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ANALYSIS OF 2 meter TEMPERATURE AND RELATIVE HUMIDITY

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ABSTRACT

This note documents the recent installation of the analysis of the near surface parameters into the HIRLAM system. It is intended to explain why this analysis is primarely needed for the new surface parameterization that is being developed, although a version able to run within the old surface parameterization context has been prepared also. A procedure for the vertical reduction of the first guess fields to the station height has been introduced, and is specially useful in complex terrain. Since the method of analysis is Optimum Interpolation, a re-evaluation of the statistics of the first guess errors was necessary. First guess error covariances have been obtained for a selection of stations in Spain and in Scandinavia for winter and summer, in order to study the possible dependence on season and latitude. The effect of the orography as source of anisotropy, both because to the coastline and the inland topography, is included in the formulation of a new structure function.

CONTENTS

1 Introduction

Within the HIRLAM 3 project, a new surface parameterization is being developed (Bringfelt, 1995). In this new scheme five subgrid types of surface exist in each grid square: water, ice, forest, agriculture land, and bare ground (fig 1). The treatment of the 3 types defined over land is basically the ISBA model (Interaction Soil-Biosphere-Atmosphere) proposed by Noilhan and Planton (1989). The soil is represented by two layers: a thin reservoir at the top, and the root layer. Rainfall interception and transpiration by the plants are taken into account as sources of evapotranspiration in the equation for the water budget.

Because the soil variables (temperature and water content) evolve without any forcing imposed by climatological values from the deepest layer, and because the root layer wetness is a slow model variable, a data assimilation procedure for such variables is needed to avoid a possible drift. In this way, the model deficiencies are corrected using information based on near surface observations, keeping a realistic description of the soil hydrology, without the risk that a drift similar to that experienced by the ECMWF model in the 1994 spring could happen (Viterbo, 1996).

The method of initialization chosen is that proposed by Mahfouf(1991), and implemented practically into a mesoscale model by Bouttier et al.(1993). During the dry season of the mid latitudes, the values of the near surface temperature and relative humidity reflect the partitioning between sensible and latent heat fluxes, that in zones with vegetation is controlled by the water availability at the root zone. So, making use of the routinely measured 2m temperature and relative humidity observations, it is posible to cure the lack of measurements of soil water content at different depths.

In the method developed by Mahfouf, the analysis increments of the near surface variables are used to correct the values of the soil variables forecasted by the model, at each grid point. Soil variables increments could be produced at observation points and spread out to grid points, but instead T2m and RH2m increments at observation points are extended spatially to grid points positions because it is possible to compute an structure function for these variables. The analysis of 2m temperature and relative humidity is thus the necessary first step. Although in the new surface scheme 2m temperatures are defined for up to five surface types in each grid square, only an average over the 3 land types is analysed, and similarly for relative humidity.

In November 1995, a HIRLAM Workshop on Soil Processes and Soil/Surface Data Assimilation took place at the INM, Madrid (Spain). A more detailed description of the new parameterization itself, and the adaptation of the Mahfouf-Bouttier data assimilation procedure, as well as some preliminary tests with the HIRLAM system, can be found in the Workshop Proceedings presentations by Ayuso, Bringfelt, Navascues and Rodriguez et al.

The ultimate benefits of the analysis of screen level variables will be achieved once it is used to update the soil variables in the ISBA model. Nevertheless, the screen level analysis described here has a value on its own, e.g. for verification purposes.

The starting point has been the surface field analysis developed at the SMHI. The method of analysis used in the case of T2m and RH2m is Optimum Interpolation. The choice of relative humidity as humidity variable is due to its larger characteristic spatial scale with respect to other variables as dewpoint or specific humidity. It makes the relative humidity to have better behaved structure function.

In section 2 the main characteristics of the analysis, and some modifications introduced needed to improve the performance of the analysis are described. In section 3, the results of a reevaluation of the first guess error statistics are discussed, and as a consequence a new structure function is formulated. As last, the technical aspects of the implementation into the HIRLAM reference system are commented in section 4.

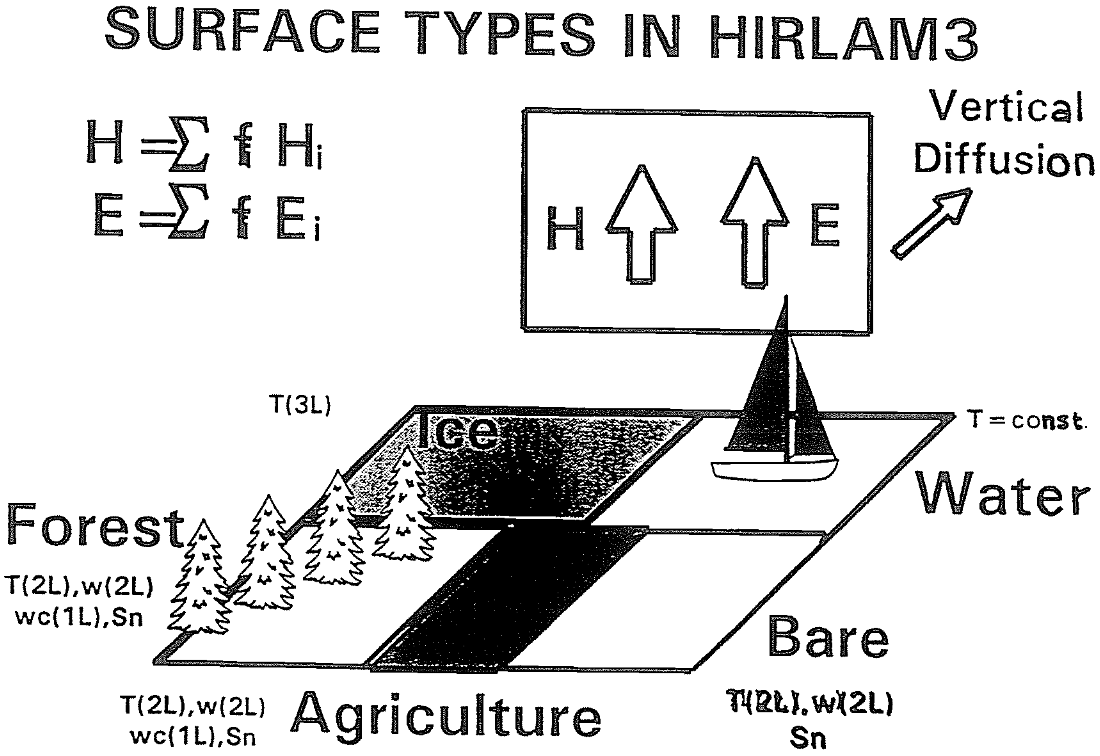

FIGURE 1

2 Characteristics of the analysis

As it has been mentioned, for the analysis of T2m and RH2m, Optimum Interpolation method is used. The scheme takes into account the anisotropy induced by the land sea contrast in the formulation of its first guess error autocorrelation function (Gustafsson, 1985). For this, observations and grid points are classified according to their vicinity to the coast, and a factor decreases the correlationship between two points when they belong to different classes:

$$\mu(r_i, r_j) = \alpha(class_i, class_j)\beta(r_{ij})$$

where $\beta(r_{ij})$ is an isotropic function depending on the horizontal distance between the two points i and j. Possible classes are inland(1), near coast(2 and 3), coast(4) and sea(5), and $\alpha(class_i, class_j)$ is a 5x5 matrix form function.

In order to classify the stations, the land sea mask at the corresponding resolution is read from the model state file. The fraction of land is then interpolated to each station position and the classes are formed according to this value in the folllowing way: If the interpolated fraction of land is higher than 80% the station is considered as an inland station (class number 1). Otherwise, if it is higher than 50% it is a near coast station(class number 2). If it is higher than 20% is a near coast station (class number 3). If it is higher than 5% the station is considered as a coastal station (class number 4). The stations which the interpolated fraction of land is smaller or equal to a 5% are considered as sea stations (class number 5).

