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500 MILLIBAR TROUGHS PASSING OVER LAKE BAIKAL AND THE ARRIVAL OF SURGES AT HONG KONG

BY
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JUNE, 1976

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Summary

According to the data for one cool season (October, 1974 to April, 1975), it was found that, out of fifty 500 mbar troughs passing over Lake Baikal, thirty-nine gave rise to surges arriving at Hong Kong. For those cases with surges arriving at Hong Kong, the average time lag between the two events was two days. It was also shown that other factors have to be considered in order to forecast the weather associated with the arrival of a surge.

A case study was included to illustrate the causal relationship between a 500 mbar trough passing over Lake Baikal and a surge at Hong Kong.

1. Introduction

Many times while discussing the weather forecast for Hong Kong during routine weather conferences held in the Central Forecasting Office, it has been noted by G.J. Bell and W.K. Chu that there was usually a 2-day lag between the passage of a 500 mbar westerly trough over Lake Baikal and the occurrence of a "surge" at Hong Kong during the cool season. The major purpose of this note is to assess to what extent a forecaster can rely on this rule. In order to assist the forecaster in preparing weather forecasts in surge situations, a brief statistical description of the weather associated with the arrival of surges, in terms of wind, air temperature, dew point, cloud amount, and rainfall is also given.

The causal relationship between the two events related by the 2-day lag is easy to understand. It is well known that subsiding motion occurs behind upper level troughs propagaing eastward in the westerly zonal flow at mid-latitudes. At the same time, anticyclogenesis occurs at the surface. The result of these developments is to bring cooler air southward, representing an outburst of the winter monsoon. The 2-day lag may be very crudely interpreted as the approximate time required for cooler air to travel from its place of origin near Lake Baikal to Hong Kong. A brief description of a case study to illustrate this causal relationship is given in Appendix I.

2. Procedure

1) Passage of westerly trough over Lake Baikal

For the sake of definiteness, a reference point (R) near Lake Baikal was chosen at 55°N, 105°E. The position of the trough line was determined manually from the JMA 500 mbar analysis chart (valid at 1200 GMT daily) and the special high-latitude 500 mbar streamline chart (0000 GMT and 1200 GMT) prepared by the Central Forecasting Office. The time of passage of the trough line over the point R was inferred from the positions of the trough line on successive charts. It was estimated to the nearest hour.

Usually, it was possible to determine the speed of movement in degrees longitude per day, of the point where the trough line intercepted the 55°N latitude circle. This is denoted by PM. A typical situation is illustrated in Fig. 1. However, there were occasions when a trough extended southward from higher latitudes in which case PM became undefined.

2) Arrival of a "surge" at Hong Kong

There is no generally accepted definition of "surge". In this study, the following sources of information were utilised to determine whether a surge had arrived at Hong Kong :

(a) Royal Observatory time-height cross-section,

(b) Royal Observatory and Waglan Island logbooks, and,

(c) South East Asia surface chart (7°N to 36°N, 100°E to 140°E, Mercator projection, 1:7 500 000 at 22.5°N).

Significant changes in wind, air temperature, dew point, or any combination of these, occurring about one to three days after the passage of a 500 mbar trough at point R were assumed to be the results of the trough and interpreted as the arrival of a surge at Hong Kong.

Four consecutive 3-hourly Waglan Island wind observations from 340 to 030 with mean speed above 10 knots (force 4 or above) would constitute a northerly surge. Four consecutive 3-hourly Waglan Island wind observations from 060 to 120 with mean wind speed above 15 knots (force 5 or above) would constitute an easterly surge. Occasionally, other significant changes were noted, such as an abrupt change in wind direction or speed. These were also taken to signify the arrival of a surge.

Cases with a drop of at least 2°C in the daily mean temperature between the day before and the day after a surge were recorded. (This is Chu's criterion for a surge). An abrupt fall in temperature of at least 2°C within an hour (not associated with thunderstorm downdraught) was also taken to be a surge. Occasionally, one could observe a fairly rapid fall in temperature lasting for a number of hours but not sufficient to meet both criteria above. Personal judgement was employed to decide whether the occasion should be labelled as a surge. The same criteria were used in the case of dew point temperature.

Whenever a surge was considered to have arrived at Hong Kong, the total cloud amount and rainfall around that time were recorded.

