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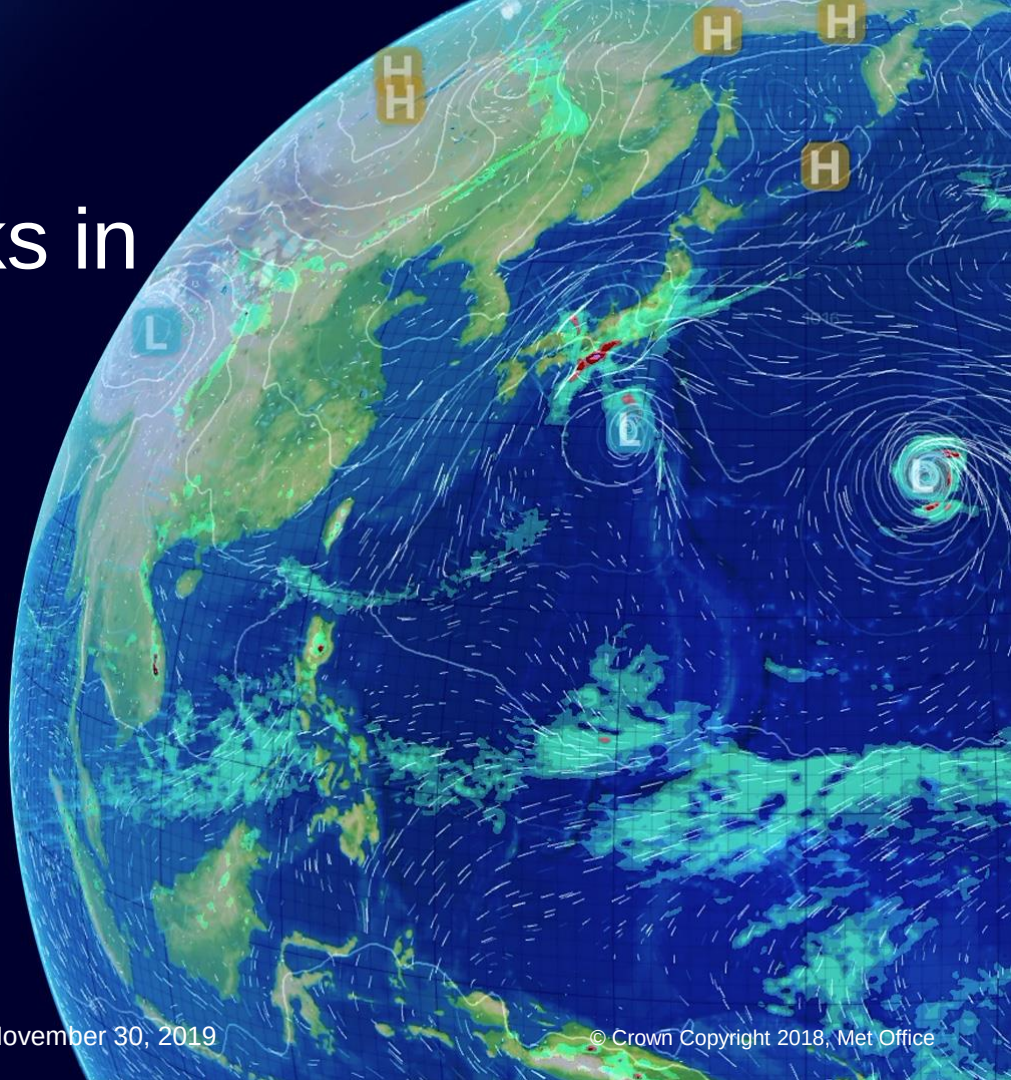
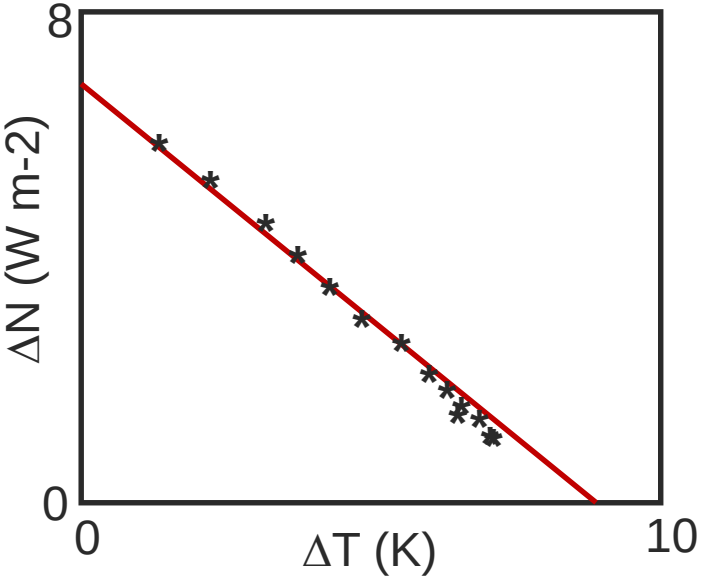
Atmospheric feedbacks in HadGEM3

