Criteria for Forecasting Cold Surges Associated with Strong High Pressure Areas over Thailand during the Winter Monsoon

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Abstract: At present, the arrival of a 1020 hPa isobar at the border of Thailand is assumed to define a strong high pressure area over the country associated with a cold surge. Using this definition, with the National Centers for Environmental Prediction (NCEP) analysis data, twenty-four strong high pressure cases were found in the five winters (October-February) from 2002 to 2006. The 24 cases were studied using the Advanced Research WRF (ARW) Modeling System in order to determine the extent to which they were cold surges as defined by a mean sea level pressure (MSLP) rise, a sudden increase in wind speed, and sharp drops in surface air temperature and dew point temperature. The 24-hour changes of meteorological elements for five days at Udon Thani station during the strong high pressure cases were examined to find detailed criteria for forecasting cold surges in Thailand. It was found that the indicators of a cold surge are an increase in wind speed of at least 2.6 m/s, a rise in MSLP of at least 1.8 hPa and drops in surface air temperature and dew point temperature of at least 1.7°C and 2.1°C, respectively, at Udon Thani station.

Keywords: Cold surge, strong high pressure area, winter monsoon.

1. Introduction

During the winter monsoon period, the source of cold surface air in the Siberian-Mongolian high pressure system [1] will generate large anticyclonic flows moving southward [2] to low latitudes and strong high pressure systems affecting the tropical region. An intense outflow causing a widespread outbreak of cold continental air, rapidly increasing surface pressure accompanied by strong northeasterly winds and sharp drops in surface temperature and dew point temperature [3] is called a cold surge. Sometimes it is associated with strong gusty winds, widespread rain and severe thunderstorms [4]. Furthermore, a cold surge often causes heavy rainfall and floods in southern Thailand [5], strong convective activity over the South China Sea [6], and a strengthening cyclonic disturbance north of the Borneo coast [7-8].

Zhang et al. [2] suggested that the criteria for identifying cold surges over an area depend on the location and distance of the area from the source of the surges (the Mongolian HSP), and some criteria are purposely defined for the convenience of weather forecasting. The Korea Meteorological Administration (KMA) used a 1-day temperature drop of 10°C as the cold surge criterion at their main observing station, while Ryoo et al. [9] used a 2-day temperature fall larger than 7.5°C for the whole of South Korea. Chang et al. [10] observed that over the South China Sea and vicinity the cold surge passages occurred in two stages: firstly a rise in surface pressure (edge) and secondly a sharp drop in the surface dew point temperature (front). Chen et al. [11] and Lu et al. [12] selected the Pengehiayu station (25.63° N 122.07° E) in Taiwan as the reference point to define the criteria for cold surges in their study with surface pressure increases of at least 5 hPa, surface temperature drops of at least 4°C, and surface wind speeds of at least 3 m/s in a 24-48 hour interval. In addition, Wu and Chan [3] selected Waglan Island (22.10° N 114.18° E) of Hong Kong for analysis of the local wind to define the type of cold surge. They used a change in easterly wind speed of at least 1.39 m/s on day 0 for selecting easterly surges, and a drop in daily mean air temperature from day 0 to day 2 of at least 2°C associated with wind speed greater than 8 m/s for selecting northerly surges.

At present, no standard criteria are being used to define cold surges over Thailand. Strong high pressure events have hitherto been defined only by the arrival of a 1020 hPa isobar at the border of NE Thailand; this is normally associated with a cold surge. Because the definitions of cold surges vary depending on the regions of interest [2], objective criteria to identify cold surges over Thailand are sought in this study. Cold surge definitions usually consist of a mean sea level pressure rise and a sudden increase in wind speed accompanied by sharp drops in air temperature and dew point temperature. Therefore, we have used numerical simulations to seek definitions of this type for cold surges in the winter monsoon over Thailand.

2. Methods

The simulations for the study covered the winter monsoon periods October to February in the five years 2002-2007. Analysis data sets published by the National Centers for Environmental Prediction (NCEP) with grid resolution 1° × 1° at 00, 06, 12 and 18 UTC (Universal Time Coordinate) were used for 24 hourly initial and lateral boundary conditions in the Advanced Research WRF (ARW) Modeling System (Version 2.2.1).

A model domain over latitudes 10° S to 60° N and longitudes 70° to 140° E (see Fig. 1) with resolution 45 km was used to select the high pressure events when a mean sea level pressure (MSLP) of at least 1040 hPa occurred in the Mongolian high and a 1020 hPa isobar reached the border of Thailand. An example, taken from a time series of weather maps at 00 UTC produced for this purpose by the Grid Analysis and Display System (GrADS) program, is illustrated in Figure 2.

In order to determine suitable criteria for identifying cold surges a model over latitudes 0° to 35° N and longitudes 90° to 120° E (see Fig. 1) with resolution 15 km was used to plot time series graphs of MSLP, wind speed at the 850 hPa level, and temperature and dew point temperature at the surface (2 m height) at Udon Thani meteorological station. This station was selected because it is in the area of Thailand that is first affected by a cold northerly surge during the winter monsoon. It lies on a plateau without any high blocking mountains, and it makes regular surface and upper air observations. Furthermore, it was used as a reference station in the Winter MONEX (Monsoon Experiment) by Chang et al. [10] to study the gravitational character of cold surges. When a 1020 hPa isobar reaches the border of Thailand the MSLP at Udon Thani normally reaches at least 1019 hPa.

