Influence of Atmospheric Errors on Weeks 2-4 California Current System Predictions

Maria Gehne[1,2], Juliana Dias[2], Michael Jacox[3,2], Allison Cluett[3,4], Dillon Amaya[2], Michael Alexander[2], Jamie Scott[1,2]

1 - CIRES CU Boulder, 2 - NOAA PSL, 3 - NOAA Southwest Fisheries Science Center, 4 - UC Santa Cruz

Forecast SST (MLD, SSH) anomalies in the CCS on S2S time scales

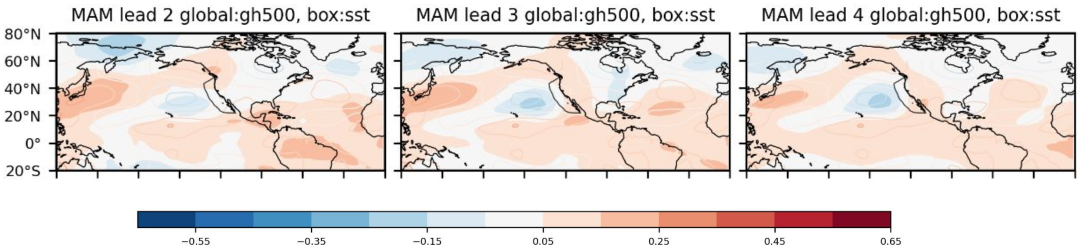
We know on seasonal time scales that California Current System (CCS) SST anomalies, and seasonal upwelling in particular, can be influenced by ENSO, PDO or the North Pacific Gyre Oscillation (NPGO).

Not much known on what influences CCS SST forecasts on S2S time scales. Oceanic Kelvin waves from the tropical Pacific generate ocean teleconnections that influence CCS SSTs, SSH and bottom temperatures (Amaya et al. 2022).

Using Ensemble Sensitivity Analysis (ESA) we identify regions where conditioning forecasts on better atmospheric states at early lead times improves the forecasts of SST anomalies in the CCS at later lead times.

Focus on MAM, the spring upwelling season.

Can we identify atmospheric phenomena the model picks up in the better initial states?



Correlation between SST anomalies in the CCS and Z500 during MAM. Shading are model anomalies at different lead times (valid during MAM) and contours are ERA5/ GLORYS correlations.

CCS climatological evolution in the ECMWF 2022 S2S reforecasts

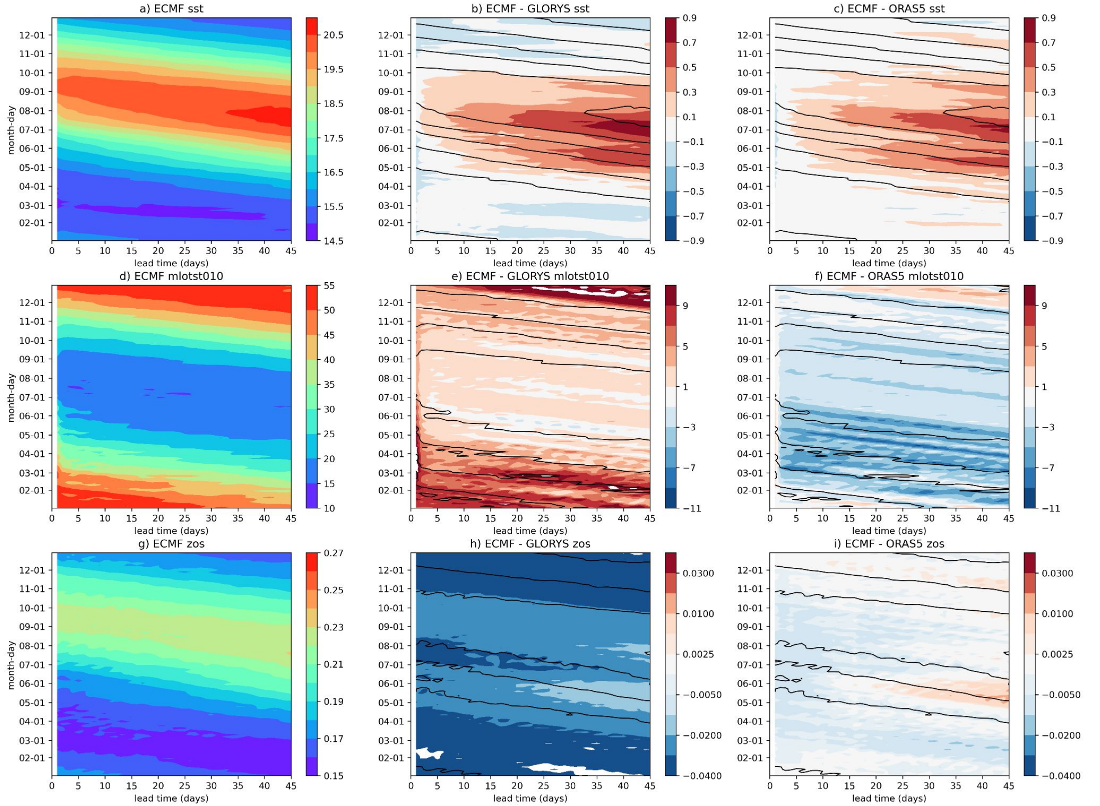
Model: 2022 ECMWF S2S reforecast dataset (2002-2021), initialized twice per week and daily output out to 45 days.

