Non linearity correction of IASI on board MetOp-A and MetOp-B

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OUTLINE

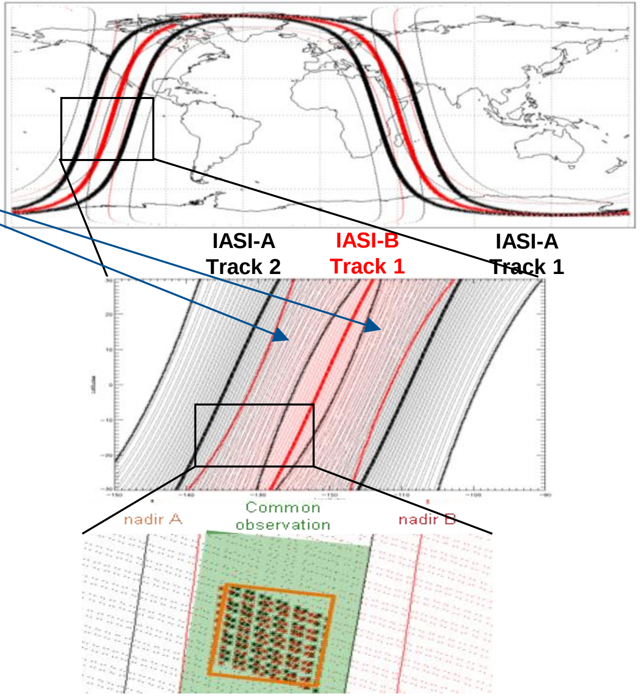
- 1 – IASI inter-calibration results
- 2 – Detection chain non-linearity & correction
- 3 – New non-linearity correction proposal
- 4 – Discussion on the implementation

IASI inter-calibration

- **IASI inter-calibration is performed @CNES (Denis Jouglet)**
- **Objectives of the inter-comparison**
  - For the IASI TEC: External monitoring of the IASI radiometric and spectral calibration
    - Ensure the continuity of IASI-A, IASI-B and IASI-C
  - For the users (Climatology, Meteorology, GSICS):
    - To ensure the consistency of the IASI calibration with the TIR sensors community
    - Checks the long term data quality

- **Principles**
  - Statistics on a large dataset made of common geophysical scenes observed by two sensors
    - Quasi-SNOs for IASI-A / IASI-B, SNOs for IASI / CRIS, IASI / AIRS
  - ➔ Assesses the calibration difference only (removes meteorological dependencies)
  - Observations in normal operations (IASI L1C)

Methodology for direct IASI-A / IASI-B inter-comparison



"Similar" scenes:

IASI-A and B are on the same orbit with a 180° shift ➔ Numerous common observations (CO) between 2 consecutive tracks.

But: never simultaneous (~50min temporal shift) and off-nadir (from 0° to 39°, opposite angles)

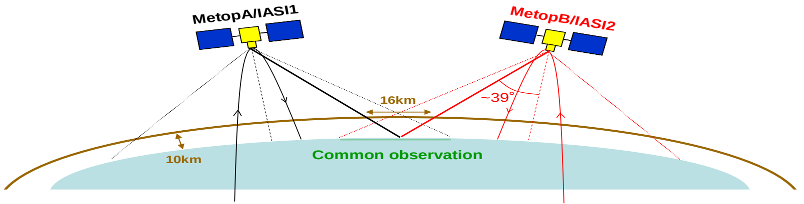
Selection on the most relevant scenes

- Use of geoloc., geom., IIS, AVHRR, ECMWF data
- Focus on stable and **homogeneous scenes** = Night, mostly oceans, 0% or 100% clouds. Balance "A before B" and "A after B"

