ROYAL OBSERVATORY, HONG KONG

Technical Note (Local) No. 66

AN ASSESSMENT OF ROYAL OBSERVATORY'S LIMITED AREA MODEL IN FORECASTING ARRIVAL OF WINTER MONSOON SURGES IN HONG KONG

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1. INTRODUCTION

Forecasters of the Royal Observatory have been using outputs of several numerical weather prediction models as forecasting aids, one of which is the Royal Observatory's Limited Area Model (ROLAM). On a routine basis ROLAM provides forecasts of various weather elements for grid points (22°N, 114°E) and (23°N, 114°E). As this information sheds light on the preparation of forecasts in the Central Forecasting Office, its accuracy is of importance. In this brief study, the performance of ROLAM during one winter on the forecast of monsoon surges was investigated.

2. METHODOLOGY

The winter season of Hong Kong generally starts from mid-October and ends in early April. During this period Hong Kong is influenced by anticyclones originating from high latitude, which occasionally bring surges of the winter monsoon to the coast of South China. Operationally, monsoon surges reaching Hong Kong can be identified by the following observations (Lam, 1976) :

a.) four consecutive 3-hourly Waglan Island wind observations from 340 to 030 degrees with mean wind speed above 5 m/s is considered as a *northerly* surge;

b.) four consecutive 3-hourly Waglan Island wind observations from 060 to 120 degrees with mean wind speed above 7.5 m/s is considered as an *easterly* surge;

c.) abrupt increase in wind speed or change in wind direction (which is not due to light wind condition);

d.) drop of at least 2°C in the daily mean temperature between D-1 and D+1, or an abrupt fall of at least 2°C in temperature within an hour which is not associated with thunderstorm downdraughts, is considered as a temperature surge.

Using the above criteria 26 surges of the winter monsoon were identified during the period October 1991 to April 1992 and were employed for this investigation.

ROLAM's forecasts on these 26 occasions were extracted for verification. ROLAM's prognoses 24 hour before, on, and 24 hour after the arrival of surges at the grid point (22°N, 114°E) were extracted. The present study will concentrate on surface elements such as wind speed and direction, precipitation and mean sea level pressure. The model's temperature forecast will be dealt with in other studies. Also, due to the fact that the model's prognostic product was made at 6-hourly intervals, criteria (a) and (b) stated above was modified slightly to 'two consecutive 6-hourly Waglan wind observations' for relevancy during verification.

ROLAM offers forecasts at 6-hourly intervals up to 72 hours on a daily basis, based upon lateral boundary data provided by Japan Meteorological Agency. Since these boundary data are of 6-hourly intervals up to 48 hours and at 12 hourly intervals there after, a change in forecast accuracy is expected after 48 hours. Therefore ROLAM's forecasts of up to 48 hour were taken in this verification exercise. Also, the latest set of ROLAM forecast is usually not available to forecasters until after 00Z every morning, i.e., slightly more than 12 hours after the start time of the model's forecast. Hence only the forecasts from 18 hour onward are of use to forecasters. As a result only the 18 to 48 hour forecasts were examined for practical reason.

As in the Monthly Weather Summary, the Royal Observatory's mean sea level pressures and rainfall amounts, Waglan Island's surface wind speed and direction were used as standards, with which ROLAM's forecast at 22°N-114°E will be verified against. As the positions of the actual and forecast elements are in fact some 38 kilometres apart (the Royal Observatory is 38 kilometres north-northeast of the grid point 22°N-114°E, and Waglan Island is 37 kilometres east-northeast of it), some allowance in deviations should be given when comparing the actual observations and ROLAM's forecast. In this study, the tolerance of errors are set at ± 2 hPa for mean sea level pressure, ± 30° for wind direction, ± 5 knots for wind speed and ± 5 mm for precipitation. These criteria are intended to reflect the values forecasters have in mind when interpreting ROLAM and other numerical products. Also, an allowance of ± 12 hours for the timing of surge arrivals was used in determining how well the model performs in this respect.

With an objective of setting an easy reference for forecasters, a simple descriptive approach is taken in this study. After all, only surges in one winter are studied and a detail statistical approach would not be very meaningful.

3. FINDINGS

If we take condition (c) in the previous section as the arrival time of a monsoon surge, then 12 out of the 26 selected cases (46%) fall into the 12 hours allowance and hence were said to be correctly prognosticated. Most of the forecasts failed to depict the arrival of a surge, because the relatively lower wind speed condition before the arrival was overestimated, hence affected the recognition of the sudden strengthening of wind (see Case 1 in Annex). Also, the model seems unable to distinguish the change in wind direction when a northerly replenishment arrived shortly after the preceding easterly surge (see Case 2 in Annex). Sometimes even though the model did forecast an increase in wind speed, the change is too gradual and cannot reflect the actual situation well enough (see Case 3 in Annex).

Now if one scrutinizes each of the four forecast elements, that is, wind speed and direction, mean sea level pressure, and amount of precipitation, one will notice that in these 26 selected cases of winter monsoon, only 10, or 38%, of ROLAM's forecasts in wind speed were considered correct (see Table 1). The forecasts of wind direction is better with 18 cases (or 69%) accuracy. The model is more indicative in the forecast of pressure and precipitation within 12 hours of the surge's arrival, in which 22 occasions (or 85%) and 24 occasions (or 92%) were deemed correct respectively.

Table 1 : Number and percentage of ROLAM's forecasts considered as correct.

Date	Direction	Force	Pressure	Precipitation
9110 / 0506 Z	✓	×	✓	×
9110 / 1400 Z	×	×	✓	✓
9110 / 1700 Z	✓	✓	×	✓
9110 / 1912 Z	×	×	✓	✓
9110 / 2618 Z	✓	✓	✓	✓
9111 / 0406 Z	✓	×	✓	✓
9111 / 0818 Z	×	×	✓	✓
9111 / 1018 Z	✓	×	✓	✓
9111 / 1512 Z	×	×	×	✓
9111 / 2400 Z	×	✓	✓	✓
9111 / 2500 Z	×	✓	✓	✓
9112 / 0818 Z	✓	×	✓	✓
9112 / 1118 Z	✓	✓	✓	✓
9112 / 2600 Z	×	✓	✓	✓
9112 / 2718 Z	✓	✓	✓	✓
9201 / 0400 Z	✓	×	×	✓
9201 / 1306 Z	✓	✓	✓	✓
9201 / 3106 Z	✓	×	✓	✓
9202 / 0100 Z	✓	×	✓	✓
9202 / 0418 Z	✓	×	✓	✓
9202 / 0800 Z	✓	×	✓	✓
9202 / 1606 Z	✓	×	×	✓
9203 / 0312 Z	×	×	✓	✓
9203 / 1712 Z	✓	✓	✓	✓
9203 / 2112 Z	✓	✓	✓	✓
9204 / 0412 Z	✓	×	✓	×
Total	18 ✓	10 ✓	22 ✓	24 ✓
Percentage	69%	38%	85%	92%

4. CONCLUSION

The performance of ROLAM on predicting winter monsoon surges was studied for one winter. Of the weather elements (wind speed and direction, mean sea level pressure and amount of precipitation) predicted for two grid points in the vicinity of Hong Kong, ROLAM seems to be able to give fairly good indications of changes in pressure and precipitation that accompany the arrival of a monsoon surge.

One major drawback for this investigation result is that the formulation for ROLAM's forecasts had been modified after the period in study, and some of the problems stated above may be corrected since then. To keep up with the ever advancing formulation of numerical models, it may be best to have a computerized verification scheme done on a regular basis. For instance, the temperature forecasts produced by regression, Kalman filter as well as ROLAM are already verified daily to meet the operational need in the forecasting office.

Further investigations on factors affecting the accuracy of the model's output are necessary to improve the forecasts' precision. Other possible areas of research are (i) study the performance for each forecast hour to see if the accuracy deteriorate with time; (ii) relate the values of Delta P, Delta P_s and Delta P_{972}* with the performance of the model's forecasts; (iii) compare the results of ROLAM's forecast with the synoptic analog performed by the Royal Observatory's computer system.

* Note :

Delta P -- difference in surface pressure between Hong Kong and the highest pressure within the area 22.5°N-36°N, 105°E-114°E.

Delta P_s -- difference in surface pressure between Hong Kong and Shanghai (station number 58362).

Delta P_{972} -- difference in surface pressure between Hong Kong and Chenzhou (station number 57972).

Case 1

The following example illustrates the case when the wind speed of a pre-surge situation was overestimated by ROLAM's forecast, hence making the signature of surge arrival unrecognizable.

Example : Easterly surge arrived at 18Z on 11 December 1991.

Date & Hour	Actual Wind Speed at Waglan (in knots)	ROLAM's Forecast Wind Speed at 22°N-114°E (in knots)
10 Dec 91, 18Z	1	6
11 Dec 91, 00Z	5	9
11 Dec 91, 06Z	4	9^a / 8^c
11 Dec 91, 12Z	5	9^b / 8^d
11 Dec 91, 18Z	15	10
12 Dec 91, 00Z	10	9

Note : [a] and [b] represents ROLAM's 42 and 48 hour forecast based on 9 Dec 91;
[c] and [d] represents ROLAM's 18 and 24 hour forecast based on 10 Dec 91.

By comparing the analyzed charts with ROLAM's forecast charts, it was noticed that a surge of the easterlies prior to the one in study brought tight pressure gradient to the northern part of the South China Sea. The gradient remained tight even after the surge had weakened and a broad area of low pressure dominate South China on 9 December. When the high pressure cell that brought the easterly surge on the 11th gradually spread south, the South China coastal region was sandwiched between the two sets of tight pressure gradients (Fig. 1 - 10).

In the actual case, the South China coastal region was in a light wind condition until the arrival of the easterly surge on the 11th . ROLAM, however, had a hard time resolving the two sets of pressure gradient. As a result the wind speed before the onset of the surge was overestimated, and the sudden strengthening of winds due to the arrival of the surge was blurred in ROLAM's forecast (Fig. 11 - 14).

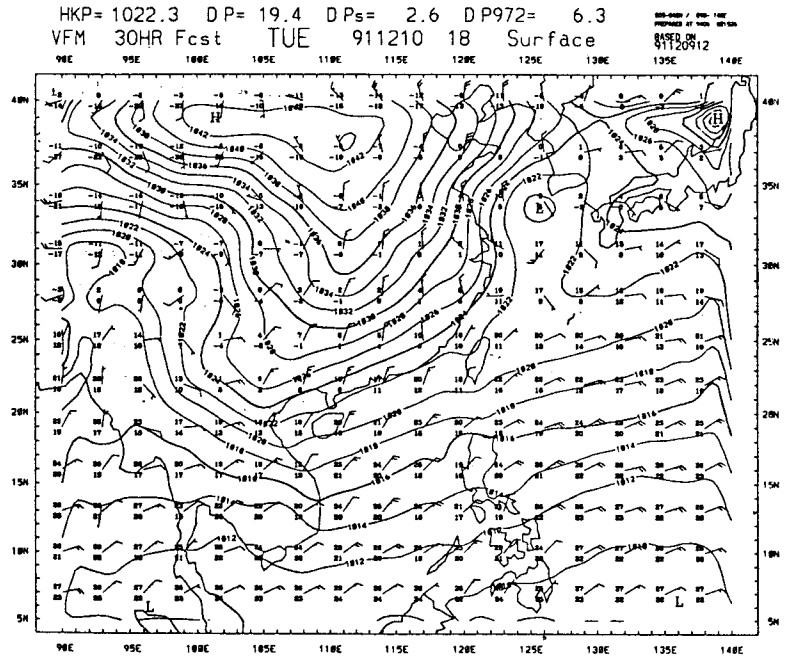

Fig. 1 ROLAM's 30-hour forecast for 10 Dec 91, 18Z based on 9 Dec 91, 12Z.