OBS. CLASSES: 1=inland 2=near coast 3-4= coast 5=sea

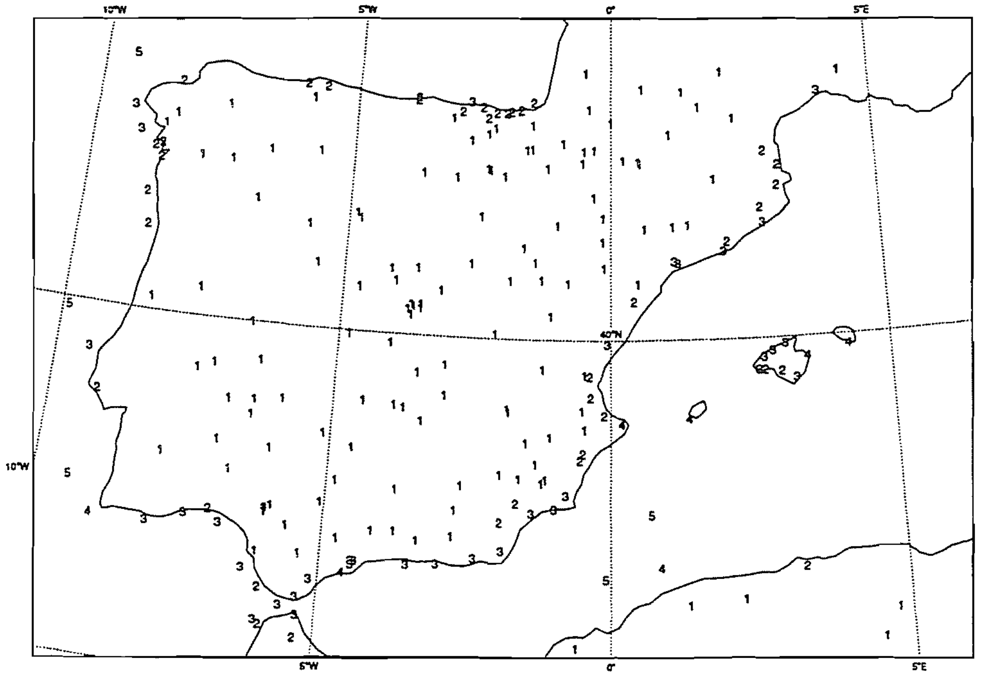

FIGURE 2

Figure 2 shows how the observations over Spain and surrounding areas are classified into the five classes defined. The first guess is the six hours forecast from the preceeding assimilation cycle, and the observations employed are those included in the SYNOP reports.

Other additional features present in the code are the analysis organization in boxes for the data selection and the possibility to form superobservations (Lorenc 1981).

2.1 Recent modifications

With the implementation of the original code into the HIRLAM system and the subsequent tests, the introduction of the following modifications to the original code became necessary.

Because of the purpose of the analysis, only land observations are used, those from ships and buoys are being rejected.

In order to make a better use of the available observations, a vertical reduction of the first guess to the station height has been introduced. This is specially important in complex terrain. The need appeared when the analysis was first run over Spain, where the real orography is quite different from its representation by the model, as can be observed in figures 3 and 4 when we move from the model orography at 0.5 to 0.2 degrees resolution. At 0.5 degree resolution most of the station heights differ from the model orography by an absolute amount ranging from tens of meters to more than 1000 m, as seen on fig.5. For larger values of the mismatch, the direct use of model first guess fields interpolated to the observation position, followed by hydrostatic correction, would lead to erroneous values. Instead, a new procedure for the reduction of the first guess fields to the station height at the four nearest grid points to each observation site has been developed. This is done in three steps: first, the whole vertical profile (u, v, T, q and ps) at the model surface is vertically interpolated to the station height, in the same way that the boundary conditions are interpolated in the HIRLAM model (detailed information in HIRLAM 1 Documentation Manual and Majewski(1985)). In a second step, the new surface temperature is evaluated preserving surface layer lapse rate, i.e., keeping the potential temperature increment between the lowest model level and the earth surface constant. When moving from the surface layer of the original model data (1) to that of the vertically interpolated data (2) we will have:

$$\theta_s^2 = \theta_{NLEV}^2 - (\theta_{NLEV}^1 - \theta_s^1)$$

$$T_s^2 = \theta_s^2 (\frac{P_s^2}{P_0})^{\frac{R}{C_P}}$$

In the last step the screen level temperature and relative humidity are rediagnosed in the new surface layer, making use of the formulae proposed by Geleyn (1987) and based on the Monin Obukhov similarity theory:

$$q(z) = q_s + zred(q_{NLEV} - q_s)$$

$$s(z) = s_s + zred(s_{NLEV} - s_s)$$

where, q(z) and s(z) are the specific humidity and the dry static energy at the height z above the ground in the surface layer, and subscripts s and NLEV at the surface, and at the lowest model level respectively. Temperature at the measurement height is obtained from s(z) and q(z). The factor zred is :

$$zred = \frac{1}{b_h}[(ln(1 + \frac{z}{z_{NLEV}}(e^{b_n} - 1)) - f(z)]$$

where $f(z)$ is depending on the stability and on the surface exchange coefficients, C_n and C_h, through b_n and b_h :

$$b_n = \frac{\kappa}{\sqrt{C_n}}$$

$$b_h = \frac{\kappa\sqrt{C_d}}{C_h}$$

where κ is the Von Karman constant,

$$f(z) = \frac{z}{z_{NLEV}}(b_n - b_h)$$

for stable case, and

$$f(z) = ln(1 + \frac{z}{z_{NLEV}}(e^{b_n - b_h} - 1))$$

for the unstable case.

The algorithm used to diagnose the screen level temperature and relative humidity is different from that currently employed in the physics routine ANEMLV , but identical to the one used by the upper air analysis (routine GPCALC2) when the near surface variables are not present in the first guess field. So, in order to have coherence along the surface analysis, the T2m and RH2m first guess at the grid points over land are re-diagnosed using the Geleyn algorithm. This is needed when the surface analysis is run together with HIRLAM 2 reference system based on the old surface parameterization, but is no longer necessary when it is run with the new surface parameterization, in which the diagnosis of the near surface parameters is based on the Geleyn formulae.

The first step of the whole procedure is performed in practice with a call to the ETAETA routine used for the vertical interpolation of lateral boundary conditions. For the last steps a new routine has been written. The advantage of the procedure is that the final vertical gradient applied depends on stability structure and because of this, it varies from one grid point to the other, although in many cases it is very close to 0.6 deg per 100 meters.

FIGURE 3:
MODEL OROGRAPHY AT 0.5 DEG.RESOLUTION

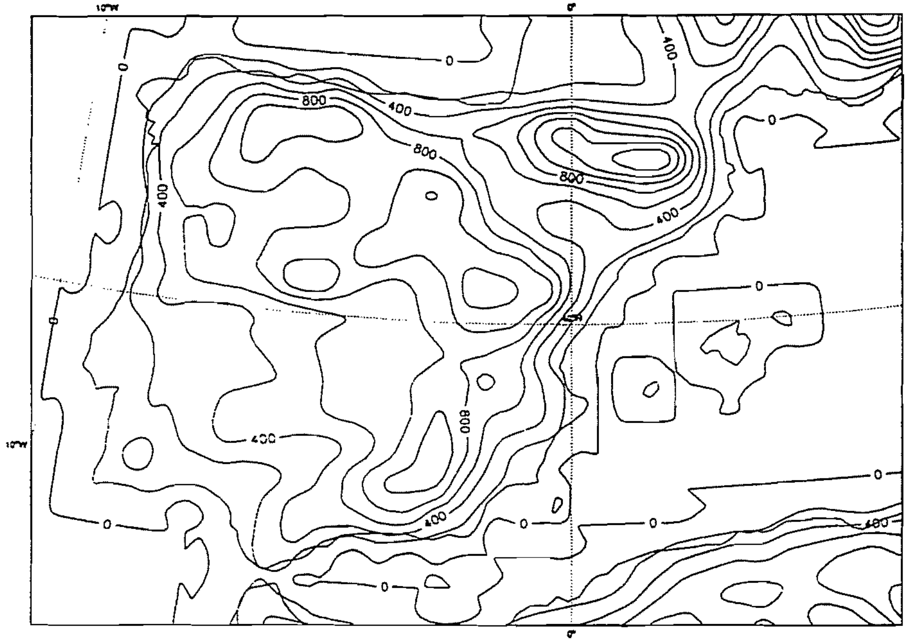

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FIGURE 4:
MODEL OROGRAPHY AT 0.2 DEG.RESOLUTION

