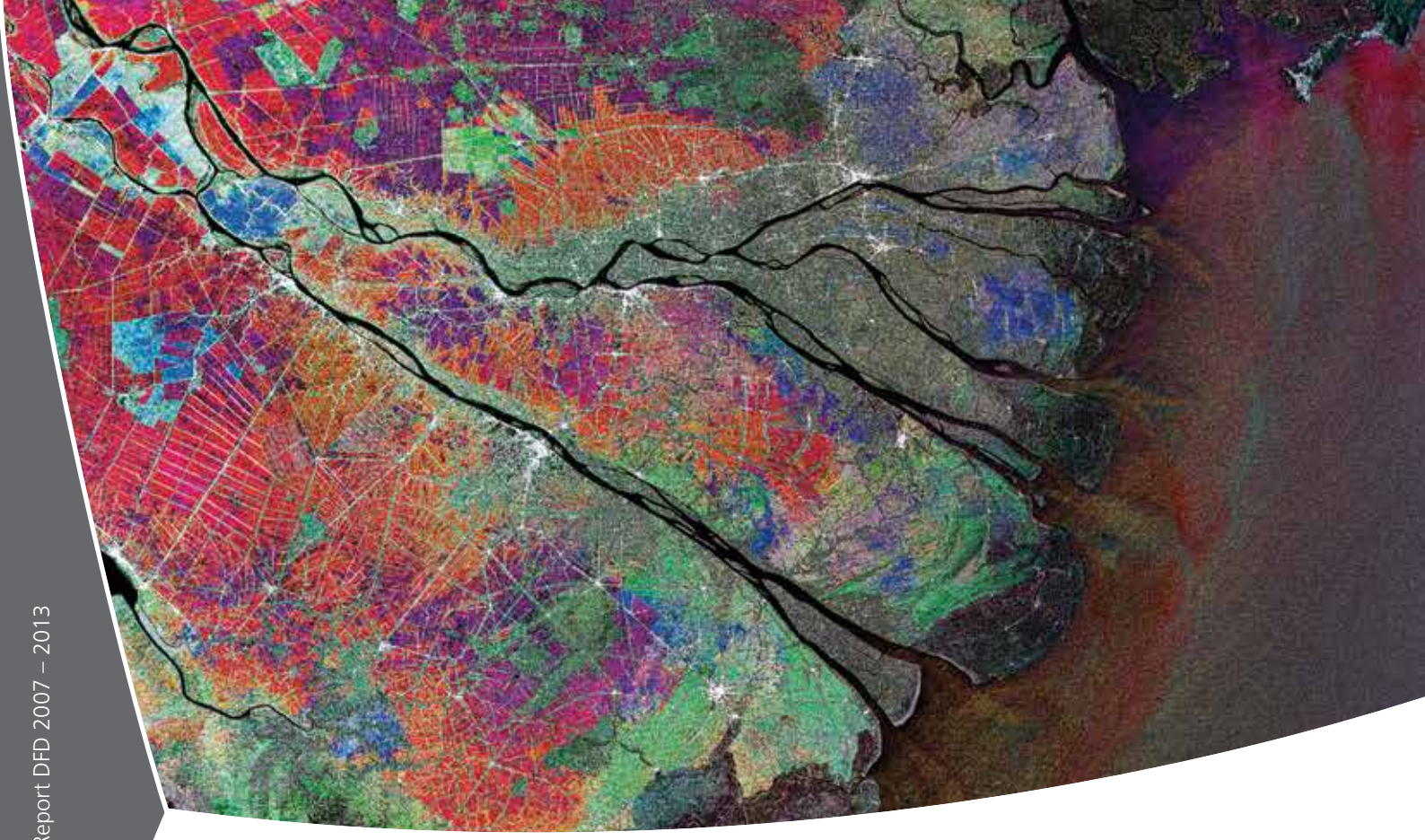

Status Report DFD 2007 – 2013

German Remote Sensing Data Center

Deutsches Fernerkundungsdatenzentrum

Status Report 2007 – 2013

DLR

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Cover Multi-temporal radar image mosaic from the Mekong River Delta (ENVISAT ASAR © ESA)

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Foreword

The German Remote Sensing Data Center (DFD) was founded 33 years ago–in 1980. Today it is Germany's most important Earth observation institution. DFD is a valued partner both nationally and internationally. With our recognized competence and abilities in technology and science we are a driving force in the operation of Earth observation missions and in the development of remote sensing geoproducts and approaches.

We have set ourselves the task of turning remote sensing into an indispensable tool for Earth stewardship. To accomplish this we require engineers and scientists from the most varied disciplines, and it is this exceptionable range of expertise which distinguishes us. The spectrum extends from engineering and operational responsibilities to information technology systems development to methodological and geoscience research. This interdisciplinarity allows us not only to receive data, but also to develop geoinformation products and generate them around the clock. It is the source of DFD's competence as a developer of end-to-end solutions.

We are motivated by the question of what influence human activity has on our planet: its climate, terrestrial ecosystems, natural resources and the environment. Our goal is to make neutral and objective information available about these effects, based on unambiguously characterized measurement data. This is something that remote sensing can achieve as no other technology. We concentrate our efforts on this capability and continuously provide wide-coverage measurement values and robust information about their accuracy.

The data basis for researching global change is still incomplete. We need long time series, not only for the atmosphere, but also for the land surface and the fragile coastal regions. We want to contribute to closing the gaps and to provide information about important ongoing processes of change at different spatial and temporal scales.

Similarly, we are actively involved in the area of civil security. We not only make data available as rapidly as possible after natural disasters and humanitarian emergencies, but also intensify our efforts in the area of early warning, for example, by documenting ongoing processes of change and estimating the associated georisks.

All this crucially depends on the ability to technically implement what has been determined by our specialists. This is what fundamentally distinguishes us from university research, and is the justification for our unique position as a remote sensing institute in a major research institution.

This systems expertise is clearly evident at DFD's payload ground segment, an in-house development which has repeatedly proved its worth in national and European missions. But today it is becoming increasingly difficult to make a distinction between developments in the payload data ground segment and product development and research in the geosciences. Science and operational data reception go hand in hand and continue to merge. Ambitious services like identifying ships in near real time would not otherwise be possible. Projects initiated in-house like CATENA, GeoFarm, Timeline and UKIS represent the type of comprehensive systems development achieved by our institute and by EOC as a whole. They are intended to provide long-term remote sensing solutions and services. For the sake of research, but also for the welfare of the population. And implicitly to benefit a strong economy.

In addition to safeguarding what has been achieved, we want to deepen our specialization and more reliably interconnect our expertise. We are closely observing trends like cloud processing, analyzing the advantages and disad-

vantages in order to discover for us the best solutions, whose top priorities are sustainability and continuity. GeoFarm is an example of this development.

Also in the future we want to team up with strong, complementary partners in all the domains of our diverse responsibilities. Our most important partner is our DLR sister institute, the Remote Sensing Technology Institute (IMF). That is where the physical basis is laid along three major technological lines for the transformation of data into products. Since 2000 DFD and IMF have formed a cluster of institutes: the Earth Observation Center (EOC). Both institutes coordinate the focal points of their work so that systems capability can be achieved. IMF and DFD act cohesively in the best sense of that word. This is also reflected in the fact that both institutes are being evaluated together as EOC. The reports which follow were jointly coordinated. An innovation compared with the cluster review in 2007 is that the status reports for both institutes have a common section which describes their shared EOC foundation. Despite many similarities, each institute has its own expertise and both profit from their differing cultures and approaches.

All this taken together puts DFD as a component of EOC in a distinctive position within DLR.

Many members of staff have been involved in the preparation of the documents for this review. It is my pleasure to take this opportunity to express my sincere appreciation to all of them. Very special thanks go to the editorial team around Nils Sparwasser, Dr. Tanja Kraus, Monika Wildegger, Gunter Schreier, Hans Voß, Heidi Westphal and Susan Giegerich for their exceptional support in creating this report.

At the same time I would like to expressly thank all staff members of the German Remote Sensing Data Center and our cooperation University departments in Würzburg, Augsburg and at TU München for their support and dedication in achieving our common goal of utilizing remote sensing to understand and protect our changing planet Earth.

Oberpfaffenhofen, September 2013

Stefan Dech
Univ.-Prof. Dr. rer. nat. habil.

Director, German Remote Sensing Data Center

Earth Observation Center

Earth Observation Center

DLR's Earth Observation Center (EOC) was established at the beginning of 2000 as the major result of an extensive external review of two DLR research fields, 'Earth Observation' and 'Communication and Navigation.' Since then it is composed of the Remote Sensing Technology Institute (IMF) and the German Remote Sensing Data Center (DFD), supported by a joint financial controlling unit.

Until 2010, EOC was operated under the Name 'Cluster for Applied Remote Sensing.' The entitlement to continue its activities as DLR´s Earth Observation Center reflects its gain in importance within DLR as the core institution to transfer EO data into geoinformation, operate the payload ground segment facilities and run dedicated user services. EOC supports many DLR, national and international missions and research projects in the geosciences and atmospheric sciences by processing and making available the data and information which are a prerequisite to knowledge gain. To fulfill this interdisciplinary challenge, EOC puts to work its expertise in physics, geosciences, mathematics, information technology, and engineering, as well as its technical know-how.

EOC is embedded in a wide range of international activities. Just to name a few: we are developing and will operate one of ESA's Processing and Archiving Centers as part of Europe's Copernicus program. We are a partner in EUMETSAT's Satellite Application Facilities and operate a World Data Center on behalf of the International Council for Science and the World Meteorological Organization. We perform ground segment functions for European and international customers and deploy remote-sensing-based project solutions in many countries around the world. Finally, we are responsible for all operational duties in the framework of DLR's membership in the International Charter Space and Major Disasters.

Our central strength is the ability to design, engineer, build, and operate end-to-end systems for EO-based demands and missions. EOC drives and participates in almost all state-of-the-art developments in the field of remote sensing. This covers the entire scientific and engineering portfolio from sensor-based signal processing and parameter retrieval to time-series analysis for gaining geophysical or biophysical quantities to integration with relevant geoinformation layers from other sources within dedicated geoinformation systems to user-specific solutions and services.

Mission and Expertise

The mission of EOC is to establish remote sensing as an indispensable tool for obtaining geoinformation relevant to global change and environment, planning, and civil security, in order to meet scientific, social, economic, and national needs.

We devote our research activities, development efforts and services to this goal since we are convinced that remote sensing from space can competently satisfy the continually growing global demand for objective and reliable geoinformation. The research and development activities of EOC therefore focus on socially relevant issues like:

- environment
- global change and climate monitoring
- sustainable development
- well-being and security of the population
- specific information requirements of our project partners and customers in science, the public sector, industry, and government.

DFD and IMF staff in May 2013 in the atrium of the common EOC building in Oberpfaffenhofen

The EOC building in Oberpfaffenhofen

EOC's major fields of expertise are:

- basic research on remote sensing principles and the relevant physical, mathematical and information-theory problems
- developing algorithms for information retrieval from remote sensing data and implementing them in operational processing systems
- developing generic components for the configuration of dedicated geoinformation systems with optional decision support solutions
- processor development, system integration and operational mass processing of remote sensing data, as well as development of the information technology required to manage extensive data inventories
- defining and generating value-added geoinformation products for environmental research and the associated management tasks
- developing and operating customized services for rapid and sustainable access to relevant data, value-added products, information, and decision support
- conceiving, designing and operating multimission ground infrastructure in support of national, European and international Earth observation missions (both public and private) to assure worldwide access to primary remote sensing data for DLR's own research, and, as requested, for customers in the private sector
- operating, calibrating and validating optical sensor systems for airborne remote sensing as precursors of spaceborne systems and for the development of novel information products
- contributing to the design of new sensor systems and missions (SAR, hyperspectral, resp. spectrometric, multispectral, thermal infrared).

Allocation of Tasks

The two institutes, IMF and DFD, are pools of complementary expertise. Almost any large EOC mission or research and development project is carried out by teams composed of staff from both institutes. This matrix structure allows on the one hand the continuous build-up of scientific and engineering expertise over many years. On the other hand, it allows this knowledge to be assembled for challenging projects in a flexible and responsive way. In rough terms, IMF and DFD share their responsibilities as follows:

- IMF focuses on basic physical and mathematical research and algorithm and processor development for information retrieval from sensor signal data
- DFD's science departments are concerned with research projects, and product and service development

- DFD's engineering and operations departments develop geoinformation technologies for ground segment and partially for geoscientific needs. They develop and operate the ground segment, including payload data receiving stations and processing facilities.

There is, however, not a strict and complete separation of tasks. In response to the ever evolving challenges posed by missions and programs, the research fields of IMF and DFD have been mutually adjusted from time to time. This approach also accommodates the needs of our scientists and engineers, whose commitment, enthusiasm, and initiative are the core of EOC's success.

User Services

EOC hosts four user services with different characteristics and mandates:

IMF operates DLR's airborne optical sensor suite and a calibration lab for these instruments (OpAiRS).

DFD operates:

- the Center for Satellite Based Crisis Information (ZKI)
- the World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT)
- the German Satellite Data Archive (D-SDA).

Program

The research and development program of EOC is subject to the program-oriented funding of the Helmholtz Association, as is the case with all DLR institutes. Its activities are part of the Helmholtz research field 'Transport and Space.' DFD works almost exclusively within the program topic 'Earth Observation' of the 'Space' program, whereas IMF also substantially contributes to the 'Transport' and 'Aeronautics' programs.

The EOC institutes finance large parts of their activities with third party projects, the major customers being the European Space Agency (ESA), German industry, and the Federal Ministry of Education and Research (BMBF).

Locations and Structure

EOC is to be found at four DLR locations, in Oberpfaffenhofen (ca. 280 staff and the headquarters of both institutes), Neustrelitz (ca. 45 staff), Berlin-Adlershof (ca. 10 staff), and Bremen (ca. 10 staff). In addition there are teams at work at cooperation chairs at the Technische Universität München and at Julius-Maximilians-Universität Würzburg (ca. 30 staff in all).

EOC is structured into 12 departments, whereby the financial controlling and logistics department performs a central function for both institutes.

Other EOC-wide functions like IT, quality management and web services are performed by the 'Information Technology' and 'Science Communication and Visualization' departments of DFD.

EOC is led by a team of two directors, each of whom is assigned to lead one institute, for IMF Prof. Richard Bamler and for DFD Prof. Stefan Dech. A spokesman function alternates between the two directors on a three-year basis.

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National and International Context

Satellite Earth observation covers national territories as well as global land and oceans areas. Earth observation science, technologies and satellites therefore form an important asset for national development, industrial policy and national security as well as international relations. With its capabilities in Earth observation science, technologies and ground segments, EOC is in this context an important player on national, European and international levels.

National

The German national space program calls for an integration of space technologies by nearly all domains of public life. Specifically, Earth observation based information should be used by government agencies and commercial entities to improve the management of the environment, public health and civil security. The national space program supports European initiatives such as Copernicus (formerly GMES, Global Monitoring for Environment and Security).

EOC is challenged by this national strategy for Earth observation at all levels of skills, expertise and infrastructure in its institutes IMF and DFD.

EOC's institutional funding is provided via the Earth observation section of the Helmholtz research program 'Space'. We also use instruments of the Helmholtz Initiating and Networking Fund, such as the PostDoc program, Young Investigators Groups, and Helmholtz Alliances.

Substantial funding also comes from several BMBF programs. EOC conducted projects e.g. with BMBF support, such as WASCAL, WISDOM, Exupéry and GITEWS.

Further federal ministries are interested in benefiting from the Earth observation expertise and services of EOC. For example, the capability of rapid crisis mapping as implemented in the ZKI has been mandated as a service by the Ministry of the Interior (BMI) since the beginning of 2013.

Several governmental agencies in charge of maritime and coastal security are demonstrating the use of EOC-generated near-real-time SAR based products in their work. EOC's research and demonstration efforts related to maritime security are funded by the Federal Ministry of Economics and Technology and by the Federal Ministry of Education and Research (BMBF). One result was the establishment in 2012 of maritime safety and security labs in and Neustrelitz. Maritime security applications are also one of the major EOC contributions to the Copernicus collaborative services.

In order to strengthen the role of German contributors to Copernicus, DLR and the state of Bavaria, complemented by activities in the state of Mecklenburg-Western Pomerania, initiated in 2010 the concept of a GMES Center (later Copernicus Center). This center will focus on sharing with external partners, including industry, the technical capabilities and expertise of DLR both in the Copernicus ground segment and in the processing of Earth observation data. The first part of the concept supports the setting up of Copernicus ground segment functions (such as. ESA Processing and Archiving Centers, or PACs) in order to grant access to primary Sentinel data. The second part contributes to the setting up of computing and pre-processing facilities and interfaces to industrial partners in order to give them easy access to Copernicus data and quality products.

Europe

The treaty of Lisbon put the European Commission in charge of defining the strategy for space science research and major European projects. Next to the independent navigation system Galileo, the European Commission has defined its strategy on Earth observation within the Copernicus program. Therein the Commission, supported by its agencies, is in charge of implementing the Copernicus services. Complemented by ESA programs and national contributions, ESA has the responsibility to build and operate the space and ground segments for Copernicus. From the very beginning, EOC contributed to the development of Copernicus services in the domains of land, ocean, atmosphere, disaster mapping, civil security and global change. Most of these projects were and are funded by ESA and European research framework programs. As to Copernicus operations, ESA has selected EOC to set up and operate the PACs for Sentinel-1, Sentinel-3 (OLCI part), and for the Sentinel-5 precursor mission, as well as to handle Sentinel processor development. These PACs will be established at EOC in Oberpfaffenhofen and will continue the series of our duties in the processor development, setting up and operation of data centers under contract to ESA, which started in 1991 with ERS-1, ERS-2 and ENVISAT. Work is also progressing on the Copernicus 'collaborative ground segment,' where national facilities add further capabilities, products and services to the core ground segment.

Besides the focus on Copernicus, other work with ESA is progressing on the development of new algorithms, processing and data management, for example, in the framework of the Climate Change Initiative and long term data preservation. Cooperation with EUMETSAT to provide global ozone maps as part of the 'Satellite Application Facilities' continued during the reporting period. Improved products have been developed in particular in conjunction with the new EUMETSAT polar orbiting MetOp missions. We are also collaborating with other European actors from academia, large research labs and the space industry, as well as with such European agencies as ECMWF, EEA, EUSC and EMSA.

International

The number of Earth observation missions has dramatically increased. New nations as well as new industrial entrepreneurs with their own national or commercial space systems are entering the space arena. Amongst other drivers, global security challenges are nourishing the demand for very high resolution optical and radar surveillance.

EOC is contributing to the operation of these missions with its international data acquisition stations, established in science cooperation schemes with the host countries Canada (Inuvik), Mexico (Chetumal) and Chile (O'Higgins).

International organizations such as the Group on Earth Observation (GEO) are aiming to manage the ideas, concepts and access channels relating to global change data. EOC participates in many working groups of the GEO societal benefit areas. This often results in projects in which EOC researchers contribute to

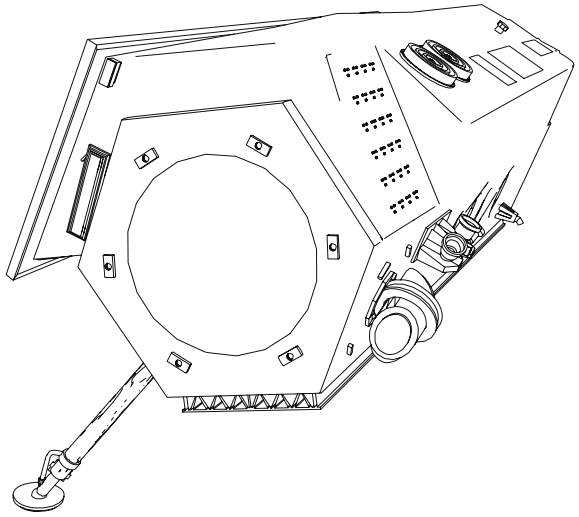
Earth observation applications and environmental monitoring systems in other countries. Mostly funded by German ministries, these projects range from cooperative work with Mexico to delivery of environmental information in West and South Africa to water systems monitoring in Central and Southeast Asia. An EOC flagship project was work on the development of the German-Indonesian Tsunami Early Warning System (GITEWS), now in operation.

The capabilities of Earth observation missions to deliver a fast overview of areas affected by disasters were recognized by space agencies in creating the International Charter Space and Major Disasters in 2000. With TerraSAR-X and the DFD Center for Satellite Based Crisis Information ZKI, DLR became an official member of the Charter in 2010. In the same direction, DLR has actively supported UN-SPIDER (United Nations Platform for Space-based Information for Disaster Management and Emergency Response) with the secondment of personnel to the UN office in Bonn. In 2009, the World Meteorological Organization (WMO) assigned the EOC-based Data Center for Remote Sensing of the Atmosphere a role within the WMO World Data Center network. This role complements the World Data Center function DFD gained from the International Council for Science in 2003. These activities undertaken together with international agencies are supplemented by the engagement of EOC in international science organizations. EOC staff is actively involved in chairing technical working groups, commissions and conferences in science and engineering organizations such as EARSEL, ICSU, ISPRS, IEEE and IAF.

Important Earth Observation Missions

As a leading Earth observation facility, EOC participates in and contributes to a large number of national and international Earth observation missions. Our portfolio of past, current and future mission involvement illustrates the reputation EOC has gained in these areas.

Depending on the EO mission our involvement can range from providing only data acquisition services up to hosting an entire payload data ground segment including the full chain of tasks from receiving data downlinked from a spacecraft to processing to product dissemination and archiving. The required ground segment systems and subsystems are continuously developed and maintained at EOC. Our commitments now extend to 2020 and beyond. This will ensure continuous data availability, a must for developing state-of-the-art Earth observation applications and for our contributions to global climate change exploration.



National and DLR Missions

TerraSAR-X

TerraSAR-X is a German radar satellite mission providing high resolution Synthetic Aperture Radar (SAR) image data to scientific and commercial users since 2007.

The satellite's main instrument is an advanced high-resolution X-band imaging SAR which is based on active phased array technology. This technology allows electronic beam steering and thus the operation of many different SAR imaging modes characterized by their individual resolution, polarization and image size. Especially the maximum resolution of 0.5 m in spotlight mode surpasses the performance of previously available systems by an order of magnitude.

The mission is implemented in a public private partnership model between DLR and the German space industry. EADS Astrium manufactured the TerraSAR-X spacecraft, with its subcompany Infoterra GmbH dealing with the commercial product service aspects. Several DLR facilities developed and operate the entire TerraSAR-X ground segment. For EOC this comprised prior to launch the development of:

- the payload data receiving stations and data links
- a multimode SAR processor (TMSP)

- the complete SAR data payload ground segment
- a service segment for scientific users.

During the in-orbit mission phase, we are now responsible for all major elements, such as:

- product ordering
- high rate satellite data reception
- SAR processing
- product archiving and dissemination.

Furthermore, we coordinate the scientific use of the SAR data. More than 800 science data proposals with applications in geology, georisks, hydrology, glaciology and other fields are being handled. The ever increasing use of TerraSAR-X data is reflected at international conferences and in publications in remote sensing journals.

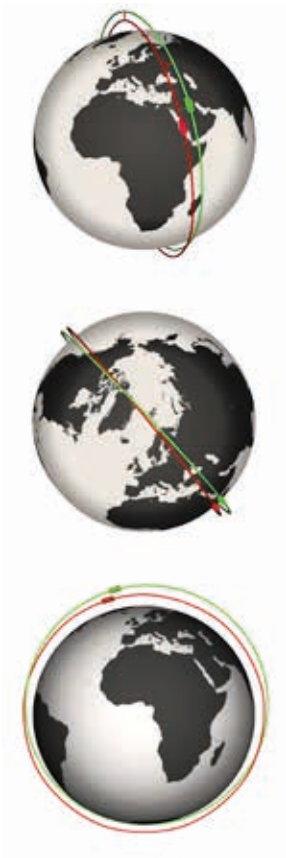
The success accomplished so far has provided EOC with the opportunity to contribute to future missions such as the Spanish PAZ, which is based on Astrium's TerraSAR-X platform and our SAR processor, and TerraSAR-X HD, a commercial follow-on mission with even higher resolution and performance.

TanDEM-X

TanDEM-X is an innovative radar mission consisting of two cooperating satellites with the purpose of producing a global Digital Elevation Model (DEM) with 12 m horizontal resolution.

To calculate 3D elevation maps from 2D radar images, the TerraSAR-X satellite was complemented by a second satellite in 2010. Both are now flying in close formation only some hundred meters apart. They are jointly operated to form a bistatic interferometer, i.e., one satellite transmits and both satellites synchronously receive the echoes.

TanDEM-X at IABG in Ottobrunn ready for dispatch to the launch site in Baikonur



The close formation flight and the smooth cooperation of the radar systems posed numerous technical challenges which were all successfully met with the help of newly developed algorithms and techniques.

The TanDEM-X mission is financed and operated in a public private partnership like the TerraSAR-X model. Concerning data products, EADS Infoterra is again responsible for commercial DEM distribution while DLR handles the scientific data usage.

Our major contributions to the TanDEM-X mission are the development and, since launch, the operation of the complete SAR data payload ground segment, including:

- payload data receiving stations and data transfer links
- a bistatic InSAR DEM processor (ITP)
- a calibration and global mosaicking processor.

By 2013, two gapless coverages of the major land surfaces will have been acquired and processed in a first step, with calibrated and mosaicked products to follow. The final global TanDEM-X DEM will be a milestone in remote sensing with benefits for all disciplines of the geosciences and for commercial geo-applications.

MERLIN

The Franco-German collaborative MERLIN mission is intended to measure atmospheric methane concentrations with unprecedented accuracy. It will carry an active SWIR instrument which exploits a differential-absorption lidar technique as a novel sensor approach.

The workload shared by the mission participants is such that France provides an extension of the Myriade platform together with its operations while Germany develops the lidar instrument and takes care of all aspects of the payload.

MERLIN has successfully passed the mission definition (pre-phase A) and preliminary readiness (phase A) reviews. Phase B started in April 2013. It is planned to launch the satellite in 2016 for a mission duration of at least three years.

Our development responsibilities for MERLIN include:

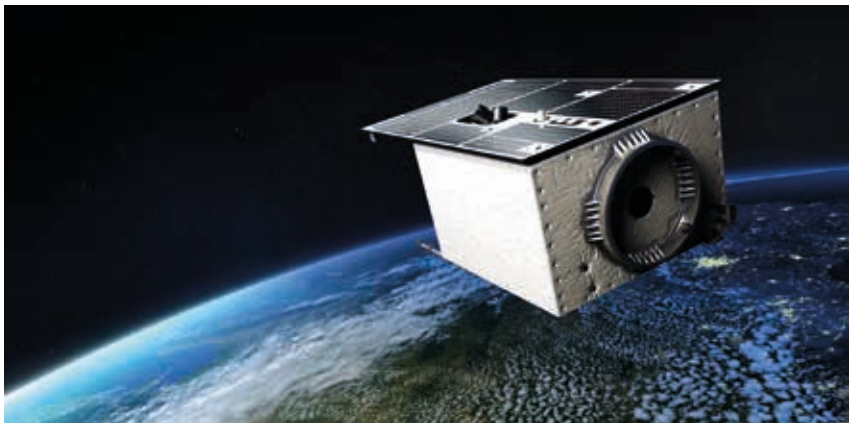
- operational data processors for level 0-1a and level 1a-1b
- long-term instrument performance monitoring
- short-term instrument health and safety monitoring
- payload command and control facilities
- host interface structures for data processing, data archiving and a data user interface via WDC-RSAT.

EnMAP

The Environmental Mapping and Analysis Program (EnMAP) establishes the first national hyperspectral remote sensing satellite mission. It is based on the long German heritage and expertise in imaging spectroscopy.

EnMAP is a scientific pathfinder mission, driven by the need to quantify the status and processes of Earth's environments in the context of growing anthropogenic impacts.

The 228 channels of EnMAP's imaging spectrometers cover the reflectance spectrum from the VNIR to the SWIR range with geometric resolution of 30 m. Operational geometric and atmospheric correction is applied to ensure products of excellent quality. With its 30° pointing capability and capacity of 30 km × 5000 km per day in a sun-synchronous



The German hyperspectral Satellite EnMAP forseen to be launched in 2017

orbit, EnMAP will permit frequent and global acquisitions. Currently, only airborne sensors such as EOC's HySpex are capable of delivering products reflecting similar performance.

The EnMAP mission, managed by the DLR Space Agency, assigned to EOC responsibility for the complete mission ground segment, which is realized in a collaborative effort with DLR's GSOC. Our role comprises:

- project management of the complete ground segment for all mission phases
- instrument pre-flight simulations and in-flight calibration
- X-band data reception
- processor development and operation with data quality control
- long-term data archiving
- web-based acquisition and product request handling using EOC's multimission infrastructures.

EnMAP has an anticipated launch date in late 2017.

Tandem-L

Tandem-L is a DLR scientific SAR mission proposal to monitor dynamic processes in the bio-, litho-, cryo- and hydro-sphere. The variables to be assessed–among them seven essential climate variables– include biomass, tectonic and volcanic activity, soil moisture, ice extent and ice dynamics. The mission employs two fully polarimetric L-band SAR systems flying in formation and operating in either bistatic Pol-InSAR (for forest profiling) or repeat-pass InSAR (for deformation measurements) modes. An innovative digital beam-forming concept provides a mapping capacity two orders of magnitude better than TanDEM-X: mapping of Earth's entire land mass is achieved twice in eight days.

Fully polarimetric L-band SAR system: Tandem-L

A pre-phase-A study together with JPL was conducted during the last few years. Most of the technological concepts and the performance estimates have been finished. The Helmholtz Alliance 'Remote Sensing and Earth System Dynamics' has been charged with supporting algorithm development and federating the scientific user community for Tandem-L.

EOC will be in charge of:

- developing and operating a payload ground segment handling unprecedented data rates and volumes
- developing algorithms for geotectonic, cryospheric and oceanographic parameter retrieval.

These operational duties will be complemented by participation in science team activities.

FireBIRD

The FireBIRD mission consists of two satellites, TET-1 and BIROS. Its primary objective is the spaceborne detection and characterization of high-temperature events such as wildfires and volcanoes.

The first platform, TET-1, was launched in July 2012. Its purpose is to provide national industry and the science community the possibility to verify and demonstrate new technologies under space conditions. The second satellite, BIROS, has an anticipated launch date in 2013.

The principal imaging payload on both satellites is a bi-spectral IR sensor with channels in the mid-IR and thermal IR range, supplemented by a three-band VNIR camera.

EOC is responsible for satellite data reception. In addition, the standard processors are integrated into DIMS for the operational processing of the FireBIRD products.

RapidEye

The commercial RapidEye system consists of five identically designed satellites. The entire configuration was launched in August 2008 and became operational in 2009. The optical imaging payload covers the VNIR wavelength range and captures about five million km^2 per day with a maximum spatial resolution of 6.5 m.

EOC is a scientific coordinator in partnership with the RapidEye company and provides the German user community with RapidEye data on the basis of peer-reviewed proposals. In this context EOC has established and is hosting the corresponding data pool.

Additionally, we provide advice to the DLR Space Agency on integrating RapidEye services into the European Copernicus initiative in order to assure the safeguarding of national interests.

CHAMP

CHAMP, a German satellite mission addressing Earth science needs concerning the geosphere and the atmosphere, was operational from 2000 to 2010. Its prime mission goal was high precision gravity field and magnetic measurements. In addition, radio occultation technology and GPS measurements delivered information about the state of the atmosphere and space weather.

The mission was managed by GFZ Potsdam and operated by DLR's GSOC. We contributed the CHAMP raw data center, including data reception, pre-processing, near-real-time dissemination to the project partners and long term archiving.

GRACE

Since 2002 the twin satellite mission GRACE continues the CHAMP mission goals to generate a global high-resolution model of Earth's gravity field with unprecedented accuracy. Its secondary mission is to provide globally distributed status profiles of the ionosphere and atmosphere using limb sounding.

GRACE is a joint effort between DLR and NASA/JPL, with GSOC handling spacecraft operations and GFZ functioning as one of the science centers. As for CHAMP, EOC hosts the raw data center for data processing, archiving and dissemination to the mission control center and to the scientific centers.

ESA and EUMETSAT Missions

ERS-1 and ERS-2

ERS-1 was Europe's first Earth observation mission, operated between 1991 and 2000. The platform carried a payload suite of active and passive sensors, including an imaging SAR and a wind scatterometer.

In 1995, ESA launched ERS-2, the successor to ERS-1. It was decommissioned after 16 successful years of in-orbit service. In a short-track development, ERS-2 was equipped with GOME to carry out atmospheric measurements, particularly ozone and chemical composition, for the first time from a European spaceborne platform. The rest of the payload was identical to ERS-1.

On behalf of ESA, both for ERS-1 and ERS-2, we hosted the German Processing and Archiving Facility D-PAF. For the SAR instrument the tasks assigned to the D-PAF included:

- acquisition and archival of level 0 data, particularly from our acquisition stations located on the Antarctic peninsula and in Chetumal, Mexico
- on-request processing and dissemination of products to users.

For GOME, we developed the required algorithms for trace gas retrieval and implemented the resulting processor in D-PAF. D-PAF's role for GOME included:

- acquisition, reception, and archival of the entire level 0 data repository

Multitemporal ERS 1/2 radar image, City of Madrid, 2004

- systematic near-real-time and offline processing and dissemination services for level 1 radiances and level 2 total column products
- repeated reprocessing campaigns using continuously improved versions of the GOME processors.

The work successfully accomplished in the framework of D-PAF formed the basis for our manifold involvement in other ESA and EUMETSAT Earth observation missions.

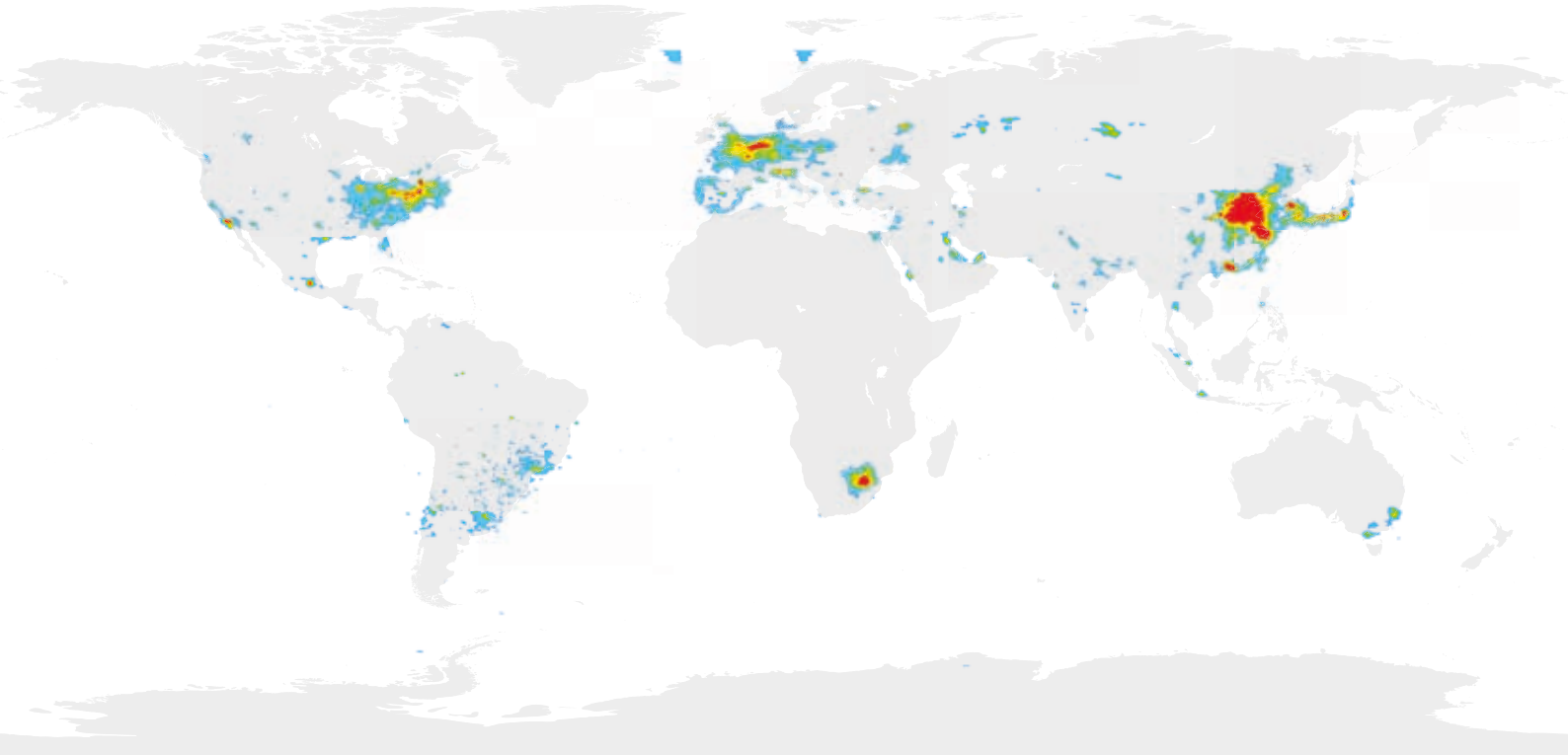
ENVISAT

ENVISAT was ESA's Earth observation flagship mission in the first decade of the 21st century. Launched on March 1, 2002 the mission operated until April 8, 2012. It carried a payload of ten instruments suitable for studying the entire Earth system from polar orbit. Seven instruments of the payload complement had the status of an ESA-developed instrument. SCIAMACHY, AATSR and DORIS were Announcement of Opportunity instruments. They were provided by national agencies, with tasks in instrument operation and data processing shared by ESA and the instrument providers.

EOC was tasked by ESA and DLR to be one of the major facilities in the ENVISAT ground segments for the atmospheric science instruments SCIAMACHY, MIPAS and GOMOS, together with the radar sensor ASAR and the imaging spectrometer MERIS.

For SCIAMACHY, jointly provided by Germany and the Netherlands, both flight operations and data processing functions

Global NO_2 concentration in 2007 measured by SCIAMACHY on ENVISAT



were hosted by EOC. In cooperation with IUP-IFE, University of Bremen, we were responsible for instrument operations comprising mission planning, instrument configuration control and performance monitoring. In the data processing domain, algorithm development for instrument calibration (level 0-1) and atmospheric parameter retrieval (level 1-2) was pursued as part of a Europe-wide quality working group. The algorithms finally selected formed the basis of the operational data processors that had been implemented in the framework of the German D-PAC, a de-centralized ESA facility in the ENVISAT payload data segment. EOC operated the D-PAC on behalf of ESA not only throughout the now completed in-orbit phase, but also continues its operation in the current post-mission phase for the purpose of product generation, archiving and dissemination.

For the other payload instruments, D-PAC's role comprised:

- MIPAS: externally developed processors were implemented for the generation and subsequent storage and dissemination of operational level 1 and level 2 data products
- GOMOS: hosting all level 1 and 2 products for the complete mission
- ASAR: all production steps, as well as archiving and disseminating products derived from data when the instrument operated in high rate mode, were assigned to D-PAC. This was complemented by systematic dissemination of wave-mode data
- MERIS: archiving all level 0 data which had been acquired at EOC's Neustrelitz station together with the corresponding level 1 and 2 processing under national auspices.

MetOp

The series of three MetOp satellites defines EUMETSAT's polar Earth observation system. With MetOp-A launched in October 2006 and MetOp-B launched in September 2012 two components are presently operational. Lifting MetOp-C into orbit is currently envisaged for 2018. One of the prime goals of MetOp is to provide unique operational data products for Copernicus until at least 2020.

The MetOp payload includes the GOME-2 instrument, an advanced version of GOME which was successfully flown on ESA's ERS-2 mission from 1995 to 2011. With MetOp, remote sensing of atmospheric composition was successfully transferred to the domain of operational meteorology.

The Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (O3M-SAF) is responsible for providing the operational atmospheric products based on MetOp data. EOC plays a prominent role in the O3M-SAF that is hosted by the Finnish Meteorological Institute but implemented as a decentralized facility in cooperation with a Europe-wide network of research organizations.

At EOC the O3M-SAF project builds on the experience gained over almost two decades in algorithm development and systematic operational processing of data from atmospheric sensors. The share of responsibilities at EOC includes:

- development of retrieval algorithms and operational processors for MetOp/GOME-2 total column products
- operational data processing and data dissemination in the distributed O3M-SAF payload data ground segment.

Copernicus Sentinel Missions

The space segment of Copernicus extends the capabilities of the former and existing European Earth observation missions. In addition to the national platforms for high resolutions optical and radar observations and to the pure science (Earth Explorer) and operational meteorological (EUMETSAT) missions, the Sentinels provide a basic range of measurements with global coverage for operational needs in Europe. Five Sentinel series satellites have been identified. Their full operational scenario calls for having two spacecraft of one kind in orbit at any time.

The core ground segment of the Sentinel missions is managed by ESA and to some extent by EUMETSAT. Processing of the raw data occurs at Sentinel-specific PACs, where products are generated, archived and sent to users.

All Sentinel data will be free of charge and access to all product information will be unrestricted for public, private and science use. In addition, ESA member states can directly access the Sentinel satellites with their own national stations and offer their own services.

Sentinel-1

The first Sentinel-1a satellite, to be launched early in 2014, will ensure the continuity of the C-band SAR data from the ERS-1/2 and ENVISAT missions, with the second Sentinel 1-b following in 2015. The SAR on Sentinel-1, operating in four modes, has higher capabilities than its predecessor instrument on ENVISAT.

Both Sentinel-1 satellites will provide coverage of Europe, Canada and most global areas in 1-3 days. For some areas and in sight of a local ground station, products can be delivered within one hour.

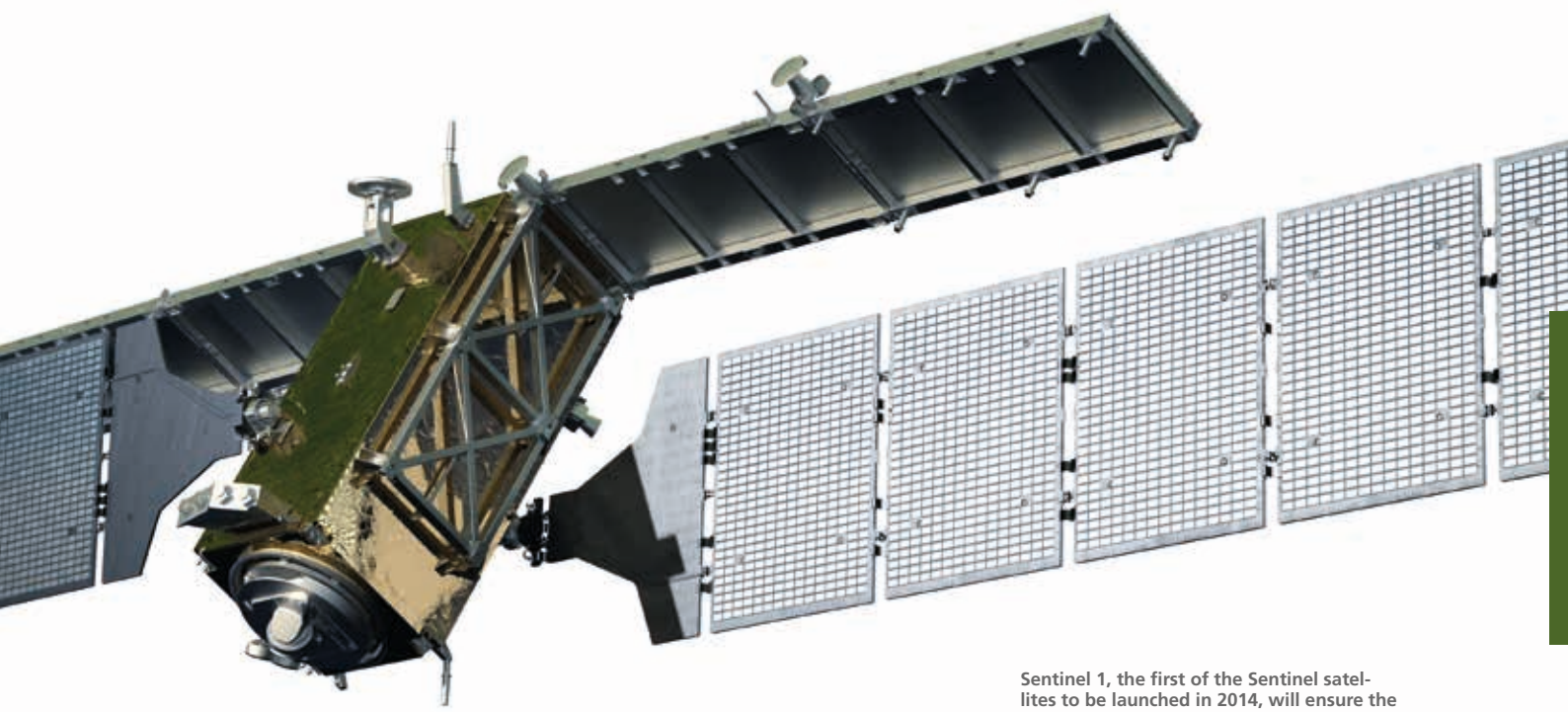
EOC was selected to host a PAC for Sentinel-1. The data will also be received at the EOC data acquisition stations and via the European Data Relay Satellite System, primarily for use in a national maritime security project.

Sentinel-2

The pair of Sentinel-2 satellites (Sentinel-2a being launched in 2014 with Sentinel-2b following about one year later) will routinely deliver high resolution optical information on all land masses of Earth. It complements other systems such as the Landsat series. The two satellites will have a revisit time of 2-3 days at mid-latitudes, which increases to 5 days at the equator.

Sentinel-2 will carry an optical payload for the VNIR-SWIR range with 13 spectral bands providing a maximum spatial resolution 10 m. The Sentinel-2 products will be used for land cover mapping, agriculture, vegetation and ecologic change monitoring.

EOC plans to acquire, process and use Sentinel-2 data as part of the national collaborative Copernicus ground segment and initiatives such as the Bavarian Copernicus Center.



Sentinel 1, the first of the Sentinel satellites to be launched in 2014, will ensure the continuity of the C-band SAR data from the ERS-1/2 and ENVISAT missions

Sentinel-3

The goal of the Sentinel-3 mission is derivation of sea and land surface parameters with high accuracy and reliability in support of ocean forecasting systems and for environmental and climate monitoring. Its products will contain information about the state of the sea and the land surface.

Owing to the wide range of objectives, the extensive Sentinel-3 payload includes a multitude of sensors of ENVISAT or Cryosat heritage. Of particular importance is the Ocean and Land Colour Instrument (OLCI), which is based on ENVISAT's MERIS. It will permit the retrieval of parameters related to sea surface temperature, water quality, water pollution and marine ecosystems.

EOC has been selected to set up and operate the PAC responsible for Sentinel-3 OLCI data. In addition, Sentinel-3 data is also planned to be received and used in the national collaborative ground segment.

Sentinel-4 and Sentinel-5

Both Sentinels focus on the state of Earth's atmosphere and its chemical composition. Their payloads will be implemented on operational EUMETSAT missions.

Sentinel-4, on board MTG-1, carries a UV-VNIR spectrometer into geostationary orbit for frequently monitoring the northern hemisphere over Europe. It will be launched in 2019, with the second spacecraft following in 2026.

Sentinel-5 will operate on the MetOp Second Generation platform. The payload complement includes a UV-VNIR-SWIR spectrometer. Sentinel-5 is targeted for launch in 2020.

Currently, in the early phases of instrument design, EOC is involved in developing algorithms for the instrument calibration of both sensors and for specification of level 0-1 processing.

Sentinel-5 Precursor

The Sentinel-5 Precursor (S5p) spacecraft, also part of Copernicus, will deliver a key set of atmospheric composition, cloud and aerosol data products for air quality and climate applications. The UV-VNIR-SWIR imaging spectrometer TROPOMI together with the operational level 1 and level 2 processors will achieve a significant improvement in the precision as well as temporal and spatial resolution of derived atmospheric constituents. S5p is planned for launch in 2015.

ESA has overall responsibility for the development of S5p. The TROPOMI sensor is jointly developed by The Netherlands and ESA. In the ground segment domain we have been assigned major tasks in the key areas of the payload data ground segment and algorithm and processor development.

For the payload data ground segment, the whole chain of on-ground payload data handling, including data reception, processing, archiving, and near-real-time and offline delivery to end users, will be developed and hosted by EOC. In the algorithms and processors domain we develop, in cooperation with partner institutes, the tools for the retrieval of key atmospheric trace gases and cloud products.

Thus S5p continues our strong heritage relating to atmospheric missions that started with GOME, SCIAMACHY and GOME-2. The work on S5p will, in addition, prepare for EOC involvement in the Sentinel-4 and Sentinel-5 missions.

ADM-Aeolus

The primary aim of the ESA Earth Explorer mission ADM-Aeolus is to provide global data on vertical wind profiles to improve numerical weather forecast and climate modeling. The launch of the mission is planned for 2015.

The ADM-Aeolus atmospheric instrument ALADIN is based on a direct detection Doppler lidar operating in continuous mode in the UV. It is a novel design and provides an enormous challenge not only for its development but also for operating the sensor during the in-orbit phase. The instrument measures the backscattered Doppler shifted signal emitted by the laser for retrieving profiles of the line-of-sight velocity in the troposphere and parts of the stratosphere.

Our responsibilities include:

- development of new instrument models and their implementation in the ADM-Aeolus end-to-end simulator
- elaboration of the codes for the operational level 0-1b and level 1b-2a processors
- maintenance of the ADM-Aeolus mission long-term archive.

All EOC tasks in support of the ADM mission are carried out in close collaboration with DLR's Institute of Atmospheric Physics.

ESA's Earth Explorer mission ADM-Aeolus will provide global data on vertical wind profiles from 2015 on

CarbonSat

CarbonSat is a proposed mission in the framework of the ESA Earth Explorer program with the goal to measure global concentrations of carbon dioxide and methane.

These are the two most important greenhouse gases with partially anthropogenic origin. The CarbonSat mission is intended to lead to a better understanding of the cycles of both gases in the context of climate change and global warming, including the identification of their sources and sinks. Crucial for successfully accomplishing these objectives is measuring the atmospheric concentrations of carbon dioxide and methane with very high spatial resolution and unprecedented accuracy.

In the present phase, CarbonSat competes with another mission proposal for the role of Earth Explorer 8. The mission is currently in phase A/B1 with feasibility studies of the different subsystems being performed on the way to constituting a fully qualified Earth observation mission.

ESA has tasked EOC with the definition of level 0-1 processing and with studies on the spectral calibration of the instrument.

International Missions

NOAA, Terra and Aqua

These missions are relevant because of the on-board AVHRR and MODIS sensors. The AVHRR sensor constitutes one of the most frequently used data sources in Earth observation. It is part of the payload complement of several NOAA missions dating back to 1978 and is now also installed on EUMETSAT's MetOp satellites. MODIS flies on NASA's Terra (since 1999) and Aqua (since 2002) platforms. Both instruments provide medium resolution optical imagery data from the VNIR and thermal IR ranges.

EOC began to receive such data in the early 1980s and continued direct reception until 2011. Meanwhile, AVHRR data from MetOp is also being received. Similarly, MODIS data are received at the EOC facilities in Oberpfaffenhofen and Neustrelitz.

The entire data archive of AVHRR and MODIS data at EOC covers more than 30 years. Parameters like temperatures of water and land surfaces or vegetation indices are derived on a regular basis. Furthermore, an automated value adding processing chain harvests this data repository.

The resulting products are made available for various applications including near-real-time services for fire detection.

Landsat-8, the Landsat Data Continuity Mission, has begun its normal operations on May 30th, 2013

Landsat

Landsat is the longest running spaceborne Earth imagery program, a cooperative effort between NASA, NOAA and USGS together with a private data vendor. Started in 1972 it has meanwhile seen the successful launch of eight satellites.

The Landsat program supports a wide range of user communities worldwide. The applications addressed by analyzing the data acquired from the VIS-NIR-SWIR

WorldView-2 with its 1100 mm aperture allows for the differentiation of details in the sub-meter range

and thermal IR bands cover areas such as global change research, agriculture, forestry, geology, resource management, mapping, water quality and oceanography.

In the past, Landsat-5 and Landsat-7 were the platforms providing the data. Currently, the Landsat Data Continuity Mission, now known as Landsat-8, has begun its operational in-orbit lifetime with enhanced imagery capabilities.

EOC's international ground station network supported local data reception for Landsat-5 and Landsat-7. In addition, our Neustrelitz ground station is a European acquisition node in the ESA third party mission network for acquiring Landsat data. In preparation for receiving data for Landsat-8, joint tests with two other European ground stations in that network, Kiruna and Matera, have been successfully carried out.

Ikonos-2 and WorldView-2

The Ikonos-2 spacecraft, launched in 1999, provided for the first time civilian access on a commercial basis to optical very high resolution satellite data of 1 m panchromatic and 4 m multispectral resolution. Even higher resolution is now available: 0.5 m panchromatic and 2 m multispectral with WorldView-2, which was sent into orbit in 2009. Both satellites can acquire imagery on either side of the ground track. They permit local regional tasking, which can be performed and optimized up to about one hour before the satellite passes occur.

DLR established a partnership with European Space Imaging EUSI, Munich, to exploit the data from both satellites. While EUSI handles all commercial aspects, DLR contributes its EOC ground segment facilities and engineering know-how. In exchange, the acquired data can be used for research purposes and in the framework of the Center for Satellite Based Crisis Information.

EOC operates and maintains, at least partially, the Earth terminal for both satellites. These functions include:

- direct tasking
- payload commanding
- payload data reception, processing and archiving.

In order not to be hampered by clouds, we developed and implemented a concept for efficient cloud-free tasking that uses up-to-date weather information in the planning process. Until 2009 this was implemented at the German regional operations center for the Ikonos satellite. In 2010 it was replaced by the direct access facility for WorldView-2, featuring nearly identical functionality.

ALOS

The Japanese Advanced Land Observing Satellite was operated between 2006 and 2011. It carried the L-band radar PALSAR and two optical remote sensing instruments. One was PRISM, providing a geometric resolution of 2.5 m for digital elevation model production. The other was the four-band radiometer AVNIR-2 with a geometric resolution of 10 m for disaster monitoring and precise land coverage observation.

On behalf of ESA, we assumed tasks for processing ALOS data, including the establishment of:

- operational processors for high-precision orthorectification of optical data starting from level 1 products
- prototype processors for systematic, radiometric, geometric corrections, quality improvements for PRISM, and atmospheric correction for AVNIR-2 starting from level 0 products

- provision of a quality-controlled service for orthorectification of ALOS optical data covering major European urban areas.

ALOS contributed to ESA's third party mission program.

