ROYAL OBSERVATORY, HONG KONG

Technical Note (Local) No. 56

MOVEMENT OF TROUGHS AND COLD FRONTS OVER SOUTH CHINA IN THE LATE COOL SEASON

by

S.Y. Lau

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Published June 1990

Prepared by

Royal Observatory
134A Nathan Road
Kowloon
Hong Kong

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SUMMARY

Fronts and troughs that formed over central China between February and April, 1983 - 1986, were surveyed to gain understanding of their movement during the late cool season. The survey showed that the presence of an anticyclone to the west of longitude 115 degrees east is crucial to the arrival of these fronts/troughs at Hong Kong. On the other hand, in the presence of a narrow ridge along the southeast China coast, the fronts/troughs over south China will slow down or even move back towards the Nanling range. A set of criteria was devised to assist the forecasters in predicting their arrival at the south China coast.

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TABLES

FIGURES

1. INTRODUCTION

Climatologically, the northeast monsoon predominates in winter. But breaks in the monsoon become increasingly frequent in Hong Kong from February to April and the southward advance of cold air becomes more changeable. After a surge of the winter monsoon, a high pressure area over China typically moves eastward into the East China Sea and at the same time extends southward to cover the southeast China coast (Fig. 1a). An area of low pressure starts to develop off the southeast edge of the Tibetan Plateau and relatively warm and moist southwesterlies intrudes into south and central China. Where this air mass meets the cooler air from the north, a trough or quasi-stationary front is usually formed (Fig. 1b). This is often accompanied by cyclogenesis off the coast of east China (Fig. 1c). The front/trough will linger over central China and the Nanling range until a replenishment of cold air from the north pushes it southward to affect south China (Figs. 1d and 1e). Since the movement of the front/trough depends on a number of factors, notably meteorological and topographical ones, the time taken for it to move from the Nanling range to Hong Kong can vary considerably.

In this study, fronts/troughs that formed over central China from February to April 1983-1986 were studied with a view to setting up a new criterion for forecasting their arrival at the south China coast. The period, February to April, was loosely defined as the "late cool season" in this paper. This, however, is different from that used by Lai (1989).

As a north-south temperature gradient still exist at this time of the year, the troughs may bear some frontal characteristics. However, no attempt was made to differentiate between fronts and troughs in the present study and they were collectively called fronts/troughs in the present study.

Due to the difference in speed of movement of the front/trough over land and sea as well as the funnelling effect over Taiwan Strait, the front/trough does not appear as a smooth line but exhibits undulating structure (Fig. 2). Depending on the position of the pressure pulse, it may approach Hong Kong either from the north or from the east. As the pool of cooler air approaches Hong Kong from the east, it is gradually modified as it travels over Taiwan Strait. The associated temperature drop and weather change usually exhibit characteristics different from those that approach Hong Kong from the north. In the present study, only fronts/troughs that approach Hong Kong from the north were considered. Those that approach from the east were classified as failed cases.

Three cases illustrative of fronts/troughs that arrive early, late or never arrive at Hong Kong are discussed together with the associated synoptic situation in Appendices I, II and III respectively.

2. REVIEW OF EXISTING FORECASTING TOOLS

For some years, the Royal Observatory has been using prognostic charts from the European Centre of Medium Range Weather Forecast and the British Meteorological Office as the basis for short- to medium-range forecast. The resolution of these models at the surface level is 2.5° by 2.5°. This prohibits an accurate determination of the position of the front/trough over south China, and hence its time of arrival at the south China coast.

In early 1989, a very-fine mesh limited area model (ROLAM) adopted from a similar model used by the Japanese Meteorological Agency became operational. The fine resolution of the model, namely 1° by 1°, would in theory allow fronts/troughs to be located fairly accurately. However, because the topographic representation of the Nanling range was highly smoothed, there was a tendency for the model to predict unrealistically early arrival of the fronts and troughs. The ridge of high pressure along the southeast China coast, often observed in the later stages of winter monsoon surges, also became a much less prominent feature. Subsequently, a merged topography which represented the Nanling range in a more realistic manner, was introduced in July 1989. This along with other improvements makes it necessary to re-evaluate the model performance, at least for the late cool season in 1989/1990, before more confidence can be put on the model results.

There were other forecasting methods developed to predict the arrival time of cold fronts during the cool season. These include: Morrice's (1973) 15-hPa criterion (time of arrival will be about 24 hours after the difference, dubbed 'delta-P' in the Royal Observatory, between the highest pressure south of 35°N and west of 114°E and the pressure in Hong Kong reaches the said value); and Lai's (1989) rule which makes use of the pressure difference ('delta-P972') between Hong Kong and Chenzhou (station no. 57972) north of the Nanling range.

During the late cool seasons of 1983 - 86, there were a total of 29 fronts/troughs. The performance of Morrice's criterion in predicting the arrival of these fronts/troughs was given in Table 1a. Of the 21 cases when a front/trough did arrive, the criterion captured 14 but missed 7 cases (i.e.33 % of the time). The performance of Lai's rule was similarly tested. A low threshold value of 7 hPa for the pressure difference was selected to cater for the weaker push from the north in the late cool season. The results, given in Table 1b, indicated that the rule also missed front/trough arrival 29 % of the time.

It therefore appeared that the existing forecasting tools were still inadequate in forecasting accurately the arrival of fronts/troughs in the late cool season.

3. ANALYSIS OF TROUGH ARRIVAL TIME

Troughs and fronts that formed over central China during the late cool seasons of 1983 to 1986 were first identified. There were a total of 29 cases. Because of the small number of cases, no attempt was made to categorise the data by month.

A front/trough is said to lie over the Nanling range if it is south of Chenzhou 郴縣 (station no. 57972) but north of Fogang 佛岡 (station no. 59087). The location of these places is shown in Fig. 3.

Unlike surges in the early cool season, northerly winds with a strength of over 5 ms^{-1} accompanying the arrival of a front/trough are seldom sustained. Thus the definition used by Lam (1979) is not applicable in this study. The arrival time of the fronts/troughs were therefore made subjectively basing on: winds turning northerly, temperature dropping, as well as the occurrence of precipitation at a station.

Table 2 presents a summary of the travel time taken by fronts/troughs moving from station 57972 to Hong Kong. Of the 29 cases, 17 (59 %) took less than 2 days and 4 (14 %) took 2 to 4 days while 8 cases (28 %) never arrived at Hong Kong. Table 3 presents a summary of the time of day these fronts/troughs arrived at Hong Kong. 48 % these arrived between 15 to 21Z (11 p.m. to 5 a.m. local time).

4. PROPOSED FORECAST CRITERION

(a) Typical synoptic patterns

A survey of the synoptic patterns associated with the fronts/troughs in the late cool seasons was first conducted to identify the features associated with the southward movement of the fronts/troughs as well as the reasons for their failure to arrive.

A front/trough starts to move when there is a pressure build-up, or a "push", from the north. However, because in the late cool season this "push" is usually weak, and the layer of cold air on the surface shallow, the southward advancement of the front/trough is often checked as it reaches the Nanling range. The situation may be further complicated if the continental anticyclone (i.e. the pressure build-up) moves rapidly to the East China Sea. Frictional effects result in a difference in the speed of movement over land and over water, and this can significantly distort the shape of the front/trough (Fig. 2). The hilly terrain on both sides of the Taiwan Strait further accelerates the southward advance of the monsoon down the Strait, resulting in a ridge of high pressure extending from northeast to southwest along the southeast China coast. With the establishment of this ridge and in the absence of cold air advancing towards south China, the front/trough may fall short of arriving at Hong Kong even if it has come as close as southern Guangdong (Fig. 4).

(b) Parameters with indicative value

Based on the above, primary considerations were given to three basic elements for use in forecasting the arrival of fronts/troughs in the late cool season:-

i) delta-P, representing the strength of northerly push;
ii) delta-P972, representing the pressure build-up due to cold air over south China; and
iii) delta-Ps, i.e. the pressure difference between Shanghai (station no. 58367) and Hong Kong, to represent the strength of monsoon likely to advance southward down the Taiwan Strait.

After a series of tests, a set of parameters constructed from the basic elements above were found useful in forecasting the arrival or non-arrival of fronts/troughs:-

a) a threshold value for delta-P, below which fronts/troughs over south China are not likely to arrive at Hong Kong;
b) tendency of delta-P972 during the past 6 hours, to indicate whether the push behind the cold air over south China is sustained; and
c) tendency of [delta-P minus delta-Ps] during the past 6 hours, in order to describe the movement and evolution of the continental anticyclone, in particular, the movement of the

anticyclone into the East China Sea. It also acts as a first indicator of the possible development of a ridge along the southeast China coast in case the anticyclone moves eastward into the East China Sea.

A set of guidelines was established from these three parameters and is shown in the form of a flow chart in Fig. 5.

(c) Performance of the proposed criterion

The set of guidelines (Fig. 5) was first applied to the original data set of 1983 - 86. The results are presented in Table 4. Out of 21 cases when fronts/troughs did arrive, 5 cases were missed. The false alarm rate was low, 3 out of 19, and is comparable to the other two schemes described in Section 2.

On average, the fronts/troughs arrived 31 hours after the proposed criterion (viz. delta-P > 10, delta-P972 increasing in the past 6 hours and [delta-P - delta-Ps] increasing in the past 6 hours) was met. However, the spread was quite large. The standard deviation amounts to 16 hours. Of the arrival cases, nearly 90 % of the fronts/troughs arrived within 2 days (Table 5). This criterion can thus be used as a first estimate to capture the possible changes in the local weather due to the arrival of a front/trough in the next day or two.

The scheme was further tested against the fronts/troughs in the late cool seasons (February - April) of 1987 - 89. A total of 19 fronts/troughs were identified within the period of which 16 of them did reach Hong Kong. Verification results of this proposed scheme together with those of Morrice's criterion and Lai's rule were given in Table 6a, b and c. That the proposed scheme performs slightly better than the old ones is indicated by the slightly lower missed and false alarm rates.

5. DISCUSSION

The performance of the proposed scheme could be improved upon with the help of forecaster's subjective inference from actual observations and prognostic charts. Apart from closely monitoring the continuity of the advancement of the front/trough, the forecaster could consider the following:

i) when there is a frontal depression over east China, an increase in delta-Ps may only reflect that the frontal depression is moving away and not necessarily that a narrow ridge is establishing over southeast China. In this case, the results from the scheme should not be taken at face value.

ii) especially during night-time, reduction in data density over China might cause some artificial fluctuations in delta-P over that period, thus resulting in considerable variations in the tendency of [delta-P minus delta-Ps]. When this occurs, the forecaster should exercise some care when interpreting the results obtained from this new scheme.

6. CONCLUSIONS

In the present study, surface patterns associated with fronts/troughs over south China were surveyed. A set of guidelines was developed to assist the forecasters in predicting the arrival of troughs/fronts from the north. A summary of the scheme, in the form of a flow chart, is given in Fig. 5. The fronts/troughs arrived 31 hours on average after the criterion was met. Verification of this scheme using 1987-89 data indicates that it performs better than the two objective schemes developed by previous workers. Both Morrice's (1973) criterion and Lai's rule (1989) were in general too stringent and missed a number of front/trough arrivals during the period 1983 - 86.

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3. Lam, C.Y. 1976 500 millibar troughs passing over Lake Baikal and the arrival of surges at Hong Kong. R.O. Technical Note (local) No. 31

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Appendix I Rapid Arrival

Chosen is the case in April 1985. As there was a large pressure and temperature gradient behind the cold front, it took only 15 hours to move from Nanling to Hong Kong.

Synoptic situation

At 24 06Z, a high cell responsible for a previous surge already moved to Japan. A ridge remained over the southeast China coast. Extending from a low pressure area over southwest China was a trough running across central China. To the south of the trough, because of the generally fine weather, temperatures went up to the thirties during the day. Meanwhile another high cell appeared over the northwest corner of China where temperatures were generally in the region of 15 degrees. The temperature gradient across the front was marked. This high cell built up rapidly and delta-P rose to 14.1 at 25 03Z. The pressure gradient tightened behind the front with surface winds of over 10 kts and the front started to advance south. Cyclogenesis occurred off the east China coast at 25 12Z. The front reached Nanling at 25 15Z. Meanwhile, the subtropical ridge along the south China coast weakened rapidly, allowing the cold front to move rapidly south and arrive at Hong Kong in just 15 hours. The sequence of weather patterns is shown in Fig. 6a-k.

Appendix II Slow arrival

This trough took nearly 7 days to reach Hong Kong after it formed over central China. There were three distinct pressure pulses during the 7 days and the trough failed to reach Hong Kong until after the third pulse occurred. The first pressure pulse pushed the trough to around Guangzhou but fell short of Hong Kong as the push weakened and became shifted to the east. The trough retreated to the Nanling range before the third push arrived and pushed it south and finally past Hong Kong at 25 00Z Mar 1987.

Synoptic situation

A trough formed over central China at 06Z 18 Mar 1987 (Fig. 7aa-ba). A high cell appeared at 18 12Z at around 36°N 110°E. The pressure gradient behind the trough became tightened to around 3 hPa/deg at 18 18Z. The trough reached the Nanling range at around 18 21Z. Cyclogenesis occurred off the east China coast at 19 00Z. With the tight pressure gradient persisting behind the trough, it crossed the Nanling range by 19 06Z. The trough moved south at first but then slowed down near Guangzhou. At 19 09Z, the main high centre moved to east of 117°E. This high cell then moved east rapidly and delta-Ps started to drop at 19 15Z. Cooler easterlies originating from further north failed to arrive. With the pressure gradient decreasing to around 1.5 hPa/deg, the trough became slow-moving and lingered around Guangzhou. At 20 03Z, a high cell, at 36°N 108°E, moved east and strengthened, replenishing the ridge along the east China coast. Delta-Ps rose to 7.3 at 20 06Z. Delta-Ps continued to increase afterwards and easterlies headed south along Taiwan Strait. Delta-Ps peaked at 9.8 at 20 21Z. Winds backed to easterlies by 21 06Z and the trough gradually retreated to Nanling. At 22 00Z, a ridge started to build along 110°E. The pressure gradient tightened behind the trough. At 22 12Z, a high cell appeared at 36°N 108°E. This high cell was rather weak and no significant increase in the delta-P value was observed. Nevertheless, as the gradient had already tightened behind the trough, it moved south gradually passing the Nanling range at 23 18Z. The high cell intensified at 23 21Z. The gradient spread south and the front passed Guangzhou at 24 12Z and Hong Kong at 25 00Z.

Appenix III Failure to reach Hong Kong

In this case, because of the rapid movement of the centre of high pressure to east China, the trough failed to reach Hong Kong even though the pressure gradient behind the trough was as high as 8 hPa/deg at one time.

Synoptic Situation

A trough formed over the southern part of central China at 06Z 12 Mar 1987 (Fig. 8a-t). An anticyclone moved east at 12 12Z. Delta-P was 5.1. As the anticyclone intensified, delta-P rose to 14.4 hPa at 13 18Z. The pressure gradient behind the trough was tight, around 8 hPa/deg. With such a tight gradient behind the trough, it moved south and crossed Nanling at 14 09Z. The gradient remained very tight at this moment, around 3.6 hPa/deg. However, the push from the north has substantially weakened after the high centre moved east of 115°E at 14 00Z. A narrow ridge began to form along the southeast China coast and easterlies marched down Taiwan strait. Locally, winds backed to easterlies at 14 21Z and picked up at around 15 12Z. The trough stayed at around Guangzhou which then gradually dissipated.

Table 1a Performance of Morrice's criterion (1973) in forecasting the arrival of front/trough in the late cool seasons of 1983 - 1986

	Criterion not fulfilled	Criterion fulfilled
Arrival at HK	7 cases (missed 33%)	14 cases
Nil arrival	6 cases	2 cases (false alarm rate 13%)

Time taken	average	standard deviation
	29.6 h	19.8 h

Table 1b Performance of Lai's rule (1989) in forecasting the arrival of front/trough in the late cool seasons of 1983 - 1986

	criterion not fulfilled	criterion fulfilled
Arrival at HK	6 cases (missed 29%)	15 cases
Nil arrival	4 cases	4 cases (false alarm rate 21%)

Time taken	average	standard deviation
	17.4 h	12.4 h

Table 2 Time taken for a front/trough at the Nanling range to reach Hong Kong in the late cool seasons of 1983 - 1986

no. of days	no. of occurrences
≤ 1	8
1 - 2	9
2 - 3	3
3 - 4	1
never	8

	29

Table 3 No. of arrivals of fronts/troughs at various synoptic hours in the late cool seasons of 1983 - 1986

synoptic hour	no. of occurrences
00	2
03	2
06	2
09	4
12	1
15	3
18	3
21	4

Table 4 Performance of proposed criterion in forecasting the arrival of front/trough in the late cool seasons of 1983 - 1986

	criterion not fulfilled	criterion fulfilled
Arrival at HK	5 cases (missed 24%)	16 cases
Nil arrival	5 cases	3 cases (false alarm rate 16%)

	average	standard deviation
Time taken	30.9 h	16.2 h

Table 5 Lead time of the proposed criterion

Lead time	no. of occasions	Cumulative frequency (%)
≤ 12	1	6.25
13 - 24	6	43.75
25 - 36	5	75.00
37 - 48	2	87.50
49 - 60	0	87.50
61 - 72	2	100.00

Table 6a Performance of Morrice's criterion in predicting the arrival of fronts/troughs in the late cool seasons of 1987 - 1989

	criterion not fulfilled	criterion fulfilled
Arrival at HK	4 cases (missed 25%)	12 cases
Nil arrival	2 cases	1 case (false alarm rate 8%)

Table 6b Performance of Lai's rule in predicting the arrival of fronts/troughs in the late cool seasons of 1987 - 1989

	criterion not fulfilled	criterion fulfilled
Arrival at HK	5 cases (missed 31%)	11 cases
Nil arrival	2 cases	1 case (false alarm rate 8%)

Table 6c Performance of proposed criterion in predicting the arrival of fronts/troughs in the late cool seasons of 1987 - 1989

	criterion not fulfilled	criterion fulfilled
Arrival at HK	1 case (missed 6%)	15 cases
Nil arrival	3 cases	0 case

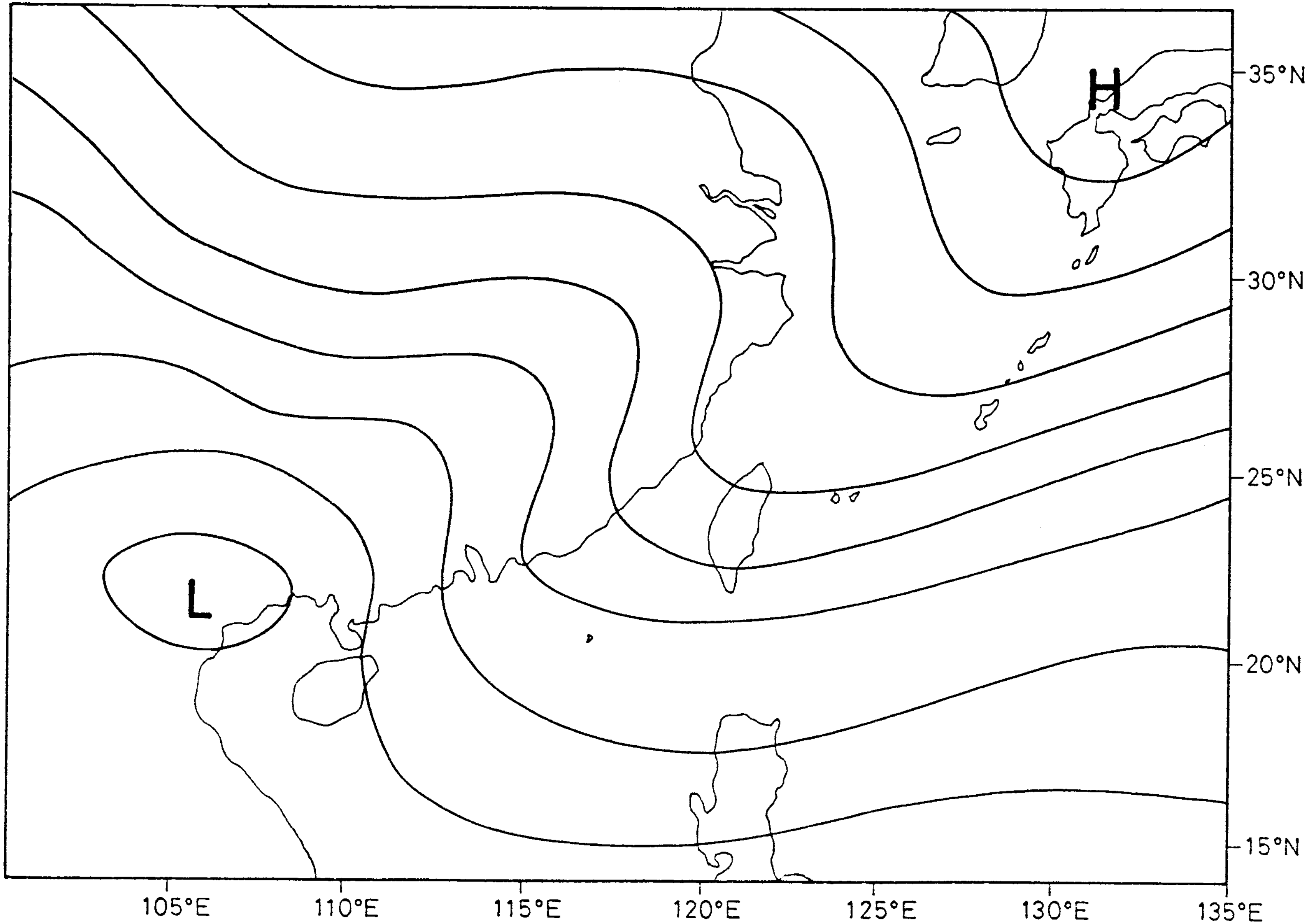


Fig. 1a   Formation of an area of high pressure over Japan which extended southwestward to cover the southeast China coast in the late cool season

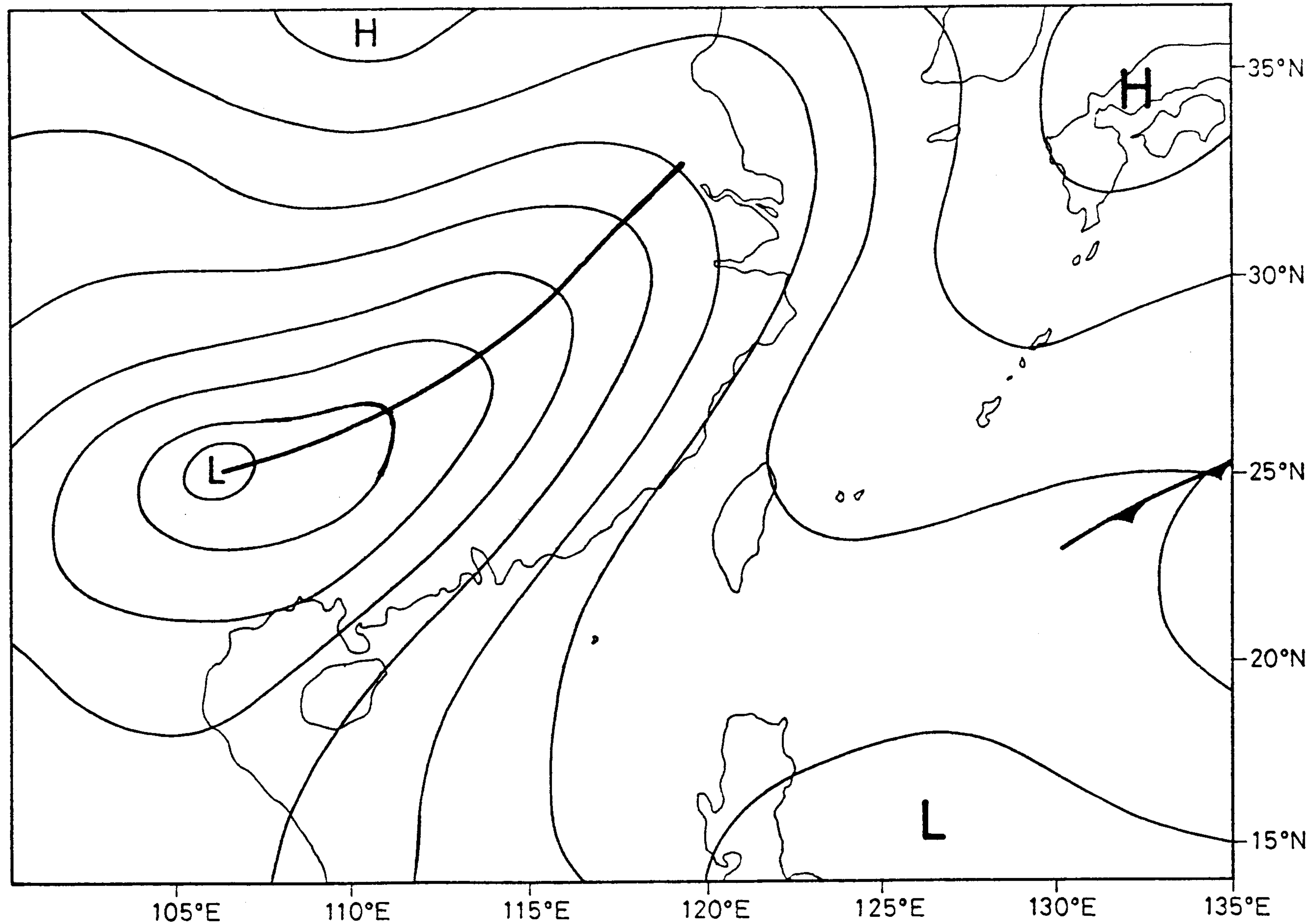


Fig. 1b   A trough or quasi-stationary front forming over Central China

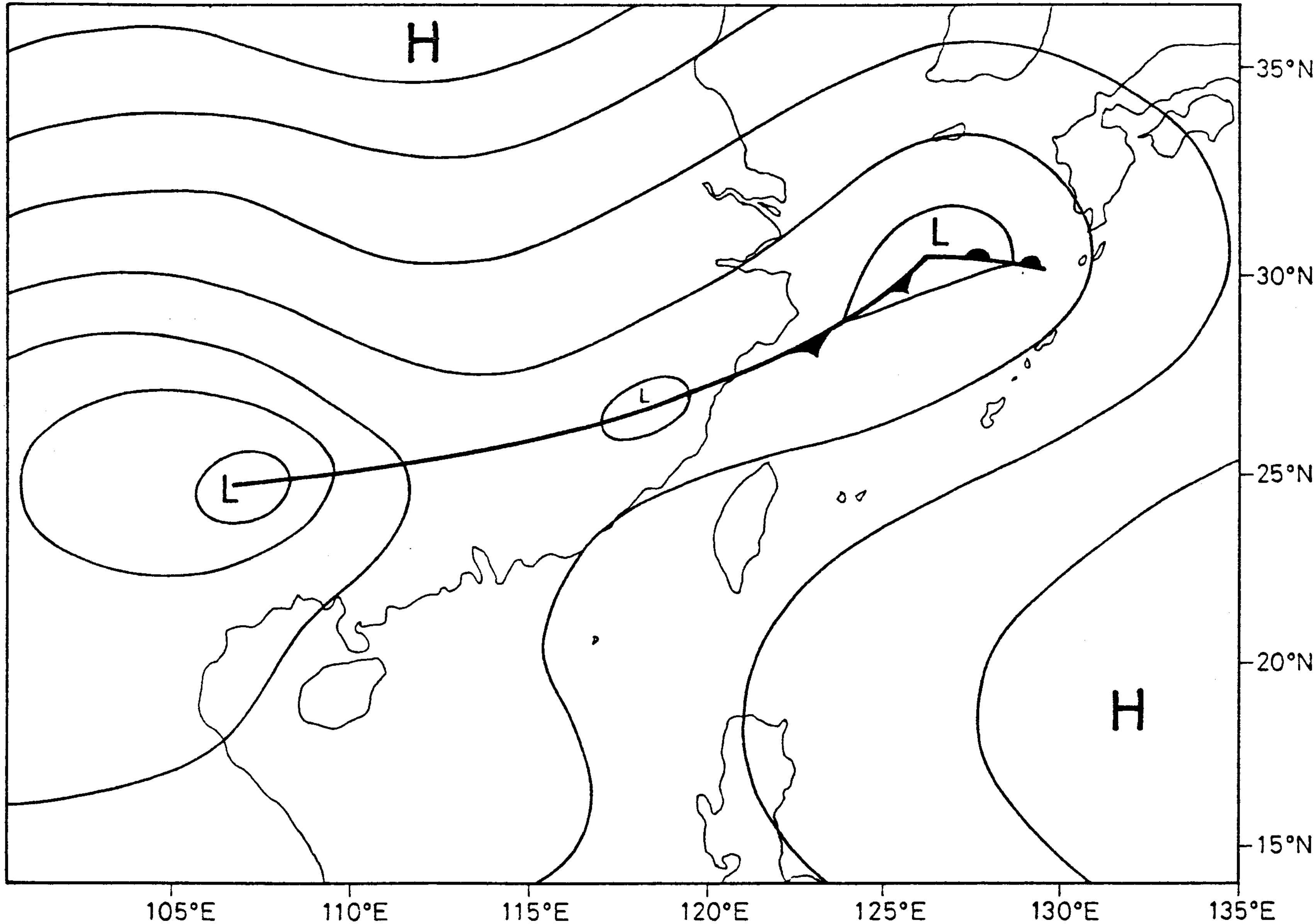


Fig. 1c   Cyclogenesis over East China with a cold front linking to the trough over Central China

