INTRODUCTION

AND

THE PROBLEM OF WEATHER INTERPRETATION

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Numerical forecasts of the atmosphere based on the fundamental dynamical and thermodynamical equations have now been carried out for almost 30 years. The very first models which were used, were drastic simplifications of the governing equations and permitting only the prediction of the geostrophic wind in the middle of the troposphere based on the conservation of absolute vorticity. Since then we have seen a remarkable development in models predicting the large-scale synoptic flow. Verification carried out at NMC Washington indicates an improvement of about 40% in 24h forecasts for the 500 mb geopotential since the end of the 1950's.

The most advanced models of today use the equations of motion in their more original form (i.e. primitive equations) which are better suited to predicting the atmosphere at low latitudes as well as small scale systems. The model which we have developed at the Centre, for instance, will be able to predict weather systems from a scale of 500 - 1000 km and a vertical extension of a few hundred millibars up to global weather systems extending through the whole depth of the atmosphere.

With a grid resolution of 1.5^{o} and 15 vertical levels and covering the whole globe it is possible to describe rather accurately the thermodynamical processes associated with cyclone development. It is further possible to incorporate sub-grid-scale processes such as radiation,exchange of sensible heat, release of latent heat etc. in order to predict the development of new weather systems and the decay of old ones. Later in this introduction I will exemplify this by showing some results of forecasts by the Centre's model.

However, in this seminar we are not directly concerned with the numerical prediction of the large-scale motion per se but instead how we can use the result of the predictions in the forecasting of the weather.

By weather prediction we will understand the forecasting of rain and snow, cloud and visibility as well as temperature and wind in the lowest part of the atmosphere.

In principle, the "weather" can be predicted from a numerical model giving the basic meteorological parameters, temperature, wind, humidity, pressure and temperature with a resolution in time and space which is satisfactorily high. However, due to the complexity of atmospheric motions, mainly caused by differences in the surface conditions, the weather is characterised by a considerable variation in space,and a meaningful and useful weather forecast therefore often implies a forecast for a local area. On the other hand, due to computational limitations, we will most likely have to limit, in the foreseeable future, the general numerical predictions to a scale of motion associated with synoptic disturbances with a highest resolution of 50 - 100 km and a vertical resolution of about 50 - 100 mb.

Even such a high resolution is insufficient to resolve all weather systems, in particular when they are modified by orography, lakes, coastal zones, large urban areas and other factors. Also the different phases of water vapour as well as aerosols necessary for the prediction of clouds, visibility and kind of precipitation need a more detailed physical modelling than feasibily can be incorporated in models for the prediction of the synoptic scale.

For these reasons, it seems therefore necessary to approach the problem of weather forecasting in two steps; the first step being the prediction of the large-scale flow and the second step to interpret the large-scale parameters obtained in the first step, into weather parameters for specific local areas.

Needless to say, this is an area of utmost importance since improved weather forecasts are one of the fundamental objectives of all our efforts in meteorology, and if we do not devote enough attention to solving (or optimizing) this last link, we will not be getting a good return for all our work in building up a global observing network as well as sophisticated systems for telecommunication and numerical modelling and experimentation.

Two methods have been followed in developing weather interpretation techniques. The first has been the development of numerical models with a very fine resolution of 5-10 km. Very interesting results have been obtained by such 3-dimensional meso-scale models. Dr. White and Dr. Pielke will in their lectures discuss how such systems are set up and show results from integration with meso-scale models. The meso-scale models are not directly intended to predict very small-scale, transient phenomena, but mainly to adjust the large-scale flow to local peculiarities in topography and boundary conditions, such as sea-breeze prediction and to interpret them into local weather using the dynamic and thermodynamic equations and the corresponding physical processes which are likely to be of importance.

Similar meso-scale models have successively been used operationally for a long time in the prediction of sea surges and are for the prediction of these processes remarkably accurate if the large-scale wind and pressure fields are well predicted.

The second approach to local weather forecasting is to use statistical methods, when the local observations and the predicted large-scale parameters are used as predictors. This technique has been found to be potentially fruitful and several Weather Services have developed operational systems along these lines. Drs. Klein, Lönnqvist and Söderman will in their lectures present how such systems have been built up and illustrate how the results could be used.

A natural question to ask is to what extent it is possible or feasible to make weather forecasting automatic and basically rely upon the two methods of approach which I have described. The fundamental question we thereby have to answer is if the meteorologists are able to improve the numerical predictions and if they can make a subjective interpretation of the numerical forecasts into local weather which is superior to the automatic interpretation systems.

Let me try to answer the first part of the question. There are different opinions about the possibility to improve subjectively a numerical forecast. In cases when this is possible, it is mainly where simple quasi-geostrophic models have been used and where some systematic deficiencies have been relatively apparent. Another area where a positive modification has been possible has been where the forecasters have had more observations at their disposal, which either were not used in the numerical integration (e.g. recent surface observations) or consisted of qualitative information (satellite cloud observations or radar pictures). It is evident that direct subjective improvements of numerical predictions become successively more difficult as we improve the models and the data assimilation procedures.

With for instance a model and a data-assimilation system of the complexity of the Centre's , I would think it is practically impossible to improve the numerical forecasts by subjective methods,in particular after the first or second day.

In trying to answer the second question,we must admit the local interpretation processes are extremely difficult to perform satisfactorily in a fully automatic system. Certain forecasts of a routine character could certainly be automized and have been so at a few Weather Services. In practice, however, the forecasting practices are rapidly changing due to different needs of the customers and the ways of interpretation have also to be changed since the numerical models are changing. In view of this dynamical character of the process there is a great need for establishing a dissemination system which will make it possible for the forecaster to communicate with the computer systems in a rational and efficient way. Such a system, the AFOS (Automation of Field Operation and Services) system, is presently being established in the United States,and Dr. Klein will in a lecture present this system and its function. The way the Centre will disseminate its operational products will be described in lectures by Mr. Newson and Dr. Söderman.

