Study on Nocturnal Development of Cloud Clusters During the Meiyu Period in Eastern China

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Abstract

The evolution of 61 long-lived mesoscale cloud clusters that developed in Eastern China during the Meiyu period in 1998 and 1999 were traced and analyzed by hourly GMS data in this study. It was found that 2/3 of them tend to peak at nighttime (Nocturnal type), others peaked in the evening (Evening type). Most of the Nocturnal type clusters peaked immediately south to the Meiyu front. The nocturnal strengthened LLJ and the resultant low-level moisture convergence immediately south to and within the Meiyu frontal zone was suggested to mainly contribute to the dominant convection peak of the Nocturnal type.

1. Introduction

Cloud clusters are composed of deep convective clouds with an organized structure that can persist long time. The cloud shield that tops the convection is noticeable in satellite imagery as a circular or oval area of low blackbody temperature (TBB). Cloud clusters cause heavy rainfall and greatly influence energy and water cycles on earth (Maddox 1980).

Many studies (Trier and Parsons, 1993, et al.) indicate that cloud clusters over Tropical oceans and Central America show clear diurnal variation with a nocturnal convection peak. In Eastern Asia during Meiyu period, many cloud clusters with a meso-α or β scale and multiscale structure occur and propagate along the Maiyu-frontal zone (Akiyama, 1984; Iwasaki and Takeda, 1993), they can cause heavy rainfall and floods over the Yangtze and Huaihe River valleys. However, in contrast with the many studies on the diurnal variation of cloud clusters in America and tropical oceans, few studies have noted the diurnal variation of cloud clusters over Eastern Asia. Present study investigated whether the development of cloud clusters in Eastern China has a diurnal variation and explored the mechanism under the diurnal cycle.

2. Data and methods of analysis

In this study, 61 cloud clusters with life time longer than 12 hours and maximum area exceeds 60,000 km^2 developed in eastern China (25-40N, 110-120E) during the Meiyu period in 1998 (June, July and August) and 1999 (June and July) were traced and analyzed. The movement and evolution of individual cloud clusters was traced manually by hourly TBB distributions in GMS-IR images. The grid size of the TBB data was 20km in 1998 and 10km in 1999.The GAME Reanalysis 1.5 that

based on HUBEX (Huaihe River Basin Experiment) observation data with a spatial resolution of 50 kilometers and temporal resolution of 6 hours (2, 8, 14 and 20 LST everyday) was used to investigate the diurnal variation of atmospheric conditions in the development environment of cloud clusters.

3. Diurnal variation of cloud clusters

The 61 analyzed cloud clusters can be divided into two types by their dominant peak time as follows: (I) Nocturnal-type: More than two thirds (43/61) of the cloud clusters peaked between midnight and early morning (21 to 06 Local Standard Time (LST)), and more than half of the nocturnal peaks (23/43) occurred between 00 and 02 LST. Some long-lived clusters showed a secondary evening peak or two midnight peaks. (II) Evening-type: The remaining cloud clusters (18/61) peaked mainly from afternoon to early evening (from 15 to 18 LST).

Nocturnal-type cloud clusters have characteristics different from Evening-type clusters. Table1 shows the main characters of the cloud clusters of these two types. The Nocturnal type clusters are much more intense with larger area of inner deep convection (TBB below –70°C) that related to the heavy rainfall more directly (Mapes and Houze, 1993), longer lifetime and more frequent occurrence than the Evening type ones. In present study, we studied the developed environment of the convection peak of the Nocturnal type cloud cluster.

4. Diurnal variation of wind and moisture field over Eastern China during Meiyu Period

It was found that most (38/41) of the Nocturnal-type cloud clusters tend to develop largely just over or immediately south of the Meiyu front at nighttime and there is a significant southwesterly synoptic-scale LLJ (S-LLJ, > 10 m s^{-1}) existed in the south of the Meiyu front, extends from the South China Sea to Korea and Kyushu.

4.1 Diurnal variation of the low-level wind field

We mainly examined the diurnal variation in the low-level wind fields over Eastern China during the period from 1 to 15 August in 1998 when frequent Nocturnal-type cloud clusters and almost stationary Meiyu front that can simplify the study of time variation of wind fields.

Fig.1 indicates the diurnal variation in the low-level (925 hPa) wind field. A distinct diurnal variation exists in the horizontal wind field at 925 hPa over the domain south of the Meiyu frontal zone (25-32N,hereafter the South Domain.). The low-level wind velocity, especially its southerly component, was much larger at 02 LST than that at other times, especially than 14 LST (about 2 times). By contrast, the velocity of the southwesterly wind within the Meiyu frontal zone was small at all times with slight time change. The nocturnal strong southerly wind over the South Domain weakened dramatically after it arrived the area immediately south to and within the Meiyu frontal zone. The southerly wind at 14 and 20 LST also decreased over that domain, but in a much smaller range.