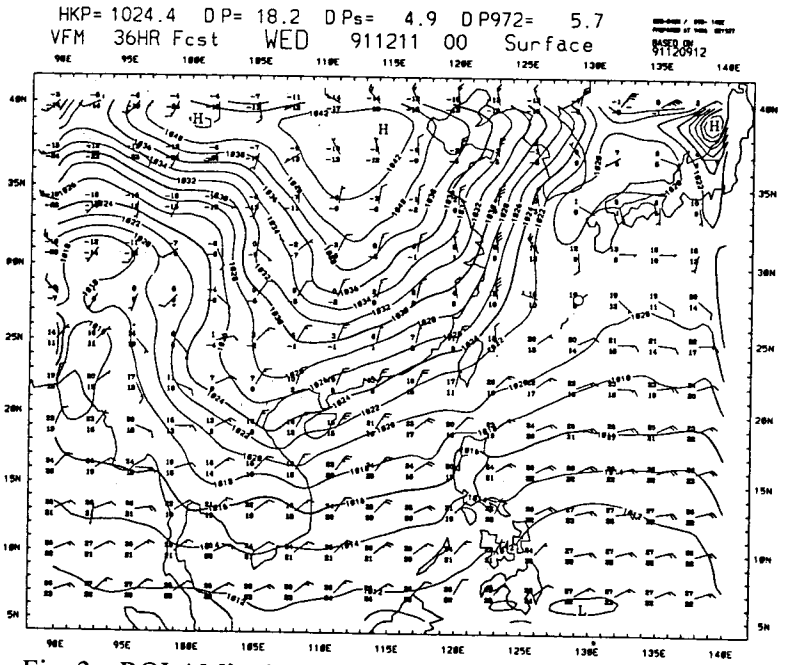

Fig. 3 ROLAM's 36-hour forecast for 11 Dec 91, 00Z based on 9 Dec 91, 12Z.

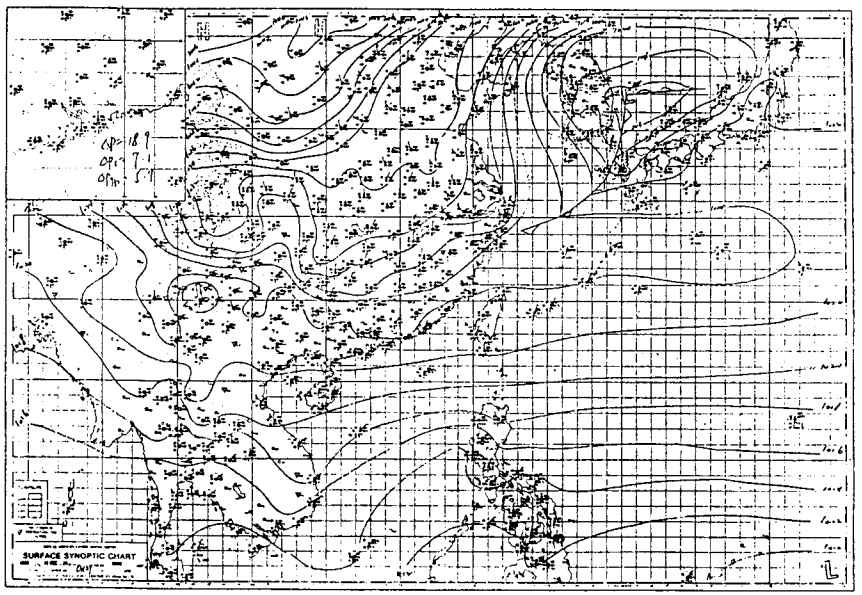

Fig. 2 Actual analysis for 10 Dec 91, 18Z.

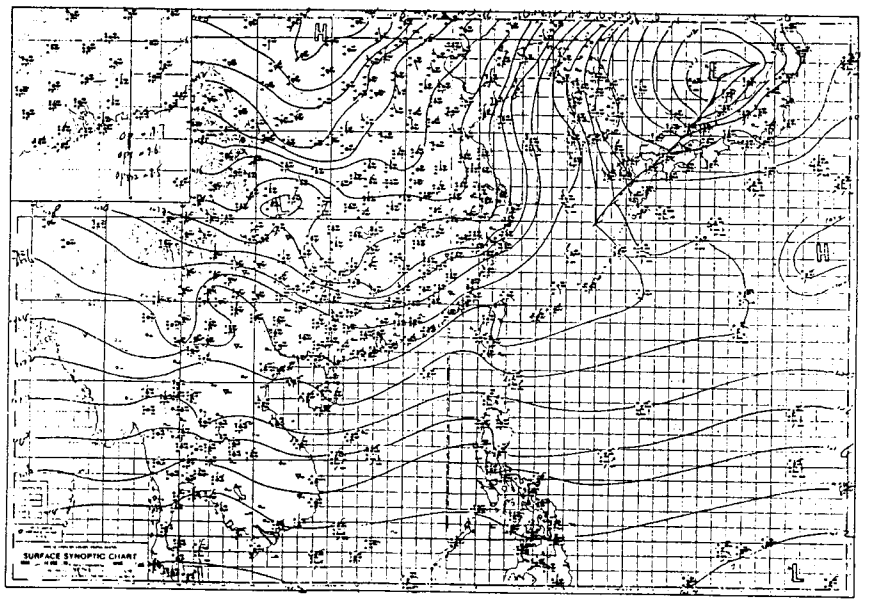

Fig. 4 Actual analysis for 11 Dec 91, 00Z.

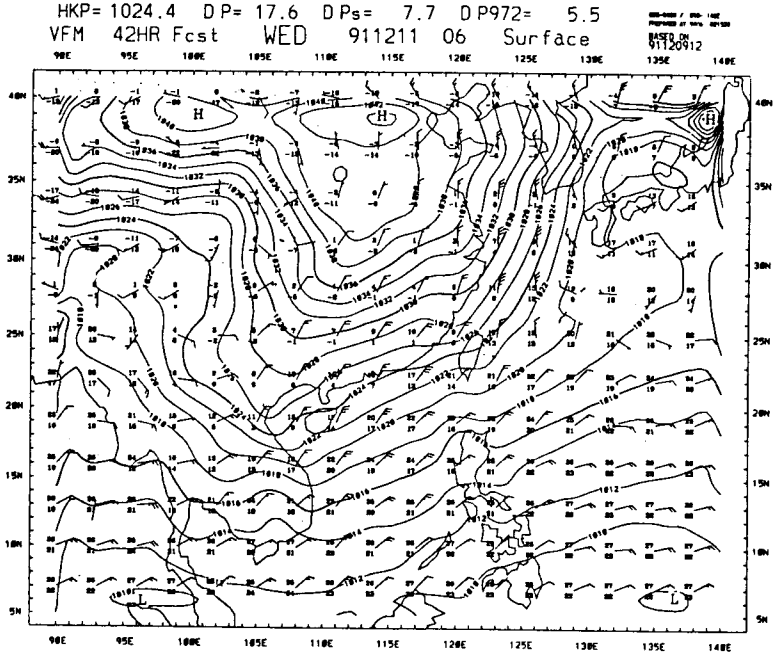

Fig. 5 ROLAM's 42-hour forecast for 11 Dec 91, 06Z based on 9 Dec 91, 12Z.

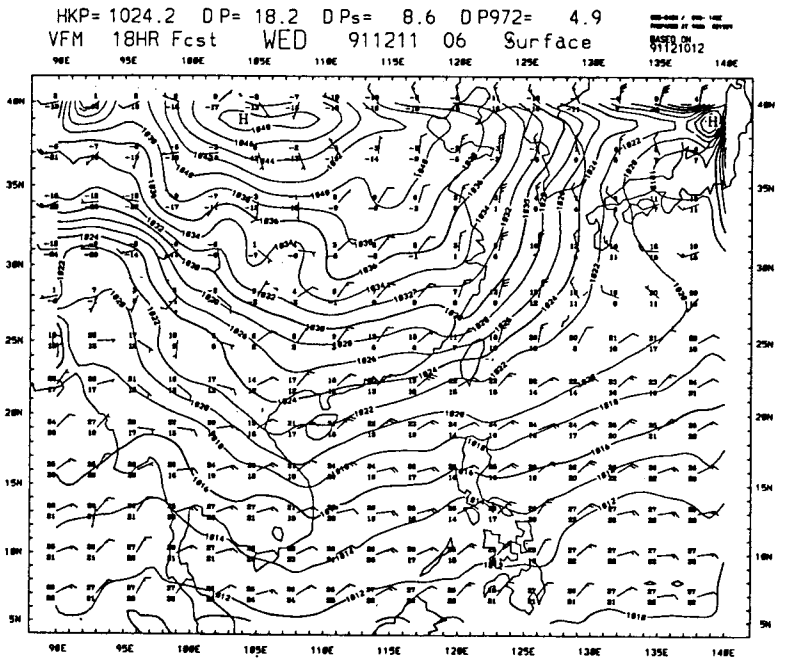

Fig. 6 ROLAM's 18-hour forecast for 11 Dec 91, 06Z based on 10 Dec 91, 12Z.

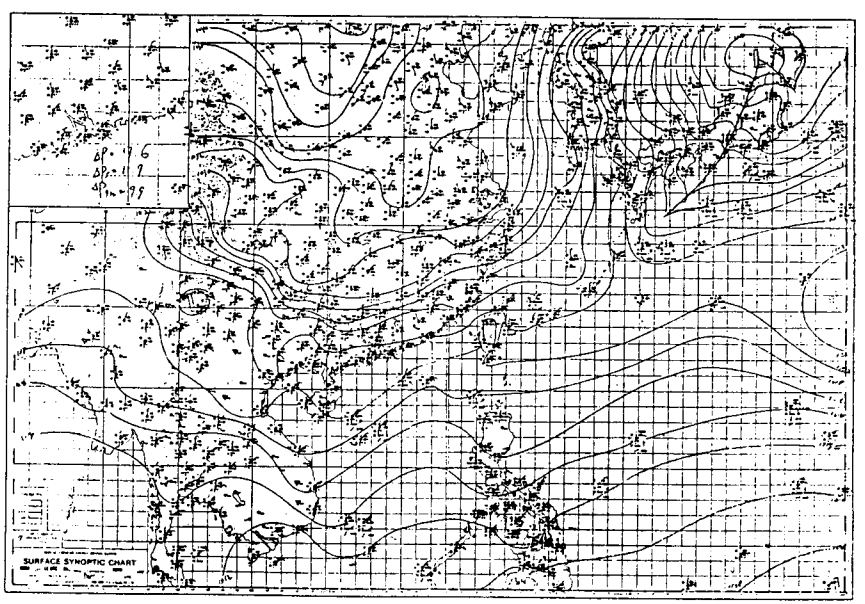

Fig. 7 Actual analysis for 11 Dec 91, 06Z.

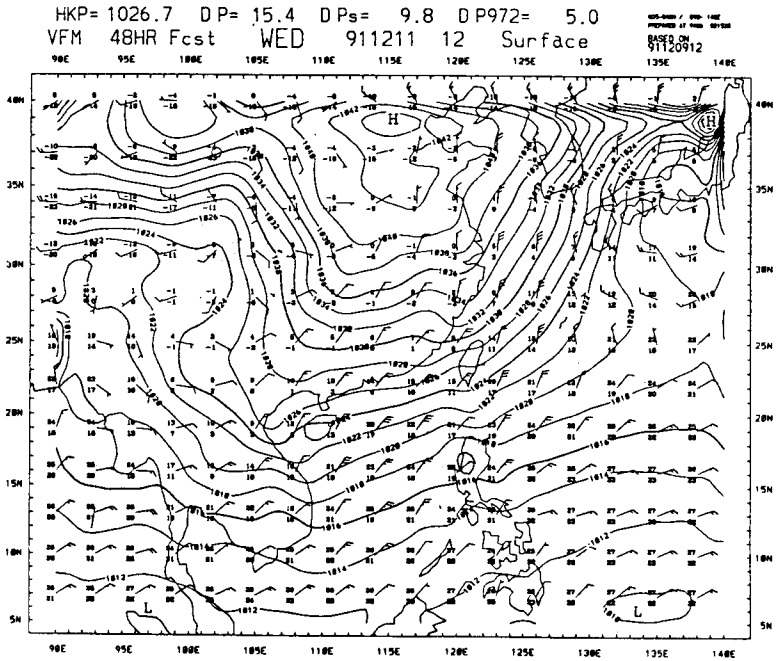

Fig. 8 ROLAM's 48-hour forecast for 11 Dec 91, 12Z based on 9 Dec 91, 12Z.

