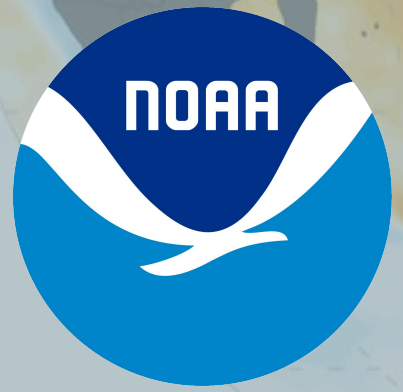
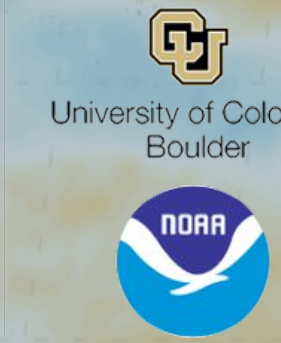
ASSESSING FUTURE CLIMATE PREDICTABILITY USING PERFECT MODEL ANALOGS IN LARGE ENSEMBLES

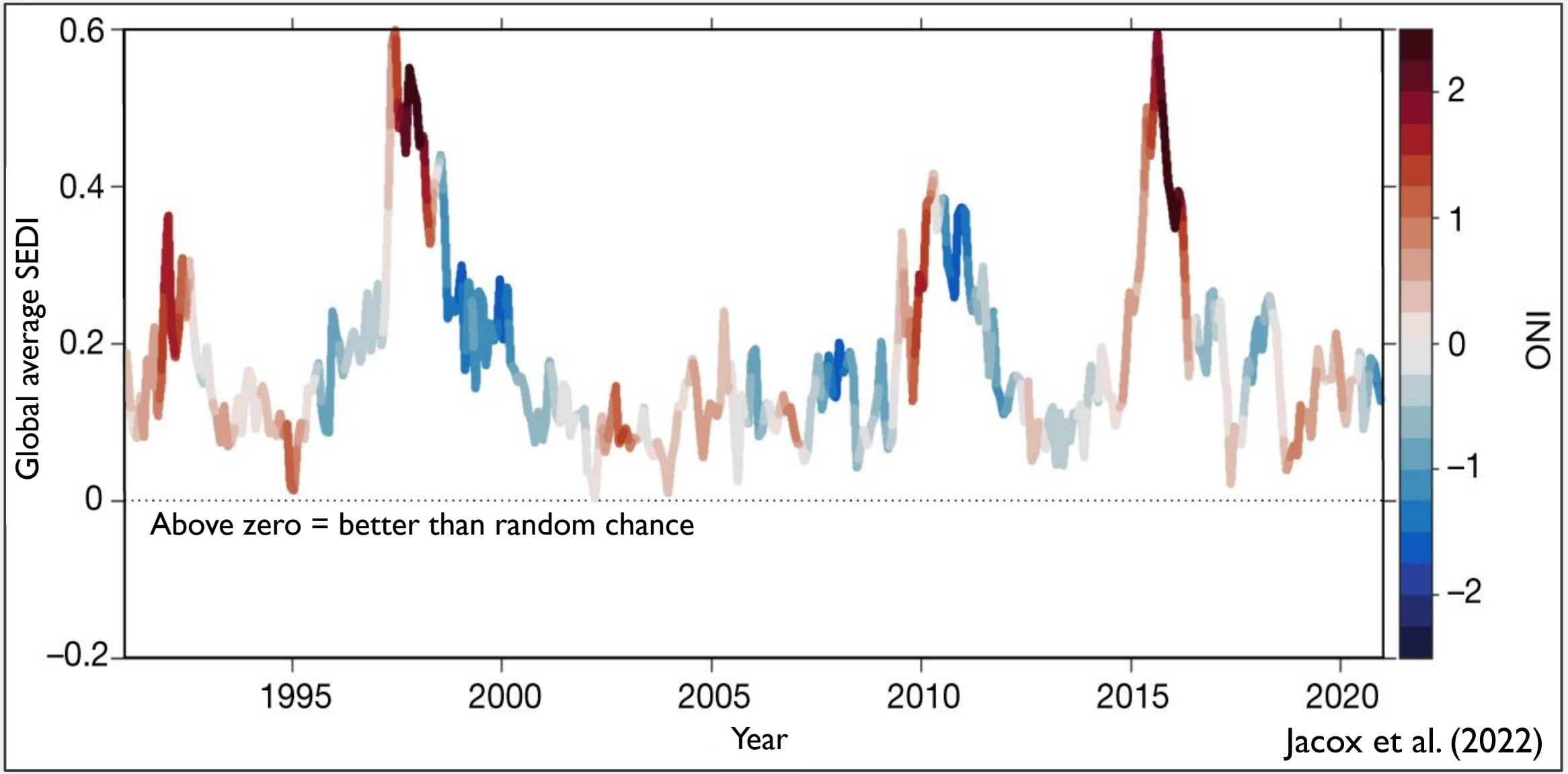
Dillon Amaya, Nicola Maher, Clara Deser,
Mike Jacox, Mike Alexander, Matt Newman, Jiale Lou





Email: dillon.amaya@noaa.gov February 22, 2023 Twitter: @DillonAmaya

Global average marine heatwave forecast skill at 3.5 month lead

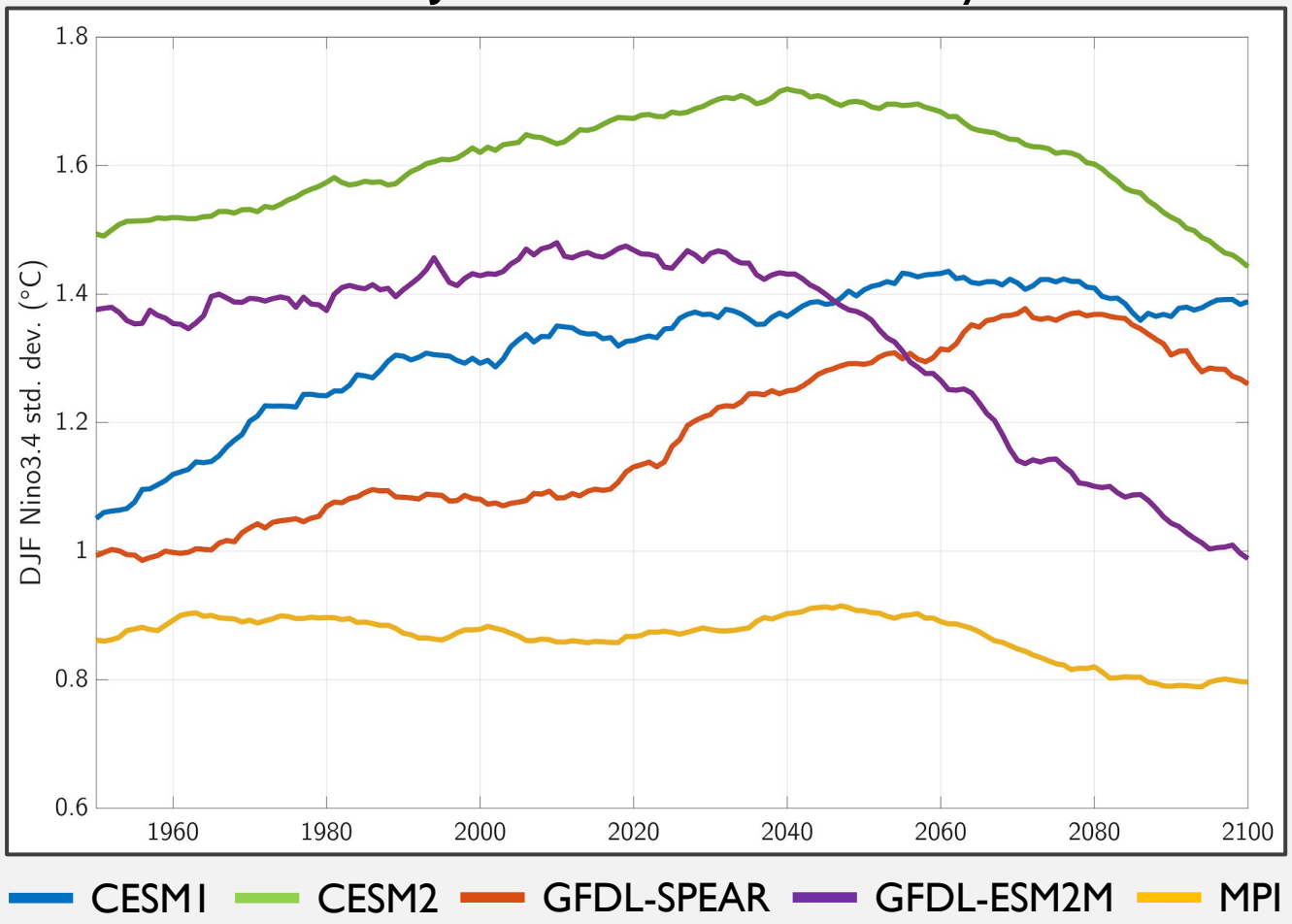


ENSO is the main source of deterministic seasonal forecast skill

Climate models project significant changes to ENSO and its teleconnections.

