The Weakening of the Asian Monsoon Circulation after the End of 1970′s①

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ABSTRACT

The transition of the global atmospheric circulation in the end of 1970′s can clearly be detected in the atmospheric temperature, wind velocity, and so on. Wavelet analysis reveals that the temporal scale of this change is larger than 20 years. Studies in this work indicate that the trend of the transition over the mid–latitude Asia is opposite to that of global average for some variables at the middle troposphere. Another finding of this research is that the African–Asian monsoon circulation is weaker and the trade wind over the tropical eastern Pacific is weaker as well after this transition. Such a signal may be found in the summer precipitation over China as well.

Key words: Asian monsoon circulation, Weakening, Transition

1. Introduction

It is becoming widely accepted that human activities have changed the global climate. As a result of the increase of the greenhouse gases in the atmosphere the global temperature will be higher, together with many related changes occurring in the climate system (Wang et al., 1993). In order to realize and predict the climatic change scientifically, we need to know the decadal to centennial scale climate variability and its mechanism. Therefore, the decadal to centennial scale climate variability is listed as one of the major objectives of the International Program on Climate Variability and Predictability (CLIVAR).

Many facts in the decadal scale climate variability have been found through the analysis on the observed records and the reconstructed data for the surface air temperature (Jones et al., 1999; Kelly and Jones, 1999; Wang et al., 1999; Shi et al., 1999), for example, the 10a scale climate variability. Researches revealed that the 1940′s and the 1990′s are the warm decades, while the 1960′s is a cold decade. The variability in 20a or longer time scale was also found as well in the variation of the general circulation (Karoly et al., 1996; Chen et al., 1998; Wang and Zhu, 1999). Abrupt climatic change in the 1960′s is another field of interest (Yan et al., 1990).

In this paper, long–term changes of the Asian monsoon accompanying the transition of the general circulation in the decadal scales are studied by using the reanalysis data (1949–1998) from the National Centers for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR). The sudden transition in the end of the 1970′s for the general circulation is examed in different pressure levels. In this analysis,

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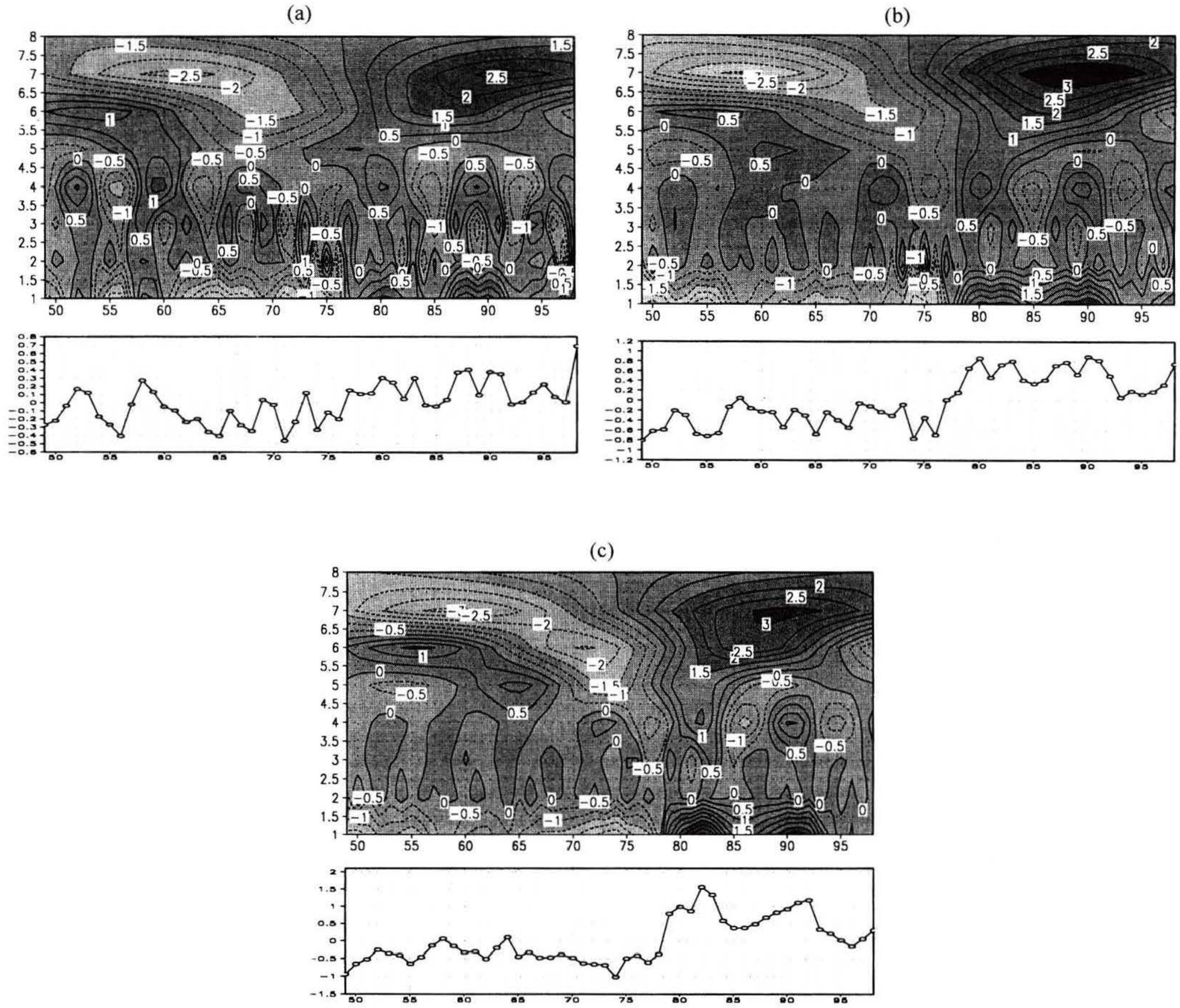