An additional purpose of this Seminar is to present to you the system for medium range forecasts with which we are working and which will be put into operation about one year from now.

The way of the interpretation of forecasts of more than 3-4 days into weather is much more complicated than the interpretation of short range forecasts. The reason for this is that there is a rather clear connection between the cyclonic disturbances and the weather. Consequently as long as we can predict the synoptic disturbances with good skill, there is also a good chance that we can predict the weather with a similar skill.

However, as we extend the forecast interval the synoptic scales become less and less predictable, while there are indications that the long planetary waves can be predicted longer. Our present experimentation which is based upon roughly 14 integrations shows useful predictability up to around 6 days. Still after that period the forecasts look rather realistic but with large errors in individual forecasts when evaluated day by day. On the other hand the overall predictability in cyclonic activity and cyclone tracks seems generally to be useful even beyond the 6 days.

R. Newson will give a general description of the Centre's forecasting system after this introduction and I will, therefore, only highlight the performance of the present model by presenting some results of a recent 10-day integration. K. Arpe will show you some more results towards the end of this seminar and he will also talk about the general research work going on at the Centre to evaluate the performance of numerical forecasts for medium range periods.

Fig. 1 shows the initial state for the 1000 mb and the 500 mb at 18 August 1975 00Z. The heavy lines are 1000 mb contour lines for every 40 m and similarly for 500 mb for every 80 m respectively. The thin lines are isotherms for every $2^{O}C$ at 850 mb and 500 mb respectively.
I will concentrate the presentation and discussion of this forecast for the North Atlantic and the European area.

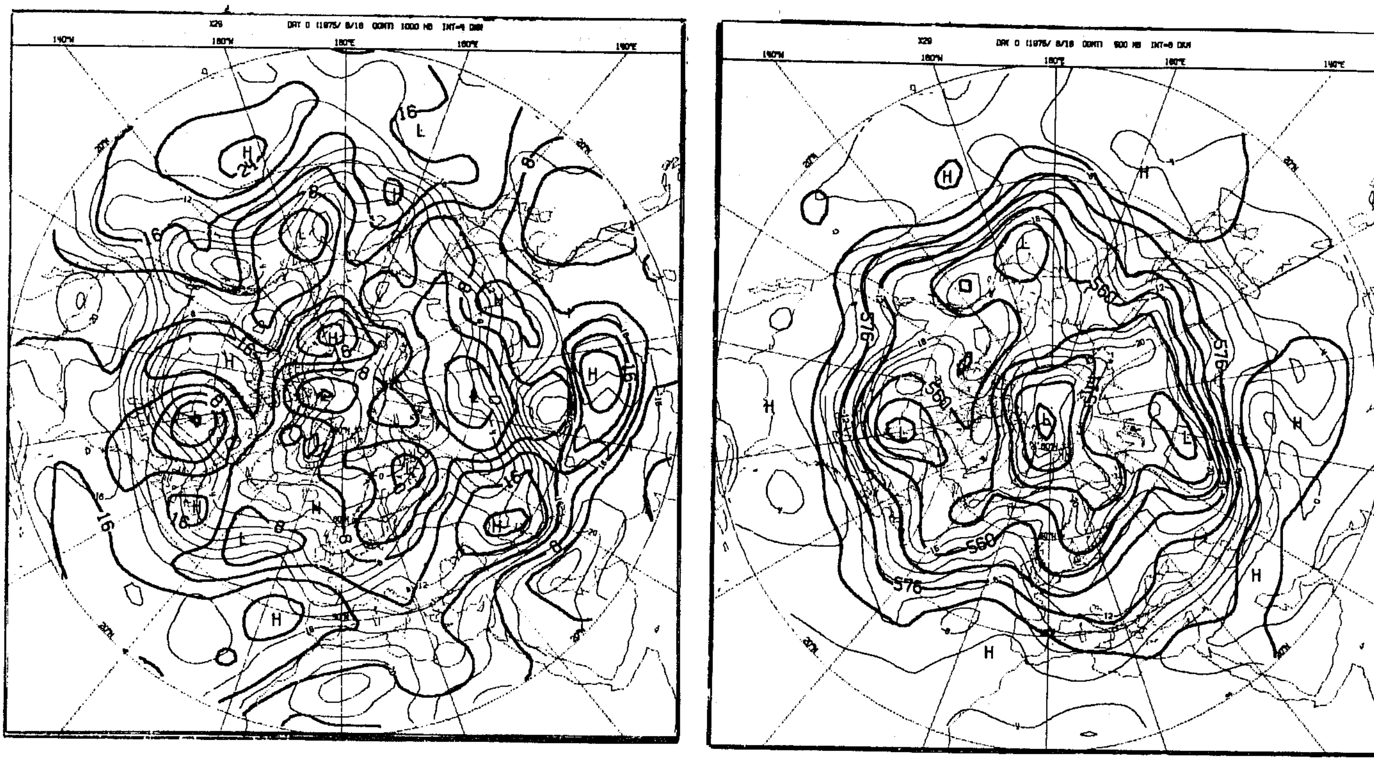
The initial weather situation is characterised by a series of rather weak disturbances moving eastwards along the polar front which is situated between 50 and 60^{O}N. The Atlantic trough which initially is around 40^{O}W moves first fast eastward and at the same time it is slightly weakening.From the second day onwards this trough is strongly activated to the west of the British Isles and after that moves very slowly eastwards under further vigorous amplification . On day 5 this main trough is situated around 5^{O}E and dominates the weather completely over most of Europe. An outbreak of cold air over Western Europe can be seen on the surface maps for day 5 and day 6. An upper air cut off low is created over the Western Mediterranean around day 6. This low becomes stationary for the rest of the forecast. A breakthrough of a strong westerly flow over Northern Europe takes place between day 9 and day 10.

