The E3SMv2.1 Seasonal-to-Multiyear Large Ensemble (SMYLE) Forecast System

A Comparative Global Skill Assessment

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catalyst

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Extended Seasonal (S2I) Prediction

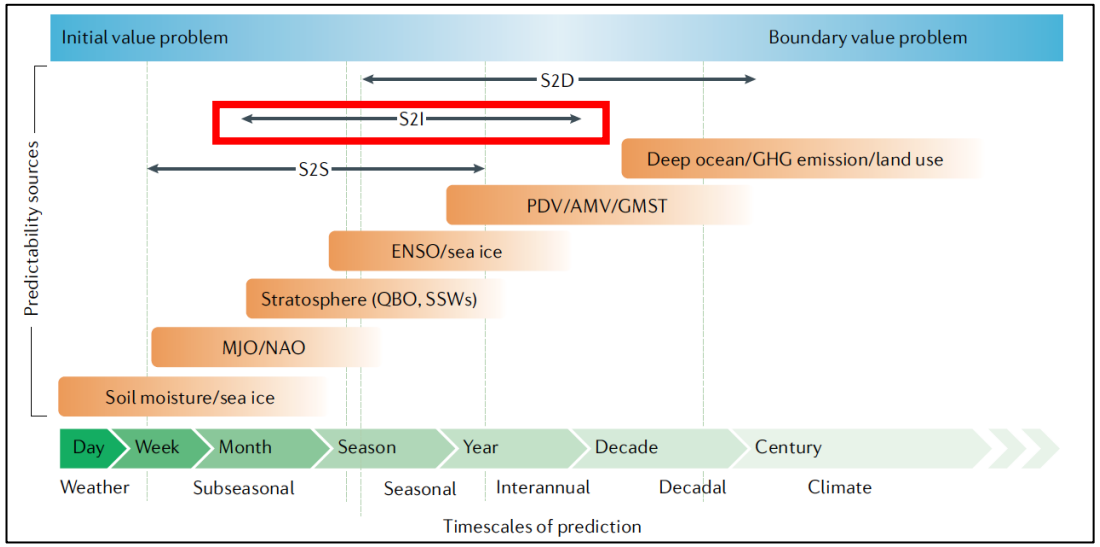
- Predictability knowledge gap for timescales in-between traditional seasonal (0-12 month) and decadal (1-10 year) efforts
- New experimental protocol needed to fill that gap:
  - **Seasonal**: 12-month hindcasts initialized monthly
  - ★ **Ext-Seasonal**: 24+-month hindcasts initialized quarterly
  - **Decadal**: 10-year hindcasts initialized yearly

The Seasonal-to-Multiyear Large Ensemble (SMYLE) prediction system using the Community Earth System Model version 2

Stephen G. Yeager[1], Nan Rosenbloom[1], Anne A. Glanville[1], Xian Wu[1], Isla Simpson[1], Hui Li[1], Maria J. Molina[1], Kristen Krumhardt[1], Samuel Mogen[2], Keith Lindsay[1], Danica Lombardozzi[1], Will Wieder[1], Who M. Kim[1], Jadwiga H. Richter[1], Matthew Long[1], Gokhan Danabasoglu[1], David Bailey[1], Marika Holland[1], Nicole Lovenduski[2], Warren G. Strand[1], and Teagan King[1]

Yeager et al. (2022, *Geosci Mod Dev*, 10.5194/gmd-15-6451-2022)

Predictability Sources and Timescales:



Meehl et al. (2021, *Nature Reviews*, 10.1038/s43017-021-00155- x)

Extended Seasonal (S2I) Prediction

Skilful predictions of the Summer North Atlantic Oscillation (2023, *Communications Earth & Environment*)

Nick Dunstone, Doug M. Smith, Steven C. Hardiman, Leon Hermanson, Sarah Ineson, Gillian Kay, Chaofan Li, Julia F. Lockwood, Adam A. Scaife, Hazel Thornton, Mingfang Ting & Lei Wang

A multiyear tropical Pacific cooling response to recent Australian wildfires in CESM2 (2023, *Science Advances*)

JOHN T. FASULLO, NAN ROSENBLOOM, AND REBECCA BUCHHOLZ Authors Info & Affiliations

Robust Changes in North America's Hydroclimate Variability and Predictability (2023, *Earth's Future*)

Sanjiv Kumar, Candida F. Dewes, Matthew Newman, Yanan Duan

Multi-month forecasts of marine heatwaves and ocean acidification extremes (2024, *Nature Geoscience, in review*)

Samuel Mogen, Nicole Lovenduski, Stephen Yeager, Antonietta Capotondi, and 7 more

A Simple Statistical Postprocessing Scheme for Enhancing the Skill of Seasonal SST Predictions in the Tropics (2024, *Mon Wea Rev*)

Ingo Richter, Jayanthi V. Ratnam, Patrick Martineau, Pascal Oettli, Takeshi Doi, Tomomichi Ogata, Takahito Kataoka, and François Counillon

The Seasonal-to-Multiyear Large Ensemble (SMYLE) prediction system using the Community Earth System Model version 2

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Skillful Multi-Month Predictions of Ecosystem Stressors in the Surface and Subsurface Ocean (2023, *Earth's Future*)

