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by

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STUDY OF DYNAMIC CHARACTERISTICS OF A MONSOON CIRCULATION TUBE

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Abstract

In China with a prevailing summer monsoon, there is often on mainland China a shear line with east-to-west trend, or a quasistationary rainfall belt on the northern side of a subtropical high pressure. There is ascending movement along the rainfall belt; however, there is a subtropical high ridge line with east-to-west trend to the south of the shear line or the quasistationary front rain belt. Between the shear line and ridge line, there is a meridian circulation system with ascending movement in the north and descending movement in the south. The structure of this (more than 1000 kilometers long, in an east-to-west direction) secondary vertical circulation system is like a tube with east-to-west trend. In this article, the tubular secondary meridionally vertical circulation system (along the east-to-west trend shear line or quasistationary front cloud and rain belt) in summer on mainland China is called the monsoon circulation tube. Its characteristics reveal the configuration relationship and mutual correlation of easterly and westerly air

currents, as well as subtropical high systems in the East Asia monsoon zone.

The article discusses the correlating relationship of the structure characteristics and nonadiabatic factor of the secondary meridionally vertical circulation system mentioned above, plateau topography and planetary scale circulation system, thus revealing the physical mechanisms of formation and maintenance of the monsoon circulation tube.

I. Dynamic System of Secondary Meridionally Vertical Circulation System

To study the secondary meridian circulation dynamic system, the article presents vorticity equations with x and y components, describes the vortex feature rotating around the horizontal axis, and discusses factors affecting the above-mentioned secondary meridian circulation dynamic system.

$$\frac{\partial \eta}{\partial t}+u\frac{\partial \eta}{\partial x}+v\frac{\partial \eta}{\partial y}+w\frac{\partial \eta}{\partial z}=\frac{1}{\rho^2}\left(\frac{\partial p}{\partial x}\frac{\partial \rho}{\partial z}-\frac{\partial p}{\partial z}\frac{\partial \rho}{\partial x}\right)+f\frac{\partial v}{\partial z}+\zeta\frac{\partial v}{\partial z}+\xi\frac{\partial v}{\partial x}-\tilde{f}\left(\frac{\partial w}{\partial z}+\frac{\partial u}{\partial x}\right)$$
$$-\eta\left(\frac{\partial w}{\partial z}+\frac{\partial u}{\partial x}\right) \qquad (1)$$

$$\frac{\partial \xi}{\partial t}+u\frac{\partial \xi}{\partial x}+v\frac{\partial \xi}{\partial y}+w\frac{\partial \xi}{\partial z}=\frac{1}{\rho^2}\left(\frac{\partial p}{\partial z}\frac{\partial \rho}{\partial y}-\frac{\partial p}{\partial y}\frac{\partial \rho}{\partial z}\right)+f\frac{\partial u}{\partial z}+\tilde{f}\frac{\partial u}{\partial y}+u\frac{\partial \tilde{f}}{\partial y}+\eta\frac{\partial u}{\partial y}-\zeta\frac{\partial u}{\partial z}$$
$$-\xi\left(\frac{\partial w}{\partial z}+\frac{\partial v}{\partial y}\right) \qquad (2)$$

In the equations, $\zeta=\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}$, $\eta=\frac{\partial u}{\partial z}-\frac{\partial w}{\partial x}$, $\xi=\frac{\partial w}{\partial y}-\frac{\partial v}{\partial z}$, $f=2\Omega\sin\varphi$, $\tilde{f}=2\Omega\cos\varphi$.

By using an equation of state, the dynamic tube terms in Eq. (1) and (2) are transformed; in addition, consideration is given to excitation on this secondary meridionally vertical circulation system with monsoon circulation background. After analysis of an order of magnitude, the first order of Eq. (2) and (3) is simplified into linearization; by introducing the dynamic and thermal fundamental fields (if the advection term is ignored for the time being), the equations can be written as

$$\frac{\partial\eta'}{\partial t}=\left(B'_y+f\frac{\partial v'}{\partial z}\right)+\zeta'\frac{\partial\bar{v}}{\partial z}+\bar{\zeta}\frac{\partial v'}{\partial z}+\xi'\frac{\partial\bar{v}}{\partial x}+\bar{\xi}\frac{\partial v'}{\partial x}-$$
$$\eta'\left(\frac{\partial\bar{w}}{\partial z}+\frac{\partial\bar{u}}{\partial x}\right)-\bar{\eta}\left(\frac{\partial w'}{\partial z}+\frac{\partial u'}{\partial x}\right) \tag{4}$$

$$\frac{\partial\xi'}{\partial t}=\left(B'_x+f\frac{\partial u'}{\partial z}\right)+\zeta'\frac{\partial\bar{u}}{\partial z}+\bar{\zeta}\frac{\partial u'}{\partial z}+\eta'\frac{\partial\bar{u}}{\partial y}+\bar{\eta}\frac{\partial u'}{\partial y}$$
$$-\xi'\left(\frac{\partial\bar{w}}{\partial z}+\frac{\partial\bar{v}}{\partial y}\right)-\bar{\xi}\left(\frac{\partial w'}{\partial z}+\frac{\partial v'}{\partial y}\right) \tag{5}$$