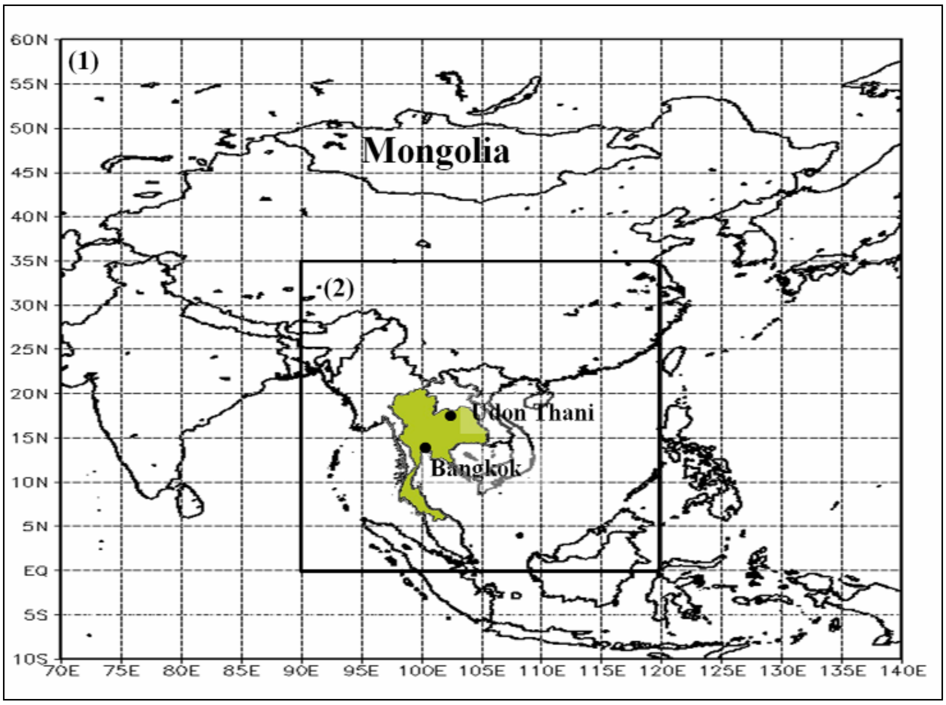
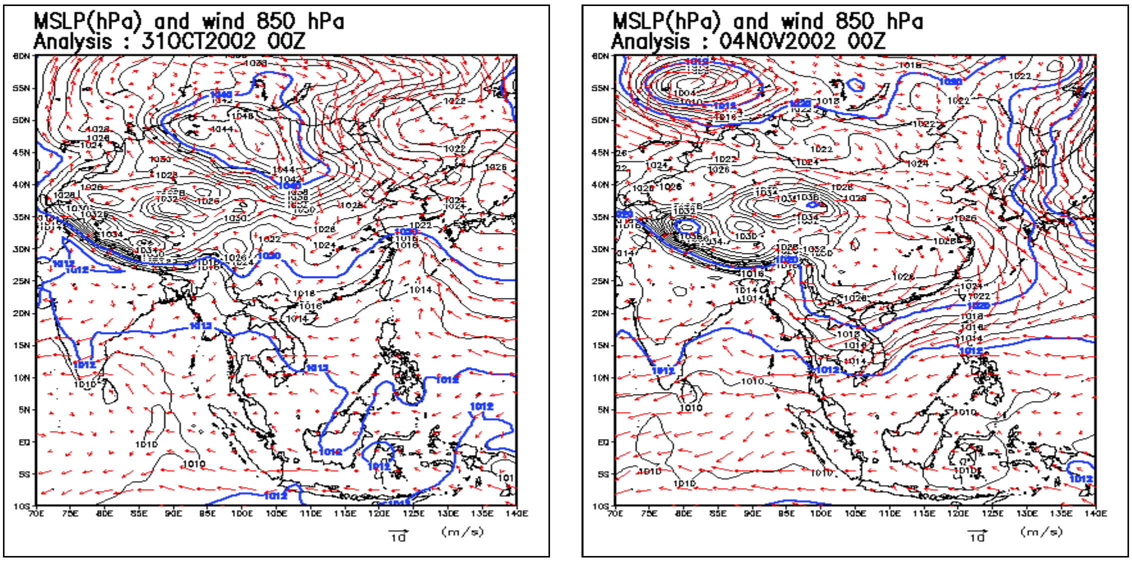


Figure 1. Domain for (1) 45 km resolution and (2) 15 km resolution models.



(a) (b)

Figure 2. A selected example of (a) a Mongolian high pressure maximum and (b) the onset of a strong high pressure event over Thailand five days later.

The criteria used for identifying cold surges in Thailand were 24h changes at Udon Thani station in the MSLP, the 850 hPa level wind speed, the surface temperature, and the surface dew point temperature during the period 2 days before to 2 days after an arrival of a 1020 hPa isobar.

3. Results and discussion

3.1 The observed high pressure events

During the study period the Mongolian high reached a MSLP of 1040 hPa 37 times, but a 1020 hPa isobar reached Thailand in only 24 of these cases, as listed in Table 1. These figures show that the relative frequency of a high pressure event over Thailand after a high pressure event in the Mongolia high was approximately 2/3. Of the high pressure events in Thailand approximately 80% were south-moving and approximately 20% were east-moving.

The results in Table 1 also show that the south-moving high pressure events took an average of 3.2 days to reach Thailand and the east-moving events took an average of 3.4 days.

3.2 Criteria for identifying cold surges

The extreme changes in 24 hours of the selected meteorological elements during the five-day period from two days before to two days after the arrival of a 1020 hPa isobar at Udon Thani station are given in Table 2. The cold surges were associated with average 24h increases of MSLP and 850 hPa-level wind speed of 2.8 hPa and 4.8 m/s respectively. The average drops in surface air temperature and dew point temperature were 3.1°C and 4.1°C, respectively.

If we assume that all four meteorological elements must have 24 h changes greater than the average in a cold surge, then only three cases (2, 9, and 14 in Table 2) are identified as cold surges. If, however, these criteria are relaxed by one standard deviation from the average change, then our criteria for a cold surge become: a 24 h change in MSLP of +1.8 hPa, a 24 h change in 850 hPa wind speed of +2.6 m/s, a 24 h change in surface air temperature of -1.7°C, and a 24h change in surface dew point temperature of -2.1°C (see Table 2). Altogether 15 cases in Table 2 satisfy all four of these criteria during the high pressure events. More than half of these cold surge cases occurred in December.

3.3 Time series graphs of meteorological elements at Udon Thani station

Time series graphs of the meteorological elements at Udon Thani station in the 15 cases identified as cold surge events are plotted in Figs. 3 to 17. In each case five days are shown from two days before to two days after the high pressure event.

Table 1. Dates of the Mongolian high reaching 1040 hPa and a 1020 hPa isobar reaching Thailand.

Year	Case	Mongolian high reaching 1040 hPa	1020 hPa reaching Thailand	
			South-moving	East-moving
2002-2003	1	31 Oct.	4 Nov.	-
	2	6 Dec.	9 Dec.	-
	3	1 Jan.	3 Jan.	-
	4	25 Jan.	-	28 Jan.
	5	2 Feb.	4 Feb.	-
2003-2004	6	6 Nov.	12 Nov.	-
	7	27 Nov.	29 Nov.	-
	8	5 Dec.	13 Dec.	-
	9	17 Dec.	19 Dec.	-
	10	24 Dec.	27 Dec.	-
	11	22 Jan.	24 Jan.	-
2004-2005	12	22 Nov.	-	26 Nov.
	13	5 Dec.	7 Dec.	-
	14	28 Dec.	31 Dec.	-
	15	17 Jan.	-	21 Jan.
2005-2006	16	18 Nov.	21 Nov.	-
	17	9 Dec.	15 Dec.	-
	18	19 Dec.	21 Dec.	-
	19	3 Jan.	7 Jan.	-
	20	31 Jan.	-	4 Feb.
	21	7 Feb.	-	9 Feb.
2006-2007	22	15 Dec.	17 Dec.	-
	23	4 Jan.	6 Jan.	-
	24	22 Jan.	24 Jan.	-

Table 2. 24-hour extreme changes of meteorological elements during the high pressure events at Udon Thani station.

