Mid-latitude response to Slow MJO episodes in large ensemble of CFSv2 experiments

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Motivation and Basic Idea of Experiments

The Observational study of Circulation response to Fast and Slow MJO episodes (Yadav and Straus, 2017) shows that the responses to MJO episodes with different propagation speeds are not the same. Key results from observations include:

1. Development of NAO+ teleconnection pattern is stronger in Slow than in Fast MJO episodes, and occurs with a greater time lag after MJO heating is in the Indian Ocean (phase 3).

2. Development of NAO- teleconnection pattern in previous studies is entirely due to the SLOW episodes.

The motivation behind the ensemble experiments presented in this study is

- To understand the role of phase speed in setting up the mid-latitude response.
- To understand the mechanisms that distinguish fast and slow types of response.

The CFSv2 experiments consist of a number of reforecasts in which the identical MJO evolution of three-dimensional diabatic heating has been added. The phase speed of the MJO in these added heating experiments can then be varied. Mechanistic modes of response can then be extracted using Predictable Component Analysis.

Model Reforecasts Experiment

Model: The Climate Forecast System Version 2 (CFSv2) model of NOAA: resolution T126 and 64 levels in vertical

Ensemble size: 4

Initial Conditions: December 1 for 31 years (1980-2011) from CFS reanalysis

Control Reforecasts: length 4 months

SLOW Added Heating Reforecasts: length 4 months, with added heating to produce MJO cycles (phase speed of 3 deg/day), and 2 active events during the 120-day boreal winter season. 31 x 4 = 124 reforecasts in total

Total Model Heating = Added Heating + Model-Generated Heating

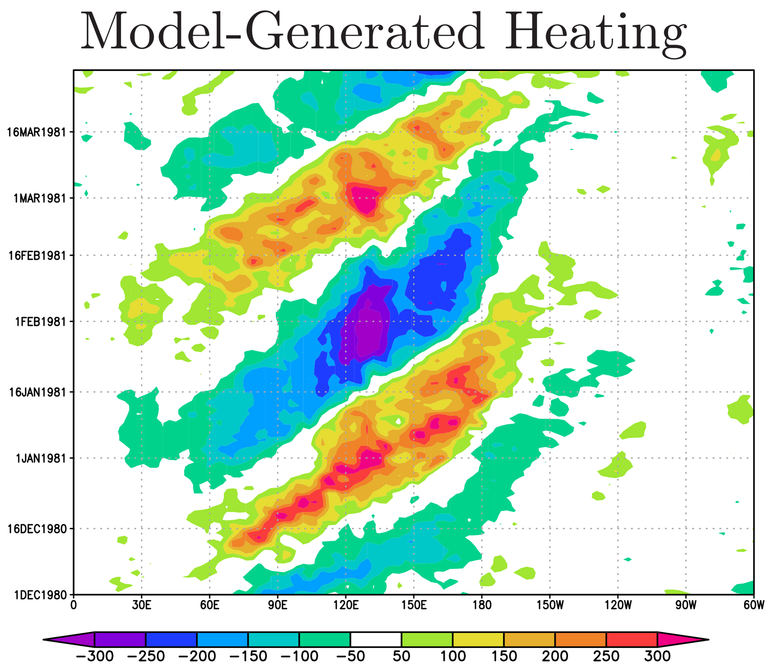

Figure 1: Total Diabatic heating anomalies averaged from 15S-15N Unit is Wattsm^{-2}

Methods

Predictable Component Analysis
(Signal-to-Noise Optimizing EOF analysis) Goal of the analysis:

- Distinguish the signal forced by common diabatic heating signal from noise
- Determine the evolution of signal most in common among all 124 reforecasts
- Analysis identifies patterns and coefficients (variates) with maximum signal to noise ratio

Reference

Yadav, P. and D.M. Straus, 2017: Circulation Response to Fast and Slow MJO Episodes. *Mon. Wea. Rev.*, 145, 1577–1596

Most Predictable Modes

Raw Signal = standard deviation of ensemble mean time series
Raw Noise = standard deviation of all deviations about the signal.

