ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

MONASH University

# The ARCCSS: Overview and modelling activities

Duncan Ackerley

https://www.climatescience.org.au/

# Outline

- What is the ARCCSS?
- What are the scientific activities within the centre?
- Specifically, what modelling activities are we undertaking?
- Summary.
- https://www.climatescience.org.au/

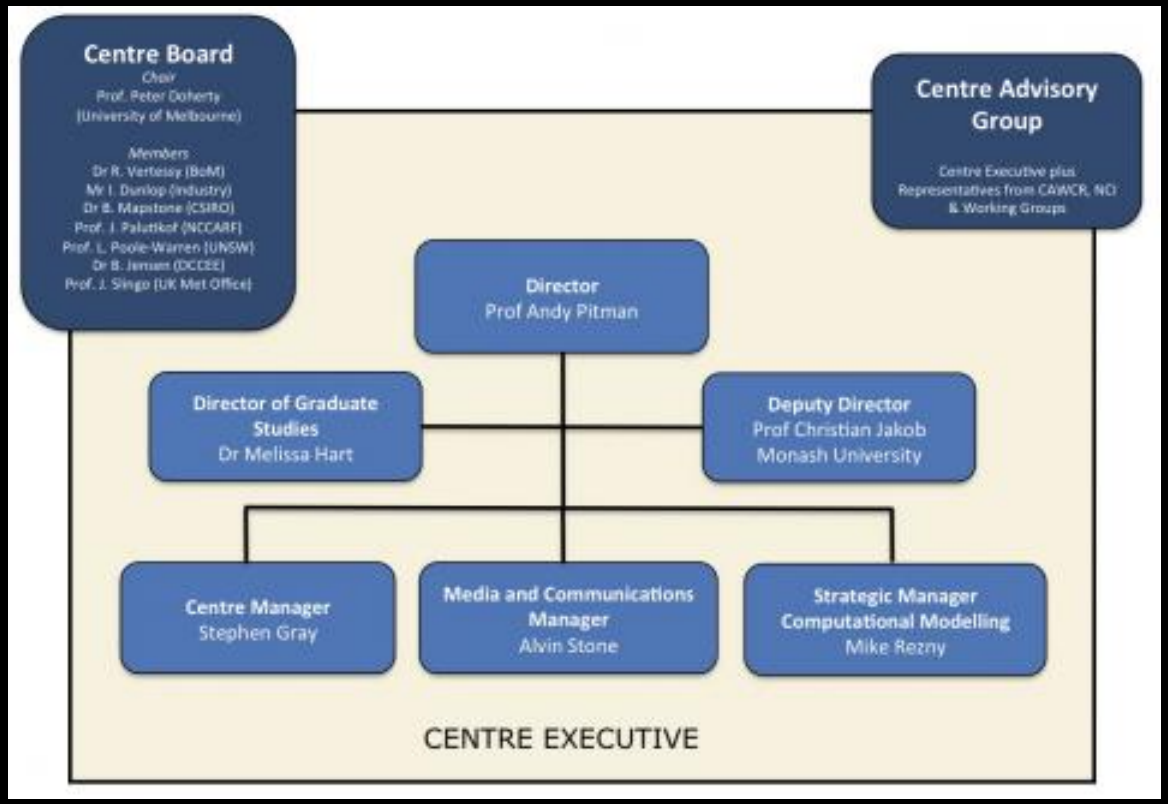
# What is the Australian Research Council's Centre of Excellence for Climate System Science (ARCCSS)?

- Major initiative established in 2011 with investment from:
  - Australian Research Council (ARC).
  - The universities: UNSW, Monash University, the Australian National University, the University of Melbourne and the University of Tasmania.
  - Non-university: Department of Climate Change and Energy Efficiency.

- Partner organisations:
  - Australian: BoM, CSIRO, NCI, NSW Office of Environment and Heritage.
  - International: GFDL, UKMO Hadley Centre, LMD, NASA GSFC, NCAR, University of Arizona, IGBP, WCRP.

- Focus: "*…the quantitative study of the climate system designed to enable modelling of the future of the climate system… built on a core of the sciences of the atmosphere, ocean, cryosphere and land surface.*

- Very successful: > 400 publications (>40 Nature and Science), Second most collaborative Centre in Australia, Impact in ACCESS model.




## Organisational structure

- Employs numerous research staff and students at each institute.
- Contains a wide variety of graduate opportunities (see Graduate program).
- Has a strong and developing early career researcher support program.
- Also has excellent communication and computational support teams to support the research program.

