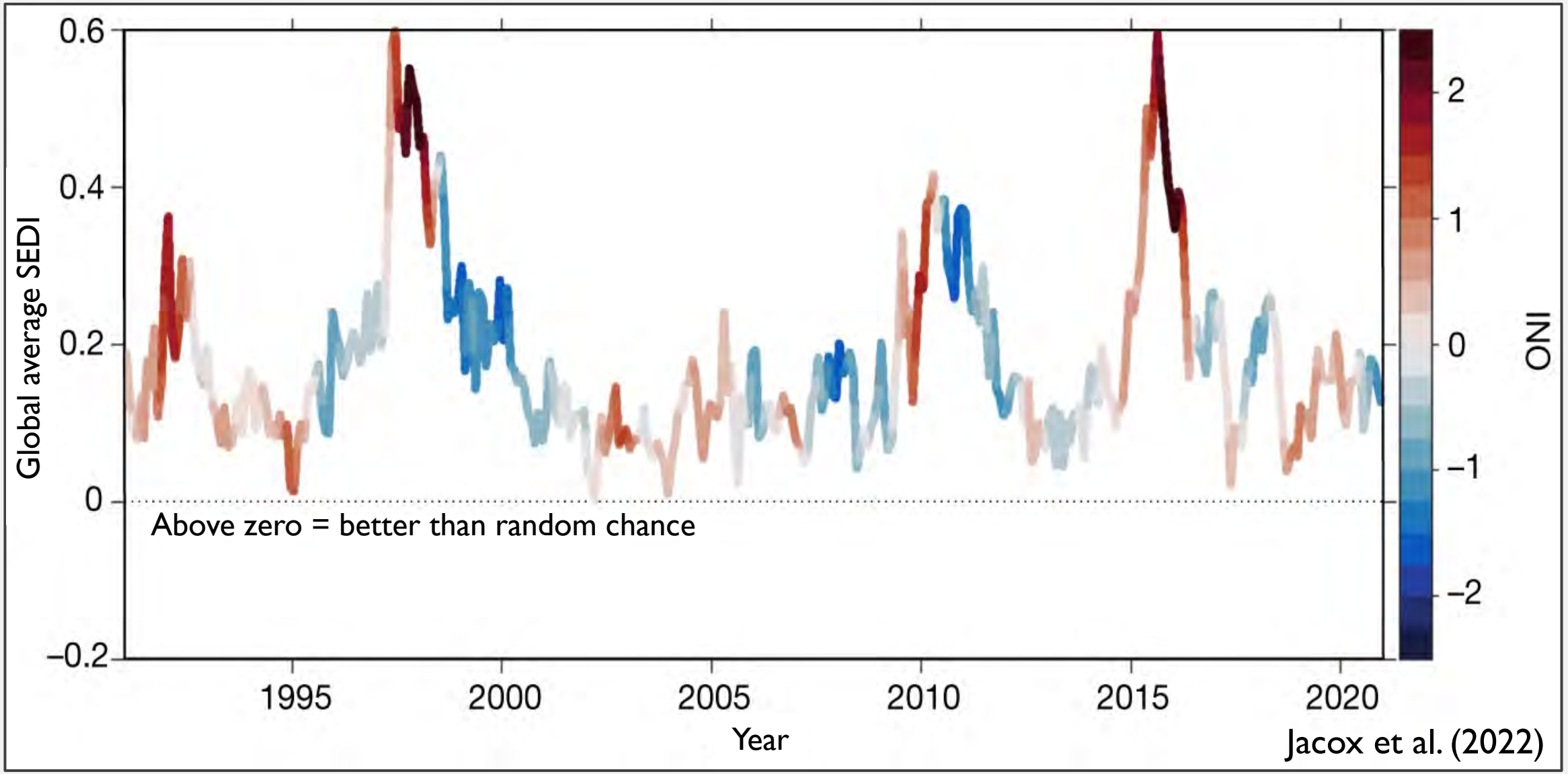
FUTURE CHANGES IN SEASONAL CLIMATE PREDICTABILITY

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

Email: dillon.amaya@noaa.gov June 12-14, 2023 Twitter: @DillonAmaya

Global average marine heatwave forecast skill at 3.5 month lead

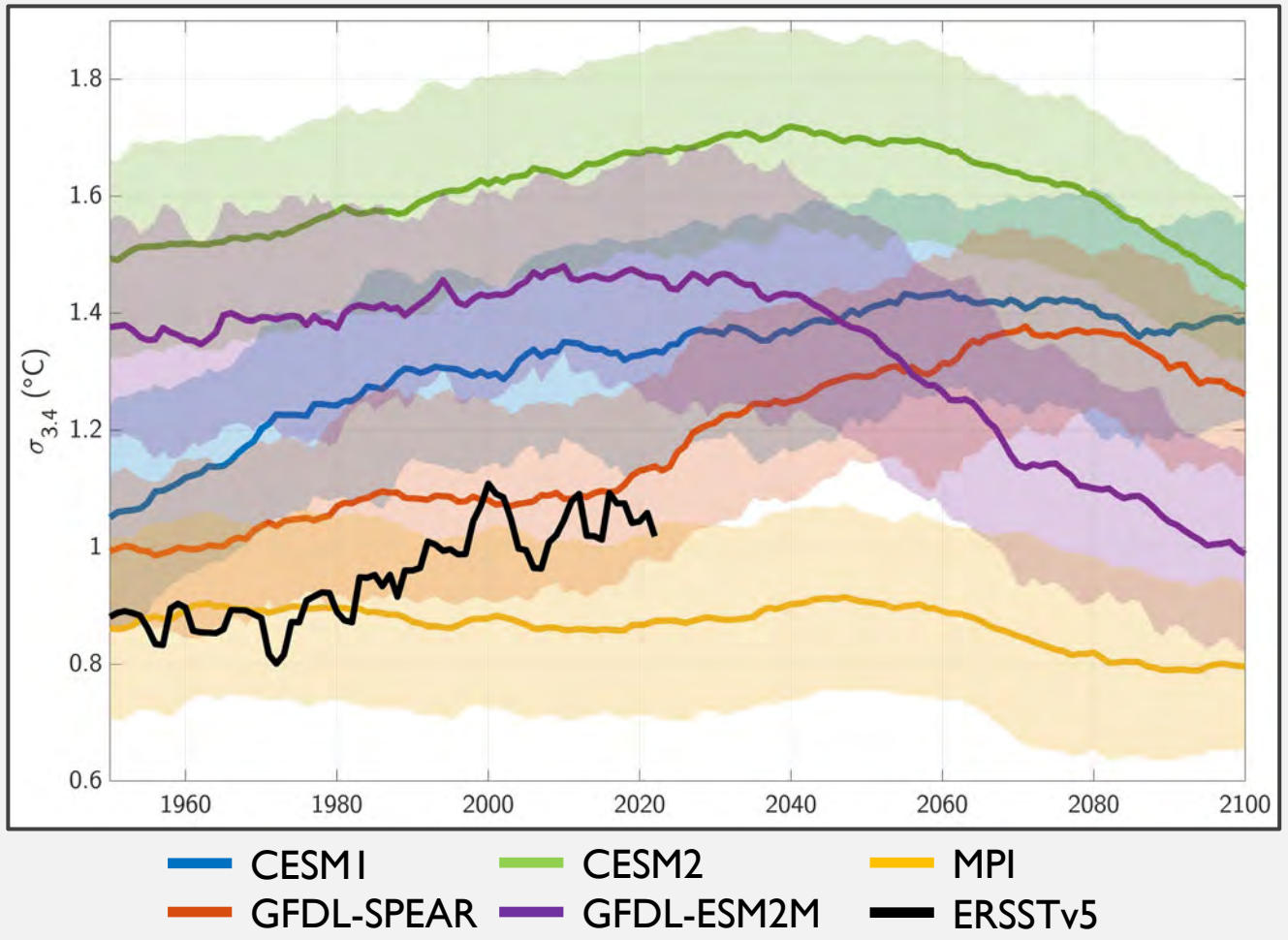


ENSO is the main source of deterministic seasonal forecast skill

Climate models project significant changes to ENSO and its teleconnections

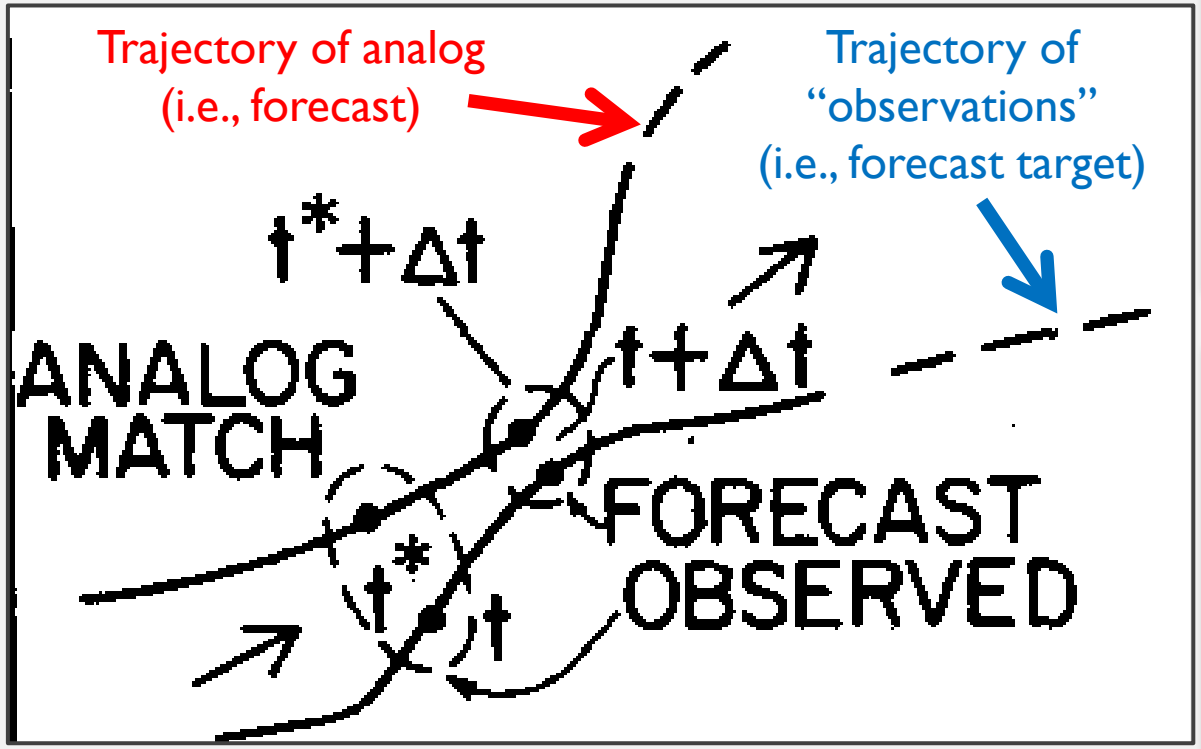
(e.g., Maher et al. 2023; O'Brien and Deser 2022)

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



Does seasonal climate predictability change in the future?

Model analog framework



Barnett and Preisendorfer (1978)

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

Perfect model analog:

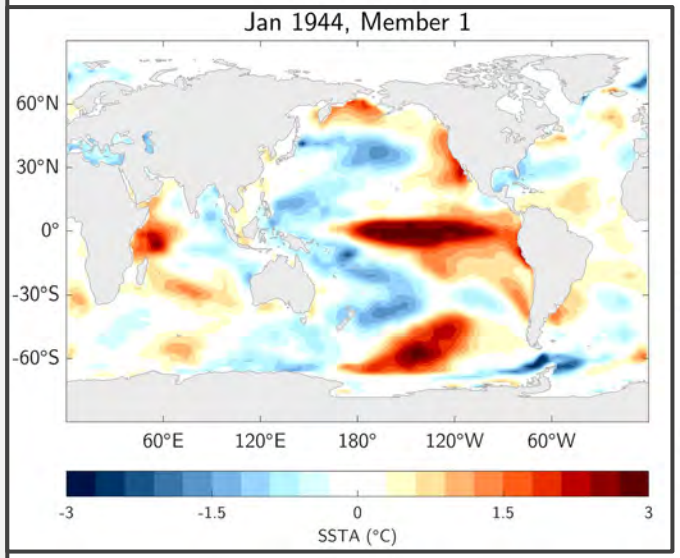
- Use a model to predict the same model.
- "Perfect" because resulting forecasts have no unconditional or conditional biases.
- Quantifies limits to climate predictability.

