MESOSCALE ANALYSIS AT

"DIRECTION DE LA METEOROLOGIE"

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Abstract : This paper describes a mesoscale analysis scheme which is still at the stage of research in the French Weather Service. Before the end of 1984, this analysis scheme could be used to prepare initial information for an operational mesoscale prediction model covering an area over France.

1. INTRODUCTION

The results which are shown in these pages take place in the French numerical weather prediction project called "PERIDOT" ("Prévision à Echéance Rapprochée Intégrant les Données d'Observations Télédectées"). The purpose of the project is to produce operational numerical forecasts out to 30 hours with a high horizontal resolution over France (mesh size = 35 km - see area below).

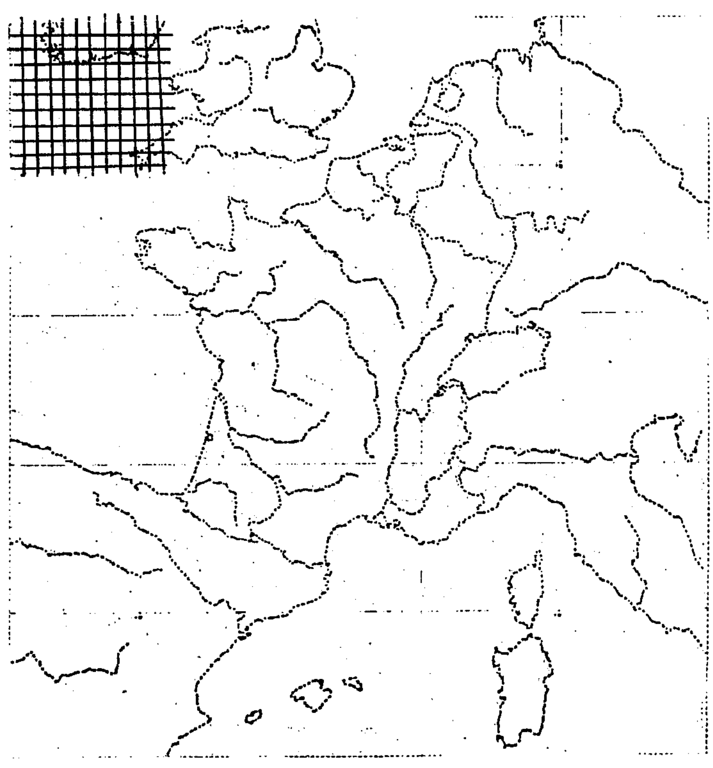

Figure 1

The PERIDOT project includes 3 components :

- a 15 - layer PE prediction model in σ coordinate, with boundary values provided by a large - scale model, see Coiffier (1982)

- a non linear normal mode initialisation, see Brière (1982),

- a meso - scale analysis scheme using all the usual observations, and also high resolution satellite data (produced by the space meteorological centre of Lannion).

The following paragraphs discuss the last part; that is the analysis techniques which are being experimented with to provide the prediction model with mesoscale information.

Figure 1 shows the area which has been used until now for developing and testing the programs. This area wil be probably enlarged for the operations, taking into account the capacities of the new computer to be implemented in the French Weather Service.

2. THE ANALYSIS SCHEME

2.1 Analysed parameters

For the mass and wind fields the analysis is directly performed on the prognostic variables of the forecast model.

