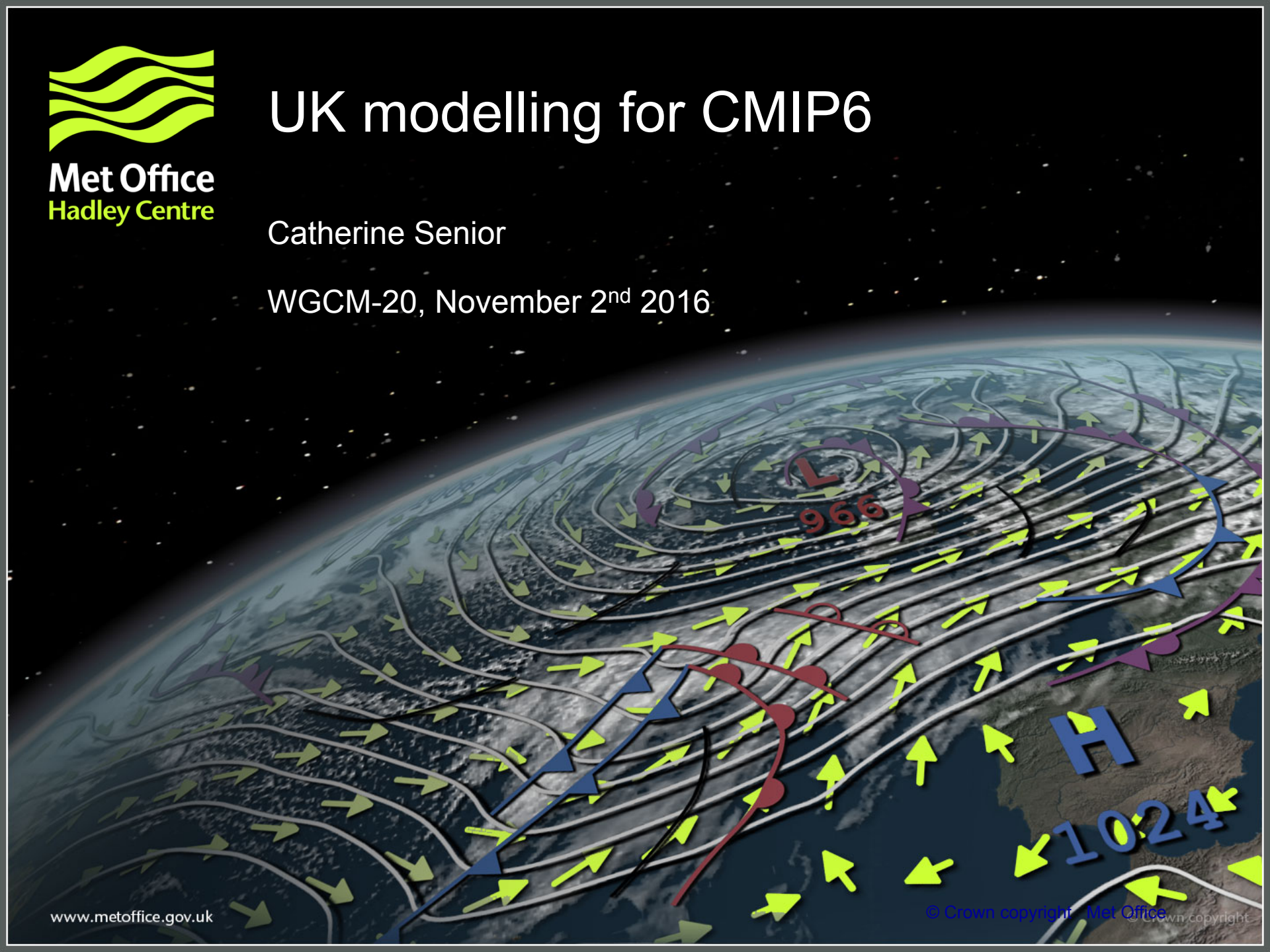
UK modelling for CMIP6

Catherine Senior

WGCM-20, November 2nd 2016



Model Configurations

- Physical model configurations:
  HadGEM3-GC3.1=GC3.0(GA7+GL7+GO6+GSI8) + …
  - HadGEM3-GC3.1-N96ORCA1
  - HadGEM3-GC3.1-N216ORCA025
- ESM configurations: UKESM1=HadGEM3-GC3.1 + UKCA, GLOMAP-mode, JULES-CN, TRIFFID, MEDUSA2, BISCICLES
  - UKESM1.0-N96ORCA1
  - UKESM1.0-N216ORCA025hybrid
    at degraded resolution)
    - under development – See Jeremy Walton's talk in model hierarchy workshop

Physical Model development

HadGEM3-GC3.0

- **Global Atmosphere and Land (GA-7/GL-7)**
  - GA6 (Walters, 2016 - ENDGame dynamical core)
  - Convection
    - improved numerics & vertical velocity dependent CAPE closure
  - Radiation, Cloud,& Microphysics
    - improved treatment of gaseous absorption
    - McICA upgrades
    - convective cores seen by radiation
    - warm rain microphysics
    - forced" shallow cumulus
    - new ice optical properties and realistic ice PSD
    - turbulent production of liquid water
    - revised cloud top entrainment
    - new variable RHcrit for cloud formation
  - New unified stochastic physics scheme
  - UKCA-MODE aerosol scheme with offline oxidants
  - Multi-layer snow scheme into JULES

These changes all relative to **HadGEM3-GC2** (Williams et. al. (2015); Senior et. al. (2016)).

Completely new relative to **HadGEM2** used for CMIP5 (new dynamical core for the atmosphere, new NEMO ocean, new CICE sea-ice model, and new land surface model JULES)

Global Ocean (GO-6)

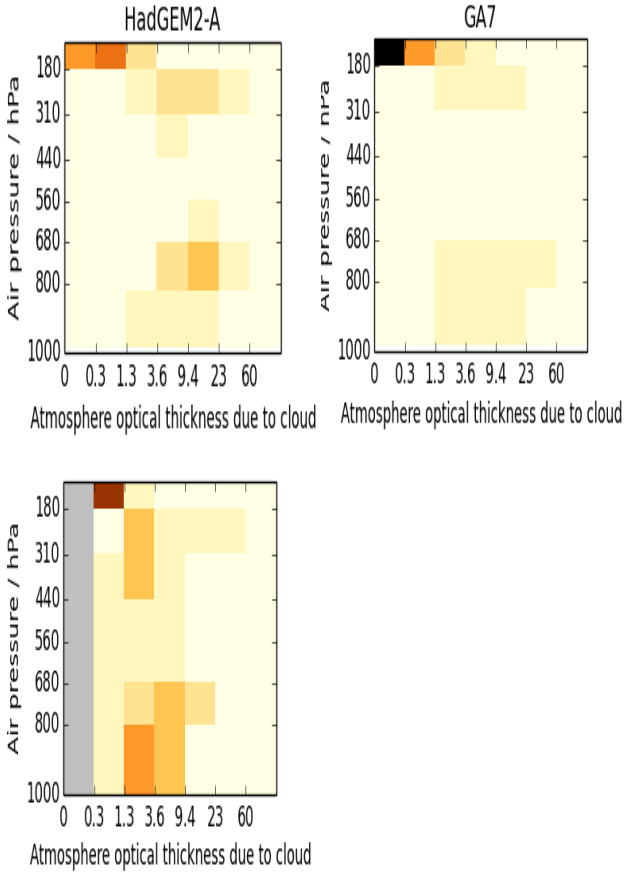
- non-linear free surface,
- Lagrangian icebergs
- extended grid around Antarctica
- ice shelf scheme
- revised ocean mixing