Alejandro Bodas-Salcedo

Jane Mulcahy, Tim Andrews, Keith Williams, Mark Ringer, Paul Field, and Gregory Elsaesser



Background



$$\Delta N = F + \lambda \Delta T$$

EffCS, estimated using a Gregory plot and abrupt-4xCO2 experiments.

	Model	EffCS (K)	
	HadGEM2	4.4	**CMIP5**
GA6.0	HadGEM3-GC2.0	3.2	
GA7.1	HadGEM3-GC3.1	5.5	**CMIP6**

Large fraction of EffCS increase between GC2.0 and GC3.1 driven by **atmospheric feedbacks**.

(Andrews et al, submitted)

Experimental design

Model changes between GA6 and GA7

- #11 Implement new ice PSD
- #13 Revised cloud top entrainment
- #15 McICA upgrades
- #16 Improved treatment of gaseous absorption
- #17 New ice optical properties
- #44 Convective cores
- #52 Implement new warm rain microphysics scheme
- #58 PC2 / Convection Coupling
- #60 UKCA-MODE aerosols with offline oxidants
- #64 Improved updraught numerics in the 6a convection scheme
- #83 Include forced convective clouds
- #84 CAPE closure for deep & mid_level convection dependent on large-scale vertical velocity
- #87 Implement heating due to gravity-wave dissipation
- #89 Replace fixed RH crit profile with a variable one
- #98 Improvements to PC2 for high ice clouds (cirrus)
- #117 Introduce standard GA stochastic physics settings
- #120 Turbulent production of liquid water in mixed phase clouds
- #127 New ancillary for topographic index data
- #134 Retuning of low cloud
- #135 Moisture advection: Hermite Cubic Vertical Interpolation and Priestley Conservation
- #138 Minor bug-fix to methane oxidation scheme.
- #141 Fix Raymond filtering in ENDGame global orography ancillaries.
- #145 Retune the adaptive detrainment parameter (RDet) in response to the 6A convection scheme
- #146 Priestley conservation of mass weighted potential temperature
- #151 Switch on temporary logicals not used in pre-GA7 science configurations.
- #153 Reduce atmospheric solver tolerance.
- #154 Generate Kettle (1999) DMS datasets through general regridding.
- #155 Generate Reynolds SST ancils via general regridding.
- #156 New land fraction files for coupled models for use with the GO6.0 grid.
- #158 Fix bit-comparison issue with TRIP river routing in UM/JULES.
- #161 Set reference height used in the ENDGame w-damping code to 85km rather than 80km in L85 runs.
- #162 Retune cloud threshold for shear dominated BL in GA7.
- #165 Non-orographic (USSP) GWD scheme launch factor tuning in response to GA7.0 changes

- GL:#4 Implementation of the multilayer snow scheme
- GL:#30 Further Improvements to the surface albedo
- GL:#31 Implement the COARE4.0 Algorithm
- GL:#38 Revised roughness lengths for sea ice
- GL:#43 Improved parameterisation of the ocean surface albedo in JULES
- GL:#45 Pass rain fraction to JULES surface hydrology
- GL:#56 Fix bit-comparison issue with TRIP river routing in UM/JULES.

