Mausam, (1990), **41**, 2, 193-195

551.515.8

Studies on the cold surge in China

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सार — यह शोधपत्र, सिनॉप्टिक और सैद्धांतिक दृष्टिकोण से चीन में शीत महोर्मि पर हाल ही में किए गए कार्य की समीक्षा करता है। चीन के आर-पार और शीत मानसून के प्रदेश में शीत महोर्मि की रचना और प्रसारण में भूमंडलीय माप (प्लैनेटरी स्केल) तरंगों की भूमिका पर चर्चा की गई है।

ABSTRACT. The paper reviews the recent work done on the cold surges in China from the synoptic and theoretical points of views. The role of planetary scale waves in the formation and spreading of cold surge across China and into the region of winter monsoon is discussed.

1. Introduction

In China, meteorologists usually call the winter monsoon as the cold surge. For the purpose of routine forecasting, the Beijing Meteorological Centre defines the outbreak of cold air such that the total drop of temperature during the whole process is larger than 10°C and larger than 5° C for the daily fall as the cold surge. According to this definition, there appear, 136 cold surges out of which 65 cold surges attain to the national scale during the winters of 1951-1980. This means that there are 4.4 cold surges per year on the average (2.2 in national scale). Fig. 1 shows the data of cold surge that influence to the southern China during the winters of 1951-1980 (Feng *et al.* 1985). The most strong cold surge occurred in 28 Nov-3 Dec 1952. The total drop of temperature in the Changjiang river valley is 16° C-18° C. Because the cold surge severely influence the Chinese economy, the research on the cold surge is one of the important programmes in China.

2. Climatology of cold surge

As early as 1957, Tao (1957) studied the original regions and the tracks of cold air that influenced the mainland of China. Fig. 2 shows the tracks and the key regions of cold air. It can be divided into three stages for the whole period of a cold surge. They are stages of preformative, formative and outbreak. For the first stage (preformative), the cold airs that come from the Barents Sea (56%), Kara Sea (25%) and the Atlantic Ocean (15%) move to the eastern Siberia (45° N-65° N, 70° E-90° E, shaded area in Fig. 2). This is a key region for cold surge in east Asia. The cold air stays there and enhances its intensity during the formative stage. In general, these can be divided in four tracks of outbreak as shown in Fig. 2. The NW track that spread from Innermongolia to the Changjiang river valley occurs with about 50%. Besides E & W tracks account for about 33% and 10%, respectively. Fig. 3 shows the distribution of appearance percentage of V component at 1000 mb for V <-5 m/s during winters of 1980-1984. It can be seen in the figure that a belt of maximum percentage spreads from the Yellow Sea to the South China Sea with two centres located over the East China Sea and the middle part of the South China Sea. This is a main outbreak track of cold air. There are other three belts of strong northerly wind which are located over the Arabian Sea, the Bay of Bengal and the western Pacific. The belts in the South China Sea and western Pacific can spread to the equator and form two cross-equatorial air flow over there. Liu and Chen (1983) pointed out the existence of strong cross-equatorial air flow over 105° E and 130° E in winter and discussed their influence on the summer monsoon in the southern hemisphere.

3. Planetary scale atmospheric wave system and the cold surge

There is a close connection between the planetary scale waves and the cold surge. Several Chinese investigators have discussed their relationship. Like Fig. 2, we can divide the change of circulation pattern into three stages. In the preformative stage, the main features are : (1) The ridges at 500 mb over Atlantic and Pacific strengthen and expand over Arctic area, (2) The polar vortex then breaks into two parts. The strongest one moves southward over the European and Asian continent. Following the movement of polar vortex, the Arctic cold air leaves its region of origin and finally arrives in the above mentioned key region. At this stage, the zonal second wave dominates the area of 40° -70° N. In the formative stage, a new ridge develops over the Ural mountain and usually enhances to a blocking high. The zonal third wave controls the belt of 40° N-70° N. At the same time, the cold air strengthens in the key region until the breakdown of Ural ridge. Yeh *et al.* (1962) discussed the formation and breakdown mechanisms of Ural blocking high. At the outbreak stage, the Ural blocking high breaks down and moves eastward. The trough ahead of the high deepens in its intensity and moves eastward. Finally, a new east Asian trough is re-established.

Meanwhile, the cold air breaks out and begins a cold surge in east Asia. If there exists a Bengal trough, the warm and moist SW air flow will strength the cold front and then causes the cold surge move southward. Some authors studied the process of energy transformation associated with the cold surge. In the preformative stage, the available potential energy of second zonal wave $P(2)$ can increase through the diabatic process and then transforms into the kinetic energy of the same wave $K(2)$. At the formative stage, $K(2)$ is transformed into the third zonal wave through the barotropic process of wave-wave energy with the establishment of Ural blocking high.

Zhu and Xie (1988) have discussed the relationships of circulation between two hemispheres in the winter of 1986-87. They found that it was a winter of abnormal warm and a few cold surge in east Asia. Meanwhile, the onset date of Australian summer monsoon delayed by about one month as compared with the normal. They explained these phenomena with the abnormal warming of SST at equator of western Pacific during the summer and autumn of 1986.