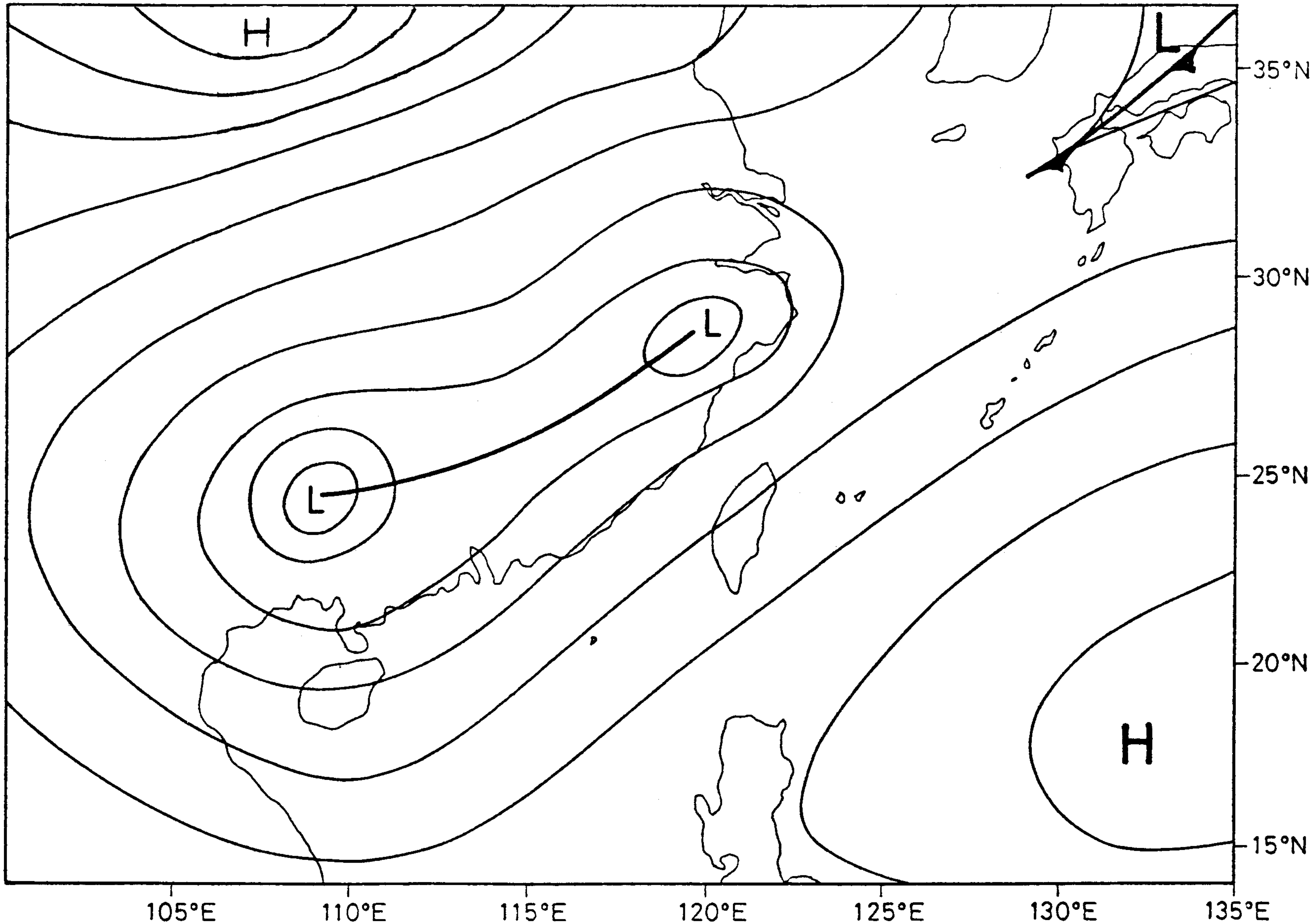


Fig. 1d   Pressure rise over China followed by tightening of pressure gradient behind the trough

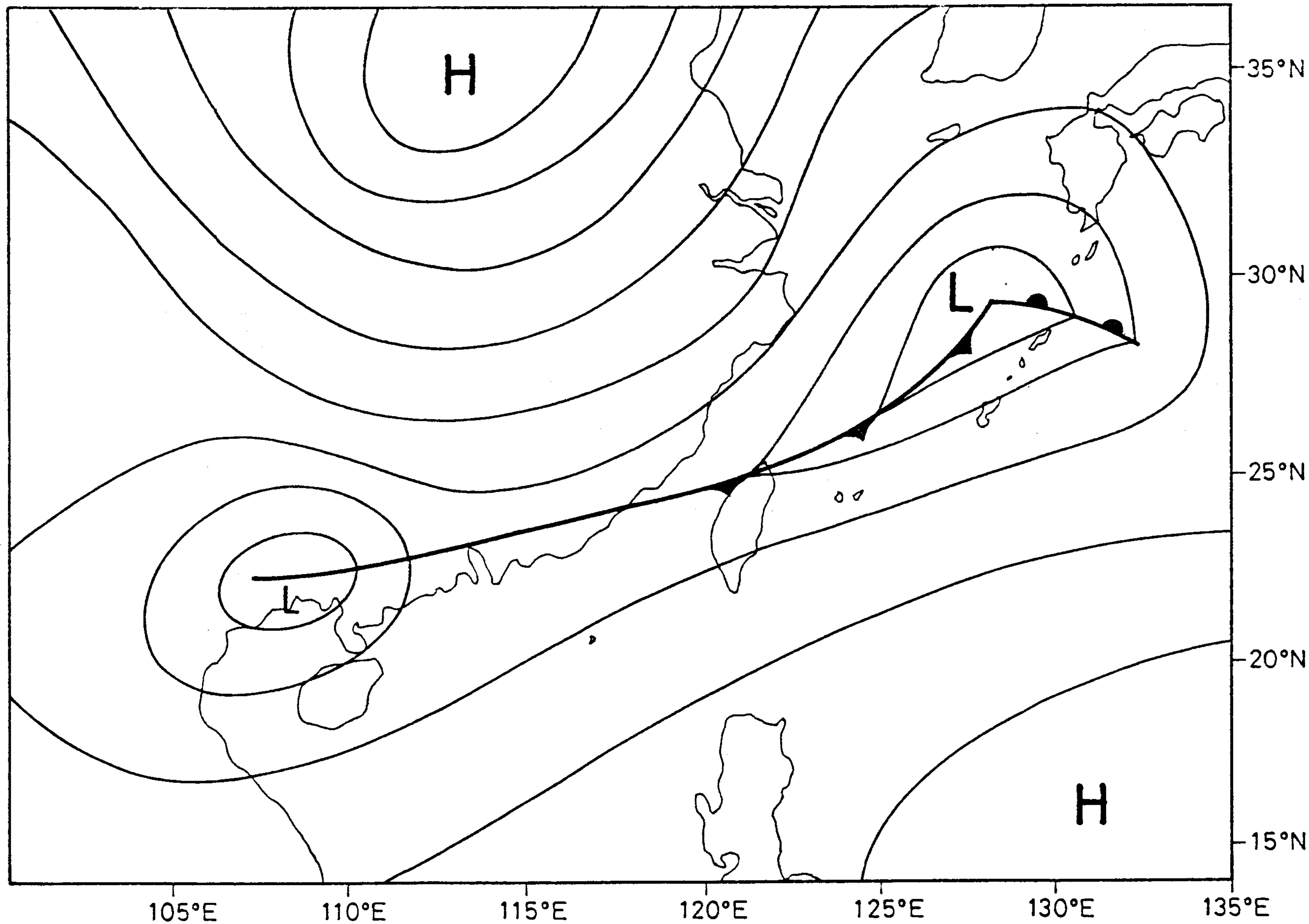


Fig. 1e Southward movement of trough to south China

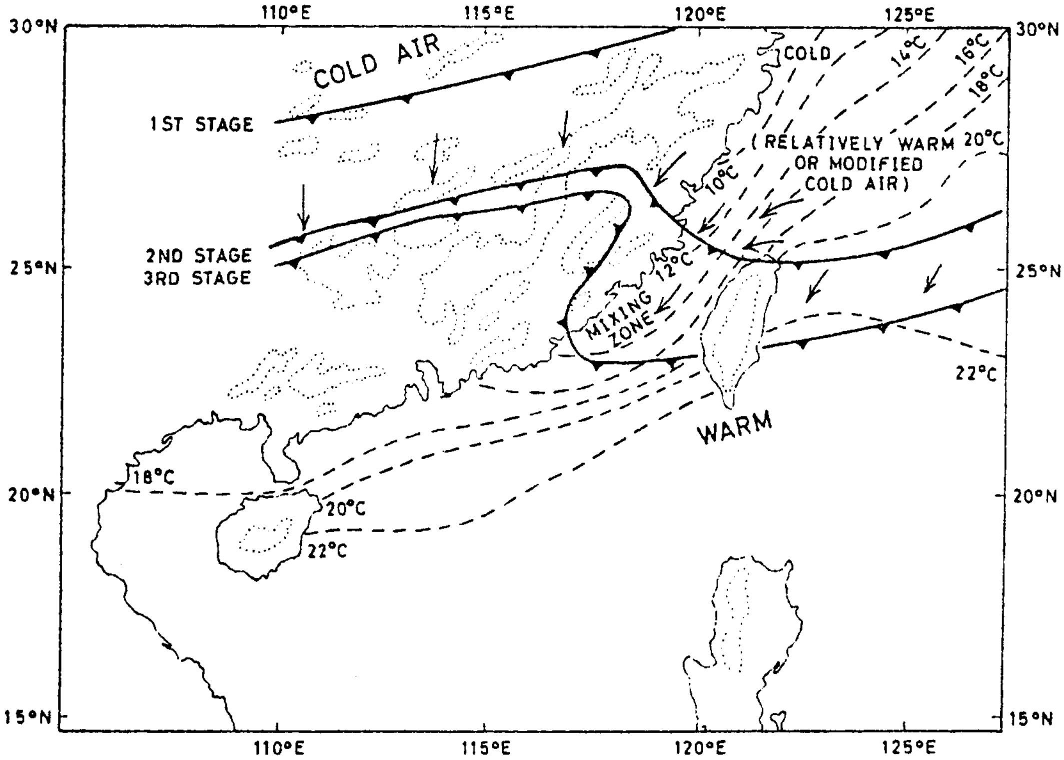


Fig. 2 Southward movement of a cold front over south China

Isotherm of mean sea surface temperature for February

Cold front

(Adapted from Chin (1969))

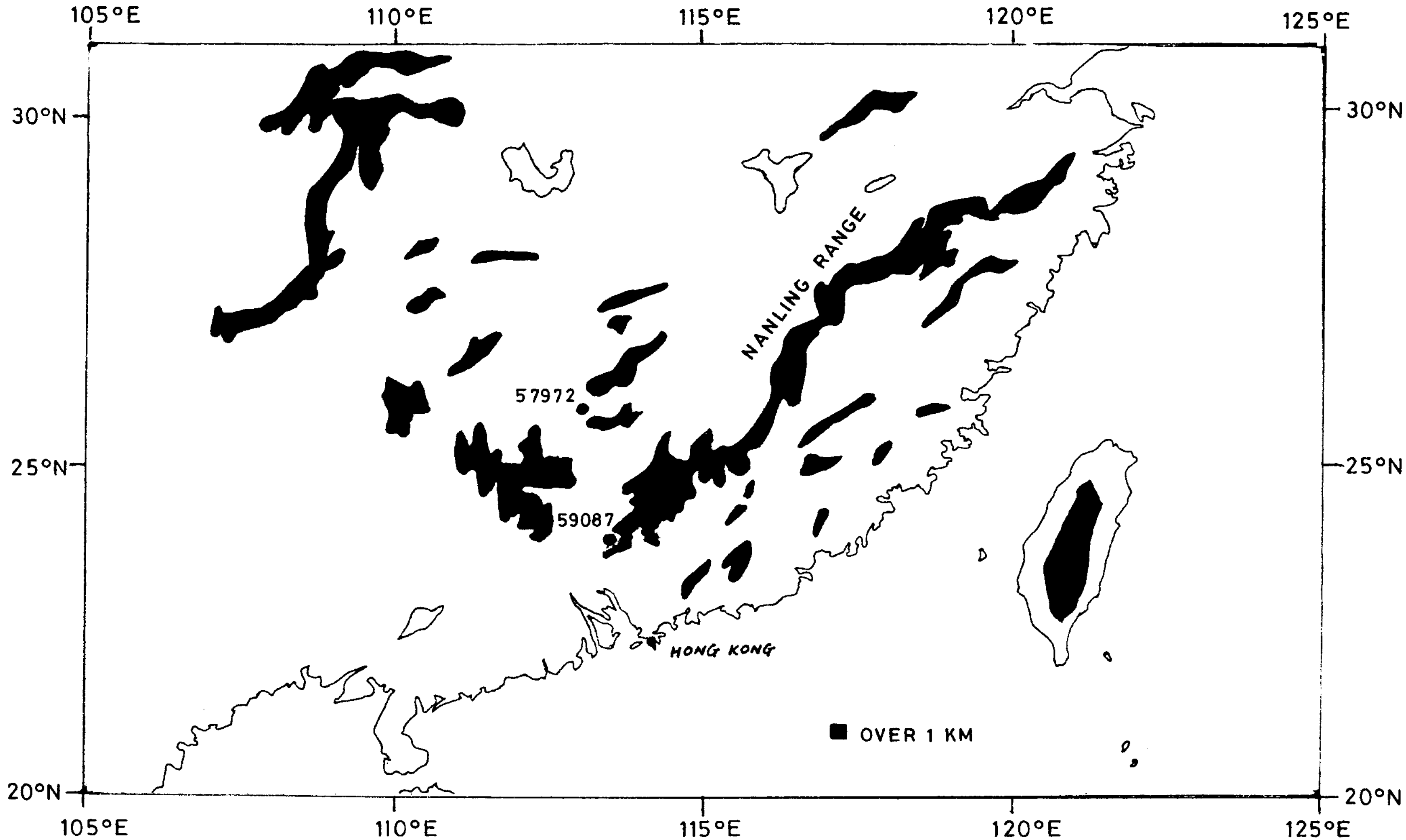


Fig. 3 Location of Chengzhou (57972) and Fogang (59087) and the topography over central and south China

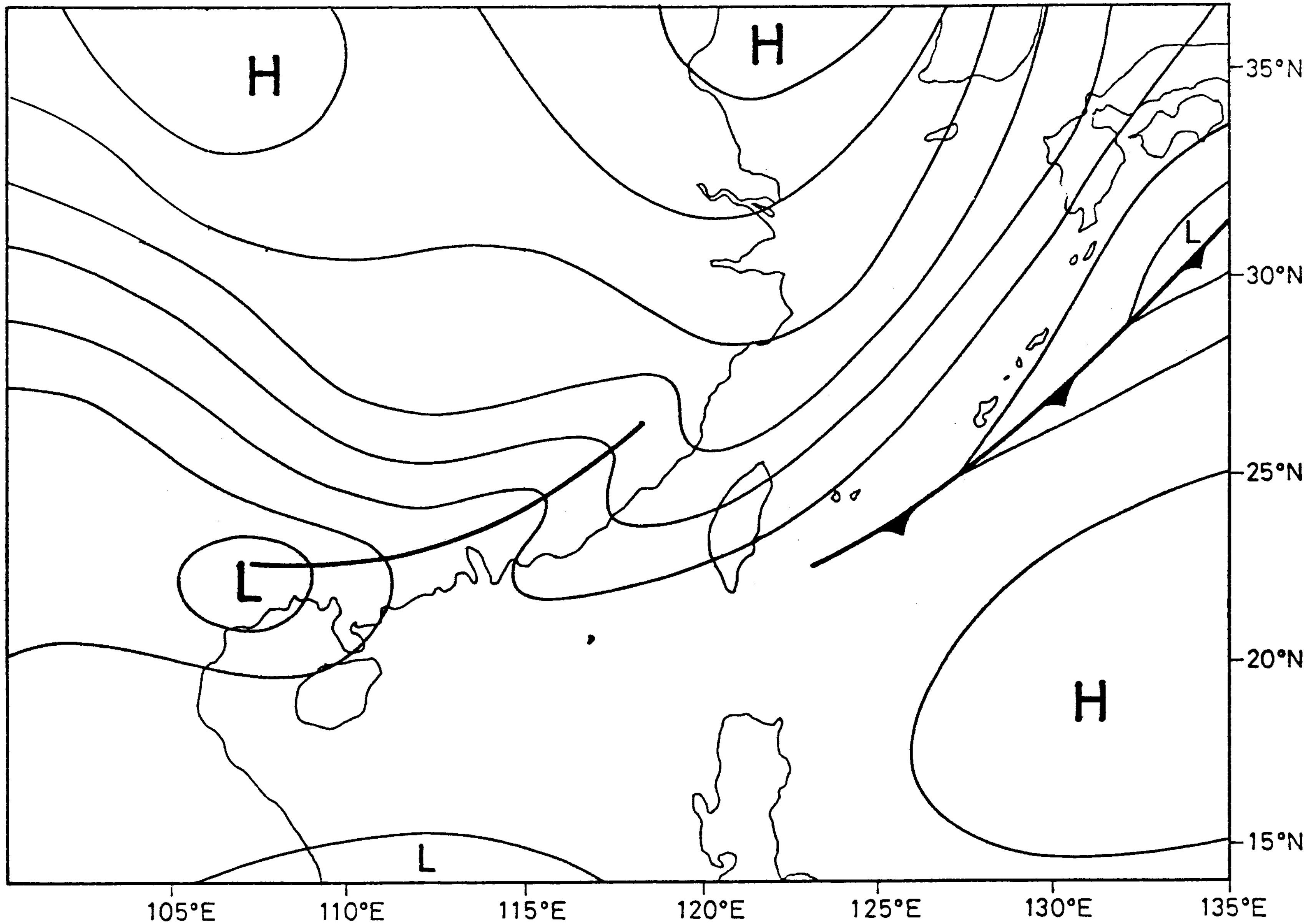


Fig. 4 A ridge of high pressure extended southwestward along the Southeast China Coast checking the southward advancement of the trough

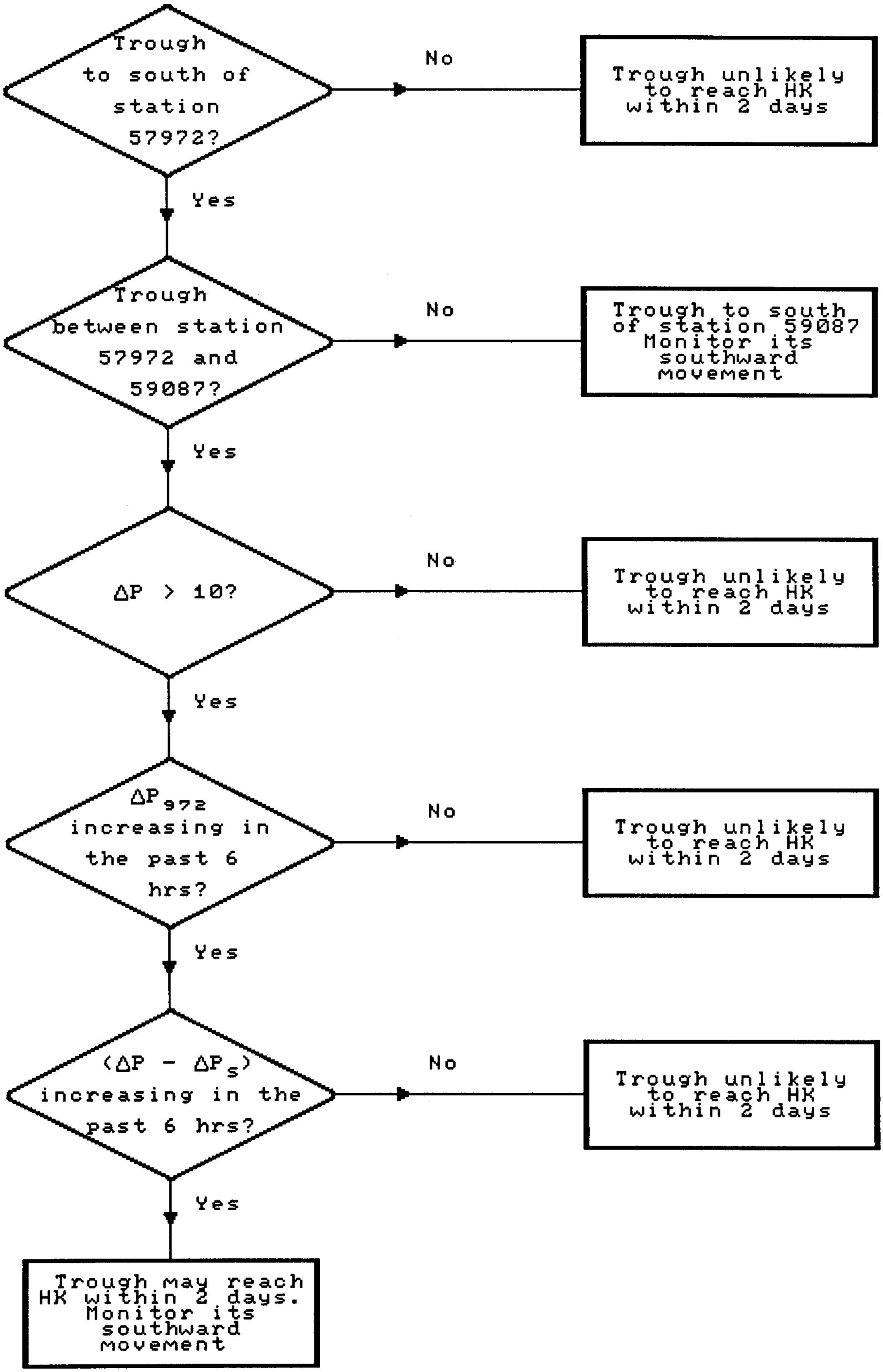


Fig. 5 Flow chart of the arrival of front/trough in late cool season (February - April)

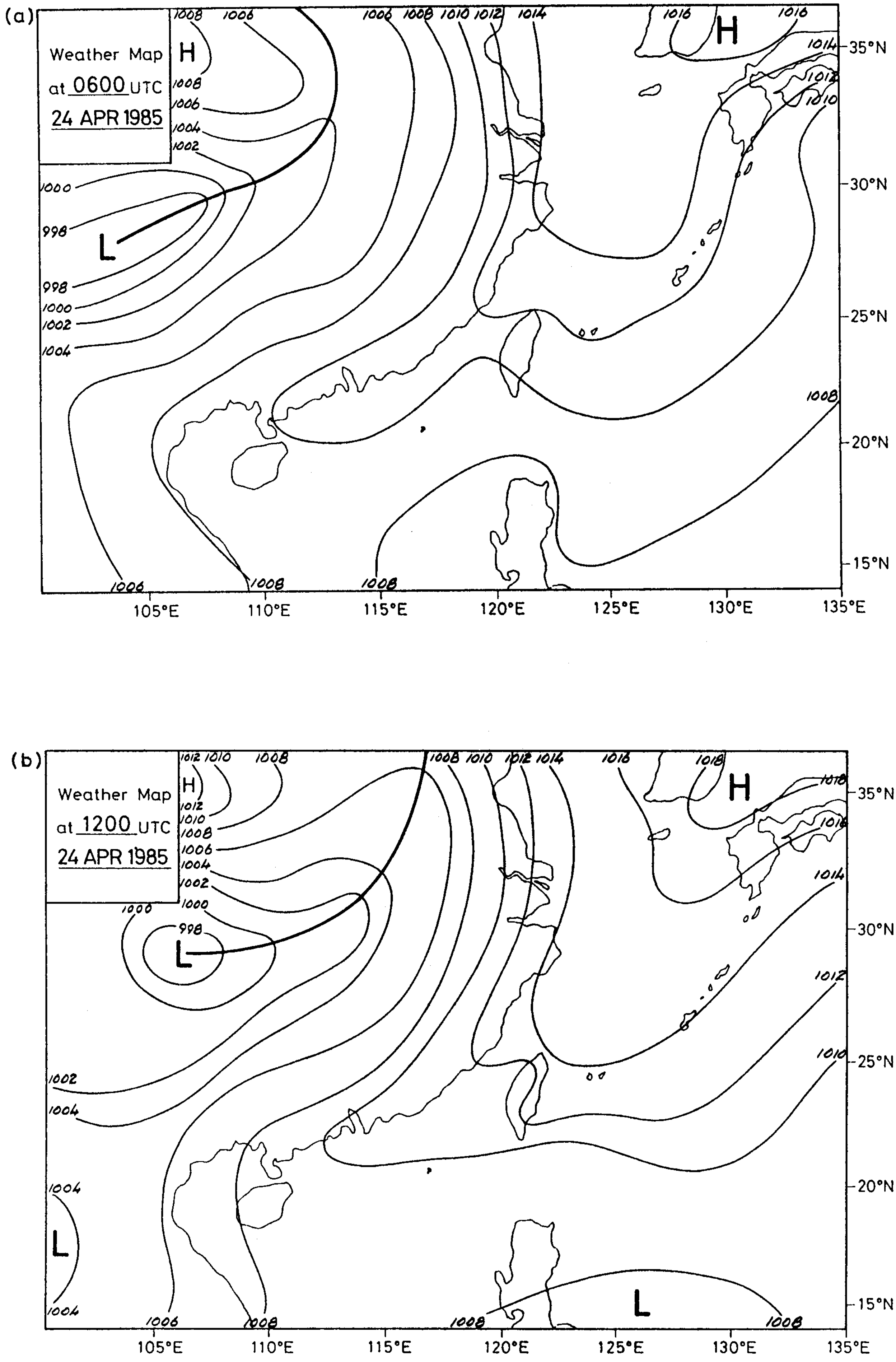
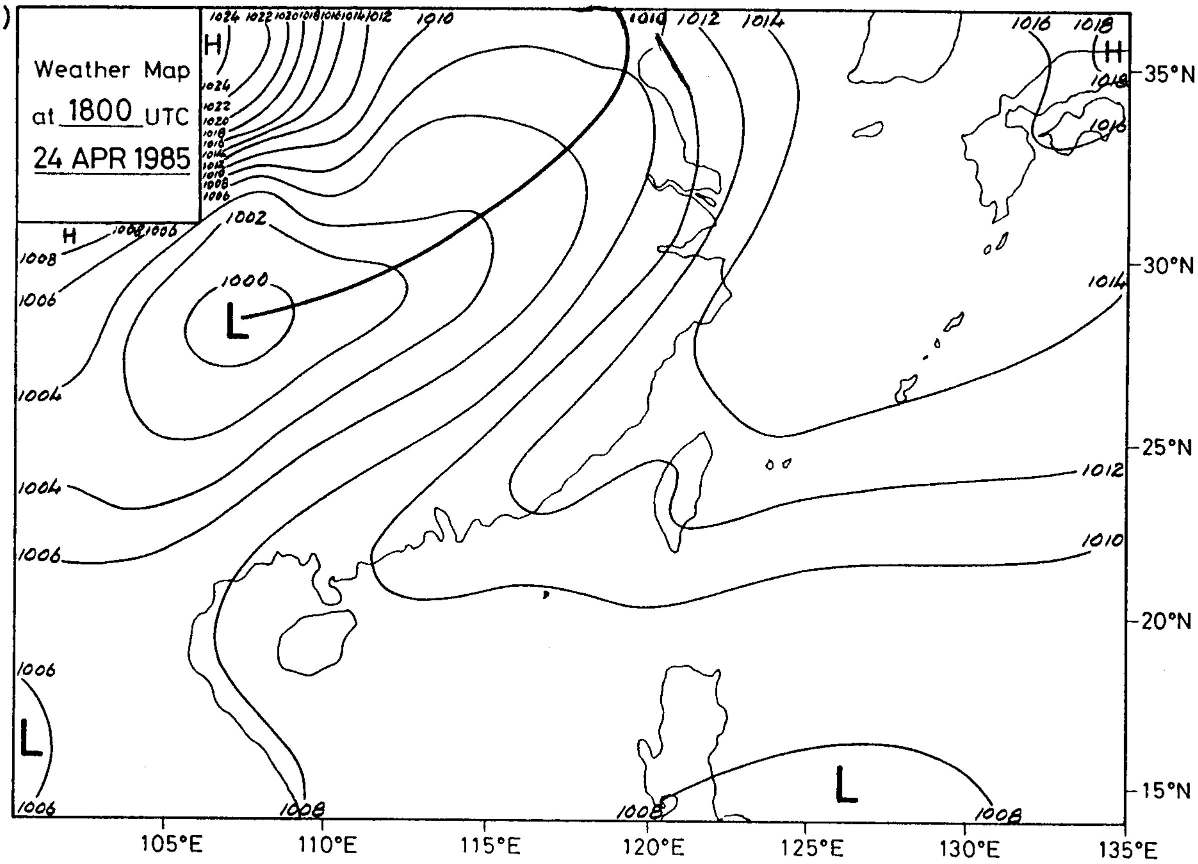


Fig. 6 Weather map associated with a rapid arrival
(0600 UTC 24 Apr 1985-1800 UTC 26 Apr 1985)

(c)