Radarsat

Radarsat-1, nonoperational since early 2013, and Radarsat-2 are SAR spacecraft owned and operated by the Canadian Space Agency and Radarsat International. Since 1995 they have delivered C-band SAR coverage for a wide range of applications such as the monitoring and mapping of ice, marine and land surfaces, and resource management in Canada and globally. In 2018 Radarsat-2 will be supplemented by the Radarsat Constellation Mission (RCM), consisting of three satellites.

Radarsat data can also be directly received and used by other nations. In order to contribute to maritime security applications over European waters, we are receiving Radarsat-2 data in Inuvik. Additionally, preparations are ongoing for acquiring data from Radarsat-2 and RCM at Neustrelitz.

IRS-P6 and IRS-P5

Both satellites are part of India's Earth observation remote sensing program. IRS-P6, also known as Resourcesat-1, was launched in 2003. It provides multispectral and panchromatic imagery of Earth's surface with medium to high spatial resolution using three sensors. In 2005, IRS-P5, termed Cartosat, was launched. Its payload comprises two panchromatic cameras especially designed for in-flight stereo viewing to support applications like cartography and terrain modeling.

Since the mid-1990s, collaboration between DLR and ISRO, the Indian Space Research Organization, ensures access to data from the IRS program. It permits acquisition of raw data from IRS spacecraft at EOC and the harvesting of an IRS science data pool by DLR staff. Data reception occurs in support of the remote sensing company Euromap on the basis of a mutual cooperation agreement. It addresses the exchange of data products and software, such as the EOC-developed processor for the generation of digital elevation models from Cartosat data, which has been licensed for usage by Euromap.

ACE

ACE, NASA's Advanced Composition Explorer, a mission for studying solar-terrestrial interactions by measuring the properties of the solar wind upstream from Earth, was launched in 1997. Placed at the Earth-Sun libration point L1 at a distance of 1.5 x 10^6 km from Earth, ACE carries out in-situ-measurements of particles originating in the solar corona.

Cooperation between NOAA and DLR focuses on the development of real time solar wind detection capability using instruments on ACE. These data can be used to provide accurate alerts of impending geomagnetic storms with a lead time of one hour. The ground-based portion of the infrastructure consists of a worldwide network of antennas, each of which acquires the continuously transmitted solar wind data during local daytime hours when the satellite is in view.

The EOC facility at Neustrelitz is the European acquisition node. It sends the acquired data to the Space Weather Prediction Center in Boulder, Colorado. In joint projects with DLR's Institute of Communication and Navigation and national and international partners, the data are used for scientific purposes and for such applications as those relating to the Space Weather Prediction Center.

The sun releases a stream of charged particles, the solar wind, potentially damaging for Earth observation and communication satellites as well as for technical infrastructure on Earth

Earth Observation missions and EOC involvement
Blue marked tasks indicate where EOC is active either based on mission provider's and/or national assignments. Light blue cells illustrate our intentions for missions well into the future.

Mission	Operator/Partner	EOC Task						Task Period	Mission Objective
National and DLR Missions									
TerraSAR-X	DLR/Infoterra	MD	ACQ	A&P	PRC	ARC	DIS	2007 →	X-SAR
TanDEM-X	DLR/Infoterra	MD	ACQ	A&P	PRC	ARC	DIS	2010 →	X-SAR IF, Global DEM
MERLIN	DLR/CNES	MD		A&P	PRC	ARC	DIS	2016 →	ATM
EnMAP	DLR	MD	ACQ	A&P	PRC	ARC	DIS	2017 →	HYPER
Tandem-L	DLR	MD	ACQ	A&P	PRC	ARC	DIS	beyond 2019	L-SAR IF
FireBIRD	DLR		ACQ		PRC	ARC	DIS	2012 →	IR Fire
RapidEye	RapidEye AG/DLR					ARC	DIS	2008 →	MULT
GRACE	DLR/GFZ,JPL		ACQ		PRC	ARC	DIS	2002 →	GRAV
CHAMP	DLR/GFZ,JPL		ACQ		PRC	ARC	DIS	2000-2010	GRAV
ESA, EUMETSAT Missions									
ERS-1	ESA/DLR		ACQ		PRC	ARC	DIS	1991-2000	C-SAR, OPT, ALT
ERS-2	ESA/DLR		ACQ	A&P	PRC	ARC	DIS	1995-2011	C-SAR, OPT, ALT, ATM
ENVISAT	ESA/DLR	MD	ACQ	A&P	PRC	ARC	DIS	2002-2012	C-SAR, OPT, ALT, ATM
MetOp	EUMETSAT/DLR			A&P	PRC	ARC	DIS	2006	OPT, ALT, ATM
Sentinel-1	ESA/DLR		ACQ		PRC	ARC	DIS	2013 →	C-SAR
Sentinel-2	ESA/DLR		ACQ	A&P	PRC	ARC	DIS	2014 →	OPT
Sentinel-3	ESA/DLR		ACQ		PRC	ARC	DIS	2014 →	OPT, ALT
Sentinel-4	EUMETSAT/DLR		ACQ	A&P	PRC	ARC	DIS	2019 →	ATM
Sentinel-5	EUMETSAT/DLR		ACQ	A&P	PRC	ARC	DIS	2020 →	ATM
Sentinel-5 Pre.	ESA/DLR		ACQ	A&P	PRC	ARC	DIS	2015 →	ATM
ADM-Aeolos	ESA/DLR			A&P		ARC	DIS	2015 →	ATM (wind)
CarbonSat	ESA/DLR		ACQ	A&P	PRC	ARC	DIS	beyond 2020	ATM

Mission	Operator/Partner	EOC Task						Task Period	Mission Objective
International Missions									
NOAA-7 –19	NOAA/DLR		ACQ	A&P	PRC	ARC	DIS	1981 →	OPT, ATM
Terra	NASA/DLR		ACQ	A&P	PRC	ARC	DIS	1999 →	OPT, ATM
Aqua	NASA/DLR		ACQ	A&P	PRC	ARC	DIS	2002 →	OPT, ATM
Landsat-5, -7, -8	NASA,USGS/ESA,DLR		ACQ				DIS	1984 →	MULT
IKONOS	GeoEye/EUSI		ACQ		PRC	ARC		1999 →	OPT
WorldView-2	DigitalGlobe,EUSI/DLR		ACQ		PRC			2009 →	OPT
ALOS	JAXA/DLR			A&P	PRC			2006-2011	L-SAR, OPT
Radarsat	MDA,CSA/DLR		ACQ		PRC	ARC	DIS	1995 →	C-SAR IF
IRS-P6 Resourcesat	ISRO/Euromap,DLR		ACQ					2003 →	MULT
IRS-P5 Cartosat	ISRO/Euromap,DLR		ACQ	A&P				2005 →	OPT ST
ACE	NASA/DLR		ACQ		PRC		DIS	1997 →	Solar wind, Space Weather

MD: Mission Design, ACQ: Acquisition, A&P: Algorithm & Processor Development, PRC: Processing, ARC: Archiving, DIS: Dissemination

ALT: Altimetry
ATM: Atmospheric sounding
GRAV: Gravity mapping
HYPER: Hyperspectral imaging
IR Fire: Infrared fire detection
MULT: Multispectral imaging
OPT ST: Optical stereo mapping
OPT: Optical imaging

C-SAR, L-SAR, X-SAR: C-, L-, X-Band SAR imaging
X-SAR IF: Global DEM via X-band SAR interferometry
C-SAR IF, L-SAR IF: L-band SAR interferometric global imaging

System Developments

End-to-end system capabilities are required for the continuous derivation of information describing changes to Planet Earth. For the key technology areas in this context, EOC has established system development lines in order to safeguard the essential expertise beyond the limited lifetime of single projects.

This approach enables us to maintain generic solutions, advance their functionality, and at the same time increase their level of maturity. Common standards and operational stability can be achieved and enhanced in this way.

On a technical level, the abstraction of requirements, scenarios and system architectures is necessary, resulting in system components that are modular, scalable and configurable for different project applications. Step by step, the pool of well tested, configuration controlled and quality assured building blocks is enlarged, which gives upcoming projects a favorable starting point.

Sustainable system developments require a structured approach, staying power and effective collaboration in order to reach a common scientific and technical viewpoint–one basis for the success of EOC.

SAR-Lab/GENESIS – Processing SAR Data

Processing spaceborne synthetic aperture radar data has been a principal EOC business for decades. Because each evolutionary step of SAR sensors (ERS-1, X-SAR, ASAR, SRTM, TerraSAR-X, TanDEM-X …) posed new challenges for algorithms and processing power, we have established a generic SAR software development environment and software library–the SAR-Lab–which has been maintained and improved for 25 years. The library has powerful features for version management and automatic documentation and hosts a large number of ready-to-use subroutines, such as for signal processing or orbit interpolation. This environment is used both to develop new research prototypes and to create operational end-to-end high performance processing chains. By design, a SAR processor is typically highly specialized, complementing a specific sensor, while the subsequent interferometric (InSAR) processor GENESIS is largely sensor independent. Both the SAR and InSAR processors are coded in C++ and decomposed into functional modules, each taking full advantage of multiprocessor computers to provide the enormous throughput required by modern Earth observation ground segments such as TanDEM-X.

CATENA – Processing Optical Data

Fully automatic processing of optical remote sensing data is still a big challenge, and also a necessity for coping with the ever increasing number of images and user demands. EOC has developed the CATENA software system to process high resolution optical satellite data from SPOT, IRS, RapidEye, Worldview, and many other sources. It consists of three main components: image processing modules, processing chains, and a framework for task scheduling and execution. Due to the wide variety of optical sensor systems, CATENA has been constructed in a very generic and effective way to

CATENA – automatic processing of optical remote sensing data

allow the pre-processing (for example, orthorectification or atmospheric correction) of all relevant sensor data using the same software components. Higher level thematic processing to generate specific products like DEM or soil sealing maps has been integrated into the processing workflow. Processing can be performed in a local computer grid or in the DIMS environment and allows thousands of scenes to be processed fully automatically in a short time frame (1500 SPOT and IRS data sets within one day, for example). A new development at EOC is the CATENA Timeline system, which extends the current system to medium resolution data, like AVHRR and MODIS data, and to the processing of image time series.

UPAS –
Processing Atmospheric Measurement Data

Operational processing of atmospheric composition satellite data is a core activity of EOC. It started in the early 1990s with the GOME sensor on board ERS-2, with continuation ensured for the forthcoming missions extending well beyond 2020. The development of a generic multimission system for the retrieval of trace gases and cloud properties, called UPAS (Universal Processor for Atmospheric UV/VIS/NIR Sensors), was initiated in 2002, with the first version of UPAS being ready in 2004. It became the processor of choice for the generation of operational near-real-time, offline, and reprocessed GOME products. Key design features of UPAS are the flexibility to incorporate new state-of-the-art retrieval algorithms and easy adaptability to different sensors. UPAS is presently used to reprocess SCIAMACHY nadir measurements and for the operational processing of GOME-2 data available since 2007 and 2013, respectively. A second UPAS generation is currently being developed to cope with the huge amount of data expected from the future atmospheric composition missions Sentinel 5 Precursor, Sentinel 4 and Sentinel 5.

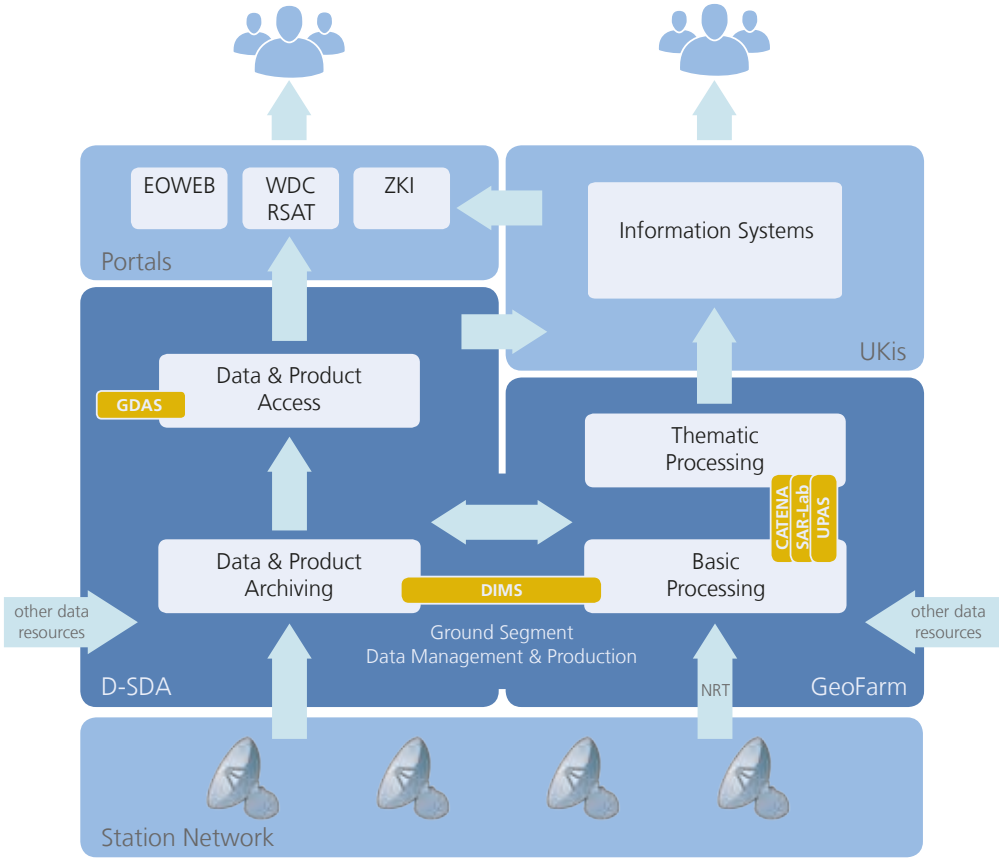
GCAPS –
Processing Atmospheric Sensor Data

The processing of raw instrument data (Level 0) to calibrated data (Level 1), usually radiances, is the first step in the chain for finally deriving geophysical parameters of the atmosphere. In the past two decades EOC had developed Level 0-1 processors for GOME and SCIAMACHY. Both relied on instrument specific approaches. However, with several new atmospheric composition missions becoming operational in the near future, another concept was required to be able to accommodate the needs of advanced instrument designs. This led to the development of GCAPS, the Generic Calibration Processing System. It is compliant with:

- instrument independency
- configurability of calibration chains
- independency from input/output data formats
- usage of standard libraries
- capability of multithreading.

The generic processing is realized as a configurable framework, to which calibration as well as input/output plugins can be added. The first implementation of GCAPS occurs for SCIAMACHY after it has been decided that its new operational Level 0-1 processor shall be developed according to this concept.

EOC's System Landscape



DIMS –
Data and Information Management

Data and information management is a core function for a remote sensing data center and especially for a payload data ground segment. Therefore, EOC decided in the mid-1990s to start a system development line covering cataloging, archiving, ordering, processing control and distribution of Earth observation data. Since then, the multimission Data and Information Management System (DIMS) has been developed, operated and maintained. In order to respond to future mission requirements DIMS is continuously adapted and extended in close cooperation with an industrial partner, Werum Software & Systems, who also takes care of the deployment of DIMS components to other Earth observation data providers such as ESA (six multimission facility infrastructure sites, Sentinel 1 and 3 payload data ground segments), Astrium/Infoterra, and the South African National Space Agency (SANSA). DIMS is designed to be highly configurable, with data models and processing workflows adapting to individual mission requirements. The in-house development of DIMS is a proven key asset ensuring adaptability, independence and sustainability.

GeoFarm –
Processing Infrastructure

Driven by the various needs of Earth observation data users and application projects, EOC developed a concept for a generic Earth observation exploitation service platform. The main elements provided are service-oriented hardware for projects and users, and hardware management and workflow management for data processing. In contrast to former, project-specific solutions, a generic, multipurpose approach is pursued.

Hardware organization follows the cloud-like virtualization of processing hardware, and different environments suitable for

most scientific algorithm implementations can be provided. Hardware can be individually allocated to different users, and for the time being this is accomplished with an operator-based configuration. Further development to achieve dynamic, automated hardware allocation will be necessary. The software realizing the workflow management for Earth observation data processing follows the generic methodology previously developed and used at EOC, but significant further evolution is foreseen and has been initiated, for example, to support bulk processing. Thanks to initial investments, the current system already supports a number of users and projects.

UKIS – Environmental and Crisis Information Systems

Information derived from Earth observation data is invaluable as crisis information or for environmental management. High-level information not restricted to remote sensing specialists can be made available through dedicated information systems.

In 2012, EOC therefore started a project called UKIS to answer the need for user-specific crisis and environmental information. The concept foresees the development of a system framework that is able to combine modular and generic components for monitoring, decision support and early warning in the fields of environment, planning, atmosphere and civil security. The solution completes the end-to-end system chain in the sense that data received by the EOC station network and processed to higher level products can finally be integrated into user-specific analyses and models and assessed together with data from other sources. The results can be used to answer specific questions in the context of crisis and environmental management and are displayed in an easily understandable way, even by those who are not remote sensing specialists. Apart from the benefits for external users, UKIS is also of high in-house value: algorithms developed for specific projects are transferred to generic modules and thus made available for both internal and external future use.

Software Engineering

The development of software is of major importance at EOC. High software quality and our capabilities to further tailor software contribute to a large extent to our own expertise and to internationally acknowledged results. Our in-house developments are also increasingly used in projects with partners outside DLR. In some cases this involves technology transfer to industrial partners.

Our own major developments are conducted and maintained in autonomous product development lines. They originally filled requirements originating in concrete projects, but were consciously evolve to meet additional future requirements. Toward this end, appropriately qualified teams were supplied with dedicated resources and well defined procedures. Powerful tools for requirements analysis, source code management, testing, release and documentation management as well as troubleshooting are the result.

The resulting software systems are configured for use in concrete projects, applications and missions, with the goal of efficient and reliable services with uniform operating and system interfaces and proven and robust components. System integration and software systems operation are organized separately from the development activity; the transfer to operations and software maintenance is performed according to defined procedures. Many in-house developments apply highly-rated standards for software and system engineering, not only the DLR basis standard for software engineering but also those issued by the European Committee for Space Standardization.


Center for
Satellite Based
Crisis Informat

User Services

User services are EOC's link to its customers in science, industry, government and the public sector. They target different user groups to accommodate their specific community needs and diverging levels of knowledge about Earth observation data. Therefore, the user services offer different types of information, from air- and space-borne Earth observation image data to highly sophisticated information products.

All user services at EOC have in common that users can access data and services through a single point of contact or web portal. Further, there are no structural elements, but rather EOC-wide functions. The motivation behind their establishment is that users and customers of Earth observation products and services are not a priori remote sensing specialists. All user services are supplied by EOC as a whole, but coordinated and hosted by one of the two institutes.

In the following, the four current user services are described in more detail.

Center for Satellite Based Crisis Information (ZKI)

The Center for Satellite Based Crisis Information (ZKI) provides a 24/7 service for the rapid delivery, processing and analysis of satellite imagery during natural and environmental disasters, for humanitarian relief activities and civil security issues worldwide. The resulting information products are provided to relief organizations and public authorities and are also freely available on the ZKI website. According to user requirements, the information products are delivered as thematic maps, GIS-ready geodata or dossiers. The latter are used to support disaster management operations, humanitarian relief activities or civil security efforts.

ZKI services provide information products for the various disaster management phases, in other words, before, during, and after a disaster. Each phase places different demands on the satellite information products. ZKI delivers information in rush-mode during the emergency relief phase, but also products for rehabilitation and recovery actions as well as for early warning and disaster prevention. Crisis maps are generated immediately after an event with specific information about the extent of the disaster (for example, the area flooded) and the estimated damage (the affected houses, infrastructure, etc.) in order to assist decision making in situation centers and during relief actions in the field. Further analysis and monitoring of the disaster situation is performed to support reconstruction activities. Moreover, dedicated risk mapping is carried out to support disaster preparedness and mitigation efforts.

ZKI services are offered in three focus areas:

- service provision for German users (ZKI-DE) under contract to the Federal Ministry of the Interior (BMI) since January 2013
- contributions to the European Copernicus program
- international involvement, for example in the 'International Charter Space and Major Disasters.'

Since its establishment in 2004 the ZKI service has been activated more than 140 times and over 800 products have been generated and delivered to users.

World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT)

EOC hosts and operates WDC-RSAT under the auspices of the nongovernmental International Council of Science (ICSU). In line with ICSU regulations, WDC-RSAT's mission is to help support both basic and

Center for Satellite Based Crisis Information

applied scientific research by providing atmosphere related and satellite based data, information products and services. These are offered free of charge through a simplified, standardized and sustainable access channel. Its users are mainly of scientific, administrative, and industrial background.

In 2009 WDC-RSAT received the mandate from the UN World Meteorological Organization, WMO, to also serve as a WMO World Data Center. In accord with WMO's Global Atmosphere Watch Program, WDC-RSAT has been included into the architecture of the new WMO Information System, WIS, being enrolled as a Data Collection and Processing Center. WDC-RSAT's data sets can thus be discovered and retrieved from anywhere within WIS, and vice versa.

Supporting proper data citing in order to advance progress toward open data usage, WDC-RSAT received in 2011 a mandate to operate as a Data Publication Agent on behalf of the Technische Informationsbibliothek Hannover. Data sets can be registered through WDC-RSAT by assigning to them a permanent and searchable DOI (Digital Object Identifier).

Following CEOS recommendations, WDC-RSAT together with NASA established a portal for satellite-based atmospheric composition data to better serve the Global Earth Observation System of Systems (GEOSS).

Contributing to the UN World Climate Research Program, WDC-RSAT hosts and manages the data and information platform of the international Network for the Detection of Mesospheric Change, NDMC.

DSDA
German
Satellite Data Archive

German Satellite Data Archive (D-SDA)

The German Satellite Data Archive (D-SDA) provides Earth observation data management, archiving and access services to EOC's internal and external customers.

D-SDA data management services are based on components of the Data and Information Management System (DIMS), an in-house development. They are a key element of national and third party Earth observation mission ground segments, examples being the national radar missions TerraSAR-X and TanDEM-X and the Copernicus mission Sentinel-5 Precursor. Internal projects also use the services provided by D-SDA for large volume data archiving and retrieval and to provide customized data access by a specific user community.

In data archiving D-SDA focuses on providing long-term data preservation (LTDP). In line with international procedures and guidelines LTDP provides sustainable archiving and ensures the usability of the data and products by future generations.

Users can access D-SDA data by selecting from several discovery and data retrieval options. Systematic data dissemination on a subscription basis is supported as well as interactive acquisition tasking, data discovery, and ordering via the main D-SDA data portal EOWEB®-NG.

In order to ensure the interoperability of data discovery and access systems, D-SDA observes the standards set forth by the Heterogeneous Mission Accessibility initiative and the Open Geospatial Consortium (OGC).

In line with these developments D-SDA has recently introduced the EOC Geoservice to supplement existing services with convenient, state-of-the-art data discovery, visualization, and direct download functionality. Through the

OGC-compliant EOC Geoservice D-SDA, Earth observation data and products are integrated into the German geospatial data infrastructure GDI-DE of the Federal Agency for Cartography and Geodesy and are accessible via its central data portal Geoportal.DE as well as via compliant spatial data portals worldwide.

Optical Airborne Remote Sensing and Calibration Home Base (OpAiRS)

An essential part of EOC's remote sensing competence is its long-term experience in the field of airborne remote sensing with imaging optical sensors. Since 1995, DLR has been calibrating and operating its own airborne imaging spectrometers and is developing software tools for data processing and evaluation for different application fields. This service, called the Optical Airborne Remote Sensing and Calibration Home Base (OpAiRS), has been ISO certified since 2007.

OpAiRS operates different airborne hyperspectral sensors (in the time period 2007-2013: HyMap, HySpex, ROSIS) and field spectrometers, and it runs the Calibration Home Base (CHB) as a facility for the calibration of such sensors. The CHB allows accurate radiometric, geometric and spectral sensor characterization in the wavelength range from 350 to 2500 nm.

Hyperspectral image data are also processed at OpAiRS. The pre-processing software consists of modules for system correction, fully parametric orthorectification and geocoding, as well as atmospheric modeling for the conversion of imaging spectrometer data to ground reflectance values.

Calibrated field spectrometers are used for the spectral and radiometric validation of airborne sensor data and to determine the spectral properties of land and water targets and of the atmosphere during field campaigns.

Several national and international campaigns have been organized, coordinated and managed by EOC. They cover the system chain from sensor integration/ adaptation to aircraft, system calibration, campaign management, data processing, evaluation, distribution, and archiving.

ZKI provides a 24/7 service for the rapid provision, processing and analysis of satellite imagery during natural and environmental disasters, for humanitarian relief activities and civil security issues worldwide

Central Services

EOC greatly profits from the synergies rsulting from the close collaboration of its two institutes. Central services like IT management, controlling, quality management, science visualization and web services are jointly financed, used, and further developed.

This makes available an extensive range of services that could not be realized to this extent by each institute alone.

IT Management

The IT management is responsible for EOC's IT infrastructure.

Especially EOC's numerous operational tasks in connection with reception, processing, archiving and distributing remote sensing data impose special requirements. Data integrity, data security, data throughput, data transfer over WAN, near-real-time response, and availability are key factors.

Several tasks performed by EOC use infrastructure provided by partners, examples being the processing and archiving center for ESA's Sentinels or the reception and processing equipment for WorldView-2. This equipment is usually located in a separate network environment with separate WAN access and therefore increases the complexity of IT management.

A further complexity arises from our infrastructure located across the globe. Four receiving stations, inter alia in the Arctic and Antarctica, and four sites in Germany require communication over WAN, including satellite links.

The EOC office, research and operational environments require a number of IT infrastructure elements, the most important being:

- LAN and WAN
- computer rooms including air conditioning and an Uninterruptable Power Supply
- servers, blade centers and virtual machines
- disk storage and a Storage Area Network (SAN)
- long term archiving elements (robot libraries and tape drives)
- personal computers
- central services (home service, backup service, print service, license service)
- communication systems (phones, video conference systems).

IT core elements such as servers and storage systems are installed and operated by EOC personnel. Standard administrative tasks such as installing personal computers or installing and operating office communication infrastructure are procured from the DLR IT service provider.

Every five years the IT management is reviewed by a team of external experts. The last IT audit was performed in 2012 when the IT management was declared to be of high standard.

Quality Management

EOC is committed to the concept of quality management and its application to all working practices. Since 2007 EOC has operated a quality management system complying with the requirements of ISO 9001; the system is subject to external audit certification.

EOC's quality management system is based on a two-tiered management model, consisting of 'Business Management' and 'Product Realization'.

Business management covers the domains of top management, resource management, quality management and project management.

Project management is the predominant method of conducting business at EOC. Management methods and guidelines are defined with a focus on satellite ground segment projects. Risk management and product assurance form an integral part, which assures that the product fulfills customer requirements and that the product is safe, available and reliable.

A principle characteristic of EOC's quality management system is the adoption of a generic entity model approach in the domain of 'Product Realization.' Entities are self-contained operational units, clearly defined through functionality and specific products and services. They are supported by facilities. Entities are independent of the EOC organization, i.e., they may span organizational units and various local sites. EOC has identified two operational areas in which entities are defined, namely Ground Segment Operations and User Services. The aim is to assure stable product and service delivery.

The detailed design of the EOC quality management system and its processes are documented in the EOC Quality Manual.

Controlling

Controlling supports the EOC management level in planning, controlling and monitoring both institutes. EOC scientists find assistance here in drawing up proposals and carrying out complex international projects. A third-party financing quota of almost 50%, financing from three DLR program areas (space, transport and aeronautics), institutional financing by HGF, by various national Earth observation missions, and through industrial partnerships requires elaborate planning and monitoring processes.

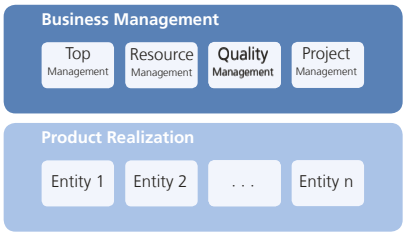
Controlling comprises the following tasks:

- personnel management
- provision of financial information to facilitate decision making
- project-related support services
- carrying out planning and control processes.

Planning and control processes are implemented in the following areas:

- staff allocation planning
- overheads
- major technical facilities
- in-house project financing
- third-party financing (projects/allocations)
- investment management.

These processes are governed by the DLR planning calendar and relevant guidelines. Data is handled via SAP. The EOC directors and unit heads provide at regular intervals up-to-date target vs. performance comparisons.



Two-tiered Quality Management System of EOC, where Business Management deals with the management of EOC and Product Realization is related to EOC's operational units, so called Entities

ISO 9001

DNV

Certified Company

The two operational areas User Services and Ground Segment Operations are ISO 9001 certified with their entities WDC, ZKI, OpAiRS, Ground Station Services – Neustrelitz, Ground Station Services – O' Higgins and CATENA (status 2013)

Science Visualization

Science is judged by its value for society. This value must be visible and comprehensible by laypeople, which is why EOC engages in science visualization. It provides a graphic, understandable interpretation of research data and complex topics. Animations facilitate the analysis of time series; audio-visual research presentations depict relationships succinctly and clearly; mobile apps bring data to the user.

At EOC an entire department is involved in this task, which is unique in DLR. Geoscientists work closely with designers to combine science data processing with Hollywood visualization techniques. They produce films and animation sequences, plan entire exhibitions and individual interactive exhibits, carry out international book projects, and use web and app technologies to distribute information products.

The effort is considerable, but it secures public support, financial resources, and the next generation of scientists. In the meantime, the service is used DLR-wide and not only by EOC.

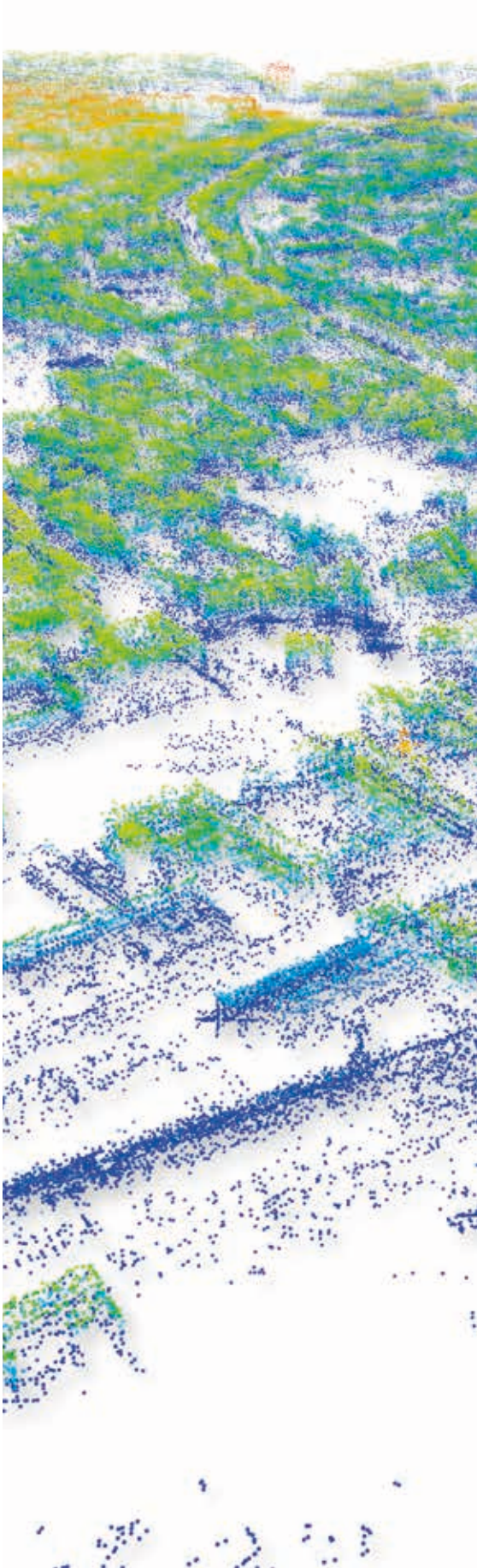
Web Services

Having direct contact with users, the media and the public at large is important for us. For this reason, EOC operates an elaborate web portal with news, an event calendar, its own media library, and a collection of articles. It also assists users to quickly find an appropriate EOC contact. A data guide helps users find what they are looking for. An EOC help desk answers questions and supplies nonscientists like media representatives, commercial agencies, publishers and educational institutions with images and information.

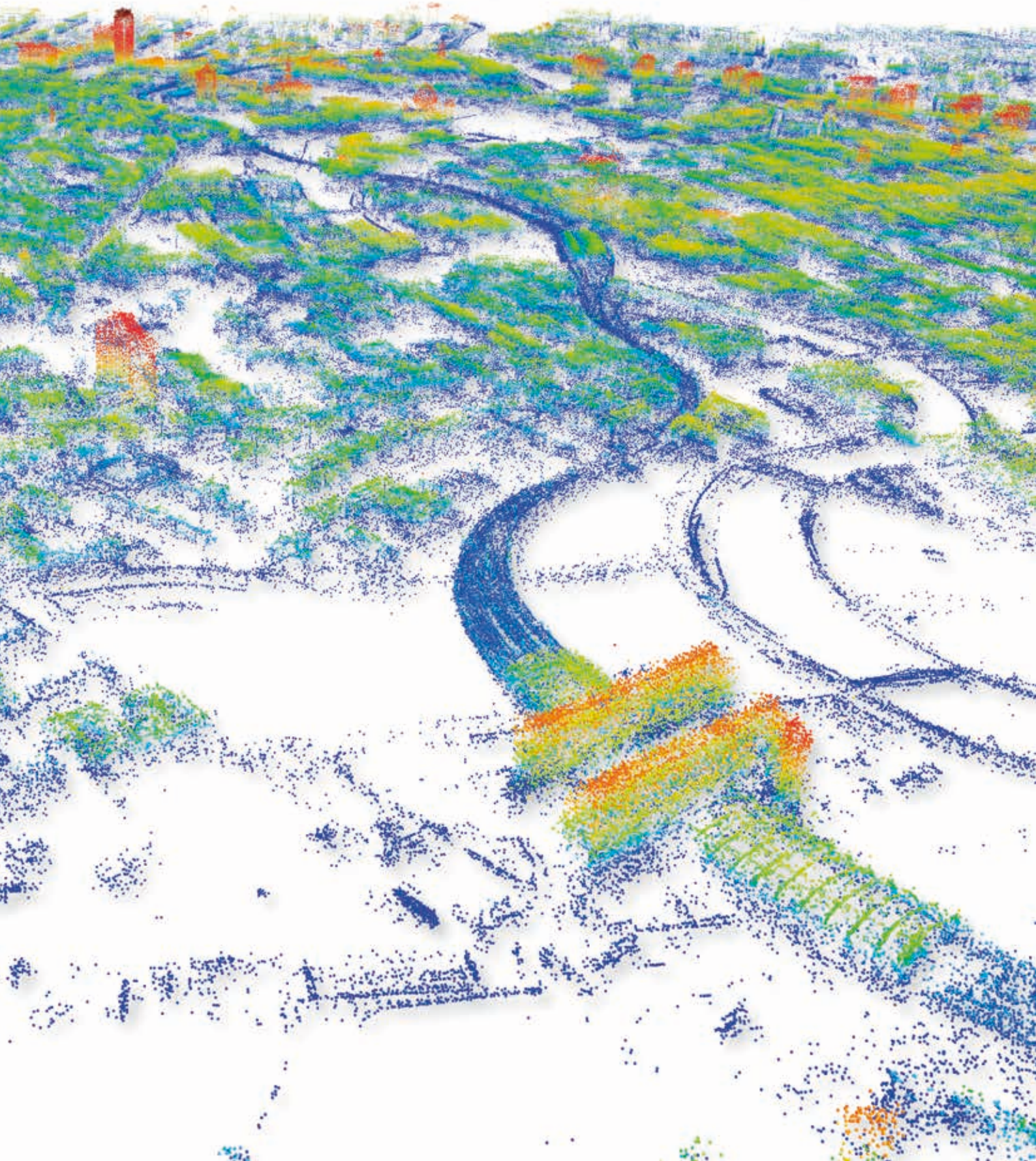
The EOC web portal is the largest DLR subportal and is kept up-to-date on a daily basis. In 2011 the portal was streamlined to contain just three navigation levels and in 2012 was the first DLR subportal to incorporate DLR's new corporate design specifications.

In addition to the official EOC portal, EOC supports other portals not governed by the DLR corporate design. These are used to present projects and partners. All external project portals have a uniform software basis.

The public-access EOC portal is complemented by an EOC intranet of comparable size which supports internal knowledge management. Here organizational information is made centrally available to EOC staff.



More than four million permanent scatterer points derived from numerous SAR data sets are depicted in this scientific visualization of downtown Berlin. Permanent scatterer analysis permits detection of elevation changes in the range of millimeters.



German Remote Sensing Data Center

German Remote Sensing Data Center

Overview

Since 1993–exactly 20 years ago–the German Remote Sensing Data Center (Deutsches Fernerkundungsdaten-zentrum, DFD) has borne its present name. It had been brought into being 13 years earlier, in 1980. Then called the 'Hauptabteilung Angewandte Datentechnik,' its role was to develop systems for processing, archiving and distributing to users the expanding data streams coming from Earth observation satellites.

Since that time, Earth observation has made rapid advances. And DFD has significantly evolved during the past three decades as well. The construction of an Antarctic ground station in the early 1990s and the integration of the Neustrelitz remote sensing station after German unification were decisive steps. Since then we completed a payload ground segment and established and expanded an internationally recognized network of receiving stations. This infrastructure in turn formed the basis for many other developments, such as the data management system DIMS. Without the payload ground segment, important milestones like the TerraSAR-X and TanDEM-X missions could not have been envisioned.

In parallel to this technical expertise, we have increased our competence in the area of applications development. In no comparable European institution is there an analogous architecture comprised of geoscience research, engineering advances, around-the-clock uninterrupted operation of receiving stations, and a national data archive.

Empowered by the multiplying technical possibilities, at DFD we increasingly focus on analyzing and using data. We develop processes, methodologies, and products that make Earth observation data comprehensible for research and practical use. Our priority topics in the areas of Atmosphere, Land Surface, Georisks and Civil Security are selected with relevant applications in mind. The aim is to provide answers and methodological tools for addressing questions and problems relating to a changing Earth.

Today we are in a position to provide operational-quality information systems, from data reception to product chains, all from one source. DFD has taken the step from being only a data provider to a systems developer and is preparing itself for the next paradigm shift, to become a provider of comprehensive information based on Earth observation data relevant to society.

In Neustrelitz and Oberpfaffenhofen some 230 staff are at work in seven specialized departments. Institutional cooperation with universities in Würzburg (land surface) and Augsburg (atmosphere) and close collaboration with working groups there complement our research and ensure access to the next generation of scientists.

DFD staff in Oberpfaffenhofen in May 2013 in the atrium of the EOC building

DFD staff in Neustrelitz in June 2013 in front of their new institute building

Activities and Basic Skills

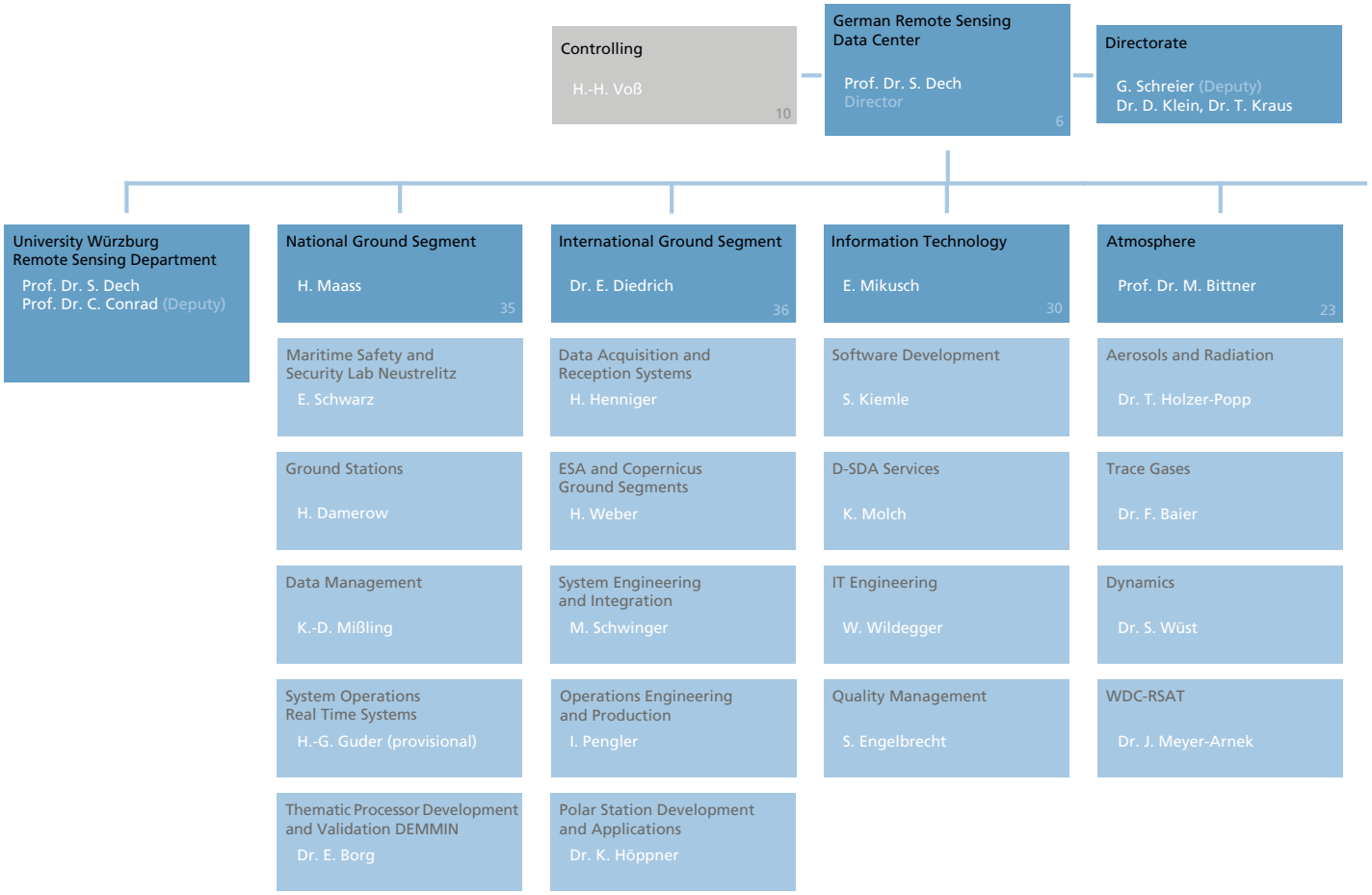
DFD develops and operates a payload ground segment for national, European and international Earth observation missions. Through its ground station network it establishes direct and autonomous access to the payload data of these missions. It produces information products, distributes them to users, and archives all data and products long term in the German Satellite Data Archive, which is a key component of Germany's infrastructure.

DFD supports not only research, but also the public and private sectors: with its technical infrastructure and data access points like the German Satellite Data Archive (D-SDA) and with services like the World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT) and the Center for Satellite Based Crisis Information (ZKI).

Our strengths are our expertise in multimission ground infrastructure, satellite data processing systems, and data management, combined with our specialist skills in such matters as deriving time series of atmosphere and land surface data.

DFD premises in Neustrelitz

Staff at the Remote Sensing Unit at Würzburg University


Controlling
H.-H. Voß
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German Remote Sensing Data Center
Prof. Dr. S. Dech
Director
6
Directorate
G. Schreier (Deputy)
Dr. D. Klein, Dr. T. Kraus
University Würzburg
Remote Sensing Department
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Prof. Dr. C. Conrad (Deputy)
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Maritime Safety and Security Lab Neustrelitz
E. Schwarz
Ground Stations
H. Damerow
Data Management
K.-D. Mißling
System Operations Real Time Systems
H.-G. Guder (provisional)
Thematic Processor Development and Validation DEMMIN
Dr. E. Borg
International Ground Segment
Dr. E. Diedrich
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Data Acquisition and Reception Systems
H. Henniger
ESA and Copernicus Ground Segments
H. Weber
System Engineering and Integration
M. Schwinger
Operations Engineering and Production
I. Pengler
Polar Station Development and Applications
Dr. K. Höppner
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Software Development
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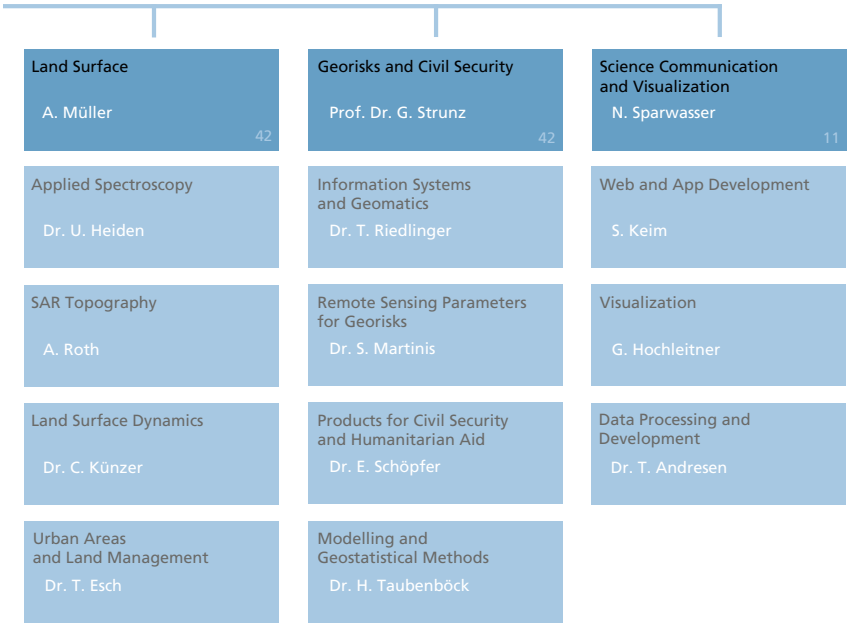
Aerosols and Radiation
Dr. T. Holzer-Popp
Trace Gases
Dr. F. Baier
Dynamics
Dr. S. Wüst
WDC-RSAT
Dr. J. Meyer-Arnek



DFD organigram

Our work establishes these information sources for specific environmental and civil security applications. We develop technologies to support decision making and approaches to disaster management. Experts in data visualization and information design help to reduce the obstacles for users.

DFD is widely involved internationally and carries major responsibilities in long-term research projects with partner organizations around the world.

Role within DLR

DFD is both a research institute and a central development and operations facility.

DFD's geoscience activities complement DLR research in the Institute of Atmospheric Physics and assist other DLR institutes by providing infrastructure as well as technical and scientific expertise for joint services and projects.

The following sections, Payload Data Ground Segment and Geoscientific Research and Applications, describe in detail the activities of DFD.

The DFD user services are introduced in the joint EOC presentation.

The institute's key statistical indicators are to be found at the end of this document.

Payload Data Ground Segment

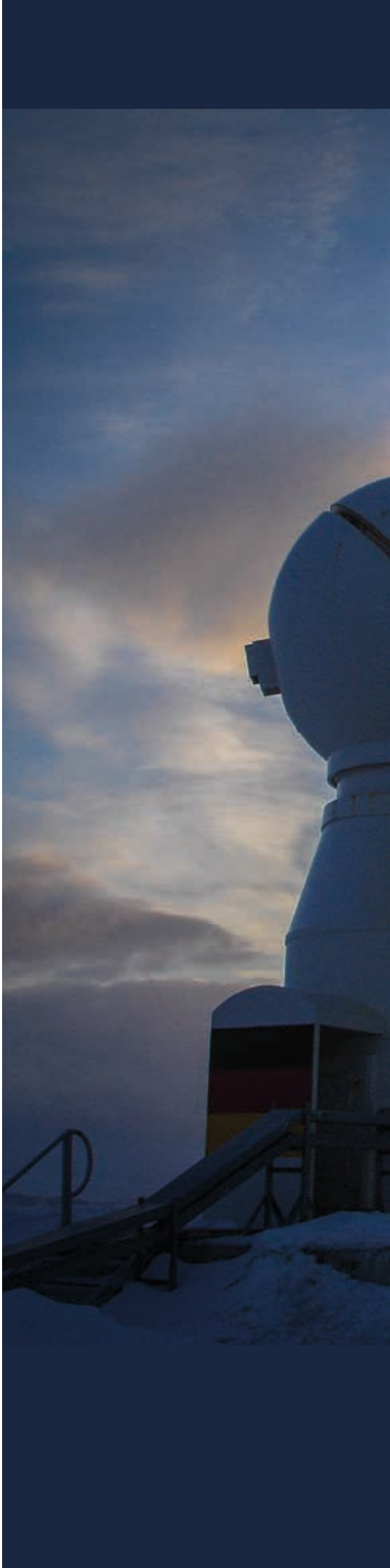
Payload Data Ground Segment

The roots of science and engineering work at DFD are inherited from its predecessor institute, the 'Hauptabteilung Angewandte Datentechnik,' created in 1980. Acquisition of Earth observation satellite data and processing, archiving and distributing these data was the main focus of this institute before it was renamed the German Remote Sensing Data Center (DFD) in 1993. Since then, DFD has added new technologies and new skills to these functions, which comprise the Payload Data Ground Segment (PDGS) for Earth observation missions.

The work and systems of this part of DFD aim to advance engineering in Earth observation data handling and to set-up the necessary infrastructure to make mission data, products and services available for science, the economy and society. Being part of national missions, DFD develops skills and systems in order to be self-reliant in the set-up and operation of space based environmental and security information systems. We share these skills and systems with European missions, in international science networks and to support commercial partners.

The ground segment engineering and PDGS functions at DFD can be therefore itemized as:

- acquiring mission payload data from observation satellites, by receiving the data downlink with DFD antenna systems and data recorders
- routine processing of the acquired data to base level and higher level products. This includes reprocessing historical data as well as fast near-real-time product generation
- cataloging archiving all acquired and processed data for on-line access as well as for the long term storage of



German Antarctic Receiving Station O'Higgins

The German Remote Sensing Data Center emerged from the 'Hauptabteilung Raumflugbetrieb' in 1980. The 4th person from left to right is DFD´s founding Director, Prof. Winfried Markwitz, at that time also responsible for the Space Operations Department. Some of the depicted staff member still work in the EOC today.

all global mission data beyond the petabyte range, including both access to the archives and the distribution of Earth observation data and products

- automated management of the entire data flow in a flexible, operational workflow, including interfacing with external functions and data sources.

These functions and the physical locations in Oberpfaffenhofen and Neustrelitz determine the duties of the three DFD departments engaged in PDGS engineering and operations:

- National Ground Segment (NBS) with staff, data acquisition antennas and processing systems in Neustrelitz
- International Ground Segment (IBS) with staff, data acquisition antennas and processing systems in Oberpfaffenhofen as well as further acquisition antennas in Inuvik, Canada; Chetumal, Mexico and O'Higgins, Antarctica
- Information Technology (INF) with staff, systems and the national Earth observation data archive in Oberpfaffenhofen.

These three departments represent about half of the DFD staff. Their work in the reporting period is described in the following sections of this chapter.

The development of DFD's current capabilities and expertise in the PDGS was to a large extent driven by its involvement in national missions. Before this involvement, we successfully participated as a core ground segment partner of ESA in many European Earth observation missons. Within the ground segment of the European flagship missions ERS-1/2 and ENVISAT, DFD was a Processing and Archiving Center (PAC). While major parts of the processing, especially for the atmospheric science payloads on ERS-2 and ENVISAT, were developed and engineered by DFD, ESA determined the overall concept and supervised the PDGS.

For national Earth observation missions, such as the Shuttle Radar Topography Mission (SRTM) and the TerraSAR-X and TanDEM-X satellites, DFD was responsible for the concept, system engineering, realization and operation of the entire PDGS. Data from these missions are commercialized through Public Private Partnerships (PPP), for example with Infoterra/ASTRIUM Geoinformation Services. In parallel, further industrial partners requested DFD to support their commercial ventures in ground segment design and operations. This includes PDGS services for Indian Earth observation satellites together with the Euromap company, Neustrelitz, and services for very high resolution U.S. optical satellites together with the European Space Imaging company, Munich.

Besides our increased duties and responsibilities in the ground segment, we are also benefiting from rapid developments in computing and information technology. Just to give two examples, expensive data recording technologies are now entirely substituted by direct digital recording using standard components, and data archiving in the petabyte range is now possible with new media technology. The internet and the corresponding evolu-

tion of 'Big Data' computing is a further development. Users nowadays access products only via the internet and expect convenient web-based portals. Global data sets and time series can now be processed on a farm of standard computers using shared computing resources in a cloud environment. We accommodate all these new developments in our systems and services. In doing so, we are careful to meet the requirements of the missions and their users without losing the ability to adapt these new technologies for our own systems.

In order to serve national missions and to guarantee sustainable, independent access to the satellites, our international data acquisition antenna network was expanded by a further station in the North Polar Region (Inuvik, Canada). As with our other international stations, these systems are embedded in collaborative agreements on science and data use with the host countries. We have also started to explore new data transfer technologies, such as data relay via the European Data Relay Satellite System (EDRS). Near-real-time data and information provision, as required for disasters mapping and maritime security, are further drivers of our acquisition and processing technologies.

During the last few years, this processing was increasingly transferred from specialized computers to general purpose multiprocessor systems. Today, we are working on the 'virtualization' of processors in order to flexibly accommodate the needs of missions, our science projects and our partners with large-scale computer farms (GeoFarm) and to share these capabilities with others.

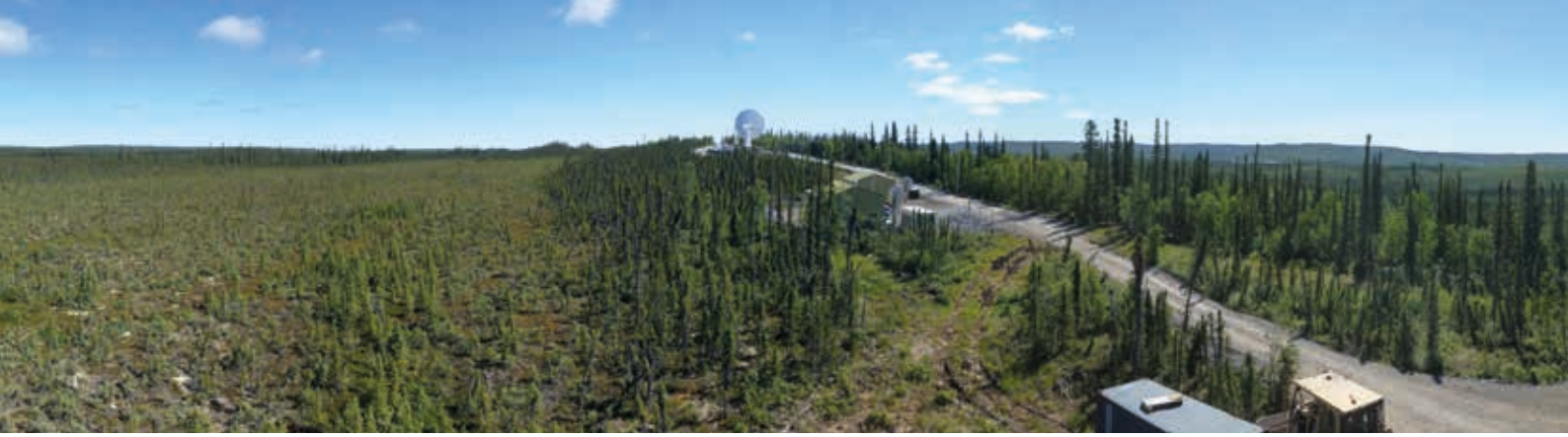
DFD is a key European player in the transparent sharing of data and information via the internet. We have participated in corresponding European projects, have adopted international standards (OGC) and are registered with the national governmental data initiative (IMAGI). Based on our robotic archive systems and standard open user interfaces, we are setting up a national German Satellite Data Archive (D-SDA). Apart from fast and convenient access to all our data, our concern is also long term data preservation in order to allow future users to generate time series of regional and global change patterns.

