# TESTING THE NORTH ATLANTIC OBSERVING NETWORK USING DIFFERENT ANALYSIS SCHEMES.

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Abstract: Two kinds of experiments concerning the North Atlantic observing network are performed:

- Different configurations are imagined for the future observing network, then they are tested by network studies using a multivariate optimum interpolation analysis scheme.

- The impact of high resolution satellite data on short-range forecasts is examined through the French fine-mesh numerical prediction system (called the "Peridot" system).

## 1. INTRODUCTION.

The North Atlantic observing network is very important for short-range forecasts over Europe. For several reasons it is likely that this network will change in the next few years: development of new observing systems (ASDAR, ASAP, drifting buoys), and the high costs for the present weather ships. So it is interesting to study in details the present and the future North Atlantic observing systems by carrying out several tests, including numerical experiments like OSE's and OSSE's.

In the work which has been initiated by the WMO bodies concerning the future Global Observing System (GOS), special attention is given to the

"Composite Observing System for the North Atlantic" (COSNA). In WMO (1983), several guidelines are given concerning the COSNA studies:

- 8 possible configurations have been retained for the future observing system in the N Atlantic. They have been built by gathering all the available information about the present and the future observing systems, and then by assuming different levels of development for each individual observing system. Then it has been recommended to evaluate these configurations by OSE's, OSSE's or network studies.
- A high priority has been given to the evaluation of high resolution satellite data which is recognised as being of primary importance for the future COSNA.

In the present paper, we first try (par. 2) to evaluate some COSNA configurations through simple network studies. The numerical tool which is used is the French large-scale analysis program written for the operation on a Cray computer. Then an OSE is performed (par. 3) to assess the impact of high resolution satellite data on mesoscale analyses and forecasts.

## 2. NETWORK STUDIES ON DIFFERENT COSNA CONFIGURATIONS

### 2.1 COSNA configurations to be tested.

The 8 configurations that are described in the WMO report were built in 2 steps:

- For each individual observing system (RS, satellite,...), different "scenarios" were imagined. Example: RS scenario number 4 = FGGE scenario.
- Some realistic combinations of the scenarios were built, producing the 8 configurations A to H.

Let us describe again some of these configurations (for full details see WMO (1983)).

- Configuration A: the present observing system with no radiosonde and no Airep. A kind of "space-based configuration" which is not realistic for the future, but gives a very pessimistic reference for the other experiments.
- Configuration B: the FGGE configuration which is equivalent to the present network + 40 ASDAR Atlantic crossings per day.
- Configuration D: equivalent to B except that we replace the fixed weather ships R and M by 4 mobile ships making soundings (ASAP system). Let us note that, due to the special position of the ship M in the Norwegian Sea, this is equivalent to replacing a weather ship by 4 ASAP ships if we look at the results of network studies over the Atlantic ocean.
- Configuration F: configuration D + 4 additional ASAP ships + 10 additional ASDAR crossings per day.
- Configurations C and E are intermediate (intermediate levels of development are assumed for ASDAR and ASAP systems).
- Configurations G and H are equivalent to B and F except that we assume an improved accuracy for large-scale satellite data (SATEM and SATOB).

The observations needed to get the above configurations are all contained in the present operational data sets or in the FGGE II-b data set, except the ASDAR and ASAP observations. For the network study purposes we can assume that the ASDAR distribution does not vary from one day to another,and then we have to imagine the position of the ASDAR observations on a 24-hour period only. Figure 1 indicates the position of the ASDAR winds for a typical day at 0 GMT (±3 hour in fact).

But we decided to describe the ASAP scenarios on a 15-day period because of the long time needed for a ship to cross the Atlantic ocean,and because of the great differences in the ASAP distribution from one day to another. The 4 ASAP ships of configuration D are imagined on the route UK - Saint Lawrence (2)