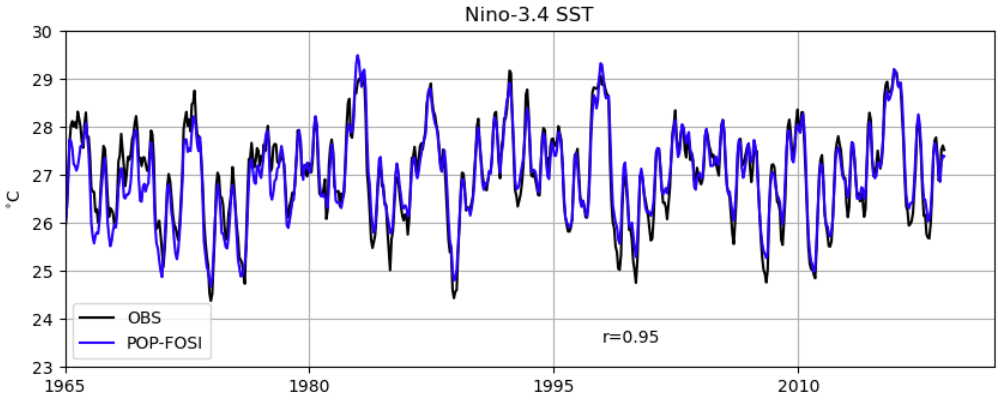
Samuel C. Mogen, Nicole S. Lovenduski, Stephen Yeager, Lydia Keppler, Jonathan Sharp, Steven J. Bograd, Nathali Cordero Quiros, Emanuele Di Lorenzo, Elliott L. Hazen ... See all authors

Yeager et al. (2022, *Geosci Mod Dev*, 10.5194/gmd-15-6451-2022)

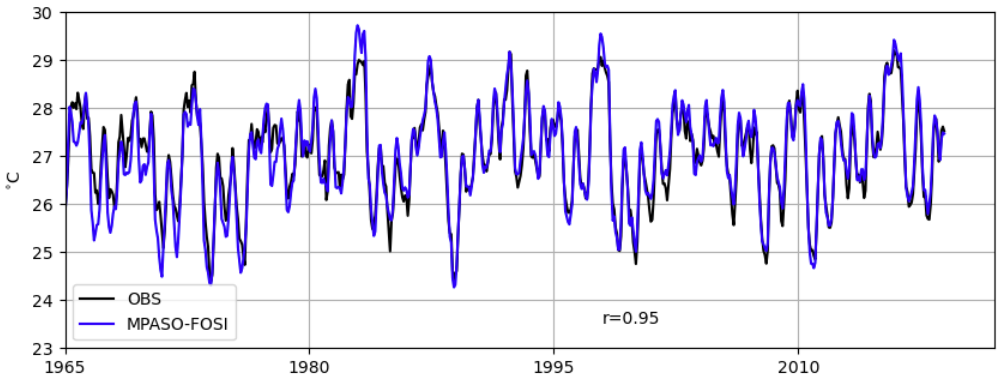
Seasonal-to-**M**ulti**Y**ear **L**arge **E**nsemble Hindcast Experiments

	CESM2 SMYLE	E3SMv2.1 SMYLE
Model -ocean -atmosphere -land -sea ice	CESM2 POP2 (1°, 60L) CAM6-FV (1°, 32L) CLM5 (1°) CICE5 (1°)	E3SMv2.1 MPAS-O (1°, 60L) EAMv2 (1°, 72L) ELMv2 (1°) MPAS-SI (1°)
Forcing -through 2014 -2015 onwards	CMIP6 SMBB historical RCP3.70	CMIP6 SMBB historical RCP3.70
Initialization -ocean -atmosphere -land -sea ice	Full field POP2 FOSI (1°, OMIP2) JRA55 forced CLM5 (CRU-JRA) POP2 FOSI (1°, OMIP2)	Full field MPAS-O FOSI (1°, OMIP2) ERA5 forced ELMv2 (CRU-NCEP) MPAS-O FOSI (1°, OMIP2)
Hindcasts -start dates -initialization years -length -ensemble size	1st of Nov, Feb, May, Aug 1970-2019 24 months 20	1st of Nov, Feb, May, Aug 1970-2019 28 months 20

CESM2 POP FOSI:



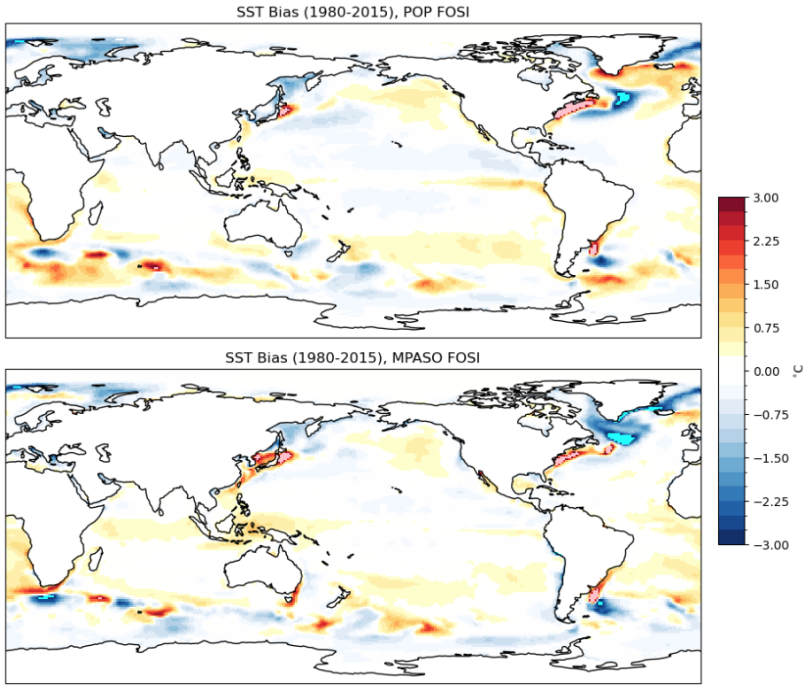
E3SMv2.1 MPAS-O FOSI:



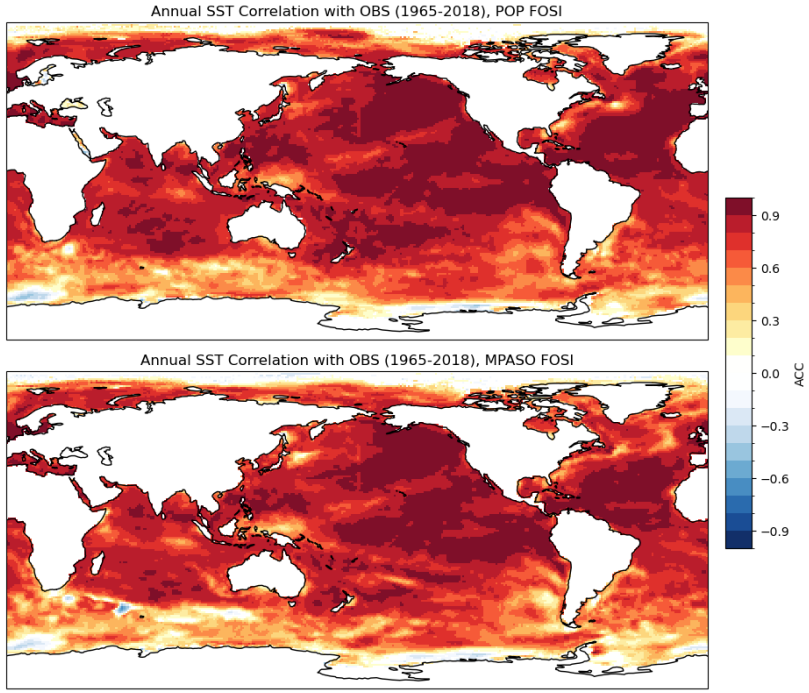
- Forced Ocean/Sea-Ice (FOSI) simulations yield reasonable reproduction of historical ocean/sea-ice states (in particular, tropical Pacific)

Fidelity of Ocean Initial Conditions

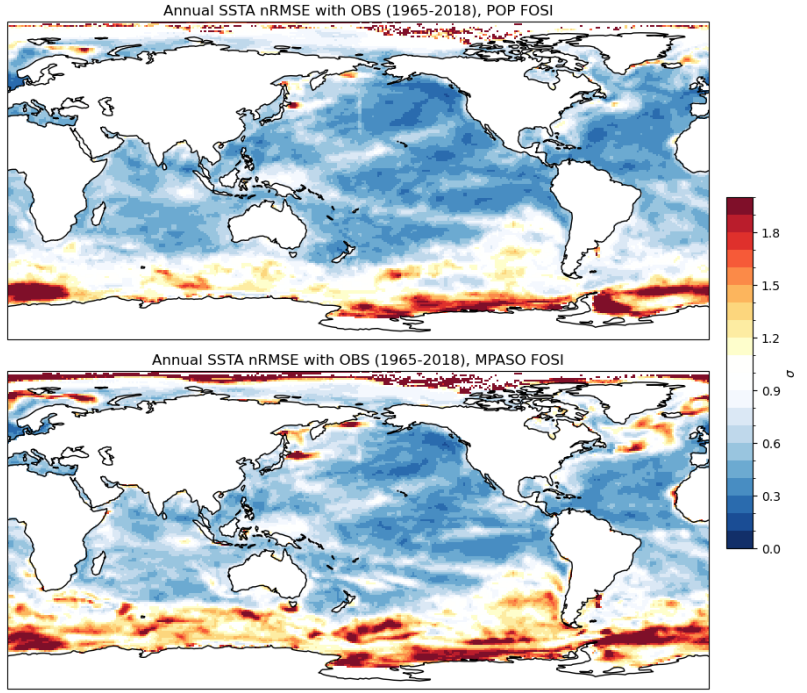
Mean SST Bias:



SST Correlation:



SST RMSE:

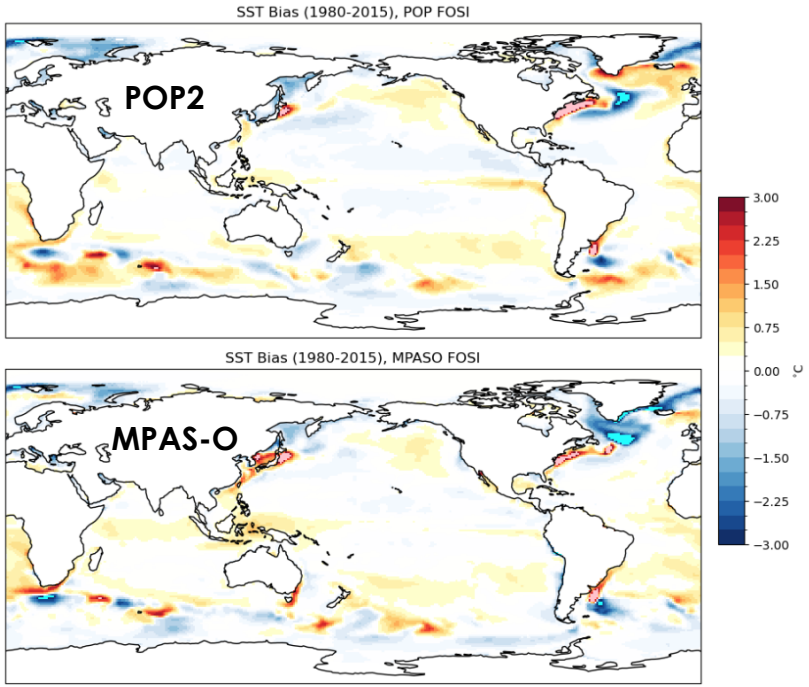


TOP ROW: POP2
BOTTOM ROW: MPAS-O

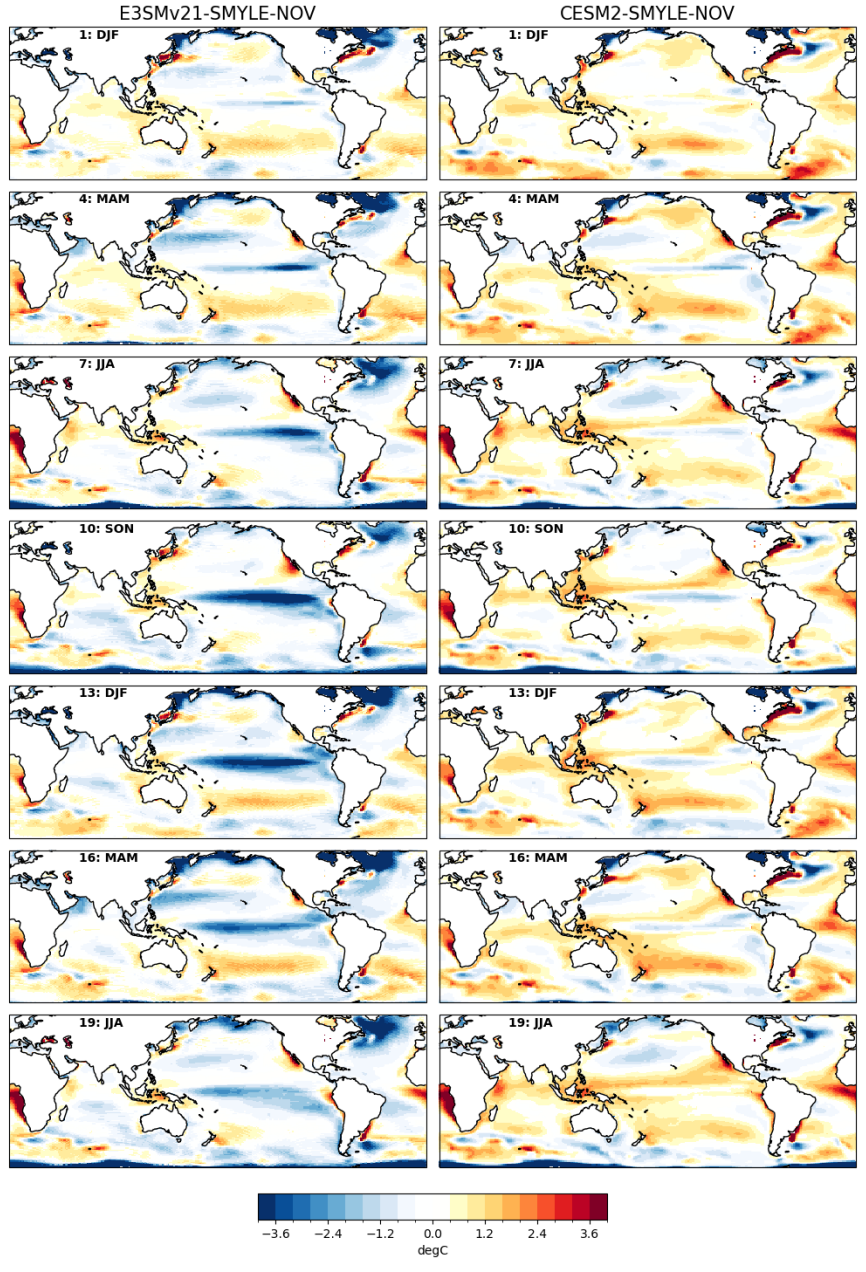
- "Poor man's data assimilation" for ocean/sea-ice → far from perfect!
- Ocean initial conditions for E3SMv2.1-SMYLE are comparable to those used for CESM2-SMYLE

Hindcast Drift

SST Bias (FOSI):



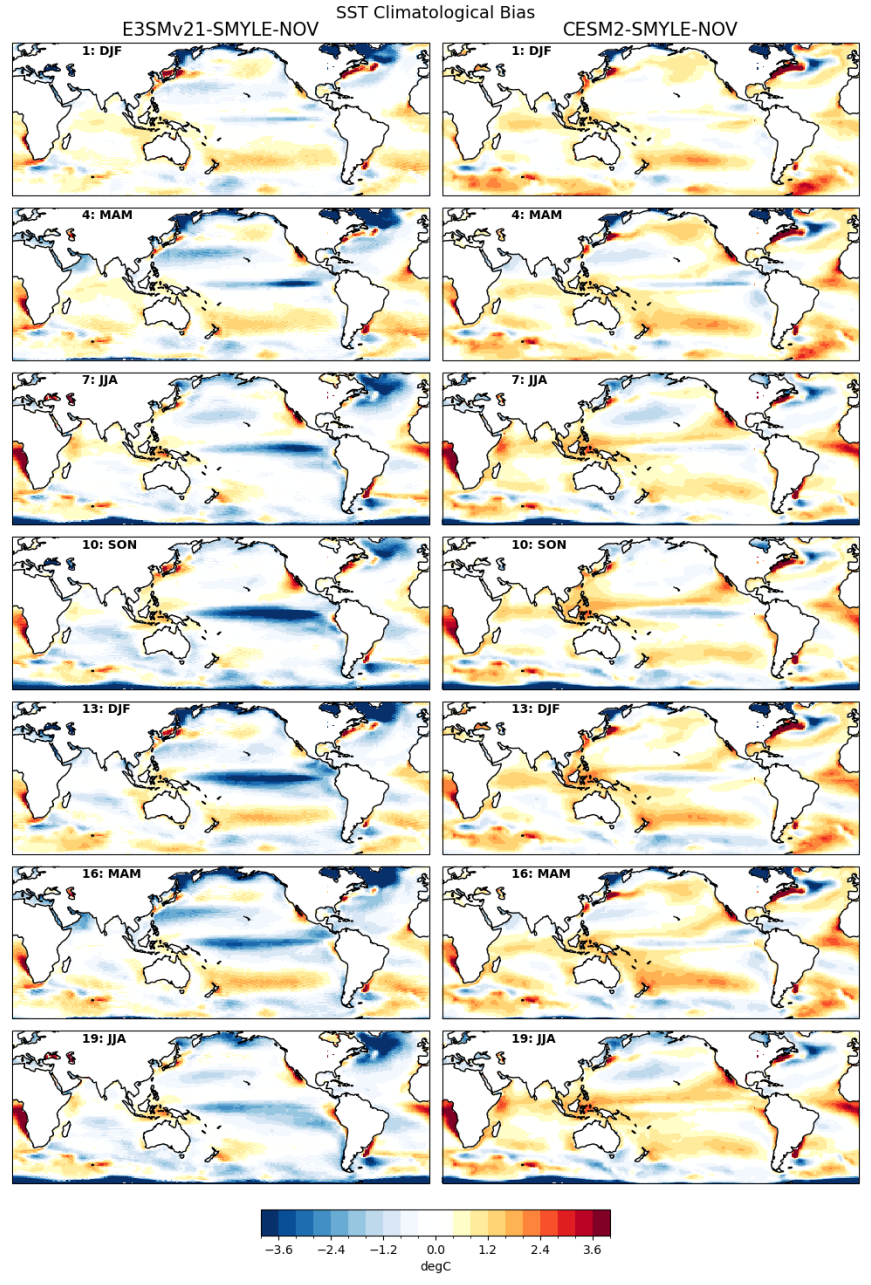
SST Bias (Coupled Hindcasts):



