An assessment of monsoon precipitation changes during 1901-2001

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Introduction & Objective

Detecting the long-term changes of monsoon precipitation and understanding the potential mechanisms are of great scientific and societal importance. Although previous analyses of land precipitation include all the monsoon regions, the changes of monsoon precipitation during the whole 20th century have never been examined specifically. All regional monsoons are coordinated by the annual cycle of solar radiation. Hence, it is desirable to examine the monsoon variability from a global perspective.

The present study aims to address the following questions:

- 1) Is there any long-term trend in global land monsoon precipitation over the 20th century?
- 2) Does the precipitation over different monsoon regions change coherently and what is the distinctive leading mode?

Data & Analysis Method

➢Data Description:

(1) GPCC Full Data Reanalysis Version 4 for 1901-2002[1], resolution: 0.5º*0.5º ;

(2) CRU for 1901-2002, resolution: 0.5º*0.5º ;

(3) Precipitation anomaly data compiled by Dr. Aiguo Dai (Dai-dataset) for 1901-1995, resolution: 2.5º*2.5º;

(4) GHCN2, provided by NOAA/National Climatic Data Center, 5 degrees latitude/longitude grid for 1901-2002. This data set is gridded precipitation anomalies data calculated from the GHCN V2 monthly precipitation data set[2].

(5) The original station rainfall monthly data from the GHCN2 is also used.

➢ Analysis Method: As Wang and Ding (2008)

1. Global Monsoon Domain:

(1) Precipitation Index (GMPI): GMPI=Annual Range/ Total Annual Rainfall

Annual Range= $PR_{JJA}-PR_{DJF}$ (in North Hemisphere)

$PR_{DJF}-PR_{JJA}$ (in South Hemisphere)

(2) Global monsoon precipitation domain can be delineated by Annual Range exceeds 180 mm and AR exceeds 35% of the annual total rainfall

2. Monsoon Intensity Index (MII)

NH MII: NH-averaged JJA rainfall falling in the monsoon domain

SH MII: SH-averaged DJF rainfall falling in the monsoon domain

GH MII: SH MII + NH MII

Changes of global land monsoon precipitation

a. Monsoon domain

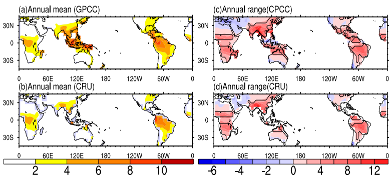
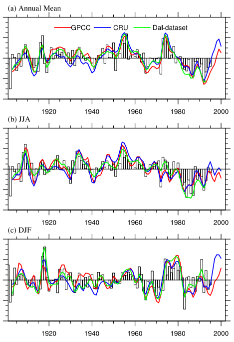


Figure1: The climatologically mean rainfall and annual range, The bold lines in (c) - (d) are the global monsoon domain.

➢The main features of Fig. 2a and Fig.2b, Fig.2c and Fig.2d resemble each other. The largest discrepancy is over Central America, where GPCC has heavier rainfall than CRU.

b. Seasonality of global land monsoon precipitation changes



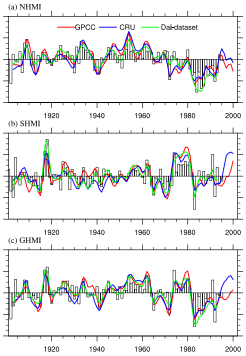
➢The standard deviation of three datasets ensemble mean is 34.9 mm, 15.4 mm and 12.4 mm for the annual, JJA and DJF, respectively.

➢The above-normal anomalies during the period of 1950-1960 of annual and JJA precipitation are robust from the perspective of the 20th century.

➢The increasing trends of annual precipitation for 1901-1955 and drying trends of annual and JJA precipitation since 1955 derived from all datasets are statistically significant at 5% level by using Trend-to-Noise(T-N), M-K and Monte Carlo (MC) significance test methods.

Figure 2: Normalized time series of monsoon precipitation: (a) annual mean, (b) in JJA, (c) in DJF.

c. Changes of global land monsoon precipitation intensity



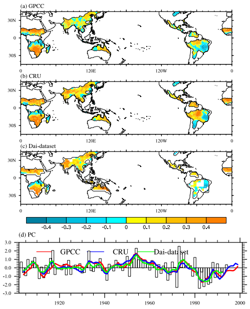
➢The standard deviation of ensemble mean is 25.4 mm, 28.0 mm and 33.6 mm for the NHMI, SHMI and GMI, respectively.

➢Overall, the time series indicate significant decreasing trend in the NH MII index and global MII indices (Fig.3a, c) across the entire 100 years, particularly after 1950,and only the trend of NHMI are statistically significant at the 5% level.

