# COMPARISON OF THE INFLUENCE OF DIFFERENT RADIATION PARAMETERIZATIONS ON 10 DAY FORECASTS

U. Cubasch

ECMWF

## 1. INTRODUCTION

In order to illustrate the importance and the impact of radiation parameterisation on numerical forecasts and to have by this a practical background information for this workshop, a number of 10-day forecasts, using different radiation parameterisation schemes, but an identical forecast model, have been performed at the ECMWF. Similar experiments, but less praxis orientated, have been carried out also by the U.K. Met Office (Slingo, see paper to this Workshop) while in most other research work a change in the radiation scheme was accompanied by change in the whole parameterisation package (Hollingsworth et al 1979). While a parallel evolution of the diagnostic radiation variables of these runs has been carried out by Hense (see his article for this Workshop), in this paper the ECMWF standard evaluation (Hollingsworth et al 1979) results are discussed.

## 2. THE EXPERIMENTS

All experiments were carried out using the ECMWF operational forecast model. This model, enstrophy conserving and using a semi implicit time stepping scheme, has a horizontal resolution of 1.875$^{o}$ and 15 levels in the vertical (top level at about 25 mb). The parameterisation of diabatic processes includes vertical and horizontal diffusion, large-scale cloud generation and convective cloud parameterization (details see Tiedtke et al 1979).

The initial data were taken from the global analysis from NMC for the 15.2.76 and the 25.8.75 (Hollingsworth et al, 1979).

Three parameterisation schemes for the radiation calculation were incorporated in this model:

i) The GFDL-radiation scheme (GF)
   As one of the earlier developed radiation schemes this one uses only the temperature field as input variable. Every other parameter (water vapour, cloud, ozone, $CO_2$) is prescribed after a seasonal climatology. (Manabe et al, 1964).

ii) The Köln radiation scheme (CO)
   This has been developed for use in the DWD (German Meteorological Office). This scheme is interactive, i.e. it uses besides the temperature also the humidity field as input information. The cloud cover is calculated from the humidity field. If clouds exist in different layers, then their overlapping is distributed randomly (Hense, et al 1980).

iii) The ECMWF radiation scheme (EC)

This scheme has now been used for more than one year to perform the regular 10 day forecasts at the ECMWF. Although it is formulated in details different from the Köln-scheme it uses the same input variables. The cloud amount is calculated the same way as the Köln scheme, but in the vertical they overlap each other in such a way that the smaller clouds in one level are sheltered by larger ones in different levels (Tiedtke et al, 1979).

## 3. EVALUATION

A subjective synoptic evaluation revealed only minor differences between the experiments, as long as those resemble the analysis within reasonable limits. The height field in 1000 mb and 500 mb for the experiments starting on the 25.8.75 at day 6 is displayed in Fig. 1. While the North Atlantic Region is predicted fairly well in all three cases, the Pacific area does not agree very much with observation. The flow pattern in 1000 mb is weakest in the Köln experiment, but strongest with the GFDL package. In single disturbances (North America) the height difference between those two runs amounts to about 20 dkm.

The objective verification (Figs. 2,3) does not show differences so bluntly. Up to the point where the forecast can be considered useful, the radiation schemes produce similar results and eventual differences are not systematic.

The time evolution of the temperature ($C_pT$) for both seasons can be found in Fig. 4. The EC-radiation scheme curve reflects the well known problem of a continuous temperature drop within the first 10 days of the forecast. While in the February integration the Köln-scheme produces almost no temperature loss, it looses about $1^{\circ}K$ within the 10 August days.

The evolution of the total (zonal and eddy) kinetic energy (Fig. 5) shows an increase with the EC radiation with time, so does also the GFDL scheme, while the Köln scheme seems to damp it with time. The ratio between zonal and eddy kinetic energy (Fig. 6) gives us some information about the interaction between the radiation scheme and baroclinic waves in the atmosphere. Since the GFDL scheme applies a zonally averaged cloud cover to the radiation, one must assume that the model responds with an increase in zonality. Compared to the EC scheme only one finds this assumption confirmed. But also the Köln scheme increases zonality, what, if one takes the drop of total kinetic energy into account, means an overproportional disappearance of eddies.

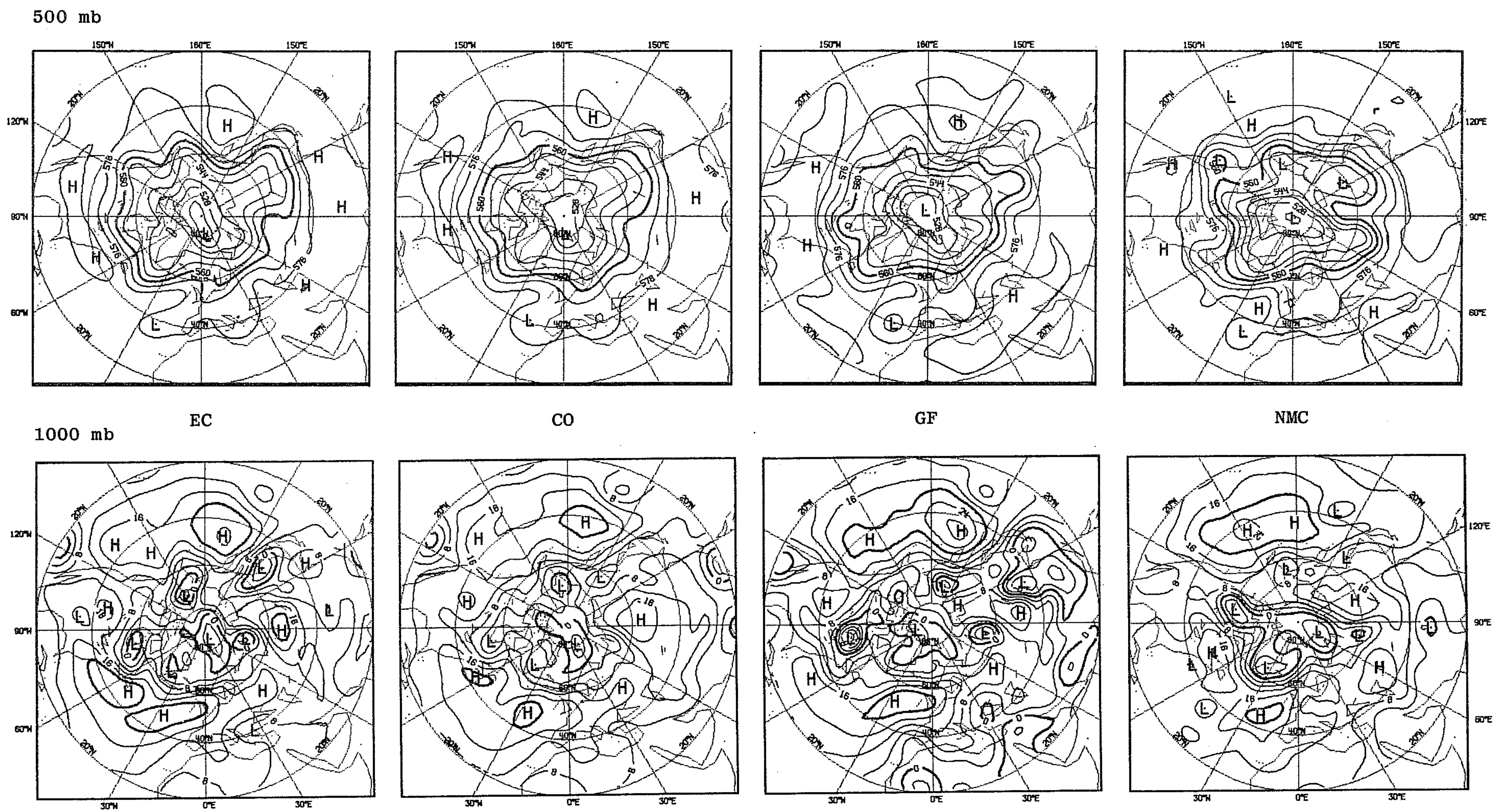


Fig. 1 The 1000 mb and 500 mb height field at day 6 of the forecast of the 25.8.75. Contouring intervals: 500 mb : 80 m, 1000 mb : 40 m (northern hemisphere)

