VALIDATION OF ARPEGE/IFS FOR OPERATIONAL SHORT-RANGE PREDICTIONS

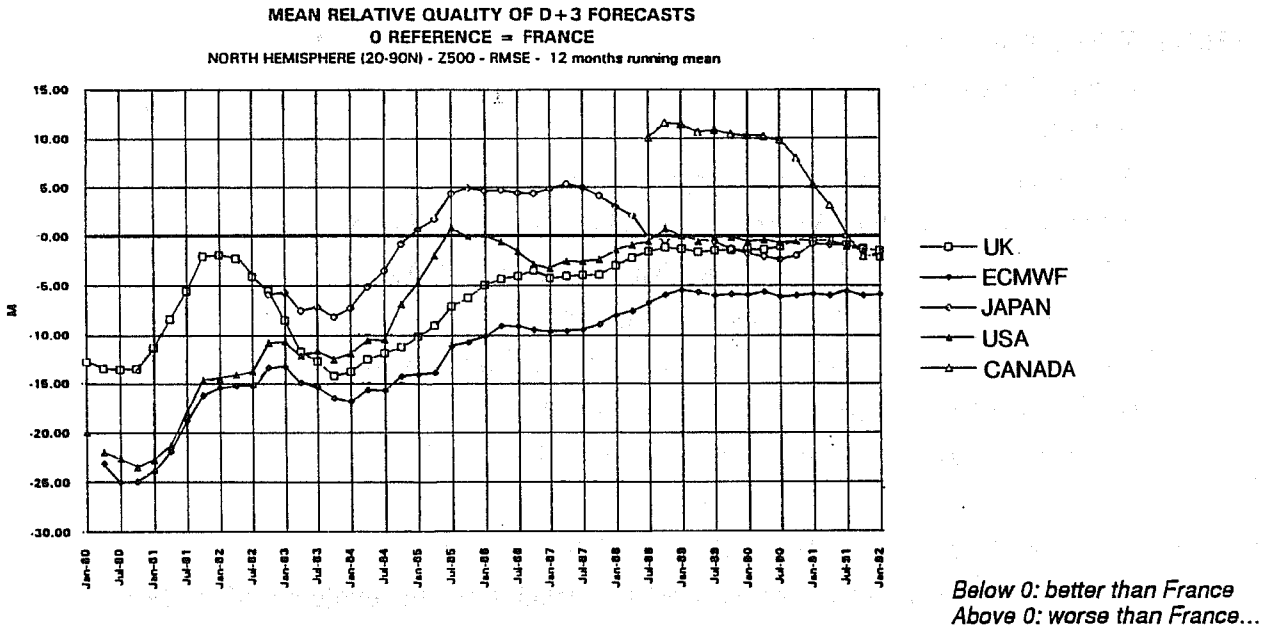
P. Bénichou, E. Legrand
Météo-France
Toulouse, France

Summary: In order to replace its old NWP system, Météo-France has developed in collaboration with ECMWF a new model called ARPEGE/IFS. Validation experiments have been made to check if this new model can be used in operational context or not, making short-range predictions. Further experiments are planned in variable-mesh mode.

1. INTRODUCTION

In order to improve the accuracy of weather predictions, Météo-France decided to develop a new NWP system. This development has been made in co-operation with ECMWF: it is called ARPEGE (Action de Recherche Petite Echelle Grande Echelle) in France and IFS (Integrated Forecast System) at ECMWF.

Some work is being done in order to validate ARPEGE/IFS for operational use in short-range predictions (0-72h). It is not yet finished, because the model hasn't achieved a sufficient stage of completion. This paper describes the actual state of the validation of ARPEGE/IFS, and gives a few words on the works to do in the next monthes.



Below 0: better than France
Above 0: worse than France...

This first figure, presenting the difference of quality in Z500 models from various countries, shows that all countries improved their forecasts since 1991, except France. However one has to consider that no further development has been made on the french operational global model EMERAUDE for the last 3 years, all the developers working on the new model ARPEGE/IFS. So EMERAUDE doesn't correspond with the current state of art in 1992.

2. PRESENTATION OF THE MODELS

2.1. The old models: EMERAUDE & PERIDOT

Until today, Météo-France has used a system of 2 nested models:

- EMERAUDE, spectral global model

  The main characteristics of EMERAUDE are:

  ◊ Primitive equations system
  ◊ T79 (equivalent mesh: 120 km at 45° in latitude)
  ◊ L15 (hybrid (σ,p) co-ordinate from Simmons and Burridge
  ◊ global since 1988
  ◊ Eulerian scheme
  ◊ temporal discretization using leap-frog semi-implicit scheme (time step: about 20 minutes)
  ◊ analysis: bidimensional univariate optimal interpolation scheme at standard levels
  ◊ first operational appearance: January 30th 1985

- PERIDOT, local area grid point model:

  ◊ Primitive equations system
  ◊ C-grid (finite differences scheme)
  ◊ Domain: 119 x 119 points since beginning of 1991
  ◊ Horizontal mesh: about 35 km; 15 vertical levels (σ co-ordinate)
  ◊ Semi-implicit scheme for temporal advance; time step: 200 s
  ◊ tridimensional univariate optimal interpolation analysis
  ◊ direct use of TOVS clear radiances (provided by CMS-Lannion)
  ◊ initial and boundary conditions given by EMERAUDE
  ◊ first operational appearance: February 15 th 1985

Those two models were up to date in 1985. Of course they are no more.
Coupling two models is not a perfect solution: after a certain time, the evolution of the local area model is only driven by the boundary conditions. Data assimilation is also problematic near the limits of the Local Area Model.

2.2. The new model: ARPEGE/IFS

This is a common development Météo-France/ECMWF, started in 1987. Human forces devoted to ARPEGE/IFS have been more than 1000 man **x** month. Today, ARPEGE/IFS software includes about 300000 code lines.

Recent experience in NWP countries shows that the improve of model's accuracy is no longer obtained by systematic increase of the horizontal resolution or truncature of the model:

- ◊ high quality in data assimilation is necessary
- ◊ a good vertical resolution, including levels in the stratosphere, is desirable

In fact, the model that Météo-France has in view for 1993 has the same horizontal resolution as the old system, but has some new characteristics so that some improvements of the forecasts can be expected.

Main characteristics:

- ◊ Primitive equations system
- ◊ global spectral model
- ◊ Tn Lp
- ◊ stretched or not: Cq; it means that the equivalent resolution is Tn **x** Cq on the stretching-pole, Tn / Cq on the antipode.
- ◊ position of the stretching-pole *ad libitum*
- ◊ eulerian or semi-lagrangian
- ◊ optimal interpolation analysis or (later) variational analysis
- ◊ improved physics (convection...)
- ◊ different parametrizations available (e.g. Ozone) selected by switches
- ◊ suitable for
  - short-range prediction and predictability studies
  - medium-range prediction
  - climate research

Forecasted operational use at Météo-France:

In the operational context, Météo-France will use ARPEGE as short-range prediction tool:

- ◊ stretched mode, with high resolution over France
- ◊ run up to 72h
- ◊ relatively short cut-off for the data assimilation (<3h)
- ◊ results of the 0UTC run available before 5 UTC (20 min. "real" time for 24 hours computation is the maximum value)

3. STRATEGY FOR OPERATIONAL STARTING

In order to separate different problems which can occur at the operational starting of ARPEGE, we decided to split it in 3 main phases:

◊ replacement of EMERAUDE by a first version of ARPEGE:

- non-stretched, non-tilted pole axis
- same horizontal resolution (T79)
- same vertical resolution (L15)
- eulerian scheme

During that phase, PERIDOT will be maintained, with boundary conditions given by ARPEGE. Only a few improvements are expected at this stage, due to:

- analysis at model's levels (standard pressure levels for EMERAUDE)
- better physic parametrizations

◊ use of semi-lagrangian scheme, with increased number of vertical levels ($20 \leq L \leq 30$) other characteristics unchanged (including alimentation of PERIDOT)

◊ replacement of both EMERAUDE and PERIDOT

- pole in France
- stretched mode: C=3.5, T127
- vertical resolution unchanged

The equivalent resolution that we obtain is about 30 km over France, 300 km over New Zealand: it is about the same as EMERAUDE/PERIDOT's.

At this step ARPEGE must be used in semi-lagrangian configuration. In eulerian mode, the maximum stable time step would be given by the high resolution area (equivalent truncature $T \approx 450$, time step < 200 s), and would be to expensive in CPU for an operational use.

Current state (September 1st, 1992)

The ARPEGE/IFS is not yet ready for operational use in stretched-mode. So validation experiments have been carried out in non-stretched eulerian mode. The forecasted date for getting rid of EMERAUDE is September 29th.

4. STRATEGY FOR THE VALIDATION OF THE NON-STRETCHED VERSION OF ARPEGE/IFS

This action of validation is of paramount importance before a further evaluation of the model in a stretched mode. The aim of this action is to make sure that this ARPEGE/IFS version performs at least as well as the operational global french model EMERAUDE. This validation action strongly relies on various comparisons with the current French model EMERAUDE.

It has been carried out in three steps :

- S1 : validation upon 12 independant situations
- S2 : monitoring of the parallel ARPEGE assimilation cycle
- S3 : parallel run of ARPEGE and EMERAUDE suites

S1 : validation upon 12 independant situations

This action intends to qualify the forecast part of the model, on a representative set of meteorological situations. The ARPEGE forescasts (FA) as well as the EMERAUDE forecasts (FE) are compared according to a *unique* reference given by the EMERAUDE analysed fields (AE).

S2 : monitoring of the parallel ARPEGE assimilation cycle.

This action is complementary to the first one. Its purpose is to make an objective evaluation of the analysis part of the system, on the longest possible time-period. The monitored elements of the system are mainly the analysed and initalized increments fields, as well as the use which is made of the observations within the assimilation.

S3 : parallel run of ARPEGE and EMERAUDE suites.

This action has been launched only after satisfactory results were obtained during steps S1 and S2. It is an important step since its results make possible or not the putting into operation of the experimental ARPEGE suite. In the same time, a daily comparison of the mesoscale model PERIDOT outputs according to the coupling large scale model (ARPEGE vs EMERAUDE) is carried out.

Software environment

Software environment has of course been changing from the beginning of step S1 to the end of step S3, partly because of the results yielded by the validation process. Here are the periods of time during which the different steps of validation have been carried out, together with the versions of the ARPEGE source code which have been used for the runs :

validation step	**performed during**	**ARPEGE source code**
S1 : 12 situations	may 1992	analysis : CY8+bugfix forecast : CY9_3
S2 : parallel assimilation cycle	february-june 1992	from CY8 to CY9
S3 : parallel run of ARPEGE and EMERAUDE	july-september 1992	from CY9 to CY10i2

5. RESULTS OF THE VALIDATION IN NON-STRETCHED MODE

5.1. Step S1 : validation upon 12 independant situations (may 1992)

5.1.1. Purpose and definition

The purpose of this validation consists in an objective comparison of the EMERAUDE and ARPEGE forecasting systems, over a representative set of meteorological situations. In a first step, it has been decided to select situations all over the year in order to give the best representation of the annual cycle on the one hand, to span the global atmospheric variability in a convenient manner in the second hand, and at last to have a set of statistically independant elements. One situation at the beginning of each month seemed necessary to fill these conditions. Situations were chosen within the period **February 1989 - January 1990, the closest possible to the 1st of each month.**

The French archive system was used to retrieve, for each selected situation, the results from EMERAUDE analyses and forecasts from D to D+3, as well as the meteorological environment (guess fields at D-1, and observations) necessary for running the ARPEGE system.

The first twelve selected situations were:

89/02/01-05, 89/03/01-05, 89/04/04-08, 89/05/01-05, 89/06/01-05, 89/07/02-06, 89/08/01-05, 89/09/01-05, 89/10/04-08, 89/11/01-05, 89/12/01-05, 90/01/03-07.