Fig. 1. The temporal variation of the global annual mean temperature (°C) and the real part of its wavelet transformation at 500 hPa (a), 200 hPa (b), and 100 hPa (c). In the lower panel, the abscissa is time in year, and the ordinate is ' a' (2^{a-1} is the time scale in year).

we find that the African–Asian monsoon circulation is weakened. At the same time, the trade wind over the eastern Pacific is also reduced significantly.

2. The transition of the global mean air temperature

As the basis of this study, the changes of the global mean temperatures in the free atmosphere are analyzed. First we plot the temporal variation and the wavelet analysis on the air temperature at the 500 hPa, 200 hPa, and 100 hPa pressure levels in Fig. 1. The temperature changed suddenly from a cold phase to a warm phase in the end of the 1970's at the three levels. Table 1 shows the global annual mean temperature differences between 1979–1998 average and 1949–1976 average for 17 pressure levels. The changes for the above three levels are 0.32°C, 0.91°C, and 1.08°C, respectively, and the changes are statistically significant at

Table 1. The global annual mean air temperature before and after the transition and their differences at pressure levels

pressure (hPa)	1949–1976 average (K)	1979–1998 average (K)	differences (°C)	significance (t–test)
1000	287.91	288.17	0.27	>99%
925	283.81	284.20	0.39	>99%
850	280.21	280.79	0.58	>99%
700	272.81	273.19	0.38	>99%
600	266.14	266.57	0.43	>99%
500	257.82	258.15	0.32	>99%
400	247.08	247.47	0.39	>99%
300	233.03	233.69	0.66	>99%
250	225.60	226.37	0.77	>99%
200	218.71	219.62	0.91	>99%
150	211.77	212.88	1.11	>99%
100	205.66	206.74	1.08	>99%
70	208.30	208.15	−0.14	<90%
50	212.74	212.03	−0.71	>99%
30	217.94	217.73	−0.21	<90%
20	221.53	222.01	0.48	<90%
10	227.69	230.76	3.06	>99%

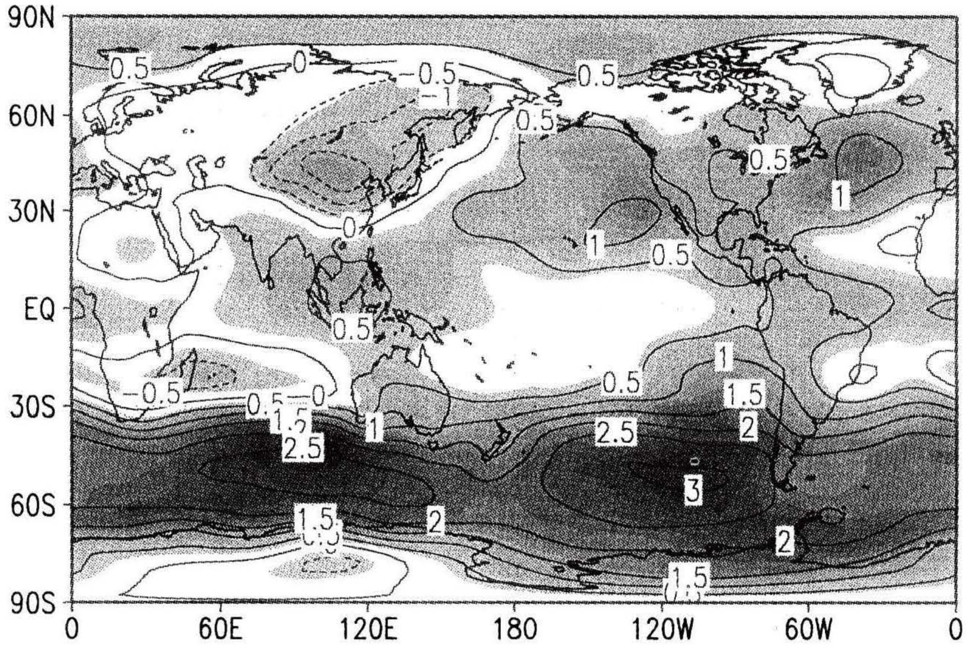

Fig. 2. The geographical distribution of the annual mean temperature differences (°C) between 1979–1998 average and the 1949–1976 average at 300 hPa. Shaded areas indicate significant changes at 95% level, estimated by a local student t–test.