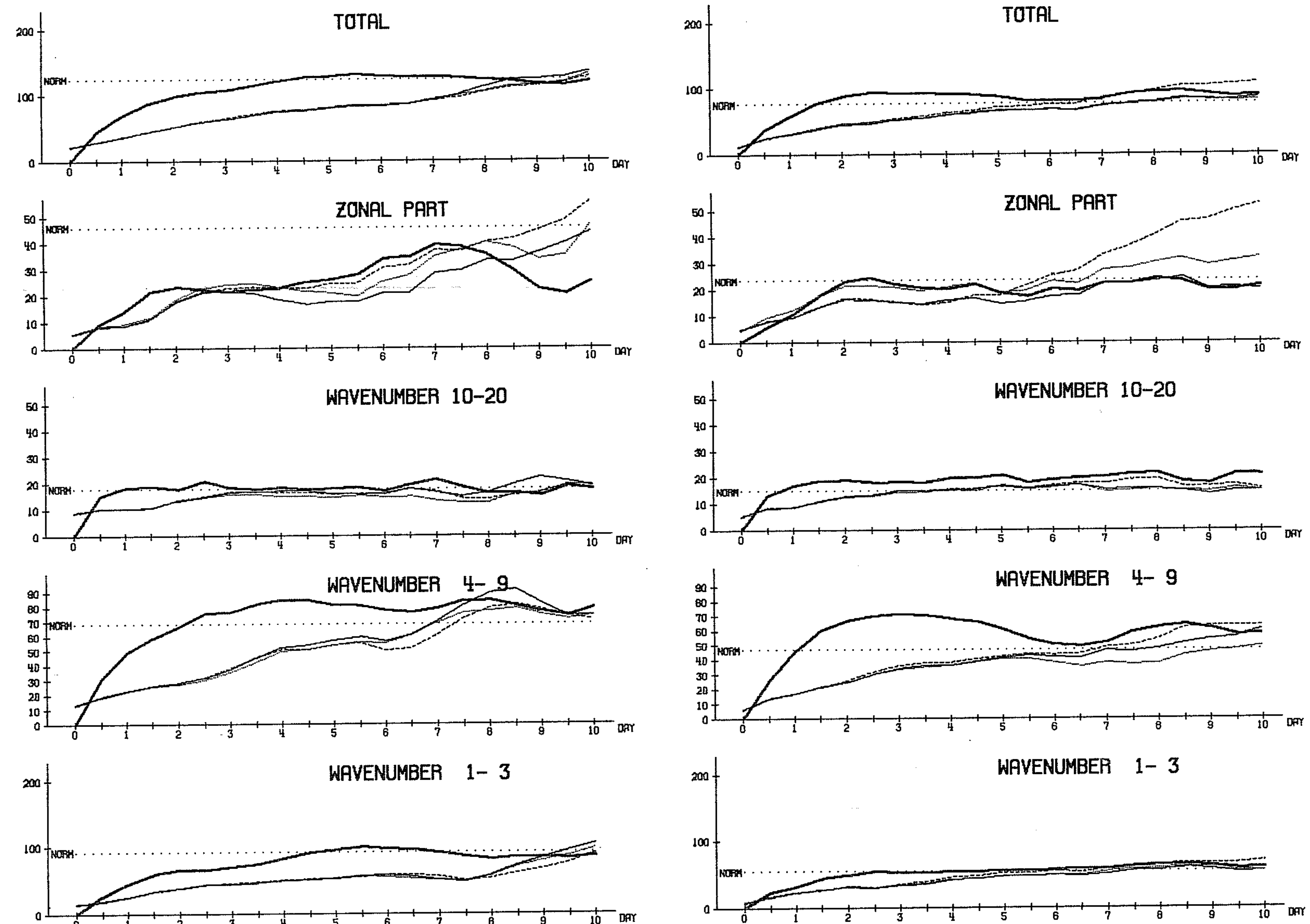


Fig. 2 The standard-deviation of height as function of forecast time (mean of 1000...200 mb, area: $20^{o}...82.5^{o}N$)
left: 15.2.76 right: 25.8.75 ..... Cologne ——— ECMWF ----- GFDL ▬▬ Persistence

