

The Geospatial Service Infrastructure for DLR's National Remote Sensing Data Library

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Abstract — This paper describes the motivation, requirements and challenges of integrating a geospatial infrastructure, based on standardized web services, into an earth observation (EO) data library. The design of harmonized data and information models of the EO and geospatial community is a precondition for interoperability at metadata, data and semantic levels. A major challenge arises from raising the awareness that interoperability is essential for an interdisciplinary use of EO data in Geographic Information System (GIS) and value-adding services.

Index Terms— SDI, data access, data management, earth observation ground segment, interoperability.

I. INTRODUCTION

Harmonizing and facilitating the access to remote sensing data archives is a crucial step towards interdisciplinary use of earth observation (EO) data, derived-products and model data. The importance of geospatial interoperability in general has been discussed for many years and goes beyond technical/syntactical interoperability between systems [1], [2], [3]. Over the last decades, the geographic information science and community has developed sophisticated methods and systems to manage, process and visualise geospatial data and information [4]. During the last decade the advances of Web Service technology and the concept of Spatial Data Infrastructures (SDI, [5]) have laid the foundation for interoperable access between distributed data archives and user communities. Nevertheless, interoperability between EO and geospatial systems is not self-evident. Therefore it is addressed in current infrastructure programmes such as the European Global Monitoring of Environment and Security (GMES, described in chapter II) and the Global Earth Observation System of Systems (GEOSS).

The payload ground segment of the German Aerospace Center (DLR) supports national and international earth observation missions that contribute to GMES, such as TerraSAR-X, TanDEM-X, EnMAP, Ikonos-2 and IRS [6]. The data are archived in the National Remote Sensing Data

Library (NRSDL) which is operated by the German Remote Sensing Data Center (DFD) of DLR. The NRSDL is a central part of DLR's payload ground segment infrastructure. It provides earth observation data management functions such as processing, archiving, catalogue access, ordering and delivery of data products [7]. Although DLR is a governmental non-profit organisation and promotes free access to EO datasets, issues concerning property rights, security restrictions and data policy issues such as fees and quotas for commercial datasets need to be addressed within the NRSDL. In addition, harmonized and standardised access to georeferenced earth observation data and services is an important goal for the current and future development of the NRSDL especially when contributing data to corporate, national and international SDIs. The standardized data access will be addressed in the Geospatial Service Infrastructure (GSI).

Since the early 1990s the Open Geospatial Consortium (OGC) started to develop, in consensus with international industry, government and academic members, publicly available interface specifications and standards (also called OpenGIS[®] specifications and standards) which support interoperable solutions for exchanging geospatial information [8]. The OGC Web Services (OWS) Implementation Specifications define how to access geospatial information. The semantics of the exchanged data is derived from an abstract feature model, were “a feature is an abstraction of a real world phenomenon” [9], that is represented by different encodings, e.g. the Geographic Markup Language (GML, [10]). The encoding is usually tailored through profiles such as the GML simple features profile [11]. Additionally, the OGC Sensor Web Enablement (SWE) initiative has extended the OWS framework with services and encodings in order to integrate sensors and sensor-systems [12].

This paper points out the benefits and challenges of integrating geospatial services into the NRSDL. To establish interoperable geospatial services to access free EO datasets is the primary focus of development. Therefore the paper examines the technological perspectives rather than the legal (privacy and property rights, liability, security constraints), economic (pricing, accounting) or organizational (operations, maintenance, management, quality of service) perspective. However, legal requirements and constraints which need to be taken into account when designing the infrastructure are briefly outlined. Furthermore the overall architecture is described and its limitations are pointed out.

The remainder of the paper is summarized as follows: first

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we describe the related context followed by an overview of the NRSDL, then the geospatial service infrastructure is presented and finally the conclusions are given, including a short evaluation of the current achievements.

II. RELATED CONTEXT

Efforts to harmonize data access between multiple user communities and data provider vary from policies on data exchange over standardized access interfaces to data formats and models. This chapter points out efforts related to the NRSDL and GSI development on those distinct but interwoven subjects.

A. Policies

Several initiatives and programmes are promoting the harmonization of access interfaces to different data providers. The GMES programme intends to create innovative, operational structures for delivering customized geo-information and knowledge to governmental and industry decision makers [13]. GMES interoperability on a global level shall be achieved by the consolidation of the data exchange interfaces with the GEOSS, an initiative of the Group on Earth Observation (GEO, [14]). Fig. 1 shows a simplified GMES overall architecture composed of three main components: space, in-situ and services.

The GMES In-situ Component supports the GMES Services with comprehensive, long-term observations and auxiliary data for the forecasting or analysis models. The GMES Space Component (GSC) supports the GMES Services with earth observation products by providing discovery and subscription functionalities through the GSC Data Access System (GSCDA-S). The GSCDA-S retrieves data from different GMES Contributing Mission (GCM) and future satellite missions known as GMES Sentinels through interfaces defined in the frame of the Heterogeneous Missions Accessibility (HMA) project [15]. These interfaces are based on ISO and OGC specifications and are tailored to comply with EO specific requirements and needs, e.g. the Programming and Ordering Service Specification or the GML Application Schema for EO Products [16]. DLR currently serves two GCM projects by hosting TerraSAR-X [17] and Indian Remote Sensing (IRS, [18]) data in the NRSDL and providing HMA interfaces towards the GSCDA system.

On the legal side, INSPIRE (Infrastructure for Spatial Information in Europe, [19]) provides a framework for the EU member states to harmonize spatial data and services in Europe. The German SDI (GDI-DE) implements INSPIRE policies at national level [20].

B. Interfaces

Concerning the use of such standardized interfaces, several efforts have shown that their use can facilitate the exploitation of data archives, both for users that are not familiar with complex EO data ordering systems [21] as well as for scientific users that need to execute complex multidimensional analysis based on heterogeneous data sources (e.g. Giovanni,

[22] and DataFed [23]). Both Giovanni and the DataFed are examples of sophisticated workflow-based systems that utilize among others OGC interfaces as data sources to generate information products such as analytical plots, vertical profiles and animated maps. Extending the NRSDL with OGC compliant data access services lay the foundation to integrate NRSDL data in Giovanni and similar systems.