# The 5 main ARCCSS research areas

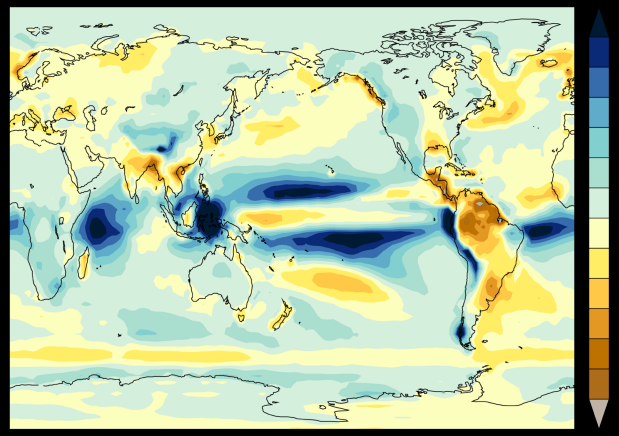
| | |
|---|---|
| The effects of tropical convection on Australia's climate. | •Tropical convection is a driver of the global circulation and hugely important.<br>•Imperative to model correctly; however, this is currently a weak point and needs to be developed. |
| Risks, mechanisms, and attribution of changes in Australian climate extremes. | •Extreme events pose a significant risk to Australian biogeophysical systems.<br>•Understanding their driving mechanisms and subsequently improving forecasting of such events is therefore important. |
| The role of land surface forcing and feedbacks for regional climate. | •Atmospheric dynamical processes operate similarly; however, the local response may be dependent on the land surface characteristics.<br>•Understanding how local feedbacks develop in response to dynamical forcing is important for regional climate projections. |
| Drivers of spatial and temporal climate variability in extratropical Australia. | •Long-term Australian climate variability (years, decades, beyond).<br>•El Nino Southern Oscillation, Indian Ocean Dipole, Southern Annular Mode, etc.<br>•Ocean-atmosphere interactions and modes of variability.<br>•Understand how such variability will change as the climate changes. |
| Mechanisms and attribution of past and future ocean circulation change | •Ocean is the main store of energy within the climate system (>80%) and the re-distribution of this energy is essential for driving the global circulation.<br>•Projections of ocean heat content, sea level rise and carbon storage are very different and need to be improved. |

N.B. Not named all researchers in the following slides, just those who contributed. There are LOADS of people working on these areas within the ARCCSS.

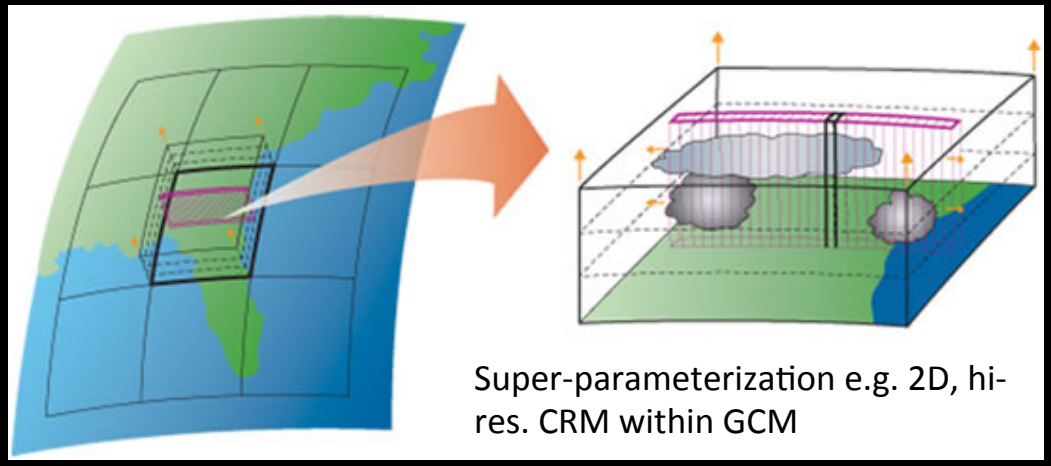
# Tropical Convection: Christian Jakob

- Numerous problems representing tropical climate.
- Strongly associated with the representation of tropical convection.
- Lots of known shortcomings of convection modelling:
  - No co-existence of different types of convection.
  - No organisation.
  - No memory, no propagation.
  - Poor microphysics.
  - Low resolution of host model vs. convective scale.
- Attempting to design a modelling framework that addresses all of the issues above (and more).
- Use stochastic cloud models that can calculate convective area fraction.