Verification: ERA5 reanalysis for atmospheric variables, GLORYS (and ORAS5) for SST, MLD and SSH.

We are using data from 2002 - 2018.

Right: Climatological evolution of CCS averaged SST, MLD and SSH in the model and differences to GLORYS and ORAS5.

Depending on the verification used, model biases can be very different!

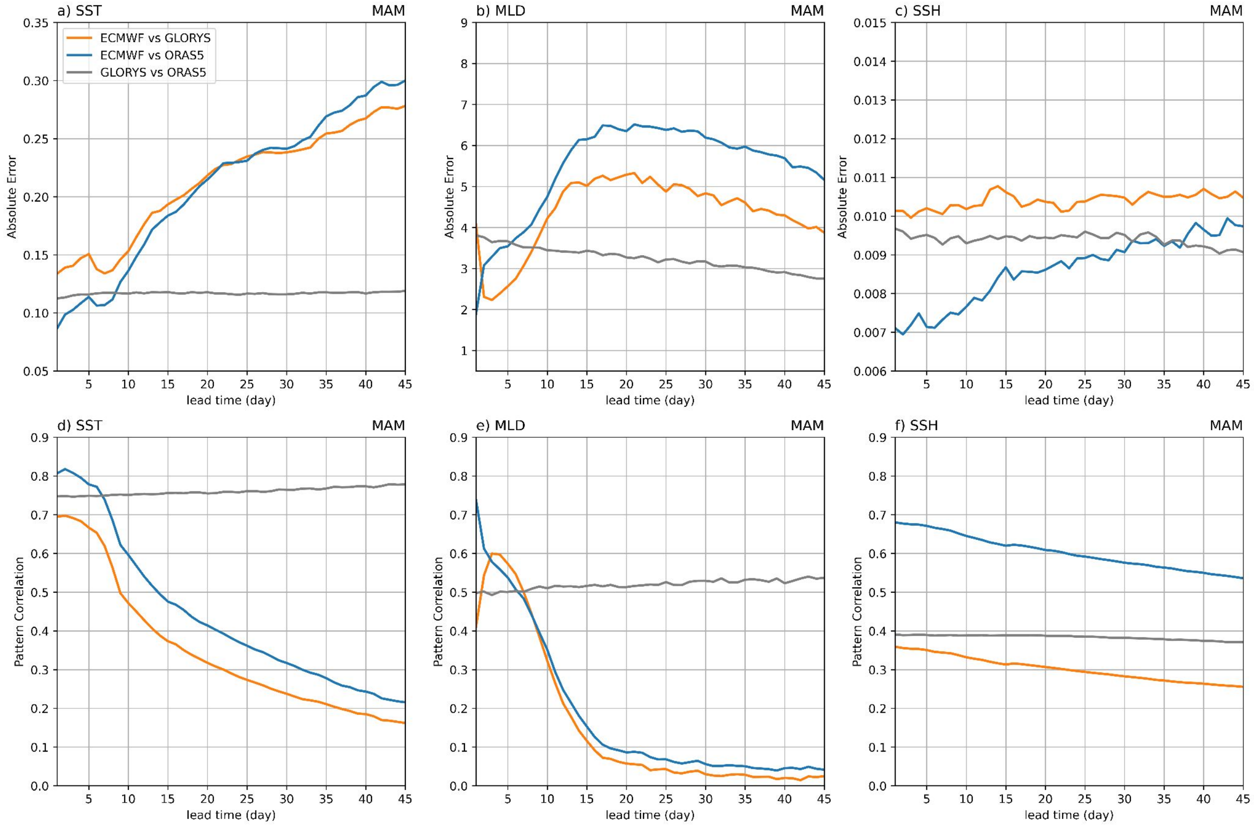


Representation of CCS in the ECMWF 2022 S2S reforcasts

Absolute Error and Pattern Correlation during MAM.

Initial adjustment of model ocean state (days 2-3).

Larger differences between GLORYS and model (as expected), but similar error growth for both verifications.



Identifying regions of model sensitivity

Ensemble Sensitivity Analysis

- Ensemble sensitivity provides accurate estimates of the impact of initial condition changes to a forecast metric.
