Article ID: 1006-8775(2006) 02-0101-04

A CHARACTERISTIC CORRELATION ANALYSIS BETWEEN THE ASIA SUMMER MONSOON MEMBERS AND THE WEST PACIFIC SUBTROPICAL HIGH

YU Dan-dan (余丹丹)[1,2], ZHANG Ren (张　韧)[1,2], HONG Mei (洪　梅)[2], MIN Jin-zhong (闵锦忠)[3] GUO Pin-wen (郭品文)[3]

(1. Institute of atmospheric physics, Chinese academy of sciences LASG, Beijing 100029 China; 2. Institute of Meteorology, PLA University of Science and Technology, Nanjing 211101 China; 3. Nanjing University of Information Science & Technology, KLME, Nanjing 210044)

Abstract: In this paper, by using the pentad-mean NCAR/NCEP reanalysis data for the period of 1958-1997, some characteristic indices of describing the activity of Asian summer monsoon system members are defined and calculated. Based on the above works, a time-lag correlation analysis method is introduced for the correlation analysis between the Asian summer monsoon system and the west Pacific subtropical high (WPSH) area index, and some meaningful interaction processes and characteristic phenomena between them are revealed and discussed accordingly. It is shown that there exists some remarkable time-lag correlations in various degree between the Asian summer monsoon system members and the WPSH area index, and they interact and feedback with each other, which consists of the whole Asian summer monsoon system.

Key words: west Pacific subtropical high (WPSH); Asia Summer Monsoon; time-lag Correlation Analysis

CLC number: P732.2 **Document code:** A

1 INTRODUCTION

The subtropical high over the west Pacific is one of the most important atmospheric circulation components which influence the weather and climate of China. In recent years, with deep investigation into the monsoon, significant progresses have been made in the field of the monsoon system [1-4]. Another trend is to study and discuss the subtropical high as a member of the monsoon system [5-6]. For this purpose, a time-lag correlation analysis method is applied in this paper to explore the correlation between the Asian summer monsoon system members and the west Pacific subtropical high (hereafter WPSH), study and extract their objective and quantitative characteristics and discuss interactive mechanisms. In view of the phenomenon revealed, some analytical reviews are also given accordingly.

2 DATA AND INDICES

We use the NCEP/NCAR 10-year pentad-mean reanalysis data on a 2.5°x 2.5° latitude – longitude mesh, including four independent periods of 1958 – 1967, 1968 – 1977, 1978 – 1987 and 1988 – 1997. We select summer data (May 1 – Dec. 1) to calculate various indices.

To further explore correlation characteristics between the Asian summer monsoon system members and the WPSH, with base on previous researches and in the light of relevant literatures [7], the WPSH area index is used to define the shape and strength of WPSH. Some characteristic indices are also calculated to describe the Asian summer monsoon system members' activities (see detailed definitions in Chinese version of this article). All indices in this paper are for the normalized time series in order to facilitate comparison.

Received date: 2005-12-08; **revised date:** 2006-09-06

Foundation item: National Natural Science Foundation of China (No.40375019), Jiangsu Provincial Key Laboratory of Meteorological Disasters Research Program (KLME0507) and LASG Open Project

Biography: YU Dan-dan (1979-), female, native from Yingshan County, Hubei province, Ph.D., mainly undertaking the study of ocean meteorology.

E-mail: yyllyc@126.com

We diagnose and analyze the correlation between the Asian summer monsoon members' indices and the WPSH area index in order to find some new features, which provide the basis for further exploration of the mechanisms.

