Currently data from high resolution sounders, such as AIRS (Atmospheric Infrared Sounder on the NASA satellite Aqua) and IASI (Infrared Atmospheric Sounding Interferometer on the EUMETSAT satellite Metop-A), are used with diagonal observation error covariance matrices (R) within the Met Office 4D-Var assimilation scheme, assuming no correlation between channels. This is inadequate due to the presence of errors of representativeness, forward model error and errors associated with the pre-processing of the data. Previous work both at the Met Office (Stewart et al. 2009) and ECMWF (Bormann et al. 2010) has demonstrated that correlations exist in IASI data particularly for channels sensitive to water vapour. It is likely that a better description of the error correlations in 4D-Var will allow for improved use of the water vapour channels. This paper shows the results of performing a diagnostic technique described by Desroziers [2005] on AIRS and IASI data to estimate the true structure of the R matrices. Initial tests using the full matrices resulted in the 4D-Var minimisation becoming unstable leading to non-convergence and increased computational cost. To counter this, the raw matrices have been reconditioned. Results from trailing these matrices in the Met Office assimilation scheme are also shown.

2) Desroziers Diagnostic

To estimate the structure of the full R matrix I have used the diagnostic procedure introduced by Desroziers et al. (2005). This uses observation minus background (O-B) and observation minus analysis (O-A) statistics to produce observation error variances and covariances. The formula is:

\[ R = E\left((y - H(x)) (y - H(x))^T\right) \]

A key assumption which is used in the derivation of the above formula is that the R and B matrices used in the assimilation to produce the O-A and O-B stats are exactly correct. However, in this project we know that the R matrix is not correct initially. Therefore the results should not be entirely trusted. However it has been shown, in very simple examples, that iterating the Desroziers diagnostic after starting with incorrect errors can lead to convergence to the true errors which is encouraging.

3) IASI channels used

Window channels
- Temperature sounding channels
- Channels sensitive to water vapour

4) 4D-Var Results

Inflated operational standard deviations

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5) Conditioning

A similar procedure has been used to condition the matrices in the Met Office 4D-Var assimilation scheme results in a very small decrease in the number of iterations. Operationally at the Met Office a conjugate gradient based minimisation is now used where a fixed number of 60 iterations are performed. This minimisation fails when using the raw matrices, but using the reconditioned matrices results in a successful convergence of the minimisation. Figure 5 compares the standard deviations from the raw matrices and the reconditioned ones.

7) Conclusions

The Desroziers diagnostic is not perfect but gives a good general idea of what the correlation structure is. Therefore the raw diagnostic matrices need to be modified to make sure they are symmetric and positive definite, before being used in the assimilation. The inter-channel error correlations are largest in channels sensitive to water vapour and so, as predicted, the biggest positive impact of modelling the correlations should be in these channels. Using the full R matrices in the assimilation scheme results in a very small increase in processing time but does result in the minimisation needing many more iterations to converge. Because of this the raw matrices need to be reconditioned before use operationally. Results from trailing the use of these matrices show positive impact and an improvement in forecast accuracy. Therefore, correlated errors for IASI will be implemented operationally in November 2012.

8) Future Work

Once correlated observation errors have been implemented for IASI the aim is to implement them for the other high spectral resolution sounders, AIRS and CH4. Investigate the potential benefits of accounting for inter-channel error correlations for other instruments such as AMSU-A, MHS, SSMIS, ATMS and SEVIRI.

Further research into accounting for inter-channel error correlations in the 1D-Var pre-processor. A more accurate representation of the errors here should lead to better quality control and a more accurate retrieval of skin temperature, cloud parameters and emissivities.

Investigate the effect of accounting for correlated observation error on the optimal channel selection for high resolution sounders.

References


Bormann N, Bauer P. 2010. Estimates of spatial and interchannel observation-error characteristics for current sounder radiances for numerical weather prediction. I: Methods and application to AMSU-A, MHS, SSMIS, ATMS and SEVIRI.