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Climate of the Past Discussions
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Interactive comment on "Changing correlation structures of the Northern Hemisphere atmospheric circulation from 1000 to 2100 AD" *by* C. C. Raible et al.

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General Comments

This manuscript concerns a very interesting subject, namely the temporal stability of atmospheric teleconnections. With respect to out knowledge of past climates, this paper addresses the important question: Can we use the structure of atmospheric teleconnections that are derived from observations during the instrumental period to interpret paleoclimate records? The paper has the potential to be an important contribution to this subject. However, I believe that there are some significant issues with respect to the data used, its interpretation and the presentation of the results that need to be addressed before publication.

Major Comments

1) The paper makes extensive use to the 20th Century Reanalysis (20CR). I believe that readers of the paper need to be given more information on this novel reanalysis so as to place into proper context the results that are presented. Most importantly, the 20CR only assimilates surface pressure data and so there is some concern about its ability to represent tropospheric climate variability as opposed to just the mean tropospheric climate. I'm concerned that the authors use the 500mb geopotential height field from the 20CR and present no information on the ability of the 20CR to capture the variability in this field. At a minimum, the authors should confirm that 20CR is able to represent the variability in the 500mb height field over the period for which upper-air data is available (i.e. the late 1940s onwards). This could be accomplished by comparing the teleconnectivity structure over this period with that from a more traditional reanalysis (such as the NCEP Reanalysis or ERA40) that assimilates this upper-air data. Alternatively, the authors could look at the teleconnectivity structure in the sea-level pressure field. Given the 20CR's reliance on surface pressure data, there is probably greater confidence in its ability to represent this field. Moore et al (2013, "Multidecadal Mobility of the North Atlantic Oscillation", J. Climate) present such a comparison with respect to the ability of the 20CR to represent the surface climate variability in the North Atlantic region.

The 20CR also has an issue at high northern latitudes that is related to the representation of sea ice in coastal regions that is discussed in the Compo et al (2011) paper. Given this documented problem with the 20CR, I'd be careful to show teleconnectivity patterns in the Arctic.
We are aware of this problem and do not discuss any teleconnection over Arctic. We specifically mention this problem in section 2. (Please see suggested changes in section 2 mentioned above).

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Interactive Comment

In addition, the ECMWF has just released its ERA-CM reanalysis product that uses a similar approach to provide a representation of the state of the atmosphere since 1900. Unlike the 20CR, they provide the actual ensemble members and so it would be possible with the ERA-CM to validate the results obtained with the 20CR as well as providing some measure of the spread in the ensemble members, something that is not possible with the 20CR. It also presumably doesn't suffer from the same issue at high northern latitudes.
The 20CR consists of 56 ensemble members that are all available. We now include all ensemble members of 20CR in Figs. 3 and 4. As suggested we also analysed the ERA-CM data. However, we realized that the ERA-CM is not a reanalysis in the classical sense as it does not assimilate any atmospheric observations. It is a model driven by observed sea surface temperature and sea ice. In other words, it is much less constrained than 20CR and in that sense does not add value to the study here as it does not outperform the 20CR.

2) On a related note, the authors use the 500mb height field to define the NAO. Most of the research on the NAO focuses on its expression in the sea-level pressure field and so for completeness and to provide a bridge to the large body of work on the NAO, I recommend that the authors include the teleconnectivity structure of the sea-level pressure field.
We decided to use Z500 for several reasons. One point is that we are able to reduce the number of figure. More importantly, the NAO has an equivalent barotropic structure, thus the NAO should be detectable on this level, whereas PNA is only found in the mid troposphere. Given this comment we applied our analysis method also to sea level data of TCR. We find a similar behaviour as for the Z500 data, i.e., the pattern correlation decreases when going back in time. However there are also some deviations compared to our Z500 results, e.g., we do not identify the same period 1940-1969 as the one which disagrees most. There are several reasons for this. First, the new patterns (BWA and AWAVE) in

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Z500 do not necessarily have an equivalent barotropic structure. Similarly, sea level pressure-deduced patterns in a different period do not necessarily have an equivalent barotropic structure. This is clearly an interesting point and deserves a more in-depth analysis (which is beyond the scope of this manuscript). We added a few line on this issue in the conclusions.