➢The NHMI derived from GPCC, CRU and Dai-dataset all exhibits an increasing trend during the first half century and significantly different from zero at the 95% confidence level by using three significance test methods.

Figure3: Normalized time series of MII, in (a) NH, (b) SH, (c) Global. The lines are 5-yr flitted indices.

d. Temporal and spatial structures of the global land monsoon precipitation changes



➢The leading modes show that most monsoon domains are dominated by positive anomalies. It may indicate the major characteristics of the spatial distribution of the global monsoon precipitation.

➢The PCs of three datasets all show an increasing tendency from 1901 to 1955, followed by a decreasing trend from 1950s, and then a recovery since 1980s.

➢The largest discrepancy is seen over the southern part of Tibetan Plateau. It may be due to the sparse data coverage over the Tibetan Plateau.

Figure4: The spatial pattern of the leading EOF mode of the normalized annual range over the continental monsoon regions and the corresponding principle components.

➢During 1901-1955 (Fig.5a,d), significant increasing trends are seen in most monsoon region, especially in northern hemispheric land monsoon.

➢For the period of 1901-2001 (Fig.5c, f), the monsoon rainfall intensity decreased significantly over North Africa and eastern India, but increased significantly in western Indian, Central American and Australian monsoon domains.

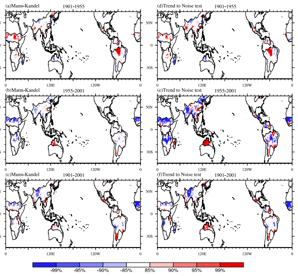


Figure5: Statistical significance of the linear trends in precipitation annual range at each grid point for different epochs

e. The impact of station-coverage on monsoon precipitation changes

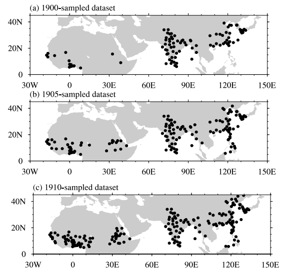


Figure 7: Distribution of rain-gauge stations with continuous or nearly continuous data in (a) 1900-sampled data, (b) 1905-sampled data, (c) 1910-sampled data.

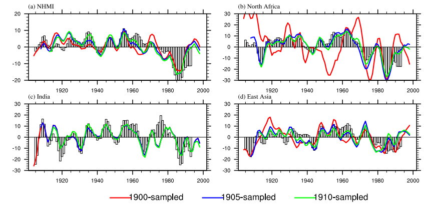


Figure8: Time series of JJA precipitation anomalies (unit: mm) for NH mean and regional monsoon domains in NH.

➢To estimate the magnitude of the station-coverage induced bias, we extract the stations with available observational JJA rainfall data since 1900, 1905 and 1910 from the updated GHCN2 dataset, respectively (Figure 7).

➢ The largest discrepancy is seen over the North African monsoon region. This is caused by the sparse station coverage over North African monsoon region in 1900-sampled dataset

➢The major features of NHMI, Indian monsoon and East Asian monsoon land precipitation changes can be seen in all the sampled datasets.

Summary

➢1) Over the 20th century, the global land monsoon precipitation (GMI) changes show an overall increasing trend from 1901 to 1955, and then a decline trend up to the present time. Overall, only the NHMI has experienced a significant decreasing trend across the entire 100 years, but this overall trend is actually resulted from the downward trend since the 1950s.

➢2) For the first half century, both the GMI and NHMI show increasing trends, and NHMI is statistically significant at 5% level. The obvious increasing trend of the northern hemispheric land summer monsoon precipitation during the period of 1901-1955 is mainly caused by the North African, Indian and East Asian monsoon precipitation.

➢3) EOF analyses of the precipitation annual range suggests that the first leading mode of global monsoon may be the major characteristics of the spatial distribution of the global monsoon precipitation.

➢4) Examination on the impact of station-coverage on monsoon precipitation changes reveals a relatively small influence of station-coverage, especially after 1905. the increasing tendency of the Indian and East Asian monsoon precipitations during the period of 1901-1955 is reliable. The upward trend during 1901-1955 and downward trend during 1955-2001 NHMI are real.

Discussion

➢ A clear explanation of the observed changes is needed.

➢ The impact of external forcing on global monsoon precipitation is still inconclusive.

➢ This study serves as a useful observational reference for the future modeling studies of long-term drought and pluvial frequency changes.

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☆ [1] ftp://ftp-anon.dwd.de/pub/data/gpcc/html/fulldata_download.html [2] http://www.ncdc.noaa.gov/oa/climate/research/ghcn/ghcngrid-prcp.html#data

☆ Ref. Lixia Zhang and Tianjun Zhou, 2011: An assessment of monsoon precipitation changes during 1901-2001, *Climate Dynamics*, **37**, 279-296. DOI 10.1007/s00382-011-0993-5