

Progress, potential and challenges for predicting future weather and climate extremes

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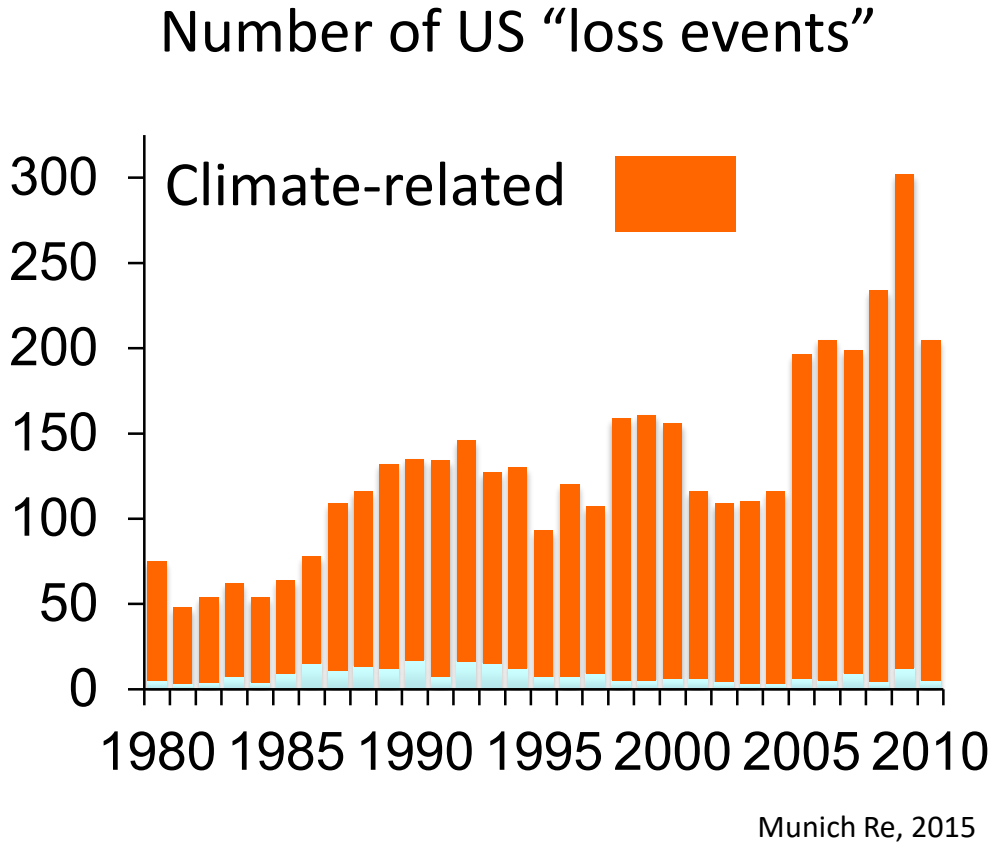
Outline

- Observed trends in extremes
- Modelling extremes in climate models
- What might be achieve within a decade?

Why Climate Extremes?

- Biggest global health threat of the 21st century [The Lancet Commission, 2015]
- Financial risk: Investors managing $24 trillion signed the 2014 Global Investor Statement on Climate Change



