



ACCESS Climate Modelling

Australian Community Climate and Earth System Simulator

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CLEX Winter School, June 2019

OCEANS AND ATMOSPHERE
www.csiro.au



ACCESS FAQ

- What is ACCESS? Who uses it?
- Why are there so many ACCESS versions and which one should I use?
- Where is ACCESS run? How long does a run take? What compute resources does it need?
- What is ACCESS used for?
- What do you do if you find a bug in ACCESS?
- Why do you run an experiment more than once?
- What ACCESS model output is available for community use?

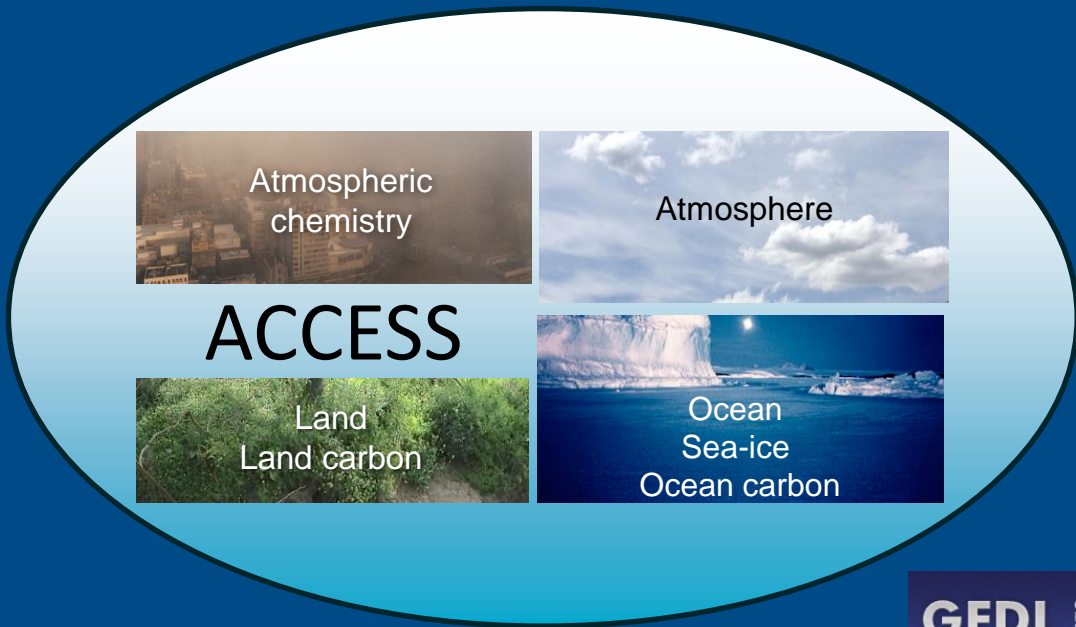
Australian Community Climate and Earth System Simulator

National effort since 2005

- All timescales, weather to climate
- Local and imported components
- Fortran
- CSIRO, BoM, Universities
- NCI

Support from

- NESP Earth System and Climate Change Hub
- NCRIS (scoping stage)

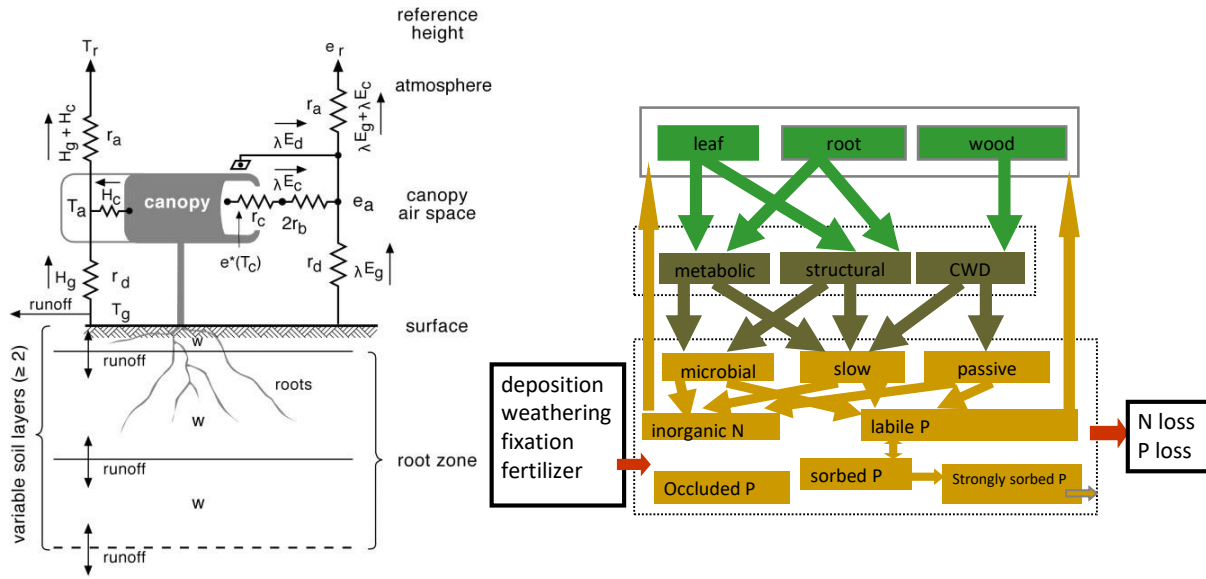


Components - Atmosphere

- UK MetOffice Unified Model (UM)
- Code versions in current use for climate: vn7.3, vn8.4, vn10.6
- Configurations: HadGEM2(r1.1), ~GA1, GA7.1
- Resolutions:
 - 'N96', $1.875^\circ \times 1.25^\circ$, 38 levels
 - 'N96', $1.875^\circ \times 1.25^\circ$, 85 levels
 - 'N216', $0.833^\circ \times 0.556^\circ$, 85 levels
 - 'N320', $0.5625^\circ \times 0.375^\circ$, 38 levels
 - 'N512', $0.352^\circ \times 0.235^\circ$, 85 levels

Components - Land

- Community Atmosphere Biosphere Land Exchange (CABLE)
- CASA-CNP - biogeochemistry



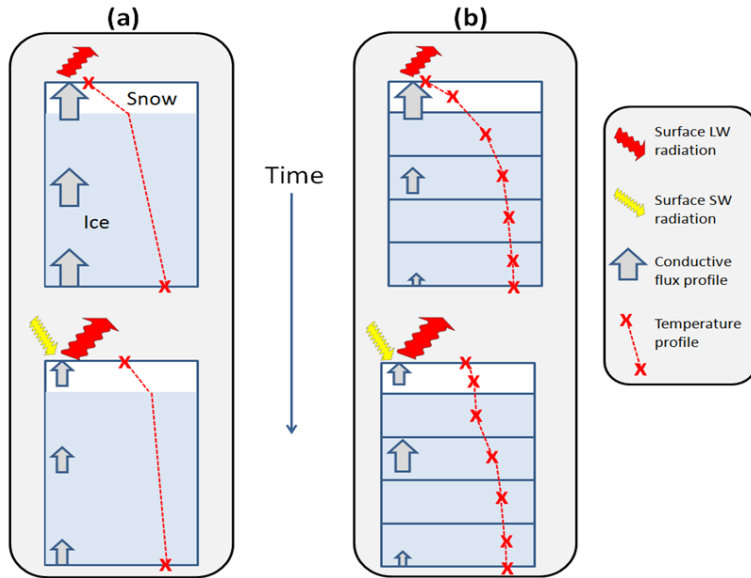
- Directly coupled into atmosphere. Replaces most parts of UM land scheme (MOSES or JULES)
- Different code versions and configurations of CABLE in different ACCESS versions
- CASA-CNP switched on for carbon-cycle (ESM) ACCESS versions.

Components – Ocean and ocean biogeochemistry

- NOAA/GFDL MOM4p1 or MOM5
- Tri-polar grid
- $\sim 1^\circ$ resolution, with higher resolution at equator and in southern ocean, 50 levels
- Also 0.25° and 0.1° ACCESS-OM2 versions
- Some use of 0.25° version with coupled model (more cores)
- World Ocean Model of Biogeochemistry and Trophic-dynamics (WOMBAT)
 - Nutrient, phytoplankton, zooplankton, detritus (NPZD) model

Components – Sea Ice

- Los Alamos National Lab (LANL) CICE4.1 (ESM), CICE5.1.2 (CM2)
- Sea-ice area, thickness. Dynamics and thermodynamics of ice

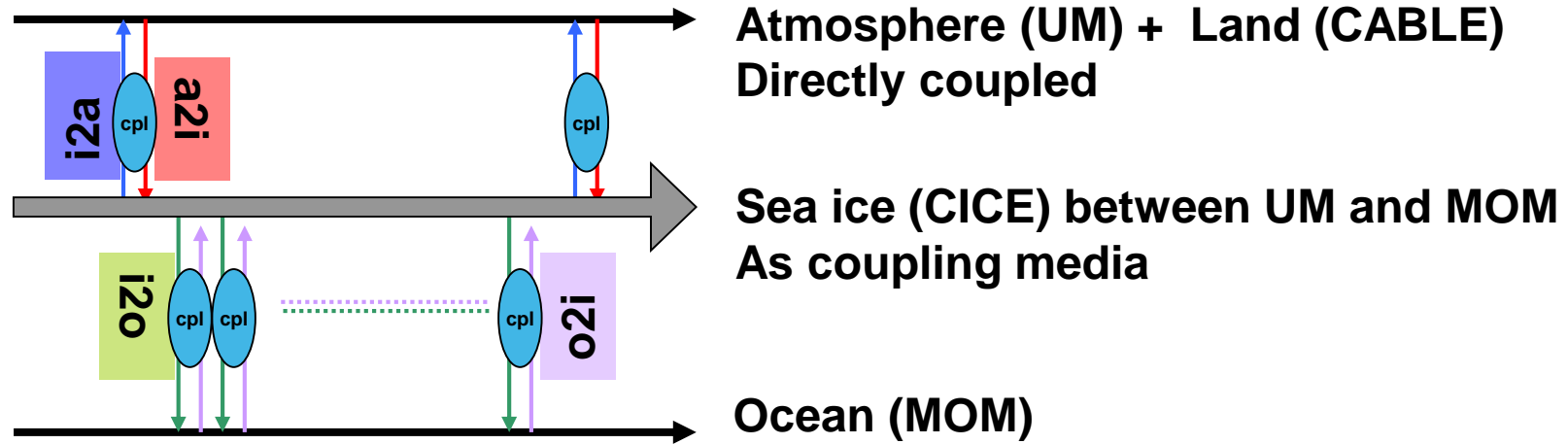


ACCESS versions use either multi-layer thermodynamics (profile b) or zero layer thermodynamics (profile a).
(Figure from Ridley et al, 2018)

