Earth System Prediction using CESM

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NCAR

July 14, 2023

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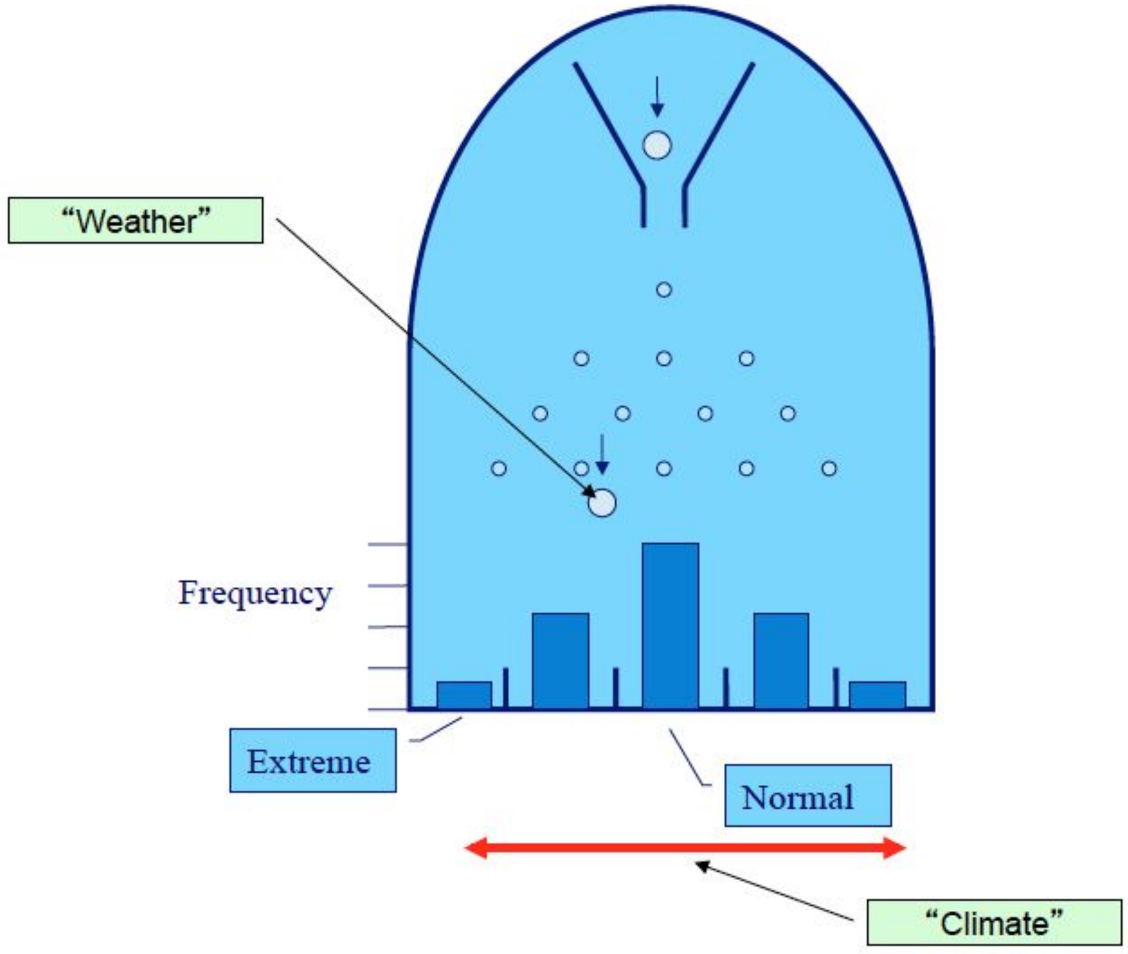
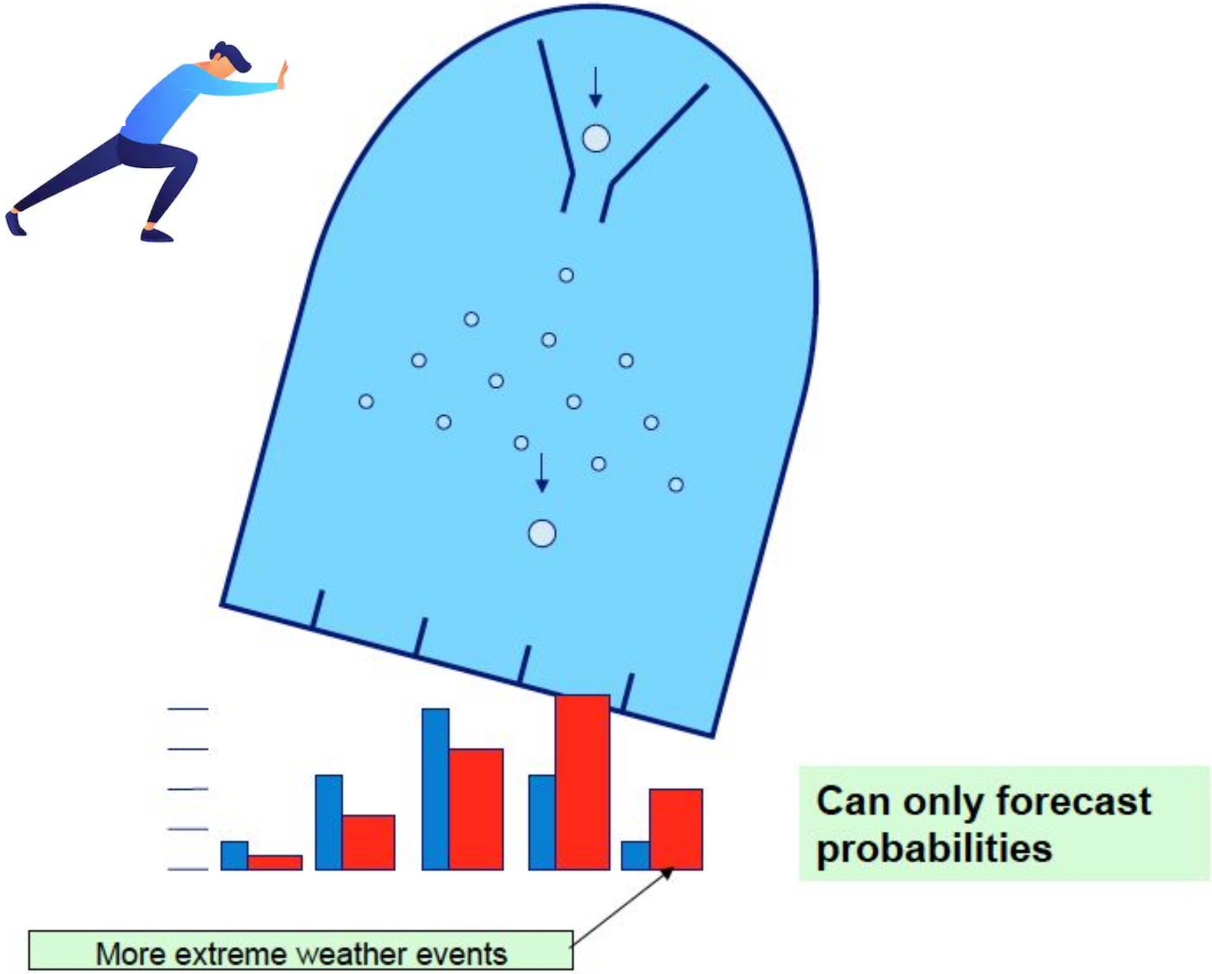
If we can’t predict weather beyond 1-2 weeks, how can we say anything about what will happen in the next few months, years, or decades?

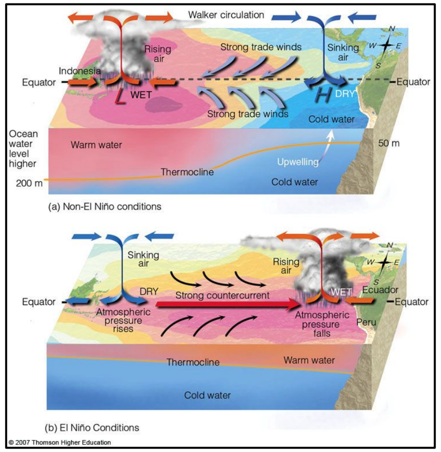
Answer: use CESM for
climate prediction, not weather prediction!



