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INTERANNUAL VARIATION CHARACTERISTICS OF EAST HEMISPHERIC CROSS-EQUATORIAL FLOW AND ITS CONCURRENT RELATIONSHIPS WITH TEMPERATURE AND RAINFALL IN CHINA

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Abstract: The NCEP/NCAR global reanalysis data were used to analyze the interannual variation characteristics of the cross-equatorial flow (CEF) and its concurrent relationships with temperature and rainfall in China. The results indicated that CEF changes more in summer than in winter. As the main flow channel in summer, the Somali CEF changes in a way that does not markedly influence the changes in the CEF total except for winter. The summer CEF total has two sudden increases and one sudden decrease during the last century while the winter total has just one decrease. Long-period data show that the correlation between CEF and summer rainfall in China is not very significant, but is different before and after the 1970s, which is due to CEF's close links with the East Asia summer monsoon. Winter CEF's correlation with concurrent winter temperature in northern and southern China varies with the relationship between CEF and sea-level pressure in different areas.

Key words: cross-equatorial flow (CEF); interannual variation characteristics; rainfall; temperature; correlation

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1 INTRODUCTION

Being a channel for the exchange of mass and momentum between the Northern and Southern Hemispheres, the cross-equatorial flow (CEF) is one of the important factors governing the weather and climate abnormality in both of the hemispheres. In a preliminary investigation, Peng et al. used 21-year (from 1979 to 1999) data to investigate into the characteristics of the CEF and its interannual variation, with the finding that significant spatial asymmetry exists in the distribution of global CEF and low-level interannual variation in the Eastern Hemisphere is mainly subjected to Tropospheric Biennial Oscillation (TBO, with periods of 2 – 3 years) and El Niño/Southern Oscillation (ENSO, with periods of 4 – 7 years) [1]. Taking the 1996 and 1999 floods as special cases, Li et al. gave detailed analysis of the links between the CEF and precipitation in China and concluded that the former might be a basis to predict damages inflicted on China by floods [2]. With a study of the effect of summertime CEF on South China Sea monsoons and droughts in eastern China, Shi et al. suggested the association of significantly strong CEF with drought years in the latter area [3]. In accordance with a study of the effect of the interannual variation of CEF and its impacts on the summertime precipitation in northwestern China, Li et al. found that the Somali jet was an important circulation factor responsible for summertime precipitation in the eastern part of northwestern China [4]. In their discussion of the relationships between two Asian CEFs and torrential rains in southern China, Li et al. discovered that meridional disturbance was enhanced around the equator near Somali and the longitude of 105°E [5]. All of the works above have shown that the interannual variation of CEF and its impacts on the climate of China have been much concerned about by meteorologists. In this study, the characteristics of CEF's interannual variation are first analyzed in great detail and then the correlation is discussed and analyzed between wintertime and summertime CEFs and concurrent air temperature and precipitation in China via that between the CEFs and monsoons.

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2 DATA PROCESSING AND METHODS OF ANALYSIS

In this study, monthly mean reanalysis for the 850-hPa wind field from January 1948 to December 2005 are used together with sea surface air pressure from January 1948 to December 1999 in a mesh with intervals of 2.5° long. × 2.5° lat. Monthly data of precipitation and air temperature from 160 weather stations across China covering the period from 1951 to 2001, which are provided by National Climate Center, China Meteorological Administration, are also used. Methods employed in this study are mainly the composite, running mean, running *T*-test, variance analysis and correlation analysis, and all of the involved equations follow Wei [6].

3 ESTABLISHMENT OF CEF CHANNELS

By definition, the CEF is active across the longitudes over the equatorial area (5°S – 5°N) at 850 hPa where multi-year mean meridional wind ≥1.4 m/s. In a way that is similar to Zhao's [7], a 58-year (1948 – 2005) dataset is used to reestablish the location of the channels of CEFs by the magnitude of the 850-hPa meridional wind on the equator.

Fig.1 gives the longitude-dependent variation of the 850-hPa meridional wind averaged over multiple years on the equator in the Eastern Hemisphere in summer (from June to August) and winter (from December to February). The positive values indicate the southerly wind and the negative ones the northerly wind (the same below) and their respective channels are set at the peak and valley of the values.

It is known from Table 1 that there are six channels for the southerly CEF (20°E, 42°E, 87°E, 105°E, 125°E and 147°E) and two channels for weak northerly CEF in summertime.

From the location and flow direction of different CEF channels (figure omitted), the 850-hPa flow field is known for summer and winter at 20°S - 80°N.

