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Predictability of the North Atlantic Oscillation on Intraseasonal Time Scales

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LONG-TERM GOALS

Recent evidence clearly shows that the intra-seasonal variability of the atmospheric circulation in the North Atlantic, and in particular the North Atlantic Oscillation (NAO), is impacted by tropical convection related to the phase of the Madden-Julian Oscillation, or MJO (Cassou 2008; Lin et al. 2009). The long-term goals of this project are:

(1) To understand the dynamics of the extratropical response to the components of the MJO heating and cooling.

(2) To understand what components of the heating in various MJO phases are critical. Does the propagation speed of the MJO play any role?

(3) To assess the potential added predictability of the NAO based on the potential predictability of the MJO.

OBJECTIVES

(1) To understand how the extratropical responses to the components of the MJO heating and cooling interact to affect the NAO.

(2) To pin down the roles of the Rossby wave source, synoptic eddy momentum flux convergence, Rossby wave breaking and storm track shifts in altering the North Atlantic circulation.

(3) To utilize the MJO as a source of tropical predictability to improve (a posteriori) dynamical reforecasts of the North Atlantic intra-seasonal variations within a seamless prediction system.

APPROACH

In order to gauge the impact of the MJO on the North Atlantic variability, MJO-related tropical diababtic heating derived from TRMM satellite data is added to the CESM as it runs: at each time step the four-dimensional (time varying) MJO-heating is added to the temperature tendencies produced by the model's dynamics and physical parameterization subroutines before these tendencies are used to update the temperature field. This techique has been used in the seasonal mean context by Jang and Straus (2012, 2013). Large ensembles of seasonal simulations (1 Oct – 31 Mar) made with (HTG simulations) and without (CTL simulations) the added heating are used to assess the effect on the NAO. The HTG experiment has the MJO-heating identical for each winter simulation, following several MJO episodes whose properties (e.g. dependence on the annual cycle evolution) are derived from the TRMM observations.

To estimate the potential improvement in extratropical predictability based on the skillul predictions of the near-term MJO using the CFSv2 seasonal prediction model, a three step approach is needed. First, a control set of 4-month ensemble reforecasts is made from observed initial conditions of 01 Nov, 01 Dec and 01 Jan for the years 1980-2011. Second, the reforecasts are rerun with the tropical fields strongly nudged to the observed MJO-related circulation during the first 15 days of the forecast (an esimate of the predictability time for the MJO in the near-future). Third, the reforecasts are rerun with the nudging applied throughout the forecast preriod.

Key individuals and the roles they play are given here:

David . Straus (GMU): Supervises design and execution of project; carries out diagnoses of all results.

J. Shukla (GMU): Aids in overall project planning.

Priyanka Yadav and Sara Amini (GMU): Diagnosis of model experiments

Erik Swenson (GMU and APCC, Korea): Running CESM, CFSv2 experiments

WORK COMPLETED

Straus et al. (2014) added a pre-determined seasonal evolution of three-dimensional MJO diabatic heating (derived from satellite data) to each of 50 extended boreal winter simulations with the coupled climate model (CESM) of the National Center for Atmospheric Research. The CTL simulations consisted of 50 simulations without any added heating, the HTG simulations had the same pre-determined diabatic heating added to each simulation. Because each simulation had the identical heating evolution added, it was possible to use predictable component analysis to construct highy coherent modes connecting the tropical heating, Rossby wave source and the mid-latitude response.

RESULTS

Straus et al. (2014), in the simulations described above, achieved a synthesis of relationships between the MJO-related cycle of tropical heating and cooling, the upper level tropical and subtropical Rossby wave source, and the far-field responses. The leading two predictabe component modes of total tropical diabatic heating, Rossby wave source, geopotential height, synoptic scale vorticity flux, and storm track kinetic energy are synthesized below. Figures 1 and 2 show the synthsis of these evolving modes as a function of time for the period 01 Oct - 31 Mar. Remarkably, the evolution of these modes

is related to the daily evolution of the state of the North Atlantic circulation, which is assessed indepedently with a cluster analysis based on unfiltered daily data. In terms of the impact on overall variability, the NAO in its postive (negative) phase is under- (over-) represented in the CESM control runs in comparision to the recent reanalysis of the European Centre for Medium Range Weather Forecasts (ECMWF), known as ERA-Interim (Dee et al., 2011). This error in the circulation regime statistics is corrected in the simulations with added MJO heating.

