TECHNICAL MEMORANDUM

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Monthly report on ECMWF's operational model's performance

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September 1979

European Centre for Medium-Range Weather Forecasts
Europäisches Zentrum für mittelfristige Wettervorhersage
Centre européen pour les prévisions météorologiques à moyen

Monthly Report on ECMWF's operational model's performances: September 1979

This report is the first of its kind. In fact operational forecasts at ECMWF started at the beginning of August 1979 but the August system was suffering from many weaknesses and the retrieval of archived data proved too difficult.

Each month a similar report will be produced and will be divided into two parts : - a standard set of diagrams, tables and maps which will indicate the major characteristics of one month's behaviour of the model from a statistical and objective point of view; this set may be evoluting with time in its form but not in its themes - some specific topics chosen as either strikingly representative of the past month as compared to other months or as recurrent problems not yet described in a previous issue of these reports.

This time we will concentrate essentially in the written part of the report, on the standard set in order to familiarise the reader with it; thus the special topic part of the report will be quite small.

I. Standard verifications of the model's performance

a) Objective scores

Figs.1,2 and 3 show the average performance of the operational model (18 cases for September 79 as will be for all subsequent cases) with persistence and climatological (norm) forecasts in terms of standard deviation of height (200 - 1000 mb, 20^{O}N - 82.5^{O}N) correlation of anomalies of height (same domain) and correlation of anomalies of temperatures (200 - 850 mb, 20^{O}N - 82.5^{O}N).

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From the standard deviation point of view (Fig.1) one might define the predictability limit as the time at which the model's curve for height crosses the norm; a simple comparison with subjective verification indicates how misleading this might be (almost 7 days in this case). One might also use the correlation of anomalies (Fig.2) but then the limit is more difficult to define. 0.6 and 0.5 are the most often suggested values. In earlier ECMWF experience 0.6 seemed to agree quite well with the standard deviation results; here it is not the case and it looks like the 0.5 limit is less in contradiction with it, although giving a more realistic value of 5.7 days. This means broadly that on the whole our average forecast ceases to have useful skill after 5 and a half days. This does not prejudge any individual forecast on any special geographical array where things might be better or worse depending on the case. From the temperature's point of view useful predictability is one day less than for heights. Regarding the spectral distribution of predictability the usual results of better forecasting skills for longer waves and for zonal flow are apparent. For quick reference and comparisons the RMS and anomaly correlation of height (vertical average, 500, 1000 mb) and temperature (vertical average ,500, 850 mb) for every 12 hours to 5 days are given in Table 1.

b) Energetics

Figs.4 to 15 give a comparison of height/latitude cross section of zonally averaged main energetic terms both in the model (ENS) and in reality (OBS) : kinetic energy (KE) , conversion of zonal to eddy kinetic energy (CK), available potential energy (AE), conversion of zonal to eddy available potential energy (CA), northward momentum flux and northward sensible heat flux. From all of these it appears that the model's energetics and energy transfers are underestimated especially in the long waves.On the whole the geographical position of their activity is well captured but not their intensity. The worse situation is for the kinetic energy and the best for the conversion of available potential energy. The northward stratospheric fluxes of momentum and sensible heat are far worse than the tropospheric ones.

c) Energy spectra

Figs. 16 to 19 show the decrease with time of the quality of the model's energetics. While the baroclinic waves remain at an acceptable level of kinetic energy (even too high for wavenumber 5 between days 4 and 7), long and short waves are losing energy, leaving waves 4 to 6 alone and outstanding in comparison with the truth. The picture is very similar for the spectrum of 500 mb height. This distortion might explain the overdevelopment of big centres of activity frequently reported in the synoptic evaluations of the model's behaviour. This is certainly one of the major deficiencies of the model and an investigation of its causes will be necessary (see below).

d) Wind and temperature deviations

These deviations (from the truth) are zonally averaged and presented in height/latitude diagrams (Fig.19). One can notice that the main errors are in the stratosphere where an increased thermal contrast between equator and pole creates a northward shift and increased confinement of the sub-tropical jet. The strong cooling in the lower tropical troposphere probably explains the high wind error in the atmosphere aloft. On the whole tropospheric errors are less than previous experience might have shown.

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e) Systematic errors

Figs.20,22 and 24 show maps of the averaged observed and forecast 500 mb height, 1000 mb height and 850 mb temperature fields respectively,valid at day 10. Figs. 21, 23, 25 show the corresponding difference fields at both day 7 and day 10. Looking first at 500 mb, we see that the systematic error has a distinctive large scale component to it, characterised by a lack of amplitude in the wavenumbers 2 and 3 (also seen in the 500 mb height spectrum, Fig. 18). We also notice a phase error : indeed most troughs and ridges in the averaged observed 500 mb height can be recognised in the forecast and appear shifted by about 15° towards the east. The error pattern also appears related to land and sea distributions with the two main error dipoles centered at the western edges of both North America and Europe with positive differences between forecasts and observations over the Pacific and Atlantic oceans. Similar error patterns can be found at 1000 mb, although it might also be noted that the observed mean Aleutian low for September 1979 is much more intense than its climatic value. The 850 mb temperature error pattern shows that the forecast temperatures in the subtropics and over continental land masses are too low, while they are too high over oceans, especially in middle latitudes.

II. Special topics

a) Kinetic energy spectra

Figs. 26 and 27 show the spectra of kinetic energy averaged from forecast day 7 to 10, both observed (OBS) and forecast (ENS) at various levels in the atmosphere (300, 500, 850, 1000 mb). Note that forecast spectra are smoother than the observed and show lower energy levels at both the high and low wavenumbers with a relative maximum at wavenumber 5 comparable to the observed. This is true throughout the atmosphere, but the differences increase with height.

b) Average energetics

Figs. 28 and 29 show the 10-day time evolution of the vertically integrated available potential energy (AE) and zonal to eddy available energy transfer (CA) in the model (ENS) and observed (OBS) for various wavenumber bands. Note that model AE is always underestimated with differences slowly increasing with time. For the first 7 days of the forecast period, however, the conversion (CA) from zonal to wavenumbers 4 to 9 of AE is overestimated, showing that the model has been much more efficient than the atmosphere in this wavenumber band.

c) Zonal averages

Zonal averages of temperature at 850 and 500 mb, zonal wind at 300 mb and height at 1000 mb are presented in Figs. 30 and 31 time-averaged between day 4 to 7 and day 7 to 10 respectively. At 850 mb the northern hemisphere is shown to cool down gradually, the magnitude of the cooling increasing equatorward. At 500 mb, no mean cooling is noticeable but the mean north-south temperature gradient in the middle latitudes is seen to increase in the final forecast period (7 - 10 days) in conjunction with a strengthening and northward shift of the mean zonal wind at 300 mb and lowering of the 1000 mb heights north of 55°N and increasing of the 1000 mb heights in the 30° - 55 N belt. Note the presence of mean easterlies south of 25°N in the forecast but not in the analyses.

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d) Energetics of average

One of the oustanding aspects of the performance of the operational model during September 1979 has been its failure to forecast the correct amplitude of the planetary waves. This fact is emphasised by comparing the energetics of the average (standing) flow. Both the spectra of 500 mb height and tropospheric kinetic energy (Fig.32) show largest discrepancies between observed and forecast mean flow for wavenumbers 2,3,4. The consequences for the conversion terms CK and CA (Fig.33), and fluxes UV and TV (Fig.34) are very striking. It is a well known fact that large scale stationary waves are maintained by topographical as well as thermodynamical forcing. The systematic error patterns are well correlated with the distribution of land masses and suggest lack of sensible heating, in the lower troposphere (850 mb) over continents, as a contributing cause to these large planetary wave errors.

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T A B L E 1

	12	24	36	48	60	72	84	96	108	120
Height Correlations (%)										
1000 - 200	97	94	91	87	82	77	71	65	60	55
1000	93	91	85	81	76	70	65	59	55	51
500	97	94	92	87	83	77	72	66	62	57
R M S E (m)										
1000 - 200	21	28	35	42	48	55	61	68	73	78
1000	19	24	31	34	39	43	47	51	54	56
500	18	26	31	39	45	53	58	65	68	74
Temperature Correlations (%)										
850 - 200	91	86	81	77	71	66	60	54	49	45
850	90	87	81	77	72	68	63	57	54	48
500	93	89	85	80	74	69	62	56	49	44
R M S E ($0.1^{\circ}K$)										
850 - 200	14	17	20	22	25	27	29	32	34	35
850	15	18	22	24	27	29	32	34	36	38
500	11	14	17	19	22	24	27	29	32	33

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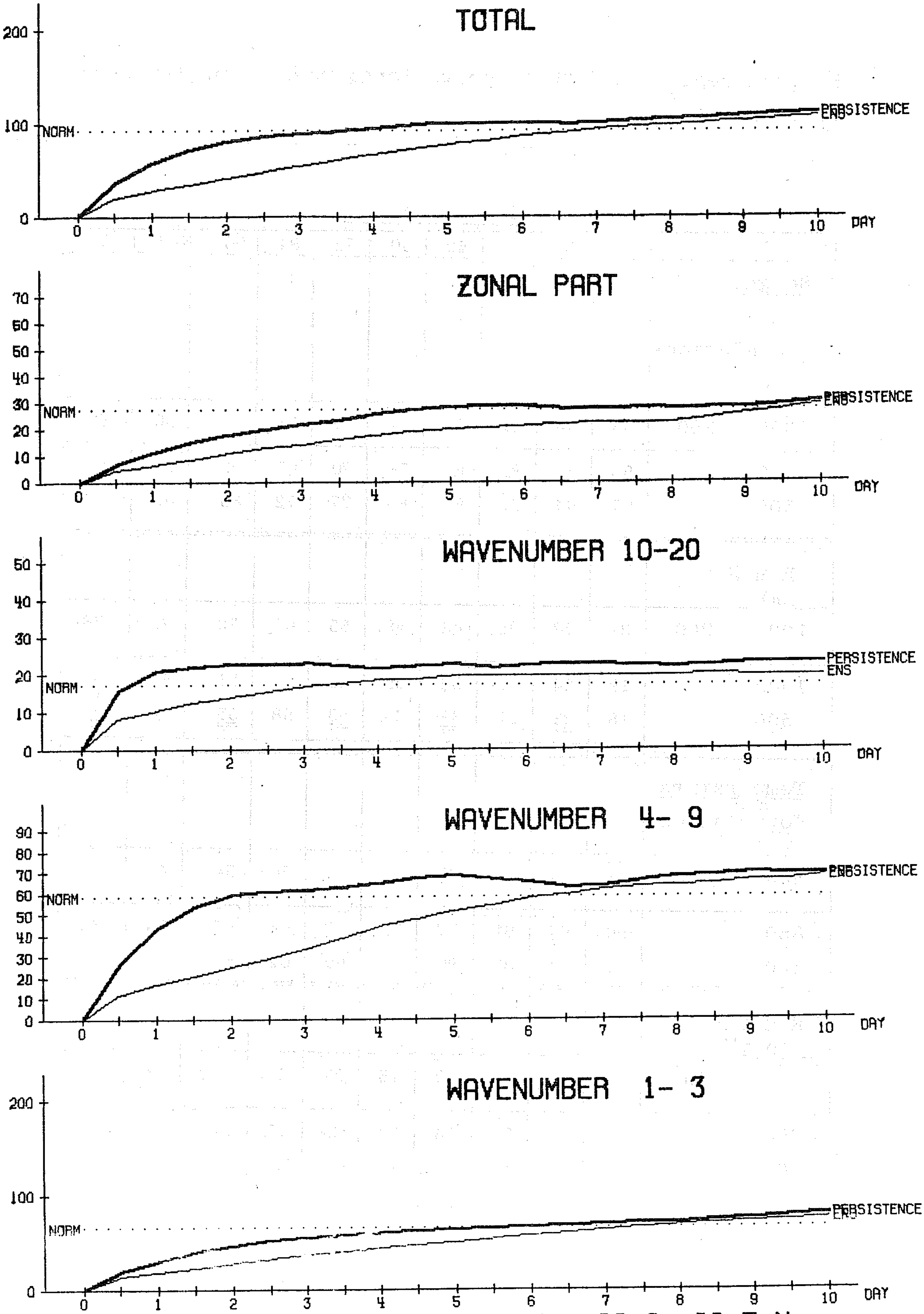


MEAN 1000- 200 MB AND 20.0- 82.5 N
RMS ERROR OF HEIGHT (M) 18 CASES

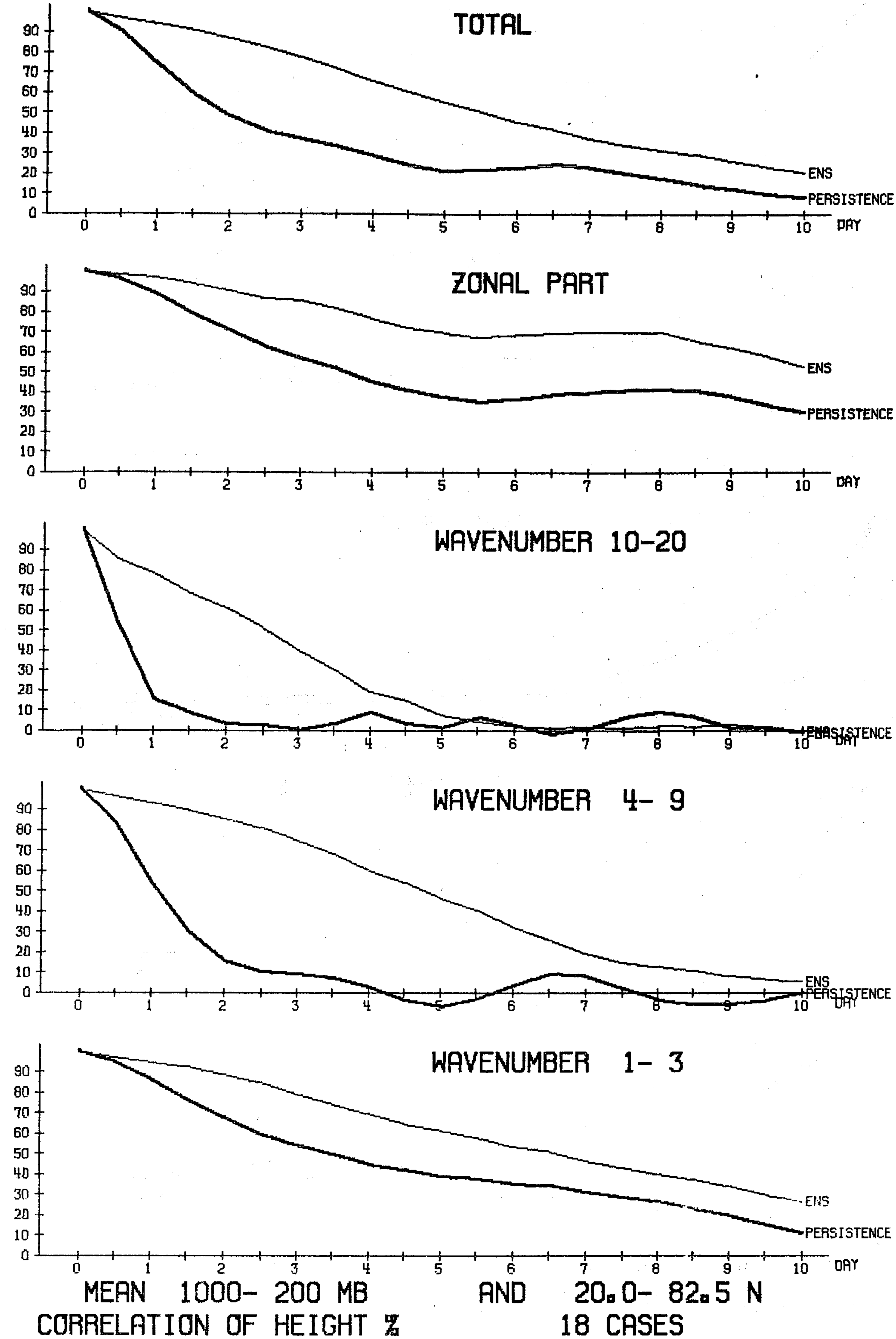

TOTAL
ZONAL PART
WAVENUMBER 10-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
ENS
PERSISTENCE
DAY
MEAN 1000- 200 MB AND 20.0- 82.5 N
CORRELATION OF HEIGHT % 18 CASES

Fig. 2

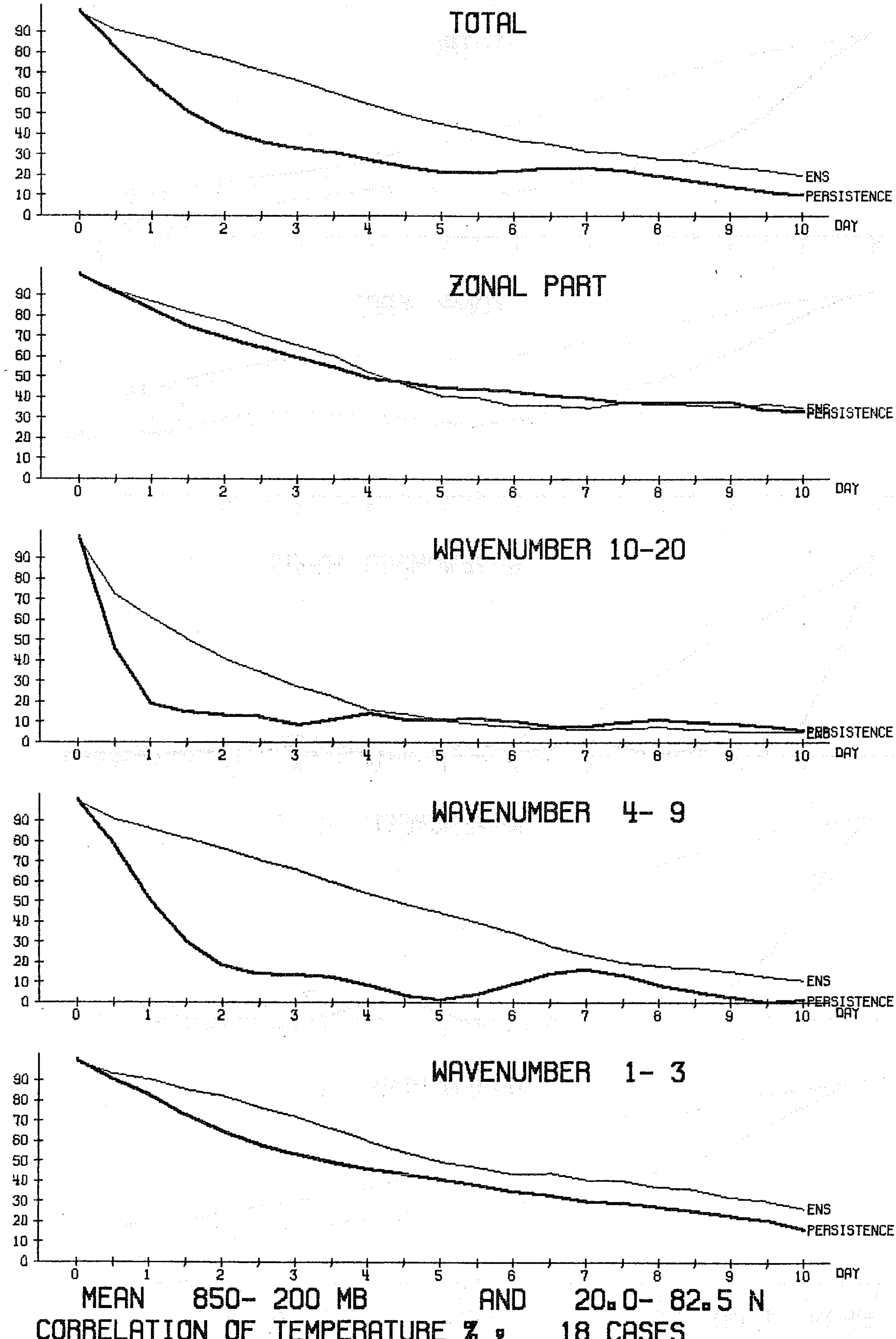

TOTAL
ZONAL PART
WAVENUMBER 10-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
ENS
PERSISTENCE
DAY
MEAN 850- 200 MB AND 20.0- 82.5 N
CORRELATION OF TEMPERATURE % , 18 CASES

