Radiometric and spectral inter-comparison of IASI: IASI-A / IASI-B, IASI / AIRS, IASI / CrIS

Denis Jouglet, Jordi Chinaud, Claire Maraldi, Elsa Jacquette, Vincent Lonjou, Denis Blumstein, Olivier Vandermarcq (CNES) and Xavier Lenot (C-S)

Contact: denis.jouglet@cnes.fr

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• Introduction

• IASI-A / IASI-B direct inter-comparison by quasi-SNOs

• IASI / CrIS, IASI / AIRS direct inter-comparison by SNOs

• IASI-A / IASI-B inter-comparison via CrIS & AIRS

• IASI-A / IASI-B inter-comparison by massive means

• Conclusions
Introduction

● Objectives of the inter-comparison
  ✦ For the IASI TEC: External monitoring of the IASI calibration
    » Participation to the in-flight commissioning (IASI-B) and routine monitoring (IASI-A and B)
  ✦ For the users (in particular GSICS):
    » To ensure the consistency of the IASI calibration within the TIR sensors community
    » To check the long term data quality (climatology)

● Principles:
  ✦ Observations in normal operations (IASI L1C)
  ✦ Statistics on a very large dataset to detect calibration biases
  ✦ Work by couples:
    » IASI-A / IASI-B, IASI-A / AIRS, IASI-B / AIRS, IASI-A / CrIS, IASI-B / CrIS
  ✦ Focus on same geophysical scenes observed by a pair of two sensors:
    Common observations ~ same place, same time, same viewing conditions
    ➔ Assesses the calibration difference only
  ✦ No correction of spectra by simulation
Methodology for direct IASI-A / IASI-B

- **Similar scenes:**
  IASI-A and B are on the same orbit with a 180° shift
  ➔ Numerous common observations between 2 consecutive tracks, but:
    » never simultaneous: ~50min temporal shift
    » off-nadir: from 0° to 39°, opposite angles

- **The numerous common observations makes a pre-filtering compulsory**
  ➔ On the most relevant scenes

- **Spatial match:**
  ✤ Regional averaging of the soundings
    (area 300km * 300km or less)

- **Spectral match:**
  ✤ \( \Delta T \) calculated at elementary channel level

\[
\Delta T = \frac{\left( L_{\text{IASI}-B} - L_{\text{IASI}-A} \right)}{\frac{\partial L_\sigma}{\partial T}(\sigma, 280K)}
\]

  ➔ Mean and stdev computed over the dataset
IASI-A / IASI-B : selection of scenes

- Selection aims at reducing the effects of:
  - **50 min time delay**
    - Need for stable scenes
    - Need for homogeneous atmospheres (same atm. even if moving)
  - **Off-nadir geometry** = The lines of sight A & B are always different
    - Focus on the central area ⇒ same atmospheric thickness
    - Need for homogeneous atmospheres (typical size ~16km)

- Selection by a relevance index
  Assessment of several parameters, each parameter is given a mark, then a global mark is computed with weights
  - **For homogeneous scenes:**
    - Low inter-pixel and intra-pixel variance of the IIS imager for A & B
    - Clouds & snow: none or full in A & B
  - **For stable scenes:**
    - Focus on oceans at night
    - Low differences in IIS imager A & B temperatures
    - Clouds & snow: same amount between A & B
    - Low variations in ECMWF profiles ("Geophysical NeDT")
Direct IASI-A / IASI-B inter-comparison: results

- Biases and standard deviation over the selected dataset
  (homogeneous and stable scenes, night, as many “A before B” as “A after B”)

With 1 year of data:
- Biases < ~0.1K
  ➔ Very good cross calibration
- Compliant with the radiometric absolute specification of 0.5K
- Highest bias in B1
- Shape not understood, still under investigation
Necessity of tuning the dataset selection

Nominal case (night, oceans, as many “A before B” as “A after B”):

- Only “A before B”:
  - IASI-B = IASI-A (SB method)
  - Only diurnal data:
  - Stringent quality index:
    - Standard deviation mainly due to geophysics

- Only “A before B”:
  - IASI-B = IASI-A (SB method)

- Only diurnal data:
  - Mean
  - StdDev

- Stringent quality index:
  - Standard deviation mainly due to geophysics

→ Major impact of the input dataset, all parameters must be balanced
Features of the selected dataset

**Latitudes**

**Longitudes**

**IASI BT @ 870cm-1**

**Sat Zen Angle**

**Difference of mean IIS**

**Intra-pixel IIS variance**

**Inter-pixel IIS variance**

**Cloud fraction**

**Difference of cloud fraction**

**Continental fraction**

**Goal for these parameters:**
- **diversity**
- **minimization**
The inter-comparison IASI-B / IASI-A is very stable with time.
Shape in B1 under investigation

- Is the effect in B1 due to non-linearity?
  - Small increase in B1, amplitude ~+0.1K
  - Slight non-linearity?
  - Under investigation

NB: Be aware of the cross variations of some parameters (latitude / Scan Position / surface temperature / A before or after B)
Direct IASI-A / IASI-B spectral inter-comparison

- Specification for each IASI: $\Delta v/v < 2$ ppm (~1% of the spectral sampling)

- Methodology:
  - Definition of 30 spectral windows
  - For each window, cross-correlation of the IASI-A and -B spectra for different spectral shifts
  - The maximum of correlation gives the actual spectral shift