For each common observation

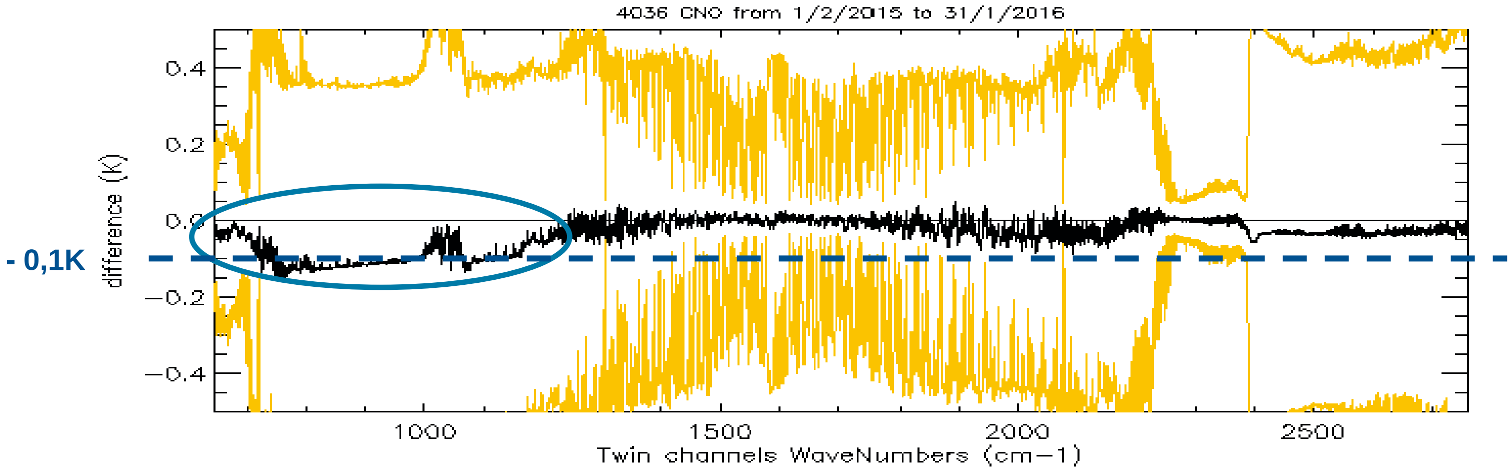
- Focus on the central area (same atmospheric thickness)
- **Regional averaging** of the soundings (300*300km)
- ΔT calculated at elementary channel level

$$\Delta T = \left(L_{IASI-B} - L_{IASI-A}\right) \Big/ \frac{\partial L_\sigma}{\partial T}(\sigma, 280K)$$



Direct IASI-A / IASI-B inter-calibration results

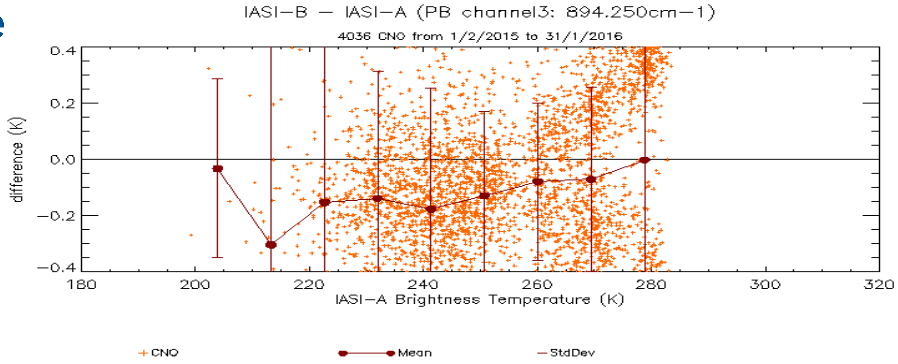
- For each common observation: mean and stdev computed over the dataset
  - Radiometric residual bias, higher in band 1 ~ 0.1 K, very stable with time
  - IASI-B “colder” than IASI-A



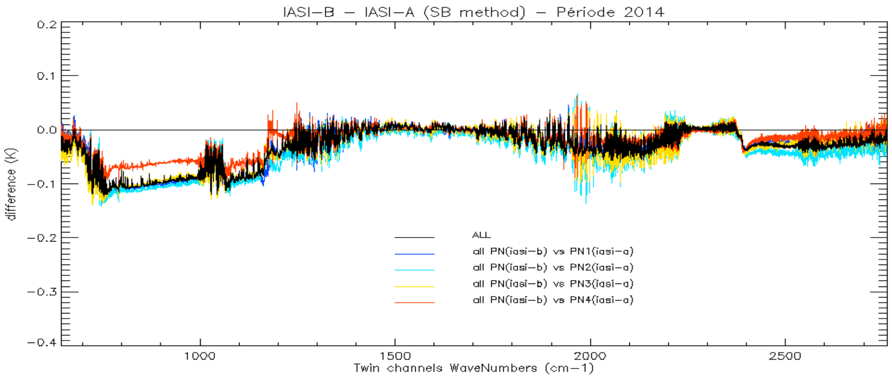
- A residual default of the analog non-linearity correction in band 1 of at least one instrument is a possible explanation of this bias. A study started to go further into this effect.

