ACCESS Climate Modelling

Australian Community Climate and Earth System Simulator

Rachel Law | Climate Science Centre

CLEX Winter School, June 2019

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?

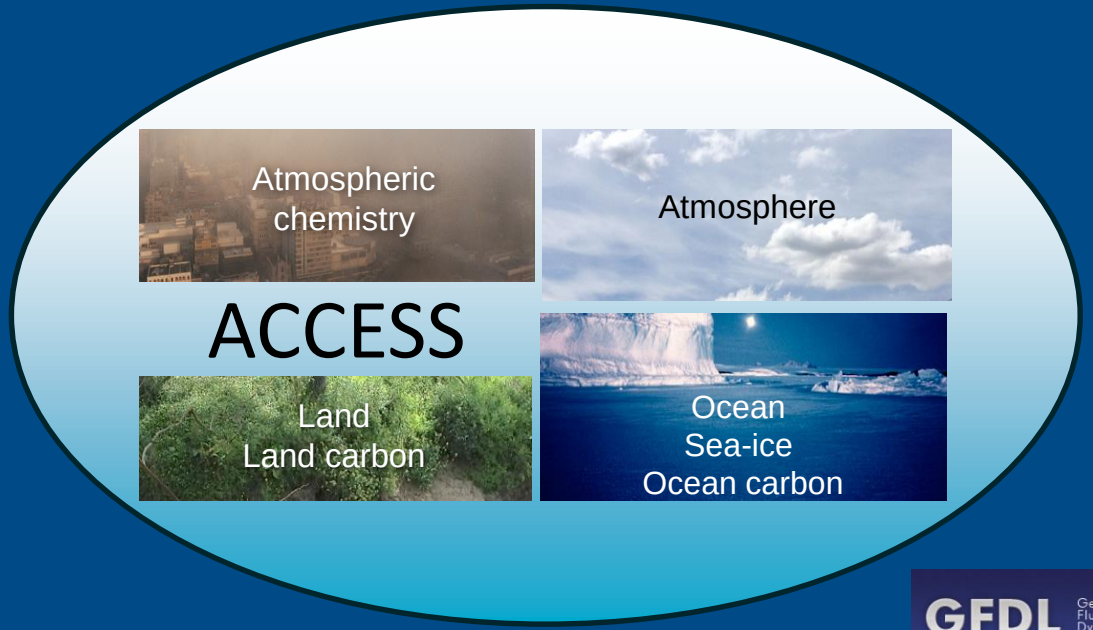
Australian Community Climate and Earth System Simulator

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)



Met Office
NCMRWF
KMA
Australian Government
Bureau of Meteorology
CSIRO
NIWA
Taihoro Nukurangi

GFDL Geophysical Fluid Dynamics Laboratory

Australian National University
MONASH University
THE UNIVERSITY OF MELBOURNE
UNSW SYDNEY
UNIVERSITY of TASMANIA

Los Alamos NATIONAL LABORATORY EST. 1943

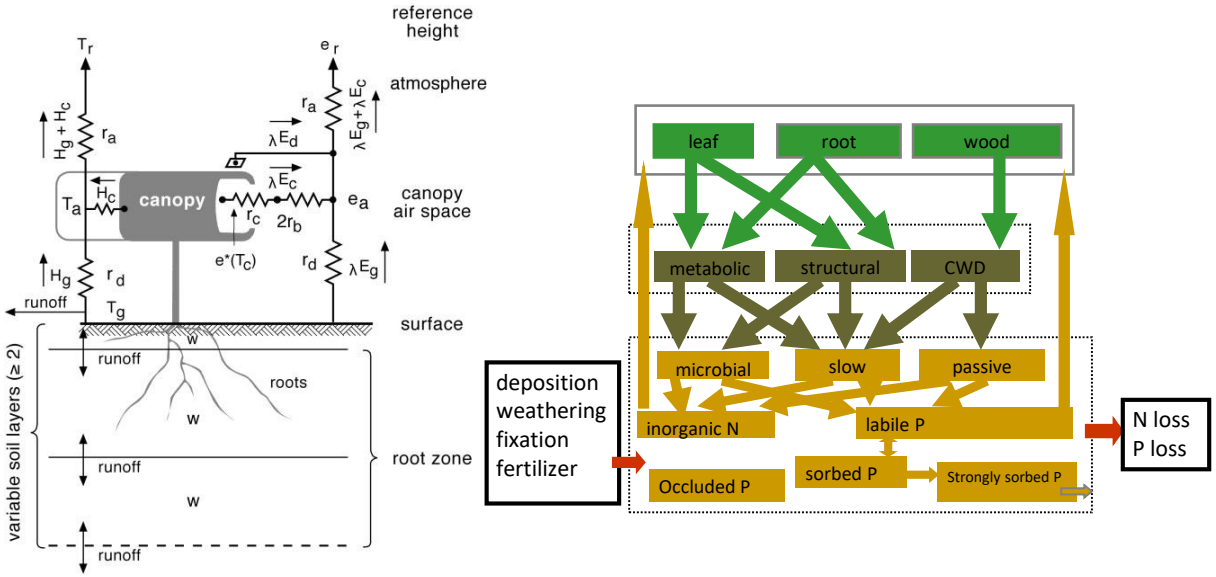
CSIRO

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^{o} x 1.25^{o}, 38 levels
  - 'N96', 1.875^{o} x 1.25^{o}, 85 levels
  - *'N216', 0.833^{o} x 0.556^{o}, 85 levels*
  - *'N320', 0.5625^{o} x 0.375^{o}, 38 levels*
  - *'N512', 0.352^{o} x 0.235^{o}, 85 levels*

Components - Land

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



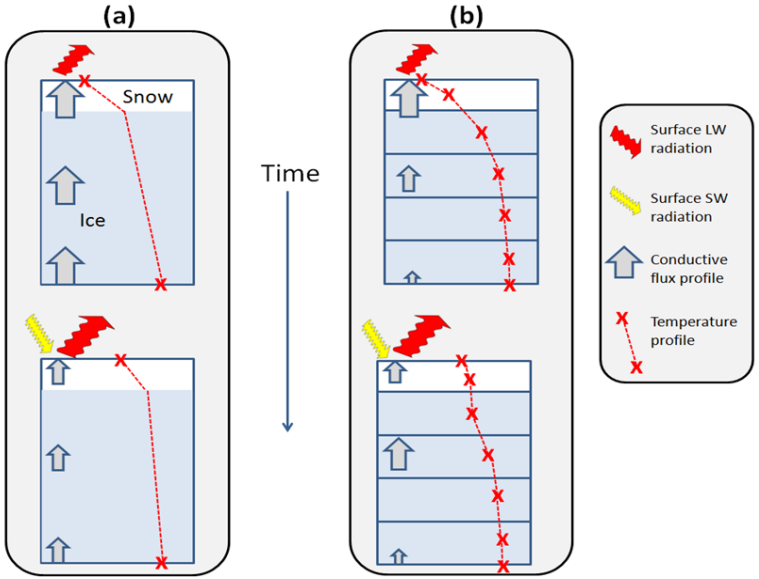
- Directly coupled into atmosphere. Replaces most parts of UM land scheme (MOSES or JULES)
- Different code versions and configurations of CABLE in different ACCESS versions
- CASA-CNP switched on for carbon-cycle (ESM) ACCESS versions.

Components – Ocean and ocean biogeochemistry

- NOAA/GFDL MOM4p1 or MOM5
- Tri-polar grid
- ~1^{o} resolution, with higher resolution at equator and in southern ocean, 50 levels
- Also 0.25^{o} and 0.1^{o} ACCESS-OM2 versions
- Some use of 0.25^{o} 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

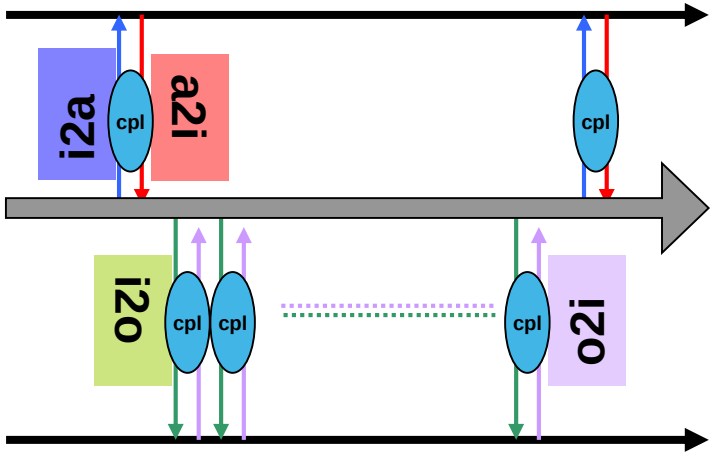


ACCESS versions use either multi-layer thermodynamics (profile b) or zero layer thermodynamics (profile a).
(Figure from Ridley et al, 2018)

