North Atlantic climate far more predictable than models imply

Article

Supplemental Material

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Supplementary Information for

Climate models underpredict North Atlantic atmospheric circulation changes

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This PDF file includes:

Supplementary Figures S1 to S5

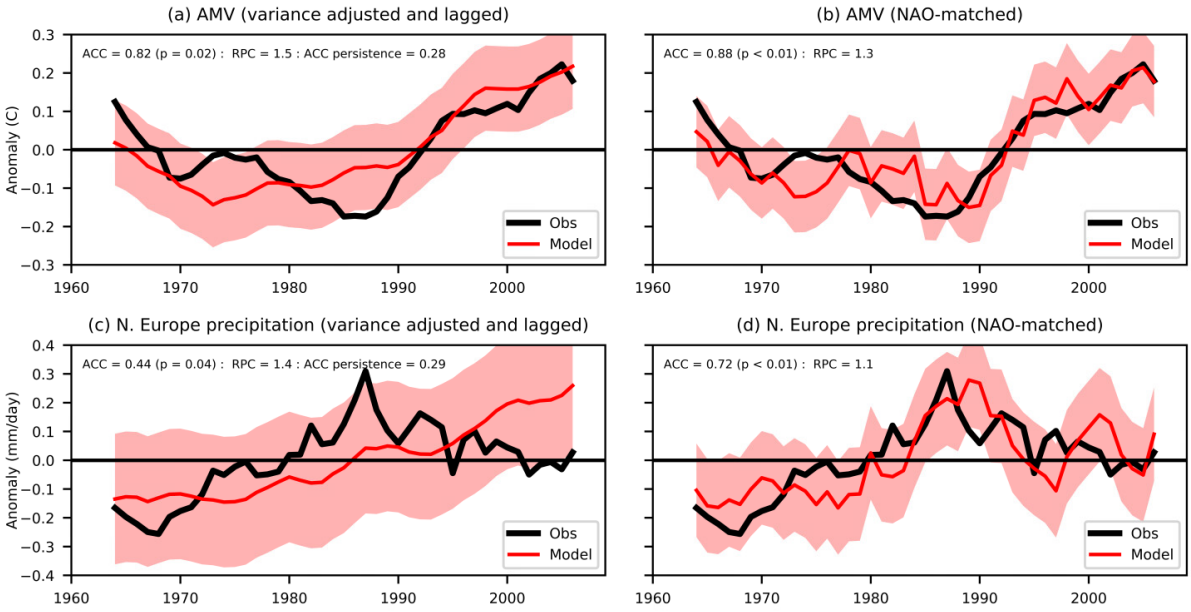

Figure S1: Improvement of NAO-matching over variance adjustment. Panels are as Figure 2 c-f but the lagged forecasts in (a) and (c) are additionally variance adjusted. Variance adjustment does not affect the correlation skill, but the uncertainties (red shading) capture the observations better, especially for N. Europe precipitation (compare Figure S1c with Figure 2e). However, NAO-matching clearly improves predictions of the timing of the AMV minimum in the late 1980s and the subsequent rapid warming, and captures the observed increase in N. Europe precipitation from the 1960s to late 1980s and decrease thereafter.