Weather Map
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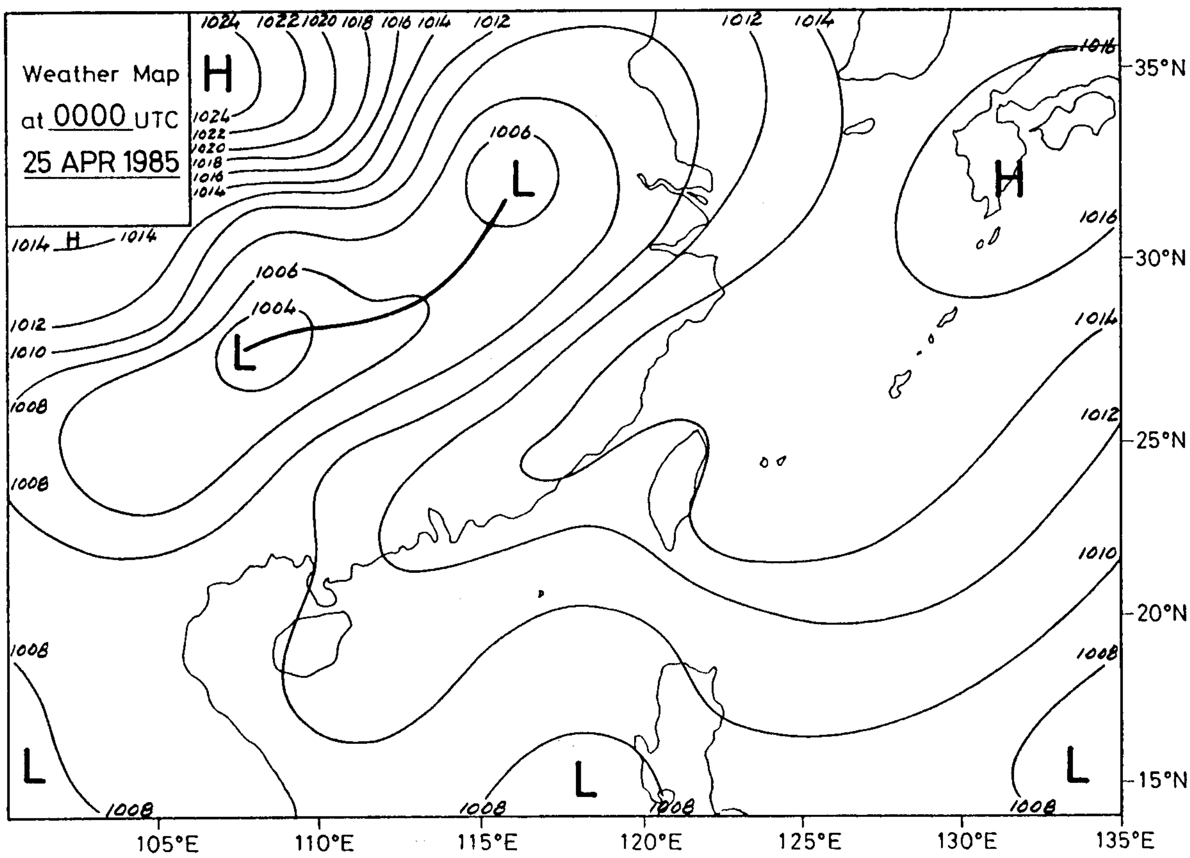
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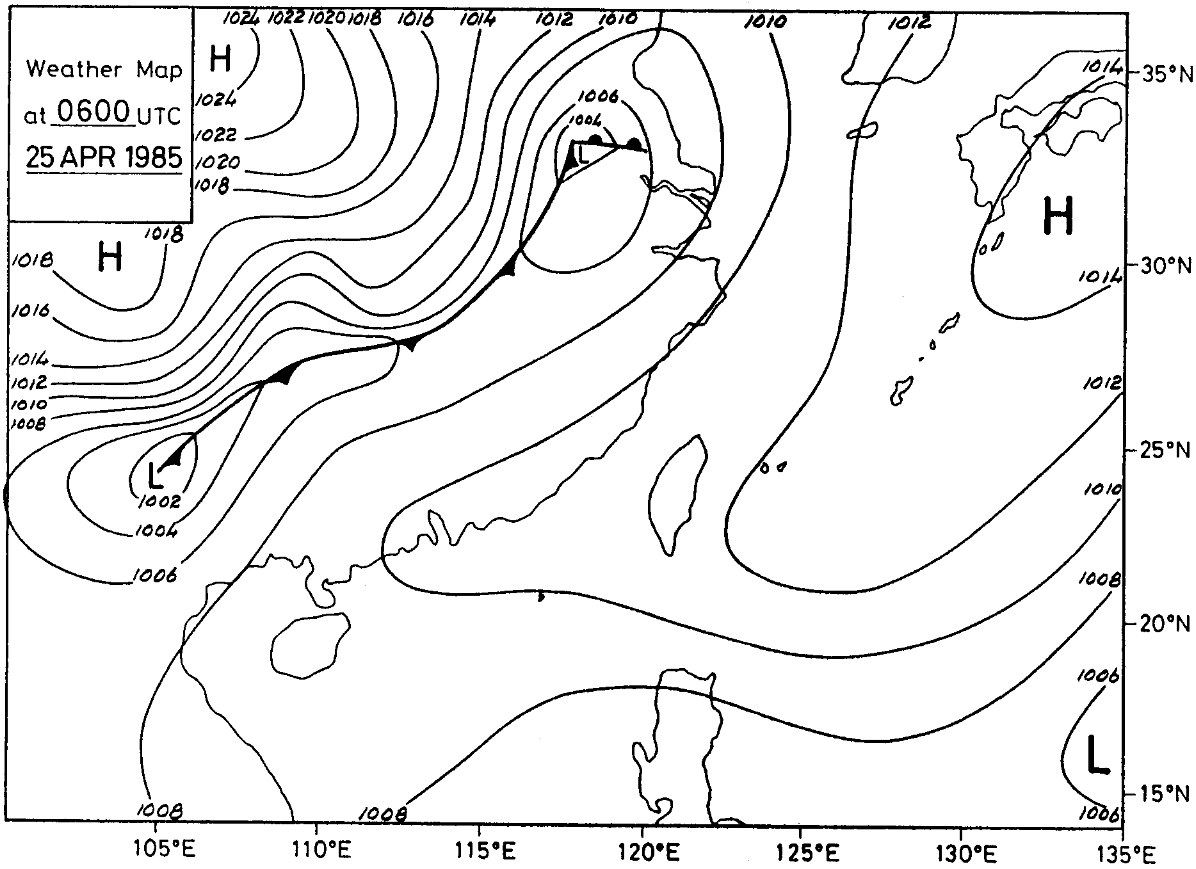
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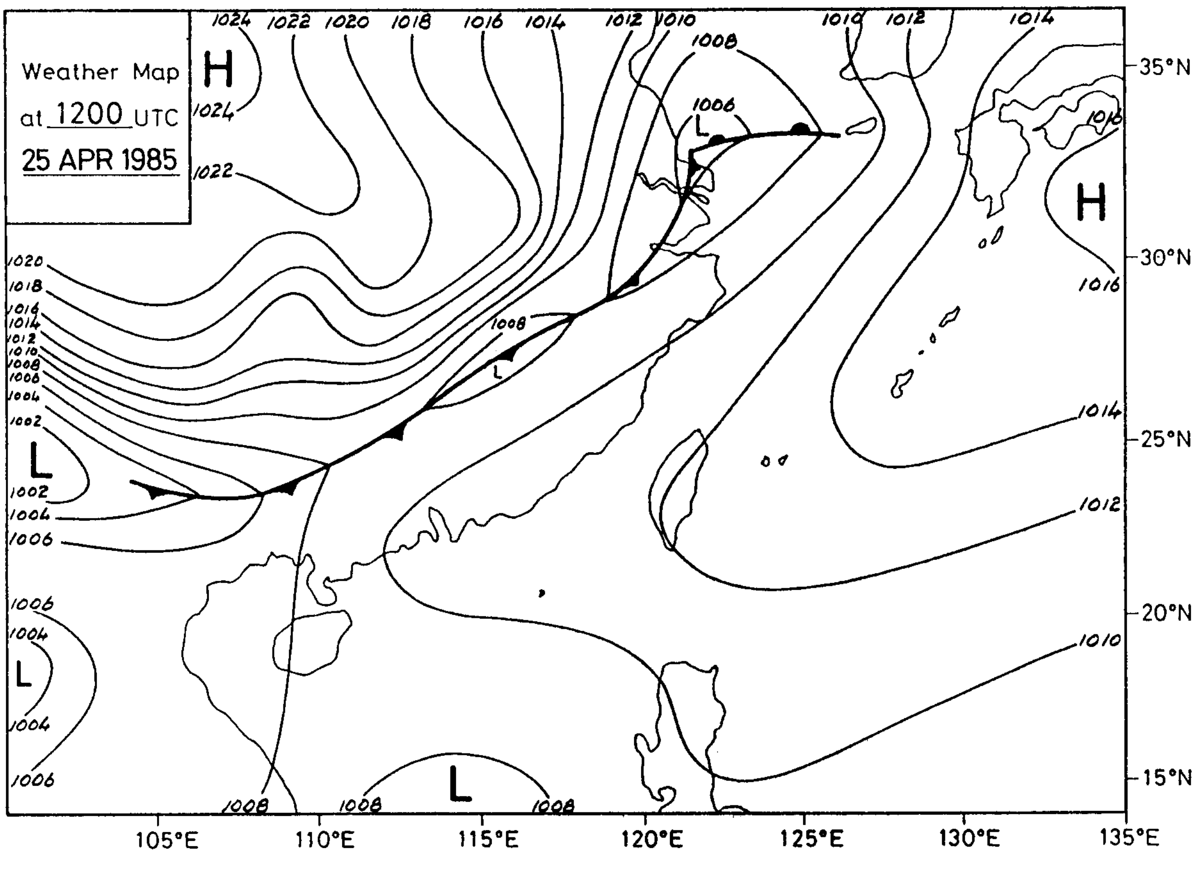
(f)


Weather Map
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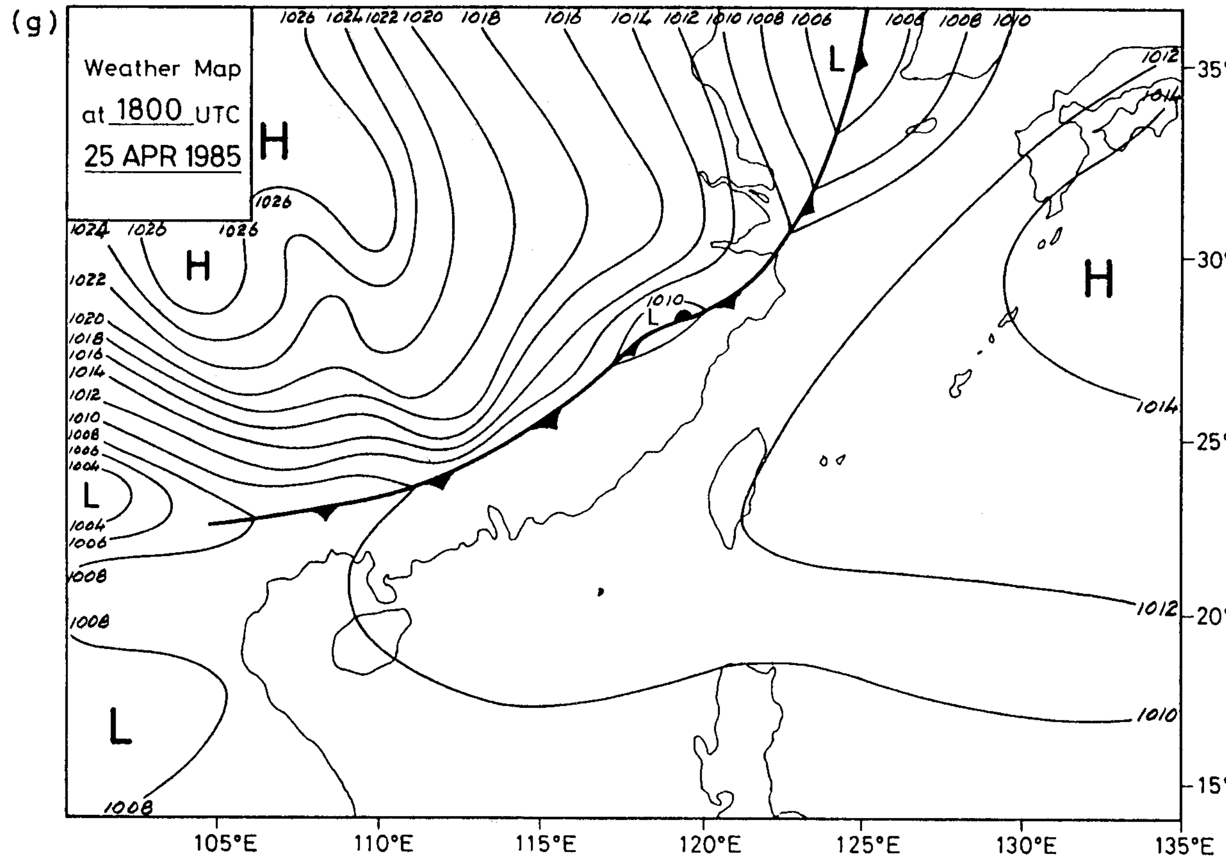
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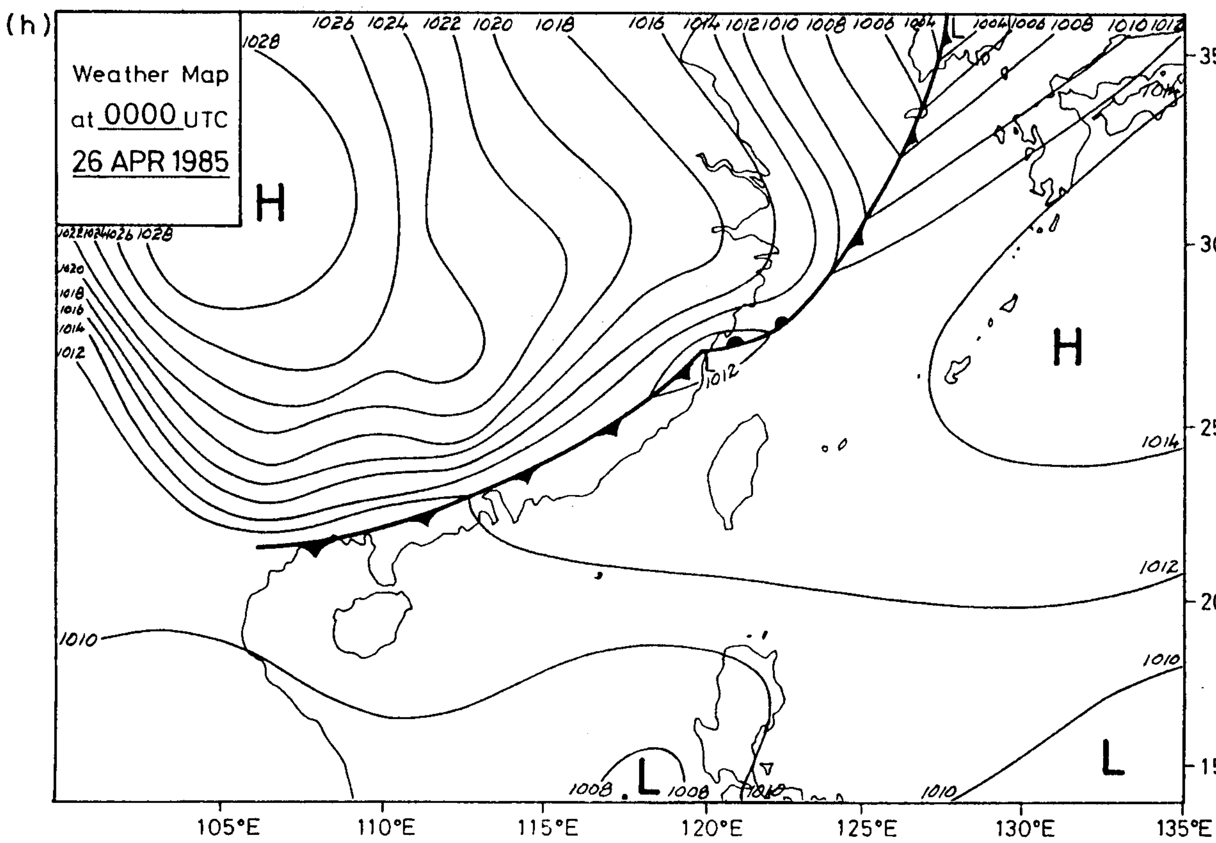
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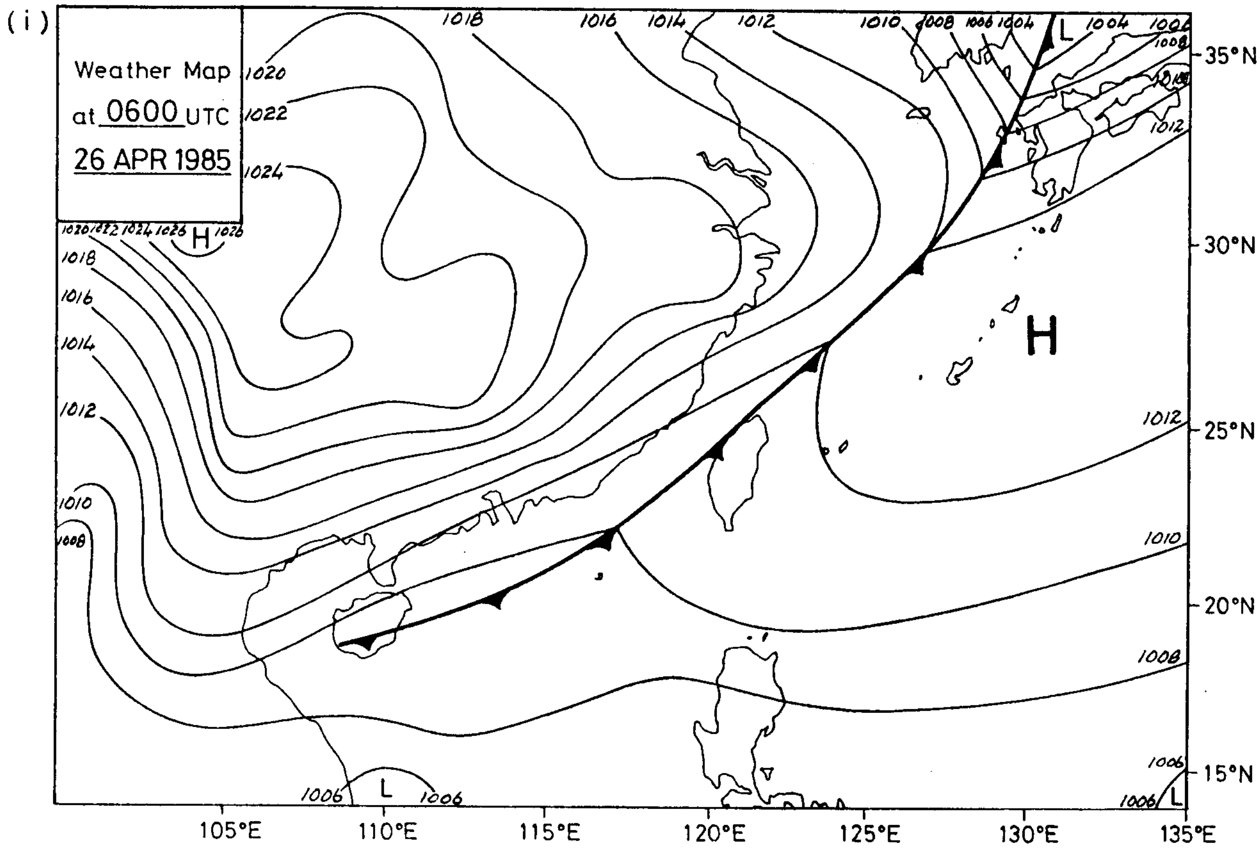
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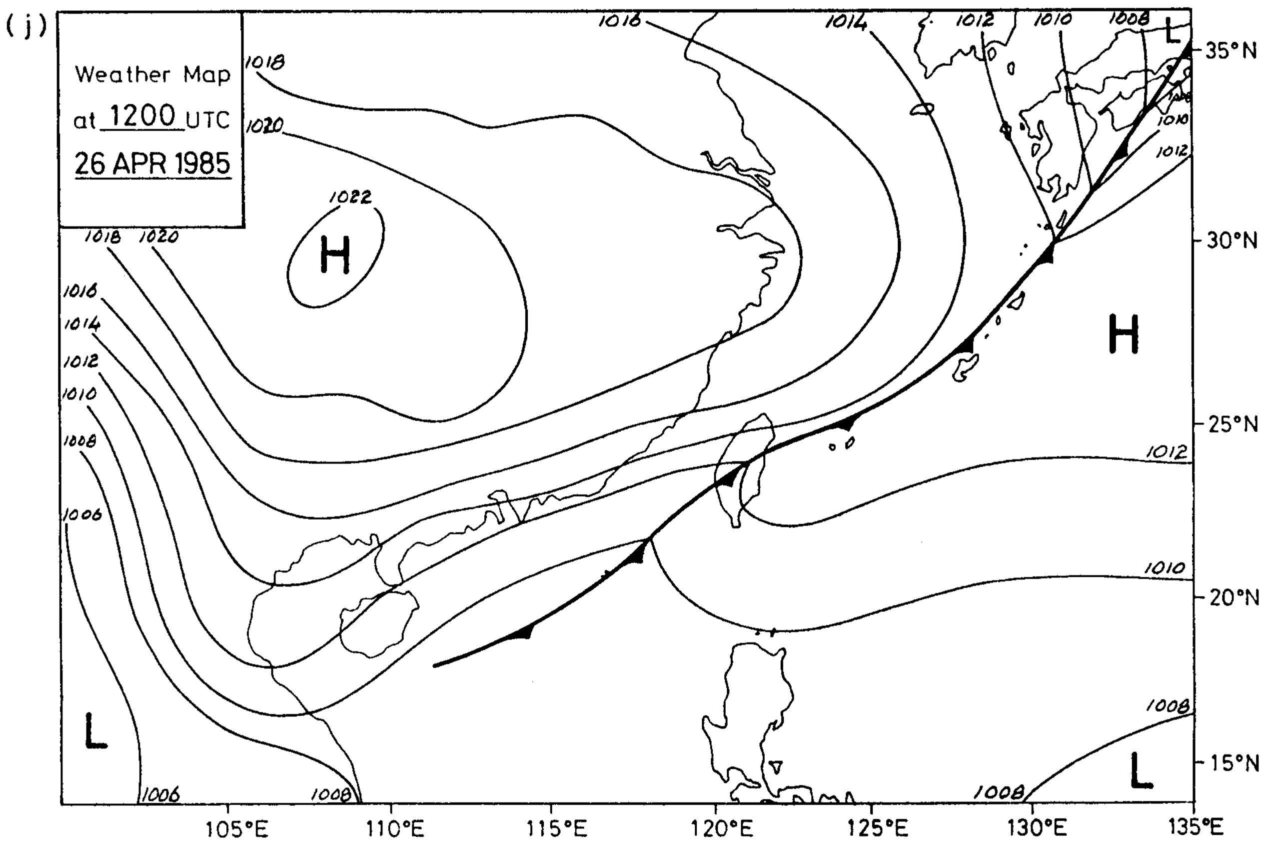
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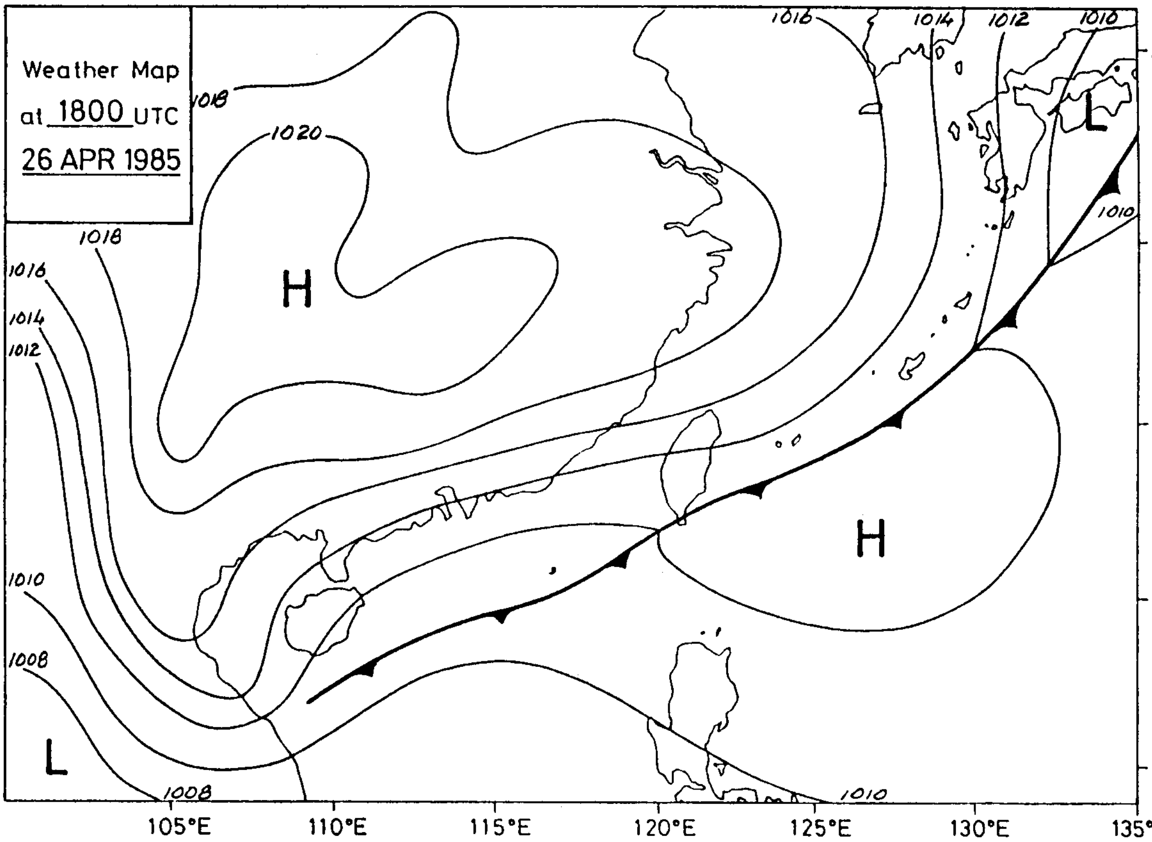
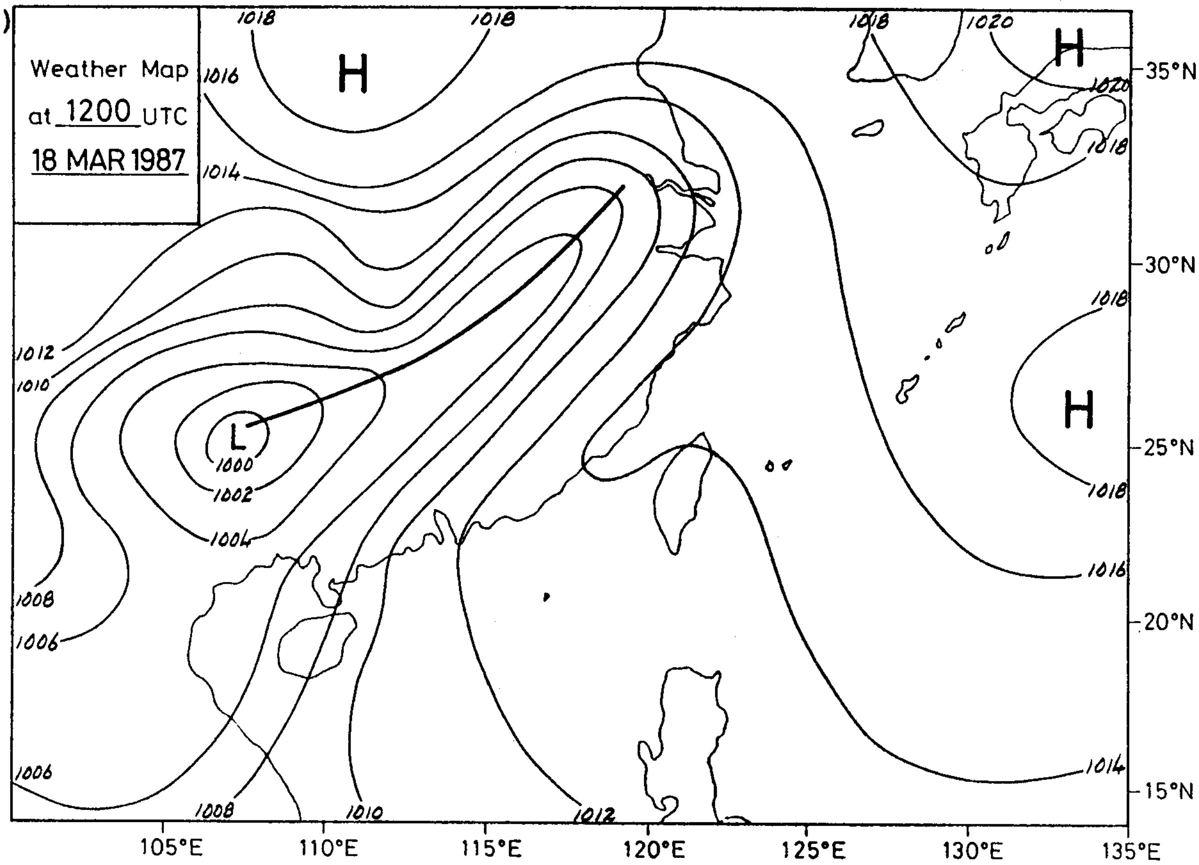
125°E
130°E
135°E

(k)


Weather Map
at 1800 UTC
26 APR 1985
1020
1018
1016
1014
1012
1010
1008
H
H
L
L
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(aa)



(ab)