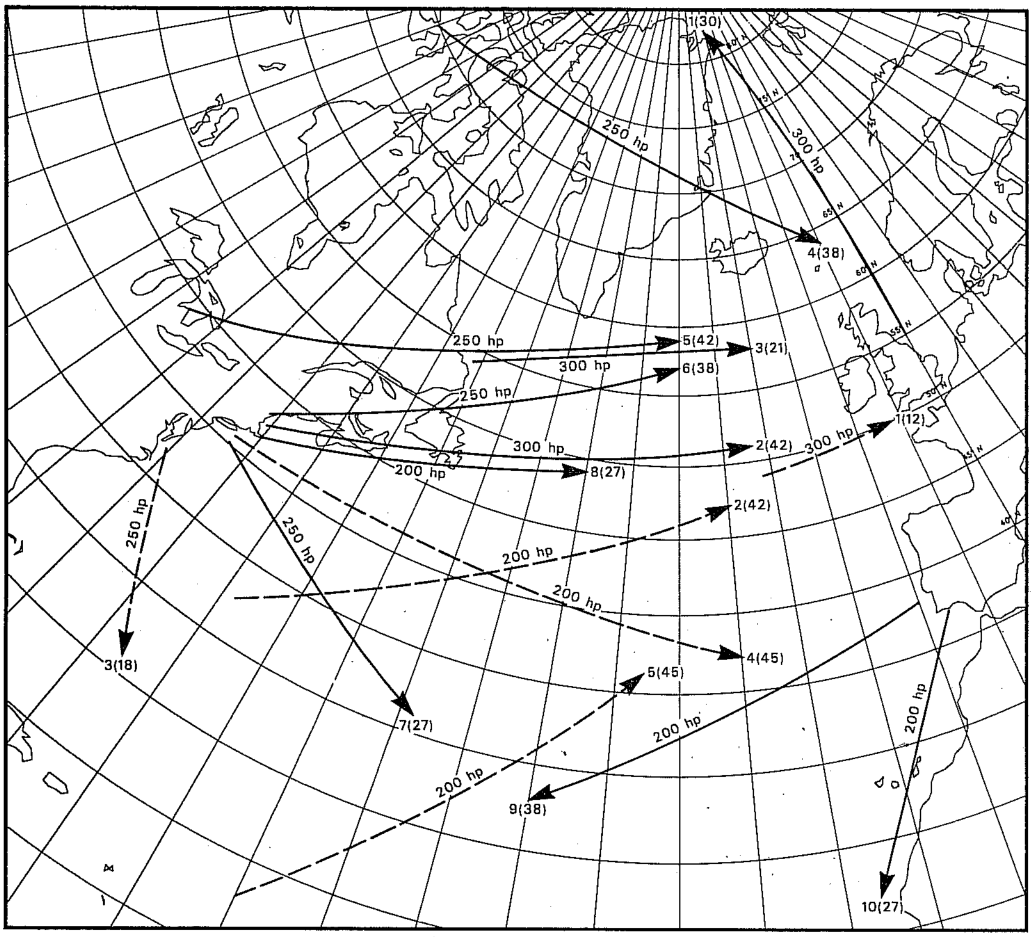


Fig. 1 ASDAR distribution assumed for 00 GMT.
Full lines = FGGE scenario - Dotted lines = additional tracks
The number of observations along a track is in parentheses.

and on the route France - Martinique (2). For configuration F we imagine 2 additional ships on each of the routes Gibraltar-Boston and Scotland - Saint Lawrence (total number of ASAP = 8). Figure 2 gives the positions of one ship on a 15-day period that are imagined on a route between UK and Saint Lawrence, and figure 3 is a "snapshot" of configuration F and its radiosondes in one of the best cases: day 1 00GMT, when 7 ASAP ships out of 8 are available to produce useful soundings, and when only ship No5 (usually on the route Gibraltar - Boston) is stopped in Gibraltar harbour.

The best way to examine the configurations A to H is probably OSE's and OSSE's. That would be a very long job because:

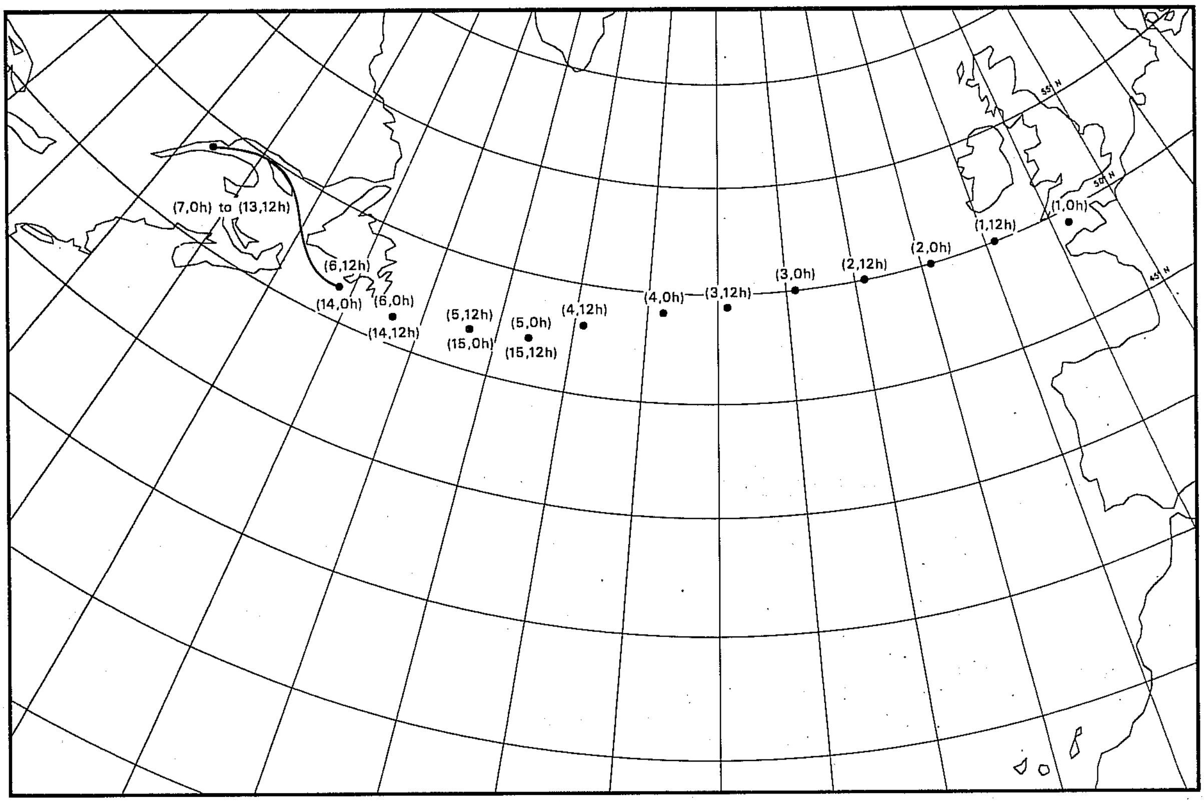


Fig.2 Positions of an ASAP ship between UK and Saint Lawrence on a 15-day period. The number of the day and the time are in parentheses.

