Quantifying the Impact of Spatial and Temporal Atmospheric Variability on GSICS Inter-Calibration algorithms

or How Close is “Close Enough”?

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The Problem

- Quantifying the Impact of Spatial and Temporal Atmospheric Variability on GSICS Inter-Calibration algorithms
  - Contribution to error budget

- Specifying collocation criteria
  - or How Close is “Close Enough”?
The Method

- Calculate RMS Differences
  - in radiances
  - or brightness temperatures
- From GEO images

- Between all pixels within an image
  - separated by $\Delta x$ in E/W direction
  - separated by $\Delta y$ in N/S direction
  - $RMSD_x = \langle [T_b(x+\Delta x) - T_b(x)]^2 \rangle^{1/2}$

- Between pixels in series of images
  - separated by $\Delta t$ in time series
  - $RMSD_t = \langle [T_b(t+\Delta t) - T_b(t)]^2 \rangle^{1/2}$

Parameters:
- $\Delta x$: 3km
- $\Delta y$: 3km
- $\Delta x$: 6km
- $\Delta x$: 9km
- $\Delta y$: 3km
- $\Delta t$: 5min
- $\Delta t$: 10min
- $\Delta t$: 15min
Spatial Variability Results

- From single MSG image
  - 01:00 on 1 Feb 2006
  - (night-time)
  - But, Spatial Variability Varies!

- $RMSD_x = \sqrt{\left[ T_b(x + \Delta x) - T_b(x) \right]^2}$
- Calculated for each IR Channel

- Limited to ±30°N/S ±30°E/W
  - GEO/LEO collocation domain
  - Pixel spacing ~uniform

- More variability in N/S than E/W
  - latitudinal temperature gradient
  - Difference negligible for $\Delta x \leq 10$ km

R.M.S. Differences in Meteosat-8 10.8 μm brightness temperatures with spatial separation in North-South direction (black) and West-East direction (red).
Temporal Variability Results

- From 24hrs of rapid scan MSG data
  - 5 min sampling 18 April 2008
  - 15°N 30°W-30°E, 45°N 45°W-45°E
- Similar results from other case
  - 15 min sampling on 4 Feb 2006
  - Subset of full disc: ±30°N/S ±30°E/W
  - But, Temporal Variability Varies!

\[ RMSD_t = \langle [T_b(t+\Delta t) - T_b(t)]^2 \rangle^{1/2} \]

- Calculated for each IR Channel

- Maximum variability for \( \Delta t \sim 12 \) hr
  - for all channels
  - but most in window channels
  - Diurnal cycle dominates variability on time scales longer than \( \sim 1 \) hr
  - causing \( RMSD_t \) to increase more rapidly for increasing time intervals

R.M.S. Differences in Meteosat-8 10.8 μm brightness temperatures with time intervals from Rapid Scanning Meteosat data
Results for other channels

- Calculated for 8 IR channels of MSG
  - $RMSD_t(\Delta t=15\text{min})$
  - $RMSD_x(\Delta x=10\text{km})$
  - $RMSD_y(\Delta y=10\text{km})$

- Window channels most variable

- $RMSD >>$ Instrument noise

- Variability is comparable on these space and time scales
  - So omitting spatial variability will cause uncertainty on collocation to be underestimated by $\sim \sqrt{2}$

**Table 1:** Temporal and Spatial Variability of Meteosat brightness temperatures on scales of 15 min and 10 km, respectively.

<table>
<thead>
<tr>
<th>Channel [µm]</th>
<th>$RMSD_t(\Delta t=15\text{min})$ [K]</th>
<th>$RMSD_x(\Delta x=10\text{km})$ [K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9</td>
<td>3.0</td>
<td>2.5</td>
</tr>
<tr>
<td>6.2</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>7.3</td>
<td>1.7</td>
<td>2.2</td>
</tr>
<tr>
<td>8.7</td>
<td>3.2</td>
<td>4.0</td>
</tr>
<tr>
<td>9.7</td>
<td>1.9</td>
<td>3.0</td>
</tr>
<tr>
<td>10.8</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>12.0</td>
<td>3.6</td>
<td>4.0</td>
</tr>
<tr>
<td>13.4</td>
<td>2.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>
• Spatial and temporal variability comparable on scales of:
  – 3 – 25 km (in N/S)
  – 5 – 45 min

• \( \text{RMSD}_t(\Delta t=15\text{min}) \approx \text{RMSD}_y(\Delta y=10\text{km}) \)

• Suggest mesoscale features typically evolve at \( \sim 13 \text{ m/s} \)
  – faster than advection (in tropics)

• Spatial and temporal collocation criteria are not independent!

R.M.S. Differences in Meteosat-8 10.8\( \mu \text{m} \) brightness temperatures with time intervals from Rapid Scanning Meteosat data (red) and spatial separation in N-S direction (black pluses) and W-E direction (black stars).
**Impact of Mean Difference on RMSD**

- **RMSD** statistics include any *systematic differences* in radiance differences

- Compare with Standard Deviation
  - Equivalent to subtracting mean difference before calculating RMSD

- But, mean differences tend to cancel
  - over large domain ~global
  - over long time series

- No differences in **RMSDx** or **RMSDy**

- 3% difference in **RMSDt(Δt >12hr)**
  - But test period only 24hr
  - Difference $\rightarrow 0$ for longer test periods?

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**R.M.S. Differences in Meteosat-8 10.8 μm brightness temperatures with time intervals from Rapid Scanning Meteosat data**
Impact of Homogeneity Filtering

- Apply homogeneity filter by excluding ‘noisy’ pixels
  - SD of radiances within 5x5 pixels are >5% of the mean radiance
- Need to account for missing data when calculating $RMSD$

- $RMSDt$ drops by a factor of 2.0
- $RMSDx$ reduces by a factor of 2.6

- On very small scales or for homogeneous scenes
  - atmospheric variability $<<$ instrument’s radiometric noise
  - $RMSD$ will become constant with time and space (white noise)
Conclusions

• Q: “What should collocation thresholds be in time and space?”
• A: “It depends”!

• It depends on how much noise is acceptable to introduce into each collocation due to atmospheric variability

• e.g. These results suggest thresholds of 15 min and 10 km would each introduce errors of 1-4 K into each collocation

• May be reduced to insignificant levels if many hundreds of collocations are combined in the analysis
Thank you

Questions and Answers