Skillful predictions of Eurasian winter climate by constraining variability in CMIP6 simulations using NAO-temperature teleconnection

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Introduction

Predicting climate over Europe and northern Asia remains challenging as both the initialized predictions and uninitialized climate projections show limited skill in reproducing the observed variability on multi-annual to decadal timescales. Here we present a novel approach to constrain variability in climate model simulations over Eurasia by exploiting the observed teleconnection between the North Atlantic Oscillation (NAO) and the regional climate.

Methodology

1. Compute NAO-temperature teleconnection based on their first order linear regression in observational (i.e. ERA5) data and separately for each individual model member for a 20-year winter window (see Figure 1).

2. Compute pattern correlation between the observed regression (i.e. teleconnection) and the model member regression, resulting in one pattern correlation value for each member.

3. From the ranked members we selected the top ranking ten members (hereafter referred to as "Best10") to make predictions after the selection period (i.e. after the 20-year window).

4. The above procedure is repeated every year by moving the 20 year winter windows by one year.

Results

Figure 2 shows that for the multi-annual mean predictions the constrained ensemble (i.e. Best10) can outperform both the full ensemble (AllEnsemble=250 members) and the initialized climate predictions (i.e. DCPP-A) over the Eurasian region.

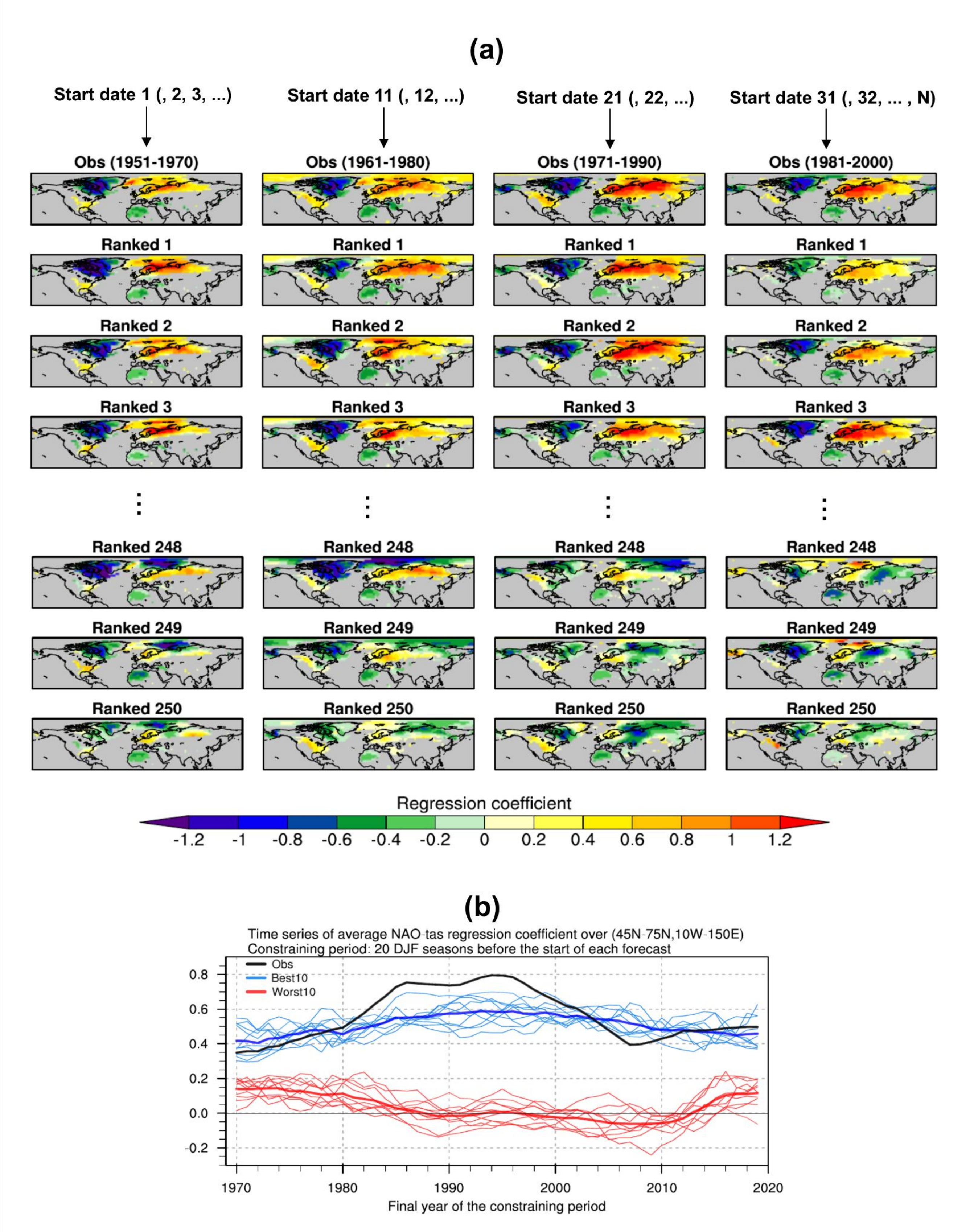

Figure 1: (a) A schematic comparison of the observed (in the top row) and simulated (subsequent rows) regression values between winter NAO and SAT during 20 year windows prior to making a prediction (see details in methods). For each start-date a spatial pattern correlation is calculated between the observed and simulated NAO-temperature regressions to sort the members from highest to lowest ranking members. We select for each start date the top ranking 10 members to build hindcasts for evaluation. Here we only show comparisons for four start dates, however, a total of 40 start-dates (i.e. 1971 - 2010) were used in building a full hindcast. **(b)** Area-weighted average of regression values over Eurasian region (45°N-75°N, 10°W-150°E) during the 20 year period prior to the start of the forecast. The black line represents observation and blue (red) lines are for the top (bottom) ranking ten members. The years on x-axis represent the final year of the 20 year windows starting from 1951-1970, 1952-1971 and so on. A five point running average was applied to the area-weighted time series. Thick blue (red) lines represent the ensemble means of the top (bottom) ranking ten members.

