Analysis on dry-wet characteristics in the Zhujiang River Basin in recent 55 years

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Abstract. Based on Palmer Drought Severity Index (PDSI), this paper analysed the spatial distribution of dry-wet condition in the Zhujiang River Basin in 1961-2015, and studied the dry-wet climatic regionalization by Rotated Empirical Orthogonal Function (REOF). The results show most areas in the Zhujiang River Basin was in normal state of dry-wet condition and the whole basin can be divided into 7 dry-wet climate zones. The above conclusions reflect the dry-wet characteristics in the basin reasonably, which can provide a reference on prediction, monitoring and evaluation of some kinds of extreme climatic disasters such as floods and droughts inextricably linked with dry-wet condition.

1.  Introduction
In 2013, the Fifth Assessment Report that was published by the Intergovernmental Panel on Climate Change (IPCC) thought that warming of the climate system is unequivocal [1]. Under the global warming background, various extreme climatic events occurred in the Zhujiang River Basin [2-3]. Hence, production and living in the region has been seriously affected.

At present, there are a lot of researches on dry-wet climatic regionalization in the whole Zhujiang River Basin. Most researchers thought the basin is a humid climatic region [4]. However, there are little understanding about the distribution and division of dry-wet condition in the interior basin, which is regional essentially important. Therefore, it is necessary to analyze the characteristics of dry-wet events in the basin and study the occurrence regularity from the perspective of regional differences.

The annual PDSI values in 1961-2015 were selected to analyze the spatial distribution of dry-wet condition in the Zhujiang River Basin. Simultaneously, based the spatial patterns of REOF, the interior basin was divided. These results can provide theoretical basis about the understanding of dry-wet characteristics in the area and forecasting and relieving extreme climatic events.

2.  Study area, data and methods
2.1. Study area and datasets
The Zhujiang River is an important river in the Southern China. It is composed by the Xijiang River, the Dongjiang River, the Beijiang River and the Delta Rivers. The total length of the river is about

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2400 km, and the total area of its basin is about 4.6×105 km2. The Xijiang River Basin is further divided into four sub zones: Nanbeipan, Guibeit, Guizhong and Yuegui in this paper. The basin belongs to subtropical monsoon region. In the whole basin, the mean annual temperature is between 14-22°C and the mean annual precipitation is about 1525.1mm that is markedly reduced from east and west. Moreover, the distribution is uneven in one year time and there are big differences in regional distribution and inter annual variation. [5]

The weather data that was used to calculate PDSI is from China Meteorological Data Website (http://data.cma.cn). There are 45 stations in all and the time period is from 1961 to 2015. The soil data is from Harmonized World Soil Database of the Food and Agriculture Organization (http://www.fao.org).

2.2. Methods

2.2.1. Calculation of Palmer Drought Severity Index (PDSI)

PDSI can well represent regional dry-wet condition and is suitable for dry-wet monitoring and evaluation in different time scales [6]. Considered the impact of multiple factors of temperature, precipitation and soil type, the index was established by water supply and demand. In 2006, PDSI became the national standard in China after correction. The calculate steps can be found in [7]. The dry-wet classification is shown in Table 1. The classifications (Table 1) shows PDSI<=-1.0 indicates dry while PDSI>=1.0 indicates wet.

| Category     | Index value |
|--------------|-------------|
| extreme wet  | PDSI>=4.0   |
| severe wet   | 4.0>PDSI>=3.0 |
| moderate wet | 3.0>PDSI>=2.0 |
| mild wet     | 2.0>PDSI>=1.0 |
| normal       | 1.0>PDSI>-1.0 |
| mild dry     | -2.0<PDSI<=-1.0 |
| moderate dry | -3.0<PDSI<=-2.0 |
| severe dry   | -4.0<PDSI<=-3.0 |
| extreme dry  | PDSI<-4.0   |