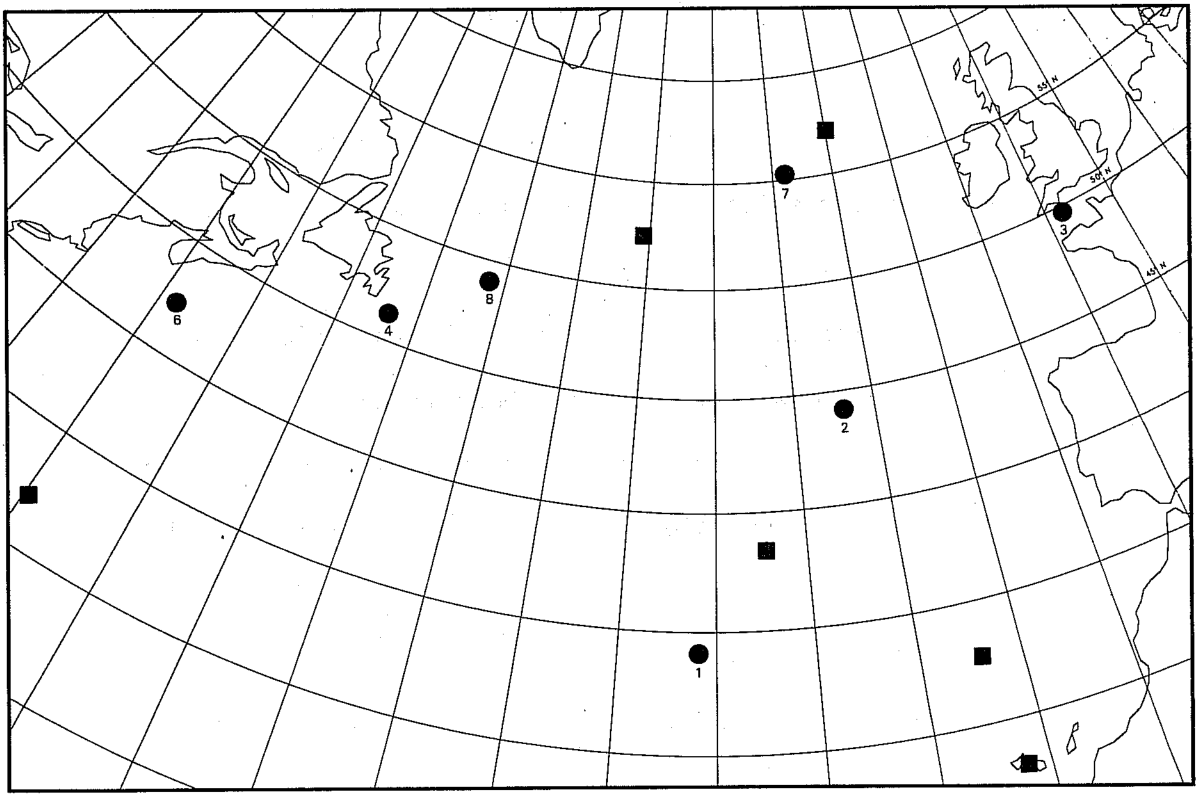


Fig.3 Distribution of available radiosondes for configuration F on day 1, 00 GMT.

● ASAP soundings ■ Fixed soundings in the COSNA area

- We need simulated data for ASDAR and ASAP on a 15-day period.
- Then we would have to run 8 parallel data assimilations on the 15-day period.

In the present study we perform only network studies through an optimum interpolation analysis scheme. Moreover we test only the configurations A, B,D and F which received the highest priority.

## 2.2 Analysis system used for the network studies.

The tool which is used for the network studies is the multivariate optimum interpolation analysis program run in Paris for the operations on a Cray 1. Its characteristics are the following:

- Analysed parameters: $\Phi$ ,u,v and T at 16 p levels from 1000 to 50 hP, plus relative humidity of 9 layers from 1000 to 300 hP, plus surface parameters.
- Every kind of observation is used in a multivariate way, which means for example that ASDAR winds and SATEM thicknesses are used to analyse the 500hP geopotential height.
- Interpolation method: 3-dimensional optimum interpolation.
- Area and horizontal resolution: the Northern hemisphere is analysed on a latitude/longitude grid- $\Delta$lat = 1.5° , $\Delta$lon = 2°.
- In the normal context of the operations, the data assimilation cycle is 6 hour, so the usual guess-field is the 6-hour forecast produced by a 15-level PE model which is spectral and covers the Northern hemisphere. If no forecast is available a climatology is used as guess-field (cold start).

The present network studies consist in computing the RMS analysis error $\sigma_a$ for the 500 hP geopotential height. $\sigma_a$ is a direct product of optimum interpolation :

$$\sigma_a^2 = \sigma_p^2 - \sum_{i=1}^{n} W_i . C_i$$

$\sigma_p$ is the RMS guess-field error, $W_i$ the different weights given to each of the n observed parameters retained for analysing $\Phi 500$ at one grid-point, and $C_i$ the different covariances between the analysed parameter $\Phi 500$ and each of the n observed parameters. $\sigma_p$ is usually the RMS prediction error (normal assimilation context); it is the RMS climatology for a cold start.

The RMS analysis error $\sigma_a$ is calculated in two different contexts:

- In a cold start context: the guess-field is a climatology which cannot bring any information concerning the synoptic features, so this kind of network study generally overestimates the impact of observations.
- In a normal assimilation context: the guess-field is the last 6-hour forecast, and it is important to note that in the present system, $\sigma_p$ is evaluated in a "dynamical way" taking into account the quality of the forecast obtained from the previous runs (6h before, 12h before,...).

