Reply on RC1

Rudolf Brázdil et al.

Author comment on "Documentary-based climate reconstructions in the Czech Lands 1501–2020 CE and their European context" by Rudolf Brázdil et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2021-168-AC2, 2022

General comments

Based on documentary-based sources, annual and seasonal temperature, precipitation and drought indices were reconstructed in the Czech lands from 1501 to 2020 AD. The study was supplemented by wavelet analyses and an attribution analysis. The temperature series exhibits a statistically significant increasing trend, rising from about 1890 and particularly from the 1970s. In particular, it could be shown that temperature drops in summer are influenced by volcanic events, and that the fingerprint of the North Atlantic Oscillation becomes visible in the other seasons. Certain drought indices show an astonishing decrease over the last decades.

The resulting data set is extremely rich and extensive. The number and scope of the statistical analyses are, in my view very large (e.g. the high number of wavelets), and dynamic analyses are rather sparse. The text is very dense and precisely written, but it is a little short in view of the large number of figures. However, I would rather reduce the number of figures than vote for a text expansion.

I propose to accept the paper after a number of specific revisions.

RESPONSE: We would like to thank Heinz Wanner for a careful evaluation of our paper and raising important critical comments which we are trying to answer below.

Specific comments

-Page 3, line 19-24: Is it really necessary to calculate four drought indices? What is the increase in knowledge if the SPEI and the Z-index are added to the SPI and PDSI?

RESPONSE: The four drought indices belong to those used most frequently in drought papers. Each of them shows different aspect of drought both in terms of considered drivers as well as time scale. SPI reflects particularly to the deficit of precipitation compared to normal patterns, SPEI combines effects of precipitation and temperatures including evapotranspiration, Z-index and PDSI reflect particularly soil drought, calculated

without memory in monthly step (Z-index) or taking memory of drought into account (PDSI). There is not surprising high relationship between precipitation and SPI, but we do not see it as a reason to exclude SPI from our analysis. Because of reflecting of different aspects of drought, we would like to preserve all four drought indices in our paper since it would make the study useful to wider audience.

-Page 4, line 19-21: Why did you not use the most complete and modern volcanic data, e.g. by Toohey and Sigl, 2017?

RESPONSE: Using Toohey and Sigl (2017) data (eVolv2k) would also be potentially possible, but their dataset only covers period up to 1900 CE (and extension by a different series would therefore be needed). Moreover, as discussed by Toohey and Sigl themselves, only relatively minor differences exist between eVolv2k and prior reconstructions (including volcanic aerosol optical depths by Crowley and Unterman, 2013, i.e. the data employed in our paper) after *c.* 1250 CE, i.e. no major change in volcanism-related results should result from switching to eVolv2k data.

-Page 4, line 28: You suggest to include PDO, combined with AMO. Are you convinced PDO (combined with an AMO Index) can significantly affect the climate of the Czech Lands? AMO correlates with the NAO and is – in a new paper - additionally questioned as an explaining mode by Mike Mann.

RESPONSE:

Regarding inclusion of PDO: as previous analyses (such as Mikšovský et al., 2019) have suggested, there is a quite distinct (and statistically significant) component in multicentennial central European drought series correlated with PDO phase, both on its own and in combination with AMO. This is also reflected in our results (as seen from the regression coefficients in Fig. 11, which indicate a significant link between all the drought indices and the AMO-PDO predictor).

Regarding relation of NAO and AMO: While there certainly may be dynamical links between AMO/AMOC and NAO (a matter that is still a subject of ongoing research and debate), please note that for predictors included in our analysis, almost no correlations exist (as seen from Fig. 10b – now Fig. S1 in the Supplement of the revised manuscript, Pearson correlations of NAO to AMO+PDO and AMO-PDO series are 0.00 and 0.01, respectively). As such, these series each represent a relevant explanatory factor, while being mutually independent (at least in linear statistical sense).

-Page 5, line 39, Fig. 2 a: Can you explain the changing correlations around 1900?

RESPONSE: Accepted, we created the new section 5.1, where we added the paragraph with this explanations (please check it in the context of the whole Section 5.1): "An interesting aspect of lost common signal manifested by a decrease in running correlations below the 0.05 significance level can also appear in the "instrumental part" of the reconstructed series as documented in Fig. 2a. Running correlations of annual temperatures with other five climate variables are highly significant from the 16th century up to the early 19th century. These negative correlations are physically consistent as they show that higher temperatures usually correspond to low precipitation and *vice versa*. Approximately from the mid-19th to the mid-20th centuries correlations among all

compared series are not significant. Despite the fact, that annual means express some mixture of different seasonal patterns, this gradual loss of common signal may be interpreted as follows. The fact, that before the 19th century the series are reconstructed from dependent (and thus less variable) temperature and precipitation indices, can be reflected in significant correlations. The instrumental parts of series (target data) are mutually less dependent and more variable than indices. The same patterns as in annual values (Fig. 2a) are well expressed also in SON series and partly in MAM and JJA series, while they do not occur in DJF series (non-significant correlations over the whole period) (not shown). The stronger common signal (significant negative correlation) occurring during the last decades can be attributed to a clearly expressed opposite tendency of rising temperatures and decreasing drought indices. The same pattern does not change even when correlating the detrended series or when changing the length of the window, for which running correlations were calculated."

