Synoptic Features of the Second Meiyu Period in 1998 over China*

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ABSTRACT

The synoptic circulation features, moisture transport and water vapor budget over the central and eastern China during 21-31 July 1998 are studied by utilizing the daily $1° \times 1°$ data of the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) and observational data of 24-h rainfall recorded by meteorological stations in China. The results clearly indicate that a dew-point front (it was revealed by Gao et al. 2002), marked by a large horizontal moisture gradient in the mid-lower troposphere, located near the periphery of the West Pacific subtropical high (WPSH), can conjugate with the Meiyu front, and form a predominant double front structure (the Meiyu front system), which is related to the intense rainfalls over the Yangtze River Basin in China. The precipitation over China for 21-31 July 1998 was characterized by a narrow intense rainfall zone over the Yangtze River Basin, and it was against the southern side of the Meiyu front and bounded by the dew-point front. The water vapor transport and budget over three domains, corresponding to the location of the dew-point front, the passageway of the Meiyu front and the dew-point front, and the Meiyu front, respectively, bounded by $20°-25°N, 25°-30°N,$ and $30°-35°N$, and $105°-121°E$, indicate that the convergence of the moisture flux within the passageway is mainly due to the southwesterly and southerly moisture inflow across the dew-point front. Persistence of the water vapor gradient located at both sides of the passageway is correlated highly with the southwesterly and southerly moisture inflow and its convergence in the passageway. Water vapor budgets over the three domains indicate that the water vapor is mainly converged at lower levels, and is uplifted from low levels to upper levels through convective transport. The passageway has net water vapor budget and is the area corresponding to the most water vapor transport and convergence during the analyzing period. The diagnosis results further manifest that the water vapor mainly comes from the Indian Ocean and the Pacific, and that the water vapor convergence of regional torrential rain is also provided by the semi-hemisphere scale water vapor transport.

Key words: Meiyu front, rainfall, vapor transport, vapor budget

1. Introduction

The Meiyu, translated as plum rain, is a major annual rainfall event over the Yangtze River Basin in China and southern Japan in June and July. The heavy rainfall is mainly caused by a quasi-stationary front, known as the Meiyu front, extended from eastern China to southern Japan (Tao, 1958; Matsumoto et al., 1971; Akiyama, 1990; Gao et al., 1990). Studies of Zhang and Zhang (1990) and Chen et al. (1998) pointed that the Meiyu front is one of the most significant circulation systems for the hydrological cycle in the East Asia monsoon region. During Meiyu period, proper precipitation is favorable to industry and agriculture, but large amount of rainfall can cause tremendous damage to infrastructure, industry and agriculture, adversely affects people’s daily activities, their property, and even their lives. Therefore, to study its forming and maintenance factors is important for preventing floods, fighting against droughts and disaster reduction.

