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Climate of the Past Discussions

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Interactive Comment

Interactive comment on "Climate patterns in north central China during the last 1800 yr and its possible driving force" *by* L. Tan et al.

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Thanks the three reviewers for their constructive suggestions and interesting discussion. Our replies are as follows:

Reviewer 1 (Dr. A. Mangini)

It is rather concise, and my suggestion is to slightly enlarge the part describing the application of the PCA. The authors should test how sensitive the PCA method is to uncertainties in the age models. A very simple test would be to run the PCA for slightly different chronologies (but not a whole Montecarlo test!) and to show how much the derived Precipitation Index varies as a function of the uncertainty of chronology.

Thanks for the constructive suggestion. Generally speaking, historical climate records have accurate dates, so we just test the influence of chronological uncertainties of the stalagmite records on the synthesized result. We run the PCA for an average age error of $\pm$ 8 yr (the drilling thickness, the dating errors, and the uncertainty in the slope of the linear fit in the age model were considered) to the Wanxiang record (Zhang et al., 2008) and an average age error of $\pm$ 26 yr to the Huangye record (Tan et al., 2011), respectively. The derived PC1 results show significant positive correlations ($R > 0.84$, $P < 0.001$) with the original one, indicating that the chronological uncertainties of the stalagmite series have no significant influences on the synthesized precipitation record.
We have added this paragraph to the revised manuscript. Please see line 79-107.

Reviewer 2

1. The authors do not present a figure in which they show the curves of the PCA. I would like to see such a figure of all PC 1-3 for all individual records, including the D/F index records. What is the influence of chronological uncertainties on the stacked precip. record?

Thanks for the constructive suggestions. We have added a figure to show the PCA result. Please see Fig. 3 in the revised manuscript.
For the influence of the chronology uncertainties, please see the reply to Reviewer 1.

2. Figure 5 and associated text: On page 1035 (lines 21-23), Tan et al. state that "On multi-decadal- to centennial-scale, there is a one-to-one correspondence between the peaks of the two series (synthesized precip. record and APO index)". I agree that there

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is a visual and also statistically significant correlation between both records shown in Fig. 5. However, there are also clear dissimilarities, such as between 1500-1600 AD and 1000-1100 AD. Thus, I would soften the statement ": : :one-to-one correspondence: : :". Furthermore, the numbering of the peaks in the synthesized precip. record is quite mysterious (at least to me). For instance, peak 7 is barely visible, whereas a distinct peak at around 1580 AD (between peaks 6 and 5) is not labeled. Please clarify.

Yes, there are some discrepancies between the two series at around 1000-1100 AD and 1500-1600 AD. These are probably caused by the uncertainties of the two reconstructions. We accept the suggestions and deleted the numbering of the peaks.
Meanwhile, we modified the state as "On multidecadal- to centennial- scale, there is good correspondence between the peaks of the two series". Please see line 186-187.
These modifications will not affect the conclusions of the manuscript.

3. It appears that solar activity has some influence on precipitation in north-central China. However, the spectral peaks of $\sim$ 160 and $\sim$ 35 yrs (Page 1036; lines 16-18) are not the typical solar cycles. Why is there no evidence for a 90-yr (Gleissberg cycle) or 200-yr (de-Vries cycle)?

There is a $\sim$ 80 yr cycle in our record, but it is not significant. Although we don't know exactly why there are no significant $\sim$ 88-yr and $\sim$ 200 yr solar cycles in our record, the $\sim$ 160 (from 142 yr to 178 yr) cycle was also found in the spectral results of atmospheric Delta ^{14}C residual data ($\sim$ 148 yr, Sonnett and Finney, 1990; Stuiver and Braziunas, 1993) and the TSI data (Scafetta and West, 2006). According to an energy balance model simulation (Wigley, 1988), the climate sensitivity to a 160-year TSI cycle might be 3–4 times stronger than the climate

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sensitivity to a 10-year TSI cycle.

We think the 160 yr (from 142 yr to 178 yr) cycle may have a close relationship with the Gleissberg cycle. Firstly, the Gleissberg cycle is not a strictly cyclic component. Ogurtsov et al. (2002) proposed that the Gleissberg cycle has a wide frequency band with a double structure, i.e., 50–80 year and 90–140 year periodicities. Usoskin and Mursula (2003) also suggested that the Gleissberg cycle is a typical variation with a characteristic time between 60 and 150 years. Secondly, the Gleissberg cycle may be modulated by the $\sim$ 200 yr de-Vries cycle (Peristykh and Damon, 2003). Finally, the $\sim$ 160 yr cycle may be a double Gleissberg cycle consisting of two Gleissberg cycles with different strengths (Javaraiah et al., 2005), like the double sunspot (or Hale) cycle consisting of two 11 yr cycles with reversing magnetic polarities (Georgieva et al., 2005).

Reviewer 3

1. In data and method section, the author used the drought/flood index to synthesize the precipitation variation. However, the index is not only affected by the precipitation, but also connected with the temperature, especially the drought. So the authors should give the evidences to support the changes of the drought/flood index most due to the precipitation.

