TECHNICAL MEMORANDUM

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# Preliminary assessment of long range integrations performed with the ECMWF global model

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## 1. INTRODUCTION

In the last year the French and the German Meteorological Office started a numerical experiment, a ten year global forecast, using a low resolution version (T21 for details, see Appendix 1) of the ECMWF-spectral model.

It was hoped that the experience gained from this test integration might give some information about the feasibility of long term forecasts.

Details about the data available from this long integration can be found in Appendix 2, whilst the boundary conditions are discussed in Appendix 3. At the end of this discussion paper one can find some recommendations for the further evaluation of this experiment.

The 1000 mb and 500 mb height field for the Januarys (30 day mean) are displayed in Fig. 1 and Fig. 2. Each of these maps appears to be meteorological. They also show an inter-annual variability. (The temperature field, on the other hand has a large temperature error over North America which is persistent throughout the winter integration period. This and all other systematic errors of the ECMWF model are described in Arpe (1980), Savijärvi (1980) and Tiedtke (1980)).

The model is able to simulate seasonal changes in the atmosphere as can be seen in Fig. 3. In this figure we have then 850 mb height and wind vector field taken from one summer and one winter day of the 5th year of the integration, a summer and winter monsoon circulation has been established over India.

To date, no further evaluation of this long integration has been carried out at the ECMWF but the ability of the model to produce meteorologically sensible height fields beyond the medium range prediction period (10 days) encouraged us to start some pilot experiments in order to investigate if one could use the model for long range forecasting.