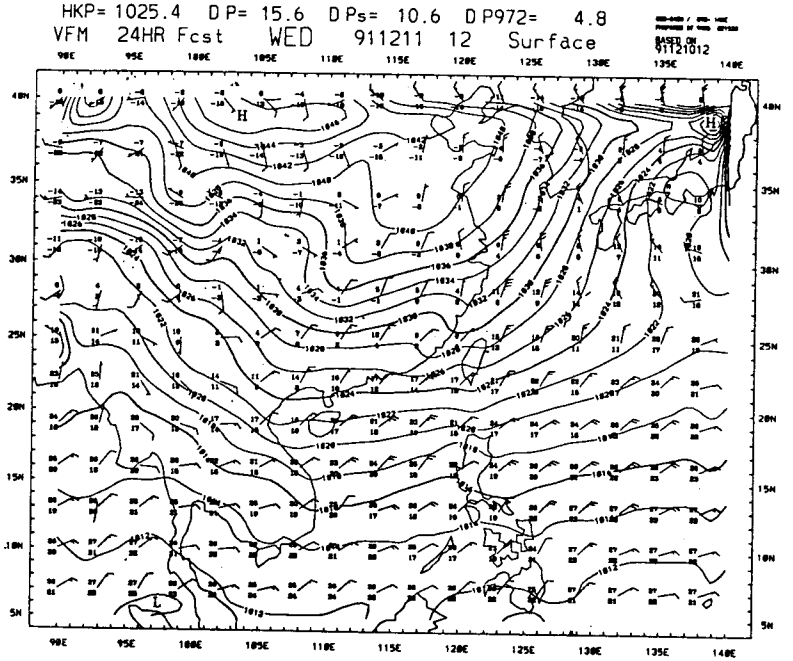

Fig. 9 ROLAM's 24-hour forecast for 11 Dec 91, 12Z based on 10 Dec 91, 12Z.

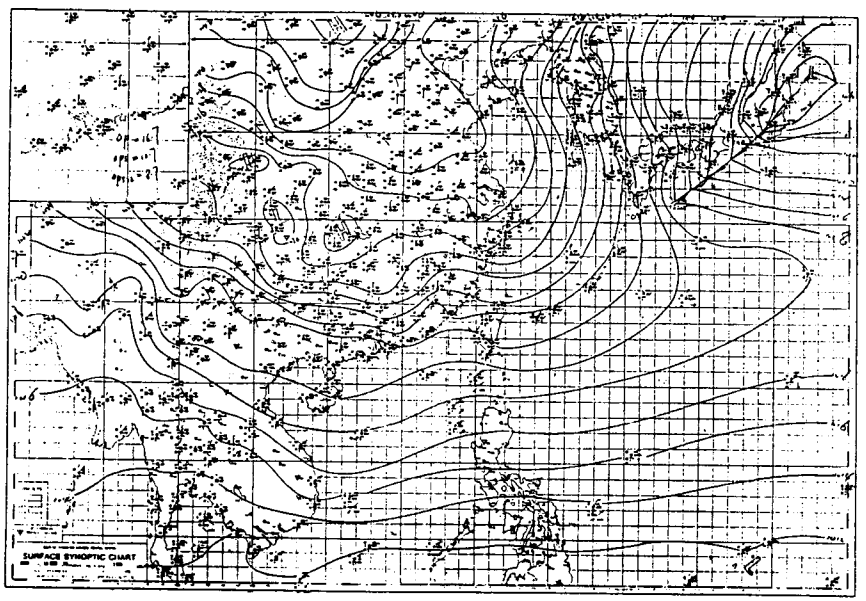

Fig. 10 Actual analysis for 11 Dec 91, 12Z.

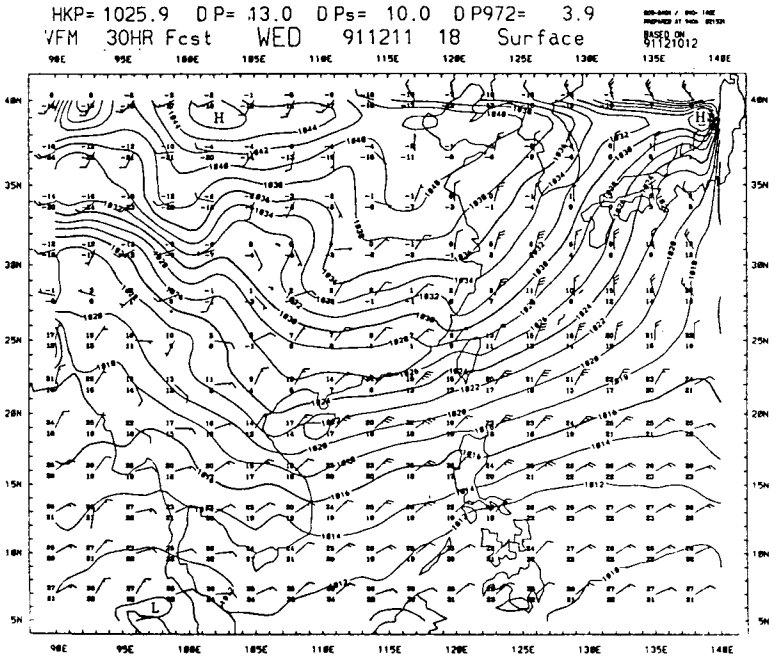

Fig. 11 ROLAM's 30-hour forecast for 11 Dec 91, 18Z based on 10 Dec 91, 12Z.

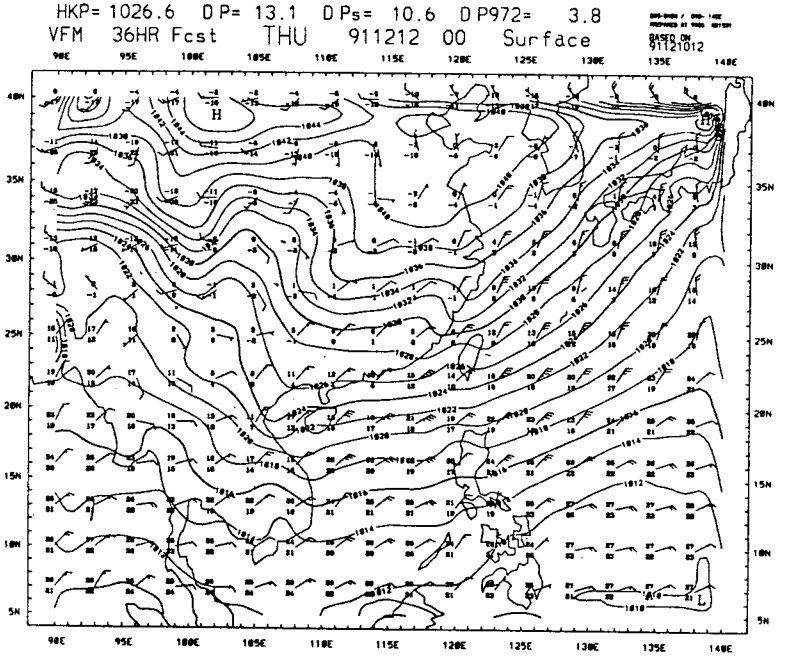

Fig. 13 ROLAM's 36-hour forecast for 12 Dec 91, 00Z based on 10 Dec 91, 12Z.

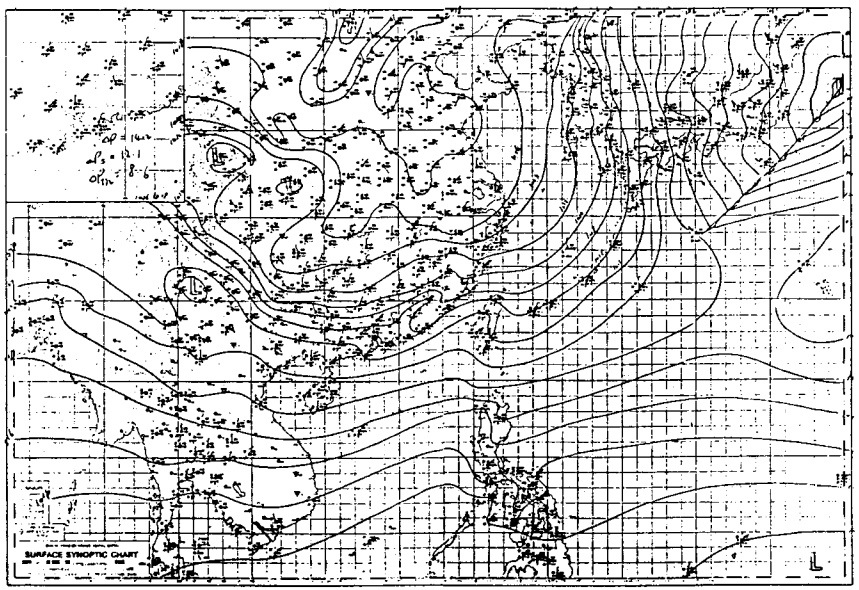

Fig. 12 Actual analysis for 11 Dec 91, 18Z.

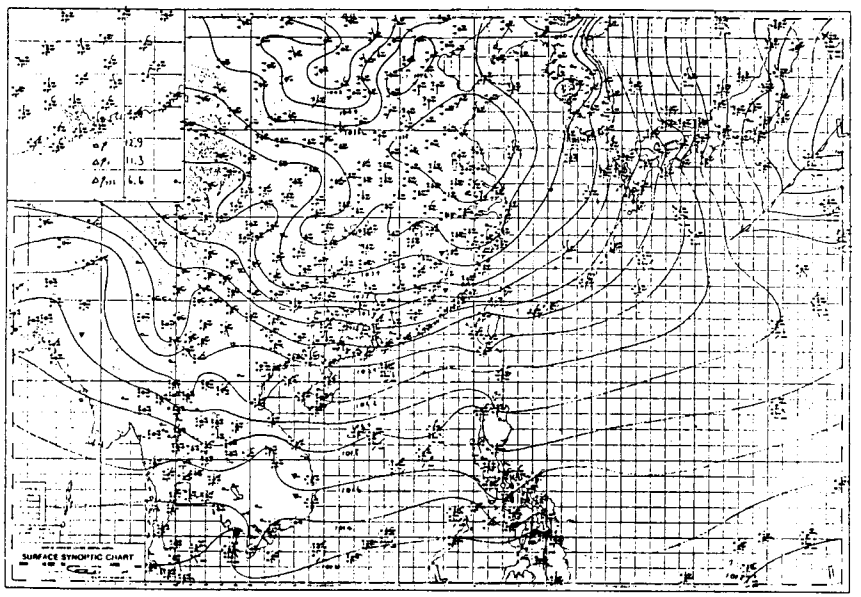

Fig. 14 Actual analysis for 12 Dec 91, 00Z.

Case 2

The following example illustrates the situation where abrupt change in wind direction due to the arrival of a northerly surge on 25 November was not reflected in ROLAM's forecast, probably because a significant easterly surge had arrived just 24 hours ahead of it and biased the directional component of the model's forecast. Note that ROLAM forecast the wind strength of the easterly surge on the 24th to persist well on to the 25th, indicating that the model was aware of the enduring strength of the monsoon.

Example : Northerly surge replacing the prevailing easterlies at 00Z on 25 November 1991.