Case	MSLP (hPa)	850 hPa wind speed (m/s)	Surface temperature (°C)	Surface Dew point temperature (°C)
1*	1.8	5.4	-2.9	-4.4
2*	5.3	8.2	-6.5	-9.8
3	2.2	2.3	-3.4	-2.5
4	4.8	1.6	-4.4	-3.7
5*	2.5	5.7	-2.7	-4.0
6*	2.6	3.1	-2.8	-2.8
7	3.1	3.6	-3.8	-1.5
8	1.6	3.1	-2.3	-3.0
9*	3.0	10.3	-5.8	-5.1
10*	2.7	4.1	-2.5	-3.4
11*	2.9	4.8	-2.7	-5.0
12	1.1	4.0	-1.8	-5.9
13*	2.5	7.2	-3.6	-5.5
14*	4.3	6.0	-4.1	-7.9
15	2.3	3.6	-0.7	-0.7
16*	2.2	3.7	-3.2	-3.2
17*	2.0	3.9	-1.7	-2.4
18*	3.1	7.2	-1.7	-3.6
19*	3.1	4.1	-4.6	-6.7
20*	2.7	7.0	-2.5	-3.9
21	2.5	5.9	-0.6	-2.1
22*	3.4	5.9	-2.8	-4.2
23	2.9	1.7	-4.6	-3.4
24	1.5	2.2	-2.1	-4.3
Average	2.8	4.8	-3.1	-4.1
Standard deviation	1.0	2.2	1.4	2.0
Criteria	+1.8	+2.6	-1.7	-2.1

Stars indicate 15 cases identified as cold surges (see text)

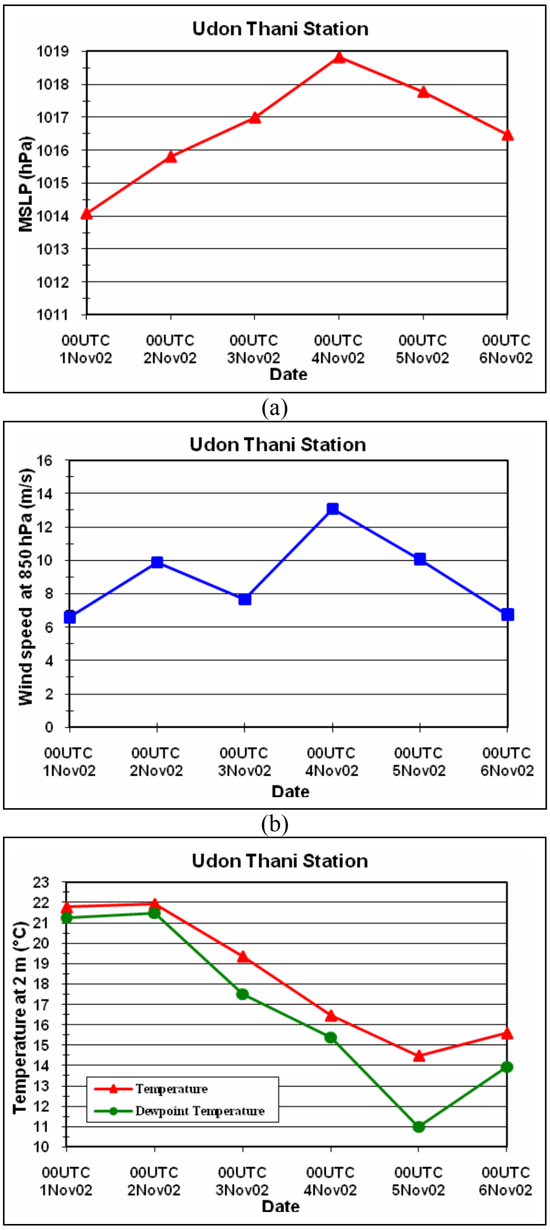


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Figure 3. Case 1: Time series graphs from two days before to two days after the arrival of a 1020 hPa isobar in Thailand on 4 Nov 2002. (a) MSLP, (b) wind speed, (c) air temperature and dew point temperature at 2 m at Udon Thani station.

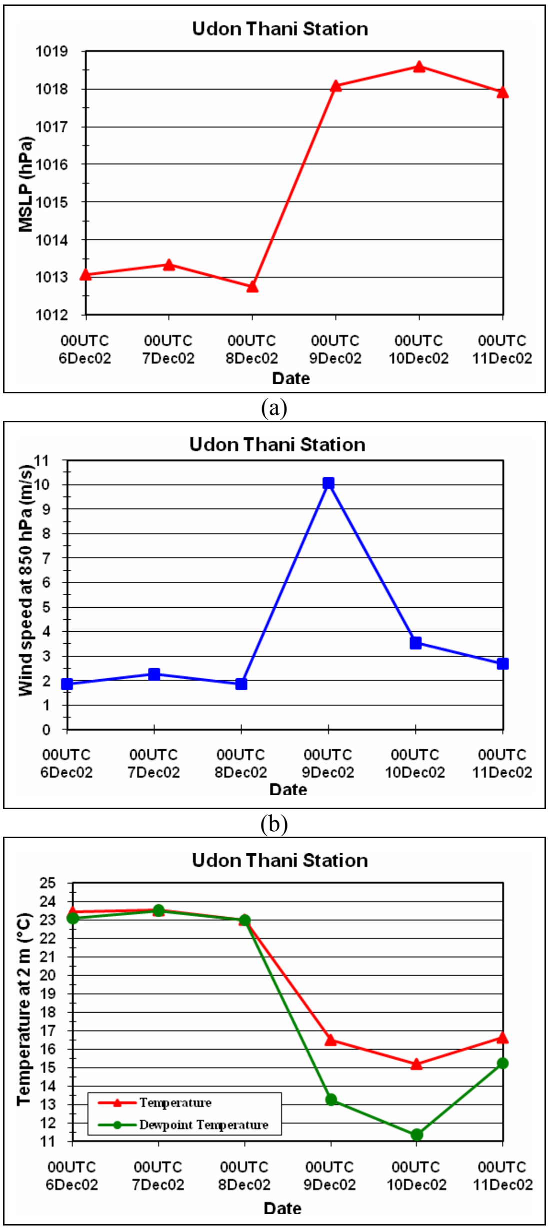

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Figure 4. Case 2: As Figure 3, but 9 Dec 2002.