5.1.2. Forecasting experiences and ARPEGE environment

For each selected situation, there has been a 24-hour data assimilation on the day D-1, followed by a 72 hour forecast (days D to D+3) :

- for day D-1 :
  - 00.UTC : ARPEGE analysis (EMERAUDE guess field basis); initialisation; 6-hour ARPEGE forecast
  - 06, 12, 18.UTC : ARPEGE analysis (ARPEGE guess field basis); initialisation; 6-hour ARPEGE forecast.
- for day D :
  - 00.UTC : ARPEGE analysis; 72-hour ARPEGE forecast with model outputs every 24 hours at D, D+1, D+2, D+3.

One must keep in mind that at this time of the ARPEGE validation (may 1992), the available source code of ARPEGE was not yet the operational version. That makes the results of this step S1 not fully comparable to those that could be obtained on the same situations at the end of step S3.

Main characteristics of the ARPEGE runs :

- ◊ assimilation cycle : 6 hour cycle; to initiate the cycle, we need a first guess from EMERAUDE. This EMERAUDE file is converted into an ARPEGE file and thus can be processed by the assimilation.
- ◊ analysis : at this time of the validation, the observation files are the same as for EMERAUDE assimilation. This allows an objective comparison between ARPEGE and EMERAUDE analyses. On the contrary, at this step of the validation, the ARPEGE analysis scheme cannot yet fully use the information of all the messages : for instance the EMERAUDE observation files only contain information from the standard levels of the TEMP messages.
- ◊ initialization : a non linear normal mode initialization was used, with 5 levels and 3 iterations, with allowance for tides.
- ◊ forecast : same configuration as EMERAUDE : T79, 15 levels, eulerian scheme (900s time step).
- ◊ post processing : all the comparisons between the new and the former model have to be made on the same **model-independent** basis. This supposes that the ARPEGE and EMERAUDE files are projected on the same grid with the same format. For this purpose, the "standard" BDAP (Analyzed and Forecast Field Database) format is used.

5.1.3. Strategy of verification

The verification of the ARPEGE outputs versus EMERAUDE outputs is carried out by computation of distances, scores on standard geographical domains. This objective verification is complemented with a subjective evaluation performed by a forecaster.
The reference analyses used for the verification of forecast and analyses fields are the 00.UTC EMERAUDE analyses with long cut-off time. This choice allows to have the same reference for both models and to prevent from a poor analysis quality of one of the models. In return, this choice slightly disadvantages ARPEGE. On the second hand, the **persistence** model (according to EMERAUDE analyses) has also been considered for comparison.

After the model runs, the comparison between ARPEGE and EMERAUDE is easily performed by the VERIFY software developed at Meteo-France on the same principle as at ECMWF. This software works on the BDAP format basis and allows the plotting of charts as well as the computation of difference fields and various scores.

5.1.4. Computed scores and verified fields

For each situation, spatial scores have been computed, for the 00, 24, 48, 72 hour forecasts and for the analyses.

The verified fields are : MSLP, T850, HU700, Z500, (u,v)500, (u,v)250, Z100.

The geographical domains are WMO standard domains :

- N20 (above 20°N)
- S20 (below 20°S)
- Tropics (20°N-20°S)
- Western Europe (35°N-60°N/20°W-20°E)
- Europe-Atlantic (30°N-70°N/55°W-35°E)

The computed scores for the comparison between forecasts and reference analyses are :

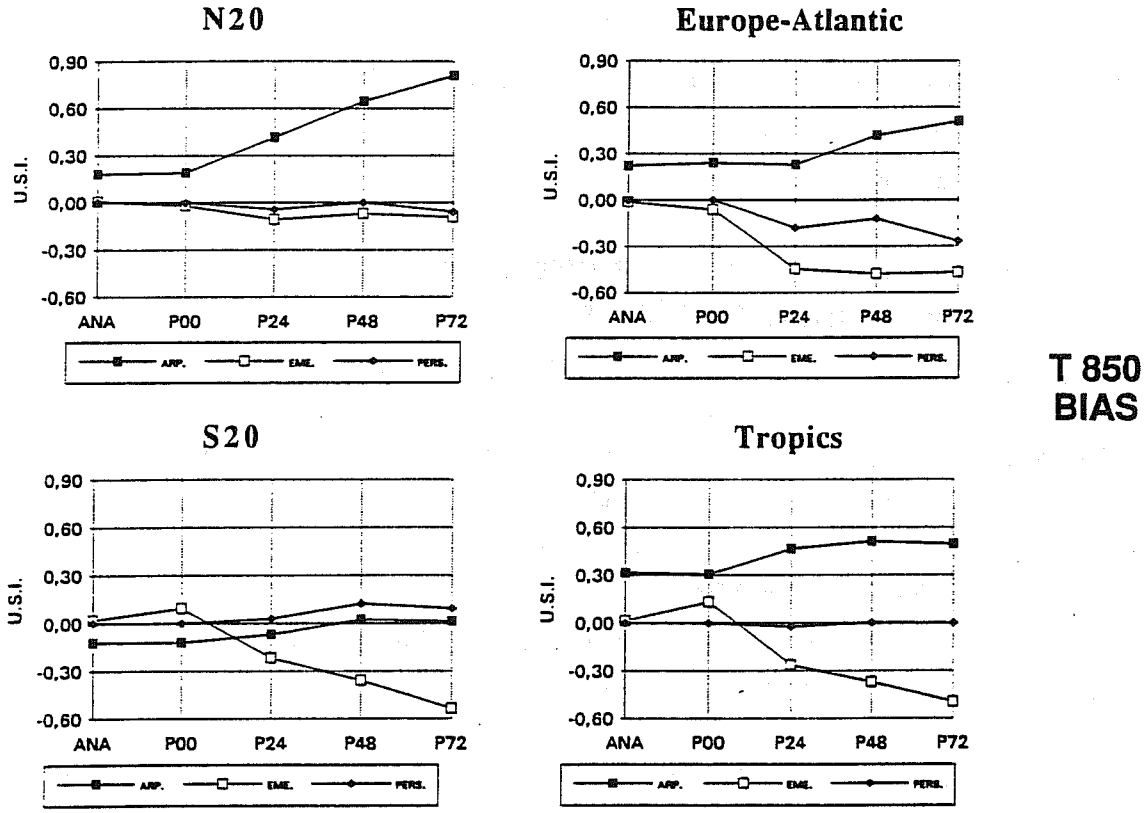
- bias (mean error between F and A)
- standard deviation (or vectorial standard deviation)
- RMSE (or vectorial RMSE)
- tendency correlation (for forecasts scalar fields only)
- anomaly correlation (for scalar fields only)

On this basis, synthetic scores have been calculated on the whole set of meteorological situations, in order to give a global evaluation of the models.

5.1.5. Results of S1

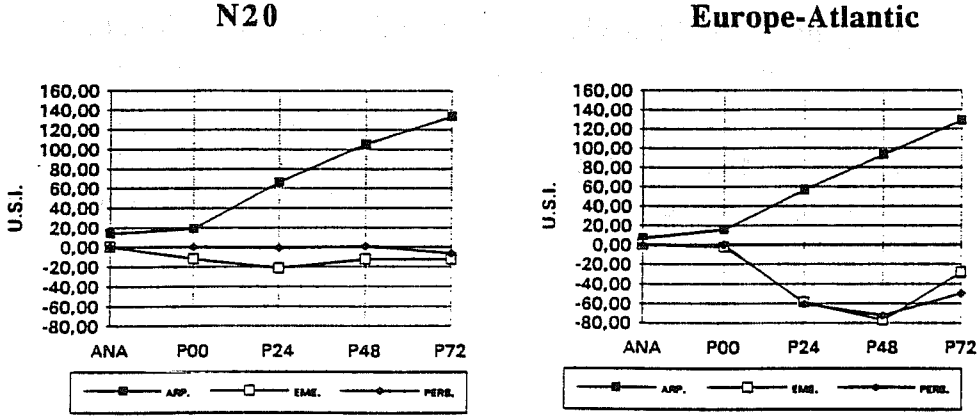
Statistical representativity of the sample: the synthetic scores obtained from the whole set of situations are strikingly similar to the preliminary results that have been obtained from two, and five situations. That shows the satisfactory speed of convergence of the evaluation results on a small sample. On the other hand, the observed stationariness of the mean forecast errors for persistence confirm the representativity of the sample. Therefore, this set of situations will be of interest for further validations, in particular on the occasion of major changes in ARPEGE code.

A warm bias is detected in the troposphere : at 850 hPa, ARPEGE shows a warm bias compared with EMERAUDE : this bias tend to correct the cold bias of EMERAUDE at this level, except in the North hemisphere where it introduces a warming that grows with range.



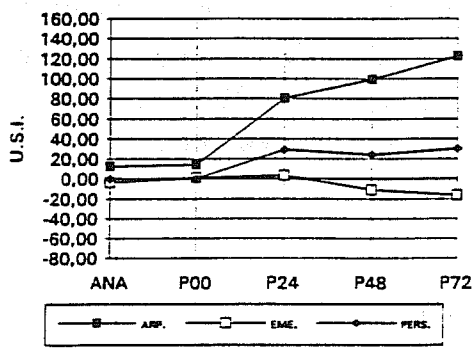
T 850 BIAS

This tropospheric warming is confirmed at 500 hPa, for which it occurs on the whole globe:

