TECHNICAL MEMORANDUM

162

Synoptic characteristics of the ECMWF Chernobyl data set

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Centre européen pour les prévisions météorologiques à moyen

1. INTRODUCTION

On 25 April 1986 at 21.23 UTC a reactor block in the nuclear power station at Chernobyl (51.28°N,30.25°E) went out of control. During the following days large amounts of radioactive materials were released. The wind transported radionucleides over hundreds of kilometres and radioactive fallout was detected at many places in Europe.

In order to allow the evaluation of atmospheric transport models ECMWF has produced a special dataset of six hourly analyses for the period 25 April to 10 May 1986, when the Chernobyl incident occurred. The dataset also includes one forecast based on the 12 UTC analysis of 25 April 1986. The specification of the dataset is given in Annex 1. The purpose of this memorandum is to give a synoptic evaluation of the quality of the forecast of 25 April 1986 in the European-Ukrainean region with respect to the meteorological parameters which are important for the transport and deposition of the radio-active material.

A qualitative verification of the pressure and wind field against the ECMWF analysis is given in paragraph 2. In order to verify the forecast distribution of the precipitation in the synoptic scale, the rainfall between 26 April 12 UTC and 29 April 12 UTC was accumulated over 24-hour time intervals and compared with the corresponding observations. The results are commented in paragraph 2 as well.

The forecast stability conditions are determined by the vertical moisture and temperature distribution across the model levels. In this particular case the transport occurred mainly between the surface and an altitude of 2500 metres. This layer is represented by 6 model levels. A qualitative verification of the stability conditions and some related near surface parameters is given in paragraph 3.

2. VERIFICATION OF THE PREDICTED SYNOPTIC SITUATION

Figures 1 to 10 display the forecast surface pressure fields together with the verifying analyses for the time of the incident and the subsequent 84 hours. The wind fields are represented by streamlines in Figures 11 to 20.

On 25 April 1986, eastern Europe was influenced by a high which covered the area between Lapland and the Caspian Sea. Central and south western Europe were affected by a low, but the pressure differences were small in that area. A front stretched from the western Mediterranean across the Alps to Scandinavia.

In accordance with the pressure field, the streamlines have an almost easterly direction in the Chernobyl area. At around 25°E there is a sharp bend to the north so that the streamlines point towards the Baltic.

During the following 72 hours a ridge expanded from Portugal towards Germany and later towards Denmark. Over central Europe it replaced the shallow low, which moved to northern Italy, where the pressure was falling. This development is important, because it opened a transport path for contaminated air from western White Russia to central Europe. In fact, central Europe was affected by radioactive deposition from 28 April onwards. This development was not forecast accurately. The model did not expand the ridge further east than France. Central Europe was covered by a trough, the associated vortex being first positioned over the Golf of Genoa, later over Germany. Consequently, the forecast maintained a relatively strong southerly flow between this low and the Russian high, whereas, in reality, the flow had an easterly direction from the 28th onwards (see Figs. 17 to 20.).

Another important development occurred in northern Scandinavia: on 27 April and the following days, a low moved from the Norwegian Sea across Lapland towards the Arctic. It directed cold air towards Sweden and Finland, where it replaced the warm Continental airmasses. The forecast low movement was in phase with the analysis, but at the beginning, the intensity of the low was forecast to be too weak. This, however, did not affect the forecast of the cold front position.

The forecast distribution of the precipitation (Figs. 21 to 23) reflects the fact that the rain over Europe was mainly related to the front which stretched from the Mediterranean to Lapland. In this context, Sweden is of particular interest because it was affected by the deposition of radionucleides from 27 April onwards. In this area we find good agreement between the forecast precipitation field and the observed distribution of the rain, though at the beginning, the precipitation was underestimated over the Baltic. Over central Europe, however, the quality of the rainfall prediction suffers from the fact that the forecast of the pressure field was incorrect.

3. VERIFICATION OF THE FORECAST IN THE CHERNOBYL AREA AND ALONG THE TRANSPORT PATH

The weather conditions in the area of the power plant during the night of the incident have been described (C. Persson et al, 1986) as calm and almost cloudfree, the 2-m temperature being around 1 degree. There was an inversion at an altitude of 500m. The wind speed below the inversion increased immediately above the ground to 5-10 m/s. During the following days, temperatures rose to about 16 to 20 degrees during daytime and occasional showers formed in unstable conditions, but at night it was mainly dry in stable conditions.

The first night after the explosion the ascent of the radioactive cloud was limited by the inversion. The initial transport of the radioactive material therefore occurred at an altitude below 600 metres. On the 26th, during the day the cloud crossed White Russia. As the ground surface was warmed by the sun to a maximum of 20-22 degrees, the lower layer of the troposphere became more unstable, resulting in an increased vertical mixing due to mainly dry convective processes. The next day the contaminated cloud passed the Baltic sea under very stable conditions. On 27 April, the first radionucleides were detected in eastern Svealand (Sweden). The deposition was forced by convection in an unstable layer between the surface and 1000 metres.

The forecast stability conditions are described by tephigrams (Figs. 25 to 28), using temperature and humidity values from all model levels. The forecast near surface parameters in the area of the power plant are interpolated from the four surrounding grid points and displayed in a meteogram (Figure 24).

The meteogram and the tephigrams confirm that these conditions were forecast successfully in most of their essential features. In the night of the incident, the inversion level was predicted at 950 hPa, corresponding to an altitude of approximately 550 metres. The forecast wind was weak at ground level, but increased to 15 m/s in the layer below the inversion.

Under the forecast conditions over White Russia, vertical mixing occurred up to a height of 1700 to 2000 metres due to convection. Occasional development of cumulus might have taken place and led to an even deeper vertical mixing.

Over Svealand, however, the model predicted too stable conditions, because the model soil was covered with snow, which was not the case in reality.

4. CONCLUSION

The characteristics of the ECMWF 4-day forecast over Europe based on 25 April have been presented, highlighting the main qualities and deficiencies. From a statistical point of view, the quality of the forecast, as measured by the RMS error of the 850 hPa geopotential field, was slightly better than average (Figure 29); this confirms that the accuracy of the prediction of the synoptic flow over Europe was typical of what can be expected from a numerical model of the atmosphere.

Reference

C. Persson, H. Rodhe, L. De Geer: The Chernobyl Accident, SMI RMK NR 55, December 1986.

ANNEX I

CHERNOBYL DATA SET

The Chernobyl data set has been prepared with the following specifications:

AREA: 81.000°W to 40.500°E
29.250°N to 90.000°N

GRID: Regular latitude/longitude grid

RESOLUTION: 1.125° by 1.125°

TYPE: Uninitialised analysis and forecast

PERIOD:

a) Uninitialised analysis:
from 25.4.1986, 1200 UTC, to 10.5.1986, 1800 UTC inclusive
at 6-hourly intervals

b) Forecast:
25.4.1986, 1200 UTC
120 hours in 6-hourly intervals

c) Surface geopotential:
16.7.1986, 0000 UTC

PARAMETERS:

a) Uninitialised analysis

Model levels:
u-, v- and w-components of wind,temperature, and specific humidity at model levels, plus log surface pressure

Pressure levels:
u-, v- and w-components of wind, temperature, relative humidity, and geopotential at pressure levels

Surface:
u-, v-components of 10m wind, 2m temperature, total cloud cover

b) Forecast

Model levels:
u-, v- and w-components of wind,temperature, and specific humidity at model levels, plus log surface pressure

Pressure levels:
u-, v- and w-components of wind, temperature, relative humidity, and geopotential at pressure levels

Surface:
u-, v-components of 10m wind, 2m temperature, total cloud cover, convective precipitation and large scale precipitation

c) Surface geopotential

Uninitialised analysis, one field, time invariant.

LEVELS: Model levels: 8 to 16 inclusive of the 16 level ECMWF forecast model used at that time (i.e. all levels up to and including 500 hPa)

Pressure levels: 1000/850/700/500 hPa

FORMAT: FM 92 GRIB (WMO standard binary representation)

ACCURACY: 16 bit per grid value

STRUCTURE:
File 1 - GRIB unpacking software
File 2 - surface geopotential
File 3 - uninitialised analysis/model level data
File 4 - uninitialised analysis/pressure level data
File 5 - uninitialised analysis/surface data
File 6 - forecast/model level data
File 7 - forecast/pressure level data
File 8 - forecast/surface data.

The complete data set will consist of files 1-8 and needs 1 tape written with 6250 bpi or 3 tapes written with 1600 bpi.

Files 1, 2, 4, 5, 7 and 8 form the pressure level data set, which can be accommodated on 1 tape written with 1600 bpi.

Requests for the data set should be addressed to

The Director
E C M W F
Shinfield Park
Reading/Berks.
RG2 9AX
England

ECMWF Analysis VT: Saturday 26 April 1986 00z
MSLP + 850 hPa temperatures

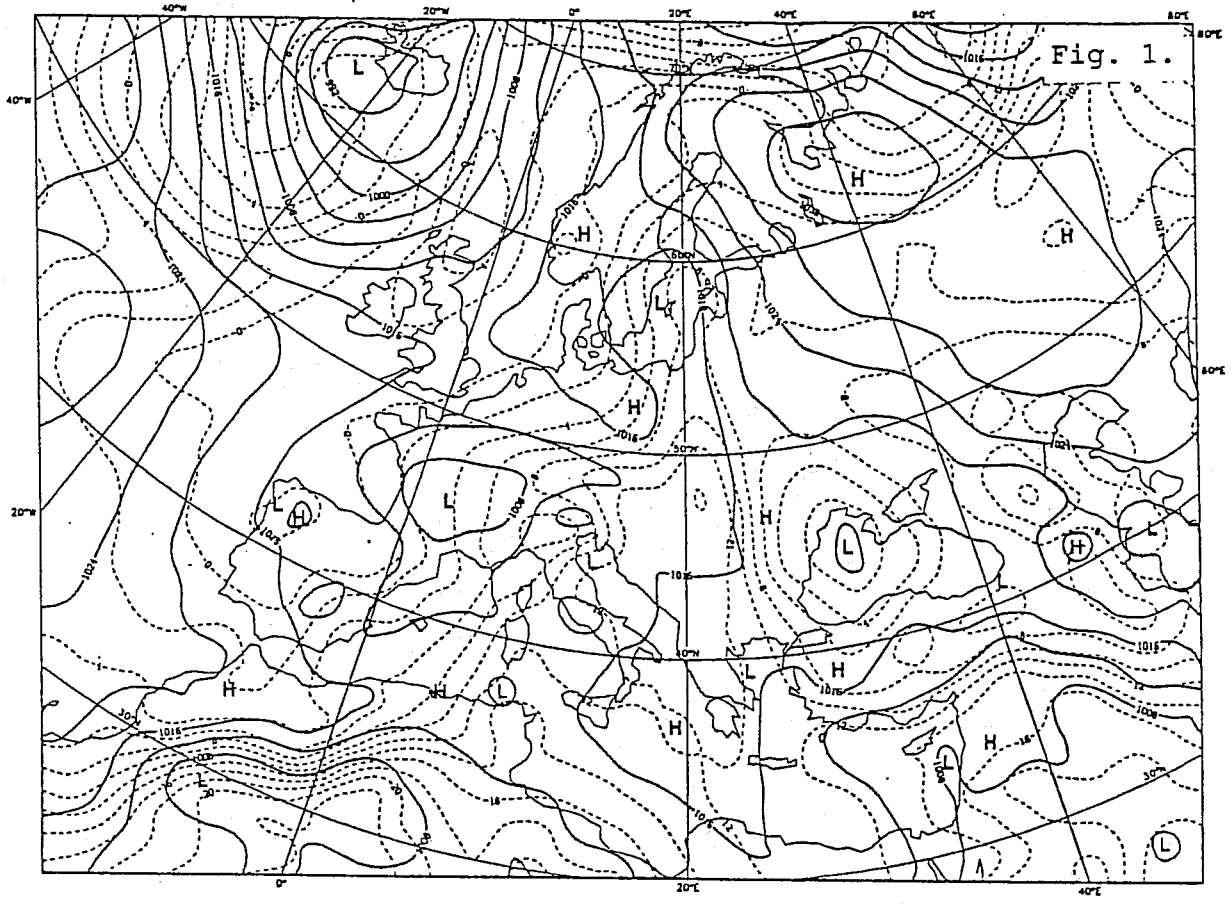


Fig. 1.

