Understanding the Carbon and Water Cycles using SMOS Data and Models

CESBIO, Toulouse, France, 13-14 November 2014

The 2nd SMOS workshop dedicated to land applications was held 13 and 14 November at CESBIO, Toulouse. Approximately 50 participants attended the meeting that was organised around four sessions focussing on vegetation parameter retrievals from SMOS, SMOS data applications related to the global carbon and water cycle, and data assimilation.

Presentations will be made available through the workshop www site. This document summarises the discussions and presents the main conclusions mapped against the following 5 objectives and the status as presented in February 2013 during the 1st SMOS land workshop.

The main objectives of the workshop were:

1. To review the current advances on SMOS observations, products and capacity to improve the characterization of the land surface processes at different time and spatial scales;
2. To accelerate the development of novel and robust SMOS data products exploiting the synergies with other complementary EO missions;
3. To foster the integration of SMOS data products into advanced coupled models capable of describing and forecasting main land processes;
4. To increase the scientific understanding of main land interactions and their impacts on the Earth system and climate by exploiting SMOS observations;
5. To consolidate a scientific roadmap outlining priorities and scientific requirements to further advance in the development and exploitation of SMOS global observations for land surface processes.

Objective 1:

Continuous progress has been made with respect to the quality of the Level 1 brightness temperature and soil moisture products. The soil moisture Level 2 processor shall be continuously updated and improved. A 2nd reprocessing of the entire measurements has been performed in 2014 and data will become available in the first quarter of 2015. It was stressed that there is a strong need for harmonised high quality soil moisture products spanning the full 5+ year period. This is especially true for research addressing the carbon and water cycles.
New products are emerging and / or are being matured. The SMOS based sea ice thickness product has been consolidated and has been made available operationally through the ICDC at University of Hamburg. Remote sensing of sea ice has become an additional mission objective for the extended operational phase. The work on the SMOS based NRT soil moisture product is progressing well and it is expected to have an operational processing chain ready by the second quarter of 2015. With respect to the evaluation of different soil moisture products it was stated that a common performance metric or a widely accepted standard is still missing. The need for a paper outlining a “best practise”

for soil moisture validation including recommendations on the performance matrix was expressed.
The community expressed a very strong interest in the vegetation optical depth (VOD) product. A number of potential applications were presented and it was shown that information on above ground biomass, vegetation water content, tree height, evapotranspiration, etc. is contained in the data. However, product validation is very difficult to carry out and even verification is complex. Consequently verification is still incomplete and it was felt that resources could be used for retrieval algorithm improvement as well as for the development and the synergistic exploitation of measurements obtained in different wavelengths spanning the visible to low frequency microwave spectrum.
In general, a need for a quicker and easier data access was expressed. In addition, the data format could be revisited and netCDF was suggested as a potential solution offering a large variety of available IO routines. For the soil moisture NRT product, again netCDF was suggested. Dissemination through EUMETCAST and GTS as a baseline shall be complemented through an ftp dissemination service using a GUI.

Recommendation 1: Resources shall be devoted towards improving the understanding of the VOD product leading to an improved understanding of uncertainties, limitations and potential application and science areas.

Recommendation 2: A SMOS data portal could be developed facilitating an improved accessibility of matured products. As an example, the NSIDC was mentioned.

Objective 2:

It was reported that a number of science activities address synergetic exploitation of SMOS and complementing EO data sets. There has been a close collaboration with the Aquarius team on level 1 and 2 data products; a similar collaboration is foreseen with the SMAP team.
For the synergetic exploitation of the soil moisture product a number of results was shown, mainly comparing output from numerical models against SMOS, AMSR, and ASCAT soil moisture products. Initial results from the SMOS Passive Microwave Data Fusion Study were presented. In addition, new applications were presented, e.g. SMOS based water fractions that were compared against altimeter based river heights measurements.
For the VOD product, synergies with AMSR data sets and vegetation indices from sensors operating in the visible spectral range have been addressed. However, more work is needed to enhance our understanding of the complementarity of the different products. New measurements and products related to fluorescence or biomass originating from OCO-2 and FLEX type missions and BIOMASS, respectively, could also be exploited.

