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A TRIAL OF A SCHEME TO CORRECT THE ANALYSED POSITION OF TROPICAL CYCLONES IN THE OPERATIONAL COARSE-MESH MODEL

by

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1. Introduction

There is evidence that, even without resolving the detailed structure near a tropical cyclone centre, it is possible to forecast the track, and that a large model domain is required to achieve the best medium-range forecasts (M DeMaria, 1987). The coarse-mesh model has successfully provided very good guidance for the movement of tropical cyclones, which strongly indicates that the operational coarse-mesh system is able to organize and build up features with the similar track characteristics to actual tropical cyclones. Hall (1987) has examined the performance of the coarse-mesh model for all the tropical cyclones occurring in the northern hemisphere in 1986, and indicated that the coarse-mesh model performs at least as well as most other methods of forecasting tropical cyclone tracks in the period T+48 to T+72. However, 24-hour forecasts did not compare as favourably. This was probably due to inferior analyses of the cyclone positions at T+0. He has suggested that better bogus techniques could improve the ananlysis of cyclone position. An alternative approach considered here uses a method of shifting the model's centre to an improved position by a means which does not rely on standard bogus techniques.

Although prediction of the intensity of tropical cyclones is also important, the resolution of this model is such that a good track forecast is a more reasonable aim. In this trial, attention is focused on the effect of the correction of the initial position error of tropical cyclones. We look at the (subsequent) analysed positions and forecast tracks, using the mean sea level pressure minimum to determine the cyclone centre. The effect of bogus data on both analysis position and forecast track of the cyclones is also briefly discussed.

2. Description of correction method

The distance between the position of the model's cyclone centre and the observed position has to be determined before the correction. In the trial we take the observed position from reports received over GTS from the major tropical cyclone forecasting centres. The mean sea level pressure has been used to calculate the model's cyclone centre using the method described in Appendix 1.

The cyclone centre is moved by applying a combined transformation consisting of a bilinear distortion and a displacement. This is performed on all the fields of the analysis at beginning of every cycle of assimilation, i.e. the transformation is applied at HH-6 before the 6-hour assimilation which produces the analysis valid at HH. No further transformation is applied before proceeding with the forecast. The displacement is used near the centre of the cyclone to maintain the cyclone central structure, and the distortion area is around the central portion to blend with the fields outside the area of influence. To save computation and improve accuracy, the effects of these transformations are calculated on the grid (see Appendix 2) and the fields interpolated with a bilinear scheme.

The surface pressure field is calculated from the transformed mean sea level pressure (MSLP) and an extrapolation of the temperature to mean sea level as the same way used in the PRINTFILE program, rather than transformed directly from the previous surface pressure field (see Appendix 3). The transformation is applied to all other model fields on each model level.

At present tropical cyclone positions are often analysed badly due to insufficient data over low latitude ocean areas. Effects of analyses are cumulative in the operational system so a method which improves one poor analysis will lead to better background fields and therefore better analysis at subsequent hours. So, in our trial, we have carried out the correction for successive analyses and several assumilation cycles. However, forecasts are run from the analysis before correction.

Tropical cyclone Lynn is chosen to test this scheme in this trial. Lynn was first reported at 00 GMT, 16 Oct 1987 in the West Pacific Ocean area (about 14.3 N, 154.1 E), moving northwestwards. It was upgraded to Typhoon at 06 GMT, 18 Oct at 13.7 N, 146.6 E, when its maximum sustained winds were estimated at 65 knots and gusts 80 knots. The last report of Lynn was at 00 GMT, 27 Oct, in the South China Sea (about 21.3 N, 117.5 E). The motion of Lynn is almost westward (Figure 1). Figure 1 also contains the operational forecast tracks, which gave very good track direction, but had some large analysis position errors (more than 1 degree).

In this trial, we have run several assimilation cycles and a number of forecasts. The main assimilatin cycles are:

A> the new scheme from 00Z 17/10/87 to 00Z 23/10/87 without bogus data (NEW-BOG)

B> the new scheme from 00Z 17/10/87 to 00Z 20/10/87 with bogus data (NEW+BOG)

C> operational, but from 00Z 17/10/87 to 00Z 19/10/87 without bogus data (OP-BOG).

The operational run is abbreviated to OP+BOG.

The difference in the length of these runs are due to the high cost of computation, and comparisons will be made for coincident times only. Bogus data used in this trial are given in Section 5.

3. Effect of the correction on analyses

(1) Analysis Error

Table 1 gives the analysis position errors of Lynn from 00Z 17/10/87 to 00Z 23/10/87 for the OP+BOG and NEW-BOG runs. They both start from the same large error at 00Z 17/10/87. The NEW-BOG run has a smaller analysis position errors than the operational run by an average of 60% (excluding the start position error). The large position error (NEW-BOG) at 00Z 18th suggests that the assimilation improvements are cumulative. Resolution and modelling deficiencies may explain some of the remaining error.

Table 2 gives Lynn's central pressure from the two runs. Clearly the new run is somewhat less deep in central pressure than the operational run, probably due to lack of bogus data and the interpolation used in the transformation. The effect of filling of Lynn on the track forecast will be discussed in Section 4.

(2) Effect of the scheme on the surrounding areas.

Since the model has very good performance in the middle latitudes, it is better to maintain all the features of analysis fields outside of the cyclone area as much as possible. To demonstrate that the scheme has not caused too much problem with this, we look at a comparison between 2 parallel runs:

A> NEW-BOG
B> OP-BOG.

Figures 2a, 2b and 3a, 3b are the MSLP and 850 mb wind analyses after 2 days assimilation for the 2 runs, respectively.

Differences are confined to a very small region around the hurricane centre.

Comparing Figures 2a and 3a, the 100 mb contour has been moved about 1.5 degrees in S-N direction and 0.5 degree in W-E direction. But the 1012 contour is unchanged. The centre is 3 mb higher in Figure 2a, probably due to interpolation employed in the run NEW-BOG.

Comparing Figures 2b and 3b, the wind centre is also moved, but the overall wind speeds are quite similar, although there are 4 knots speed differences for some grid-points near the centre between the two runs.

Comparing all these charts, the correction method moves the model's centre towards the real position and does not change the surrounding areas too much.

However there is still some problems associated with the correction scheme, eg some different vertical maxima and minima produced after correction (see Figure 4a, 4b). Fortunately, the differences seem to mostly disappear during the first 6 hours of model integration (see Figures 5a, 5b).

4. The effect of the correction on the cyclone track forecast.

1> Forecast Error

Table 3 contains the mean forecast position errors of hurricane Lynn from 5 3-day forecasts from analyses between 00Z 19/10/87 and 00Z 23/10/87 for both the OP+BOG and the NEW-BOG runs.

The mean forecast errors have been improved out to 72 hours, and the largest benefit was in the short term, namely T+12 and T+24. The forecast error of T+24 was reduced by about 46%.

For this cyclone, the reduced improvements of the medium-range forecasts (T+48 and T+72) indicates that the medium-range forecast skill depends more on the forecast model and on large-scale analysis errors as well than on the initial position. Improved skill in the forecast model may help our system at these medium ranges to compete with other hurricane forecasting systems.

2> Impact of the correction in the assimilation cycles on the forecast

Table 4 gives the forecast errors of hurricane Lynn at 00Z 20/10/87 for following runs:

a> OP+BOG forecast;
b> forecast from the analysis after three days NEW-BOG assimilation;
c> the forecast from the operational analysis but with the central position of the tropical cyclone corrected.

Table 4 shows that the forecast of run b> has the least error, and we have also made some improvement by just correcting the cyclone's central position. Although forecast c> has the best initial position, its track forecast is not as good as that from the new run, especially at T+48 and T+72, eg its error at T+72 is about 20% larger. This indicates that the cumulative effect of assimilation cycles with the correction seems to have greater effect on the cyclone motion than a single correction.

3> Effect of the central pressure of a cyclone on its track

The scheme has the effect of smoothing model fields and has slightly filled the central pressure value of Lynn, but its size (the central area) and strength (the outer circulation) have not been changed (see Figures 2 and 3). Holland (1984) has suggested that the intensity variation of the cyclone (without outer circulation changes) will not affect the motion. To find out the effect of the central pressure value of the cyclone on the track prediction in the coarse-mesh model, we compare two forecasts. One is the operational forecast at 00Z 21/10/87. The other one uses the same analysis, except that the cyclone has been shifted twice, firstly to the real position and then back to th original position (note, after we employ a distortion algebra forwards and backwards in our transformation, the cyclone centre does not exactly coincide with the original position (Figure 6)).

