Estimation of structure functions for the analysis of two-meter temperature and relative humidity

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ABSTRACT
Time series of innovations at a number of European land surface stations in one year long period have been used to estimate first guess errors autocorrelations and observation and first guess error variances for two-meter temperature and relative humidity. Statistics have been obtained separately for each month and time of the day. Parallel runs have been carried out to test the impact of these new error statistics in the subsequent forecasts.

1. Procedure

The one year long assimilation experiment described in the Hirlam Technical Report No. 59 has been used to study the two meter temperature and relative humidity error statistics.

Time series of innovations (observations minus first guess values) have been used to estimate first guess errors autocorrelations and to separate the total observation minus first guess variances into forecast error and observation error contributions.

The fairly good spatial and time density of surface stations over Europe allows us to examine in particular the background error variances at the smallest scales. Data from around 800 stations in Europe (latitudes between 42.0N and 57.5N, longitudes between 2.5E and 28E) have been used. In order to study the diurnal and monthly variation of first guess errors, different datasets have been created corresponding to each month and time of the day (00, 06, 12 and 18UTC).

Anisotropies induced by the orography can be examined in this dataset provided it includes important European mountain ranges, as the Alps and Carpathians.

The procedure has consisted of the following steps for each station:

i. Calculation of mean squared observation minus first guess values.
ii. Calculation of observation minus first guess bias.
iii. Computation of observation minus first guess variance by removing the bias obtained in ii) from i) .
iv. Computation of error covariances with each of the rest of stations in the same Area (the bias of departures of each station is removed previously).
v. Computation of autocorrelations normalising covariances with the error standard deviations of each of two stations obtained in iii)

1.1 Autocorrelations

The current model used to represent autocorrelations is a homogeneous anisotropic analytical function (Rodriguez et al., 2003). It is defined as the product of two Gaussian functions representing the dependence on the horizontal (r) and vertical (Δz) distances respectively.

$$\rho(r,\Delta z) = \rho_h(r)\rho_v(\Delta z)$$
$$\rho(r,\Delta z) = e^{-0.5r^2/L_h^2} e^{-0.5\Delta z^2/L_z^2}$$

The second factor tries to model the observed anisotropy introduced by the orography observed in a previous study of near surface parameters error statistics obtained for the former Hirlam land surface parameterisation (Navascués, 1997).

In this work we have assumed that the same type of separability in the horizontal and the vertical distances is valid. So, in absence of complex topography, error correlations are supposed to be homogeneous and isotropic, depending only on the horizontal distance.

The existence of anisotropy linked to orographically induced error structures is further searched through examination of correlations as function of horizontal distance observed in different datasets corresponding to different vertical distance intervals.

1.1.1 Horizontal part of autocorrelations

In order to find an analytical function fitting the empirical autocorrelations, the full correlations dataset has been reduced to an array of horizontal distance interval-averaged values. The interval over which correlations are averaged is 30km. Interval averaged correlations are not produced for intervals containing less than thirty station pairs. Only empirical autocorrelations from stations whith altitude less than 300m have been used to calculate the interval-average. By doing it, anisotropies induced by orography seems to be filtered in some way.

The first function that has been fitted to data to represent the isotropic part of autocorrelations is the negative squared exponential model used currently in the surface analysis code. However, it has been seen that the empirical data agree very poorly with this analytical function, due to the long tails observed in the data. Following Mitchell at al.(1990) and Brasnett(1999) a second model consisting in the sum of two Third Order Autoregressive (TOAR) functions has been tried and found to produce a fairly good fit to the data. Third Order Autoregressive functions are expressed as:

$$\rho(cr) = (1 + cr + \frac{c^2r^2}{3})e^{-cr}$$

TOAR functions drop asymptotically to zero, and the large scale horizontal component may be represented by a second broader TOAR function. The final horizontal correlation representation, ρ_h, then becomes:

$$\rho_h(r) = a(1 + cr + \frac{c^2r^2}{3})e^{-cr} + (1-a)(1 + \frac{cr}{3} + \frac{c^2r^2}{27})e^{-cr/3}$$

A specific NAG routine for non linear problems, called E04GYF, has been used to fit the interval averaged background departures correlations to the analytical function expressed as a combination of two different scale TOAR functions. E04GYF routine is a quasi-Newton algorithm for finding an unconstrained minimum of a sum of squares of m nonlinear functions or residuals in n variables, that are the parameters defining the autocorrelation model. These three parameters to determine by the fitting procedure are the scaling constant b (the zero intercept), the component amplitude a, and the scale parameter c.

1.1.2 Dependence with vertical distance of autocorrelations

In order to examine the anisotropic structure of autocorrelations linked to orographic features the whole empirical observation minus autocorrelations dataset was splitted in eight different classes according to the difference in altitude (Δz) for station pairs.

