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The Drivers and Forecasting of Summer Precipitation over the Yangtze-Huai River Basin Based on the Empirical Orthogonal Teleconnection

Ailiyaer Aihaiti[1], Zhu Lianhua[1], Yao Yiyi[1], Zhao Weihao[1], Xu Fanran[1]
1. School of Mathematics and Statistics, Nanjing University of Information Science & Technology, Nanjing 210044, China
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Abstract: In this paper, the Empirical Orthogonal Teleconnection (EOT) analysis is applied to extract the leading modes of summer precipitation from 1951 to 2010 over the Yangtze-Huai River Basin. To analyze the time period of precipitation, the spectrum analysis is performed on the time series of EOT modes. Furthermore, the correlation analysis is used to discuss their drivers, and the major drivers are introduced to construct the forecasting model of summer precipitation. Results show that, the first three leading EOTs can explain about 63% variability of precipitation. The inter-annual, nearly decadal and decadal period signals of the EOT time series (T1-T3) are most significant, respectively. The East Asian summer monsoon (EASM), East Asia/Pacific pattern (EAP), Nino3.4 and Southern Annular Mode (SAM) indices are correlated with T1; the Nino3.4, the Northern Annular Mode (NAM) and SAM indices are correlated with T2, and Indian Ocean Dipole mode (IOD) is correlated with T3. The forecasting model can well capture the main characteristic of summer precipitation.

Keywords: EOT; Summer precipitation; EASM; EAP; Nino3.4; IOD; NAM; SAM.

1. Introduction

The summer (June-July-August, JJA) precipitation over the Yangtze-Huai River Basin (YRB) is main part of the East Asian summer monsoon (EASM). They have experienced the Quasi-biennial Oscillation, 3~5 year oscillation, quasi decadal or more oscillation and linear tendency [1]. It is notable that EASM experiences strong inter-annual variations associated with El Nino-Southern Oscillation (ENSO). Nan et al [2] found that the boreal spring Southern Hemisphere annular mode index (SAM) was positive correlated with the following summer precipitation in middle and lower reaches of Yangtze River. Huang et al [3] found that East Asia/Pacific pattern (EAP) is significantly affected the climate anomalies in East Asia. Inter-annual and decadal variability of summer precipitation over YRB has also been strongly linked to the Northern Hemisphere annular mode (NAM) index and the Indian Ocean dipole mode (IOD) [4-6]. This study aims to extract the leading modes of summer precipitation in YRB by using the Empirical Orthogonal Teleconnection (EOT), analyze the time period of the leading modes and discuss the relation between leading modes and drivers, construct the forecasting model of summer precipitation by using dominating drivers.

2. Datasets and methods

2.1 Datasets

The monthly and seasonal total precipitation from 1951 to 2010 are taken from Chinese National Climate Center (CNCC) dataset which including 160 observed stations. The data are interpolated by Kriging method into 1°×1° spatial grid. The EASM, Nino3.4, NAM and SAM indices, sea surface temperature (SST) are obtained from the National Oceanic and Atmospheric Administration (NOAA), and the SST is used to calculate the IOD index. The 850hPa zonal wind is obtained from the NCEP-NCAR reanalysis to compute the EAP index.

2.2 EOT analysis

Assuming that the total precipitation (T) is a discrete space-time (s,t) dataset

$$T(s,t),\ (1 \le t \le nt \ \text{ and } \ 1 \le s \le ns) \tag{2.1}$$

[1] Corresponding Author *E-mail*: ahualian@126.com.