Greenhouse
Gas Emissions

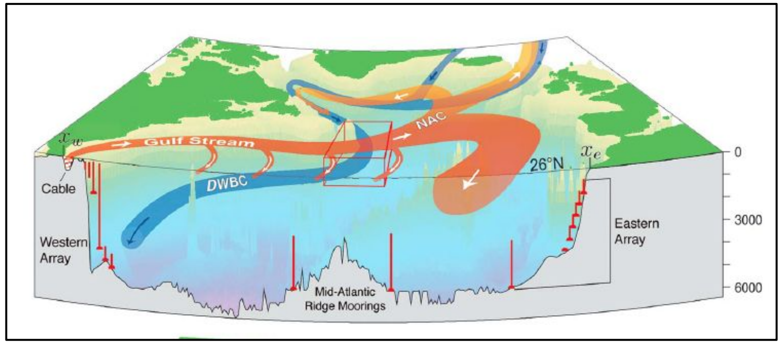


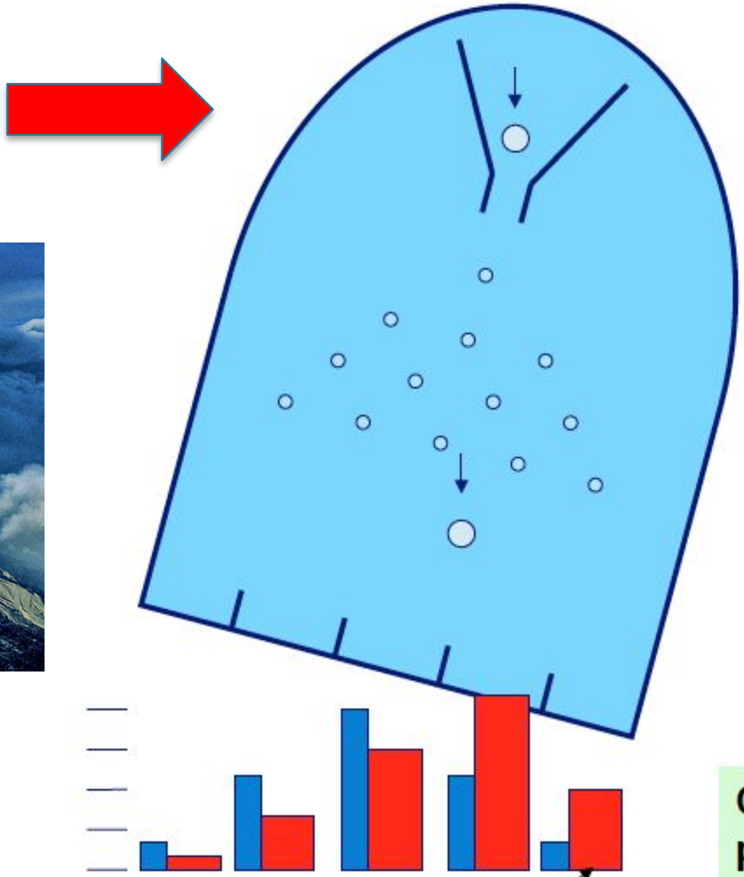
ENSO Cycles



Volcanic Eruptions

Ocean Heat Transport

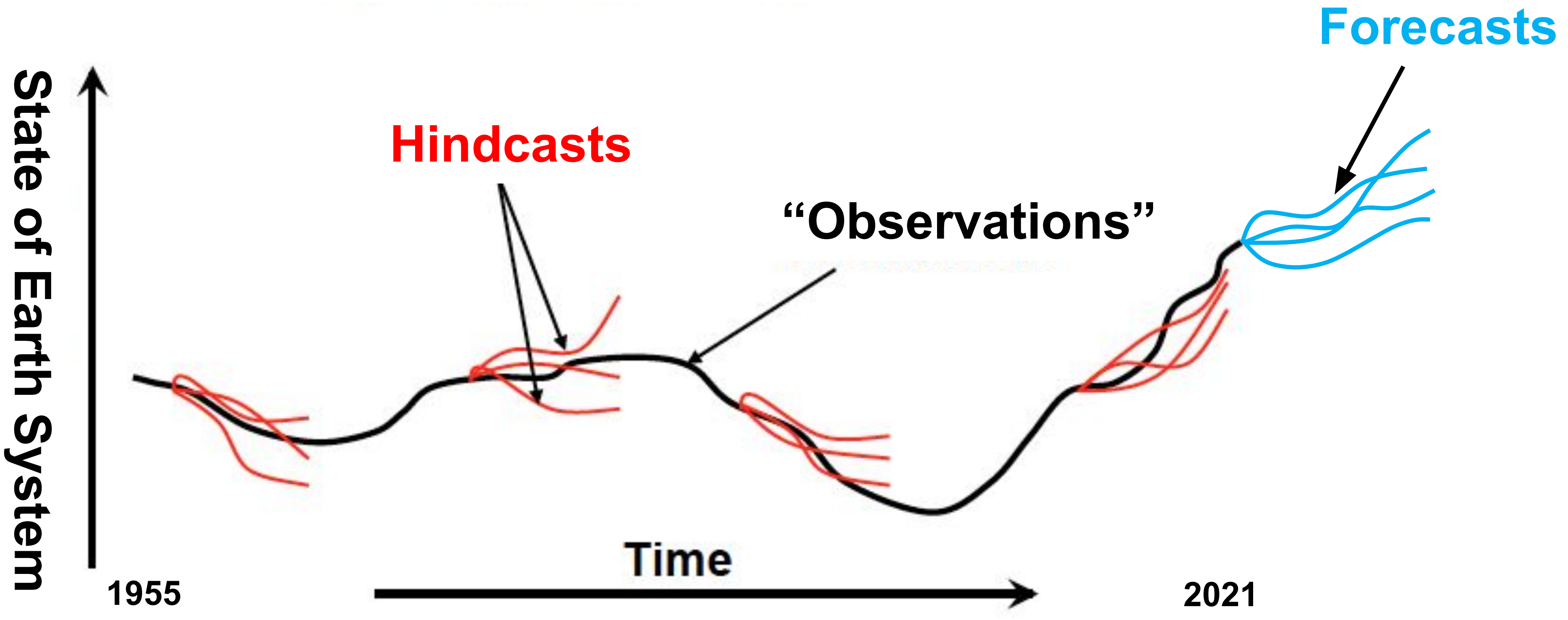




Can only forecast probabilities

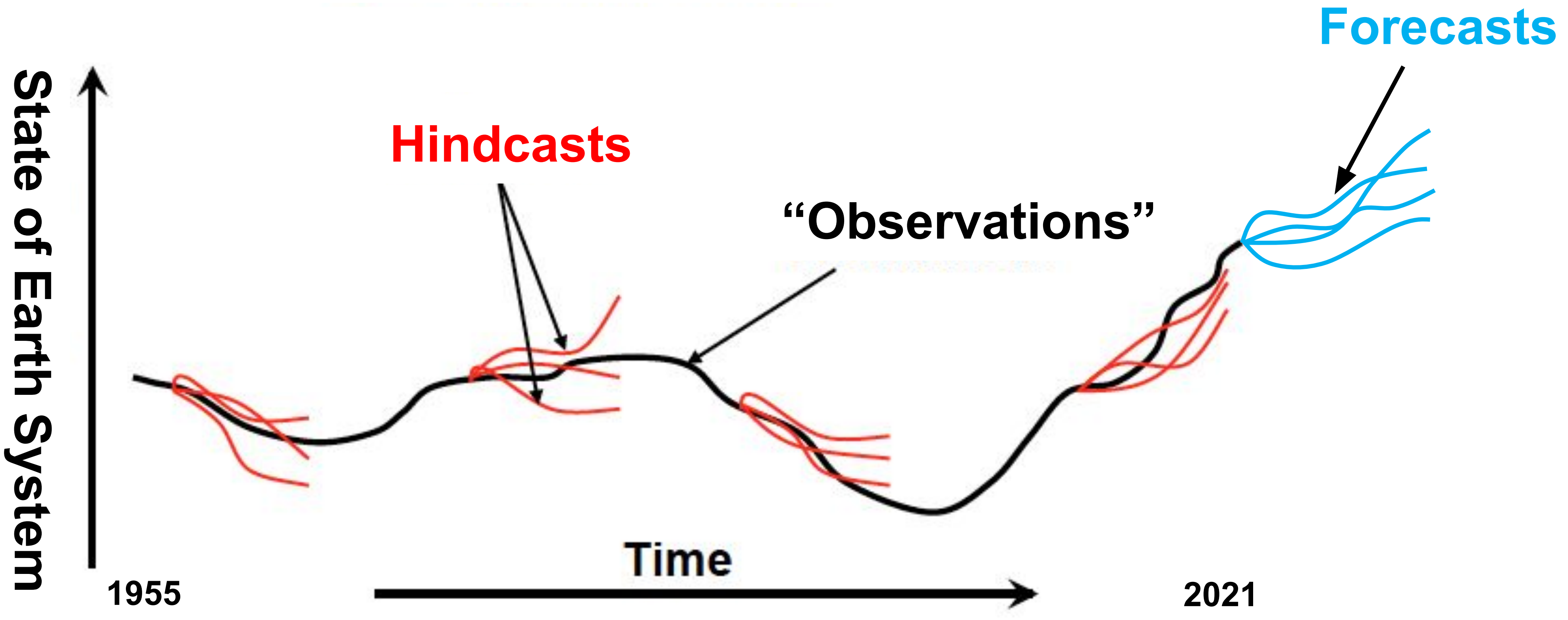
More extreme weather events

How does climate prediction work?