Based on these developments and technical infrastructure, DFD is prepared to be a key partner in future national as well as European Earth observation missions. We therefore participate in developing ground segment mission concepts for the next generation SAR, optical and hyperspectral missions. Therein, DFD and the Flight Operations/Missions Control division of the DLR German Space Operations Center (GSOC) complement each other in order to guarantee a state-of-the-art, autonomous national ground segment.

In the European long term Earth observation program Copernicus, DFD was awarded a contract to operate a Processing and Archiving Facility (PAC) for the Sentinel-1 and -3 missions, as well as for the Sentinel-5 precursor. Specifically for atmospheric measurements, we also continue to play an important role in the Eumetsat network. This work is complemented by the continuation of ground segments for non-European missions, using the excellent location of our German stations to provide full European coverage.

We complement these European functions with further developments toward establishing national access to these missions and sharing the Copernicus data with national science projects and commercial partners. Therefore, DFD is currently working to create a national data hub in the framework of an initiative of DLR, the Bavarian Ministry of Economic Affairs, and commercial partners.

Relevant Publications: [216], [272], [286], [451]



Arctic satellite station in Inuvik, Canada inaugurated in 2010 and used particularly to receive data for the German TanDEM-X satellite mission

Data Acquisition

Global Earth observation requires fast, reliable and global access to remote sensing satellites. DFD operates national facilities in Neustrelitz and Oberpfaffenhofen and an international station network in Inuvik (Canada), O'Higgins (Antarctica) and Chetumal (Mexico).

With its own global network DFD can be an independent player in the Earth observation market with the ability to perform highly complex tasks such as those associated with the TanDEM-X mission. Data acquisition from national, European and international Earth observation missions encompasses the design, setup, operation, maintenance and continuous upgrade of large and complex equipment systems.

The rationale behind this station network lies in the missions' needs for the reception of very high data volumes, avoidance of spots on Earth that cannot be covered by the orbit, and near-real-time performance. In addition, this station network complements the mission operation capabilities to perform telemetry and telecommand functions for the polar location at O'Higgins and the station in Inuvik. For previous missions like ERS-1 and ERS-2 the station network was needed for direct broadcast downlink after data take or because an on-board data recorder was lacking. Back then, data could only have been acquired for regions within the visibility circles of an available station. Despite today's on-board storage capacities of satellites, this scenario remains valid in cases of conflicting resource demands.

Using near-polar stations has a major benefit: the number of stations can be kept low. Such extremely high latitude stations provide the nearly complete daily coverage of all satellite orbits at the expense of higher costs for logistics and communication.

The TerraSAR-X and TanDEM-X missions are examples showing the advantages of this station concept. A daily downlink of about 450 gigabytes of data requires a total contact time of more than three hours per day. This is only made possible by using the full DLR station network comprising Neustrelitz, O'Higgins, Inuvik, Chetumal (for certain peak load orbits) and the station of the Swedish Space Corporation SSC in Kiruna.

A multimission station concept and comprehensive in-house development of software solutions enable DFD to quickly adapt its infrastructure to new missions and to operate receiving stations remotely. DFD developed various control systems and software tools for a high degree of automation, high reliability, and maximum support for the operators. Together with an elaborated operating and maintenance concept the station network can be run in a highly efficient and flexible way.

Ground Station Neustrelitz

In 2012 the national ground station in Neustrelitz received a new building with modern infrastructure, now hosting rooms for development, integration, data reception, data processing and the operation of ground segment functions. The station is used as the main national ground station for high rate data stream reception in X-band, as well as for satellite housekeeping S-band data reception in special cases. The ground station consists of three 7.3 m S/X-band antenna systems, which fulfills present Earth observation mission requirements. The ground station complex is operationally used for remote sensing missions and several small exploration missions. On behalf of the European Space Agency, Neustrelitz is part of ESA Earthnet for data acquisition and processing. Two dedicated antenna systems (6 m and 4 m dishes) are used to acquire data from NOAA's solar sentinel satellite ACE (Advanced Composition Explorer). DFD is in the framework of this cooperation the

European node in a worldwide network for the Space Weather Prediction Center in Boulder, Colorado, USA.

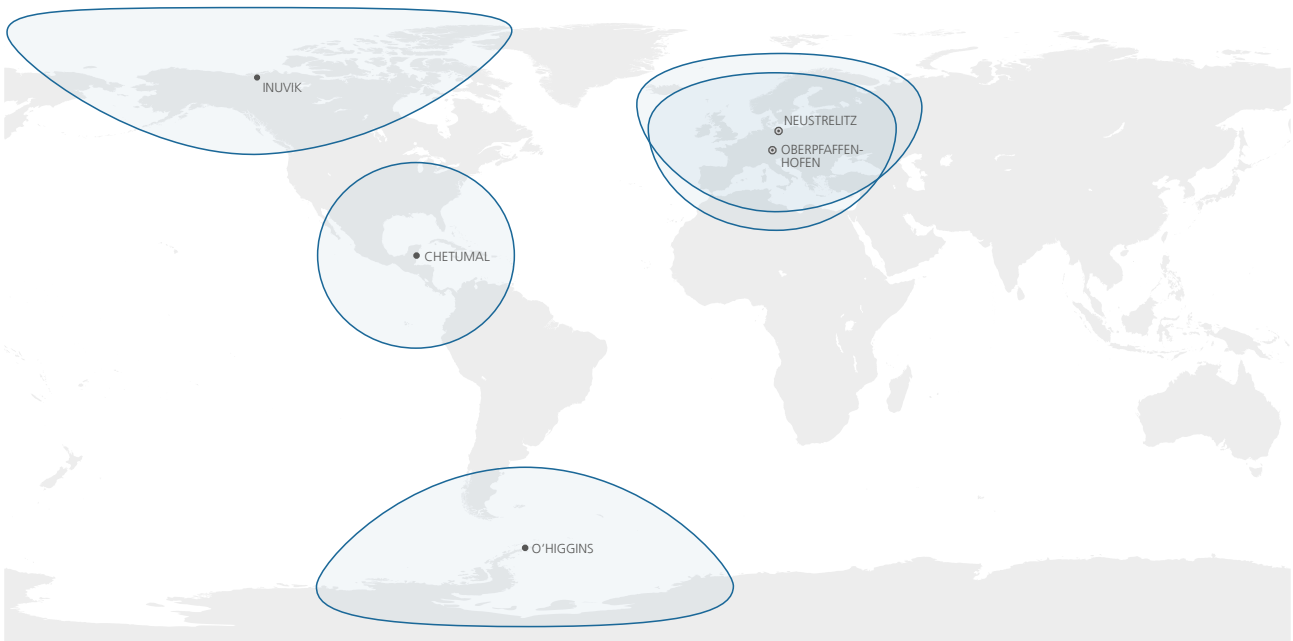
All reception antennas are combined in a multimission reception system, which is monitored and controlled by one operator on a 24/7 basis. A concept for redundancy has been implemented that allows for reconfiguration of the system to redundant devices in case of need.

Ground Station Oberpfaffenhofen

The historic starting point for DFD data acquisition activity was the reception of meteorological data at Oberpfaffenhofen in 1982. This activity was continued in the reporting period, providing lengthy time series for further exploitation in global change research. The data are used to produce value added products from NOAA AVHRR and MODIS data. For example, DFD provides near-real-time hot spot detection for the European Forest Fire Information System as well as data services for commercial companies such as EOMap GmbH.

Since 2003, satellite images with a high resolution of one meter have also been received in Oberpfaffenhofen. The ground station for high-resolution data was originally established for the IKONOS regional operations center for the tasking and acquisition of IKONOS satellite data. The equipment is owned by the Munich-based company European Space Imaging. In an agreement with European Space Imaging, DFD handles all types of technical maintenance and operations, whereas all investments in the facility are covered by its owner.

Visibility circles of the receiving stations



Under the same framework agreement, Oberpfaffenhofen became a World-View-2 European direct access facility for image data with a resolution of fifty centimeters. Therefore, a new antenna was set up on the roof of the freshly renovated EOC building. EOC is also hosting the operations room as well as the necessary technical equipment.

On duty for DFD throughout the year 14 000 kilometers from home – their only neighbors: the Chilean military and penguins

The agreement with European Space Imaging guarantees EOC for research purposes noncommercial and direct access to very high resolution optical data of otherwise commercial satellite systems. Scientists and engineers thus have priority access to the data in order to develop new processing and information extraction algorithms, including those developed in the DFD Center for Satellite Based Crisis Information (ZKI).To optimize the data collection, DFD has developed a tasking system that takes into account the latest meteorological information in order to gather cloud-free images over Europe.

German Antarctic Receiving Station, GARS O'Higgins, Antarctic Peninsula

The GARS O'Higgins Station is located on the Antarctic Peninsula in the vicinity of the Chilean Antarctic Base General Bernardo O'Higgins (63.32° S 57.90 W). It was established to provide remote sensing data support within the European ERS mission for the German Polar and Oceanographic Research Program. The station also provides Very Long Baseline Interferometry (VLBI) support to the German Geodetic Research Program under a cooperation agreement with the German National Cartography and Geodesy Agency, BKG. The station became operational in October 1991 and has been operational since then in a campaign scenario. Since 2010 GARS O'Higgins has been in operation and manned during the whole year, specifically to support the TanDEM-X mission. The facility is designed for autarchy in operation. This means that all major infrastructure elements, such as Diesel generators and technical equipment, have sufficient redundancy and spare parts on site. Only thus can uninterrupted support to satellite missions be guaranteed, and indeed it was achieved over 99% of the time from the start of year-round operations in

2010. The nearby Chilean base provides only logistic and emergency support. A cooperation agreement based on the Inter-Governmental Research and Technology Framework Agreement was established to specify the relationship between the Chilean base and the German ground station, in cooperation with the Chilean Antarctic Institute INACH (an organ of the Chilean foreign ministry) partner.

In recent years the station was upgraded for new satellites, which included the installation of an additional permanent satellite communication link with bandwidth up to 15 Mbit/s (in addition to 256 kbit/s for internet and telephone services plus a 128 kbit/s ISDN link for satellite operations). This allows limited data transfer from the station to Europe.

Since 2010, two operation engineers staff the station, working a shift/backup schedule and being exchanged after about six weeks. In parallel, a contractor company provides infrastructural support from an engineer and one to three technicians, depending on the required station maintenance. Remote operation of the antenna system from Germany is realized successfully with a DFD-developed station monitoring, control and scheduling system. Logistics operations are handled by the Chilean Antarctic operators (Air Force, Navy and Army), coordinated by the Chilean Antarctic Institute. To a limited extent, commercial aircraft and ships (full or partial charters) are involved. Heavy equipment and fuel are transported to O'Higgins by ship; personnel and electronics by aircraft. Access is possible throughout the year by aircraft, depending on weather conditions.

Aerial view of the German Antarctic Receiving station in winter conditions. The red buildings belong to the Chilean base, whereas the white buildings belong to DFD

A Twin Otter DHC-6 takes off – logistics operations are handled by the Chilean Antarctic operators, coordinated by the Chilean Antarctic Institute. To a limited extent, commercial aircraft and ships are involved.

German Arctic Station at the Inuvik Satellite Station Facility, Canada

Initially triggered by the needs of the German TanDEM-X mission, DLR investigated a possible station set up in the Canadian Arctic. Fact-finding missions, location analysis and infrastructure analysis in 2008/2009 led to the selection of Inuvik, North West Territiories, Canada for the station location. A property outside the town of Inuvik in the western Canadian Arctic (68.3 N 133.5 W) was made available to DLR by the Canadian Center for Remote Sensing (CCRS), acting on behalf the Canadian government. Since 2010 DFD has successfully placed, tested and operated the first satellite antenna system at this site. DLR and the CCRS have signed cooperation agreements on hosting the DLR facilities at this site and on the regulative issues for receiving data from Earth observation satellites in Canada. The site in Inuvik, the northernmost settlement in Canada that can be accessed by road, marks the first ground station north of the Arctic circle in Canada. This facility is especially important for the German satellite mission TanDEM-X. Inuvik was chosen together with Neustrelitz to cover most of the orbits of this mission. In combination with a northern European station, such as Kiruna, all orbits can be covered.

After the TanDEM-X satellite was launched on 21 June 2010 the DLR antenna at the Inuvik satellite station facility supported the commissioning phase of this mission and is now used for fully operational support. A further identical antenna system owned by the Swedish Space Corporation (SSC) was set up and has been operational at Inuvik since August 2011. An agreement between DLR and the SSC regulates free-capacity sharing and backup-service provision.

The Inuvik station is connected by a fiber link to the town of Inuvik. The hosting of DLR electronic equipment and the maintenance of basic infrastructure (like power, communications, roads, fencing,

DFD satellite receiving station in Inuvik, in the Northwest Territories of Canada 200 kilometers north of the Arctic Circle

The Tropical Chetumal on Yucatán peninsula in Mexico imposes special conditions for an Earth observation satellite receiving station

webcams) is guaranteed by a long-term service contract with PrioraNet Canada. On-call services, including engineering, are available.

DFD operates and maintains the system. Except for maintenance and upgrade, DFD operates the station remotely from Oberpfaffenhofen utilizing its own station monitoring, control and scheduling system. Support of telemetry, tracking and command services for critical mission phases is provided by on-site DFD personnel on a case-by-case basis, for example for launch and early orbit phases or the initial phase of the close formation flight of TanDEM-X.

German Ground Station in Chetumal, Mexico

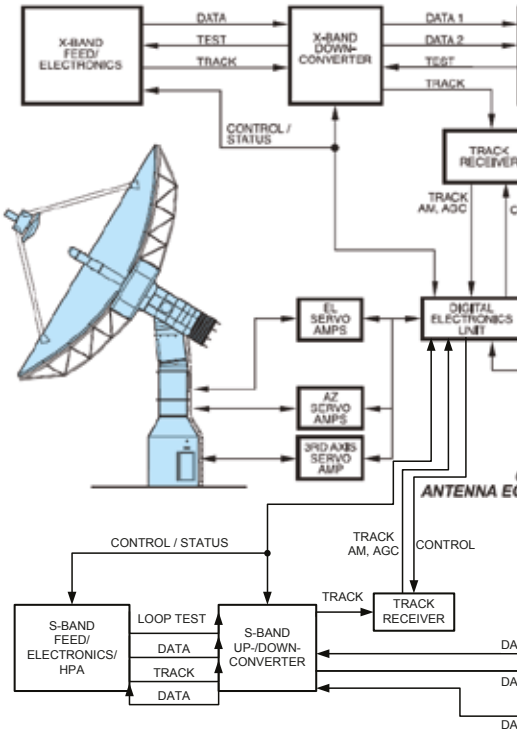
The 'Estación para la Recepción de Información Satelital' in Chetumal, Mexico, consists of DFD's transportable receiving station. It is an 8-meter antenna that uses X-band frequencies (reception and tracking between 8.0 GHz and 8.4 GHz) and L/S-frequencies (reception and tracking between 1.7 GHz and 2.3 GHz). When first used at a site in Gabon, Africa, it supported missions like ERS, Landsat, and Aqua/Terra. DFD now operates this antenna in cooperation with Conabio (Mexican National Commission for Knowledge and Use of Biodiversity). The antenna is installed on a new building of ECOSUR (El Colegio de la Frontera Sur) at the University of Chetumal.

The primary purpose of the station is to support the needs of Mexican governmental agencies for direct Earth observation satellite data reception, processing and value added product generation in partnership with DLR. In addition, the Chetumal station complements the DFD station network.

Multimission Concept

In order to operate efficiently the large and cost-intensive equipment systems of DFD's station network, a generic and flexible approach was needed. DFD therefore realized a multimission concept for its modular ground segment infrastructure encompassing all components of the payload data ground segment.

The functional layers at each station are antennas, demodulators and front end processors. These layers are connected via matrix infrastructures to obtain a flexible system for the parallel acquisition of data from several missions. The antennas at DLR station facilities use X-, L- and S-band frequencies to meet data stream



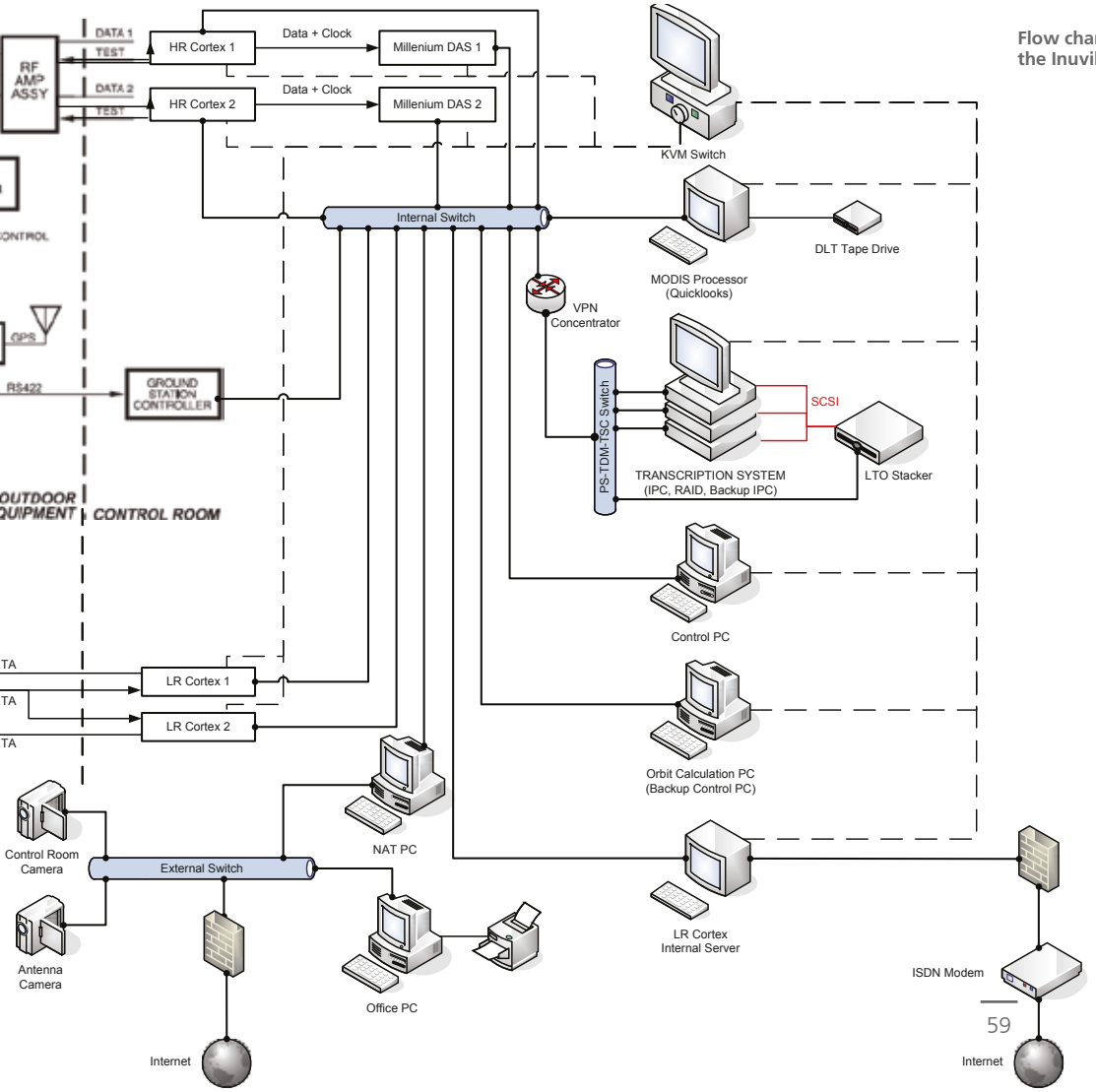
and telemetry and telecommand requirements. Specified interfaces and protocols permit the exchange of equipment as required for specific missions. The harmonized demodulator configuration at DFD stations also ensures an information exchange during development and operation. Cooperation between DFD and world leader ground segment operators and suppliers helps to develop and maintain the technology.

Automated Remote Station Control

Key for efficient cooperative operation of the international stations is the concept of automated remote control and monitoring. DFD developed a system to allow remote monitoring and control of international station locations from Oberpfaffenhofen. Reliable automated operations for remote, completely or part time unmanned stations requires attention to such concerns as network latency or the impossibility of immediate on-site interaction with the station hardware.

The Station Monitoring, Control and Scheduling System (SMCS) is implemented and in operational use for all functionality necessary for remote operation of the DFD global stations. It is used for:

- completely unmanned automated remote routine operations of the DLR Inuvik station in Canada



Flow chart of the remote control concept for the Inuvik station

Large server farms in Neustrelitz allow for near-real-time processing of satellite data

- automated station operations with local support and short periods of unmanned station operation at GARS O'Higgins, Antarctica
- unmanned, automated remote operations for selected missions in Chetumal, Mexico
- DLR equipment at the partner station in Kiruna, Sweden
- Ka-band station in Oberpfaffenhofen.

Furthermore, concepts like operational procedures and staff roles are also defined in detail in the framework of SMCS-supported operations.

In addition, for each of the stations connected and operated under SMCS full or partial control, a concept for the IT network was established and implemented to meet current security and bandwidth requirements

Multimission Front-End Processors

The multimission front-end system is a core element of the distributed ground station software; it provides the functions of first-stage storage, telemetry processing up to level 0 or specific higher product levels, reporting, and near-real-time data distribution. The front-end processor system is designed to perform ground station monitor and control functions to realize a station integration component for a heterogeneous set of station devices.

DFD designed and developed the front-end processor software, which synchronizes and processes the raw data stream in real time. This specific expertise is important for DFD, as it enables configuration of the ground segment to meet new mission requirements. The software is structured into components that are adaptable with minor extension or modification for a wide range of current and future missions. The system supports payload telemetry data reception for quasi-unlimited data rates, currently approximately 1.6 GBit/s. This depends on the industry demodulator types used and on the applicable licenses. The software design allows the provision of data reception capacity in a time- and cost-saving manner. The design and the development process enable easy maintenance and configuration of code and production routines. The different mission requirements in combination with the local constraints of DFD stations require an adequate control concept. Both automated remote control and operator monitoring and control are common approaches.

Station Control Software

Finally, station control software for the Neustrelitz ground station was developed to cover all key aspects of managing a modern multimission receiving station, like planning, station setup, monitoring, telemetry processing, distribution and reporting. The station control software is an in-house development that can be adapted to meet specific hardware and mission requirements. It integrates the access to several interfaces and protocols based on mission constraints. It further provides a high grade of automation and fault tolerance capabilities, and also operator guidance through a process-centered user interface. The station control software tool for the operator allows the exploitation of unique operational opportunities.

Future Acquisition Concepts

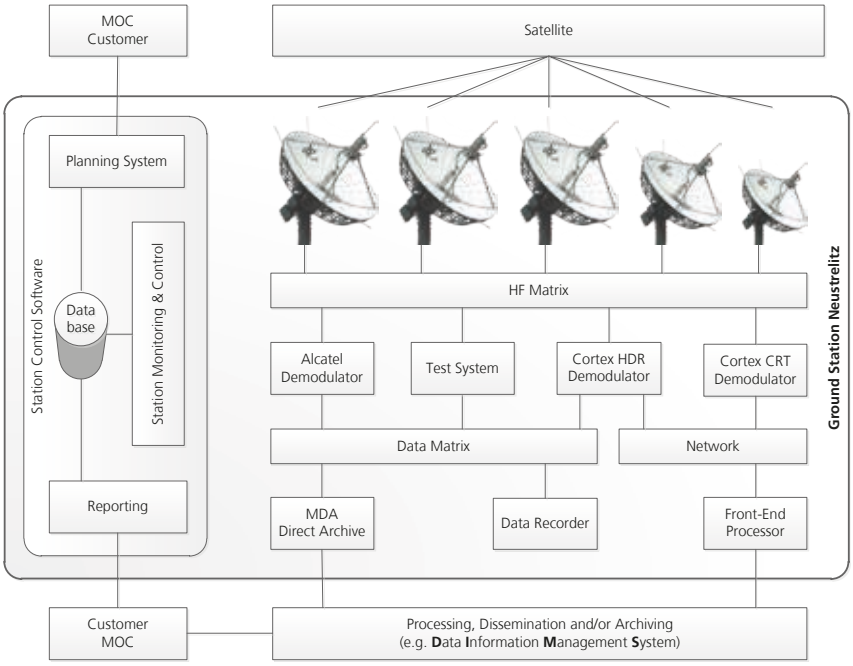
In the future, global station networks will be complemented by geostationary communication satellites allowing for live transmission of satellite data with high data rates, for example in order to realize new real-time services. DFD already participates in early validation missions for the upcoming technology. This concept will be tested in the framework of ESA's AlphaSAT program.

The geostationary relay satellite AlphaSAT carries a laser communication terminal for data transfer to Earth observation satellites in low orbits as well as a Ka-band antenna for downlinking data to the ground station.

DFD provides the ground station for data transfer from the AlphaSAT satellite. For this purpose a 7.3 meter Ka-band antenna was erected in Oberpfaffenhofen. The system is able to receive up to 600 Mbits/s.

For communication with AlphaSAT the upcoming ESA satellites Sentinel 1A and 2A will carry laser communication terminals. They will be used to test and validate the whole transmission chain from satellites in low orbits via the geostationary Alphasat down to the ground station.

DFD is in charge of the overall technical design and system engineering for this link, including definition of the Ka-band downlink, specification of the ground station, and participation in the overall transmission scheme from the Sentinel onboard memory down to the Ka-band ground station. Of special importance is the generation of a data format analog and identical to the usual direct X-band downlink as well as the test, verification and validation of the geo-relay communication channel. DFD will actively participate in the overall validation of this transmission channel and is prepared to provide pre-operational extended test phase support and subsequent operation of this data transmission system in accordance with the overall progress of this program.



Multimission antenna concept

DFD Ground Station Facility Neustrelitz

Data Processing

The chain of a typical Earth observation mission data flow starts with data reception and recorded raw data and goes on to consolidated level 0 data where the data still represent the original physical measurements and no algorithms are applied. The data flow towards higher level processed data, leading to the possibility to exploit these data, requires the application of in most cases complex algorithms. In recent years exponentially growing data volumes and more complex processing chains required an evolution of the corresponding methodology. Futhermore, the TanDEM-X mission posed for us the most complex processing task so far. To achieve fully operational, automated data processing, we have to consider different and somehow contradictory points of view: dynamic and creative scientific algorithm development has to accommodate engineering standards and stringent configuration control. A change from a mission-driven to an application-driven layout in a multipurpose environment was necessary. Service-oriented resource allocation for both mission-specific processing in upcoming missions and subsequent application-oriented processing is currently being achieved.

These challenges required of EOC a steep learning curve. The experience gained in achieving full operational status for TerraSAR-X processing and developing, integrating and operating the very complex and performance demanding TanDEM-X processing chain led to the development of a multipurpose Earth observation exploitation platform.

Methodology

The scientists developing algorithms need to establish methods of data processing. They have to apply their development procedure for models to prototype software development. Since they need flexibility, they often implement the algorithms using software- or tool-based methods (IDL, MATLAB, …) unsuitable for later operational processing. Therefore, prototypical software packages normally have to be converted into software that assures operational stability and performance. The development cycle for processing software does not end with the initial operational processing. Quite often, the results of early operational processing lead to changes and adaptions, and software engineering has to supply the necessary flexibility to implement those changes.

Software suitable for operational data processing needs to be embedded into a framework managing and controlling the processing tasks. This includes the workflow, the input and output data flow, the flow of necessary auxiliary data, etc. At this point the knowledge of the algorithm developers and the integration engineers establishing this framework has to be combined to achieve an operational processing system. The processing system in turn has to be interfaced with the data management infrastructure, which requires knowledge about this infrastructure (DIMS).

The operations team receives a fully tested and well documented system. But experience shows that a broad variety of measures to overcome design errors as well as all kinds of typical teething troubles are required to achieve the desired operational stability. Operator-based troubleshooting is time-consuming and thus costly and needs careful analysis and attention in order to avoid having to repeatedly overcome deficits originating in the development process.

TerraSAR-X radar image of an antartic Ice shield – TerraSAR-X and TanDEM-X made complex processing tasks necessary

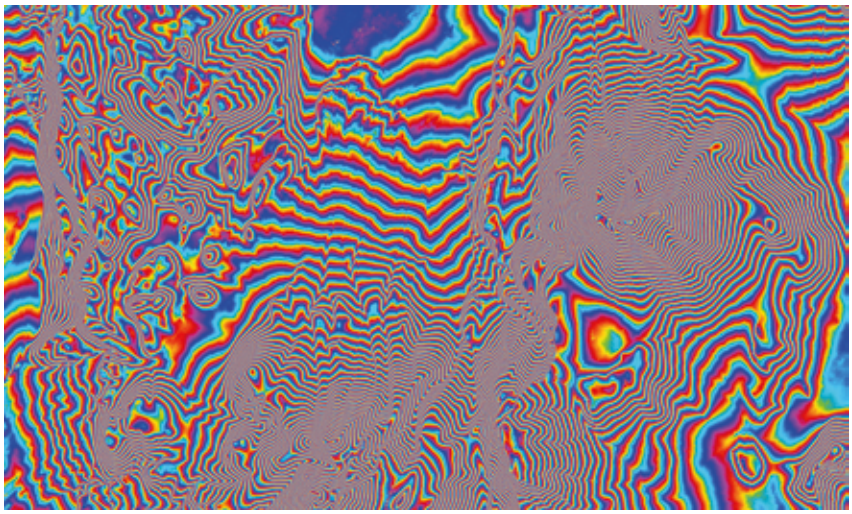
The approach starts with single mission developments which were state-of-the-art methodology in the beginning of the reporting period. Typically, a computer cluster is composed of several, mostly identical, computer devices. Each node is linked to the other nodes with a high-performance network connection (e.g., Infiniband). A cluster of computers is therefore an expensive capital asset. By forming a homogenous resource, the administration effort is less than the effort to construct a grid. Homogenous hardware allows for good scalability within the high performance network and similar hardware, and makes it easy to clone installations onto new hardware. High availability can be easily achieved since hardware is identical in a matching virtualization environment. For peak load processing part time only, cluster computing does not have any advantages. All responsibility, financing of resources and organization are ascribed to the corresponding project. The control framework is adapted to the needs of the project.

Using the framework described above, in the following we give some details about the most important and performance-demanding missions. Each case is embedded in the corresponding ground segment project and underwent a development phase of typically three to four years.

Evolution of Mission-Specific Processing

Since 2007 DFD's ground segment divisions have operated the Payload Data Ground Segment (PDGS) of the first national German radar satellite mission. For details on the TerraSAR-X mission see the section on National Missions in the joint EOC introduction above.

The payload ground segment provides both scientific and commercial user communities with a variety of advanced SAR products. Among other tasks DFD is responsible for the processing and distribution to users of the generated



TanDEM-X interferogram – from 2 to 6 terabytes per day must be ingested in the system

SAR basic products. The TerraSAR-X processing facility is a high performance state-of-the-art, scalable processing unit, dedicated to the mission but well embedded in the multimission data management environment. The operational SAR processing chain starts after data reception, mainly at the satellite receiving station in Neustrelitz, with a dedicated data transcription and decryption system and the TerraSAR-X Multimode SAR Processor, TMSP. It is data-driven and works automatically. The high degree of integration allows support of near-real-time scenarios provided directly from the station. Several projects and applications, such as traffic monitoring and maritime security, require product deliveries in less than 15 minutes. Since 2007 the payload ground segment has acquired and processed 250 terabytes (TB) of payload data. It operates with nearly 100% availability. The processing hardware was extended and modernized several times and its operational status is up to date.

Since 2010, EOC has operated the TanDEM-X (TerraSAR-X Add On for Digital Elevation Measurement) payload data ground segment. The processing task is specific to the bistatic interferometric data being acquired with the EOC international station network and required for a global elevation model. The data are then transferred, ingested and consolidated at the processing center in Oberpfaffenhofen.

The amount of data produced by this mission exceeds that of all preceding missions. The input per day ranges from 2-6 TB. The daily amount of data production is between 1 TB and 3 TB. The intermediate products are generated by the Integrated TanDEM-X Processor (ITP), which includes screening, bistatic focusing and Interferometric Synthetic Aperture Radar (InSAR) processing. Processing is done on an x86 platform with almost 1000 processor cores and 2.5 TB RAM.

A special challenge of the mission is the continuously changing formation of the two satellites TSX-1 and TDX-1, which is required to optimize the interferometric characteristics of the data collected. If an acquisition does not have the sufficient quality, it must be repeated during a small time window. As the huge amount of data received by the TanDEM-X ground station network cannot be transferred to the payload ground segment online, data has to be evaluated directly at the ground station. Therefore a so-called interferometric quality pre-check is performed at each ground station and the test outcome is transferred online to the payload ground segment. If the quality is inadequate, this triggers a request for re-acquisition of the data take.

After interferometric data processing the TanDEM-X raw data are processed in further steps to calibrated and mosaicked digital elevation model data products ready for delivery.

The processing and archiving of data from ESA's ERS-2 and ENVISAT missions were unified in the ESA Multi-Mission Facility Infrastructure (MMFI). DFD led this development activity in a consortium with partners, and the transfer from the mission-specific ERS-1/2 Processing and Archiving Facility (D-PAF) and the

ENVISAT Processing and Archiving Center (D-PAC) to the MMFI was finalized in 2007.

Since then the MMFI served both missions until their end, for ERS-2 in July 2011 and ENVISAT in April 2012. Nevertheless, the mission data are still being archived and are frequently requested by users, with MMFI still serving those needs. It and the attendant processing were transferred from the former mission-specific payload ground segments to a modern processing infrastructure.

Processing, archiving and dissemination were performed for the following ERS-2 sensors:

- Synthetic Aperture Radar (SAR)
- Global Ozone Measurement Instrument (GOME): re-processing and hosting of all level 1 and level 2 data.

Processing, archiving and dissemination were performed for the following ENVISAT sensors:

- Advanced Synthetic Aperture Radar (ASAR): processing and dissemination as well as systematic delivery of wave mode data
- SCIAMACHY
- MIPAS
- GOMOS: hosting of consolidated level 2 data.

In addition, the MMFI is hosting high resolution optical data from the IKONOS and WorldView-2 missions in those cases where ESA holds the licenses for the Copernicus data warehouse.

In the future, MMFI at Oberpfaffenhofen is foreseen for the long term archiving, as well as re-processing and dissemination, of data from the ESA ADM-Aeolus mission.

The overall performance of MMFI in terms of data holding, processing, dissemination and reprocessing is also significant. Hundreds of terabytes of data are delivered each year to users and the complete SCIAMACHY and MIPAS data holdings are re-processed more or less on a yearly basis.

Other Processing Facilities

At DFD more processing facilities are in now routine operations than are described in detail here. For example, the Ozone Satellite Application Facility (SAF) for the GOME-2 instrument on the METOP satellites, processing of NOAA AVHRR data, processing of MODIS data, processing of numerous atmospheric data sets producing input for WDC-RSAT, processing of Meteosat data, processing of high resolution optical data from the WorldView-2 satellite, routine processing with the CATENA processing suite, and the Ionosphere Monitoring and Prediction Center (IMPC) for reliably and easily accessible data products in near real time as a 24/7 service.

All these processing activities were formerly project driven and designed independently on a project by project basis. Considerations relating to hardware as well as the method of organizing the workflow and the data flow for processing led to consolidating hardware use and establishing generic data flow methodologies. The next section describes the current status of this long-term activity.

GeoFarm: a Generic Exploitation Platform

Satellite payload data processing today places requirements on a processing facility differing from those of the past. The main drivers are the huge amount of data (with a tendency toward exponential growth) and more and more complex processing chains. This not only includes processing a data stream (possibly in near real time) but also reprocessing large amounts of data with new processor versions, new auxiliary data, and new calibration data. The amount of data and the rate of growth may simply be estimated by the growth of the German Satellite Data Archive (D-SDA).

To meet these requirements, new strategies for hardware use, software deployment and interfaces to cataloging and archiving systems have to be employed.

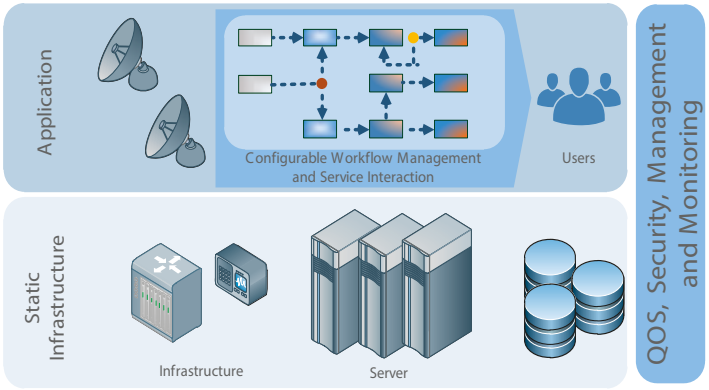
A general purpose environment usable for multiple, simultaneous projects differs significantly from a dedicated environment. A common processing environment has to be handled as a project itself, with its own financial and human resources. Projects requiring hardware resources simply request these resources from the common processing environment and do not have to be concerned with obtaining and maintaining hardware.

A first step toward the realization of this concept is the start of DFD's GeoFarm initiative. GeoFarm is available to projects conducted within EOC and in future to those projects of selected external partners which are the framework of the Copernicus concept in Bavaria.

Initial installation of GeoFarm took place in 2011 and 2012 to set up a general purpose processing environment. Aside from the hardware, this also included human resources for set-up, coordination of WAN and LAN integration, configuration and virtualization of the environment.

Hardware is allocated to projects in the form of virtual machines running in a virtualized environment. The virtual machines assigned to a project are configured according to project need, and resources are assigned to projects by configuration. For the time being, the resources allocated for one specific project can be changed by the Geofarm administrative staff as necessary.

The methodology for organizing and controlling processing work flows and data flows is currently under review in order to achieve a solution compatible with this platform service approach.



Abstract description of processing systems organization on a project by project basis as still applied for TerraSAR-X and TanDEM-X with dedicated hardware

A number of projects are meanwhile served by this initial infrastructure; examples are the Ozone SAF mentioned above and CATENA processing. Further projects are currently being integrated.

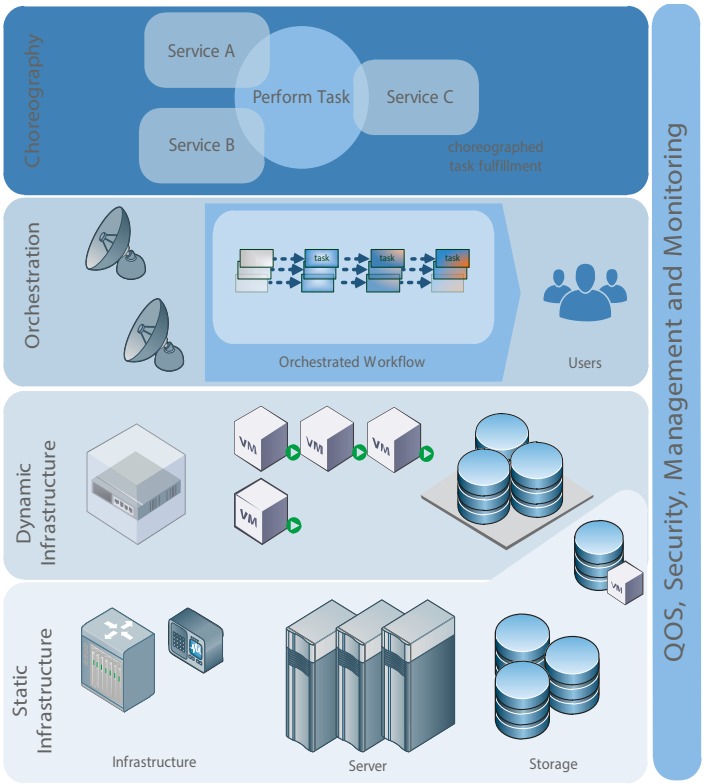
The GeoFarm initiative accompanies the global trend of new developments in the IT sector, which might be summarized with the catchwords Cloud Computing and Big Data. Its concept will be further developed in cooperation with national, European and international partners.

Near-Real-Time Processing

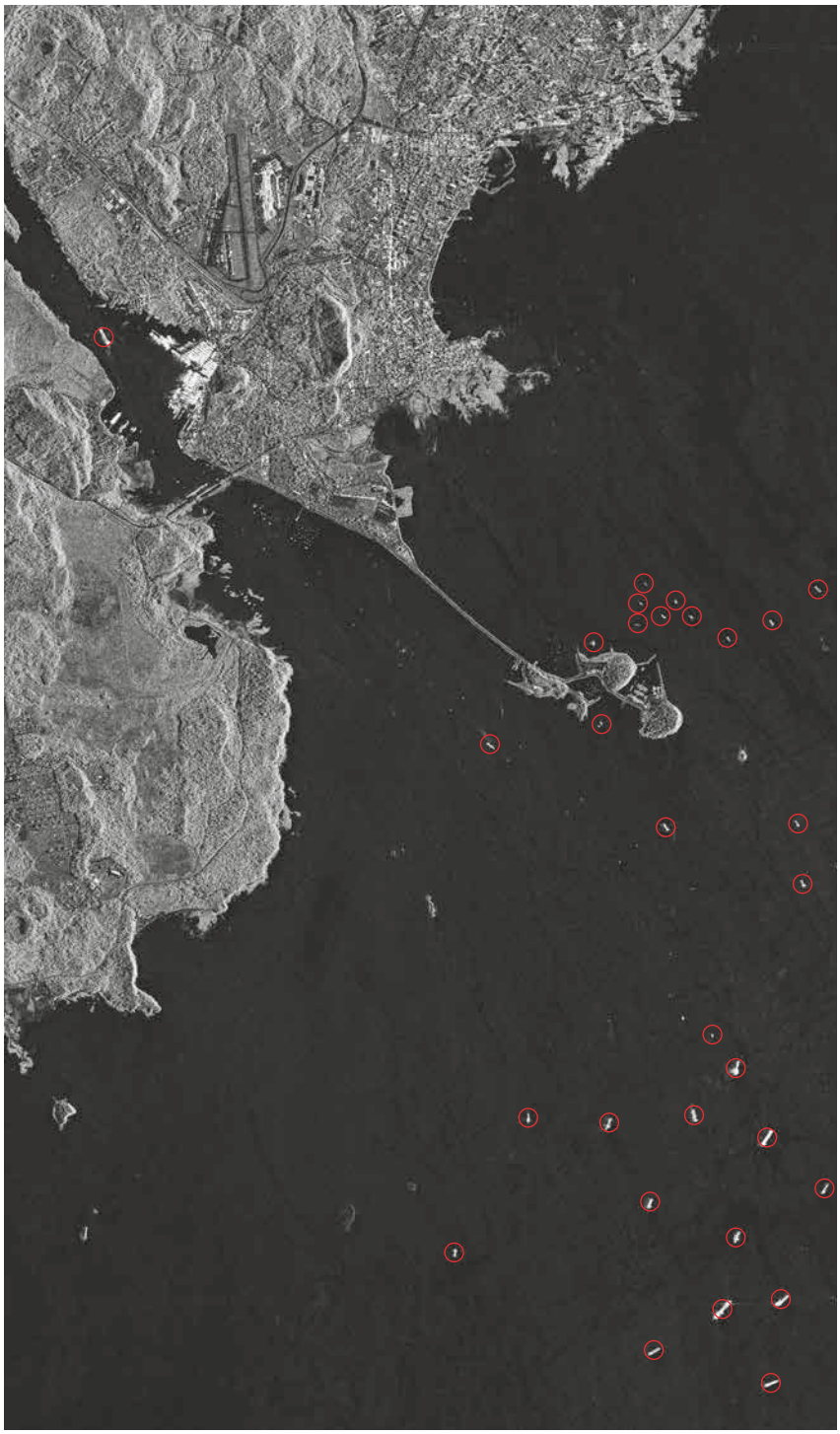
Another paradigm shift has taken place in the provision of Earth observation data: in addition to the routine processing results, more and more emphasis is being given to near-real-time information products.

The use of satellite-based information products increases constantly. Especially critical applications require up-to-date information. The entire chain from ordering to data delivery must therefore be optimized. This includes near-real-time processing immediately after data acquisition and value-added processing. The installed and operating applications meet maritime, land, hot spot and atmospheric requirements. Near-real-time data delivery is one of the main future challenges in the domain of Earth observation.

For example, modern piracy, illegal fishing, and dense traffic confront maritime authorities with growing challenges. Earth observation together with navigation and communication techniques contribute toward protecting the oceans and enhancing the safety of navigation. Satellite-based maritime security services



In the new GeoFarm concept hardware is managed dynamically and assigned to the processing task according to needs. The management of the processing workflow is separated from the services providing interaction with the data management in order to achieve an optimization of input and output streams, and storage management.



can enhance security from attack, the safety of operation, and warning of heavy seas and approaching vessels.

At DFD's National Ground Station Neustrelitz in Mecklenburg-Vorpommern, up-to-date information from the high-resolution radar satellites TerraSAR-X and TanDEM-X is processed in near real time and fused with auxiliary data like Automatic Identification System (AIS) data from terrestrial and satellite sources. The processing chain can deliver ship movement data within 15 minutes and forward it within another 15 minutes to authorities and clients with statutory powers.

The more data sources available, the better the real-time product gets. Consequently, our scientists plan to include other international satellite systems in the acquisition of data.

Services were successfully demonstrated by various projects and in different test campaigns for users like the European Maritime Safety Agency (EMSA) or the Joint Research Centre (JRC). The ship detection service was developed for ERS-2 and ENVISAT. After successful launch of the TerraSAR-X satellite a new level of high-quality radar images became available and the development of maritime applications was extended. Currently, a first version of a ship-detection application for the TerraSAR-X and TanDEM-X satellites is being implemented to demonstrate the new opportunities to determine more details like ship size and ship heading as well as to identify small vessels. The development of further maritime products based on satellite technologies is a main task which will involve the integration and operation of processors for oil detection, ice detection, and wind and wave monitoring into a near-real-time processing chain.

In order to achieve the required processing performance, it is not enough to scale the hardware for sufficient CPU power. Since the data relevant for

near-real-time services are often just a part of a mission's overall payload data acquisition flow, priorities have to be established. This requires knowledge about these data and subsequent management of this knowledge. In addition to managing priorities for processing, fast lane concepts were introduced in the data flow.

As another example, forest fires not only significantly contribute to the carbon cycle but also constitute a threat to agriculture and human settlements. The European Commission has therefore established the European Forest Fire Information System (EFFIS). In support of this system, the DFD stations in Oberpfaffenhofen and Neustrelitz acquire the daily passes of the U.S. Aqua and Terra satellites, preprocess the data of the MODIS sensor on these satellites, and deliver the data to the Joint Research Centre of the European Commission. From there, the assembled fire information is made available on a public web page within 2-3 hours of satellite data acquisition. The Joint Research Centre contracted DFD for this near-real-time service because of its redundant station locations and its proven capabilities in mass data processing. The MODIS data supplied for this service is also used for an enhanced Hot Temperature Event (HTE) service, delivered by DFD's Center for Satellite Based Crisis Information. The hot spot detection capability was developed in cooperation with the Mexican Institute CONABIO.

The Ionosphere Monitoring and Prediction Center is a joint project of DFD and DLR's Institute of Communications and Navigation (IKN). It combines IKN's significant scientific expertise in the ionosphere with DFD's powerful data processing and management capabilities.

The radio signals transmitted by modern communication and navigation systems may be heavily disturbed by space weather hazards. Thus, severe temporal and spatial changes in the electron density of the ionosphere and plasmasphere may significantly degrade the signal quality of various radio systems, which may even lead to a complete loss of the signal. The Ionospheric Monitoring and Prediction Center serves users in the European region by providing warnings, nowcast and forecast information as well as historical data about the state of the ionosphere and related space weather issues. The data collected in near real time include ionosphere observations and related solar-terrestrial data.

The data are collected, quality checked, calibrated, adjusted, analyzed and fed into models for generating high-level data products. The aim is to provide reliable and easily accessible data products to the science community, governmental and commercial partners in near real time as a 24/7 service. The Ionosphere Monitoring and Prediction Center provides ionosphere weather maps showing the Total Electron Content (TEC) over Europe and on a global scale in near real time at an update rate of five minutes.

The extensive data management at this center is performed by the Data Information and Management System (DIMS) of EOC. DIMS offers a single integrated solution with comprehensive functionality for the management of large amounts of heterogeneous digital data, including cataloging and long-term preservation, online access to the data catalog, data ordering, processing and delivery. An integrated workflow management system is used for processor integration, processing, and subscription direct delivery.

Last but not least, numerous real-time services exist for atmospheric variables such as concentrations of particulate matter, ozone, nitrogen and sulfur dioxide, carbon monoxide, further trace gases, and various cloud parameters. All these data and prediction services are bundled in DFD's WDC-RSAT, described elsewhere in this report.

Ship detection requires near-real-time processing capabilities

Data Management

Data management organizes the primary data flow from acquisition, processing and archiving to user access, the flow of orders and request throughout the system and also the monitoring and reporting of the payload data ground segments in the context of mission participations. It is not restricted to handling huge data volumes but also copes with their diversity, which increases with more and more Earth observation missions. Distinct processing and access scenarios add to the complexity of workflow management.

For a data center the evolution of systems and processes is of crucial importance. Besides the classical scene-by-scene processing, archiving, and distribution scenarios, layer-based direct access mechanisms must be provided for comfortable data download. Information technology advances from single computer solutions to virtualized server clusters with storage area networks. However, hierarchical storage management with automated tape robot libraries in the background is still an up-to-date concept for reliable long-term storage. The initiatives in big data and cloud computing are carefully introduced, monitored and tested to prove their operational capabilities in order to ensure systems reliability and data throughput.

Near-real-time services and the evaluation of long-term trends are more and more in demand, posing a challenge to extend the data management capabilities at both ends: faster, even sub-scene-oriented flow through the system and on the other hand effective bulk handling ('mission-at-once') of historical remote sensing data.

- TanDEM-X
- TerraSAR-X
- ENVISAT
- ERS-1/-2
- MODIS
- NOAA AVHRR
- METEOSAT
- MSG
- METOP
- SRTM
- X-SAR
- Airborne SAR

Data and Services

The German Satellite Data Archive (D-SDA)–hosted by DFD–manages an exponentially growing data volume of currently more than 2.5 petabytes. In addition to low level unprocessed Earth observation data, introduced into the archive by the Earth observation missions served, higher level processed data and derived thematic information products up to aggregated and assimilated model outputs are also handled.

The current highlight missions in terms of growing data volume in D-SDA are TanDEM-X and TerraSAR-X. ENVISAT moved to the set of historical missions, although data is still being added from reprocessing tasks. At the beginning of 2013 less than 20% of the D-SDA volume consisted of historical data of phased-out missions. This rate is expected to grow, gradually magnifying the task of long-term preservation of unique historical data sets.

D-SDA handles all aspects of large-volume data management with the key services of data archiving, data administration, and data access. Meticulous cataloging of each data set entering the archive ensures that data remain discoverable over time. Through interactive and system-to-system interfaces users can directly retrieve or order archived data or initiate future acquisitions. Processing chains are triggered automatically to generate user-specified, customized products on demand. In this context interoperable technical interfaces are also provided for access to Copernicus Sentinels and contributing missions.

Due to our background we are also prepared to extend our services and contribute to the national archive for remote sensing data NAF to improve data access for public authorities. For this initiative of the Federal Ministry of the Interior, DFD has the lead in preparing the NAF concept together with the Federal Agency

for Cartography and Geodesy and the National Agency for Geo-Information of the German Army.

D-SDA is a distributed infrastructure with locations in Oberpfaffenhofen and Neustrelitz. Connected by a 600 MBit high-speed network, the distributed archive is being operated as one entity by a joint operations team. Invisible to the user, archive services are provided from either location. Data safety is ensured by keeping two copies of all data at separated locations on site. For the future, a cross site solution is envisaged.

Data Access

Users can access D-SDA data through distinct discovery and data retrieval options. Systematic data dissemination on a subscription basis is supported as well as interactive data discovery and ordering via EOWEB®-NG, the main D-SDA data portal.

Additionally, a range of EOC community data portals provide access to EOC Earth observation data and products. Portals are operated, e.g., by the World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT), the Center for Satellite Based Crisis Information (ZKI), the Space Weather Application Center Ionosphere (SWACI), and the Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (O3M-SAF).

Interoperability in spatial data discovery and access, promoted in Europe in particular by INSPIRE, the Spatial Data Infrastructure for Europe, is becoming increasingly important. DFD ensures interoperable data accessibility by adhering to the corresponding standards developed by the Heterogeneous Mission Accessibility project (HMA), an ESA initiative, and by the Open Geospatial Consortium (OGC).

In line with these initiatives, we have set up the EOC Geoservice. This spatial data infrastructure adds to the existing data access options convenient data discovery, data visualization, and direct data download functionality. Through these spatial data services Earth observation data can now be discovered and visualized via OGC-compliant internal and external spatial data portals, such as the portal of the German spatial data infrastructure, Geoportal.DE, or the portal of GEOSS, the Global Earth Observation System of Systems.

Long-Term Data Preservation

DFD puts particular emphasis on long-term data preservation (LTDP) with the objective to archive, catalog, and keep accessible valuable Earth observation data and products for future generations.

Earth observation data are snapshots of the Earth's surface or atmosphere that cannot be regenerated. Meanwhile, D-SDA holds over 20 years of individual observations. Available and accessible long time series of Earth observation data are indispensable for investigating slowly evolving phenomena relevant to global change, such as annual variations of the Antarctic ozone hole or the changing air quality of German cities. However, to be able to utilize these data in the future, they need to be carefully preserved today.

