Exploring algorithms for Meteosat-HIRS Inter-Calibration

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Contents

• HIRS v IASI as Inter-Calibration Reference

• Collocation criteria

• Spectral Convolution
  – Empirical Stepwise multiple regression
  – Manual Channel selection
  – Training dataset
  – Regression method
  – Model Errors

• Spatial Convolution

• Regression

• (Results)

• Conclusions
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Use of HIRS v IASI as a Reference

Meteosat Geostationary Imager
+ High-resolution InfraRed Sounder, HRIS, on Metop polar-orbiting satellite

Benefits of HIRS as reference:
• Established instrument
  – Operated by NOAA since 1970s
  – Used in climate records
  – Potential reference for archive data
• Includes on-board calibration
• On same platform as IASI
  – Well characterised against IASI
  – Can close inter-calibration triangle

Can cross-check with AIRS and other HIRSSs:
• Simultaneous Nadir Overpasses: SNOs
• Inter-calibrating Meteosat-AIRS
High-resolution Infrared Radiation Sounder on Metop/A in Sun-synchronous polar-orbit

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 Infrared Channels</td>
<td>3.8 – 15 μm</td>
</tr>
<tr>
<td>IFOV size at Nadir</td>
<td>10km</td>
</tr>
<tr>
<td></td>
<td>(20km on HIRS/3)</td>
</tr>
<tr>
<td>Sampling at Nadir</td>
<td>26 km</td>
</tr>
<tr>
<td>Scan Rate</td>
<td>6.4 sec</td>
</tr>
<tr>
<td>Swath</td>
<td>±49.5°/56 pixels</td>
</tr>
<tr>
<td></td>
<td>(± 1092 km)</td>
</tr>
<tr>
<td>Blackbody cal.</td>
<td>Every 256 sec</td>
</tr>
</tbody>
</table>
Introduction to Metop/IASI

Infrared Atmospheric Sounding Interferometer on Metop/A in Sun-synchronous polar-orbit

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Range</td>
<td>645-2760 cm⁻¹ (3-15 μm)</td>
</tr>
<tr>
<td>Spectral Sampling</td>
<td>0.25 cm⁻¹</td>
</tr>
<tr>
<td>IFOV size at Nadir</td>
<td>12 km</td>
</tr>
<tr>
<td>Sampling at Nadir</td>
<td>18 km</td>
</tr>
<tr>
<td>Scan Rate</td>
<td>8 sec</td>
</tr>
<tr>
<td>Swath</td>
<td>± 48.98° (± 1066 km)</td>
</tr>
</tbody>
</table>
• HIRS v IASI as Inter-Calibration Reference

• **Collocation criteria**

• **Spectral Convolution**
  – Empirical Stepwise multiple regression
  – Manual Channel selection
  – Training dataset
  – Regression method
  – Model Errors

• **Spatial Convolution**

• **Regression**

• **(Results)**

• **Conclusions**
1. Collocation
   - Finding observations coincident in space and time

2. Transformation
   - To allow direct comparison
   - Spatial averaging
   - Spectral averaging

3. Filtering
   - Selecting scenes of interest
   - Reducing noise & rejecting outliers

4. Analysis
   - Comparing observations
   - Calculating biases and errors

5. Developing corrections
1. Collocation
   • Finding observations coincident in space and time

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Collocation Criteria

Simultaneous near-Nadir Overpasses of Meteosat and Metop

- Only night-time data
- $\Delta \text{Lat} < 35^\circ$, $\Delta \text{Lon} < 35^\circ$ of SSP
- $\Delta t < 15$ mins (scan period)
- $\Delta \theta < 1\%$ (Atmospheric path diff.)
- $3 \times 3$ MSG pixels / HIRS/4 iFoV

Restricts collocations to Tropics
- $\sim 1$ orbit/day
- $\sim 200$ good collocations?
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**IASI Tb Spectrum + HIRS SRFs + MSG SRFs + MTP SRFs**

**IASI Tb Spectrum – Covers all HIRS IR channels**

**HIRS SRFs**

**MTP SRFs – WV Channel ~ HIRS Ch12, IR Channel ~ HIRS Ch8**

**MSG SRFs – 7.3 & 8.7μm Channels not covered by HIRS**

- Single Ch for 10.8/12.0 μm
- 3.9μm Ch covered by HIRS Ch17+18+19
Accounting for SRF Differences

- Meteosat and HIRS have different SRFs
  - Would introduce errors into direct comparisons of radiance
- Need to ‘correct’ HIRS radiances
  - to account for spectral differences
- And/or combine HIRS channels
  - with different weights
- Use Radiative Transfer Model (RTM)
  - to generate synthetic radiances
  - for Meteosat & HIRS
- Calculate coefficients by regression
  - and uncertainty introduced
  - compare this uncertainty with variability
Stepwise Regression to Select Channels

- Attempted Stepwise Regression
  - to select channels match-ups
  - and estimate relative weights of each HIRS channel to simulate each Meteosat channel
  - Completely empirically
  - Results are obviously nonsense!
  - e.g. MSG 3.9μm channel fitted HIRS Ch18,13,5 & 11 (not 17&19)
  - Some HIRS channels can be given negative weights

- However, stepwise regression may be a useful tool to analyse results
  - e.g. dependence of bias on scan angle, latitude, time of day, phase of moon, etc.
### Selecting Channels for Comparison ‘Manually’

