**Motivation:** Observed & projected surface warming and freshening $\rightarrow$ stratification $\rightarrow$ impacts on ventilation & ecosystems (light, nutrients)

**Method:** Optimal fingerprinting applied to CMIP5 models and observations for change in upper ocean density stratification (0–200 m), sample piControl to estimate $V_0$

**Results:** Detectable change ($\beta > 0$) in observed stratification in response to ALL external forcings, cannot be explained by historicalNat fingerprint $\rightarrow$ most models overestimate response ($\beta < 1$), response detected above $V_0$
The inconstancy of climate feedbacks
Timothy Andrews¹, Jonathan Gregory¹,² & Mark Webb
¹Met Office Hadley Centre; ²NCAS-Climate, Uni. of Reading

Is climate sensitivity estimated from the historical record biased low?

- Observations and AGCMs forced with observed SSTs show strong negative feedbacks and hence low ECS values (~1-2K) if feedback strengths are assumed constant.

- Targeted AGCM experiments – included in the CFMIP3/CMIP6 experimental design – forced with idealised & observed SST warming patterns are introduced to understand:
  
  (i) the physical processes & mechanisms
  
  (ii) the implication for observed estimates of climate sensitivity
**Carbon Cycle Models**

- Terrestrial
- Ocean
- Human

**Surface Satellite Data**

- GOSAT/OCO-2 xCO₂
- MOPITT CO
- OMI NO₂
- GOSAT xCH₄

**CMS-Flux Framework**

- "Bottom-up"
  - Surface Satellite Data
  - Carbon Cycle Models
  - Composition Transport Model
  - Inverse modeling
  - Reconciliation

- "Top-down"
  - Atmospheric Satellite Data
  - Total CH₄
  - NO₂
  - CO
  - Top-down estimates
  - Posterior fluxes and uncertainties

**Equation**

\[
C_{\text{prior}}(x) = \|x - x_{a}\|_{S_{a}}^{-1}
\]

\[
C_{\text{obs}}(x) = \|y - F(x)\|_{S_{n}}^{-1}
\]

\[
\min_{x} C(x) = C_{\text{obs}}(x) + C_{\text{prior}}(x)
\]
Analysis of the Future Emission Changes in Mineral Dust Aerosol in CMIP5

Young-Hwa Byun, TaeHee Kim, Kyung-On Boo, Johan Lee, ChunHo Cho
National Institute of Meteorological Sciences, Korea Meteorological Administration

- Investigation of future change in dust emission over the East Asian region (30-55°N, 80-145°E) based on CMIP5 model simulations
- 10-model simulations with 4 RCPs (HG2-AO, HG2-ES, GISS-E2-H, GISS-E2-R, MIROC5, MIROC-ESM, MRI-CGCM3, CSIRO-Mk360, CanESM2)

Change in dust emission rate [ g km⁻² mon⁻¹, (2071~2100) – (1971~2000) ]

Change in dust emission rate in each model [ %, (2071~2100) – (1971~2000) ]

Annual mean dust emission rate (g km⁻² mon⁻¹) and soil moisture (kg m⁻²) over the East Asia region
Climate sensitivity of the Brazilian Earth System Model, version 2.5

Vinicius Capistrano, P. Reyes, S. Figueroa, E. Giarolla, C. Fonseca, M. Malagutti, M. Baptista, P. Nobre

piControl vs. Abrupt4xCO2

Equilibrium Climate Sensitivity (ECS) of 2.95 K
Cloud Radiative Effect (CRE) of -0.11 W m\(^{-2}\)K\(^{-1}\)
Response of monsoon variability to a 190 year ramp-up/ramp-down RCP8.5 forcing as simulated by five ESMs models (EC-Earth, HadGEM2-ES, MPI-ESM, GFDL-ESM and IPSL).

- **Inter-model spread** between the models is still very large. This is particularly the case with respect to precipitation responses over Africa and South Asia.
- The South Asian monsoon rainfall appears to show a general tendency to increase as GHG forcing increases which largely reverses during the ramp-down period.
- Over West Africa, a large surface temperature response is seen through the ramp-up phase which is reversed during the ramp-down.
- Models have widely different simulated precipitation climatologies over West Africa and no clear signal is seen in terms of precipitation change across the models. Likewise, there is no consistent change in monsoon onset or duration across the 2 models analysed.
- There is little evidence of abrupt or irreversible changes in any of the monsoon systems.
- Due to greatly differing simulations, improved models seem to be a pre-requisite before reliable estimates of future change in any of these three phenomena can be delivered.
A catalogue of abrupt shifts in IPCC climate models

Sybren Drijfhout, Sebastian Bathiany, Claudie Beaulieu, Victor Brovkin, Martin Claussen, Chris Huntingford, Marten Scheffer, Giovanni Sgubin, Didier Swingedouw

Washington Post last week:
Record Cold 'Blob' in North Atlantic: Sign of Future Climate Woes?