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



Atmosphere (UM) + Land (CABLE)
Directly coupled

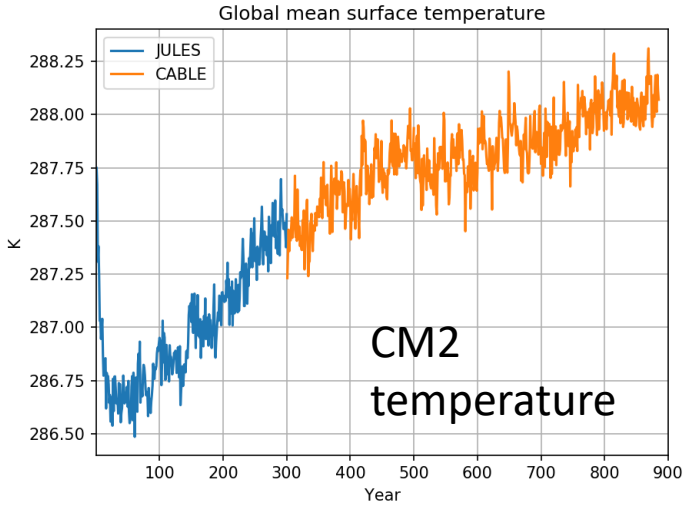
Sea ice (CICE) between UM and MOM
As coupling media

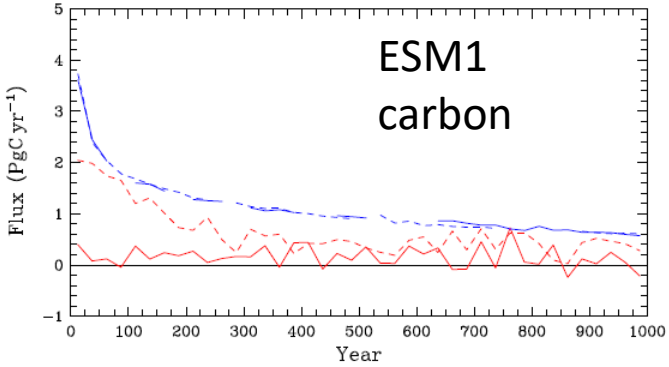
Ocean (MOM)

- Coupler OASIS3-MCT is used for UM-CICE and CICE-MOM coupling – data re-gridding and passing.
- Different coupling frequencies: atm ⇔ ice (3 hours), ice ⇔ 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





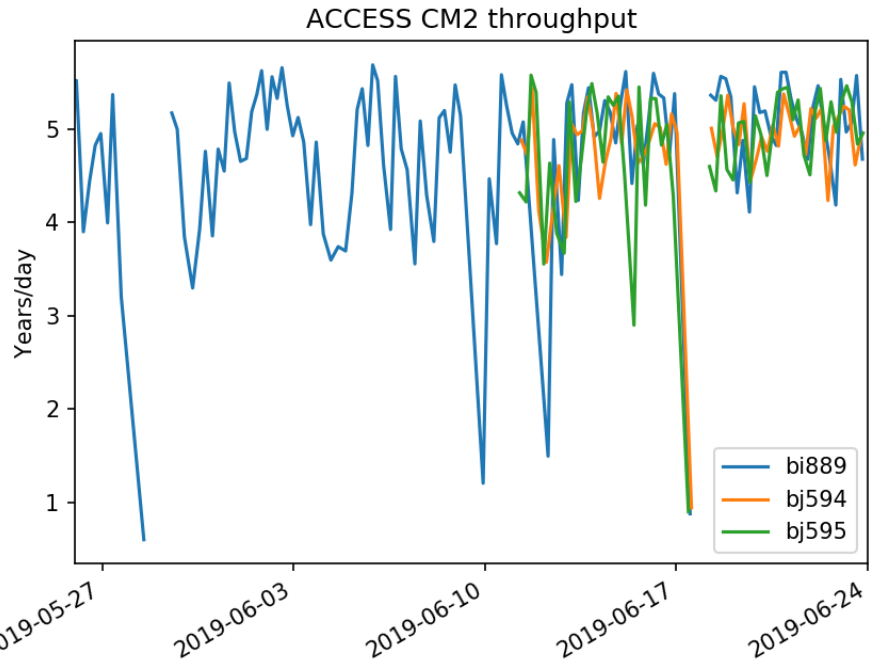
ACCESS versions – climate timescales

- 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



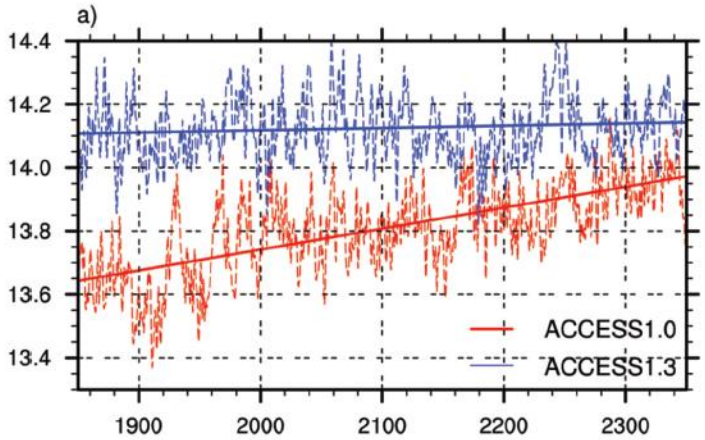
Types of model simulations

1. Control (Pre-industrial or present day: constant forcing)
2. Climate sensitivity (1% increasing CO_2, 2x or 4x CO_2)
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

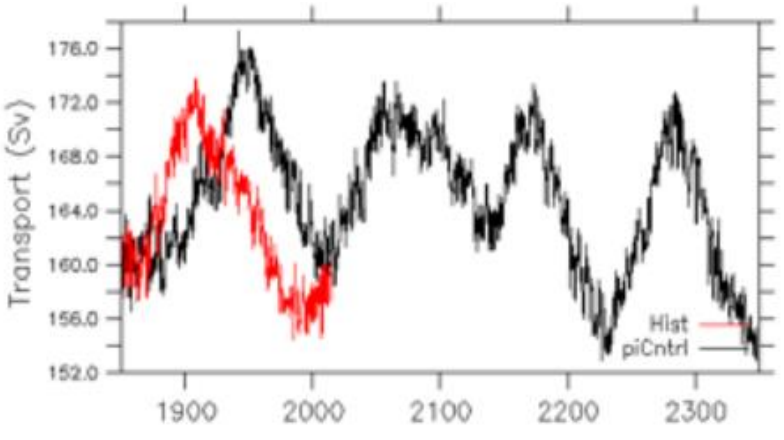
- Concentration-driven (CO_2, CH_4, O_3) or emissions-driven

1. Control simulations

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



Global surface air temperature

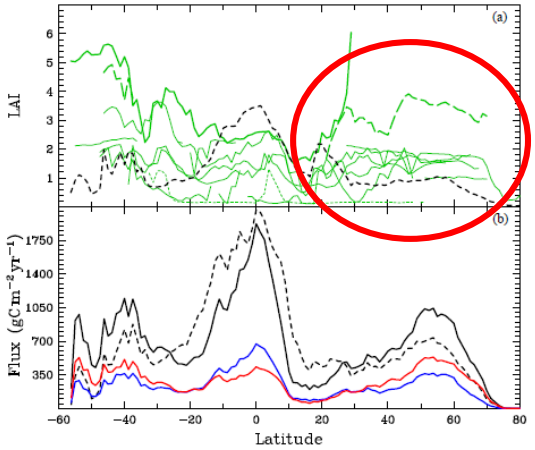


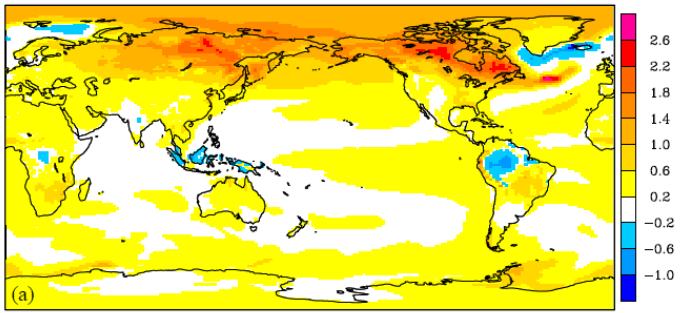
ESM1.5: Drake passage transport (Sv)

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

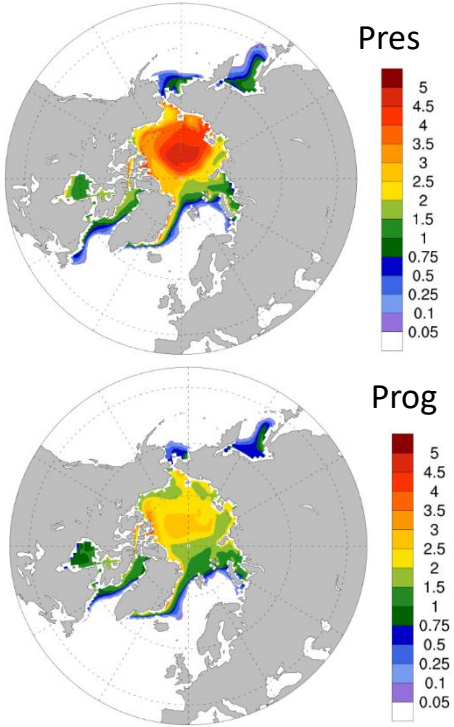
Zonal mean LAI





Temperature difference (PROG – PRES LAI)