4. Enhancement mechanisms of surface cold high pressure and cold surge

The cold high is rapidly enhanced during the formative stage. Ding and Krishnamurti (1987) have discussed the heat budget of Siberian high and pointed out that the strong radiative cooling and large scale descending motion (with large scale mass convergence over the upper and middle troposphere and divergence over the lower troposphere) contributes to a rapid build up of the Siberian high. Heating in the upper troposphere due to subgrid scale heat transfer is also an important factor in the maintenance of mass convergence in the upper tropospheric trough accompanied by the enhancement of the warm upper tropospheric anticyclone lying over the Siberian high. During the outbreak stage, there usually are two fronts in the mainland of China. One is the cold front ahead of the cold high that causes the cold surge and the other, the quasi-stationary front that usually exists over the southern China. The most significant factor that causes the strong drop rate of temperature is the strengthening of ageostrophic wind between two fronts. Lu and Ding (1988) studied the factors which can affect the ageostrophic wind is strong cold air outbreak in winter over east Asia. Fig. 3 shows the distribution of ageostrophic wind at 850 mb for 28 Jan 1980, 12 GMT. In the figure, the full line is the geopotential height at 850 mb, the dashed line the isothermal and the arrow, the ageostrophic component of wind. The ageostrophic component dominates between the two fronts. It is shown that ageostrophic secondary circulations are formed near the frontal zones as well as in the entrance and exist regions of the upper level westerly jet, resulting in the strengthening of the jet stream and local Hadley circulation in east Asia. Besides, the allohypsic wind, inertial advection and friction effect are the main factors which influence the ageostrophic wind. For the Hadley cell, Wu (1988) suggested that not only the ITCZ is influenced by the cold surge, but also the subtropical and polar jet over Japan can be enhanced by the upper divergent flow over the ITCZ area.

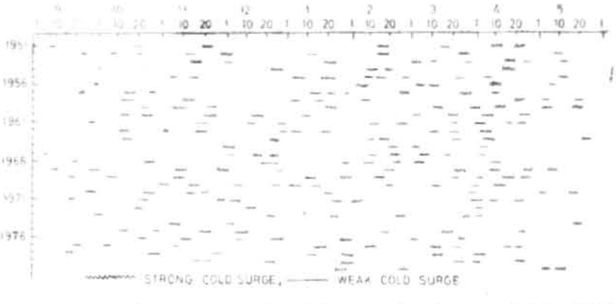

Fig. 1. Data of cold surge that influence to the southern China during the winters of 1951-1980

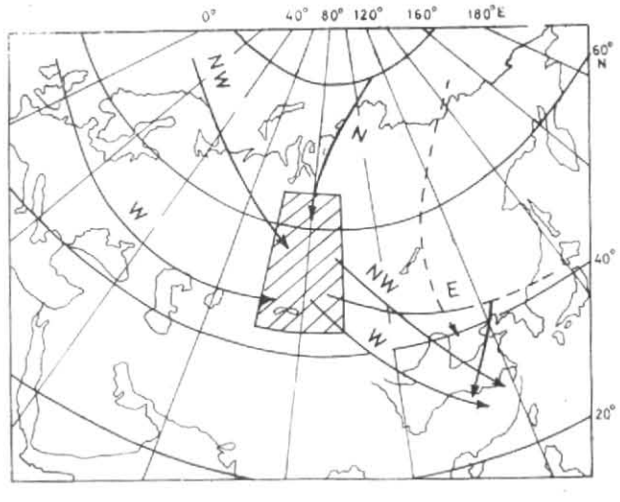

Fig. 2. The tracks of cold air that influenced the mainland of China for the stages of preformative, formative (shaded area) and outbreak.

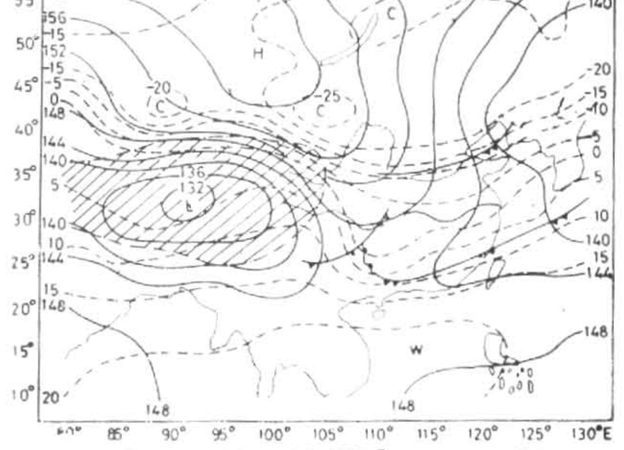

Fig. 3. The distribution of V-V_g (m/s) at 850 mb on 29 Jan 1980, 12 GMT. Full line is geopotential height at 850 mb (interval is 4 decade metres), dashed line is isothermal line (interval is 5°C)

The dynamical effect of the Tibetan plateau plays an important role on the movement of cold surge. A series of numerical experiments about this topic have been conducted by several workers by using the five layers P.E. Model. The results show that the cold air likely moves around the plateau as shown in Lu and Ding's Fig. 3.

5. Low-frequency oscillations in winter monsoon

Murakami and Sumi (1981) found the 12-20 day oscillation. Qin and Wang (1988) also indicated the existence of bi-weekly oscillation in the cross-equatorial air flow at the equator of east Asia. Some authors have studied the features of bi-weekly and 30-60 day oscillations using OLR data set. Eastward propagation dominates in winter. The fact we have to emphasize is that the most active area of this kind of oscillation was located over 160° E-180° E, *i.e.*, near the date line during the winters of 1980-1981 and 1981-1982. However, the active centre shifted to the equator in Indian Ocean and eastern Pacific during the *El Nino* of 1982-1983. Therefore, it seems that the low-frequency oscillation in winter can stimulate the occurrence of *El Nino*. Besides, we also can find the bi-weekly oscillation of cold air and that the relationship between the oscillations of cold air in the middle latitudes and OLR at the equator is close.

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