Assimilation of IASI surface-sensitive channels over land at convective scale AROME Model

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PhD supervised by Vincent Guidard & Nadia Fourrié
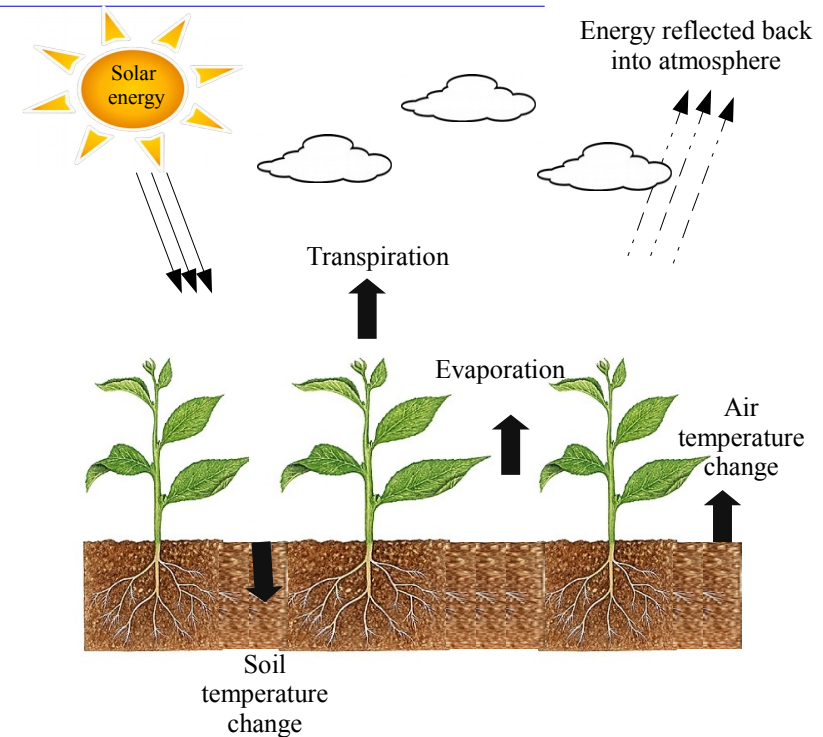
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OUTLINE

1 Motivation & Challenges

2 LST retrievals from IASI

3 The impact of retrieved LST on the simulation and assimilation of IASI surface-sensitive infrared observations in the AROME model

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].
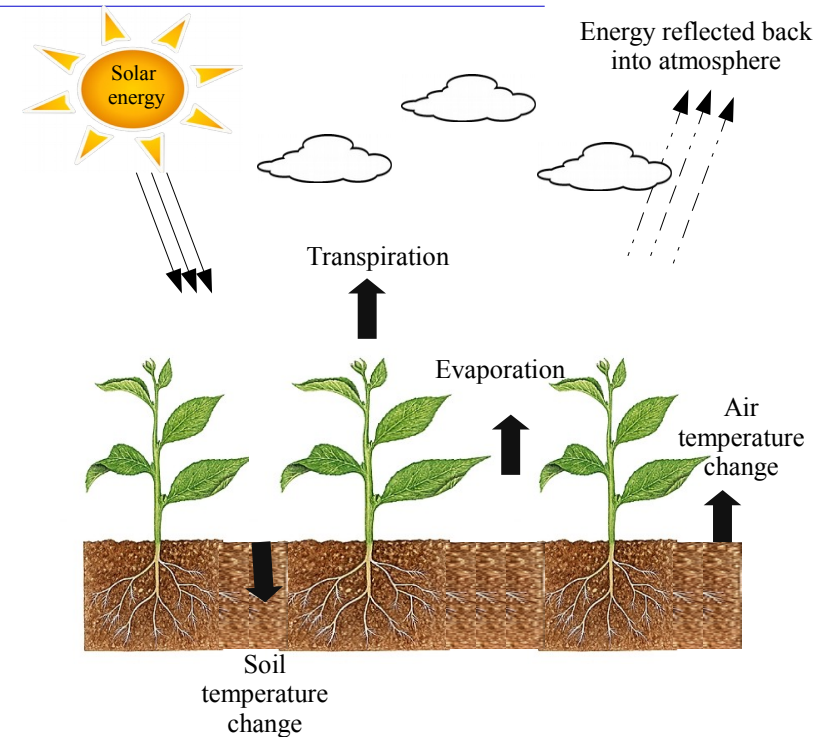
Motivation

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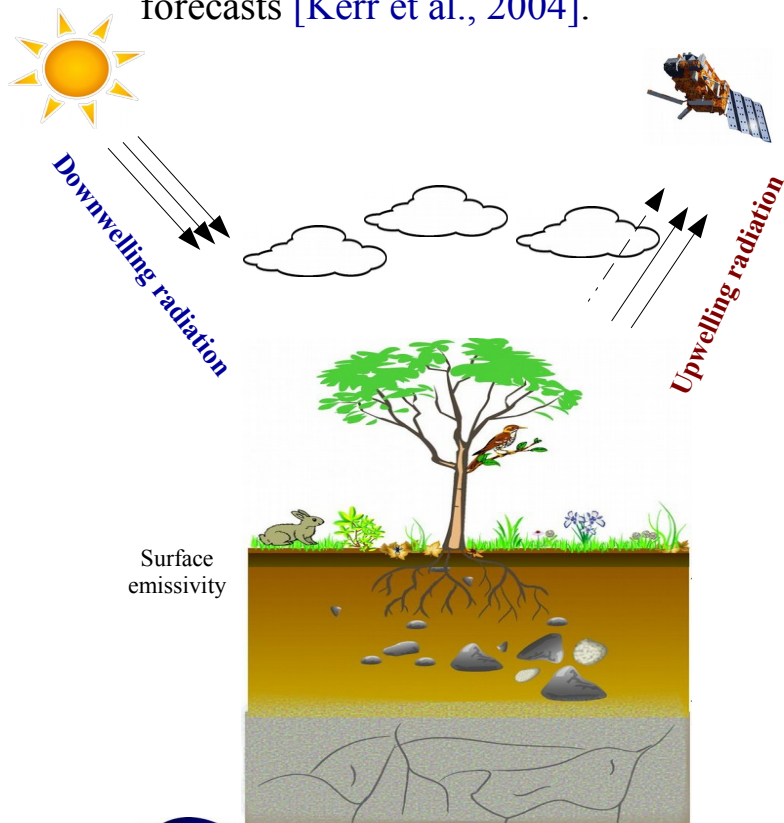

Downwelling radiation

Upwelling radiation

Surface emissivity

Solar energy

Energy reflected back into atmosphere

Transpiration

Evaporation

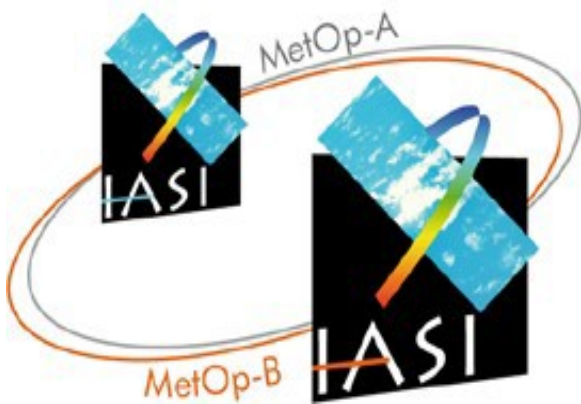Air temperature change

Soil temperature change

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.
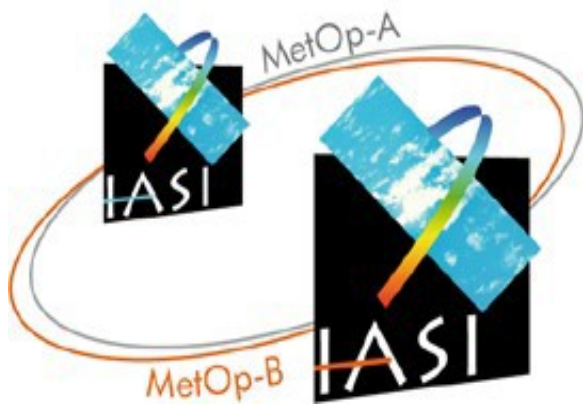

- IASI-A and B are on the same orbit with a 180° shift.
- ~50 min temporal shift.
- Off-nadir: from 0° to 39°, opposite angles.
- Regional averaging of the soundings (area 300 × 300 km or less). [Jouglet et al., 2013]

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Motivation

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Assimilation of IASI at Météo-France

- The assimilation of IASI in the AROME model is already well developed.