1. Initialize climate model simulations from an estimate of the historical Earth system state
2. Force the simulations with observed external forcings
3. Repeat steps #1-2 many times, to generate a collection of "hindcasts".
4. Use hindcasts to evaluate model skill at predicting past change.
5. If model has hindcast skill, then forecasts (using projected forcings) of future change are more credible.

How does climate prediction work?



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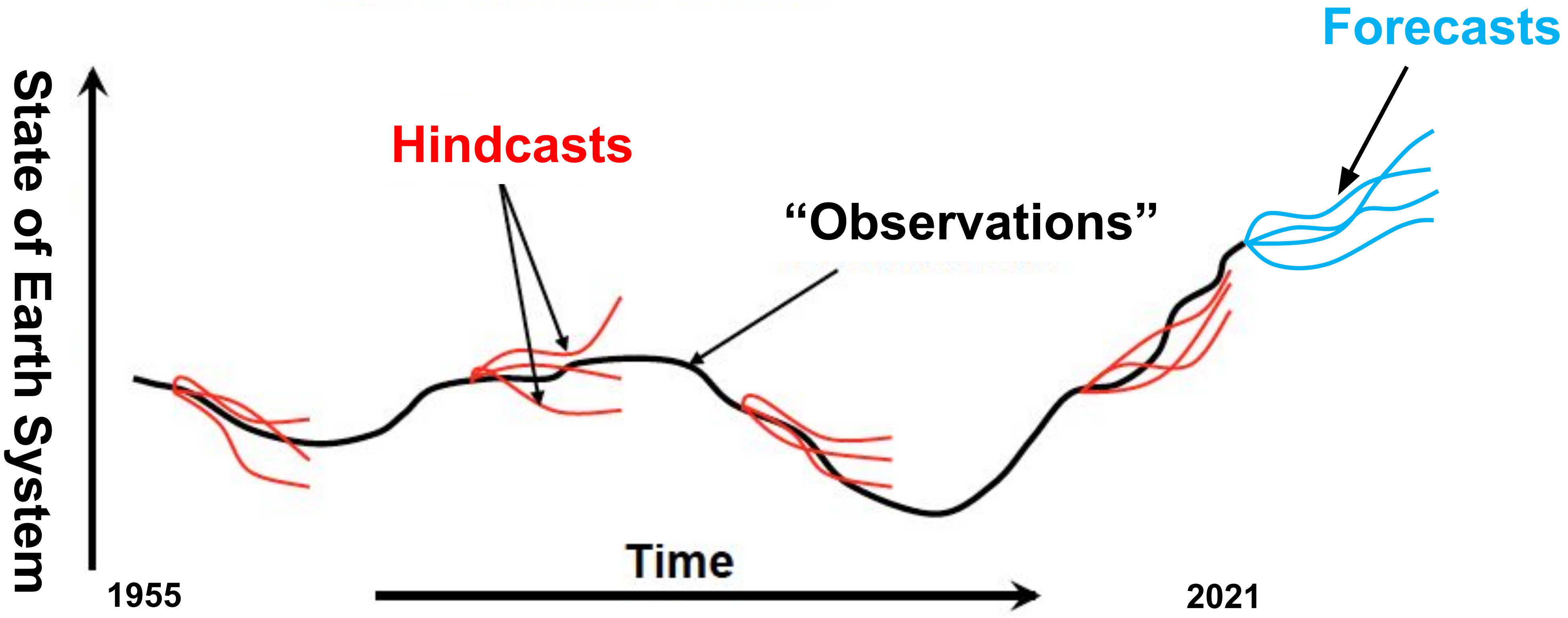
 This helps in predicting the **internal** variability

How does climate prediction work?



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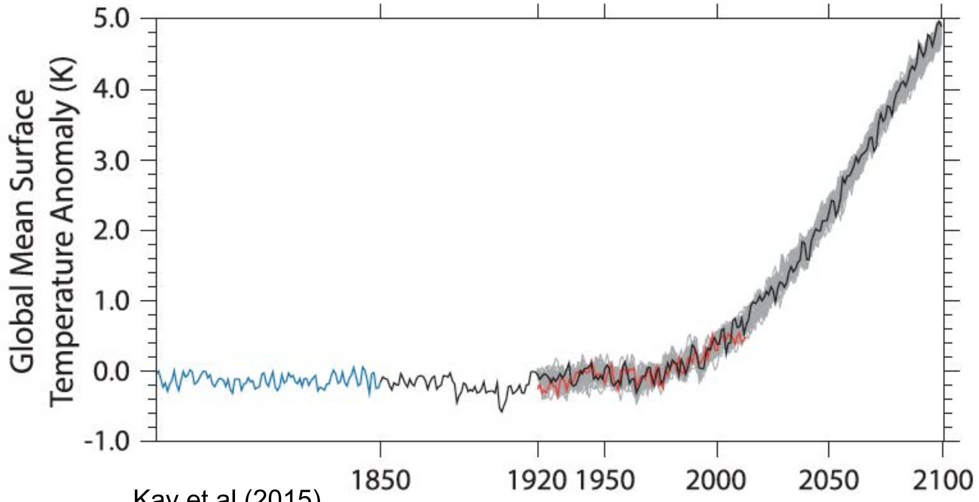
5. If model has hindcast skill, then forecasts (using projected forcings) of future change are more credible.

□ This helps in predicting the **forced** variability & change

Two Kinds of Climate Prediction Systems with CESM

“Uninitialized”

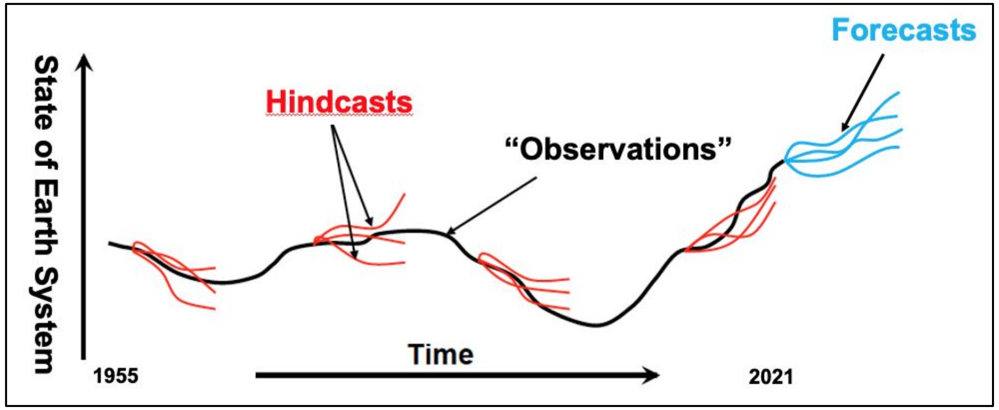
- The CESM Large Ensemble (LE)
- Skill comes from correctly simulating **forced** variability & change
- Expect skill for long timescales, large spatial scales



Kay et al (2015)

“Initialized”

- The CESM Decadal Prediction Large Ensemble (DPLE)
- Skill comes from correctly simulating both **forced** & **internal** components
- Expect better skill for short timescales, small spatial scales