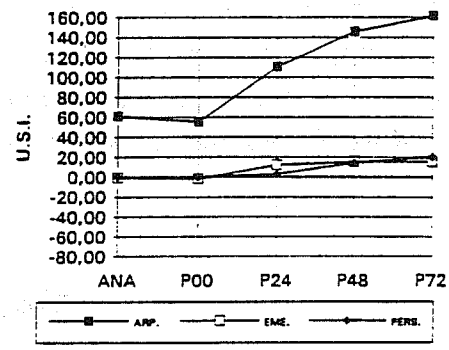


Z 500 BIAS

S20

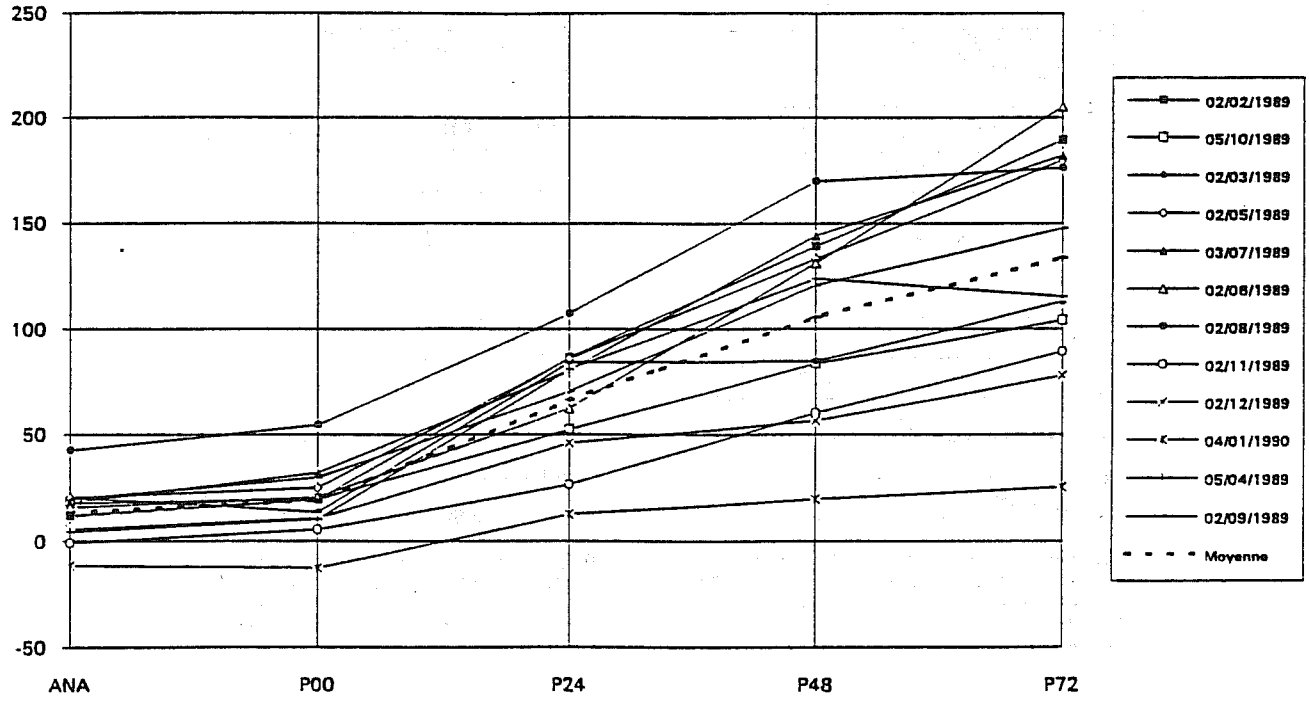


Tropics



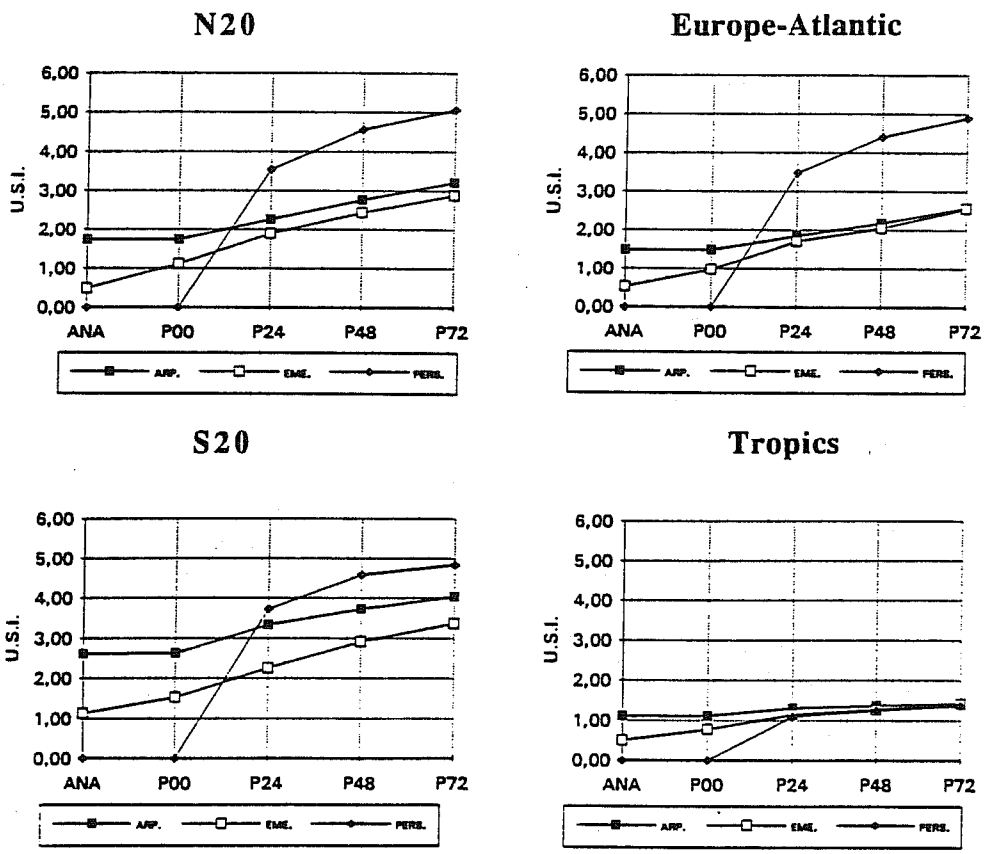
Z 500 BIAS

A plotting of the Z500 biases is carried out for the 12 situations, which confirms the diagnostic:



At this time of the development of the model, ARPEGE is not as good as EMERAUDE, except at Z100 where the error is lower for ARPEGE, the RMS error is slightly higher in the N20 domain and a bit more important elsewhere. This may be explained by important differences in the analyzed fields. These differences may come either from a bad ARPEGE analysis, or from the fact that the ARPEGE assimilation is only 24 hours long for this experience.

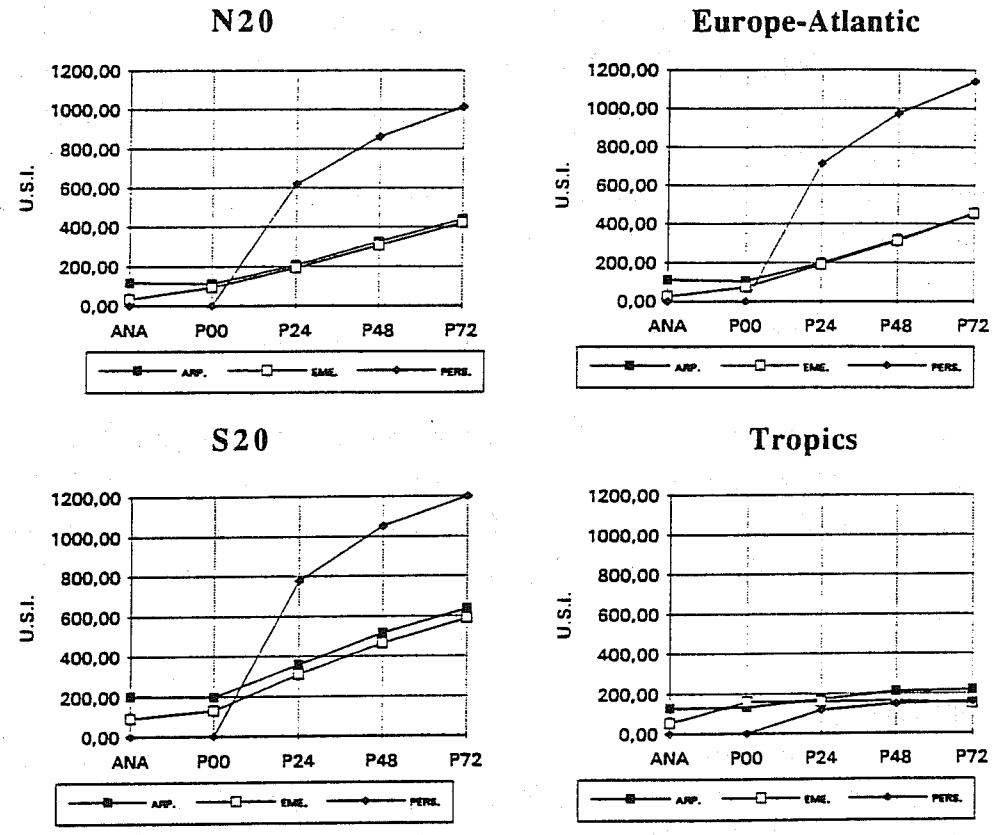
RMS T850



By-product : it is interesting to notice the impact of the cut-off time on the EMERAUDE analyses through the RMS difference between the operational analysis (white squares) and reference analysis (horizontal axis).

The same construction can be done at 500 hPa (geopotential height):

RMS Z500



Verification by forecaster: a forecaster has focused on the Europe-Atlantic domain ARPEGE and EMERAUDE outputs. On the set of situations, he found no significant difference between the two models except the tropospheric warm trend and a tendency to be a bit more energetic in dynamic situations for ARPEGE.

Conclusion : at the end of this step S1, the forecast part of the ARPEGE system has proved satisfactory enough to go on with the validation process. The main problems detected during this step were the tropospheric warm trend and a possible bad working of the ARPEGE analysis at that time. The choice of EMERAUDE analyses as reference analyses may look disputable since these analyses are not perfect. That is why an objective triangular comparison between ARPEGE, EMERAUDE and ECMWF model is presented in the next section.

5.2. Step S2 : monitoring of the parallel ARPEGE assimilation cycle (february-june 1992)

5.2.1. The context of evaluation of the cycle

A parallel assimilation cycle has been run since December 1991. This cycle was initially a T42 12 hour cycle, and then became a T79 6 hour cycle by the end of March 1992. Although it was possible to evaluate this parallel assimilation cycle after February 1992, the daily monitoring only began on 20th March, 1992.
Since the spatial quality control of the observations was put into operation only on 2nd May, 1992, we present validation results from this date.

The characteristics of the ARPEGE cycle are quite the same as for the step S1.

To give sense to the evaluation of the cycle, it was decided, together with the ARPEGE project head, that the necessary modifications to the code should be made only every 10 days, which would make possible the evaluation of the impact of the modifications. In fact, until the end of June, errors occurred too frequently and this rule was not followed : the cycle was reinitiated at each time with EMERAUDE guess fields.

5.2.2. Monitoring strategy

The common basis of comparison of the numerous fields produced by the cycle is again the model-independent "BDAP" format. The French BDAP database is routinely fed with EMERAUDE analyses, and with ARPEGE analyses and forecasts, as follows:

- ◊ verification analyses AE and AA : every 6 hours (00, 06, 12, 18.UTC), from EMERAUDE and ARPEGE
- ◊ ARPEGE forecasts FA0 and FA6 : ranges 0 (initialized analyses) and 6 hours (guess fields) from the ARPEGE analyses.

The evaluation that have been made consists in triple comparison :

- ◊ the AE/AA comparison gives an idea of the distance between the analysis schemes of the two models and the time series of the results is a good indicator of a possible divergence of ARPEGE from EMERAUDE.
- ◊ the FA6/AA comparison gives a measure of the increments that are produced by the ARPEGE analysis scheme.
- ◊ the FA0/AA comparison evaluates the impact of the NNMI within ARPEGE.

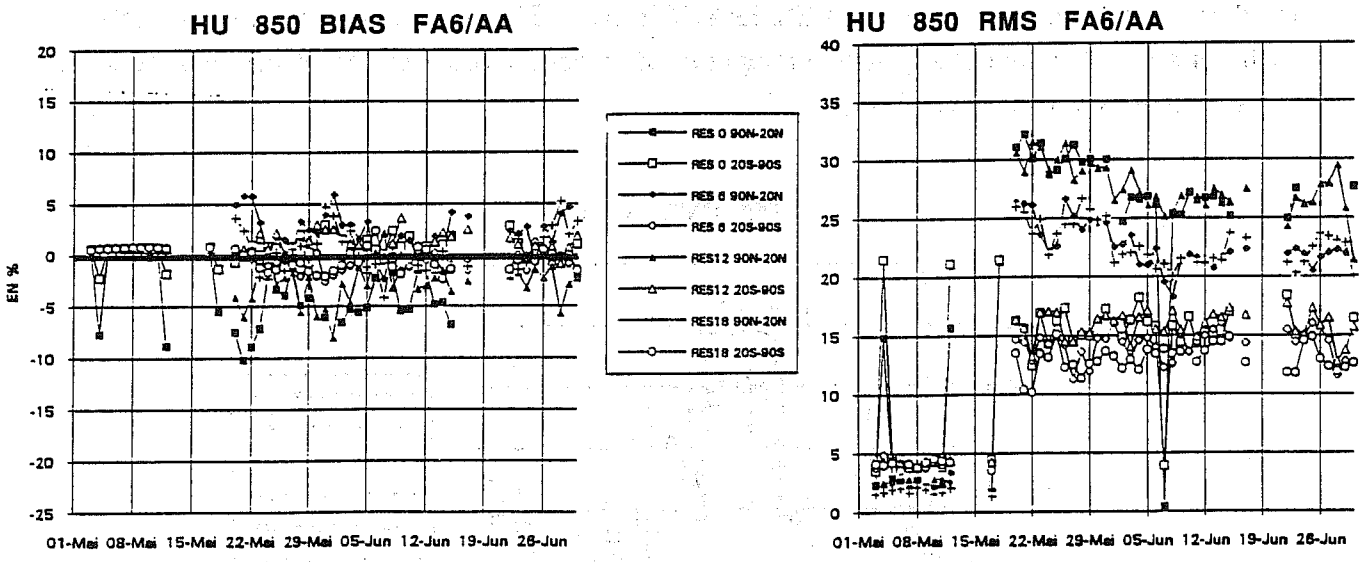
The individual daily scores computed during this step are the same as during step S1; every 6 hours they are computed over the same areas for the same meteorological fields. Furthermore, monthly scores may be computed if the cycle works continuously during the month (this has not been the case until July 1992). In a favourable case, it would be possible to plot charts of these scores, which show the geographical patterns of the increments or of the differences AA/AE (see next section for an example).