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

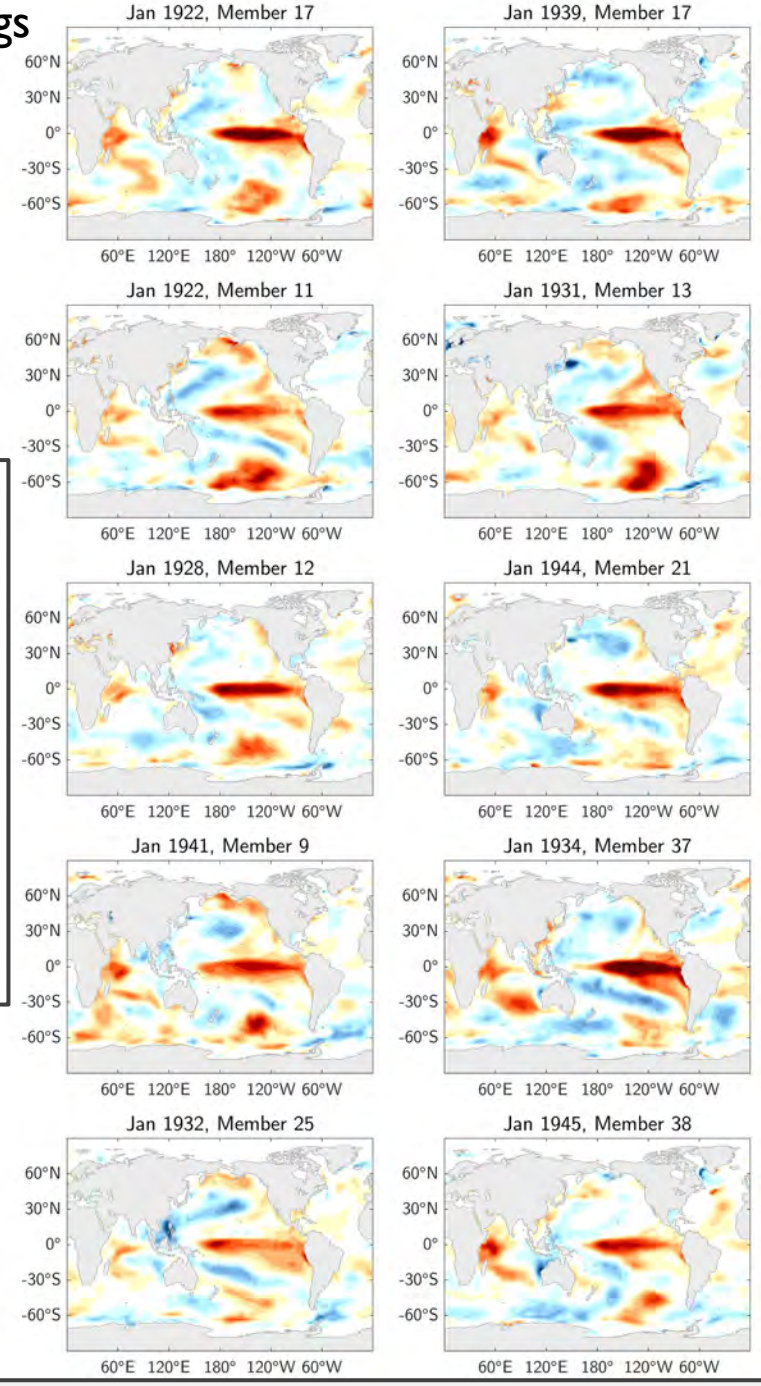
Perfect model analog forecast workflow:

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 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, treating each remaining ensemble member 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



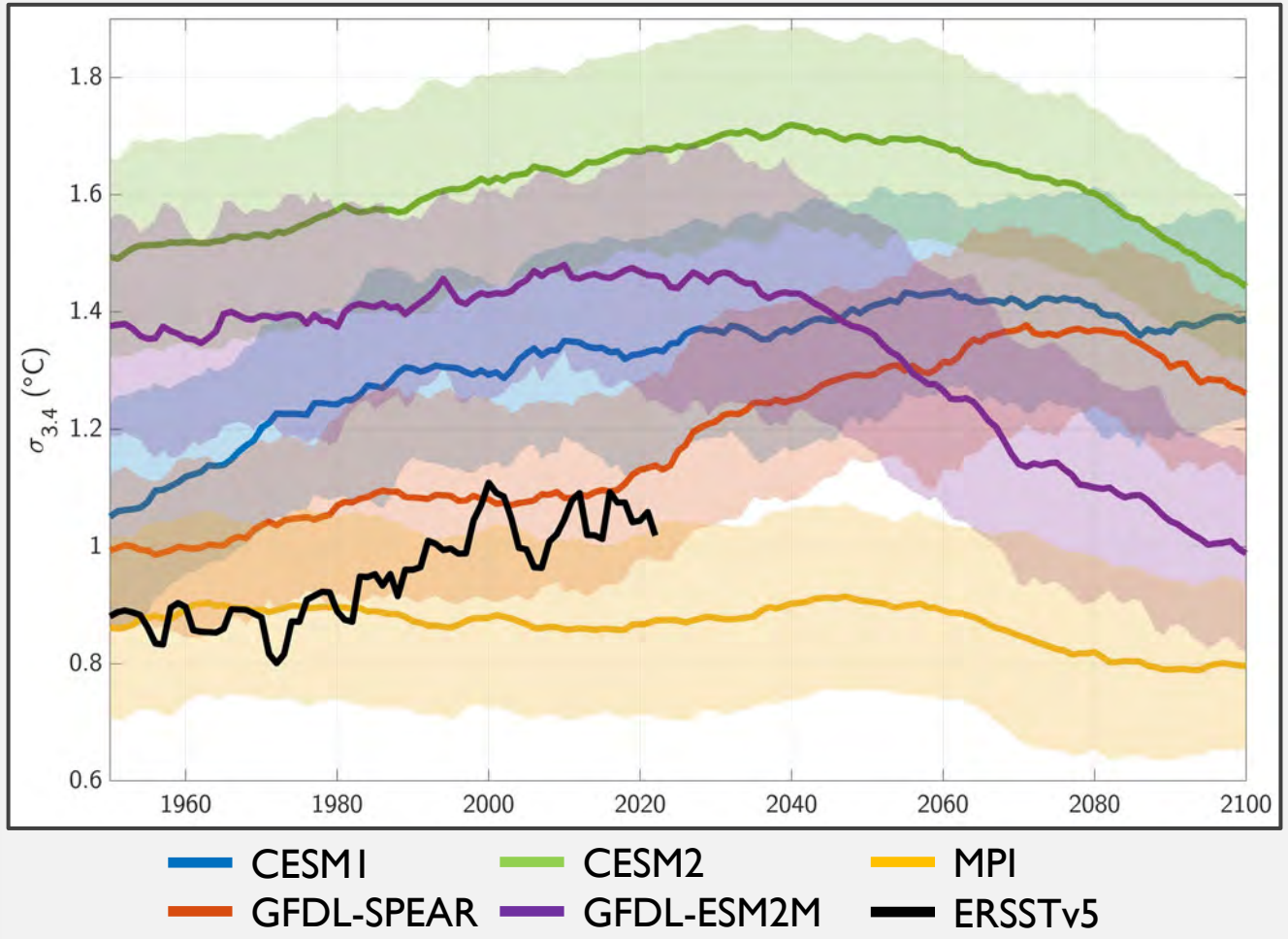
Date and Methods

Single model initial condition large ensembles (SMILEs):

Nino3.4σ trend:

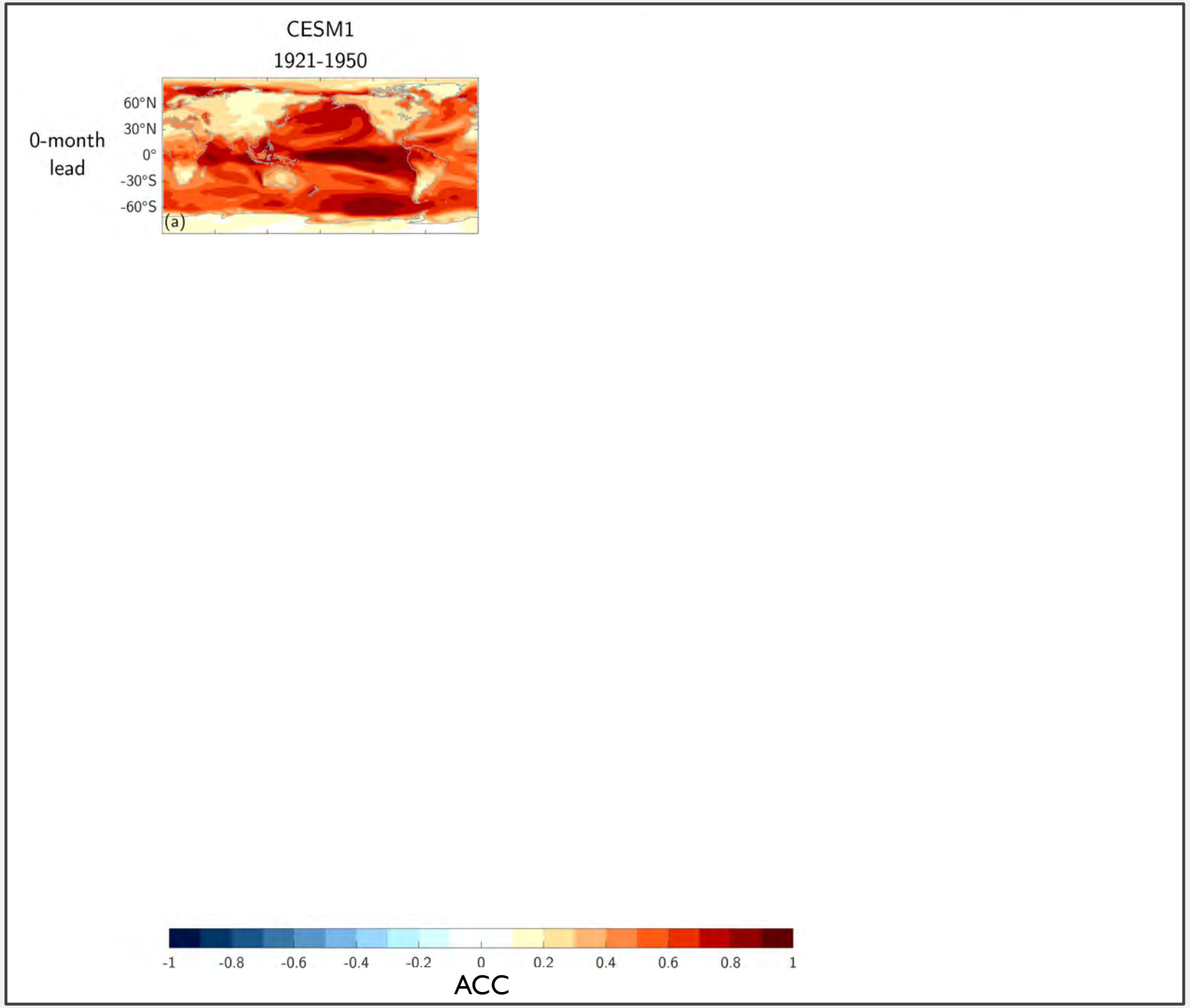
- CESM1 – 40 members ↑→
- CESM2 – 100 members ↑↓
- GFDL-SPEAR – 30 members →↑
- GFDL-ESM2M – 30 members →↓
- MPI – 100 members →→
- All data 2.5˚ x 2.5˚, 1920-2100.
- Forecast skill evaluation based on anomaly correlation coefficient (ACC) and reliability.