(e.g., Maher et al. *in review*; O'Brien and Deser 2023)

Ensemble mean DJF Nino3.4 std. dev. in 30-year windows

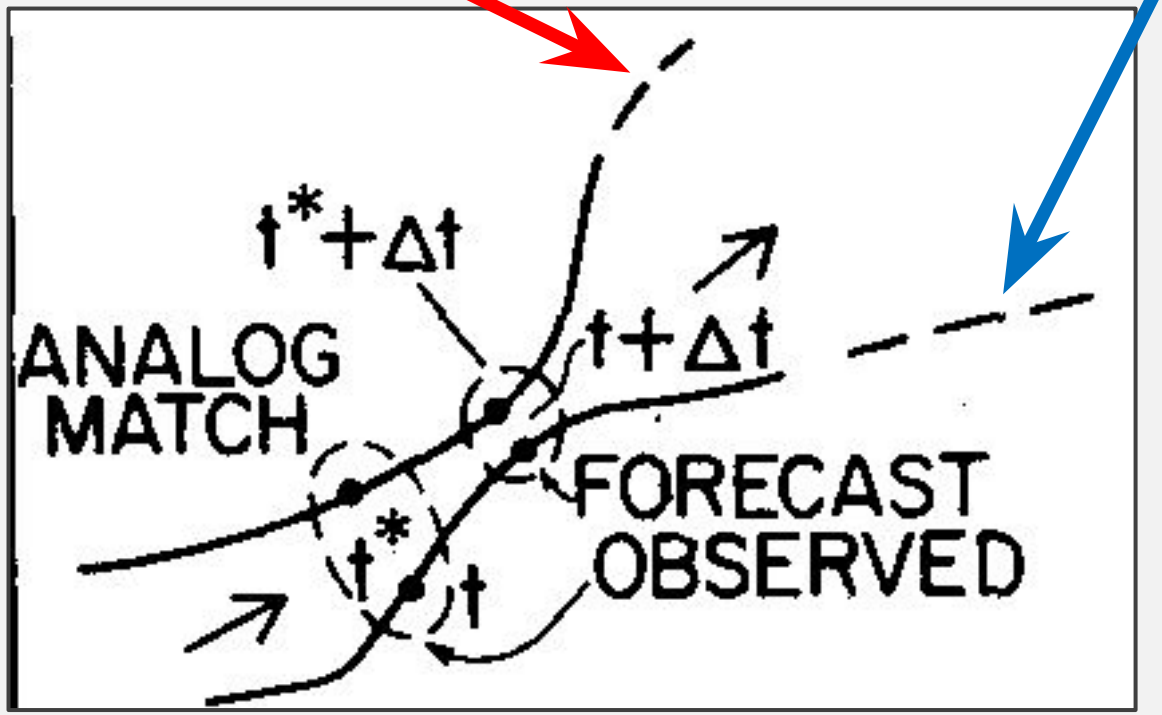


Does seasonal climate predictability change in the future?

Perfect model analog

Trajectory of analog
(i.e., forecast)

Trajectory of "observations"
(i.e., forecast target)



Barnett and Preisendorfer (1978)

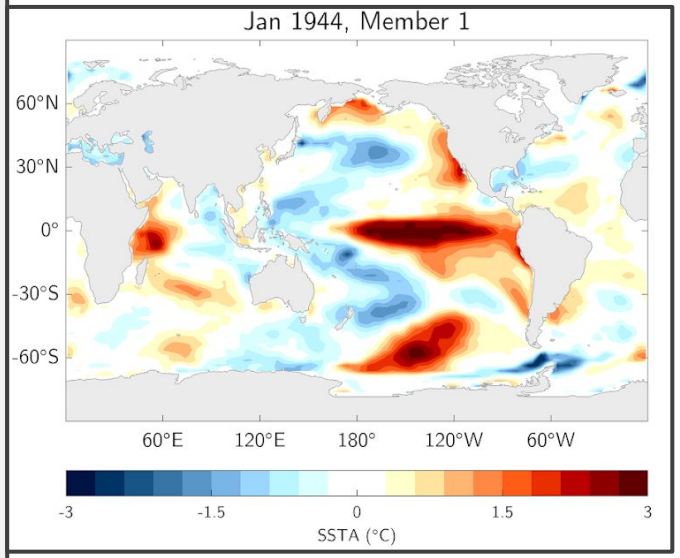
If two states in the atmosphere or climate system are very close to each other, they can be called each other's "analog".

Assess time-varying predictability using perfect model analogs from large ensembles

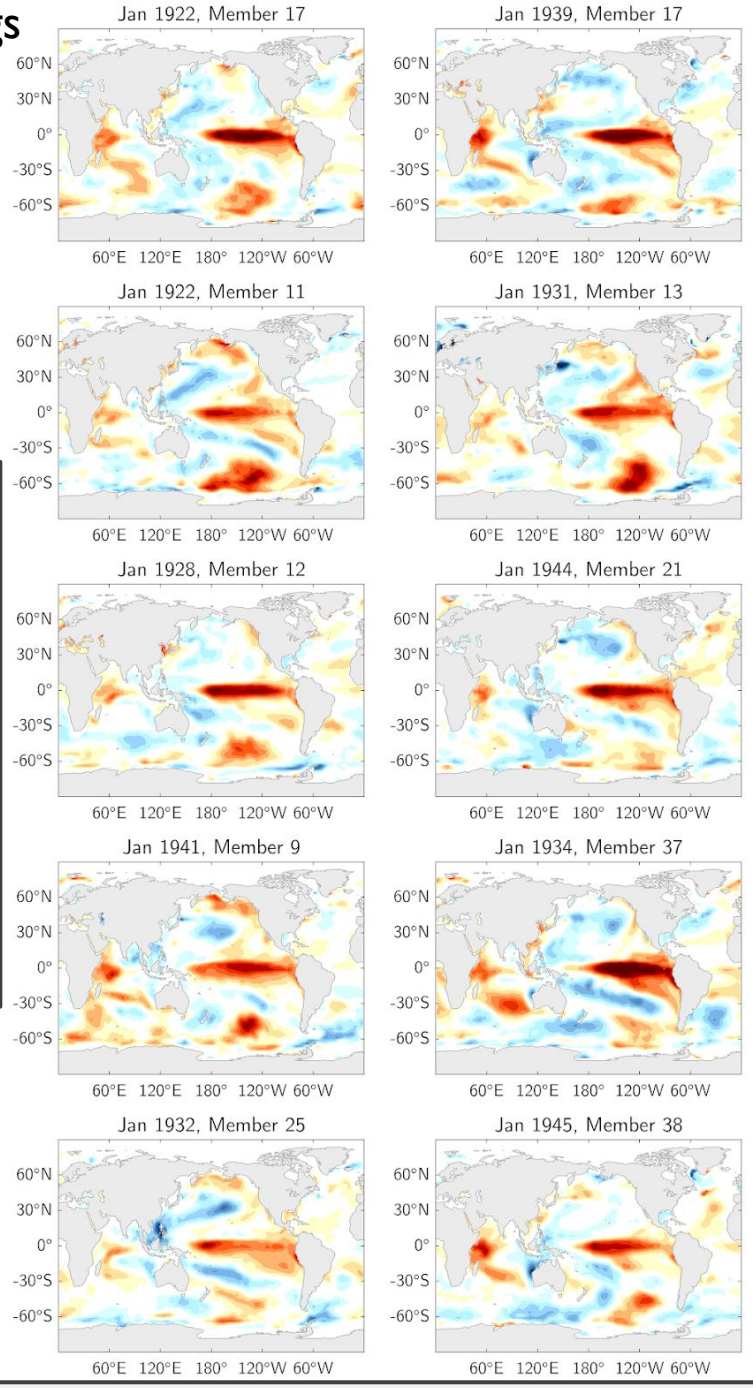
Perfect model analog forecast workflow:

- Analogs based on maps of global SSTA* at each time step in a 30 year period (e.g., 1921-1950).
  - SSTA* = ensemble mean removed.
- Within a large ensemble, take turns treating each ensemble member as "truth".
  - Draw analogs from remaining members.
- CESM1: 40 members x 10 forecast members x 12 months x 30 years = 144,000 forecasts.
- Repeat for different 30 year periods (e.g., 2071-2100).

"Initialization" – CESM1 example



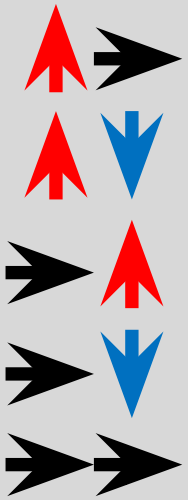
Top 10 best analogs



Date and Methods

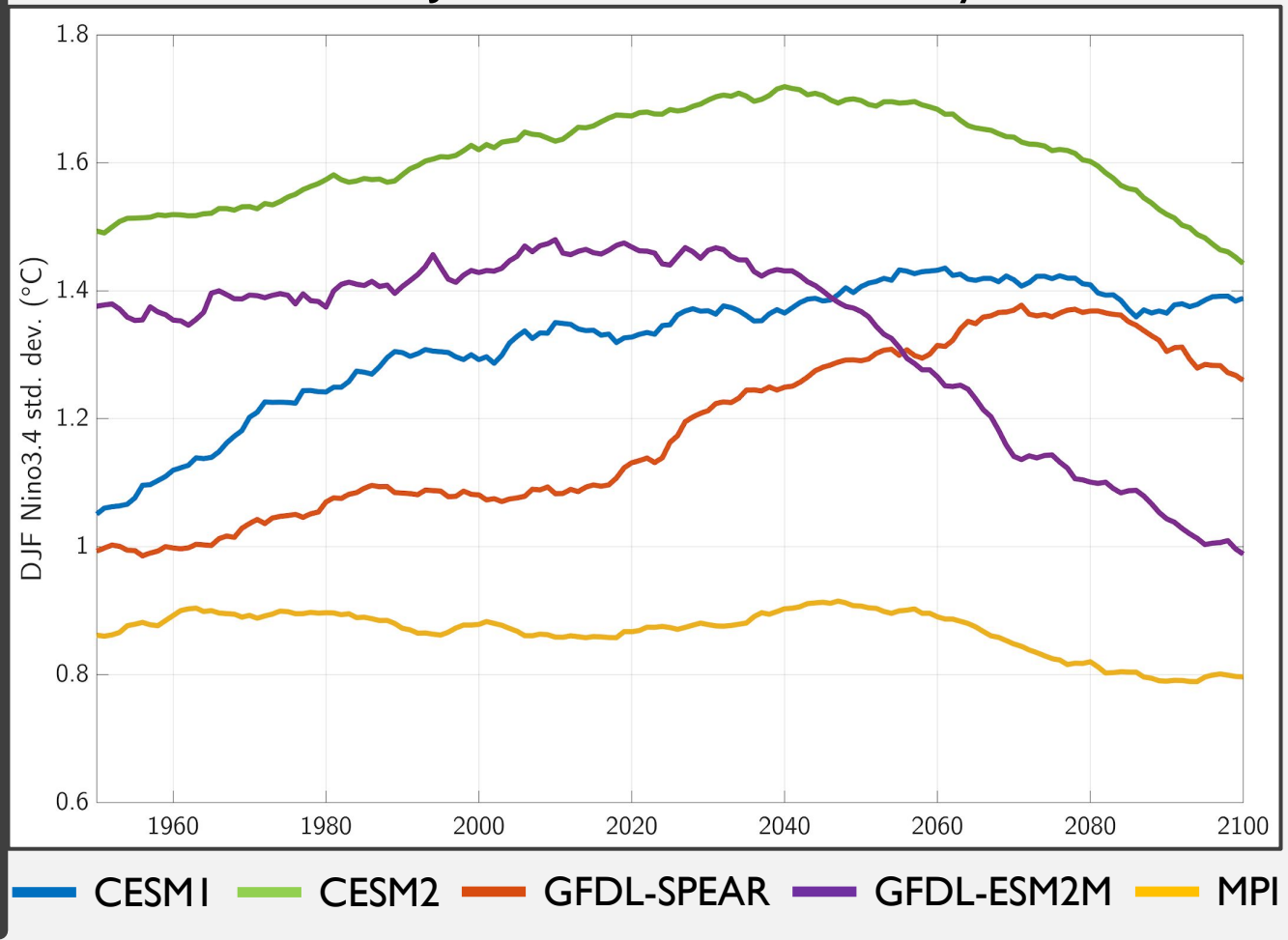
Single model initial condition large ensembles (SMILEs):

Nino3.4σ trend:



- CESM1 – 40 members
- CESM2 – 100 members
- GFDL-SPEAR – 30 members
- GFDL-ESM2M – 30 members
- MPI – 100 members
- All data 2.5˚ x 2.5˚, 1920-2100.
- Forecast skill evaluation based on anomaly correlation coefficient (ACC).

