Research Topic: Hydrosphere

Quantifying water cycle dynamics for hydrological prediction

Goals of the Research Topic Hydrosphere

• Retrieval and sensor data fusion: How can we optimally retrieve and synergistically merge different remote sensing technologies in order to improve hydrological variables/parameters?

• Validation: How precise are hydrological variables observed using remote sensing technologies at different spatial and temporal scales?

• Data assimilation: How can remotely sensed hydrological products be further used in order to better understand and predict the hydrological cycle?

⇒ Quantitative understanding of dynamic processes in the Hydrosphere
⇒ Strong focus on soil moisture
Why is soil moisture important for hydrology?

• Plays an essential role in the prediction of …
  • regional weather (lower atmospheric boundary)

➢ Soil moisture remote sensing data not yet routinely included in operational forecast models (e.g., ECMWF)
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  • groundwater recharge (sustainable WRM)
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⇒ Exhaustive characterization of soil moisture in very high spatial and temporal resolution

⇒ Better hydrological, meteorological and climatic predictions
Where are we now and what are the problems?

In-situ soil moisture measurements:

- 150 Sensor units
- 18 Router units
- 900 Soil moisture sensors
- 300 Temperature sensors
Where are we now and what are the problems?

In-situ soil moisture measurements:

- Only few measurements (~dm³), high spatio-temporal variability
- Hardly long time series
- No standard procedure for intermediate scale (~ hm²)
Where are we now and what are the problems?

Available remote sensing offers large scale data, but with limitations:

- **SMOS (~35km)**
- **ASCAT (~25km)**

High temporal resolution, but low spatial resolution

Not adequate for integration into regional scale models
Where are we now and what are the problems?

Available remote sensing offers large scale data, but with limitations:

⇒ Large differences between prediction and measurements
⇒ No relevance for utilization in hydrological models by data assimilation
Where are we now and what are the problems?

Available remote sensing offers large scale data, but with limitations:

⇒ Small differences between prediction and measurements

⇒ Improved estimation of soil moisture profile in the root zone by integration into hydrological models
Where are we now and what are the problems?

Available remote sensing offers large scale data, but with limitations:

- Model needed for translating measurement in soil moisture (uncertainty, bias)
- Disturbances: vegetation, surface roughness
- Lack of ground truth verification
- Infrequent visits (e.g., ALOS) OR
- Low spatial resolution (e.g., SMOS, ASCAT)
- Limited to upper 5 cm of soil
Remote sensing for improving hydrological predictions:

- Synthetic study, (potential of data)
- Small well controlled studies with real data
- Large scale studies incl. verification of improved predictions
- Operational use for improving large scale predictions

⇒ Spatio-temporal scales of Tandem-L observations move us forward to enhanced hydrological predictions
WORK PACKAGES
WP H1: Derivation of surface soil moisture under the vegetation cover using multi-parametric SAR

Jagdhuber & Hajnsek (DLR-HR)

Validation with *in situ* data for all crops

RMSE = 5.22 vol.%
WP H2: Multi-scale ground measurements data for the validation of remotely sensed soil moisture products - Bogena & Montzka (FZJ)
WP H3: GNSS based soil moisture measurements – Wickert & Güntner (GFZ)

Global GNSS network

Correlation of the GNSS multipath signal (L-band) (reflected from ground) with soil moisture

Sutherland, South Africa, 2013
Tidal currents at Orkney Islands measured with TerraSAR-X (2009, 2010)
WP H4: Ocean Surface Current Measurement with SAR along-track Interferometry - Suchandt & Lehmann (DLR-IMF/GEOMAR)

- Understanding & modeling the ocean response to climate variability and extremes is essential for climate projection studies. Models must be validated by observations.

- Space borne SAR Along-track interferometry provides large-area information on ocean surface motion with high spatial and velocity resolution.

- **Main objective**: Combination of remote sensing data, models and in-situ measurements to obtain climatologic relevant information

- **Milestones**:
  - Adaption & validation of TerraSAR-X data processing system
  - Cross-data analysis for a pilot study area: in-situ data (ADCP), numerical circulation model (BSIOM), surface current velocities (TanDEM-X)
  - TanDEM-L mission requirements for ocean current measurements
The SMAP active/passive fusion approach

F-SAR backscatter overlayed with PLMR brightness temperature
WP H6: Demand-driven observation of soil moisture - Dietrich & Wollschläger (UFZ)

**Aim:** provide demand-driven, detailed information on near surface to deeper vadose zone soil water content and subsurface architecture

**Approach:** improve process understanding and predictive capability by demand generated through:

- interaction with modeling and data assimilation
- interaction with ground based measurement
- consideration of underlying characteristics of observed processes

For calibration and gathering of additional data suitable for processing of remote sensing data
WP H7: The use of hyperspectral optical and L-band radar data for retrieving surface soil moisture – Itzerott (GFZ)

Detection of promising band ratios

\[ NSMI = \frac{(R_{1800} - R_{2119})}{(R_{1800} + R_{2119})} \]

NSMI (Haubrock et al. 2007)

Polarimetric decomposition and inversion

Bronstert et al. 2012
WP H8: Data assimilation of multi-scale soil moisture - Hendricks Franssen (FZJ)

Assimilating SMOS, SMAP, Tandem-L, CRP, TDR: scale dependence.