5.2.3. Results

All the time-series of daily scores have been plotted over the time-period May-June 1992.

Comparison between ARPEGE guess-fields (FA6) and ARPEGE analyses (AA) : this comparison reflects the efficiency of the analysis scheme in ARPEGE. The warm bias that had been detected in the forecasts during step S1 is confirmed by a "cold" bias (5 metres at Z500) of the analysis increments.

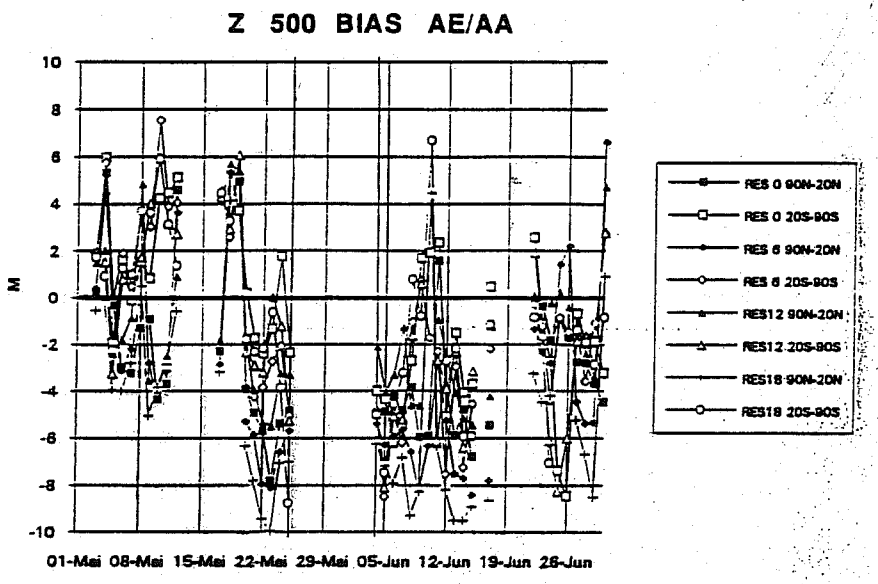
On the other hand, it can be seen for instance that before the 15th of May 1992, the HU850 analysis was inefficient (it was the case for all the HU fields).



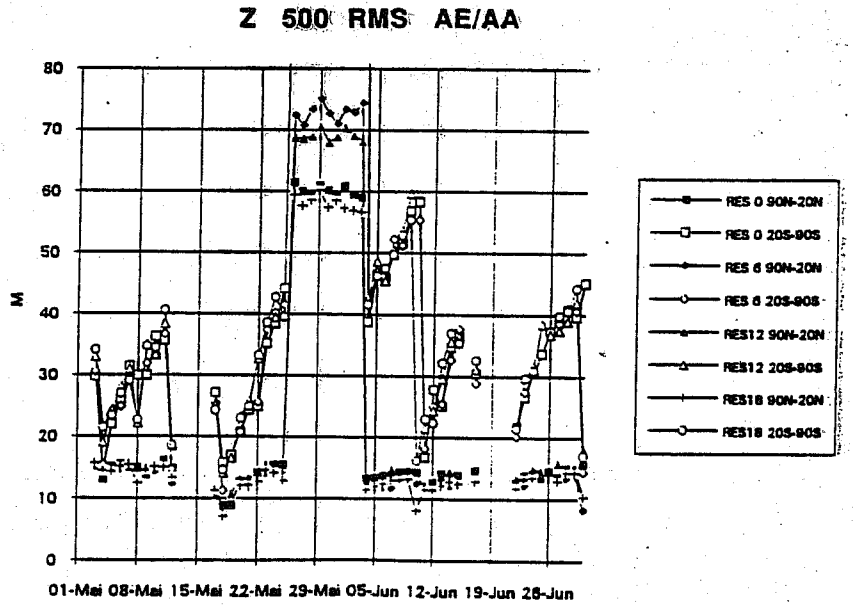
black symbols for north hemisphere, white symbols for south hemisphere

From this date, we can see that the analysis increments become strong and higher over N20 than S20, and at 00 and 12.UTC than at 06 and 18.UTC (see next section for the reliability of these increments).

Departure of the ARPEGE analyses (AA) from the EMERAUDE analyses (AE) : as an example, the next figure shows the time evolution of the mean and standard deviation of the differences AE-AA.

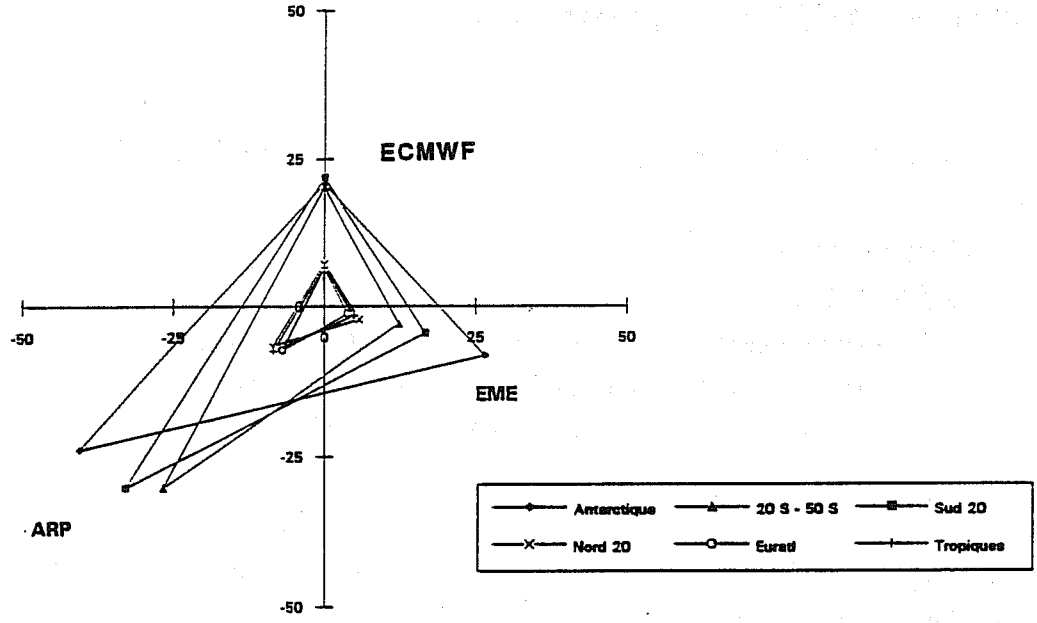


Except the May 25th-June 04th period (bug in the post processing), the curves show dramatically different results on the N20 and S20 domains: the distance AA/AE (as illustrated by the standard deviation of AE-AA) looks constant over the N20 domain while it shows a dangerous positive trend with time after each restart on EMERAUDE basis. The two analyses tend to depart from each other and there is not any long enough period of continuous working of the cycle to let us see a possible stationariness of this trend.



Triangular comparison ARPEGE/EMERAUDE/ECMWF : it has been seen than strong differences may exist between EMERAUDE and ARPEGE analyses after several days of assimilation. These observed differences may come either from ARPEGE or from EMERAUDE. In order to make sure that the problem lies in the ARPEGE assimilation scheme, an analysis is retrieved from ECMWF is converted onto the same basis (BDAP format) . The date of June 9th, 1992 has been chosen because it shows the highest standard deviation between the two models (see previous page).

The conversion from a T213L31 ECMWF file to a T79L15 ARPEGE file is made in two steps. Then the ARPEGE file is again converted onto the same BDAP format than the EMERAUDE and ARPEGE analyses. The VERIFY software yields all the possible scores between the 3 analyses.



This figure shows in a triangular form, and for several geographical domains, the positions of the Z500 fields analyzed by the three models. It is noticeable that the distances ARP/ECMWF are higher than the distances EME/ECMWF, which shows that if ECMWF is assumed to be the reference in meteorological analysis, residual problems may lie in the ARPEGE assimilation scheme.

The charts from Annex 1 give the reason for the high distance ARP/ECMWF: the ARPEGE analysis tends to produce a too zonal pattern in the Southern Hemisphere, probably because of an insufficient use of the observations.

Conclusion : this S2 step is complementary from the previous one. It was very important to monitor a real parallel assimilation cycle. This has led to the detection of a systematic divergence between the operational and the experimental assimilation schemes, especially on the Southern hemisphere. Such a feature could not have been detected during step S1 because the assimilation was too short.

5.3. Step S3: parallel run of ARPEGE and EMERAUDE suites (July-September 1992)

It was planned initially that this final step should last about 15 days and should be launched only on the basis of satisfactory results from the previous validation steps. In the reality, things were more complex.

After the warm bias on the model and the divergence of the cycle were brought to light, it was decided that this phase would last longer than planned, at least for the 2 summer-vacation monthes.

It was also decided to spend one month whith "final stabilized" code before getting rid of EMERAUDE, in order to study the behaviour of statistical temperature forecasts made every day by adaptation of PERIDOT. These forecasts are operationally very useful, so we have to continue to perform them with ARPEGE replacing EMERAUDE.

The choice was made to build a parallel suite to EMERAUDE with ARPEGE so that every day there would be :

- a full assimilation cycle
- a 72h forecast from 00. UTC
- a fine-mesh forecast by the mesoscale model PERIDOT coupled with ARPEGE.
- during the last month two temperature forecasts on 169 places in France, by adaptation of PERIDOT/EMERAUDE and of PERIDOT/ARPEGE.

The end of this period was scheduled for the beginning of September 1992. It was expected that this step would yield interesting results :

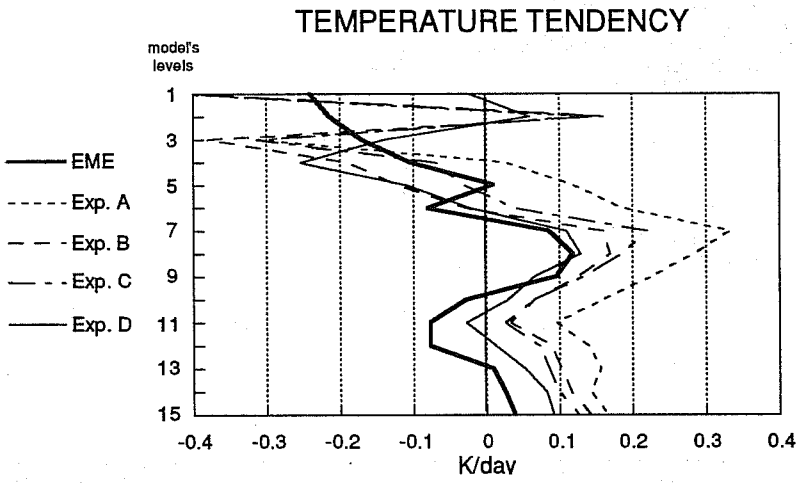
- on the way the known shortcomings would be corrected
- on the skill of the ARPEGE forecast model using a long assimilation cycle.
- on the sensitivity of the mesoscale PERIDOT model to initial conditions (coupling with EMERAUDE or ARPEGE).

Different aspects of that double suite are treated below; they are not classified in chronological order, but by explained phenomenon.

5.3.1. Bias in temperature

As discovered by performing step S1, ARPEGE produces a warm bias in the troposphere at the beginning of step S3. One of the purposes of step S3 is to reduce, as much as possible, this warm bias.

Some experiments have been done by adjusting physical parameters: optical coefficients, water content and precipitation thickness of clouds, in stratiform as well as convective case. This adjustment, made in collaboration with our climate research group, took place in 4 steps named A, B, C and D in the figure below. D is now the current state of ARPEGE; it works since August 27th.