Components – Aerosol and Chemistry

- Many earth system processes occur through aerosol and chemistry interactions and connections
- CLASSIC or GLOMAP-mode aerosol scheme
- Full chemistry scheme available, representing tropospheric and stratospheric chemistry (e.g. ozone hole) using UKCA
- Aerosol and chemistry code is ‘in line’ with the atmospheric code, and are coupled to the radiation scheme directly and via clouds.
- Inputs of various aerosol and chemistry species mostly come from offline files, though emissions of some species (e.g. sea spray) are calculated online
- The greatest challenge is the computational cost; the aerosol and chemistry fields represent extra tracers which must be carried around in the model
- Nudging to reanalyses (chemistry with ‘real’ transport)

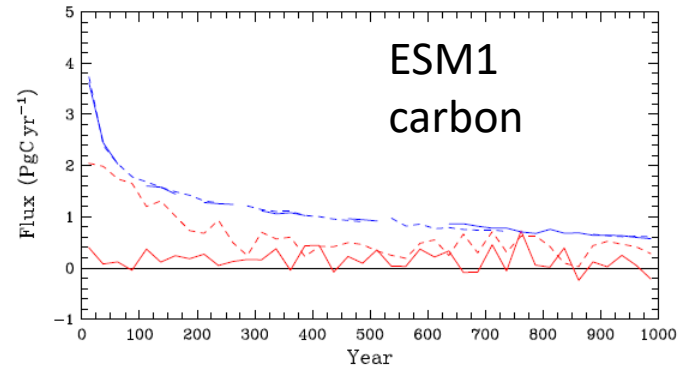
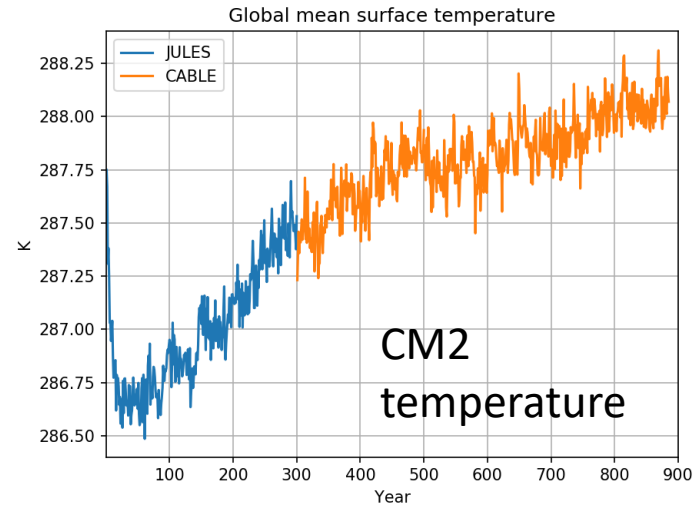
Coupling ocean to atmosphere



- Coupler OASIS3-MCT is used for UM-CICE and CICE-MOM coupling – data re-gridding and passing.
- Different coupling frequencies: atm \leftrightarrow ice (3 hours), ice \leftrightarrow ocean (every time step, e.g., 1 hr)
- ~70-110 coupling fields (2D) between the component models (depending on model version)
- Allocation of compute resources between components
UM/CABLE = 768 or 192, CICE = 12, MOM = 84

Spin-up

- Atmosphere-only: a few years for deep soil layers
- Coupled model: many hundreds of years for deep ocean
- Carbon cycle: many hundreds (thousands) of years for soil carbon, ocean carbon

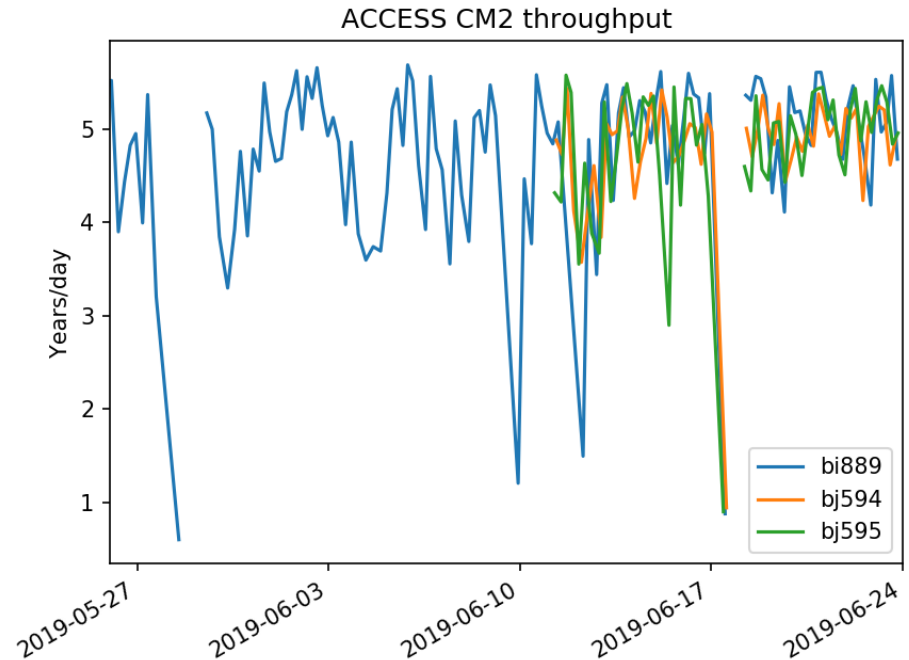


ACCESS versions – climate timescales

- ACCESS1.0 and ACCESS1.3
 - Used for CMIP5
 - Bi et al., AMOJ, 63, 41-64, 2013
 - Models differ in land surface scheme and atmospheric settings e.g. cloud scheme
- ACCESS1.4
 - Coupler change + minor fixes
 - Law et al., GMD, 10, 2567–2590, 2017, Appendix A
- ACCESS-CM2
 - Model component upgrades and new configuration
 - Being used for CMIP6
 - Bi et al., JSHESS, in prep.
- ACCESS-ESM1
 - ACCESS1.4 + carbon (CASA-CNP and WOMBAT)
 - Law et al., GMD, 10, 2567–2590, 2017
 - Ran some CMIP5 but not submitted
- ACCESS-ESM1.5
 - Code and parameter fixes
 - Simple land-use change
 - Being used for CMIP6
 - Ziehn et al., JSHESS, in prep.
- ACCESS-CM2-Chem
 - Version with chemistry
 - Run atmosphere-only or coupled

Compute resources

- National Computational Infrastructure – raijin
- 300-900 cores (N96, 38/85 levels)
- 1-5 kSU/model year
- 4-5 model years / day (CM2)
- 7-8 model years / day (ESM1.5)
- 2-3 weeks for 100 model years
- Storage for model output

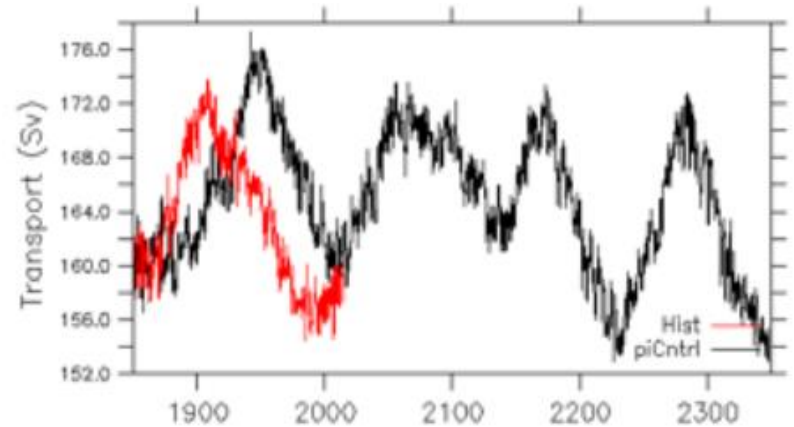
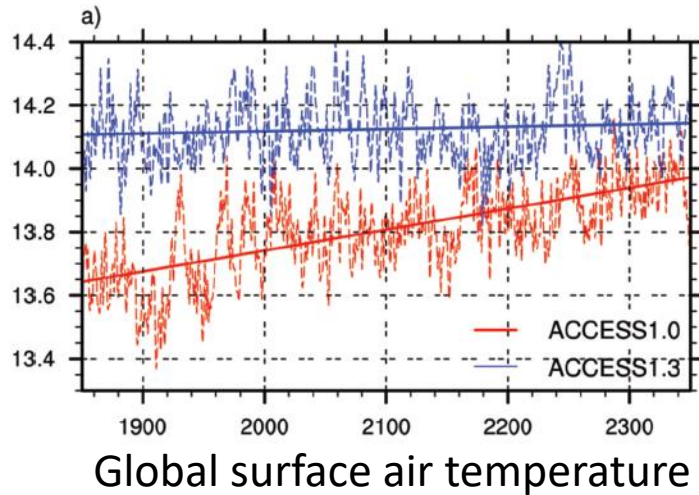


Types of model simulations

1. Control (Pre-industrial or present day: constant forcing)
2. Climate sensitivity (1% increasing CO₂, 2x or 4x CO₂)
3. Historical simulations (1850 – 2005 / 2014) including
 - Atmosphere-only (AMIP, 1979 – present)
 - Atmosphere-only with chemistry
4. Climate projections (to 2100 or beyond)
5. ‘What if’ experiments
 - Concentration-driven (CO₂, CH₄, O₃) or emissions-driven