Friday 25 April 1986 12z ECMWF Forecast t+ 12 VT: Saturday 26 April 1986 00z
MSLP + 850 hPa temperatures

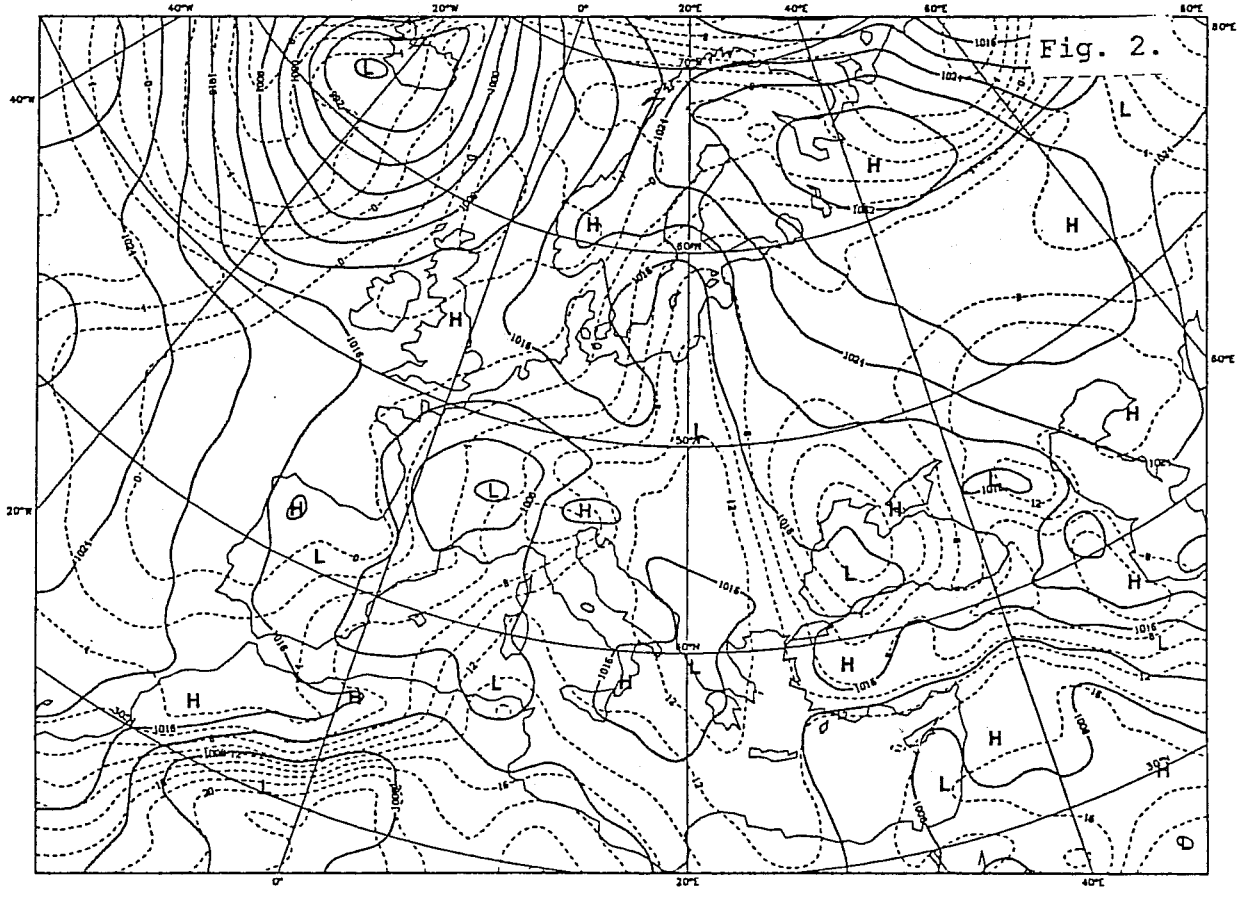
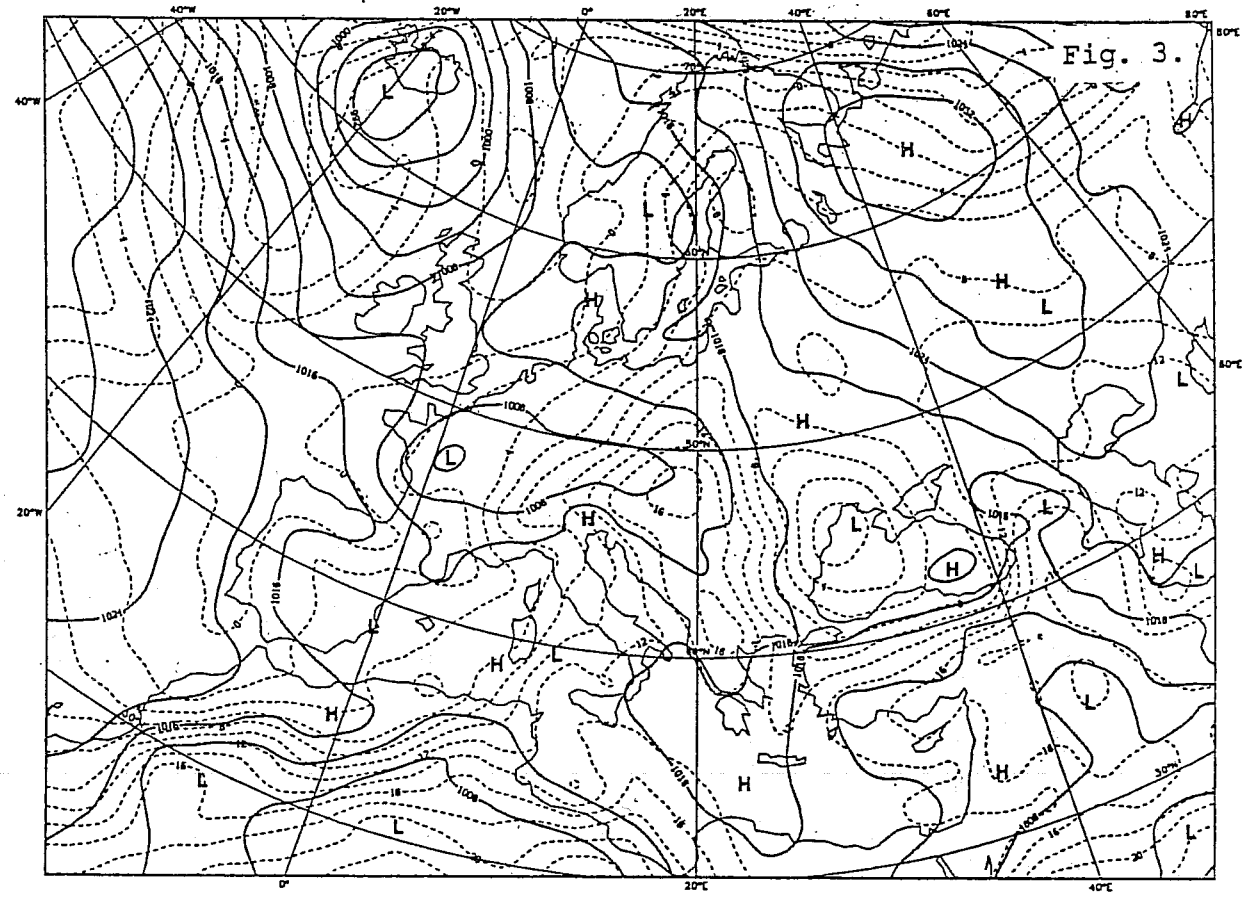
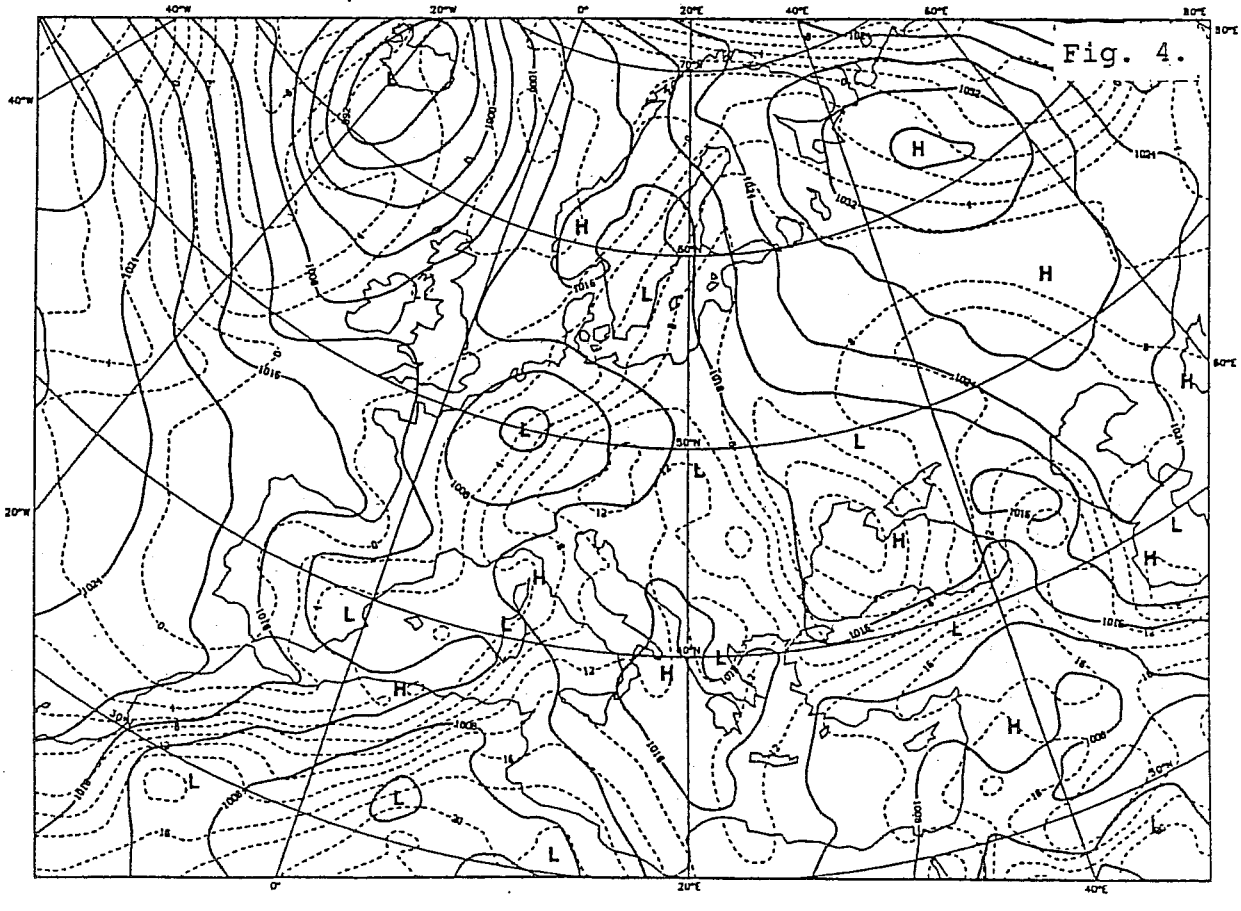


Fig. 2.

ECMWF Analysis VT: Saturday 26 April 1986 12z
MSLP + 850 hPa temperatures



Friday 25 April 1986 12z ECMWF Forecast t+ 24 VT: Saturday 26 April 1986 12z
MSLP + 850 hPa temperatures



ECMWF Analysis VT: Sunday 27 April 1986 12z
MSLP + 850 hPa temperatures

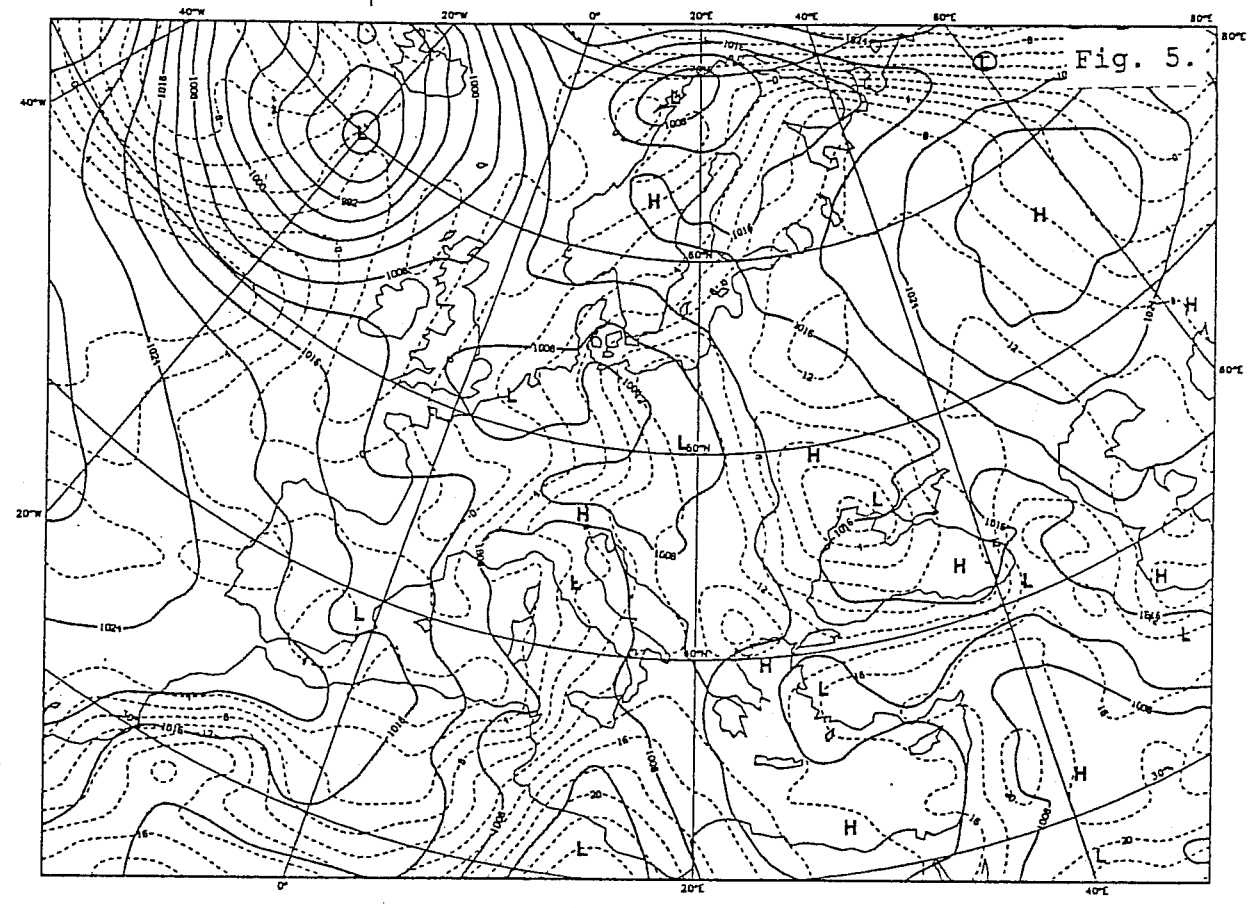


Fig. 5.