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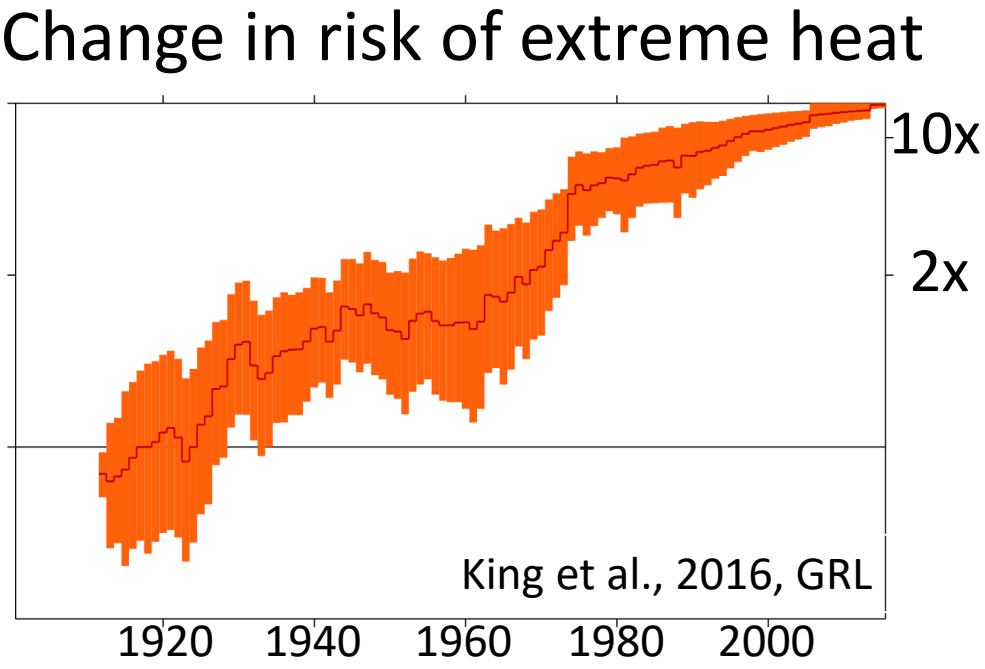
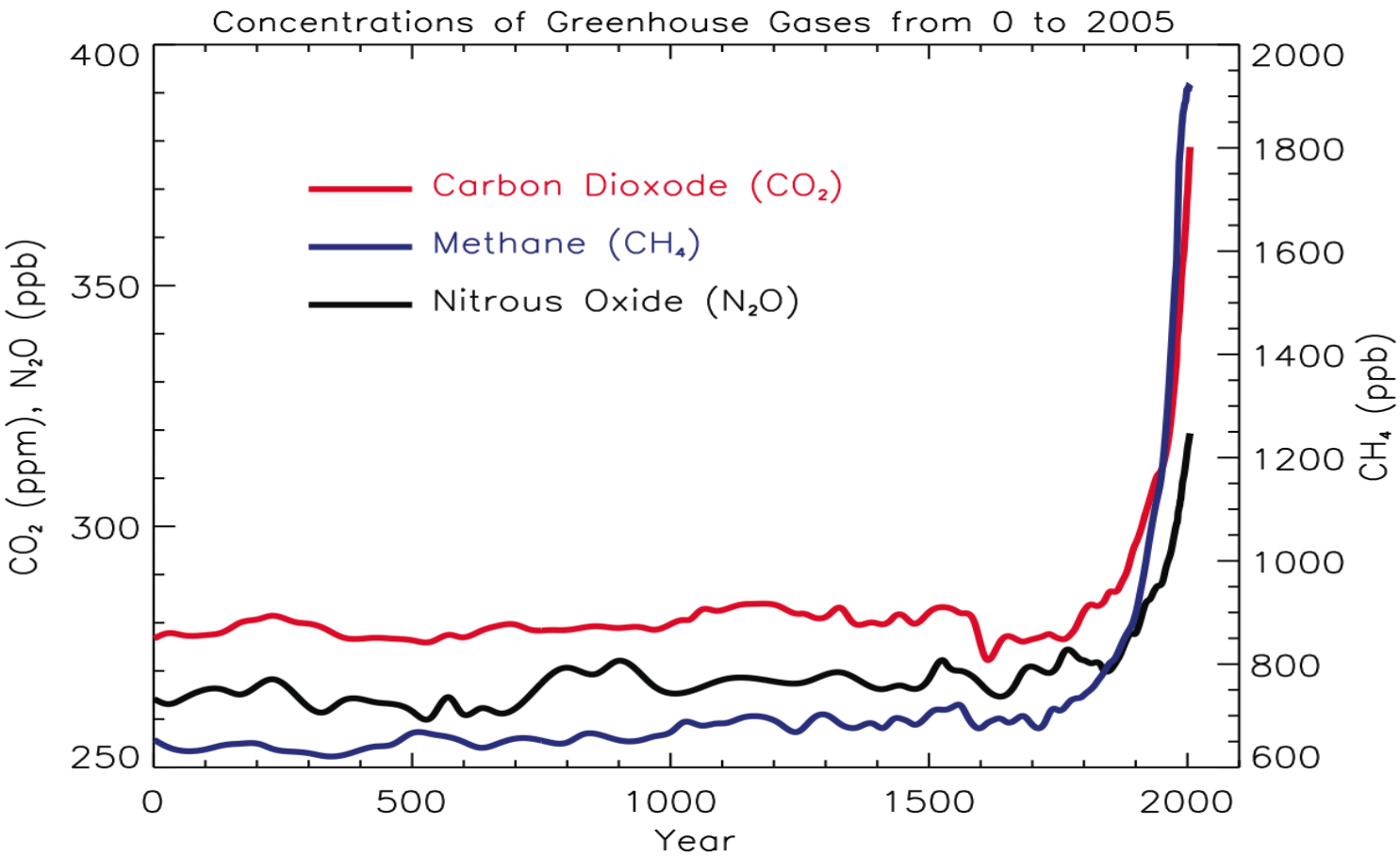
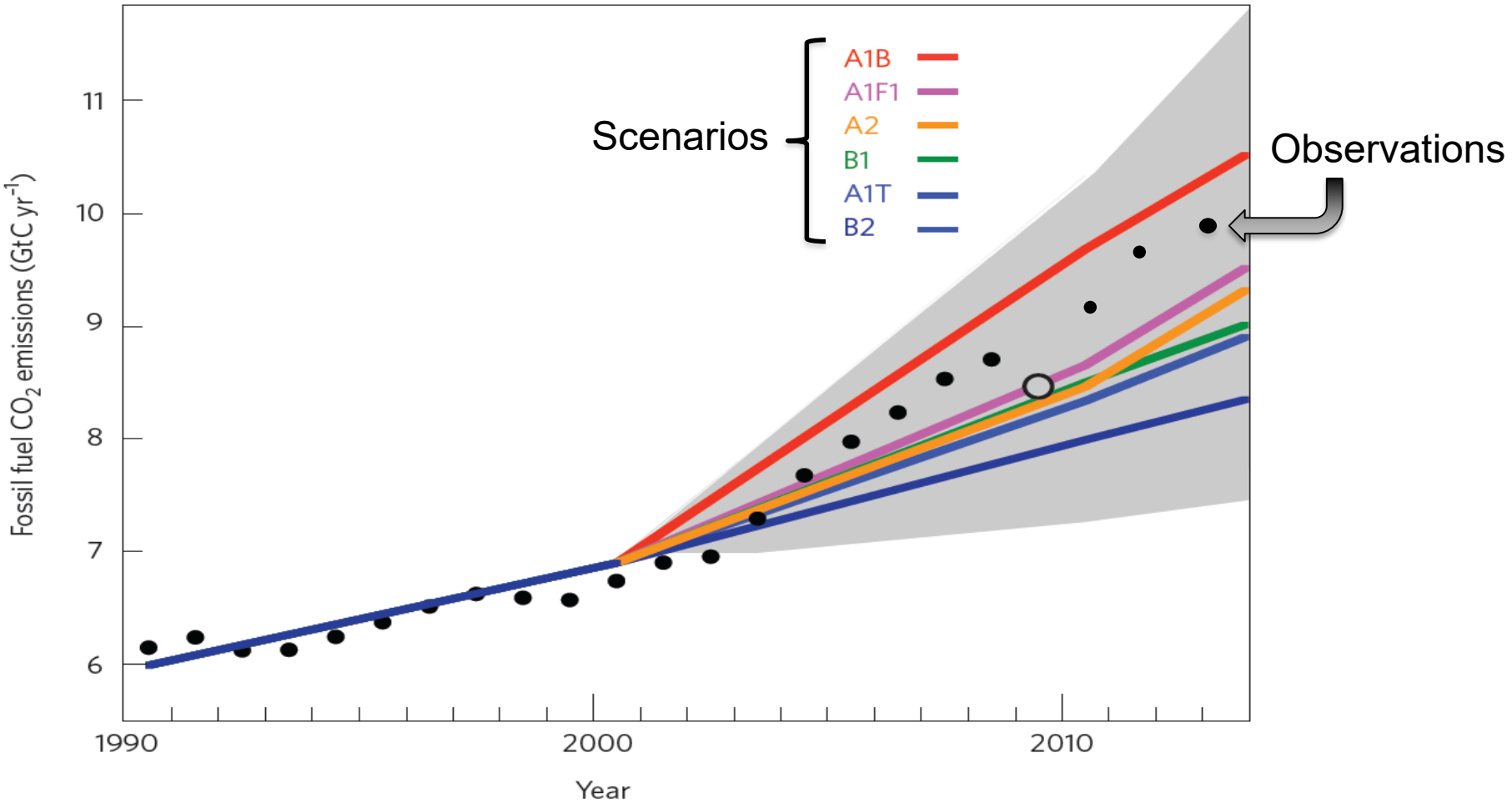