1. Control simulations

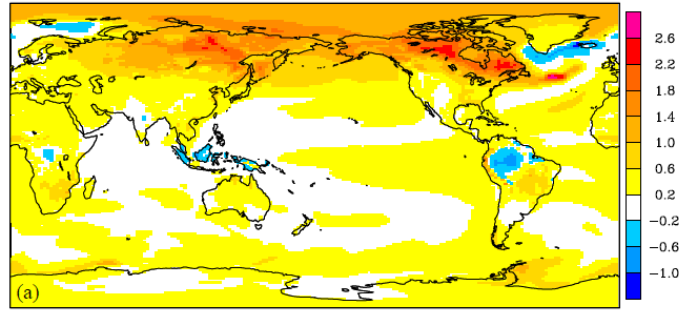
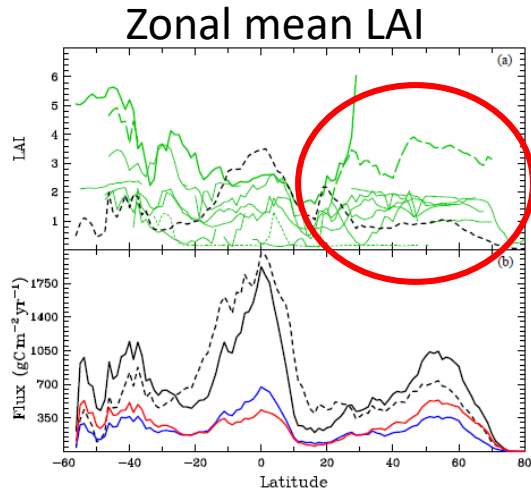
- Assess model drift
- Understand natural variability of model
- Test sensitivity to different model configurations



ESM1.5: Drake passage transport (Sv)

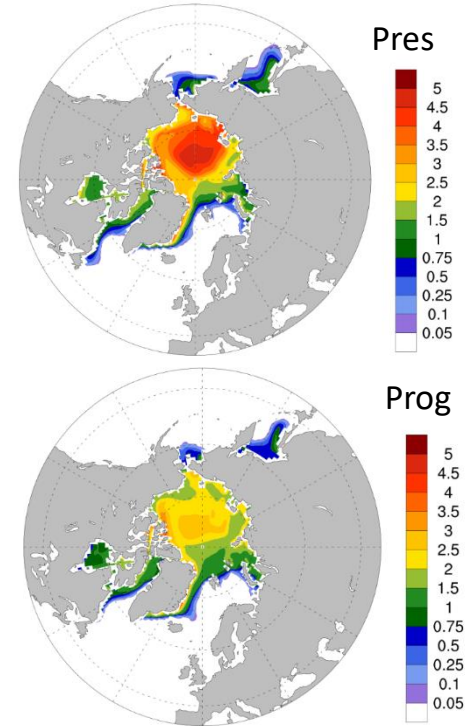
Impact of leaf area index: ACCESS-ESM1

- Prognostic LAI overestimated LAI of evergreen needleleaf vegetation
- Warmer temperature in northern high-latitudes
- Reduced Arctic sea-ice



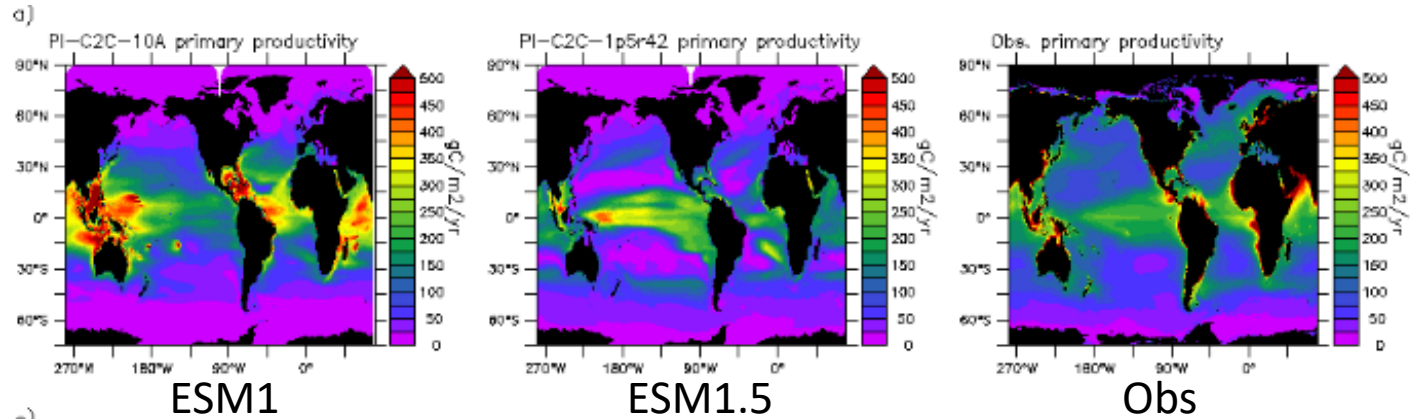
Temperature difference (PROG – PRES LAI)

April sea-ice thickness

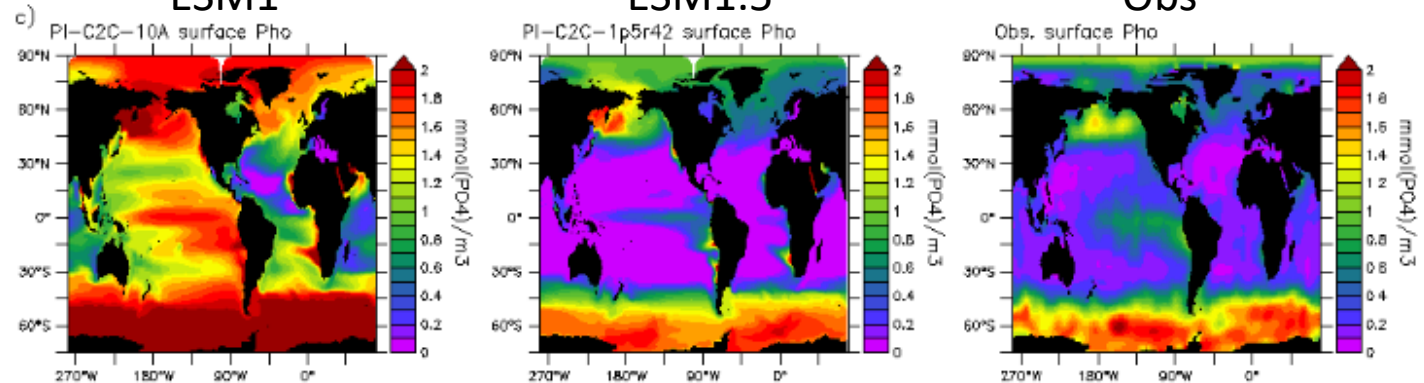


Ocean carbon improvements

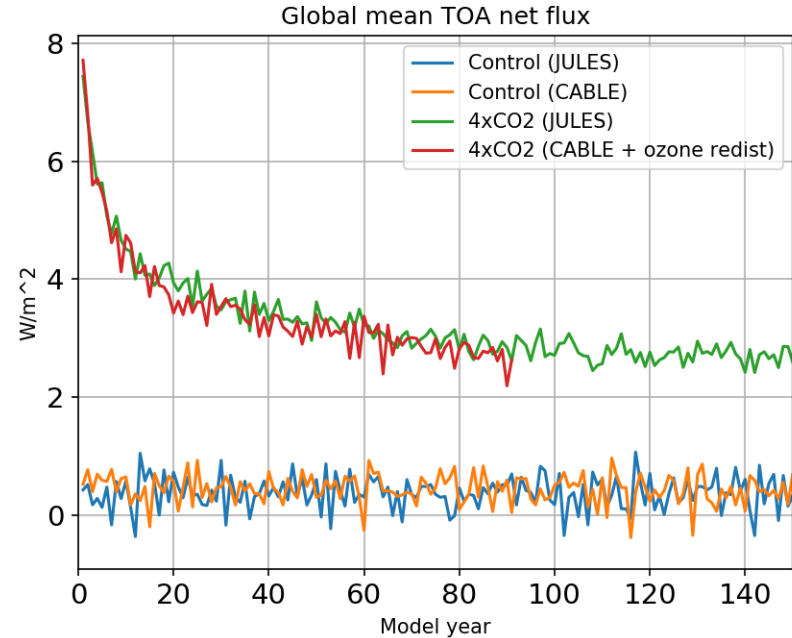
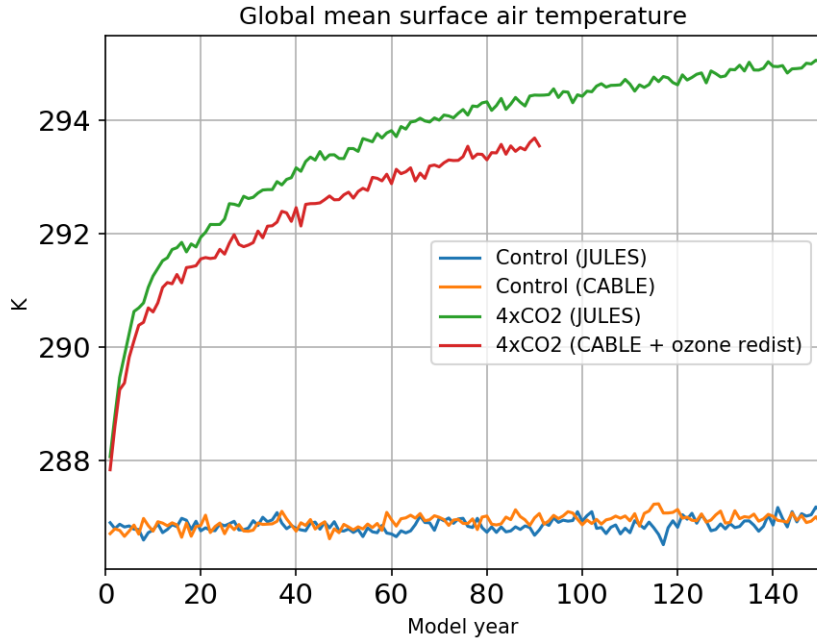
Primary
Production



