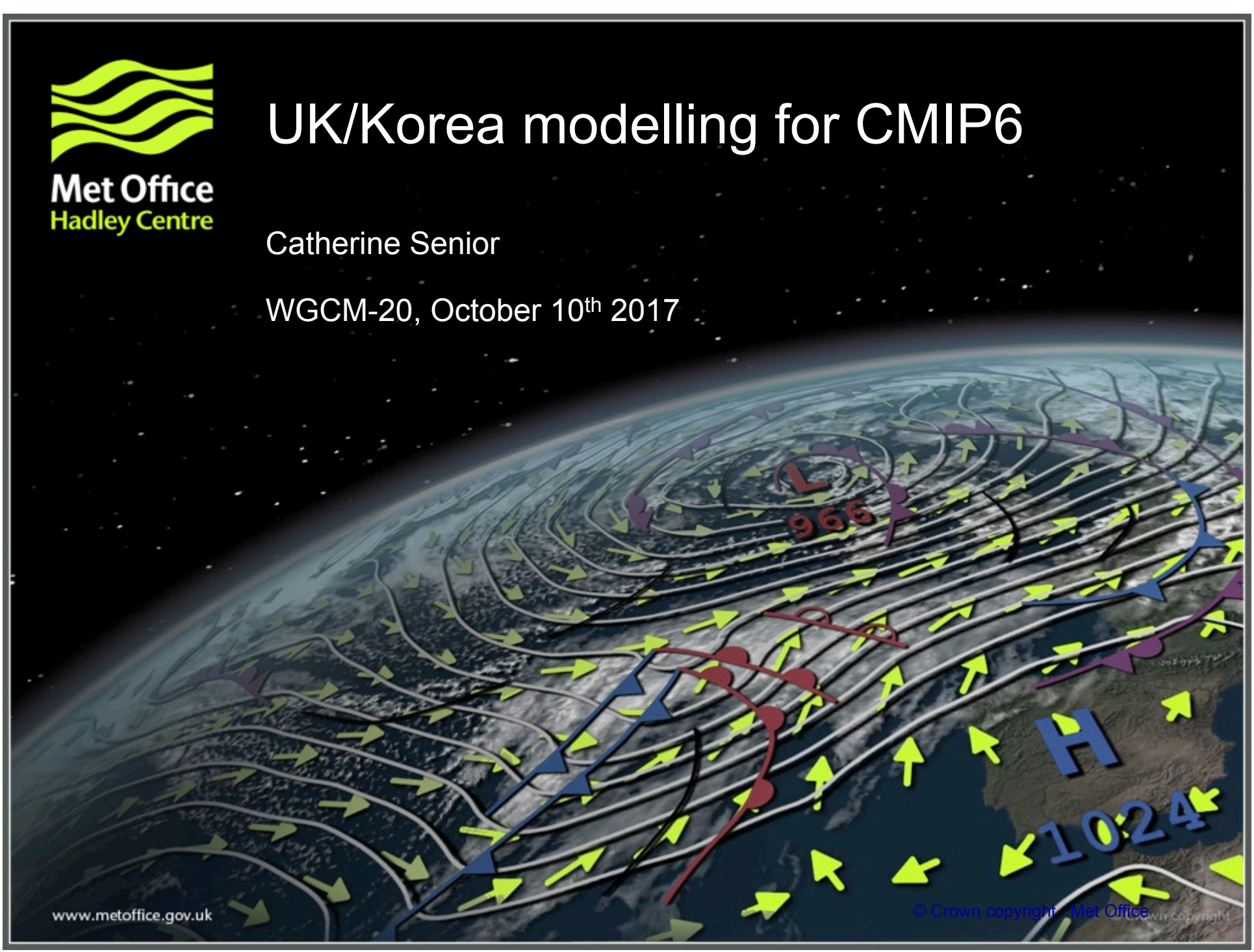
UK/Korea modelling for CMIP6

Catherine Senior

WGCM-20, October 10th 2017



HadGEM3 & UKESM1

	Physical climate model	Earth system model
CMIP5	HadGEM2-AO	HadGEM2-ES
CMIP6	HadGEM3-GC31-LL HadGEM3-GC31-MM Developed by UK Met Office (with input from UM partners & UK universities)	UKESM1-0-LL Jointly developed by UK Met Office & UK universities

Physical Model development:

HadGEM3-GC3.1

Global Atmosphere and Land (GA-7.1/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,

Earth System Model Development

UKESM1 (compared to HadGEM2-ES)

- **Terrestrial carbon-nitrogen cycle**
  - TRIFFID vegetation dynamics (9 plant functional types), RothC soil carbon, simple N-limitation scheme (Wiltshire, in prep.)
- **Ocean BGC**
  - MEDUSA2 intermediate complexity plankton ecosystem model, inc. prognostic diatoms/non-diatoms with variable C:N (Yool 2013)
- **Aerosols**
  - UKCA-GLOMAP-mode, 2-moment, 5-mode aerosol scheme (Mann 2014)
- **Chemistry**
  - UKCA stratospheric-tropospheric chem w/ isoprene chemistry (Morgenstern 2009, O'Connor 2014)
- **Ice sheets**
  - BISICLES land ice model (Cornforth 2013) over Antarctica and Greenland (*active in ISMIP only*)

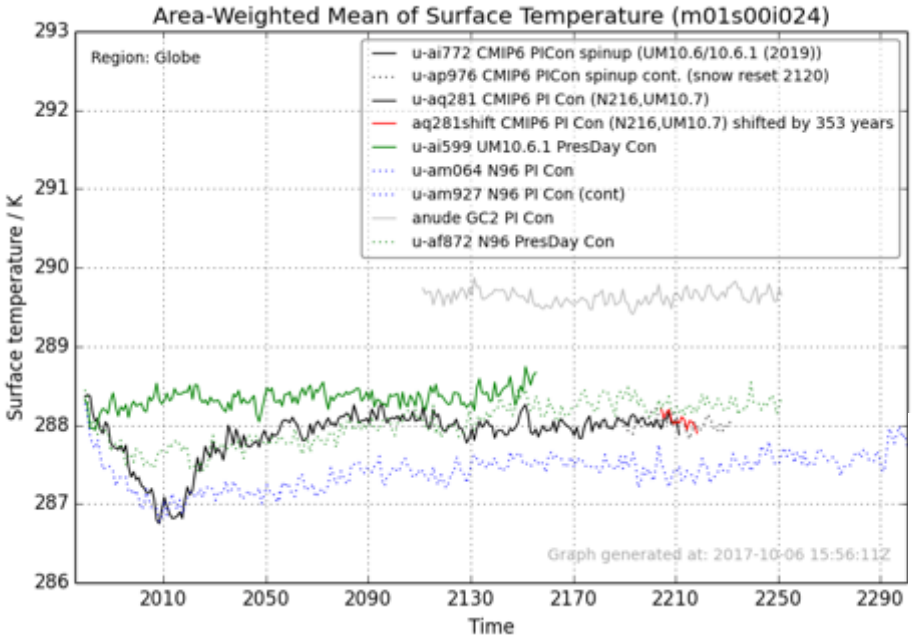
Model Configurations for CMIP6

- Physical model configurations:
  HadGEM3-GC3.1=GC3.0(GA7+GL7+GO6+GSI8) + …
  - HadGEM3-GC3.1-N96ORCA1 (HadGEM3-GC31-LL)
  - HadGEM3-GC3.1-N216ORCA025 (HadGEM3-GC31-MM)
- ESM configurations:
  UKESM1=HadGEM3-GC3.1 + UKCA, GLOMAP-mode, JULES-CN, TRIFFID, MEDUSA2, BISCICLES
  - UKESM1.0-N96ORCA1 (UKESM-1-0-LL)
  - UKESM1.0-N216ORCA025hybrid atmospheric chemistry, ocean BGC at degraded resolution)
    - under development