- Is useful for identifying a target region for additional observations because, unlike adjoint sensitivity, the analysis-error statistics are included in the ensemble calculation.
- The equation for ESA represents linear regression where the independent variable is an analysis grid point and the dependent variable is the forecast metric.
- Examples for forecast metrics are ACC or absolute error over a region.

$$\frac{\partial J}{\partial x} = \frac{\mathrm{cov}(\mathbf{J}, \mathbf{x})}{\mathrm{var}(\mathbf{x})},$$

Identifying regions of model sensitivity during MAM

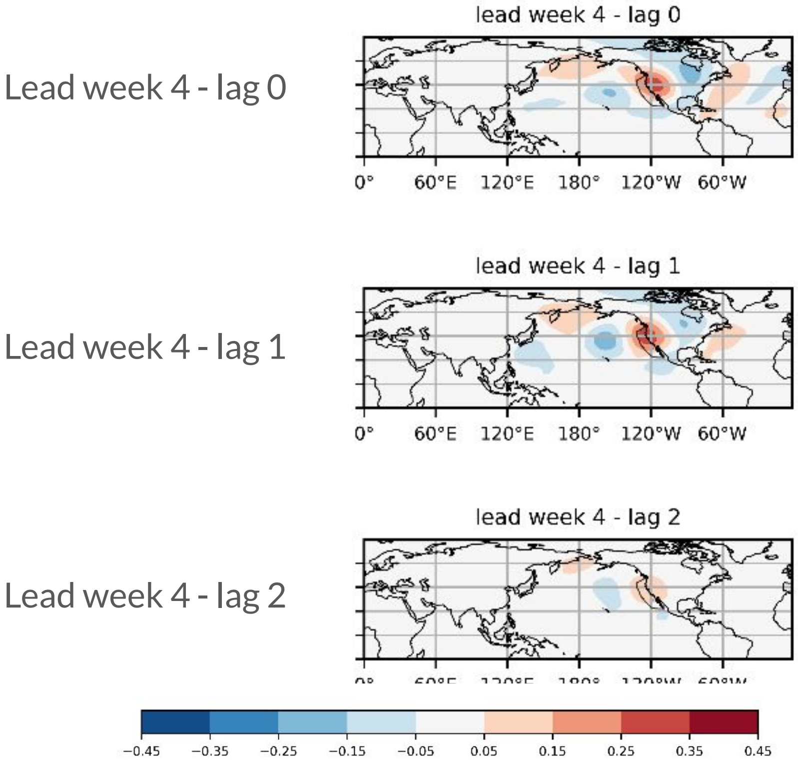
Location of sensitivity to Z500 for CCS SST error are wavetrain signatures over the North Pacific.

