Towards CMIP6: Met Office Modelling Plans and Expectations

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Presentation to CAWCR Workshop, Melbourne, Australia, 22 October 2015

Acknowledgements

- Co-authors for slides and briefs for this talk
- GC3 physical model developers, UKESM1 component model developers and core team
- Various climate scientists in the Hadley Centre for post-CMIP5 and pre-CMIP6 experimental design and analysis

Overview

- Model developments post-CMIP5
  - Physical climate model (HadGEM3-GC)
  - Earth System Model (UKESM1)
- What will our engagement in CMIP6 look like?
- HadGEM3-GC2 pre-CMIP6 idealized experiments
  - Compare/contrast with HadGEM2-ES
- Summary

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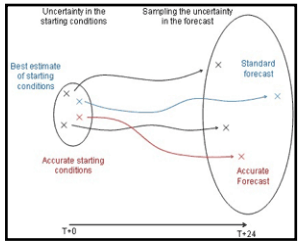
- What will our engagement in CMIP6 look like?

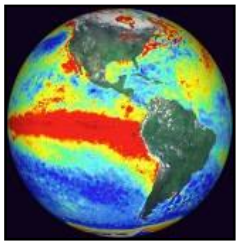
[*after Sean Milton*]

Global Coupled Physical Model: GC2 (Williams et al. 2015) ...

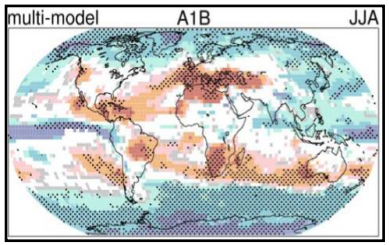
Coupled NWP and MOGREPS



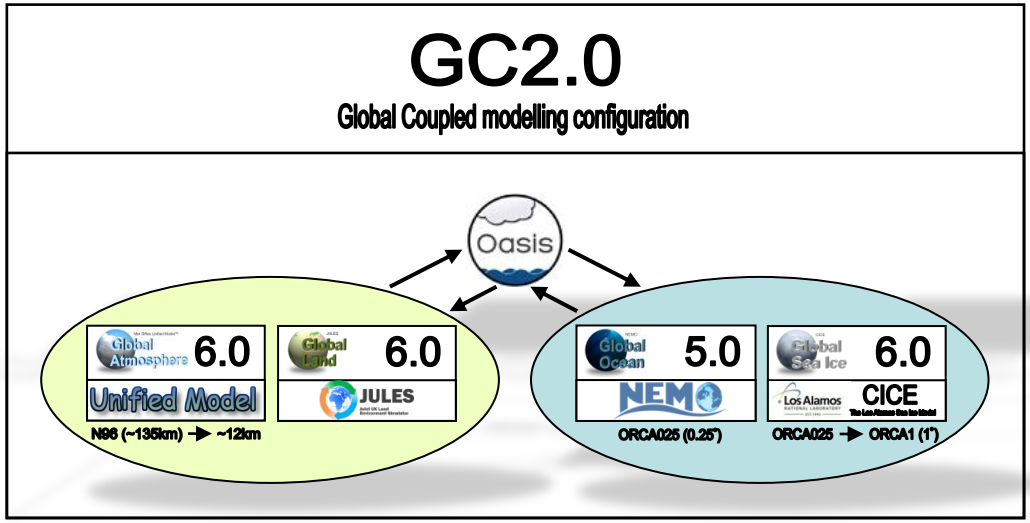
GloSea seamless EPS



Decadal Prediction



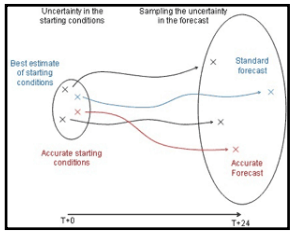
Climate Change studies (HadGEM3-GC2)



[*after Sean Milton*]

Global Coupled Physical Model: ... GC3 (for CMIP6)

Coupled NWP and MOGREPS



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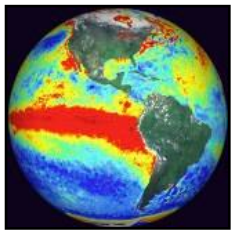

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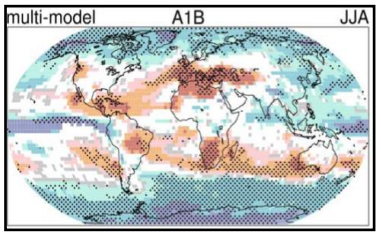
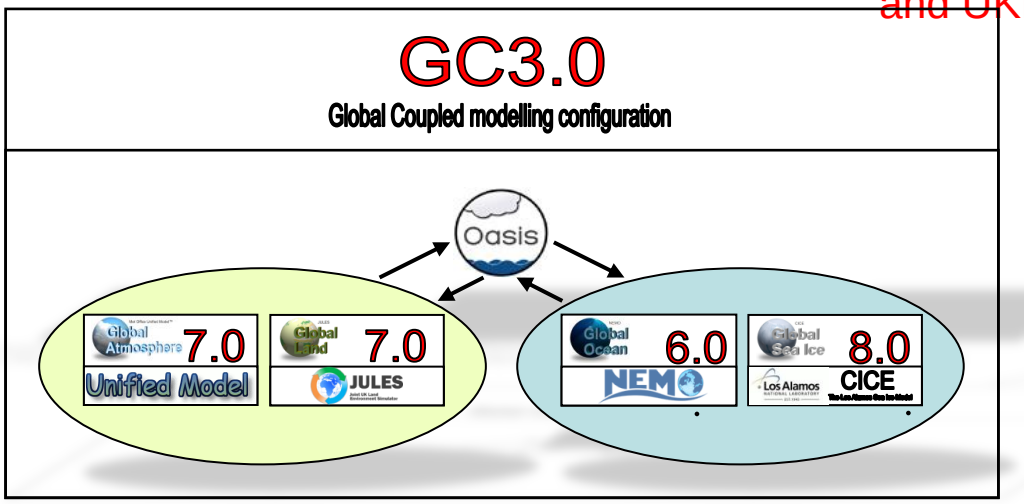


Climate Change studies (HadGEM3-GC3 and UKESM1)