3 ANALYSIS AND DISCUSSION

3.1 Time-lag correlation analysis

Using the averaged summer data of four periods, the time-lag correlation analysis is done of the time series of the WPSH area index and the characteristic indices of the other members of the summer monsoon system. Significant correlation coefficients and time-lag numbers can be shown in a table not shown here. There exist high correlation between different indices of the summer monsoon system members and the WPSH area index respectively, all of the absolute correlation coefficients are greater than 0.4 with confidence level greater than 95%, and most are positive. According to the absolute correlation coefficients, we find that the WPSH strength is most closely related to the East Asian monsoon circulation, the South Asia high, the low altitude and equatorial flow and the high altitude easterly jet, therefore the monsoon circulation and activity are the most important factors which influence the WPSH strength. In addition, the influence of the Indian summer monsoon on the WPSH strength is higher than that of the South China Sea and the East Asian summer monsoon, the vertical wind at 200 hPa (V200hPa) of the Indian monsoon plays a very important role in the variation of the WPSH.

The above researches indicate that the relationship of the WPSH to other members of the Asian summer monsoon system is close, they interact and feedback with each other in the whole organic system. Their correlation is mainly related to the following features (figure omitted):

(1) When the Northern Hemisphere Tibetan High is at western Qinghai-Tibet plateau (YZ ↑), the WPSH is located on the east;

(2) With the increasing of the monsoon circulation on the Indian subcontinent (J3V ↑), the Australia high (B ↑) is developed and strengthened with a lag of around 5-10 days, the Mascarene high (A ↑) is enhanced accordingly, and its northern Somalia jet (D ↑) makes the westerly wind over the western equatorial Indian ocean region expand and spread eastward obviously;

(3) Then, in the South China Sea near 110 °E, the equatorial low-level jet (E ↑) is intensified, which leads to severe convection over the Indochina Peninsula, the surface heat flux (C1↓) is also declined rapidly; the zonal westerly wind at 850hPa (FU ↑, GU ↑) of both India and the South China Sea monsoon is significantly increased. At the same time the zonal monsoon circulation indices (J3U ↑, J2U ↑,J1U ↑) in the region of India, the Bay of Bengal and the South China Sea are also strengthened.

(4) Vertical monsoon circulation indices (J2V ↑, J1V ↑) in the region of the Bay of Bengal and the South China Sea area are also further strengthened rapidly, the South China Sea is controlled by the southwestern airflow and severe convective action, which lead to the onset of the summer monsoon over the South China Sea;

Tab.1 Analysis of time-lag correlation between various indices and subtropical high area index

Subtropical high area index SI	Coverage of significant correlation	Maxima
Mascarene high A	Significant positive correlation between -1 and 0 pentad (>0.65)	0.694 at 0 pentad
Australian high B	Significant positive correlation between -4 and -2 pentad (>0.5)	0.559 at −3 pentad
*sensible heat from Indo-china peninsula C1	Significant negative correlation between -2 and 0 pentad (>-0.5)	−0.518 at −1 pentad
*sensible heat from Indian subcontinent C2	Significant negative correlation between 1 and 3 pentad (>-0.45)	−0.45 at 2 pentad
Somali low-level jet stream index D	Significant positive correlation between -1 and 0 (>0.6)	0.720 at 0 pentad
South China Sea low-level jet stream index E	Significant positive correlation between -2 and 0 pentad (>0.6)	0.671 at -1 pentad
Indian Monsoon (rainfall) FCP	Significant positive correlation between 0 and 1 pentad (>0.55)	0.681 at 0 pentad
*Indian Monsoon (OLR) FULW	Significant negative correlation between 0 and 1 pentad (>-0.6)	-0.684 at 0 pentad
Indian Monsoon (850-hPa zonal wind) FU	Significant positive correlation between -1 and 0 pentad (>0.65)	0.708 at 0 pentad

