Northern Hemisphere stationary wave biases and their effect on upward troposphere-stratosphere coupling in sub-seasonal prediction models

ETH zürich
האוניברסיטה העברית בירושלים THE HEBREW UNIVERSITY OF JERUSALEM
Unil UNIL | Université de Lausanne

Chen Schwartz, Chaim I. Garfinkel
Daniela Domeisen, Priyanka Yadav, and Wen Chen
Correspondence: chen.schwartz1@mail.huji.ac.il

1. Introduction

- Wintertime Northern Hemisphere large-scale stationary Rossby waves are forced by Earth's lower-boundary asymmetries which include large-scale topography, land-sea contrast, zonal anomalies of sea-surface temperatures and tropical/extra-tropical diabatic heating
- Stationary waves (SWs) play a major role in modulating the trajectories of storms, and in distribution of heat and moisture along comparable latitudes
- SWs extend from the troposphere to the stratosphere, with wave-1 and wave-2 dominant in the stratosphere
- Realistic representation of stationary waves in subseasonal forecast models is crucial as they shape the wintertime stratospheric mean state, which is directly related to polar vortex transient variability, hence to subseasonal predictability

4. Possible Sources for the Biases

relationship among biases, week 3 NDJF

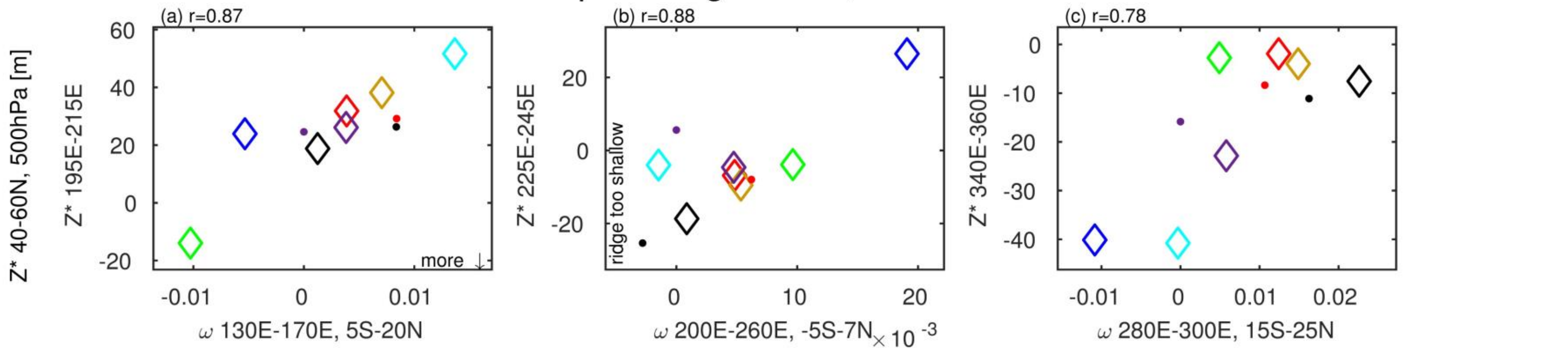

Figure 6. Summary of relationship among biases of mid-latitude (40N-60N) regional biases of 500 hPa Z* over: (a) The Northwest Pacific (195E-215E) and (ω) over the subtropical Western Pacific (130E-170E, 5S-20N); (b) Western North America (225E-245E) and 500 hPa (ω) over the Tropical Eastern Pacific (200E-260E, 5S-7N); (c) The North Atlantic (340E-360E) and (ω) over the Caribbean (280E-300E, 15N-25N); r denotes the correlation between indices; Dots are for older versions of ECMWF, UKMO and CNRM; All correlations are significant at the 95% level. Note that for panel (a), we focus on the eastward extension of the North Pacific low which differs more dramatically among the models, rather than the Northwest Pacific low itself which is better represented by the models.