- More research is still needed to allow an increase of its use.

Satellite observation   In-situ observation
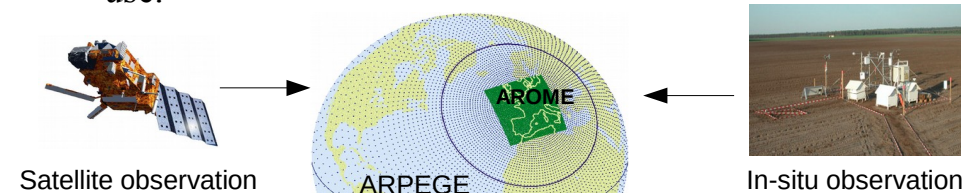
**Retrieved LST from IASI channel 1191 at night in the AROME model**
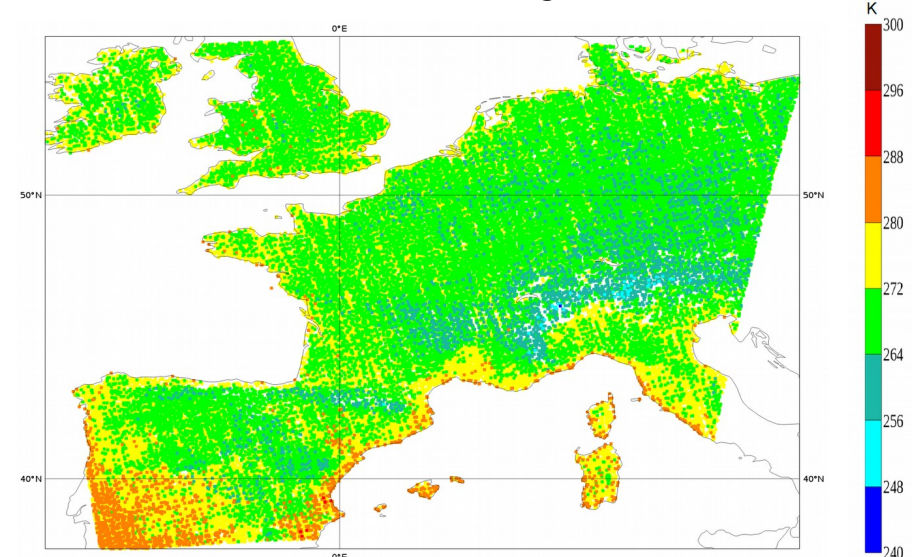
Challenges

□ Identification of the best IASI surface-sensitive channel for LST retrieval.

□ Study the impact of this retrieved LST on the simulation and assimilation of IASI in AROME model.

LST retrievals from IASI

IASI		
Channels	**Wave number (cm⁻¹)**	**Wavelenght (µm)**
1027	901.50	11.09
1191	942.50	10.61
1194	943.25	10.60
1271	962.50	10.39
1884	1115.75	8.96
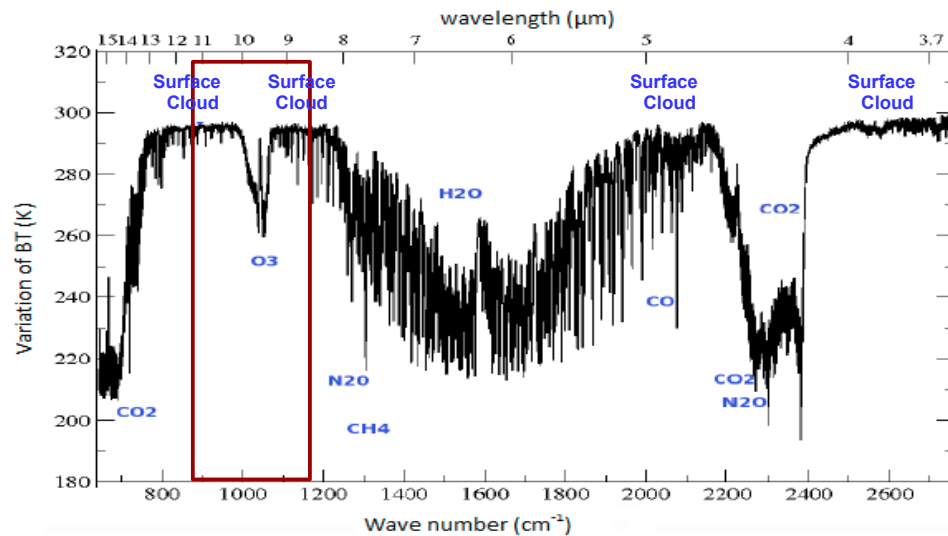
Example of IASI spectrum in clear sky conditions
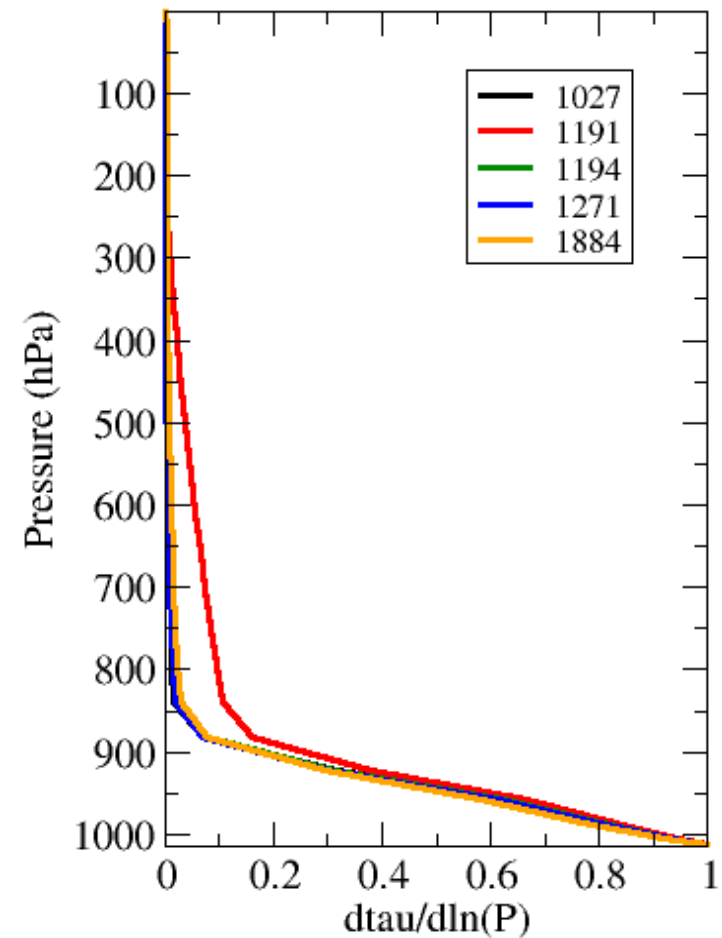
Weighting function of the 5 IASI surface-sensitive channels selected

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LST retrievals from IASI

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, $Lv^{\uparrow}$ and $Lv^{\downarrow}$: atmospheric upwelling and downwelling radiances at channel v.

