

We thank this fourth separate reviewer for the insightful comments and suggestions on the paper, which we provide detailed responses to below. We have enacted the majority of these, however for a few we felt there was good reason not to expand/develop or modify the text as suggested. We hope that the editor and reviewer are happy with our justifications and modifications made here and to the previous reviewers. Our responses are provided in italics below.

### **Responses to reviewer #4**

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)

1. The manuscript presents a data-driven study, meaning the authors should be more careful about the data quality. The authors checked the data homogenization between NCAR dataset and station observations in manuscript. However, station NO. 54342 **relocated** many times, **i.e. the year of 1970, 1976, 1989, 2006**, etc. A study mentioned (Li et al, 2014. Title: Effect of data homogenization on estimate of temperature trend and urban bias in Shenyang station; The abstract in English) relocations could affect record (i.e. temperature) due to the non-uniformity during observations. Therefore, it will be good to check: Whether and how does the relocations affect the precipitation?

***We thank the reviewer for drawing attention to this, we undertook this analysis originally but excluded from the paper, so we have inserted the homogenisation testing that we did, with a comment inserted on Line 257:***

*“The precipitation record for Shenyang has four station relocation’s/instrument renewals during its monitoring record (October 1970, October 1976, January 1989 and June 2006). An analysis of the homogeneity of the record was undertaken using the approach presented by Li et al. (2014), when assessing temperature changes in Shenyang. A correlation analysis of Shenyang with the nearby Benxi precipitation station record (~41 km southeast of Shenyang) demonstrates a stable difference (prediction ration) between the two series for all periods and an  $R^2$  throughout of  $>0.88$  (Table S2). In the absence of any evident changes within the precipitation record resulting from localised station relocation/instrument renewal we consider the precipitation data at Shenyang to be homogeneous and reliable.”*

***We have also include a supplementary table (S2) demonstrating this***

**Table S2.** Influence of relocated in Shenyang on precipitation data

Periods between station location changes	Shenyang (mm)	Benxi (mm)	Rainfall ratio	Relative change	R <sup>2</sup>
1955 JAN - 1970 SEP	60.61	67.75	0.89	0.118	0.89
1970 OCT - 1976 SEP	60.72	68.38	0.89	0.126	0.90
1976 OCT - 1988 DEC	57.14	64.28	0.89	0.125	0.88
1989 JAN - 2006 MAY	55.78	62.89	0.89	0.127	0.87
2006 JUN - 2012 DEC	60.87	72.16	0.84	0.185	0.88

2. Could you discuss the reason to use SPI-12 instead of SPI-6 more specific?

***Re: Line 357: We opted to use the SPI-12 in preference to SPI-6 (or shorter timescales), as precipitation in Shenyang has such a strong seasonal skew toward the summer months, use of SPI-12 also permits a stronger analysis of interannual drought, a key feature in this paper over the long-period analysed.***

3. The long-term drought series and documentary records from C.E. 1200 was a very interesting point of this study. This study period covers at least three types of government in China, including empire era, warlord era, and the current stage. Could you discuss the difference on societal impacts when a same/similar level of drought occurred during the different era/period, in particular for the pre-instrumental observation period? If possible, a further question, what's the difference on societal response when a same or similar level of drought occurred during the different period? Such as the leading group, government or local group/companies; the supporting funding, etc.

***This is an interesting point and we do discuss this briefly in section 4.3, however a detailed but concise discussion of this is not possible within the paper, though we acknowledge that it is an interesting and challenging point, such a discussion would require unpacking a number of socio-political aspects. We plan to explore this further within a subsequent paper for Beijing in which we have reconstructed a long monthly instrumental precipitation series back to 1724, with extensive historical records, we feel that this type of analysis is better suited to the Beijing study.***

4. Is **ENSO** the best natural driving factors for drought in Shenyang? Did you consider about sunspots, temperature/heatwave, or volcano eruptions (normally have signal in extreme climatic events)?

***In exploring long-term drought in Shenyang we considered the role of ENSO as several previous studies, using shorter series as noted in the paper, identify a relationship between drought and ENSO. Whilst we undertook a brief analysis of the relationship between volcanic events and droughts, no clear discernible relationship was identified. It is difficult using historical records to differentiate between***

***drought/temperature/heatwave, with these phrases and terms often interchangeably used to define the events. The influence of sunspots, or a proxy solar energy signal is something we are currently exploring further.***

5. ENSO effect precipitation was not a point to point impact (i.e. Wang et al, 2000; [https://doi.org/10.1175/1520-0442\(2000\)013<1517:PEATHD>2.0.CO;2](https://doi.org/10.1175/1520-0442(2000)013<1517:PEATHD>2.0.CO;2)). Each step need energy and time cost, thus, it may cause you hard to get high confidence on correlation if you use the ENSO series and droughts in the same season. Did you try correlated the pre-season ENSO to drought series (the level data, therefore your historical data could be included)? Such as spring drought to autumn/winter ENSO, summer drought to spring ENSO, etc.