Although there is 2 mb difference for the Lynn's central pressure between the two analysis, there is little difference in forecast tracks. It appears that the forecast track is not very sensitive to the central pressure value.

4> An experiment moving cyclone centre in one constant direction

To test the accumulative effect of the correction on the track forecasts, an experiment that constantly moved the cyclone centre in one direction was conducted.

In the experiment, two 3-day forecast tracks have been made from two one-day NEW-BOG assimilations. The central positions were moved as follows:

1> northwestwards
2> southeastwards

with the same distance of 0.75 degree in longitude and 0.6 degree in latitude, respectively (Figure 7).

For the 24-hour forecast, the tracks have very different directions, this is probably caused by the different gradients on the T+0 fields, which have different cyclone central positions but the same surrounding areas (see Section 3.2).

The parallel movement for the medium-range tracks suggests that the correction of the cyclone centre might have little effect on the medium-range forecast track direction.

In the operational situation, the cyclone would not be moved constantly in one direction and also there would be some data to support the correction, so the gradient would not be changed too much.

This experiment also suggests that we should choose the influence area big enough to spread out the gradient change.

5. Impact of bogus data on tropical cyclone assimilation and track forecast

CFO forecasters put a lot of effort into production bogus data to improve tropical cyclone analyses; some improvements have been noted, especially in introducing the systems. However, it is much more difficult to alter the analysis of cyclone position, especially where operational analyses have large error (see Table 1). In the operational run, some bogus data have been used to move the model cyclone to the real position though will be of only limited success. Table 1 indicates this new scheme is much more effective than the bogus data in moving the tropical cyclone.

If this new scheme were used operationally, then bogus observations could be used to correct central intensity and the movement of centres would be left to the new scheme.

Table 6 gives the bogus data produced by CFO forecasters for operational runs 00Z/17 to 00Z/20/10/87. Using these bogus data in the new trial, we find that the cyclone was deepened (as Table 2), and had a slightly better initial position than the one without bogus (Table 1). But, although this run has smaller analysis position error, it has almost the same mean track forecast error as the operational one (Table 7). One explanation is probably these bogus data are not suitable for the new run, and it is not easy for forecasters to assign reasonable wind speeds. Bogus techniques would be revised for tropical cyclones on implementation of the system.

One possible system for the operational implementation of this scheme is as follows. First the intervention team in CFO update information on tropical cyclones; they may define new cyclones, and give new positions to cyclones already defined. Each tropical cyclone will be identified by a name and will be given a true position and search position for each analysis hour. Next, this information is transmitted on a data file to a program that runs after the present analysis/assimilation step and before the forecast. Using the search position specified by CFO as a guide, the program finds the model's analysis position and (within certain constraints) moves the centre to the true position. This modified analysis is used as the start cyclone position data file, is stored in the model archive. A number of checks are an essential part of this procedure. Possible numerical values of the checked parameters are given in brackets.

1. The model's analysed position of the cyclone centre must be close to the search position provided by CFO (200 km).

2. The distance between the analysed position and the true position must be small (200 km).

3. Both the analysed position and the true position must be within the equatorial region 20 N to 20 S and over ocean areas (defined by a bit mask).

4. If more than one tropical cyclone have true positions defined by CFO, the areas of deformation must not be overlapping.

Note that tropical cyclones do not have to be given a true position at each analysis hour; CFO will decide whether the model's fields are satisfactory. If no circulation exists or is too weak, then the model's analysis is best improved through the use of bogus data. A verification scheme could also be incorporated into system by using the information on cyclone position.

6. Summary

In this trial, we have demonstrated that this new scheme effectively moves tropical cyclone Lynn, and does not deteriorate the analysis in the surrounding area. By correcting the central position of starting fields in the assimilation cycles, not only the analysis of cyclone central positions, but also the forecast cyclone tracks have been improved, especially in the short term.

There is some further work to do with this scheme, before it can be put into the operational suite.

Better handling of the vertical velocity would be necessary for operational implementation. More careful account of the effect of orography on the shifting algorithm might improve the forecast track near the coast. Capability of dealing with two cyclones near each other also is needed for the operational purposes.

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Reference:

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Devrell, C., Watkins, F., Kitchen, J. 1985 Printfile. Met O 2b Operational Numerical Weather Prediction Scheme Documentation Paper No 7.

Hall, C. D. 1987 Verification of global model forecasts of tropical cyclones in the North Atlantic and North Pacific during 1986. Met O 2b Technical Note No 112.

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Appendix

1. Defining the model's tropical cyclone central position

We define the cyclone's geometrical centre in the MSLP field as the model's central position.

A subgrid (I,J) centred at the grid-point with the lowest MSLP value is used, and spans:

(-MI,MI) in I direction
(-MJ,MJ) in J direction.

If the highest value of MSLP in the subgrid is PHIGH, the central point (MODELI,MODELJ) can be given by:

$$\text{MODEL}=\frac{\sum_{J}\sum_{I}\text{(PHIGH-MSLP(I,J))*C(I,J)*I)}}{\sum_{J}\sum_{I}\text{(PHIGH-MSLP(I,J)*C(I,J)}}$$

$$\text{MODEL}=\frac{\sum_{J}\sum_{I}\text{(PHIGH-MSLP(I,J))*C(I,J)*J)}}{\sum_{J}\sum_{I}\text{(PHIGH-MSLP(I,J))*C(I,J)*J)}}$$

where C(I,J) is a weight function, used to emphasize the importance of central portion of the cyclone:

```
C(I,J)=2./SQRT(I**2+J**2+4).
```

The current values of parameters are:

```
MI=MJ=3.
```

2. Subgrid transformation

Define a local grid (I,J), with centre at the nearest gridpoint to the actual position of the tropical cyclone.

Assume PDX and PDY are the I and J direction components of the distance between the true centre position and model's. (X,Y) is position of new gridpoint (I,J) in the original grid. (X1,Y1) and (X2,Y2) are the positions of the new gridpoint (I,J) in the original grid after a displacement and a bilinear transformation, respectively.

```
    X1=I+PDX
    Y1=J+PDY
and X2=I+PDX*(1-ABS(I)/MGRIDIP)*(1-ABS(J)/MGRIDJP)
    Y2=J+PDY*(1-ABS(I)/MGRIDIP)*(1-ABS(J)/MGRIDJP)
```

where MGRIDIP and MGRIDJP are the half lengths of the transformation area in I and J direction, respectively.

So the combination of the two transformations is given by

```
X=W(I,J)*X1+(1-W(I,J))*X2
Y=W(I,J)*Y1+(1-W(I,J))*Y2
```

where W(I,J) is the weight function, given by

```
W(I,J)=CX(I)*CY(J)
```

and CX(I) and CY(J) are defined by

```
      (1.0                                    I<NIP
CX(I)=(COS((ABS(I)-NIP)/(NOUIP-NIP)*90) NIP<I<NOUIP
      (0.0                                    I>NOUIP

      (1.0                                    J<NJP
CY(J)=(COS((ABS(J)-NJP)/(NOUJP-NJP)*90) NJP<J<NOUJP
      (0.0                                    J>NOUJP
```

where NIP,NJP are used to define the area of displacement, and NOUIP,NOUJP are used to define the area of the combination of teh two transformations (Figure 8).

In this trial, the values of these parameters are used as follows:

```
MGRIDIP=MGRIDJP=9
NIP=NJP=1
NOUIP=NOUJP=8
```

3. Surface Pressure calculation

Assuming the transformed mean sea level pressure is MSLP, and the model orographic height Htop, the extrapolation of the temperature to mean sea level TO:

$$TO=Ts+.0065Htop$$

Where Ts is the surface temperature (Devrell, etc, 1985). Then the surface pressure (P*) is given by:

$$P^*=MSLP*\left(\left(\frac{TO}{TO-RATE*Htop}\right)**\left(\frac{-G}{RATE*R}\right)\right)$$

where RATE is the constant lapse rate, R gas constant and G gravity.

Figures:

Fig. 1 Tropical cyclone Lynn's track and the operational forecast tracks (same notation as Hall used)

Fig. 2 Analysis after 2 days OP-BOG assimilation (00Z 17/10 to 00Z 19/10/87)

Fig. 3 Same as Fig. 2, but for NEW-BOG run.

Fig. 4 850 mb vertical velocity analysis a>. before the cyclone centre shifted; b>. after the centre shifted.