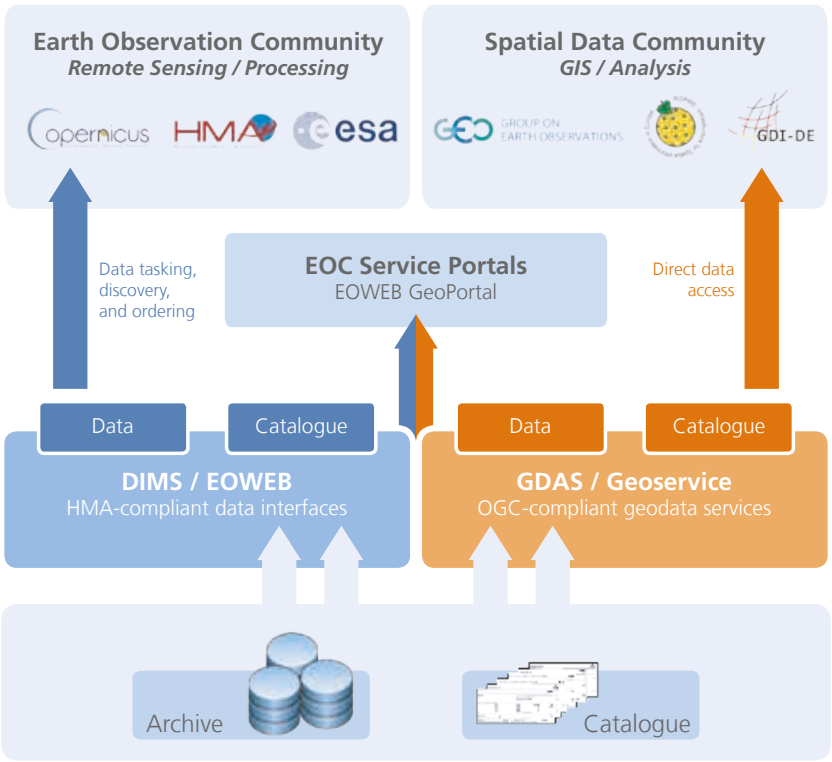
TerraSAR-X and TanDEM-X increased exponentially the volume of Earth observation data in the German Satellite Data Archive

DFD has been contributing considerably to the development of ESA-wide guidelines for the long-term preservation of Earth observation data. In accordance with these LTDP guidelines all Earth observation data at DFD, including all additional information and documentation required for understanding the data in the future, will be preserved, managed, and made accessible to users. Within this scope, safeguarding the data against loss is essential. D-SDA thus maintains two separate copies of its data holdings at two distant locations using different archiving technologies.

LTDP activities will have to be intensified over the next few years. Data sets need to be consolidated to obtain complete and consistent time series. In addition to preserving data and metadata as done today, measures need to be implemented to preserve also the remaining information relevant for understanding and using the products in the future, such as mission documentation, calibration information and processing software.

Systems, Developments and Operations

The information technology systems for processing, archiving and disseminating Earth observation data are composed of distributed collaborative software systems operated on high-end hardware facilities. In order to cope with the demanding specific requirements of payload data ground segments for current and planned Earth observation missions, DFD develops and operates its own systems: the Data and Information Management System (DIMS) for Earth observation data management and the Geospatial Data Access System (GDAS) for Earth observation data access provision. Both

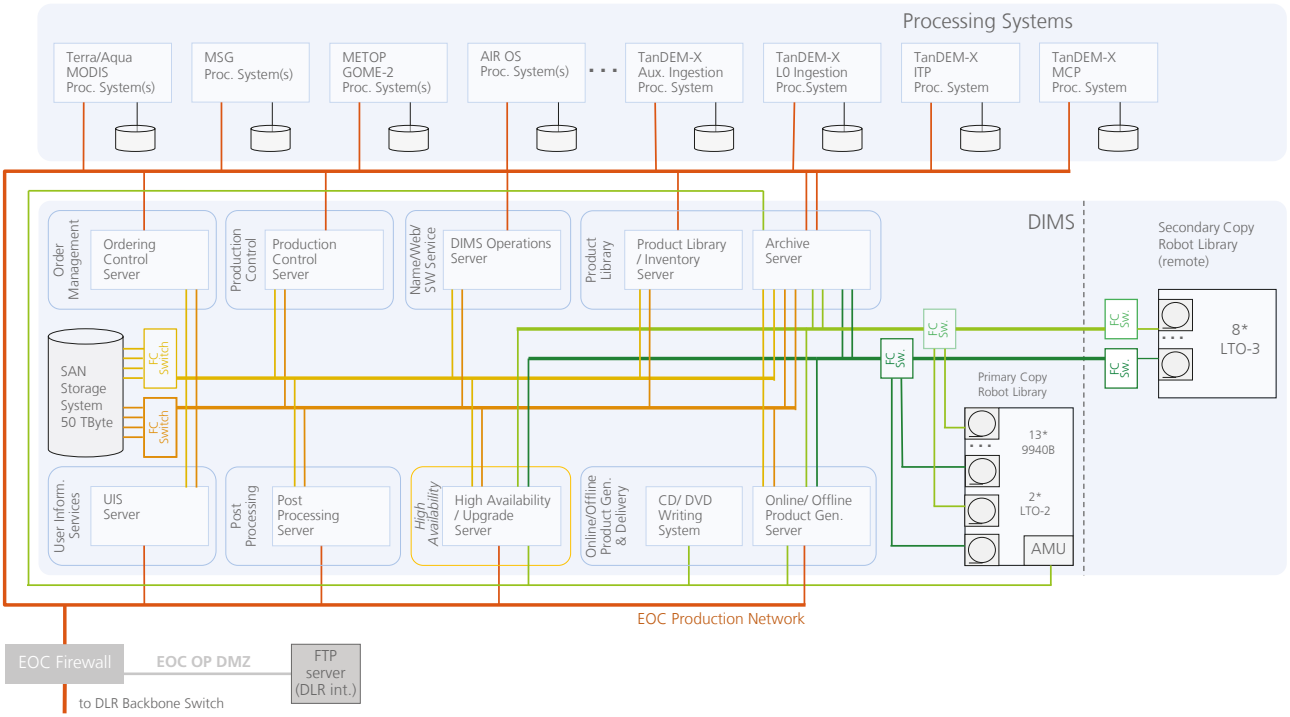


Through the use of standardized protocols EOC Earth observation data can be accessed by users in the Earth observation community as well as by the general spatial data community

Fully automated robot libraries handle thousands of tapes for archiving and access. For data safety two copies of each data set are being preserved.

systems are continuously maintained and enhanced at DFD. The software systems make use of standard commercial off-the-shelf software for basic functions such as hierarchical storage management in robot-driven tape libraries, database management systems, and data servers providing web mapping functions.

With its highly configurable and distributed components, DIMS supports various payload ground segment scenarios such as the systematic processing, archiving and dissemination of data products and the delivery of individually ordered and processed data products based on previously ingested and archived raw data. Complementary functions include product subscription, production control, processing management, reporting, and the systematic publishing of products in the user service systems EOWEB® (metadata catalog and order) and GDAS (data browse and download). GDAS provides standard OGC-compliant services to access higher level Earth observation data. This allows any kind of standard GIS client to directly import and use Earth observation data as published, up to full spectral, spatial and temporal resolution. The download functions allow the selection of projections, spatial and temporal sub-setting, and file format.



The IT infrastructure provides computing and storage capacity for the data and information management services. The processing systems are connected via a high-bandwidth local area network to the multimission facility. The principle configuration is the same for the distributed sites in Oberpfaffenhofen and Neustrelitz.

Both system operations as well as system development are performed by entities with ISO 9001 quality certification. All processes of software development and system engineering, including integration, verification and validation, transfer to operations, system acceptance, and operations engineering, are performed by trained staff following documented and traceable steps. Continuous monitoring and reporting functions are used to assess the system's production behavior and to deduce any need for enhancements. In the case of the ongoing mission TanDEM-X these improvements have proved to be essential.

The same entities closely collaborate in preparing upcoming missions by analyzing requirements and scenarios, planning operations, developing system configurations and software extensions, integrating the payload ground segment components, and deploying them in the production environment. This is currently being done for the Sentinel-5 Precursor and EnMAP missions.

IT Infrastructure

The IT Infrastructure of D-SDA has to fulfill high requirements with respect to data safety, throughput and system availability. A main driver is the TanDEM-X mission, whose data processing demands reach a new order of magnitude.

The DIMS and GDAS software components implementing the D-SDA service functions run on a number of powerful servers. Apart from the operating system all data are stored on storage systems connected to the servers via a double disk storage area network (SAN). Several robot libraries and their tape drives are attached to the archive server via a second, so-called tape SAN, again in a redundant way. Data safety is achieved by a disk cache using RAID 5 technology (redundant array of independent disks)

and by writing two copies to tape on two different types of media and in two different locations, as a precaution against fire or any other kind of physical damage. System availability is achieved by a number of measures: the disk storage systems have redundant controllers and redundant internal data paths and the SANs are duplicated to keep all data accessible even if one SAN switch fails. The most critical DIMS components run on a server cluster. In order to prevent system down times in case of hardware failure or planned maintenance activities, there is a high availability server in hot standby. The throughput is achieved by using fiber channel SAN and gigabit/s Ethernet, and in the case of cutting edge throughput requirements (e.g., with TanDEM-X), a separate 10 gigabit/s Ethernet archive transport network is installed.

Harmonization and Standardization

In cooperation with partner institutions we are engaged in several activities of the relevant data management communities in order to strengthen our role as an Earth observation data center.

In the area of long-term data preservation we are a member of the LTDP working group in the framework of the Ground Segment Coordination Body GSCB. The major space agencies in Europe contribute to this initiative headed by ESA. Together with EUMETSAT, ASI (I), CNES (F), CSA/CCRS (CAN), DLR (D), and UKSA (UK), technical concepts are being developed and a common LTDP framework is envisaged to jointly tackle the emerging data preservation issues and give guidance to European space data holders. In addition, we contribute to the EU project SCIDIP-ES, which builds and evaluates preservation tools for Earth science. Re-processing and bulk-delivery are key scenarios in the ESA project Climate Change Initiative. Besides involvement on the algorithm side, system architectures have been developed by DFD.

On a political and technical level we contribute to cooperative activities addressing harmonization, with a view to increasing the interoperability of D-SDA on the national and international level. On the political side we support the German delegation of the Group on Earth Observations D-GEO and are active in the working group of the German Interministerial Committee on Geoinformation, AG IMAGI. Within the Heterogeneous Mission Accessibility (HMA) initiative and the Open Geospatial Consortium (OGC) we actively contribute to shaping the associated technical standards. The main focus of interoperability is data discovery and access. Thus, implementing these harmonized standards within D-SDA is key to widening the scope and use of Earth observation data and products by a broader and more diverse user community and to integrating D-SDA into virtual geospatial data infrastructures on national, European and global levels.

Another important facet of the harmonization effort at the international level is our active role at several conferences relevant for data management. We are a member of the program committee of the European PV conference series ‘Ensuring the Long-Term Preservation and Adding Value to Scientific and Technical Data‘ and organize national conferences as well. Regarding storage technology, we have a long tradition in carrying out some of the leading national conferences in this field, including ‘Storage Technology‘ and ‘SAM-FS/QFS User Conference,‘ both important events for users and developers of the latest large-scale storage solutions.

Relevant Publications: [125], [179], [223], [282-273], [287], [408], [572], [604]

Satellite passages acquired at DFD ground stations

Mission/Sensor	Operator/ Partner	2006	2007	2008	2009	2010	2011	2012	2013
BIRD	DLR	1476	1452						
Champ	DLR/GFZ	1156	1149	1151	1122	710			
ENVISAT	ESA/DLR	983	998	1018	1018	981	1074	324	
ERS-2	ESA/DLR	276	1497	2095	1297	2426	2140		
Landsat-7	USGS/ESA,DLR							12	
SRTM	NASA/DLR, Infoterra								
TUB-, MarocSAT	TU Berlin/DLR		234	119	171	103	18	1	
ACE	NOAA/DLR				121	364	354	366	180
Grace 1/2	DLR/GFZ,JPL	2123	2133	2348	2609	2350	2234	2312	1416
IRS-P5 Cartosat	ISRO/DLR, EuroMap		17	676	622	611	565	585	306
IRS-P6 Resourcesat	ISRO/DLR, EuroMap	486	434	565	528	614	544	637	301
Landsat-5	USGS/ESA,DLR		30	268	480	213	688	283	13
Landsat-8	USGS/ESA,DLR								207
Terra, Aqua/MODIS	NASA/DLR	747	4977	5755	6855	6352	6884	6829	3563
NOAA/AVHRR	NOAA/DLR		5701	4051	4821	5844	2517	2564	1250
Radarsat-2	MDA/DLR							227	566
TanDEM-X	DLR/Infoterra					523	8040	8312	4228
TerraSAR-X	DLR/Infoterra		890	2476	2434	2424	2789	2685	1385
TET-1	DLR							454	514

Earth observation data and products hosted at DFD in the national facility as well as in partner and ESA facilities

ESA Facility	Data Volume [TB]
ERS-1/-2	185.05
ENVISAT	504,06
Landsat-7	17,33
LDCM	7.68
Total volume	**714.12**

D-SDA National Facility	Data Volume [TB]
Aircraft	
DAIS	0.23
ROSIS	0.14
HYMAP	0.61
E-SAR/F-SAR	17.63
Space Shuttle/Space Station	
Shuttle Radar Laboratory (X-SAR)	5.69
Shuttle Radar Topography Mission (SRTM)	17.04
MOMS-D2/PRIRODA	2.41
Satellite	
SEASAT	0.09
ERS-1/-2	5.91
ENVISAT	350.12
TerraSAR-X	421.80
TanDEM-X	1,907.77
NOAA AVHRR	47.18
Terra, Aqua MODIS	26.61
Beesat	5.29
RapidEye RESA	6.14
BIRD	0.47
CORONAS	0.11
METEOSAT MVIRI	19.64
METEOSAT 2nd Generation SEVIRI	25.38
METOP GOME-2	28.80
ECMWF	0.01
CHAMP	1.15
GRACE	1.74
SWACI	2.5
TET-1	0.13
Other data and products	
ZKI data and products	15.30
DBBU	2.86
Total volume	**2,912.77**
Scientific/Commercial Partner Facility	**Data Volume [TB]**
IRS	6.9
Total volume EOC	**3,633.78**

Geoscientific Research and Applications

Geoscientific Research and Applications

DFD has the goal to develop information products which address specific problems of scientific, societal and economic relevance. Our focus is on global change in all its facets, the ensuing georisks, and civil security.

In recent decades the value of remote sensing could be demonstrated in international collaborative projects and programs. Despite the numerous advantages, it has only achieved a partial breakthrough on the way to operational use, positive examples being in meteorology, atmosphere research, and in the military and security sector. There are several reasons for this situation, the most important being that:

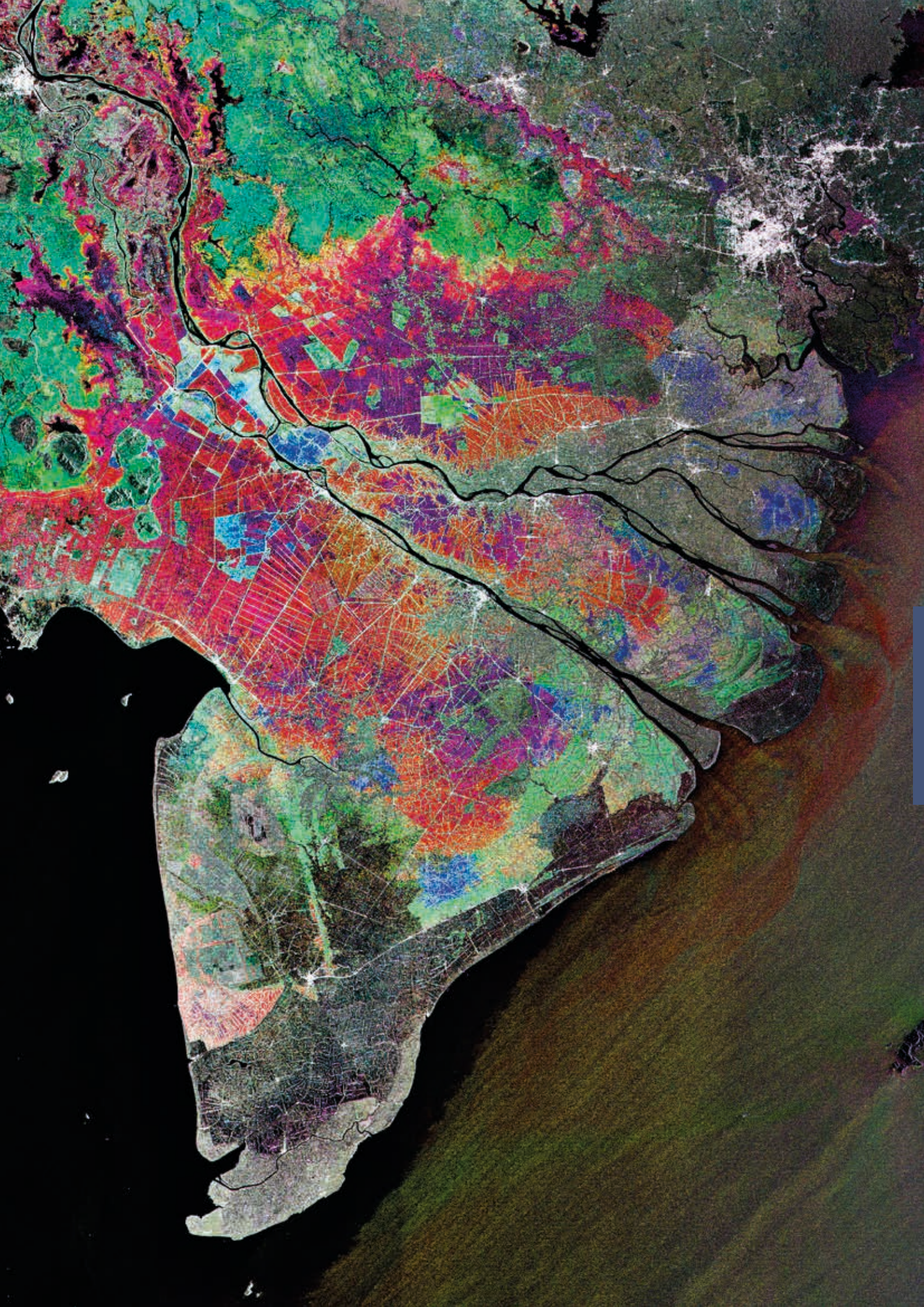
- in most cases developments evolve in the context of science projects of limited lifetime. Results are not thereafter widely applied and standardized. A long-term generic approach is needed
- the end user is not in a position to readily use Earth observation products. He lacks the know-how and the information-technology framework required to link the data with other types of geoinformation, to analyze them, and to keep them up to date long term
- global products based on land surface data are inadequate especially at regional scales. Land surface processes are highly dynamic and heterogeneous. They occur simultaneously on both extremely small and global scales. So Earth observation systems offering differing spatial and temporal resolutions are required. But this leads to jumps in scale and local solutions restricted to particular magnitudes. Standardized geoinformation products with quality indicators valid for different scales are extremely challenging to produce
- in the civilian Earth observation segment, satellite series with assured long-term availability do not exist. Product lines for 'paying customers' (government, industry, etc.) can therefore hardly be developed. The one exception is meteorological remote sensing
- politicians see civilian Earth observation as being on the verge of commercialization. Industry is supposed to develop and operate the satellites and finance the next satellite generation from income. This model disregards the public sector. But without the state as a paying consumer, Earth observation cannot as a whole be put on a stable commercial footing. The successful meteorological and military satellite series show the way ahead
- there is no free-and-open data policy in Germany. In the USA, data from missions financed by public taxes are free of charge. In Germany, development and production costs have to be refinanced by the data users. This is also true for GIS data and aerial images. The result is high start-up barriers hindering the development of innovative services.

DFD operates in this dynamic environment and contributes to breaking down these barriers step by step. For us this means working closely with users when developing products and services. Internally, we have adopted a variety of measures in the last seven years to make the use of remote sensing more effective and efficient.

We have restructured DFD and initiated EOC procedures which transcend project, department and institute boundaries to develop sustainable solutions for remote sensing use. Key aspects are:

- generic processing of optical high and medium resolution data
- developing thematic processors
- modularizing and operationalizing processors

Multitemporal radar image of the Mekong River Delta (ENVISAT ASAR © ESA) for the differentiation of land cover types on the basis of varying surface roughness and inundation



- enabling the processing of large data collections
- assembling time series and expanding reprocessing capabilities to include also high resolution data sets
- integrating data streams in configurable (geo)information systems.

In the area of geoscience research, DFD today has three departments: Atmosphere, Land Surface, and Georisiks and Civil Security. In addition, a virtual EOC working group under DFD leadership is concerned with 'Cold Regions.' This research is rounded out by work undertaken at remote sensing cooperation chairs at universities in Würzburg and Augsburg. The Science Communication and Visualization department augments and supports the specialist departments at the interface to users.

The success of these efforts is reflected in our algorithm and product development. Remote sensing data is increasingly being combined with geophysical and dynamic models to operationally generate value-added standardized products. Our extensive participation in establishing 'turnkey' geoinformation systems in large international collaborative projects is another positive indication.

We want to safeguard the capabilities gained through participation in these projects so they can be applied in subsequent projects. We are gradually modularizing our innovations, that is, encapsulating them in a way that facilitates their ready integration in new processing chains. The modules themselves are to a large degree generically designed so that new sensor data streams can be quickly incorporated. This means that efficient, long-term product lines can be established despite short project financing cycles.

In the future we want to increasingly make available standardized geoinformation products for global change research.

The time series we generate objectively document for large areas the changes on Planet Earth. And only on the basis of such information can reliable statements be made about causes, consequences and possible developments. Models alone are insufficient. Only unbiased evidence coming from actual measurements collected over long time periods can provide an adequate foundation for making far-reaching political decisions and meeting other objectives.

This foundation of information technology and algorithms also allows us to establish customized environmental and crisis information systems. Thanks to their technical maturity they can continue to be operated by project partners after the projects themselves have come to an end. For us this is a reason to commit ourselves to developments in information technology alongside our (geo)science research.

Atmosphere

As the link connecting Earth's surface with outer space, the atmosphere is a major component of 'System Earth.' Its multitude of gaseous, liquid and solid substances compose a complex network of interrelating phase transitions, radiative and scattering processes, as well as dynamic and chemical processes which themselves reflect interactions with Earth's surface and outer space.

A Science Service – Data as Raw Material for Knowledge Gain and Information

Data on the state of the atmosphere are raw material for scientific questions in atmospheric physics, meteorology and climate research. They are also the information basis for numerous applications in such areas as public administration, air quality monitoring being one example, or industry, like controlling solar power plants.

Depending on the terms of reference and the problem to be investigated, requirements vary as to the precision, the spatial and temporal resolution of the raw data, or the information to be derived from them. For many purposes, evidence based on individual cases is adequate, such as to test scientific hypotheses; other applications require limited-duration around-the-clock operation, for example to forecast pollution distribution resulting from volcanic eruptions or fires. And yet others demand long-term uninterrupted continuous operation, which would be the case when attempting to detect and record temperature trends in the upper mesosphere and lower thermosphere.

Satellite based measurements provide wide-coverage global data on the atmosphere. Combining these with other types of data, like balloon or ground measurements, and then assimilating them in numerical computer models that contain our present knowledge about the physical and chemical processes in the at-

"When you look out the window, you notice how incredibly thin our atmosphere is, how such a fragile shell of air we have that surrounds our planet and makes it habitable. And you can read that in a book, but until you see it it doesn't strike home."
(Sandra Magnus, astronaut)

View on Earth's atmosphere from the International Space Station on 08. September 2006

Dust outbreaks from the Sahara can significantly increase the aerosol concentration over Europe with major impact on human health and solar radiation for solar electricity generation (MODIS: © DLR/NASA)

mosphere, such as 3D chemical transport models, make it possible to obtain the relevant customized information.

DFD concentrates its efforts on developing innovative data and information products that are characterized by a quality heretofore unachieved, an example is quantifying the composition of mineral dust, or by their novelty, like quantifying the impulse and energy balance of cyclones by monitoring the atmospheric gravity and infrasound waves they radiate.

In addition, basic research is carried out wherever our understanding of the physical fundamentals is inadequate. The basic research and development called for on aerosols, trace gases, radiation and dynamics of the atmosphere is frequently carried out in the context of international task-sharing networks and partnerships. Instruments are also developed to give access to entirely new types of information, such as infrared spectrometers for optical detection of infrasound at the border to outer space.

With a view to later services, some with uninterrupted around-the-clock operation, pilot products are developed and their added value demonstrated. For example, products based on early detection of climate signals can be used to distinguish anthropogenic from natural effects, to verify climate models, or to validate satellite measurements. After testing, product generation is gradually automated to the required degree, and the results are incorporated in the DFD hosted WMO/ICSU World Data Center for Remote Sensing of the Atmosphere, WDC-RSAT, and made generally accessible.

From science to products ('science service') is a unique capability of DFD. Based on data that is becoming ever more complex and diverse, plus in some cases numerical atmospheric models, services are devised that are tailored to the needs of particular customers or to address specific problems.

The subjects of air quality and health, climate variability, natural hazards, and energy are of strategic relevance for EOC as a whole. During the reporting period these aspects were dealt with in the framework of numerous projects involving basic and applied research, technology development, and technology transfer.

Selected results from this period are featured below. Most of them have meanwhile been published in peer-reviewed specialist journals.

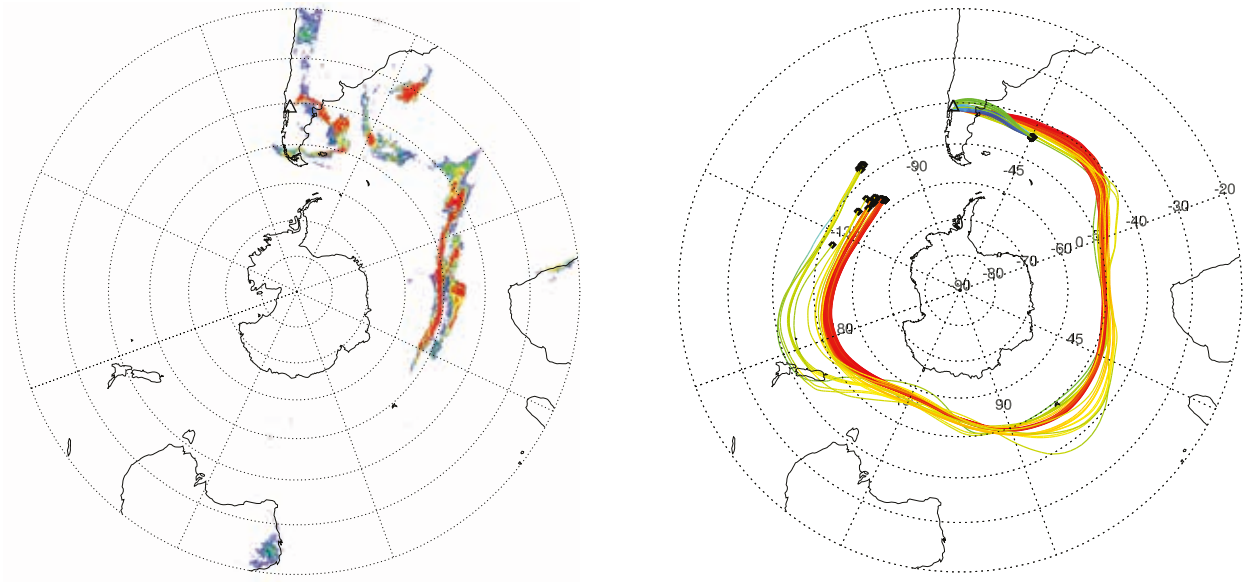
Aerosols and Radiation

Tiny atmospheric particles, so-called aerosols, affect the energy balance of the atmosphere in complex ways. Depending on their chemical composition, size, and other characteristics they can either cool or heat the atmosphere. Aerosol sources can be natural, for example, volcanic eruptions, dust mobilization in deserts, salt mobilization over the oceans, as well as anthropogenic, combustion of fossil fuels being just one example. Aerosols interact with each other, with atmospheric gases, are nuclei for cloud formation, impair our health, and have many other effects. It is therefore of great importance to monitor aerosols with the utmost precision, to quantify their frequency, and to characterize them.

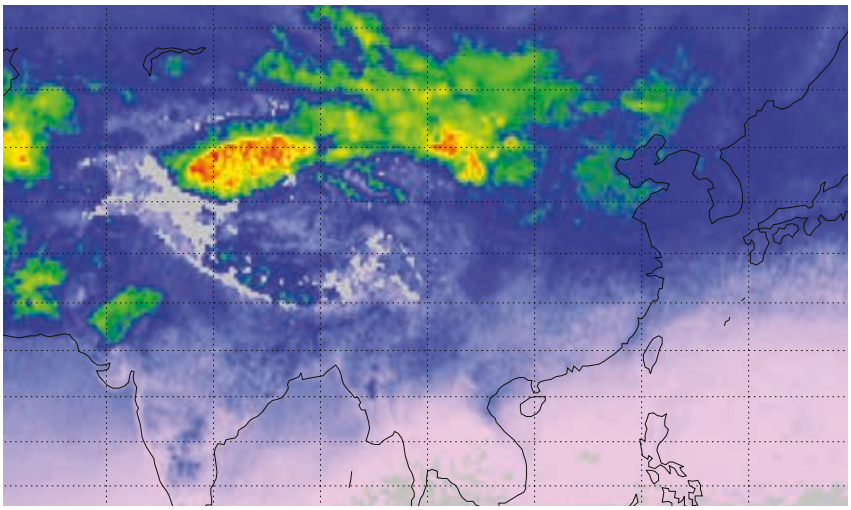
In the reporting period, methodologies and products related to aerosols, clouds and solar radiation were developed and evaluated at DFD, and how they can address questions in the areas of air quality, health, renewable energy and climate variability was exemplarily demonstrated. The focus was on creating synergies from satellite retrieval, modeling and monitoring. In particular, atmospheric soot and mineral dust were studied.

In the field of satellite-based aerosol remote sensing, two new procedures were developed and optimized: SYNAER uses complementary information from two sensors on different platforms to determine aerosol composition in secondary aerosols, sea salt, soot, and mineral dust. Infrared spectra from IASI were used to derive the optical thickness, particle size, and composition of mineral dust and volcanic ash. The cloud detection algorithm APOLLO was adapted to meet new requirements and to generate innovative quantitative products. The procedure now benefits the community by making possible pixel-level error estimation.

The lengthy time series and near-real-time data resulting from these new procedures are being integrated in atmospheric models with creative and complex methods of numerical data assimilation, making possible wide-coverage monitoring and forecasting of aerosol distribution. An important aspect of numerical data assimilation is detailed investigation of the information content of the satellite data and thus a mathematically consistent formulation of the covariances for measurement and model inaccuracies.



A novel retrieval method using MetOp/IASI observations enables global detection, tracking and quantification of volcanic ash. The combination with Lagrangian modeling further allows the determination of the eruption and plume characteristics. The images show the eruption of the Chilean volcano Puyehue in June 2011 (left: ash AOD 0.55 µm – blue 0.5, green 1.0, yellow 1.5, red 2.0/right: long distance trajectory at different heights – blue: 5 km, green: 10 km, red: 15 km).



Monthly mean of the mineral dust burden over Central Asia as derived from MetOp/IASI for March 2009 (Dust AOD 0.55 µm – blue: 0.3, green: 0.8, red: 1.5, gray: no value)

The aerosol information obtained in this way, combined with satellite-based observations of cloud cover, water vapor columns, ozone content and snow cover, form the basis for a precise description of ground-level solar radiation.

Applications based on this information include site assessments for photovoltaic and solar thermal power plants, monitoring photovoltaic installations, potential and scenario analyses, load management for power and gas facilities, scheduling conventional thermal power plant operation, and anticipatory heat management for buildings.

Besides mapping historic solar irradiance data, new developments relate to predicting irradiance for the next few hours and days, as needed for solar plant monitoring, controlling, and grid integration. For such purposes, an improved data basis is being developed for forecasting aerosols and cloud cover. This includes optimizing how dust mobilization is incorporated in aerosol models, and short-term forecasting of cloud movement based on geostationary data. In addition, LIDAR data from the CALIPSO satellite are used to study the vertical distribution of aerosols, an important consideration for solar tower power plants.

In addition to the applications in the area of renewable energy mentioned above, aerosol data are also used to determine when air quality pollution limits are exceeded, to analyze the connection between respiratory diseases and particulate matter in the air, as well as to investigate the interrelationships among aerosols, clouds and precipitation over wide areas. Average annual concentrations of ground level particulate matter are derived from aerosol content and composition data from satellites combined with model data for the vertical stratification of aerosols. How aerosol particles interact with clouds and precipitation (Twomey and Albrecht effect, semi-direct effect) is studied using time series extending over several years of satellite measurement of these variables. Special attention is paid to evaluating AVHRR data, since they are almost the only satellite data that allow derivation of cloud and possibly also aerosol information going back to the early 1980s.

The sample products generated, revealing aerosol content, particulate matter, clouds, and solar irradiance, are

optimized in European projects to meet specific customer requirements. They include the products offered as part of the Copernicus services on the composition of the atmosphere, on air quality, and on solar energy. Lengthy time series of aerosol parameters benefit climate research and are especially exploited as part of the ESA Climate Change Initiative. DFD plays a leading role in all these projects.

Dynamics

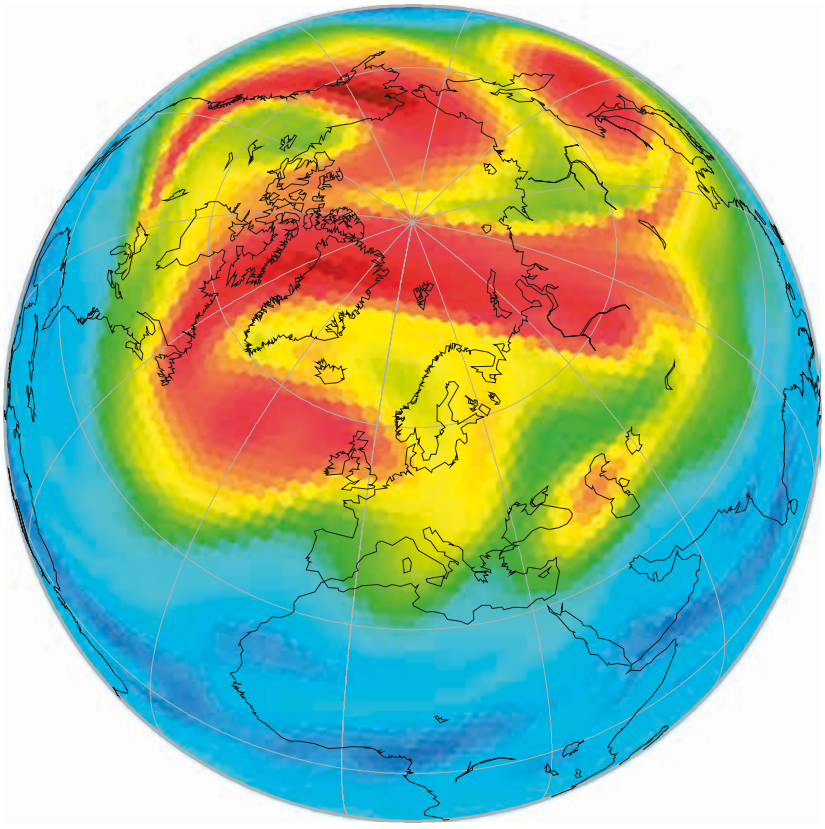
Waves can transport energy and impulse over long distances, leading to the linkage of widely separated atmospheric regions. Such processes are not always taken into account in atmospheric models. This is especially the case for the relatively small-scale gravity waves. So far, the focus has been on effects of wave drag, nonlinear wave-wave interaction as in triads, and wave conduction effects ('an energy freeway in the atmosphere'), since their occurrence and stability are so far inadequately understood. For this reason, forecasts based on atmospheric and climate models are on principle open to attack. In this context, powerful spectral analysis methodologies like bispectral analysis, maximum-entropy methods, harmonic analysis, and 2D Morlet wavelet autoregressive and moving average approaches are being further developed.

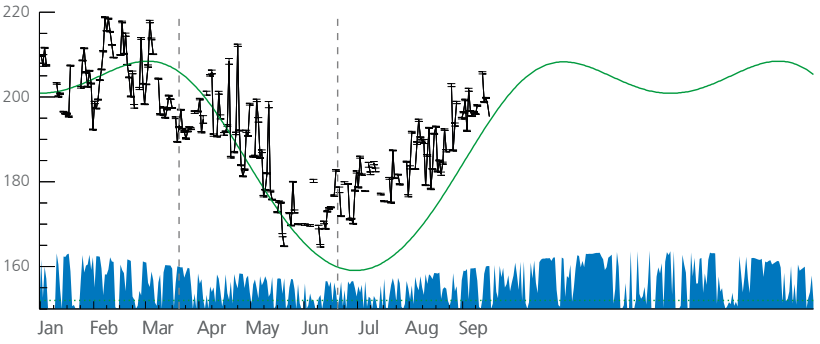
To parameterize wave activity in models as realistically as possible, it is necessary to characterize gravity wave activity. This means quantifying the structure function of the waves, including their wavelength and frequency. It must be done globally since the atmosphere is a coupled system, so satellite-based measurements are essential. Accordingly, a gravity wave climatology was derived from ten years of TIMED-SABER (V 2.0) temperature profile measurements.

On large scales, planetary waves in particular are responsible for the transport of air masses over wide areas. They are the cause of such spectacular phenomena as stratospheric warming. It has been shown that especially nonlinear resonant interactions between planetary waves are indicators of impending stratospheric warming. Wave-drag effects lead to irreversible mixing of air masses from different geographic latitudes and initiate processes which considerably influence the trace gas budget of the atmosphere. So-called 'streamers,' finger-shaped extensions of ozone-poor air masses from subtropical to mid-latitudes, are partially caused by planetary waves. They are responsible for sudden increases in the amount of ultraviolet radiation in central Europe from one day to the next, for example. The morphology of streamers is not yet fully understood.

Against the background of global change, the question arises as to how the state of the atmosphere is being affected. An analysis of satellite-based and other measurements suggests gradual

Monitoring total ozone variability from satellites enables investigation of the dynamics of the middle atmosphere. This satellite based analysis of ozone at 20 km altitude shows a situation where strong dynamic activity led to the destruction of the polar vortex and permitted mixing of ozone rich air into lower latitudes (ozone in ppm: light blue: 1, green: 2, orange: 3, dark red: 4 ppm).





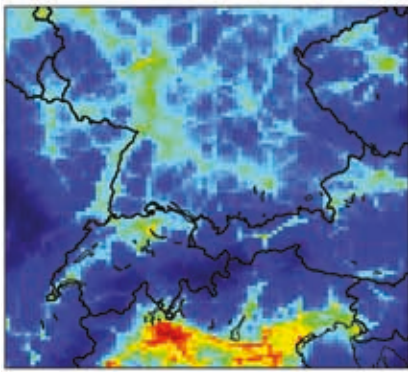
Since January 2009 the temperature in the mesopause region has been observed routinely at DFD in Oberpfaffenhofen. Each night the infrared spectrometer GRIPS 7, which is placed on the Zugspitze mountain, measures fully automatically the emitted radiation at an altitude around 87 km. Note that the annual cycle of the mesopause temperature is opposite to the annual cycle on the ground.

alterations in planetary wave activity, and consequently in wide-area flux patterns. Solar phenomena like the Hale cycle and solar rotation seem to play a role. Relevant correlations have been identified, and simple, practical indicators derived for testing the correct representation of planetary waves in climate models.

When assessing the results it is essential to know the quality of the data employed. In the case of satellite based measurement this is usually determined by comparison with ground or balloon measurements. But the spatial offset between measurements that are to be compare as well as the difference in the sensitivity of different instruments to atmospheric dynamics lead to quite significant variations in the results ('observational filter'). In the framework of two elaborate field measurement campaigns carried out with international participation in Norway and in the Alpine piedmont, BHEA and SIGMA, 200 radiosondes were launched during satellite overflights. This led to the development of a tool that estimates the expected differences caused by any spatial and temporal offsets in the validation measurements, solely on the basis of the natural variability of the atmosphere. It is freely available from WDC-RSAT.

Powerful cyclones and fronts radiate gravity and infrasound waves. In principle, continuously recording the changes in the intensity of these wave fields induced in the atmosphere allows conclusions about changes in the intensity of the cyclone itself. This information makes it possible, generally speaking, to improve midterm forecasts of the intensity, lifetime and path of storm systems (like Track V weather situations), and thus to obtain an early assessment of their damage potential.

In the field measurement campaign CESAR over the western Mediterranean Sea, this approach could be validated by measuring a tropical cyclone in November 2011. It could be demonstrated that the vertical impulse flow of gravity waves during a Medicane ('Mediterranean Hurricane') was higher by a factor of four to five compared with calm conditions. An increase in vertical impulse flux could also be identified in connection with weather front passages. Since this is essential information for atmosphere and climate models, work has commenced on a method using an infrared spectrometer (GRIPS) to monitor from the perspective of a satellite changes in the intensity of storm-induced impulse fluxes. It is being planned as part of the Infrasound Explorer Satellite (InES) mission.



A novel particle filter based assimilation method from DFD improves air quality forecasts. Shown are ozone concentrations over Europe after assimilation of satellite data and in-situ measurements into the POLYPHEMUS/DLR ensemble system (in µg/m3 – dark blue: 0.0, green: 12.5, dark red: > 22.5 µg/m3).

Trace Gases

Trace gases like CO_2 that affect solar radiation have a significant influence on the energy balance of the atmosphere. They contribute to the natural greenhouse effect, without which Earth's surface temperature would be far below the freezing point. The increase in their concentration in the atmosphere is a global threat which likely directly influences the energy balance of the atmosphere. This process requires careful monitoring. The trace gas ozone filters out unhealthy solar ultraviolet radiation in the stratosphere. Thus the global ozone problem is likewise a global threat. The actual extent of the recovery of the ozone shield expected from the Montreal Protocol's ban on substances which break down ozone has to be monitored. In the troposphere, air pollution leads to an increase in harmful trace gases like ozone. This threat also has to be carefully watched. In the reporting period work was undertaken on all these topics.

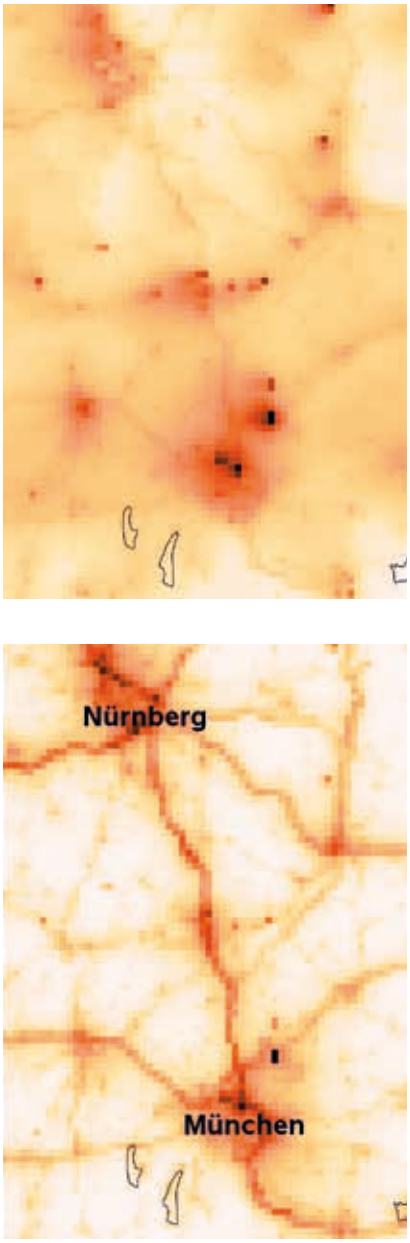
One focus of DFD activity is numerical data assimilation, in other words the linking of measurements and atmospheric models. The assimilation in numerical atmospheric models of data from remote sensing satellites and from ground stations leads to higher-quality atmosphere monitoring. Models are thereby linked more closely to the actual state of the atmosphere, data gaps are filled, and information is made available which cannot be obtained from the various measuring instruments themselves. In particular, the complex and innovative methodology of 4D variational data assimilation was further developed. This work contributes to the implementation of the WMO-IGACO (Integrated Global Atmospheric Chemistry Observation) strategy. This is a plan to generate the best possible data sets, in the sense of complete, precise and with high spatial and temporal resolution, by combining ground- and satellite-based observations with atmospheric models using modern data assimilation methodologies.

Specifically to monitor the stratospheric ozone layer, assimilation methods like 4D variational data assimilation were developed to link the complex 3D chemical transport models ROSE/DLR and SACADA/DLR with measurements from the GOME (ERS-2), SCIAMACHY, MIPAS (ENVISAT) and GOME-2 (MetOp-1) instruments for around-the-clock operation.

This development work was and continues to be consistently carried out in close cooperation with national and international partners on a task-sharing basis; the resulting methodology is a component of Europe's Copernicus atmosphere service. In addition to daily mapping of stratospheric ozone, the service is used for both detailed and trend analysis of chemical ozone breakdown.

As to air quality monitoring, DFD has built up expertise in regional modeling. The air quality model POLYPHEMUS/DLR is being used, driven by the meteorological model WRF, which was configured and adapted for various target regions. Air quality, defined in terms of the concentration of ground-level ozone, NO_2 and particulate matter, is routinely determined daily as well as one and two days in advance for Bavaria and Baden-Württemberg. In order to take chemical altitude effects into account, a downscaling concept was developed for high-resolution topographical data. This service was part of the ESA-PROMOTE and Copernicus Downstream PASODOBLE projects, both coordinated by DFD, and is now consolidated at WDC-RSAT and freely available. Together with industry in the EU project obsAIRve, technologies were developed to provide information on current air quality also via a mobile telephone app.

The expertise in air quality that has been acquired could also be employed to develop a satellite-based environmental information system for Saudi Arabia in cooperation with industry.



Air quality forecasts and analyses are provided at high spatial resolution. Shown is the spatial variability of surface NO_2 during one day. At night (top), O_3 is destroyed to form NO_2. During daytime hours (bottom), NO_2 is emitted by traffic and quickly destroyed by solar radiation. (NO_2 in µg/m³ – yellow: 4, dark brown 44 µg/m³).

The Network for the Detection of Mesospheric Change comprises more than 50 stations worldwide. The Schneefernerhaus environmental research station on the Zugspitze mountain is one of them. The measurements will aid timely detection of climate signals in the mesopause altitude region (ca. 90 km altitude).

The connection between air quality and health is evident. Nevertheless, the functional relationship is complex and in individual cases not easy to clearly indicate. The first promising studies were carried out in cooperation with the medical and tourism sectors.

Gas and ash emitted by volcanos can affect the atmosphere on continental and intercontinental scales if injected at a high enough altitude. In extreme cases, clouds of ash can even negatively affect air traffic, as happened in 2010 after the eruption of the Icelandic volcano Eyjafjallajökull. A significant uncertainty factor in forecasting ash distribution has turned out to be the inadequate spatial and temporal description of the source function at the volcano. Efficient methodologies were accordingly developed based on GOME-2 measurements of SO2, IASI measurements of ash, and using trajectory calculations such as Flexpart and Flextra in order to significantly improve quantification of the injection height of ash and SO2.

GRIPS – A Contribution to the International NDMC Network to Observe Temperature Trends at the Border to Outer Space and to Detect Natural Hazards

According to present knowledge, an increase in the CO_2 concentration of the atmosphere should lead to cooling in the mesosphere. This cooling is supposed to be considerably stronger than the heating at the surface, by at least one order

of magnitude. The mesosphere might therefore be an early indicator of climate signals.

DFD is accordingly working to further develop the infrared spectrometer GRIPS (Ground-based Infrared P-branch Spectrometer), which measures at ca. 1.5 micrometers the emission of OH molecules displaced by radiation at around 87 kilometers altitude ('Airglow'), and from this value derives the temperature there– the coldest place of System Earth.

At present DFD and its partners operate a total of ten ground-based GRIPS systems at locations in Norway, Germany, France, Spain, Italy, Georgia, Israel, and the Antarctic. The instruments run day and night, fully automatically, and the automatic processing of their data takes place in near real time. The data are archived at WDC-RSAT and distributed from there.

These measurements are supplied to the international Network for the Detection of Mesopheric Change (NDMC), which is coordinated by DFD and the University of Buenos Aires, Argentina, and includes over 50 stations worldwide in over 20 countries. NDMC participates in the United Nations World Climate Research Program (WCRP).

Two so-called airglow imager systems at Oberpfaffenhofen and at the Schneefernerhaus environmental research station on the Zugspitze mountain have also been put into operation. In order to record the temperature at about 95 kilometers altitude, the photometer TANGOO (Tilting-filter spectrometer for Atmospheric Nocturnal Ground-based Oxygen & hydrOxyl emission measurements) was developed. It measures the emission of radiation-activated molecular oxygen.

Since the temporal resolution of the GRIPS system is now in the range of one second, it can also be used to record for the first time infrasound signals in the airglow, whose source is frequently in the lower atmosphere or even at the Earth surface.

In principle, this could make possible the rapid detection of natural events like tsunami, volcanic eruptions or major explosions.

A challenge in data interpretation is distinguishing the various infrasound sources. To do this, numerical propagation modeling for infrasound signals (HARPA/DLR) was optimized, for example by taking into account such factors as topography and realistic damping processes and background atmospheres. Heating rates for the upper mesosphere and the lower thermosphere were estimated based on infrasound measurements.

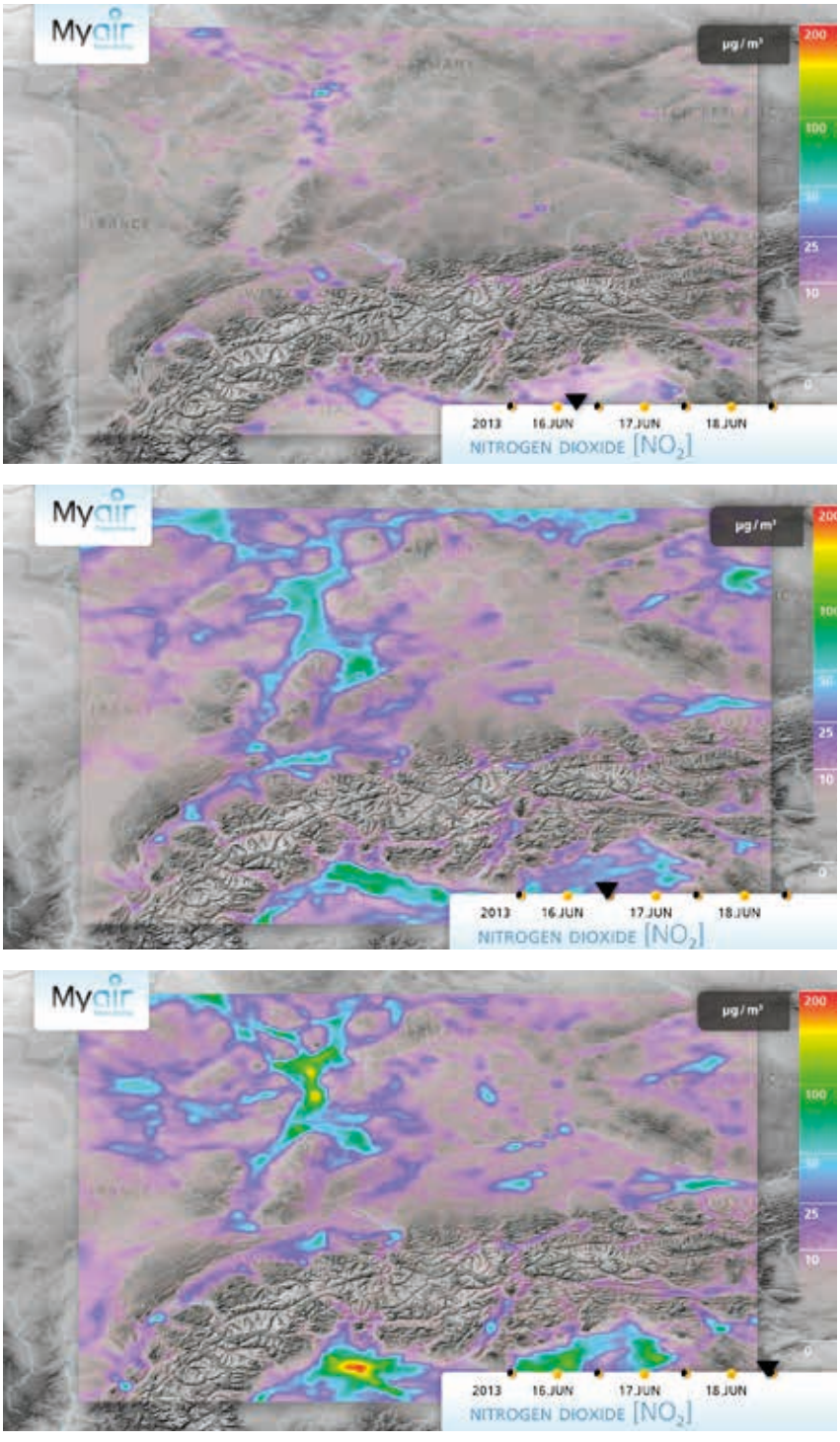
A GRIPS system is presently being made ready for aerial deployment in cooperation with the DLR Institute of Atmospheric Physics. Likewise, first plans are being made to install it on a satellite (the Infrasound Explorer Satellite, InES).

WDC-RSAT – World Data Center for Remote Sensing of the Atmosphere

WDC-RSAT offers free of charge, unrestricted access to data, information and services based on remote sensing of the atmosphere. Its function as a World Data Center is performed under mandates from the International Council for Science (ICSU) and the World Meteorological Organization (WMO).

The data and information products available from WDC-RSAT are archived, documented and made available without restriction and free of charge to the international science community and the interested public via an easy-to-use internet portal (http://wdc.dlr.de). In addition to its own data and information products at DLR, primarily from current and concluded European missions such as MetOp-A/B, ENVISAT, ERS-2, and MSG, worldwide access is possible to a multitude of existing information products

WDC-RSAT provides daily air quality forecasts from POLYPHEMUS/DLR for several regions, including southern Germany and the Alps. The products comprise animations and web services.



based on satellite data, giving WDC-RSAT the character of a 'one-stop-shop'. This is made possible by a Letter of Agreement with NASA that regulates mutual data exchange, and similar arrangements.

Connected with the WMO mandate both as to content and information technology is the linkup of WDC-RSAT with the new WMO information system WIS. For this purpose WDC-RSAT and the German Weather Service, DWD, join efforts in a data processing and distribution center. WDC-RSAT is especially involved in WMO's international Expert Team WDC.