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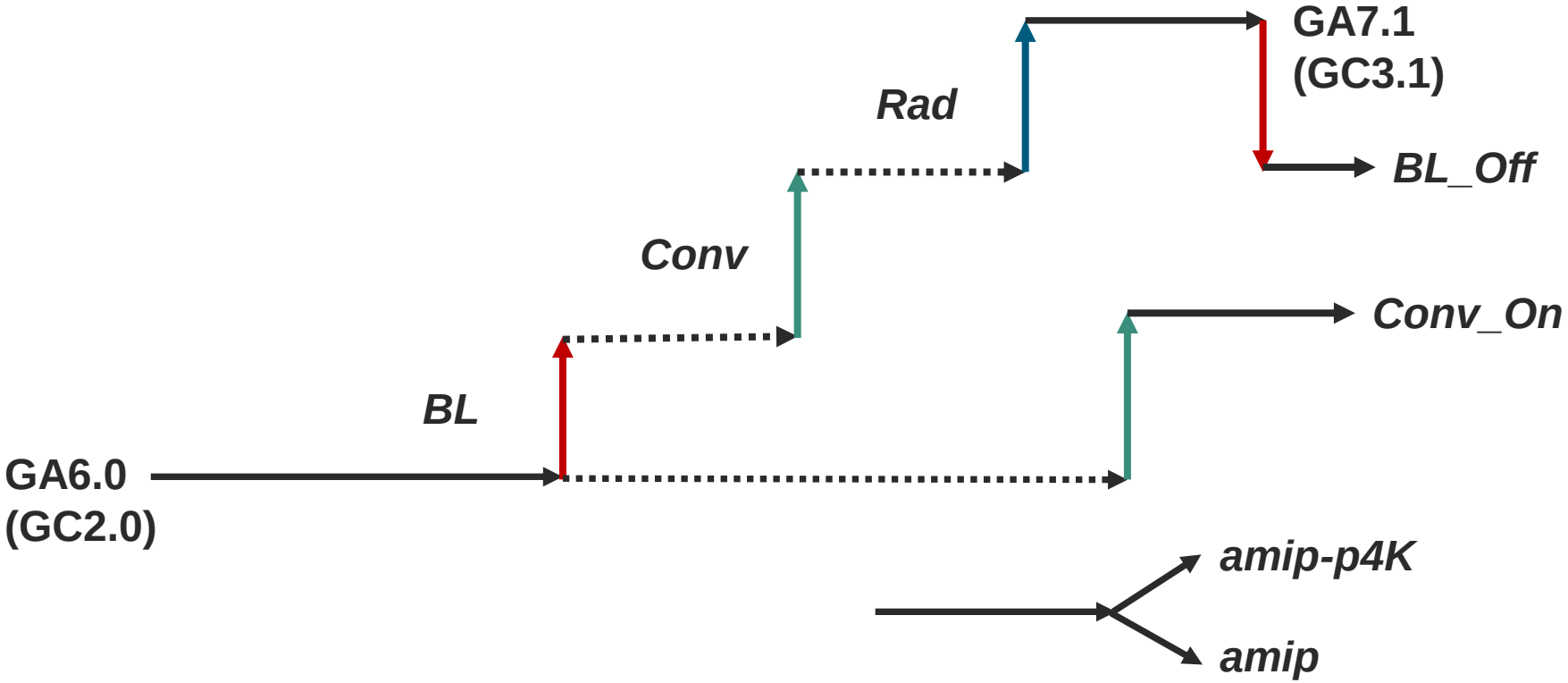
Package: collection of changes that are logically related.

Experiments:

- amip and amip-p4K
- 1979/01 – 1989/12 (11 yr) and 1979/01 – 2014/12 (36 yr)
- N96L85
- 30+ experiments
- 1000+ years of simulations

Packages
Convection
Radiation
Microphysics and L-S precipitation
Cloud
Boundary layer
Dynamics
Gravity wave drag
Stochastic physics
Aerosols
Effective Radiative Forcing
Land surface