3) The authors present two new teleconnection patterns (WADP and AWAVE) to describe their results. I'm concerned that this approach may be suboptimal and doesn't address other teleconnection patterns from the current climate (such as the East Atlantic pattern and the Scandinavian pattern) that may be invoked to describe the variability in the North Atlantic and North Pacific regions. The authors should also refer to Shabbar et al (1997, "The association between the BWA index and winter surface temperature variability over eastern Canada and west Greenland" Int. J. Climatol.) who describe an upper-tropospheric dipole-like pattern in the western Atlantic that may be related to the WADP. The impact that this dipole has on the NAO has been discussed in Moore et al (2011, "Complexities in the Climate of the Subpolar North Atlantic", Q. J. Roy. Met. Soc.). I am also curious why the authors did not use a more traditional EOF analysis to capture other modes of climate variability. The approach that the authors use appears to be somewhat ad-hoc.
Thank you for this comment. We were not aware of BWA index and certainly it is not our intension to add more names for the same or similar patterns. We compared the WADP and found that it is similar to BWA, thus BWA is used in the revised version.
The AWAVE pattern is a bit more difficult. There are several teleconnection which may be related to this pattern. The North Sea-Caspian pattern (e.g., Kutiel and Benaroch 2002, Theor. App. Climatol.) describes a dipole pattern at these two locations which is similar to two centers of the three centers of AWAVE.
The Eastern Mediterranean pattern (Hatzaki et al. 2007, Int. J. Clim.) is shifted westwards compared to the North Sea-Caspian pattern. Given that these au-

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thors always suggest a dipole structure but we describe a wave-train structure with three center of action we think that we could still keep AWAVE, however we include a hint that it is partly related to the North Sea-Caspian pattern identified by Kutiel and Benaroch (2002).

Concerning EOF analysis, there are several reasons why we refrain from applying an EOF analysis to the data. The EOF analysis, applied to sectors can be sensitive to the selected area in the sense that the positions of the identified patterns could change. More importantly we are interested in teleconnections, i.e., the correlation structure of the Z500 field and not in the variability structure (as commonly assessed by the EOF analysis). The easiest way to do so is the teleconnectivity suggested by Wallace and Gutzler (1981), which is one of most popular paper concerning teleconnection (and maybe even more traditional as correlation techniques applied to pressure data in e.g. the North Atlantic was already performed by Walker and independently by Defant 1924, both identifying the NAO). We still find it interesting that changes discussed in Moore et al. (2013) using the EOF technique also point in a similar direction as ours.

The mentioned references for BWA and the North Sea-Casoian pattern are included in the revised version.

4) The issue of multi-decadal variability in the structure of the NAO that the authors discuss is a very interesting one that has been identified previously using the sea-level pressure field from the 20CR. For example, please refer to Moore et al (2013, J. Clim.). A discussion of how the variability that is observed at 500mb maps into the surface variability would be a useful addition to the paper.
Please see our answer to your point 2. We revised our section 4 and also include a discussion on how the different teleconnection patterns deduced in Z500 impact surface variables like temperature and precipitation.

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5) I found the quality of the figures to be very low. The colour map used to describe the teleconnectivity field does not have enough contrast to pick up the important features of this field. It should be revisited so as to allow readers to identify these features The size of the individual fields in Figures 2,3 and 4 should also be increased so that readers can see the important fine-scale features in these figures.
We changed to a different color map. The increase of the figures is not possible as the final paper will have portrait pages and the figures 2, 3, and 4 will match on a page. In the review style we agree that landscape-shape figures would be more appropriate. However, we think that as it is a pdf-file and the resolution of the figures is high the figures could be easily increased.

6) As commented on by another reviewer, the paper has a number of typos and awkward sentence structures that should be corrected prior to publication.
Paper will be proof read by a native speaker.

Additional figures for the responses (please see next two pages)

Fig. 1: Comparison of teleconnectivity (based on Z500) for (a) the period 1871 -2008 and (b) the period 1915-2008 using TCR ensemble mean data. Please see also Fig. 2 in the revised version of the manuscript.

Fig. 2: Running spatial correlation time series using a 30 yr window and the reference teleconnectivity pattern (inset in Fig 3a or 4a in the revised manuscript) for (a) the Atlantic and (b) the Pacific. The correlation is estimated for the ensemble mean of TCR from 1871 to 2010 and ERA40 data. Please note that the y-axis has a different scale compared to Figs 3 and 4 in the revised version of the manuscript.

Interactive comment on Clim. Past Discuss., 9, 4987, 2013.