Atmospheric transmission, atmospheric upwelling and downwelling radiances were 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

a)

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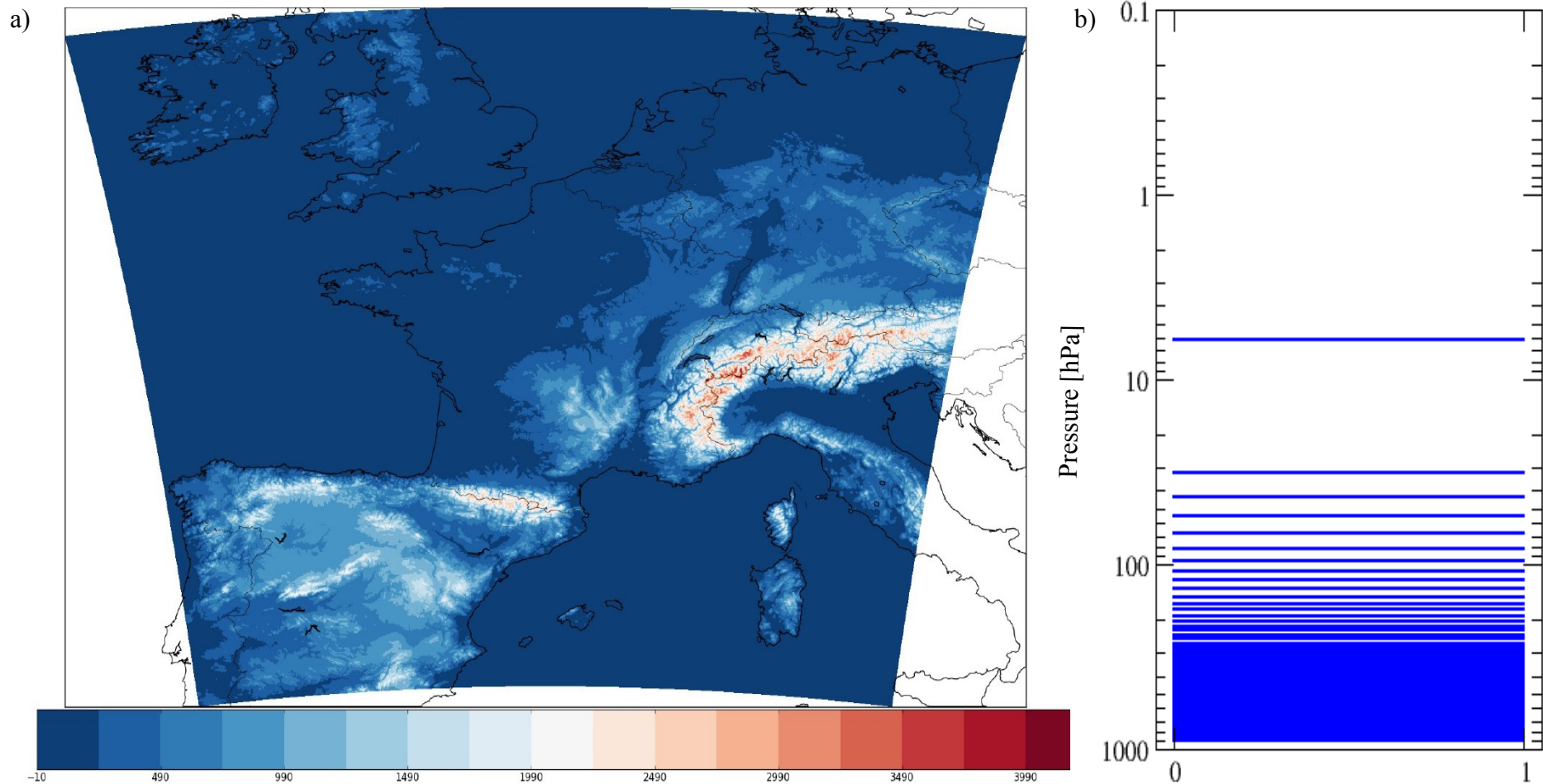
The geographical domain (a) and vertical levels (b) of AROME model (colours indicate orography in the Model).
Horizontal resolution: 1.3 km, 90 vertical levels, 36 h forecasts every 3h and hourly 3DVar Data Assimilation.

LST retrievals from IASI

Conditions of identification of the best IASI surface-sensitive channel

- ◆ Good surface representation with lower sensitivity to clouds and atmospheric molecules.

- ◆ Lower bias and standard deviation between background and retrieved LST.

- ◆ Best correlation with other IASI and SEVIRI channels LST.

LST retrievals from IASI

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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].

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# LST retrievals from IASI
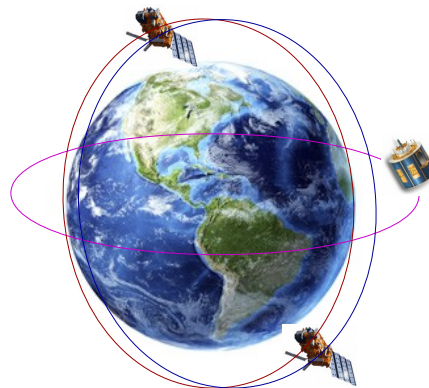
Conclusions of this part of study

- 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. and Fourrié, N., 2016. Surface temperature retrievals from IASI and SEVIRI channels in the convective scale numerical prediction AROME-France model. The 4th IASI Conference. 11-15 April 2016, Antibes Juan-les-Pins, France. (**Poster S5-114)**

- **Boukachaba, N.**, Guidard, V. and 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.**, Guidard, V. and Fourrié, N., 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
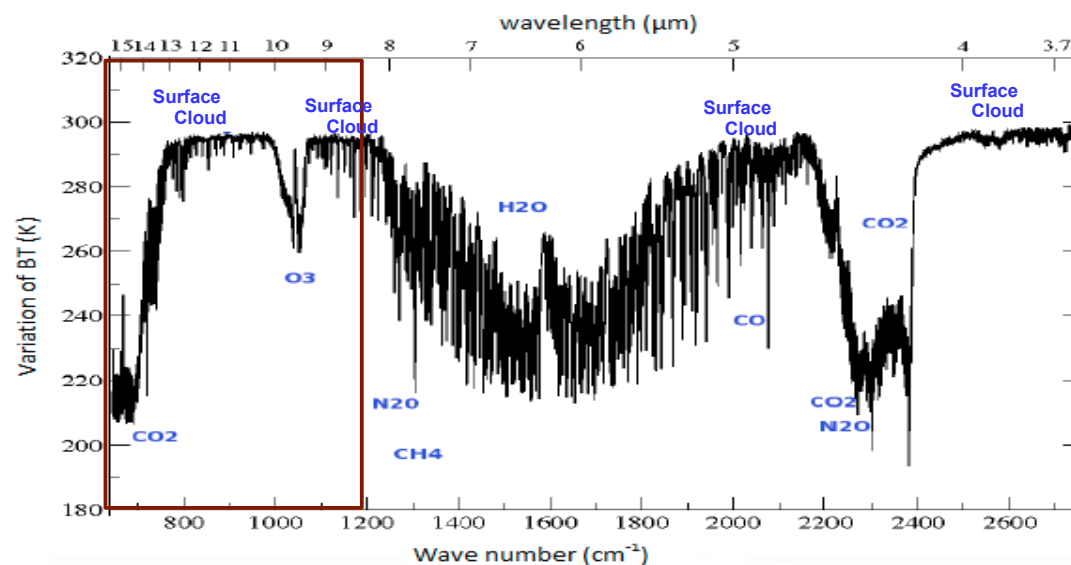
Example of IASI spectrum in clear sky conditions