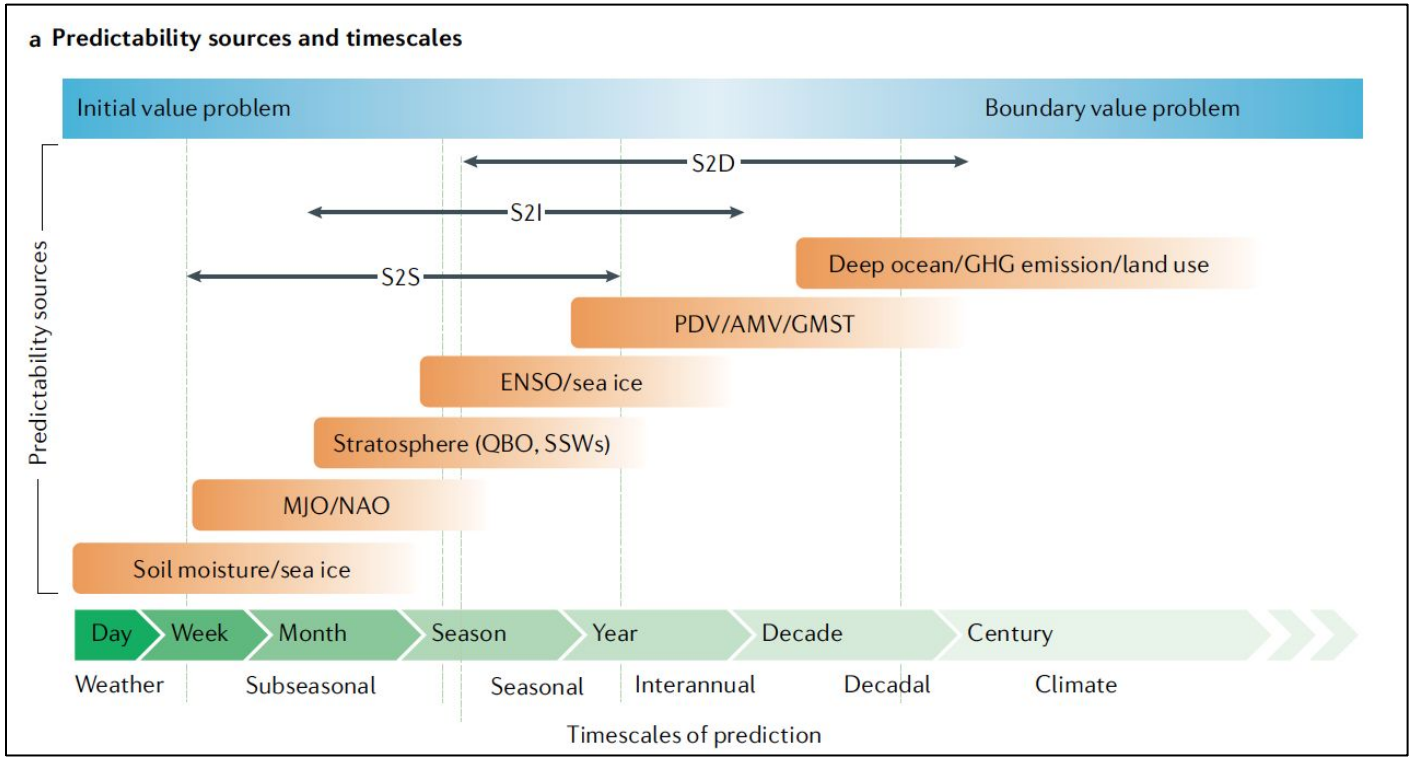


Initialized Earth System Prediction with CESM

- The CESM Earth System Prediction Working Group (ESPWG) started in 2020 to coordinate initialized prediction research across the CESM community

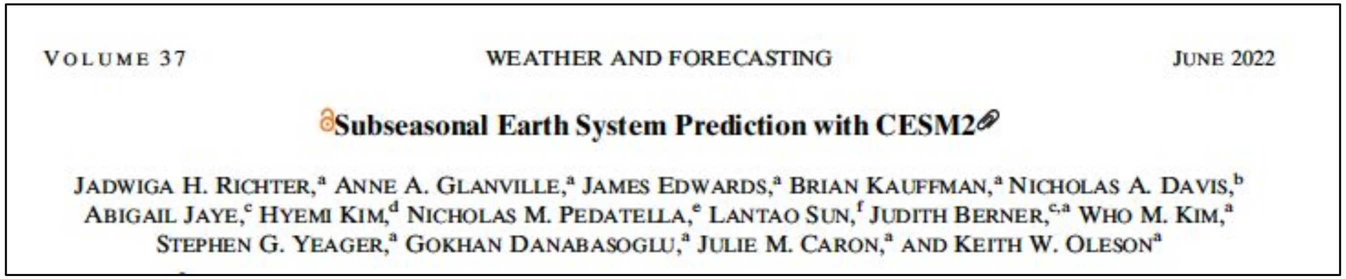
- A community nexus for research into:
  - the fundamental origins, mechanisms, and limits of Earth system predictability
  - the fidelity of coupled model behavior
  - the potential to deliver reliable, actionable advanced warning of near-term regional environmental change

Initialized Prediction **Forced Projection**



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

S2S Prediction with CESM



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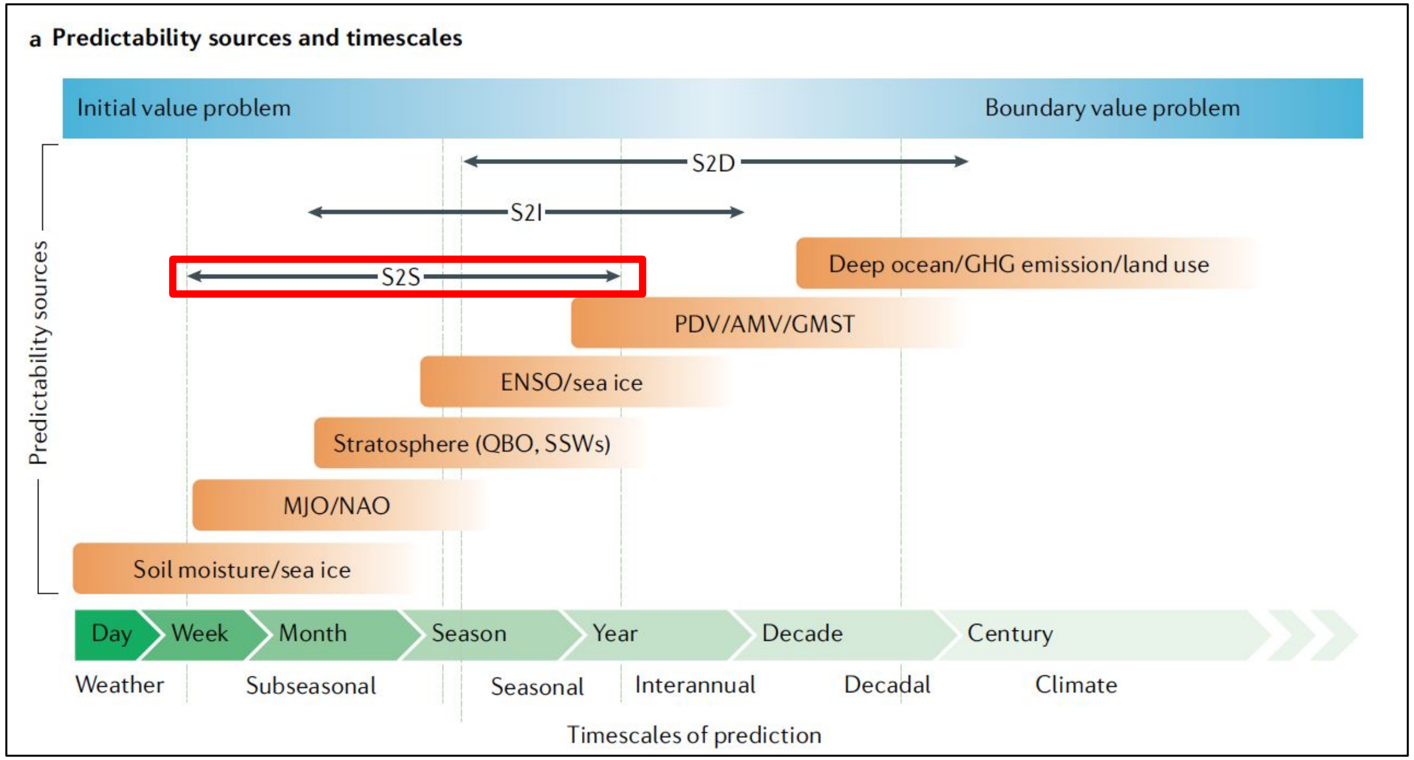
Subseasonal Earth System Prediction with CESM2