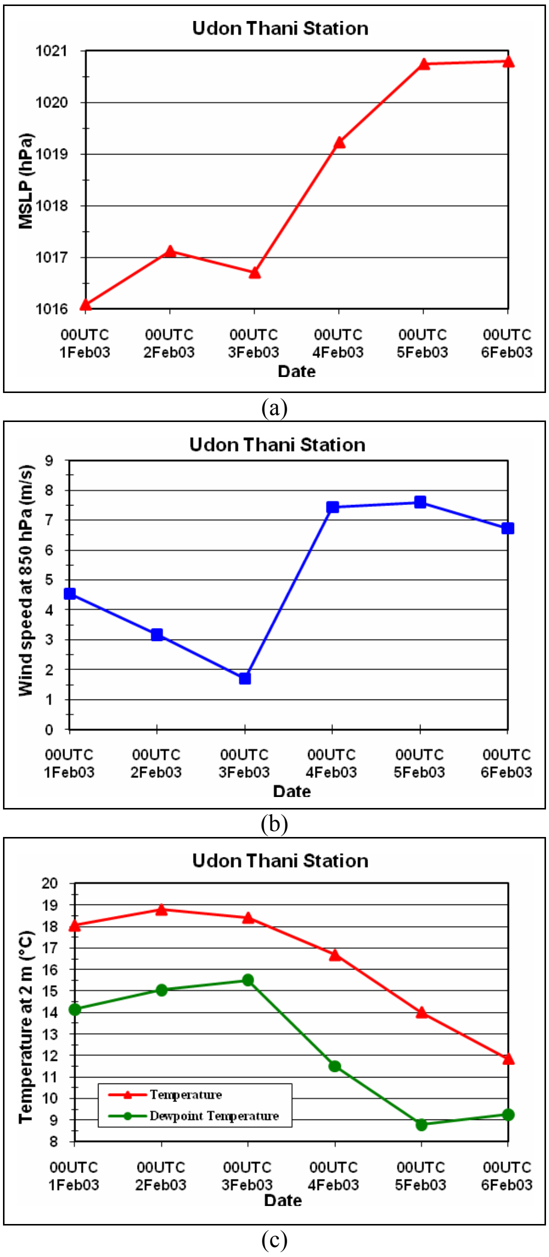


Figure 5. Case 3: As Figure 3, but 4 Feb 2003.

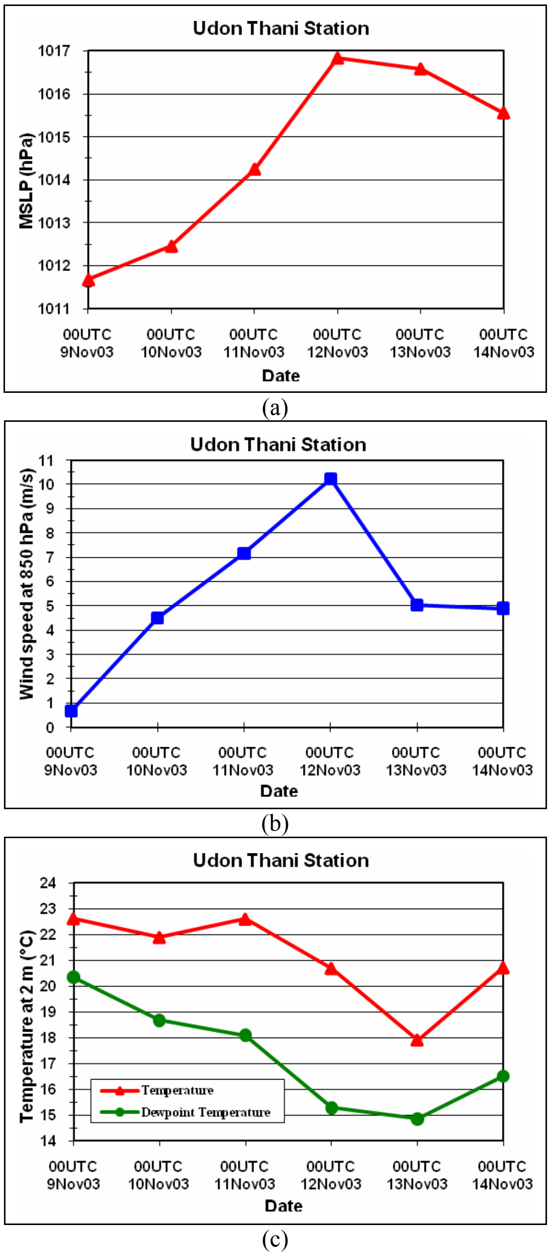
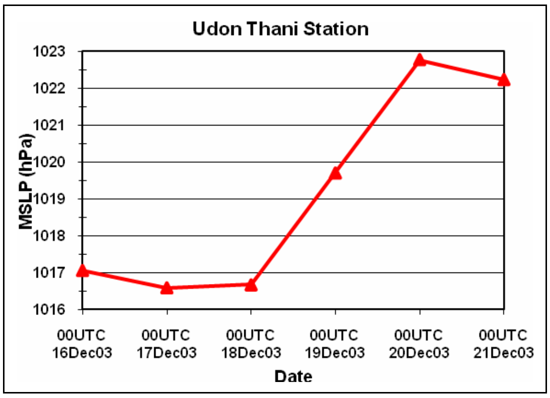


Figure 6. Case 4: As Figure 3, but 12 Nov 2003.



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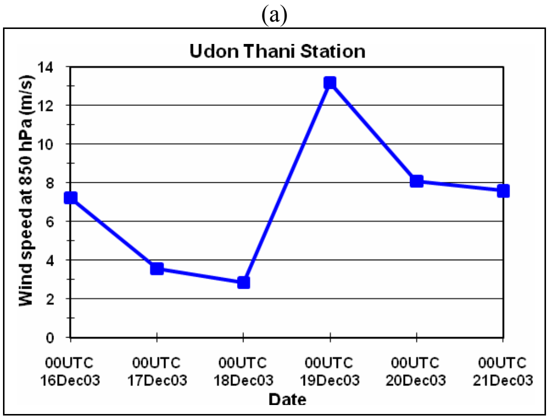

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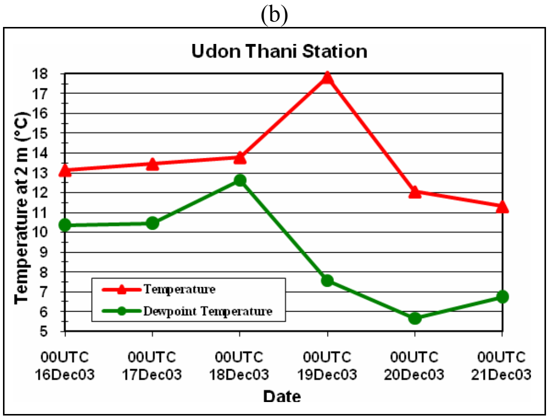

