Spatial and inter-channel observation error characteristics for AMSU-A and IASI and applications in the ECMWF system

Niels Bormann, Andrew Collard, Peter Bauer
Outline

1) Estimation of observation errors
   • AMSU-A
   • IASI
2) Applications in 4DVAR
3) Summary
Outline

1) Estimation of observation errors
   • AMSU-A
   • IASI
2) Applications in 4DVAR
3) Summary
Background

- Current observation errors (O+F) for radiances are specified largely in an ad-hoc way, loosely based on FG-departures and other considerations.
- Any error correlations are neglected (spatial/inter-channel).
- Likely sources of error correlations:
  - Radiative transfer (spectroscopy, assumed gas concentrations, ...)
  - Representativeness
  - Instrument design; calibration practices; etc
  - Quality control
- Thinning/error inflation is used to reduce the impact of spatial error correlations; choices largely based on intuition.
- Observation error correlations could be accounted for in the assimilation.
Methods

- Estimating observation errors is not straightforward.
- Estimation methods rely on a range of (questionable) assumptions or have other problems.
- Use three methods, based on bias-corrected assimilated FG/AN-departures:
  - Hollingsworth/Lönnberg (Hollingsworth & Lönnberg 1986)
  - "Background error method"
  - Desrozières diagnostic (Desrozières et al. 2005)
- Used for ATOVS instruments, AIRS, and IASI; see Bormann and Bauer (2010) and Bormann et al. (2010), both QJ.
Methods: “Background error method”

- Based on covariances calculated from pairs of FG departures, binned by separation distance.
- Subtract a scaled version of the assumed background error, mapped to radiance space.

Scaling such that FG-departure covariances match scaled assumed background errors for separations > threshold (scaling ≤ 1).

- Relies on adequate background error covariance; problems for $T_{\text{skin}}$ error.
N-18 AMSU-A: Estimated observation errors ($\sigma_o$)

- Good agreement between different methods.
- Estimated errors close to instrument noise – RT error largely taken out by bias correction?
- Estimated errors lower than errors currently used in the assimilation (~half).
AMSU-A: Spatial observation error correlations by separation distance

Ch 5  |  Ch 6  |  Ch 7  |  Ch 8
--- | --- | --- | ---
Ch 9  |  Ch 10 |  Ch 11 |  Ch 12
Ch 13 |  Ch 14

Distance [km]

0  |  400  |  800  |  1200

0  |  400  |  800  |  1200

0  |  400  |  800  |  1200

0  |  400  |  800  |  1200

0  |  400  |  800  |  1200

0  |  400  |  800  |  1200

0  |  400  |  800  |  1200

0  |  400  |  800  |  1200

0  |  400  |  800  |  1200

Number [Millions]

Background error method
Desrozier's
**AMSU-A:**
Inter-channel observation error correlations

- Hollingsworth/Lönnberg
- Background error method
- Desroziers
IASI: Observation errors (σ₀)

Temperature sounding

LW Window WV
IASI:
Spatial error correlations

Wavenumber [cm⁻¹]

Correlation

Temperature sounding

Channel number

Desroizers at 50 km
Desroizers at 125 km
Desroizers at 250 km
Desroizers at 500 km
Background error method at 50 km
Background error method at 125 km
Background error method at 250 km
Background error method at 500 km

LW Window WV
IASI: Inter-channel error correlations

Desroziers

Hollingsworth/Lönnberg

Background error method
IASI: Inter-channel error correlations (Desroziers)
Outline

1) Estimation of observation errors
   • AMSU-A
   • IASI
2) Applications in 4DVAR
3) Summary
Forecast impact: Less thinning for AMSU-A

CTL: 125 km thinning for AMSU-A
EXP: 62.5 km thinning for AMSU-A

T511 experiments:
NH Winter: Dec 2008/Jan 2009
NH Summer: June/July 2009

- Impact larger for summer hemisphere
- Some degradation for Z in the stratosphere for the winter hemisphere

Normalised RMSE differences (123 cases):

NH, Z 500 hPa
Half thinning bad
Half thinning good

SH, Z 500 hPa
Modifying IASI observation errors: Forecast impact

Experiments with modified IASI observation errors (July/August 2009):

- **CTL**: Old (diagonal) observation errors
- **EXP1**: Updated diagonal observation errors for T-sounding channels (factor 2.5)
- **EXP2**: As EXP1, but with error correlations for all channels

Normalised difference in the RMSE, EXP1 vs CTL, (54 cases):

![NH, Z 1000 hPa](chart1)

- EXP1 worse

![SH, Z 1000 hPa](chart2)

- EXP1 better

![NH, Z 500 hPa](chart3)

- EXP1 better

![SH, Z 500 hPa](chart4)
Modifying IASI observation errors: Forecast impact

Experiments with modified IASI observation errors (July/August 2009):
- **CTL**: Old (diagonal) observation errors
- **EXP1**: Updated diagonal observation errors for T-sounding channels (factor 2.5)
- **EXP2**: As EXP1, but with error correlations for all channels

Normalised difference in the RMSE, EXP2 vs CTL, (54 cases):

![NH, Z 1000 hPa](image1)
![SH, Z 1000 hPa](image2)

![NH, Z 500 hPa](image3)
![SH, Z 500 hPa](image4)
Outline

1) Estimation of observation errors
   • AMSU-A
   • IASI
2) Applications in 4DVAR
3) Summary
Summary

- Small observation error correlations (<0.2) for surface-insensitive temperature-sounding channels at current thinning scales.
- Some inter-channel error correlations for:
  - IASI water-vapour channels
  - IASI long-wave window channels
  - Neighbouring IASI channels (apodisation)
- Some spatial error correlations for:
  - Water-vapour channels at small scales
- Role of RT errors and bias correction?
- See Bormann and Bauer (2010) and Bormann et al. (2010), soon in QJ.
- Application in 4DVAR:
  - Improved forecast impact from assimilating AMSU-A more densely.
  - Encouraging results from taking IASI inter-channel observation error correlations into account, but scaling of errors required.
Modifying IASI observation errors

- Use Desroziers-estimated observation errors in 4DVAR, with correlations, and scaling factor (July/August 2009).

- Standard deviations of Obs-FG, normalised to 1 for no-IASI experiment:
Modifying IASI observation errors

- Use Desroziers-estimated observation errors in 4DVAR, with correlations, and scaling factor (July/August 2009).

- Standard deviations of Obs-FG, normalised to 1 for no-IASI experiment:

Horizontal lines: Values using old (diagonal) observation errors.
Modifying IASI observation errors

- Use Desroziers-estimated observation errors in 4DVAR, with correlations, and scaling factor (July/August 2009).

- Standard deviations of Obs-FG, normalised to 1 for no-IASI experiment:

Horizontal lines: Values using old (diagonal) observation errors.
IASI inter-channel error correlations

Eigenvalues of the error correlation matrix:
Single IASI spectrum assimilation experiments (I)

Observation-forecast departure (all channels considered cloud-free)

Temperature increment [K]

Humidity increment [g/Kg]
Single IASI spectrum assimilation experiments (II)

Temperature increment [K]
Humidity increment [g/Kg]

Model level

Obs-FG departure (all channels considered cloud-free)

Without correlation
With correlation

Channel number

Temperature increment [K]
Humidity increment [g/Kg]
Single IASI spectrum assimilation experiments (III)

Temperature increment [K]
Humidity increment [g/Kg]

Model level

Obs-FG departure

Channel number
Single IASI spectrum assimilation experiments (IV)

Temperature increment [K]
Humidity increment [g/Kg]

Model level

Obs-FG departure (all channels considered cloud-free)