Date & Hour	Actual Wind Direction at Waglan (in degrees)	ROLAM's Forecast Wind Direction at 22°N-114°E (in degrees)	Actual Wind Speed at Waglan (in knots)	ROLAM's Forecast Wind Speed at 22°N-114°E (in knots)
23 Nov 91, 18Z	80	30	6	5
24 Nov 91, 00Z	90	50	17	9
24 Nov 91, 06Z	90	60[a] / 70[c]	17	9[a] / 12[c]
24 Nov 91, 12Z	90	60[b] / 60[d]	20	10[b] / 11[d]
24 Nov 91, 18Z	80	60	16	11
25 Nov 91, 00Z	10	60	11	11
25 Nov 91, 06Z	20	60[e] / 60[f]	10	10[e] / 10[f]

Note : [a] and [b] represents ROLAM's 42 and 48 hour forecast based on 22 Nov 91;
[c] and [d] represents ROLAM's 18 and 24 hour forecast based on 23 Nov 91;
[e] represents ROLAM's 42 hour forecast based on 23 Nov 91.
[f] represents ROLAM's 18 hour forecast based on 24 Nov 91.

In this wrestling between the northerlies and the easterlies, the easterlies reached the coast of Guangdong first on the 24th (Fig. 15 - 26), but the northerlies managed to arrive 24 hours later and replaced the easterly airstream over the region. Well organized northerly winds prevailed over South China in general on the 25th (Fig. 27 - 31).

ROLAM did forecast the arrival of a significant surge of the winter monsoon, but the forecast wind direction was neither easterly nor northerly but northeasterly. From the forecast surface pressure pattern, it was noticed that model prognosticated a slightly more prominent ridge along the east coast of China on the 25th (pressure value over Taiwan Strait was higher than that observed in the actual situation). Moreover, the ridge that built up just northwest of the Guangdong Province was underestimated, resulting in the dominance of the eastern ridge. Wind directions at grid points over South China were all biased and gave northeasterly winds instead of northerly in the actual situation.

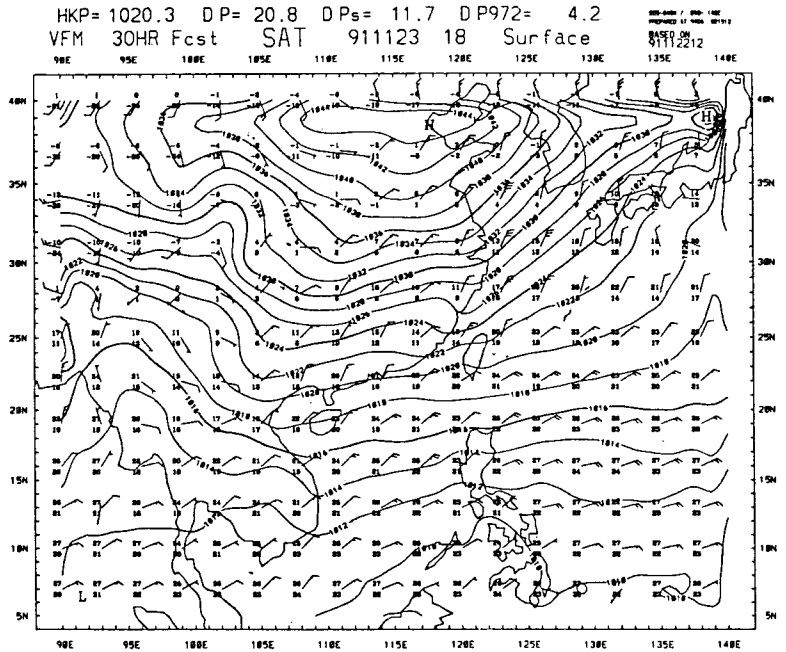

Fig. 15 ROLAM's 30-hour forecast for 23 Nov 91, 18Z based on 22 Nov 91, 12Z.

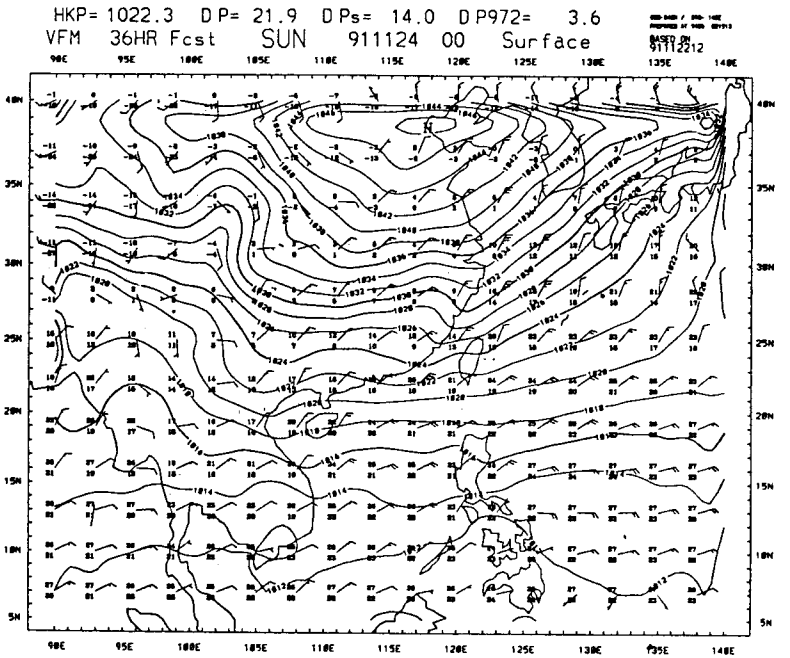

Fig. 17 ROLAM's 36-hour forecast for 24 Nov 91, 00Z based on 22 Nov 91, 12Z.

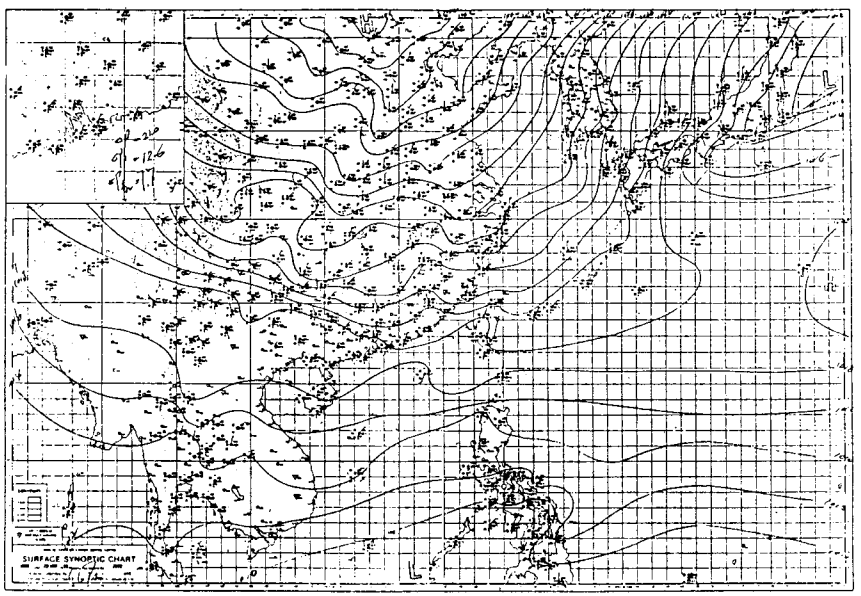

Fig. 16 Actual analysis for 23 Nov 91, 18Z.

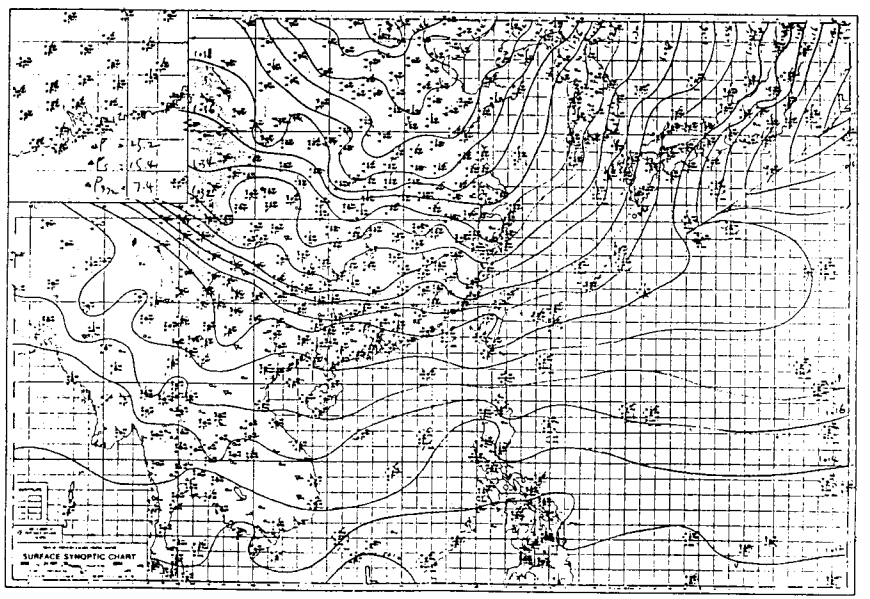

Fig. 18 Actual analysis for 24 Nov 91, 00Z.

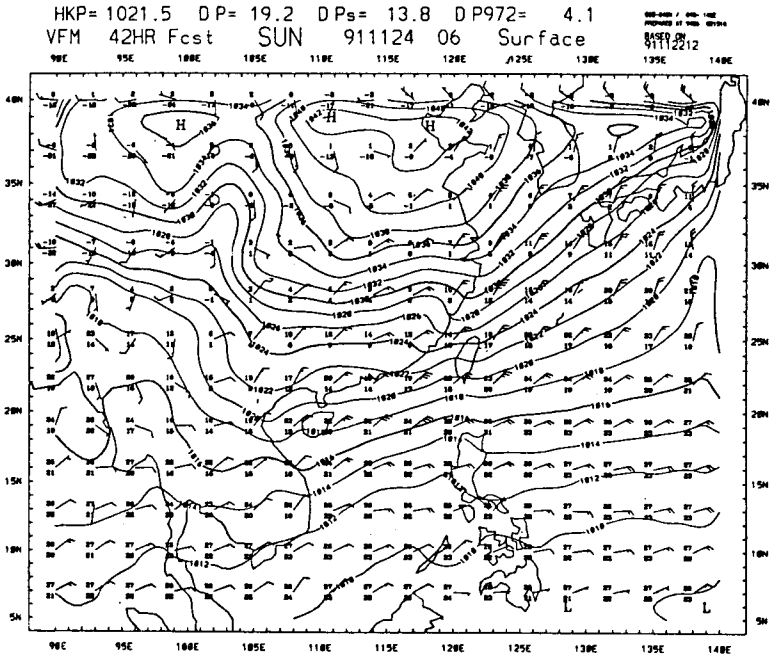

Fig. 19 ROLAM's 42-hour forecast for 24 Nov 91, 06Z based on 22 Nov 91, 12Z.