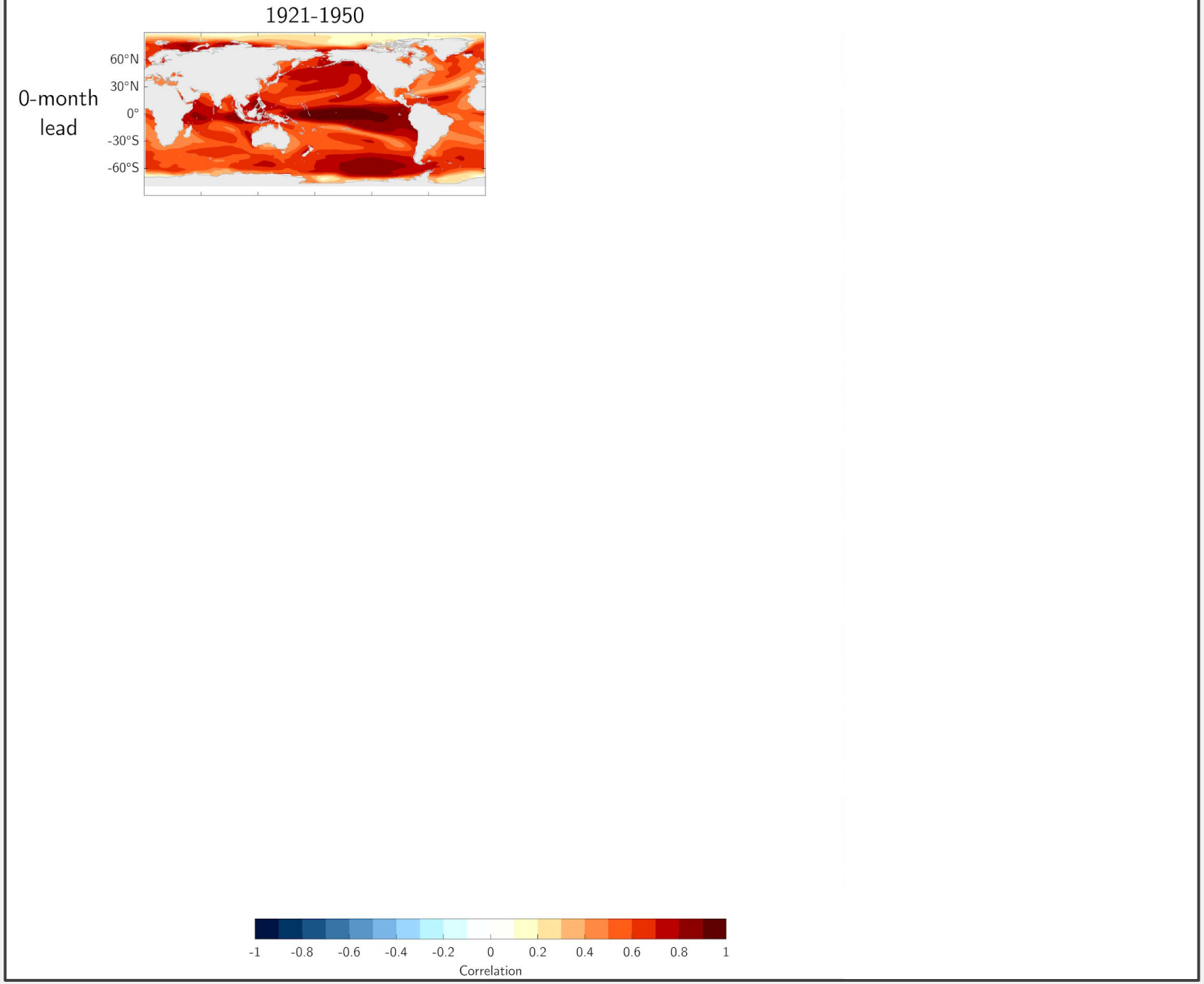
Ensemble mean DJF Nino3.4 std. dev. in 30-year windows



CESM1 forecast skill

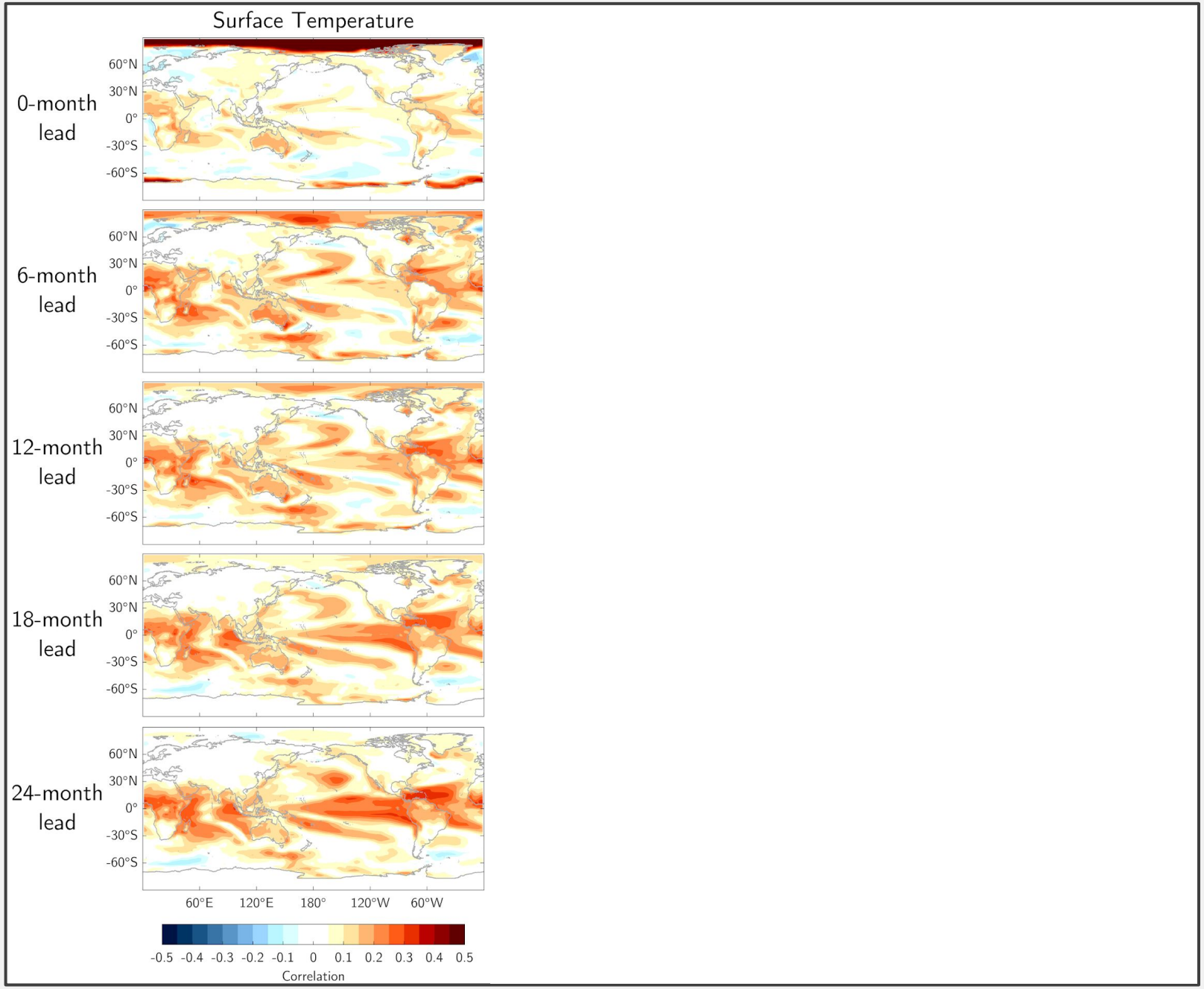
Sea surface temperature forecast skill increases nearly everywhere, particularly at long leads

Shading: Ensemble mean forecast skill (ACC) across all months



CESM1 forecast skill

ΔACC: [2071-2100] – [1921-1950]