In the equations

$$\begin{pmatrix} B'_x \\ B'_y \end{pmatrix}=\begin{pmatrix} \frac{R}{\bar{p}}\left(\frac{\partial T'}{\partial z}\frac{\partial\bar{p}}{\partial y}-\frac{\partial T'}{\partial y}\frac{\partial\bar{p}}{\partial z}+\frac{\partial\bar{T}}{\partial z}\frac{\partial p'}{\partial y}-\frac{\partial\bar{T}}{\partial y}\frac{\partial p'}{\partial z}\right) \\ \frac{R}{\bar{p}}\left(\frac{\partial T'}{\partial x}\frac{\partial\bar{p}}{\partial z}-\frac{\partial T'}{\partial z}\frac{\partial\bar{p}}{\partial x}+\frac{\partial\bar{T}}{\partial x}\frac{\partial p'}{\partial z}-\frac{\partial\bar{T}}{\partial z}\frac{\partial p'}{\partial x}\right) \end{pmatrix} \tag{6}$$

II. Numerical Analysis and Diagnosis

Fig. 1 a and b indicate the positions and intensity variations of the secondary meridian circulation as vertical profile diagrams at 115°E on 7 and 8 July 1982. Both figures reveal that the vertical circulation system tended to move northward with development toward intermediate and low layers from the high layer.

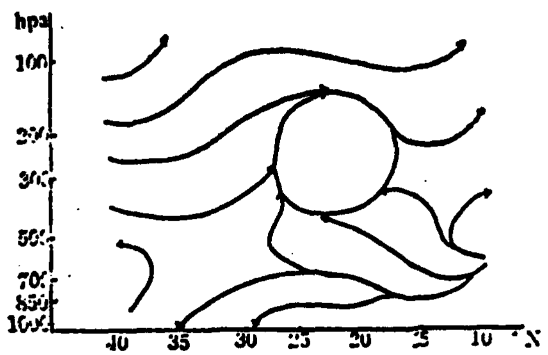

Fig. 1 a Positions of Secondary Meridian Circulation System on a Vertical Profile Diagram at 115°E at 20.00 Hours on 7 July 1982

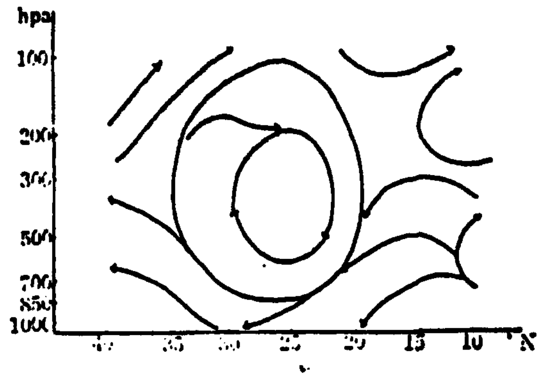

Fig. 1 b Positions of Secondary Meridian Circulation System on a Vertical Profile Diagram at 115°E at 20.00 Hours on 8 July 1982

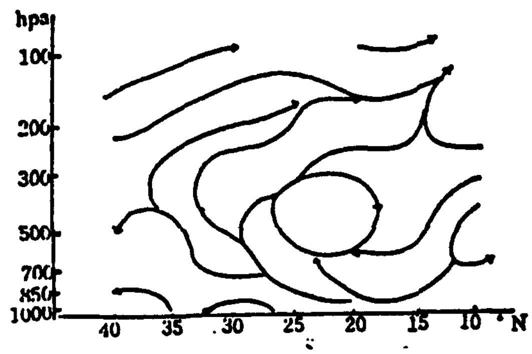

Fig. 1 c Positions of Secondary Meridian Circulation System on a Vertical Profile Diagram at 120°E at 20.00 Hours on 8 July 1982

Fig. 1 c shows a profile diagram of the vertical section of 120°E on 8 July. From Fig. 1 b and c, we know that the secondary meridionally vertical circulation system (situated at 25°N corresponding to a rain belt in the vicinity of 500 hPa altitude) constituted a nearly east-to-west direction tube system; the corresponding cloud and rain belt was situated over the middle and lower reaches of the Yangtze River. Worthy of particular attention were the heavy rains over the middle and lower reaches of the Yangtze River due to intensification of the secondary meridian circulation system in the middle and lower layers of the troposphere with subsequently apparent development of a corresponding rain belt, which was also along the east-to-west direction. This indicates the correlating feature between the secondary meridionally vertical circulation system and the rain belt.