99% level (using student t–test). It is noted that the magnitude of the changes is larger at the higher levels than at the lower levels in the troposphere.

The temporal scale of the transition is larger than 20 years, as could be seen from the wavelet analysis. However, in the scale of about 10a, there is also a transition in the end of the 1970's. At 50 hPa, the trend of the change is opposite to that at the levels mentioned above in the troposphere.

3. The spatial structure of the transition and the specialty over Asia

The geographical distribution of the temperature change at 300 hPa between the two periods (1979–1998 and 1949–1976) is presented in Fig. 2. The change of the temperature is positive at most areas of the globe, with significant changes over the tropical Indian Ocean, the western Pacific, the mid–latitudes of the Southern Hemisphere, America, and the mid–latitudes of Asia. Interestingly, the sign of the change over the mid–latitudes of Asia is negative, opposite to that over most areas of the globe. Such a reverse change in Asia exists at all the levels below 200 hPa, with slightly different geographical locations. This is called by us the specialty at the mid–latitudes of Asia for this transition.

Now we consider the vertical structure of the transition for the air temperature. The cross section of the change along 120°E is depicted in Fig. 3. The sign of the change over the troposphere is positive for most latitudes, except the Northern mid–latitudes (in Asia) at the levels below 200 hPa and at the high latitudes in the Southern Hemisphere near 500 hPa. At the lower levels near 50 hPa in the stratosphere, the sign of the change is negative, which is opposite to that in the troposphere in general. From the geographical location of the mid–latitudes of Asia, the specialty at this area may be connected with the existence of the Tibetan Plateau, but the physical reasons remain unclear at present.

Our analysis also reveals that the above–mentioned transition in the end of the 1970's exists for not only the annual average, but also for the summer and winter seasons. Our interest is in the JJA case in this paper. Figure 4 depicts the June–July–August (JJA) 500 hPa geopotential height difference for the above–mentioned two periods. Significant positive

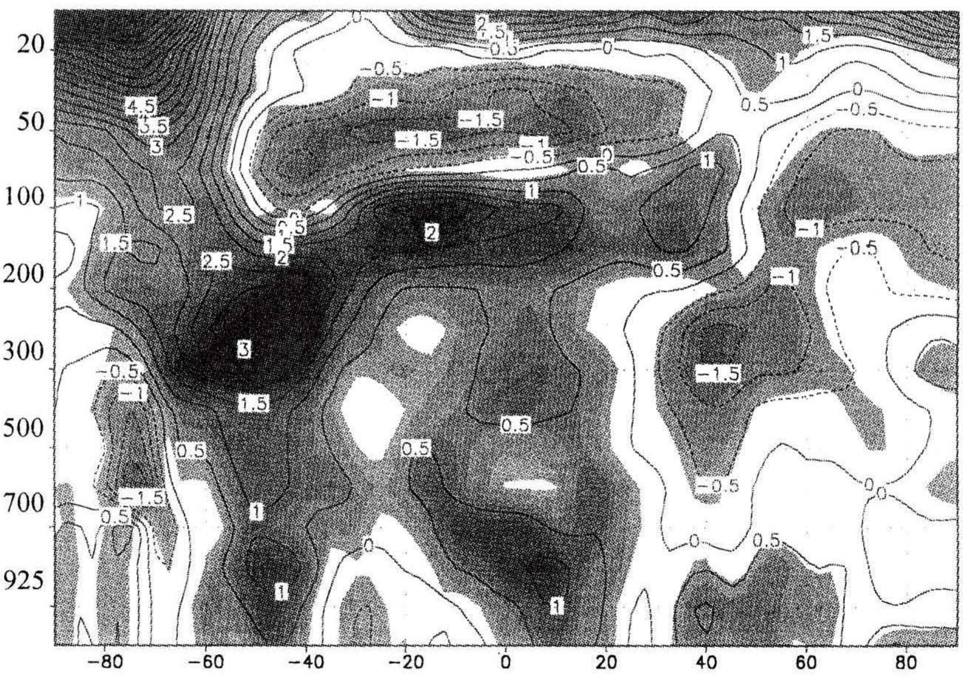

Fig. 3. The latitude–height distribution of the annual mean temperature differences (°C) between 1979–1998 average and the 1949–1976 average at 120°E. Shaded areas indicate significant changes at 95% level, estimated by a local student t–test. The abscissa is latitude with negative value in the Southern Hemisphere, and the ordinate is the pressure levels corresponding to 1000, 925, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 50, 30, 20, and 10 hPa.