WDC-RSAT also participates in the Atmospheric Composition Constellation working group of the Committee on Earth Observation Satellites (CEOS), with the goal of simplifying data exchange between producers and users.

Visualization and data retrieval by downloading the products archived at WDC-RSAT are enabled with service-oriented interoperable and ISO-compatible access method following the standards of the Open GIS Consortium. The complete range of standard services is supported, like Web Map Service, Web Feature Service, Web Coverage Service, Web Processing Service, Catalogue Service for the Web and the Sensor Observation Service. Concepts for specific product-access procedures are developed and realized in cooperation with WDC-RSAT partners, including NASA, CNES, CNRS, and WMO-GAW. Post-processing is one of the options, such as selection of data sets according to spatial or temporal criteria, merging different data sets, computing-on-demand services, or the user-oriented interpretation of products. WDC-RSAT supports its data suppliers in defining ISO-conform metadata.

The role of WDC-RSAT as a data publication agent should be seen in this context. This function is carried out on the basis of a mandate from the Technische Informationsbibliothek (TIB) Hannover and supported by the Deutsche Forschungsgemeinschaft (DFG), a German research foundation. Unique Digital Object Identifiers (DOI) are assigned, which make it possible to quote and reference data products, giving them a rank similar to that of a scientific publication.

On behalf of the Bavarian Ministry of Environment and Health, WDC-RSAT operates a data analysis center for the Schneefernerhaus environmental research station (UFS). This gives UFS researchers access to the measurement data collected at UFS as well as to satellite-based data and information products and atmospheric models via a link to WDC-RSAT. For such purposes there is also a direct link to the Leibniz High Performance Computing Center (LRZ) in Garching.

WDC-RSAT is also a component of the Copernicus atmosphere service. And the role of WDC-RSAT as a communication and data platform for the international global program, Network for the Detection of Mesospheric Change (NDMC), mentioned above, should also be underlined in this context.

Relevant Publications: [5-6], [10], [14-15], [17], [21], [33-34], [36], [49], [51], [56], [64], [83], [121], [144], [147], [159], [163], [167], [173-174], [181], [188], [192], [198], [204], [205], [212], [217], [224-225], [230], [258], [355]

Land Surface

Human activities leave their marks on an estimated 80% of the global land surface. These 'fingerprints' are even visible from space. From the herringbone patterns of tropical deforestation to the large square patches of agricultural fields to the concrete splotches of urban sprawl, humans have attained the magnitude of a geological force in reshaping the environment.

Deviation from mean snow cover duration in Europe for 2005/2006 from the 10 year mean derived from long time series MODIS data (deviation in days: red: -80, orange: -40, light blue +40, dark blue +80 days)

Worldwide changes to the environment are being driven by the immediate need to provide food, water, clothing and modern comforts to an increasing global population. The expansion of croplands, pastures and urban areas comes along with a rising consumption of water, energy, and fertilizer. The demand for mineral and fossil energy resources influences natural ecosystems by direct impact and secondary effects like pollution and socio-economic changes. These effects potentially undermine the capacity of ecosystems to sustain their biodiversity, maintain freshwater and regulate air quality and climate. Hence, to find the right trade-off between immediate human needs and the long-term protection and conservation of our environment and its resources is one of mankind's major challenges.

Access to up-to-date, wide-area geoinformation on the current status of the environment and on major trends of change and transformation is a key requirement for meeting the challenges of global change and developing and implementing effective and efficient adaptation and mitigation strategies.

Earth observation can provide this information with its distinct capability to achieve frequent and spatially detailed monitoring of the environment–from the global scale down to local analyses.

Earth observation techniques facilitate assessment of the actual state of the environment as well as the detection, analysis, and evaluation of its natural and anthropogenic transformations.

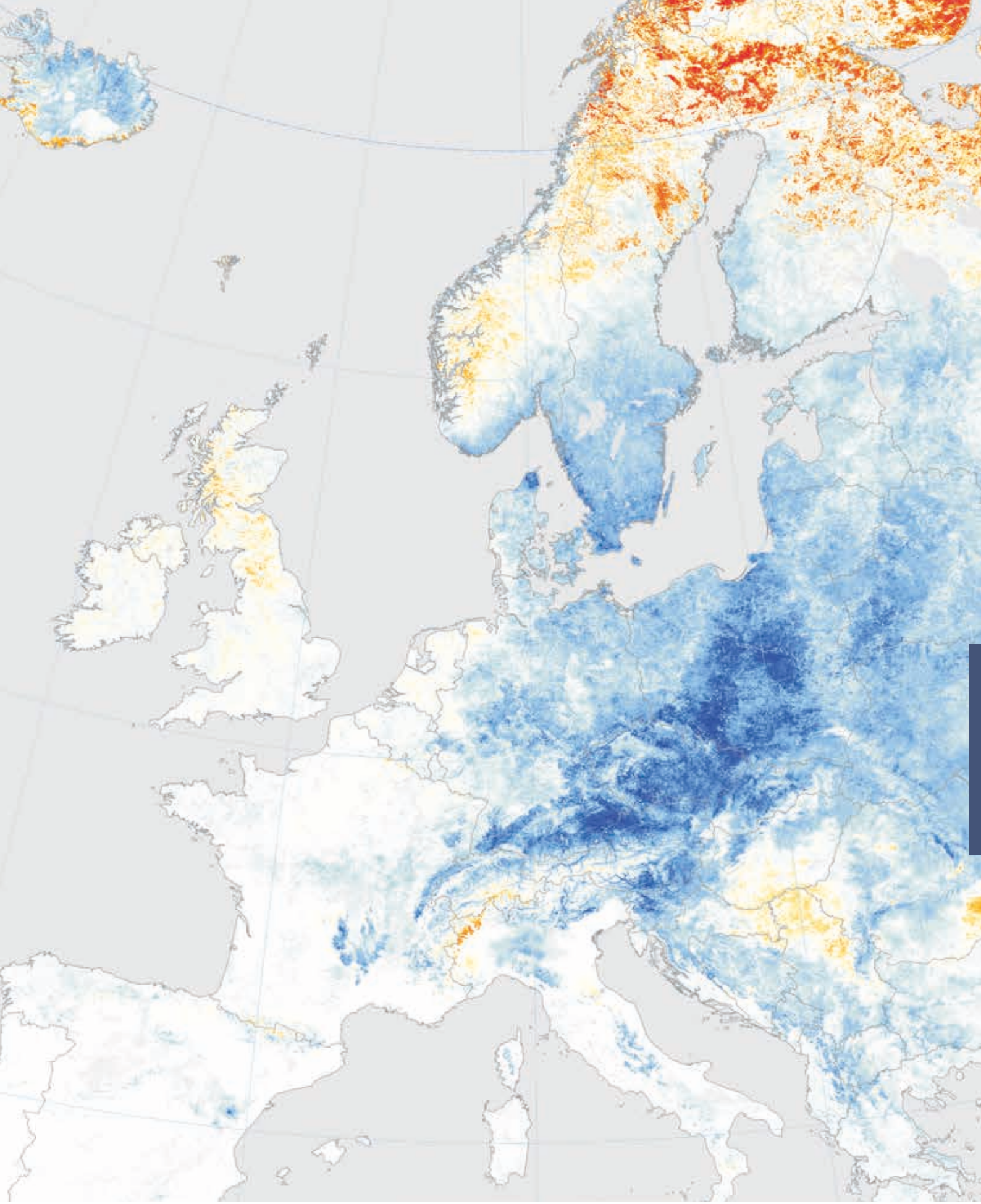
In view of the major challenges of global change and the resulting need for information on the underlying drivers and phenomena, a new department called 'Land Surface' was established at DFD in 2009. The primary mission of this new department is to bridge the gap between remote sensing technology and applied geoscience by developing targeted methods that turn Earth observation data into information of practical use for nature conservation and sustainable land management. The activities of this department are documented in more than 100 peer-reviewed publications.

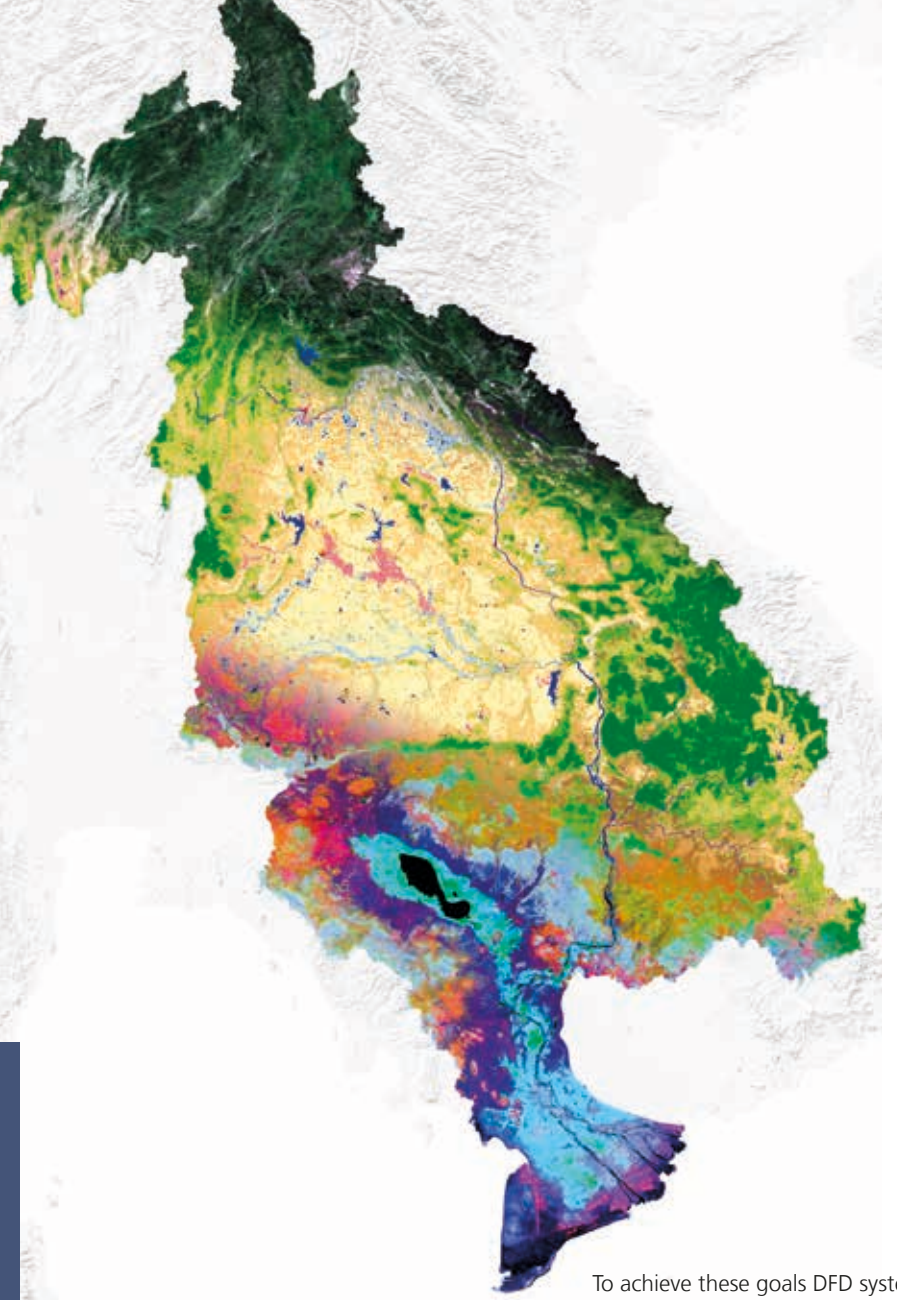
The research and development activities in the Land Surface department focus on three main application areas:

- land surface dynamics
- resource informatics
- urban development and land management.

The corresponding geoscientific research is expected to facilitate:

- characterizing and monitoring the status of the land surface
- understanding land surface processes and interactions
- detecting changes and distinguishing long term trends from natural variation
- implementing viable and environmentally friendly land use concepts and practices.





Land surface analysis for the lower Mekong basin derived from MODIS 250 m time series data (upper part: cloud free mosaic, middle: land cover, lower part phenological information)

To achieve these goals DFD systematically spurs the development of methodological and technical solutions based on Earth observation that provide quantitative and qualitative variables and indicators characterizing the condition, quality and development of natural and cultivated landscapes. These products and knowledge contribute input for decision making and modeling future developments. At the same time the geoscientific and methodological knowledge gained is used to support mission engineering for future Earth observation missions.

The following sections provide more detailed information on selected research and development activities. The examples are ordered according to the three major foci: land surface dynamics, resource informatics, and urban development and land management. In addition, major technological developments with a bearing on all three areas are described.

Land Surface Dynamics

The land surface is constantly changed by natural processes like the vegetation growth cycle, the water cycle, erosion, and climate effects. In order to distinguish long term trends from short term variations in these processes it is essential to analyze data from lengthy time series.

Time Series

Long-term data records of land surface variables can not only answer pressing questions on changes of our planet, but are also of high relevance as input for hydrologic, phenologic, or climate modelling on regional and global scales. When analyzing these data records strong emphasis needs to be put on the consistency of the measurements and on the accuracy and reliability of the estimates. By producing descriptive quality indicators we can quantify changes to the land surface and potentially link land surface changes to natural and anthropogenic forcing.

For example, time series documenting the spatial extent of fire disturbance for several years are an important input variable for global climate models. This information can be derived from long-term data records from sensors like VEGETATION, MERIS or AATSR. Similar products already exist, although their acceptance in the climate modeling community is limited due to the lack of consistent quality and reliability indicators. ESA's Climate Change Initiative aims at increasing the quality of preprocessed global-scale Earth observation data and providing quality indicators describing the error budget of the products.

EOC in this context has developed methods to improve the geometric and radiometric quality of MERIS and AATSR data. For example, DLR's own atmospheric correction software ATCOR was extended to handle MERIS and AATSR data. To overcome known errors in the fire disturbance product introduced by confusion between the representation of

burnt areas and water bodies, a dynamic water mask was developed based on static water masks derived for SRTM and ASAR data combined with localized spectral learning algorithms. For all individual preprocessing steps fuzzy-logic based quality indicators are assigned to document the quality of atmospheric and geometric correction, cloud, water and snow masks. Global coverage based on AATSR data for the year 2008 is already available. A consistent climate record containing three years of MERIS, AATSR and VEGETATION global coverage will soon be available to the climate modeling community.

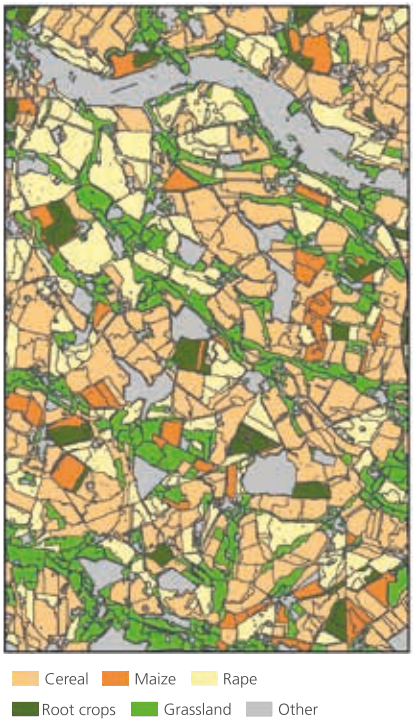
When aiming to distinguish long-term trends from short-term natural variation and anthropogenic effects one has to carefully eliminate sensor and observational artifacts from the remote sensing time series. For example, when producing continental-wide snow cover products from medium resolution Earth observation data extensive cloud coverage and effects such as polar darkness have to be dealt with. Based on data assimilation techniques a temporal cloud filter was developed for the MODIS daily snow cover products and at the same time the polar darkness effect was removed from the input data. Using the optimized data sets, mean snow cover duration, snow cover inception and snow cover melting indicators were derived for all of the northern hemisphere based on data for the period from 2000 to 2011 with an accuracy above 90% for 87% of the area. The results can be utilized for e.g. abnormal event analysis, glacier inventories, and studies on possible impacts of climate change on snow cover characteristics. The methodology developed will also be used in studies of other climate situations with high cloud coverage and in conjunction with new sensors (Sentinel 2 and 3) to increase the usability of optical data based on time series analysis.

Information products like those showing mean snow cover duration gain further value with extended temporal coverage. Accordingly, in 2013 reprocessing of DLR's 30-year NOAA AVHRR archive for Europe started. We aim to derive a consistent series of biophysical, geophysical, and thematic variables (such as land surface temperature, phenologic metrics, fragmentation metrics, etc.) as well as interpretive trend indicators (for example, exceptionally cold/warm periods, variations in onset and duration of vegetation periods). First products are expected to be generated by the end of 2013.

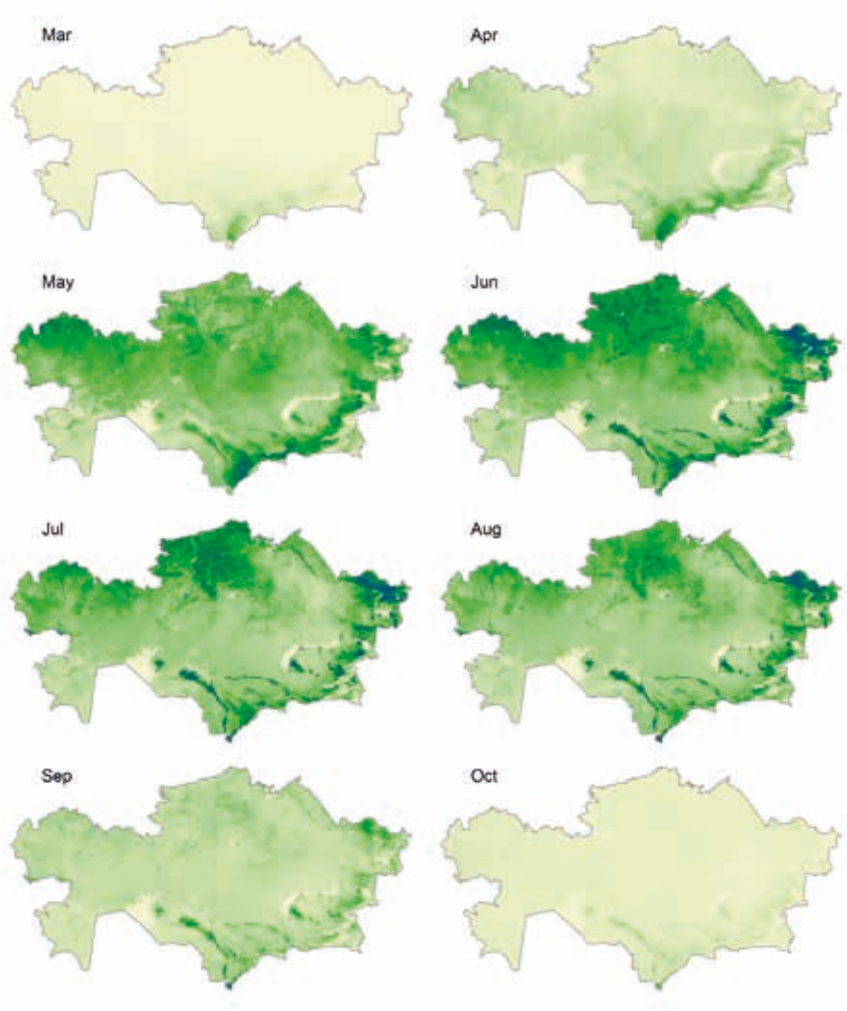
Land Cover

Reliable, reproducible and up-to-date land cover and land use maps from satellite imagery provide basis data for interpreting human induced changes to the land surface on regional and global scales. They also support planning activities in many fields of land management such as integrated water resources management, agricultural management, and regional climate modeling.

Producing land use maps by common image classification techniques often includes a high degree of manual operator interaction, such as for data preparation or sampling that employs a variety of software tools. However, manual interaction increases the costs of the product and reduces reproducibility when dealing with large amounts of data, such as when the goal is to cover large areas or to handle time series. It is thus a major DFD goal to reduce the number of manual sequential processing steps. The developed approach TWOPAC (Twinned object- and pixel-based automated classification chain) realizes pixel- and object-based supervised classification of multisensor and multiresolution satellite imagery in an automated way. It supports the management and processing of sample data and the classification of Earth observation data in either vector or raster form. The approach utilizes a database of pixel and object samples that permits the training and validation of classifiers at many points in time. TWOPAC currently supports C5.0, but can be expanded to



Earth-observation-based monitoring approaches are used to detect, analyze and document policy-driven transformations and trends regarding land use patterns and intensity



Mean monthly Net Primary Productivity (NPP) for Kazakhstan from 2003 to 2011 ,(NPP in g C m^{-2}: yellow areas 0, dark blue values > 100 g C m^{-2})

different modular classification methods as e.g. Maximum Likelihood Estimation, and Support Vector Machines. The software meets the specifications for OGC-conform Web Processing Services. The automated modular classification process chain has been tested on several data sets from study areas in the Mekong Delta, Central Asia and West Africa. Classifier stability and classification accuracy are analyzed and documented. The method provides stable results with accuracy comparable to established classification approaches.

Biomass

Besides land cover information the amount and change of terrestrial biomass is an important land surface parameter. It is valuable not only for global climate change research but also for assessing the status of natural ecosystems or estimating the bioenergy potentials of managed ecosystems. To estimate above ground biomass remote sensing variables can be used to drive plant physiological process models. DFD operates the BETHY/DLR (Biosphere Energy Transfer Hydrology Model) process model to estimate Net Primary Productivity (NPP) of terrestrial ecosystems. BETHY/DLR was adapted to be driven by remote sensing data and produce information on the state of biomass for a particular time frame. Remote sensing input (land cover information and time series for the leaf area index) can be derived from SPOT-VEGETATION, MODIS or MERIS data, while the meteorological input data comes from the European Centre for Medium-Range Weather Forecasts. We have developed methods to validate modeled Net Primary Productivity and to estimate energy potentials for forests. Germany's forests were chosen as a test area to validate the methodology. To validate the modeled NPP, we use the increase in above ground biomass (AGB), derived from the National Forest Inventory of Germany for the country's four main tree species (beech, oak, pine and spruce). The validation is performed by converting modeled NPP to AGB. Additionally, theoretical energy potentials were substituted based on the modeled and validated results. Here, sustainable use forestry practices are assumed: only the annual increase in AGB is used to derive energy production. This is done by using tree species and age-dependent heating values. With this approach, theoretical annual energy potentials for vegetated areas in Central Europe can be estimated. The model has also been successfully applied in different climate zones ranging from semi-arid areas in South Africa and Central Asia to alpine regions in Pakistan.

Resource Informatics

In the field of resource informatics DFD's research activities are focused on the balance of resource needs and availability, with particular interest in arable soils, water and mineral resources.

Soil Fertility

Close to 100% of the arable land on Earth is already in use. Thus, the conservation of fertile soil is one of our key challenges. Quantification of soil carbon stocks and assessment of associated ecosystem parameters and processes are of major importance in the context of food production, carbon sequestration and ongoing land degradation due to climatic variations and human activity.

Particularly in semi-arid regions the degree of degradation and the fertility status of soils can often be linked to the mineral composition and the content of organic matter in the top soil layer. DFD is using spectroscopic methods to determine the type and abundance of indicative soil constituents. Spectral absorption features in soil minerals and soil organic matter allow their identification and quantification in soils using multiregression tools.

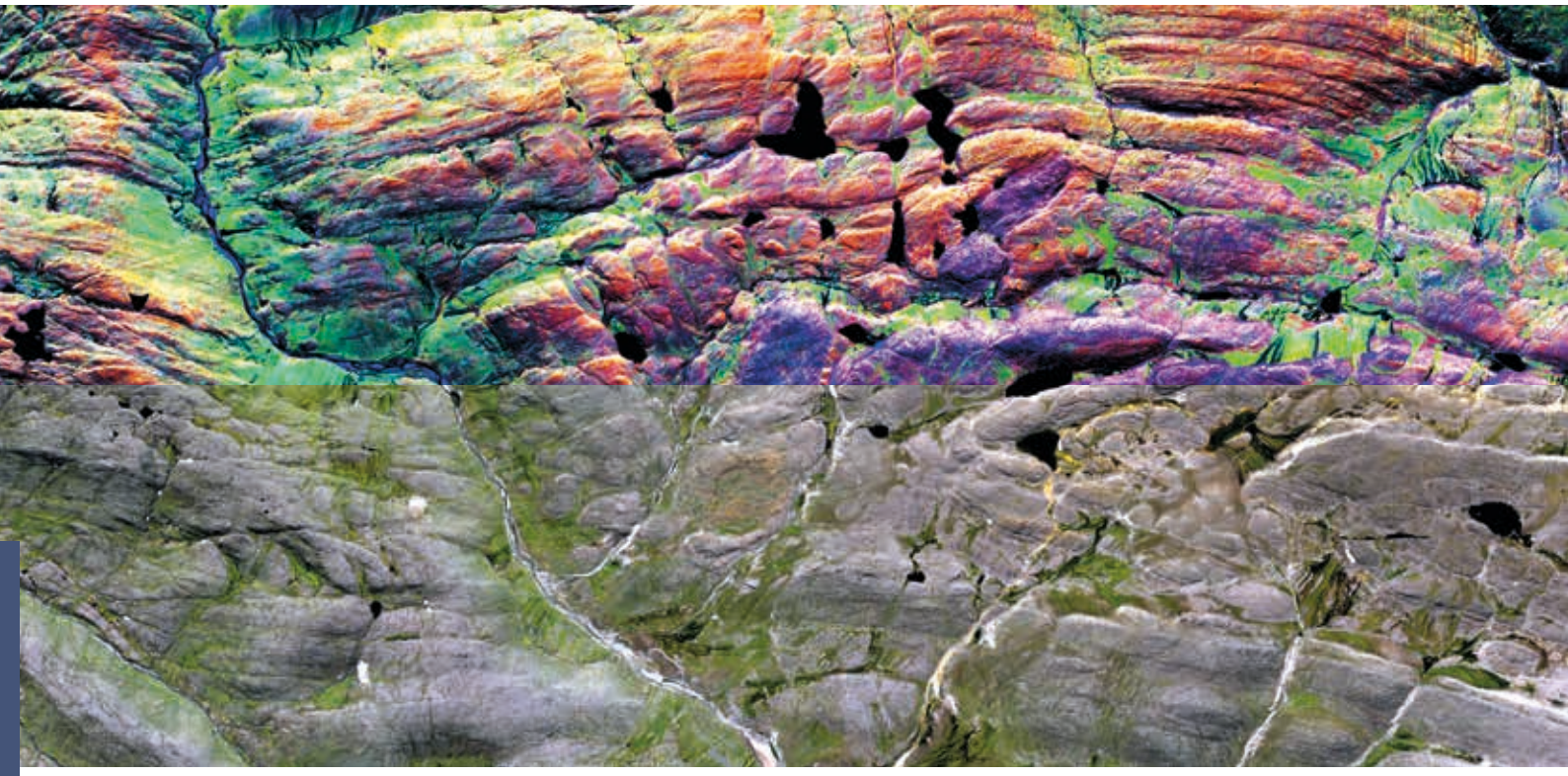
Methods are developed that use a combination of measurements from field and airborne or–once they become available– spaceborne spectrometers and the results of laboratory analysis of soil samples to map various soil constituents, including soil organic carbon, iron oxides and clay content. To quantify soil properties, physically-based soil prediction models are built based on laboratory and field reference data using spectral feature analysis and multiple linear regression techniques. In the resulting soil constitution maps, observed spatial patterns are linked to geomorphic features and land surface processes, such as soil erosion. Traditionally, in approaches like this, image elements showing a bare soil abundance under 90% are excluded from the analysis. But in a heterogeneous semi-arid landscape this could mean that in an area of interest fewer than10% of the observations would be considered valid.

Thus, we combine a multivariate regression technique with spectral mixture analysis. By doing so, the spectral signature of dry, green vegetation for an observed pixel can be eliminated and the bare soil spectral component can be reconstructed under certain validity criteria. Applying the regression model to these reconstructed bare soil pixels may increase the spatial coverage by a factor of ten.

The approach accounted for significant benefits in collecting data from semi-arid areas with very inhomogeneous land cover, for example, in the semi-arid Albany Thicket Biome in South Africa where the technique was applied and assessed. We could show that soil constituent maps provide basis data for local restoration efforts including site-specific management, while soil carbon maps provide a direct assessment of current topsoil ecosystem carbon pools that may support ongoing carbon sequestration initiatives. The applicability of the developed methods to other geographic regions and for satellite based imaging spectrometer data will be investigated over the next few years.

Water Resources

Like fertile soils the availability of clean water is one of the key issues of the coming decades. Large watersheds do not only contain water; they are the foundation of natural resources for millions of inhabitants. Use conflicts and overexploitation threaten these limited resources. In large river deltas population increase, changing climatic conditions and regulatory measures at the upper reaches of rivers lead to severe changes in their downstream section. Extreme flooding is more frequent, drinking water availability is increasingly limited, soils show signs of salinization or acidification, species and complete habitats diminish.



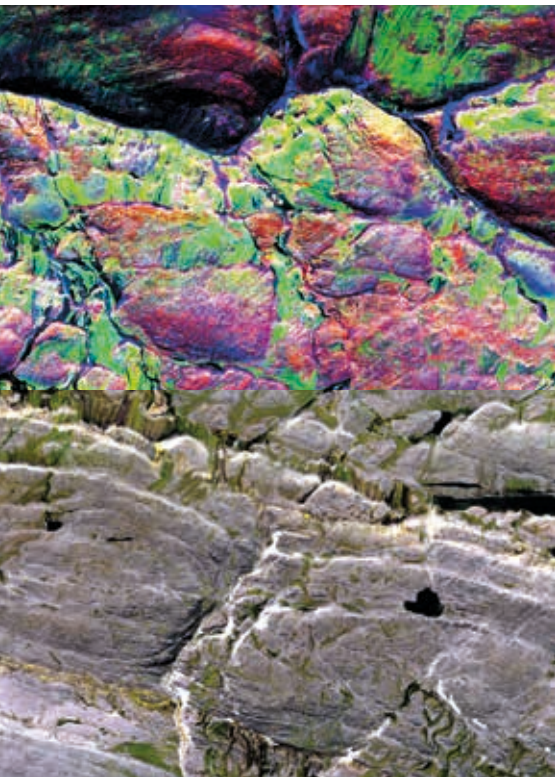
Large amounts of hyperspectral airborne survey data are used to simulate the ability of EnMAP to discriminate lithological units in exploration fields in northern Canada. The Raglan District in northern Quebec contains some of the most prodigious deposits of nickel, copper and platinum group elements in Canada (above: false color, below: true color).

In semi-arid watersheds one major problem is the salinization of soil and groundwater as a consequence of inappropriate irrigation systems. At the same time the withdrawal of large amounts of water from the main rivers enhances desertification processes and causes ecological disasters like the well-known shrinkage of the Aral Sea. As water resources are often distributed unevenly and water use differs widely in politically unstable environments, water-related problems may even bear a potential for conflicts.

The complexity of these issues calls for optimized, integrated resource management. For assessing and analyzing water availability and use, detailed knowledge of hydrologic, hydraulic, ecological, and sociological factors must be available. In many areas in the world objective, spatially distributed time series data of this kind at a regional level can only be obtained by using remote sensing. Therefore we applied remote sensing data and techniques to analyze and monitor:

- spatio-temporal land cover changes
- spatio-temporal changes in vegetation characteristics and soil moisture
- albedo and leaf area index
- spatiotemporal changes in snow cover and thermal characteristics
- irrigated agriculture using time-series information and
- inundation extent and duration.

Remote sensing data from passive microwave sensors, medium resolution optical instruments or very high spatial resolution SAR missions are used to assess parameters of the hydrological cycle including



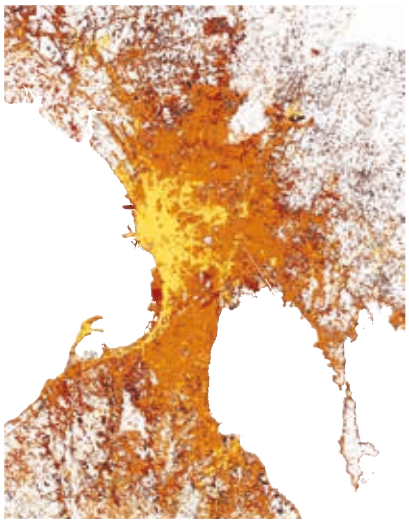
vegetation characteristics, evapotranspiration, temperature, soil moisture, and snow cover. The derived information is used in hydrological modeling to assess water availability and use.

To be successfully used in water management these information products always have to be tailored to the specific needs of different stakeholders in a particular geographic region. DFD has built up expertise in involving stakeholders, assessing their specific user requirements and incorporating them in product specifications. In the framework of a joint Vietnamese and German project an Information System for the Mekong Delta was designed and implemented containing information from the fields of landcover, landuse, hydrology, hydrography, water quality, and socio-economy. The remote-sensing-based information products include frequent updates of inundation, land use and land cover change maps as well as urban area maps. All information is integrated in an information system developed by DFD that assures easy access by scientists, water managers and policy makers. The integration of all data enables the end-users of the system to perform analyses relating to very specific questions, and thus supplies decision makers with a powerful tool for regional planning activities.

The described multisensor, multiresolution approach in combination with a dedicated information system has already been used in Central Asia to support activities of the German Federal Foreign Office in the region. Activities in the Yellow River delta in China have started.

Mineral Resources

To a large extent our modern society depends on the availability of mineral resources. The mineral extractive industry strongly affects the environment and society on local and regional scales. Earth-observation-based information can provide objective information on mine site development, potential pollution and the success of remediation activities for the mining industry, regulators and the general public. In the context of various research activities DFD investigated the potential for reducing the socioeconomic and environmental impact of mining activities by means of Earth observation technologies. This requires precise understanding of the geological, environmental and socioeconomic setting of a mining district. The specific information needs of the respective stakeholders have to be identified and appropriate Earth observation instrumentation and techniques have to be chosen in order to produce tailored information products. Depending on the specific needs satellite and aerial data may have to be combined with in-mine proximal sensing and process monitoring. Hyperspectral and thermal imaging data from airborne sensors have proven to be most useful for mining areas.



Documenting urban sprawl in Manila from 1972 to 2010 (yellow: 1972, orange: 1988, dark orange: 2001, brown: 2010)

Procedures have been developed and tested for mine sites in the Czech Republic, South Africa, and Kyrgyzstan. For the Sokolov Mine in the Czech Republic, pollution related to acid mine drainage has been mapped. In the Emalahleni coal mining district of South Africa, subsurface coal fires are identified using high resolution thermal imaging, as requested by that country's Council of Geoscience. For a Kyrgyz mine operator wastewater flow is modeled using remote sensing derived high resolution digital elevation models.

The developed products increase operation efficiency with respect to energy consumption, mine waste generation, and the overall footprint of operations, and thus the acceptance of Earth observation approaches in the mining community. Imaging solutions are powerful tools for addressing these needs. Combining remote sensing observations from a range of spatial and temporal scales provides a tool for planning operations and the more efficient utilization of resources.

Such environmental monitoring is necessary to ensure that the consequences of resource extraction, for example the final state of the landscape, meet regulatory requirements as well as the expectations of stakeholders and the general public.

Urban Development and Land Management

Already today more than half of the world's population lives in cities. This global trend of urbanization continues at an increasing pace. Urban sprawl, high traffic density, social tensions, and the vulnerability of urban conglomerations to natural hazards are some of the associated challenges.

They reveal that sustainable management of the urban-suburban complex is essential for maintaining the many functions of human settlements. A key aspect of sustainable urban development and the management of cultural landscapes is profound understanding of the processes and interactions of the natural environment, the built-up areas and the socio-economic context. The principal input for obtaining this knowledge is in turn a sound basis of geoinformation which reveals the related spatial and socio-economic phenomena.

DFD develops remote sensing methodologies and information products to support the sustainable management of urban areas and cultural landscapes. To do so, primarily high spatial resolution data obtained from active and passive remote sensing sensor systems (multispectral, hyperspectral and SAR) are employed and analyzed with the help of (semi-)automatic image processing techniques. The applications focus on three main areas:

- settlement patterns, trends of urbanization and characteristics of the urban environment
- transformation of the landscape and land use intensity
- sustainable energy supply and renewable energies.

Regarding the analysis of settlement patterns, trends of urbanization and characteristics of the urban environment, we conduct two global analyses: the Global Urban Footprint initiative aims at the worldwide mapping of human settlements in unprecedented spatial detail, and the Mega Cities Development program describes the spatiotemporal development of Earth's current 27 megacities.

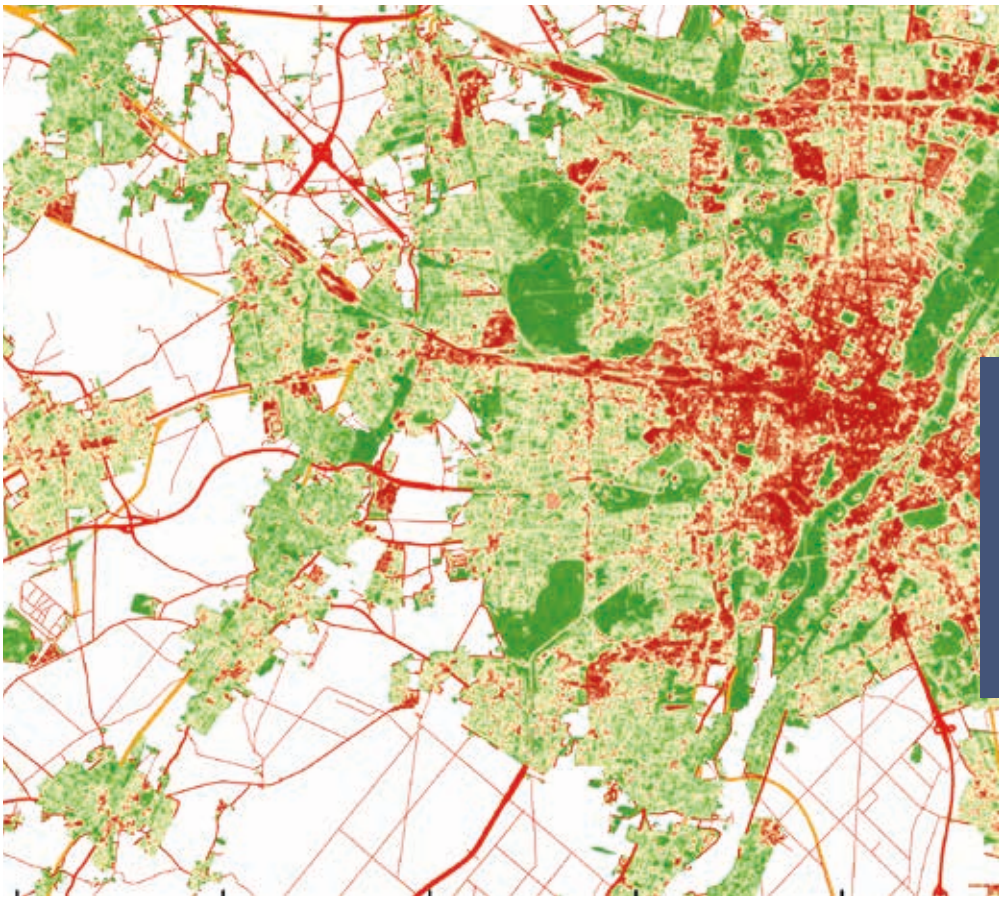
At regional and local levels we address a broad spectrum of applications ranging from modeling imperviousness and the urban microclimate to characterizing urban morphology (building density, building volume) to the provision of socio-economic (population density) and ecological (vegetation volume) parameters. In the GEOURBAN project, for instance, such

parameters are used to bridge the gap between Earth observation scientists and urban planners by demonstrating the ability of current and future systems to depict information on urban structure and the quality of the urban environment over large areas at a detailed level. The innovative potential of the project also lies in the development of a web-based information system which reflects the multidimensional nature of urban planning and management. It is being operationalized to provide versatile indicators which can be easily understood by the public at large. Three cities with different typologies and planning perspectives are included as case studies: Tyumen (Russia), Tel-Aviv (Israel) and Basel (Switzerland). The project uses a 'community of practice' approach, which means that in each of the case studies local stakeholders and scientists meet on a regular basis to learn from each other and to take the different stakeholders' perceptions into consideration during indicator development.

This may lead to a conceptual and practical linking of two traditionally very different research disciplines: social science and remote sensing. The combination yields information about human spatial behavior.

In a first attempt high resolution Earth observation data is analyzed in order to derive the urban structure. Various image analysis methods were developed and applied to identify small-scale urban structures. The derived information shows land cover and built-up structures and can be further aggregated to reveal spatial neighborhood features.

For the German cities Munich and Berlin such spatial features were linked in conformity with data safeguarding regulations to data from the German Socio-Economic Panel Study. An explicit, quantifiable link between the spatial urban structure as determined from Earth observation data and societal spatial characteristics could be proven. Combining information from the panel with the spatial features may facilitate derivation of important variables for the empirical investigation of societal spatial behavior.



Imperviousness for the Munich city area (in percent – green 0%, red 100%)

Global urban footprint mosaic of Japan, derived from VHR SAR data from the German TanDEM-X Mission

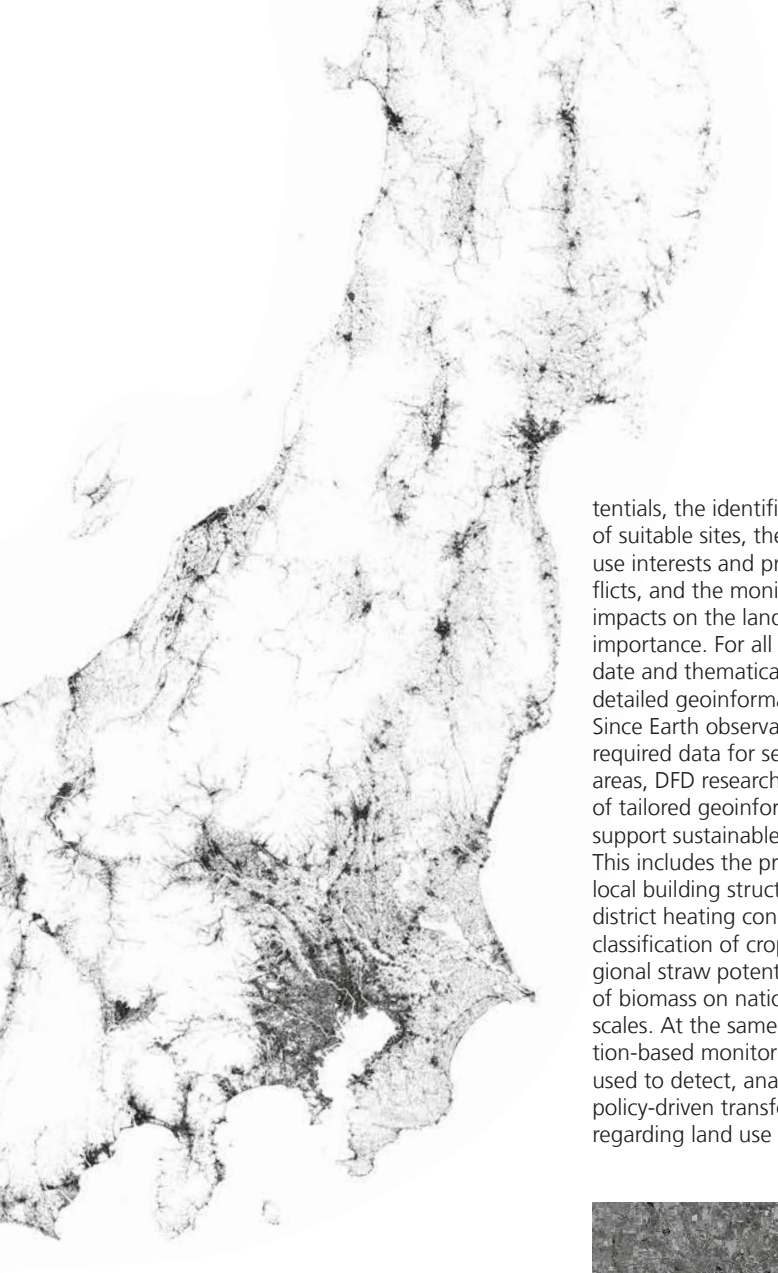
Global Urban Footprint

The German TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement) mission collects between 2011 and 2013 two global data sets of very high resolution (VHR) synthetic aperture radar (SAR) images with a geometric resolution of three meters. Such imagery provides a unique information source for the delineation of built-up areas in a spatial detail that could not be supplied from globally available data sets so far. A single global coverage includes a total of some 180,000 complex SAR scenes. A high degree of automation is a must if global information is to be produced in a short time frame to assure temporal consistency.

Hence, DFD has developed and implemented a novel, fully-automatic processing system to identify and delineate built-up areas worldwide based on the SAR data provided by the TanDEM-X mission–our so-called Urban Footprint Processor. This processing chain includes three main stages:

- the extraction of texture information suitable for highlighting regions characterized by highly structured and heterogeneous built-up areas
- the generation of a binary settlement layer (built-up, non-built-up) based on an unsupervised classification scheme accounting for both the original backscattering amplitude and the extracted texture
- post-editing and mosaicking to provide the final urban footprint product for geographical regions of choice.

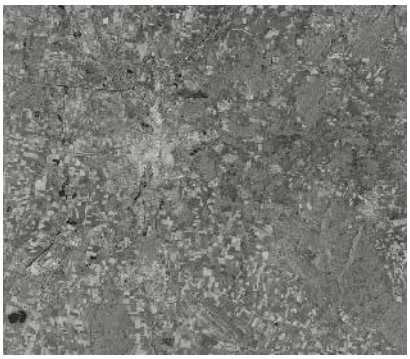
The accuracy of the mosaics provided by the Urban Footprint Processor has been assessed globally and the results indicate the high potential of the TanDEM-X data and the proposed processor to provide accurate and spatially detailed geodata for improved mapping of human settlement patterns and trends of urbanization worldwide

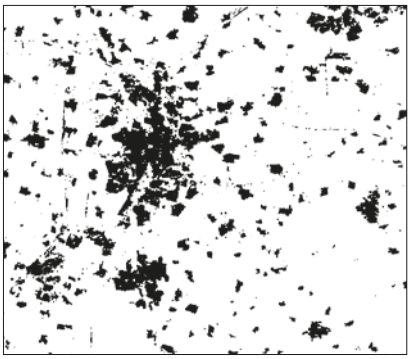


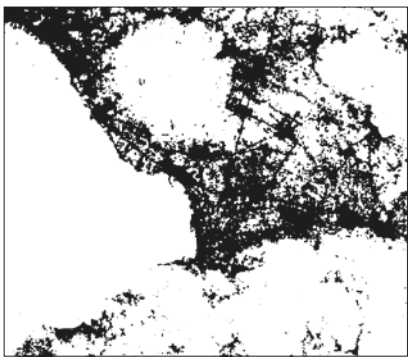
Monitoring Managed Lands

In the context of monitoring managed lands and analyzing land use intensity we mainly support corresponding activities in the framework of the 'Land' component of the European Copernicus program. This includes the development of Earth-observation-based techniques to set up a continental area frame sampling system for quantitative and qualitative characterization of land use changes in Europe, to generate a Europe-wide grassland product (GIO Land), to identify grassland and crop types on the level of field parcels using optical and/or SAR-based seasonal time series data, and to develop semi-automated techniques for updating CORINE land cover data.

The effective and efficient exploitation and utilization of renewable energy resources represents one of today's major challenges. Here, the assessment of potentials, the identification and evaluation of suitable sites, the weighting of land use interests and prevention of conflicts, and the monitoring of trends and impacts on the landscape are of central importance. For all these tasks, up-to-date and thematically as well as spatially detailed geoinformation is required. Since Earth observation can provide the required data for several application areas, DFD researches the development of tailored geoinformation products to support sustainable energy concepts. This includes the provision of data on the local building structure as an input for district heating concepts, the per-parcel classification of crop types to estimate regional straw potentials, and the modeling of biomass on national and continental scales. At the same time Earth-observation-based monitoring approaches are used to detect, analyze and document policy-driven transformations and trends regarding land use patterns and intensity.







Side by side view of amplitude data and derived global urban footprint mask (above: Braunschweig, Germany, below: Naples, Italy)

Cross-cutting Technology Development

DFD concentrates on developing new methods and techniques that are tailored to specific application needs. On the other hand, it should also be possible to implement them in a generic way. This takes place by direct DFD involvement in methodology and application development, quality control and system engineering in large mission projects to guarantee the necessary link between technological mission developments and a wide variety of user needs.

Imaging Spectroscopy

Imaging spectroscopy allows the physically based identification and quantification of land surfaces materials such as organic carbon content in soils, chlorophyll content in vegetation, and urban surface materials. Such information holds the potential to upscale high precision field plot measurements into area-wide information and enables the spatial integration of physically based values into ecosystem models for spatial modeling. In this context DFD is investigating suitable techniques and algorithms to exploit the reflective and thermal wavelength domains.

Advanced analytical tools need to be developed and tested that consider the variety of land surface materials, the large amount of data, and different wavelength domains.

Most of the information extraction tools are based on material-specific spectral wavelength features. At DFD we evaluate and further develop other techniques as well. We have introduced spectral feature parameterization techniques based on robust feature functions, scale-wavelength decomposition (wavelet analysis) for separation of superposed spectral features, and a spatial-spectral approach for eigenvector derivation enabling better separation between eigenvectors representing signals as opposed to noise.

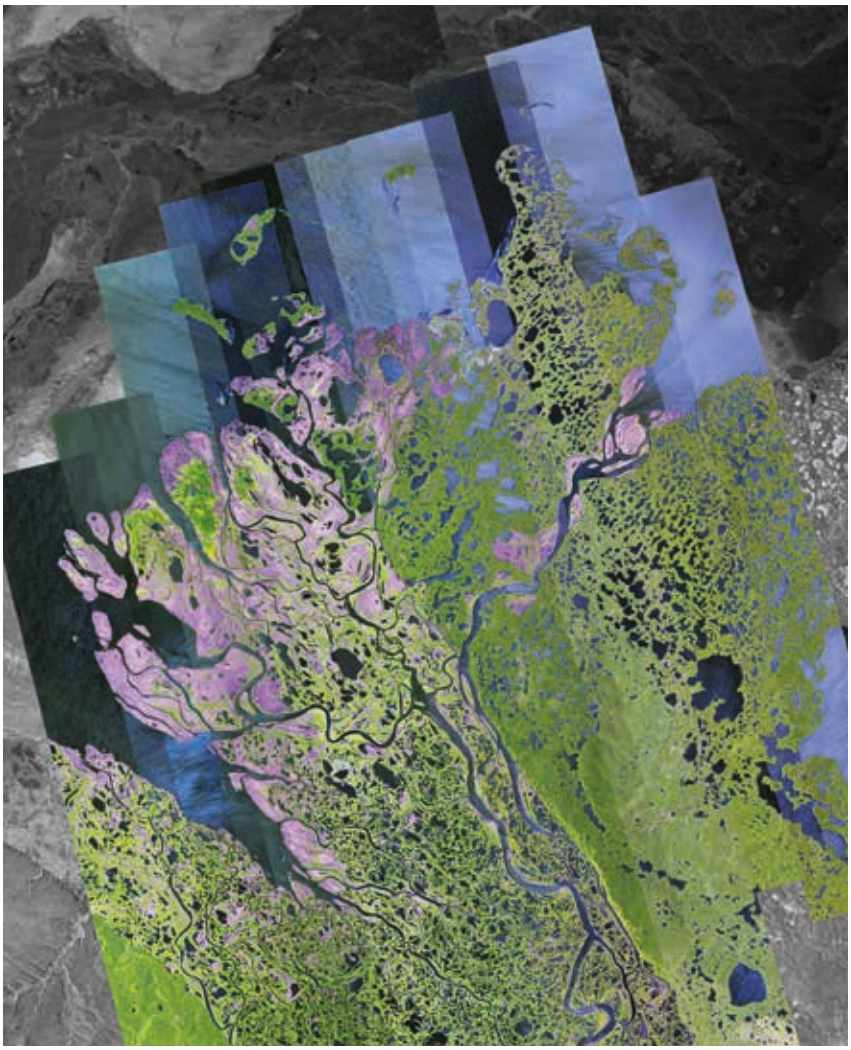
Another aspect concerns the analysis of large quantities of data. Recent large scale airborne hyperspectral surveys using the HYSPEX sensor suite and future hyperspectral satellite sensors such as EnMAP collect significant quantities of data, commonly terabits. Thus, we aim at developing computationally cost effective algorithms that speed up processing while retaining essential data quality and information. As an example, there is a need to create a 'seamless' mosaic for hyperspectral surveys that includes multiple adjacent flight lines. An appropriate empirical solution has been developed for both visual continuity and to remove line-to-line radiometric inconsistencies for subsequent analysis. It consists of a two-fold procedure. The first involves per-pixel scattering correction to adjust for BRDF effects and the second a leveling procedure that treats each line equally to derive a band-by-band correction factor that is weighted based on the scan angle of a given pixel. This technique has been proven in various environments, such as sparsely vegetated areas as well as forested test sites. High quality mosaics were produced that enable reliable quantitative analysis of surface material conditions.

Another example is the development of a spatially and spectrally efficient endmember extraction tool. Endmember extraction is critical in the hyperspectral data processing chain. Existing methods have primarily been demonstrated on small data sets so their usefulness for large data sets has not been fully explored. We have adapted the Orthogonal Subspace Projection and Spatial Spectral Endmember Extraction algorithms to run efficiently on large data sets without the loss of global image endmember quality. This was demonstrated using one simulated and two real hyperspectral data sets, one of the latter being from a multi-flight-line survey in northern Canada.