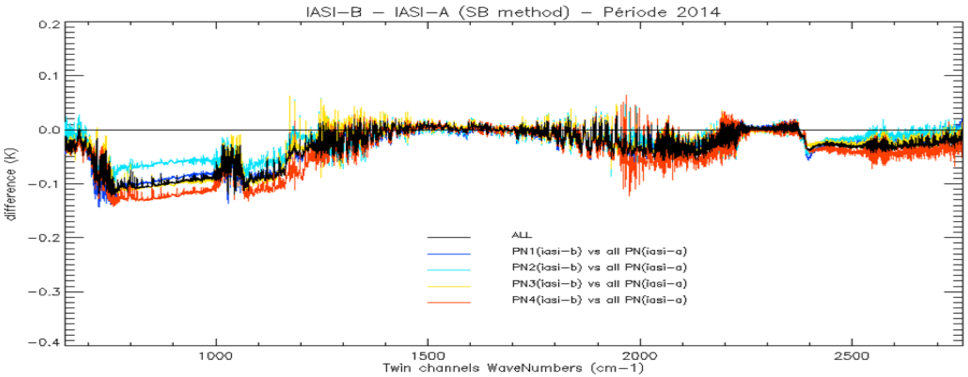
Sensitivity studies in B1

- Trend in IASI B1 with brightness temperature

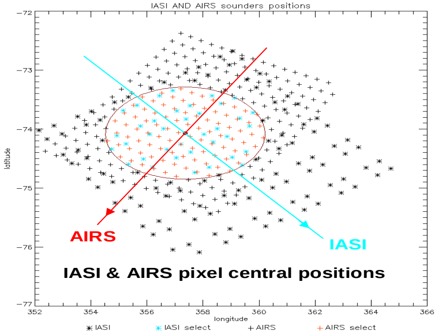


- The effect also depends on the Pixel Number

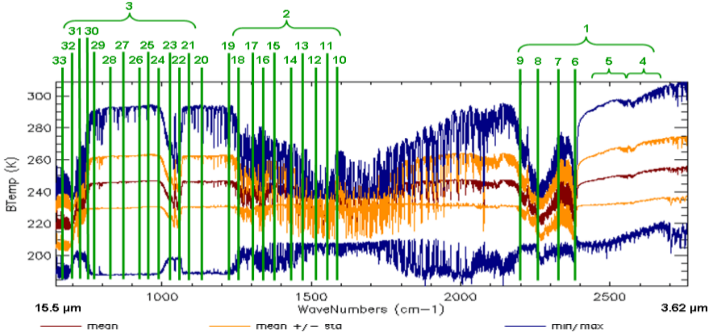




Methodology for IASI / AIRS, IASI / CRIS inter-comparison



- **Similar scenes: SNOs** (Simultaneous Nadir Overpasses)
  - Tolerance in **simultaneity** : 20 min, Always at high latitudes
  - ~30 scenes every 3 days for IASI / AIRS (12000 in 5 years)
- **Spatial match:**
  - **Regional averaging** of the soundings pixels over a 300km*300km area around the orbit crossing point



- **Spectral match:**

  Construction of 33 broad **pseudo-bands**
  - Each PB = intelligent averaging of ~100 elementary channels to get the similarity of the PB spectral functions
  - The AIRS missing channels and varying spectral resolution are considered when calculating the IASI coefficients

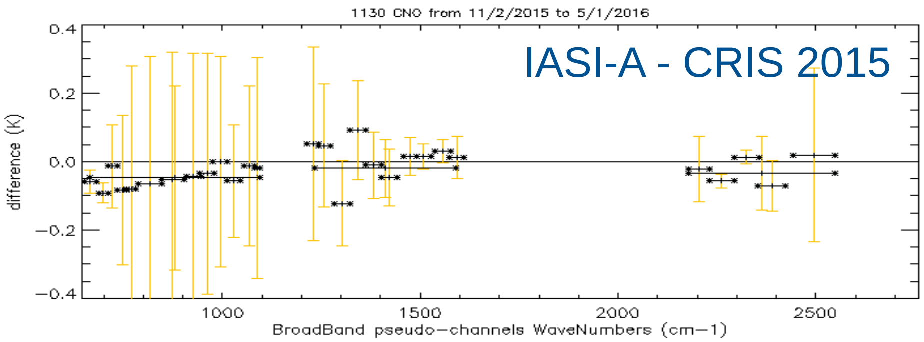
  NB: the convolution of IASI by the CRIS or AIRS SRFs has been performed but is still under exploitation

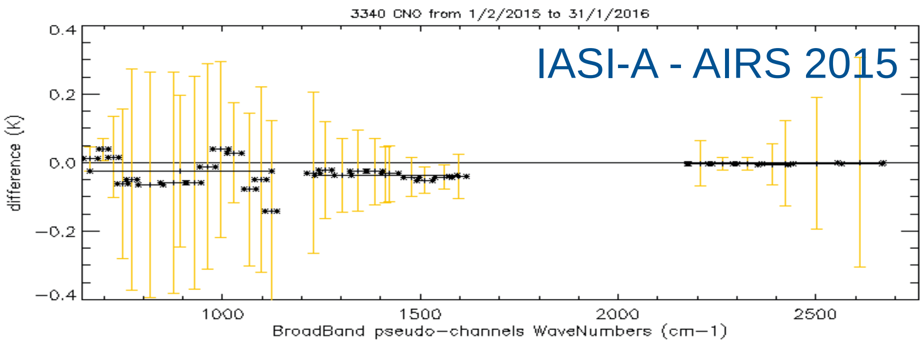
For each pseudo-band:

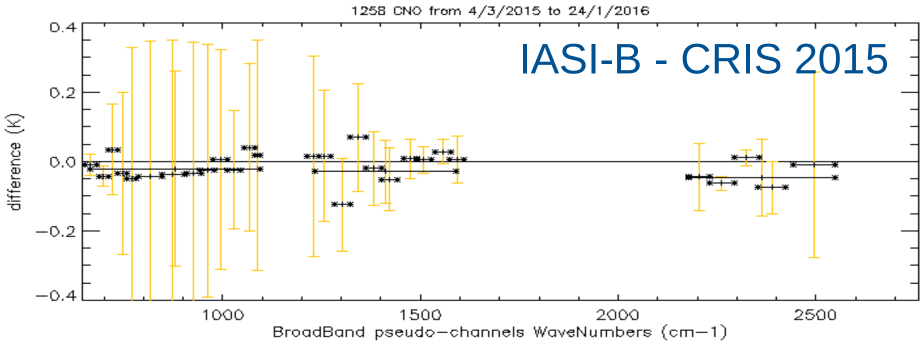
$$\Delta T = \frac{(L_{IASI} - L_{AIRS})}{\frac{\partial L_\sigma}{\partial T}(\sigma, 280K)}$$

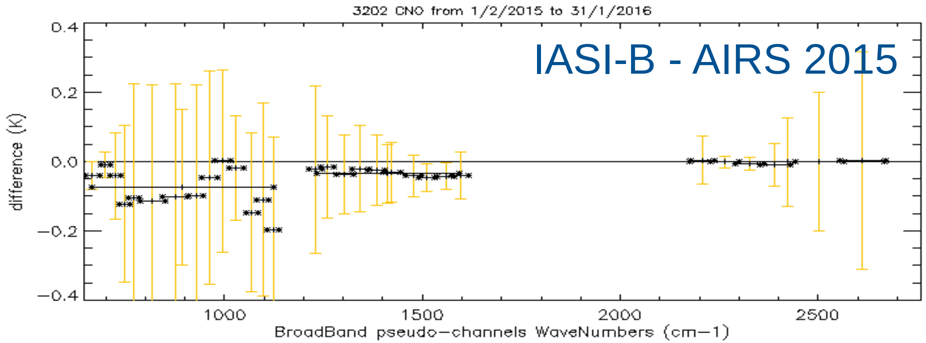
IASI / CRIS & IASI / AIRS inter-comparison

- Results on SNOs :
  - Biases between 0 and 0.15K
  - Highest bias for shortest wavenumbers









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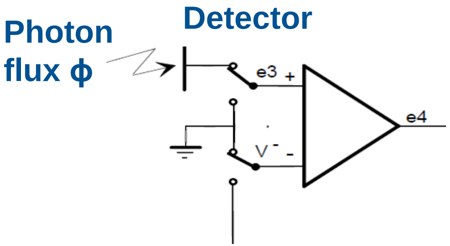
IASI detection chain non-linearity

- Analog non-linearity of the detection chain function (due to detector imperfection): $\phi = f(e_3)$



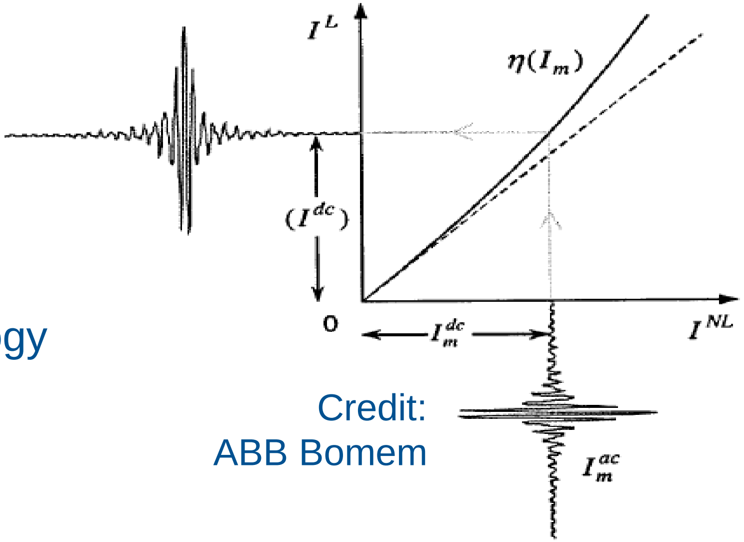
- Detector sensitivity slightly varies with the entrance photon flux, especially for Mercury Cadmium Telluride (MCT) photoconductive IR detector used in band 1.

