# Cold surge in developing phase of northeasterly Asian monsoon and their relationship with heavy rainfall in central Vietnam

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There are many and many studies dealing with cold surges (CS) observed in East and Southeast Asia during the mature phase of winter northeasterly monsoon (from December to February), and much knowledge about their synoptic structures has been accumulated. However, CSs found during the developing phase of winter monsoon (October and November) have not been described so much, although their characteristics may be different from those during mature phase (Compo et al. 1999). On the other hand, the CS in the developing phase is considered as one candidate for bringing much rainfall in Vietnam which is located along eastern coast of the Indochina Peninsula.

One of the heavy rainfall events in coastal region of central Vietnam occurred on 2-3 November 1999. For example, precipitation observed during these two days in Hue city (16.4N, 107.7E) reached 1,841mm, which is more than twice climatological November monthly precipitation in the city. At the same time, northeasterly monsoon wind at 925hPa over northern South China Sea (SCS) intensified due to the CS. The wind blew against the Annam Range which lies along eastern coast of the Indochina Peninsula, resulting in continuous orographic rainfall processes which brought precipitation in windward side of the range. Because such CSs were occurred almost every year, it is interesting to study why the CS event in that period could bring heavy rainfall.

With the use of JRA-25 reanalysis data, we analyze characteristics of the heavy-rainfall CS (HRCS) event. In order to clarify its unique feature, we identified twenty events of prominent CS events from October and November in the 25 years from 1979 to 2003, and compare their composite characteristics with those of the HRCS event. We find prominent differences in the behavior over the SCS. While the composite CS blows through southern SCS to the Gulf of Thailand as it circumvents the Indochina Peninsula, the HRCS did not propagate into the southern SCS but blew into the Indochina Peninsula with having strong easterly wind anomalies. In addition, strength of the HRCS wind anomaly over the northern SCS was 1.5 times as large as that of composite anomaly.

Cyclonic circulation anomalies over the southern SCS probably played a major role on the peculiarity of the HRCS. The circulation anomalies had their center at 10N, 110E, and possessed southerly wind anomalies over the southern SCS just south of the HRCS. The southerly anomaly seemed to hinder the HRCS from propagating further southward. The circulation anomaly exhibited almost in-phase structure from the surface up to the 300-hPa level, and had maximum amplitude at 700hPa. The anomaly had its zonal scale of about 40 degrees in longitude and propagated westward from the equatorial Pacific Ocean with its speed of about 7 m/s. These spatial and temporal structures suggest that the cyclonic circulation anomaly was classified into so-called 'TD-type' (Takayabu and Nitta 1993) disturbance. Such westward-propagating disturbances were predominant in low latitudes east of 100E during October and early November 1999.

In summary, we conclude that the heavy rainfall event occurred on 2-3 November 1999 resulted from two atmospheric disturbances: CS from mid latitudes and TD-type disturbance in the tropics.