RAPIT: Assessing the uncertainty of AMOC projections using a 10,000 member perturbed physics ensemble.

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Summary

RAPIT is a RAPID-WATCH consortium project that aims to produce a risk assessment for a possible collapse of the Atlantic Meridional Overturning Circulation (AMOC) in the coming century. Our approach involves a very large perturbed physics ensemble of HadCM3, forced with a range of idealised CO_2 scenarios. State-of-the-art emulation techniques are being employed to search parameter space for regions in which a collapse is more likely, and to produce a risk assessment that takes into account the plausibility of the model's past and present climate across parameter space.

1. Objectives

Produce a risk assessment of the probability and impacts of large, rapid AMOC changes. A novel aspect of our approach is that rather than constraining the ensemble from the outset we explore the model's parameter space, searching for regions that contain "non-implausible" climate states which could otherwise be overlooked. This method has the advantage that regions of space where the AMOC might behave differently are not discarded at the outset.

2. Methods

a) Ensemble

- Conducted a perturbed physics ensemble where parameters controlling model physics are perturbed within given ranges.
- Running thousands of versions of unfluxadjusted HadCM3.
- Using www.climateprediction.net – a distributed computing network where members of the public run models in the background on their PCs.
- 50 years of spin up and then pre-industrial controls and X% CO2 increase experiments for 70 years (0 < X < 4).

b) Constraints

- Use large scale constraints to rule out wildly implausible models (see *Williamson et al, 2012*)
- Use: - global mean surface air temperature (SAT)
  - meridional gradient of N hemisphere SAT
  - seasonal cycle of N Hemisphere SAT
  - global mean precipitation
- Models within constraints are referred to as 'Not Ruled Out Yet' (NROY).

c) Emulation and Analysis - ongoing

- Statistical emulation to fill in parameter space and search for regions where interesting behaviour may occur.
- 'History Matching' to constrain models and parameters using observations.
- Analysis to understand how AMOC properties, mechanisms and impacts vary.
- Aim to produce a 'risk assessment' of the plausibility and impacts of a large, rapid AMOC change.

3. Parameter sensitivity

- Constraints remove parts of parameter space
- The 7 parameters most impacted by constraints are shown in Fig. 1. These are the most important parameters for obtaining a model in NROY space.
- Most of these parameters control the amount and distribution of cloud and water vapour which can have a large impact on SAT.
- The final parameter ahi1_si controls isopycnal diffusivity so may influence ocean heat uptake.

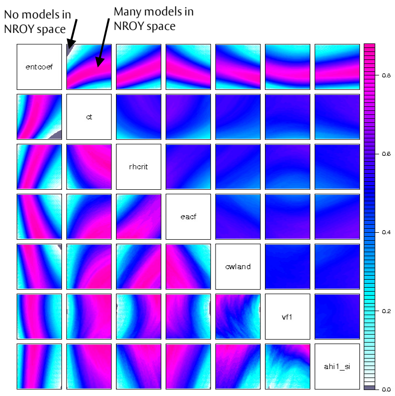

Fig 1. Percentage of models in NROY space as a function of different parameters. Plots on the right use the scale on the right, plots on the left use a normalised scale.

4. AMOC in Pre-Industrial Controls

- AMOC has range ~ 10-25 Sv
- Nonlinear relationship between SAT and AMOC
- Cold models (not in NROY space) have initial large increase in AMOC before a gradual decrease during spinup. Ongoing analysis suggests that the peak at year 15 is caused by the excitation of certain climate modes.

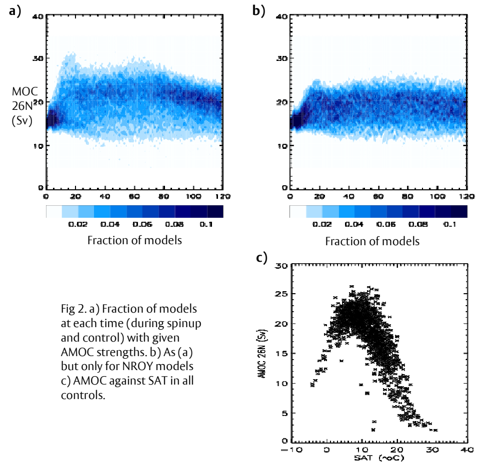

Fig 2. a) Fraction of models at each time (during spinup and control) with given AMOC strengths. b) As (a) but only for NROY models c) AMOC against SAT in all controls.

5. AMOC change with increasing CO_2

- Projection of AMOC change in NROY models are shifted to have a greater decrease and narrower range than the full set of models.
- Greater CO_2 increase leads to greater SAT increase and greater AMOC decrease.

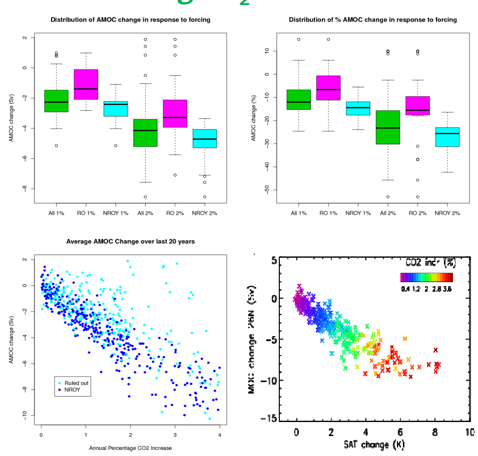

Fig. 3. Top panels show absolute and percentage AMOC decrease for models experiencing ~ 1% and 2% CO_2 increase. Green bars show results for all models, pink for 'Ruled Out' models and cyan for NROY models. Bottom left panel shows AMOC change against CO_2 increase and bottom right shows AMOC change against SAT change (only for NROY models).

6. Impacts

- Greater decrease in AMOC strength leads to a greater decrease in Atlantic ocean heat transport
- For models with the greatest AMOC decrease there is a greater relative cooling over Europe. For small AMOC change there is a large model spread of relative European temperature.

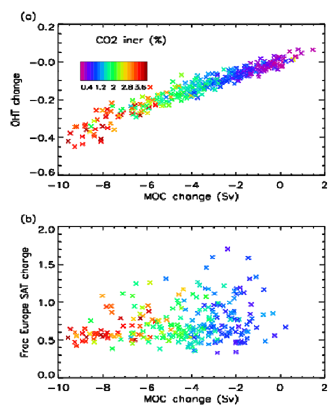

Fig 4. a) Change in Atlantic ocean heat transport against change in AMOC. b) Fractional change in European temperature ($\Delta SAT_{Eur}/\Delta SAT_{Global}$) against change in AMOC. Colours are annual CO_2 increase. Only models in NROY space are plotted.

References

Williamson, D., Goldstein, M., Allison, L., Blaker, A. T., Challenor, P., Jackson, L., 2012. History matching for the quantification and reduction of parametric uncertainty in climate model projections, Climate Dynamics, submitted.

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