Satellite Soil Moisture Validation & Application Workshop 2014

Abstract Book

10-11 July 2014

Amsterdam, the Netherlands

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Abstract Book

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Foreword

Over the years the use and availability of satellite soil moisture products has been expanding. This development has been boosted by the launch of new dedicated soil moisture satellites (SMOS, SMAP), the development of (near-real-time) soil moisture products from operational satellites (ASCAT, AMSR-E/2, Sentinel-1), and the construction of long-term multi-satellite soil moisture data sets such as provided by ESA's Climate Change Initiative.

However, the data quality and potential use of these datasets in (research) applications is for a large community still unknown. The objective of this workshop is to shed a light on these topics and to further explore the methodological advances in the validation and application of these global satellite soil moisture datasets. With this workshop we focused on both the derivation and exploration of soil moisture from both passive and active microwave satellite missions.

The workshop dealt with the following (research) questions:

- What is the quality of the current satellite products and what can we expect in the near future?
- Who is using satellite soil moisture data and for what purpose?
- What are the main limitations of satellite soil moisture data from a users perspective?

The workshop was held in Amsterdam on July 10-11, 2014 and consisted of 26 oral presentations and 14 poster presentation. The abstracts of these presentations can be found in this book and only the first author of each abstract is given.

Program

Thursday, 10 July 2014

09:00 Welcome and workshop objectives

Session 1.1: Sensors
Chair: Yann Kerr

10:50 Coffee break

Session 1.2: Validation, Data Products and Networks I
Chair: Peter van Oevelen

12:35 Lunch

Session 1.3: Validation, Data Products and Networks II
Chair: Matthias Drusch

13:50 The Updated CCI Soil Moisture Product: 35 Years of Observations for Climate Research
Dorigo, Wouter
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14:10 Assessing the Large-Scale Spatial Representativeness of Temporal Dynamics of Soil Moisture over the United States Using Point and Global Scale Datasets
Nicolai-Shaw, Nadine
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14:30 Evaluation of a Global Soil Moisture Product by Means of Finer Spatial Resolution SAR Data and Ground Measurements over Europe
Pratola, Chiara
UCC *17*

14:50 Toward Assimilation of Satellite Soil Moisture Products over Europe
Lahoz, William
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15:10 Coffee break

15:30 Discussion

16:00 Poster Session and Drinks

19:00 Dinner at In the Waag

Friday, 11 July 2014

Session 2.1: Soil Moisture Applications I
Chair: Wolfgang Wagner

10:30 Coffee break

Session 2.2: Soil Moisture Applications II
Chair: Jaap Schellekens

12:20 Lunch

Session 2.3: Soil Moisture Applications III
Chair: Richard de Jeu

14:30 Global Land Evaporation from Satellite Data: Applications for Hydrology and Climate
Miralles, Diego
Ghent University 23

14:50 Coffee break

Session 2.4: Algorithm Development
Chair: Susanne Mecklenburg

15:15 An Application of ANN Techniques for the Soil Moisture Retrieval from Active and Passive Microwave Satellite Acquisitions
Santi, Emanuele
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15:35 Considering Combined Roughness and Vegetation Effects in Soil Moisture Retrievals
Parrens, Marie
INRA CESBIO...24

15:55 A Study Towards the Integration of SMOS Soil Moisture in a Consistent Climate Record
de Jeu, Richard
VUA..25

16:15 Closure workshop

Poster Sessions

Abstracts

The NASA Soil Moisture Active Passive (SMAP) Mission Combined Instrument Surface Soil Moisture Product

Entekhabi, Dara
MIT, United States

NASA's Soil Moisture Active Passive (SMAP) Mission is scheduled for launch in early November 2014. The objective of the mission is global mapping of soil moisture and freeze/thaw state through combined use of active and passive sensors. SMAP utilizes L-band radar and radiometer sharing a rotating 6-meter mesh reflector antenna. The instruments will operate onboard the SMAP spacecraft in a 685-km Sun-synchronous near-polar orbit, viewing the surface at a constant 40-degree incidence angle with a 1000-km swath width. Merging of active and passive L-band observations of the mission will enable an unprecedented combination of accuracy, resolution, coverage and revisit-time for soil moisture and freeze/thaw state retrieval. The Level-2 Active-Passive soil moisture product (L2_SM_AP) at 9 km is retrieved from the disaggregated/downscaled brightness temperature obtained merging of active and passive L-band observations. The baseline L2_SM_AP algorithm disaggregates the coarse-resolution (~40 km -3 dB beam) brightness temperatures of the SMAP L-band radiometer using the high-resolution (~3 km) backscatter cross-sections from the SMAP L-band radar with synthetic aperture processing. The algorithm architecture and its key features such as consistency with radiometer-only retrievals, error propagation and uncertainty estimation will be outlined. Results of algorithm testing with airborne and observing system simulation experiments will be presented. The science questions to be addressed with these retrievals will be described with examples.

ESA's Soil Moisture and Ocean Salinity Mission - An Overview on the Mission's Performance and Scientific Results

Mecklenburg, Susanne
ESA

The Soil Moisture and Ocean Salinity (SMOS) mission, launched in 2009, is the European Space Agency's (ESA) second Earth Explorer Opportunity mission. The scientific objectives of the SMOS mission directly respond to the need for global observations of soil moisture and ocean salinity, two key variables used in predictive hydrological, oceanographic and atmospheric models. SMOS observations also provide information on the characterization of ice and snow covered surfaces and the sea ice effect on ocean-atmosphere heat fluxes and dynamics, which affects large-scale processes of the Earth's climate system. This paper will provide an overview on:

1. The performance of the mission after more than 4 years in orbit, including the technical and scientific status of the mission, the status of the RFI detection and mitigation and its effect on the data products as well as an overview on the MIRAS instrument performance. The paper will summarize the recent improvements in the level 1 and 2 processors.
2. The current and future SMOS data products.
3. On the overall validation approach and recent activities.
4. The collaboration with other space-borne L-band sensors, such as NASA's Aquarius and SMAP missions.

Towards Sentinel-1 Soil Moisture Data Services: The Approach Taken by the Earth Observation Data Centre for Water Resources Monitoring

Wagner, Wolfgang
TU Wien

The experiences gathered with the ENVISAT ASAR have demonstrated that Sentinel-1, its successor SAR mission, will be well suited for global monitoring of soil moisture at a scale of 1 km or higher. Sentinel-1 will thus provide soil moisture data at a much higher spatial resolution than other active and passive microwave sensors such as ASCAT, SMOS, AMSR-2, or even SMAP. The high spatial resolution of Sentinel-1 comes however at a cost. Firstly, the data volume acquired by Sentinel-1 will be very large, in the order of 1-2 Terabyte per day; over the complete mission the data archive will grow to several tens of Petabyte. Secondly, the soil moisture retrieval algorithms for Sentinel-1 will have to become more elaborated as compared to the lower resolution sensors in order to account for the higher diversity of land surface processes at finer scales. The high costs to establish such a large data centre and building up fully-automatic processing chains for the provision of Sentinel-1 soil moisture data services can hardly be stemmed by one organization alone. Therefore, close cooperation between public and private partners is deemed essential if one wants to succeed in building up robust and reliable soil moisture data services for Sentinel-1. This is the approach taken by the Earth Observation Data Centre for Water Resources Monitoring (EODC) which aims to foster the use of earth observation (EO) data for monitoring of global water resources. This presentation will introduce EODC and its partners, and describe the plans for the roll out of the first Sentinel-1 soil moisture services.

