ISSI TEAM MEETING REPORT TEMPLATE:

Title: “Land Data Assimilation: Making sense of hydrological cycle observations”

Objective: The objective of the “International Team” is to provide a multi-disciplinary platform to make sense of hydrological cycle observations, with a focus on SMOS soil moisture data.

Date & Place: Team Meeting 1, 2nd – 4th February 2010, ISSI, Bern, Switzerland.

Participants: William Lahoz, Tove Svendby (NILU, Norway); Yann Kerr (SMOS; U. Toulouse, France); Pavel Sakov (NERSC, Norway); Valentijn Pauwels (U. Ghent, Belgium); Olivier Talagrand (LMD, France); Paul Houser (CREW/GMU, USA); Gabriëlle De Lannoy (CREW/GMU, USA & U. Ghent, Belgium); Jean-François Mahfouf (Météo-France, France); Nils Gustafsson (Met.no, Norway & SMHI, Sweden); Chris Schmullius (U. Jena, Germany); Jörg Schwinger (U. Köln, Germany); Kari Luojus (FMI, Finland); Lennart Bengtsson (ISSI); Michael Berger (ESA).

Meeting summary:

Day 1:

(i) Discussion of SMOS soil moisture data

SMOS status and capabilities; access to SMOS data (simulated/actual); cal-val activities for SMOS data; type of SMOS data for possible use in assimilation.

All these presentations were made by Yann Kerr (PI SMOS). Comprehensive information on SMOS, with focus on soil moisture, was provided. SMOS is an L-band passive microwave platform. Of particular interest were the status of the SMOS data, including resolution (~43 km in space, 1-3 days revisit time) and error characteristics (accuracy 4% vol. before launch, maintained after launch), and the mechanisms for accessing SMOS data (commissioning phase ends in May 2010, after which access is by AO, e.g., for Category-1 users). The different data levels (1a, 1b, 1c, 2, 3 and 4) were described. Participants were mostly interested in 1c (radiances) and 2 (geophysical products). The ECMWF soil moisture is the starting point for the minimization taking place in the SMOS retrieval (level 2). The SMOS soil moisture retrieval does not depend on this starting point; because of this, it would be misleading to describe ECMWF soil moisture as the a priori in the SMOS retrieval, as this would imply that it has an impact on the solution (which as mentioned above, is not the case).

Cal-val of SMOS has just started. Good quality has been found so far. The cal-val process makes use of anchor sites (Valencia, Danube basin) and special sites (e.g. Antarctica, Takla Makan desert). The data assimilation framework is being used for evaluation of the SMOS soil moisture data, for example, by comparison of analyses and assimilated observations (tests of self-consistency), and by comparison of analyses against independent data to build up statistics on biases in SMOS data. Contamination from RFI (radio frequency interference) is a particular concern.

SMOS soil moisture data could be provided at a higher horizontal resolution (~15 km) than the current one (~43 km). This would not be provided by a downscaling procedure involving ancillary information at higher resolution, but simply by oversampling (implying data redundancy). This raises questions about the value of this higher resolution product, but use of these data could help address issues about the potential benefit of SMOS soil moisture data for understanding the hydrological cycle in regions with complex orography (e.g. Norway).

A point discussed in some detail was the definition of soil moisture and the importance of keeping this definition as close as possible to the physical condition of soil moisture (e.g. bucket of soil which is dried, what is removed is the soil moisture). The importance of consistency between the soil moisture represented by a model and an observation was highlighted. As mentioned by J.-F. Mahfouf in the discussion about this point, assessment of this consistency is possible at the local scale from field experiments owing to the availability of important input parameters characterizing the soil, the vegetation, and the atmospheric forcing, and to the possibility of comparing a local model output to a gravimetric sample.

There have been many field experiments in the past (e.g. HAPEX-MOBILHY, FIFE, HAPEX-SAHEL, EFEDA, BOREAS, ARM, SGP) where land surface schemes have shown a capability for describing accurately soil moisture evolution, in agreement with measurements of turbulent fluxes. When incorporating a land surface scheme into an atmospheric model, this desirable local scale consistency is difficult to achieve owing to incorrect model forcing and uncertainties in physiographic databases and corresponding tables. This is why model deficiencies can be compensated by incorrect soil moisture values leading to more realistic turbulent fluxes. This undesirable feature arises because the problem is ill-posed: there are not enough observations to constrain the parameters in the land surface scheme. It is hoped that synergy between various sources of satellite information of the land surface will provide a better constraint of the land surface schemes, so that model deficiencies are identified rather than hidden by, e.g., compensation of model features.