In that context the evaluation of $\sigma_a$ generally underestimates the impact of observations, because $\sigma_a$ is a statistical criteria which does not take into account special cases with severe meteorological conditions.

### 2.3 A few results.

The results that are presented here concern only a typical day at 00GMT for configurations A and B, because we assume that the network does not change very much from one day to the other. But, because of the ASAP soundings, we have to evaluate configurations D and F at different times of the 15-day period. The best way to do that is probably to run a network study on all the cases of the period and then to calculate an average of the results; but here the study of D and F is limited to 3 cases:

- The best case which has been found on the 15-day period: it is generally obtained when the maximum number of ASAP ships are in the open ocean. This case is called D1 or F1 depending on the configuration.
- The case which is the most typical for the mean configuration, or the

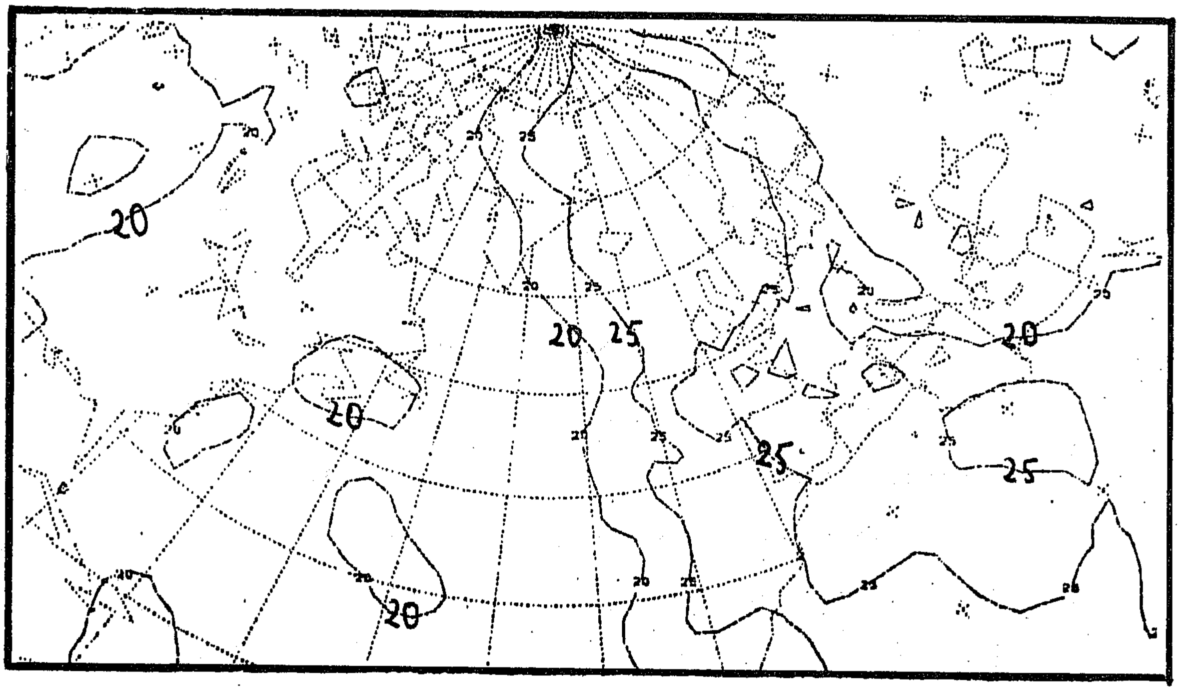


Fig. 4: RMS analysis error for 500hP geopotential height.

Configuration A - Normal assimilation context.

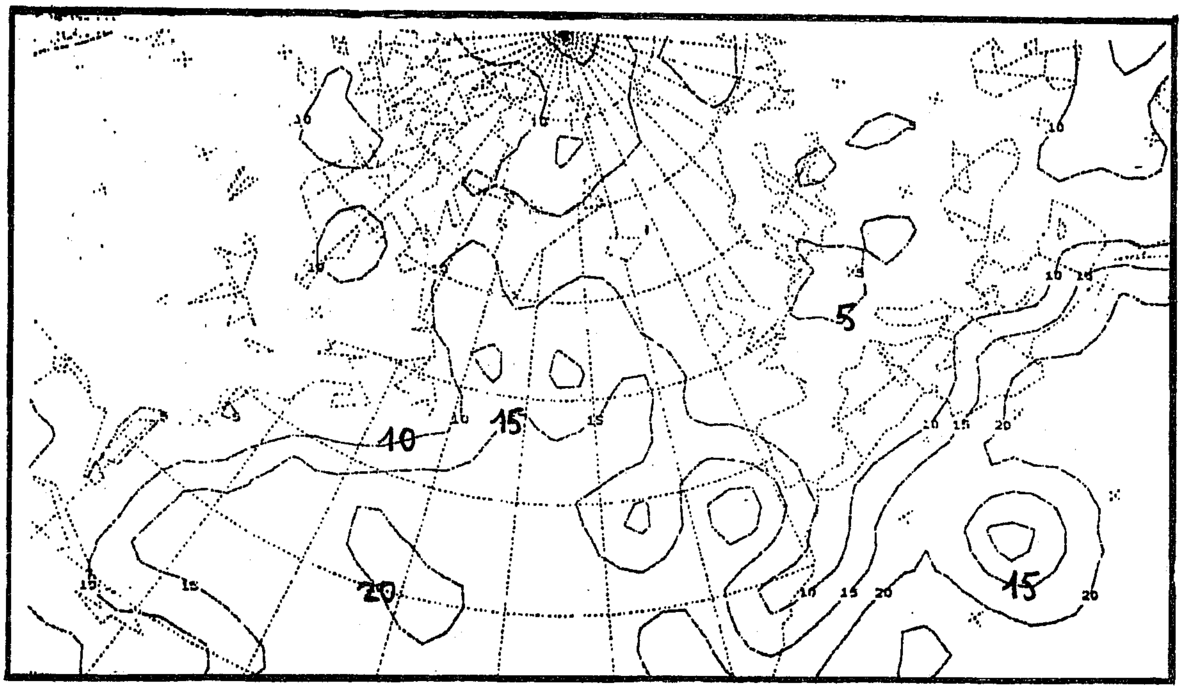


Fig. 5: Same as fig. 4 for configuration B.