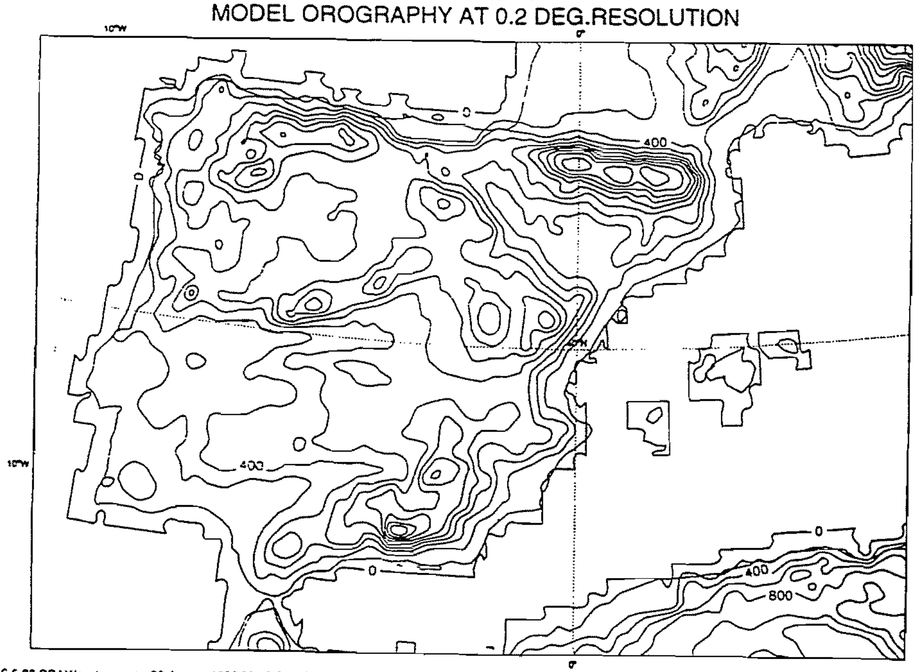

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FIG.5: real MINUS its representation in the 0.5 x 0.5 deg. model STATIONS HEIGHT (units: meters)

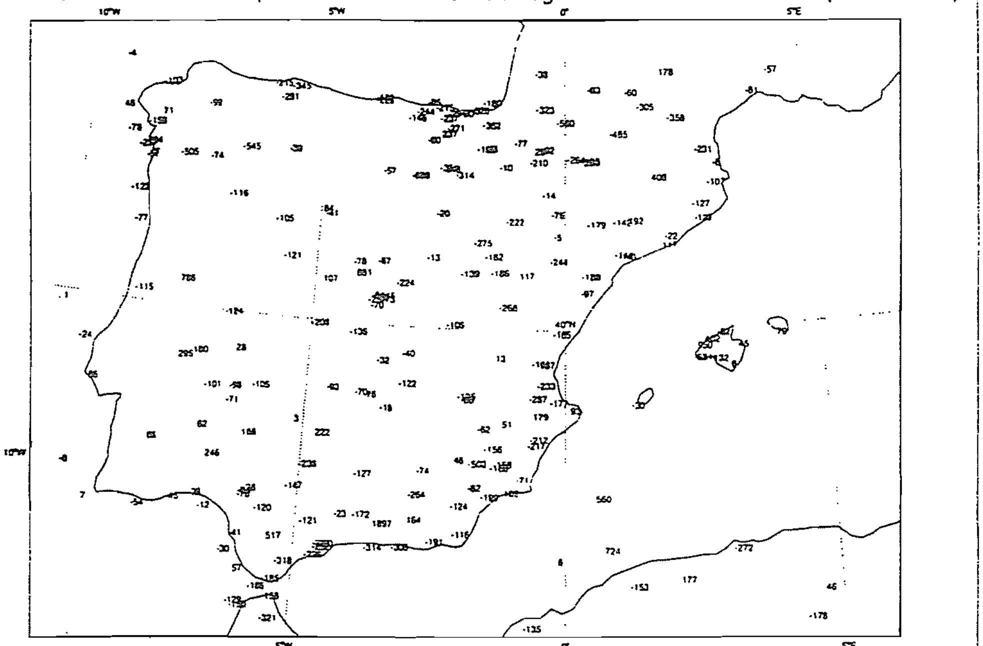

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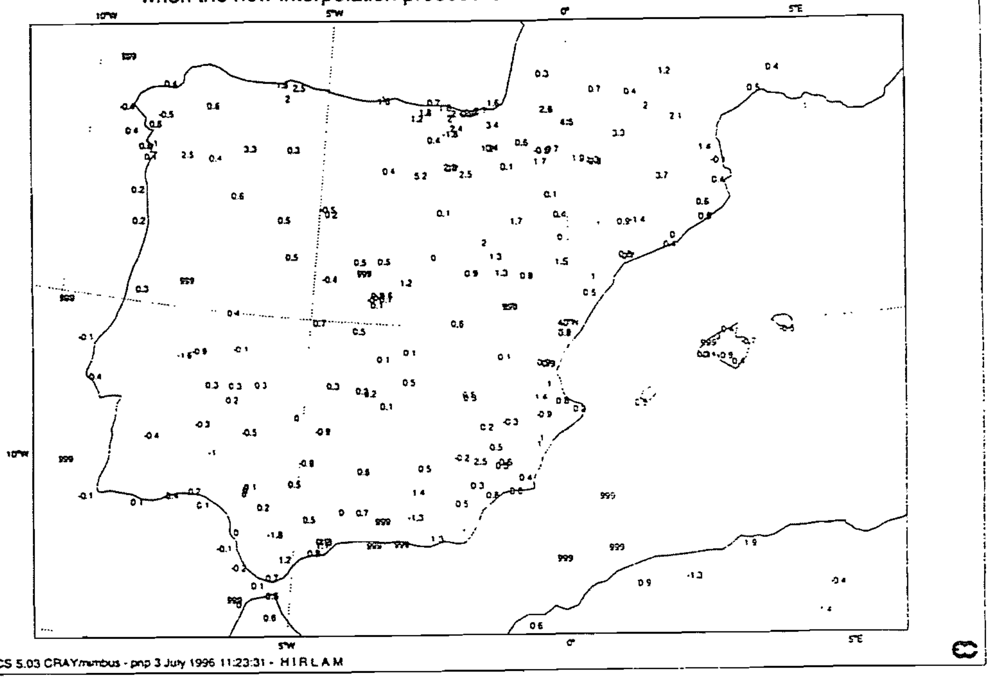
FIG.6: Difference between the obs. increments obtained when the new interpolation procedure is introduced



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At last, the horizontal interpolation from the vertically reduced first guess values to the observation point has been revised: the horizontal distance but also the vicinity to the coast of grid point and the observations are taken into account. This is put in practice decreasing the weight dependent on the distance assigned to each nearest gridpoint when the observation and the grid point belong to different classes (see section2). This weight is set to zero if the mismatch between the station height and the model orography exceeds 500m. Significant differences in the observation increments appear when the modifications refering to the interpolation of first guess fields to the observation position are introduced (figure 6). The magnitude varies between some tenths of a degree to more than one degree, the vertical reduction being the main responsible factor. On the other hand, the selective horizontal interpolation can exclude some stations from the analysis if they are located in terrain features that are misrepresented by the model orography field., (999 in figure).

3 Reevaluation of first guess errors statistics

In the O.I. method, the observation increments evaluated at the observation points are spread out to the analysis grid points using the spatial structure of the background error covariance, or its derived correlation function.