Figs. 2, 3, 4, 6 and 7 show the daily forecasts for the 500 mb flow. The development up to the 7th day is reasonably good, although the cut off over the Western Mediterranean is not predicted. However, as can be seen from the surface forecasts on day 5 and 6 on figure 5 the cold outbreak over Western Europe is well predicted in spite of this. Except for certain areas, as for instance over Scandinavia, where the forecast continues to be remarkably good, the forecast after 7 days has large errors mainly connected with the inability to predict the above mentioned cut off low. This causes for instance the westerlies at the end of the forecast to be established at a more southerly latitude than in reality.

I should like to stress already now the immense complexity of the forecasting problem and that you must understand it will take a long time of research and development before we can produce forecast information which can be really useful to predict the weather up to 10 days. With the first model,which will be operational next year, I am confident that we can produce forecasts useful in a more conventional way up to 5 - 6 days and predict the time average flow which at least in a limited sense,is practically useful for the last 4 - 5 days. NMC in Washington have been producing such mean maps with a much simpler model than the Centre's for about 1 year operationally which are regarded to be of great practical use.

The research programme which the Centre is now planning for the next five years will be devoted to an understanding of atmospheric processes from 5 - 10 days. Substantial efforts to improve the model in this respect as well as trying to extract the useful information from the integration which we shall produce with the first system will be carried out. In that connection I hope that we can establish a very close cooperation between the research groups in the Member States and at the Centre.

With these final words I will open this seminar, and I hope that we shall have a successful seminar with many discussions and that we can give you as many guidelines as possible in the building up of a system of making use of the Centre's numerical forecasts.



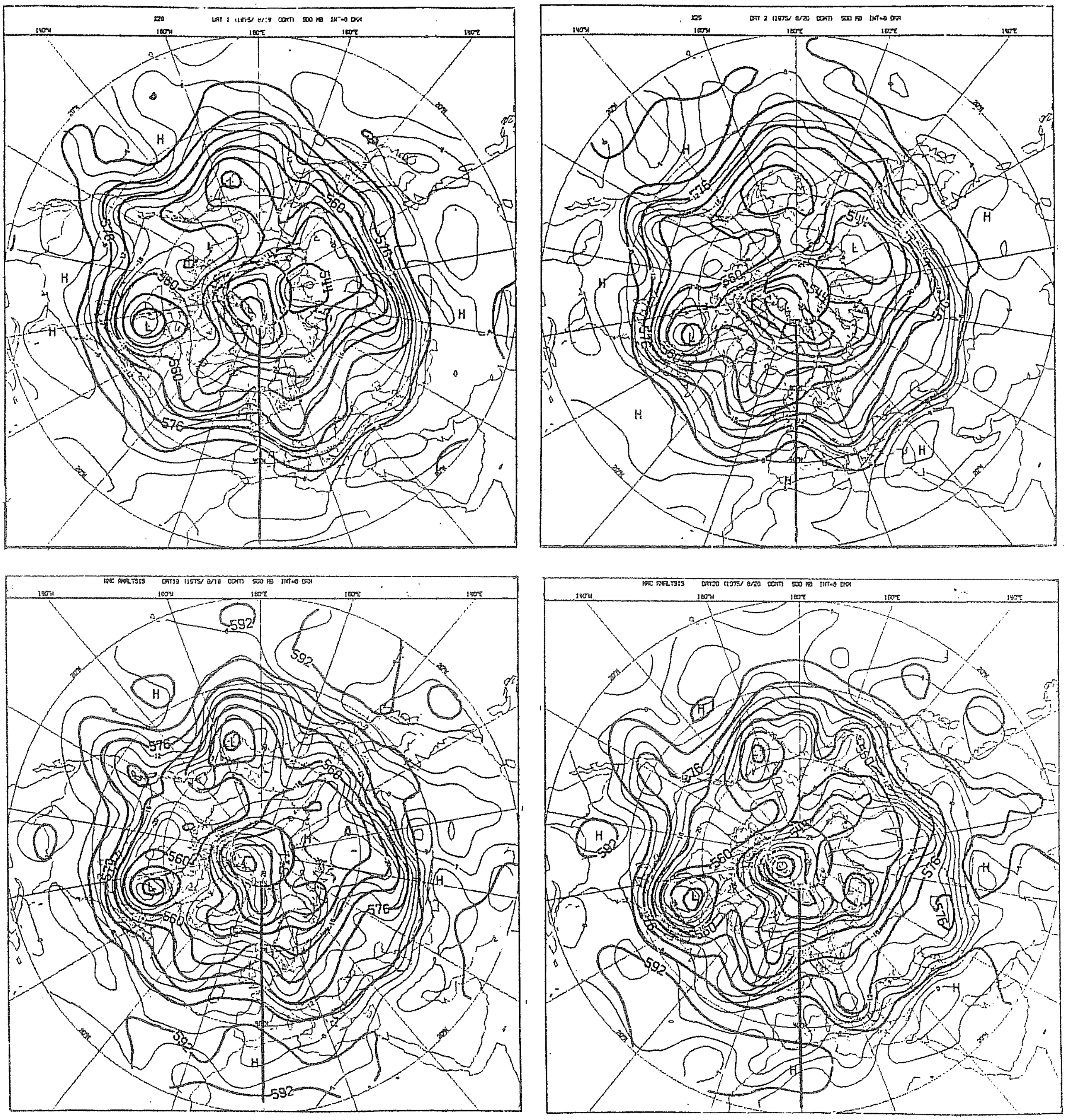
(a) (b)

Fig. 1 : Initial state for 18 August 1975 00Z

(a) shows the geopotential at 1000 mb (full lines, every 40 m) and the temperature at 850 mb (thin lines, every $2^{O}C$)

(b) shows the geopotential at 500 mb (full lines, every 80 m) and the temperature at 500 mb (thin lines, every $2^{O}C$).