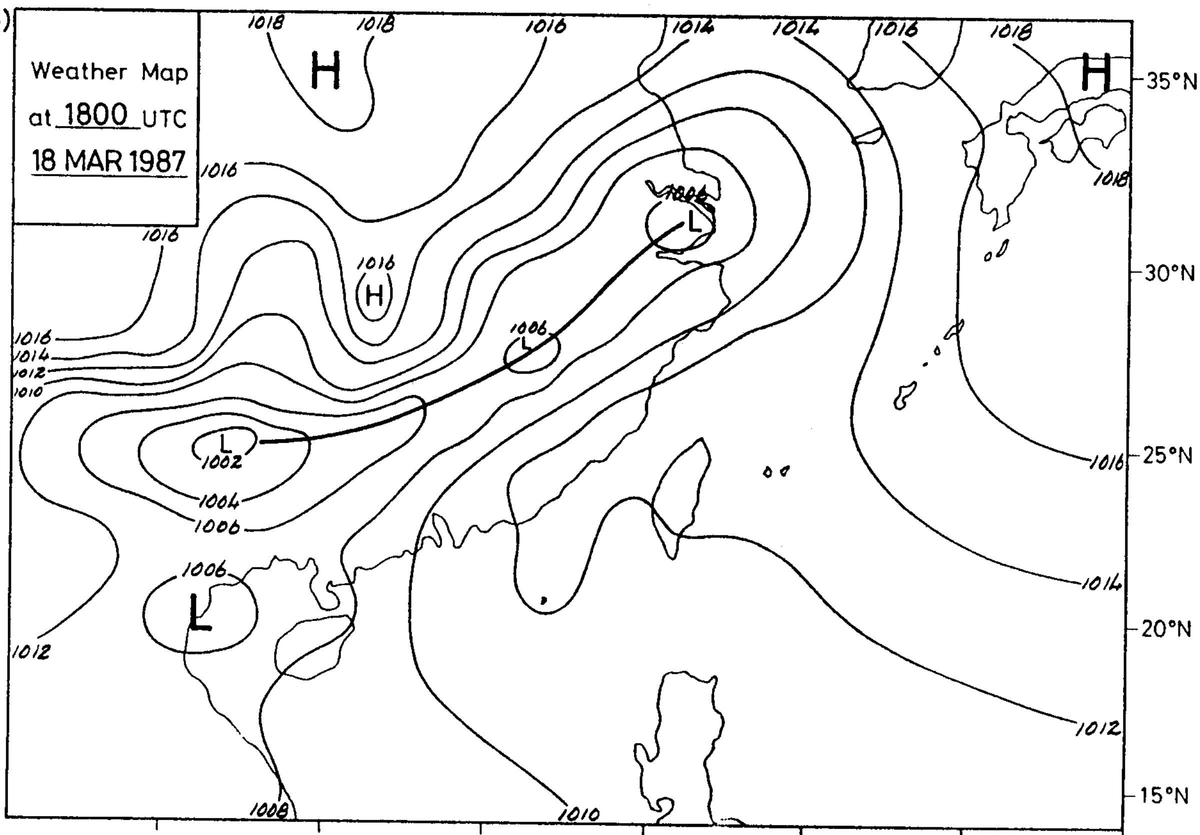
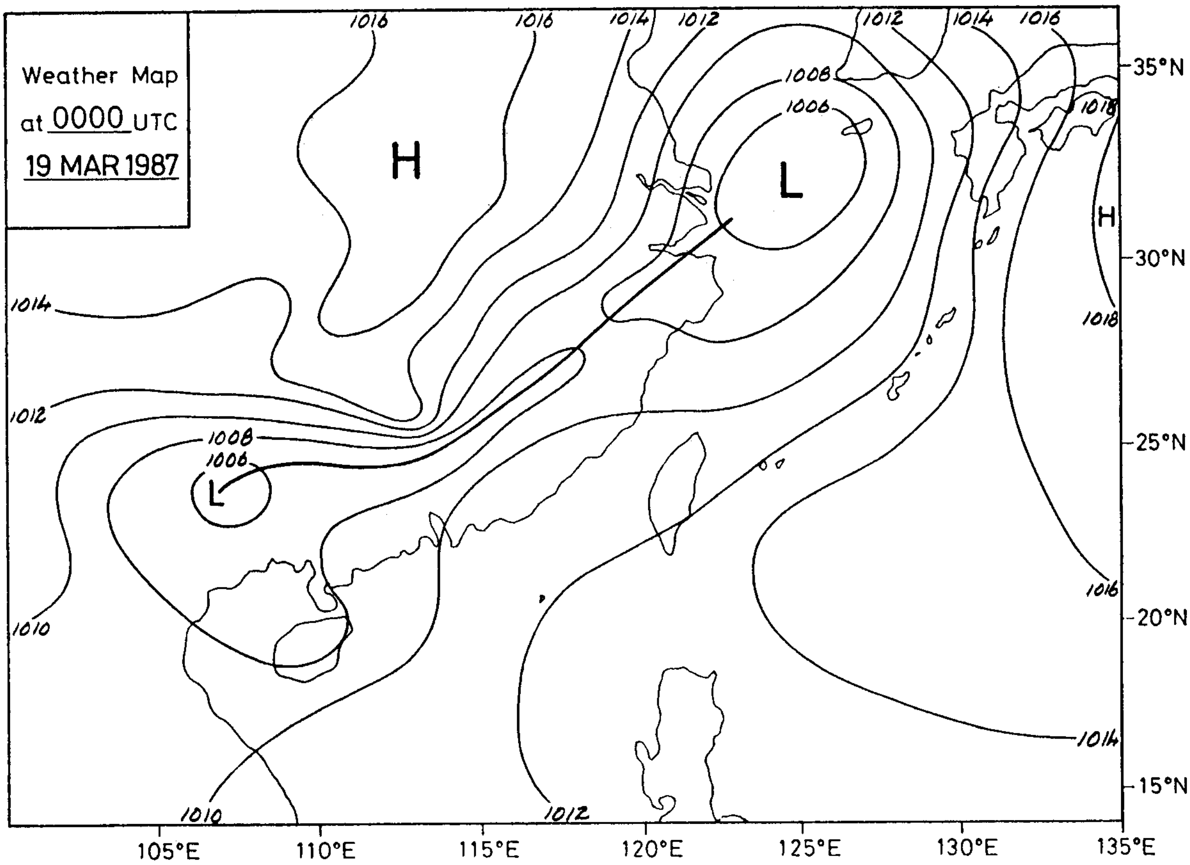
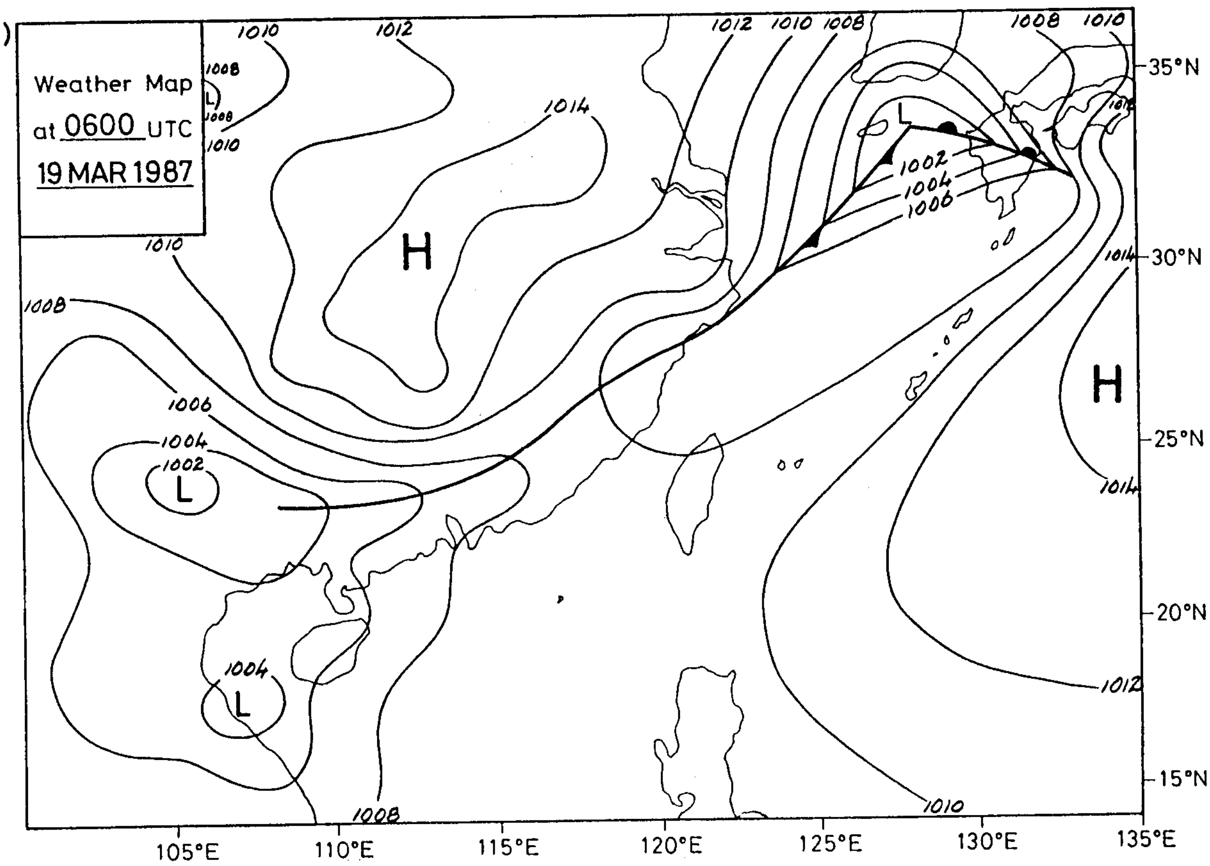


Fig. 7 Weather map associated with a slow arrival (1200 UTC 18 Mar 1987-0000 UTC 25 Mar 1987)

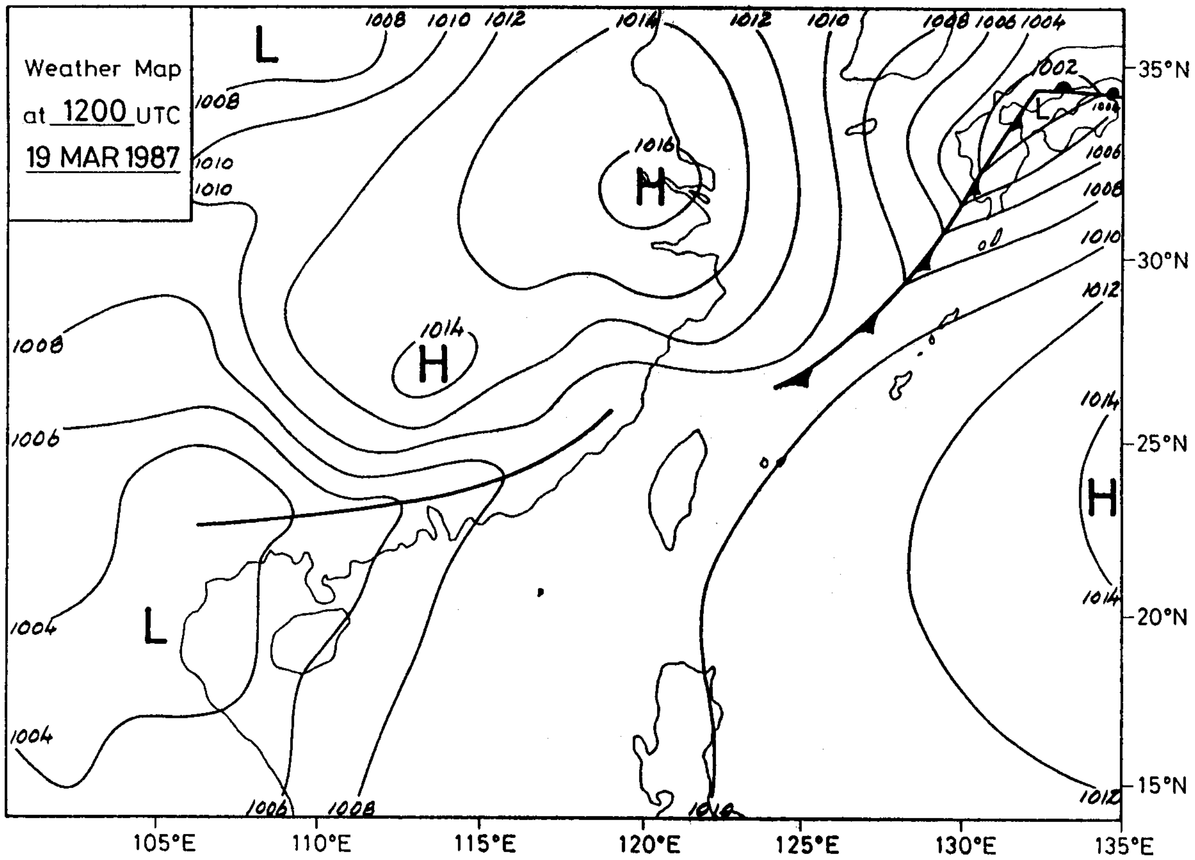
(ac)


Weather Map
at 0000 UTC
19 MAR 1987
H
L
L
H
1016
1016
1014
1012
1012
1014
1016
1008
1006
1018
1014
1012
1008
1006
1010
1010
1012
1016
1014
1018
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

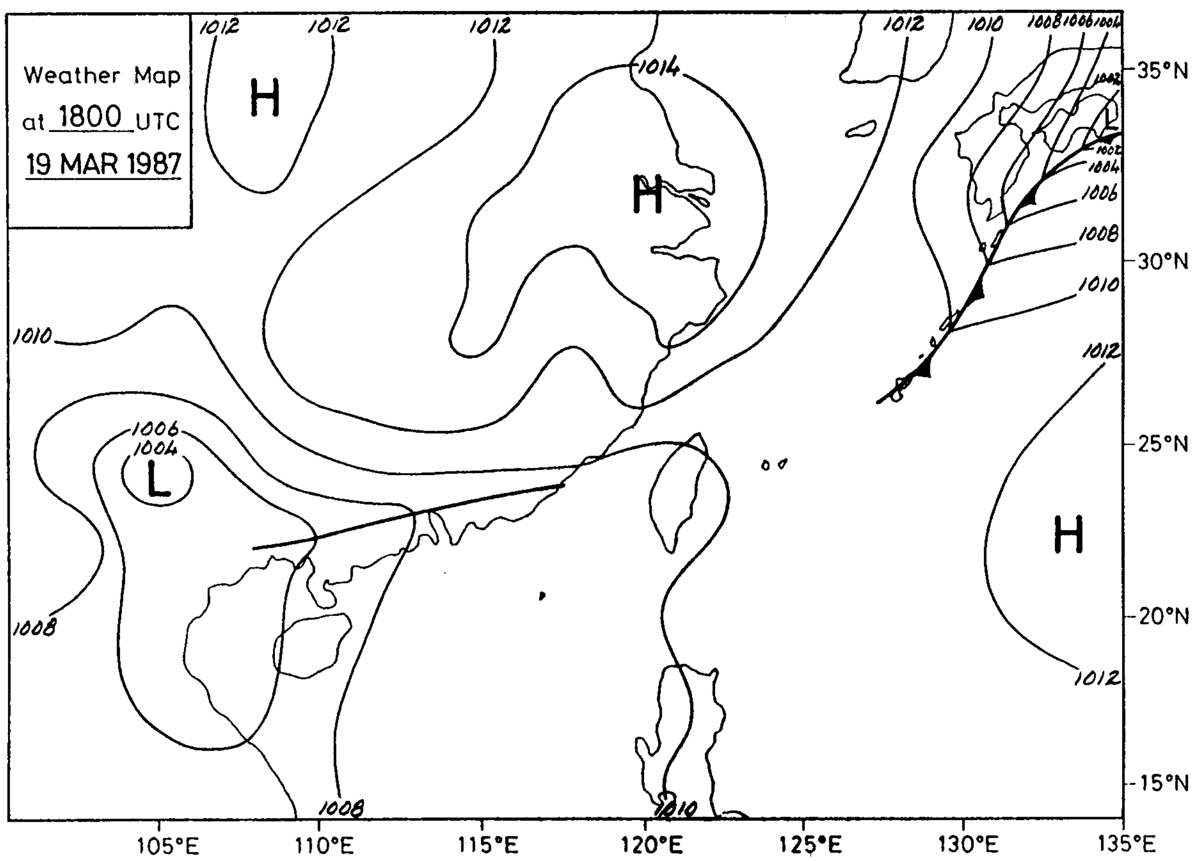
(ad)


Weather Map
at 0600 UTC
19 MAR 1987
1010
1012
1008
1008
1010
1014
H
1010
1008
1006
1004
1002
L
1004
L
1008
1012
1010
1008
L
1002
1004
1006
1008
1010
H
1014
1014
1012
1010
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

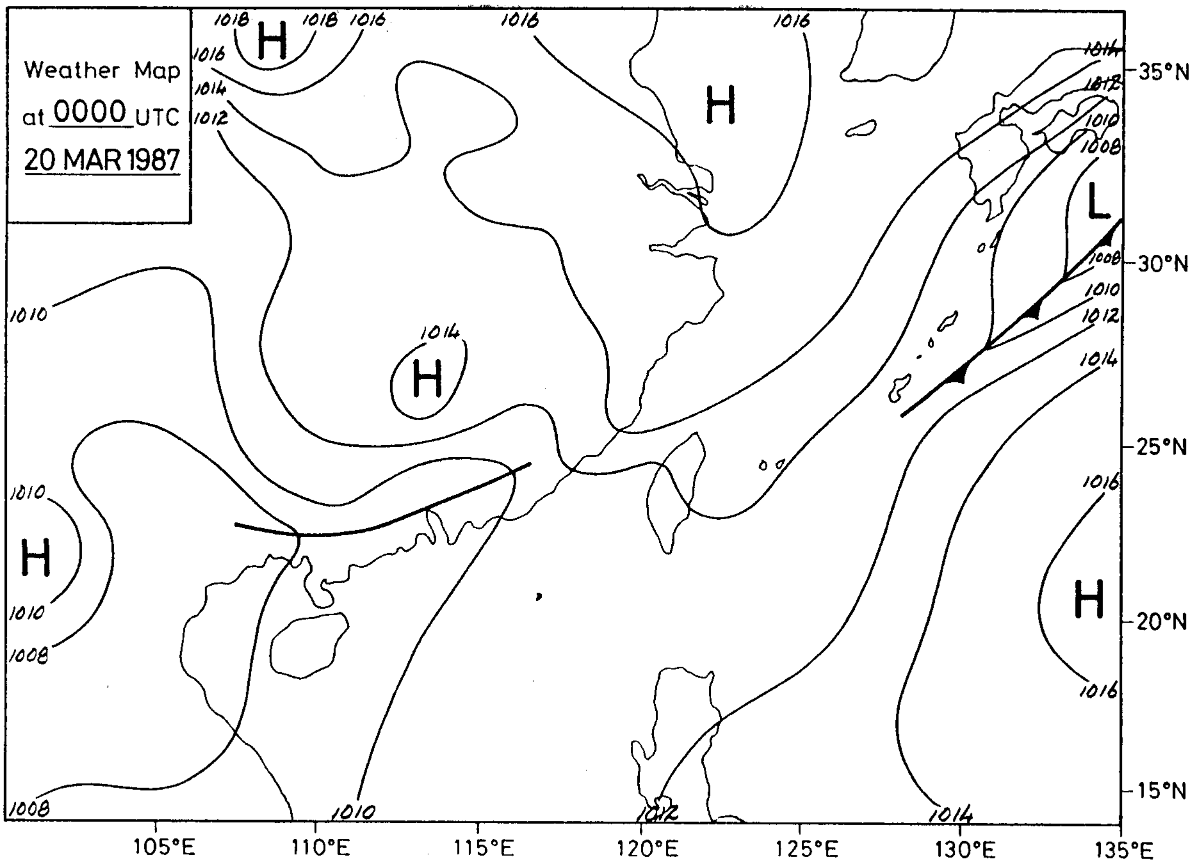
(ae)


Weather Map
at 1200 UTC
19 MAR 1987
L
H
H
H
L
L
1008
1010
1012
1014
1016
1006
1004
1002
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(af)

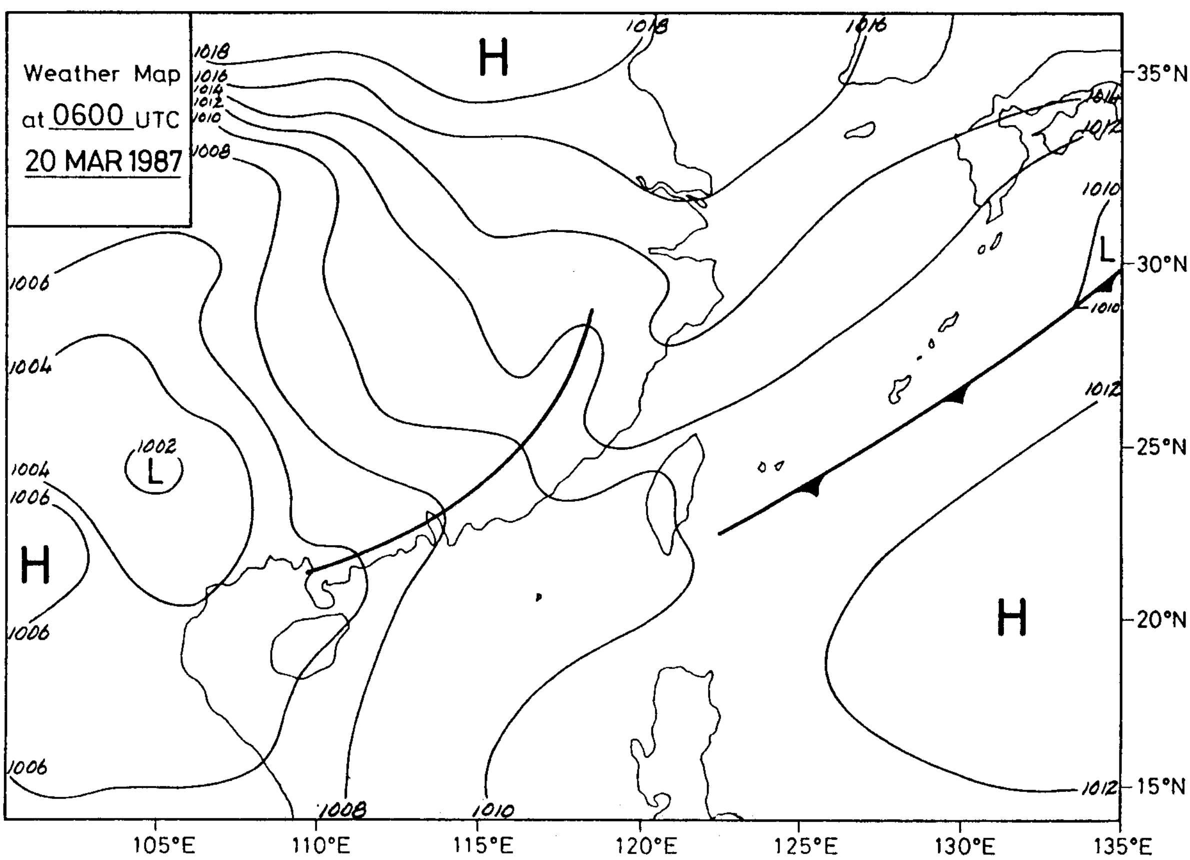

Weather Map
at 1800 UTC
19 MAR 1987
H
H
L
H
L
1012
1014
1010
1008
1006
1004
1002
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(ag)



Weather Map
at 0000 UTC
20 MAR 1987
H
H
H
H
H
L
1018
1018
1016
1016
1016
1016
1014
1012
1010
1014
1010
1010
1008
1008
1010
1012
1014
1012
1010
1008
1008
1010
1012
1014
1016
1016
1014
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(ah)



Weather Map
at 0600 UTC
20 MAR 1987
H
H
H
L
L
1018
1016
1014
1012
1010
1008
1018
1016
1006
1004
1002
1004
1006
1006
1006
1008
1010
1014
1012
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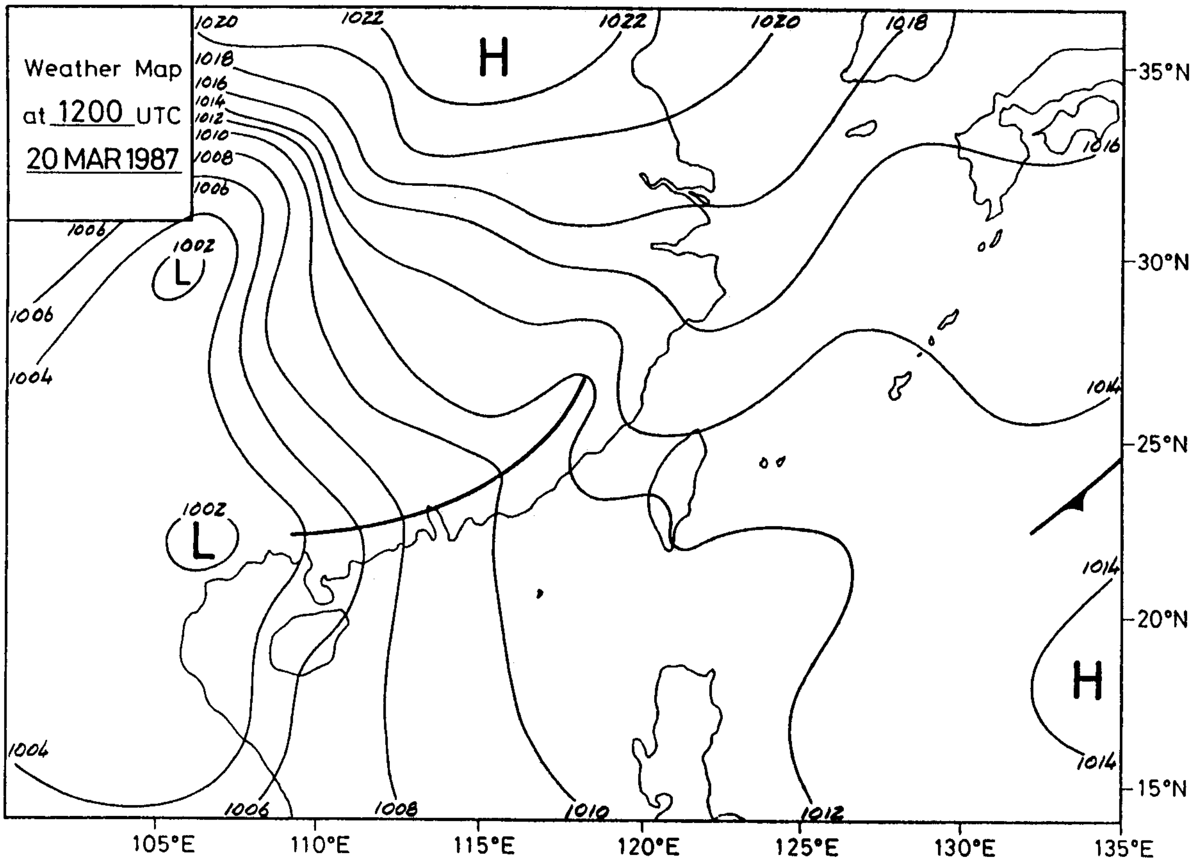
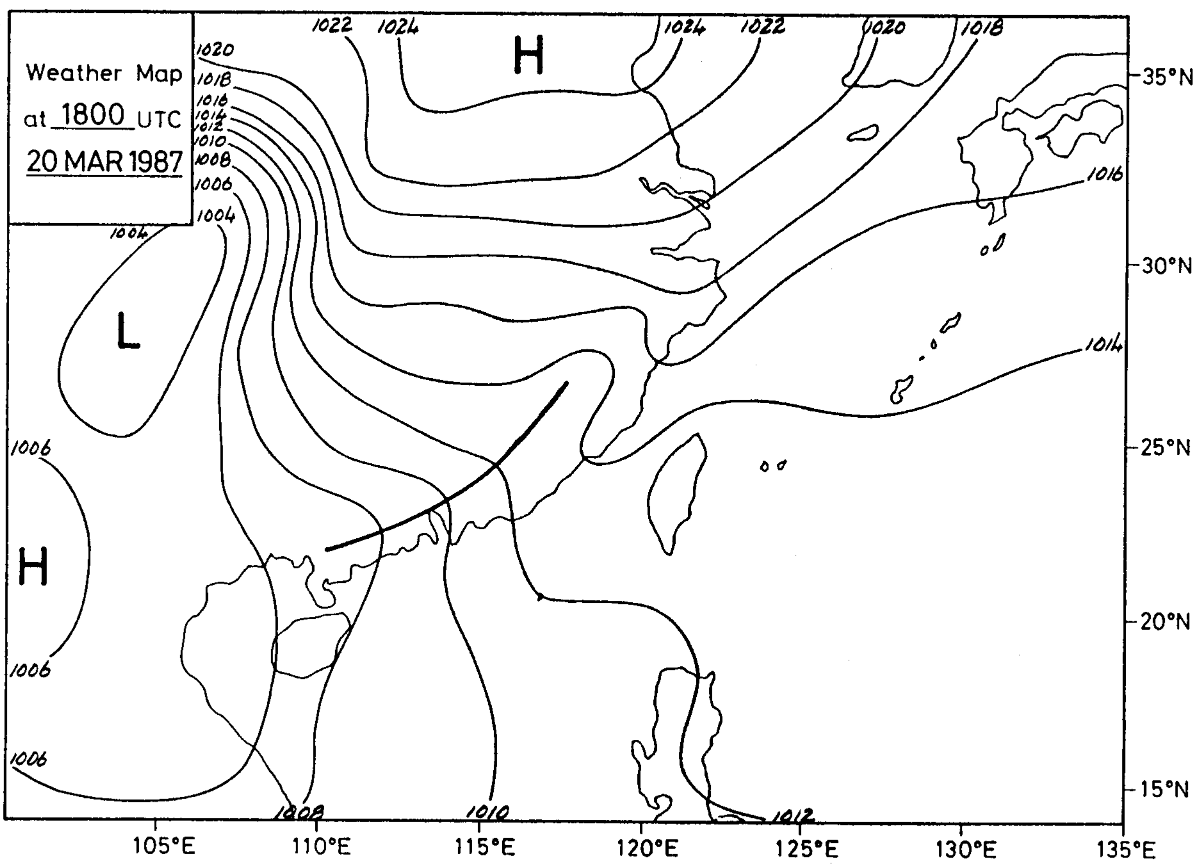
1010
1012
1012
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

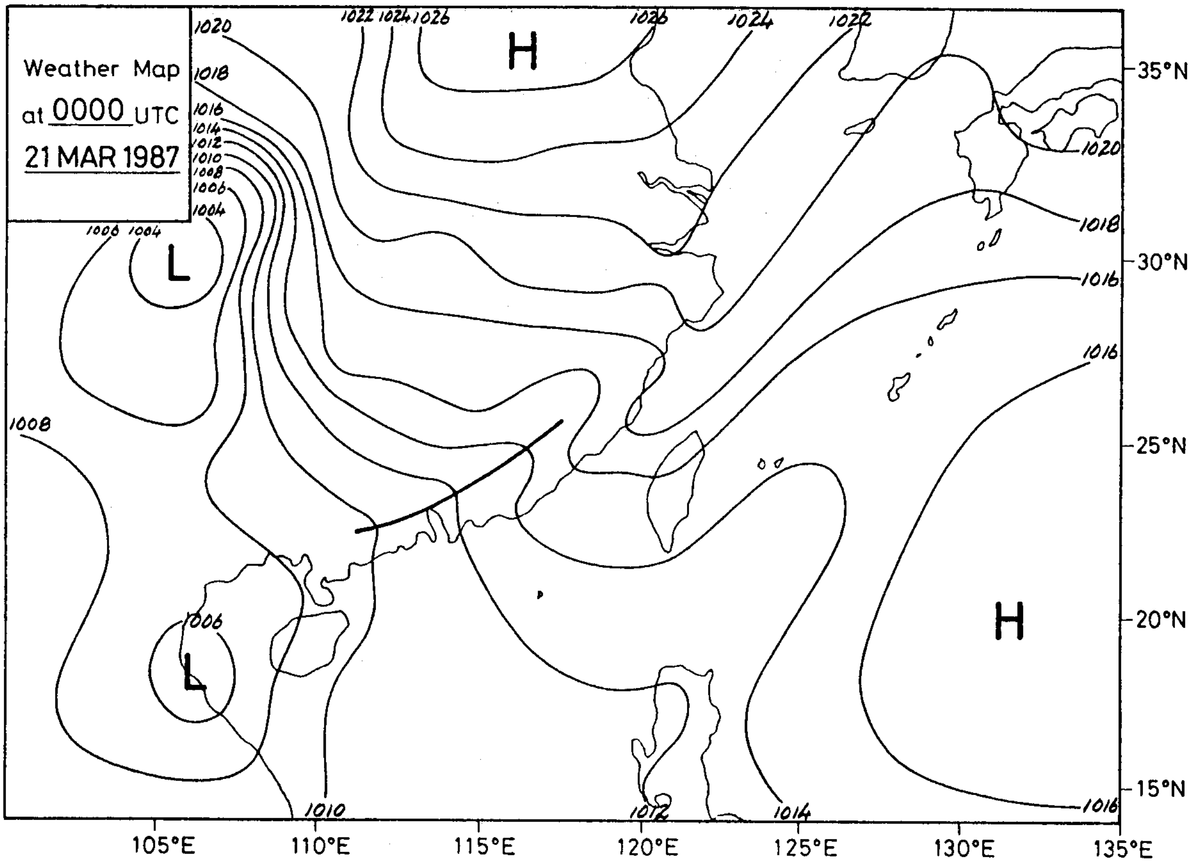
(ai)


Weather Map
at 1200 UTC
20 MAR 1987
H
L
L
H
1020
1018
1016
1014
1012
1010
1008
1006
1002
1004
1022
1014
1012
1010
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