C. Data

However, standardised data access services alone are not sufficient to establish interoperability. Syntactical and semantic encoding of data is as important as the interface to access them. Without harmonized data models the use of data access services in a broader context is impeded [24]. Therefore several community driven initiatives are harmonizing their information models. Interoperability experiments [25] have shown that Fluid Earth Sciences data and models based on the netCDF markup language and its GML based extension NcML-GML [26] can be integrated in traditional GIS through the use of OGC Web Coverage Service (WCS, [27]). Nevertheless, a modification to the WCS specification is recommended to facilitate the exchange of multi-dimensional datasets. Focussed on atmospheric data, the ADAGUC project uses OGC data services on top of a well defined HDF5 based file format to facilitate the integration of atmospheric data in GIS [28].

III. THE NRSDL

The National Remote Sensing Data Library (NRSDL) hosted by the DFD is a central part of the DLR's payload ground segment infrastructure. Through its interactive user interface EOWEB[®] [30], the NRSDL provides multi-mission and multi-level access to the long term data archive from numerous earth observation satellite, space shuttle and airborne missions with DLR participation. The NRSDL is based on the Data Information and Management System (DIMS) which is a component based software library for building distributed services hosting earth observation data management functions, including reception, processing, archiving, ordering and delivery of data products [31].

Payload data handling is a task that usually outlives an earth observation mission's duration. Acquired payload data have to be preserved and handled far beyond the initial satellite platform's lifetime, since their value often increases with their age, for example in the domain of global change monitoring. Thus preservation and migration is required not only for data but also for the systems handling the data. At the same time near realtime applications arise requiring instantaneous access to newly acquired and value-added data, such as in the domain of hazard management. The combination of the long-term operations perspective and the flexibility to serve new value-added data and services is a real engineering challenge for earth observation data management.

DIMS tries to face this challenge by providing generic multi-mission system modules which can be extended and customized for upcoming EO missions. Additional

functionality such as complex value-adding and cross-mission production workflows, ordering of future acquisitions, data subscription, near realtime delivery and online data access services are developed and configured to meet concrete mission requirements. DIMS relies on abstract metadata, data and service models that allow identification and encapsulation of required functions, configuration of new workflows and extension of data structures, usually performed during nominal interruption-free system operation. This has also been exercised for the German TerraSAR-X mission [32]. Endowed with this flexibility, multi-mission systems like DIMS are optimally suited to provide system and payload data sustainability and operating cost savings through unified operative processes.

In October 2009, the NRSDDL hosts 2 million data products with 10 million data files in approx. 100 collections for various sensors, temporal and spatial resolutions and processing levels acquired by DLR ground stations and generated by about 60 DLR processing systems. The main part of the 350 terabytes of data consists of raw data which are archived for the long term to allow future reprocessing with enhanced geophysical retrieval algorithms. The remainder consists of ready-to-use georeferenced raster data representing optical, hyperspectral and radar imagery of the earth surface, concentrations of atmospheric constituents and digital elevation models. Mainly the data processing causes a monthly data throughput of approx. 6 terabytes.

The German EO mission TanDEM-X [33], aiming at creating a high-resolution global digital elevation model of the earth will start at the end of 2009. It will extend the amount of archived data up to 1.5 Petabytes and increase the throughput by a factor of 10. Another supported future German mission is the EnMAP mission, carrying a high end hyperspectral sensor [34].

As a requirement in all EO payload ground segments the NRSDDL is driven by the following basic group of processes:

- systematic, product data driven processes
- event-based, request driven processes
- operations support processes

The DIMS system supports these processes through its distributed service components, as depicted in Fig. 2.

The systematic processes are driven by sensor data which are continuously acquired, ingested and processed. The Processing System Management (PSM) component supports these data-driven *processing* workflows, up to the *ingestion* into the Product Library (PL), a digital library for the long-term *archiving* of EO data products. In addition, newly available products are automatically disseminated to subscribed users and uploaded into *online* catalogues (EOWEB[®]) and data *access* systems.

Request driven processes are usually triggered by *orders* submitted from online catalogues containing existing and potential future products. The orders are processed by Ordering Control (OC), which is responsible for checking the data policy, initiating *acquisition* (Mission Planning Interface MPI, Receiving Station Interface RSI), *retrieval* from the

Product Library, *post-processing* and finally data *dissemination* and *delivery* either online or through storage media and shipment. Thereby other DIMS components come into action such as Production Control (PC) and Offline/online Product Generation and Delivery (OPG).

Operation support processes are very important to keep these continuously active services, with high availability requirements, up and running. *Monitoring* and *control* of the NRSDDL is supported by the unified DIMS Operating Tool (OT), a single, highly configurable graphical operator interface allowing interaction with every running service to control system activities. This is complemented by the Monitoring and Alarm (MA) component supporting automatic supervision of all services and all kinds of underlying resources, creating alarm messages to operators if critical situations are detected.

IV. GEOSPATIAL SERVICE INFRASTRUCTURE

The geospatial service infrastructure (GSI) extends the NRSDDL to support the access to georeferenced EO data through OGC compliant service interfaces. Furthermore, GSI provides a corporate framework to support the development of business processes and infrastructure modules for geospatial data and services. This is closely related to the definition and the goals of a Corporate Spatial Data Infrastructure (CSDI, [35]). The business process and infrastructural requirements for the GSI are deduced from a set of iterative

- demonstrations to show the potential benefits of service-oriented data access;
- workshops to describe the technical concepts and tools to access services as well as requirements for data producers to be fulfilled in order to allow integration of datasets in GSI
- interviews with potential users and interest groups to understand their business processes and discuss integration strategies.

Beside the core integration of NRSDDL datasets, two value-adding user services have been chosen for evaluation as they are closely related to the NRSDDL and are believed to benefit from common service infrastructure functions. Their business process and the infrastructure constraints are described in the following two paragraphs. Then results and goals are summarized which lead to the high-level technical concept of the GSI.

A. Business Process Requirements

The functionalities and datasets provided by the NRSDDL are used directly for the production of data products and services. Two operational value adding service workflows are described in the following paragraphs.

Within the distributed EUMETSAT Polar System ground segment, DLR acts as an integral part of the Satellite Application Facility for Ozone and Atmospheric Chemistry Monitoring (O3M-SAF) and is responsible for the processing, archiving and delivery of GOME-2/MetOp atmospheric composition products. Based on the continuous reception of

GOME-2 level 1b data, different processing chains for generation and dissemination of near-real-time (only two hours after sensing) and off-line data products are triggered. The resulting level 2 datasets provide the total and tropospheric column density of different trace gases such as O₃, NO₂, BrO, SO₂, H₂O, OClO and HCHO, as well as cloud properties [36]. Aggregated (level 3) and assimilated (level 4) data products are generated in the context of the World Data Center for Remote Sensing of the Atmosphere (WDC/RSAT) [37]. The GDP 4.3 algorithm is currently being used to generate these value added products described in [38]. Finally, the data products are stored in NRSDL and are made available through GSI (Fig. 3).