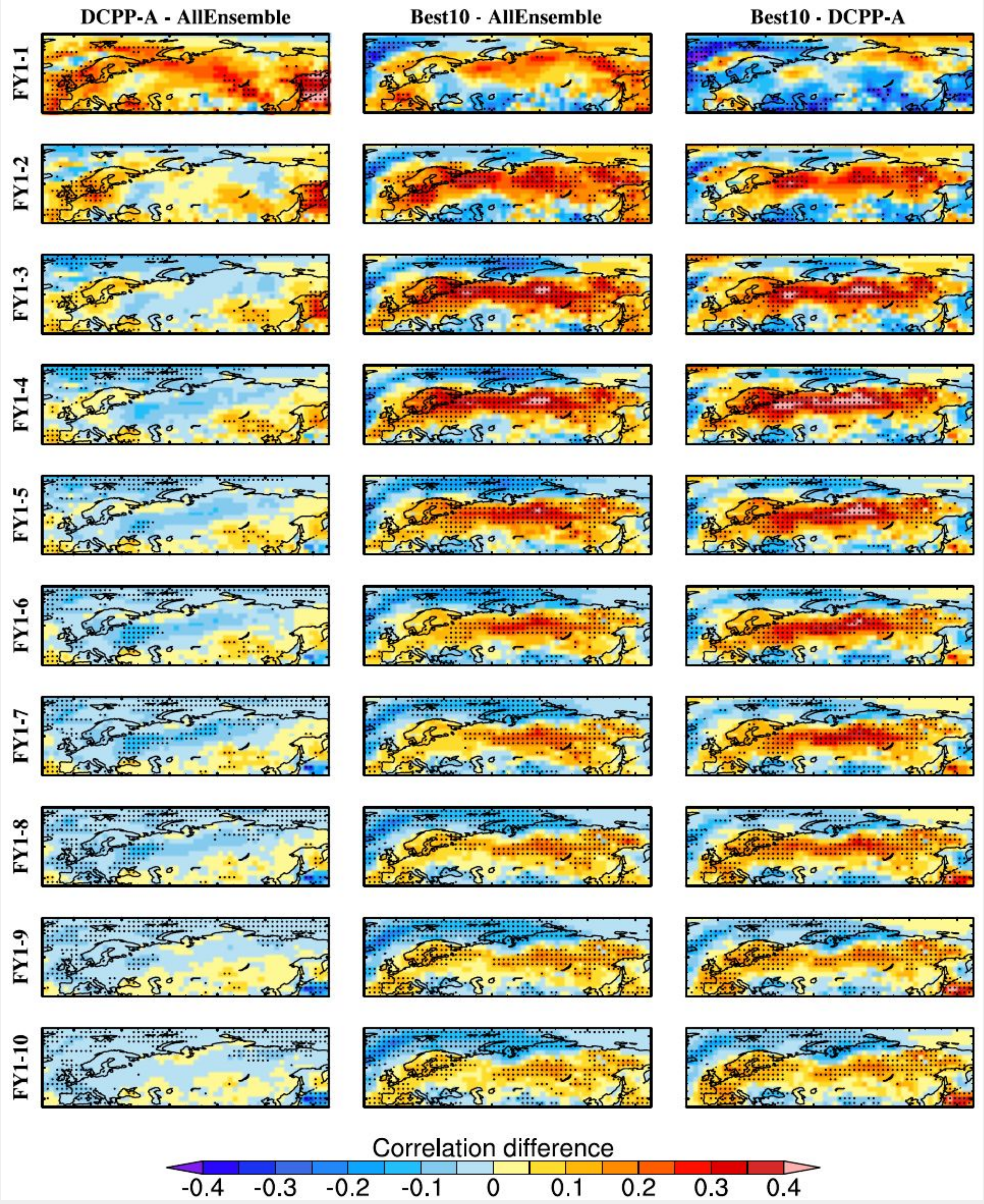

Figure 2: ACC difference for winter surface air temperature between DCPP-A and historical ensemble (left panels), Best10 and historical ensemble (center panels) and Best and DCPP-A (right panels) for different forecast periods. Stippling indicate regions where the correlation difference is statistically significant at the 95% confidence level.

Discussion

In order to understand how the NAO-temperature teleconnections can align the phases of variability of the constrained ensemble with those of observations, we further explore the relationship between the linear trends in NAO and in the SAT averaged over Eurasia (45°N-75°N, 10°W-150°E) during the 20-year windows (Figure 3). In general, the observed linear trends between NAO and the SAT are aligned with positive correlation, meaning that an increasing (decreasing) SAT in the region is often associated with an increase (decrease) of NAO during the 20-year period. The Best10 