The improvement of assimilation of IASI surface-sensitive channels over land at convective scale AROME model

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OUTLINE

1. Motivation & Challenges
2. LST retrievals from IASI
3. The impact of retrieved LST on the simulation of IASI surface-sensitive infrared observations in the AROME assimilation system
4. Conclusions and prospects

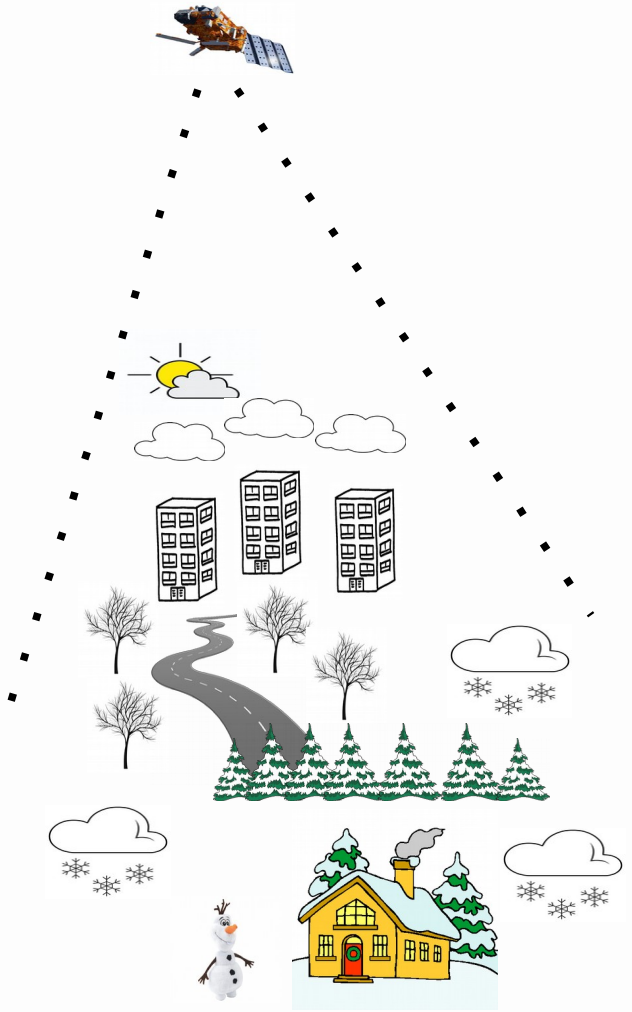
Motivation

The importance of Land Surface Temperature (LST)

- LST plays an important role in surface-atmosphere exchange [Niclòs et al., 2009].
- It is one of the key surface parameters which indicates the energy balance at the Earth's surface and is particularly relevant for domains such as agriculture, climatology, hydrology and weather forecasts [Kerr et al., 2004].

The definition of satellite LST products

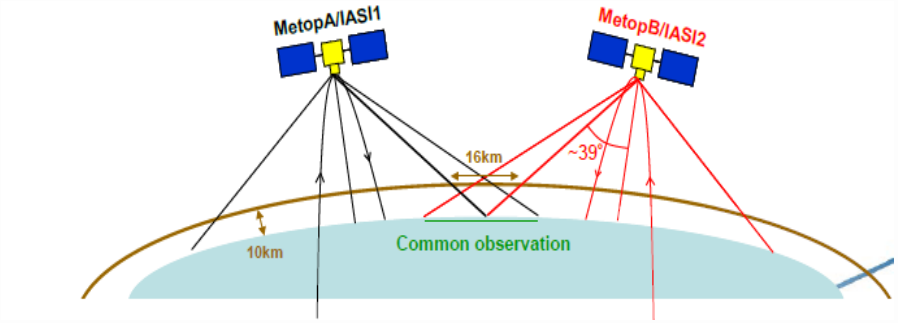
- The estimate of the kinetic temperature of the earth's surface "skin" [Dickinson, 1994].
- LST from satellite observation is a challenging task due to the cloud cover and variation of surface emissivity.



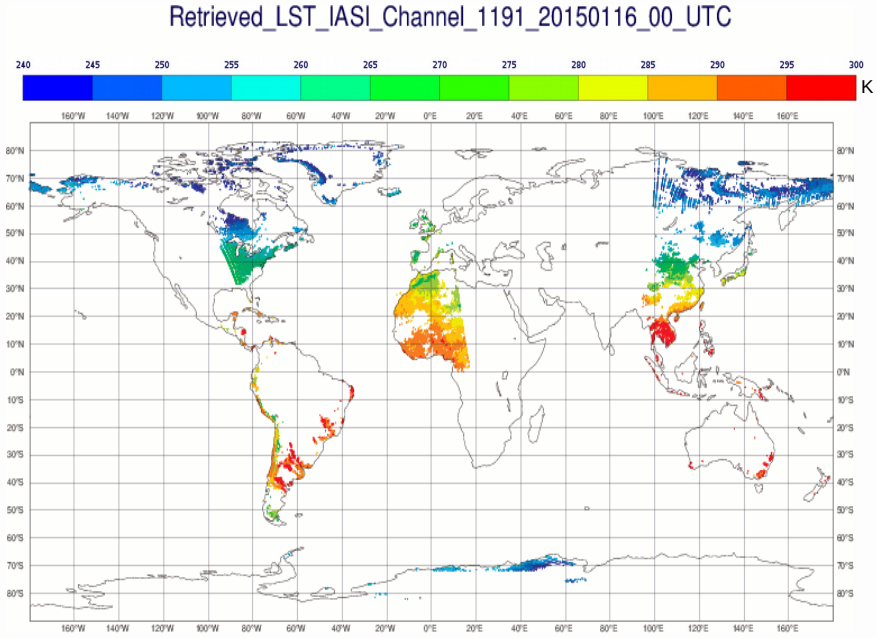
Motivation

LST from IASI radiances

- IASI (Infrared Atmospheric Sounding Interferometer) is an IR hyperspectral sensor onboard polar orbiting satellites MetOp A & MetOp B.
- It contains 8461 channels operating between 645 and 2760 cm^{-1} but less than 200 channels are assimilated in NWP centres.



- 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]



Retrieved LST from IASI channel 1191 in the global ARPEGE model

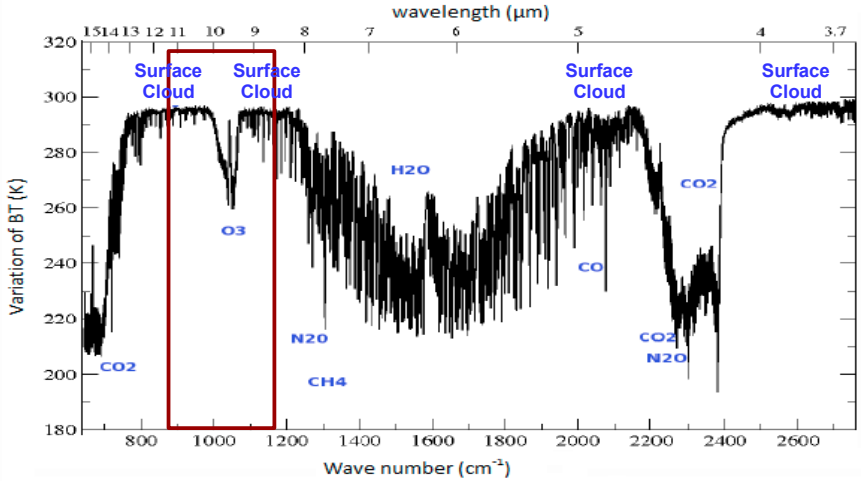
- The assimilation of IASI in the AROME model is already well developed.
- More research is still needed to allow an increase of its use.

Challenges

- Identification of the best IASI surface-sensitive channel for LST retrieval.
- Study the impact of this retrieved LST on the assimilation of IASI in AROME model.