Another operational service based on EO data handles emergency response for disaster management. The “Center for satellite-based Crisis Information” (ZKI, [39]) is a DLR service for the rapid acquisition and analysis of satellite data as well as creation of maps and other information products in the context of disaster situations, humanitarian relief efforts, and civil security [40]. The ZKI operates in GMES projects such as RiskEOS and RESPOND, as well as in national and international contexts and in close cooperation with national authorities, non-governmental organizations, satellite operators and space agencies. This close relationship to a variety of EO data providers is crucial for requesting a particular type of datasets for the specific disaster. E.g. in case of a flooding disaster, TerraSAR-X data is ordered from the NRSDL to create a water mask. Then other spatial core datasets such as transportation networks, administrative boundaries and population densities are combined in a GIS to create the final map. The map is then immediately transferred to local authorities and humanitarian organisations working in the field, as well as being published on the ZKI web portal including georeferencing information and a KML file for visualization in Google Earth (Fig. 4).

B. Infrastructure Requirements

Providing geospatial services on top of the NRSDL is a challenging task, as the NRSDL hosts multi-level and multi-domain datasets with different scales, temporal and spatial resolutions and data policies and licenses. Furthermore the requirements from different user communities have to be taken into account. Legal constraints add an additional layer of complexity. Although the extensive discussion of the legal issues is out of the scope of this paper, an overview is given to derive system requirements for the NRSDL and GSI.

The German law on satellite data security (“Satellitendatensicherheitsgesetz”, or for short SatDSiG) from November 2007 governs the dissemination of remote sensing data from German satellites and ground segments on German territory in order to ensure that satellite data can not compromise the security of the acquired regions. This affects the access to high resolution datasets, such as TerraSAR-X payload data. Requests for such data need to be verified by taking into account criteria such as the residence of the requesting user, the requested area, sensor specific settings

(e.g. radar polarization mode) and sensor resolution (<2.5m). Should the verification (also known as sensitivity check) fail, fulfilment of the requests must be denied in the first place. The users may then either modify request criteria to be uncritical or choose to undergo an exhaustive security classification by the executive authorities. Access control that complies with SatDSiG is implemented in the asynchronous ordering workflow of the NRSDL.

German law on access to digital geospatial (“Geodatenzugangsgesetz”, or for short GeoZG) data has recently become effective (February 2009). It implements the European Commission’s INSPIRE directive and is associated with the creation and development of the German SDI (GDI-DE). The GeoZG governs the provision of and access to geospatial data. It provides the legal framework for access to geospatial datasets, services and metadata of legally mandated organisations (LMOs) as well as data and service providers appointed by the LMOs. The public use of geospatial data should basically be allowed if it has no negative effects on international relationships, safety-related subjects of protection and defence.

C. Motivation

Although both use cases differ significantly in the core value-adding process – algorithm development and processor integration on the one hand and traditional GIS mapping by skilled personnel on the other – both production processes share a similar set of tasks. Those tasks include the discovery of input products, pre-processing steps such as reprojection and spatio-temporal sub-setting, metadata creation and publishing the data on a web page, data access service or portal. In particular the publication of products through interoperable web services is the main goal for integrating NRSDL datasets.

However developing and maintaining the GSI is not only related to infrastructural functions and standards but also to organizational policies and partnerships. Developing and maintaining the GSI for public and internal use is therefore motivated by:

- Facilitation of exploration, browsing, validation and extraction of data and information from the archive through the use of portrayal and data access services
- Fostering the use of standards to enhance reuse of software and services
- Consolidation and support of interdisciplinary efforts in the development of software modules
- Provision of a centrally controlled and distributed data and user repository for easier identification, lookup, metadata maintenance and access control
- Facilitation of interoperability with SDIs
- Reduction of costs and complexity for the development of value-adding services by providing application oriented, high level service structures and reusable software modules

D. Concept

Based on the requirements and motivations described above this section gives a brief overview of the technical concept of the GSI. The GSI needs to support secure OGC compliant data access to NRSDDL as well as the creation of products and dedicated services instances for different data providers.

The high level concept is depicted in Fig. 5. GSI is conceptually a platform that provides interfaces to ingest and access geospatial datasets. The NRSDDL uses the ingestion interface to actively and systematically publish selected datasets. Other external data sources are harvested by the GSI. For data access, GSI offers OGC compliant interfaces that are provided by different OWS Service Implementations (OSI).

The ingestion process is handled by a central GSI Ingestion Component (GIC) that abstracts from the actual service implementation to ensure future upgrades. It is responsible for instantiation, configuration and registration of services as well as processing and caching data for faster access. Furthermore, data ingestion is supported either through an active ingestion request or passively through a harvest process. The active ingestion of products is integrated into the systematic and operator driven processes of the NRSDDL and is triggered upon insertion, update or deletion of data in the archive.

Both ingestion processes are based on the GSI Service Providers (GSP) interface which is a deployment configuration unit and represent a set of services in the platform. A GSP specifies all relevant information for a group of product types, including data descriptions, feature types, coverage hierarchy and according metadata as well as service endpoints, access control rules, and presentation styles (e.g. colormaps, legends, web map contexts). Through this level of abstraction the GSP units focus on the data type specification, presentation and access constraints. The GIC takes care of provision of service implementations and data store binding as well as the actual ingestion process.

The legal and commercial constraints are enforced by the GSI Security Service (GSS). The GSS acts as a Policy Enforcement Point (PEP) and Policy Decision Point (PDP) that either denies or grants the request to the service by evaluation of the GSP access constraints. The GSP also acts as a proxy for OGC interfaces provided by the OSIs.

E. Geospatial Services for the NRSDDL

The concept described above allows the separate and independent creation of services instances for different GSI Service Provider: Web Coverage Service (WCS) 1.0.0, Web Feature Service 1.1.0 (WFS), Web Map Service (WMS) 1.3.0 and Catalogue Service (CSW) 2.0.2 based on the eBIM profile. In addition, a CSW that serves ISO-compliant metadata enables service and data discovery as part of the German SDI.