Maintenance of the Meiyu front is one of the important background for the occurrence of the intense
The synoptic structure of the Meiyu front is characterized by a weak temperature gradient, but is accompanied by a strong moisture contrast of high equivalent potential temperature ($\theta_e$) gradient (Ding, 1992). It corresponds to strong vertical wind shear. In the lower troposphere (850-700 hPa) the signatures of the Meiyu front in the wind field are more pronounced than in the thermal field. From various points of view, many studies of the moisture transport and moisture balance related to the Meiyu front rainfall have been extensively performed (Murakami et al., 1984; Ninomiya, 1984, 1999; Pearce, 1992; Si, 1995; Gao et al., 2002abc; Gao et al., 2004; Zhou et al., 2004), which mainly emphasized the importance of the moisture balance of the whole summer monsoon and concentrated in Meiyu period in a large area. The second period of the Meiyu for 21-31 July 1998 is an extreme example. Generally, the rainfall belt in this period should shift to North and Northeast China from the Yangtze River Basin with the West Pacific subtropical high (WPSH) and the monsoon moving northward. But in 1998, the WPSH moved backward and its ridge stopped at about 22°N, and the monsoon suddenly retreated to the Yangtze River Basin in mid July after a short visit over North China from 5 to 16 July, thus bring about the unusual second Meiyu period and heavy rainfall and severe floods over the Yangtze River Basin. The severity and long duration of this flooding are rare in the history over the Yangtze River Basin (Ding et al., 1999; Wang et al., 2003). By far, the activities of the Meiyu front (Ding et al., 1999; Kato et al., 1999; Fujiyoshi et al., 1999), the onset and evolution of the summer monsoon (Ding and Liu, 2001), the large-scale circulation features and synoptic systems in East China (Ding et al., 2001), and the structures of the Meiyu front during the intensive rainfall period (Gao et al., 2002) have been studied. Ding and Hu (2003) studied the global background of the water vapor budget in the whole flooding period of 1998, whose studies included seven flooding periods over the Yangtze River and Songhua River from May to August, and the flooding regions were divided into eleven zones. Their studies aimed at large spatial and temporal scales, but no more attention was paid to the moisture balance of the Meiyu front over the mid-lower Yangtze River in 1998. Especially, Gao et al. (2002) revealed a counterpart of the Meiyu front—a dew-point front associated with intense rainfall in their study of the structures of the Meiyu front in 1998 and 1999. The dew-point front, located near the periphery of the WPSH, conjugates with the Meiyu front to form a predominant double front structure. This double front structure is called as Meiyu front system and is an important phenomenon just only occurring in intensive Meiyu year. Its occurrence and maintenance are a strong indicator of the intensity of the Meiyu front and the WPSH, and are key factors to the occurrence of a strong Meiyu (Gao et al., 2002). Though the Meiyu front system related to the intense rainfalls over China was revealed, and its structural features were analyzed, the moisture balance over the Meiyu front system was not studied yet. Because the moisture transport and balance are key factors for the intense rainfall, to study moisture transport aiming at the Meiyu front system during this extreme Meiyu period is favorable to understand the formation mechanism of the intense precipitation.

2. Overview of rainfall, synoptic situation and the Meiyu front system during 21-31 July 1998

In this paper, the 24-h interval observational data of precipitation were obtained from meteorological stations in China, the weather systems and the Meiyu front system were analyzed by using daily $1^\circ \times 1^\circ$ data of NCEP/NCAR (the National Centers for Environmental Prediction/National Center for Atmospheric Research).

2.1 Overview of rainfall

During the monsoon/Meiyu season in 1998, a severe flooding event occurred in the Yangtze River Basin ($26^\circ-32^\circ N, 110^\circ-122^\circ E$) that was the worst event recorded since 1955 and brought about great economic losses in China. This severe flooding event was induced by severe precipitation events associated with the activities of the summer monsoon and the Meiyu front system over East Asia (Ding and Liu, 2001; Gao
et al., 2002). Figure 1 presents the total precipitation amounts accumulated from 0000 UTC 21 to 0000 UTC 31 July 1998. It is found that heavy rainfall with the total amount of 200-700 mm occurred over the Yangtze River Basin during 21-31 July 1998. The rainfall area took mainly east-west direction along the mid-lower Reaches of the Yangtze River Basin (within 27°-32°N, 105°-120°E), but rainfall region with the total amount of 100-200 mm took southwest-northeast orientation within 21°-27°N and 105°-112°E. From daily rainfall analysis (figures not shown), on 22 July, one station recorded rainfall over 300 mm within 24-h, and four stations recorded over 200 mm. A maximum of 77.0 mm rainfall was observed from 2300 UTC 21 July to 0000 UTC 22 July at Ezhou Station, and 76.4 mm from 2200 UTC to 2300 UTC July at Huangshi Station. This heavy precipitation episode was the most severe flooding event in this area since 1950. The large precipitation over the mid-lower Reaches of the Yangtze River Basin maintained until the later of July 1998.

![Fig.1. Total precipitation for 21-31 July 1998. Rainfall contours are in mm. Areas of rainfall exceeding 100 mm are shaded.](image)

**2.2 Overview of synoptic situation**

Since a full description of the 1998 East Asian summer monsoon and severe precipitation event over China can be found in studies of Kato et al. (1999), Ding and Liu (2001), and Wang et al. (2003), only some major features of the weather systems, synoptic situation and their relationship to the severe precipitation events are highlighted here.

