Clim. Past Discuss., 2, S627–S634, 2006
www.clim-past-discuss.net/2/S627/2006/
© Author(s) 2006. This work is licensed
under a Creative Commons License.

Climate of the Past Discussions

Interactive comment on "Atmospheric multidecadal variations in the North Atlantic realm: proxy data, observations, and atmospheric circulation model studies" *by* K. Grosfeld et al.

K. Grosfeld et al.

Received and published: 24 November 2006

Point by point reply to R. Greatbatch: cpd-2-S353p.pdf

Dear Richard,

first of all we thank you for your careful reading and positive evaluation of our manuscript. In the following we try to clarify your suggestions in a point-by-point reply. In the revised version of the manuscript, these argumentation and additions will be included.

R. Greatbatch (Referee)
Received and published: 8 September 2006

Major Comments:
This paper is concerned with what is often called the Atlantic Multidecadal Oscillation (AMO), as seen in observations and models, including proxy data. A number of issues came to mind when reading the paper, as outlined below.

1. A recent paper, Mann and Emanuel (2006, EOS) has questioned the existence of the AMO, at least the influence of the AMO on tropical Atlantic SST, including the area of the sediment core discussed by the authors. In fact, Mann and Emanuel claim that the interdecadal SST fluctuations in the tropical Atlantic are radiatively forced. I am sure that the paper under review has bearing on Mann and Emanuel's work, and visa versa, an issue I think the authors should address. A complication that I see myself is that it is quite possible that the variability associated the AMO and the radiatively forced signal have actually been varying in phase during the 20th century. Whether or not this is chance is another, related issue.

Answer: Indeed, the work of Mann and Emanuel (2006, EOS) shows that mainly the tropical Atlantic SST anomalies are responsible for increasing hurricane activity in the region. They suggest that such anomalies are radiatively forced. Because the Cariaco sediment core time series is negatively correlated with most of the North Atlantic SST during the instrumental period, the AMO is a detectable signal in Cariaco basin. However, only a part of the Cariaco sediment core is explained by AMO. The remaining part of the variability can be related to processes that are independent of AMO (e.g., Lohmann et al., 2004; Dima et al., 2005), in a similar way as the part of tropical Atlantic hurricane variability that are connected with radiatively forced SST anomalies. Also, as reviewer suggested, part of AMO and radiatively forced signal can vary, by chance, in phase during the observational period.

2. Another paper, which takes the more usual view that the AMO is real, and associated with changes in the North Atlantic Meridional Overturning Circulation (MOC) is by Latif, Böning, Willebrand, Biastoch, Dengg, Keenleyside, Madec and Schweckendiek

CPD
2, S627–S634, 2006

EGU

with title ”Is the thermohaline circulation changing”. As I understand the situation, the Latif et al. paper is in press in Journal of Climate, and I hope the authors can get hold of it, as it is certainly very relevant to the authors’ paper. Latif et al take the view that interdecadal changes in the MOC are driven by the NAO through NAO related modulation of the deep water formation in the Labrador Sea. The mechanism had earlier been demonstrated in a numerical model by Eden and Jung (2001, Journal of Climate), another paper that is very relevant to the authors’ paper and should be referenced. The Eden and Jung paper provides convincing evidence that it is the NAO that drives multidecadal fluctuations in the MOC and the associated SST variability. I am a bit surprised that the authors claim that it is not the NAO itself that is associated with the multidecadal SST variability they discuss, but an NAO-like pattern that has its centres of action shifted from those of the NAO. I assume this is because the authors focus on the SLP pattern that varies in phase with the AMO, whereas the AMO actually lags the NAO by about 10 years. (In fact, there is no reason why the SLP that varies in phase with the AMO - if, indeed, there is such a pattern - should look like the NAO.) Anyway, we know from the spectrum of the winter NAO index that there is significant energy at the interdecadal time scales (see, for example, Wunsch(1999, Bull.Amer.Met.Soc.)) and the Eden and Jung paper shows that there is more than enough energy in the observed NAO index to drive significant interdecadal fluctuations in the North Atlantic MOC (see also Delworth and Greatbatch, 2000, Journal of Climate, who show that a white noise heat flux forcing derived from a coupled model can driven significant MOC variability at interdecadal times in the same coupled model). So, I do not agree with the statement on page 646, line 22, that ”While the NAO is defined on an interannual time scale and is manifested in the NAO-index, AMO acts on longer time scales and modulates the Atlantic climate system...”. Rather, I would argue that it is the NAO that drives the AMO. By the way, the SLP pressure pattern shown in Figure 4e surely looks like the winter NAO? - and presumably reflects the upward trend in the NAO index between 1970 and the mid-1990’s?

