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A STUDY ON THE RELATIONSHIP BETWEEN SPRING SOIL MOISTURE OVER CHINA AND EAST ASIA SUMMER MONSOON

LE Yi-long (乐益龙)[1, 3], LUO Yong (罗勇)[2], GUO Pin-wen (郭品文)[1]

(1. Nanjing University of Information Science & Technology, Nanjing 210044 China; 2. Laboratory for Climate Studies, National Climate Center, CMA, Beijing 100081 China; 3. Ningbo Meteorological Observatory, Ningbo 315012, China)

Abstract: The correlation analysis has been used to study the relationship between spring soil moisture over China and East Asian summer monsoon (EASM). It is shown that EASM has a strong positive correlation with spring soil moisture over southwest China and the Great Bend region of the Yellow River. A standard soil moisture index (SMI) has been defined using the observed soil moisture of the two regions. The results show that SMI has a strong correlation with EASM. The years of strong (weak) SMI are associated with stronger (weaker) summer monsoon circulation. In the years of strong SMI, the west Pacific subtropical high is much northward in position and weaker in intensity; the westerlies zone is also more to the north. All of these make EASM circulation move northward and cause the rainfall belt to relocate to North China and Northeast China. SMI can reflect the variation of the summer rainfall anomaly over eastern China. In the years of strong SMI, the rainfall belt is mainly located over the northern part of China. However, during the weak years, the summer rainfall belt is largely located over the mid- and lower-reaches of the Yangtze River. Additionally, the SMI has obvious oscillations of quasi 4 – 6 years and quasi 2 years. Moreover, negative SMI predicts EASM better than positive SMI.

Key words: soil moisture; East Asia summer monsoon; summer rainfall; prediction ability

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1 INTRODUCTION

Being a key parameter in the research on land surface processes, soil moisture plays an important role in climate change and anomalies by altering the fluxes of sensible and latent heat and longwave radiation transported to the atmosphere. Changes in soil moisture affect its own thermal and hydrological processes as well, resulting in the variation of ground surface parameters to cause further changes and anomalies in climate [1- 5]. Evapotranspiration from land surface in summer is very important for the maintenance of normal Indian Southwest airflows and increase of precipitation over the Asian continent, especially over eastern China [6]. In the meantime, Asian-monsoon-induced precipitation is also subject to land-surface evapotranspiration over North America and it is true otherwise. Numerical experiments have been conducted with major regional climate models for soil moisture anomalies to show that dry soil increases temperature and precipitation while wet soil decreases them in the future.

Due to the lack of data, the research on the relationships between moisture humidity and monsoon is currently focusing on numerical simulation while few efforts have been spent on data analysis. From a preliminary study on the effect of large-scale precipitation anomalies on surface processes, it is known that the increased precipitation anomalies can reduce the temperature of ground surface and just above it, increase soil moisture and evaporation of latent heat from the surface and decrease surface albedo [7]. The persistence of climate anomalies are linked with the state of soil moisture [8]. Both studies have shown intense interactions between soil moisture and climate anomalies. In the region of China, soil humidity is marked with significant temporal and spatial structure and has close links with climate change, as shown in Ma et al.[9]

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Biography: LE Yi-long, male, native from Zhejiang province, B.S., mainly undertaking the short-term climate prediction.

E-mail: leyl@cma.gov.cn

2 DATA

The data of soil moisture from the National Meteorological Information Center are used. Covering a period from 1981 to 2002 and being available over every 10-day period of the month, it distributes across China in 10 layers from 0 cm to 100 cm beneath soil surface. 150 out of the 230 nationwide moisture stations are chosen for the data of the 0 – 10cm surface layer, due to their relative completeness in data series (figure omitted). The data and precipitation and surface temperature are the monthly mean extracted from 744 weather stations across China for 1960 – 2004. The gridpoint data are the 1948 – 2004 geopotential height of NCEP/NCAR that are monthly averaged and reanalyzed and the SST is the ERSST from NOAA.

3 SPRING CHARACTERISTICS OF SOIL MOISTURE FIELD

It is known from the climatological mean of soil moisture in spring (figure omitted) that there are two wet centers over Guizhou and Hunan and Northeast China, and a dry center over central Inner Mongolia, showing a pattern of increasing moisture from northwest to southeast.