During this period, the ridge line of the WPSH was located between 18° and 24°N at 500 hPa, and the 5880-gpm height contour extended to 114°E, which are favorable to the intense rainfall occurring over the Yangtze River Basin. It is very extreme for the WPSH to locate at so west and south position during this period (generally, it should be located at 26°-28°N). In the middle latitudes, a deep trough was located over the Japan Sea and the East China Sea. Between southwesterly and northwesterly winds, a weak shear line existed along the Yangtze River Basin and a
shortwave trough with its center at 27°N was located near 110°E. At 850 hPa, the 1480-gpm height contour, which is often used by Chinese meteorologists to identify the periphery of the WPSH at 850 hPa, extended to 102°E. Strong southwesterly flow appeared on the west and northwest sides of the WPSH. The cyclonic shear line over the Yangtze River Basin was still evident at 700 hPa (Fig.2b). The shear line between northeasterly and southwesterly winds maintained in this period. To the south of this shear line, namely, near the periphery of the WPSH, a southwesterly synoptic-scale LLJ with wind speeds over 12 m s⁻¹ stretched from the Bay of Bengal and the South China Sea to the Yangtze River Basin. A strong South Asia high prevailed at 200 hPa (Fig.2c), and very strong upper-level west jet appeared to the north of the South Asia high, and upper-level east jet to its south. Divergence flow controlled over the Yangtze River Basin and its south region at upper levels. No obvious temperature gradient occurred over the Yangtze River Basin. All systems and their deposition from low levels to upper levels are favorable to the generation of heavy precipitation events in the Meiuy season.

Fig.2. Averaged of the geopotential height (every 20 gpm at 200 hPa, and 10 gpm at 850, 700, and 500 hPa) and temperature (every 2°C) fields at (a) 850 hPa, (b) 700 hPa (c) 500 hPa, and (d) 200 hPa for 21-31 July 1998.

2.3 Overview of the Meiuyu front system

The main front systems for 21-31 July 1998 were characterized by a quasi-stationary Meiuyu front and a dew-point front. The dew-point front is a new moisture front revealed by Gao et al. (2002), the two fronts are two large moisture gradients which take on a southwest-northeast direction at horizontal levels and elongate with height along longitude-height cross section. In Fig.3, two clusters of large gradient zones of \( \theta_e \) are separately located to the north and south of 28°N. The northern one corresponds to the Meiuyu front, and the southern one represents the dew-point front, and the two fronts construct a ‘Meiuyu front system’. From
the periphery location of the WPSH marked by 1480-gpm at 850 hPa (in Fig.3a), 3120-gpm at 700 hPa (in Fig.3b), 4440-gpm at 600 hPa (in Fig.3c), 5870-gpm and 5880-gpm at 500 hPa (in Fig.3d), it is very clear that the dew-point front just occurs near the periphery of the WPSH. And the strong southwesterly flow prevails along the dew-point front at 850 hPa (Figs.2a and 3a).

The Meiyu front was located to the north of the shear line with a $\theta_e$ gradient of about 0.03 K km$^{-1}$ (Fig.3), and the dew-point front to the south of the shear line with the gradient of $\theta_e$ about 0.027 K km$^{-1}$. Its intensity is almost as strong as the Meiyu front during this period. Very warm, moist ($\theta_e > 335$ K), and potentially unstable ($\partial \theta_e / \partial p > 0$) air between the Meiyu front and the dew-point front provided a favorable environment for the onset of the heavy precipitation. Between the two fronts, a passageway with a remarkably high specific humidity $q$ extended from the surface to 300 hPa indicated by the dashed line in Fig.4a. A thicker layer with nearly moist netural stratification existed in mid-lower levels of troposphere between the two fronts. Ascending motion prevailed in the passageway, but at low levels, descending motion existed on the dew-point front below 700 hPa (Fig.4b). The descending motion may be related to the descent flows along the periphery of WPSH. Weak descending motion also existed to the northern side of the Meiyu front, the ascending in the passage way and the descending in its sides formed a secondary vertical circulation.

From the aforementioned description of rainfall, synoptic situation and maintenance of the Meiyu front system for 21-31 July 1998, their key features can be summarized as follows: 1) favorable weather pattern for the severe Meiyu precipitation, 2) formation and maintenance of a double front structure generated by the Meiyu front and the dew-point front, and 3) heavy precipitation over the Yangtze River Basin against the southern side of the Meiyu front.