At the end of this session, a proposal for a workshop on the hydrological cycle was discussed with L. Bengtsson. A first draft has been circulated for comment.

(ii) Links between land, atmosphere & biosphere

This presentation was made by Chris Schmullius, with focus on research on Siberia (e.g. vegetation cover) and the various links and synergies between the land, atmosphere and biosphere.

Day 2:

Discussion of questions to be addressed to fulfill SMOS potential using data assimilation (based on proposal):

(i) What type of observations do we assimilate: retrievals, radiances, thinning (P. Houser, G. De Lannoy)

(ii) What are the observation errors: Gaussianity, bias (V. Pauwels)

(iii) What models do we use, coupled, uncoupled, link to NWP (J.-F. Mahfouf)

(iv) Developments in assimilation theory, variational methods, ensemble methods, hybrid methods, with reference to the land (O. Talagrand)

(v) What are the model and analysis errors, and how to represent them and evaluate them (O. Talagrand)

The motivation for land data assimilation (produce the best state given model and observations and their errors) was restated. Some features of land data assimilation were highlighted: because most processes in the land are 1-D, assimilation is relatively cheap; constraints in manpower for coding and development of the adjoint for 4D-Var currently can make this method less attractive in comparison to, e.g., ensemble methods such as the Ensemble Kalman Filter. Land data assimilation can be implemented to assimilate radiances (level 1c products) or retrievals (level 2 products); ECMWF and

Environment Canada have plans to assimilate SMOS radiances. Several satellite missions measuring soil moisture were described. Snow assimilation was also discussed. The GlobSNOW co-ordinator was present at the meeting, and presented the GlobSNOW project on the last day.

Models used in land surface, and with reference to SMOS, were discussed. Two types of models were given some attention: SVAT scheme models (SURFEX, JULES, LIS – working with level 2 data), microwave emission models (CMEM – working with level 1c data). A number of issues in land modelling were discussed (e.g. representation of lakes; influence of soil vertical structure; importance of correct representation of the fraction of water). The final message is that improved land surface modelling is needed.

Possibility theory was discussed. While currently esoteric, it may be of benefit for representing errors in land surface variables. Very recent developments (theory and application) were mentioned and discussed. A comprehensive review was provided, and issues with the various algorithms discussed. The differences between consistency, optimality and accuracy were spelt out. It was stressed that external knowledge is required to resolve difficulties concerning consistency.

Selected challenges in land data assimilation were mentioned: algorithm development, land observing systems, land modelling, assimilation of new types of data, and representation of coupled feedbacks. Of note is the use of different assimilation techniques by the participants in the ISSI Team: 4d-var (U. Köln); EKF (Météo-France); EnKF (CREW; NILU); and Particle filter, PF (NILU). This provides an opportunity to compare the performance of the various assimilation approaches.

Day 3:

Forward look: developments in land data assimilation, collaborations and future work for project partners

(i) Use of hydrological cycle observations (satellite, in situ, GlobSNOW; validation) for, e.g., cal-val, assimilation, testing models (J.-F. Mahfouf)

(ii) What assimilation algorithms do we use, e.g., hybrid ensemble methods (P. Sakov)

(iii) Description of GlobSNOW project (K. Luojus)

(iv) Description of ESA data assimilation activities (M. Berger)

(v) Developments in land surface models, focus on soil moisture and snow; weaknesses (P. Houser)

(vi) Future work: collaborations, networking, papers (review, other), proposals (national funding, EU funding, ESA-CCI calls, other calls), workshops (ISSI), summer schools (Svalbard, elsewhere) (W.A. Lahoz)

(vii) Wrap-up and suggestions for next meeting (W.A. Lahoz)

A forward look, including what would be desirable in land modelling, and how we could get there, was provided. Very novel developments in EnKF and PF were presented.

Requirements for the use of hydrological cycle observations were spelt out: data assimilation, land surface forcing, data assimilation validation, NWP reanalyses, and observations to be considered (platform/area/time/period of interest). Evaluation of satellite observations against field experiments and models was discussed. Some time was spent discussing the evaluation of satellite soil moisture by using in situ measurements from the soil moisture network in the South West of France; the SMOSREX and SMOSMANIA activities were described. The GEWEX initiative on soil moisture was mentioned.