Furthermore the GSI provides community-driven specifications such as Tile Map Service (TMS, [41]) and Web Mapping Service – Cached (WMS-C, [42]) which greatly enhance the delivery of maps and portrayed datasets over the

internet.

Fig. 6 shows the integration of the GSI in context of the NRSDDL, internal value-adding user services and external user systems. GSI distinguishes between public and internal interfaces and providers. The internal “basemap” provider currently offers geospatial core datasets through WFS/WMS and WMS-C to internal user services and webpages, commonly required for background layers in information products and interactive maps.

The public “eoweb” provider supports WCS/WMS compliant data access to selected EO products archived in the NRSDDL. The selection is required, because non-georeferenced datasets are not suitable for service-oriented data access. Therefore only a subset of the NRSDDL products is available through the OGC compliant services.

Furthermore other thematically providers are configured for datasets that are not archived in the NRSDDL. These datasets are usually produced by value-adding services and include e.g. models calculations, simulations, assimilated and forecast products.

V. DISCUSSION AND OUTLOOK

While the main goal of establishing standardized data access services into the NRSDDL and facilitate the provision of services for different data provider has been reached, the current version of the GSI still faces important challenges to be tackled in near future.

A. Operability

The maintenance aspect of the GSI should not be underrated. Measures have been taken to reduce the complexity of the data provision and enhance the operability by defining a single set of configuration items for each data provider (GSP, Fig. 5). Thus the configuration is the main contract between the data provider, development and operation team. It also succeeds in keeping implementation specific details out of discussion. Nevertheless, the operations team need to monitor additional databases, service instances and server in general.

B. Access Control

The GSI security subsystem is not yet in use as intended. For encoding of the access rules GeoXACML [41] is envisioned, a geospatial extension for the OASIS eXtensible Access Control Markup Language (XACML). GeoXACML allows fine grained, product-type specific evaluation of service requests including spatial functions such as intersects and union. However, due to the lack of GeoXACML implementations and administration tools, the security features from the specific service implementations are currently used for access control. Also, developments and suggestions in HMA and INSPIRE are tracked to facilitate identity management integration.

C. Service Model

Concerning the services, the presence of different metadata

models and CSW profiles limits the discovery of datasets through current catalogue client implementations. A solution is discussed in [45]. However there is currently no implementation that supports it. Currently, two different CSW implementations are needed to support the discovery process in both INSPIRE and HMA.

In the context of the GSI, the NRSDDL is currently represented as one provider, i.e. one WCS/WMS service. This granularity might be too coarse, because the NRSDDL hosts many EO datasets that are referenced in the *getCapabilities()* response of the service. Therefore the current implementation only returns the aggregating layers and coverages, not the single datasets. An alternative solution and best practice advice to enhance the browsing of multidimensional EO products through the WMS protocol is described in [44].

Future investigations will also evaluate the integration of other services into the GSI platform as part of new projects and emerging business process requirements, especially the Web Processing Service (WPS) and SWE technology have shown its benefits in EO related contexts [46], [47].

Further advanced use of WFS and WCS services in the internal NRSDDL processes are also currently evaluated, e.g. to enhance order management, acquisition planning and for accessing and visualisation of hyperspectral EO datasets. Furthermore a steady integration of GSI in EOWEB[®] is being undertaken to enhance user experience.

D. Feedback

Concerning data access services, GSI currently offers only WCS compliant data access including portrayal through WMS. WFS based feature access to MetOp GOME-2 Level 2 products has been tested and is currently under investigation. Feedback from users during demonstrations have been very positive, especially the possibility to filter features based on a user defined query (see Fig. 3) without having to order, download and process many single files is seen as a big advantage. Furthermore the combination and evaluation of geospatial and multi-dimensional EO datasets through web portals and GIS is seen as a real value for processor and algorithm cross-validation as well as for producing value added data products. The relatively low resolution makes this a good candidate for data access through a WFS, although, given the size of roughly 15000 features per orbit at ~14 orbits a day, the resulting database exceeds 75 million features a year. Nevertheless, keeping one week of tropospheric NO₂ concentration data online could be a very valuable source for an air quality monitoring service including alerts if a location-dependent threshold is exceeded. Furthermore it will be evaluated if the NetCDF Climate and Forecast Metadata Conventions can be applied to the feature type definition in order to harmonize the data with other projects [28].

VI. CONCLUSION

This paper outlined the concept for a geospatial service infrastructure (GSI) that supports standardized data access and facilitated provisioning of data through OGC compliant

interfaces with the help of ingestion and harvest services.

The infrastructure is being integrated in the NRSDDL to enable standardized data access to a variety of long-term and near realtime EO datasets. Subsequently further datasets will be added to enrich other national, regional and global SDI efforts with data from mostly German EO missions and value-adding DFD user services.

Nevertheless, providing a geospatial service infrastructure to access multi-level and multi-domain datasets is a challenging task. On the technological level, it is crucial to take into account heterogeneous data and access standards for different user communities. Furthermore data specific policies, property rights and access restriction increase security needs for the infrastructure. In addition, the computational, network and storage requirements for new high-resolution earth observation products challenges the information technology infrastructure. Above all skilled personnel to develop, maintain and operate as well as educate and train users about new capabilities are required for a sustained success of the GSI. The maintenance and operation of the NRSDDL is ensured through the close cooperation of the development and operations team as well as sophisticated software tool support. However, the operation of the GSI requires comprehensive education and training on geospatial information technologies and its underlying concepts.

Therefore the development of the geospatial service infrastructure for the NRSDDL is an ongoing process and long term commitment. While the GSI provides primarily technical solutions for standardized data access, it is also a platform to discuss and implement requirements with users that are involved in the production and dissemination of spatial data products in the context of the NRSDDL.