Friday 25 April 1986 12z ECMWF Forecast t+ 48 VT: Sunday 27 April 1986 12z
MSLP + 850 hPa temperatures

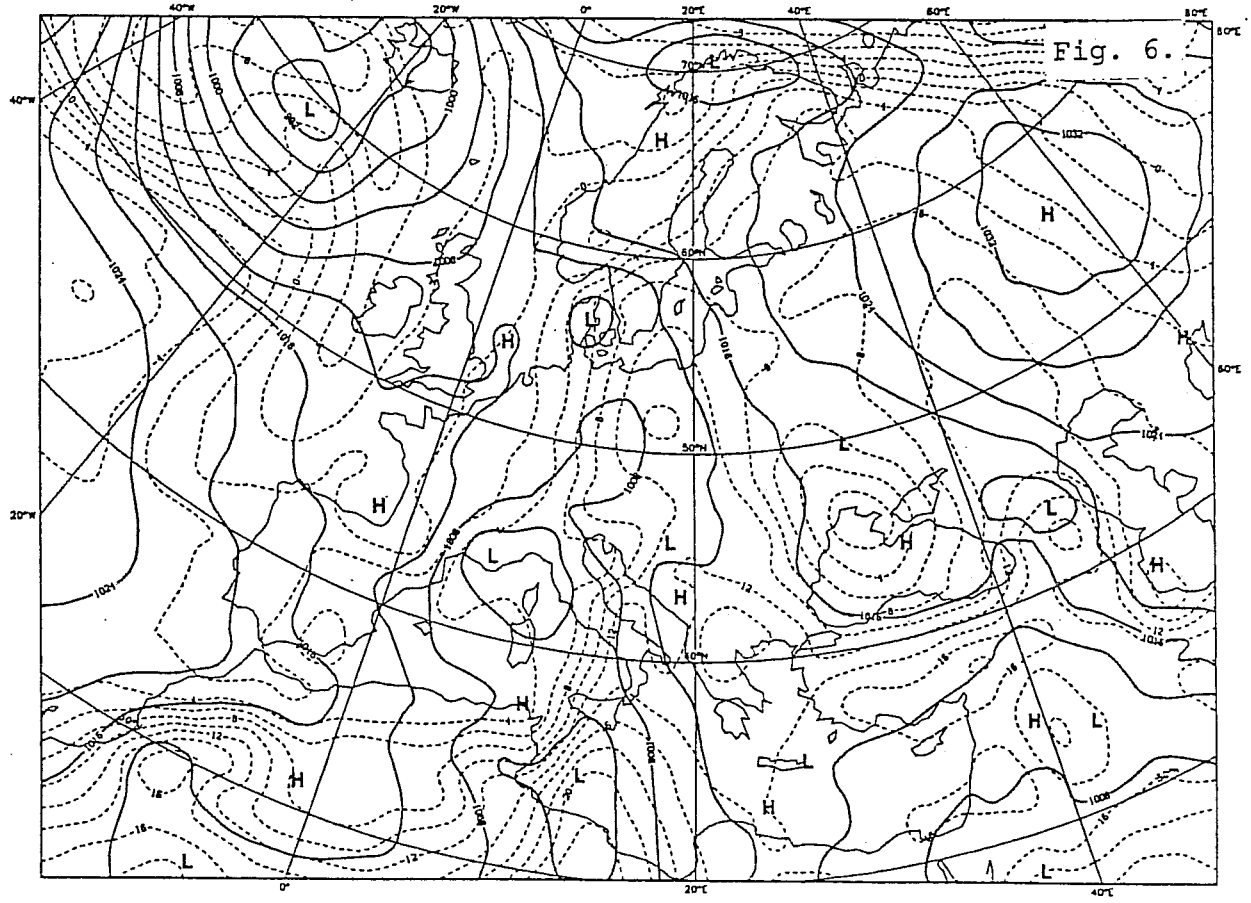


Fig. 6.

ECMWF Analysis VT: Monday 28 April 1986 12z
MSLP + 850 hPa temperatures

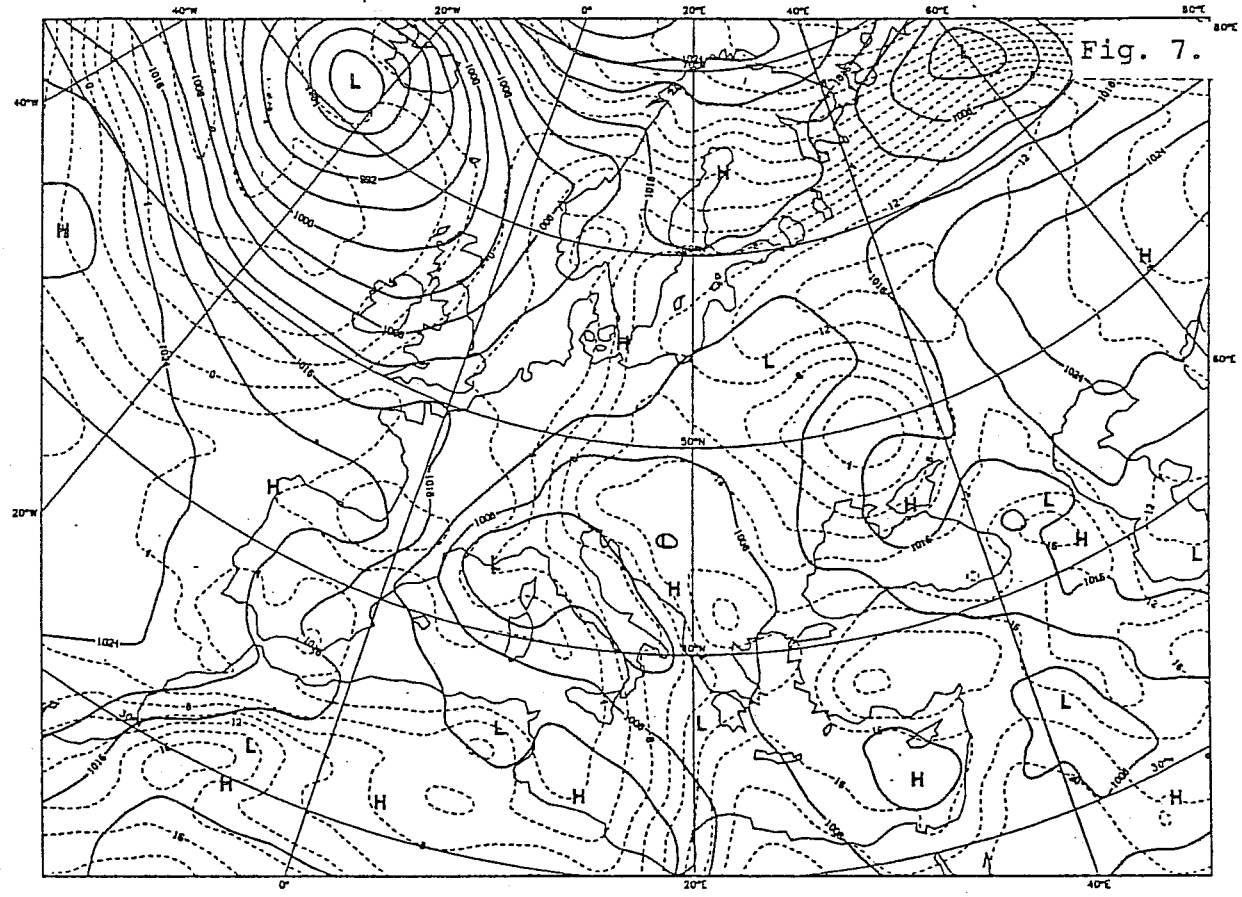


Fig. 7.

Friday 25 April 1986 12z ECMWF Forecast t+ 72 VT: Monday 28 April 1986 12z
MSLP + 850 hPa temperatures

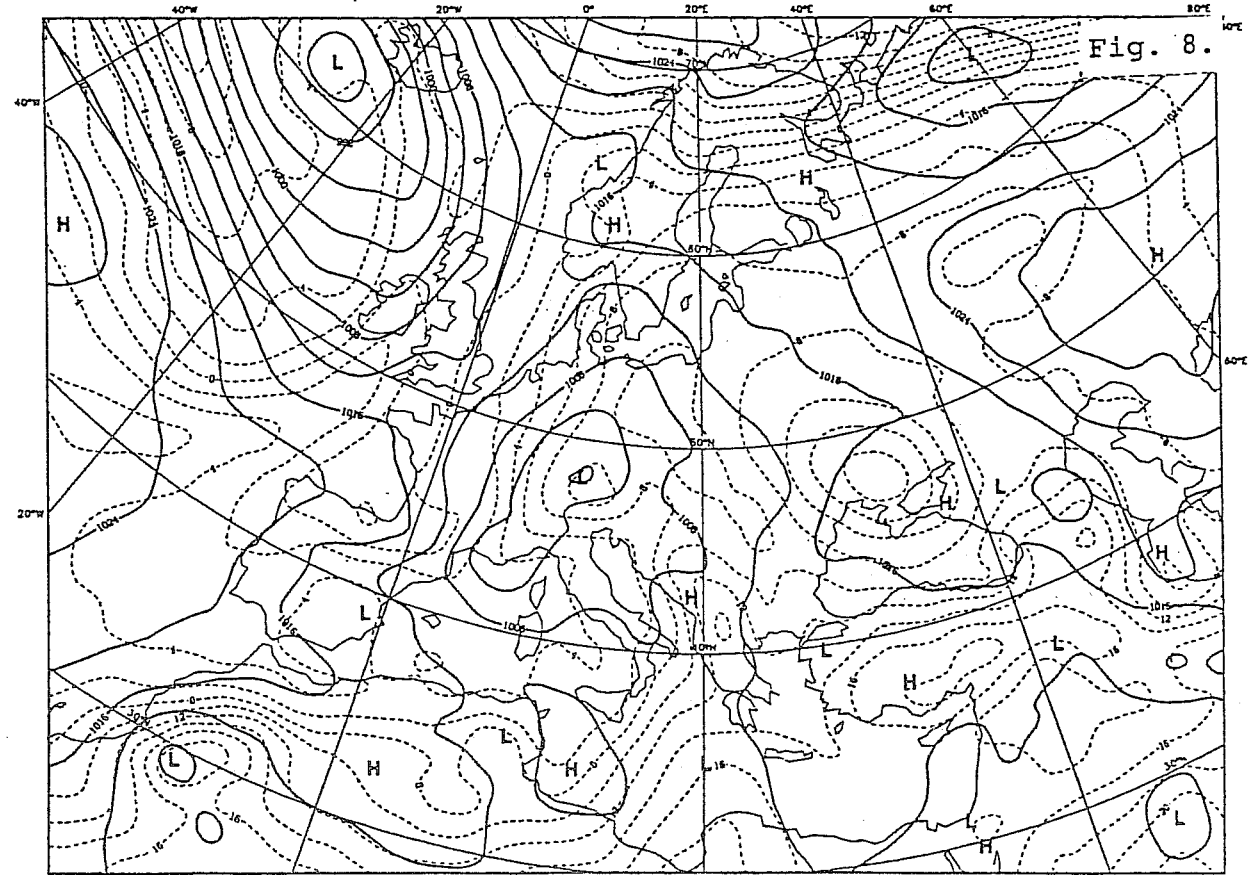


Fig. 8.

ECMWF Analysis VT: Tuesday 29 April 1986 12z
MSLP + 850 hPa temperatures

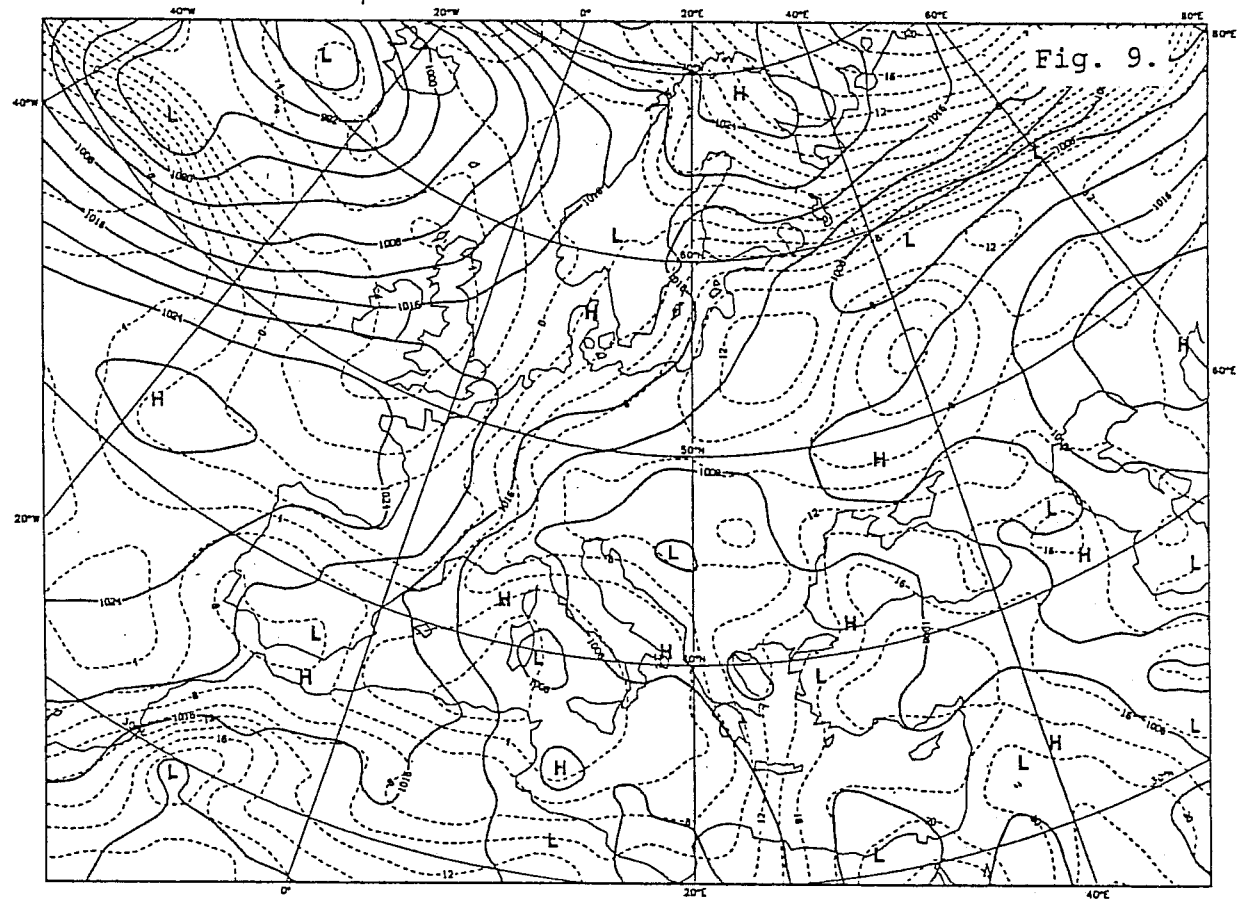


Fig. 9.