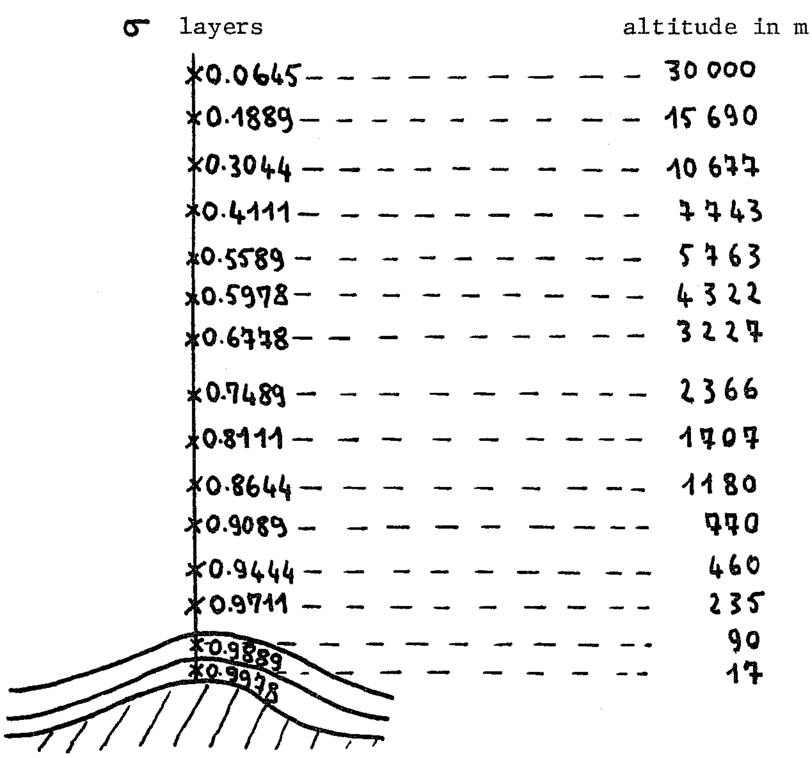

Figure 2

The vertical structure of the model is given on figure 2, with the 15σ layers. The analysed parameters are :

- surface pressure : p_s
- wind components in the middle of the 15 σ layers : u and v
- temperature in the middle of the σ layers : T (in fact we analyse the thickness of the σ layers).

The prognostic variables analysis avoids the interpolations form p to σ (or σ to p) in which some analysed information could be lost, especially mesoscale details.

The rule is not applied to humidity : we analyse the relative humidity of 5 layers between the surface and 300 mb. Then these values are converted to the σ layers mixing ratio.

2.2 Observations

The mesoscale analysis uses all the data which are available for the large - scale operational analysis (SYNOP - SHIP - DRIBU - TEMP - PILOT - AIREP - SATOB - SATEM - bogus data). But among these observations, only surface data can provide the 35 km mesh model with significant mesoscale details. For the heights it is planned to use high resolution satellite remote soundings instead of american SATEMS. Such retrieved soundings are not yet available, but raw satellite data can be used, and some experiments are being performed to directly insert these raw data in the humidity analysis.

2.3 Guess - field

The guess-field is the last numerical forecast issued from the PERIDOT model. No decision has been taken about the assimilation cycle (3 h, 6 h, ...).

2.3 Interpolation scheme

A 3-dimensional multivariate optimum interpolation scheme in σ coordinate, is performed on the increments (observation - prediction) for the prognostic variables of the model determining the mass and wind fields. This scheme is very similar to the method used in the NMC global data - assimilation system - Bergman (1979).

- The first step is the analysis of p_s. In fact the 3-dimensional multivariate interpolation is done on the geopotential height of the predicted surface pressure $\Phi(p_s^p)$. The increments $\Phi(p_s^p) - \Phi_0$ (Φ_0 = orography of the grid-point) are then converted to surface pressure increments, to determine the surface pressure analysis p_s^a . For such an application, it would be better to get the observed pressure at the station in the SYNOP message, instead of the sea-level pressure (as abready mentioned by Mac Pherson and Bergman (1979).

- The second step is the computation of the pressure value corresponding to the 15 σ levels, taking into account the new surface pressure p_s^a. The guess-field is then interpolated to the new σ levels.

- The third step is the analysis of the 15 thicknesses $\Delta\Phi$ and wind components for each grid point. The interpolation is performed with a limited number of observed data (8 maximum) for each analysed parameter.