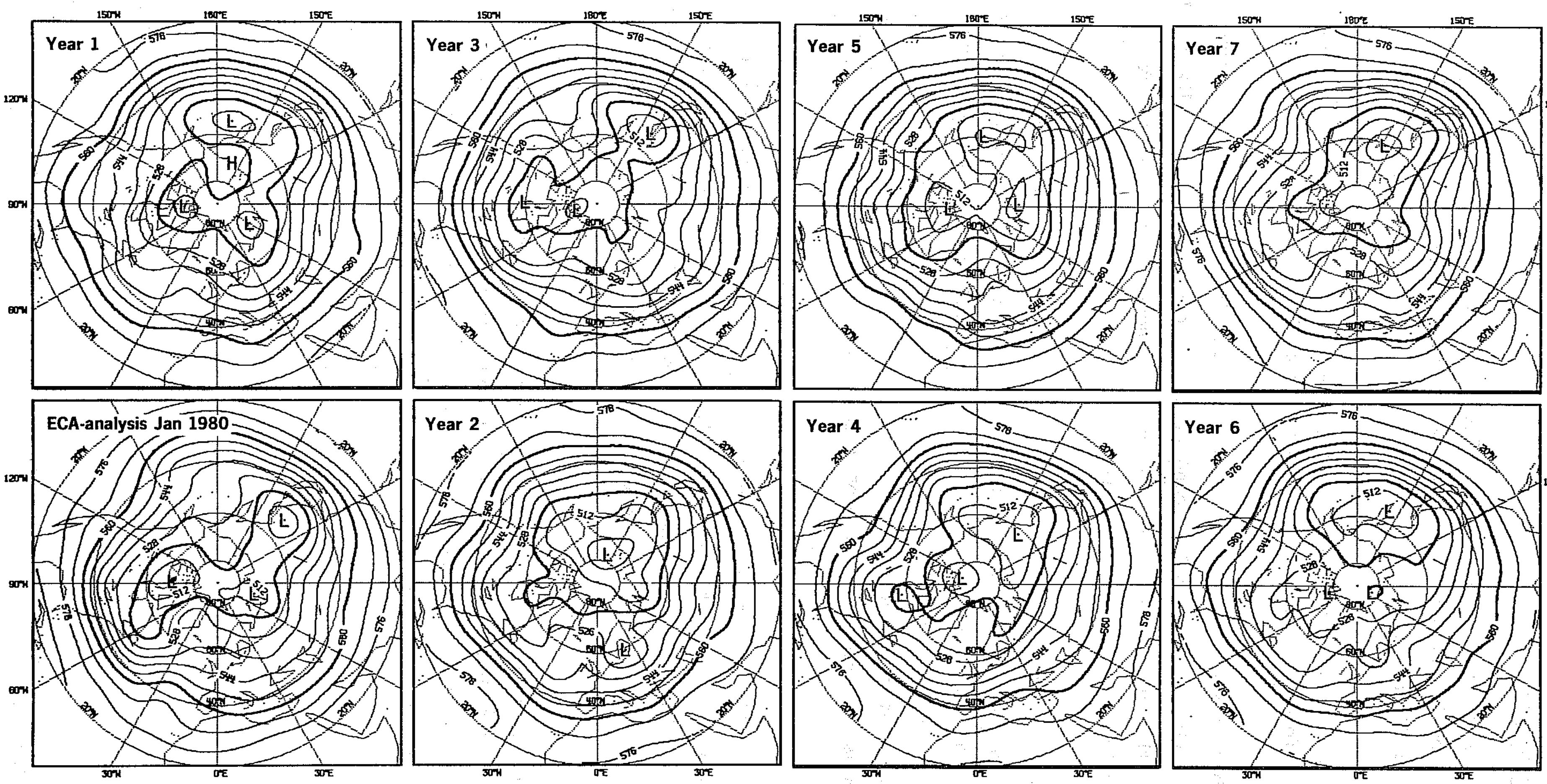



Fig. 1  500 mb 30 day mean height field for January for 7 years

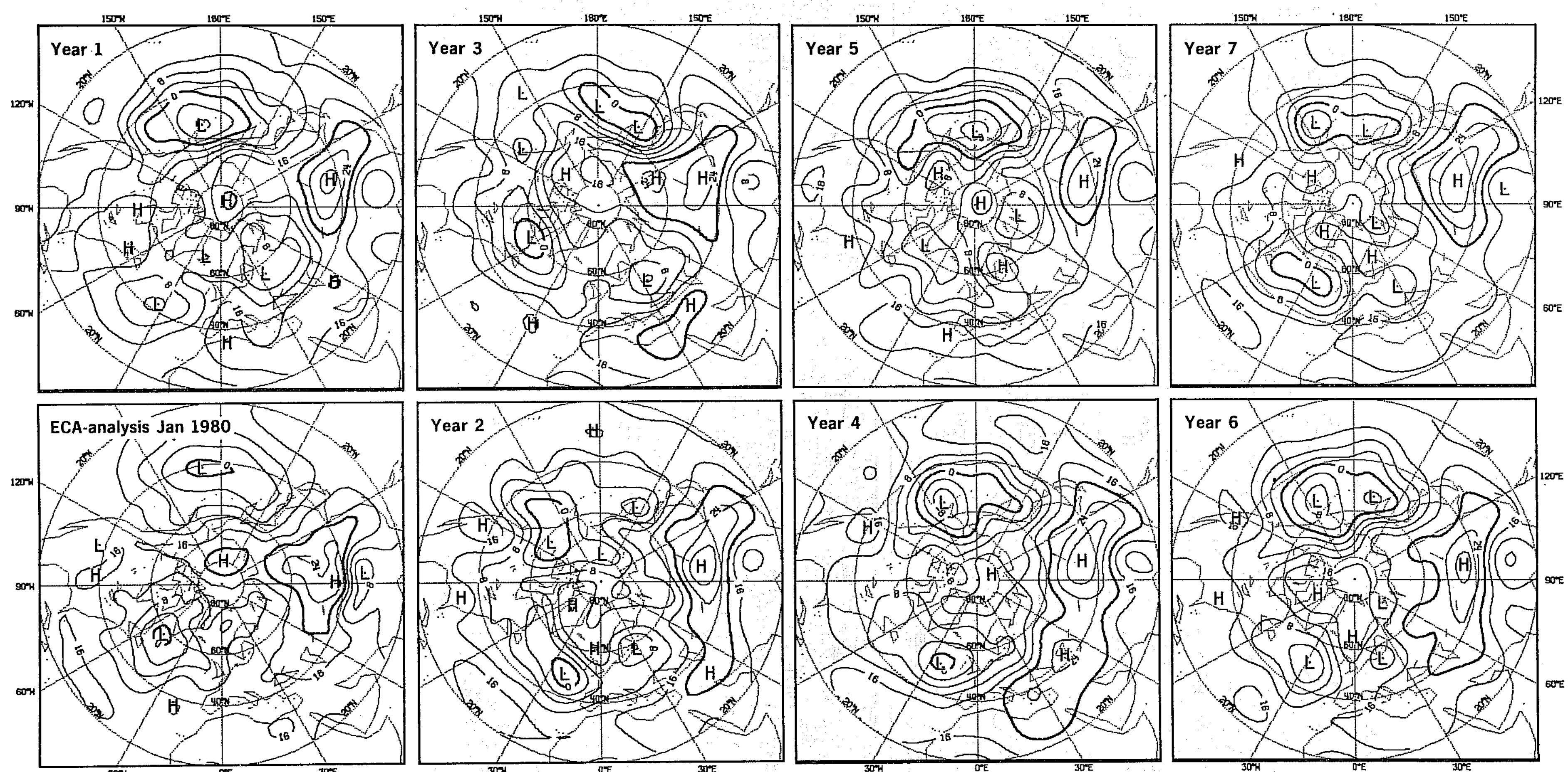



Fig. 2 1000 mb 30 day mean height field for the Januarys

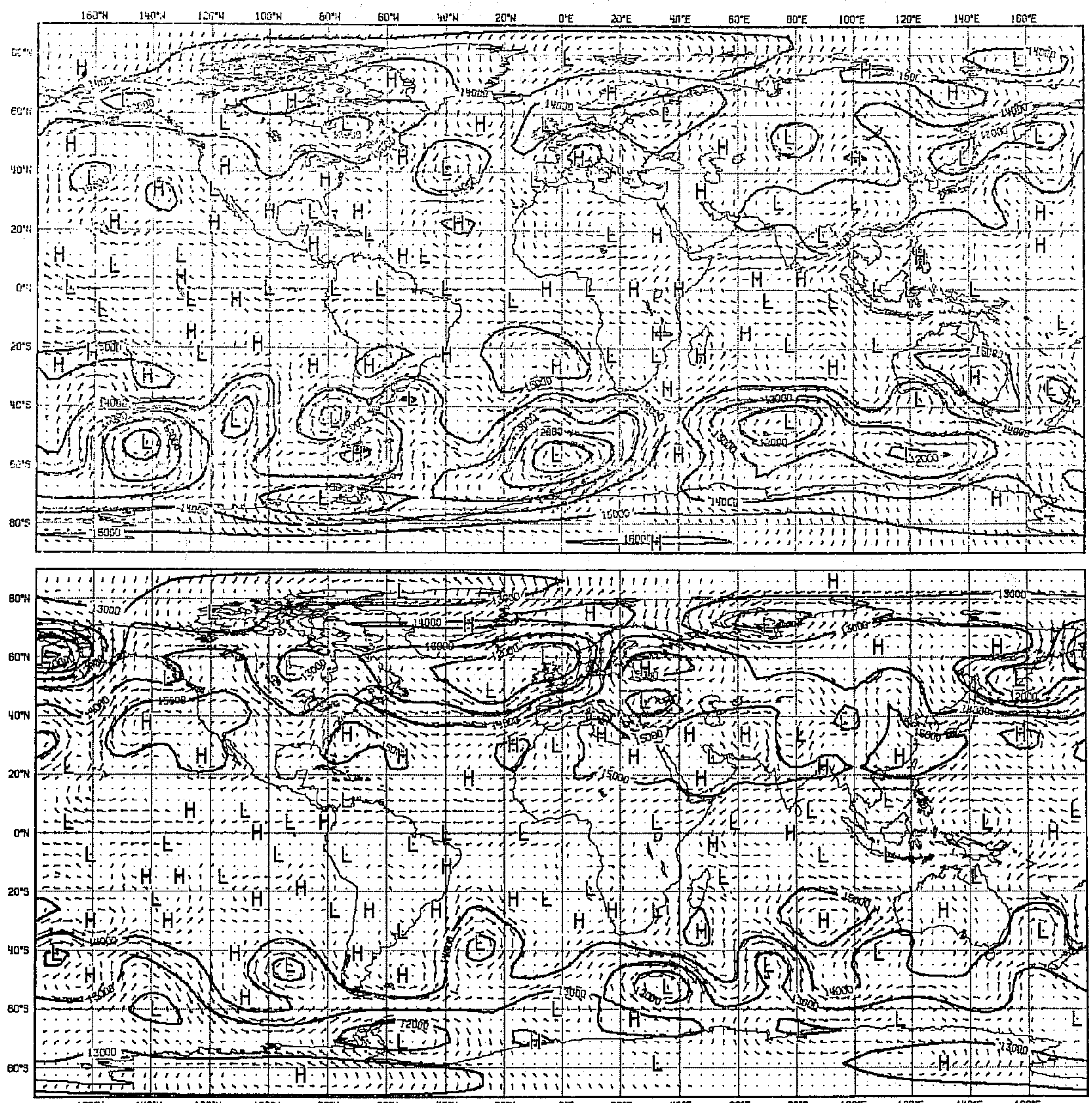



Fig. 3 Flow in the 5th year of the integration for one summer (21 June, top) and one winter day (21 December, bottom) in 850 mb.

## 2. THE PILOT EXPERIMENTS

The quality of a numerical forecast is influenced by three factors

- the initial data
- the model (formulation, resolution, parameterization)
- the boundary conditions

A number of extended range prediction experiments have been carried out at the ECMWF to test the sensitivity of our model to each of those factors individually.

## 3. THE IMPACT OF INITIAL DATA

To test the impact of initial data a series of 60-day forecasts were made, each one starting on the consecutive days:

13.1.79
14.1.79
15.1.79
16.1.79
17.1.79
18.1.79 } not yet integrated
19.1.79 }

The datasets were prepared by the FGGE group. The dataset from the 16.1.79 has been used by Bengtsson (1979) for an investigation of a blocking situation and was known to give an excellent forecast with our operational model.

## 4. EVALUATION

For an objective evaluation of these forecasts a modified version of the ECMWF verification package (Hollingsworth et al, 1979) was used. Instead of making an objective comparison between individual height fields one now compares 10 day mean height fields.

For our purposes we define a mean anomaly correlation and a mean standard deviation as follows:

Correlation

$$\phi_K - \overline{\phi_F}^{\,t} \quad \Box \quad \phi_K - \overline{\phi_A}^{\,t}$$

$\phi_K$ climatological height field

$\phi_F$ forecast height field

$\phi_A$ analysed height field

$\overline{\phantom{x}}^{\,t}$ time average $\frac{1}{t} \sum_{K=1}^{t} \phi^K$

$\Box$ correlations operator

Standard deviation

$$\overline{\phi_F}^{\,t} \quad \Delta \quad \overline{\phi_A}^{\,t}$$

$\Delta$ standard deviation operator

The average period t for the mean height field maps has been chosen at 10 days, since a 30 day mean as selected by Shukla (1980) (which, as he admits was only arbitrarily chosen) seems to produce too smooth fields.

The averaging time span has been chosen in a way that the mean of the forecasts verifies in the same time period:

Let $X_{1,0}$ be the forecast starting at date 1

$X_{n,o}$ be the forecast starting at date n

and $X_{a,b}$ : X forecast started at date a, verifying at day b

averaging period

$X_{1,0}$ $X_{1,1}$ $X_{1,2}$ $X_{1,3}$ $X_{1,4}$ ..................

$X_{2,0}$ $X_{2,1}$ $X_{2,2}$ $X_{2,3}$ ..................

. . . $X_{n,0}$ $X_{n,1}$ $X_{n,2}$ ..................

then the averaging for the forecast $X_{1,0}$ has been started at day $X_{1,0+n}$ and for forecast $x_{n,0}$ at $x_{n,0}$.

The advantage of this method is that the mean maps can be compared directly since they verify at the same date. The disadvantage is that the skill scores for forecasts started on later days are higher, because the effective prediction period is shorter.

These skill scores are displayed in Fig. 4.

In medium range forecasting an anomaly correlation coefficient of 60% has been adopted as a threshold value below which a forecast is not any longer considered to be useful synoptically. Even though it is difficult to justify the use of this criterion for our mean anomaly correlation it has been chosen for this first evaluation.

While the experiments starting on the 13.1. and 14.1. have already at the beginning (day 0 - 10) a correlation of less than 60% (which might be a consequence of the averaging method), the forecasts from the other initial dates start at more than 70% and cut the 60% mark between day 5-15. The forecasting starting at the 15.1 stays above the 60% threshold until day 10-20. This is remarkable since these skill scores are valid for the whole northern hemisphere (20 - 80°N) and not only for a single pressure anomaly. If one considers solely those (Miyakoda,*) one can find in the mean 500 mb height field for day 30 to 40 (Fig. 5) a number of pressure anomalies which coincide with the observed mean, such as the cold air mass over Europe in the forecasts from the 13., 14., 15., or the high pressure anomaly over the Pacific which is simulated in the runs of the 15., 16., and 17.

Whether these anomalies have any significance or if they are just one state of the model, which happens to coincide with the real atmosphere, should be the subject of further investigation. It is hoped that in the course of the evaluation of the 10 year integration one might be able to define confidence limits with which these runs can be tested.

