A Community Project: Extending CESM-LE to Include Uncertainty due to Ocean Initial Conditions

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• A CESM community project
  – 30+ ensemble members for historical (1920-2005) and RCP8.5 (2006-2100) simulations along with the 2200-yr long 1850 control

• To investigate climate change in the presence of internal climate variability (Kay et al. 2015, BAMS)
  – Key issue: how to sample internal climate variability?

round off T perturbations in air temp.
Motivation

Probability of a cooling trend
First 20 yr  First 30 yr

* Each 1% CO₂ increase simulation starting with different ocean initial conditions and 50 ensemble members are generated by perturbing SST

Hawkins et al., submitted to Clim. Dyn.

- The ocean has a relatively long “memory” (~decadal time scales)
- Spread and uncertainty of internal variability are expected to be large when considering different ocean initial conditions (OICs)
• Start from different ICs from 1850 control (496) for all components (First ensemble member)
• Generate ensemble members in 1920 as for the existing CESM-LE
• 10 members are integrated to 1999 (historical simulations only)
• Otherwise, followed the CESM-LE protocol (https://www2.cesm.ucar.edu/models/experiments/LENS/instructions)
Selecting Initial Conditions

AMOC EOF1 in 1850 CTRL (300-599)

New E#1

Old E#1

New E#1

Old E#1
Selecting Initial Conditions

Differences (old – new) in initial temperature (upper 1000m) in 1920

SST regression on AMOC PC1* (1850 CTRL)

* AMOC PC1 leads $T_s$ by 2 years
AMOC

AMOC at 26.5ºN

2.5th – 97.5th percentile range of 2000-times randomly selected 10 ensemble members

Upper 1000m temperature over the subpolar NA

* Anomalies are with respect to the 1951-1980 mean
Global Surface Air Temperature ($T_s$)

Global mean (annual) $T_s$ anomalies (wrt 1951-1980)

First n-yr trends from 1920

10-yr trends
1920-1970 Sea-ice concentration trends

Old LE (all 30 members)
DJF $T_s$ in western Europe

10-yr trends

15-yr trends

Trend & Spread [Million km$^2$ dec$^{-1}$]
Varying ocean initial states have strong implications on, from hemispheric scale to regional scale, especially in the Southern Hemisphere, 
  – “externally forced signals”
    : ensemble mean time series are significantly different, leading to substantially different long-term trends 
  – Distribution of short-term (decadal) trends

The differences, at least for the long-term trends, likely related to differences in ocean initial states (heat contents) associated with different AMOC states

Is distribution of short-term trends significantly different from that of old LE? If so, is it ultimately due to different ocean initial states?

**Status of the new LE:** Output time series from the new LE are available on (along with the old LE) Yellowstone:/glade/p/cesmLE/CESM-CAM5-BGC-LE for selected variables
  (https://www2.cesm.ucar.edu/models/experiments/LENS/data-sets)