![Fig.3](image-url). Averaged equivalent potential temperature (solid lines every 1 K) and geopotential height (dashed lines every 10-gpm) at (a) 850 hPa, (b) 700 hPa, (c) 600 hPa, and (d) 500 hPa for 21-31 July 1998.
3. Features of the stream function and potential function of water vapor transport

For the one of main characteristics of the Meiyu front system is the large gradients of the water vapor, therefore, to analyze the water vapor transport is meaningful for understanding the mechanism of their formation and maintenance. Because the stream function and nondivergent component mode of the water vapor transport can describe most of the atmospheric water vapor transport, and potential function and divergent modes of the water vapor transport can answer for the local maintenance of the high water vapor content (Chen, 1985), in this section, the stream function and potential function of water vapor transport, and its nondivergent (rotational) and divergent (irrotational) components are analyzed. The equations are as follows

$$Q = k \wedge \nabla \psi - \nabla \chi = Q_\psi + Q_\chi,$$  \hspace{1cm} (1)

Rosen et al. (1979) and Salstein (1980) used $\psi$ and $\chi$ to represent the water vapor transport, which can be obtained from

$$\nabla^2 \psi = k \cdot \nabla \times Q_\psi,$$

$$-\nabla^2 \chi = \nabla \cdot Q_\chi.$$

(2)

Figure 5a shows that three centers of stream function of water vapor transport are located at the Indian Ocean, the Pacific Ocean and the Atlantic Ocean. Water vapor from the Indian Ocean, the Bay of Bengal, the South China Sea and the Pacific Ocean transports the moisture to continental China, which is consistent with previous studies. Distribution of the potential and divergent components of water vapor transport manifests that eastern China and the East China Sea are the strong moisture sink (negative potential function of moisture transport) over the globe for 21-31 July 1998 (Fig.5b). Strong moisture source (positive potential function of moisture transport) is mainly located at three Oceans. The minimum potential region (maximum convergent region) of water vapor transport vector consists with the passageway of the Meiyu front system and corresponds to intense heavy rainfall region. The water vapor convergence of the heavy rain region is supplied by the hemispheric scale water vapor transport.

4. Water vapor budget and transport over the Meiyu front system

In order to explain the formation and maintenance of the Meiyu front system, it is necessary to analyze water vapor budget associated with them. Here, three regions are selected to analyze water vapor budget corresponding to the Meiyu front system. Region
1 is 20°-25°N and 105°-121°E, mainly the region of the dew-point front; Region 2 is 20°-25°N and 105°-121°E, mainly the region of the passageway of the Meiyu front system; and Region 3 is 30°-35°N and 105°-121°E, mainly the region of the Meiyu front. The water vapor budget comes from the following equation

\[ P - E_s = \frac{1}{\sigma g} \int_{p_s}^{p_f} \int d\sigma \left( \nabla \cdot \mathbf{qv} + \frac{\partial \mathbf{wq}}{\partial p} \right) d\sigma d\sigma \tag{3} \]

where \( P \) is precipitation amount, \( E_s \) is evaporation, \( \sigma \) is total areas of the selected region, \( g \) is the gravity acceleration, \( p_s \) is the surface pressure and \( p_f \) the pressure at the top, defined as 1000 and 100 hPa, respectively. \( \frac{\partial \mathbf{q}}{\partial t} \) is the local change of the water vapor budget, \( \nabla \cdot \mathbf{qv} \) is horizontal divergence, and \( \frac{\partial \mathbf{wq}}{\partial p} \) is the vertical transport of the water vapor. The three terms in the right of Eq.(3) are the key terms in following discussions. Horizontal divergence term \( \nabla \cdot \mathbf{qv} \) can be expanded into

\[
\nabla \cdot \mathbf{qv} = \frac{1}{\sigma g} \int \nu_\sigma \mathbf{q} d\sigma = \frac{1}{\sigma g} \sum_{i=1}^{m} -\nu_i \bar{q}_i \Delta s_i \\
+ \sum_{j=1}^{n} \bar{u}_j \bar{q}_j \Delta l_e + \sum_{i=1}^{m} \bar{v}_i \bar{q}_i \Delta l_n \\
+ \sum_{j=1}^{n} -\bar{v}_j \bar{q}_j \Delta l_w), \tag{4}
\]

the four terms in the right of Eq.(4) represent water vapor transport from the different boundary of selected regions. \( \nu_\sigma \mathbf{q} \) is the normal component of the boundary, \( m \) and \( n \) are grid numbers in selected regions along zonal and meridional directions, respectively. '-' represents the averaged value in each spatial step length. \( \Delta l_s \), \( \Delta l_e \), \( \Delta l_n \), and \( \Delta l_w \) are grid spacings of each boundary.