* personal communication

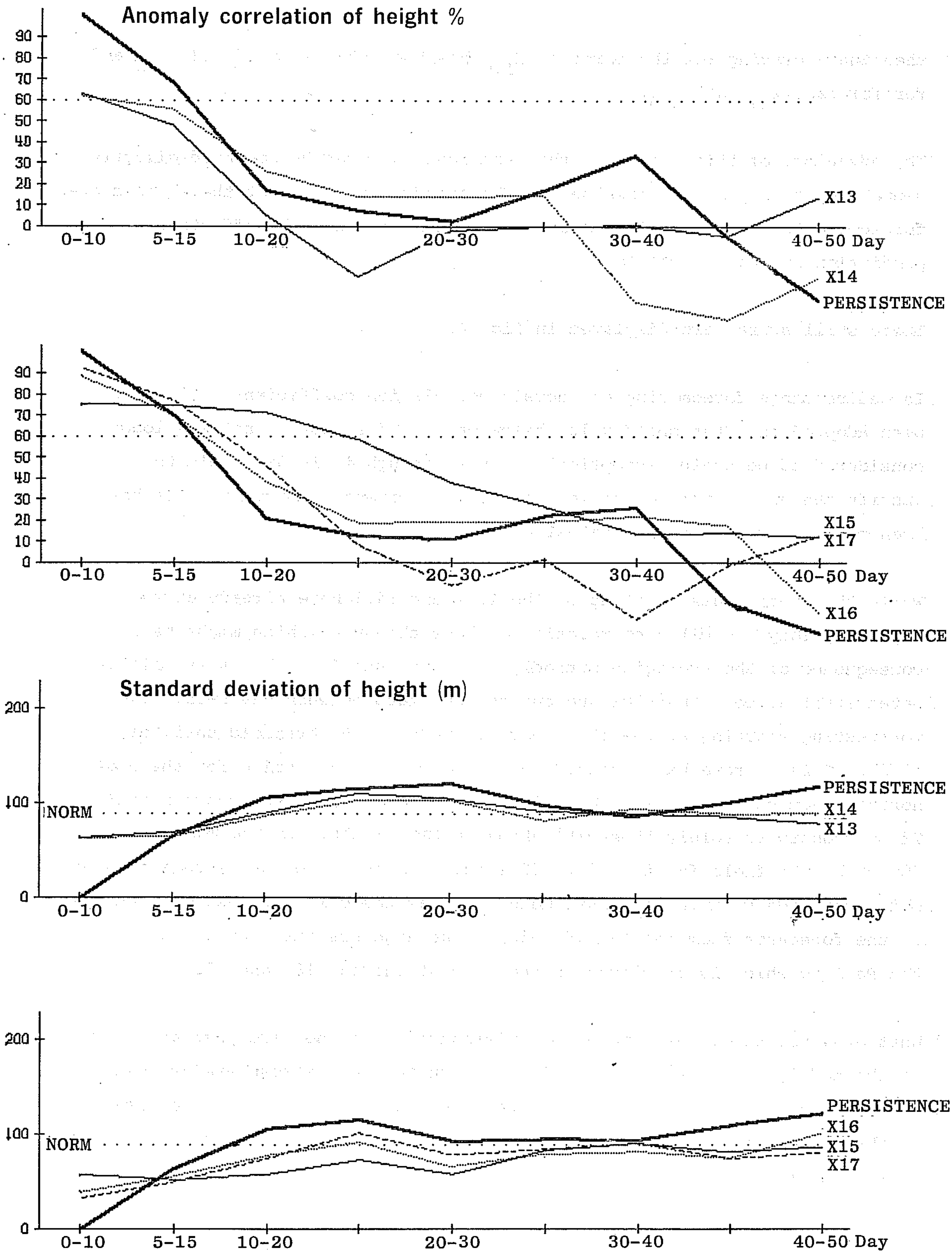



Fig. 4 Objective 10 day mean verification for wavenumber 1-3 (X13: forecast started at the 13 Jan 1979; X14: 14 Jan 1979), for the 500 mb height field.