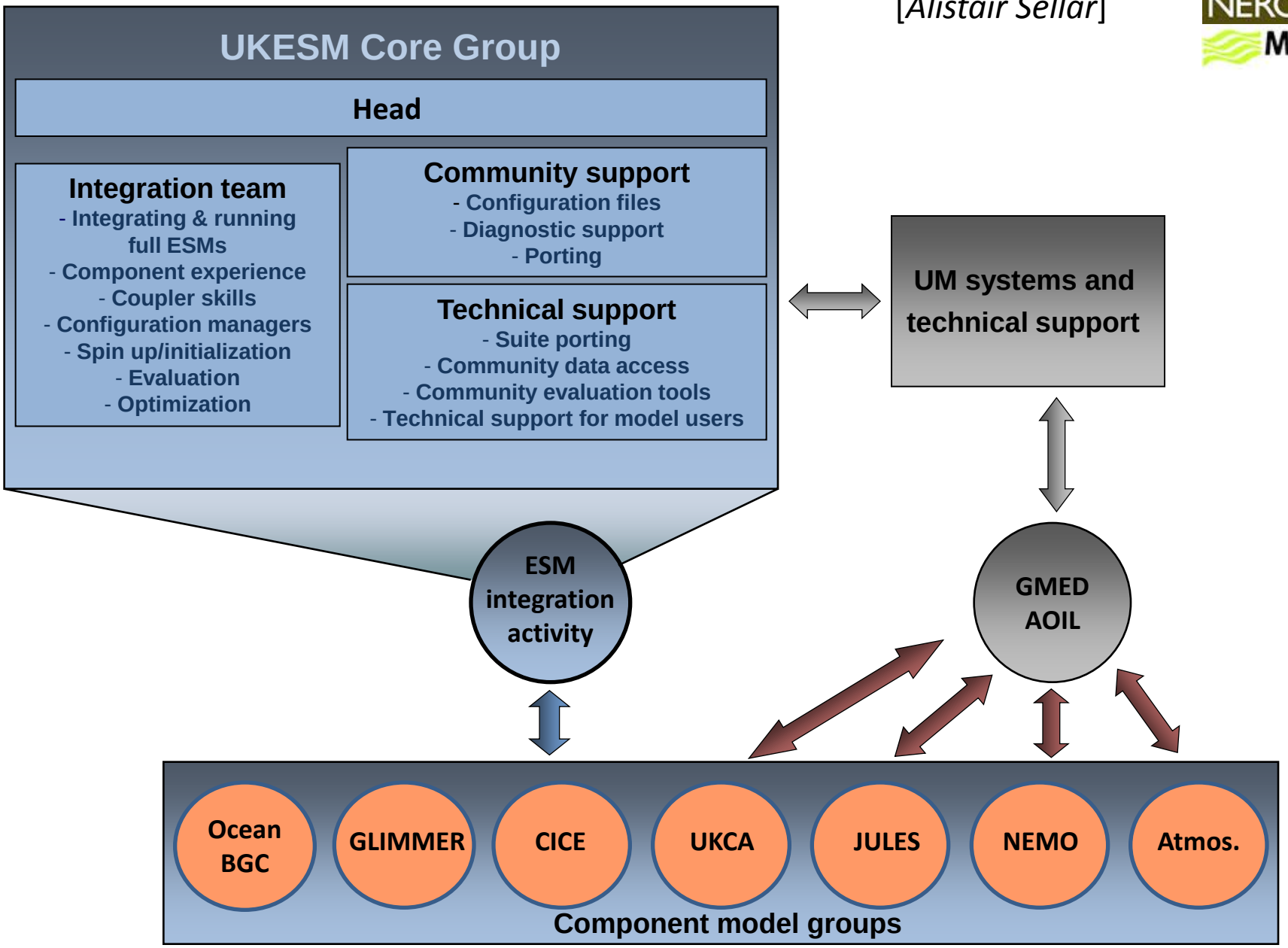
[after *Jeremy Walton*]

The UKESM project

- JWCRP NERC / Met Office collaboration
- Two objectives
  - Develop and apply a world-leading ESM
  - Grow a community of ESM scientists in the UK*
- Core group *develops*, *applies* & *evaluates* model
- Two model resolutions
  - UKESM1-HI for key CMIP6 simulations
    - at highest possible resolution given HPC resources
  - UKESM1-LO for long simulations & large ensembles
    - and investigating range of future emission scenarios

- *Technical infrastructure supporting collaborative UKESM1 development and CMIP6 science shares common features with that available for other MetUM-based partnerships*

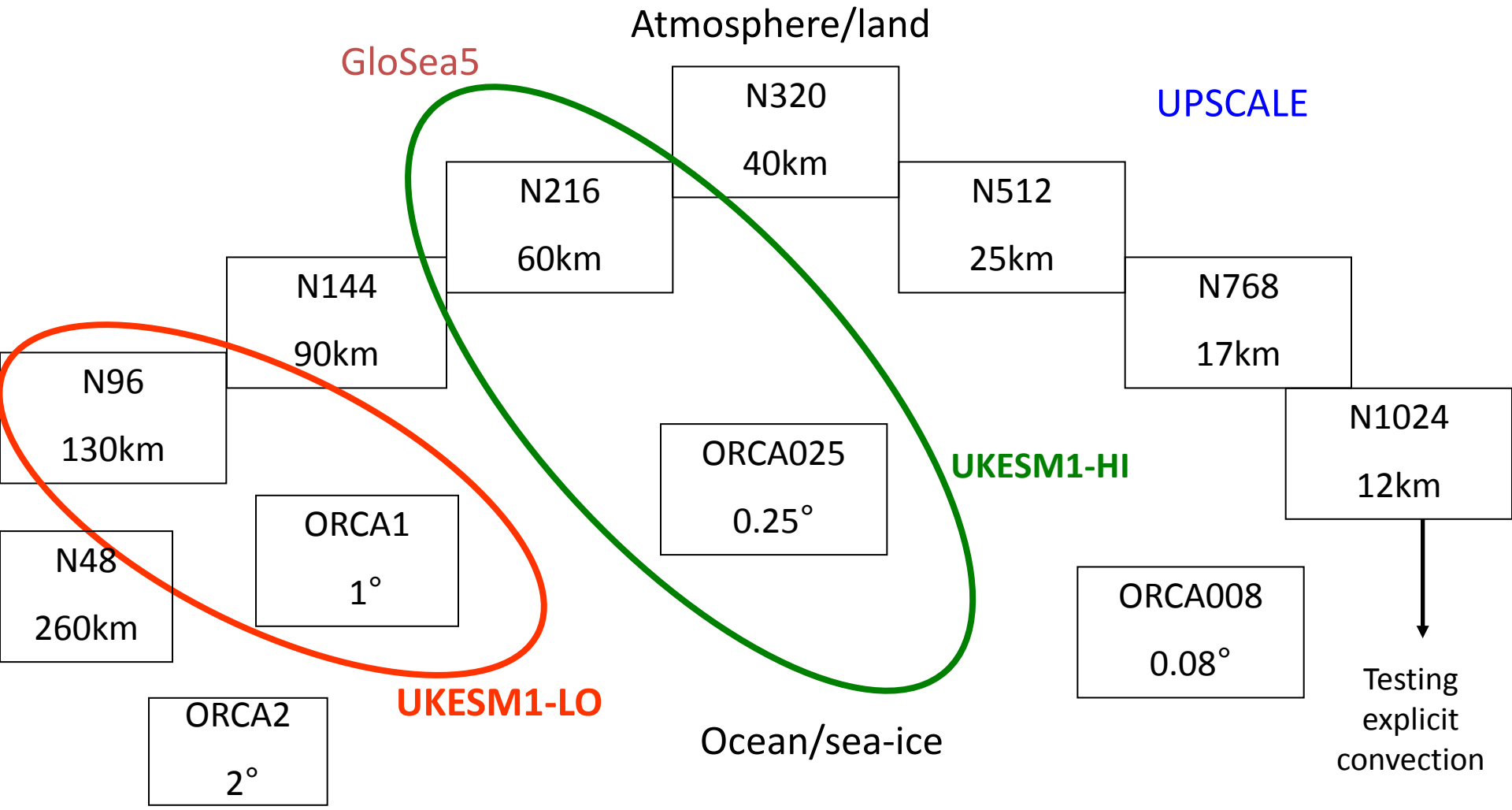
[*Alistair Sellar*]