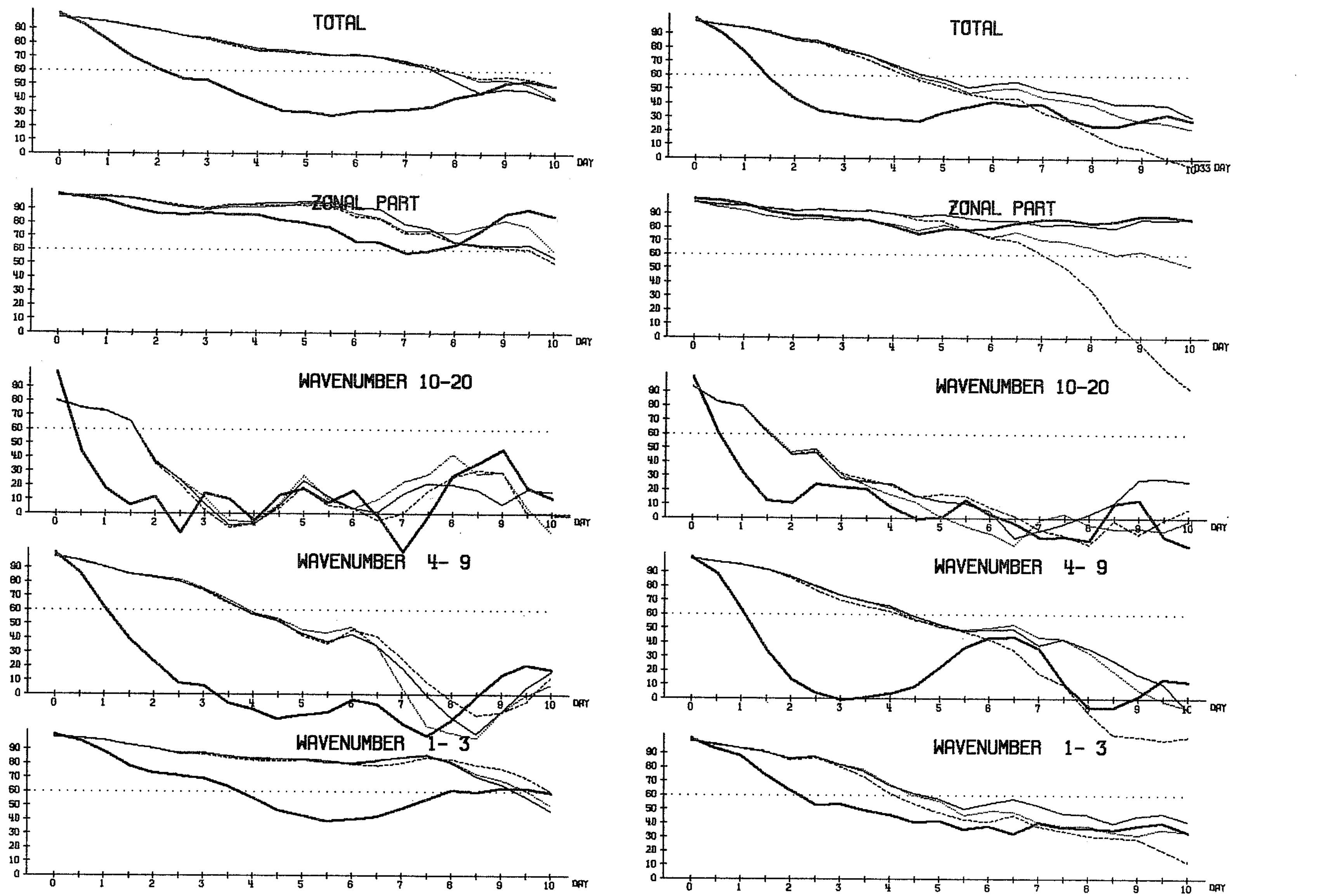


Fig. 3 The anomaly-correlation of height as function of forecast time (mean of 1000...200 mb, area: $20^{o}...82.5^{o}$N)
left: 15.2.76 right: 25.8.75 ..... Cologne ——— ECMWF ----- GFDL ━━━ Persistence

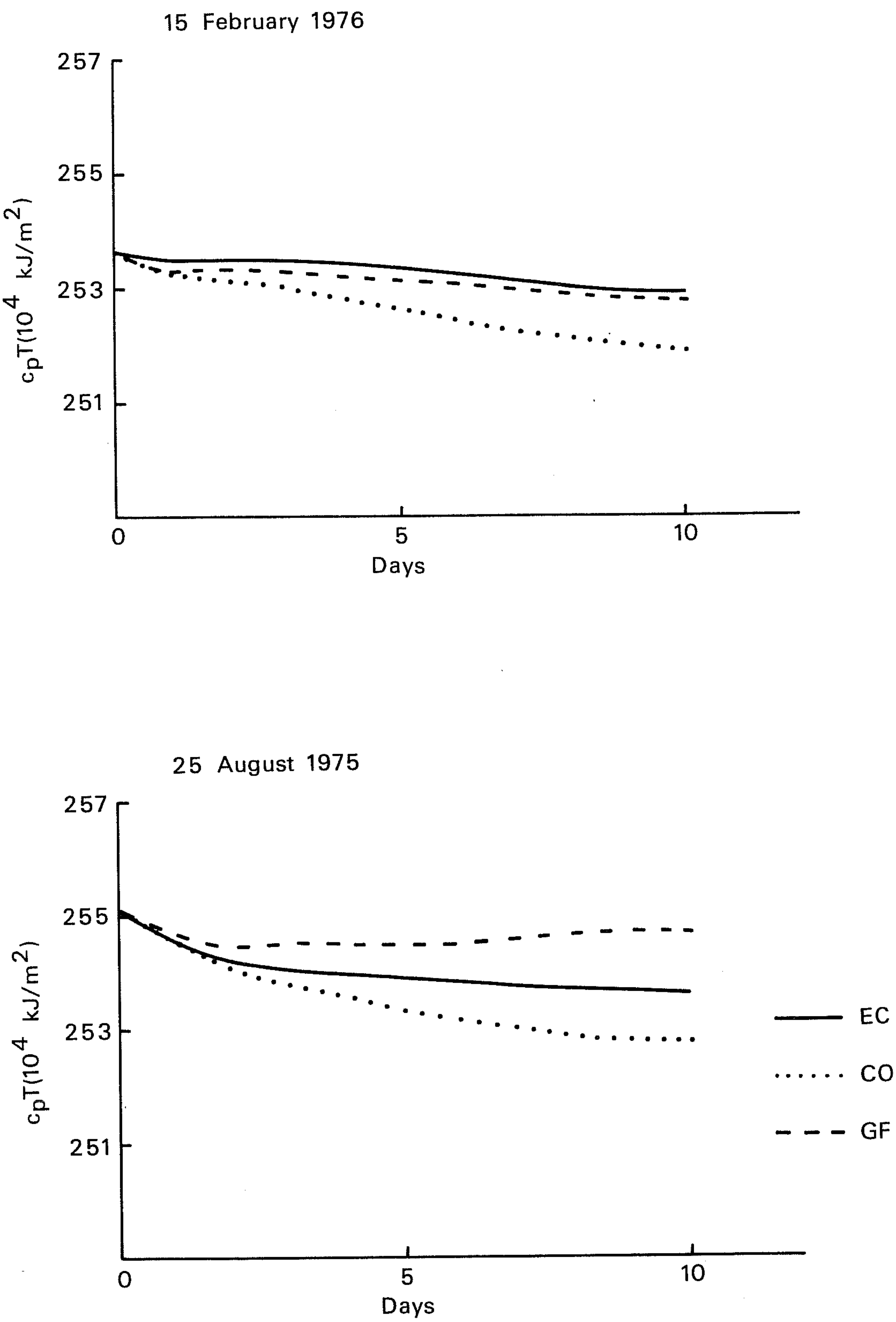


Fig. 4 The global mean enthalpy ($c_pT$) as function of forecast time.