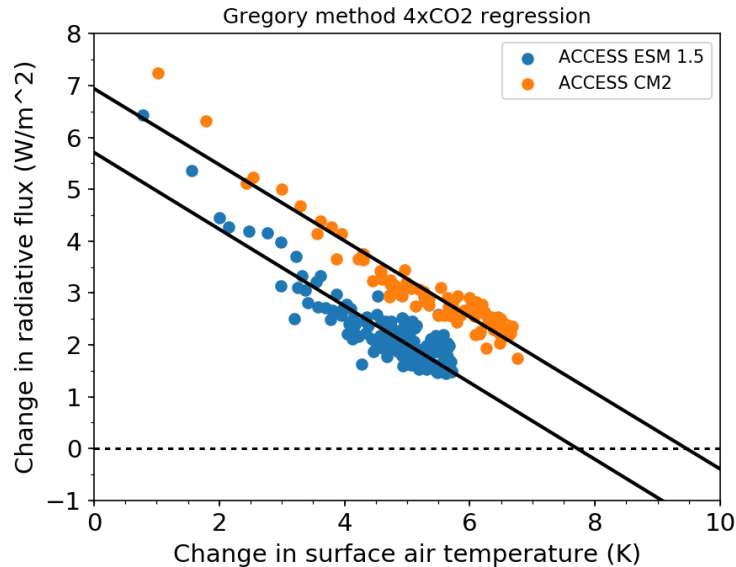
Surface
phosphate
(nutrients)



2. Climate sensitivity (4xCO₂)



Equilibrium Climate sensitivity

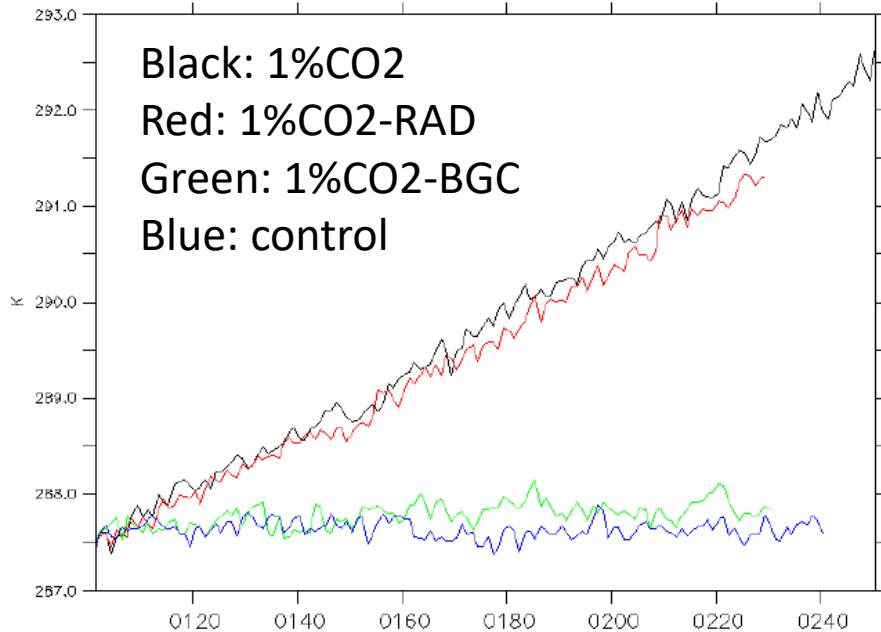


Case	2xCO ₂ ECS
ESM1.5 150 years	3.9
CM2 (90 years)	4.7
CM2 (150 years)	Estimate 5.0-5.1

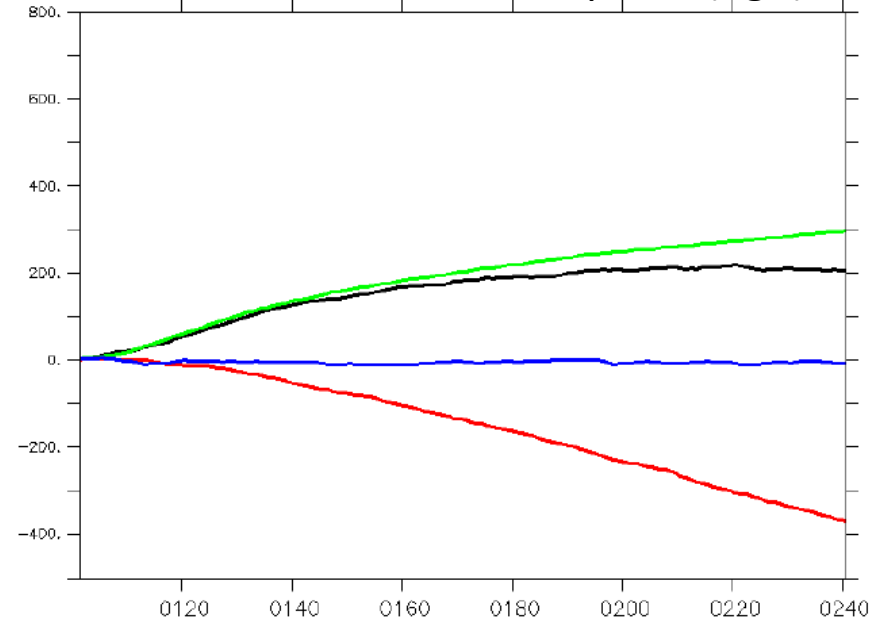
Gregory, J. M., and Coauthors, 2004: A new method for diagnosing radiative forcing and climate sensitivity. *Geophys. Res. Lett.*, **31**, L03205, doi:10.1029/2003GL018747.

Climate sensitivity (1%CO₂)

Global temperature



Cumulative land carbon uptake (PgC)



3. Historical simulations

- Model assessment compared to present-day observations
- Sensitivity of model to historical forcing

Global surface temperature increase from pre-industrial with/without changing greenhouse gases and aerosols

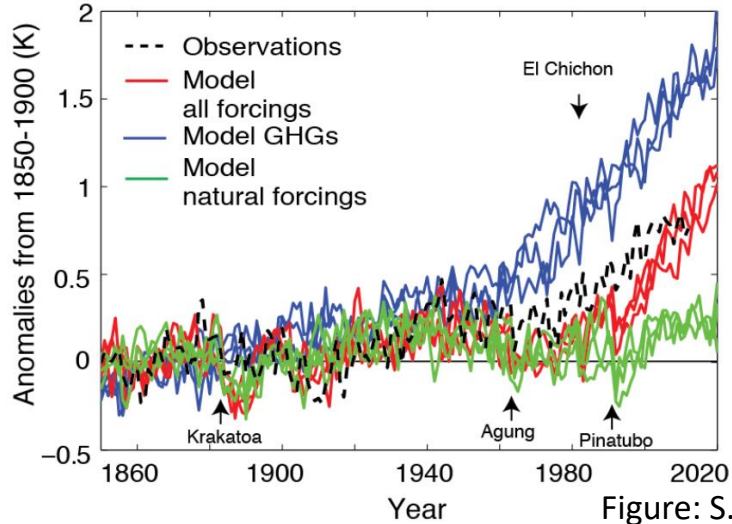
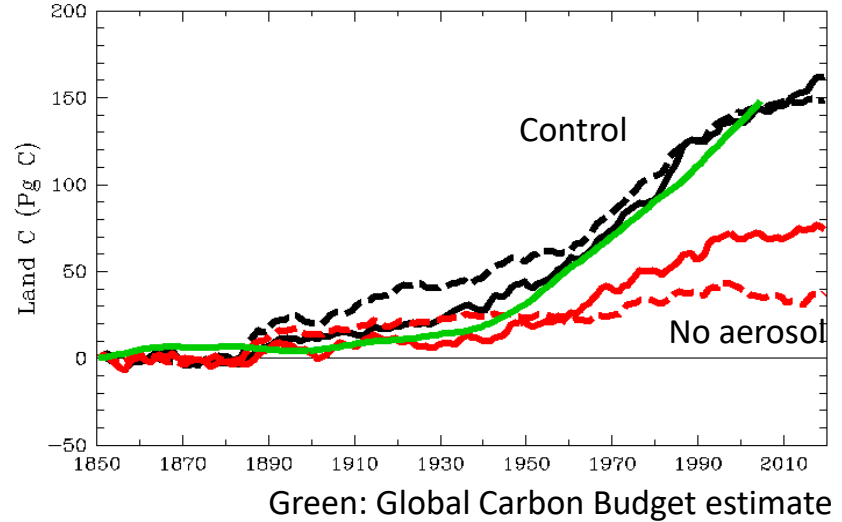