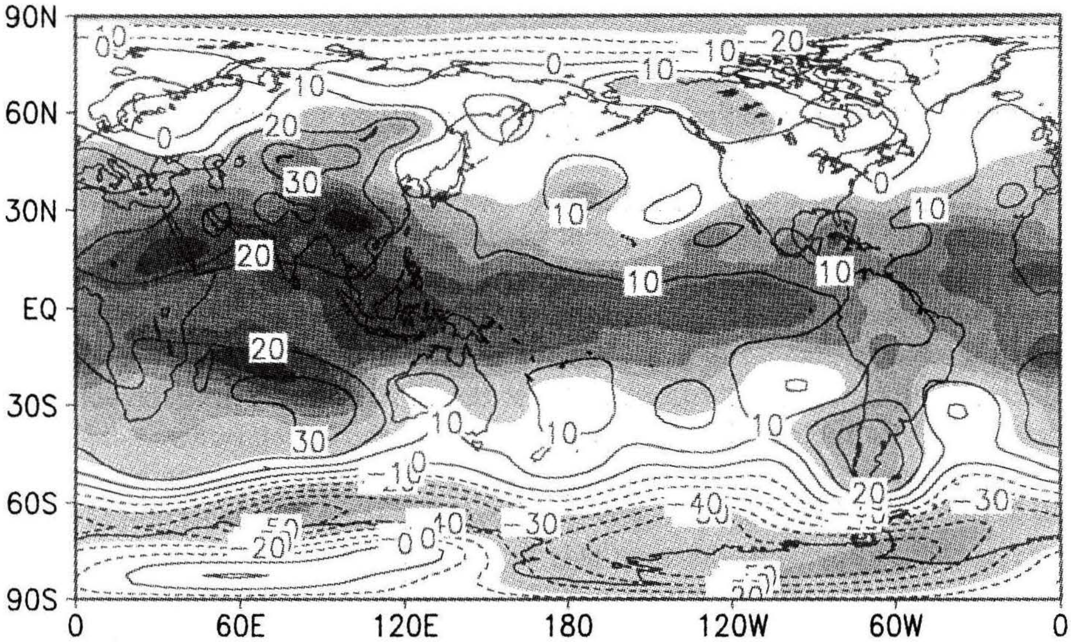

Fig. 4. Same as Fig. 2, but for the 500 hPa geopotential height in m.

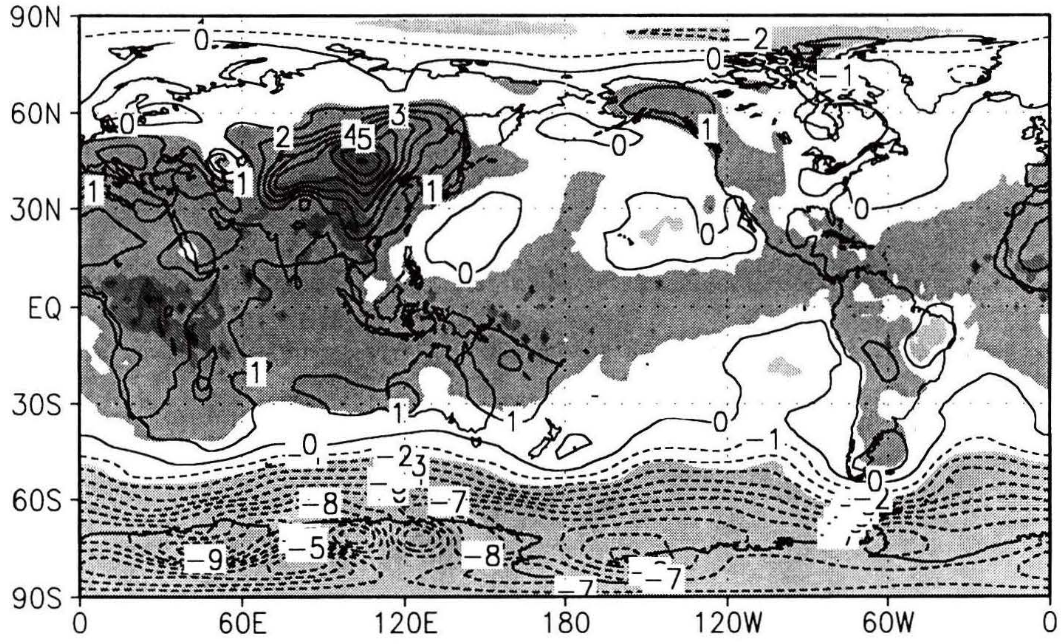

Fig. 5. Same as Fig. 2, but for the sea–level pressure in hPa.

changes appear in the tropics, with the largest changes in the African–Asian monsoon region, the subtropical Indian Ocean, and part of the Antarctica. It is interesting to note that the changes between the African–Asian monsoon region and the Antarctica have the