It is also known from comparisons of climatological mean soil moisture and spring precipitation (figure omitted) that they have similar patterns of distribution. It is then inferred that the distribution of soil moisture is much affected by precipitation; the atmosphere being a main external forcing factor for the change in soil moisture, the distribution of precipitation determines that of soil moisture to a large extent. Large-scale forcings like precipitation are not the only factors responsible for the change in soil moisture, as soil texture, vegetation condition, evaporation and other meso- and fine-scale ones are also having some role.

4 CORRELATION BETWEEN SOIL MOISTURE AND EAST ASIAN SUMMER MONSOON

From comparisons of various indexes for East Asian summer monsoon [10], it is found that the index involving land-sea thermal contrast in East Asia performs quite well in indicating the anomalies of summer precipitation and temperature in eastern China and describing the intensity change in the summer monsoon in the region.

To further study the relationships, regionally averaged spring soil moisture for the Great Bend area is added to that for Southwest China before being standardized for an index, called SMI here, to depict the change in soil moisture in these areas. The index is correlated with the regional averages by 0.93 and 0.82, showing that they are representative of these changes.

For the ease of identifying the characteristics of anomalous years, the soil moisture index (SMI) is defined as follows. SMI≧0.5 indicate the years of high index of soil moisture, -0.5<SMI<0.5 those of normal one, and SMI≦-0.5 those of low one. The results are presented in Tab.1.

Tab.1 Years with high, normal and low SMI from 1981 to 2002

SMI intensity	Years
SMI≧1.0	1990, 1981, 1991
0.5≦SMI<1.0	1982, 1996, 1994, 1986
-0.5<SMI<0.5	1984, 1988, 1985, 1997
-1.0<SMI≦-0.5	1983, 1989, 1992, 2002
SMI≦-1.0	1998, 1999, 1993, 1987, 2001, 1995, 2000

Fig.1 gives the distribution of coefficients of correlation between the index of East Asian summer monsoon and soil moisture field in the spring of China (1981 – 2002). It is known from the figure that there is significant correlation between the index and the field.

From the index of soil moisture in the spring from 1981 to 2002 and that of East Asian summer monsoon in the summer of the same year (the climatological state is used from 1960 – 2004), significant interannual changes can be seen in the former index (figure omitted). Over the past 20 years, southwest China and the Great Bend area of Yellow River have been in the trend of decreasing soil moisture.

As shown in comparisons, the two indexes have similar trends of variation and are correlated at a coefficient of 0.57 and pass the 99% confidence test over all time but the last 20 years in which they show a generally decreasing tendency. It shows that the index of soil moisture is well correlated with the intensity of the summer monsoon in the same year over the areas of Great Bend and southwest China.

From a composite 850-hPa anomalous flow field based on high and low SMI (figure omitted), it is shown that the summer monsoon circulation is significantly stronger and northward in the years of high SMI but anomalously weak in the years of low SMI.

For high SMI years, the easterly jet stream is strong south of the South Asia high, cross-equatorial airflows are active and upper-level summer monsoon is stronger than average. For low SMI years, cross-equatorial airflows are relatively weak, the South Asia high is weak, with the whole tropical area in the control of westerly anomalous flows. It indicates the presence of an anomalously weak summer monsoon.