(a) Forecast 500 mb, day 1 (b) Forecast 500 mb, day 2

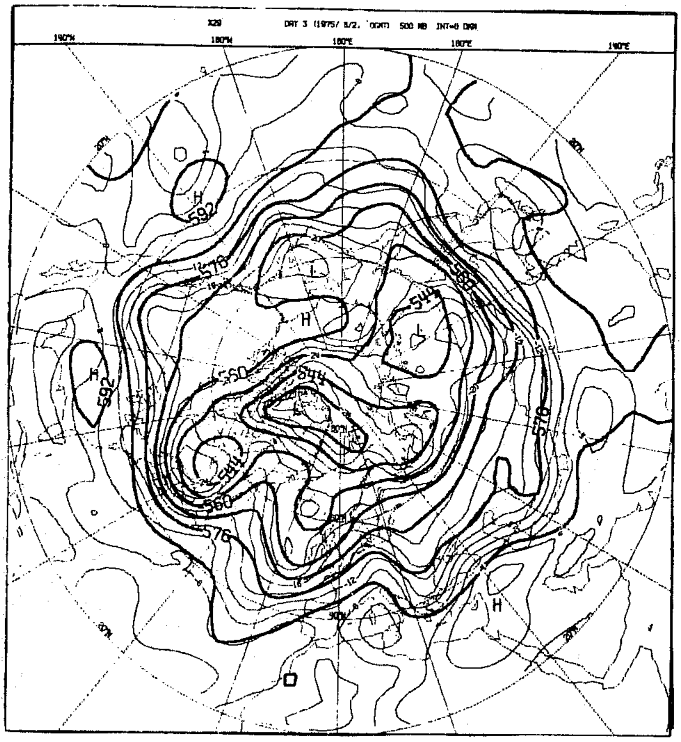


(c) Verification 500 mb, day 1
19 August 1975 00Z

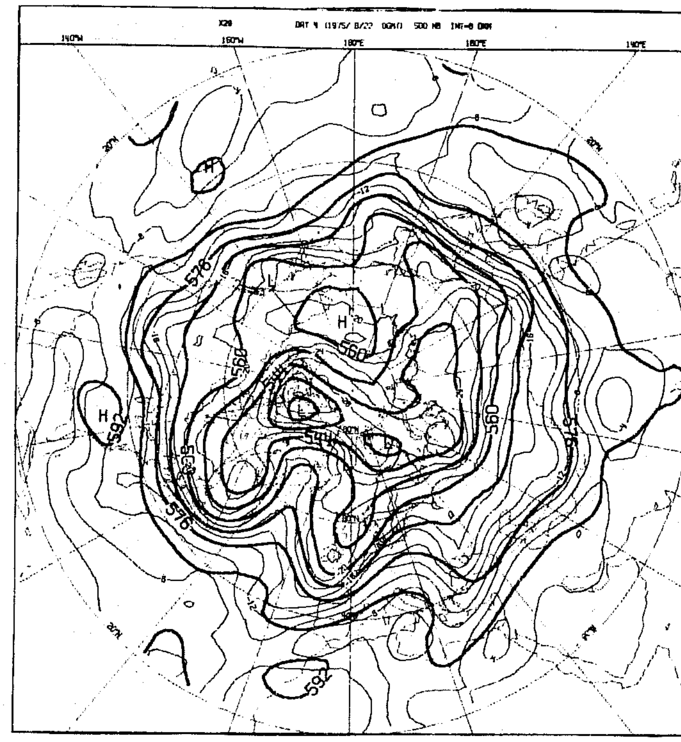
(d) Verification 500 mb, day 2
20 August 1975 00Z

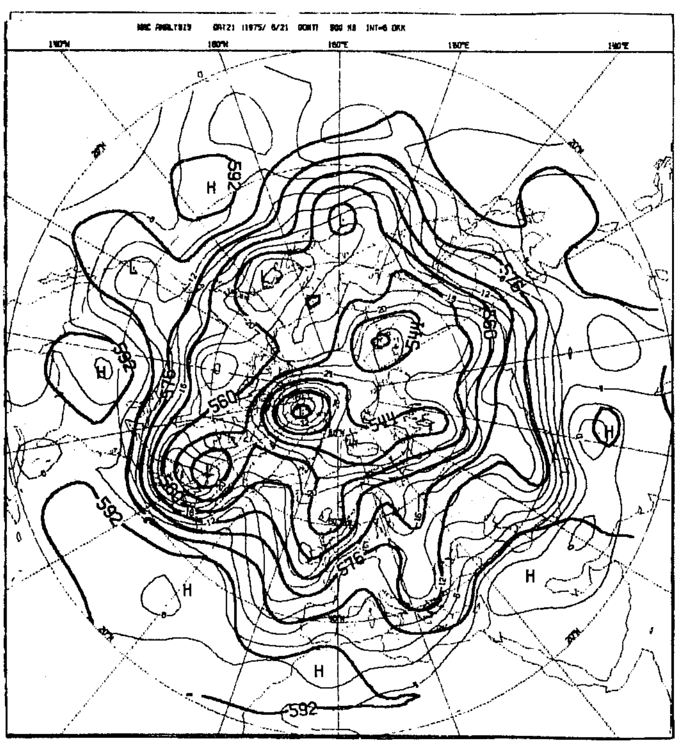
Fig. 2: (a) and (b) show the predicted geopotential at 500 mb (full lines every 80 m) and predicted temperatures at 500 mb (thin lines every 2°C) for day 1 and day 2 respectively. (c) and (d) show the observed geopotential at 500 mb (full lines, every 80 m) and observed temperatures at 500 mb (thin lines, every 2°C) for 19 and 20 August 1975 00Z respectively.