members tend to show a similar relationship indicating that the constraint exploits both temporal variations in the NAO-temperature teleconnections, as well as the changes in spatial distribution of the teleconnection patterns.

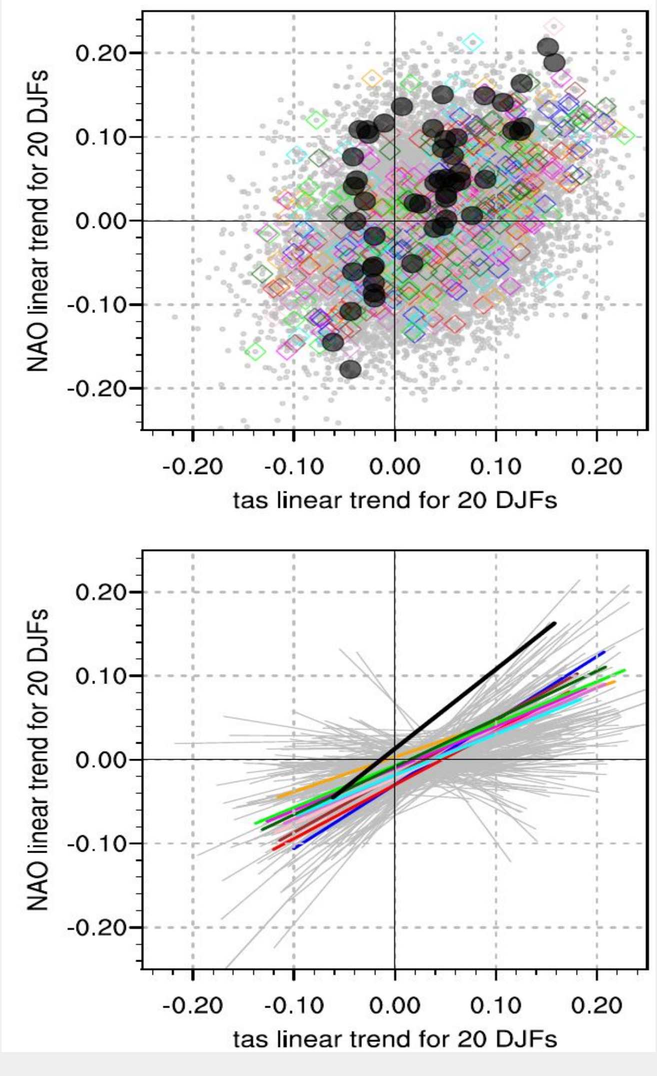

Figure 3: Upper panel: Relationship between linear trends in NAO and Area-weighted average of SAT over Eurasian region (45°N-75°N, 10°W-150°E) during the 20 year selection windows. Each grey dot represents the relationship for a given individual historical member. The colored markers are for each of the Best10 members (i.e. one color for each top ranked member for all 20 year windows). Black markers show the relationship in observations for all 20 year windows. **Lower panel:** Linear regression lines for each model member (in gray) and observation (black) for the scatter points shown in the upper panel with the colored lines for the Best10 members.

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