➢ Distortions in the measured interferogram:

$$I_m = R(I_L)$$

➢ Dependent on detector temperature

➢ Detectors in band 2 and 3 use photovoltaic technology ➔ linear



Credit:
ABB Bomem

IASI detection chain non-linearity

- Non-linearity model: $\mathrm{I}(x) = \sum A_n (I_{mod}(x))^n$

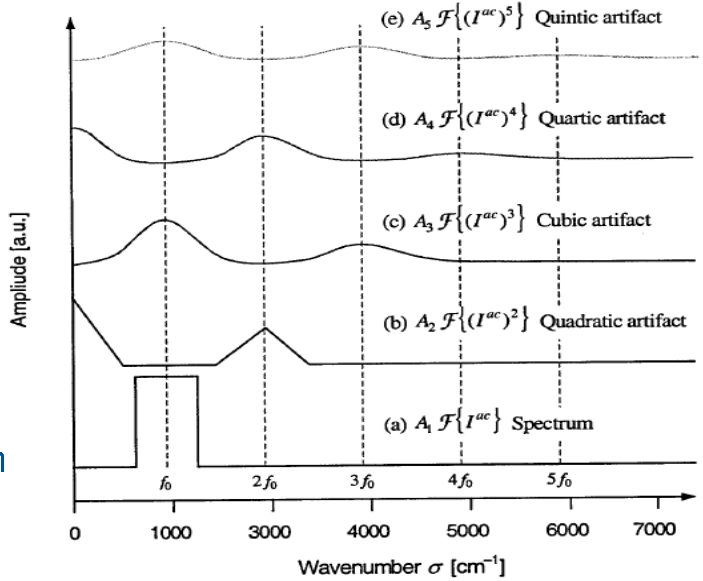
$$I(x) = A_1 (I_{mod}(x) + \alpha_2 I^2{}_{mod}(x) + \alpha_3 I^3{}_{mod}(x) + \cdots), \text{ with } I(x) = I_c + I_{mod}(x)$$

- In the spectral domain:

$$S(\nu) = A_1 T(\nu) + \underbrace{S_2(\nu) + S_3(\nu) + \ldots}_{\text{Undesirable spectral artifacts}}, \text{ with } T(\nu) = FT(I_{mod}(x))$$

Undesirable spectral artifacts

- Example with a spectrum = rectangular pulse function



Credit:
ABB Bomem

IASI non-linearity correction

- For an accurate spectrum measurement and to avoid important radiometric errors, it is important to record a signal exactly proportional to the corresponding radiation intensity striking the instrument detector.

➢ Correction of the measured interferogram: $I_L = P(I_m)$, with $P = R^{-1}$

- Non-linearity is corrected in the IASI interferograms by on board processing, with pre-computed correction tables (cannot be corrected by a simple scaling), that also depends on the detector temperature.

- This characterization has been done on ground before launch for both IASI-A and IASI-B.

- The in-flight focal plane temperature of IASI-B was set 0.5 K lower than the predicted temperature, IASI-B non linearity has been re-computed during Cal/Val.

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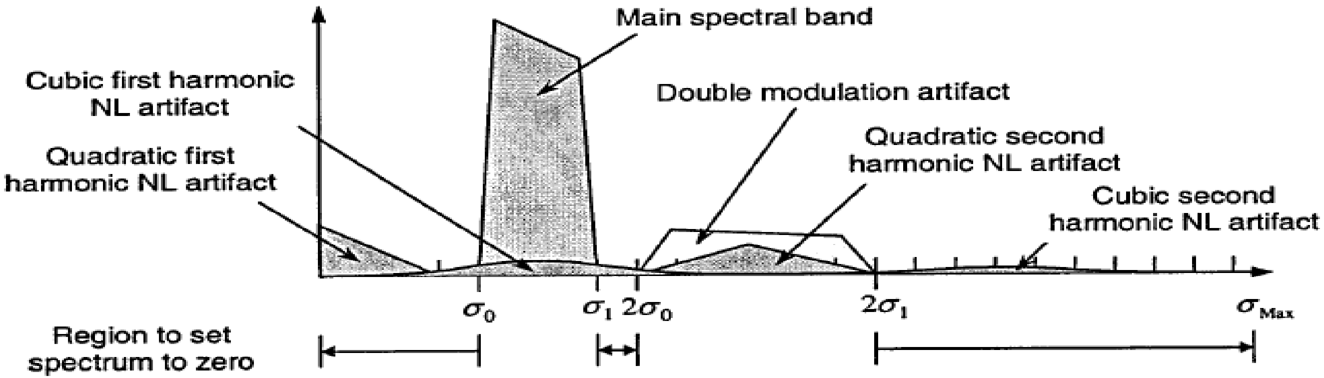
IASI non-linearity correction

- The non-linear transfer function is computed on ground from the raw interferograms (verification interferogram, 1/line) by a convergent iteration minimizing the out-of-band spectral artifacts.