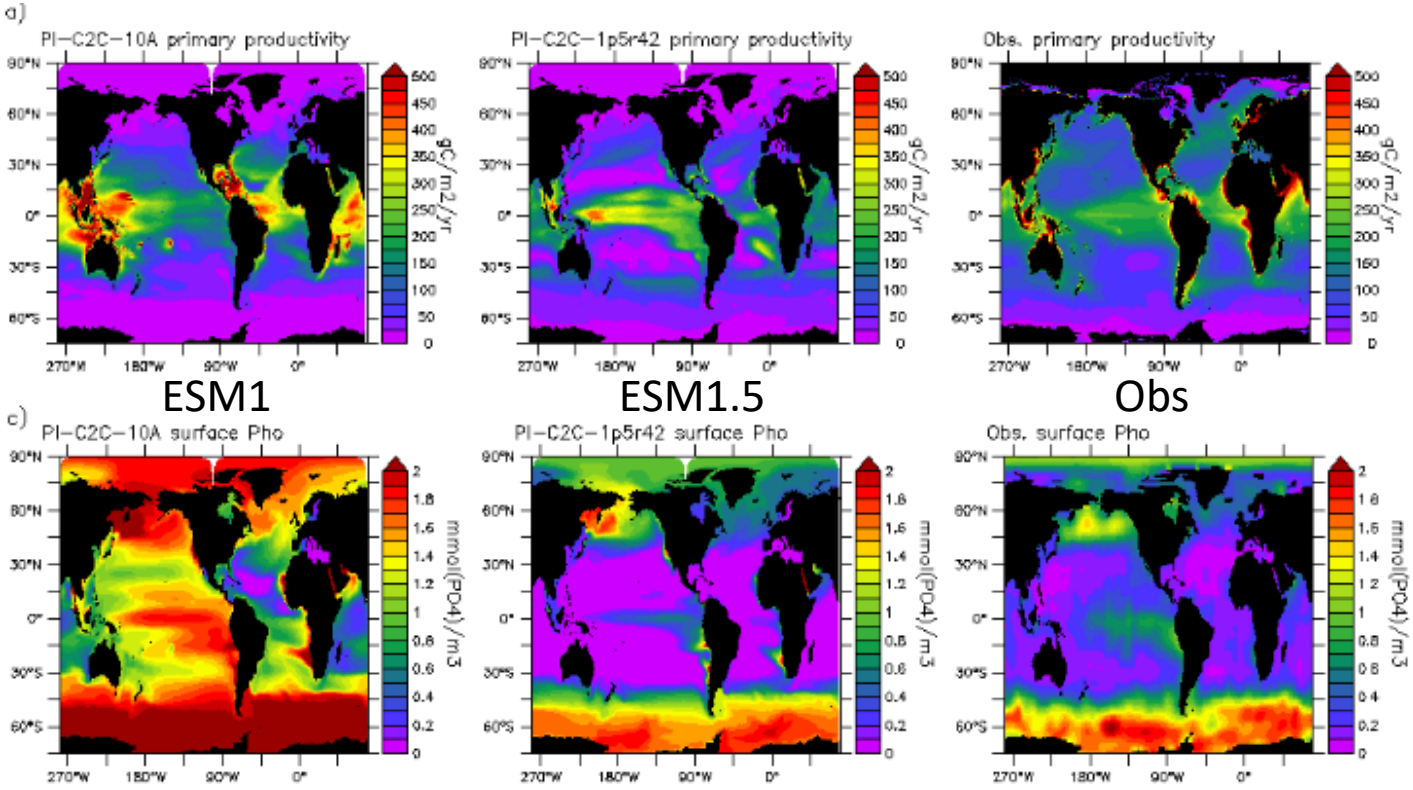
April sea-ice thickness



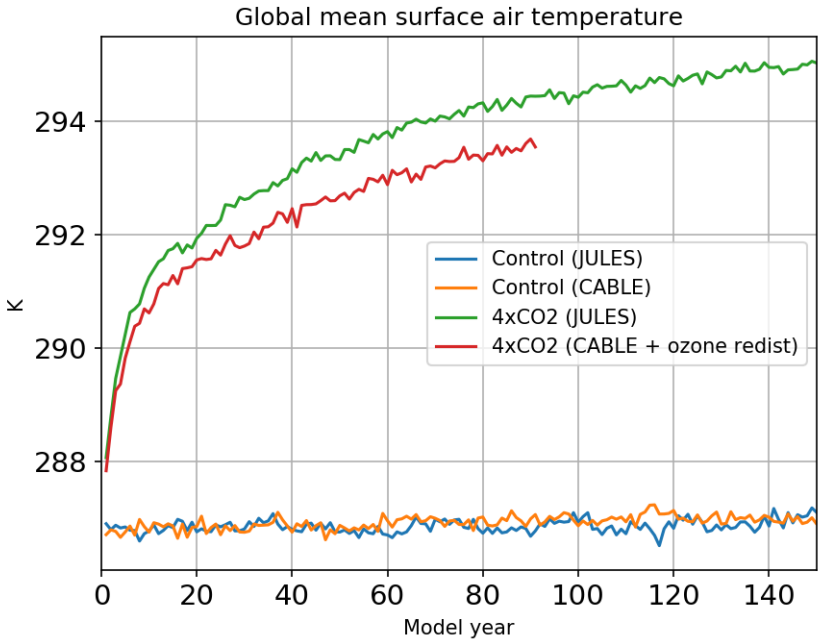
Ocean carbon improvements

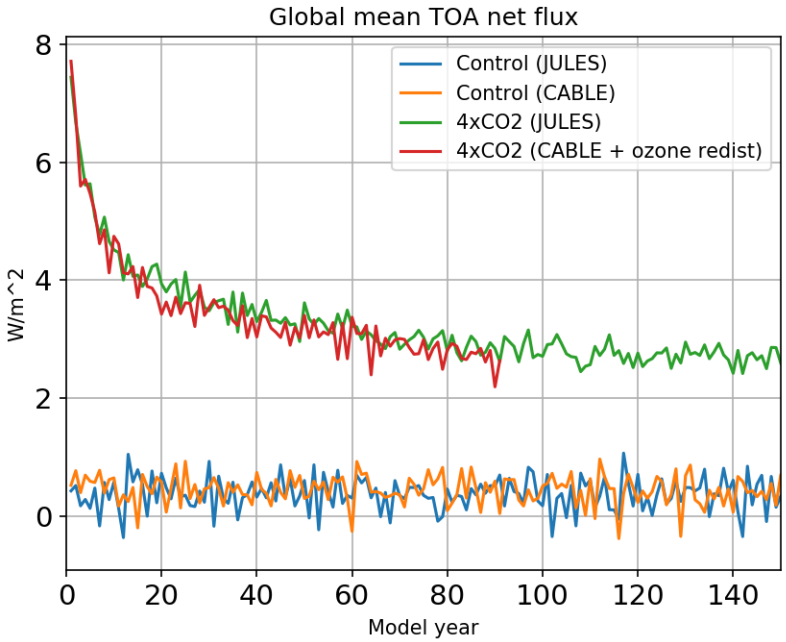
Primary Production

Surface phosphate (nutrients)