Global Sea-Ice (GSI8)

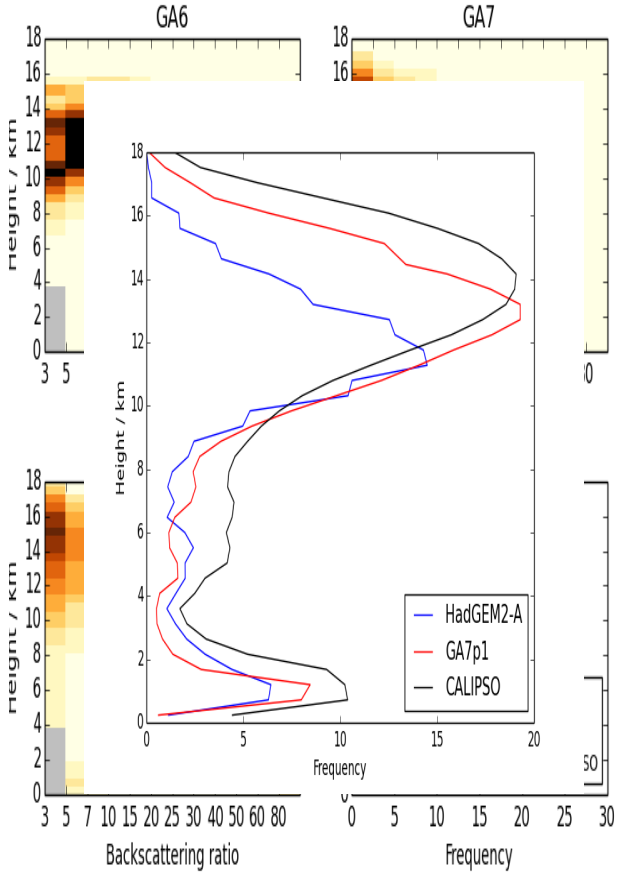
multi-layer thermodynamic sea-ice
Improved representation of melt-ponds,