LST retrievals from IASI

IASI		
Channels	**Wave number (cm^{-1})**	**Wavelenght (µm)**
1027	901.50	11.09
1271	942.50	10.61
1191	943.25	10.60
1194	962.50	10.39
1884	1115.75	8.96



Example of IASI spectrum in clear sky conditions
[Fourrié, 2010]

Radiative transfer equation inversion:

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

[Karbou et al., 2006]

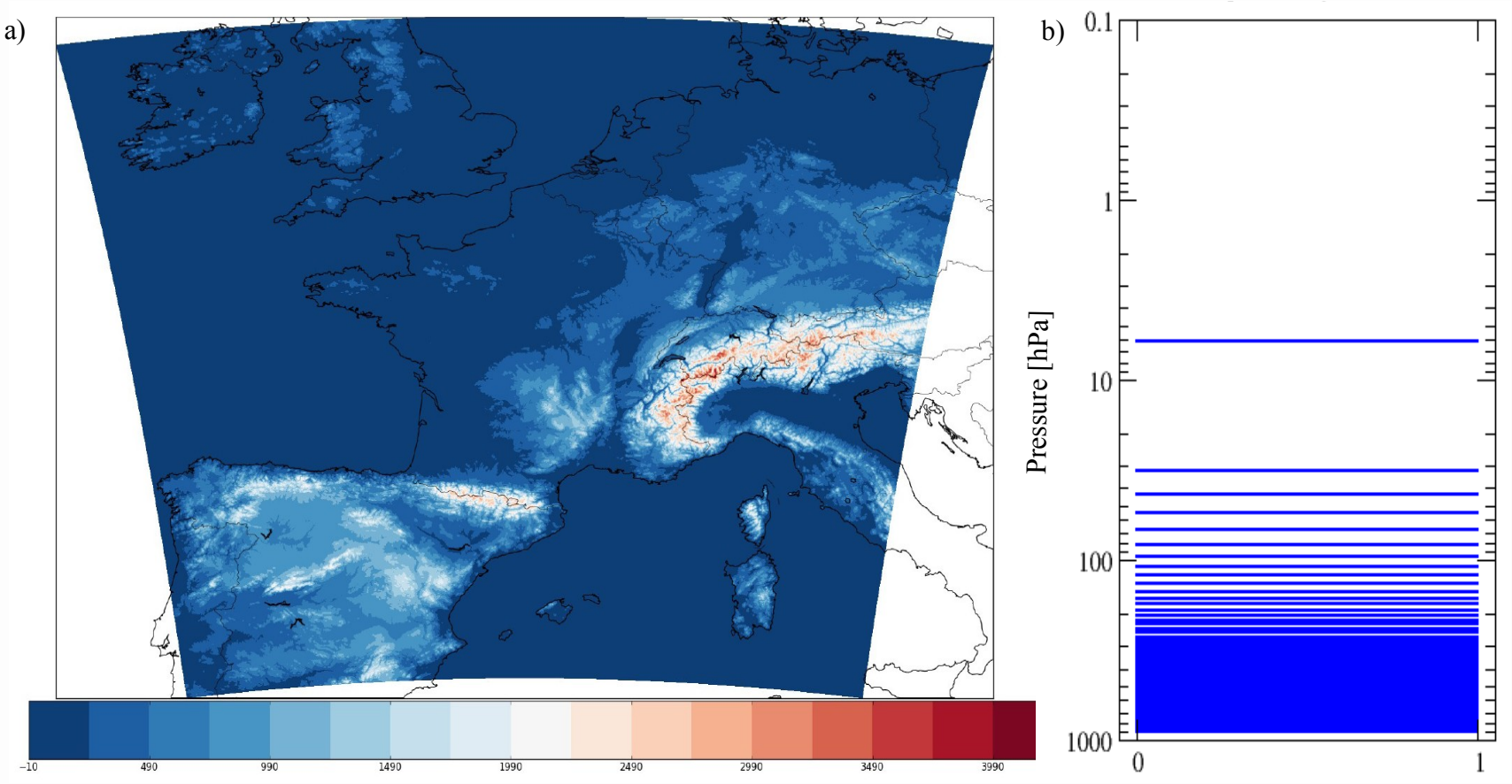
εv: surface emissivity, Γv: atmospheric transmission, $L_v^{\uparrow}$ and $L_v^{\downarrow}$: atmospheric upwelling and downwelling radiances at channel v.

Atmospheric transmission, atmospheric upwelling and downwelling radiances was computed using **RTTOV model** v11.

For emissivity, we used:

- **Constant emissivity** equal to 0.98 (operational).
- **Emissivity atlas** developed by the Space Science and Engineering Centre at University of Wisconsin.

LST retrievals from IASI



The geographical domain (a) and vertical levels (b) of AROME model (colours indicate orography in the Model).
Horizontal resolution: 1.3 km, 90 vertical levels, 36 h forecasts every 3h, hourly 3DVar Data Assimilation.

LST retrievals from IASI

Retrieved LST from IASI radiances

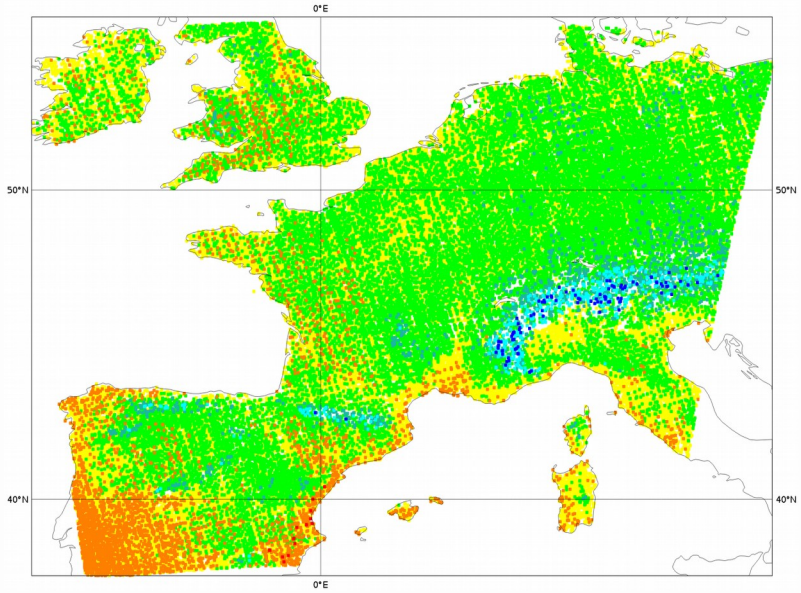
- Comparison of retrieved LST from IASI MetOp A vs MetOp B.
- Comparison between background and retrieved LST IASI.
- Inter-channels IASI LST comparisons.

Validation of IASI surface-sensitive channel

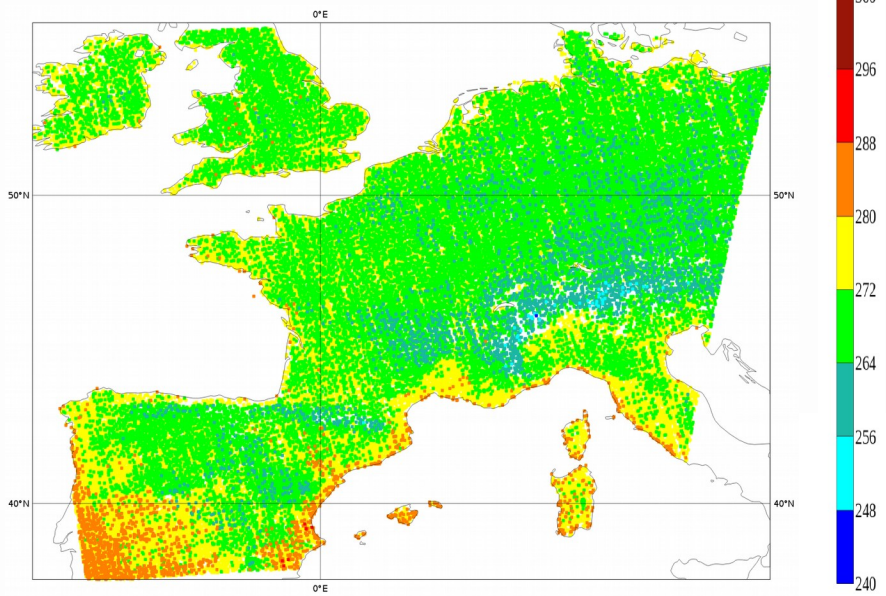
- Comparison of retrieved LST from IASI vs retrieved LST from SEVIRI and AVHRR.

- Study period: from January 15th to February 28th 2015.
- Using constant emissivity (0.98) vs emissivity atlas developed by the Space Science and Engineering Center at University of Wisconsin [Borbas et al., 2007].