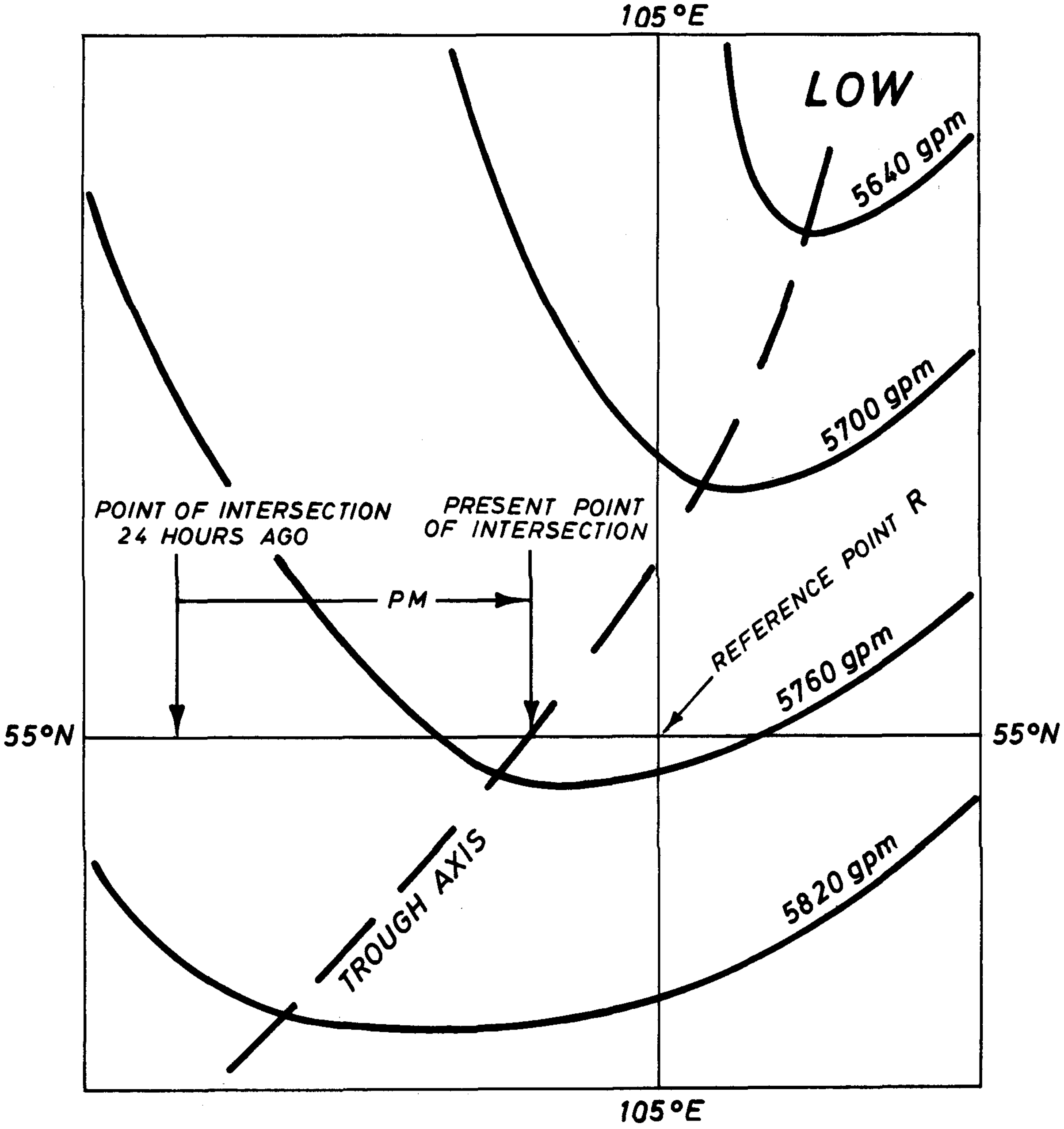


Figure 1. A typical situation when a 500 mbar trough approaches the reference point R from the west. PM is the past movement of the point of intersection of the trough axis and the 55°N latitude circle in 24 hours.

3) Determination of forecast time error

Forty-eight hours were added to the estimated time of arrival of the trough line at the reference point R to serve as the forecast time of arrival of a surge at Hong Kong (FTA). The actual time of arrival of the surge at Hong Kong (ATA), if it arrived at all, was determined by a combined analysis of the wind, air temperature, and dew point profiles to the nearest hour. The difference "ATA-FTA" was the forecast error.

3. Results

1) The sample

Throughout the seven-month period from October, 1974 to April, 1975, 50 forecasts of the arrival of a surge at Hong Kong were made. 39 surges did arrive subsequently. For the other 11 cases, nothing appreciable could be detected at Hong Kong within one or two days of the forecast arrival time. A list of the 50 forecasts and the forecast time errors is given in Appendix II.

2) Past movement of troughs at 55°N

The distribution of troughs according to the past movement PM (in degrees longitude per day) is given in the following table.

Past movement PM	undetermined	0-5	6-10	11-15	16-20	21-25	26-30	⩾30	Total
No. of cases	10	1	6	10	9	10	3	1	50

The 10 "undetermined" cases refer to troughs with their axes running E-W and which moved basically from north to south.

3) Forecast time error

For the 39 cases of surge arrival :

(a) mean forecast error = 0 hour;

(b) standard deviation = 11 hours.

The extreme values of forecast error are +26 hours and -16 hours. No obvious relationship between forecast error and past movement can be detected.

4) Weather associated with surge

(a) Wind

Out of the 50 forecasts, 33 cases gave a "surge" in terms of wind (i.e. about 70%). There are 6 surges that involve no change in wind. A point to note is that troughs with undetermined PM seem to give rise to a somewhat greater frequency of northerly surge. A possible explanation is that troughs moving southward rapidly tend to be associated with subsiding cool air pockets moving in the same direction.

	Past movement PM						
Wind	undetermined	0-10	11-20	21-30	⩾ 31	Total	
no change	2	2	5	7	1	17	
northerly	5	3	6	3	0	17	70% approx. of all cases
easterly	1	1	4	2	0	8	
other sig. ch.	2	1	4	1	0	8	
	10	7	19	13	1	50	

(b) Air temperature

Out of the 50 forecasts, 18 cases resulted in surges that satisfied Chu's criterion or showed other significant changes in the temperature at Hong Kong. The chance of having a surge in terms of temperature appears to be (1) slightly enhanced when PM is undetermined or 11 ≤ PM ≤ 20, and (2) slightly reduced when PM ≥ 21.

	Past movement PM					
Wind	undetermined	0-10	11-20	21-30	≥ 31	Total
no change	5	5	10	11	1	32
Chu's criterion	3	2	6	2	0	13
other sig.ch.	2	0	2	1	0	5
	10	7	18	14	1	50

35% approx. of all cases

(c) Dew point

Out of 50 forecasts, 34 cases resulted in surges in terms of dew point, satisfying Chu's criterion and/or showing other significant changes at Hong Kong. There appears to be little difference between troughs with various PM's. However, troughs with undetermined PM tend to be associated with a slightly higher chance of surges actually arriving in Hong Kong.

	Past movement PM					
Dew point	undetermined	0-10	11-20	21-30	≥ 31	Total
no change	1	3	7	4	1	16
Chu's criterion	6	4	9	8	0	27
other sig.ch.	3	0	3	1	0	7
	10	7	19	13	1	50

70% approx. of all cases

(d) Cloud amount

If the daily mean cloud amount on the day of surge arrival is within ± 1 okta of that of the previous day, no "significant change" is considered to have occurred.

	Past movement PM					
Cloud amount	undetermined	0-10	11-20	21-30	≥31	Total
cloudy + sig. inc.	0	1	1	0	0	2
not cloudy + sig. inc.	1	1	0	0	0	2
cloudy + no sig. change	3	2	10	1	0	16
not cloudy + no sig. change	5	0	4	3	0	12
sig. dec.	0	1	0	6	0	7
	9	5	15	10	0	39

70% approx. of surges

20% approx. of surge

Only about 10% of surges are associated with significant increase in cloud amount. In fact, the table suggests that the relation between surge and cloud amount is small.

