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Climate of the Past Discussions

Interactive comment on "Reconciling reconstructed and simulated features of the winter Pacific–North-American pattern in the early 19th century" *by* D. Zanchettin et al.

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We thank the Reviewer for his/her appreciation of our work and appreciate his/her helpful comments. Below, we reply to his/her specific comments.

1. Pg. 4430. Ln. 23-25 Because the authors argue that volcanic activity can play a role in anomalous positive PNA values from early 19th century, an aspect not discussed in TT2010 paper, it would be useful at this point to have more information in the manuscript about the processes behind volcanic activity and PNA dynamics.

Reply: The possible link between volcanic eruptions and the PNA was briefly mentioned in the introduction (page 4428, lines 9-12). In section 2.1 of the revised

manuscript, we refer to Li et al. (2013) and Zanchettin et al. (2014) for details on possible mechanisms underlying this link.

2. Pg. 4430. Ln. 20-25. It is argued that anomalous long period of positive PNA index during early 19th century could be related to both low solar activity (Dalton minimum) and strong volcanic activity. Is this coincidence unique in the observational and simulated periods considered in this study?

Reply: No, the coincidence is not unique: reconstructions of solar and volcanic forcing for the last millennium suggest that volcanic clusters also occurred during other periods of weak solar activity (e.g., mid 15th century). We briefly mention this in the discussion of the revised manuscript by adding the following sentence: "Further supporting this hypothesis, the simulations ensemble does not point to coherent positive PNA anomalies during other periods of the last millennium with concomitant strong volcanic forcing and weak solar forcing, e.g., the mid 15th century and the late 17th century (Figure 4a)."

3. Pg. 4432. Ln. 1-5. Usually the anomaly centers of teleconnection patterns in model simulations are located in different positions, according to model characteristics. Therefore is better to define the PNA index according to model characteristics, usually through an EOF analysis of Z500 in the Pacific North American sector. Is the PNA the dominant pattern of Z500 winter variability in the Pacific North American sector in the model simulations? Furthermore, are the results presented in the paper sensitive to the definition of the PNA index?

Reply: We agree with the Reviewer that centers of action of climate variability modes in climate simulations are sometimes displaced compared to observations. Our choice to use the modified pointwise method for PNA calculation stems from the need to base the pseudo-proxy analyses on an index that is independent of the temporal domain considered for its construction. EOF-based indices are, instead, dependent on the chosen temporal domain. Furthermore, if PNA centers are displaced in a model, we

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should then accordingly modify the regions used in that model to sample predictors for the pseudo-reconstruction experiments. Therefore, using an EOF-based PNA index would complicate the interpretation of our results on several levels. Besides, our definition allows for a straightforward description of models' skills in reproducing observed PNA features. We nonetheless recognize the importance to assess, at least briefly as done here, the differences between PNA indices in order to increase confidence in our conclusions. We added supplement Table S1 to the revised manuscript, which provides a comparison between PNA indices calculated based on the modified pointwise method (mpm, as originally used in this study) and on EOF analysis. It is difficult to individuate the PNA pattern consistently across models as given EOF or rotated EOF based on northern hemispheric 500 hPa geopotential heights (Z500), so we focus on the Pacific/North American domain (0-90°N: 120-300°E) and define a PNA index for the observational period as the principal component of the first EOF of DJF Z500 over such domain. The results indicate overall highly significant correlations between the mpm-based and EOF-based PNA indices. The correlation is strongest for reanalyzed indices that are practically undistinguishable (see caption of Table S1). In the following, we provide more detailed information about the comparison, which we do not include in the revised manuscript. Spatial correlations between simulated and reanalyzed northern hemispheric patterns of EOF-based PNA indices vary quite remarkably across the simulations, similarly to what was diagnosed for the mpm-based indices. The quality of the EOF-based PNA pattern worsens for FGOALS-gl compared to the mpm-based pattern, due particularly to a $\sim$20° westward displacement of the negative center over the subtropical western Atlantic (a similar issue affects also MIROC-ESM). The EOF-based PNA patterns of both GISS-E2-R simulations worsen compared to the corresponding mpm-based patterns, as the hemispheric imprint in the former incorporates features of the annular mode. Patterns remain overall unchanged for BCC-CSM1-1, CCSM4 and especially IPSL-CM5A-LR and MPI-ESM-P.

We have summarized the above in the following paragraph, which has been added to section 4 of the revised manuscript: "Our definition of the PNA index does not ac-

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count for possible displacements of its centers of actions in simulated patterns compared to reanalyses. An alternative definition based on empirical orthogonal functions (EOF) results in PNA indices that share between half (MIROC-ESM) and almost the whole (CCSM4) total variance with the pointwise-based PNA indices over the observational period (see supplementary Table S1). Spatial differences between simulated EOF-based and pointwise-based patterns also vary considerably across the ensemble (Table S1). It is not yet clear whether and how these uncertainties related to the index definition affect the details of the pseudo-reconstructions. The validity of our general conclusions clearly stands for the sub-ensemble including only models with the most consistent PNA indices across the two definitions (CCSM4, IPSL-CM5A-LR, MPI-ESM-P)."

4. Pg. 4433. Ln. 17-19. Please define clearly the three regions over the North America used for pseudo-reconstructions.

Reply: done (see changes in section 2.1 of revised manuscript).

5. Pg. 4435, Ln. 9-10. It is expected to have a PNA like structure in all models due to the definition of the PNA index. An EOF analysis of Z500 in the Pacific North American region would confirm better if the PNA structure is captured or not in the model simulations.

Reply: see our reply to comment 3.