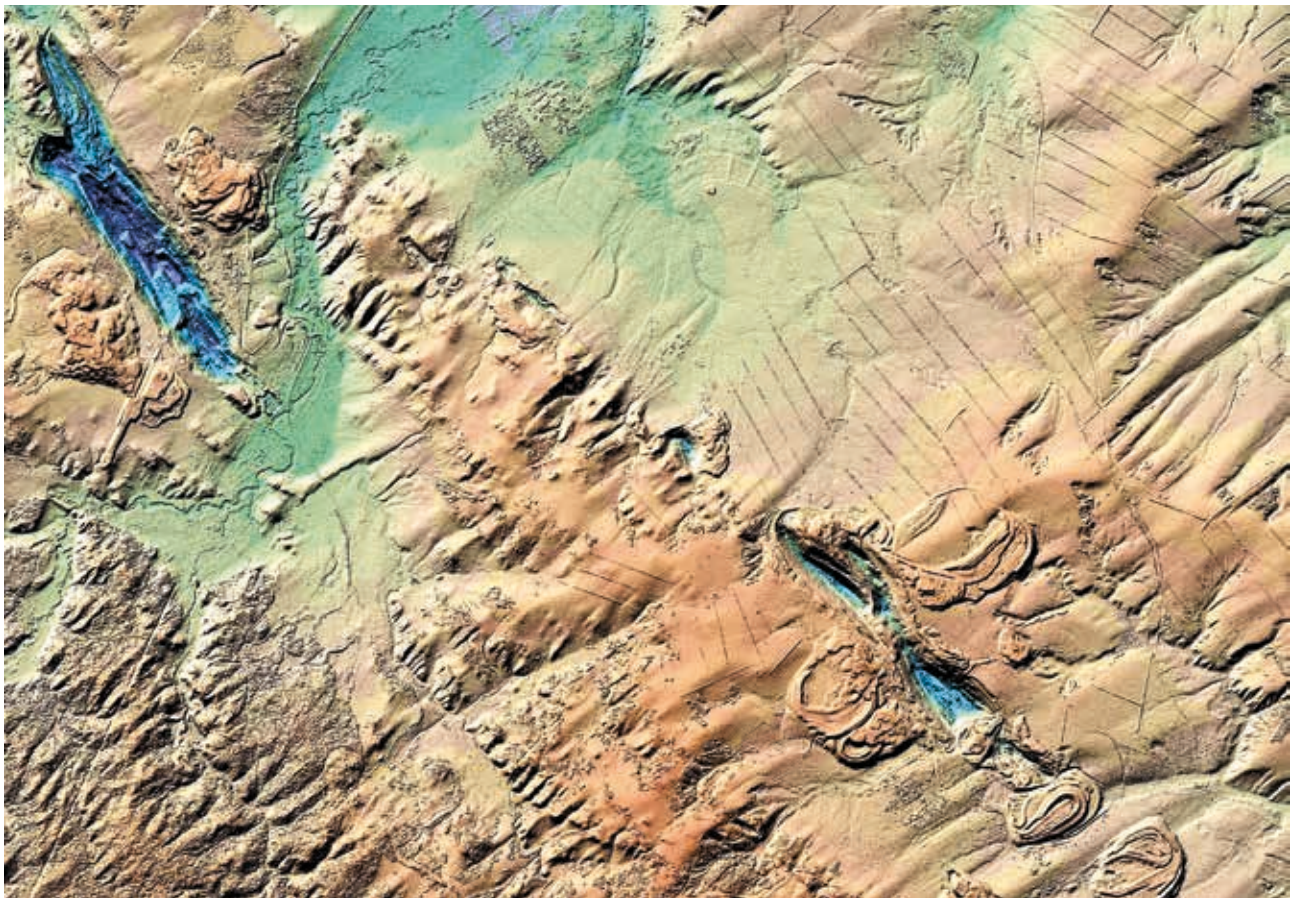
In preparation of the upcoming German hyperspectral satellite mission EnMAP, the described methodical developments are additionally being tested on simulated EnMAP scenes.

Curvelet Analysis of Synthetic Aperture Radar Data

DFD is developing methods of image enhancement and information extraction applied to polarimetric SAR data based on curvelet transform. This technique can be used for noise minimization, structure enhancement and automated change detection. The practicality has been tested for monitoring wetlands and urban building activities. Curvelets can be denoted as a two dimensional further development of the well-known wavelets. The original image is decomposed into linear ridge-like structures that appear in different scales (longer or shorter structures), directions (orientation of the structure) and locations. The influence of these single components on the original image is weighted by the corresponding coefficients. By means of these coefficients one has direct access to the linear structures present in the image. To reduce noise in a given SAR image, weak structures indicated by low coefficients can be suppressed by setting the corresponding coefficients to zero. To enhance structures, only coefficients for the scale of interest are preserved and all others are set to zero. On a pair of same-sized images change can be detected in the curvelet coefficient domain. The curvelet coefficients of both images are differentiated and manipulated in order to enhance strong and suppress small changes pixel-wise. After the inverse curvelet transform the resulting image contains only structures chosen via the coefficient manipulation. Our approach was applied to TerraSAR-X and Radarsat data in various test areas ranging from urban structures to natural environments. The method is very sensitive to changes in structures, in contrast to single pixel or large area changes. Therefore, for purely urban structures or construction sites this method provides excellent and robust results. While this approach runs without operator interaction, interpretation of the detected changes still requires knowledge about the underlying objects.



TerraSAR-X image mosaic of the Mackenzie Delta, Northwest Territories, Canada, where large natural gas and oil deposits were detected. TerraSAR-X data are used for shoreline mapping and monitoring purposes. Ten adjacent data takes of approximately 150 km length were merged to an image mosaic.



TanDEM-X digital elevation model of open pit mining area in Kiselyovsk, Siberia, Russia (deep pits in bluish colors; the noticeable straight, diagonal lines are forest strips planted to protect the large fields against wind erosion)

Calibration and Validation

An important precondition for developing remote sensing applications and quantitative value added information products is continuous operational calibration and validation on the basis of in-situ-measurements.

For this purpose DFD established and operates the calibration and validation test site DEMMIN (Durable Environmental Multidisciplinary Monitoring Information Network) in Mecklenburg-Western Pomerania about 180 km north of Berlin.

In addition to providing support to individual aerial campaigns, automatic, operational, simultaneous measurement of different environmental parameters for each Earth observation mission is at the center of interest. Therefore, the test site is equipped with a spatially dense agro-meteorological and hydrological measurement network as well as with a lysimeter hexagon to derive environmental parameters suitable for remote sensing approaches.

Currently, the DEMMIN site cooperates intensively with the Terrestrial Environmental Observatories (TERENO) initiative of the Helmholtz German research community. This initiative strives to link ground-truth measurements from sensor measurement networks with Earth observation mission data.

Environmental Information and Visualization System

Land surface information derived from remote sensing data in many cases needs to be combined with other terrestrial measurements or socioeconomic data to support the development of sustainable and environmentally friendly land use concepts as well as effective adaptation and mitigation strategies. For example, in integrated water resource management multiple disciplines bring together Earth observation data and results and ground-based observations, such as land use change maps, water equivalent snow cover, inundation duration, population density, regional economic development, and infrastructural systems. These large amounts of heterogeneous data, including spatial data, statistics and ground-based observations, have to be managed by an information and decision support system.

Web-based data models and management components are developed to meet user requirements. These data models cover all relevant aspects on both semantic and actual data set levels.

DFD invented the Environmental Information and Visualization System (ELVIS) that uses semantic tagging of data sets. This allows for efficient and simple identification, access and management of spatial, statistical and observational data. Our models are compliant with existing international standards for metadata description (ISO19115), Map Styling Information (OGC Styled Layer Description) and data set distribution (such as Web Map Service and Web Coverage Service). The data management utilizes an object-relational database management system also supporting the management and processing of spatial data, an XML database for managing and querying XML-structured information, and web-based Distributed Authoring and Versioning (WebDAV) for managing files collaboratively on web servers.

Mission Engineering Support

Based on its experience with land surface applications and methodology development, DFD builds a link between the needs of the land surface community and the technical elements of Earth observation missions. In the framework of national Earth observation missions DFD not only contributes to the payload ground segment but also provides the interface to the scientific user community. DFD is the science coordinator for the TerraSAR-X mission, preparing calls for science proposals relating to methodology and application development. Particular emphasis is put on assuring compliance with the German satellite data security law and the regulations of the public-private partnership under which the TerraSAR-X mission is carried out.

In the context of the hyperspectral mission EnMAP, DFD provides the system engineering for the ground segment as well as application support. Its involvement in the mission goes back to the early definition phases where instrument and mission requirements for EnMAP were defined based on long experience in methodology and application development for hyperspectral data from a number of airborne sensors such as HyMap, AHS and HySpex.

Experience gained using the DAIS 7915 sensor in the thermal spectral region led to the space mission proposal TES-GAP submitted to ESA as part of the eighth Earth Explorer Opportunity Mission call. A hyperspectral thermal space mission was proposed to globally measure organic carbon content in soils and volcanic emissions and thermal anomalies as indicators of precursor activities.

Relevant Publications: [38], [66], [68], [71-73], [76], [81], [95], [99], [129], [131], [139], [249], [269], [274], [302], [306], [436]

Georisks and Civil Security

The challenges to protect citizens and to mitigate the threats arising from natural disasters, technical accidents and international crises are increasing worldwide. Political, societal or ideological conflicts lead to critical situations where international support and humanitarian relief is needed. Civil security and individual freedom, key pillars of our society, are facing increasingly diverse threats. Global climate change imposes new challenges for adaptation and prevention in the future. Therefore, there is a growing demand to address such global challenges and provide user-oriented solutions based on innovative scientific and technical developments.

Georisks and Civil Security—from scientific research to operational systems and services

DFD's research and development activities in the field of 'Georisks and Civil Security' clearly target these challenges and focus on an integrated end-to-end approach to cope with the demands. This concept is based on a systematic approach that includes consecutive steps and feedback loops ranging from 'Scientific Research' to 'Technical Developments' to operational 'Systems and Services'.

The research activities focus on the following main fields:

- development of methods for information extraction for natural hazards and georisks
- information products for civil security and humanitarian relief
- risk and vulnerability modeling and geostatistical methods
- information systems for monitoring and early warning
- development and operation of high-quality services for the Center for Satellite Based Crisis Information (ZKI).

Methodological research on information extraction from Earth observation data aims at helping to improve the prevention of and immediate response to natural hazards. The main focus is on natural disasters like floods, storms, fires, earthquakes, volcanoes, landslides and droughts, as well as technical accidents like oil spills.

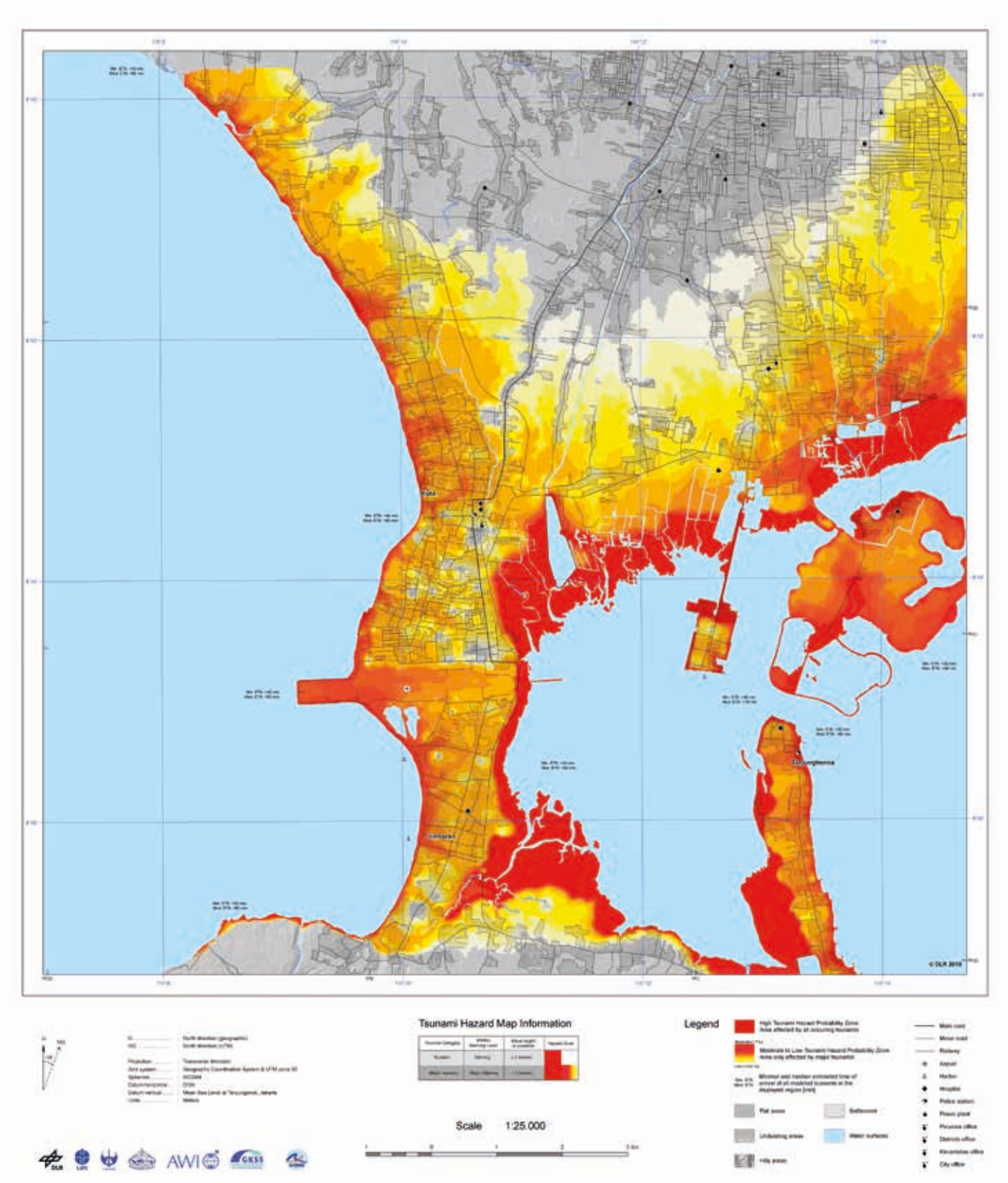
Product development for civil security purposes covers a large variety of applications, from near-real-time monitoring of major events to support for early identification of conflict situations caused by critical shortages of resources, population pressure, land degradation, or illegal mining and timber logging activities. To support humanitarian aid activities, our research is targeted to support the logistics of relief efforts, e.g., by mapping refugee camps and the dynamic changes in refugee flows.

Risk assessment can provide information for disaster preparedness and mitigation, for early warning, and for rapid damage estimation after emergencies. Our research activities aim at the development of models and information extraction methods based on Earth observation data, and their combination with geostatistical and other types of data for hazard, vulnerability and risk mapping.

The development of systems for environmental and crisis monitoring and early warning is another important pillar of our activities. It integrates our expertise in data processing, information extraction, situation assessment, and decision support in sustainable system solutions.

Finally, our research activities to a large extent aim at achieving that these developments lead to improvement and extension of the product and service portfolio of ZKI.

Tsunami hazard map for Denpasar (Bali)


Tsunami Hazard Map Information
Legend
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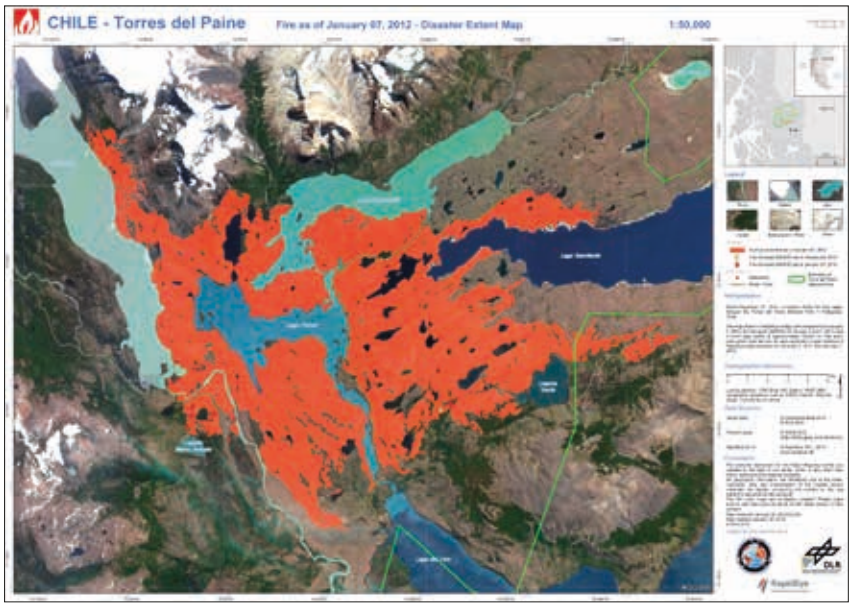
As examples, the progress achieved in some of these research areas is described in the following subsections.

Flood Mapping

Optical as well as radar satellite remote sensing have proven to provide essential crisis information in cases of natural disasters, humanitarian relief activities and civil security challenges. Due to their near all-weather and day-night acquisition capabilities, Earth observation based on space-borne Synthetic Aperture Radar (SAR) sensors is optimally suited to provide information on extensive flood situations, which usually occur during long periods of precipitation and cloud cover.

Combined use of optical and SAR data for burned area mapping (shown in red) of forest fires in Torres del Paine National Park (Chile) in January 2012



The detectability of water in SAR data depends on the contrast of the SAR backscatter between water and non-water areas. This is influenced by the roughness characteristics of the water surface and the system-specific parameters wavelength, incidence angle and polarization. Different types of reflection and scattering, such as specular and corner reflection, diffuse surface and volume scattering, and Bragg scattering, are caused by the interaction of the radar signal with smooth and rough open water surfaces, and flooded vegetation or urban areas. In most cases the surface of open water bodies is smooth compared to the surrounding non-water areas.

Our research focus of the last few years was on the development of automatic and semi-automatic SAR-based flood detection methods as well as on the implementation of these methods in operational software tools for use in the rapid mapping activities of ZKI. The basis of these tools is a parametric tile-based thresholding procedure, which has proven to be an effective method for the unsupervised detection of the inundated areas in SAR data in a time-efficient manner. Different segment-based post-classification algorithms have been developed that can subsequently be applied both automatically and semi-automatically. In this context a hybrid multicontextual Markov model, which incorporates scale-dependent and spatial-temporal contextual information into the segment-based classification process, has been implemented.

Fire Detection and Burnt Area Mapping

Forest fires are major threats worldwide and are likely to increase in the future due to global warming. Large wildfires require immediate attention and reaction to prevent damage to property, life and ecosystems.

At DFD a semi-automatic, object-based, accurate and transferable tool for the rapid detection of forest fires and wildfires in optical as well as SAR data has been developed. The algorithm for optical data is based on a multicriteria approach using spectral indices such as the Modified Soil-Adjusted Vegetation Index, Burnt Area Index and the Normalized Difference Shortwave Infrared Index. It covers very high resolution satellite

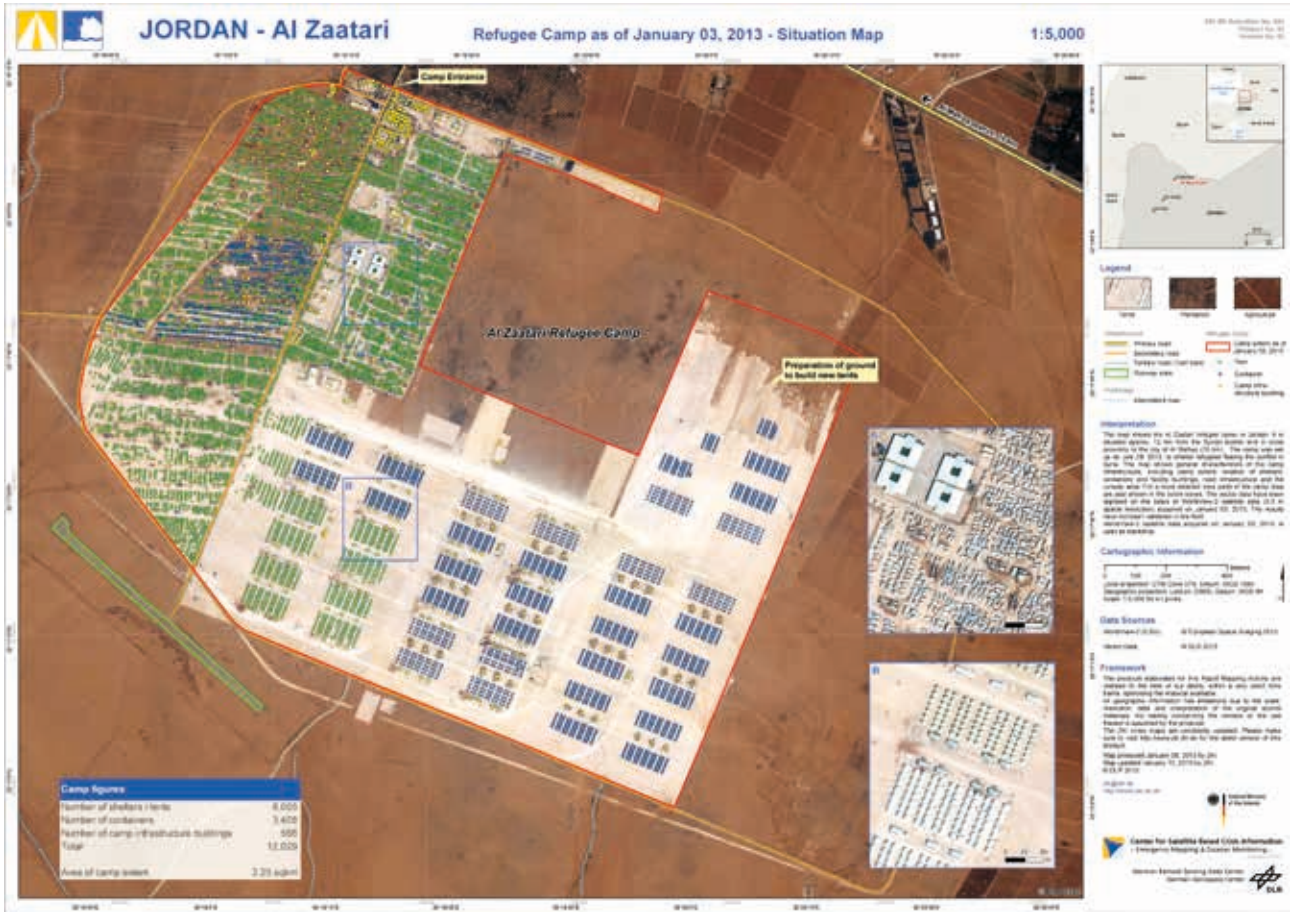
Smooth surfaces such as oil spills or relatively calm water reflect the radar signal away from the satellite, resulting in low backscatter and dark areas in the image. Drilling rigs and ships are visible as bright points on the water's surface.

data and includes a decision-tree classifier. To reduce limitations in optical data due to cloud cover, haze or shadows, the algorithm was extended by integrating SAR data. The SAR burnt area algorithm applies different pixel-level change detection techniques based on image differencing, rationing and index calculation, as well as an object-based fuzzy classification approach. The simultaneous use of both optical and SAR data allows all-weather and day-night burnt area mapping as well as improved detection capability. Additional geoinformation, for example, land cover or digital elevation models, can be integrated into the algorithm to enhance classification accuracy.

In addition to these 'on-demand' rapid mapping activities DFD provides an automatic operational service for active fire detection from space. An automatic end-to-end processing chain has been realized as a Web Processing Service (WPS), which is compliant to the specifications of the Open Geospatial Consortium (OGC). It derives fire hot spots on a daily basis from MODIS Terra and Aqua data. The fire service is publically accessible through the ZKI internet portal. Users can view, download and automatically retrieve information on currently active fires in Europe.

Oil Spill Detection

Oil pollution on sea surfaces, such as those due to illicit vessel discharges, tanker accidents or oil-rig release, usually impact vast areas and seriously affect both the marine environment and human safety. SAR satellites can help to improve the timely detection and continuous monitoring of the extent and location of oil spills. The potential to detect oil pollution in SAR data relies on the fact that the spill dampens the Bragg waves on the water surface. This locally generates



Refugee camp mapping in Jordan (January 2013)

a low backscatter area, which contrasts with the surrounding slick-free water surfaces of higher SAR signal return.

We developed a semi-automatic tool for oil spill detection using single-polarized high resolution SAR data to rapidly provide information about the disaster extent and its spatial-temporal evolution in near real time during critical situations. The method is based on a hybrid multicontextual Markov image model. To improve the classification results, scale-dependent and spatial contextual information is integrated on irregular hierarchical graphs into the segment-based classification process.

Support for Humanitarian Relief: Refugee Camps Mapping

Complex crisis situations usually force many civilians to flee the affected areas and gather in refugee or Internally Displaced Persons (IDP) camps. For effective camp management and planning, the decision makers and humanitarian organizations in the field require reliable and up-to-date information about the ground situation. Due to the huge and rapidly increasing number of refugees in crisis situations, relief organizations often have problems in assessing the number of people in the camp and the amount of resources needed for the refugees.

In this context products based on Earth observation data can provide valuable information.

In the framework of several EU-funded projects we developed semi-automatic methods for counting dwellings in such camps in order to estimate the total number of people. These object-based image analysis procedures are used to monitor the camp size, the number of shelters, the number of people, and any changes. In addition, the impact on the environment and the pressure on natural resources is a critical issue in conflict regions. Different approaches on multiple scales have been developed to identify the impact of certain camps on natural resources, for example, the availability of firewood in their vicinity. Since the developed algorithms are mainly based on robust and transferable rules they can be adapted to different sites and further satellite sensors. Current research focuses on generating improved and robust approaches to map complex structures and dense settlements.

Near-Real-Time Monitoring and Support for Large Public Events

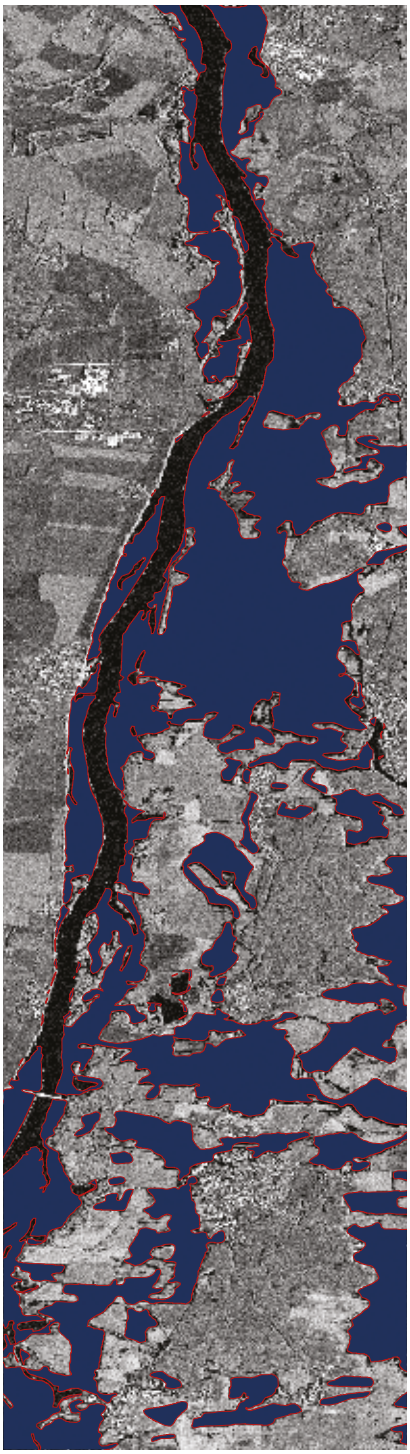
Effective traffic monitoring and management is an important requirement to ensure the quick and coordinated response of security and rescue teams or relief organizations in cases of large public events or natural disasters. Within the VABENE project a near-real-time decision support system for national rescue forces integrating various ground-based as well as airborne sensors is being developed. The system integrates all components from the acquisition of raw aerial optical and SAR imagery to the delivery of highly-value-added information to users. This includes the on-board pre-processing and transmission of imagery to a mobile ground receiving station, the thematic processing of imagery, product generation, and the dissemination of derived products.

In this context DFD developed a software system for generic information extraction and dissemination based on optical aerial imagery. Applications are the classification of flooded areas or the estimation and dynamic near-real-time updating of occupancy in pre-defined areas of interest. Immediately after receiving the airborne real-time pre-processed images in the mobile ground station, the thematic analysis, including the combination of prior knowledge concerning the traffic system, is automatically executed. Depending on the temporal dynamics of the observed event and the repetition rate of data collection, the derived information, which may be the flooded areas, impassable streets, or areas with an estimated degree of occupancy, is visualized by using static maps and dynamic web mapping applications.

Natural Resources Mapping in Conflict Regions

Exploitation of natural resources in most cases impacts the environment, often even spoiling natural habitats and affecting people's livelihoods. In some cases, mineral exploitation and trading can even fuel armed conflicts, as in the case of the Democratic Republic of the Congo. The use of Earth observation data to support the monitoring of mining activities can provide valuable information to aid political decision making in this context.

In order to develop pre-operational services, we focused our research activities on monitoring illegal mining activities based on robust and transferable multiscale image analysis approaches. On a regional scale high resolution optical images provided information about potential hot spots in mining exploitation areas. Very high resolution optical images were analyzed to highlight mining areas



Scattering mechanisms of water and land surfaces are used for mapping floods in SAR data

and important infrastructure on a local scale. To analyze the satellite imagery on both scales an object-based image analysis approach utilizing Cognition Network Language in eCognition 8 was selected. This scripting language allows the development of application-specific solutions by turning expert knowledge into complex, reproducible and adaptable rules.

Further technological enhancement is performed in the recently started project G-SEXTANT. This project aims at consolidating the portfolio of Earth observation products and services that support the geospatial information needs of the European External Action Service (EEAS).

Maritime Security: Near-Real-Time Detection of Shipping Vessels Using Optical Satellite Data

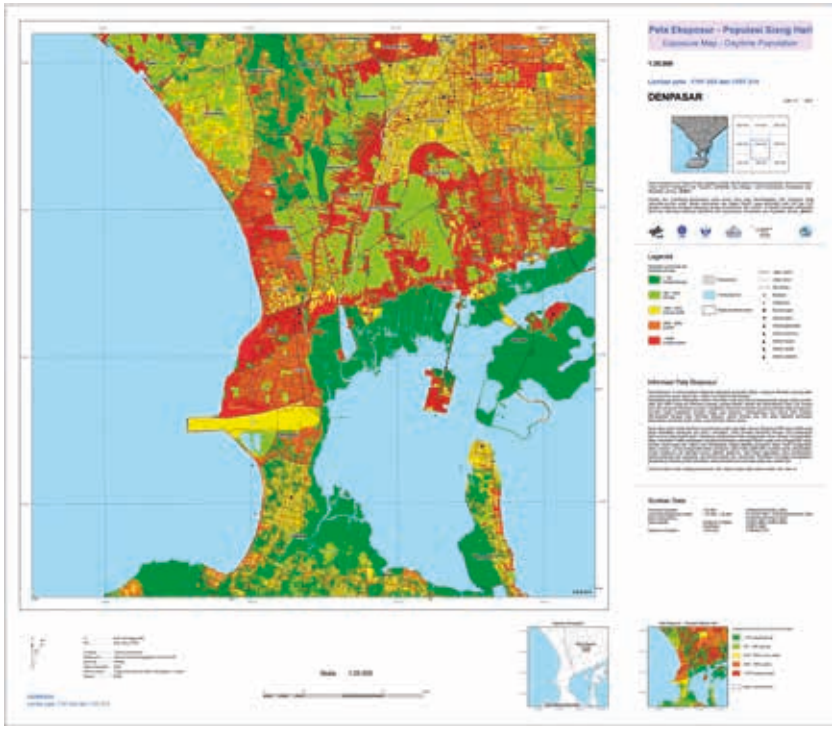
Rapid access to satellite data and derived information is needed to enhance maritime situational awareness and to reduce the risk of maritime accidents, marine pollution from ships, and the loss of human life at sea.

In the framework of a joint project with European Space Imaging we developed a service to detect vessels and vessel activities with optical satellite imagery in near real time for the European Maritime Safety Agency (EMSA). Satellite data from very high resolution satellites are provided in near real time (less than one hour). Value added products such as timely information on vessel locations and activities are generated using a semi-automatic procedure. In a first step, vessel candidates are detected automatically, and then visually confirmed and interactively annotated in a second step. Satellite images as well as value adding services sent to the CleanSeaNet Data Center.

Exposure Mapping, Vulnerability Assessment and Rapid Loss Estimation

Risk is a function of the natural hazard, the exposed elements and their respective vulnerability. At DFD classification algorithms for radar as well as optical data sets at various scales have been developed to provide information on exposed elements. We developed and implemented pixel-based as well as object-based algorithms to classify urbanized areas and their temporal development. Systematic monitoring of urban footprints over almost 40 years has been achieved at medium resolution. For example, the spatial urbanization of all 28 current megacities across the globe has been mapped. DFD has also developed algorithms to extract thematically and geometrically highly resolved 3D city models for a more detailed view of exposed elements. These 3D city models are derived from digital surface models in combination with very high resolution optical data. Thus, identification and mapping of urban structural types such as central business districts or slums has been accomplished. Beyond this, multidisciplinary approaches like combining area-wide spatial knowledge of urban morphology from Earth observation and punctual information from civil engineering allowed the limitations of individual disciplines to be overcome. Extrapolation of model-based capacity curves has been performed in order to assess building vulnerability for large areas and for various earthquake scenarios.

Moreover, rapid estimation of direct losses and damage is urgently needed especially in the emergency response phase shortly after a disaster. We developed algorithms that combine hazard information such as flood extent and depth, derived by an integrated use of on-line modeling, remote sensing and in-situ data, with exposure and vulnerability data. This allows for rapid and spatially explicit estimation of direct losses during



Tsunami exposure map of Denpasar, a city of some 800 000 inhabitants on Bali

a disaster situation. Methods and applications are currently being developed and tested for floods, fires and earthquakes.

Monitoring Services

The continuous, reliable and near-real-time provision of crisis information is an important task in disaster management. In this context a pre-operational multiscale flood monitoring system has been developed that consists of two fully automated processing chains at different resolutions. The processing system is based on medium resolution MODIS and high resolution TerraSAR-X data and will be further extended with Sentinel 1 and Sentinel 3 data in the future. This development significantly contributes to DFD's strategy to develop, implement and operate so-called 'thematic processors.' By minimizing the time delay between data delivery and product dissemination, the service provides highly valuable information during flood management activities.

The processing chains include the following consecutive steps: download of the delivered data to a local directory using an FTP pull, pre-processing of the optical and radar satellite data, computation and adaption of global auxiliary data (digital elevation models, topographic slope information, and reference water masks), unsupervised initialization of the classification, as well as post-classification refinement. Finally, the classification results are disseminated through a web-based user interface. The processing is based on a framework of web processing services in compliance with Open Geospatial Consortium (OGC) specifications.

The medium resolution component of the flood monitoring service is based on MODIS data from NASA's Terra satellite that provide information about the disaster extent in even large watersheds on a national to continental scale at a spatial resolution of 250 m. The thematic analysis of the MODIS data is based on

Tsunami early warning system at BMKG (Jakarta, Indonesia)

thresholding of indices computed from the spectral channels of radiometrically calibrated MODIS data in combination with region growing algorithms and global auxiliary data. Based on a flood alert derived from this MODIS flood service, the high resolution flood service component can be triggered on demand to derive more details about the flooding on local to regional scales at improved spatial resolution.

The high resolution component of the flood monitoring service is based on TerraSAR-X StripMap and ScanSAR data. Parametric thresholding and a fuzzy logic-based algorithm that combines SAR backscatter information with different globally available auxiliary data sources is applied, as well as a subsequent region growing approach. The results are provided as flood masks together with quality information indicating the probability of the flood classification results.

Early Warning and Crisis Information Systems

On 26 December 2004 the Sumatra-Andaman seaquake of magnitude 9.3 led to a catastrophic tsunami that devastated large areas of Southeast Asia and caused more than 220,000 deaths. In order to support the development and implementation of an effective tsunami warning system and to mitigate the effects of future tsunami threats in the Indian Ocean, the German government in close collaboration with Indonesia decided to substantially contribute to these efforts in the framework of the German-Indonesian Tsunami Early Warning System (GITEWS).

In cooperation with national and international partner organizations, researchers from Germany under the leadership of the National Research Centre for Geosciences (GFZ) and its partners in the Helmholtz Research Centers (DLR, AWI) as well as further partner organizations and universities worked on the development of a tsunami early warning system. The activities were integrated in the coordinating activities of the UNESCO Intergovernmental Oceanographic Commission (IOC) for all Indian Ocean countries. The system was officially handed over to the Indonesian government in March 2011 and is being operated at the National Tsunami Warning Center at BMKG.

The main contributions of DLR to the system included an early warning center with a decision support system as well as tsunami risk assessment. The newly developed decision support system is the core of the system, where all information is integrated to provide situation awareness to the operator and to support the early warning decision making process under uncertainty and severe time constraints. The decision support system receives and analyzes data input from different sensor systems, such as a seismic sensor network. Based on a comparison of the input data with simulations of tsunami propagation, the decision support system projects the current situation into the future and assesses the consequences, taking into account how input data are expected to evolve over time and space. To provide this information in a user-friendly way, a graphical user interface was realized as a multiple-screen desktop application. It displays an overall situation perspective, a detailed observation perspective, a decision perspective, and an interface for the configuration of warning products.

The Indonesian personnel and experts were trained and qualified to operate and maintain the system in more than 60 training courses accompanying the system's evolution and implementation. In addition to systems development on the Indonesian level, further efforts enabled Indonesia to act as so-called Regional Tsunami Service Provider for the Indian Ocean.

To support disaster preparedness and mitigation, knowledge about the tsunami risk in coastal areas is an essential component of an end-to-end early warning

system. In cooperation with Indonesian and international researchers we developed a concept and provided risk maps to disaster management institutions in Indonesia at the regional and national level. Tsunami risk assessment was performed at an overview map scale covering all the Indian Ocean coastal areas of Sumatra, Java and Bali. As a result, a complete set of thematic maps was generated and delivered to the national disaster management agency BNPB. In selected pilot areas a very detailed analysis was performed and the results were jointly elaborated and delivered to the regional and local planning institutions as maps as well as digital GIS data. Moreover, key parameters and risk indicators were derived from these maps and integrated into the decision support system.

In addition, detailed technical descriptions and guidelines were elaborated to explain the developed approach, to allow future updates of the results, and to enable the local authorities to conduct tsunami risk assessment using their own resources. Amongst other documents, we contributed to the Guidelines for Tsunami Risk Assessment of UNESCO's IOC.

At DFD the research activities on early warning systems are being further extended. The development of generic, 're-usable' software components for multihazard warning systems is of high priority. In the framework of the DLR internal UKIS project such software components are currently being developed.

ZKI Services

As described before in the relevant chapter on DFD's User Services, the Center for Satellite Based Crisis Information (ZKI) provides operational services for the rapid provision, processing and analysis of satellite imagery during natural and environmental disasters, for humanitarian relief activities, and to meet civil security challenges worldwide.

The graphical user interface of the decision support system consisting of the Situation Perspective, the Observation Perspective, the Decision Perspective and (not shown) the Product Perspective

As one of the key players in this field ZKI participates in numerous national and international projects and programs in security research and disaster management. In general, the activities can be grouped into three main focus areas:

- service provision for German users
- contributions to the European Copernicus program
- international involvement, such as in the 'International Charter Space and Major Disasters'.

Service Provision to German Users (ZKI-DE)

In January 2013 the German Federal Ministry of the Interior established a framework contract with DLR that enables national authorities and other authorized users to order products from ZKI. Authorized users can gain access to products and services for virtually any geographic region worldwide. The ZKI-DE service provides valuable and timely information for different kinds of natural disasters, humanitarian crisis and other emergency situations based on the processing and analysis of aerial and satellite based remote sensing data. The products are provided in a wide range of scales from 1:500 to 1:200,000 and can be used for different phases of crisis management. A comprehensive portfolio of products has

been developed, customized to the needs of German users and authorities. According to user requirements this portfolio will be further developed and extended in close cooperation with the users.

Selected Copernicus (GMES) projects with ZKI involvement

Project	Description	
SAFER	Services and Applications for Emergency Response	EU
LinkER	Supporting the implementation of operational GMES services in Emergency Response	EU
GSE Respond	GMES Services related to humanitarian relief	ESA
GSE RISK-EOS	GMES Services related to flood and fire risk	ESA
GSE MARISS	GMES Services related to maritime security	ESA
GMOSS	GMES Network of Excellence for global monitoring of security and stability	EU
G-MOSAIC	GMES services for Management of Operations, Situation Awareness and Intelligence for regional Crises	EU
G-SEXTANT	GMES Service Provision of geospatial intelligence in EU External Actions support	EU
G-NEXT	GMES pre-operational security services for supporting external actions	EU
LIMES	Land and Sea Monitoring for Environment and Security	EU
GIONET	GMES Initial Operations – Network for Earth Observation Research Training	EU
DITAC	Disaster Training Curriculum	EU
SYMIN	System for Monitoring Law Enforcement of Informal Mining	ESA

Contributions to the European Copernicus Program

ZKI substantially contributed to the development and implementation of the 'Emergency Response Service' of the European Copernicus program. DLR was one of the key partners in the European FP7 project SAFER, where the pre-operational service provision and validation of the Emergency Response Service was performed.

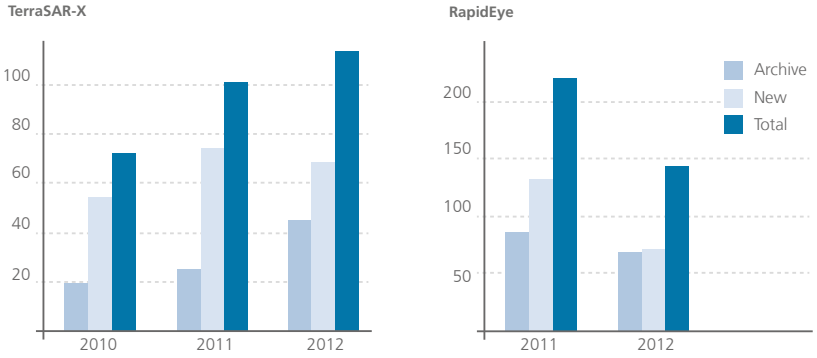
The SAFER project not only succeeded in providing operational rapid mapping, but also ensured that research and development results evolved and were qualified for operations. ZKI provided products within the Emergency Response Service for more than 60 emergency mapping and 10 emergency support activations. We covered various disaster types and delivered more than 300 products.

DLR-ZKI organized training for users at different levels (disaster management teams, assessment teams, technical search and rescue teams) and different communities (UN organizations, civil protection agencies, humanitarian aid organizations).

Moreover, DLR was involved in a substantial number of EU and ESA funded projects in the European GMES (now Copernicus) Program. The table below gives an overview of selected projects.

International Charter Space and Major Disasters

The International Charter 'Space and Major Disasters' is a consortium of space agencies and satellite data providers aiming at providing a unified system of rapid space data acquisition and delivery in cases of natural or man-made disasters. Each member agency of the Charter has committed resources to support authorized users, such as relief organizations and civil protection organizations, with



DLR's data delivery to the Charter from October 2010 to June 2013

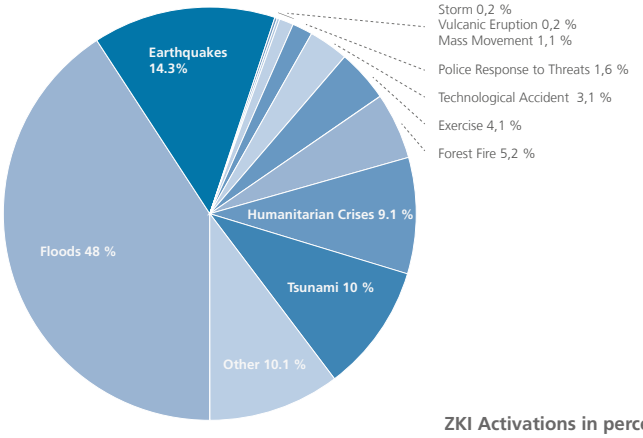
free of charge satellite data in order to help mitigating the effects of disasters on human life and property.

DLR has been a full member of the Charter since 2010. The main operational tasks of DLR's contributions to the Charter are performed by ZKI. They comprise satellite tasking and data delivery of TerraSAR-X and TanDEM-X data, the ordering and delivery of RapidEye data, project management for selected Charter activations, and emergency on-call officer duties for the Charter. Since October 2010, more than 300 TerraSAR-X data sets in ScanSAR, StripMap and Spotlight Mode as well as about 350 data tiles of RapidEye have been delivered to the users of the Charter.

ZKI Quality Management and Certification

To guarantee products of high quality, the services of ZKI are qualified according to an extensive quality management system and certified under the ISO 9001 standard. This ensures that ZKI services fulfill high quality requirements with consistent products and services which meet customer expectations. Each year the certificate has to be renewed by an independent consortium of auditors.

In summary, ZKI has established itself in recent years as one of the leading institutes in satellite-based crisis information, nationally, in Europe, and in the wider international field. The factors that have been crucial for its success include its capability to provide information reliably and quickly, advise and train people competently, and keep in close contact with users. To be successful in the long run, the ZKI must continuously develop its services and adapt them to new user requirements and technical resources.



ZKI Activations in percent

Relevant Publications: [3], [8], [11], [29-30], [45], [59], [61-62], [70], [87], [105], [113], [120], [127-128], [135], [137], [142], [146], [153], [158], [162], [169], [171], [187], [189], [195], [209], [219-220], [226], [232-234], [245], [250], [271], [275], [277], [315], [324], [362], [369-370], [381], [386], [389], [411], [453-454], [459], [475-476], [487], [499-500], [506], [526], [528], [533], [539-541], [546], [550-551], [555-556], [561-567], [571], [575], [578], [580], [586-588], [594-595], [612], [614], [618]

Documentation

Documentation

Teaching and Education

Lectures at Universities

University courses conducted by DFD staff between 2007 and June 2013 (lectures of the Department of Remote Sensing at University Würzburg in *italic typeface*). Winter semester courses are listed in the year of beginning.

DFD has special relations to the following Universities: University Würzburg (Chair for Remote Sensing, Prof. S. Dech), University Augsburg (W2 professorship, Prof. M. Bittner), TU München (honorary professorship, Prof. G. Strunz) and University Bayreuth (participation in Master program 'Global Change Ecology).

University	Title	Lecturer	2007	2008	2009	2010	2011	2012	2013
Würzburg	**Vorlesungen**								
	Einführung in die Geographische Fernerkundung	Dech, S./ Schmidt, M.	■						
		Dech, S. / *Conrad, C.*		■	■	■	■		
		Dech, S./ *Latifi, H.*							■
	Anwendungen der Fernerkundung in der Geographie	Dech, S/ *Conrad, C..*	■	■	■	■	■	■	■
	Regionale Geographie Außereuropa: Mittelasien	*Conrad, C.*						■	
	Statistische Arbeitsmethoden mit Übungen	*Schramm, M.*	■						
	Physikalische Grundlagen und Methoden der Fernerkundung	Künzer, C.					■		
	Seminare Bachelor (eingeführt 2010)								
	Methoden der fernerkundlichen Datenauswertung	Klein, D./ *Cord, A.*			■				
		Conrad, C, Kübert, C.				■			
		Asam, S./ Kübert, C.					■	■	■
	Fernerkundung im Ressourcenmanagement	*Conrad, C.*				■	■	■	■
	Seminare Master (eingeführt 2011)								
	Fernerkundliche Parameter der Landoberfläche	*Conrad, C./ Kübert, C.*					■		
		Conrad, C.						■	■

University	Title	Lecturer	2007	2008	2009	2010	2011	2012	2013
	Dynamik der Landoberfläche	*Kübert, C.*					■		
		Künzer, C./*Conrad, C.*						■	
		Conrad, C.							■
	Methodenseminare								
	Auswertung optischer Fernerkundungsdaten unter ENVI	Bachmann, M.	■	■			■		■
		Geßner, U.	■						
		Heldens, W.		■					
		Zeidler, J.			■				
	Bildverarbeitung mit ERDAS (ab 2010 fortgeführt als 'Methoden der fernerkundlichen Datenauswertung')	*Vogel, M.*	■						
		Machwitz, M./ Rüth, N.	■						
		Hüttich, C.	■						
		Cord, A./ Machwitz, M.		■					
		Rüth, N.			■				
	Praktische Einführung in die Geoinformatik	*Schorcht, G.*	■						
		Schmidt, Ma.		■					
		Thiel, M.				■			
		Kübert, C./Löw, F.				■			
	Fernerkundliche Analysen mit dem Open Source Programm R	*Wegmann, M./ Latifi, H.*							■
	Einführung in die objektorientierte Satellitenbildverarbeitung mit Definiens eCognition	Esch, T.	■						
		Taubenböck, H.			■				
		Thiel, M.	■						
	Feldmethoden der Fernerkundung	Bachmann, M./ Kraus, T.	■						
		Cord, A.			■				
		Conrad, C./Cord, A.				■	■		
		Lex, S.						■	■
	Einsatz der Fernerkundung in der Global Change Forschung	*Landmann, T./* Klein, D.		■					
	Oberseminare								
	Hotspots der Biodiversität	*Schmidt, M./ Landmann, T.*	■						
	Anwendungen der Fernerkundung in der Geographie	Dech, S./ Kraus, T.	■						

University	Title	Lecturer	2007	2008	2009	2010	2011	2012	2013
	Nachhaltiges Wassermanagement in Mittelasien – Herausforderung oder Illusion	Dech, S./ *Conrad, C.*	■						
	Quantifizierung des Globalen Klimawandels: Techniken und Beitrag der Fernerkundung zur Erfassung der Landbedeckungs-Veränderung	Dech, S./ Schmidt, M./ *Landmann, T*	■						
	Quantifizierung des Globalen Klimawandels: Techniken und Beitrag der Fernerkundung zur Erfassung der Landbedeckungs-Veränderung	*Landmann, T.*		■					
	Fernerkundung in Ressourcen-Exploration, Ressourcen-Überwachung und Ressourcen-Schutz	Künzer, C.			■				
	Fernerkundung urbaner Räume	Esch, T.	■						
	Fernerkundung im urbanen Raum	Taubenböck, H.			■	■	■		
	Improving agricultural land use mapping in West Africa with multi-sensor satellite data	*Forkuor, G.*						■	
	Megastädte, Stadtgeographie & Erdbeobachtung	Taubenböck, H.						■	
	Risikoanalyse und -management mit Methoden der Fernerkundung	Taubenböck, H.							■
	Mittelseminare								
	Analyse der Landoberfläche mit Methoden der Fernerkundung	*Landmann, T.*	■						
	Anwendungen der Fernerkundung für ökologische Fragestellungen	*Wegmann, M.*/ Geßner, U.	■						
	Exkursionen								
	Norddeutschland	*Conrad, C.*	■						
	Fränkische Saale	*Conrad, C.*		■		■			
	Mainzer Becken	*Conrad, C.*			■				
	Ostdeutschland	*Conrad, C.*			■				
	DLR – Oberpfaffenhofen	*Conrad, C./ Cord, A.*			■				
	DLR – Oberpfaffenhofen	*Kübert, C.*				■	■		
	Zentralasien	*Conrad, C.*/Klein, D.				■			
	Fichtelgebirge	*Fritsch, S.*				■	■		
	Regen	*Lex, S.*						■	
	Sonstiges								

University	Title	Lecturer	2007	2008	2009	2010	2011	2012	2013
	Fernerkundung Vortragsübung	*Wegmann, M.*		■					
	Übungen zur wissenschaftlichen Präsentation	*Wegmann, M./ Fritsch, S.*			■				
	ArcGIS für Nebenfachstudierende (Schlüsselqualifikation)	*Thiel, M.*				■			
	GIS und Fernerkundung in der Biodiversitätsforschung – Teil I u. II	*Wegmann, M.*	■						
Others									
Augsburg	Atmosphärenphysik (Seminar/Praktikum)	Bittner, M.				■	■	■	■
		Wüst, S.				■	■	■	■
Augsburg	Geographie (Seminar/Praktikum)	Höppner, K.				■	■		
Augsburg	Geographie	Günther, K.	■	■					
Augsburg	Geographie	Höppner, K.			■				
Augsburg	Physik der Atmosphäre I	Bittner, M.	■	■	■		■	■	
Augsburg	Physik der Atmosphäre II (Vorlesung mit Übung)	Bittner, M.							■
Bayreuth	Dynamics of the Land Surfaces (Seminar mit Ubung)	*Conrad, C.*		■					
		Wegmann, M.			■				
Bayreuth	Global Change Ecology	*Wegmann, M.*				■	■		
Bayreuth	Global Change Impacts on Species Distribution (Vorlesung mit Übung)	*Wegmann, M.*					■	■	■
Bayreuth	Patterns of Land Use and Ecosystem Dynamics (Vorlesung mit Übung)	*Wegmann, M.*				■	■	■	
Bayreuth	Progress in Global Change Research (Seminar)	*Wegmann, M.*				■	■		
Bayreuth	Remote Sensing (Vorlesung mit Übung)	*Conrad, C.*		■					
		Wegmann, M.			■	■	■	■	
Bayreuth	Remote Sensing and Biodiversity (Vorlesung mit Übung)	*Conrad, C.*	■	■					
		Wegmann, M.			■	■	■	■	
Bayreuth	Summer School: Climate and Landcover Change in West Africa (Oberseminar)	*Conrad, C.*		■					
Beijing, CN	Asian River Deltas Experiencing Slow-onset Hazards: Vulnerability, Resilience and Adaptation to Environmental Degradation and Climate Change	Künzer, C.					■		
Beijing, CN	Earth Observation for Integrated Water Resources Management	Künzer, C.				■			
Beijing, CN	WISDOM: Water-related Information System for the Mekong Delta	Künzer, C.				■			
Beijing, CN	Remote Sensing for the Mekong Delta	Künzer, C.				■			

University	Title	Lecturer	2007	2008	2009	2010	2011	2012	2013
Delft, NL	Earth Observation Systems	Diedrich, E.		■					
Delft, NL	Systems Engineering	Diedrich, E.			■				
Eichstätt	Fernerkundung/Geographie (Vorlesung, Seminar)	Sparwasser, N.			■	■	■	■	
Eichstätt	Physische Geographie (Seminar/Praktikum)	Sparwasser, N.		■					
Eichstätt	Physische Geographie	Meisner, R.	■						
Graz (KF Uni)	Urbane Fernerkundung	Wurm, M.							■
Jena	Abbildende Spektroskopie (Seminar/Praktikum)	Bachmann, M.						■	
Jena	Geographie/Geoinformatik (Seminar/Praktikum)	Habermeyer, M.	■		■		■		■
Jena	Geographie/Fernerkundung (Seminar/Praktikum)	Bachmann, M. Müller, A.		 ■		■	■		
München (LMU)	Geoinformatik	Kiefl, R. Strobl, C.	 ■	 ■	■ ■	 ■	 ■		
München (LMU)	Kartographie/GIS	Kiefl, R. Strobl, C.	 ■	 ■	■ ■	■ ■	■ ■	■ ■	
München (TU)	Earth Observation Ground Segment and Users	Reiniger, K.-D.		■					
München (TU)	Fernerkundung/GIS	Strunz, G.	■	■	■	■	■	■	■
München (TU)	Geoinformatik (Spezialvorlesung)	Diedrich, E.						■	
München (TU)	Geostatistik (Spezialvorlesung)	Strobl, C.			■			■	
München (TU)	Informatik und Hydrogeologie	Zoßeder, K.	■	■	■	■			
München (TU)	Kartographie und Fernerkundung	Diedrich, E.		■					■
München (TU)	Photogrammetrie und Fernerkundung IV	Schreier, G.		■	■	■	■	■	■
München (TU)	Raumfahrttechnik II	Schreier, G.							■
Neubrandenburg	Datenmanagement – Fernerkundung	Borg, E.		■	■	■	■	■	■
Osnabrück	Fernerkundung/Geoinformatik	Gähler, M.					■	■	
Potsdam	Ringvorlesung Methoden der Fernerkundung	Borg, E.			■	■			
Stuttgart (HTF)	Photogrammetry and Remote Sensing (Spezialvorlesung, Seminar/Praktikum)	Esch, T.					■	■	■