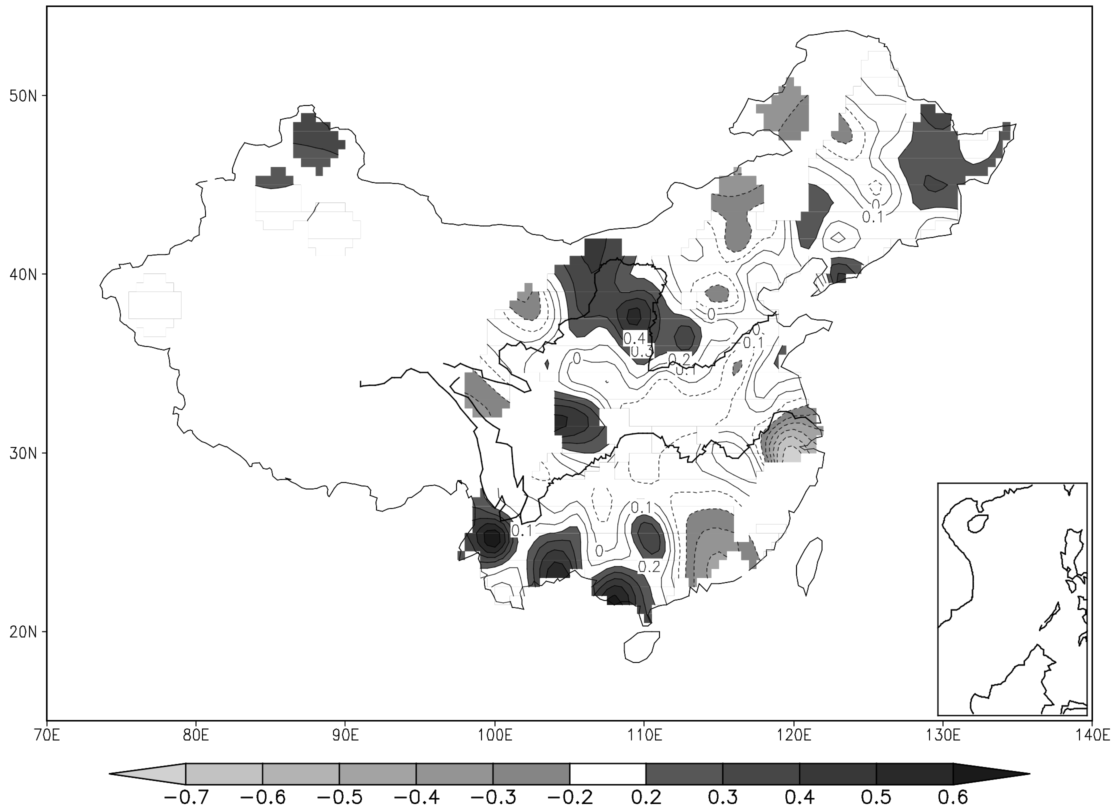

Fig.1 Correlation between East Asian summer monsoon index and spring soil moisture in China.

5 RELATIONSHIPS BETWEEN SMI IN SPRING AND PRECIPITATION OF CHINA IN SUMMER

It is discovered from the analysis above, the circulation patterns in high SMI years may push the rain zone northward, drying up the area between the Yangtze and Huaihe Rivers and middle and lower reaches of the Yangtze while those in low SMI years may be favorable for the rain zone to move southward, bringing more rain to the above areas. To verify the conclusion, the variation of precipitation field in both high and low SMI years are examined.

From the correlation between SMI and summer precipitation in China, it is known that the summer monsoon is strong in the high SMI years, in which monsoonal flows strengthen, progress northward and converge with northern cold air over North China and Great Bend area, resulting in a northward-located and weaker subtropical monsoon convergence zone. Consequently, there is more rain over North China and Great Bend area but less rain over the middle and lower reaches of the Yangtze due to the control of monotonous summer monsoon flows. In the low SMI years, however, weak summer monsoon flows converge with northern cold air over the middle and lower reaches of the Yangtze, resulting in a southward-located and stronger subtropical monsoon convergence zone. Consequently, there is more rain over the middle and lower reaches of the Yangtze but less rain over North China and Great Bend area due to the control of monotonous northerly flows.

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

6 CONCLUSIONS AND DISCUSSIONS

(1) The spring SMI is well correlated with the intensity of summer monsoon in East Asia. For the years with high SMI, low-level summer monsoonal flows and upper-level easterly flows strengthen significantly, indicating a relatively strong summer monsoon. For the years with low SMI, it is true otherwise. It is then known that SMI can be used to determine the intensity of the East Asian summer monsoon for the year, being helpful for short-term climate prediction.

(2) SMI corresponds well with the circulation pattern of summer precipitation in eastern China, which gives reasonable explanation of the circulation background of precipitation anomalies in summer.

(3) In the years of high SMI, the rain zone is

relatively northward, resulting in less precipitation over the middle and lower reaches of the Yangtze but more precipitation in North China and the Great Bend area. It is otherwise true in the years of low SMI. It has good indication for the forecast of summer wetness in the middle and lower reaches of the Yangtze.

(4) Significant oscillations (4 – 6 and quasi-2 years) exist in the SMI, though with substantial variation in their amplitude and period. For the ability to forecast the intensity of East Asian summer monsoon, negative SMI is better than positive SMI.

In summary, SMI is well correlated with the summer monsoon in East Asia, which is indicative for the forecast of monsoon and precipitation in China. More work needs to be done to learn about the physical ways by which soil moisture anomalies in spring affect the East Asian summer monsoon.

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