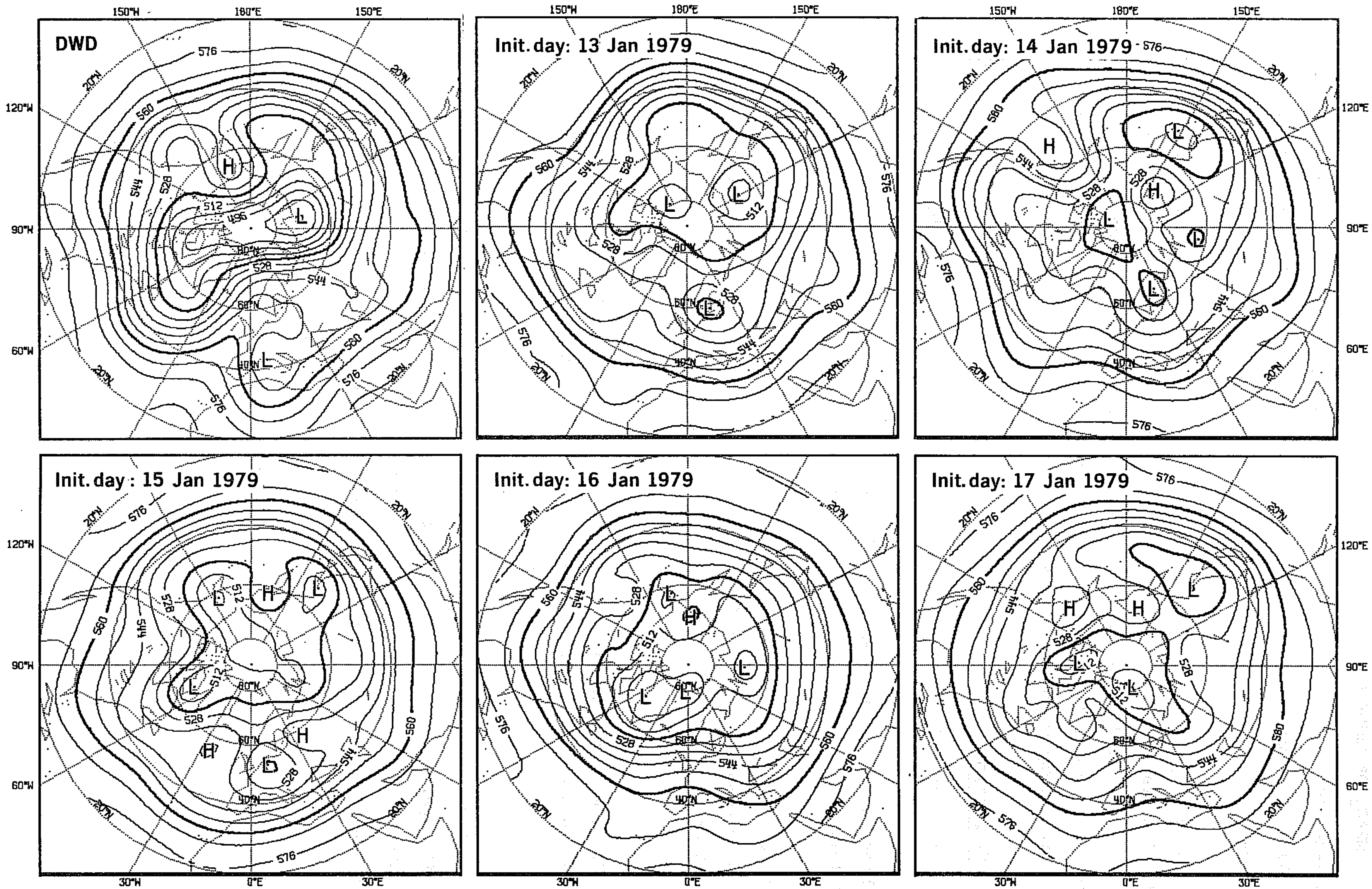



Fig. 5 The 10 day mean 500 mb height field (averaging period: day 30-39 for 17.1.79)

## 5. IMPACT OF RESOLUTION

Bengtsson (1979) discussed the impact of resolution on a number of 10-day forecasts made from the 16.1.79 and reached the conclusion that an increase in resolution improves the performance.

To find out, if that rule is also valid for longer prediction time, some 50-day integrations using T63 and T40 resolution have been reevaluated and compared with the T21 forecast discussed above. These high resolution runs started from older FGGE analysis and did not contain any adjustment of the sea surface temperature with time.

## 6. EVALUATION

The skill scores for these three experiments are displayed in Fig. 6.

The high resolution run has up to day 5-15 a higher anomaly correlation coefficient than any others and it is still better than 60% at day 10-20.

It thereafter drops off quite rapidly. The T40 integration is at the beginning comparable to T21 (this might be caused by the use of a poorer initial data set for this run) but stays at about 40% correlation until day 25-35.

The 500 mb mean height maps for day 26-35 can be found in Fig. 7. The trough over north-east America is predicted quite well in the T40 and T63 integration, but is shifted too far to the east.

This feature together with the low over the Pacific (instead of a ridge) exhibits again one systematic error of the ECMWF model, the tendency to overdevelop lows over the oceanic regions. It seems that this systematic error, which is not apparent with T21 resolution, reduces the variability of the high resolution models, but this should be the subject for further investigation though the costs in computer time are probably prohibitive.

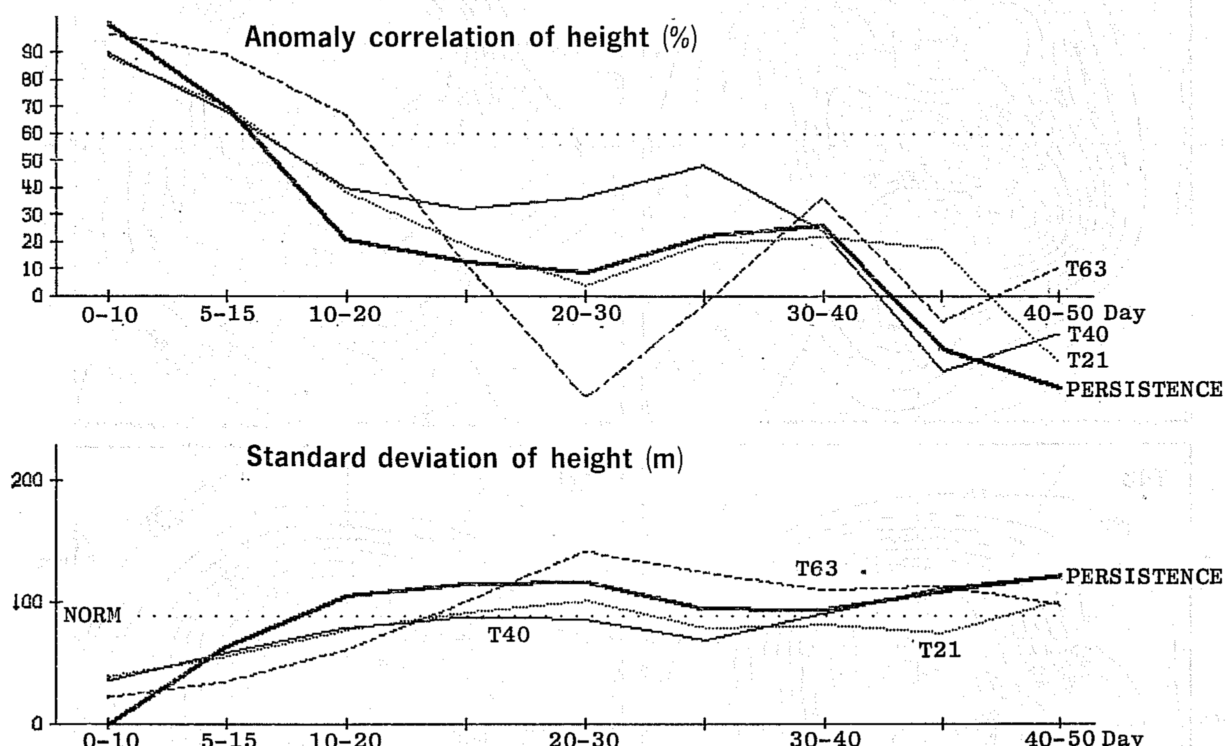



Fig. 6 Objective 10 day mean verification for wavenumber 1-3 in dependence of resolution, for the 500 mb height field.