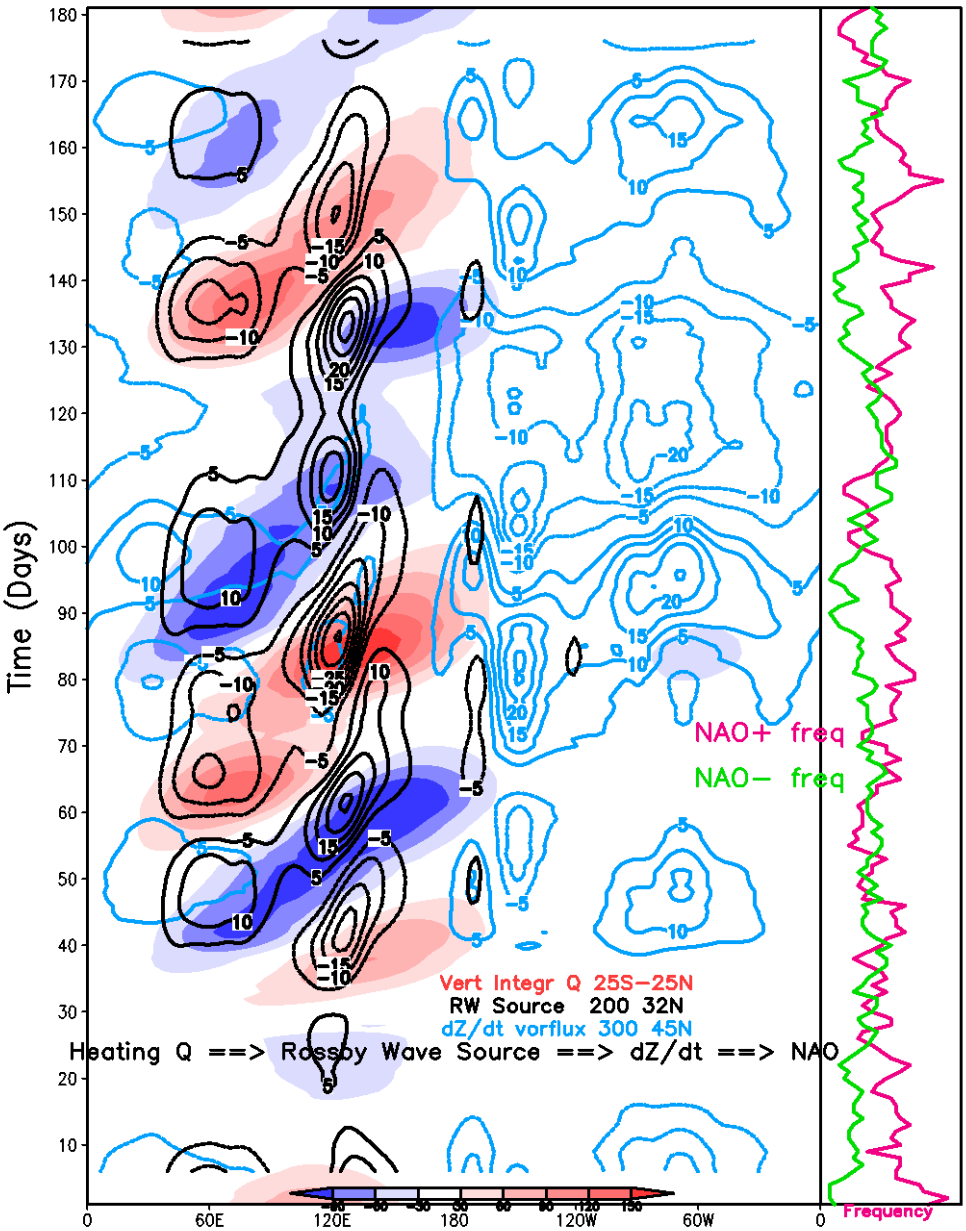

Figure 1. Synthesis of the leading two most predictable components at all times for the Rossby wave source at 200 hPa, 32°N (black contours, interval 5 x 10^{-11} s^{-1}), 300 hPa height tendency from synoptic scale vorticity flux 45°N (blue contours, interval 5 m d^{-1}), vertically integrated diabatic heating, averaged from 25°S to 25°N, in W m^{-2}. Heating scale shown below figure. Red (green) curves on right show frequency of occurrence of NAO+ (NAO-) circulation regimes. Abscissa is longitude, ordinate in time in days starting 01 October.