Cloud simulation:
comparison against satellite data over the tropics

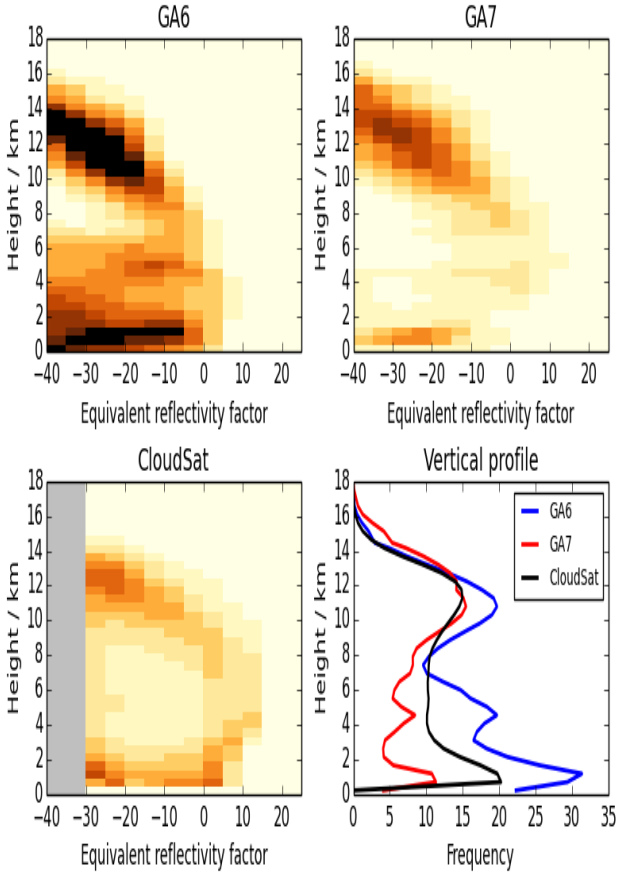
ISCCP



CALIPSO

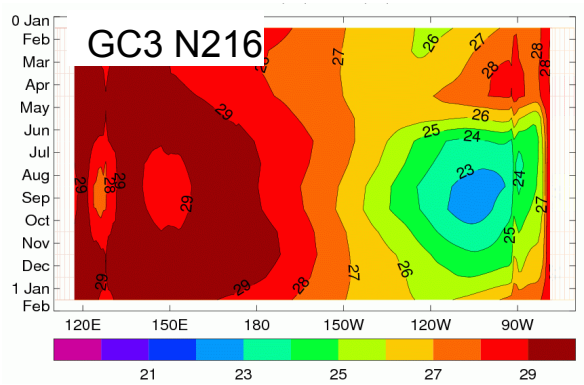


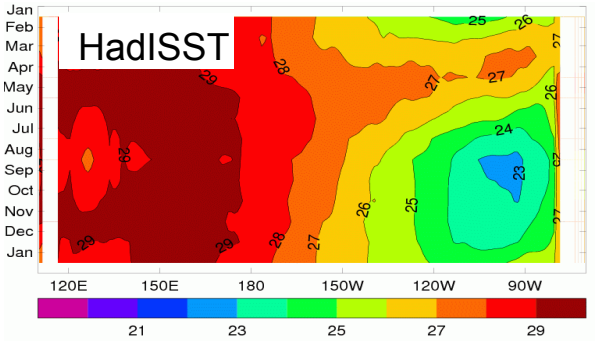
CloudSat

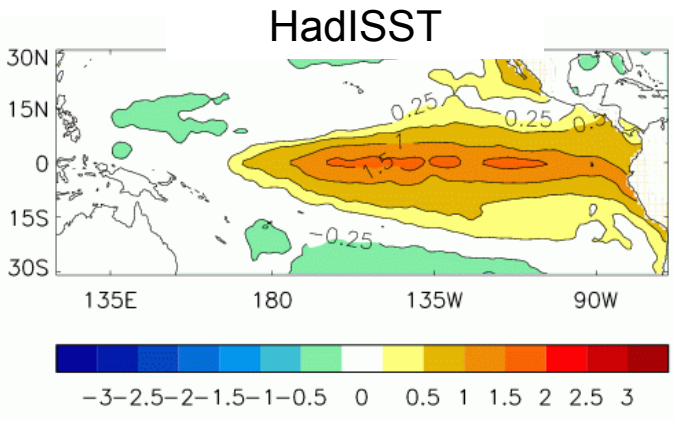


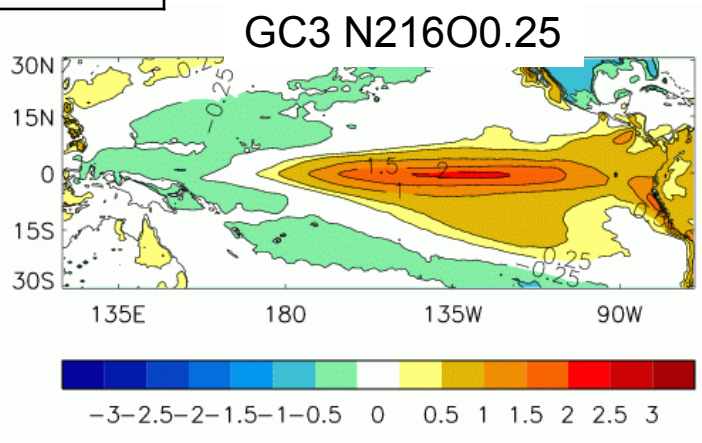
ENSO simulation

	Obs	HadGEM2	N96 ORCA025 100 yr	N216 ORCA025 100 yr
Nino3 standard deviation SST	0.79	0.86	0.71	0.82
Nino4 standard deviation SST	0.54	0.47	0.43	0.45
Nino3 SST power spectrum timescale (yrs)	3.5 5.3	3.4 4-5 6-8	3.4,4.2,6.2	2.7, 4.2
Ann. Mean Nino3 SST	25.9	25.2	26.5	26.4
Ann. Mean Nino4 TAUX	-0.029	-0.047	-0.037	-0.034
Nino4 standard deviation PPTN	2.7	1.9	2.1	2.4





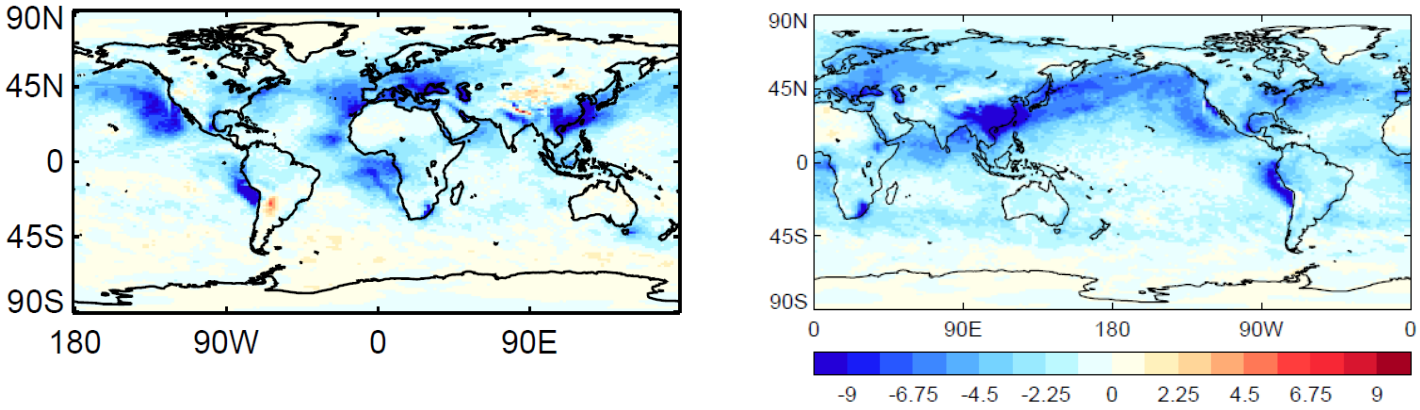




GA7 ERFs

ERF (1850-2000)	HadGEM2-A	GA7 (GC3)
Aerosols	-1.4 Wm-2	-2.3 Wm-2
of which: **direct** effect	-0.2 Wm^{-2}	-0.5 Wm^{-2}
indirect effect	-1.3 Wm^{-2}	-1.8 Wm^{-2}
Total anthropogenic ERF (aerosols, GHGs, ozone, land use*)	1.1 Wm^{-2}	0 Wm^{-2}

HadGEM2-A Aerosol ERF GA7

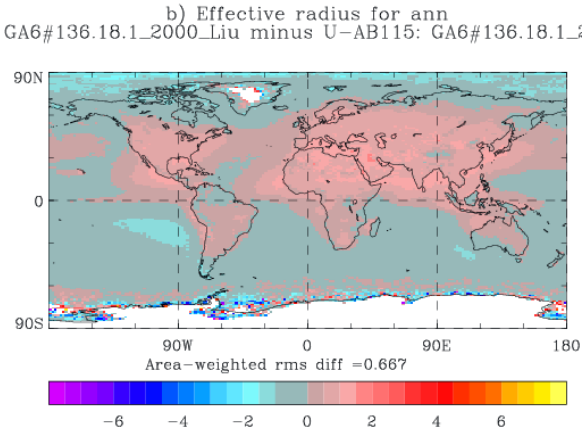


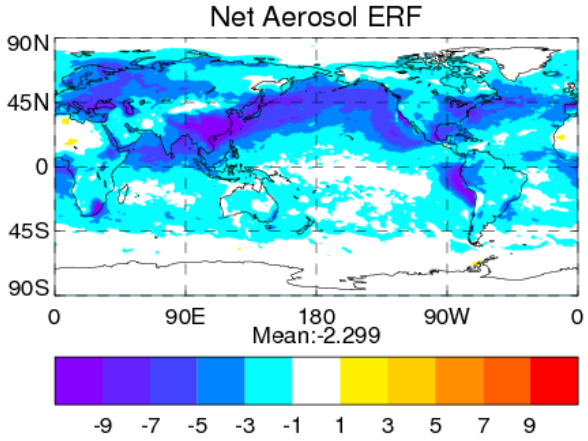
Jane Mulcahy, Tim Andrews

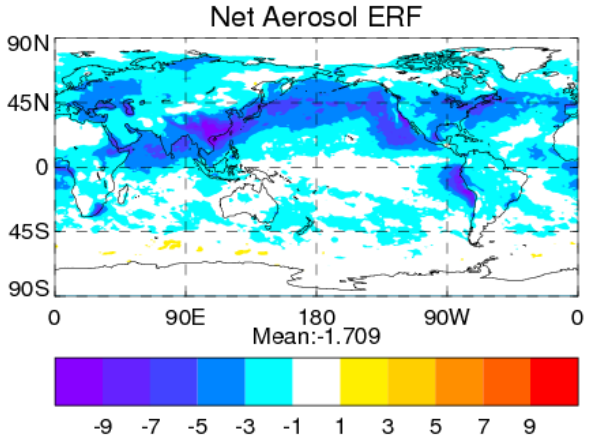
GC3.1 Model improvements

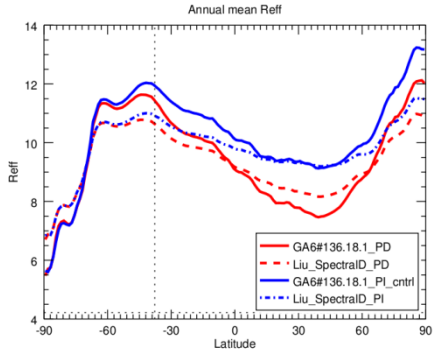
- Liu et al (2008) cloud droplet spectral dispersion scheme
- Increase to black carbon refractive index (absorption component) from 1.75 – 044i to 1.85 – 0.71i in light of recent evidence (Bond and Bergstrom 2006; Bond et al., 2013).
- RADAER look-up-tables which store aerosol optical properties have been improved to better resolve absorption of solar absorption
- Correct an error in SO_2 emissions from continuously erupting volcanoes
- Increase marine emissions of DMS (x1.7) as a proxy for missing emissions of primary marine organic aerosol