Background LST at night



Retrieved LST from IASI channel 1191 at night



LST retrievals from IASI

Conclusions of this part of study

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

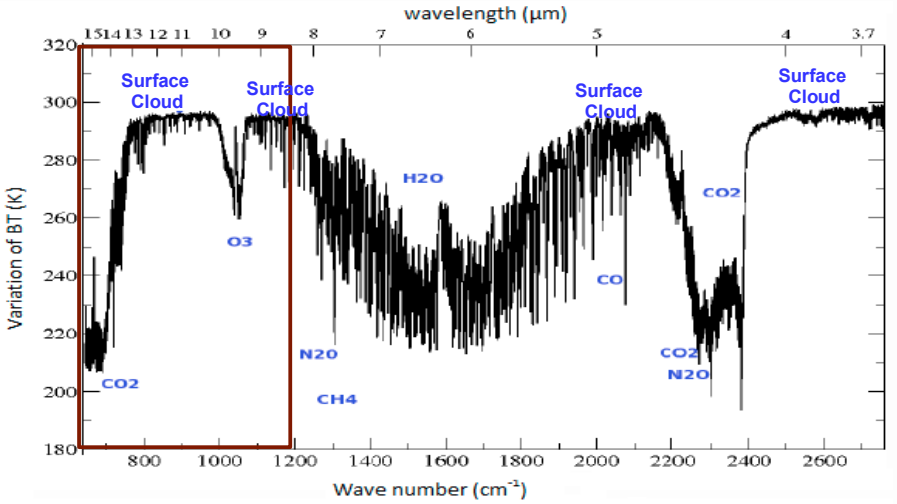
Attached communication

- **Boukachaba, N.**, Guidard, V., Fourrié, N., 2015. Improved assimilation of IASI land surface temperature data over continents in the convective scale AROME France model. The 20th International TOVS Study Conference. 28 October - 3 November 2015, Lake Geneva, Wisconsin, USA.
- **Boukachaba, N.**, Fourrié, N., and Guidard, V., 2015. Land surface temperature retrieval from IASI for assimilation over the AROME-France domain. EUMETSAT Meteorological Satellite Conference, 21-25 September 2015, Toulouse, France.

Using retrieved LST in the AROME assimilation

EXP	LST retrieved from IASI channel 1191 used for IASI BTs simulation
REF	LST from AROME forecast (= operations) used for IASI BTs simulation

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



Example of IASI spectrum in clear sky conditions [Fourrié, 2010]

- Study period: from January 15th to February 28th 2015.
- Emissivity atlas.
- Analyse sea/land.
- Clear/cloudy pixels according to AVHRR and McNally & Watts algorithms.

Total obs

Using retrieved LST in the AROME assimilation

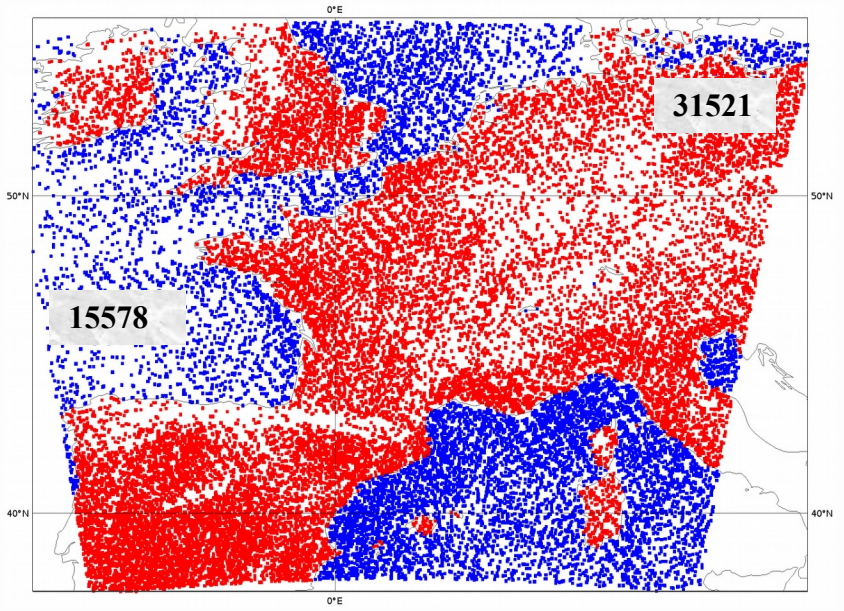
Total clear/cloudy IASI observations
according to AVHRR