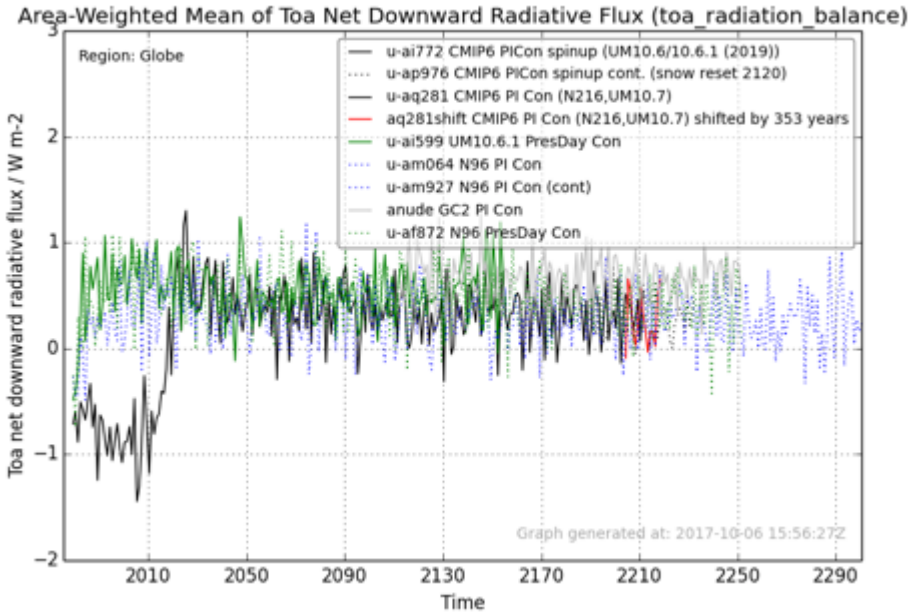
CMIP6 forcing data

- **Input4MIPs**
  - a standardised approach to version control is a good thing
  - cf. previous distributed approach from independent suppliers
- **Delays**
  - make it harder to plan experiments & plan effort for processing and testing
  - very little communication on slipping timeline
- **Quality control**
  - many forcing datasets released before papers published
    - Seems risky
    - Should CMIP forcings be “cutting-edge”?
- **Volcanic bug fix (v6.2.0)**
  - impact on PI is not quite as small as promised
    - (we are still exploring this)
- **Replication**
  - 29 files don’t get replicated to UK ESGF node
    - Incompatibility between file contents and ESGF/synda?

PI Spinup (black) and Control (red) GC3.1 N216/ORCA026



- Spinup from 1970s ocean state
- Model error corrected at year 2019

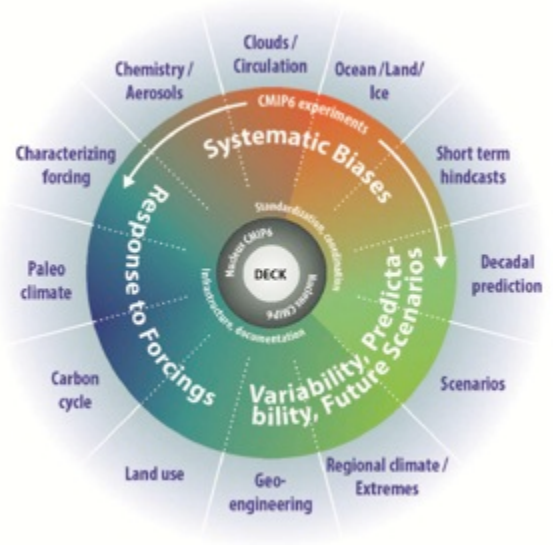


Data submission/ ES-Doc

- We don't deliver our data directly
  - but pass it to CEDA for publication on ESGF
- Monthly & daily data from DECK+hist
  - ready by Nov 2018, published to ESGF by Jan 2019
  - Sub-daily data due to follow 3 months later
- Data from earlier runs could be ready earlier
- Data from MIP experiments
  - second half of 2018?
- Questionnaire not released yet (scheduled for end 2017?)
- We're generating the ES-DOC directly from our metadata system
- Verified our process by documenting NEMO
  - using draft specifications
  - was more efficient than for CMIP5
- Documenting other components to start soon
  - still using draft specifications
  - followed by update once they're finalized