6. Pg. 4437. The paper is focused on TT2010 PNA reconstruction which is based on three tree ring records. As the relationship between tree ring variability and climate forcing present strong seasonal characteristics, would be interesting to see if significant simulated temperature or precipitation anomalies are recorded over northwestern North America during early 19th century not only in winter (Fig. S11) but also in other seasons. The TT2010 tree rings records are significantly correlated with temperature and precipitation not only from winter but also from other seasons. In fact the highest correlation is obtained for MTE tree ring record and summer temperature (Fig. 2

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from TT2010). Therefore the anomalous reconstructed PNA values during early 19th century could reflect also the autum, spring or summer temperature or precipitation anomalies from the northwestern North America.

Reply: as we stated on page 4434 of the originally submitted manuscript, we detect the strongest signals in winter temperature and precipitation. As we stated in the manuscript, the latter are needed to be included as predictors in order to obtain calibration skills comparable to the original reconstruction by Trouet and Taylor (2010). The best skills (in analogy with Figure 7b) of a pseudo-reconstructions obtained using winter temperature for the Alaska box, winter precipitation for the Montana box, and summer temperature for the Wyoming box (a setting reflecting the strongest correlations in Figure 2 of Trouet and Taylor, 2010) are presented in the figure below. Many of the so-obtained pseudo-reconstructions are not skillful, with only a few of them exceeding the R2 value of 0.4. Calibration skills are similarly below the scores obtained by Trouet and Taylor (2010). We have added in the revised manuscript the following sentence in section 2.3: "In particular, reconstruction skills considerably degrade if the predictor for "Wyoming" is defined as summer temperature instead of winter temperature (see section 2.1)."

Figure caption – Same as Figure 7b of the main manuscript but using winter temperature for the Alaska box, winter precipitation for the Montana box, and summer temperature for the Wyoming box as predictors.

7. Pg. 4436: It would be useful to investigate systematically the stability of the correlation of the PNA index and temperature and precipitation from model grid points over nortwestern North America by drawing running correlation curves similar to those represented in Figure 5 for climate indices. Selection of the temperature and precipitation anomalies from the grid-points where the correlation is stable, according to a certain stability criteria, as predictors could lead to an improvement of PNA reconstruction.

Reply: this would be an interesting exercise, but beyond the scope of this study, whose

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aim is to determine how reliable the pseudo-reconstructions are based on selection of proxies only from the observational period (the only period when in reality calibration is feasible). Nonetheless, the results presented in Figure 7c partly respond to the question raised by the Reviewer: the reconstruction skills improve if information from a longer period is used to calibrate the model (i.e., more stable predictors are selected).

8. Pg. 4438. It would be useful to give some hints related to physical processes that explain the negative correlation between PNA and NAO in most of the simulations (Fig. 5b).

Reply: We have included the following statement in section 3.2 referring to Figure 5: "The negative PNA-NAO correlations represent periods when the atmospheric bridge linking Pacific and Atlantic climate variability is active (for a dynamical description see, e.g., Raible et al. 2001; Pinto et al., 2010; Baxter and Nigam, 2013). Decadal active phases of such bridge in the form of persistent negative PNA/positive NAO pattern have been attributed to both, internal variability (Pinto et al., 2010) and strong volcanic forcing (Zanchettin et al., 2012)."

Technical notes

1. Pg. 4428. Ln, 19. Please correct the period of Dalton minimum (_ 1790-1830)

Reply: Done, thanks

2. The labels of the axis from most of the figures are too small. Also there are many curves on the same figure and is difficult to identify them only by color.

Reply: We checked all figures for readability, and will be available to tune their format further for best appearance in the published version, if the manuscript is accepted.

Interactive comment on Clim. Past Discuss., 10, 4425, 2014.

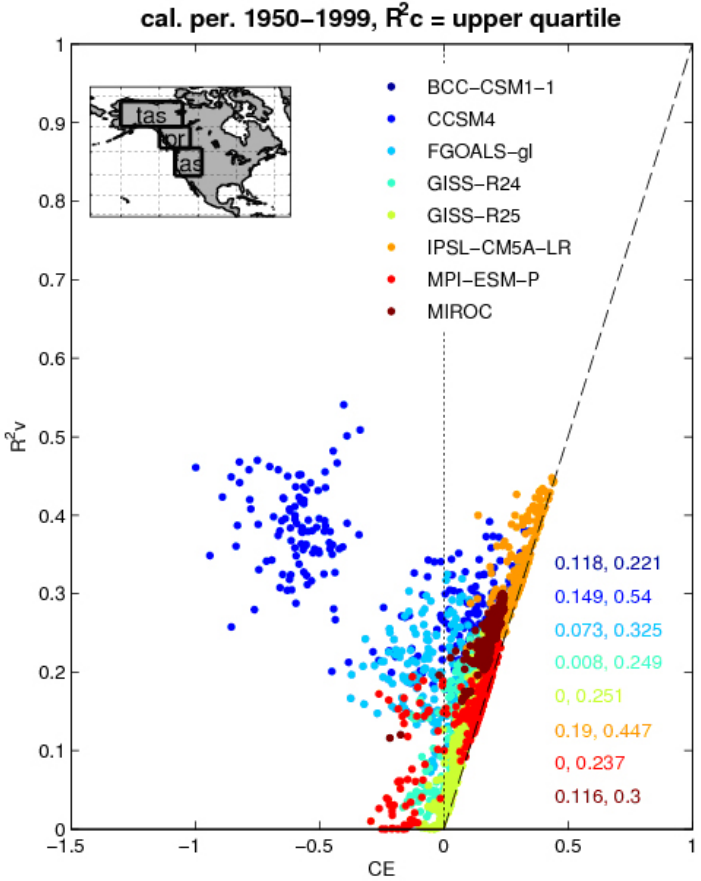

Fig. 1.

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