Figure: S. Lewis

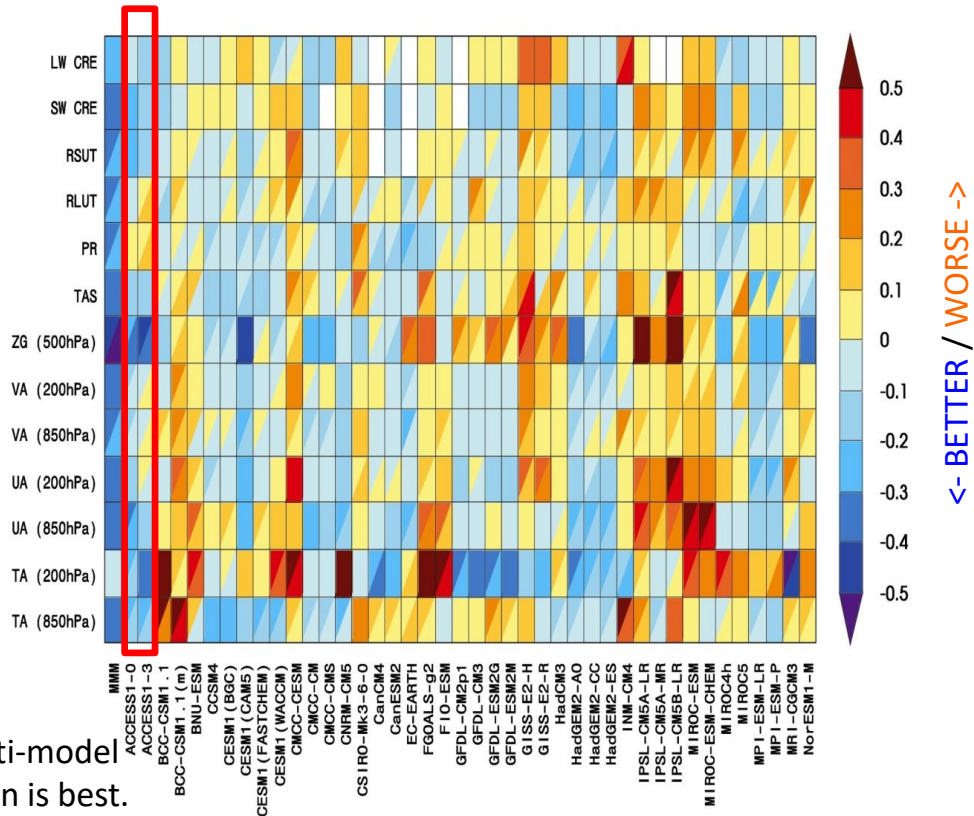
Land carbon uptake from 1850 with/without anthropogenic aerosols



Green: Global Carbon Budget estimate

IPCC-AR5 WG1 Fig 9.7

Assessment versus 13 metrics from CMIP5



Skill score for Australia combining seasonal temperature, pressure and precipitation for 25 CMIP5 models

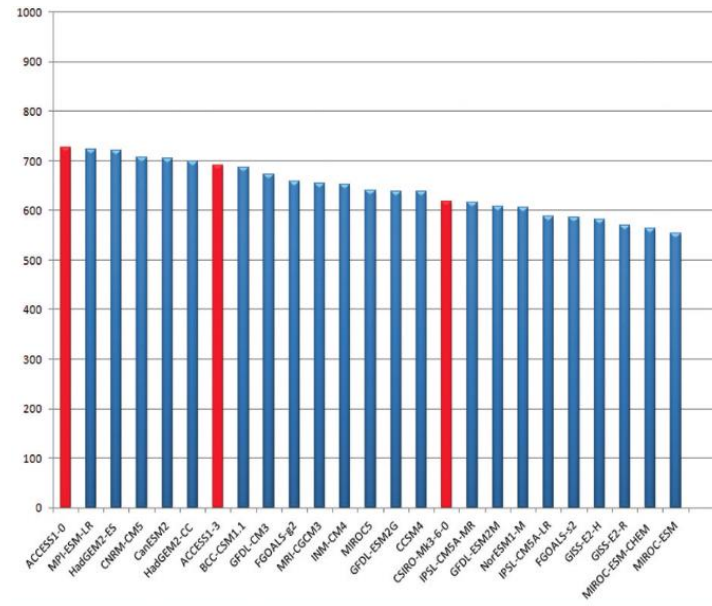
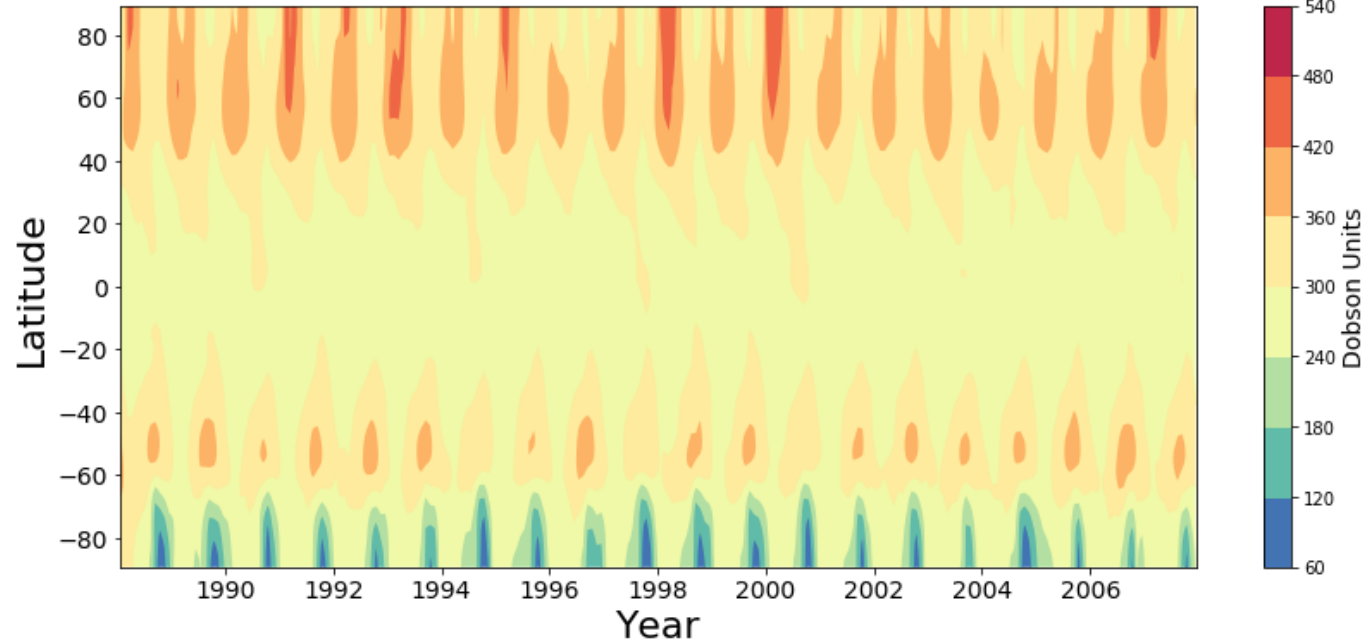


Fig 3b: Watterson et al., AMOJ, 2013



AMIP with chemistry

ACCESS-CM2 Zonal Mean Total Column Ozone



ACCESS-CM2-Chem produces an ozone hole with interannual variability

4. Climate projections

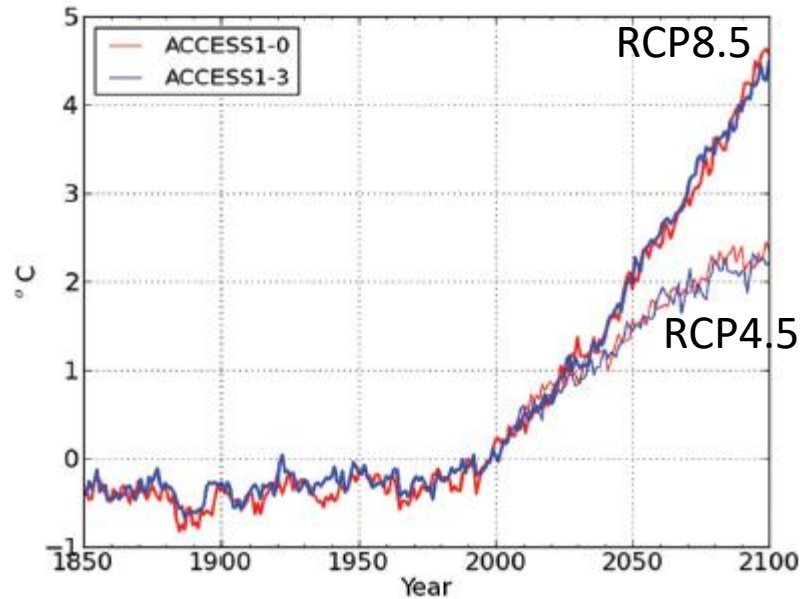
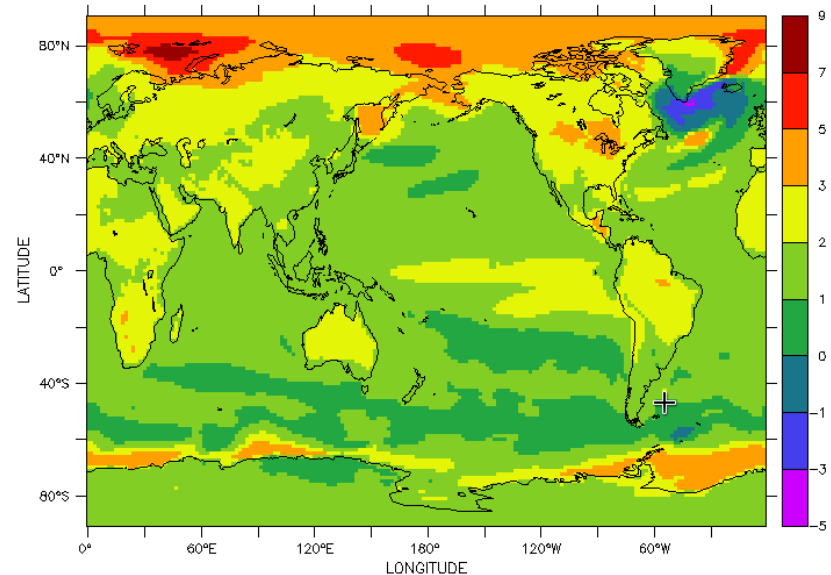