(a) Forecast 500 mb, <u>day 3</u>

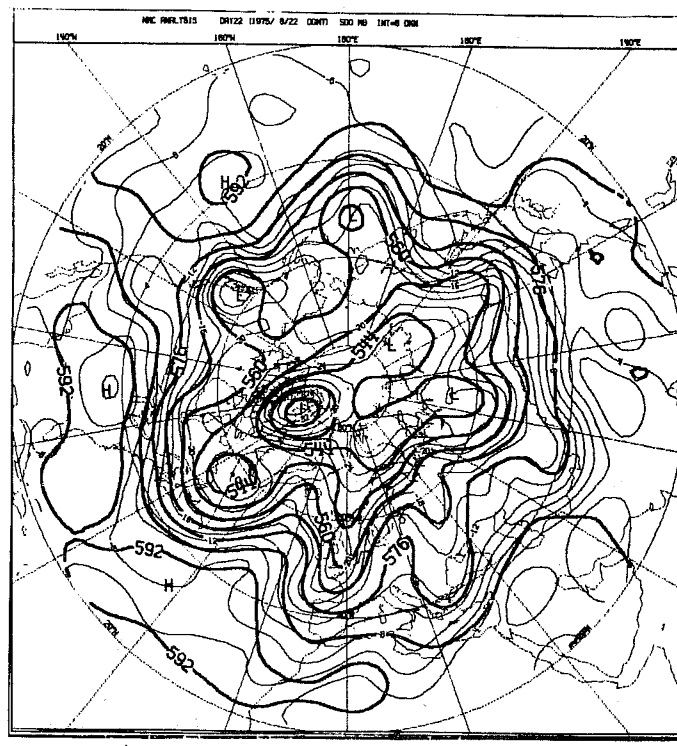


(b) Forecast 500 mb, <u>day 4</u>





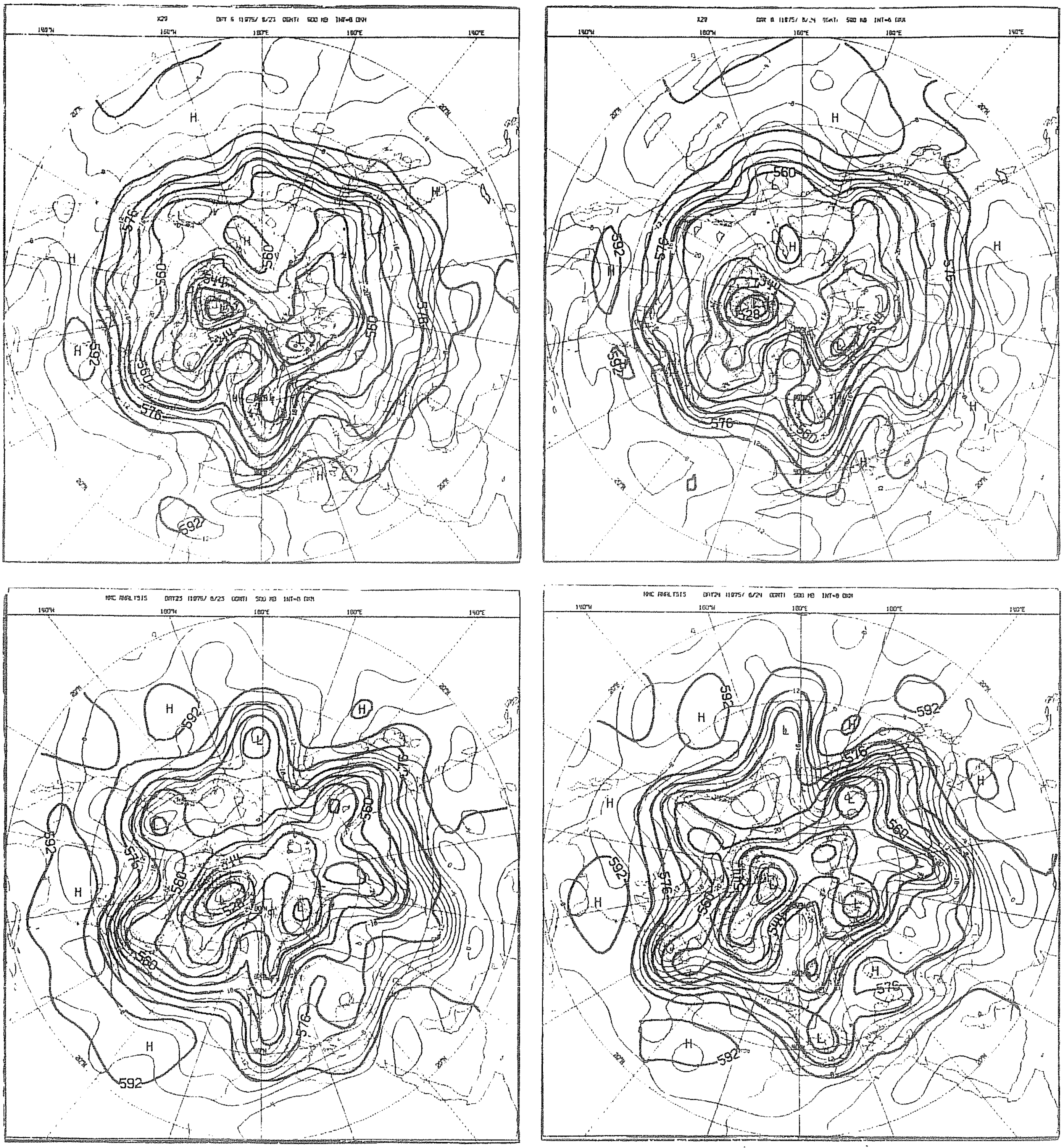
(c) Verification 500 mb, <u>day 3</u>
21 August 1975 00Z