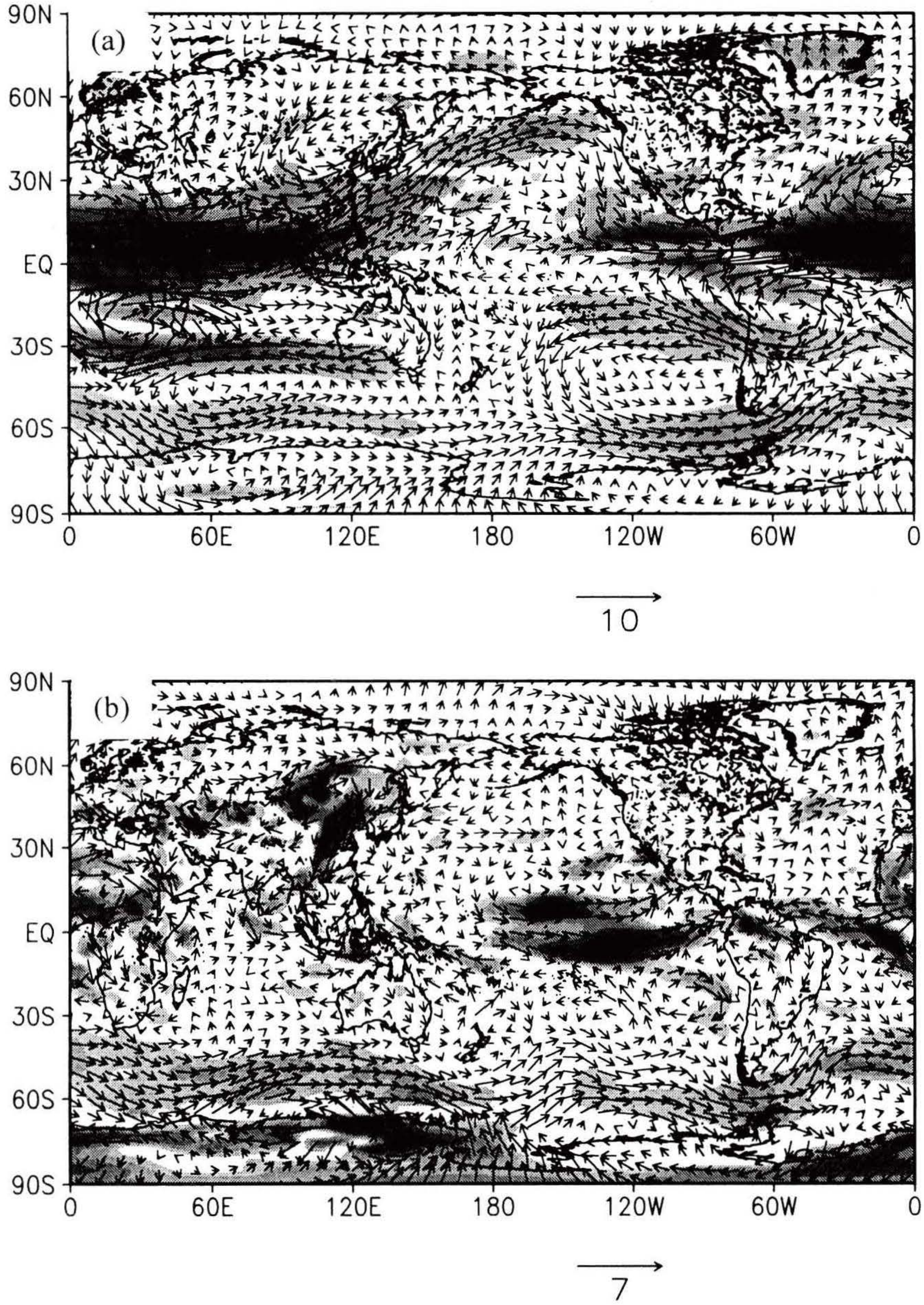

Fig. 6. The geographical distributions of the July wind differences (m / s) between 1979–1998 average and the 1949–1976 average for 850 hPa (a) and 100 hPa (b). Shaded areas indicate significant changes at 95% level, estimated by a local student t–test.

opposite signs. Such a feature could be found in the whole middle and lower troposphere. From the change of 1000 hPa geopotential height, we would see that the largest changes are located over the mid–latitude Asia and the Antarctica, with positive and negative signs, respectively (figure not shown).

The above transition can also be found in the changes of other quantities. But the spatial patterns of the transitions may be slightly different from that of temperature.