Computed on the test-situations from step S1 (§ 5.1)

Some energy budgets have been computed, corresponding to these steps. The values are yearly averages given in W/m^2:

	EMERAUDE	EXP A	EXP B	EXP C	EXP D
Top net flux	12.74	25.40	3.29	3.26	0.58
Bottom net flux	-19.75	-14.42	-4.00	-2.65	1.53
Δs	-4.67	12.68	-0.39	3.12	0.24
ΔLq	-1.65	-2.11	-0.71	-2.92	1.41
Δh	-6.32	10.57	-1.10	0.20	1.65
ΔKE	-0.39	-0.31	-0.30	-0.29	0.00

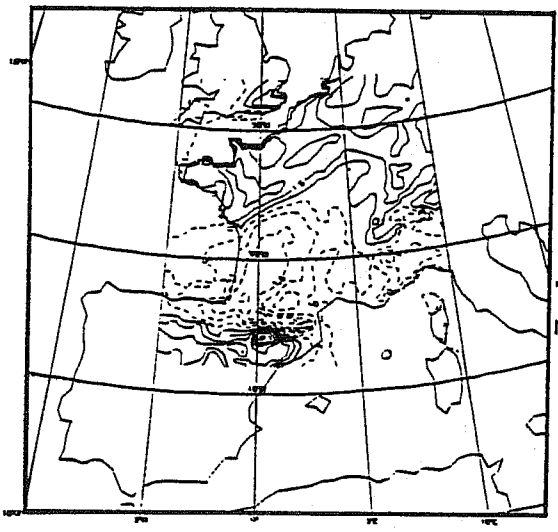
(friendly supplied by J.F. Geleyn)

One can state that the warm bias is strongly reduced !!!

5.3.2. Humidity analysis

A particular problem was not identified at the end of step S2, although it was maybe possible to discover it at this stage: the humidity analysis was incorrect.

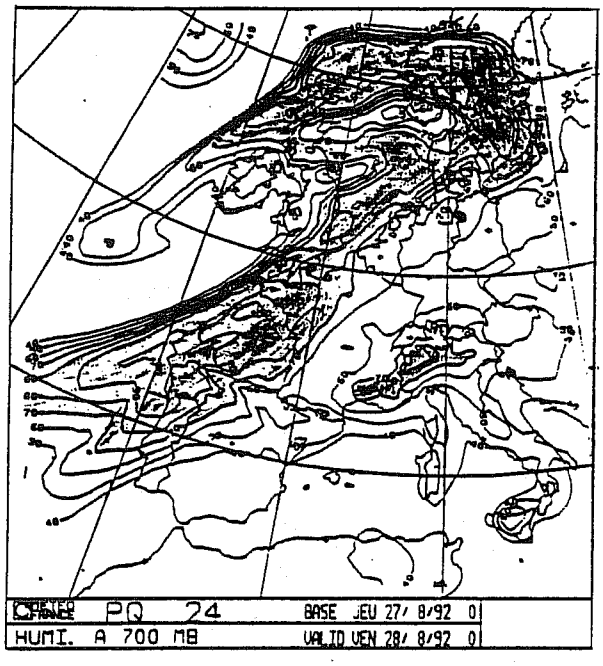
We discovered it by concentrating on 2m temperature forecasts produced by both PERIDOT versions (coupled by EMERAUDE vs. coupled by ARPEGE), between which the difference was sometime large: here is the difference in 2m temperature between these models.



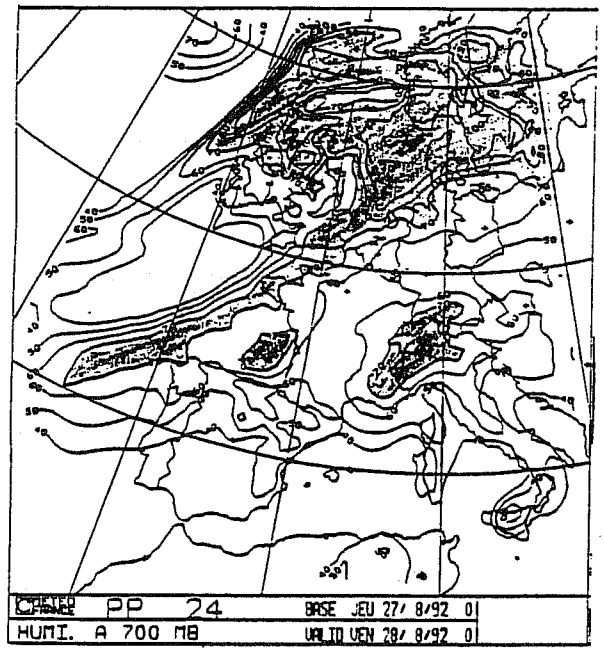
Base: August 27th

Range: 24h

Such differences over Brittany are suspicious. Relating to the humidity fields, one could observe (considering areas where HU>70%):

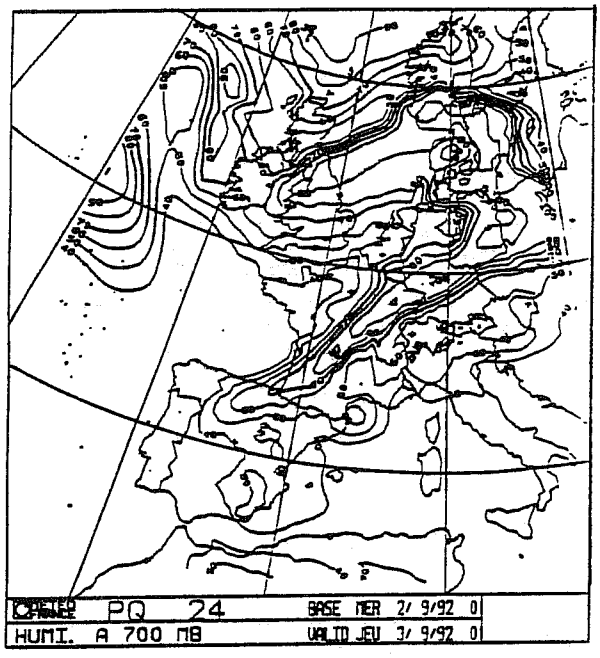


Coupled with ARPEGE

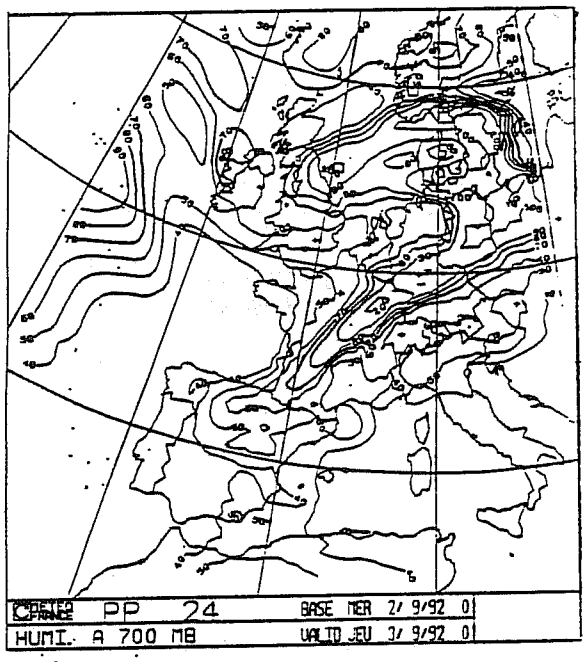


Coupled with EMERAUDE

After correction of ARPEGE's analysis (which occured on August 29th), the differences between both PERIDOTs have been reduced to "reasonable" values: here are the same charts, September 2nd, for the same range (24h).



Coupled with ARPEGE



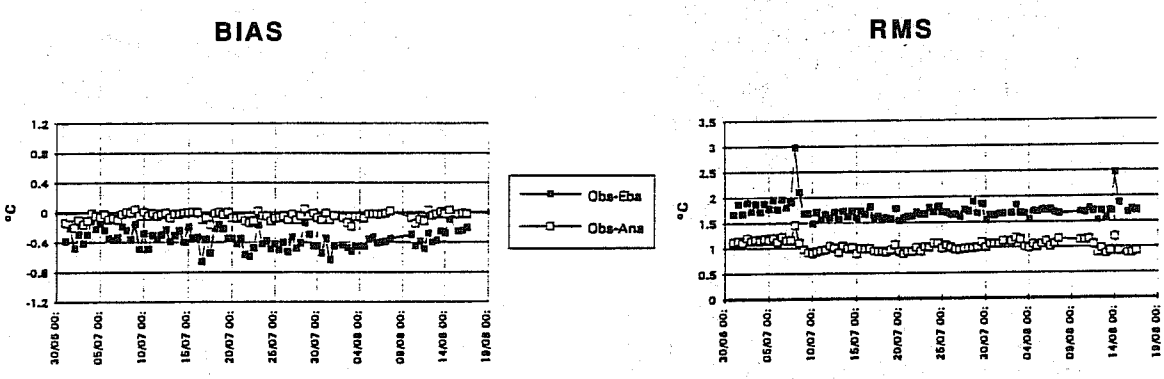
Coupled with EMERAUDE

Although PERIDOT's analyses were exactly the same, one could see a major impact of the initial and boundary conditions given by the coupler model. This allows us to expect some forecast improvements by using a single stretched model in the future.

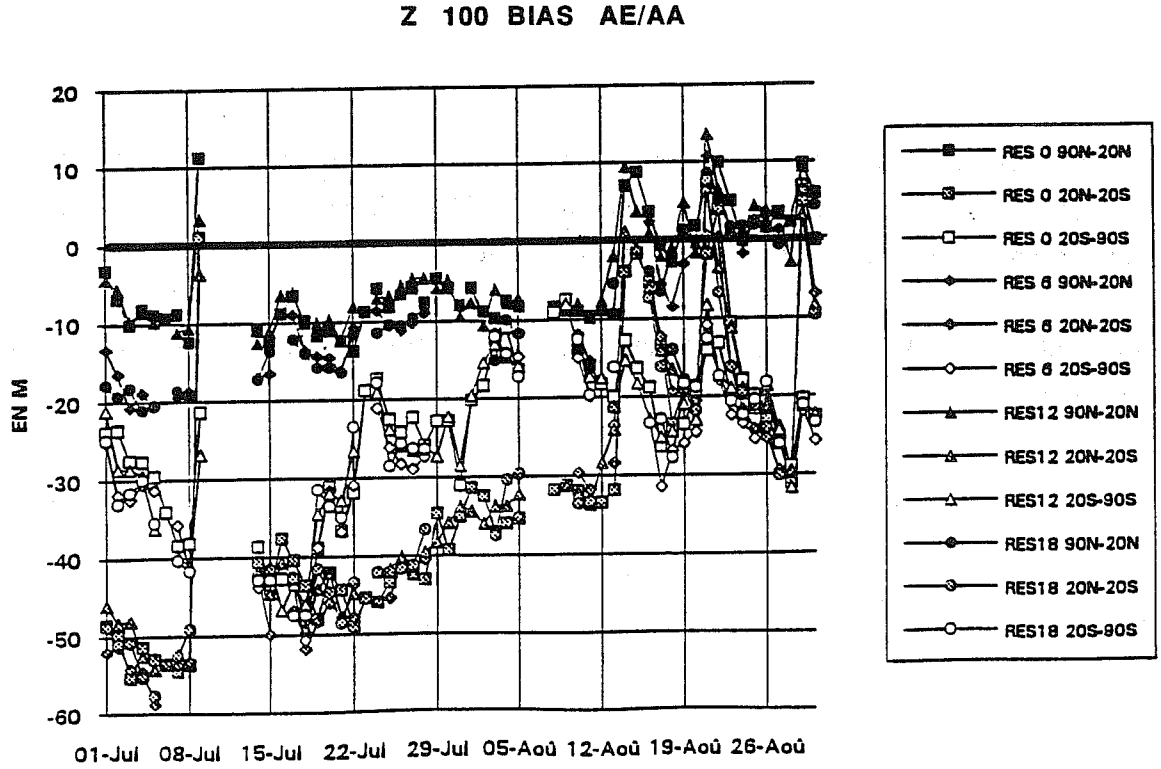
Please refer to § 5.3.4 and 5.3.5 for further details about the impact of a new coupler model on PERIDOT.

