Troposphere-Stratosphere Coupling In S2S Models and Its Importance for a Realistic Extratropical Response to the MJO

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Introduction

- The MJO has been linked to the North Atlantic sector via both tropospheric and stratospheric pathways (Cassou, 2008; L'Heureux & Higgins, 2008; Lin, 2009; Garfinkel 2012, 2014)
- Improved modeled extratropical response to MJO-related anomalous convection can enhance subseasonal predictions
- In this work, we focus on the stratospheric pathway in 5 subseasonal operational models. We first examine the representation of troposphere-stratosphere upward and downward coupling in the models, which is a necessity for simulating this pathway, then consider the upward coupling following MJO events and the MJO-SSW connection in these models

Models and Data

- We used 5 models which are part of the joint S2S project launched by the World Weather Research Programme (WWRP) and the World Climate Research Programme (WCRP)
- The models were chosen based on their initialization frequency and duration of each run

model (ensemble members)	years	reforecasts analyzed	vertical levels	model top
CMA (4)	1999-2014	6 per month	40	0.5hPa
NCEP (4)	1999-2010	9 per month	64	0.02hPa
ECMWF (11)	1996-2013	4 per month	91	0.01hPa
BoM (33)	1981-2013	6 per month	17	10hPa
UKMO (3)	1998-2009	4 per month	85	85km

Stationary Wave Pattern in the Models

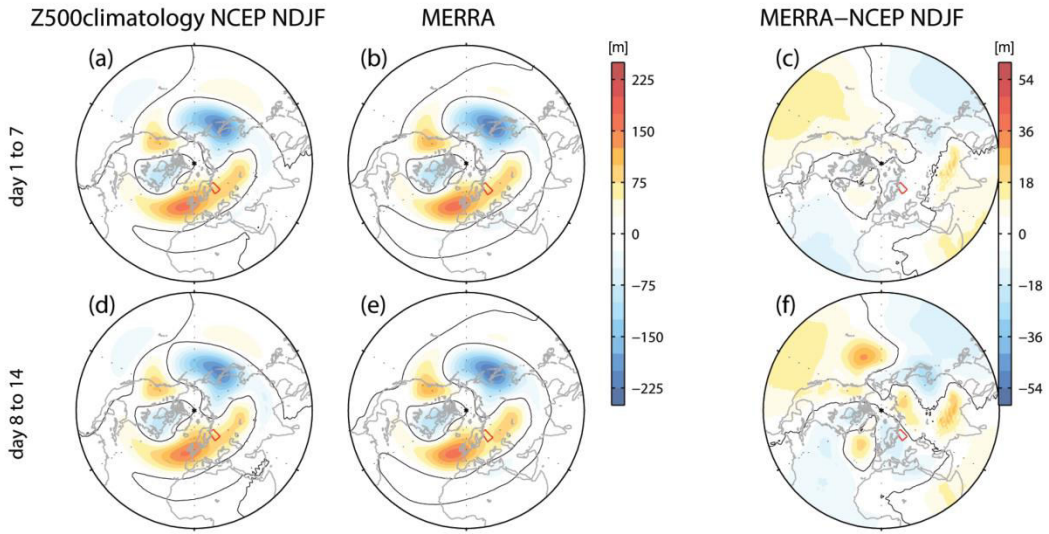

Fig 1. Anomalies from the zonal mean of 500hPa geopotential height for initializations in NDJF during the (a) first week (d) second week; The middle column (b,d) is for MERRA subsampled to match the dates chosen for NCEP;
The right column (c,d) is for the difference between MERRA and NCEP

- Realistic climatological wave structure is essential for simulating upward coupling
- The NCEP, ECMWF and UKMO simulate a relatively realistic time-mean zonal eddy field
- During the second week of integration, the ridge over the northeast Pacific is weaker in the models
- Biases are more pronounced in the CMA and BoM models