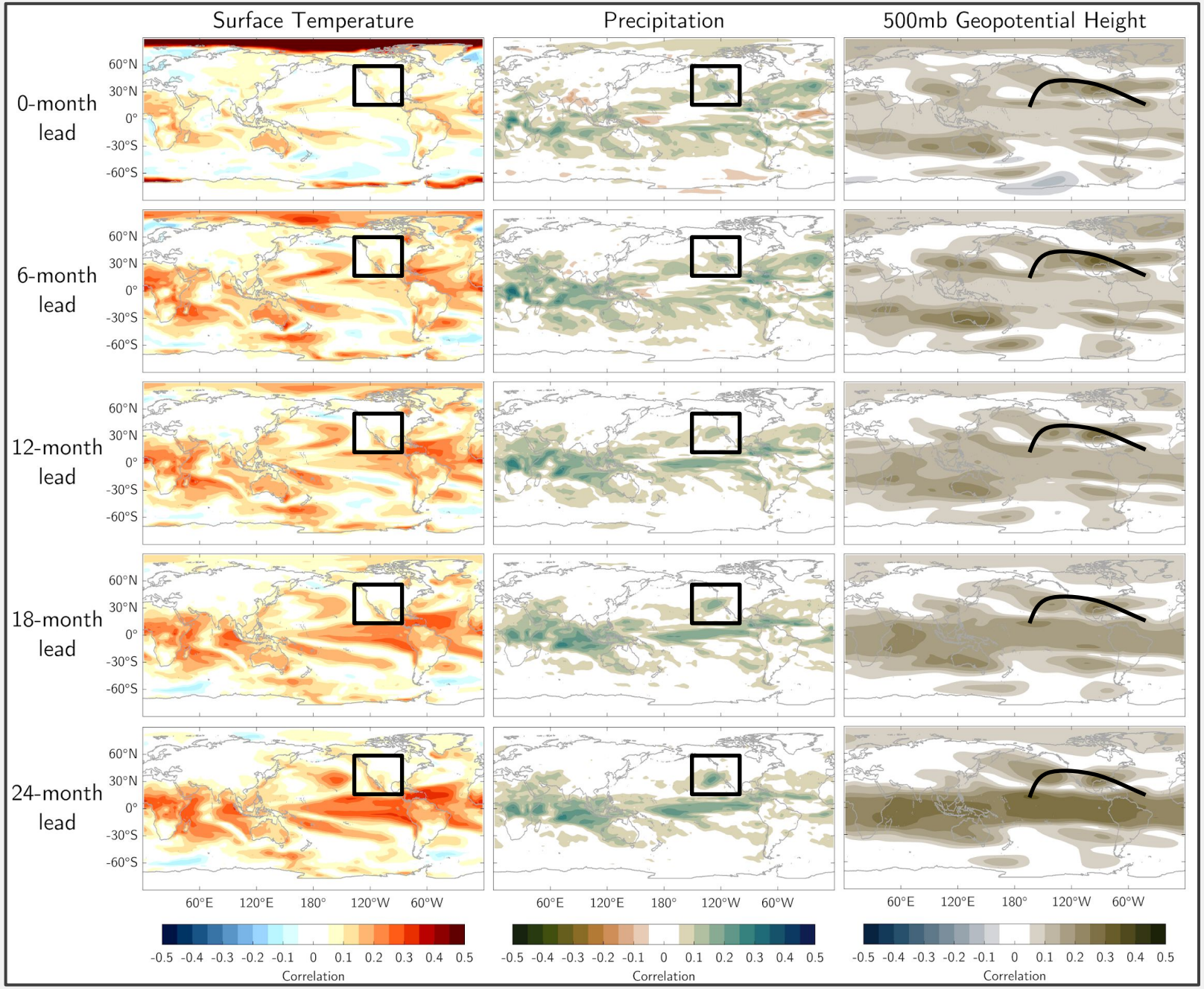
Shading: Change in ensemble mean forecast skill (ACC) across all months

CESM1 forecast skill

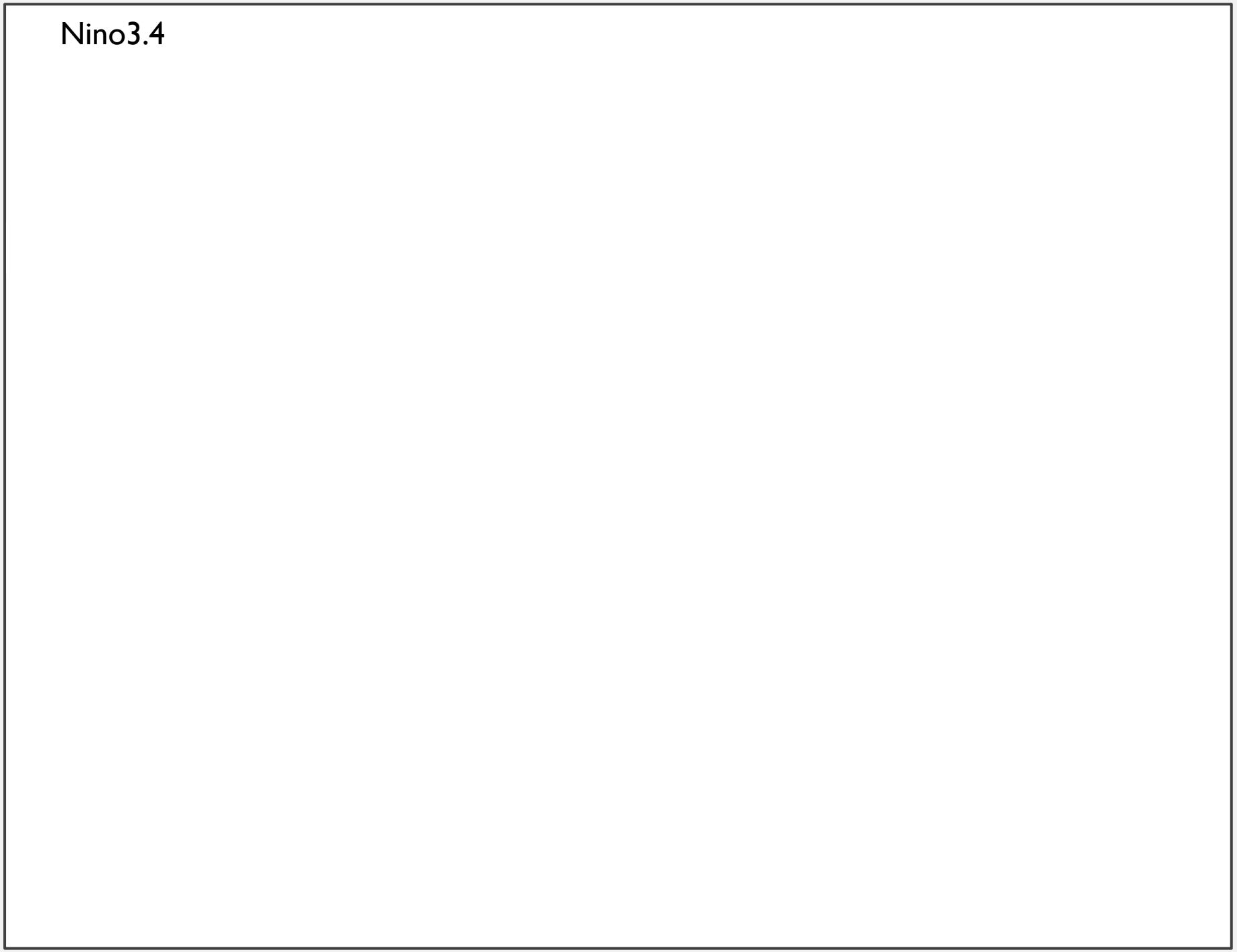
Predictability increases for remote ENSO impacts

Shading: Change in ensemble mean forecast skill (ACC) across all months

ΔACC: [2071-2100] – [1921-1950]



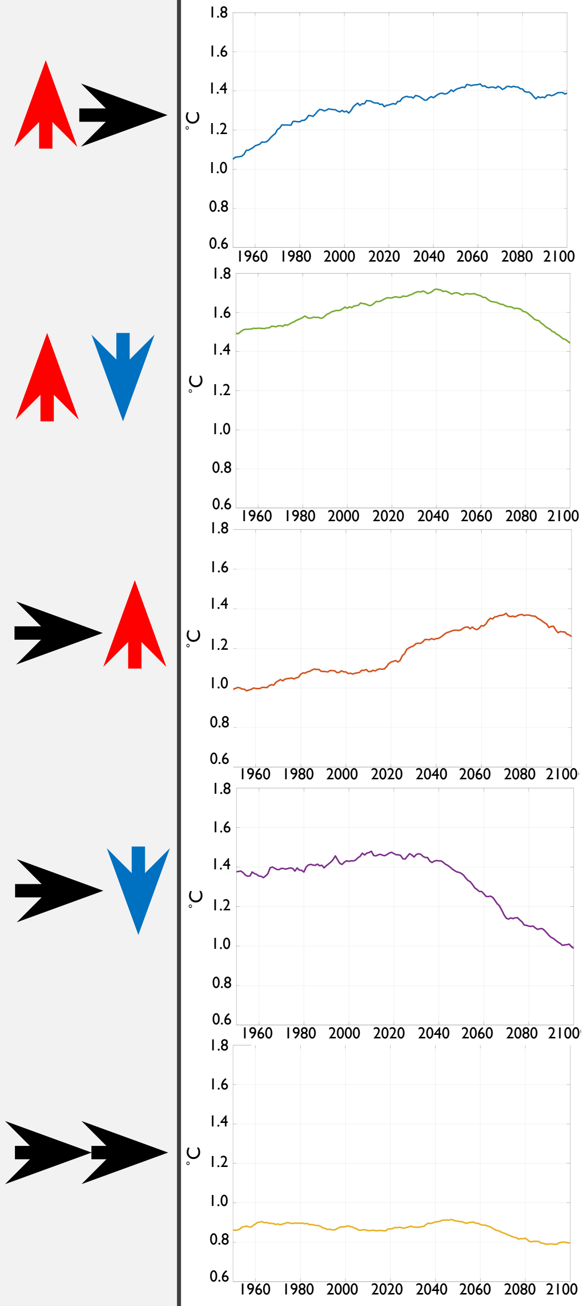
ΔACC relative to 1921-1950



Nino3.4

Trend:

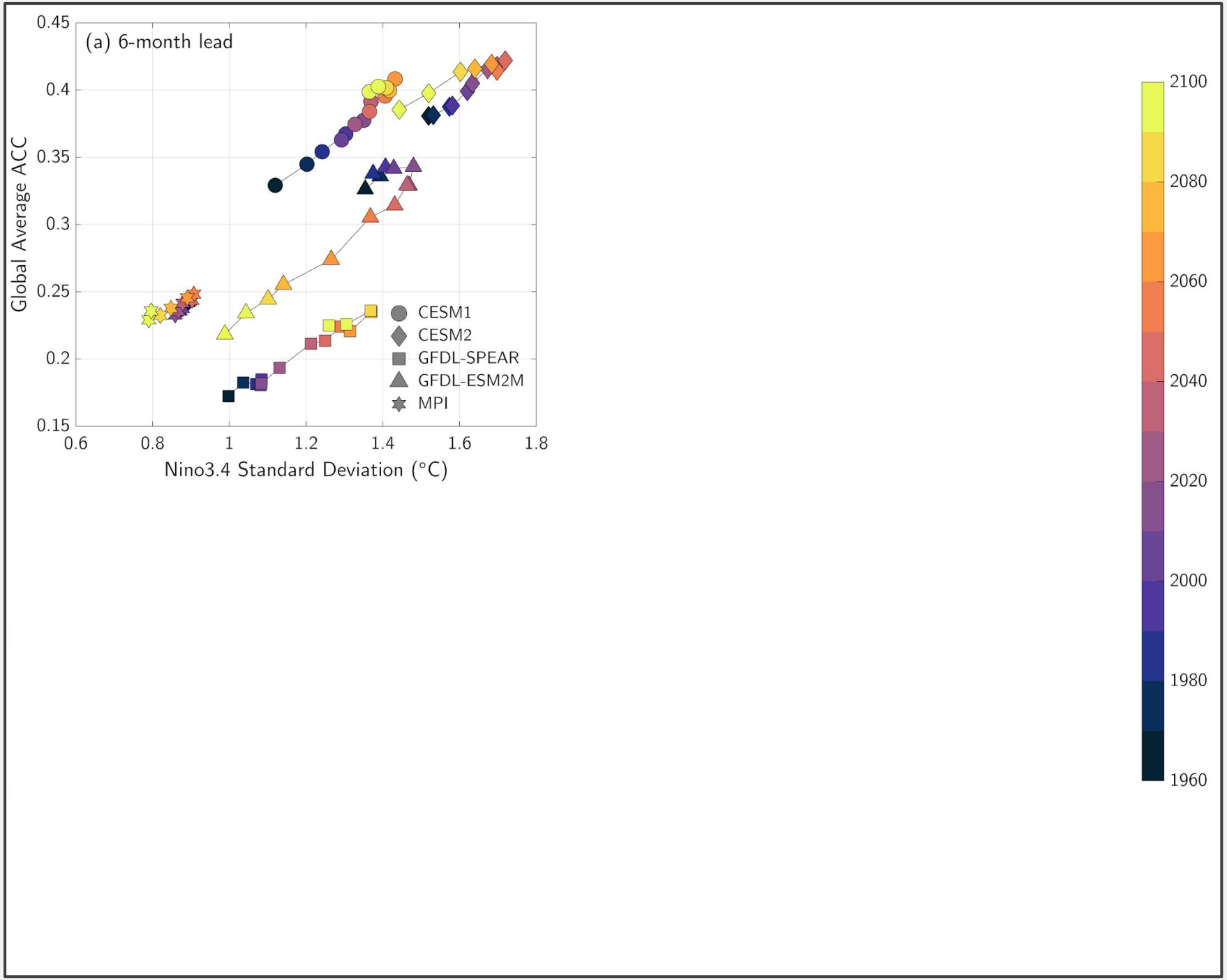
DJF Nino3.4 std. dev.



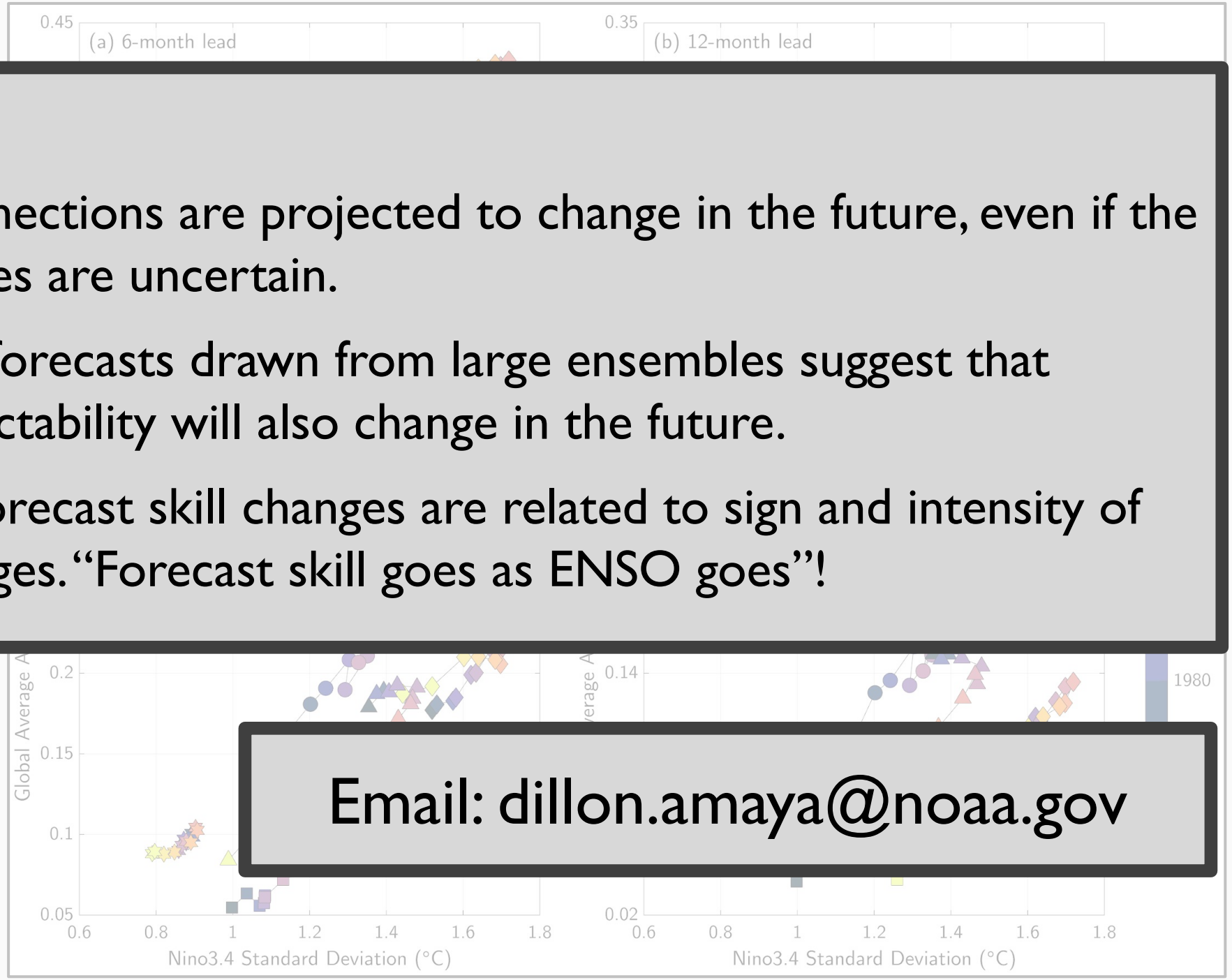
Global SST skill
vs
ENSO variability

Forecast skill goes
as ENSO goes

*Values are for DJF
*Note changes in y-axis



Global SST skill



Summary:

- ENSO and its teleconnections are projected to change in the future, even if the nature of those changes are uncertain.
- Perfect model analog forecasts drawn from large ensembles suggest that seasonal climate predictability will also change in the future.
- Sign and intensity of forecast skill changes are related to sign and intensity of ENSO variability changes. "Forecast skill goes as ENSO goes"!

Questions?

Email: dillon.amaya@noaa.gov

*Values are for DJF

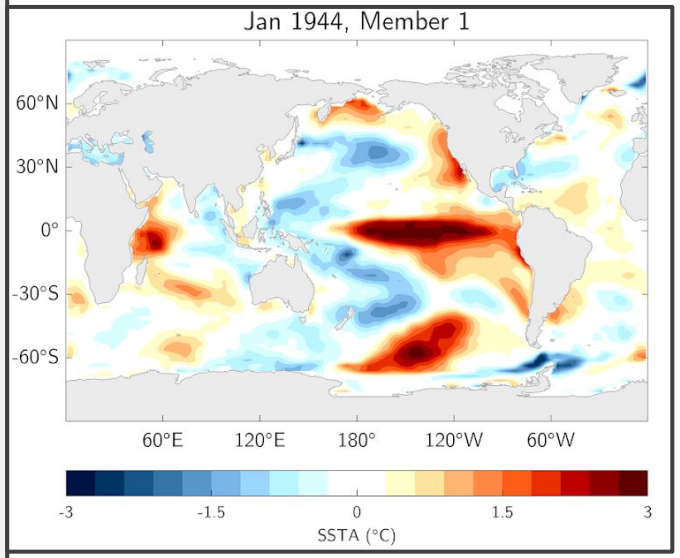
*Note changes in y-axis

Extra Slides

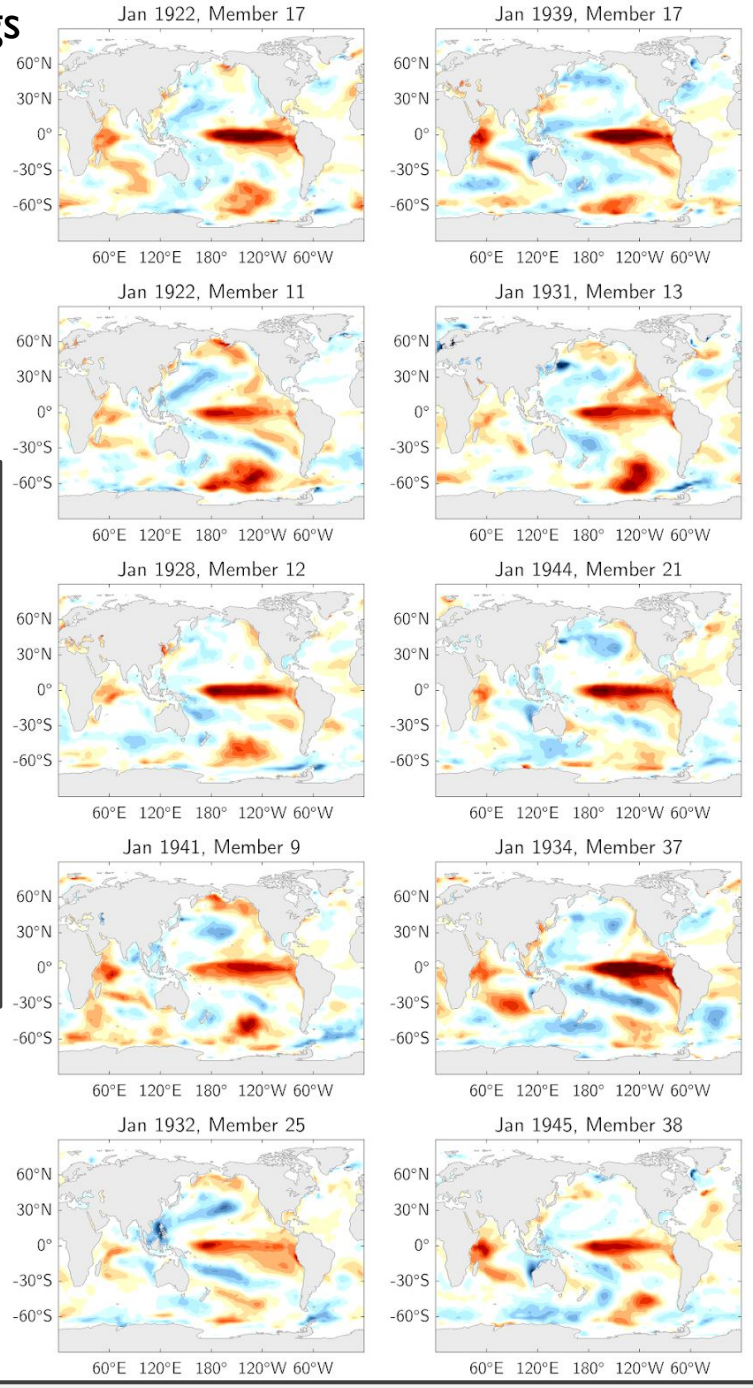
Perfect model analog forecast workflow:

1. Extract SST for 30 year period (e.g., 1921-1950) in all large ensemble members.
2. Remove seasonal cycle. Remove ensemble mean.
3. Arbitrarily take 1st ensemble member as "truth".
4. Construct data libraries using other members. For example, all Januarys, all Februarys, etc.
5. "Initialize" with global SSTA map and keep subsequent 24 months as the forecast target.
6. Choose analogs from library using RMSE.
7. Keep top 10 matches and subsequent 24 months as forecasts.
8. Repeat steps 1-7, taking each remaining ensemble members as "truth".
9. CESM1: 40 members x 10 forecast members x 12 months x 28 years = 134,400 forecasts
10. Repeat steps 1-9 for new 30 year period (e.g., 2071-2100).

