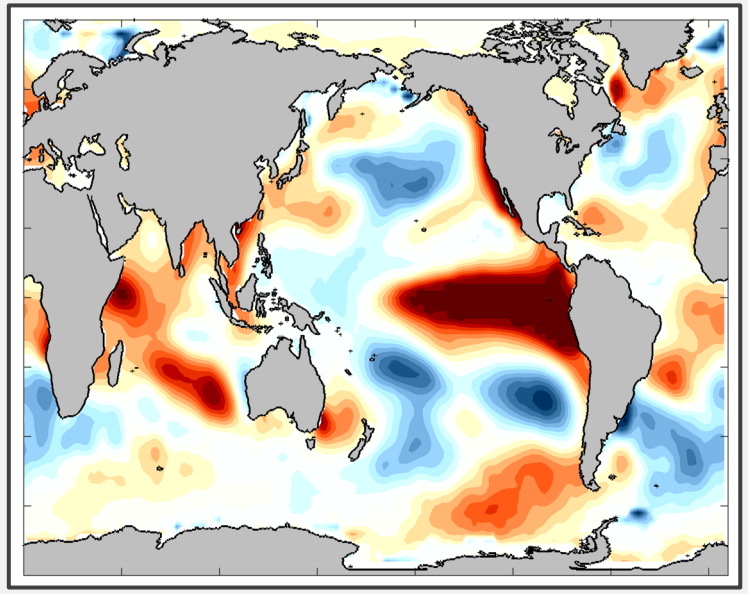
BUILDING SEASONAL CLIMATE FORECASTS FROM LARGE ENSEMBLES+

Dillon Amaya, Stephen Yeager, Mike Jacox,
Matt Newman, and Mike Alexander

CESM Workshop
June 10-12, 2024

Model-analog framework

ERSSTv5 SSTAs, January 1998

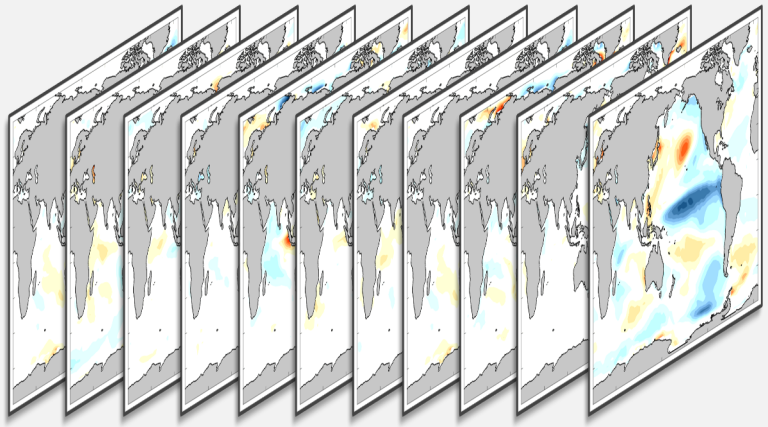


If two states in the climate system are very close to each other, they can be called each other's "analog"

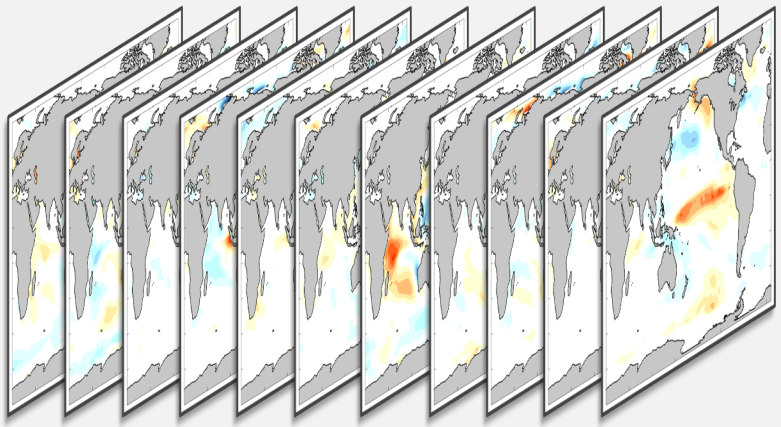
Compare to data library

Pre-Industrial Control Simulation

January, year 1



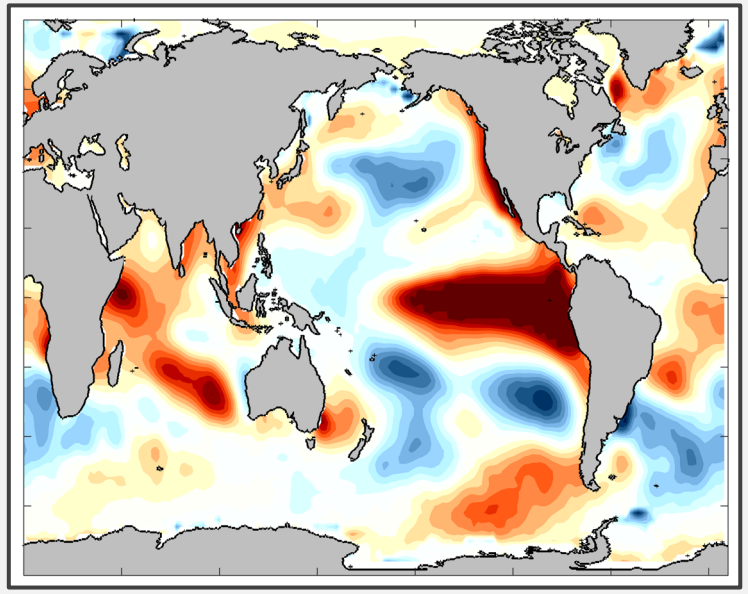
• • •



January, year N

Model-analog framework

ERSSTv5 SSTAs, January 1998

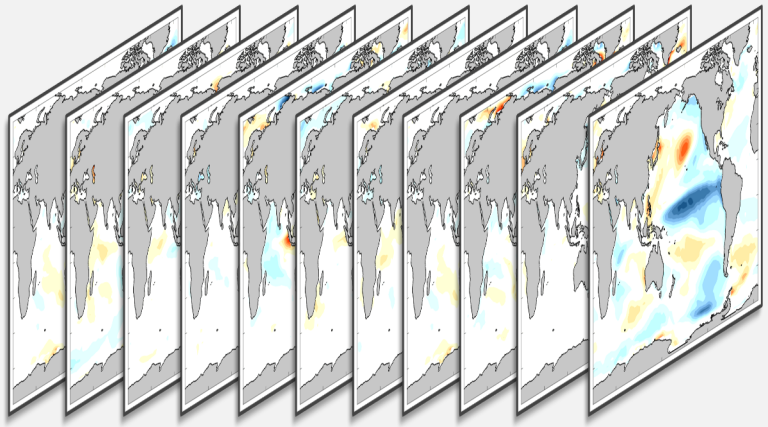


If two states in the climate system are very close to each other, they can be called each other's "analog"