Recommendation 3: Define campaign activities (either in combination with planned or as stand alone activities) addressing open question related to vegetation parameters (e.g. VOD, VWC, and biomass) retrieved from passive microwave, active microwave, and optical measurements, preferably over a homogeneous area equipped with a FLUXNET tower.

Objective 3:

Over land, SMOS measurements (either L1 brightness temperatures or L2 soil moisture fields) have been used extensively in scientific and semi-operational applications. The NRT products are used by ECMWF for numerical weather prediction; soil moisture data have been used for the improved prediction of stream-flow; drought and flood monitoring applications were shown; crop yield forecasts; and the assimilation of SMOS observations into global carbon models. Using SMOS data to validate phenology data in the semi-arid regions could potentially be very interesting as this can be linked to crop yields and improve yield forecasts in important regions. The degrees of maturity vary for the individual applications but, in general, the soil moisture analyses are improved and the impact on the subsequent forecast parameters is neutral to positive.

Recommendation 4: It was recommended to actively approach "the next level of users", i.e. operational agencies and organisations like FAO or treaties like UNCCD with mature products, e.g. drought monitor, flood risk. For emerging applications an earlier collaboration with the end-user was suggested.

Objective 4:

The assimilation of SMOS measurements and the analysis of model – obs statistics revealed some limitations in our understanding of exchange processes between the land, the biosphere and the atmosphere. These findings already led to a number of developments in numerical modelling, e.g. a new soil hydrology in the global carbon model BETHY, an improved description of lakes and soil hydraulic parameters in ECMWF's land surface model. Again, global vegetation parameters and the biosphere in general were identified as one thematic area where further progress in model development can be expected when SMOS data are used.
For many applications involving models, long time series from EO data sets are instrumental. Currently, several data fusion methods for the generation of long-term soil moisture data sets are under development. In integration of SMOS data in the CCI data sets is envisaged; however, depending on the outcome of on-going study activities it can be preferable to generate different soil moisture ECV data series.

Recommendation 5: It is recommended to complement a future campaign activity (Recommendation 3) with a modelling component addressing the vegetation component and exchange processing between compartments of the biosphere.

Objective 5:

The consolidation of a scientific roadmap was eventually beyond the scope of the workshop and the discussions. It was stated that – over land – the heritage of SMOS (or the main potential achievements) are probably related to global change (trend analyses, extreme events, acceleration of the water cycle) and process understanding.
Although, a lot has been already achieved we expected to see a range of new scientific results and products, which can be related to the global carbon cycle. The corresponding research ranges from very basic research (e.g. laboratory measurements of dielectric constants) to new data sets (e.g. soil frost depth or vegetation water content) and large-scale applications (e.g. global carbon modelling).

Over land, SMOS soil moisture and VOD represent an opportunity to link both the carbon and the water cycle. Exploring this connection and the opportunities offered by SMOS to link both cycles is recommended.
Also, the opportunities offered by SMOS providing two key parameters characterising the water cycle over land (soil moisture) and ocean (salinity) represent an excellent opportunity for global water cycle studies connecting both reservoirs and studying their interactions (e.g., through river discharge, E-P over land and ocean).
The community expressed concerns with respect to the lack of planned follow on L-band missions. It was identified that L-band radiometers offer a unique means to measuring quantitatively and homogeneously soil moisture and tentatively VOD. Operational users are also keen to see long term plans before investing further in operational applications. It is thus recommended to aggressively pursue follow on initiatives.

Potential implementation routes for the recommendations:

Recommendations 1, 3, and 5 could be further defined through a **virtual carbon mission**. A group of international experts (~ 10-15) forming a "science team" can define a dedicated campaign and a complementing numerical modelling activity. The members of this group could for example be related to the SMOS, SMAP, OCO-2, BIOMASS, and FLEX missions.

Recommendation 4 can be addressed through an international user workshop.

A first steps addressing Recommendation 2 could be made for the dissemination of the NRT soil moisture product.