Multi-scale data assimilation with two different algorithms will be tested in synthetic and real world application:

- Prior downscaling
- Utilization of retrieval operator for downscaling during assimilation

Main Result: Value of Tandem-L data for improving predictions with land surface models.
WP H9: Assimilation of soil moisture and snow water into the mesoscale hydrologic model - Samaniego (UFZ)

Research Questions

• Assimilation SM & SWC → minimize parameter uncertainty of mHM?
• Subgrid-scale variability of state variable → better effective parameters at larger scales (e.g. 1-5 km)?

Phases

• Statistical data exploration (dimensionality, stochastic dependency)
• Data assimilation, parameter inference, and model improvement
• Evaluation at TERENO sites
WP H10: High resolution soil moisture parameterization of land surface models – Bendix & Thies (Uni Marburg)

Investigation of growth and competition processes of pasture grass (Setaria sphacelata) and southern bracken in southern Ecuador

Adaptation of the Community Land Model

Soil moisture information with high spatio-temporal resolution by Tandem-L:

- Improved model accuracy
- Enhanced understanding of growth and competition processes

Development of DA scheme for level 3 Tandem-L soil moisture product

1. Development of a downscaling method for SMOS and SMAP soil moisture product to 50m Tandem-L resolution

2. Model validation (EC data)
WP H10: High resolution soil moisture parameterization of land surface models – Bendix & Thies (Uni Marburg)

Location of the study site and vegetation units from satellite

Göttlicher et al. 2011

Curatola et al. 2012
Problem: Inconsistencies in the spatial and temporal resolution as well as spatial and temporal availability of current (large-scale) soil moisture products.

Main objective: Data merging of satellite- and airbourne-based, in-situ, and modeled soil moisture in order to provide reliable and consistent estimates of gridded soil moisture.

Methods: Application of Copula-techniques in order to describe the dependency between different sources of soil moisture and other climatic variables (e.g. temperature, precipitation, …).

Data assimilation based on the statistical dependency between the different input-datasets.
WP H11: Copula Based Merging of Modeled and Satellite-Derived Soil Moisture Fields and Ecosystem Fluxes – Kunstmann & Lorenz (KIT)

First experiments over the Mississippi basin using SMOS, NLDAS-data and observations from the ISM-Network

Empirical (left) and theoretical (right) Copula density between observed and modeled soil moisture

Observed (black) and modeled (gray) soil moisture over five observation stations of the ISM-Network
L-band test data sets

DLR F-SAR on Do228

TERENO – Terrestrial Environmental Observatories
Expected impact

- A strong improvement in the characterization of soil moisture contents and associated hydrological and energy fluxes:
  - A better understanding of what is exactly measured and therefore a better conversion of measured signals of individual products (e.g., radar, microwave) to soil moisture.
  - The spatial and temporal interpolation of soil moisture products to achieve a higher resolution (fusion, downscaling).
  - Additional interpolation and extrapolation in space and time (e.g., root zone soil moisture), making use of land surface models and data assimilation techniques.
  - Insights in the relative value of different data products.

- Main impact: improved hydrological, meteorological and climatic predictions and sufficient understanding for operational use.
Links and joint efforts with project partners: Within Hydrosphere and beyond

Direction towards multi-sensor approaches

- Link with passive sensors / multi-sensor platform efforts to link active and passive sensors (SMAP-mission)
- Link with hyperspektral sensors -> hybrid soil moisture inversion
- Link with GNSS reflectrometry-based soil moisture patterns
- Link with ground-based measurements (pattern comparison with geophysical techniques)

Direction towards data assimilation into models

- Assimilation
- Direct input

Link through common test sites
Scientific questions

- Does the assimilation of soil moisture help to minimize parameter uncertainty of hydrological models?
- To what extent does the assimilation of subgrid-scale (e.g. 50-500 m) variability of state variables contribute to the derivation of effective parameters at larger scales (e.g. 1-5 km) in order to characterize hydrological processes?
- Is Tandem-L able to improve the regionalization of land surface models?
- What are further techniques to be used for a global soil moisture monitoring and validation system in conjunction with remote sensing products?
- Can an improved land surface model enhance our understanding about soil-vegetation – atmosphere water fluxes and coupled plant water/nutrient dynamics?
Scientific questions…

You may find first answers to these questions in the Hydrosphere session on

**Wednesday 9th October, 9:00 – 11:45**

and the Poster session on

**Tuesday 8th October, 15:00**