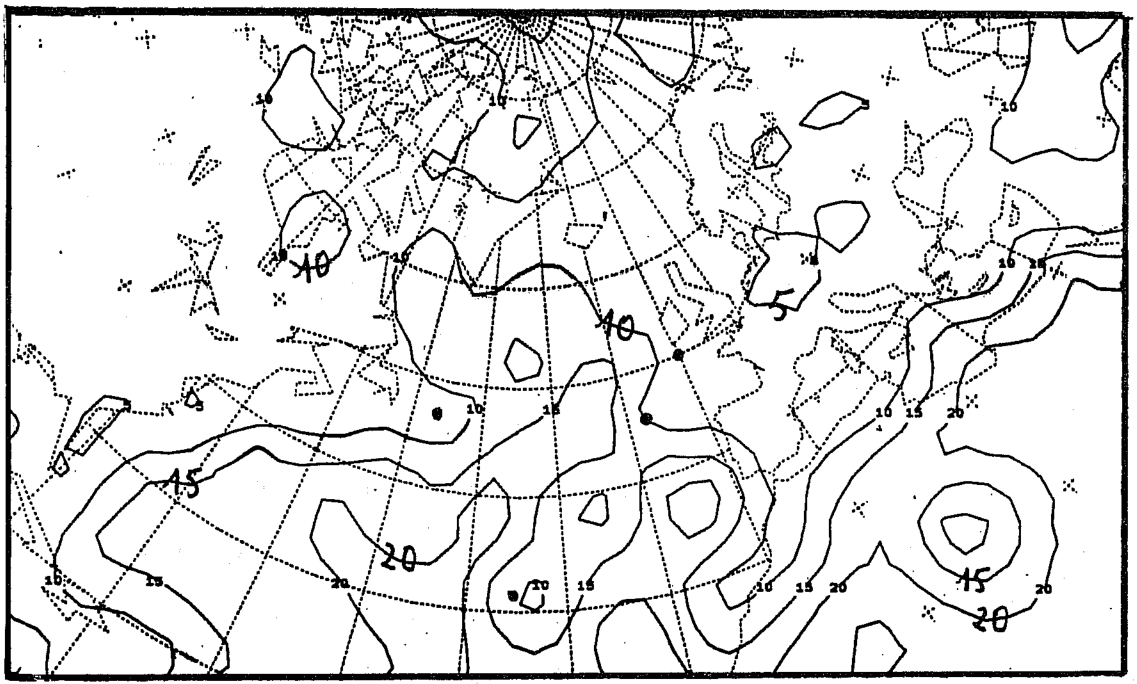


Fig. 6: RMS analysis error for 500hP geopotential height.

Configuration D1 - Normal assimilation context.

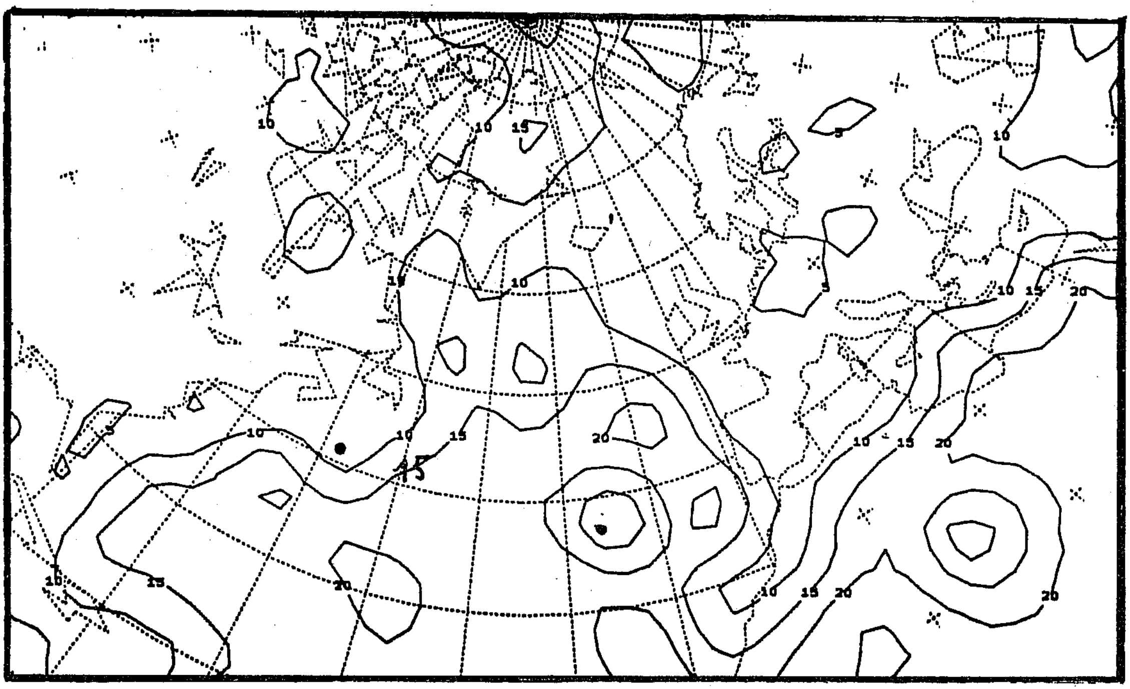


Fig 7: Same as figure 6 for configuration F3.

most frequent. Let us call this case D2 for configuration D and F2 for configuration F.