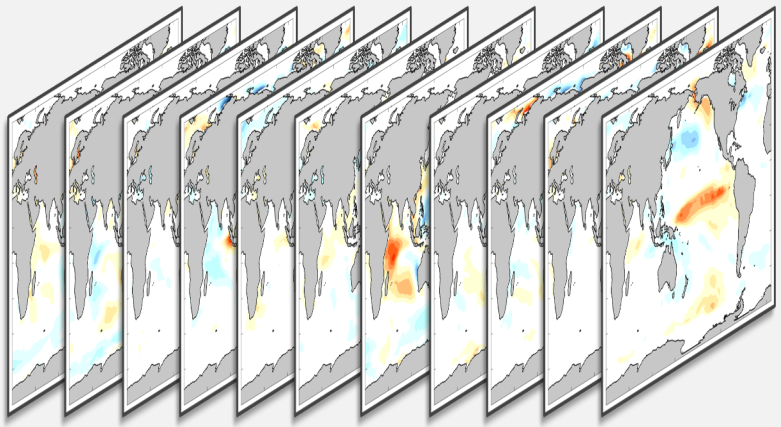
Compare to data library

Pre-Industrial Control Simulation

January, year 1



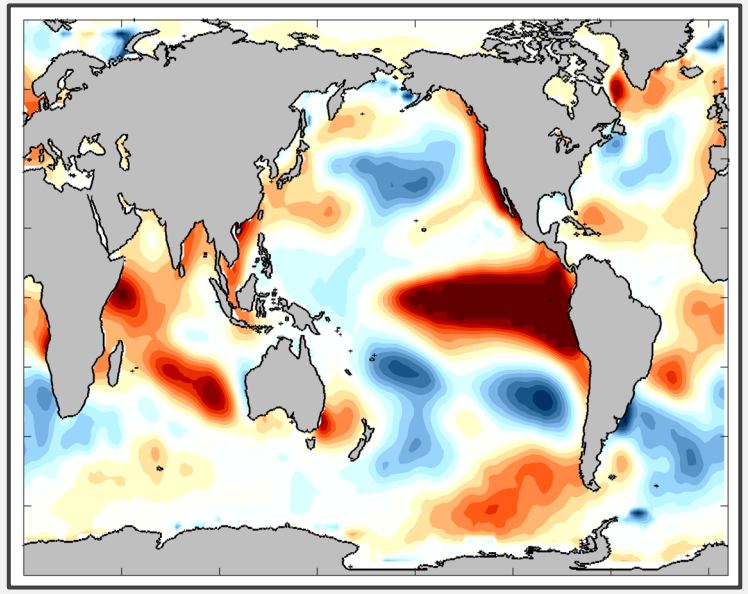
• • •



January, year N

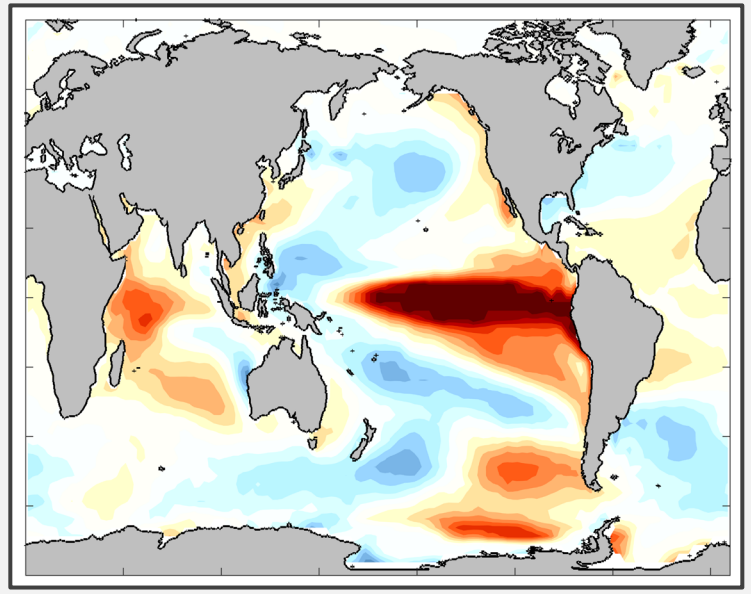
Model-analog framework

ERSSTv5 SSTAs, January 1998



Model-analog

PiControl: January, year 336

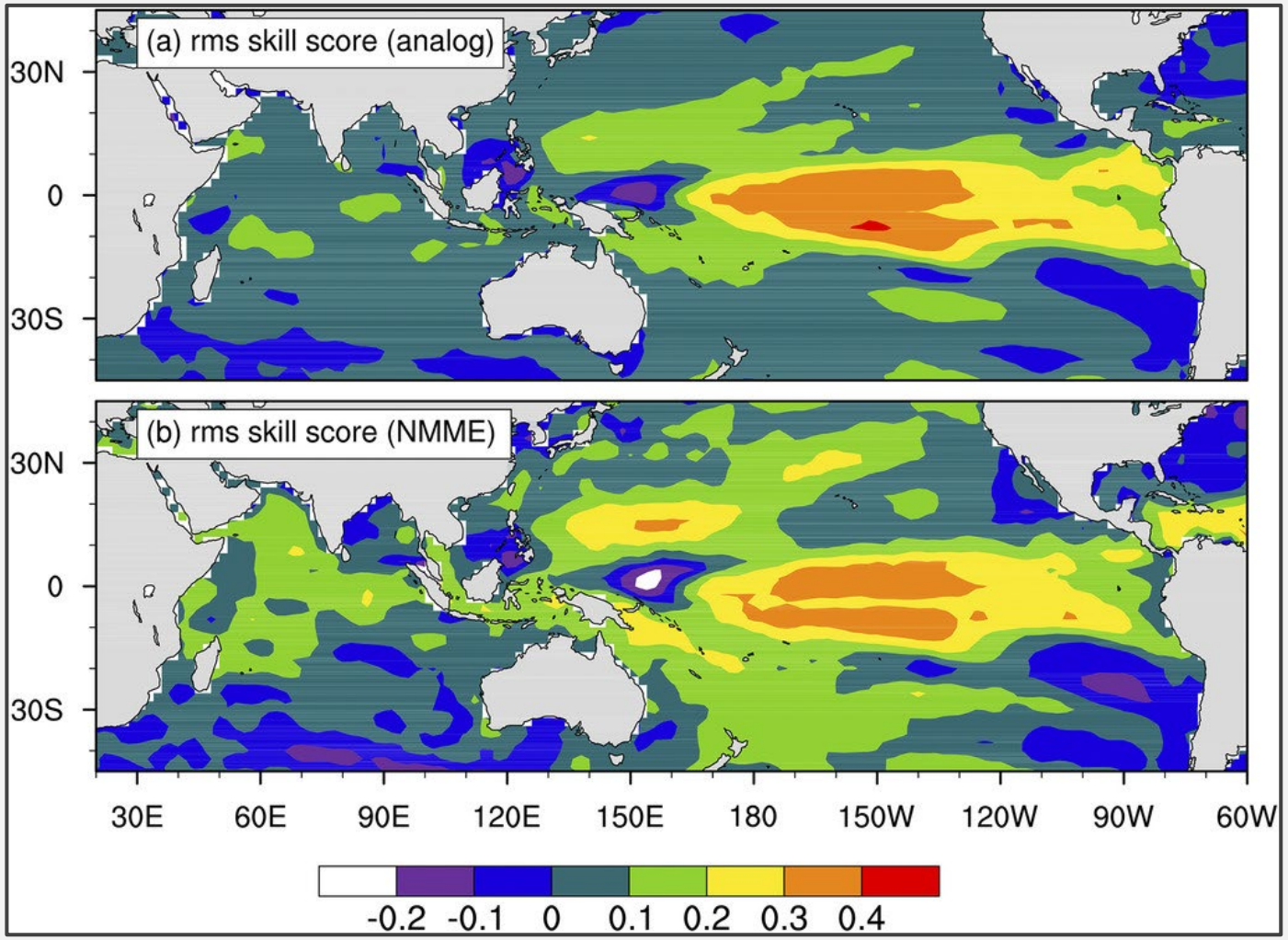


Use the subsequent evolution of the model-analog match as a forecast

Model-analog framework

For some applications, model-analogs forecasts can be as skillful as dynamical forecasts (e.g., Ding et al. 2018, 2019)

But….



Ding et al. (2018)

Model-analog framework

- Comparisons between model-analog forecasts and dynamical forecasts are rarely apples-to-apples.
  - Skill differences could be related to myriad factors (e.g., different models and/or different initialization data).
- Makes it difficult to fully understand the added value of the model-analog technique (or fully initialized dynamical forecasts).
- **<u>Part 1</u>: Create model-analogs from CESM2-LE using the same data used to initialize CESM2-SMYLE.**

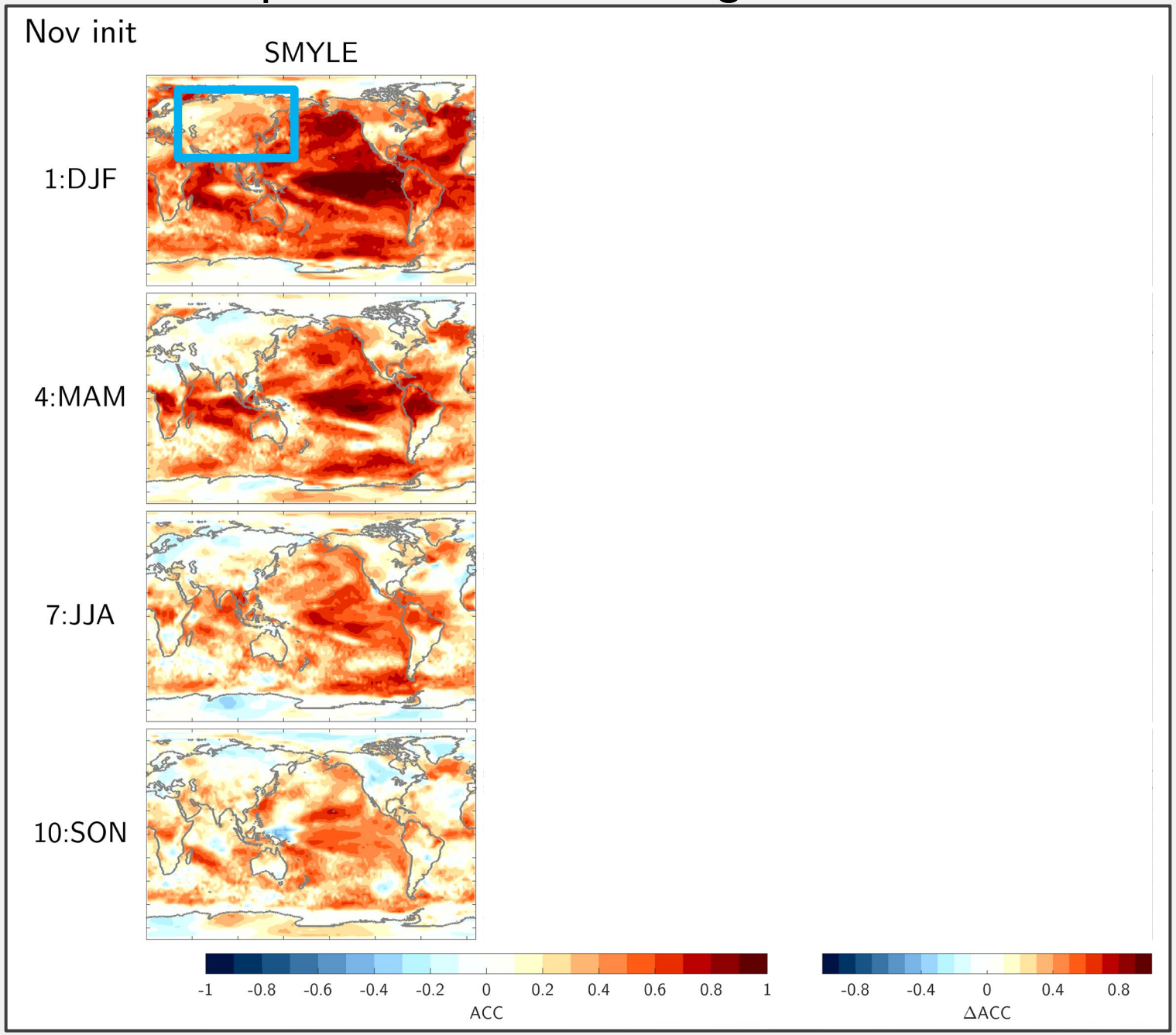
	Single-to-Multiyear Large Ensemble (SMYLE)	CESM2 Model-Analogs (CESM2-MA)
Model:	CESM2	CESM2-LE (50-members) N_{lib} = 2500
Record length:	1970-2019	1970-2019
Forcing scenario:	Hist+SSP3-7.0 (SMBB)	Hist+SSP3-7.0 (SMBB)
Initialization fields:	FOSI (ocn), JRA-55 (atmo), TRENDY (lnd), globally	Monthly mean FOSI SST 60°S-60°N
Initialization times:	1st of Feb, May, Aug, Nov	Jan-Dec
Ensemble size:	20 members	20 members

SMYLE vs Model-Analogs

Far from the initial condition, CESM2-MA skill is largely indistinguishable from SMYLE

Stippling: Significantly better ACC at 95% confidence

Surface temperature skill verified against ERA5

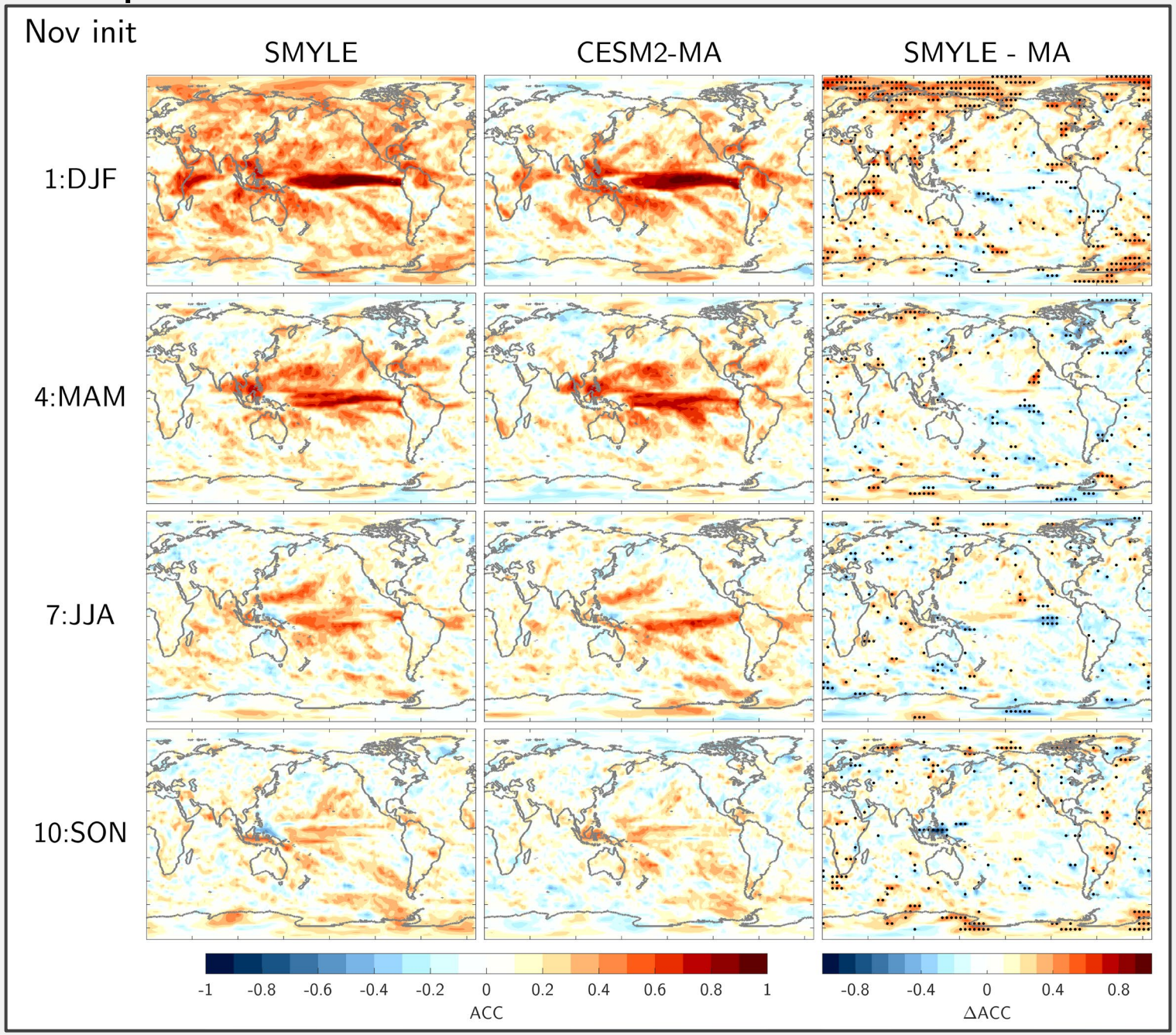


SMYLE vs Model-Analogs

Far from the initial condition, CESM2-MA skill is largely indistinguishable from SMYLE