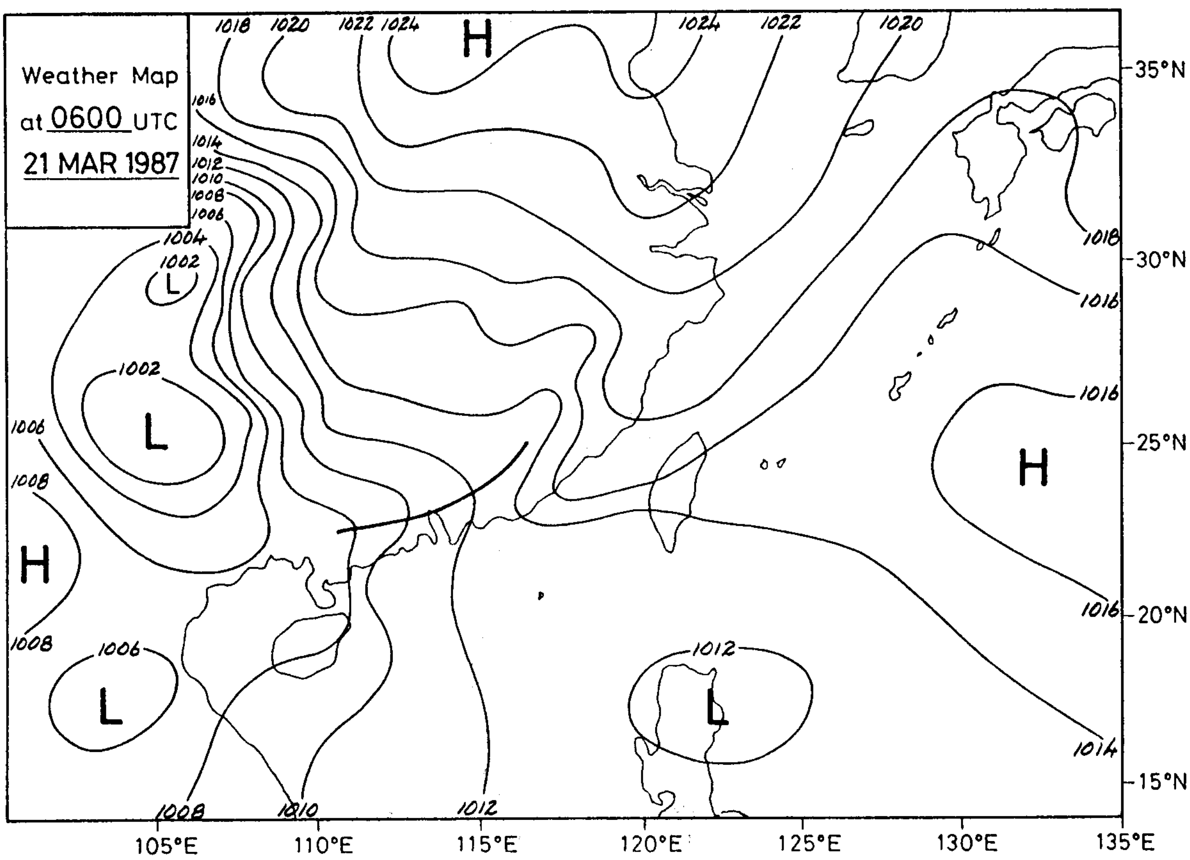
(aj)


Weather Map
at 1800 UTC
20 MAR 1987
H
L
H
1020
1018
1016
1014
1012
1010
1008
1006
1004
1022
1024
1012
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(ak)


Weather Map
at 0000 UTC
21 MAR 1987
1020
1018
1016
1014
1012
1010
1008
1006
1004
1022 1024 1026
1026
1024
1022
1020
1018
1016
1016
1014
1012
1010
1008
1006
H
H
L
L
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(al)


Weather Map
at 0600 UTC
21 MAR 1987
1018
1020
1022 1024
1024
1022
1020
1016
1014
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1010
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1004
1002
1002
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1008
1008
1006
1018
1016
1016
1016
1014
1012
1008
1010
1012
H
H
H
L
L
L
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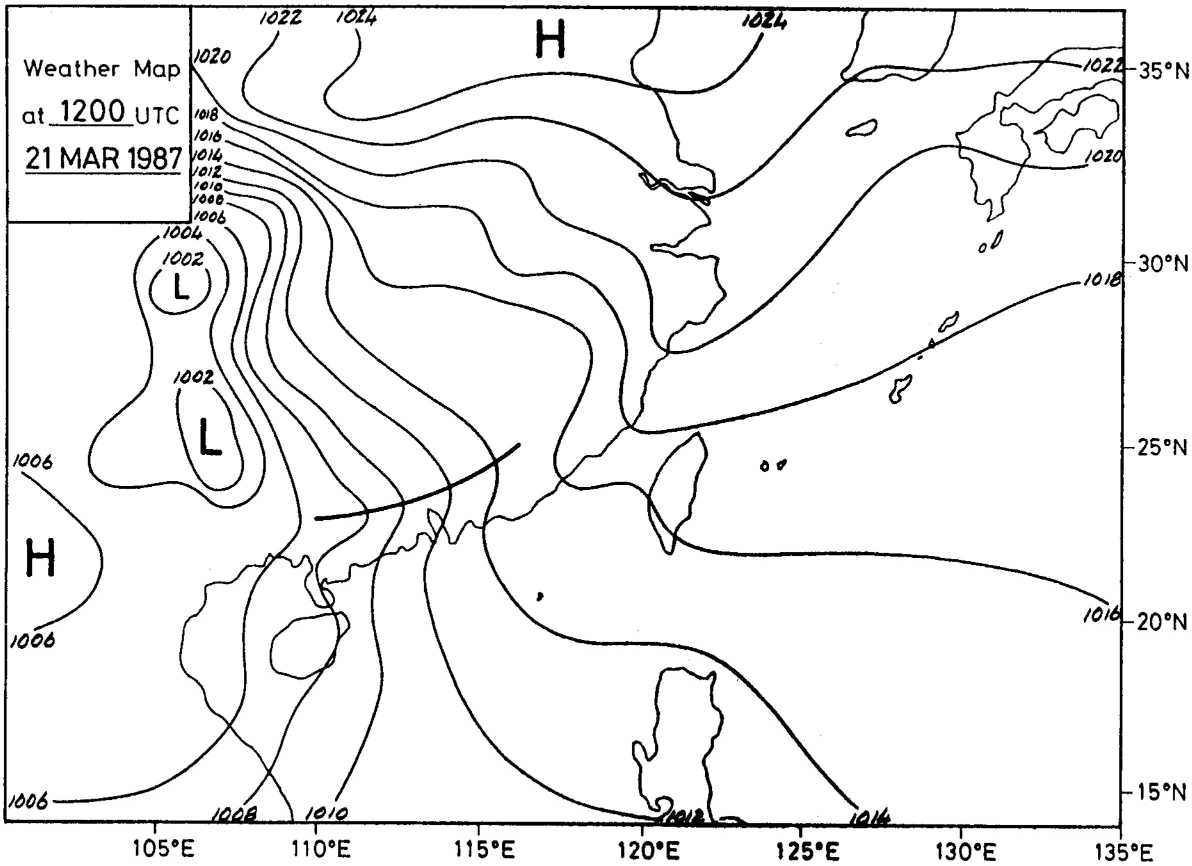
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(am)


Weather Map
at 1200 UTC
21 MAR 1987
H
L
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H
1022
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1008
1006
1004
1002
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1016
1018
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35°N
30°N
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20°N
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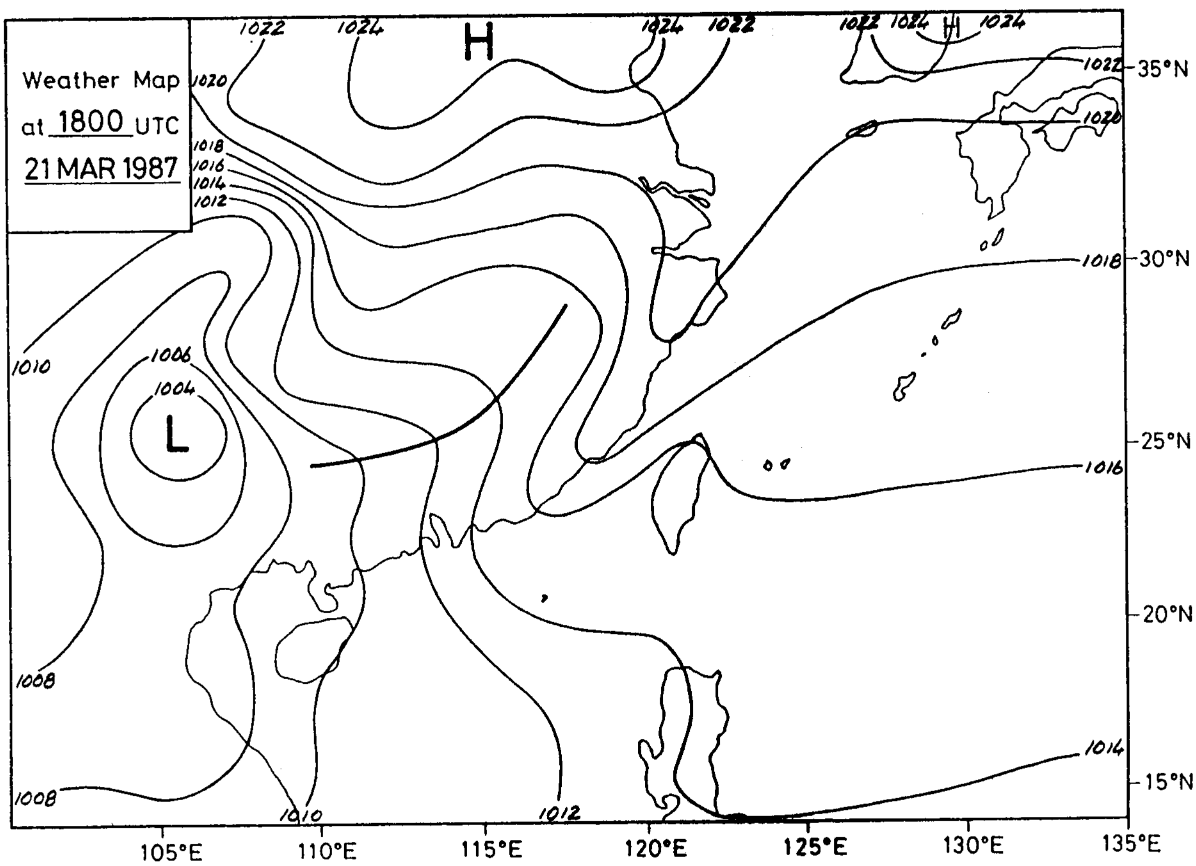
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(an)


Weather Map
at 1800 UTC
21 MAR 1987
H
H
L
1022
1024
1024
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1012
1010
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1016
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35°N
30°N
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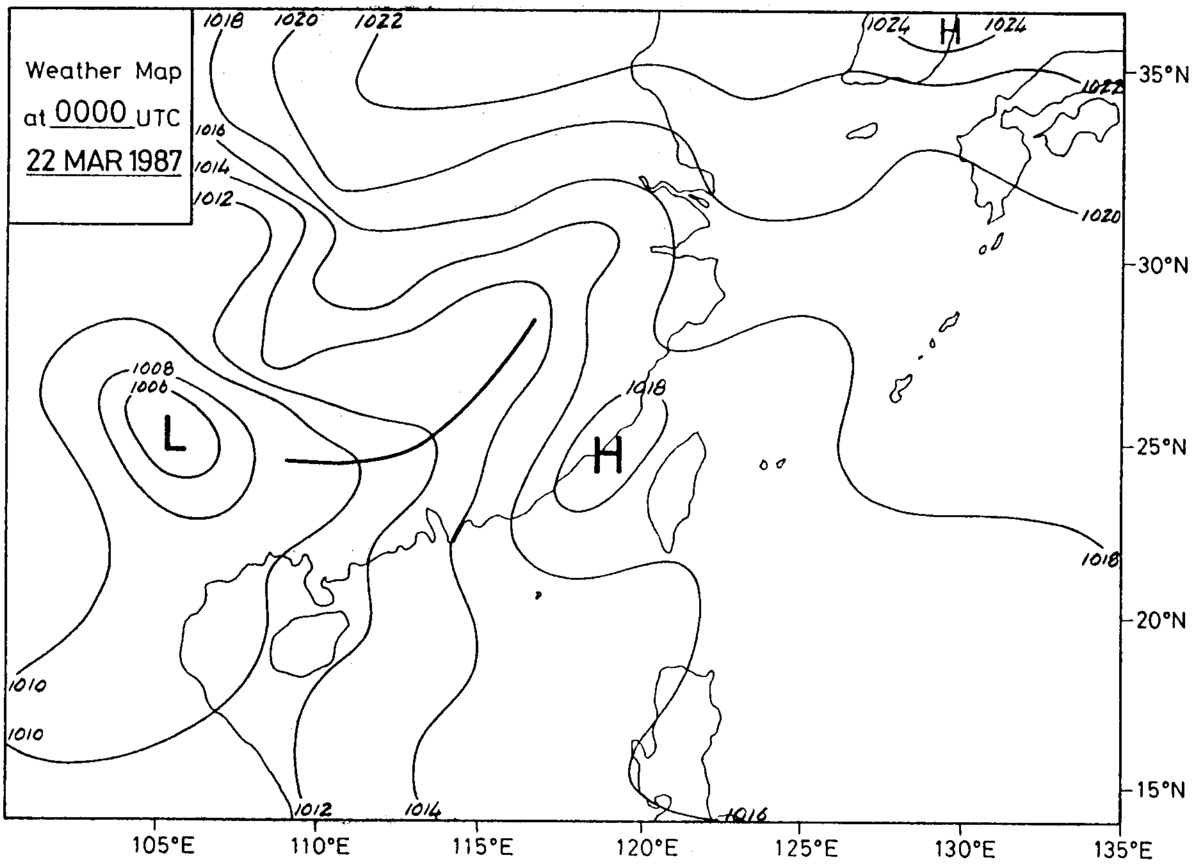
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(ao)


Weather Map
at 0000 UTC
22 MAR 1987
1018
1020
1022
1024
H
1024
1016
1014
1012
1022
1020
1008
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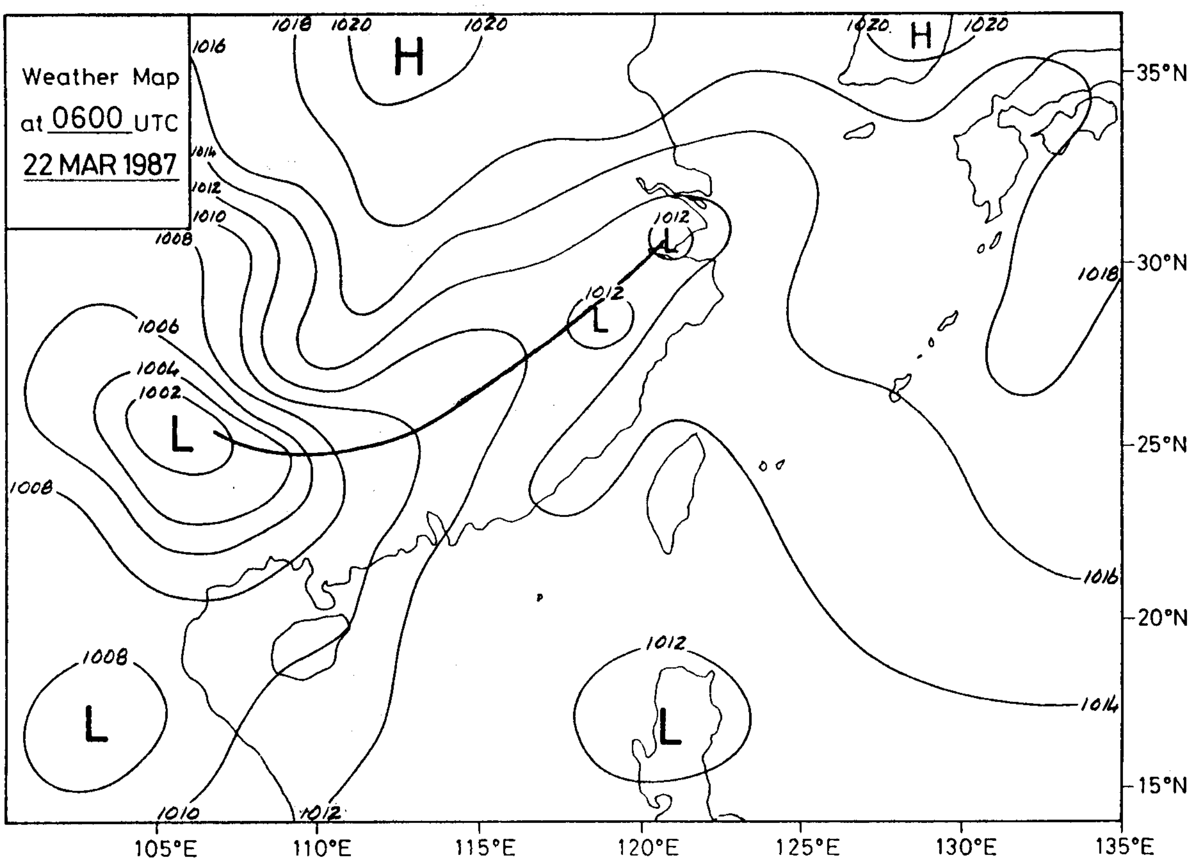
L
1018
H
1018
1010
1010
1012
1014
1016
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(ap)


Weather Map
at 0600 UTC
22 MAR 1987
1016
1018
1020
H
1020
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H
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1014
1012
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1006
1004
1002
L
1012
L
1012
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1018
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1016
1008
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L
1014
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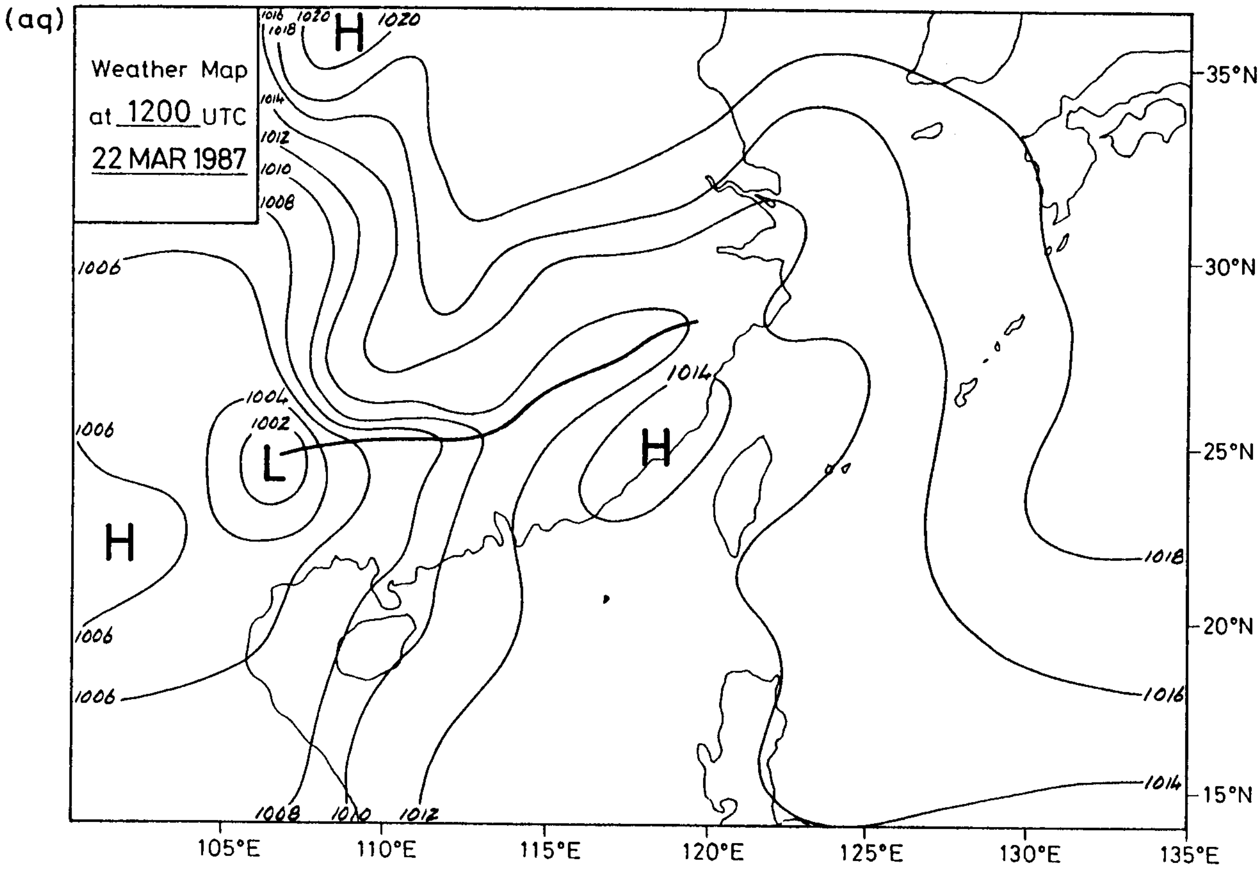
1012
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(aq)


Weather Map
at 1200 UTC
22 MAR 1987
1016
1018
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H
1020
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H
1014
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1006
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1008
1010
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1018
1016
1014
35°N
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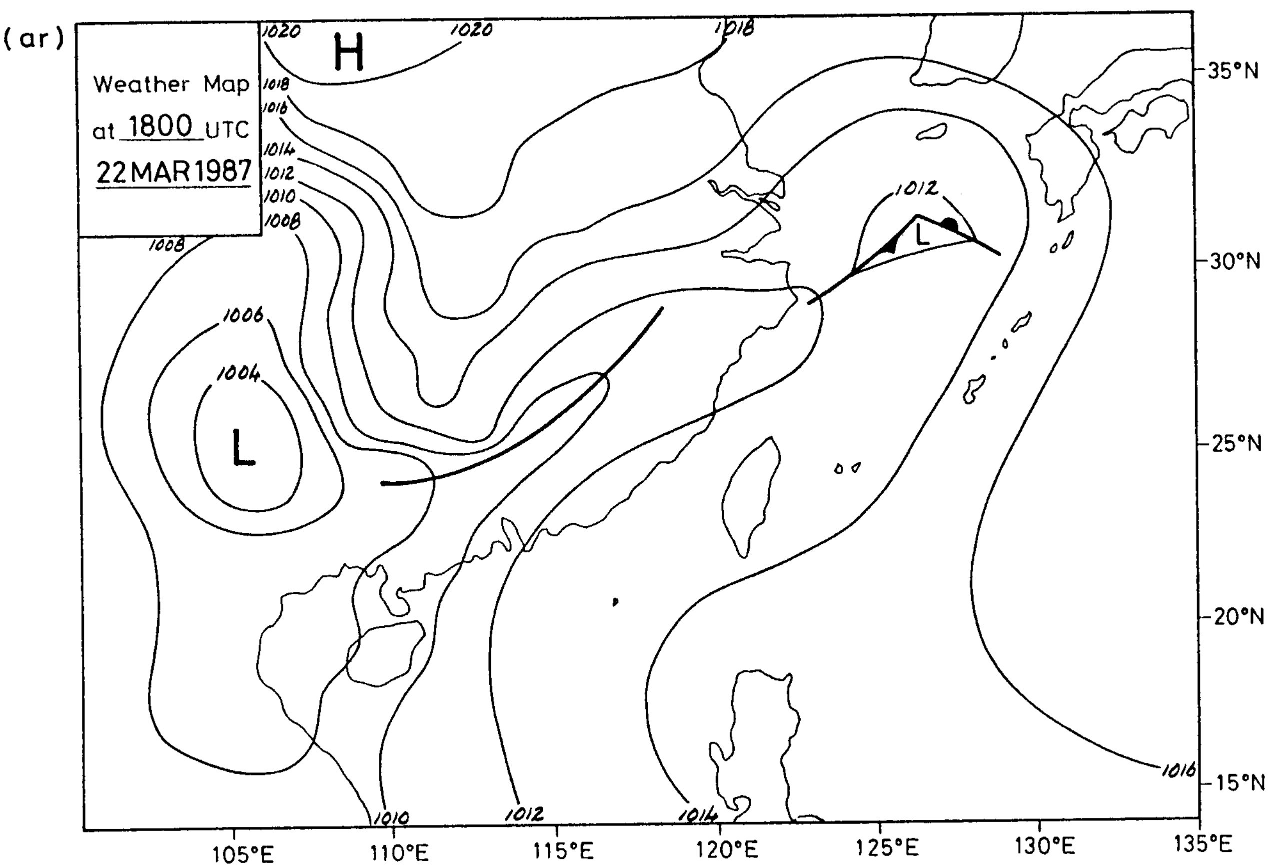
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(ar)


Weather Map
at 1800 UTC
22 MAR 1987
1020
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1016
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1010
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1016
35°N
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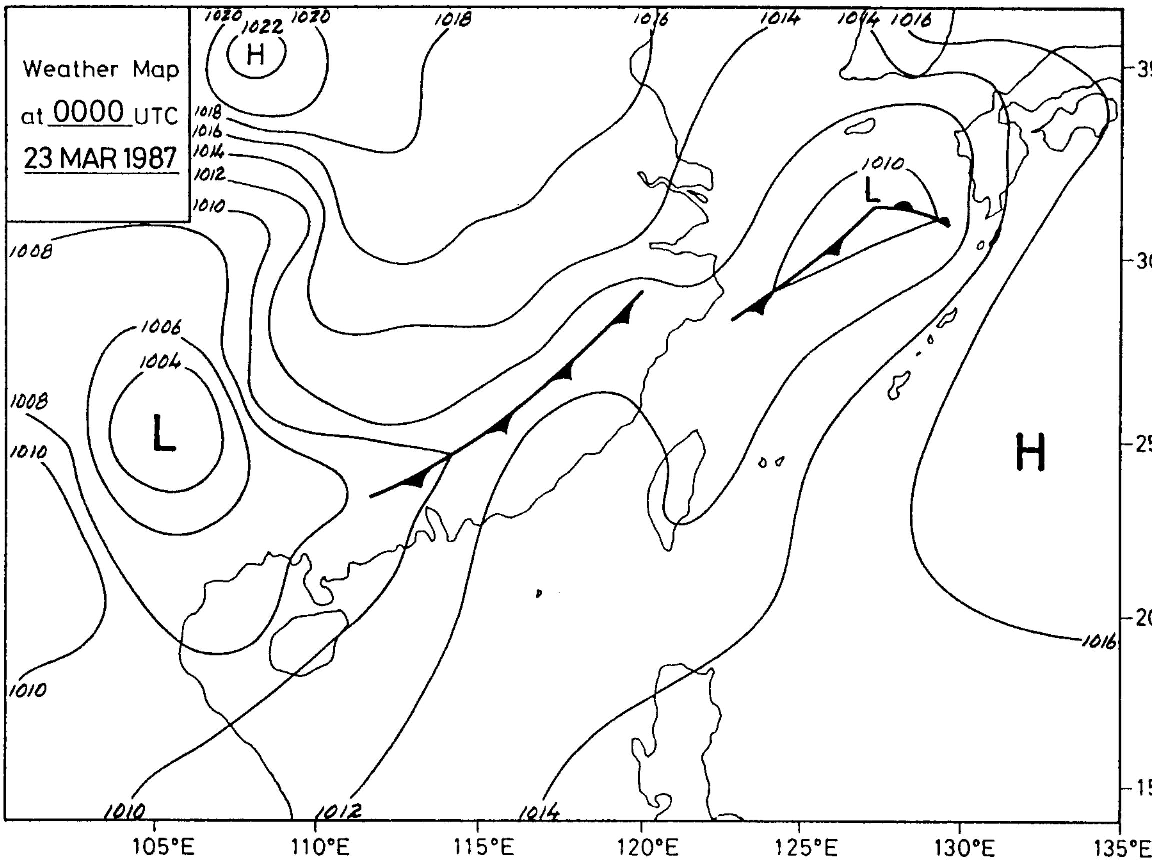
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(as)


Weather Map
at 0000 UTC
23 MAR 1987
H
L
L
H
1020
1022
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1018
1016
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1016
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1014
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1010
1008
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1004
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1010
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1010
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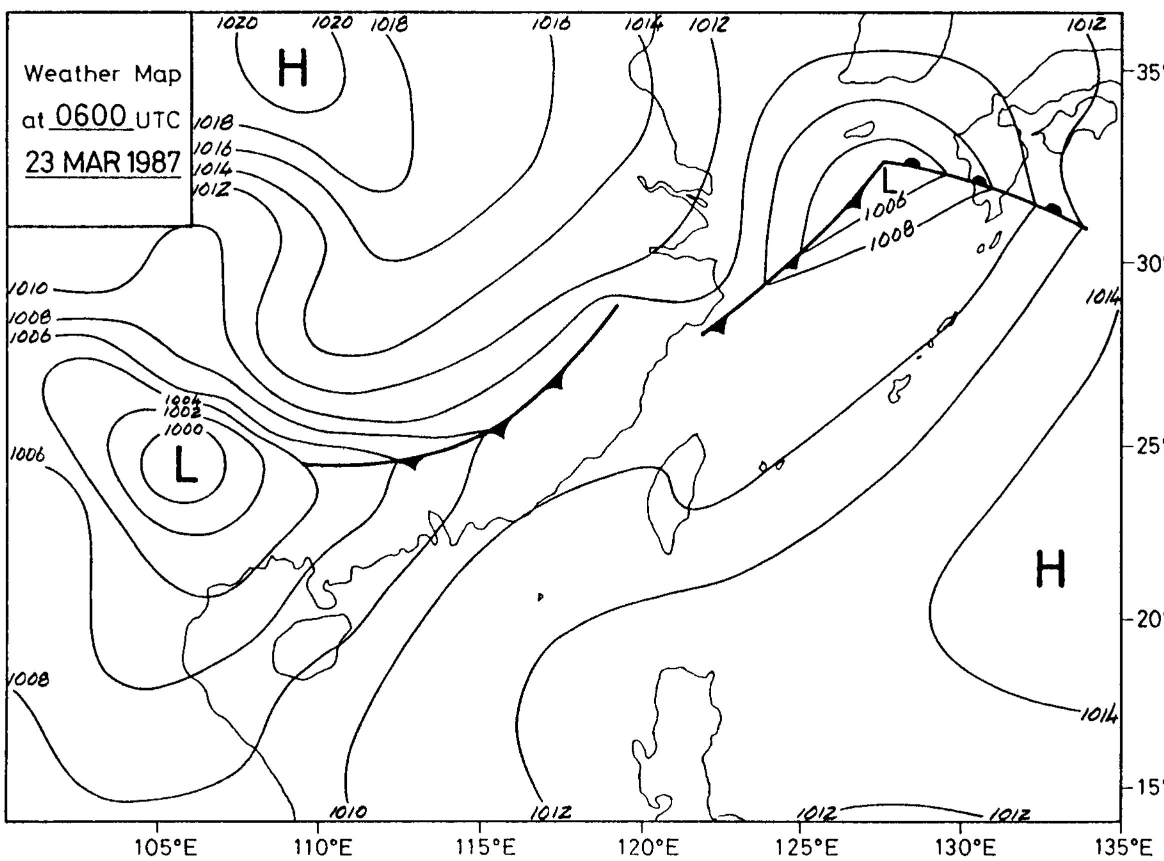
1016
1010
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(at)