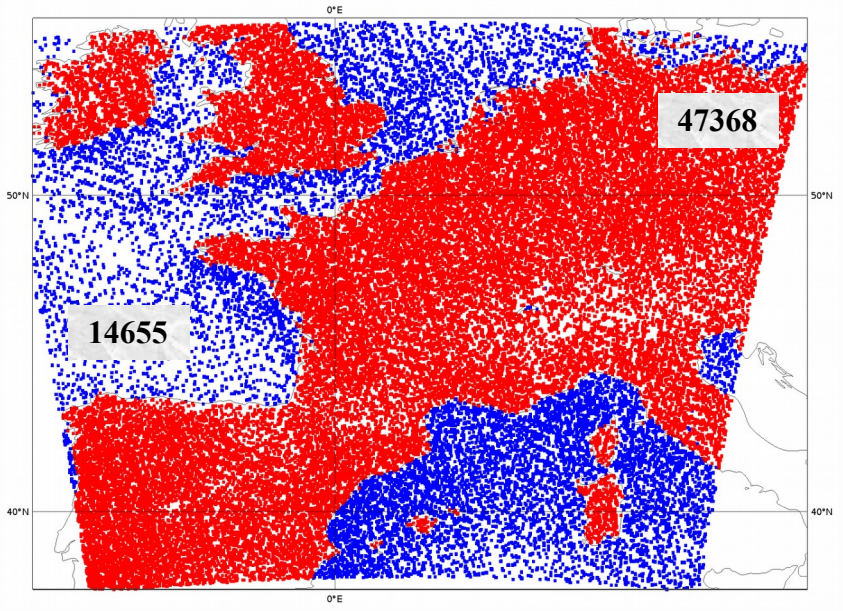
Day

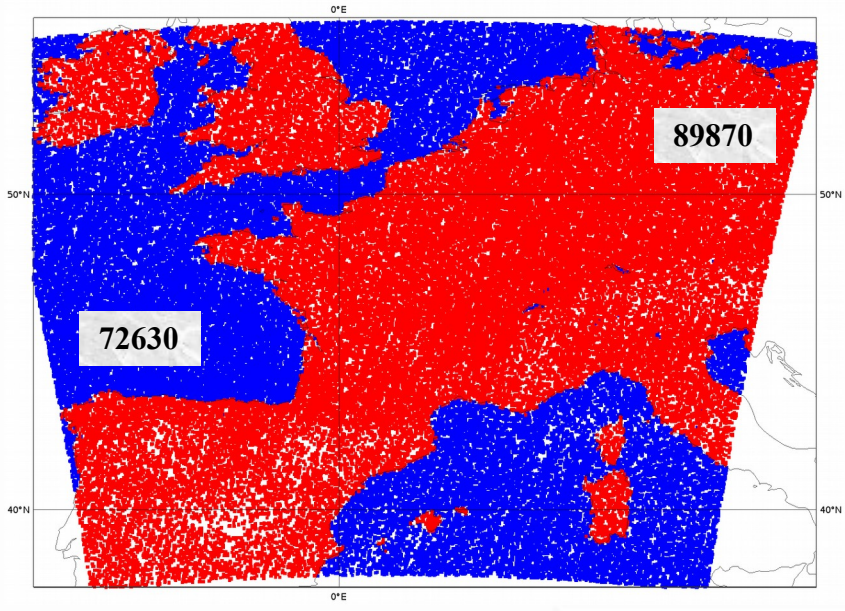
Night

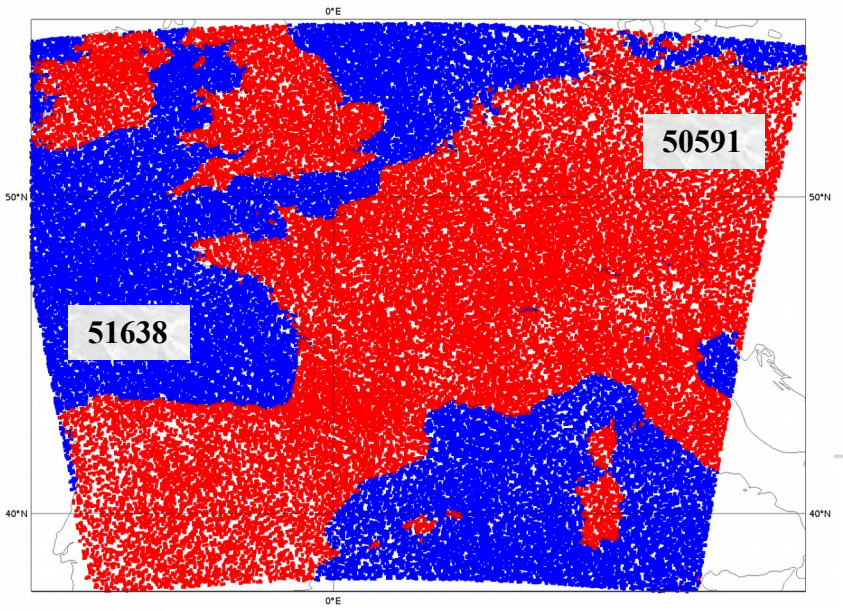
Clear

Cloudy









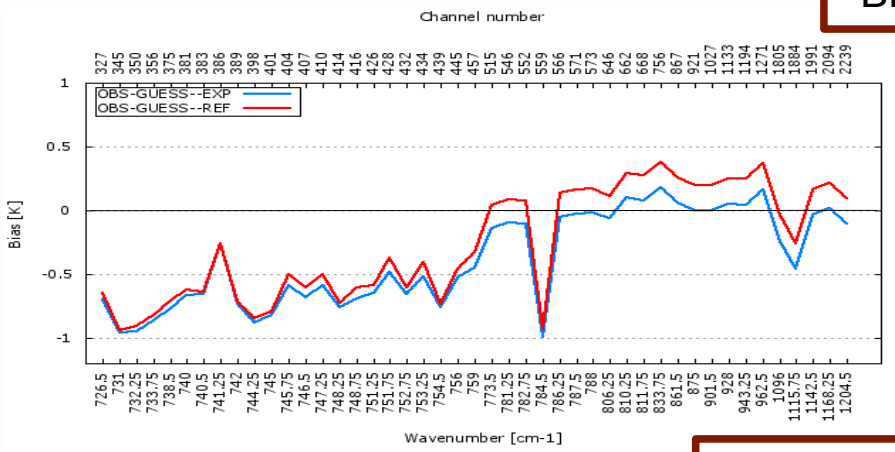
Using retrieved LST in the AROME assimilation

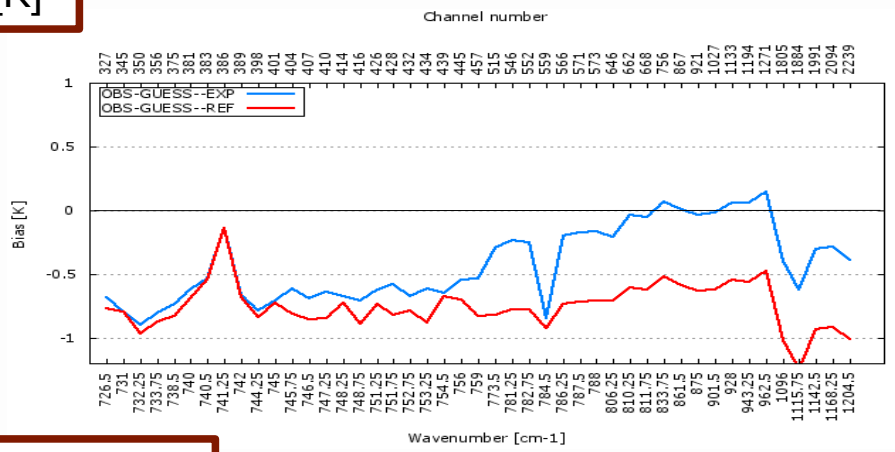
IASI clear observations according to AVHRR
(without bias correction)

Day

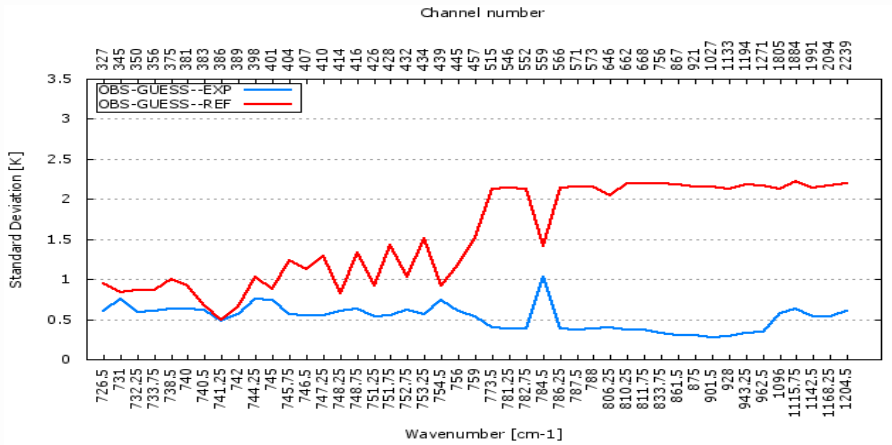
Night

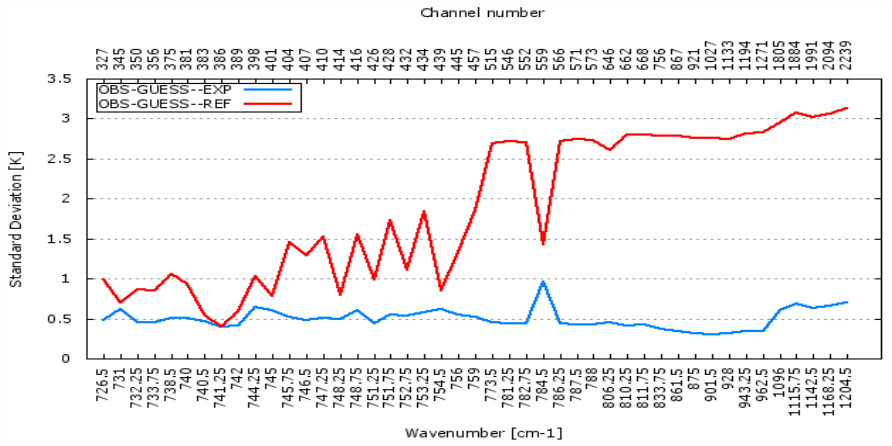
Bias [K]





Standard deviation [K]



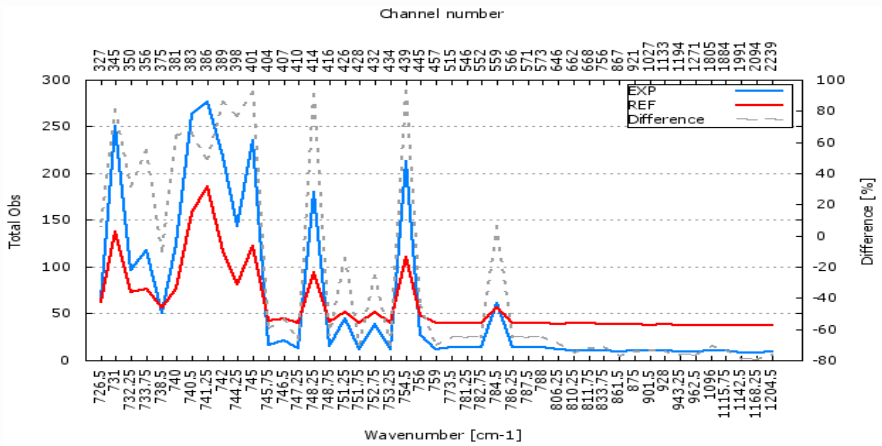


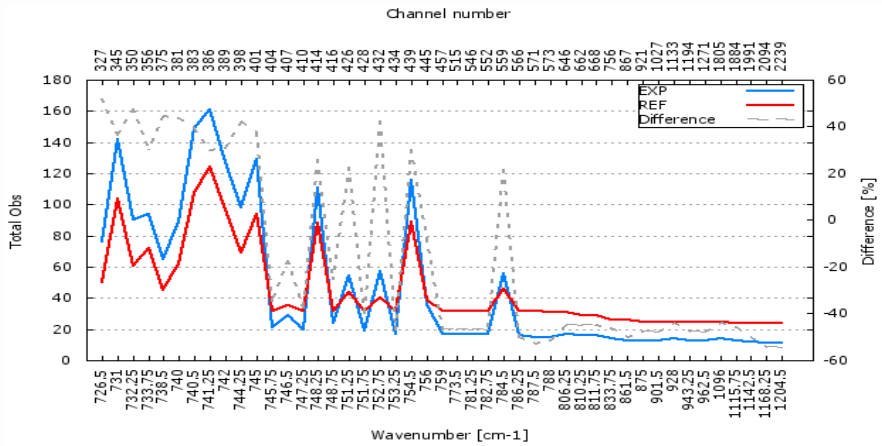
The Obs-Guess of EXP and REF (combined IASI data from MetOp A & B) is very similar at daytime. A small difference is observed in surface-sensitive channels. At night-time, Obs-Guess of REF decreases. However, Obs-Guess of EXP changes a litlle. The StdDev was reduced in EXP compared to REF for both cases with large difference in surface-sensitive channels.

