SMOS data assimilation for Numerical Weather Prediction (NWP)

Patricia de Rosnay

Thanks to: Nemesio Rodríguez-Fernández, Joaquín Muñoz-Sabater, Clément Albergel, David Fairbairn, Phil Browne, Heather Lawrence, Lars Isaksen, Steve English, Filip Aires, Catherine Prigent, Matthias Drusch, Yann Kerr and Susanne Mecklenburg
ECMWF Integrated Forecasting System (IFS)

- Coupled land-atmosphere Forecast Model
- Data Assimilation: atmosphere (4D-Var), land (SEKF, OI), ocean (3D-Var)
Current operational NWP system at ECMWF
weakly coupled land-atmosphere-wave and sea ice assimilation

→ Importance of the interface observations for consistent initialisation of coupled land-atmosphere forecasts
→ SMOS observations highly relevant for coupled assimilation
ECMWF Soil Analysis submitted for IFS 46r1 (2019)

Ensemble Data Assimilation (EDA)

Jacobians

T2m, RH2m & soil moisture

Background

NWP Forecast Coupled Land-Atmosphere

Soil Analysis (SEKF)

SM1, SM2, SM3

\[ \sigma_{O_{T2M}} = 1 \text{K} \]
\[ \sigma_{O_{RH2M}} = 4\% \]
\[ \sigma_b = 0.01 \text{m}^3/\text{m}^3 \]
\[ \sigma_{ASCAT} = 0.05 \text{m}^3/\text{m}^3 \]
\[ \sigma_{SMOS_{NN}} = 0.02 + 3\varepsilon \]

Screen level analysis (2D-OI)

T_2m RH_2m

\[ \sigma^0_{T2m} = 2K \]
\[ \sigma^0_{RH2m} = 10\% \]

Satellite

ASCAT SM SMOS SM

In situ Observations

T_2m RH_2m

Land initial conditions

SMOS EC Neural network

SMOS TB

SMOS_NN = 0.02 + 3\varepsilon

\[ \sigma_{ASCAT} = 0.05 \text{m}^3/\text{m}^3 \]

\[ \sigma_{SMOS_{NN}} = 0.02 + 3\varepsilon \]

0-7cm
7-28cm
28-100cm
100-289cm
SMOS TB assimilation
Atmospheric forecasts evaluation for MJJAS 2013

Muñoz Sabater et al 2018, in prep
SMOS neural network assimilation in H-TESSEL

SMOS neural network soil moisture data assimilation
N. Rodríguez-Fernández (1), P. De Rosnay (2), C. Albergel (2), F. Aires (4), C. Prigent (4)
P. Richaume (1), Y. Kerr (1), M. Drusch (5)

Creating a new SMOS soil moisture dataset specific for the data assimilation experiment

- One interesting application will be efficient Data Assimilation. The retrieved datasets are similar to the model fields, but they are driven by the remote sensing input data Aires, Prigent, Rossow 2005, JGR
- Neural network SM can be produced in near-real-time and with associated errors Rodríguez-Fernández, Muñoz-Sabater et al. (in prep)

The ECMWF surface-only Land Data Assimilation System

Offline surface model (HTESEL, Balsamo et al. 2009) forced by ERA-Interim reanalysis

Soil moisture analysis: T2m, RH2m, ASCAT SM, SMOS NN SM

Simplified EKF equation. The analysis state is applied at the beginning of the assimilation window

Poster on Wednesday morning, WEP1.PR.10 poster area R (10:10-11:10)
2018: New SMOS neural network processor for data assimilation

Example on 01 June 2016:
- 27 NRT TB files received → 27 SMOS NN Netcdf files produced and archived at ECMWF (ECFS)

Preprocessing (NRT):
Regridding, conversion GRIB, 6-hours grib files,
[SSM, SSM error (ε), obs time, RFI proba, nb obs]
→ Suitable and ready to DA in IFS
SMOS neural network assimilation in the IFS: Numerical experiments

Best candidate SMOS and EDA-SEKF proposed for operational usage in IFS cycle 46r1:

- **CTRL**: current IFS 45r1 (Finite difference SEKF, uses T2m, RH2m, ASCAT SM)
- **SMOS_DA**: CTRL+SMOS NN DA (obs error =0.02+3*ε, RFI filter 20%)
- **EDA_SMOS_DA**: proposed for 46r1 (SMOS_DA + EDA_SEKF with 50 EDA members)

Two sets of experiments (standard for ECMWF future IFS cycle testing):
- Summer June-July-August 2017
- Winter December-January-February 2016-2017

Resolution testing for candidates 46r1: Tco399 (25 km)
New soil analysis: EDA SEKF and SMOS NN DA

Technical work for 46r1
- Use the EDA to compute the SEKF Jacobian
- SMOS neural network soil moisture assimilation
- CPU reduction from EDA_SEKF, cost neutral for SMOS

Reduction of the SEKF CPU cost by a factor ~3.6

<table>
<thead>
<tr>
<th></th>
<th>NPES*THREADS</th>
<th>45r1</th>
<th>46r1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tco</td>
<td>1279</td>
<td>300*9</td>
<td>1580</td>
</tr>
<tr>
<td>TCo399</td>
<td>54*6</td>
<td>815</td>
<td>235</td>
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</table>

SMOS innovation (obs-model)
01 August 2017 (m3/m3)

Confidence range 95% with AR(2) inflation and Sidak correction for 8 independent tests

EDA_SMOS_DA -CTRL
SMOS_DA– CTRL

Atmospheric impact (T2m) compared to CTRL
SMOS neural network data assimilation: forecast impact

Normalised RMSE [SMOS_DA – CTRL]

Near surface air temperature

Soil temperature
SMOS neural network data assimilation: forecast impact

Normalised RMSE \([\text{SMOS}_{\text{DA}} - \text{CTRL}]\)

- (summer)
- (winter)

Snow Water Equivalent

Normalised RMSE \([\text{EDA}_{\text{SMOS}_{\text{DA}}} - \text{CTRL}]\)

Graph: SD: NH 20° to 90°, sfc

Forecast day
SMOS neural network data assimilation: Fit between IFS first guess and independent observations (obs-model)

Aircraft humidity (JJA 2017)

EDA_SMOS_DA minus CTRL

SMOS_DA minus CTRL

Improved fit in low troposphere

Aircraft temperature (JJA 2017)
### Evaluation of surface and root zone soil moisture against in situ data

More than 300 stations in US and Europe (SCAN, USCRN, SNOTEL and SMOSMANIA)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>R surface</th>
<th>R root Zone</th>
<th>Ranom Surface</th>
<th>Ranom root zone</th>
<th>uRMSD surface</th>
<th>uRMSD root zone</th>
<th>Bias surface</th>
<th>Bias root zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTRL (oper)</td>
<td>0.617</td>
<td>0.65</td>
<td>0.518</td>
<td>0.428</td>
<td>0.052</td>
<td>0.031</td>
<td>0.06</td>
<td>0.058</td>
</tr>
<tr>
<td>SMOS DA (oper+SMOS DA)</td>
<td>0.609</td>
<td>0.667</td>
<td>0.507</td>
<td>0.443</td>
<td>0.052</td>
<td>0.030</td>
<td>0.058</td>
<td>0.052</td>
</tr>
<tr>
<td>SMOS+EDA (oper+SMOS+EDA)</td>
<td>0.623</td>
<td>0.64</td>
<td>0.521</td>
<td>0.421</td>
<td>0.051</td>
<td>0.029</td>
<td>0.055</td>
<td>0.052</td>
</tr>
</tbody>
</table>

SMOS Neural Network assimilation in the IFS combined with the EDA SEKF

→ Small impact, but on a slight improvement side in soil moisture

SMOS contribution to improve root zone soil moisture (systematic on all four networks)
Summary and perspectives

- Current: SMOS neural network SM assimilation in review for operational NWP
- Next: Assessment of SMOS NN soil moisture assimilation for consistent NWP and flood forecasting systems

The Global Flood Awareness System

www.globalfloods.eu