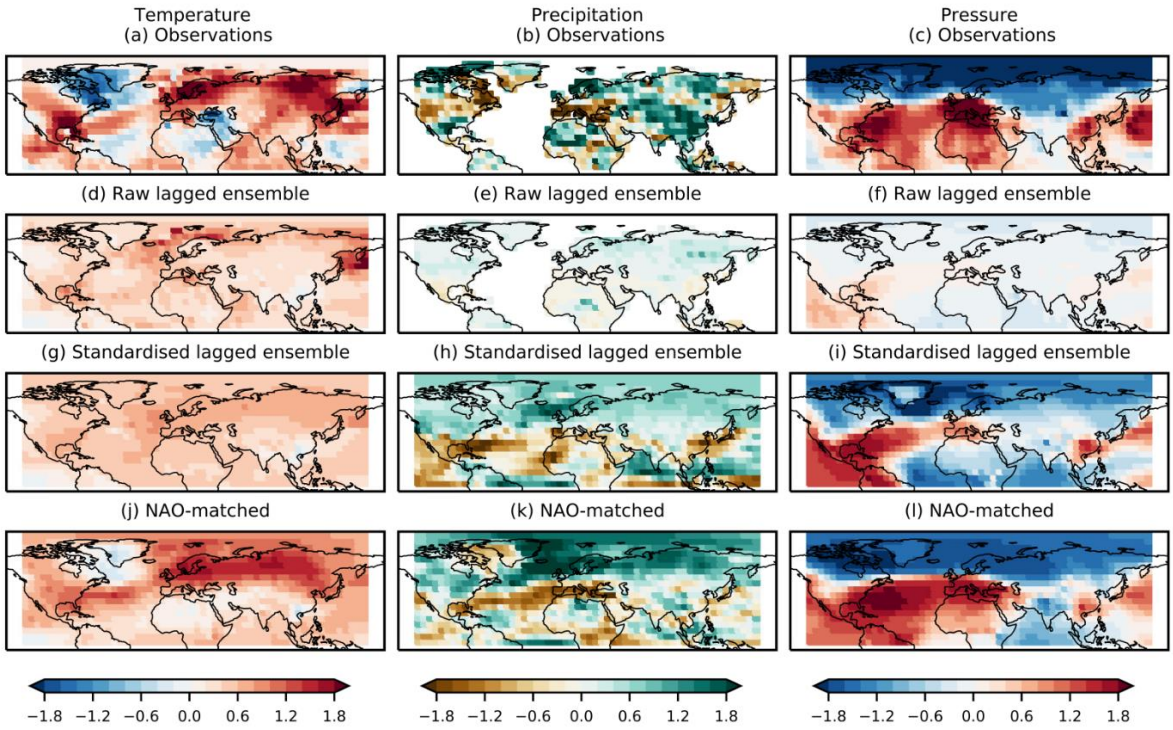

Figure S2: Effect of NAO-matching on trends during Increasing NAO period. As Figure 3 but for linear trends over hindcast start dates 1973 to 1989 inclusive. NAO-matching clearly improves the cooling trend over the Labrador Sea and the warming trend over Eurasia, as well as the drying/wetting trends over southern/northern Europe.

