Assimilation of satellite retrieved land surface temperature in AROME

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Outline

• Introduction
• Land surface temperature assimilation: implementation
• Land surface temperature assimilation: evaluation on assimilation and forecasts
• Conclusions and future work
Introduction

- Near surface atmospheric layers are crucial in NWP to modelize heat and water fluxes between surface and atmosphere
- Satellite radiances are informative on surface and near surface atmosphere, but are not assimilated in surface model
- The assimilation of satellite radiance in the upper air assimilation needs realistic surface conditions:
  - Surface temperature retrieval for infrared sensors; surface emissivity retrieval for microwave sensors) at each assimilation time

\[
T(p,\nu) = \varepsilon(p,\nu) \cdot T_s \cdot \tau + (1 - \varepsilon(p,\nu)) \cdot \tau \cdot T(\nu, \downarrow) + T(\nu, \uparrow)
\]

- \( T(p,\nu) \): brightness temperature
- \( \varepsilon(p,\nu) \): surface emissivity
- \( T_s \): surface temperature
- \( \tau \): atmospheric transmittance
- \( T(\nu, \downarrow) \): downward radiation
- \( T(\nu, \uparrow) \): upward radiation

\[ T(p,\nu) = \varepsilon(p,\nu) \cdot T_s \cdot \tau + (1 - \varepsilon(p,\nu)) \cdot \tau \cdot T(\nu, \downarrow) + T(\nu, \uparrow) \]
Introduction

- **Surface assimilation in AROME limited-area model** in two steps

  - Assimilation of T2m and Hu2m observations in a 2D Optimal interpolation → analysed fields of T2m and Hu2m

  - Analysis of soil variables \((T_s, T_2, w_g, w_2)\) with a 1D Optimal Interpolation assimilating the increments of T2m and Hu2m

  - **Use of satellite retrieved Land Surface Temperature in surface analysis**
    
    • Better consistency between model surface temperature and surface temperature used for the assimilation of satellite radiances
    
    • Improvement of coupling between surface and upper air assimilations

1h forecast

\(T_{2m}, RH_{2m}\)

Screen level
parameters analysis
2D OI (CANARI)

Analysis increments
\(\Delta T_{2m}, \Delta RH_{2m}, \Delta LST\)

Soil analysis
1D OI

Analysis
\(T_s, T_2, w_g, w_2\)
Land surface temperature assimilation: implementation

- Assimilation of SEVIRI retrieved land surface temperature in AROME model
- Assimilation of LST by night-time only (0h and 3h)
- Diagnostics of observation and background errors using Desroziers diagnostics
  - $\sigma_o = 3$ K, $\sigma_b = 1.8$ K, background correlation length = 30 km

![Observation error standard deviations](image1)

![Background error standard deviations](image2)

23, 30 June
Land surface temperature assimilation: implementation

- Case studies
  - Threshold on innovation: obs – guess lower than -4.5 K removed to avoid undetected/misclassified clouds

![Obs LST – guess LST distribution](image-url)
**Land surface temperature assimilation: results**

- Assimilation of SEVIRI LST at 0h and 3h in an AROME experiment over 2 months in summer 2019 (July and August)

- Evaluation of land surface temperature assimilation on the assimilation of near-surface parameters

![Graphs showing differences between observations and background for T2m and Hu2m](image1)

Mean differences between observations of T2m (left) and Hu2m (right) and background for each analysis time, for EXP-ARO and EXP-REF experiments

**Smaller differences between observations and background for the first assimilation times (up to 6h)**
Land surface temperature assimilation: results

- Evaluation of land surface temperature assimilation on the assimilation of satellite radiances

Impact on emissivity retrieval for MW sensors

Average decrease of RMSE: 0.29 %
Land surface temperature assimilation: results

- Evaluation of land surface temperature assimilation on AROME forecasts: impact on Synops

<table>
<thead>
<tr>
<th>Forecast ranges</th>
<th>0h</th>
<th>6h</th>
<th>12h</th>
<th>18h</th>
<th>24h</th>
<th>30h</th>
<th>36h</th>
<th>42h</th>
<th>48h</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2m (K)</td>
<td>-0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td><strong>0.01</strong></td>
<td>0.01</td>
<td>0</td>
<td>0.01</td>
<td><strong>0.01</strong></td>
</tr>
<tr>
<td>Hu2m (%)</td>
<td>-0.02</td>
<td>0.01</td>
<td>0.04</td>
<td><strong>0.08</strong></td>
<td>0.06</td>
<td>0.06</td>
<td>-0.02</td>
<td>0.01</td>
<td><strong>0.07</strong></td>
</tr>
</tbody>
</table>

Relative difference of mean quadratic errors for T2m and Hu2m with respect to observations for forecast ranges up to 48h

**0.01**: significant with 99.5 % confidence
**0.01**: significant with 95 % confidence

- Improvement of forecasts of T2m and Hu2m up to 48h, with significant impact by nighttime
- Improvement of forecasts of temperature and humidity below 400 hPa up to 24h
Conclusions and future work

- The assimilation of SEVIRI land surface temperature improves the assimilation of 2 metre and satellite observations

- Improvement in temperature and humidity forecasts up to 36h in low atmospheric layers

- Sassi et al, 2021: Assimilation of satellite retrieved land surface temperature in AROME NWP model, *in preparation*

- Future work: contribution of coupled surface and atmosphere assimilations for the representation of fluxes between surface and atmosphere in AROME model
  - Use of ensembles of data assimilation for T2m and Hu2m analyses
  - Evaluation on other kinds of observations: precipitation, land surface temperatures retrieved from SEVIRI

- Experiments of assimilation of land surface temperature at all analysis times, and over different periods in AROME
Conclusions and future work

- Application of the methodology to IASI observations: land surface temperature retrieval and assimilation in ARPEGE for land surface analysis

Land surface temperatures retrieved from IASI instrument (canal 10.8 µm)