Package testing

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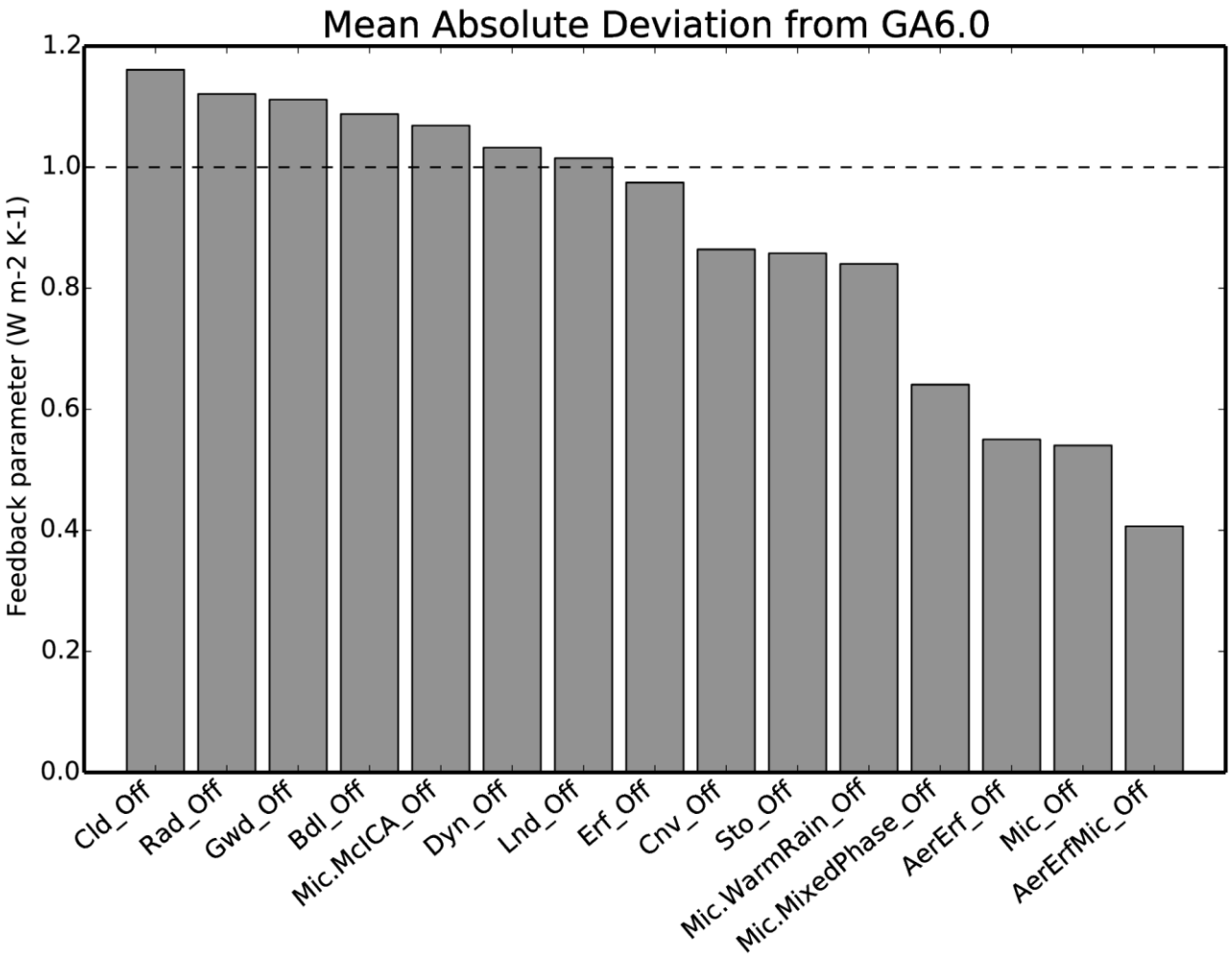