"Initialization"



Top 10 best analogs

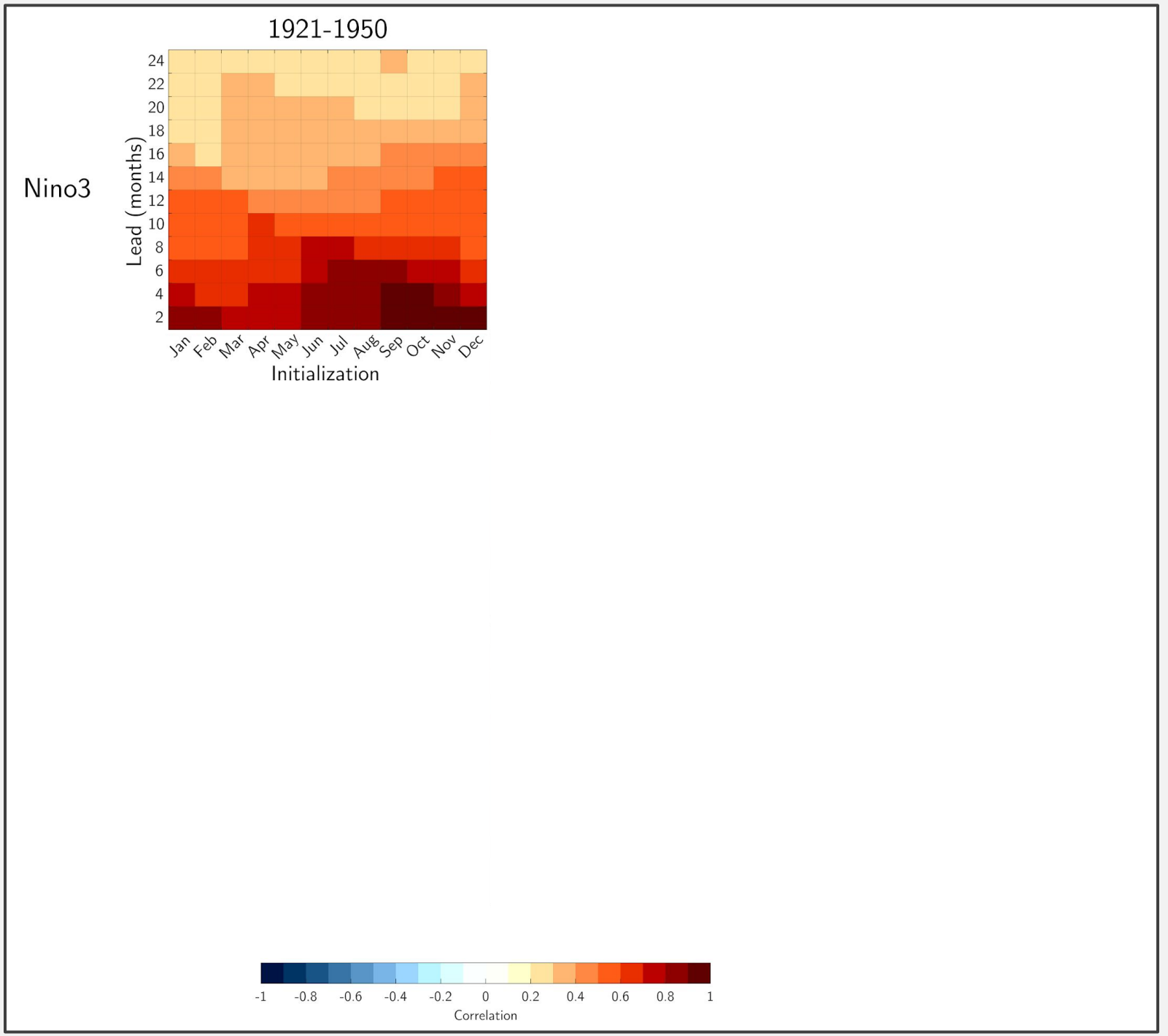


CESM1 forecast skill

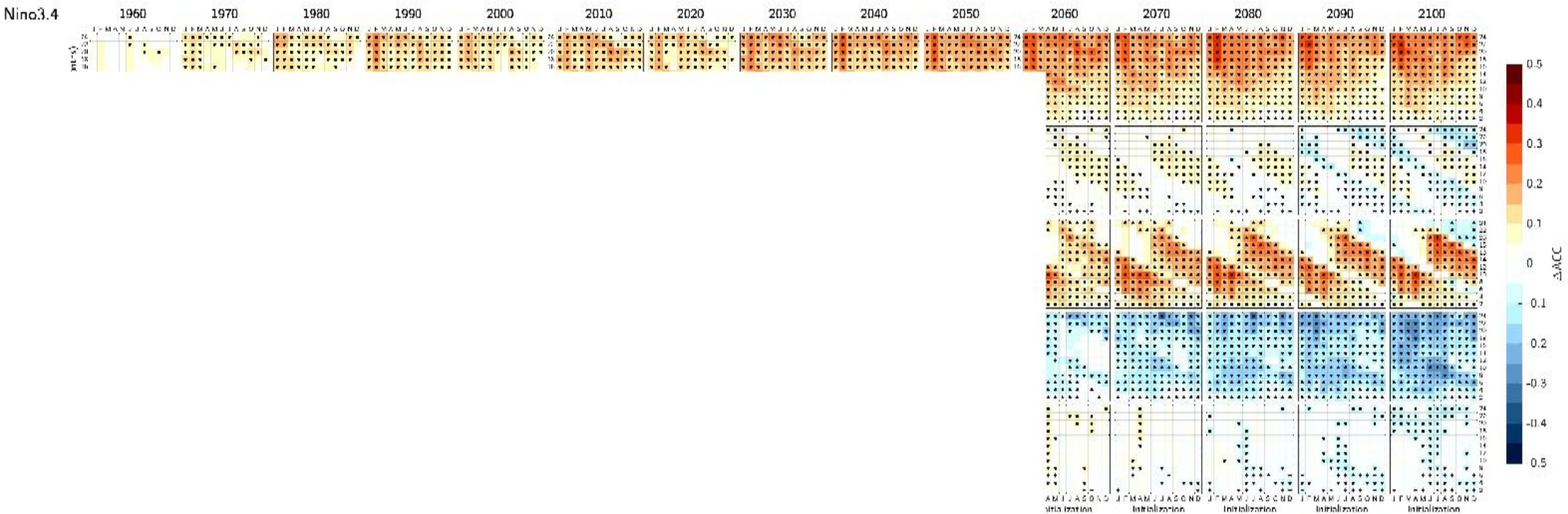
ENSO predictability increases in all seasons, particularly at long leads

Shading: Ensemble mean forecast skill (ACC)