Stippling: Significantly better ACC at 95% confidence

Precipitation

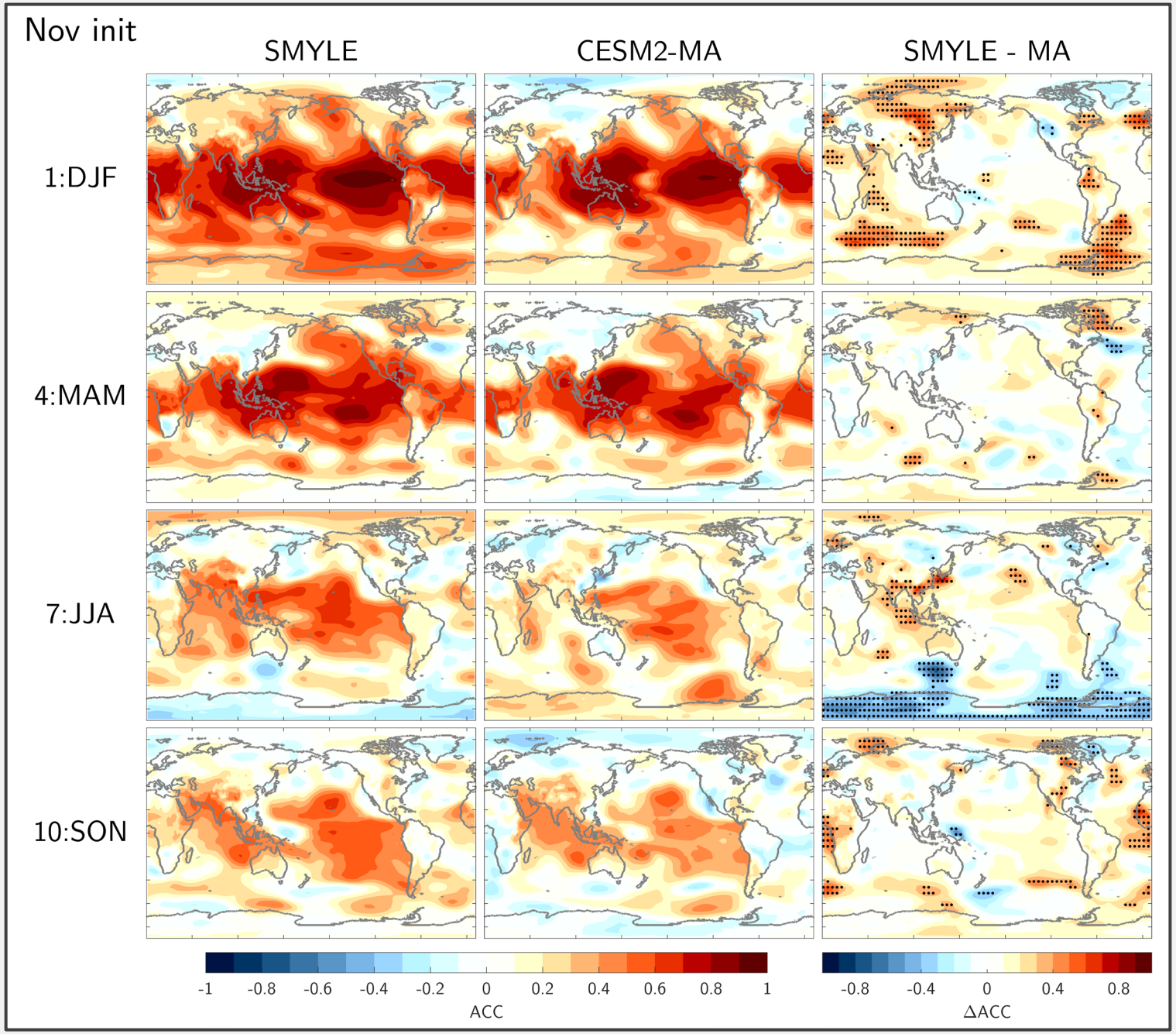


SMYLE vs Model-Analogs

Far from the initial condition, CESM2-MA skill is largely indistinguishable from SMYLE

Stippling: Significantly better ACC at 95% confidence

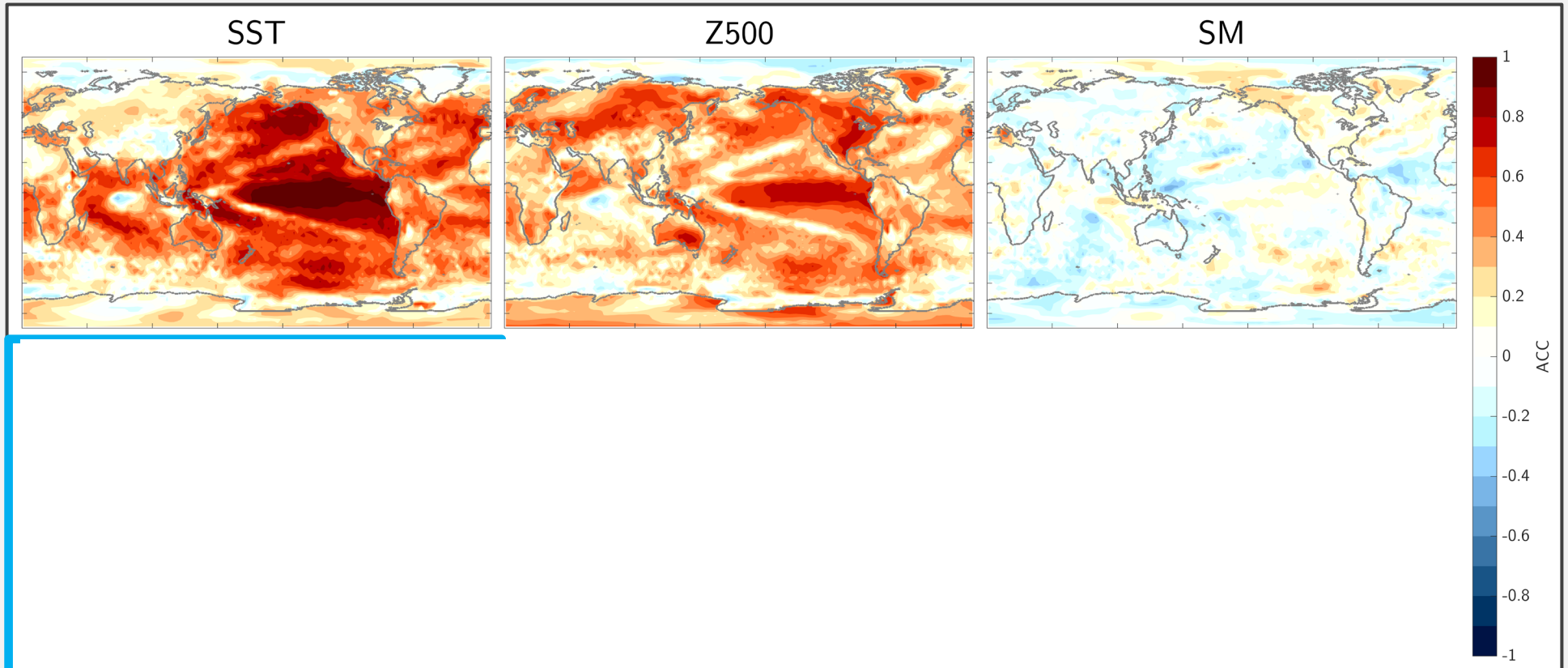
Sea Level Pressure



	SMYLE	CESM2-MA
Model:	CESM2	CESM2-LE (50-members) N_{lib} = 2500
Record length:	1970-2019	1970-2019
Forcing scenario:	Hist+SSP3-7.0 (SMBB)	Hist+SSP3-7.0 (SMBB)
Initialization fields:	FOSI (ocn), JRA-55 (atmo), TRENDY (lnd), globally	**FOSI SST, JRA-55 Z500, and/or TRENDY Soil Moist. (SM), 60°S-60°N**
Initialization times:	1st of Feb, May, Aug, Nov	Jan-Dec
Ensemble size:	20 members	20 members

SMYLE vs Model-Analogs

Choosing analogs using different variables



CESM2-MA
Nov initialization
0-month lead forecast

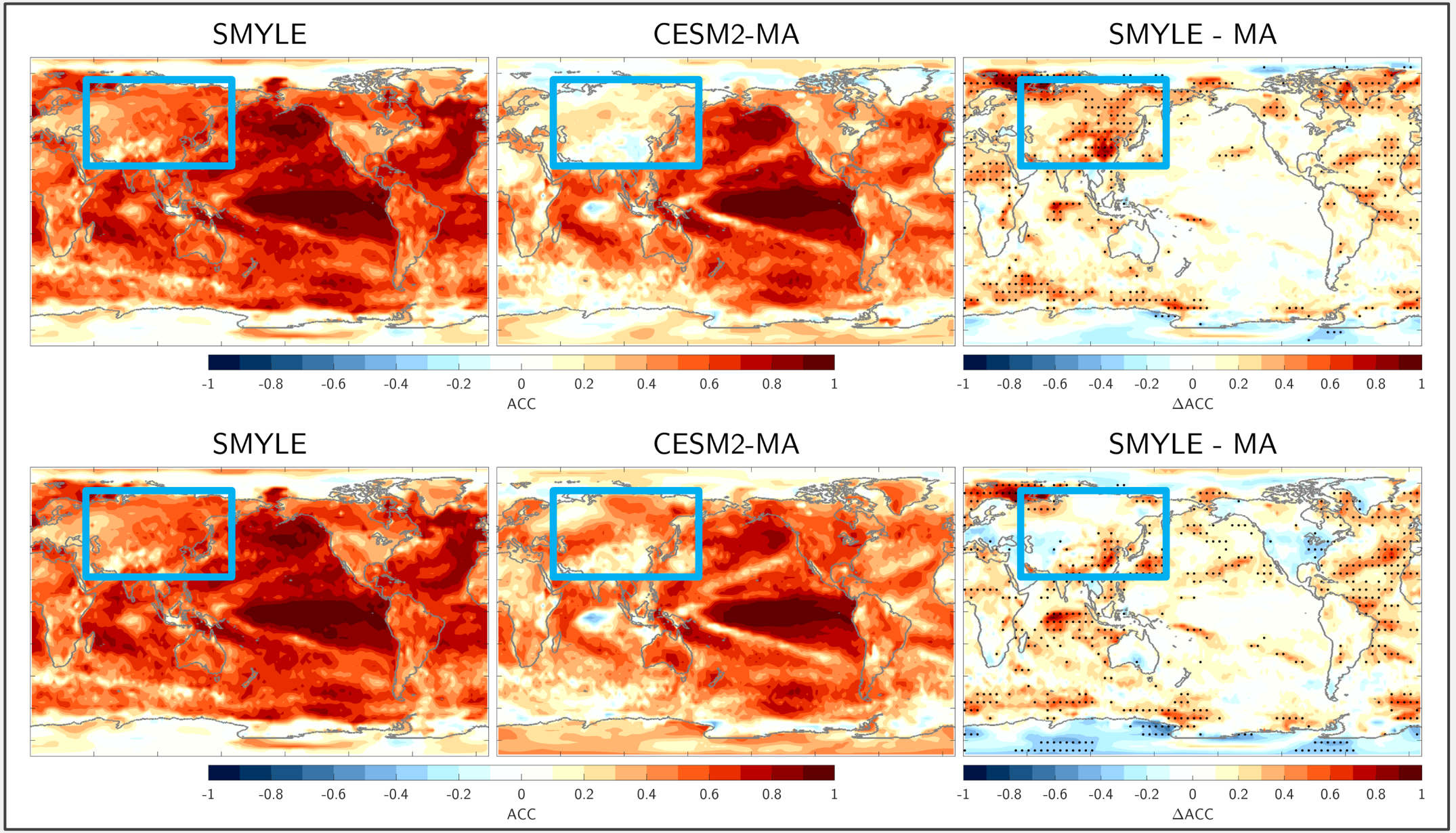
SST = Sea surface temperature (FOSI)
Z500 = 500mb geopotential heights (JRA-55)
SM = Soil moisture (TRENDY)

SMYLE vs Model-Analogs

November initialization, 0-month lead forecast

SST

SST +Z500

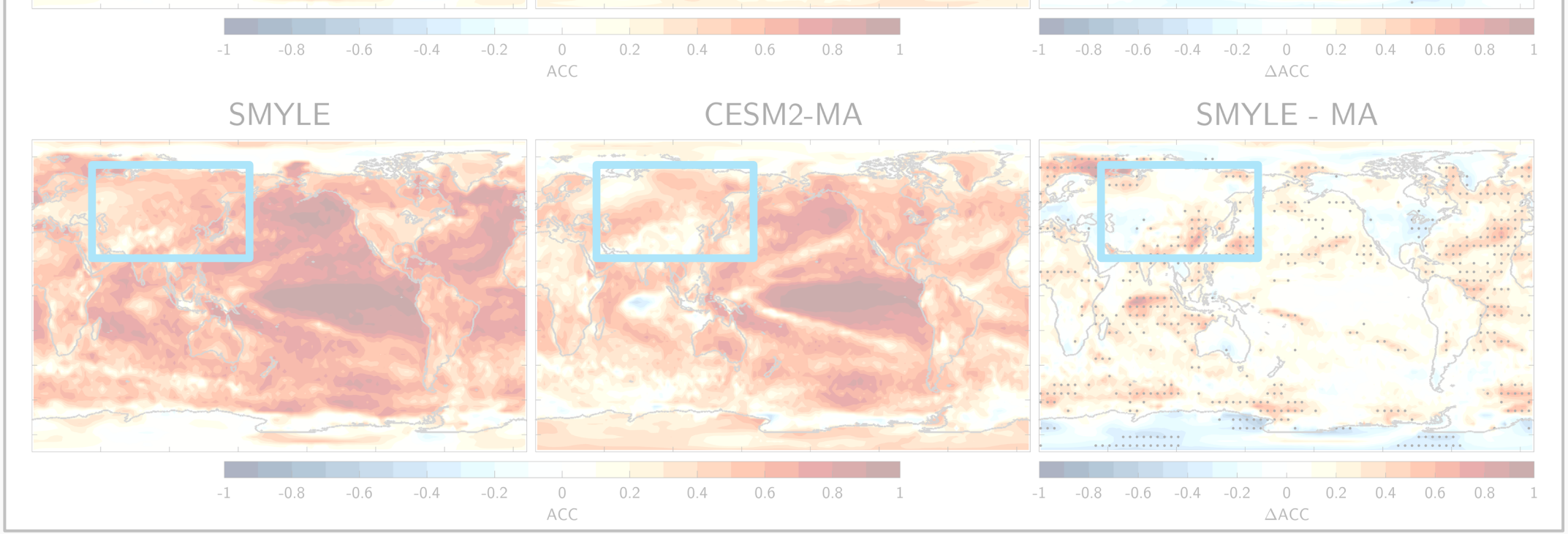


SMYLE vs Model-Analogs

Part I Summary:

- Using the same* ocean initial state, model-analog forecasts from CESM2-LE are largely indistinguishable from SMYLE.
- Model-analog skill at short lead times can be improved by including the atmosphere as part of the selection criteria.