- Coupled model systematic bias develops rapidly
- Very different lead-dependent bias patterns in E3SMv2.1 and CESM2

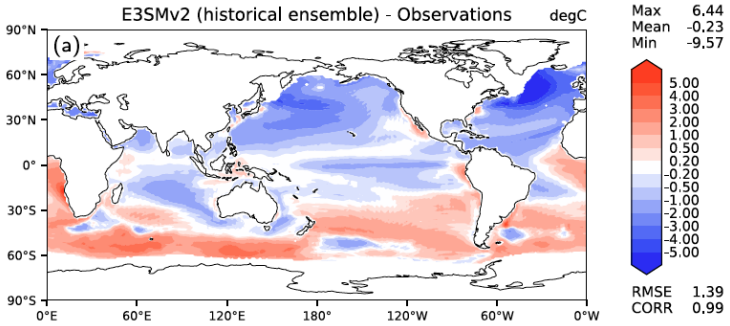
Hindcast Drift

SST Bias (Coupled Hindcasts):



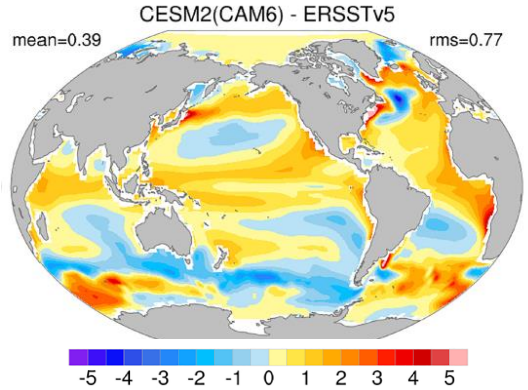
SST Bias (Coupled Historical):

E3SMv2



Golaz et al. (2022, *JAMES*, 10.1029/2022MS003156)

CESM2

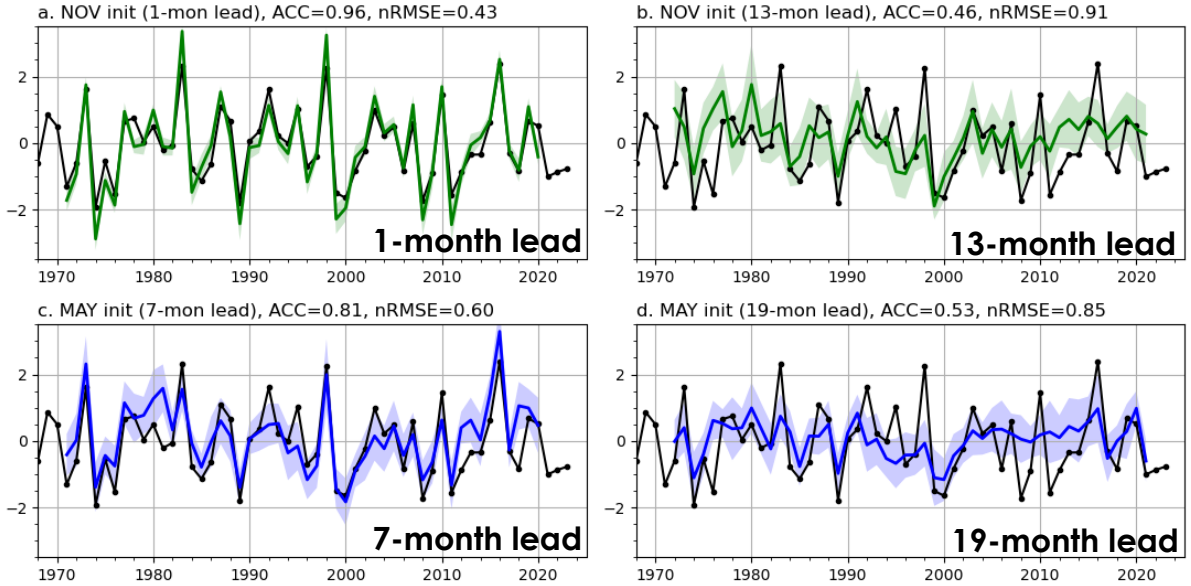


Danabasoglu et al. (2020, *JAMES*, 10.1029/2019MS001916)

