Inter-Calibration of Meteosat IR and WV channels using HIRS data

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Content

• Fundamental Climate Data Record for geostationary satellites – The Challenge
• Approach to Inter-calibration using HIRS/IASI as a reference
• Spectral Conversion Functions
• Conclusions
FCDR Creation - Scale of the Challenge

- International community has embarked on the creation of FCDRs for archived data (EUMETSAT, NOAA-CDR program and similar programs);
- It is essential for fulfilling GCOS ECV requirements;
- Inter-calibration of the sensors to allow seamless products is a weakness in existing data records, e.g., GEWEX data projects;
- The creation of FCDRs has a large science component calling for collaborations of space agencies and scientists;
- GSICS and SCOPE-CM are the right frameworks to make progress and achieve GCOS goals.

Figure: Courtesy of Ken Knapp, NOAA-NCDC
Scale of the Challenge

**Fig:** Satellites used for the ISCCP climate data record. (Courtesy of Ken Knapp, NOAA-NCDC)
Scale of the Challenge

Original Instrument changes
Calibration changes
Objective:
To recalibrate time-series Meteosat First Generation and Meteosat Second Generation infrared radiances from 1982 till date using an external reference (polar orbiting sounders).

Prerequisites:
• Inter-calibration back to 1982
• Target accuracy over the time-series better than 1 K
• Inter-calibration with uncertainty estimate

Method
• Define reference instrument and standards (HIRS and ultimately IASI)
• Define the inter-calibration approach
• Estimate the uncertainties (spectral conversions, reference drift, calibration transfer uncertainty (e.g. for SNOs)
• Reprocess, verify and validate the re-calibrated data record
Error and Uncertainties sources

1. Differences between reference instruments over time \((HIRS/2 \text{ vs. } HIRS/3 \text{ vs. } HIRS/4)\)

2. Differences between monitored instruments \((MVIRI \text{ vs. } SEVIRI)\)

3. Differences between reference and monitored instruments \((HIRS-MVIRI, \text{ etc.})\)

4. Synchronization errors & \(\text{Collocation errors}\)

5. Instrument drift

6. Error and Uncertainties sources

- Different resolutions & Imperfect overlap
  - -0.2
  - 0.0
  - 0.1
  - Jan-08
  - May-09
  - Sep-10
  - 1.0
  - Function
Define the Calibration Method:
Cumulative uncertainty from calibration transfer

Transfer Calibration by inter-calibration

Uncertainty
due to spectral conversion,
SNO noise and
instrument drift

Schematic only!
Define the Calibration Method:
Reduced number of calibration transfers
Define the Calibration Method:
Taking a reference in the middle of time series
• Cloud-cleared and limb-corrected HIRS channel BTs (Nov. 1978 to Mar. 2009)
• Technique applied to all HIRS channels
• Monthly differences of inter-calibrated instruments mostly within ±0.2 K.
• Unclear: Uncertainty estimates for the HIRS inter-calibration.

Courtesy of Lei Shi, NOAA-NCDC
Define the Calibration Method:
Suspension Bridge Model of Transferring References
Alternative: Zipper Model of Transferring References

Use Meteosats as transfer standards to inter-calibrated HIRS

Delta Correction to transfer from one reference to another
- Defined as differences between inter-calibration functions
- Defined in channel-space of monitored instrument
- No need for direct comparisons of references

Delta time steps inserted for illustration only
In practice, deltas defined from simultaneous double-differences
Estimate Uncertainty: Spectral Conversion Functions

Objective

To develop Spectral Conversion Functions to account for Spectral Response Function differences and select which HIRS channels represent the MFG and MSG infrared channels best.

Method

- Restricted evaluation to a sounding (~6μm) and a window (~10μm) channel;
- MFG, MSG and HIRS brightness temperatures are calculated for a selection of ECMWF profiles (from Chevallier 2001) using RTTOV;
- Uncertainties are assessed for three conditions: all latitudes, all sky, two angles (nadir and 60°);
- HIRS channels that fit best to MFG or MSG are determined by assessing different fitting methods and using RMSD as a verification metric.
## Statistics of different Spectral Conversion Functions