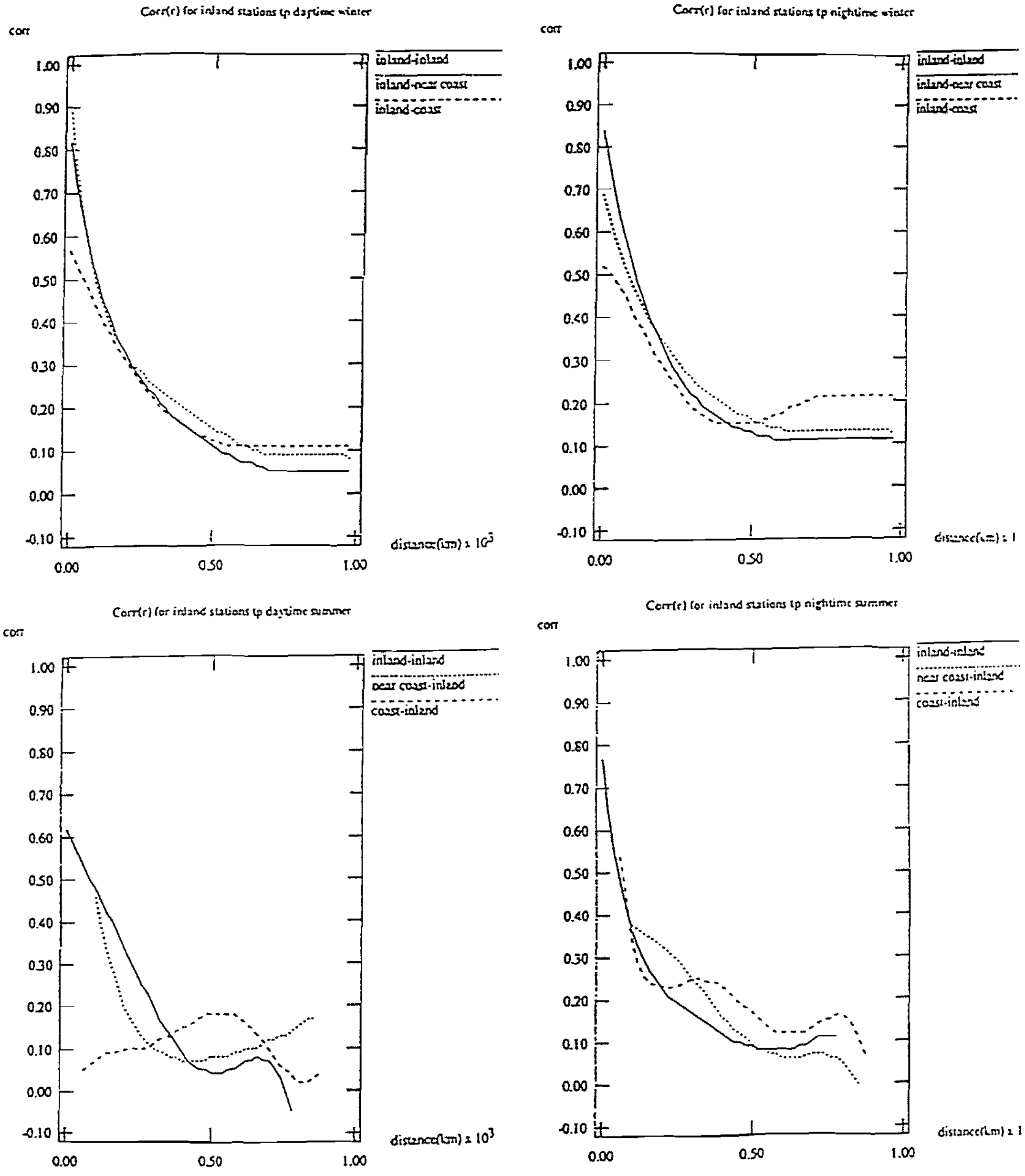
In this process the ratio between the first guess errors and the observation errors determines in some sense the assumed amplitude of the analysis increments.

3.1 Correlations

Because we could not safely use the new parameterization without the corresponding soil variable assimilation, it was decided to use the first guess error statistics of the old surface parameterization, in which the soil variables are forced by the climatology, to model in a first approach the analysis correlation function. T2m and RH2m first guess error covariances between stations from the Iberian peninsula and from Scandinavia have been obtained for one month of winter(January) and one month of summer(July) of 1995. Derived correlations have been computed both during daytime and nightime, and the dependence on the horizontal distance as well as the anisotropy due to the orography (both with regard to the proximity to the coast and with regard to the induced effects of the mountains) have been analysed.

- Land-Sea anisotropy: In order to study the anisotropy due to the proximity to the coast, three families of station pairs: inland-inland, inland-nearcoast and inland-coast have been generated. Both the horizontal length scale and the magnitude of the anisotropy show dependence on:
    - Season: Figure 7 shows the dependence on the horizontal distance of three classes of Spanish station pair T2m correlation data for winter(upper graphs) and

summer (lower graphs) during daytime (left) and nightime (right). It can be observed that the correlation decreases sharply for short distances (in both seasons the e-folding distance is around 250 km), but the decrease with larger distances is slower in winter. In this season T2m and RH2m values are mainly imposed by the synoptic regimes, whereas in summertime the local conditions (determined basically by the soil wetness availability in the case of inland stations and by the land sea circulations for the coastal stations) determine the behaviour of these near surface parameters. The strongest decoupling between inland and coastal stations occurs during daytime of the dry season because of the two different mechanisms mentioned above that influence T2m and RH2m.



Corr(r) for inland stations tp daytime winter

Corr(r) for inland stations tp nightime winter

Corr(r) for inland stations tp daytime summer

Corr(r) for inland stations tp nightime summer

FIGURE 7: T2m first guess error correlation for inland-inland, inland-near coast and inland-coast Iberian Peninsula station pairs in winter(upper graphs) and summer(lower graphs).

- Latitude: Looking at the following figure (fig.8) , where the results for the Scandinavian stations for summer time appear on top of those obtained for the Spanish dataset, it is possible to appreciate the dependence on the latitude. The horizontal length scale is larger and the observed anisotropy smaller for Scandinavia than for Spain. Smaller differences depending on latitude are found in winter.