The observed parameters which are retained to analyse u and v components are not the same as those used to analyse $\Delta\Phi$: the observed data which are highly correlated with $\Delta\Phi$ at a grid point are generally the observed thicknesses provided by radiosondes and satellite soundings while observed winds or geopotential heights are the most interesting data to analyse u and v components.

- The assumptions which are made to determine the structure functions are the usual ones.

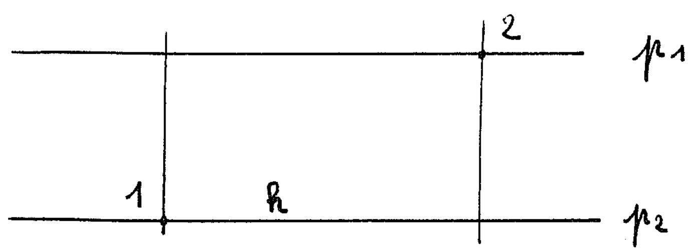

Figure 3

$$r\left[\varepsilon\Phi_1^{p}, \varepsilon\Phi_2^{p}\right] = r_h(h) \cdot r_v(p_1, p_2)$$

r_h is the horizontal correlation function for Φ (isotropic-gaussian function or polynomial), r_v is the vertical correlation function which has the form proposed by Mac Pherson and Bergman : $r_v(p_1,p_2) = 1/(1 + k\,[\ln(p_1/p_2)]^2)$,with a k value adapted to the model. The structure function for the u and v components and $\Delta\Phi$ are deduced from the geotrophic assumption and other simple computations.

- The humidity analysis is performed by 2-dimensional multivariate optimum interpolation for each layer. Four different types of data can be used :

. radiosonde observations

. pseudo-observations calculated from the information SYNOP and

SHIP (method very similar to ECMWF technique to generate these observations).

. raw satellite data providing either clear radiances or cloudiness information (we need some statistics on the radiances, to enter them in the multivariate scheme - cloud information from satellite is used to generate pseudo-observations equal to 100 %).

. bogus data (which could be prepared manually by a forecaster).

Plenty of statistics are necessary to compute the "optimum mixing" of these data coming from different sources. The correlation function for humidity prediction error is dependent on the guess-field at the analysed point, and is not isotropic : the correlation is weaker along the direction of the predicted humidity gradient than along the orthogonal direction.

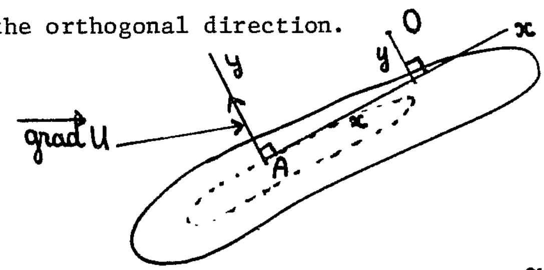

Figure 4

$$r[\varepsilon U_A^{p}, \varepsilon U_O^{p}] = f(x) \cdot g(y) = e^{-\frac{x^2}{2a^2}} \cdot e^{-\frac{y^2}{2b^2}} \text{ (for example).}$$

3. SOME RESULTS

For the moment no experiment has been run with high resolution satellite data, so the only results which are interesting to look at concern the meteorological fields which are directly influenced by the surface data.

The structure function for $\varepsilon^{p}(SLP)$ is given on figure 5 for 20/9/80 OGMT ($\varepsilon^{p}(SLP)$ = 12 h prediction error for sea-level pressure issued from the PERIDOT model).