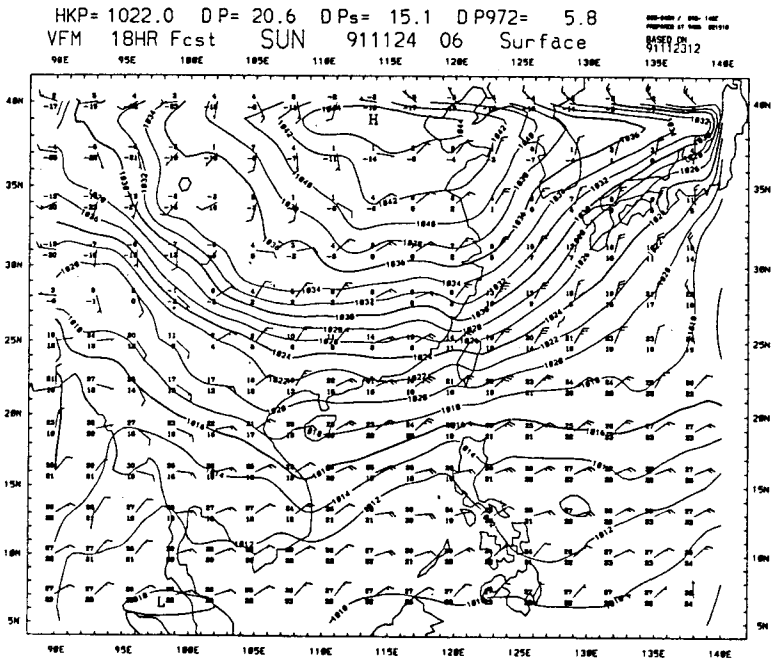

Fig. 20 ROLAM's 18-hour forecast for 24 Nov 91, 06Z based on 23 Nov 91, 12Z.

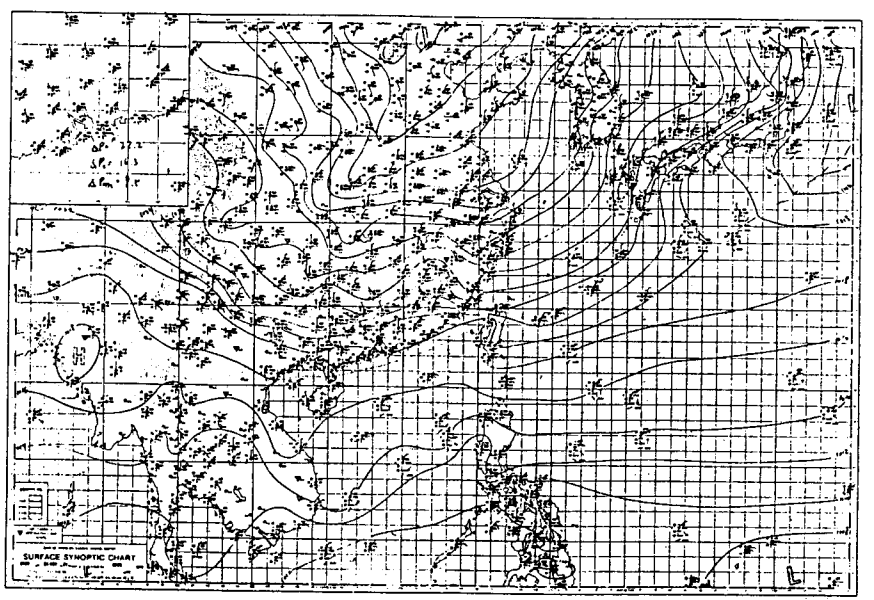

Fig. 21 Actual analysis for 24 Nov 91, 06Z.

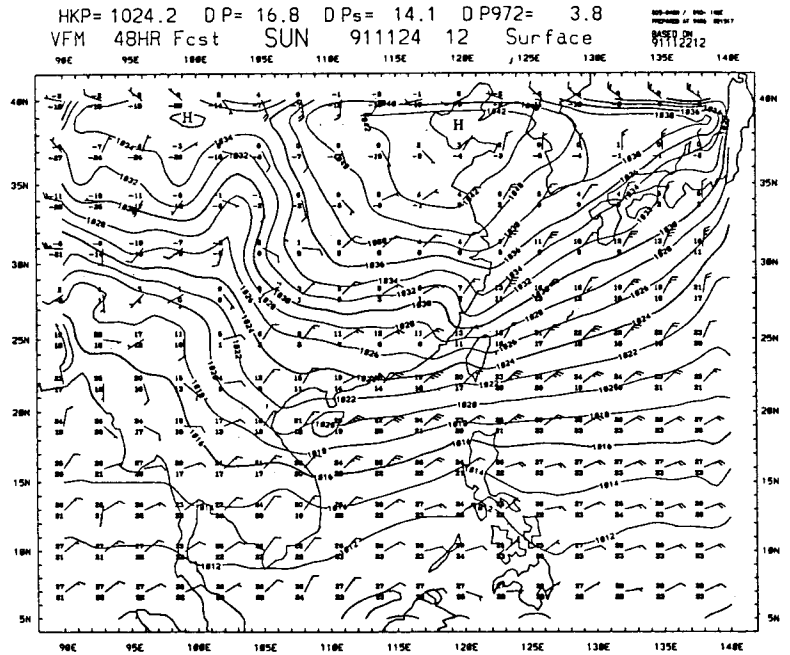

Fig. 22 ROLAM's 48-hour forecast for 24 Nov 91, 12Z based on 22 Nov 91, 12Z.

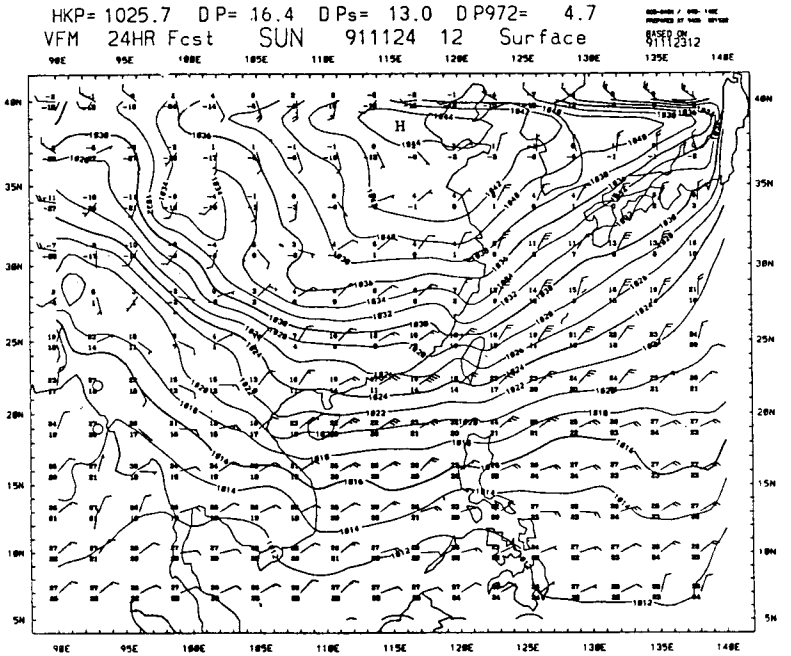

Fig. 23 ROLAM's 24-hour forecast for 24 Nov 91, 12Z based on 23 Nov 91, 12Z.

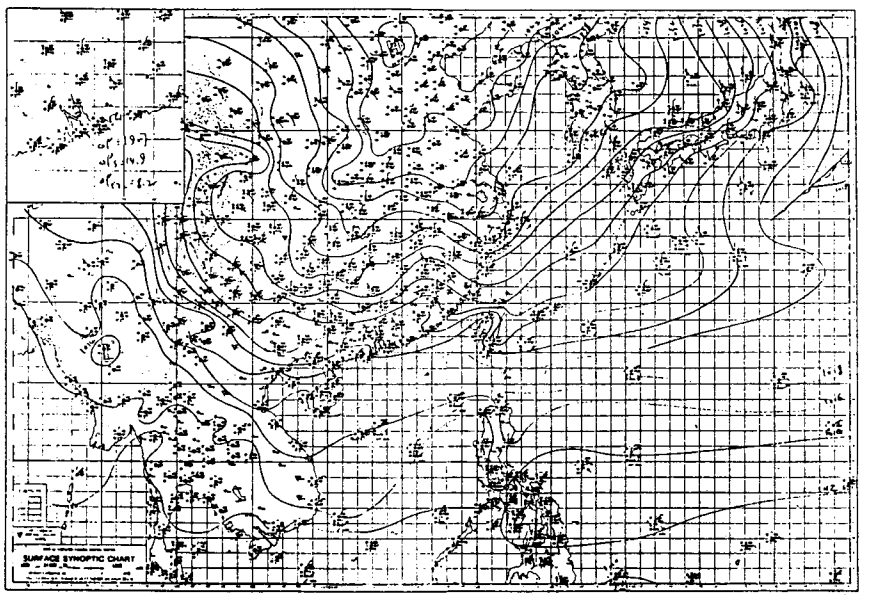

Fig. 24 Actual analysis for 24 Nov 91, 12Z.

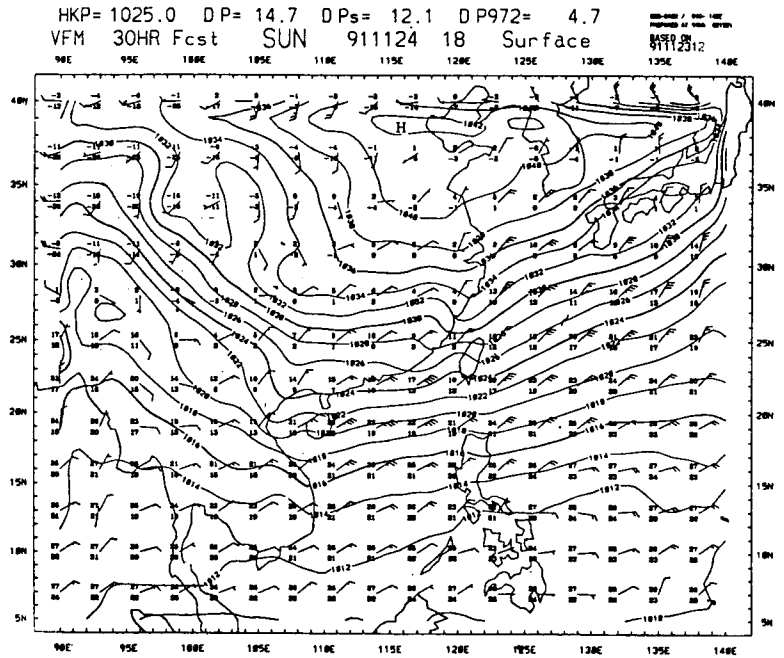

Fig. 25 ROLAM's 30-hour forecast for 24 Nov 91, 18Z based on 23 Nov 91, 12Z.

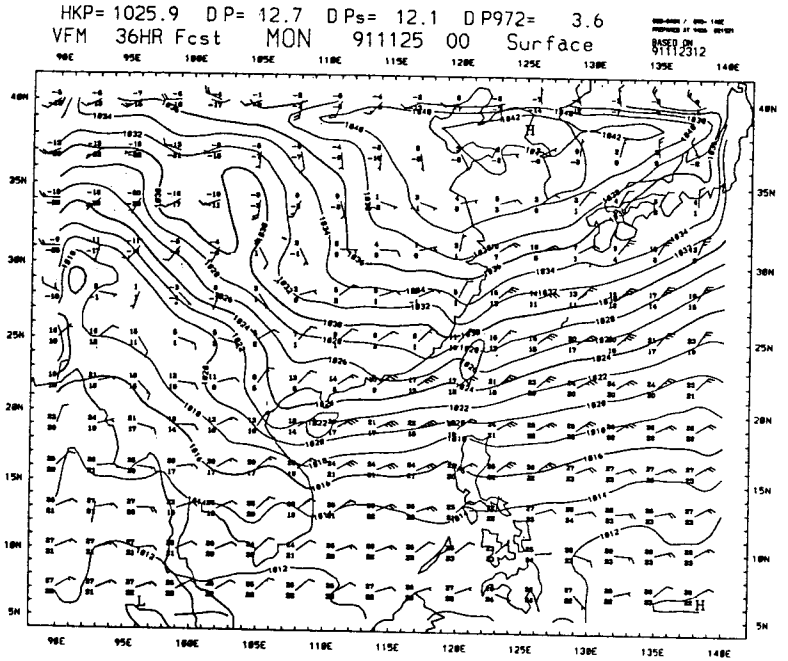

Fig. 27 ROLAM's 36-hour forecast for 25 Nov 91, 00Z based on 23 Nov 91, 12Z.

