

Response to Referee #1's comments

Review of the manuscript, Linkages between ENSO/PDO signals and precipitation, streamflow in China during the last 100 years.

Many thanks for the invaluable comments from the reviewer for improving the quality of our manuscript. Each of reviewer's comment has been responded carefully, and also, the following sentence was added in the acknowledgement section: *"We wish to thank the editor and all anonymous reviewers for their invaluable comments and constructive suggestions used to improve the quality of the manuscript"*.

General comments: The paper under review investigated the relationship between ENSO/PDO and precipitation, streamflow in China. This study is interesting and the presented results are relevant for water resources prediction and management in China. However, the presented analysis did not consider the impacts of human activities on streamflow when examining the relationship between the ENSO/PDO signals and streamflow in major rivers of China, where human activities are the dominating factor leading to significant changes in runoff during the past decades. In this case, the observed streamflow is not expected to reflect the natural variability well. Overall, I recommend the MS to be published after some revision.

We totally agree with the referee that the observed streamflow is affected by human activities over the past 50 years, and there is no doubt that *"natural runoff"* is the best choice for researching the linkages between streamflow and ENSO/PDO. However, the methods for estimating *"natural runoff"* always require many detailed information which is extremely difficult to collect in China. Moreover, the accuracy of the naturalized runoff series is hard to test. Actually, we aimed to examine whether the observed streamflow was also affected by ENSO/PDO after human activities/land use changes in this study. Considering the observed streamflow is a mixed signal influencing by climate variability and human activities, the precipitation data which has limited impacts by human activities was used simultaneously for comparing its responses to ENSO/PDO with that for streamflow. Some comparisons and discussions could be found in our paper, for example:

(1) P4244 L8-L10: *"Moreover, the ENSO influences on streamflow are spatial-temporally consistent with that on precipitation for the major river basins over China with obviously differences among months and basins."*

(2) P4247 L2-L4: *"The 'annual' streamflow changes shown in Fig. 7 are basically consistent with those for precipitation during warm and cool PDO phases against the long-term average, although there are no significant trends tested."*

(3) P4249 L21-L29: *"Overall, the El Niño/La Niña-related precipitation/streamflow experience similar variability during the warm/cool PDO phase except for the Songhua River basin in the cool PDO phase. Moreover, the streamflow, which is also influenced by many other factors such as global SST, longwave radiation, snow and human activities (Xu et al., 2007), seems to be more sensitive than the precipitation during the El Niño/La Niña periods in both warm and cool PDO phases (Fig. 9). However, the general influence patterns of the combined effects are*

basically consistent.”

Specific comments 1. P4239, The background information of the 4 major river basins such as basin average precipitation, runoff, size etc. are necessary to give readers an idea of the river basins under study. Furthermore, there is a general lack of justification of the selection of the 4 river basins, gauging stations and the study period. Also, the information are missing regarding the spatial extent of the precipitation data, the sources and quality of streamflow data, the geographical characteristics of the gauging stations.

We totally agree with the reviewer, and more background information about the four major river basins (including the drainage area, data periods, annual mean streamflow/precipitation, the geographical characteristics of the gauging stations...) have been added in the revised manuscript (see the added paragraph below and Table R1).

How about the streamflow data quality? How the 4 river basins represent water resources in China? Do these stations represent the study basins well? Are they homogeneous? Any missing data? Since the study period is very long (1901- 2009), there could be discontinuities in the data set, the stations also could be relocated during the period. For example, there is missing data from 1919-1933, 1935- 1946, 1947-1948 at Huayuankou station. How the authors deal with the missing data and data nonhomogeneity?

Actually, there are only a few gauging stations (which generally locate at the main channels of several big rivers and play an important role on the water resources in China) have continuous streamflow observations during the last 100 years in China. The river basins chosen in this study cover the locations from approximately the northern China to south and main representative climate zones in China. Therefore, they are expected to be able to represent the water resources variability over China. For the precipitation data, as we mentioned in the manuscript, the spatial extent we used is the entire China extracted from the CRU gridded data. Moreover, the streamflow data used in the study is the quality-controlled observed records obtained from the National Hydrology Almanac. Additionally, there is a mistake in the Table 1 in the old version because that we did not use the 100 years data at Huayuankou station due to the missing data. We used continuous 100 years annual streamflow record at Sanmenxia station and monthly streamflow record at Huayuankou station to represent the streamflow change in Yellow River. For more information, please refer to the added paragraph below and the modified Table 1.

“Only a few gauging stations have continuous observational records during the last 100 years in China. The gauging stations were chosen considering the location, length of the observation period and quality of the data observed. The four selected gauging stations are Harbin Station in Songhua River basin, Shanxian Station (renamed Sanmenxia Station in 1950) in Yellow River basin, Hankou Station in Yangtze River basin and Wuzhou Station in Pearl River basin. All of them are located on the main channel of the rivers as control stations. The location of the gauging stations and the four river basins can be referred to Fig.1. Songhua River basin, Yellow River basin, Yangtze River basin and Pearl River basin, being the four major large river basins in China, cover approximately from the north to south of China and almost climate types of

China. Songhua River basin located in the north of northern China belongs to the zone of temperate monsoon climate. Yellow River basin can be divided three sub-regions (i.e. the eastern monsoon sub-region, the arid and semi-arid sub-region, and the high-elevation subregion), which is accordance with the three natural zones in China (Liang et al. 2014). The southern part of Yangtze River basin is close to the tropical zone and the northern part is close to the temperate zone. Pearl River basin covers a region of subtropical to tropical monsoon climate straddling the Tropic of Cancer. The study basins are expected to be able to present the streamflow variability over China under climate change. Then, in this study, one hundred years (1901-2009) of continuous quality-controlled annual streamflow data and fifty to a hundred years of monthly streamflow data were collected from National Hydrology Almanac.”

