Recent Decadal Prediction Efforts at NCAR

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## The CESM Decadal Prediction Large Ensemble

<table>
<thead>
<tr>
<th>Experiment Name</th>
<th>CCSM4-DP</th>
<th>CESM-DP-LE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td></td>
<td></td>
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<tr>
<td>-atm</td>
<td>CCSM4</td>
<td>CESM1.1</td>
</tr>
<tr>
<td>-ocn</td>
<td>CAM4 (FV 1°, 26lvl)</td>
<td>CAM5 (FV 1°, 30lvl)</td>
</tr>
<tr>
<td>-ice</td>
<td>POP2 (1°, 60lvl)</td>
<td>POP2 (1°, 60lvl) w/ BGC</td>
</tr>
<tr>
<td>-Ind</td>
<td>CICE4 (1°)</td>
<td>CICE4 (1°)</td>
</tr>
<tr>
<td></td>
<td>CLM4</td>
<td>CLM4</td>
</tr>
<tr>
<td><strong>Uninitialized Ensemble (UI)</strong></td>
<td>6-member CCSM4 20th century ensemble (Meehl et al., 2012)</td>
<td>40-member CESM 20th century Large Ensemble (Kay et al., 2015)</td>
</tr>
<tr>
<td><strong>Forcing</strong></td>
<td></td>
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<tr>
<td>-2005: CMIP5 historical</td>
<td>-2005: CMIP5 historical</td>
<td></td>
</tr>
<tr>
<td>2006-: CMIP5 RCP 4.5</td>
<td>2006-: CMIP5 RCP 8.5</td>
<td></td>
</tr>
<tr>
<td><strong>Initialization</strong></td>
<td></td>
<td></td>
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<tr>
<td>-method</td>
<td>full field</td>
<td>full field</td>
</tr>
<tr>
<td>-atm</td>
<td>UI</td>
<td>UI</td>
</tr>
<tr>
<td>-ocn</td>
<td>CORE-forced FOSI</td>
<td>CORE*-forced FOSI</td>
</tr>
<tr>
<td>-ice</td>
<td>CORE-forced FOSI</td>
<td>CORE*-forced FOSI</td>
</tr>
<tr>
<td>-Ind</td>
<td>UI</td>
<td>UI</td>
</tr>
<tr>
<td><strong>Ensembles</strong></td>
<td></td>
<td></td>
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<tr>
<td>-ensemble size</td>
<td>10 annual; Jan. 1st 1955-2014 (N=60)</td>
<td>40 annual; Nov. 1st 1954-2015 (N=62)</td>
</tr>
<tr>
<td>-start dates</td>
<td>Variable January start days + round-off perturbation of atm initial conditions 120 months</td>
<td>round-off perturbation of atm initial conditions 122 months</td>
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<tr>
<td>-ensemble generation</td>
<td></td>
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<tr>
<td>-simulation length</td>
<td>120 months</td>
<td>122 months</td>
</tr>
</tbody>
</table>

CMIP5-era (2011)  
CMIP6-era (2017)  

25000 simulation years
Improvements over CCSM4-DP

Annual mean (LY1-5):

- ACC improvement over CCSM4-DP
- MSSS relative to CCSM4-DP
Annual Sea Surface Temperature

- Anomaly correlation coefficient (ACC)
- Skill improvement over persistence
- Skill improvement over UI

(OBS = Hurrell)
Annual Ocean Heat Content (295m)

- Anomaly correlation coefficient (ACC)
- Skill improvement over persistence
- Skill improvement over UI

(OBS = EN4)
Annual Ocean Heat Content (500m)

Hindcast skill for subpolar North Atlantic heat content:

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>CESM1-DP</td>
<td>EC-Earth (full field, low-res)</td>
<td></td>
</tr>
<tr>
<td>HadCM3</td>
<td>EC-Earth (anomaly, low-res)</td>
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<tr>
<td>HiGEM</td>
<td>EC-Earth (high-res)</td>
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<tr>
<td>MPI</td>
<td>IPSL</td>
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<tr>
<td>Persistence</td>
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</tbody>
</table>

