WG Uncertainty in models - Notes

Quantification of uncertainty in complex models

The uncertainties in the output of the (complex and high-dimensional) models in use must be well-understood. This theme includes topics like model inter-comparison, (Bayesian) model averaging, statistical emulation, the study of more tractable models which still capture essential features of the problem, measures for uncertainty (e.g. entropy), and error propagation through models

Discussion session Thursday Afternoon

Present: Bette Otto-Bliesner, Anna von der Heydt, Jonty Rougier, Lindsay Lee, Jan Viebahn, Jill Johnson, Eduardo Moreno Chamarro, Ruca Ivanovic, Matt Carmichael, Elisa Carraro, Alice Marzocchi, Lauren Gregoire, Charles Camp, Alan Haywood.

1. *Relevant challenges where progress can be made during the lifetime of the network:*
   - Uncertainty can be only quantified with ensembles of models
   - Statisticians prefer weighted **ensembles**!
   - How many ensemble members are necessary:
     - Depends on the quantity under study
     - Depends on the expected internal variability in that area
     - For only quantifying uncertainty less members may be necessary than for understanding uncertainty
     - Statisticians should help in the design of perturbations: not a Markovian scan of parameter space, instead careful design of perturbations.
     - For time slice experiments: Potentially 1 spinup + a long simulation is enough to quantify initial condition uncertainty (split long time series in $\sim$ 30 year pieces)
   - Determine the **cone of uncertainty** for each individual model (for e.g. LGM, Pliocene): This gives more confidence in the quality of simulations. In particular, if the cones of uncertainty of two different models diverge, the two models are more likely to be different than if only the single simulations diverge.
   - Deep-time simulations: estimate of uncertainty to a change in continental boundary conditions (bathymetry, topography, gateways), how to quantify?
   - **Model averaging**:
     - Look at IPCC plot with different model skills
     - Best model seems to be the average of the models (which is unphysical and does not exist)
     - Strongest information lies in the variance
     - Better ways to show the model spread: cone of uncertainty (see above)

- **Emulators** can help to increase the number of ensemble members. For this to work the design of the ensemble is important: The original ensemble members should be parameter-space-spanning, such that the emulator can fill the gaps.
    - Usually a choice needs to be made on which the most important parameters are (depends on the goal of the study).
    - Models need to be "detuned", which is usually not done in the modelling community (the initial tuning process is difficult and usually not very well accessible)

2. *What topics/aspects are working group members interested in?*
    - Common way for comparing model ensembles, e.g.
        - Time slices: long simulation split into pieces
        - Common boundary conditions
    - Resolution: what is meaningful to compare?
        - Coupled/uncoupled models
        - Tests how the spinup can be achieved by coupled/uncoupled techniques
        - Low/high resolution: averaging of cells?
    - Decision on whether model averaging should be done. (CMIP does it, should the palaeo community also do?, is it a CMIP paradigm?)
3. *Benefits from collaboration*

Communication between modellers and statisticians is extremely important for the design of model ensembles.

4. *Interaction with other groups*
    - Model-data WG:
    - Data WG:
        - Proxy-modelling?
        - Ecosystems
        - Isotope models
        - Uncertainty quantification to things that are usually not changed (e.g. forcings, boundary conditions, soil, …): How to do that?

5. *Ideas for feasibility studies*
    - Extract model uncertainty (cone of uncertainty) from existing long simulations by splitting the simulation in short pieces (30 years or longer/shorter). LGM or Pliocene might be good candidates (Bette checks which have the longest simulation, how many models are there). Potential outcomes:
        - Optimal length of spinup phase?
        - Length of simulation?
        - Length of time pieces?
        - How can emulators help?

Discussion session Friday morning

Science:
There are different types of uncertainty:

- Forcing (includes CO2, orbital forcing, continental boundary conditions): Partly this may be addressed using emulators, e.g. orbital parameters or CO2 if it is a smooth change. Continental boundary conditions are more difficult for emulators, and should possibly better assessed by performing sensitivity studies with extreme settings.
- Initial conditions: If ergodicity can be assumed this may be assessed by using long simulations split into pieces. This does not inform about the existence or uncertainty around multiple equlibria/tipping points/. For deep-time studies the initial condition uncertainty may be less relevant as other, larger uncertainties on e.g. forcings exist.
- Parameters: As the parameter space is large in complex models, always a choice needs to be made which parameters will be explored (for the problem at hand). Emulators can help here in an efficient way. It is essential that the design of the initial model ensemble is such that it allows the (later) use of an emulator. Interaction with statisticians is therefore vital. What also should be explored are the simulations that "fail" because of some "impossible" parameter value. We note here, that most models are heavily tuned towards the present day climate, and some solvers may not allow too large deviations from these optimal parameter values.

Organisation:

- Group leaders should be 2-3: Apart from a good balance between career stages there should be at least one statistician and one modeller. The group will make suggestions to Edward Yorke within short time and these suggestions will be evaluated by the Steering committee.
- Budget: 25k£ are available for the feasibility study. Call will appear over ~ 1 year. 50k£ available for travel and meetings. Of this 25k£ will be available to the group directly, while the other half will be distributed by the Steering committee after functioning of the group.
- Until we have group leaders Bette and Anna will help to set up the organization of the group and make a summary of what we aim for right now. Jonty will write up initial ideas on the methods for initial condition uncertainty using long simulations.
- Establish a member list on the PEN webpage (people should be able to sign up for the group)
- Email-list for further discussions
- Eventually organise regular meetings/seminars potentially via WebEx or other virtual meeting applications.