Improved assimilation of IASI land surface temperature data over continents in the convective scale
AROME France model

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OUTLINE

★ Assimilation of IR observation over continents

★ IASI vs SEVIRI channels for land surface temperature (LST) retrieval and comparison method

★ IASI channel selected for LST retrieval and its impact on the assimilation

★ Conclusions and prospects
IASI (Infrared Atmospheric Sounding Interferometer) has 8461 spectral samples but just 314 channels are used in NWP.

The forecast of continental surface temperature is not realistic enough to use the infrared information in the lower troposphere and close to the surface over continents.
IASI (Infrared Atmospheric Sounding Interferometer) has 8461 spectral samples but just 314 channels are used in NWP.

The forecast of continental surface temperature is not realistic enough to use the infrared information in the lower troposphere and close to the surface over continents.

Radiative transfer equation inversion:

$$LST = L \left[ \frac{R_v(\theta) - L^\uparrow_v(\theta) - \Gamma_v(\theta) (1 - \varepsilon_v(\theta)) L_v^\downarrow(\theta)}{\Gamma_v(\theta) \varepsilon_v(\theta)} \right]^{-1}$$

$\varepsilon_v$: surface emissivity, $\Gamma_v$: atmospheric transmission, $L_v$ and $L_v^\downarrow$: atmospheric upwelling and downwelling radiances at channel $v$.

The geographical domain of AROME model
Assimilation of IR observation over continents

Challenges

- What is the best IASI surface-sensitive channel for LST retrieval?
- What is the impact of this retrieved LST on the assimilation of IASI in AROME model?
IASI and SEVIRI channels for LST retrieval and comparison method

<table>
<thead>
<tr>
<th>Channels</th>
<th>Wave number (cm(^{-1}))</th>
<th>Wavelength (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1027</td>
<td>901.50</td>
<td>11.09</td>
</tr>
<tr>
<td>1271</td>
<td>942.50</td>
<td>10.61</td>
</tr>
<tr>
<td>1191</td>
<td>943.25</td>
<td>10.60</td>
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<tr>
<td>1194</td>
<td>962.50</td>
<td>10.39</td>
</tr>
<tr>
<td>1884</td>
<td>1115.75</td>
<td>8.96</td>
</tr>
</tbody>
</table>

**Exemple of IASI profiles in clear sky conditions**

[Fourrié, 2010]

<table>
<thead>
<tr>
<th>Channels</th>
<th>Wavelength (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3.9</td>
</tr>
<tr>
<td>04</td>
<td>8.7</td>
</tr>
<tr>
<td>07</td>
<td>12.0</td>
</tr>
</tbody>
</table>

**Weighting function of SEVIRI channels**

[Schmetz et al., 2002]

**Study period from 20150115 to 20150228**
Comparison method between IASI and SEVIRI data

Retrieval LST IASI channel 1191 (in squares) and SEVIRI channel 04 (in circles) over Sardinia at day

Mean retrieval LST IASI channel 1191 (in squares) and SEVIRI channel 04 (in circles) over Sardinia by box of 0.5° * 0.5° at day
Comparison between retrieved LST: IASI vs SEVIRI

- Retrieved LST: IASI channel 1191 and SEVIRI channel 04 (by box of $0.5^\circ \times 0.5^\circ$)

The correlation between LST from IASI channel 1191 and LST from SEVIRI channel 04 is even better at night.
Comparison between retrieved LST: IASI vs SEVIRI

Difference between retrieved LST (IASI channel 1191 and SEVIRI channel 04) (by box of 0.5° * 0.5°)

Mean difference between retrieved LST (IASI channel 1191 and SEVIRI channel 04) (by box of 0.5° * 0.5°)

The mean difference between IASI and SEVIRI is around 0.8K at day and less than 2K at night. The correlation is much better at night.
Conclusions of this part

- IASI MetOp A & MetOp B produce similar LST retrievals.
- The use of variable emissivity provides a more realistic LST.
- The comparison between IASI and SEVIRI channels present good results allowing to study the complementarity between polar and geostationnary satellite.
- The comparison between channels in AROME model enable us to keep only the relevant IASI channels for temperature retrieval (the same resultats in the global ARPEGE model): we chose channel 1191.

Using retrieved LST in the AROME assimilation

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP</td>
<td>LST retrieved from IASI channel 1191 used for IASI BTs simulation</td>
</tr>
<tr>
<td>REF</td>
<td>LST from AROME forecast (= operations) used for IASI BTs simulation</td>
</tr>
</tbody>
</table>

IASI channels used for cloud detection (McNally & Watts) in LW temperature band

The geographical domain of AROME model:
horizontal resolution: 1.3 km, 90 vertical levels, 36 h forecasts every 3h, hourly 3DVar Data Assimilation.