Non University Courses and Tutorials

Non-university courses and tutorials conducted by DFD staff since 2007 (courses of the Department of Remote Sensing at University Würzburg in *italic typeface*)

Lecturer	Location	Subject	2007	2008	2009	2010	2011	2012	2013
Bachmann, M.	CCG, Weßling	Vorverarbeitung abbildender Spektrometerdaten		■				■	■
Bachmann, M.	CCG, Weßling	Spektrale Entmischungsverfahren					■	■	
Bachmann, M.	Singapore, Indonesia	ATCOR Atmospheric Correction Training			■				
Bachmann, M.	Manchester, UK	ATCOR Atmospheric Correction Training				■			
Barkmann, H.	Huntsville, AL, USA Neustrelitz, Germany	2nd Joint Space Weather Summer Camp 2012						■	
Barkmann, H.	Huntsville, USA Neustrelitz, Germany	3rd Joint Space Weather Summer Camp 2013							■
Conrad, C., Schorcht, G., Fliemann, E.	Batken, Kirgistan	Landnutzungskartierung im Isafara Becken						■	
Esch, T.	Mexico City	Workshop on 'Use of remote sensing for environmental and civil security applications'	■						
Esch, T.	Mexico City	Tutorial on 'Image analysis with Definiens Developer'	■						
Förster, A., Radestock, C., Schneiderhan, T.	Oberpfaffenhofen, Germany	RESPOND User Training for Humanitarian Crisis Response – Satellite-based Information to support humanitarian aid		■					
Friedemann, M., Kukofka, T., Raape, U., Steinmetz, T. Teßmann, S.	Jakarta, Indonesia	GITEWS Decision Support System, Chief Officers On Duty Trainings		■	■				
Friedemann, M., Mühlbauer, M., Schöckel, T., Strobl, C.	Jakarta, Indonesia	DSS Administrator Training					■	■	■
Friedemann, M., Raape, U., Teßmann, S.	Jakarta, Indonesia	Introduction to the GITEWS Decision Support System (DSS)		■					
Gähler, M., Lechner, K. Voigt, S.	Ahrweiler, Germany	Schulungskurs der Akademie für Krisenmanagement, Notfallplanung und Zivilschutz (AKNZ): Satellitenfernerkundung im Krisenmanagement			■				

Lecturer	Location	Subject	2007	2008	2009	2010	2011	2012	2013
Gähler, M., Schneiderhan, T.	Oberpfaffenhofen, Germany	BKA-Workshop: Praxis trifft Forschung – Möglichkeiten und Grenzen von Fernerkundung und Navigation		■					
Gähler, M. Schneiderhan, T. Zwenzner, H.	Oberpfaffenhofen, Germany	Schulung für ZKI-DE Nutzer							■
Heinen, T. Rotzoll, H.	CCG, Weßling	Verteilung von Fernerkundungsdaten über interaktive Katalogschnittstellen und standardisierte Geodatendienste					■	■	
Kiefl, R. Steinmetz, T. Strobl, C. Künzel, W.	Jakarta, Indonesia	Introduction to Geospatial Data Analysis		■					
Klein, D., *Lex, S.*	GFZ Potsdam	Remote Sensing for Land Use and Land Cover Mapping in Water Management					■		
Kranz, O, Lechner, K., Voigt, S.	Brussels, Belgium; Berlin, Germany; Amsterdam, Netherlands	User Trainings on the GMES Emergency Response Service			■	■	■		
Kranz, O.	Cyprus	EU Assessment Mission Course (AMC): Rapid Mapping Capabilities	■	■	■				
Kranz, O.	Snekkersten, Denmark	EU Staff Mission Course (SMC): Theoretical presentation on activation mechanisms and map interpretation			■				
Kranz, O., Lechner, K., Lorch, H., Nagel, R.,	Oberpfaffenhofen, Germany	BKA-Workshop zu den Projekten ARGOS und DELPHI			■				
Kranz, O., Mund, J.P.	Windhoek, Namibia	UN-SPIDER Training on remote sensing data, interpretation, technology for flood mapping in Namibia			■				
Kranz, O., Schöpfer, E.	Oberpfaffenhofen, Germany	LIMES Disaster management and simulation training				■			
Künzer, C.	ESA, Beijing, China	Physical Principles and Data Analyses Methods of Optical Remote Sensing						■	
Künzer, C.	ESA Summer School, Frascati, Italy	Physical Principles of Remote Sensing						■	
		Theory and Application of Classification Methods and Feature Extraction Approaches						■	
		Thermal Infrared Remote Sensing: Theory and Applications						■	

Lecturer	Location	Subject	2007	2008	2009	2010	2011	2012	2013
Künzer, C.	IRSA, Beijing, China	Remote Sensing Data Preprocessing: Atmospheric Correction					■		
		Pixel- and object based Image Classification Methods					■		
		Principles of Thermal Remote Sensing					■		
		Remote Sensing Applications: Analyses of River Delta Vulnerability					■		
Künzer, C.	Ho Chi Minh City Institute of Resources Geography, VAST, Vietnam	Physical Background of Remote Sensing			■				
		Digital Image Processing Methods: Preprocessing, Transformations and Information Extraction			■				
Latifi, H.	University Würzburg	MICMoR Technical Shourt Course: Remote Sensing of the Land Surface						■	
Lex, S., Conrad, C	Bishkek, Kirgistan	Remote Sensing for Hydrological Monitoring							■
Löw, F., Schorcht, G	Urgench, Usbekistan	Developing capacity in the fields of GIS and remote sensing				■			
		Training program in GIS and remote sensing for higher education in Uzbekistan					■		
Martinis, S. Mund, J.-P., Twele, A.	UASVMB, Bucharest, Romania	ROSA/ESA/DLR – Radar Remote Sensing Course			■				
Mück, M.	Denpasar, Indonesia	Training: Use of risk information for tsunami evacuation planning			■				
Mück, M., Post, J. Stein, E.	Jakarta, Indonesia	Use of tsunami risk information in the Decision Support System (DSS)			■				■
Mück, M., Post, J., Wegscheider, S.	Cilacap, Padang, Denpasar, Indonesia	Technical training for the development and interpretation of tsunami risk products			■				
Mühlbauer, M., Plattner, S., Schmidt, S., Schöckel, T.	Jakarta, Indonesia	DSS & Regional Tsunami Service Provider (RTSP) Operator Trainings					■	■	■
Mühlbauer, M., Schöckel, T., Strobl, C.	Jakarta, Indonesia	DSS Installation Training						■	■
Müller, A.	CCG	Hyperspektrale Datenverarbeitung		■					
Post, J.	Jakarta, Indonesia	DSS Operator-Schulung			■				
Radestock, C.	Neustrelitz, Germany	DLR Summer School: Fernerkundung für die Kriseninformation			■				

Lecturer	Location	Subject	2007	2008	2009	2010	2011	2012	2013
Radestock, C.	London, UK	Using Satellite Mapping in Humanitarian Response			■				
Rüth, N., Landmann, T.	Cotonou, Benin	BIOTA West GIS training workshop		■					
Rüth, N. Landmann, T. Eilertz, E.	Accra, Ghana	GIS & Remote Sensing for effective resource management				■			
Schöckel, T., Strobl, C.	Jakarta, Indonesia; Oberpfaffenhofen	DSS Data Management Training					■	■	■
Schöpfer, E., Spröhnle, K.	Ispra, Italy, Madrid, Spain	GMOSAIC User workshop and training				■	■		
Schorcht, G., Fliemann, E.	GFZ Potsdam, Germany	Remote Sensing for Hydrometeorological Monitoring						■	
Schorcht, G., Löw, L.	Urgench, Usbekistan	GIS and remote sensing on the way to application					■		
Schneiderhan, T. Förster, A.	Bonn, Germany	Respond-Nutzertraining für das THW			■				
Schneiderhan, T. Kranz, O.	Oberpfaffenhofen, Ottobrunn, Germany	Workshop Erdbeobachtung und Satellitenkommunikation					■		
Schneiderhan, T. Gähler, M.	Oberpfaffenhofen, Germany	ZKI-DE Nutzertraining für das BMI							■
Schroedter-Homscheidt, M.	Almeria, Spain	SFERA SOLLAB Summer school: Energy meteorology/Solar Resource Forecasting					■		
Thiel, M.	Kumasi, Ghana	'Fortgeschrittene Fernerkundung' als Baustein des WASCAL Graduierten Programms 'Klimawandel und Landnutzung'						■	■
Wegscheider, S.	Aix-en-Provence, France	User Training for the Emergency Response Service					■		

Abbreviations: CCG – Carl-Cranz-Gesellschaft, GFZ - GeoForschungszentrum Potsdam

Internal Seminar Series

Title	Comments
DFD Seminar	6-8 presentations per year, DFD and guest scientists
Seminars of DFD sections	seminars of DFD-GZS, DFD-LAX and DFD-ATM, 20-25 presentations per year, DFD and guest scientists
Doktorandentage University Würzburg	annual event with on average 7 PhD status presentations
R-Werkstatt University Würzburg	8 presentations since July 2012
Werkstattberichte University Würzburg	5-7 presentations per year, 33 since 2007

Contributions

Title	Comments
Wissenschaftliches Kolloquium of DLR Oberpfaffenhofen	7 presentations since 2007
Diplomanden-/Doktorandenseminar der Physischen Geographie, University Würzburg	15 presentations since 2007

In-House Interns and Trainees
256 students received practical training and supervision from DFD staff during short-term periods of stay at DFD between 2007 and 2013.

Academic Degrees

Professorship Appointments

Professorship appointments at universities

Name	Professorship	University	Year
Bittner, M.	Associate Professor of Remote Sensing of the Atmosphere (W2-Professur für Fernerkundung der Atmosphäre)	Augsburg	2012
Conrad, C.	Assistant Professor of Geografic Remote Sensing (Junior-Professur für Geographische Fernerkundung)	Würzburg	2011
Strunz, G.	Honorary Professor of Applied Remote Sensing (Honorarprofessur für Angewandte Fernerkundung)	München (TU)	2007

Habilitations and Venia Legendi

Habilitations awarded, supervised or completed by DFD or Würzburg University staff (in *italic typeface*) staff between 2007 and June 2013

Name	Subject	University	Year	Reviewers
Conrad, C.	Neue Konzepte der Fernerkundung und Geoinformatik für ein nachhaltiges Land- und Wassermanagement in Trockengebieten	Würzburg	Ongoing	Prof. Dech Prof. Hahn Prof. Baumhauer
Künzer, C.	Potenziale der Erdbeobachtung für ein nachhaltiges Management der Naturraumressourcen in großen Fluss-deltaregionen	Würzburg	Ongoing	Prof. Dech Prof. Baumhauer Prof. Rauh
Wüst, S.	Wellen in der mittleren Atmosphäre - Untersuchung von Kopplungsmechanismen und Entwicklung von Validationskonzepten	Augsburg	Ongoing	Prof. Reller Prof. Horn Prof. Hoppe
Höppner, K.	Network for the Detection of Mesopause Change (NDMC): ein Beitrag zum Verständnis des Klimawandels	Augsburg	Ongoing	Prof. Jacobeit Prof. Bittner Prof. Wetzel

Doctoral Theses

Doctoral Theses being supervised or completed at DFD or Würzburg University staff (in *italic typeface*) between 2007 and June 2013 (only DFD or University Würzburg supervisors are listed)

Name	Title	University	Year	Betreuer (DFD/LS)
Asam, S.	Multiskalige Ableitung des Blattflächenindex aus Fernerkund-ungsdaten	Würzburg	Ongoing	Dech, S. (1) Kunstmann, H. (2)
Bergemann, C.	Probabilistic air quality forecasts using POLYPHEMUS/DLR	Augsburg	Ongoing	Bittner, M. (1) N.N. (2)
Dietz, A.	Ableitung von Schneeflächen und Schnee-Wasser-Äquivalent aus Zeitreihen von Fernerkundungsdaten in Zentralasien	Würzburg	Submit-ted	Conrad, C. (1) Dech, S. (2)

Name	Title	University	Year	Betreuer (DFD/LS)
Ehrler, C.	Scale-Wavelength Decomposition of Hyperspectral Signals – Benefits for Mineral Mapping in a Reflective-Thermal Study of a Lignite Mining Site – (vorläufiger Arbeitstitel)	Karlsruhe (KIT)	Ongoing	Hinz, S. (1) Reinartz, P. (2)
Forkour, G.	Mapping Landuse and Landuse Change Pathways in the	Würzburg	Ongoing	Conrad, C. (1) N.N. (2)
Fourie, C.	Sample supervised approaches for geographic object-based image analysis	Jena	Ongoing	Hese, S. (1) N.N. (2)
Geiß, C.	Characterization of urban areas based on multi-sensor remote sensing for seismic building vulnerability assessment	Berlin	Ongoing	Lakes, T. (1) Taubenböck, H. (2)
Kerr, G.	Entwicklung eines Konzeptes zur Qualitätssicherung von Daten und Produkten hochauflösender optischer Bilddaten im Hinblick auf eine Quantifizierung ausgewählter Landoberflächen-parameter am Beispiel ausgewählter Bergbauregionen	Berlin	Ongoing	Reulke, R. (1)
Klüser, L.	Satellite analysis of aerosol-cloud-interactions over semi-arid and arid subtropical land regions	Augsburg	Ongoing	Bittner, M. (1) N.N. (2)
Knauer, K.	Analyse der Vegetationsdynamik in Westafrika anhand von Fernerkundungszeitreihen	Würzburg	Ongoing	N.N. (1) N.N. (2)
Knöfel, P.	Konzeption und Anpassung von fernerkundlichen Algorithmen zur Erfassung und Bewertung der Wassernutzungseffizienz in Baumwollkökosystemen Zentralasiens	Würzburg	Ongoing	Conrad, C. (1) Paeth, H. (2)
Kramer, R.	Aktivitäts-und Energieanalyse von Wellen in der mittleren Atmosphäre zur Verbesserung der energetischen Einschätzung von Tiefdruckgebieten und deren Vorhersage	Augsburg	Ongoing	Bittner, M. (1) N.N. (2)
Kübert, C.	Multi-sensor-concepts for the assessment of land surface phenology using spatial and temporal high resolution remote sensing data	Würzburg	Ongoing	Dech, S. (1) Conrad, C. (2)
Leinenkugel, P.	Analysing spatio-temporal patterns of land cover in the Mekong Basin	Kiel	Ongoing	Oppelt, N. (1) Künzer, C. (2)
Leutner, B.	Multisensorale Fernerkundung zur Modellierung von Biodiversitätsmustern	Würzburg	Ongoing	Dech, S. (1) N.N. (2)
Lex, S.	Ableitung des Leaf Area Index für ein optimiertes Wassermanagement im Ferghanatal in Zentralasien	Würzburg	Ongoing	Conrad, C. (1) N.N. (2)
Löw, F.	Development of a satellite-based multi-scale land use monitoring system for land and water management in the inner Aral Sea Basin in Uzbekistan and Kazakhstan	Würzburg	Ongoing	Conrad, C. (1) Michel, U. (2)
Martynenko, D.	Boundary layer aerosol characterization from space by 3D-VAR Data Assimilation into tropospheric chemistry transport model	Augsburg	Ongoing	Bittner, M. (1) N.N. (2)
Moser, L.	Remote sensing based indicators for analysing water stress impacts on land use in sub-Saharan West-Africa	Jena	Ongoing	Schmullius, C. (1) N.N. (2)
Niklaus, M.	Modellierung des Kohlenstoffkreislaufes zur Bewertung der Landdegradation im ariden und semi-ariden südlichen Afrika	Göttingen	Submitted	Kappas, M. (1) Günther, K. (2)
Schmidt, C.	Entwicklung eines Infrarotspektrometers zur operationellen Beobachtung des OH-Luftleuchtens mit hoher zeitlicher Auflösung	Augsburg	Ongoing	Bittner, M. (1) N.N. (2)
Schmidt, M.	Ableitung von Stadtstrukturtypen mit Methoden der Fernerkundung	Würzburg	Ongoing	Dech, S. (1) N.N. (2)

Name	Title	University	Year	Betreuer (DFD/LS)
Schorcht, G.	Estimation of water distribution performance and design of an expert tool in irrigated river basins using remote sensing and geoinformation techniques. A case study for the province Khorezm in Uzbekistan	Würzburg	Ongoing	Conrad, C. (1) N.N. (2)
Streicher, F.	Modellierung der Ausbreitung und Interaktion atmosphärischer Wellen (Infraschall, Schwerewellen)	Augsburg	Ongoing	Bittner, M. (1) Jacobeit, J. (2)
Wachter, P.	Räumliche und zeitliche Charakteristik atmosphärischer Wellen in OH*-Airglowdaten: Aufbau und Anwendung eines wellenklimatologischen Messverfahrens	Augsburg	Ongoing	Bittner, M. (2) Jabobeit, J. (1)
Walz, Y.	Multiskalige Analyse von satellitengestützten Umweltfaktoren zur Risikoabschätzung der Schistosomiasis	Würzburg	Ongoing	Dech, S. (1) Utzinger, J. (2)
Wendt, V.	Entwicklung und Erprobung neuartiger Verfahren zur Validierung satellitenbasierter Messungen in der Atmosphäre	Augsburg	Ongoing	Bittner, M. (1) N.N. (2)
Wiesner, M.	Modellentwicklung zur Bewertung von Siedlungsmustern in Bezug auf Grade der räumlichen Dispersion (Arbeitstitel)	Würzburg	Ongoing	Siedentop, S. (1) Dech, S. (2)
Wildner, S.	Entwicklung eines bodengebundenen optischen Messinstrumentes für die Vermessung des Sauerstoff (OH*)-Airglows zur Beobachtung von Klimaveränderungen, atmosphärischer Wellen (planetare Wellen, Schwerewellen, Infraschallwellen) und zur Validierung satellitenbasierter Messungen	Augsburg	Ongoing	Bittner, M. (1) N.N. (2)
Wohlfahrt, C.	Spatio-temporal analyses of ecosystem dynamics in the Yellow River Basin (China)	Kiel	Ongoing	Oppelt, N. (1) Künzer, C. (2)
Wolters, M.	Potential of Earth Observation for the Assessment Vulnerability and Resilience of Coastal Ecosystems: a case study in the Yellow River Delta, China	Kiel	Ongoing	Oppelt, N. (1) Künzer, C. (2)
Zeidler, J.	Analyzing landscape alterations and the spatio-temporal transferability utilizing multi-temporal, multi-scale, multi-sensorial satellite data in southern Africa.	Würzburg	Ongoing	Dech, S. (1) Conrad, C. (2)
Bayer, A.	Methodological Developments for Mapping Soil Constituents using Imaging Spectroscopy – Quantitative Analysis of Degradation Processes in South Africa	Potsdam	2013	Kaufmann, H. (1) Dech, S. (2)
Fritsch, S.	Regional crop growth modeling and yield prediction by utilization of remote sensing and production efficiency models	Würzburg	2013	Conrad, C. (1) Paeth, H. (2)
Gerighausen, H.	Modellierung der Bodenerosion landwirtschaftlicher Ökosysteme mit Methoden der Fernerkundung	Bonn	2013	Menz, G. (1) Kaufmann, H. (2)
Thiel, M.	Nutzung von Texturinformationen hochaufgelöster SAR-Daten zur Beschreibung von Siedlungsflächen	Jena	2013	Schmullius, C. (1) Conrad, C. (2)
Vo Quoc, Tuan	Valuation of Mangrove Ecosystems along the Coast of the Mekong Delta in Vietnam – an approach combining socio-economic and remote sensing methods	Kiel	2013	Oppelt, N. (1) Künzer, C. (2)
Wurm, M.	Verknüpfung von Fernerkundungsdaten und Survey-Daten (SOEP und BASE-II) in städtischen Räumen für sozialwissenschaftliche Analysen	Graz	2013	Schardt, M. (1), Wagner, G. (2)
Binh, T.	The knowledge-based search for water-related information system for the Mekong delta, Vietnam	Vietnamese Academy of Science	2012	Greve, K. (1) Birkmann, J. (2)
Cord, A.	Potential of multi-temporal remote sensing data for modeling tree species distributions and species richness in Mexico	Würzburg	2012	Dech, S. (1) Reineking, B. (2)

Name	Title	University	Year	Betreuer (DFD/LS)
Eisfelder, C.	Modeling Net Primary Productivity and Above-Ground Biomass for Mapping of Spatial Biomass Distribution in Kazakhstan	Dresden	2012	Buchroithner, M. (1) Dech, S. (2)
Plank, S.	Pre-survey suitability analysis of the differential and persistent scatterer synthetic aperture radar interferometry method for deformation monitoring of mass movements and subsidence	München (TU)	2012	Thuro, K. (1) Bamler, R. (2) Strunz, G. (3)
Schmitt, A.	Änderungserkennung in multitemporalen und multipolarisierten Radaraufnahmen	Karlsruhe (KIT)	2012	Hinz, S. (1) Bähr, H.P. (2) Hajnsek, I. (2)
Tum, M.	Modelling and validation of agricultural and forest biomass potentials for Germany and Austria	Göttingen	2012	Kappas, M. (1), Günther, K. (2)
Pilger, C.	Modellierung von Infraschall in der Atmosphäre: Auswirkungen auf die Mesopausentemperatur	Augsburg	2011	Bittner M.(1) Horn S. (2)
Hüttich, C.	Mapping Vegetation Types in a Savanna Ecosystem in Namibia: Concepts for Integrates Land Cover Assessments	Jena	2011	Schmullius, C. (1) Dech, S. (2)
Kersten, J.	Ein Rahmenwerk zur interaktiven Klassifikation hochauflösender optischer Satellitenbilder mittels graphenbasierter Bildmodellierung	Berlin (TU)	2011	Hellwich, O. Hinz, S.
Machwitz, M.	Integration von Fernerkundungsparametern für die raumzeitliche Modellierung der Kohlenstoffbilanz im Voltabecken in Westafrika	Würzburg	2011	Dech, S. (1) Paeth, H. (2)
Römer, H.	Assessment of tsunami vulnerability and resilience of coastal ecosystems at the Andaman Sea coast of Thailand – potential and limitations of remote sensing and GIS techniques for a local scale approach	Kiel	2011	Sterr, H. Ludwig, R.
Rüth, N.	Räumlich-zeitliche Feuermuster in Westafrika aus MODIS Feuerdaten für die Biodiversitätsforschung	Würzburg	2011	Linsenmair, E. (1) Dech, S. (2)
Geßner, U.	Räumliche und zeitliche Muster der Vegetationsstruktur in Savannen des südlichen Afrika	Würzburg	2010	Dech, S. (1) Herold, M. (2)
Heldens, W.	Use of airborne hyperspectral data and height information to support urban micro-climate characterization	Würzburg	2010	Dech, S. (1) Kaufmann, H. (2)
Jamil, A.	Entwicklung und Anwendung eines automatischen Prozessors zur Erfassung der Stadtkartierung am Beispiel von Sanaa	Potsdam	2010	Asche, H. (1) Kaufmann, H. (2) Borg, E. (3)
Khomarudin, R.	Tsunami risk and vulnerability: Remote Sensing and GIS approaches for surface roughness determination, settlement mapping and population distribution modelling	München (LMU)	2010	Strunz, G. (1) Ludwig, R. (2)
Martinis, S.	Automatic near real-time flood detection in high resolution X-band synthetic aperture radar satellite data using context-based classification on irregular graphs	München (LMU)	2010	Ludwig, R. Bamler, R. ?
Schramm, M.	Unüberwachte lineare spektrale Entmischung mit Anwendungen für Baumdichteabschätzungen in semiariden Regionen Afrikas	Hannover	2010	Heipke, C., (1), Kutterer, H. (2) Strunz, G. (3)
Sumaryono	Assessing Building Vulnerability to Tsunami Hazard using Integrative Remote Sensing and GIS Approaches	München (LMU)	2010	Ludwig, R. (1) Strunz, G. (2)
Höppner, K.	Beobachtung des Hydroxyl (OH*)-Airglow: Untersuchung von Klimasignalen und atmosphärischen Wellen	Würzburg	2009	Paeth, H. (1) Bittner, M. (2)

Name	Title	University	Year	Betreuer (DFD/LS)
Schroedter-Homscheidt, M.	Beobachtungsoperator zur Assimilation satellitenbasierter Messungen verschiedener Aerosoltypen in ein Chemie-Transportmodell	Köln	2009	Elbern, H. (1) Kerschgens, M. (2)
Wegmann, M.	Analyse von räumlichen Mustern und deren Determinanten mittels Fernerkundungsdaten	Würzburg	2009	Dech, S. (1) Linsenmair, E. (2)
Wüst, S.	Wechselwirkungen zwischen atmosphärischen Schwerewellen, planetaren Wellen und dem Grundstrom während der DYANA-Kampagne	Augsburg	2009	Bittner, M. (1) Horn, S. (2) Hoppe, U.-P. (3)
Breitkreuz, H.-K.	Solare Strahlungsprognosen für energiewirtschaftliche Anwendungen – der Einfluss von Aerosolen auf das sichtbare Strahlungsangebot in Europa	Würzburg	2008	Baumhauer, R. (1), Paeth, H. (2)
Colditz, R.	Time series analysis of value-added remotely sensed products for biodiversity applications in tropical and subtropical regions	Würzburg	2008	Dech, S. (1) Hansen, M. (2)
Dorigo, W.	Retrieving canopy variables by radiative transfer model inversion – a regional approach for imaging spectrometer data	München (TU)	2008	Melzer, A. (1) Bamler, R. (2)
Kirschke, S.	Modellierung des CO2- und CH4-Austauschs zwischen Biosphäre und Atmosphäre in Periglazialräumen und Bilanzierung des Methanaustauschs zwischen Biosphäre und Atmosphäre in Periglazialräumen mit Hilfe von Fernerkundung und Modellen am Beispiel des Lena Deltas	Würzburg	2008	Baumhauer, R. (1) Hubberten (2)
Kraus, T.	Ground-based Validation of the MODIS Leaf Area Index Product for East African Rain Forest Ecosystems	Erlangen-Nürnberg	2008	Samimi, C. (1) Baumhauer, R. (2)
Taubenböck, H.	Vulnerabilitätsabschätzung der Megacity Istanbul mit Methoden der Fernerkundung Fernerkundungsprodukte zur Risiko- und Gefährdungsabschätzung bei Naturkatastrophen am Beispiel der Megacity Istanbul	Würzburg	2008	Dech, S.(1) Zschau, J. (2)
Bachmann, M.	Automatisierte Ableitung von Bodenbedeckungsgraden durch MESMA-Entmischung	Würzburg	2007	Dech, S. (1) Kaufmann, H. (2)
Borg, E.	Entwicklung und Anwendung eines automatischen Prozessors zur Erfassung der Wolkenbedeckung und Datennutzbarkeit am Beispiel von LANDSAT7/ETM+-Daten	Potsdam	2007	Asche, H. (1) Kaufmann, H. (2) Albertz, J. (3)
Post, J.	Integrated process-based simulation of soil carbon dynamics in river basins under present, recent, past and future environmental conditions	Postdam	2007	Cramer, W. (1) Smith, P. (2) Franko, U.(3) Krysanova, V. (4)
Strobl, C.	GIS-gestützte Beckenanalyse am Beispiel des Französischen Juragebirges	München (LMU)	2007	Lammerer, B. Altermann, W.
Wehrmann, T.	Automatisierte Klassifikation von Landnutzung durch Objekterkennung am Beispiel von CORINE Land Cover	Würzburg	2007	Dech, S. (1) Glaser, R. (2)
Wloczyk, C.	Entwicklung und Validierung einer Methodik zur Ermittlung der realen Evapotranspiration anhand von Fernerkundungsdaten in Mecklenburg-Vorpommern	Rostock	2007	Miegel, K. (1) Bernhofer, C. (2) Bronstert, A. (3)
Zoßeder, K.	Heterogene Verteilung von PAK-Kontaminationen im Grundwasser	Bochum	2007	Wohnlich, S. (1) Bender, S. (2)

Diploma/Magister/Master/Bachelor Theses

Diploma (D) /Magister (MA) /Master (M) /Bachelor (B) theses being supervised or completed at DFD or at Department of Remote Sensing at University Würzburg (in *italic typeface*) between 2007 and June 2013

Name	Subject	University	Year	D/MA/M/B
Bettinger, M.	Verbesserung eines automatischen MODIS-Hochwasserprozessors durch Methoden zur Trennung von Wasserflächen und Wolkenschatten	München (HS)	Ongoing	B
Birkholz, R.	Multitemporale Analyse von Landbedeckungs-/Landnutzungsänderungen entlang des Ili-Flusslaufs und deren Auswirkungen auf das Ökosystem des Flussdeltas	Jena	Ongoing	M
Cao, W.	Change detection using TerraSAR-X data	Stuttgart	Ongoing	D
Fliehmann, E.	Entwicklung der kasachischen Bewässerungsregion Kyzlorda – fernerkundliche Analyse der Degradierung landwirtschaftlicher Nutzflächen mittels Landsat-Zeitserien	Würzburg	Ongoing	D
Gaub, V.	Untersuchung der Lebensräume in 3D: Wie ändert sich das Mikroklima unter verschiedenen Einzelbaumbedingungen im Nationalpark Bayrischer Wald	Würzburg	Ongoing	D
Hanrieder, B.	Hochwasser in Thailand- Erstellung und Validierung von Flutmasken aus HR-/ VHR- Daten	München (TU)	Ongoing	M
Hartmann, A.	Landbedeckungsqualifikation für Westafrika basierend auf MODIS- und Landsat-Daten	München (LMU)	Ongoing	M
Klenk, K.	Übertragung einer internationalen Erdbebenskala auf fernerkundungsbasierte Schadensanalysen	München (HS)	Ongoing	B
Konetschny, C.	Beobachtung der Landoberflächenveränderung durch das Auftauen des Permafrostbodens auf Herschel Island mit Hilfe von verschiedenen Radarzeitreihen des TerraSAR-X	München (LMU)	Ongoing	B
Roch, M.	Revealing Deforestation Patterns in Paraguay's Atlantic Forest	Salzburg	Ongoing	M
Rupp, A.	Potenziale von Landressourcen in China: Eine fernerkundliche Längsschnittanalyse zur Entwicklung der Reisanbaugebiete am Dongting-See	Würzburg	Ongoing	D
Stanzel, S.	Kartierung von Siedlungsmustern und Bebauungstypen über Langzeitkohärenzen aus TerraSAR-X/TandDEM-X Daten	Berlin (HS)	Ongoing	M
Warth, G.	Automatische Hochwassererkennung anhand der Verwendung bistatischer Kohärenzdaten der TanDEM-X Mission	Tübingen	Ongoing	MA
Alavi, S.	Analyzing urban spatial patterns in conjunction with urban heat patterns	Bayreuth	2013	M
Aravena, P.	Estimation of seismic building structural types using remote sensing and machine learning	München (LMU)	2013	D
Bell, A.	Application of behavioral change point analysis and species distribution models in conservation	Bayreuth	2013	M
Binnig, J.	Multitemporale Auswertung hyperspektraler Bilddaten zur Veränderungsanalyse ausgewählter Bodenparameter am Beispiel eines Braunkohletagebaugebietes	Würzburg	2013	B
Bolkart, M.	Lidar-Daten und Waldstrukturmaße: eine sinnvolle Kombination?	Würzburg	2013	B
Braun, D.	Estimating the current and future human impact in Tanzania for wildlife corridor management	Bayreuth	2013	M

Name	Subject	University	Year	D/MA/M/B
Camerer, A.	Fernerkundungsbasierte Bestimmung der Landnutzung zur Verbesserung der Wasserproduktivität in Punjab, Pakistan	Würzburg	2013	D
Dambros, C.	Analyzing forest fragmentation characteristics along continuous vegetation gradients	Bayreuth	2013	M
Gnovke, P.	Analyzing landgrabing in Africa using Remote Sensing Data	Bayreuth	2013	M
Hanke, N.	Statistische Beziehung zwischen hydrologischer Abflussmenge und Ausdehnung der Bewässerungslandwirtschaft in Zentralasien	Würzburg	2013	D
Hoffmann, A.	Risiko- und Unsicherheitsanalyse hydrologischer Gefahren im Mittelmeerraum	München (LMU)	2013	D
Hütten, L.	GIS- und fernerkundungsbasierter Aufbau sowie Konzeption einer Geodatenbank als Grundlage für die Risikobewertung des Auftretens von Buruli Ulcer in Zentralkamerun	Osnabrück	2013	M
Kachelreiss, D.	Analysis of the effectivity of marine protected areas - a case study using remote sensing for the Cargos Archipelago	Bayreuth	2013	M
Mancera, D.	Generation of a climatology of near-surface boundary layer aerosols for solar energy application	Oldenburg	2013	M
Ortmann, A.	Using remote sensing within the UN-REDD framework	Bayreuth	2013	M
Petersen, M.	Einfluss von Umweltparametern auf Käferpopulationen im Nationalpark Bayerischer Wald – Ein Ansatz mit LiDAR	Würzburg	2013	B
Plum, C.	Global Survey of Earth Observation for Biodiversity and Conservation	Bayreuth	2013	M
Reischmuth, A.	Erfassung des Forstbestandes und der Forstqualität auf der Basis hyperspektraler HySPEX-Daten	Dresden (HS)	2013	M
Schack, J.	Ableitung von Signalen laufender planetarer Wellen aus dem Dynamischen Aktivitätenindex (DAI) und Vergleich der mesosphärischen Aktivität planetarer Wellen	München (HS)	2013	B
Schumann, B.	Raum-zeitliche Charakterisierung von Borkenkäferbefallen mit Hilfe von Zeitreihen mittel- und hochaufgelöster Fernerkundungsdaten	Würzburg	2013	B
Von Uslar, J.	Statistische Ableitung des LAI für Wälder im bayrischen Voralpenraum basierend auf RapidEye-Daten und Feldmessungen	Würzburg	2013	B
Wegner, M.	Evaluierung des Deutschen Satellitendatenarchivs auf Nachhaltigkeit und Effizienz	München (HS)	2013	M
Wohlfart, C.	Mapping tropical dry forest in South East Asia using a continuous cover approach	Bayreuth	2013	M
Zellner, P.	Optimierung regionaldifferenzierter Landnutzungsparameter für das hydrologische Modell ArcEGMO am Beispiel zweier Einzugsgebiete in Brandenburg	Würzburg	2013	B
Abdullahi, S.	Development of a generic algorithm for population modeling and application in a test area in Western Africa	Graz	2012	M
Abel, C	Combination of Remote Sensing and Socio-Economic Data for Population Estimation and Monitoring	Dresden	2012	D
Anhorn, J.	Flood extent mapping from high resolution TerraSAR-X Data in Samar, Philippines in the context of an Integrated Disaster Risk Management and Local Flood Early Warning Systems	Heidelberg	2012	D

Name	Subject	University	Year	D/MA/M/B
Beyer, S.	Analyse der raumzeitlichen Entwicklung der Bewässerungsregion in Karakalpakstan, Usbekistan, zur Ermittlung von degradierten landwirtschaftlichen Nutzflächen	Heidelberg (HS)	2012	D
Buchta, K.	Interaction of geo-features and conflicts exemplified by the Darfur conflict – Potential and limits of remote sensing and GIS applications in the context of a humanitarian crisis	München (TU)	2012	D
Ewald, M.	Assessing the influence of vegetation structure on roe deer habitat selection using airborne lidar	Bayreuth	2012	M
Fabritius, H.	Statistische Ableitung des LAI für Grünland aus RapidEye-Daten und in-situ-Messungen	Würzburg	2012	B
Fingerhut, L.	Bestimmung der Brandungshöhe und Unterwassertopographie aus TerraSAR-X-Daten	Würzburg	2012	B
Firmbach, L.	Fernerkundliche Analyse der Relevanz urbaner Struktureinheiten für ein integriertes Wasserressourcen-Management am Beispiel des Distrito Federal do Brasil	Würzburg	2012	D
Früh, A.	Flooding and Ecosystem Services	Bayreuth	2012	M
Gössl, A.	Fernerkundliche Kartierung von Strohpotentialen in Nord-Baden-Württemberg	Würzburg	2012	D
Grett, J.-P.	Entwicklung eines Modellverfahrens für die Erstellung einer Potenzialstudie für Wasserkraft der Insel Saint Vincent auf Basis von Fernerkundungsdaten und hydrologischen Aufzeichnungen	Würzburg	2012	M
Hodrius, M.	Die Ableitung von Überflutungstiefen aus hochaufgelösten SAR-Daten in Kombination mit LIDAR-Geländemodellen?	Augsburg	2012	D
Hummel, F.	Uncertainty analysis of hydrological model results and assessment regarding water risks in the Mediterranean Basin – Case study: Chiba, Tunisia	München (LMU)	2012	D
Jilge, M.	Ableitung von Tag-/ Nachtkarten aus Fernerkundungsdaten und zusätzlichen Geoinformationen	München (HS)	2012	B
Keim, St.	iSAT – die Entwicklung einer iPhone-Anwendung Satellitentracking und Orbitprediction im Kontext der Satellitenfernerkundung	Eichstätt-Ingolstadt	2012	D
Klotz, M.	Delimiting the Central Business District – A physical analysis using Remote Sensing	London (King´s College)	2012	D
Kretz, D.	Detecting changes in land cover and developing future management strategies in the face of global change, Kafue National Park, Zambia	Bayreuth	2012	M
Lange, X.	Verbesserung und Evaluierung eines Emissionskatasters für Luftschadstoffe am Beispiel der Tourismusregion Schwarzwald	Göttingen	2012	D
Leichtle, T.	Synergetische Untersuchung von Zeitreihen von polarimetrischen RADARSAT-2 und TerraSAR-X-Daten über RAM/SAR Feuchtgebiet Oberrhein	Graz	2012	M
Leutner, B.	Spatially expicit assessment and modelling of biodiversity patterns in the Bavarian Forest National Park by means of hyperspectral and LIDAR remote sensing	Bayreuth	2012	M
Lieberknecht, B.	Untersuchungen zur klimatischen Eignung des Amu Darya Deltas in Zentralasien für den zukünftigen Anbau von Baumwolle, Weizen und Mais auf Basis eines regionalen Klimamodels	Würzburg	2012	B

Name	Subject	University	Year	D/MA/M/B
Malec, S.	Raum-zeitliche Veränderungsanalyse von Feuchtgebieten im Großraum Bengasi	Würzburg	2012	B
Meyer, A.	Möglichkeiten der 3D-Visualisierung von Erdbebenschadensanalysen	München (HS)	2012	B
Müller, T.	Vergleich von Distanzmetriken beim automatisierten Bildabgleich von hyperspektralen Bilddaten	Würzburg	2012	B
Obermaier, E.-M.	Human Schistosomiasis in sub-Saharan Africa: The impact of environmental parameters on disease transmission	Bayreuth	2012	M
Ottinger, M.	Analysis of the Yellow River Delta in the Context of Climate Change	Dresden	2012	D
Pengler, I.	Entwicklung eines Konzepts für die Erweiterung der Benutzerschnittstelle für die Instrumentenplanung im Rahmen der Satellitenmission EnMAP mit dem Ziel der Vernetzung wissenschaftlicher Anwender aus dem Bereich der Erdbeobachtung	München (HS)	2012	M
Ramanauskas, A.	Automatic mapping of tsunami-induced damage using multi-temporal multi-spectral satellite imagery?	Jena	2012	D
Reise, J.	Spatial Modeling of species distribution in Camodia using RE Data	Bayreuth	2012	M
Ring, C.	Klassifikation von sehr hoch aufgelösten Daten in semiariden Gebieten – Vergleich von pixel- und objektbasierten Ansätzen	Würzburg	2012	B
Rossi, M.	Messung hyperspektraler Signaturen verschiedener Oberflächen und Analyse deren Variabilität	Würzburg	2012	B
Schäfer, F.	Fernerkundungsbasierte Modellierung und Kalibrierung der tatsächlichen Evapotranspiration in Khorezm, Usbekistan	Würzburg	2012	B
Schaumberger, St.	Klassifikation einer Zeitserie von AWiFS-Multispektraldaten	Würzburg	2012	D
Schiller, C.	Entwicklung und Anwendung eines Prozessors zur automatischen Generierung flächendeckender Parameterkarten unter Nutzung von In-siitu-Daten des Kalibrations- und Validationsstandortes DEMMIN	Berlin	2012	B
Standfuß, I.	The physical growth of informal settlements in Dhaka, Bangladesh	Dortmund (TU)	2012	D
Streicher, F.	Verbesserung/Optimierung der Hintergrundmodellierung für eine reale Infraschallausbreitung	Augsburg	2012	D
Wiesner, M.	Entwicklung eines Index zur Bestimmung der Polizentrizitätsgrade von Städten basierend auf urbanen Fußabdrücken	Würzburg	2012	D
Besser, T.	Sprawling crisis? – Urbanization from the perspective of protected areas near Kolkata, India	Bayreuth	2011	M
Eberle, J.	Erstellung von OGC konformen Prozessketten in der Fernerkundung am Beispiel von MODIS-Daten	Jena	2011	M
Edlinger, J.	The Soviet heritage – monitoring the expansion of cotton cultivation areas in the Aral Sea Basin	Bayreuth	2011	M
Eilertz, D.	Satellitengestützte Indikatoren zur vergleichenden Analyse und Bewertung der agrarischen Landnutzung im Raum Khorezm, Usbekistan	Würzburg	2011	B
Firdausy, T.	Supporting forest fire management by using Earth observation and GIS analysis	Stuttgart (HS)	2011	M

Name	Subject	University	Year	D/MA/M/B
Fischer, H.	Erfassung und räumliche Analyse ausgewählter mineralischer und pedologischer Parameter unter Nutzung hyperspektraler Bilder	Jena	2011	D
Grote, J.	Forstliche Bestandesaufnahme einer Versuchsfläche zur Bereitstellung von Basisdaten für die Methodenentwicklung zur Auswertung von Hyperspektral- und EnMAP-Daten (Bachelor)	Eberswalde (HS)	2011	B
Kalia, A. C.	TerraSAR-X basierte Pre- und Post-Desaster Analyse zur Abschätzung vulkanbedingter Landbedeckungsveränderungen Fallbeispiel: Merapi	Gießen	2011	D
Kapherr, M.	Erfassung von lokalem Holzeinschlag in der Demokratischen Republik Kongo – Vergleich von pixel- und objektbasierten Klassifikationen und Veränderungsanalysen auf Grundlage optischer Satellitenbilddaten	Freiburg	2011	M
Kirmaier, S.	Radiometrische Normalisierung und Trainingsdatengenerierung als Grundlage zur Landnutzungsklassifikation von Zeitseriendaten	München (HS)	2011	B
Klett, S.	Rapid Mapping for Earthguake Disasters – A team-based Method for Visual Damage Assessment Using Optical VHR Satellite Data	Tübingen	2011	D
Knauer, T.	Monitoring ecosystem health of Fynbos remnant vegetation in the City of Cape Town using remote sensing	Würzburg	2011	D
Kompter, E.	Bodenkundliche Standortuntersuchung und –Charakterisierung in Hinblick auf Landdegradation in Südafrika	Jena	2011	D
Kraff, N.	Vergleiche megaurbaner Marginalviertel Mumbais durch ausgewählte Vulnerabilitätsfaktoren mittels hochaufgelöster Satellitendaten und Interviews, im Hinblick auf Beeinträchtigungen durch den Monsun	Trier	2011	D
Kukofka, T.	Situationsbewertung und Entscheidungsunterstützung bei georäumlichen Umweltfragestellungen – Ein Methodenvergleich zum Umgang mit unsicheren georäumlichen Umweltinformationen am Beispiel der Tsunamifrühwarnung	Koblenz-Landau	2011	D
Lüthje,	Object-based image analysis using optical satellite imagery and GIS data for the detection of mining sites in the Democratic Republic of the Congo	Heidelberg	2011	D
Müller, H.	Modelling of Forest Structure with Remote Sensing	Bayreuth	2011	M
Pitt, A.	Erstellung automatisierter Prozesse für die Generierung von 3D-Notfallszenarien zur Unterstützung von Kriselagezentren	Dresden (HS)	2011	B
Rahmann, M.	Klassifikation der Landnutzung und Landbedeckung zur Ermittlung des Wasserbedarfs von Baumwolle und Winterweizen im Ferghana-Tal (Usbekistan)	Würzburg	2011	D
Reinsch, F.	Auswirkungen des Flüchtlingscampwachstums auf die lokale Konfliktressource Holz	Jena	2011	D
Reinwand, M.	Untersuchung der Vegetationsdegradation in den Savannen des südafrikanischen Hochplateaus unter Nutzung von Fractional Cover und multitemporalen Fernerkundungsdaten	Würzburg	2011	D
Riegler, C.	Ermittlung von Bebauungsparametern mittels hochaufgelöster SAR-Daten	Würzburg	2011	D
Rößler, S.	Der dynamische Aktivitätsindex (DAI): Natürliche Einflüsse und Trend	Augsburg	2011	B

Name	Subject	University	Year	D/MA/M/B
Rudloff, M.	Untersuchung der Anwendbarkeit bestehender Methoden zur Siedlungsdetektion auf ScanSAR-Daten des TerraSAR-X	Würzburg	2011	B
Rupp, M.	Von der Einzel- zur Multi-Hazard-Analyse – Eine Untersuchung am Beispiel Cilacap, Java, Indonesien	Heidelberg	2011	D
Schellenberger Th.	Exploitation of high resolution X-band SAR images for monitoring snow cover in alpine areas	Würzburg	2011	D
Schiller, Ch.	Entwicklung eines operative Prozessors zur Ableitung flächendeckender thematischer Informationsprodukte für das Wettermessnetz DEMMIN	Berlin	2011	B
Schneiderhan, T.	Führung in Krisensituationen – Am Beispiel des Zentrums für satellitengestützte Kriseninformation (ZKI)	Lahr (HS)	2011	M (MBA)
Schwethelm, F	Entwicklung eines semi-automatischen Ansatzes zur objektbasierten Extraktion von Wohneinheiten in Flüchtlingscamps in Darfur aus Erdbeobachtungsdaten	München (HS)	2011	D
Simang, A.	Influence of policy, socio-economics and ecology for landscape level conservation – A case study on Asian elephants	Bayreuth	2011	M
Stark, H.-S.	Optimierung der Verfahren zur Aufbereitung krisenbezogener Fernerkundungs- und GIS-Daten des ZKI für ein webbasiertes Kriseninformationssystem	München (HS)	2011	B
Tampubolon, W.	Analysis and integration of open access geoinformation in a spatial data infrastructure for emergency response and disaster preparedness	Stuttgart (HS)	2011	M
Ullmann, T.	Nutzen polarimetrischer TerraSAR-X Daten für die Charakterisierung der Landbedeckung tropischer Regionen	Würzburg	2011	D
Vollmuth, M.	Analyse von Diversitätsmustern in der Landwirtschaft von Khorezm (Usbekistan) anhand einer RapidEye Klassifikation	Würzburg	2011	B
Wachter, P.	Aufbau eines Spekrtometerarrays zur Vermessung von Schwerewellenparametern in OH*-Airglowdaten	Augsburg	2011	D
Wolf, C.	Aufbereitung von hochgenauen DOMSs für den Einsatz in der Atmosphärenkorrektur	München	2011	D
Xiaoxuan, Y.	Einsatz von Fernerkundungsdaten für die Bestimmung grundwasserhöffiger Gebiete in Flüchtlingsregionen Afrikas	Clausthal (TU)	2011	B
Abelen, S.	Development of a user interface for optimizing urban area classification from Landsat data	München (TU)	2010	D
Ahrens, M.	Integration raumbezogener Daten in ein Umweltinformationssystem – Konzeption und Implementierung eines grafischen Assistenten für die Eingabe, Zusammenstellung und Integration von Geodaten in ein WebGIS. Erweiterung der Integrationssoftware für den Import von in-situ Sensormessdaten	Karlsruhe (HS)	2010	D
Asam, S.	Water Availability in the Aral Sea Basin: Derivation of Fractional Vegetation Covers from Multi-scale Remote Sensing Date for Hydrological Modeling in Central Asia	Würzburg	2010	M
Back, M.	Untersuchung der Entwicklung von Feuchtgebieten in Regionen der Türkei, unter Nutzung von Landsat TM und Landsat MMS Daten, als Beitrag für die 'Mediterranean World' Initiative	München	2010	D
Bernhard, E.-M.	Brandflächendetektion im mediterranen Raum auf Basis von SPOT 5 und TerraSAR-X Satellitendaten	Innsbruck	2010	D

Name	Subject	University	Year	D/MA/M/B
Dahms, T.	Einschätzung des Potentials hochauflösender SAR-Daten zur Erfassung von Stadtstrukturen	Würzburg	2010	B
Dalatrée, C.	Texture Analysis and Feature Extraction from Very High Resolution TerraSAR-X Imagery for Land Cover Classification	Würzburg	2010	D
Dieterle, S.	Automatisierte Auswertung von multi-temporalen Fernerkundungsdaten zur Aktualisierung botanischer Datenbankeinträge für das Studiengebiet Mexiko	Würzburg	2010	D
Dürbeck, T.	Land Suitability Analyse und Marginales Land in der Bewässerungsregion Khorezm, Usbekistan	Würzburg	2010	MA
Geiß, Ch.	Potenzialmodellierung von Nahwärme auf Grundlage von Fernerkundungsdaten	Salzburg	2010	D
Grett, J.-P.	Standortbestimmung für erneuerbare Energiegewinnungsträger im Bereich Wasserkraft anhand von ASTER-Höhendaten am Beispiel von Saint Lucia	Würzburg	2010	B
Haas, S.	Fire regime analysis in Mpumalanga Province, South Africa, based on MODIS and Landsat data	Köln	2010	MA
Jobst, C.	A case study for Caprivi: Assessing land cover change and change drivers using remote sensing and socio-economic data	Würzburg	2010	D
Kern, C.	Entwicklung einer grafischen Benutzeroberfläche zum Generieren, Bearbeiten und Ausführen von Transformationsprozessen zwischen Xml-Meterdaten und dem internen Metadatenformat des DLR	Neubrandenburg (HS)	2010	D
Klein, I.	Abschätzung physischer Vulnerabilität gegenüber Hochwasser im urbanen Raum – Das Potenzial der Fernerkundung	Augsburg	2010	D
Klotz, M.	Spatiotemporal analysis of urbanisation in Mexican major cities using multisensoral remote sensing data	München (LMU)	2010	D
Knispel, B.	Entwurf, Implementierung und Integration eines Prozessors zur Auswertung von Schiffsdetektions- und AIS-Signalen	Berlin	2010	D
Kriegel, M.	Entwicklung eines generischen Prozessors zur Bewertung der Datennutzbarkeit verschiedener optischer Satellitenfernerkundungssensoren	Neubrandenburg (HS)	2010	B
Kubank, J.	Comparison of GIS-based and high resolution satellite imagery population modeling – a case study for Istanbul	Göttingen	2010	D
Leimbach, D.	Untersuchung der Einflüsse staatlicher Umsiedelungsprogramme in Namibia auf die Landbedeckung unter Verwendung von MODIS-Zeitreihen	Würzburg	2010	D
Leinenkugel, P.	The Combined Use of Optical and SAR Data for Large Area Impervious Surface Mapping	Salzburg	2010	M
Lex, S.	Identifizierung der Antriebskräfte von Landnutzungs- und Landbedeckungsveränderungen in der Region Kavango in Namibia anhand der Vorgehensweise des Modells CLUE-S	Würzburg	2010	D
Müller, A.	Multitemporale Auswertung von HyMap-Hyperspektraldaten am Beispiel der Referenzsite Oberpfaffenhofen	München (LMU)	2010	D
Pfletschinger, Ph.	Einsatz von Texturmaßen zur Erfassung von Baustellen aus höchstauflösenden SAR-Daten	Würzburg	2010	D
Schönberg, A.	Land Cover Change Analysis around IDP/refugee Camps based on multitemporal MODIS Data in Sudan	Dresden (HS)	2010	D

Name	Subject	University	Year	D/MA/M/B
Spröhnle, K.	Earth Observation for Environmental Impact Assessment in the Surroundings of Refugee Camps in Darfur	Bamberg	2010	MA
Sturm, C.	Entwicklung einer Flash-basierten Darstellung der Funktionsweise des satellitengestützen Radarprinzips	München (HS)	2010	D
Weitnauer, C.	Analyse und Schwerewellensignaturen in OH-Airglowdaten im Alpenraum	Augsburg	2010	D
Woditsch, S.	Die 3D-Visulaisierung von Notfallkarten am Beispiel der Software 'TerraExplorer'	Eichstätt	2010	D
Bohovic, R.	Modeling evapotranspiration at different scales by means of remote sensing	Brno, Tschechien	2009	M
Coldt, S.	Modellierung von raumzeitlichem urbanen Wachstum auf der Basis von Fernerkundungsdaten am Beispiel der indischen Metropole Hyderabad	Bochum	2009	D
Dietz, A.	Abschätzung der Nutzbarkeit von MODIS Zeitreihen für die Analyse von Feuchtgebietsvariabilitäten in Westafrika	Würzburg	2009	D
Förster, J.	Reducing Emissions from Deforestation and Degradation (REDD): A case study of Western Ghana	Bayreuth	2009	M
Harmann, A.	Modellint dust emissions in the Mediterranean Basin for improfes solar energy yield predictions	Augsburg	2009	D
Indrajit, A.	Development and Application of Remote Sensing Techniques to Support the Mapping of Settlement Areas as Contribution to Tsunami Vulnerability Assessment in Indonesia	München (TU)	2009	M
Pfitzner, A.	Bewertung der Aussagekraft fernerkundlich generierter Produkte zur Versiegelung im Hinblick auf ein flächendeckendes Monitoring	Dresden (TU)	2009	D
Podwyszynski, M.	Knowledge-based search for Earth Observation Products	Passau	2009	D
Römisch, P.	Anforderungen an die Fernerkundung aus der Sicht von Nutzern in Land- und Forstwirtschaft	Neubrandenburg (HS)	2009	M
Schmitt, O.	Automatische Ableitung von Stadtstrukturtypen auf Basis von hochaufgelösten, multisensoralen Fernerkundungsdaten	München (LMU)	2009	D
Schneider, R.	Untersuchung des Einflusses planetarer Wellen auf stratosphärische Erwärmungen und Ozonstreamer	Augsburg	2009	D
Seidenberger, K.	Bestimmung der Charakteristik vulkanischer Emissionen mit satellitenbasierten Messungen, Trajektorenensembles und Chemie-Transport-Modellierung	Augsburg	2009	D
Stein, E.	Entwicklung einer merkmalbasierten Klassifikation für urbane Räume unter Verwendung von Hyperspektraldaten am Beispiel der Stadt München	Jena	2009	M
Tüngerthal, S.	Fernerkundungsbasierte 3D-Visualisierung im Katastrophenmanagement	Göttingen	2009	D
Werner, K.	Programmierung einer Web-Anwendung zur dynamischen Editierung eines UMN MapServer	Osnabrück	2009	D
Zeidler, J.	Field based classification of multi-temporal ASTER data for the analysis of agricultural land-use in Khorezm, Uzbekistan	Bayreuth	2009	M