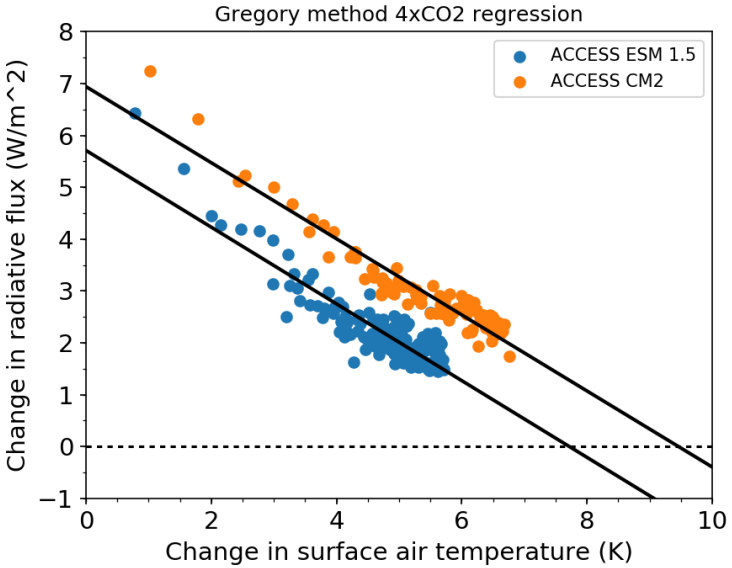


2. Climate sensitivity (4xCO2)





Equilibrium Climate sensitivity

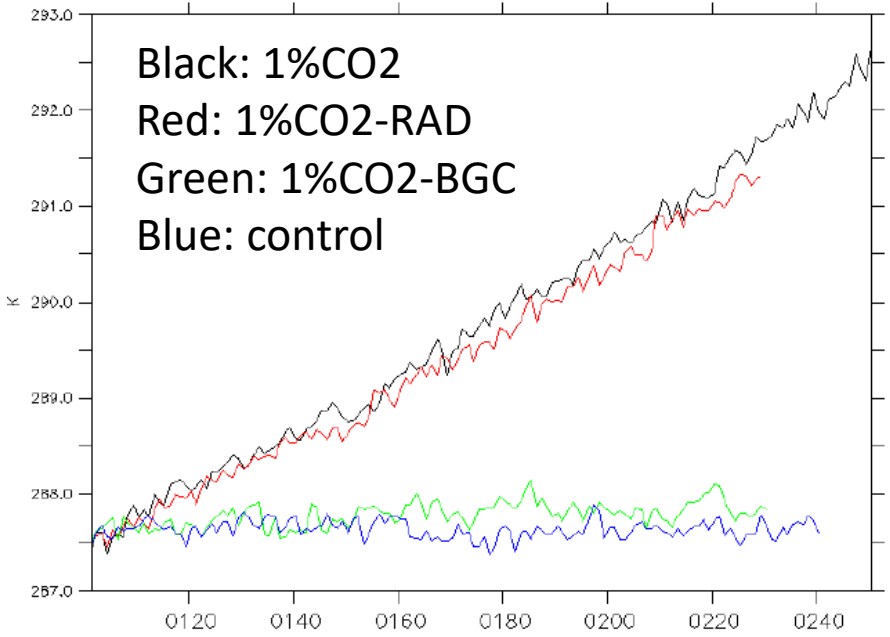


Case	2xCO2 ECS
ESM1.5 150 years	3.9
CM2 (90 years)	4.7
CM2 (150 years)	Estimate 5.0-5.1

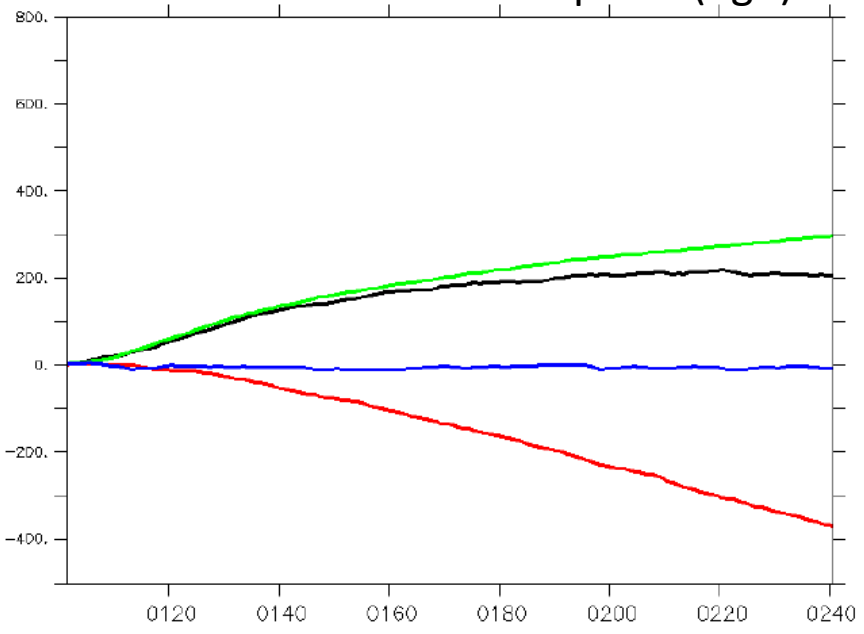
Gregory, J. M., and Coauthors, 2004: A new method for diagnosing radiative forcing and climate sensitivity. *Geophys. Res. Lett.*, **31**, L03205, doi:10.1029/2003GL018747.

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

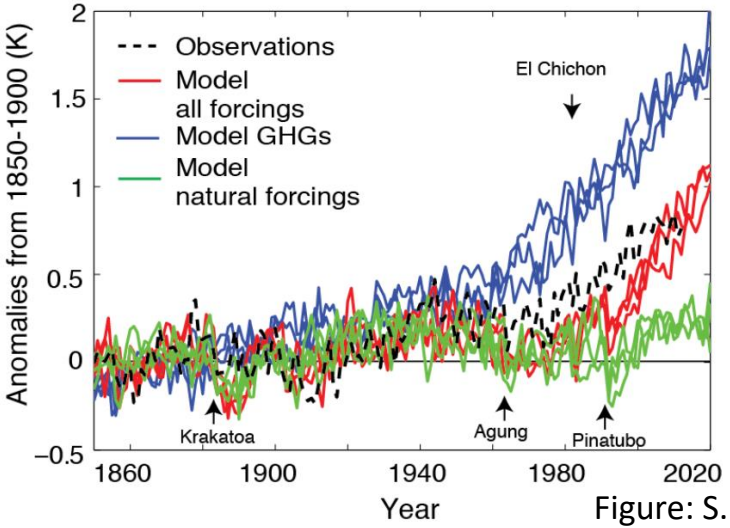
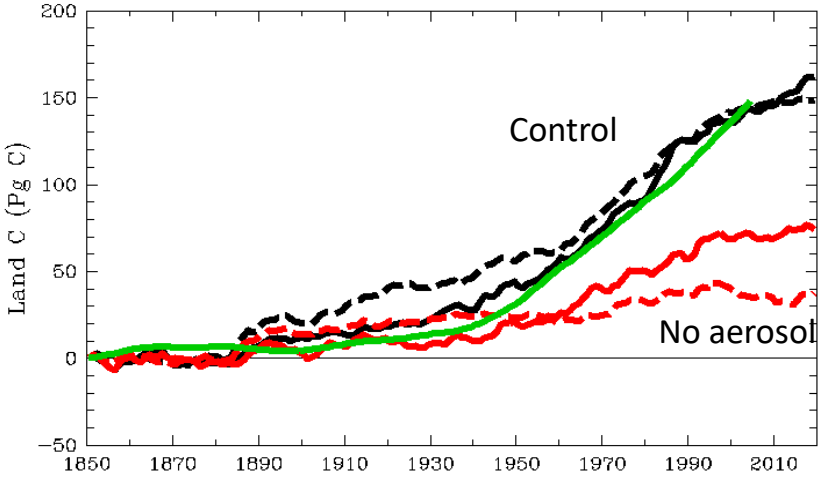


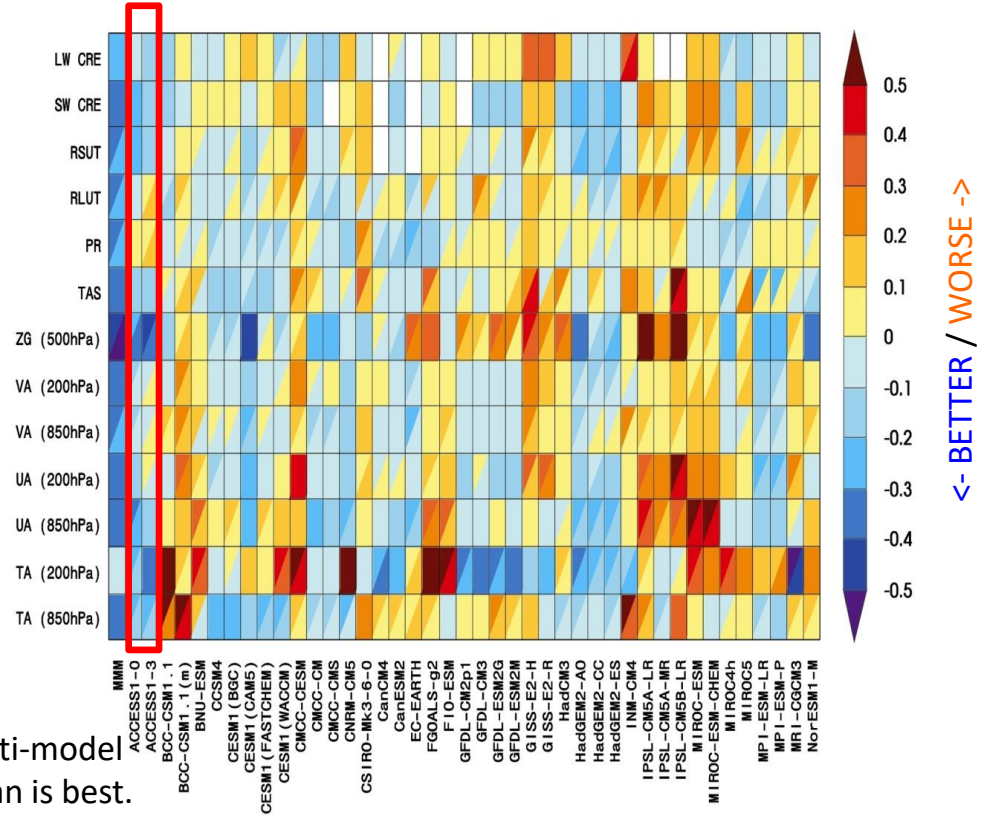
Figure: S. Lewis

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



Multi-model mean is best.