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



Surface temperature

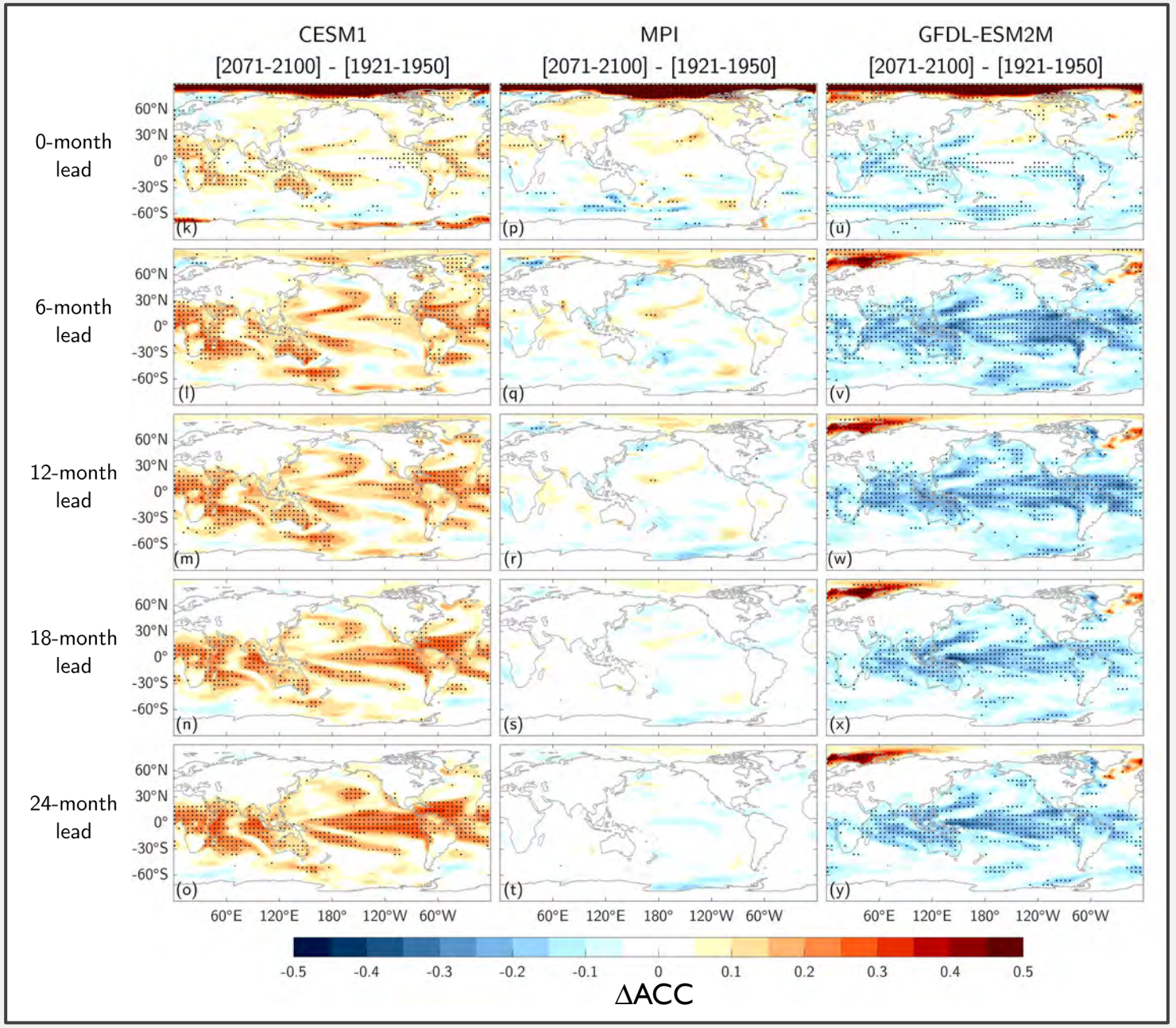
CESM1 surface temperature forecast skill increases nearly everywhere, especially in tropics and at long leads



Shading: Ensemble mean forecast skill (ACC) across all months
Stipples: 90% members agree on ΔACC sign

Surface temperature

Nino3.4σ trend: ↑→ →→ →↓



Sign/strength of forecast skill change highly dependent on model

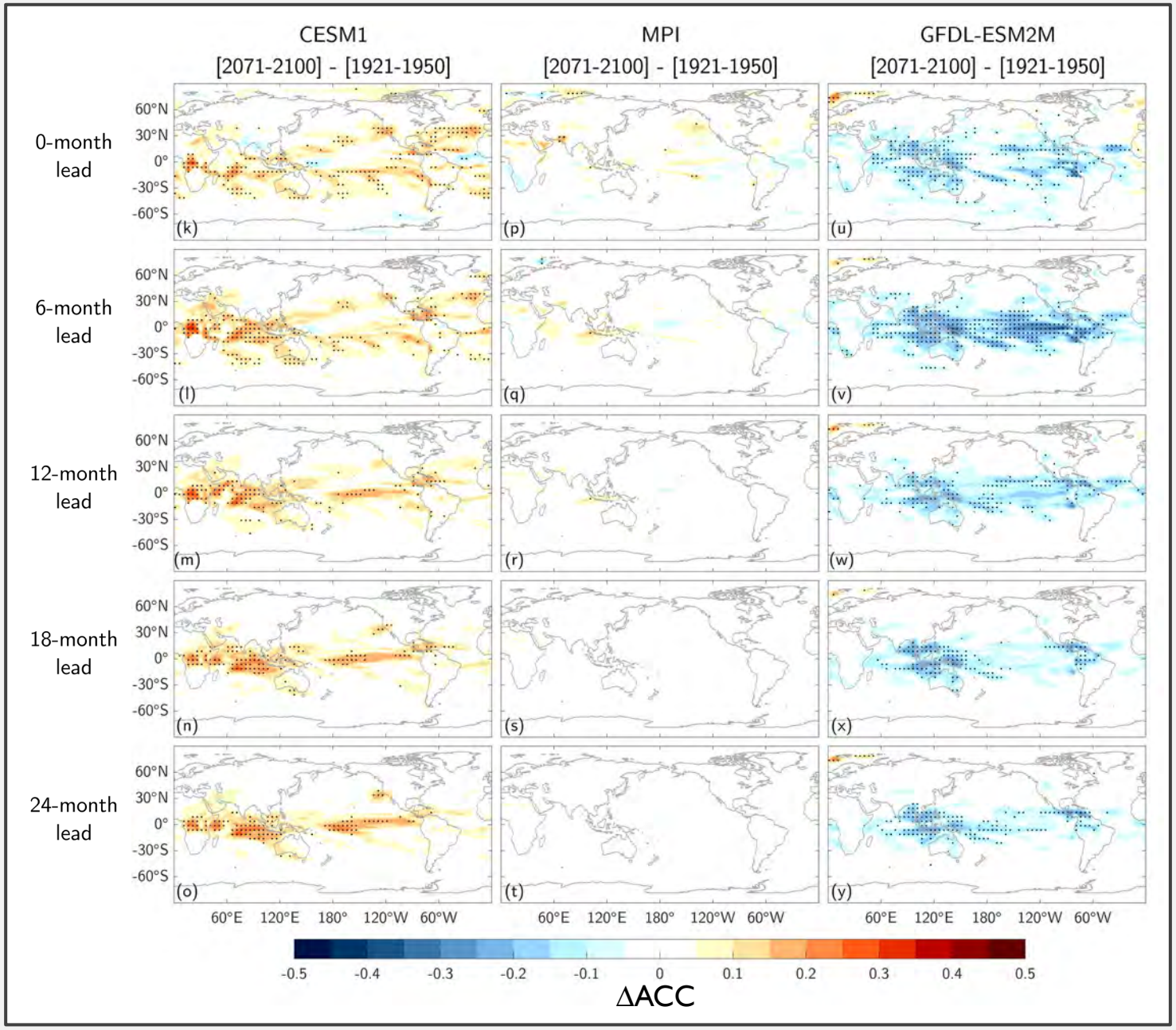
Shading: Ensemble mean forecast skill (ACC) across all months

Stipples: 90% members agree on ΔACC sign

Precipitation

Nino3.4σ trend: ↑→ →→ →↓

Sign/strength of forecast skill change highly dependent on model



Shading: Ensemble mean forecast skill (ACC) across all months
Stipples: 90% members agree on ΔACC sign

Forecast reliability

Reliability Categories:

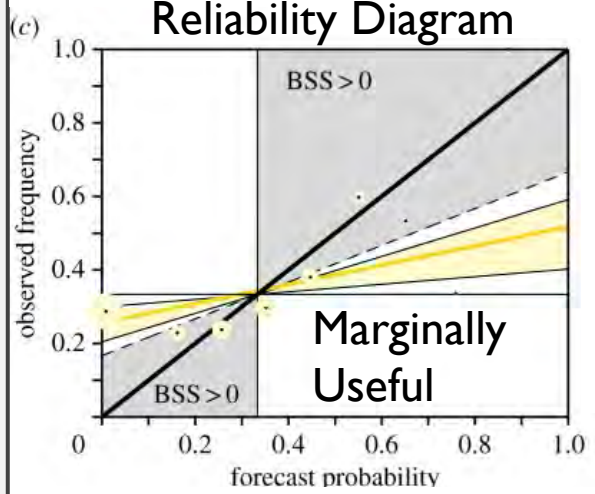
Category 5: *Perfect*
Category 4: *Very Useful*
Category 3: *Marginally Useful*
Category 2: *Not Useful*
Category 1: *Dangerously Useless*

Brier Skill Score = BSS

Forecast probability = fraction of forecast members in given tercile

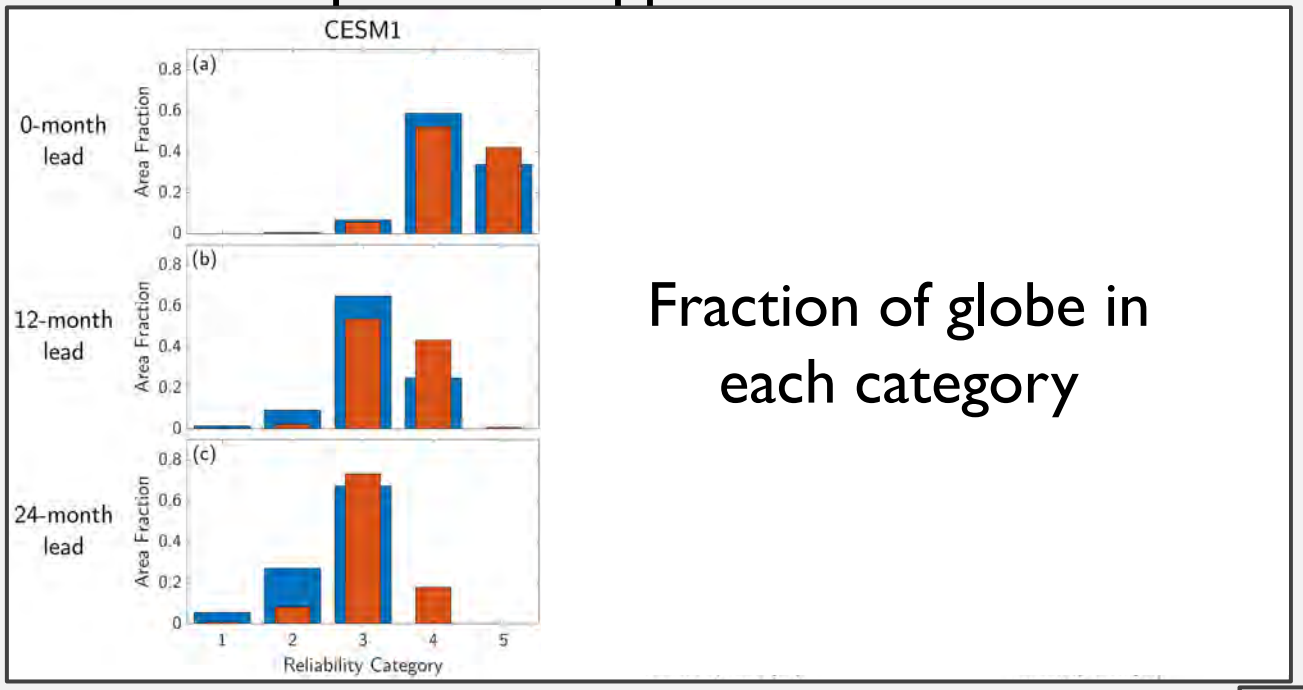
Observed frequency = fraction of timesteps with observed event in tercile

Reliability Diagram



Weisheimer and Palmer (2014)