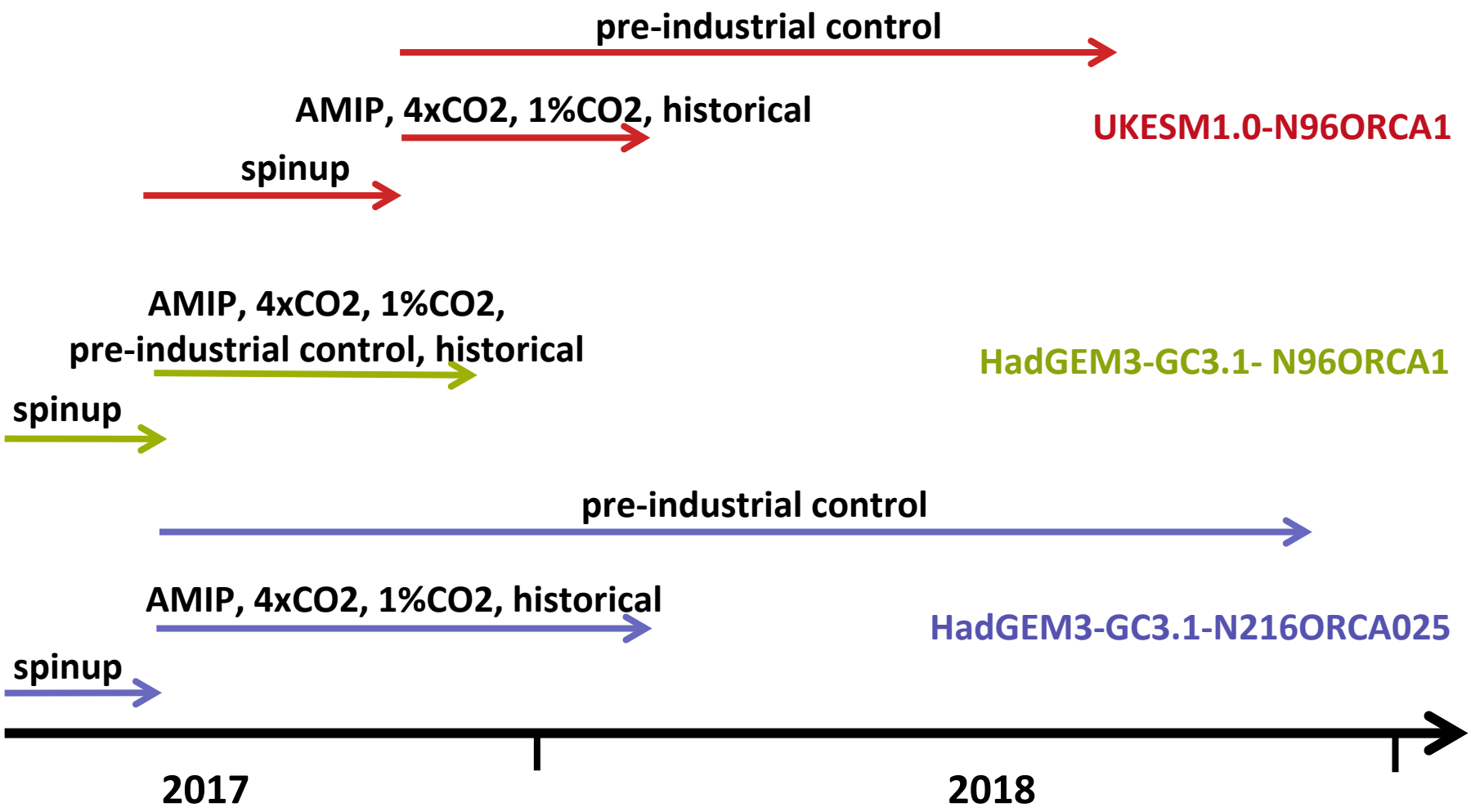
MIP Experiments

- 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

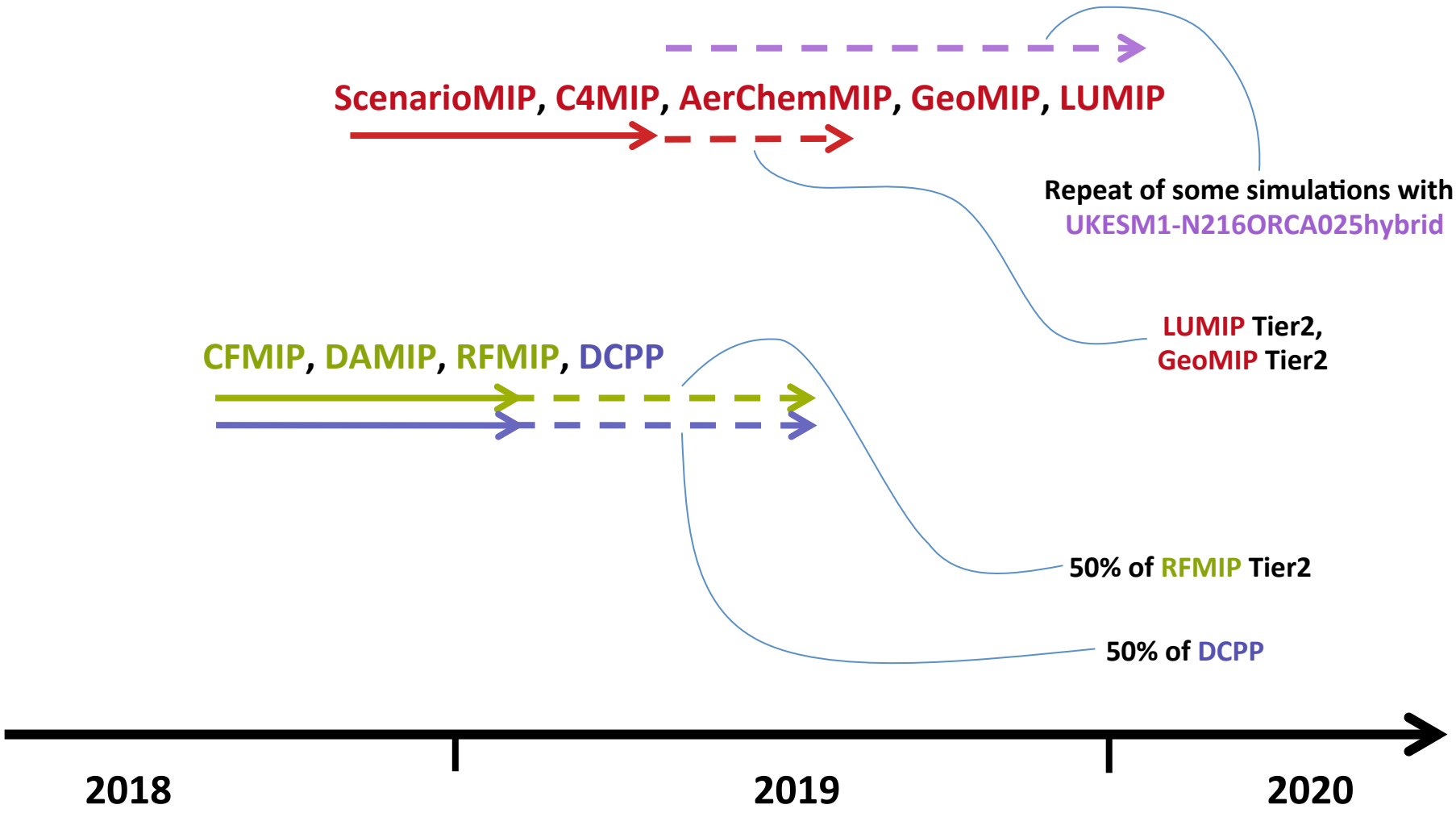


* Jointly with KMA and NIWA runs

Timeline 1: spinup & DECK



Timeline 2: MIPs



KMA's CMIP6 Participation (I)

❖Global model

Model	K-ACE	UKESM (KMA run under collaboration with UKMO)
Brief Description	K-ACE for CMIP6 = GA7.1 + GL7 + MOM4-SiS + OASIS-MCT compared to UKESM * Used HadGEM2-AO in CMIP5	UKESM for CMIP6 = GA7.1 + GL7 + GO6-GSI7 + OASIS-MCT + ES modules * Same configuration as UKMO
Simulations (MIPs)	DECK, HIST, ScenarioMIP	HIST, ScenarioMIP, AerChemMIP, C4MIP
Current Progress	Freezing K-ACE and testing DECK run (pi-Control & AMIP with CMIP6 forcing) DECK results from K-ACE are expected to be submitted in early next year	Implementation of UKESM newest version and consistency check to UKMO results
Plan of Data Submission	DECK & HIST : ~2018 Other MIPs : ~2019	HIST : ~2018 Other MIPs : 2019
ES-Doc	Preparing	Preparing

KMA's CMIP6 Participation (II)

❖Regional model

Model	HadGEM3-RA
Brief Description	Same model as UKMO
Simulations (MIPs)	CORDEX (East Asia domain)
Current Progress	According to CORDEX-II CORE project proposal, Done with ERA-Interim forcing doing CMIP5-GCM forcing runs
Plan of Data Submis sion	2018~2019 (ESGF node for CORDEX-EA will be constructed from next year including improv ement of web page of CORDEX-EA Data Center)

SAM0-UNICON (Seoul National University Atmosphere Model Version 0)

Sungsu Park and Jihoon Shin
Seoul National University, Seoul, Korea.

Overview

•SAM0-UNICON is a CAM5/CESM1-based GCM with a new convection scheme (UNICON, Park 2014a,b) and the revised treatment of convective detrainment process (Park et al. 2017).

•UNICON (Unified Convection Scheme) replaces the CAM5's deep and shallow convection schemes.

•Compared to CAM5, SAM0 substantially improved the simulations of MJO, diurnal cycle of precipitation and tropical cyclones with reasonable climatologies and ENSO.

CMIP6 forcings :

•SAM0 uses CMIP6-specified GHGs, solar irradiance, aerosol emission, volcanic aerosols, land state, ozone concentration and nitrogen deposition forcings and also SST and sea ice fraction for AMIP simulation.

•SAM0 ran successfully with the CMIP6 forcings. A test simulation in a pre-industrial configuration with CMIP6 forcings produced little cooler Earth (-0.3K for SST) than that with CMIP5 forcings.

•Production simulations will use the most recently released v6.2.0 CMIP6 forcing data set.

	SAM0-UNICON	CAM5-CESM1
Boundary Layer Turbulence	Bretherton-Park (09) UW Moist Turbulence	Same
Shallow Convection	**Park (14)** **UNICON** **(A Unified Convection Scheme)**	Park-Bretherton (09) UW Shallow Convection
Deep Convection		Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)
Cloud Macrophysics	**Park et al. (17)** Park-Bretherton-Rasch (14) Revised Cloud Macrophysics	Park-Bretherton-Rasch (14) Revised Cloud Macrophysics
Stratiform Microphysics	Morrison and Gettelman (08) *Double Moment*	Same
Radiation / Optics	RRTMG Iacono et al.(08) / Mitchell (08)	Same
Aerosols	Modal Aerosol Model Liu & Ghan (2009)	Same

Progress

•We are testing/tuning the pre-industrial coupled simulation with CMIP6 forcings to obtain reasonable global energy balance at the top of the atmosphere.