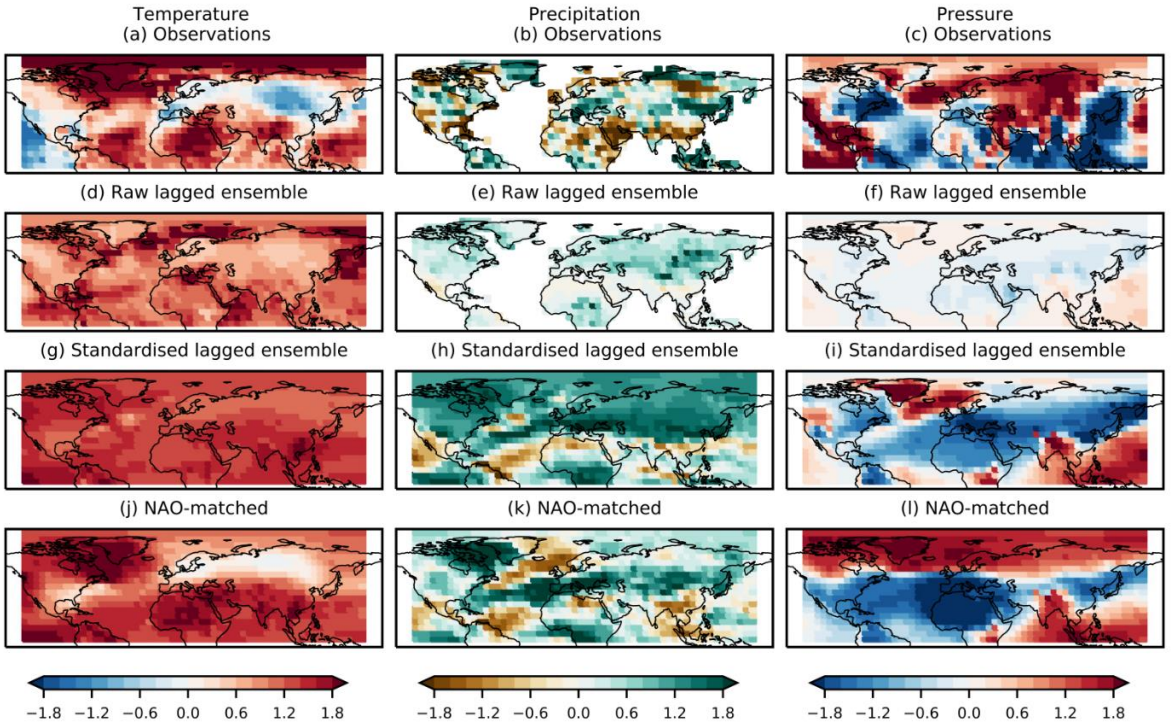

Figure S3: Effect of NAO-matching on trends during decreasing NAO period. As Figure 3 but for linear trends over hindcast start dates 1989 to 2005 inclusive. NAO-matching improves the cooling trend over northern Eurasia, drying/wetting over northern/southern Europe, and the increasing pressure trend across most of the Arctic.