Surface temperature, upper tercile



Fraction of globe in each category

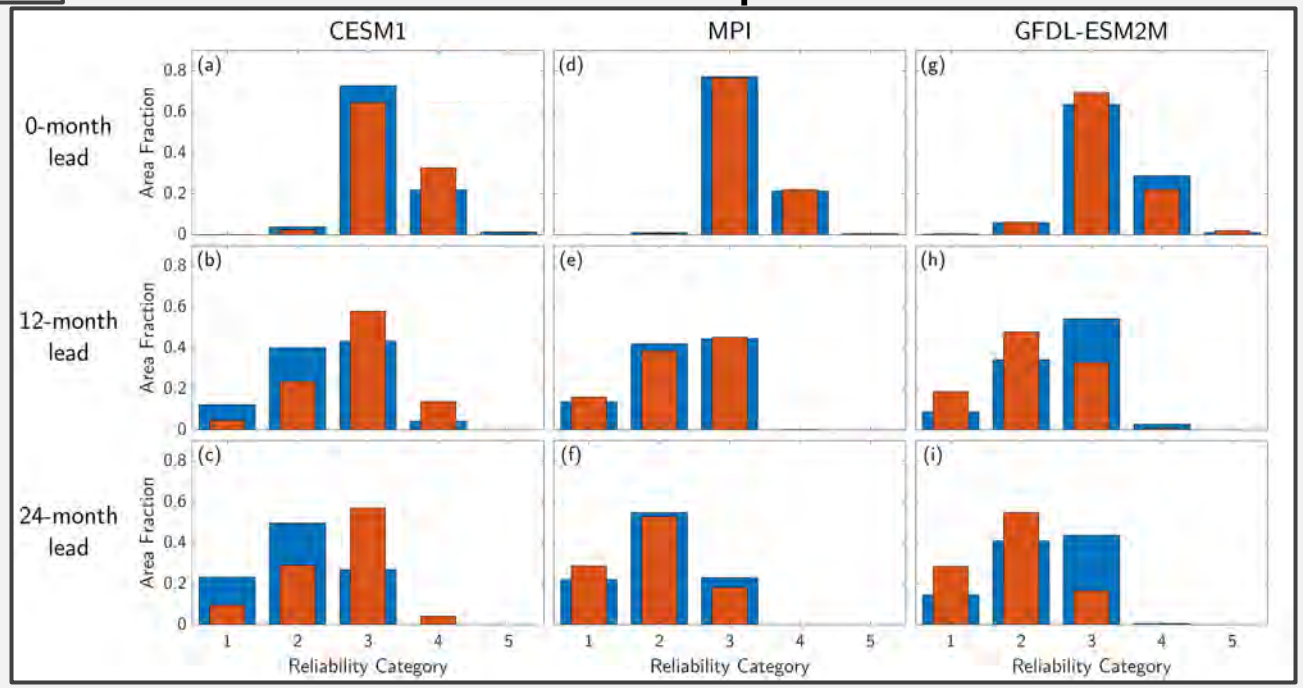
1921-1950 2071-2100

Reliability Categories:

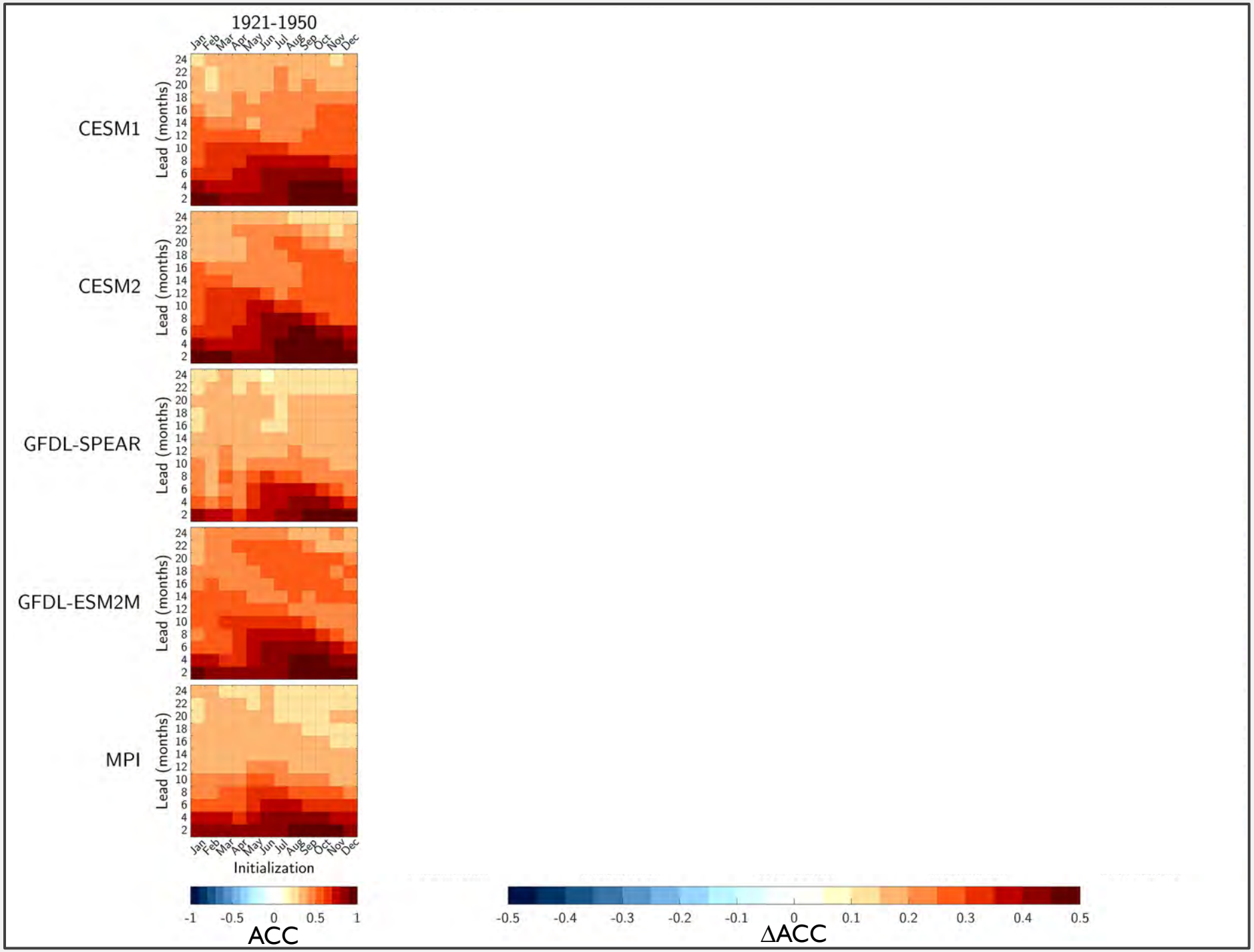
Category 5: *Perfect*
Category 4: *Very Useful*
Category 3: *Marginally Useful*
Category 2: *Not Useful*
Category 1: *Dangerously Useless*

Forecasts become more reliable/useful in CESM1, less reliable/useful in GFDL-ESM2M

Precipitation, lower tercile



ENSO skill

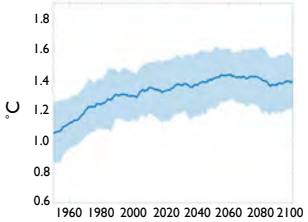


Shading: Ensemble mean ACC across all months

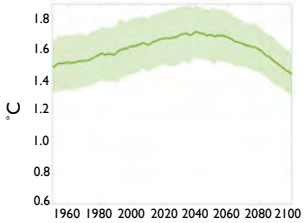
Stipples: 80% members agree on ΔACC sign

Trend:

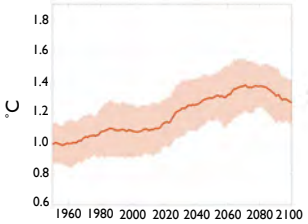
DJF Nino3.4 std. dev.