All greenhouse gases are increasing



Increasing due to human emissions



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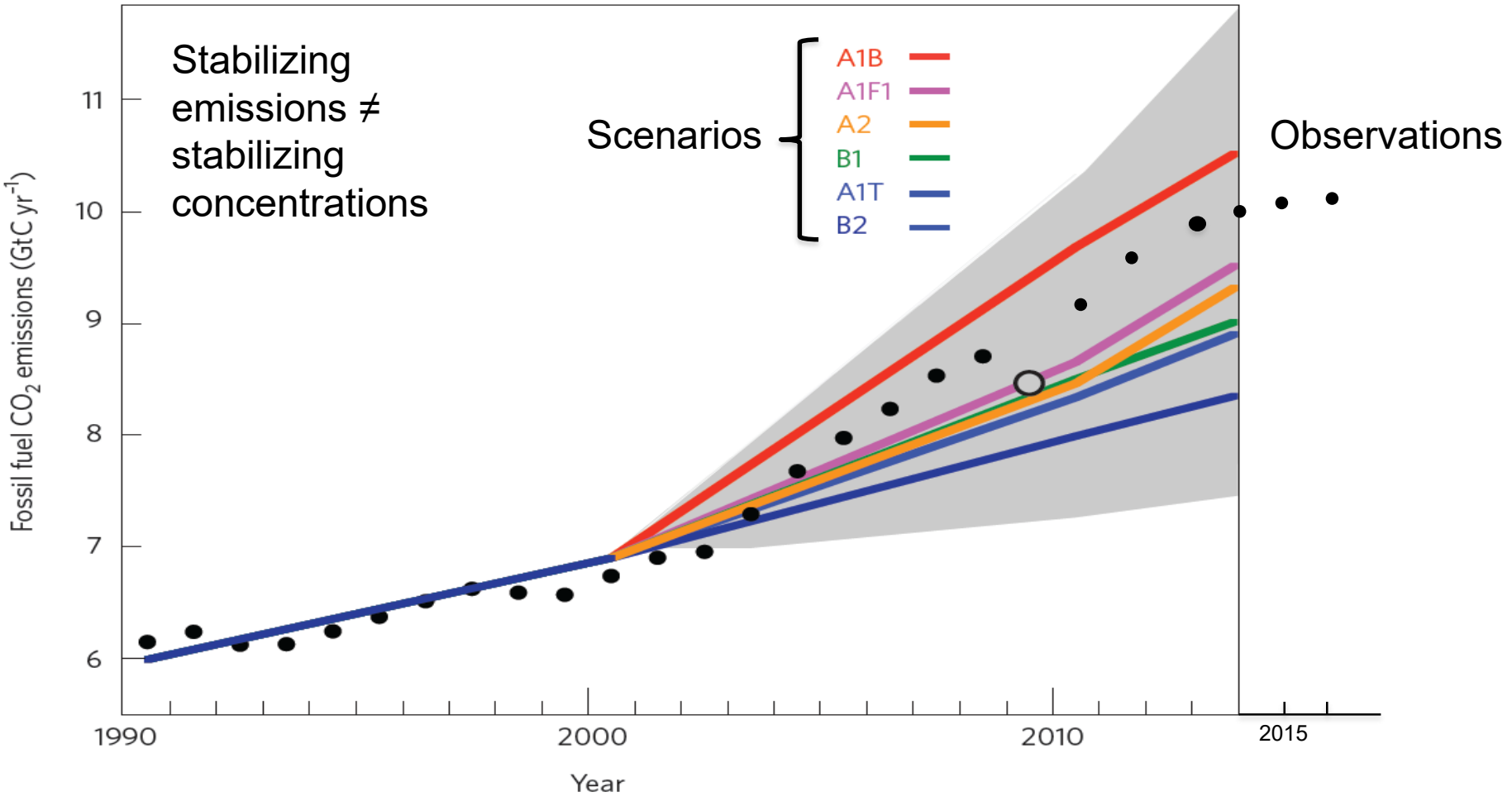

1.5^{o} IPCC report

- http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf
- Warming will reach 1.5^{o}C between 2030 and 2050 if emissions continue at the current rate
- Virtually everything worse at 2^{o}C cf. 1.5^{o}C
  - Mean & extreme temperatures
  - Heavy rainfall
  - Sea level
  - Ecosystem health
  - Health impacts

Emissions to avoid warming

- To have any chance of avoiding warming > 1.5^{o}C
  - emissions decline by ~45% from 2010 by 2030
  - net zero around 2050
  - Removal of 100-1000 Gt CO_2 over 21st Century
  - "subject to multiple feasibility and sustainability constraints"

Emissions to avoid warming

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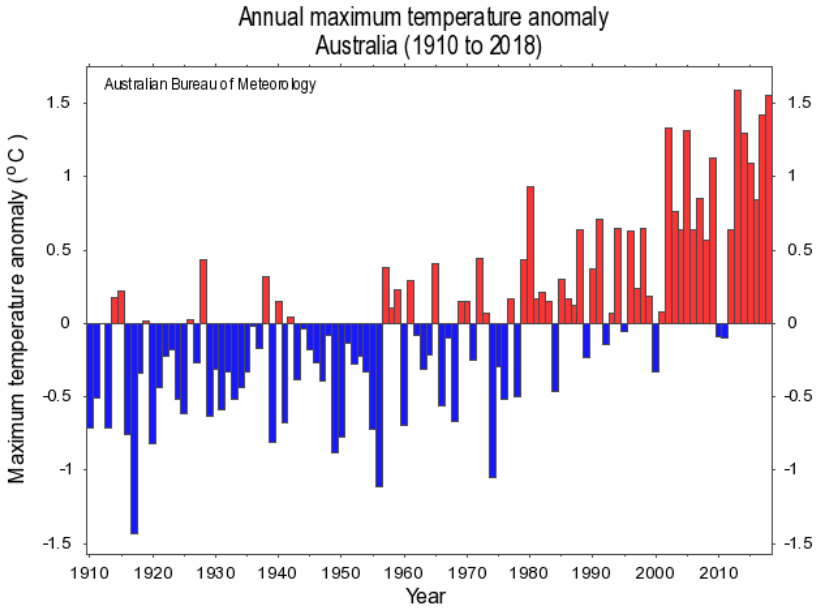
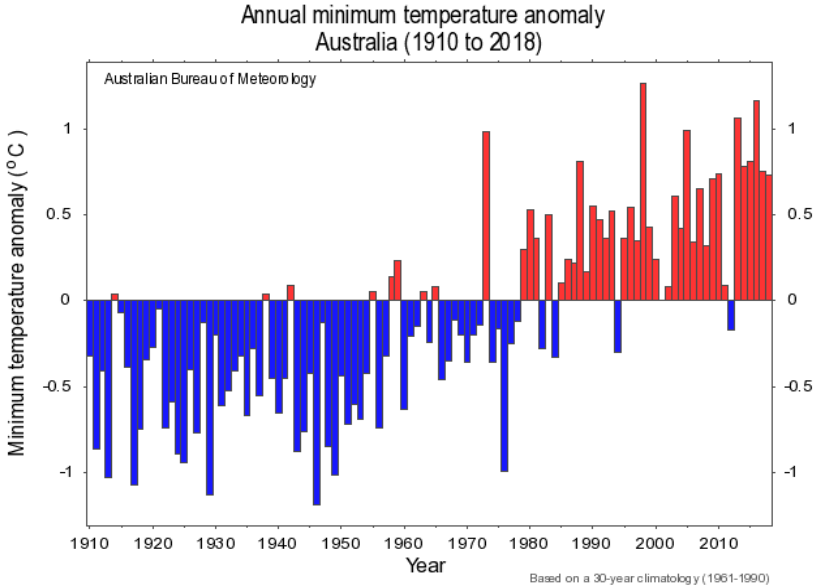
  - Removal of 100-1000 Gt CO_2 over 21st Century
  - "subject to multiple feasibility and sustainability constraints"
- To limit warming to 2°C
  - Emissions decline by ~20% by 2030
  - net zero around 2075
- Current Paris targets:
  - Currently targeting ~3°C – increase risk of tipping points