Recent Developments in ASCAT Soil Moisture Services

Figa Saldaña, Julia
Eumetsat

The Advanced SCATterometer (ASCAT) is a real aperture, vertical polarisation, C-band radar designed primarily to provide global ocean winds operationally. The basic measurement provided by the ASCAT is the normalised radar backscatter from the Earth surface. This has made it also one of the main microwave remote sensing instruments used for retrieving soil moisture globally, on temporal scales spanning from near real time (NRT) applications to climate monitoring. The ASCAT surface soil moisture services are provided within the EUMETSAT Satellite Applications Facility on support to Hydrology and Water Management (H-SAF) and the processing is based on the TU-Wien soil moisture retrieval algorithm, implemented in soil water retrieval package (WARP).

This paper discusses the recent soil moisture algorithm and service developments, including improvements in the vegetation characterisation, challenges in the retrieval algorithm, extension of time series and data dissemination formats (NetCDF).

[1]
S. Hahn, W. Wagner, M. Vreugdenhil, T. Melzer, A. Abdulrahman:
"Challenges for Soil Moisture Retrieval from C-band Backscatter";
Talk: EUMETSAT Meteorological Satellite Conference, Wien; 2013-09-16 - 2013-09-20; in: "Proceedings of the 2013 EUMETSAT Metereological Satellite Conference"

[2]
T. Melzer:
"Vegetation modelling in WARP6.0";

Talk: EUMETSAT Meteorological Satellite Conference, Wien; 2013-09-16 - 2013-09-20; in: "Proceedings of the 2013 EUMETSAT Metereological Satellite Conference"

Towards Validation of SMAP Downscaled Soil Moisture

Walker, Jeffrey
Monash University

The Soil Moisture Active Passive (SMAP) satellite will be launched by NASA in November 2014 with the aim to provide soil moisture data at 9km spatial resolution. The approach is to use 3km resolution radar data at L-band to downscale the 36km resolution L-band brightness temperature data to 9km. The well-established tau-omega model will then be used to derive the 9km resolution soil moisture product. However, apart from some fairly limited field experiments, including SMAPEx in Australia and SMAPVEX in Canada, this is a largely untested approach. Therefore it is critical that airborne field experiments be conducted soon after launch under a diversity of conditions to confirm the accuracy of the downscaled brightness temperature data. Unless the accuracy of these brightness temperature data can be confirmed, then comparisons against the derived downscaled soil moisture product will provide little insight to the validity of the approach.

A series of airborne field experiments are scheduled for the period immediately following commissioning of SMAP, including the Australian summer (Feb 2015) and spring (Sept 2015). These experiments will extend over three-week long intensive campaign periods that include airborne brightness temperature and backscatter measurements, together with soil moisture, roughness and vegetation sampling at focus farms. The brightness temperature data will be measured at 1km spatial resolution across multiple SMAP sized radiometer pixels as close to SMAP overpass times as practically possible. These brightness temperature measurements will then be corrected to the 6am SMAP overpass time and normalized to the 40° incidence angle of SMAP before aggregation to 9km spatial resolution and compared with SMAP downscaled brightness temperatures. The brightness temperature measurements will also be converted to soil moisture and validated with ground measured soil moisture prior to comparison with SMAP derived soil moisture products.

Synergies and Complementarities between ASCAT and SMOS Soil Moisture Products

Escorihuela, Maria Jose
isardSAT

In this study we compared two different surface soil moisture remote sensing products; one derived from active microwave data of the ASCAT scatterometer instrument onboard METOP and the other from passive microwave data of the SMOS mission the first dedicated to estimate soil moisture. SMOS measuring frequency (1.4 GHz) is theoretically more suited to measure soil moisture than ASCAT measuring frequency (5.255 GHz) because of its lower vegetation effects. On the other hand, ASCAT-like instruments have been providing measurements for more than 2 decades and have been a key input in building the CCI Soil Moisture Variable. In order to get the best global soil moisture products it is thus essential to understand their respective performances and restrictions.

The comparison has been carried out in Catalonia where we have implemented the SURFEX/ISBA land-surface model, which we forced with the SAFRAN meteorological analysis system. A downscaling algorithm has been also implemented and validated over the area to provide SMOS derived soil moisture fields at 1 km spatial resolution. Catalonia is located in the northeast of the Iberian Peninsula and its climate is typically Mediterranean, mild in winter and warm in summer. Given its varied landscape, in which plains alternate with mountainous areas, Catalonia has a wide range of bioclimatic habitats.

The comparison concerns ASCAT soil moisture product and SMOS at its native and increased resolution versus the hydrological model outputs. The comparison shows in general good agreement for both ASCAT and SMOS on the temporal series simulated over flat, non irrigated areas which are not close to the sea. This result gives us confidence, as both methods of estimating the soil moisture (simulation and remote sensing) are very different. However, the comparison also shows the limitations of the different products. On the one hand, SMOS has difficulties in areas close to the sea and in areas with steep relief. On the other hand, the hydrological model is not able to simulate non natural processes such as irrigation. ASCAT, in its turn, shows some limitations over agriculture surfaces where it shows an increase of soil moisture from June to October clearly correlated with vegetation cycle but seems to show better performances in areas close to the sea.

Monitoring Surface Soil Moisture by Combining SMOS and MODIS Products with In-Situ Measurements

Qu, John
George Mason University

Soil moisture is one of the most important indicators for agriculture drought, and, is a fundamentally critical parameter for decision support in crop and irrigation management. Significant technological advances have been made for remote sensing of surface soil moisture from space with passive microwave measurements. However, the spatial resolution of soil moisture products from passive microwave remote sensing is still relatively low. For regional and local applications in agricultural management, it is critical to monitor soil moisture at high spatial resolution. During the past years, we have conducted a series of studies and developed a multi-scale approach for soil moisture estimation at high spatial resolution by integrating microwave and optical/infrared remote sensing measurements as well as in-situ observations. We have tested our approach with SMOS and MODIS measurements in multiple regions, including China, South Africa, Brazil, and Mozambique. However, there are vast differences in each network of in-situ measurements of soil moisture. There is an urgent need to develop standards and guidelines for global in-situ observations of soil moisture. WMO is planning to initiate and coordinate a Soil Moisture Demonstration Project (SMDP) conducted by Agricultural Meteorology Programme (AgMP) and Commission for Agricultural Meteorology (CAgM). The major goal of this project is to develop and recommend standards and guidelines for observations and maintenance to promote a more standardized and sustainable ISMN network. The SMDP will also provide valuable support to international soil moisture communities.

The Joint Assessment of Soil Moisture Indicators (JASMIN) Project: A Community Effort to Respond to User Needs in Agricultural and Water Resources

Berbery, Ernesto Hugo
University of Maryland

The Joint Assessment of Soil Moisture Indicators (JASMIN) Project is a community effort that has the main objective of bringing together currently independent efforts at estimating soil moisture in southern

South America. This is a region with large expanses of rainfed agriculture and as such it is highly reliant on soil moisture availability. Climate scientists and stakeholders in agriculture and water resources in this region are in need of reliable products describing current soil moisture that can be used as a model benchmark, for planning purposes, and as a drought indicator. Adequate estimates of soil moisture are critical for crop management and planning purposes. JASMIN seeks to identify strengths and weaknesses of the different approaches, which comprise in-situ measurements, water balance estimates with different levels of complexity, land surface model computations and satellite estimates.

The JASMIN Project consists of four stages. A first stage has been completed with a documentation of the different products and methods. The ongoing second stage consists of the development of a database with common protocols for the assessment of the products. This will be followed up exploring ways of harmonizing those estimates into a consistent product that can be easier to interpret by the users than the individual components. A final stage will be the dissemination of the combined products to the community.

The Updated CCI Soil Moisture Product: 35 years of Observations for Climate Research

Dorigo, Wouter
TU Wien

The first long-term multi-satellite soil moisture, developed within the framework of the Climate Change Initiative (CCI) of the European Space Agency (ESA), has created new avenues for global climate and water cycle research. Since its release in 2012 more than a thousand users downloaded the soil moisture product for using it in a wide range of applications in the fields of hydrology, meteorology and climate. This makes it one of the most intensively used soil moisture products currently available.