SST +Z500



Model-analog framework

- High-resolution forecasts are ***expensive!***
- **<u>Part 2</u>: High-resolution model-analog hindcasts based on CESM-HR.**

High-res model-analogs

CESM-HR

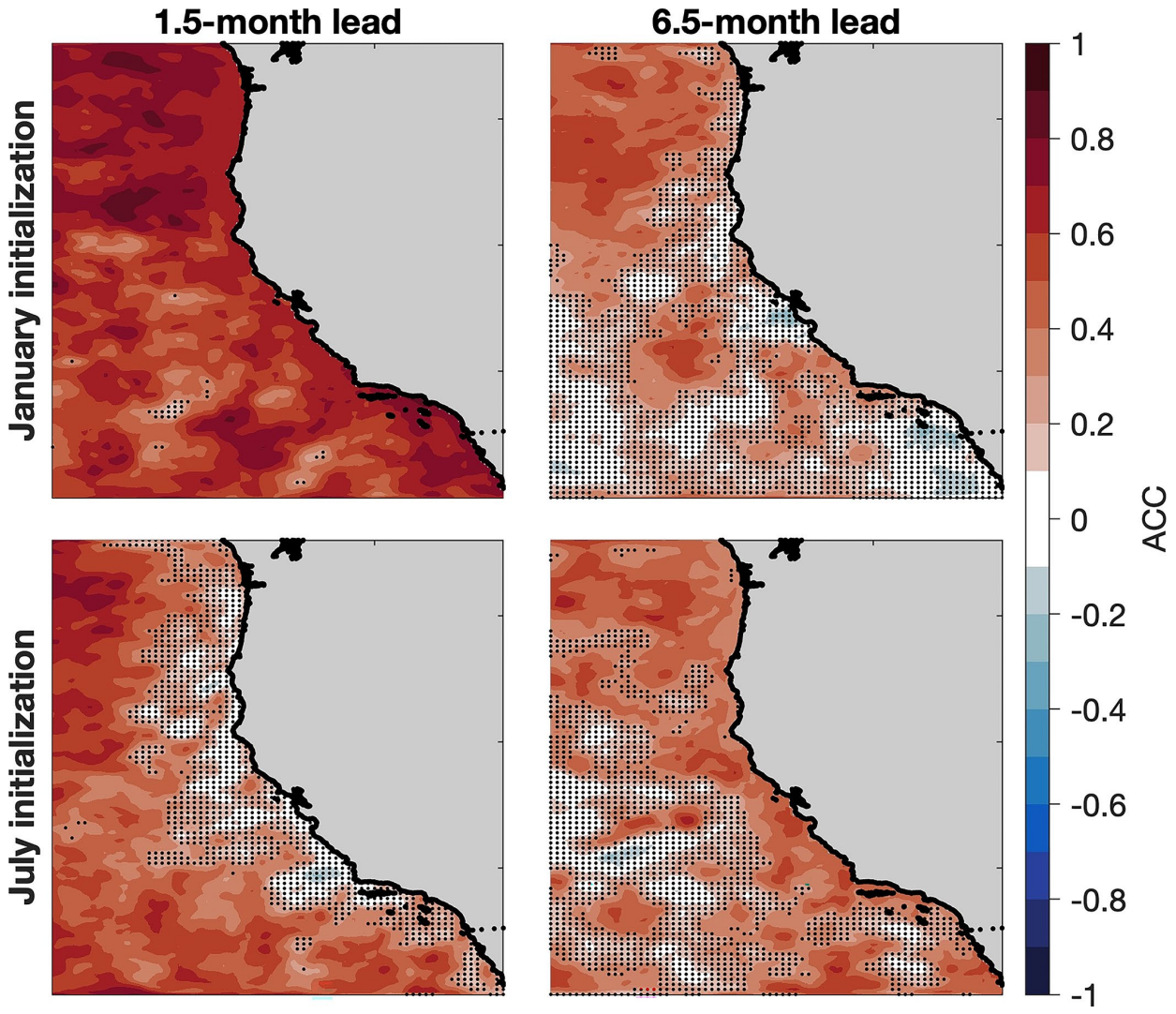
- 350-year picontrol, 0.1° ocean and 0.25° atmosphere (Chang et al. 2020)

HR-MA

- Model-analog forecasts drawn from CESM-HR.
- Analogs are selected by matching to detrended monthly mean SSTA from GLORYS ocean reanalysis from 30°S-30°N at 1° resolution.
- Based on chosen climate states, create forecasts at 0.1° for specific regions.
- Skill verified against GLORYS from 1993-2020. Keep top 10 matches.

Sea Surface Temperature

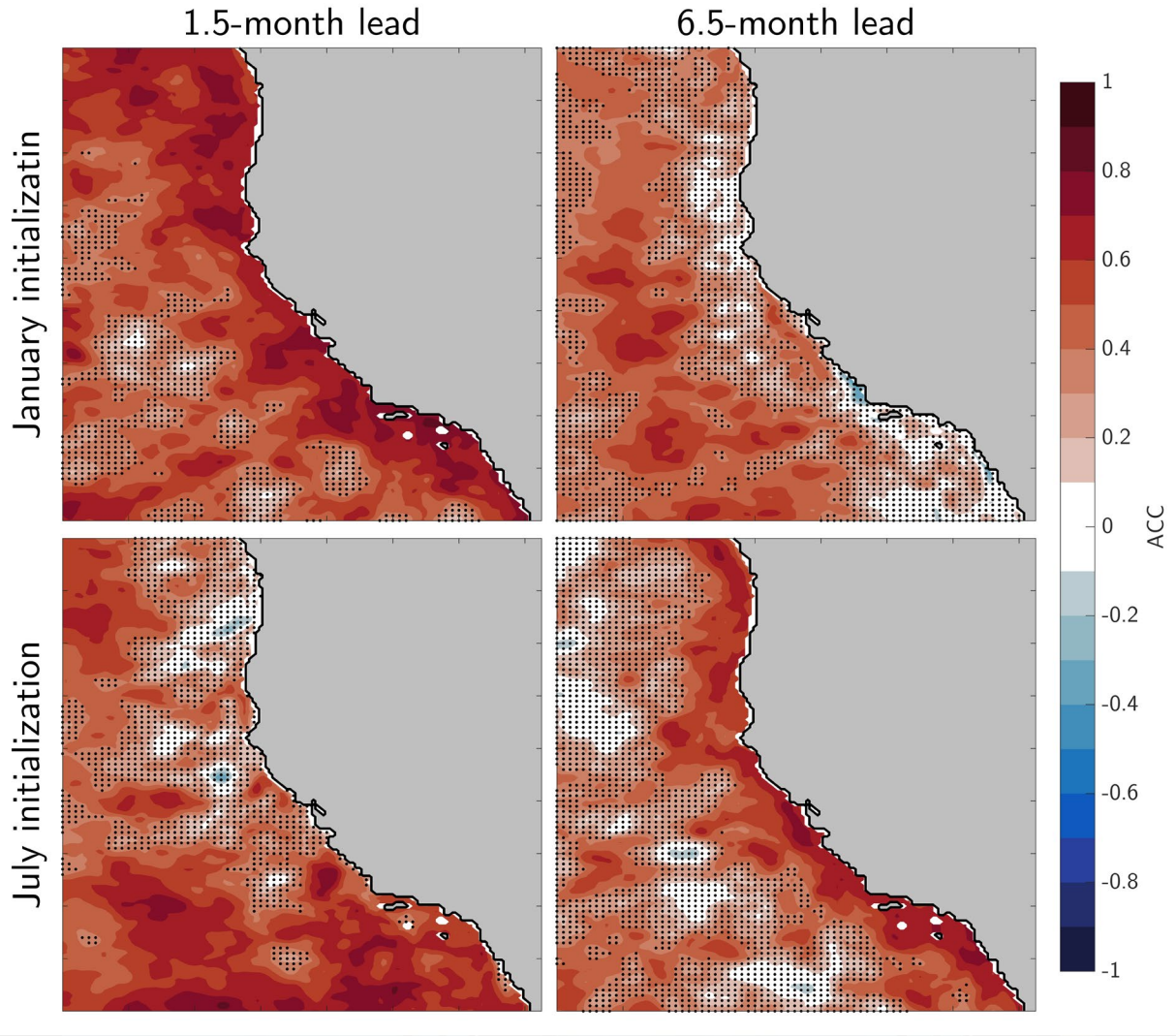
Dynamically downscaled seasonal forecasts



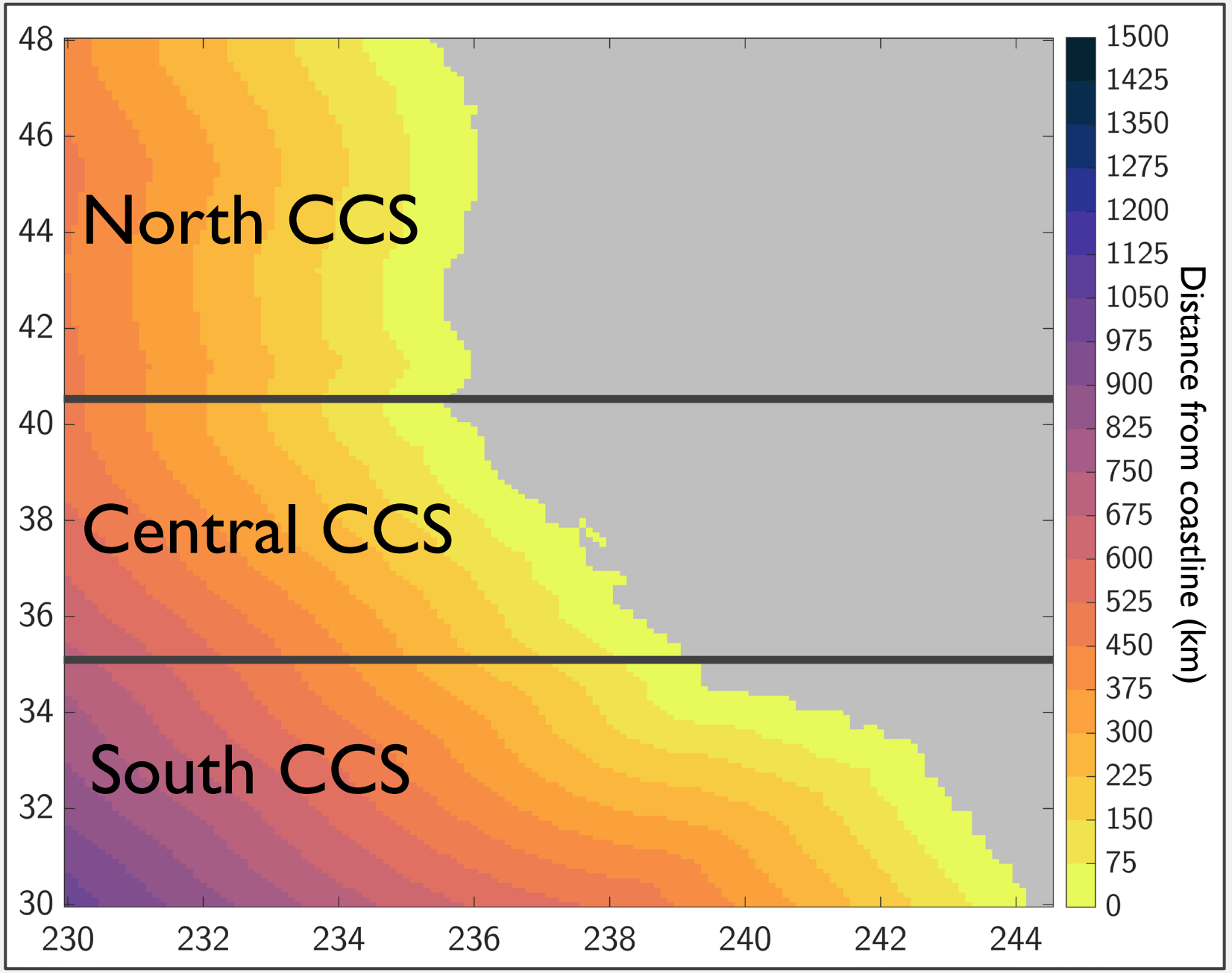
Jacox et al. (2023)