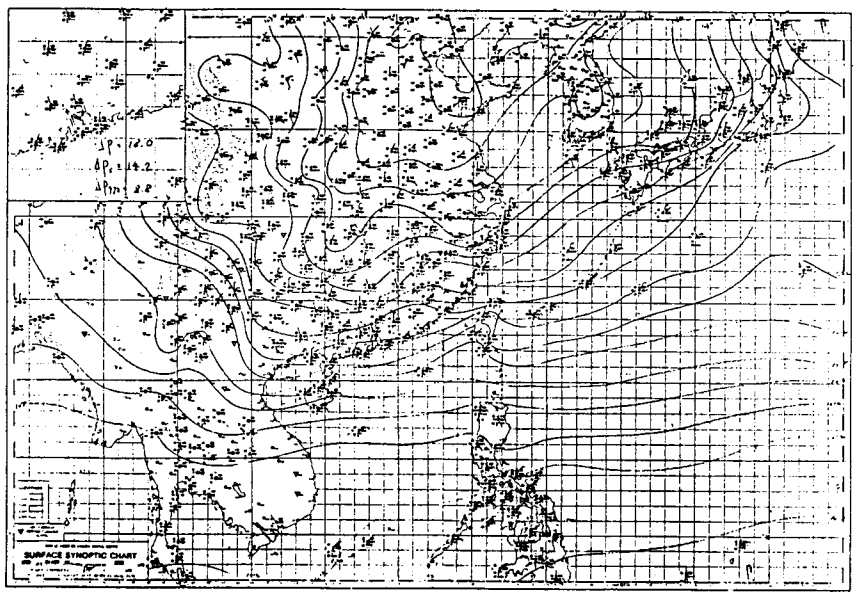

Fig. 26 Actual analysis for 24 Nov 91, 18Z.

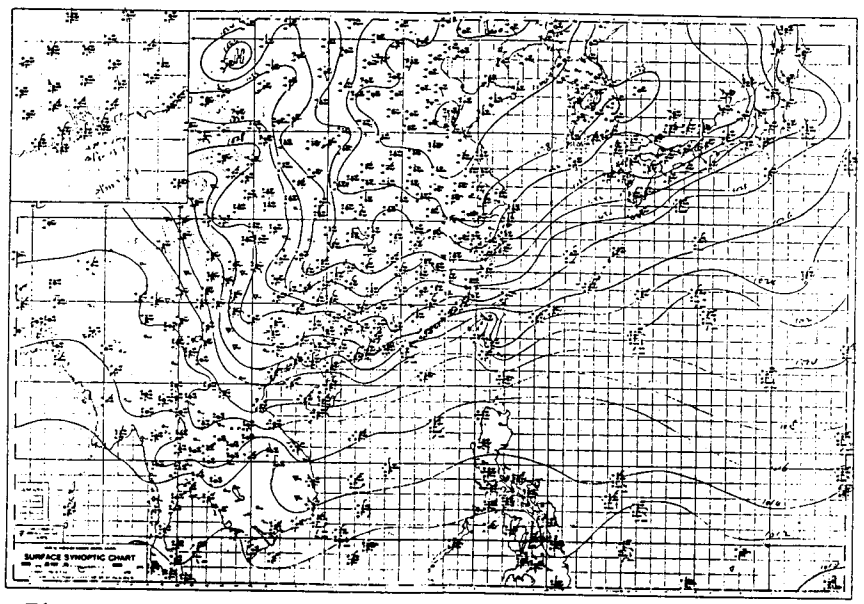

Fig. 28 Actual analysis for 25 Nov 91, 00Z.

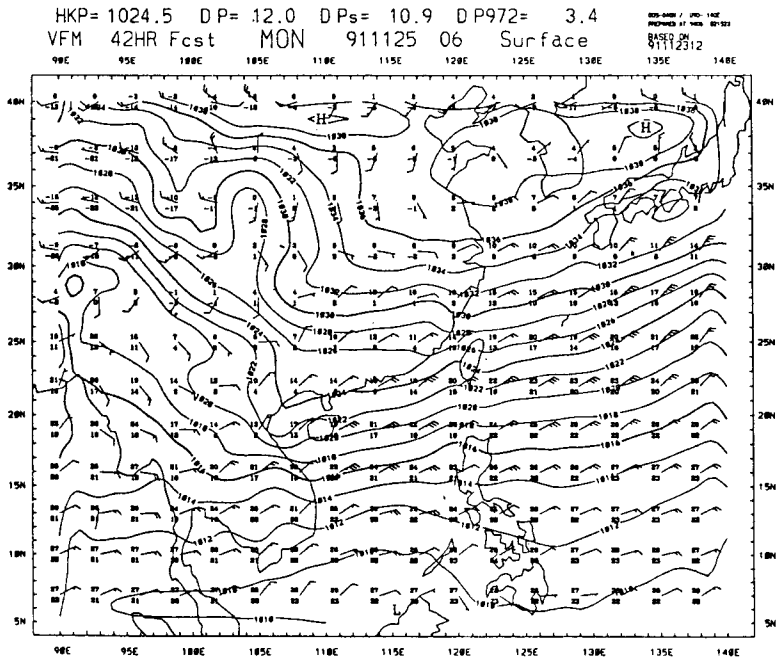

Fig. 29 ROLAM's 42-hour forecast for 25 Nov 91, 06Z based on 23 Nov 91, 12Z.

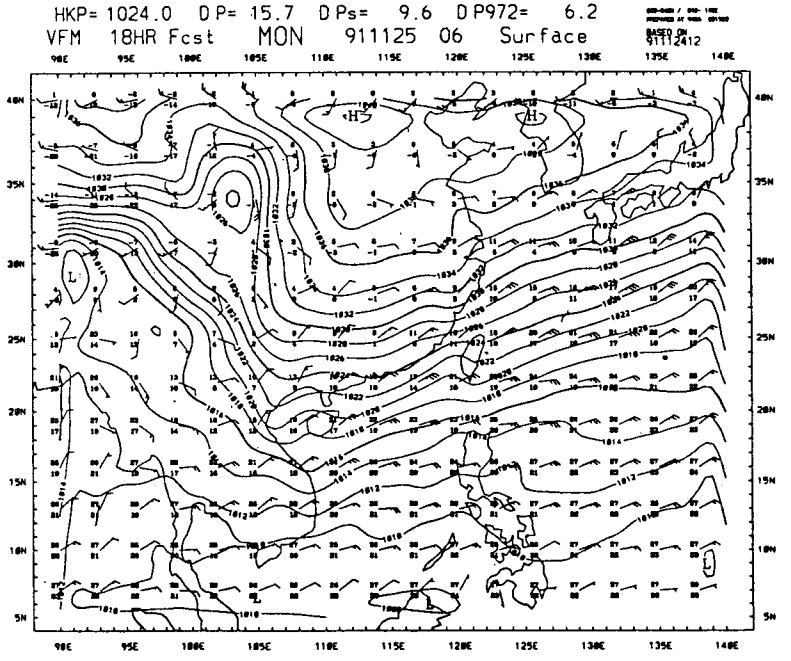

Fig. 30 ROLAM's 18-hour forecast for 25 Nov 91, 06Z based on 24 Nov 91, 12Z.

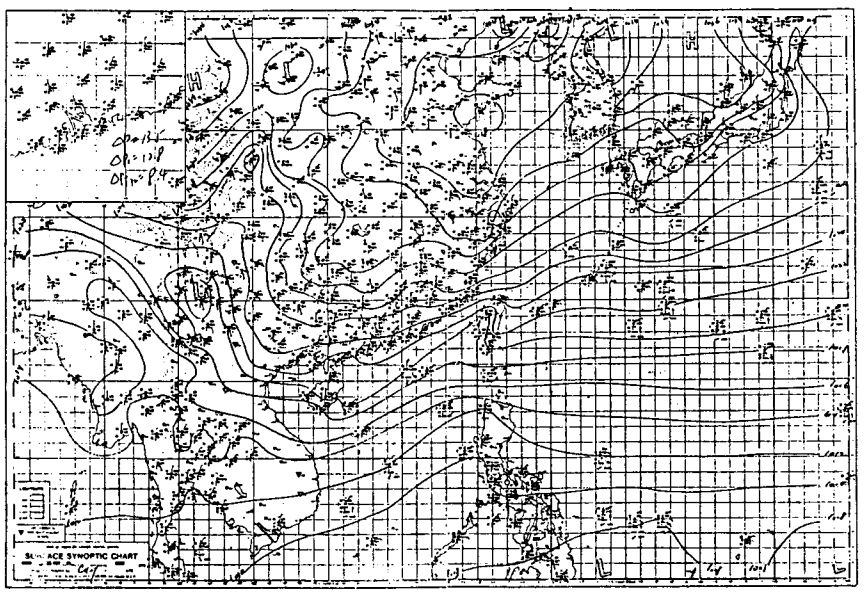

Fig. 31 Actual analysis for 25 Nov 91, 06Z.

Case 3

The following example illustrates the case when ROLAM's forecast of increase in wind speed is too gradual and cannot portrait accurately the sudden strengthening of wind at the onset of monsoon surges.

Example : Easterly surge arrived at 18Z on 4 February 1992.

Date & Hour	Actual Wind Speed at Waglan (in knots)	ROLAM's Forecast Wind Speed at 22°N-114°E (in knots)
3 Feb 92, 18Z	3	3
4 Feb 92, 00Z	3	4
4 Feb 92, 06Z	1	5^a / 6^c
4 Feb 92, 12Z	1	7^b / 7^d
4 Feb 92, 18Z	7	8
5 Feb 92, 00Z	10	8

Note : [a] and [b] represents ROLAM's 42 and 48 hour forecast based on 2 Feb 92;
[c] and [d] represents ROLAM's 18 and 24 hour forecast based on 3 Feb 92.

In this case the tight pressure gradient was packed behind a cold front over the Guangdong Province while the gradient along the coastal region as well as over the northern part of the South China Sea was rather slack (Fig. 32 - 41). The cold front moved slowly probably due to the blockage of the Nanling Range. The monsoon did not reach the coastal area until the high cell over the mainland moved to the East China Coast, and winds picked up from the east in Hong Kong at 18Z of the 4th (Fig. 42 - 45).

The deceleration of the cold front was not resolved by ROLAM, hence contributing to the forecast of gradual increase of wind strength. Another factor of such prognosis was due to the fact that the intensity of the high cell over north China was overestimated, where in the actual situation the push from the north was not as strong.

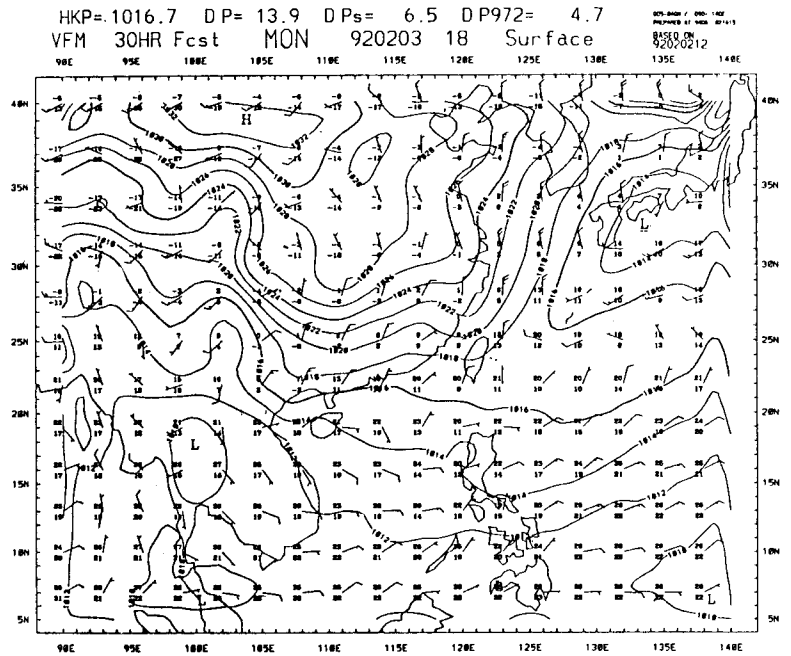

Fig. 32 ROLAM's 30-hour forecast for 3 Feb 92, 18Z based on 2 Feb 92, 12Z.