***The use of SPI-12 actually helps address this issue, as in using the SPI-12 and lag or delay in the signal from the ENSO to precipitation should hopefully be captured, this is particularly true in Shenyang where the majority of the precipitation falls in the summer months, we also considered longer SPI- series timescales, however these failed to determine any further relationships. We do though recognise that there is a risk in using a longer SPI that some dilution of signal may occur.***

6. A brief comment on one of your results mentioned in manuscript many times (just a view sharing, you do not need add or explain this in detail in your work): It make sense of documentary records did not have pre-drought information, and the drought records normally started from spring. The dominant economic sector in historical China was agriculture, which is normally start from spring in north/northeast China. Therefore, personal diaries and govern documents record 'extreme/abnormal/disaster events' more than 'common records'.

**We agree, irrespective of location (co-authors have extensive experience of historical droughts in Europe), the recording of conditions of drought are difficult to analyse and the nature of the impact actually is a good indicator as to the point 'within a drought' that it starts to get recorded, as the impacts of drought are felt at different stages relative to the drought type, so a meteorological drought is often noted first, with a groundwater drought much later, with other droughts, hydrological, agricultural, socioeconomic in-between.**

Minor comments

1. line 63 remove the comma between author name and the following sentence, 'Wilhite and Glantz (1985), classified droughts'. Remove the dot between 'and' and 'drought' in line 90.

***Accepted. We are unable to find the issue on line 90***

2. Why you emphasis the ground water drought in line 64 to 65? And what the difference between the ground water drought and hydrological drought? According to the definition from USGS (<https://water.usgs.gov/ogw/drought/>), ground water drought is a type belonging to the hydrological drought. And in this study, you did not separate them into two types when classify drought types (line 334).

***We make the comment here simply to recognise that for some studies have separated groundwater droughts for hydrological droughts, this however is not a particularly important issue for Shenyang, but is for some areas of China and globally, with the two treated independently. Here in the UK they are now viewed separately.***

3. Line 75-76: the author list many events there. Two minor comments: a. add the season instead of year only, i.e. the spring and summer of 1975 and 1976 in Europe; b. add the special name of those events, just like you did for the USA event.

***We have not enacted this suggestion, as whilst the greatest impact may be felt in a particular season, the drought itself may span multiple seasons/year(s). Only one of these droughts is named as far as we are aware, that of the 'Dust Bowl' drought, which is internationally recognised and therefore appropriate in this instance we feel.***

4. Line 75 and line 80: check the reference published year: Zaidman et al. According to the paper name from your reference below, this paper published in 2002 (<https://www.hydrol-earth-syst-sci.net/6/733/2002/>), not the year of 2010.

***Accepted, this should be 2002.***

5. Line 100, I would suggest to keep number in the same format: 'four years' into '4 years'.

***Accepted.***

6. Line 116, 'a record of droughts' into 'the record of droughts'

***Accepted.***

7. Please pay attention to the abbreviations you used, they may confused your

readers. i.e. Line 137, 8'M' to 8 million; Capital 'M' also appear in line 395 and line 396. If you wish to abbreviate the million into 'M', please define it at the first place it shown. Line 248 'WWII' to the Second World War.

**Accepted.**

8. Line 170, you may need show the full name of 'REACHES' (Reconstructed East Asian Climate Historical Encoded Series) to your readers, which could help them understand the data type you used.

**Accepted.**

9. Line 186: you can directly write 'Shenyang was called Shengjing' in the brackets after Shengjing Times.

**Accepted. We have also linked to Table S1.**

10. Line 192: just need a quick check, are those NCAR data were gridded data or real station data? As you mentioned 'This dataset covers 60 relatively evenly distributed sites in China', which is, somehow, quite counter-intuitive. China has 60 stations with long term data series, but distribution were not 'evenly', at least east more than west; and from the link you attached this dataset was describe itself as 'Temporal/Geographical Coverage (each dot represents a 3° box containing one or more observations)', I'm not sure whether your 'evenly distribution' result from this. You need to check it, as gridded data with a spatial resolution of 3° x 3° (~300 km x 300 km) won't be a good choice for a city-scale study.

**We have removed this sentence as unnecessary and clearly caused some confusion. All data used is observed 'real' station data.**

11. Line 217 & 218 Could you put the period of the Han dynasty and Dong Han Dynasty?

**Accept, The beginning year of the dynasty and the name change of Shenyang are listed in Table S1 with details. We have added a reference to the Table here.**

12. Line 442: please give a percentage or number instead of the phrase 'most of'.

**Accepted, we have clarified and inserted (66%) after most.**