Fig 7: Dix et al, AMOJ, 2013

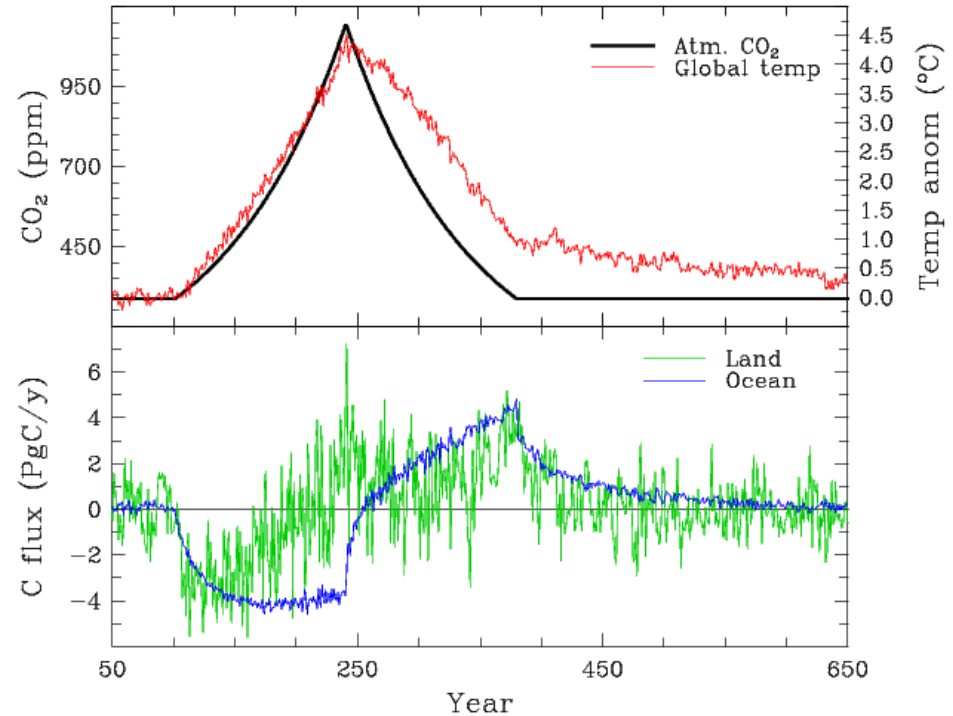


Surface air temperature in 2091-2100 relative to 1850-1859 under RCP2.6

5. 'What if' experiments

- Geo-engineering
 - Solar radiation management
 - Carbon dioxide removal

CO₂ reversibility experiment, response of carbon fluxes
Ziehn et al., Mitigation and Adaptation Strategies for Global Change, submitted.



Coupled Model Intercomparison Project 6

About 100 registered model versions, but only 5 led from Southern Hemisphere
Core CMIP (DECK + historical)

- AMIP, piControl, 1pctCO2, 4xCO2, esm-piControl
- Historical, esm-historical (1850-2014)

21 affiliated MIPs including ScenarioMIP

ACCESS-CM2 (climate only)

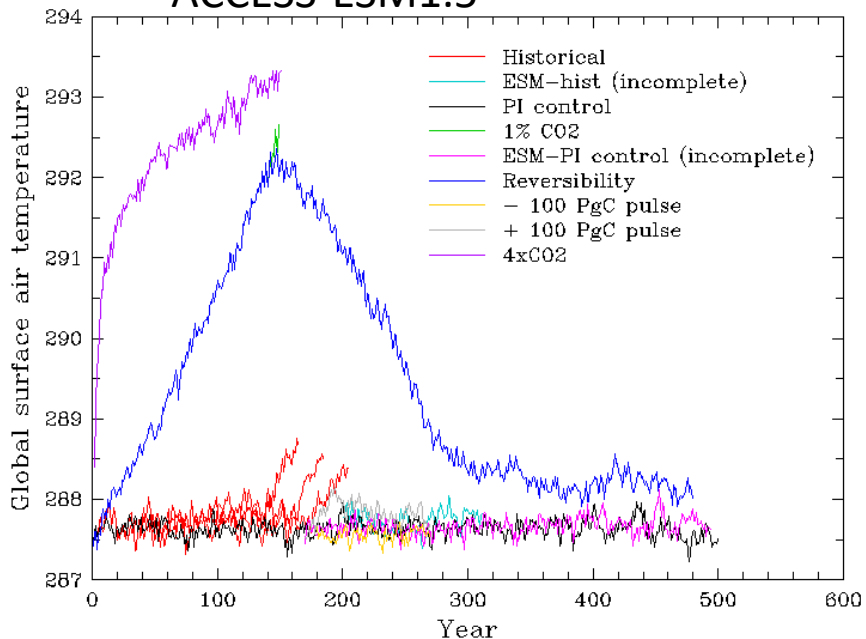
- Entry-level experiments (DECK, historical)
- ScenarioMIP
- Ocean, OMIP
- Flux-Anomaly-Forced ,FAFMIP
- Radiative-forcing, RFMIP

ACCESS-ESM1.5 (with carbon cycle)

- DECK, historical
- ScenarioMIP
- Coupled climate-carbon cycle, C4MIP
- Carbon Dioxide Removal, CDRMIP
- Radiative forcing, RFMIP

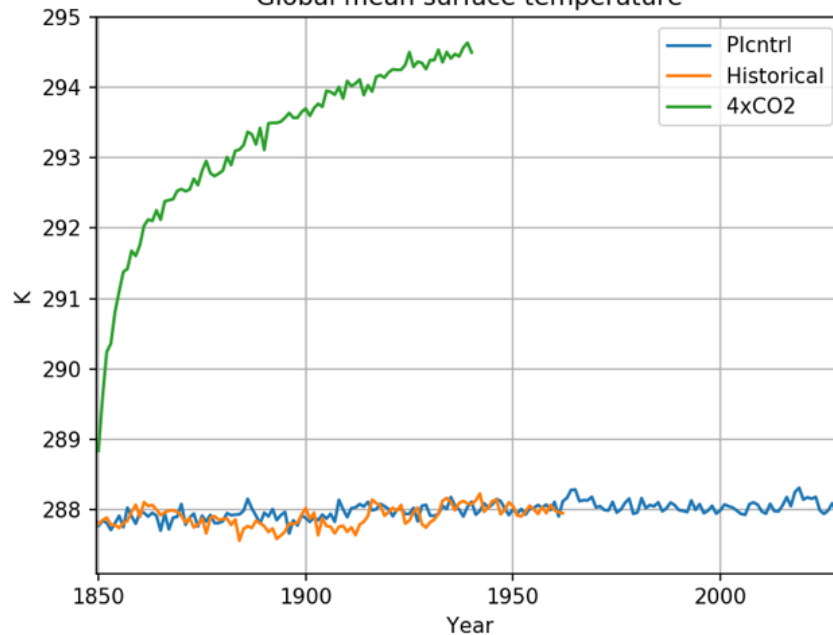
Status of CMIP6 runs

ACCESS-ESM1.5



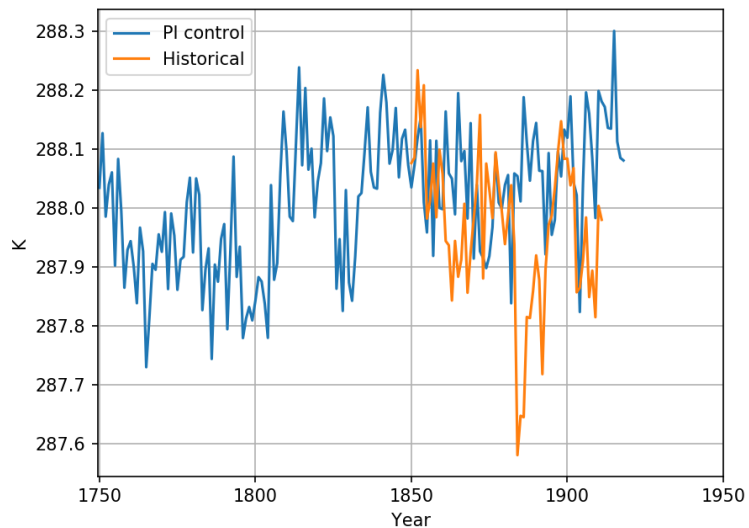
ACCESS-CM2

Global mean surface temperature

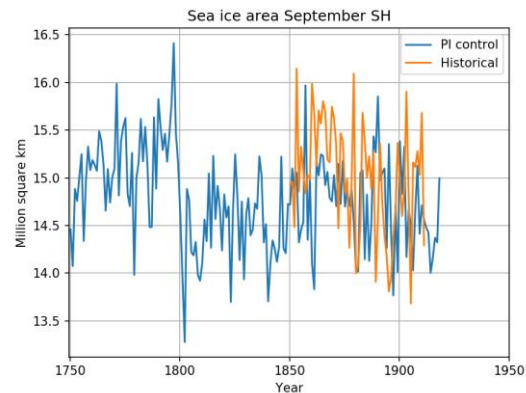
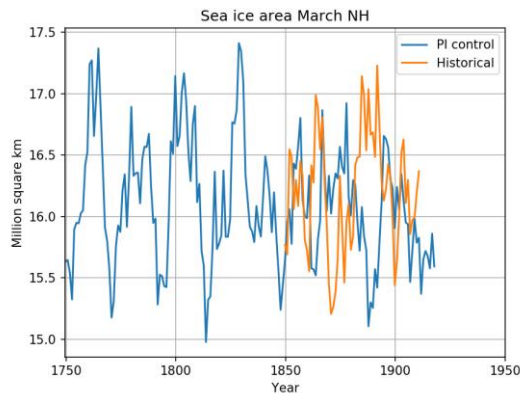


ACCESS-CM2 at 2019-06-24 23:06 UTC

Global mean surface temperature



Sea-ice area: March (NH), September (SH)