5.3.3. Monitoring of data assimilation

Moreover, the monitoring of the data assimilation was continued. New data monitoring tools were developed to give elements on the use made of observations by the ARPEGE analysis scheme. For example, here are given the bias and the RMS between radiosonde observations (Obs) and analysis (Ana) or guess field (Eba — due to the french name "Ebauche"), for the N20 domain:

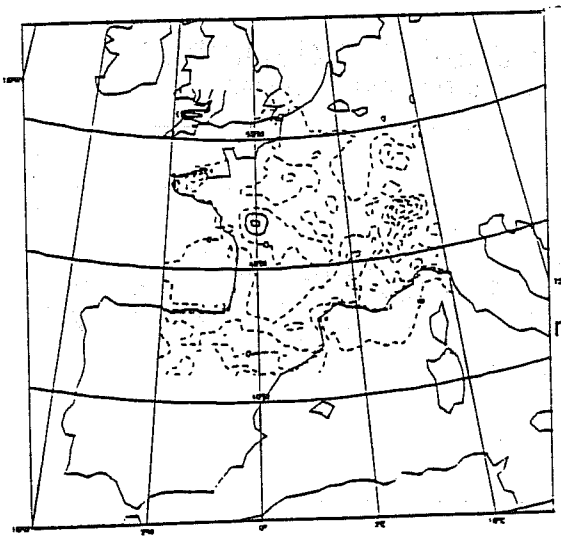


The latest results show the improve of quality due to both corrections on temperature bias and on humidity analysis:



5.3.4. Impact on PERIDOT

As we saw by speaking about humidity analysis, the main impact on PERIDOT was due to that feature. Here is an example of difference of temperature forecasts after humidity analysis correction, for the same date as shown above:



Base: September 2nd

Range: 24h

5.3.5. Impact on statistical adaptation

As explained above, an error in the humidity analysis caused some trouble on PERIDOT's temperature forecasts. The statistical adaptation of these forecasts, which usually reduces the RMS of the error from about 3.5° to less than 2°, was of course also affected by this error: as Model Output Statistic (MOS), it only uses the direct 2m temperature output as predictor.

The current operational method is based on a projection of the 2m temperature observed field on its first 15 principal components, and after on a regression between this projection and the forecasted fields. This gives a set of regression equations, which is applied every day.
Here are presented some results that have been obtained using only 10 principal components, in order to keep a sufficient stability by replacing EMERAUDE by ARPEGE.

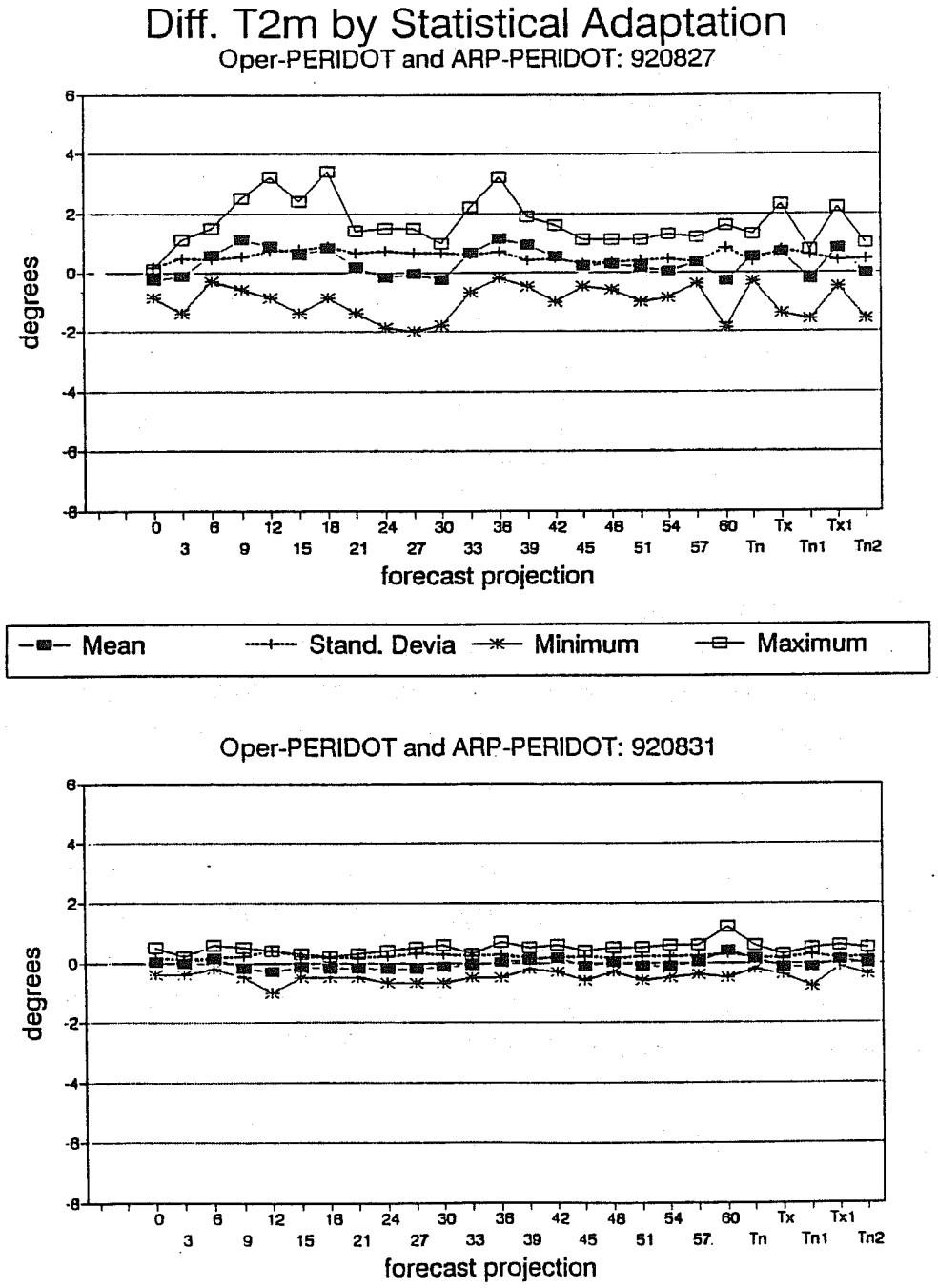
The same set of regression coefficients is of course used for both PERIDOTS.

Hereafter are two examples of behaviour of the statistical adaptation computed on PERIDOT/ARPEGE vs. computed by PERIDOT/EMERAUDE:

◊ the first one before the correction of humidity analysis, showing a high dispersion

◊ the second one after correction, with nicer behaviour.

Values are computed for a set of 169 French weather stations.



5.3.6. Evaluation by forecasters

As part of the evaluation of the new ARPEGE model, forecasters have at their disposal some direct outputs from this model since the end of June 1992. These products, on EURATL domain, are:

- ◊ MSLP and 1000/700hPa thickness
- ◊ temperature and geopotential height at 700 and at 500 hPa
- ◊ 500 hPa absolute vorticity
- ◊ 700 hPa vertical velocity

Every day, the fields from both models are compared (0. UTC run): the analyses, and the 24h, 48h, 72h forecasts. The main features are:

- a problem in data assimilation was detected: surface observations related to a low over Ireland were wrongly refused in ARPEGE's analysis. This anomaly was immediately pointed out to the numerical development team, and corrected.
- in case of disagreement between ECMWF and EMERAUDE, ARPEGE seems to be in general closer to ECMWF, although its characteristics are very close to EMERAUDE's. That may be due to the improved physics in ARPEGE.

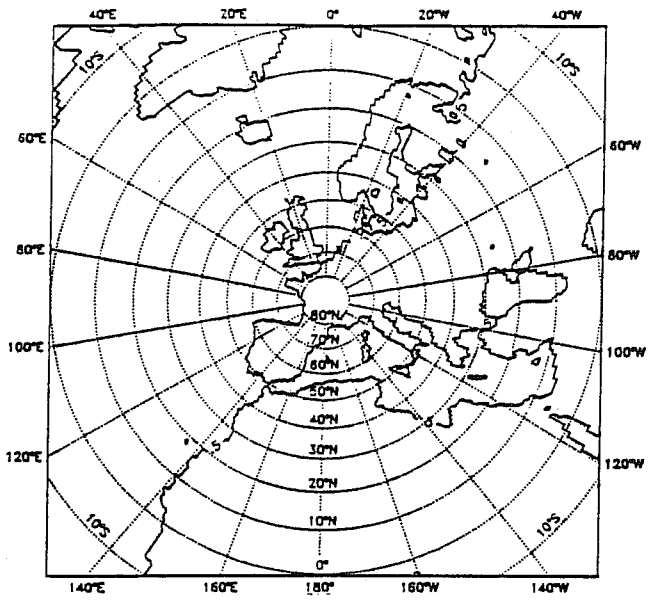
So the first impression given by ARPEGE is a surprise: model conceivers always said that ARPEGE shall be very close to EMERAUDE, due to similar characteristics, and the forecasters were expecting a relatively "soft" model. In fact they have found a more energetic, active and contrasted model.

An example of disagreement between ARPEGE and EMERAUDE is given in Annex 2, as well as the same forecast by ECMWF model and the corresponding analysis.

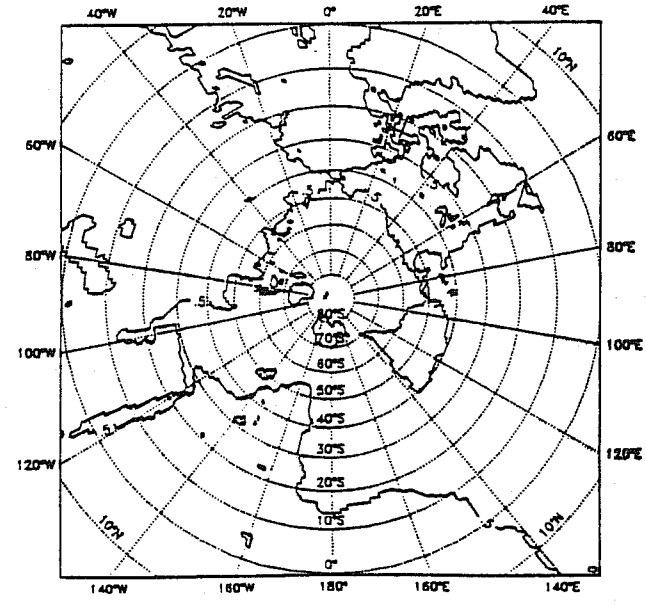
6. PLANS FOR 1993

6.1. Stretched mode

The validation of ARPEGE in stretched-mode brings some new problems: one can estimate them simply by considering the geometry of both hemispheres of the transformed sphere (C=3.5):



"North hemisphere"



"south" hemisphere

These maps show clearly that the approach we followed in non-stretched mode is no longer usable:

◊ on the "real" sphere, regions in the vicinity of France have a much greater influence on scores than other regions. So we have to be very careful by choosing a set of test-situations: in non-stretched mode one can consider that there are always regions with active phenomena and regions without active phenomena, and the first of each month is a good sample. On the contrary, in stretched-mode, there isn't always an interesting phenomenon in the vicinity of France. So forecasters from the French regional services have been requested to choose "interesting" situations, including local phenomena.

◊ due to the postition of the streching-pole at 45°N, standard zonal domains like WMO's are not adapted to the variable resolution: each domain contains low-resolution and high-resolution areas.

We have decided to concentrate on local domains provided by the BDAP database. As explained above, this database provides a model-independent format.
We will of course continue to produce scores on standard domains, but their importance for helping us in the validation will be lower than in non-stretched mode.
Finally, the data assimilation cycle will be strongly tested, because it seems to be one of the most difficult problems caused by variable-mesh.