Name	Subject	University	Year	D/MA/M/B
Bachhofer, F.	Ableitung von Versiegelungsgraden basieren auf hochaufgelösten Fernerkundungsdaten mittels 'Support Vector Regression'	Tübingen	2008	D
Bayer, A.	Modellierung der Temperaturentwicklung oberflächennaher Boden- und Gesteinsschichten arider Gebiete unter Berücksichtigung der solaren Einstrahlung und der Topographie	Stuttgart	2008	D
Bindel, M.	Entwicklung eines objektorientierten Ansatzes zur Ableitung von Brandnarben im mediterranen Raum aus multisenoralen, hochauflösenden Satellitendaten	Jena	2008	D
Breunig, M.	Potentiale hoch auflösender Radarsatelliten im urbanen Raum	Würzburg	2008	D
Dokupil, A.	Regionale Biomasse-Modellierung im südlichen Afrika: Vergleich der Biomasse-Modelle BETHY/DLR und RBM	Bonn	2008	D
Eisfelder, C.	Entwicklung einer automatisierten objektbasierten Kartierung von Waldflächen mit IKONOS-Daten	Dresden (TU)	2008	D
Fritsch, S.	Field-based classification of agricultural land use by combining object- and pixel based methods – a case study for the region of Khorezm (Uzbekistan)	Würzburg	2008	D
Gayer, M.	Advance Methods for IDP and Refugee Camp Mapping with Very High Resolution Satellite Imagery	Freiburg	2008	MA
Gstaiger, V.	Multisensorale Ableitung von Wasserflächen aus SAR-Daten	Innsbruck	2008	D
Hahn, M.	Räumliche und zeitliche Analyse der Lufttemperaturverteilung in Bewässerungsgebieten des Aralsee-Beckens (Zentralasien) und deren Korrelation mit der Vegetationsentwicklung (2000-2006)	Frankfurt	2008	D
Himmler, V.	Erhebung von Versiegelungsdaten mittels Fernerkundung und geographischer Informationsverarbeitung	Würzburg	2008	D
Koch, C.	Entwicklung und Erprobung einer Software zur Rahmensynchronisation und Qualitätsüberprüfung von CCSDS-kompatiblen Satellitendaten	Hamburg (HS)	2008	D
Kübert, C.	Erfassung von Energieaustauschprozessen im System Landoberfläche – Atmosphäre mittels Fernerkundung und Eddy-Kovarianz-Analysen in Burkina Faso	Würzburg	2008	D
Mück, M.	Tsunami Evacuation Modelling Development and application of a spatial information system supporting tsunami evacuation planning in South-West Bali	Regensburg	2008	D
Pauschert, C.	Mapping damages on infrastructure and buildings due to earthquakes: A comparison of remote sensing based methods	Karlsruhe	2008	M
Schmidt, M.	Abhängigkeiten der interanuellen Vegetationsdynamik von Klimaparametern in Afrika	Würzburg	2008	D
Schulz, M.	Archivierung und Bereitstellung von heterogenen Geodaten für das Testfeld DEMMIN	Neubrandenburg (HS)	2008	M
Tum, M.	Variabilitätsuntersuchungen der NPP von Energiepflanzen für das Gebiet Deutschland – Österreich	Göttingen	2008	D
Widvaningrum, E.	Tsunami Evacuation Planning using Geoinformation Technology considering Land Management Aspects – Case Study Cilacap Central Java, Indonesia	München (TU)	2008	M

Name	Subject	University	Year	D/MA/M/B
Witt, T.	Entwicklung des Webauftritts für das Projekt SWACI-II	Neubrandenburg (HS)	2008	B
Wouters, K.	Object-oriented classification of land cover units and vegetation status using spectral indices and hyperspectral imagery of thornbush savannas, Namibia	München (LMU)	2008	D
Berger, C.	Raum-zeitliche Analyse indischer Megastädte mit Landsat-Daten	Jena	2007	B
Cord, A.	Classifying landcover using FAO-LCCS standards in a tree savanna of Burkina Faso with ASTER and IKONOS data – A Case study for the region of Dano (Burkina Faso)	Würzburg	2007	D
Damerow, H.	9th international 'Master of Space Systems Engineering' (MSE) Programme (SpaceTech)	Delft (TU)	2007	M
Eisele, A.	Spektroskopische Ableitung pedogener Parameter aus Böden eines semiariden Untersuchungsgebietes in Zentralnamibia	München (LMU)	2007	D
Herbst, B.	Sensiblity study for optimizing the classification of remote sensing time-series	Bayreuth	2007	M
Herty, C.	Correlation between satellite remote sensed changes in land cover and social and economical factors as well as political and land tenure practices	Rottenburg	2007	D
Kaas, S.	Analyse eines urbanen Raumes mit höchst aufgelöster Fernerkundungsdaten zur Abschätzung physischer Vulnerabilität: Die Stadt Padang (Indonesien) als Fallbeispiel	Innsbruck	2007	D
Pannowitsch, C.	Generalisierungsklassen für einen Ingestion Prozessor	Stralsund (HS)	2007	B
Pengler, I.	Stadtstrukturtypenkartierung mit Methoden der Fernerkundung am Beispiel der Stadt Hyderabad (Indien)	München (HS)	2007	D
Wirth, G.	Identifikation von Schneebedeckung auf Solaranlagen mit Hilfe von Satellitenmessungen	München (HS)	2007	D

Abbreviations: Würzburg – Julius-Maximilian-Universität Würzburg, LMU – Ludwig-Maximilian-Universität München, TU – Technische Universität, HS/FH – (Fach)Hochschule

Scientific Exchange

Guest Scientists

Visiting scientists hosted by DFD between 2007 and June 2013 (≥ 4 weeks stay) or by Department of Remote Sensing at University Würzburg (in *italic typeface*)

Name	Period	Home Institution	Funding
Anwar, H.	Aug - Sep 2007 & Jun 2010	Indonesian Institute of Sciences (LIPI), Indonesia	GITEWS
Ayanou, Y. A.	Jul - Aug 2012	Universität Bayreuth	Universität Bayreuth
Banks, S.	Oct 2012 - Mar 2013	University of Alberta, Edmonton, Canada	DLR
Bo, Y.	Jul - Sep 2010	Hunan Normal Universität, China	DAAD, WISDOM
Bohovic, R.	(six weeks) 2010	Masaryk Universität Brno, Tschechische Republik	Masaryk Universität Brno, Tschechische Republik
Bruck, A.	Jun - Sep 2009	Tel Aviv Universität, Israel	GIF
Buzzi, J.	Jun - Sep 2010	-	IGME
Cipriano, A.	May - Jun 2013	Universidad Católica de Chile, Santiago, Chile	DAAD
Dubovyk, O.	Jun - Jul 2012	ZEF Bonn	ZEF Bonn
Firdausy, T.	Jul 2008 - Jun 2009	Indonesian Institute of Sciences (LIPI), Indonesia	Guest Scientist (DLR)
Hideomi, G.	Sep 2012 - Mar 2013	Tohoku University, Sendai, Japan	Japan Society for the Promotion of Science (JSPS)
Khomarudin, R.	Mar 2007 - Dec 2010	National Institute of Aeronautics and Space (LAPAN), Indonesia	United Nations University
Llongo, J. G.	2008 - 2010	Universidad Valencia, Spain	EU Marie Curie Trainings Network HyperINET
Marconcini, M.	2012	ESA	DLR
Muhari, A.	Sep - Nov 2008 & Feb - Mar 2009	Ministry of Marine Affairs and Fisheries, Indonesia	GITEWS
Nielsen, A.	May - Oct 2012	University of Denmark, Copenhagen	DAAD
Oleziuk, D.	Jun - Sep 2009	Warschau Universität, Poland	Warschau Universität
Peterson, E.	Mar - Sep 2010	University of Alberta, Edmonton, Canada	DLR
Rivard, B.	Jul - Aug 2012	University of Alberta, Edmonton, Canada	DAAD
Rogge, D.	2012	University of Alberta, Edmonton, Canada	DLR
Scheer, J.	Apr - Jun 2007, 2008, 2009, 2010, 2011, 2012	CONICET, Argentina	CONICET, Argentinien/DLR

Name	Period	Home Institution	Funding
Sumaryono	Mar 2007 - Dec 2010	National Agency for Surveys and Mapping (BAKOSURTANAL), Indonesia	United Nations University
Wirth, G.	Mar - Aug 2007	Hochschule München	EnerGeo-EC
Yang, B.	Jul - Sep 2010 & Jun - Sep 2013	Hunnan Nomral University	DAAD
Zakšek, K.	Feb - May 2007	Ljubljana Universität, Slowenien	Ljubljana Universität, Slowenien
Zhipeng Q.	Apr - May 2011	Ecole des Mines, France	Ecole des Mines + frz. Stipendienprogramm
Zhou, G.	Dec 2011	Bejing University of Aeronautics & Astronautics, China	IB-Projekt, DONGTING
Zhou, Z.	Dec 2011	Bejing University of Aeronautic & Astronautics, China	IB-Projekt, DONGTING

Professional Leaves

Periods of stay by DFD staff at external institutions between 2007 and June 2013 (≥ 4 weeks stay)

Staff Member	Institution	Period	Funding
Barkmann, H.	Joint Space Weather Summer Camp 2011 und 2012	Jul - Aug 2011 Jul - Aug 2012	DLR, University Rostock, IAP Kühlungsborn
Fourier, C.	University of Leicester	Oct - Dec 2012	EU Marie Curie
Huth, J.	VAST-GIRS in Ho-Chi-Minh City	Oct - Nov 2011	RICEMAN, WISDOM
Kopp, V.	APL, John Hopkins University, Baltimore, Maryland, USA	Feb - Apr 2010	DLR
Moser, L.	University of Leicester	Oct - Dec 2012	EU Marie Curie
Riedlinger, T.	European Commission GMES Office, Seconded National Expert	May 2011 - Jul 2013	DLR
Roth, A.	Environment Canada	Jul - Oct. 2013	DLR
Schöckel, T.	BMKG Jakarta, Indonesia	Oct 2010 - Mar 2014	BMBF-CIM
Schroedter-Homscheidt, M.	NCAR Boulder, Colorado, USA	Jan - Feb 2007	DLR
Sparwasser, N.	NASA, Goddard Space Flight Center, Greenbelt, Maryland, USA	Apr - Jun 2011	DLR
Strunz, G.	National University Singapore (NUS)	May - Aug 2012	DLR-Forschungssemester
Wernicke J.	APL, John Hopkins University, Baltimore, Maryland, USA	Feb - Apr 2010	DLR
Wildner, S.	University of Buenos Aires, Argentina	Aug - Sep 2007	DLR
Wüst, S.	NASA-GSFC and Howard University Beltsville, Maryland, USA	Jun - Jul 2006	DLR

Conferences

Major conferences, colloquia and workshops
(co-) organized by DFD and Department of Remote Sensing at University Würzburg between 2007 and June 2013

Date	Event	Location	Participants
10 - 12 Jun 2013	5th TerraSAR-X Science Team Meeting	Oberpfaffenhofen (DLR)	ca. 200
05 - 07 Jun 2013	6th SAM-FS/QFS Nutzerkonferenz	Klink	ca. 50
04 - 06 Jun 2013	3rd Fachtagung Energiemeteorologie	Grainau	ca. 40
20 - 21 Mar 2013	5th RESA – Workshop 'RESA – Data for Science – From the Basics to the Service'	Neustrelitz (DLR)	ca. 75
05 - 07 Mar 2013	Mekong Environmental Symposium 2013	Ho Chi Minh, Vietnam	ca. 400
14 - 15 Nov 2012	2nd Strategieforum Fernerkundung u. GMES Thementage	Düsseldorf	ca. 200
08 - 10 Oct 2012	CEOS SBA Biodiversity Workshop	Oberpfaffenhofen (DLR)	ca. 40
26 - 27 Sep 2012	2nd UFS Symposium	Oberpfaffenhofen (DLR)	ca. 60
13 - 15 Jun 2012	Storagetechnology 2012	Neustrelitz (DLR)	ca. 70
08 - 10 May 2012	5th NDMC Workshop	Oberpfaffenhofen (DLR)	ca. 40
21 - 22 Mar 2012	4th RESA – Workshop 'RESA – Daten für die Wissenschaft – Vom Algorithmus zum Produkt'	Neustrelitz (DLR)	ca. 70
13 - 15 Nov 2011	Wissenschaftliches Symposium zum 20.-jährigen Jubiläum von GARS O'Higgins	Punta Arenas, Chile	ca. 80
13 - 14 Oct 2011	1st Strategie-Forum 'Chancen und Möglichkeiten der Fernerkundung für die öffentliche Verwaltung'	Oberpfaffenhofen (DLR)	> 200
11 - 12 Oct 2011	1st EOC Symposium	Oberpfaffenhofen (DLR)	> 200
23 Aug 2011	GMES Workshop Mecklenburg-Vorpommern	Neustrelitz (DLR)	ca. 50
25 - 27 May 2011	5th 'Storage Archive Managers (SAM)'	Fleesensee	ca. 70
09 - 13 May 2011	4th NDMC Workshop	Oberpfaffenhofen (DLR)	ca. 40
23 - 24 Mar 2011	3rd RESA – Workshop 'RapidEye Science Archive (RESA) – Erste Ergebnisse'	Neustrelitz (DLR)	ca. 70
11 - 15 Oct 2010	Assessing and Communicating the Loss of Biodiversity and Ecosystem Services	Bayreuth, Global Change Ecology	ca. 60
22 - 24 Jun 2010	Kick-Off and First User Workshop for the 'PASODOBLE' Project	Oberpfaffenhofen (DLR)	ca. 70
09 - 11 Jun 2010	5. Storage Technology 2010	Heringsdorf	ca. 70
01 Jun 2010	Workshop 'European Contributions to GEO with respect to the SBA Disaster Management'	Brussels, Belgium	ca. 40
19 - 21 May 2010	2nd International Conference on Coal Fires	Berlin	ca. 110
14 May 2010	3rd NDMC Workshop	Herrsching	ca. 40
12 - 13 Apr 2010	Padang Consensus Workshop	Padang, Indonesia	ca. 50

Date	Event	Location	Participants
24 - 25 Mar 2010	2nd RESA – Workshop 'RapidEye Science Archive (RESA) – Erste Erfahrungen'	Neustrelitz (DLR)	ca. 64
04 Dec 2009	GENESI-DR Data Policy Workshop	Villafranca, Spain	ca. 40
26 - 28 Oct 2009	EOS-Herbstschule	Herrsching	ca. 50
21 - 23 Oct 2009	UN-SPIDER Workshop 'Disaster Management and Space Technology – From Concepts to Application'	Bonn	ca. 100
13 - 14 Oct 2009	EnMAP-Nutzerworkshop am GFZ	Potsdam	ca. 120
08 - 10 Jun 2009	4. SAM-FS/QFS Nutzerkonferenz 2009	Fleesensee	ca. 65
04 - 08 May 2009	2nd NDMC Workshop	Bad Reichenhall	ca. 40
18 Mar 2009	1st RESA – Workshop 'RapidEye Science Archive (RESA) – Daten für die Wissenschaft'	Neustrelitz (DLR)	ca. 89
26 Jan 2009	1st GENESI-DR workshop on EO data policy issues	Ispra, Italy	ca. 50
25 - 26 Nov 2008	TerraSAR-X Science Meeting	Oberpfaffenhofen (DLR)	ca. 175
07 Nov 2008	Fachkonferenz der Landeskriminalämter & BKA	Oberpfaffenhofen (DLR)	ca. 40
13 - 15 Oct 2008	UN-SPIDER Conference 'Disaster Management and Space Technology – Bridging the Gap'	Bonn	ca. 100
30 Jun – 04 Jul 2008	Workshop on Risk Modeling and Vulnerability Assessment	Bandung, Indonesia	ca. 60
04 - 06 Jun 2008	Storage Technology 2008	Fleesensee	ca. 60
22 - 23 Apr 2008	DLR EO Workshop	Mexico City, Chetumal, Mexico	ca. 120
29 - 31 Jan 2008	3rd German-Polish Workshop 'Dendromass Estimation using Remote Sensing and Modelling'	Neustrelitz (DLR)	ca. 56
29 - 30 Nov 2007	2nd German-Polish Workshop 'Dendromass Estimation using Remote Sensing and Modelling'	Neustrelitz (DLR)	ca. 40
15 - 19 Oct 2007	CEOS WGISS Workshop (Committee on Earth Observation Satellites)	Oberpfaffenhofen (DLR)	ca. 60
09 - 11 Oct 2007	PV 2007 International Conference 'Ensuring the long-term preservation and value adding of scientific and technical data'	Oberpfaffenhofen (DLR)	ca. 100
31 Jul - 03 Aug 2007	Workshop of the Joint German – Indonesian Working Group on Risk Modeling and Vulnerability Assessment	Bandung, Indonesia	ca. 50
14 - 18 May 2007	NDMC Kick Off-Meeting	Oberpfaffenhofen (DLR)	ca. 40
09 - 11 May 2007	3. SAM-FS Nutzerkonferenz	Göhren-Lebbin	ca. 70

Patents

Filed Patent Applications

Name	Patent	Patent No	Year	Countries
Günther, A.	Verlustfreie Kompression von Bilddaten	DE 10 2012 218854.1	2012	DE
Günther, A.	Verfahren und Vorrichtung zur Verbesserung einer Bildauflösung	DE 10 2012 215527.9	2012	DE
Vajen, H.-H.	Vorrichtung und Verfahren zum Verarbeiten von Fernerkundungsdaten	DE 10 2012 221667.7	2012	DE
Raape, U.	Verfahren und Vorrichtung zur Darstellung von Informationen mehrerer Sensorsysteme in einem Frühwarnsystem		2011	
Raape, U.	Verfahren und Vorrichtung zur Darstellung von Informationen mehrerer Sensorsysteme in einem Frühwarnsystem	DE 10 2010 052711.4 PCTPCT/EP2011/005947	2010	DE EP
Raape, U. Hunold, M. Tessmann, S. Friedemann, M.	Verfahren und Vorrichtung zur Visualisierung von räumlich verteilten Informationen in einem Frühwarnsystem	DE 10 2010 011186.4-52	2010	DE
Bittner, M. Wüst, S.	Verfahren zum Erfassen des Energiegehaltes von Zyklonen durch Analyse atmosphärischer Wellen	DE 10 2010 013607.7	2010	DE
Post, J. Zoßeder, K. Wegscheider, S. Mück, M. Raape, U. Steinmetz, T.	Verfahren und Vorrichtung zum Ermitteln von Warnungen in einem sensorgestützten Frühwarnsystem	W00201104291 DE 10 2009 019606.4	2010 2009	ID DE
Raape, U. Hunold, M. Teßmann, S. Friedemann, M.	Eingabemodus für Benutzereingaben von Warn- oder Steuerungseinrichtungen	DE 10 2009 23727.5-31	2009	DE
Post, J. Zoßeder, K. Wegscheider, S. Mück, M. Raape, U. Kiefl, R.	System und Verfahren zum Segmentieren einer Zielregion in räumliche Warneinheiten eines sensorgestützten Frühwarnsystems	DE 10 2009 056777.1.	2009	DE
Post, J. Zoßeder, K. Wegscheider, S. Mück, M. Raape, U. Tessmann, S. Strobl, Ch.	Vorrichtung und Verfahren zur risikobasierten Zuweisung von Warnstufen	DE 10 2009 057948.6.	2009	DE
Günther, A.	Resampling von digitalen Bildern	DE 10 2008 008707.6-53	2008	DE
Bittner, M. Höppner, K. Wüst, S.	Mustererkennungsverfahren zur Früherkennung von infraschallwirksamen Ereignissen	W00200902489 DE 10 2007 011964.1	2008 2007	ID DE

Name	Patent	Patent No	Year	Countries
Bittner, M. Höppner, K.	Verfahren zur Standardisierung der Ableitung der Temperatur in der Mesopausenregion aus Hydroxyl (OH*)-Airglow	WO200900460	2007	ID
Borg, E., Reulke, R. Börner, A.	Anlage und Verfahren zur Kalibrierung sowie Messung der Lagegenauigkeit der geometrischen Auflösung optischer Fernerkundungsdaten	D 10 2012 212 516.7	2011	DE
Vajen, H.-H.	Vorrichtung und Verfahren zur Verfeinerung der örtlichen Auflösung von Fernerkundungsdaten	DE 10 2010 004 232.2	2010	DE

Country Abbreviations: DE – Germany, ES – Spain, FR – France, GB – United Kingdom, IT – Italy, US – USA, AU – Australia, EP – European Patent Organization, SE – Sweden

Granted Patents

Name	Patent	Patent No.	Year	Countries
Bittner, M. Höppner, K. Wüst, S.	Mustererkennungsverfahren zur Früherkennung von infraschallwirksamen Ereignissen	2118685 2118685	2012	DE IT
Bittner, M. Höppner, K.	Method for standardizing the derivation of the temperature in the mesopause region from hydroxyl (OH*)-airglow	8,007,168	2011	US
Borg, E. Günther, K. P. Meier, S. W. Fichtelmann, B.	Verfahren und Vorrichtung zur mindestens teilweise automatisierten Auswertung von Fernerkundungsdaten	502004012808.4	2011	DE
Borg, E., Fichtelmann, B., Böttcher, J., Günther, A.	Processing of remote sensing data	EP 1 637 838 B1	2009	EU
Borg, E.; Fichtelmann, B.; Böttcher, J.	Process of Remote Sensing	US 7.246.040 B2	2007	US
Borg, E. Fichtelmann, B	Verfahren und Vorrichtung zur mindestens teilweise automatisierten Auswertung von Fernerkundungsdaten	502004012808.4	2011	DE
Borg E. Gerighausen, H.	Erzeugung von Endmember-Spektren Creation of endmember spectra	502008000636.2 1986127 1986127 EP1986127	2010	DE FR GB EU
Günter, K.-P. Fichtelmann, B. Maier, St. W. Borg, E.	Method and device for the at least semi-automated evaluation of remote sensing data	2004297326	2009	AU
Borg, E. Fichtelmann, B	Verarbeitung von Fernerkundungsdaten	502005008173.0	2009	DE

Name	Patent	Patent No.	Year	Countries
Jakowski, N. Borg, E. Stankov, S. Klähn, D.	Ermittlung eines Atmosphärenzustandes	7,502,689	2009	US
Richter, R.	Automatisches Verfahren zur atmosphärischen Korrektur von Sensoren im Spektralbereich 400 – 1000 nm	DE 10 2007 006644	2008	DE
Bittner, M. Höppner, K.	Verfahren zur Standardisierung der Ableitung der Temperatur in der Mesopausenregion aus Hydroxyl (OH*)-Airglow	DE 10 2006 045578	2008	DE
Borg, E. Fichtelmann, B Günther, A.	Process and device for the automatic rectification of single-channel or multi-channel images	US 7.356.201 B2	2008	US
Vajen, H.-H.	Verfahren und Vorrichtung zur Abgabe eines Notrufes	DE 10 2004 039635.3	2008	DE
Borg, E. Fichtelmann, B. Richter, R. Bachmann, M.	Verfeinerung der örtlichen Auflösung multispektraler Fernerkundungsdaten	502005002268 1626256	2007	DE FR
Borg, E. Fichtelmann, B	Verfeinerung der örtlichen Auflösung multispektraler Fernerkundungsdaten	502005002268.8 1626256	2007	DE FR
Borg, E. Fichtelmann, B	Verfahren und Vorrichtung zum Feststellen einer Nutzbarkeit von Fernerkundungsdaten	502005000512.0	2007	DE
Borg, E. Fichtelmann, B	Nutzbarkeit von Fernerkundungsdaten	1591961 1591961 1591961 2282968 1591961	2007	GB FR SE ES IT

Country Abbreviations: DE – Germany, ES – Spain, FR – France, GB – United Kingdom, IT – Italy, US – USA, AU – Australia, EP – European Patent Organization, SE – Sweden

Awards

Awards granted
to DFD and Department of Remote Sensing at University Würzburg (in *italic typeface*) staff

Year	Award	Laureate	Subject
2013	2. Platz 'Best Student Paper Award', 7th International Workshop on the Analysis of Multi-temporal Remote Sensing Images (25 – 27 June), Banff, Canada	*Asam, S.*	'Comparison of Leaf Area Indices for Alpine grasslands based on multi-scale satellite data time series and radiation transfer modeling'
2013	'Wiesnet Medal', 70th Eastern Snow Conference (4-6 June 2013), Huntsville, Canada	*Dietz, A.*	'Changes of Snow Cover Characteristics in Central Asia between 1986 and 2012 derived from AVHRR and MODIS time series'
2012	'Best Paper Award', 12. Internationale Konferenz für Computerwissenschaften ICCSA, 2012, Brasilien	Borg, E. Fichtelmann, B. Asche, H.	'Data Usability Assessment for Remote Sensing Data – Accuracy of Interactive Data Quality Interpretation'
2011	'Best Poster Award', ESA Advanced Land Remote Sensing Training Course	*Fritsch, S.*	'Crops and vegetation monitoring'
2011	'Student Competition Award', Joint Urban Remote Sensing Event Munich 2011	Geiß, C.	'Comparison of selected impervious surface products derived from remote sensing data'
2011	'1. Platz AGEO Diplomarbeitswettbewerb', AGIT 2011, Salzburg	Geiß, C.	'Potenzialmodellierung von Nahwärmenetzen auf Basis von Fernerkundungsdaten'
2011	'Hansa-Luftbildpreis' für wissenschaftlichen Beitrag in der Fachzeitschrift Photogrammetrie, Fernerkundung, Geoinformation (PFG), Jahrestagung der Deutschen Gesellschaft für Photogrammetrie Fernerkundung, Geoinformation (DGPF)	Kersten, J.	'General framework for fast and interactive classification of optical VHR satellite imagery using hierarchical and planar Markov Random Fields?'
2011	'Best Interactive Presentation', International Symposium of Remote Sensing of the Environment, Sydney, Australia	Künzer, C.	'Environmental- and climate change related trends in river deltas – examples from the Mekong'
2010	'Best Student Paper Award', International Congress on Environmental Modelling and Software	*Cord, A.*	'Remote sensing data for modeling invasive species distributions: A case study for Tamarix spp. in the U.S. and Mexico'
2010	'MedStorms Prize for Young Researchers', Europäische Geophysikalische Gesellschaft (EGU)	Wüst, S.	'Monitoring the changing energy content of a orm system through the observation of gravity waves in the strato- and mesosphere'
2009	2. Platz, Wettbewerb der Visionen (DLR)	Bittner, M., Wüst,S., Höppner, K., Pilger, C., Schmidt, C.	Projekt EDDY
2009	Qualitätspreis des Deutschen Zentrums für Luft- und Raumfahrt e.V.	Engelbrecht, S.	Erreichung hoher und systematisch gesicherter Qualität in Projekten und Vorhaben sowie persönlicher Einsatz auf dem Gebiet Qualitätsmanagement

Year	Award	Laureate	Subject
2008	Verleihung der Lohrmann-Medaille der Universität Dresden	Eisfelder, C.	Hervorragende Studienleistungen
2008	'Professor Mariolopoulos Trust Fund Award', Weltmeteorologische Organisation (WMO)	Wüst, S. Bittner, M.	'Non-linear resonant wave-wave interaction (triad). Case studies based on rocket data and first application to satellite data'
2008	Einladung zur Teilnahme, 58th Meeting of Nobel Laureates	Wüst, S.	Für hervorragende Jungwissenschaftler
2007	'Best Paper Award', International Symposium on Remote Sensing of Environment (ISRSE, 2007, Costa Rica)	Dech, S. Roth, A.. Taubenböck, H.	'Vulnerability assessment using remote sensing: The earthquake prone megacity Istanbul, Turkey'
2007	Preis des Science & Engineering Visualization Challenge 2006, National Science Foundation und Zeitschrift Science	Sparwasser, N.	'Hawaii, the Highest Mountain on Earth'
2007	Oskar-Niemczyk-Preis, 2007	Walter, D.	Für die Diplomarbeit

Publications

This chapter lists in reverse chronological order for the time period between January 1, 2007 and June 30, 2013:

- publications in ISI and SCOPUS journals
- other publications with full paper review
- books
- book contributions
- other publications

Internal reports as well as doctoral, diploma, Master and Bachelor theses are not listed.

DFD authors appear in **bold** typeface, employees of the University of Würzburg are ***in bold and italic*** typeface.

Publications in ISI or Scopus Journals

2013 under review

[1] **Bergemann, C.**, Frank, B.: *Particle filter based data assimilation into an air quality model*, Nonlinear Processes in Geophysics, submitted, 2013.

[2] Biberacher, M., **Tum, M.**, **Günther, K.-P.**, Jilani, R., Mansha, M.: *Availability assessment of bioenergy and power plant location optimization: A case study for Pakistan*, Renewable and Sustainable Energy Reviews, submitted, 2013.

[3] **Geiß, C.**, Aravena Pelizari, P., **Marconcini, M.**, Sengara, W., Edwards, M., Lakes, T., **Taubenböck, H.**: *Estimation of Seismic Building Structural Types Using Multi-sensor Remote Sensing and Machine Learning Techniques*, ISPRS Journal of Photogrammetry and Remote Sensing, submitted, 2013.

[4] **Klein, D.**, **Asam, S.**, **Gessner, U.**, ***Lex, S.***, **Dech, S.**: *Monitoring and assessment of mountainous ecosystems in Kyrgyzstan using remote sensing based vegetation parameters*, Global and Planetary Change, submitted, 2013.

[5] **Kramer, R., Wüst, S., Bittner, M.**: *Climatology of convectively generated gravity waves at Prague based on operational radiosonde data from 13 years (1997-2009)*, Journal of Atmospheric and Solar-Terrestrial Physics, submitted, 2013

[6] **Kramer, R., Wüst, S., Schmidt, C., Bittner, M.**: *Gravity wave characteristics in the middle atmosphere during the CESAR campaign at Palma de Mallorca in 2011/2012: impact of extratropical cyclones and fronts*, Journal of Atmospheric and Solar-Terrestrial Physics, submitted, 2013

[7] ***Leinenkugel, P.***, Wolters, M., **Künzer, C.**, Oppelt, N.: *Sensitivity analysis for predicting continuous fields of tree cover and fractional land cover distributions in cloud prone areas*, International Journal of Remote Sensing, submitted, 2013.

[8] **Martinis, S.**, **Kersten, J.**, **Twele, A.**: *A fully automated TerraSAR-X based flood service*, ISPRS Journal of Photogrammetry and Remote Sensing, submitted, 2013.

[9] Petzold, A., Ogren, J. A., Fiebig, M., Laj, P., Li, S., Baltensperger, U., **Holzer-Popp, T.**, Kinne, S., Pappalardo, G., Sugimoto, N., Wehrli, C., Wiedensohler, A., Zhang, X.: *Recommendations for the interpretation reporting of "black carbon" measurements*, Atmospheric Chemistry and Physics, submitted, 2013.

[10] **Pilger, C., Wüst, S., Schmidt, C., Streicher, F. Bittner, M.**: *Airglow observations of orographic, volcanic and meteorological infrasound signatures*, Journal of Atmospheric and Solar-Terrestrial Physics, submitted, 2013

[11] **Römer, H.**, **Kersten, J.**, **Kiefl, R.**, **Plattner, S.**, **Mager, A.**, **Voigt, S.**: *Airborne near real-time monitoring of open spaces in case of large scale public events and natural disasters*, International Journal of Geographical Information Science, submitted, 2013.

[12] **Schmitt, A.**, Hinz, S.: *Consistent description of multi-temporal, multi-polarized, and multi-sensor SAR data for change detection and characterization by normalized Kennaugh elements*, IEEE Transactions on Geoscience and Remote Sensing, submitted, 2013.

[13] **Tum, M.**, **Borg, E.**: *A 1D Soil Water Infiltration Model for Regional and Global Applications*, Journal of Hydrologic Engineering, submitted, 2013.

[14] **Wüst, S., Bittner, M***: Gravity wave activity In the mesosphere region in advance of a minor stratospheric warming, GW und Stratwarming,* Journal of Atmospheric and Solar-Terrestrial Physics, submitted, 2013

[15] **Wüst, S., Pilger, C., Streicher, F., Wendt, V., Bittner, M.**: *Aspects of determination of an uncertainty radius for back tracing infrasound signal sources caused by atmospheric wave activity - A case study*, Journal of Atmospheric and Solar-Terrestrial Physics, submitted, 2013

[16] Zhang, B., Zhang, L., Guo, H., ***Leinenkugel, P.***, Shen, Q.: *Climate and Drought Impacts on Vegetation Productivity in the Lower Mekong Basin*, International Journal of Remote Sensing, submitted, 2013.

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[19] Beltman, J. B., Hendriks, C., **Tum, M.**, Schaap, M.: *The impact of large scale biomass production on ozone air pollution in Europe*, Atmospheric Environment, 71, pp. 352-363, 2013.

[20] ***Conrad, C.***, **Dech, S.**, Hafeez, M., Lamers, J., Tischbein, B.: *Remote sensing and hydrological measurement based irrigation performance assessments in the upper Amu Darya Delta, Central Asia*, Physics and Chemistry of the Earth, pp. 52-62, 2013.

[21] de Leeuw, G., **Holzer-Popp, T.**, Bevan, S., Davies, J., Decloitres, J., Grainger, R. G., Griesfeller, J., Heckel, A., **Klüser, L.**, Kolmonen, P., Litvinov, P., Martynenko, M., North, P., Ovigneur, B., Pacal, N., Poulson, C., Ramon, D., Schulz, M., Siddans, R., Sogacheva, L., Tanre, D., Thomas, G., Virtanen, D., von Hoyningen-Huene, W., Vountas, M., Pinnock, S.: *Evaluation of seven European aerosol optical depth retrieval algorithms for climate analysis*, Remote Sensing of Environment, in press, 2013.

[22] **Dech, S.**: *A personal perspective on future paths for remote sensing to proceed in earthquake science*, Natural Hazards, pp. 1-2, 2013.

[23] **Dietz, A. J.**, **Künzer, C.**, ***Conrad, C.***: *Snow-cover variability in central Asia between 2000 and 2011 derived from improved MODIS daily snow-cover products*, International Journal of Remote Sensing, 34 (11), pp. 3879-3902, 2013.

[24] **Eisfelder, C.**, ***Klein, I.***, **Niklaus, M.**, **Künzer, C.**: *Net primary productivity in Kazakhstan, its spatio-temporal patterns and relation to meteorological variables*, Journal of Arid Environments, accepted, 2013.

[25] **Esch, T.**, **Marconcini, M.**, **Felbier, A.**, **Roth, A.**, **Heldens, W.**, **Huber, M.**, **Schwinger, M.**, **Taubenböck, H.**, **Müller, A.**, **Dech, S.**: *Urban Footprint Processor – Fully Automated Processing Chain Generating Settlement Masks from Global Data of the TanDEM-X Mission*, IEEE Geoscience and Remote Sensing Letters, accepted, 2013.

[26] **Esch, T.**, **Metz, A.**, **Keil, M.**, **Marconcini, M.**: *Combined Use of Multi-seasonal High and Medium Resolution Satellite Imagery for Parcel-related Updating of Crop- and Grassland Distribution.*, International Journal of Applied Earth Observation and Geoinformation, accepted, 2013.

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[28] Fernández-Prieto, D., Kesselmeier, J., Ellis, M., **Marconcini, M.**, Reissell, A., Suni, T.: *Earth observation for land–atmosphere interaction science*, Biogeosciences, 10, pp. 261-266, 2013.

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[34] **Holzer-Popp, T.**, de Leeuw, G., Griesfeller, J., **Martynenko, D.**, **Klüser, L.**, Bevan, S., Davies, W., Ducos, F., Deuze, J., Graigner, R. G., Heckel, A., von Hoyningen-Huene, W., Kolmonen, P., Litvinov, P., North, P., Poulson, C., Ramon, D., Siddans, R., Sogacheva, L., Tanre, D., Thomas, G. E., Vountas, M., Decloitres, J., Kinne, S., Schulz, M., Pinnock, S.: *Aerosol retrieval experiments in the ESA Aerosol_cci project*, Atmospheric Measurement Techniques, accepted, 2013.

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[37] Kraas, B., **Schroedter-Homscheidt, M.**, Madlener, R.: *Economic merits of a state-of-the-art concentrating solar power forecasting system for participation in the Spanish electricity market*, Solar Energy, 93, pp. 244-255, 2013.

[38] **Künzer, C.**, Guo, H., **Huth, J.**, ***Leinenkugel, P.***, Li, X., **Dech, S.**: *Flood Mapping and Flood Dynamics of the Mekong Delta: ENVISAT-ASAR-WSM Based Time Series Analyses*, Remote Sensing, 5, pp. 687-715, 2013.

[39] **Künzer, C.**, Guo, H., Schlegel, I., **Vo Quoc, T**., Li, X., **Dech, S.**: *Scale and the Capability of Envisat ASAR-WSM and TerraSAR-X Scansar and Stripmap Data to assess urban Flood Situations: A Case Study in Can Tho Province of the Mekong Delta*, Remote Sensing, accepted, 2013.

[40] **Künzer, C.**, ***Knauer, K.***: *Remote Sensing of Rice Crop Areas – A Review*, International Journal of Remote Sensing, 34 (6), pp. 2101-2139, 2013.

[41] **Künzer, C.**, **Vo Quoc, T.**: *Assessing the Ecosystem Services Value of Can Gio Mangrove Biosphere Reserve: Combining Earth-Observation- and Household-Survey-based Analyses*, Applied Geography, accepted, 2013.

[42] ***Leinenkugel, P.***, **Künzer, C.**, **Dech, S.**: *Comparison and enhancement of MODIS cloud mask products for Southeast Asia*, International Journal of Remote Sensing, 34 (8), pp. 2730-2748, 2013.

[43] ***Leinenkugel, P.***, **Künzer, C.**, Natascha, O., **Dech, S.**: *Characterisation of land surface phenology and land cover based on moderate resolution satellite data in cloud prone areas — A novel product for the Mekong Basin*, Remote Sensing of Environment, 136, pp. 180-198, 2013.

[44] **Marconcini, M.**, Fernández-Prieto, D., Buchholz, T.: *Targeted Land Cover Classification*, IEEE Transactions on Geoscience and Remote Sensing, accepted, 2013.

[45] **Mück, M.**, **Taubenböck, H.**, **Post, J.**, **Wegscheider, S.**, **Strunz, G.**, Sumaryono, S., Ismail, F.: *Assessing building vulnerability to earthquake and tsunami hazard using remotely sensed data*, Natural Hazards, pp. 1-18, 2013.

[46] ***Naeimi, V.***, ***Leinenkugel, P.***, Sabel, D., Wagner, W., Apel, H., **Künzer, C.**: *Evaluation of Soil Moisture Retrieval from the ERS and Metop Scatterometers in the Lower Mekong Basin*, Remote Sensing, 5 (4), pp. 1603-1623, 2013.

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[48] ***Ottinger, M.***, **Künzer, C.**, Liu, G., Wang, S., **Dech, S.**: *Monitoring land cover dynamics in the Yellow River Delta from 1995 to 2010 based on Landsat TM*, Applied Geography, accepted, 2013.

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[50] **Vo Quoc, T.**, Oppelt, N., ***Leinenkugel, P.***, **Künzer, C.**: *Remote Sensing in Mapping Mangrove Ecosystems: An Object-Based Approach*, Remote Sensing, 5 (1), pp. 183-201, 2013.

[51] **Schmidt, C.**, **Höppner, K.**, **Bittner, M.**: *A ground-based spectrometer equipped with an InGaAs array for routine observations of OH(3-1) rotational temperatures in the mesopause region*, Journal of Atmospheric and Solar-Terrestrial Physics, pp. 125-139, 2013.

[52] ***Schmidt, M.***, **Klein, D.**, ***Conrad, C.***, **Dech, S.**, Paeth, H.: *On the relationship between vegetation and climate in tropical and northern Africa*, Theoretical and Applied Climatology, pp. 1-13, 2013.

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[56] **Schroedter-Homscheidt, M.**, **Oumbe, A.**: *Validation of an hourly resolved global aerosol model in answer to solar electricity generation information needs*, Atmospheric Chemistry and Physics, pp. 3777-3791, 2013.

[57] Storch, T., **Habermeyer, M.**, Eberle, S., **Mühle, H.**, Müller, R.: *Towards a Critical Design of an Operational Ground Segment for an Earth Observation Mission*, Journal of Applied Remote Sensing, 7 (1), pp. 1-12, 2013.

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[59] **Taubenböck, H.**, Goseberg, N., Lämmel, G., Setiadi, N., Schlurmann, T., Nagel, K., Siegert, F., Birkmann, J., Traub, K.-P., **Dech, S.**, Keuck, V., Lehmann, F., **Strunz, G.**, Klüpfel, H.: *Risk Reduction at the "Last-Mile": an attempt to turn science into action by the example of Padang, Indonesia*, Natural Hazards, pp. 915-945, 2013.

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Acronyms and Abbreviations

AATSR	Advanced Along-Track Scanning Radiometer on board ENVISAT
ACE	Advanced Composition Explorer (NOAA)
ADM-Aeolus	Atmospheric Dynamics Mission
AGB	Above Ground Biomass
AGIT	Symposium und Fachmesse für Angewandte Geoinformatik (Symposium and Trade Fair for Geoinformatics)
AIS	Automatic Identification System for Ships
AKNZ	Akademie für Krisenmanagement, Notfallplanung und Zivilschutz (Academy for Crisis Management, Emergency Planning and Civil Protection)
ALOS	Advanced Land Observing Satellite (JAXA)
AMC	Assessment Mission Course
APL	John Hopkins Applied Physics Laboratory
ARGOS	Satellite positioning system (CNES)
ASAR	Advanced Synthetic Aperture Radar on ENVISAT (ESA)
ATCOR	DLR's own atmospheric correction software
AVHRR	Advanced Very High Resolution Radiometer (NOAA)
BETHY/DLR	Biosphere Energy Transfer Hydrology Model
BIOTA	Biodiversity Transsect Analysis in Africa
BIROS	Berlin InfraRed Optical System (DLR)
BKA	Federal Criminal Police Office
BKG	Federal Agency for Cartography and Geodesy
BMBF	German Ministry of Education and Research
BMI	Federal Ministry of the Interior
BMKG	Indonesian Meteorological, Climatological and Geophysical Agency
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CarbonSat	Carbon Monitoring Satellite (ESA)
CATENA	Automatic Processing System, developed at IMF
CCG	Carl-Cranz-Association
CCRS	Canada Center for Remote Sensing
CEOS	Committee on Earth Observation Satellites
CHAMP	CHAllenging Minisatellite Payload (German satellite)
CHB	Calibration Homebase
CNES	Centre National d'Etudes Spatiales
CNRS	Centre National de la Recherche Scientifique
Conabio	Mexican National Commission for Knowledge and Use of Biodiversity
CONICET	Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina
Copernicus	(since 2013:) European Earth Observation Programme (EU, ESA), former GMES
CPU	Central Processing Unit
CSA	Canada Space Agency
DAAD	German Academic Exchange Service
DELPHI	Deutschlandweite Echtzeit Verkehrs-Lage und Prognose im Ereignisfall (Decision Support Application for Real Time Traffic Situation Analysis and Prognosis, Information Exchange and Cooperation)
DEM	Digital Elevation Model
DEMMIN	Durable Environmental Multidisciplinary Monitoring Information Network
DFD	German Remote Sensing Data Center
DFG	German Research Foundation
DIMS	Data and Information Management System (developed at DFD)
DLR	German Aerospace Center
DOI	Digital Object Identifier
D-PAC, PAF	German Processing and Archiving Center/ Processing and Archiving Facility
D-SDA	German Satellite Data Archive
DSS	Decision Support System
DWD	German Weather Service
EADS	European Aeronautic Defense and Space
EARSEL	European Association of Remote Sensing Laboratories
ECMWF	European Centre for Medium-Range Weather Forecasts
ECOSUR	El Colegio de la Frontera Sur
EDRS	European Data Relay Satellite System
EEAS	European External Action Service
EFFIS	European Forest Fire Information System
EGU	European Geosciences Union
ELVIS	Environmental Information and Visualization System

EMSA	European Maritime Safety Agency
EnMAP	Environmental Mapping and Analysis Program
ENVISAT	Environmental Satellite (ESA)
EO	Earth Observation
EOC	Earth Observation Center
EOC-CON	Controlling Department of the EOC
EOS	Integrated Earth Observation System
ERS	European Remote Sensing Satellite (ESA)
ESA	European Space Agency
ESA-PROMOTE	Protocol Monitoring for the GMES Service Element Atmosphere
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUSC	European Union Satellite Centre
EUSI	European Space Imaging
FH/HS	University of Applied Sciences
FireBIRD	DLR infrared Satellite mission
GDAS	Geospatial Data Access System
GENESIS	DLR's Generic System for Interferometric SAR Processing
GEO	Group on Earth Observation
GeoFarm	DFD's Generic Exploitation Platform
GEOSS	Global Earth Observation System of Systems
GFZ	Geo Research Center Potsdam
GIS	Geoinformation Systems
GITEWS	German-Indonesian Tsunami Early Warning System
GMES	Global Monitoring for Environment and Security (EU, ESA)
GMOSAIC	GMES services for Management of Operations, Situation Awareness and Intelligence for regional Crises
GOME	Global Ozone Monitoring Experiment (auf ERS-2, GOME-2 auf MetOp)
GOMOS	Global Ozone Monitoring by Occultation of Stars
GPS	Global Positioning System
GRACE	dual satellite system: Gravity Recovery And Climate Experiment (JPL; Germany)
GRIPS	Ground-based Infrared P-branch Spectrometer (developed at DFD)
GSCB	Ground Segment Coordination Body
GSFC	NASA Goddard Space Flight Center
GSOC	German Space Operation Center
HGF	Helmholtz Association
HMA	Heterogeneous Mission Accessibility Project
HySpex	Airborne hyperspectral camera
IAF	Indian Air Force
IBS	International Ground Segment (DFD Department)
ICCSA	International Conference on Computational Science and Its Applications
ICSU	International Council of Scientific Unions
IDP	Internally Displaced People
IEEE	Institute of Electrical and Electronics Engineers
IKN	DLR Institute for Communication and Navigation
IKONOS	US commercial EO satellite (Digitalglobe)
IMAGI	German Interministerial Committee on Geoinformation
IMF	DLR-Remote Sensing Technology Institute
IMPC	Ionosphere Monitoring and Prediction Center
INACH	Chilean Antarctic Institute
InES	Infrared Explorer Satellite
INF	Information Technology (DFD Department)
InSAR	Interferometric SAR
INSPIRE	Infrastructure for Spatial Information in Europe
IOC	International Oceanographic Commission
IR	Infrared
IRSA	IRSA - Institute of Remote Sensing Applications, CAS
ISPRS	International Society for Photogrammetry and Remote Sensing
ISRO	Indian Space Research Organization
ISRSE	International Symposium on Remote Sensing of Environment
ITP	Integrated TAnDEM-X Processor
IUP-IFE	Institut für Fernerkundung und Umweltphysik der Universität Bremen (Institute of Remote Sensing and Environmental Physics of the University of Bremen)
JMU	Julius-Maximilian-University Würzburg
JPL	Jet Propulsion Laboratory (USA)
JRC	Joint Research Center

JSPS	Japan Society for the Promotion of Science
Landsat	US land Earth Observation System (USGS)
LAX	Landsurface (DFD Department)
LIMES	Projekt EU?
LIPI	Indonesian Institute of Sciences
LMU	Ludwig-Maximilian-University, Munich
LRZ	Leibniz High Performance Computing Center
LSFE	Department of Remote Sensing at Julius-Maximilian-University Würzburg
LTDP	Long-term Data Preservation
Medicane	Mediterranean Hurricane
MERIS	MEdium Resolution Imaging Spectrometer
MERLIN	Methane Remote Sensing Lidar Mission (Deutsch-französische Mission)
MetOp	Meteorological Operational Satellites (EUMETSAT)
MICMoR	Helmholtz Research School on Mechanisms and Interactions of Climate Change in Mountain Regions
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding (auf ENVISAT)
MIPAS-B	MIPAS version tailored to the operation on a stratospheric balloon gondola
MMFI	Multi-Mission Facility Infrastructure
MODIS	Moderate-resolution Imaging Spectroradiometer
MSVAI	Modified Soil-Adjusted Vegetation Index
NAF	National Archive for Remote Sensing Data
NASA	National Aeronautics and Space Administration (USA)
NBS	National Ground Segment (Department of DFD)
NCAR	National Center For Atmospheric Research
NDMC	Network for the Detection of Mesospheric Change
NDSWIR	Normalized Difference Shortwave Infrared Index
NOAA	National Oceanic and Atmospheric Administration
NPP	Net Primary Productivity
NUS	National University Singapore
O3M-SAF	Ozone Monitoring Satellite Application Facility (EUMETSAT-Projekt)
OGC	Open Geospatial Consortium
OLCI	Ocean Land Color Instrument
OpAiRS	Optical Airborne Remote Sensing Facility and Calibration Home Base (EOC User Service)
PALSAR	L-band radar on ALOS (JAXA)
PASODOBLE	Project of the European Copernicus Programme
PDGS	Payload Data Ground Segment
Pol-InSAR	Polarimetric SAR Interferometry
POLYPHEMUS	Air quality modeling system
PPP	Public Private Partnership
PRISM	Picosatellite for Remote-sensing and Innovative Space Missions
QM	Quality Management
Radarsat	Canadian SAR satellite
RapidEye	German optical satellite system
RCM	Radarsat Constellation Mission
RESA	RapidEye Science Archive
ROSIS	Reflective Optics System Imaging Spectrometer
RTSP	Regional Tsunami Training Provider
S5p/SP5	Sentinel-5 Precursor (ESA)
SAF	Ozone Satellite Application Facility
SAFER	EU-Project „Services and Applications for Emergency Response“
SAM (G) FS	Storage Archive Managers (Quick) File System
SAN	Storage Area Network
SANSA	South African National Space Agency
SAR	Synthetic Aperture Radar
SAR-Lab	Search and Rescue Laboratory
ScanSAR	Imaging mode for TerraSAR-X (18m resolution)
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (onboard ENVISAT)
SFERA SOLLAB	Solar Facilities for the European Research Area
SMCS	Station Monitoring, Control and Scheduling System
SPOT	Satellite Pour l'Oberservation de la Terre (EO Satellite France, CNES, ASTRIUM)
SRTM	Shuttle Radar Topography Mission (NASA, DLR)
SSC	Swedish Space Corporation
StripMap	Imaging mode for TerraSAR-X (3 m resolution)

SWACI	Space Weather Application Center Ionosphere
SWIR	Short-wave infrared
Tandem-L	DLR Proposal for an innovative new satellite mission for mapping dynamic processes and biomass
TanDEM-X	German TerraSAR-X add-on for Digital Elevation Measurement
TANGOO	Tilting-filter Spectrometer for Atmospheric nocturnal ground-based Oxygen and Hydroxyl Emission Measurements
TEC	Total Electron Content
TERENO	Terrestrial Environmental Observatories
TerraSAR-X	German high resolution X-Band radar satellite (DLR)
TET-1	Satellite of the FireBird mission (DLR)
THE	Hot Temperature Event
THW	German Federal Agency for Technical Relief
TIB	German National Library of Science and Technology, University Library Hannover
Timeline	DFD project to analyse long time series of AVHRR data
TMSP	TerraSAR-X Multimode SAR Processor
TROPOMI	Spectrometer on board of Sentinel-5 precursor
TU	Technical University
TUM	Technical University Munich
TWOPAC	Twinned Object- and Pixel-based automated Classification Chain
UFS	Environmental Research Station Schneefernerhaus
UKIS	Environmental and Crisis Information System
UKSA	United Kingdom Space Agency
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
UPAS	Universal Processor for Atmospheric UV/VIS/NIR Sensors
UPS	Uninterruptable Power Supply
USGS	United States Geological Survey
UV	Ultra-violet
VABENE	Traffic Management for Major Events and Disasters
VEGETATION	Sensor for measurements of the main characteristics of the Earth's plant cover
VHR	Very high Resolution
VLBI	Very long Baseline Interferometry
VNIR	Visible and near-infrared
WAN	Wide Area Network
WASCAL	West African Science Service Center on Climate Change and Adapted Land Use
WCRP	World Climate Research Programme
WDC-RSAT	World Data Center for Remote Sensing of the Atmosphere
WIS	WMO Information System
WISDOM	Water-related Information System for the sustainable development of the Mekong Delta
WISENT	Wissensnetz Energiemeteorologie (Knowledge Network Energy Meteorology)
WMO	World Meteorological Organization
WMO-IGACO	Integrated Global Atmospheric Chemistry Observation
WorldView-2	US commercial Earth observation satellite (Digitalglobe)
WPS	Web Processing Service
ZEF	Center for Development Research
ZKI	Center for satellite-based Crisis Information at DFD
ZKI-DE	ZKI Service for German users

DLR at a glance

DLR is the national aeronautics and space research center of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency DLR has been given responsibility by the federal government for the planning and implementation of the German space program. DLR is also the umbrella organization for the nation's largest project execution organisation.

DLR has approximately 7400 employees at 16 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Goettingen, Hamburg, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington, D.C.

The German Remote Sensing Data Center

The German Remote Sensing Data Center (DFD) is an institute of the German Aerospace Center (DLR) with facilities in Oberpfaffenhofen near Munich and in Neustrelitz in the state of Mecklenburg, Western Pomerania. DFD and DLR's Remote Sensing Technology Institute (IMF) together comprise the Earth Observation Center EOC, which has become a center of competence for Earth observation in Germany.

DFD supports science and industry as well as the general public. With its national and international receiving stations DFD offers direct access to data from Earth observation missions, derives information products from the raw data, disseminates these products to users, and safeguards all data in the National Remote Sensing Data Library for long-term use. Its geoscience research related to the atmosphere, global change and civil security facilitates access to products and approaches based on remote sensing and consolidates their utilization in scientific and commercial domains. DFD operates thematic user services, in particular the World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT), and the Center for Satellite Based Crisis Information (ZKI).

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