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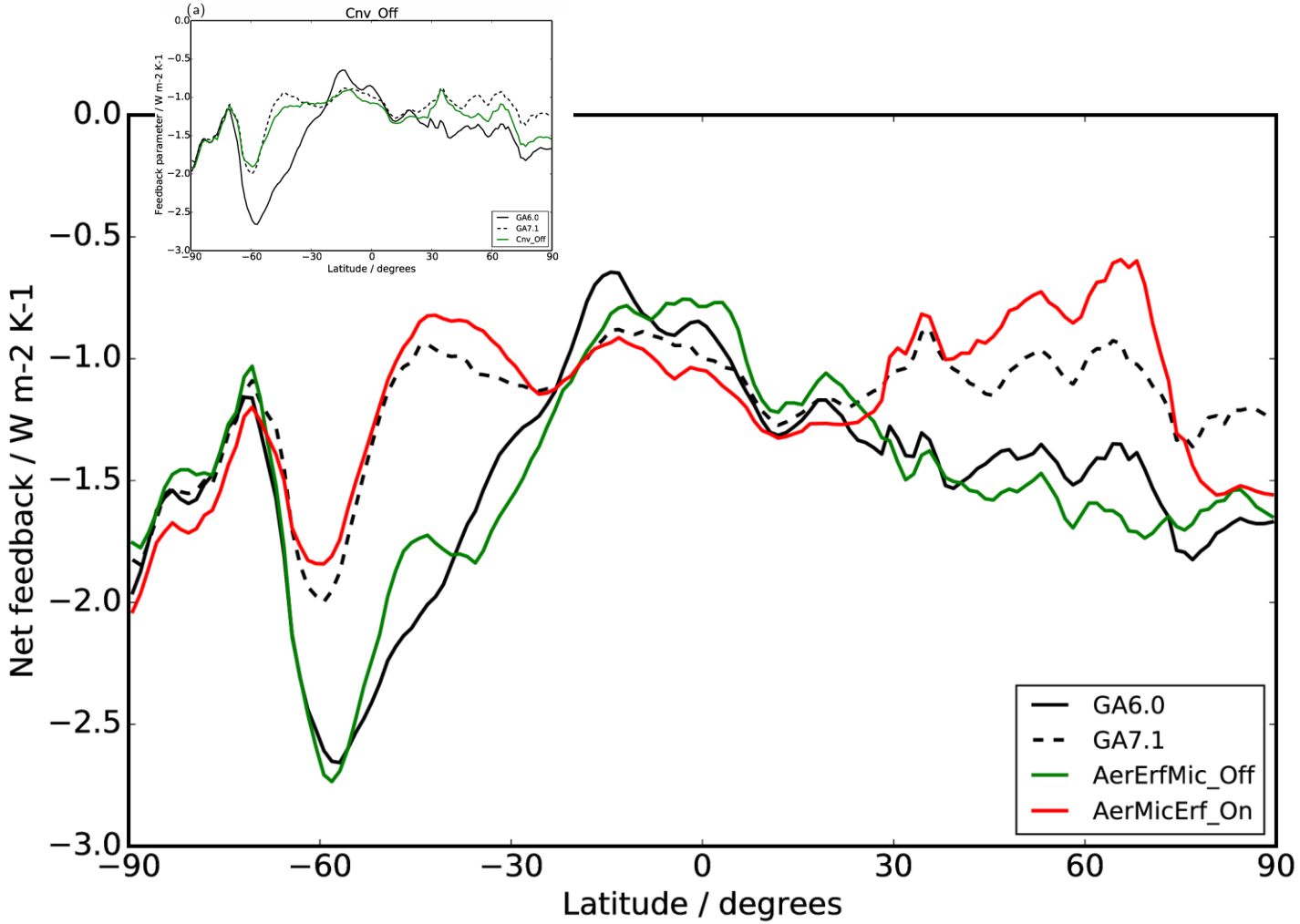

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Microphysics

- New mixed-phase cloud scheme
- Changes to warm rain microphysics
- Upgrades to McICA

Aerosol + Erf

- UKCA-MODE: new aerosol scheme
- Scaling of DMS to account for marine organic
- Cloud droplet spectral dispersion
- Tuning of mixed-phase scheme