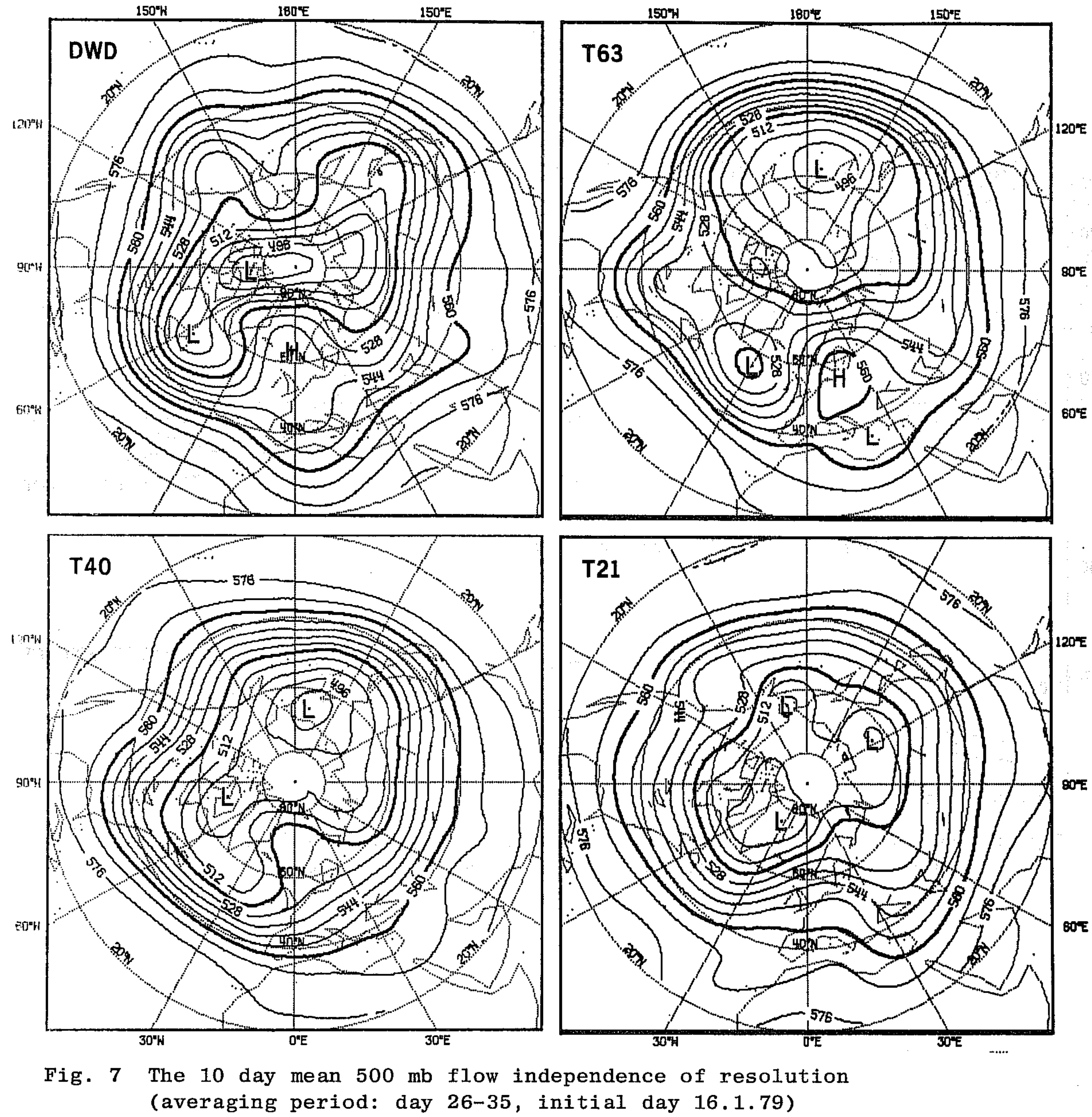



Fig. 7 The 10 day mean 500 mb flow independence of resolution
(averaging period: day 26-35, initial day 16.1.79)

## 7. IMPACT OF CHANGES IN THE BOUNDARY CONDITION

An estimate of how sensitive the model is to changes in the boundary conditions can be obtained from the experiment carried out for the MPI (Hamburg). This test integration was started from the same initial date as that for the 10 year integration. The only difference between both integrations was that the MPI run had the addition of the sea surface temperature anomaly shown in Fig. 8. This experiment has not yet been evaluated but an objective comparison (for single days) between the run with and without this anomaly shows (Fig. 9) that the effect of this change in the boundary condition is felt in the forecast after about 10 days and makes them completely different after 15 days.

## 8. SUMMARY

These experiments gave the following results:

The ECMWF model is able, on occasions, to simulate atmospheric anomalies beyond day 10 which match with the observed mean pressure pattern. The statistical significance of this result has still to be proven. However, the initial data seem to have influence on the development of a similar mean pressure pattern between analysis and model forecast.

Higher resolution definitely improves the medium range forecast. The results for long integrations are less clear cut.

Changes in the boundary layer affect the forecast on a large scale time range (after about 1 week).

The model integration shows an inter-annual and seasonal variability.