Study period from 20150115 to 20150228 using clear observations according to AVHRR

Results from 20150115 to 20150116

Exemple of IASI profiles in clear sky conditions

[Fourrié, 2010]
Using retrieved LST in the AROME assimilation

Location of IASI observations

The total clear observations is 988 at day and 1215 at night for each IASI channel (according to AVHRR)
Using retrieved LST in the AROME assimilation

The Obs-Guess of EXP and REF (combined IASI data from MetOp A & B) is very similar at day and night. A small difference is observed for surface-sensitive channels. The Std is much better in EXP for both cases.
Using retrieved LST in the AROME assimilation

- Total clear observation according to AVHRR and McNally & Watts algorithms

At day, the impact on cloud detection is slightly improved. At night, a small degradation is observed.
Conclusions

The comparison between channels in AROME model enable us to keep only the relevant IASI channels for temperature retrieval (the same resultats over global ARPEGE model): we chose channel 1191.

The first results of assimilation are encouraging and present a slightly positive impact on some other observation such as temperature from radiosoundings.

Future work

Select IASI surface-sensitive channels to be assimilated over land and evaluate the improvement of assimilation and forecasts in the AROME-France domain.

Assimilate the recent sensors like CrIs and prepare the assimilation of the new hyperspectral sensors such as IRS and IASI-NG over continents.
Thank you for your attention
IASI MetOp A and MetOp B characteristics

- IASI-A and B are on the same orbit with a 180° shift.
- ~50 min temporal shift.
- Off-nadir: from 0° to 39°, opposite angles.
- Regional averaging of the soundings (area 300 × 300 km or less).
  [Jouglet et al., 2013]

Comparison between cloud cover IASI MetOp A vs MetOp B from 20150201 to 20150221 (according to AVHRR)

<table>
<thead>
<tr>
<th></th>
<th>Metop A</th>
<th>Metop B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td></td>
<td>Clear</td>
</tr>
<tr>
<td>Cloudy</td>
<td>80%</td>
<td>79%</td>
</tr>
<tr>
<td>Day</td>
<td>20%</td>
<td>21%</td>
</tr>
<tr>
<td>Night</td>
<td>43%</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>57%</td>
<td>67%</td>
</tr>
</tbody>
</table>

Around 80% of IASI MetOp A & MetOp B are affected by clouds at day and more than 50% at night

Comparison of retrieved LST IASI MetOp A vs MetOp B from 20150115 to 20150228

Very good correlation between retrieved LST IASI MetOp A vs MetOp B (a little better at night)
Comparison between background and retrieved LST

Comparison between background and retrieved LST IASI channels

<table>
<thead>
<tr>
<th>Channel number</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std</td>
</tr>
<tr>
<td>1027</td>
<td>0.161</td>
<td>2.238</td>
</tr>
<tr>
<td>1271</td>
<td>0.337</td>
<td>2.177</td>
</tr>
<tr>
<td>1191</td>
<td>0.165</td>
<td>2.217</td>
</tr>
<tr>
<td>1194</td>
<td>0.212</td>
<td>2.194</td>
</tr>
<tr>
<td>1884</td>
<td>-0.324</td>
<td>2.191</td>
</tr>
<tr>
<td>Total observation</td>
<td>66191</td>
<td></td>
</tr>
</tbody>
</table>

- Mean difference between background and retrieved LST is less than 0.4K at day and 0.7K at night for all IASI channels.
- Standard deviation is around 2K at day and 3K at night.
- Better correlation at day.

Comparison between retrieved LST IASI 1191 and 1027 channels

- The comparison between retrieved LST IASI channels present a very good result with a correlation higher than 0.9.
Comparison between retrieved LST IASI vs SEVIRI channels per hour

Retrieved LST @ 09 UTC (in K)

$0.783013x + 58.142731$
$r = 0.851836$

Retrieved LST @ 10 UTC (in K)

$0.940242x + 16.054886$
$r = 0.95228$

Retrieved LST @ 11 UTC (in K)

$0.998091x + 0.996506$
$r = 0.996086$

Retrieved LST @ 20 UTC (in K)

$0.896555x + 20.537658$
$r = 0.8996425$

Retrieved LST @ 21 UTC (in K)

$0.989767x + 0.998153$
$r = 0.922545$

Retrieved LST @ 22 UTC (in K)

$0.845717x + 40.590947$
$r = 0.846192$
Difference between retrieved LST using constant vs variable emissivity over ARPEGE model
For October 2014