6.2. Hyper-stretched mode vs. ALADIN

ARPEGE, as single model, allows us to make predictions at about 30km equivalent horizontal mesh. Some experiments have shown that there is an interest in making predictions at higher resolution, even when no observations are available at such a resolution:

- ◊ research version of PERIDOT (mesh: 10 km): see Ph. Bougeault's lecture (sem. 92-ECMWF)
- ◊ "SUPER-PERIDOT" (mesh: 3.5km) for the winter Olympic Games

Several ways can be followed in order to make predictions at 10 km resolution:

- ◊ use of ARPEGE in an "hyper-stretched" mode

  For example, a T127 C10 version leads to 10 km resolution near the stretching-pole, 1000 km at the antipode. We can expect predictions up to 24 hours. Of course the problems in data assimilation or physic parametrizations over the "transformed sphere" are more acute than in "normal-stretched mode"
- ◊ use of a limited area version of ARPEGE, coupled whith the operational ARPEGE version

  Such a version is now being developed, in pure adaptation mode (no data assimilation). It is called ALADIN. As part of ARPEGE it is a spectral model, unlike PERIDOT.
- ◊ use of a new non-hydrostatic model

  10 km in horizontal mesh is known to be the approximate limit under which non-hydrostatic effects begin to be large. Some non-hydrostatic models are now existing, in research mode. However, they are not ready to function now operationally (every day, with real observed data...).

So Météo-France has decided to develop both approaches hyper-stretched ARPEGE and ALADIN, and to compare their results at the end of 1993. Furthermore, a specific research effort in the non-hydrostatic domain is planned, in order to prepare the next generation of operational models.

7. CONCLUSION

This work is the first step of the validation of ARPEGE/IFS for short-range predictions. Although the current operational state of ARPEGE/IFS is not significantly better than EMERAUDE's, the effort on validation has been very profitable:

◊ it allows problems to be separated: a simultaneous validation of a new code, with semi-lagrangian scheme, with analysis and forecasts in stretched mode could lead to unexpected difficulties...

◊ a lot of problems which have been solved are valid for the stretched-mode

◊ new young people working in NWP teams have acquired experience in analyzing the behaviour of numerical models

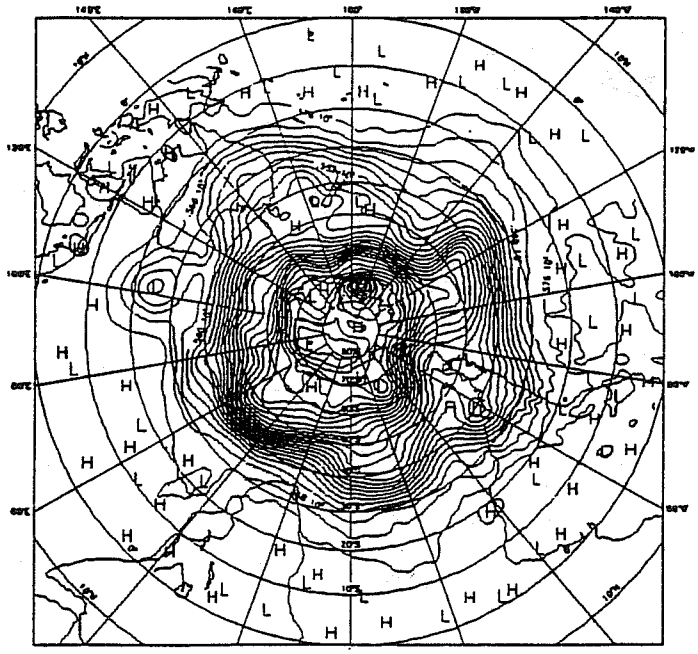
◊ we have now a new knowledge on problems occuring by coupling models and/or statistical adaptations; that will be useful e.g. for studying ALADIN

◊ **We probably can get rid of EMERAUDE at the end of September 1992**

8. ANNEXES:

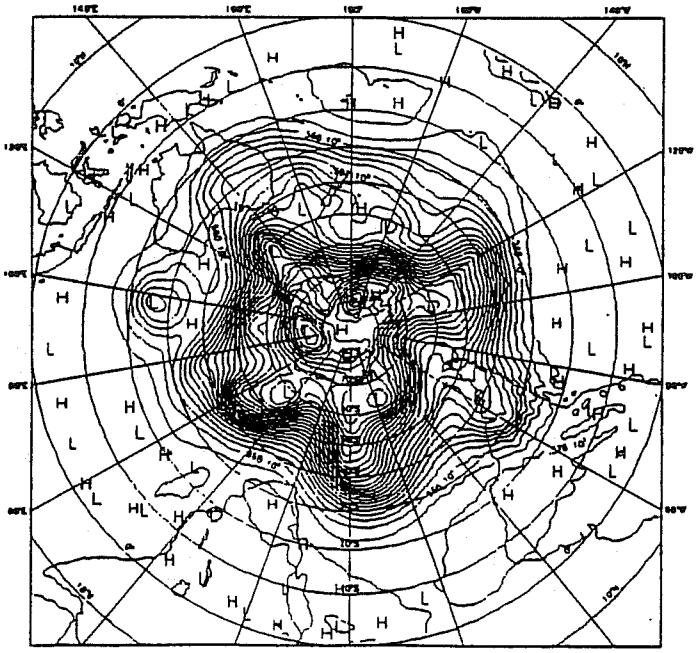
A-1: ARPEGE ANALYSIS VS. ECMWF ANALYSIS, JUNE 9th 1992

Min : .455 10^5 Max : .581 10^5 Moy : .551 10^5 Rms : .552 10^5



ARPEGE Southern hemisphere

Min : .462 10^5 Max : .578 10^5 Moy : .550 10^5 Rms : .551 10^5



ECMWF Southern hemisphere

A-2: EXAMPLE OF DISAGREEMENT EMERAUDE/ARPEGE

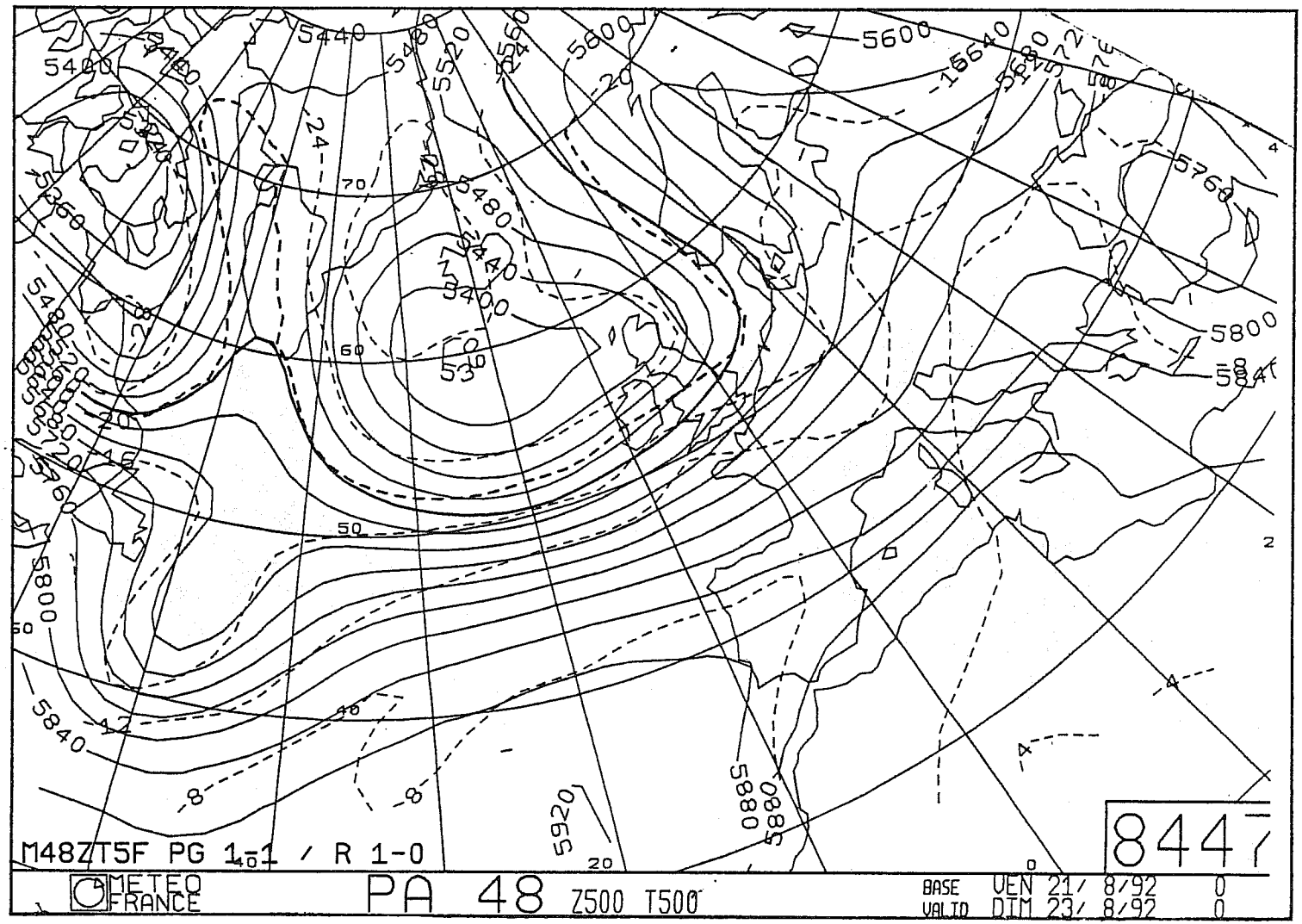


Fig. 1 ARPEGE 48 h forecast for 2 and 500 hPa (valid 23/8/92 00 UTC).

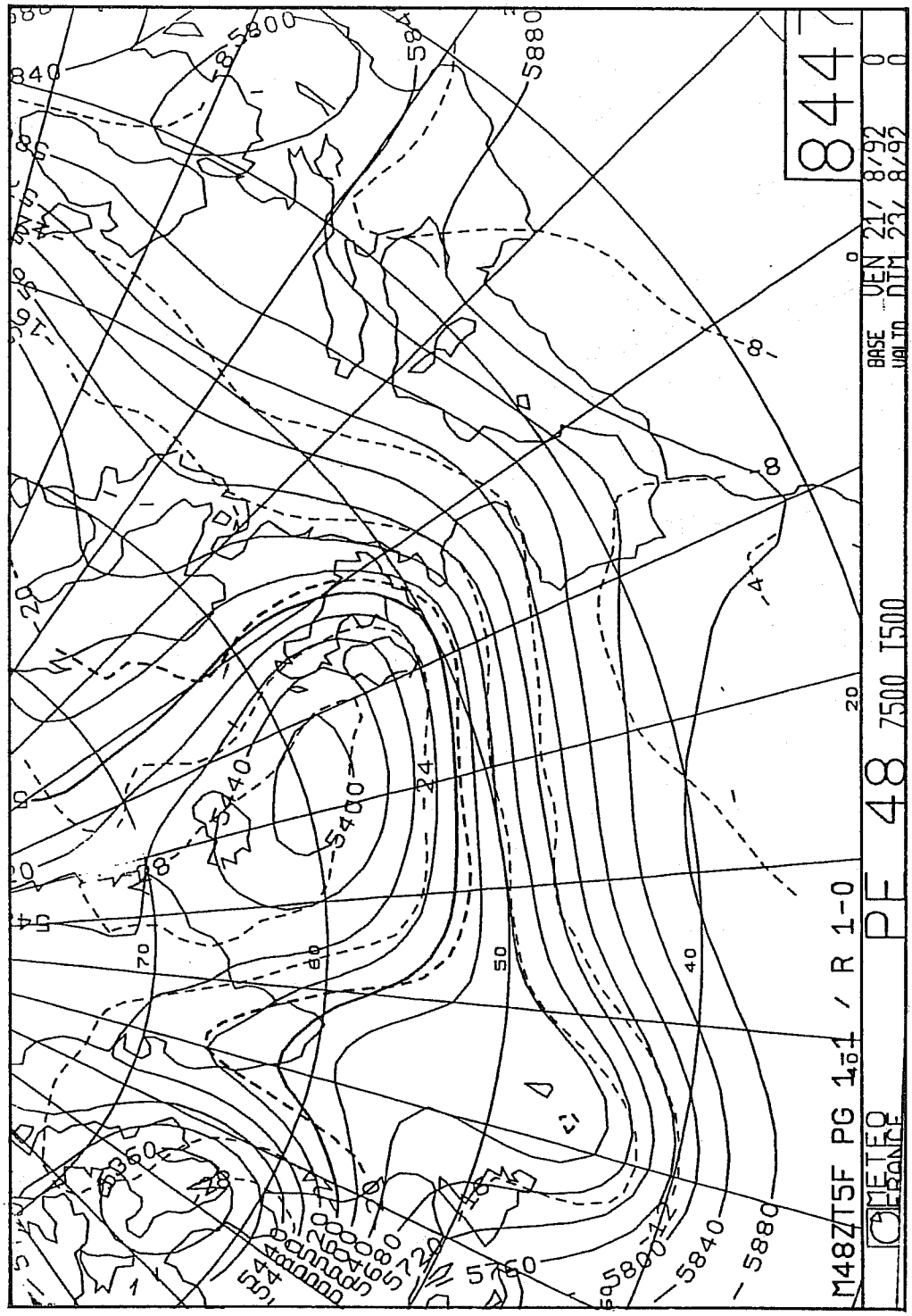


Fig. 2 Same as Fig. 1 but for EMERAUDE.