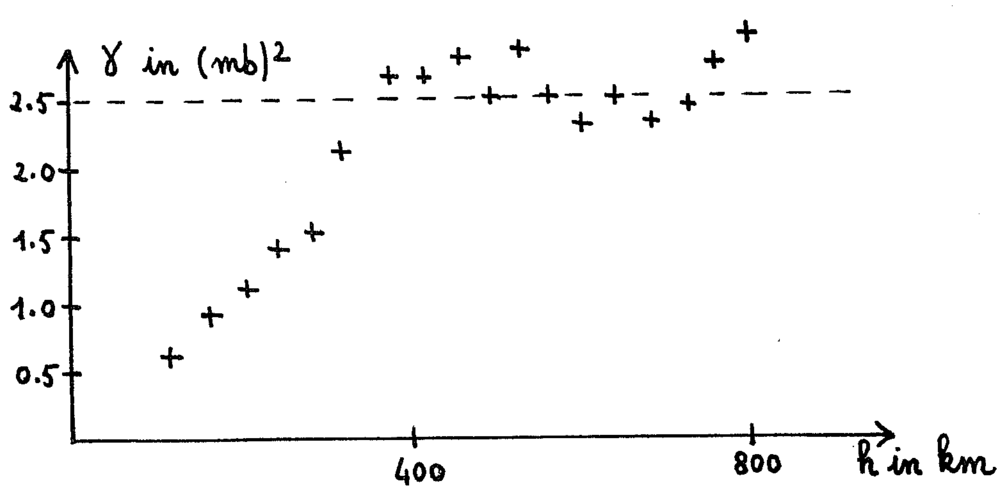

Figure 5

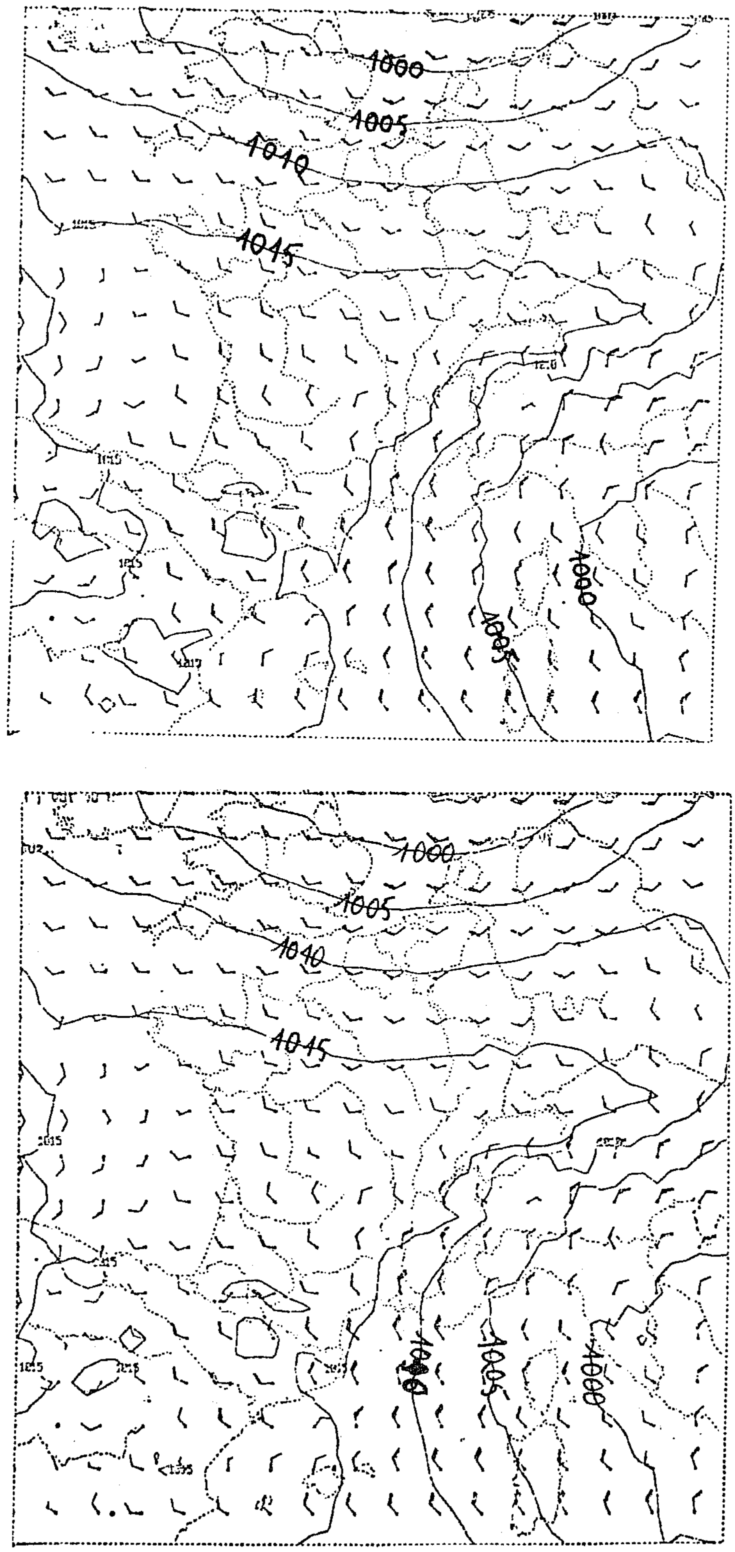

Figure 6 : Sea - level pressure and 17 m wind analysis for 19 March 1981 OGMT

- Top : without SYNOP and SHIP temperatures.
- Bottom : SYNOP and SHIP temperatures used in the analysis.