Friday 25 April 1986 12z ECMWF Forecast t+ 96 VT: Tuesday 29 April 1986 12z
MSLP + 850 hPa temperatures

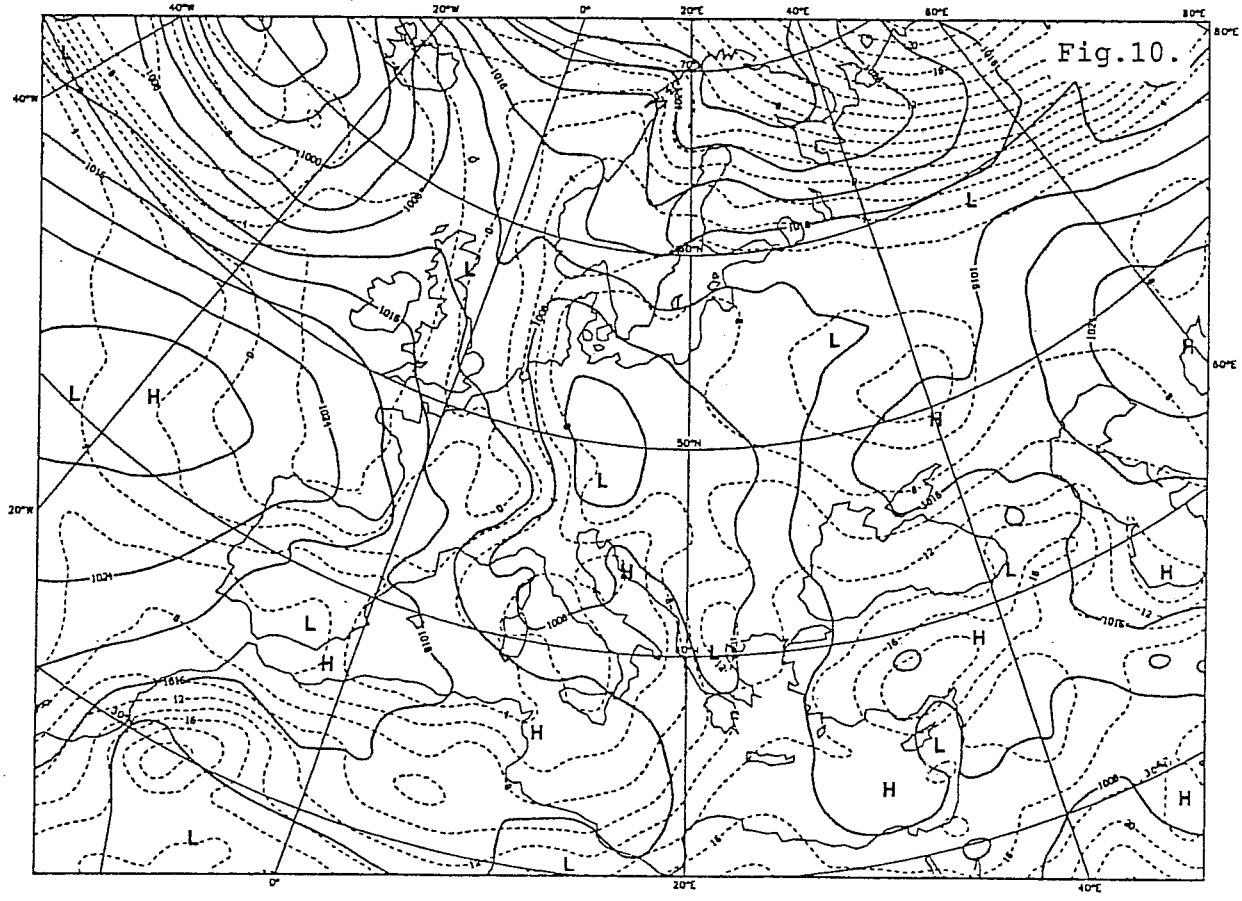
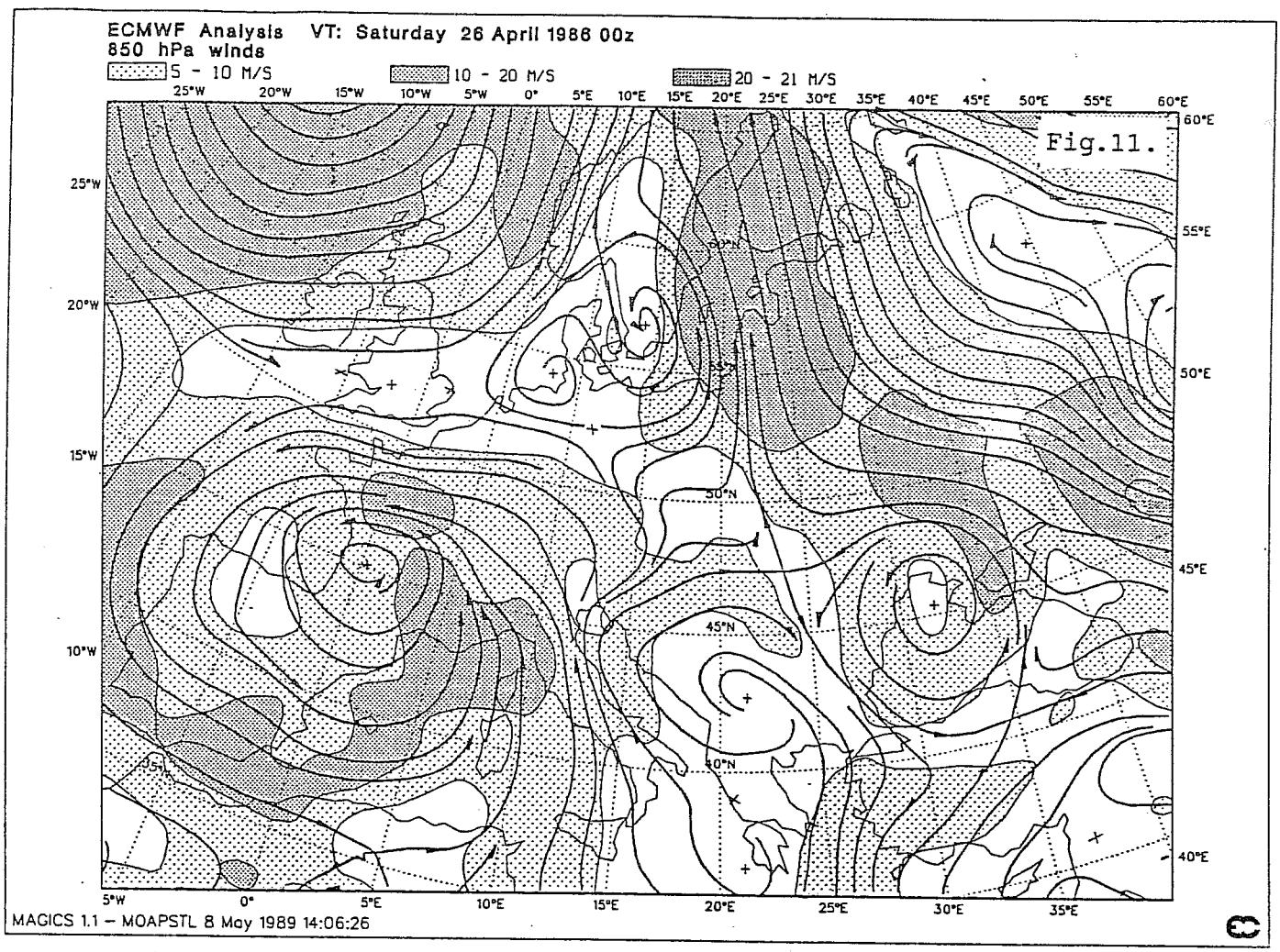
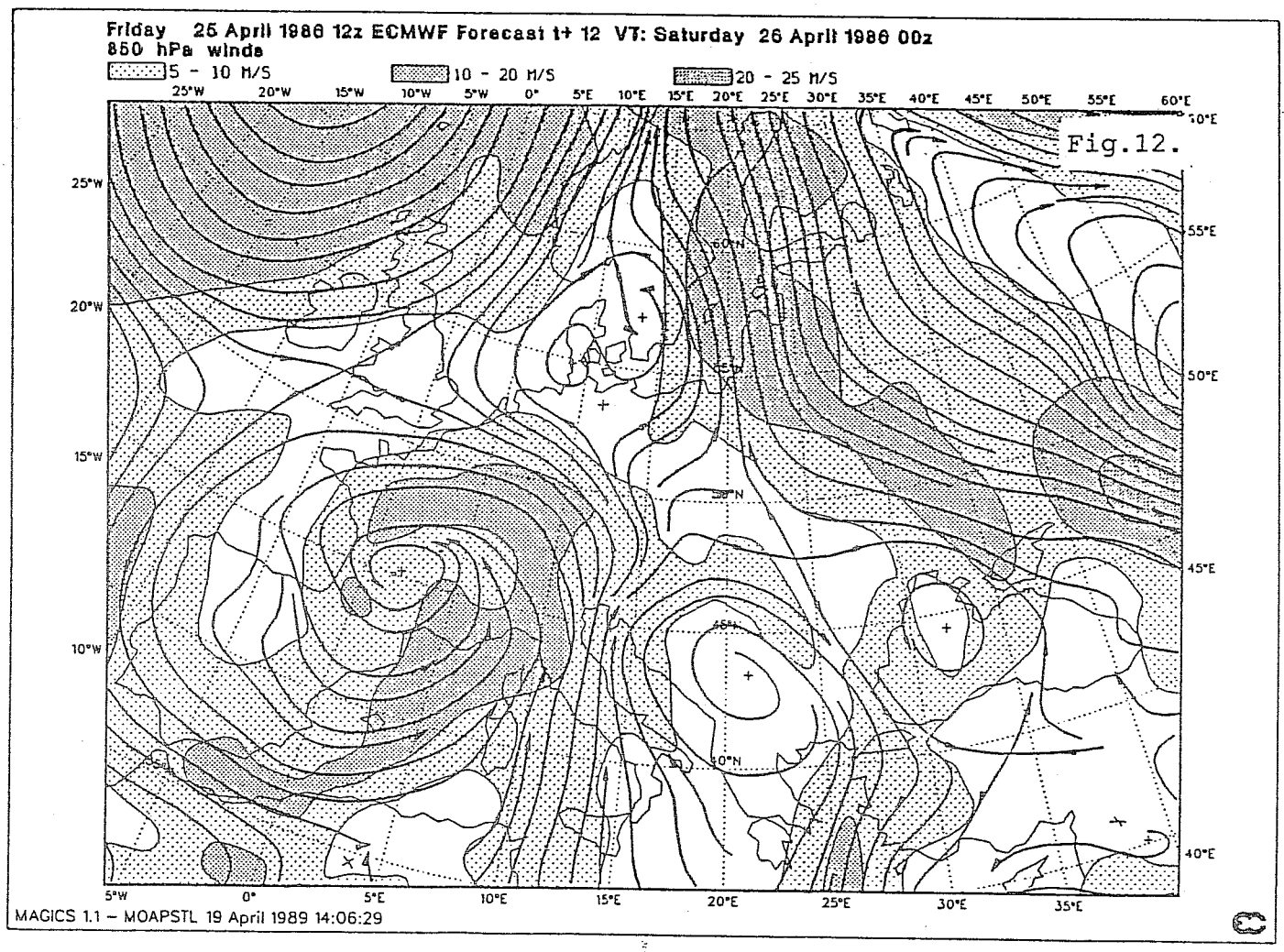
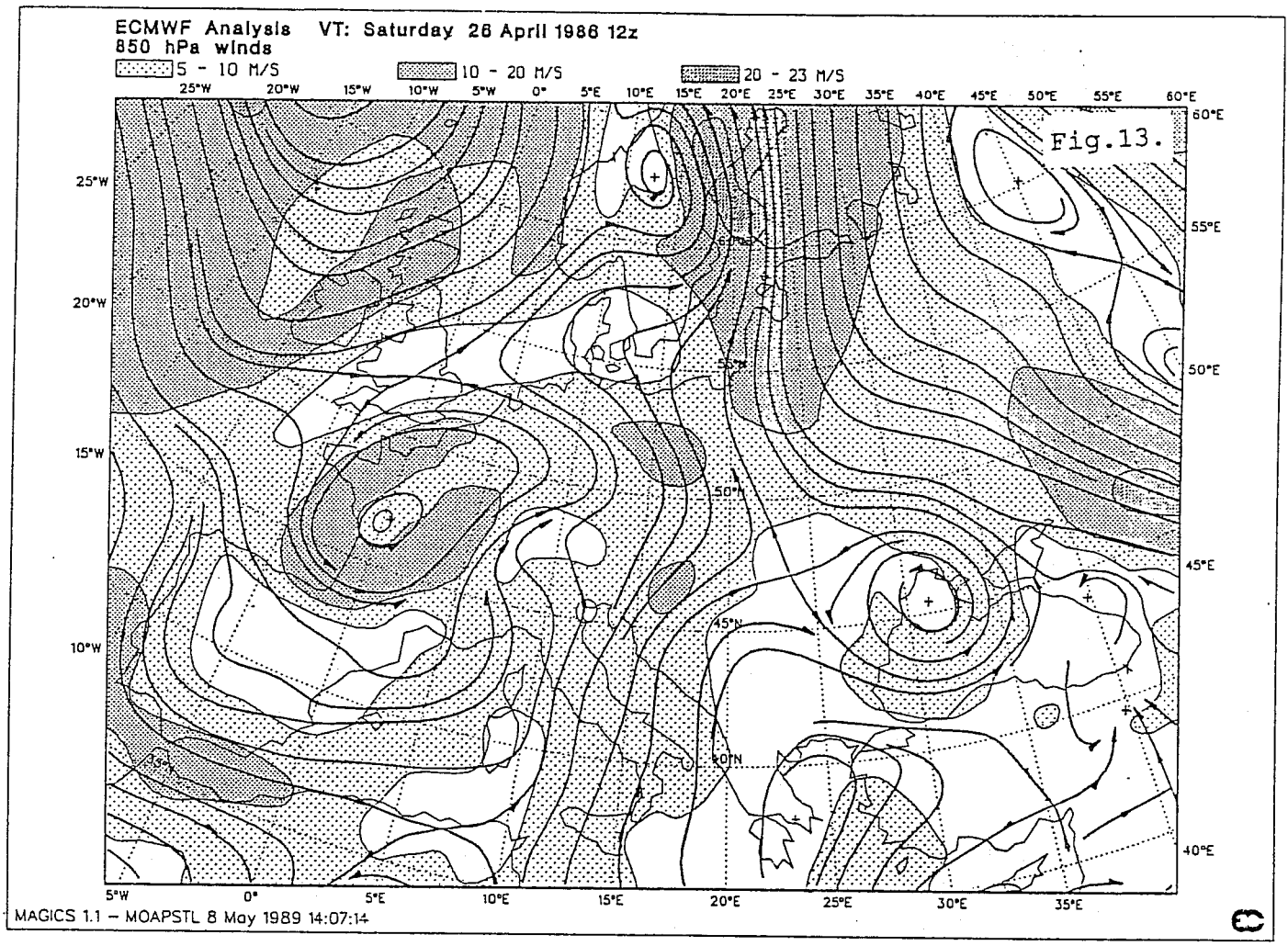
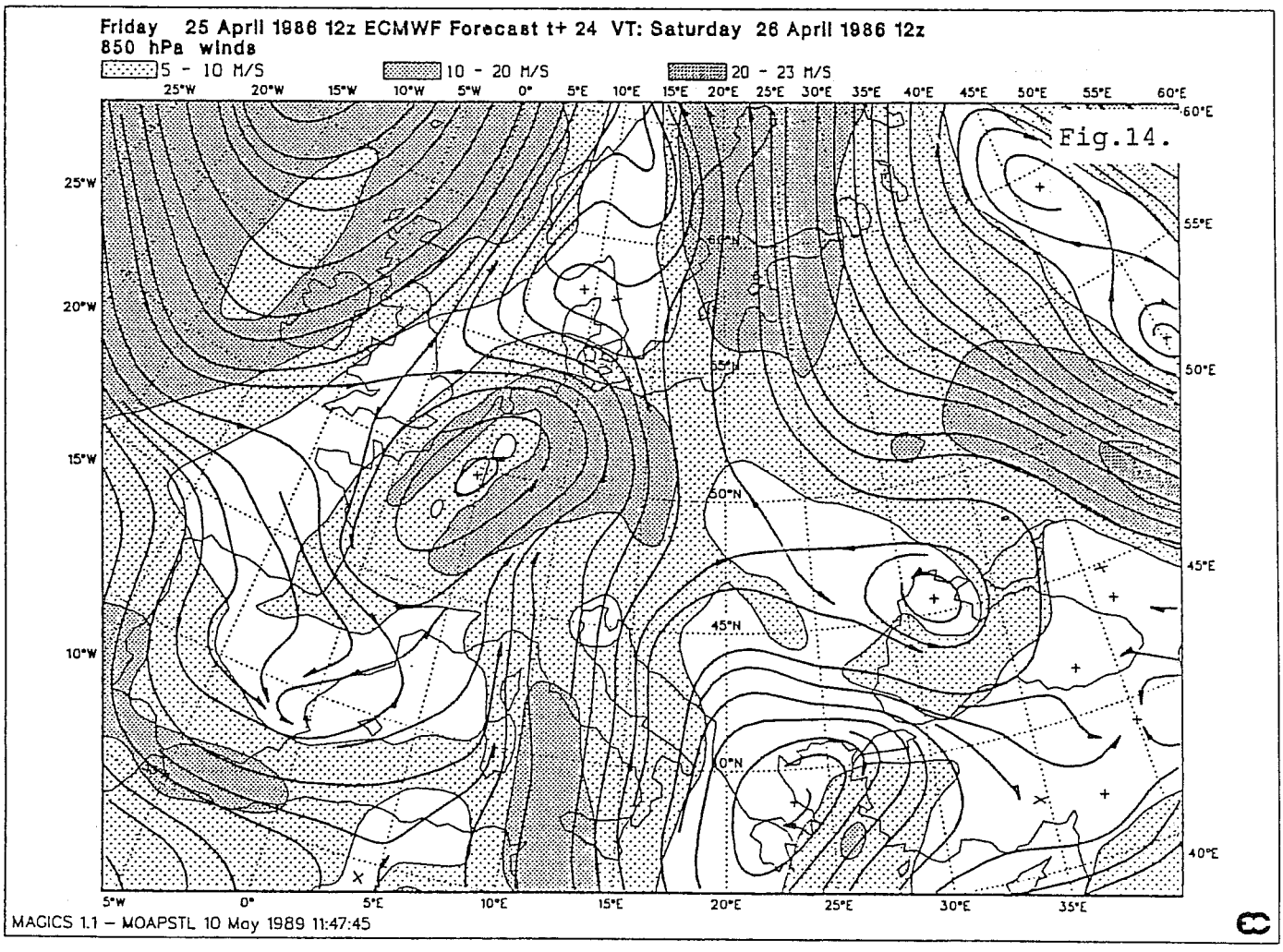