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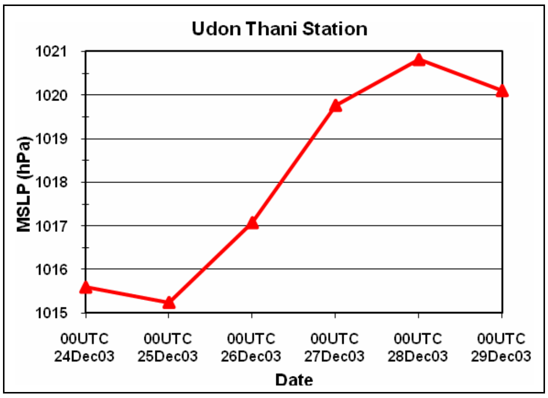
Figure 7. Case 5: As Figure 3, but 19 Dec 2003.



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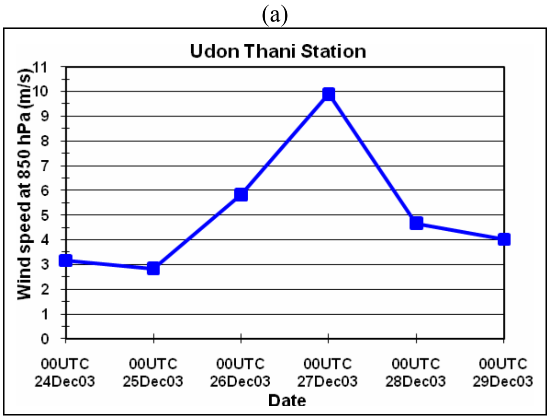

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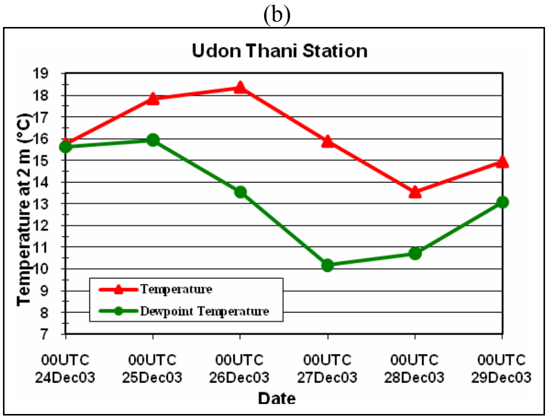

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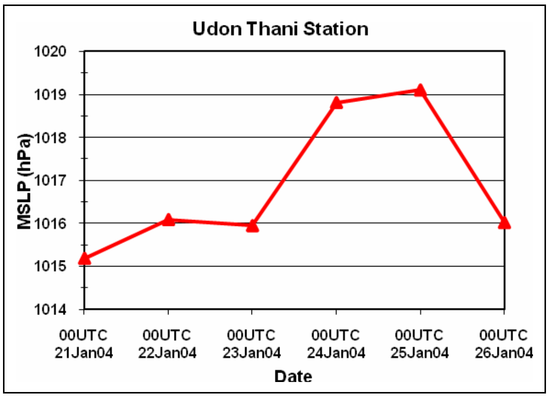
Figure 8. Case 6: As Figure 3, but 27 Dec 2003.



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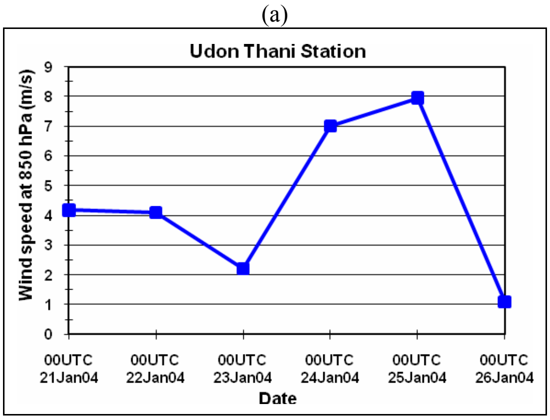

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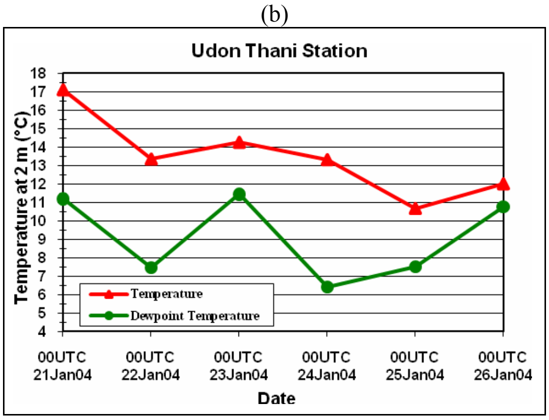

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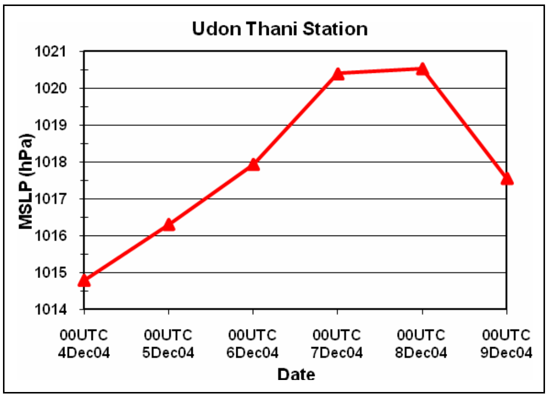
Figure 9. Case 7: As Figure 3, but 24 Jan 2004.