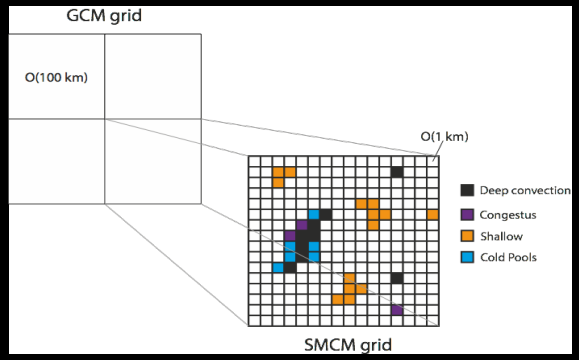
CMIP5 precipitation errors



Grid-box vs. convection scale



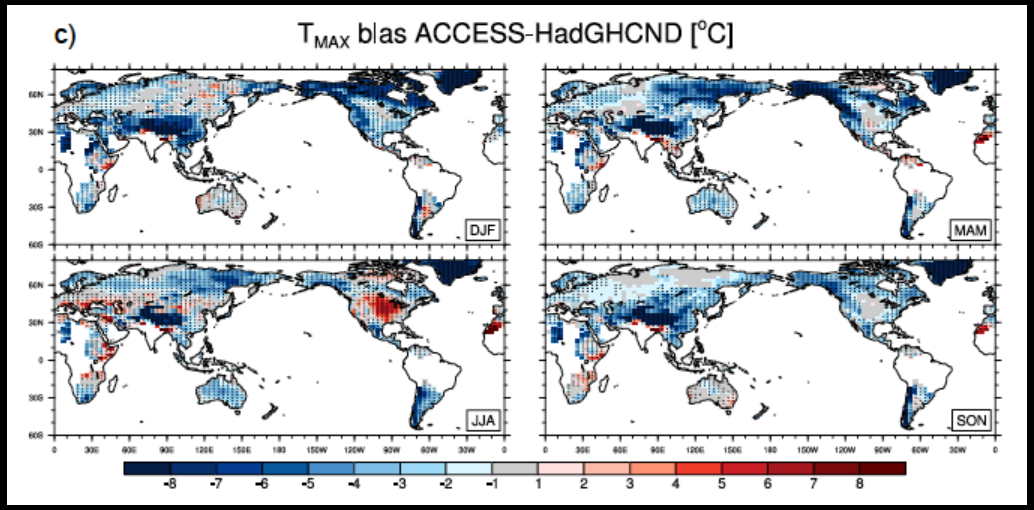
Super-parameterization e.g. 2D, hi-res. CRM within GCM

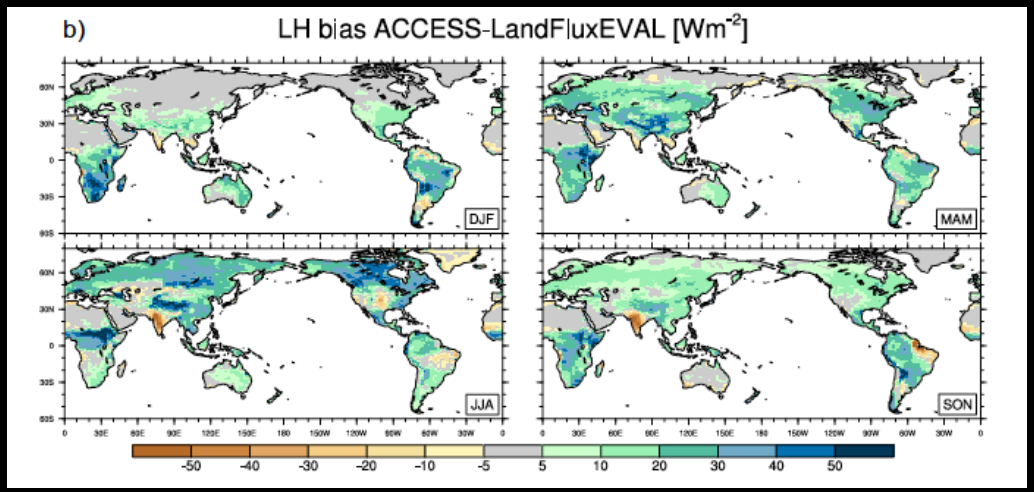



Stochastic sub-grid scale modelling of convection: propagates, organises, etc.

**Land surface:**
**Ruth Lorenz and Andy Pitman**

- ACCESS1.3 poor at representing extreme indices such as Tmax and Tmin.
- E.g. Tmax – generally negative biases in each season, apart from North America and SE Europe in JJA.
- Biases appear to be associated with latent heat flux biases (particularly evapotranspiration).
- Common in other models and not just the CABLE land surface scheme.
- More details can be found in Lorenz et al. (2014).




Lorenz, R., Pitman, A. J., Donat, M. G., Hirsch, A. L., Kala, J., Kowalczyk, E. A., Law, R. M., and Srbinovsky, J.: Representation of climate extreme indices in the ACCESS1.3b coupled atmosphere–land surface model, Geosci. Model Dev., 7, 545-567, doi:10.5194/gmd-7-545-2014, 2014.