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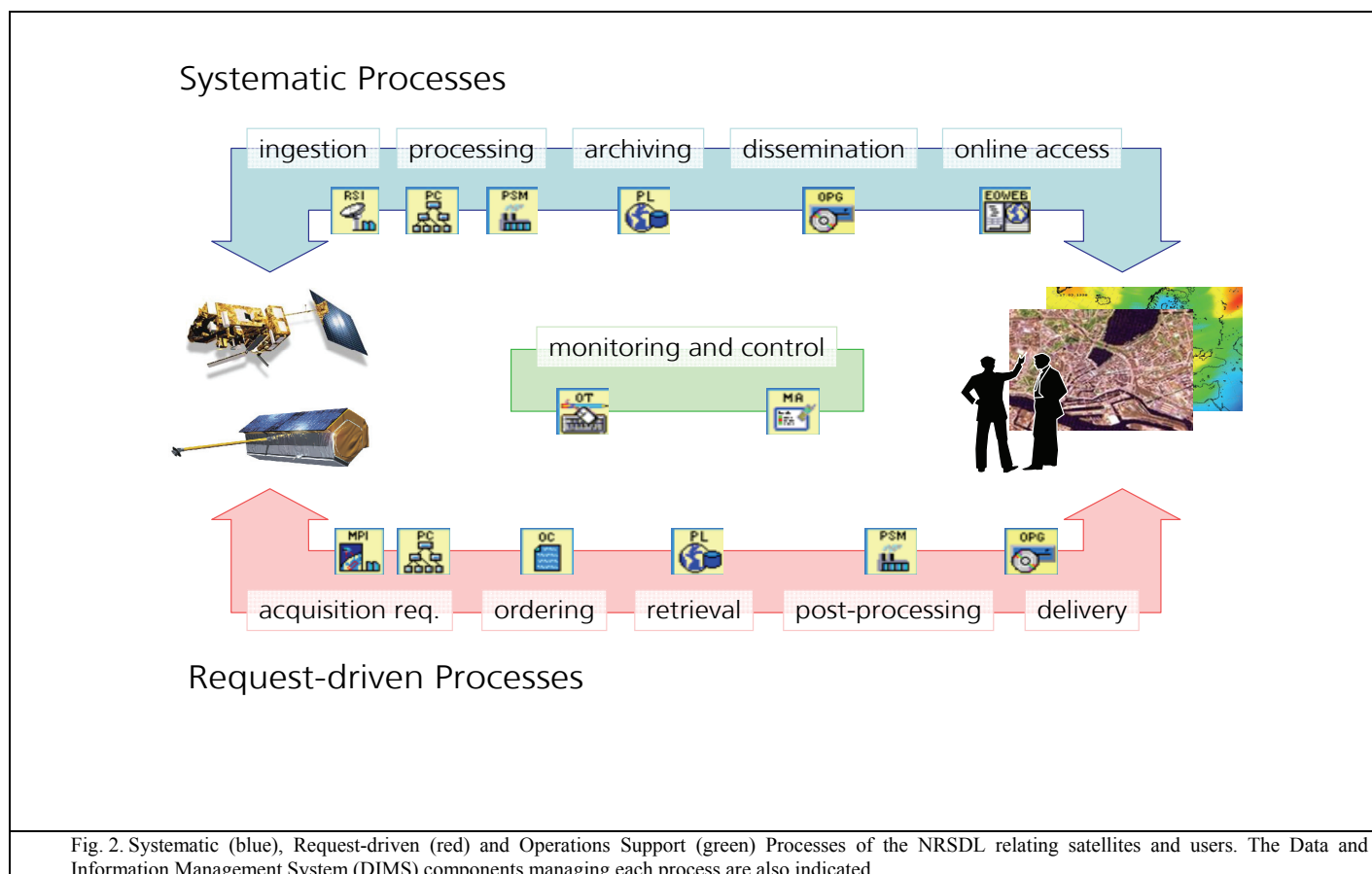
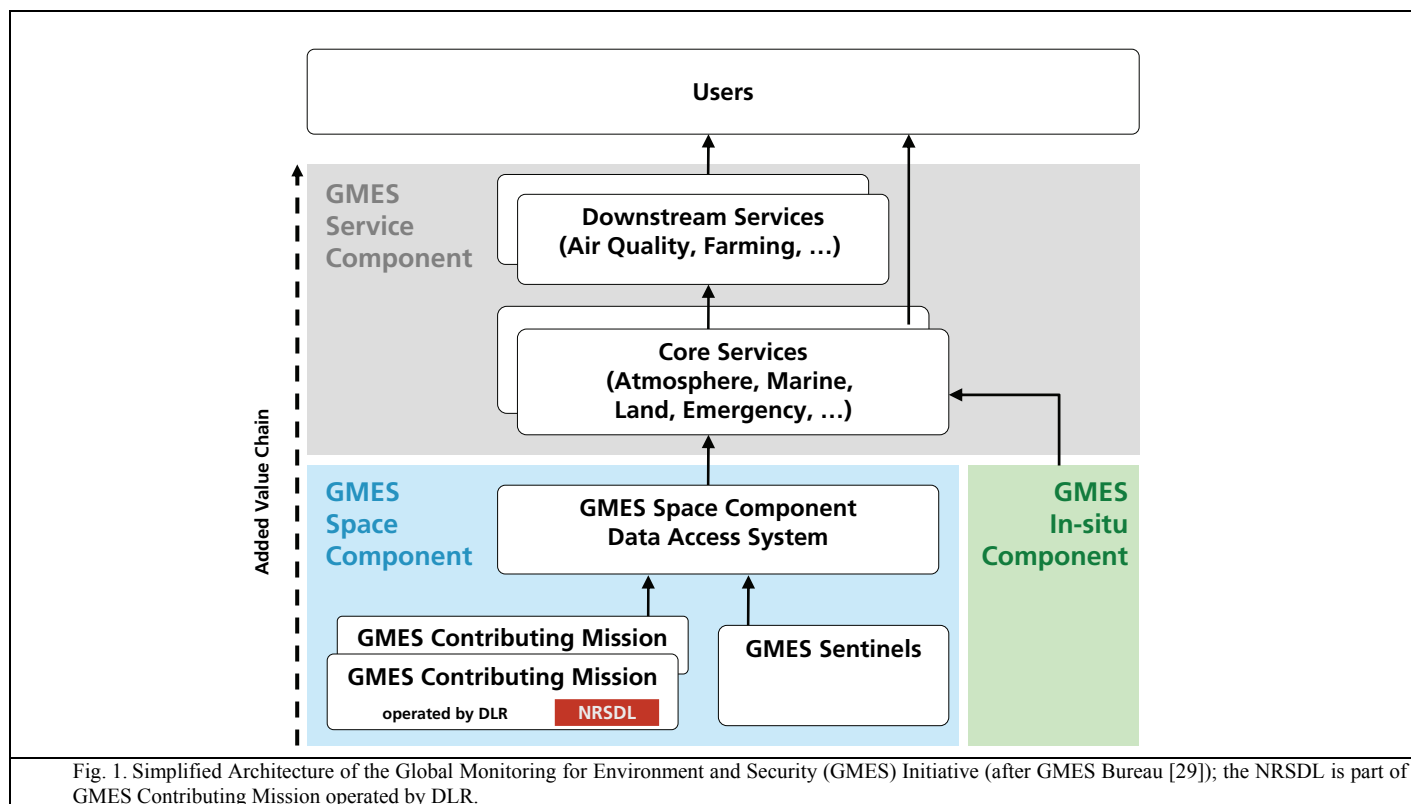
Since 1983 he is with the German Aerospace Center (DLR), where he has been involved in developments of distribute ground segments of various challenging space projects. From 1983 to 1987 he was development engineer for the Electrical Ground Support Environment and designer of the DLR's image processing system for the Halley Multicolour Camera (HMC) of the European Giotto Mission. From 1987 to 1992 he was system engineer responsible for the design of the distributed Ground Support Program Equipment (GSPE) for the telemedicine experiment Anthrorack in the framework of the German D2 Spacelab Mission. In the years 1993 to 1997 he jointly designed and developed the ozone retrieval processor for the Global Ozone Monitoring Experiment (GOME) onboard the ERS-2 satellite. From 1996 to 2003 he was leading the development team establishing the multi-mission Data and Information Management System (DIMS) for several ground segments (incl. TerraSAR-X). Since 2004 he is head of the information technology department of DLR's German Remote Sensing Data Center (DFD).