4 INTERANNUAL VARIATIONS OF CEF AND ITS ABRUPT CLIMATE CHANGE

The interannual change of the total CEF is studied first in order to understand that of the 850-hPa CEF. In view of the fact that the southerly prevails in summer while the northerly prevails in winter, wind speed is synthesized for the six channels of summertime CEF as shown in Table 1 and the data so obtained are defined as the total summertime CEF, which follows the same methods in Li et al. [4]. Wind speed is also synthesized for the five channels of wintertime CEF as indicated in the same table and the resultant data are defined as the total wintertime CEF, which is changed to positive for it is northerly. Fig.2 gives the anomalies (in columns) of total CEFs for both summer and winter and the curves of respective 7-year running mean variation.

It is known from Fig.2a that the variation of total summertime CEF can be divided into four main stages of (1) the late-1940s through mid-1960s when it is relatively weak, (2) the mid-1960s through mid-1970s when it becomes stronger than the previous stage, (3) the mid-1970s through mid-1990s when it is relatively strong, and (4) the mid-1990s till the present day when it gets weaker again; the total value for early 21st century is lower than the average. It can be known that the summertime CEF experienced a process in which the intensity was getting stronger while an average state is being witnessed in the early time of the 21st century.

It is known from Fig.2b that the tendency is not as obvious as in summer for the total wintertime CEF to change with the interannual variation but in a much more complicated way. The total was weak in the mid-1950s and before and then began intensifying afterwards; a sinusoidal wave-shaped change was formed over a period of about 14 years from the late-1950s to mid-1970s, which marked a decreasing intensity; it was persistently strong from the mid-1970s to the mid-1990s but began decreasing afterwards, making early 21st century a time of relatively weak CEF, though with a leveling-off trend.

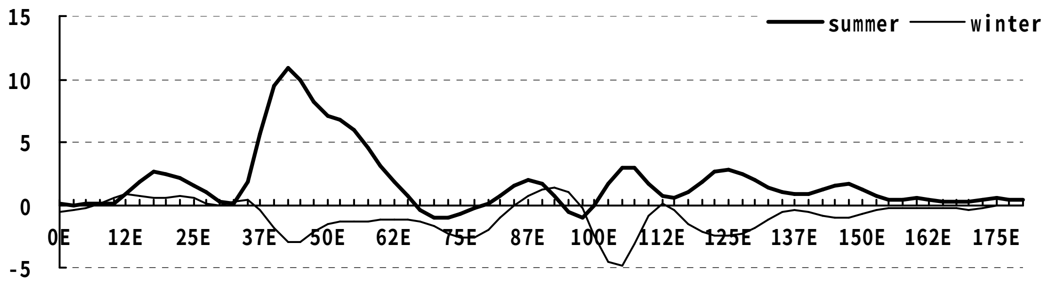

Fig.1 Longitude-dependent variation of the 850-hPa meridional wind averaged over multiple years on the equator in the Eastern Hemisphere in summer and winter. The positive values indicate the southerly and negative values the northerly.

The total CEF is obtained from the composite of different channels. How do these channels affect the interannual variation of the total? It is known from calculations of the correlation between different channels and total CEF (table omitted) that it has reached a significance level of 0.05 ($r_{0.05}$=0.273 2).

Although it is the most intense channel for transporting summertime CEF, the Somali jet stream does not significantly affect the total amount via its interannual variation; in contrast, it has significant impacts on the interannual variation of the total in winter and CEFs near the East Asia have important influence on the change in total in both winter and summer, indicating a close relationship between the area and CEF.

Table 1 The location of channels, wind speed (with positive values indicating the southerly and negative the northerly) and range of channels for CEFs in winter and summer

Seasons	Location of channels/ °E	Wind speed/ (m/s)	Range of channels/ °E
Summer	20	2.5	17～20
	42	10.9	40～45
	72	−1.1	70～72
	87	1.9	85～90
	97	−1.0	95～97
	105	3.0	105～107
	125	2.8	122～127
	147	1.6	145～147
Winter	42	−3.0	40～47
	75	−2.7	72～80
	92	1.4	90～95
	105	−4.8	100～107
	125	−2.5	120～127
	145	−1.1	145～147

5 CORRELATION BETWEEN CEF AND PRECIPITATION AND AIR TEMPERATURE IN CHINA

CEFs are closely linked with global atmospheric circulation, especially of the middle and low latitudes. It is known from the analysis above that CEFs are associated with the East Asia area where monsoons prevail; how do East Asian monsoons work with the CEFs? The impacts of East Asian monsoons on the climate in China can be used to infer those of CEFs on the climate in China. In view of the fact that little work has been done in this aspect, monthly precipitation and temperature data from 160 Chinese stations are used in this study to analyze their correlation with the CEFs. Main conclusions have been drawn as follows.