Eighteen out of 37 forced abrupt shifts occur in simulations for global warming levels below 2 degrees, a threshold often proposed as a potentially safe upper bound on global warming.
Global Ocean Heat Content (OHC) Changes in CMIP5 from the Upper Layers to the Abyss

CMIP5 MMM is consistent with estimates of OHC changes in the upper, intermediate and deep ocean.

Large intermodel differences in trends & variability but no evidence of a systematic bias across models.

Models and data suggest the industrial era global ocean heat uptake has doubled in recent decades.

Observed and simulated OHC trends (1971-2005) and 35 year internal variability.

For most models the forced trends (green triangle) are distinct from estimated internal variability, especially in the upper layer.

A few models are cooling in the intermediate layer – excessive indirect aerosol effects?

Individual models straddle observed estimates in each layer and there is therefore no evidence of a systematic bias.

Green triangles: Trends from individual Historical realizations.

Grey dashes: 35 year trends from non-overlapping chunks of model’s picontrol.

Simulated Total Global Ocean Heat Uptake Cumulative Distribution Function.

Individual models are normalized by their OHC at 2015.

CMIP5 MMM is consistent with Argo-Challenger estimates (~1875-2005; Roemmich [2012]).

Large spread in modeled OHU.


References
Decelerating AMOC main cause of future west European summer atmospheric circulation changes

Reindert J. Haarsma, Frank M. Selten and Sybren Drijfhout (KNMI, Netherlands)

- Weakening of AMOC is main cause for Atlantic high in future CMIP5 simulations
- Uncertainty in atmospheric summer response over Europe is connected to uncertainty in the AMOC response

CMIP5 model mean response

Regression of MSLP on negative AMOC change

Standard deviation of MSLP

CMIP5 inter-model spread

"Atlantic high"  "Warming hole"

Haarsma et al., Env. Res. Lett, 2015
Conclusions:

- models reproduce forced response compatible with reconstructions for Northern Hemisphere regions, in particular for the Arctic and Europe
- multiple realisations from single models and the multi-model ensemble improve test statistics
- agreement between simulations and PAGES2k regions is poor for the Southern Hemisphere
- simulations are regionally more coherent than reconstructions
- discrepancies may stem from model deficiencies, but also from the uncertainty in proxy-based reconstructions.
Zooplankton control on future changes in marine biological carbon fluxes

Corinne Le Quéré, Erik T Buitenhuis, Oliver Andrews, and Rósín Moriarty
Tyndall Centre for Climate Change Research, University of East Anglia, UK

Surface Chla data

The Past

PlankTOM10

PlankTOM6

The Future

Correlations of modeled changes in 2100 with explanatory variables

zooplankton (again!) co-vary the most with changes in carbon fluxes, suggesting top-down rather than bottom-up control

the overestimation of summer biomass in the Southern Ocean summer is reduced in a model with multiple zooplankton (Le Quéré et al BGD 2015)
CMIP5 Climate Projections for North America and Development of a Process-Oriented Model Diagnostics Framework

Eric D. Maloney, Yi Ming, Andrew Gettelman, David Neelin
NOAA MAPP CMIP5 and Model Diagnostics Task Forces

**Process-Oriented Diagnostics Framework**

The newly christened NOAA MAPP Model Diagnostics Task Force is leading development of a software framework to entrain process-oriented diagnostics into model evaluation packages.

**Process-Oriented Diagnostic:**
- Goes beyond a simple diagnosis of whether a model can simulate a phenomenon or aspect of climate to provide physical insight into why
- Targets a specific physical process or emergent behavior and can guide parameterization improvement

Sahany et al. (2014)
Evaluation of the forest biomass in CMIP5 models over the northern high-latitudes

Jiafu Mao1,*, Cheng-En Yang2, Forrest M. Hoffman3, Daniel M. Ricciuto1, and Joshua S. Fu2

1Climate Change Science Institute and Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN
2Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN
3Climate Change Science Institute and Computer Science and Mathematics Division, Oak Ridge National Laboratory, Oak Ridge, TN

Poster 13 in Session 4

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The impact of global warming on ENSO has been shown to be uncertain in the CMIP3/5 ensembles.