**Extremes (drought):**
**Anna Ukkola and Andy Pitman**

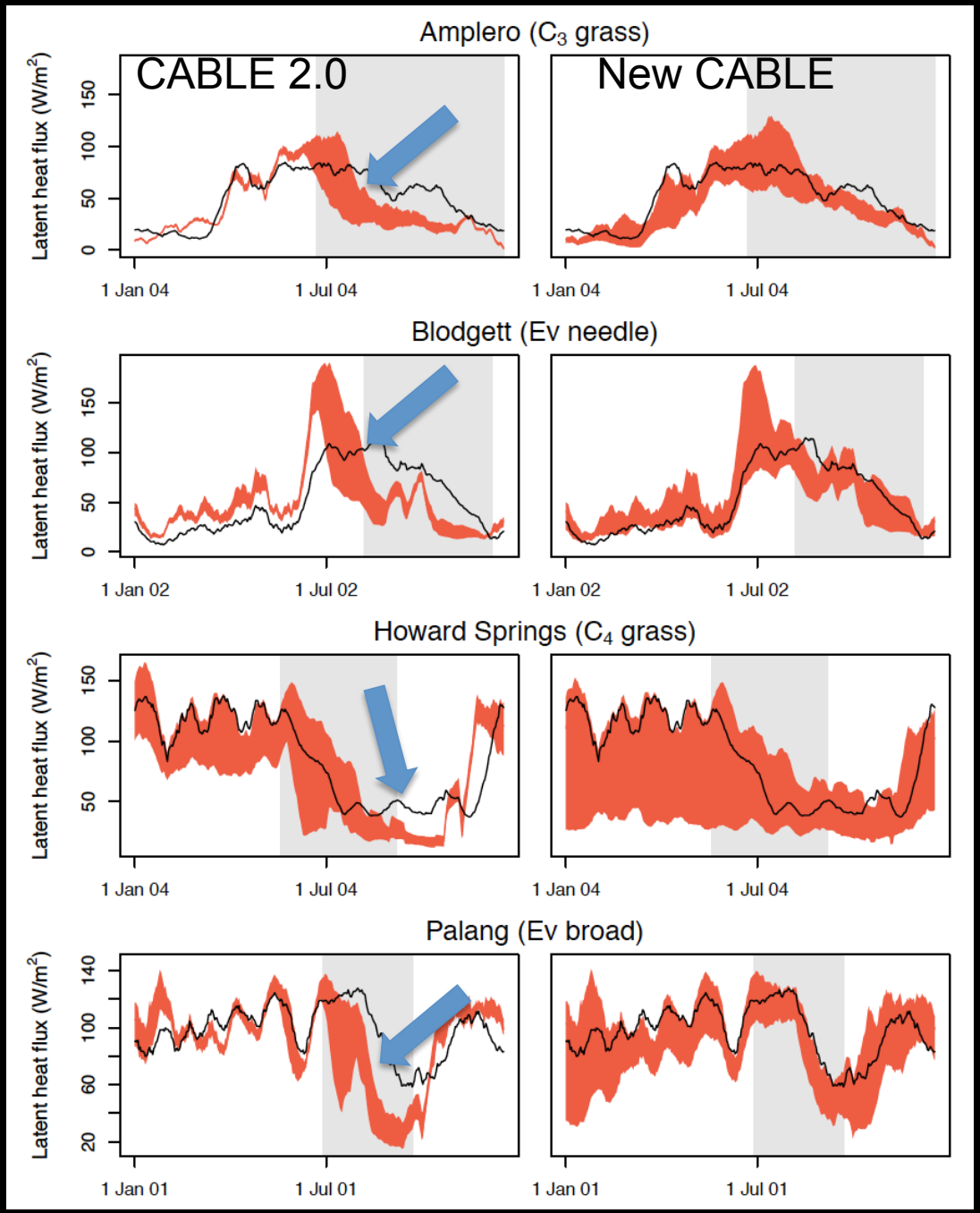
CABLE2.0:

- transitions into “drought” too fast.
- generates too intense a drought.

- Furthermore – almost all land models do a bad job of representing the transition into drought (not shown here), not just CABLE.

