Klausur: Advanced Atmospheric Dynamics

26.07.2012

1. You are given two measurements of humidity, $q_1 = 6.5$ g kg^{-1} and $q_2 = 7.3$ g kg^{-1}. The observation error variance for each measurement is $\sigma_1^2 = \sigma_2^2 = 1.0$ (g kg^{-1})^2. A background forecast obtained from an earlier measurement has a value of $q_b = 5.0$ g kg^{-1}, with an error variance of $\sigma_b^2 = 2.0$ (g kg^{-1})^2.

a) [10 Points] State the definition of the observation error covariance matrix. Write the observation error covariance matrix for the humidity measurements above, assuming that the errors are uncorrelated.

b) [10 Points] Write the 3DVAR cost function for this problem, and compute the analysis humidity that minimises it.

c) [15 Points] Now assume that the error covariance between the two observations is $\sigma_{12}^2 = 0.5$ (g kg^{-1})^2. Write the new observation error covariance matrix and find the new analysis temperature. Discuss the difference between this result and the result obtained in (b).

2. a) [15 Points] The AMSU-A satellite instrument provides information on atmospheric temperatures from emission in several microwave bands. Discuss the advantages and disadvantages of AMSU-A for temperature observations in comparison to radiosonde measurements.

b) [15 Points] In practice, the majority of satellite data are discarded and only a small fraction of the measurements are used. Give three reasons why this is done.

3. a) [10 Points] the background error covariance matrix in the Ensemble Kalman filter is written:

$$\mathbf{P}_k^b = \frac{1}{N-1}\mathbf{X}_k^b \left(\mathbf{X}_k^b\right)^T$$

Define the symbols that appear in this equation.

b) [15 Points] The shading in Figure 1(a) shows the background error correlations associated with a single observation of surface pressure near Japan, calculated using an EnKF with 200 members (Contours show the ensemble mean background sea level pressure). Explain the location, size, and shape of the correlation pattern.

c) [10 Points] Figure 1(b) is the same as 1(a), except that the calculation was made using a 25 member ensemble. Explain why the correlation pattern is different in this calculation.