But the individual CMIP5 models show a rich spectrum of behavior: from a strongly reduced to a strongly enhanced ENSO amplitude.

What determines this differing behavior among the models?

- We find that the changes in ENSO amplitude are strongly correlated (r = 0.92) with the changes in zonal wind stress forcing efficiency of SST in the equatorial Pacific.
- The coupling between the low-level zonal wind and deep convection in the central Pacific is found to be crucial in determining the nature of ENSO response to GW.

More details may be found in the poster.
Ozone-mediated forcing of the Southern Annular Mode by Greenhouse Gases

O. Morgenstern¹, S. M. Dean¹, G. Zeng¹, M. Joshi², N. L. Abraham³, and A. Osprey⁴

¹NIWA, New Zealand  ²U. East Anglia, Norwich, UK  ³U. Cambridge, UK  ⁴U. Reading, UK

![Diagram showing the relationships between climate, ozone, and greenhouse gases.]

- **Direct GHG effect**
  - Radiative forcing

- **Indirect GHG effect**
  - Dynamical feedbacks

- **ODS effect**
  - Ozone depletion

- **Dynamics**
  - GHGs (CO₂, CH₄, N₂O, ...)

- **Chemistry**
  - Ozone

- **ODSs (CFCs, CH₃Br, ...)**
Last Millennium Ensemble (LME)

CESM1 (CAM5): ~ 2° resolution atmosphere and land, ~ 1° resolution ocean and sea ice.

Three long control runs to assess internal variability.

29-member ensemble set (850-2005 AD) includes single and full forcing simulations.

Post-Tambora, Winter 1816/1817

A proxy-based study suggested the probability for El Niño to occur following large tropical eruptions doubled.

- 9 (60%) of the individual members with volcanic forcing exhibit El Niño warming in second winter after the April 1815 Tambora eruption.
- But other 6 members show a neutral or La Niña response.
The Earth’s Energy Budget across CMIP5 Models  
Robert Portmann & Erik Larson

Cumulative Energy Budgets
CMIP5 Models

- GHG Forcing
- Strat. Aerosol
- Residual Forcing (Aerosol)
- Outgoing Radiation
- Ocean Heating

Similar to Observational study of Murphy et al. 2009 but using models

- How well can we estimate energy budgets from models?
- What are the limits of drift removal?

Emitted vs. Retained Energy since 1950 (Time series)

Multi-dimensional test of models against observations.
Radiative forcing remains a significant uncertainty in projections of climate change.

Modeling centers should calculate and archive radiative forcing as part of CMIP6.
How should we represent terrestrial carbon-nitrogen cycle interactions in Earth system models? A roadmap for model development

Benjamin D. Stocker¹, I. Colin Prentice¹,²

¹Department of Life Sciences, Imperial College London, Silwood Park, Ascot, SL57PY, UK ²Department of Biological Sciences, Macquarie University, North Ryde, Australia

P-model
Wang et al., 2014 BG

DyN-LPJ
Xu-Ri & Prentice, 2008

LPJ/new
sensu Manzoni et al., 2008

NEW
above / below-ground allocation,
C exudation,
N uptake
Bidecadal North Atlantic ocean circulation variability controlled by timing of volcanic eruptions

Swingedouw et al.

What is the impact of volcanic eruptions of decadal variability in the North Atlantic?

Use of CMIP5 models, *in situ* data and last millennium proxy data to show:

① A reset of 20-yr variability in the Atlantic Overturning (AMOC)
② Explanation for some recent Great Salinity Anomalies (GSA)
③ Interferences for the AMOC over the recent period
At what magnitude of change in Global Average Temperature or Radiative Forcing do we start experiencing significant change “on the ground”?

Why do we ask?

**mitigation costs/overshoots/missing targets:**
- e.g., If instead of stabilizing climate at 2°C we stabilize it at 2.5°C, does that matter for impacts? It would definitely cost less for mitigation…

**experimental design of new scenarios:** How far apart do scenarios need to be to justify running them through ESMs? How close do they need to be to approximate what has not been run and still be consistent with SSPs’ assumptions?

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We acknowledge the WCRP’s Working Group on Coupled Modelling and we thank the climate modeling groups for producing and making available their model output.
C4 MIP includes experiments for diagnosing Carbon feedbacks for models with interactive Nitrogen cycles.

We propose a method for generating Nitrogen Deposition Forcing

In JULES-CN Nitrogen limitation reduces the net carbon uptake