ENSO Prediction Skill

E3SMv2.1-SMYLE

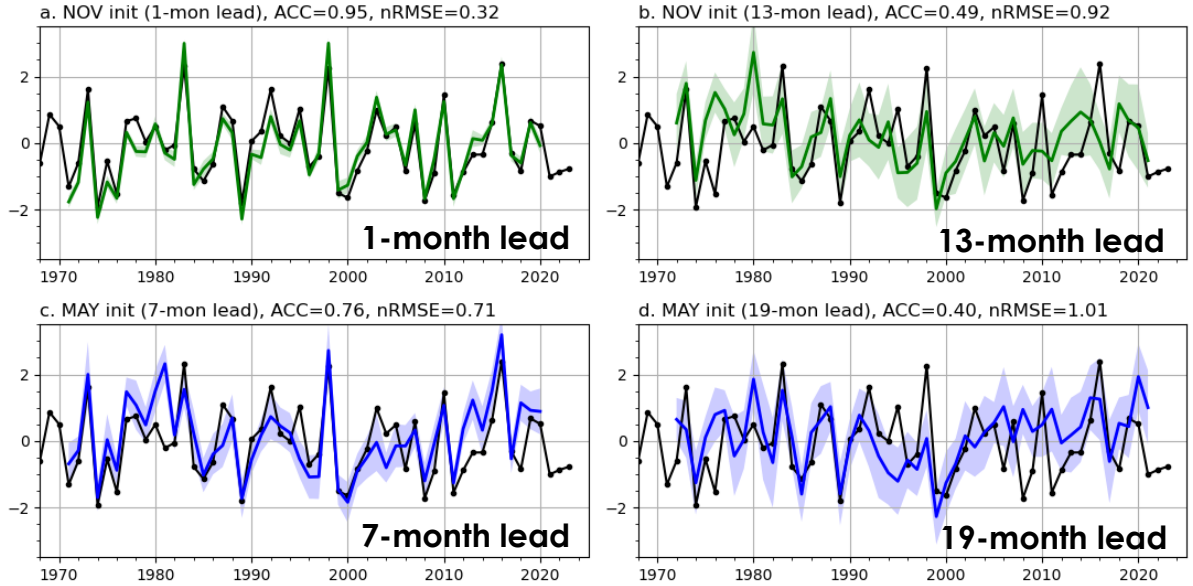
DJF Niño – 3.4 Index



- Remarkably similar ENSO skill despite very different mean model biases
- Both systems are competitive with the NMME multi-model mean

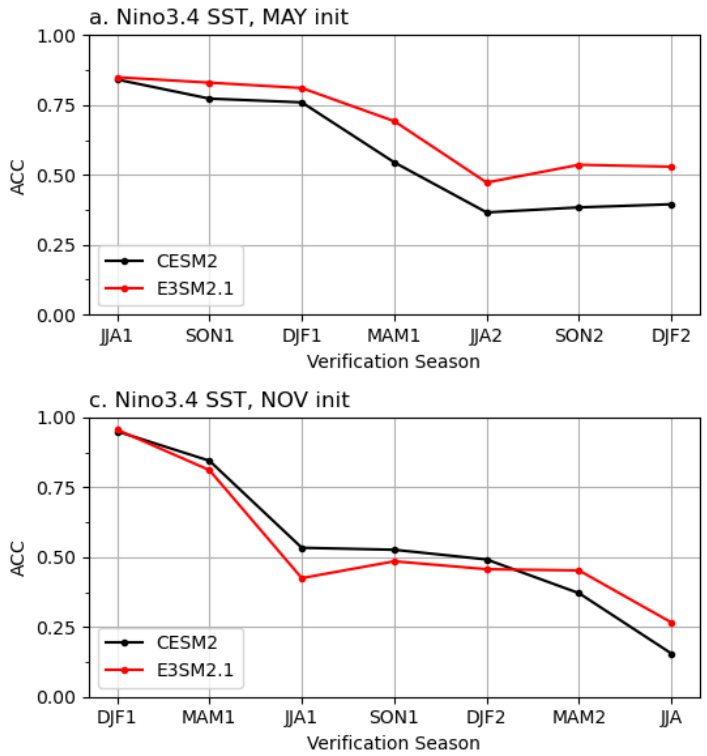
CESM2-SMYLE

DJF Niño – 3.4 Index



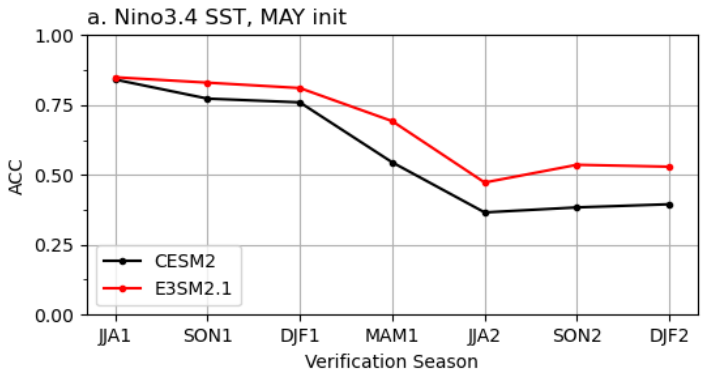
- Evidence of robust multiyear-lead ENSO forecasts-of-opportunity

