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Climate of the Past Discussions

Interactive comment on "Teleconnection between the climates of the Polar Regions during the last ice age" *by* Xiao Yang and Jose A. Rial

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We would like to start our response by thanking both reviewers for their efforts in evaluating and commenting on our manuscript. The reviewers have offered constructive suggestions for a comprehensive and objective discussion of the models to not only base on their skills to reproduce climate records, as done in this study, but also on the abundance and strength of the supporting evidence from past literature. We will integrate these changes into the revised manuscript. At the same time, we found and would like to further clarify some of the misunderstandings in the reviewers' comments, especially the ones associated with the physical mechanisms of the PhaseSync model and with the concept of phase synchronization itself. We hope that through the following clarifications, we have resolved some of the major criticisms from the reviewers.

Response to Reviewer 1:

The criticism from "Anonymous Referee #1", or AR1, focused on three points. First AR1 argued that the content of this research is of little contribution to the literature, stating the authors aimed at a "minimum publishable unit". Then, AR1 argued that the I/D and TBS models are based on N-S directionality of the polar teleconnection, thus applying or testing them in the S-N, that is to reconstruct the Greenland records from the Antarctic ones, falls outside the scope of the models. Third, AR1 argued that the different strength in paleoclimate evidence supporting the models should be acknowledged along with their ability to reconstruct the existing records. In the following text, we will address the three criticisms from AR1.

First, it may appear that a model comparison study to conclude which model is superior among three which produce close results does not advance science much, hence the criticism "minimum publishable unit". The problem here is that some of the models we contrast against each other have already entered the scientific literature as the established, if not the only, models defining climate dynamic between the poles (for example, the TBS model was included in a textbook on climate modeling (Stocker, 2011)). Further, Markle et al. (2016) in an article about teleconnections during D-O events, treated the I/D model as if it was the obvious and correct one, ignoring all other models.

This is why we could not agree with the characterization of our paper as a "minimum publishable unit". Our paper is self-contained, its objectives are clearly independent of our published record, and its results important to be known, especially since it shows an alternative mechanism, as also being pointed out by referee 2. AR1 writes that our paper offers "no new dynamical insights". We would respectively argue that, quite the contrary, phase synchronization is a new dynamical explanation of the polar climate fluctuations that is consistent with the data and modeling results (Rial, 2012; Rial and Saha, 2011).

Second, while initially the TBS models and I/D models were proposed or tested under Greenland to Antarctica direction (or N-S direction), such construct of the models does not prohibit reconstructing records in the reverse direction, provided that the defining models demonstrate a one to one relationship between polar climates, a condition which all three models satisfy. In fact, TBS and I/D models have been used to reconstruct or extend Greenland records based on the much longer Antarctic one (Barker et al., 2011; Siddall et al., 2006). It seems to us that by invalidate testing the TBS and I/D models in the S-N direction, as suggested by AR1, automatically invalidates their usage to reconstruct the Greenland climate. Therefore, the PhaseSync model naturally becomes the only one of the three models that has been constructed with the interactive role of polar teleconnection in mind, thus should be valid for reconstructing the Greenland record as it assumes bidirectional coupling.

AR1 has also argued that the PhaseSync (Rial 2012) model was not built upon physical processes. We respectfully disagree with AR1 and present the physics of the PhaseSync model below. The PhaseSync model was originally proposed to describe and model the polar climate interaction for the abrupt millennial scale events during the last glacial period (Rial, 2012). It was built as an extension of a van der Pol oscillator (Saltzman, 2002) that has strong physical support and was originally constructed by Saltzman et al. (1981). This model closely reproduced the entire GRIP record and closely simulated the sea ice extent (including large relative amplitudes) and average oceanic temperature obtained with the much larger and detailed ECBilt-Clio (Rial and Saha, 2011), a GCM of intermediate complexity (Goosse and Fichefet, 1999). Building upon this, the PhaseSync model was constructed by using two van der Pol oscillators (one for each polar region), coupled through the temperature difference and heat storage of the ocean (Rial, 2012). For details of this model and its applications, interested readers should refer to the following literature(Oh et al., 2014; Rial, 2012; Rial and Saha, 2011; Yang et al., 2014).

We also disagree with AR1's description of oscillator behavior in the absence of the

phase synchronization. AR1's comments suggest that the oscillatory amplitude would stay the same before the polar climates were synchronized. This is not true as phase synchronization does not necessarily corresponds to changes in amplitude. Such phenomenon has been documented widely (Balanov et al., 2008; Maraun, 2005; Pikovsky et al., 2003) and in fact, these authors described it as follows: phase synchronization results when two or more nonlinear oscillators couple and therein adjust their (initially different) natural rhythms to a common frequency and constant relative phase, while amplitudes are not necessarily correlated. So having strong D/O events during the synchronized state of polar climates does not imply amplitude of the same strength for the individual oscillators when the synchronization is lacking.

