A Comparison of NAO Related Seasonal to Interannual Variability in the SOC Air-Sea Flux Dataset and HadAM3

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Results are presented from a comparison of variability in the Southampton Oceanography Centre (SOC) air-sea flux dataset with output from the Hadley Centre Atmospheric Model (HadAM3). The aim is to determine whether the model provides a reasonable description of the observed air-sea flux variability at seasonal to interannual timescales and the focus is on the North Atlantic Oscillation (NAO). In addition, the possible role of sea surface temperature (SST) anomalies in changing the state of the NAO has been explored.

Time series of HadAM3 and SOC winter (December-March) NAO indices are shown in Fig. 1 and compared with values from Hurrell. The SOC and HadAM3 series are well correlated ($r^2=0.98$) indicating that the SOC ship-based NAO index can be used as a proxy for that obtained from land station data. In contrast, Hurrell clearly does not capture the timing of the interannual variations in the winter index when compared either with SOC ($r^2=0.85$) or HadAM3 ($r^2=0.81$). Note the Hurrell index values are from http://www.cgd.ucar.edu/cas/jhurrel/nino/nao.html.

HadAM3 and SOC fields have been composited on NAO extremes to determine whether the model can simulate similar seasonal to interannual variability patterns to those observed despite the differences in time evolution. Composite fields have been generated by separately selecting winter months in the period 1980-1995 with normalised NAO index greater than (1.5 for the NAO+ state) or less than (−1.5 for the NAO− state) from the SOC and HadAM3 datasets. Differences (NAO+ − NAO−) p-values of the SLP, near surface temperature (nST), air-sea flux (Qnet) and SST fields are shown in Fig. 2.

The SLP fields both show the familiar dipole structure associated with the NAO. Likewise, the dominant feature in both the SOC and HadAM3 Qnet composites is a dipole between the UK and Greenland with heat flux anomalies of up to 100 Wm$^{-2}$. However, the HadAM3 SST composite differs from SOC from the tropics to mid-latitudes. This suggests that differences in the SST fields have a similar qualitative impact on the model to produce an atmospheric pressure oscillation which interacts with the ocean in a manner similar to that observed for the NAO.

The role of the ocean in driving (leading to) the NAO at seasonal to interannual timescales has been investigated via an EOF analysis. The first three EOFs of SLP and Qnet for SOC and HadAM3 are shown in Fig. 3; the first mode corresponds to the NAO. In each case, the spatial patterns of corresponding modes show strong similarities between SOC and HadAM3. However, the time series of monthly EOF scores (not shown) are essentially uncorrelated, $r^2<0.01$. Similar results are obtained for the other surface meteorological variables. It therefore appears that the major modes of North Atlantic interannual variability in the model are spatially similar to those observed but that their time variation is not well represented. As the only time dependent information supplied to the model in the SST (this suggests that the ocean does not play a major role in setting the time evolution of the model atmospheric variability at interannual timescales.)

Comparisons of the pressure variations in the North Atlantic and Pacific indicate that the atmospheric link between these two basins is too strong in HadAM3, see Fig. 4. The NAO time series is not significantly correlated with either of the Pacific indices in the SOC dataset but does show a strong correspondence in HadAM3. Hence, the model’s poor performance in representing the time evolution of the NAO appears to be largely due to an unrealistically strong link between the atmospheric variability over the Pacific and the Atlantic such that the NAO is being driven to a significant extent by the Southern Oscillation.

Conclusions: 1) HadAM3 provides a reasonable representation of the spatial but not the temporal variations of the principal modes of interannual variability in the North Atlantic. 2) At seasonal to interannual timescales the ocean does not strongly feedback on the NAO. 3) The time evolution of the NAO in the model does not correspond to that observed. Hence, the suggestion by Rodwell et al. (1998, Nature, 398, 320-323) that the European winter climate could be predicted ‘up to several years in advance’ from the atmospheric variability over the Pacific and the Atlantic such that the NAO is being driven to a significant extent by the Southern Oscillation.

The model representation of other modes of variability has been investigated via an EOF analysis. The first three EOFs of SLP and Qnet for SOC and HadAM3 are shown in Fig. 4; the first mode corresponds to the NAO. In each case, the spatial patterns of corresponding modes show strong similarities between SOC and HadAM3. However, the time series of monthly EOF scores (not shown) are essentially uncorrelated, $r^2<0.01$. Similar results are obtained for the other surface meteorological variables. It therefore appears that the major modes of North Atlantic interannual variability in the model are spatially similar to those observed but that their time variation is not well represented. As the only time dependent information supplied to the model in the SST (this suggests that the ocean does not play a major role in setting the time evolution of the model atmospheric variability at interannual timescales.)

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