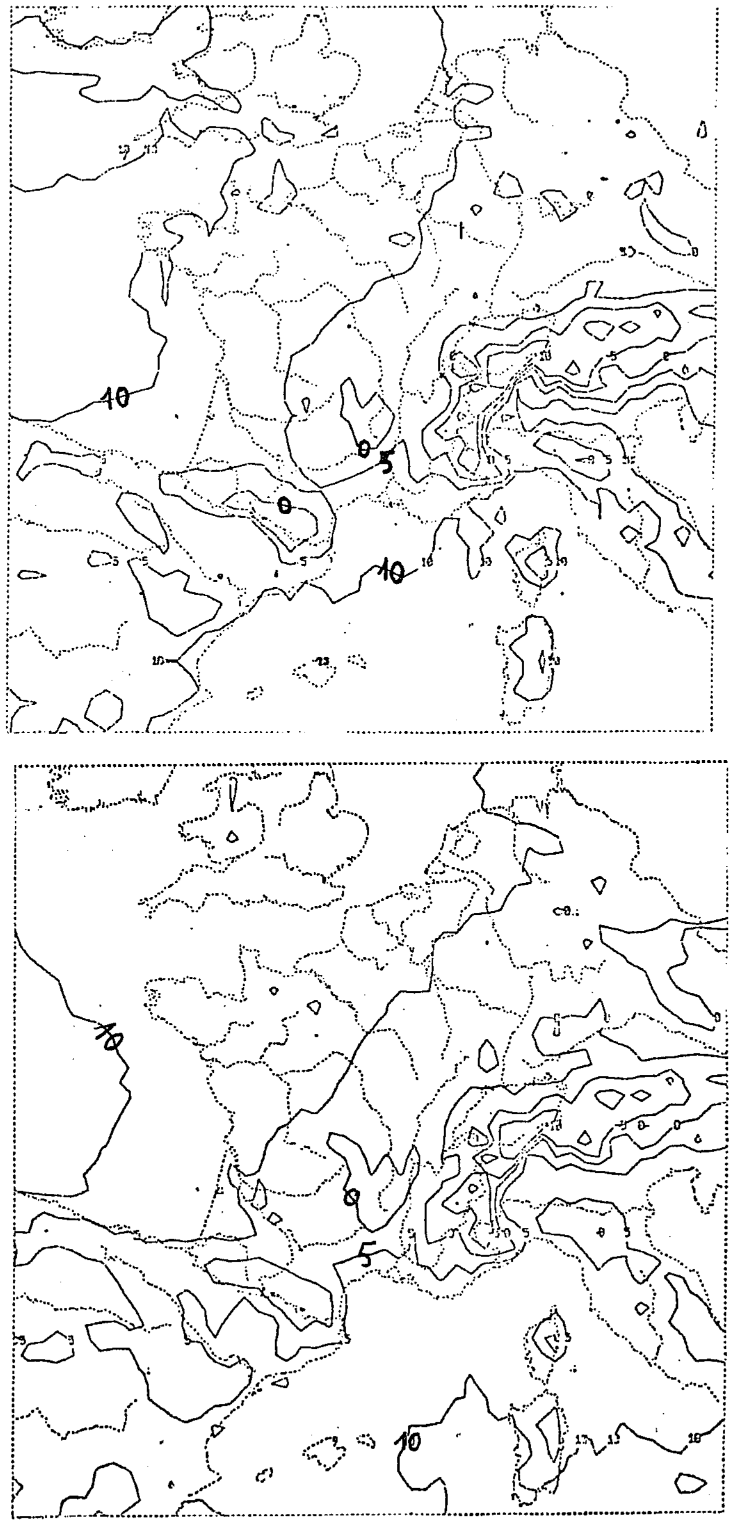

Figure 7 : 17 m temperature analysis for 19 March 1981 OGMT

- Top : without SYNOP and SHIP temperatures.
- Bottom : SYNOP and SHIP temperatures used in the analysis.

As expected the correlation decreases very quickly with the distance, compared to the correlation function of the prediction error of a large - scale model.

The analysed map (see figure 6) for 19 March 1981 0GMT presents the sea - level pressure and the wind of the lower σ layer (17 m). It is difficult to say if the mesoscale details of the pressure field are significant or not ; on the other hand some details of the wind field seem interesting (South part of France).

Experiments have been done in which the temperature of SYNOP and SHIP messages is considered to be representative of the temperature of the lower layer. So these data are directly inserted into the multivariate analysis scheme (see impact on figures 6 and 7 for sea - level pressure, wind and temperature of the lower layer).

