A process-based evaluation of biases in extratropical stratosphere-troposphere coupling in subseasonal forecast systems

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Introduction

- Two-way coupling between the stratosphere and troposphere is recognized as an important source of subseasonal-to-seasonal (S2S) predictability and can provide forecast windows of opportunity.
- Model biases can, however, lead to a poor representation of such coupling processes; at lead times of one to two weeks, drifts in a model's circulation related to model biases, resolution, and parameterizations have the potential to feed back on the circulation and affect stratosphere-troposphere coupling.

Conclusions

Northern Hemisphere:

- Nearly all S2S forecast systems underestimate the strength of the observed upward coupling from the troposphere to the stratosphere and downward coupling within the stratosphere.
- While downward coupling from the lower stratosphere to the near surface is well represented in the multi-model ensemble mean, there is substantial inter-model spread. This is likely related to overly fast decay of simulated lower stratospheric temperature anomalies.

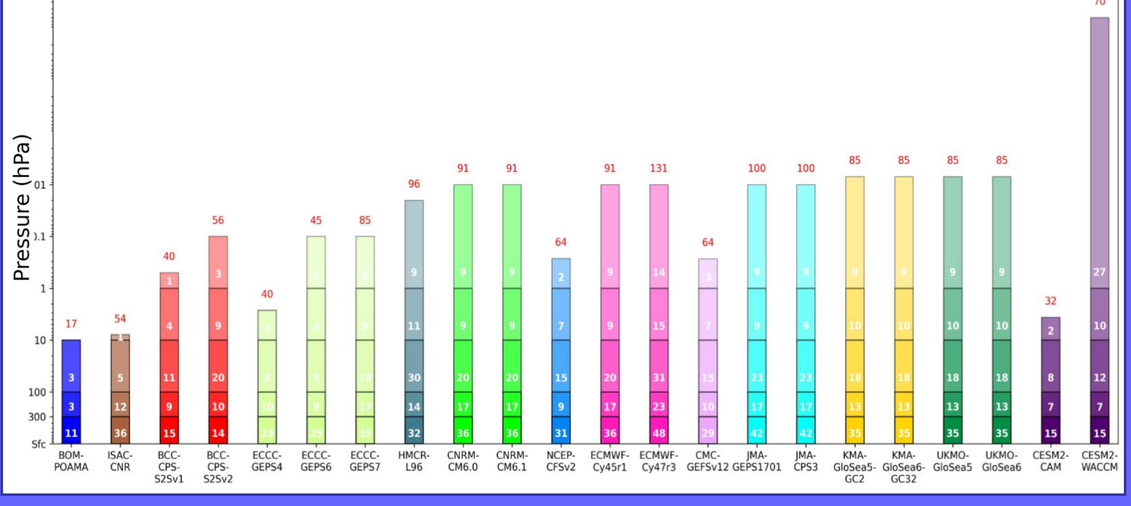
Southern Hemisphere:

- The forecast systems overestimate the upward coupling of wave-1 from the troposphere to the lower stratosphere, and the stratospheric vortex is over-sensitive to upward propagating wave flux.
- Forecast systems generally overestimate the strength of downward coupling from the lower stratosphere to the troposphere, even as they underestimate the radiative persistence in the lower stratosphere.

- In both hemispheres, models with higher lids and a better representation of tropospheric quasi-stationary waves generally perform better at simulating these coupling processes.

