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Does the order of the horizontal and vertical transforms matter in the representation of an operational static covariance model in global atmospheric DA?

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A major difference in the formulation of the univariate part of static covariance models arises from the order in which the horizontal and vertical transforms are applied. This is because the atmosphere is non-separable with large horizontal scales generally tied to large vertical scales and small horizontal scales tied to small vertical scales. Also horizontal length scales increase dramatically as one enters the stratosphere. A study is presented which evaluates the strengths and weaknesses of each approach with the Unified Model. The two static covariance models can be viewed in terms of their implied background error covariances B_{s1} B_{s2} and their respective parameter, horizontal and vertical transforms:

$$B_{s1} = U_p U_h U_{hv} U_{hv}^T U_h^T U_p^T \tag{1}$$

$$B_{s2} = U_p U_v U_h U_h^T U_v^T U_p^T \tag{2}$$

where U_p is the parameter transform from control variables to model variables, U_h is a spectral horizontal transform from spectral space to grid point space, U_v is a vertical transform applied in grid-point space and U_{hv} is a vertical transform applied in spectral space.

The covariance model associated with B_{s1} captures the full global homogeneous and isotropic spectral characteristics of the training data but does not allow latitudinal variability in the variances; the latitudinal variability comes solely from the parameter transform. The horizontal length scales are conserved. Also it preserves the global variance of the training data on each model level for both control variables and model variables. This is because it conserves both horizontal and vertical derivative information to give the correct wind and temperature variances.

In contrast, the covariance model associated with B_{s2} can take account of latitudinal variability in the variance at the cost of not conserving the spectral characteristics of the training data. It does not preserve length scale information. If latitudinal variation is removed it will conserve the temperature variances.

Preliminary trial results with a variational DA system that uses purely a static background error covariance have shown a clear improvement in forecast verification with the covariance model associated with B_{s1} when compared to the operational static covariance model associated with B_{s2}.