-Page 6, line 13 and 14: Can you explain the dryness between 1991 and 2020? The positive temperature trend should nevertheless lead to an increase in humidity and precipitation.

RESPONSE: The expectation that "the positive temperature trend should nevertheless lead to an increase in humidity and precipitation" is not followed by measured data. Despite there is statistically significant and quite dramatic increase in temperatures (cf. Zahradníček et al., 2021), it is not followed by precipitation totals, which are generally keeping the same level without any statistically significant trends (cf. Brázdil et al., 2021). It is then reflected in quite dramatic increase in dryness.

-Page 6 + 7, Figs. 7 and 8: I think the inclusion of phenological data is really excellent!

RESPONSE: Thank you.

-Page 7, Figure 9: For me this Figure looks a little like an "overkill". What is the dynamic interpretation behind the very dense Figures?

RESPONSE: Fig. 9 is meant to illustrate variations of wavelet spectra between different variables and seasons (both their similarities and contrasts), plus to compare the spectral structure of documentary/instrumental series to their phenoclimatic counterparts. For this reason, we decided to include all seasons and a reduced selection of target variables (temperature, precipitation and SPEI). Although this admittedly results in a somewhat sizeable figure, it allows the reader to assess robustness of individual spectral features (or lack thereof). We do not provide a dynamical interpretation specifically for the (cross-)wavelet spectra, as they only consider harmonic oscillations in the data (which are typically not dominant components in the series analysed, and thus only capture part of eventual links); we do however use these results in our aggregate interpretation of the results in Discussion.

-Figure 10, attribution analysis: The information on this Figure is extremely dense and not easily readable. Would it not make sense to simplify the Figure and to sort out the really significant correlations, which can point to significant dynamic processes?

RESPONSE: Fig. 10 may have indeed conveyed information that is not essential to the message of the paper. We have therefore moved the correlation matrix (Fig. 10b) to the Supplement (while the mutual correlations of predictors and predictands may be of some interest to the readers, they have mostly been included to illustrate structure of the regression design matrices). As for correlations pointing to significant dynamic processes, please note that even significant correlations do not necessarily imply dynamical/causal links (e.g., the strongest inter-predictor correlation (r = 0.45) is indicated between greenhouse gases forcing and solar activity in our analysis, yet this does not represent an actual causal link). We do therefore not attempt to interpret correlations this way.

-Figures 12 and 13: Same comment as for Fig. 9. Do the numerous figures allow plausible dynamic statements?

RESPONSE: Similarly to Fig. 9, these represent a selection that is supposed to capture differences/similarities between spectra pertaining to different pair-wise relationships (so that the most robust features can be inferred), but only using the most relevant plots (since there are dozens of potential combinations of predictor/predictand/season). Again, the results are not discussed on their own, but rather alongside other analyses in the Discussion. Moreover, we decided to move Fig. 13 to the Supplement (as Fig. S2).

-The question of the spatiotemporal representativeness of the Czech data is extremely important. I only wonder whether 5 Figures are needed for this (Fig. 14 - 18). Figure 15 in particular is highly interesting and should be interpreted further.

RESPONSE: All Figs. 14-18 (newly Figs. 13-17) we see as very important to demonstrated the spatial representativeness with respect to temperatures, precipitation and drought. Moreover, Fig. 18 (newly Fig. 17) shows if this spatial representativeness depends on reconstructed (from documentary data) and measured parts of our 520-year series (the related paragraph was moved to the end of Section 4.4, where it fits better than in Discussion). All these figures we see as very important in the manuscript to show European context of our Czech series. To follow the referee request we tried to extend description to Fig. 15 (newly Fig. 14) in different parts of the new Section 5.1 (please check in the context of the whole new section): "However, a closer look at relationships between the two compared reconstructions in Figure 14a reveals another problem. Calculation of JJA temperature differences between reconstructions by Dobrovolný et al. (2010) and Luterbacher et al. (2004) shows positive differences before the mid-18th century and negative afterward. This shift is responsible for a sharp decrease in running correlations. In order to evaluate this inconsistency, differences of these two series with regard to completely independent JJA multiproxy temperature reconstruction for the Alps by Trachsel et al. (2012) were calculated. For better comparison, the series were first transformed to have a mean of zero and a standard deviation of one. While the differences with the series by Dobrovolný et al. (2010) were distributed more or less randomly around zero, the differences with the Luterbacher et al. (2004) series showed the same patterns as described above: positive differences before the 1750s (i.e., higher temperatures by Trachsel et al., 2012) and negative differences afterward. This indicates that the problem of lost coherence around the 1750s in Fig. 14a cannot be attributed to Dobrovolný et al. (2010) reconstruction."

Formal aspect

Reconsider the order of quotations with the same name: Oldest or youngest quotation first?

RESPONSE: We used standard style of quotations as requested by the journal.