•We will start DECK simulations in early October 2017.

•Post processing for submission will be done simultaneously with the production simulation.

ESGF submission

•We will start to submit the output of DECK simulations to the ESGF in December. 2017.

•We will start to submit the output of historical simulations to the ESGF in December. 2017.

•We are also planning to participate in the Scenario-MIP. Submission will be made in early 20 18.

References

•A unified convection scheme (UNICON). Part I: Formulation. Sungsu Park.
3902-3931. *Journal of the Atmospheric Sciences*, 2014. Nov.

•A unified convection scheme (UNICON). Part II: Simulation. Sungsu Park.
3931-3973. *Journal of the Atmospheric Sciences*, 2014. Nov.

•Impact of detrained cumulus on climate simulated by the Community Atmosphere Model Version 5 with a u nified convection scheme. Sungsu Park et al.

Journal of Advances in Modeling Earth Systems, 2017. May. 10.1002/2016MS000877.

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

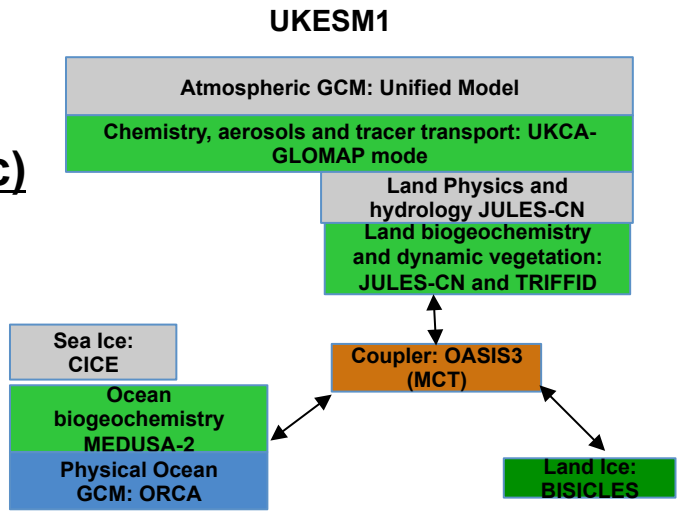
MEDUSA2 within NEMO ocean model.

Interactive Land ice sheets (Greenland and Antarctic)

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

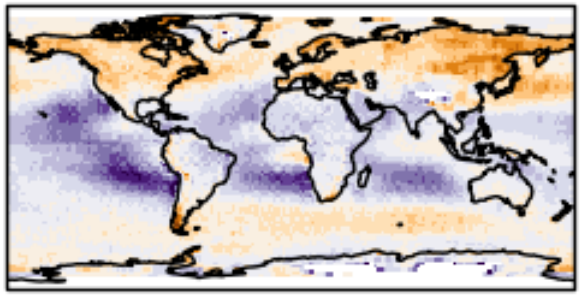
Coupler

OASIS3-MCT

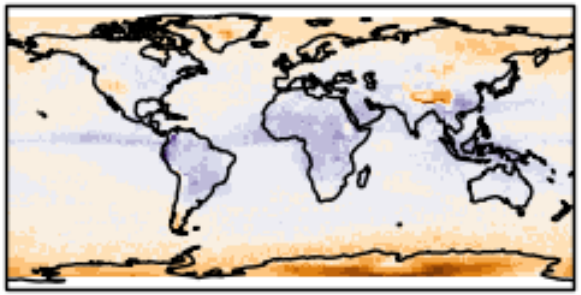


Bias in cloud cover
(against CALIPSO)