The dataset amalgamates existing soil moisture products from historical and current missions into a consistent global data set with a 0.25 degree spatial resolution and a daily time stamp. Recently, the CCI soil moisture product has undergone several algorithmic improvements and has been complemented with observations from the Coriolis WindSat and GCOM-W AMSR2 sensors to continue the legacy of C-band observations in the passive microwave domain. The observation record now spans a 35 year period between late 1978 and December 2013.

In this presentation we will give an overview of the recent improvements of the dataset and highlight its contributions to an improved understanding of climate variability and change. This includes land-atmosphere interactions, land-biosphere interactions, and water cycle trend analysis. The usability of the CCI dataset will be confronted with that of alternate sources of soil moisture, including reanalysis and drought index products.

Assessing the Large-Scale Spatial Representativeness of Temporal Dynamics of Soil Moisture over the United States Using Point and Global Scale Datasets

Nicolai-Shaw, Nadine
ETH Zurich

Several studies highlight the important role of soil moisture in the global and regional water and energy exchanges. Soil moisture is highly variable in both space and time, spanning local to continental scales as well as daily to decadal time scales. In this study we assess the large-scale spatial representativeness of soil moisture over the United States, using point-scale observations and global gridded data sets with regional-scale resolution. The following data sources are used: At the point scale in-situ measurements obtained through the International Soil Moisture Network (ISMN) and the North American Soil Moisture Database (NASMD), both defined as reference data sets; at the regional scale gridded soil moisture estimates from the land surface model ERA Interim/Land as well as from two remote sensing based data sets from the ESA Climate Change Initiative (ECV-SMv1 (publicly available) and ECV-SMv2 (internal release within the ESA Climate Change Initiative for validation). The spatial representativeness of soil moisture is calculated for the period April to September 2003-2010 and inter-compared between the single products for absolute values, as well as for the inter-annual and short-term anomalies. The spatial patterns are then related to several dynamic forcing and static site characteristics.

Evaluation of a Global Soil Moisture Product by Means of a Finer Spatial Resolution SAR Data and Ground Measurements over Europe

Pratola, Chiara
Coastal and Marine Research Centre

Within the ESA funded Soil Moisture Climate Change Initiative project, both passive and active C-band microwave sensors are exploited to produce a complete and consistent global Essential Climate Variable (ECV) soil moisture (SM) record. A first prototype of the global ECV SM product was released by the University of Technology of Vienna in 2012 and provides almost daily SM maps on coarse spatial resolution, which may be not adequate to efficiently describe the dynamics of SM behavior. To evaluate the quality of the ECV SM product and its capability in representing the actual soil moisture dynamics, we compared it with the finer spatial resolution data retrieved from ENVISAT ASAR WS images acquired between 2002 and 2012, and in-situ soil moisture measurements taken in three regions across Europe: Southern Ireland, Duero basin in Spain and Sodankylä in Finland. These areas are characterized by different climate, topography, soil type and land uses, which allow understanding the main factors affecting the soil moisture spatial variability and the ECV SM values.

In order to analyze the soil moisture temporal behavior, the derived ASAR pixel-based information has been averaged over the corresponding ECV pixel, which includes at least one in-situ station. Then, a comparison between ASAR WS, ECV and in-situ soil moisture time series has been carried out by evaluating the correlation and unbiased RMSD between the datasets. The spatial variability of the soil moisture within the ECV size pixel has been successively studied by exploiting the finer spatial resolution of the ASAR WS images.

Toward Assimilation of Satellite Soil Moisture Products over Europe

Lahoz, William
NILU

The ESA CCI for soil moisture will produce a multi-year soil moisture dataset from various satellite datasets: ASCAT (Advanced SCATterometer), AMSR-E (Advanced Microwave Scanning Radiometer - Earth Observing System), SSMR (Scanning Multichannel Microwave Radiometer), SSM/I (Special Sensor Microwave Imager), TMI (TRMM Microwave Imager) and the ERS Scatterometer. Furthermore, in the future, the following satellite datasets are also likely to be used: Windsat, AMSR-E-2, Feng Yun and SMOS (Soil Moisture and Ocean Salinity).

To add value to this product, data assimilation experiments where these satellite data are assimilated singly and together over the European domain of the NILU Ensemble Kalman Filter (EnKF) system, are being carried out. In the first instance, these experiments will be carried out for the period of northern summer 2011 using ASCAT, AMSR-E and SMOS soil moisture. The results of these experiments provide information on the relative strengths and weaknesses of each satellite dataset, and provide soil moisture analyses, which can add value to the satellite datasets, singly and merged, and help assess their error characteristics.

In this presentation, we show the roadmap toward these assimilation experiments, including an assessment of the error characteristics of the soil moisture analyses by comparison against independent ground-based in situ soil moisture data from the ISMN (International Soil Moisture Network). We provide an initial assessment of the relative contribution of each satellite dataset to soil moisture analyses over Europe, and of the ensuing benefits of the combined assimilation of these satellite datasets.

Downscaling Coarse-scale Satellite Soil Moisture for Validation Studies and Applications

Wood, Eric
Princeton University

Validation of soil moisture retrievals using in-situ measurements remains a challenge due to the footprint mismatch. Similarly, many potential applications of satellite soil moisture products require fine-scale estimates, on the order of 100 to 1000 *m*. Current retrievals of satellite soil moisture have spatial resolutions that range from ~10 to 50 *km*. This mismatch in scales provides a significant challenge in effectively downscaling the coarse-scale retrievals. Sub-grid soil moisture variability is driven by variability in local topography, vegetation, soil texture, and precipitation. Here we present a method that combines the spatial information of high-resolution land surface modeling and (if available) ground truth, in-situ networks through a multi-scale assimilation methodology. The core of the proposed framework is an accurate depiction of the controls on the spatial variability, the grouping of grids into multidimensional histograms of similar features that control variability, and the sub-sampling (modeling) from these histograms so that sub-grid variability is preserved with only modeling a small percentage of the fine-scale grids. An alternative modeling approach will be presented where the output of the full-scale land surface model, along with the covariates features that drive variability is used to develop a “machine learning” algorithm that mimics the full physics-resolving land surface model. Both approaches allow for accurate downscaling of the coarse-scale retrievals as well improved areal averaging for footprint-scale validation and optimal validation network design.

As a test study, we run the distributed dynamic TOPLATS land surface model between 2002 and 2009 over the 335 *sq km* Little River Experimental watershed (LREW) in the United States, at a 10-meter spatial resolution, which results in 3.35 million grid cells. The simulations utilize a series of high resolution data sets that include a reprocessed SSURGO (soil texture), NLCD (land cover type), NCEP' Stage IV radar product (precipitation), NLDAS (for other meteorology), MODIS (vegetation condition), and USGS NED topography. AMSR-E 25 *km* retrieved soil moisture is then downscaled to the 10 *m* resolution. The USDA in-situ probes located in the catchment can used in the assimilation at the model's collocated grid cells, and their average can be assimilated with the retrieved coarse-scale satellite soil moisture retrievals, thus providing accurate fine scales fields for applications such as agriculture management. Applications at very large scales (e.g. The continental U.S.) could be limited by the realtime computer requirements. So we investigate developing a predictive model based on a machinelearning algorithm trained using time-series from the 10 *m* TOPLATS simulations and the covariates that control the space-time variability in soil moisture across the catchment.