(e) Rainfall

The total rainfall at R.O. on the day of surge arrival and the day after is taken to represent rainfall associated with each surge.

Rainfall amount	no. of cases	
0.0 - 0.1 mm	14	70% approx. of surges
0.2 - 1.0 mm	9	
1.1 - 5.0 mm	5	
5.1 - 10.0 mm	4	
10.1 - 50.0 mm	4	
50.1 - 100.0 mm	1	
more than 100 mm	2	
Total	39	

Two of the three wettest occasions are associated with late season tropical cyclones. One is associated with a trough situation in late April. The other wetter situations are usually associated with organised surface flow with southerly component over the South China Sea.

About 70% of the surges gave 5 mm or less. As the cloud systems accompanying surges are typically stratiform, this figure is what one would have expected.

5) Surges not forecast by the 500 mbar trough criterion

In the course of this investigation, several cases of surge arrival at Hong Kong without 500 mbar troughs passing over Lake Baikal about two days before were noted. Examples included the surges arriving on the following dates :

(a) 9 January, 1975: significant fall in dew point;

(b) 15 January, 1975: northerly surge with significant fall in dew point, and

(c) 1 April, 1975: significant fall in dew point.

Since this study does not aim at developing a procedure to forecast all surges arriving at Hong Kong, these cases will not be discussed further. It suffices to point out that these cases of surges tend to be associated with quasi-stationary low centres at 500 mbar near Korea at about 45°N.

4. Conclusions

1. Timing of surges

The 2-day lag proposed by Bell and Chu is useful as a guide to surge forecasting. Although no surge arrived in Hong Kong in about 20% of the cases (11 out of 50), this could have been the result of counting even fairly minor perturbations in the westerlies, which an experienced forecaster might easily ignore.

2. Meaning of surge

Judging from the results of sub-sections 3.4(a)-(e) a surge should probably be understood to represent a change in air mass, usually identified by different dew point temperatures at the surface. The change in wind (speed and/or direction) may be interpreted as the consequence of the quasi-frontal characteristics of the boundary between air masses.

3. Forecast of "temperature surge"

About half of the surges in this analysis satisfy Chu's "2-degree drop" criterion or show other significant changes in terms of temperature. Although the occurrence of a "temperature surge" depends to a small extent on PM (see sub-section 3.4(b)) other factors e.g. temperature at 500 mb behind the trough will need to be considered, if temperature fall in Hong Kong is what one would like to forecast.

4. Weather associated with surges

Nothing conclusive can be said about the weather associated with surges. The arrival of surges seems to have little effect on cloud amount, while the rainfall associated with surges can vary over a wide range. In order to forecast whether a surge is wet or dry, the intensity of the southerly flow over the South China Sea at the time the surge reaches Hong Kong is also an important factor. The effect of tropical cyclones, if occurring in the proximity of Hong Kong, has also to be taken into account.

Acknowledgements

Discussions with my colleagues at the Royal Observatory, especially Mr. G.J. Bell, and Mr. E.W.K. Chu, have been very helpful. The advice from the R.O. Review Board were useful and have led to improvements in the presentation of this note.

Appendix I

A 500 mbar trough passing over Lake Baikal and its associated surge

1. Introduction

This case study aims at illustrating how a surge at Hong Kong may be related to a 500 mbar trough passing over Lake Baikal. The example chosen for analysis is the northerly surge arriving at Hong Kong at around 1500 GMT on 29 January, 1976.

2. Movement of upper air troughs and the surface cold front

A 500 mbar trough moved from west to east and crossed Lake Baikal at about 1200 GMT, 26 January, 1976. Figure A1 shows the progress of this trough between 25 January, 1976 and 30 January, 1976. By 12 GMT on 30 January, the trough was weak and not well-defined. Winds behind the trough axis were mainly from the northwest while those ahead were from the southwest. As the trough axis moved southward during the period studied, the northwest winds advanced southward also. Figure A1 also portrays the movement of the surface cold front which could be associated with this trough. The front was quasi-stationary over southern China between 27 January and 28 January. Subsequently, it moved rapidly southward. On the eastern flank, frontal characteristics were not acquired up to 28 January. The surface system was therefore analysed as a pressure trough on 27 January and 28 January. It was analysed as a cold front from 29 January onwards and was also linked to the front over China.

The movements of troughs at 700 mbar and 850 mbar are given in figure A2. The trough at 700 mbar could be detected in the operationally available charts (northern boundary at 46°N) at as early as 12 GMT on 25 January. It became well-defined at 12 GMT on 26 January about the same time when the 500 mbar trough passed Lake Baikal. The trough moved ahead of the 500 mbar trough, separated by a distance of approximately 500 km. The movement of the trough just east of Tibetan Plateau was southeastward until 28 January, becoming stationary thereafter. The first signs of the trough at 850 mbar could be seen at 00 GMT on 27 January. It became very well-defined at 12 GMT on the same day, one day after the 500 mbar trough passed Lake Baikal. The movement of the trough was generally towards the southeast and fairly steady over China during the next two days. It was about 300 km ahead of the 700 mbar trough over China and very close to it at higher latitudes. It then became quasi-stationary near the 110°E longitude line. In the meantime, the eastern flank of the trough had become separated from the trough over China and moved rapidly towards the east. Winds north of the 700 mbar and 850 mbar troughs were generally from the north and cooler than air in the southwest winds south of the troughs.