Third, AR1 suggested that, a comprehensive intercomparison study needs to consider the supportive literature behind each model. We appreciate the reviewer's suggestion such information will be added when revising the manuscript. We also appreciate the reviewer's suggestion of reconstructing a 800,000 year Greenland climate using the PhaseSync model. However, it feels a bit out of place to us to include a climate reconstruction in a model intercomparison paper.

To conclude, we appreciate the constructive suggestions AR1 has provided, pointing us to the gap of our literature review for some of the models. However, we disagree with most of the reviewer's criticisms. To our knowledge, our study is the first one to both theoretically and numerically compares three prominent conceptual models that describe the links between the abrupt climate changes registered in records from both polar regions. As all three models have their own extensive supporting studies, we tried to be objective in our intercomparison methods in this study, so that the results can serve as a starting point for future refinement of these models or, as foundation upon which new conceptual models can be established.

References

Balanov, A., Janson, N., Postnov, D. and Sosnovtseva, O.: Synchronization: From

Simple to Complex, Springer Science & Business Media. [online] Available from: https://market.android.com/details?id=book-Fx_6pPCxXWAC, 2008.

Barker, S., Knorr, G., Edwards, R. L., Parrenin, F., Putnam, A. E., Skinner, L. C., Wolff, E. and Ziegler, M.: 800,000 years of abrupt climate variability, Science, 334(6054), 347–351, doi:10.1126/science.1203580, 2011.

Goosse, H. and Fichefet, T.: Importance of ice-ocean interactions for the global ocean circulation: A model study, J. Geophys. Res., 104(C10), 23337–23355, doi:10.1029/1999JC900215, 1999.

Maraun, D.: Epochs of phase coherence between El Niño/Southern Oscillation and Indian monsoon, Geophys. Res. Lett., 32(15), 274, doi:10.1029/2005GL023225, 2005.

Markle, B. R., Steig, E. J., Buizert, C., Schoenemann, S. W., Bitz, C. M., Fudge, T. J., Pedro, J. B., Ding, Q., Jones, T. R., White, J. W. C. and Sowers, T.: Global atmospheric teleconnections during Dansgaard–Oeschger events, Nat. Geosci., 10(1), 36–40, doi:10.1038/ngeo2848, 2016.

Oh, J., Reischmann, E. and Rial, J. A.: Polar synchronization and the synchronized climatic history of Greenland and Antarctica, Quat. Sci. Rev., 83, 129–142, doi:10.1016/j.quascirev.2013.10.025, 2014.

Pikovsky, A., Rosenblum, M., Kurths, J. and Kurths, J.: Synchronization: A Universal Concept in Nonlinear Sciences, Cambridge University Press. [online] Available from: https://market.android.com/details?id=book-FuIv845q3QUC, 2003.

Rial, J. A.: Synchronization of polar climate variability over the last ice age: in search of simple rules at the heart of climate's complexity, Am. J. Sci., 312(4), 417–448, doi:10.2475/04.2012.02, 2012.

Rial, J. A. and Saha, R.: Modeling Abrupt Climate Change as the Interaction Between Sea Ice Extent and Mean Ocean Temperature Under Orbital Insolation Forcing, in Geophysical Monograph Series, pp. 57–74., 2011.

Saltzman, B.: Dynamical paleoclimatology, volume 80 of International Geophysics Series, 2002.

Saltzman, B., Sutera, A. and Evenson, A.: Structural Stochastic Stability of a Simple Auto-Oscillatory Climatic Feedback System, J. Atmos. Sci., 38(3), 494–503, doi:2.0.CO;2">10.1175/1520-0469(1981)038<0494:SSSOAS>2.0.CO;2, 1981.

Siddall, M., Stocker, T. F., Blunier, T., Spahni, R., McManus, J. F. and Bard, E.: Using a maximum simplicity paleoclimate model to simulate millennial variability during the last four glacial periods, Quat. Sci. Rev., 25(23-24), 3185–3197, doi:10.1016/j.quascirev.2005.12.014, 2006.

Stocker, T.: Introduction to Climate Modelling, Springer Science & Business Media. [online] Available from: https://market.android.com/details?id=book-D4zulgFb5JwC, 2011.

Yang, X., Rial, J. A. and Reischmann, E. P.: On the bipolar origin of Heinrich events, Geophys. Res. Lett., 41(24), 9080–9086, doi:10.1002/2014gl062078, 2014.

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