Earth System Prediction Working Group Update

Steve Yeager (NSF NCAR) & Kathy Pegion (U. Oklahoma), WG Co-chairs
Sasha Glanville (NSF NCAR), WG liaison
Nan Rosenbloom (NSF NCAR)

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ESPWG:

The goal of the ESPWG is to **advance fundamental understanding of Earth system predictability** on time scales ranging from **subseasonal to decadal**. Towards that end, this working group will bring together a **multidisciplinary** group of researchers interested in **how initial conditions influence the near-term evolution of the Earth system**. A key focus will be the **generation and analysis of initialized ensemble simulations** that shed light on the predictability of different components of the Earth system.

- Web page: https://www.cesm.ucar.edu/working-groups/earth-system
- See web page for mailing list link
- As a “model user” WG, ESPWG is a synthesis activity that would not be possible without the domain expertise contributed from each of CESM’s foundational component model WG/development efforts

ESPWG Production Datasets

- https://www.cesm.ucar.edu/working-groups/earth-system
- ***In-progress*: migration of production datasets to CISL RDA (data DOIs)**

CESM1:

- CESM1 **Subseasonal-to-Seasonal (S2S)** reforecasts
  - *Ref: Richter et al., 2020 (doi:10.1175/WAF-D-20-0029.1), Data in IRI SubX library*

- CESM1 **Seasonal** reforecasts
  - 10-member, 12-month ensembles initialized monthly (1st of month 1980-2010)
  - *NMME (https://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/.NCAR-CESM1/)*

- CESM1.1 **Decadal Prediction Large Ensemble (DPLE)** reforecasts
  - 40-member, 122-month ensembles initialized annually (Nov. 1st 1954-2017)
  - *Ref: Yeager et al., 2018 (doi:10.1175/BAMS-D-17-0098.1)*

ESPWG Production Datasets

- https://www.cesm.ucar.edu/working-groups/earth-system
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CESM2:

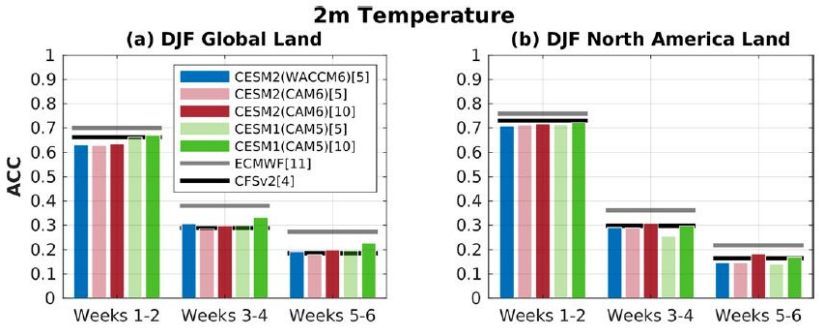
- CESM2 **S2S** reforecast sets (CAM6 & WACCM6)
  - **CAM**: 11-member, 45-day ensembles initialized weekly (1999-2020)
  - **WACCM**: 5-member, 45-day ensembles initialized weekly (Sep - Mar, 1999-2020)
  - *Ref: Richter et al., 2022 (doi:10.1175/WAF-D-21-0163.1)*

- CESM2 **Seasonal-to-MultiYear Large Ensemble (SMYLE)** reforecasts
  - 20-member, 24-month hindcasts initialized quarterly (Feb, May, Aug, Nov 1970-2023)
  - *Ref: Yeager et al., 2022 (doi:10.5194/gmd-2022-60)*

- CESM2 **Decadal Prediction (CESM2-DP)** reforecasts
  - 20-member, 122-month hindcasts initialized Nov. 1 1958-2023)
  - *Ref: Yeager et al., 2022 (doi:10.5194/gmd-2022-60)*

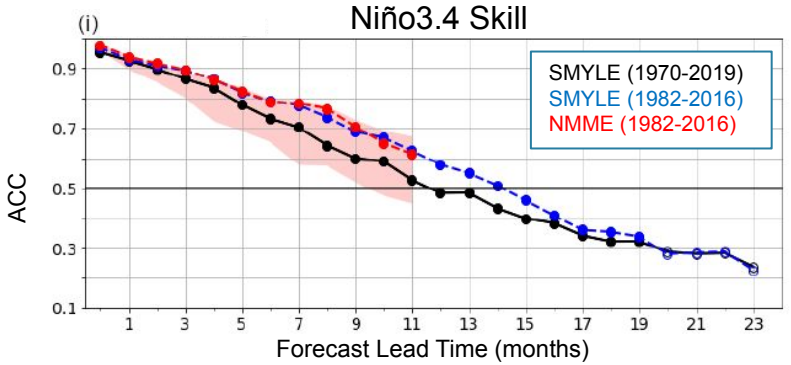
ESPWG Production Datasets

CESM2-S2S



Richter et al. (2022)