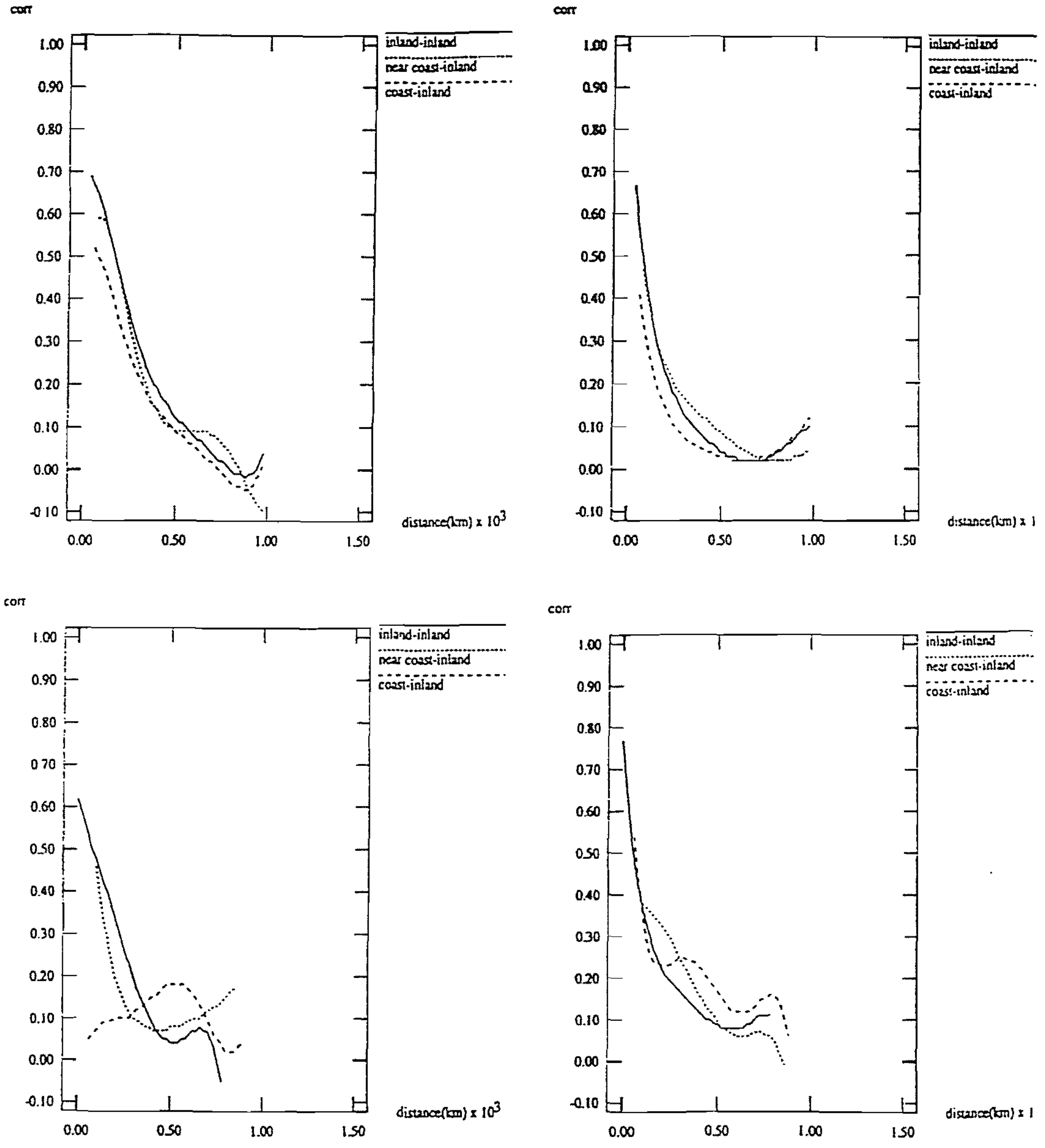


FIGURE 8: T2m first guess error correlation for inland-inland, inland-near coast and inland-coast Scandinavian station pairs (upper graphs) and Iberian peninsula station pairs (lower graphs) in summer. (left graphs correspond to daytime, and right graphs correspond to nightime)

- Mountain-valley anisotropy:

  With regard to the inland-inland correlations of the Spanish dataset, a broad scattering still remains. In order to isolate the possible effect of the orography as source of anisotropy, families of inland-inland correlation data corresponding to different relative vertical distance intervals were generated. Figure 9 shows the distribution of the whole Spanish station pair dataset into height difference intervals. The maximum occurs between 200 and 400 m of relative vertical distance, and there is a significant amount of pairs of stations separated vertically more than 1000m. For each family, a curve depending on the horizontal distance has been fitted. Figure 10 shows all curves superimposed. As it can be seen, the correlation for short horizontal distances decreases when the vertical displacement between stations increases.

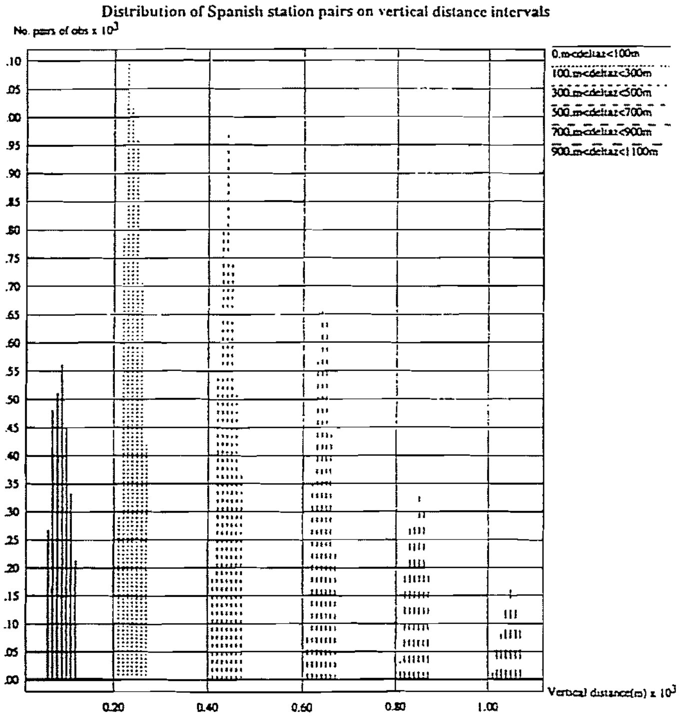


FIGURE 9: Distribution of Spanish station pairs on vertical distance intervals. At every vertical distance, observations are also distributed on horizontal distance subintervals corresponding to 100km, 200km, 300km, 400km, 500km, 600km, and 700km.

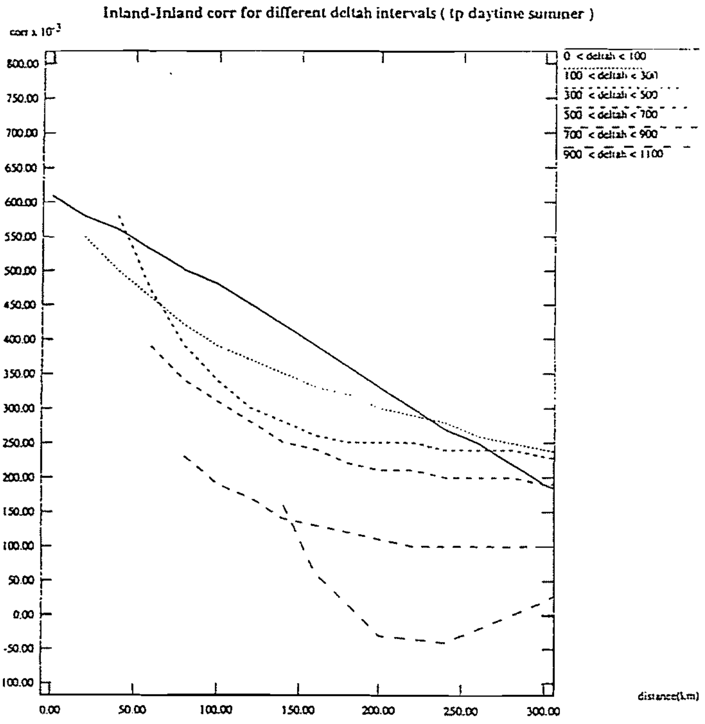


FIGURE 10: T2m first guess error correlation vs horizontal distance for inland-inland Spanish station pairs in summer during daytime. Each curve corresponds to a different vertical distance interval, deltah(in meters), between stations.

With respect to RH2m, the same kind of dependences have been observed, but with smaller horizontal length scales (e-folding distance around 150km)than those for T2m. Figure 11 shows the results found for the Spanish datasets (lower panels) and the Scandinavian datasets (upper panels) during summer.

