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Earth System Dynamics
Discussions

Interactive comment on "ESD Ideas: The stochastic climate model shows that underestimated Holocene trends and variability represent two sides of the same coin" *by* Gerrit Lohmann

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Thanks for your detailed comments on the manuscript *ESD Ideas: The stochastic climate model shows that underestimated Holocene trends and variability represent two sides of the same coin* . In the following, I give answers to all the issues raised.

Answer to the General comments:

1. Comment: "The results show that the observational SST trends are poorly defined, varying from -4K to +2K over the 6 kyr period. The modeled trends are considerably smaller, being confined mainly to the range -1K to +1K over the same period (Figure 1(a))."

Answer: The analysis is a local one, i.e. the points at high latitudes have a general cooling trend whereas the low latitude points show a warming trend through the late Holocene. The general pattern of warming and cooling are consistent in the data and models (Figures 5a, 7a, 8a in Lohmann et al., 2013; see also Braconnot et al., 2012). In any of the analysis of the local temperature trends based on proxy reconstructions and climate simulations were taken.

Action: In the revised manuscript, I will explicitly state that it is the local temperature trend as the response to latitude-varying orbital forcing. I wrote this in the ESD manuscript at line 20: " Note that the orbital forcing has different signs at high and low latitudes (Berger, 1978)."

2. Comment: "In view of the poor definition of the observational trends and the lack of knowledge regarding the partitioning of the observational variability, very strong caveats should be placed on any conclusions drawn from this observational/modelling comparison. In particular, since there is no global mean orbital forcing over the 6 kyr period studied, extreme care should be exercised in drawing any conclusions from the study as to the value of climate sensitivity to greenhouse gas increase."

Answer: As written above, we are considering the local temperature trends based on proxy reconstructions and climate simulations. Indeed the global forcing is weak. The pattern of climate response to orbital forcing is a combination of the system's response to precession and obliquity. On the basis of the observed insolation-temperature re-

lationship, different temperature response regimes across the Earth can be identified. Linear relationships dominate extratropical land areas whereas in midlatitude oceans, the seasonally varying mixed layer depth renders the temperature more sensitive to summer than to winter insolation (Laepple and Lohmann, 2009).

Action: In the revised manuscript, I will explicitly state that I am not analyzing the value of climate sensitivity to greenhouse gas increase.

Answer the Referee's Specific comments:

3. Comment: "In the theoretical part of the study, a zero-dimensional stochastic model represented by Equation (1) is used in an attempt to gain conceptual understanding of the observational and modelling results described above. The term f(t) is used to describe the deterministic forcing and this is assumed to be of the form f(t) = c u(t), where c is a constant and u(t) is a unit Heaviside step function. This means that a non-zero global average forcing is assumed, in contrast to the situation prevailing in the late Holocene period 6 kyrs to present, where the global average orbital forcing is zero. "

Answer: Indeed, the global average orbital forcing is almost zero. In the approach analyzing the climate sensitivity to external forcing such as orbital forcing, a local analysis is necessary.

Action: In the revised manuscript, I will explicitly emphasize that the global average orbital forcing is almost zero and therefore a regional analysis of the temperature trends and variability are analyzed.

4. Comment: "From this conceptual model, it is concluded that an underestimation of variability forced by a white noise stochastic forcing implies an underestimation of

climate sensitivity to the c u(t) forcing. However, this form of conceptual model does not adequately describe the climate system as forced by the late Holocene orbital forcing. A conceptual model of minimum complexity to do this would be a three-box model such as used by Stap et al. (2018) to study paleoclimate sensitivity. I recommend that such a model instead of that represented by Equation (1) be used to gain theoretical insight into the observational and modelling results described above."

Answer: I know the approach of Stap et al. (2018). Here the attempt is made to define a minimal model for global climate sensitivity and response to greenhouse gases. Here I refrain from this approach and show that the underestimated local variability in the models can be reconciled with the underestimated local responses. Future work may follow a more explicitly resolved low and high-latitude climate model (Bates, 2016; Stap et al., 2018).

Action: In the revised manuscript, I will strongly emphasize the regional aspect of the stochastic climate model in the revised version.

References:

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