In this article, data on 7 July 1982 were used by utilizing the transformed orginal equation and the time variation rate $\left(\frac{\partial}{\partial t}\frac{\partial v}{\partial p}\right)$ of the meridian wind vertical shear line. As revealed in numerical computation, the distribution feature of the $\frac{\partial}{\partial t}\frac{\partial v}{\partial p}$ field is correlated with the position and intensity of the vertical circulation system on the next day. As shown in Fig. 2 a and b, the high-value region of $\frac{\partial}{\partial t}\frac{\partial v}{\partial p}$ corresponds to the real situation of the secondary vertical circulation system on the next day. This result can lead to the following: by adopting the transformed original equation or the vorticity equation of x and y components, computation of the time variation rate can be used to predict displacement and development of the monsoon circulation tube, thus forecasting the future variation of the monsoon rain belt and rainfall intensity in order to establish a new forecasting tool or to study the method of the dynamic mechanism of monsoon rain belt.

According to numerical analysis in the article, various contributions to time variation rates for calculating the meridionally wind vertical shear line are listed in Table 1.

III. Nongeostrophic Baroclinic Tube and Nonadiabatic Enforcement Effect

From Table 1 in the last section, the baroclinic term and vertical shear term of a wind field are the two major terms of

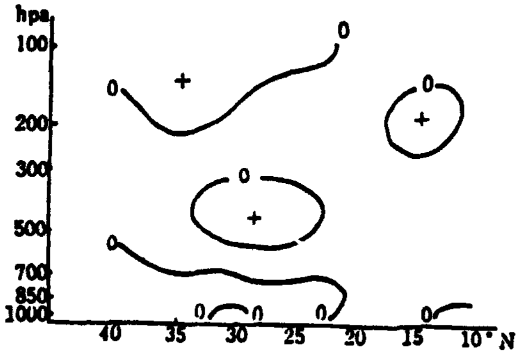

Fig. 2 a Characteristic Amounts of Time Variation Rate on a Vertical Profile $\frac{\partial}{\partial t}\left(\frac{\partial v}{\partial p}\right)$ at 115°E at 20.00 Hours on 8 July 1982

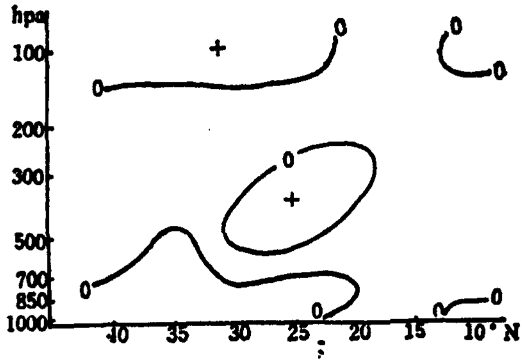

Fig. 2 b Characteristic Amounts of Time Variation Rate on a Vertical Profile $\frac{\partial}{\partial t}\left(\frac{\partial v}{\partial p}\right)$ at 120°E at 20.00 Hours on 8 July 1982

the x direction vorticity equation; these two are unbalanced. Values of other terms are lower than these two terms by about one order of magnitude. This numerical analysis conclusion is consistent with scale analysis. With respect to the excitation process and the unbalanced feature of the latitude-direction and longitude-direction vertical circulation, the following equation can be derived from Eq. (4) and (5).

Table 1 Meridian Distribution of Various Contributions of 500 hPa Terms in $\frac{\partial}{\partial t}\left(\frac{\partial v}{\partial p}\right)$ Equation

各项 a / 数值 b / 纬度 c	$\frac{R}{P}\frac{\partial T}{\partial y}$	$-f\frac{\partial u}{\partial p}$	$-\frac{\partial u}{\partial p}\frac{\partial v}{\partial x}$	$-u\frac{\partial}{\partial x}\left(\frac{\partial v}{\partial p}\right)$	$-\frac{\partial v}{\partial p}\frac{\partial u}{\partial y}$
40	−1.1	1.4	0.0	0.0	−2.2
35	−7.4	5.1	−0.5	0.2	0.3
30	−5.1	11.5	−0.7	1.4	1.7
25	3.4	5.1	0.1	0.3	0.8
20	13.4	−17.8	−1.1	−0.7	−0.0
15	14.9	−23.5	−2.1	−0.2	0.1
10	8.0	−21.8	0.0	0.0	−0.1

