CESM1 Single Forcing Ensembles

Thanks to: Nan Rosenbloom, Dani Coleman, Gary Strand, and Isla Simpson for running and postprocessing

Available on the ESG

Clara Deser, CVCWG Winter Meeting, 27 Feb 2019
CESM1 Single Forcing Ensembles
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Identical model configuration and forcings as the CESM1 Large Ensemble (LENS; Kay et al., 2015) except:
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Identical model configuration and forcings as the CESM1 Large Ensemble (LENS; Kay et al., 2015) except:

1) GHG held fixed at 1920 levels (20 members)

2) Anthropogenic aerosols held fixed at 1920 levels
   a) Energy sector (20 members)
   b) Biomass burning (15 members; to 2030)
CESM1 Single Forcing Ensembles

Infer GHG and anthropogenic aerosol influences by subtracting from all-forcing LENS

\[
\begin{align*}
\text{LENS} - \text{fixed GHG} & \quad \Rightarrow \quad \text{inferred GHG influence} \\
\text{LENS} - \text{fixed AER} & \quad \Rightarrow \quad \text{inferred AER influence}
\end{align*}
\]
Some Results and Guiding Questions

1. What are the relative contributions of anthropogenic aerosols and greenhouse gases to evolving historical climate trends in the CESM1 Large Ensemble?

2. How many ensemble members are needed to detect the forced responses?

Focus: 50-year trends in annual precipitation and SST

*Deser et al., in preparation for J. Climate*
Ensemble Mean Precipitation Trends

Stippled areas insignificant (95%)

LENs

1930-1980

1950-2000

1970-2020
Ensemble Mean Precipitation Trends

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Ensemble Mean Precipitation Trends

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Stippled areas insignificant (95%)

Ensemble Mean Precipitation Trends

1930-1980
LENSS

AER .84

1950-2000

1970-2020

.21
Stippled areas insignificant (95%)
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Ensemble Mean Precipitation Trends

<table>
<thead>
<tr>
<th>Period</th>
<th>LENS</th>
<th>AER</th>
<th>GHG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930-1980</td>
<td></td>
<td>.84</td>
<td>.15</td>
</tr>
<tr>
<td>1950-2000</td>
<td></td>
<td>.21</td>
<td>.79</td>
</tr>
<tr>
<td>1970-2020</td>
<td></td>
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</tr>
</tbody>
</table>
Pattern Correlation with LENS
Running 50 year Precipitation Trends

Starting year of 50-year trend

AER
GHG

1953-2003
How many ensemble members are needed to confidently detect the forced response?
How many ensemble members are needed to confidently detect the forced response?

\[ N_{\text{min}} \text{ (95\% confidence)} \]
\[ = 8 \times \left( \sigma \text{ trends} / \text{Ensemble Mean Trend} \right)^2 \]

*Based on standard error of the mean (Deser et al., 2012)*
LENS Precipitation Trends

1930-1980

Nmin

Mean

Precipitation (mm mo$^{-1}$)
1930-1980
Nmin

Mean

Member A

Member B

1970-2020
Nmin

Mean

LENS Precipitation Trends

Precipitation (mm mo⁻¹)
LENSS Precipitation Trends

1930-1980
Nmin
Mean
Member A
Member B

1970-2020
Nmin
Mean
Member A
Member B

Precipitation (mm mo$^{-1}$)
How many ensemble members are needed to confidently detect the forced response?

Patterns
Pattern Correlation: Individual Members vs. Ensemble Mean

Running 50 year Precipitation Trends

Significant relative to control run
Pattern Correlation: Individual Members vs. Ensemble Mean

Running 50 year Precipitation Trends

$r^2 = 75\%$

$r^2 = 50\%$

Significant relative to control run

Starting year of 50-year trend
Pattern Correlation: N-member vs 40-member averages (200 bootstrapped samples)

LENS Running 50-year Precip Trends

\[ r^2 = 75\% \]
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Pattern Correlation: N-member vs 40-member averages
(200 bootstrapped samples)

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LENS Running
50-year Precip Trends

N=1
N=5
N=10
N=15
Pattern Correlation: N-member vs 40-member averages (200 bootstrapped samples)

LENS Running 50-year Precip Trends

N=1

N=5

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$\text{LENS Running 50-year Precip Trends}$

$N=1$

$N=5$

$N=10$

$N=15$

$r^2 = 75\%$

$r^2 = 50\%$
Thanks
Extra
Pattern Correlation: Individual members vs ensemble mean

LENS Precip Trends

Significant relative to control run

Starting year of 50-year trend

GPCC
GHG Ensemble, 1970-2020 Trends
Pattern Correlations of N-member ensemble means with the 40-member EM (all from LENS)

Annual Tropical Precipitation 50-year running trends starting in 1920-2030

Individual members vs LENS_EM40

Bootstrapped 5-member means vs LENS_EM40

Bootstrapped 10-member means vs LENS_EM40

Bootstrapped 15-member means vs LENS_EM40

\[ R^2 = 50\% \]

\[ R^2 = 75\% \]

\% of members with pattern correlation > 0.70

(0.86)

1920-2030 start years for 50-yr trends
How many ensemble members are needed?

<table>
<thead>
<tr>
<th>SST* Nmin</th>
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<tbody>
<tr>
<td>1930-1980</td>
<td><img src="image1" alt="Map" /></td>
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<td>1950-2000</td>
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<td>1970-2020</td>
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<td><img src="image8" alt="Map" /></td>
<td><img src="image9" alt="Map" /></td>
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NH Air Temperature (°C)

Evolving 50-year trends