Answer: The recent paper of Latif et al. (2006) suggests that meridional over-

CPD

2, S627–S634, 2006

turning circulation (MOC), which is related to AMO, can be understood as the lagged response to multidecadal variations in NAO and the associated variations in Labrador Sea convection. A similar mechanism is proposed in earlier paper of Eden and Jung (2001). However, our paper is focused on the atmospheric response to SST forcing during the phase of maximum amplitude of AMO (i.e. entire North Atlantic is covered by SST anomalies of the same sign). We mentioned that the SLP response pattern for this phase of AMO does not exclude a NAO SLP pattern in the early phase of AMO. Therefore, our results are not in contradiction with Latif et al. (2006) and Eden and Jung (2001) mechanisms. In a recent paper, Dima and Lohmann (2006, J. Clim., in press) propose a deterministic mechanism relying on atmosphere-ocean-sea-ice interaction. Anomalies in North Atlantic SST are associated with a hemispheric wave-number-one SLP structure in the atmosphere, which is amplified through atmosphere-ocean interactions in the North Pacific. This pattern projects on NAO, but is different.

Dima, M., and G. Lohmann, A hemispheric mechanism for the Atlantic Multidecadal Oscillation, J. Clim, 2006 (in press).

3. It is good to see that a simplified atmospheric model like PUMA can do such a nice job. But there is also no documentation referenced on the moist version of PUMA. Are there some other references that can be given? Is there is any documentation on the unperturbed, moist PUMA model?

Answer (same as for Reviewer 2): The 'former' version of PUMA as used by Frisius et al. (1998) and Franzke et al. (2000) considered dry dynamics, where moisture is not explicitly considered. In the so called 'recent' version this deficit has been improved. The recent version as described in the paper represents also a precursor of the Planet Simulator (Fraedrich 2005b,c), an Earth system model of intermediate complexity to investigate climate and paleo-climate simulations for time scales up to millennia in acceptable computation time.

CPD

2, S627–S634, 2006

In addition to our papers Romanova et al. (2006a,b) a reference of PUMA is given by Fraedrich et al., 2005a and will be included in the revised version.

Fraedrich, K., E. Kirk, U. Luksch, and F. Lunkeit, 2005a: The Portable University Model of the Atmosphere (PUMA): Storm track dynamics and low frequency variability. Meteorol. Zeitschrift, 14, 735-745.

Fraedrich, K., H. Jansen, E. Kirk, U. Luksch, F. Lunkeit, 2005b: The Planet Simulator: Towards a user friendly model. - Meteorol. Zeitschrift, 14, 299-304.

Fraedrich, K., H. Jansen, E. Kirk, F. Lunkeit, 2005c: The Planet Simulator: Green planet and desert world. - Meteorol. Zeitschrift, 14, 305-314.

4. Are 3 ensemble members enough to give statistically robust results from the atmospheric models? Presumably PUMA can be run in a much bigger ensemble?

Answer: You are right, 3 ensemble members could not provide for statistically robust results in ensemble mean. However, we chose only 3 ensemble members to be comparable to the ECHAM4 simulation which is by far more run-time consuming. In a paper investigating the role of different oceanic basins as forcing for the AMO we apply 20 ensemble members for each experiment and examine the ensemble mean pattern. Depending on the forcing regime, the spread between the ensemble members is different. For globally and Atlantic-only forced experiments the spread of the model response over Atlantic is small compared to Pacific-only forcing. For the current experiment, we apply only three ensemble runs to be based on the same spread for the evaluation of the model results for both experimental setups, ECHAM and PUMA. The 20 ensemble member results with Puma are similar with the 3 ensemble members only. We will include that in the revised version.