<table>
<thead>
<tr>
<th>Channels</th>
<th>Fit</th>
<th>Latitude</th>
<th>Cloud</th>
<th>Angles</th>
<th>WV Tb RMSD [K]</th>
<th>IR Tb RMSD [K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>Linear</td>
<td>±90°</td>
<td>All</td>
<td>0°, 60°</td>
<td>2.18</td>
<td>0.60</td>
</tr>
<tr>
<td>Multiple</td>
<td>Linear</td>
<td>±90°</td>
<td>All</td>
<td>0°, 60°</td>
<td>1.19</td>
<td>0.046</td>
</tr>
<tr>
<td><strong>Multiple</strong></td>
<td><strong>Quadratic</strong></td>
<td>±90°</td>
<td>All</td>
<td>0°, 60°</td>
<td><strong>0.74</strong></td>
<td><strong>0.034</strong></td>
</tr>
<tr>
<td>Multiple</td>
<td>Quadratic</td>
<td>±60°</td>
<td>All</td>
<td>0°, 60°</td>
<td>0.62</td>
<td>0.034</td>
</tr>
<tr>
<td>Multiple</td>
<td>Quadratic</td>
<td>±45°</td>
<td>All</td>
<td>0°, 60°</td>
<td>0.56</td>
<td>0.034</td>
</tr>
<tr>
<td>Multiple</td>
<td>Quadratic</td>
<td>±90°</td>
<td>Clear only</td>
<td>0°, 60°</td>
<td>0.76</td>
<td>0.040</td>
</tr>
<tr>
<td>Multiple</td>
<td>Quadratic</td>
<td>±90°</td>
<td>No high cloud</td>
<td>0°, 60°</td>
<td>0.78</td>
<td>0.035</td>
</tr>
<tr>
<td>Multiple</td>
<td>Quadratic</td>
<td>±90°</td>
<td>Cloudy only</td>
<td>0°, 60°</td>
<td>0.65</td>
<td>0.017</td>
</tr>
<tr>
<td>Multiple</td>
<td>Quadratic</td>
<td>±90°</td>
<td>All</td>
<td>0° only</td>
<td>0.77</td>
<td>0.029</td>
</tr>
</tbody>
</table>

- Fit much improved using multiple channels & quadratic form
- But not much by limiting range – **So keep it general: global, all sky, all angles!**
### Uncertainties due to Spectral Conversion for each class of instrument: WV

<table>
<thead>
<tr>
<th>Monitored Reference</th>
<th>HIRS/2 NOAA6-14</th>
<th>HIRS/3 NOAA15-17</th>
<th>HIRS/4 NOAA18-MetopB</th>
<th>MVI RI Meteosat 2-3</th>
<th>MVI RI Meteosat 4-7</th>
<th>SEVIRI Meteosat 8-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIRS/2 NOAA6-14</td>
<td>0.04</td>
<td>1.03</td>
<td>1.07</td>
<td>0.07</td>
<td>0.16</td>
<td>0.41</td>
</tr>
<tr>
<td>HIRS/3 NOAA15-17</td>
<td>0.78</td>
<td>0.05</td>
<td>0.06</td>
<td>X</td>
<td>0.67</td>
<td>0.51</td>
</tr>
<tr>
<td>HIRS/4 NOAA18-MetopB</td>
<td>0.84</td>
<td>0.06</td>
<td>0.03</td>
<td>X</td>
<td>0.74</td>
<td>0.57</td>
</tr>
</tbody>
</table>

**Mean RMSD Tb [K] of Spectral Conversion Functions for each class of instrument: WV**

Also need to:
- Estimate Calibration Transfer Uncertainty (e.g. by SNO)
- Estimate drift in reference transfer standards
Conclusions

- The international community faces a complex and large task to inter-calibrate the whole fleet of geostationary and HIRS instruments for the IR and WV channels.
- GSICS is the framework that needs to work to solve these issues and SCOPE-CM is to provide the community with the inter-calibrated radiances.
- Identified two different approaches to inter-calibrate Meteosat-HIRS:
  - Using SNOs or regional subsamples to inter-calibrate HIRS as a homogenised FCDR
  - Use Meteosats as transfer standards to inter-calibrate HIRS
- Developed a systematic way to define spectral conversion functions.
- Need to analyse uncertainties in final inter-calibrated radiances for each proposed method separately – will also use new reanalysis feedback archive.
- We aim to produce inter-calibrated Meteosat WV & IR archive by 2013.