Extreme events will continue to increase in severity and frequency for many decades irrespective of policy responses

Over just Australia: temperature

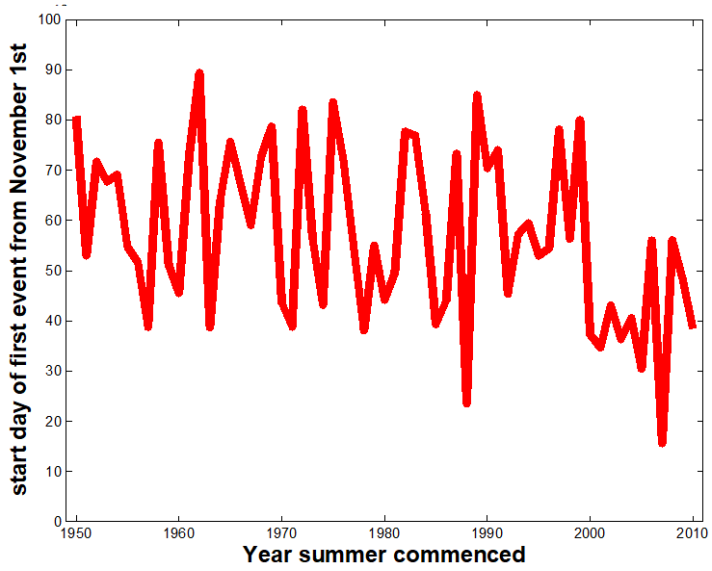




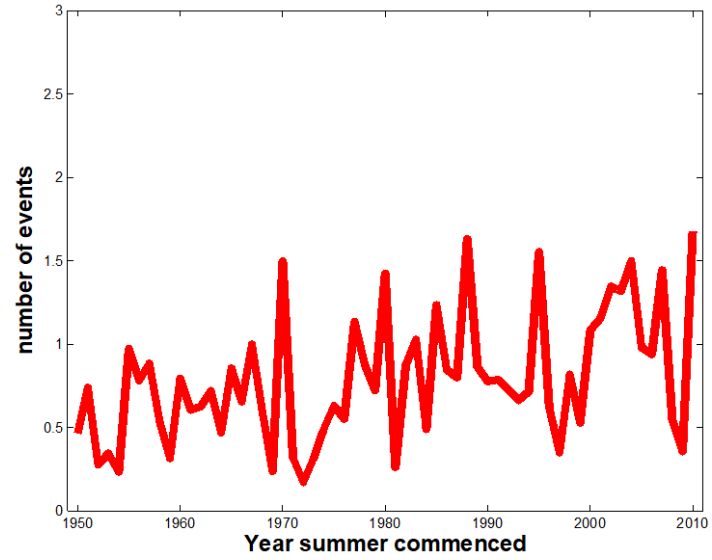
- Average temperature is rising
- Maximum temperature is rising
- Minimum temperature is rising
- Heatwaves are getting:
  - Hotter
  - Longer
  - More frequent
- Directly attributable to increasing CO_2

More? See Bureau web site or Perkins and Alexander, 2013. doi:10.1175/JCLI-D-12-00383.1.