These observations indicated that the troughs at the three isobaric levels (500 mbar, 700 mbar, and 800 mbar) and the surface cold front were related and might be interpreted as the intersections of an inclined frontal surface with the various isobaric surfaces. Figure A3 shows the relative positions of the troughs at different levels at 1200 GMT on each of the four days from 27 January to 30 January. Over China, the frontal surface was inclined towards north-northwest, which was consistent with the fact that cooler air from north of Tibet plateau was located on the northern side of this frontal surface. Figure A4 gives the

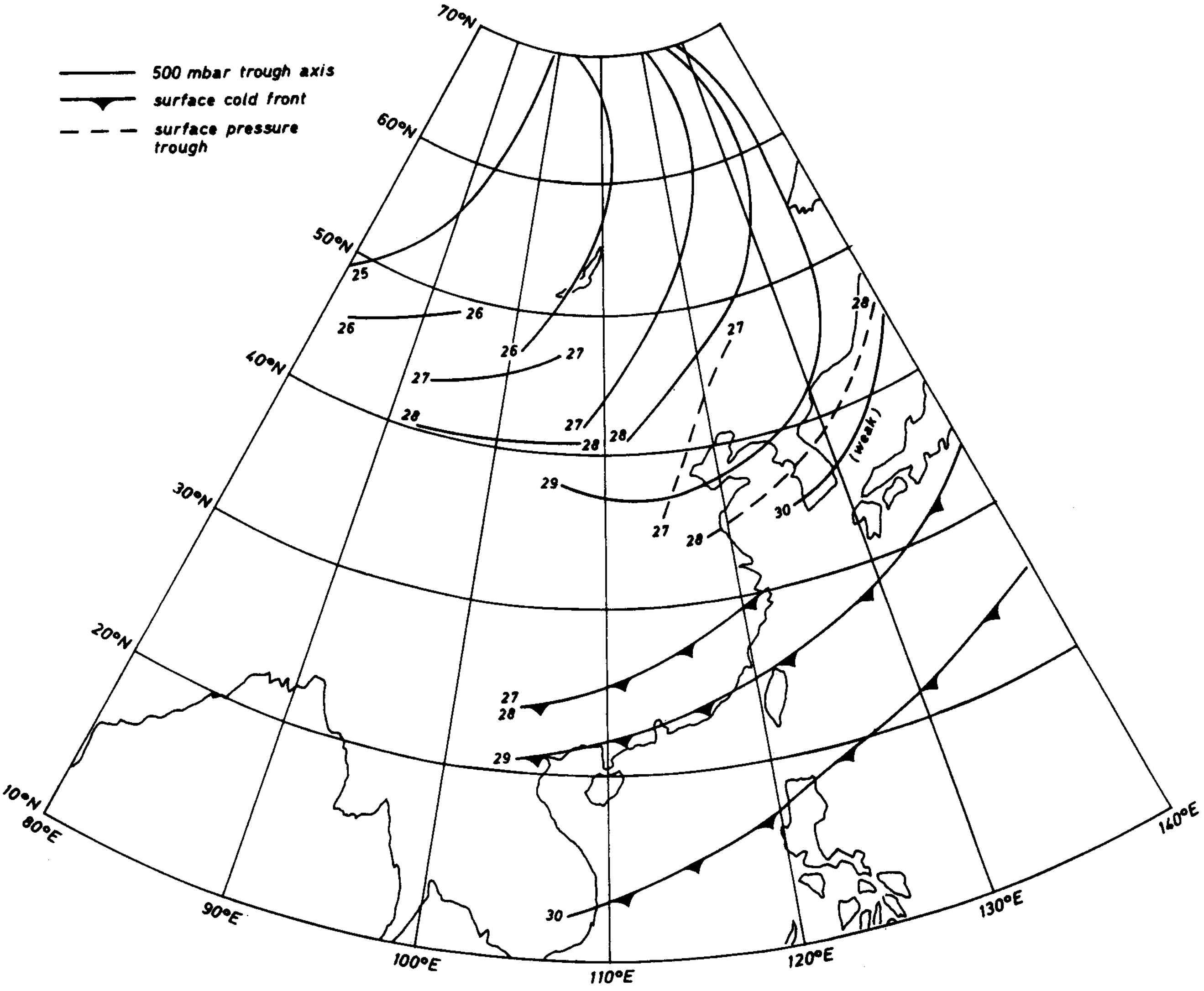
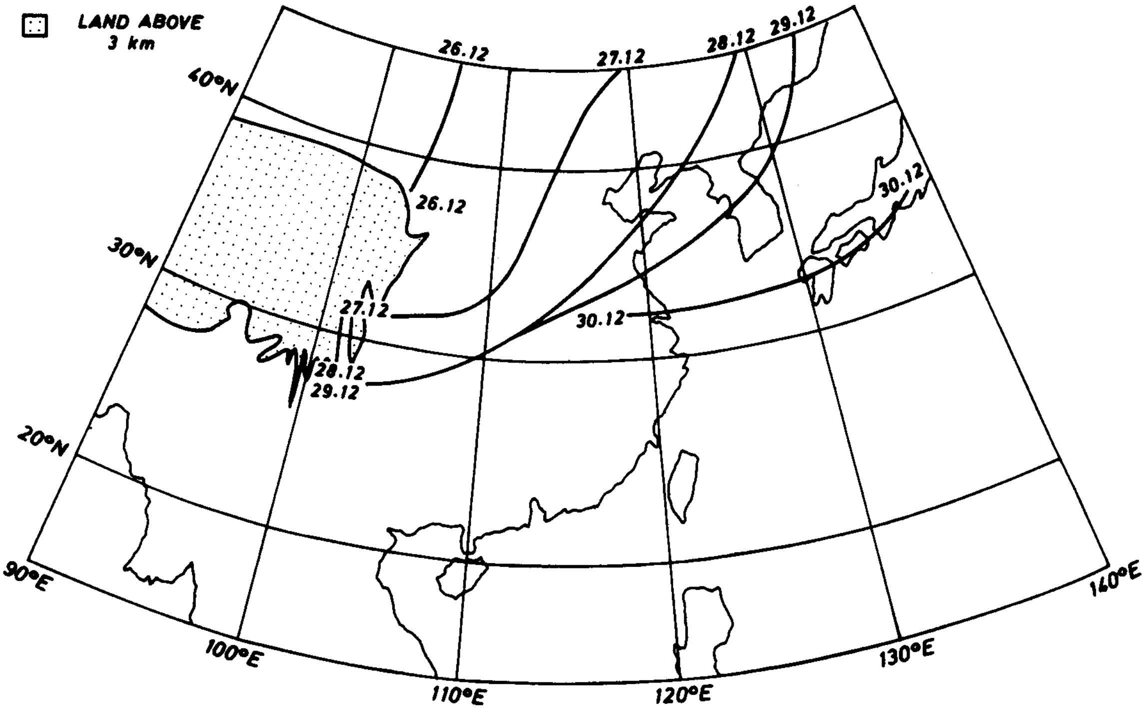
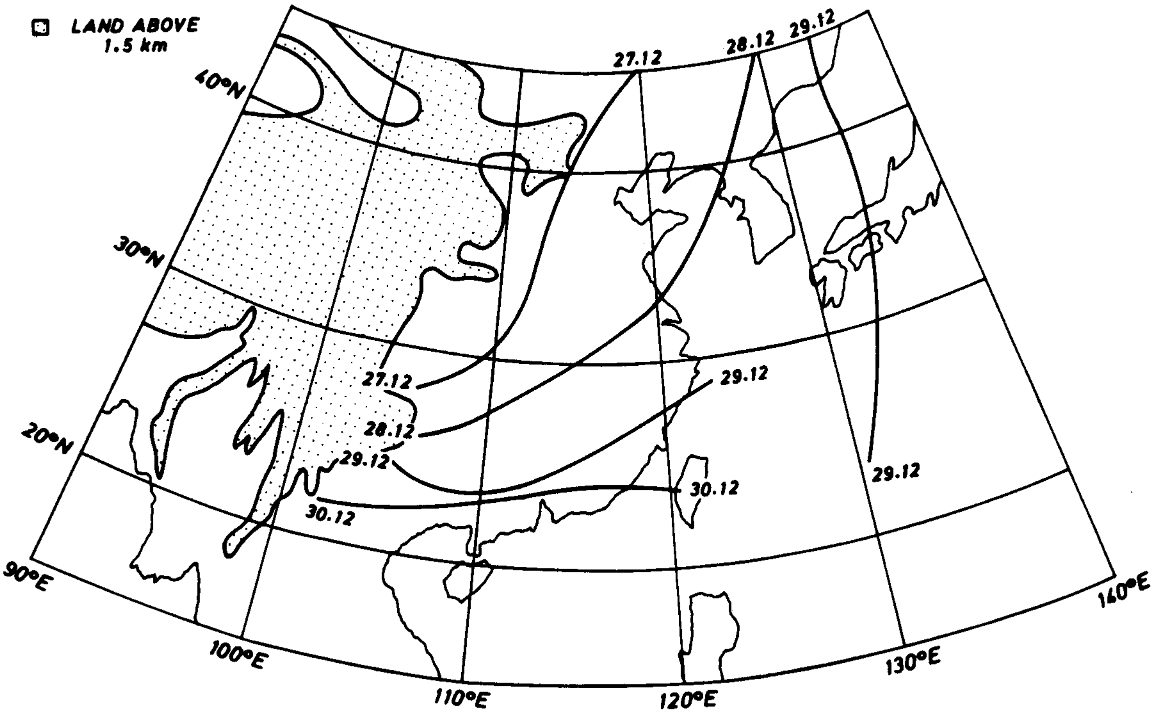