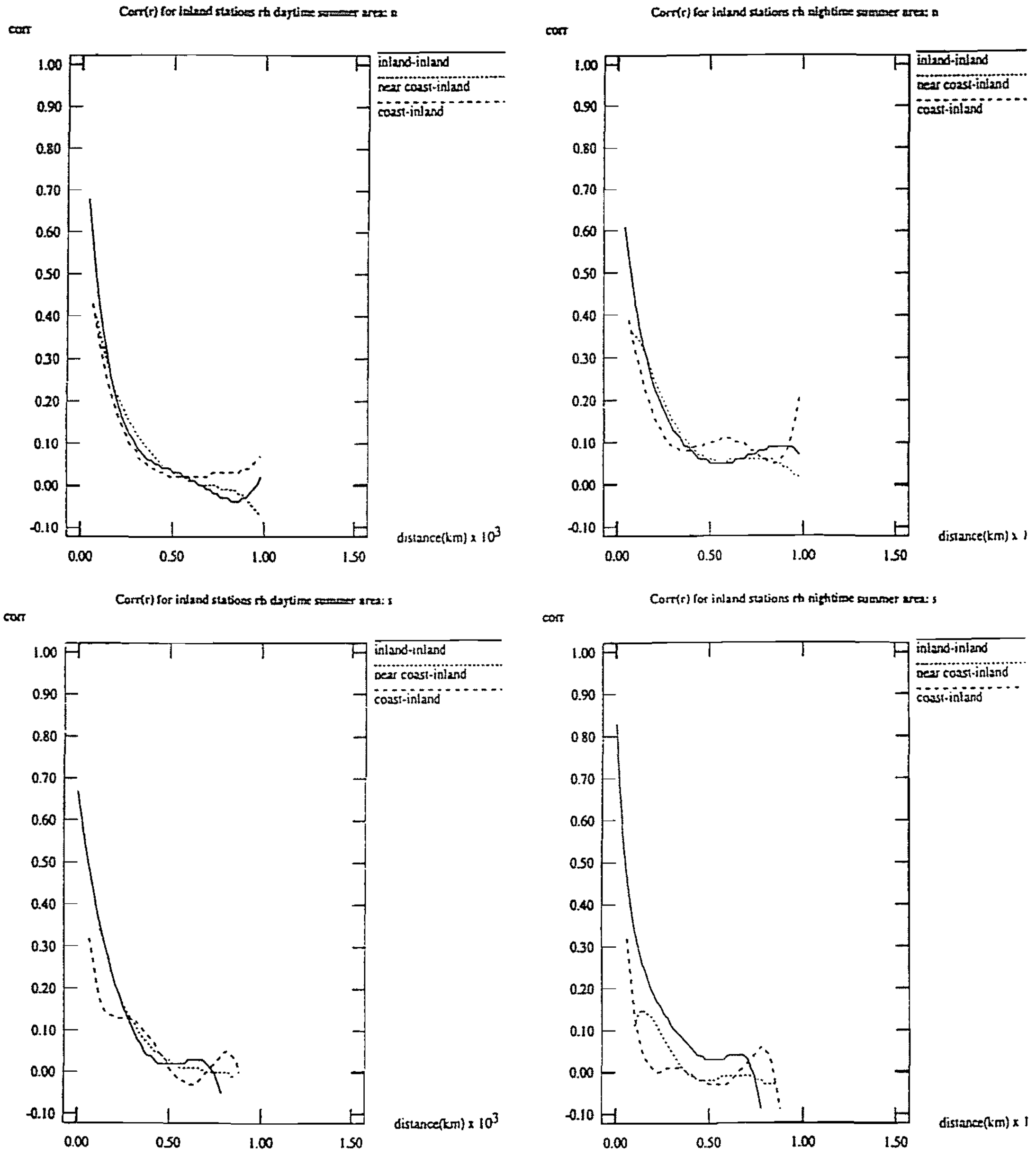


FIGURE 11: RH2m first guess error correlation for inland-inland, inland-near coast and inland-coast Scandinavian station pairs (upper graphs) and Iberian peninsula station pairs (lower graphs) in summer.

3.2 First Guess and Observation errors

With the aid of the fitted curve of the isotropic part of the correlation function it is possible to estimate the first guess and the observation error variances. The total variance, E_T^2 under homogeneous conditions should be independent of observation point. It can be obtained from the observation increment time sequence:

$$E_T^2 = \frac{1}{N}\sum_{i=1}^{N}\overline{(O_i - B_i)^2}$$

the subindex i indicating the station, N the total number of the stations of the network, and the overbar the average over a long sequence of events of the observation increments at the station i, O the observation value and B the first guess values.

If the observation and the first guess errors are not correlated, the total variance is the sum of the first guess and the observation errors:

$$E_T^2 = \frac{1}{N}\sum_{i=1}^{N}\overline{(O_i - T_i)^2} + \frac{1}{N}\sum_{i=1}^{N}\overline{(B_i - T_i)^2} = {E_O}^2 + {E_B}^2$$

where T_i is the true value at the point i.

According to Daley, the zero intercept of the fitted curves, is a measure of the horizontally correlated part of the total error:

$$\lim_{r\to 0}\beta(r) = \frac{{E_B}^2}{{E_O}^2 + {E_B}^2}$$

If the observation error is horizontally uncorrelated its only contribution to $\beta(r)$ is at $r = 0$. In ${E_0}^2$ both the instrument error and the representativeness error are included.

The values of the total error standard deviation, E_T, obtained for T2m and RH2m in winter and summer for Spain and Scandinavia, both for daytime and nightime are summarized in the following tables:

Spanish stations				
	summer		winter	
Parameter	day	night	day	night
t2m	2.03	1.36	2.04	2.47
rh2m	0.10	0.11	0.11	0.11

Scandinavian stations				
	summer		winter	
Parameter	day	night	day	night
t2m	1.79	1.36	2.51	2.82
rh2m	0.10	0.10	0.11	0.10

As it can be appreciated, the highest errors correspond to the Scandinavian stations in wintertime. But in summertime the total variance in the Spanish stations is higher than in the North of Europe. Because this analysis is focused to correct the soil wetness content mainly during the dry season, when plants have to control their evapotranspiration rates according to their water resources, a compromise of the values for summer during daytime has been employed to represent the total errors. From it, and from the zero intercept of the fitted correlation function, that approximately produces a partitioning between first guess and observation errors as 0.7 and 0.3 of the total variance, leads to 2. and 1. degrees values for T2m first guess and observation error standard deviations respectively. In the case of RH2m, the first guess and the observation errors have been approximated by 0.10 and 0.05.

3.3 Formulation of a new structure function

To describe all effects that have been pointed out in the correlation subsection above, the analysis structure function has been modified for temperature and defined for relative humidity in order to:

- introduce a seasonal dependence of the isotropic part of the correlation function $\beta(r_{ij})$, in respect to the speed of decreasing for larger distances(from 400km) ;
- fit the land-sea decoupling observed in summertime in the southern regions in the tabulated function representing the land sea anisotropy $\alpha(class_i, class_j)$;
- introduce a decreasing factor depending on the vertical distance, $\gamma(\Delta z_{ij})$ to take into account the anisotropy due to the inland topography. This kind of correction to the autocorrelation function has been used by Cacciamani et al.(1989) when designing an objective mesoscale analysis of daily extreme temperatures in the Po valley.

The final structure function, $\mu(r_i, r_j)$, is then defined as:

$$\mu(r_i, r_j) = \alpha(class_i, class_j)\beta(r_{ij})\gamma(\Delta z_{ij})$$

where,

- $\alpha(class_i, class_j)$ is currently defined as follows:

$$\alpha(class_i, class_j) = \begin{pmatrix} 1.00 & 0.75 & 0.50 & 0.25 & 0.00 \\ 0.75 & 1.00 & 0.75 & 0.50 & 0.00 \\ 0.50 & 0.75 & 1.00 & 0.75 & 0.00 \\ 0.25 & 0.50 & 0.75 & 1.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 1.00 \end{pmatrix}$$

- the functional dependence of $\beta(r_{ij})$ on the horizontal distance has been kept as it was in the original code :

$$\beta(r_{ij}) = exp(\sum_{n=1}^{6} a_n (\frac{r_{ij}}{R})^{n-1}) - 1.$$

$$R = 1000km$$

only varying the coefficients of the polynomial a_n,

$$a_1 = 0.69, a_2 = -2.27, a_3 = 4.43, a_4 = -6.43, a_5 = 5.11, a_6 = -1.53$$

for T2m and

$$a_1 = 0.69, a_2 = -3.30, a_3 = 5.98, a_4 = -4.37, a_5 = 0.47, a_6 = 0.53$$

for RH2m in summer. In figure 12, $\beta(r_{ij})$ for T2m and RH2m is plotted.