Upward Coupling

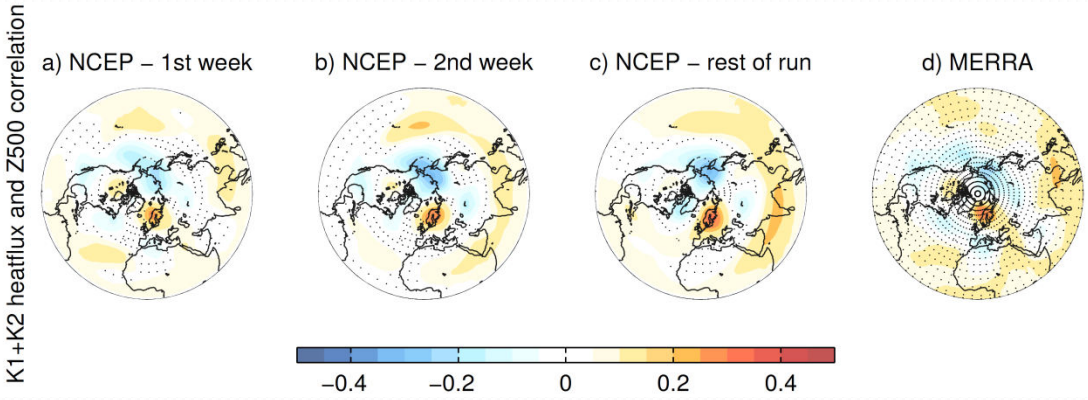

Fig 2. Correlation between NDJF time anomalies of the ensemble mean 500hPa height and mid-latitude wavenumber 1,2 meridional eddy heat flux at 100hPa lagged by 3-days in NCEP during the (a) first week (b) second week and (c) rest of the run; (d) is for the corresponding years in MERRA (1999-2010)

- In the models, the correlation pattern mostly projects onto the stationary wave structure
- The time evolution of the pattern slightly differs between the models
- In the CMA model, the pattern fades out after week two
- Overall, the models can potentially simulate a realistic polar stratospheric variability in response to tropospheric forcing

Downward Coupling

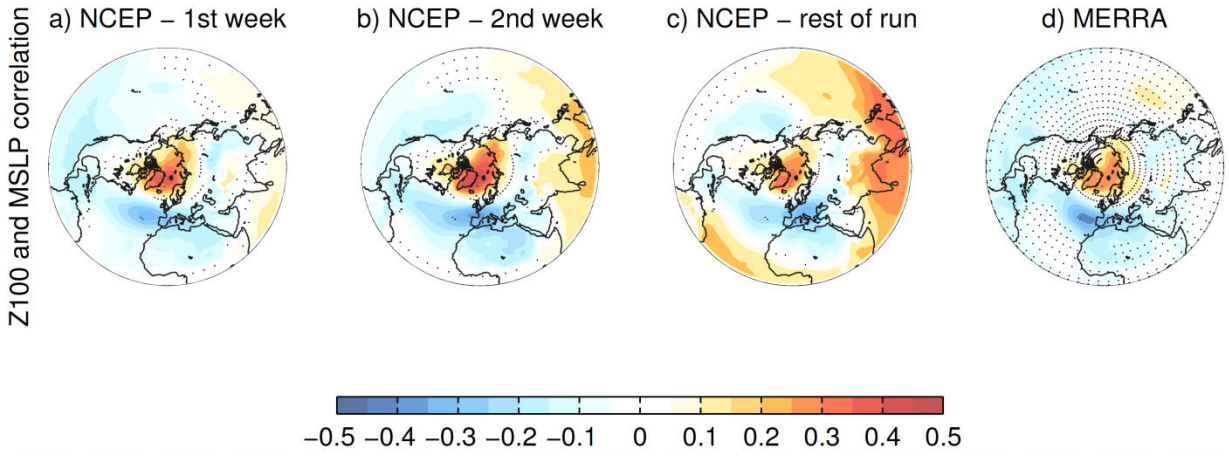

Fig 3. Correlation between NDJF time anomalies of the ensemble mean cosine-weighted 100hPa height averaged over the polar cap (60°N-90°N) and MSLP lagged by 7-days in NCEP during the (a) first week (b) second week and (c) rest of the run; (d) is for the corresponding years in MERRA (1999-2010)

- In all models, 100hPa polar cap height anomalies are positively correlated with surface pressure lagged by 7 days
- The correlation projects onto a NAM pattern, stronger than that observed, particularly in the ECMWF, CMA and BoM models

Upward Coupling Following MJO Events

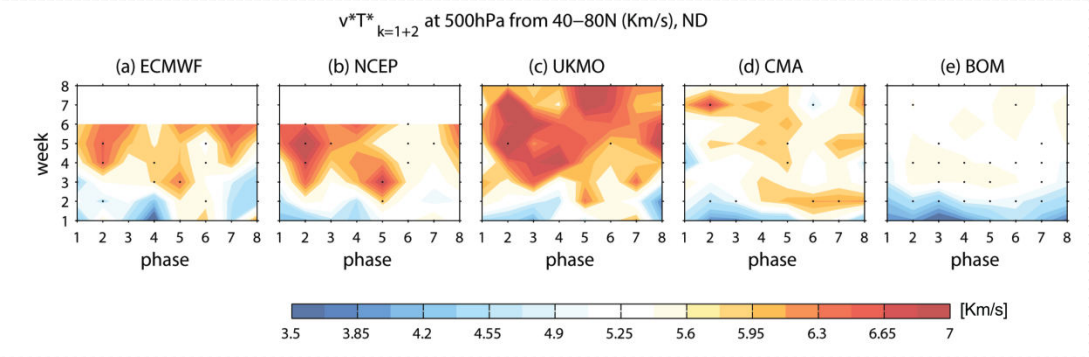

Fig 4. November-December wavenumber-1 and wavenemuber-2 components of meridional heat flux at 500hPa following MJO phases 1-8 for each S2S model; black dots denote significance at the 95% level by a two-tailed student's t-test.