JADWIGA H. RICHTER,[a] ANNE A. GLANVILLE,[a] JAMES EDWARDS,[a] BRIAN KAUFFMAN,[a] NICHOLAS A. DAVIS,[b] ABIGAIL JAYE,[c] HYEMI KIM,[d] NICHOLAS M. PEDATELLA,[e] LANTAO SUN,[f] JUDITH BERNER,[c,a] WHO M. KIM,[a] STEPHEN G. YEAGER,[a] GOKHAN DANABASOGLU,[a] JULIE M. CARON,[a] AND KEITH W. OLESON[a]

S2S system design:

- Weekly initializations (1999-2020)
- 45-day simulations
- 10-member ensembles

 ~1,600 sim-years



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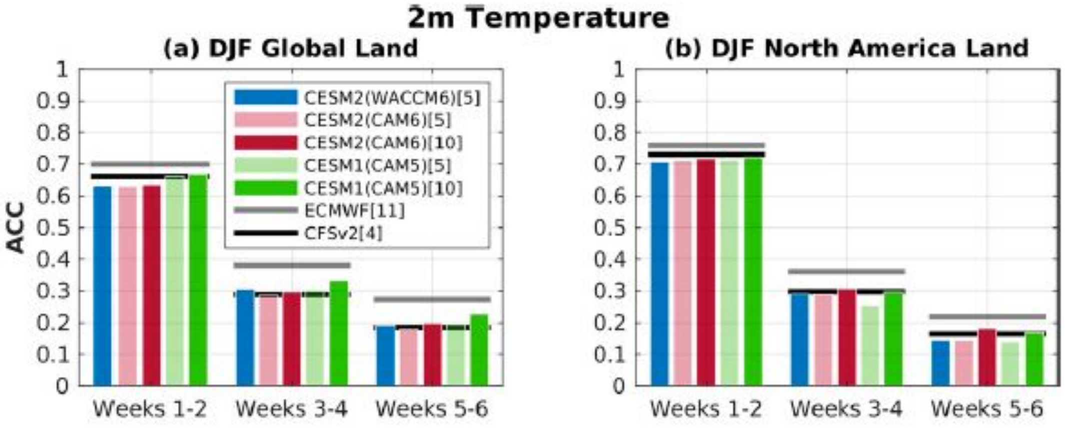
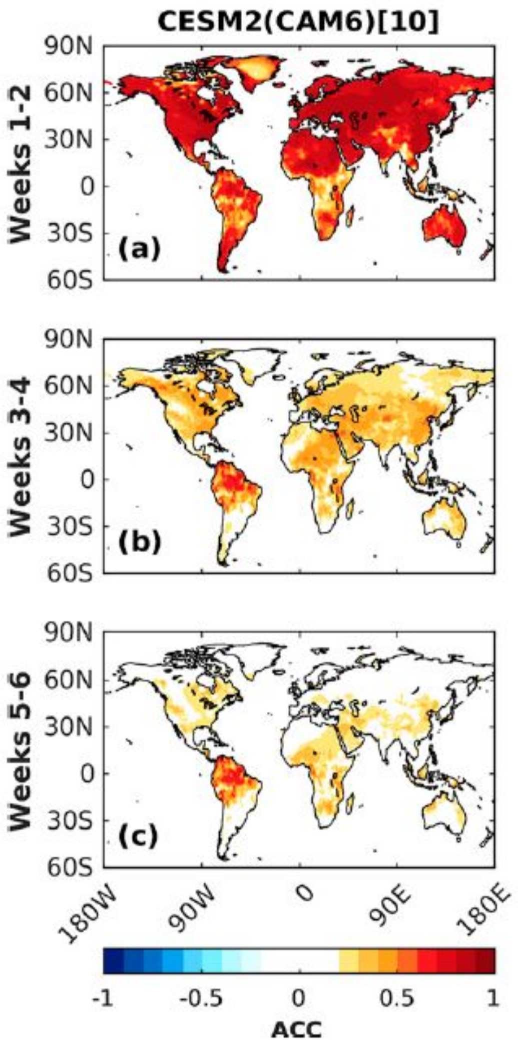
S2S Prediction with CESM

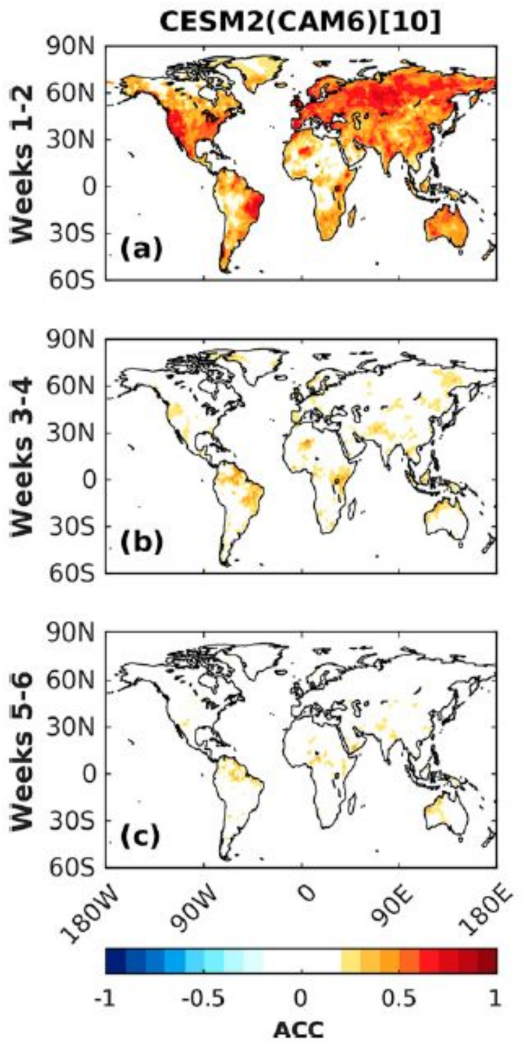


- Much lower skill for precipitation than temperature, consistent with previous findings
- CESM systems comparable to (or slightly better than) CFSv2; slightly lower than ECMWF

DJF 2m Temperature:

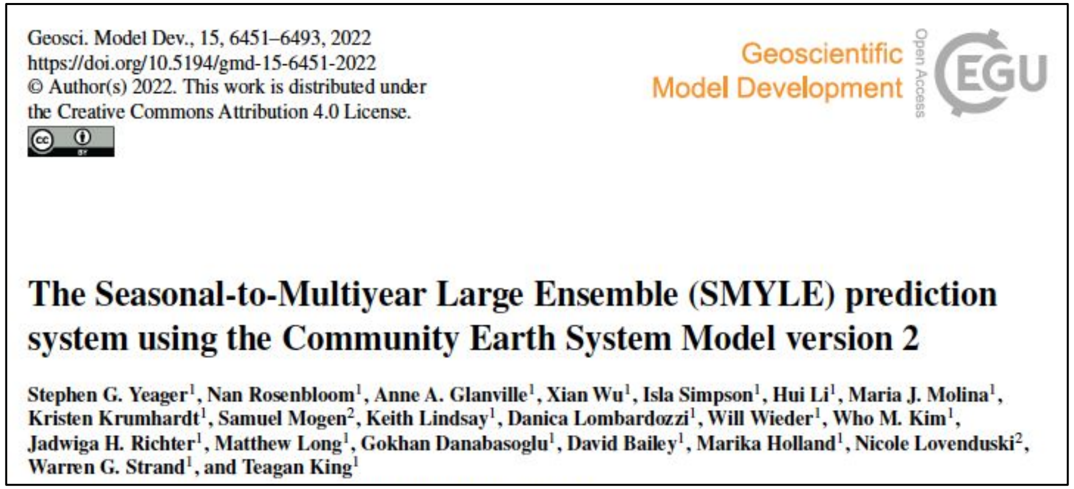


DJF Precipitation:



Richter et al. (2022)

S2I Prediction with CESM


Geosci. Model Dev., 15, 6451–6493, 2022
https://doi.org/10.5194/gmd-15-6451-2022
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Geoscientific Model Development
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EGU