Signal is visible out to lag 2 weeks.

MLD anomalies are consistent.

Similarly for other variables and lead times:

Ensemble Sensitivity of SST AE in the CCS to Z500



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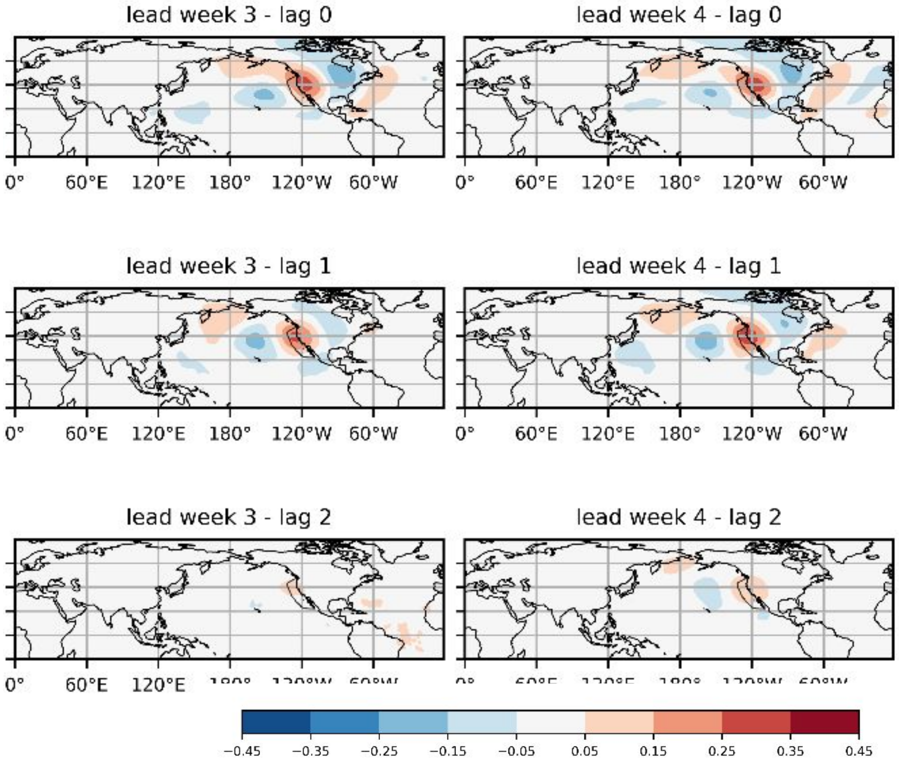
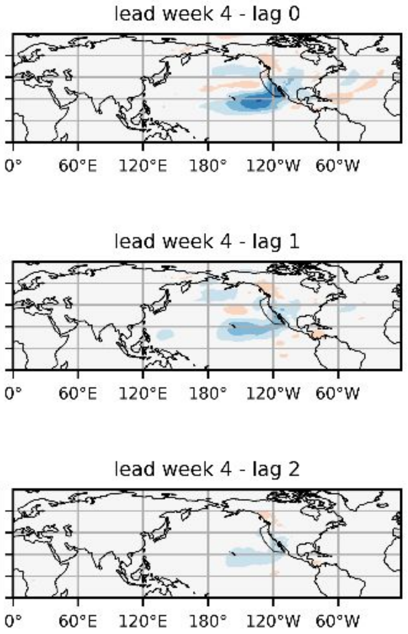
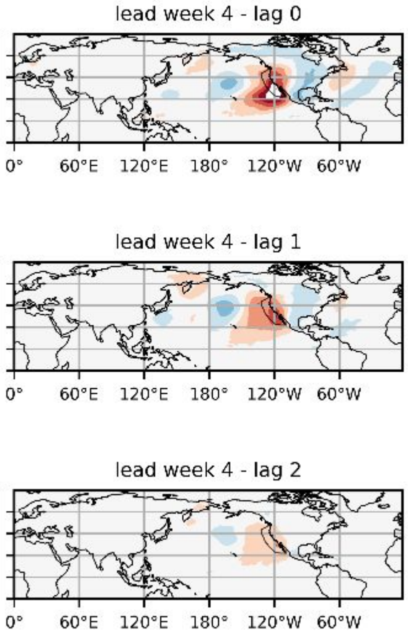


