Decadal Variability of Summer Precipitation over Eastern China in Observation, Historical Reconstruction and CESM Simulation

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Introduction
Many recent studies have confirmed that precipitation over eastern China experienced decadal variation during the last 50 years. It has been found that these decadal shifts in precipitation are significantly associated with changes in global- or large-scale circulation, especially the shift of the Pacific Decadal Oscillation (PDO). However, not all of these studies were mainly based on observational data limited to within the last 50 years. Over longer timescales, the stability of these observation-based findings is unclear. Accordingly, in this paper, we investigate the decadal variability of summer precipitation over eastern China using long-term reconstructed and simulated precipitation data.

Data
(1) Observed and simulated precipitation
The monthly precipitation observations, which is from the China Meteorological Administration, includes data from 403 stations over eastern China (east of 105°E) for 1951–2014.

The simulated data is the control-run of the Community Earth System Model (CESM), which is started with a fixed pre-industrial external forcing. The simulation has a time span of 1200 years and spatial resolution of 2.5° longitude × 1.9° latitude for atmosphere (Fig.1).

(2) Reconstructed precipitation
The first is the Meiyu (rainy season dominated by the Asian summer monsoon) precipitation over the middle and lower reaches of the Yangtze River Valley (YZR) (Ge et al., 2008) and the JJA (June–August) precipitation over the middle and lower reaches of the Yellow River (Zheng et al., 2005) for the period 1736–2000. Both of them were reconstructed from Chinese historical archives of rainfall since 1736 (Fig.2).

The second is the regional dry–wet index (DWI) series over the North China Plain (NCP), the Jiang–Huai (JH) area, and the Jiang–Nan (JN) area during A.D. 500–2000 (Fig.3). These data were reconstructed from the grade of drought/flooding derived from descriptions of drought and flood disasters (with direct impacts on agriculture and society) recorded in Chinese historical documents.

Results
(1) Observed precipitation
Summer precipitation exhibits evident decadal variability with various phases in different sub-regions (Fig.4). There are significant correlation between the low-pass smoothed PDO index and precipitation in NCP (r=0.52), yet no correlations are found for JH and JN (r=0.04, -0.06).

(2) Reconstructed precipitation since 1736
Dominant cycle for the decadal variation of summer precipitation is 22–24yr over the NCP, and quasi-36yr over the YZR (Fig.5). Correlation coefficient for the 30-yr running interval between the decadal variation of JJA precipitation over the NCP and the Meiyu precipitation over the YZR shows that an opposite pattern of change occurs during 1736–80 and 1966–91, but a consistent pattern occurs in 1785–1834, 1886–1915, and 1942–60 (Fig.5 a-b). Generally, less/more precipitation over the NCP corresponds to a warm/cold PDO phase. Although the reverse pattern is found during 1916–78 between Meiyu precipitation and PDO index, their correlation during 1900–2000 is not statistically significant.

(3) PDO index from observation and reconstruction
PDO index series derived both from observations during 1900–2015 (released by the Joint Institute for the Study of the Atmosphere and Ocean) and tree-ring-based reconstruction for 993–1996 (MacDonald and Case, 2005).

Method
The sub-regions for decadal variation of summer precipitation over eastern China are identified by EOF analysis of the observation and simulation data of summer (May–September) precipitation (Fig.3). We identify three sub-regions according to the spatial patterns of the three leading EOFs, as follows: the NCP (35°–50°N, approximately); the JH area (30°–35°N, approximately); and the JN area (20°–30°N, approximately). Power spectrum analysis is then employed to detect the cycles of decadal variations of summer precipitation for each sub-region, and low-pass or band-pass fast Fourier transform (FFT) filtering smoothing is adopted to investigate their temporal evolutions. Correlation analysis is then performed to investigate the consistency of the decadal variations.

(4) Simulated precipitation
Dominant cycles of precipitation in three sub-regions: 22–24yr for NCP; 38yr for JH area; 22-23yr for JN area. PDO has dominant cycles of quasi-29yr and 42yr (Fig. 8).

(5) Proxy precipitation since A.D. 500
Dominant cycles of DWI in three sub-regions: 22-24yr and 70-74yr for NCP, 32yr, 45-48yr, 82yr for JH area; 44yr for JN area.

Conclusions
(1) Generally, dominant cycles of sub-regions in these datasets agrees with each other. The spectrum power of precipitation change in individual period bands varies greatly with time, which resulted in the change of correspondence between precipitation and PDO.

(2) Precipitation shows complicated variation even if there are no change of external forcing, which indicates decadal change of precipitation in recent years might be result of internal variability.