Fig. 5 850 mb vertical velocity forecasts (T+6) from the analysis
a>. without cyclone centre correction;
b>. with the correction.

Fig. 6 3-day forecast tracks for the operational (●——●) and from the filled start field (◘——◘).

Fig. 7 Forecst tracks from analyses of 00Z 20/10/87 for the constant moving cyclone centre in one direction, southeastward (§——●——§) northwestward (■——●——■)

Fig. 8 Different transformation areas:

I. displacement;
II. displacement+bilinear transformation;
III. bilinear transformation.

	00Z 17/10/87	00Z 18/10/87	00Z 19/10/87	00Z 20/10/87	00Z 21/10/87	00Z 22/10/87	00Z 23/10/87	Mean error (18-23/10)
OP+BOG	488.3	180.7	231.3	116.2	115.6	122.3	178.2	157.4
NEW-BOG	488.3	95.8	44.5	43.7	47.8	39.6	61.4	55.5
NEW+BOG	488.3	94.0	11.0	44.5				49.8 (3 days)
OP-BOG	488.3	67.5	211.5					

Table 1 Lynn analysis position errors for OP+BOG, NEW-BOG, NEW+BOG and OP-BOG (unit = km)

time run	12Z 17/10/87	00Z 18/10/87	12Z 18/10/87	00Z 19/10/87	00Z 20/10/87	00Z 21/10/87	00Z 22/10/87	00Z 23/10/87
OP+BOG	999	997	992	989	989	993	991	993
OP-BOG	1003	1000	995	993				
NEW-BOG	1003	1001	997	996	996	996	996	998
NEW+BOG	998	999	996	994	995			

Table 2 Lynn's central pressure (mb) for different runs

	T+0	T+12	T+24	T+36	T+48	T+60	T+72
OP+BOG	151.8		146.5		238.3		431.8
NEW-BOG	47.4	56.7	78.8	120.5	229.3	240.1	410.4

Table 3 Lynn's mean forecast errors (km) for 5 forecasts with starting analyses valid 00Z 19-23/10/87

	T+0	T+12	T+24	T+36	T+48	T+60	T+72
Operational run	116.2		122.7		349.3		542.3
New one Without Bogus	43.7	62.6	10.6	94.1	217.5	275.8	357.8
From corrected start field	33.6	74.8	49.3	133.3	276.4	337.1	452.4

Table 4 Hurricane Lynn 00Z 20/10/87 forecast error (km)

	T+0	T+12	T+24	T+36	T+48	T+60	T+72
Operational	231.3		231.1		387.3		843.0
New one without Bogus	44.5		123.1		359.2		834.1

Table 5 Hurrican Lynn 00Z/19/10/87 forecast error (km)

Time	Latitude	Longitude	P*	P*-P*(OP fg)	P*-P*(NEW fg)	DDFF	DDFF(OP fg)	DDFF (NEW fg)
6Z/17/10/87	15.0	150.5	1000.0	-4.5	-4.6	90/40	149/16	73/11
6Z/17/10/87	12.9	143.5	1005.0	-1.0	-3.1	330/14	321/11	344/7
6Z/17/10/87	13.0	148.5	1000.0	-3.9	-5.5	0/30	224/17	343/9
6Z/17/10/87	13.0	152.5	1000.0	-7.4	-4.5	184/30	195/17	214/17
6Z/17/10/87	11.0	150.5	1000.0	-7.2	-6.0	270/20	198/24	245/17
18Z/17/10/87	13.5	147.5	996.0	-4.0	-2.8			
18Z/17/10/87	11.0	149.5	1002.0	-3.3	-1.5	220/30	212/30	228/33
6Z/18/10/87	13.8	144.7	996.0	-2.8	-0.9	290/24	257/30	279/17
6Z/19/10/87	17.0	139.0	996.0	-1.9	-6.1			
6Z/19/10/87	17.0	139.0	850.0			0/40	345/47	11/34
6Z/19/10/87	17.0	145.0	996.0	-1.3	-1.4			
6Z/19/10/87	17.0	145.0	850.0			184/40	244/64	173/40
6Z/19/10/87	14.0	142.0	996.0	-6.1	-4.2			
6Z/19/14/87	14.0	142.0	850.0			270/44	251/38	283/32
6Z/19/10/87	20.0	142.0	996.0	6.7	-4.3			
6Z/19/10/87	20.0	142.0	850.0			90/50	92/47	73/38

Table 6 Bugus data used in operational run (00Z/17-00Z/20/10/87)

Note: P* = surface pressure or standard level pressure
Op fg = operational first guess
NEW fg = new runs's (NEW+BOG) first guess

	T+0	T+12	T+24	T+36	T+48	T+60	T+72
OP+BOG	176.8		180.9		404.8		716.0
NEW+BOG	49.9	103.0	178.9	270.8	407.4	554.3	738.7

Table 7 Lynn's mean forecast error (km) for 3 forecasts with starting analyses valid 00Z 18-20/10/87