各项 a / 数值 b / 纬度 c	$-v\frac{\partial}{\partial y}\left(\frac{\partial v}{\partial p}\right)$	$\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)\frac{\partial v}{\partial p}$	$-w\frac{\partial^2 v}{\partial p^2}$	$\frac{\partial}{\partial t}\left(\frac{\partial v}{\partial p}\right)$
40	0.5	2.2	0.2	0.9
35	−0.2	−0.2	0.2	−2.5
30	0.5	−0.3	−0.5	8.5
25	−0.6	−0.9	0.0	8.4
20	−0.4	−0.1	−0.0	−6.8
15	−0.0	0.0	0.0	−10.7
10	−0.1	0.1	−0.0	−13.9

Key: a - terms b - value c - latitude

$$\begin{pmatrix} \frac{\partial \eta'}{\partial t} \\ \frac{\partial \xi'}{\partial t} \end{pmatrix} = \begin{pmatrix} B'_y \\ B'_z \end{pmatrix} + f \begin{pmatrix} \frac{\partial v'}{\partial z} \\ \frac{\partial u'}{\partial z} \end{pmatrix} \tag{7}$$

Since atmospheric pressure has the most intense baroclinic feature at y-z plane, the effect of B'_z is relatively high in the above-mentioned baroclinic vector component, capable of exciting a circulation system on the y-z vertical plane due to the unbalanced $-f\frac{\partial u'}{\partial z}$ term. In particular, with regard to the edge at the northern side of the subtropical high, the gradient feature of the temperature field and the atmospheric pressure field can possibly induce belt distribution of the B'_z term. Thus, distribution of the meridionally vertical circulation· circle is like a tubular structure.

From vorticity equations (5), (6) and (7) of the x component, we can derive

$$\frac{\partial \xi'}{\partial t} \propto \frac{R}{\bar{p}}\left(\frac{\partial T'}{\partial z}\frac{\partial \bar{p}}{\partial y} - \frac{\partial T'}{\partial y}\frac{\partial \bar{p}}{\partial z} + \frac{\partial \bar{T}}{\partial z}\frac{\partial p'}{\partial y} - \frac{\partial \bar{T}}{\partial y}\frac{\partial p'}{\partial z}\right) \qquad (8)$$

After summer arrives, temperature in mainland China rapidly rises. The ascending branch of the monsoon circulation tube occurs in the shear line zone north of the subtropical high pressure; the descending branch occurs in the vicinity of the subtropical high ridge line. With regard to the westerly average situation, $\frac{\partial \bar{p}}{\partial y}<0$, for average atmospheric configuration and meridian distribution of temperature, $\frac{\partial \bar{T}}{\partial z}<0, \frac{\partial \bar{T}}{\partial y}<0$, and $\frac{\partial \bar{p}}{\partial z}<0$. Let us consider the existence of temperature and pressure background of warm, moist air flow and relatively high gradient of the atmospheric pressure in low altitudes, that is $\frac{\partial T'}{\partial z}<0$ $\frac{\partial T'}{\partial y}>0$, and $\frac{\partial p'}{\partial y}<0$ $\frac{\partial p'}{\partial z}<0$.

From the above-mentioned conditions, with regard to positive and negative signs in various terms on the right side of Eq. (8), we can discover that weather scale meridian-direction circulation can be abruptly changed at an instant in the zone controlled by warm, moist air flow at the edge in the north of the subtropical high. In addition, along the fringe of the subtropical high, a tubular system is constituted, $\frac{\partial \xi'}{\partial t}>0$.

This manifests the maintenance and intensification of monsoon circulation tube, having a correlation with the planetary scale circulation background of the East Asia monsoon zone. If the subtropical high moves northward, the circulation tube (constituted by the secondary meridionally vertical circulation system) also moves northward.

As pointed out by Zhang Jijia et al. [3], at the beginning of the rainy season in north China, the monsoon circulation tube protrudes northward, forming an important feature of variation for the monsoon circulation tube, as shown in Fig. 3.

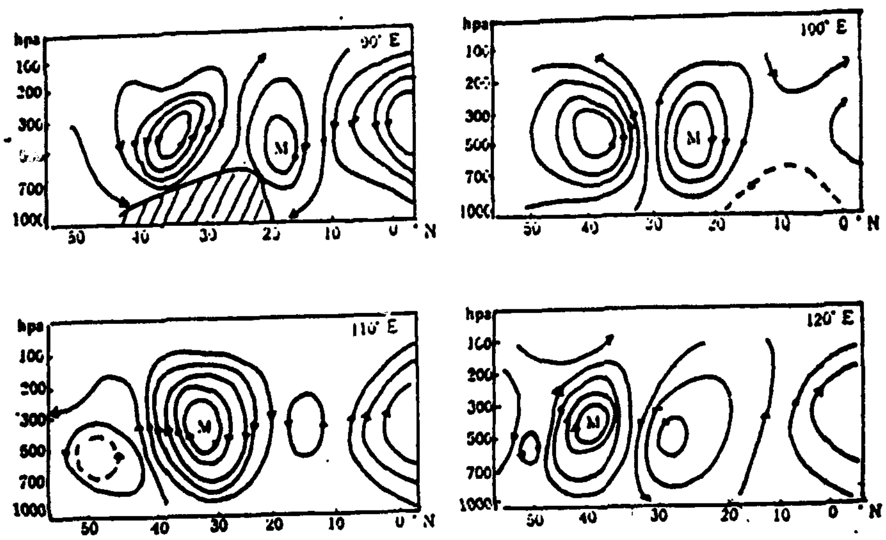

Fig. 3 Monsoon Circulation Circles on Profiles of Various Meridian Circles in 90°-120°E) on 26 July 1979
(M indicates monsoon circulation circles.)