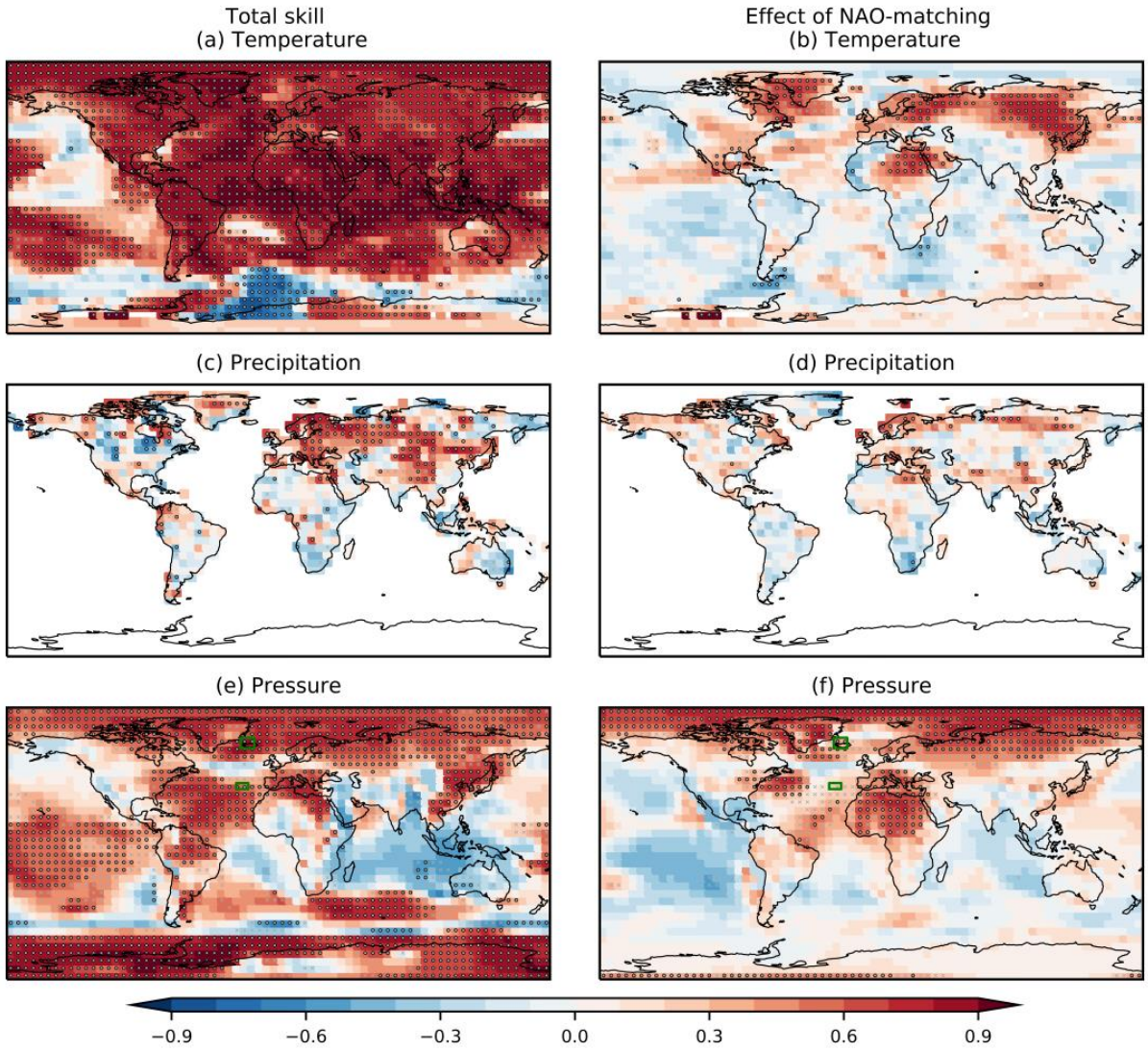

Figure S4: Effect of NAO-matching on skill. Anomaly correlation skill (left panels) of 20 member NAO-matched ensemble mean, and the effect of NAO-matching (right panels), for year 2-9 boreal winter (DJFM) forecasts of (a,b) near-surface temperature, (c,d) precipitation and (e,f) mean sea level pressure (mslp). The effect of NAO-matching on skill is computed as the partial correlation between observed and forecast residuals after regressing out the lagged ensemble mean forecast (ref 19), thereby focussing on the variability not already captured by the lagged ensemble mean. Improvements from NAO-matching are consistent with the NAO-related quadrupole pattern affecting eastern North America, Greenland, western Europe, northern Africa, Eurasia, China and the Arctic. Despite the use of fewer members (20 in the NAO-matched ensemble compared to 676 in the lagged ensemble) skill is not significantly degraded in most other regions. Negative mslp skill in the Indian Ocean could be related to inconsistencies in initialisation of surface temperature and atmospheric circulation as discussed previously (ref 19).

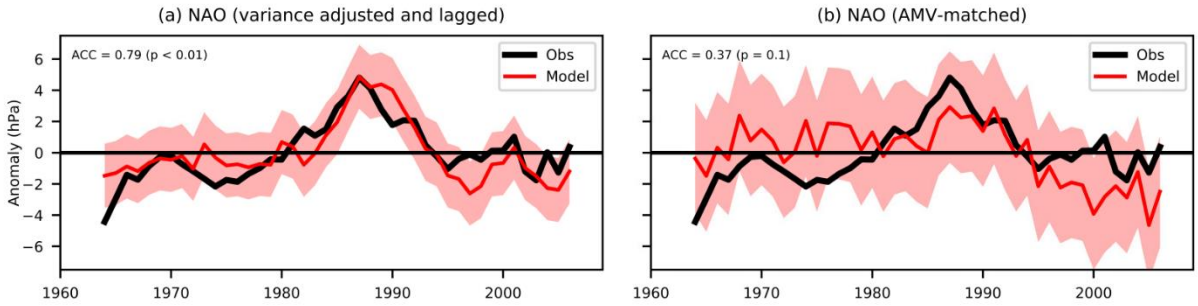

Figure S5: NAO not solely driven by AMV. (a) Variance adjusted lagged ensemble forecasts of the NAO (as Figure 2b, red curve showing ensemble mean with shading showing 5-95% confidence interval diagnosed from the error variance). (b) As (a) but for AMV-matched forecasts. AMV-matching is the same procedure as NAO-matching (see Methods) except that the 20 ensemble members are selected based on AMV instead of NAO. If the NAO signal were solely driven by AMV then selecting the most skilful AMV ensemble members by AMV-matching would be expected to increase the NAO skill. However, AMV-matching clearly reduces the NAO skill (ACC reduces from 0.79, $p<0.01$, to 0.37, $p=0.1$). In contrast, NAO-matching clearly improves the forecasts of AMV (Figure 2c and d). We therefore conclude that the NAO signal is not solely driven by AMV.