Atmospheric water vapor budget for 21-31 July 1998 (Table 1) indicates that the local change of the water vapor is much weaker than the other terms and can be neglected. The divergence term and the vertical transport term play important roles in the moisture transport, the vertical transport term always transfers water vapor from low levels to upper levels, and large moisture convergence mainly occurs at low levels.

For Region 1 (mainly corresponding to the dew-point front), the integrated moisture from 1000 to 100 hPa is almost convergent. The convergent center of water vapor is located between 850-900 hPa and 500 hPa. The vertical transport term uplifts water vapor from 800 hPa to high levels, but below 800 hPa, namely, from 950 to 800 hPa, positive values of vertical water vapor appear and it may be related to the descending motion near the dew-point front.

For Region 2 (mainly corresponding to the passageway of the Meiyu front system), water vapor is convergent below 650 hPa, and vertical transport term

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<tr>
<th>Table 1. Water budget (in 10^7 kg s^-1) for Regions 1 (20°-25°N), 2 (25°-30°N), and 3 (30°-35°N) averaged for 21-31 July 1998</th>
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Fig. 5. Stream function (a, solid line in every 100 kg s\(^{-1}\)) and nondivergent component (vector arrows in a, kg m\(^{-1}\) s\(^{-1}\)), potential function (b, solid line in every 50 kg s\(^{-1}\)) and divergent component (vector arrows in b, kg m\(^{-1}\) s\(^{-1}\)) of the water vapor transport averaged for 21-31 July 1998.

is negative below 700 hPa and positive above 700 hPa, which means ascending motion transports water vapor from low levels to upper levels.

For Region 3 (mainly corresponding to the Meiyu front), water vapor is inflow between levels 1000-850 hPa and 700-500 hPa, and outflow between 800-700 hPa, and two convergent centers are located at 975 and 650 hPa, respectively. The vertical term still transports the moisture from low levels (1000-800 hPa) to mid-upper levels (700-200 hPa).

The water vapor budget indicates that moisture comes mainly from the convergence of the water vapor transport in the mid-lower atmosphere. The vertical advection of the water vapor transports the moisture from low levels to the mid-upper levels and increases moisture content at upper layers. The horizontal transport and vertical uplifting of the water vapor provide a necessary condition for the cumulus development and latent heat release.

The detailed analysis of water vapor transport and budget at each constant-pressure surface for the selected three regions (Table 1) shows that the water
vapor transport is concentrated to the south of the Yangtze River Basin, namely, on the dew-point front and the passageway. Generally, the water vapor enters the three regions from the western and southern boundaries and outflows from northern and eastern boundary. Water vapor entering Region 1 from the southern boundary is 39.6 (in $10^7$ kg s$^{-1}$, the same hereinafter), and 11.99 from the western boundary, and outflow from eastern boundary is 12.73, and 43.58 from the northern boundary, the total water vapor budget is negative for Region 1, and the water vapor from the northern boundary of Region 1 enters Region 2. Similar to that of Region 1, water vapor originated mainly from the southern and western boundaries, and the total water budget is positive in Region 2. Water vapor transport in Region 3 is less than that of Regions 1 and 2, and the largest transport at southern boundary is 10.68. Region 3 can obtain water vapor from the northern boundary (5.71), which is different from that of Regions 1 and 2. The total water vapor budget of Region 3 is less than that of Regions 1 and 2, which indicates that the water vapor transport is mainly concentrated to the south of the Yangtze River Basin. The positive net budget of water vapor in the passageway indicates that the large convergent center of water vapor is located in this region during the analyzing period in this paper.

For the total water vapor budget of three regions, the water vapor flux from southern boundary is more significant than that from west. The moisture transport is concentrated at low levels, and enters the passageway after crossing the dew-point front from southern and western boundaries. The continuous convergence of water vapor in the passageway favors the formation of moisture gradients in its northern and southern sides, namely, favorable to the formation of the Meiyu front and the dew-point front.

5. The physical processes of the water vapor transport leading to the Meiyu front system

Both Meiyu front and dew-point front are moisture fronts, and their predominant feature takes on moisture contrast. Formation of the Meiyu front system should be related to water vapor transport in the Meiyu period. The favorable large-scale water vapor flux to the occurrence of the Meiyu front systems is discussed in the present section, which is used to explain the possible physical processes resulting in the Meiyu front system.