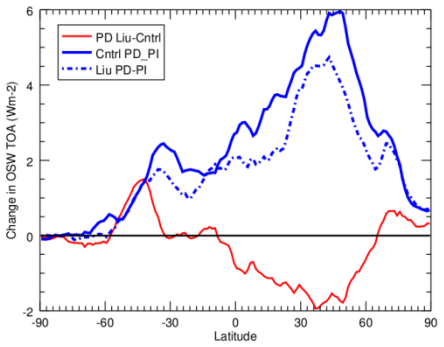
Liu Spectral Dispersion











Parameterization of cloud droplet spectral dispersion:

$$r_e = \sqrt[3]{\frac{3q_c\rho_a}{4\pi\rho_w k N_d}}$$

currently k=0.67 (land) and k=0.80 (ocean) (following Martin et al. 1994)

Liu et al. (2008): $\beta = 0.07 \cdot \left(L/N_d\right)^{-0.14}$

β=Spectral shape parameter and $k = \beta^{-3}$

Jane Mulcahy

ERFs

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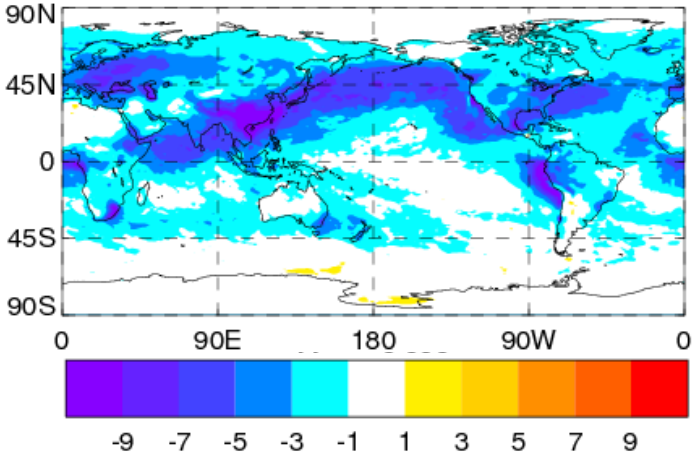
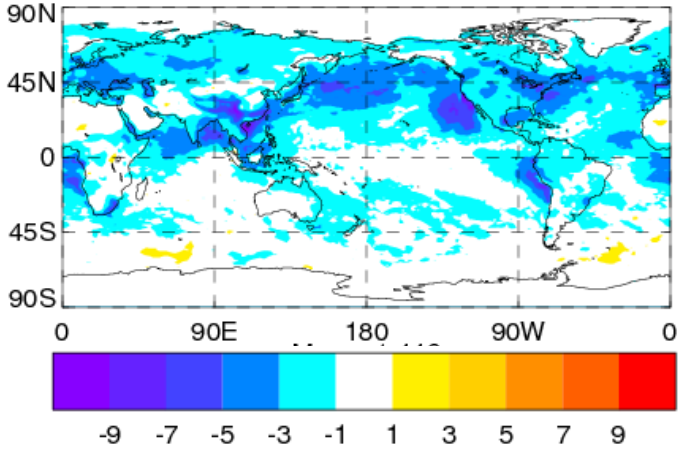
Aerosols	-1.4 Wm-2	-2.3 Wm-2	-1.4 Wm-2
of which: **direct** effect	-0.2 Wm^{-2}	-0.5 Wm^{-2}	-0.4 Wm^{-2}
indirect effect	-1.3 Wm^{-2}	-1.8 Wm^{-2}	-1.0 Wm^{-2}
Total anthropogenic ERF (aerosols, GHGs, ozone, land use*)	1.1 Wm^{-2}	~ 0 Wm^{-2}	~0.9 Wm^{-2}

Aerosol ERF: GA7



GA7.1



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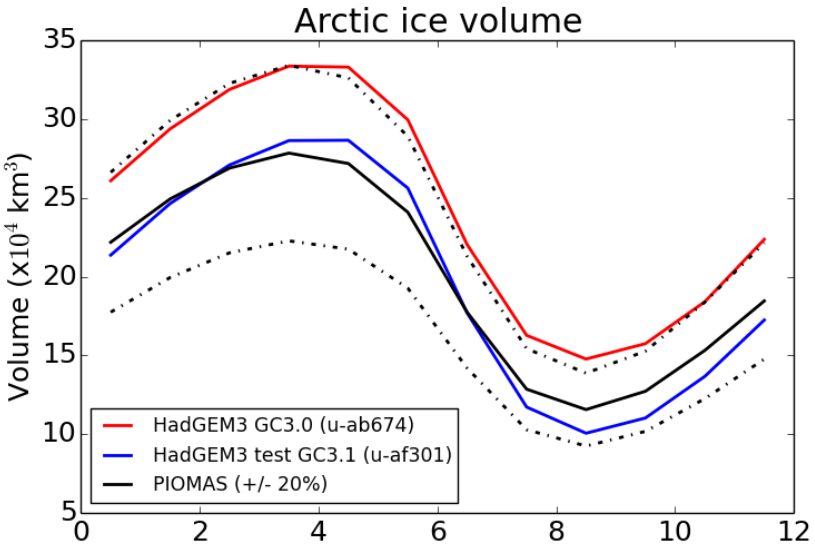
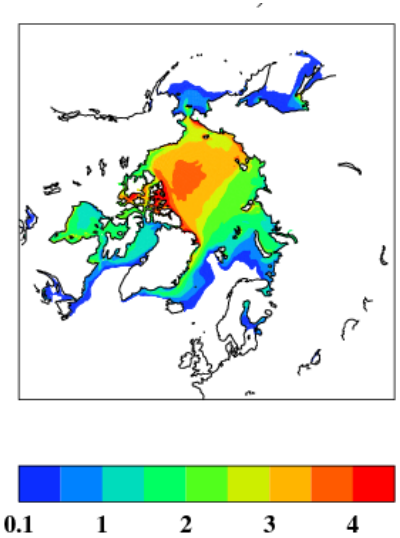
- RADAER look-up-tables which store aerosol optical properties have been improved to better resolve absorption of solar absorption
- Correct an error in SO_2 emissions from continuously erupting volcanoes
- Increase marine emissions of DMS (x1.7) as a proxy for missing emissions of primary marine organic aerosol
- Thermal conductivity of snow on sea-ice reduced from 0.5 to 0.255 $Wm^{-1}K^{-1}$
- Ice-ocean drag co-efficient increased from 0.00536 to 0.01