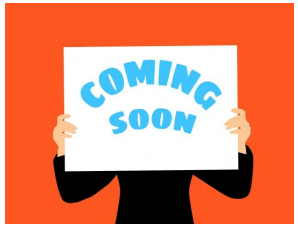
CESM2-SMYLE



Yeager et al. (2022)

- **CESM run in initialized climate prediction mode is competitive with operational systems**
- Initialization using reanalysis-forced simulations (used by WGs for model development) narrows the gap between model development & prediction application

ESPWG Production Datasets



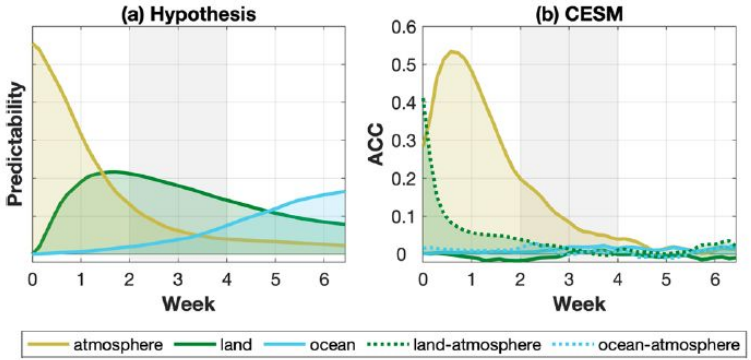
(inquire for access)

Quantifying sources of subseasonal prediction skill in CESM2

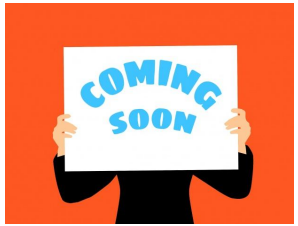
Jadwiga H. Richter, Anne A. Glanville, Teagan King, Sanjiv Kumar, Stephen G. Yeager, Nicholas A. Davis, Yanan Duan, Megan D. Fowler, Abby Jaye, Jim Edwards, Julie M. Caron, Paul A. Dirmeyer, Gokhan Danabasoglu & Keith Oleson

npj Climate and Atmospheric Science **7**, Article number: 59 (2024) | Cite this article

- CESM2 **S2S** single- and dual-climo initialization reforecasts (CAM6)
  - CESM2-S2S used as control reforecast set
  - 11-member, 45-day ensembles initialized weekly (1999-2020)
  - *Ref: Richter et al., 2024 (doi:10.1038/s41612-024-00595-4)*



ESPWG Production Datasets



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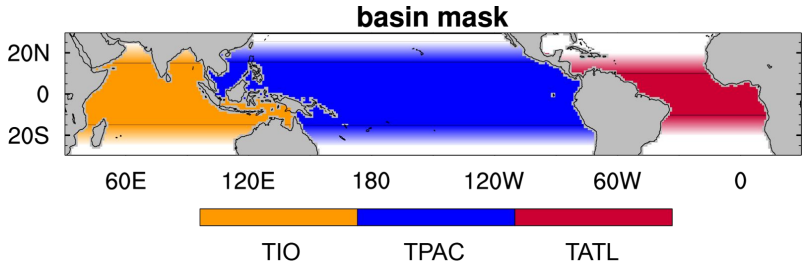
The Tropical Basin Interaction Model Intercomparison Project (TBIMIP)

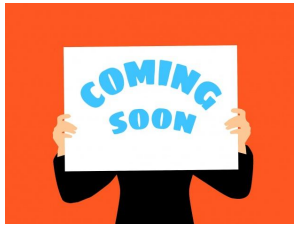
Ingo Richter, Ping Chang, Gokhan Danabasoglu, Dietmar Dommenget, Guillaume Gastineau, Aixue Hu, Takahito Kataoka, Noel Keenlyside, Fred Kucharski, Yuko Okumura, Wonsun Park, Malte Stuecker, Andrea Taschetto, Chunzai Wang, Stephen Yeager, and Sang-Wook Yeh

https://doi.org/10.5194/egusphere-2024-3110

- CESM2 **SMYLE-TBIMIP** pacemaker reforecasts
  - CESM2-SMYLE used as control reforecast set
  - 10-member, 23-month ensembles initialized Feb. 1 1982-2021
  - 3 different reforecast sets with anomaly SST restoring in each of:
    TIO, TPAC, TATL
  - *Ref: Richter et al., 2025 (doi:10.5194/egusphere-2024-3110)*