Since the 1970s, Chinese climatologists have cooperated to extract climatic information from more than 2000 kinds of historical documents over the last 500 years, beginning in AD 1470. They used the method of 5-level classification to estimate series of yearly drought/flood (D/F) levels in the principal rainy seasons at 120 sites throughout the entire country, and have gained great success (Central Meteorological Bureau, 1981). The method of 5-level classification is based mainly on the time of occurrence, the affected area and the degree of drought

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and flood in spring, summer or autumn (Zhang, 1983). Detailed standards are as follows: Wet, heavy rain lasting a long time or occurring over a large area; Mildly wet, sustaining rain in spring or autumn that does not cause disaster or heavy rain break just in a local area; Fitting climate that gives rise to a big harvest year, or describes as rainy (dry) in spring but dry (rainy) in autumn; Mildly dry, seasonal drought within a month that does not cause disaster or severe drought just in a local area; Dry, severe drought that lasts several months, spans two seasons or occurs in a large area (Zhang, 1983). When there were drought records in historical document, there were usually accompanied descriptions such as "no rain from xx to xx, no rain for xx days", indicating that no rain was the main force of the drought.

There was continuous meteorological observation in China since the 18th century, recording in two documents: *Clear and Rain Records and Depths of Rainfall infiltration and Snowfall records* (Zhang, 1996). Based on Clear and Rain Records, Wang Zhang (1992) quantitative reconstructed the summer rainfall in Nanjing, Suzhou and Hangzhou since the 18th century. When compared with the independent drought/flood index series in the three sites, good coherences were observed. In addition, Zhang et al. (2008) and Tan et al. (2011) have compared their stalagmite δ^{18}O records with the D/F index record (Tan et al., 2008) in the same area. Broad similarities among these records not only support the interpretation of calcite δ^{18}O, but also confirm the precipitation interpretation of the D/F index.

These had been discussed a lot in many historical climatology studies (e.g., Gong et al., 1983; Zhang, 1996; Tan et al., 2008; and references therein), so we prefer not to discuss in the manuscript.

2. For the synthesized precipitation index, what the method be used to synthesize the index? the average value of four records, or the value weighted by the areas? It may be induce the different results using different methods. The authors need the

explanations in details. At the same time, please show the standard deviation or error bar for the statistics in the Figure 2.

The monsoon precipitation in north central China is positively correlated with the intensity of the EASM (e.g. Huang and Yan, 1999; Zhang et al., 2003). The analysis of rainfall datasets from all the meteorological stations in north central China showed a collective decreasing trend in precipitation during the last several decades (Qian and Lin, 2005). In addition, Tan et al. (2011) compared several high-resolution precipitation records from this area, and suggested synchronous precipitation changes in north central China on centennial- to multidecadal- scale during the last two millennia (please see introduction of the paper). This is the base of our synthesized reconstruction.
So, we just do PCA to the four individual records and assume the leading mode (PC1) of the four records represents regional (north central China) precipitation variability on centennial- to multidecadal- scale.
Two reasons caused that it's hard to give the error bar. On one hand, it's hard to evaluate the errors in the four selected series. On the other hand, the contemporary observation records are too short (1950-1980 AD) to calibrate our synthesized record, so we don't quantitatively reconstruct the precipitation amount. For this study, we think this will not affect the discussion and the conclusions in the paper.

3. For the precipitation and temperature patterns, because the variations of precipitation and temperature may be not the same in different areas, e.g., stalagmite δ^{18}O records in Huangye cave and Wangxiang cave, the trends of variations before 1000 AD are mostly reverse on the centennial scales (Figure 2). So the comparison of pattern of precipitation and temperature need choose the records at the same area, and the authors should give the reasonable explanations for why the temperature

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record of tree ring in Dulan, Tibeatu Plateau can represent the changes for northern central China.

As discussed before, the precipitation variations in north central China show regional synchronous on centennial- to multidecadal- scale during the last 2000 years. When discuss the precipitation and temperature patterns, we take north central China as an integer. There are discrepancies between the Wanxiang record and the Huangye record in 500-700 AD, but not reversed before 1000 AD, if compared carefully. As pointed out by Reviewer 2, single proxy record may be affected by local climate or uncertainties of reconstruction (chronology/proxy). Synthesizing multiple reconstructions is an important way to reduce the uncertainties of a single record, and to reflect objectively the regional climate change. Further comparisons show that our synthesized precipitation index can well reflect the common changes in precipitation of north central China on centennial- to multidecadal- scale (Fig. 4).
Liu et al. (2009) had compared the Dulan (DL) tree ring series with the observed temperature records in 13 stations over north central China during 1958-2000 AD, and found significant positive correlations. Therefore, the authors suggested the reconstruction can also represent temperature changes in north central China (Liu et al., 2009). We just follow the explanation as Liu et al. (2009) gave. As temperature may show consistent variability over a large region, it's no surprise to see this result. Broad similarities between the DL record and BQ record during the last 1000 years further confirm this explanation (Fig. 5).

4. In page 1035, lines 3-10, authors reveal that "This warm-dry pattern in the late 20th century is distinctly anomalous as compared to earlier times, which was characterized by warm-humid or cool-dry pattern." But in fact during the periods of 800-900 AD, and 1300-1400 AD, the warm-dry pattern is same as the 20th century in Figure4,

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so the authors can not deduce the conclusion “The anomaly may suggest that the dominant forcing of climate variability in north central China changed from natural to anthropogenic in the late 20th century”.

It seems that there were warm-dry climate in the late 9th century and the middle 14th century from the Figure. However, we have reason to believe that the slightly out-of-phase relationship between temperature and precipitation during these two periods were caused by uncertainties of chronologies in the reconstructions, if carefully compared. So, we still think the observed warm-dry climate in the late 20th century is anomalous under the background of the climate pattern during the last 1800 years.

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