Using retrieved LST in the AROME assimilation

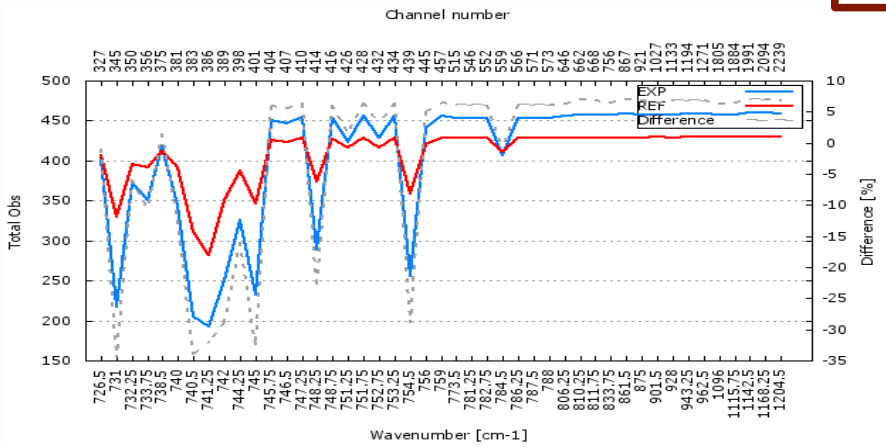
Total clear/cloudy channels according to McNally & Watts algorithm within
to clear pixels according to AVHRR for the 15th January 2015

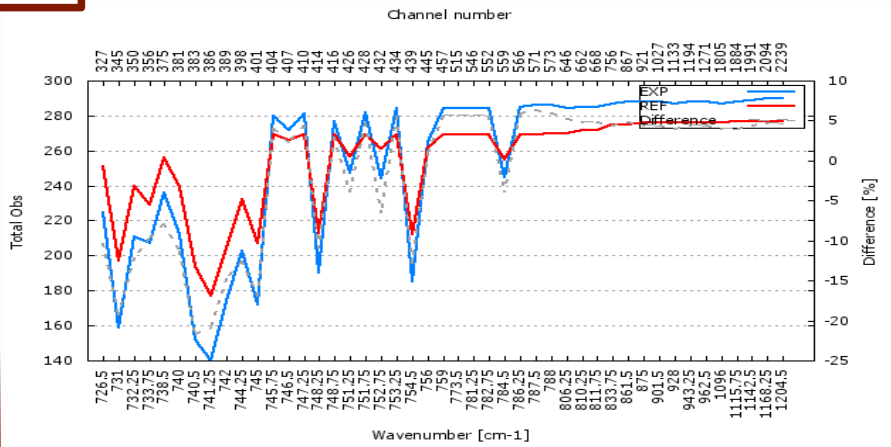
Day | **Clear** | **Night**





Cloudy

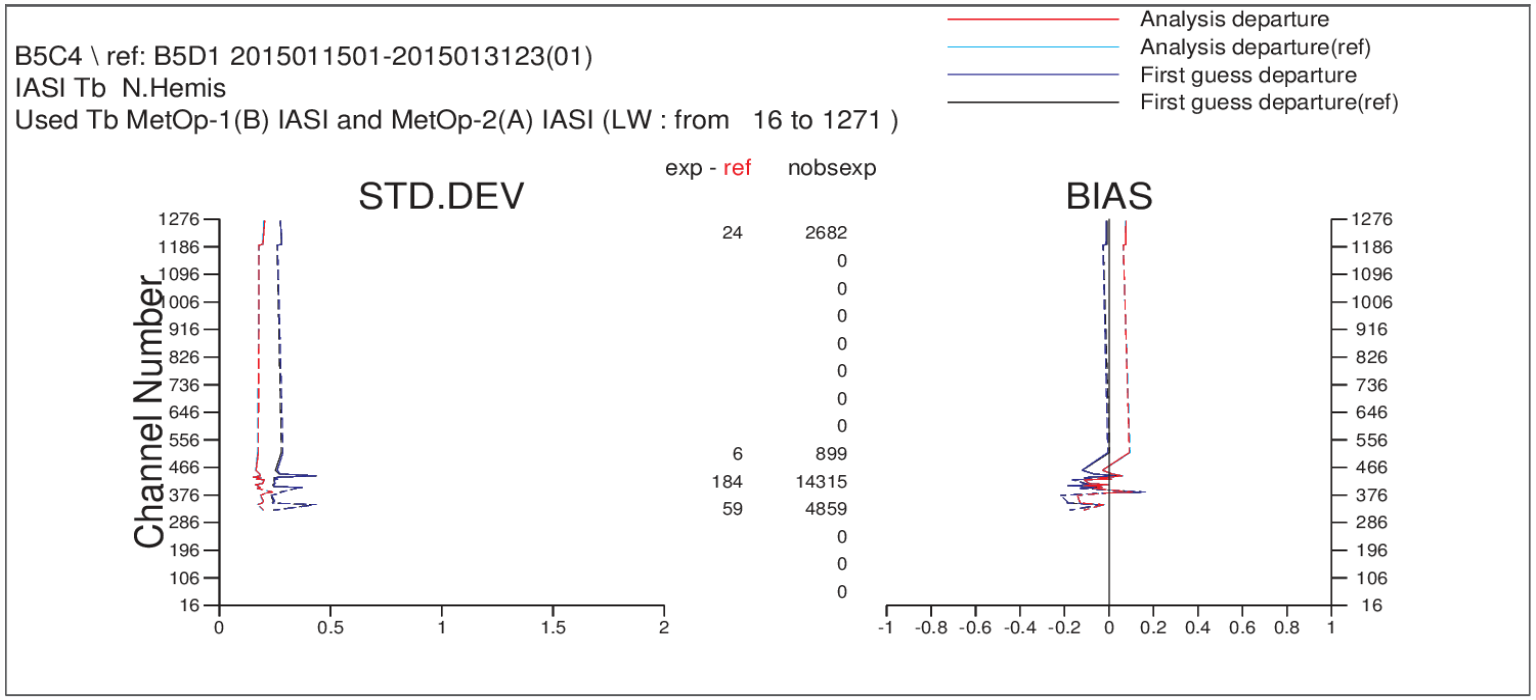




Both at daytime and night-time, the impact on cloud detection provides more clear channels in EXP than in REF (~ +30%) for atmospheric channels. The clear channel number is slightly decreased. This may be due to incorrect bias correction.