Besides, the secondary meridionally vertical circulation system has its circulation tube transformed; the break-up and splitting of the tube are frequently correlated with the eastward movement of the westerly trough and transformation of the subtropical high. The southward movement of a cold air mass behind the westerly trough induces the formation or disappearing phenomenon in a certain segment of the shear line and quasistationary front in the northern edge of the subtropical high. In other words, in a certain segment of the circulation tube, $\frac{\partial p'}{\partial y}>0$ and $\frac{\partial T'}{\partial y} < 0$. From Eq. (8), $\frac{\partial \xi'}{\partial t}<0$ is deduced; reverse rotation occurs along the direction of vertical circulation. This segment of the circulation tube breaks up. If the westerly trough moves eastward into the sea, the air flow (from southwest) and shear line in the north of subtropical high are again active; the secondary vertical circulation system again intensifies, maintaining a circulation tube along the east-to-west trend.

The nonadiabatic enforcement factor also has an important function in formation and maintenance of the vertical circulation mentioned above. Fig. 4 a and b indicate, respectively, the vertical distribution outlines of Q_1 (other nonadiabatic heating besides radiation heating), Q_2 (heating source caused by net gain of water vapor) and ω in the ascending branch and descending branch of secondary circulation of the 120° E vertical profile plane. Fig. 4 reveals the nonadiabatic Q_2 and Q_1 distribution features in secondary meridionally vertical circulation. Heating is mainly in the layers below 500 hPa; summation of Q_2 and Q_1 is very small or even a negative value. This type of nonadiabatic heating configuration may induce $\frac{\partial T'}{\partial y}>0$ and $\frac{\partial T'}{\partial z}<0$ in the zone in the northern fringe of the subtropical high. Here, T' indicates the disturbance portion of the temperature field caused by nonadiabatic heating. By applying the mean conditions of the atmospheric pressure field and this type of heating effect, in other words, $\frac{\partial \bar{p}}{\partial y}<0$, and $\frac{\partial \bar{p}}{\partial z}<0$, we know from Eq. (8), that these conditions are beneficial to intensification of the rain belt and the secondary meridionally vertical circulation system in the northern edge of the subtropical high, that is, $\frac{\partial \xi'}{\partial t}>0$. Intensification of the circulation tube (mentioned above) in the north of the subtropical high also induces intensification of rainfall in the monsoon rain belt. As mentioned above, the feedback mechanism of condensation heating, and evolution of the secondary meridian circulation circle are similar to the CISK mechanism.

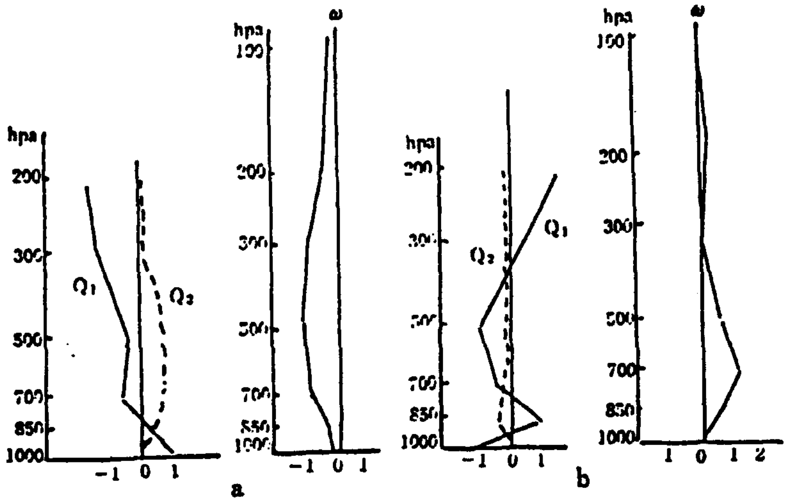

Fig. 4 Vertical Distribution Outlines of Q_1, Q_2 and ω in an Ascending Branch (a) and Descending Branch (b) at 20.00 Hours on 24 June 1979
(Unit for Q_1 and Q_2 is 4186.8×10^{-7} Jg^{-1} s^{-1}; unit for ω is 10^{-3} hPa s^{-1})

IV. Configuration Correlation Between the Secondary Meridian Circulation System and the Prevailing Wind Belt

After summer arrives, the westerly belt moves northward. In southern Asia, an intense tropical easterly exists in the troposphere. Beneath it, there are the prevailing summer winds (southwesterly and southeasterly monsoon). From Fig. 5, the meridionally vertical circulation system is situated in the lower reaches of westerly and easterly air currents, slightly toward the place between the high layer of easterly air currents and the low layer westerly (or southwesterly).