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

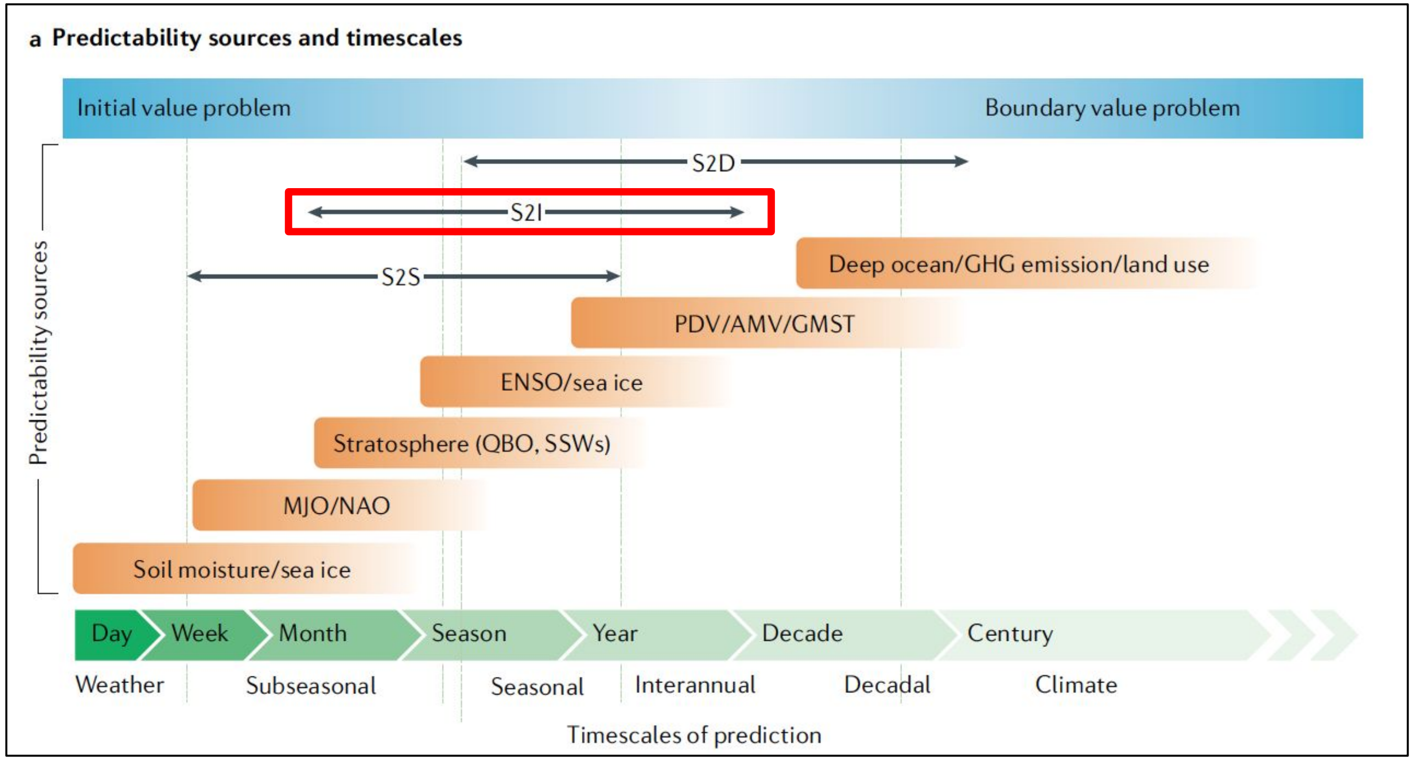
Stephen G. Yeager[1], Nan Rosenbloom[1], Anne A. Glanville[1], Xian Wu[1], Isla Simpson[1], Hui Li[1], Maria J. Molina[1], Kristen Krumhardt[1], Samuel Mogen[2], Keith Lindsay[1], Danica Lombardozzi[1], Will Wieder[1], Who M. Kim[1], Jadwiga H. Richter[1], Matthew Long[1], Gokhan Danabasoglu[1], David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

"CESM2-SMYLE"

S2I system design:

- Quarterly initializations (1st of Nov/Feb/May/Aug 1958-2020)
- 24-month simulations
- 20-member ensembles

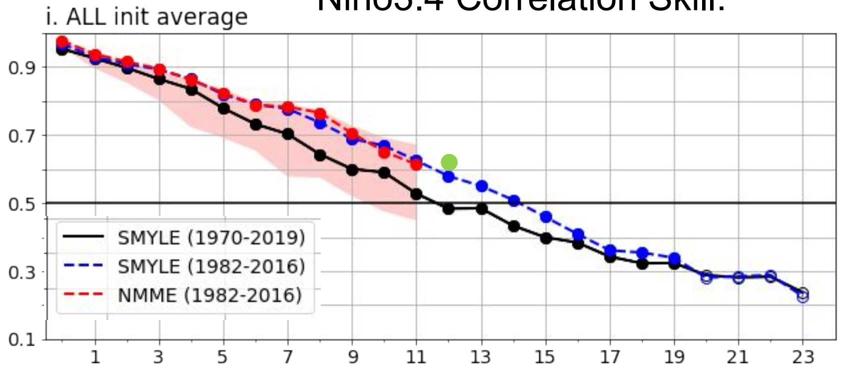
□ ~10,000 sim-years



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

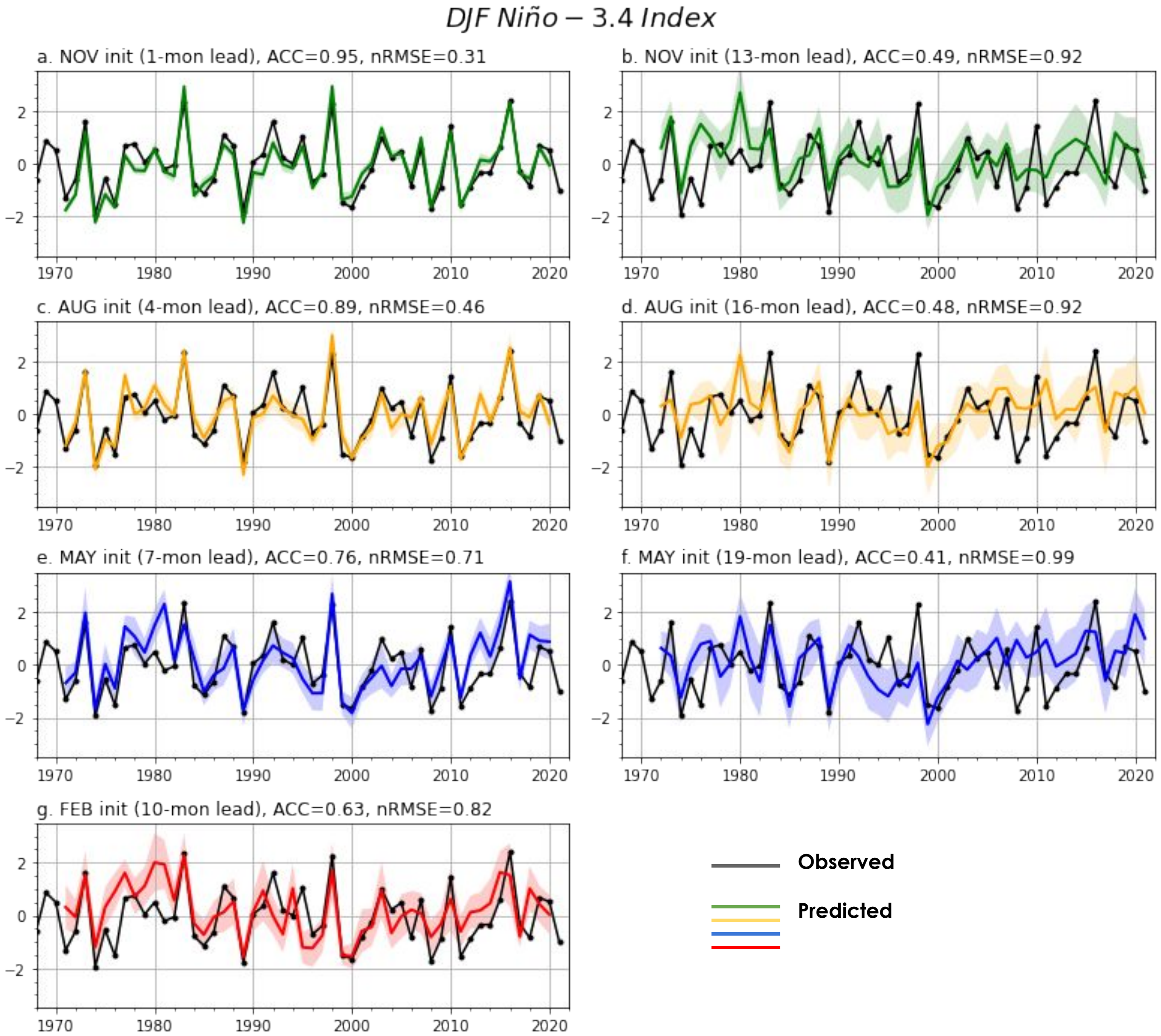
S2I Prediction with CESM

Nino3.4 Correlation Skill:



- CESM2-SMYLE is competitive with other leading ENSO prediction systems (NMME, ECMWF)

Yeager et al. (2022)



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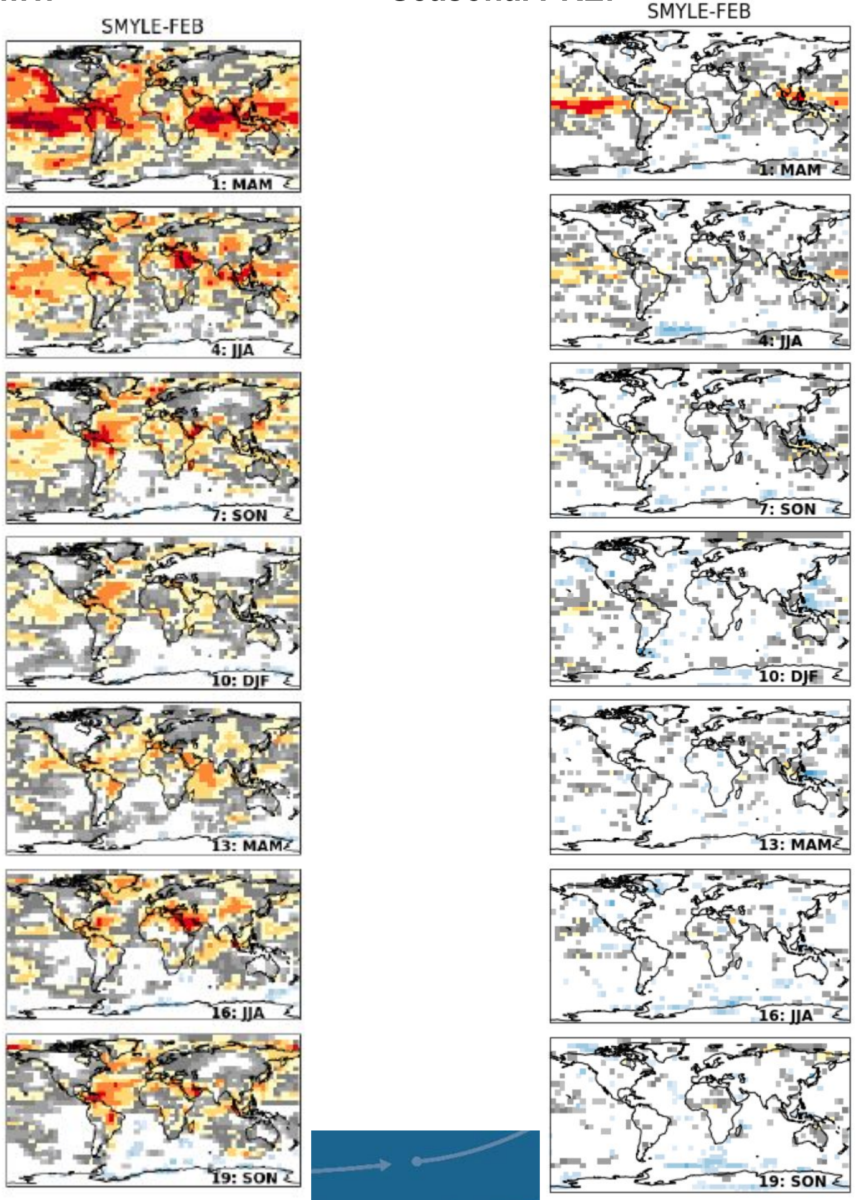
S2I Prediction with CESM

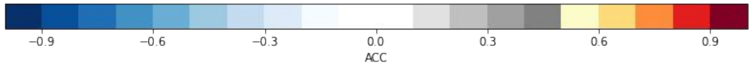
- Why does high ENSO skill not translate into high precipitation skill (over land)?

Seasonal 2mT:

Seasonal PRE:

Lead Month:
Target Season





Yeager et al. (2022)

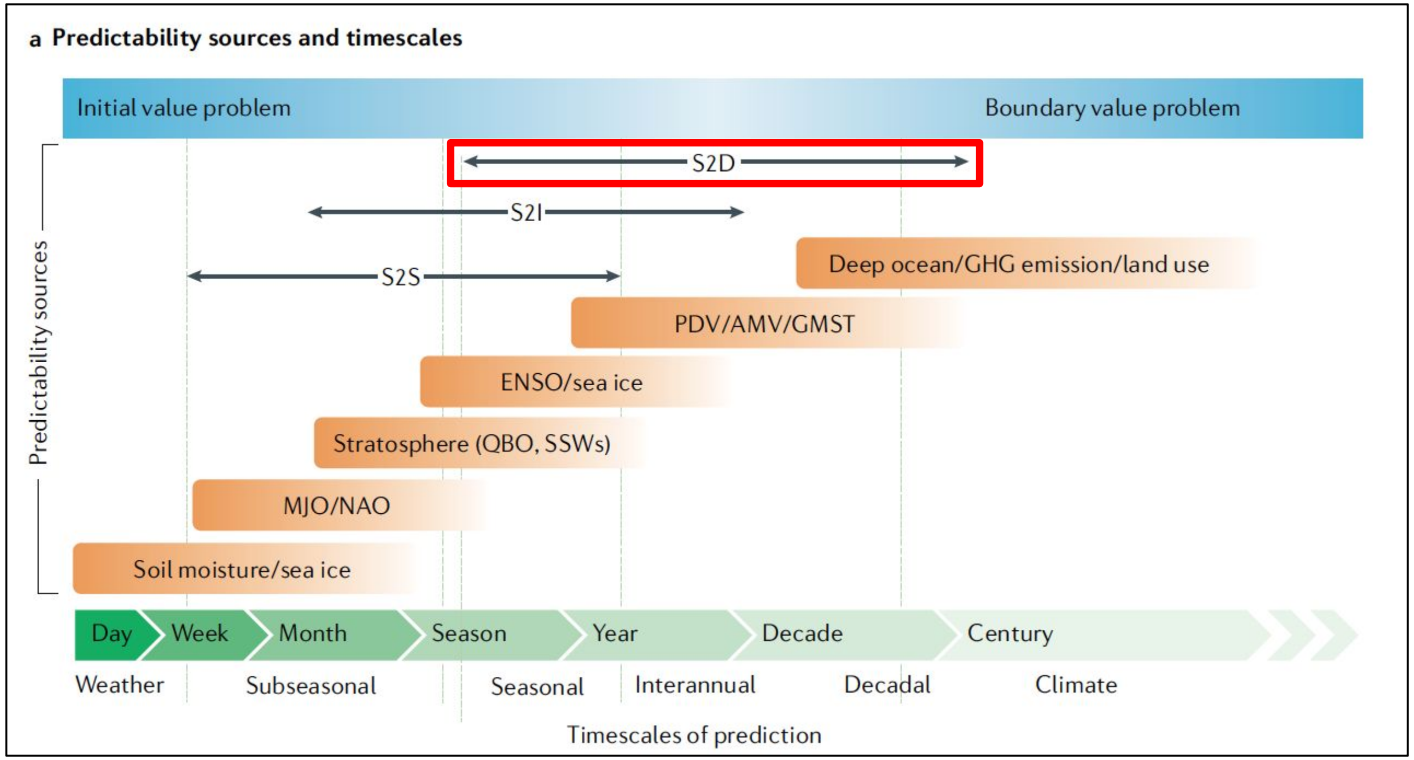
S2D Prediction with CESM

PREDICTING NEAR-TERM CHANGES IN THE EARTH SYSTEM

A Large Ensemble of Initialized Decadal Prediction Simulations Using the Community Earth System Model