The high resolution modeled soil moisture is able to capture the time evolution of the spatial variability in soil moisture over a number of years; demonstrating that the high resolution simulated soil moisture fields captures the space-time variability in soil moisture that is critical in down-scaling or upscaling soil moisture. The up-scaled results from the 10 *m* simulations are important for validating the coarse scale satellite retrievals. Results for the Little River catchment suggest that the current in-situ network under samples areas of high soil moisture in the catchment, leading to a systematic underestimation of the mean. The average of the current network improves when accounting for the main drivers of soil moisture spatial variability. It is demonstrated that the in-situ network performance can be reproduced and improved with fewer probes in key points throughout the catchment. Thus, this framework can be applied to other catchments worldwide for network design, footprint averaging and coarse scale validation.

SMOS – Land Product Developments and Applications

Drusch, Matthias
ESA

SMOS is ESA's water mission observing key-elements of the Earth's water cycle, providing high quality measurements to a large user community since 2009. SMOS also features, as the 1st Earth Explorer, a dedicated Near-Real-Time (NRT) processing chain for its Level 1 observations in the operational ground segment.

Over land, a large variety of matured products address a growing number of applications. Polarized L-band brightness temperatures have been made available in NRT for the timely assimilation into ECMWF's operational Integrated Forecasting System. First results indicate a positive impact in the soil moisture analysis when compared against in-situ observations (e.g. the US's SCAN network) and improved forecasts for low-level air temperature and relative humidity.

SMOS brightness temperatures have also been assimilated into the Variable Infiltration Capacity model predicting streamflow for the Upper Mississippi Basin und its sub-catchments, again slightly increasing the skill of the forecast on sub-catchment scale when using SMOS measurements in the analysis.

For further applications related to numerical weather prediction and hydrological forecasting a NRT L2 soil moisture product is under development. This product is based on a neural network trained with outputs from the operational L2 soil moisture processor and aggregated NRT brightness temperatures and has shown that the accuracy of the resulting soil moisture estimates is comparable to the current data products available, also reducing the latency of the product substantially.

The presentation will also provide an update on the evolution of the soil frost depth product and the assimilation of SMOS observations into global carbon models.

Using Satellite Soil Moisture in Large-Scale Water Resources Estimation

van Dijk, Albert
Australian National University; CSIRO

The availability of several decades of harmonized passive and active satellite-derived soil moisture (SSM) records has enabled new applications in model evaluation and data assimilation. Here, we draw some lessons from our recent attempts to develop such applications. There has been relatively extensive and successful validation of SSM for Australia. The estimates have also proven valuable to independently evaluate model-based soil moisture estimates and to study climate-water interactions. Data assimilation experiments have demonstrated very good potential to improve soil moisture estimation in areas with poor rainfall information, but typically limited benefit for surface and groundwater resource estimation. We attempted to use SSM in assimilation or independent validation as part of a global water cycle reanalysis. The shallow signal source depth made this very difficult, although increasing the sophistication of the assimilation scheme may help overcome this to some extent. Currently the most promising operational application of SSM appears to be in agricultural drought monitoring and forecasting, particularly when combined with satellite vegetation observations in a water balance model. Such an experimental system is currently being developed. Truly (non-research) operational use of NSSM retrievals is likely to require greater continuity in missions and data supply.

Soil Moisture Monitoring for Agricultural Risk Assessment in Canada Using a Multi-Sensor Dataset

Champagne, Catherine
Agriculture and Agri-Food Canada

Soil moisture is a critical variable for characterizing agricultural growth, since it provides a measure of plant available water, controls evaporation rates that impact meteorological conditions, and control rates of key biogeochemical processes in the soil that impact soil fertility. Satellite soil moisture offers a promising way of monitoring conditions over large areas where ground measurements are often sparse or non-existent. For many agricultural applications, the relationship between current conditions and normal conditions are sometimes just as important as the absolute measurements. One of the limitations of satellite data record is that there is often not a long enough record of data to establish normal conditions. The recent development of the soil moisture Essential Climate Variable (ECV) data, which provides a multi-sensor satellite record of soil moisture, provides an interesting opportunity to monitor soil moisture conditions relative to normal over a longer period of record. The paper will discuss recent use of the soil moisture ECV data set, and report on the usefulness of the data set for establishing relevant indicators of agricultural risk in Canada. The paper will further touch on the needs for soil moisture by Agriculture Canada.

Joining Forces for Food Security – Linking Earth Observation and Crowd-Sourcing for Improved Decision-Support to Aid Organizations

Enenkel, Markus
TU Wien

Droughts statistically exceed all other natural disasters in spatio-temporal extent, number of people affected and financial loss. Triggered by crop failure, food insecurity is a major manifestation of agricultural drought and water scarcity. However, other socio-economic precursors, such as chronically low levels of disaster preparedness, hampered access to food security or a lack of social safety nets are equally important factors. Consequently, this study is focused on two complementary developments that are carried out within a project named SATIDA (Satellite Technologies for Improved Drought-Risk Assessment) – a new satellite-derived agricultural drought index and a mobile phone application. The Combined Drought Index (CDI) is enhanced by replacing field measurements of temperature and rainfall with modeled/assimilated data. The vegetation component is replaced by a smoothed NDVI dataset. A soil moisture component is introduced to close the gap between rainfall deficiencies and the first visible impacts of atmospheric anomalies on vegetation. The mobile phone application enables the validation of drought index outputs and gives aid organizations an opportunity to increase the speed of socio-economic vulnerability assessments. Supported by Doctors without Borders (MSF) this approach aims at decreasing uncertainties in decision-making via a more holistic framework for risk assessment.

Data Assimilation of Satellite Observed Soil Moisture in the Vegetation Model SiBCASA, and the Effects on Carbon Turnover

van der Molen, Michiel
WUR

Remote sensing based soil moisture is assimilated in the vegetation model SiBCASA to improve the temporal variability of soil moisture and its effects on transpiration, carbon uptake and turnover. We verify if the data assimilation improves the model results by comparison with flux tower data at 14 stations in Siberia. We pay particular attention to the representation of drought years in the 10 years period of record of the observations.

Correction of Real-Time Global Precipitation Measurements with Multi-Sensor Satellite Observations

Wanders, Niko
Utrecht University

Precipitation is an important hydro-meteorological variable, and is a primary driver of the water cycle. In large parts of the world, real-time ground-based observations of precipitation are sparse and satellite derived precipitation products the only information source.

We used changes in satellite derived soil moisture (SM) and land surface temperature (LST) to reduce uncertainties in the real-time TRMM Multi-satellite Precipitation Analysis product (TMPA-RT). The Variable Infiltration Capacity (VIC-model) was used to model the response of LST and SM on precipitation, and a particle filter was used to update TMPA-RT. Observations from AMSR-E (LPRM and LSMEM), ASCAT, SMOS and LST from AMSR-E were assimilated to correct TMPA-RT over the continental United States.

Assimilation of satellite-based SM observations alone reduced the false detection of precipitation (by 85.4%) and the uncertainty in the retrieved rainfall volumes (5%). However, a higher number of observed rainfall events were not detected after assimilation (34%), compared to the original TMPA-RT (46%). Noise in the retrieved SM changes resulted in a relatively low potential to reduce uncertainties. Assimilation of LST observations alone increased the rainfall detection rate (51%), and annual precipitation totals were closer to ground-based precipitation observations. Combined assimilation of both satellite SM and LST, did not significantly reduce the uncertainties compared to the original TMPA-RT, because of the influence of satellite SM over LST. However, in central United States improvements were found after combined assimilation of SM and LST observations. This study shows the potential for reducing the uncertainties in TMPA-RT estimates over sparsely gauged areas.