Stippling: insignificant skill at 95% confidence

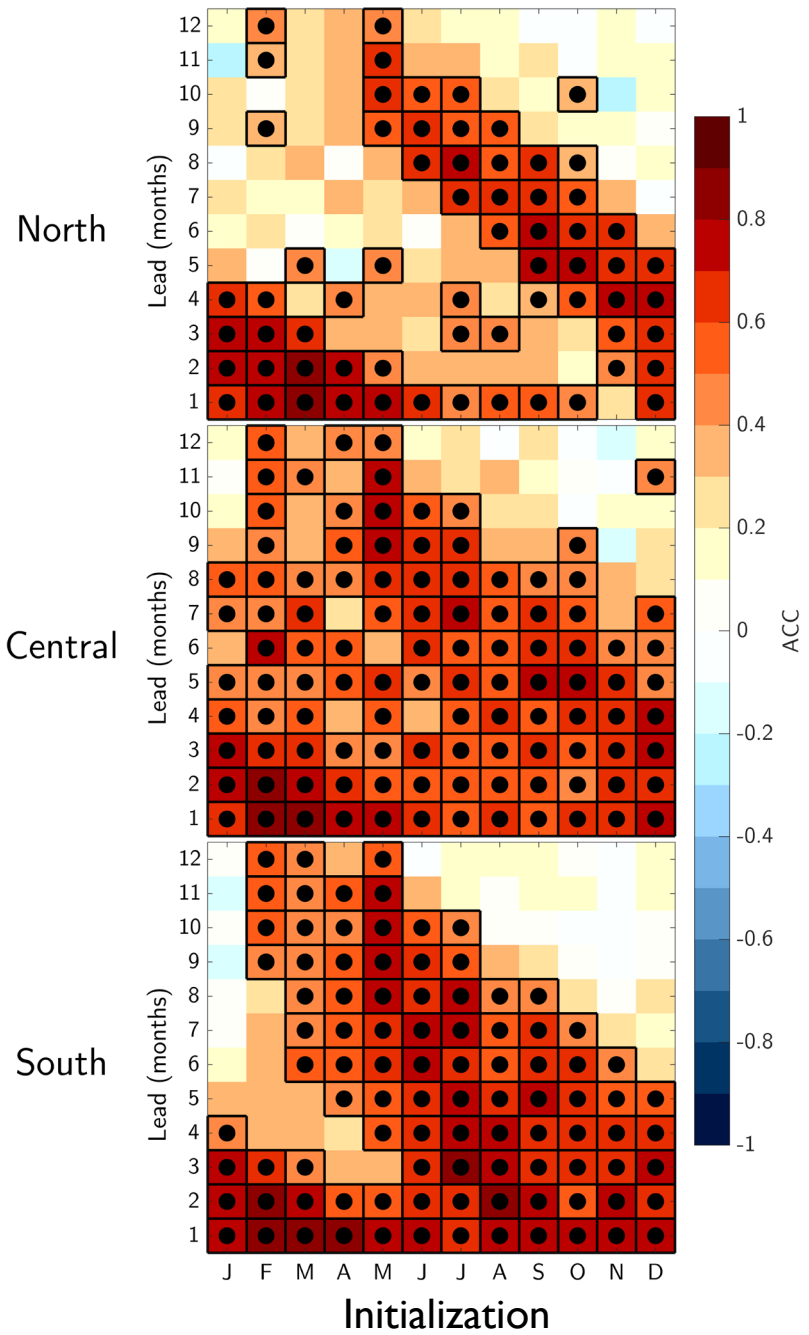
HR-MA

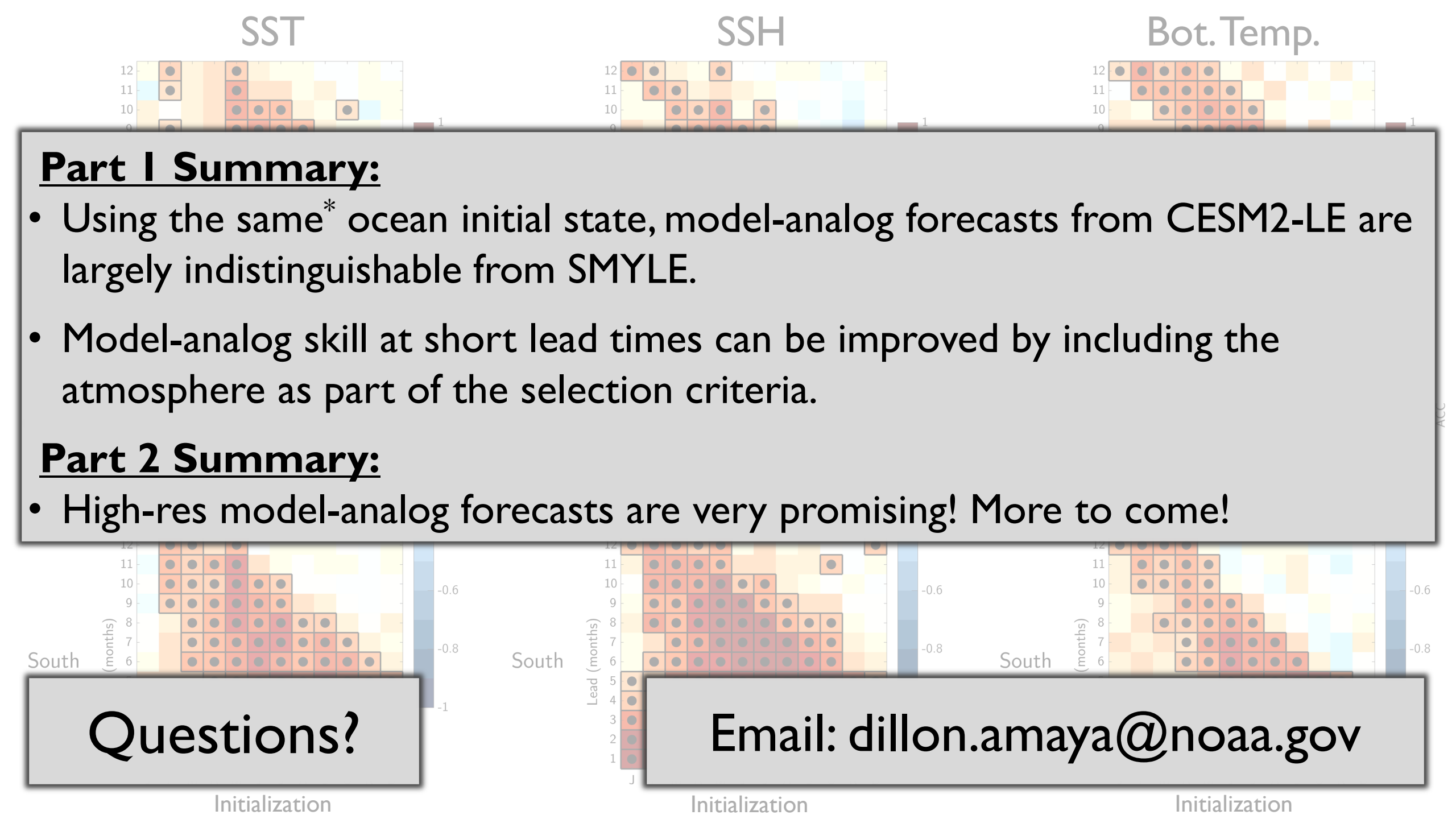


Averaging within 75km of the coastline…



SST


North
Central
South
Lead (months)
12
11
10
9
8
7
6
5
4
3
2
1
J F M A M J J A S O N D
Initialization
ACC
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


SST
SSH
Bot. Temp.
Part 1 Summary:
• Using the same* ocean initial state, model-analog forecasts from CESM2-LE are largely indistinguishable from SMYLE.
• Model-analog skill at short lead times can be improved by including the atmosphere as part of the selection criteria.
Part 2 Summary:
• High-res model-analog forecasts are very promising! More to come!
Questions?
Email: dillon.amaya@noaa.gov
South
Lead (months)
Initialization
ACC

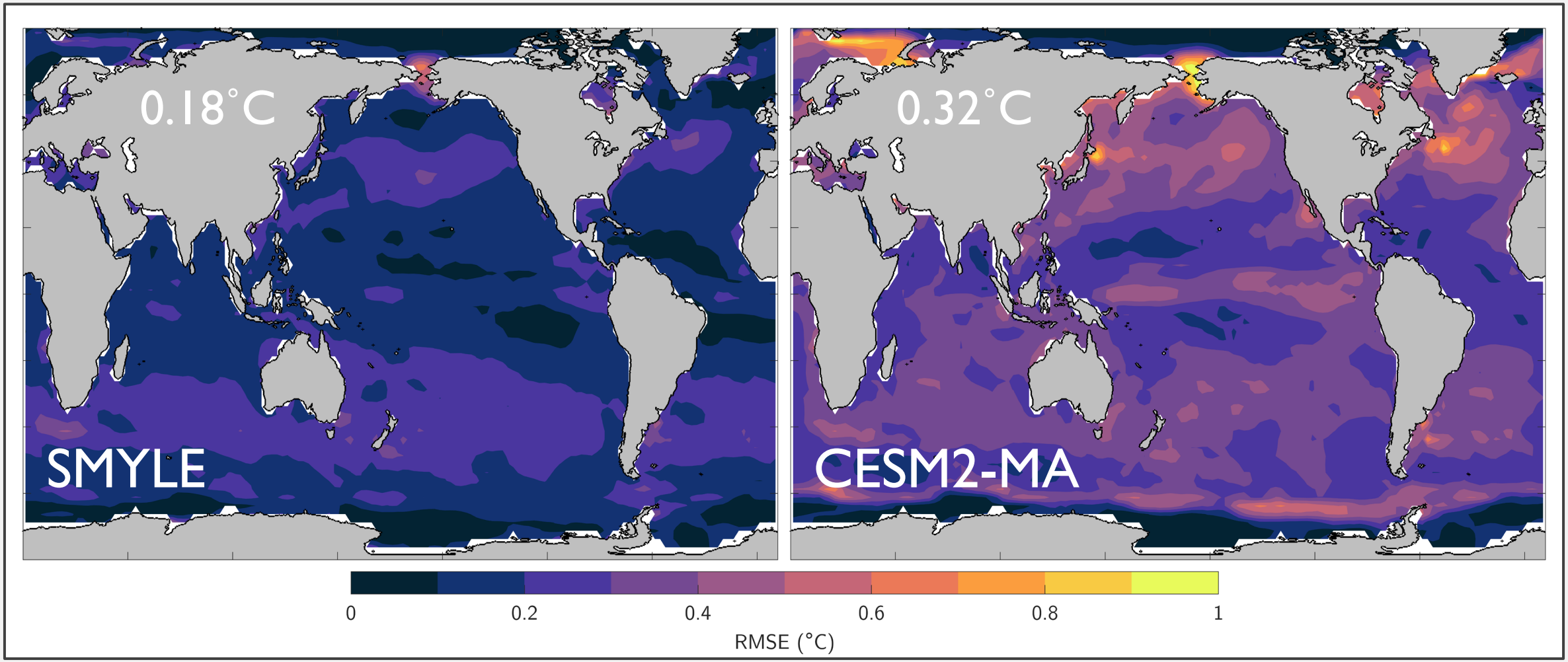
Extra Slides

SMYLE vs Model-Analogs

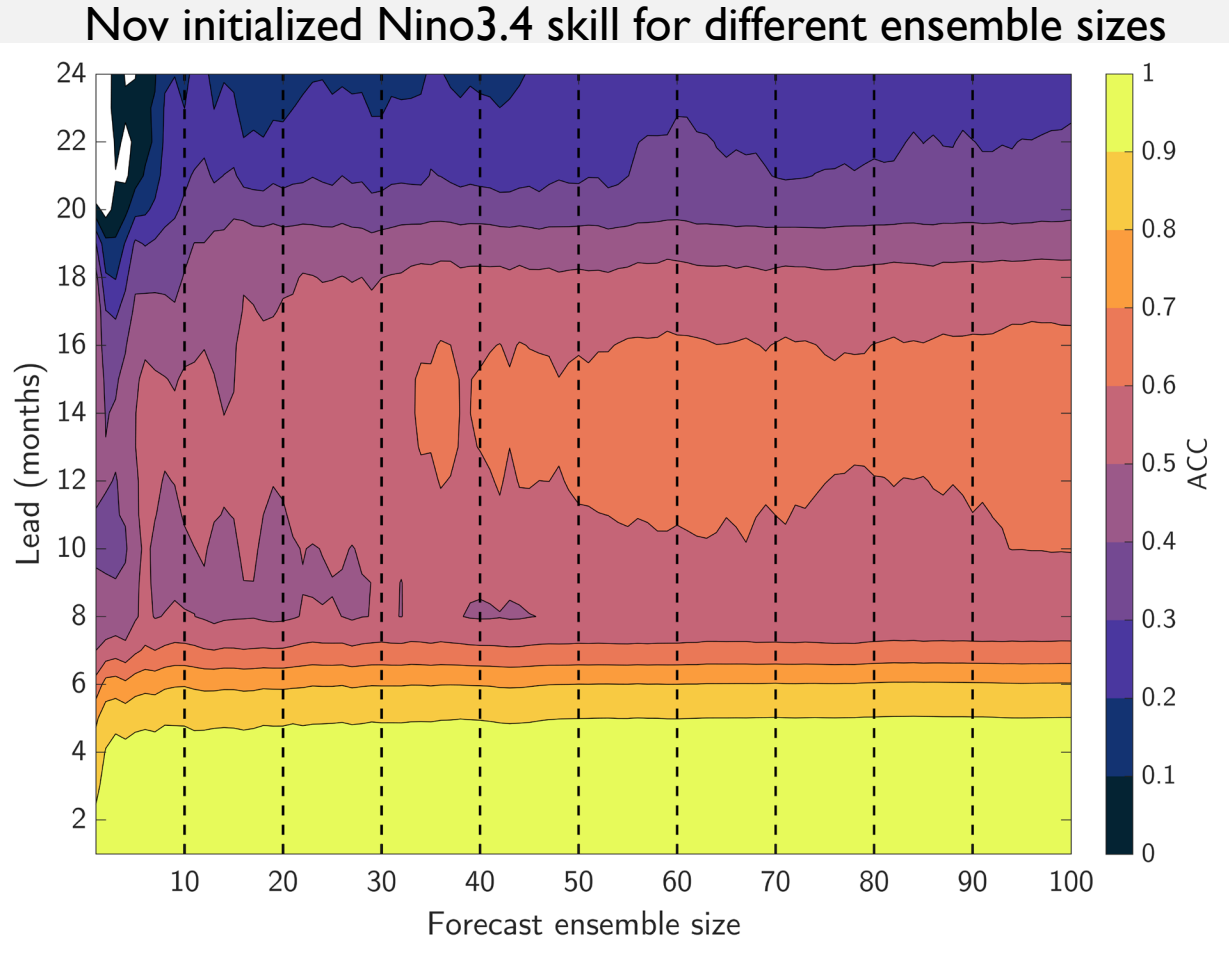
Not perfect, but close…average RMSE is ~2x larger in CESM2-MA than in SMYLE