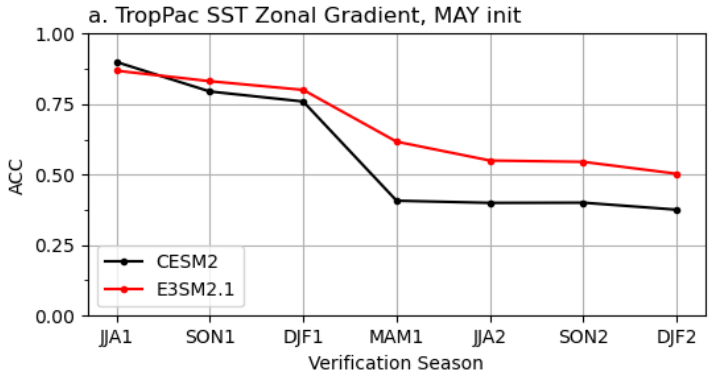
ENSO Prediction Skill

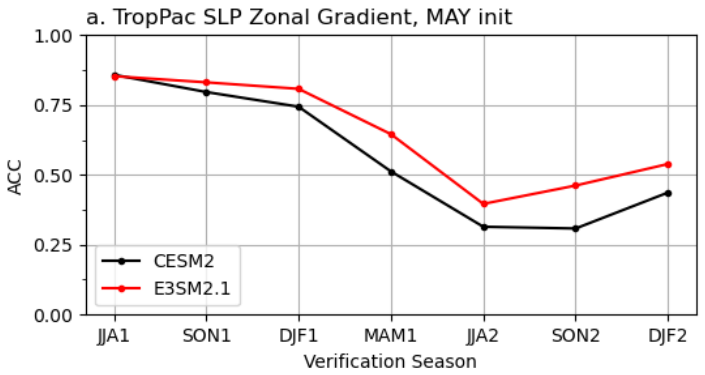


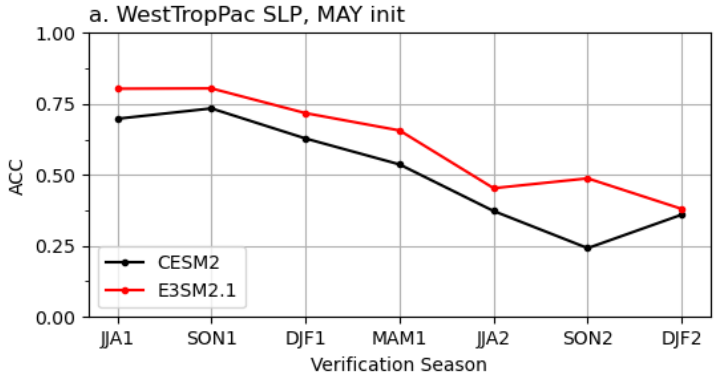
- Start-month dependence on skill comparison
- E3SMv2.1 outperforms CESM2 for MAY hindcasts