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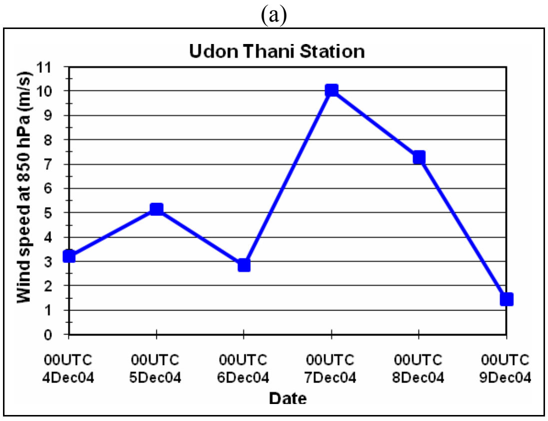

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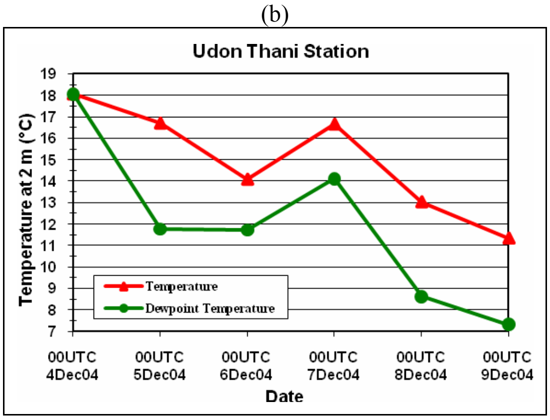

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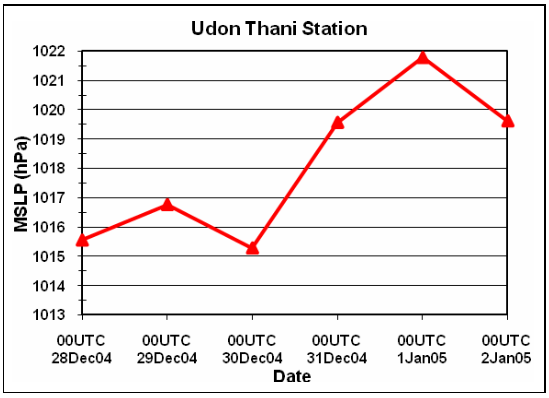

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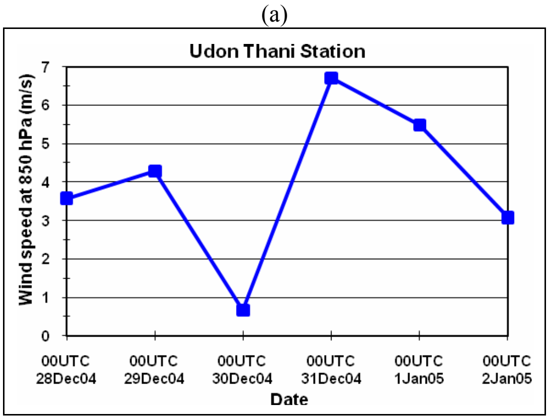

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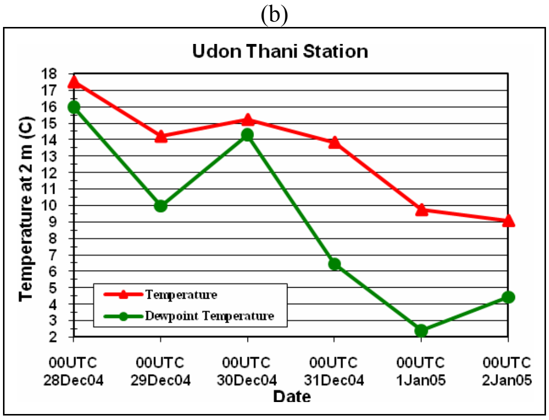

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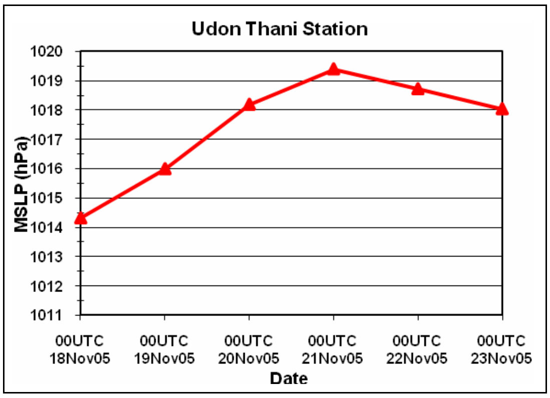

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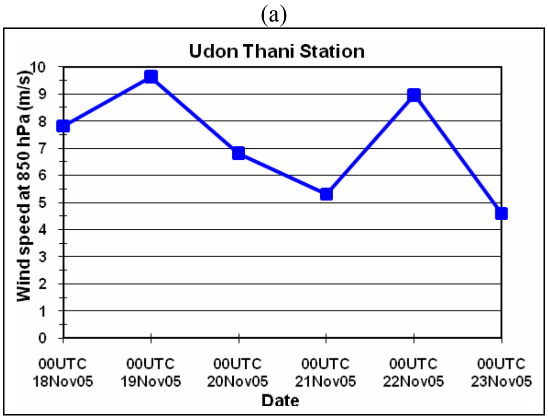

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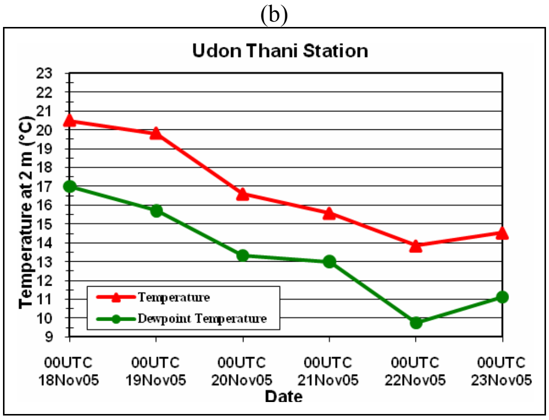

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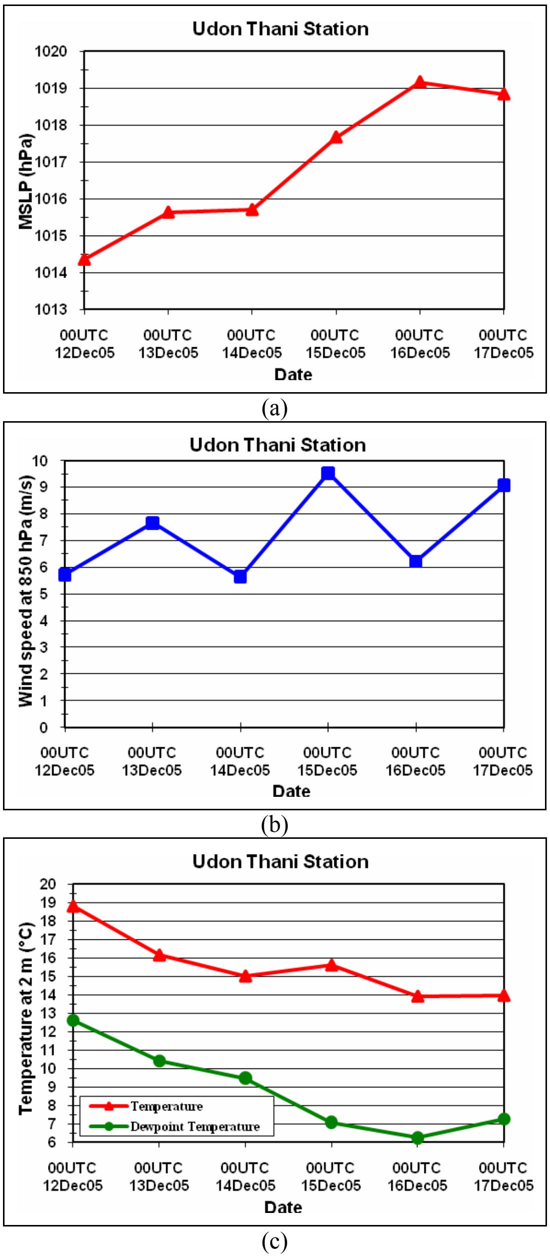
Figure 12. Case 10: As Figure 3, but 21 Nov 2005.



