Arctic sea ice loss and warming in large initial condition ensembles (and implications for the CESM2 (CAM) Arctic “thin ice” bias)

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Sea ice and clouds off the coast of Alaska
Observed warming and Arctic sea ice loss
(updated through 2018)

Data Source: GISTEMP (Hansen et al. 2010)

Data Source: NSIDC Sea Ice Index
Can climate models reproduce observed Arctic warming and Arctic sea ice loss? Large ensembles are needed to answer this question.

Kay, Holland, and Jahn (2011, GRL)
CLIVAR Working Group on Large Ensembles

New frontiers enabled by comparing LEs.
Co-led by Clara Deser and Keith Rodgers

The Large Ensembles Workshop

July 24 – 26, 2019
Boulder, Colorado

https://usclivar.org/meetings/large-ensembles-workshop

<table>
<thead>
<tr>
<th>Model Name</th>
<th># Ens Mem</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CESM1</td>
<td>40</td>
<td>Kay et al. 2015</td>
</tr>
<tr>
<td>GFDL CM3</td>
<td>20</td>
<td>Sun et al. 2018</td>
</tr>
<tr>
<td>CANESM2</td>
<td>50</td>
<td>Kirchmeier-Young et al. 2017</td>
</tr>
<tr>
<td>CSIRO MK3.6</td>
<td>30</td>
<td>Jeffrey et al. 2013</td>
</tr>
</tbody>
</table>

Table of Large Ensemble data used here. Thanks Flavio Lehner.
Can any member reproduce observed Arctic Sea Ice Loss?

Fig 1. Time series of September Arctic Sea Ice Extent. Observations in red are the NSIDC Sea Ice Index (Fetterer et al. 2017). Ensemble mean in black, Individual ensemble members in grey.
How do the signal and the noise evolve over time?

Fig 2. Arctic September sea ice extent signal and noise
Can any member reproduce observed Arctic Warming?

Fig 3. Time series of Arctic surface air warming (base period 1950-1989). Observations in red are GISTEMP (Hansen et al. 2010). Ensemble mean in black, Individual ensemble members in grey.
How do the signal and the noise evolve over time?

Fig 4. Arctic warming signal and noise
Why? Hints that sea ice thickness important...

In the 2020s, GFDL has the largest Arctic warming and the least Arctic sea ice. In the 2020s, CSIRO has the least Arctic warming and the most Arctic sea ice.
Summary – Kay, Sala, Bodini

1. Arctic sea ice thickness controls both the internal climate variability ("noise") and the forced response ("signal"). Large initial condition ensembles show models with thin Arctic sea ice in the 2020s have more Arctic sea ice loss/warming but also more sea ice/temperature variability. Feedback very welcome...
<table>
<thead>
<tr>
<th></th>
<th>Reproduce observed Arctic warming?</th>
<th>Reproduce observed Arctic sea ice loss?</th>
</tr>
</thead>
<tbody>
<tr>
<td>CESM1</td>
<td>Yes.</td>
<td>Yes.</td>
</tr>
<tr>
<td>CanESM</td>
<td>Yes.</td>
<td>No. Trend ok, but insufficient sea ice extent.</td>
</tr>
<tr>
<td>GFDL</td>
<td>Barely. Excessive warming.</td>
<td>Almost. Hints that sea ice loss is faster than observed.</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Barely. Insufficient warming.</td>
<td>Much slower ice loss than observed.</td>
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