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Climate of the Past Discussions

Interactive comment on "Simulated climate variability in the region of Rapa Nui during the last millennium" *by* C. Junk and M. Claussen

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The authors would like to thank the reviewer for her/his constructive suggestions and the time he/she devoted in carefully reading the manuscript. In the following, we would like to reply to her/his comments.

Reviewer 2: "My main problems with the paper pertain to the models themselves, and their use in evaluating local climate changes on Easter Island, which is far smaller than a grid box in the models. One model produces about half the precipitation that occurs on Easter Island today, seemingly making it a rather poor tool even for a sensitivity analysis. The authors should show a map of the model precipitation in the tropical Pacific, akin to the climatological data in Fig. 1. Do either of the models reproduce the

modern pattern of precipitation in the tropical Pacific? I.e., do they have an ITCZ, an SPCZ and an eastern Pacific dry zone? If they don't reproduce those primary features of the precipitation field in the modern climate it is hard to imagine them producing credible rainfall changes in a single grid box under a different climate forcing regime."

Authors: Model evaluation is a challenge in this case. Firstly, we suggest to not compare simulated rainfall with rainfall measured on Easter Island as the island effect is not resolved in the coarse-scale climate model (we will point out this issue more clearly in the revised version of our paper). Hence we compare rainfall estimated by satellite climatologies with simulated rainfall in the region *around* Easter Island. Moreover, we will show measured and simulated precipitation pattern of the equatorial and southern Pacific (Fig. 1,2 and 3).

Fig. 1 (already in the discussion paper) shows the climatological mean (1987-2005) of the precipitation rates in the Pacific region from the HOAPS-3 climatology. For the region *around* Easter Island, the precipitation is approximately 2.0 mm/d. Andersson et al. (2011) compare the precipitation climatology of HOAPS-3 with other climatologies like ERA-INTERIM, GPCP V2 and TRMM 3B43. Around Easter Island, ERA-INTERIM precipitation is $\sim$0.12 mm/d (6%) higher compared to HOAPS-3 precipitation while TRMM 3B43 (GPCP V2) precipitation is $\sim$0.36 mm/d or 18% ($\sim$0.14 mm/d or 7%) lower. Since the differences of the precipitation rates in the HOAPS-3 climatology are relatively small compared to ERA-INTERIM, GPCP V2 and TRMM 3B43, we think that the HOAPS-3 climatology is useful for the comparison with simulated rainfall. Moreover, HOAPS-3 is the only precipitation climatology which is consistently derived from the same type of satellite instrument.

Fig. 2 shows the climatological mean (1987-2005) of the precipitation rates in the Pacific region from the Millennium simulations with time dependent forcings with the ECHAM5/MPIOM model. The mean precipitation rates (1972-1990) from the simulations Erik1 and Erik2 with ECHO-G are shown in Fig. 3. Since the simulations

Erik1 and Erik2 were not extended beyond 1990 AD, we show the climatological mean of 1972-1990 and tentatively compare it with the HOAPS-3 climatology of 1987-2005. We argue that in comparison to the HOAPS-3 climatology, both models reproduce the ITCZ well and reveal the typical pattern of the SPCZ and the eastern Pacific dry zone. However, the SPZC is more zonally orientated in the ECHAM5/MPIOM model compared to HOAPS-3 precipitation data. Therefore, ECHAM5/MPIOM tends to underestimate precipitation in the region around Easter Island while ECHO-G tends to overestimate the precipitation since the SPCZ reaches further southeastwards in this model. In ECHAM5/MPIOM, the climatological precipitation rate around Easter Island is $\sim$1.5 mm/d which is 25% less compared to HOAPS-3 precipitation while ECHO-G simulates $\sim$3 mm/d which is 50% higher.

Reviewer 2: "Likewise with ENSO. Do the models demonstrate a true ENSO-like behavior? If not, why would the model Nino-3.4 SST time series be informative?"