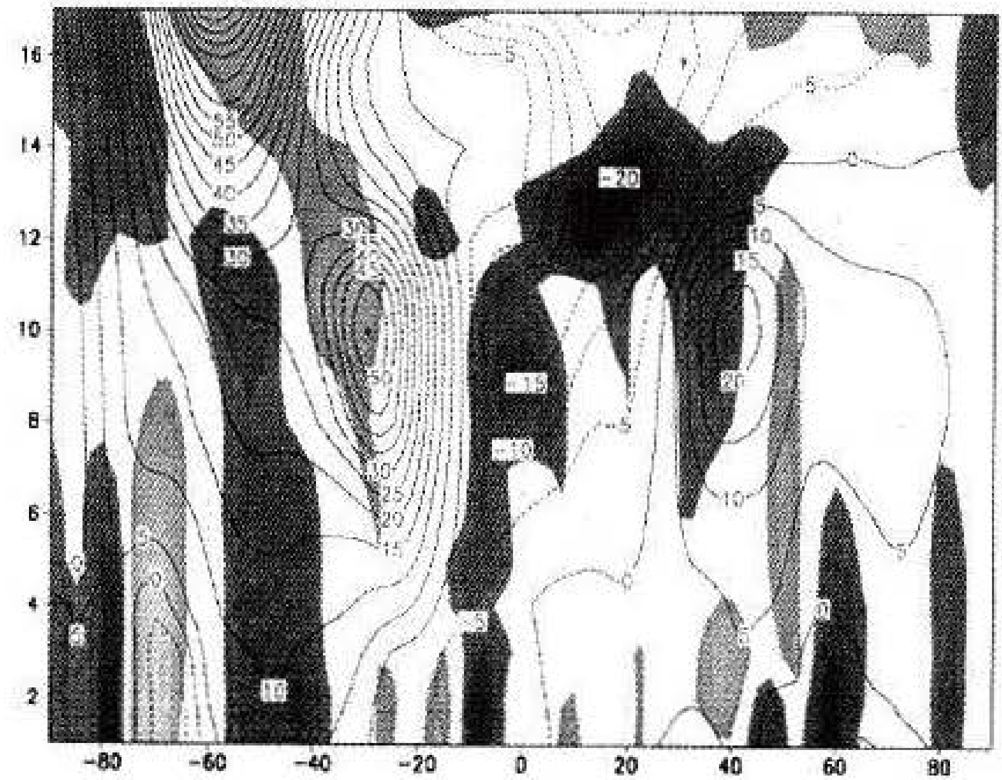

Fig. 7. The cross-section of the zonal wind change for JJA at 120°E, in which the contours show the climatological state and the shaded areas show the significant changes. The dark and tint shadings indicate positive and negative changes, respectively. Shaded areas indicate significant changes at 95% level, estimated by a local student t-test. The abscissa is latitude with negative value in the Southern Hemisphere, and the ordinate is the pressure levels corresponding to 1000, 925, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 50, 30, 20, and 10 hPa.

4. The weakening of the Asian monsoon circulation

Monsoon is basically originated by the land-sea contrast, which can be expressed by the low-level air temperature, the sea-level pressure (SLP), and so on. We first plot SLP change for JJA in Fig. 5. As mentioned above, SLP is increased over the Asian continent, while the change over the Indian and western Pacific Oceans is much smaller. Therefore, the change of SLP between Asian continent and the neighboring oceans is decreased (because, in the climatological state, SLP is smaller over the Asian continent than over the neighboring oceans). Hence, the Asian monsoon is suppressed after this transition.

We may find the decreasing of the summer monsoon directly from the change of the wind in Fig. 6. The significant change of the wind for July exists over limited regions like Asian monsoon regions and the tropical eastern Pacific. The South Asian and East Asian summer monsoon winds at 850 hPa become weaker after the end of the 1970's. In Fig. 7, we depict the cross-section of the zonal wind change for JJA at 120°E, in which the contours show the climatological state and the shaded areas indicate the significant changes (at 95% significance level). The dark and tint shadings indicate positive and negative changes, respectively. Therefore, Fig. 7 indicates that the mid-latitude jet at the troposphere is