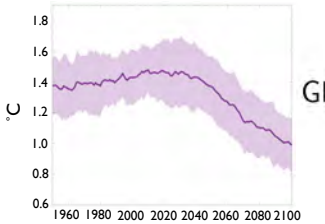
CESM1



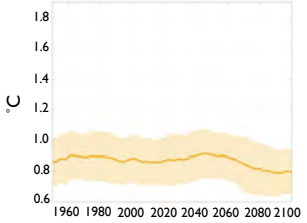
CESM2



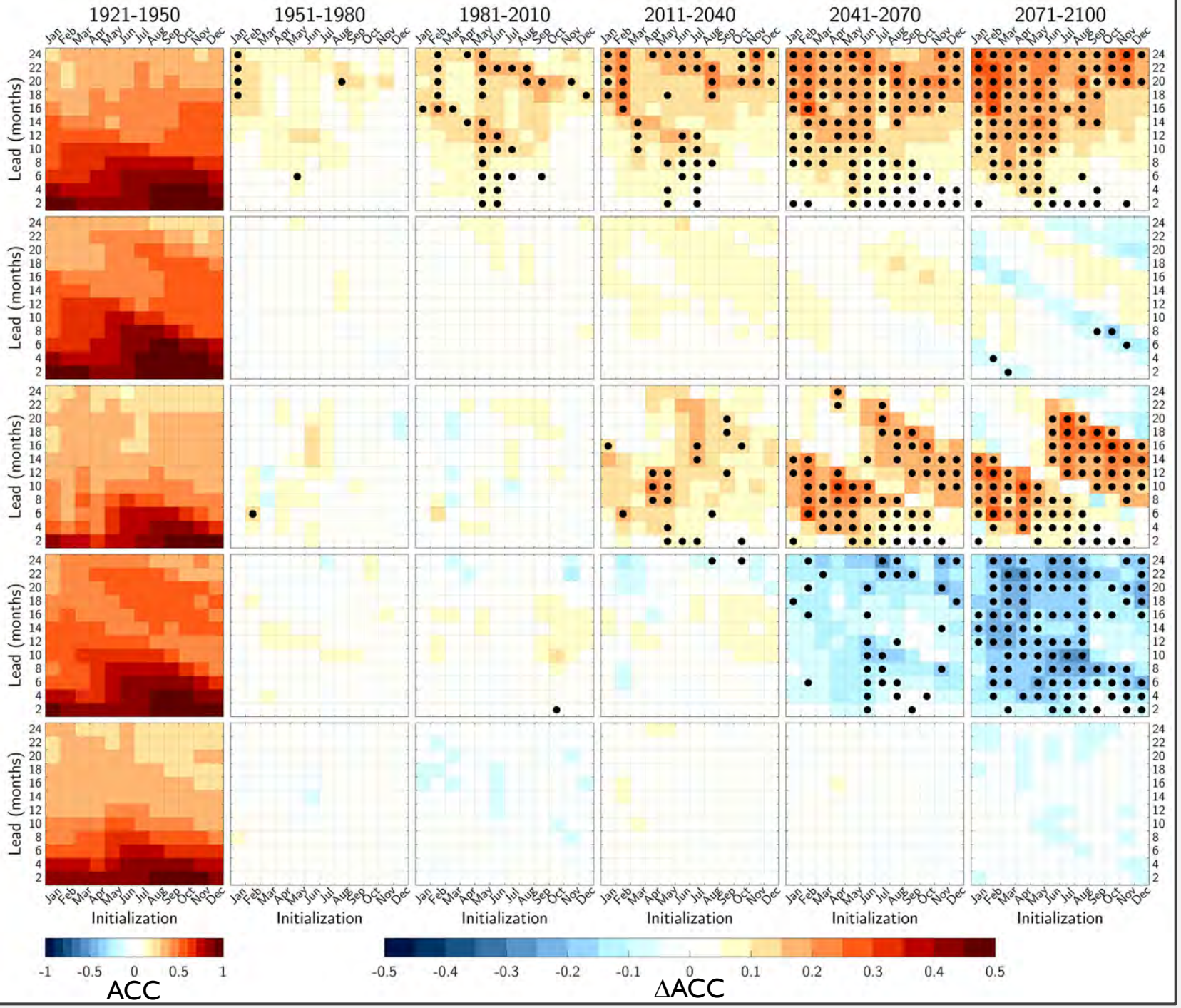
GFDL-SPEAR



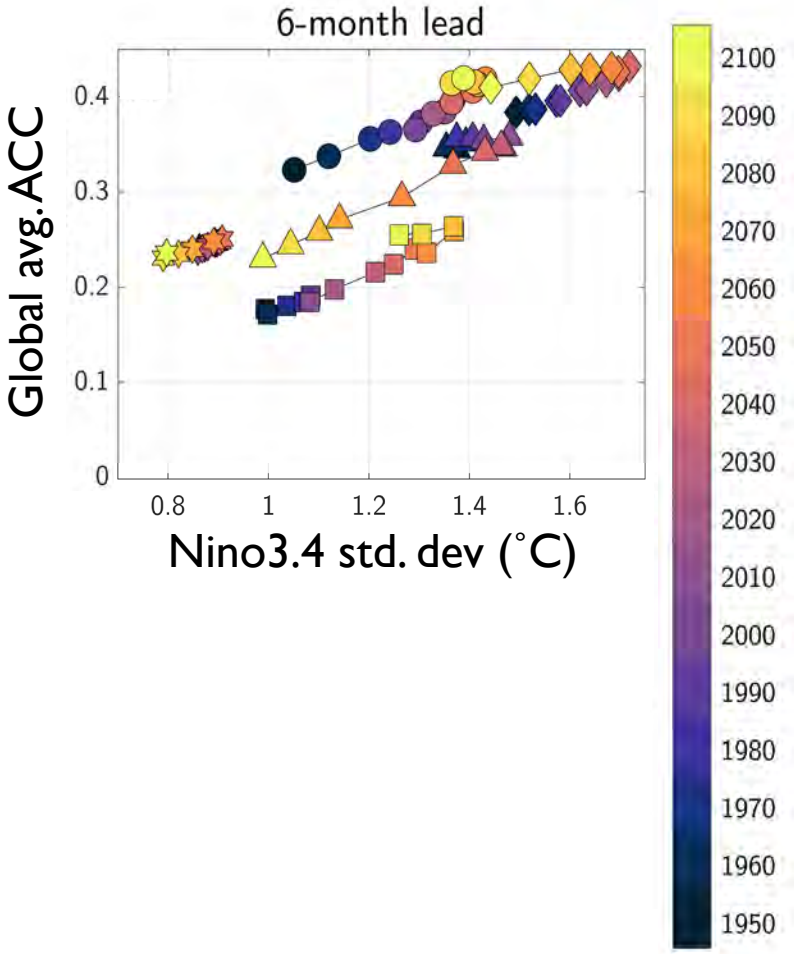
GFDL-ESM2M



MPI



Sea surface temperature

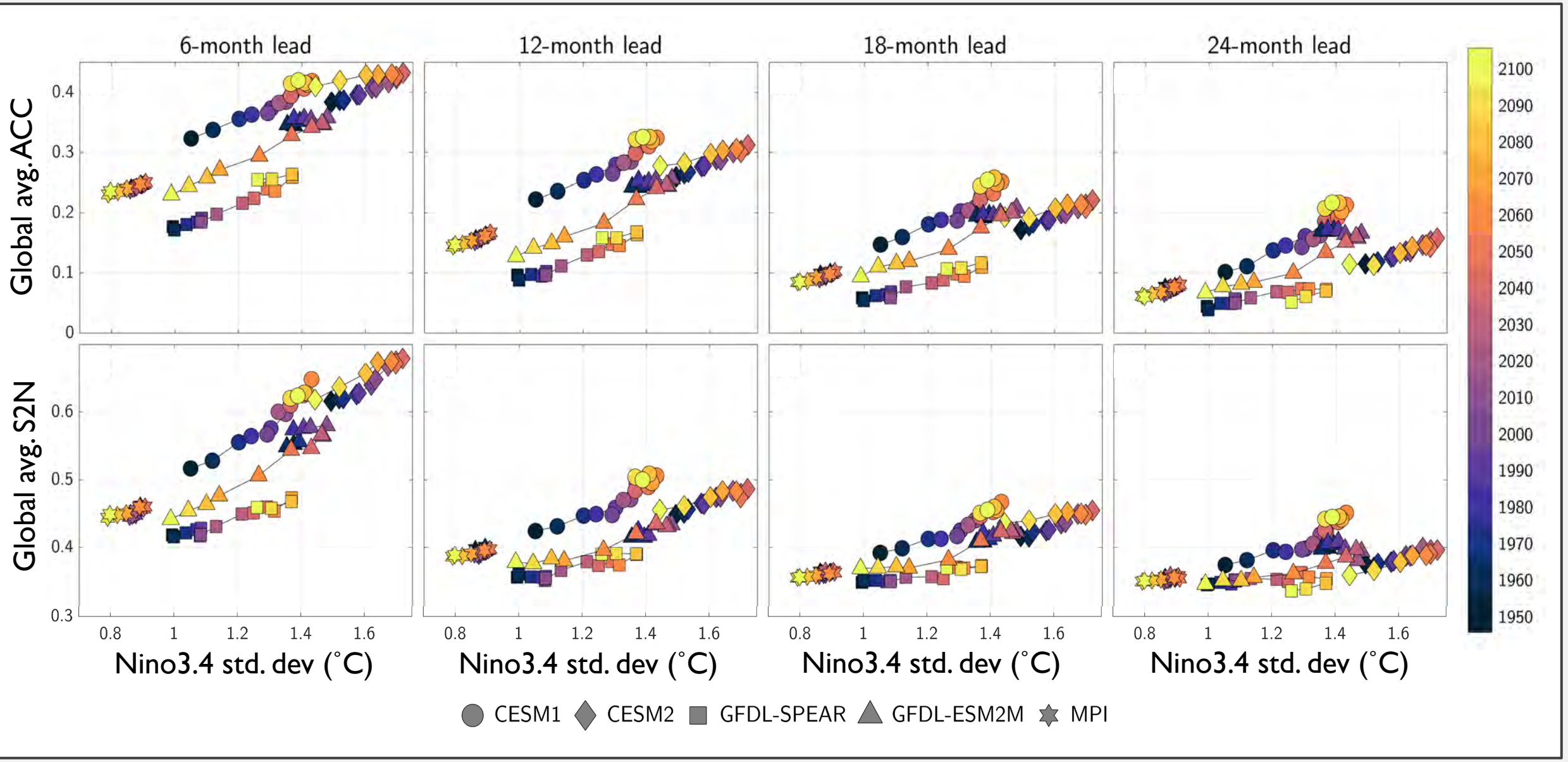


Analog forecast $= f_i\ (t, x, y) = \bar{f} + f_i'$

Signal-to-noise $= \left(\frac{\sum \bar{f}^2}{\sum f'^2}\right)^{1/2}$

CESM1 CESM2 GFDL-SPEAR GFDL-ESM2M MPI

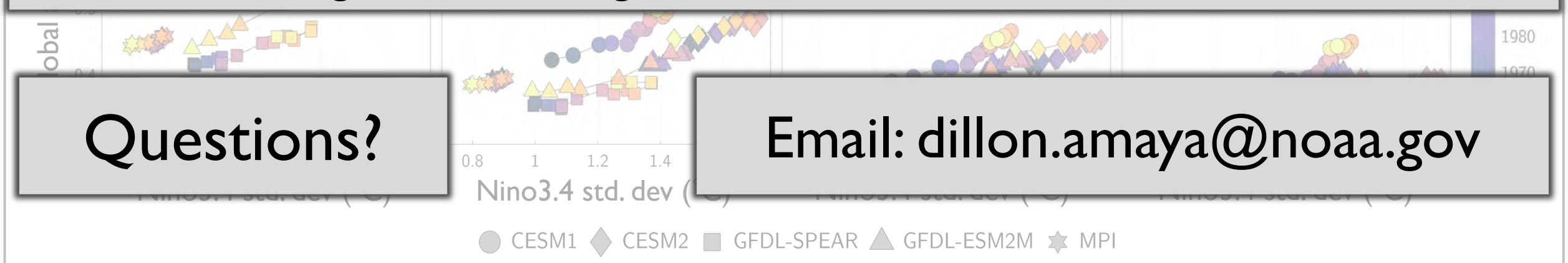
Sea surface temperature



Sea surface temperature

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/intensity of predictability changes (deterministic/probabilistic) are related to sign/intensity of ENSO variability changes. Stronger ENSO = higher S2N!
- "Forecast skill goes as ENSO goes"!

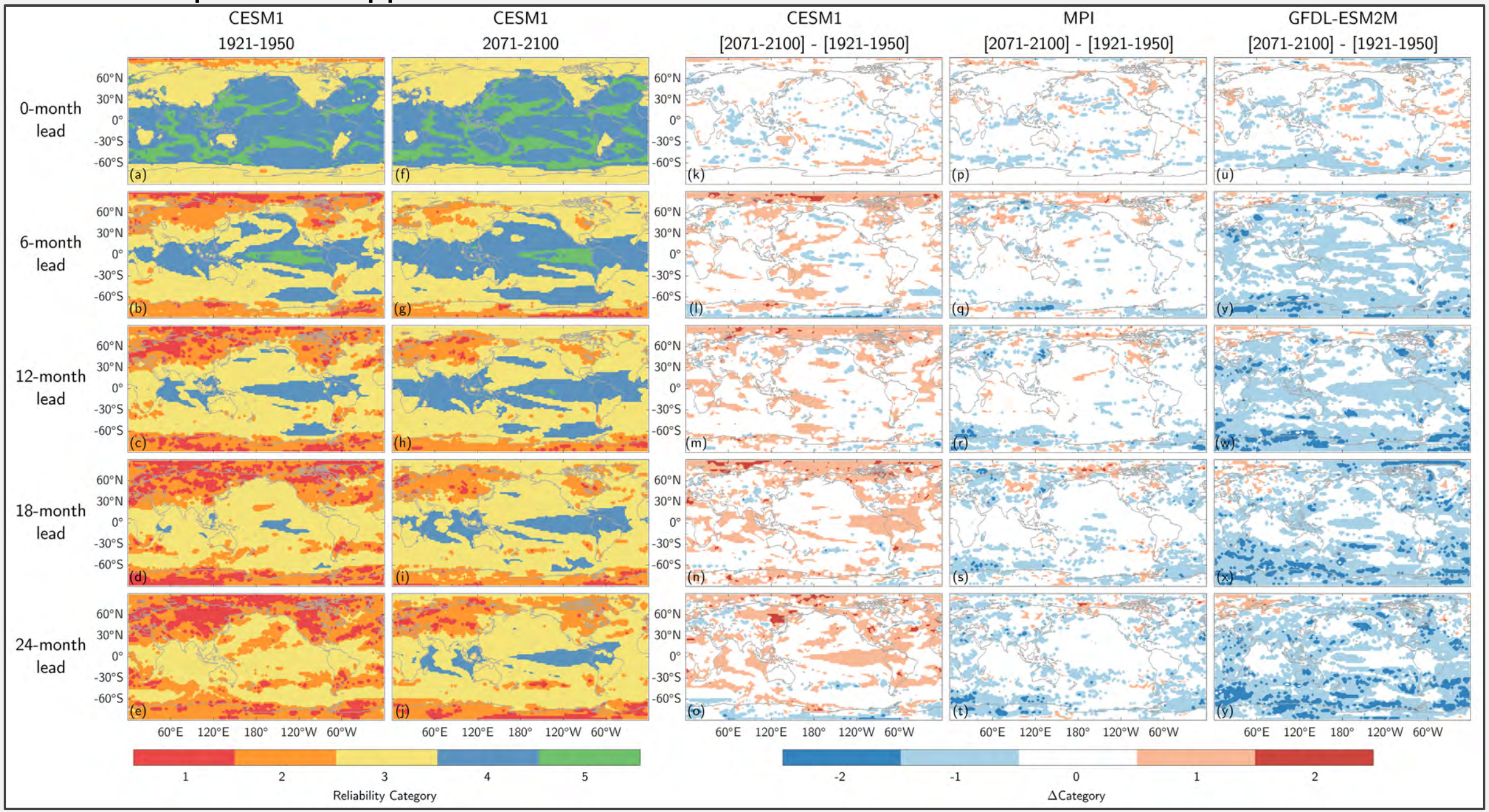


Questions?

