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Climate of the Past Discussions

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Interactive comment on "Climate variability of the mid- and high-latitudes of the Southern Hemisphere in ensemble simulations from 1500 to 2000 AD" *by* S. B. Wilmes et al.

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General comments

I have reviewed the manuscript "Climate variability of the mid- and high-latitudes of the Southern Hemisphere in ensemble simulations from 1500 to 2000 AD" by S. Wilmes, C. Raible, and T. Stocker. In my opinion, this paper shows interesting results about the climatic variability of the Southern Hemisphere during the past 500 yr. Using a climate model authors describe characteristics of three atmospheric indexes, the temperature and precipitation of four specific areas of South America and links between these variables. The influence of solar, greenhouse gas and volcanic forcing is also analyzed.

I recommend the paper as appropriate for publication but after some important revisions. I have written my comments below and the authors should consider it in their revision.

Specific comments

I am not an expert on numerical simulations and therefore I have not commented it. My comments are focused in the results.

1) In Figs. 2a-d should be given more detail (colors or contours) because it is not easy to distinguish the characteristics that the authors mention in lines 18-19 of page 3096.

As suggested by the referee we changed the figure and increase the detail of Figures 2 a-d to 5 m increments instead of 10 m before.Note that we also clarified the caption: "...(a) to (d) are shown as a regression of the time series of the respective mode onto the Z850hPa field. Units are m per standard deviation change of the index...."

2) In my opinion, the definition of SPD mode is unclear. I recommend see Fig. 1 in Mo (2000). The SPD of the model (Fig. 2c) resembles the EOF3 showed by Mo while the SPD of ERA40 (Fig. 2d) resembles the EOF2 of Mo. The authors should confirm that they are comparing the modeled SPD with the SPD of the ERA40. They may be comparing different modes of circulation. Please, also see the ENSO mode and the South Pacific wave train described by Kidson (1999).

We recalculated the EOFs 2 and 3 for both the CTRL1990 simulation and the ERA40 reanalysis in order to allow a comparison. EOFs 1 to 4 for both CTRL1990 and ERA-40 can be seen in Figures 1 and 2, respectively, in this response. EOF2 for the ERA40 analysis most closely resembles Fig. 2b in Mo (2000), whereas EOF3 corresponds closely to the pattern found in their Fig. 2c. The differences between the patterns we found in the ERA40 dataset and the ones of Mo (2000) may originate from several different points: First, the dataset we used ranges from 1979 AD to 2002 AD whereas

Mo (2000) uses an earlier ECMWF dataset which only spans the period 1979 AD to 1993 AD. Second, they calculate the EOFs for 500 hPa anomalies whereas we perform the EOF analysis with 850 hPa data. Third, their dataset is interpolated to a lower horizontal resolution of 5° x 5°.

In the model, in our opinion, EOF2 in the CTRL1990 simulation most closely resembles EOFs 2 both for NCEP/NCAR and ECMWF data (Fig. 2b and 2d in Mo (2000)). Their EOF3 shows strong similarities to a wave number 3 pattern around Antarctica whereas in the CTRL1990 simulation the Pacific–South American connection is especially prominent. One centre of action is located in proximity to New Zealand, a second with opposite sign lies over the Amundsen-Ross Sea, a third can be found over the tip of the Antarctic Peninsula, similar to the pattern found of the EOF2 in Mo (2000). Again, however it appears that the enhanced zonality of the model plays a role in distorting the patterns, and that the Amundsen low pressure system is not located in the correct position. In the CTRL1990 EOF3 resembles a SAM pattern as is found for EOF1 with a strong zonality; i.e., the pattern found in ERA40 for EOF3 is not at all present in the model.

Therefore, we do believe that we examine the same modes of circulation; however, one aim of this paper is to emphasise that the model has deficits, especially in the correct representation of the spatial structures of various modes in the Southern Hemisphere.

3) In the definition of index ZW3 the authors compare the first EOF of the model and ERA40 finding a shift of 30° among them. It is important to know how are the other EOFs since, as it was previously mentioned, the authors may be comparing different structures and this is the reason for the shift. In other words, is the EOF1 of the model different from, for example, the EOF2 of ERA40? In my opinion, it is not clear why the authors consider both SAM and ZW3 because part of the SAM structure is a wave 3 in subpolar latitudes (see Fig. 7 in Kidson 1999 or Fig. 1d in Mo 2000). Therefore, it is not clear that the ZW3 is a circulation mode independent of the SAM. Authors should analyze this point. See the similarity of the circulation field associated to the

temperature in the region SA1 (Fig. 8) and the structure of the SAM in Fig. 1d of Mo (2000). See also the influence of the SAM on the temperature of southern South America in Fig. 10 of Garreaud et al. (2009).