Relations between Meteorological, Soil Moisture and Hydrological Drought in a Region with Complex Regional Groundwater Flow (Gelderland, the Netherlands)

Teuling, Ryan
WUR

Drought is a severe natural disaster all around the world. In the Netherlands, recent drought events have caused serious impacts on, amongst others, navigation, agriculture, and water supply for vulnerable ecosystems. Different indices exist to measure the severity of drought events. Currently, the Dutch Royal Meteorological Service (KNMI) provides information on the cumulative potential rainfall deficit (precipitation minus potential evaporation) for the period April to October as a drought indicator. In this study, our aim was to test this metric and compare it with other drought indices, among which a soil moisture drought index derived from ASCAT data. We were especially interested to see if the KNMI metric can capture the propagation of meteorological drought into hydrological drought and the resulting regional complexity resulting from groundwater flow by comparing it with indices based on hydrological variables from in situ and satellite data. We used an extensive observational dataset for the province of Gelderland in the eastern part of the Netherlands, where free-draining areas exist and human-influence is low compared to the western part of the Netherlands. Based on numerous observations, we could quantify relations between meteorological drought, soil moisture or agricultural drought and hydrological drought, and evaluate the use of satellite soil moisture for regional-scale drought monitoring.

Recent Progress in Land Data Assimilation at the Met Office

Candy, Brett
Met Office

An Extended Kalman Filter (EKF) has been operational at the Met Office for over 1 year, providing global analyses of soil moisture and temperature. It uses both in situ and satellite observations (soil wetness from ASCAT).

Monitoring the performance of the scheme over this long period has allowed us to devise several potential improvements to the system including more realistic observation and background errors.

In addition to this we have tested the use of two satellite instruments (ASCAT on MetopA and MetopB) to provide surface soil moisture estimates. The impacts of these developments to the EKF on both soil moisture analyses and atmospheric numerical weather prediction forecasts will be examined. At the Met Office a convective scale model is also an important forecasting tool and up to now the global soil moisture scheme has provided the initial conditions for this limited area model. We will also present initial work on implementing the EKF into this model configuration. As the convective scale model is at high resolution this brings new challenges, particularly the need for high resolution data sources.

Soil Moisture and Vegetation Trend Shifts in the African Sahel?

Verbesselt, Jan
WUR

Soil moisture is one of the main drivers of the exchange of water, energy, and carbon between the land surface and the atmosphere. Vegetation plays a large role in this interaction and its response to variations in soil moisture (among other factors) can be measured using satellite sensors. Trends, anomalies and associated ecosystem impacts can now be studied with a combination of long-term soil moisture (1978-2011) and vegetation activity records (1982-2011). However, the integration of consecutive satellite sensors to create these time series, together with residual cloud and atmosphere effects, can introduce data artifacts and affect trend analysis. Here, we revisit techniques for the detection of structural trend shifts in vegetation activity and soil moisture observations for the overlapping time period from 1982-2011. Subsequently, we apply a classification scheme to describe ecologically meaningful change types. The analysis uses satellite-based ESA Climate Change Initiative (CCI) soil moisture and GIMMS NDVI3g time series. Our focus is on the African Sahel, where soil moisture and vegetation growth are tightly linked. The fact that soil moisture drives vegetation growth in semi-arid ecosystems helps to disentangle potential data artefacts from real changes driven by climate and human influences. Monotonic decreasing soil moisture trends have been reported, while rainfall has been increasing since the Sahel drought of the 1970s and early 1980s. By accounting for structural changes and potential data artefacts in soil moisture and vegetation activity trends, we aim to find answers for the increasing rainfall and decreasing soil moisture ambiguity.

Global Land Evaporation from Satellite Data: Applications for Hydrology and Climate

Miralles, Diego
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Terrestrial evaporation is a critical process that links the water, energy and carbon cycles. Changes in atmospheric composition and land use lead to immediate changes in evaporation that can propagate to other components of the climate system in the form of feedbacks. Despite its importance, evaporation at continental scales remains poorly understood, due to the difficulties measuring the flux at large spatial scale and during long periods. Motivated by this need of continental-scale climatic records of evaporation, several initiatives have raised in recent years to derive estimates from satellite observations. However, evaporation is not directly observable from satellite data, and current efforts are limited to combining observable variables that are important for the evaporative process (e.g. temperature, radiation, soil moisture, etc). In the present, a total of six–eight methodologies exist that are being used for different hydrological and climatic applications. First, these datasets can be used to benchmark climate model estimates of evaporation. Second, they can be used on their own to get a better understanding of the dynamics of the water cycle at different spatiotemporal scales, and to give evidence of the effect of radiative forcing on the terrestrial water cycle. Finally, they can help understanding land-atmospheric interactions better, opening new pathways to study the effect of soil moisture during extreme events like droughts and heatwaves. This talk show results from recent studies that represent clear examples of the applicability of satellite-based land evaporation data for the fields of hydrology and climate.

An Application of ANN Techniques for the Soil Moisture Retrieval from Active and Passive Microwave Satellite Acquisitions

Santi, Emanuele
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Frequent and spatially distributed measurements of the moisture of soil (SMC) are advisable for the applications related to the environmental disciplines, such as climatology, meteorology, hydrology and agriculture. The satellite sensors operating in the low part of microwave spectrum are an important tool for this purpose, and their measurements can be related to the moisture content of the observed surface, provided that all the contributions from soil and vegetation to the measured signal are properly accounted for. ANN based algorithms for the SMC retrieval have been developed and adapted to several radar and radiometric satellite sensors, in order to generate SMC products at a resolution varying from hundreds of meters to tens of kilometers. These algorithms have been adapted to the C- band acquisitions from Synthetic Aperture Radar of Envisat/ASAR and real aperture radar of ASCAT, to the radiometric multifrequency measurements of AMSR- E and the L- band active and passive acquisitions of the incoming SMAP mission. The latter satellite will carry on board a radar and a radiometer operating at the same frequency but at a different spatial resolutions. Large datasets of co-located satellite acquisitions and direct SMC measurements on several test sites located worldwide have been used along with simulations from forward electromagnetic model for setting up, training and validating these algorithms. An overall quality assessment of the obtained results in terms of accuracy and computational time was carried out, and the main advantages and limitations for an operational use of these algorithms have been evaluated.

Considering Combined Roughness and Vegetation Effects in Soil Moisture Retrievals

Parrens, Marie
INRA/CESBIO

For more than four years, the Soil Moisture and Ocean Salinity (SMOS) mission has provided multi-angular and full-polarized brightness temperature (TB) measurements at L-band. Geophysical products such as soil moisture (SM) and vegetation optical depth (τ) are retrieved by an operational algorithm using TB observations at different incidence angles and polarizations. However, the quality of the retrievals depends on several surface effects such as vegetation, soil roughness and texture, etc. In the microwave forward emission model used in the retrievals (L-MEB), soil roughness is modeled with empirical parameters (Qr, Hr, Nrp, with p = H or V polarizations). Presently, the calibration of these parameters is estimated from in situ and airborne studies made at local scale which is not representative of the large SMOS footprints (43 km in average) at global scale.

In this study, we propose to evaluate the impact of the calibrated values of Nrp and Hr on the SM and τ retrievals . The study is based on SMOS TB measurements (SMOS Level 3 product) over 10 stations of the SCAN network located in North America. These stations were selected as they correspond to relatively homogeneous vegetation covers (crops or grassland) at the scale of the SMOS pixel. In this study, Qr was set equal to zero and we assumed that NrH = NrV (Wigneron et al., 2011, Lawrence et al., 2013). Retrievals are performed by varying Nr from -1 to 2 by steps of 1 and Hr from 0 to 1 by steps of 0.1. The results shows that combining vegetation and roughness effects within a single parameter provides best results in terms of soil moisture retrievals, as evaluated against the in situ SM data. These new results may have key consequences in terms of calibration of roughness effects within the algorithms of the SMOS (ESA) and near future SMAP (NASA) space missions.