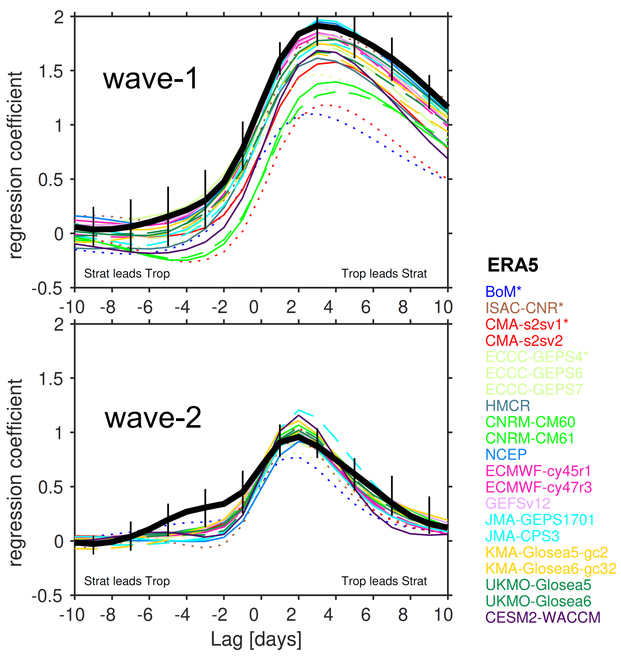
Take home message: We have introduced a set of diagnostics that can be used to evaluate strat-trop coupling in a model, and provide a baseline by applying these diagnostics to a few generations of S2S models.

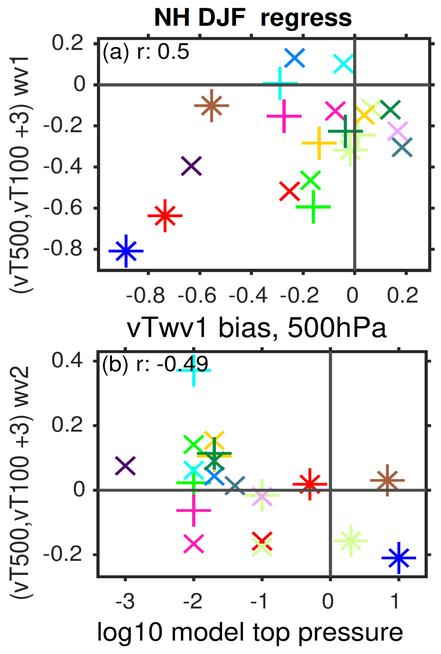
2. Models used and their vertical resolutions