Figure A1. Positions of 500 mbar trough and surface cold front at 1200 GMT each day. The period covered is from 25 January, 1976 to 30 January, 1976.

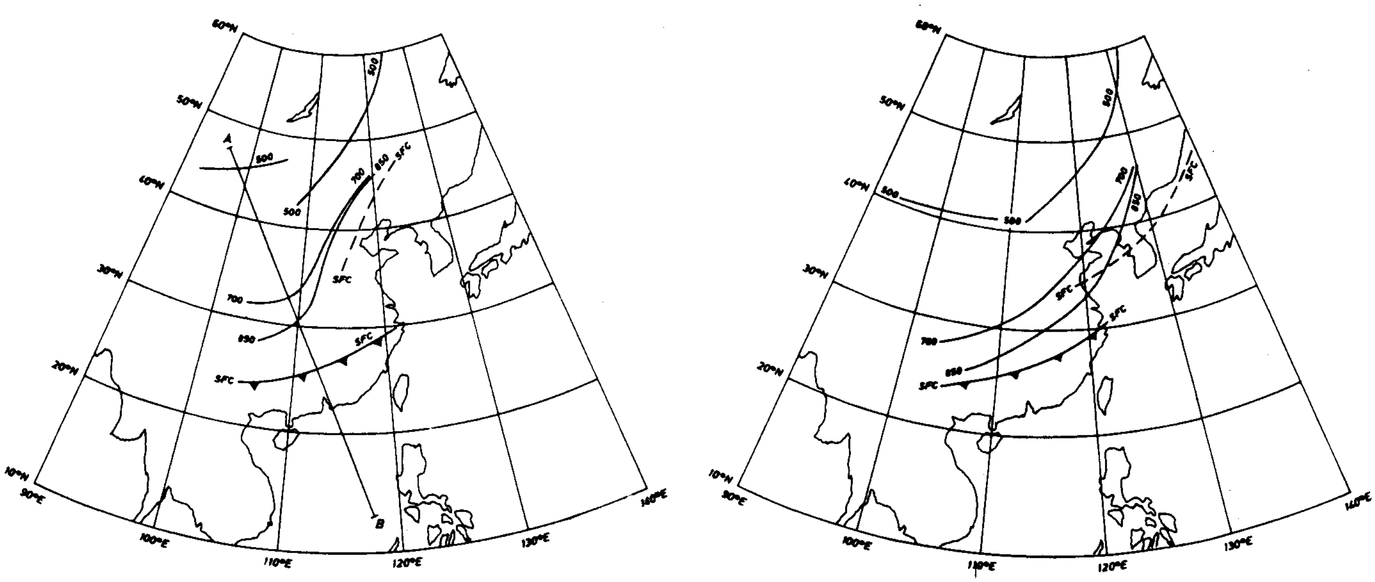


(a) 700 mbar



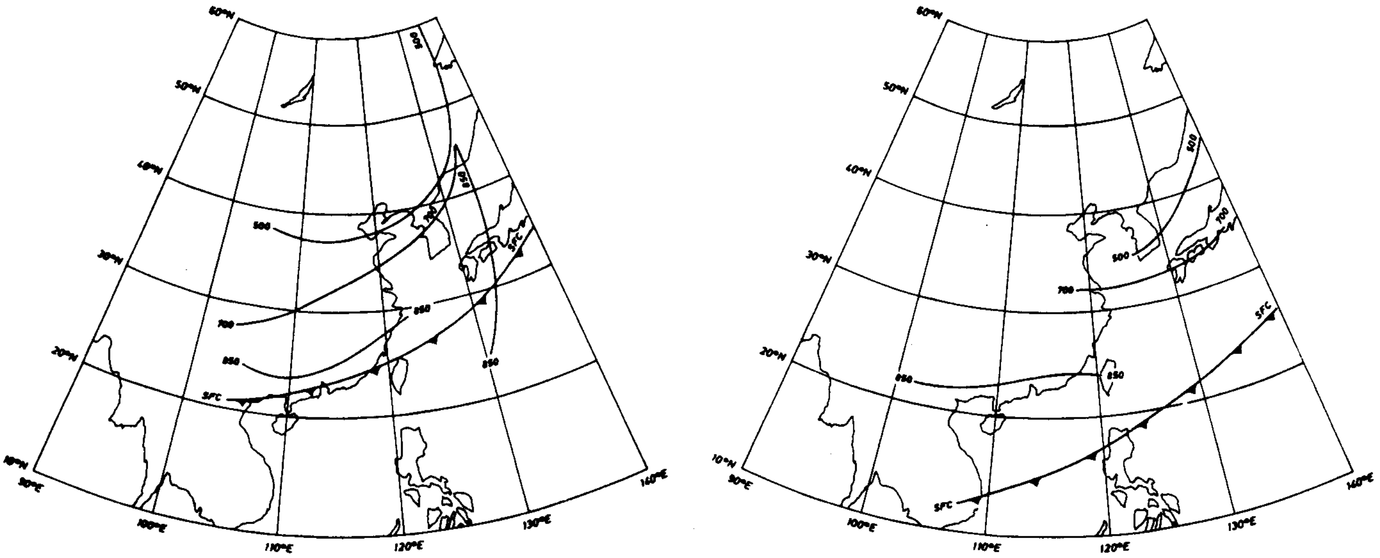
(b) 850 mbar

Figure A2. Positions of 700 mbar troughs at 1200 GMT each day, from 26 January, 1976 to 30 January, 1976.



(a) 1200 GMT, 27 JANUARY, 1976.

(b) 1200 GMT, 28 JANUARY, 1976.



(c) 1200 GMT, 29 JANUARY, 1976.

(d) 1200 GMT, 30 JANUARY, 1976.

Figure A3. Relative positions of troughs at 500 mbar, 700 mbar, 850 mbar and the surface front at 1200 GMT each day, from 27 January, 1976 to 30 January, 1976.

profile of this frontal surface along a line AB (see figure A3) roughly perpendicular to the trough axes. The average slope of the surface varied from about 1/400 on 27 January to about 1/300 on 29 January. Slopes as steep as 1/150 were found between 700 mbar and 850 mbar on 27 and 28 January and below 850 mbar on 29 January.

3. Surface pressure pattern

As the 500 mbar trough passed over Lake Baikal, the semi-permanent anticyclone over Siberia intensified by about 10 millibars within a day and reached 1070 mbar at 12 GMT on 27 January (all pressure values refer to mean sea level). A ridge also began to extend southeastward. By 12 GMT on 28 January, a high cell was formed in this ridge with a central pressure of 1050 mbar. Pressure over nearly the whole of China continued to rise during the next twenty-four hours. At the time when the northerly surge reached Hong Kong (about 15 GMT, 29 January), a broad ridge covered central and southern China. The changes in the surface pressure pattern are illustrated by figure A5.

4. Isentropic trajectories

In order to get an idea of the three-dimensional movement of air parcels behind the frontal surface, isentropic trajectories were manually constructed from isentropic analysis charts. The origin of air that arrived at Hong Kong could also be determined by such an analysis. Since the air temperature at Hong Kong immediately after the surge in this case was about 15°C, trajectories were constructed on the 15°C potential temperature surface. Selected trajectories are shown in Figure A6.

Air parcels originating from about 500 mbar near Lake Baikal behind the trough descended along cyclonic tracks during the 2-day period and reached Yellow Sea and Sea of Japan by 12 GMT on 29 January. The vertical distances travelled varied from 130 mbar to 260 mbar, corresponding to mean vertical velocities of about 1 cm/s and 2 cm/s along the respective trajectories.

Air parcels originating from about 700 mbar near the northeast corner of Tibetan Plateau were also descending behind the trough during the 2-day period. However, the trajectories became anticyclonic near the plateau. The magnitude of vertical velocities along these trajectories also tended to be smaller. The mean vertical velocity along the trajectory closest to the plateau was around 0.5 cm/s only.

The trajectory over the Yangtze basin was interesting in that the air parcel was initially ahead of the frontal surface but was subsequently overtaken by it. The air parcel was at first moving in the southwest flow. With the passage of the frontal surface, it turned anticyclonically and moved in the generally northerly flow behind the frontal surface. There was little vertical motion along this trajectory. The parcel simply experienced a "push", a term frequently used by operational forecasters to describe surge situations. The air parcel in the trajectory over East China Sea was similarly overtaken by the frontal surface.

The trajectory along the coast of South China was associated with an easterly surge which had been affecting Hong Kong for a number of days.

