# **Earth System Prediction with CESM**



Elizabeth Maroon Oceanography Section, CGD August 6, 2019



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## What is Earth System Prediction?

*Earth System*: the integrated system of physical, chemical, and biological processes in the atmosphere, ocean, land, biosphere, cryosphere, ...

**Prediction**: a declaration or indication in advance, especially on the basis of observations, experience, or scientific reasoning (*Merriam-Webster*)



## A first prediction: climatology with stationary conditions





## A first prediction: climatology with stationary conditions





## A better prediction using initial conditions





## Adding in external forcing





## Adding in external forcing





## A prediction using both initial conditions and external forcing





# Relative importance of initial conditions versus external forcing depends on timescale



### **Predictions**

Projections

From Meehl et al. (2009)



## How to make a prediction?

#### **Statistical Models:**

Regressions, linear trends, etc. Linear Inverse Models Analog Methods Machine Learning Physical models: Weather models (WRF, MPAS, GFS...) Hydrologic models Climate/Earth System models (like CESM)



# Components of the Earth System contribute to predictability at different timescales



from research.noaa.gov



## **Seasonal Prediction with CESM**

- NCAR's CESM1 is participating in the North American Multi-Model Ensemble (seasonal prediction)
- NCAR's CESM1 is showing really good skill in US precipitation forecast



Michael Ventrice @MJVentrice · 22h

New kid on the block model (NCAR CESM; recently added into the NMME suite) absolutely nailed the US Summer (JAS) forecast. Kudos to NCAR.



Contacts: Julie Caron & Joe Tribbia



## **Subseasonal to Seasonal (S2S) Prediction**

- S2S hindcasts were carried out with the default and 46-level (higher top) CESM1:
- Weekly starts, every Wed between 1999 and 2015, 45-day long runs x10 ensembles
- CESM1 has better skill than most SubX (Subseasonal Experiment) models and increases the skill of the multi-model mean
- Similar hindcast set will be generated with CESM2



Contacts: Yaga Richter



# Interannual to Decadal Prediction with CESM CESM Decadal Prediction Large Ensemble (DPLE)



CESM-DPLE described in Yeager et al. (2018) CESM-LE described in Kay et al. (2015)

Figure courtesy Lovenduski

Contacts: Stephen Yeager



## **Examples of CESM-DPLE Applications**

Sahel precipitation



Yeager et al. (2018) Maroon et al. (in prep.)

Ocean acidity



Brady et al. (in prep.)





Lovenduski et al. (in prep.)

European precip



Simpson et al. (2019)

### Phytoplankton



Krumhardt et al. (in prep.)

## Ocean carbon uptake



Lovenduski et al. (2019)

## Jet biases





## Many open questions for research...

- Where/why do we expect and have prediction skill, and where/why is there *not* skill?
- How much predictability stems from external forcing versus initial conditions as a function of timescale?
- What are the sources of predictability for various predictors, and what are the timescales?
- What's the best method to initialize CESM for Earth System Prediction to minimize drift and initialization shock?
- How to best statistically find signals in initialized ensembles?

emaroon@ucar.edu

@lizthered