Weather Map
at 0600 UTC
23 MAR 1987
H
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1020
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1018
1016
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1014
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1014
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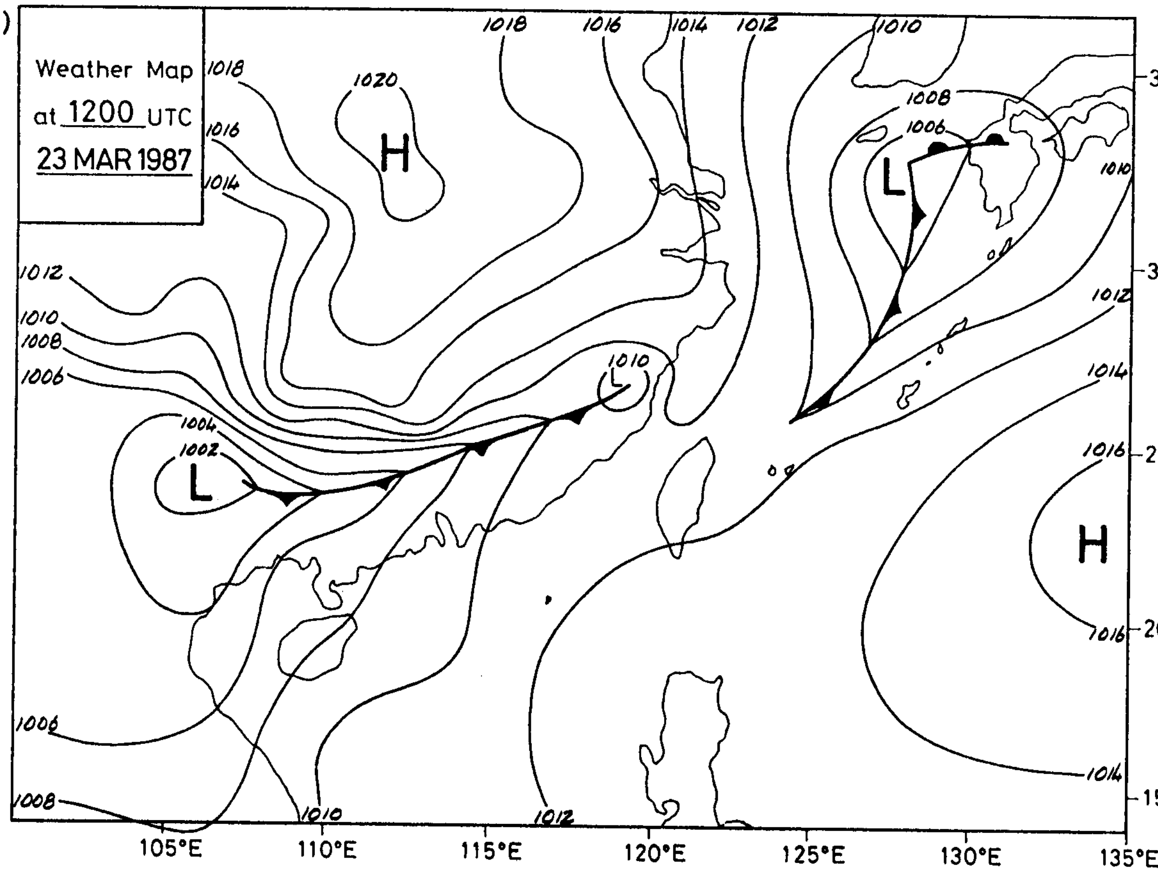
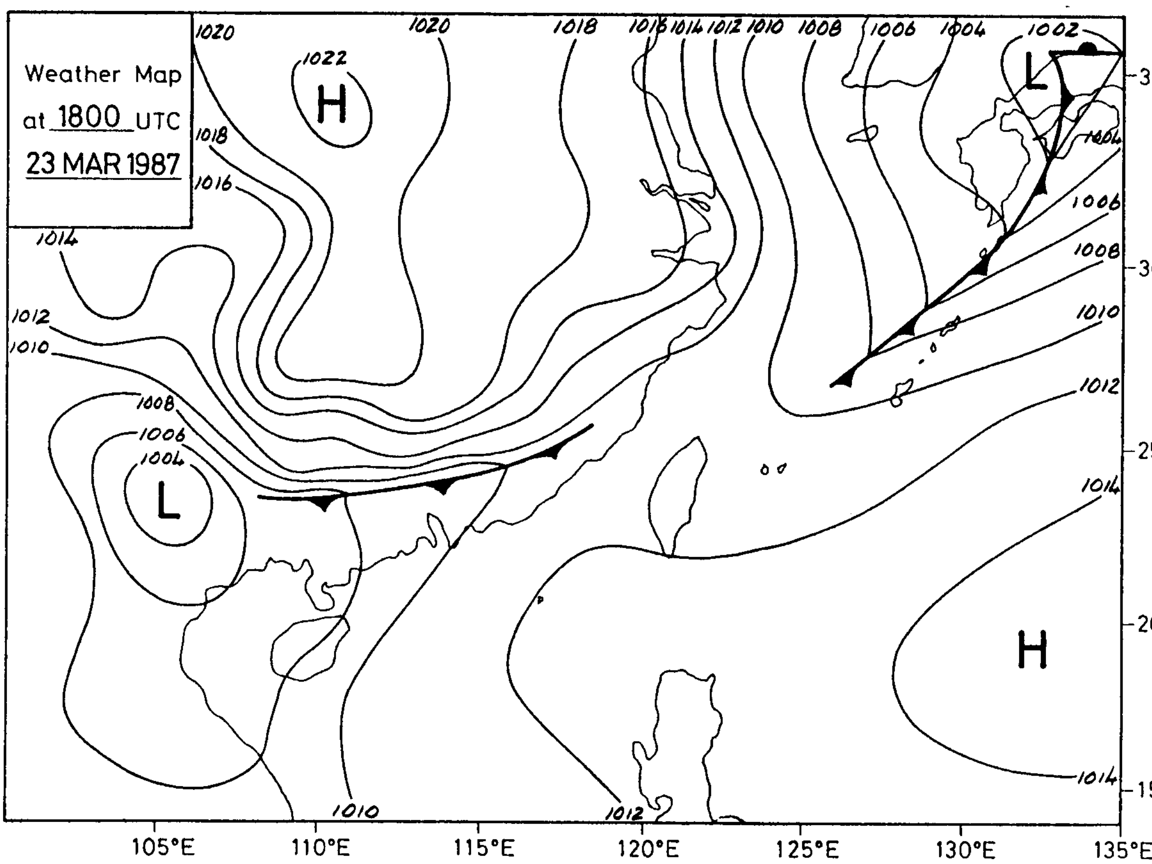
1012
1012
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

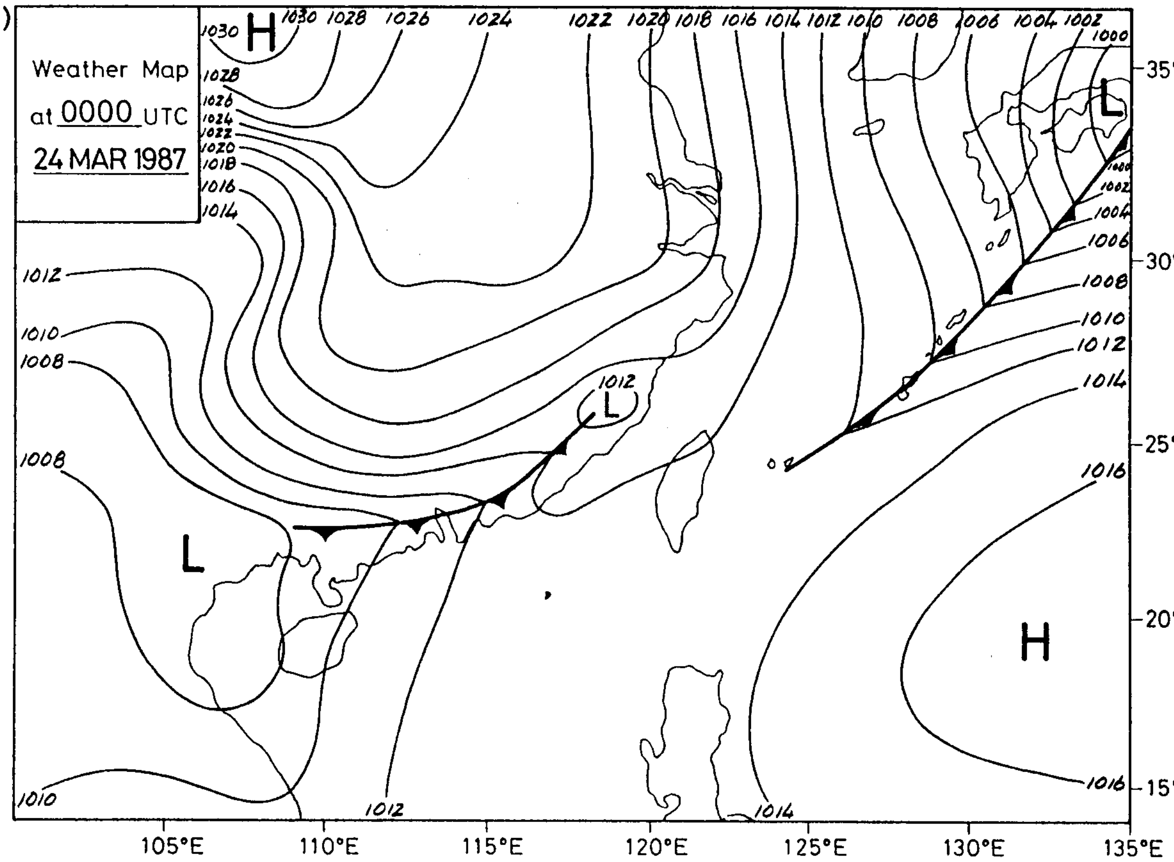
(au)


Weather Map
at 1200 UTC
23 MAR 1987
H
L
L
L
H
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

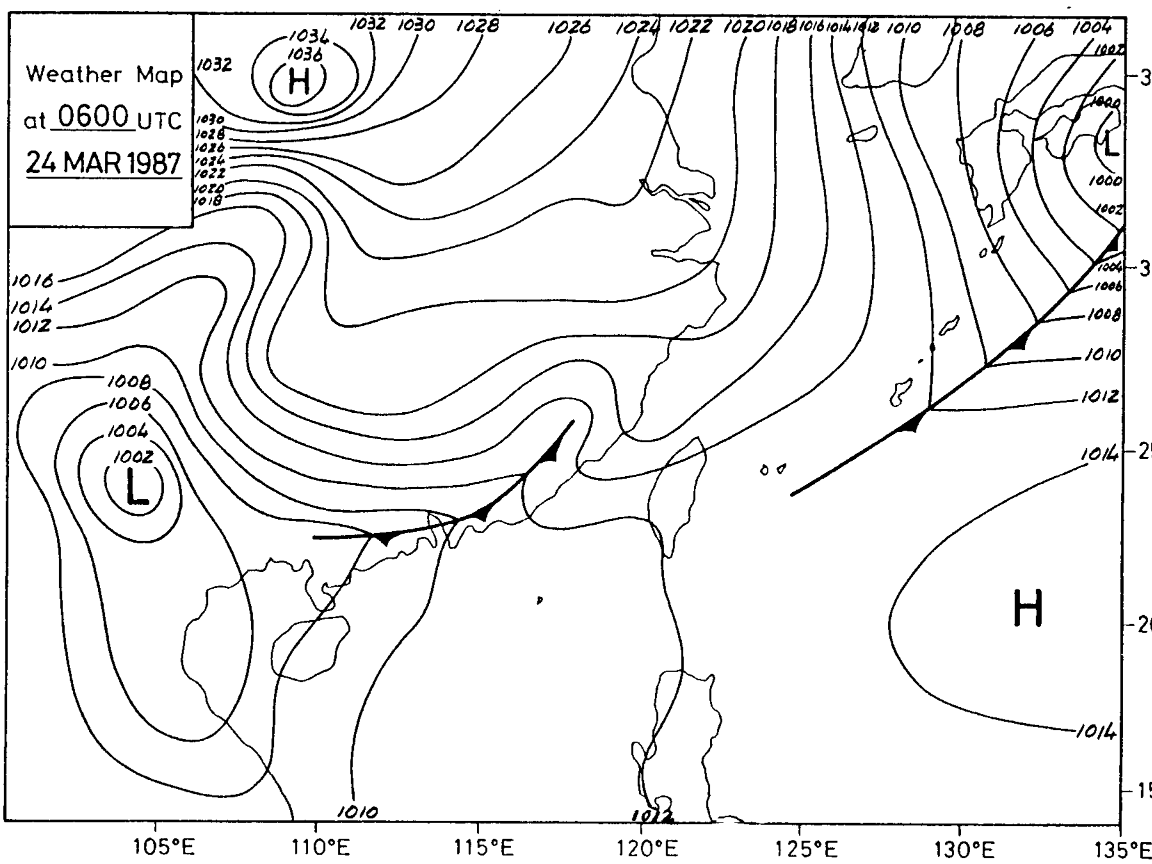
(av)


Weather Map
at 1800 UTC
23 MAR 1987
H
L
L
H
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

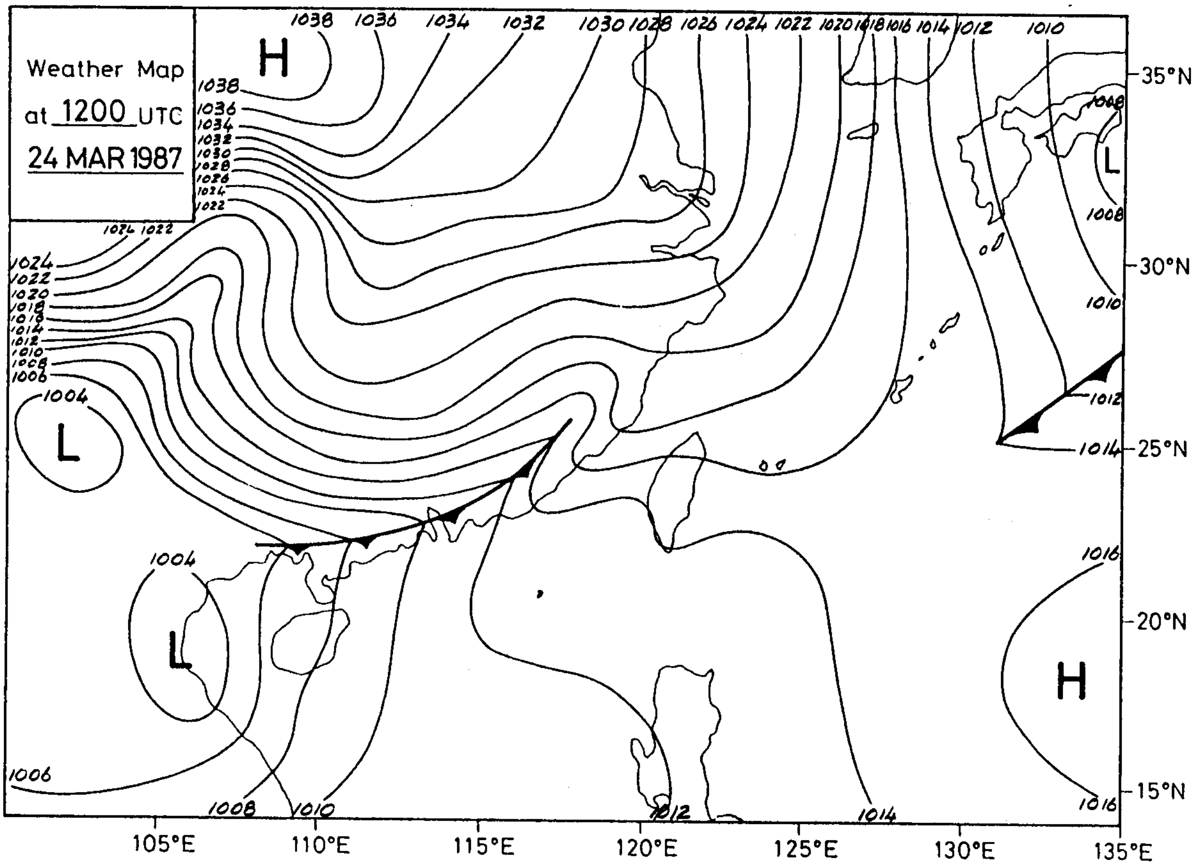
(aw)


Weather Map
at 0000 UTC
24 MAR 1987
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

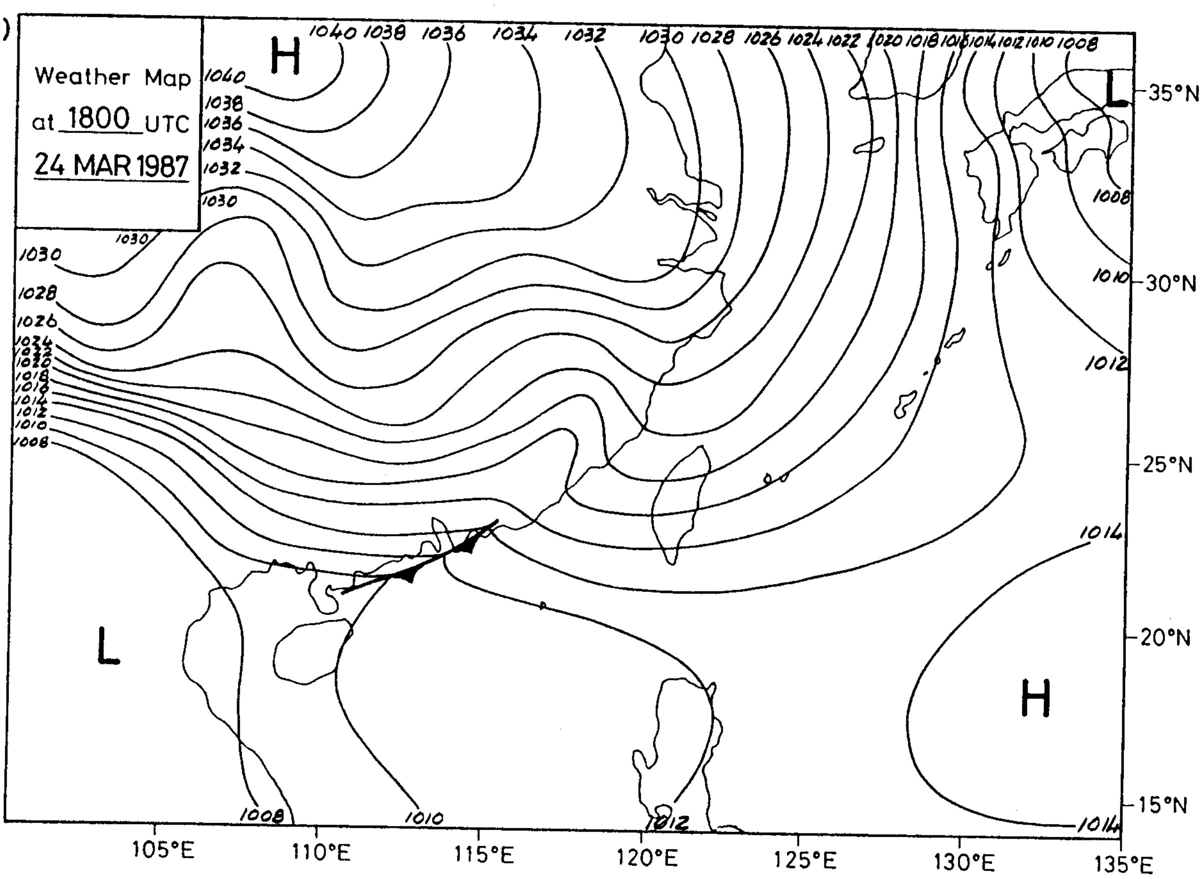
(ax)


Weather Map
at 0600 UTC
24 MAR 1987
35°N
30°N
25°N
20°N
15°N
105°E
110°E
115°E
120°E
125°E
130°E
135°E

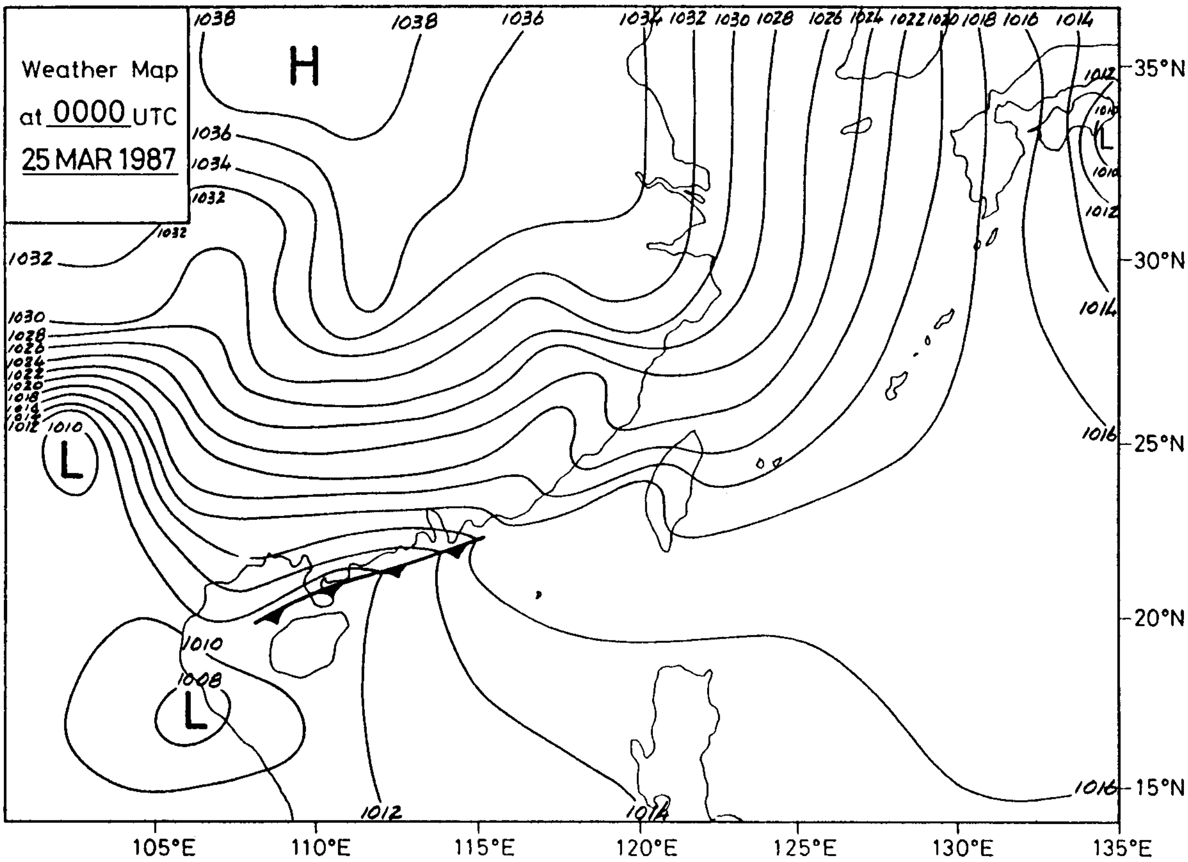
(ay)


Weather Map
at 1200 UTC
24 MAR 1987
H
L
L
H
105°E
110°E
115°E
120°E
125°E
130°E
135°E
35°N
30°N
25°N
20°N
15°N

(az)


Weather Map
at 1800 UTC
24 MAR 1987
H
L
L
H
105°E
110°E
115°E
120°E
125°E
130°E
135°E
35°N
30°N
25°N
20°N
15°N

(ba)


Weather Map
at 0000 UTC
25 MAR 1987
H
L
L
L
1038
1036
1034
1032
1030
1028
1026
1024
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1020
1018
1016
1014
1012
1010
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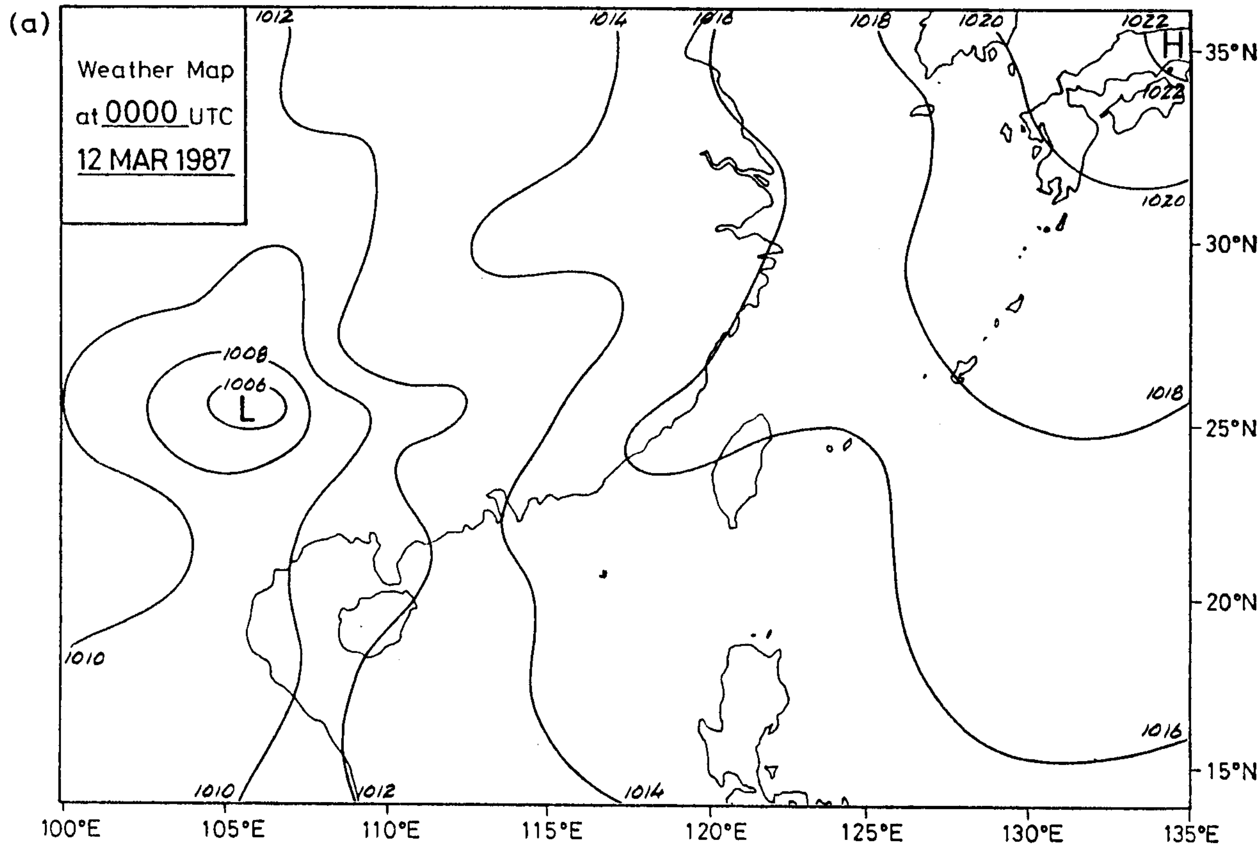
120°E
125°E
130°E
135°E