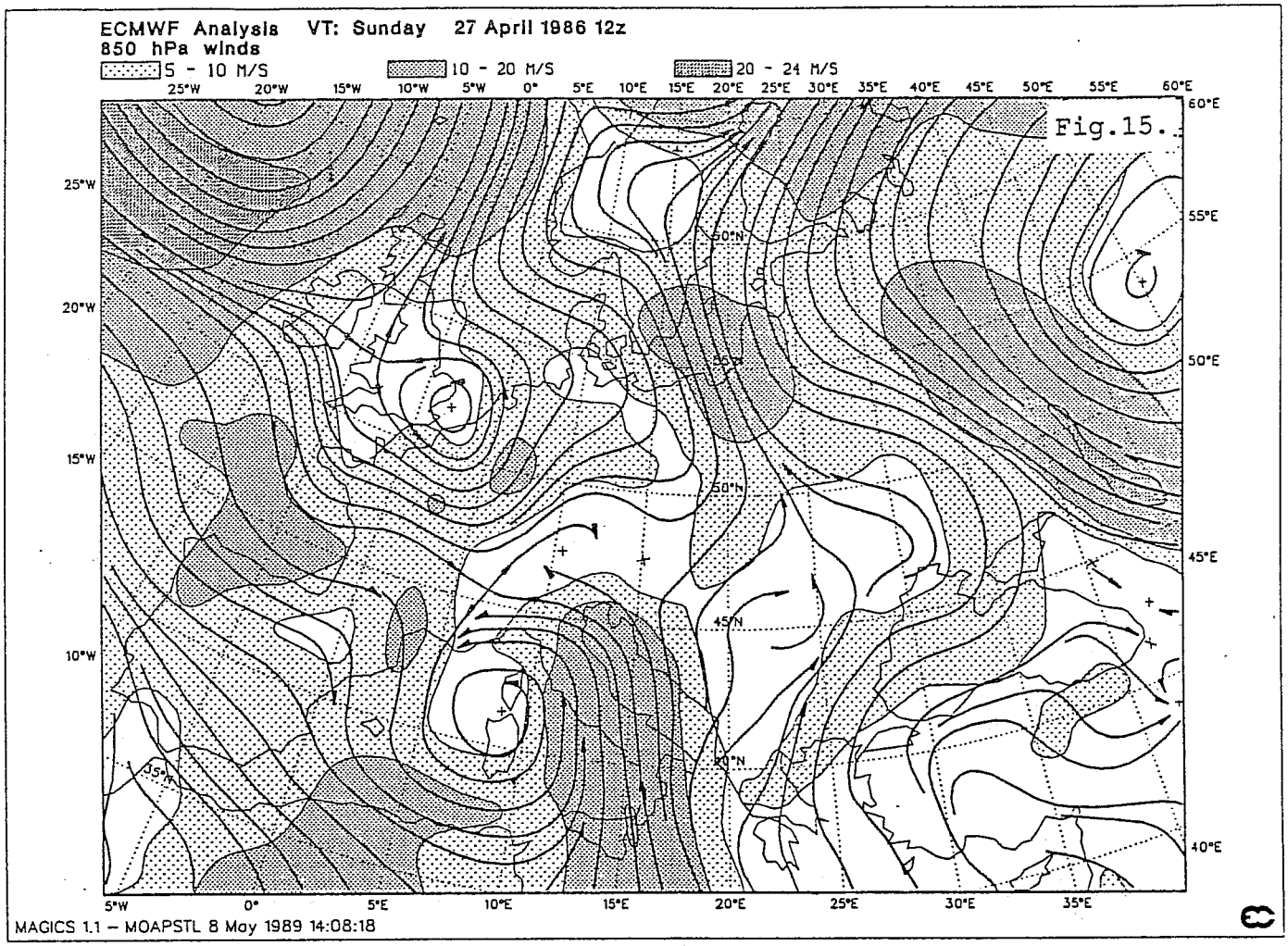
Fig.10.

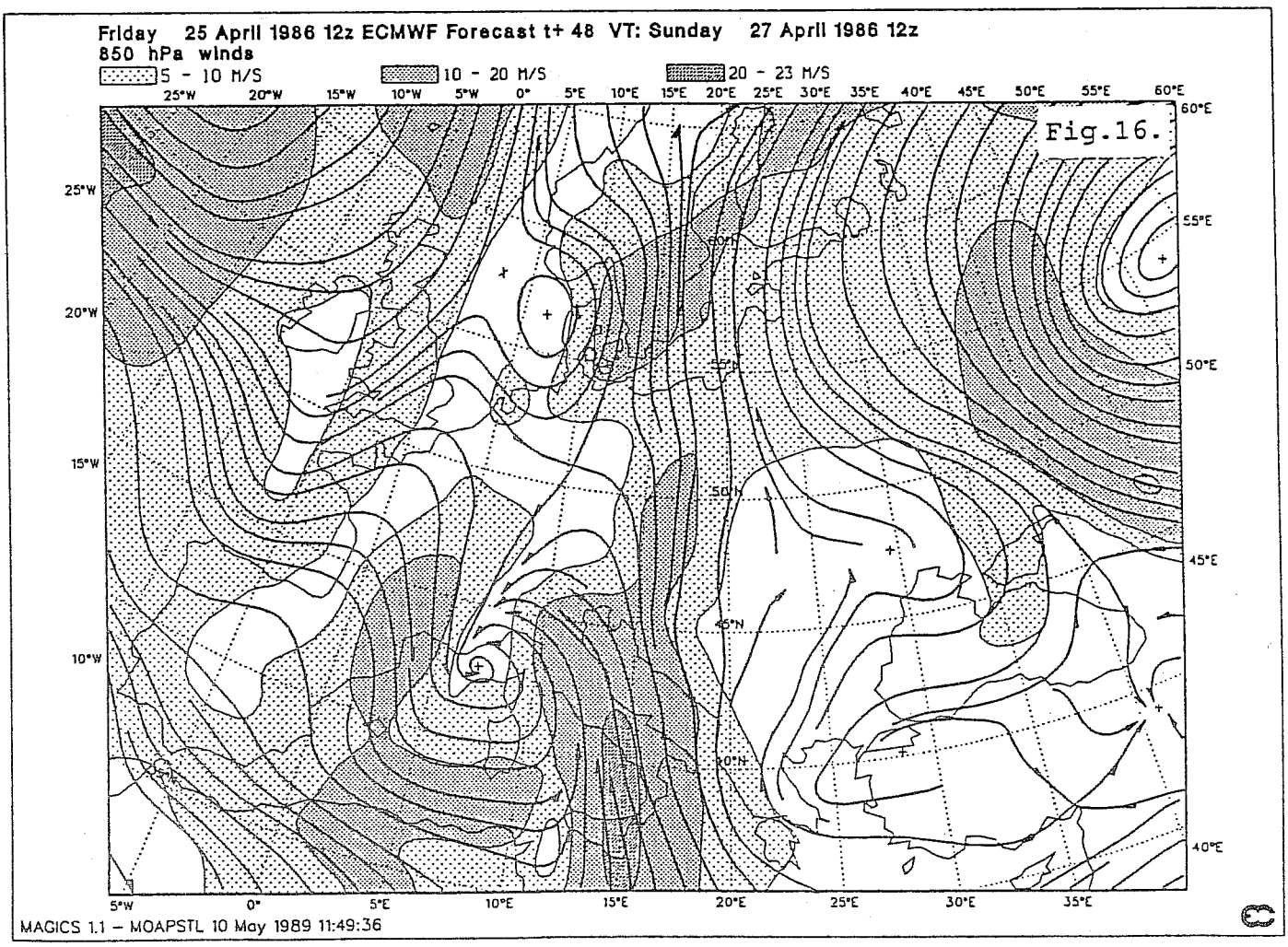

ECMWF Analysis VT: Saturday 26 April 1986 00z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 21 M/S
Fig.11.
MAGICS 1.1 – MOAPSTL 8 May 1989 14:06:26

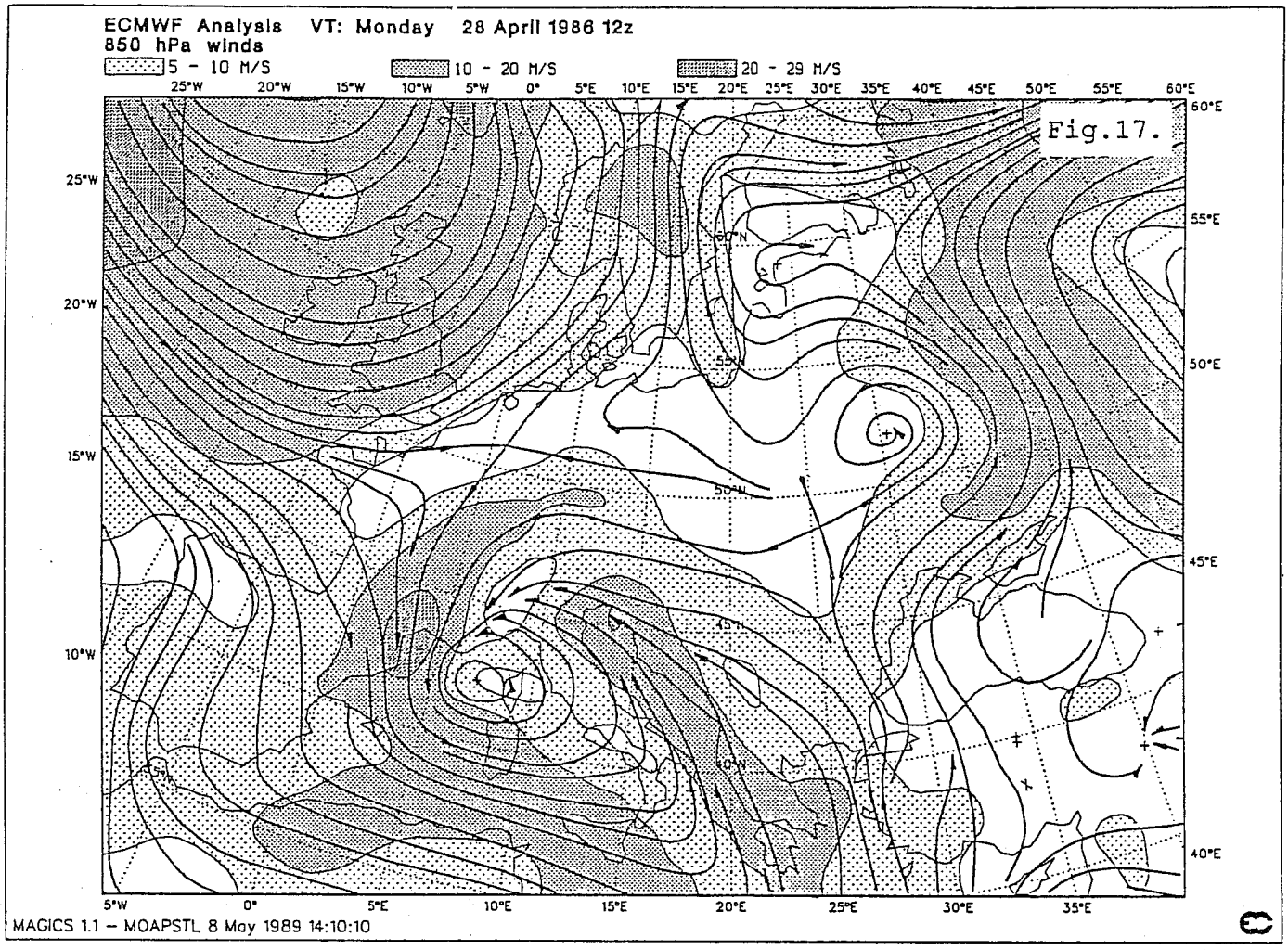

Friday 25 April 1986 12z ECMWF Forecast t+ 12 VT: Saturday 26 April 1986 00z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 25 M/S
Fig.12.
MAGICS 1.1 – MOAPSTL 19 April 1989 14:06:29