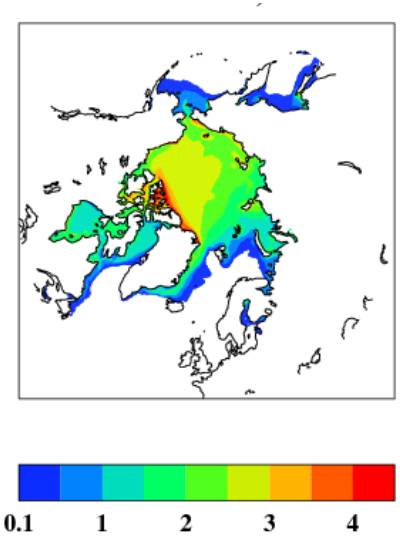
Arctic Sea-ice thickness



GC3.0: March



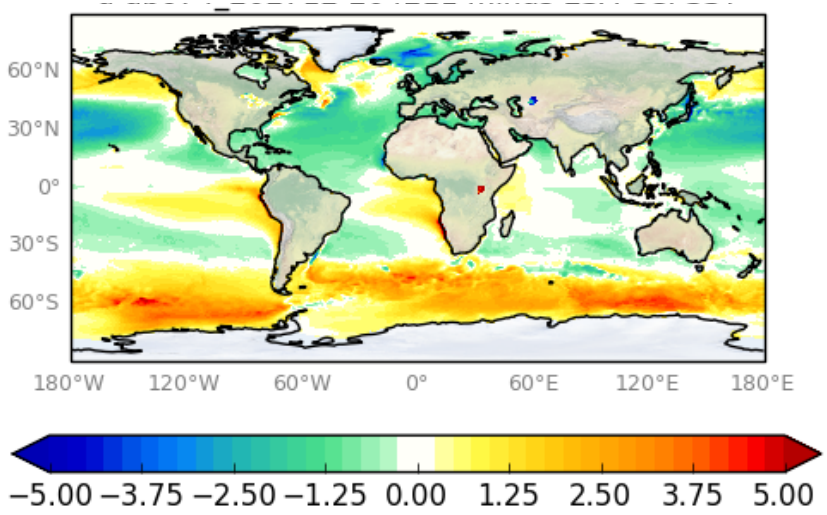
GC3.1: March



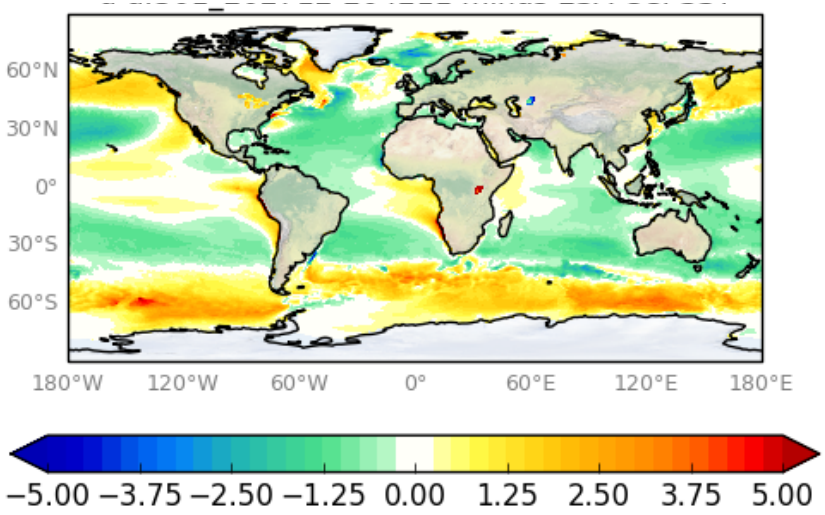
Ann Keen

SSTs

HadGEM3-GC3 – ESA CCI SSTs

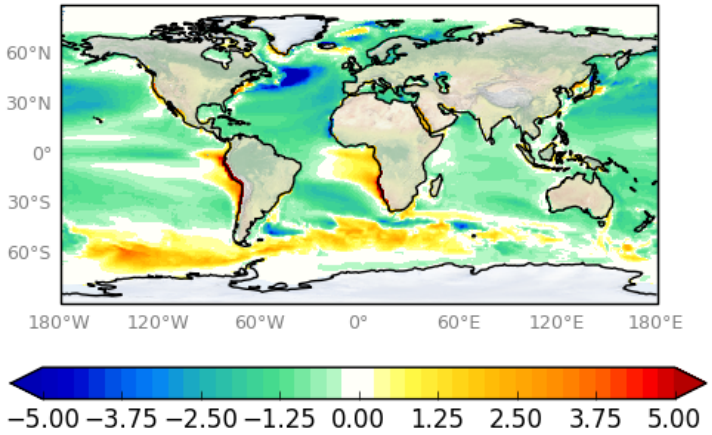


HadGEM3-GC3.1 – ESA CCI SSTs

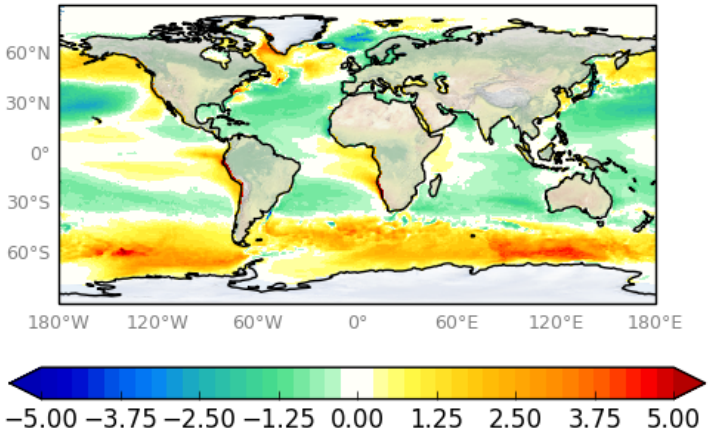


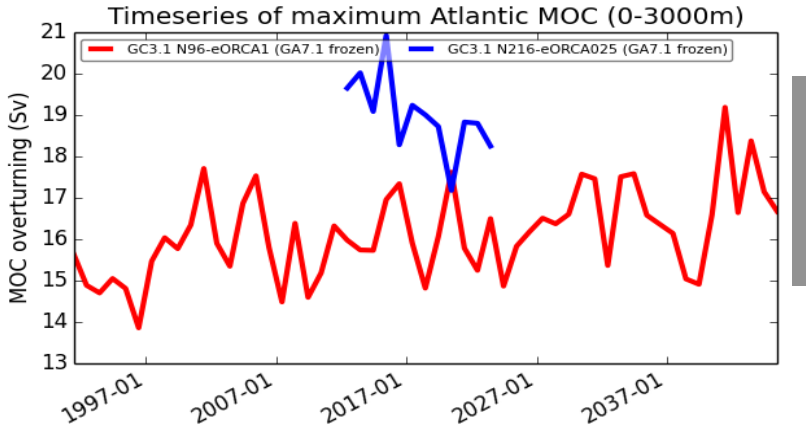
HadGEM3-GC3.1-N96ORCA1

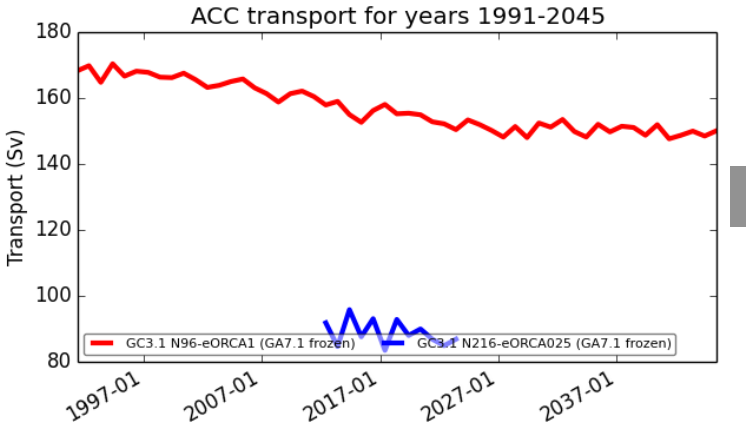
HadGEM3-GC3-N96O1 – ESA CCI SSTs



HadGEM3-GC3.1-N216O0.25 – ESA CCI SSTs

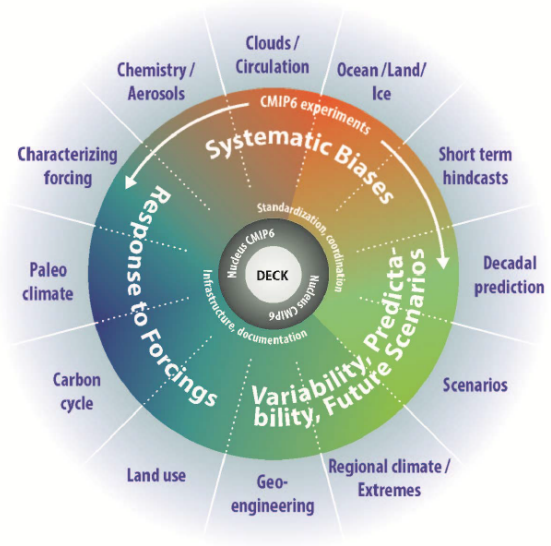






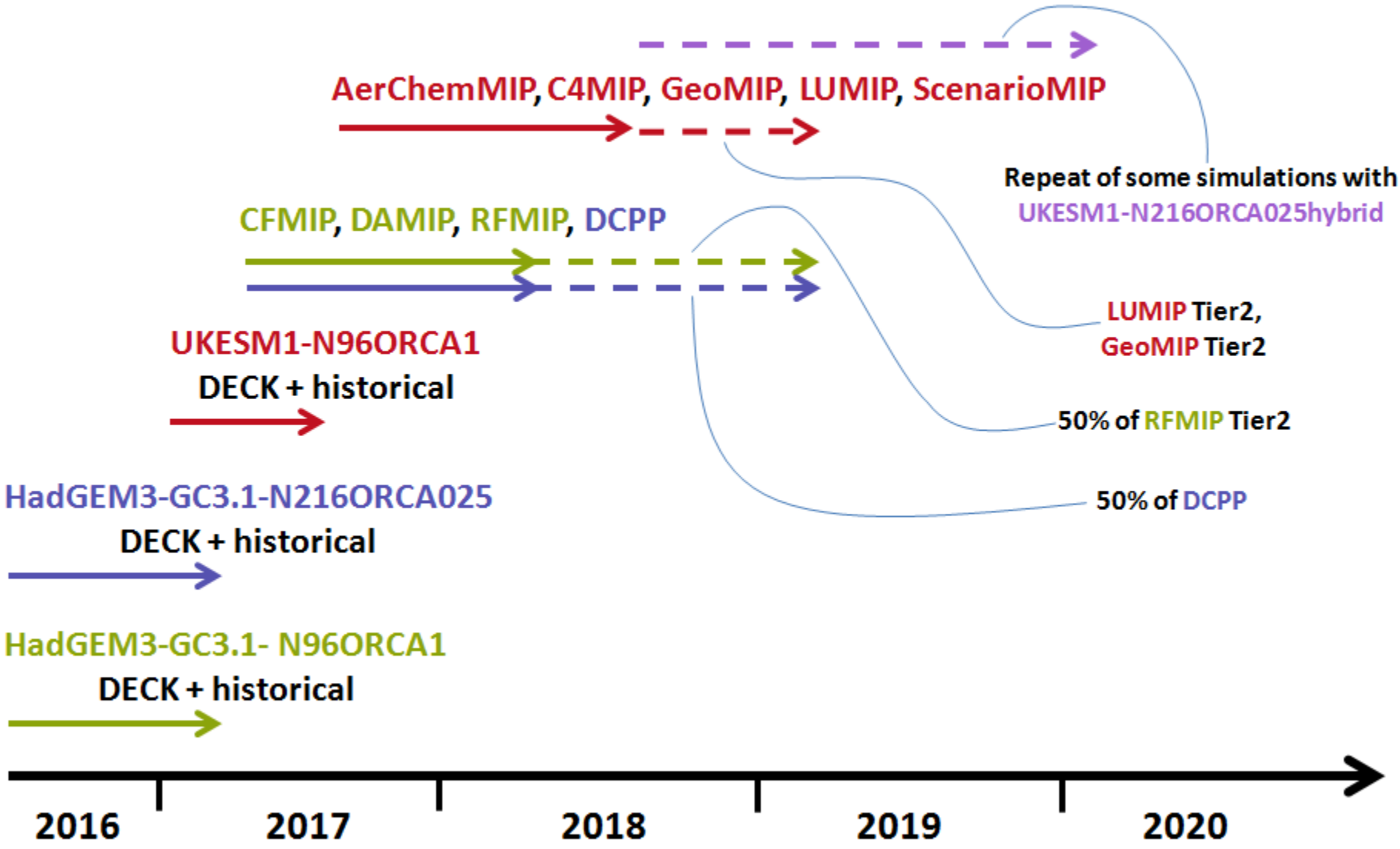
MIP Experiments

- HadGEM3-GC3.1-N96ORCA1
  - CFMIP, FAFMIP, RFMIP, DAMIP
- HadGEM3-GC3.1-N216ORCA025:
  - DCPP, GMMIP, HighResMIP, OMIP (physics runs only)



- UKESM1.0-N96ORCA1:
  - AerChemMIP, C4MIP, GeoMIP, ISMIP6, LUMIP, ScenarioMIP, VolMIP, OMIP (physics + biogeochemistry)
- UKESM1.0-N216ORCA025hybrid:
  - repeat experiments for a number of selected MIPs

UK CMIP6 Runs on Met Office HPC



KMA's CMIP6 Plan : Models & MIPs

❖ K-ACE

- KMA's developing model (physical model with aerosol, not ESM modules yet)
- Simulations
  - CMIP6 Entry : DECK and HIST
  - ScenarioMIP

❖ UKESM1

- Under collaboration with UKMO
- Simulations
  - HIST and ScenarioMIP
  - AerChemMIP and C4MIP