Core group integrates component developments into a full ESM

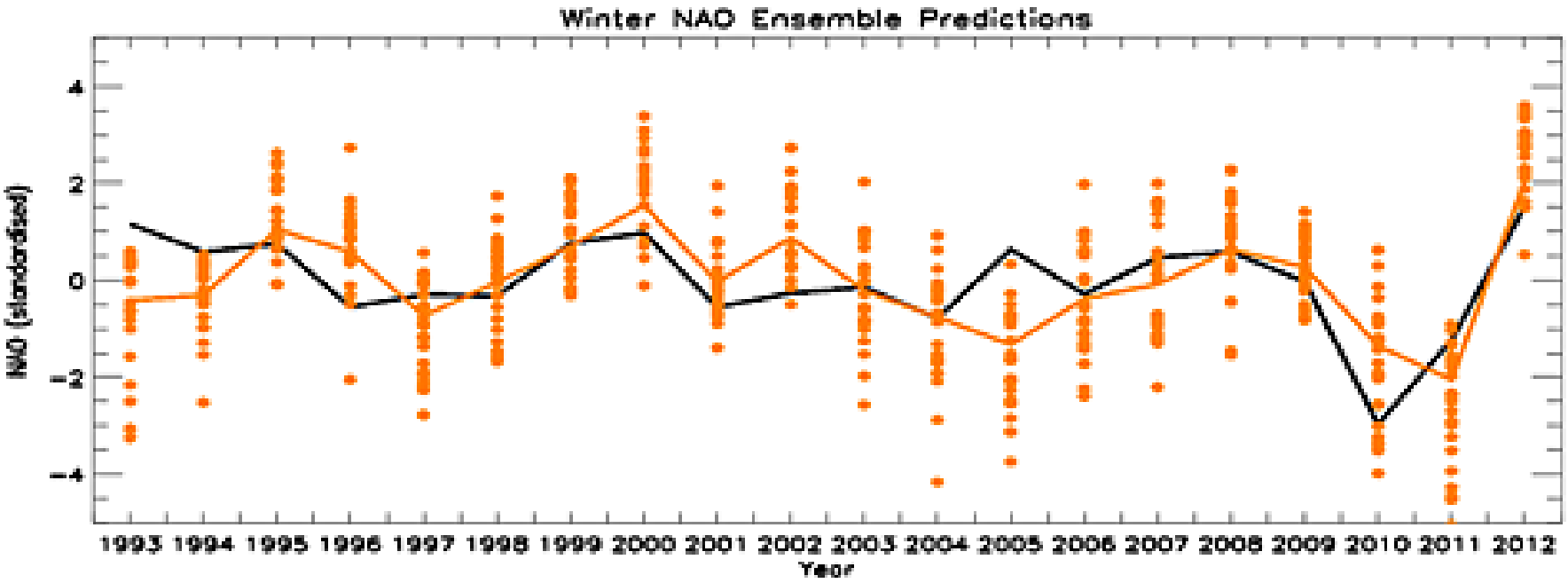
[*after Malcolm Robert/Jeremy Walton*]

UKESM1 resolutions in the context of the GA/GL and GO/GSI hierarchy



Essentially the same physics and dynamics are used throughout the GC model hierarchy

Skillful long-range prediction of European and North American winters (Scaife et al. 2014)



Predictability of the winter North Atlantic Oscillation. The NAO in observations (black line), ensemble mean forecasts (orange line), and individual ensemble members (orange dots) in winter (December to February (DJF)) hindcasts. The NAO is measured as the sea level pressure difference between Iceland and the Azores, but the skill is insensitive to the precise definition as large-scale patterns are frequently well captured (Figure S1). Observations, ensemble mean, and ensemble members are normalized by their respective standard deviations. Anomalies are for December to February, and forecasts were initialized from dates centered on 1 November. The correlation score of 0.62 is significant at the 99% level according to a t test and allowing for the small lagged autocorrelation in forecasts and observations.

Geophysical Research Letters
Volume 41, Issue 7, pages 2514-2519, 9 APR 2014 DOI: 10.1002/2014GL059637
http://onlinelibrary.wiley.com/doi/10.1002/2014GL059637/full#grl51580-fig-0001

UKESM1 components

Physical Model:

UKESM1-HI: HadGEM3-GC3: UM L85, N216(~60km)/ORCA0.25° L75, CICE
UKESM1-LO: HadGEM3-GC3: UM L85 N96(~140km) /ORCA1° L75,CICE

[**UKESM1-LO ~6 times faster than UKESM1-HI**]

Chemistry/Aerosols

UKCA full stratosphere– troposphere chemistry + GLOMAP-MODE aerosols

- Simplified version of UKCA chemistry also now developed employing offline oxidants and full tropospheric sulfur cycle (full UKCA ~4 times the cost of simplified scheme)
- GLOMAP-mode is prognostic in aerosol mass and number and allows internal mixing of aerosol species

Soil-Vegetation coupled Carbon-Nitrogen cycle:

JULES-Carbon+TRIFFID (dynamic vegetation including 9 PFTs) + soil-veg nitrogen + wildfires

Ocean Biogeochemistry

MEDUSA2 (developed at NOC) within NEMO/ORCA ocean model.