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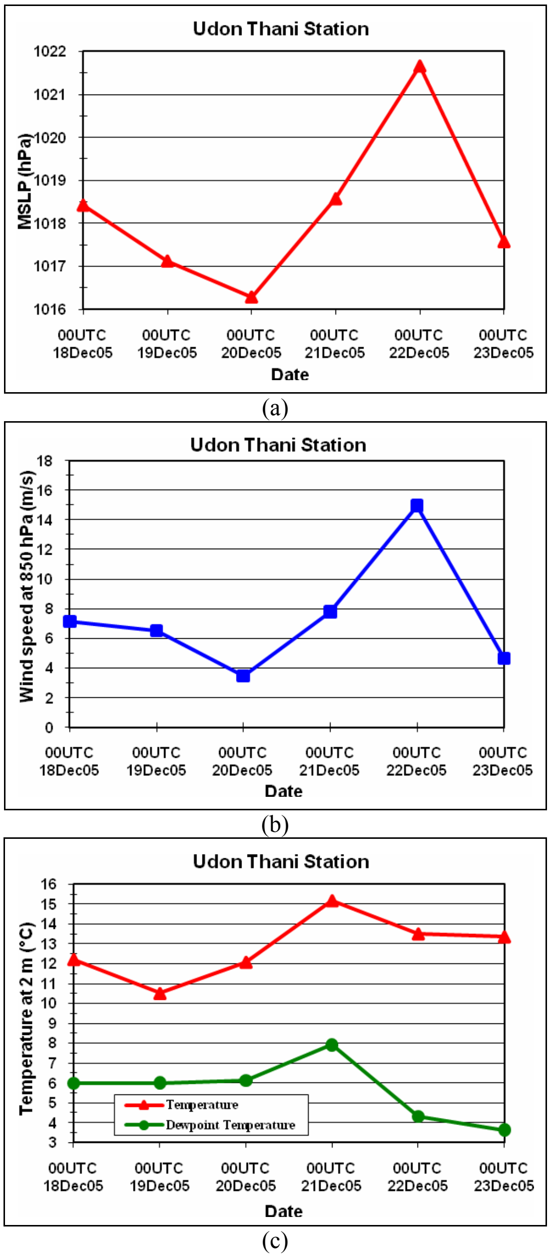

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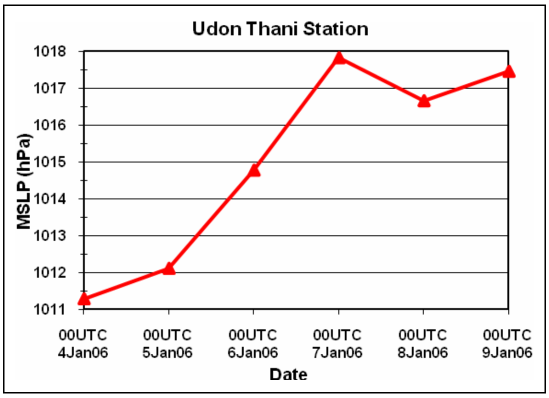

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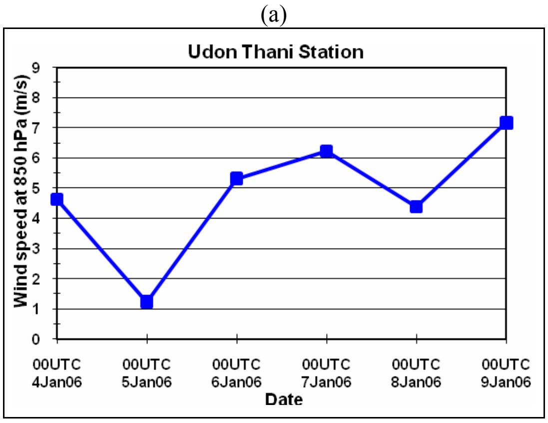

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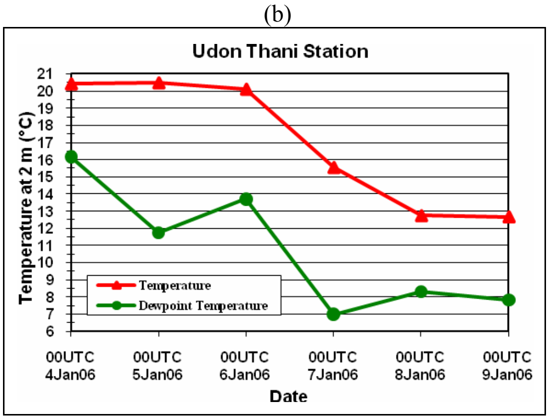

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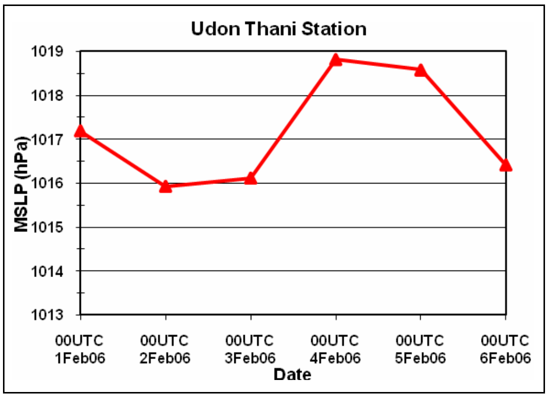