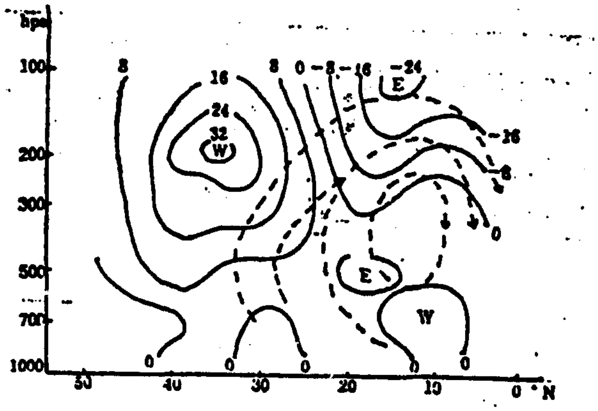

Fig. 5 Vertical Profile Plane of Latitudinal Direction Winds Along 100° E on 20.00 Hours on 27 June 1979
(Solid curves indicate isopleths for wind velocity; dotted curves indicate streamlines of monsoon circulation tube along profile of 100° E)

From Eq. (5), the relationship between the dynamic factor of the large scale flow field background (formed by the circulation tube) and vertical circulation can be expressed in an equation.

$$\frac{\partial \xi'}{\partial t} \propto \frac{\partial v'}{\partial x}\frac{\partial \bar{u}}{\partial z} - \frac{\partial w'}{\partial x}\frac{\partial \bar{u}}{\partial y} \qquad (9)$$

Based on the distribution characteristics of the wind field shown in Fig. 5, the secondary meridian circulation system is situated in a region where the shear of the fundamental air flow meets the conditions of $\frac{\partial \bar{u}}{\partial y}>0$ and $\frac{\partial \bar{u}}{\partial z}<0$. However, in the southwesterly air flow region in the northwest of the subtropical high, conditions of $\frac{\partial v'}{\partial x}<0$ and $\frac{\partial w'}{\partial x}<0$ may exist. These conditions are beneficial to intensification of the secondary meridian circulation, $\frac{\partial \xi'}{\partial t}>0$.

From those mentioned above, we know that the formation and maintenance of a monsoon tube are related to background conditions of a planetary scale flow field. In other words, there is a close relationship between the distribution characteristics and configuration correlation of main members (prevailing wind belt and subtropical high, among other systems) of the Asian monsoon.

V. Geodetic Relief Factor for Formation of Secondary Meridionally Vertical Circulation System

As revealed in the facts observed, establishment of an east-to-west direction circulation tube is closely related to summer temperature rise on the East Asia continent. In particular, the temperature rise of the Qinghai-Tibet Plateau greatly influences the formation of a circulation tube. In summer, a great rise in temperature occurs on continents; oftentimes, the continent temperature is higher than the ocean to its south. If the two stations of Lhasa and Qamdo are chosen for their mean temperatures of March through June to represent thermodynamic conditions on the plateau, we can discover that in spring and early summer, the plateau temperature is a positive value over the mean, the southwest monsoon erupts early, and the meridionally vertical circulation is intense. If the reverse occurs, vertical circulation is weak. The correlating facts mentioned above can also be explained from Eq. (8): the plateau heating condition may lead to temperature disturbance in the northwestern edge region of the East Asia subtropical high; that is $\frac{\partial T'}{\partial y}>0$ and $\frac{\partial T'}{\partial z}<0$ (T' is the temperature variation portion of nonadiabatic heating). When this type of heating condition is imposed with the mean state of atmospheric pressure field, that is $\frac{\partial \bar{p}}{\partial y}<0$ and $\frac{\partial \bar{p}}{\partial z}<0$, from Eq. (8) we know a vertical circulation system of abruptly changing weather scale will occur, that is $\frac{\partial \xi'}{\partial t}>0$. This reveals the influence of plateau thermodynamic conditions on formation of a monsoon circulation tube.

As pointed out by references [1] and [6], in the profile of 30°N and 35°N latitude circles where the Qinghai-Tibet Plateau is situated, a latitude-direction vortex and its eastward movement in the east of the plateau are an important phenomenon in the summer subtropical westerly of East Asia due to the effect of friction with turbulent flows. Fig. 6 shows the phenomenon.