[**MEDUSA2 recommended by NERC iMarNet ocean BGC MIP : Kwiatkowski et al. 2014, Biogeosciences**]

Interactive Land ice sheets (both Greenland and Antarctic) :

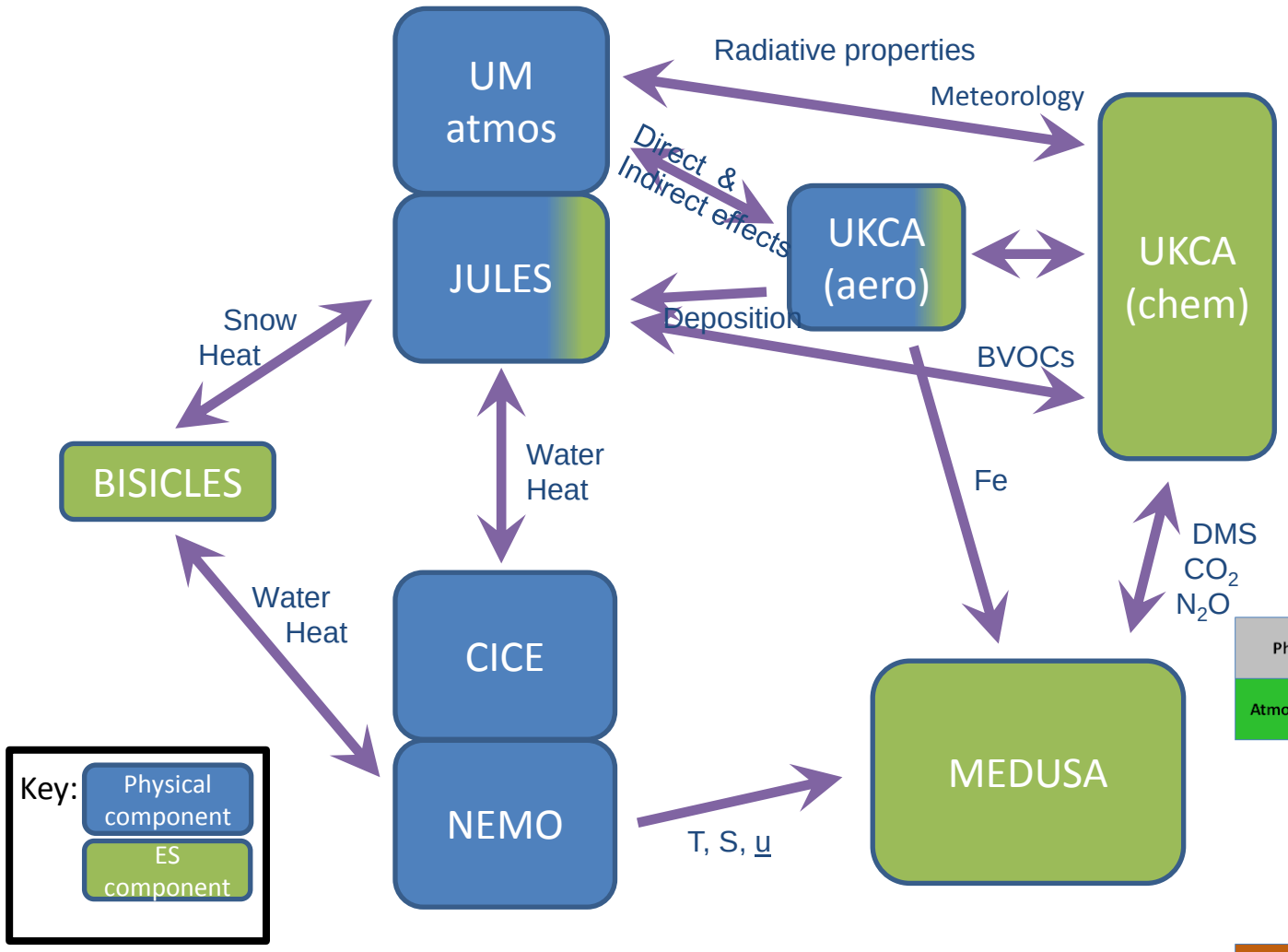
BISICLES and ice shelf basal melt description within NEMO.

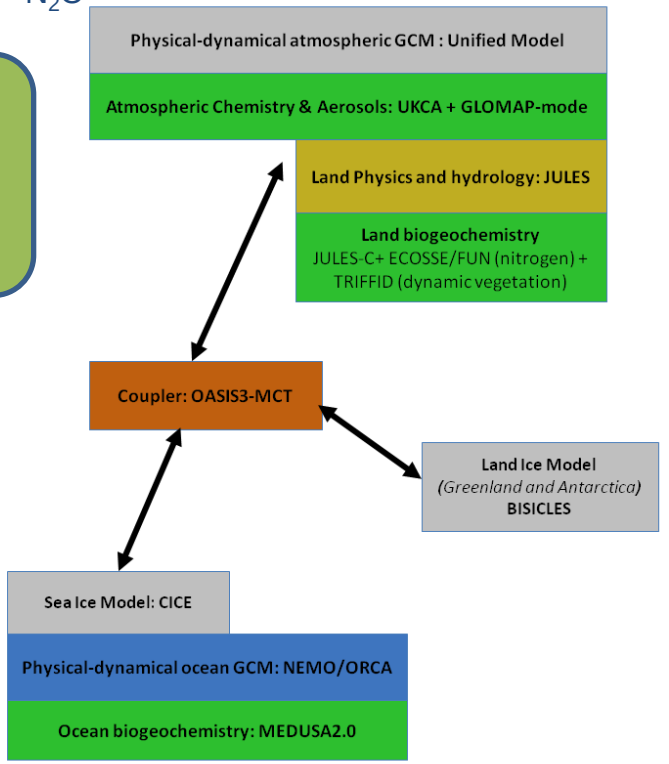
Coupler

OASIS3-MCT

[Colin Jones]