Australian heatwaves



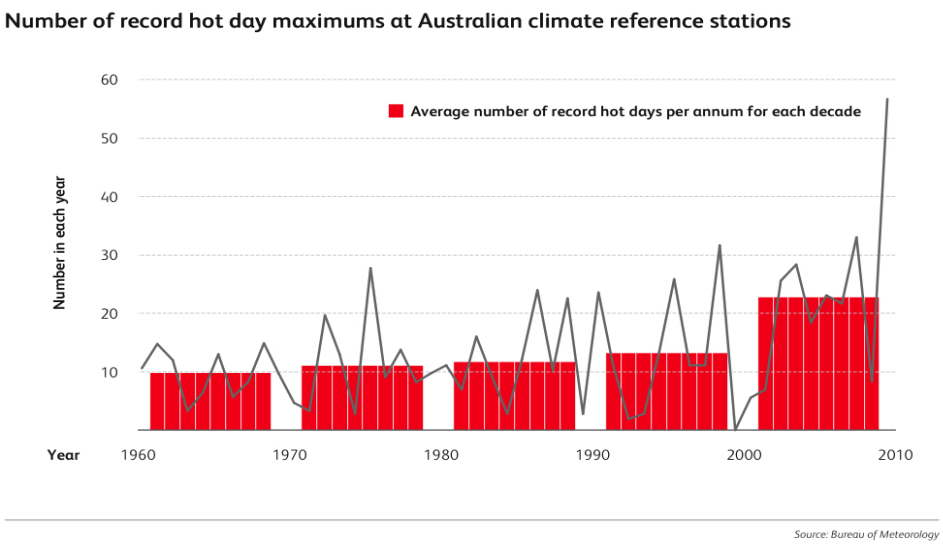
Heat waves are also getting earlier …

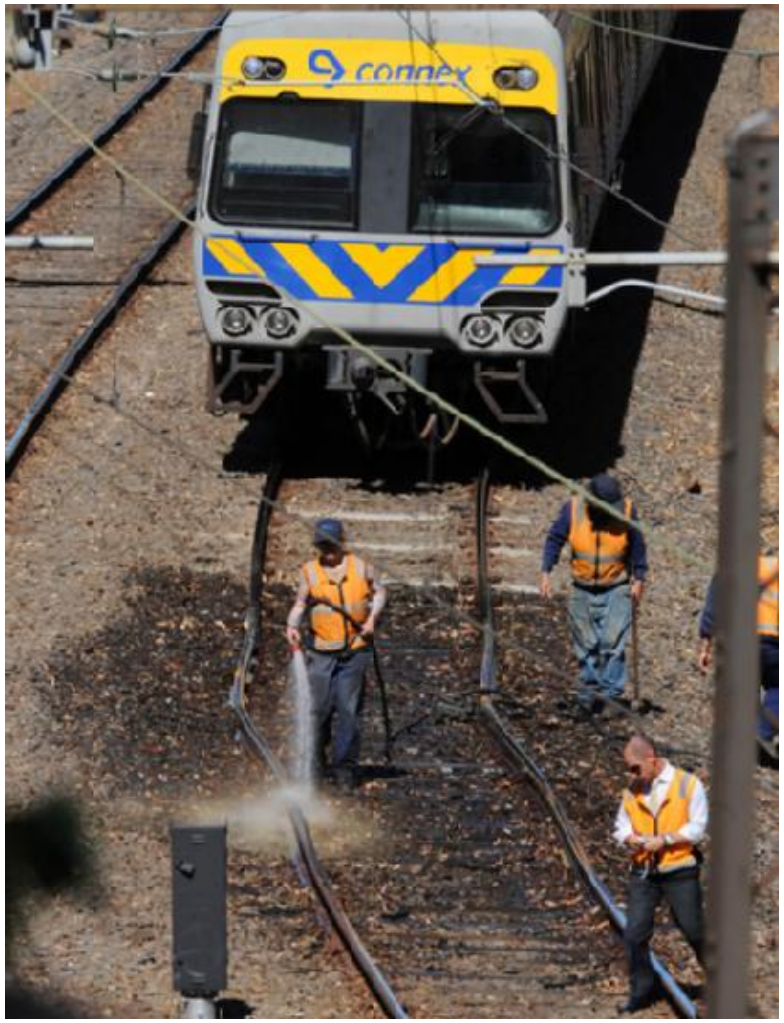


Heat waves are getting longer, earlier and more intense

Perkins and Alexander, 2013, Journal of Climate

Heat waves: health & infrastructure





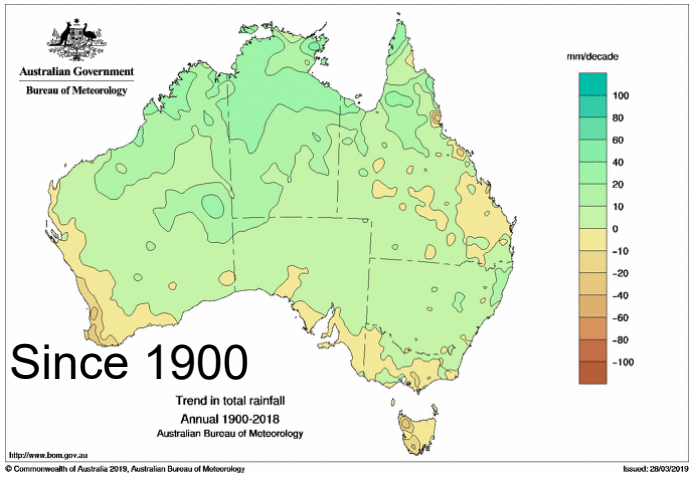
<u>January 2009 - Southern cities</u>

Costs: >200 premature deaths; losses ca. $800 M or more

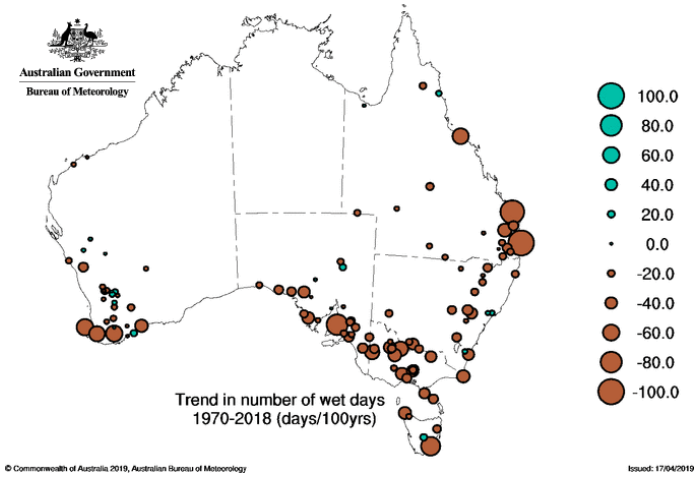
Disruption to transport and power supplies; shutdown of Basslink connector

Frequency of heat waves expected to double by 2030; triple by 2070

Over just Australia: rainfall



Number of wet days



For all measures, rainfall is getting rarer, but more intense at the high end

Links to increasing CO_2 not direct like temperature (harder to attribute)

Rainfall can change:

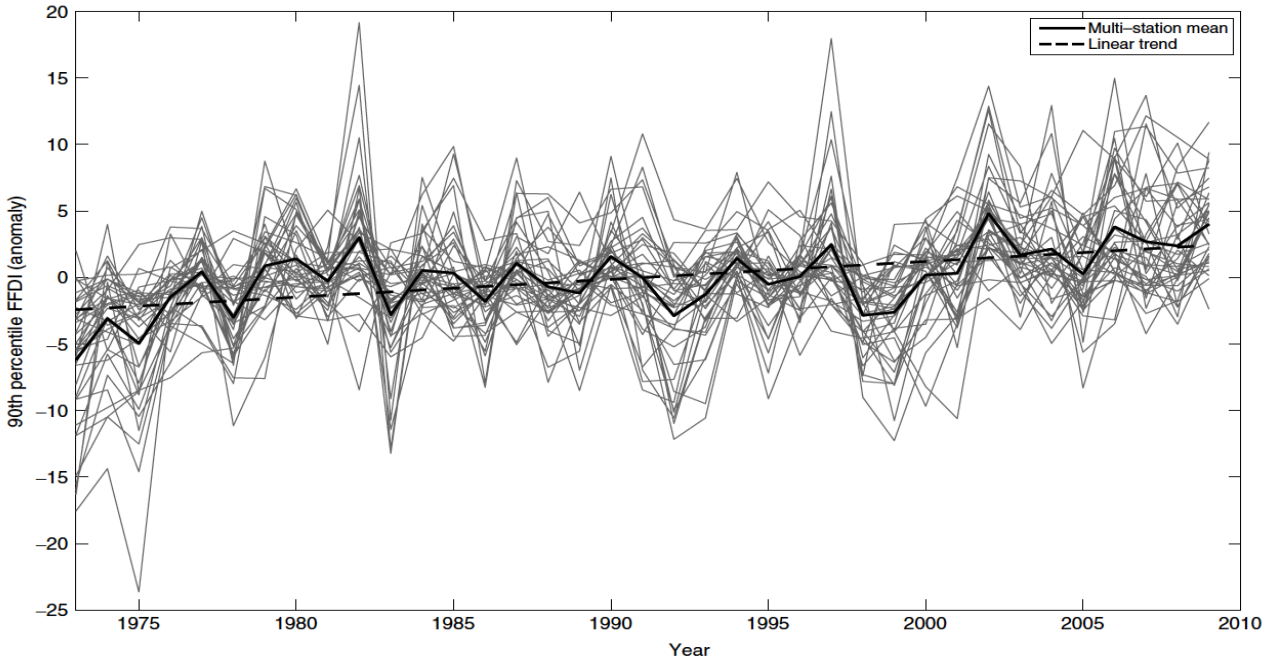
(a) Locally intensify
(b) Become more common
(c) Move location