The features of moisture transport can be shown by the moisture transport $\frac{1}{\rho c} \int_{1000}^{100} \nu \varphi d\sigma$ averaged for 21-31 July 1998, and are presented in Fig.6. The prevailing water vapor fluxes in this period are characterized by three sources: (1) the cross-equatorial jet at Somali, which passes through the Indian Ocean and the Bay of Bengal, then is divided into two branches, one branch turns to southwesterly flow and enters the southern continental China, the other continues to take westerly flow and enters the South China Sea; (2) the cross-equatorial flow from the Australian high, takes southerly, and meets with the flow coming from the Bay of Bengal at the South China Sea; and (3) the flow associated with the WPSH passes through west periphery of the WPSH, and reaches to southern continental China. The three flows are the major flows related with the Meiyu rainfall.

The water vapor transport related directly to the Meiyu front system is characterized by the southwest and southerly moisture transports within $20^\circ$-30$^\circ$N and $105^\circ$-120$^\circ$E (Fig.6), and these water vapor transports are related to the three water vapor sources mentioned above. The westerly and easterly moisture fluxes along the northwestern periphery of the WPSH meet with each other over China and turn to the southwesterly moisture, and the convergence of these two fluxes results in a very strong low-level southwesterly moisture transport over the dew-point front and enters the passageway.

From the cross section of the water vapor flux, the water vapor transport concentrates mainly at low levels (Fig.7a), and the water vapor is transported by the horizontal wind from the Indian Ocean, the Bay of Bengal, the South China Sea, and the Pacific Ocean. Based on the convergence of the large-scale water vapor, the ascent motion in the passageway can uplift the water vapor from low levels to upper levels.
between 27°N and 32°N (Fig. 7b). In the region adjacent to the dew-point front at low levels, negative water vapor flux appears, which is due to the descent motion near this region (see Fig. 4b). The results agree with those in Table 1.

6. Summary

The water vapor transport over the continental China for 21-31 July 1998 is studied by utilizing the daily 1° × 1° data from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) and observational data of 24-h rainfall recorded by meteorological stations in China. The results clearly indicate that the dew-point front, which is located near the periphery of the West Pacific subtropical high (WPSH) and marked also by a large horizontal moisture gradient in the mid-lower troposphere, is similar to the Meiyu front. The

Fig. 6. Maps of the averaged moisture transport for 21-31 July 1998. A vector barb indicated the moisture transport of 8×10^{-7} \text{ kg s}^{-1}.

Fig. 7. Cross section of |qυ| (solid lines every 0.02 kg s^{-1} m^{-1} hPa^{-1}) and θe (long-dashed lines every 1 K) in (a), and |qυ| (solid and dashed lines every 0.003 kg s^{-1} m^{-1} hPa^{-1}) and θe (long-dashed lines every 2 K) in (b) along 115°E averaged for 21-31 July 1998.
two fronts form a predominant double front structure.

Largescale weather systems and their deposition from low to upper levels are favorable to heavy precipitation events in the second Meiyu season for 21-31 July 1998, and the precipitation is characterized by a narrow intense rainfall zone against the southern side of the Meiyu front. Water vapor transport mainly comes from the Indian Ocean and the Pacific. The convergent centre is located in the passageway of the Meiyu front system. This regional heavy precipitation is also supplied by the hemispheric scale water vapor transport.

The water vapor transport and budget over three domains in central and eastern China, expressed by the main location of the dew-point front, the passageway of the Meiyu front system, and the Meiyu front over China, respectively, bounded by 20°-25°N, 25°-30°N, and 30°-35°N, and 105°-121°E, indicate that the southwesterly and southerly moisture inflows cross the dew-point front and then enter the passageway of the Meiyu front. The water vapor is mainly converged at mid-lower levels, and is uplifted from low to upper levels through convective transport. The double front structure of the Meiyu front is associated with large convergence of water vapor and its uplifting in the passageway.

The water vapor transport related to the Meiyu front system in this paper is still simple. The formation of the dew-point front should be related to other factors besides physical processes of the large-scale water vapor transport and convergence. Relations of the dew-point front with the Meiyu front, and interactions between the Meiyu front system and the low-level jet, also need to be analyzed deeply. All these still are hot topics for the further study.

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