November initialization

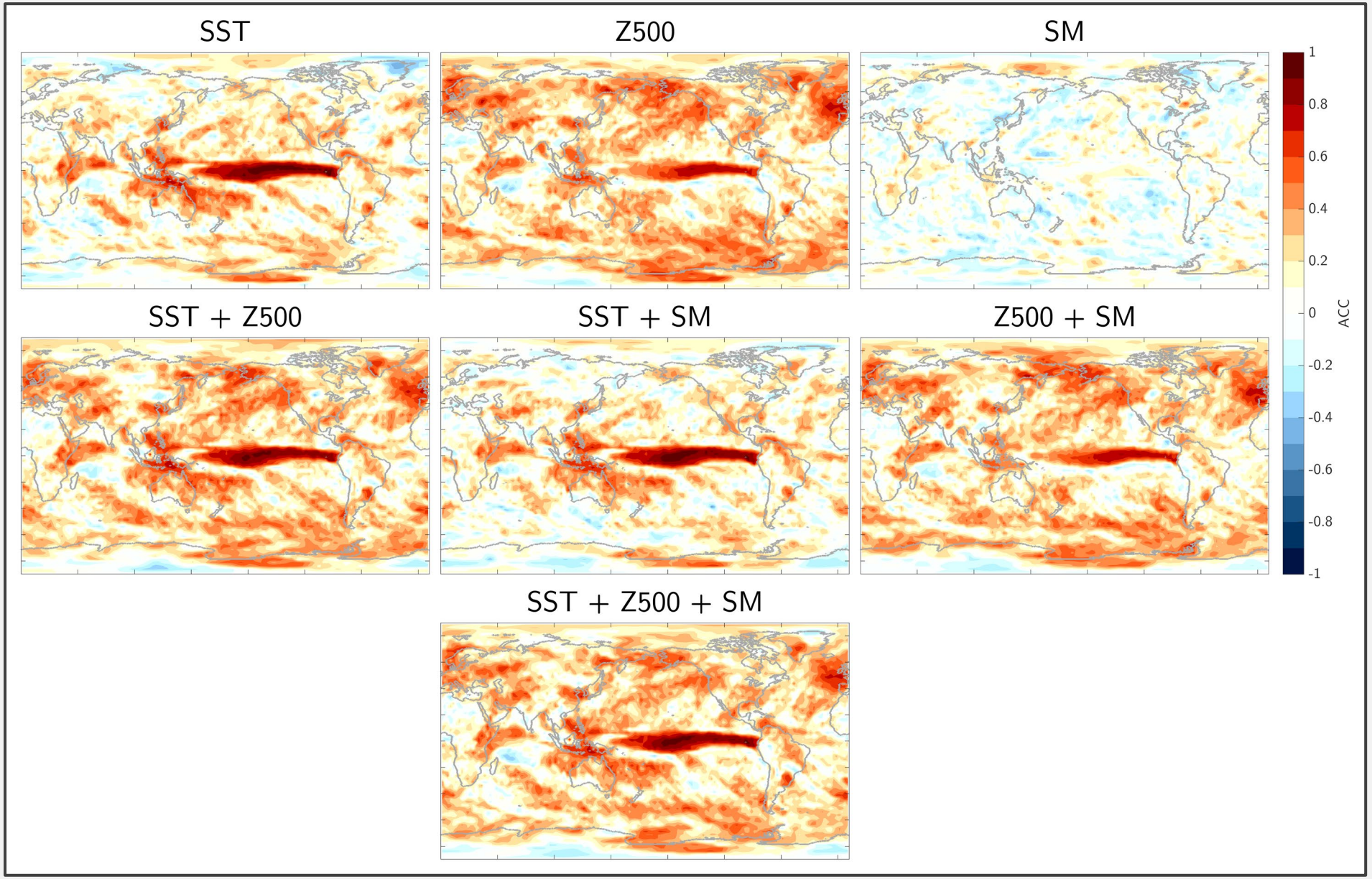
RMSE between forecasts and FOSI at 0–month lead