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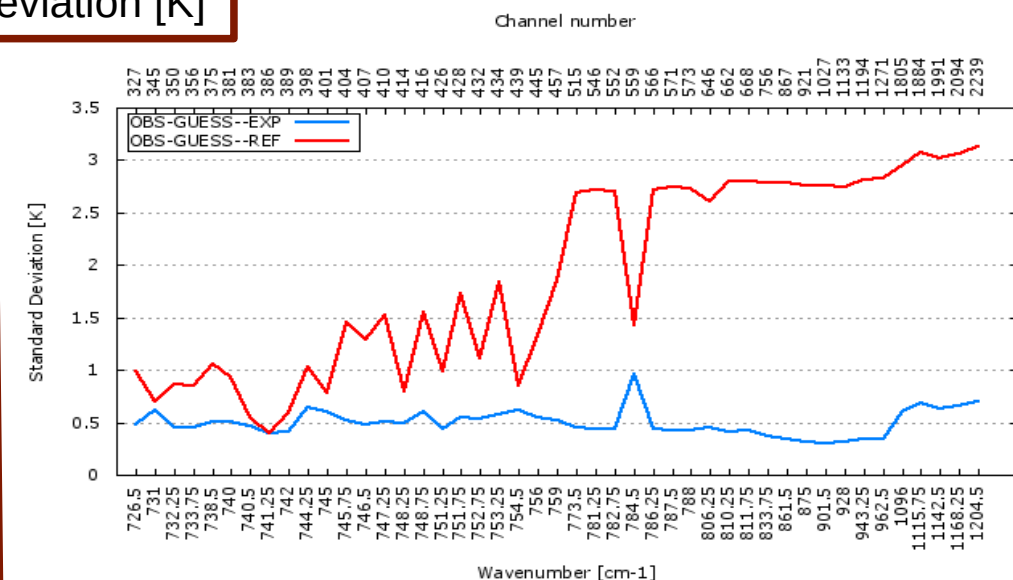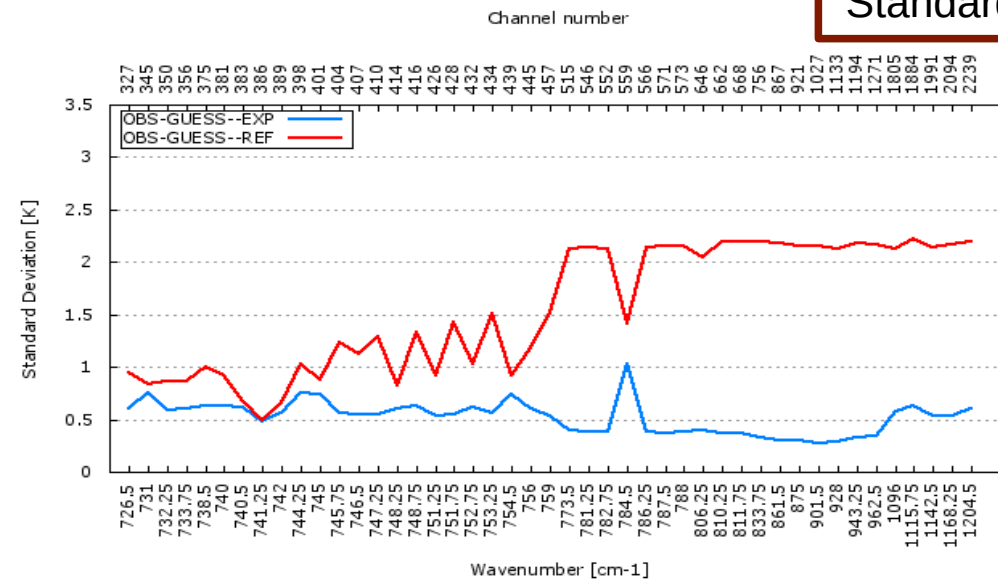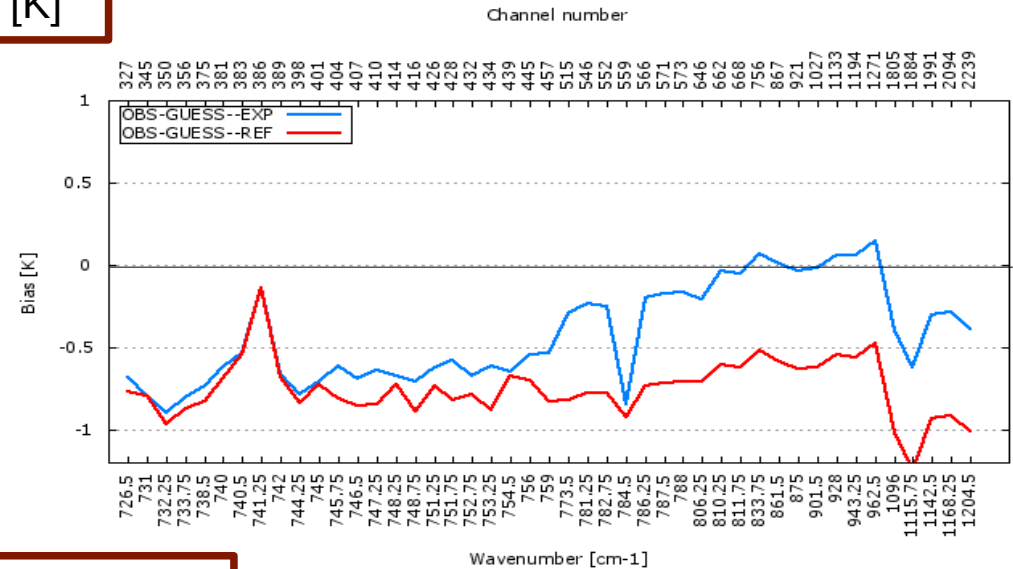- ▣ Clear/cloudy pixels according to AVHRR and McNally & Watts algorithms.

Using retrieved LST in the AROME assimilation

IASI clear observations according to AVHRR
without bias correction (from January 15th to February 28th 2015)

Day   **Night**

Bias [K]