Using retrieved LST in the AROME assimilation

Impact on IASI BT simulation

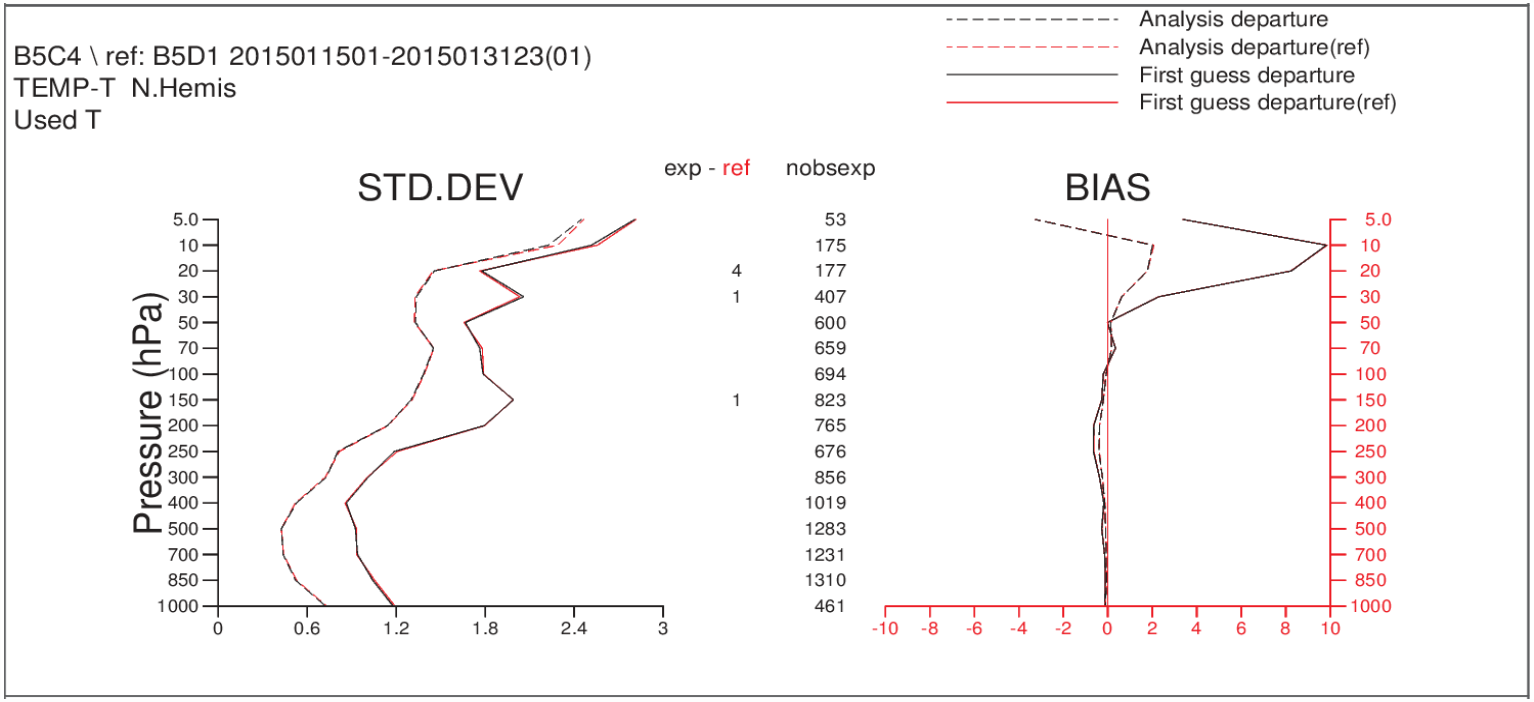


The standard deviation of the difference between observations and background simulations is decreased, especially for surface-sensitive Channels.

The bias of observations and background simulations is also reduced which allows to increase the number of observation assimilated over land.

Using retrieved LST in the AROME assimilation

Impact on the assimilation of temperature from radiosoundings



Neutral and even positive impacts on the analysis and forecast of AROME model.

Conclusions and prospects

Conclusions

- The comparison between channels in AROME model enable us to keep only the relevant IASI channels for temperature retrieval (the same results over global ARPEGE model): we chose channel 1191.
- The use of retrieved LST for IASI BT simulation leads to a decrease of the bias and the standard deviation of the difference between observations and background simulations, especially for surface-sensitive channels.
- 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.
- Improve the bias correction over land.
- 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

METEO FRANCE

cnrs

Backup

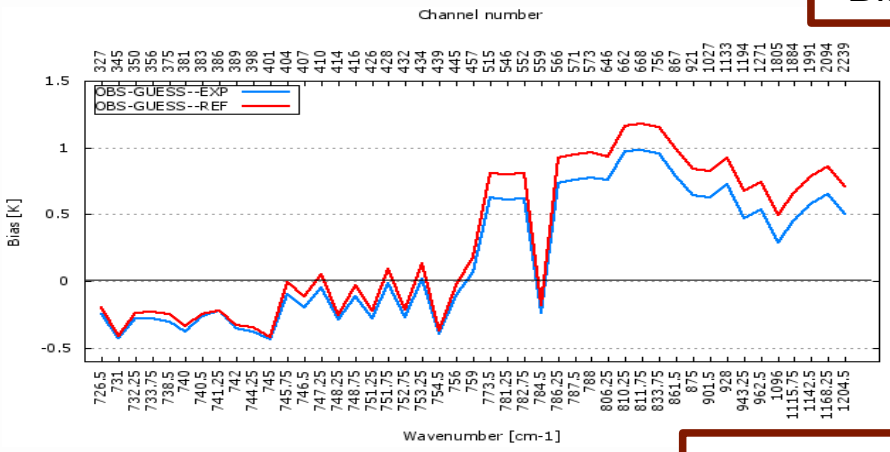
Using retrieved LST in the AROME assimilation

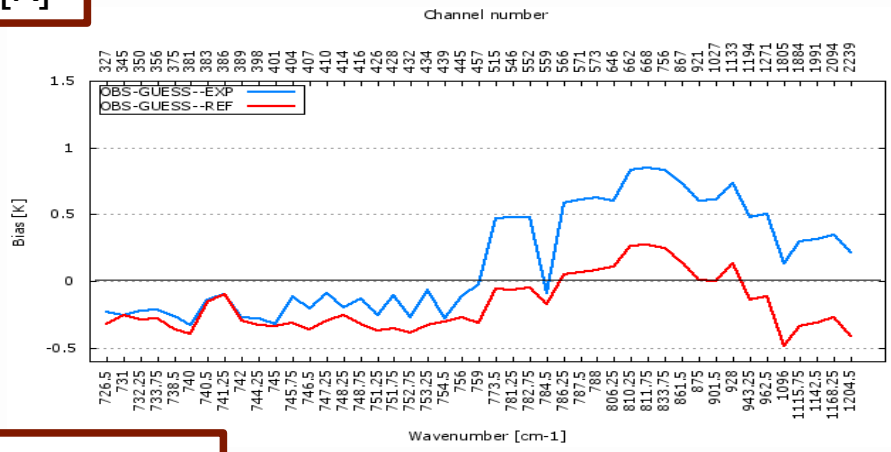
IASI clear observations according to AVHRR (with bias correction)

Day

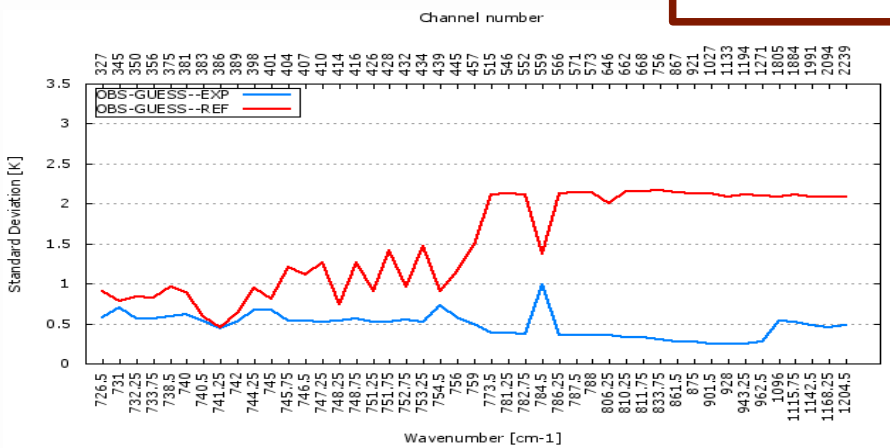
Night

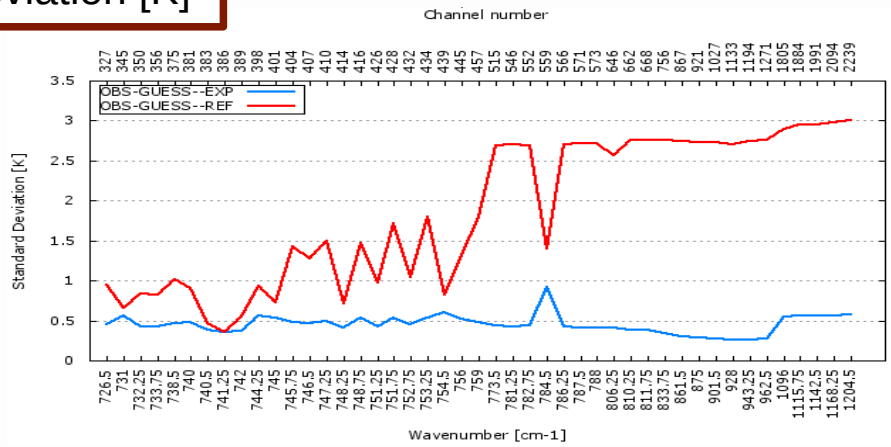
Bias [K]