ESPWG Production Datasets



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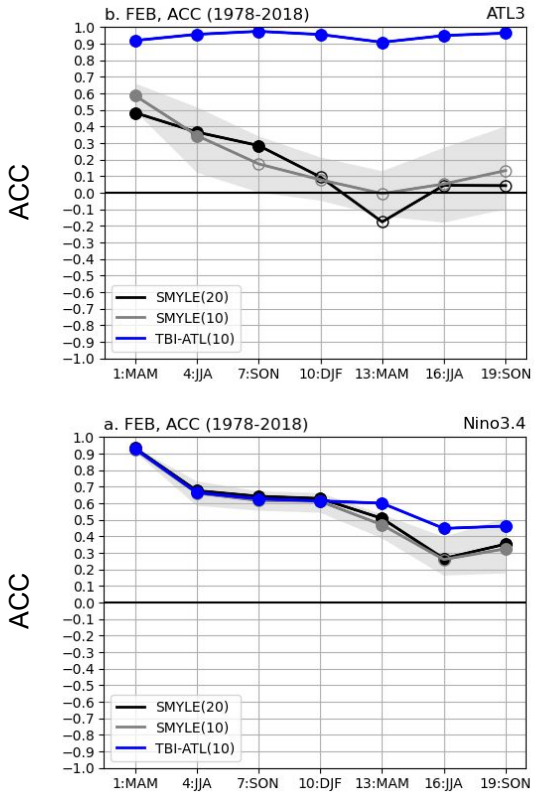
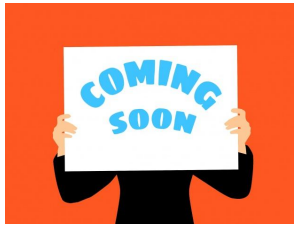
SST Skill:



Forecast Lead (months) : Target Season

ESPWG Production Datasets



(inquire for access)

- CESM2 **multidecadal prediction (MDP)** reforecasts
  - Extensions of CESM2-DP
  - 10-member, 20-year ensembles initialized Nov. 1 {1960,1965,…,2015, 2023}
  - Contributed to EU-ASPECT multi-model study

ESPWG Ongoing & Future Work

- CESM2 S2S/CAM6 sensitivity reforecasts
  - DART atmosphere/land initialization (Glanville/Raeder)
  - stochastic physics & assimilation-based nudging (Berner/Chapman)
  - machine-learned online error correction (Berner/Chapman)
  - land-atmosphere coupling (Fowler/Richter/Glanville)

- Decadal prediction mechanism experiments
  - coupled ensemble experiments with MOV-based “external” forcing
  - in support of DCPP protocol for CMIP7

- Support the CESM-wide collective effort to test CESM3 in initialized prediction mode
  - perform limited sample hindcast sets to compare against CESM2-S2S, CESM2-SMYLE
  - production hindcasts in 2026?

- Advance capability for initialized prediction case studies

Towards Initialized Prediction Case Studies

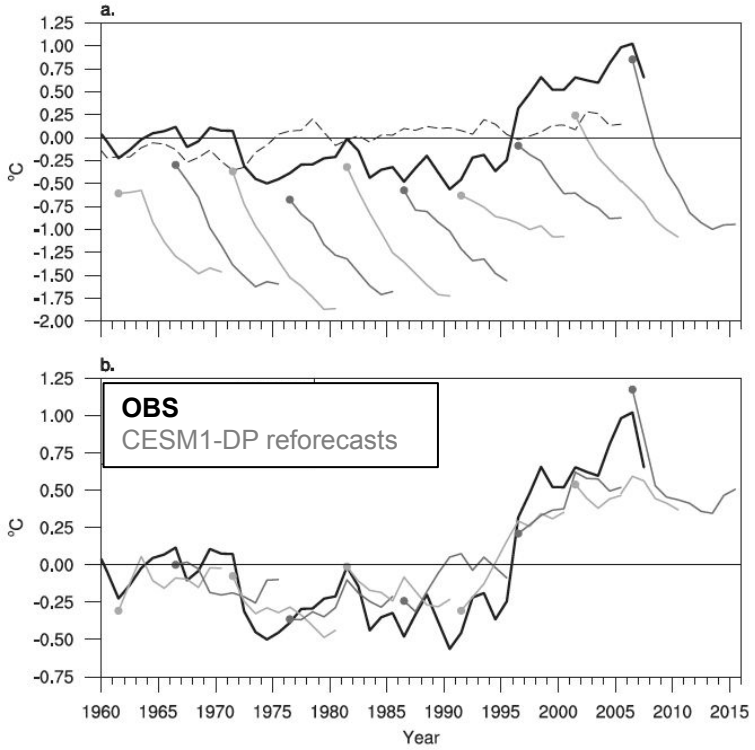
- Full-field initialization conflates initial condition signal and drift, complicating skill assessment