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

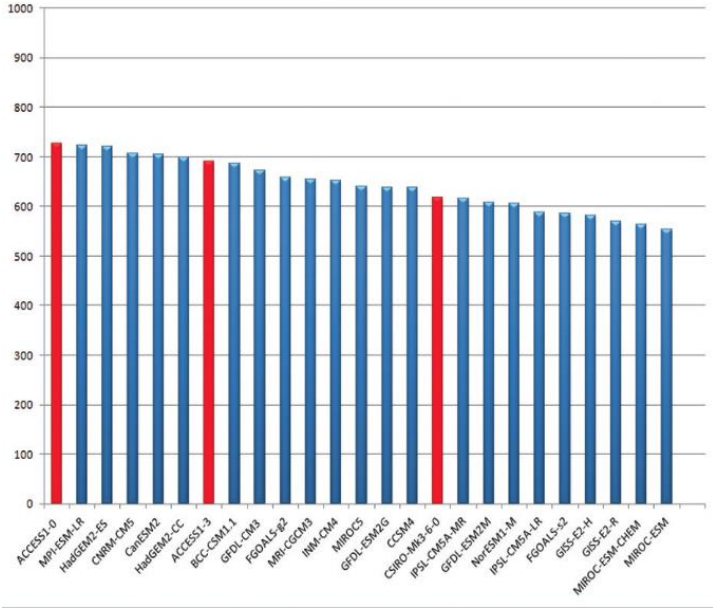
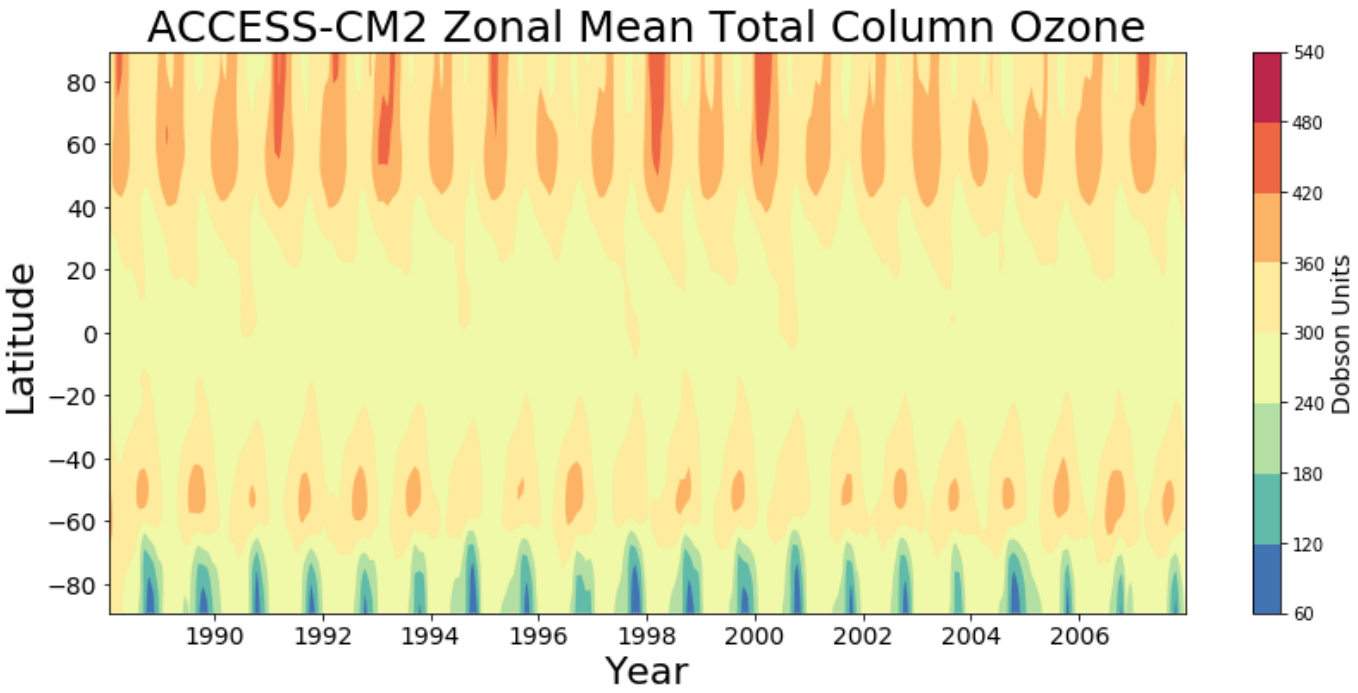


Fig 3b: Watterson et al., AMOJ, 2013

AMIP with chemistry



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

4. Climate projections

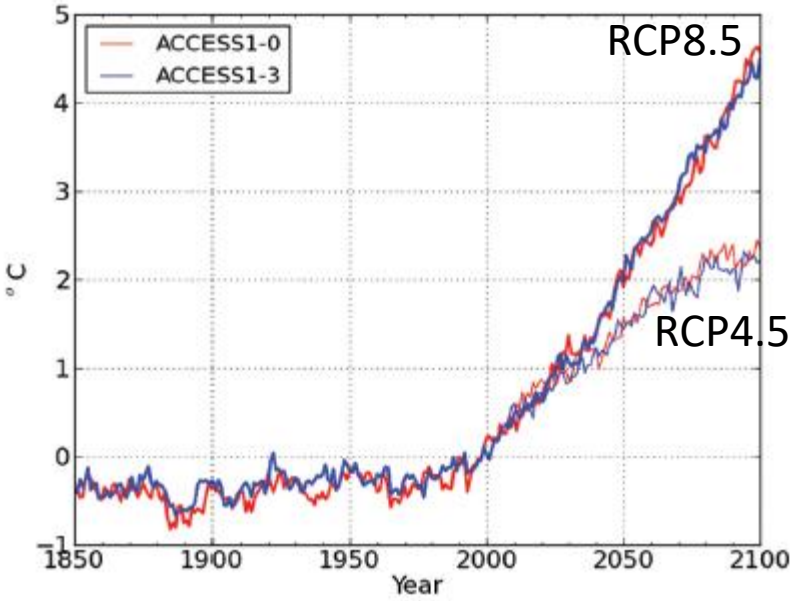
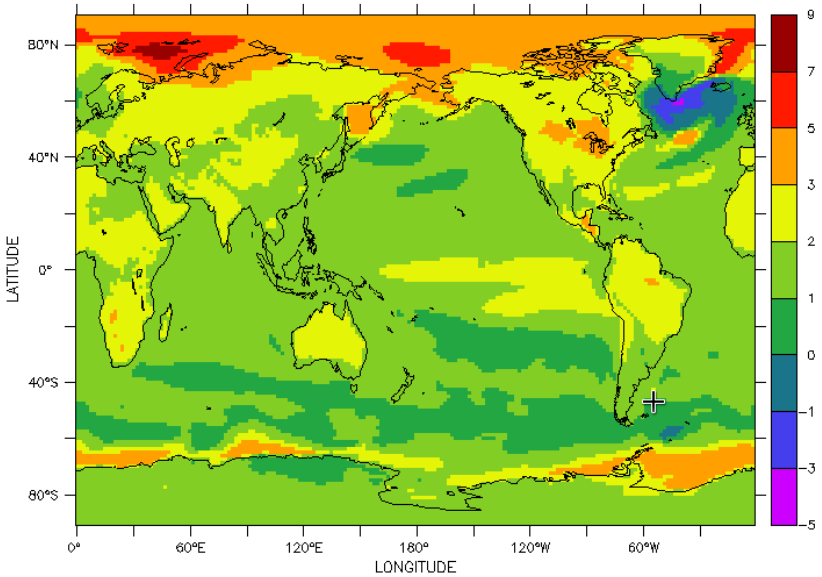