Identifying regions of model sensitivity during MAM

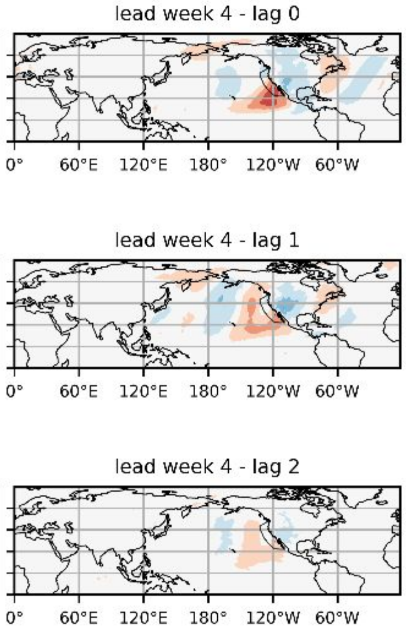
Ensemble Sensitivity of SST AE in the CCS to u*

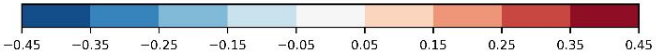


Ensemble Sensitivity of SST AE in the CCS to T2m



Ensemble Sensitivity of SST AE in the CCS to v10





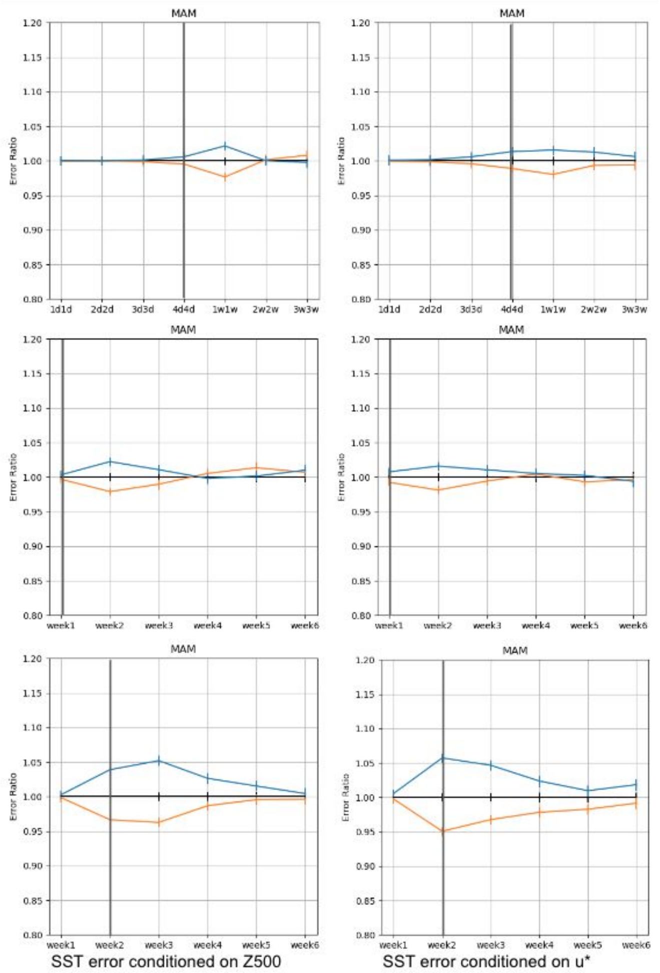
The sensitivity region indicates that the location and strength of low-pressure systems over the North Pacific may impact CCS ocean forecast skill.