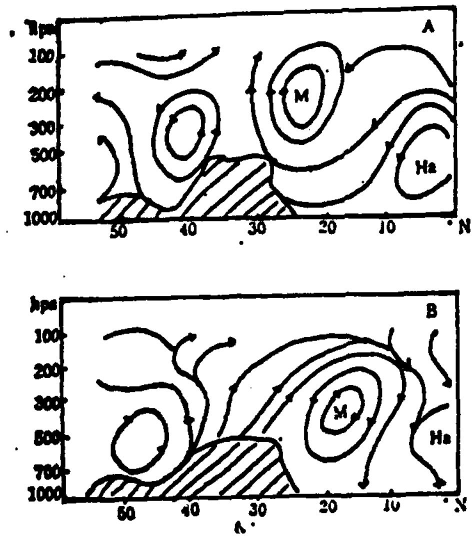

Fig. 6 a Seasonal Variation of Meridian Circulation on Profile of 90°E in Summer 1979

(A indicates 9 June; B indicates 28 June; M indicates monsoon circulation circles; H_2 indicates Hadley circulation circle)

With regard to the plateau heating effect, discussions have been made in the article when dealing with a baroclinic condition. In the following, emphasis is made on analysis of dynamic function of geodetic relief for the plateau. From Eq. (5) and (4), we derive

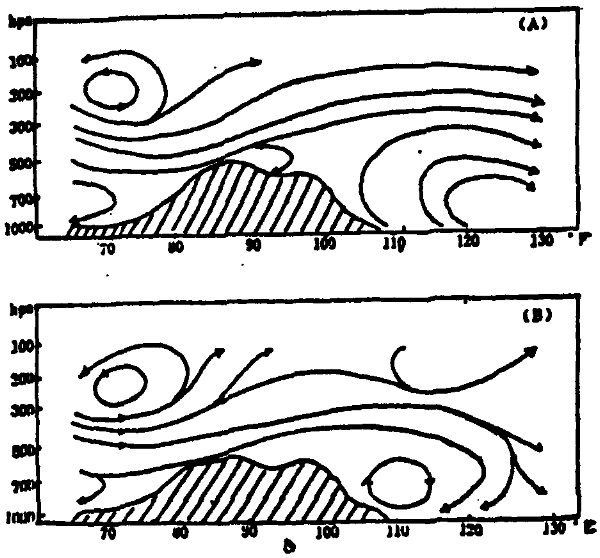

Fig. 6 b Seasonal Variation of Meridian Circulation on Profile of 30°E in Summer 1979

(A indicates five-day average meridian circulation from 26 to 30 June; B indicates the period of 1 to 5 July)

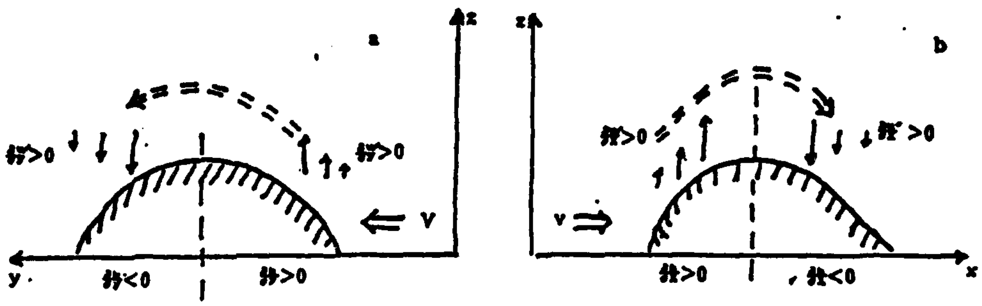

Fig. 7 Distribution Schematic Diagram of Vertical Movement Caused by Geodetic Relief

$$\begin{pmatrix}\frac{\partial\eta'}{\partial t}\\ \frac{\partial\xi'}{\partial t}\end{pmatrix} \propto -\begin{pmatrix}\eta'\frac{\partial\bar{\omega}}{\partial z}\\ \xi'\frac{\partial\bar{\omega}}{\partial z}\end{pmatrix} \qquad (10)$$

Fig. 6 a and b indicate the mutual configuration relationship of meridian circle and latitude circle circulations with geodetic relief. These are situated, respectively, on both sides of south-to-north and east-to-west, forming two pairs of circulation couples with opposite directions. Their common feature is that these circulations occur in a region of relatively intense vertical movement (ascending or descending) near a plateau. Considering the forced ascending (or descending) movement caused by fixed geodetic relief, as well as the correlation between a relief slope and ω, Eq. (10) can be written as

$$\begin{pmatrix} \frac{\partial \eta'}{\partial t} \\ \frac{\partial \xi'}{\partial t} \end{pmatrix} \propto \begin{pmatrix} -\frac{\bar{u}}{\Delta z} \frac{\partial w'}{\partial x} \frac{\partial h}{\partial x} \\ \frac{\bar{v}}{\Delta z} \frac{\partial w'}{\partial y} \frac{\partial h}{\partial y} \end{pmatrix} \tag{11}$$