Standard deviation [K]





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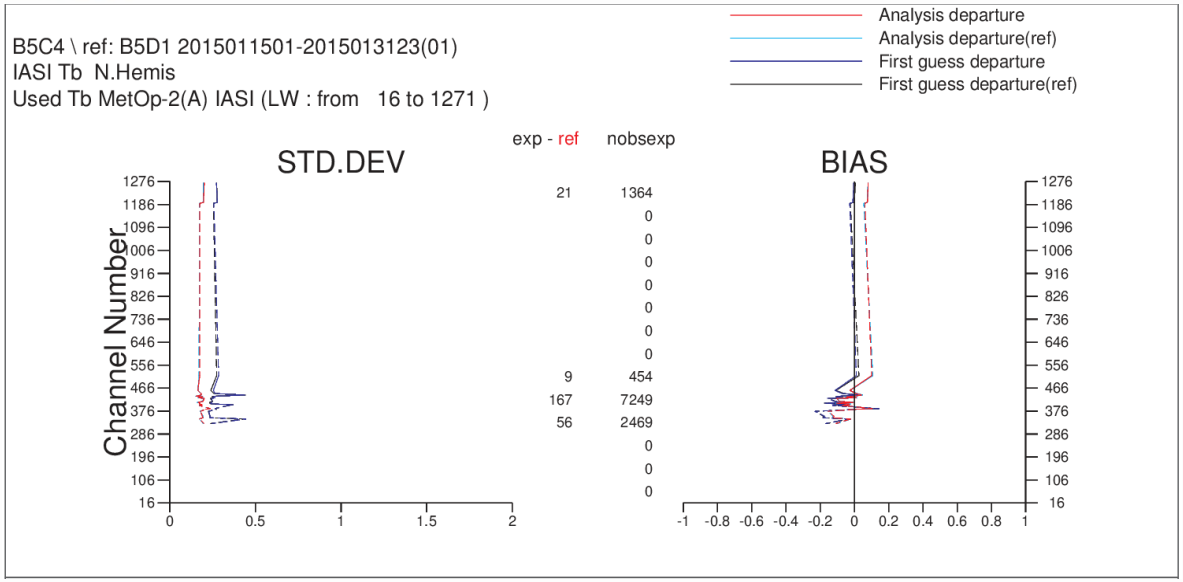
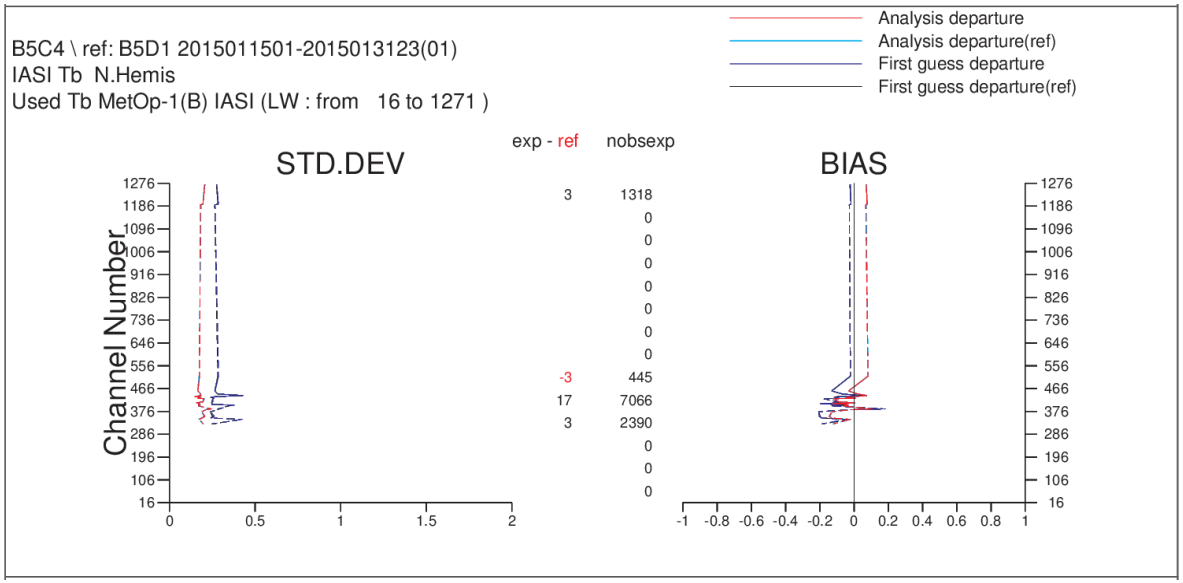
Using retrieved LST in the AROME assimilation

Impact on IASI BT simulation



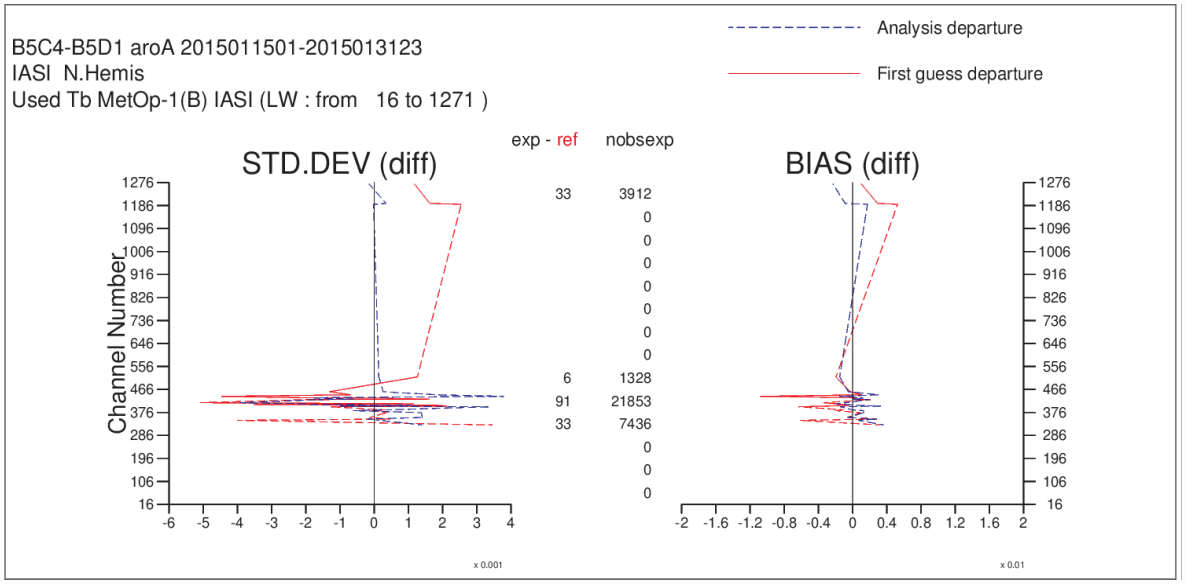


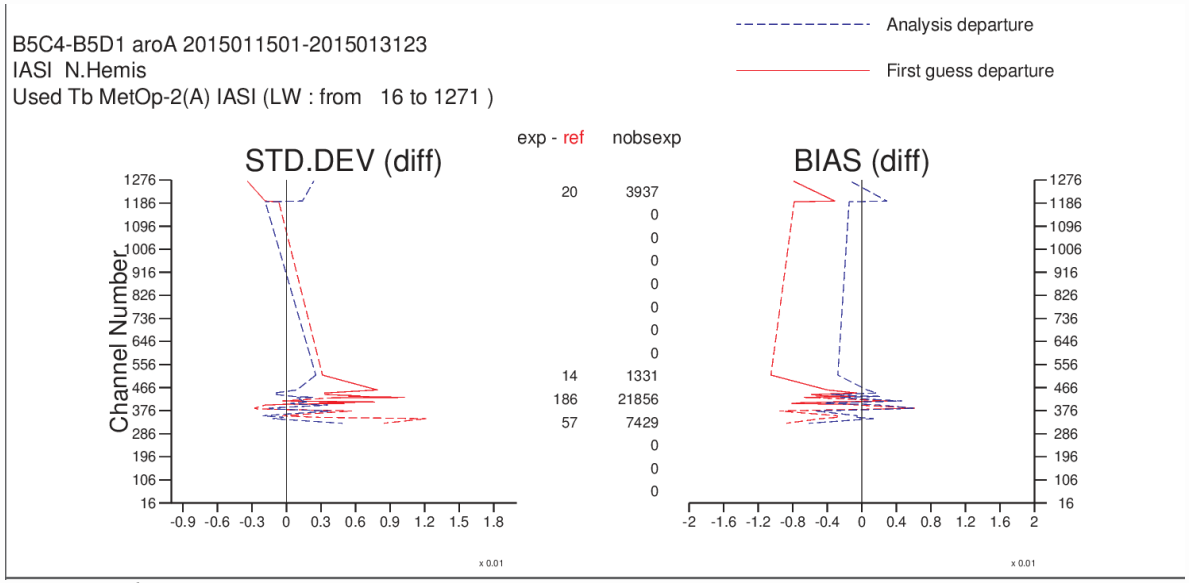
The standard deviation of the difference between observations and background simulations is decreased, especially for surface-sensitive Channels.

