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Climate of the Past Discussions

Interactive comment on “Limitations of red noise in analysing Dansgaard-Oeschger events” *by* H. Braun et al.

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Response to the referee comment by referee #2 on the manuscript "Limitations of red noise in analysing Dansgaard-Oeschger events".

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In the report, referee #2 raises three specific comments:

1. The "99-percent significance" of the 1470-year spectral peak of Dansgaard-Oeschger events in the GISP2 ice core record.

With this expression, we are referring to the publication of Schulz (2002), in which this

spectral peak was interpreted as being "statistically significant at the 99% level", based on the assumption of an AR1 random process. In other words, the null hypothesis in that study was that the corresponding time series (shown in the bottom part of figure 1 in our present manuscript) is generated by an AR1 random process (M. Schulz, "On the 1470-year pacing of Dansgaard-Oeschger warm events", Paleoceanography, 17[2], 2002). By means of a Monte-Carlo based numerical method, Schulz (2002) found that the magnitude of the 1470-year spectral peak is too large to be generated by an AR1 random process, at a confidence level of 99%. Based on this finding, Schulz (2002) regarded this spectral peak as being "statistically significant at the 99% level". Thus, under the (not very realistic) assumption that an AR1 random process is an appropriate null-hypothesis, the 1470-year spectral peak is significant at both the 99% and the 95% significance level. We will clarify this aspect in the revised manuscript.

We note, however, that Schulz (2002) questioned the statistical significance of the 1470-year spectral peak, owing to its nonstationary character, and presented another method to test the regularity in the timing of Dansgaard-Oeschger events.

2. Alternative approaches.

Possible alternative approaches could be to use ocean-atmosphere models of so-called "intermediate complexity", like the model CLIMBER-2 that we are referring to in our present manuscript. These models, however, have typically many more parameters (order of magnitude: 100 or even more). Another option could be to use simple random processes whose power spectral density distribution explicitly shows a maximum at an intermediate (i.e., non-zero) frequency. A simple example is a second-order autoregressive (AR2) random process, whose non-normalised power spectral density distribution is characterised by three parameters.

3. The random forcing.

In figure 4 of our present manuscript, we are making the comparison with a red noise (AR1) random process, because this process represents the null-hypothesis based on which the "99% statistical significance" of the 1470-year spectral peak has been concluded (Schulz, 2002), compare our answer to comment 1. We thus think that this comparison is fair. In addition to that, figure 4 (right column) of the present manuscript demonstrates that both the low-frequency part and the high-frequency part of the power spectral density distributions as simulated with the two-state model of Dansgaard-Oeschger events can indeed be fitted by an AR1 random process, while that process clearly does not describe the simulated power spectral density distribution in the "intermediate" frequency range (corresponding to periods between 1.000 and 10.000 years).

We agree with the referee that a central assumption in our present study is the choice of the specific random forcing (Gaussian-distributed, white noise power signature), which may be much more complex in nature. However, since we do not see any adequate way how to estimate this forcing from the climatic data set, we think that we have no other choice than to make some simple assumptions. At least to us, our assumption of the specific random forcing seems to be one of the simplest possible choices. Besides, we would like to stress that our data sets (figure 1 in the present manuscript) have a time resolution of at most one data point per 20 years, so that from the data it is essentially impossible to determine the high-frequency tail of the power spectral density distribution of the random forcing. We thus decided to use a simplified random forcing, in order to make things as simple as possible.

To demonstrate the robustness of our findings, we attached in this reply the results of a new model study, in which we used a random forcing with a modified power spectral density distribution (blue curve in the top panel in figure R2). Again, we find that the power spectral density distribution of the simulated Dansgaard-Oeschger events (black curve in the bottom panel in figure R2) is non-monotonic and shows a pronounced spectral hump at a frequency range corresponding to periods of about 1.000-10.000 years. We thus think that we can claim that our results are valid not only for the specific random forcing in our present manuscript, but in fact for various types of forcing functions.

Interactive comment on Clim. Past Discuss., 5, 1803, 2009.

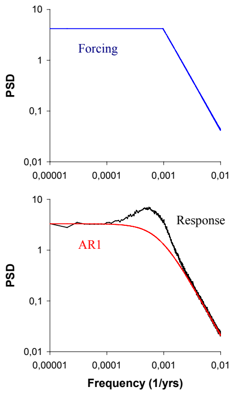

Figure R2. The power spectral density distribution of random Dansgaard-Oeschger events as simulated with the simple two-state model. The figure shows the power spectral density distributions (PSD) of the random input (blue curve, upper panel) and of the simulated Dansgaard-Oeschger events (black curve, lower panel). The standard deviation of the noise is 20 mSv (1 mSv = 1 milli-Sverdrup = 10^3 m^3/s). The power spectral density distribution of the simulated events is obtained from 100.000-year runs, averaged over 500 different realisations with the same noise magnitude. The red curve represents a theoretical AR1 random process. Note that the simulated power spectral density distribution shows a pronounced hump at the millennial time scale, in agreement with our results shown in figure 4 of our present manuscript.

Fig. 1.