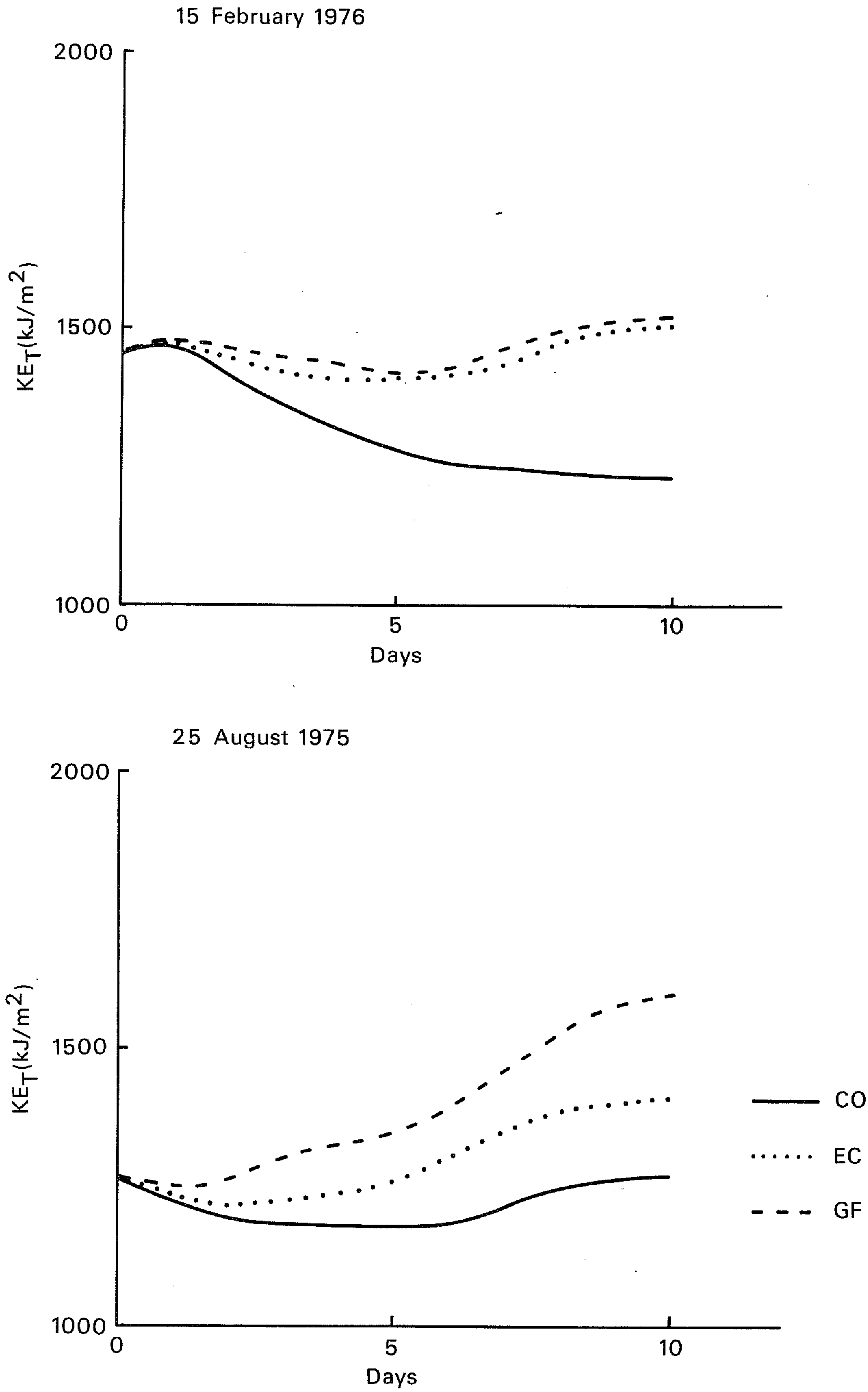


Fig. 5 The global mean total kinetic energy as function of prediction time.

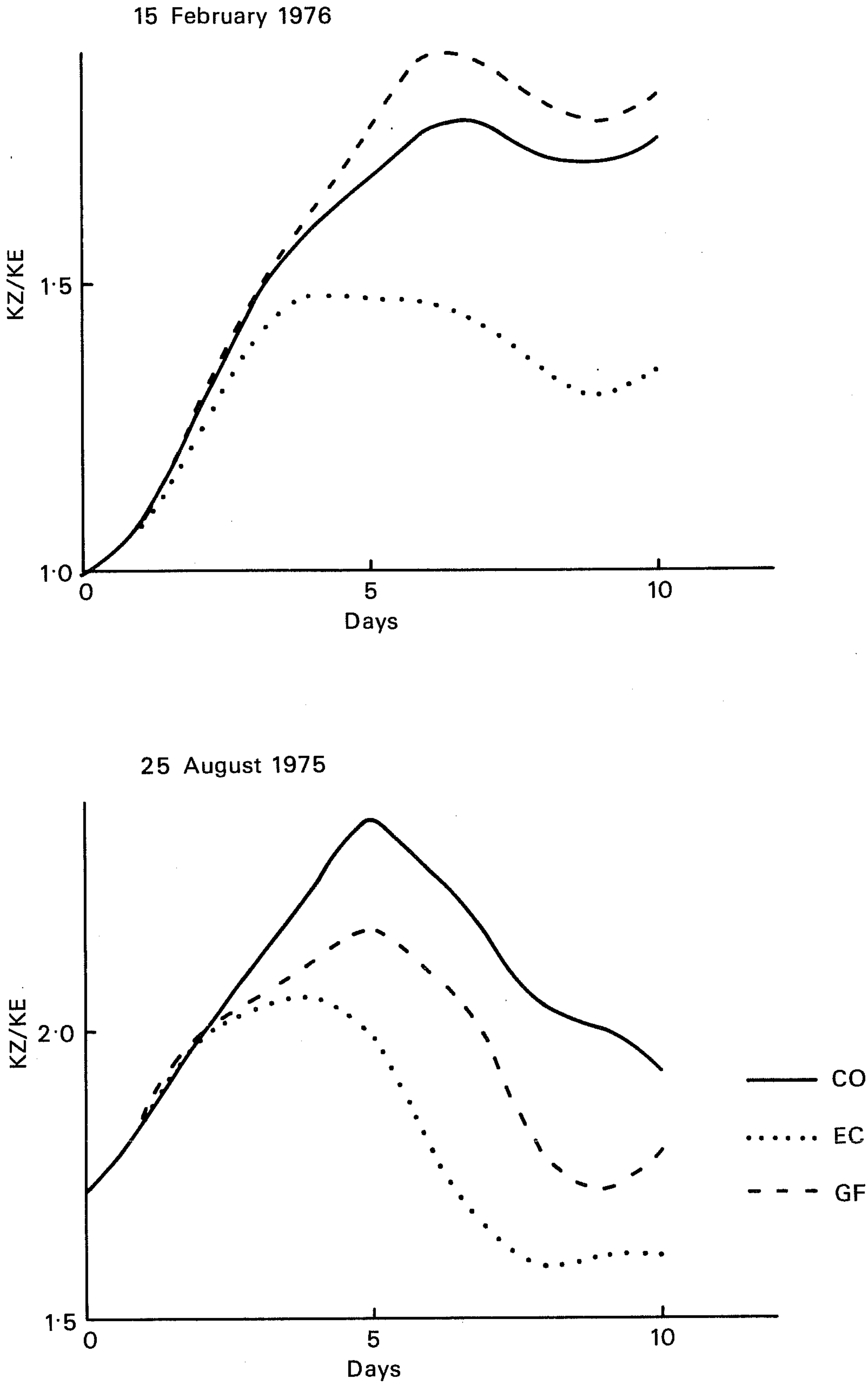


Fig. 6 The ratio of the globally averaged zonal kinetic energy to the globally averaged eddy kinetic energy ("zonality") as function of prediction time.

To gain some insight in the model atmosphere the meridional cross-sections for the temperature deviation from observation as well as the zonal mean of the zonal wind, averaged over the last 4½ days of the forecasts, are displayed in Figs. 7,8. While we find in the north winter hemisphere a too cold troposphere in all integrations, it is too warm in the GFDL summer atmosphere. The EC-scheme produces always a too cold stratosphere, while the Köln scheme and the GFDL scheme has a positive temperature deviation there. Both ECMWF as well as GFDL schemes, tend to warm the boundary layer in the polar region.

The zonal mean of zonal wind gives for all experiments a good agreement. The jet is not shifted at all in the Köln run in winter and its strength matches the observed one. The EC-radiation generated jet is too far north and too weak while the one of the GFDL radiation is too strong and too much south. In the summer all jets are too weak predicted. In this season the easterly flow in the tropical high atmosphere is too strong in all three cases.

Finally one has to consider how the energy-cycle in the model atmosphere is changed by the different radiation schemes. This will be illustrated on a number of meridional cross-sections through the atmospheres.

The 10 day mean of radiative heating is displayed in Fig. 11 for the winter and for the summer integrations. To ease the comparison the radiative heating according to Dopplick (1972) (Fig. 9) and the meridional integral of this heating can be found in Fig. 10. In a recent publication by Cox (1970) a different vertical heating distribution from Dopplick's has been found. The reason for this lies in the humidity field. While Dopplick relied for the tropics on a rough estimate, Cox uses actual data from GATE, which show a considerable higher humidity value than guessed by Dopplick. Since the tropics plays a major role in the radiation budget, it was felt necessary to correct the zonally and meridionally averaged heat profile accordingly. The stratosphere however is based solely on Dopplick's data.