The nocturnal strengthening of the southwesterly low-level wind (LLJ) over the South Domain was attributed to the distinct clockwise direction shift of the ageostrophic wind (not shown) from easterly to southerly at nighttime over there. Blackadar (1957) attributed the nocturnal veering of an ageostrophic LLJ to an inertial oscillation in wind initiated by the sudden cessation of strong turbulent mixing in the boundary layer after sunset.

The nocturnal intensification of southerly component of low-level (925hPa) winds over the South Domain, acted with the increased low-level water vapor from evening time over there caused into the large enhancement of low-level northward moisture flux at night time (2 LST).

4.2 Diurnal variation in the low-level moisture convergence

The nocturnal large southerly moisture flux (925hPa) over the South Domain dramatically weakened followed the low level southwesterly wind at that time and resulted in low-level moisture convergence with large area and intensity as shown in Fig.2 that indicates the diurnal variation in the moisture convergence at 925 hPa. The large convergence at 2 LST occurred over the domain with southern border immediately (100km) south to the Meiyu frontal zone and including its southern part (from 31-34N), it was named Meiyu Front Convergence Zone hereafter (MFCZ). Moisture convergence appeared within this region at the other times, but covered a much smaller area with weaker intensity, especially that at 14 and 20 LST.

Similar diurnal variation with maximum at 2 LST in the horizontal wind field over the South Domain and in the resultant moisture convergence field over the MFCZ occurred at 850 and 700 hPa, but with a smaller amplitude. Diurnal variation in the low level (at 925 hPa) wind field and moisture convergence fields similar to that in August also occurred in June and July of 1998.

The nocturnal strengthened LLJ and the formation of low level (925hPa) moisture convergence over MFCZ was suggested to contribute to the convection peak of individual Nocturnal type cloud cluster. The low-level moisture convergence largely increased the amount of water vapor at low level and strengthened the potential instability over MFCZ and also force weak synoptic-scale lifting to contribute to the nocturnal convection peak of cloud cluster.

5. Summary

There is a clear diurnal variation in the evolution of the cloud clusters occurred in Eastern China during Meiyu period. It was found that most of them tend to peak at nighttime (Nocturnal type), others peaked in the evening (Evening type). Most of the Nocturnal type clusters peaked immediately south to the Meiyu front. The nocturnal strengthened LLJ over South Domain and its resultant low level moisture convergence over the MFCZ are proposed to mainly contribute to the nocturnal development of the cloud clusters.

Table1 Characters of midnight and evening type cloud clusters

Type of Cloud cluster	Peak time of deep convection	Peak time of Cluster	Number of clusters	Life time	Peak area of Cloud Cluster	Peak area of very Deep convection
Nocturnal type	2.3 LST	4 LST	41		114,000 km²	33000 km²
Evening Type	17.4 LST	17.4 LST	20	14 h	109,000 km²	21,000 km²

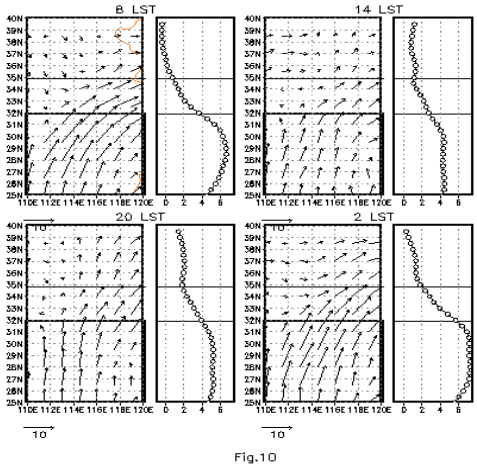

Fig.1 Diurnal cycle (8, 14, 20 and 2 LST) of horizontal wind distribution (left panel) and its longitudinal mean value (right panel) at 925 hPa averaged for 1-15, August of 1998. Area within two solid lines indicates the Meiyu frontal zone (32-35N, 110-120E).

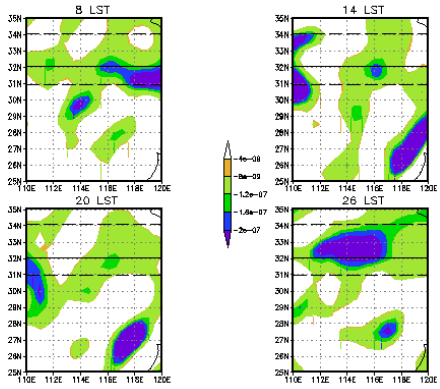

Fig.2 Diurnal cycle (8, 14, 20 and 2 LST) of horizontal moisture convergence distribution at 925 hPa. The area within the solid lines in each panel indicates the Meiyu frontal zone and within the dash lines is the Meiyu Frontal Convergence Zone (31-34N, 110-120E

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