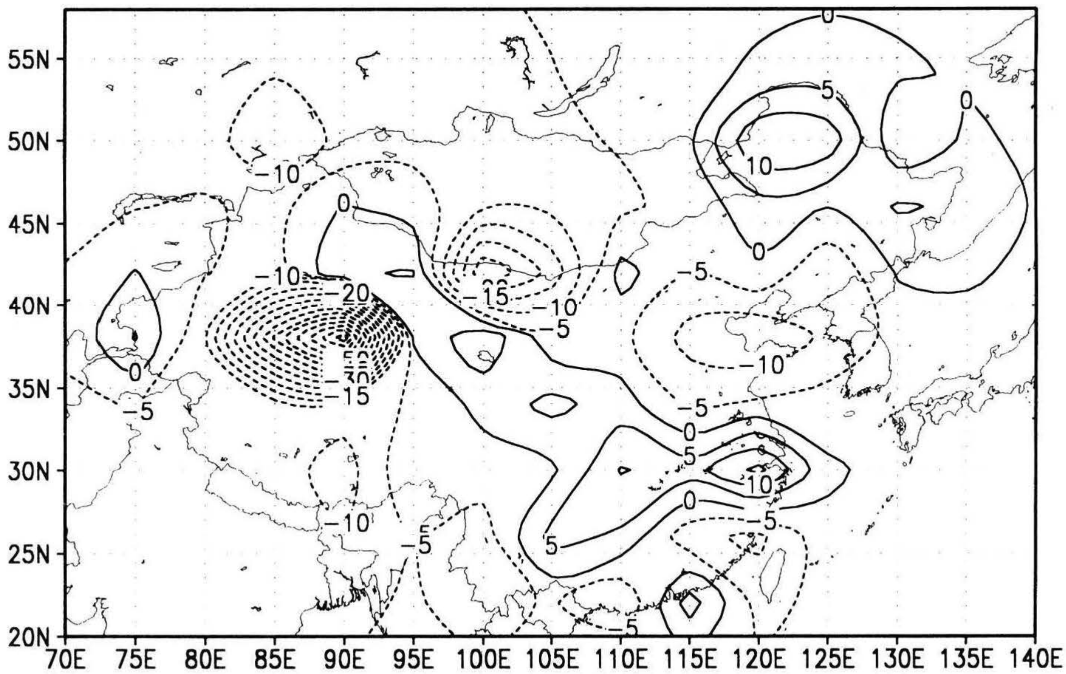

Fig. 8. The geographical distribution of the JJA rainfall differences (%) over China between 1979–1998 average and the 1949–1976 average.

enhanced and that anti–cyclonic anomalies appear over the middle and high latitudes over Asia in the lower atmosphere. This means that westerly wind is enhanced at the high–latitude Asia but weakened over the mid–latitudes Asia, which, again, indicates the weakening of the Asian monsoon circulation. At 100 hPa the eastward monsoon wind over Africa and Asia is also weaker after the transition.

Connected with this change, the JJA rainfall is decreased over the lower reaches of the Yellow River and the Huaihe River, but increased over the lower reaches of the Yangtze River (Fig. 8).

Over the tropical eastern Pacific, the trade wind velocity is decreased in both summer and winter. This is important, because the weakening of the trade wind helps to weaken the upwelling of seawater causing the increase of the sea surface temperature (SST).

To check this speculation, we depict the temporal variation of the annual mean SST anomaly and its wavelet analysis averaged over the Nino3 region (150–90°W, 5°S–5°N). We do find the significant transition to a warmer phase and that the strength of El Nino events becomes larger after the transition (Fig. 9). The 1982 / 1983 event and 1997 / 1998 event are the two strongest events in the 20th century, and 1990–1994 is the long periods with positive SST anomalies over the Nino3 region. This change of SST is consistent with the transition of the trade wind in the atmospheric circulation.

5. Summary

To summarize the study in this work, we conclude the following findings, with the emphasis on the African–Asian monsoon circulation changes.

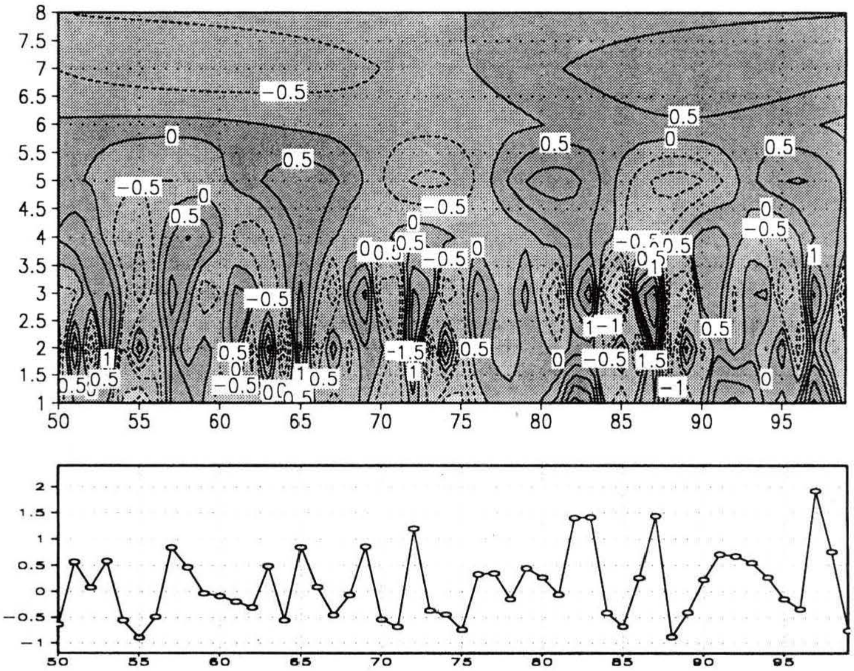

Fig. 9. Same as Fig. 1a, but for the Nino3 SST anomaly.