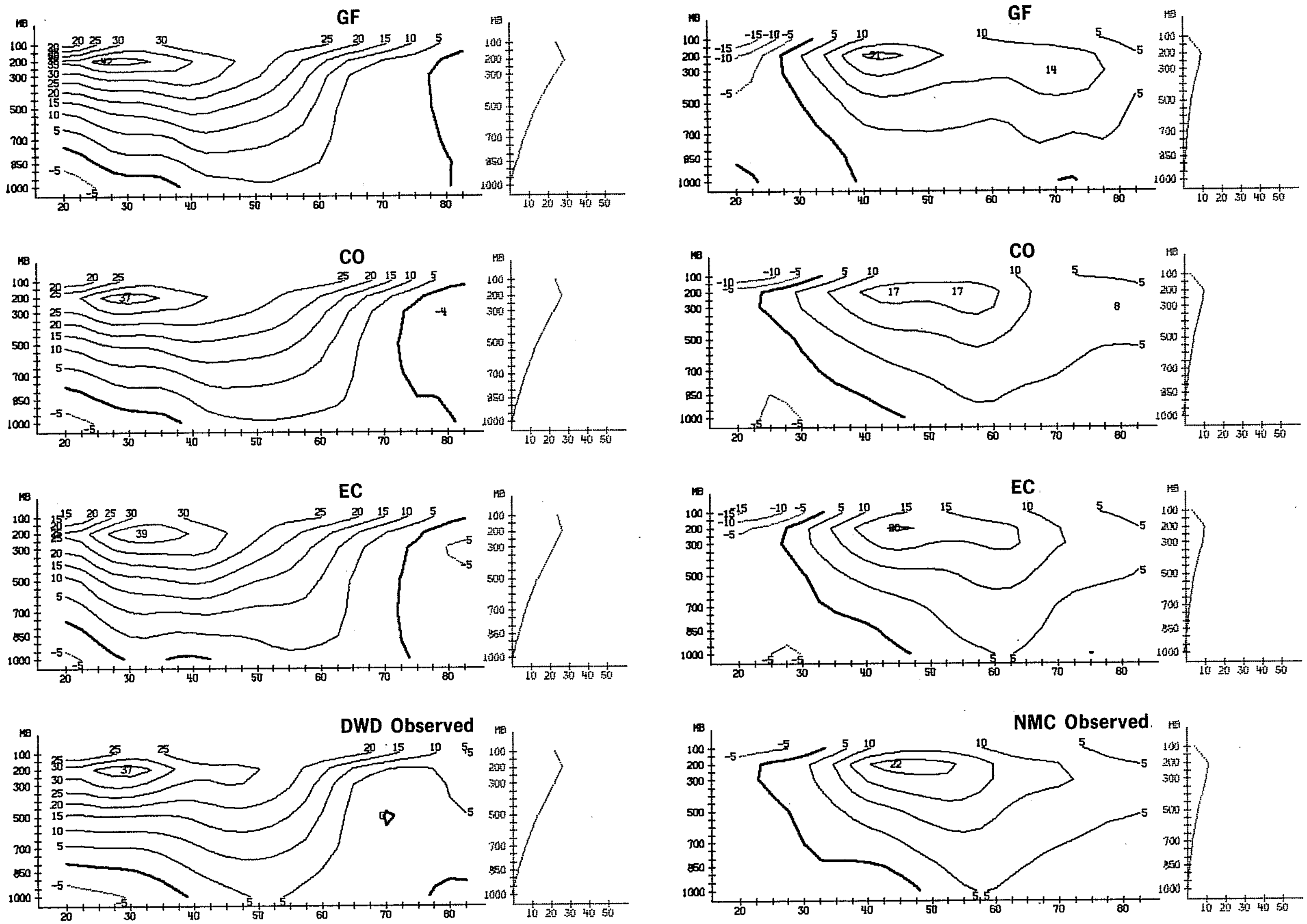


Fig. 7 Meridional crossection of the zonal wind averaged from day $5\frac{1}{2}$ to day 10 of the prediction period (left: 15.2.76, right: 25.8.75, northern hemisphere)

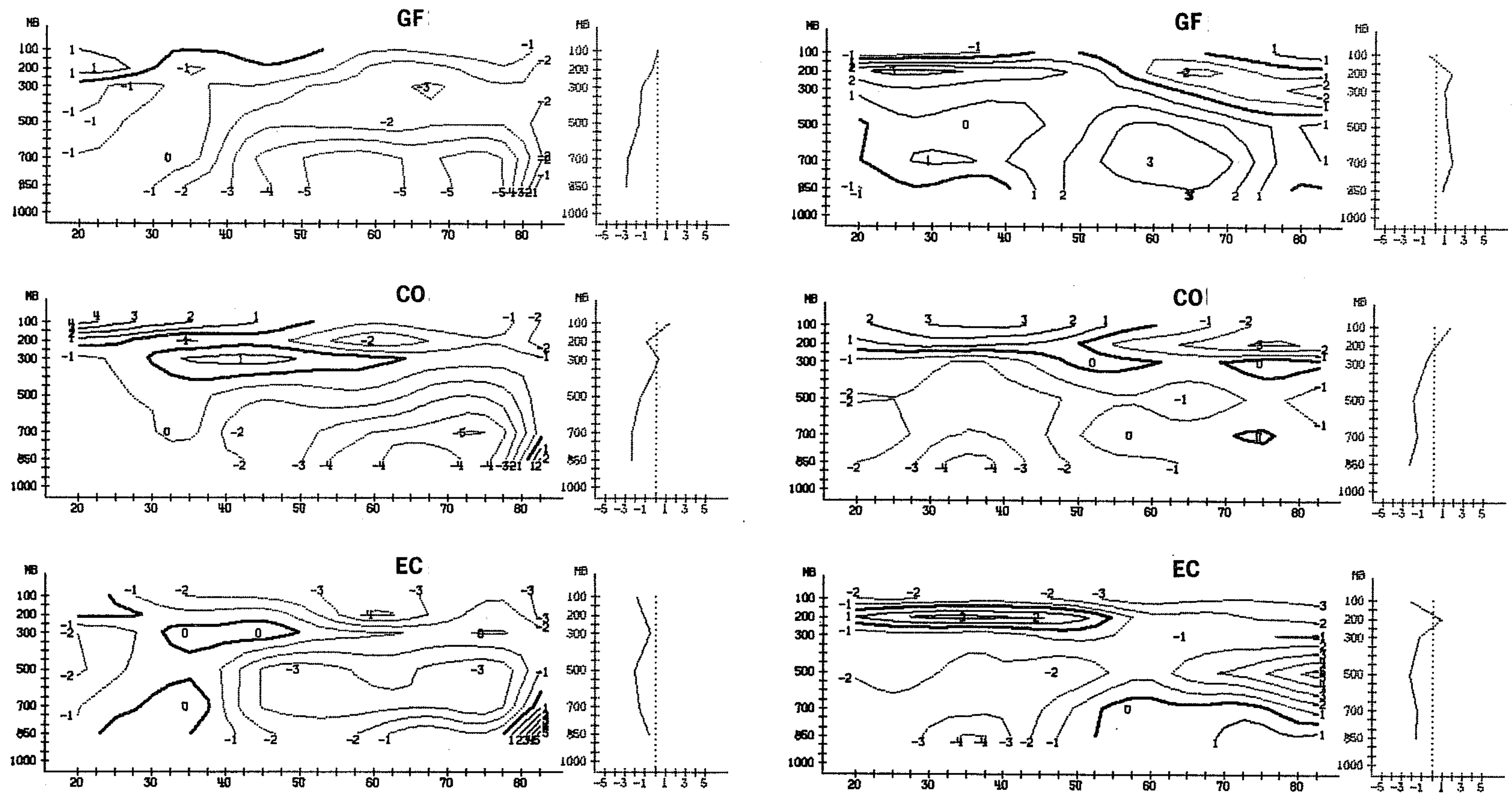


Fig. 8 Meridional crossection of the temperature deviation from observed, averaged from day $5\frac{1}{2}$ to day 10 of the prediction period (left: 15.2.76, right: 25.8.75, northern hemisphere)