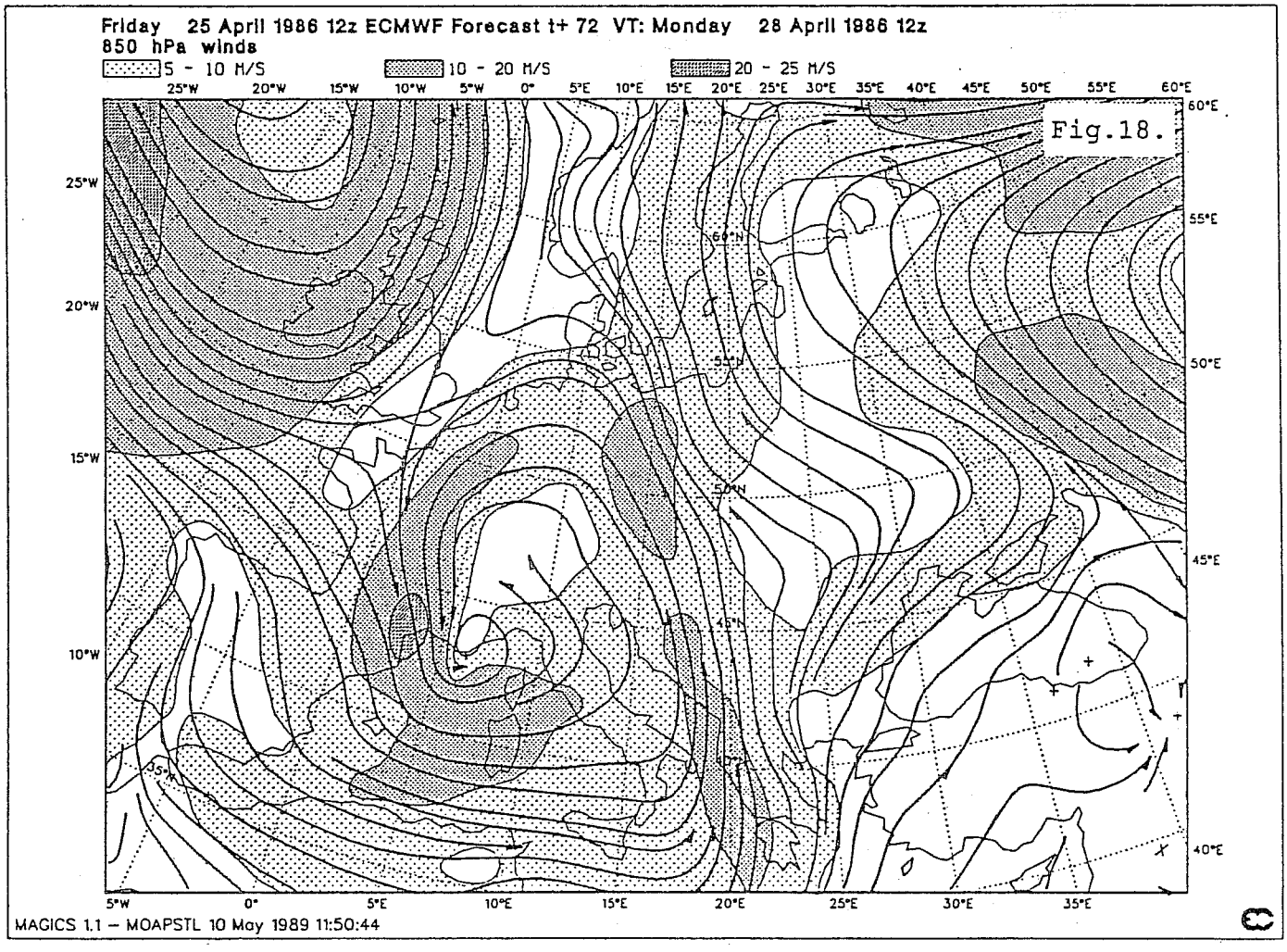

ECMWF Analysis VT: Saturday 26 April 1986 12z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 23 M/S
Fig.13.
MAGICS 1.1 – MOAPSTL 8 May 1989 14:07:14

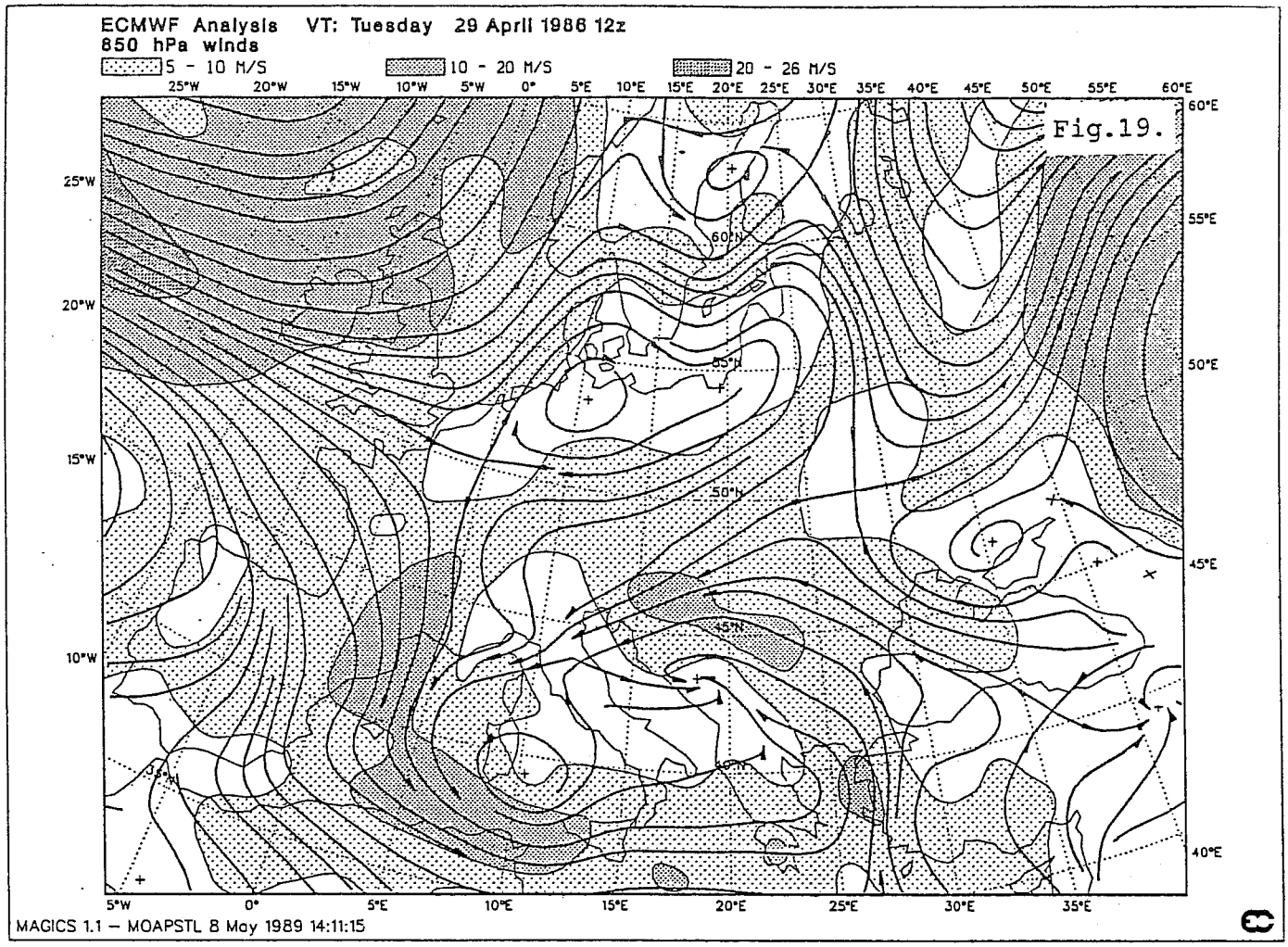

Friday 25 April 1986 12z ECMWF Forecast t+ 24 VT: Saturday 26 April 1986 12z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 23 M/S
Fig.14.
MAGICS 1.1 – MOAPSTL 10 May 1989 11:47:45


ECMWF Analysis VT: Sunday 27 April 1986 12z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 24 M/S
Fig.15.
MAGICS 1.1 – MOAPSTL 8 May 1989 14:08:18


Friday 25 April 1986 12z ECMWF Forecast t+ 48 VT: Sunday 27 April 1986 12z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 23 M/S
Fig.16.
MAGICS 1.1 – MOAPSTL 10 May 1989 11:49:36


ECMWF Analysis VT: Monday 28 April 1986 12z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 29 M/S
Fig.17.
MAGICS 1.1 – MOAPSTL 8 May 1989 14:10:10


Friday 25 April 1986 12z ECMWF Forecast t+ 72 VT: Monday 28 April 1986 12z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 25 M/S
Fig.18.
MAGICS 1.1 – MOAPSTL 10 May 1989 11:50:44


ECMWF Analysis VT: Tuesday 29 April 1986 12z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 26 M/S
Fig.19.
MAGICS 1.1 – MOAPSTL 8 May 1989 14:11:15

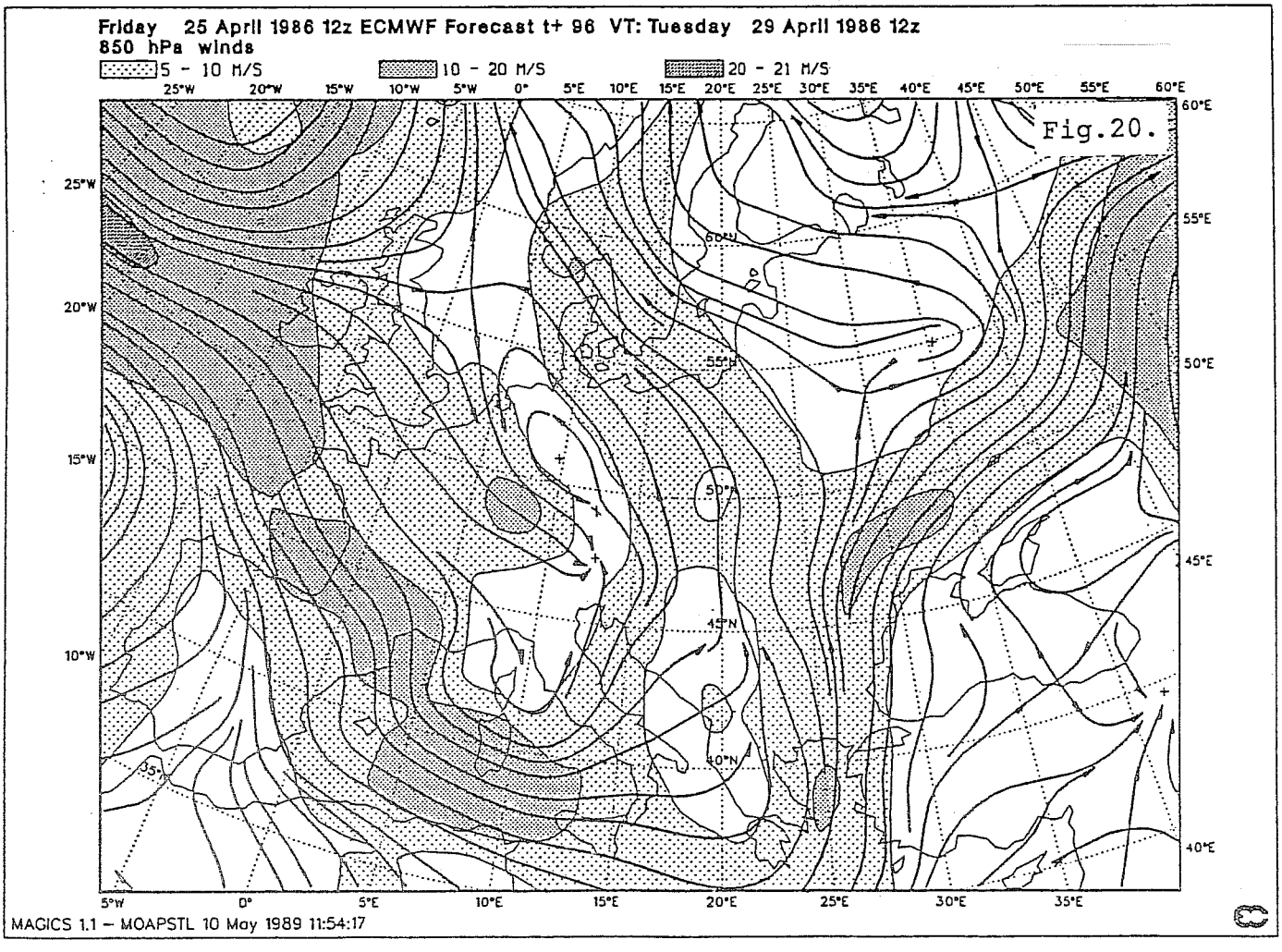

Friday 25 April 1986 12z ECMWF Forecast t+ 96 VT: Tuesday 29 April 1986 12z
850 hPa winds
5 - 10 M/S
10 - 20 M/S
20 - 21 M/S
Fig.20.
MAGICS 1.1 – MOAPSTL 10 May 1989 11:54:17