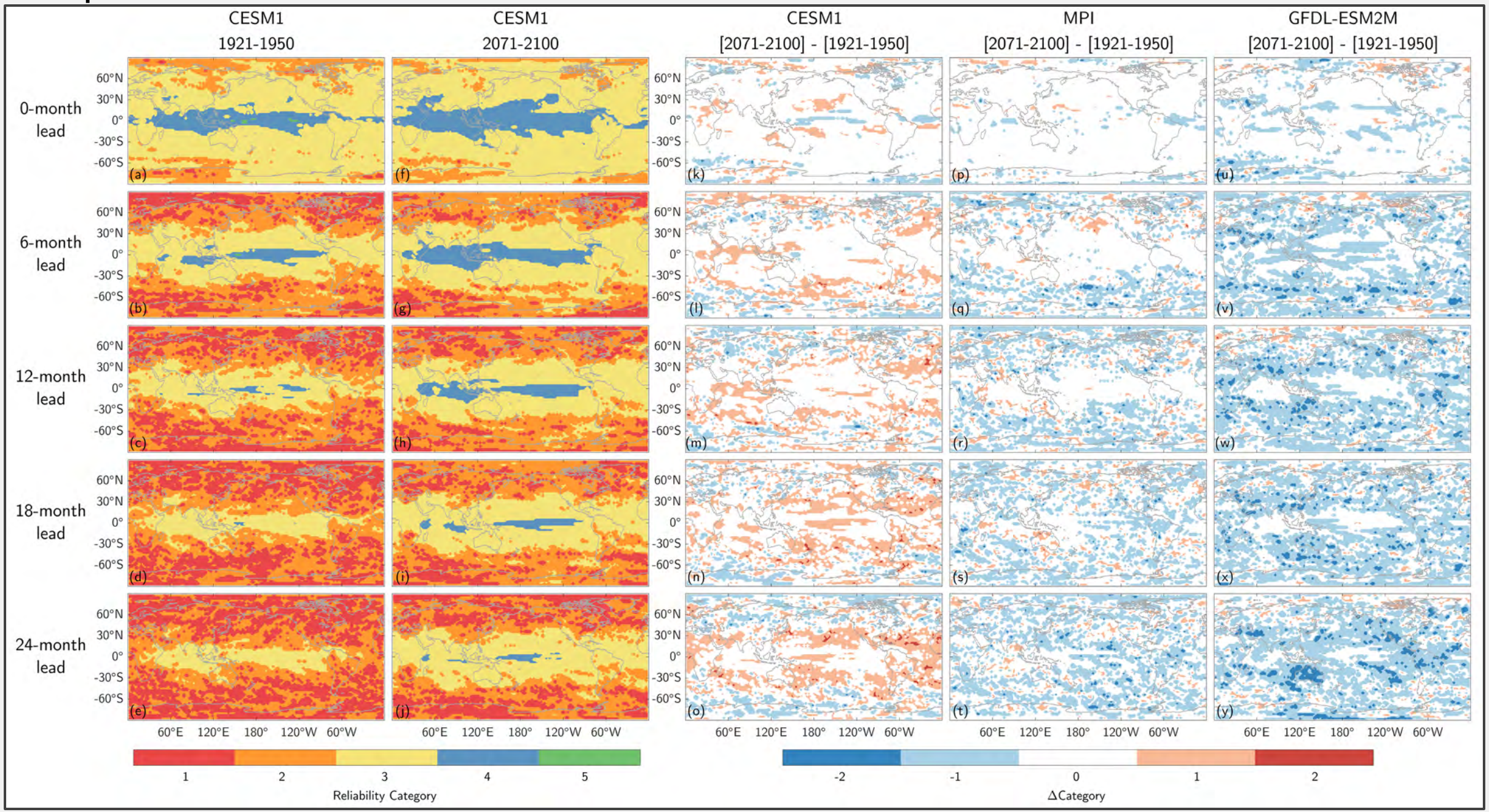
Email: dillon.amaya@noaa.gov

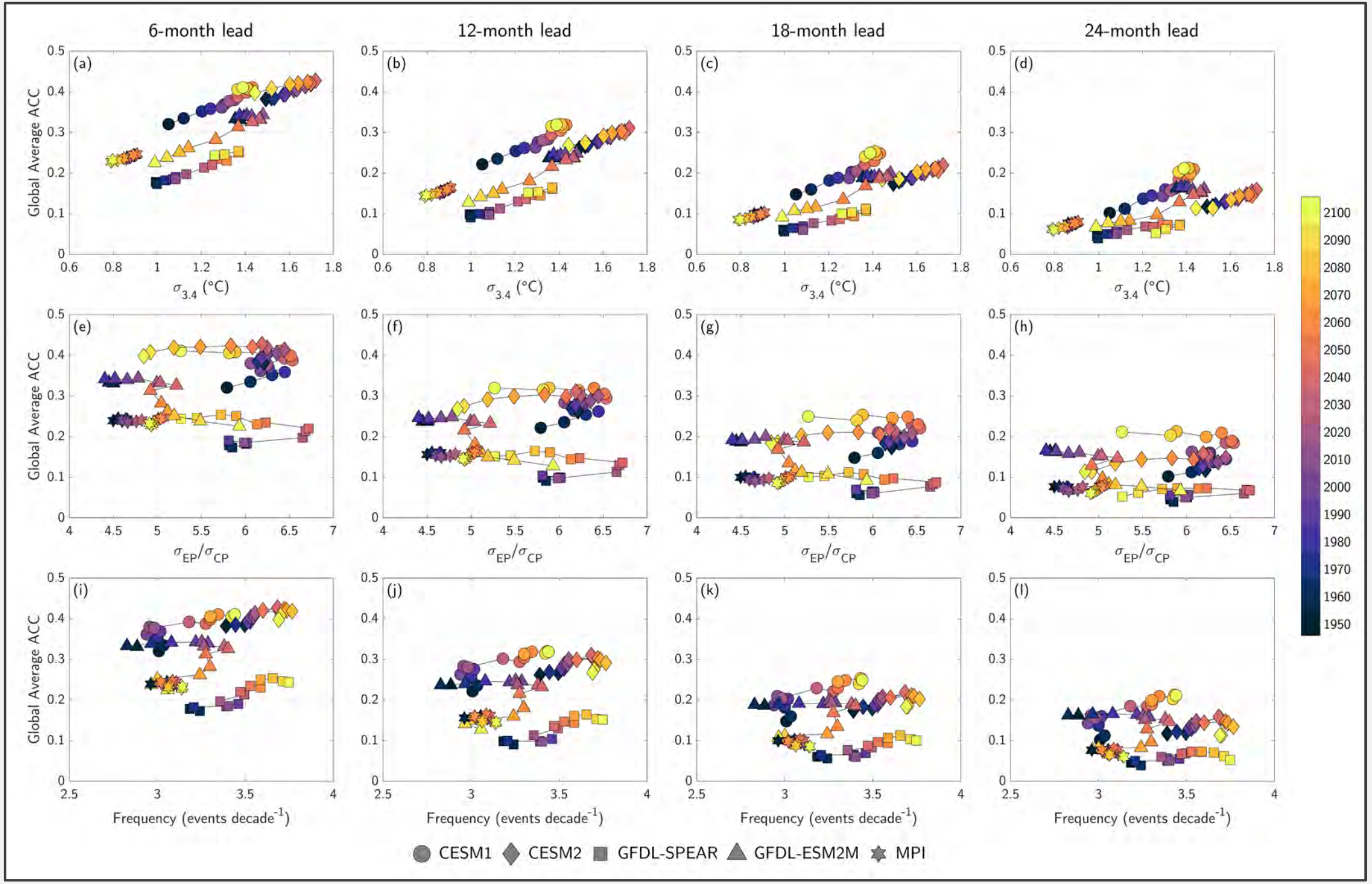
Extra Slides

Surface temperature, upper tercile

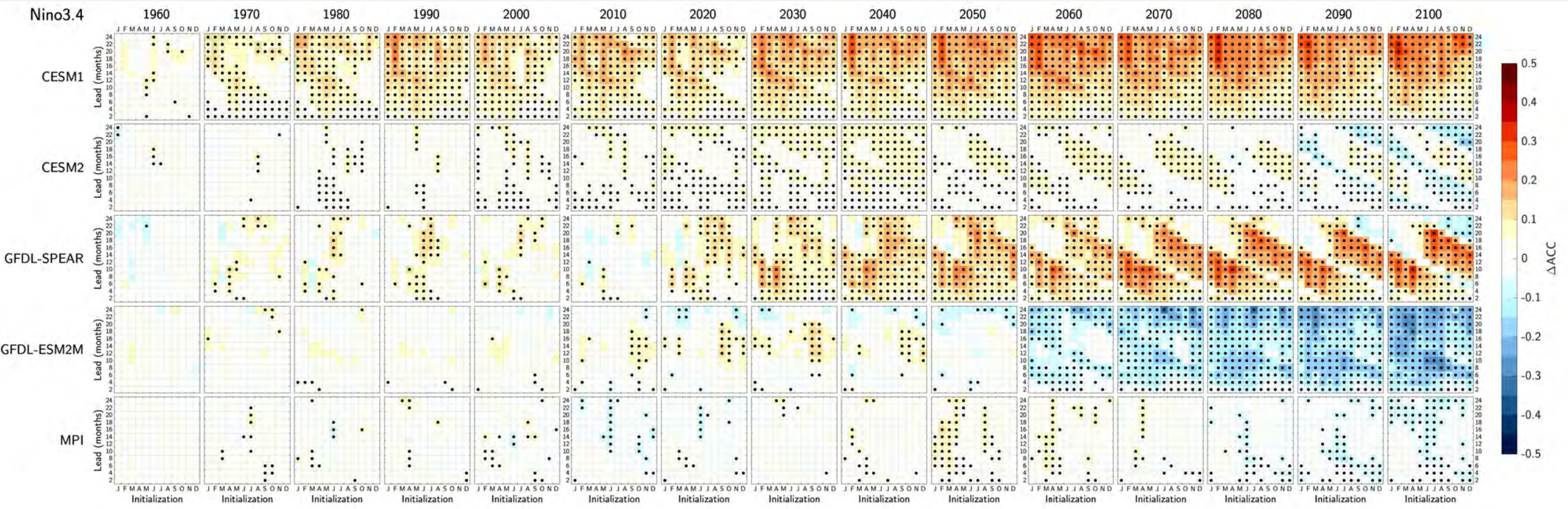


Precipitation, lower tercile

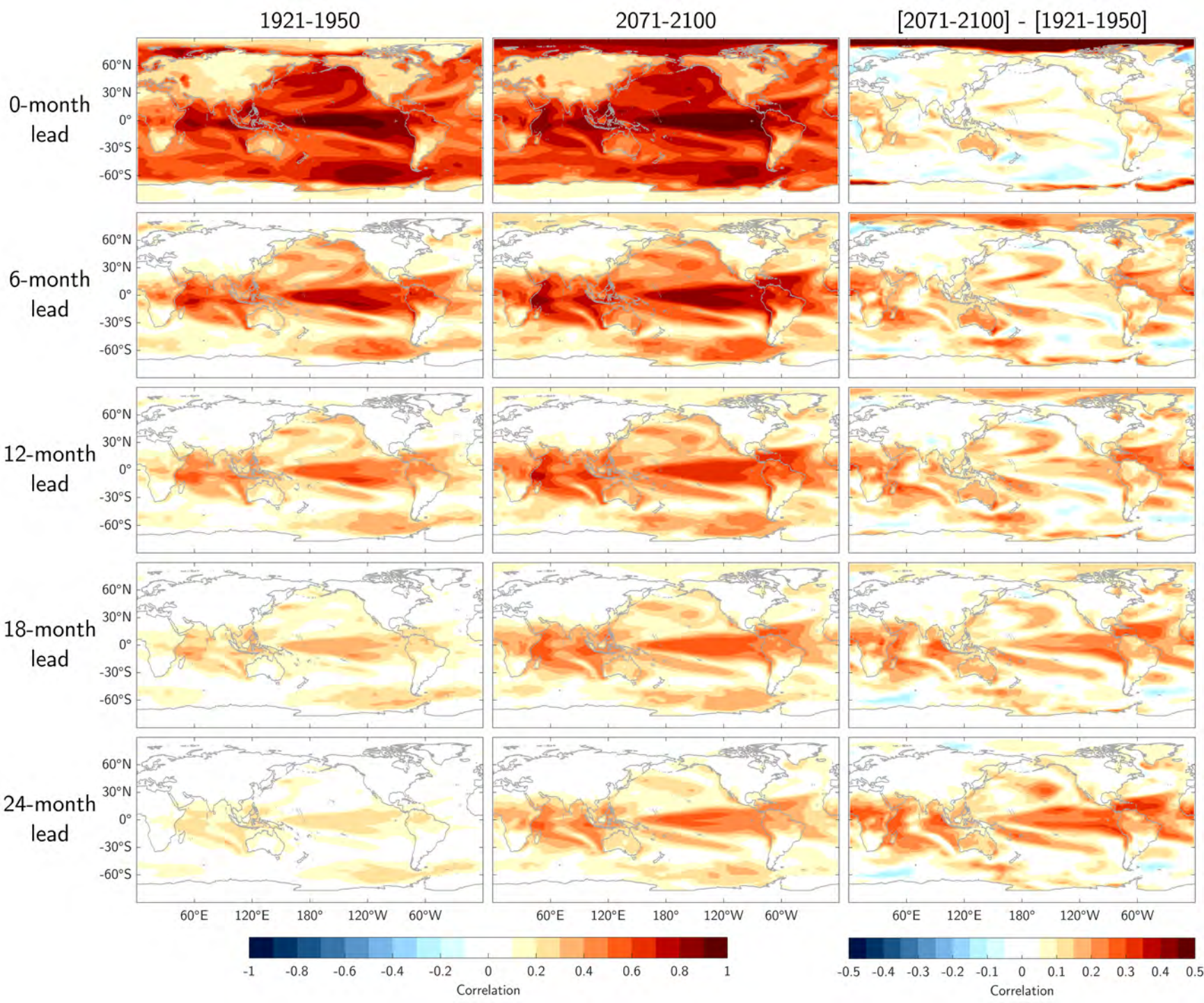



6-month lead
12-month lead
18-month lead
24-month lead
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
Global Average ACC
$\sigma_{3.4}$ (°C)
σ_{EP}/σ_{CP}
Frequency (events decade^{-1})
2100
2090
2080
2070
2060
2050
2040
2030
2020
2010
2000
1990
1980
1970
1960
1950
CESM1
CESM2
GFDL-SPEAR
GFDL-ESM2M
MPI