No complete experiment has been run until now (analysis - initialisation - forecast model), but some limited experiments in a few cases seem to indicate that most of the mesoscale details which are present in the analysis, disappear with the normal-mode initialisation... So the answer to the following question is not clear : how useful is a mesoscale analysis for a mesoscale prediction model ?

4. REMARKS ON THE STRUCTURE FUNCTIONS

The following remarks are prompted by problems which occur in the French operational large - scale analysis (and not in the mesoscale analysis), but it seems that these remarks are true for any kind of analysis performed by statistical interpolation.

The following example shows a case in which a low near Iceland has not been correctly analysed : the full lines indicate the result of objective analysis, while the dotted lines indicate two isobars added by a manual analysis.

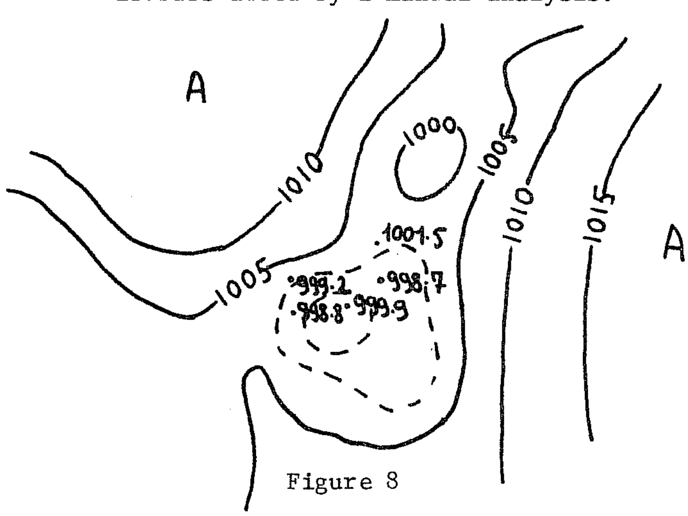

Figure 8

It is clear that the low is not deep enough when we look at the plotted observations : in other words the analysed pressure does not adequately the observed values. A detailed study of similar cases has pointed out 2 deficiencies of the data - assimilation scheme which are discussed now.