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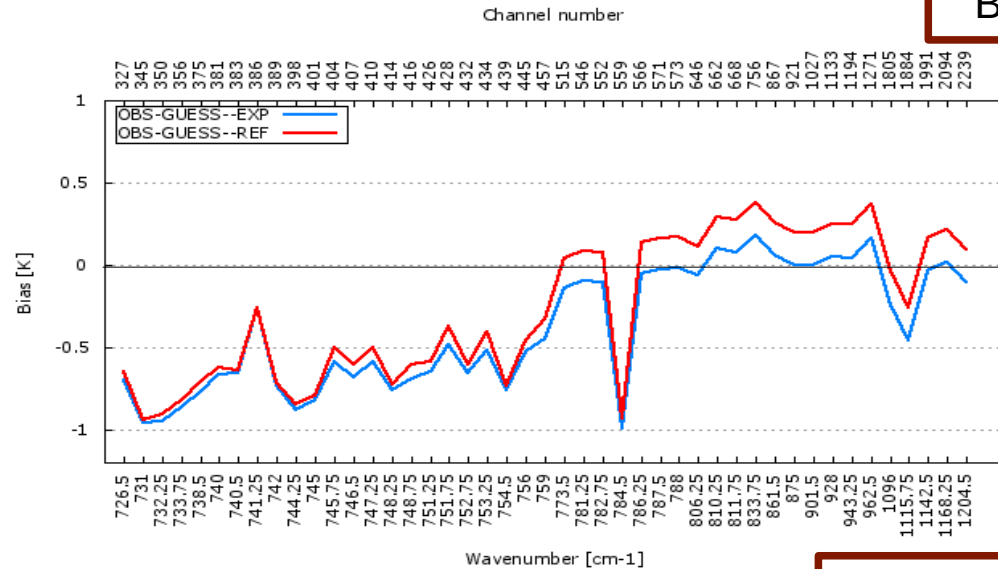
The Obs-Guess of EXP and REF (combined IASI data from MetOp A & B) is very similar at daytime. A small difference is observed in surface-sensitive channels. At night-time, Obs-Guess of REF decreases. However, Obs-Guess of EXP changes a litlle. The StdDev was reduced in EXP compared to REF for both cases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

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Using retrieved LST in the AROME assimilation

Total clear/cloudy channels according to McNally & Watts algorithm within to clear pixels according to AVHRR
from 15th to 30th January 2015

**Day**   **Clear**   **Night**
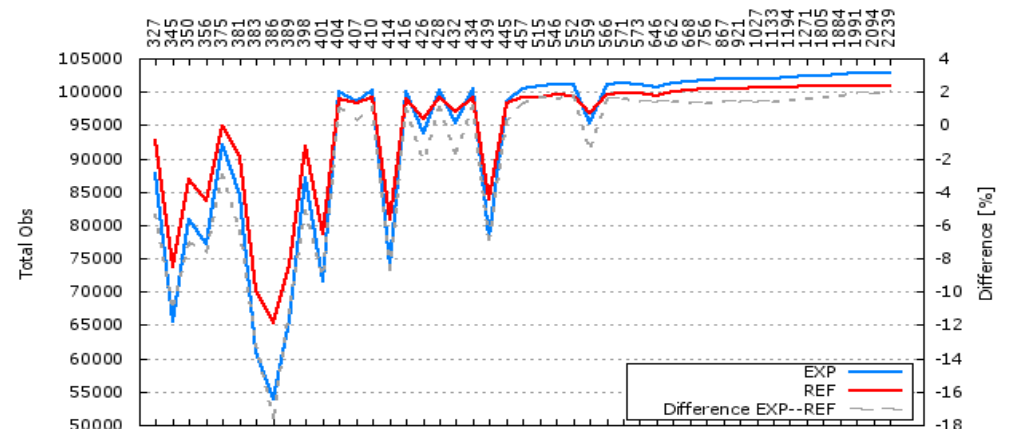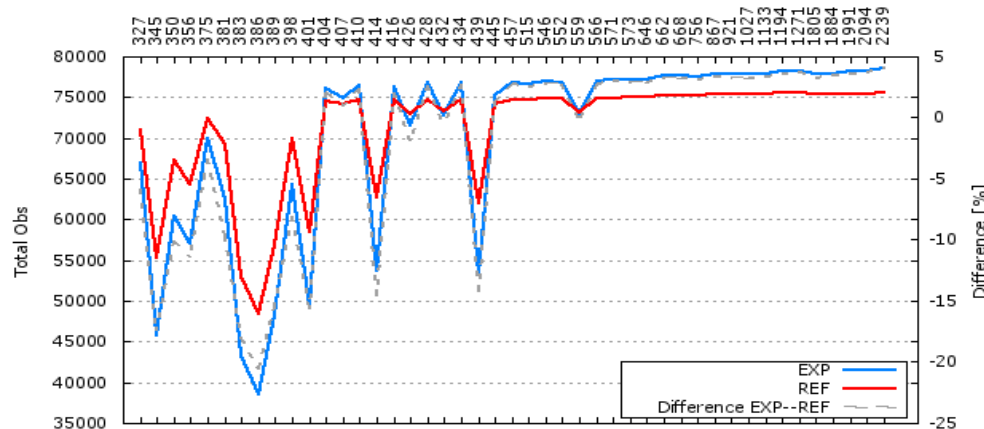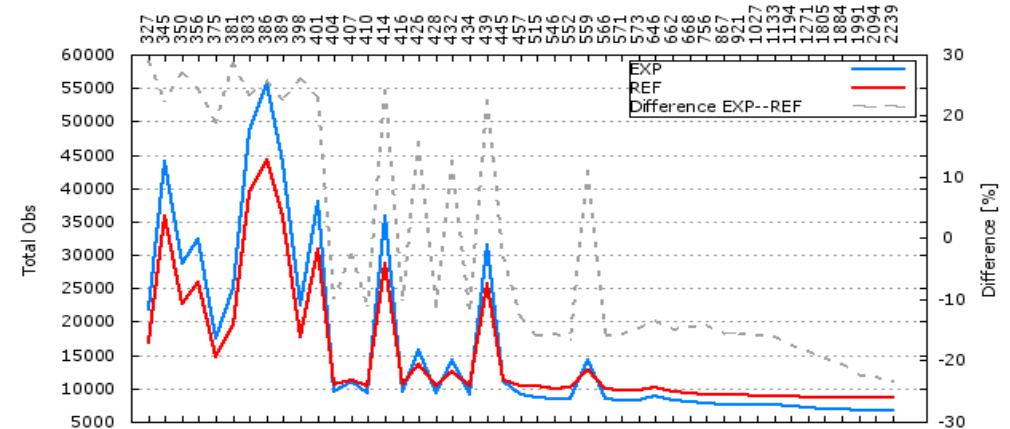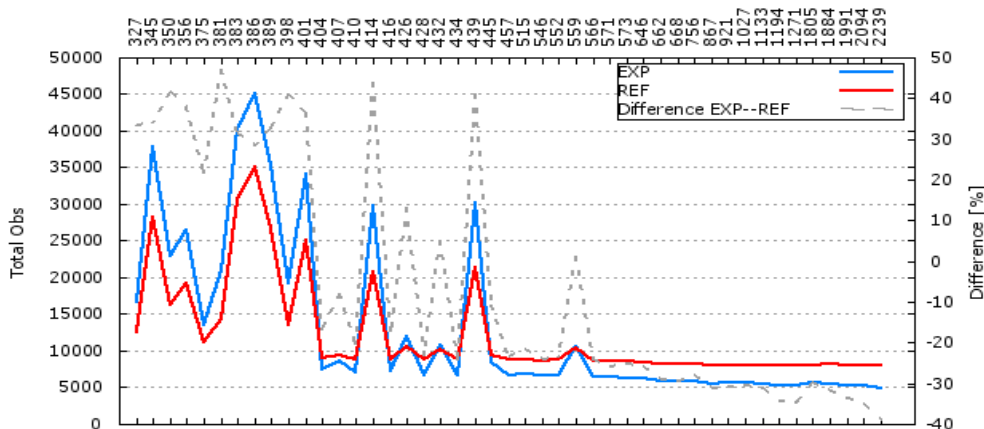
Cloudy

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.