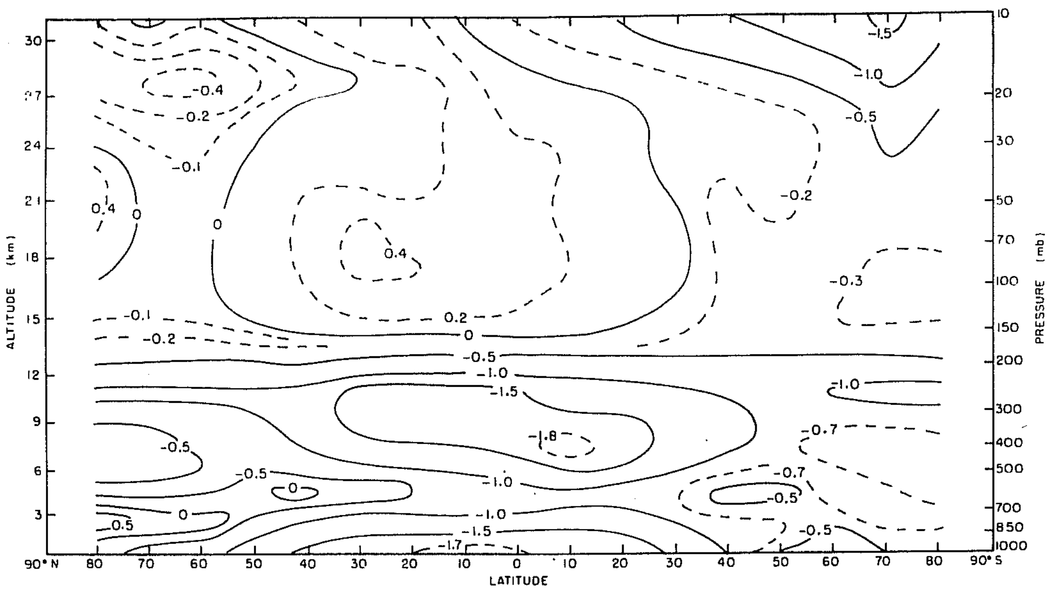


Fig. 9 The mean total radiative heating ($^{o}C$/day) from June-August (after Dopplick, 1972)

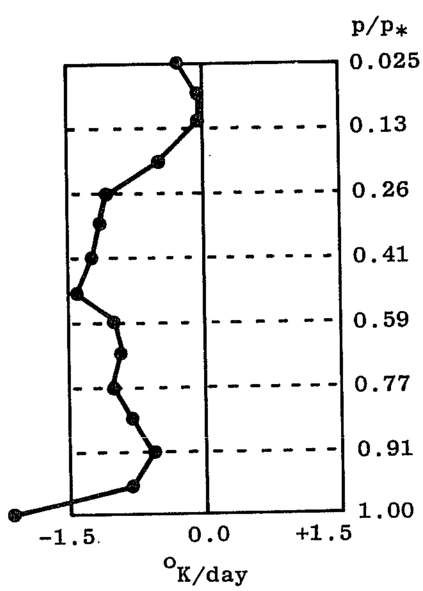


Fig. 10 Zonally and meridionally averaged heating (after Dopplick (1972), updated with data from Cox et al, 1979).

We find for all models on the winter hemisphere a cooling in the troposphere and a warming in the tropical stratosphere, which agrees quite well with Dopplick. The GFDL scheme produces a stepwise heating which is a direct consequence of its fixed cloud cover. The Köln scheme warms the mid-troposphere in the summer hemisphere, but it cools the subtropical and tropical boundary layer more than any other scheme.

The latitudinal integral of the radiative heating (on the right hand side of Fig. 11 ) shows good agreement with the "measured" data from Dopplick and Cox (Fig. 10 ).

The total diabatic heating (Fig. 12 ) in the 10 day mean exhibits clearly the problems caused by a non-interactive scheme. For the GFDL-run the cooling in the mid troposphere in mid latitudes has been replaced by a heating caused by convective processes. The fact that no link exists between actual cloud cover and radiational one seems to produce a positive feedback to generate convective clouds (see also J. Slingo's paper to this Workshop).

The positive heating in the mid troposphere in mid latitudes can be made responsible for the smaller temperature drop in the GFDL and the Köln run but it also diminishes the creation of zonal available potential energy. It is therefore no surprise to find only a weak available potential energy (Fig. 13 ) in the experiment with the Köln scheme, while the run with the GFDL scheme seems to produce a reasonable amount but on unreasonable locations in the summer integration. The destruction of available potential energy in some of the integrations is also reflected in the zonal mean of the kinetic energy (Fig.14 ). The kinetic energy is generally too weak in all experiments but reaches its lowest level in the experiment using the Köln scheme.

<u>Summary</u>

A comparison of 10 day forecasts done with the operational ECMWF model, but using three different radiation parameterisation schemes reveals only minor differences in the height fields (as long as they compare reasonably well with the analysis). An analysis made of the energy cycle in the model atmosphere on the other hand led to the discovery of deficiencies in the interaction between forecast model and radiation schemes.