Fig. 21. The forecast distribution of precipitation (isohyets) accumulated from 26th 12UTC to 27th 12UTC and observations for the same period (numbers)

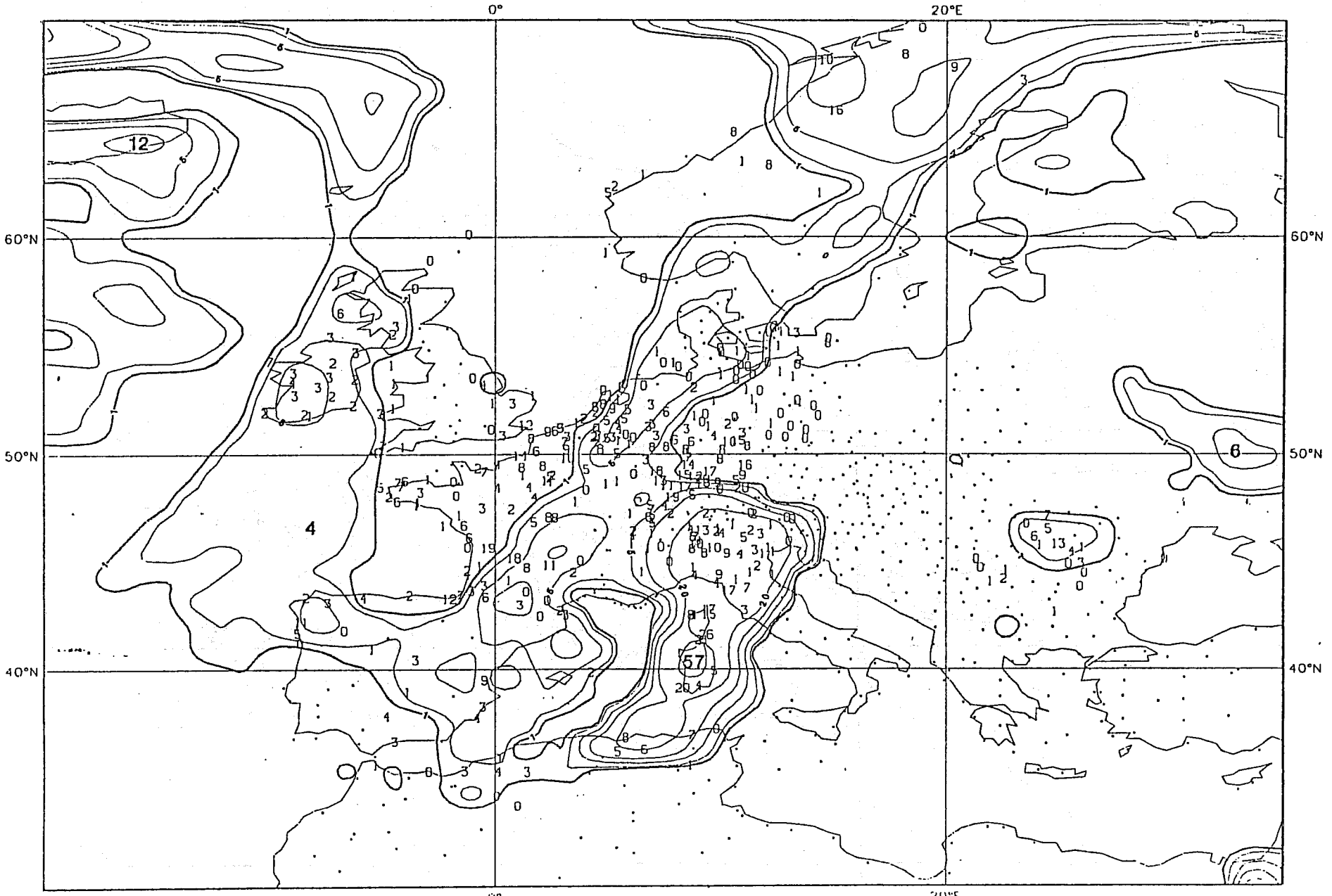


Fig. 22. Same as figure 21, but accumulated from 27th 12UTC to 28th 12UTC

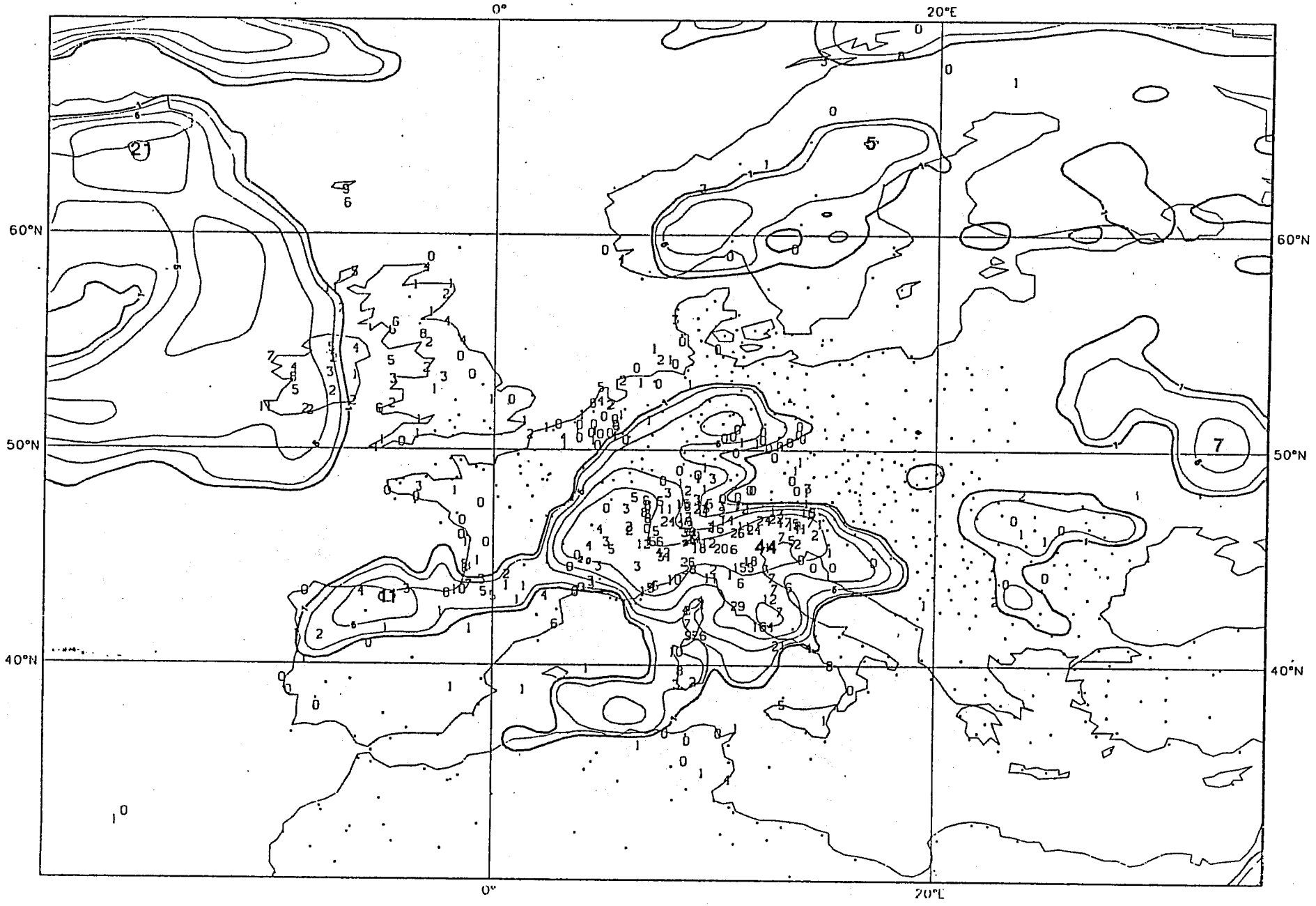


Fig. 23. Same as figure 21, but accumulated from 28th 12UTC to 29th 12UTC

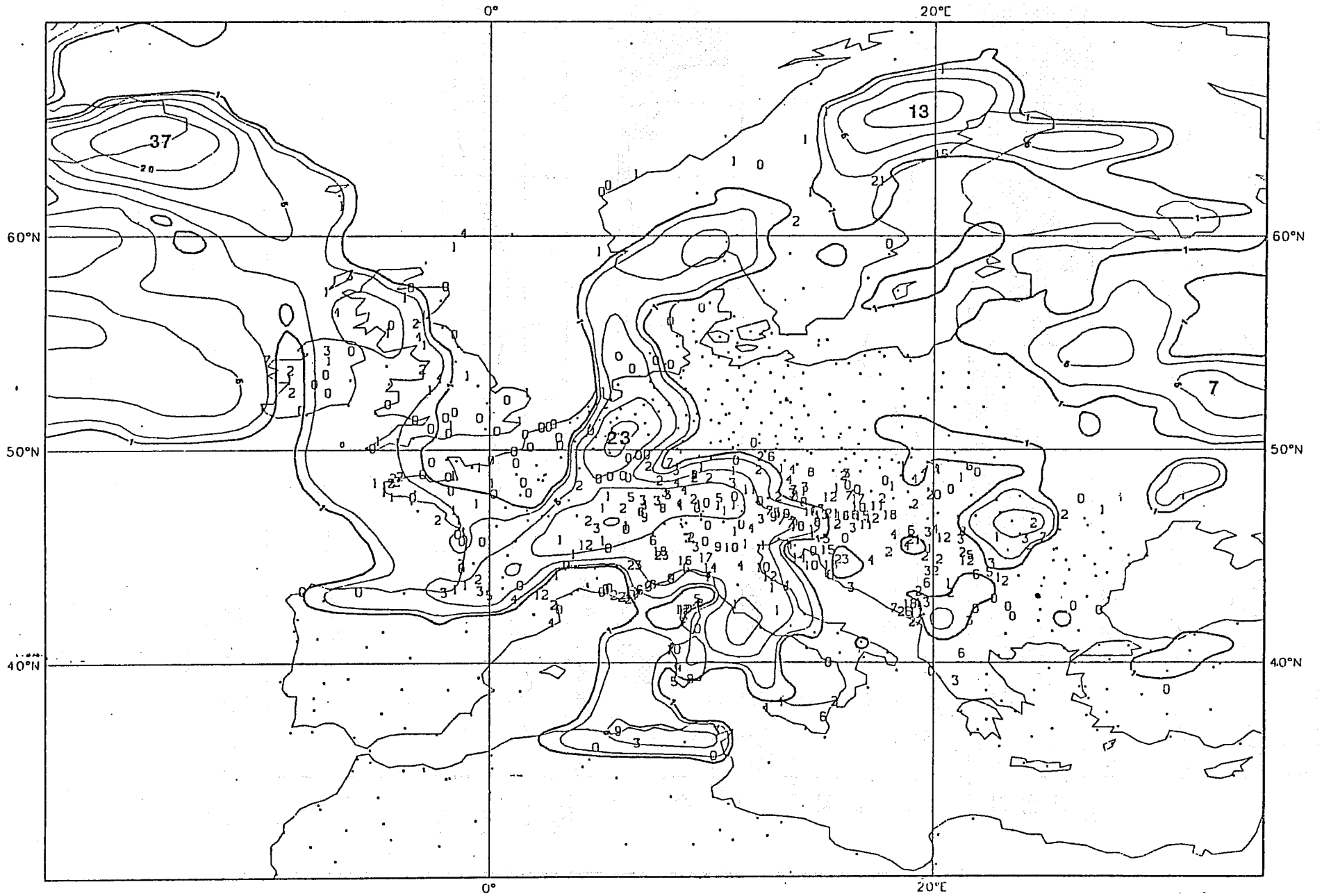


Fig.24.

CHERNOBYL (USS) 51° N 30° E

ECMWF Forecast from 25 April 1986 12 GMT

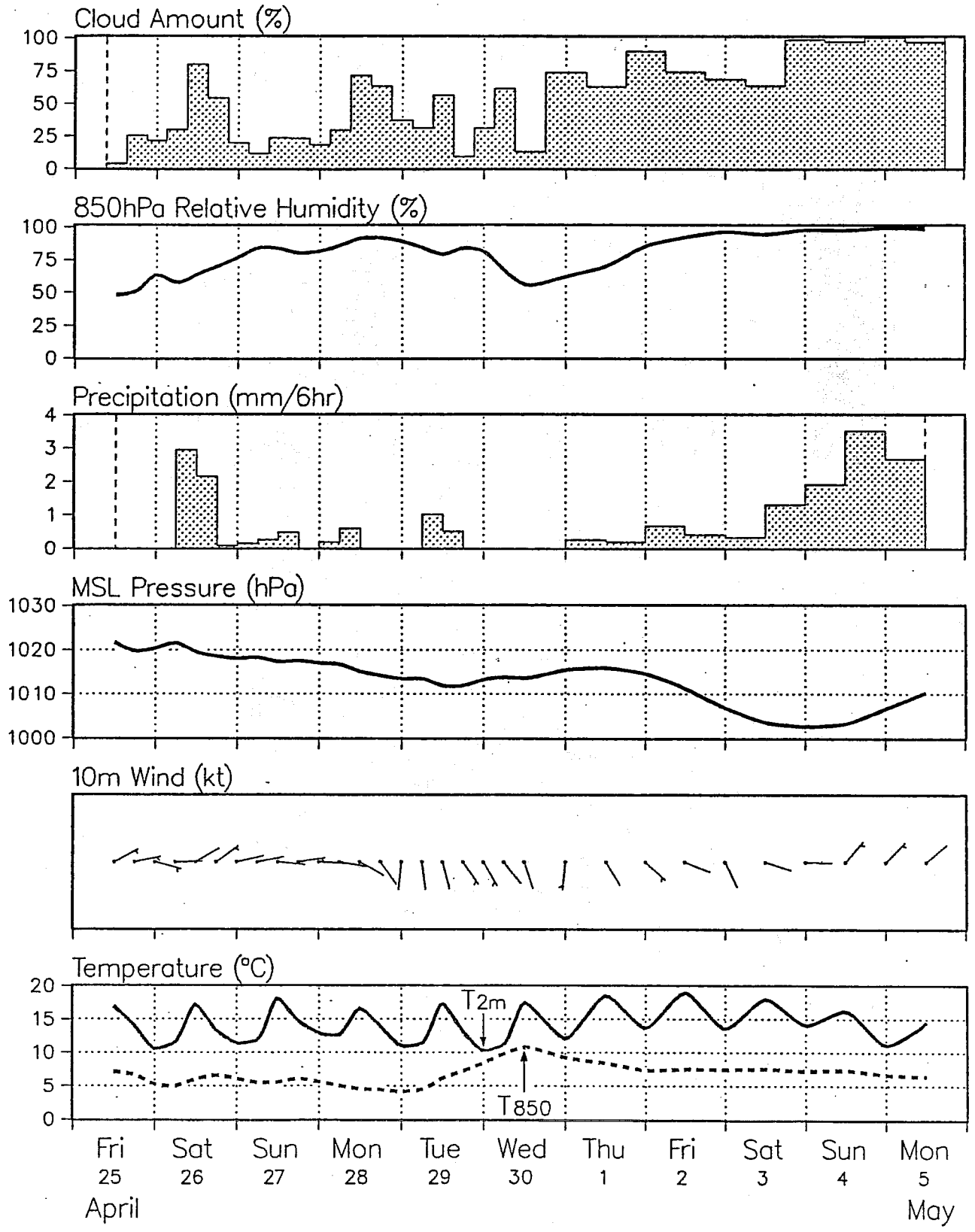


Fig.25. 12-hour forecast of stability conditions at Chernobyl for April, 26th 1986, 00UTC.