An overview of the GlobSNOW project was provided. This is a 3-year ESA DUE project. It aims to provide northern hemisphere daily fields of snow water equivalent (SWE) since 1978, using SSMR data (1978-1987), SSM/I data (1987-2002), AMSR-E data (2002-). Currently, it produces monthly fields since 1978, and daily fields since 2002. GlobSNOW also aims to provide global (northern and southern hemisphere) daily fields of snow extent since 1995, using ATSR-2 (1995-) and AATSR (2002-).

A comparison of the advantages/disadvantages of the EnKF, KF and EKF was presented. Recent developments in the EnKF, PF and hybrid EnKF/PF methods were also presented. Work on mixing static and dynamical covariances was also discussed. It was mentioned that land surface models are good test beds for testing new and expensive data assimilation techniques.

An overview of ESA activities on GMES Sentinels 1-5 was presented. The use of data assimilation ideas to understand observations was discussed. As part of this work, ESA is running a project to design a generic land data assimilation tool for use with general observational platforms.

A look at the evolution of land surface models was provided. Two approaches were identified: (i) making grid boxes smaller (conventional approach); (ii) simulate a sample of the small-scale physics and dynamics using high-resolution process-resolving models within each climate model grid box. Several desirable land surface model developments were identified: adding C/N cycle models, dynamic vegetation modelling, urban models, organic soil/deeper soil column/groundwater developments, subgridscale representation, ice sheet models, irrigation/land use/agriculture, integrated crop models, dynamic wetlands, lake models, river routing and diversions, isotopes, multi-layer snow modelling, radiance forward models, sensor webs and targeting, and implicit coupling of cloud parametrization and atmospheric turbulence schemes with patch-based land models at the highest possible resolution. The impact and role of humans was also discussed.

Some time was devoted to snow modelling issues. For example, snow layers appear and disappear; snow emissivity changes a lot; snow grain size changes continuously.

There was discussion on moving toward process-resolving Earth System Models. Several examples were mentioned: LIS coupled to a weather model; the North American LDAS (N-LDAS); and the European ELDAS effort. Model hierarchies and the use of a dynamic variable resolution were discussed. It was mentioned that the need for components in a model is application-dependent. Finally, it was mentioned that land surface models are relatively cheap, which might make coupled land-atmosphere developments attractive. Precipitation is key in land surface models, and this is generally underestimated by observations. Data assimilation may play a role in identifying biases associated with precipitation.

Finally, potential future activities of the International Team were outlined: workshops, next meeting, summer schools, visits and proposals.

Conclusions/ further steps:

All participants found the Meeting informative and conducive to vigorous discussion on how best to make sense of SMOS soil moisture observations. A key element in this outcome was the multi-disciplinary aspect of the Meeting (reflecting that of the Team), which brought together a broad spectrum of actors in the hydrological cycle (Earth Observation; models; data assimilation, theory and application; hydrological cycle; NWP; land, biosphere).

A proposal for a workshop on the hydrological cycle will be presented to ISSI for evaluation. The Team will endeavour to do this before May 2010 to allow evaluation by the ISSI Scientific Committee at their meeting in May-June 2010. Likely date for the workshop would be 2012. A first draft has been circulated.

NILU will present a Category-1 proposal to ESA to use actual SMOS data. A proposal is being prepared.

Plans for a Summer School on the hydrological cycle will be put on hold, for consideration at a later date.

Details of EU-FP7 calls likely to involve the hydrological cycle were presented. The Team agreed it would be a good idea to be prepared for possible proposals. The need to expand a proposal to include partners beyond the Team was discussed. Other funding mechanisms were discussed. For example, the use of COST funds for visits (using Short Term Scientific Missions, STSMs) was mentioned. W. A. Lahoz is in the MC of the COST Action 0804 "Advancing the intergrated monitoring of trace gas exchange between the biosphere and atmosphere", and STSMs under this COST Action could be used for visits among the Team members.

The second Team meeting will be held in October 2010. By this date, SMOS soil moisture data should have been available for about 5 months (since May 2010, at the end of the commissioning period). This meeting will be an opportunity to scrutinize SMOS soil moisture, and assess various data assimilation approaches. Experts in land data assimilation not in the International Team will be invited to attend, e.g., Patricia de Rosnay (ECMWF), Rolf Reichle (GMAO). To provide a more complete view of SMOS and the hydrological cycle, experts in ocean salinity and the broader hydrological cycle could be also invited.

ATTACHMENTS (if needed)

→ agenda (attached)

→ supporting material/publications (this should become available at the Project website, due to be set up by ISSI personnel)

William Lahoz, NILU, 18th February 2010