Issues in Satellite and Land Surface Model Soil Moisture Validation

Matthias Drusch
ESTEC
Soil Moisture Validation Strategy

- In-situ
- Aux data
- Data assimilation experiments
- Operational DA / Data denial

Complexity vs. Generality
In-situ - Revision of TESSEL

SEBEX (Savannah, Sandy soil)

BERMS (Boreal Forest)

HTESSEL improves soil moisture and marginally evaporation with respect to TESSEL in dry climates and leads to a better represented soil moisture inter-annual variability in continental climate

Balsamo et al. 2010
- in-situ observations represent the point scale

- up-scaling is difficult (presentation W. Crow et al.), there is no preferred strategy

- antenna gain, the exact shape of the footprint, and non-linearities in the radiative transfer models should be considered (for satellite observations)

- large systematic differences in the in-situ observations on comparably small scales exist (presentation by A. Robock)

- one model will be operated at different spatial resolutions (e.g. for deterministic forecasts, ensemble forecasts, short-range forecasts, seasonal forecasts, ...)
Mismatch in vertical resolution
Mismatch in vertical resolution

Wilker et al. 2006
- methods and skill scores for the evaluation of the satellite product or model forecast / analysis need to be established

- uncertainties of the (aggregated) in-situ observations need to be defined

- biases and systematic differences between data sets need to be quantified and minimized prior to data assimilation applications and inter-comparisons (e.g. triple collocation)

- bias correction can be done “off-line”, e.g. CDF matching, or within the DA scheme, e.g. through VarBC (Auligne et al. 2007) or Particle Filters (Montzka et al. 2011)
Combined Water Balance Approach (using model data)

- Terrestrial water balance:

$$\frac{\partial S}{\partial t} = (P - E) - R_s - R_g$$

- Atmospheric water balance:

$$\frac{\partial W}{\partial t} = -\nabla_h \vec{Q} - (P - E)$$

- Combined water balance:

$$\frac{\partial S}{\partial t} = -\nabla_h \vec{Q} \cdot \frac{\partial W}{\partial t} - \vec{R}$$

(reanalysis data (ERA-40))

(measured streamflow ($R_s + R_g$))

(after Oki, 1999)
Case Study: Mississippi & Illinois

Water-balance Estimates

\[ \frac{\partial S}{\partial t} = - \nabla \cdot \vec{Q} - \frac{\partial W}{\partial t} - R \]

Observations (soil moisture + groundwater + snow)

[Seneviratne et al. 2004]
If we consider 3 model versions:

- **warm climate**
  - Atmosphere
  - Land surface scheme: Dutra et al. (2010), Balsamo et al. (2009), van den Hurk et al. (2009), Viterbo et al. (1999), Viterbo and Betts (1999), Viterbo and Bejers (1995)
  - Turbulent heat fluxes
  - Surface runoff
  - Sub-surface runoff

- **cold climate**
  - Atmosphere
  - River routing: Peppenberger et al. (2009), Ngo-Duc et al. (2007), Oki and Sud (1996)
  - River discharge data
  - Synoptic reports from the GTS (Global Telecommunication System)

- Schematic representation of a global daily hydro-meteorological verification

[If we consider 3 model versions:]

- *SNOWHTESSEL*
- *HTESSEL*
- *TESSEL*

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*G. Balsamo et al. 2010*

European Space Agency
Figure 7: Indication of best correlated modelled and observed river discharges. Models include SNOWHTESSEL (blue), HTESSEL (green), and TESSEL (red). Large circles indicate the best performing scheme is significantly better than the others at a 5% significance level, while small circle indicate non-significant improvements. All river discharges plotted have positive correlation significantly different from zero.

<table>
<thead>
<tr>
<th></th>
<th>Correlation of daily river discharges</th>
<th>Number of river gauges (out of 211)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNOWHTESSEL</td>
<td>0.33</td>
<td>116 best correlate rivers</td>
</tr>
<tr>
<td>HTESSEL</td>
<td>0.25</td>
<td>81</td>
</tr>
<tr>
<td>TESSEL</td>
<td>0.09</td>
<td>14</td>
</tr>
</tbody>
</table>
EUCOS Observing System Experiments (OSEs):

- 2007 ECMWF forecasting system,
- winter & summer season,
- different baseline systems:
  - no satellite data (NOSAT),
  - NOSAT + AMVs,
  - NOSAT + 1 AMSU-A,
- general impact of satellites,
- impact of individual systems,
- all conventional observations.

→ 500 hPa *geopotential height*
  anomaly correlation

[Bauer/ECMWF, 2010]
- Comparisons against in-situ observations are very useful and the most direct source of independent information, but a range of performance indicators / skill scores should be established (Entekhabi et al 2010.). Accuracy goal of 4 % is too vague, hard to verify and not even traceable to the scientific objectives of a mission.

- Uncertainty estimates should be established at the relevant model / satellite spatial resolution.

- Biases and systematic differences can probably not be avoided and should be quantified and minimized prior to analyses.

- OSSEs, data assimilation experiments and data denial experiments can only give indirect estimates of the skill of a product but can contribute to quality assurance.

- Modelling and DA communities should be involved in mission evaluation.
THANK YOU

Matthias Drusch
matthias.drusch@esa.int