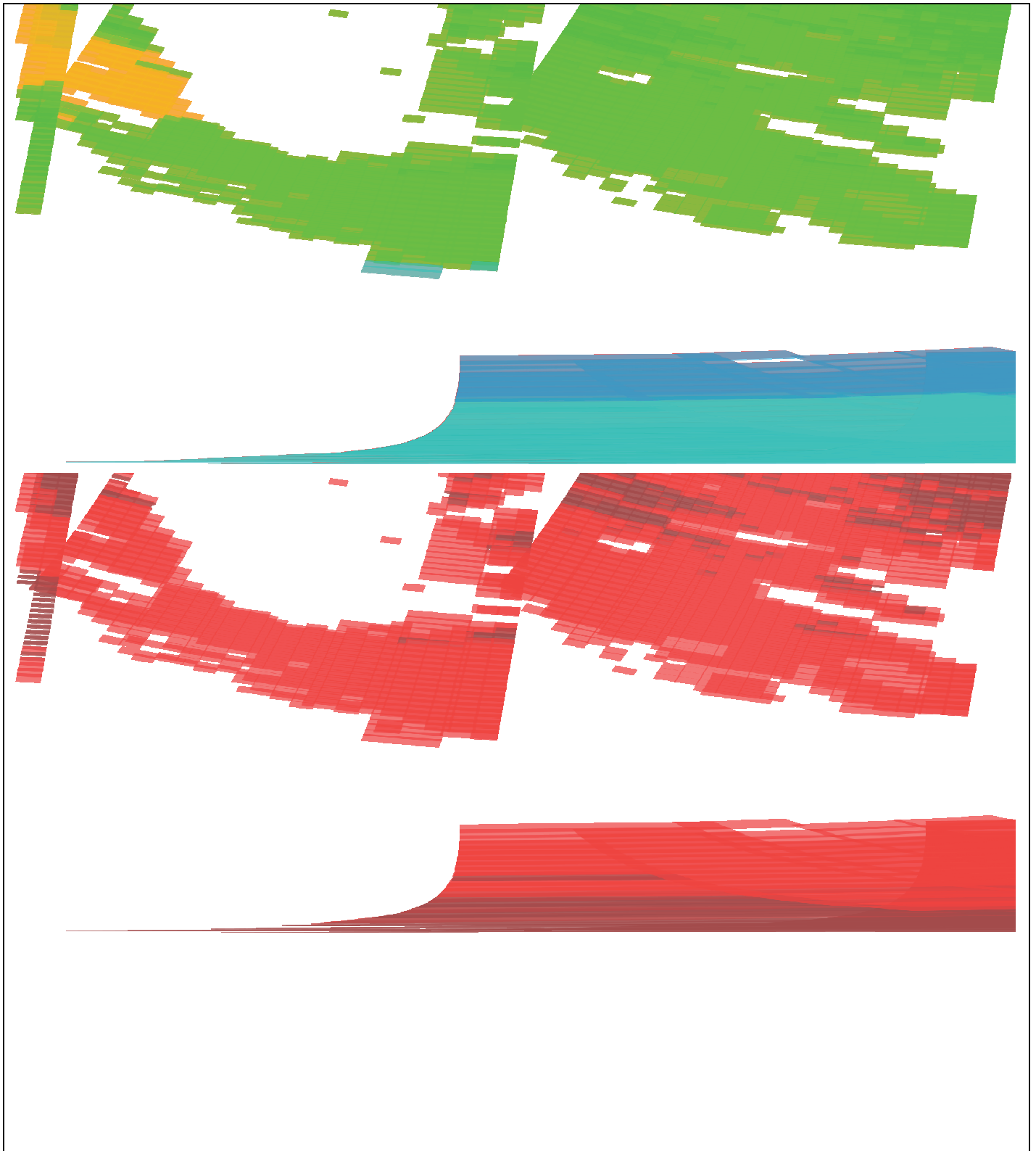


Diego G. Loyola R. received the Lic. degree in computer science from the ESLAI at the University of Lujan (Argentina) in 1988. He has been a project manager with the German Aerospace Center (DLR) in Oberpfaffenhofen, Germany since 1992 and has been a Visiting Scientist with NASA GSFC in 2000. He was first at DLR's German Remote Sensing Data Center and since 2000 he has been with DLR's Remote Sensing Technology Institute where he leads the ground segment projects for ESA's "Global Ozone Monitoring Experiment" (GOME) and EUMETSAT's "Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring" (O3M-SAF).

His research interests are with satellite remote sensing of atmospheric composition and clouds, as well as neural network and computational intelligence techniques.