Tab.1 *continued*

Subtropical high area index SI	Coverage of significant correlation	Maxima
Indian Monsoon (850-hPa meridional wind) FV	Correlation not significant	Correlation not significant
South China Sea (rainfall) GCP	Significant positive correlation between 2 and 3 pentad (>0.4)	0.437 at 2 pentad
*South China Sea Monsoon (OLR) GULW	Significant negative correlation between 2 and 3 pentad (>-0.4)	-0.479 at 2 pentad
South China Sea Monsoon (850-hPa zonal wind) GU	Significant positive correlation between -1 and 0 pentad (>0.65)	0.680 at 0 pentad
South China Sea Monsoon (850-hPa meridional wind) GV	Significant positive correlation between -1 and 0 pentad (>0.45)	0.576 at 0 pentad
Qinghai-Tibet high Z (standard)	Significant positive correlation between -1 and 1 pentad (>0.65)	0.776 at 0 pentad
* Qinghai-Tibet high XZ (eastern pattern)	Significant negative correlation between -1 and 1 pentad (>-0.69)	-0.764 at 0 pentad
Qinghai-Tibet high YZ(western pattern)	Significant positive correlation between -2 and 0 pentad (>0.6)	0.605 at 0 pentad
Bay of Bengal zonal monsoon circulation J1U	Significant positive correlation between -1 and 1 pentad (>0.8)	0.942 at 0 pentad
Bay of Bengal meridional monsoon circulation J1V	Significant positive correlation between -1 and 1 pentad (>0.8)	0.915 at 0 pentad
South China Sea zonal monsoon circulation J2U	Significant positive correlation between -1 and 0 pentad (>0.65)	0.708 at 0 pentad
South China Sea meridional monsoon circulation J2V	Significant positive correlation between -1 and 0 pentad (>0.65)	0.720 at 0 pentad
Indian zonal monsoon circulation J3U	Significant positive correlation between -1 and 1 pentad (>0.65)	0.767 at 0 pentad
Indian meridional monsoon circulation J3V	Significant positive correlation between -4 and -3 pentad (>0.55)	0.588 at -3 pentad
* Qinghai-Tibet high east-west circulation K1	Significant negative correlation between 0 and 1 pentad (>-0.65)	-0.733 at 0 pentad
Subtropical high trade wind circulation K2	Significant positive correlation between 1 and 3 pentad (>0.45)	0.472 at 2 pentad
Changjiang-Huaihe sustaining rain (rainfall) M	Significant positive correlation between -1 and 0 pentad (>0.65)	0.677 at 0 pentad

Note: The negative numbers indicate that the change of monsoon indices is ahead of that of the area of the subtropical high while the positive numbers indicate that the change of the former lags behind the latter. The monsoon indices with "*" are those with significant, negative correlation with the index of subtropical high area.

(5) A leap in the process of heating of the Qinghai-Tibet Plateau makes the Tibetan High locating on the upper troposphere increase (Z ↑), and high pressure center moves from west to east correspondingly; meanwhile the WPSH locating on the lower troposphere layer stretches westward and gets stronger and larger as well (SI ↑);

(6) After around 1 pentad, the value of OLR (FULW↓) is decreased on the Indian subcontinent, the convection is active enough to increase the Indian monsoon rainfall (FCP ↑) and decrease the surface heat flux (C1↓). At this time, three airflows, including the southwest winds of the Somali jet, the southerly wind of the South China Sea cross-equatorial low level jet stream and the southerly wind at the west edge of the subtropical high, compose a strong southwest wind, which transports from the southern Indian peninsula to the coastal areas of south China, through the Bay of Bengal, the Indo-China peninsula and the South China Sea. As a result, south China and the Middle-Lower Yangtze River valley have heavier rainfalls (M ↑);

(7) About 1 pentad later, the WPSH advances northward, followed by stronger surface heat flux in Qinghai-Tibet Plateau, especially the latent heat of rain released from the middle-lower Yangtze River valley off the eastern plateau, the Tibetan High moves out of the Qinghai-Tibet plateau and shifts northeastward. When the Tibetan High stretches eastward to the farthest, the WPSH stretches westward to the farthest, the South China Sea monsoon trough becomes active, the East Asia monsoon breaks down, and precipitation in Yangtze River valley is weak.

