Objectives & Activity

• To quantify the risks of extremes for a range of phenomena, over different regions and timescales, using large ensembles of initialised climate model simulations

• Assessment of current capability of climate models to predict extreme events (→ highlighting opportunities for operational prediction)

…by exploiting CHFP and S2S databases, other sources including ESGF and C3S

Activity in 2020-21
- WCRP Workshop on Extremes in Climate Prediction Ensembles (ExCPEns) + ECS event
  > Formulated at WGSIP 21 in Moscow, delayed 1 year by pandemic
  > Co-chaired by June-Yi, session chaired by Hongli, presentations by Asmerom, Debbie, Leon, Bill
  > June-Yi to present debrief

- UNSEEN (using hindcasts to estimate unprecedented events) activity: Leon to present update
Knowledge about potential ENSO extremes is limited by having only one realization of the modern observational record.

Climate prediction ensembles potentially can greatly multiply the number of realizations if sufficiently realistic.

This motivates examining ENSO extremes in hindcasts of the Copernicus Climate Change Service (C3S) seasonal prediction ensemble, which currently has 184 ensemble members across 8 models.

We ask: How frequently do El Niño/La Niña events stronger than any yet observed occur in the C3S hindcast ensemble?

### Extreme ENSO events in Copernicus seasonal hindcasts*

<table>
<thead>
<tr>
<th>Centre/Model</th>
<th>Country</th>
<th>Ensemble size</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMCC SPS3.5</td>
<td>Italy</td>
<td>40</td>
</tr>
<tr>
<td>DWD GCFS2.1</td>
<td>Germany</td>
<td>30</td>
</tr>
<tr>
<td>ECMWF SEAS5</td>
<td>EU</td>
<td>25</td>
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<td>Météo-France System 8</td>
<td>France</td>
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<tr>
<td>Met Office GloSea5</td>
<td>UK</td>
<td>28</td>
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<td>NCEP CFSv2</td>
<td>USA</td>
<td>16</td>
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<tr>
<td>ECC CanCM4i</td>
<td>Canada</td>
<td>10</td>
</tr>
<tr>
<td>ECC Can GEM-NEMO</td>
<td>Canada</td>
<td>10</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>184</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Presented at WCRP Workshop on Extremes in Climate Prediction Ensembles, Oct 25-27 2021*
Analysis

- Consider 6-month hindcasts initialized each month during the C3S hindcast period **1993-2016**

- Focus on hindcast values of the Niño3.4 index in December (month of peak Niño3.4 variance) **initialized in July** (5-month lead → least constrained by initial conditions)

- Use monthly NOAA OISSTv2 as observational reference

- In addition to correcting the mean bias, ENSO amplitude biases are removed by rescaling Niño3.4 variance for each month and lead time to match observed variance for that month:
Example of variance rescaling

- These plots show the ECMWF Niño3.4 plume initialized 1 July 2015, based on raw values (left) and rescaled to match observed variances (right).

Even with variance rescaling, December Niño3.4 anomalies exceed 3 or even 3.5 degrees for several ensemble members.
C3S vs observed Nino3.4 distributions
5-month lead, 1993-2016

→ distribution is realistic according to two-sample Cramér–von Mises test (also for individual models, other lead times after rescaling)
What does this imply about ENSO extremes?

- **Minimum observed**: 7.4% of hindcast values
- **Maximum observed**: 4.3% of hindcast values

*during 1993-2016
Implied frequencies of extremes

- **El Niño extremes**
  - Dec Niño3.4 > 3.0 every ≈30 years
  - Dec Niño3.4 > 3.5 every ≈80 years

- **La Niña extremes**
  - Dec Niño3.4 < -2.5 every ≈60 years
  - Dec Niño3.4 < -3.0 every ≈400 years

→ C3S distribution implies

- Obs
- C3S
- CMCC
- DWD
- ECMWF
- MF
- Met Office
- NCEP
- ECCC-C
- ECCC-G

in 1993-2016
Conclusions

• Results suggest ENSO extremes exceeding those in observed record are realizable, leading to unprecedented impacts.

• Caveats include:
  - potential model biases other than for amplitude not accounted for
  - implied occurrence frequencies differ somewhat between models
  - results are specific to 5-month lead realizations of 1993-2016 period
  - future ENSO behavior and impacts likely to be influenced by changing climate
Predicting extremes (BoM)

Other extremes research (since WGSIP22):


A new service (since 1 Nov):
- 'Chance of extreme' outlook maps for upcoming weeks, months, seasons
- For rainfall, maximum/minimum temperature
- Drill down to specific locations
For discussion

Ideas for
- further engagement with other groups
- additional WGSIP-driven or coordinated activities
- promoting new approaches for research in this area
- …