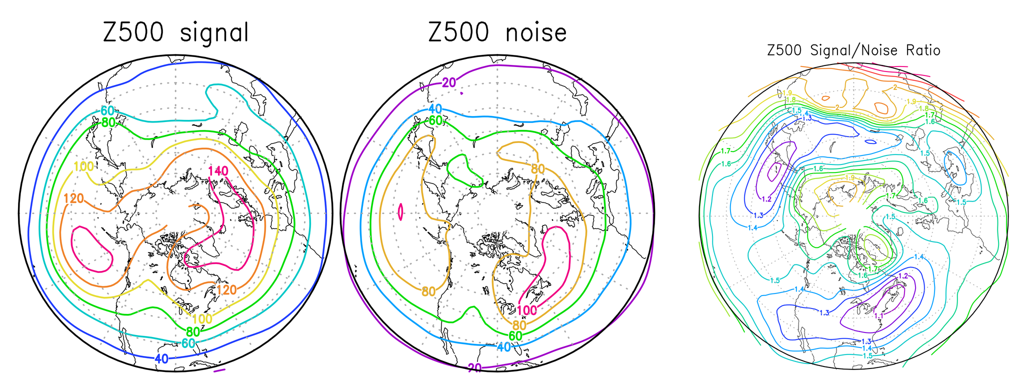

Figure 2: (left) Raw signal, (center) Noise, (right) Signal-to-Noise Ratio of 500-hPa height from 20N-80N (F-critical is 1.04 at 99% significance level).

Optimal (most predictable) Modes of Geopotential height anomalies

	Signal/Noise		F-value	
Modes	Z200	Z500	Z200	Z500
1	2.27	2.02	281.9	249.9
2	1.45	1.01	179.7	124.9
3	0.10	0.04	13.06	5.0
4	0.05	0.03	6.9	4.2
5	0.35	0.03	4.4	3.8

Table 1: Signal to noise ratio and associated F-values of optimal signal-to-noise modes for 200-hpa and 500-hPa Height

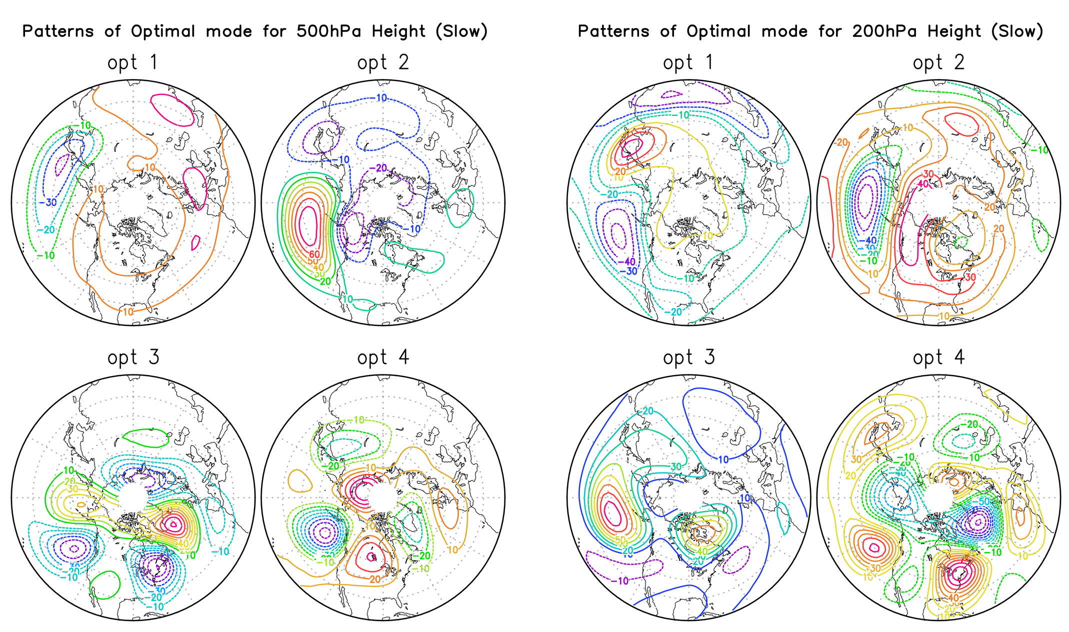

Figure 3: Patterns of the most predictable modes (optimal modes) for 200 and 500-hPa height anomalies for 20N-80N. Contour intervals are 10m. Optimal mode 2 pattern is similar to the observed Slow case composites over Atlantic sector.