(d) Verification 500 mb, <u>day 4</u>
22 August 1975 00Z

Fig. 3: The same as figure 2 but for day 3 and day 4.

(a) Forecast 500 mb, day 5 (b) Forecast 500 mb, day 6

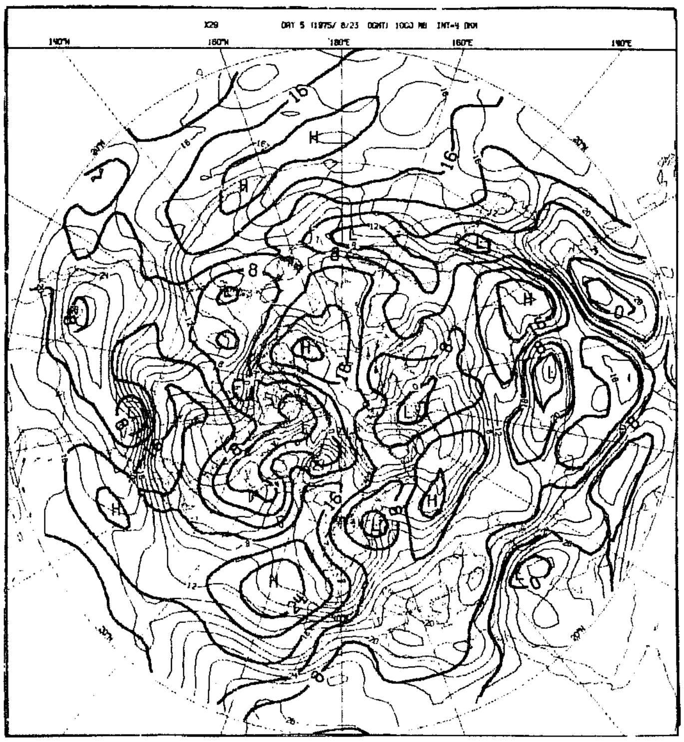


(c) Verification 500 mb, day 5
23 August 1975 00Z

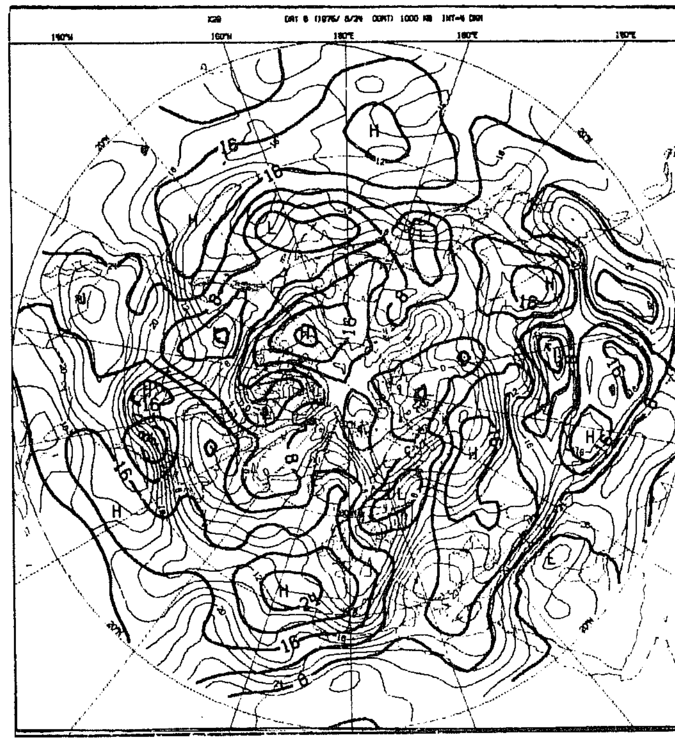
(d) Verification 500 mb, day 6
24 August 1975 00Z

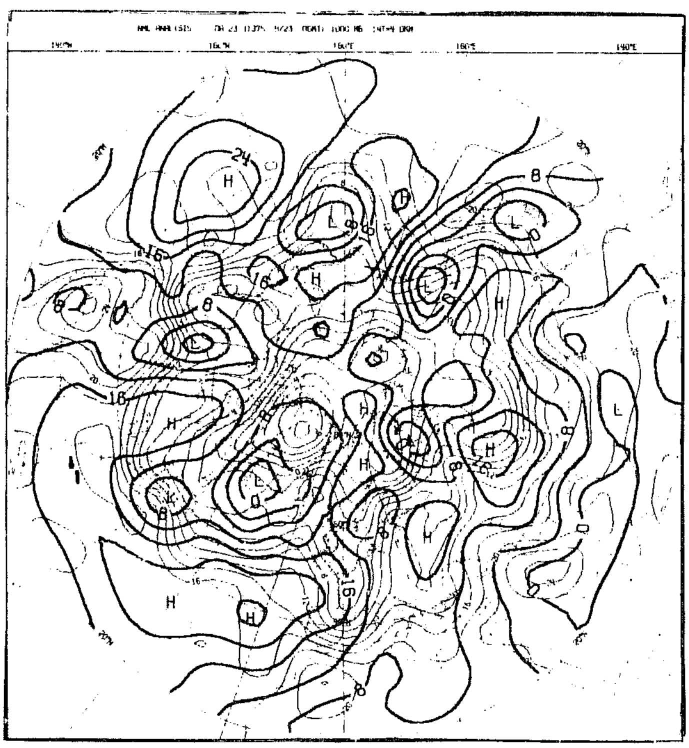
Fig. 4: The same as figure 2 but for day 5 and day 6