Fig. 3

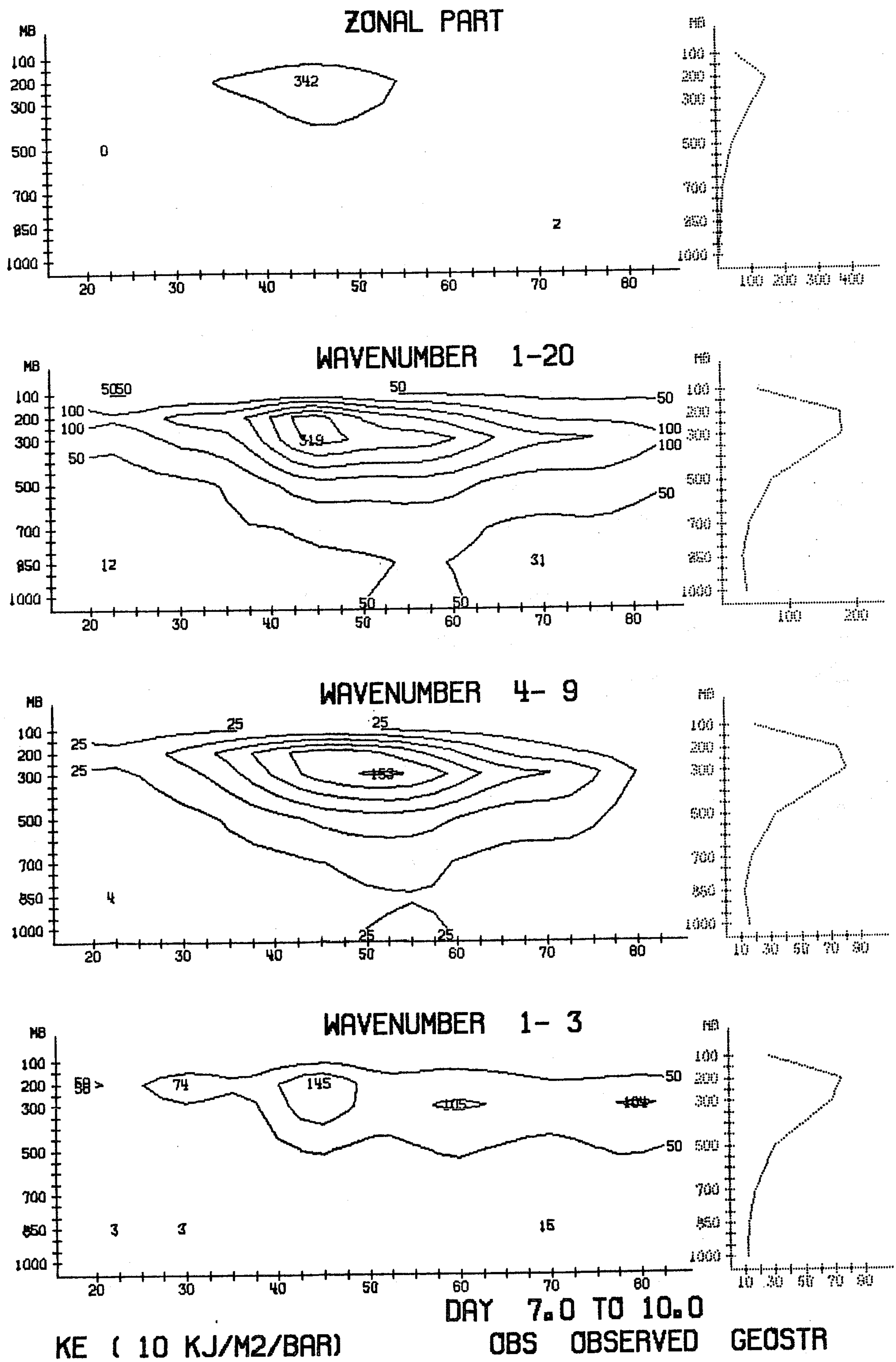

ZONAL PART
WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
KE (10 KJ/M2/BAR)
OBS OBSERVED GEOSTR

Fig. 4

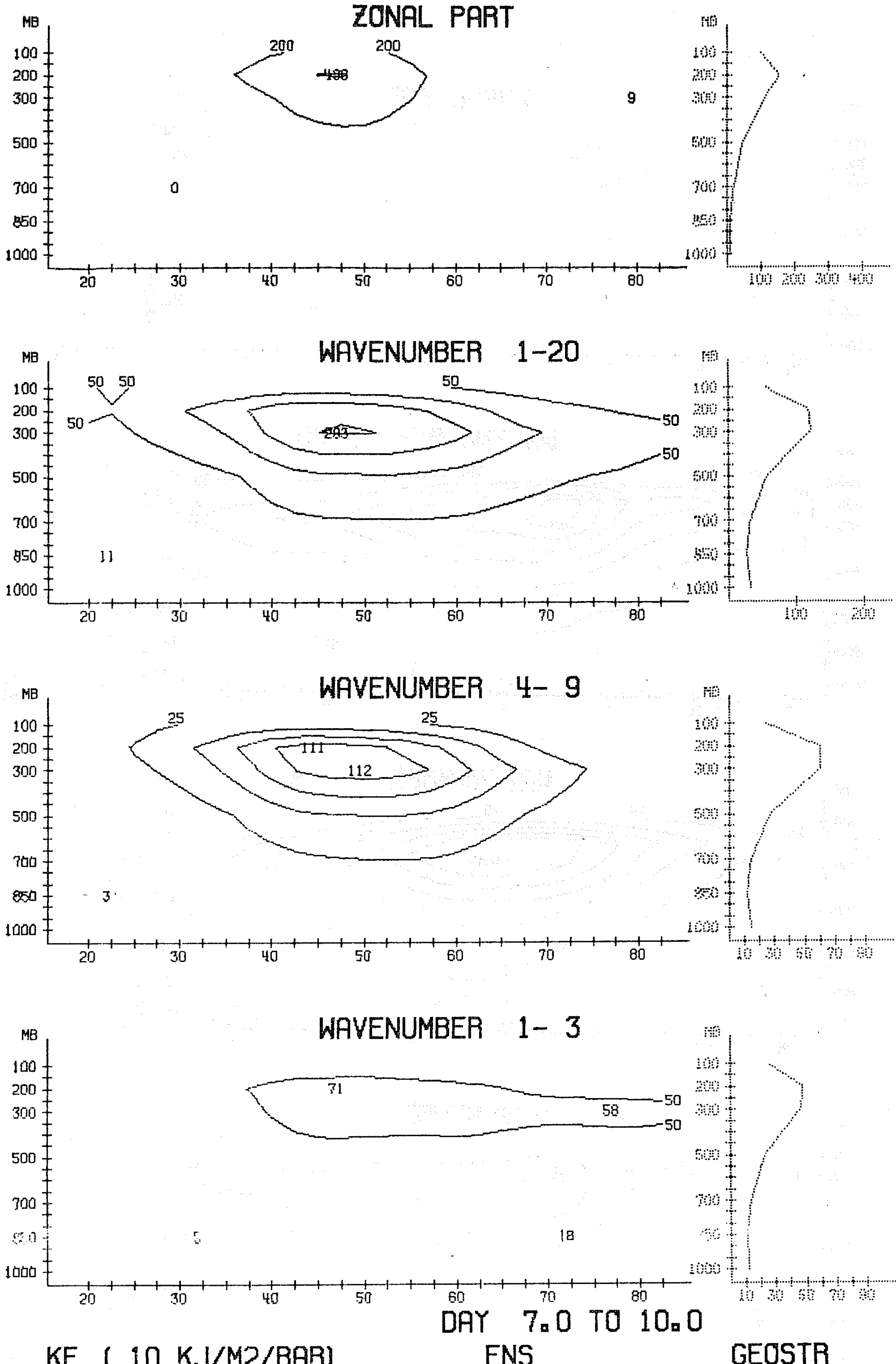

ZONAL PART
WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
KE (10 KJ/M2/BAR)
ENS
GEOSTR

Fig. 5

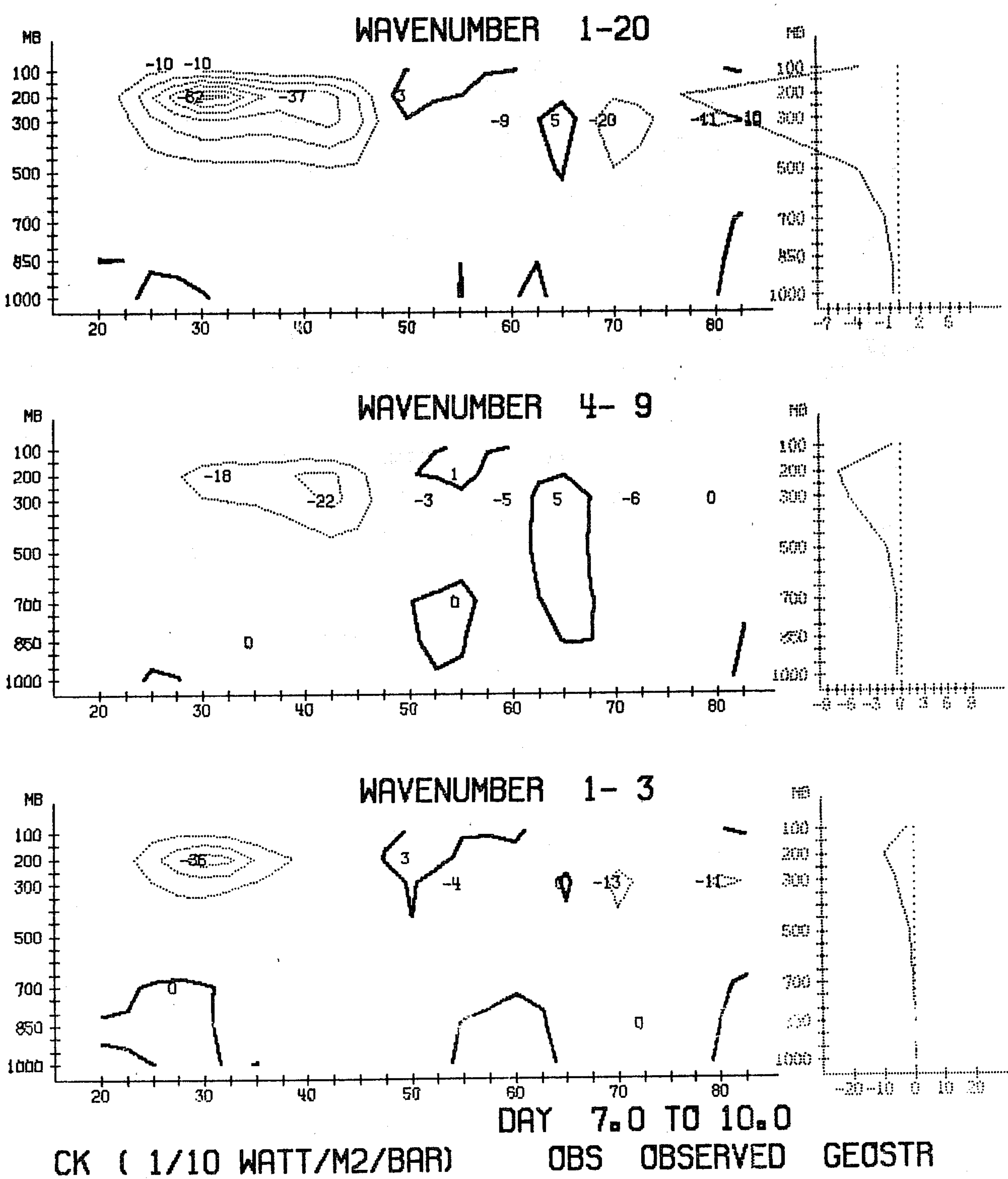

WAVENUMBER 1-20
MB
100
200
300
500
700
850
1000
-10 -10
-62
-37
3
-9
5
-20
-11
20
30
40
50
60
70
80
WAVENUMBER 4- 9
-18
-22
1
-3
-5
5
-6
0
0
0
WAVENUMBER 1- 3
-36
3
-4
0
-13
-11
0
0
DAY 7.0 TO 10.0
CK (1/10 WATT/M2/BAR)
OBS OBSERVED GEOSTR

Fig. 6

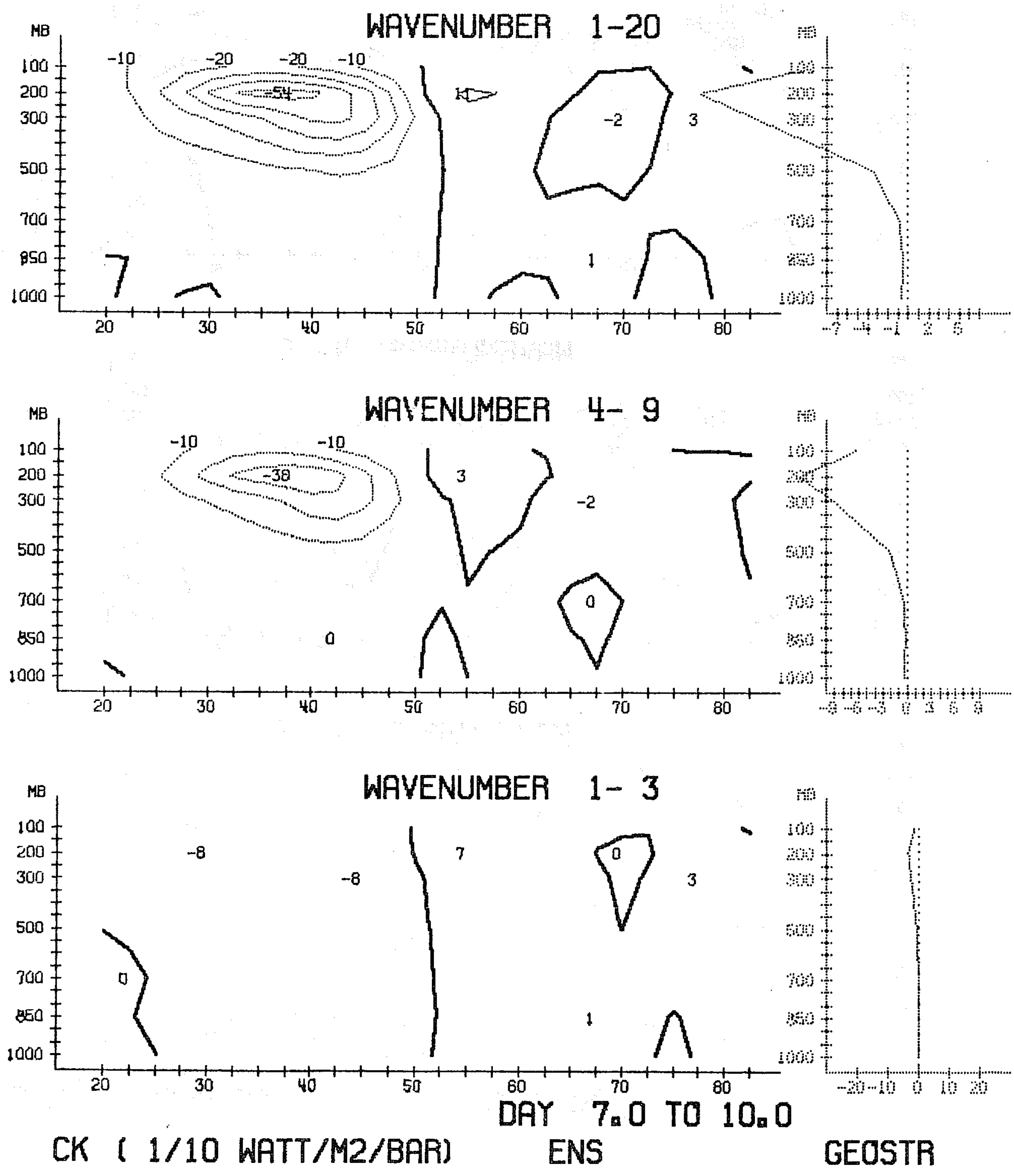

WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
CK (1/10 WATT/M2/BAR)
ENS
GEOSTR

Fig. 7

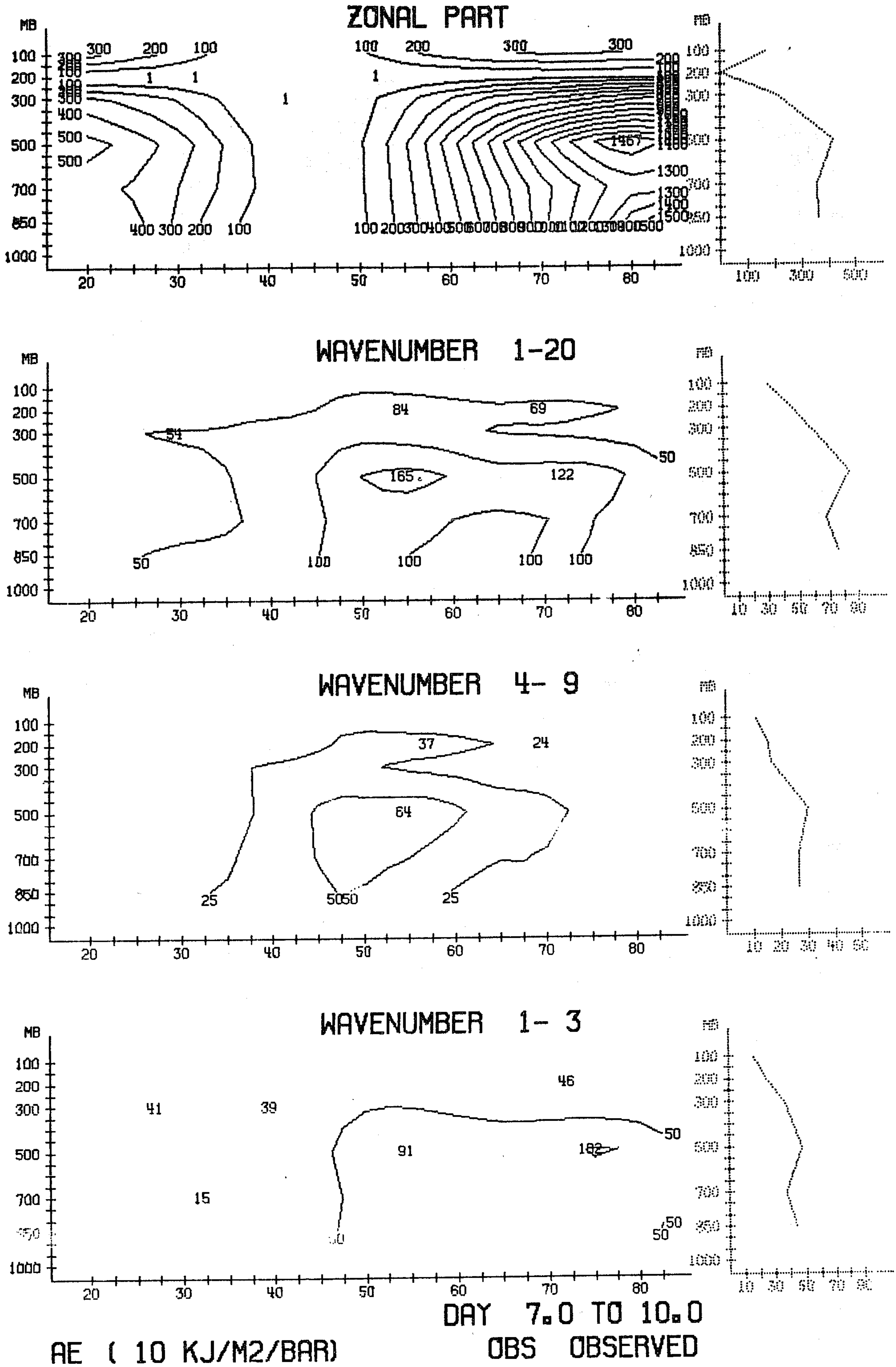
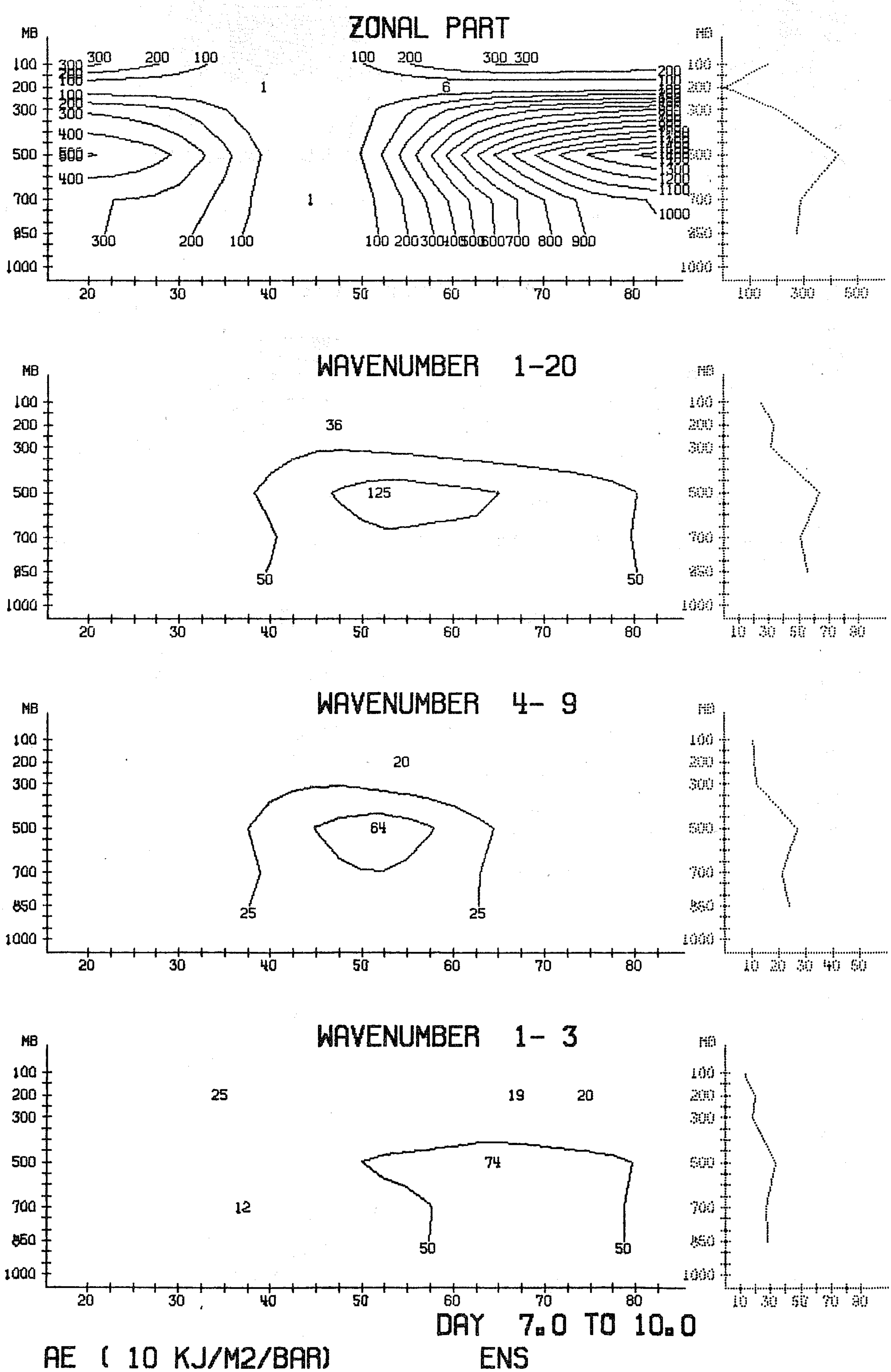