Fig 7: Dix et al, AMOJ, 2013

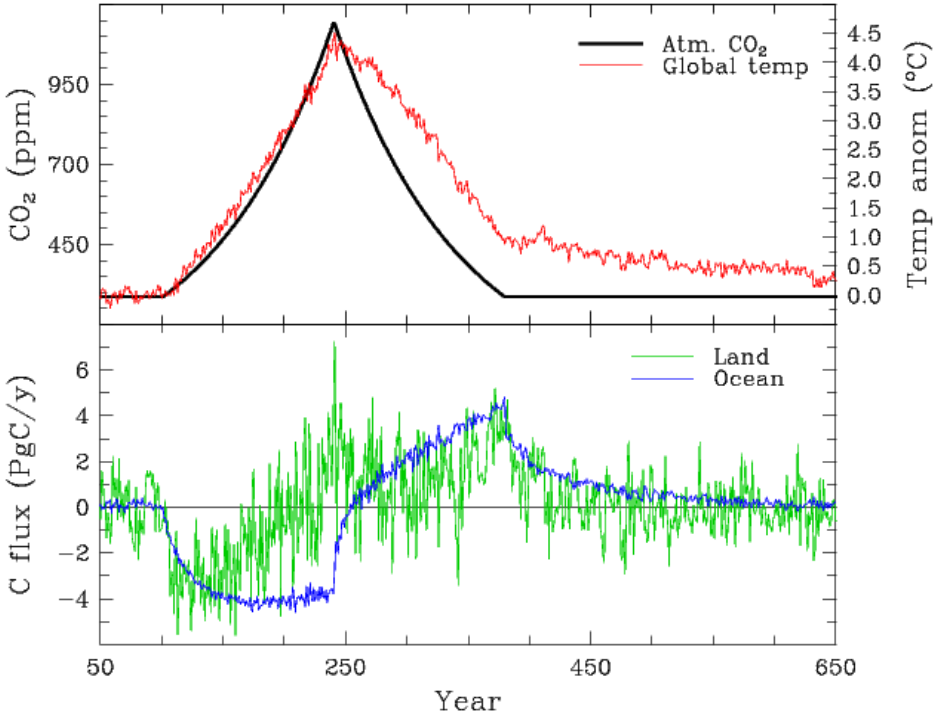


Surface air temperature in 2091-2100 relative to 1850-1859 under RCP2.6

5. ‘What if’ experiments

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

CO_2 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)

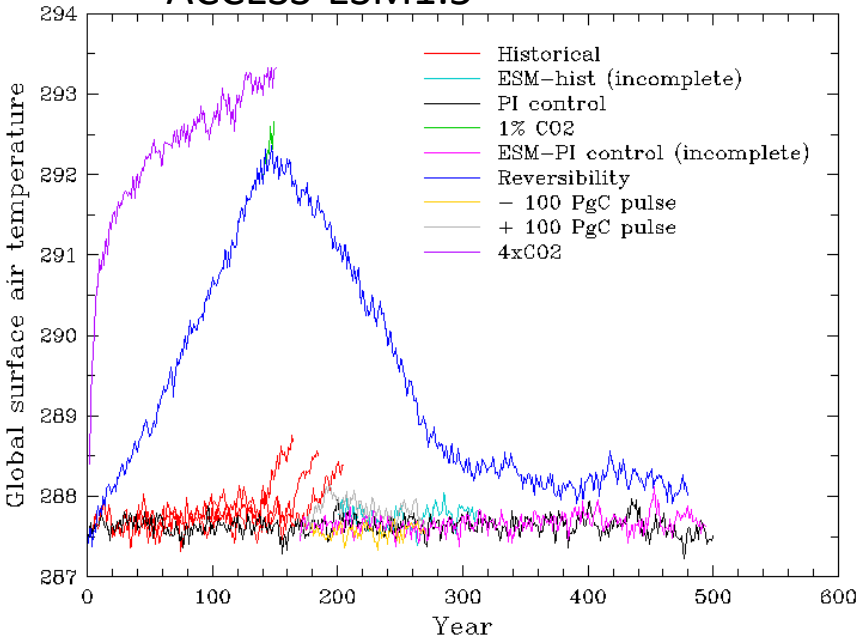
- Entry-level experiments (DECK, historical)
- ScenarioMIP
- Ocean, OMIP
- Flux-Anomaly-Forced ,FAFMIP
- Radiative-forcing, RFMIP

ACCESS-ESM1.5 (with carbon cycle)

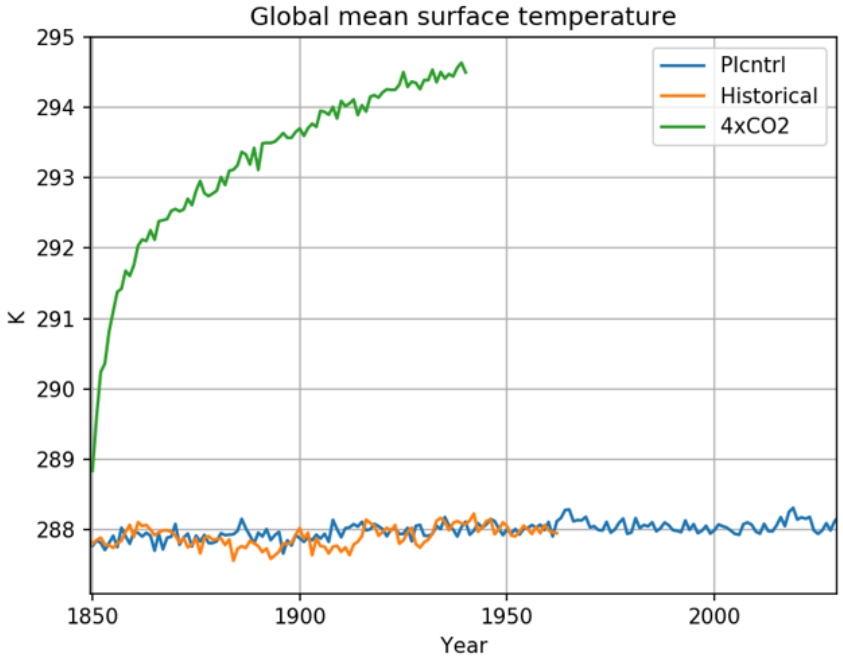
- DECK, historical
- ScenarioMIP
- Coupled climate-carbon cycle, C4MIP
- Carbon Dioxide Removal, CDRMIP
- Radiative forcing, RFMIP