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

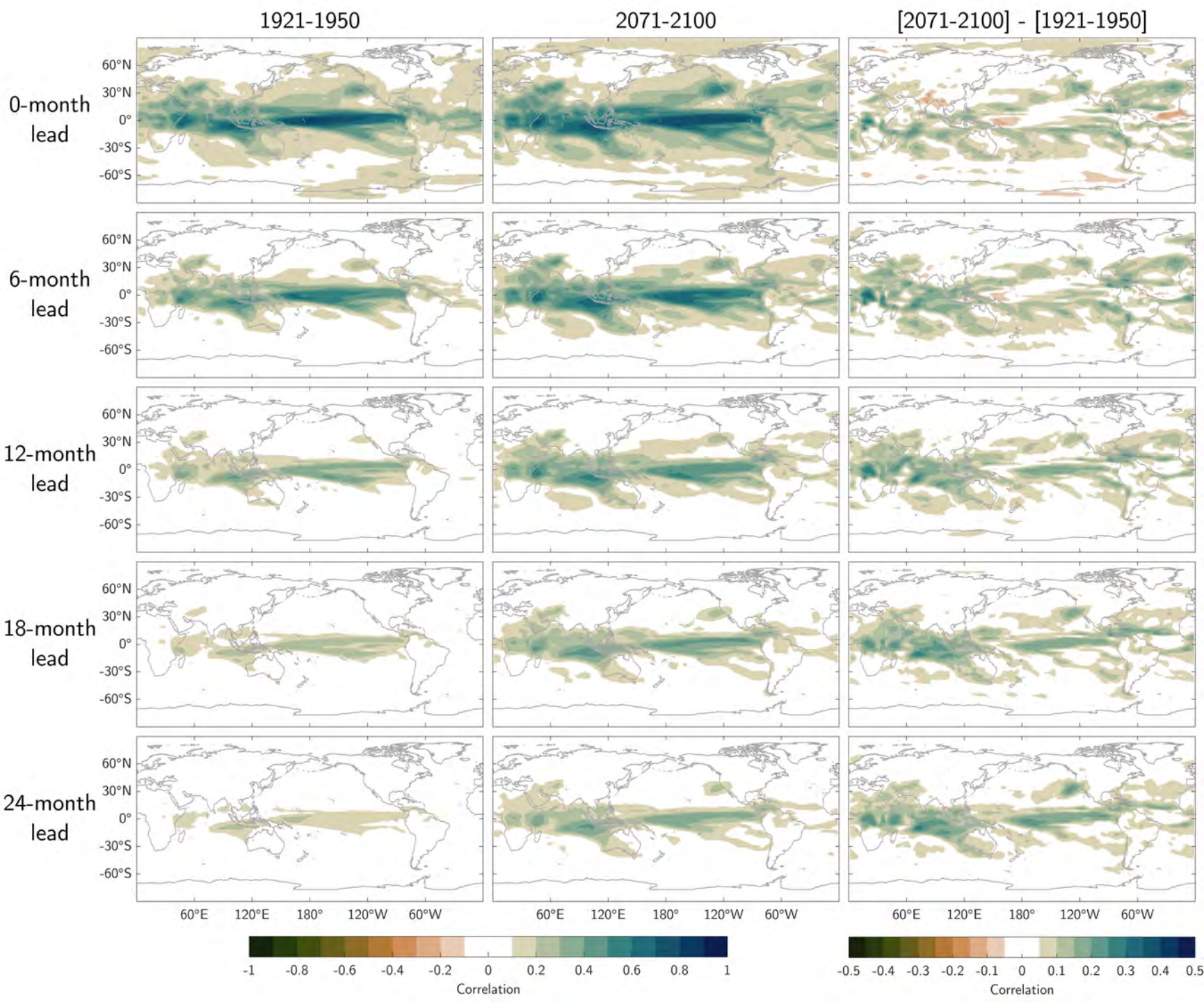


CESM1 (40 members) tas/tos combination



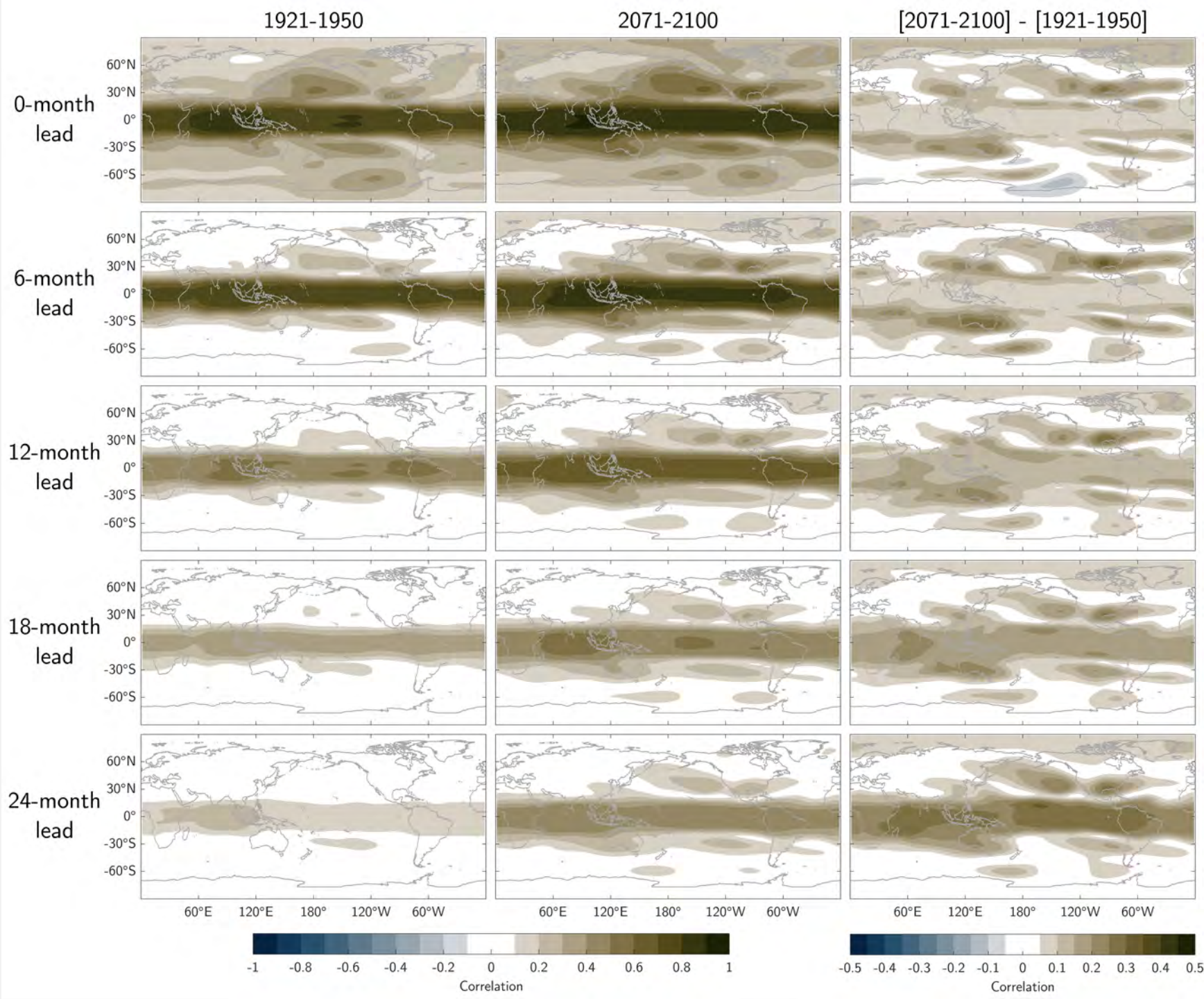
Shading: All month forecast skill (ACC) averaged across model ensemble

CESM1 (40 members) precipitation



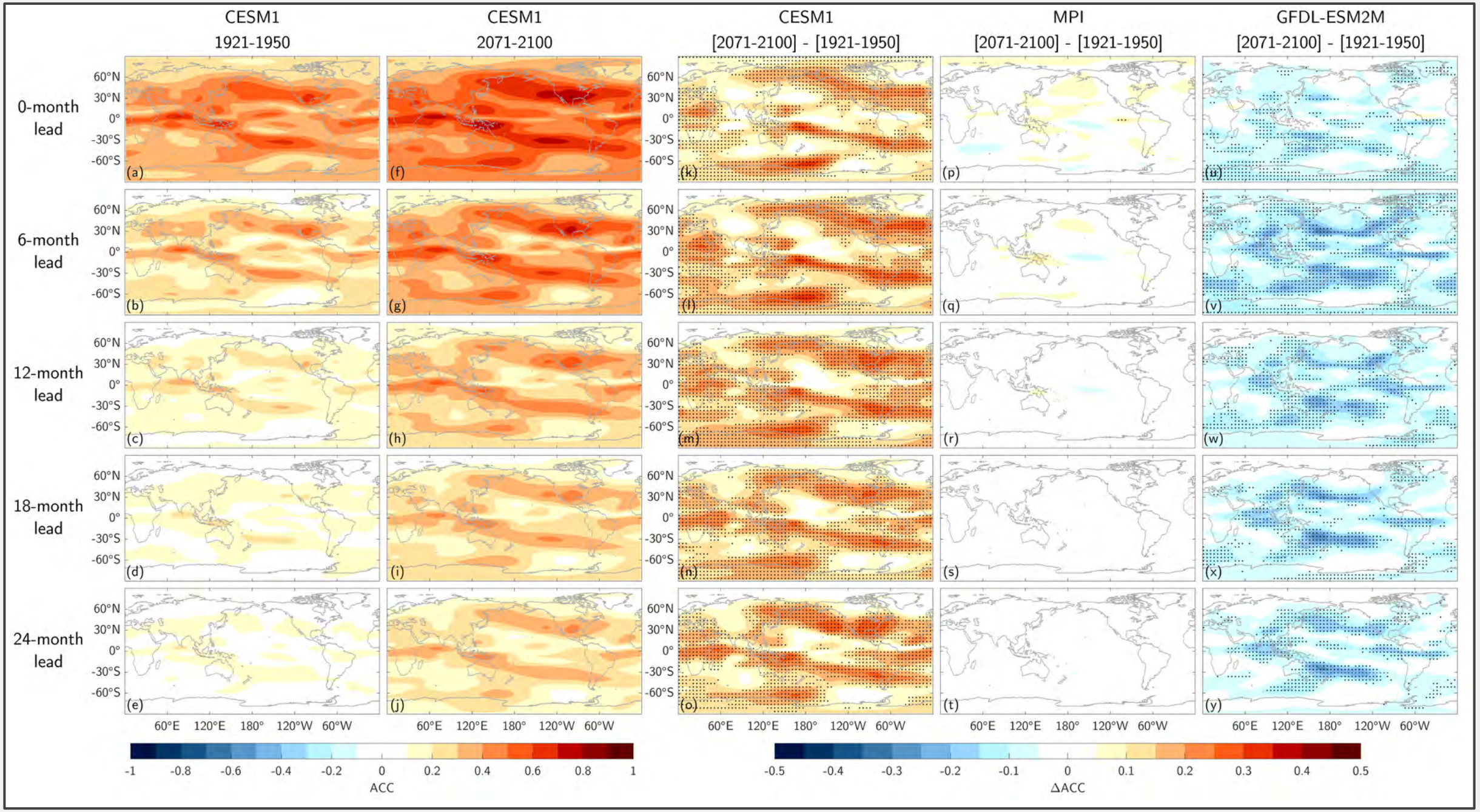
Shading: All month forecast skill (ACC) averaged across model ensemble

