Characterisation of NWP Model Biases and Uncertainties in the MW and IR Spectral Domains

Part 1: InfraRed

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Motivation

What are the biases and uncertainties in NWP temperature and humidity fields when mapped to radiance space?

Sub-Tropics
GRA; TEN
~1200 matchups
2016-2017

Tropics
MAN; NAU
~600 matchups
2011-2014

Northern Latitudes
BAR; NYA; SOD
~7000 matchups
2011-2017

Mid-Latitudes
SGP; CAB; LIN; TAT
~15000 matchups
2011-2017
Disclaimer

Simulated radiosonde-based Brightness Temperature vs Simulated NWP-based Brightness Temperature

No Satellite Data
Biases Time Series

\[ \delta y = NWP - GRUAN \]

Temperature channels:
- 657.50 cm\(^{-1}\)
- 696.00 cm\(^{-1}\)
- 697.75 cm\(^{-1}\)
- 706.25 cm\(^{-1}\)
- 731.50 cm\(^{-1}\)

Humidity channels:
- 1367.00 cm\(^{-1}\)
- 1402.00 cm\(^{-1}\)
- 1408.00 cm\(^{-1}\)
- 1540.25 cm\(^{-1}\)
Biases Time Series

**Met Office – Mid-Latitudes**

**ECMWF – Mid-Latitudes**
The total uncertainty of the difference $\delta y$ is expressed as the covariance matrix $S_{\delta y}$:

$$S_{\delta y} \cong HRH^T + HWBW^T H^T + HS_{\text{int}}H^T$$
The total uncertainty of the difference $\delta y$ is expressed as the covariance matrix $S_{\delta y}$:

$$S_{\delta y} \approx HRH^T + HWBW^TH^T + HS_{int}H^T$$

$$= HR_{temp}H^T + HR_q H^T + HR_p H^T + h\sigma_{surf}^2 h^T$$

Diagonal matrices of GRUAN uncertainties
Uncertainties

The total uncertainty of the difference $\delta y$ is expressed as the covariance matrix $S_{\delta y}$:

$$S_{\delta y} \cong HRH^T + HWBW^T H^T + HS_{\text{int}} H^T$$

$$ \cong HW B_{\text{temp}} W^T H^T + HW B_{q} W^T H^T + h\sigma_{\text{surf}}^2 h$$

Full model covariance matrices
The total uncertainty of the difference $\delta y$ is expressed as the covariance matrix $S_{\delta y}$:

$$
S_{\delta y} \approx HH^T + HWBW^T H^T + HS_{int}H^T
$$

function of $B$ and $W$ (interpolation matrix)
see paper in ref.
Uncertainties

Uncertainty ($\text{NWP}_{\text{EC}}$-GRUAN) mid-latitudes

- Total Uncertainty
- NWP contribution to total U
- GRUAN contribution to total U

ECMWF – Mid-Latitudes
Diagonal of $S_{\delta y}$
The statistical significance of $\delta y$ is assessed by testing the following:

$$\left| S_{\delta y}^{-1/2} \cdot \delta y \right| < 2$$

NWP and GRUAN brightness temperatures satisfying this test are in agreement with a confidence interval of 95.5%.

$$|m_1 - m_2| < k \sqrt{u_1^2 + u_2^2}$$
Biases Time Series

Met Office – Mid-Latitudes

ECMWF – Mid-Latitudes
## Summary tables

### Met Office – Mid-Latitudes

<table>
<thead>
<tr>
<th>Wavenumber</th>
<th>Instrument</th>
<th>Matchups</th>
<th>Q1</th>
<th>Median</th>
<th>Q3</th>
<th>Mean</th>
<th>StDv</th>
<th>Kurtosis</th>
<th>Skew</th>
<th>Uncertainty</th>
<th>Success rate (%)</th>
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<tr>
<td>657.50</td>
<td>IASI (51)</td>
<td>15513</td>
<td>0.03</td>
<td>0.17</td>
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<td>0.11</td>
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<td>0.00</td>
<td>1.22</td>
<td>7.21</td>
<td>66.46</td>
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*Note: The diagrams show the distribution of data for different wavenumbers, with box plots indicating the median, quartiles, and outliers.*
Potential outcomes

- Better understanding of geographical & temporal distribution of model biases.
- More robust NWP-based satellite assessment.
- Refine model covariance uncertainties.
- Improve bias corrections.

Caveat
It ignores the (unknown) uncertainty due to the scale mismatch between coarse model resolution and fine radiosonde measurements. It is expected to be more significant for humidity than temperature as it varies at scales generally smaller than global model resolutions.
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Part 2: Microwave

Poster 11p.01
References


Questions?

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