We calculated the EOFs 1, 2 and 3 for V500hPa and indeed find that in the model EOF 2 corresponds very closely to EOF 1 in the ERA40 data and that the 30° shift is not present. The leading and the secondary EOFs in the model are exchanged in comparison to ERA40. The pattern correlation increases to r=0.71 confirming that we are indeed looking at the mode corresponding to EOF1 in ERA40. Therefore we alter the definition of the ZW3 in the MS from the leading EOF to the second EOF for V500hPa and change the related figures and discussions.

We would, however, like to keep SAM and ZW3 separate, as e.g. a correlation analysis suggests that the modes are only very weakly related and not identical (cor(SAM,ZW3 era40)=0.23, cor(SAM,ZW3 ctrl1990)=0.02). A very important point in this context is that SAM reacts to the GHG forcing whereas ZW3 shows no reaction to the changing external forcing.

4) In Fig. 8 it is important that the authors describe the mechanisms establishing the links between the circulation fields and the South American temperature (and precipitation) since otherwise it is just a statistical exercise. More details (colours or contours) should be added in this figure to better distinguish the anomalies of circulation.

There are several possibilities to evoke changes in temperature and precipitation in a specific location. This paper focuses especially on the influence of modes of circulation, i.e. SAM, SPD or ZW3. For this we took two different approaches: Once, it is a top-down approach where the influence of the mode on regional temperature (precipitation) was determined by correlation analysis, and secondly, the dynamic pattern that relates to changes in temperature (precipitation) by advection is determined. Furthermore, we examine the impact of the external forcing on regional climate. Of course, further effects may influence regional temperature (precipitation) such as convection or local effects (e.g. topography).

In regions SA1 and SA2 the influence of advection of warmer/colder (moister/dryer) air on temperature (precipitation) is especially prominent (see Figure 8) whereas clear patterns are much harder to establish for the remaining two regions. Here other effects (as discussed above) presumably play a role in evoking temperature (precipitation) changes. However, the important message from Figure 8 is that especially for temperature never only one mode can be identified as a cause for regional temperature changes but it is always a combination of modes or further processes. This is an important message for the reconstruction community that even though temperature in a specific location may be related to a mode of variability it is not necessarily the only process influencing regional temperature and hence not only one location can be used to reconstruct a specific mode.

In order to clarify these points we change section 4.3 p.3100ff in the MS.

5) I think that it is not clear the methodology used to select the regions of temperature and precipitation SA1 to SA4. In particular, the region SA1 contains the area of Patagonia on both sides of the Andes Cordillera. Therefore, this region includes the very wet area of Chile and the arid region of Argentina. This makes unclear the analysis presented in Fig. 8 because the forcing of precipitation is different on both sides of the Cordillera. The links with the precipitation over other areas of South America (Fig. 6) can also be different.

Here, the low resolution (T31) could play a role in not expressing the differences between the west and east side of the Andes. When the correlation analysis is repeated for ERA40 (right panel in Figures 5 and 6) very similar patterns appear verifying the model correlation patterns. We changed P3099 L5-9 changed to “In order to allow comparisons between the simulations and proxy records, and to evaluate the causes of regional climatic variations, four regions in southern South America (SA1 to SA4) were selected by first correlating the temperature and precipitation time series of sin-

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gle locations throughout southern South America and then grouping the emerging patterns into four regions (SA1 to SA4) maximizing the covariability of each temperature and precipitation within the region. The regions and correlation patterns for both the CTRL1990 simulation and ERA-40 can be seen in the small insets in Figures 5 and 6 of the manuscript.

Please, correct the caption of Fig. 6 (temperature or precipitation?)

Done as suggested by the Editor/Referee #2.

6) The Fig. 7 should be after Fig. 8 following the order in the text.

As suggested by Referee #2 and the editor we decided to remove Fig. 7.

7) A comparison between model results and reconstructions of temperature is made in Section 5.2 but I do not find comments regarding the comparison between model results and reconstructed precipitation.

A comparison between the model results and precipitation reconstructions was added to this section. ..."This strong variability, however, is not apparent in the modeled temperature records. Precipitation remains fairly stable throughout the simulations and no prominent shifts or significant trends emerge such as can be seen in the proxy records, suggesting that precipitation in southern South America in CCSM3 is fairly robust against changes in external forcing. This again may be related to the small changes in strength of the westerly winds throughout the course of the simulations."

8) In lines 26-27 of page 3110: I do not agree because the influence of each mode of atmospheric circulation could be found analyzing the relationship between the time series of the mode and the temperature (and precipitation) in South America. There is abundant bibliography describing the influence of the SAM and ENSO in the region (see references in Garreaud et al. 2009).