<table>
<thead>
<tr>
<th>MTP MVIRI</th>
<th>×</th>
<th>WV</th>
<th>×</th>
<th>×</th>
<th>×</th>
<th>IR</th>
<th>×</th>
<th>×</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIRS</td>
<td>×</td>
<td>Ch12</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>Ch8</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>MSG SEVIRI</td>
<td>3.9µm</td>
<td>6.2µm</td>
<td>7.3µm</td>
<td>8.7µm</td>
<td>9.7µm</td>
<td>10.8µm</td>
<td>12.0µm</td>
<td>13.4µm</td>
</tr>
<tr>
<td>HIRS</td>
<td>Ch17 Ch18 Ch19</td>
<td>Ch12</td>
<td>Ch11</td>
<td>N/A</td>
<td>Ch9</td>
<td>Ch8</td>
<td>Ch8</td>
<td>Ch7</td>
</tr>
</tbody>
</table>
- RTTOV-9 Radiative Transfer Model

- Diverse 52 profiles at 60 levels
  - From ECMWF (Chevallier’01)
  - Temperature, Water Vapour and Ozone
  - Covers global range
  - Represents natural variability

- Duplicate profile set:
  - 1 set for clear sky
  - 1 set with mid-level cloud (700hPa)
  - 1 set with high cloud (100hpa)

- Run RTM twice at incidence angles:
  - Zenith
  - 60°
Quadratic Regression
Quadratic Regression - residuals
Regression Results

- Quadratic Regression gives better fit for IR10.8 and IR12.0
- IR6.2 show large scatter in clear sky (also IR3.9 in cloud)
  - IR6.2: Systematic difference between nadir and 60° views (WFs)
- IR8.7 doesn’t match any HIRS channel – nonsense results
- Largest scatter in clear sky cases (most spectral information)
- Could improve fit by excluding arctic data
- Should validate using independent test dataset
- Should calc uncertainty at $L_{ref}$ using coefficients full covariance
- Noise < Model Error < ~ Variability on single collocation
  - But, correlation in model errors between collocated pixels…
Compare Model Error with Variability

- Variability for 8 IR channels of MSG
  - \( \text{RMSD}_t(\Delta t=15\text{min}) \)
  - \( \text{RMSD}_x(\Delta x=10\text{km}) \)
  - \( \approx \text{RMSD}_y(\Delta y=10\text{km}) \)
  Reduced by \( \sqrt{n_{col}} \) e.g. \( n_{col}=100 \)

- Model error >> Variability for
  - IR6.2 (different weighting functions)
  - IR8.7 (no HIRS equivalent)

- Model error \( \sim \) Variability
  - for other SEVIRI channels
  - Expect increased noise on inter-calibration results by \( \sim \sqrt{2} \)

<table>
<thead>
<tr>
<th>SEVIRI Channel [(\mu m])</th>
<th>Temporal Variability ( \text{RMSD}_t(\Delta t=15\text{min})/\sqrt{100} ) [K]</th>
<th>Spatial Variability ( \text{RMSD}_x(\Delta x=10\text{km})/\sqrt{100} ) [K]</th>
<th>MSG-HIRS Modelling Error [K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9</td>
<td>0.30</td>
<td>0.25</td>
<td>0.35</td>
</tr>
<tr>
<td>6.2</td>
<td>0.08</td>
<td>0.12</td>
<td>1.07</td>
</tr>
<tr>
<td>7.3</td>
<td>0.17</td>
<td>0.22</td>
<td>0.15</td>
</tr>
<tr>
<td>8.7</td>
<td>0.32</td>
<td>0.40</td>
<td>3.11</td>
</tr>
<tr>
<td>9.7</td>
<td>0.19</td>
<td>0.30</td>
<td>0.14</td>
</tr>
<tr>
<td>10.8</td>
<td>0.35</td>
<td>0.40</td>
<td>0.18</td>
</tr>
<tr>
<td>12.0</td>
<td>0.36</td>
<td>0.40</td>
<td>0.42</td>
</tr>
<tr>
<td>13.4</td>
<td>0.25</td>
<td>0.30</td>
<td>0.56</td>
</tr>
</tbody>
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Temporal and Spatial Variability of Meteosat brightness temperatures on scales of 15 min and 10 km, respectively, compared with MSG-HIRS modelling error.
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Spatial Averaging

Average Meteosat pixels within each HIRS iFoV

Estimate uncertainty due to spatial variability as Standard Deviation of Meteosat pixels

Use in weighted regression
1. Collocation
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Offset ≠ 0  Slope ≠ 1  => Difference is scene-dependent

Reference Scene, $L_{REF}$

Weighted Regression
Error bars = Variance

Reference Scene defined as modal value (typical clear sky radiance)
Meteosat-7 – HIRS Inter-Comparisons (not GSICS!)

- Comparisons of Met-7 – HIRS
  - Processed operationally at EUMETSAT
  - Used to check Met-7 calibration
- Needs to account for different SRFs
  - Increases uncertainty
- Noisy, but stable
- WV: +2.8 ± 1.0 K
- IR: -2.5 ± 0.6 K
- Biases similar to Met-7 – IASI
- Variances much larger
Time series of brightness temperature differences between Met7-IASI for typical clear-sky radiances: Each Met7 infrared channel is shown in a different color, with different symbols, following the legend. Error bars represent statistical uncertainty on each mean bias (may be very small).
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Conclusions

- Can use HIRS as inter-calibration reference for Meteosat
  - (instead of IASI)

- Need to account for spectral differences
  - Transform HIRS observations to Meteosat-space
  - Using coefficients derived from regression of modelled radiances
  - Based on RTTOV + data set of diverse profiles + cloud
  - Not possible for IR8.7
  - Noisy for IR6.2
  - Introduces error in inter-calibration ~ Variability (for ~100 collocations)
  - “Closing the triangle”: <MSG-IASI> ≠ <MSG-HIRS> - <HIRS-IASI>

- EUMETSAT plan to implement prototype in 2009
Thank you

Questions and Answers