2. As mentioned above, the observed streamflow are largely affected by human activities over the past 50 yr. In this case, changes in streamflow are mainly due to human activities rather than natural variability such as ENSO/PDO. Moreover, changes in land use/cover have to be taken into considerations when the authors look into 100 years time period. So how do the authors know whether the variability of streamflow is due to natural variability or other factors such as human activities and land use changes, etc.? In this case, I would suggest focusing on the unregulated period or natural runoff.

Thanks for the referee’s suggestion, please refer to the same responses for the General Comments. Moreover, we also added a paragraph in Section “Summary and Conclusion” (after P4251 Line 6) as follows:

“The variability of streamflow corresponding to ENSO/PDO is roughly consistent with that of precipitation on the annual scale. On the seasonal/monthly scale, its response seems more complex than precipitation. It is obviously that the streamflow is also affected by more other factors such as human activities and land use changes. However, ENSO and PDO still showed a significant influence on the observed streamflow among all four major basins in China.”

3. The study examined the relationship between ENSO/PDO signals and precipitation, streamflow in China base on mean value. The paper could have been more valuable if the authors looked in depth at the relationship between the extreme precipitation events and ENSO/PDO. Extreme events over past 100 years will be particularly interesting to investigate.

Thanks for the referee’s suggestion. The main contributions of this study are: (1) The linkages between precipitation/streamflow and ENSO/PDO were investigated using 100 years’ data; and (2) the combined effects of ENSO and PDO were considered. Based on these two points, we conducted this study based on the mean values to add our basic knowledge on the influences of ENSO/PDO on the water resources in China. We totally agree with the reviewer that the relationships between the extreme precipitation events and ENSO/PDO as well as other forecasting works are particularly interesting to investigate, but they are beyond the scope of this study. Additionally, the potential further works of this study have

discussed in the end of Section “*Summary and Conclusion*”.

4. To quantify the strength of the teleconnection and to investigate the potential for forecasting, lag correlation rainfall, streamflow and ENSO/PDO is also necessary to determine.

Please refer to the responses in specific comments 3, thanks.

P 4241, what is the significant level?

The $p = 0.05$ significant level was chosen for determining if the average precipitation/streamflow received during the PDO warm phases/La Nina periods was statistically different from that received during the PDO cool phase/El Nino period. “at the 0.05 significant level” were added following the sentence “.../El Nino period.” In Line 23 in P4241.

P4243, “in the eastern and southern China (including the pearl River.. and Yellow River”
I don’t agree that the Yellow River is in eastern and southern China.

We have deleted the words in the brackets (“including the Pearl River ... and Yellow River” and “including the Songhua River”) in Line 9 in P4243 to make it more readable and understandable.

“ which to some extent would lead to uniformly ...” How can different ENSO influences among different parts of the basin lend to uniform streamflow response? I expect uneven streamflow response.

The descriptions are incorrect; we have deleted this sentence in the revised version.

Others P4236, L10, “especially in the October and November”. Change to: especially in October and November. L20, rephrase the sentence “with the ENSO-related precipitation/streamflow...in the cool PDO phases” P 4237, “There are various studies extensively documented the linkages...” Change to: There are various studies extensively documenting the linkages...” “ which does not assume normality....’ Change to: “and does not assume normality....” P4242, “The influence of El Nino...are found have obviously...” Change to: “The influence of El Nino...are found to have obviously...” The same applies to P4244, L10-15. L20, “discrepant” changes to “discrepancies”

All incorrect sentences/words were corrected/rephrased in the revised version based on the reviewer’s suggestion. Thank you very much.

Table R1 Background information of the four selected river basin in this study

River basin	Station (Location)	Drainage area (km ²)	Annual streamflow record period	Monthly streamflow record period	Annual mean precipitation (mm)	Annual mean streamflow (10 ⁸ m ³ /a)
Songhua River (I)	Harbin (126°46'E, 45°45'N)	390,526	1901-2009	1901-1948,1953-2004	491 (1901-2009)	386 (1901-2009)
Yellow River (II)	Sanmenxia (111°22'E, 34°49'N)	688,421	1901-2009	-	385 (1901-2009)	489 (1901-2009)
Yellow River (II)	Huayuankou (113°40'E, 34°54'N)	730,036	-	1950-2004	449 (1901-2009)	555 (1950-2004)
Yangtze River (III)	Hankou (114°18'E, 30°37'N)	1,488,036	1901-2009	1901-2004	887 (1901-2009)	7256 (1901-2009)
Pearl River (IV)	Wuzhou (111°30'E, 23°48'N)	329,705	1901-2009	1950-2004	1307 (1901-2009)	2175 (1901-2009)