ZONAL PART
WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
OBS OBSERVED
AE (10 KJ/M2/BAR)

Fig. 8


ZONAL PART
WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
AE (10 KJ/M2/BAR)
ENS

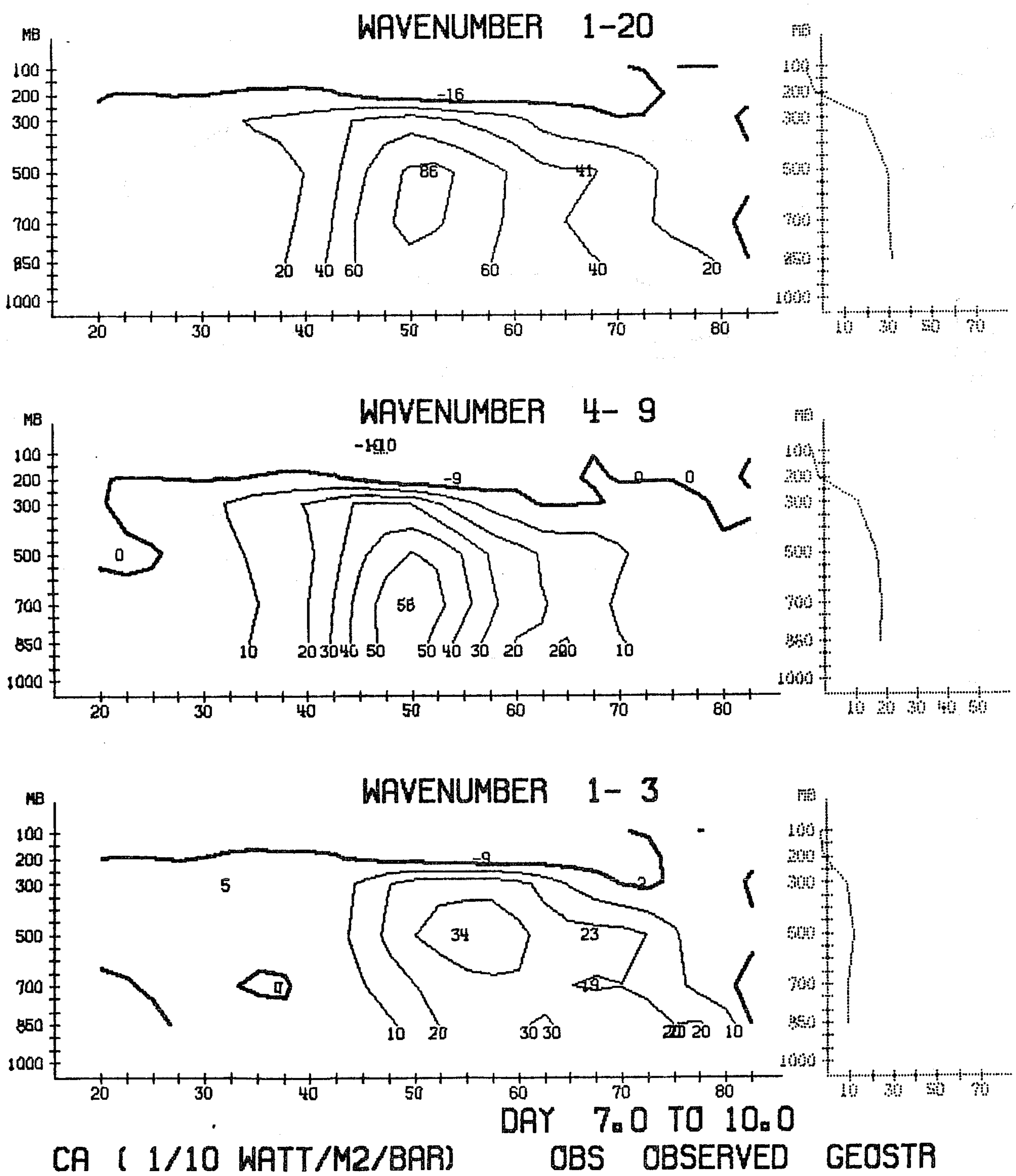

WAVENUMBER 1-20
MB
100
200
300
500
700
850
1000
20 30 40 50 60 70 80
-16
86
41
20 40 60 60 40 20
10 30 50 70
WAVENUMBER 4- 9
-10
-9
0
0 0
58
10 20 30 40 50 50 40 30 20 20 10
10 20 30 40 50
WAVENUMBER 1- 3
-9
5
-2
34
23
-19
10 20 30 30 20 20 10
DAY 7.0 TO 10.0
CA (1/10 WATT/M2/BAR) OBS OBSERVED GEOSTR

Fig. 10

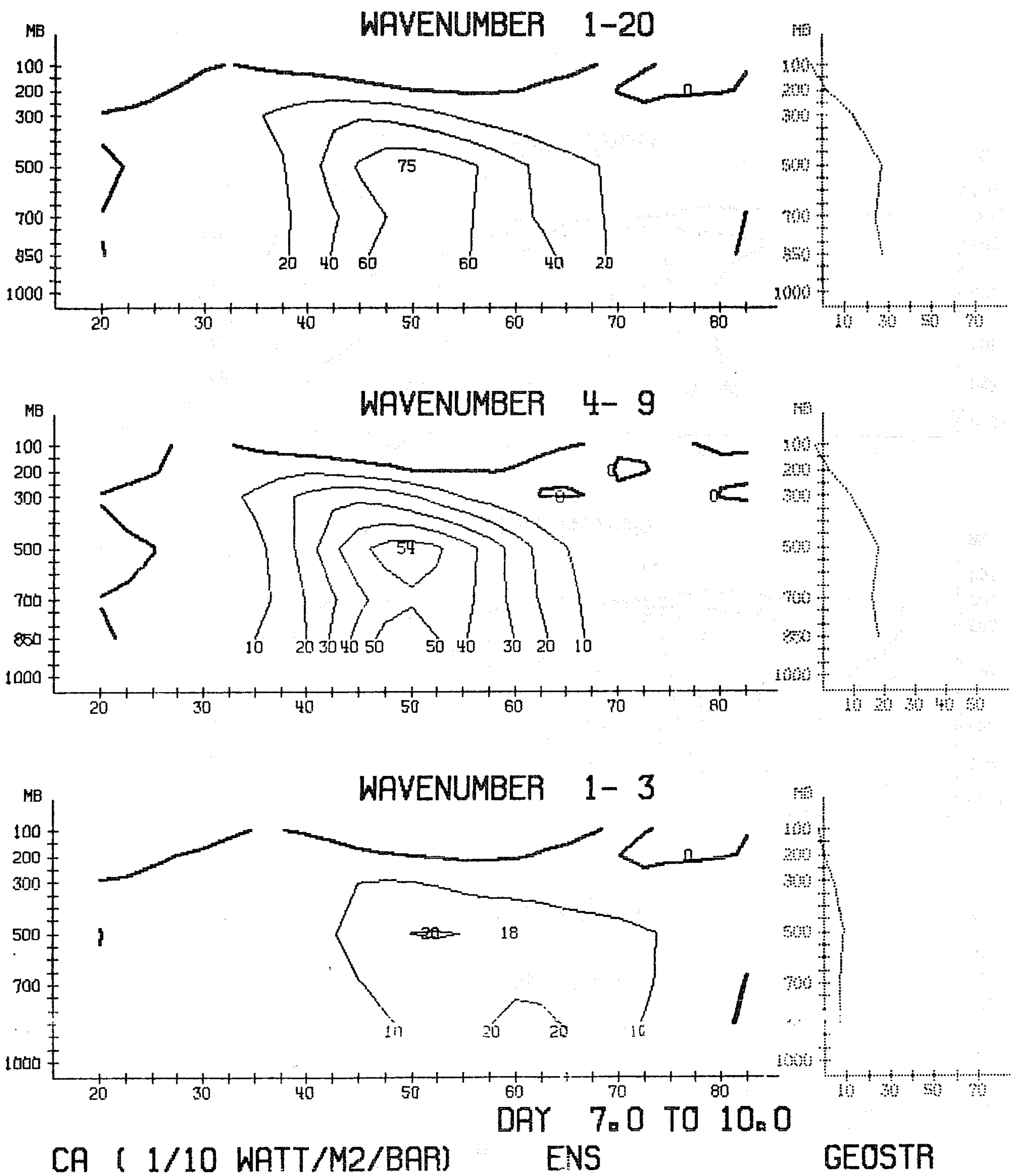

WAVENUMBER 1-20
MB
100
200
300
500
700
850
1000
75
20 40 60 60 40 20
20 30 40 50 60 70 80
10 30 50 70
WAVENUMBER 4- 9
54
10 20 30 40 50 50 40 30 20 10
10 20 30 40 50
WAVENUMBER 1- 3
18
10 20 20 10
DAY 7.0 TO 10.0
CA (1/10 WATT/M2/BAR)
ENS
GEOSTR

Fig. 11

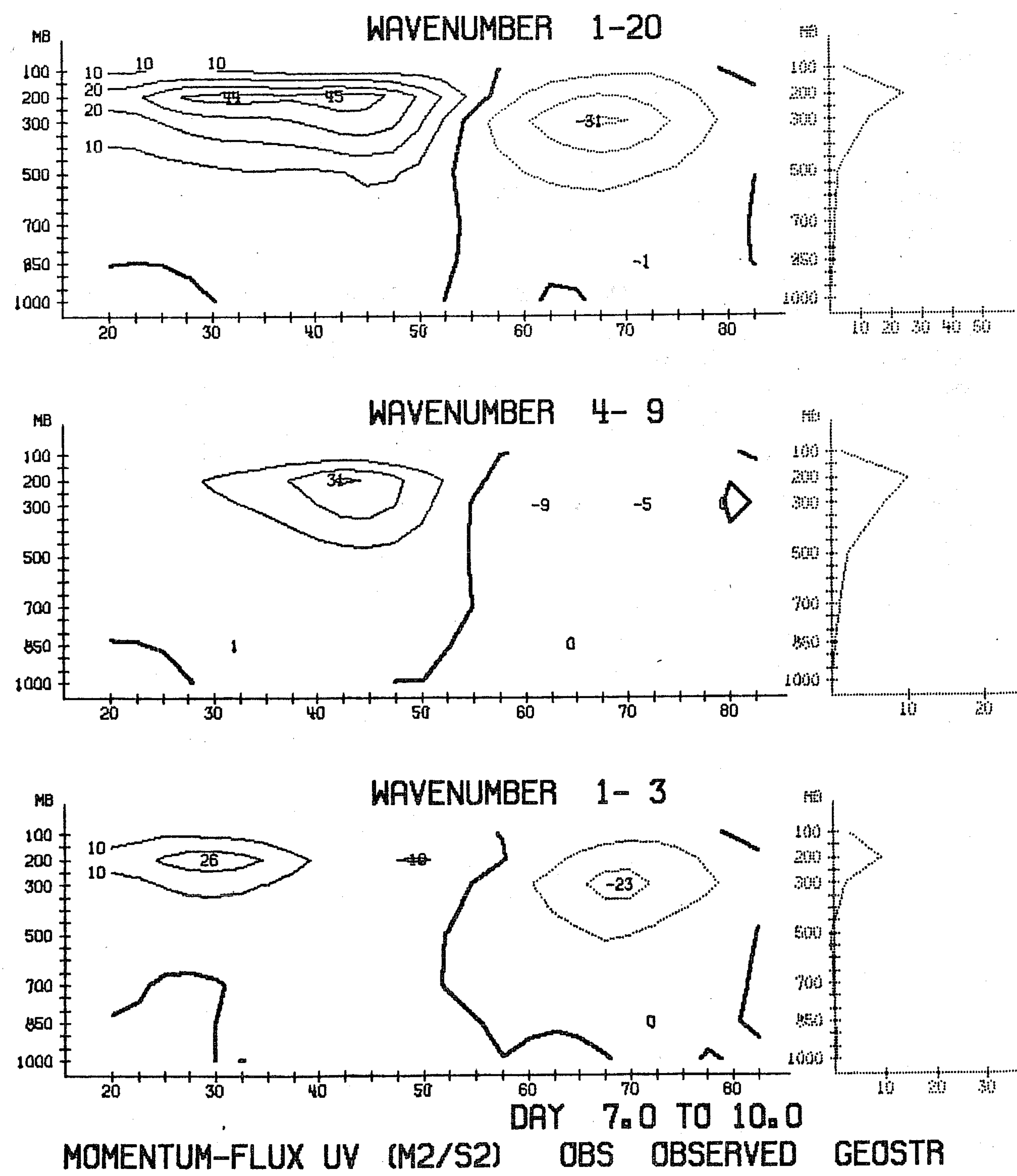

WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
MOMENTUM-FLUX UV (M2/S2) OBS OBSERVED GEOSTR

Fig. 12

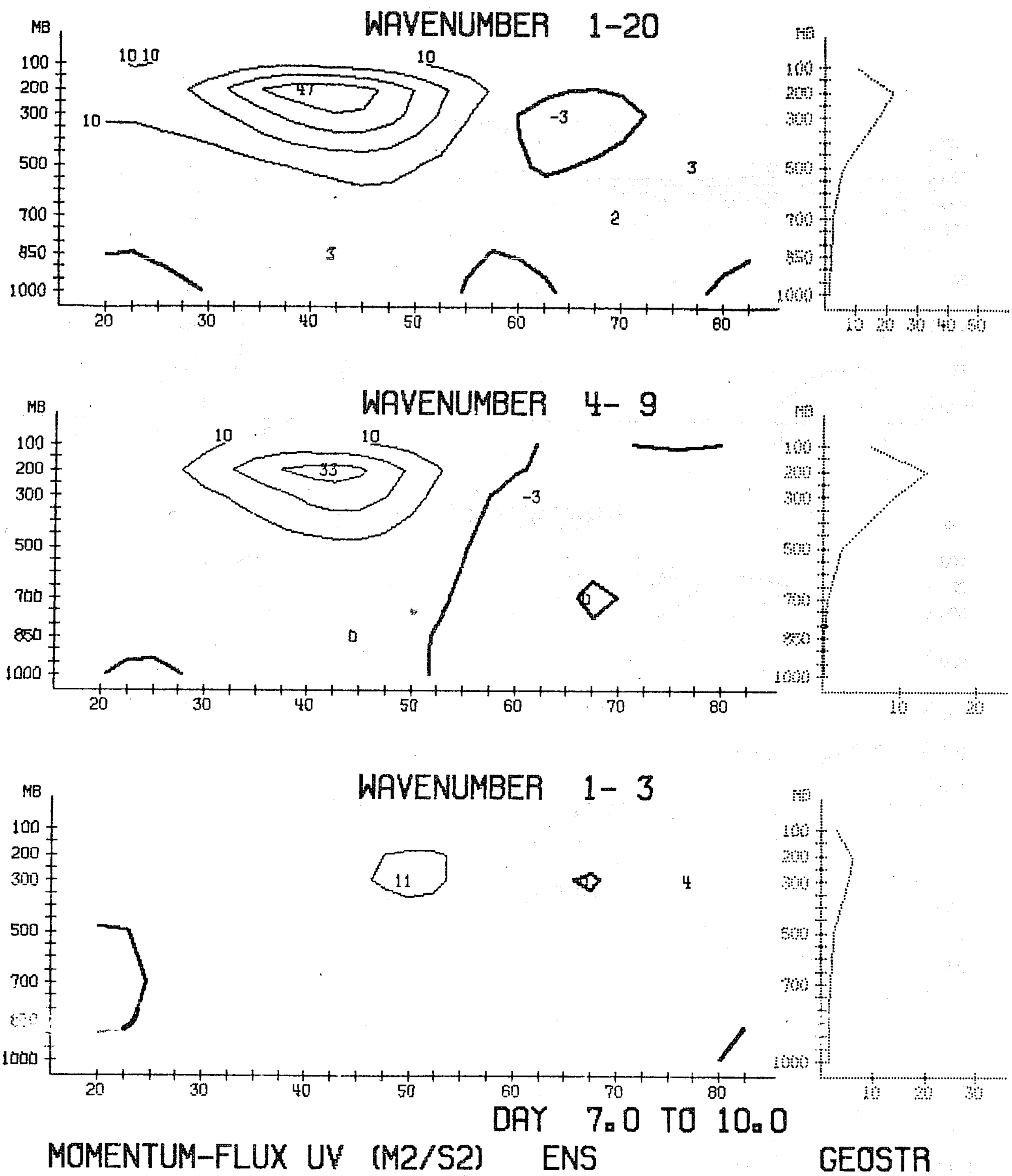
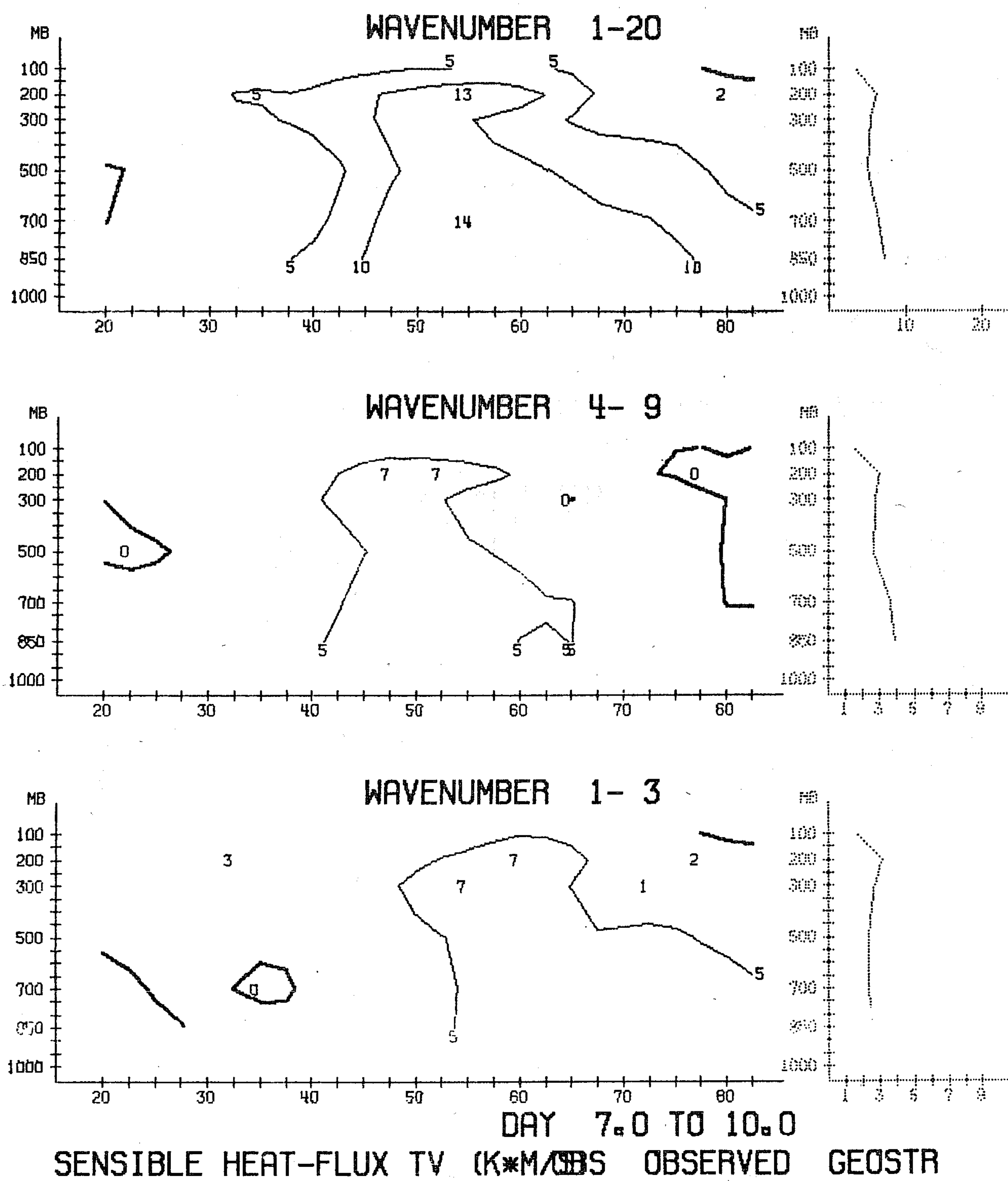

WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
MOMENTUM-FLUX UV (M2/S2) ENS
GEOSTR

Fig. 13



WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
SENSIBLE HEAT-FLUX TV (K*M/S) OBS OBSERVED GEOSTR

Fig. 14

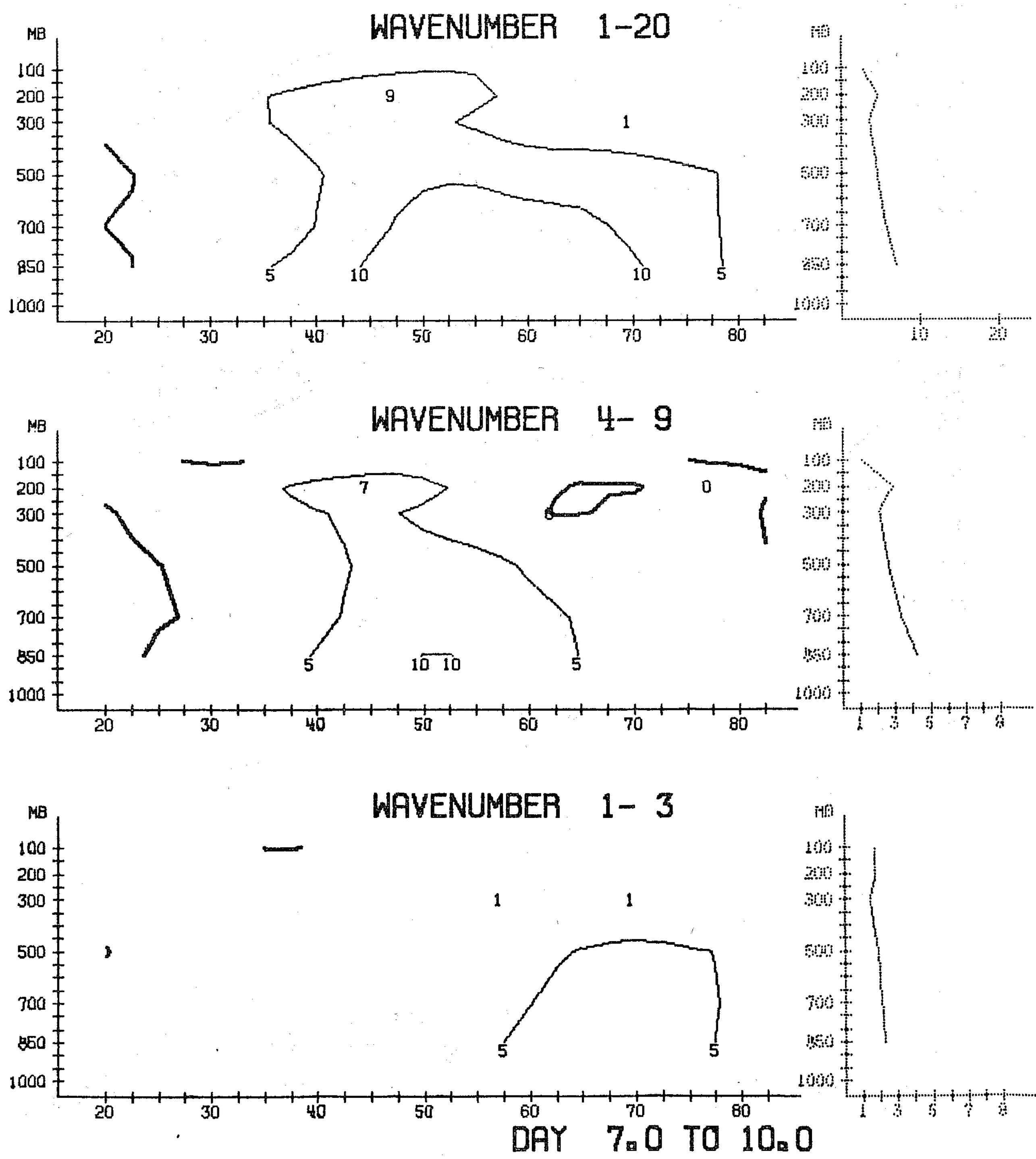
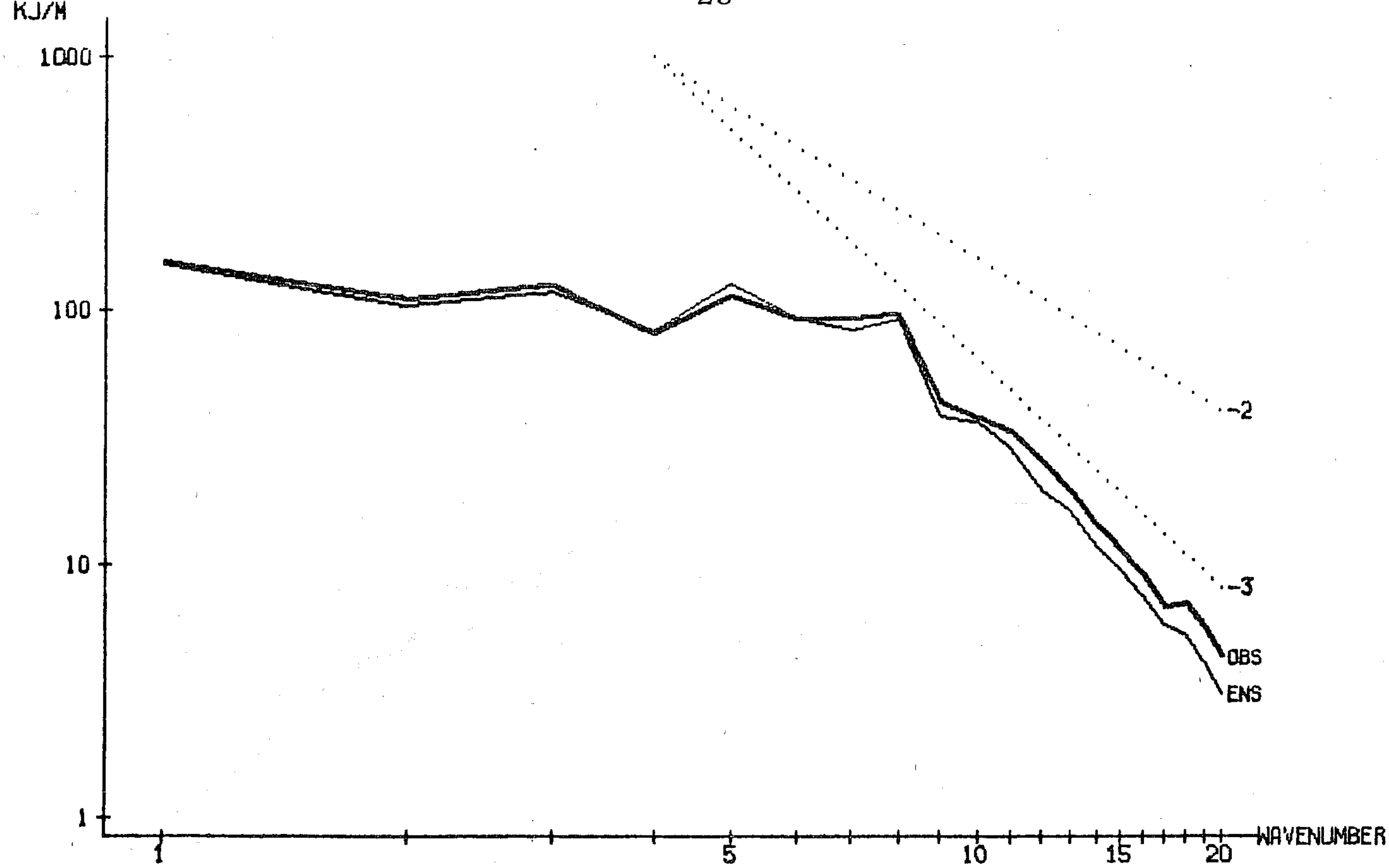
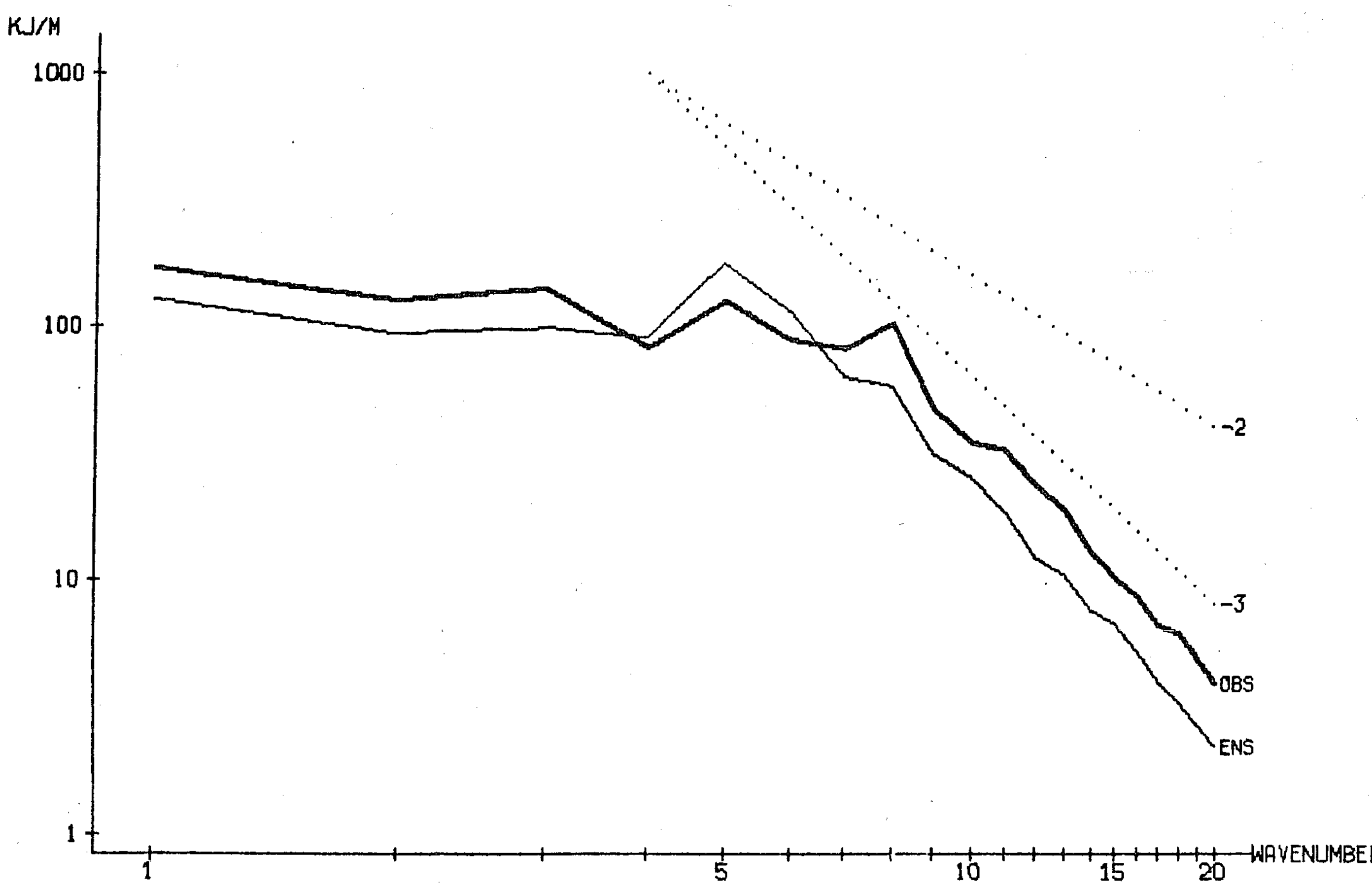

WAVENUMBER 1-20
WAVENUMBER 4- 9
WAVENUMBER 1- 3
MB
DAY 7.0 TO 10.0
SENSIBLE HEAT-FLUX TV
GEOSTR

Fig. 15



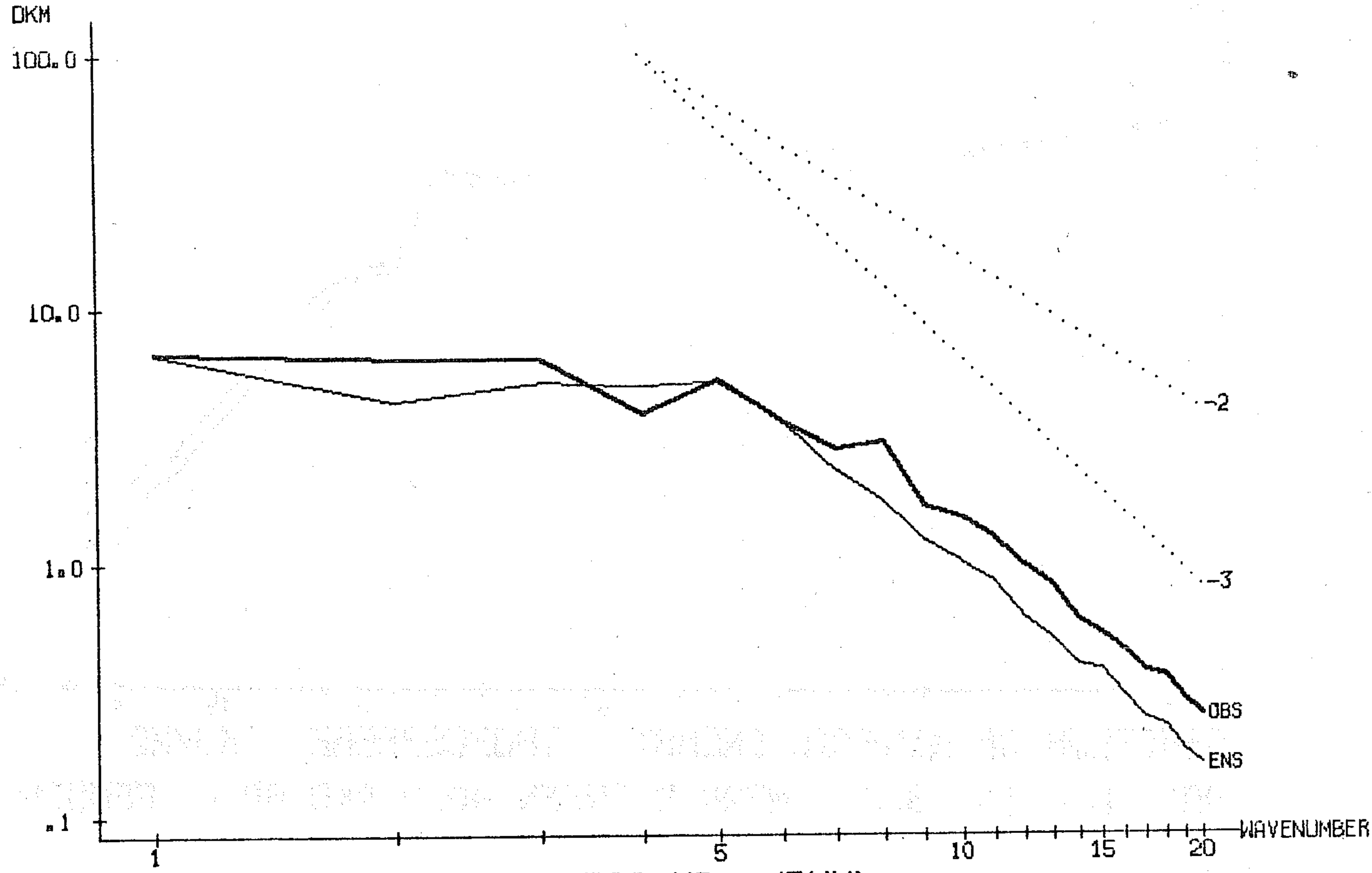
SPECTRUM OF KINETIC ENERGY TROPOSPHERE KJ/M2
DAY 0.0 TO 3.0 MEAN BETWEEN 40.0 AND 60.0 GEOSTR

Fig. 16

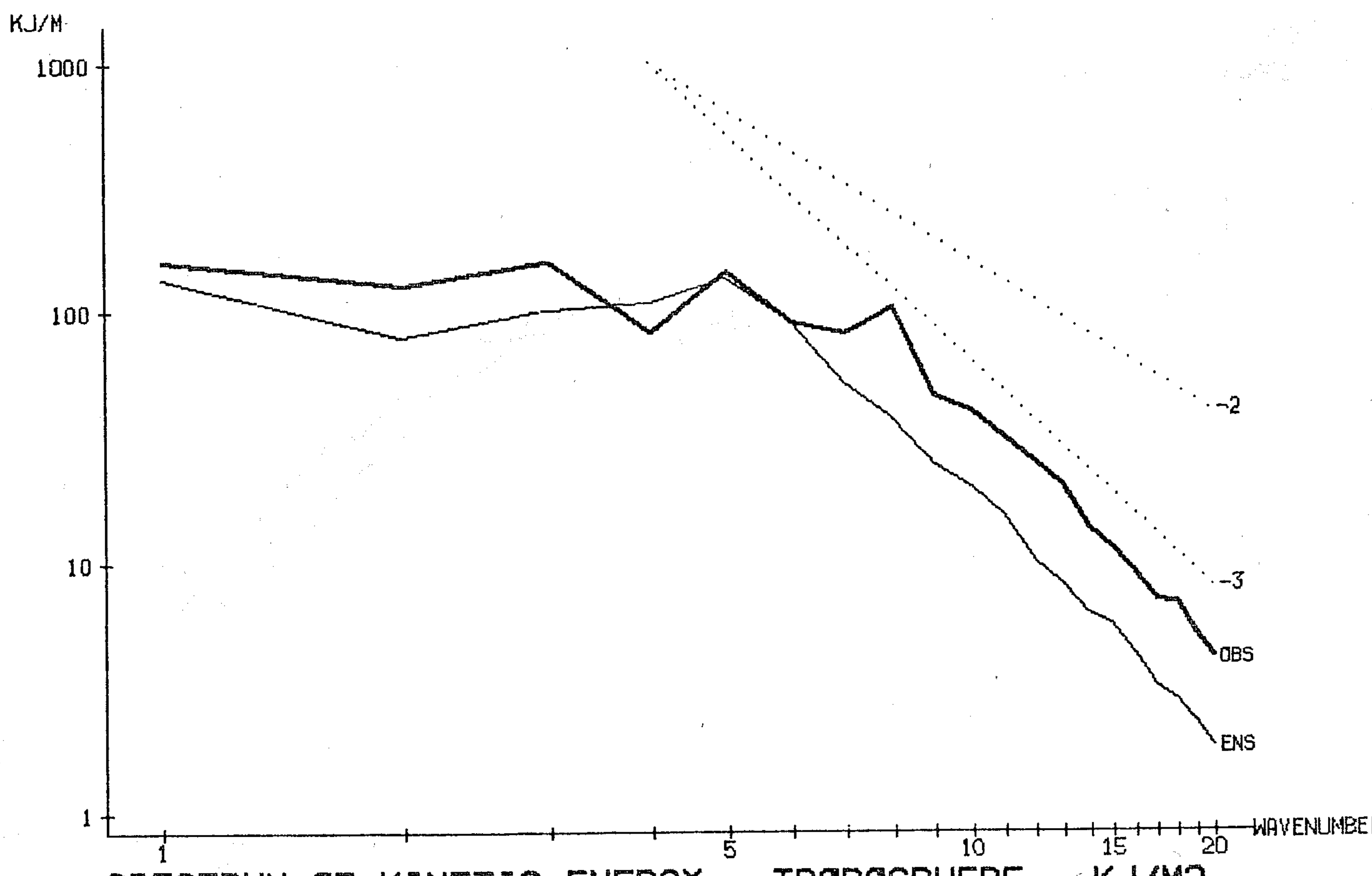


SPECTRUM OF KINETIC ENERGY TROPOSPHERE KJ/M2
DAY 4.0 TO 7.0 MEAN BETWEEN 40.0 AND 60.0 GEOSTR

Fig. 17

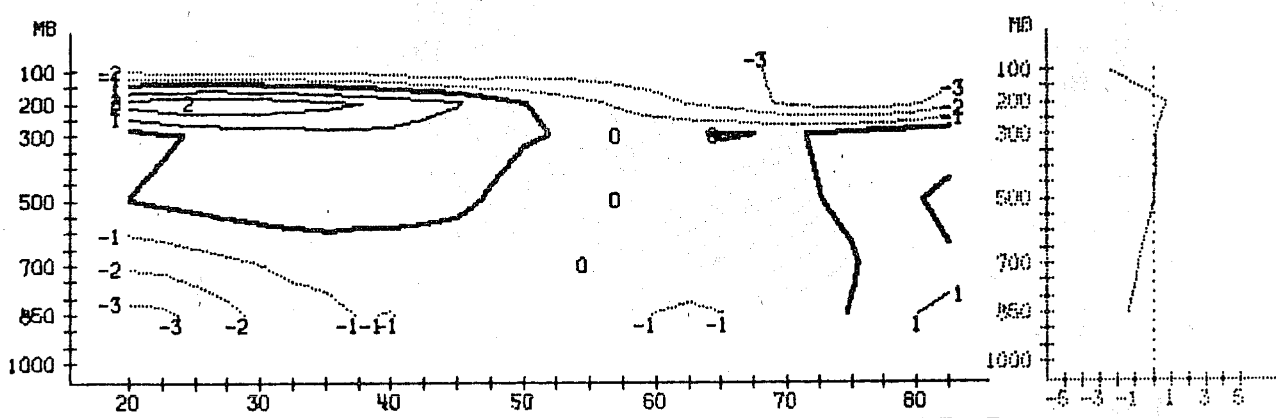


SPECTRUM OF HEIGHT 500 MB (DKM)