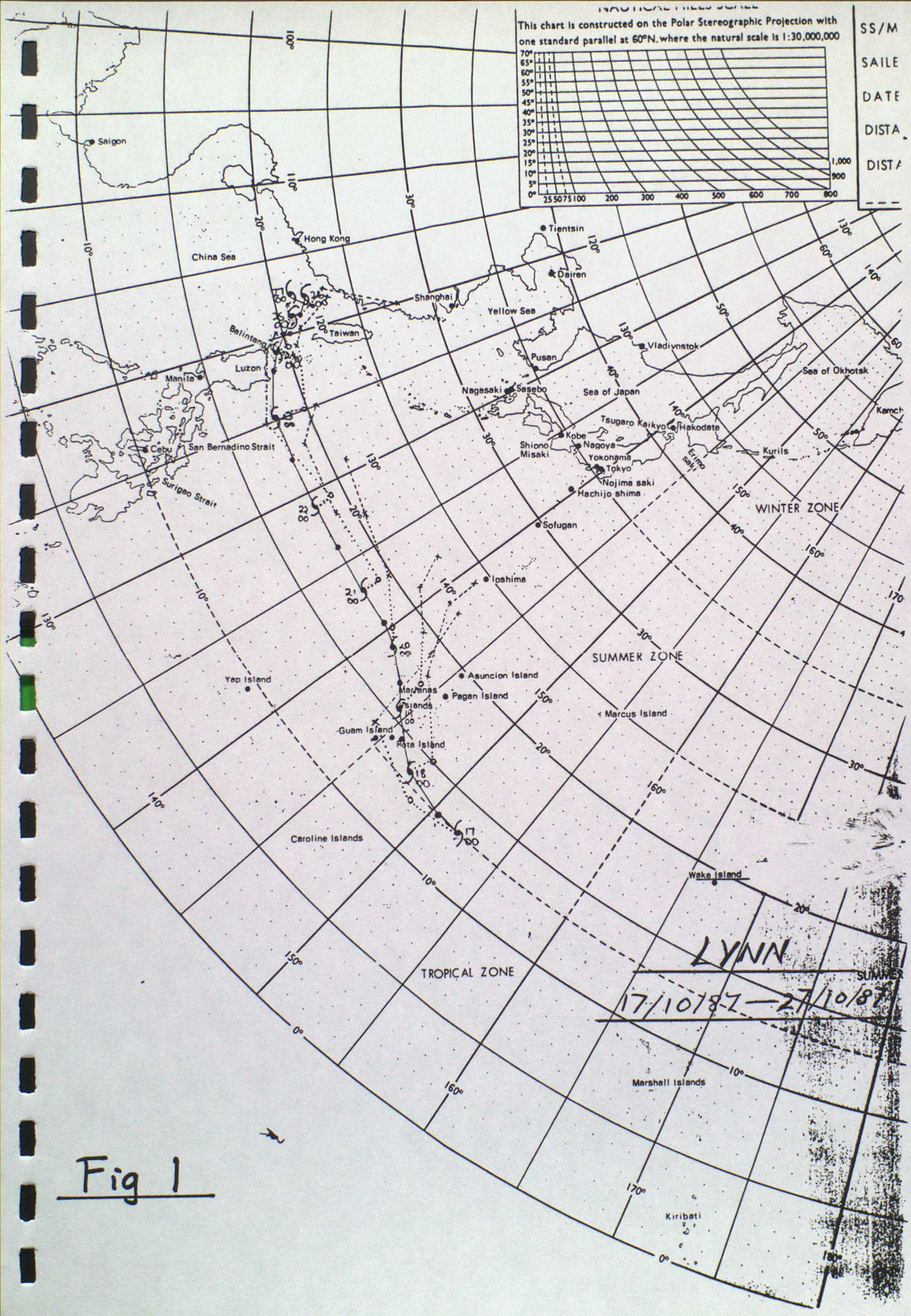
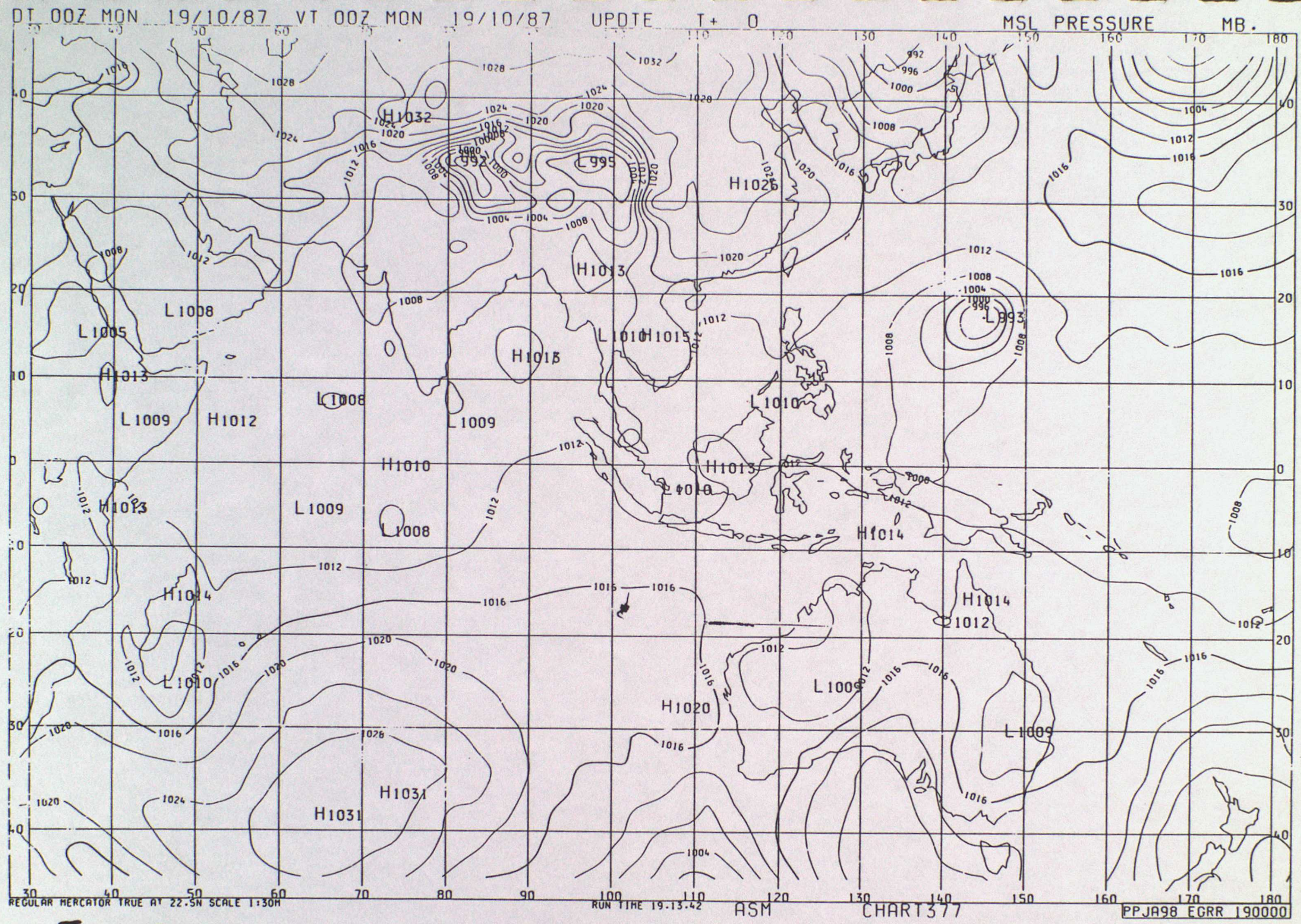

This chart is constructed on the Polar Stereographic Projection with one standard parallel at 60°N. where the natural scale is 1:30,000,000
SS/M
SAILE
DATE
DISTA
DISTA
Saigon
Hong Kong
China Sea
Tientsin
Dairen
Shanghai
Yellow Sea
Taiwan
Balintang
Luzon
Manila
Cebu
San Bernadino Strait
Surigao Strait
Pusan
Vladivostok
Sea of Okhotsk
Nagasaki
Sasebo
Sea of Japan
Tsugaro Kaikyo
Hakodate
Kamch
Kobe
Nagoya
Shiono Misaki
Yokohama
Tokyo
Nojima saki
Hachijo shima
Erimo saki
Kurils
WINTER ZONE
Sofugan
Ioshima
SUMMER ZONE
Asuncion Island
Yap Island
Marianas Islands
Pagan Island
Marcus Island
Guam Island
Rota Island
Caroline Islands
Wake Island
TROPICAL ZONE
LYNN
17/10/87 — 27/10/87
Marshall Islands
Kiribati

Fig 1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L992
L995
H1026
H1013
L1008
L1005
H1013
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H1015
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L993
H1010
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L1009
H1031
H1031
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ASM
CHART377
PPJA98 EGRR 190000