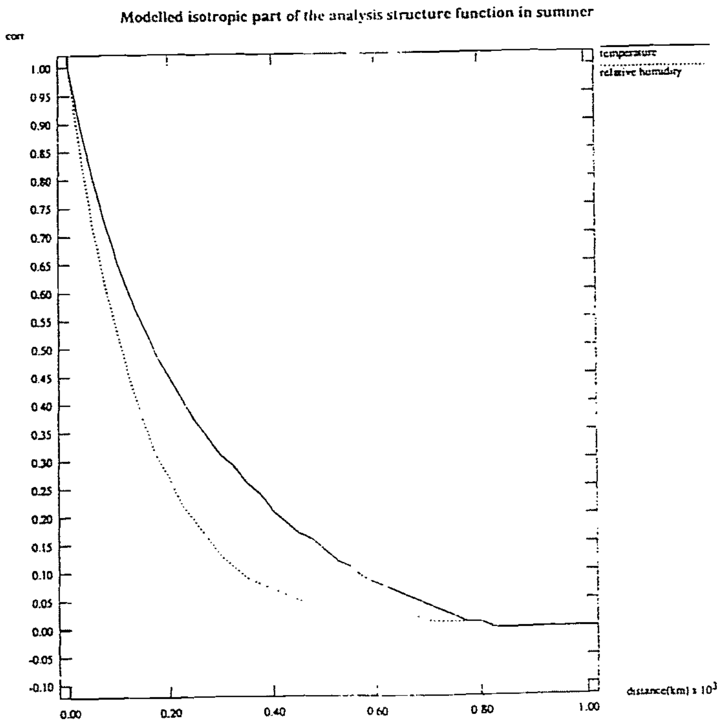


FIGURE 12: The modelled isotropic correlation function in summer for T2m and RH2m.

- Δz_{ij} is the vertical displacement between the points i and j, and $\gamma(\Delta z_{ij})$ is a continuously decreasing function:

$$\gamma(\Delta z_{ij}) = exp(\sum_{n=1}^{2}(b_n(\frac{\Delta z_{ij}}{Z})^n)$$

$$b_1 = 0.00, b_2 = 0.33, b_3 = -1.88$$

$$Z = 1000m$$

obtained by fitting the different curves depending on r_{ij} corresponding to each Δz_{ij} interval. Because temperature and relative humidity show a similar decay with increasing vertical distance, the same $\gamma(\Delta z_{ij})$ has been adopted for both parameters. It can be appreciated that the e-folding Δz_{ij} is around 800 meters (figure 13).

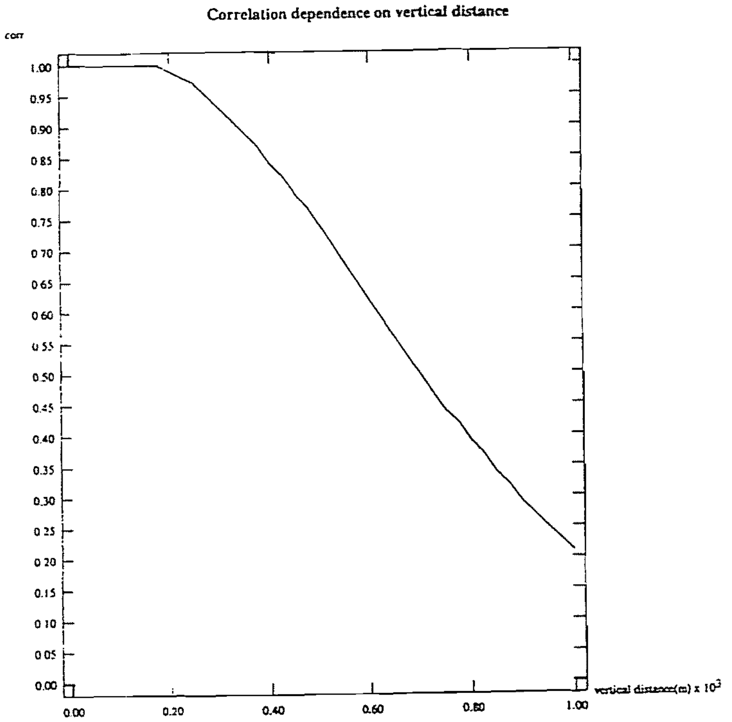


FIGURE 13: The modelled part of correlation corresponding to the dependence on the vertical distance between the two points.

The correlation maps with a fixed station located in the Ebro valley, are shown in figure 14 for the old and modified structure functions.

Not all the anisotropy present on the Spanish correlation dataset can be explained by the two factors introduced. Some work has been devoted to look into other possible sources for the anisotropy, and it has been found that stations located in irrigated areas show a higher correlation, and a decoupling with those located in non irrigated agriculture and forest zones. So, it seems that the land use property of the different soils could be employed as a source of anisotropy, if a high resolution physiographic database was available. Note that the mountain factor introduced as the last step can indirectly take into account the dependence on soil use, because irrigated zones tend to be located along the river sides.

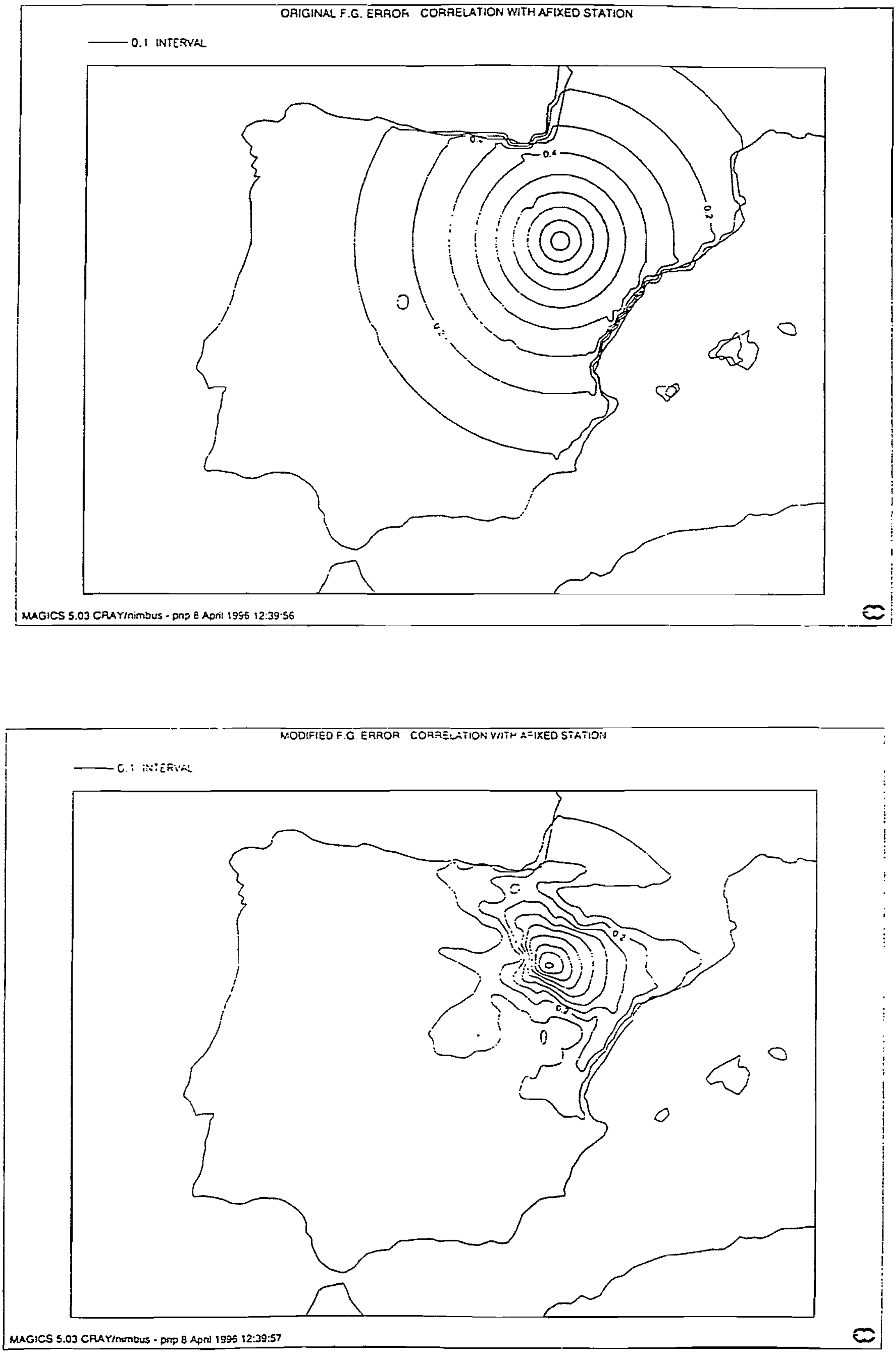


FIGURE 14: Correlation with a fixed station, Zaragoza, located in the Ebro valley, according to the original and the new formulations of the T2m analysis structure function.