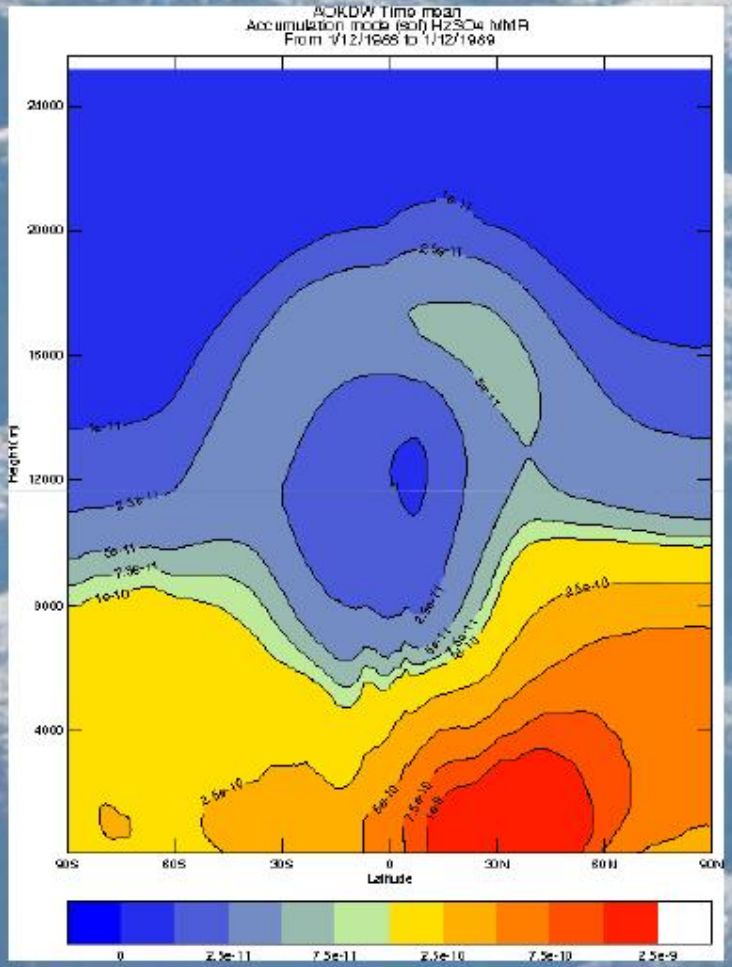
UKESM1 couplings and groupings

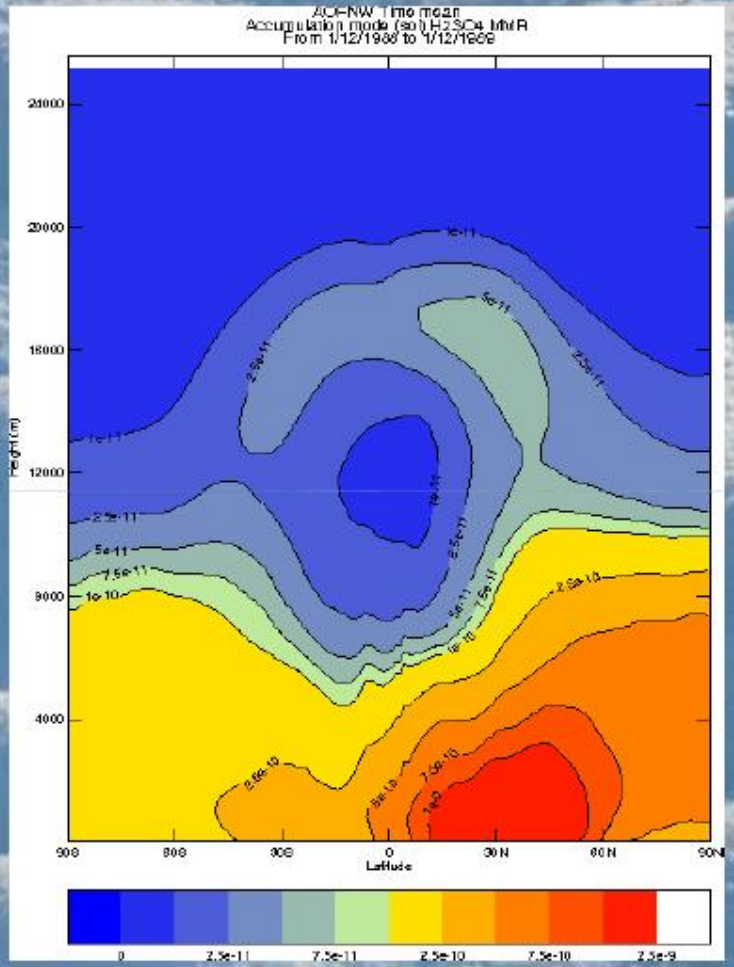




Simplified schematics of UKESM1 model components and couplings (above) and component clusters (right). Model component clusters connected to OASIS3-MCT operate as a single executable and are launched as independent executables run on separate processing elements.

1 year mean cross section of sulfate mass mixing ratio
Comparing simplified chemistry & offline oxidants versus full UKCA

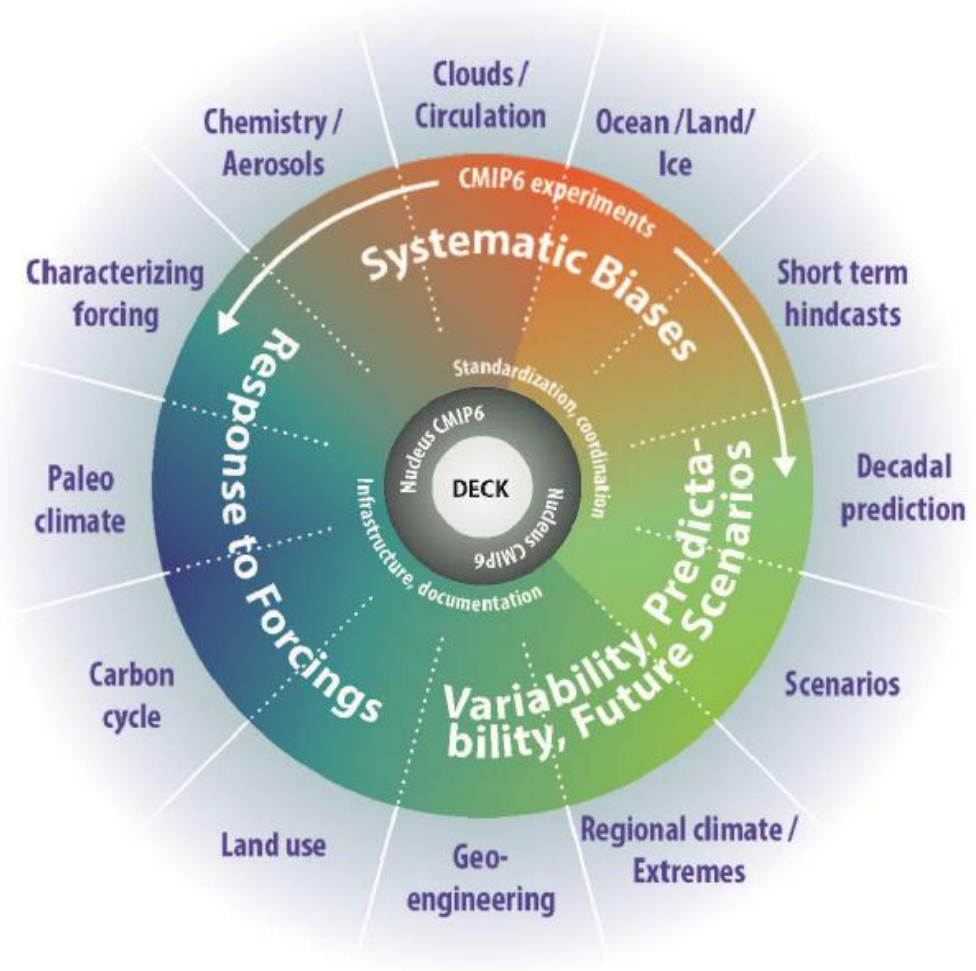




Simplified chemistry will be used in HadGEM3-GC3 with GLOMAP aerosols and likely in UKESM1-HI with oxidants generated by UKESM1-LO with full UKCA