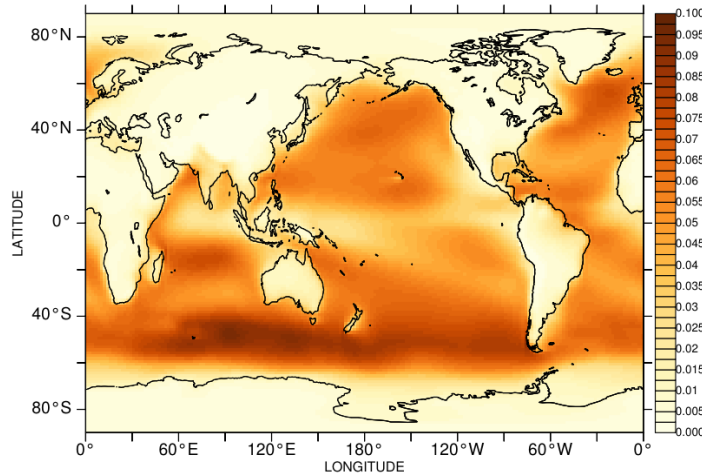


Blue: control, Orange: Historical

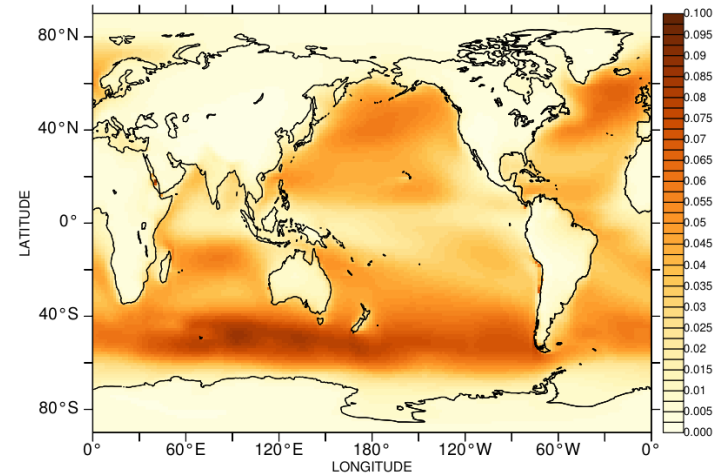
Finding bugs

- Bugs are inevitable in code of this size
- Need to assess their significance

Multi-year
mean soluble
coarse model
(sea salt)
aerosol optical
depth



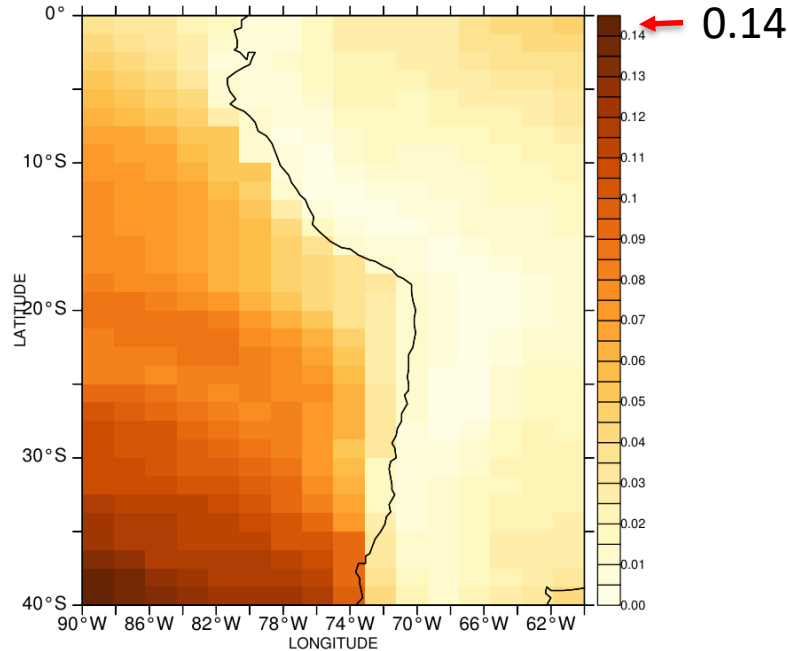
AMIP using UM/JULES



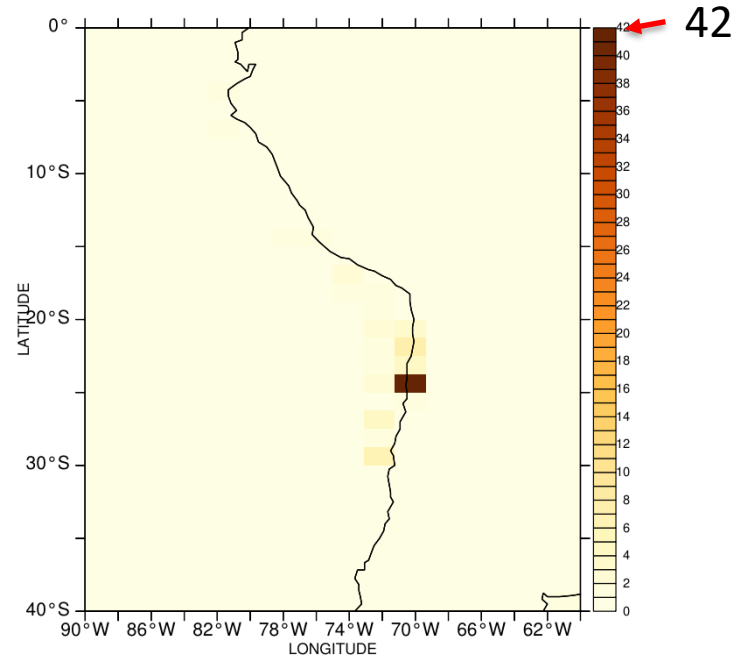
AMIP using UM/CABLE

Soluble coarse mode AOD. Max monthly value

JULES AMIP (Max over 1951-2014)

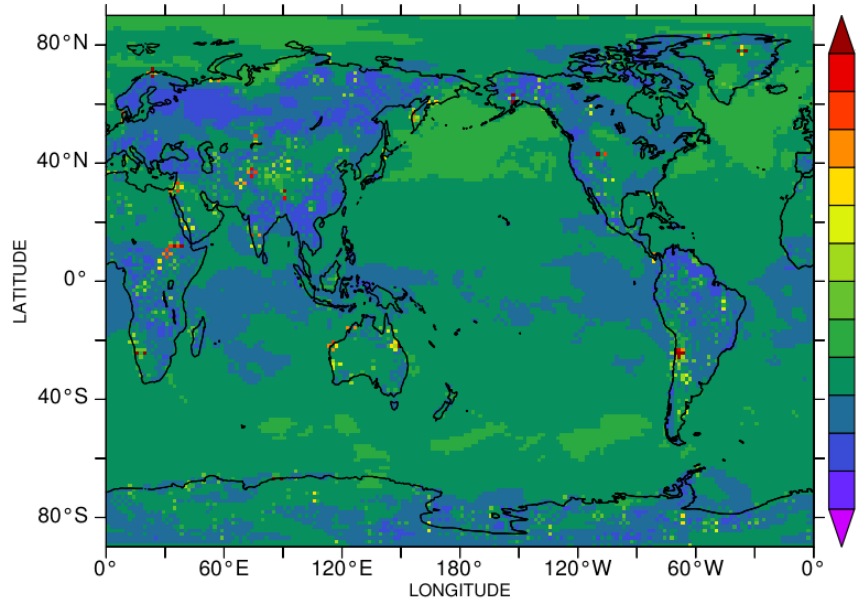


CABLE AMIP (Max over 1930-2014)