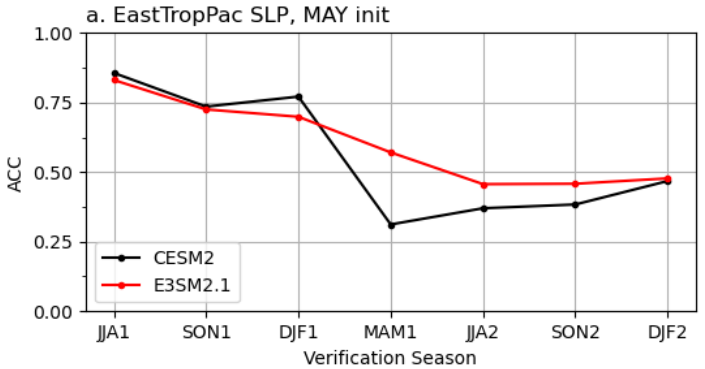
ENSO Prediction Skill





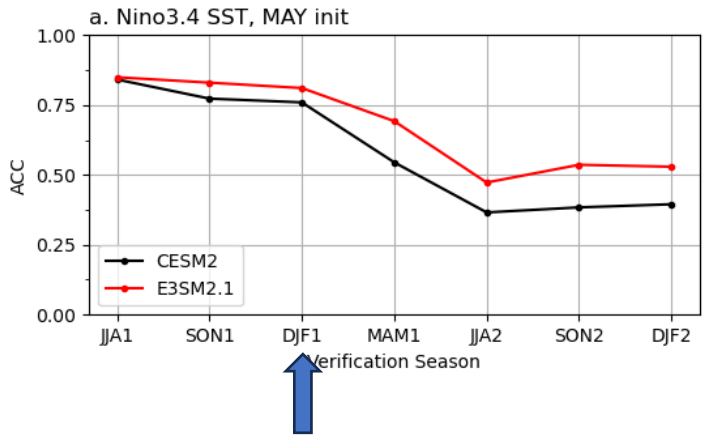




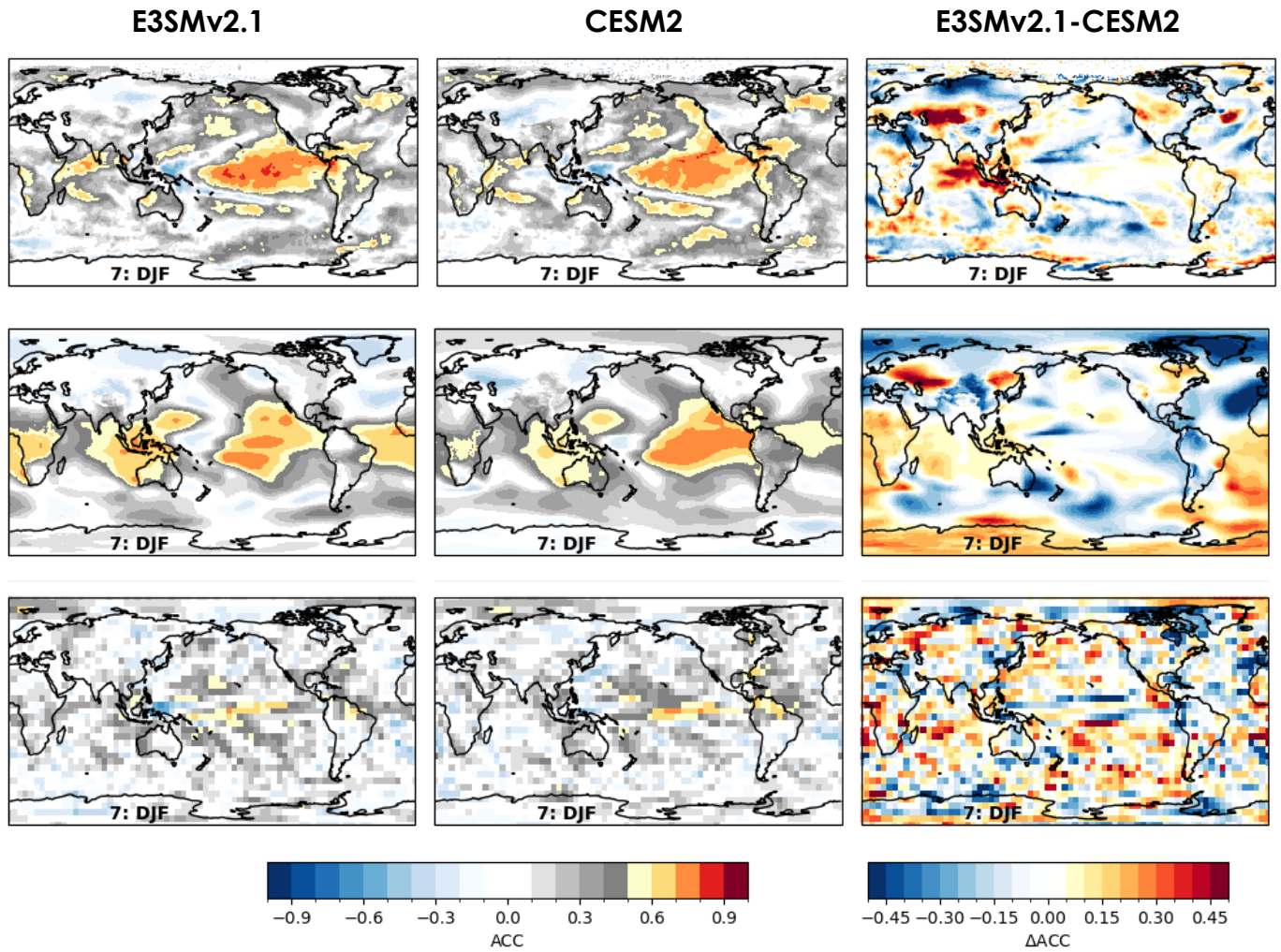


- Improved Niño3.4 skill in E3SMv2.1 due to improved prediction of Bjerknes feedback (SLP over MC/IO)?

ENSO Impacts Skill



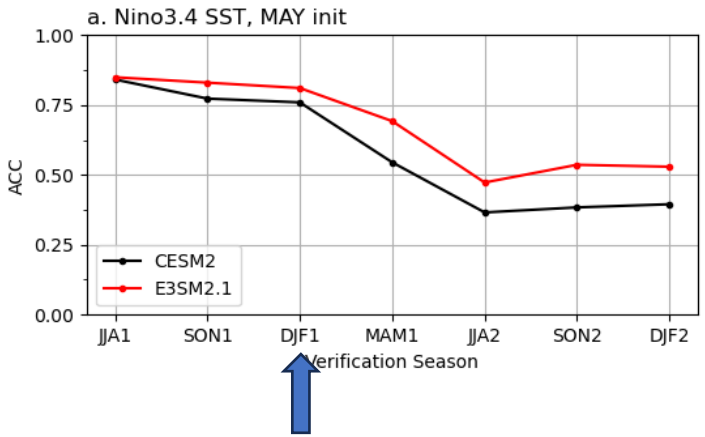
Anomaly Correlation Coefficient (after detrending):

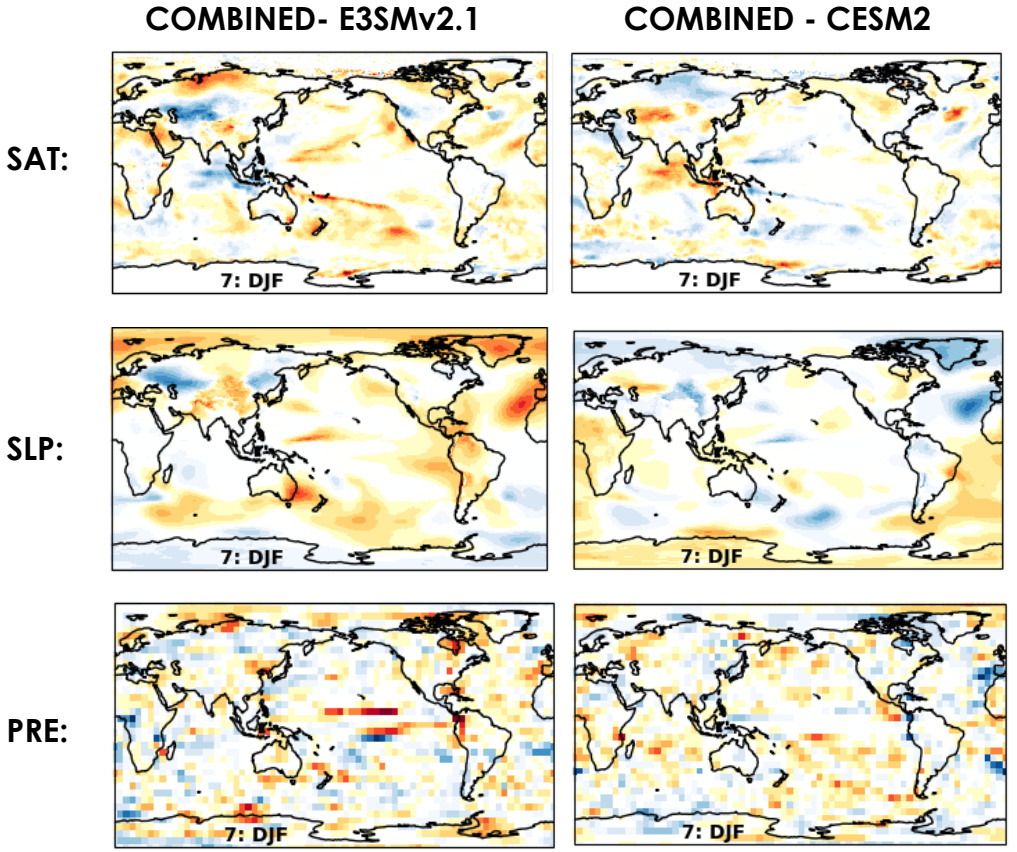


- Skill comparison for seasonal impacts is mixed

ENSO Impacts Skill

Anomaly Correlation Coefficient (after detrending):





- Combined 40-member multi-model system appears generally superior to individual systems

Summary

- Extended-seasonal initialized prediction hindcasts using E3SMv2.1 have been completed through CATALYST/E3SM collaboration
- E3SMv2.1-SMYLE skill for ENSO is similar to that from CESM2-SMYLE despite different background mean state bias
- Promising potential to explore seasonal predictability dependence on model structure & process representation