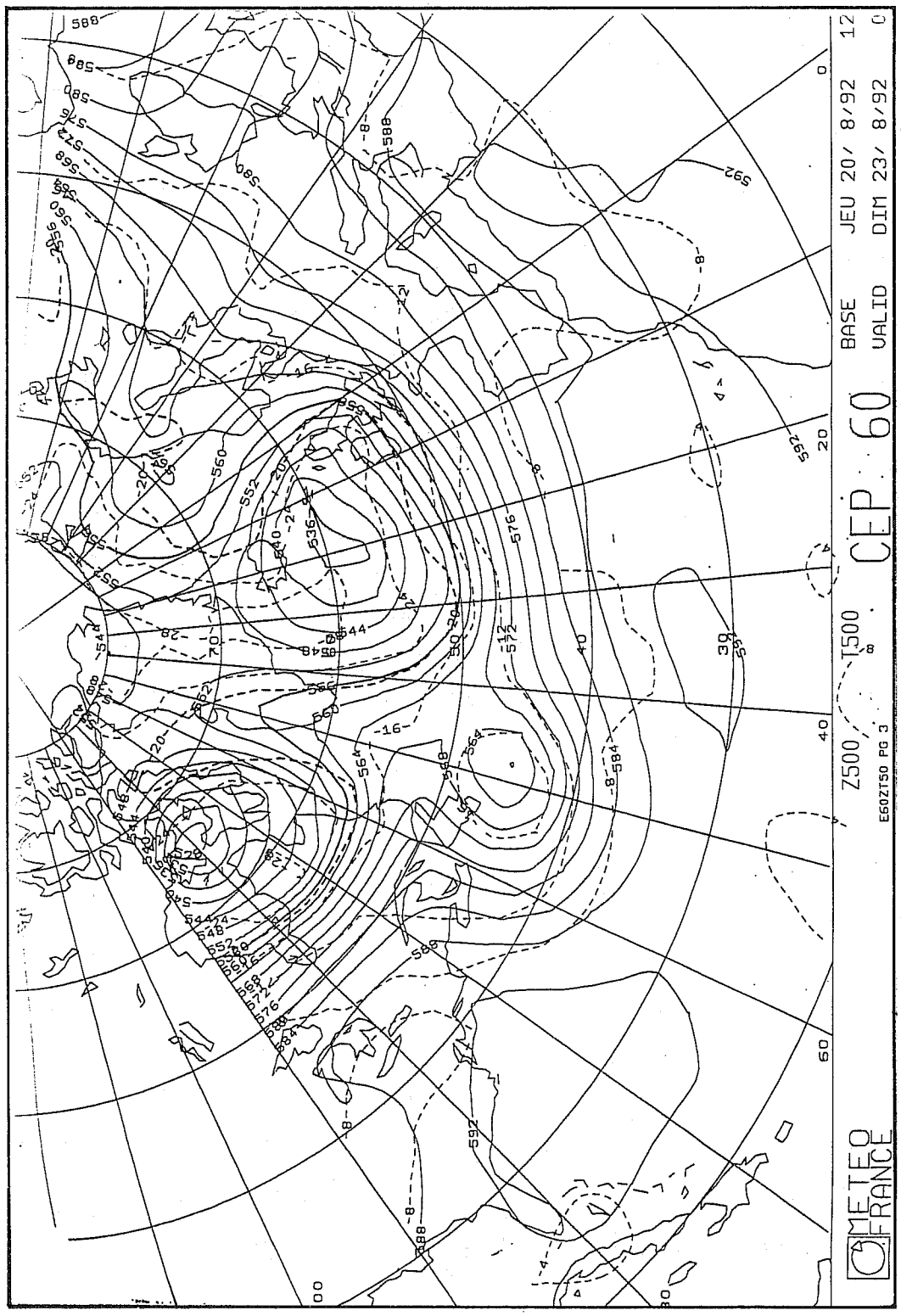


Fig. 3 Same as Fig. 1 but for ECMWF (12 hours sooner).

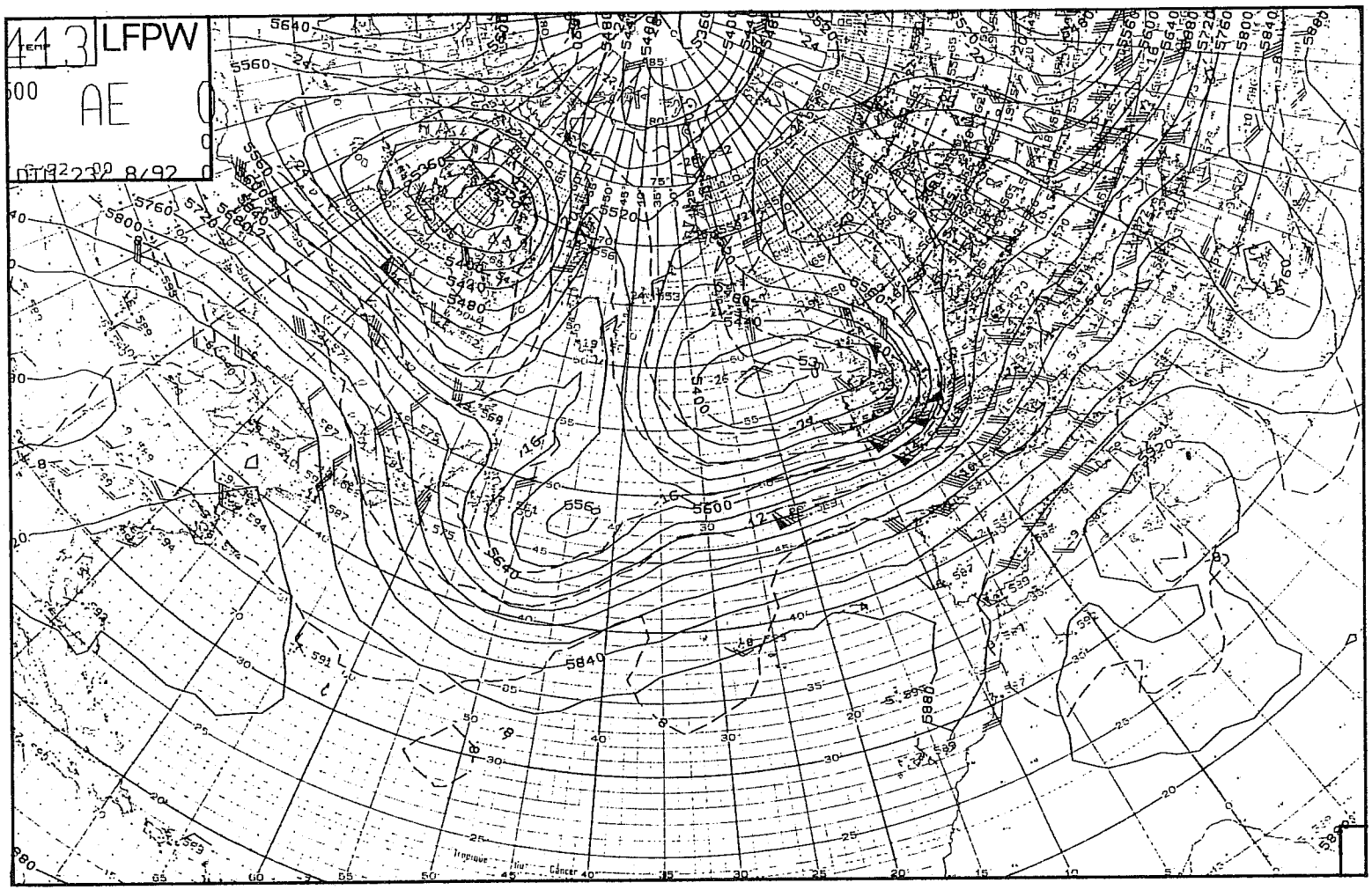
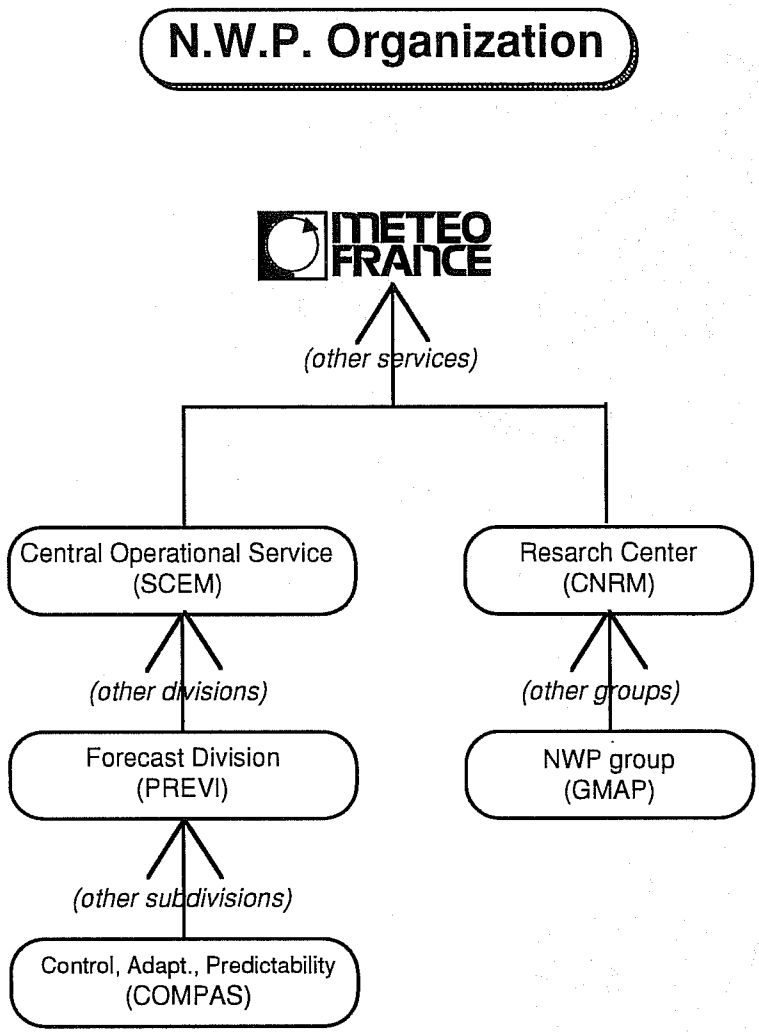


Fig. 4 Analysis 2 and T 500 hPa for 23/8/92 00 UTC, by EMERAUDE.

A-3


N.W.P. Organization
METEO FRANCE
(other services)
Central Operational Service (SCEM)
Resarch Center (CNRM)
(other divisions)
(other groups)
Forecast Division (PREVI)
NWP group (GMAP)
(other subdivisions)
Control, Adapt., Predictability (COMPAS)