A Randomisation Method to quantify the B-matrix for 1D-var.

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Why use 1D-var?

1D-var is a powerful tool. It can….

- Estimate quantities needed but not analysed in the data assimilation (e.g. surface emissivity)
- Identify which observations can be safely used in the data assimilation.
- Be used to simulate future instruments and assess their value, likely impact and assist in evaluation of specific new ideas (e.g. Sreerekha *et al*. 2008)

To deliver these benefits 1D-var should be as similar as possible to 4D-var.

In this poster we present a method for calculating a background error covariance matrix for use in 1D-var which is as consistent as possible with the vertical component of the 4D-var error covariances. The method uses randomisation of the 4D-var state variables.

$$J = J_o + J_b$$

$$J = J_o + \mathbf{v}^T \mathbf{B}^{-1} \mathbf{v}$$

The role of the B-matrix

1D-var (and 4D-var) minimises a cost function, J, which is the sum of a cost term J_o which penalises departure of the solution from the observations and a cost term J_b which penalises departures **v** of the solution from the background, taking into account the error covariance of the background **B** (see box to left, where superscript *T* denotes transpose and superscript -1 denotes inverse). The background error covariance matrix **B** is very important in determining how the analysis increment is spread in the vertical.

The Randomisation method

- Random Gaussian pertubations are assigned to **v** to which the variable transform operator, ***U***, is applied (see boxes to right). An operator ***H*** is applied to estimate **B** at the observation locations. Thus a covariance in the transformed variable is estimated appropriate to the observation type (Wlasak 2008).

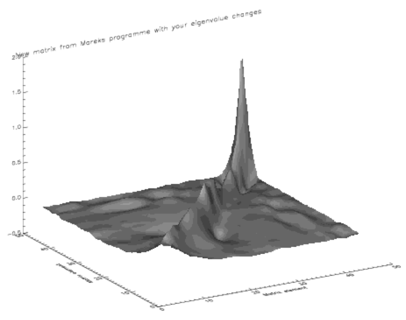
Advantages of Randomisation Method

- Allows an estimation of the vertical B covariance matrix consistent with 4D-var at the observation locations and in the required variables (e.g. temperature, pressure).
- Is extendable to different ob types (e.g. GPSRO).
- Can be used for other problems e.g. the influence of B across a 4DVAR time window.
- Numerically fast to compute – can update the 1D-var B-matrix every time the assumptions in 4D-var change.

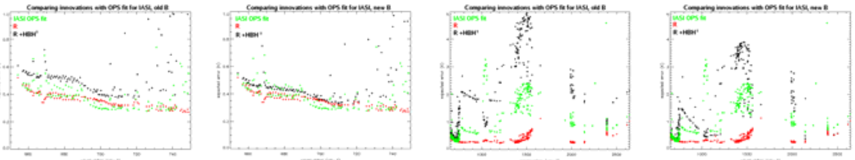
N = Gaussian, zero mean, unity variance
U = control variable transform
H = operator to observation locations.

$$\tilde{v} = \mathrm{N}(0,1) \qquad \tilde{x}_i = H_i U \tilde{v}$$

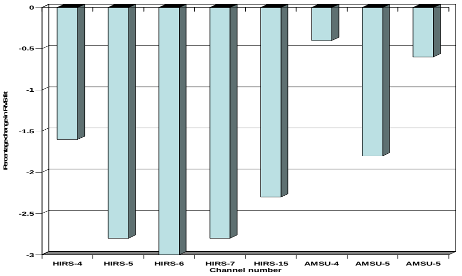
$$\begin{aligned} < \tilde{x}_i \tilde{x}_i^T > &= < H_i U \tilde{v} \tilde{v}^T U^T H_i^T > \\ &= H_i U < \tilde{v} \tilde{v}^T > U^T H_i^T \\ &= H_i B H_i^T \end{aligned}$$



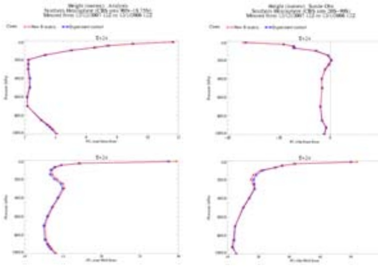
Temperature error covariance matrix on RTTOV 43 levels.



Above: Comparison of actual background departures and background error covariance matrix for IASI with old and new 1D-var B-matrix for longwave CO2 channels (left two plots) and H2O channels (right two plots). In each pair the right hand plot uses the old B-matrix and the left hand plot uses the new B-matrix.



Above: Improvement in fit of background to tropospheric infrared and microwave channels in 4D-var for MetOp (for which observation count was almost unchanged).



Above: One day forecast impact southern hemisphere mean (top) and RMS error (lower) for temperature against radiosondes (right) and analysis (left). Red = old 1D-var Bmatrix and blue = new 1D-var B-matrix.

Validation and impact

The background error expressed in terms of observation error fits IASI background departures much more closely.

A 2-5% reduction in RMS mis-fit to background for tropospheric sounding channels which use **B** in cloud screening (e.g. HIRS channels 4-7 and 15)

Forecast impact was slightly positive, but only 0.5% RMS reduction for mass and wind fields in the southern hemisphere and a slightly larger impact on humidity at short range.

Conclusions

This is a fast, efficient method for estimate a 1D-var B-matrix which is as consistent as possible with 4D-var.

It has been shown to give some small advantages for the assimilation of sounding data but will allow easy recalculation of the 1D-var B-matrix in future to ensure consistency with 4D-var.

References

Sreerekha TR,, A.M. Doherty, S.J. English, P.J. Rayer 2008b: Report on The Potential of a Microwave Sounder 229GHz Channel. EUMETSAT Contract EUM/CO/07/4600000409/CJA.

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