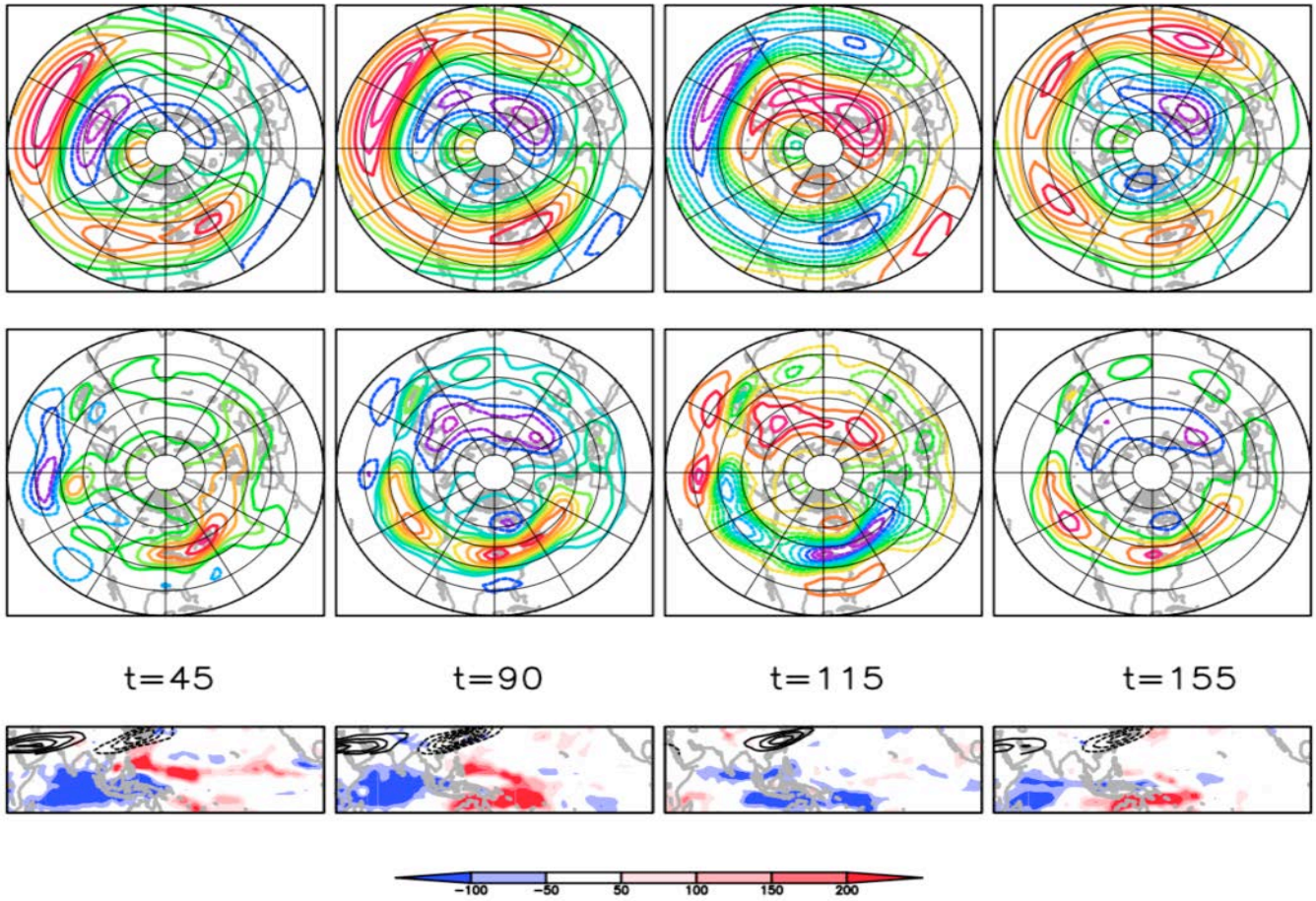

Figure 2. Synthesis of leading two most predictable components at selected times for Z200 (top row), 300 hPa height tendency from synoptic scale vorticity flux (middle row), and 200 hPa Rossby wave source (contours) and ensemble averaged diabatic heating (shaded), bottom row. Contour is 10 m for Z200, 2.5 m d^{-1} for height tendency, and 5.0 x 10^{-11} s^{-1} for Rossby wave source. Heating scale shown below figure in Wm^{-2}

IMPACT/APPLICATIONS

Our results clearly indicate that the technique of adding intra-seasonally varying diabatic heating to a state-of-the-art coupled weather/climate model is feasible, and can lead to validation of hypotheses made from observations, in this case the effects of intra-seasonal tropical heating variability on NAO variability. Since models are known to have a number of difficulties in simulating the MJO and other intra-seasonal oscilattions, we expect the this technique will see a productive use in other scientific studies.

REFERENCES

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PUBLICATIONS

Straus, D. M., E. Swenson, and C.-L. Lappen, 2014:The MJO Cycle Forcing of the North Atlantic Circulation: Intervention Experiments with the Community Earth System Model. *J. Atmos. Sci.,* doi: http://dx.doi.org/10.1175/JAS-D-14-0145.1