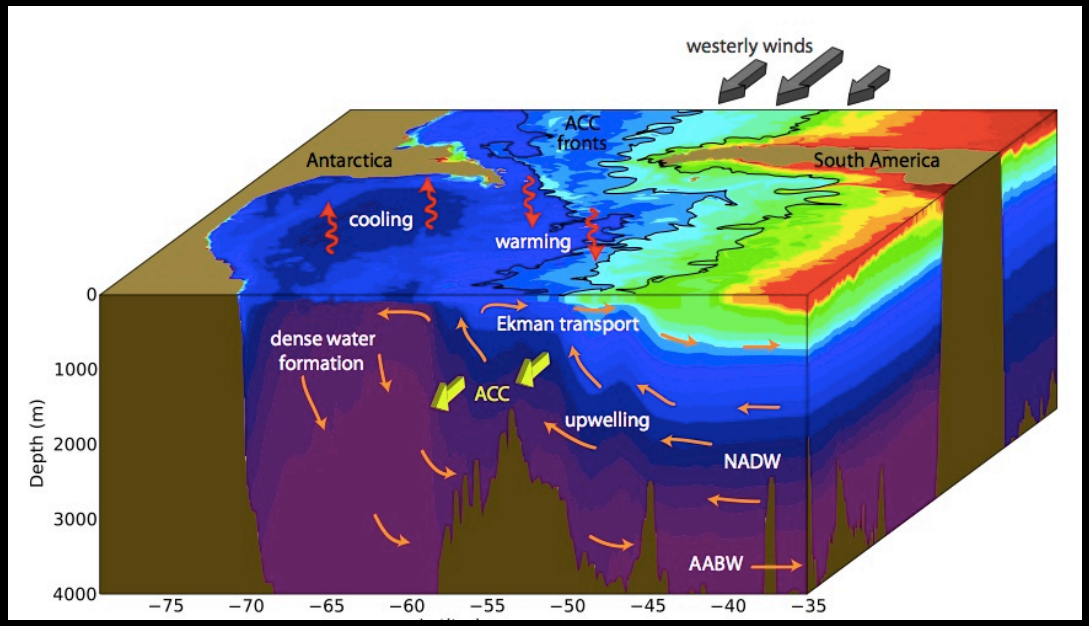
- Nevertheless, new representations of hydrology appear to significantly fix this.

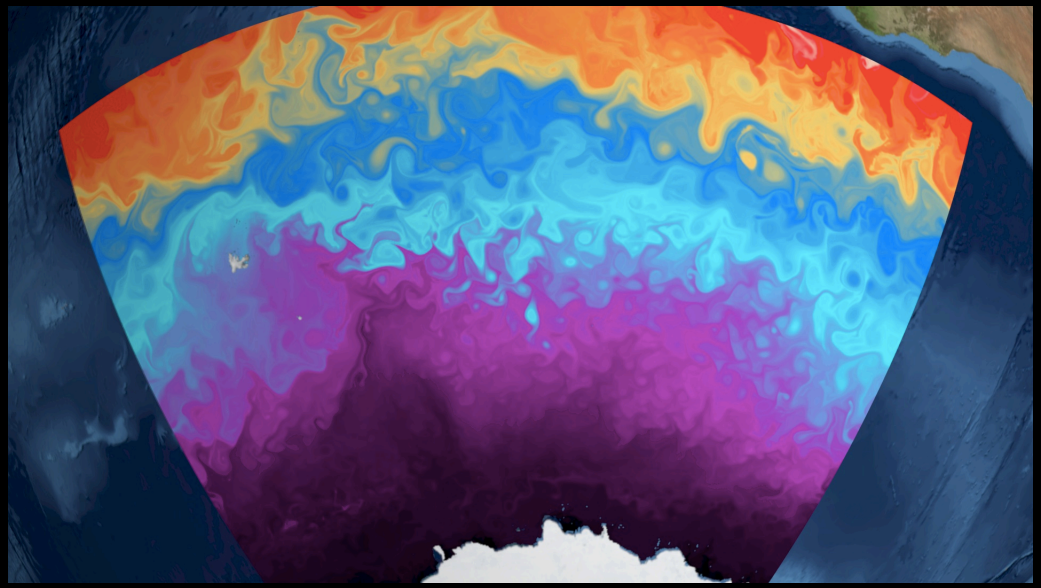
- New CABLE does not have these biases as it has a new representation of hydrology.



# Oceans
# Andy Hogg

- The Antarctic Circumpolar Current is the strongest ocean current in the world.
- Location where ancient, deep-ocean water upwells.
- Region is also important for modulating atmospheric $CO_2$ concentration.
  - Absorption.
  - Emission.
- Huge global significance to modelling the ocean processes there.
- High-resolution modelling required to represent the features in these figures.
- High-resolution model development contributing to the next generation of Australian climate models (CMIP6).
- Developed ocean scales very well (i.e. doesn't increase processing time much) with 1/4° grid spacing.
- Newest development with 0.1° grid spacing at: https://www.youtube.com/watch?v=8VMSF28J9H4&feature=youtu.be