- Tropical deep convection leads to subtropical convergence, which in turn can generate Rossby waves that propagate poleward; Time-mean tropical convection contributes to generation of stationary Rossby waves
- We focus on 3 regions of upper tropospheric convergence (positive pressure velocity - ω): subtropical Western Pacific and Caribbean and tropical Eastern Pacific
- Stronger than observed convergence over the subtropical Western Pacific is positively correlated with the longitudinally confinement of the Northwest Pacific trough (figure 6a)
- Weaker than observed convergence over the subtropical Caribbean sea and Eastern Pacific is positively correlated with the weaker ridges over Western NA and North Atlantic (figures 6b,c)

2. Biases of tropospheric SWs in S2S models

S2S – ERAI eddy height at 500hPa; 50N; week 3

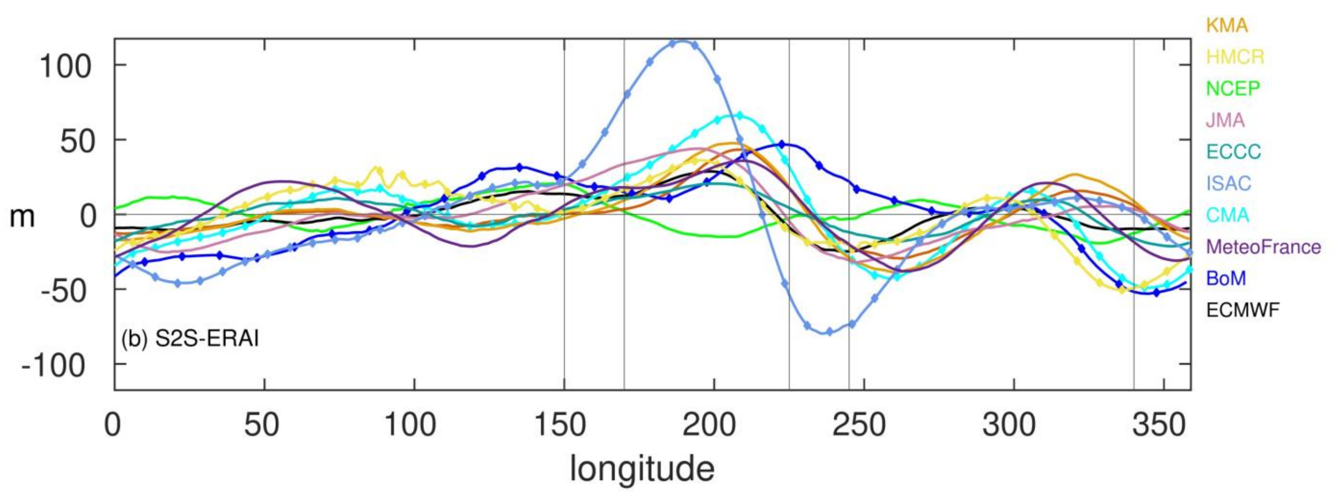

Figure 1. Longitudinal cross-section of 500 hPa eddy geopotential height at 50N during NDJF for the difference between S2S models and corresponding days in ERA-I; Vertical grey lines denote the Northwestern Pacific, Nothwestern North America, and North Atlantic regions used for figure 2; Low-top models are indicated with diamonds on the line.

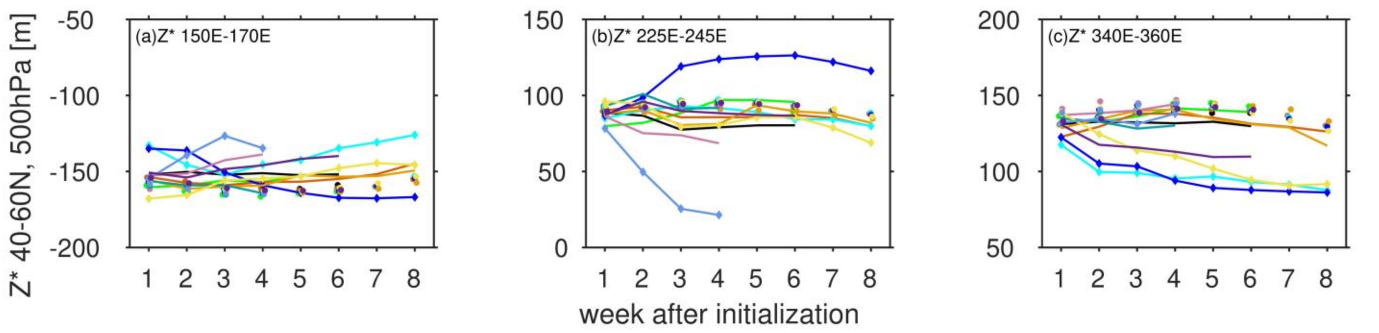

Figure 2. Time evolution of simulated 500 hPa stationary eddy height at 45N-55N in 3 key regions for all models (solid lines) and corresponding days in ERA-I (dots): (a) Northwestern Pacific (150E-170E); (b) Western North America (225E-245E); (c) North Atlantic (340E-360E); Low-top models are denoted with diamonds.

