Norsk institutt for luftforskning
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Assimilation of ASCAT, AMSR-E and SMOS soil moisture products over Europe: an assessment of the relative impact of each satellite dataset

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1. Introduction:

Soil moisture is one of the key geophysical variables for understanding the Earth's hydrological cycle (Fig. 1). The ESA climate change initiative (ESA CCI) will produce long-term datasets of essential climate variables (ECVs), including global multi-decadal soil moisture datasets from combination of active and passive satellite measurements (Fig. 2) at temporal and spatial resolutions of 6 hours and 0.25° (http://www.esa-soilmoisture-cci.org/).

The ESA CCI soil moisture datasets are being evaluated using in situ data from the International Soil Moisture Network (ISMN; Dorigo *et al.*, 2011), and analyses from data assimilation techniques (Lahoz & De Lannoy, 2014) – see panels 2-3.

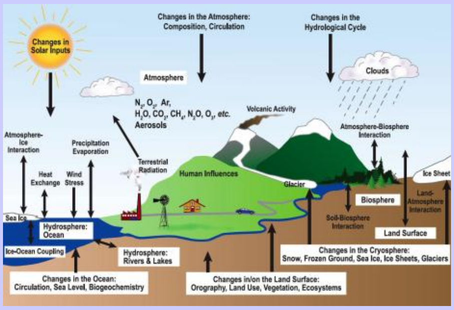

Fig.1 (left): Global climate system (Figure from IPCC, 2007).

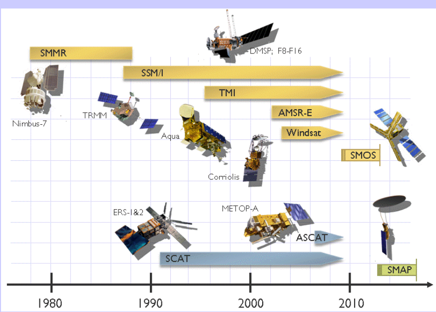

***Fig. 2 (left):** Active / passive microwave sensors used for generation of ECV soil moisture data sets. Figure from ESA CCI soil moisture website.*

2. Data Assimilation experiments – set up:

The NILU land data assimilation (DA) system (Lahoz & De Lannoy, 2014) implements variants of the Ensemble Kalman Filter (EnKF). It is an off-line 1-D system based on the SURFEX land surface model, LSM (Le Moigne, 2012). Schemes include 2 versions of EnKF where no perturbation of observations is needed (Sakov & Oke, 2008a, b). NILU also uses the Extended Kalman Filter (EKF) of Mahfouf *et al.* (2009). Soil moisture measurements from ASCAT (Advanced SCATterometer), AMSR-E (Advanced Microwave Scanning Radiometer - Earth Observing System) and SMOS (Soil Moisture and Ocean Salinity) are assimilated.

Figure 3 shows SURFEX LSM can fill in gaps in satellite soil moisture data. When combining LSM, satellite information, care must be taken to account for error characteristics of each dataset, and biases between them. This is done by scaling the satellite data to the model data (Brocca *et al.*, 2013).

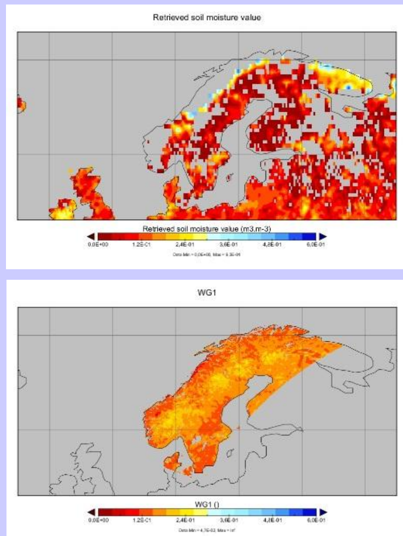

***Fig. 3 (left):** Soil moisture averaged over Scandinavia, 6 June – 9 August 2012, m^3m^{-3}. SMOS soil moisture (ascending orbit), top panel. SURFEX LSM surface liquid water content (12:00), bottom panel. Red/blue, relatively dry/wet soil.*

3. Data assimilation experiments - results:

Early examples of output from the NILU land DA system for Scandinavia and France are provided in Figs. 4-5. Results shown lend confidence to the fidelity of the soil moisture analyses.

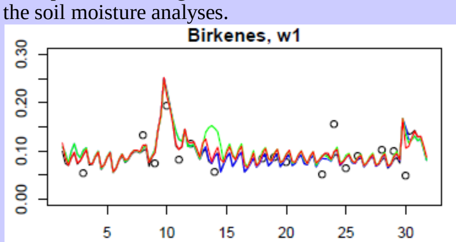

Fig. 4 (above).Time series (July 2006), land soil moisture analyses of superficial volumetric water content (m^3m^{-3}) for Birkenes, Norway (58.45N, 8.23E). Colours indicate DA setups (black: open loop; blue: EKF, with quality control, QC; green: EKF, without QC; red: square root EnKF, 10 ensemble members). Circles denote AMSR-E soil moisture observations assimilated; data were modified using CDF-matching. Results show good agreement between the EKF and EnKF analyses.

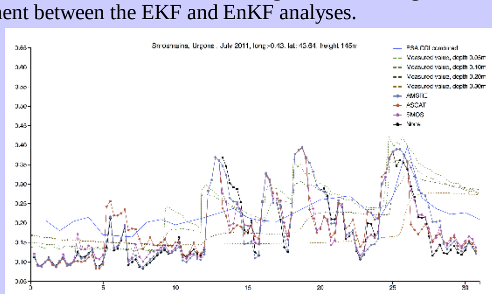

Fig. 5 (above). Time series (July 2011), soil moisture datasets (legend; m^3m^{-3}): EnKF analyses (5 ensemble members), DA of AMSR-E, ASCAT, SMOS soil moisture observations; open loop; Soil Moisture ESA CCI combined data; various depths, in situ data. Data for SMOSMANIA station Urgons (43.64N, 0.43W, 145 masl). Satellite data scaled to have same mean and standard deviation as SURFEX LSM data for July 2011. Results show analyses capture patterns of in situ data and ESA CCI combined data.

4. Conclusions and future work:

Conclusions:

- Satellite soil moisture measurements assimilated
- Short time period: results preliminary
- Self-consistency tests (O-A, O-F): *passed*
- Chi-square tests for observational errors: *consistent with published errors*
- Comparisons with independent data: *patterns agree*
- Useful information from DA: *added value*

Further Work:

- Extend time period to 1 year or more
- Use CDF-matching of another method to address biases between model and satellite data
- Assimilate the satellite datasets singly/jointly
- Assimilate ESA CCI combined data (self-consistency test)
- Evaluate analyses with ISMN in situ data

References:

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Dorigo, W, *et al.* (2011) *Hydrol. Earth Syst. Sci.*, **15**, 1675-1698, doi:10.5194/hess-15-1675-2011.
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ESA CCI Soil Moisture:
http://www.esa-soilmoisture-cci.org/.

ISSI International Team on the hydrological cycle:
http://www. issibern.ch/teams/hydrocycle

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