(a) Forecast 1000 mb, day 5

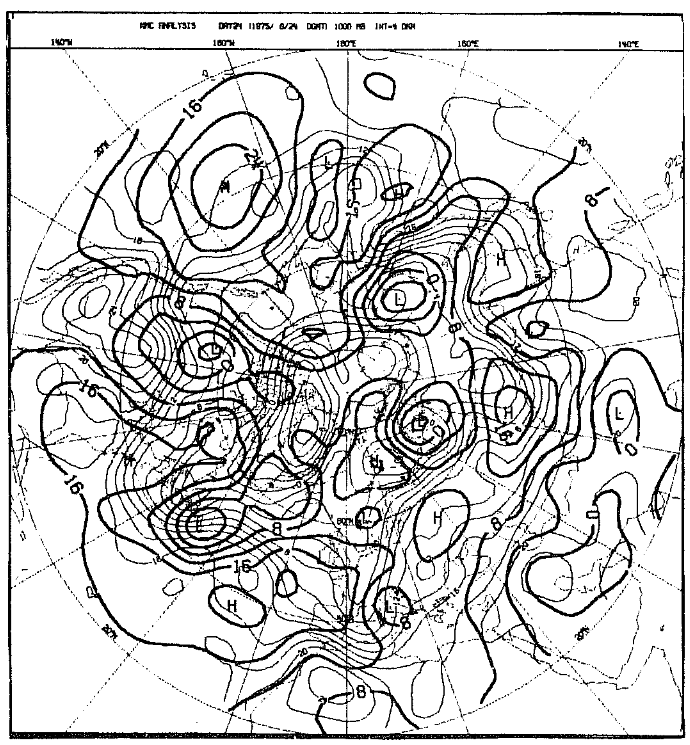


(b) Forecast 1000 mb, day 6





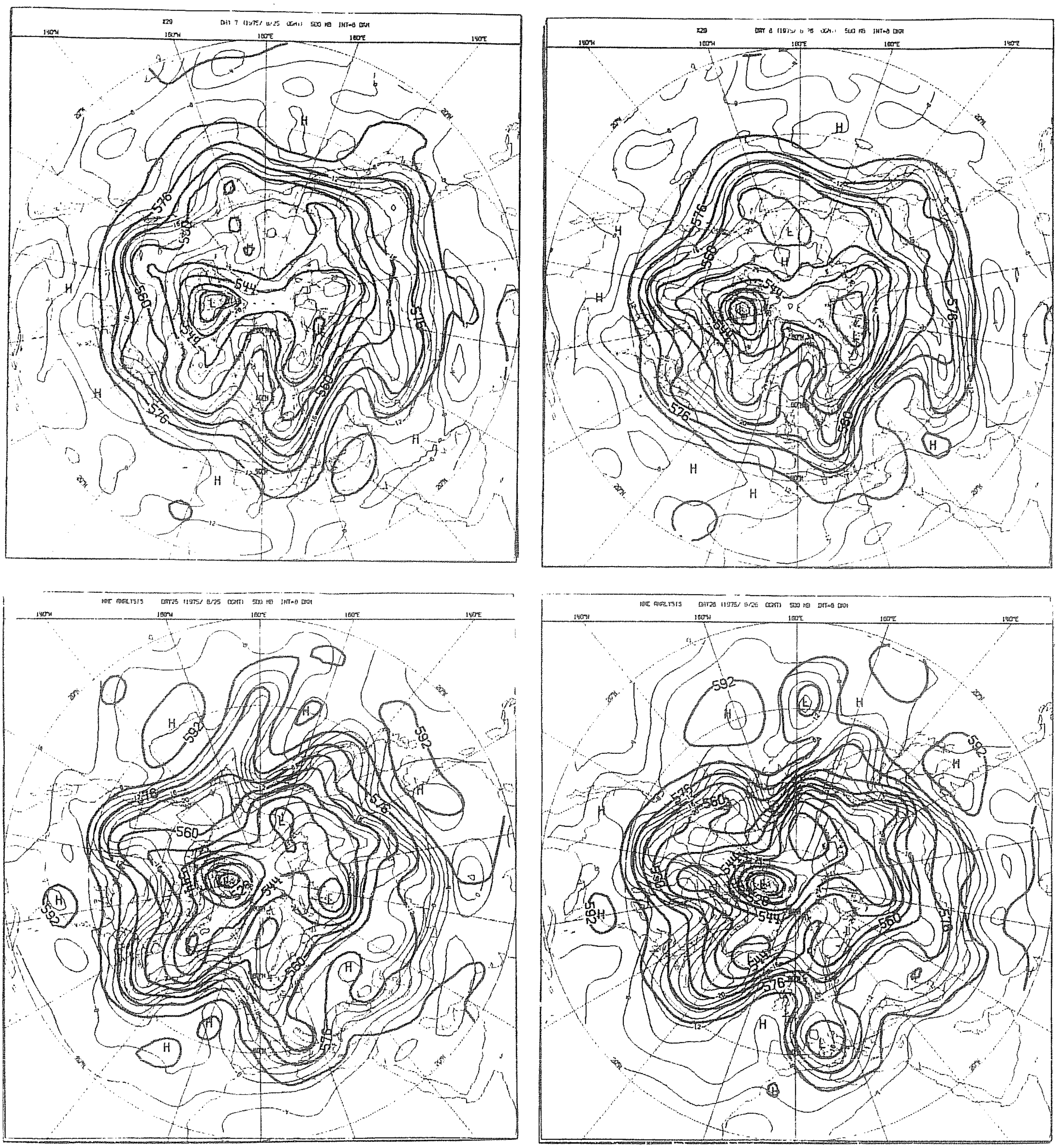
(c) Verification 1000 mb, day 5
23 August 1975 00Z



