Modeling the Variations of the North Atlantic Oscillation under Anthropogenic Scenarios

D.V. Khvorostyanov

Moscow State University,
Institute of Atmospheric Physics, Russian Academy of Sciences
e–mail: dimok@omega.ifaran.ru

The North Atlantic Oscillation is considered to be the dominant signal of Northern hemisphere wintertime decadal variability and to have a strong impact on the European winter climate.

This paper presents results of the IAP RAS climate model experiments under two anthropogenic CO_2 scenarios. The IAP RAS climate model is described in detail in Petoukhov et al. [1998]. It is an intermediate complexity model that employs splitting of physical processes into synoptic (with timescales of a few days) and larger–scale components. The latter are described by the model prognostic equations, while the former are parameterized. The model has 6x4.5° resolution, eight atmospheric, three oceanic, and two soil layers.

The first CO_2 increase scenario (IPCC IS92a, hereafter I) implies permanent concentration growth, and the second (II) refers to the constant CO_2 level after 1990 (Mokhov and Khon [2001]). Figure 1 shows the variations of the winter NAO index during 1860–2040 from the IAP RAS model for both scenarios and from the ECHAM4/OPYC3 model's greenhouse experiment (Roeckner et al. [1996]). The indices are smoothed by the running mean filter with the 30–year window length and normalized by the standard deviations (STDs) taken over 1861—1960. The mean value and STD are shown for the ECHAM4/OPYC3 model's control run by horizontal solid and dashed lines, respectively. As the figure indicates, the NAO index (both from IAP RAS scenario I and ECHAM4/OPYC3 models) continues to grow in the 20th century. The observed interannual NAO index dispersion is fairly reproduced by the IAP model: the observed STD for 1860–1997 equals 1.1, and the model yields 1.2 for both scenarios. For the ECHAM4/OPYC3 model the STDs equal 1.8 and 1.9 for the control and greenhouse experiment, respectively.

Amplitude and period of the NAO determine the strength and occurrence of its impact. The knowledge of how they change in time and how they are correlated could be useful in expecting their future changes. Using the method described in Mokhov and Eliseev [1997], time variations of NAO amplitude and period were calculated. Their relationship was estimated through the linear regression of the period (P) on the amplitude (A).

The linear regression of P on A is positive in the four cases considered: greenhouse and fixed runs of the IAP RAS model, control and greenhouse runs of the ECHAM4/OPYC3 model. This agrees with observed and reconstructed NAO index analysis (Mokhov et al. [2000b]). For the IAP RAS model forced by the IS92a (I) scenario, the regression is significant at $\geq 95\%$ level. The regression coefficient $b = 3.6 \pm 1.6$ mo, the correlation coefficient $r = 0.50$ at 15 degrees of freedom (DOF). With the scenario II, this A–P relationship turns to be significant only at the STD level: $b = 3.5 \pm 2.4$ mo, $r = 0.35$ at 16 DOF. For the ECHAM4/OPYC3 model, the control integration yields more significant positive regression of P on A than the greenhouse one. However, when considering only the variations with sufficiently high amplitudes (greater than a certain minimum value), the greenhouse forcing experiment gives much more significant result. For the amplitudes greater than 0.3 K, greenhouse run yields the A–P regression significant at $\geq 99\%$ level, while the control experiment gives only 90%–level significance.

These results allow one to conclude (see also Mokhov et al. [2000a]) that: 1) the amplitude and the period of decadal NAO variations change coherently in time, i.e., the amplitude rises are accompanied on average by period lengthening, and vice versa; 2) this positive amplitude–period correlation tends to amplify under the greenhouse forcing, at least for sufficiently strong amplitudes.

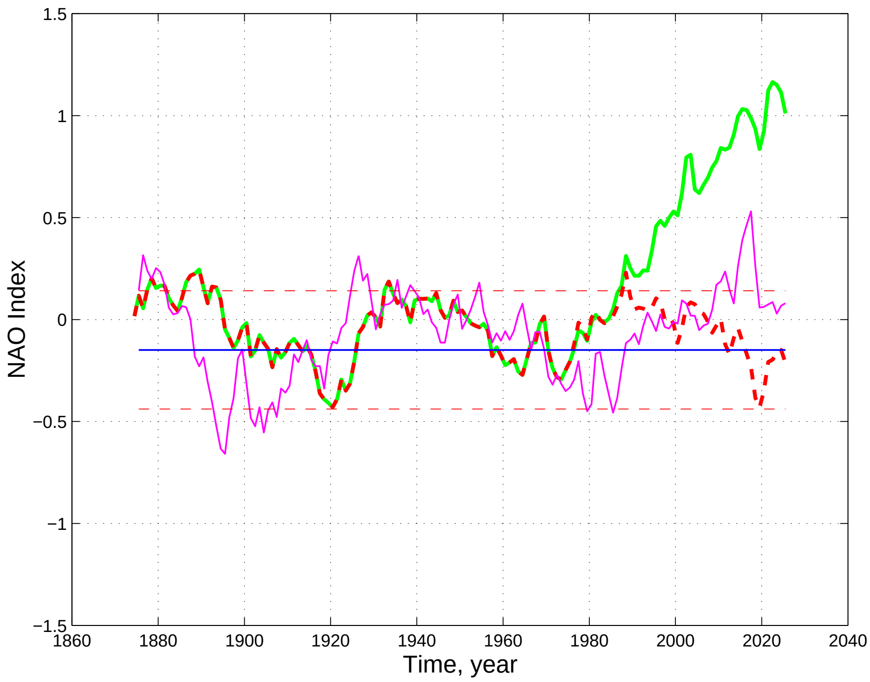

Figure 1: NAO index filtered by running means at the window I_0=30 yr. Thick lines, solid and dashed, show the IAP RAS model experiments, scenario I and II, respectively; thin lines refer to the ECHAM4/OPYC3 model: the curve denotes the greenhouse forcing run, and horizontal lines show the mean and the STD in the control experiment

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