- The worst case which has been found on the period: maximum number of ASAP ships in "bad positions" (harbour, near the coasts or the islands). This case is called D3 for configuration D and F3 for configuration F.

Figures 4 and 5 show the RMS analysis error maps for configuration A and B in the normal assimilation context, for a typical day at 00GMT. The comparison of the two maps shows the impact of the whole radiosonde and AIREP networks: $\sigma_a$, often greater than 25m in configuration A, drops generally below 20m in configuration B. In configuration A, $\sigma_a$ is much larger over the eastern part of the Atlantic ocean because of the position of satellite data (SATEM) for that special case. This should not be taken as a general result.

In configuration D1 (see figure 6) the absence of the weather ship R is exactly balanced by an ASAP ship going from Martinique to France (it happens only twice in the 15-day period!), and the positive impact of the ASAP system is very clear from western Europe to the South-West of Azores and eastwards from Newfoundland. It is surprising that near (35°N, 40°W) it turns out that $\sigma_a$ is greater for D1 than for B, which means that the addition of ASAP ships over this area seems to have a negative impact on the quality of the analysis. A careful examination of the results showed that this problem is related to quality control in the analysis system: many SATEM are used in configuration B, but are rejected in D1 when we add ASAP data.

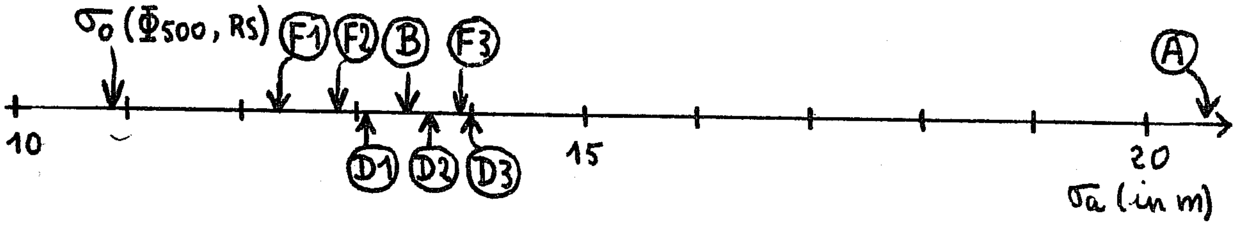
This rejection problem highlights the importance of quality control which should be examined in the special context of network studies. The consequence is that the present experiment is not very clean and that we underestimate the quality of configurations containing many ASAP (we overestimate $\sigma_a$ ), especially configurations D1, F1 and F2.

The RMS error map for F3 (figure 7) shows that even with 8 ASAP ships, in some cases (1 or 2 in the 15-day period) the analysis quality can be lower than for configuration B. Moreover the impact of the additional ASDAR tracks is not very significant, at least at 500 hP (compare F3 and B).

To summarize the quality of the different configurations, we calculate the mean value of $\sigma_a$ over two areas given on figure 8. These scores are given in the following table (in meters), their absolute valuesare not significant because they depend very much on the analysis system. Only the relative values between different configurations should be considered.

| | Small area | | Large area | |
|---|---|---|---|---|
| | Normal assim | Cold start | Normal assim | Cold start |
| A | 20.8 | 38.3 | 20.6 | 35.2 |
| B | 13.4 | 14.8 | 12.5 | 14.5 |
| D1 | 13.1 | 13.7 | 12.4 | 13.9 |
| D2 | 13.7 | 15.0 | 12.5 | 14.6 |
| D3 | 14.0 | 15.7 | 12.6 | 14.8 |
| F1 | 12.3 | 13.3 | 12.1 | 13.5 |
| F2 | 12.9 | 13.4 | 12.4 | 14.0 |
| F3 | 13.9 | 15.6 | 12.5 | 14.5 |

The most significant of the above results are probably the RMS analysis error mean values over the small area in a normal assimilation context, even if they underestimate the impact of additional data: the scores are visualized in the following diagram.



Two references are put on the scale: configuration A which gives an upper reference, and the RMS observation error assumed for a radiosonde geopotential height (10.9 m in the analysis program which has been used). It appears that configuration D is very similar to B, while F is significantly better, even better than indicated by the diagram (taking into account the rejection problem already mentioned which overestimates $\sigma_a$ especially for F1,F2 and D1.)

