Accounting for correlated observation error in the assimilation of IASI observations

Peter Weston, 3rd IASI Conference, 05/02/2013
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• Error Diagnosis
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• Acknowledgements: Laura Stewart, James Cameron, Brett Candy, John Eyre, Fiona Smith, Ed Pavelin, Bill Bell, Niels Bormann
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Introduction

- Inter-channel error correlations can be caused by:
  - Representativeness errors
  - Forward model errors
  - Apodisation

- Currently these are ignored by using a diagonal $R$ matrix with inflated error values

- Accounting for them means using a full $R$ matrix with non-zero off diagonal elements

- Should lead to improved use of IASI data by:
  - Giving the correct weight to these observations

- First step: Need to know what the correlations look like
Desroziers Diagnostic

- Initially intended as a consistency diagnostic
- Can be used to estimate the true structure of the $R$ matrix
- The method assumes that the $R$ and $B$ matrices used in the original assimilation are correct
- The method derives the following formula for $R$ which includes both ‘O-A’ and ‘O-B’ statistics

\[ R(i, j) = \frac{1}{N} \sum_{k=1}^{N} \{(y - H[x_a])_i (y - H[x_b])_j \}_k \]

- Where $i$ and $j$ are channel numbers and $N$ is the number of observations where both channels $i$ and $j$ are selected
Diagnosed IASI errors from 4D-Var

Operational and diagnosed observation error standard deviations

IASI diagnostic C matrix
Different 4D-Var Resolutions

Percentage difference in diagnosed observation error standard deviations

Difference in IASI diagnostic C matrices
MetOp-B IASI v MetOp-A IASI
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Effect of accounting for correlated errors

Down-weighted observation

Up-weighted observation
Testing the matrix in 4D-Var

• The extra time required to invert the matrix was negligible
• The minimisation took over double the number of iterations to converge as with the diagonal matrices
• Fixing the number of iterations caused the assimilation to fail
• Problems with convergence related to the conditioning
• The condition number of a matrix is:
  \[ \kappa = \frac{\lambda_{\text{max}}}{\lambda_{\text{min}}} \]
• I tried reconditioning the matrix to improve the stability of the minimisation…
Reconditioning

- Using reconditioned matrix results in:
  - Reduced weight given to IASI obs
  - Good convergence
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Trial results – Impact vs Obs

Winter

TEST VS CONTROL (DEC10)
VERIFICATION VS OBSERVATIONS
OVERALL CHANGE IN NWP INDEX = 0.299

MEAN PERCENTAGE CHANGE IN RMSE = -0.442

OVERALL CHANGE IN WEIGHTED SKILL = 0.053

Summer

TEST VS CONTROL (JUNJUL11)
VERIFICATION VS OBSERVATIONS
OVERALL CHANGE IN NWP INDEX = 0.389

MEAN PERCENTAGE CHANGE IN RMSE = -0.480

OVERALL CHANGE IN WEIGHTED SKILL = 6.095

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Trial results – Impact vs Analysis

Winter

TEST VS CONTROL (DEC10)
VERIFICATION VS ANALYSIS
OVERALL CHANGE IN NWP INDEX = 0.415

OVERALL CHANGE IN WEIGHTED SKILL = 0.030

MEAN PERCENTAGE CHANGE IN RMSE = -0.460

Summer

TEST VS CONTROL (JUNJUL11)
VERIFICATION VS ANALYSIS
OVERALL CHANGE IN NWP INDEX = 0.070

OVERALL CHANGE IN WEIGHTED SKILL = 0.000

MEAN PERCENTAGE CHANGE IN RMSE = -0.380
Analysis fit to IASI observations
Background fit to AIRS & MHS
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Conclusions

• The Desroziers diagnostic produces matrices which have:
  • Weak correlations between temperature sounding channels
  • Strong correlations between window and water vapour sensitive channels
  • Smaller diagonal values than are currently used operationally

• Using the diagnosed matrices causes convergence problems which are solved by reconditioning

• Using the full matrix in assimilation trials results in
  • Reduction in forecast errors
  • More weight being given to IASI observations
  • Improved background fit to other observations

• Error correlations are now accounted for in the Met Office 4D-Var scheme for IASI (from 16th January 2013)
Future Work

• Work on implementation for AIRS and CrIS
• Investigate the benefits of using correlated observation errors in the operational 1D-Var pre-processor
• Isolate how much forecast impact is coming from modelling the correlations
• Research whether using a full matrix affects the optimal channel selection for IR sounders
• Extend work to other instruments: ATOVS, SSMIS, ATMS, SEVIRI?
Thanks for listening
Any questions?