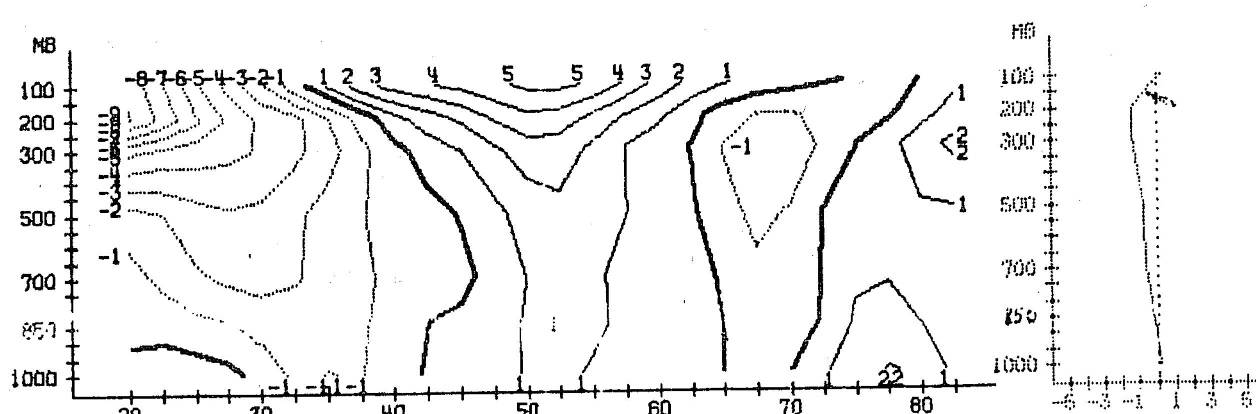
SPECTRUM OF KINETIC ENERGY TROPOSPHERE KJ/M2
DAY 7.0 TO 10.0 MEAN BETWEEN 40.0 AND 60.0 GEOSTR

Fig. 18



DAY 7.0 TO 10.0

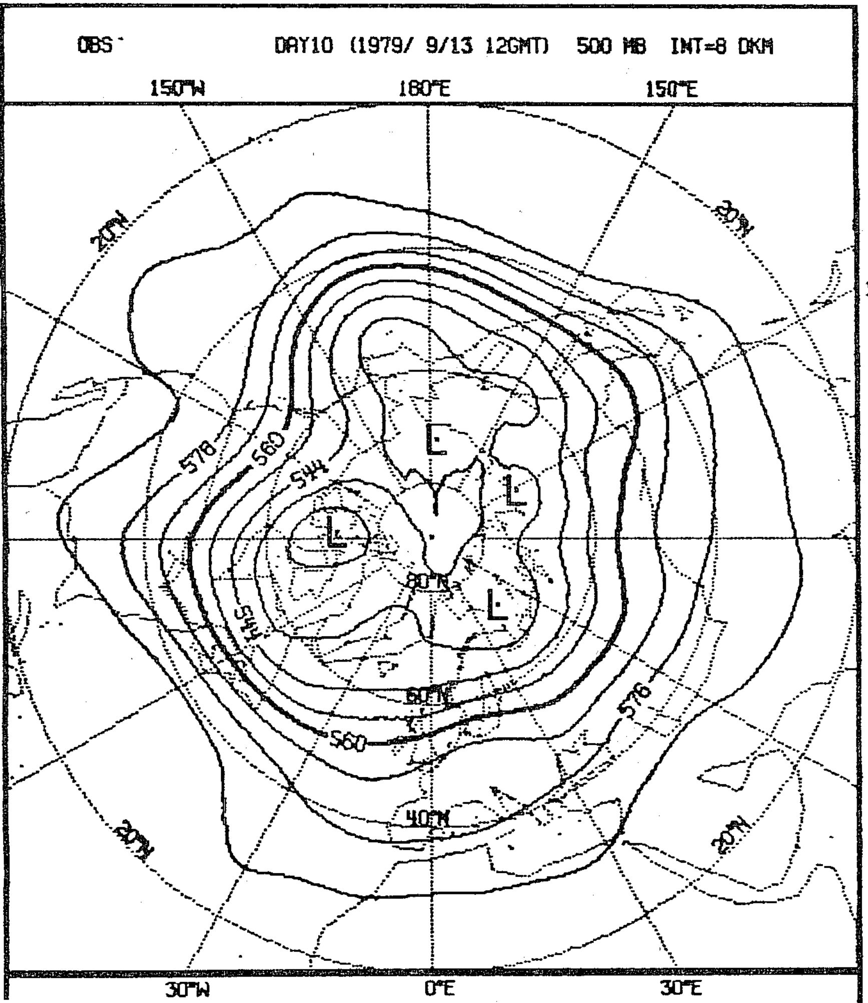
ZONAL MEAN OF T DEVIATION FROM OBSERVED



DAY 7.0 TO 10.0

ZONAL MEAN OF U DEVIATION FROM OBSERVED GEOSTR

Fig. 19


OBS
DAY10 (1979/ 9/13 12GMT) 500 MB INT=8 DKM
150°W
180°E
150°E
120°E
90°E
60°E
30°W
0°E
30°E
20°N
80°N
60°N
40°N
576
560
544
L

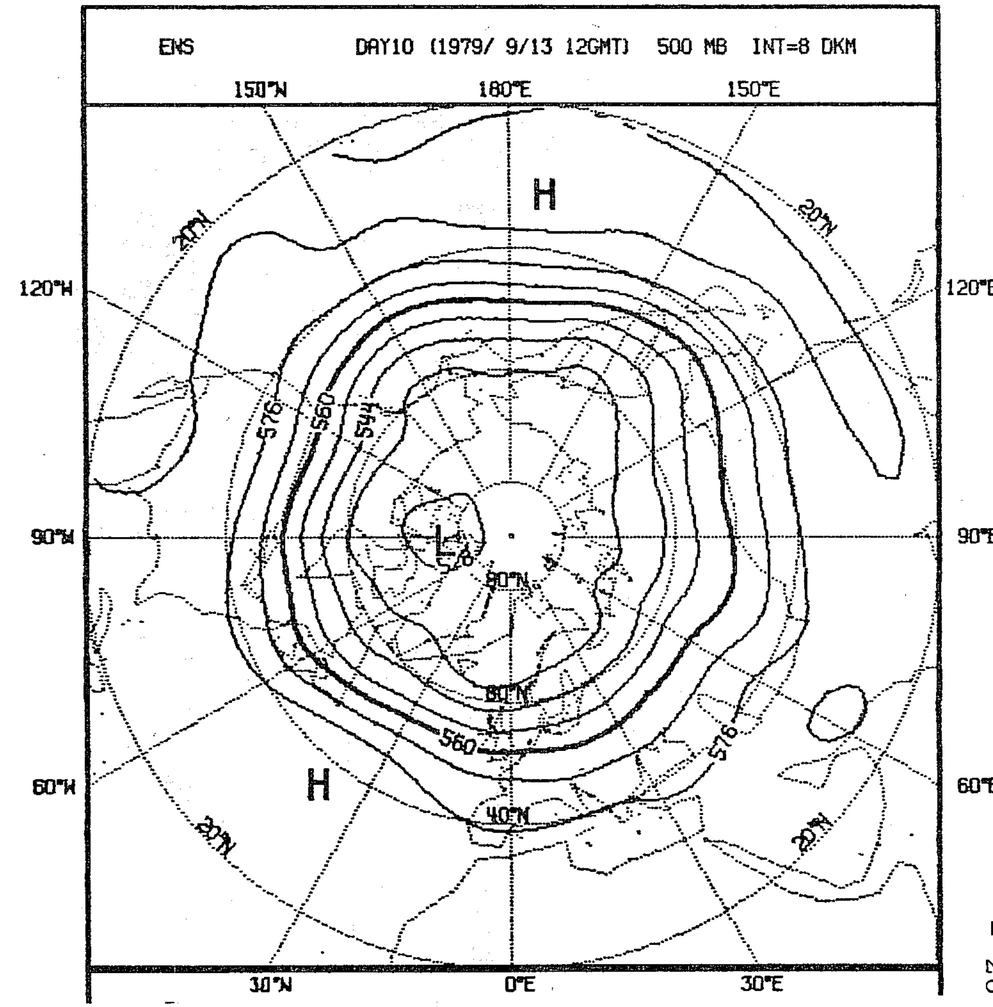

ENS
DAY10 (1979/ 9/13 12GMT) 500 MB INT=8 DKM
150°W
180°E
150°E
120°W
90°W
60°W
120°E
90°E
60°E
30°W
0°E
30°E
20°N
80°N
40°N
576
560
544
H
L

Fig. 20

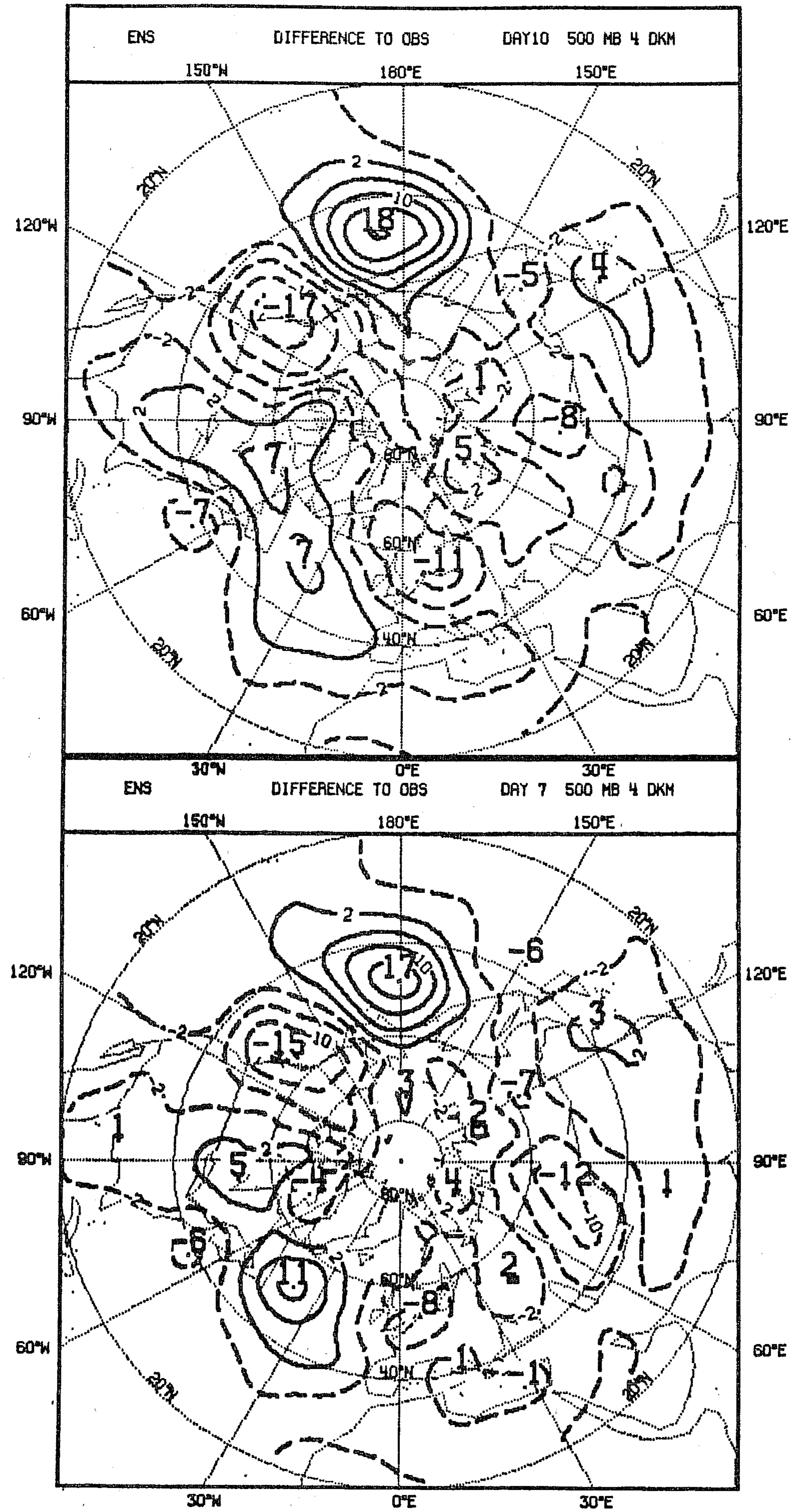

ENS
DIFFERENCE TO OBS
DAY10 500 MB 4 DKM
150°W
180°E
150°E
120°W
120°E
90°W
90°E
60°W
60°E
30°W
0°E
30°E
20°N
40°N
60°N
80°N
ENS
DIFFERENCE TO OBS
DAY 7 500 MB 4 DKM
150°W
180°E
150°E
120°W
120°E
90°W
90°E
60°W
60°E
30°W
0°E
30°E

Fig. 21

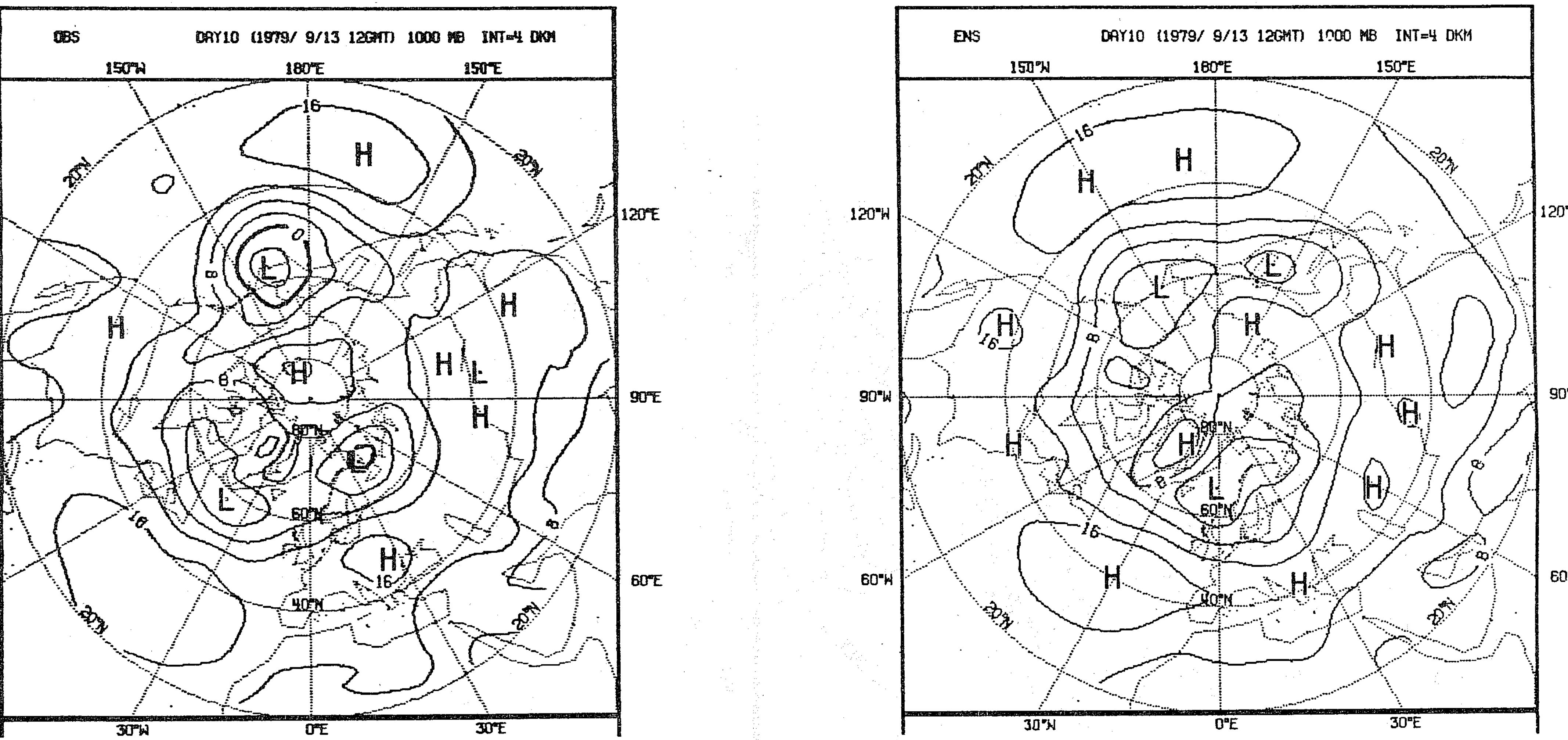

OBS
DAY10 (1979/ 9/13 12GMT) 1000 MB INT=4 DKM
150°W
180°E
150°E
120°E
90°E
60°E
30°W
0°E
30°E
ENS
DAY10 (1979/ 9/13 12GMT) 1000 MB INT=4 DKM
120°W
90°W
60°W

Fig. 22

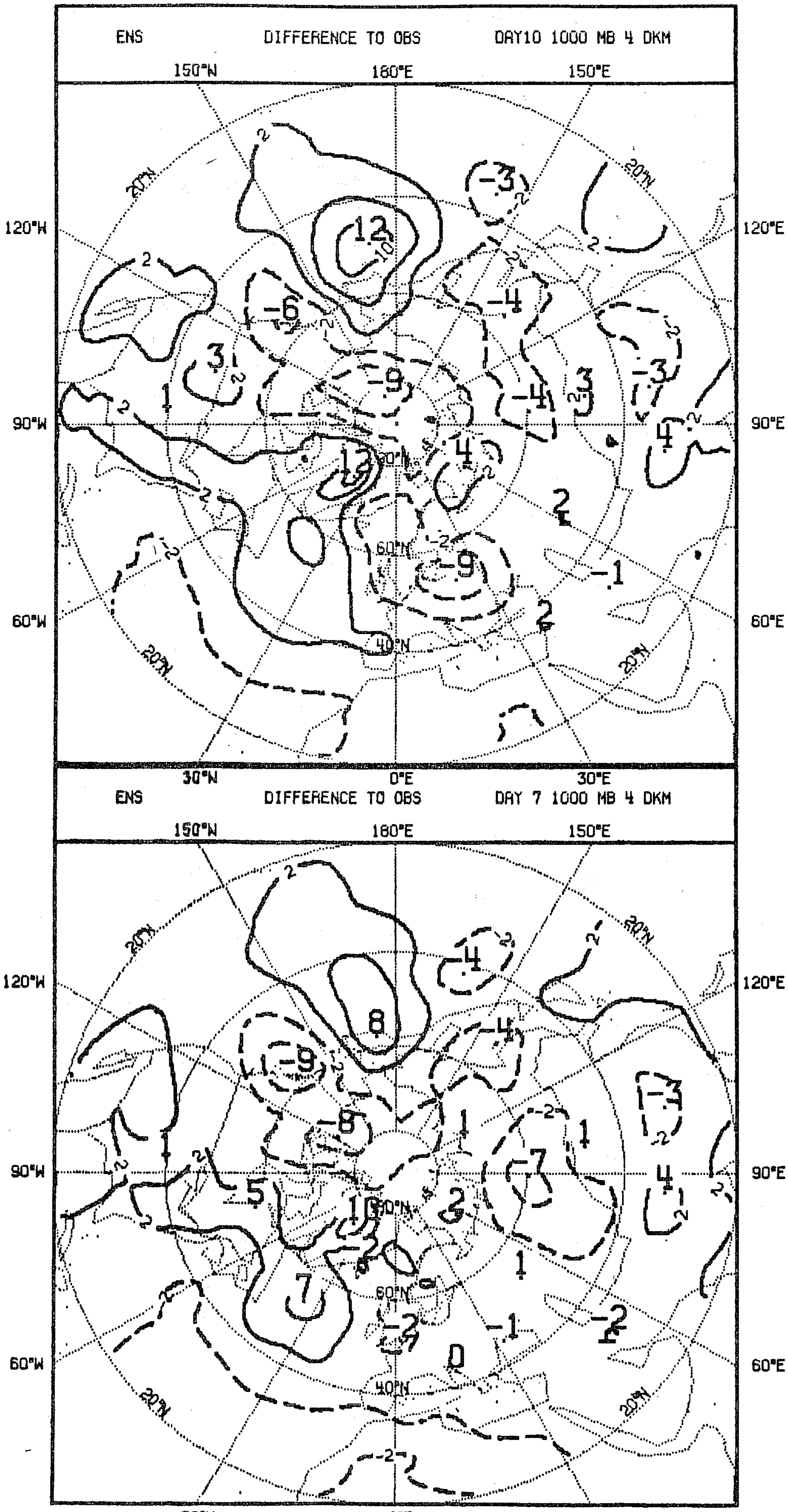

ENS
DIFFERENCE TO OBS
DAY10 1000 MB 4 DKM
150°W
180°E
150°E
120°W
120°E
90°W
90°E
60°W
60°E
30°W
0°E
30°E
ENS
DIFFERENCE TO OBS
DAY 7 1000 MB 4 DKM
150°W
180°E
150°E
120°W
120°E
90°W
90°E
60°W
60°E
30°W
0°E
30°E