The same intervals in horizontal distance described before were used to create interval-averaged autocorrelation values for each of these new eight vertical distance classes. Dividing the interval-average correlation value by the corresponding to the same horizontal distance in classe 1 produces new data of correlations as a function of the vertical distance. Plotting each new data as a function of horizontal distance allows to test the validity of the separability assumption of correlations in horizontal and vertical parts, and to explore the variation of the vertical dependence with season and time of the day

1.2 Background and Observation error variances

The observation minus first guess variances obtained for all stations with altitude lower than 300m, have been averaged to produce a single value representative of each dataset corresponding to every month and time of the day. This average observation minus first guess variance has been then splitted between observations and background error components by using the zero intercept of the fitted autocorrelation function (Daley, 1991). So, values of background and observation errors have been found for two-meter temperature and relative humidity for all months and times of day.

2. Results

The obtained values for observation error standard deviation are almost constant for all months and times of day. They are .9K for temperature and 6% for relative humidity. In the surface analysis observation error standard deviations are constant and set to 1K and 10%. This study confirms that the value for relative humidity is too large, as it was already suggested in the Hirlam Technical Report No. 59 (Navascués et al.,2003).

Background error standard deviation and background error autocorrelation length scales show monthly and diurnal variations. The largest sigma values and length scales are observed at 12UTC in early spring and in the autumn. The characteristic length scale for two-meter temperature was preliminary set to a constant value (L_c=100km) in the surface analysis code. It seems that this value is too short in the autumn and early spring at 12UTC, when observation to background error ratio is also smaller in both variables, as it it shown in figure 1 for two-meter temperature. However, at other times of the day this ratio is closer to one, leading to smaller analysis increments in both variables.

It has been observed that the separability assumption of correlations in isotropic horizontal distance and vertical displacement factors, respectively, is generally adequate, as all horizontal interval average values within the same vertical class have very similar vertical correlations. By looking at the vertical correlation for a fixed horizontal interval it has been observed that correlation decreases with altitude difference between stations. However, background errors appear much more correlated in the vertical in spring-summer than in winter, specially at night.

3. Impact

The impact of these new error statistics has been tested through one month long parallel assimilation experiments in the summer 1995 and the winter 1996. Both CONTROL and REF experiments have been performed with the Hirlam version 6.2.0., over the DMR (old Delayed Mode Run) area, at 44km resolution, and H+48 maximum forecast range at 00, 06, 12 and 18UTC. New error variances for observations and background, as the TOAR autocorrelation functions have been introduced in the code in REF experiment by slightly modifying some of the surface parameter routines. Also, monthly and diurnal variations have been allowed in background error standard deviation and parameters defining the autocorrelation function.

The verification scores of two-meter temperature and relative humidity show a neutral impact on model forecasts due to the usage of new error statistics in the surface analysis. However, a careful inspection of the analysis performance indicates a better behaviour of the new error statistics. Histograms of innovations show that the first guess is closer to observations in REF experiment, although residuals are larger, mainly at 00UTC. This is a consequence of the increased observation to background errors ratio obtained. It is also observed that soil water content in the summer experiment presents a more realistic, smoother time evolution due to the improvement on the screen level variables analysis.

4. Summary

Observation minus first guess values of two-meter temperature and relative humidity in one year long period have been used to study the error statistics of these variables. Observation and background error variances and analysis structure functions for two-meter temperature and relative humidity have been modelled with a monthly and diurnal variation. These new modelled error statistics have been tested in parallel experiments over July 1995 and January 1996 respectively. Although the verification scores show a neutral impact of these new error statistics the diagnostics of the analysis performance indicate an improvement in the analysis of two meter temperature and relative humidity that it is translated to a more realistic soil water content evolution.

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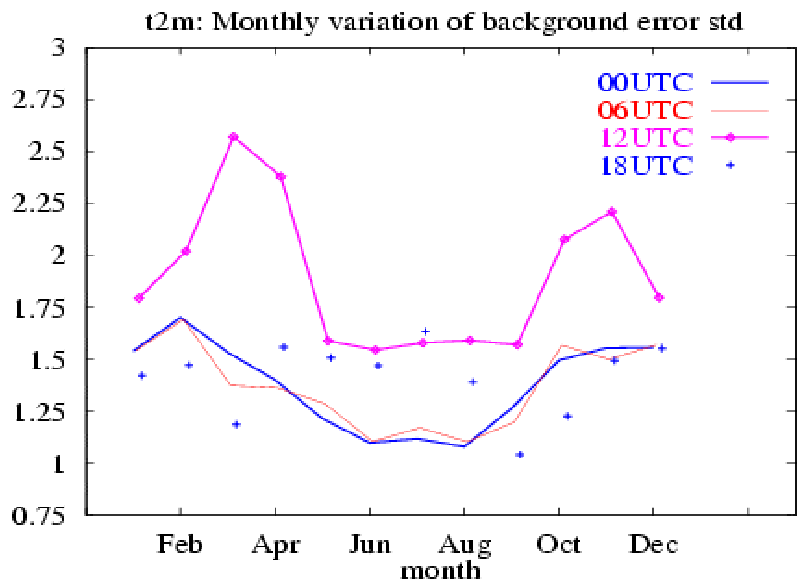

Figure 1: Monthly evolution of background error standard deviation for two-meter temperature(K) for the different times of the day