CESM1 (40 members)
500mb geopotential heights

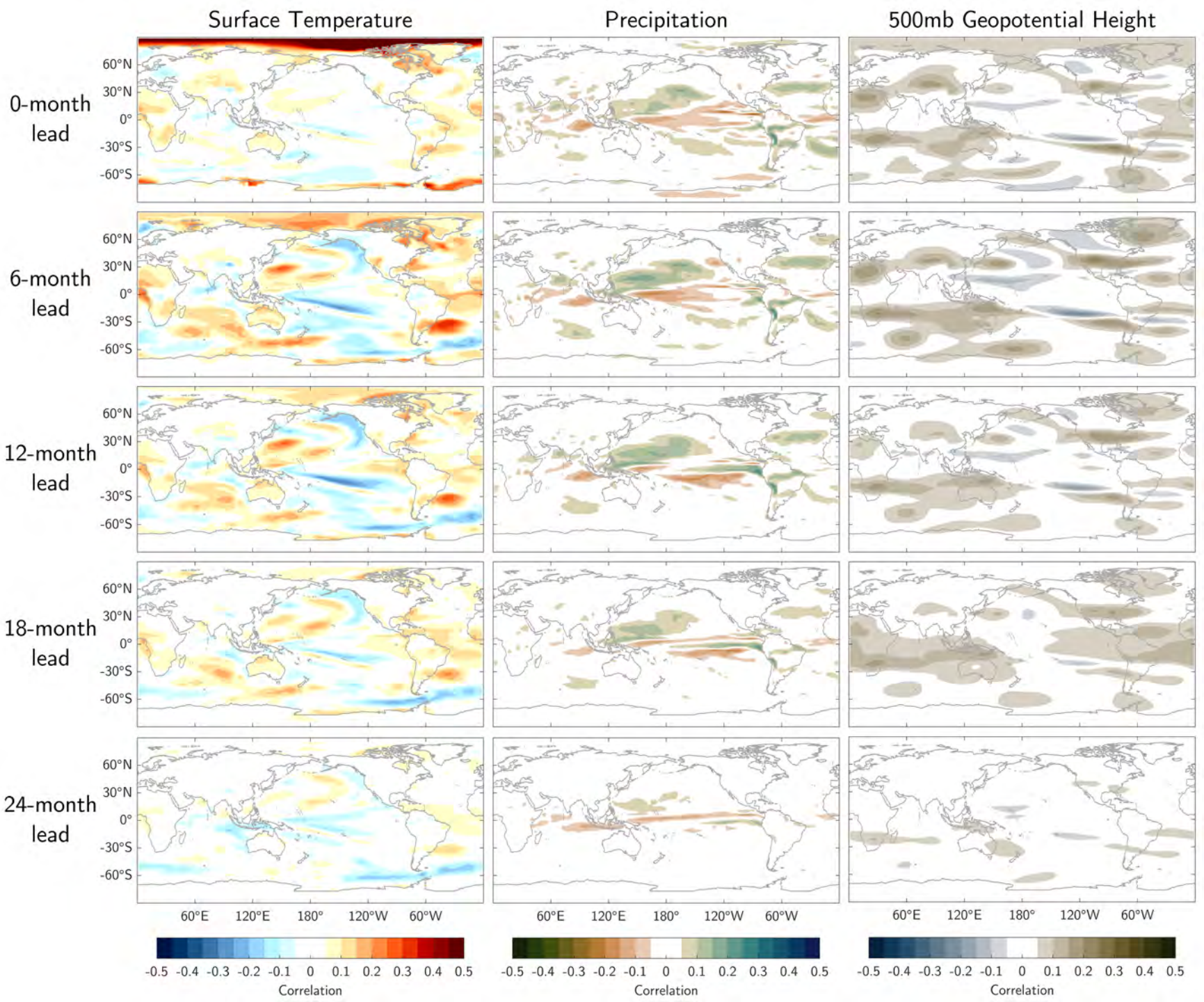


Shading: All month forecast skill (ACC) averaged across model ensemble

500mb streamfunction

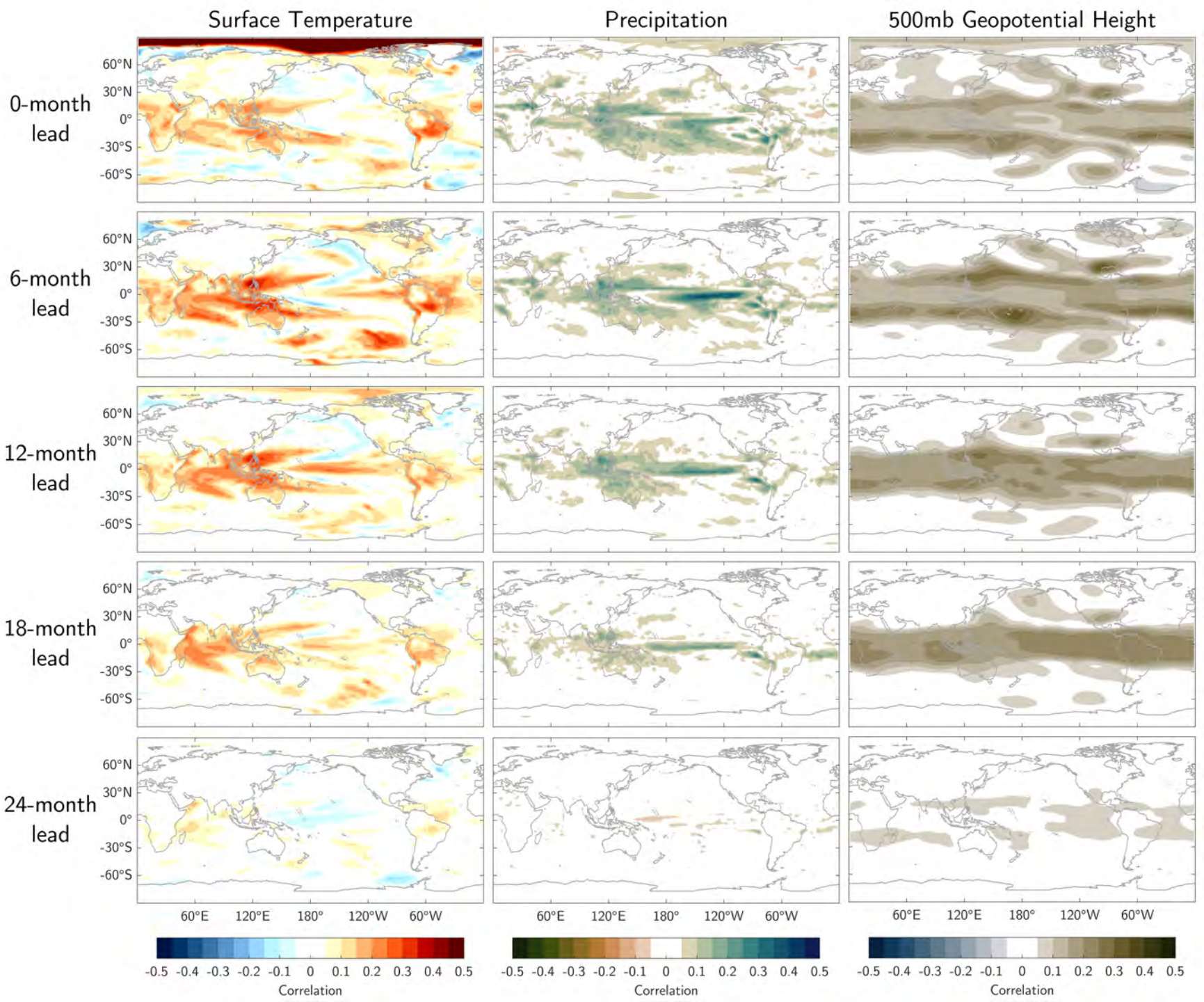


CESM2 (100 members)
All variables
[2071-2100] - [1921- 1950]



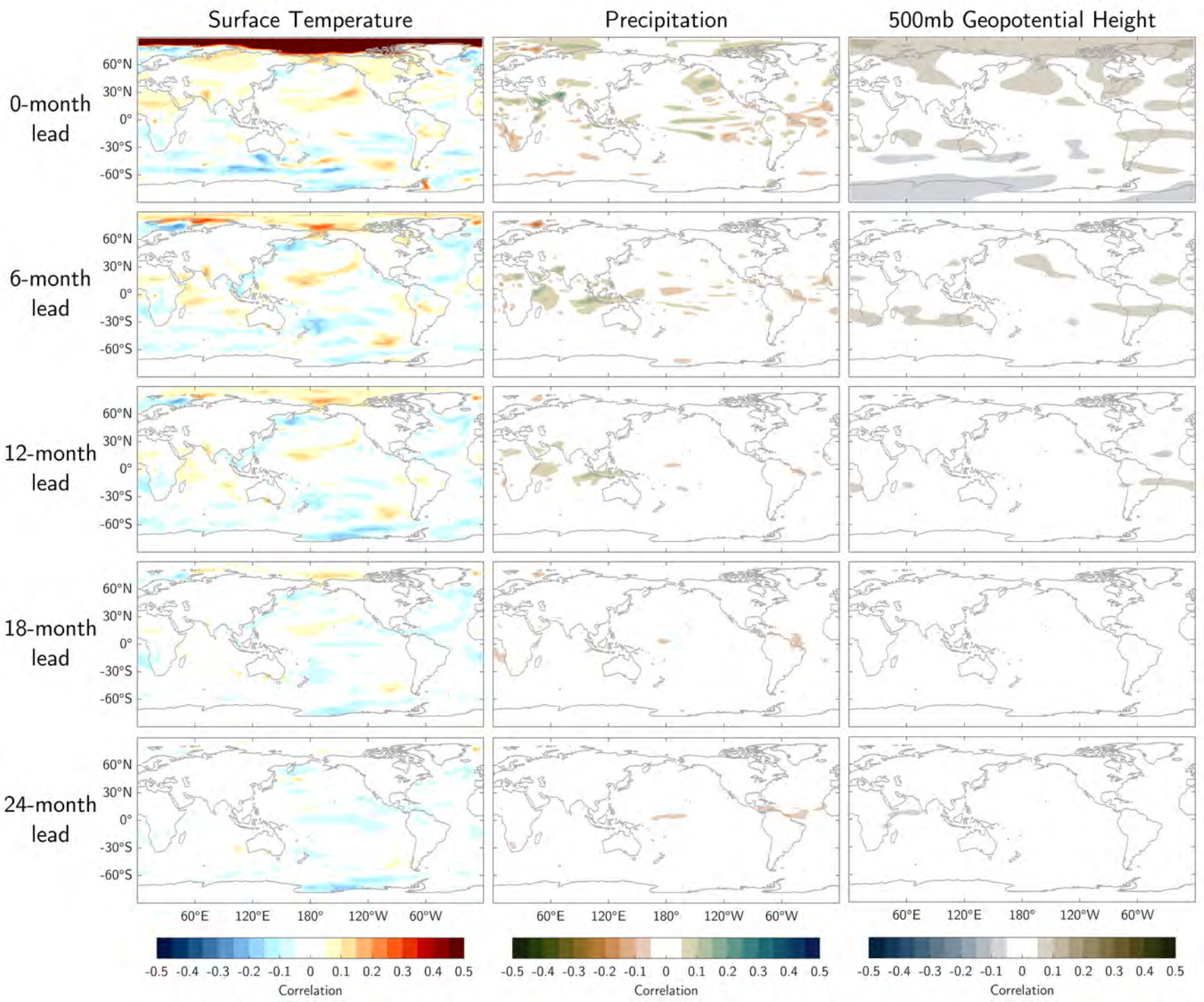
Shading: All month forecast skill (ACC) averaged across model ensemble

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

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]