Does this sensitivity translate to smaller CCS ocean errors?

SST error conditioned on atmospheric initial error

Absolute error in **CCS SST** conditioned on the best and worst ensemble members for **Z500** in the region 20-50N, 200-220E (left) and friction velocity **u*** in the region 10-30N, 200-230E (right) at lead times 4-7 days (top), week 1 (middle), and week 2 (bottom).

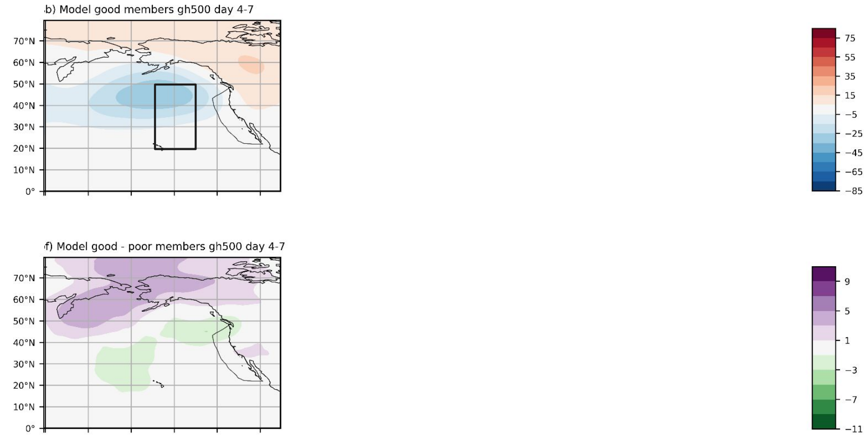
Conditioning on good ensemble members during the first week of the forecast improves CCS SST errors during week 2.
Conditioning on week 2 yields better forecasts through week 4.



What signal are the better performing ensemble members picking up?

Good vs Poor Ensemble Members

Better performing ensemble members have stronger low pressure signal in the central North Pacific at days 4-7, stronger ridge over North America.



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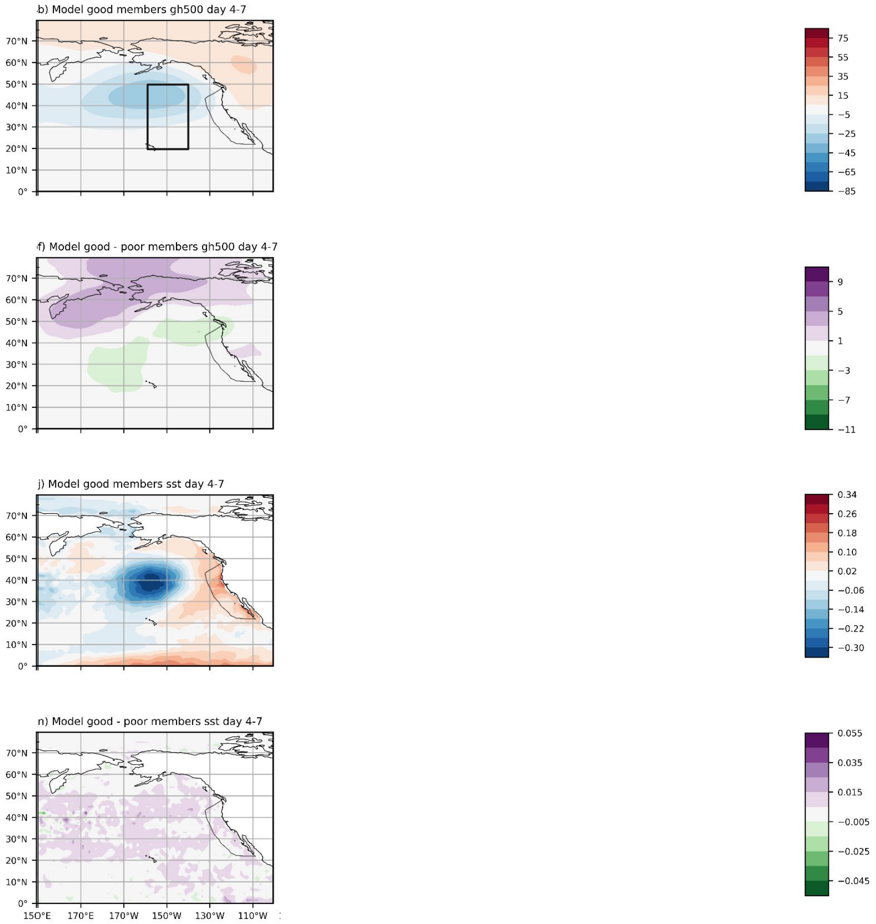
This goes along with colder SST anomalies across the North Pacific in the poor ensemble members.



