Large Ensemble design considerations, new research directions

One key in science is to ask the “right” questions.
A next step is to have the right “tools”.

Large Ensembles of climate model simulations can be an ideal tool for some questions, but not for others.

Not all Large Ensembles are alike!

- **What are the types of questions that Large Ensembles are good tools for?**
- **What are new scientific questions that Large Ensembles have not yet been used for?**
- **What attributes of Large Ensembles (ie, their design) are best suited to address the questions?**

Some examples for which LEs have been a favorite choice …

1. Distinguishing a climate signal from the "noise".

2. Assessing predictability

3. Estimation of climate "noise" to allow for uncertainty characterization of projections

4. Characterizing the tails of pdfs and how they may change with radiative forcing

5. Assessing whether internal variability changes with radiative forcing

Large Ensembles are EXPENSIVE!

- *For what questions will much less expensive techniques (such as resampling from a control simulation, or the use of an Observational Large Ensemble) be better choices?*
- *For what questions is a Large Ensemble of a complex climate model the best tool?*

One aspect to consider … to the extent that future pdfs are adequately represented by present observations, then Large Ensembles may not be necessary (statistical techniques may be fine)

- *But … when future pdfs change in response to forcing, Large Ensembles may be crucial. (But how will we know whether future pdfs will change?)*

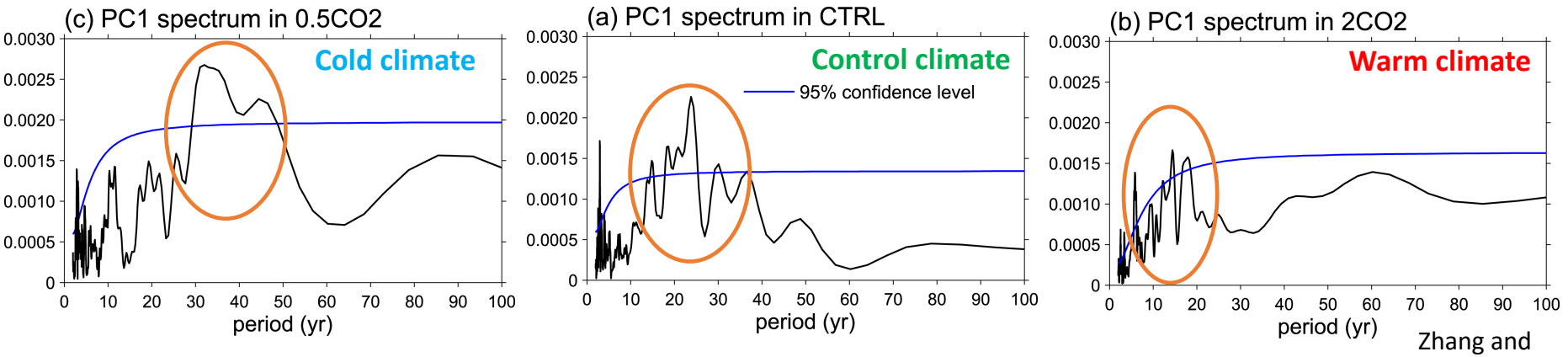
Can the question being asked be satisfactorily addressed by statistical combinations of existing data?

For example:

- If a change is characterized by a shift in the mean, but the shape of the pdf is preserved … then statistical models can be a good tool to answer questions.

- However … if there is also a change in the shape of the pdf, then it may be harder for a statistical model to emulate this behavior

Example: Changing characteristics of the Pacific Decadal Oscillation under climate change



Zhang and Delworth, 2016

➔ *If the characteristics of variability were to change in the future, then statistical tools built from existing observations might have difficulty in the future.*

Another issue … the utility of a Large Ensemble may depend on the questions being asked and the models used

Text adapted from van der Wiel et al, 2016

(In this study, the authors assess the ability of a suite of models, differing in horizontal resolution, to simulate extreme precipitation)

"The atmospheric resolution was increased from 2° horizontal grid cells (typical resolution in the CMIP5 archive) to 0.25° (tropical cyclone permitting).

It is shown that, for these models, integrating at higher atmospheric resolution improves all aspects of simulated extreme precipitation: spatial patterns, intensities, and seasonal timing.

In response to 2X CO_2 concentrations … projected regional patterns of changes in extremes are dependent on model resolution.

These results emphasize that, for the study of extreme precipitation there is a minimum model resolution that is needed to capture the weather phenomena generating the extremes."

➔ How well does the model employed simulate the phenomena of interest?

… a game of tradeoffs and optimization …

MODEL	COST per ensemble member for 100 years	Total number of ensemble members possible for 100 years
BASE (Coarse resolution, physical only)	**1**	**100**
2X resolution (grid spacing reduced by 2)	5	20
4X resolution	25	4
More comprehensive, coarse resolution	2	50
More comprehensive, 2X resolution	10	10
More comprehensive, 4X resolution	50	2

➔ Additional dimensions … perturbed physics, multiple forcing scenarios, duration, …

What is the "right" LE design? How do you spend your computer resources? Depends critically on the questions being addressed!