Controls of feedback differences

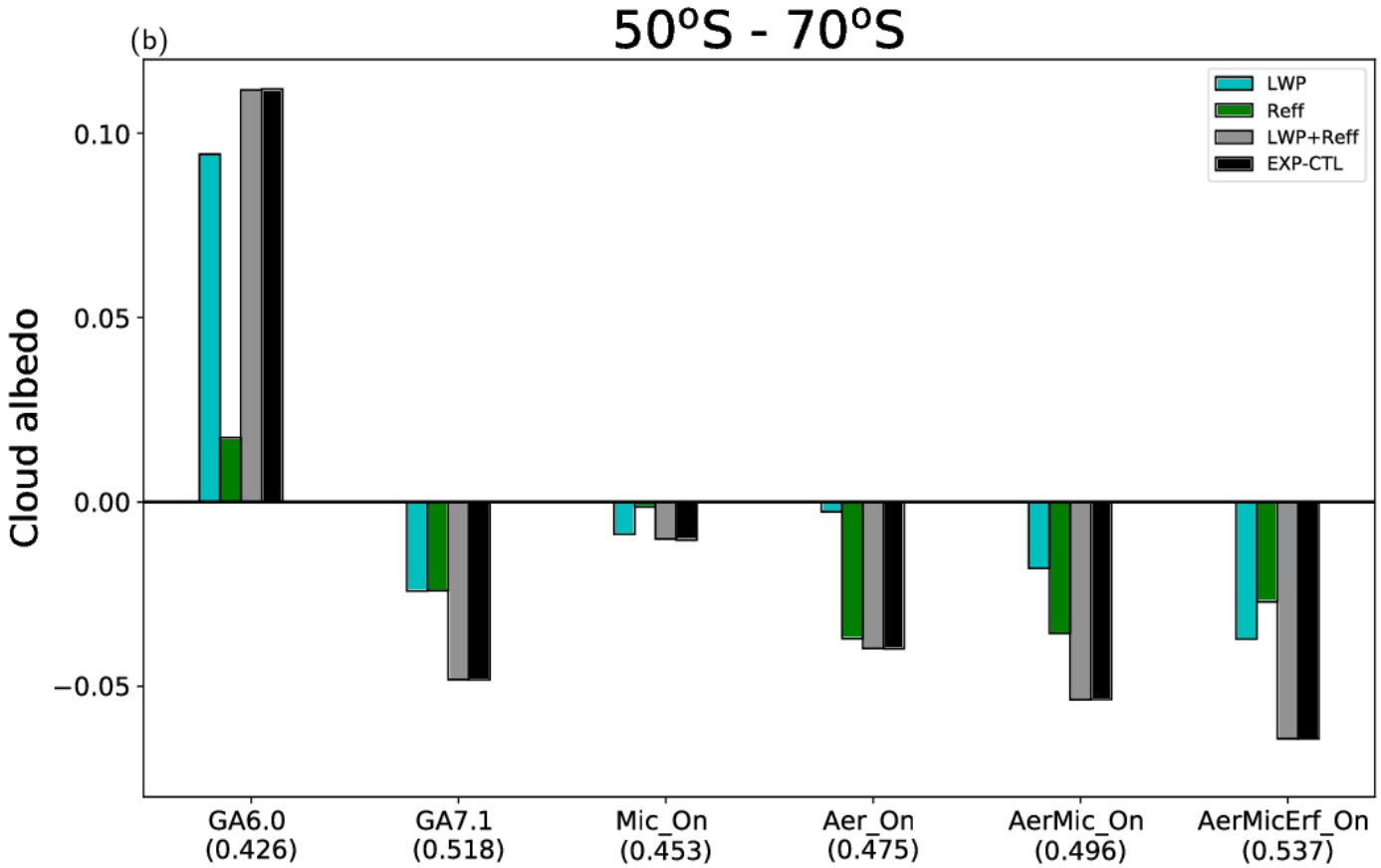
	clear scat	cloud	cloud amt	cloud scat
		70°S - 30°S		
GA6.0	-0.14	0.01	0.68	-0.61
GA7.1	0.07	0.86	0.24	0.62
AerMic_On	0.08	0.73	0.15	0.60
Aer_On	0.10	0.44	0.06	0.40
Mic_On	-0.00	0.33	0.11	0.22
		50°S - 30°S		
GA6.0	-0.07	0.68	0.97	-0.22
GA7.1	0.00	0.96	0.32	0.63
AerMic_On	0.01	0.89	0.22	0.69
Aer_On	0.03	0.53	0.08	0.46
Mic_On	-0.01	0.42	0.18	0.25
		70°S - 50°S		
GA6.0	-0.26	-1.07	0.23	-1.24
GA7.1	0.17	0.79	0.13	0.66
AerMic_On	0.19	0.54	0.04	0.51
Aer_On	0.21	0.31	0.02	0.30
Mic_On	0.00	0.21	0.01	0.21

APRP method

(Taylor et al., JClim, 2007)

- Contributions from amount and optical depth (1:2).
- Larger contribution from 30°S-50°S.
- CF feedback change much weaker in 50°S-70°S.
- Optical depth feedback changes partition quite similar in both regions. Mic_On slightly stronger in 50°S-70°S.