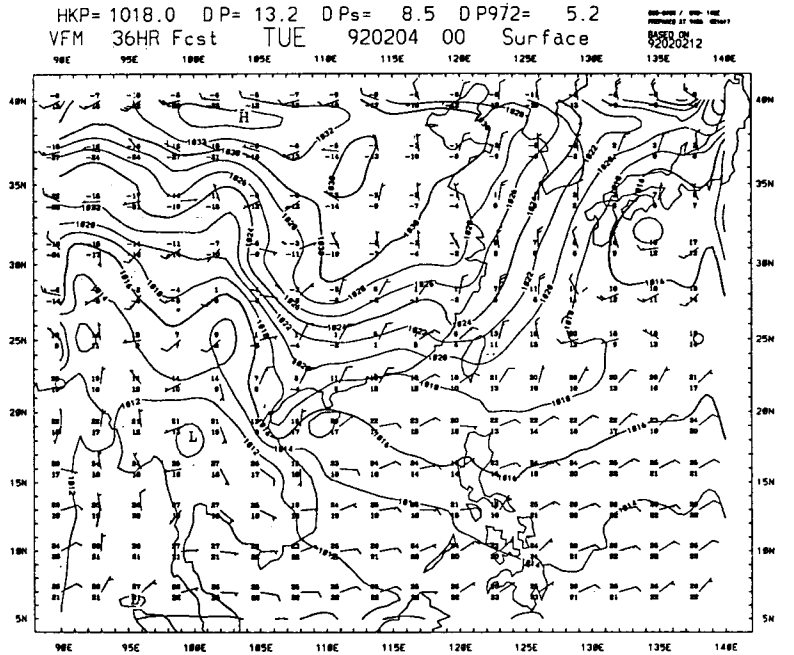

Fig. 34 ROLAM's 36-hour forecast for 4 Feb 92, 00Z based on 2 Feb 92, 12Z.

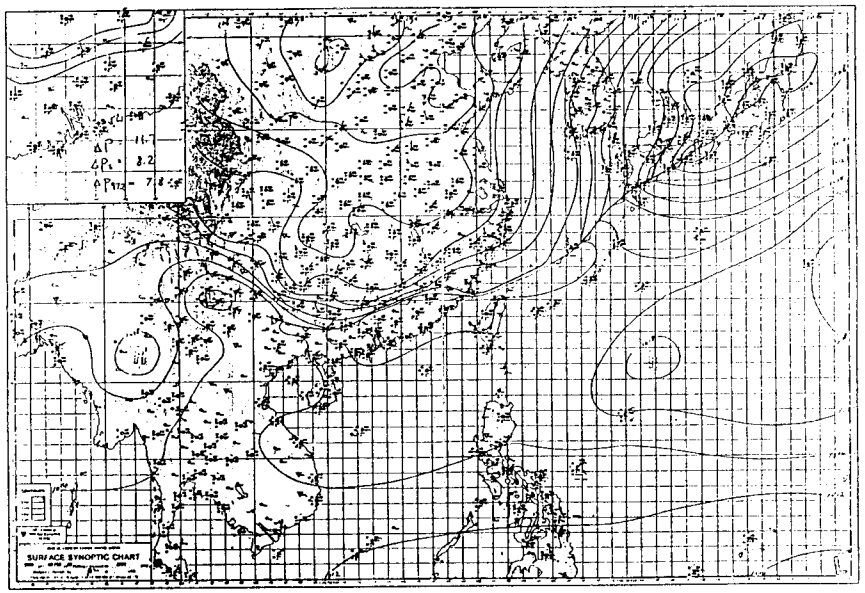

Fig. 33 Actual analysis for 3 Feb 92, 18Z.

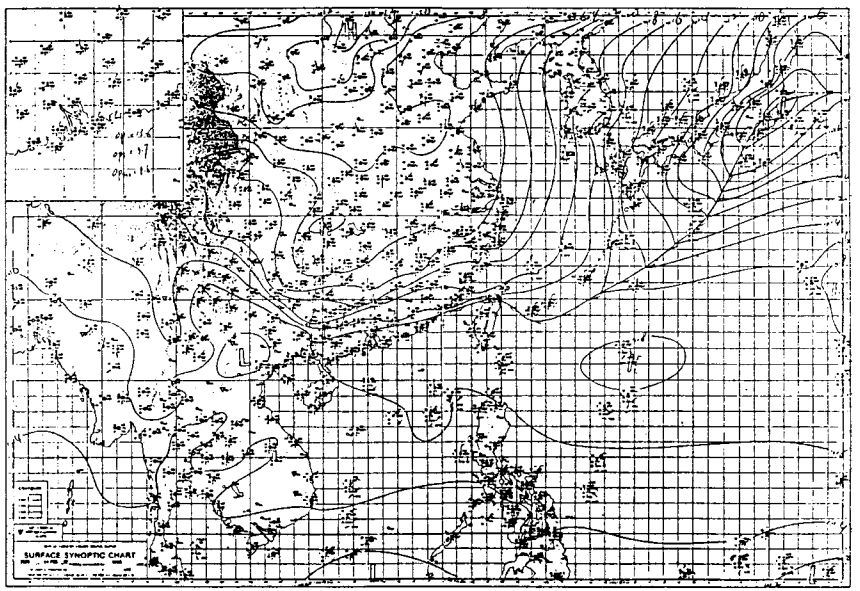

Fig. 35 Actual analysis for 4 Feb 92, 00Z.

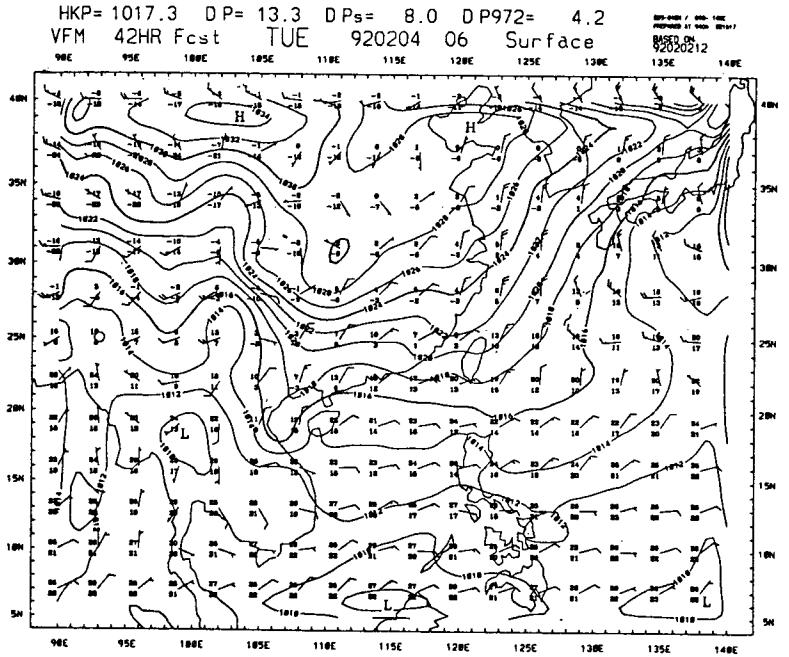

Fig. 36 ROLAM's 42-hour forecast for 4 Feb 92, 06Z based on 2 Feb 92, 12Z.

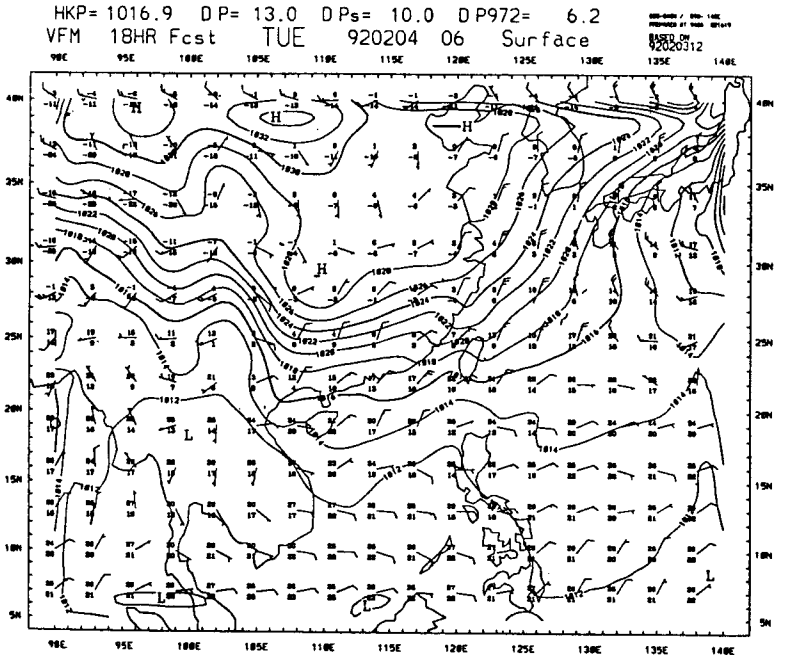

Fig. 37 ROLAM's 18-hour forecast for 4 Feb 92, 06Z based on 3 Feb 92, 12Z.

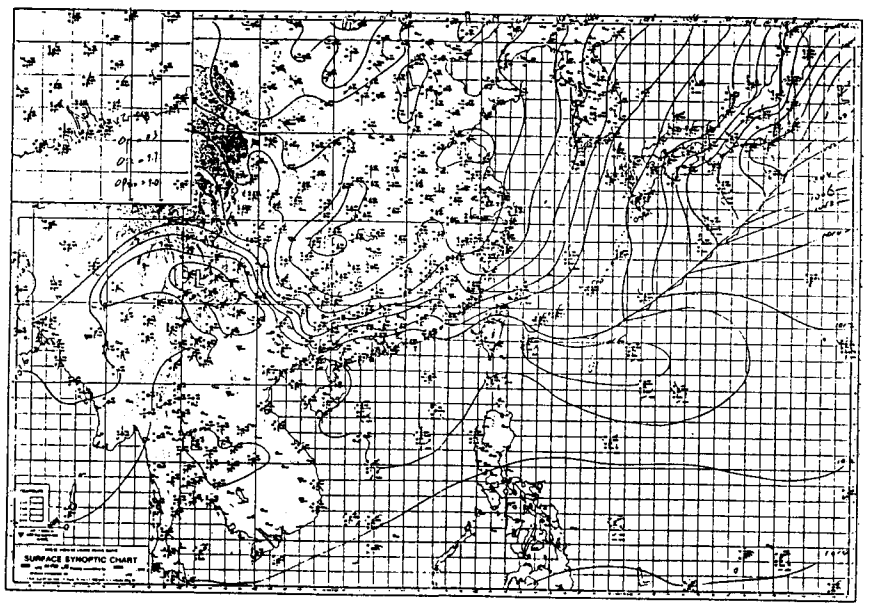

Fig. 38 Actual analysis for 4 Feb 92, 06Z.