Fig 2a

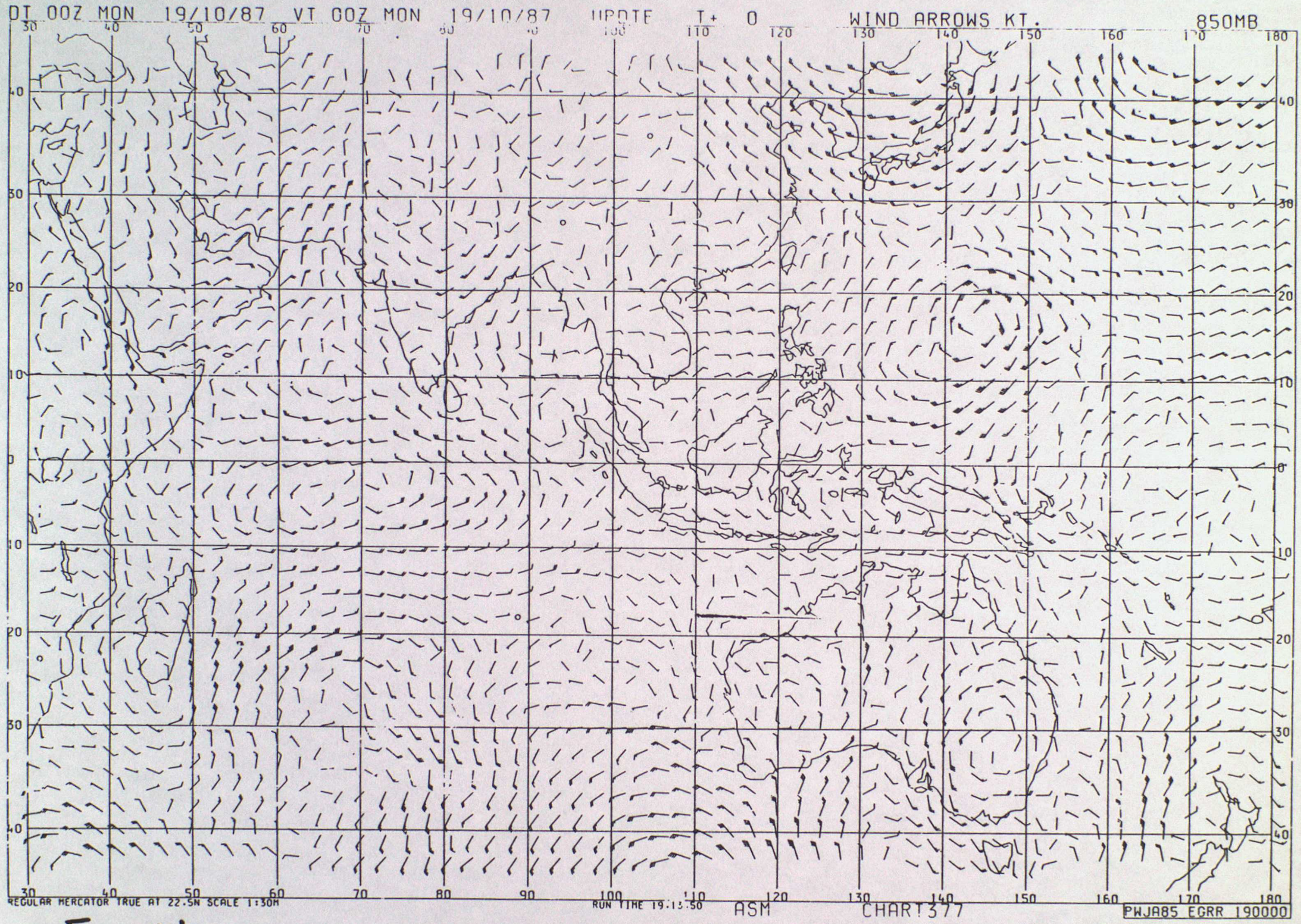
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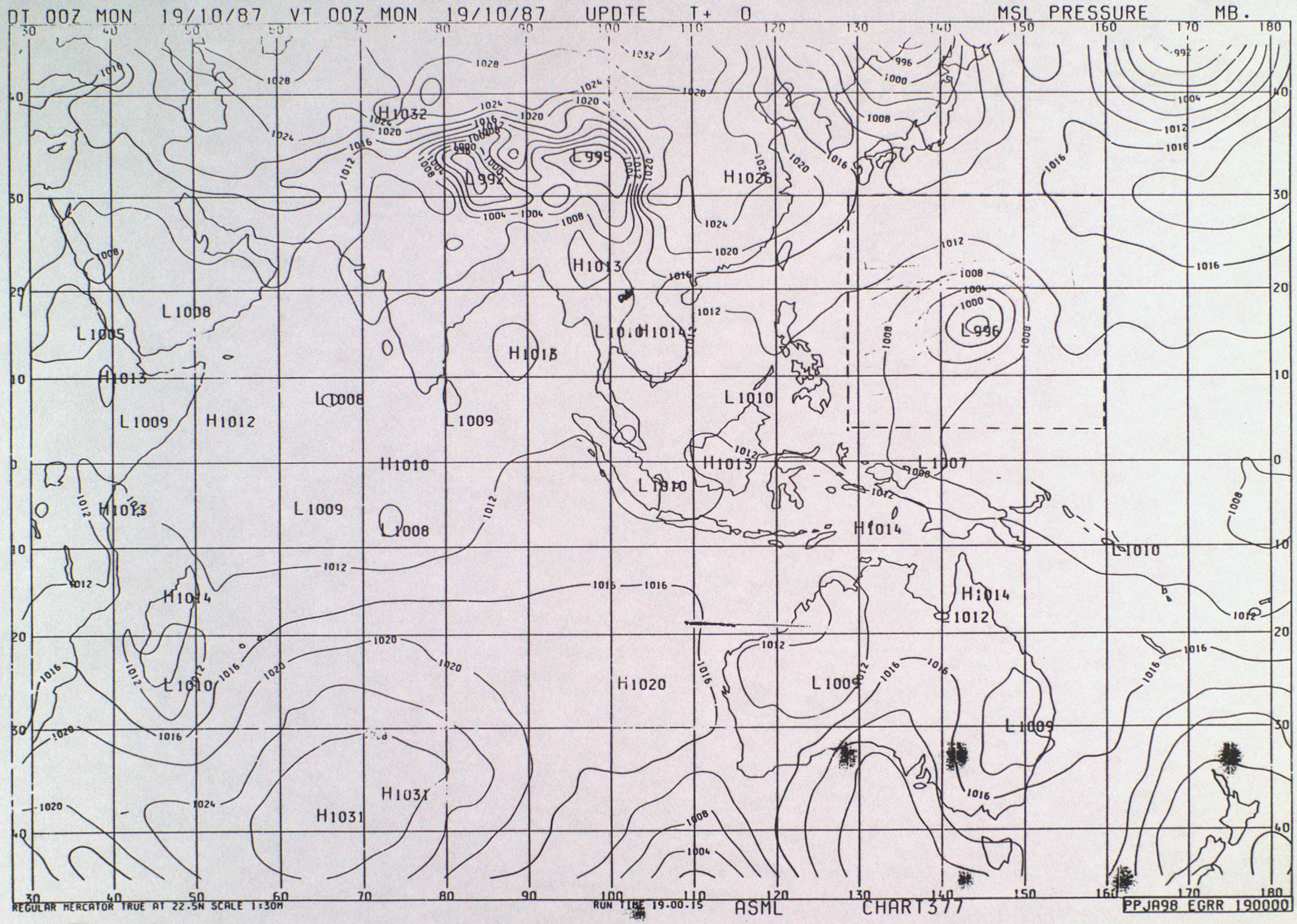
Fig 2b



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H1032
L992
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H1013
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L1005
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L1009
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L1009
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H1018
L1010
L1010
H1010
H1013
L996
L1007
H1014
L1010
H1014
H1012
L1009
H1020
L1009
H1031
REGULAR MERCATOR TRUE AT 22.5N SCALE 1:30M
RUN TIME 19.00.15
ASML
CHART377
PPJA98 EGRR 190000