- In the troposphere, SWs have three main centers: Northwest Pacific, Western North America and North Atlantic, and the S2S model biases are roughly collocated with these centers (figure 1)
- S2S models simulate reasonably well the Northwest Pacific trough in week 3, but in most of them (NCEP is an exception) the eastward extension of the trough is too shallow (figure 1)
- Biases in the Northwest Pacific trough are relatively small throughout the run compared to more pronounced biases of the ridge over Western North America (NA), and the even more severely biased North Atlantic ridge (figure 2)
- Overall, high-top models are less biased compared to the low-top models, particularly over the North Atlantic

3. Biases in stratospheric SWs and their effect on upward coupling

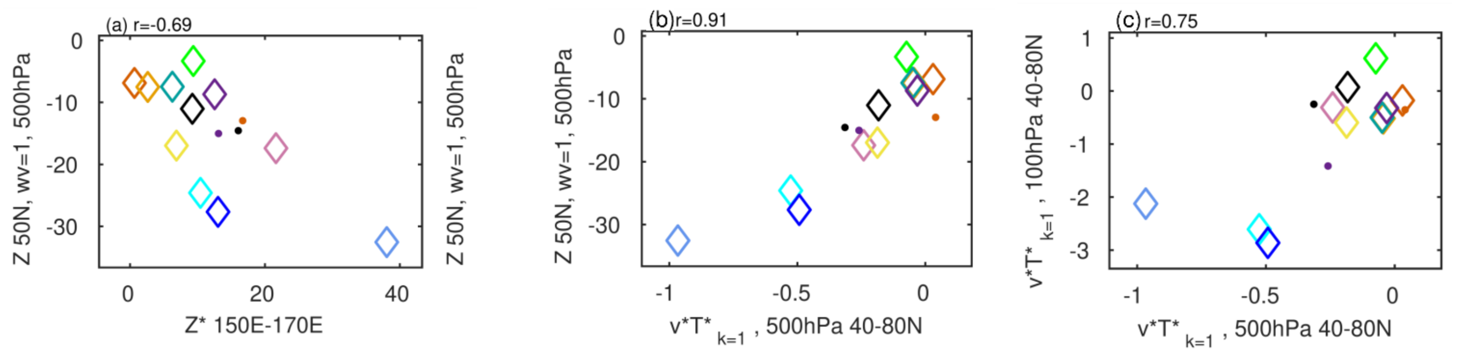

Figure 3. Summary of relationship among the S2S models biases during NDJF (the different models are represented by colors similarly to the legend of figure 1); Z at 50N wavenumber-1 and (a) 500 hPa Z* over the Northwest Pacific (150E-170E); (b) 500 hPa mid-latitude (40N-80N) wavenumber-1 v^*T^*; (c) 100 hPa mid-latitude (40N-80N) wavenumber-1 v^*T^* and 500 hPa mid-latitude (40N-80N) wavenumber-1 v^*T^*; r denotes the correlation between indices; Dots are for older versions of ECMWF, UKMO and CNRM; All correlations, except for that of panel (a), are significant at the 95% level using a two-tailed Student-t test.