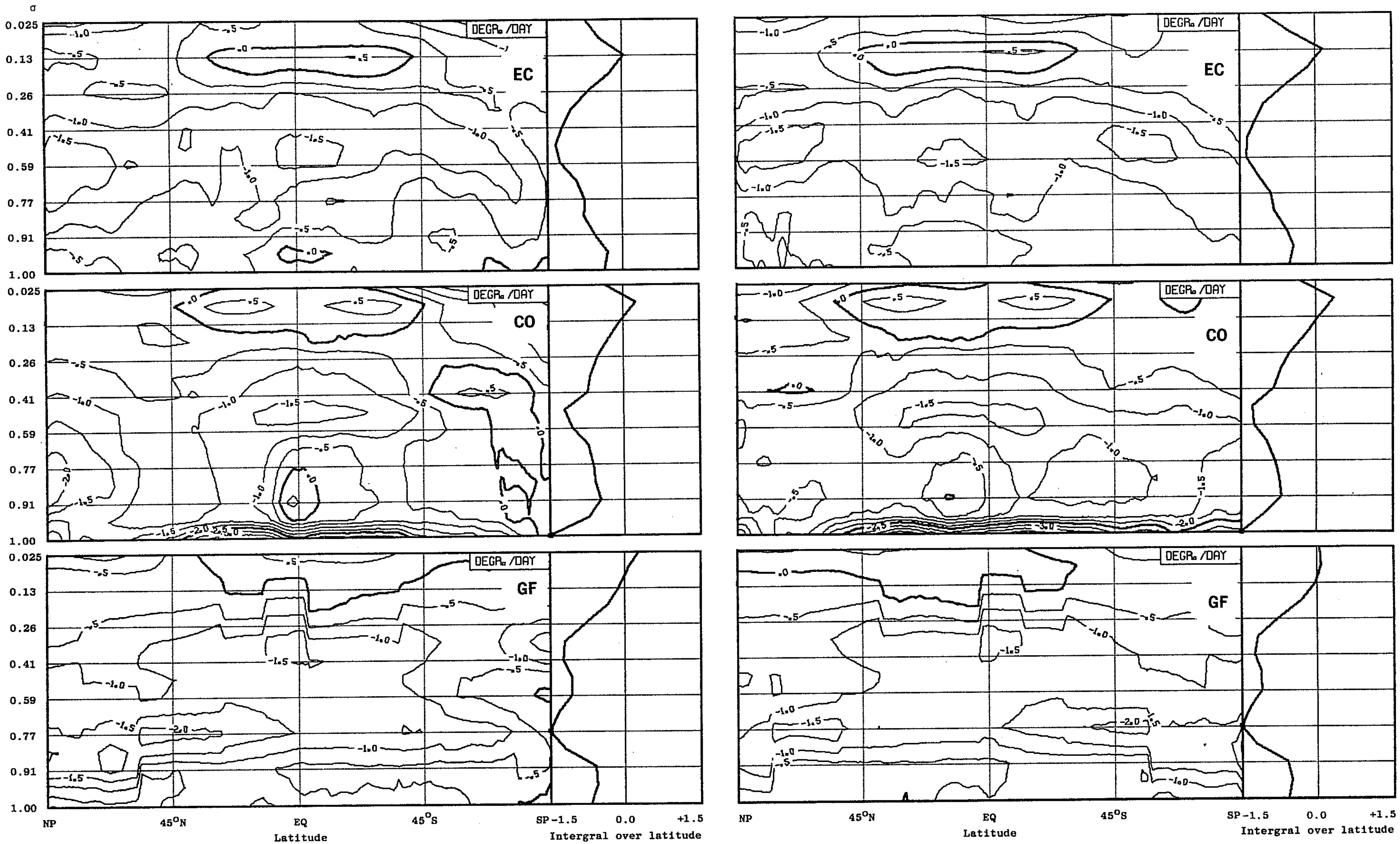


Fig. 11 The total radiative heating in the forecast experiments (mean over the 10 day prediction period) as function of latitude and height. (left: 15.2.76, right: 25.8.75)

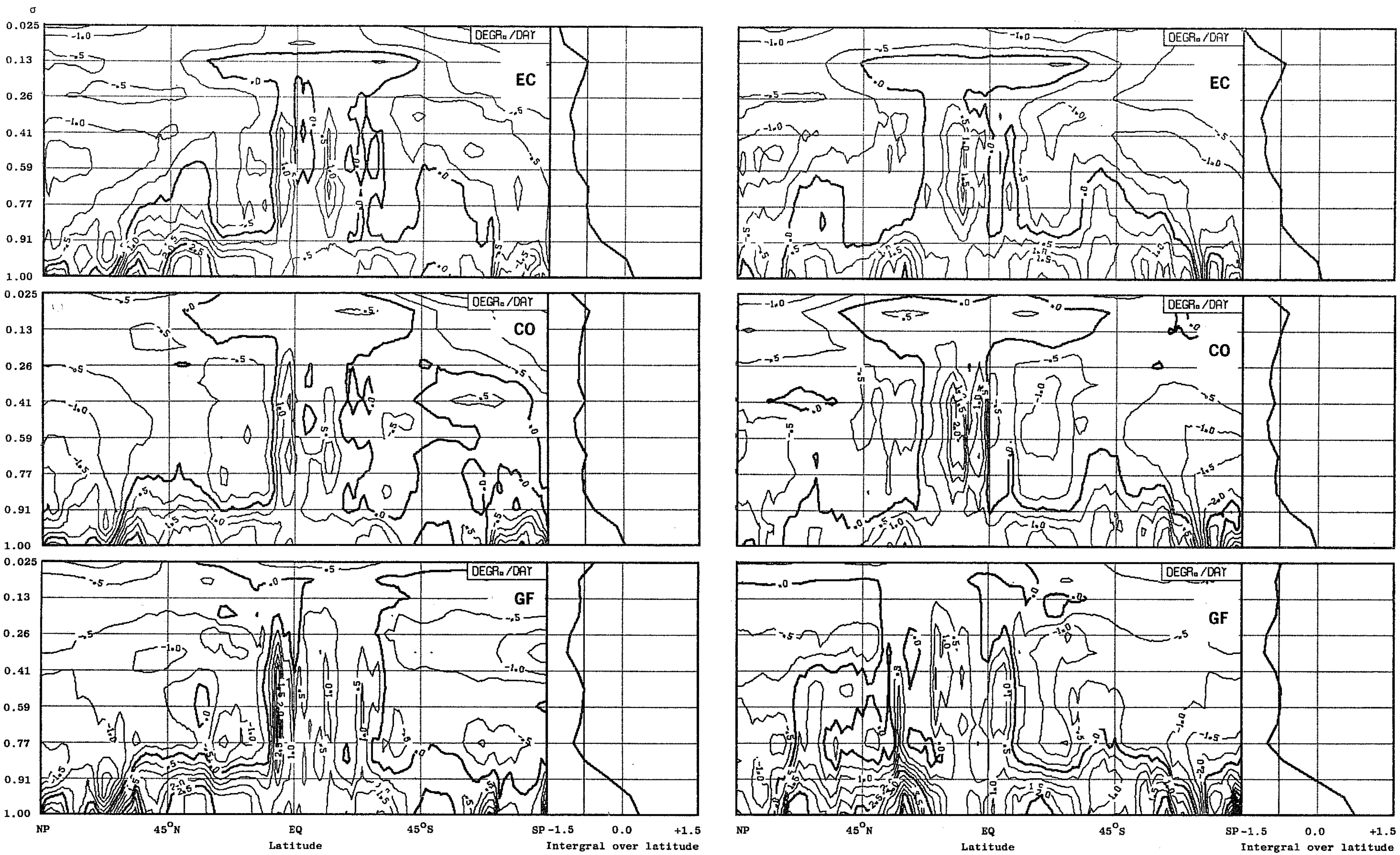


Fig. 12 The total diabatic heating in the forecast experiments (mean over the 10 day prediction period) as function of latitude and height. (left: 15.2.76 right: 25.8.75)