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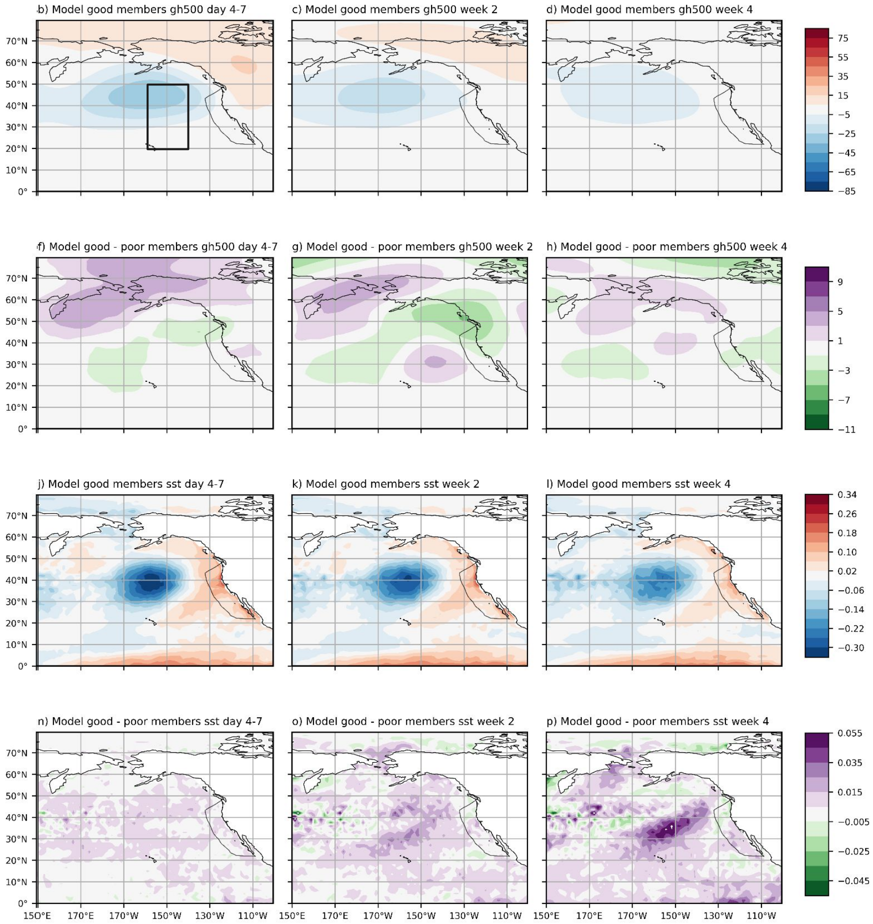
This SST bias increases with lead time, while the coherent atmospheric error differences weaken.



