

## **Historical droughts in the Qing dynasty (1644–1911) of China and the role of human interventions (cp-2019-115)**

### **Response to Referee#1**

**Note: Referee comments are shown in blue color and our responses in black.**

This is an important topic in the research on past climate change. The topic also fits the journal. It cannot be accepted for publication, because there are lots of problems must be solved seriously. First, the manuscript selected the drought and reconstruction and its impact on human society. So far, there are lots of studies in this direction. May I know the innovative points of this manuscript, in comparison with these existing findings? The authors did not make it clear.

Response: There are indeed a lot of studies focusing on historical droughts in China, Asia, Europe, North America and other continents. In the manuscript (abstract and introduction), we have mentioned that tree rings, PDSI, and documentary records are important sources for reconstructing drought. The longest and most popular approach in China especially for reconstructing drought from documentary sources is the use of the dryness-wetness index which represents a sophisticated and mature formula to judge records and assign records ordinal scale values to form the data (see page 3-4 of the manuscript). The index system is admirable and well established, however it also presents some difficulties for readers to understand how the initial records are interpreted, the statistics of the raw data (i.e. amount of the records), and the robustness of the interpretation, for instance.

Our purpose in this study is to take advantage of the database and to develop a methodology that can enhance the transparency of data processing. So, the innovation is that it advances the methodology by displaying raw data profiles of the drought frequency and categorizing them into various groups through careful interpretation of the drought vocabularies recorded in the historical documents (e.g. pure drought vocabularies as meteorological drought, vocabularies with dried water body as hydrological drought). As shown in the manuscript, this methodology can largely increase the transparency of the raw data and test the robustness of the drought series by comparing different groups of drought records. For example, figure 2 and 3 illustrate good consistency between drought and severe drought and between meteorological drought and hydrological drought. To our knowledge, this study is among the pioneer studies of the like that endeavors to reveal and test drought records in the historical climatology field.

Second, there is a big gap between their aim and their methods. In the manuscript, “our objective is to make every drought and associated variables as literally clear and operationally independent as possible.” How the authors could evaluate the objective of “clear and operationally independent”? This object has not been discussed in the later sections. Did authors achieve the aim? Please clarify.

Response: As we mentioned in the manuscript (page 2-3), interpretation and identification of drought in the documentary records are controversial because it's often not clear the drought related to meteorological, hydrological, or other socioeconomic processes. In the meantime, previous practices of dryness-wetness or drought index generally integrate all those processes into five- or seven-scaled grading. For example, occurrence of locust plague, dried waterbody, crop failure and famine are all treated as criteria in grade judgement of the index system (Page 4 Line 19-27). The approach, while meaningful, presents a methodological difficulty to distinguish among those different processes and is not possible to statistically examine their correlations because all variables have been put in the composites. Thus in this study, we purposively define and separate different drought categories, and other variables like crop failure, famine, locust and socioeconomic turmoil to maintain their independency which will allow us to conduct cross check and statistical examination over their relations in the later analysis as shown in the Kernel density spatial pattern and network analysis.

Third, the authors are very proud of REACHES. I also read the paper introducing REACHES as shown in the reference of the manuscript. In fact, the database is from Compendium of Chinese Meteorological Records of the Last 3,000 Years (Zhang, 2013). This book is the basis for whole research and makes REACHES scientific and trustable. The authors should not over-emphasize the importance and innovation of REACHES.

Response: We are thankful for this constructive comment. REACHES presents a digital database and so far now everything of it comes from the Compendium (Zhang 2013). We have made this clear in the manuscript. We shall be careful not to give readers such an impression of overriding the original source, in the meanwhile, we shall be responsible to deliberate on data retrieval from the REACHES and data processing. We will make modification on this point.