A Study Towards the Integration of SMOS Soil Moisture in a Consistent Climate Record

de Jeu, Richard
VU University Amsterdam

Recently, a one year study funded by the European Space Agency (ESA) was set up to provide guidelines for the development of a global soil moisture climate record. Three different data fusion approaches were designed and implemented on 10 year passive microwave data (2003-2013) from two different satellite sensors; the ESA Soil Moisture Ocean Salinity Mission (SMOS) and the NASA/JAXA Advanced Scanning Microwave Radiometer (AMSR-E). The AMSR-E data covered the period from January 2003 until Oct 2011 and SMOS data covered the period from June 2010 until the end of 2013.

The fusion approaches included a neural network approach, a regression approach, and an approach based on the baseline algorithm of ESAs current Climate Change Initiative soil moisture program, the Land Parameter Retrieval Model (LPRM). With this presentation we will show the preliminary results from this study based on 3 months progress, including a detailed description of the different approaches and the first validation activities. After 12 months this project should give us the scientific direction towards a seamless integration of microwave satellite datasets in order to develop a consistent soil moisture climate record.

Estimating Rainfall from Global Satellite Soil Moisture Data: Recent Improvements and Applications

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Research Institute for Geo-Hydrological Protection, CNR

Accurate estimates of rainfall are of vital importance for mitigation strategies of natural hazards such as floods and landslides as well as for disease and famine prevention and many other applications. However, over many areas, ground observations are lacking and satellite data are the only source of observations. The most common way of retrieving rainfall is by addressing the problem "top-down" by inverting the atmospheric signals reflected or radiated by atmospheric hydrometeors. However, most applications are interested in how much water reaches the ground, a problem that is notoriously difficult to solve from the "top-down" perspective. This is probably one of the reasons for the continued prominence of in situ gauge (and precipitation radar) observations in the majority of applications.

A "bottom-up" approach recently developed by Brocca et al. (2014) is illustrated here that, by doing "hydrology backwards", uses variations in soil moisture (SM) sensed by microwave satellite sensors to infer preceding rainfall amounts. In other words, the soil is used as a natural rain gauge. The method, called SM2RAIN, is applied on a global scale to three different satellite SM datasets from the

Advanced SCATterometer (ASCAT), the Advanced Microwave Scanning Radiometer (AMSR-E) and the Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) to obtain three new daily global rainfall products. The real-time version of the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis product (TMPA) product, i.e. the TRMM-3B42RT, is adopted as state-of-the-art satellite rainfall product.

The new rainfall datasets are compared with ground observations on a global scale and by considering high quality datasets in Italy and Australia showing satisfactory results. For instance, the global median correlation values (in the latitude band +/-50) are equal to 0.54, 0.28 and 0.31 for ASCAT, AMSR-E and SMOS derived products, respectively. For comparison, the median correlation for the TRMM-3B42RT product is equal to 0.53. Interestingly, the performance of the products is found to outperform TRMM-3B42RT in terms of average global root mean square error statistics, and also in terms of detection of rainfall events (Brocca et al., 2014).

In this study, the recent steps in the application of SM2RAIN are also shown and, particularly, (1) the integration of the SM-derived products with TRMM-3B42RT through a simplified nudging approach and (2) the merging of multiple SM datasets for improving the accuracy and temporal resolution of the estimated rainfall products. In both cases, further improvements in the performance are obtained thus highlighting the capability of SM data to be used operationally for enhancing the accuracy and reliability of remote sensing estimates of rainfall, mainly for their application in hydrological studies.

Reference

Brocca, L., Ciabatta, L., Massari, C., Moramarco, T., Hahn, S., Hasenauer, S., Kidd, R., Dorigo, W., Wagner, W., Levizzani, V. (2014). Soil as a natural rain gauge: estimating global rainfall from satellite soil moisture data. Journal of Geophysical Research, 119(9), 5128-5141, doi:10.1002/2014JD021489.

A Methodology to Determine Radio Frequency Interference in AMSR2 Observations

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A study to determine Radio Frequency Interference (RFI) in low frequency passive microwave observations of the Advanced Microwave Scanning Radiometer-2 (AMSR2) is performed. The AMSR2 is a passive microwave radiometer onboard the Global Change Observation Mission – Water (GCOM-W) satellite and is the successor of the Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E). Previous studies have shown the existence of RFI in AMSR-E data due to man-made emissions, whereby the 6.9 GHz channel is mainly contaminated. Since scientist use C-band frequency observations for the retrieval of soil moisture products, it is essential to detect RFI properly. Former studies used a spectral difference method for RFI detection in AMSR-E data, but the method often fails for weak RFI sources and in extreme environments. In this study, the additional 7.3 GHz channel of the AMSR2 sensor is used in a new RFI detection method to select reliable brightness temperature observations in the lowest frequency free of any man-made contamination. Correlation coefficients of time series between 6.9 and 7.3 GHz are used to detect C-band RFI sources. A decision tree approach is set up to determine the RFI-contaminated channels and decides whether 6.9, 7.3 or 10.7 GHz observations should be used. This approach needs a minimum satellite time record of 6 months in order to become statistically valid. Some pixels are flagged as ‘contaminated data’ when RFI is present in multiple channels. When 0.93 is used as a threshold value for a ‘good correlation’, about 95% of the land pixels are uncontaminated at 6.9 GHz. This number increases up to 97% when the 7.3 GHz channel is used towards 98% when also the 10.7 GHz is included. This study clearly demonstrated the added value of additional low frequency channels, because the total contaminated areas in the 6.9 GHz channel were reduced by 60% when 7.3 and 10.7 GHz were used.

The Romanian Soil Moisture & Temperature Observation Network for Satellite Soil Moisture Products Validation

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As satellite soil moisture (SSM) products are looking more and more promising for a wide range of applications, the Romanian Met Service (NMA) decided to explore the potential of space borne microwave data derived soil moisture products in practical applications. A crucial step in the evaluation of SSM products is the validation with modeled, in-situ data or other satellite products. Validation of SSM products with in-situ data depends on the availability of an adequate soil moisture network. NMA is operating a network of 158 meteorological stations. At 55 stations, soil moisture & temperature are manually measured every 10 days, for agro-meteorology applications. But the existing network is too sparse for any practical validation. However, new sensors can be easily installed and interfaced with the existing Vaisala meteorological stations – providing continuous measurements while in-house developed cheap autonomous stations can be added to increase the density of the network in selected study areas. The concept of the Romanian Soil Moisture & Temperature Observation Network and its implementation is discussed together with a possible configuration for SMOS soil moisture product validation.

Improved Downscaled Soil Moisture Product by Masking Precipitation

Gevaert, Anouk
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Space-borne passive microwave radiometers have great potential for observation of land surface parameters such as soil moisture. However, the coarse spatial resolution of the sensors limits the value of the data in studies at regional scales. Soil moisture products can be downscaled by a modulation technique in which low-frequency C-band data is adjusted based on data from the higher frequency Ka-band. Previous studies demonstrated that downscaling enhances detail and that wet and dry zones in particular are more pronounced. However, the Ka-band is more sensitive to precipitation, which introduces errors into the downscaled product. To improve quality of the product, the application of a precipitation mask is introduced in a case study over the Australian continent. Data from the Advanced Microwave Scanning Radiometer (AMSR-E) was used to create precipitation masks based on several procedures for precipitation detection and geographic screening. The masks were compared to the AMSR-E precipitation product and evaluated based on two assumptions. First, type II errors, or failure to detect rainfall, have more effect on the quality of the downscaled product than type I errors, or false identification of rainfall. Second, accurate detection of high intensity rainfall is more important than accurate detection of low intensity rainfall. A precipitation mask was chosen based on the evaluation and subsequently applied to several large catchments. A comparison is made between the original and downscaled soil moisture products, with and without the precipitation mask. The improved downscaled soil moisture product can benefit hydrological studies at regional scales.