❖ HadGEM3-RA

- Under collaboration with UKMO
- Simulation - CORDEX

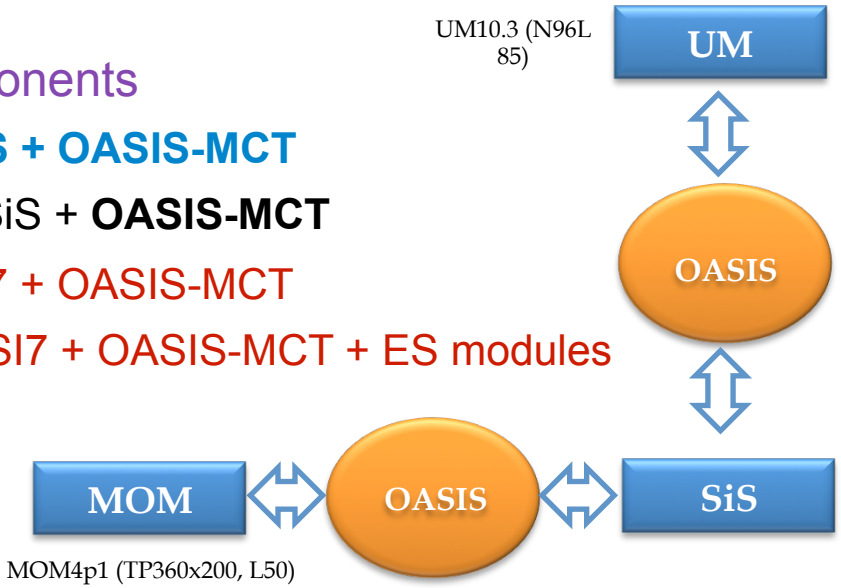
K-ACE & UKESM1

❖ Freezing K-ACE version using GC3.1 components

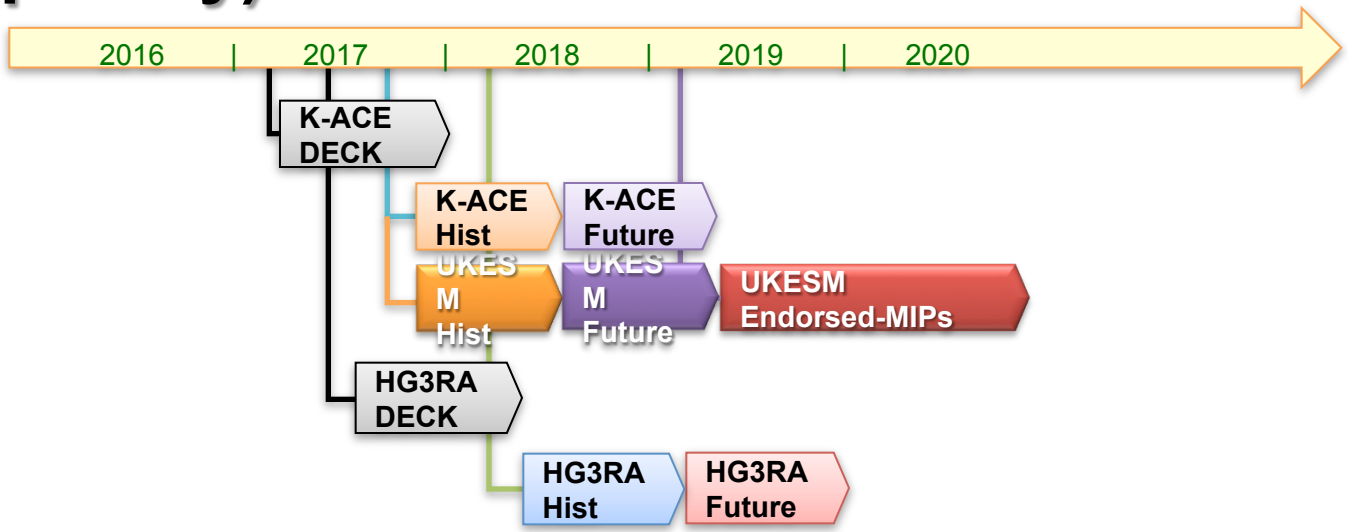
- **Current K-ACE(v0.8) = GA7 + GL7 + MOM4-SiS + OASIS-MCT**
- CMIP6 K-ACE v1.0 = **GA7.1 + GL7** + MOM4-SiS + **OASIS-MCT**

※ HadGEM3-GC3.1 = GA7.1 + GL7 + GO6-GSI7 + OASIS-MCT

※ UKESM1 = GA7.1 + GL7 + GO6-GSI7 + OASIS-MCT + ES modules



Timeline (hopefully)



UKESM1 components

Physical Model: HadGEM3-GC3

New ocean and sea-ice models (NEMO, CICE, Hewitt et al, 2011)
Enhanced vertical resolution: L85
ENDGame dynamical core (Wood et al 2014)
PC2 cloud scheme (Wilson at al, 2008)

Chemistry/Aerosols

UKCA full stratosphere– troposphere chemistry + GLOMAP-mode aerosols
* Simplified version of UKCA chemistry also available employing offline oxidants and full tropospheric sulphur cycle (full UKCA ~4.5 times UM cost, simplified scheme ~1.7 times UM)

Soil-Vegetation coupled Carbon-Nitrogen cycle

JULES+TRIFFID (dynamic vegetation) + soil/veg carbon-nitrogen + wetlands + diagnostic wildfires+ some permafrost improvements

Ocean Biogeochemistry

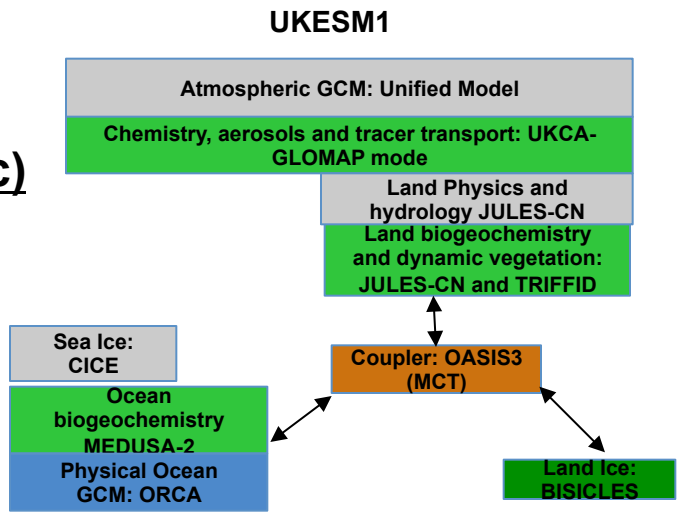
MEDUSA2 within NEMO ocean model.

Interactive Land ice sheets (Greenland and Antarctic)

BISICLES and ice shelf basal and cavity melt within NEMO-ORCA.