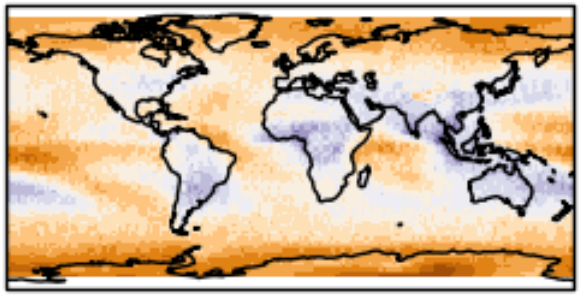
GA7p1-AMIP
Low-top cloud bias



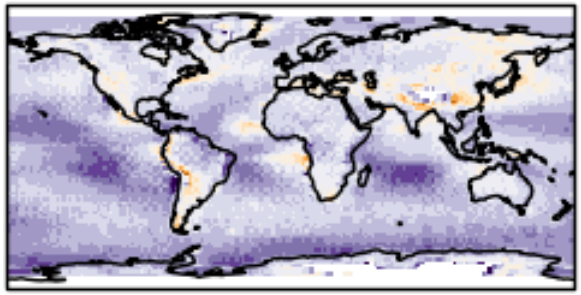
GA7p1-AMIP
Mid-top cloud bias



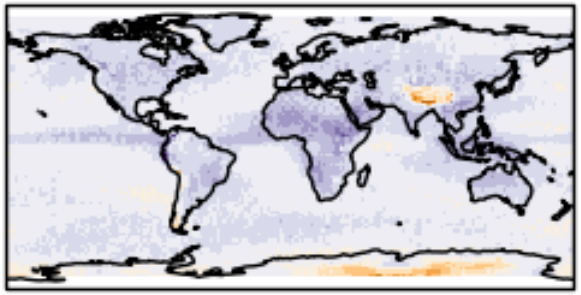
GA7p1-AMIP
High-top cloud bias



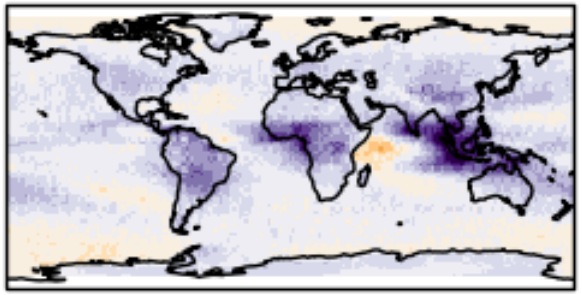
HadGEM2-AMIP
Low-top cloud bias

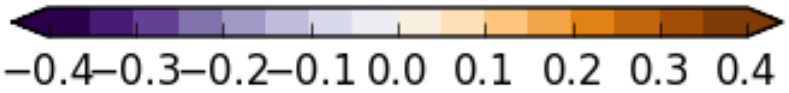


HadGEM2-AMIP
Mid-top cloud bias

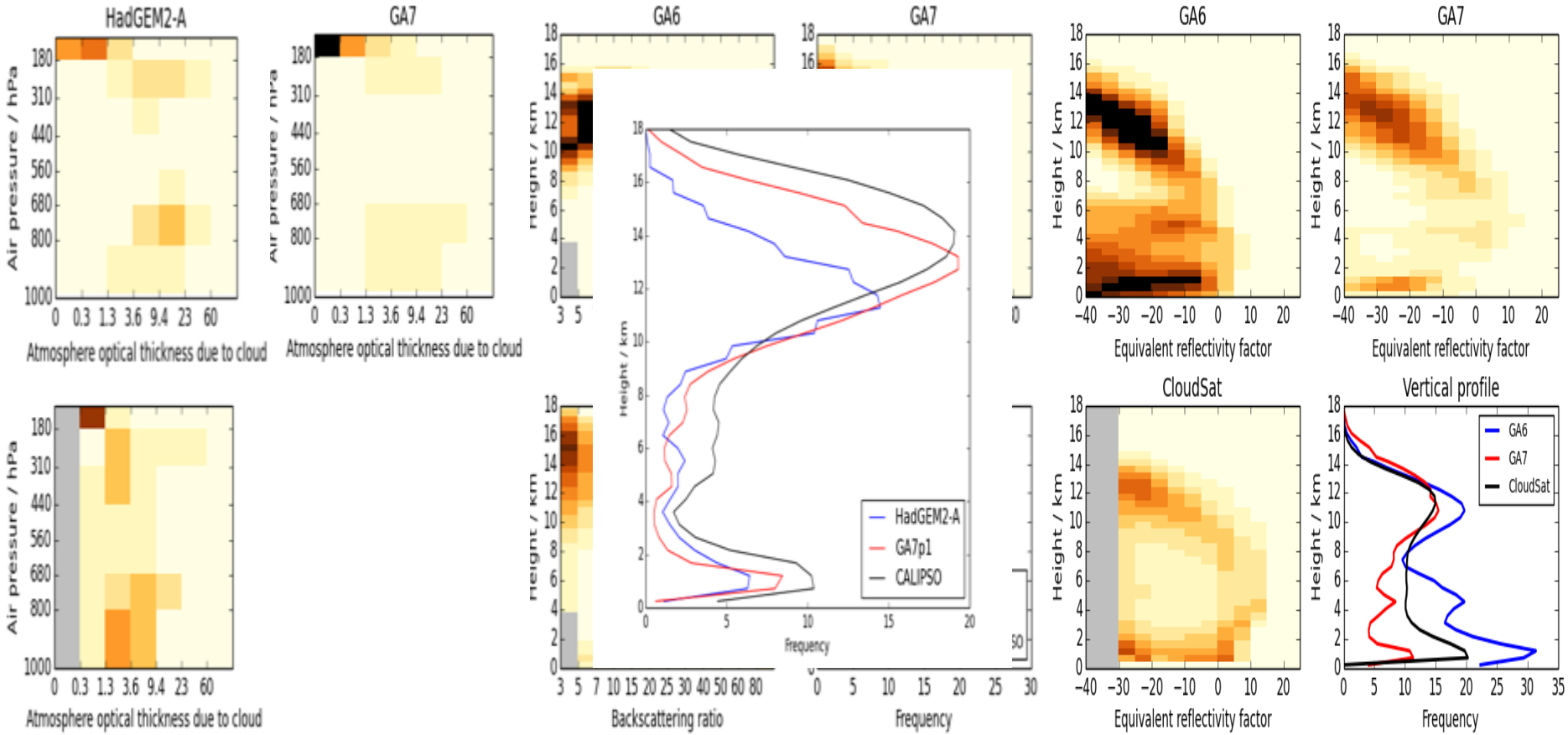


HadGEM2-AMIP
High-top cloud bias



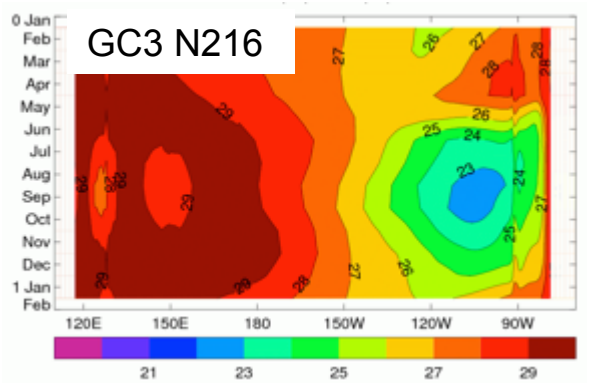


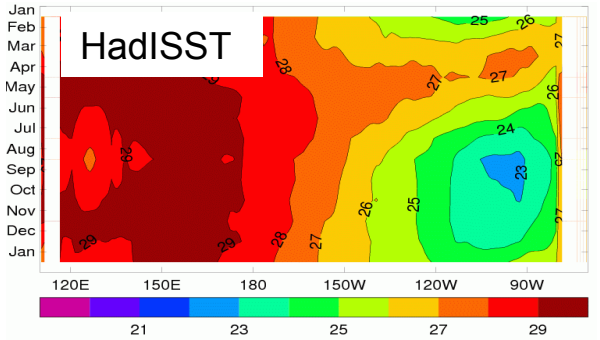
Cloud simulation:
comparison against satellite data over the tropics