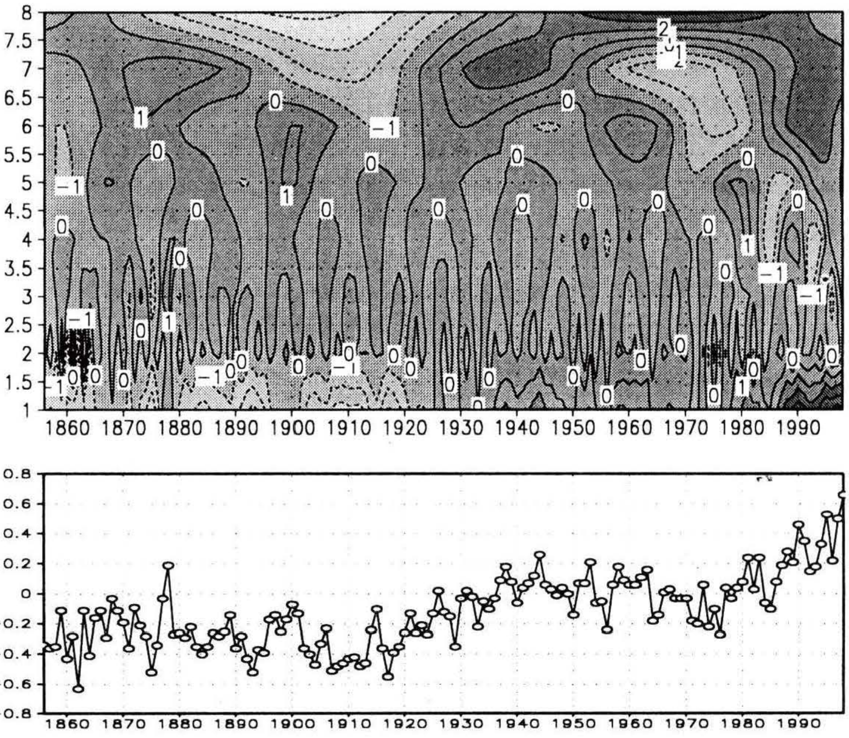

Fig. 10. Same as Fig. 1a, but for the surface air temperature anomaly (1856–1998).

(1) The global annual mean free air temperature undergoes a transition in the end of the 1970's to a warmer period at all the pressure levels below 200 hPa, with the reverse change at the levels near 50 hPa;

(2) As for the spatial pattern of the transition, the mid–latitude Asia has its clear specialty where the change of air temperature is opposite to that of the global average at the levels below 200 hPa;

(3) The Asian and African summer monsoon circulation becomes weaker after this transition;

(4) The trade wind over the tropical eastern Pacific in summer and winter is weakened after the 1970′s, and, accordingly, the SST over the Nino3 region is increased at the same time;

(5) The summer precipitation in some parts of China undergoes a transition as well, especially over the Yangtze River, Yellow River, and Huaihe River valleys.

Besides the NCEP / NCAR reanalysis, the SST, and the precipitation over China, we also analyzed the observed surface air temperature (1856–1998) data set and confirmed the sudden transition in the end of the 1970′s (Fig. 10).

The physical reasons for this transition may include both the human impacts (e.g., increases of the green–house gases, aerosols, dust etc.) and the natural climate variability at scales of 10a to several decades, and calls for further researches.

REFERENCES

Chen, L. X., W. Q. Zhu, and W. Wang, 1998: A research on the climatic change over China in recent 45 years. *Acta Meteorologica Sinica,* **56**, 257–271 (in Chinese).

Jones, P. D., M. New, D. E. Parker, S. Martin, and I. E. Rigor, 1999: Surface air temperature and its changes over the past 150 years. *Rev. Geophys.,* **37**, 173–199.

Karoly, et al., 1996: Decadal variations of the Southern Hemisphere circulation. *International J. Climotology,* **16**, 723–738.

Kelly, P. M., and P. D. Jones, 1999: Spatial pattern of variability in the global surface air temperature data set. *J. Geophys. Res.,* **104(D20)**, 24237–24256.

Shi, Y. E., Yao, T. D., and Yang, B. 1999: Decadal climate change based on ice core data in Guliya for last 2ka and comparison with documentary data in East China. *Science in China (D)*, (Supp.1): 79–86 (in Chinese).

Wang, H. J., Q. C. Zeng, and X. H. Zhang, 1993: The numerical simulation of the climatic change caused by CO_2 doubling. *Science in China (B)*, **36**, 451–462.

Wang, S. W., Ye, J. L., Gong, D. Y. et al. 1999: Reconstruction of the temperature series in China for the last one hundred years. *Quarterly Journal of Applied Meteorology,* **9(4)**, 392–401 (in Chinese).

Wang, S. W., and J. H. Zhu, 1999: Review on the researches of the decadal climate variability in abroad. *Acta Meteorologica Sinica,* **57**, 376–384 (in chinese).

Yan, Z. W., J. J. Ji, and D. Z. Ye, 1990: Climatic jump in late 1960s over the Northern Hemisphere, Science in China (B), 97–103.

亚洲季风环流在 20 世纪 70 年代末之后的减弱

王会军

摘　要

全球大气环流自 20 世纪 70 年代末之后的转变可以很清楚地在大气温度、风场等的变化上得到发现。子波分析的结果证实这次转变的时间尺度在 20 年以上。本文的研究着重揭示:在对流层中层,亚洲中纬度区域的转变趋势同全球平均的转变趋势相反;更重要的是,在这次转变之后亚洲和非洲的季风环流变弱了,同时热带东太平洋区的贸易风环流也变弱了。而在降水的变化中也可以发现这次转变。

关键词: 亚洲季风环流,减弱,转变