3.4 Assessment of the vertical displacement anisotropy

In order to assess the importance of the factor that accounts for the vertical distance between the two points in the correlation function, a set of independent observations have been selected to test the improvements on the resulting analysis when introducing it.

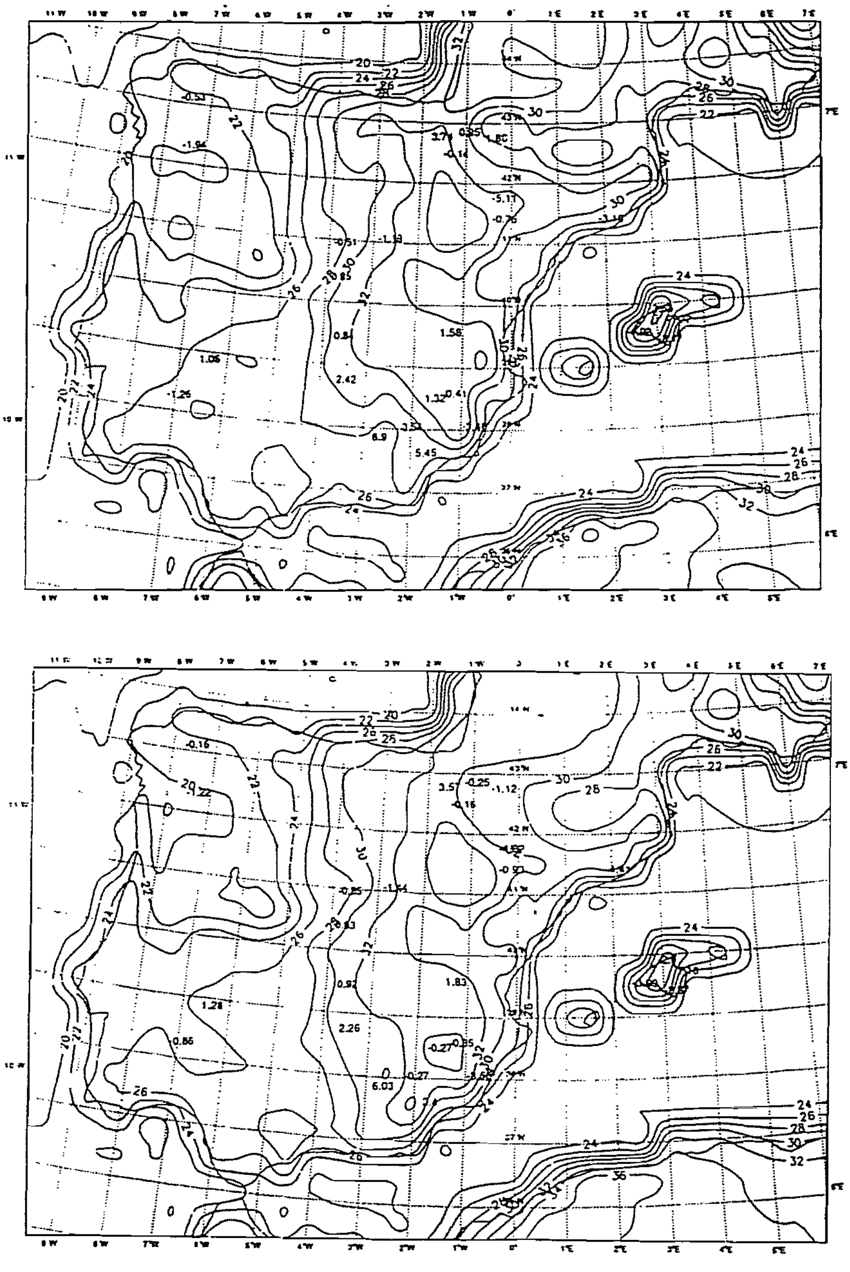


FIGURE 15: Analysis of T2m corresponding to 27 July 1995 at 18Z excluding (upper map) and including (lower map) the factor that accounts for the anisotropy due to the mountains in the analysis correlation function. The values of the analysis errors at some stations not used in the analysis are plotted for both experiments.

Of course, this factor is not significant over flat terrain, but to evaluate the analysis quality in mountainous terrain is not an easy task because the selected stations can be significantly below or above the model surface, preventing meaningful comparison of the observed parameter with the analysed values. The choice of the independent stations set has been done using only those not very far in the vertical from the model surface (less than 100 meters).It implies that most of the selected observations are located in not too sharp an environment. Thus, the verification results could be not representative enough.

In the cases that have been studied, with the observations selected located over Spain, the introduction of the anisotropy due to the orography decreases the r.m.s. analysis errors around 0.7-0.8 C, on average.

As an example, figure 15 shows T2m analysed fields obtained without(upper map) and with (lower map) the mountains dependence included in the structure function, the numbers representing the analysis error at each selected station. As it can be observed, the introduction of the mountain dependence factor not only decreases the analysis error in most of them but also changes the final analysed field over a complex terrain such as the Iberian peninsula.

The sensitivity of the analysis to this factor has been also studied in some experiments in which observations located along a valley are removed from the analysis observations file. The resulting analysed fields have shown a clear dependence to its inclusion.

As last, it should be remarked that when the first guess is very far from the truth, this factor can artificially increase temperature gradients if there is not enough observations in each topographically different area. This can occur because the real effect of the factor introduced is to reduce the horizontal length scales along the rapid varying orography directions.

4 Technical implementation

The analysis of T2m and RH2m belongs to a more general analysis package for surface parameters originated at the SMHI, in which the analysis of sea surface temperature, the diagnosis of the ice fraction, and the analysis of the snow depth are also included. This general code offers the possibility to choose the analysis method: Optimum Interpolation or Sucessive Corrections. A number of variables describing the parameters to analyze and the characteristics of the analysis for each of them, are read by means of the namelist NAMNAS.

Because the implementation of the analysis for T2m and RH2m has been carried out in Spain, and for sst,ice and snow in Finland, two slightly different shell scripts were designed to run these analysis versions in the HIRLAM 2 reference system. Also, two different versions modifying the original one, were generated in Spain and Finland respectively. So, the last work at the INM has been devoted to integrate both codes (in nasu library) and scripts in order to provide a final version for the HIRLAM reference system.

Some additional technical work to install the soil/surface data assimilation step into the HIRLAM reference context has also been done. With regard to the new surface parameterization framework, many changes appear for the soil/surface variables, and therefore a new version of the surface analysis library nasuh3 has been built. Also in this context, a new environment variable SOILASS had be defined to activate the soil data assimilation. Corrections are also needed in the span library (that prepares the first guess fields for the analysis of the sst and snow by merging the forecasted values with the climatology) and the script SurfAna has been adapted to run the soil data assimilation. The climatological file linked in this framework is different from the corresponding file of the HIRLAM 2 reference system, and it contains the new climatological fields for each gridsquare fraction.

5 Concluding remarks and further work

An analysis of T2m and RH2m has been installed into the HIRLAM reference system. It can be run along with the present surface/soil parameterization for verification purposes, but it is mandatory to assimilate the soil variables of the new more realistic soil/surface parameterization. The original code developed at the SMHI has been adapted to the HIRLAM reference system and modified mainly in two aspects:

First, the observation increments are calculated taking into account the vertical distance between the station height and the model interpolated orography, and a vertical reduction procedure has been introduced for it.

Second, the analysis structure function has been reformulated using the first guess error statistics obtained in different areas of Europe for summer and winter, and to introducing the anisotropy due to the presence of mountains. This last factor improves the analysis quality in complex terrain.

As it has been remarked, the first guess errors statistics used to model the analysis correlation function have been obtained from the errors of the present HIRLAM 2 surface and soil parameterizations. A future task is their replacement by the statistics of the new surface parameterization corrected at every assimilation step by the surface/soil data assimilation procedure.

The analysis of the T2m and RH2m for each land fraction (bare ground, agriculture land and forest) is a possible future improvement, that will be feasible when a high resolution physiographic database is available and the whole land stations set is classified into the different classes. Of course the experience gained with the operational behaviour of the new surface parameterization with the present soil data assimilation will help to reduce this problem.

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