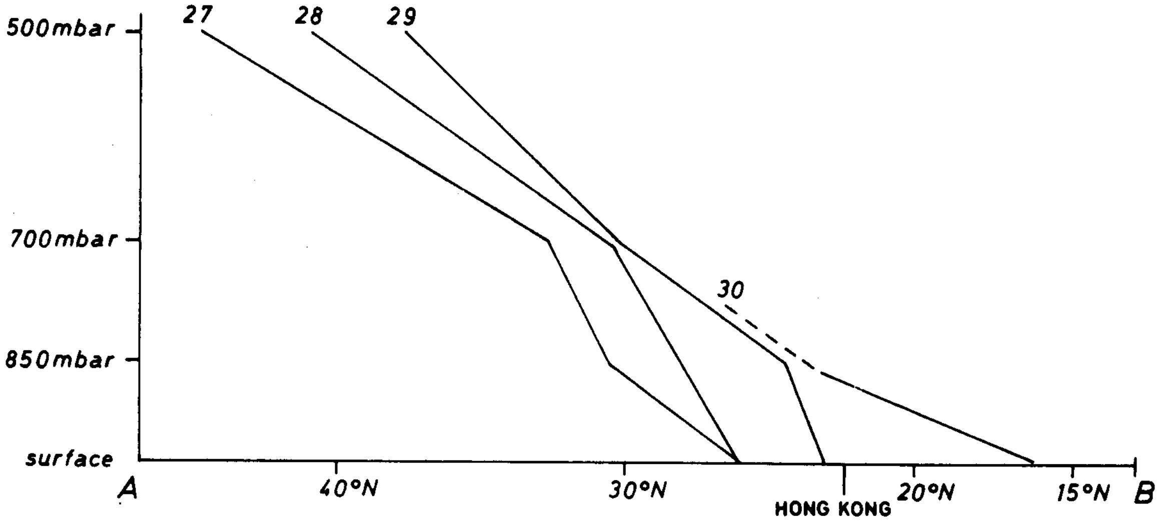


Figure A4. Profile of the frontal surface at 1200 GMT each day from 27 January, 1976 to 30 January, 1976.

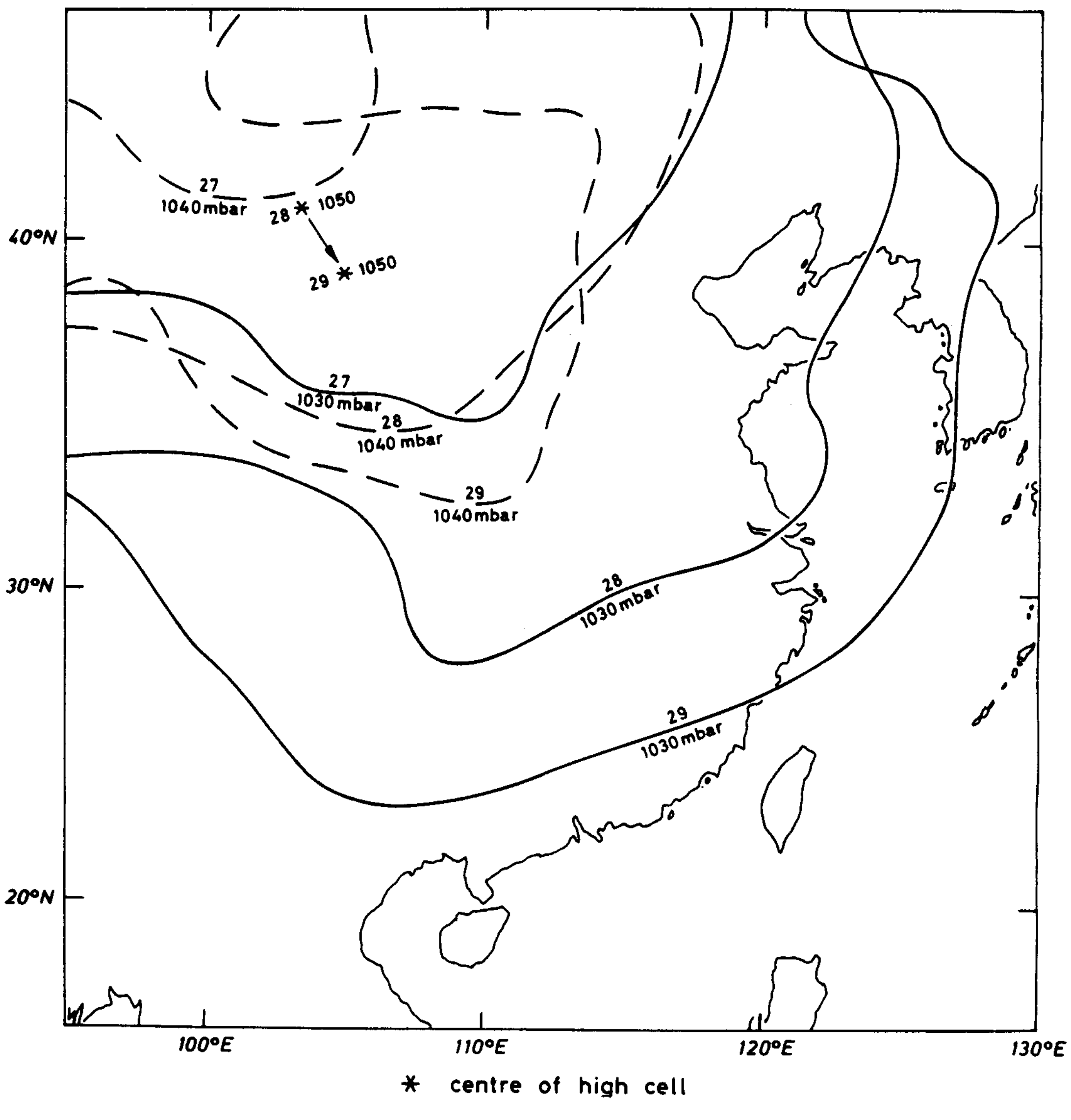


Figure A5. The extension of surface ridge from Siberia to southern China from 27 January, 1976 to 29 January, 1976. 1200 GMT positions of isobars and high cell centres are shown for each day.