(Figure courtesy Jon Robson)
Annual Mean Precipitation

(verified against CRU-TS 3.24)

ACC

ΔACC
(relative to persistence)

ΔACC
(relative to uninitialized)

Legend:

-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8
-0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4

ACC ΔACC
Annual Mean Precipitation

(verified against CRU-TS 3.24)
JFM Mean Precipitation (verified against CRU-TS 3.24)

ACC

ΔACC (relative to persistence)

ΔACC (relative to uninitialized)
JAS Mean Precipitation

(verified against CRU-TS 3.24)

ACC

ΔACC (relative to persistence)

ΔACC (relative to uninitialized)
Summer Precipitation Skill

a. JAS PRE, W_Europe (10°W-15°E, 43°N-58°N), LY1-5

- max
  - 95%
  - 50%
  - 5%

- min

ACC

Ensemble Size

b. JAS PRE, W_Europe (10°W-15°E, 43°N-58°N), LY1-5

\[ \sigma \]

\[ \Delta \text{ACC}_{\text{LE}} = 0.32 \]
\[ \text{MSSS}_{\text{LE}} = 0.21 \]
\[ \Delta \text{ACC}_{\text{PERS}} = 0.47 \]
\[ \text{MSSS}_{\text{PERS}} = 0.62 \]

OBS

Standard (10-member or less) ensembles can give misleading impressions regarding skill & skill improvement w.r.t. uninitialized
Summer Precipitation Skill

a. JAS PRE, W_Europe (10°W-15°E, 43°N-58°N), LY6-10

b. JAS PRE, W_Europe (10°W-15°E, 43°N-58°N), LY6-10
Winter Precipitation Skill

a. JFM PRE, Scandanavia (0°E-30°E, 55°N-70°N), LY1-5

- ACC = 0.68
- ΔACC_LE = 0.30
- MSSS_LE = 0.22
- ΔACC_PERS = 0.19
- MSSS_PERS = 0.34

b. JFM PRE, Ural (45°E-55°E, 48°N-60°N), LY6-10

- ACC = 0.57
- ΔACC_LE = 0.25
- MSSS_LE = 0.20
- ΔACC_PERS = 0.54
- MSSS_PERS = 0.62
Winter Precipitation Skill

a. JFM PRE, Scandanavia (0°E-30°E, 55°N-70°N), LY1-5

b. JFM PRE, Scandanavia (0°E-30°E, 55°N-70°N), LY1-5

a. JFM PRE, Ural (45°E-55°E, 48°N-60°N), LY6-10

b. JFM PRE, Ural (45°E-55°E, 48°N-60°N), LY6-10
Summer Precipitation in the Sahel

a. JAS PREC, Sahel (20°W-10°E, 10°N-20°N), LY3-7

b. JAS PREC, Sahel (20°W-10°E, 10°N-20°N), LY3-7

JAS PREC, Sahel (20°W-10°E, 10°N-20°N)

Lead Time (years)
Summer Precipitation in the Sahel

Net Primary Productivity (NPP)

- Anomaly correlation coefficient (ACC)
- Skill improvement over persistence
- Skill improvement over UI

verified against FOSI
Net Primary Productivity (NPP)

(Figure courtesy Nicole Lovenduski, University of Colorado)
Summary

• A new large-ensemble CESM decadal prediction ensemble\(^1\) represents the initialized counterpart to an existing large-ensemble of historical simulations\(^2\). Together, these experiments offer unprecedented statistical power for disentangling the external and internal sources of skill, exploring signal-to-noise characteristics, and studying climate extremes.

• CESM-DP-LE exhibits promising skill for a variety of fields across a range of forecast lead times up to decadal, both in the ocean and over land. Skill for surface climate over land appears to be related, at least in part, to skill at predicting SST forcing of the atmosphere, which is sustained by skillful prediction of ocean heat content. This explains the significantly improved SAT and precipitation skill scores compared to CESM-LE and CCSM4-DP (which share the same external forcing).

• Increasing the DP ensemble size results in further “micro” skill improvements by enhancing the atmospheric response to (presumably SST) forcing through noise reduction (Scaife et al. 2014; Eade et al. 2014).