3. Upward coupling: too-weak penetration of wv1

Regression coefficient of 500hPa heat flux with 100hPa heat flux , 45-75N, DJF



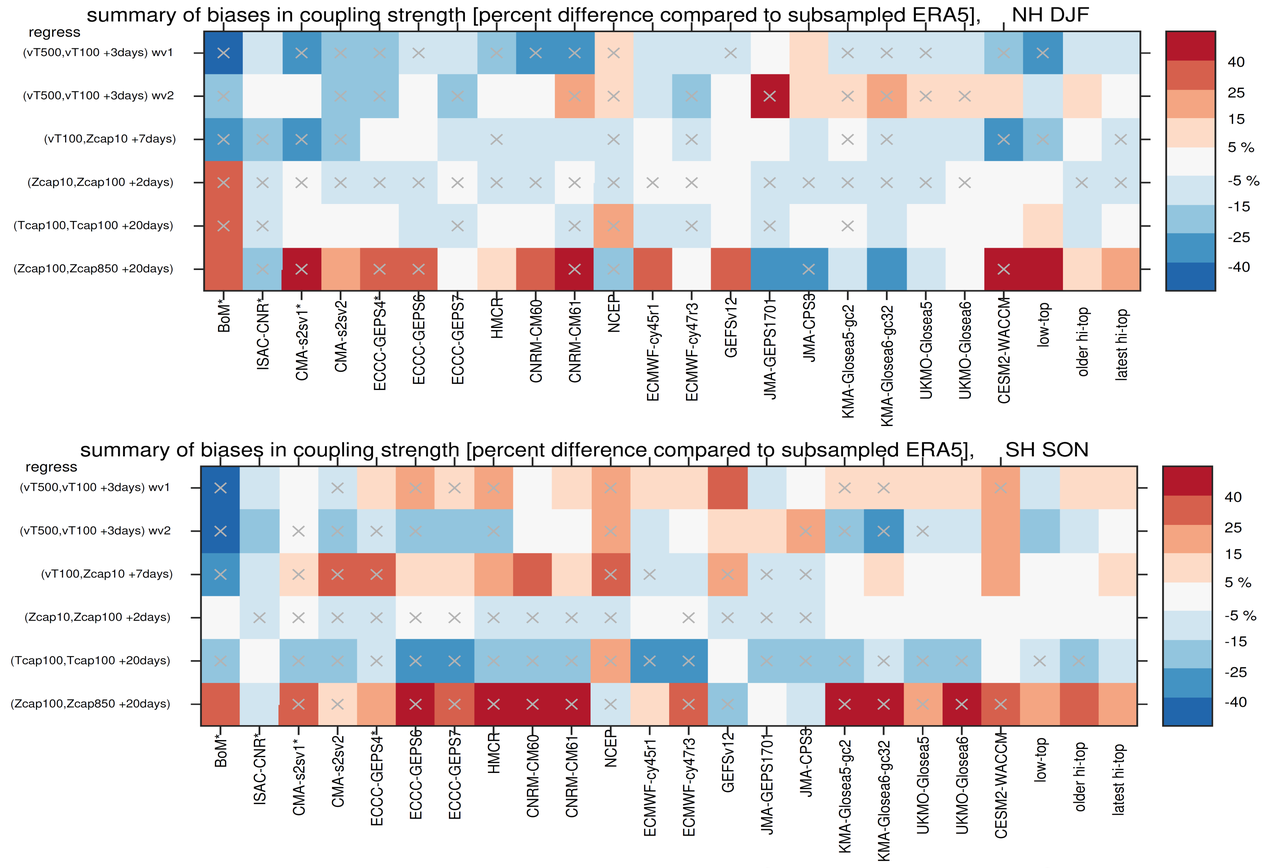


Models systematically underestimate the upward propagation of wave-1

What explains intermodel spread in the regression coefficients?

- Models with worse tropospheric quasi-stationary wave-1 tend to have a weaker wave-1 upward coupling.
- Models with low tops tend to have a weaker wave-2 coupling. This is also apparent for the SH in SON (not shown).

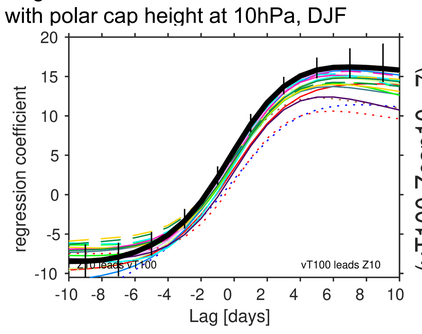
4. Summary of biases in coupling strength

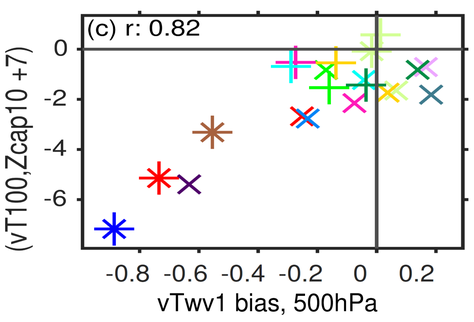


- In the NH, coupling strength is systematically too weak for nearly all models for all metrics but downward propagation from 100hPa to 850hPa. This metric has the biggest spread across models, even as the multi-model mean is realistic. In the SH, many metrics indicate too strong coupling, even though the radiative persistence in the lower stratosphere is too weak.

5. Too-weak sensitivity of polar vortex to 100hPa heat flux

Regression coefficient of 100hPa heat flux 45-75N, with polar cap height at 10hPa, DJF



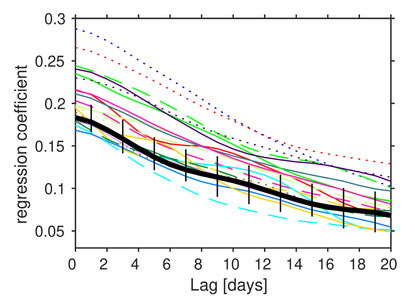


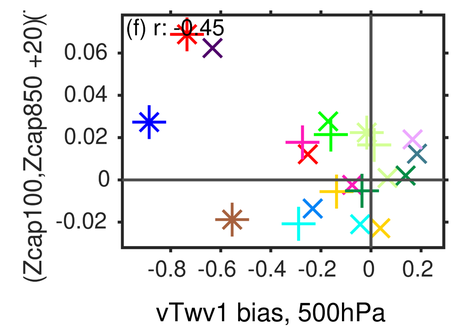
What explains intermodel spread in the regression coefficients?