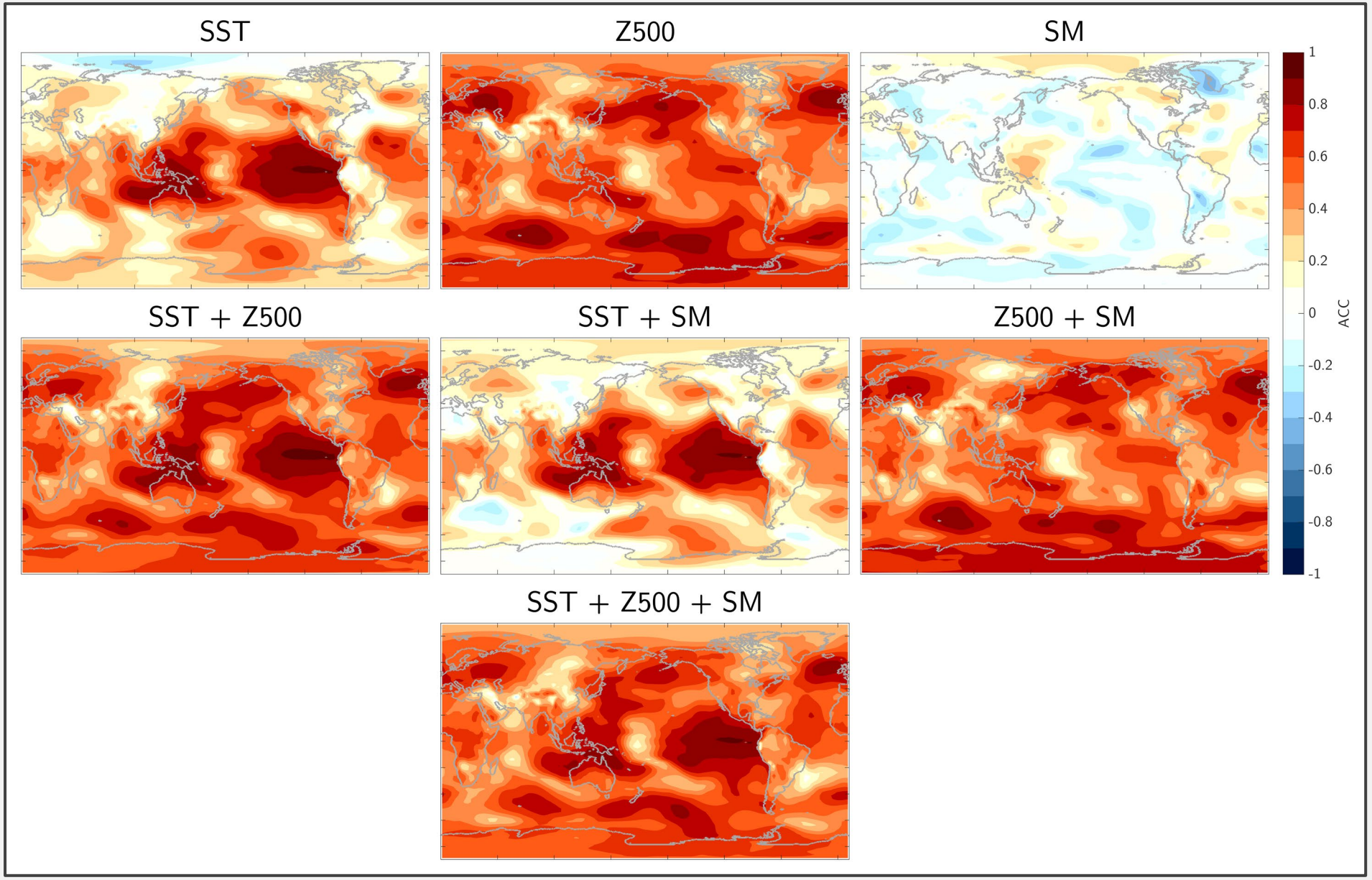
SMYLE vs Model-analogs



Sea Level Pressure

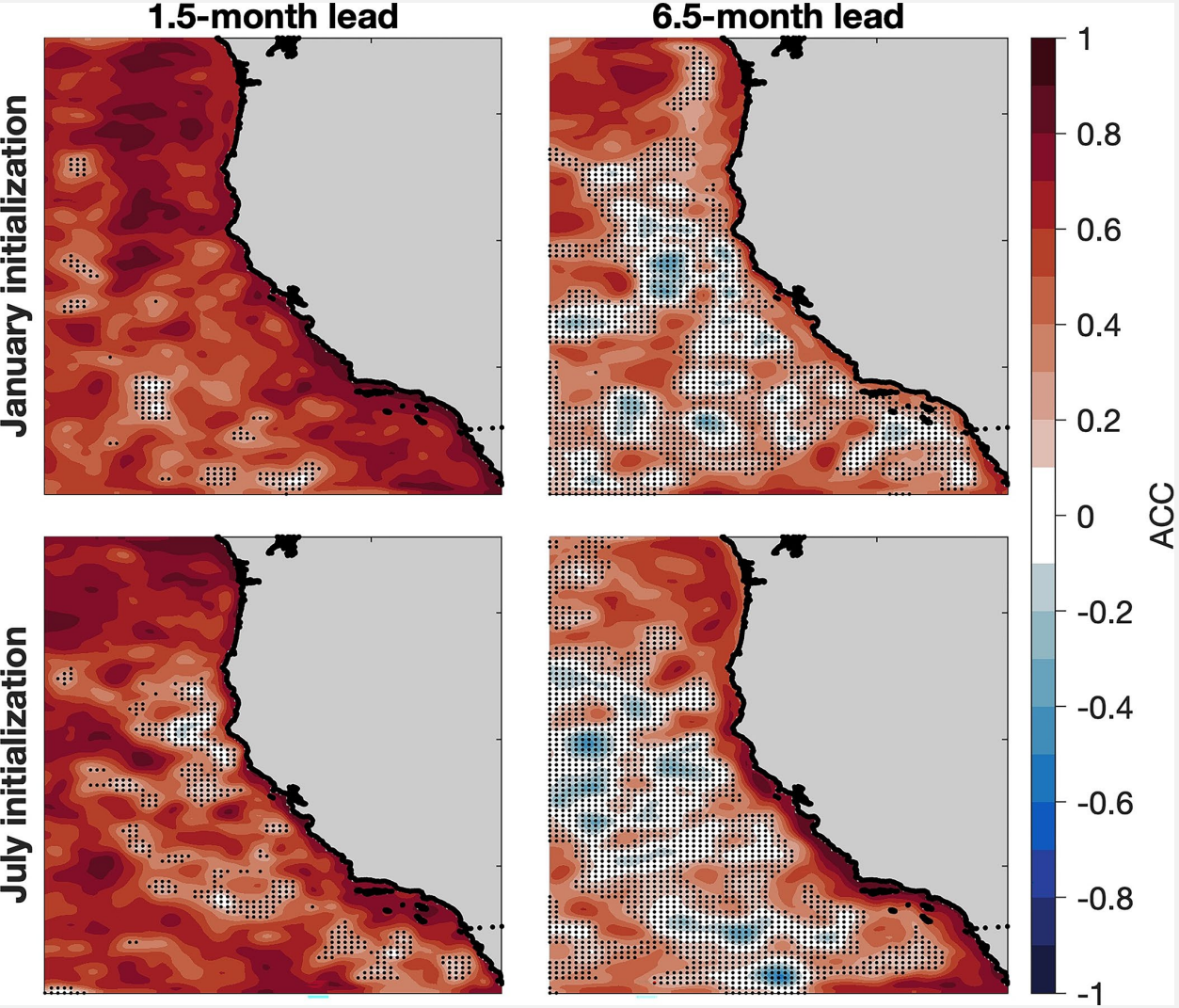


Precipitation

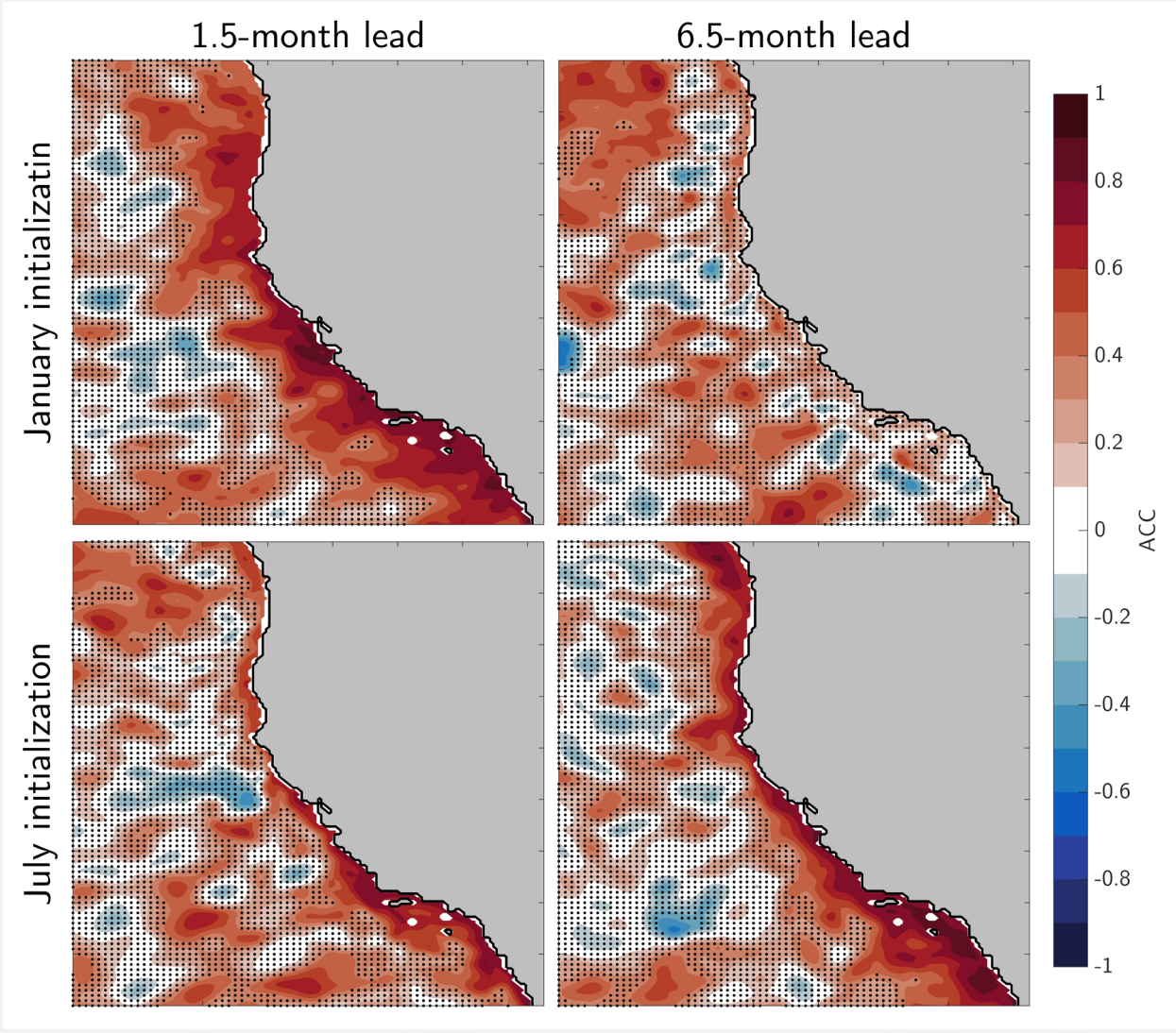


Sea surface height

Dynamically downscaled seasonal forecasts



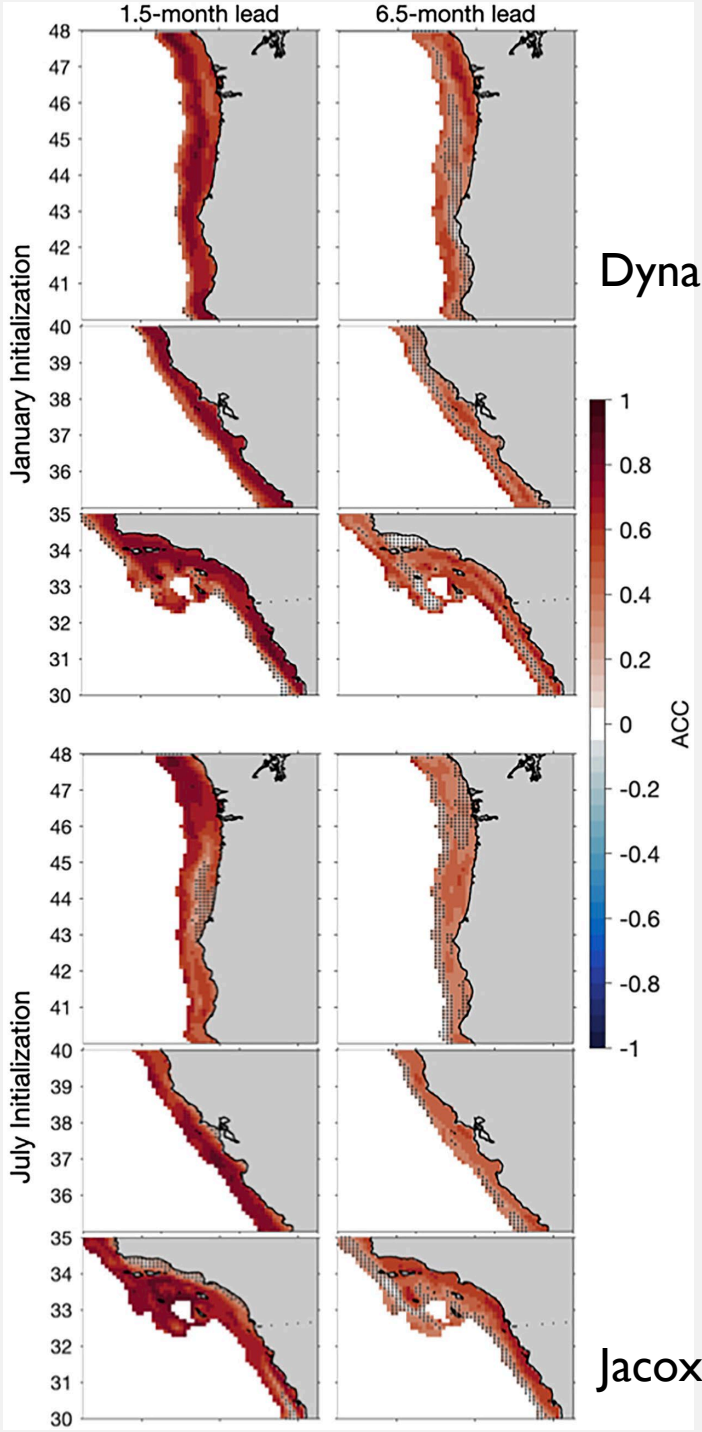
iHESP-MA



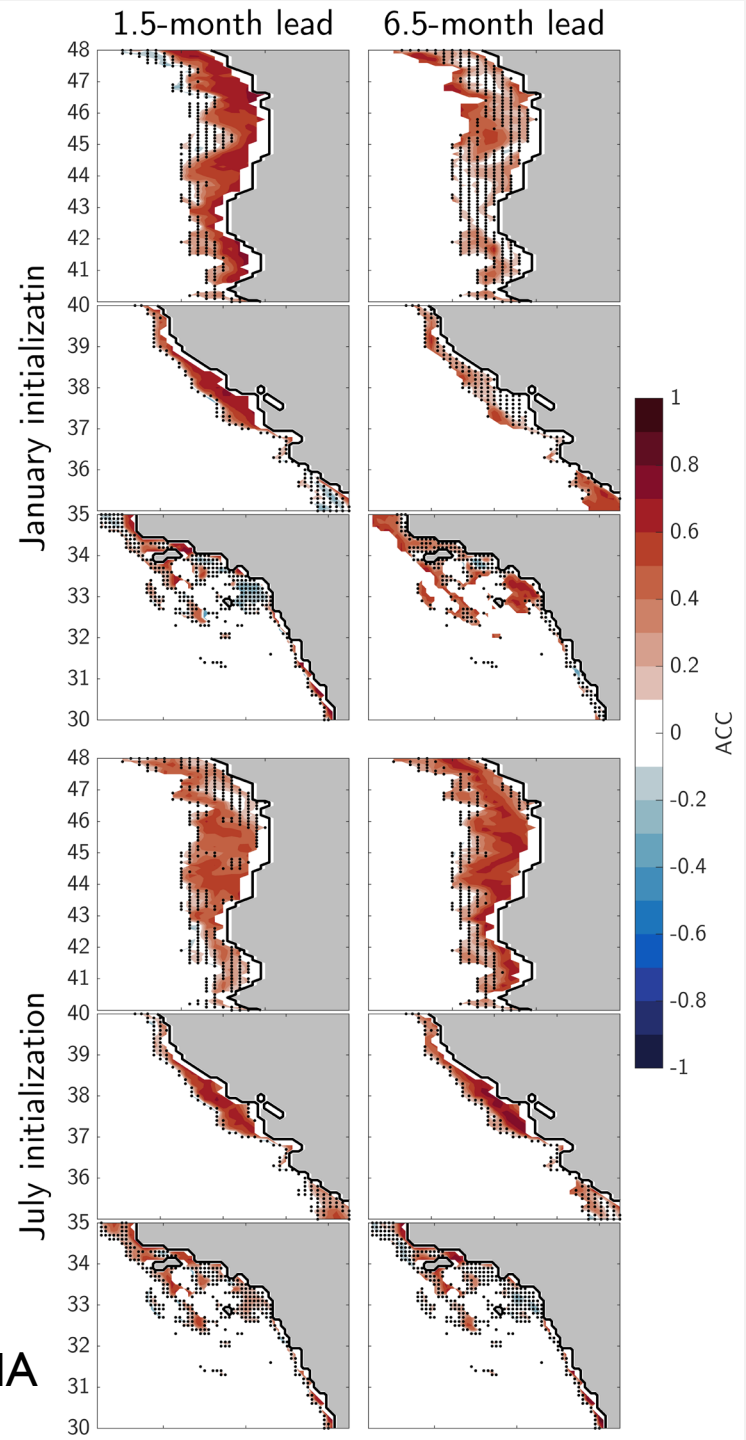
Jacox et al. (2023)

Bottom temperature

Dynamically downscaled seasonal forecasts



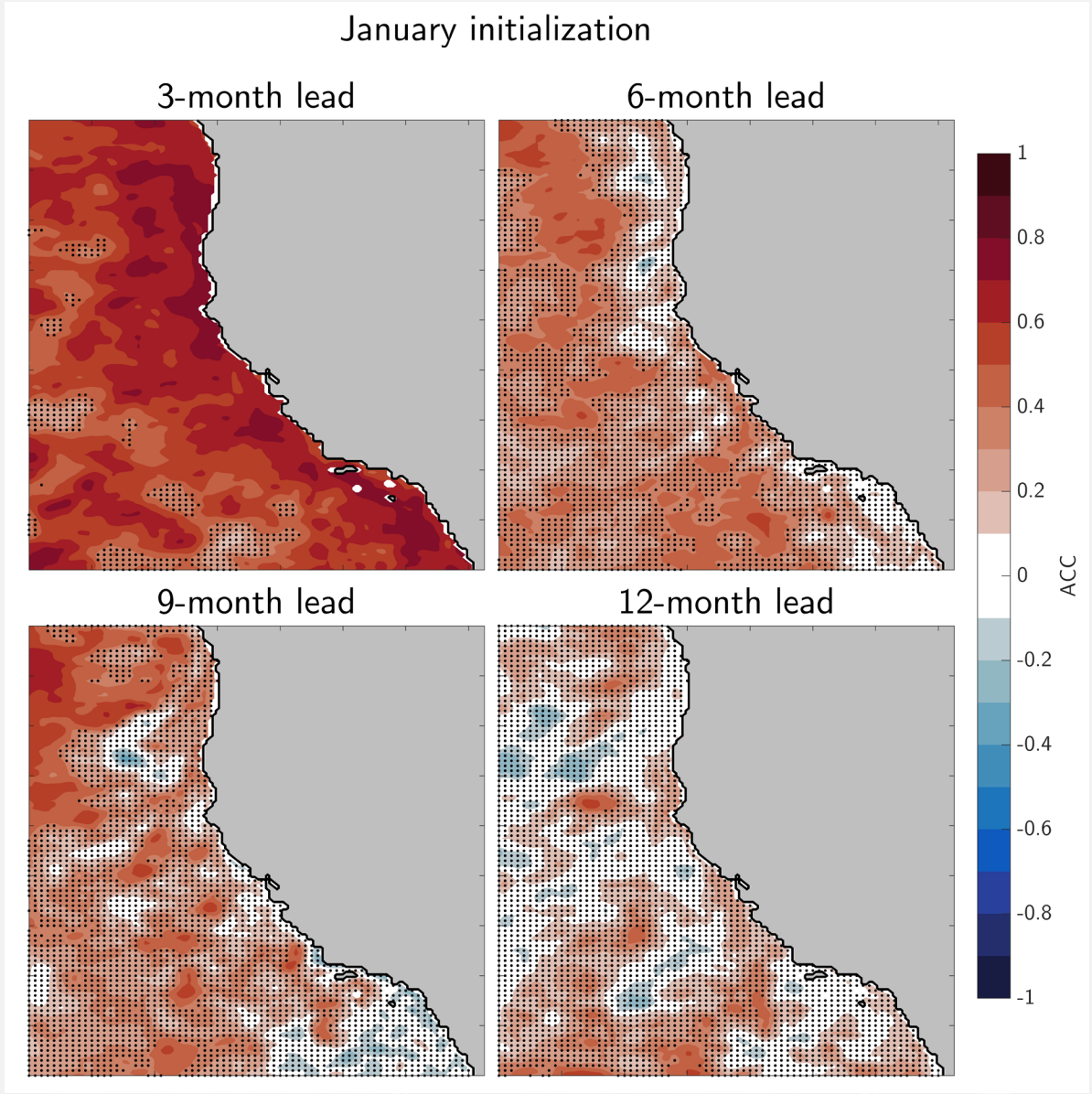
Jacox et al. (2023)