Systematic L-band Fieldscans over Agricultural Fields in the Netherlands and Belgium

Haarbrink, Ronald B.
Miramap

Miramap systematically measures agricultural fields across the Netherlands and Belgium using its mobile passive microwave radiometer system. L-band brightness temperature data of over fifty fields and hundreds of hectares have been collected earlier this year together and simultaneously with EM38 electric conductivity data. The fields have different soil and roughness properties. The resulting data are high resolution geo-referenced maps with 1-meter ground sample distance of both L-band brightness temperature in Kelvin and conductivity data in milli Siemens per meter. These unique datasets and systematic measurement approach offer an outstanding opportunity for the calibration and/or validation of current and future satellite derived soil moisture products, including those from Sentinel-1, SMAP, SMOS and AMSR-2.

Soil Moisture Assimilation in the Framework of Regional Decadal Climate Predictability

Kothe, Steffen
Goethe University Frankfurt

In the framework of the MiKlip project a model system is to be created, which is intended to deliver reliable climate forecast on a decadal time scale. The MiKlip sub-projects DecReg and DEPARTURE assess the regional decadal predictability in Europe and Africa, respectively. Due to its long-term memory, the initial state of the deep soil particularly represents an important contribution to the uncertainty in seasonal to decadal predictions. Since the knowledge about the deep soil state usually is very limited, this study investigates the possibility of optimizing the initial soil state by assimilating satellite-based soil moisture retrievals. The goal of the sequential, ensemble-based data assimilation scheme is to transfer the observational information down to the unobservable deep soil. In a first step, this general concept is confirmed with toy models. In a next step, the algorithm is tested with TERRA-ML, the land surface model of the regional climate model COSMO-CLM. Using an ideal case with few data gaps and a known data uncertainty, it is possible to optimize the soil conditions effectively. However, the success is quite sensitive to data uncertainty and temporal data coverage. Finally, the benefit of an optimized initial soil state will be demonstrated by decadal COSMO-CLM simulations for Europe and Africa.

Impacts of Assimilation of Remote Sensing Soil Moisture Products into a Continuous Distributed Hydrological Model

Laiolo, Paola
CIMA Research Foundation

Soil moisture is a key variable for many scientific applications such as climate modeling, water management and operational forecasting of flood, landslide, weather, and drought. In particular a correct estimation of soil water content can highly affect the improvement of the accuracy of flood predictions. This variable can be monitored using in situ data, but local measurements are expensive, time consuming and hard to spatialize. Consequently remote sensing can offer a chance to provide good space-time estimates of several hydrological variables and then improve hydrological model performances.

The goal of this work is to test the effects of the assimilation of satellite soil moisture on the hydrological cycle. Among the currently available different satellite platforms, four soil moisture products, from both the ASCAT scatterometer and the SMOS radiometer, have been assimilated into a continuous hydrological model using a Nudging scheme. Three soil moisture products are from ASCAT and are provided by the EUMETSAT's H-SAF (Satellite Application Facility on Support to Operational Hydrology and Water Management) project; while for SMOS the reprocessed Level 2 soil moisture product has been considered. The model has been applied to a test basin (area about 800 km2) located in Northern Italy for the period July-December 2012. The experiments have been carried out for all the above-mentioned satellite-derived measurements and the impacts on the model discharge predictions and the other hydrological variables have been tested.`

Validation of the ESA CCI Soil Moisture Product

Mittelbach, Heidi
ETH Zurich

Soil moisture is a crucial variable within the climate system through its coupling to evapotranspiration and the resulting impact on temperature and precipitation. To further understand the underlying processes of land-atmosphere interactions as well as for the evaluation of climate models and the reduction of their uncertainties, long-term and global soil moisture observations are essential. Within ESA's Climate Change Initiative (CCI) a remotely sensed soil moisture time series was developed and is currently being validated. Similar to its forerunner ECV-SMv1 (publicly available), the new time series ECV-SMv2 (internal release within ESA CCI soil moisture project) has global coverage and is based on active and passive satellite soil moisture retrieval but is extended to the time period 1979 to 2013. In addition, it includes, among others, improvements in the algorithms of both passive and active satellite soil moisture retrieval as well as a better detection of frozen conditions and snow.

The final validation of the ECV-SMv2 time series includes the comparison to several soil moisture observations and estimates across different spatial scales. Furthermore, trend analyses are conducted and compared to respective trends in atmospheric variables (e.g., precipitation, evapotranspiration), vegetation parameters, tree ring and runoff data. We present here results from the final validation comparing the new ECV-SMv2 to ground-truth soil moisture observations at the point scale and to global model simulations as well as to its forerunner ECV-SMv1. We hereby assess the temporal and spatial variability of absolute values of soil moisture as well as its short-term and long-term anomalies.

Understanding Land-Atmosphere Interactions on Mesoscales Using Observations over the Sahel

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Land surface properties such as soil moisture, albedo and vegetation cover are known to impact atmospheric moisture conditions through induced energy and moisture fluxes. Semi-arid regions such as the Sahel in Africa demonstrate higher sensitivity of surface fluxes to soil moisture, which in turn affects precipitation variability and initiation of convective rain storms.

Absence of accurate soil moisture and surface fluxes estimates together with uncertainties in model simulated soil-moisture-precipitation feedback require improved understanding of the mechanisms involved.

The study analyzes existing observational data from land surface remote sensing products. Daily estimates of soil moisture, precipitation and land surface fluxes together with atmospheric state parameters, and a unique African Monsoon Multidisciplinary Analysis (AMMA) data set of convective initiations are used to better understand coupling mechanism between soil moisture and rainfall over the Sahel at mesoscales.

Statistical approach to analyze sensitivity of afternoon convective precipitation to underlying soil moisture conditions was applied to the twice-daily Advanced Microwave Scanning Radiometer (AMSR-E) soil moisture product and 3-hourly TRMM Multi-satellite Precipitation Analysis (TMPA) precipitation data over the Sahel. Further, sensitivity of applied statistical metric to higher resolved soil moisture proxy parameters, such as Land surface analysis Satellite Application Facility (LandSAF) land surface temperature and turbulent fluxes was investigated. Finally, using ECMWF Re-Analysis (ERA Interim) atmospheric parameters, typical atmospheric conditions prior convective initiations were studied.

A Coupled Atmosphere and Land Data Assimilation System (CALDAS): a Way Forward for Enhancing the Skills of Numerical Predictions

Rasmy, Mohamed
University of Tokyo

Land surface Soil moisture plays a crucial role in determining global water and energy budgets. Several studies emphasized the necessity of realistic soil moisture initialization for improving the short- and medium-range forecasts, and the seasonal predictability. Space-borne passive microwave remote sensing provides information on soil moisture over large areas with a frequent coverage that is useful for the initialization of NWP models. However, a few studies carried out in the past on the assimilation of soil moisture observations into NWP models have shown several limitations and thus recommended for more advanced assimilation schemes. Consequently, we developed an on-line land data assimilation system (LDAS-A) by coupling a passive microwave sequential land data assimilation system with a mesoscale model (LDAS-A) to directly assimilate lower frequency microwave radiances (6.9 and 10.6 GHz) for improving soil moisture information within a mesoscale model. The results obtained in the Tibetan Plateau showed that the LDAS-A system is capable of improving land surface variables (i.e. soil moisture and surface temperature) and land-atmosphere interactions in a mesoscale model, provided that the metrological forcing (i.e. insolation and rainfall) to the land surface model is accurate.

Furthermore, a land data assimilation system can only improve the model surface conditions when satellite observations are available. Due to limited satellite observations (e.g. Advanced Microwave Scanning Radiometer (AMSR-E/AMSR-2), at a bi-daily) the improved land surface conditions often suffer from significant errors and drift from the biases in the predicted forcing (e.g. precipitation and solar radiation) that misguide the subsequent forecast. This particular issue rendered the on-line land data assimilation ineffective in NWP models. The pitfalls that arise from modeling accurate forcing are still unsolved, and are the most challenging issues faced by the land and atmosphere modeling communities.