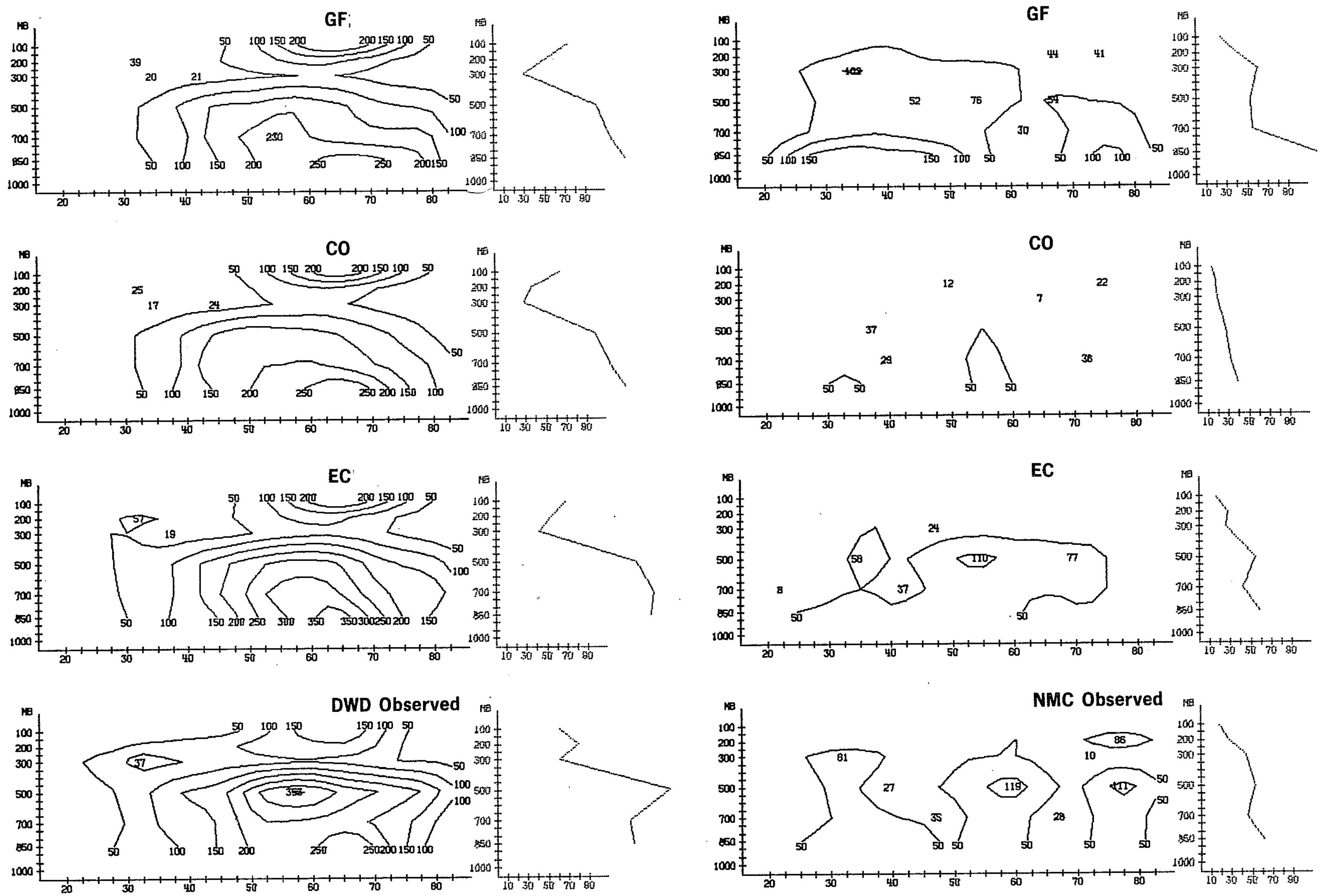


Fig. 13. The zonally averaged available potential energy in wavenumber 1-20 (mean between day $5\frac{1}{2}$ to 10, northern hemisphere) left: 15.2.76 right: 25.8.75

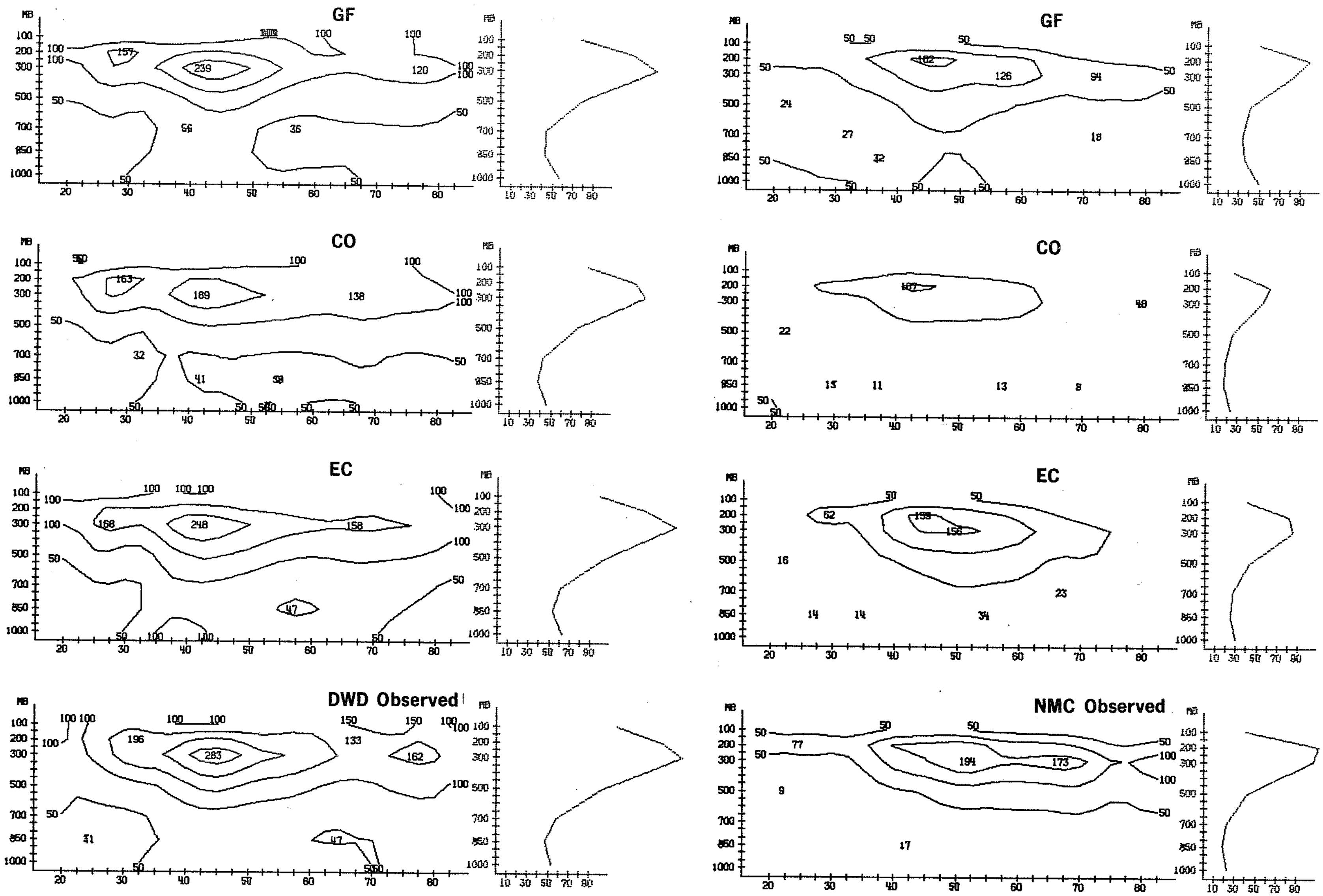


Fig. 14 The zonally averaged kinetic energy in wavenumber 1...20 (mean between day $5\frac{1}{2}$ to 10, northern hemisphere) left: 15.2.76 right: 25.8.75

References

Cox, S., Griffith, K.T., 1979 Estimate of radiative divergence during Phase III of the GARP-Atlantic Tropical Experiment. J.Atm.Sci., 36, 586-601.

Dopplick, T.G., 1972 Radiative heating of the global atmosphere. J.Atm.Sci., 29, 1278-1294

Hense, A., Kerschgens, M., Raschke, E., 1980 An economical method to compute the radiative energy transfer in circulation models. Submitted to Quart.J.Roy.Met.Soc.

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

Manabe, S., Strickler, R.F., 1964 On the thermal equilibrium of the atmosphere with a convection adjustment. J.Atm.Sci., 21, pp.361-385.

Miyakoda, K., Smagorinsky, J., Strickler, R.F., Hembree, G.D., 1969 Experimental extended predictions with a nine-level hemispheric model. Mon.Wea.Rev., 97, 1-76.

Tiedtke, M., Geleyn, J.-F., Hollingsworth, A., Louis, J.-F., 1979 ECMWF model-parameterisation of subgrid processes. ECMWF Tech. Report No.10.