(8) Under the East-Tibetan High (XZ ↑), the lower WPSH extends further westward over the plateau, the consistent pressure distribution makes it hard to maintain as a dynamic high, then the Tibetan High retreats westward and the WPSH withdraws

eastward. The divergence flow of the Tibetan High spreads westward to the Pacific region, which makes the zonal wind at 200Pha strengthen, namely, horizontal circulation of the Tibetan High is strengthened as well (K1 ↑). 10-15 days later, the low trade wind blowing from WPSH (K2 ↑) to the equator is stronger and Hadley circulation develops in low latitudes.

3.2 The relevant features for the southern hemisphere subtropical high and the WPSH

The results of the correlation analysis also demonstrate some new phenomena and features. For example, the Australian High is strengthened at first, around 2 pentads later, so is the Mascarene high through some mechanisms, thereby intensifying the Somalia jet in the vicinity of 45°E. Moreover the equatorial low-level jet in the South China Sea near 110°E is expanded significantly after that.

To further study the response of both on the WPSH, we apply the method of time-lag correlation analysis to discuss the time series of the Mascarene high and the Australian High. Results show that when the WPSH is strengthened, the earlier sea-level pressure of both the Mascarene high and the Australian High will continue to increase; when the Mascarene high is ahead of the WPSH by about 1 pentad, Australia high by around 2 pentads, their correlation coefficients are the maximum, that is, the Mascarene high lags behind the Australia high by 1-2 pentads to impact the WPSH strength significantly. The diagnostic analysis above just reveal that there are some characteristics of remarkable time-lag correlation phenomena between the Asian summer monsoon system members and the WPSH, while the relevant physical mechanisms and kinetics explanations still need further analysis and study. Tab.1 shows the interactions between the WPSH and other members of the monsoon system.

For analyses of other aspects, refer to the Chinese edition of the journal.

4 SUMMARIES

In this paper, we discussed the Asian summer monsoon system members' activities and their influence on the WPSH, revealed some instructive phenomena features and made corresponding explanations of synoptic significance. Main analytic results are as follows:

(1) Variability in the WPSH is clearly associated with the Asian summer monsoon system members' activities, and there is a chronological order in the two time series. There are interactive and feedback cycles between the Asian summer monsoon system members and the WPSH (figure not shown).

(2) The WPSH area index has positive response to both the indices of the Mascarene high and Australia high, with a remarkable time lag between them. Usually, the Mascarene high impacts the WPSH after the Australia high does.

(3) The WPSH area index is positively correlated with the West-Tibetan High and negatively correlated with the East-Tibetan High. Their close association has an uncertain time-lag relationship — the Tibetan High always acts ahead of the WPSH and sometimes the WPSH may act ahead of the Tibetan High instead.

REFERENCES:

[1] TAO Shi-yan, CHEN Long-xun. A review of Recent Research on the East Asian Summer Monsoon in China Monsoon Meteorology [M].Oxford University Press, 1987: 60-92.

[2] ZHU Qian-gen, HE Jin-hai, WANG Pan-xing. A study of circulation differences between East Asian and Indian summer monsoon with their interaction [J]. Adv Atmos Sci, 1986, 3:466-477.

[3] YU Shi-hua, YANG Wei-wu. Features of subtropical monsoon circle and its relation with the East Asian summer monsoon [J]. Journal of Applied Meteorological Science. 1991, 2 (3) : 242-247.

[4] HUANG Shi-song, TANG Ming-min. On the structure of the East Asian Monsoon [J]. Scientia Meteorologica Sinica, 1987, 7: 1-16.

[5] The long-term forecast team, the Central Meteorological Observatory. Experience in long-term weather forecasting technology (appendix) [M]. Beijing: Chinese Central Meteorological Observatory. 1976: 5-6.

[6] XUE Feng. Interannual Variability of Mascarene High and Australian High and Their Influences on East Asian Summer Monsoon [J]. Chinese Science Bulletin, 2003, 48 (3): 287-192.

[7] WU Shang-sen. Intensity index of South China Sea monsoon and its variation characteristics [J]. Journal of tropical meteorology, 2001, 17 (4): 338-344.