Colin Johnson (UKESM), Mohit Dalvi, Fiona O'Connor (ESMS), Luke Harding (U. Cambridge)

CMIP6 modelling engagement



- HadGEM3-GC3 and UKESM1 (HI or LO) comprise the main modelling tools to be used by the Met Office and UK climate science community
- Ongoing work on a mixed HI/LO resolution UKCA coupling within UKESM1, which would reduce the computational cost compared to HI
- Participation in sub-projects outside of 'DECK' to be led by the Met Office while the UK academic community will lead on other sub-projects
- Coordinated process for deployment of UKESM1 and HadGEM3-GC3 on CMIP6 activities, including oversight of science aims, HPC utilisation and data dissemination activity to ESG

[*CMIP6 expt design, after Meehl et al. 2014*]

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- What will our engagement in CMIP6 look like?
- HadGEM3-GC2 pre-CMIP6 idealized experiments
  - Compare/contrast with HadGEM2-ES

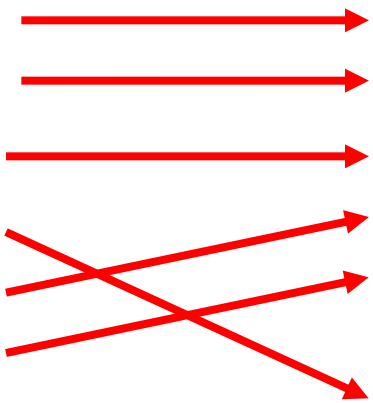
  [These results are from Senior et al. (in preparation)]

HadGEM3-GC2 experiments

A small sub-set of CMIP5 runs at

N216 (60km) and N96 (135km) both coupled to O(1/4):

- AMIP (3.3)
- Pre-industrial control (3.1)
- Historical (1850-2005) (3.2)
- RCP 8.5 (2005-2100) (4.1)
- 1% year^{-1} to 4xCO2 (6.1)
- Step change to 4xCO2 (6.3)

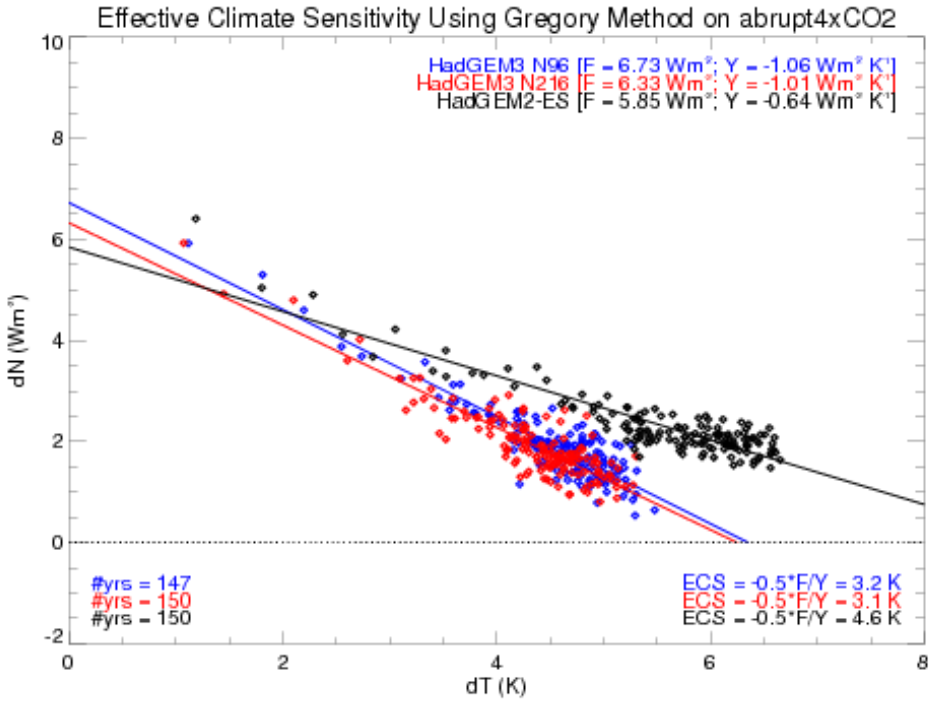


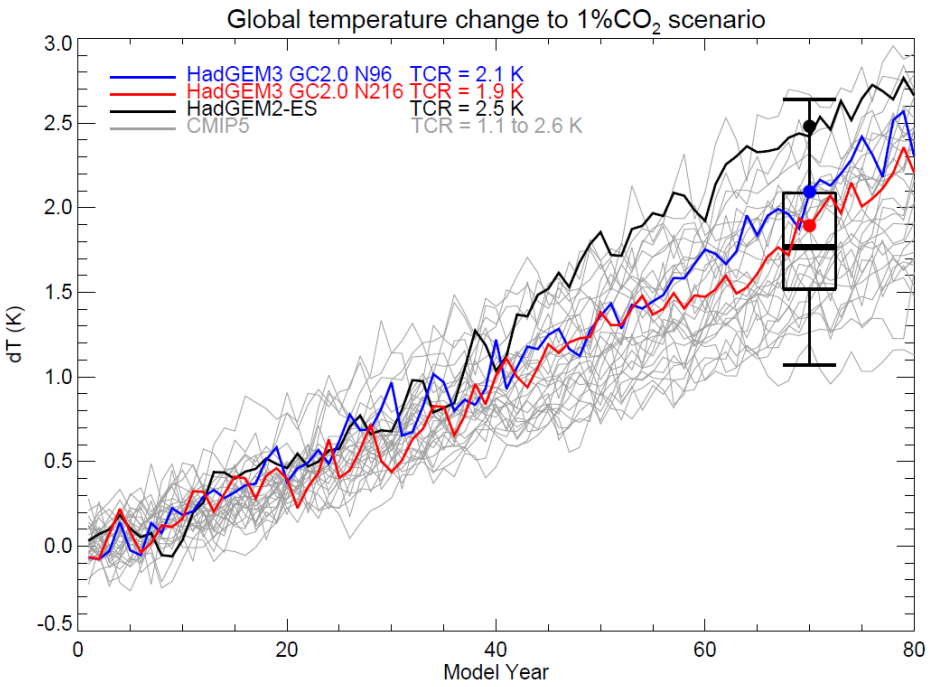
Proposed CMIP6 'Diagnosis and Evaluation' experiments

- AMIP (~1979-2010)
- Pre-industrial control
- Historical simulation
- 1%/yr CO2 to quadrupling
- Instantaneous 4 times CO2
- *Radiative forcing simulation*
- A high and low 21st century simulation

Emphasis initially on idealised scenarios rather than realistic RCPs. Understand impact of resolution (TCR, ECS, mechanisms of regional climate change) rather than focus on new projections.