Specific Comments:

1. Page 635, 24 lines from the bottom: I did not think that variations in the strength of

CPD

2, S627–S634, 2006

the Aleutian low always went along with the variations of the AMO (in the same way that variations of the Aleutian and Icelandic lows do not always go together).

Answer: We refer to previous studies (e.g., Minobe, 1997) that variations in the strength of the variation of the Aleutian low go along with the variation of the AMO. This is also seen in Dima and Lohmann (2006). However, in a different modeling study (Grosfeld et al. 2006) we show that PUMA model forced with Atlantic-only SST generate an inter-ocean atmospheric dipole with low pressure over the Atlantic accompanied by high pressure over the North Pacific at multi-decadal time scales.

2. Page 635, further down the page: I think it is rather misleading to associate the onset of the latest cold phase of the AMO with the Great Salinity Anomaly (GSA). The GSA was most likely caused by the anomalous low winter NAO index at the end of the 1960's and an associated enhanced flux of sea ice through Fram Strait (e.g. Häkkinen(1993, J.Geophys.Res.). Curiously, after that time, enhanced ice export through Fram Strait become strongly associated with the positive NAO index, as pointed out by Hilmer and Jung (2000, GRL), the opposite of the situation that led to the GSA.

Answer: The GSA is one of the most pronounce regime shift in the North Atlantic during observational period, where a basin wide change from warm to cold SST's occurred. At the same time the enhanced sea ice export associated with anomalous freshwater release from the Fram Strait to the North Atlantic provides for a reduction in the North Atlantic overturning circulation with reduction in the thermohaline circulation. Hence, we only speculate for the simultaneous AMO phase shift at the end of the 1960's about an atmospheric response mechanism to changed oceanic forcing conditions, which go in phase with the GSA.

3. Most of the data analysis is carried out using data that have been band pass filtered to pass only periods between 50 and 100 years. What happens if, for example, the SST data used to produce Figure 2 is not filtered in this way?

CPD
2, S627–S634, 2006

EGU

Answer: If we take just the mean of the periods when AMO was in extreme cold and warm phase the patterns are very similar with those based on filtered data.

4. The dipolar pattern in Figure 3a looks like the NAO to me - also the principal component time series! How does the latter correlate with the winter NAO index? Also, please clarify what season the analysis applies to.

Answer: The Luterbacher et al. (2002) SLP data in Figure 3a represent winter mean (DJF) data. In the whole study we concentrate on boreal winter data, because during this season atmospheric teleconnections are strongest. EOF1 of the Luterbacher et al. SLP data projects on the NAO pattern and therefore PC1 is highly correlated with the NAO (derived from CRU) index, but not at level 1. We will refer to it as NAO-like index in the revised version.

5. Bottom of page 640: How is the SST index referred to defined? Please clarify.

Answer: The SST index is calculated to be the time varying mean of SST over the North Atlantic (60°W- 0°W, 0°N-60°N). This definition of our index region will be included in the revised version.

Conclusions: I think this is an interesting paper that has the potential to throw light on the recent Mann and Emanuel (2006, EOS) study, particular through use of the proxy data that enables the AMO to be studied several hundred years into the past, prior to the onset of the industrial anthropogenic forcing of the climate system. However, I think the analysis is a little confusing as to cause and effect, a confusion that probably arises because the AMO exhibits a decadal lag with the winter NAO index, a decadal lag that is missing from the analysis presented here because the analysis is concerned with the simultaneous atmospheric response to the AMO-related SST anomalies. That the NAO drives the AMO seems to be clear and deserves some attention from the authors. Recommendation: This paper should make a nice contribution once the authors have addressed the above issues.

CPD

2, S627–S634, 2006

Answer: In the discussion section of the revised version we will consider the relation between NAO and AMO, as well as the Mann and Emanuel (2006) results.

Interactive comment on Clim. Past Discuss., 2, 633, 2006.