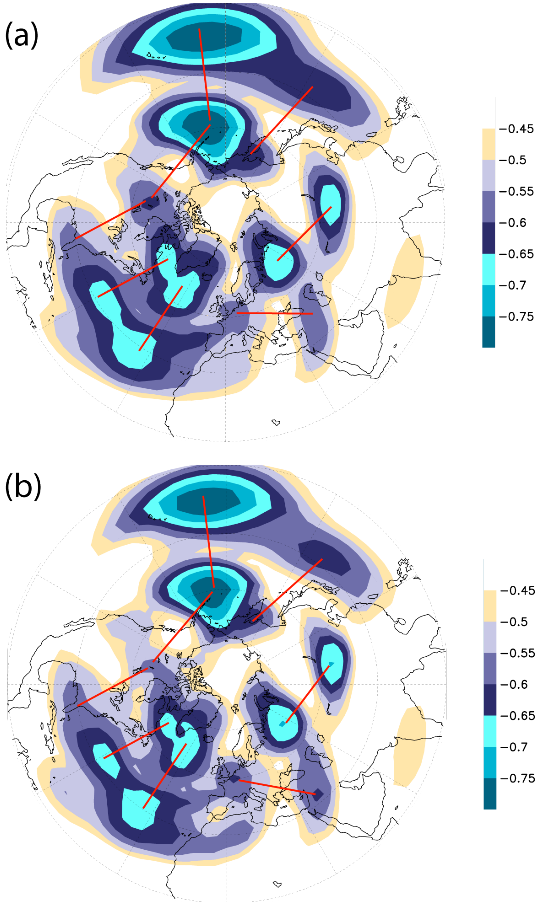

Fig. 1.

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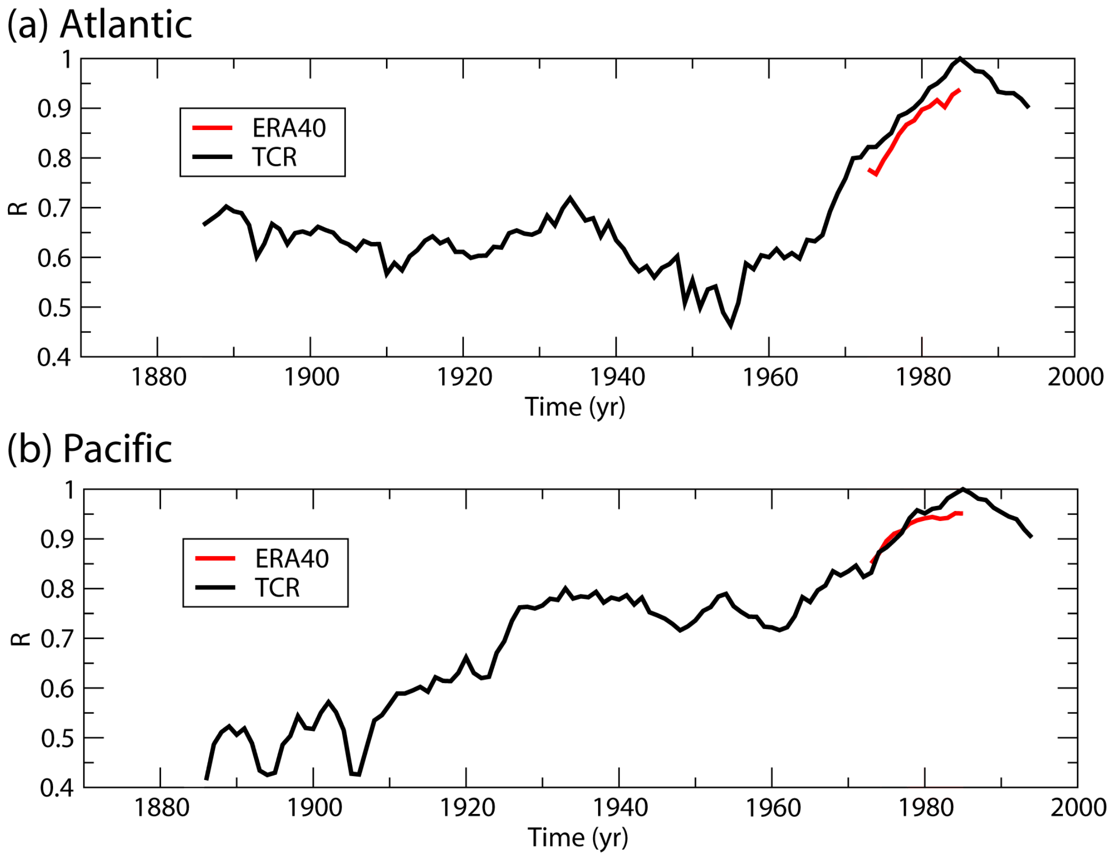
(a) Atlantic
1
0.9
0.8
0.7
0.6
0.5
0.4
R
ERA40
TCR
1880
1900
1920
1940
1960
1980
2000
Time (yr)
(b) Pacific
1
0.9
0.8
0.7
0.6
0.5
0.4
R
ERA40
TCR
1880
1900
1920
1940
1960
1980
2000
Time (yr)

Fig. 2.