4.1 The bias of the guess-field

Using the notations given by Rutherford (1976) for the optimum interpolation equations, the first deficiency consists in the fact that the predicted Ψ^{r} is biased.

$$\varepsilon\Psi^{r} = \Psi^{r} - \Psi$$ has un local bias :

$$\overline{\varepsilon\Psi^{r}} = m > 0$$ in the vicinity of the center of the

So it is interesting to "filter" that bias (assumed to be constant and equal to m in the vicinity of each grid-point G). To do that we have to modify slightly the usual equations :

$$\varepsilon^{a}(G) = \varepsilon^{r}(G) + \sum_{i=1}^{n} \lambda_i \left(\varepsilon_i^{o} - \varepsilon_i^{r} \right)$$

Usually we assume $\overline{\varepsilon^{o}} = \overline{\varepsilon^{r}} = 0$ (i. e. observations and guess-field unbiased).
Here we assume $\overline{\varepsilon^{o}} = 0$ and $\overline{\varepsilon^{r}} = m$ (constant, unknown), and we calculate the λ_i with 2 conditions :

(1) $\sigma^{2}\left[\varepsilon^{a}(G) \right]$ minimum

(2) $\overline{\varepsilon^{a}(G)} = 0$ (analysis not biased)

As $\overline{\varepsilon^{r}(G)} = \overline{\varepsilon_i^{r}} = m$, the condition (2) becomes $m \left(1 - \sum_{i=1}^{n} \lambda_i \right) = 0$,
and we have to minimize the quantity (1) <u>under the constraint $\sum_{i=1}^{n} \lambda_i = 1$</u>.

By simple computations we can see that we have to solve the following system :

$$\begin{pmatrix} & & & 1 \\ & \mathrm{Cov}(i,j) & & 1 \\ & & & \vdots \\ & & & 1 \\ 1 & 1 & \cdots & 1 & 0 \end{pmatrix} \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \\ \mu \end{pmatrix} = \begin{pmatrix} \mathrm{Cov}(i,G) \\ \\ \\ \\ 1 \end{pmatrix}$$

The matrix size is (n + 1) x (n + 1) (n = number of observed data) : it is the usual optimum interpolation matrix, with a (n + 1)'th line and column containing either "1" or "0" (see above). This technique to eliminate a local bias in not applied in the present French programs, but it will be used for surface fields in the future operational analysis.

4.2 The inability of structure functions to represent some features

A simple study has shown that we should use very specific structure functions to analyse the lows.

Figure 9 shows the comparison between 2 structure functions, for the sea - level pressure prediction errors (15 november 1979 12 GMT) :

- one has been calculated with all the observations of the Northern hemisphere : we call it "total" structure function.

- the second one has been calculated using only the couples of observations for which one at least of the observed pressure is lower that 1000 mb : we call it "low pressure" structure function.

It is clear that the distance where the correlation becomes equal to zero is shorter for the "low pressure" structure function than for the "total" structure function. Morever the RMS prediction error is smaller for the total structure function.

The problem which has not been solved is how to evaluate dynamically, for each grid - point, the "optimal structure function", according to the value of the field itself in the vicinity of the grid - point.

5. CONCLUSION

The mesoscale analysis scheme which has been described does manage to "produce mesoscale fields", but we cannot state for the moment how efficient it is for the final output : mesoscale numerical forecasts over France, especially rainfall and boundary layer temperature.

The answer cannot be clear before the end of the following developments and researches :

- insertion of high resolution satellite data in the analysis,
- detailed tuning up of structure functions and other statistical parameters,

- development of a good "coupling" with the large - scale prediction model,

- tests of the full system (analysis, initialisation, prediction) on several situation of the "Alpex" data set.