Credit:
ABB Bomem



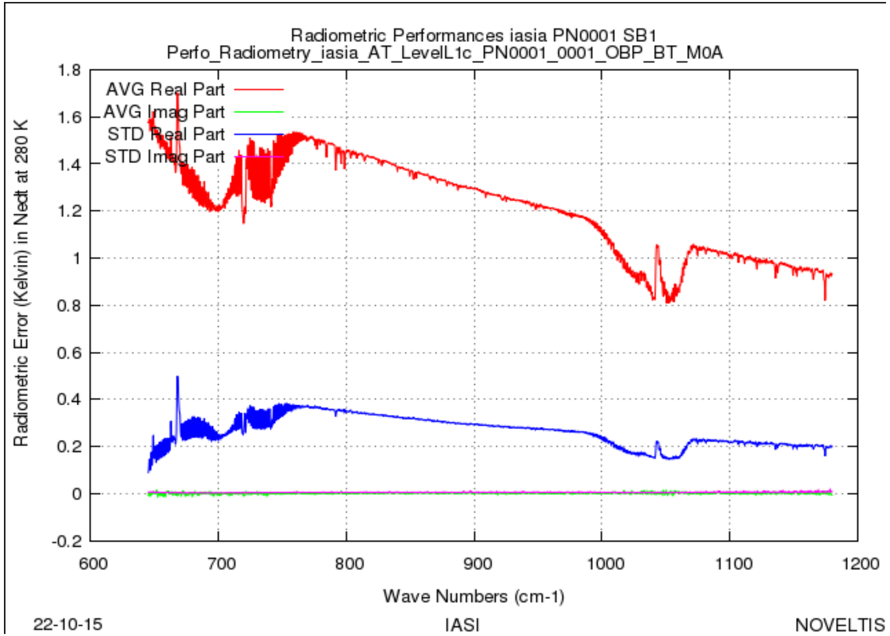
- At each iteration step, the signal is progressively corrected using the current polynomial coefficients and the iteration stops when a stable condition is obtained.
- Polynomial fit P is applied on measured interferogram : $I_L = P(I_m)$

IASI non-linearity correction

- Impact of the NL correction on the spectrum in band 1:

Mean radiometric error (NedT @ 280 K) between spectra corrected from non linearity with operational correction and without correction (bias, stdv)

Example with IASI-A, PN 1 => Important to correct it (~1/1.5 K effect)



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New non-linearity correction proposed

- Non-linearity characterization algorithm has been studied and optimized to minimize determination errors.
  - algorithm and cutoff optimizations
  - change order of the polynomial correction (order 2 -> 3)

- Tests on 2 periods for IASI-A (01/2011 and 09/2015) and IASI-B (10/2012 and 09/2015) with 300 interferograms on each period.

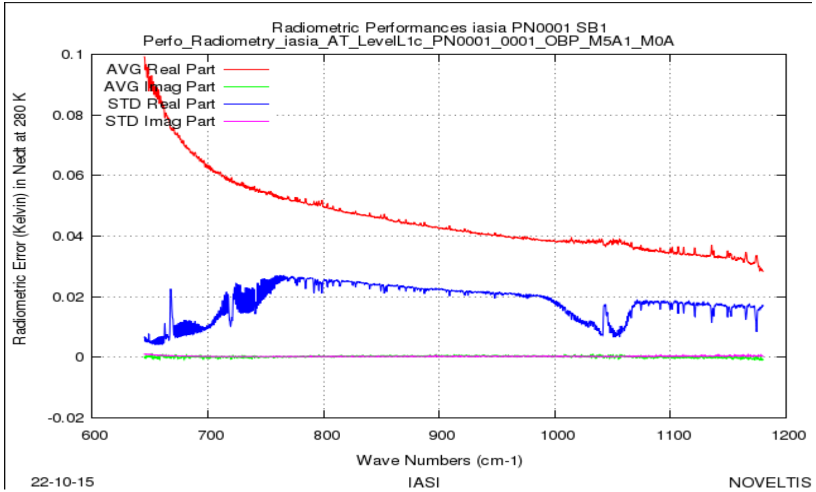
- New correction coefficients have been computed for both IASI-A and IASI-B, leading to a potential change of radiometric calibration.