- Models with worse tropospheric quasi-stationary wave-1 tend to have a particularly weak sensitivity.

6. Too-strong sensitivity of 850hPa NAM to lower strat

Regression coefficient of 100hPa polar cap height with 850hPa polar cap height, DJF





What explains intermodel spread in the regression coefficients?

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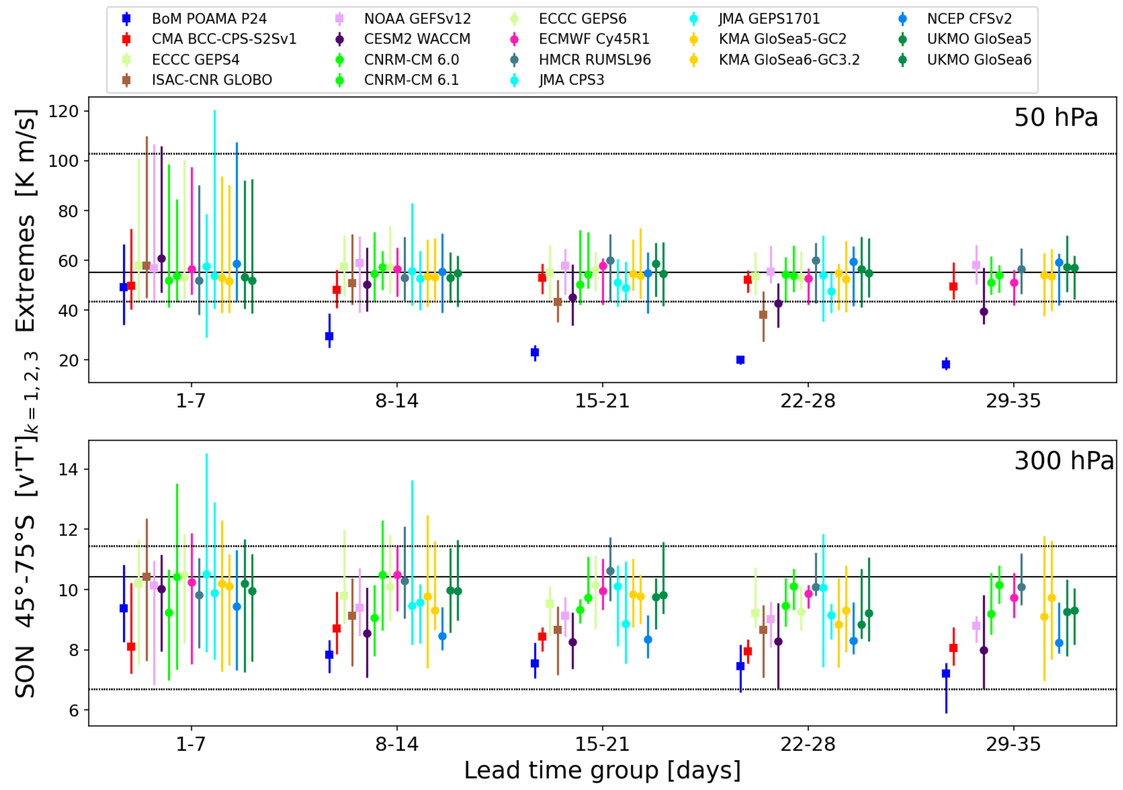
7. Underestimated interannual variability in wave extremes



- In the SH in SON, the year-to-year spread in the 95th percentile heat flux extremes in both the stratosphere and troposphere are underestimated beyond week 1 lead times (also true for the NH DJF stratosphere).
- This suggests that the S2S forecast systems quickly lose information about drivers of year to year fluctuations in heat flux extremes.