A suboptimal Kalman filter algorithm with the simplified models for calculation of the forecast error covariances

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The most fundamental difficulties of the implementation of the Kalman filter theory to the meteorological data assimilation are that it is too computationally expensive and requires too much information. One of the ways to solve this problem is to apply the simplified models in a Kalman filter for calculation of the forecast error covariances.

We shall proceed from the concept of decomposition of the dynamic operator of prognostic model. Let us present a system of prognostic equations as

$$\frac{d\phi}{dt} = A_1\phi + A_2\phi,$$

where ϕ - vector of forecast fields. The operator A_1 describes an advection of mass and temperature along trajectories of motion, operator A_2 - process of adaptation of a wind and geopotential fields. Let us consider initial model on a small time interval (t_k, t_{k+1}) and use the velocity components in the advection operator A_1 at time t_k. Then the model will be linear on this time interval. So, we consider the following models for calculation of matrices of the forecast errors covariances.

Suppose, that the true atmospheric flow is described by the baroclinic adiabatic model of atmosphere for region based on the primitive equations (we shall name it model-0).

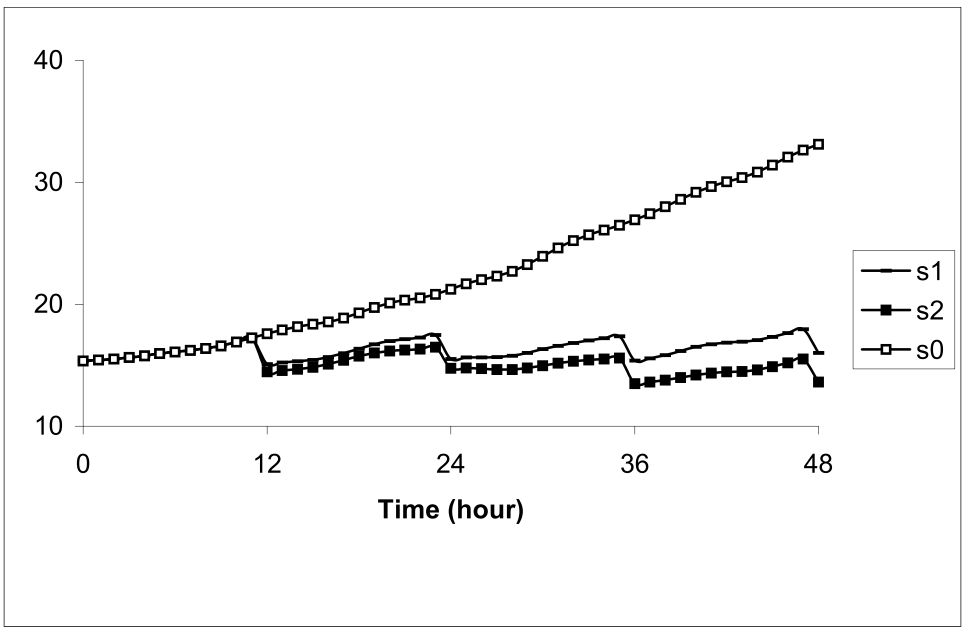
Model-1 is proposed in [1] and is obtained under following assumptions:

- an estimation of the atmospheric fields using the Kalman filter is carried out for the vertical normal modes of the forecast model;
- the calculation of the forecast error covariances is based on the assumption that the errors of vertical normal modes do not correlate; moreover, the forecast error covariances are calculated only for the geopotential field and the wind forecast error covariances are derived from them under the geostrophic assumption;
- the forecast model of our system is based on the method of splitting into the physical processes and we use only the advection step for the calculation of the forecast error covariances;
- the background fields of velocity components in the advection operator do not depend on vertical coordinate p (i.e., the background flow is close to barotropic).

Thus the model is described by the equation of advection for the coefficient of the height field h_n of n-th vertical normal mode.

In [4] is shown, that such simplified model is justified, in particular, in a case, when the forecast error covariances are homogeneous and isotropic**.** An analytical equation for a local covariance of forecast errors between two specified points is obtained in [4]. From this equation follows, that dynamics of covariances of errors of the forecast, in case they are homogeneous and isotropic, on a small time interval is described by model of advection of substation on trajectories of particles.

However, the atmospheric motion of large scales is not homogeneous and isotropic. At the same time it is known, that the large-scale atmospheric flows are well described with the help of quasigeostrophic approximation. Thus, we shall consider the following «hybrid» model: for the calculation of the forecast error covariances of first, large-scale vertical normal modes, the linearized quasigeostrophic equation is used and for others we use the model-1. With the described above simplified model the identical twins data assimilation experiments were carried out. The matrix of model errors was considered zero. In figure the time evolution of rms forecast error for the height of 500 mb is presented. In this figure s1 is the error of data assimilation based on the suboptimal Kalman filter algorithm with "hybrid" simplified model, s2 – the forecast error of traditional data assimilation algorithm with the use of optimal interpolation for the data analyses, s0 is the error of forecast without data assimilation. The main results are published in [1-5].



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