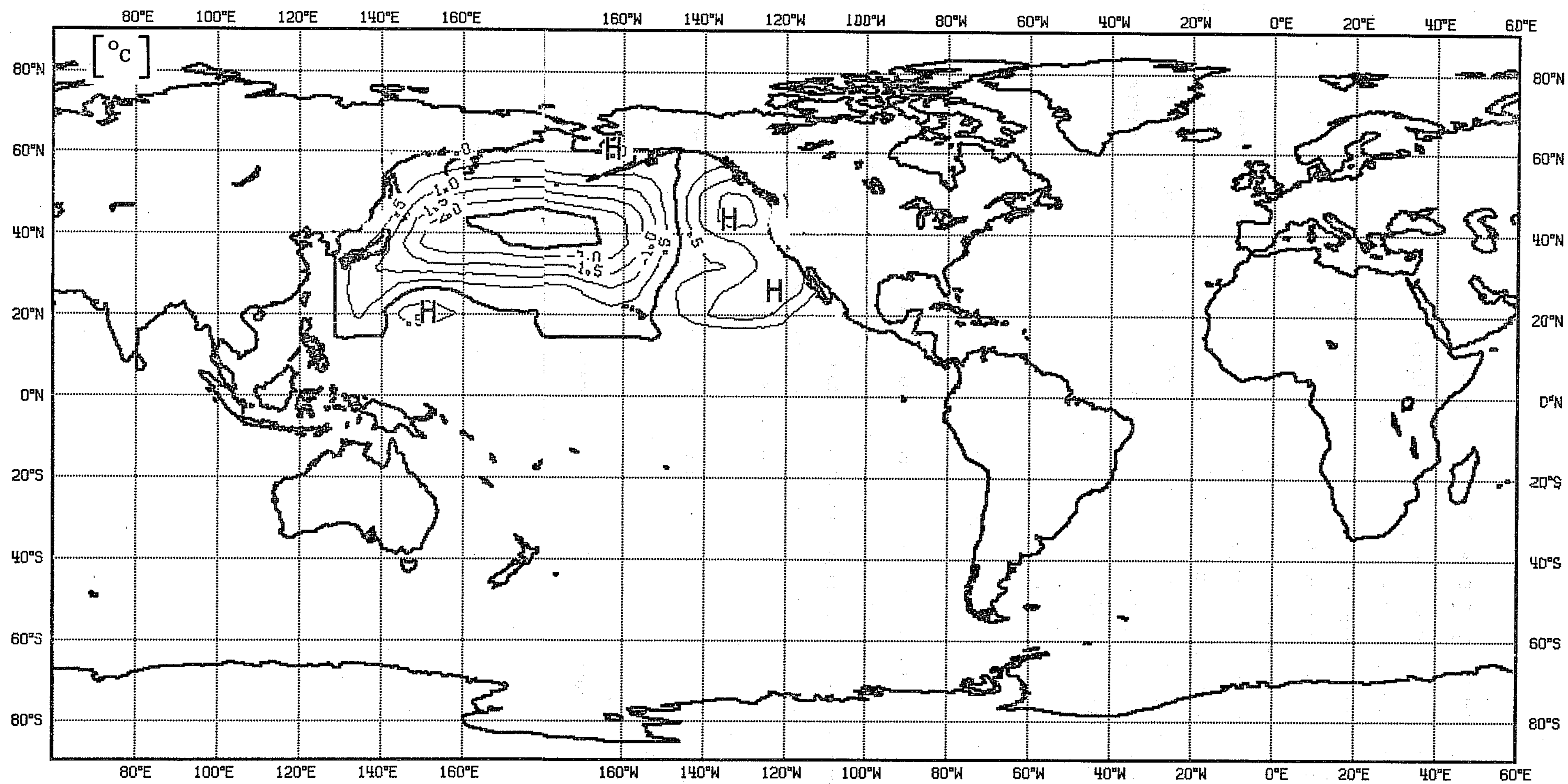
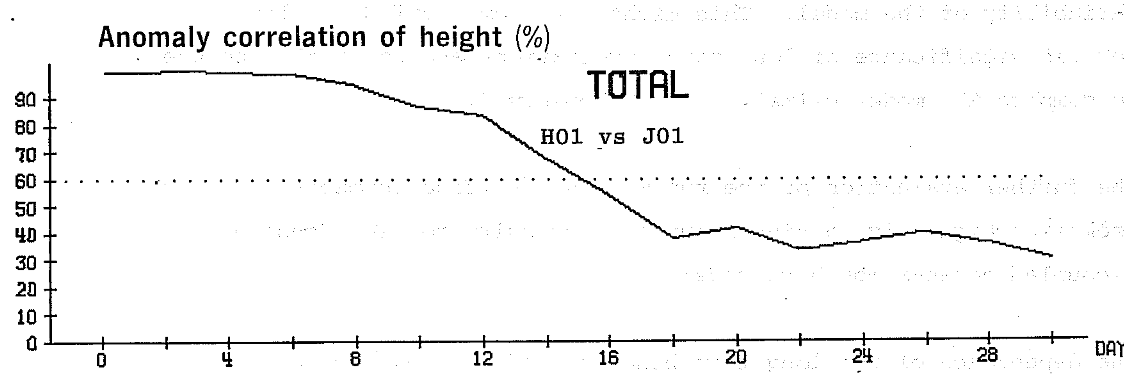



Fig. 8 The sea surface temperature anomaly used in experiment H01 (after Hannoschöck, MPI Hamburg).



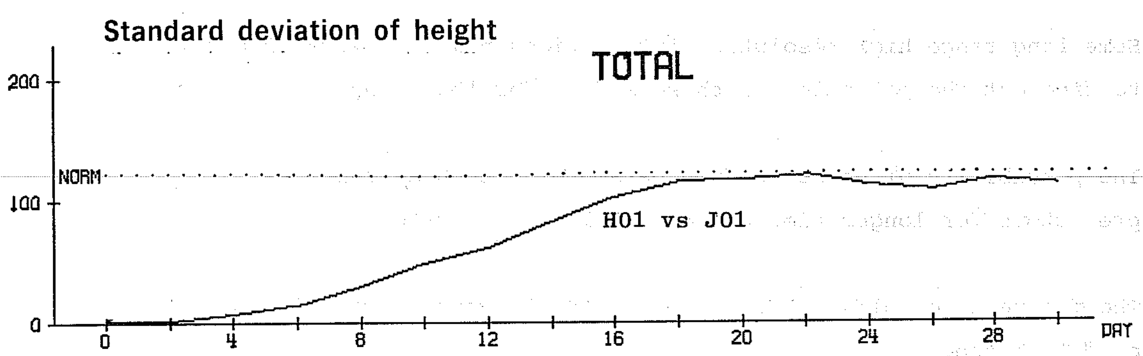




Fig. 9 Inter comparison between the standard forecast (J01) and a forecast with changed sea surface temperature (H01) (norm value for January), for the height field from 1000mb - 200mb.