The EOT is a stepwise linear regression, which identifies the grid (e.g., base point) that explains the maximum time variance of all other girds. For a given first base point, its effect (i.e., time series of T) is removed from linear regression of T in all other girds (i.e., modes). Then, search the next base point from the residual time series etc. The equation of modes is given by [7]:

$$T(s,t) = \sum_{m=1}^{sn} \alpha_m(t) e_m(s) \tag{2.2}$$

where the α and e are represent time series and spatial patterns of total precipitation, respectively. And the explain variance equation is given by

$$Expvar = \frac{1}{ns \cdot nt} T^{exp}(s,t)^2 / STVAR(100) \tag{2.3}$$

Where the $STVAR$ is given by

$$STVAR = \frac{1}{ns * nt} \sum_{t=1}^{nt} \sum_{s=1}^{ns} T(s,t)^2 \tag{2.4}$$

In this study, EOTs are computed using seasonal-total anomalies of 1951-2010 precipitation dataset over YRB, the anomalies are calculated as the difference between samples and its 30 years mean.

3. EOT modes extraction and their spectrum analysis

To capture the most variance of summer precipitation in YRB, the EOT is used to extract the modes. Fig. 1 shows the spatial distribution of the correlation between each grid and the base point of the first three modes. It can be seen that the leading mode EOT1 explains the greatest variance percentage (40.15%) of summer precipitation in YRB, which approximates half of the original variance. The pattern of EOT1 hold a zonal distribution, which represents the overall characteristic pattern of precipitation in YRB.

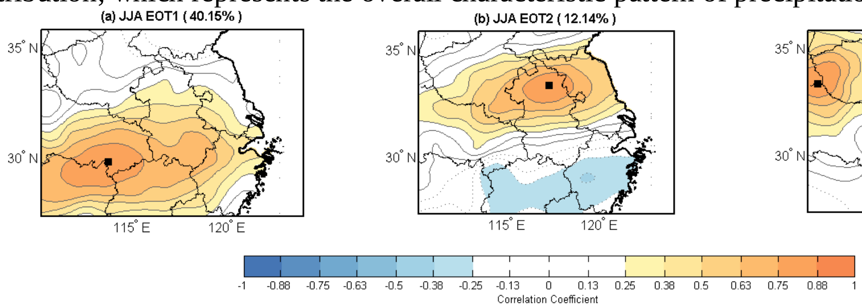

Fig. 1. Correlations of the time series of EOT1-EOT3 at each point with the EOT base point, which is marked with an oversized solid circle. The grey fine solid and dotted lines are representing positive and negative correlation, respectively.

The explain variance of EOT2 is 12.14% which represents the variability over the north region of the YRB. The third mode EOT3 explains a further 10.32% and represents the precipitation in the northwest of the YRB. Finally, the first three modes can explain 62.6% of the original variance.

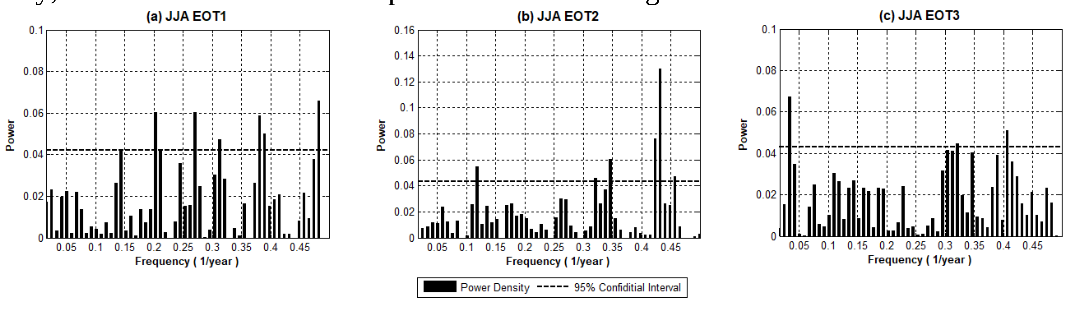

Fig. 2. The spectrum analysis of JJA EOT time series.

Further, the spectrum analysis is performed on the time series of EOT1-EOT3 (called T1-T3) to analysis the time period of each mode. In Fig. 2, the time period (frequency) is significant when the bar passes the dotted line. As the maximum explain variance, the T1 mainly covers the 2-5 year periods, which are the inter-annual signals. For the T2, except the 2.25, 3-year periods, the 8-year period is also significant, which means there is a nearly decadal period signal. The significant period of the T3 is above 20-years period, which is clearly a decadal period signal. Above all, the EOT methods successfully extract the inter-annual and decadal signals of the precipitation over the YRB.