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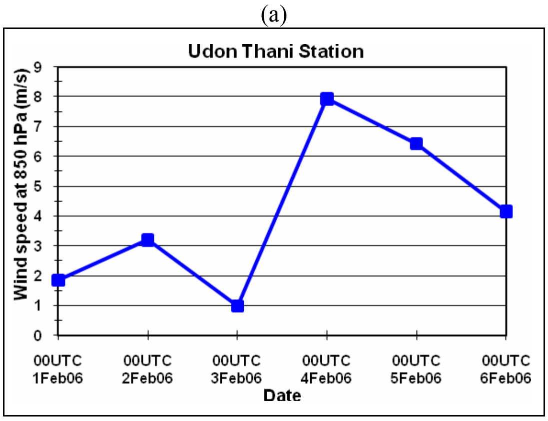

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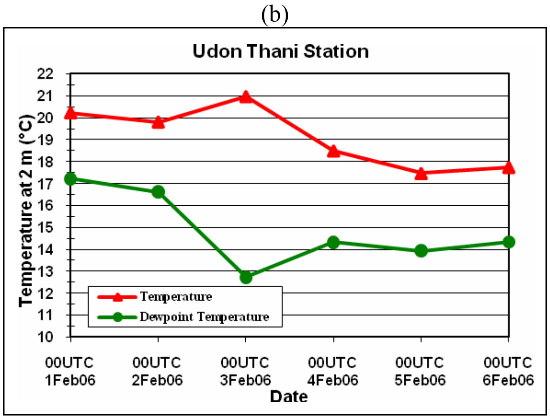

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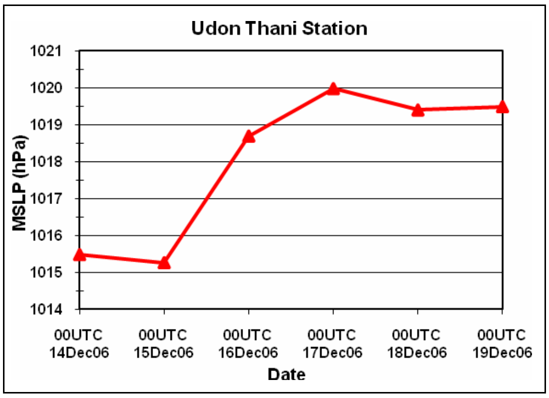
Figure 16. Case 14: As Figure 3, but 4 Feb 2006.

Table 3. The criteria for identifying cold surges in different areas: Changes in 24 h.

Area		MSLP (hPa)	Wind speed (m/s)	Air temperature (°C)	Dew point temperature (°C)
South Korea [9, 13]	KMA station	-	-	< -10	-
	Whole country	-	-	< -7.5	-
Taiwan [11]	Pengehiayu	≥ 5	≥ 3	≤ -4	-
Hong Kong [3]	Easterly surge	-	≥ 1.9	-	-
	Northerly surge	-	≥ 8	≤ -2	-
Thailand	Udon Thani	≥ 1.8	≥ 2.6	≤ -1.6	≤ -2.1

KMA: Korea Meteorological Administration.



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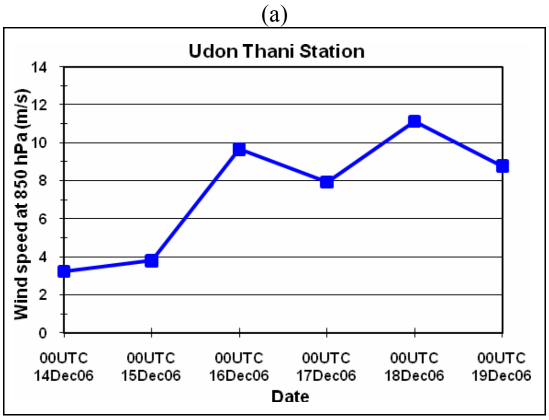

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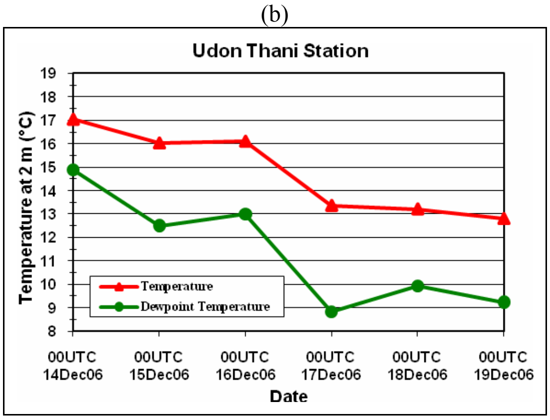

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Figure 17. Case 15: As Figure 3, but 17 Dec 2006.

The time series graphs show that the 24 h extreme changes of MSLP and 850 hPa wind speed were often on the high pressure event day accompanied by an extreme change in dew point temperature and a large dew point depression. The day to day maximum differences in MSLP, 850 hPa wind speed, and surface dew point temperature usually appeared on the first day of a cold surge occurrence. The maximum drop in air temperature was often one day later.

The strongest wind speed arrived first, frequently on the high pressure event day. The maximum value of the MSLP was often one day later and associated with a minimum surface air and surface dew point temperature.

3.4 Discussion

Table 3 shows the criteria used for identifying cold surges in different areas. The cold surges, and hence the MSLP and air temperature criteria, become weaker farther away from the Mongolian high. For simplicity, Ryoo et al. [9] used only air temperature.

In the present study for Thailand the time series graphs of meteorological elements at Udon Thani station during the 15 cold surge events showed that the first significant indicators of a cold surge are a strengthening of the wind and an increase in surface dew point depression on the high pressure event day (when a 1020 hPa isobar reaches the border of Thailand). The greatest changes in MSLP, 850 hPa wind speed, and surface dew point temperature also appeared on the high pressure event day. The extreme values of the meteorological elements usually occurred one or two days later. Therefore, these changes in the meteorological elements at Udon Thani station are considered to be acceptable for identifying cold surges in Thailand.

4. Conclusions

Our experiments using the ARW Modeling System to seek criteria for forecasting cold surges over Thailand during the winter monsoon have found that, when a MSLP of at least 1040 hPa occurs over the Mongolian area, it can be expected that in two thirds of these cases a 1020 hPa isobar will reach the border of Thailand after three days. More than half of these high pressure events in Thailand occur in December.

Among these high pressure events two thirds of them will be identified as cold surges using the following changes in 24 hours at Udon Thani station as criteria: an increase in MSLP of at least 1.8 hPa, an increase in the 850 hPa level wind speed of at least 2.6 m/s, a surface air temperature drop of at least 1.7°C, and a surface dew point temperature drop of at least 2.1°C. The greatest changes normally occur as a 1020 hPa isobar reaches Thailand. The strongest wind speed arrives first followed by a maximum MSLP and minima in the surface air temperature and dew point temperature one day later.

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