Fig 3a

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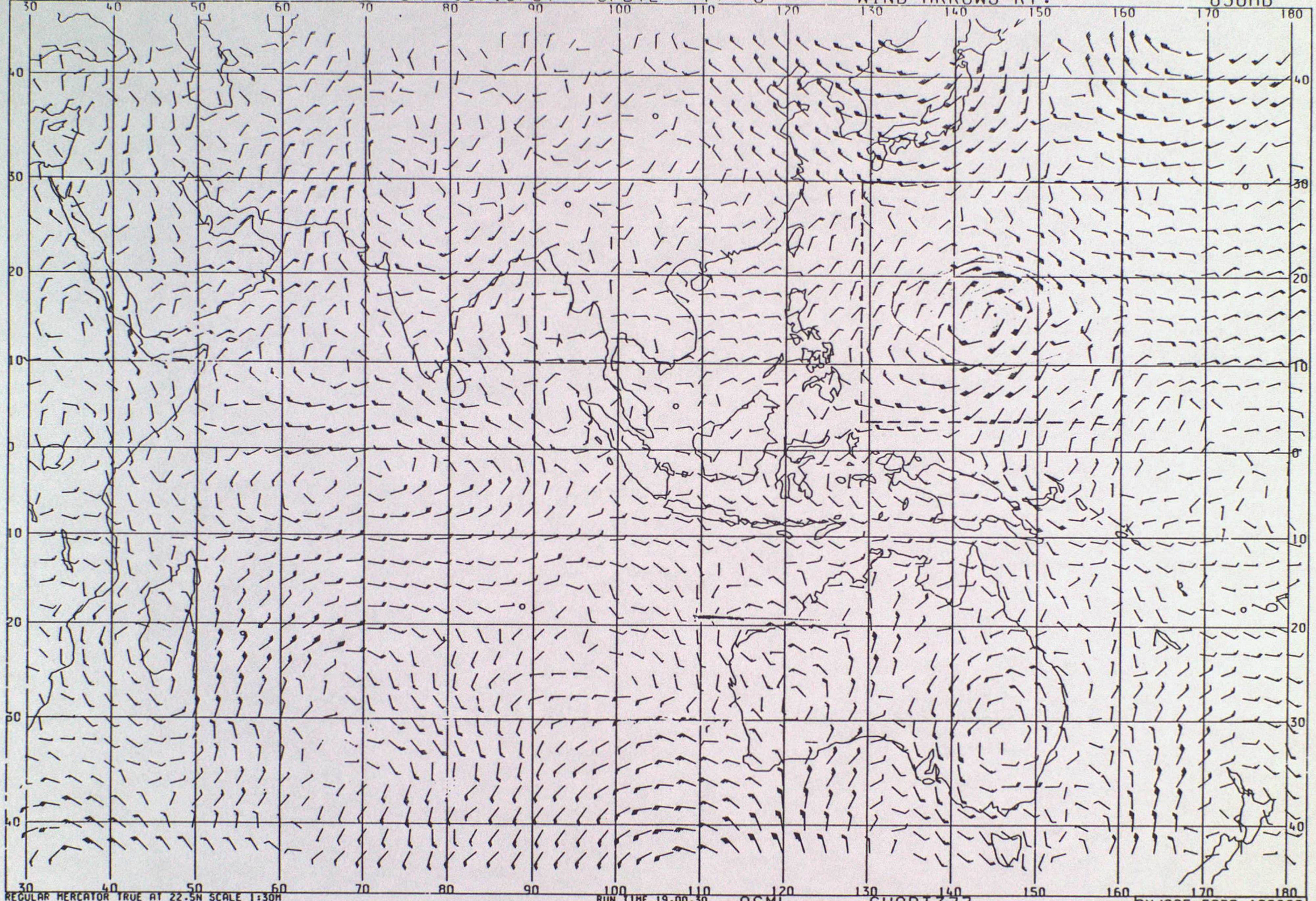
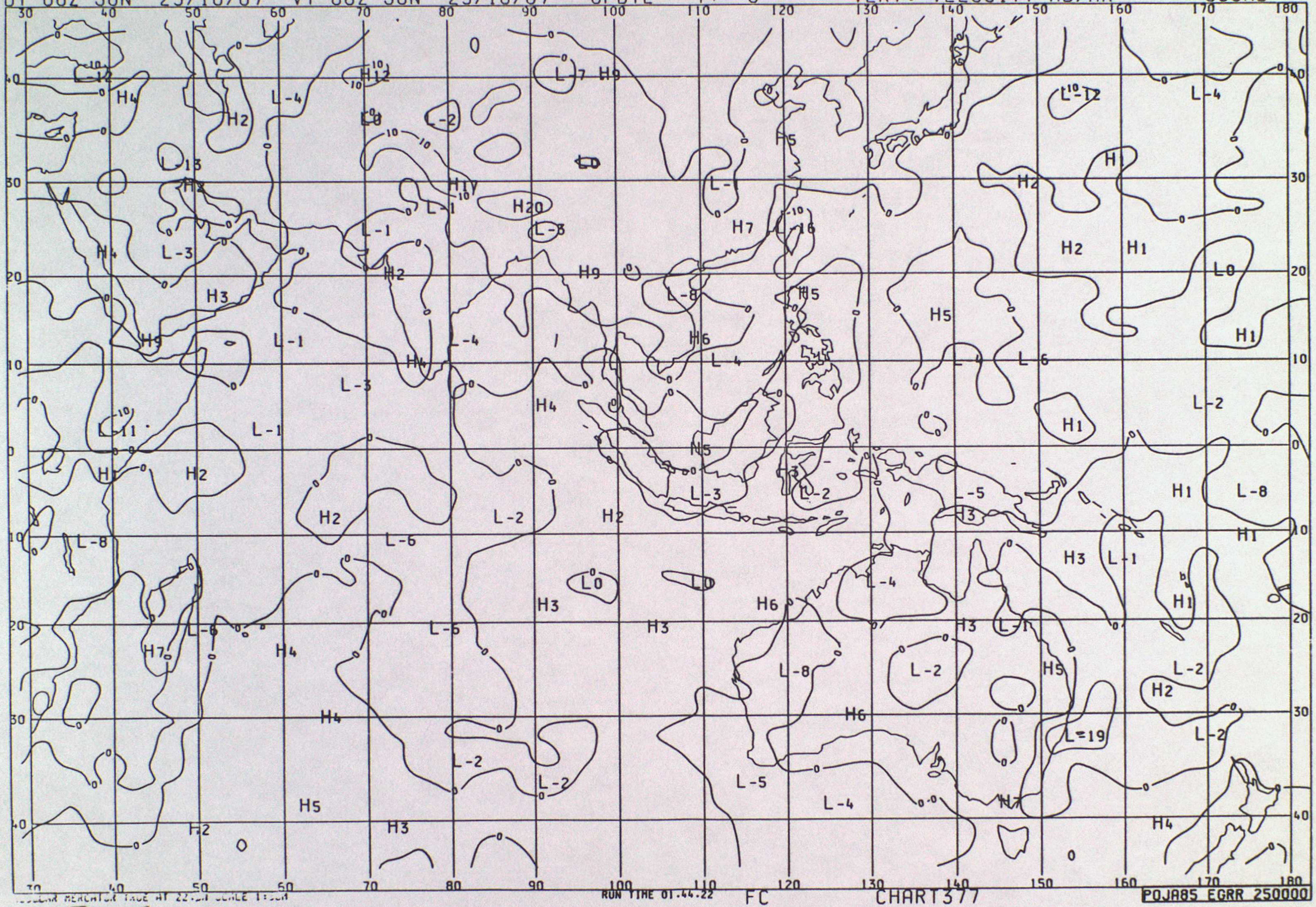