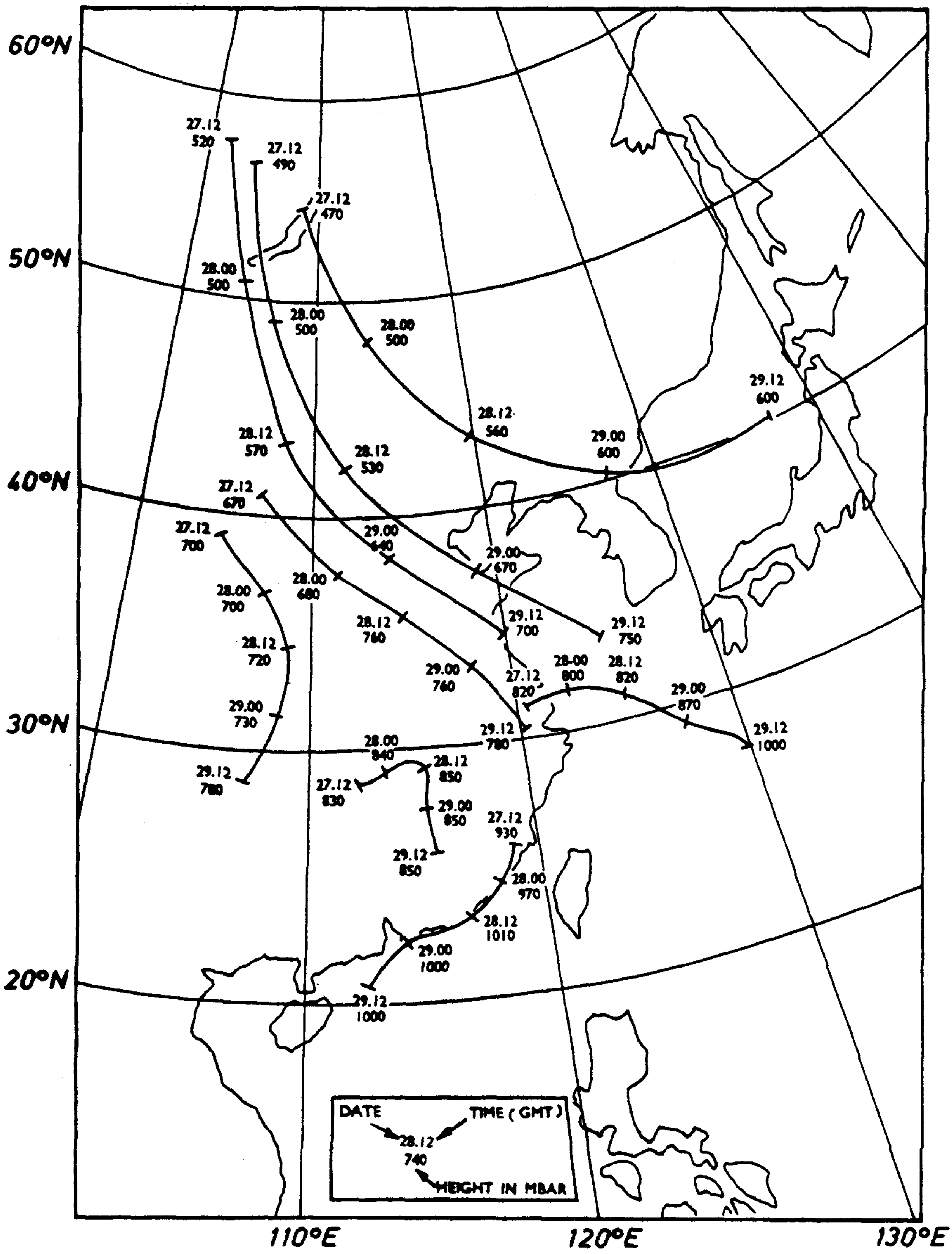


Figure A6. Isentropic trajectories from 1200 GMT on 27 January, 1976 to 1200 GMT on 29 January, 1976.

5. Conclusions

The picture that emerges from the analysis of this chosen example is as follows :-

(a) The 500 mbar trough passing over Lake Baikal was associated with the subsidence of cooler air behind the trough. At the same time, winds with northerly components at and below the 500 mbar level advanced to lower latitudes on the eastern side of the Tibetan Plateau.

(b) The Siberian anticyclone was induced to intensify and extended towards central and southern China.

(c) The air subsiding on the 15°C isentropic surface diverged as it moved into the lower latitudes.

(d) The frontal surface over China associated with this outburse of cooler air from higher latitudes was inclined towards the north-northwest with a slope of typically 1/300 to 1/400. Steeper slopes of around 1/150 were found at lower latitudes below 700 mbar.

(e) The frontal surface overtook air over southern China which was "pushed" to move southward. At the initial stage of the surge, air reaching Hong Kong therefore consisted of air originally situated over southern China and not from air subsiding from 500 mbar near Lake Baikal.

Appendix II

500 mbar troughs passing over Lake Baikal and times of arrival of associated surges at Hong Kong (October 1974 to April 1975)

Time of passage of 500 mbar trough		Time of arrival of surge at Hong Kong		Forecast time error (hour)
date	hour(GMT)	date	hour(GMT)	
4 October 1974	00	6 October 1974	00	0
7	07	9	09	2
9	14	11	07	-7
11	14	-	-	no arrival
16	13	-	-	no arrival
18	10	20	12	2
20	00	22	12	12
23	11	25	09	-2
25	08	27	18	10
26	07	28	12	5
29	14	31	06	-8
2 November 1974	00	-	-	no arrival
6	10	7 November 1974	21	-13
15	20	17	06	-14
18	00	20	10	10
21	18	23	02	-16
24	05	26	00	-5
27	20	29	15	-5
2 December 1974	04	3 December 1974	14	-14
8	00	10	12	12
11	17	13	18	1
13	13	-	-	no arrival
16	05	17	20	-9
22	10	24	00	-10
30	00	1 January 1975	10	10
2 January 1975	17	-	-	no arrival
5	17	-	-	no arrival
20	04	21	12	-16
23	02	25	03	1
24	22	27	00	2
28	00	30	07	7
30	12	-	-	no arrival
4 February 1975	21	7 February 1975	04	7
7	12	9	04	-6
16	12	18	15	3
17	12	19	22	10
25	16	-	-	no arrival
3 March 1975	20	6 March 1975	18	22
7	06	9	22	16
9	19	-	-	no arrival
12	12	14	07	-5
17	16	20	00	8
20	12	23	14	26
28	05	29	15	-14
3 April 1975	09	-	-	no arrival
6	13	7 April 1975	21	-15
10	06	-	-	no arrival
11	15	13	12	-3
21	00	23	21	21
26	16	28	01	-15