S. G. Yeager, G. Danabasoglu, N. A. Rosenbloom, W. Strand, S. C. Bates, G. A. Meehl, A. R. Karspeck, K. Lindsay, M. C. Long, H. Teng, and N. S. Lovenduski

BAMS 2018



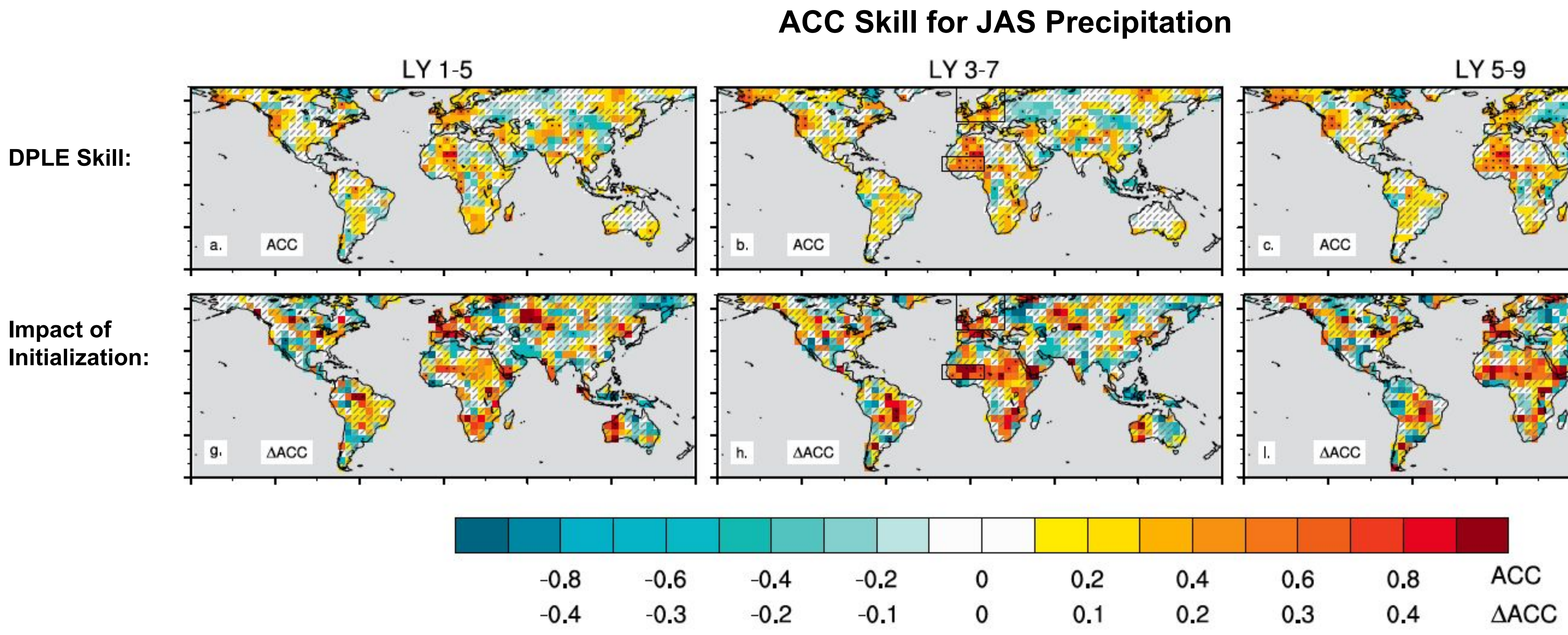
"CESM1-DPLE"

S2D system design:
- Annual initializations (Nov. 1st 1954-2020)
- 122-month simulations
- 40-member ensembles

□ ~27,000 sim-years

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

S2D Prediction with CESM

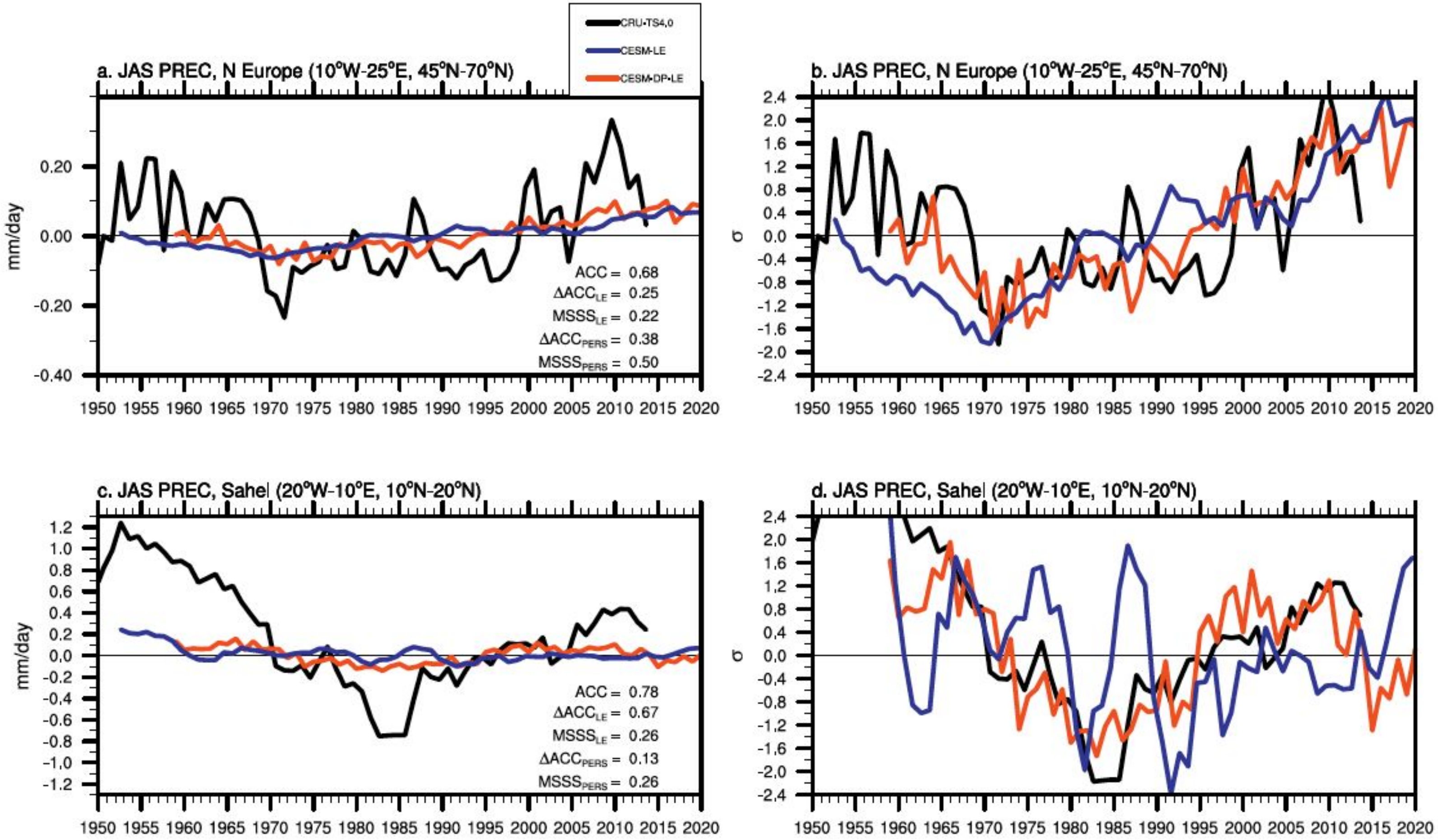


- Evidence of decadal "initialization shock"
- High skill (and clear benefit of initialization) in select regions (Sahel, N. Europe)

Yeager et al. (2018)

S2D Prediction with CESM

- DPLE LY3-7
- Skillful PRE predictions, but amplitude is weak (signal-to-noise paradox)



Yeager et al. (2018)

Interested?

- **Get involved in the CESM Earth System Prediction Working Group (ESPWG)!**

  website: https://www.cesm.ucar.edu/working_groups/earth-system-prediction/

  mailing list: http://mailman.cgd.ucar.edu/mailman/listinfo/cesm-espwg

  co-chairs: Steve Yeager (yeager@ucar.edu), Yaga Richter (jrichter@ucar.edu),
  Kathy Pegion (kpegion@gmu.edu)