Fourth, as mentioned by the authors, “To comprehensively compare and analyze drought and associated data series from the REACHES with other socioeconomic variables from independent data sources, several archival and index data were also collected for analysis.” May I know the similar or different features in the

records of these documents? The authors did not discuss enough to compare these sources

Response: The main body of the research is to deliver reliable drought and other associated variables' (e.g. crop failure, famine, locust) temporal trends and spatial patterns. Other archival and index data were used to cross check the drought analysis and to provide insightful information to explain the severe drought events. Those archival and index databases were previously established by different independent organizations. This is what we meant here for independent data sources. On page 8 Line 11-23, we have explained their sources such as grain price data (based on monthly grain price report), civil war data (from Chronology of China's Ancient Wars), and population data (from several different sources ranging from Registers of Quantities of Provincial Population and Grain Storage to The History of Population in China). One might suspect if these data series across grain price, wars, population and the Compendium (which constitutes REACHES) could come from similar groups of historical books. Our response is that the initial sources of those databases seem to have their separate specialities. There might be some coverage for a certain degree, but we are not sure the percentage and we believe this is not the work for the present study.

Fifth, there are different categories of drought recorded in the historical documents. Why there are different records in the documents? Please clearly explain the reasons to have these different records in historical documents. Then, the readers will know rationale of these categorizations and see the importance of this research.

Response: As mentioned before, 'drought' in historical documents is not a rigorous and conceptually straightforward word. (Page 3, Line 13-22) Several studies thus purpose four categories of drought: meteorological drought, agricultural drought, hydrological drought, and socioeconomic drought amplified by negative effect of drought to influence everyday life and social stability. All these definitions are explained in the manuscript. When ancient people wrote those records, they generally would describe what they saw of the phenomena and the related environmental and socioeconomic effects. This is why there are so many different descriptions of droughts phenomena in the records. So, to avoid mis-interpretation, we adopted the approach to seriously deal with and interpret the contents of the records and further categorize them instead of just putting them as same group definition of drought. We shall be more carefully discussing this in the revision.

Sixth, I am not convinced by the Kernel method. It is common to have the missing data in the documents among different regions. If using the number of records, the results will be disturbed by the data availability condition. The results are thus not reliable at all.

Response: Kernel density is an equation that calculates every grid value by considering the values of the geographically adjacent grids by assign the weights (Page 10 for detailed explanation). It is a very mature and common approach for spatial analysis. The algorithm is based on the original distribution of the raw data and not to transform the data. Its strength is to make the distribution pattern clearer by data smoothing, meaning the effect of outliers and noises can be lowered. In this case, blank (while) area mostly reflects missing value (=0) or very low value. All data analysis is subject to data availability. And compared to record frequency distribution as also shown on figure 6 (right panel), Kernel density maps clearly present rigid spatial pattern of the interested phenomena than pure frequency distribution maps.

Seventh, in Page 11, there are some linkages according to the one record, “the events would be decomposed and then displayed in a way that drought linked with rainfall, drought linked with frost, drought linked with rice price, rainfall linked with rice price, frost linked with rice price and so on to further calculate their pairwise coefficients.” It is not persuasive to have such findings by only one record. In fact, the authors should revise the whole manuscript to review their findings. Please avoid similar problems.

Response: This sentence as mentioned by the reviewer is a bad organized sentence (Page 11, Line 34-37). This single line of record does mention several different phenomena ‘occurring at different times of the year’. We will rewrite the sentence and make sure all algorithm is correct in the revision.

Eighth, please check the language. There are some typos. Such as, it should be Guang Ling but not Quang Ling in Page 11.

Response: Thanks for the correction. We will revise and check the language.

Ninth, the language is not clear and concise enough. There are many redundant sentences in the manuscript, such as Page 2 “Studying past drought and humidity has been a long practiced subject in historical climatology and paleoclimatology”. If the authors still want to keep these redundant sentences, why not add the references?

Response: We will check again the language and remove the redundant and unnecessary sentences to improve its quality.

In terms of reference, the authors have many judgements without the proofs from their articles. For example, Page 3 “Yet, tree ring reconstruction usually suffers from growing seasonality of trees and blurred interpretation of isotopes.” This is not your findings from the manuscript. There are many similar examples in the manuscript to show the authors are not careful enough to conduct the research and claim their findings.

Response: This comment is constructive; we will add references at appropriate places and avoid statements of the kind.