

# High Resolution Dynamic Data Assimilation

**AIM:** Introduce partial flow dependence into the background error covariance matrix and test this in a convective scale toy model.

## 1. Introduction

- Data assimilation is the process of combining a short term forecast, of atmospheric data with observational information.
- The accuracy of the forecast is described by forecast error statistics which are contained in a forecast error covariance matrix,  $\mathbf{P}^f$ .
- In the Kalman filter,  $\mathbf{P}^f$ ,
  - is flow dependent; i.e. it evolves in time according to model dynamics and it is explicitly calculated and retained,
  - can be considered the 'true' forecast error covariance matrix.
- Variational methods, which are most common in operational Numerical Weather Prediction (NWP), use an approximation to  $\mathbf{P}^f$  that is an essentially static matrix. This is known as the background error covariance matrix,  $\mathbf{B}_0$ , or the "B-matrix".

## 2. Motivation

- Weather systems can have large background error statistics, with large error growth. In this case
  - a static  $\mathbf{B}_0$  matrix, as used in variational assimilation, would not adequately capture the evolving error statistics,
  - a flow dependent  $\mathbf{P}^f$  matrix as in Kalman filtering would much more adequately capture the evolving error statistics.

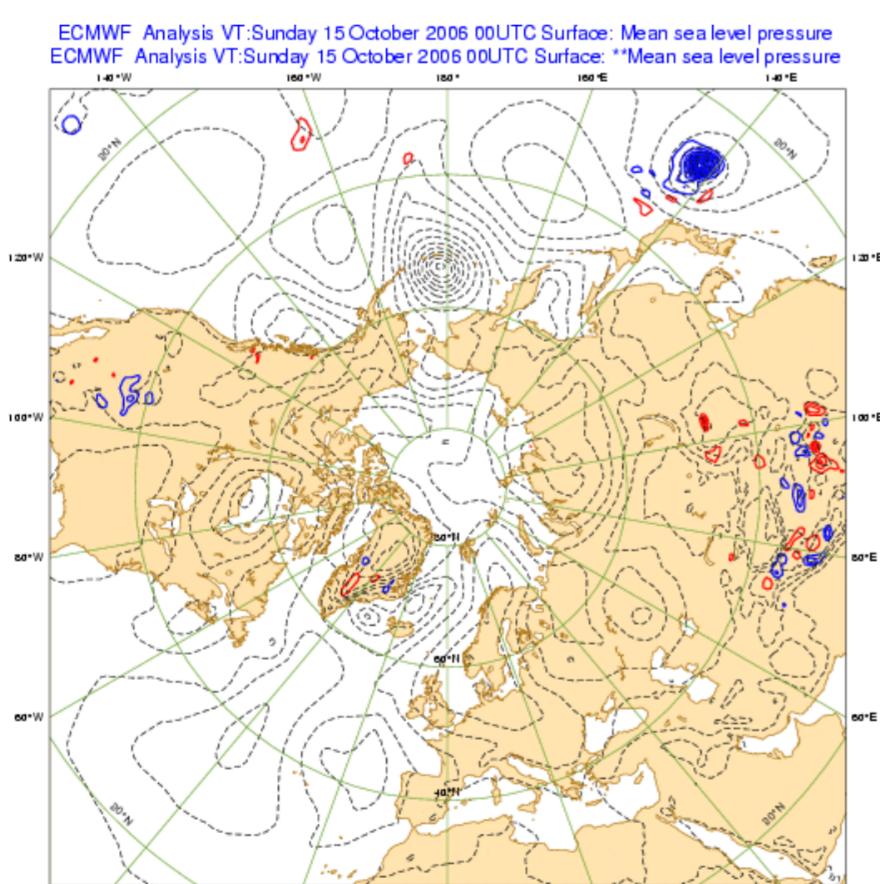


Figure 1: Analysis differences between a control and flow dependent assimilation run. Red/blue lines show positive/negative differences. Dotted lines show MSLP in 5 hPa contours. Figure taken from Isaksen et al (2007)

- There are large scale analysis differences in a cyclone south of Japan indicating that flow dependence of background errors will have most impact for systems with large error growth (Isaksen et al, 2007).
- Systems with large error growth often constitute hazardous weather. Better representation of their error statistics can lead to an improvement in the forecast scores.

## 3. Ensemble Reduced Rank Kalman Filter

- Based on the Simplified Kalman Filter (SKF) of Fisher, 2003.
- Replace static  $\mathbf{B}_0$  matrix:

$$\mathbf{B}_0 \longrightarrow \mathbf{B} = \begin{pmatrix} \mathbf{P}^f & \mathbf{F}^T \\ \mathbf{F} & \mathbf{B}_0 \end{pmatrix}$$

where

- $\mathbf{B}$  is partially flow dependent,
- $\mathbf{P}^f$  is the forecast error covariance and uses
  - the model dynamics to evolve an ensemble,
  - the ensemble to span a subspace of  $\mathbf{B}_0$ ,
- $\mathbf{F}$  is a matrix of cross covariances.
- This is a hybrid method as it uses Kalman filtering like techniques within a variational setting.

## 4. Toy Model

- In order to test the ensemble reduced rank Kalman filter a 2D, dry, toy model is under development. It will exhibit large scale balance but will allow instabilities on the small scale. The model equations are:

$$\frac{\partial u}{\partial t} + \mathbf{B}\mathbf{u} \cdot \nabla u + C_z \frac{\partial \rho'}{\partial x} - fv = 0 \quad \text{u-momentum equation}$$

$$\frac{\partial v}{\partial t} + \mathbf{B}\mathbf{u} \cdot \nabla v + fu = 0 \quad \text{v-momentum equation}$$

$$\frac{\partial w}{\partial t} + \mathbf{B}\mathbf{u} \cdot \nabla w - Ab' + C_z \frac{\partial \rho'}{\partial z} = 0 \quad \text{w-momentum equation}$$

$$\frac{\partial \rho'}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0 \quad \text{continuity equation}$$

$$A \frac{\partial b'}{\partial t} + \mathbf{A}\mathbf{B}\mathbf{u} \cdot \nabla b' + N^2 w = 0 \quad \text{thermodynamic equation}$$

- This model contains three kinds of modes: geostrophic, gravity and acoustic.
- The acoustic mode is appropriate to include on the convective scale and will simulate convection and fast error growth.

### References

- Isaksen, L., Fisher, M., Berner, J., 2007, *Use of analysis ensembles in estimating flow-dependent background error variances*, ECMWF Workshop on Flow Dependent Aspects of Data Assimilation
- Fisher, M., 1998, *Development of a Simplified Kalman Filter*, ECMWF Technical Memorandum

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