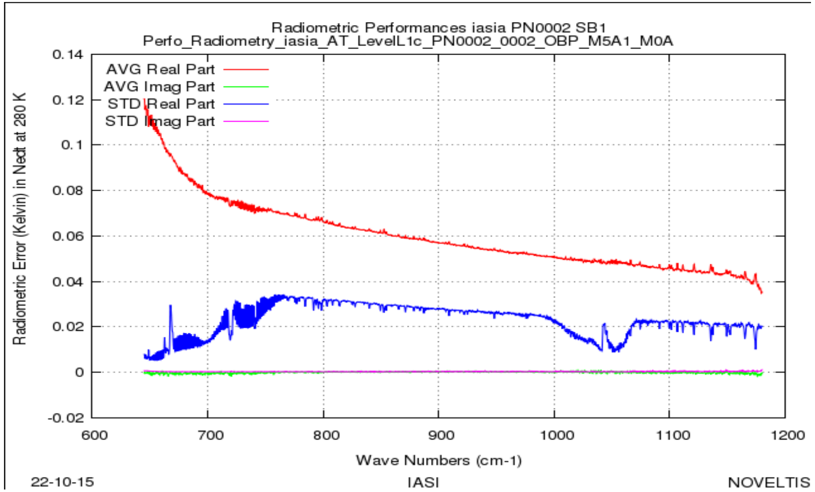
New non-linearity correction: IASI-A

- **IASI-A:** Impact of a new non-linearity correction (order 3) on the spectrum in band 1, compared with the operational configuration

Mean radiometric error between proposed new NL correction and the operational one (bias, stdv), expressed in NedT @ 280 K, PN 1 and PN2 (correction pixel dependent)

- Error between 0.1 K and 0.03 K





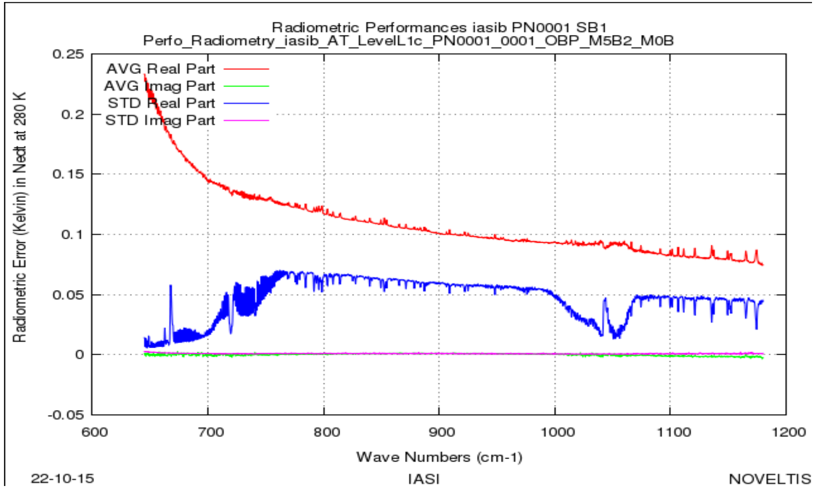
The proposed new correction “warm up” IASI-A spectra

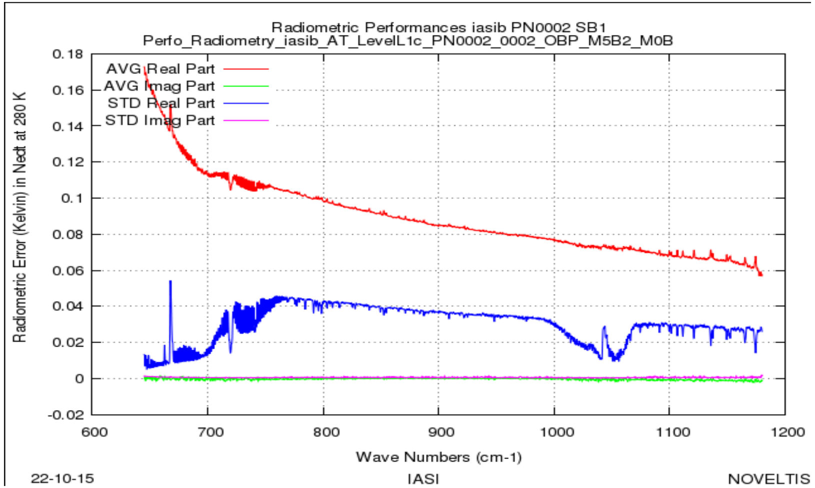
New non-linearity correction: IASI-B

- **IASI-B:** Impact of a new non-linearity correction (order 3) on the spectrum in band 1, compared with the operational configuration

Mean radiometric error between proposed new NL correction and the operational one (bias, stdv), expressed in NedT @ 280 K, PN 1 and PN2 (correction pixel dependent)