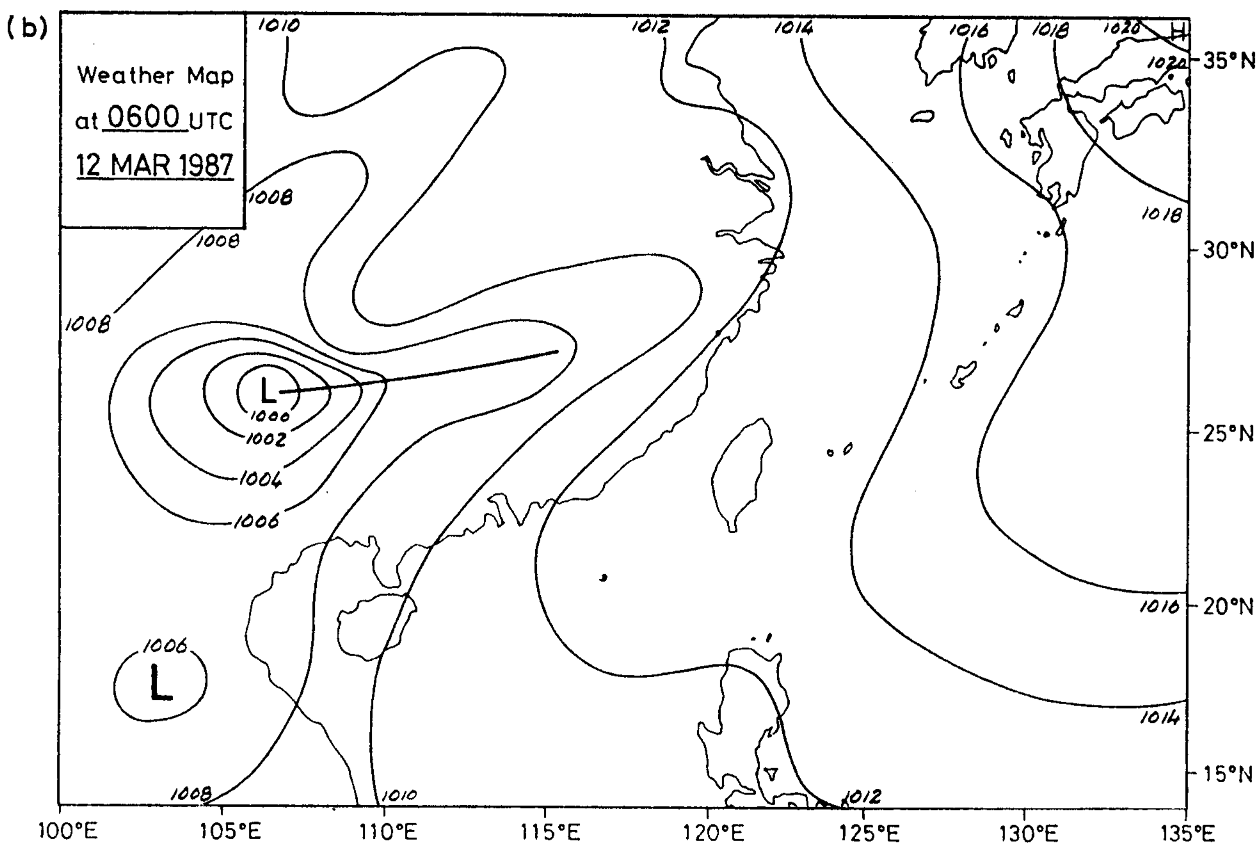
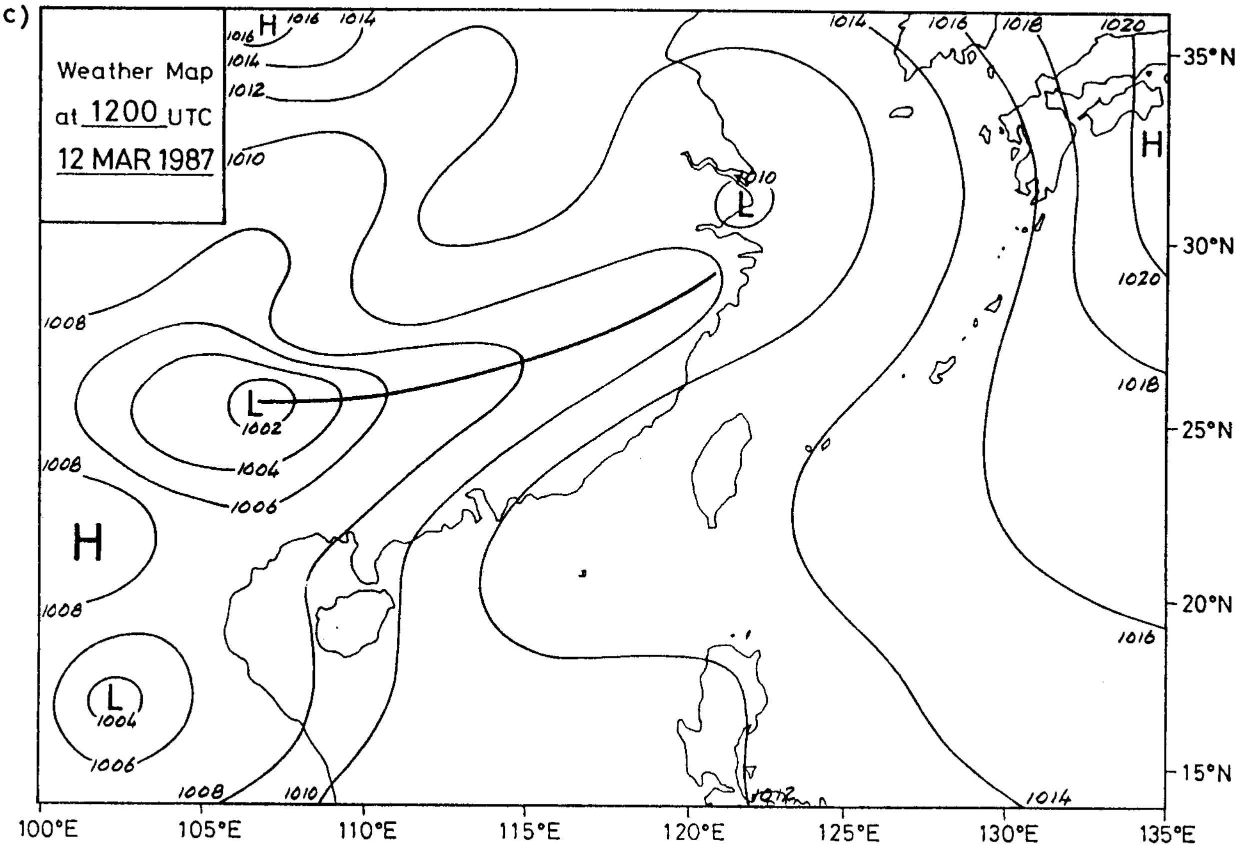
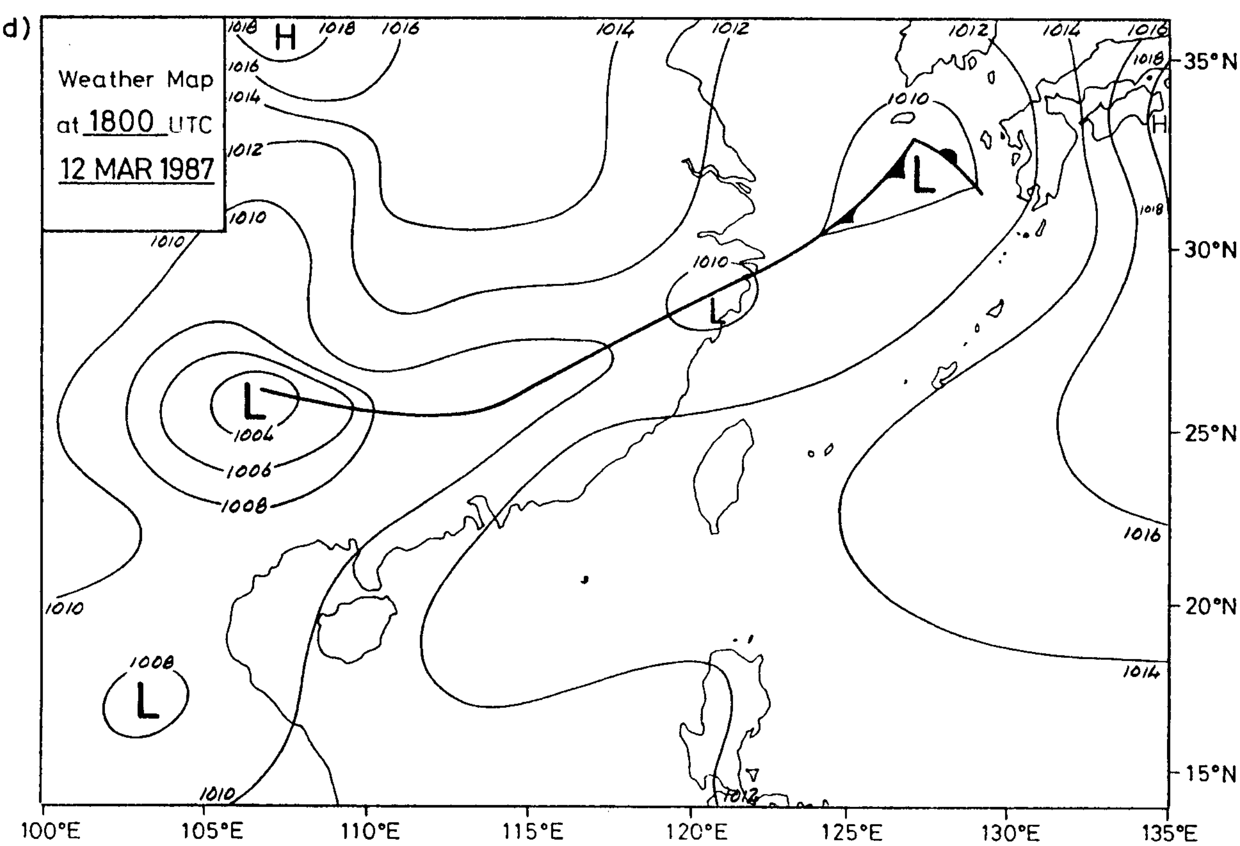


Fig. 8 Weather map associated with a front/trough that failed to reach Hong Kong (0000 UTC 12 Mar 1987-1800 UTC 16 Mar 1987)

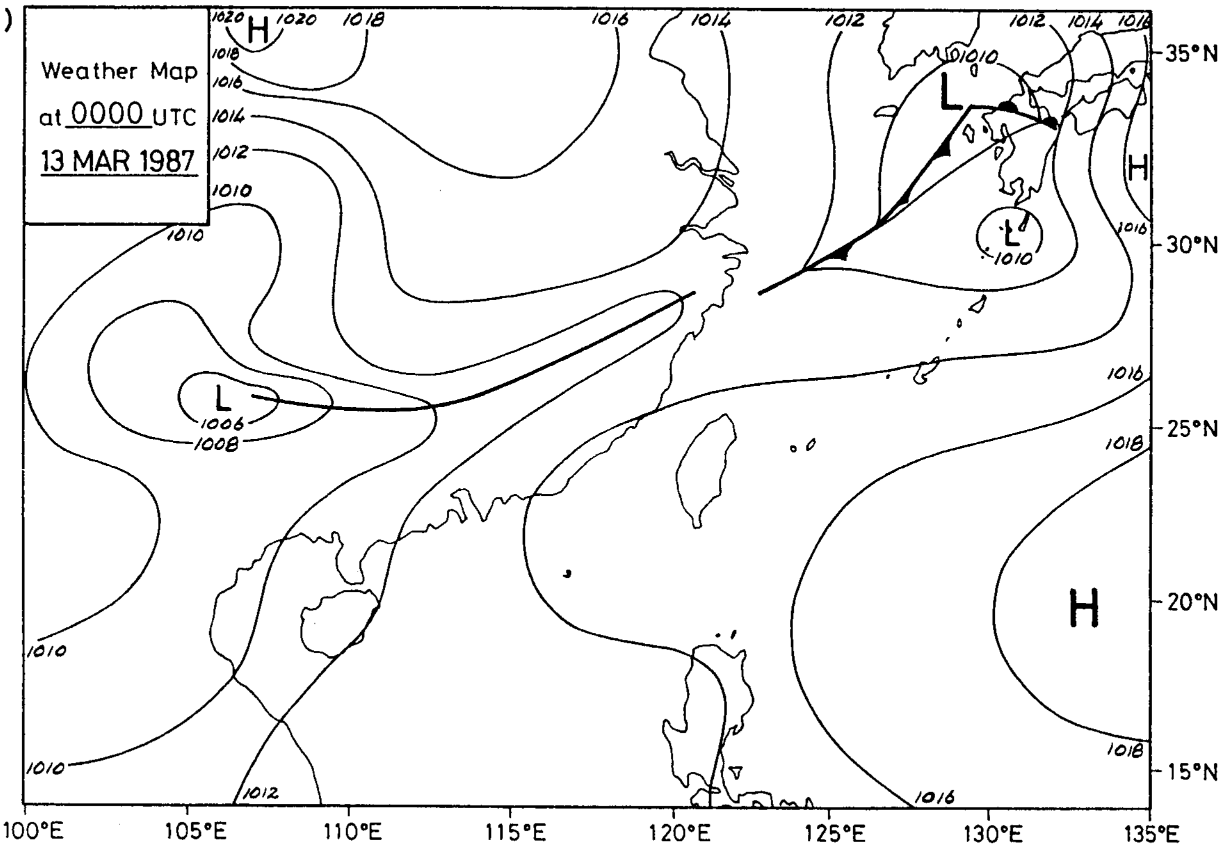
(c)


Weather Map
at 1200 UTC
12 MAR 1987
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

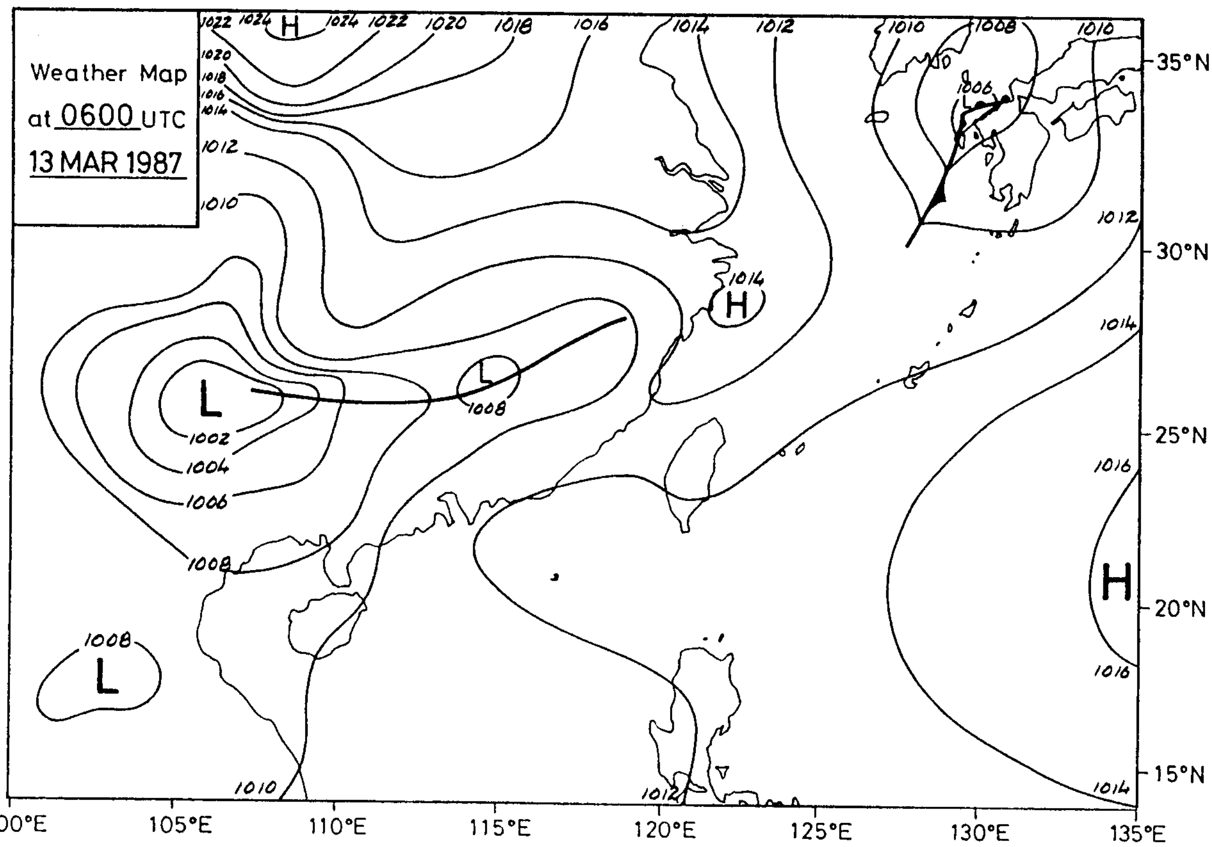
(d)


Weather Map
at 1800 UTC
12 MAR 1987
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(e)


Weather Map
at 0000 UTC
13 MAR 1987
H
L
1020
1018
1016
1014
1012
1010
1008
1006
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(f)


Weather Map
at 0600 UTC
13 MAR 1987
H
L
1024
1022
1020
1018
1016
1014
1012
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1008
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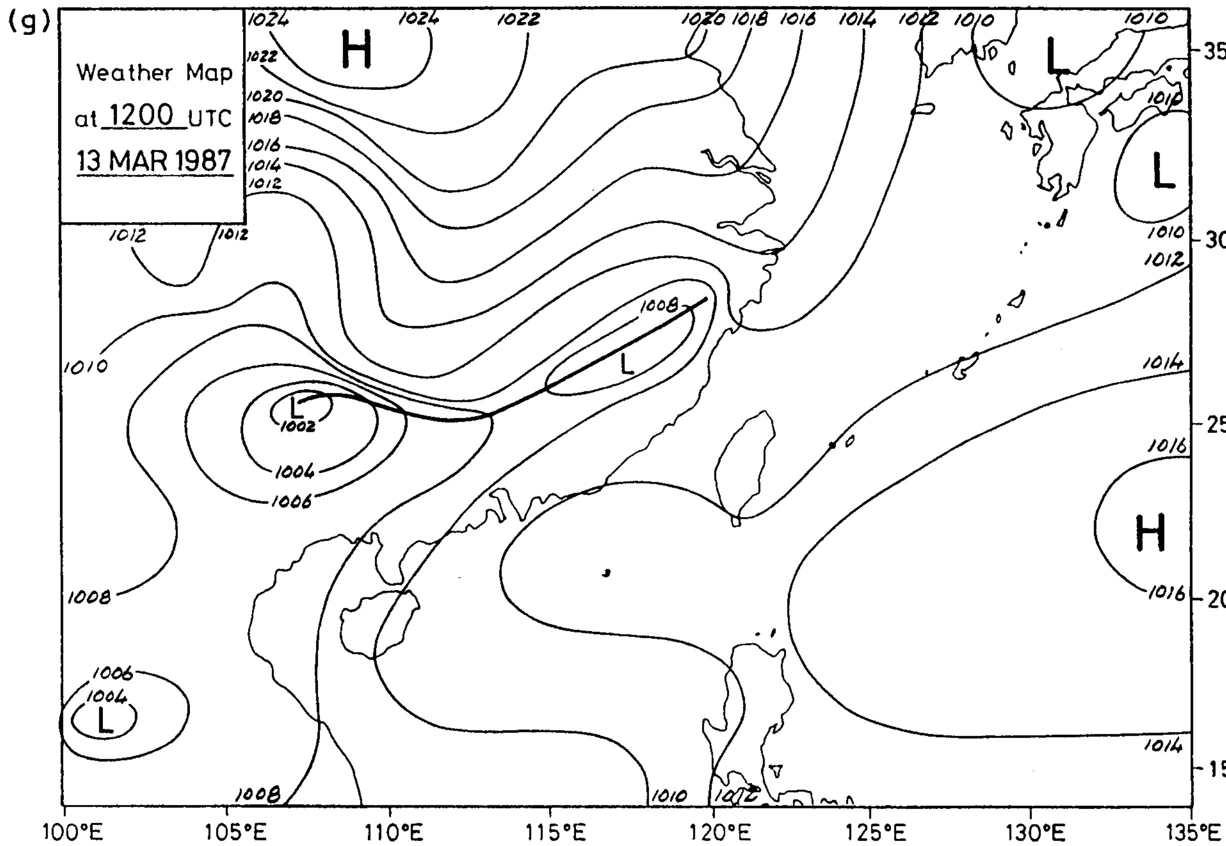
1004
1002
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E


(g)
Weather Map
at 1200 UTC
13 MAR 1987
H
L
L
L
L
H
L
35°N
30°N
25°N
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15°N
100°E
105°E
110°E
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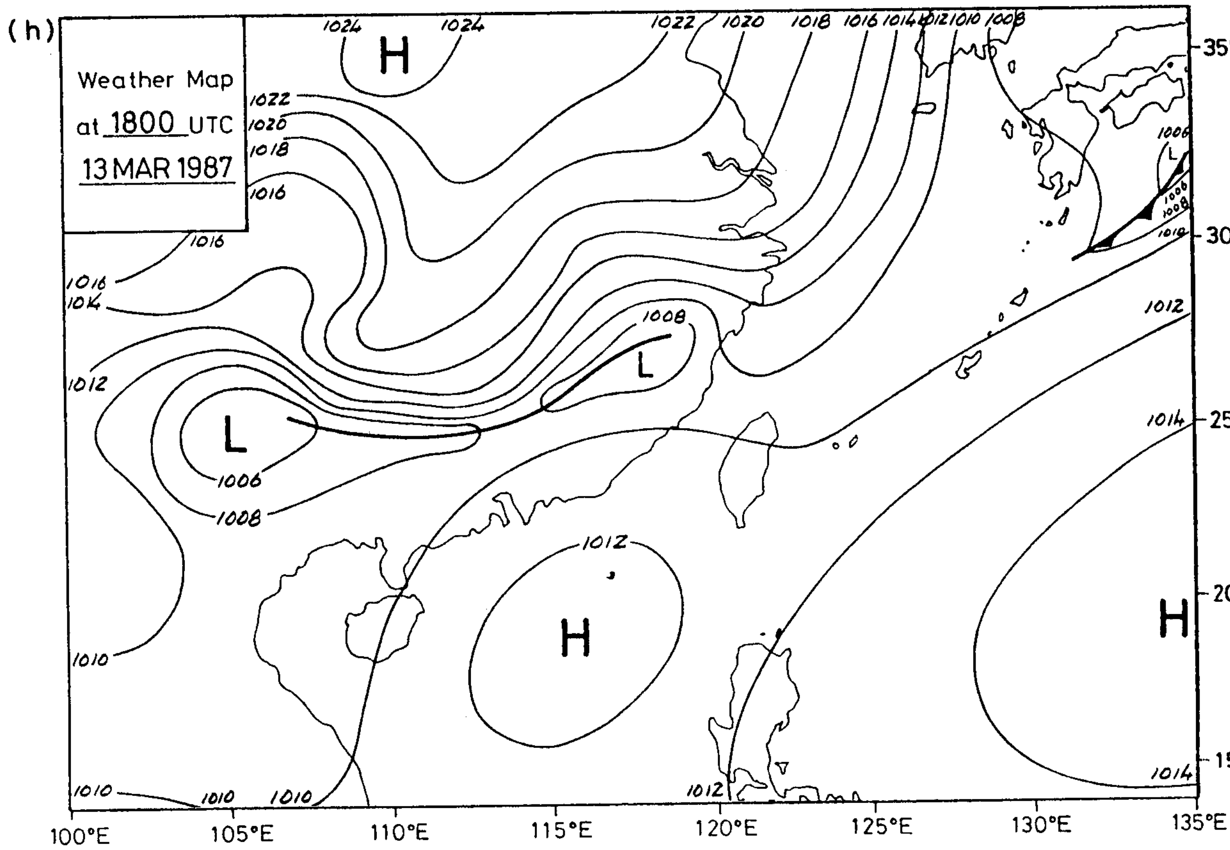
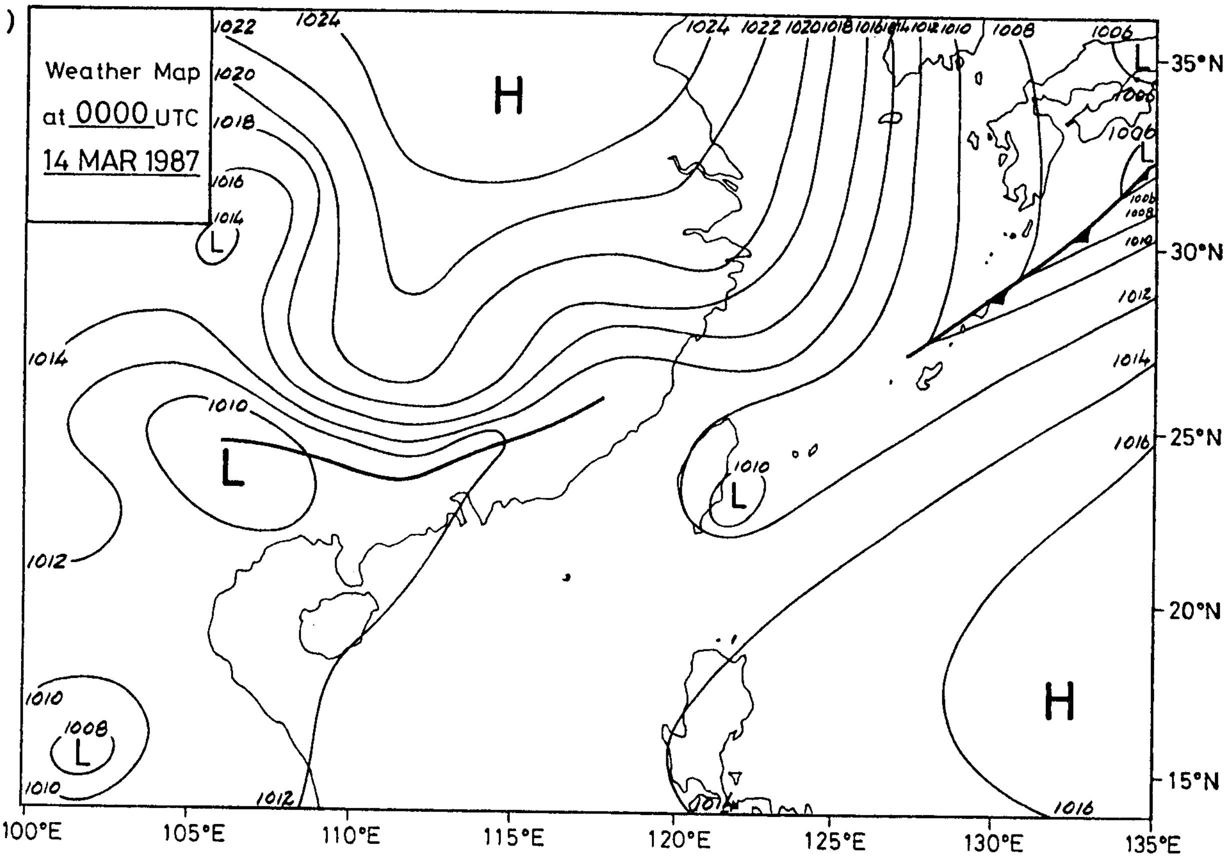
125°E
130°E
135°E


(h)
Weather Map
at 1800 UTC
13 MAR 1987
H
L
L
H
H
L
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(i)


Weather Map
at 0000 UTC
14 MAR 1987
H
H
L
L
L
L
L
L
1024
1022
1020
1018
1016
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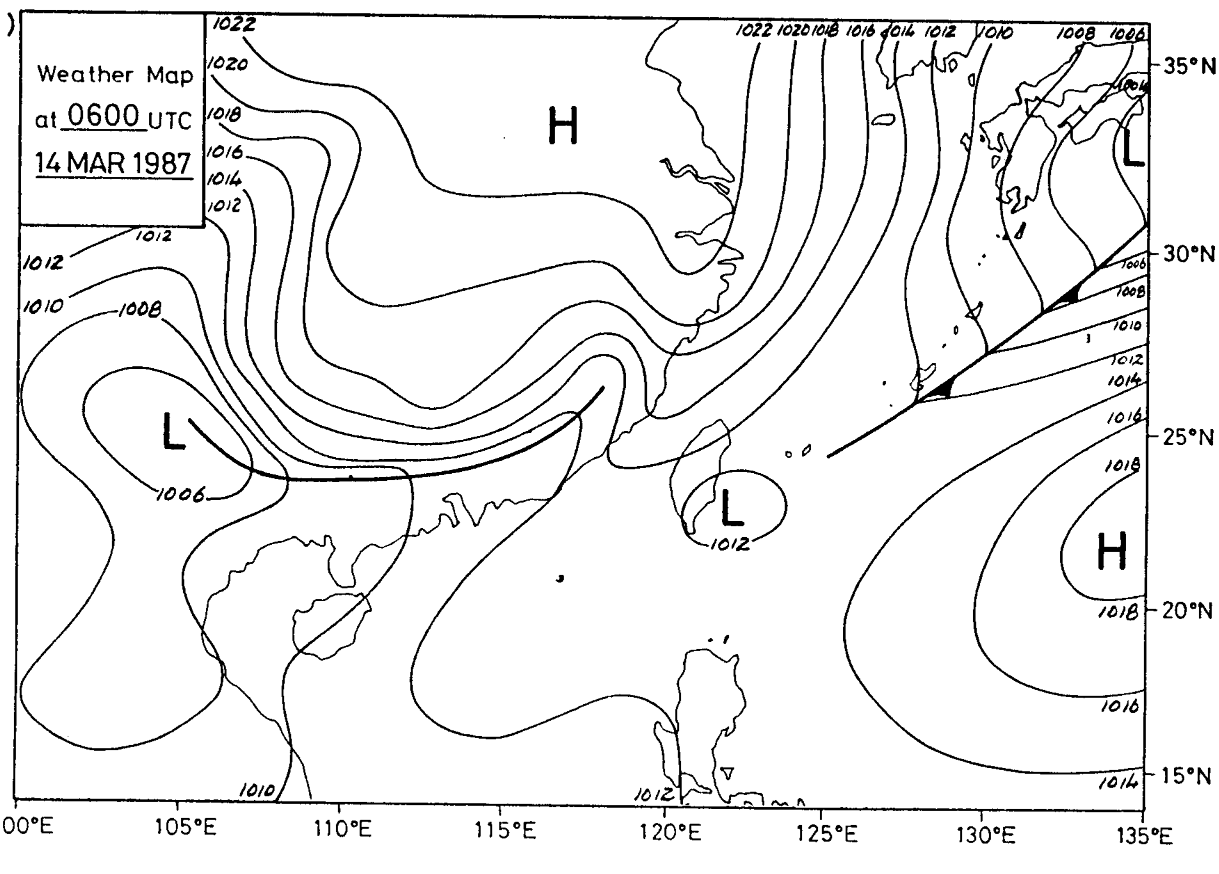
1012
1010
1008
1006
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(j)


Weather Map
at 0600 UTC
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H
H
L
L
L
1022
1020
1018
1016
1014
1012
1010
1008
1006
35°N
30°N
25°N
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15°N
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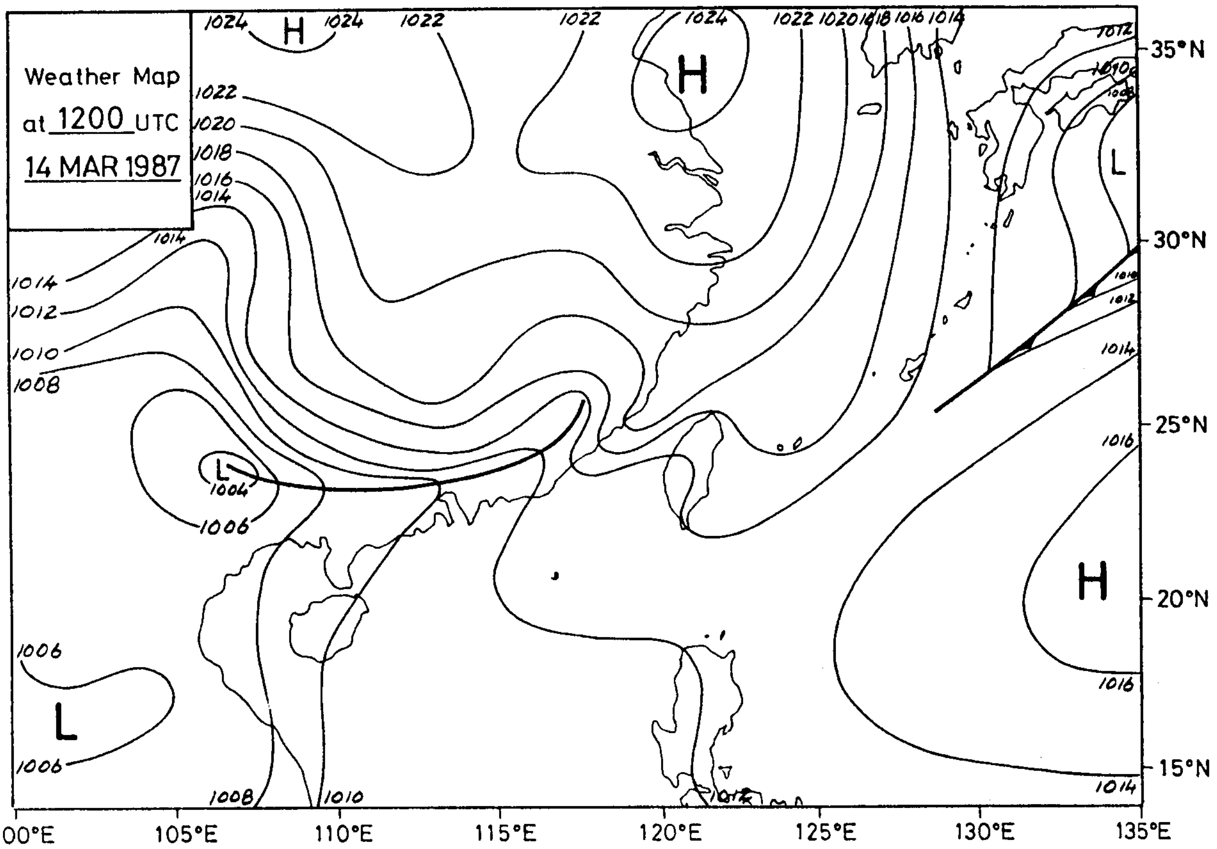
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(k)