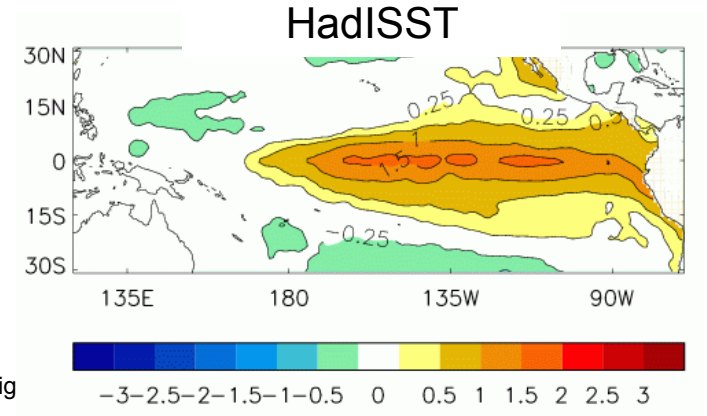


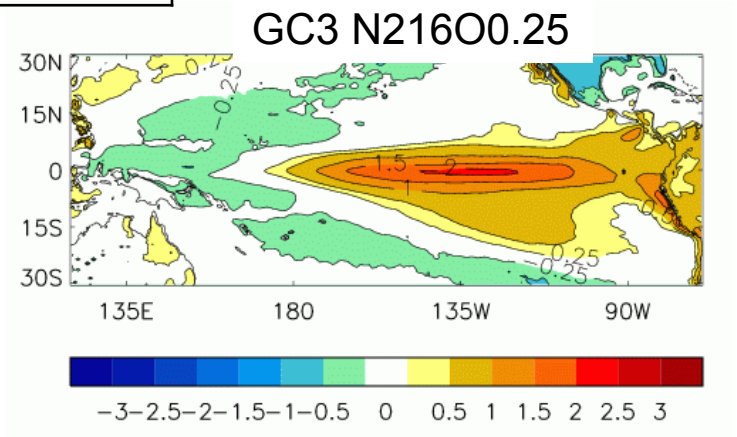
ENSO simulation

	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





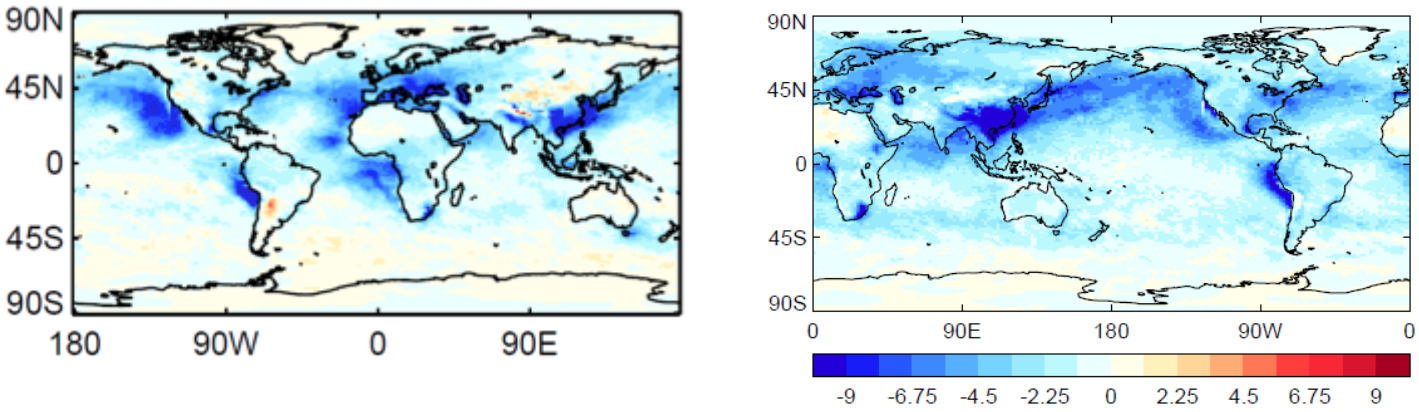




GA7 ERFs

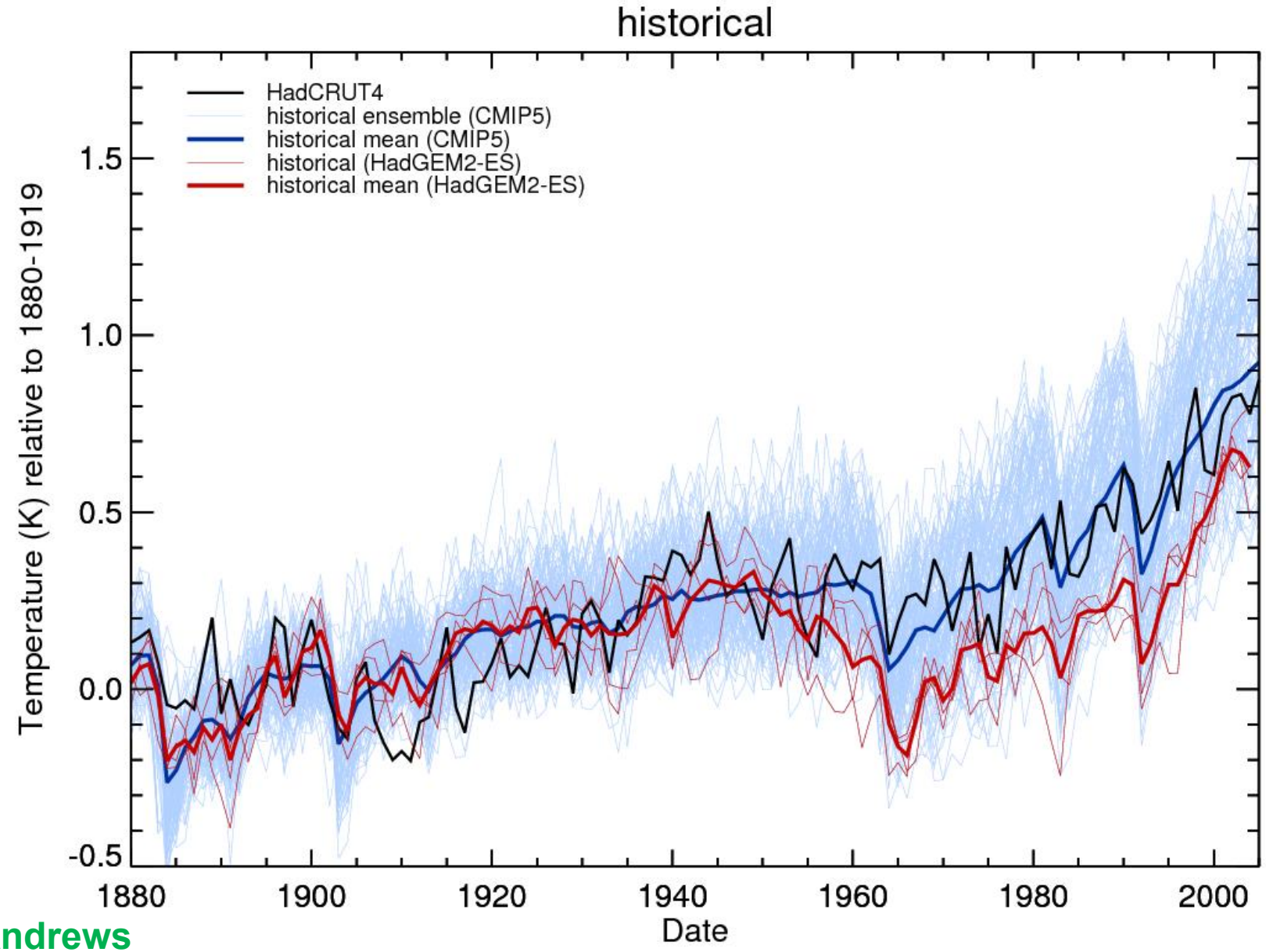
ERF (1850-2000)	HadGEM2-A	GA7 (GC3)
Aerosols	-1.4 Wm-2	-2.3 Wm-2
of which: **direct** effect	-0.2 Wm^{-2}	-0.5 Wm^{-2}
indirect effect	-1.3 Wm^{-2}	-1.8 Wm^{-2}
Total anthropogenic ERF (aerosols, GHGs, ozone, land use*)	1.1 Wm^{-2}	0 Wm^{-2}

HadGEM2-A Aerosol ERF GA7



Jane Mulcahy, Tim Andrews

HadGEM2-ES Historic runs

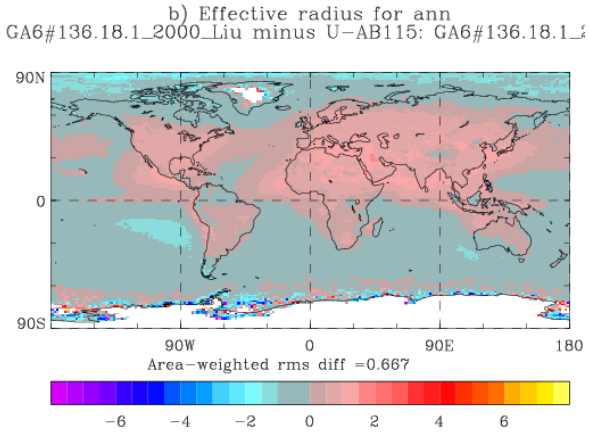


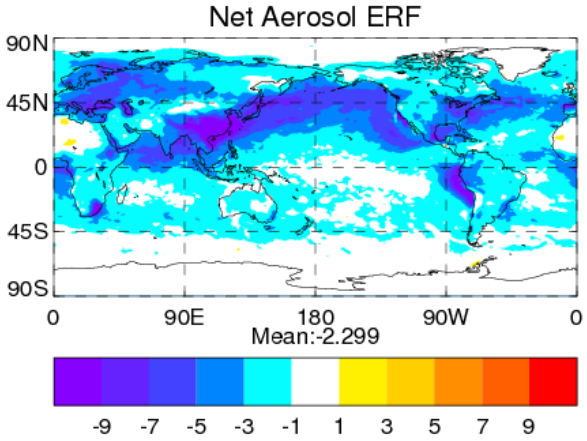
Tim Andrews

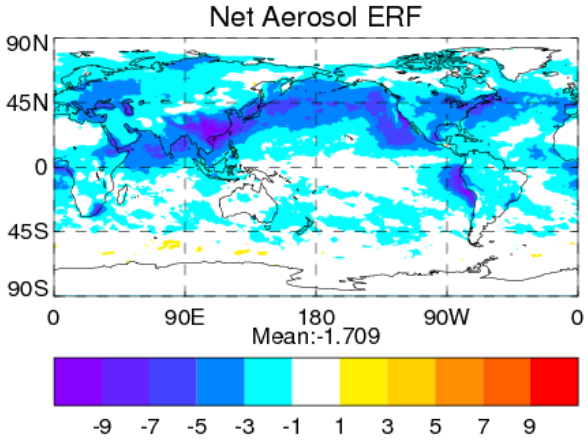
GC3.1 Model improvements

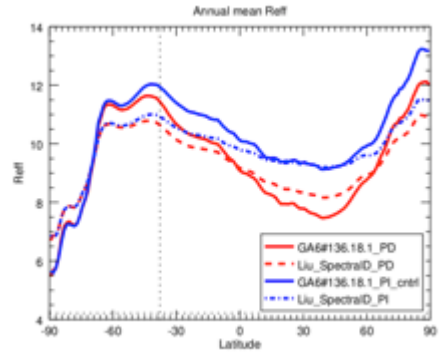
- Liu et al (2008) cloud droplet spectral dispersion scheme
- Increase to black carbon refractive index (absorption component) from 1.75 – 044i to 1.85 – 0.71i in light of recent evidence (Bond and Bergstrom 2006; Bond et al., 2013).
- RADAER look-up-tables which store aerosol optical properties have 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