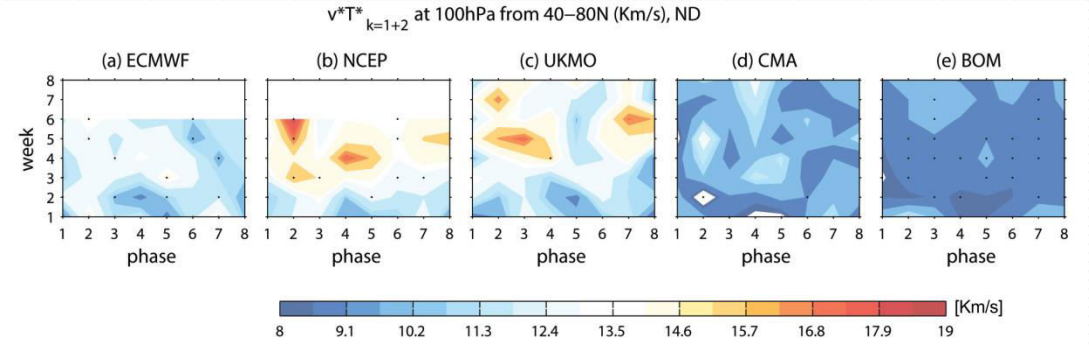

Fig 5. Same as figure 4 but for meridional heat flux at 100hPa.

- Enhanced meridional heat flux is simulated in the mid-troposphere during the first week following phases 6/7 and during week 4-5 following phases 2/3 (but not in the BoM) (figure 4)
- In the lower stratosphere, more heat flux is simulated during the first week following phases 6/7 (figure 5)
- Although the mid-troposphere and lower stratosphere response to the MJO in the models is qualitatively in agreement with observations, it is weaker in magnitude
- The models struggle to simulate the observed weakening of the polar vortex at short lags following MJO 6/7

MJO-SSW Connection in the S2S Models

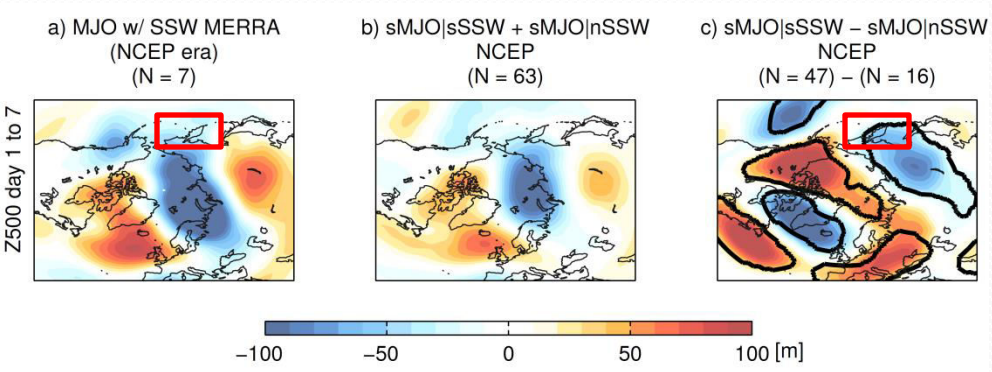

Fig 6. Anomalies of geopotential height at 500hPa in the first week (days 1-7) (a) after MJO 6/7 w/SSW in MERRA; (b) after NCEP initializations that simulate and do not simulate a SSW combined; c) difference between NCEP reforecasts the simulate and do not simulate a SSW; N is the number of MJO 6/7 events in each composite; Black contours denote significance at the 95% computed by a two-tailed student's t-test.

- SSW events associated with MJO 6/7 are preceded by anomalously negative heights in the subpolar Northwest Pacific
- The combined composite from the models shows a qualitatively similar pattern to that observed, but weaker in amplitude
- The difference composite shows negative height anomalies in the subpolar Northwest Pacific, indicating that the qualitatively realistic response in the combined composite is due to integrations that simulated the observed SSW
- Integrations that simulated the observed SSW associated with MJO 6/7, also simulated a relatively realistic North Atlantic response at longer lags

Summary

- The 5 S2S models analyzed simulate a realistic stationary wave pattern, but biases are pronounced in the BoM and CMA models during the second week
- The models can potentially simulate a realistic upward coupling response in the stratosphere to transient perturbations in the troposphere
- Although the models can simulate a qualitatively realistic downward coupling, they overestimate it compared to observations
- The simulated extratropical response to the MJO is weaker in the models compared to observations
- Integrations that simulated the observed SSWs associated with MJO 6/7, also simulated a realistic North Pacific response to the MJO at short lags and also a subsequent surface response in the North Atlantic at longer lags

References

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