Global measures of Climate Response





Equilibrium Climate Sensitivity

N216 (GC2)	3.1K
N96 (GC2)	3.2K
GEM2-ES	4.6K

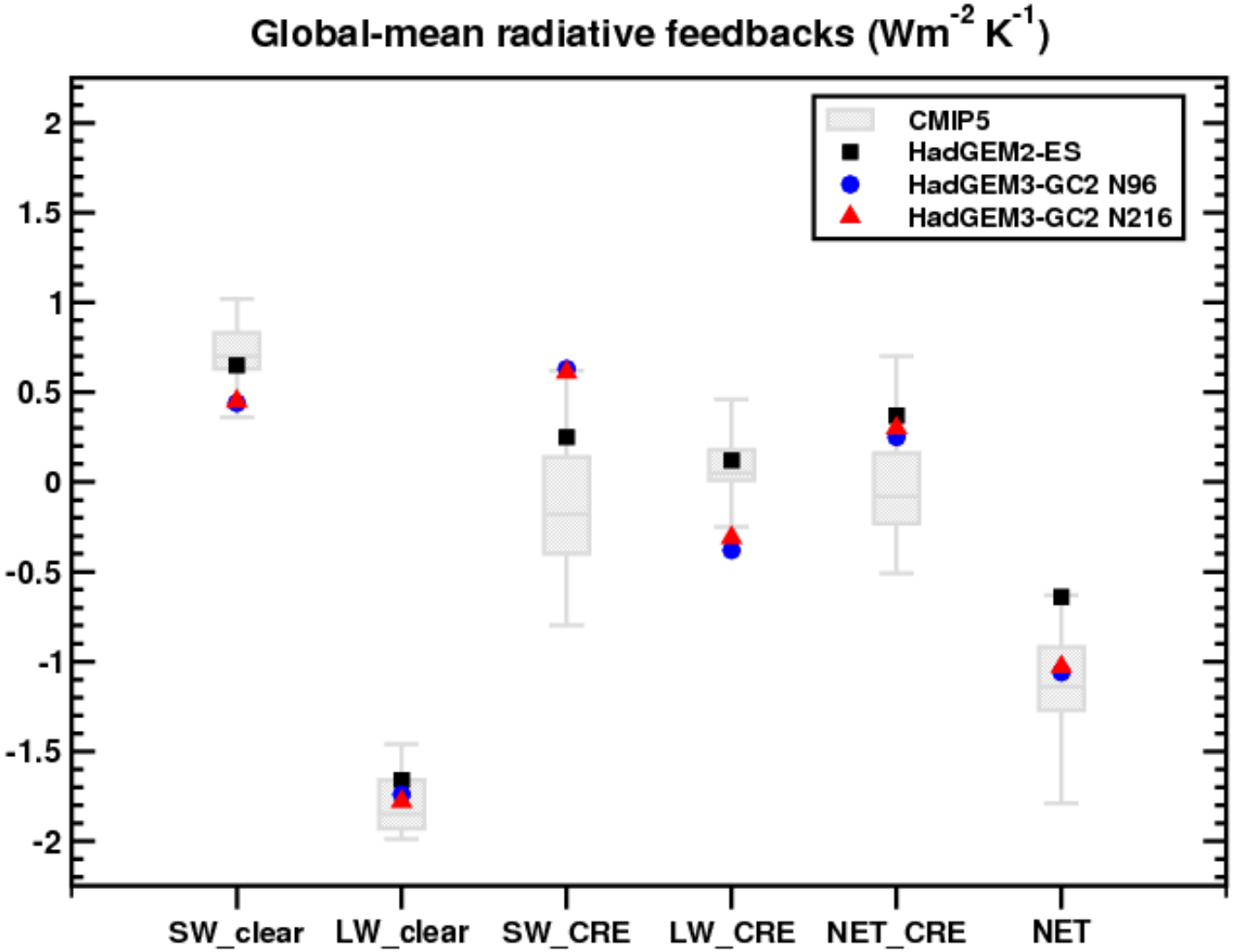
Transient Climate Response

N216 (GC2)	1.9K
N96 (GC2)	2.1K
GEM2-ES	2.5K

Tim Andrews

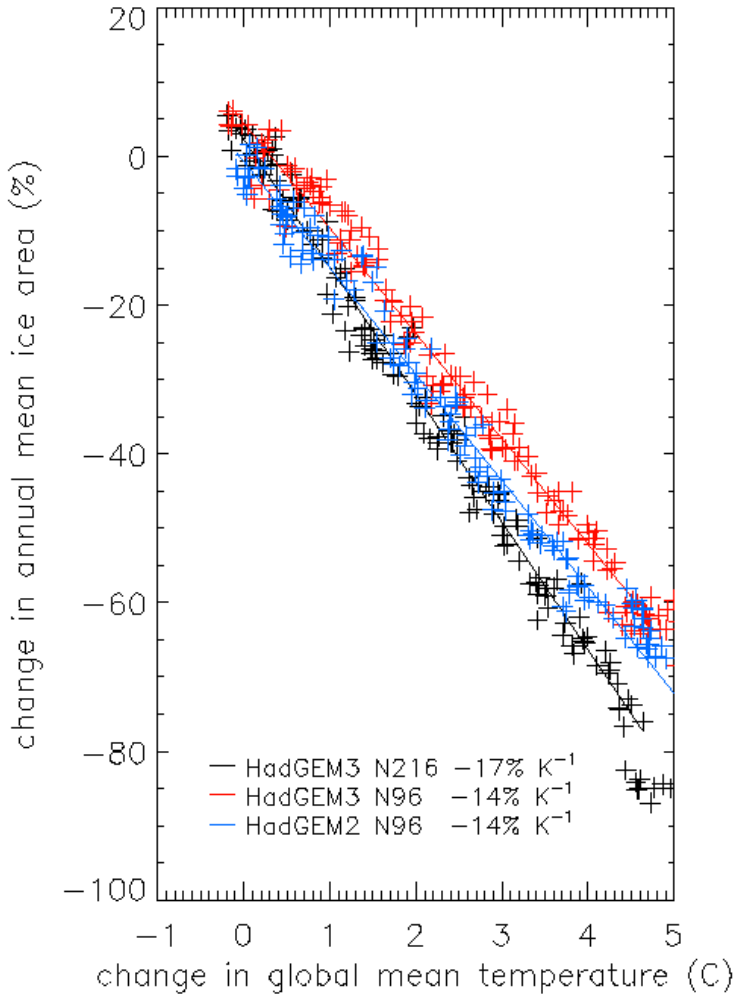
Radiative feedbacks

- No sensitivity to atmospheric resolution
- GC2 models have very different LW and SW cloud feedbacks