REGULAR MERCATOR TRUE AT 22.5N SCALE 1:30M RUN TIME 19.00.30 ASML CHART377 PWJA85 EGRR 190000

Fig 3b

DT 00Z SUN 25/10/87 VT 00Z SUN 25/10/87 UPDTE T+ 0 VERT. VELOCITY MB/HR 850MB



RUN TIME 01.44.22 FC CHART377 POJA85 EGRR 250000

Fig 4a

DT 00Z SUN 25/10/87 VT 00Z SUN 25/10/87 UPDTE T+ 0 VERT. VELOCITY MB/HR 850MB

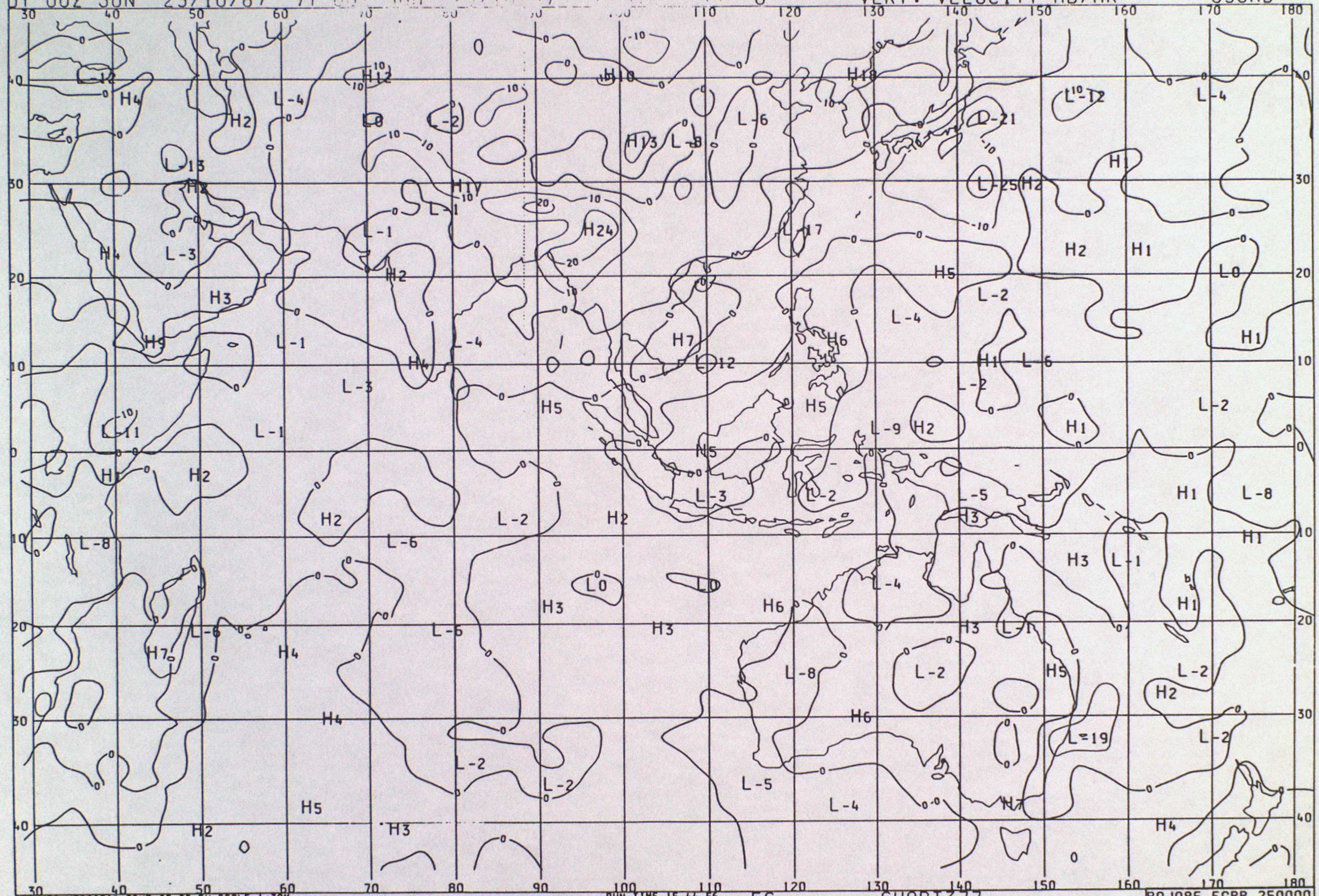


Fig 4b

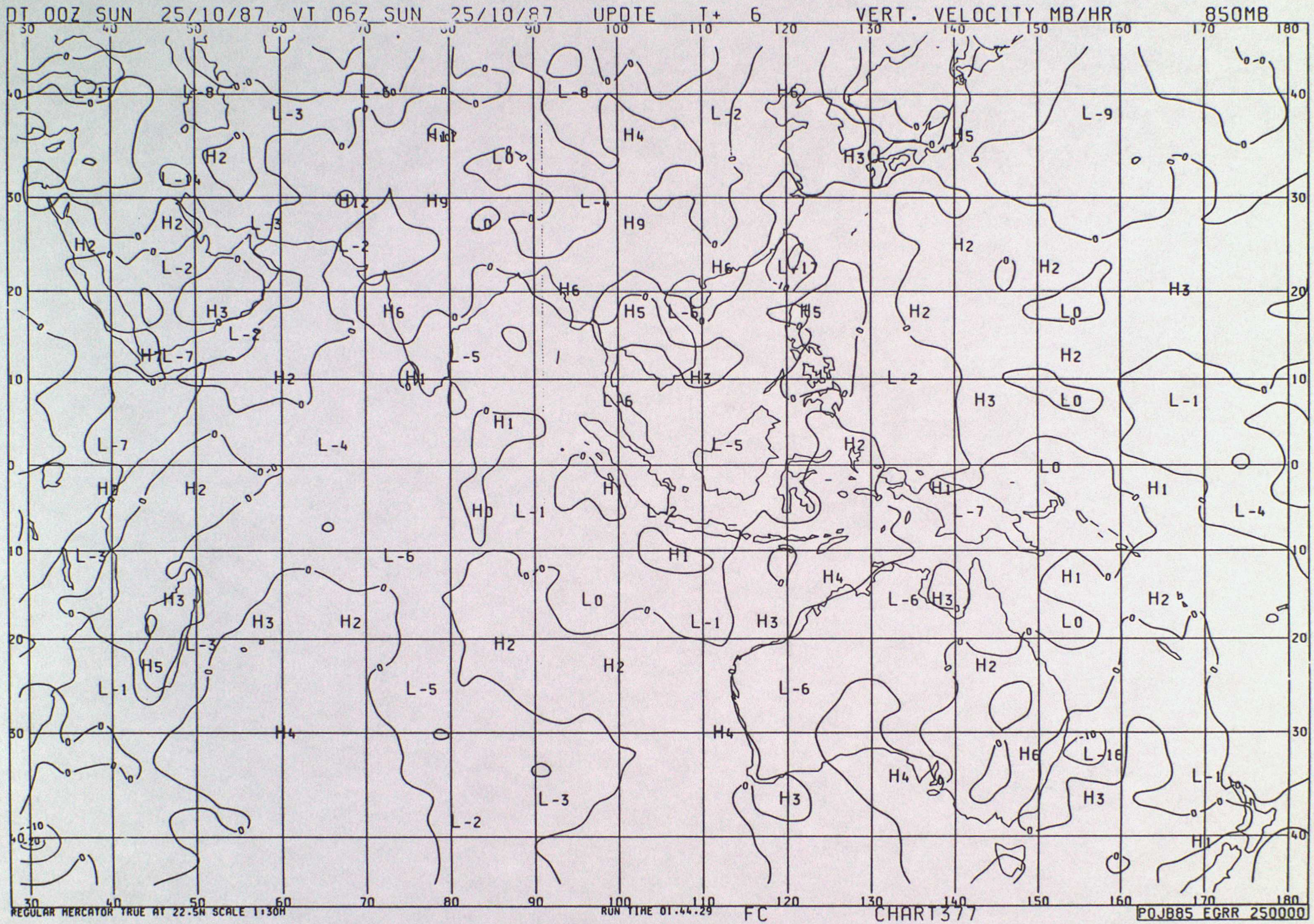

DT 00Z SUN 25/10/87 VT 06Z SUN 25/10/87 UPDTE T+ 6 VERT. VELOCITY MB/HR 850MB
REGULAR MERCATOR TRUE AT 22.5N SCALE 1:30M
RUN TIME 01.44.29
FC
CHART377
POJB85 EGRR 250000

Fig 5a

DT 00Z SUN 25/10/87 VT 06Z SUN 25/10/87 UPDTE T+ 6 VERT. VELOCITY MB/HR 850MB

REGULAR MERCATOR TRUE AT 22.5N SCALE 1:30M   RUN TIME 15.45.03   FC   CHART377   POJB85 EGRR 250000

Fig 5b

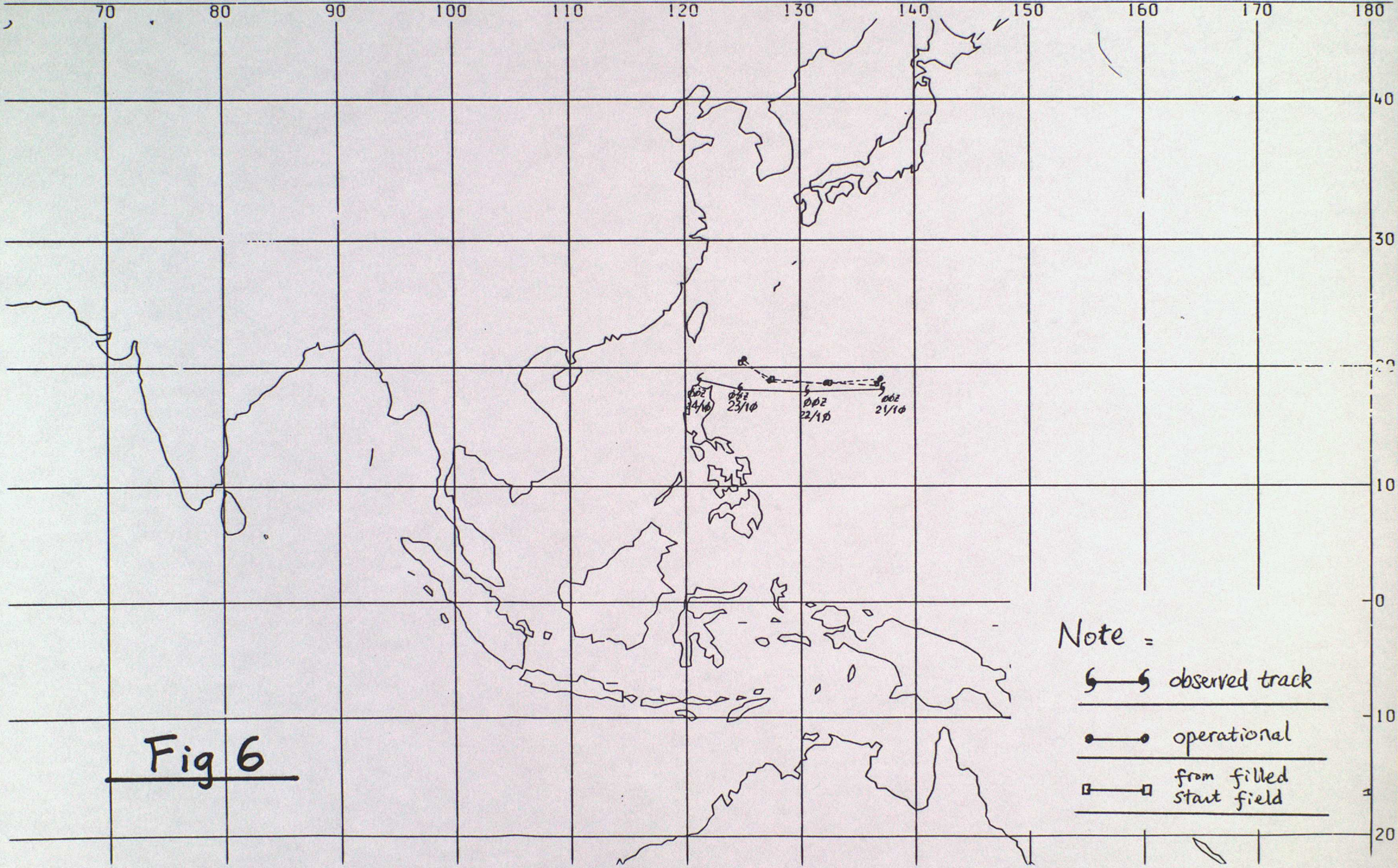

70
80
90
100
110
120
130
140
150
160
170
180
40
30
10
0
10
20
ØØZ 24/1Ø
ØØZ 23/1Ø
ØØZ 22/1Ø
ØØZ 21/1Ø
Note =
observed track
operational
from filled start field