The referee is correct that it is possible to identify the influence of a mode on temperature by assuming e.g., a linear relationship (regression) on temperature as is performed

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by Garreaud et al. (2009). However, it is rarely the case that the variability of temperature in a certain location reflects variations of only a single mode (e.g. a temperature record in Patagonia (region SA1) from the in both the ERA40 dataset and the transient simulations is significantly (at a 5% level) correlated with SAM, SPD and ZW3. Even though the influence of SAM is very prominent in this region (as can be seen in e.g. Fig.6 in Garreaud et al. (2009)) temperature changes do not solely reflect variations of SAM, as can be seen in Fig. 8 of this paper. An attempt by the reconstruction community to reconstruct a certain mode from solely temperature information for specific locations would therefore lead to incorrect results.

In this sense the statement is valid. Still we tried to clarified this: “However, as noted previously, especially temperature rarely reflects only a single mode of variability, but rather a combination of modes, i.e. SAM, SPD and ZW3, as can, for example, be seen for Patagonia (SA1), thus making it hard to find distinct locations or regions which solely reflect the signal of only one mode.”

9) References: Garreaud, R., M. Vuille, R. Compagnucci, J. Marengo, 2009: Present-day South American climate. Palaeogeography, Palaeoclimatology, Palaeoecology, 281: 180-195. Kidson, J., 1999: Principal Modes of Southern Hemisphere Low-Frequency Variability Obtained from NCEP–NCAR Reanalices. Journal of Climate. Mo, K., 2000: Relationships between Low-Frequency Variability in the Southern Hemisphere and Sea Surface Temperature Anomalies. Journal of Climate.

Thank you for the references – we included them in the revised version of the manuscript.

Dear referee #1,

Thank you for your helpful and constructive comments which substantially improve our manuscript.

Yours sincerely,

S. B. Wilmes and C. C. Raible and T. F. Stocker.

Interactive comment on Clim. Past Discuss., 7, 3091, 2011.

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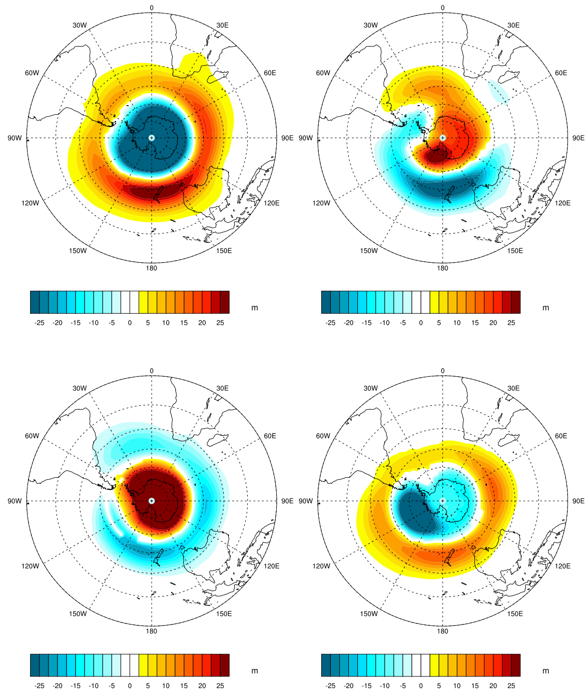

Fig. 1. EOF 1 (top right), EOF 2 (top left), EOF 3 (bottom left) and EOF 4 (bottom right) of 850-hPa geopotential height (Z850) regressed onto the Z850 field.

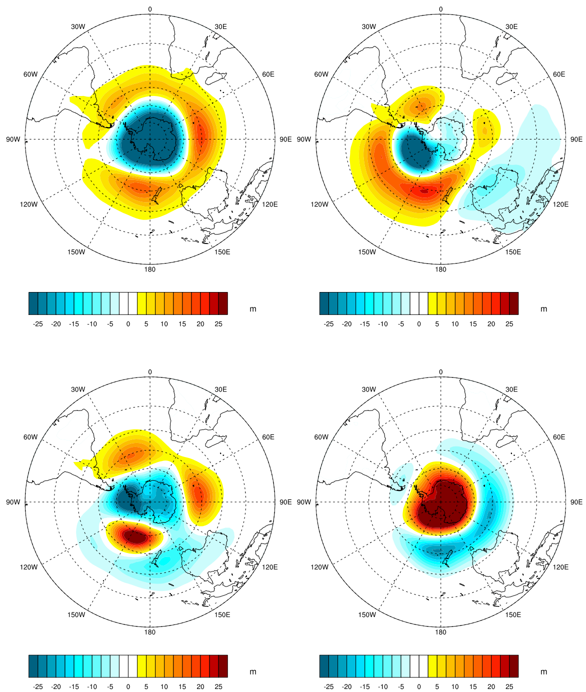

Fig. 2. As Figure 1 in this response, but for ERA40.