Clouds directly influence the surface meteorological forcing (i.e. downward radiation and rainfall) and thus strongly affect the estimation of Earth's surface water and energy budgets. Similar to microwave sounding observations, passive microwave images (e.g. AMSR-E/AMSR-2) also contain information on cloud fields at higher frequencies (e.g. 89 GHz). However, an increasing abundance of these dataset arising from several past and future missions (e.g. Global Precipitation Measurement (GPM)) has not been well utilized within NWP models. Obtaining atmospheric information from 89 GHz (land-atmosphere combined) signals is very challenging owing to strong and heterogeneous land surface emissions.

As a result, we have further extended our data assimilation capability and developed Coupled Atmosphere and Land Data Assimilation System (CALDAS). CALDAS assimilates lower frequency data of AMSR-E/AMSR-2 to improve representation of land surface conditions, and merges them with higher frequency data of AMSR-E/AMSR-2 to improve the representation of atmospheric (cloud) conditions over land surfaces. The results simulated in Tibet and Niger showed that CALDAS significantly improved correlation of cloud distribution compared with MTSAT/IR1 observation and resulted in better land surface model forcing (i.e. solar radiation and rainfall). Improvements in both atmospheric forcing and land surface conditions enhanced land-atmosphere interactions, which were confirmed by radio-sonde observations. In addition, rainfall forecast also showed high-correlation with TRMM satellite retrievals. These results are indicated the potential use of CALDAS as a promising tool in terms of producing reliable regional water and energy budgets, especially in developing regions, because it requires only satellite data as inputs. Further development of the system to accommodate several new options (e.g. physics and parameterizations) to facilitate the applicability of CALDAS in several climatic regions and to incorporate integrate more data from other satellite missions will be discussed at the conference.

Impact of Diurnal Differences in Vegetation Water Content on Radar Backscatter of Maize During Water Stress

van Emmerik, Tim
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Microwave emission and backscatter of vegetated surfaces are influenced by vegetation water content (VWC), which varies in response to availability of soil moisture in the root zone. Understanding the influence of diurnal VWC dynamics on radar backscatter will improve soil moisture retrievals using microwave remote sensing, and will provide insight into the potential use for radar to directly monitor vegetation water status.

The goal of this research is to investigate the effect of diurnal variation in VWC of an agricultural canopy on backscatter for different radar frequencies, polarizations and incidence angles. Water stress was induced in a corn (Zea mays) canopy near Citra, Florida, between September 1 and October 20, 2013. Diurnal destructive samples from the canopy were collected to determine leaf, stalk and total VWC. Water stress was quantified by calculating the evaporation deficit and measuring the soil water tension.

A water-cloud model was used to model the influence of VWC and soil moisture variations on backscatter for a range of frequencies, polarizations and incidence angles. Furthermore, radar backscatter time series were simulated to show the effect of water stress on the diurnal variation in backscatter due to VWC.

Results of this study show the very significant effects that VWC dynamics have on radar backscatter. We also highlight the potential for vegetation and soil water status monitoring using microwave remote sensing.

Linking Vegetation Parameters Derived from Active and Passive Microwave Observations

Vreugdenhil, Mariette
TU Wien

The effect of vegetation on microwave observations is a pivotal issue in soil moisture remote sensing. In the active microwave retrieval algorithm of TU Wien, the effect of vegetation on the backscatter is characterized through the relationship between backscatter and the incidence angle over the incidence angle range from 20 to 60°. Vegetation tends to decrease backscatter in the lower incidence angles due to attenuation of the surface scatter by the vegetation. In addition, vegetation increases the backscatter in higher incidence angles because of volume scattering by the vegetation. Hence, vegetation leads to a flatter slope than bare soil backscattering.

In this study the vegetation characterization in the TU Wien retrieval algorithm is related to the vegetation optical depth (τ), which is the parameter most often used for characterizing the impact of vegetation on microwave signals. First a simple radiative transfer model, a so-called cloud model, is used for separating the total backscatter into volume and surface scattering components. Then, the Integral Equation Method is used to model the surface scattering component and estimate vegetation optical depth. To assess the quality of the vegetation characterization in the TU Wien algorithm the vegetation optical depth retrieved with the cloud model is compared to the Vegetation Optical Depth retrieved from AMSR-E observations with the VUA-NASA retrieval algorithm.

A Study on the Parameter Sensitivity Analysis of L-MEB Model for Passive Microwave Soil Moisture Retrieval

Wang, Zengyan
Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences

In this paper, a global sensitivity analysis method of the extended Fourier Amplitude Sensitivity Test (eFAST) is used to conduct a parameter sensitivity analysis of L-band Microwave Emission of Biosphere (L-MEB) model. The results are analyzed from two perspectives of calibration and inversion. Firstly, the parameters of surface soil moisture, soil roughness factor, vegetation optical depth at nadir (being zero and not included for bare soils), and surface soil temperature make the four main sensitive factors, indicating their retrievability in the multi-parameter retrieval approaches. Then, the high sensitivity index values of surface soil temperature in the analyses emphasize the importance of high-precision surface soil temperature data to be provided or retrieved in the surface soil moisture retrievals, especially for rougher or more vegetated surface conditions. Lastly, the current calibration method of iteration has been proven effective in calibrating the parameters of soil roughness factor and vegetation optical depth at nadir in the L-MEB model. However, the low values of vegetation structure factor, single scattering albedo and soil roughness coefficient indicate the possibly poor behaviors of the current calibration of them, calling for some more robust calibration methods to be developed in the future.

Announcement Special Issue

“Advances in the Validation and Application of Remotely Sensed Soil Moisture”

Journal: International Journal of Applied Earth Observation and GeoInformation.

Guest Editors: Wouter Dorigo, TU Wien, Austria and Richard de Jeu, VU University Amsterdam, the Netherlands

Scientific Rationale: Microwave remote sensing of soil moisture is getting mature. While until recently the focus was primarily on algorithm development and validation of products, scientists and users are now starting to use remotely sensed soil moisture products in a broad range of disciplines including meteorology, hydrology, climate research, carbon cycle modelling, and drought, flood, and food monitoring and prediction. This development has been boosted by the launch of new dedicated soil moisture satellites (SMOS, SMAP), the development of (near-real-time) soil moisture products from operational satellites (ASCAT, AMSR-E/2, Sentinel-1), and the construction of long-term multi-satellite soil moisture data sets such as provided by ESA's Climate Change Initiative. The aim of the special issue is to provide a comprehensive state-of-the-art on the potential and limitations of the various new satellite products, in particular with respect to the various application fields. This overview will assist users in taking maximum advantage of the unprecedented wealth of soil moisture data available, and to identify needs for future sensor and algorithm development. The special issue will be related to this workshop but submissions from non workshop participants are highly welcomed.

Contributions may focus on, but are not limited to

- Advances in algorithm development for satellite soil moisture (SSM)
- SSM from new satellites (e.g. SMAP, Sentinel-1, FengYun, AMSR2)
- Multi-sensor SSM products
- Improved error characterization of SSM products
- Novel validation techniques for SSM products
- Spatial downscaling of SSM
- SSM for hydrological model validation
- Assimilating SSM in hydrological models and reanalysis products
- SSM for improving meteorological forecasts
- SSM for improved rainfall-runoff modeling
- SSM for drought monitoring and prediction
- SSM for improved carbon cycle modeling
- SSM for improving yield prediction
- Novel applications of SSM (e.g. improving precipitation estimates)
- SSM for improved understanding of land-atmosphere interactions
- Trends in SSM

Time Schedule:

- September 1, 2014: Opening of the Special Issue submission site within the Elsevier Editorial System (EES)
- 31 December, 2014: Submission deadline
- 31 May, 2015:Acceptance deadline
- July 2015: Publication date of special issue (Individual papers will be published as soon as accepted)

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