According to Eq. (11), intensification and weakening of circulation of latitude- and longitude-circles are correlated with factors of altitude of geodetic relief and large scale fundamental air flow, as shown in Fig. 7 a and b: two pairs of a circulation couple. The enforcement effect of distribution features of vertical circulation with respect to plateau relief can be written in the following expression.

$$\text{两对环流偶}\begin{cases} \text{高原}\begin{cases} \text{西侧} & \frac{\partial w'}{\partial x}>0,\ \frac{\partial h}{\partial x}>0\ \text{则}\ \frac{\partial \eta'}{\partial t}<0 \\ \text{东侧} & \frac{\partial w'}{\partial x}>0,\ \frac{\partial h}{\partial x}<0\ \text{则}\ \frac{\partial \eta'}{\partial t}>0 \end{cases} \\ \text{高原}\begin{cases} \text{南侧} & \frac{\partial w'}{\partial y}>0,\ \frac{\partial h}{\partial y}>0\ \text{则}\ \frac{\partial \xi'}{\partial t}>0 \\ \text{北侧} & \frac{\partial w'}{\partial y}>0,\ \frac{\partial h}{\partial y}<0\ \text{则}\ \frac{\partial \xi'}{\partial t}<0 \end{cases} \end{cases} \tag{12}$$

Key: 1 - two pairs of a circulation couple 2 - plateau
3 - western side 4 - eastern side
5 - southern side 6 - northern side 7 - then

We also discover by analyzing the actual data that a convergence feature exists in the flow field at the intake (90°-100°E) of the monsoon circulation tube, and a significant divergence trend exists in the flow field at the exit (140°E) of the monsoon circulation tube. Then Eq.(5) can be written as

$$\frac{\partial \xi'}{\partial t} \propto -\bar{\xi}\left(\frac{\partial w'}{\partial x}+\frac{\partial v'}{\partial y}\right)-\xi'\left(\frac{\partial \bar{w}}{\partial x}+\frac{\partial \bar{v}}{\partial y}\right) \tag{13}$$

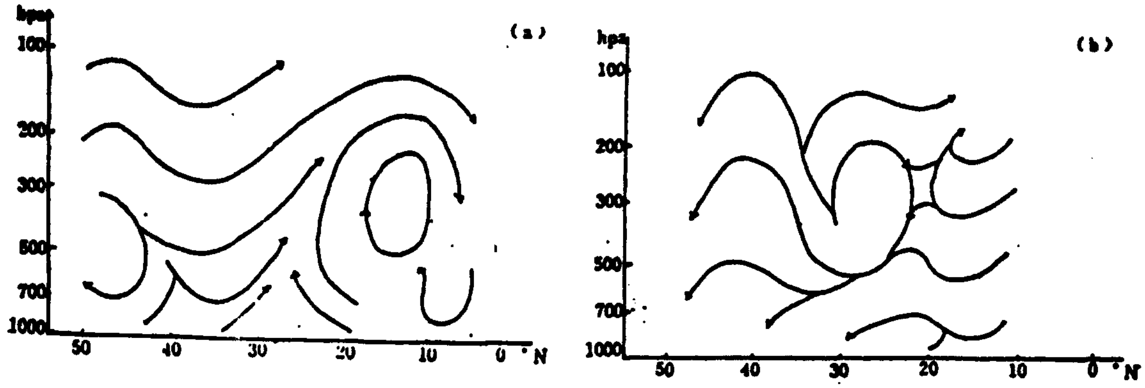

Fig. 8 Vertical Profile Diagram of Cross Sectional Monsoon Circulation Tube at 20.00 Hours on 27 June 1979

(a indicates 100°E; b indicates 140°E)

According to summer climate properties, westerly air currents (in the eastern part of the Qinghai-Tibet Plateau) and airflow (slightly south of the western side of the subtropical high) converge in middle latitudes (90°-100°E). The convergence property of the basic flow field in this region is $\frac{\partial \bar{v}}{\partial y}<0$. In addition, with imposition of the plateau dynamic effect, this will benefit the case, $\frac{\partial \xi'}{\partial t}>0$. That is, tubular circulation is generated in the vicinity of (90°-100°E), and a convergence feature exists at the intake of the circulation tube. Conversely, the effect is just the reverse at the exit of westerly air currents; there is a divergence feature at the exit of the circulation tube. As mentioned above, the convergence and divergence features of a circulation tube are closely related to the environmental features of the basic flow field as shown in Fig. 8.

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