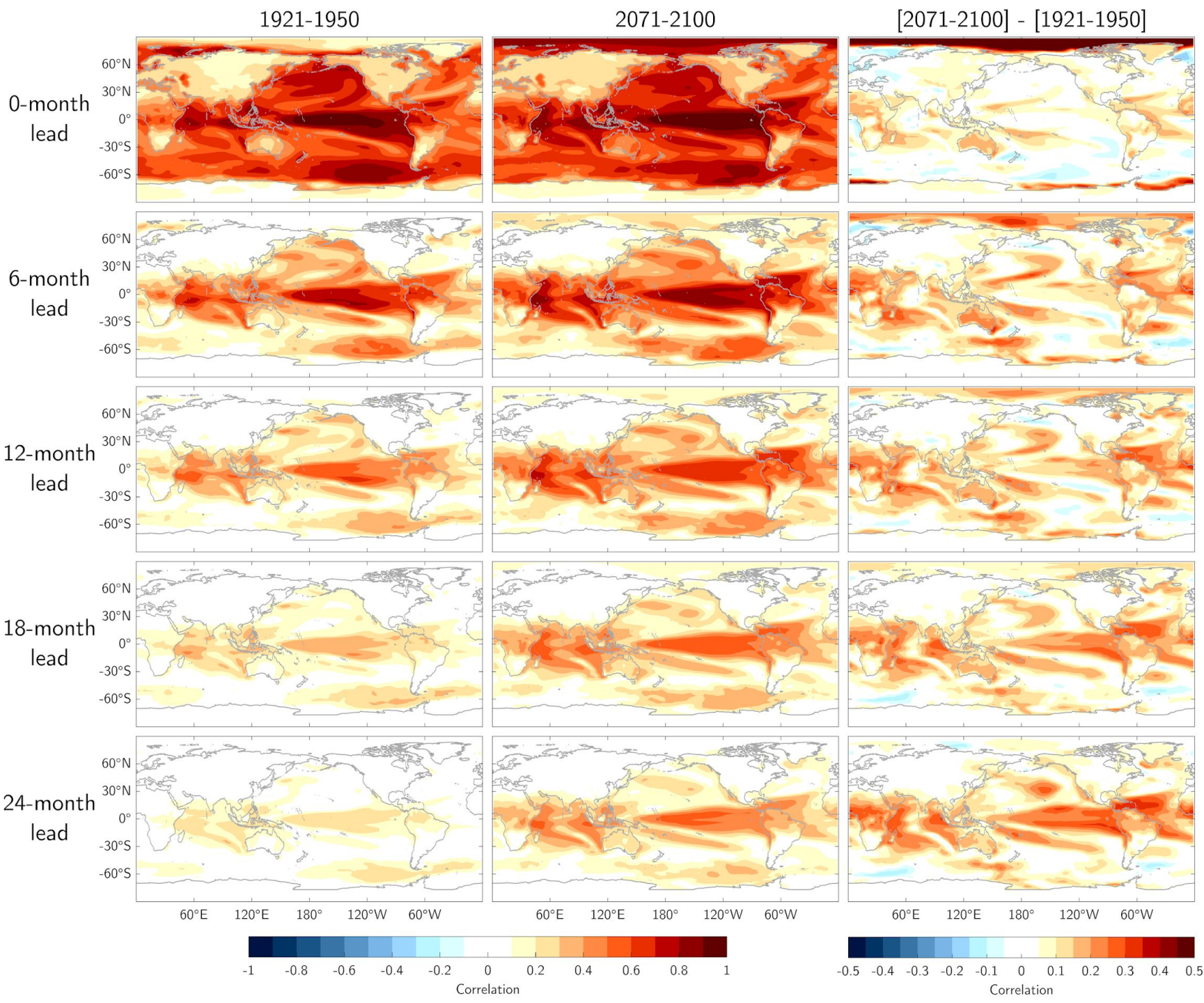
Stippling: Significantly different ACC



ΔACC relative to 1921-1950, averaged in Nino3.4

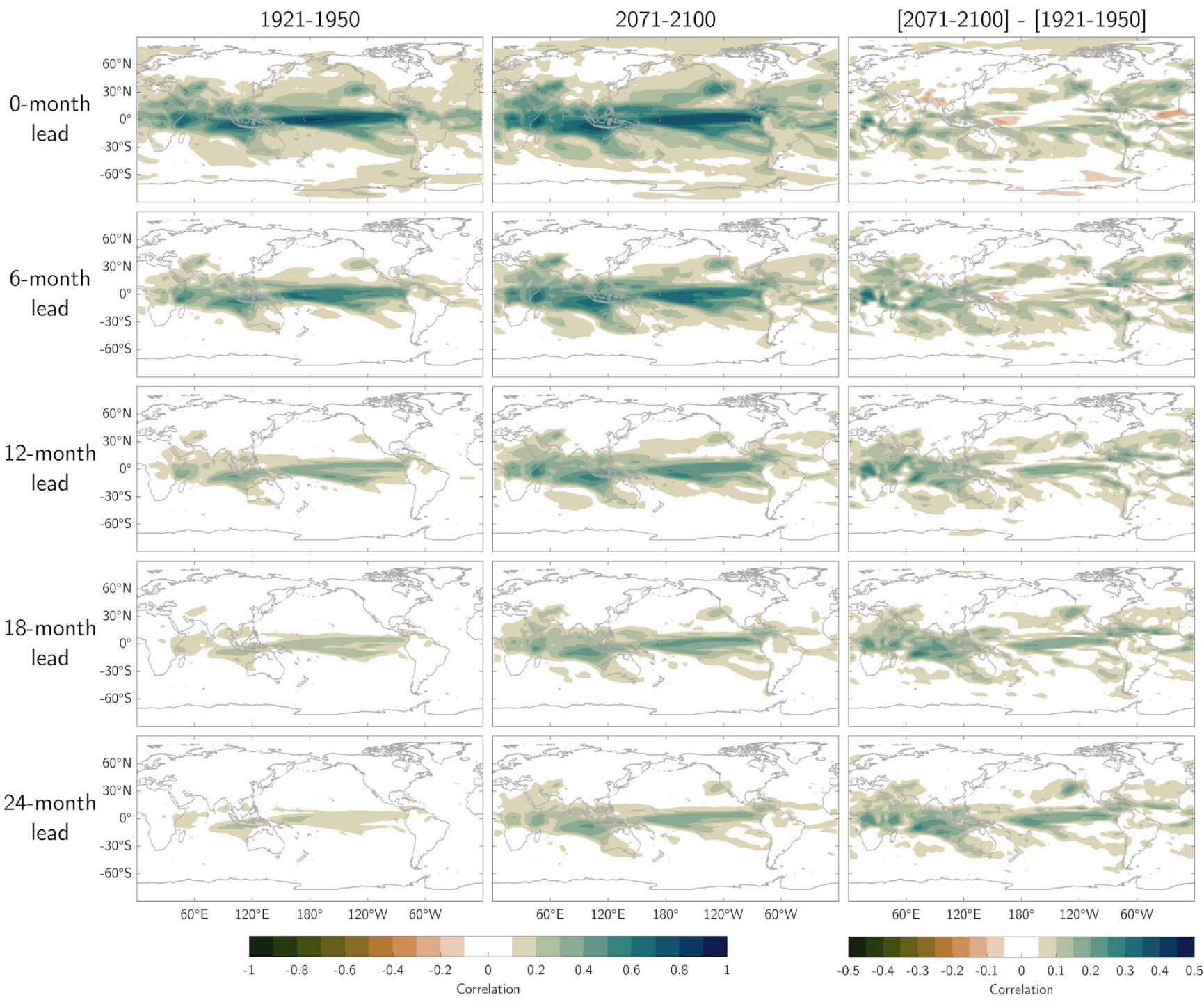


CESM1 (40 members) tas/tos combination



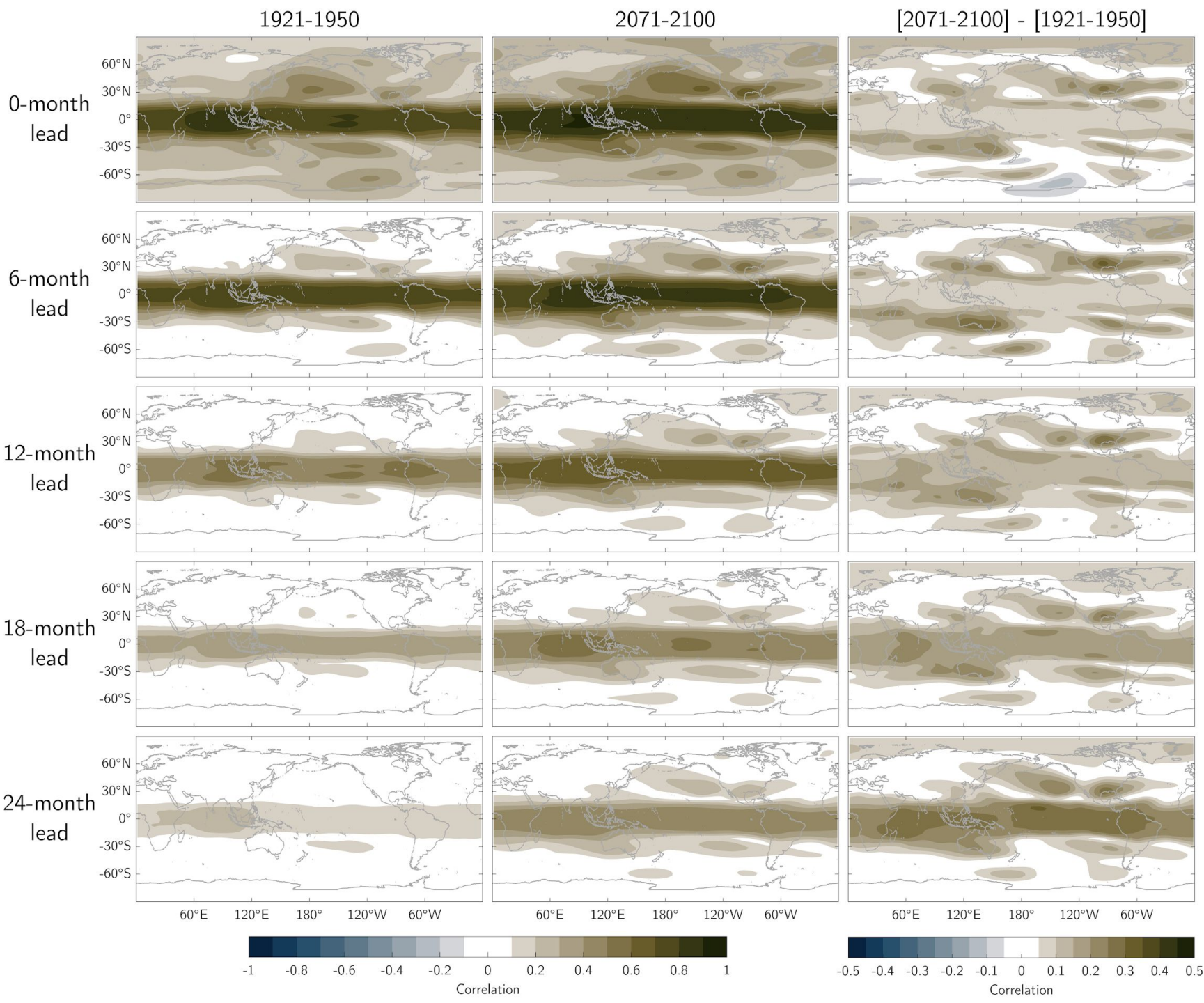
Shading: All month forecast skill (ACC) averaged across model ensemble