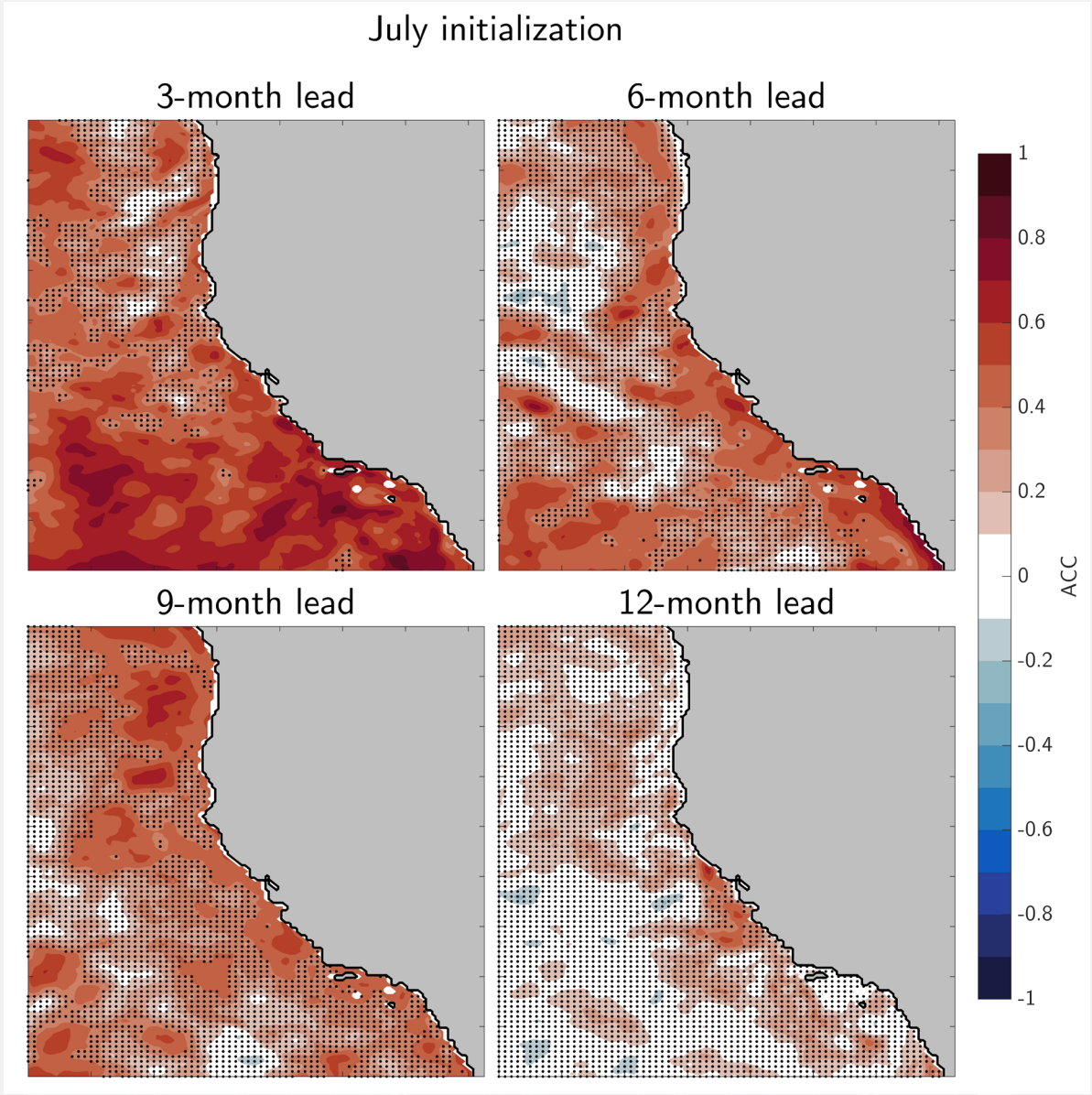


iHESP-MA

Sea surface temperature

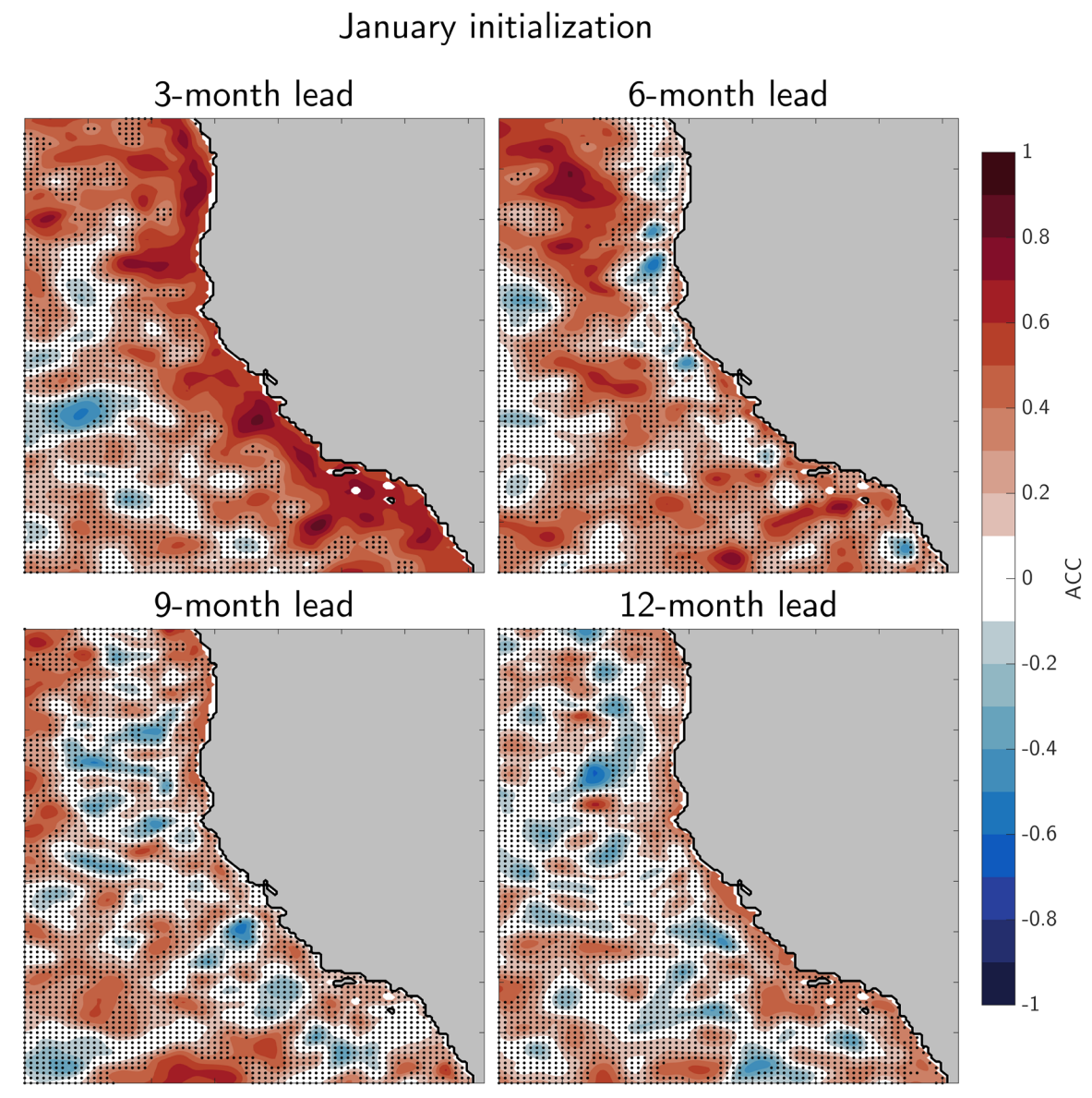
iHESP-MA

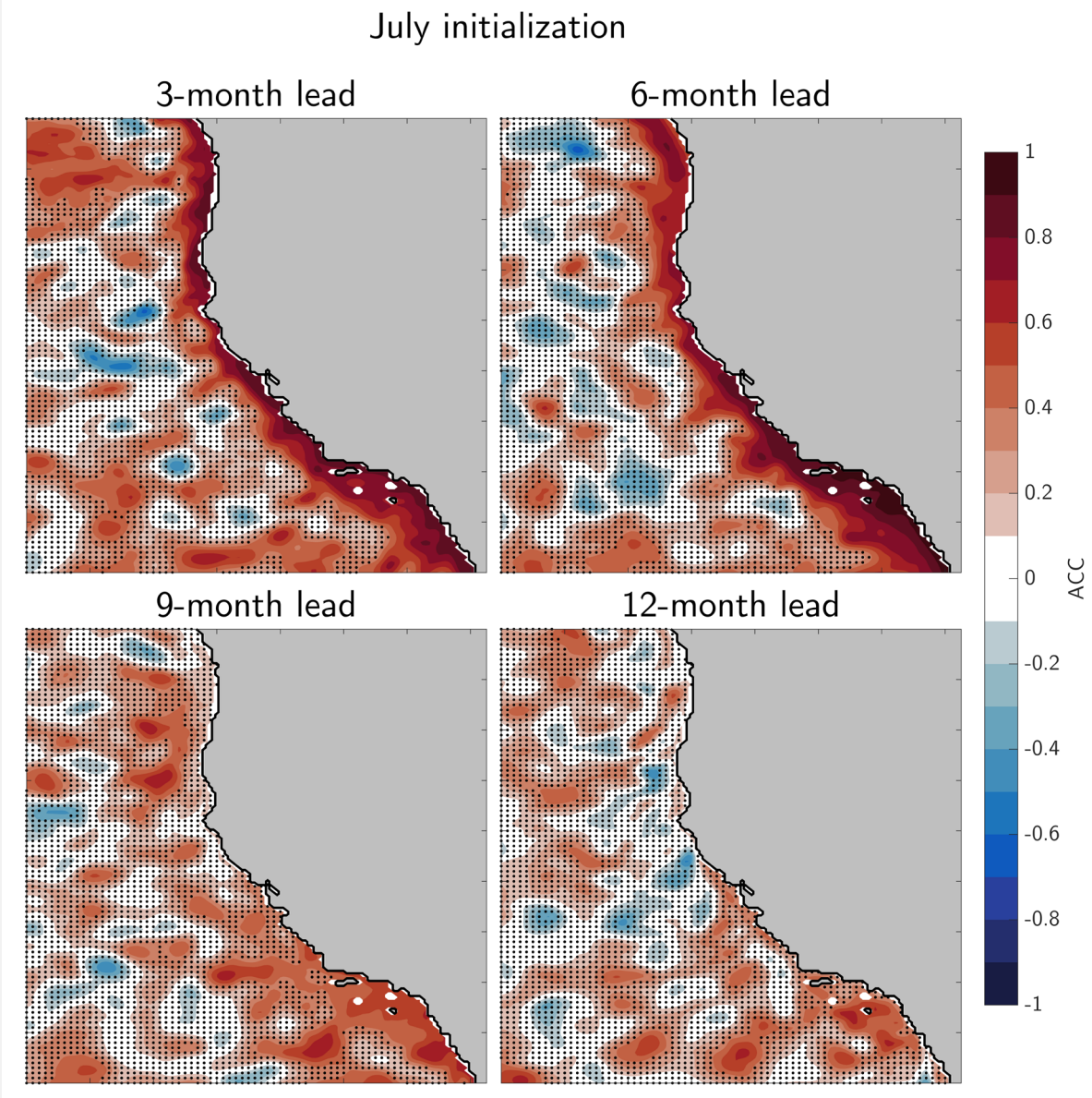




Sea surface height

iHESP-MA





Sea surface temperature