Fig. 23

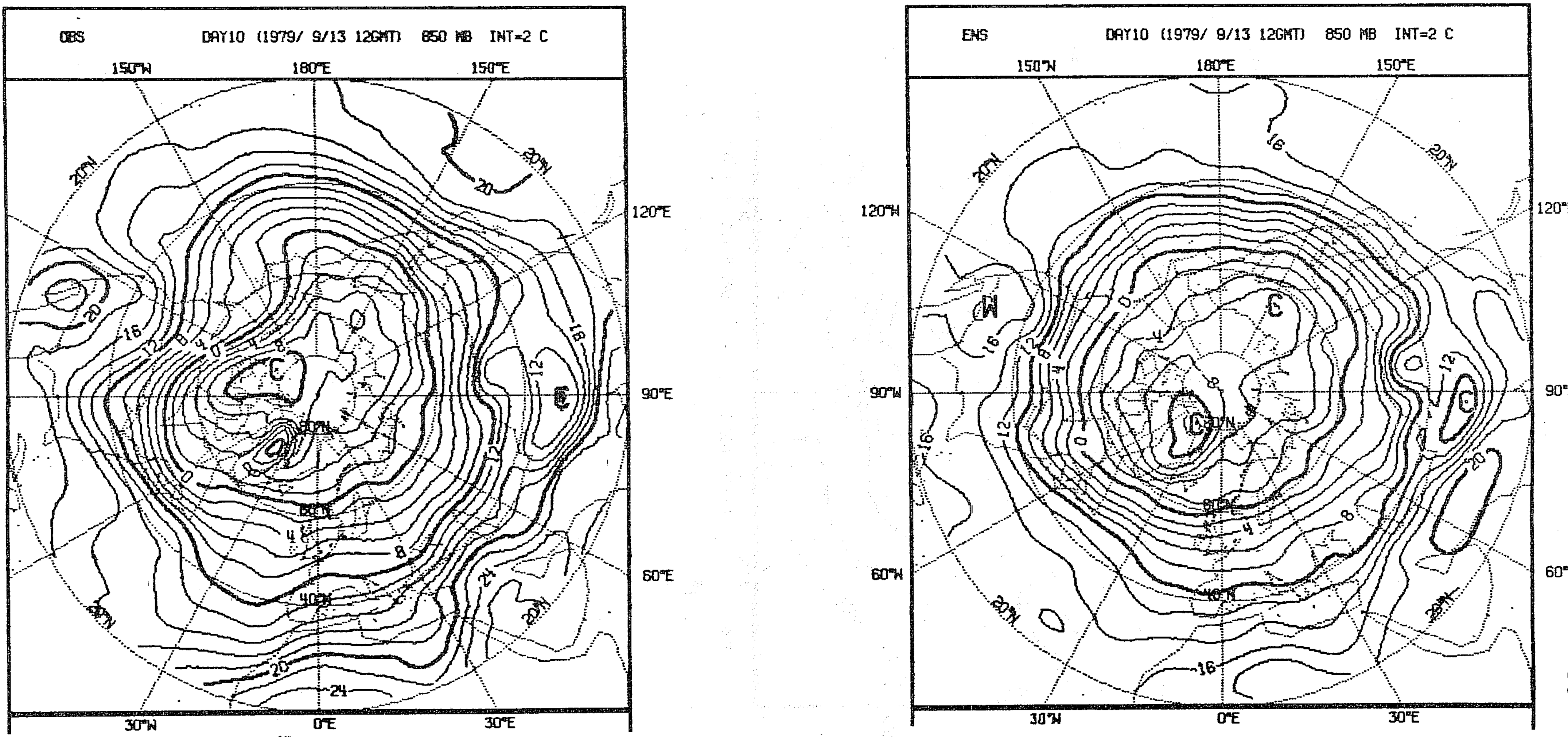

OBS
DAY10 (1979/ 9/13 12GMT) 850 MB INT=2 C
150°W
180°E
150°E
120°E
90°E
60°E
30°W
0°E
30°E
ENS
DAY10 (1979/ 9/13 12GMT) 850 MB INT=2 C
150°W
180°E
150°E
120°W
90°W
60°W
30°W
0°E
30°E

Fig. 24

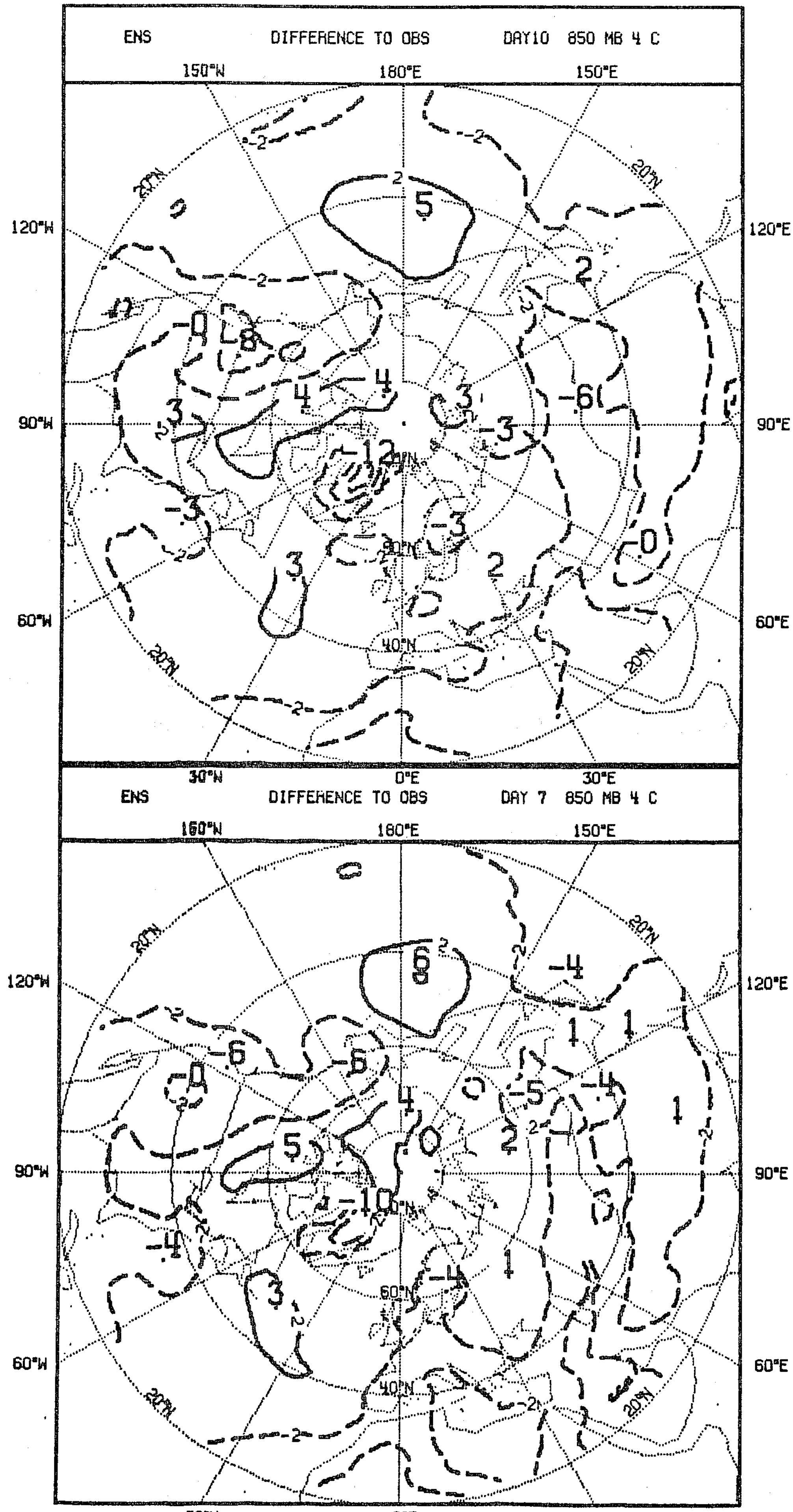

ENS
DIFFERENCE TO OBS
DAY10 850 MB 4 C
150°W
180°E
150°E
120°W
120°E
90°W
90°E
60°W
60°E
30°W
0°E
30°E
20°N
40°N
ENS
DIFFERENCE TO OBS
DAY 7 850 MB 4 C
150°W
180°E
150°E
120°W
120°E
90°W
90°E
60°W
60°E
30°W
0°E
30°E
20°N
40°N
60°N

Fig. 25

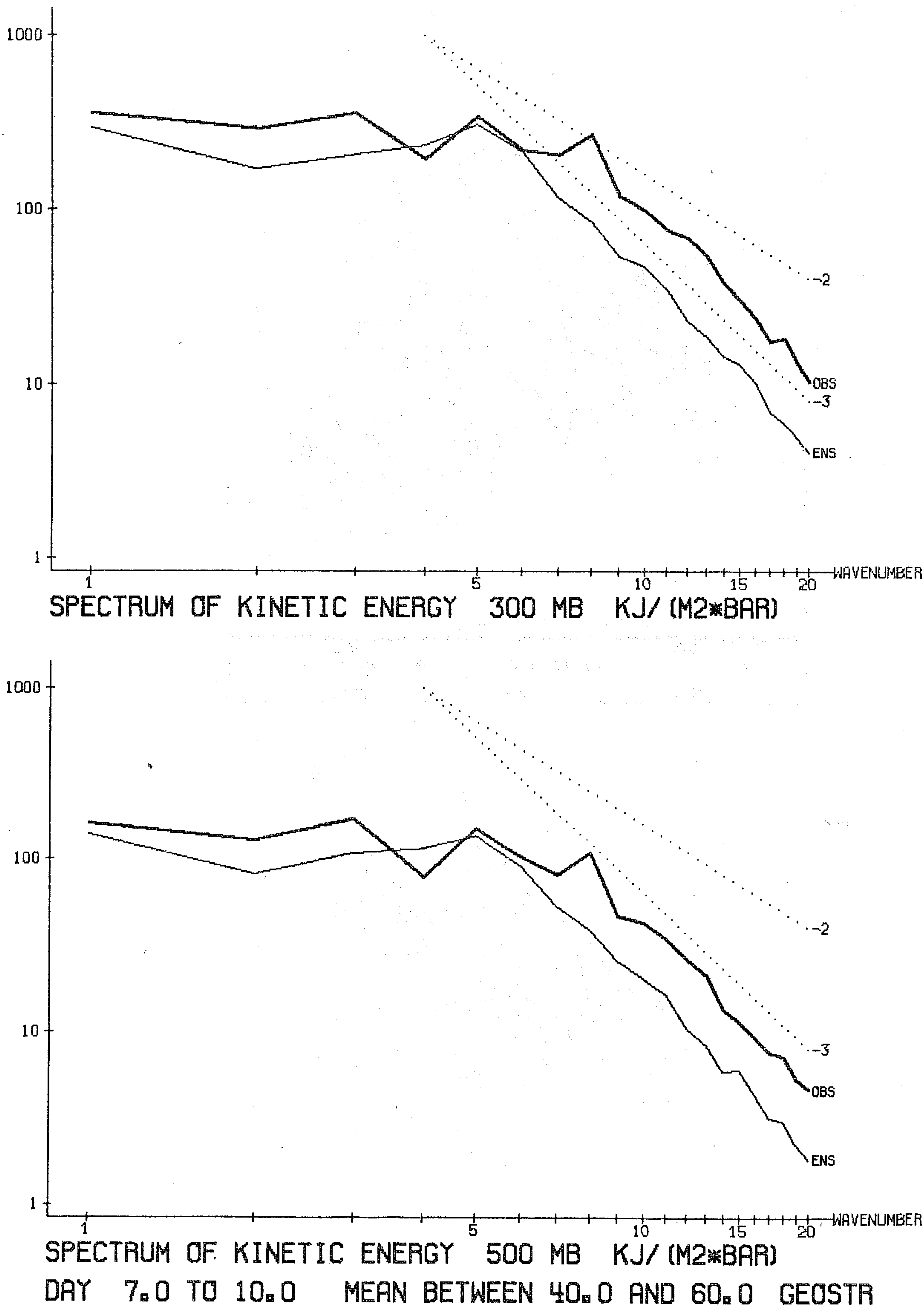
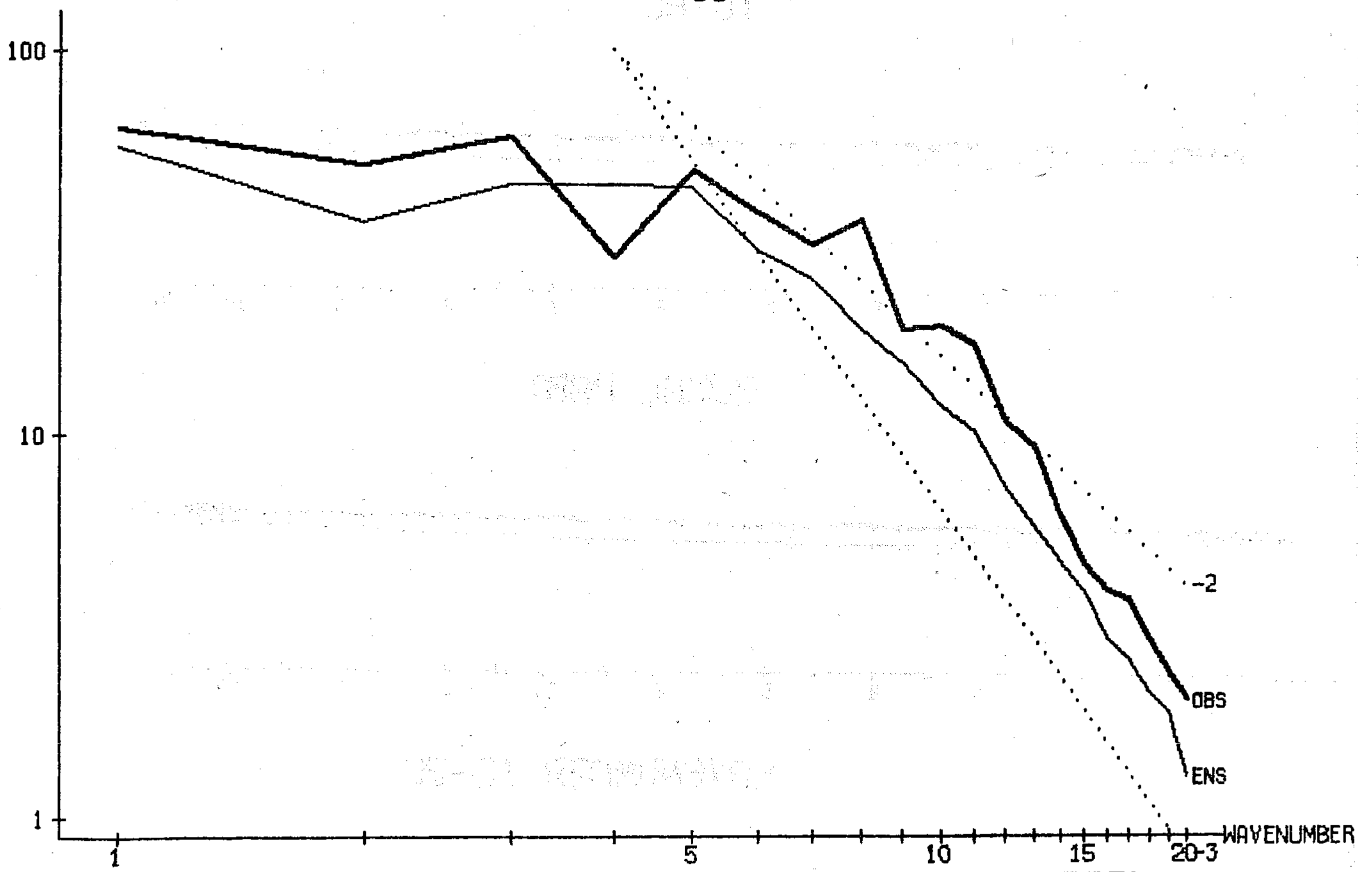
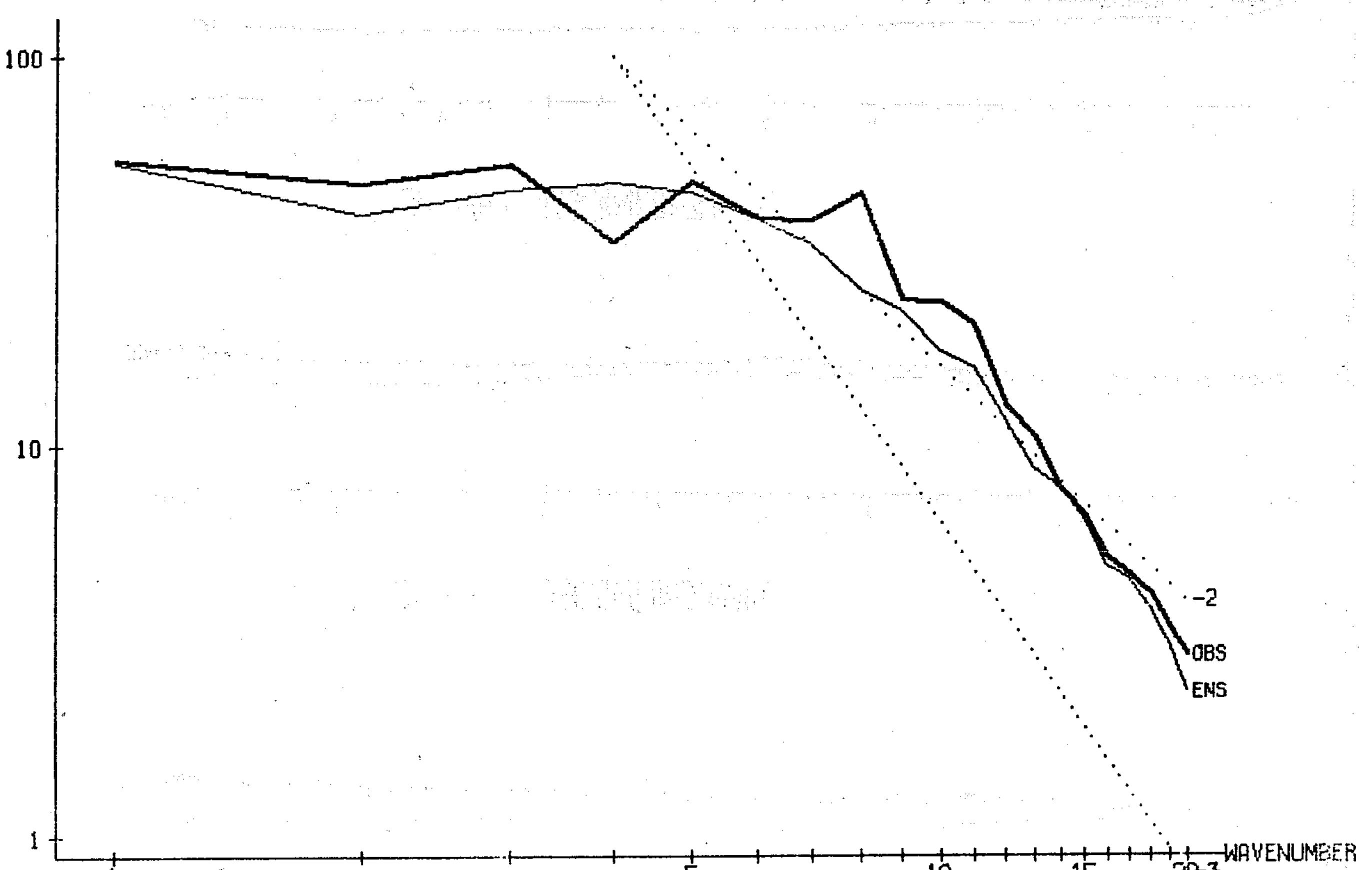

1000
100
10
1
-2
OBS
-3
ENS
1
5
10
15
20
WAVENUMBER
SPECTRUM OF KINETIC ENERGY 300 MB KJ/(M2*BAR)
1000
100
10
1
-2
-3
OBS
ENS
1
5
10
15
20
WAVENUMBER
SPECTRUM OF KINETIC ENERGY 500 MB KJ/(M2*BAR)
DAY 7.0 TO 10.0 MEAN BETWEEN 40.0 AND 60.0 GEOSTR

Fig. 26



SPECTRUM OF KINETIC ENERGY 850 MB KJ/(M2*BAR)



SPECTRUM OF KINETIC ENERGY 1000 MB KJ/(M2*BAR)