See the Chinese edition of the journal for more details.

6 CONCLUSIONS

(1) The CEFs are displayed mainly as the southerly wind in summer but the northerly in winter. There are six channels for the southerly in summer with the Somali jet stream being the most intense one; there are five channels for the northerly with the one at 105°E being the strongest; the channels of both seasons are located more westward with the interannual variation.

(2) For the 20th century, the total of summertime CEFs experience an intensifying process while that of wintertime CEFs are complicated with the interannual variation; airflow tend to be active around the average value in the early time of the 21st century.

(3) The interannual variation of CEFs is stronger in summer than in winter; that of the 125°E channel is the strongest of all in both seasons. Although it is the most intense channel for transporting summertime CEF, the Somali jet stream does not significantly affect the total amount via its interannual variation; in contrast, it has significant impacts on the interannual variation of the total CEFs. CEFs near the East Asia have important influence on the change in total in both winter and summer, indicating a close relationship between the area and CEF.

(4) Abrupt increases were experienced in the total of summertime CEF in the late-1950's and mid-1970's and abrupt decreases were found in the total of both summertime and wintertime CEF in 1994 – 1995.

(5) As shown in the computations of the correlation of 51-year (from 1951 to 2001) data, the summertime CEFs in the Eastern Hemisphere are poorly correlated with summertime precipitation in China, though they are much more correlated when treated with 7-year running average. The correlation is completely different for the time around the point of abrupt change of total CEFs in the 1970's, which is determined taking the point as a threshold. Much more significant negative correlation exists between the total CEFs and 87°E channel and the summertime precipitation in the areas to the south of the Yangtze River over the 21 years subsequent to the point of abrupt change than the 30 years precedent to it. Over the 30-year period, the Somali jet stream is in significant positive correlation with the west but not so in the 21-year period; the fact that the correlation is different across the point is consistent with the correlation between East Asia summer monsoon and CEFs and its impacts on summertime precipitation in China, showing that the difference in the impact of the East Asia summer monsoon has also changed the impacts of CEFs on Chinese precipitation in summer.

(6) In a pattern that the eastern part is symmetric with the western part of China, the wintertime total of CEFs is correlated with the

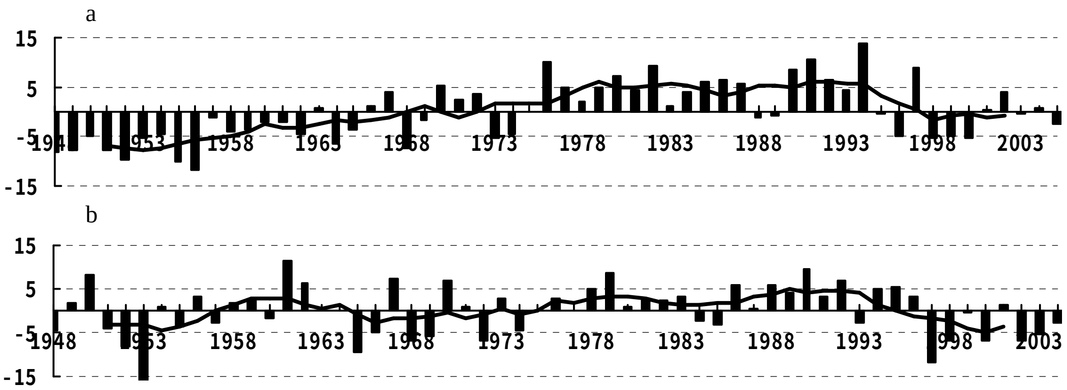

Fig.2 The anomalies (in columns) of total CEFs for both summer (a) and winter (b) and the curves of respective 7-year running mean variation.

concurrent air temperature negatively in southern China but positively in northern China. Similar to the principle for winter monsoon formation, the wintertime CEFs are also generated due to geographic differences in sea level pressure, which are in significant positive correlation with the East Asia continent but in significant negative correlation with both Australia down south and high-latitude Siberia. The variation of the correlation with geographic location also reflects the difference in the wintertime correlation between the CEF and air temperature in China.

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