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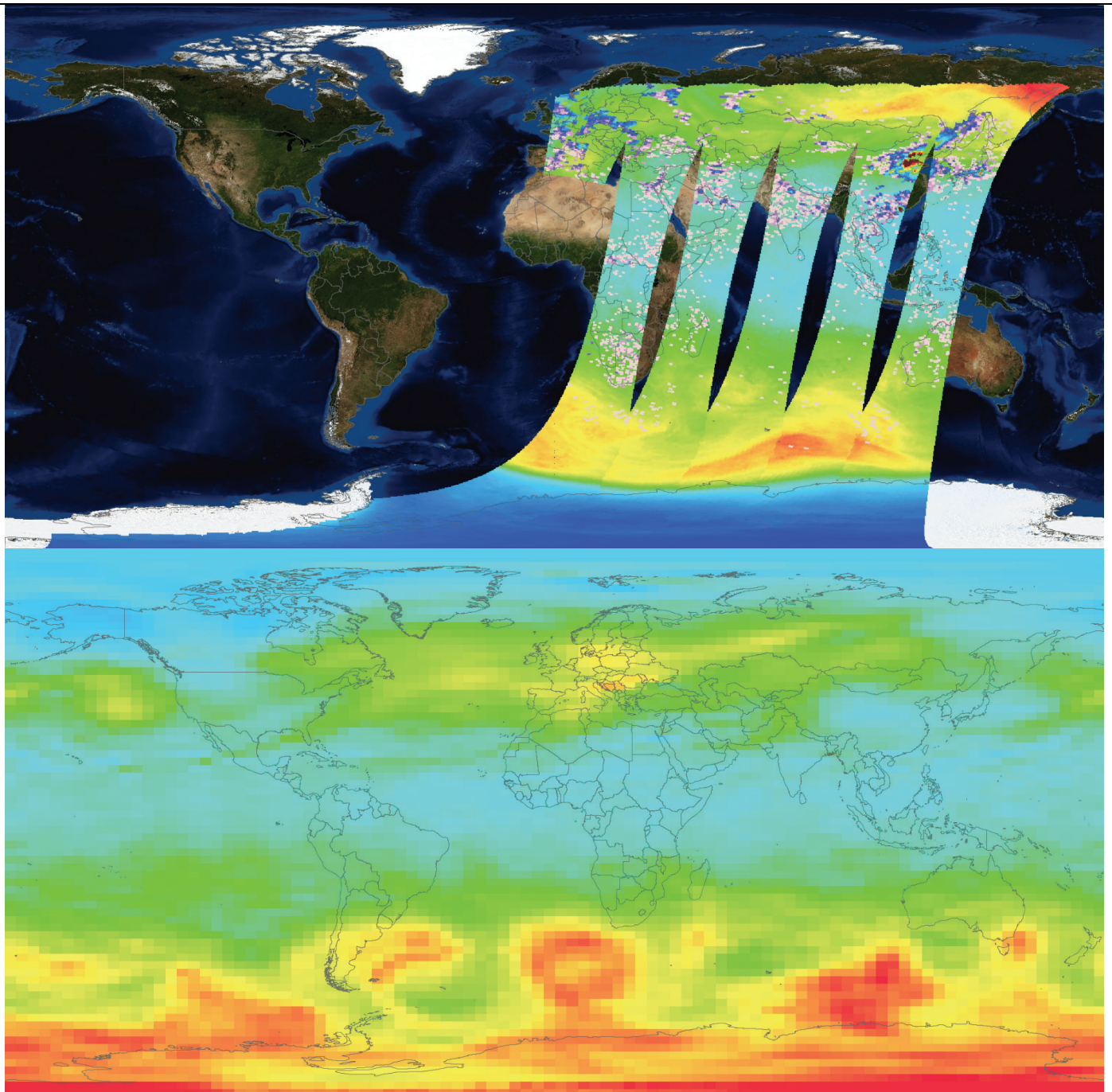


Fig. 3. Examples of atmospheric composition maps. From top to bottom: Filtered GOME-2/MetOp Level 2 products accessed through WFS/WMS with query: “O3>150 and O3_Error< 0.8 and Time between 2009-02-01 and 2009-02-02 and Region [-180,-90,-100,-50]” (first panel). Same query with visualization of errors (second panel). Overlay of GOME-2 L3 Ozone and NO2 troposphere near-realtime aggregates on top of Blue Marble [48] base layer (third panel). GOME-2 L4 Ozone assimilated data (fourth panel).