Method 1: $f'(\tau) = f(\tau) - \overline{OBS}$

(assumes model is bias-free and forecasts have no drift)

Method 2: $f'(\tau) = f(\tau) - \overline{f(\tau)}$

(requires large set of reforecasts)



Towards Initialized Prediction Case Studies

Work supported by
NOAA OAR-CPO

Method 3*: $f'(\tau) = f(\tau) - F(\tau)$

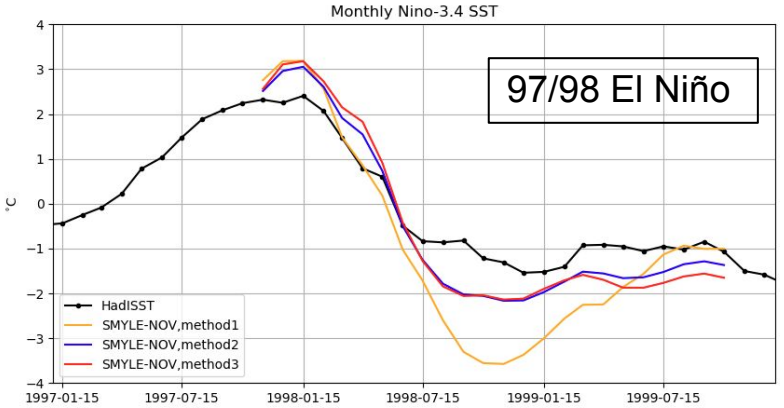
where F is a climatology-initialized reforecast

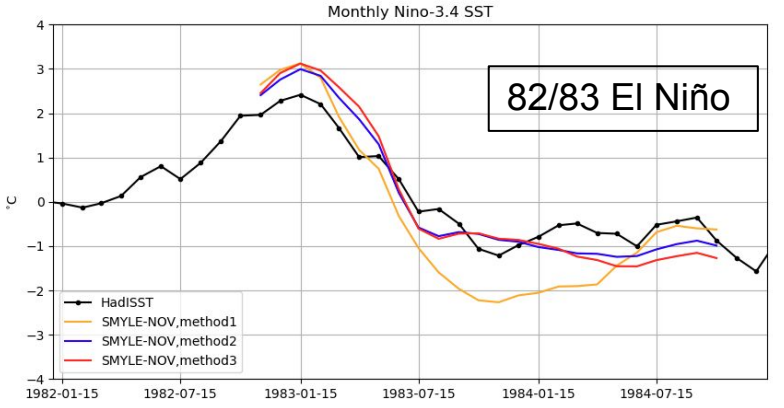
* In collaboration with Yuanpu Li and Xian Wu

- Cost comparison (20-member, 12-month reforecast):
  - Method 1: 20 sim-year
  - Method 2: 600 sim-year
  - Method 3: 40 sim-year

- Work is ongoing to assess efficacy of method across subseasonal, seasonal, and decadal timescales

- Prediction case studies as a potential new tool for model development & parameter testing?





ESPWG session on Wednesday

- Talks span a broad spectrum of disciplines, models, & methods

ocean

atmosphere

land

ML/AI

Wednesday, February 5th, Main Seminar Room

** All times are MST; **Speakers**: please leave 5 min at the end of your slot for questions.*

Time	Topic	Speakers
9:00	Predictability of tropical Pacific decadal variability is dominated by oceanic Rossby waves	Xian Wu (Remote)
9:20	North Pacific meridional mode has larger impacts on El Niño evolution than the March Madden-Julian Oscillation	Yu Liang (Remote)
9:40	Predictability of the 2020 Strong Vortex in the Antarctic Stratosphere and the Role of Ozone	Julie Arblaster
10:00	Ensemble reuse: Impact of soil moisture guided ensemble sub-selection on the forecast skill of air temperature	Daisuke Tokuda
10:20	BREAK	
10:40	An Earth-System-Oriented View of the S2S Predictability of North American Weather Regimes	Jhayron Perez (Remote)
11:00	Can Transfer Learning be Used to Identify Tropical State-Dependent Bias Relevant to Midlatitude Subseasonal Predictability?	Kirsten Mayer
11:20	Developing a Framework for Evaluating Sources of Predictability for Extreme Events on Subseasonal Timescales in Southeast Asia & Latin America	Gabrielle Brown (Remote)
11:40	An optimal strategy for GEOS-S2S-3 ensemble forecasts	Andrea Molod (Remote)
12:00	LUNCH	
1:00	Investigating the limited role of land on atmospheric predictability in CESM2	Meg Fowler
1:20	Do AI Models Produce Better Atmospheric River Forecasts than Physics Based Models? A Quantitative Evaluation	Isaac Davis
1:40	ESPWG Discussion	
2:00	BREAK	