Implications of observation error correlation on the assimilation of interferometric radiances

Reima Eresmaa, Niels Bormann and Tony McNally
Outline

• Theoretical effect of observation error correlation (OEC) on information content in linear analysis framework
• Derivation of OEC-based and reference channel selections for the assimilation of IASI radiances
  → Effect of OEC on channel selection in a realistic framework
• Performance comparison in theory and practice
• Summary
Degrees of Freedom for the Signal (DFS) in a two-parameter / two observation system

*DFS decreases with increasing BG error correlation …*

… but *increases with increasing OEC.*
Current approach for the assimilation of IASI radiances at ECMWF

8461 channels → **(pre-screening)** 373 channels → **(channel filtering)** ≤191 channels → **(4D-Var)** Analysis increments

- Normally no OEC assumed at all
- Experimental assimilation with explicitly accounting for (inter-channel) OEC in the 4D-Var step
- Most optimally, both inter-channel and spatial OEC would be explicitly taken into account in **pre-screening**, **channel filtering**, and 4D-Var steps
What do we know about OEC (in the framework of infrared sounders)?

- Errors related to representativeness and forward modelling are likely correlated, but these are difficult to quantify for all channel pairs.
- Diagnostic tools provide some information but are subject to validity of certain assumptions.
- Signal processing theory provides accurate knowledge of OEC associated to signal apodization.
  - Strong OEC between channels adjacent to each other (0.70 in the case of IASI).
  - Weaker (but non-zero) OEC between alternate channels (0.25 in the case of IASI).
→ Only a few pairs of adjacent channels are included in the operationally-assimilated subset of IASI channels.
Are there implications on channel selection?

Operational list:
- 191 channels
- Practically optimized

Reference list:
- Optimized assuming no OEC
- Pairs of adjacent channels not allowed

OEC-based list:
- Optimized assuming the signal apodization to be the only source of OEC
- Pairs of adjacent channels allowed
Optimization algorithm

• The idea is to repeatedly replace the least useful channel contained in the list by the most useful channel not yet included.

• Usefulness of a channel is measured in terms of its contribution to the overall DFS.

• Only the first 600 IASI channels are considered.

• Observation error variances set using a polynomial fit on background departure statistics on operationally-used channels.

• A representative description used for background error covariance.

• Consider analysis state vector consisting of surface temperature and 43-level profiles of temperature, humidity and ozone.

• Two reference profiles representing mid-latitude summer and winter.
The effect of OEC on channel selection

- The OEC-based list contains fewer stratospheric- and upper-tropospheric sounding channels, but more lower-tropospheric and humidity-sensitive window channels.
Theoretical performance comparison

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>OEC-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iterations</td>
<td>38</td>
<td>76</td>
</tr>
<tr>
<td>DFS @ start</td>
<td>11.02</td>
<td>10.73</td>
</tr>
<tr>
<td>DFS @ end</td>
<td>11.84</td>
<td>12.14</td>
</tr>
<tr>
<td>% of maximum available</td>
<td>76.7</td>
<td>83.7</td>
</tr>
</tbody>
</table>

→ OEC-based list performs better in retrieving mid-tropospheric temperature and tropospheric humidity information
Practical performance comparison: Observation departure statistics

83 days in 38r2 / T511 / L91 (OEC-based – Reference) / Reference

IASI analysis fits (tropics)

TEMP-Q

TEMP-T background fits

Metop-A

AMSU-A

Metop-A

MHS
Practical performance comparison: Medium-range forecast scores

<table>
<thead>
<tr>
<th>Northern extratropics</th>
<th>Tropics</th>
<th>Southern extratropics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>T</td>
<td>W</td>
</tr>
<tr>
<td>200 hPa</td>
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<td></td>
</tr>
<tr>
<td>500 hPa</td>
<td></td>
<td></td>
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<tr>
<td>850 hPa</td>
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<td></td>
</tr>
</tbody>
</table>

- **N.Hem. Z850 RMSE**
- **S.Hem. VW850 RMSE**
- **Tropics Z200 RMSE**

(OEC-based better)

(Reference better)
Summary

- Inter-channel OEC is shown to have implications on the optimization of interferometric channel selections
  - Assimilation of IASI radiances could potentially be improved by making deliberate use of spectrally-adjacent channel pairs
- Theoretical analysis benefits from improved capability to distinguish between temperature and humidity errors, when OEC is taken into account in the channel selection
- Assimilation experiments show little benefit from accounting for OEC already in the channel selection
  - It continues to be difficult to fully resolve the temperature-humidity-ambiguity in practical 4D-Var assimilation