## 9. RECOMMENDATIONS

To investigate the field of long range prediction further, it is therefore recommended:

1. To use the 10 year integration to define the inter-annual and seasonal variability of the model. This might give some confidence limits for the significance of long range predictions and could also be used to compare the model climate with the observed.

2. The further evaluation of the run with sea surface temperature anomalies might give a hint about the necessity for implementing a coupled ocean-atmosphere model.

3. The dependence of the long term behaviour of the model on the initial state has to be investigated further.

4. Some long range high resolution integrations have to be carried out to find out the potential of those models for long range prediction.

5. The possibility of using surface parameters (such as rain) as predictors for longer time scales should be evaluated.

6. The frequency of blocking patterns in the 10 year integration should be determined.

## APPENDIX 1

The ECMWF model:

The spectral model is described in Baede et al (1979).

The parameterization of subgrid scale processes can be found in Tiedtke et al (1978).

Definition of the resolution for spectral models:

T21 $\hat{=}$ triangular truncation 21 $\hat{=}$ isotrope resolution with maximum zonal wavenumber 21 $\hat{=}$ grid for physical parameterization $5.6^{\circ}$.

T40 $\hat{=}$ triangular truncation 40 $\hat{=}$ isotrope resolution with maximum zonal wavenumber 40 $\hat{=}$ grid for physical parameterization $2.8^{\circ}$.

T63 $\hat{=}$ triangular truncation 63 $\hat{=}$ isotrope resolution with maximum zonal wavenumber 63 $\hat{=}$ grid for physical parameterization $1.875^{\circ}$.

The vertical resolution was 15 levels on $\sigma$-coordinates.

## APPENDIX 2

Data available from 10 year integration (write up every second day)

multilevel fields

| | | |
|---|---|---|
| $\phi$ | geopotential height | [m] |
| T | temperature | [°K] |
| q | mixing ratio | |
| u, v | wind components | [m/sec] |
| $\omega$ | vertical velocity | [Pascal/sec] |

these data are on pressure levels in T21 spherical harmonic coefficients with 15 bit accuracy. Twelve pressure levels are stored:

1000 mb, 850 mb, 700 mb, 500 mb, 400 mb, 300 mb, 250 mb
200 mb, 150 mb, 100 mb, 70 mb, 50 mb.

single level fields

p* surface pressure in T21 spherical harmonic components

all other 2 dimensional fields are stored as grid point values.

| item | code no.* | unit |
|---|---|---|
| surface temp | 11 | [°K] |
| soil wetness | 12 | [m] |
| snow depth | 13 | [m] |
| large scale rain | 14 | [m] |
| convective rain | 15 | [m] |
| snowfall | 16 | [m] |
| boundary layer dissipation | 17 | [W/m²] |
| surface sensible heat flux | 18 | [W/m²] |
| surface latent heat flux | 19 | [W/m²] |
| surface stress | 20 | [W/m²] |
| surface radiation | 21 | [W/m²] |
| radiation at top of the atmosphere | 22 | [W/m²] |

APPENDIX 2 (Continued)

These fields are stored on Gaussian latitudes from north to south and on 64 points with an even distance from west to east (point 1 $\hat{=}$ $0^{o}$ Greenwich)

The latitude lines are

| | | | | | |
|---|---|---|---|---|---|
| 85.761, | 80.269, | 74.745, | 69.213, | 63.679, | 58.143, |
| 52.607, | 47.070, | 41.532, | 35.995, | 30.458, | 24.920, |
| 19.382, | 13.844, | 8.307, | 2.769 | | |

These latitude lines are symmetrical to the equator.

Diagnostics

The diagnostics for diabatic heating, moistening and momentum dissipation are available as zonal mean for each latitude line.

*code number as specified in ECMWF Technical Memorandum No.2.

## APPENDIX 3

## BOUNDARY CONDITIONS

1. Sea surface temperature adjusted every fourth day to the climatological mean

2. Solar angle adjusted every 12 hour prediction time. No daily cycle.

3. Deep soil temperature and soil moisture set constant to value of November.

4. Surface temperature over land is predicted.

5. Surface temperature over sea ice was not changed (consequence: once a sea point was considered as ice it could never melt again).

6. Albedo and cloud cover is calculated in the model.

7. Surface roughness over land is specified and over sea calculated from Charnock formula.

## REFERENCES


Arpe, K. 1980 The verification and diagnostics package at ECMWF Workshop on 'Diagnostics of diabatic processes', ECMWF, 101-114.

Baede, A., Jarraud, M, Cubasch, U. 1979 Adiabatic formulation and organisation of ECMWF's spectral model. ECMWF Tech. Rep. No.18

Bengtsson, L. 1979 Numerical prediction of atmospheric blocking. Proceedings of the ECMWF Seminar 1979 on Dynamical Meteorology and Numerical Weather Prediction, Vol. 2, 270-323.

Hollingsworth, A., Arpe, K., Tiedtke, M., Capaldo, M., Savijärvi, H., Åkesson, A., Wood, J.A. 1979 A comparison of medium range forecasts made with two parameterization schemes. ECMWF Tech. Rep. No.13.

Savijärvi, H. 1980 Energy budget calculations and diabatic effects for limited areas computed from ECMWF analyses and forecasts. Workshop on 'Diagnostics of diabatic processes', ECMWF, 115-134.

Shukla, J. 1980 Predictability of time averages. Part I Dynamical predictability of monthly means. Manuscript from Goddard Laboratory of Atmospheric Sciences, Greenbelt, Md., USA.

Tiedtke, M., Geleyn, J.-F., Hollingworth, A., Louis, J.-F. 1978 ECMWF model parameterization of subgrid processes, ECMWF Tech. Rep. No.10.

Tiedtke, M. 1980 Diagnostics of diabatic processes in global numerical experiments at ECMWF. Workshop on Diagnostics of diabatic processes', ECMWF, 135-152.