DAY 7.0 TO 10.0 MEAN BETWEEN 40.0 AND 60.0 GEOSTR

Fig. 27

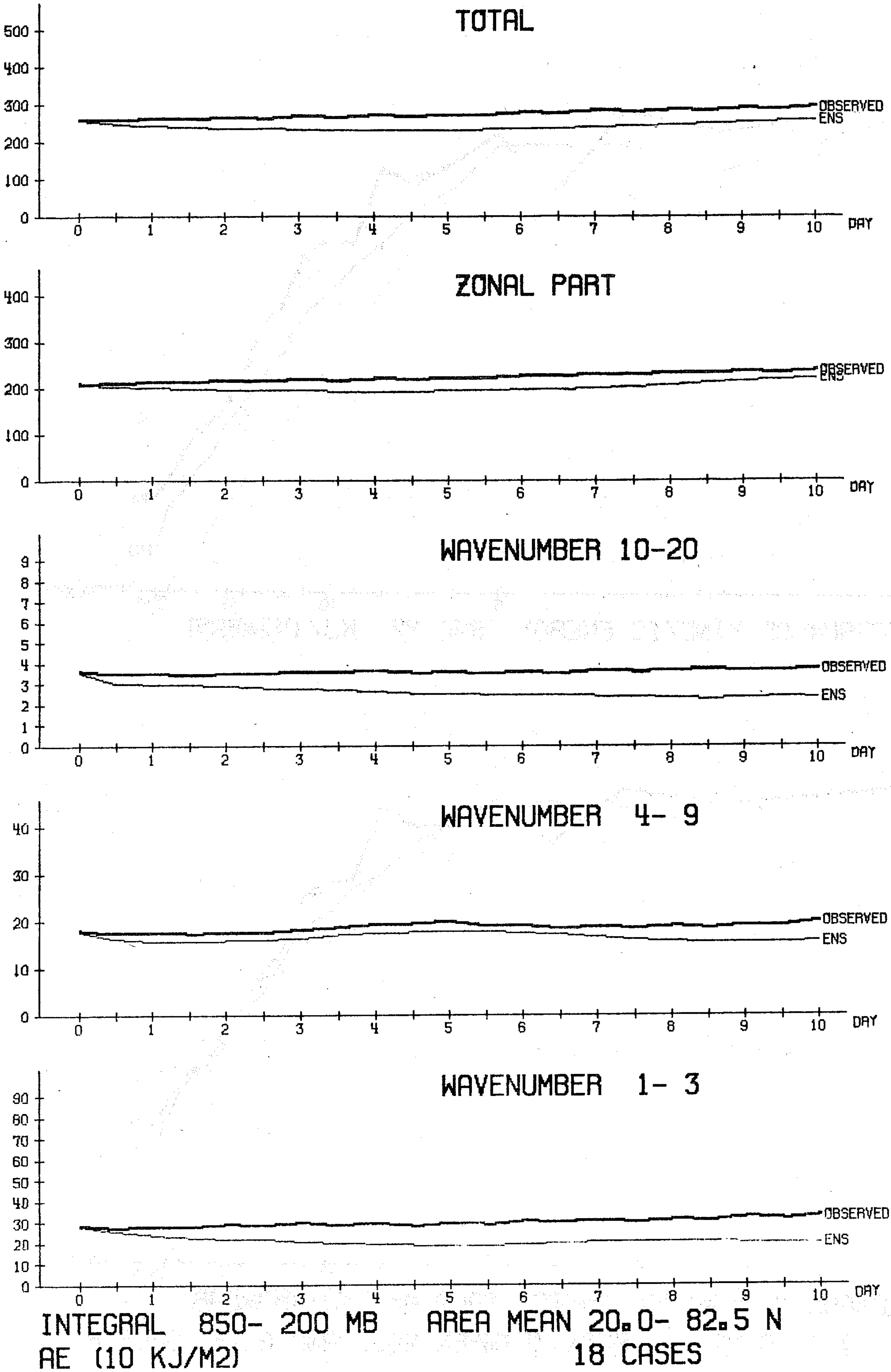

TOTAL
OBSERVED
ENS
DAY
ZONAL PART
OBSERVED
ENS
DAY
WAVENUMBER 10-20
OBSERVED
ENS
DAY
WAVENUMBER 4- 9
OBSERVED
ENS
DAY
WAVENUMBER 1- 3
OBSERVED
ENS
DAY
INTEGRAL 850- 200 MB AREA MEAN 20.0- 82.5 N
AE (10 KJ/M2) 18 CASES

Fig. 28

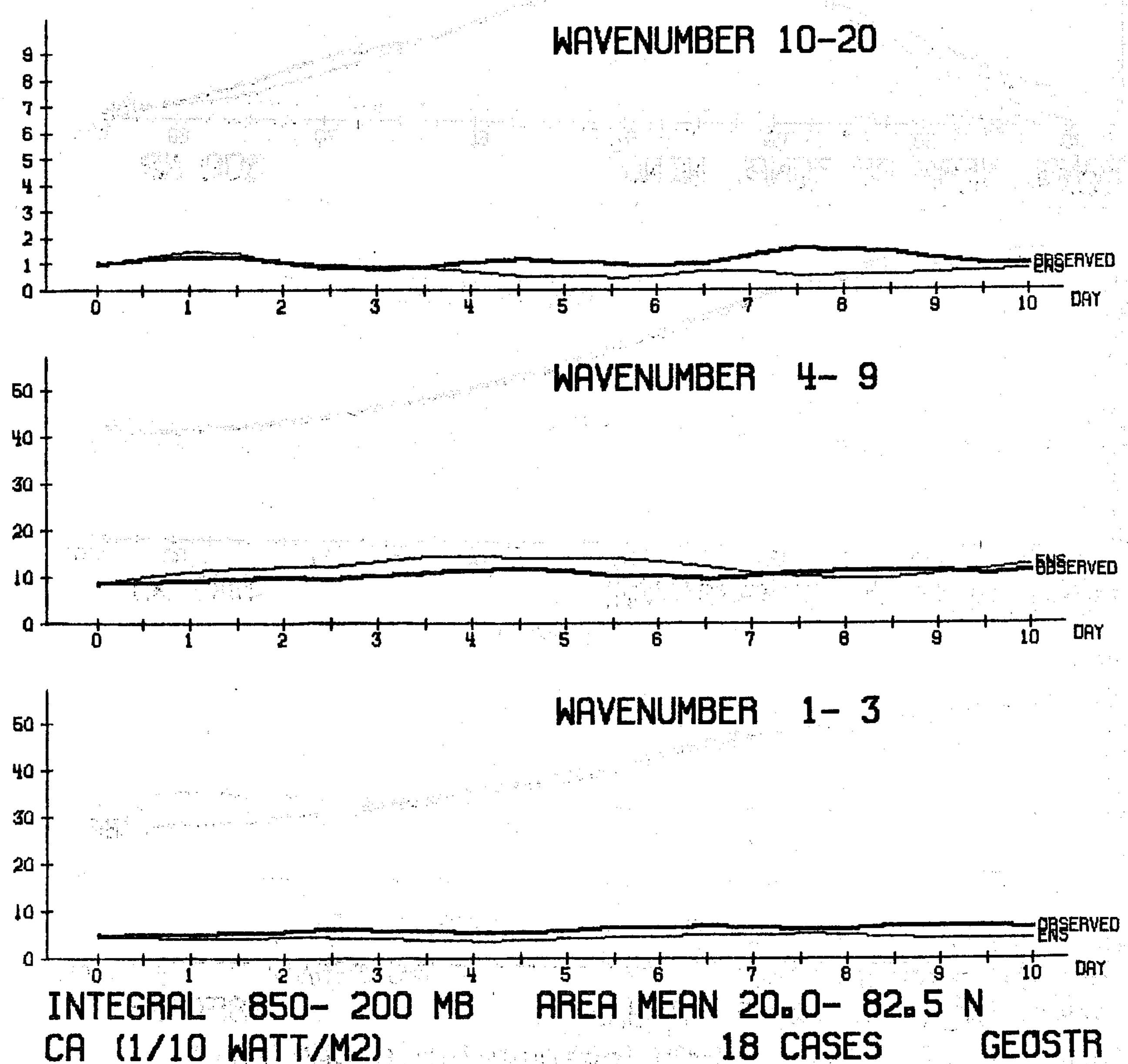
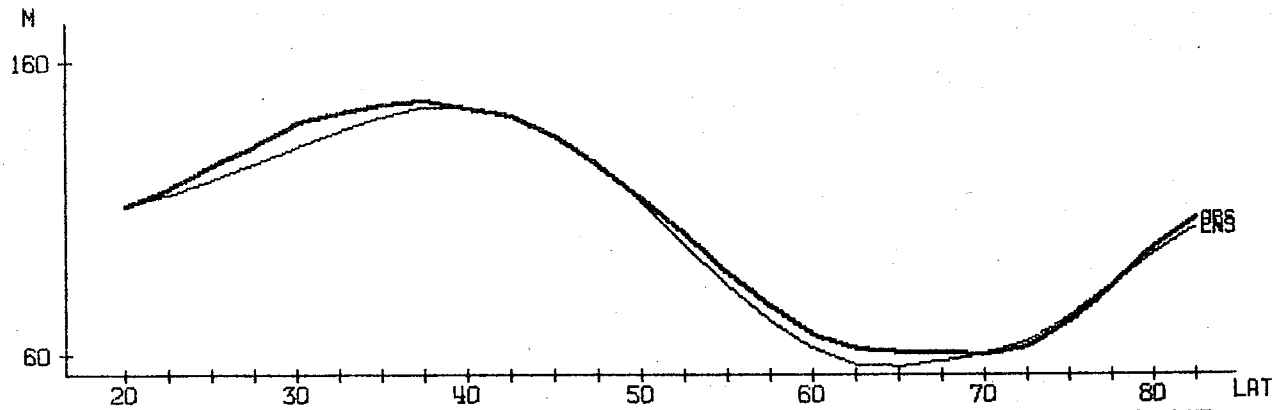
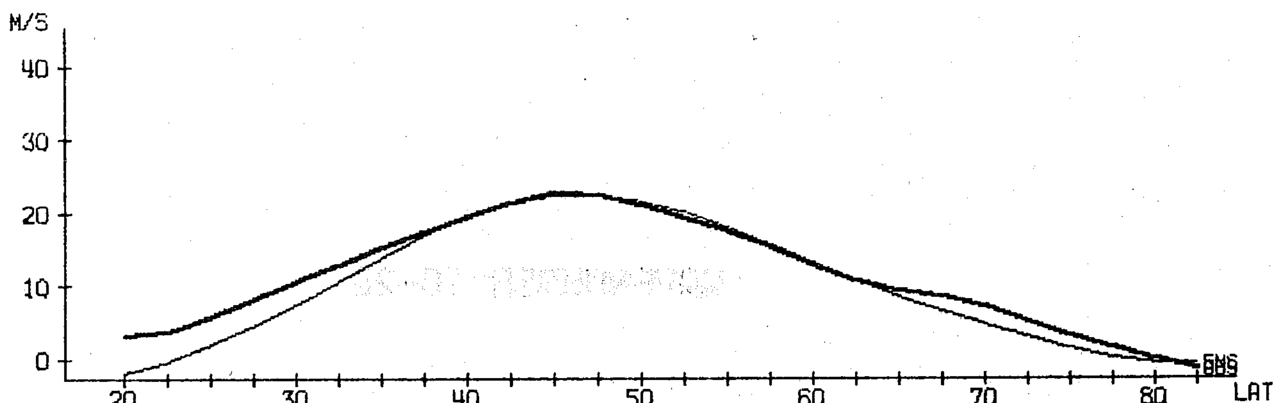

WAVENUMBER 10-20
OBSERVED
ENS
DAY
WAVENUMBER 4- 9
ENS
OBSERVED
DAY
WAVENUMBER 1- 3
OBSERVED
ENS
DAY
INTEGRAL 850- 200 MB AREA MEAN 20.0- 82.5 N
CA (1/10 WATT/M2) 18 CASES GEOSTR

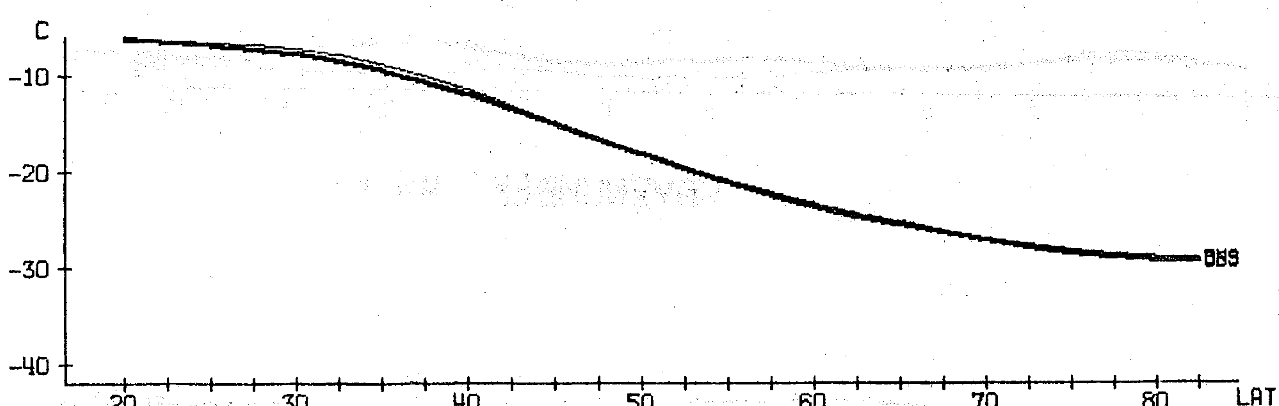
Fig. 29



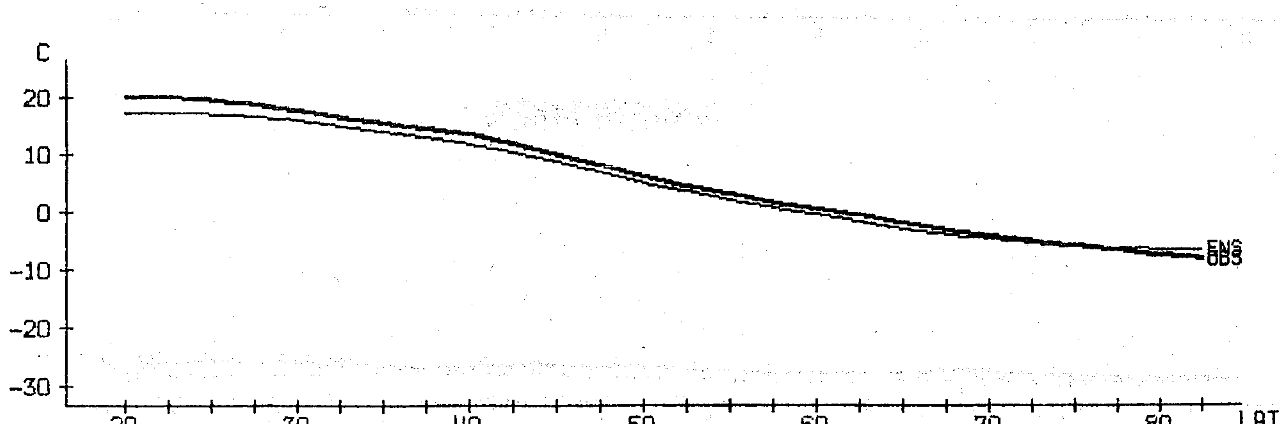
ZONAL MEAN OF HEIGHT (M) 1000 MB



ZONAL MEAN OF ZONAL WIND 300 MB



ZONAL MEAN OF TEMPERATURE 500 MB



ZONAL MEAN OF TEMPERATURE 850 MB

DAY 4.0 TO 7.0 MEAN BETWEEN 40.0 AND 60.0

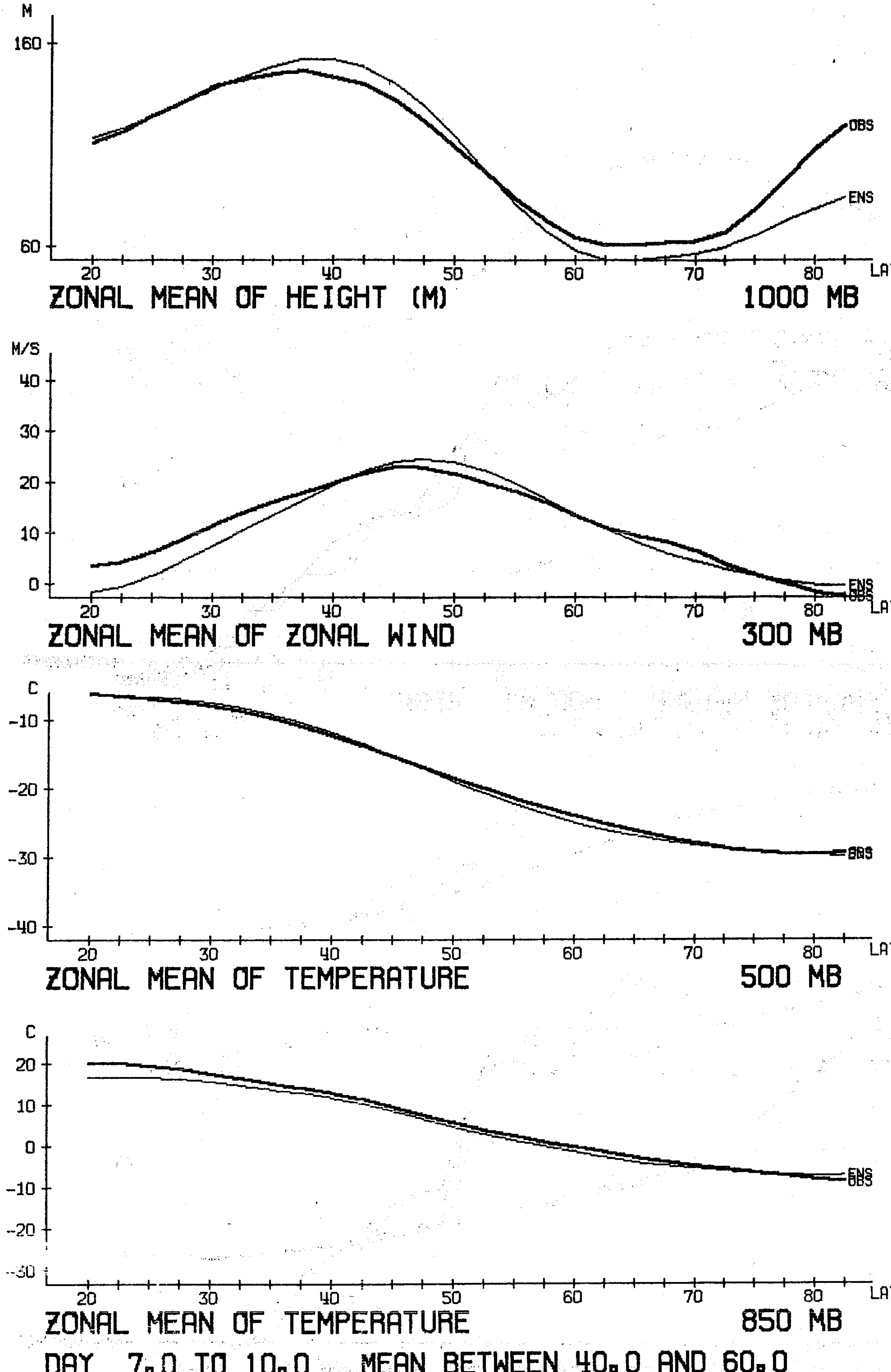
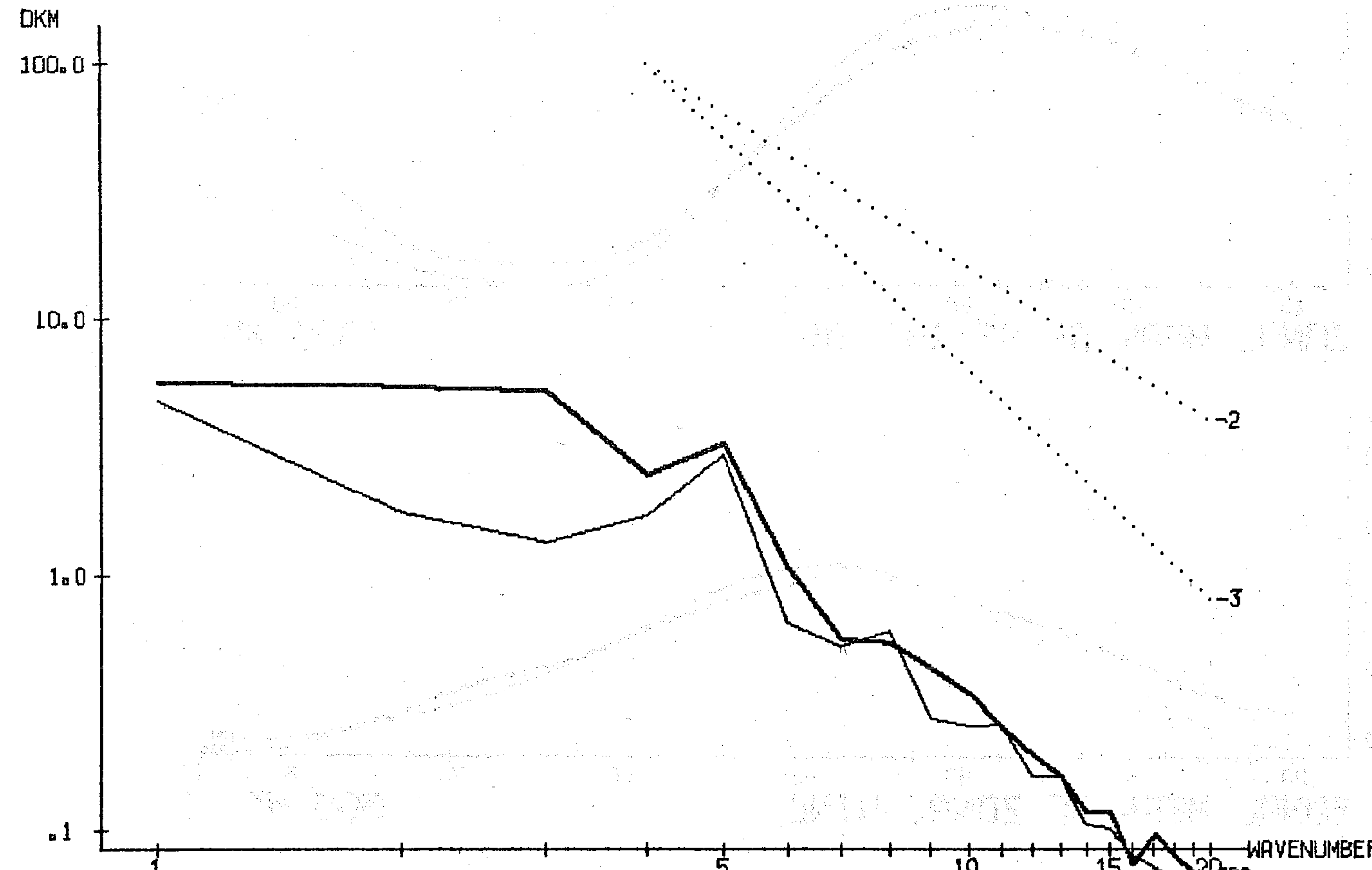
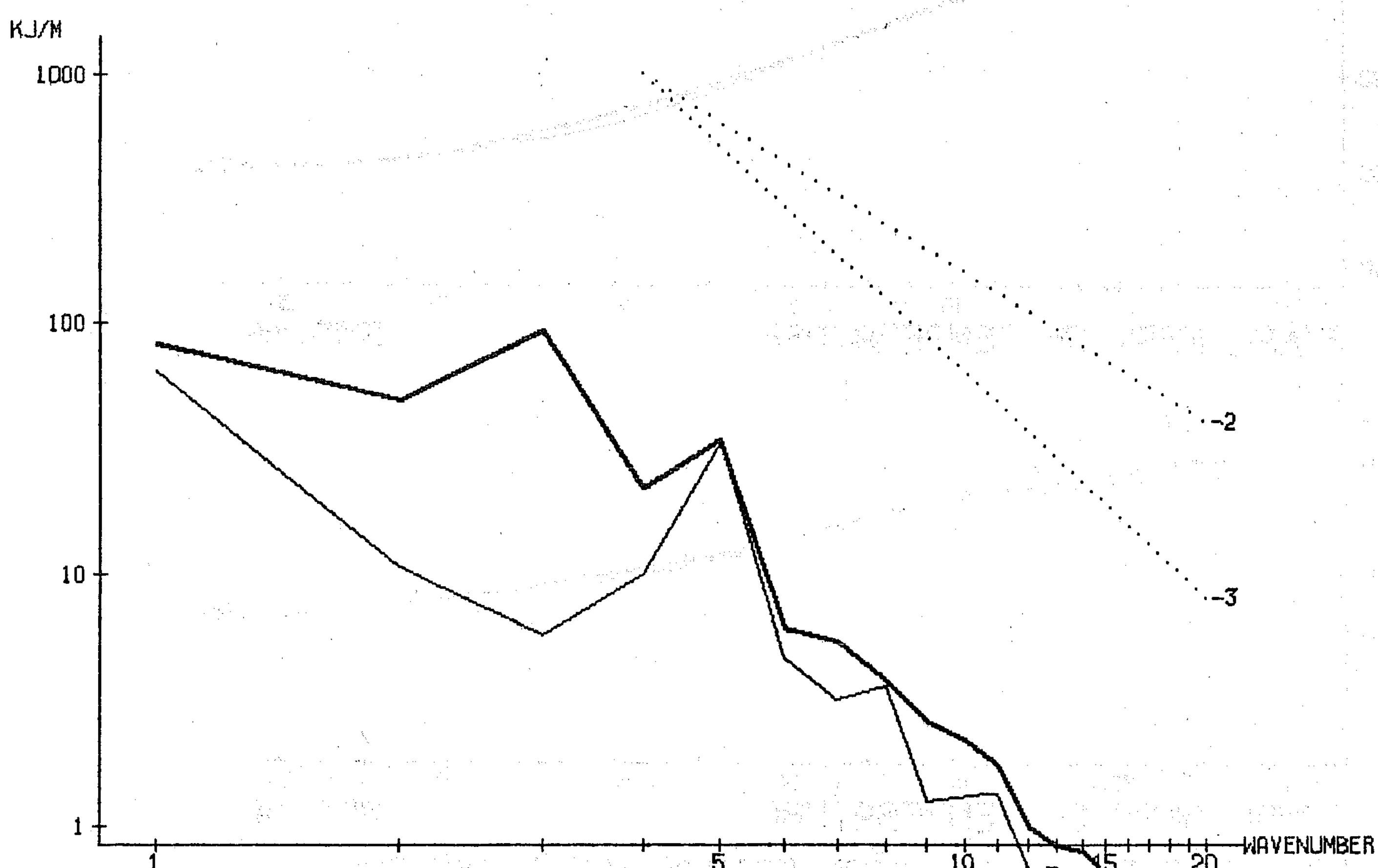