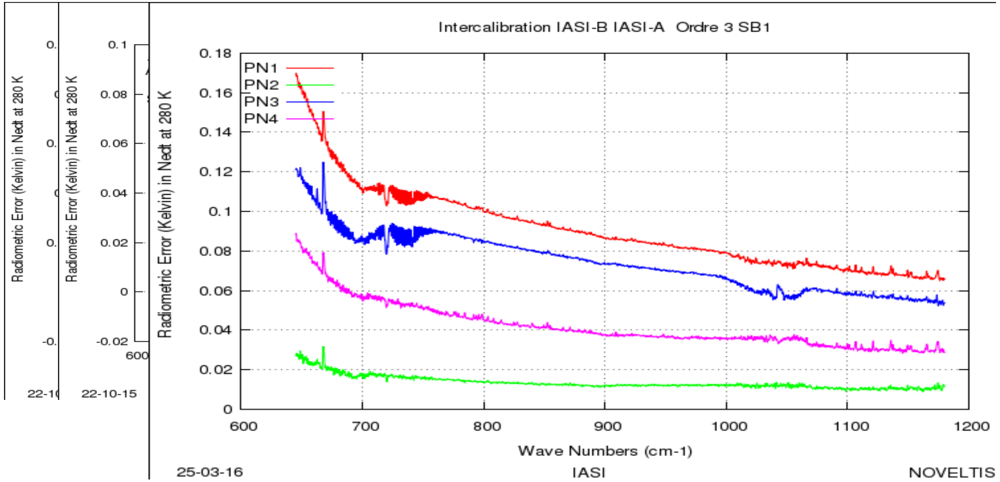
- Error between 0.22 K and 0.07 K

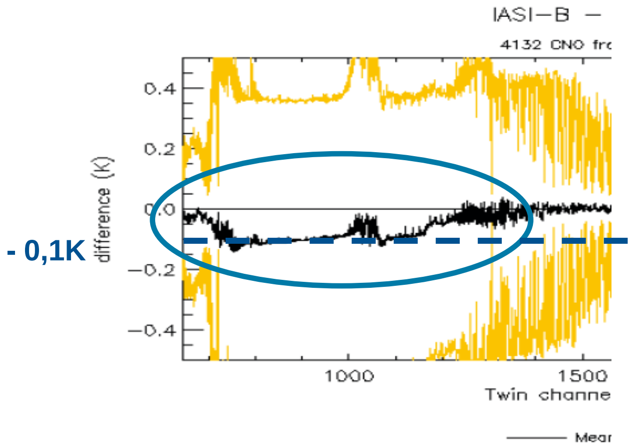




- The proposed new correction “warm up” IASI-B spectra in a larger proportion than IASI-A

New non-linearity correction proposal





- The difference between the 2 corrections of IASI-B and IASI-A is around 0.1 K
- Shape close to IASI-B/IASI-A inter-calibration results
- IASI-B spectra hotter = IASI-B – IASI-A reduced
- It is expected that this new correction largely reduce the residual radiometric bias between IASI-A and IASI-B, and also reduce the bias between IASI and AIRS and CrIS (IASI-A/B are colder than CrIS and AIRS)

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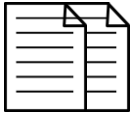
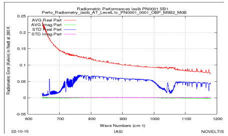
New non-linearity correction proposal

- Validation of the correction will be undertaken @IASI TEC (CNES) in the coming weeks
- Validation strategy / on-going work:

- Generate new non linearity correction tables and a new board configuration for both IASI-A and IASI-B



- Statistics on new L0 spectra processed: mean, min, max radiometric differences with operational spectra
- Verification of the expected bias with the one coming from the study.



- Process many verification interferograms with the on-board processing simulator with the new tables for both IASI
- Classification of the bias with the **pixel number** and comparison with results from inter-calibration studies
- Classification of the bias with **the scene temperature** and comparison with results from inter-calibration studies. Study the possibility and the precision of a-posteriori correction on the L1C spectra.

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Implementation of the new correction

- The study is on-going. If results are fully validated and satisfactory, new correction can be implemented on board.
- It has an impact on climate statistics by breaking the radiometric stability in the time series.
- The IASI data reprocessing with the new correction is impossible, because:
  - the correction is done in the on-board processing of interferograms
  - all the interferograms are not transmitted on ground (due to bandwidth constrains)
  - only the real part of the level 0 spectrum is transmitted on ground, the on-board Fourier transform of the interferogram is thus an irreversible processing

- ISSWG supports the change of non-linearity correction because IASI-A and IASI-B will be more consistent between them (and with IASI-C) and with the US IR sounders.