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Using retrieved LST in the AROME assimilation

EXP	LST retrieved from IASI channel 1191 used for IASI BTs simulation
EXP_FULL	Idem to EXP but assimilation over land of channels selected over sea
REF	LST from AROME forecast (= operations) used for IASI BTs simulation
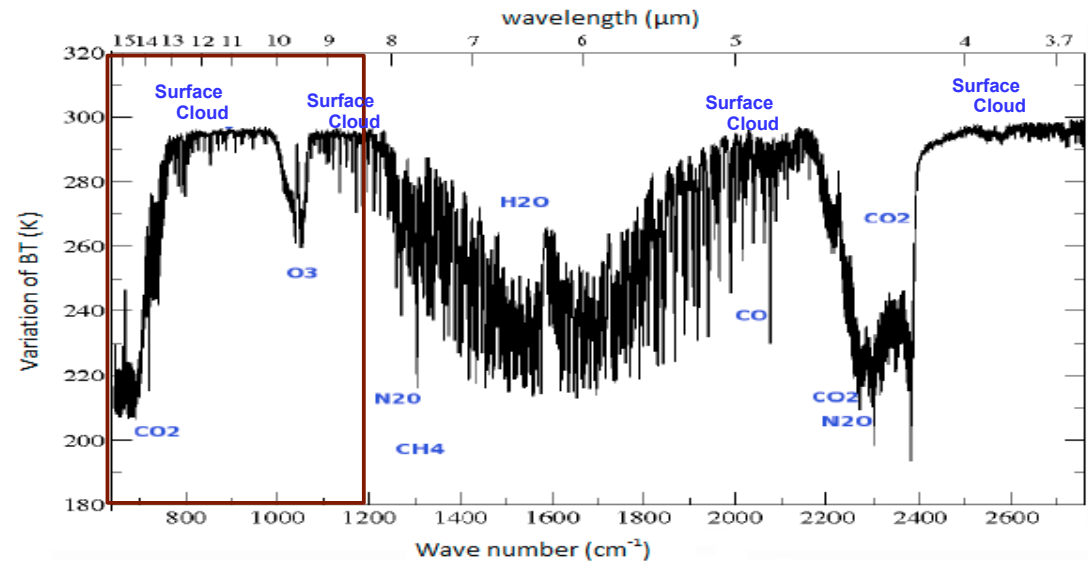
Example of IASI spectrum in clear sky conditions

- ▣ Study period: from 15th to 30th January 15th 2015.
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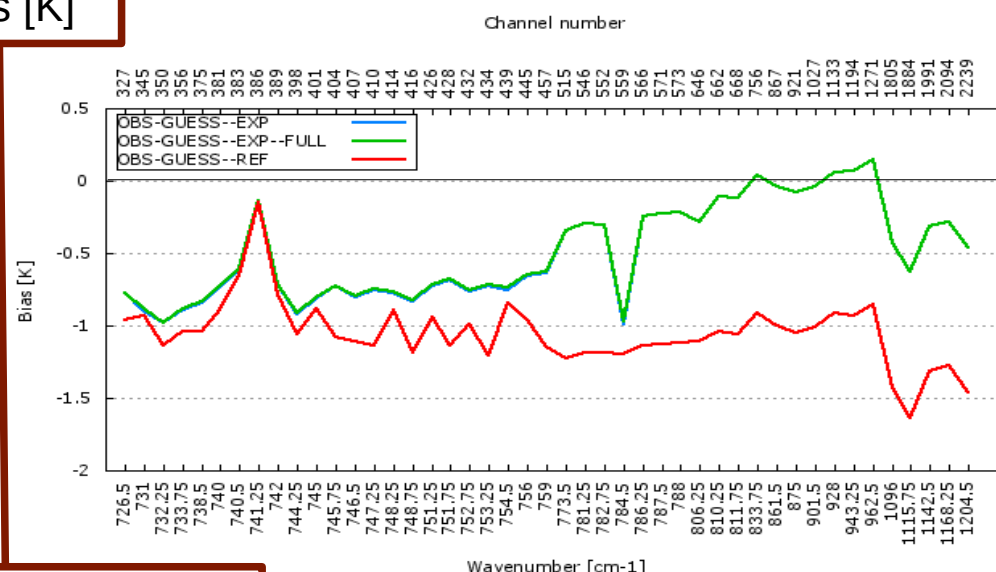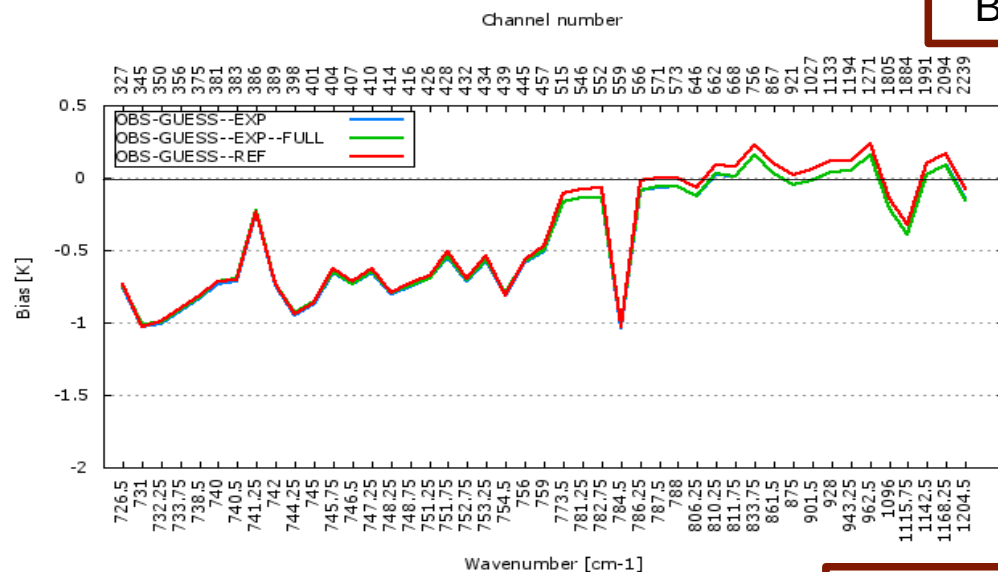- ▣ Clear/cloudy pixels according to AVHRR and McNally & Watts algorithms.