M
160
60
OBS
ENS
20 30 40 50 60 70 80 LAT
ZONAL MEAN OF HEIGHT (M)
1000 MB
M/S
40
30
20
10
0
ENS
OBS
20 30 40 50 60 70 80 LAT
ZONAL MEAN OF ZONAL WIND
300 MB
C
-10
-20
-30
-40
OBS
20 30 40 50 60 70 80 LAT
ZONAL MEAN OF TEMPERATURE
500 MB
C
20
10
0
-10
-20
-30
ENS
OBS
20 30 40 50 60 70 80 LAT
ZONAL MEAN OF TEMPERATURE
850 MB
DAY 7.0 TO 10.0 MEAN BETWEEN 40.0 AND 60.0

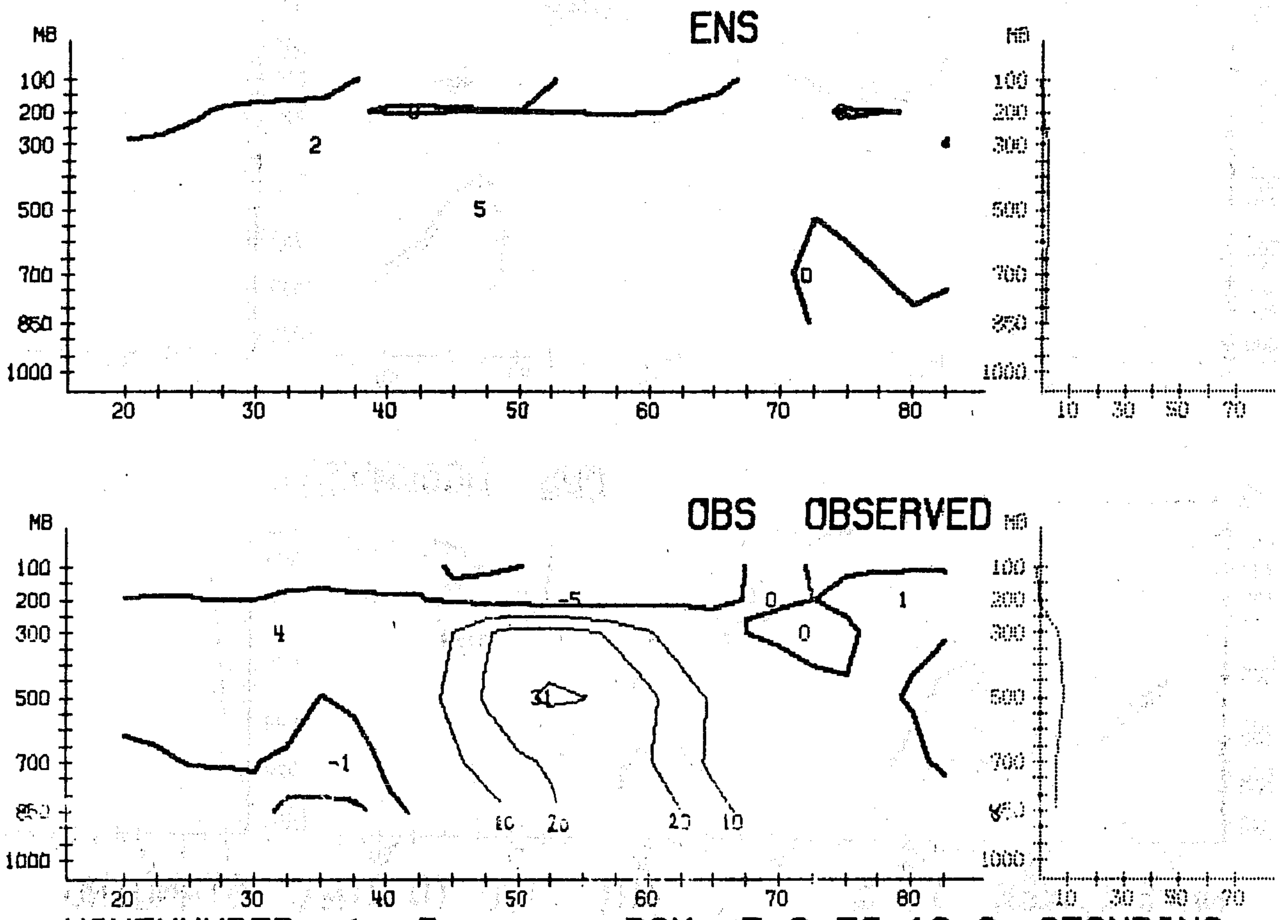
Fig. 31



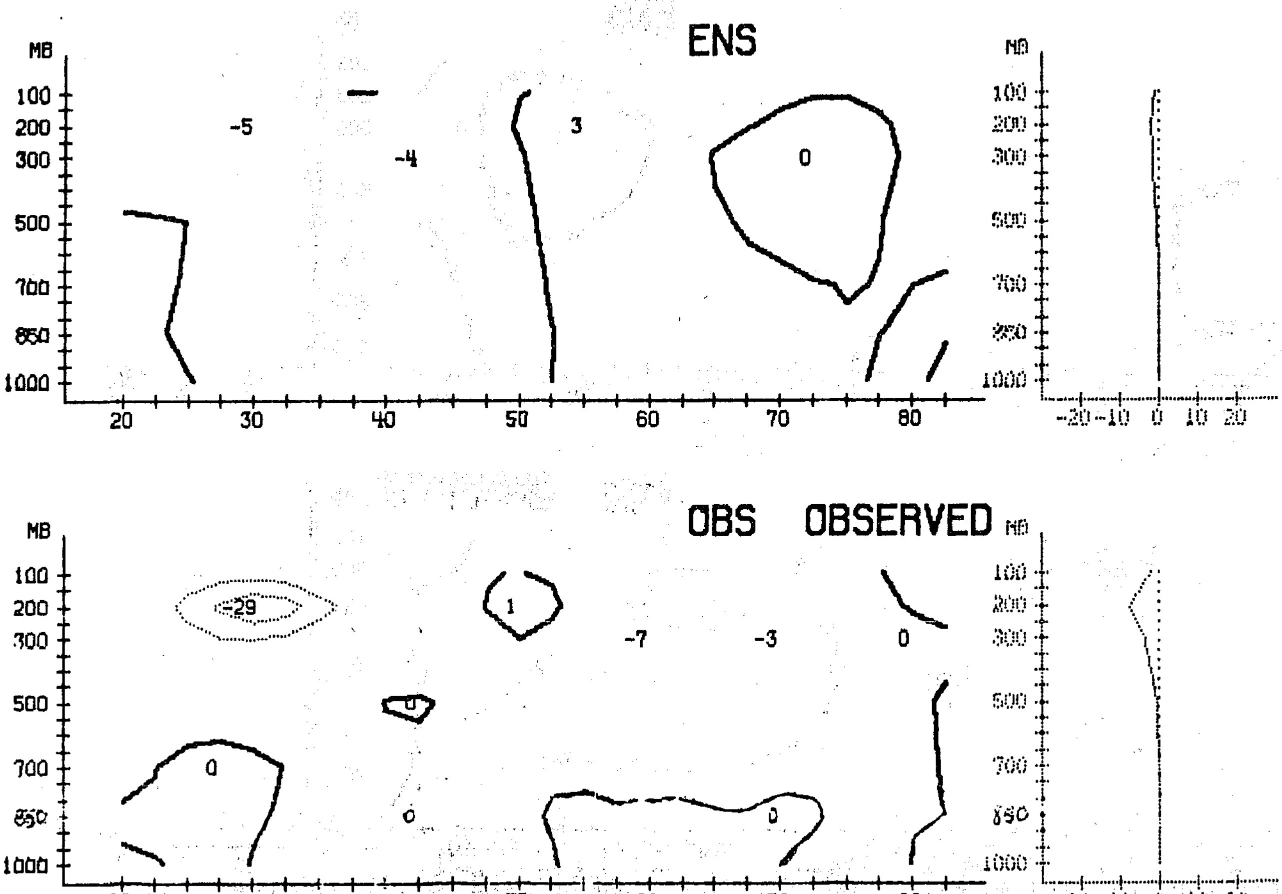
SPECTRUM OF HEIGHT 500 MB (DKM)



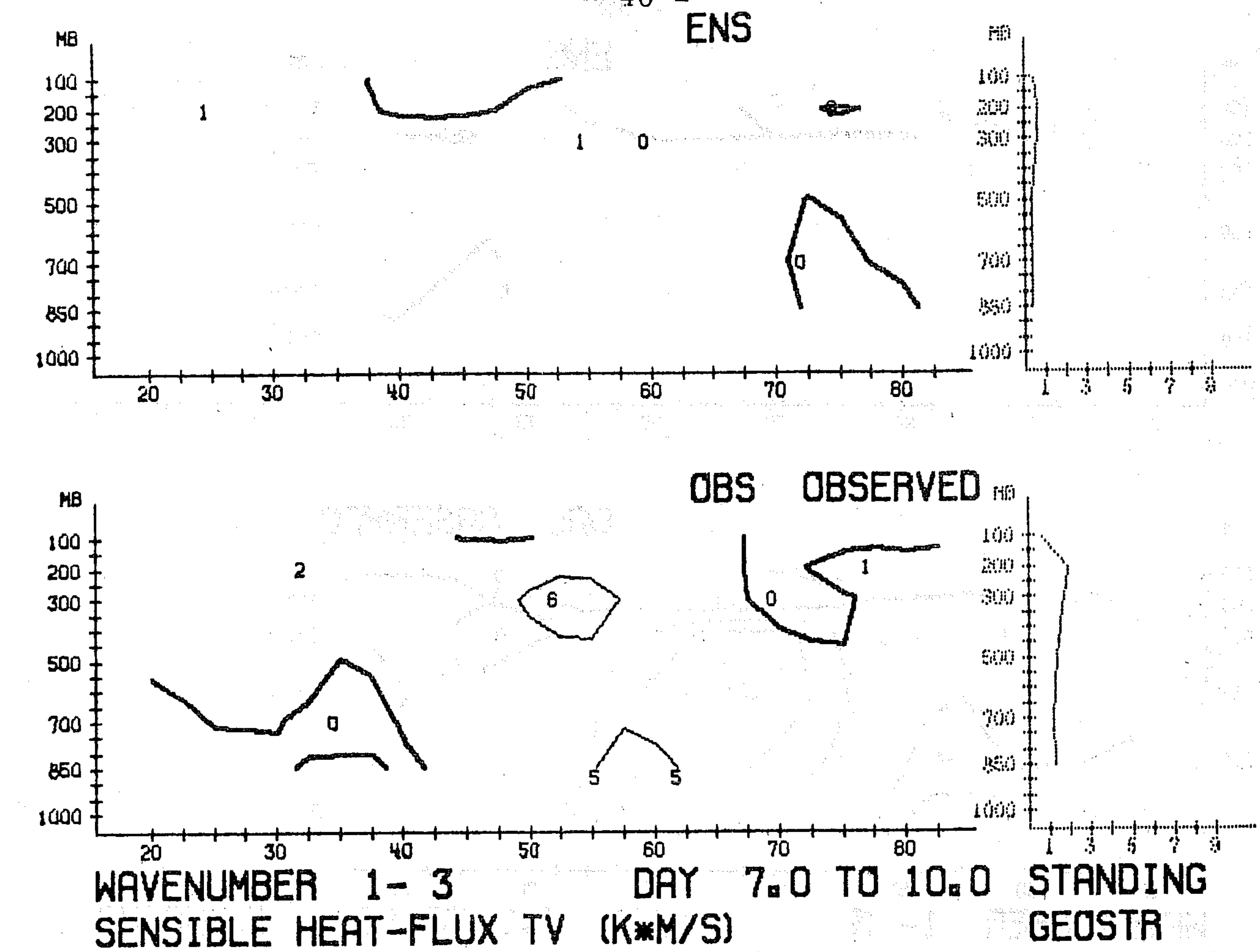
SPECTRUM OF KINETIC ENERGY TROPOSPHERE KJ/M2
DAY 7.0 TO 10.0 MEAN BETWEEN 40.0 AND 60.0 GEOSTR



WAVENUMBER 1- 3 DAY 7.0 TO 10.0 STANDING
CA (1/10 WATT/M2/BAR) GEOSTR



WAVENUMBER 1- 3 DAY 7.0 TO 10.0 STANDING
CK (1/10 WATT/M2/BAR) GEOSTR


ENS
OBS OBSERVED
WAVENUMBER 1- 3 DAY 7.0 TO 10.0 STANDING
SENSIBLE HEAT-FLUX TV (K*M/S) GEOSTR

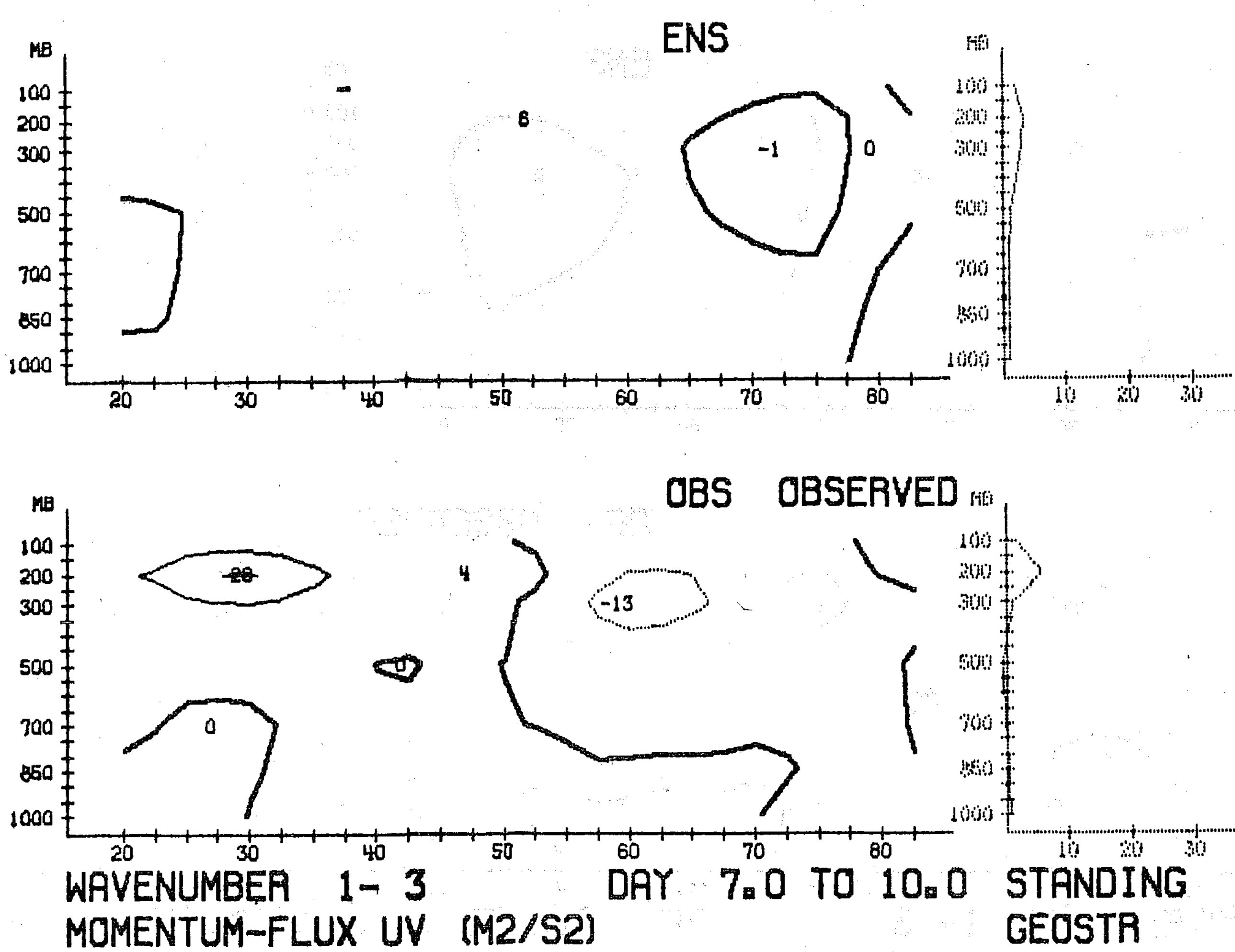

ENS
OBS OBSERVED
WAVENUMBER 1- 3 DAY 7.0 TO 10.0 STANDING
MOMENTUM-FLUX UV (M2/S2) GEOSTR

Fig. 24