Weather Map
at 1200 UTC
14 MAR 1987
H
H
H
L
L
L
35°N
30°N
25°N
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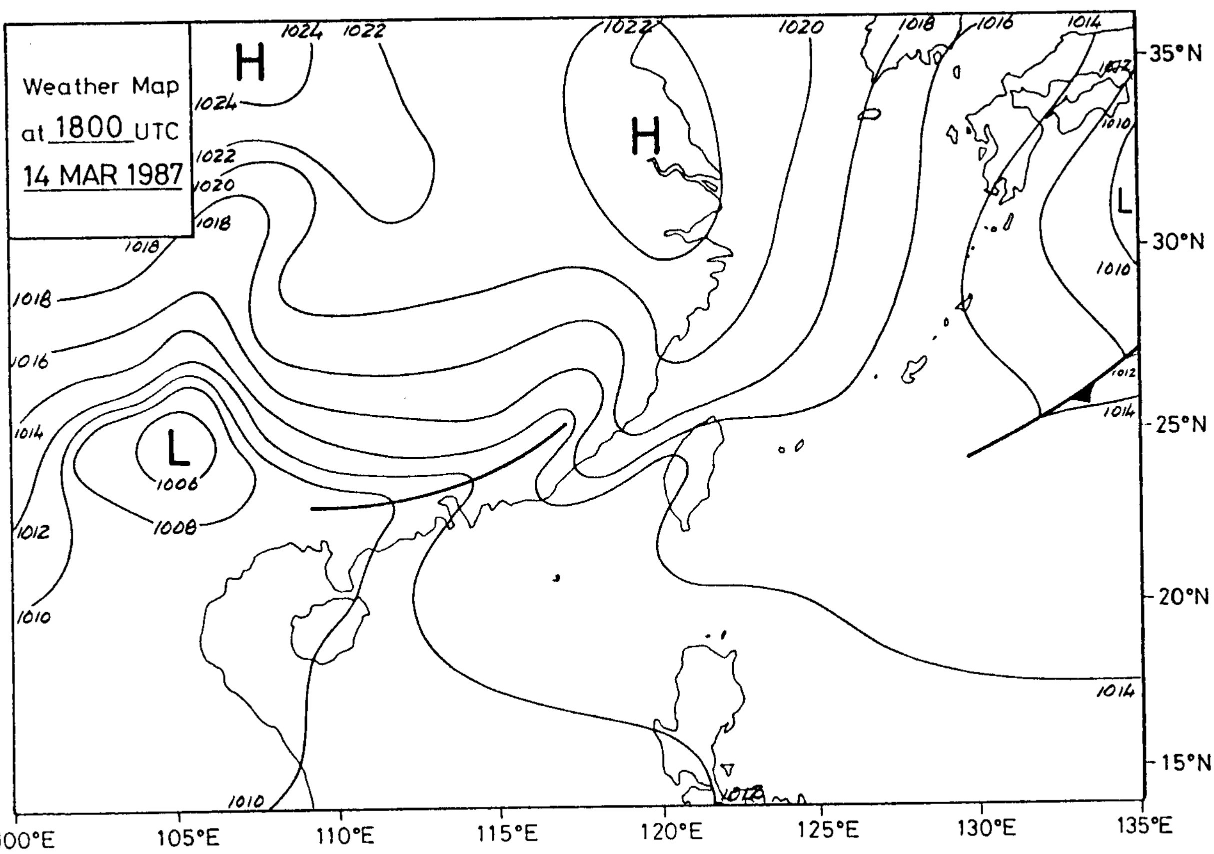
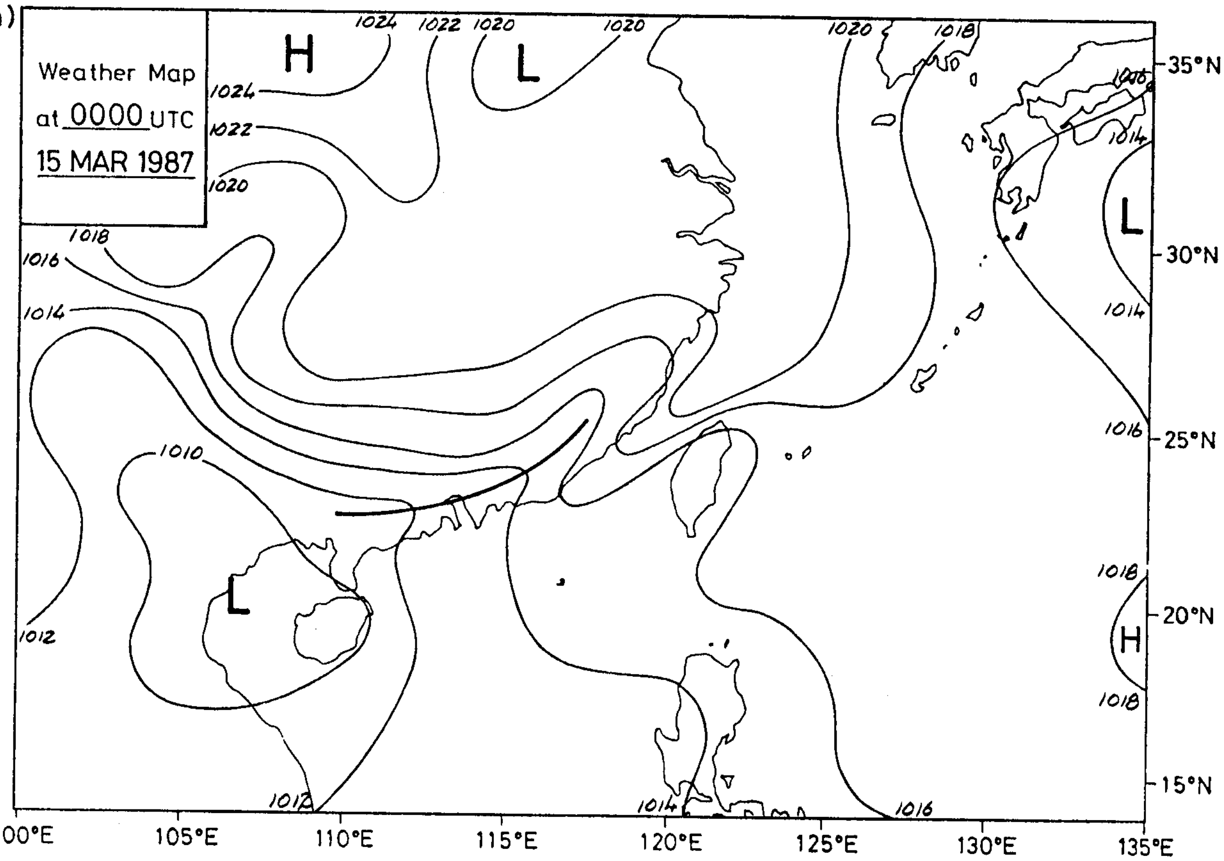
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(l)



Weather Map
at 1800 UTC
14 MAR 1987
H
H
L
L
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(m)


Weather Map
at 0000 UTC
15 MAR 1987
H
L
L
L
H
1024
1022
1020
1018
1016
1014
1012
1010
100°E
105°E
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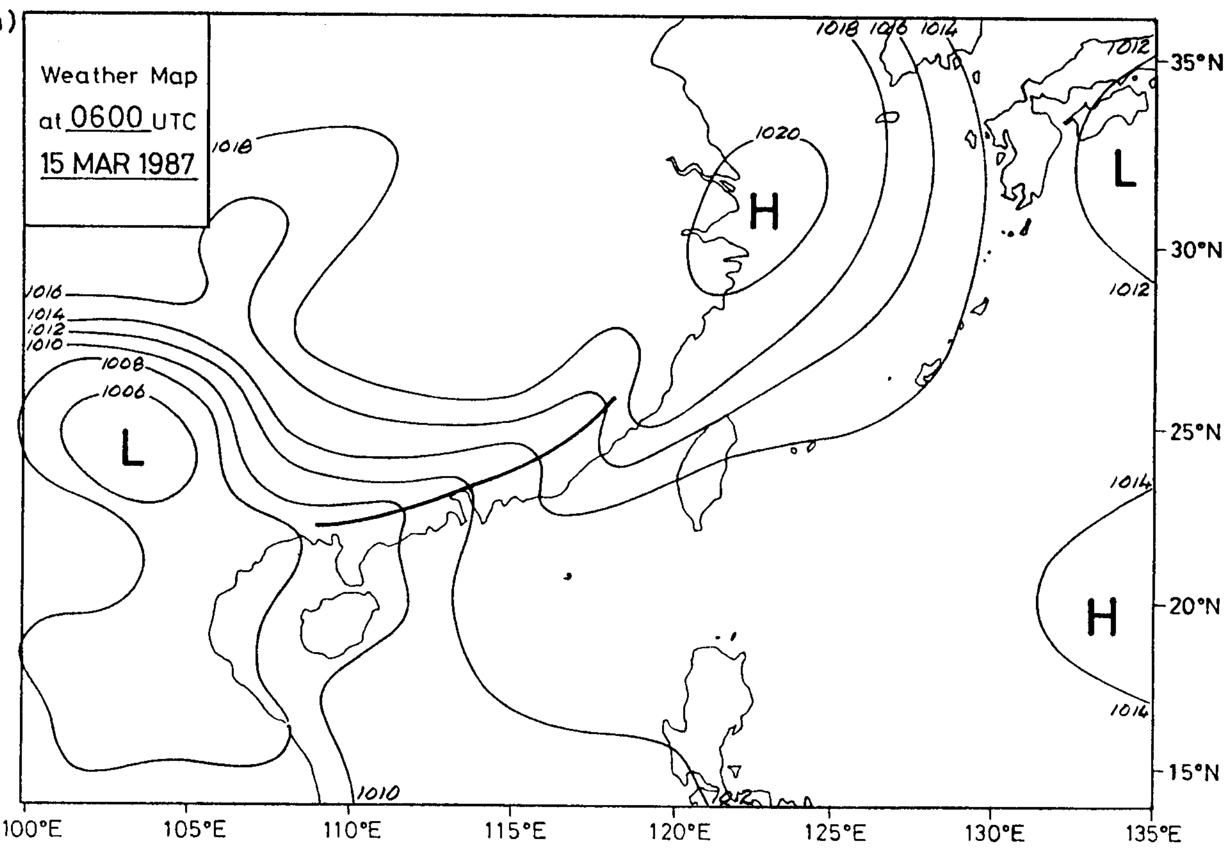
125°E
130°E
135°E
35°N
30°N
25°N
20°N
15°N

(n)


Weather Map
at 0600 UTC
15 MAR 1987
H
L
L
H
1020
1018
1016
1014
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1010
1008
1006
100°E
105°E
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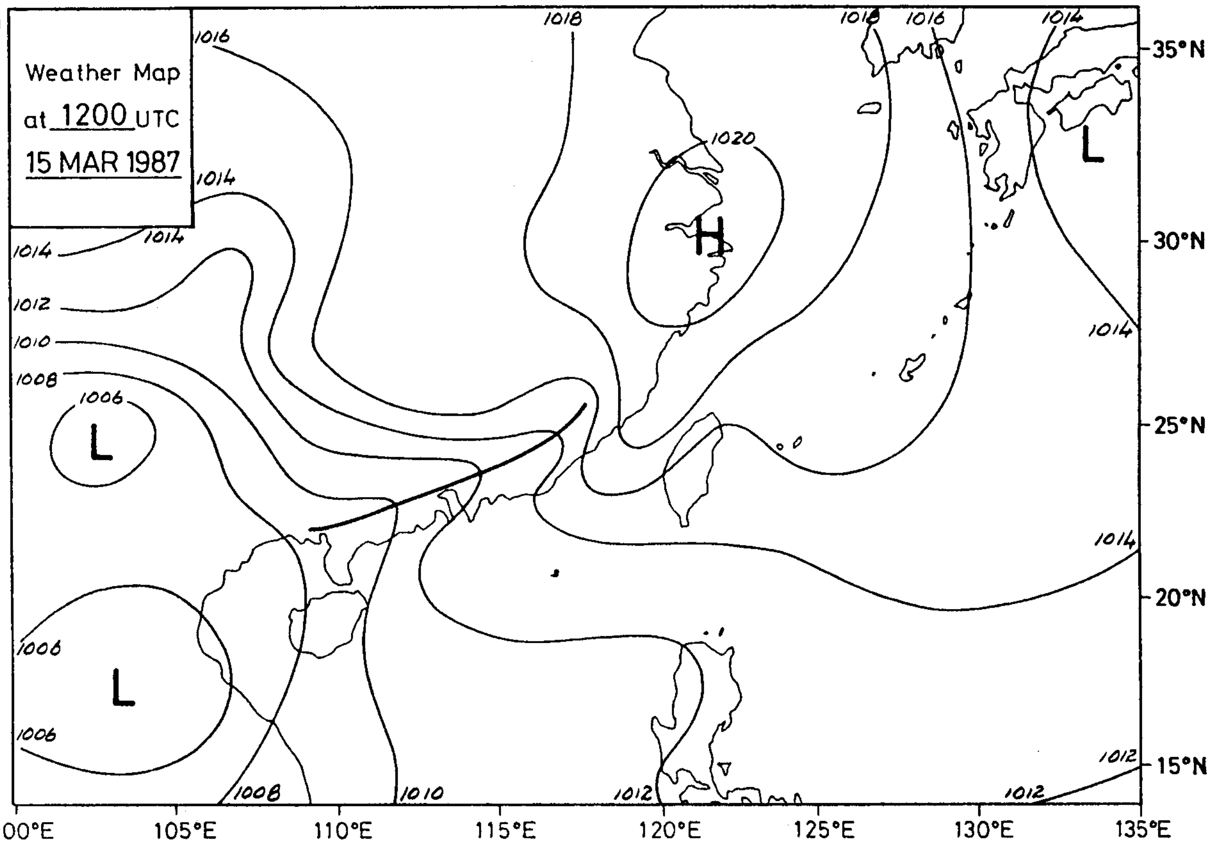
125°E
130°E
135°E
35°N
30°N
25°N
20°N
15°N

(o)


Weather Map
at 1200 UTC
15 MAR 1987
1016
1018
1014
1012
1010
1008
1006
1020
H
L
1008
1010
1012
35°N
30°N
25°N
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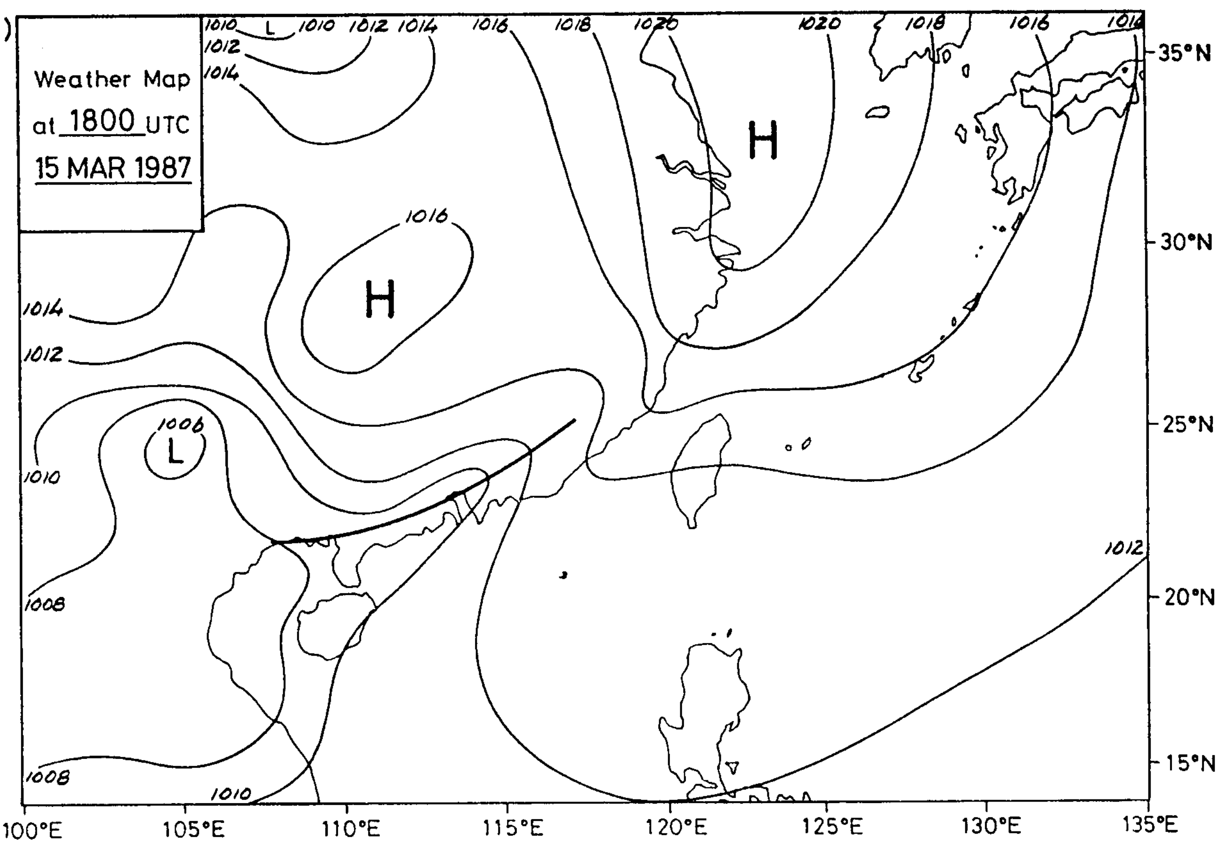
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(p)


Weather Map
at 1800 UTC
15 MAR 1987
1010
L
1012
1014
1016
1018
1020
H
1006
1008
35°N
30°N
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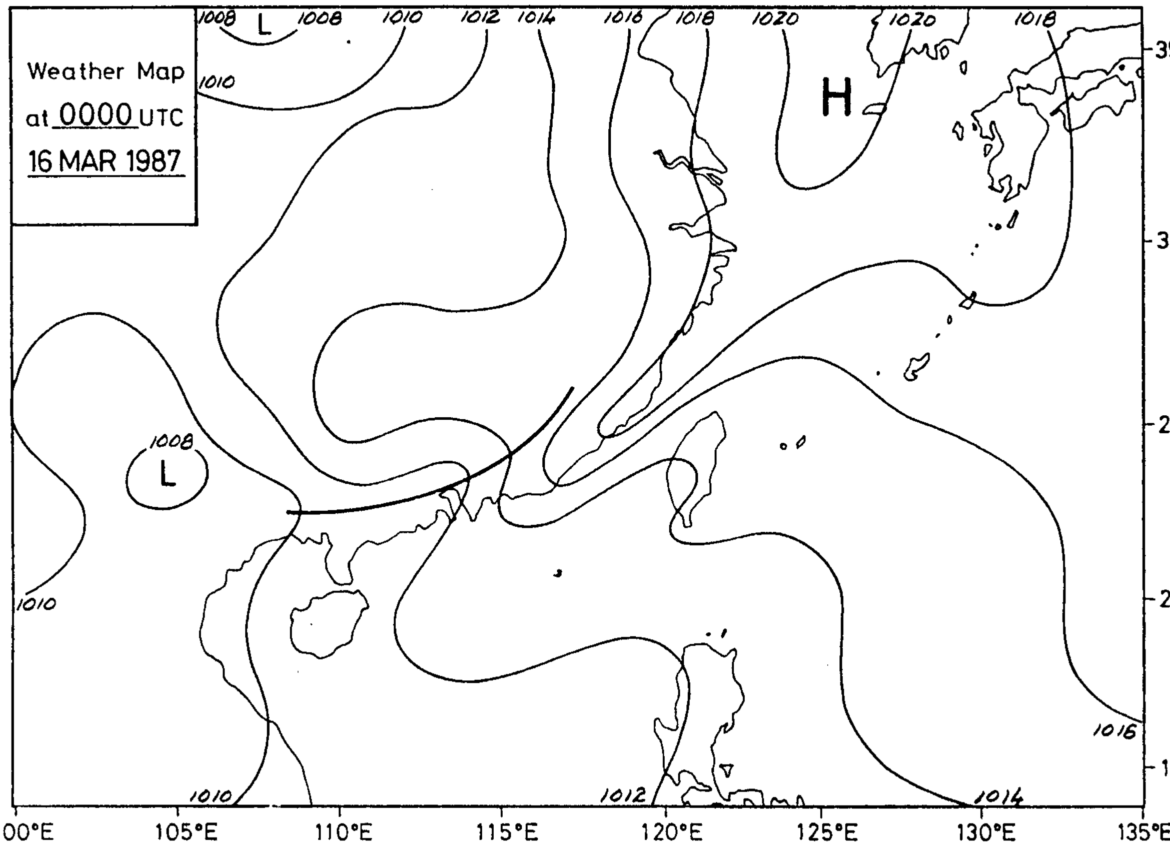
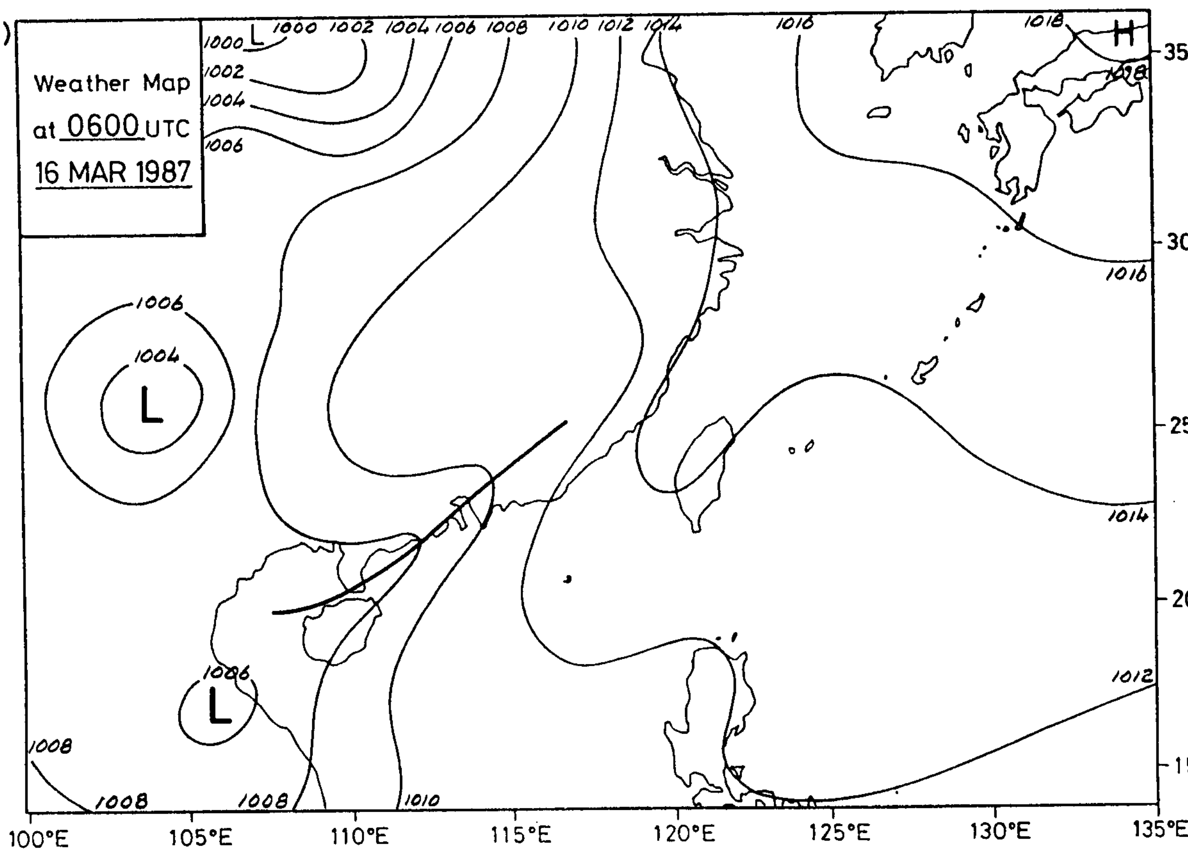
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(q)


Weather Map
at 0000 UTC
16 MAR 1987
1008
L
1008
1010
1012
1014
1016
1018
1020
1020
1018
H
1010
1008
L
1010
1016
1010
1012
1014
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

(r)


Weather Map
at 0600 UTC
16 MAR 1987
1000
L
1000
1002
1004
1006
1008
1010
1012
1014
1016
1018
H
1018
1002
1004
1006
1006
1004
L
1016
1014
1012
1006
L
1008
1008
1008
1010
35°N
30°N
25°N
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105°E
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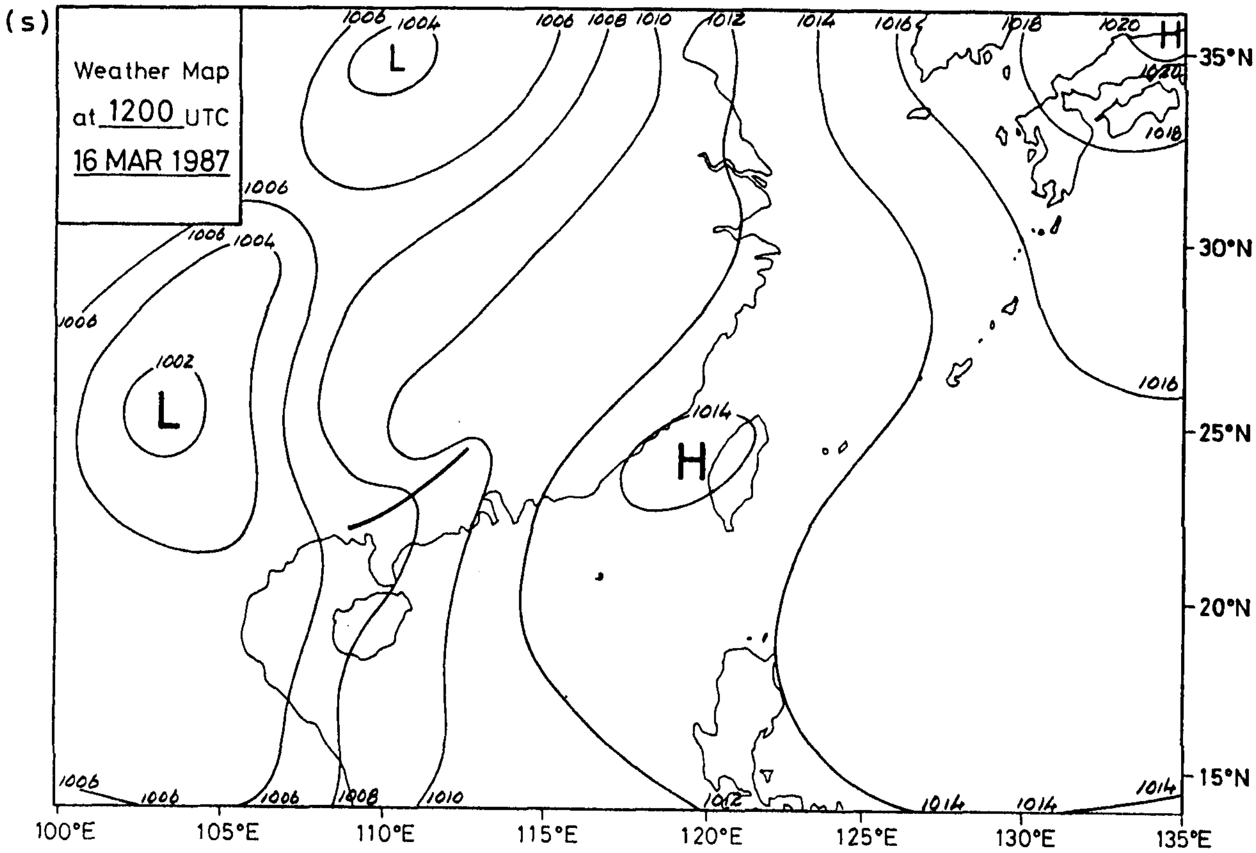
120°E
125°E
130°E
135°E

(s)


Weather Map
at 1200 UTC
16 MAR 1987
L
L
H
H
35°N
30°N
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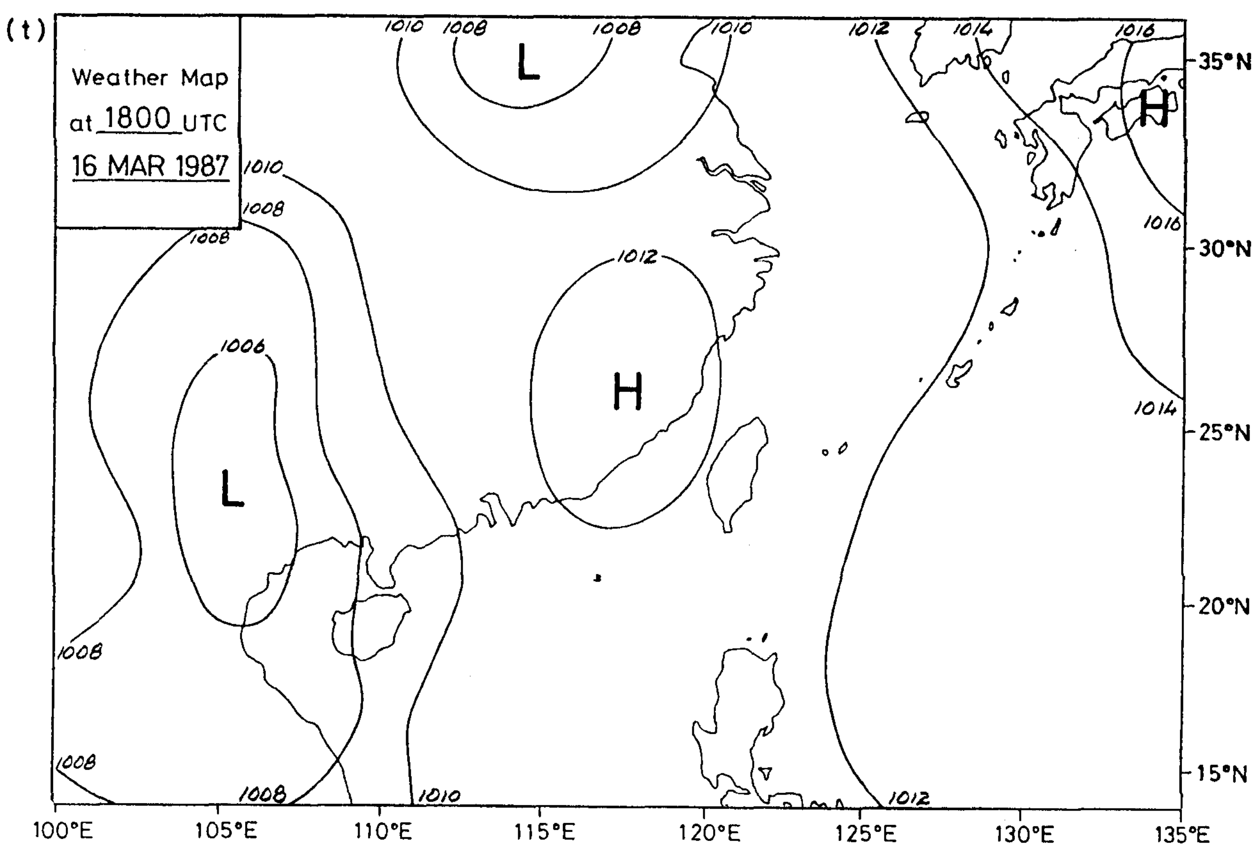
135°E

(t)


Weather Map
at 1800 UTC
16 MAR 1987
L
L
H
H
35°N
30°N
25°N
20°N
15°N
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E