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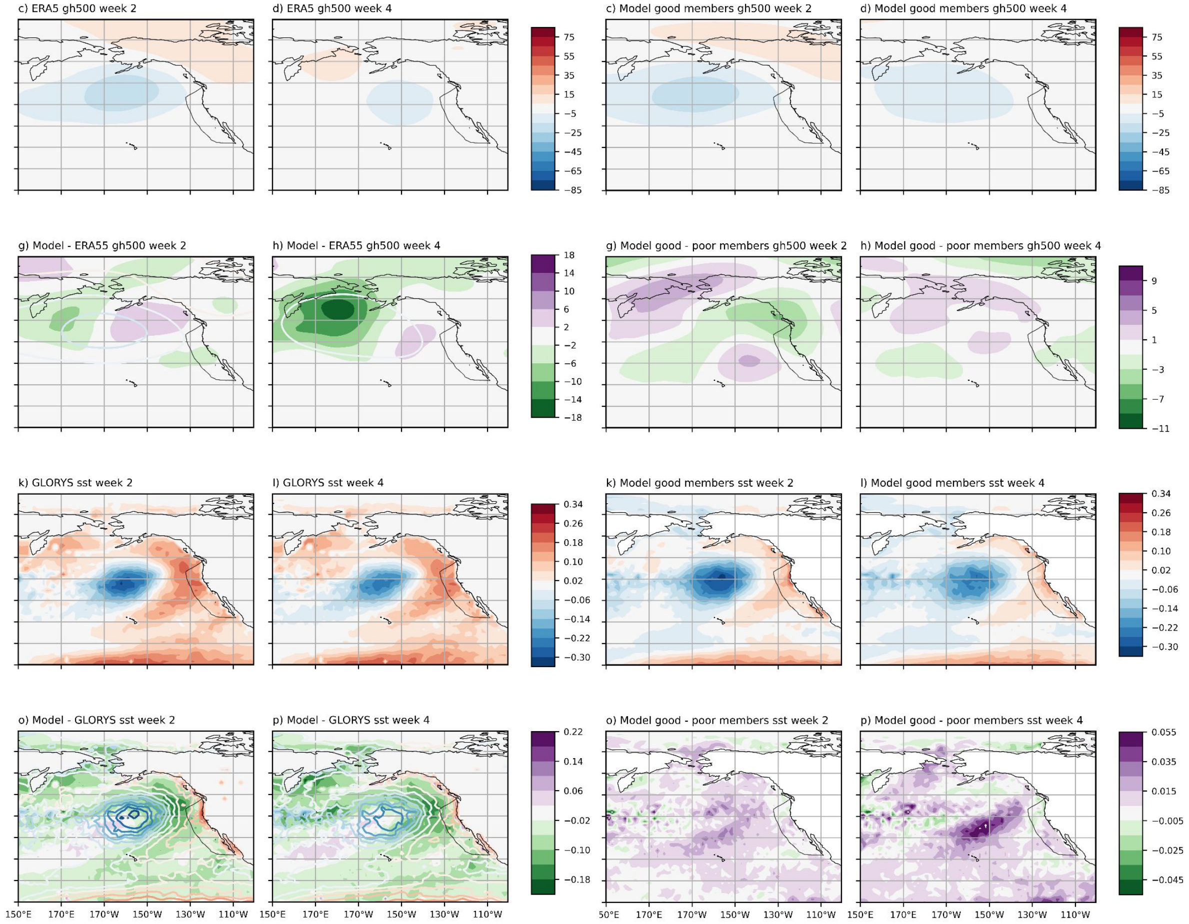
Poor members have larger bias compared to GLORYS and ERA5 than the good members.



Summary

Model bias at early lead times in the North Pacific atmospheric circulation is one of the contributors to CCS SST anomaly errors at weeks 2 - 4.

Reducing these errors leads to reduced SST anomaly errors in the California Current System at later lead times.

Errors are related to the strength of low or high pressure systems in the North Pacific.

Plan to perform a similar analysis with a UFS S2S reforecast data set once that is available.