CESM1 (40 members) precipitation



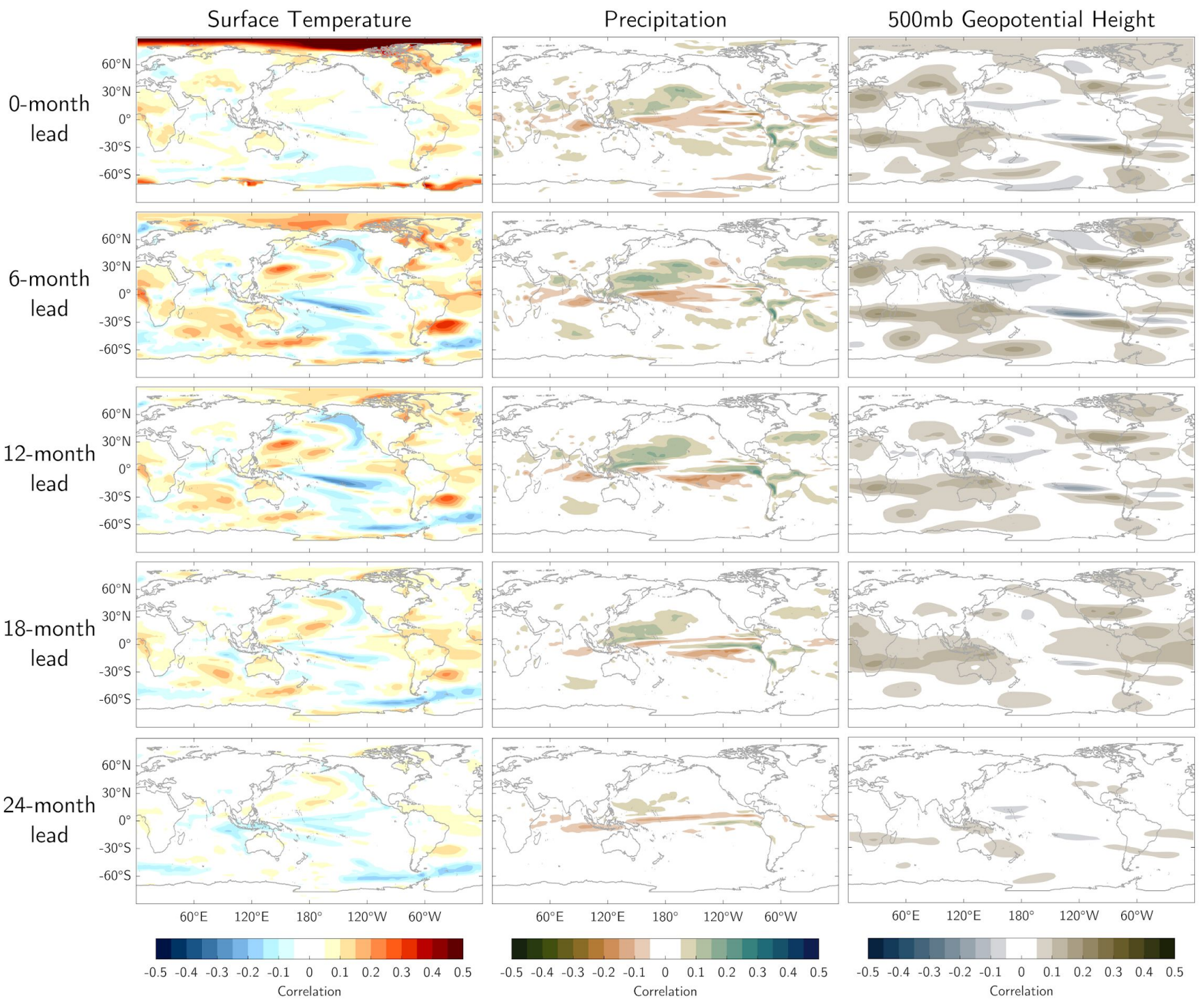
Shading: All month forecast skill (ACC) averaged across model ensemble

CESM1 (40 members)
500mb geopotential heights



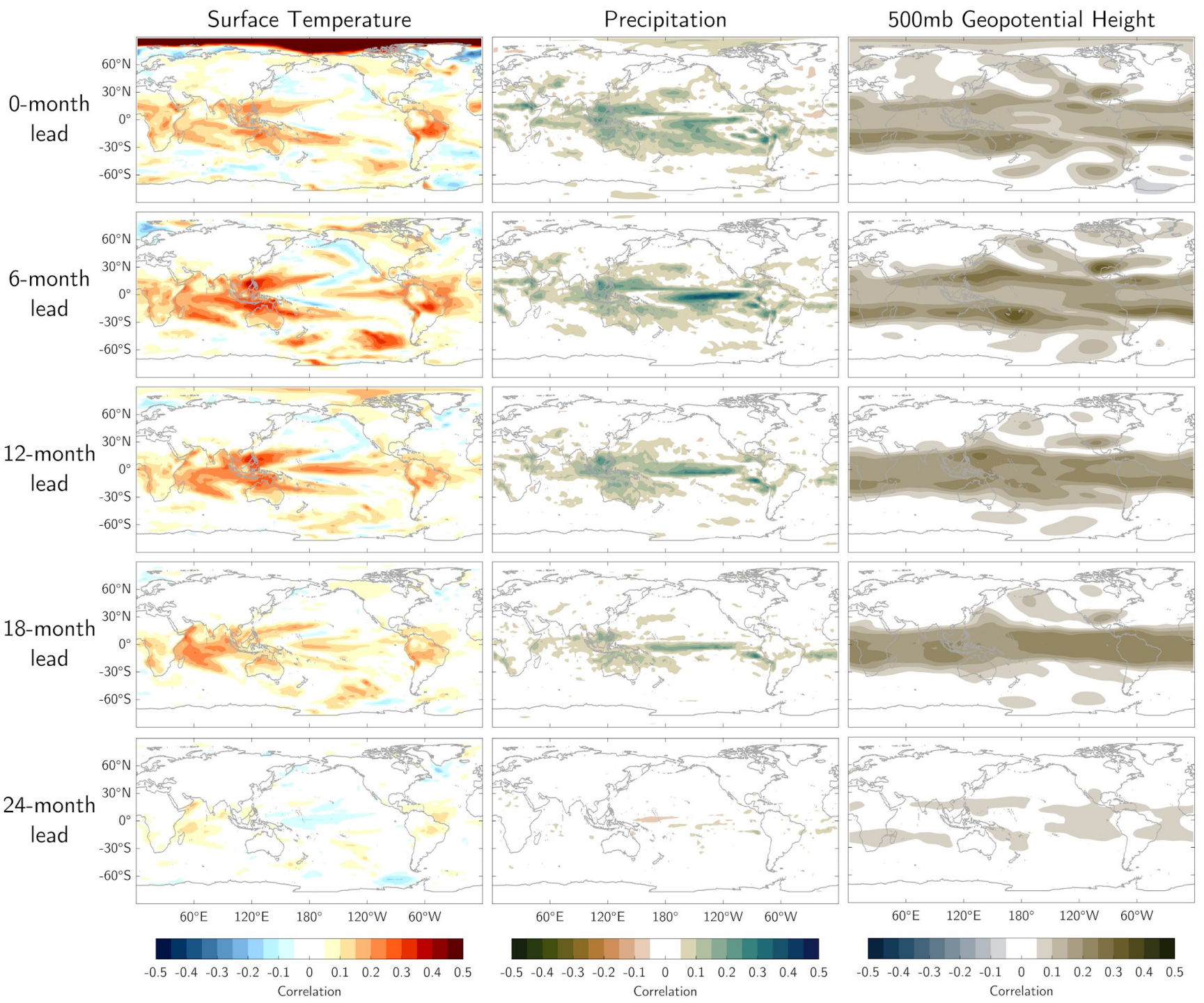
Shading: All month forecast skill (ACC) averaged across model ensemble

CESM2 (100 members)
All variables
[2071-2100] - [1921- 1950]



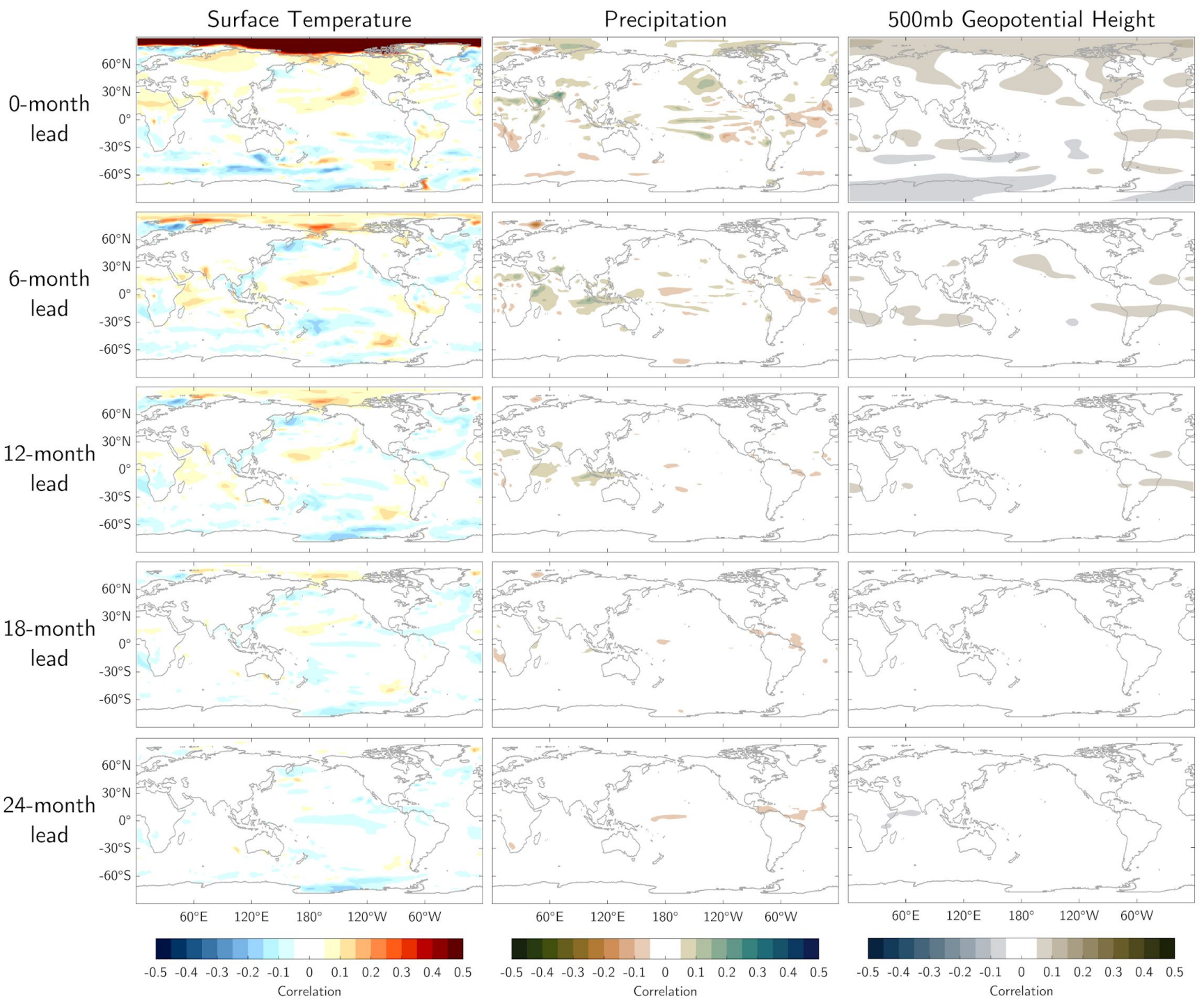
Shading: All month forecast skill (ACC) averaged across model ensemble

GFDL-SPEAR (30 members)
All variables
[2071-2100] - [1921- 1950]



Shading: All month forecast skill (ACC) averaged across model ensemble

MPI (100 members)
All variables
[2071-2100] - [1921- 1950]



Shading: All month forecast skill (ACC) averaged across model ensemble