Using retrieved LST in the AROME assimilation

IASI clear observations according to AVHRR
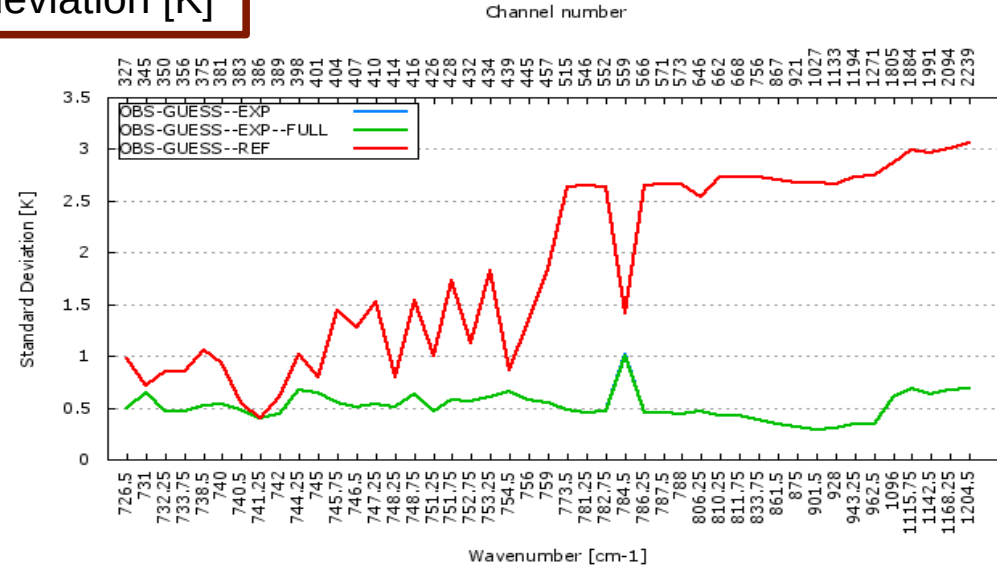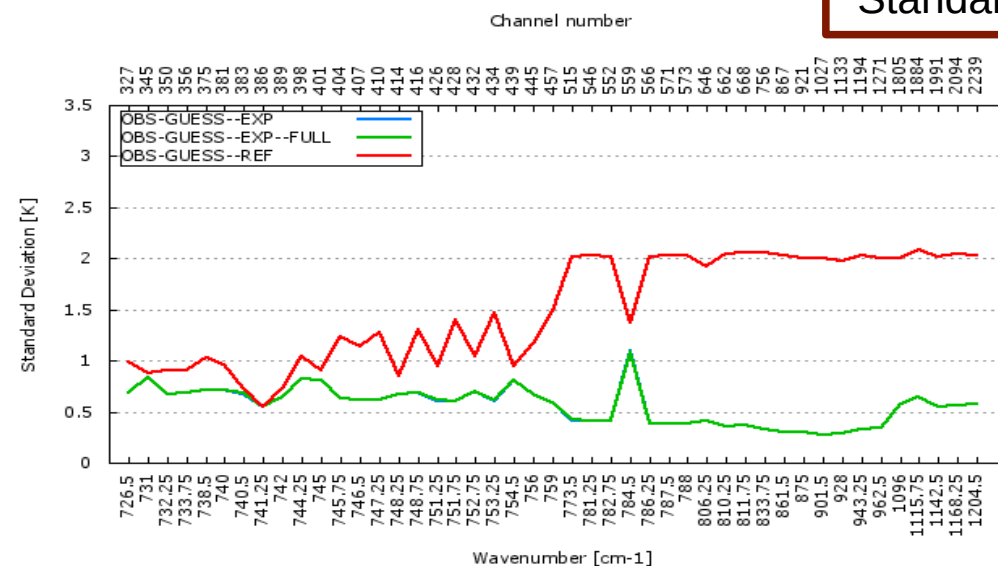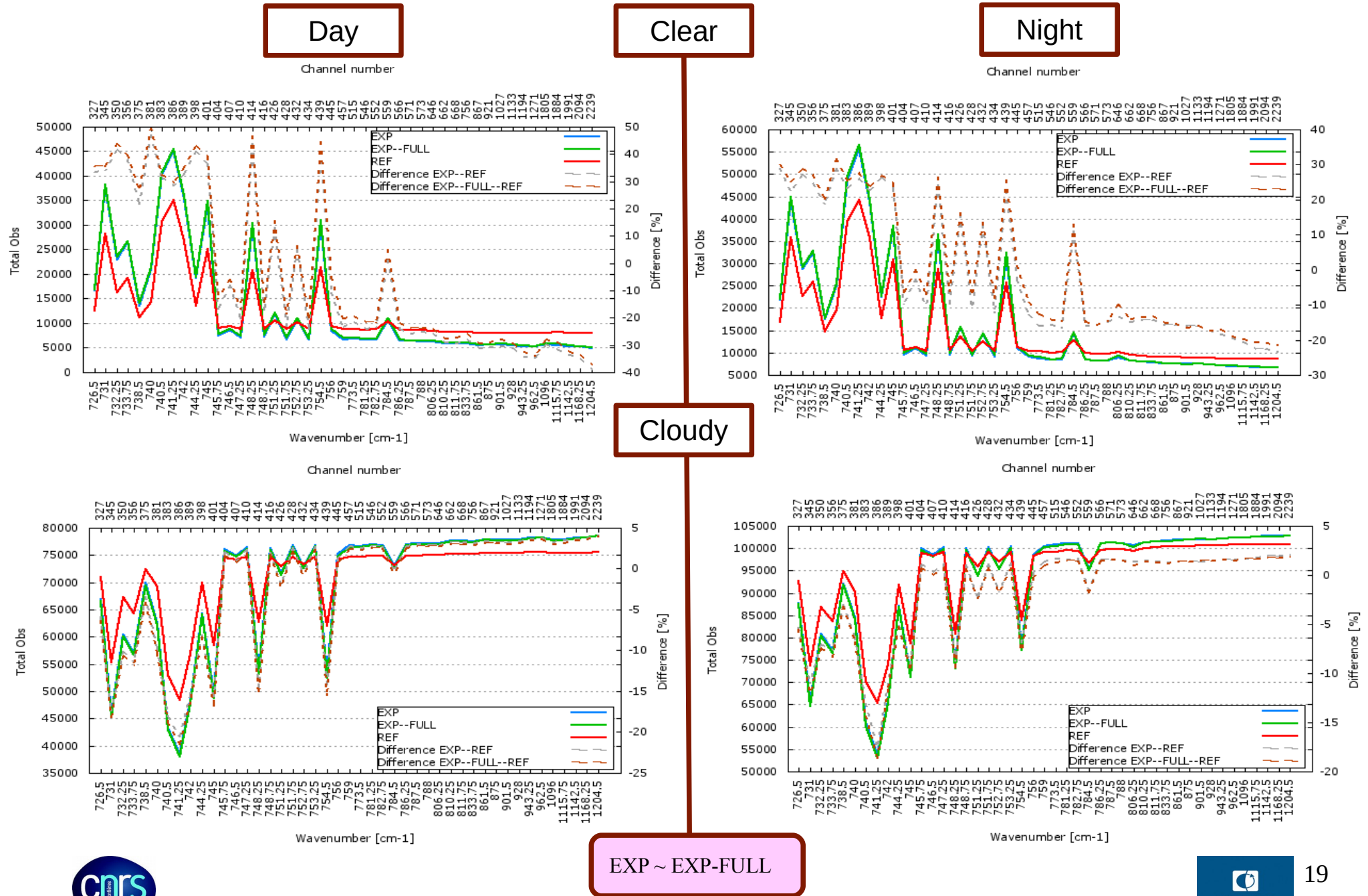without bias correction (from 15th to 30th January 2015)

Day

Night

Bias [K]

Standard deviation [K]

EXP ~ EXP-FULL

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Using retrieved LST in the AROME assimilation

Total clear/cloudy channels according to McNally & Watts algorithm within to clear pixels
according to AVHRR from 15th to 30th January 2015

Day

Clear

Night

Cloudy

EXP ~ EXP-FULL

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Using retrieved LST in the AROME assimilation