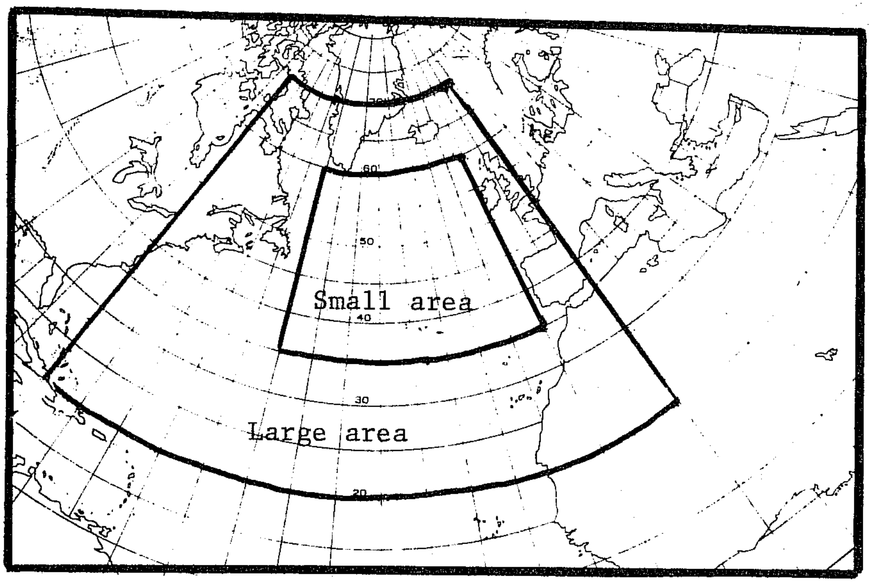


Fig. 8: Atlantic areas used to calculate the analysis quality scores ($\sigma_a$ for 500hP geopotential height).

### 2.4 Summary of the present results.

- There is no significant difference between the quality of configurations B and D, which means that the performance of 4 ASAP ships seems equivalent to 1 fixed weather ship. But the design of configuration D in the present study does not take into account long periods when one ship is out of use (repairing...), so the performance of 4 ASAP ships is probably a little lower than the scenario with a permanent weather ship at a fixed point.

- Configuration F is significantly better than both B and D, even if the impact of additional ASDAR is not obvious in the present study. To investigate correctly the ASDAR system, other configurations should be tested (C and E) and other meteorological parameters should be examined (250 hP winds for example).
- With the development of the ASAP system the Atlantic coverage in radiosondes will change very much from one day to the other. Even with 8 ASAP ships (like in F) we are far from a "quasi-stationary" data coverage.
- The development of the ASDAR system will probably give an imbalance in the data coverage between 0 and 12 GMT. We should try to reduce that imbalance when selecting the aircrafts to be equipped with the ASDAR system.
- To examine the COSNA configurations in full details we should also examine them for the whole period (15 days), run network studies for satellite data (configurations G and H), and also pay more attention to the data rejection problem in the analysis.

## 3. IMPACT OF HIGH RESOLUTION SATELLITE DATA ON A FINE-MESH MODEL.

### 3.1 The data.

The high resolution satellite data which are tested in the present experiment are not converted to temperature profiles by any inversion technique:

they consist of clear radiances obtained from 19 NOAA7 channels. They have been got by the Lannion space center for the NOAA7 orbits which are near 00GMT and then transmitted to Paris to be inserted in the fine-mesh analysis system. Note that, as cloudy and semi-cloudy radiances are not used, we get data only when the sky is clear,which underestimates the general impact of raw satellite data.

### 3.2 Analysis and forecast systems used for the OSE.

We evaluate the impact of these radiance data on the fine-mesh numerical prediction system - the "PERIDOT" system. This NWP system consists of:

- A 15-layer PE prediction model in $\sigma$ coordinate, see COIFFIER (1982).
- A nonlinear normal mode initialisation, see BRIERE (1982).
- A mesoscale analysis scheme using all usual observations and also high resolution satellite data, see PAILLEUX (1982).

The main characteristics of the analysis system are the following:

- Analysis directly performed on the prognostic variables of the forecast model for mass and wind fields (in $\sigma$ coordinate).
- 3-dimensional multivariate optimum analysis system, applied to T, u, v and $p_s$; 2-dimensional univariate analysis for relative humidity.
- Direct use of raw satellite data (radiances) through the multivariate statistical scheme; ad-hoc statistics for the use of radiances have been derived.
- Horizontal mesh: 35 km.

### 3.3 Impact of high resolution satellite data on the fine-mesh analysis.

The fine-mesh analysis has been run with and without satellite data on 11 cases in June 1984, then the analyses "with" and "without" have been compared.

- For the temperature field, many local differences are observed on the analyses "with" and "without". The order of magnitude of these differences is about 1°C and the maximum difference observed is generally 2 or 3°C when we consider all the analysis levels of a specific case. Because of the mesh size (35 km) and of the lack of reference observations, it is generally impossible to say which analysis is the best one, at the present stage.
- For the wind field, no significant impact is observed in most of the cases, which seems to indicate that the multivariate aspect of the analysis scheme does not work as well as it should do.
- For the relative humidity field, the analysis with satellite data has more details especially above 700 hP, and the differences are often larger than 10%.

### 3.4 Impact on the fine-mesh forecast.

4 forecast experiments have been made by running the PERIDOT forecast with and without satellite data: 5, 6, 7 and 13 June 1984. All these experiments have been run without normal mode initialisation because preliminary runs indicated that normal modes were damping all the analysis differences, and that no impact could be found on the forecast.

- The impact of satellite data on fine-mesh forecasts is limited to the following meteorogical fields: cloudiness,precipitation, humidity and surface fields. No significant impact is found on upper-air mass and wind fields.
- In the first 2 cases (5 and 6 June) a positive impact of raw satellite data on precipitation forecasts over the centre of France is found. See figure 9 which presents the precipitation and cloudiness forecasts for 5 June 1984 (24h). This positive impact is verified by SYNOP stations observing showers. The amplitude of the impact is small and has to be confirmed by other cases.