(c) is concerning, eg. Cyclones emerging in non-cyclone rated regions

Note rainfall since 1970 has declined. Rainfall since 1900 has not declined, except in SWWA, Tasmania and perhaps over southern Australia

Other extremes

- Bush fires
  - Clear change in risk
  - Warmer, drier, more fuel load
  - Longer growing season, reduces hazard reduction and increases load



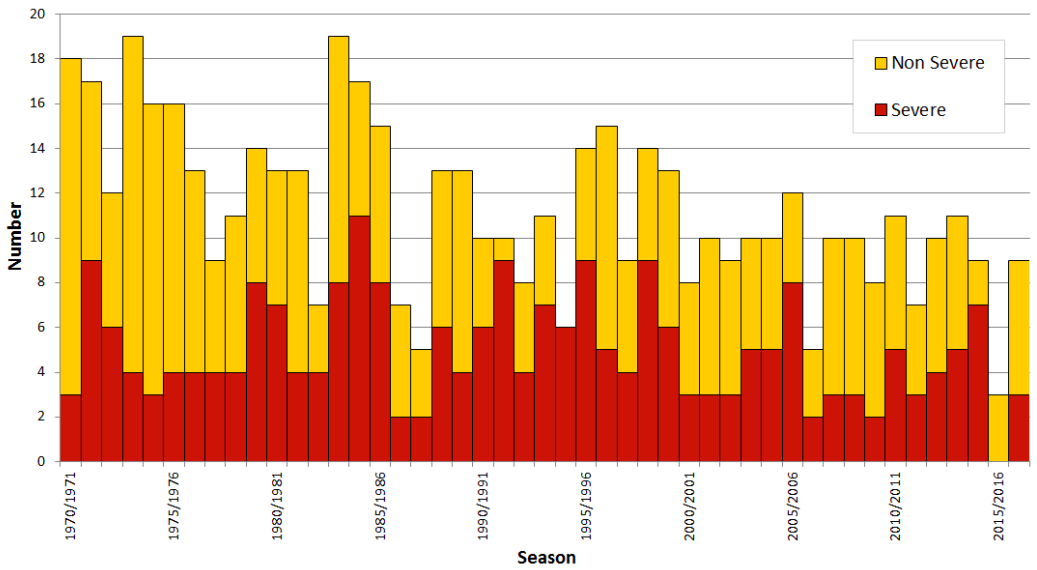
Clarke et al., 10.1002/joc.3480

Other extremes

- Cyclones
  - Not clear
- Droughts
  - Not clear

GBR

- On-going bleaching
- Marine heatwaves



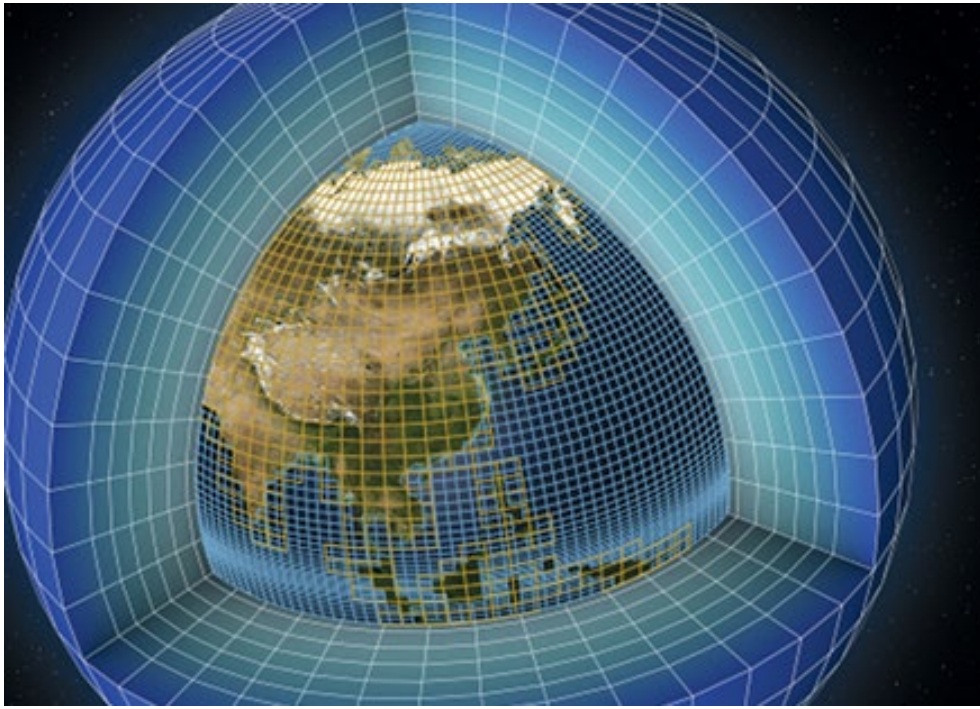
Number of severe and non-severe tropical cyclones from 1970 - 2016 (BoM)