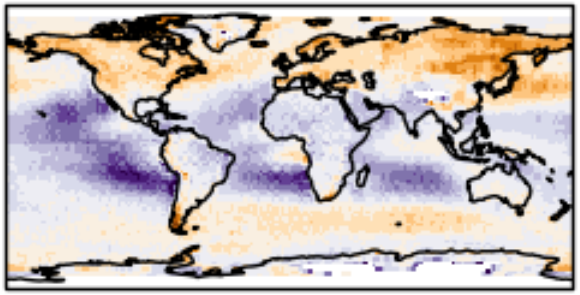
Coupler

OASIS3-MCT

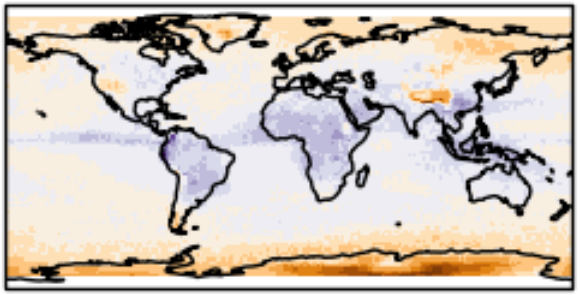


Bias in cloud cover (against CALIPSO)

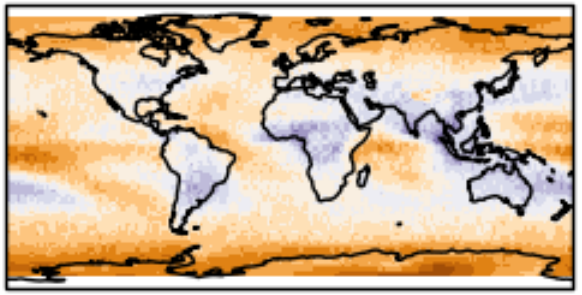
GA7p1-AMIP
Low-top cloud bias



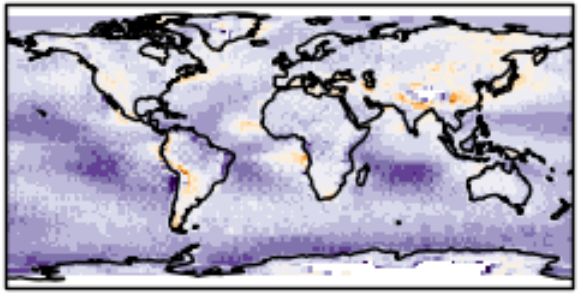
GA7p1-AMIP
Mid-top cloud bias



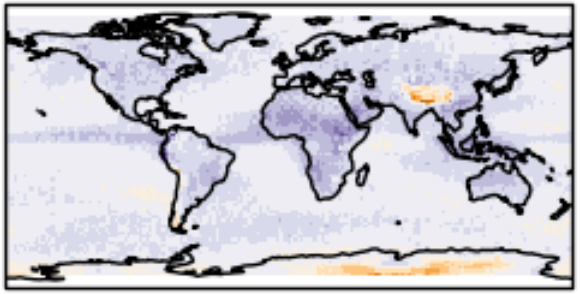
GA7p1-AMIP
High-top cloud bias



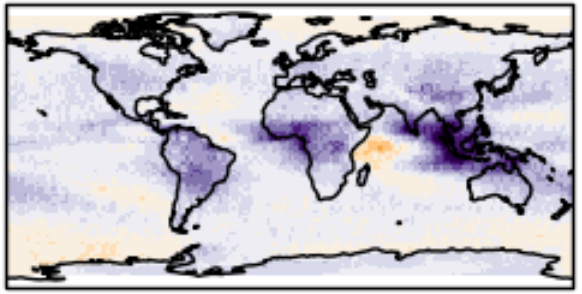
HadGEM2-AMIP
Low-top cloud bias

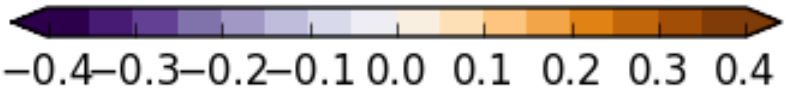


HadGEM2-AMIP
Mid-top cloud bias

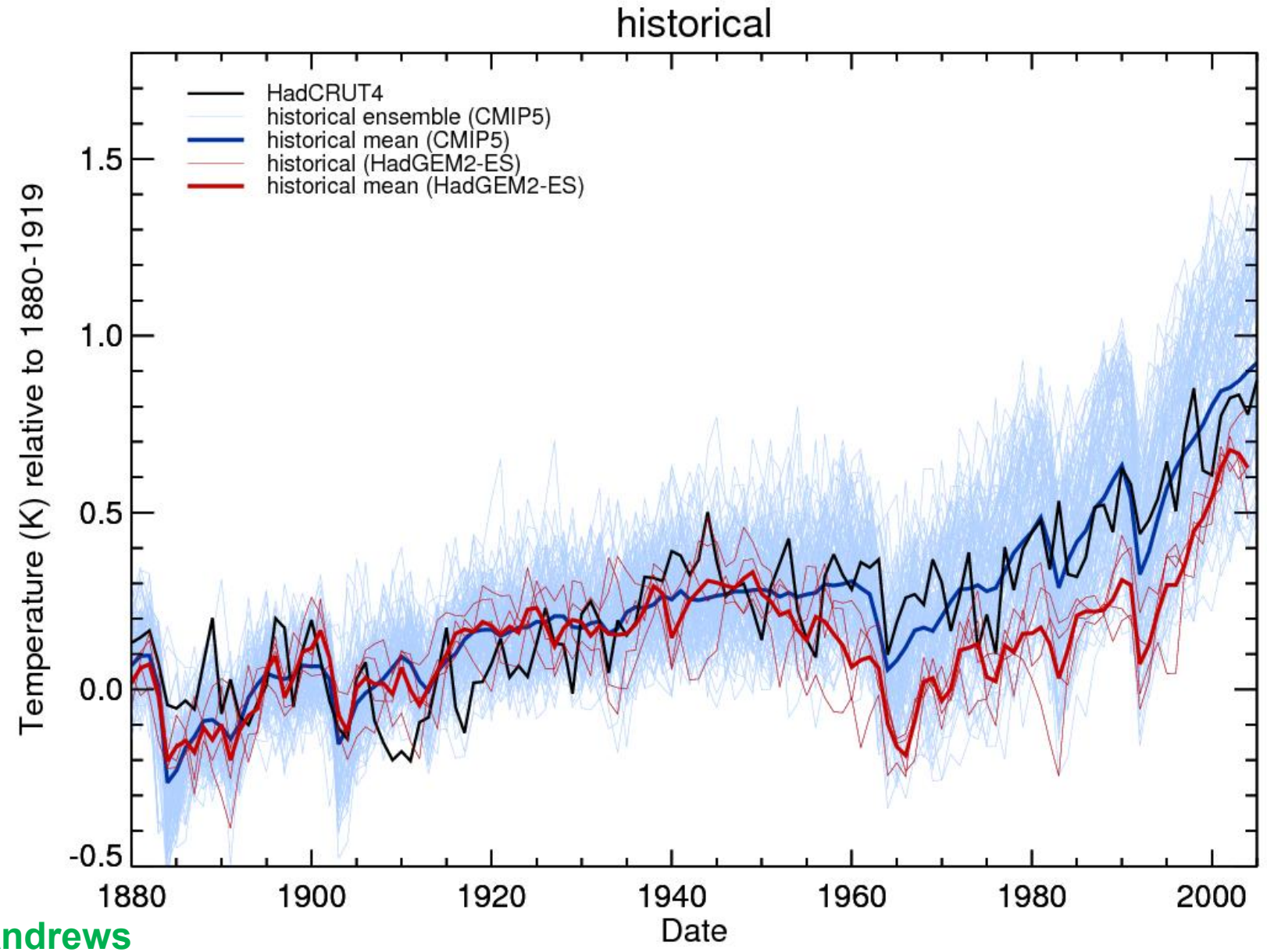


HadGEM2-AMIP
High-top cloud bias





HadGEM2-ES Historic runs



Tim Andrews

Cloud Improvements for GA7

Evaluation – COSP Simulator

Met Office

Tropics: mean profile vs CALIPSO & CloudSAT