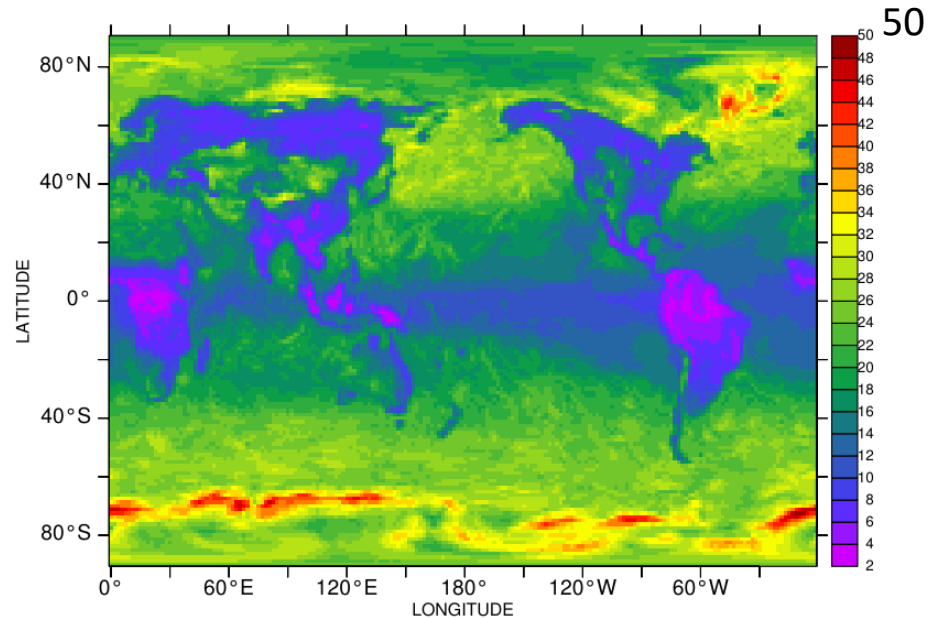


Sea salt depends on 10 m wind speed, U_{10}^3 or U_{10}^4 with no bound

Timestep maximum 10 m wind speed

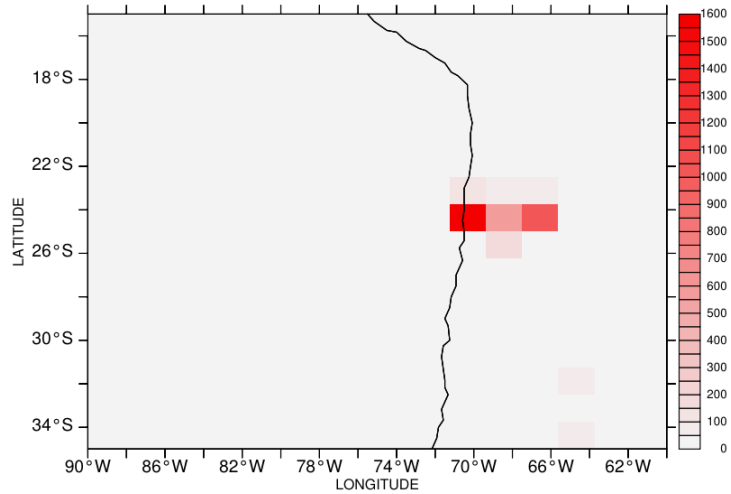


CM2 AMIP. Max over Jan 1961
Max of 1589 m/s over S America

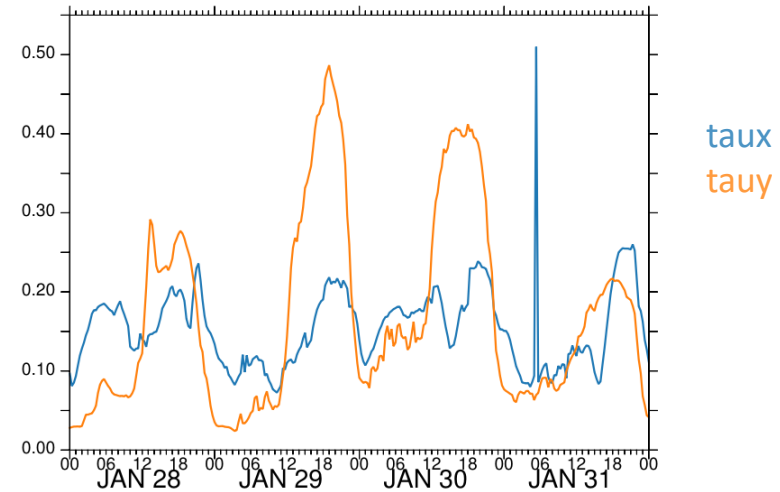
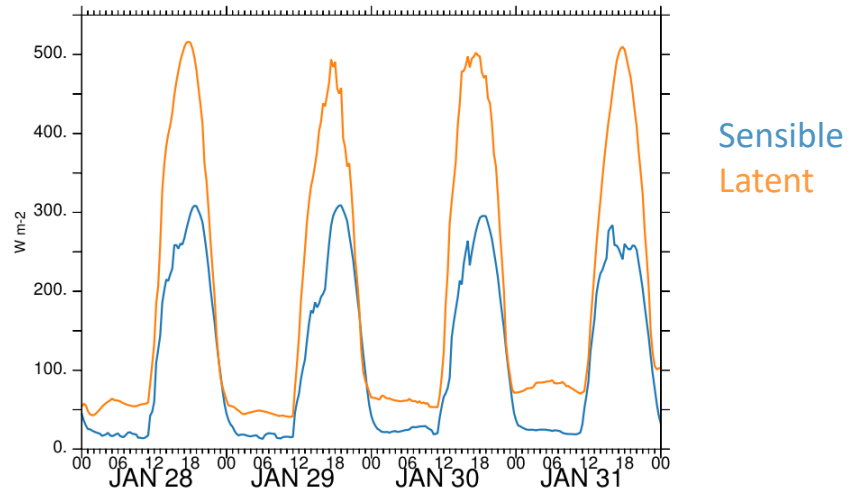
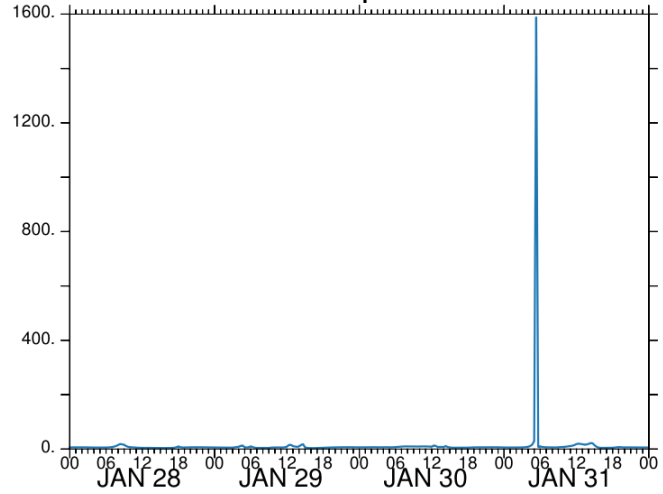


ESM1.5 Historical
Max over 1950-1959

Windspeed



Windspeed



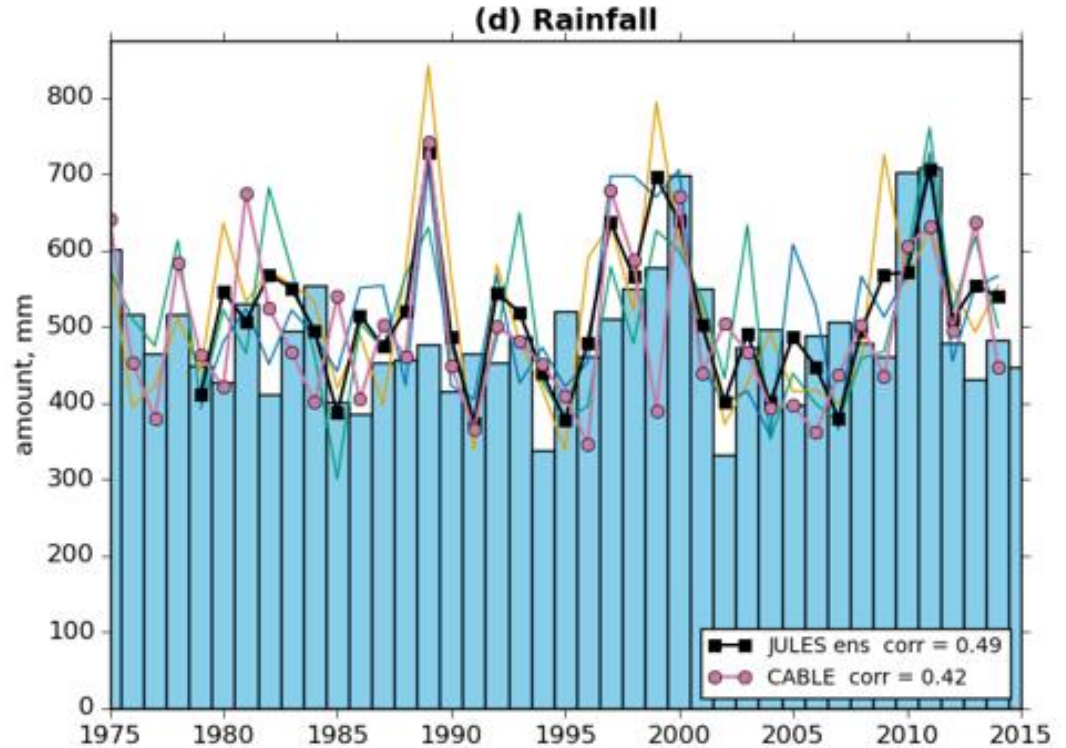
Re-start runs or not?

- Sea salt aerosol showed problems from unphysical spikes in CABLE diagnostic 10m wind speed in calm stable conditions
- Surface fluxes unaffected so expect little effect on overall climate
- However several important CMIP6 diagnostics show effect
 - E.g., daily surface net solar radiation
- Noticed some other JULES/UKCA sea-salt related bugs (accounted for mean difference between UM/JULES and UM/CABLE)
- PI control restarted with bugs fixed (lost ~8 weeks of run-time)

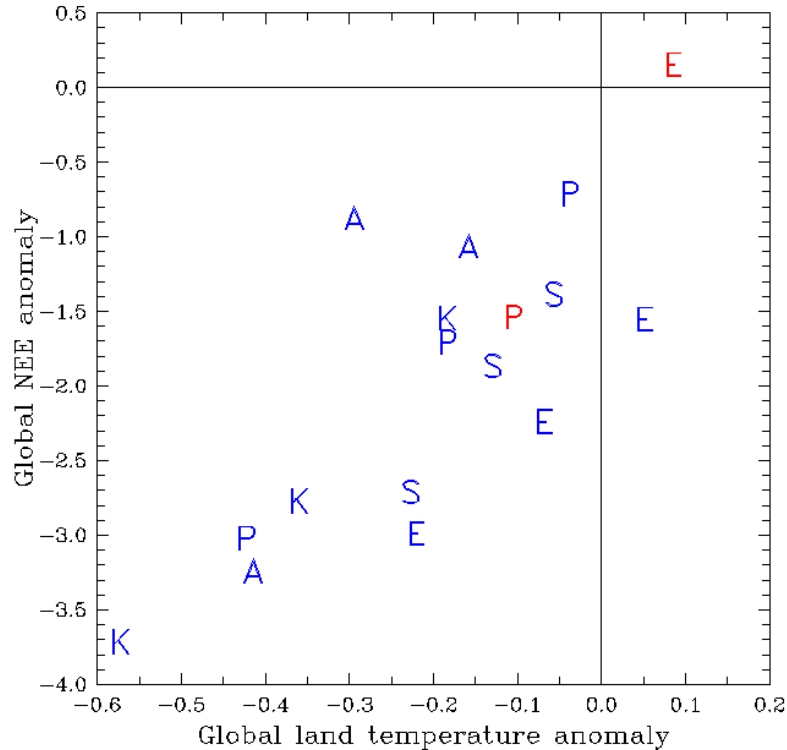
Ensembles

- Natural variability vs forced signals
- Smaller signal, larger ensemble

Australian rainfall compared to AWAP
ACCESS-CM2 AMIP



Land carbon sensitivity to volcanoes



Temperature anomaly vs land carbon flux anomaly
[Anomaly: 2 year mean post-volcano minus 6 year mean pre-volcano]

K: Krakatoa
S: Santa Maria
A: Agung
E: El Chichon
P: Pinatubo

Blue: ACCESS-ESM1
Red: 'Obs'

Availability of ACCESS model output

- ACCESS1.0 and ACCESS1.3 CMIP5 on ESFG at NCI
- ACCESS-ESM1
 - https://accessdev.nci.org.au/trac/wiki/access/ACCESS_ESM1_catalogue
 - Moved from NCI to CSIRO to make space for CMIP6 runs
- ACCESS-CM2 and ACCESS-ESM1.5
 - Available soon for wider community use
- <https://accessdev.nci.org.au/trac/wiki>
- <https://accessdev.nci.org.au/trac/wiki/access/AccessModelExperimentLibrary>
- <https://accessdev.nci.org.au/trac/wiki/access>

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