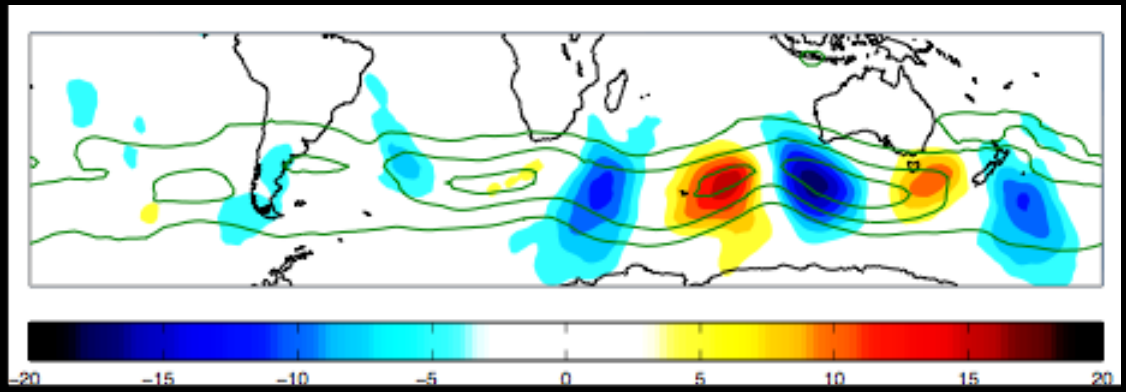


Adapted from: http://rses.anu.edu.au/research/projects/southern-ocean-circulation

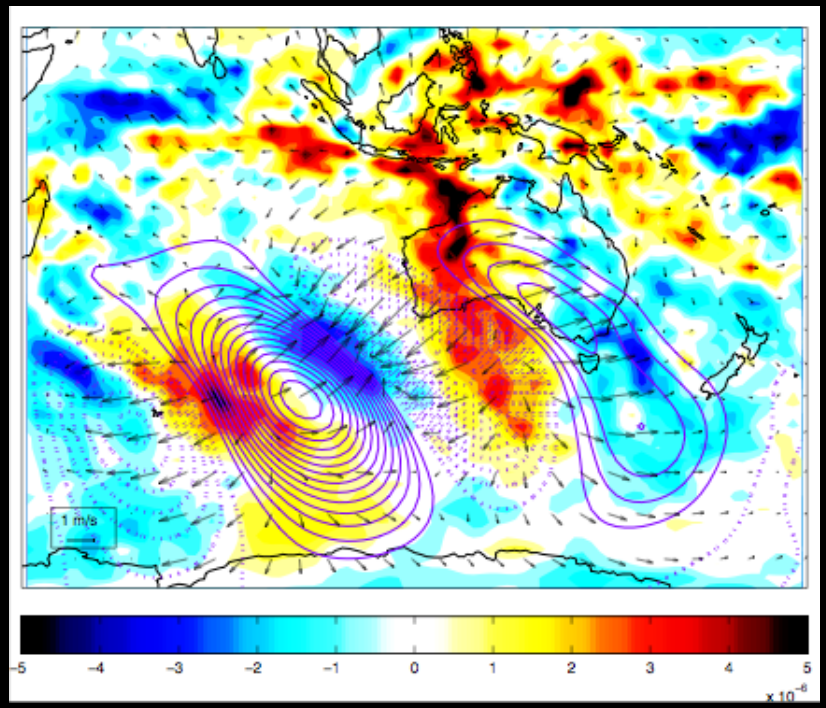
# Variability: Southern Hemisphere jet and Rossby waves:
# Laura O'Brien