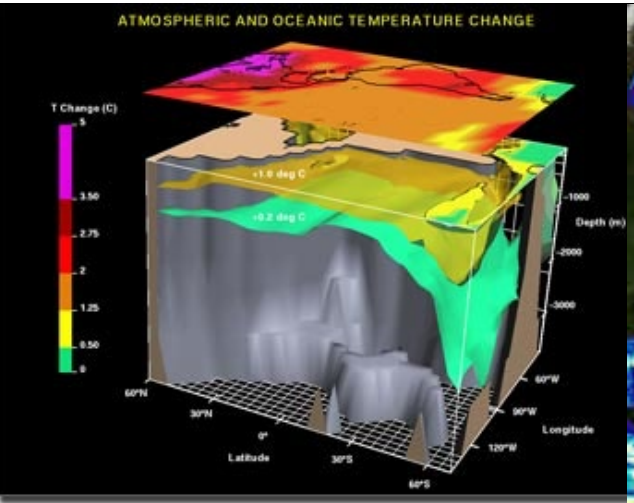
Outline

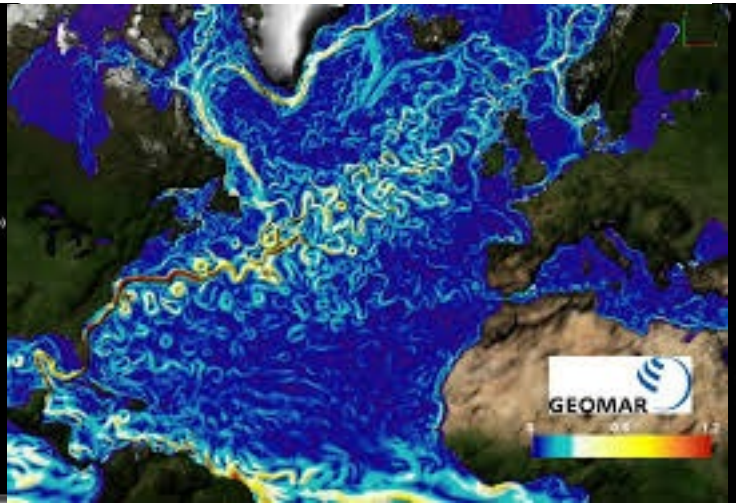
- Observed trends in extremes
- Modelling extremes in climate models
- What might be achieve within a decade?

Climate models: used to predict climate

- Use laws of physics
- 3 million lines of code
- Robust at continental scales and above
- Not fit for purpose for extremes