Authors: Here, we refer to existing literature about the ENSO-like behavior of the models. Min et al. (2005) analyse ENSO variability in a 1000-yr control simulation with ECHO-G. In the control simulation, the model reasonably simulates ENSO structures (like the tropical SST climate) and atmospheric responses to ENSO - Min et al. (2005) even state that ECHO-G belongs to the coupled atmosphere-ocean climate models that best reproduce atmospheric responses to ENSO. However, the ENSO-like variability has stronger than observed amplitudes and is too frequent and regular. Jungclaus et al. (2006) analyse the tropical variability in a 300-yr control simulation with ECHAM5/MPIOM and show that the models simulate a dominant ENSO period of 4 yrs which is more realistically simulated than in ECHO-G. The tropical sea surface temperature climatology is well simulated in ECHAM5/MPIOM. However, ENSO is still too regular in amplitude and frequency (i.e. the model underestimates the degree of nonlinearity) (Jungclaus et al., 2006). We conclude that simulations with both ECHO-G

and ECHAM5/MPIOM can be used to analyse climatic variability in the southeast Pacific during the last millennium since both models exhibit an ENSO-like behavior and reproduce the SST climatology of present times well. This discussion will be added to the revised paper.

Reviewer 2: "I do not know if these issues can be addressed in a revised paper. But if the authors attempt to do so, I would recommend that they consider the effect of a change in the position of the ITCZ during the Little Ice Age period. Several recent studies have indicated that the ITCZ was as much as 500 km closer to the equator during the LIA than it is today (Haug et al., 2001; Newton et al., 2006; Sachs et al., 2009; Tierney et al., 2010). If this were imposed in their models, what are the implications for even large-spatial scale rainfall patterns in the south Pacific?"

Authors: We have taken up this interesting issue and analysed the variability of the position of the ITCZ. The simulations with both ECHO-G and ECHAM5/MPIOM indicate a relatively constant position of the ITCZ during the Little Ice Age and the entire Millennium (not shown here). Since 500 km is just a little more than the length of one grid cell in our models, the question arises if simulations with higher resolution of the atmosphere model (which do not yet exist) would change this result.

Finally, we have to state that it is impossible to prescribe the location of the ITCZ in the models. The ITCZ is a dynamic feature that emerges owing to numerous feedback processes between simulated cycles of angular momentum, energy, water and water vapour.

List of references:

Andersson, A., Klepp, C., Fennig, K., Bakan, S., Grassl, H. and Schulz, J.: Evaluation of HOAPS-3 Ocean Surface Freshwater Flux Components, Journal of Applied Meteorology and Climatology, 50, 379-398, 2011.

Jungclaus, J., Keenlyside, N., Botzet, M., Haak, H., Luo, J., Latif, M., Marotzke, J., Mikolajewicz, U. and Roeckner, E.: Ocean circulation and tropical variability in the coupled model ECHAM5/MPI-OM, Journal of Climate, 19, 3952–3972, 2006.

Min, S., Legutke, S., Hense, A. and Kwon, W: Internal variability in a 1000-yr control simulation with the coupled model ECHO-GI: Near-surface temperature, precipitation and mean sea level pressure, Tellus, 605-621, 2005.

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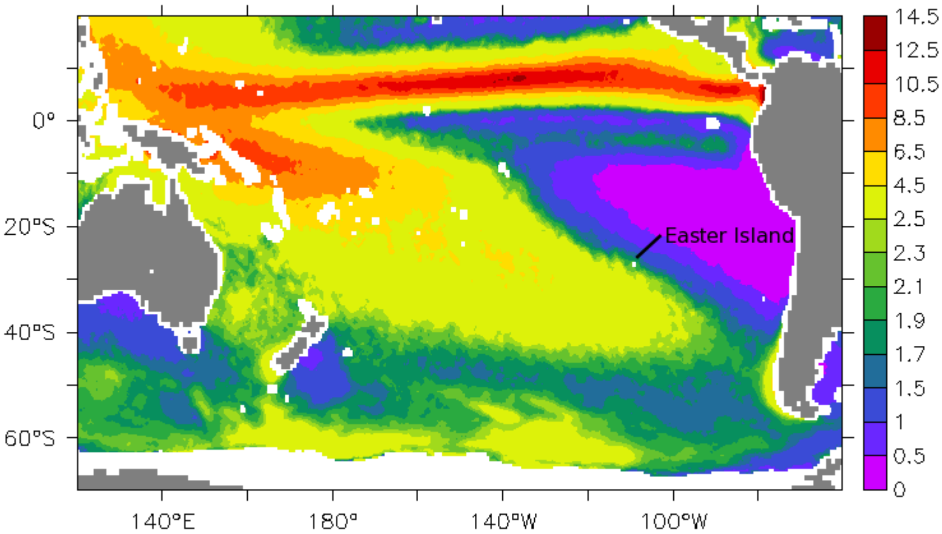

Fig. 1. Climatological mean (1987-2005) of the precipitation rates [mm/d] in the Pacific region from HOAPS-3 data.