Mark Ringer

Arctic sea ice sensitivity



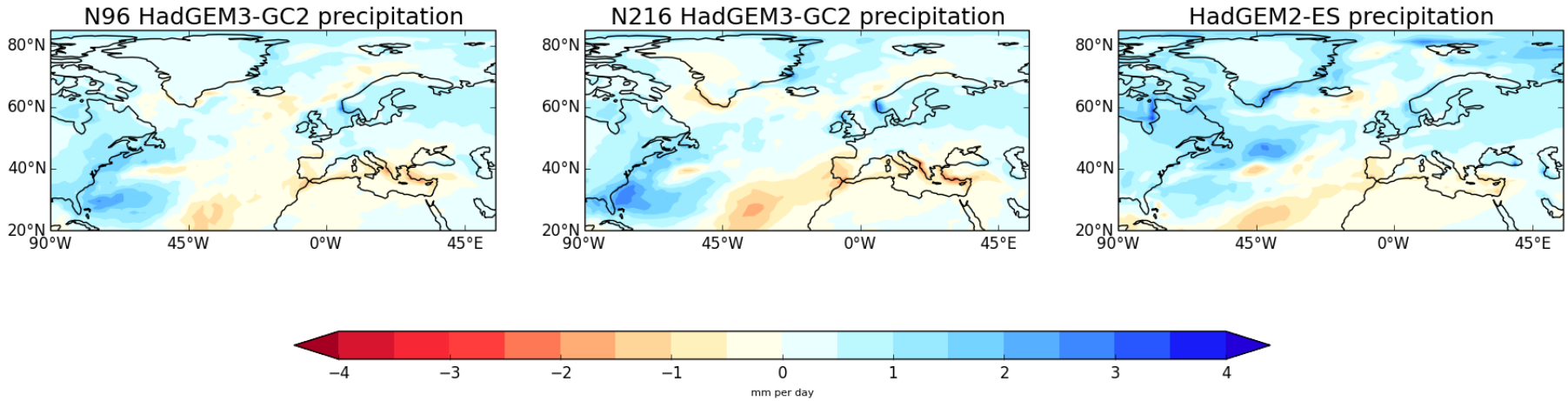
- HadGEM3-GC2 Lower ice area in N216 than N96 due to warmer 1.5m T

- HadGEM2-ES N96 has lower ice area than HadGEM3-GC2 N96 but 1.5m T similar

- Arctic sea-ice sensitivity stronger in N216

Jeff Ridley

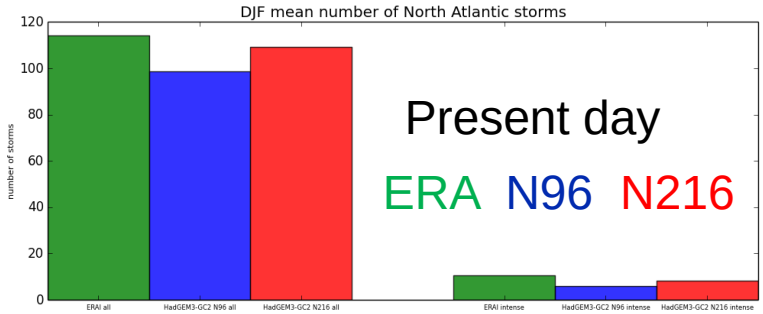
N. Atlantic winter precipitation response at 4xCO2 (GC2 N96/N216 vs. HadGEM2-ES)

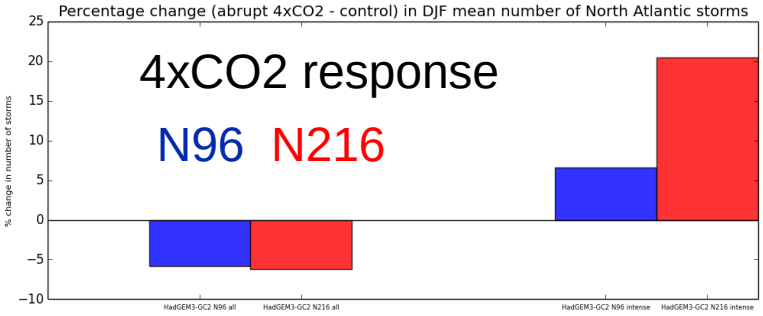


- Large-scale similar patterns of mean precipitation response for N96 and N216 with HadGEM3-GC2
- Some differences in regional pattern relative to HadGEM2-ES (structural model changes)

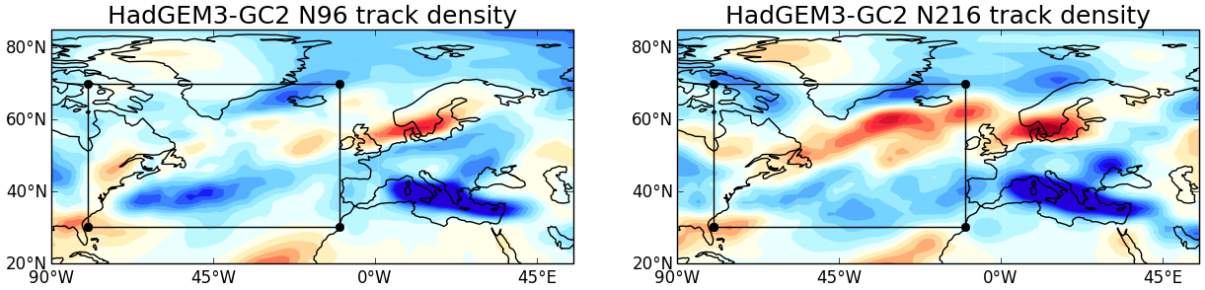
N. Atlantic winter storms: present day and 4xCO2 response

- N216 captures present day total storm numbers better than N96 (relative to ERA)
- Extreme storm frequency higher at N216
- Resolution dependence in the storm track density response at 4xCO2
- Decrease in projected total N. Atlantic storms at 4xCO2 (similar for N96/N216), but increase in frequency of the most extreme storms (considerably larger at N216)





Storm track density response



Ruth McDonald

Summary

- CMIP6 contribution will employ physical model HadGEM3-GC3 (successor to GC2) and the UKESM1 Earth System Model (UK ES community effort)
- Many differences in these CMIP6 models relative to HadGEM2-ES:
  - New dynamical core and numerous physics upgrades
  - UKCA GLOMAP-Mode aerosol scheme replacing CLASSIC
  - New ocean and sea ice components (NEMO, CICE)
  - New ES components with additional complexity and couplings
  - Higher resolution (HI)
- Different model configurations choices for different MIPs (rather than one-size-fits-all)
- Global climate sensitivity/ECS:
  - GC2 (physical model) lower than HadGEM2-ES
  - Resolution-dependence small for overall sensitivity, but some resolution-dependence for Arctic sea ice sensitivity
  - GC3 may be quite similar to GC2 (both physical models)
  - UKESM1? (ES feedbacks yet to be quantified in the full model)

References

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