Acknowledgements

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500-hPa Height Response

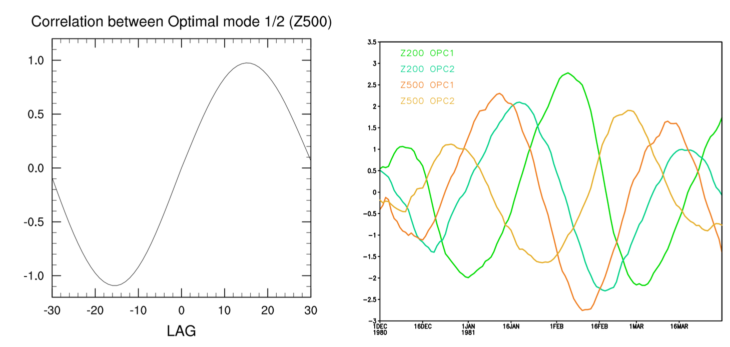

Figure 4: (Left) Lag Correlation between the leading two optimal modes for 500-hPa. (Right) Time series of optimal modes for 200-hPa (green) and 500-hPa (orange) geopotential height.

The lead-lag correlation of first two modes shows that together they form an oscillatory pair.

Geopotential height Response using Multivariate MJO Index

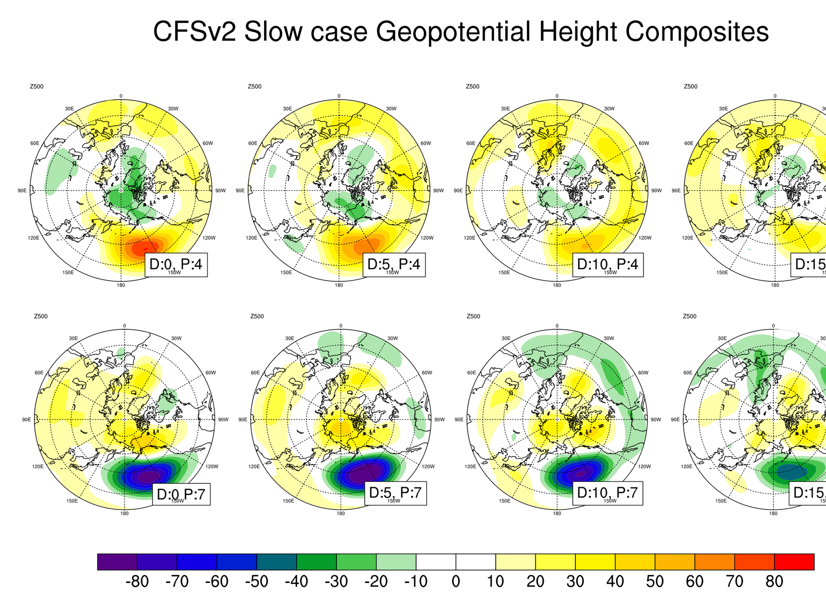

Figure 5: Lag Composite anomalies for MJO phase 4 and phase 7 of daily 500-hPa height for CFSv2 experiments in Slow case. Units are m.

Tentative Conclusions

500-hPa geopotential height response is similar to observed SLOW geopotential height composite occurring with 5 day lag from MJO heating phase 4. The mode shows the development of NAO+. The development of NAO- is seen late in the MJO cycle.

Ongoing work:

Further analysis of SLOW Added Heating Experiments

Experiments with only one SLOW episode

Experiments with repeating FAST episodes

Experiments with only one FAST episode