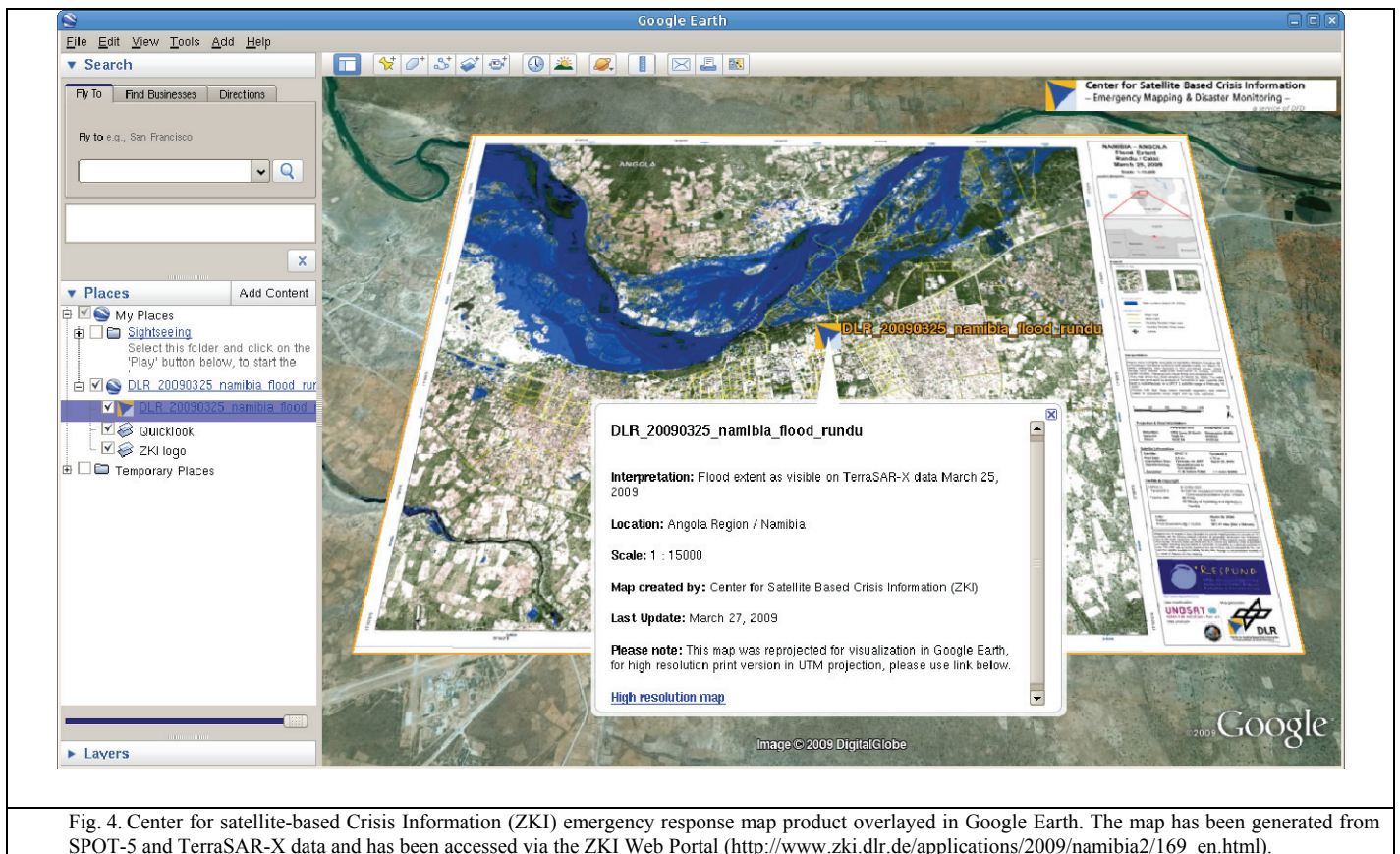


Fig. 4. Center for satellite-based Crisis Information (ZKI) emergency response map product overlayed in Google Earth. The map has been generated from SPOT-5 and TerraSAR-X data and has been accessed via the ZKI Web Portal (http://www.zki.dlr.de/applications/2009/namibia2/169_en.html).

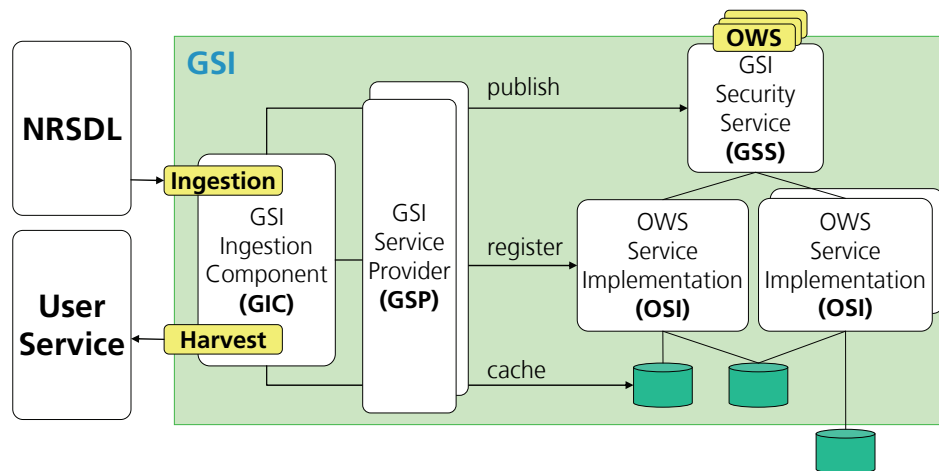


Fig. 5. Concept of the Geospatial Service Infrastructure (GSI) providing interfaces to register datasets: Through the Ingestion interface datasets are registered actively from external component (e.g. NRSDL) in GSI; the Harvest interface actively registers external datasets in GSI. The actual registration is done through the GSI Ingestion Component (GIC) with the help of GSI Service Provider (GSP) configurations. OGC Web Service (OWS) Service Implementations (OSI) provides the OGC service interfaces that are publicly published and secured through the GSI Security Service (GSS).

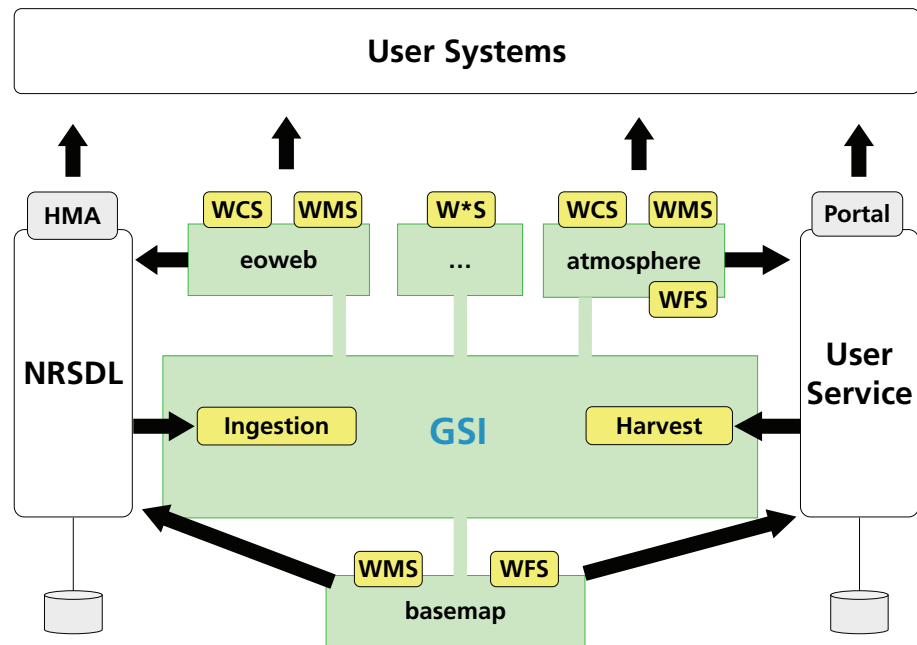


Fig. 6. GSI providing interfaces to register datasets (Ingestion, Harvest). Public and internal OGC services are instantiated to support both NRSDL and dedicated User Service infrastructures. The visibility (internal vs. external) is controlled through GSI. The “eoweb” providers hosts NRSDL data, the “basemap” provider hosts geospatial core datasets, such as administrative boundaries, land/sea mask, placenames, etc. The “atmosphere” provider hosts value-added data products not archive in the NRSDL, such as models calculations, simulations, assimilated and forecast products. Further providers are configured on demand.