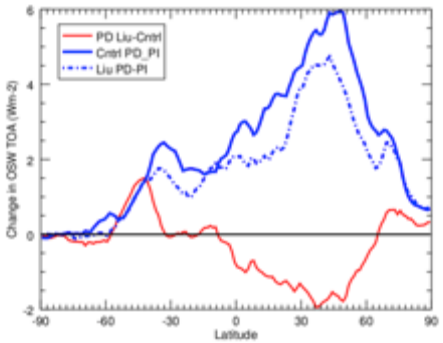
Liu Spectral Dispersion











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): $\beta = 0.07 \cdot \left(L/N_d\right)^{-0.14}$

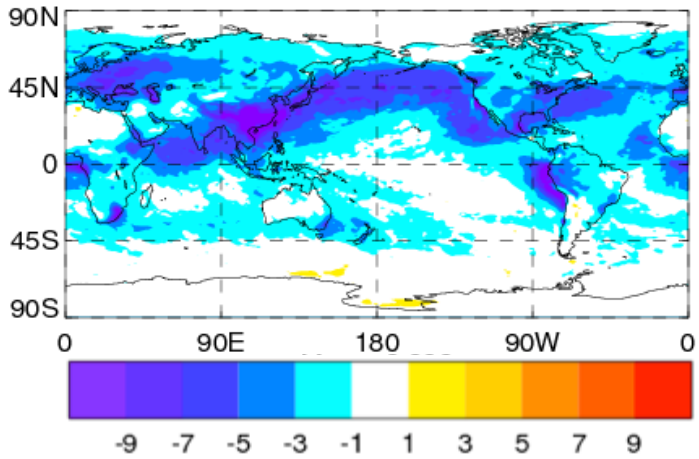
β=Spectral shape parameter and $k = \beta^{-3}$

Jane Mulcahy

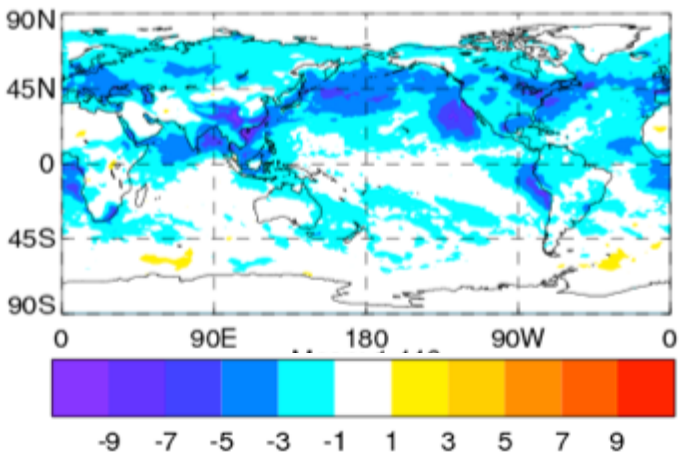
ERFs

ERF (1850-2000)	HadGEM2-A	GA7.0	GA7.1
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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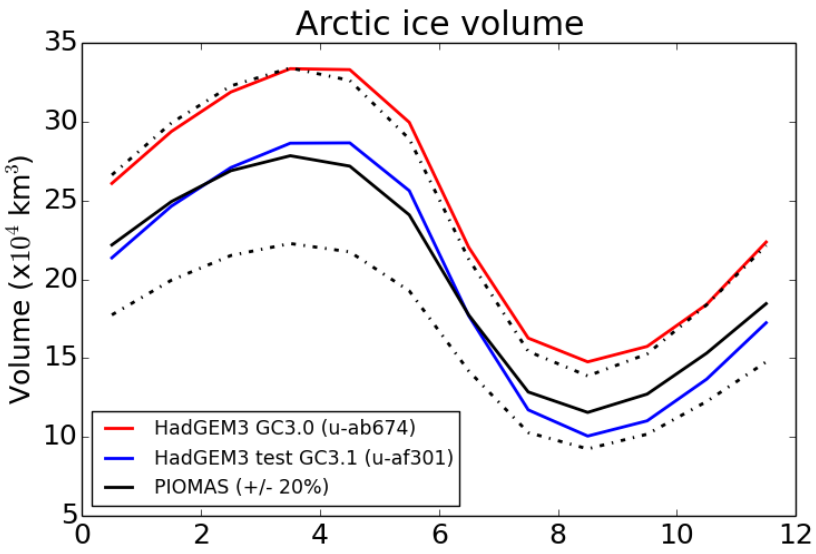
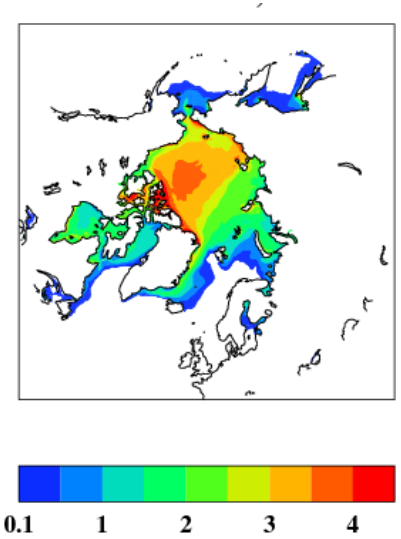
- RADAER look-up-tables which store aerosol optical properties have been improved to better resolve absorption of solar absorption
- Correct an error in SO_2 emissions from continuously erupting volcanoes
- Increase marine emissions of DMS (x1.7) as a proxy for missing emissions of primary marine organic 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