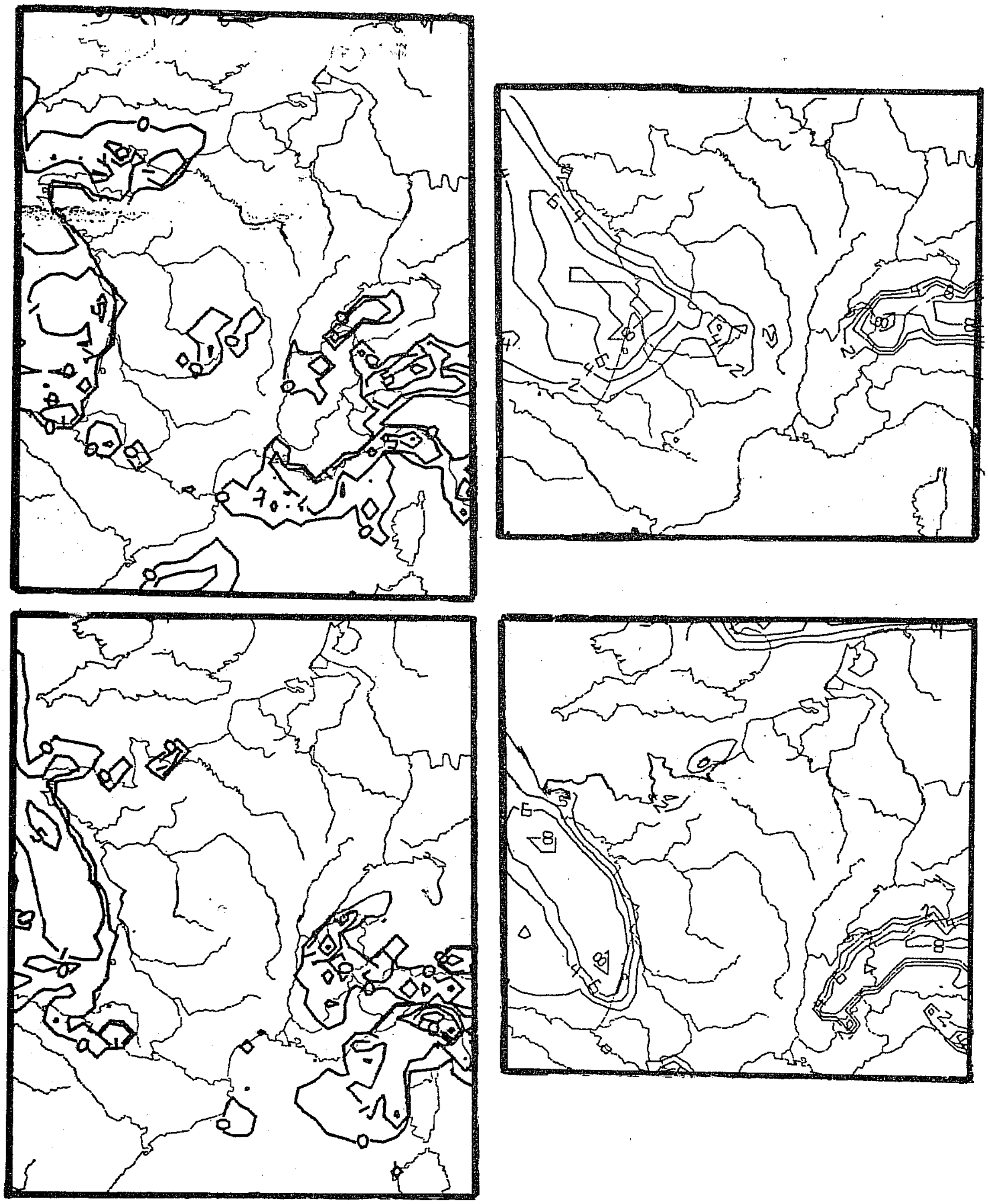


Fig. 9: 24 h PERIDOT forecast valid for 6 June 1984 (issued from 5 June 1984 0 GMT).

Top : with high resolution satellite data - Bottom : without

Left : convective precipitation maps - Right : cloudiness from 0 to 8 , low clouds only.

- On the 7 June case, some differences are observed in the cloudiness and precipitation forecast maps, but it is impossible to say which forecast is the best one. And on the 13 June case no significant impact is found on any map: this could be due to the situation in which there is fine weather without precipitation on the whole model area.

In summary the impact of high resolution satellite data on the "PERIDOT" system is small but significant. We have to be cautious before drawing definite conclusions because the system has been developed recently and is not completely tuned. For example the surprising effect of the normal mode initialisation could be due to a weakness of the whole system.

## 4. CONCLUSIONS.

By comparing the objective analysis quality in the North Atlantic area, it seems that the mean number of ASAP ships needed to get the same performance as 1 fixed weather ship is little more than 4. This ratio could certainly be reduced by a careful selection of the shipping routes; for example, equipping with the ASAP system a ship which sails on the Saint-Lawrence river is not very efficient.

The performance of the ASDAR system does not appear clearly in the present study which is too limited. Nevertheless, in building the ASDAR scenarios it appears that there is an imbalance in the geographical distribution of ASDAR observations between 0 and 12 GMT - an imbalance which could be reduced by a careful selection of the aircraft.

A small positive impact of high resolution satellite radiance data on fine-mesh numerical forecasts (until 24h) is found, especially concerning the precipitation forecasts.

All the above results have been obtained by analysis and prediction systems which are "very young": several weaknesses of these systems have been found during the studies; it is likely that these weaknesses tend to underestimate the impact of observations. So the evaluation of the future COSNA should be continued by the following tasks:

- Other network studies with an analysis system which has been operational for a long time.
- OSSE's instead of network studies for the COSNA configurations.
- Other OSE's to confirm the impact of high resolution satellite data on NWP.

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