Status of CMIP6 runs

ACCESS-ESM1.5

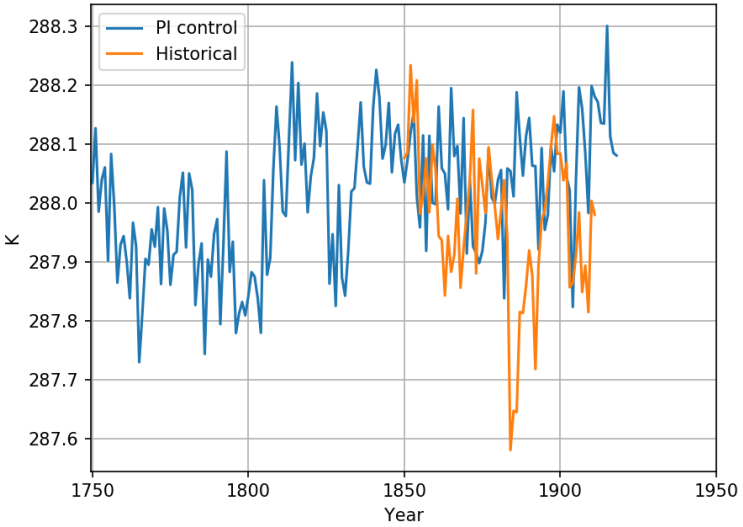


ACCESS-CM2

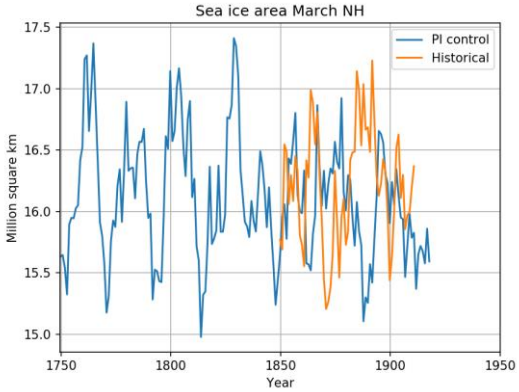


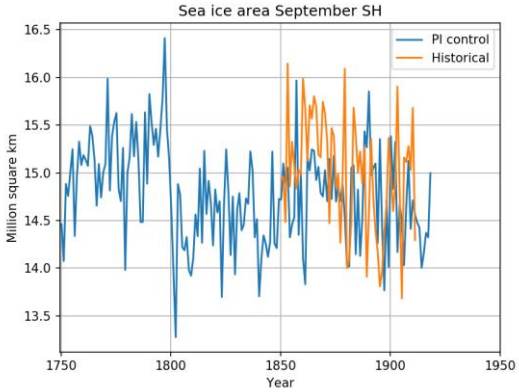
ACCESS-CM2 at 2019-06-24 23:06 UTC

Global mean surface temperature



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



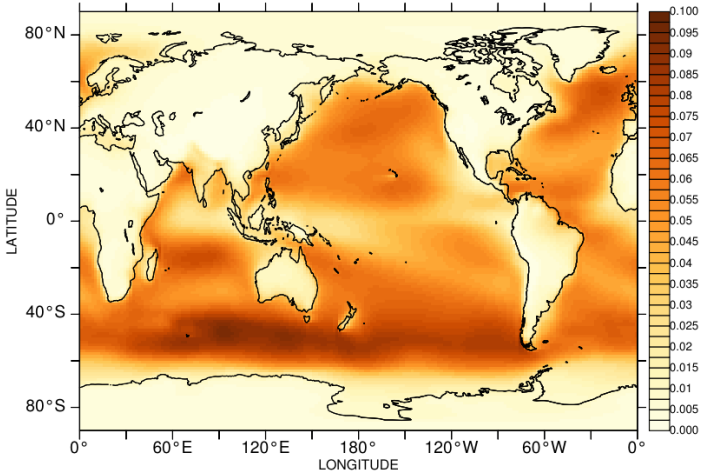


Blue: control, Orange: Historical

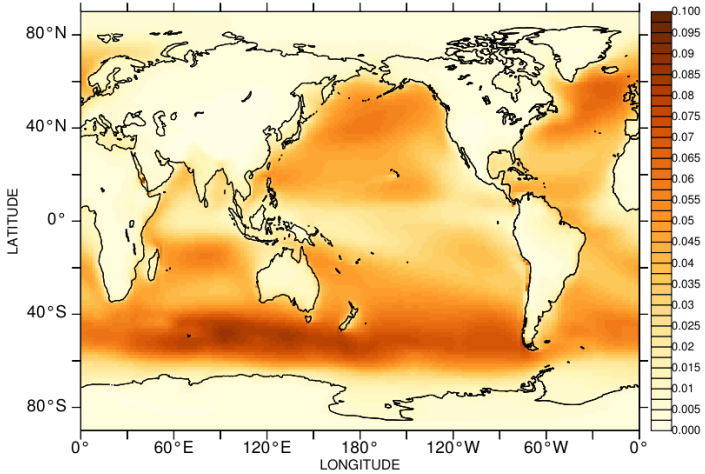
Finding bugs

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

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



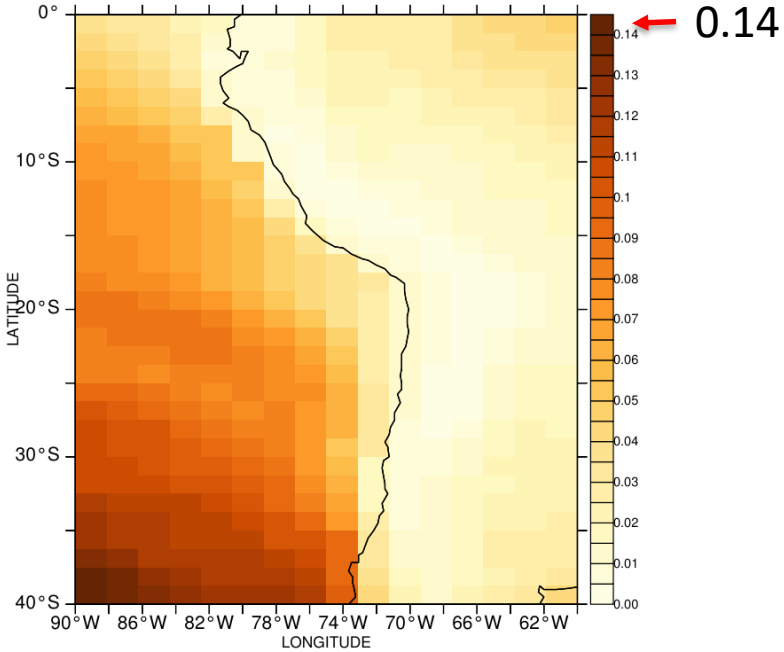
AMIP using UM/JULES



AMIP using UM/CABLE

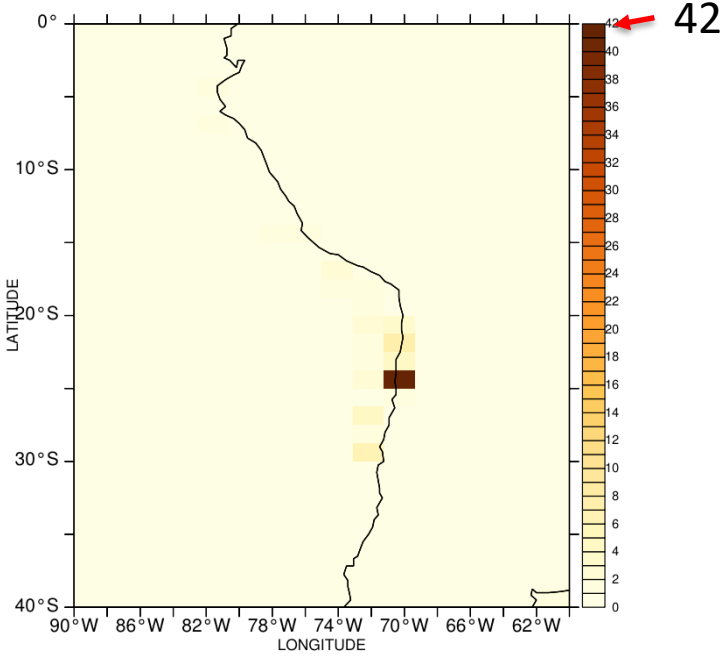
Soluble coarse mode AOD. Max monthly value

JULES AMIP (Max over 1951-2014)



0.14

CABLE AMIP (Max over 1930-2014)



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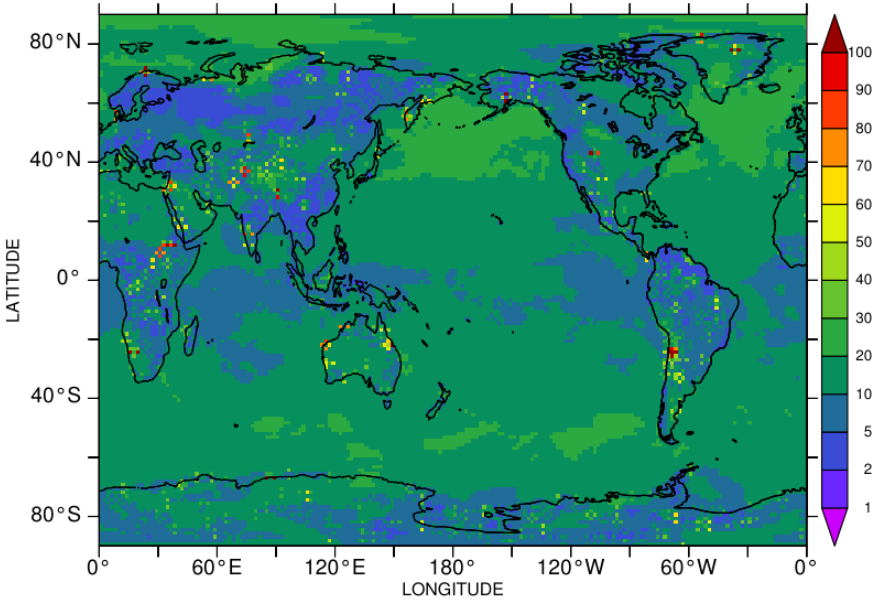
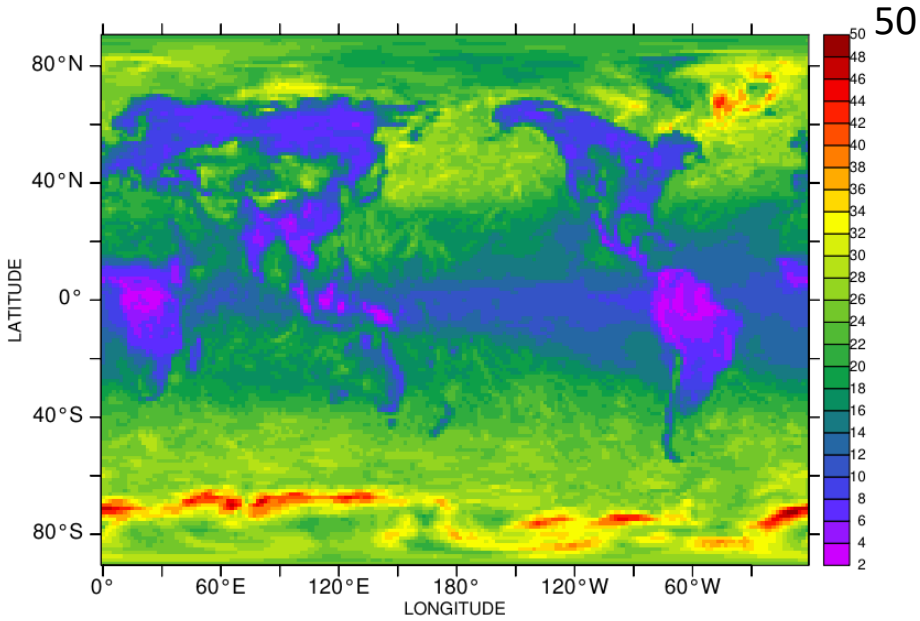
Sea salt depends on 10 m wind speed, U_{10}^3 or U_{10}^4 with no bound