- Based on the same dataset as the radiometric calibration

- Results:
  - Performances largely compliant with the requirement
Reminder of AIRS, IASI, CRIS characteristics

<table>
<thead>
<tr>
<th>Instrument</th>
<th>IASI-A</th>
<th>IASI-B</th>
<th>AIRS</th>
<th>CRIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite</td>
<td>Metop-A</td>
<td>Metop-B</td>
<td>Aqua</td>
<td>NPP</td>
</tr>
<tr>
<td>Launch date</td>
<td>2006</td>
<td>2012</td>
<td>2002</td>
<td>2011</td>
</tr>
<tr>
<td>Local time</td>
<td>21h30</td>
<td>13h30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Techno</td>
<td>FTS</td>
<td>Grating</td>
<td>FTS</td>
<td></td>
</tr>
<tr>
<td>Spatial resolution (nadir)</td>
<td>12 km</td>
<td>14 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectral range</td>
<td>645 – 2760 cm(^{-1}) / 3.62 – 15.5 μm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of channels</td>
<td>8461</td>
<td>2378</td>
<td>1305</td>
<td></td>
</tr>
<tr>
<td>Spectral coverage</td>
<td>Continuous</td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>0.5 cm(^{-1})</td>
<td>0.4 – 2.1 cm(^{-1})</td>
<td>&gt;0.825 – 2.5 cm(^{-1})</td>
<td></td>
</tr>
</tbody>
</table>

**Typical IASI, AIRS and CrIS spectra**
Methodology for IASI / AIRS, IASI / CrIS

- **Similar scenes: SNOs** (Simultaneous Nadir Overpasses)
  - Tolerance in simultaneity: 20 min
  - ~30 scenes every 3 days for IASI / AIRS (12000 in 5 years)
  - Always at high latitudes

- **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 ISRFs has been performed but is still under exploitation

- **For each pseudo-band,**
  \[ \Delta T = \left( \frac{L_{\text{IAISI}} - L_{\text{AIRS}}}{\partial L_{\sigma}/\partial T} \right) (\sigma, 280K) \]
  - Mean and stdev computed over the dataset
Biases and standard deviations (no filtering)

- Biases < ~0.2K → Very well cross calibrated
- Same shape, highest bias in B1, stronger for IASI-B. Spectral slope?
- Similar datasets:

IASI-X / CrIS
**IASI-X / AIRS inter-comparison**

- Biases and standard deviations (no filtering)

  **IASI-A – AIRS (PB method)**
  ![IASI-A AIRS (PB method)](image1)

  **IASI-B – AIRS (PB method)**
  ![IASI-B AIRS (PB method)](image2)

  - Biases < ~0.2K ➔ Very well cross calibrated
  - Same shape, highest bias in B1, stronger for IASI-B. Atmospheric shape?
  - Similar datasets:

  ![IASI-A AIRS (PB method)](image3)
  ![IASI-B AIRS (PB method)](image4)
All couples are very stable with time
Non-linearity effects of IASI/AIRS and IASI/CrIS?

- Trend of B1 NeDT wrt B1 BT

No obvious effect
Indirect IASI-A / IASI-B through AIRS and CrIS

- Combination of IASI / AIRS and IASI / CrIS for IASI-B / IASI-A

- All biases agree: ~0.1K
  - Confirms the very good cross calibration
  - Always an effect on B1, IASI origin?
  - Small differences in B1: dataset selection, e.g. colder?
Difference of massive means IASI-B - IASI-A (from T. Phulpin)

- **Independent method**: averaging of all L1C radiance spectra for IASI-B and IASI-A
- **Data from June 2013 to February 2014, via Ether, OBRstat tool**
  
  ~65% cloudy; surf. temp. distrib. (1σ): 250K-290K
- **Difference IASI-B – IASI-A (NEDT) from these mean radiances:**
  
  ➔ Same amplitude (bias ~0.1K in B1) and same shape as IASI-B / IASI-A direct comp.
  ➔ High confidence in this result
  ➔ Influence of the dataset: here also the input dataset may be a bit different between A and B (Ext. Cal., different AVHRR cloud flags, etc.)
CONCLUSIONS

● The tool for inter-comparison is operational for the 5 couples of sensors:
  IASI-A / IASI-B, IASI-A / AIRS, IASI-B / AIRS, IASI-A / CrIS, IASI-B / CrIS

● Major result: very accurate cross-calibration!
  ✦ IASI-B very close to IASI-A (bias < ~0.1K) ➔ continuity of the IASI mission
  ✦ IASI / AIRS / CrIS: Bias between 0K and 0.2K, < radiometric absolute specification of 0.5K
  ✦ Cal/val results are confirmed with a larger and more diverse dataset
  ✦ All are very stable with time
  ✦ The observed bias is still high with respect to climatic time series
  ✦ Largest bias in IASI B1, stronger in IASI-B: non-linearity in IASI?

● On-going work:
  ✦ Go further in the interpretation of the shape of the bias curves:
    ✦ Specific sensitivity studies for B1 are scheduled
    ✦ Update of the linearity tables
    ✦ Get the bias curves for each IASI pixel
  ✦ Complete uncertainty budget
  ✦ Go further in an absolute radiometric and spectral calibration