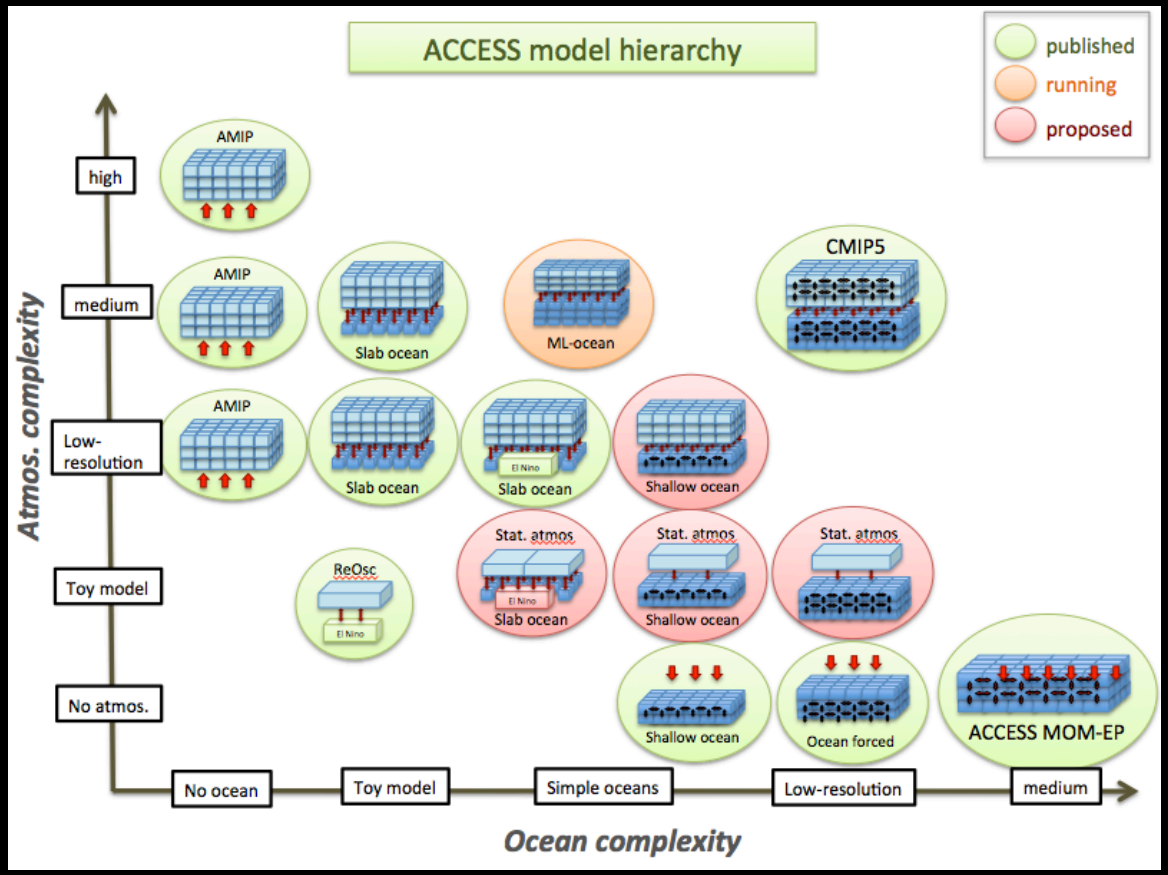
- Variability in the SH jet important as it can influence many things.
- Long-term variability e.g. Southern Annular Mode (SAM).
- Victorian heat waves: Rossby wave packet propagation.
- May be generated through anomalous tropical convection perturbing the jet.
- Tropical convection over northern Australia may also be organised my mid-lat. Rossby waves.
- Cyclic story? Tropical convection -> Rossby waves -> tropical convection.
- Important that such processes (jet, Rossby waves) are represented well in ACCESS.




**Above: Composite Rossby wave packet preceding VIC heat wave.** Meridional wind anomalies (m/s) on the tropopause (shaded), jet (contoured).

BELOW: Depth averaged diabatic heating anomalies (shaded), 200mb geopotential anomalies (contoured), divergent wind anomalies (vectors).