Fig 6

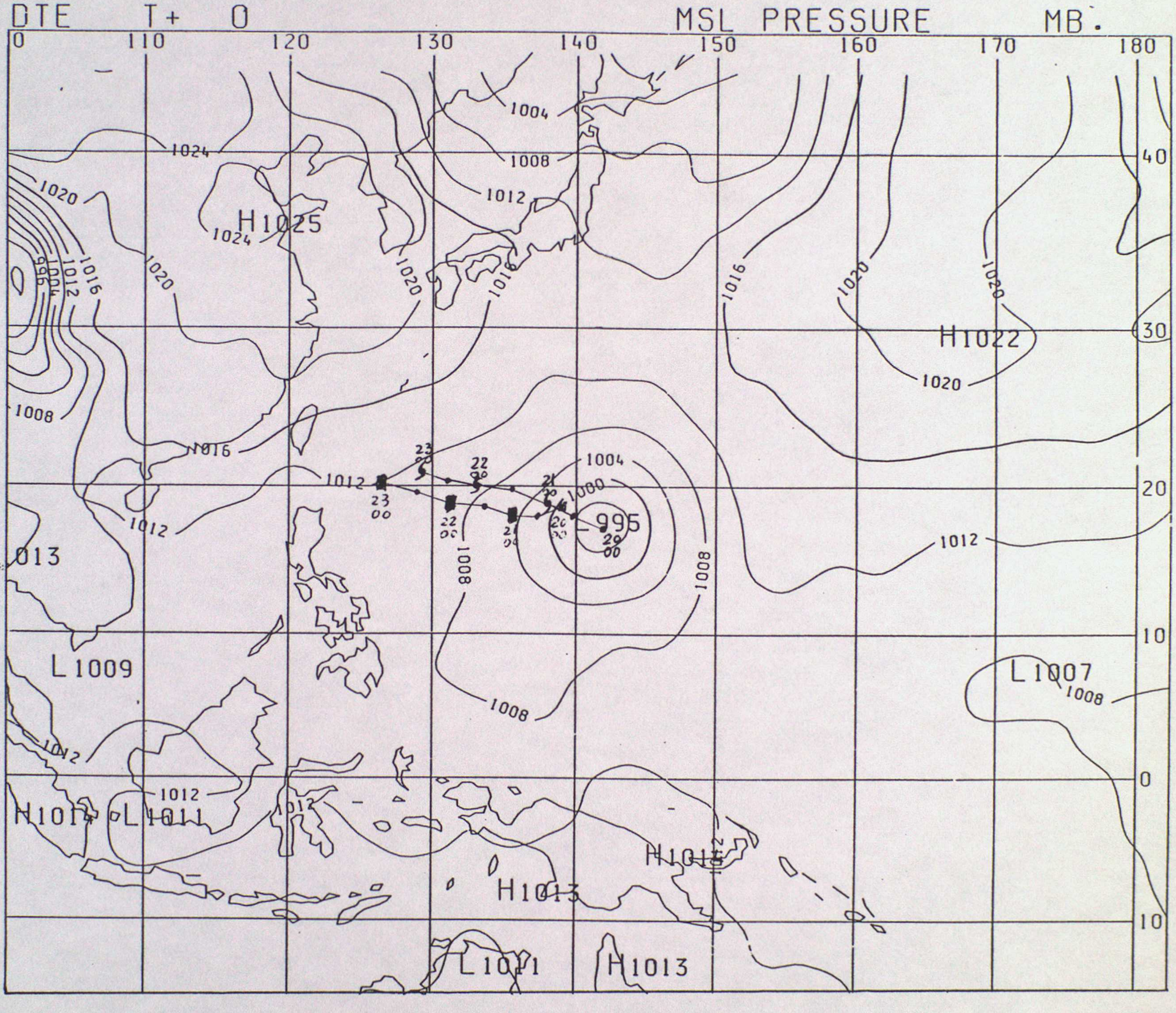

DTE T+ 0
MSL PRESSURE MB.
0
110
120
130
140
150
160
170
180
40
30
20
10
0
10
H1025
H1022
L1007
L1009
H1013
L1011
995
1024
1020
1016
1012
1008
1004
1000
013

Fig 7

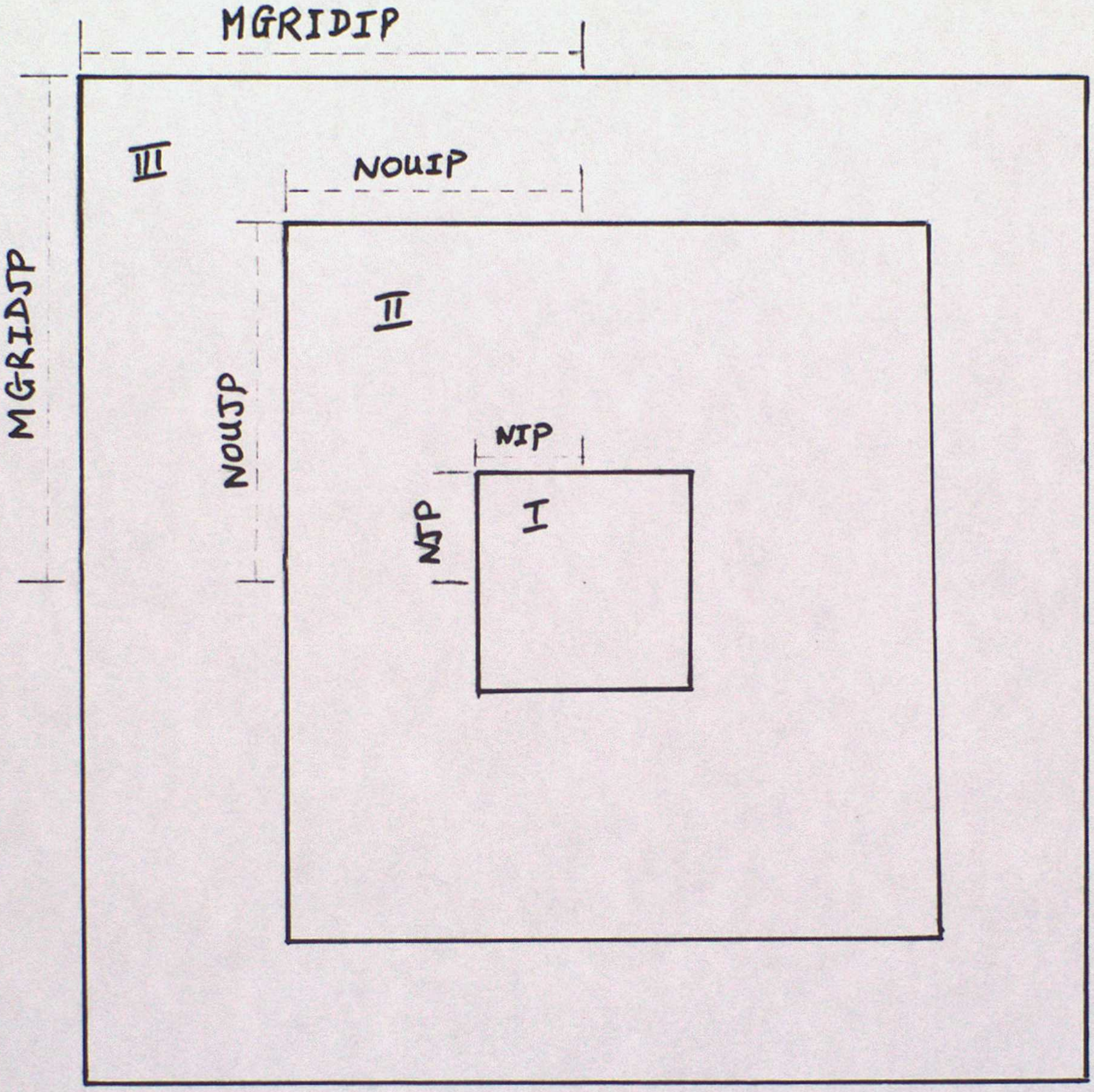


Fig 8