The bias of observations and background simulations is also reduced which allows to increase the number of observation assimilated over land.

Using retrieved LST in the AROME assimilation

Impact on IASI BT simulation



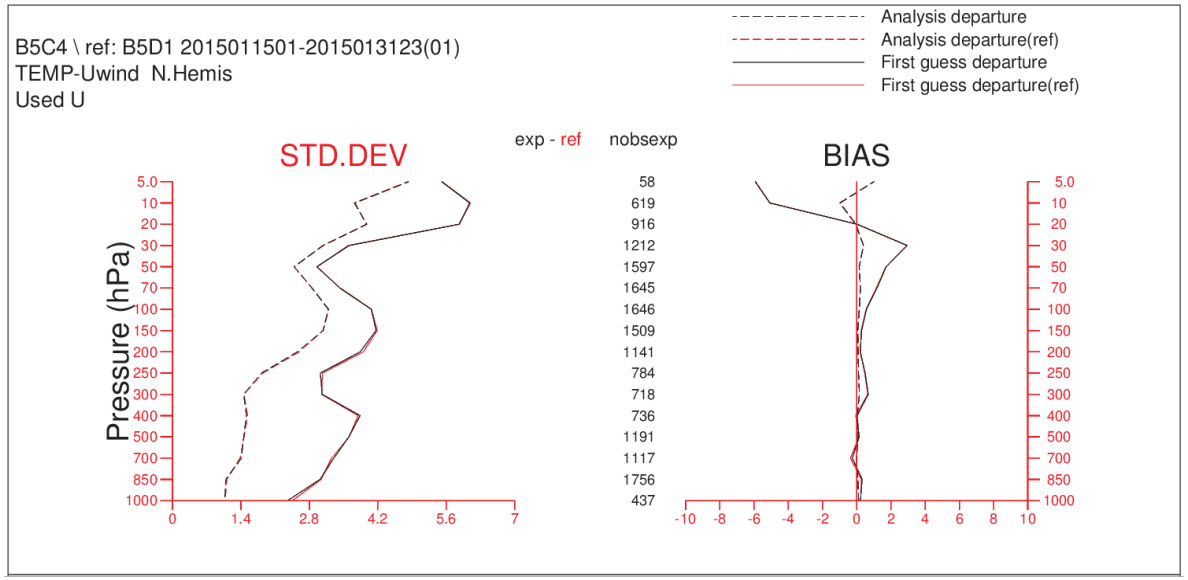


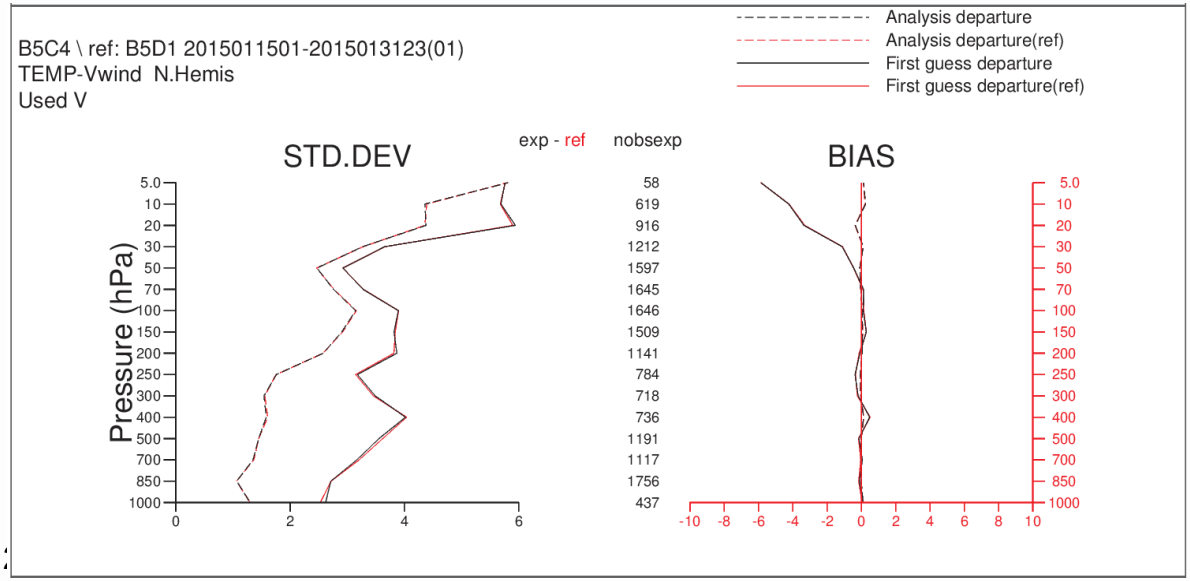
The standard deviation of the difference between observations and background simulations is decreased, especially for surface-sensitive Channels.

The bias of observations and background simulations is also reduced which allows to increase the number of observation assimilated over land.

Using retrieved LST in the AROME assimilation

Impact on the assimilation of other observation

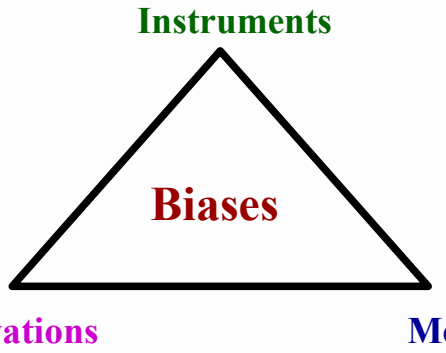




Neutral and even positive impacts on the analysis and forecast of AROME model.

Using retrieved LST in the AROME assimilation

VARiational Bias Correction (VARBC)



$$J(x) = \frac{1}{2}(x_b - x)^T B^{-1}(x_b - x) + \frac{1}{2}(y - \mathcal{H}(x))^T R^{-1}(y - \mathcal{H}(x))$$

J_b: background term — J_o: observational term

Errors in the actual observations

Errors in the observation operator

Errors in the model background

Bias correction

J_b: background term for x — J_o: **Corrected** observational term

$$J(x,\beta) = (x_b - x)^T B_x^{-1}(x_b - x) + [y - H(x) - B(\beta)]^T R^{-1} [y - H(x) - B(\beta)] + (\beta_b - \beta)^T B_\beta^{-1}(\beta_b - \beta)$$

J_o: **Corrected** observational Term — J_p: background term for β

- The separation between instrumental bias, observation bias and model bias is very difficult but not impossible!
- Météo-France uses adaptive variational bias correction (VARBC) embedded inside its global ARPEGE model assimilation system since 2008.
- VARBC separates the observation bias from the systematic errors in the background by adding predictors [Dee, 2004; Auligné et al., 2007].
- In the global ARPEGE model, this variational bias correction is refined at each analysis time, using coefficients computed during the previous assimilation as a first guess. For AROME, it was decided to use the coefficients that are computed for ARPEGE [Guidard et al., 2011].

Using retrieved LST in the AROME assimilation

VARiational Bias Correction (VARBC)

Bias correction

J_b: background term for x

J_o: **Corrected** observational term

J_p: background term for β

$$J(x,\beta) = (x_b - x)^T B_x^{-1} (x_b - x) + [y - H(x) - B(\beta)]^T R^{-1} [y - H(x) - B(\beta)] + (\beta_b - \beta)^T B_\beta^{-1} (\beta_b - \beta)$$

$$B(\beta) = \sum_{i=1}^{N} \beta_i P_i$$

Predictors

Bias-correction coefficients

For IASI

- 1 (constant)
- 1000-300hPa thickness
- 200-50hPa thickness
- 10-1hPa thickness
- 50-5hPa thickness
- nadir viewing angle
- nadir view angle **2
- nadir view angle **3