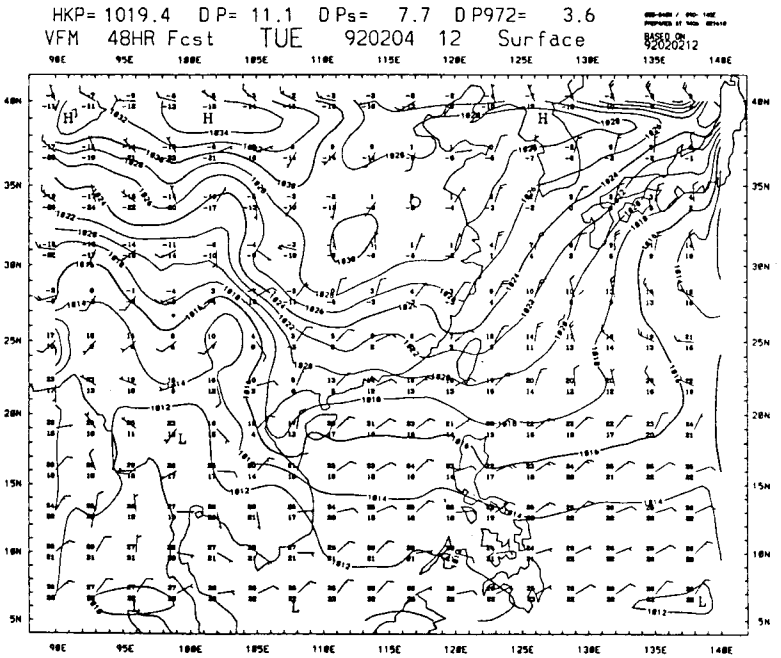

Fig. 39 ROLAM's 48-hour forecast for 4 Feb 92, 12Z based on 2 Feb 92, 12Z.

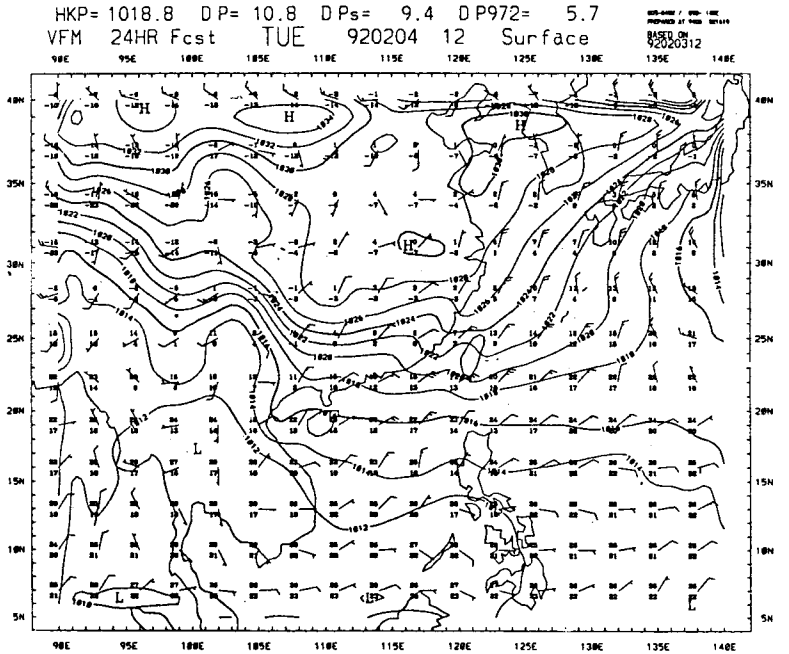

Fig. 40 ROLAM's 24-hour forecast for 4 Feb 92, 12Z based on 3 Feb 92, 12Z.

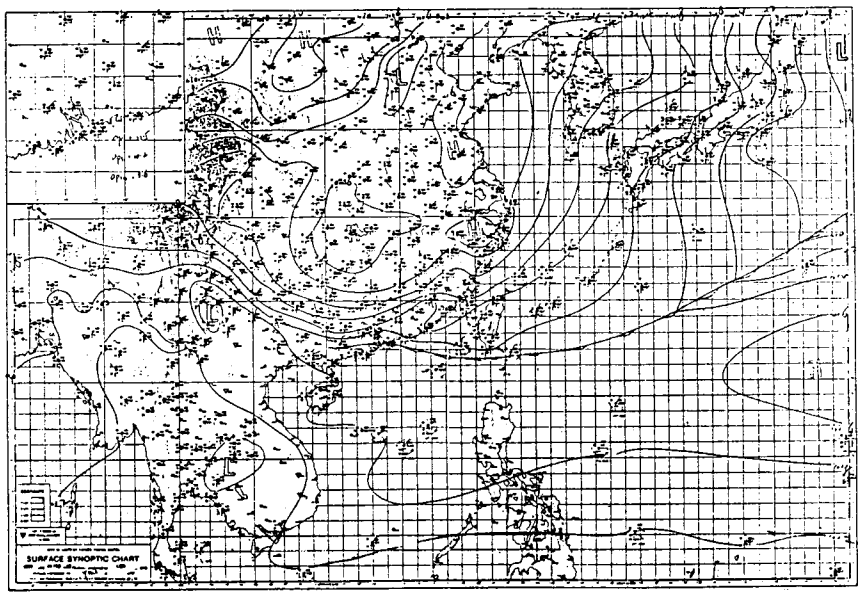

Fig. 41 Actual analysis for 4 Feb 92, 12Z.

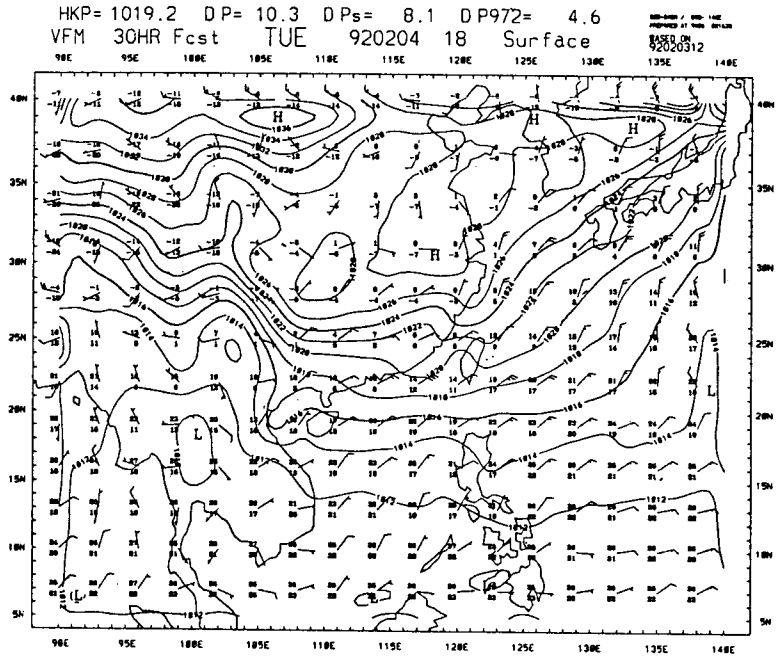

Fig. 42 ROLAM's 30-hour forecast for 4 Feb 92, 18Z based on 3 Feb 92, 12Z.

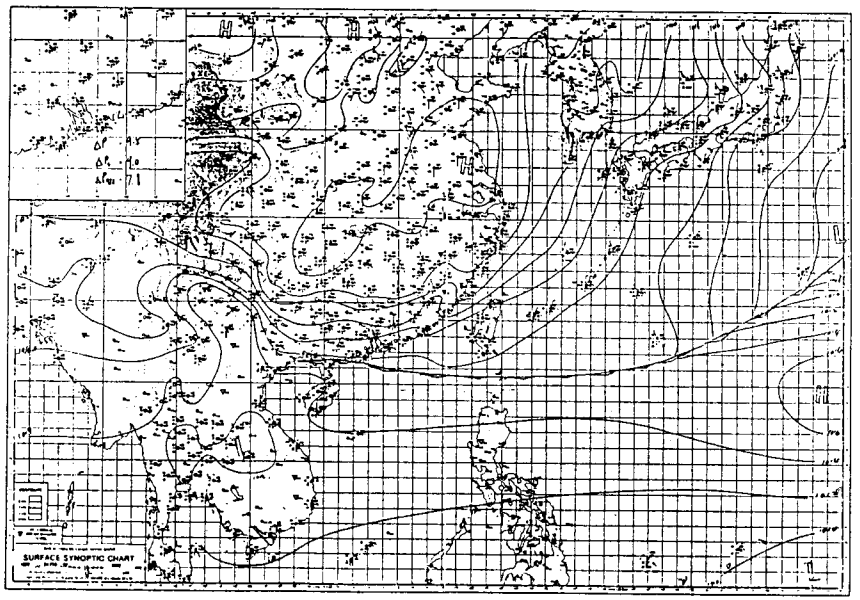

Fig. 43 Actual analysis for 4 Feb 92, 18Z.

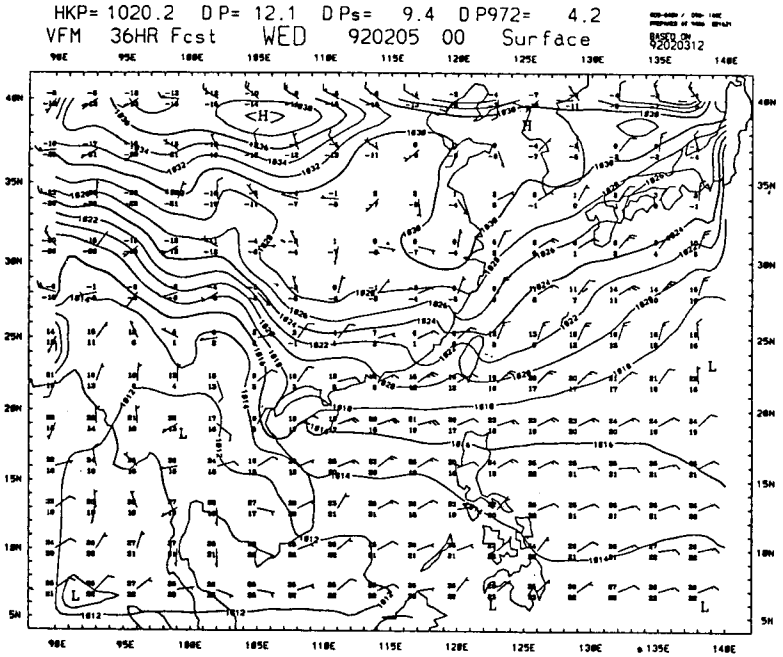

Fig. 44 ROLAM's 36-hour forecast for 5 Feb 92, 00Z based on 3 Feb 92, 12Z.

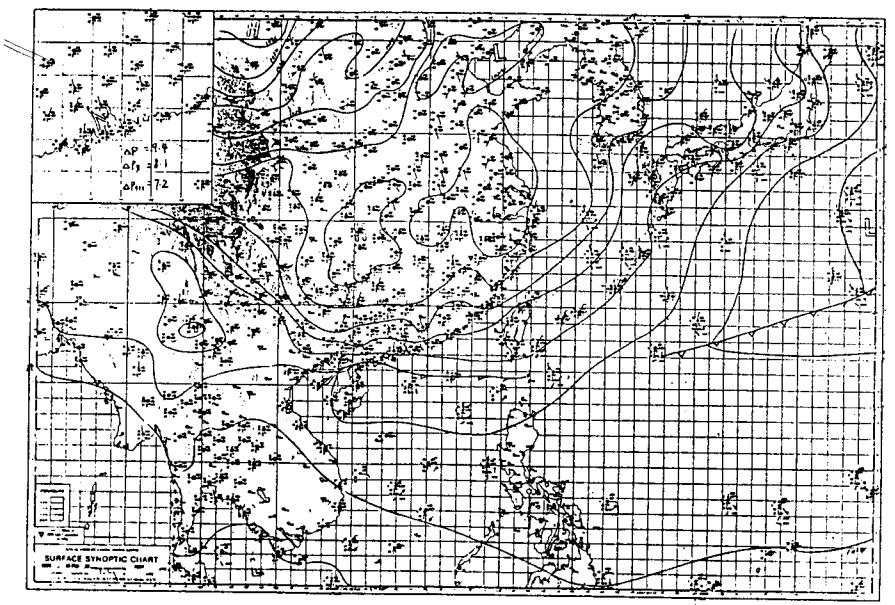

Fig. 45 Actual analysis for 5 Feb 92, 00Z.

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1. 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