Separating ΔLWP & ΔReff contributions



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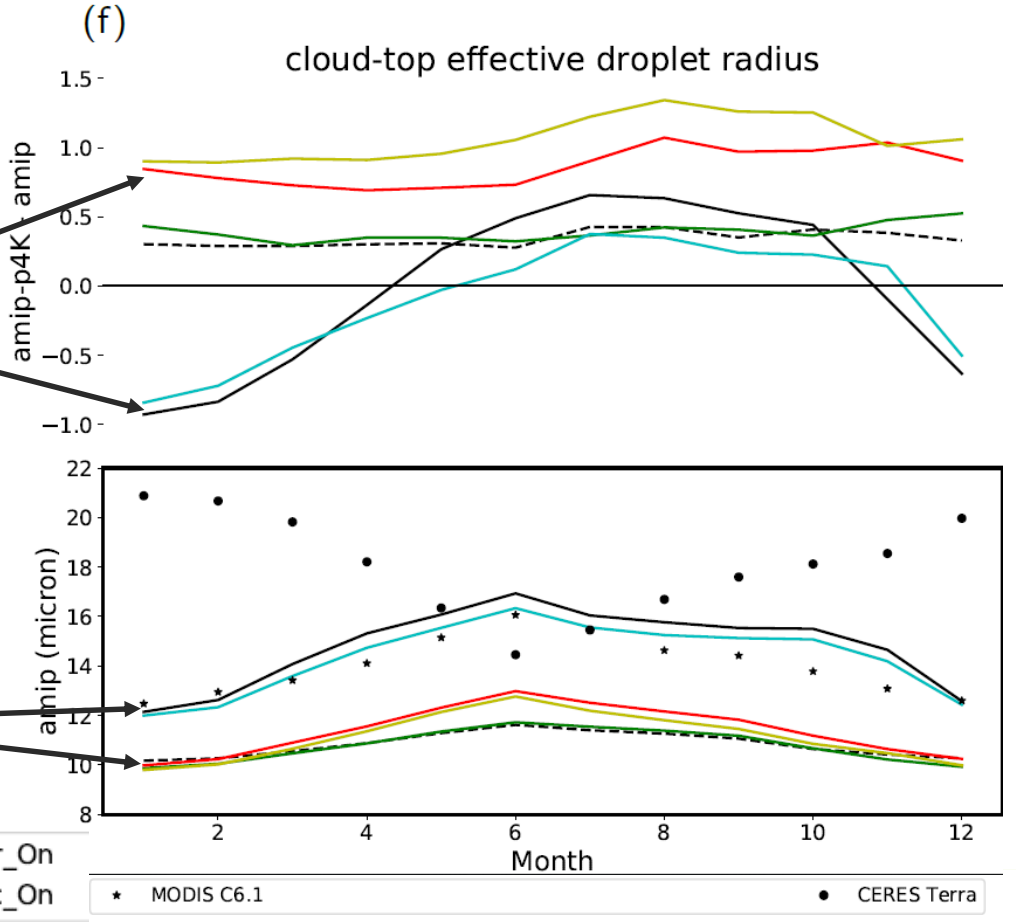
Aer_On suppresses r_{eff} feedback