2.2.2. Rotated Empirical Orthogonal Function (REOF)

Empirical orthogonal function (EOF) decomposes an original variable field X into spatial eigenvectors V, and associated time coefficients T (Eq.1) [8]. Meanwhile, EOF extracts the main information from X on some few eigenvectors in favor of analysis and processing.

\[ X_{mn} = V_{m\times p} T_{p\times n}, \]  

In this study, the REOFs are derived from the PDSI, which convert the dry-wet information into the rotated eigenvectors with both spatial and temporal significances. On the basis of EOF, REOF rotates eigenvector V further which makes the high loadings derived from the spatial patterns (denoted by EOFs in this paper) only exist in a certain region. It highlights the areas with high values in a smaller range which is easier to identify the spatial pattern. There is a high correlation between each spatial range and a loading vector after rotation. The dry-wet characteristics after rotation is more stable than that before rotation. So, the loading vectors can better represent spatial anomaly characteristics of dry-wet change. VARIMAX criterion of orthogonal rotation was selected to handle variable field PDSI. Detailed steps and formulas can be seen in [9].
3. Results and analysis

The spatial distribution of dry-wet condition in the Zhujiang River Basin (Figure 1) shown, most areas were in normal state of the dry-wet condition in 1961-2015. There are no obvious High value centers, especially in Nanbeipan Zone and Dongjiang Basin. The four low value centers of dry-wet distribution are Western Guibei Zone, Central Guizhong Zone, Northern Yuegui Zone, and the border area among Beijiang Basin, Xijiang Basin and Delta. The low centers are all in mild dry state. The dry-wet contours that locals in the neighbor of the stations in above areas are more concentrated, illustrates dry-wet spatial changes fluctuate dramatically.

Figure 1. The spatial distribution of dry-wet condition in the Zhujiang River Basin in 1961-2015

The distribution of dry-wet condition indicates there are some big differences in various areas. Therefore, this study divided the Zhujiang River Basin by REOF. In REOF1 derived from dry-wet variable field, the positive extreme areas of rotated loading vector are locating in Southern Nanbeipan Zone, Eastern Guizhong Zone and Central Yuegui Zone. The negative extreme areas are locating in Western Yuegui Zone and North-eastern Beijiang Basin. It represents the distribution pattern where the dry-wet trend in the Central Basin was opposite to the Eastern and Western Basins. In other words, the Central Basin was wet while the Eastern and Western Basins were dry, and vice versa. In REOF2, the positive areas are locating in Southern Nanbeipan Zone and Northwestern Yuegui Zone. The negative areas are locating in Northern Guibei Zone, Southern Yuegui Zone and Central Dongjiang Basin. It shows the distribution pattern in which the dry-wet trend in the Western Basin was opposite to the Eastern and Central Basins. In REOF3, the positive areas are locating in Delta and Southern Guizhong Zone. It represents the distribution pattern in which the dry-wet trend in the Eastern Basin was opposite to the Central and Western Basins. In REOF4, the positive areas are locating in North-eastern Yuegui Zone, North-western and South-eastern Beijiang Basin and Central Dongjiang Basin. The negative areas are locating in Southern and Eastern Nanbeipan Zone. It implies the distribution pattern the dry-wet trend in the Northern Basin was opposite to the other areas in the Basin. In summary, according to the distribution of the high loading areas in the first 5 REOFs, the Zhujiang River Basin is divided into 7 dry-wet climatic zones A-G (Figure 2).
4. Conclusion
Based on above results, this study found that:

1. In recent 55 years, Western Guibei Zone, Central Guizhong Zone, Northern Yuegui Zone, and the border area among Beijiang Basin, Xijiang Basin and Delta are in mild dry states. Meanwhile, the other areas are in normal state of dry-wet condition.

2. The Zhujiang River Basin can be divided into 7 various dry-wet climatic regions. To the other regional differences of dry-wet condition, for example, tendency, mutation and period, we need have further researches.

Figure 2. Climatic regionalization of dry and wet change in the Zhujiang River Basin

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