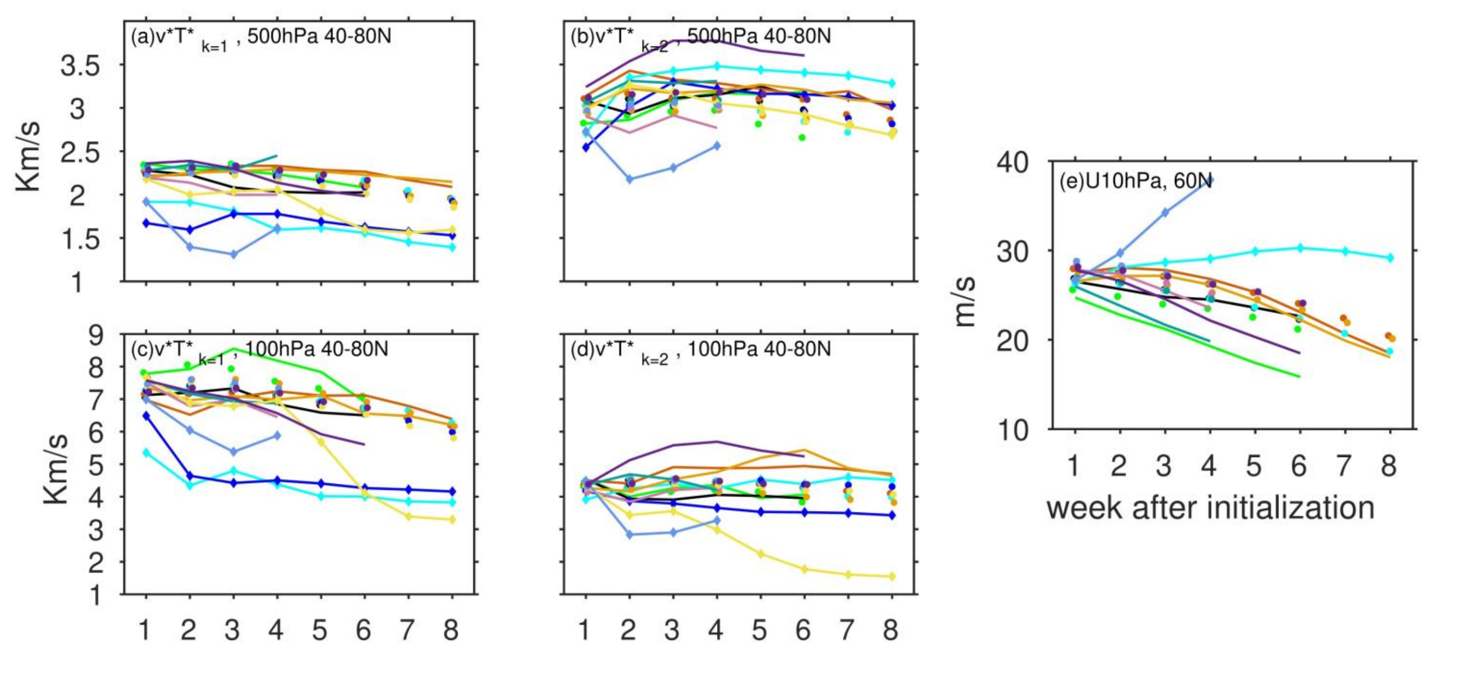

Figure 4. Time evolution of all integrations during November-December-January-February for S2S models (solid lines) and corresponding days from ERA-I (dots); older versions are denoted by a dashed line: (a) Mid-latitudes wave-1 v^*T^* at 500 hPa; (b) Mid-latitudes wave-2 v^*T^* at 500 hPa; (c) Mid-latitudes wave-1 v^*T^* at 100 hPa; (d) Mid-latitudes wave-2 v^*T^* at 100 hPa; (e) Zonal-mean zonal wind at 10 hPa at 60N; Low-top models are denoted with diamonds on lines

- Models with shallower than observed Northwest Pacific trough also simulate a weaker negative node of planetary wave-1 in the troposphere (same for the relationship of the North Atlantic ridge and the positive node of stationary wave-1, r = 0.59, and for the Western North America ridge and stationary wave-2, r = 0.74) (figure 3a)
- Weaker than observed amplitude of stationary wave-1 is positively correlated with a negative bias mid-tropospheric meridional eddy heat flux ($\boldsymbol{v^*T^*}$), which in turn is positively correlated with biases of lower stratosphere (100hPa) $\boldsymbol{v^*T^*}$ (same relationship for the amplitude of stationary wave-2 and wave-2 $\boldsymbol{v^*T^*}$) (figure 3b and 3c)
- High-top models, in general, better simulate wave-1 $\boldsymbol{v^*T^*}$ compared to wave-2, particularly in the mid-troposphere. The opposite is true for low-top models which struggle to simulate wave-1 $\boldsymbol{v^*T^*}$ but are less biased in their simulated wave-2. NCEP model is an exception; biases in the mean-state stratospheric polar vortex agree with biases in $\boldsymbol{v^*T^*}$ (figure 4)

For more information

- Schwartz C, Garfinkel CI, Yadav P, Chen W, Domeisen D. Stationary Waves and Upward Troposphere-Stratosphere Coupling in S2S Models. Weather and Climate Dynamics (under review)