(d) Verification 1000 mb, day 6
24 August 1975 00Z

Fig. 5: (a) and (b) show the predicted geopotential at 1000 mb (full lines, every 40 m) and predicted temperatures at 850 mb (thin lines, every 2°C) for day 5 and day 6 respectively. (c) and (d) show the observed geopotential at 1000 mb (full lines, every 40 m) and observed temperatures at 850 mb (thin lines, every 2°C) for 23 and 24 August 1975 00Z respectively.

(a) Forecast 500 mb, day 7 (b) Forecast 500 mb, day 8

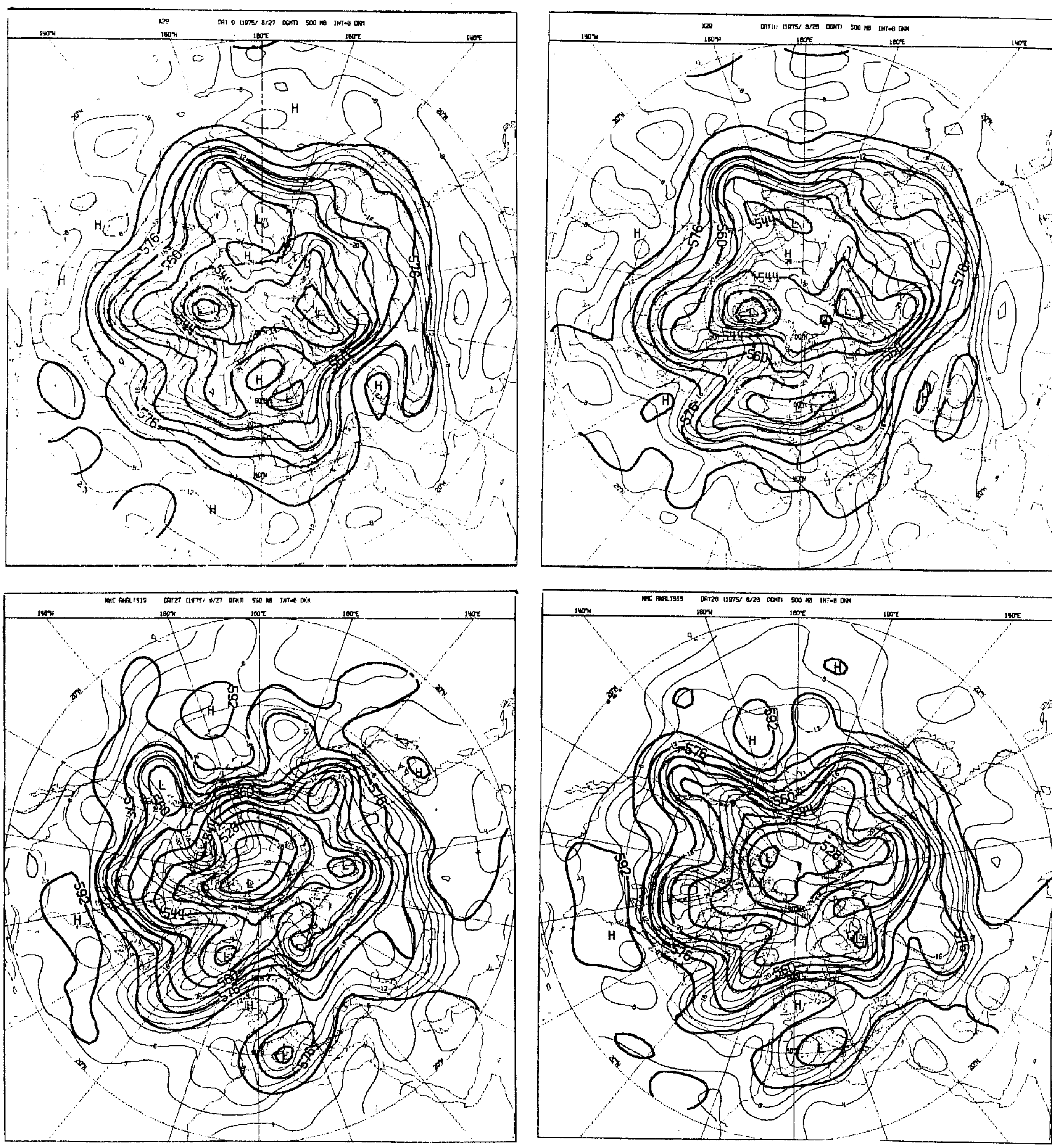


(c) Verification 500 mb, day 7
25 August 1975 00Z

(d) Verification 500 mb, day 8
26 August 1975 00Z

Fig. 6: The same as figure 2 but for day 7 and day 8

(a) Forecast 500 mb, day 9 (b) Forecast 500 mb, day 10



(c) Verification 500 mb, day 9
27 August 1975 00Z

(d) Verification 500 mb, day 10
28 August 1975 00Z

Fig. 7: The same as figure 2 but for day 9 and day 10