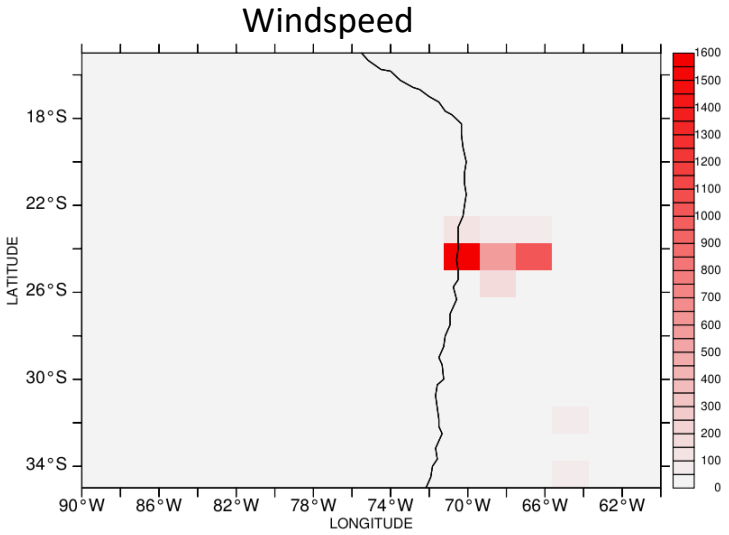
Timestep maximum 10 m wind speed

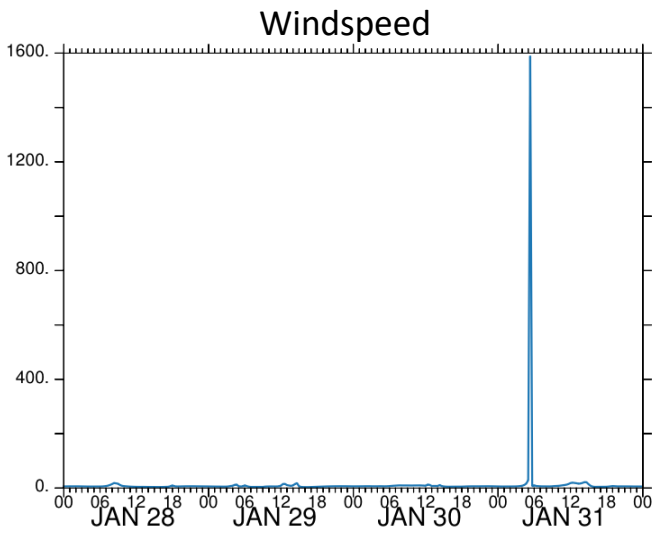


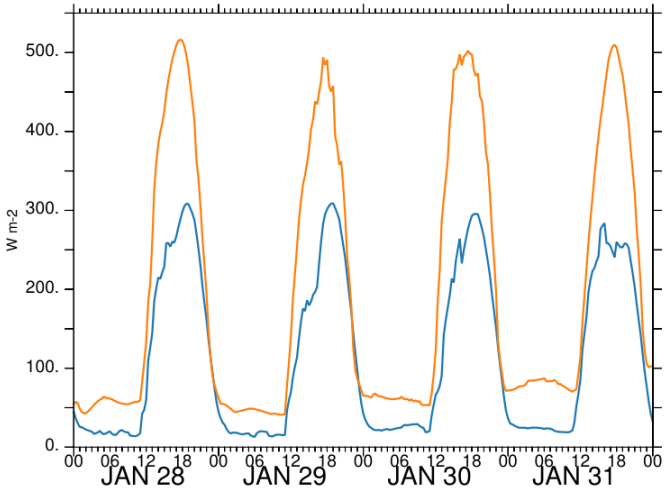
CM2 AMIP. Max over Jan 1961
Max of 1589 m/s over S America



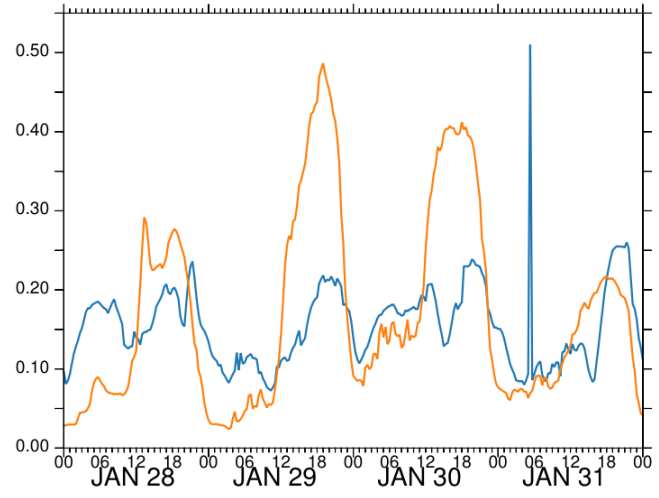
ESM1.5 Historical
Max over 1950-1959







Sensible
Latent



taux
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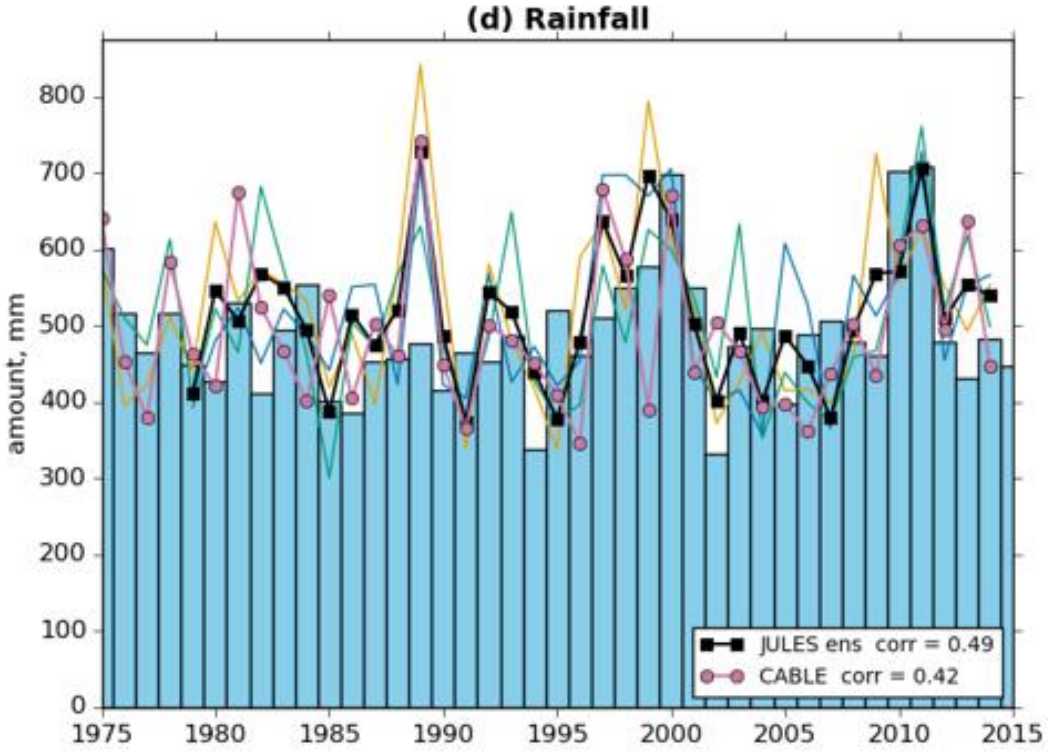
Re-start runs or not?

- 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)

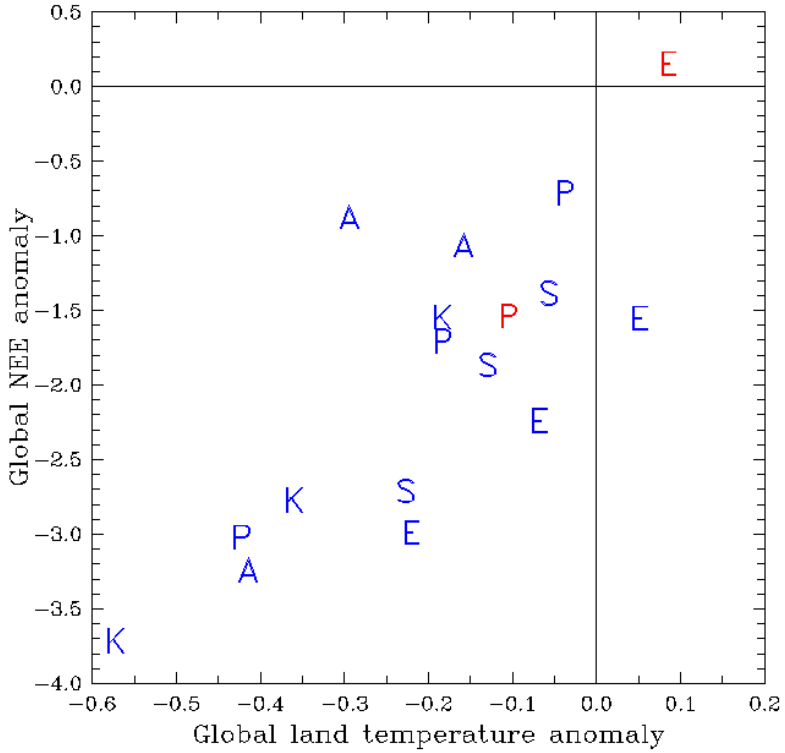
Ensembles

- 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

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?