4. Drivers and forecasting of summer precipitation

The T1-T3 are taken as the forecast objects of the precipitation in the state-wide, north and northwest of YRB, respectively. Then, linear correlations are employed to determine the associations between EOTs and potential drivers. Table 1 gives the correlations of each EOT and the drivers. It can be seen that the EASM$_{JJA}$, EAP$_{JJA}$, preceding Nino3.4$_{SON-1}$ (September-October-November, SON), Nino3.4$_{MAM}$ (March-April-May, MAM) and preceding SAM$_{SON-1}$ are significantly correlated with T1. Meanwhile, the preceding Nino3.4$_{SON-1}$, NAM$_{JJA}$ and SAM$_{MAM}$ are correlated with T2, and IOD$_{DJF}$ (December-January-February, DJF) with T3.

TABLE 1. The correlation coefficients between T1-T3 and EASM, EAP, IOD, Nino3.4, NAM and SAM indices

Mode	Expvar	EASM	EAP	IOD	Nino3.4	NAM	SAM
T1	40.15%	-0.35 (JJA)	-0.33 (JJA)	-	0.41 (SON-1) 0.34 (MAM)	-	-0.21 (SON-1)
T2	12.14%		-	-	-0.27 (SON-1)	0.25 (JJA)	0.21 (MAM)
T3	10.32%		-	0.22 (DJF)	-	-	-

The subscripts of the above indices indicate the time with the strongest signal, and their correlation coefficients are significant at 0.05 level. These drivers are introduced into the multivariable linear regression model as the predictors. Fig. 3(a-c) shows the T1-T3 and the corresponding forecasting time series. The correlation coefficient between the T1 and forecasting time series is 0.55, which of the T2-T3 are only about 0.34. The predictions of T1-T3 are then substituted into the EOT decomposition equation to assess the forecasting skill. Fig. 3(d) shows the spatial distribution of the correlation coefficient between the observation and prediction. It can be seen that the forecast model can capture the main characteristic of the precipitation, the highest coefficient can arrive 0.55.

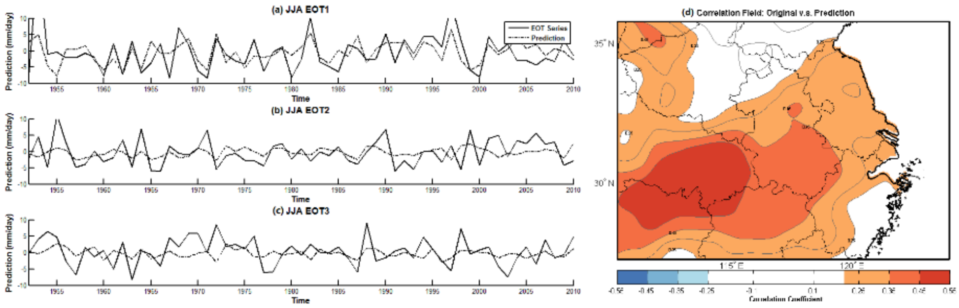

Fig. 3. (a-c) The time series of T1-T3 and the corresponding forecasting, (d) The spatial distribution of the correlation coefficients between the observation and prediction

5. Conclusions

Based on the EOT and spectrum analysis, we selected the different timescale drivers that are most relevant to the modes, and then established the forecast model. Results show that, the leading three EOTs can explain about 63% variability of summer precipitation, and the inter-annual, nearly decadal and decadal period signals of the EOT time series (T1-T3) are most significant, respectively. The T1 is correlated with the EASM, EAP, Nino3.4 and SAM, the T2 is correlated with the Nino3.4, NAM and SAM, and the T3 is correlated with the IOD. The forecast model can capture the main characteristic of summer precipitation in YRB, and the highest coefficient can arrive 0.55.

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