Impact on assimilated observation number (EXP--FULL – EXP)
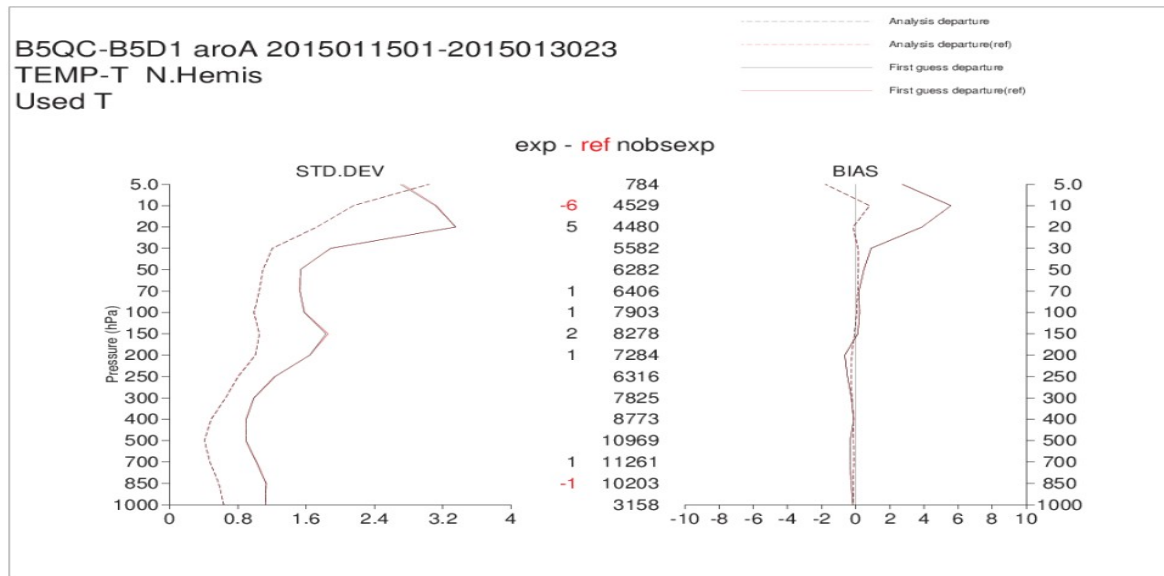from 15th to 30th January 2015
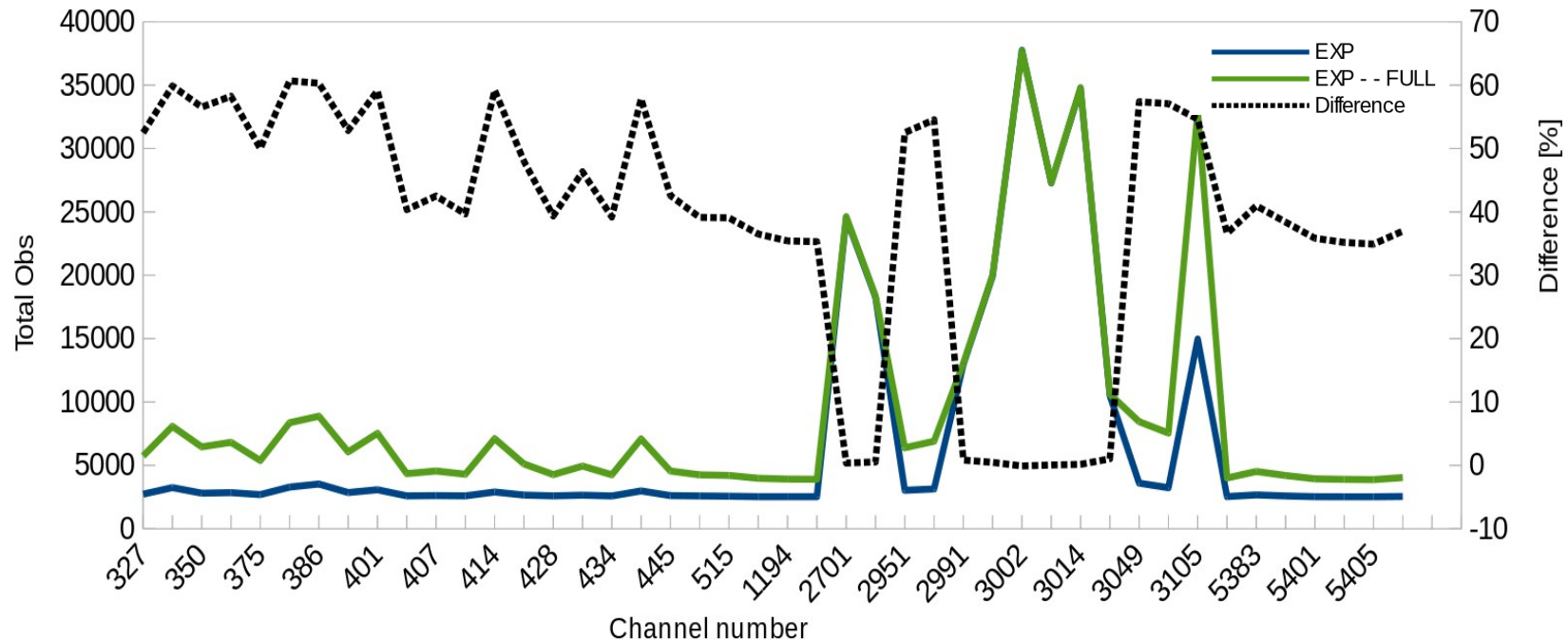
More observation assimilated in EXP--FULL up to 60%
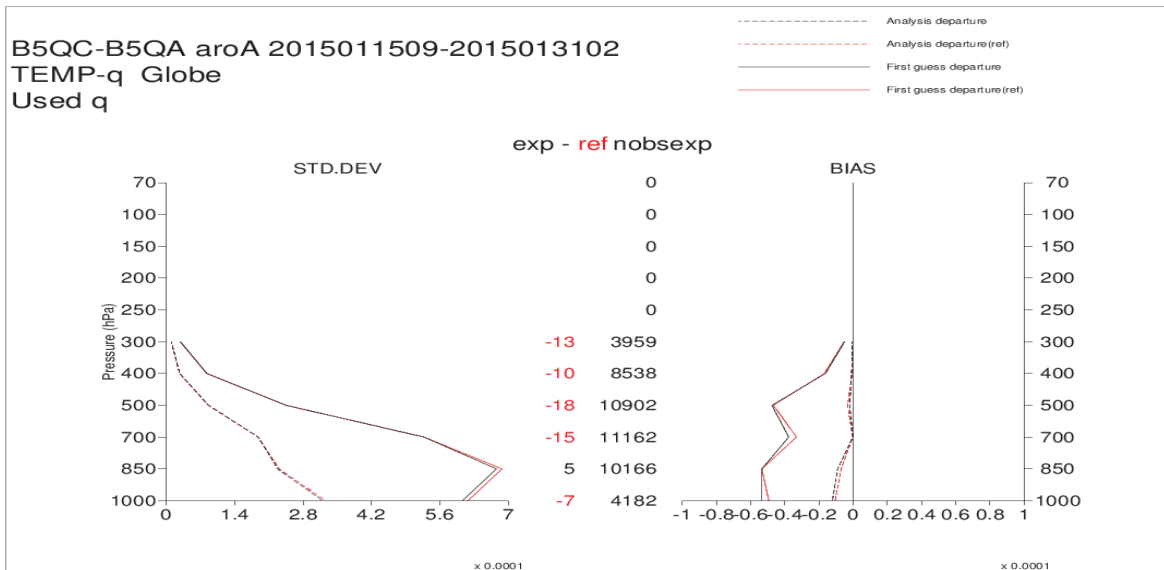comparing to EXP.

Using retrieved LST in the AROME assimilation

Impact on the assimilation of other observation types (EXP-EXP--FULL)

B5QC-B5D1 aroA 2015011501-2015013023
TEMP-T N.Hemis
Used T

Neutral impact on the assimilation of temperature data and slightly positive impact on the assimilation of humidity data (e.g radiosounding and ATMS sounder).

B5QC-B5QA aroA 2015011509-2015013102
TEMP-q Globe
Used q

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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 leading to an increase of assimilated channel number (more or less 50%).

- The first results of surface-sensitive channel assimilation with retrieved LST are encouraging and present a slightly positive impact on the analysis especially for humidity.

Future work

- Evaluate the improvement of assimilation and forecasts over the AROME-France domain.

- Improve the bias correction over land.

- Extend the methodology developed for IASI to other 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