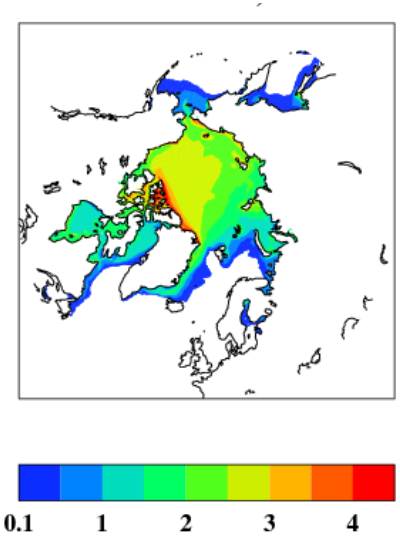
Arctic Sea-ice thickness



GC3.0: March



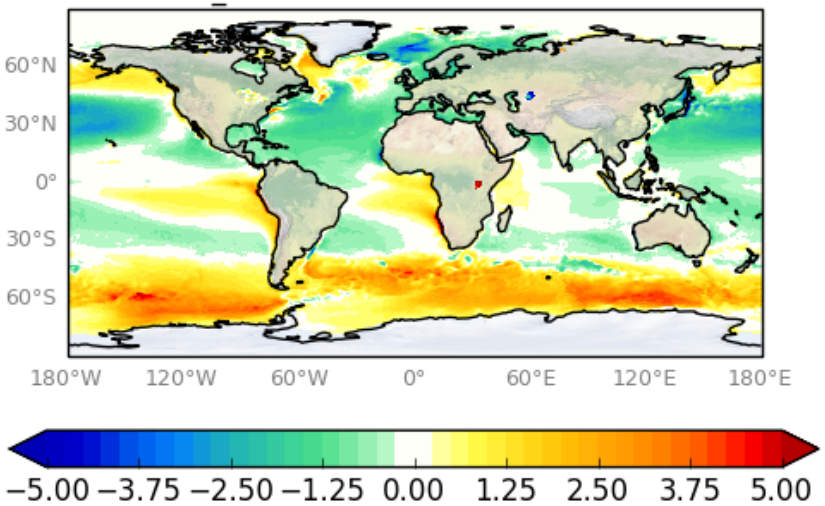
GC3.1: March



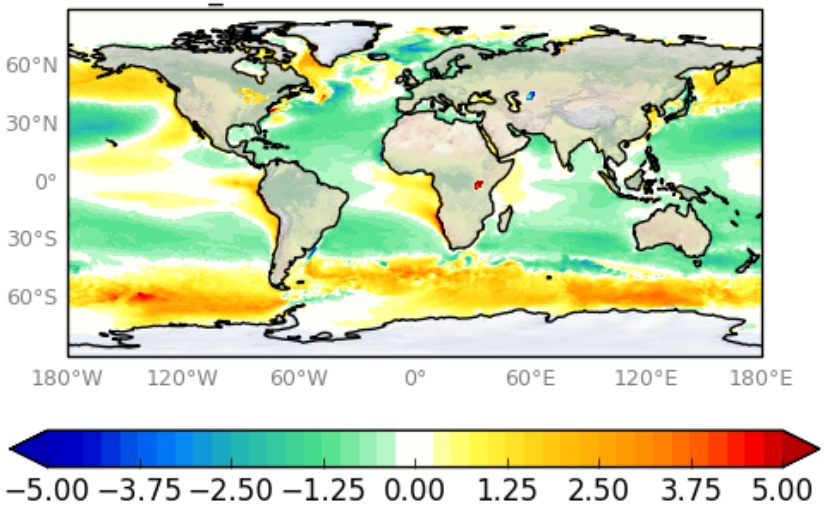
Ann Keen

SSTs

HadGEM3-GC3 – ESA CCI SSTs

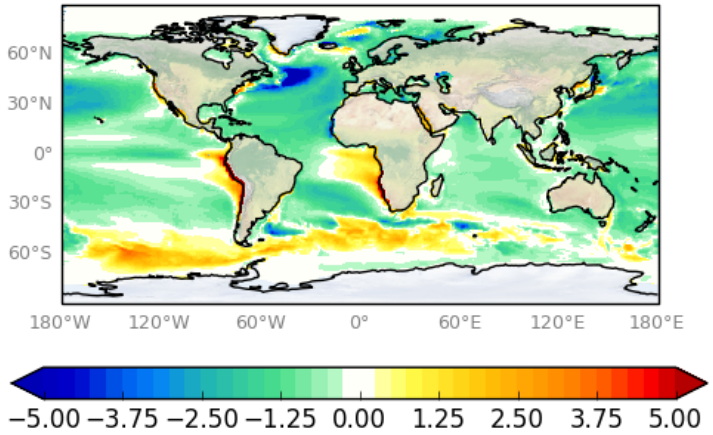


HadGEM3-GC3.1 – ESA CCI SSTs



HadGEM3-GC3.1-N96ORCA1

HadGEM3-GC3-N96O1 – ESA CCI SSTs



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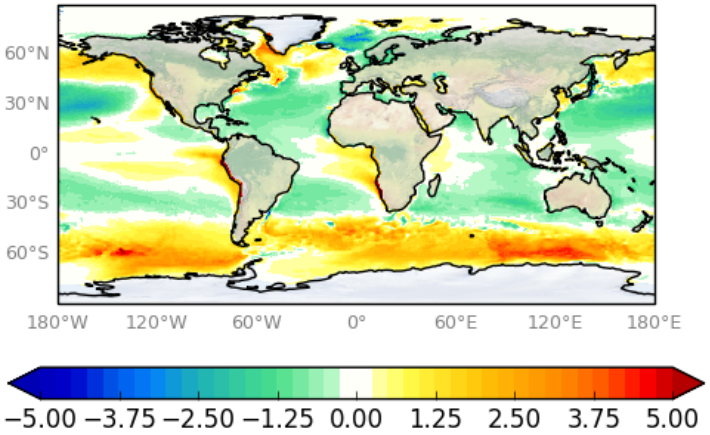

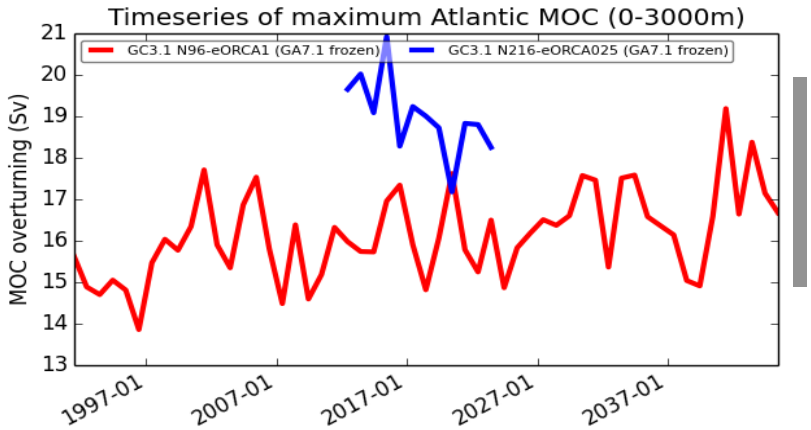

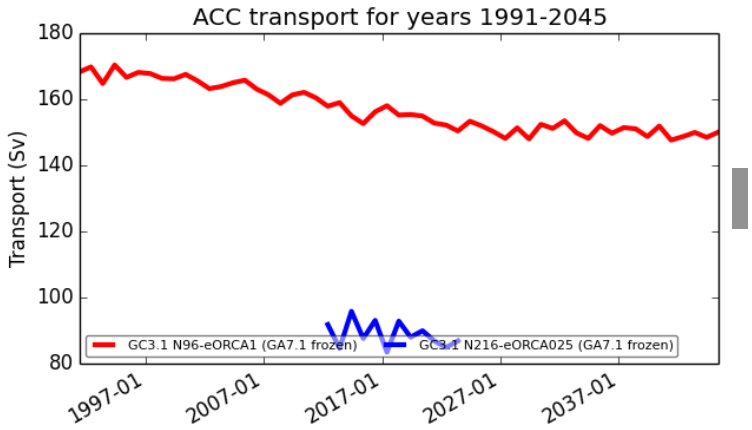

UK-CMIP6 status

- Model details
  - changes since UK-CMIP5
- Forcing data experience
- First results
- Timetables for data submission
- ES-DOC questionnaire

HadGEM3

- New versions of components
  - ocean (NEMO), sea-ice (CICE), land surface (JULES)
- Prognostic cloud, condensate and rain
- New dynamical core (ENDGAME)
- Modal aerosol scheme (UKCA-GLOMAP-mode)
- Improved cloud & radiation performance
- Resolutions
  - 130 km atmos + 1 degree ocean (N96ORCA1)
  - 65 km atmos + 0.25 degree ocean (N216ORCA025)

First results

- HadGEM3-GC3.1 N216 piControl
  - started Sep 2017
  - completion in Jul 2018
- Other HadGEM3-GC3.1 runs to start soon once e.g. historical forcings are available
- HadGEM3-GC3.1 N96 piControl about to start after 490 years of CMIP6 spin-up and 750 years of CMIP5 spin-up
- UKESM1 carbon cycle uncoupled spin-up of ~5000 years