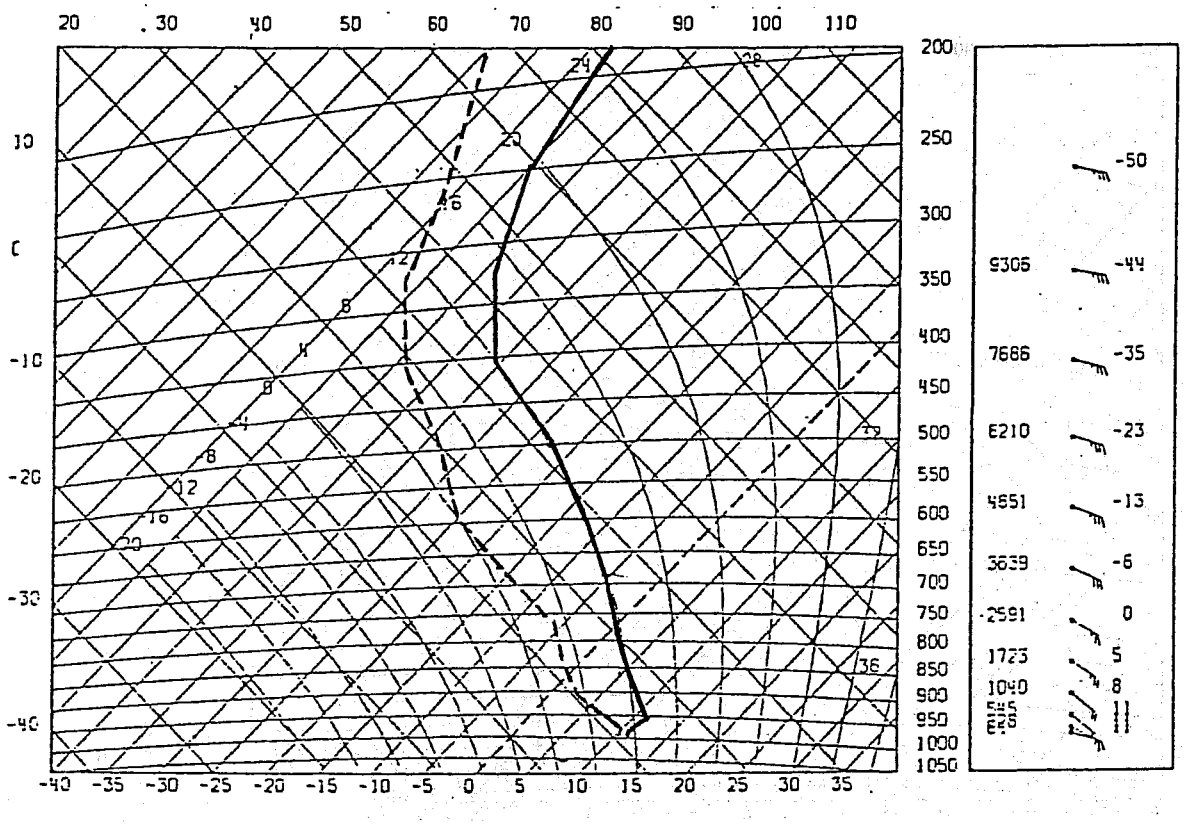


Fig.26. 24-hour forecast of stability conditions over Western White Russia (52N/27E) for April, 26th 1986, 12UTC.

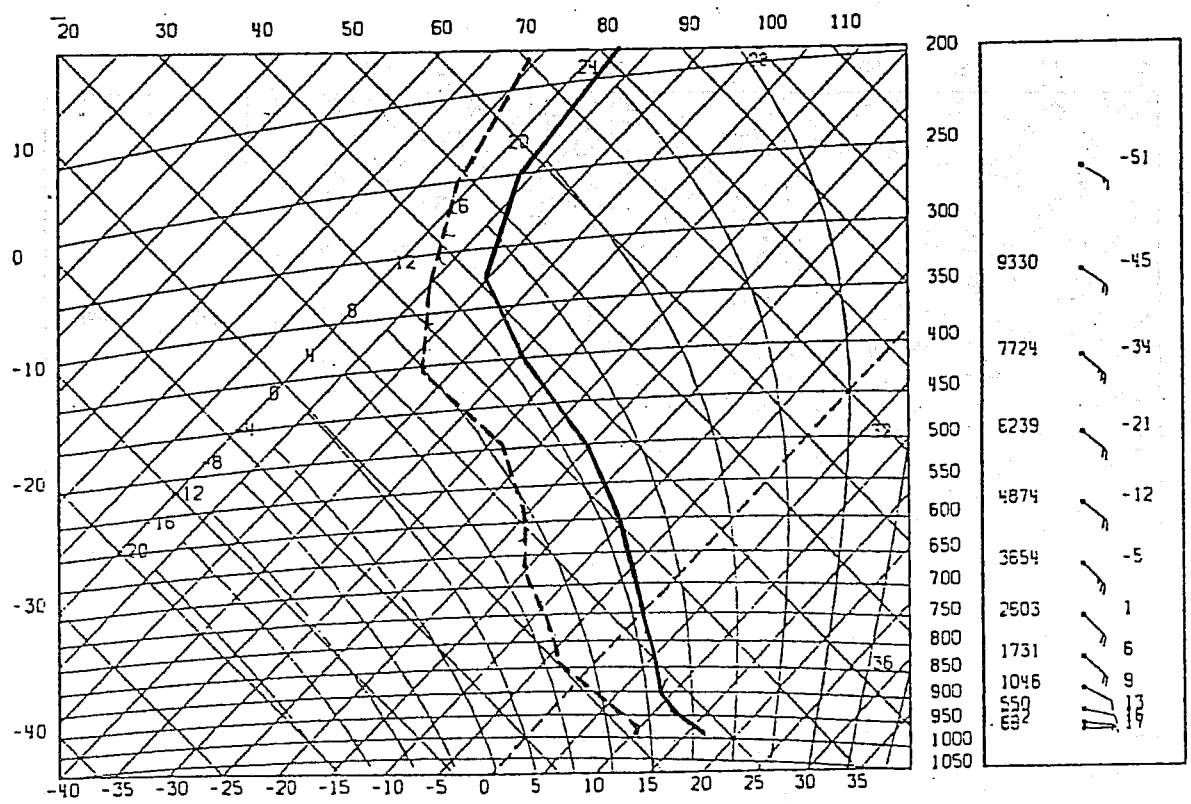


Fig.27. 48-hour forecast of stability conditions over the Baltic Sea (57N/20E) for April, 27th 1986, 12UTC.

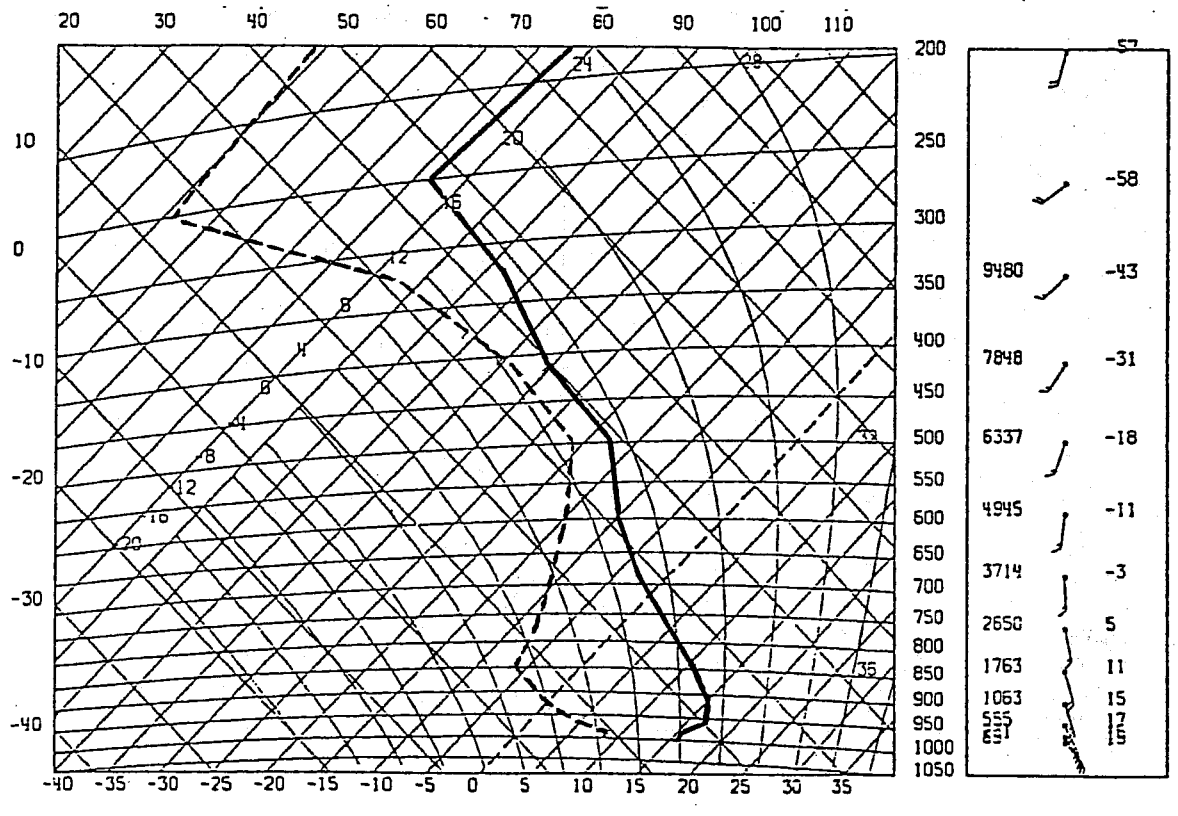


Fig.28. 48-hour forecast of stability conditions over Svealand (60N/17E) for April, 27th 1986, 12UTC.

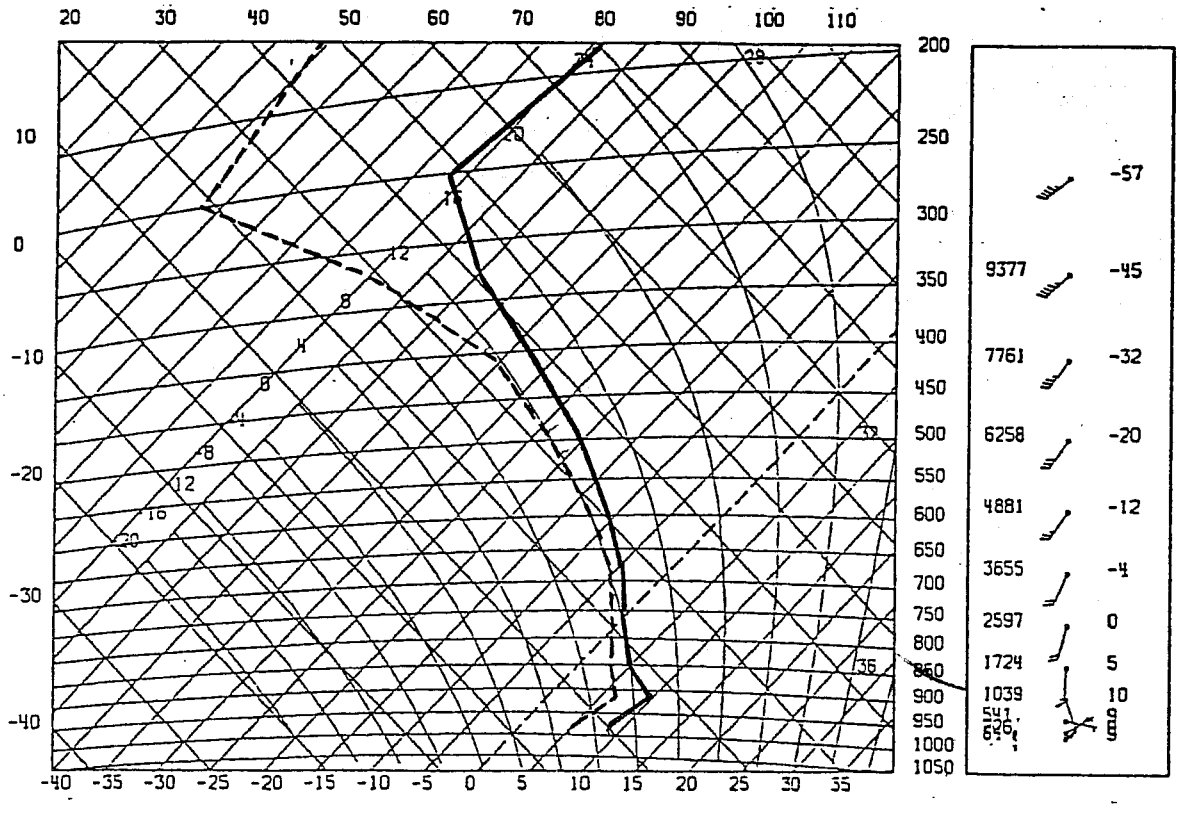


Fig.29. Verification of 850hPa geopotential for European area for forecasts up to day 4. 12-month moving averages of RMS errors (curves) are compared with the RMS errors of the forecast based on April the 25th (crosses).