50°S – 70°S

From reduction to increase in r_{eff} with warming

Smaller climatological r_{eff} in GA7.1



GA6.0
GA7.1
AerMicErf_On
AerMic_On
Aer_On
Mic_On

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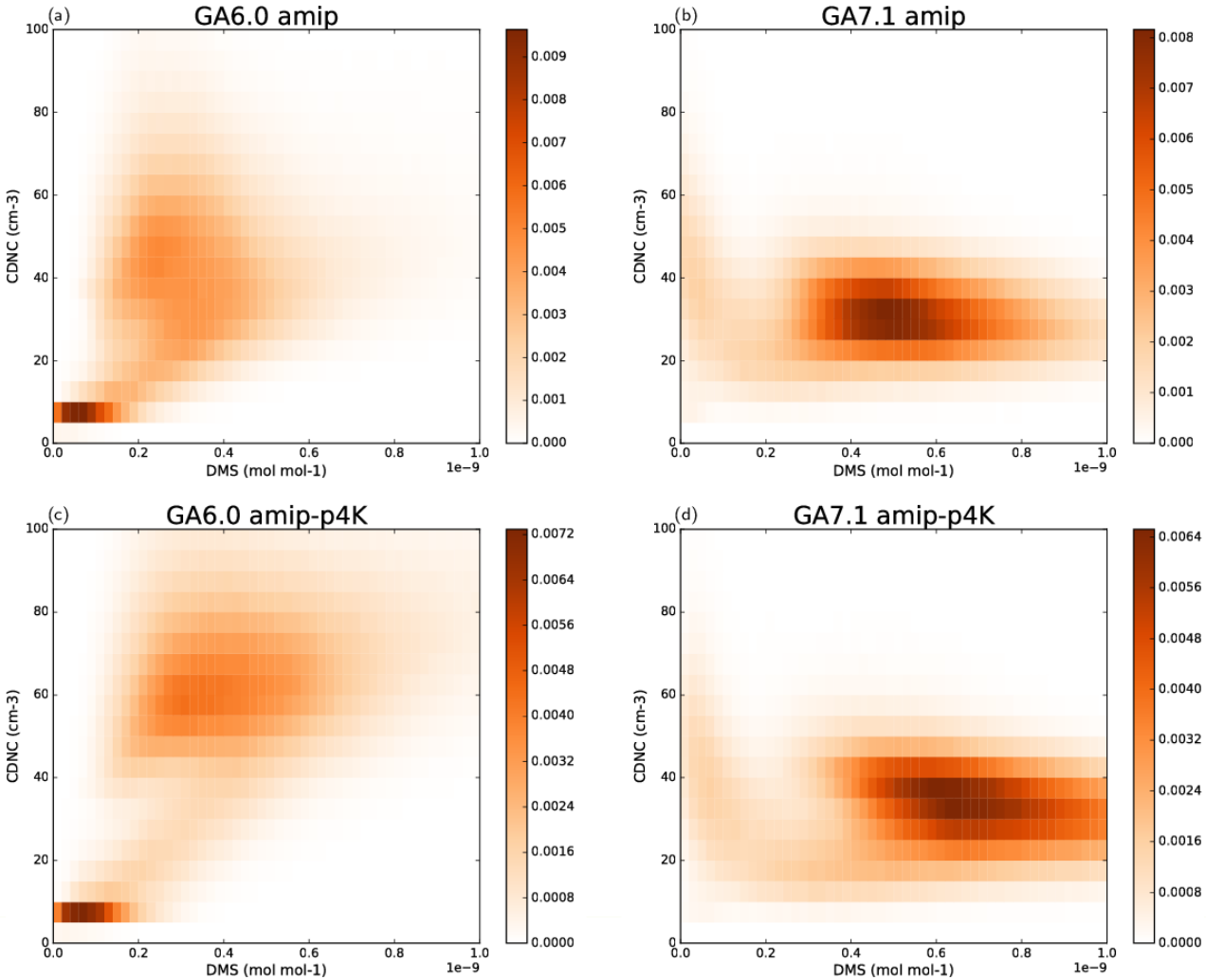
Aerosol-cloud interaction



Summary

- Changes in midlatitude cloud feedbacks explain the differences between GA6.0 and GA7.1.
- The new aerosol and mixed-phase schemes are responsible for most of the feedback differences.
- Aerosol acts through r_{eff}, and mixed-phase through LWP. Both the climatology and the response matter.

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RESEARCH ARTICLE
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Special Section:
The UK Earth System Models for CMIP6

Key Points:

Strong Dependence of Atmospheric Feedbacks on Mixed-Phase Microphysics and Aerosol-Cloud Interactions in HadGEM3

A. Bodas-Salcedo[1], J. P. Mulcahy[1], T. Andrews[1], K. D. Williams[1], M. A. Ringer[1], P. R. Field[1], and G. S. Elsaesser[2]

Future work

More work needed to assess the realism of midlatitude feedbacks using observational sensitivities, i.e. response to *cloud-controlling factors (Myers and Norris, 2016)*.

- Strong CF feedback in lower midlatitudes, is it realistic?
- Phase-change feedback in higher midlatitudes
- Aerosol-cloud interactions

Improved observations of (climatology and variability):

- Supercooled liquid clouds
- τ: LWP, CDNC and effective radius