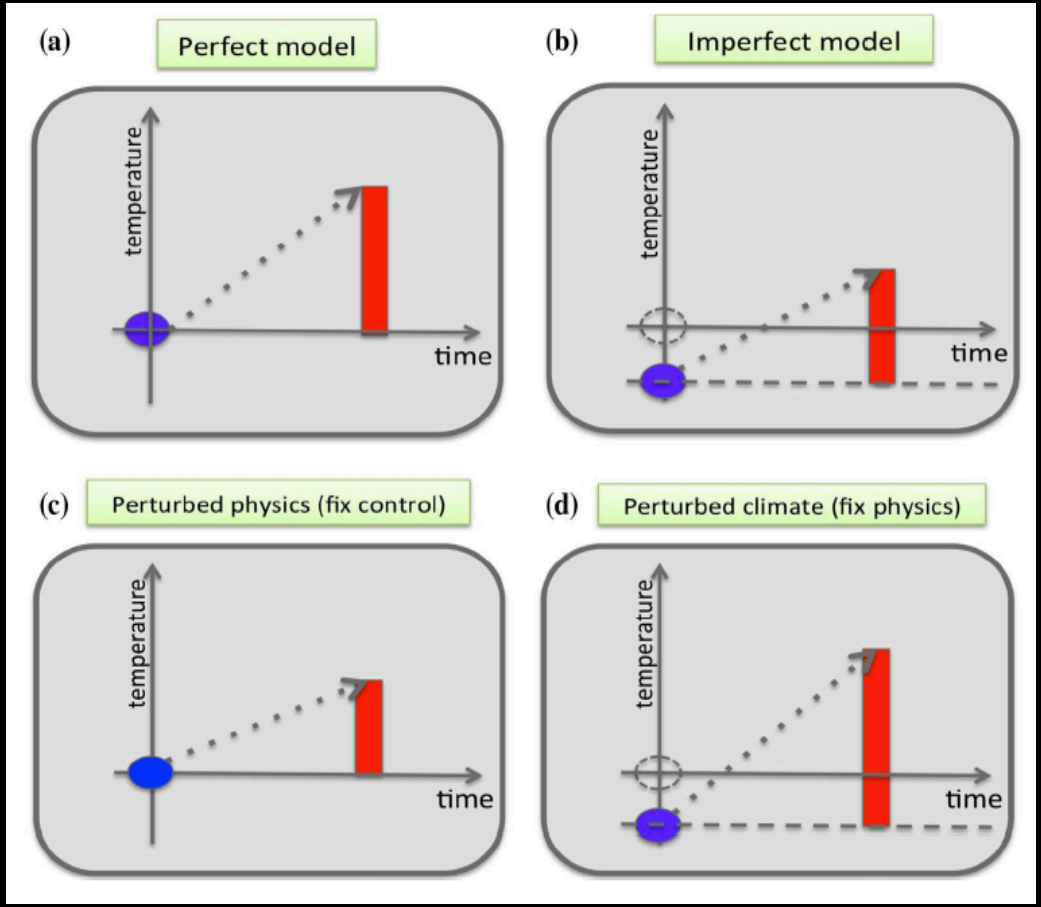



# ACCESS model hierarchy: Dietmar Dommenget

- Complexity vs. computational time: More complexity increases processing time.
- Model hierarchy developed to bridge the gap between high-resolution ocean and atmosphere models.
- Allows us to run long (multi-centennial / multi-millennial) simulations to evaluate climate variability.
- N48 atmosphere-only and atmosphere-slab ocean models available (3.75x2.5 lonxlat).
- N48 atmosphere-KPP ocean model currently being developed (running and stable, likely available soon).

# Flux correction and parameter perturbation.

- Developed a version of ACCESS with prescribed land temperatures[1].
- Provides opportunity to flux correct global surface.
- Initial state vs. perturbed physics experiments.




Ackerley, D. and Dommenget, D.: Atmosphere-only GCM simulations with prescribed land surface temperatures, Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-6, in review, 2016: http://www.geosci-model-dev-discuss.net/gmd-2016-6/

# ACCESS-slab multi-centennial simulations: Developments

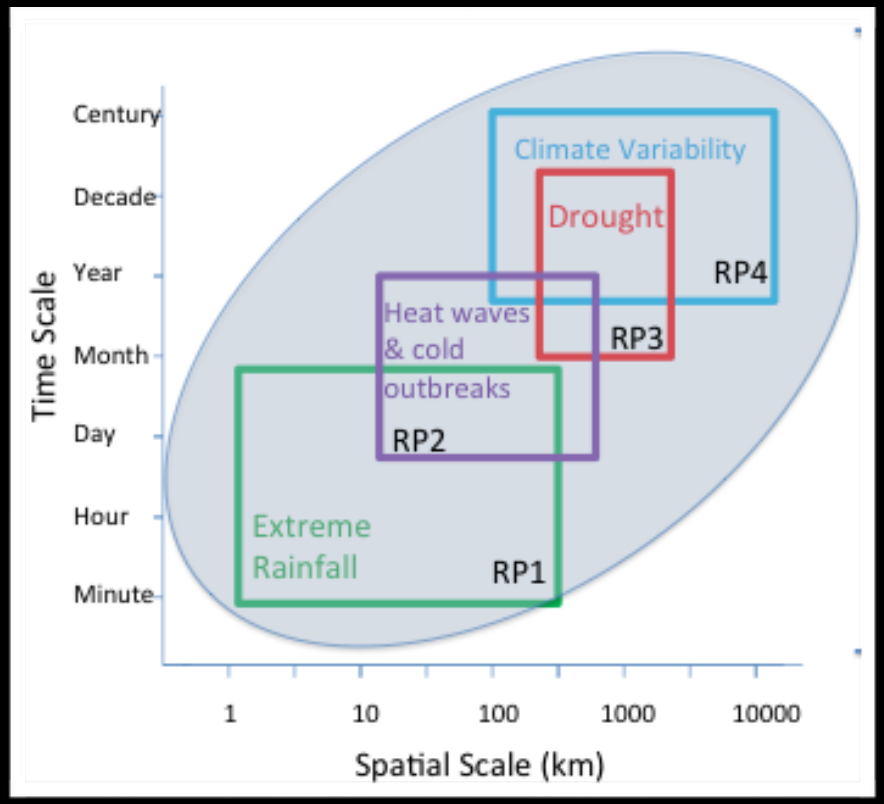
- Runs using combinations of different forcings from 1250 CE to 2005 CE.
- Developed ACCESS to use input fields for various boundary conditions over the last 750 years.
- Pick out effects of forcing vs. variability.
- Model runs include:
  - No forcing*.
  - Volcanic forcing only*.
  - Solar variability only*.
  - GHG forcing only.
  - Orbital forcing only*.
  - Aerosol forcing only*.
  - Stratospheric ozone forcing only.
  - All forcings combined.

* = currently running

# Summary

- Wide variety of scientific analyses within the centre.
- Various groups are deeply involved with model development.
- Aim to get those models available to the wider scientific community.

# The future of ARCCSS: re-bidding (slide from Christian Jakob)




- 2017-2023
- Focussed entirely on processes that help understand and predict extremes
- 4 Research Themes
- Knowledge Brokering team, likely located at Monash
- ***Large focus on ACCESS improvement, including Computational Science Support Team***