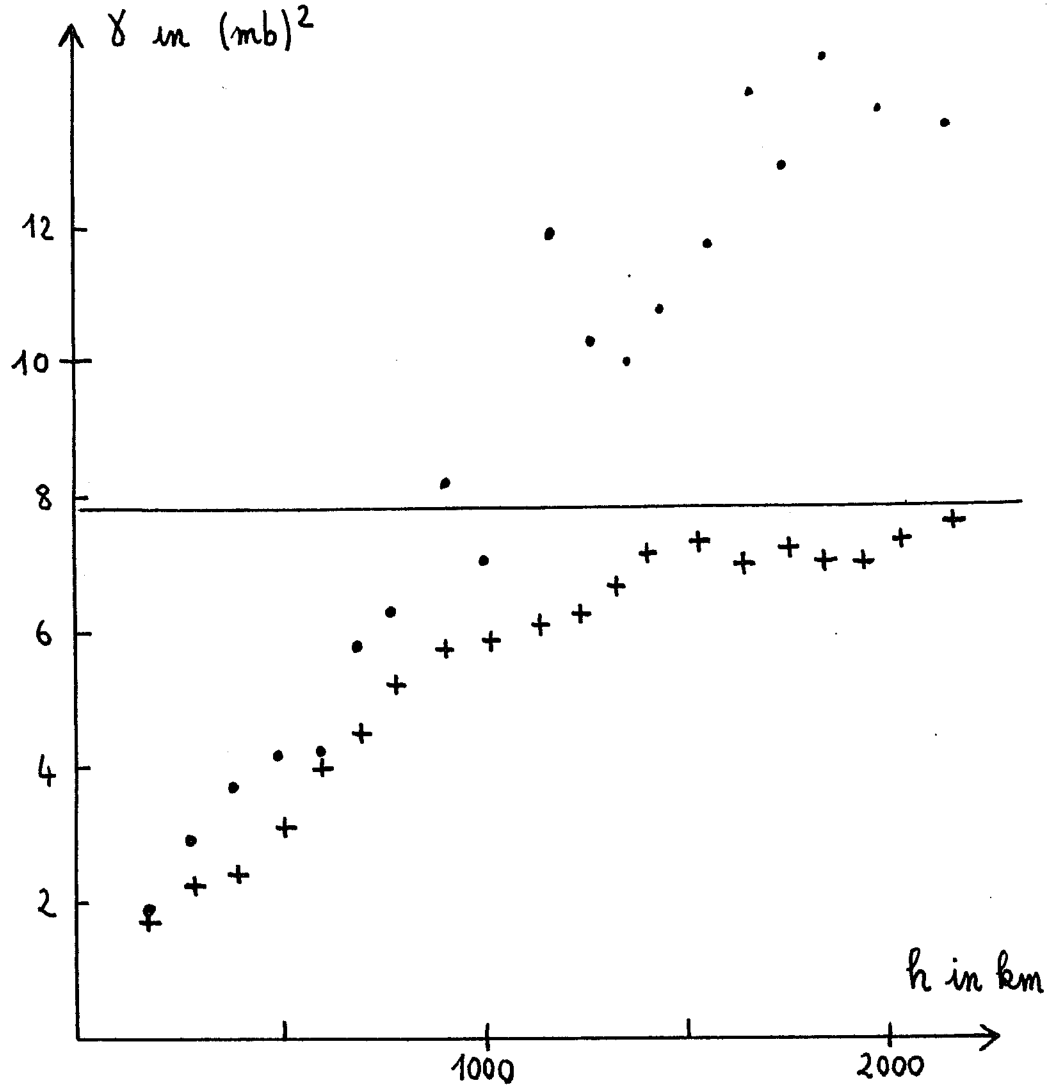

Figure 9 : Structure for sea - level pressure :

+ : "total" structure function

. : "low pressure" structure function

—— : assumed value for $\sigma^2(\varepsilon^o) + \sigma^2(\varepsilon^p)$ in the French operational program.

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