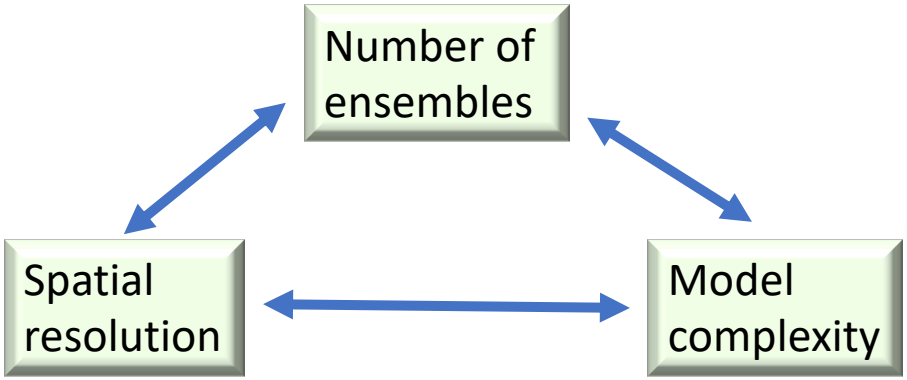
DISCUSSION QUESTIONS

(1) There are multiple types of ensembles that can be run using climate models. These include:

a. *Initial condition* ensembles, in which the ensemble members differ only by their initial conditions;
b. *Physics ensembles*, in which ensemble members use the same basic model but alter physics parameters (this would include stochastic physics ensembles);
c. *Multi-model ensembles*, in which different models are run once with similar forcings and are combined to form an ensemble.
d. *Ensembles with single forcings*.

With finite computer resources there are always tradeoffs. If there were an internationally coordinated 'Large Ensemble' program, **what type of ensembles should be the focus? What topics/questions would be key to address?** For what types of questions are large ensembles necessary, and for what questions are other approaches potentially more desirable, such as analyses derived from long control simulations?

(2) There are many attributes of the models used in an ensemble, including resolution, complexity (types of processes included, such as biogeochemical processes), number of ensemble members, and duration of simulations. If you had 100 units of computing to spend to address your science question(s), how would you allocate those units in terms of these attributes, and why?



(3) For an initial condition ensemble, there are multiple ways to initialize individual members. One is to have members differ by bitwise perturbations to the initial conditions, with the differences growing quickly. Another is by using initial conditions taken from different points in a long control integration. Given these choices and their implications, **do you have a preferred method for creating initial conditions for ensemble members**?

(4) How do we decide how many ensemble members are needed? In this context, **what defines "large"?**

(5) **What are 3 new research directions** (within your subfield) that could benefit from initial-condition (or other types of) Large Ensembles? Do these require new models and/or additional model output?

To start the discussion … we will go around the room to hear from everyone on the following:

- What are the key questions (new or old) that you plan to pursue in the future for which Large Ensembles might be useful?

- To address your needs, what types of Large Ensembles would be desirable?

Discussion Groups (both days, 3.45-5pm)

Group 1, Tower B penthouse: Flavio Lehner, Tom Delworth, Riley Brady, Amy Clement, Oscar Dimdore-Miles, Naomi Goldenson, Haruki Hirasawa, Kezhou Lu, Weiming Ma, Anna Merrifield, Gabriela Negrete Garcia, Nico Wienders, Colin Zarzycki

Group 2, Tower A room 315: Clara Deser, James Randerson, Tara Banerjee, Christopher Callahan, Neven Fuckar, Linnia Hawkins, Shihan Li, Gavin Madakumbura, Sebastian Milinski, Thierry Penduff, Hillary Scannell, Samantha Stevenson, Filippos Tagklis, Benjamin Toms

Group 3, Inner Damon Room: Karen McKinnon, Pedro Dinezio, Charles Curry, Luke Gloege, Forrest Hoffman, Xingying Huang, Alexandra Jahn, Robb Jnglin Wills, Kristen Krumhardt, Yochanan Kushnir, Valerio Lembo, Xiao-Wei Quan, Daniel Swain, Danielle Touma

Group 4, Fleishmann Building: Nikki Lovenduski, Arlene Fiore, Libby Barnes, Stefaan Conradie, Andrea Dittus, Ambarish Karmalkar, Martin Leduc, Joanna Lester, Abdul Malik, Wonsun Park, Bryn Ronalds, Deepti Singh, Detlef Stammer, Gan Zhang

Group 5, Outer Damon room: Isla Simpson, Claude Frankignoul, Sebastian Eastham, Melissa Gervais, Patrick Kinney, Giovanni Liguori, Justin Mankin, Holly Olivarez, Lorenzo Polvani, Mercedes Poso Buil, Sean Ridge, Daniel Schmidt, Haiyan Teng, Honghai Zhang, Sally Zhang

Group 6, Chapman room: Mingfang Ting, John Fyfe, Amy Braverman, Hui Ding, Mark England, Aixue Hu, Jeremy Klavans, Sydney Kramer, Elizabeth Maroon, Clio Michel, Eleanor Middlemas, Matt Newman, Daniel Vecellio, Lei Wang

Group 7, Directors conference room (215): Daniel Horton, Keith Rodgers, Dillon Amaya, Seung Hun Baek, Alejandro Flores, Fernando Garcia Menendez, Jingyuan Li, Nicola Maher, Precious Mongwe, Lawrence Mudryk, Annika Reintges, Alan Robock, Karen Smith

Group 8, Library: Shoshiro Minobe, Jen Kay, Raul Wood, Tamas Bodai, Kathleen Holman, Antonios Mamalakis, Ben Santer, Sarah Schlunegger, Kevin Schwarzwald, Abby Stevens, Jozef Syktus, Yohei Takano, Kasia Tokarska, Jiacan Yuan