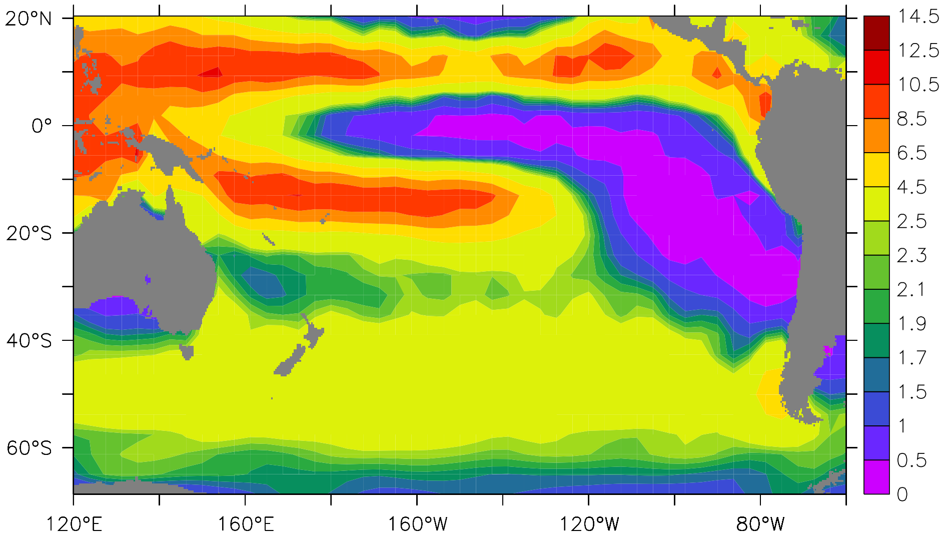

Fig. 2. Climatological mean (1987-2005) of the precipitation rates [mm/d] in the Pacific region from the Millennium simulations mil0010, mil0012 and mil0013 carried out with ECHAM5/MPIOM.

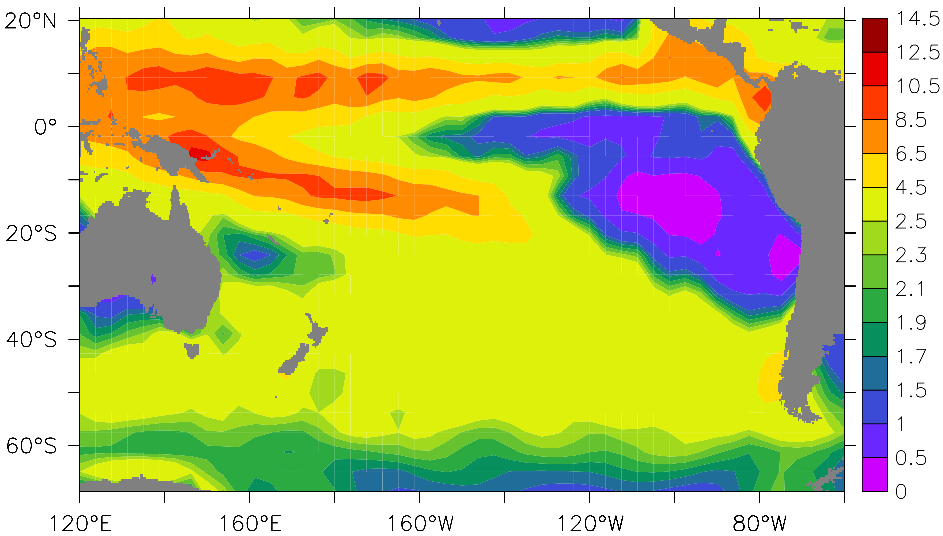

Fig. 3. Climatological mean (1972-1990) of the precipitation rates [mm/d] in the Pacific region from the simulations Erik1 and Erik2 with ECHO-G.