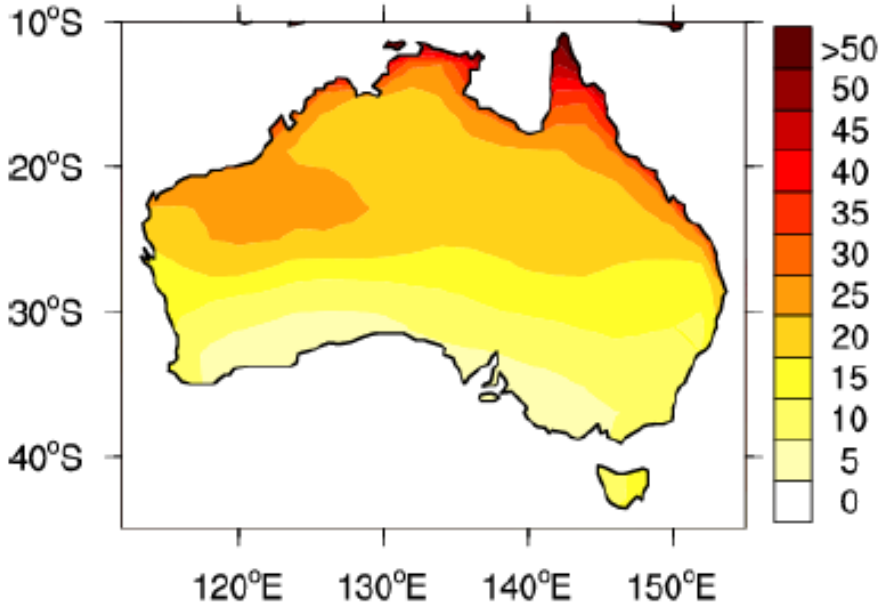




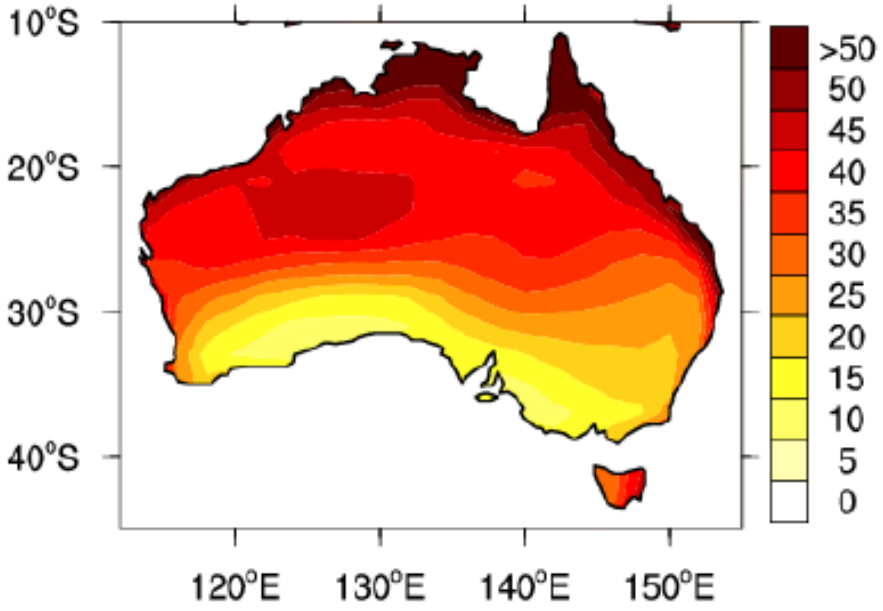


Heatwave days – CMIP5 Models

Low emissions scenario



High emissions scenario

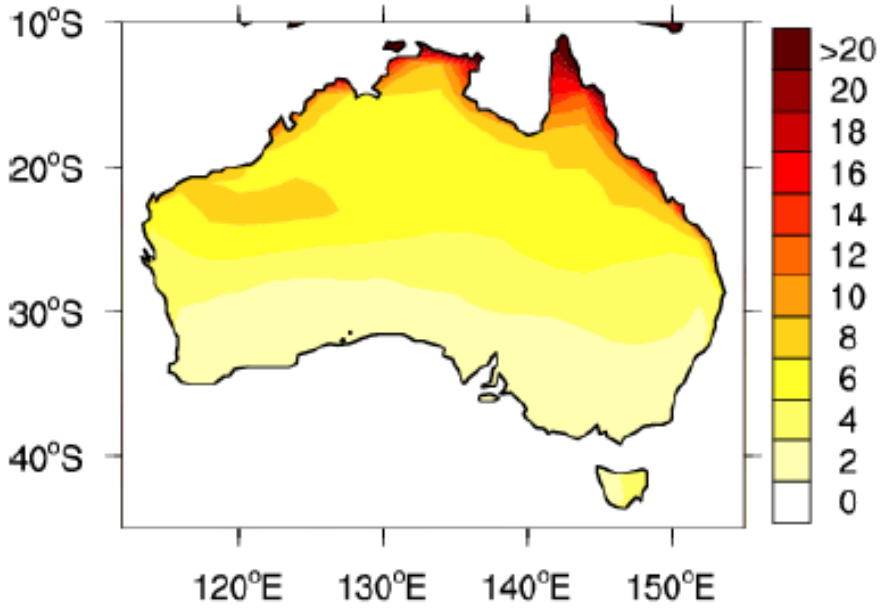


- The above are *changes* – 2081-2100 compared to 1950-2005

Cowan et al., 2014, Journal of Climate

Length of longest event– CMIP5 Models

Low emissions scenario



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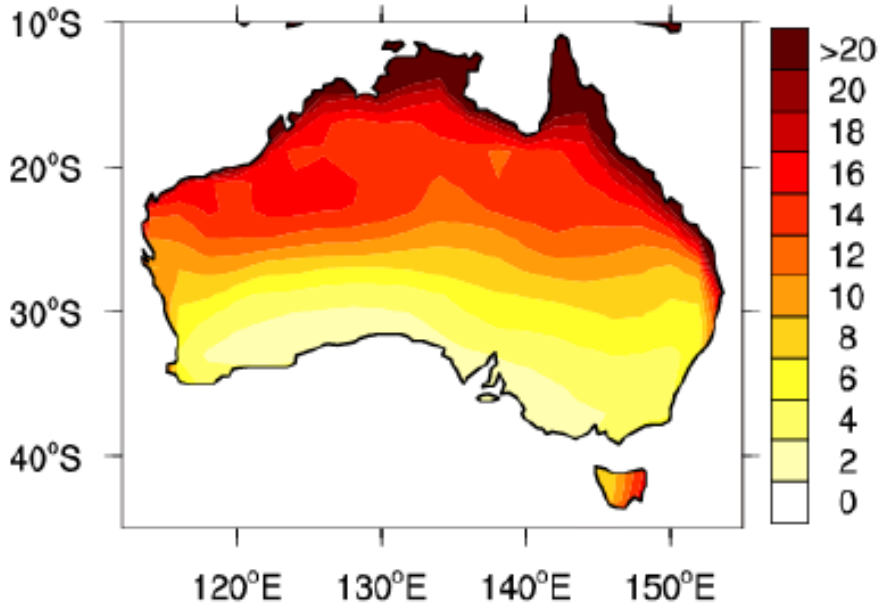

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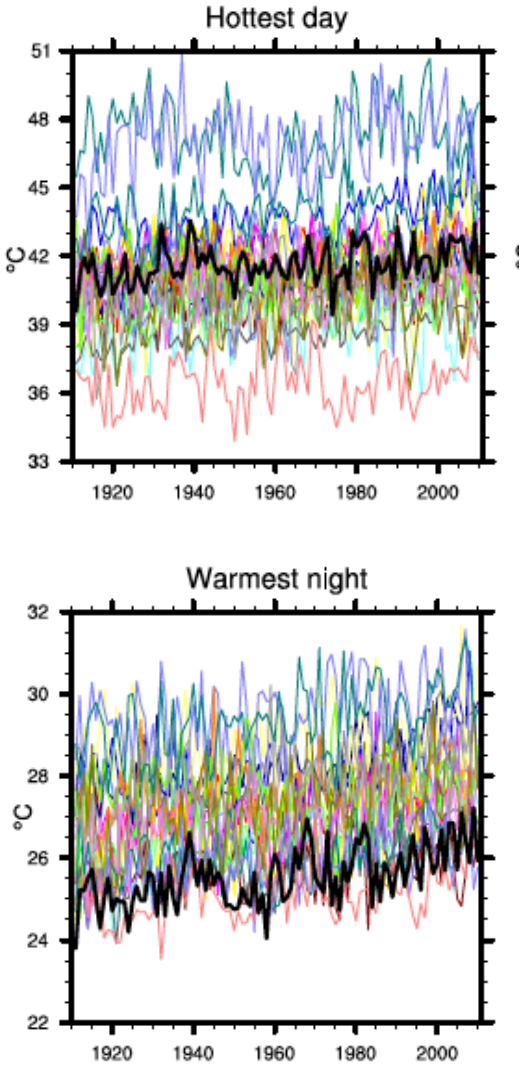
Future risk of extreme heat



Some climate Models do simulate hot days well

A few are ok on night time temperatures

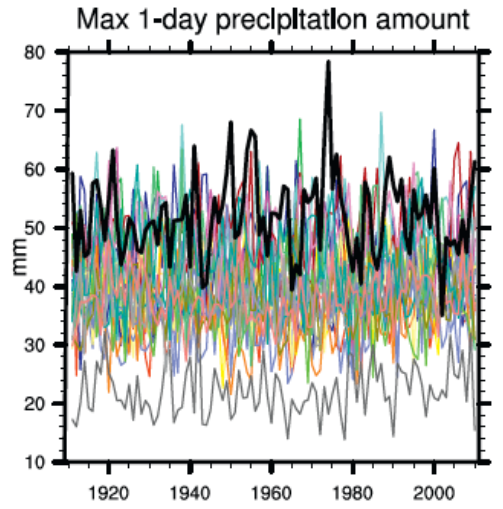
A key process, blocking, requires models at ~30 km resolution, not 100km

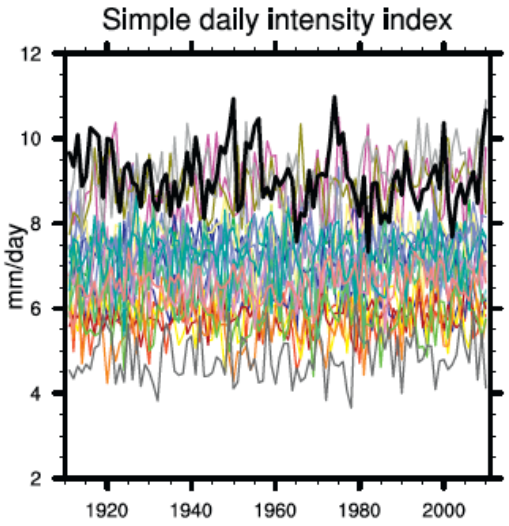
There are land feedbacks that are poorly captured in ~50% of climate models

Summary: pretty good

- Climate models are ok at simulating the magnitude of a heat event
- They do not capture the duration of heat waves well

Future risk of extreme rainfall and hail





Climate Models do not simulate rainfall well, when rainfall is intense (even weakly intense)

Weather models do simulate rainfall well, even when rainfall is intense

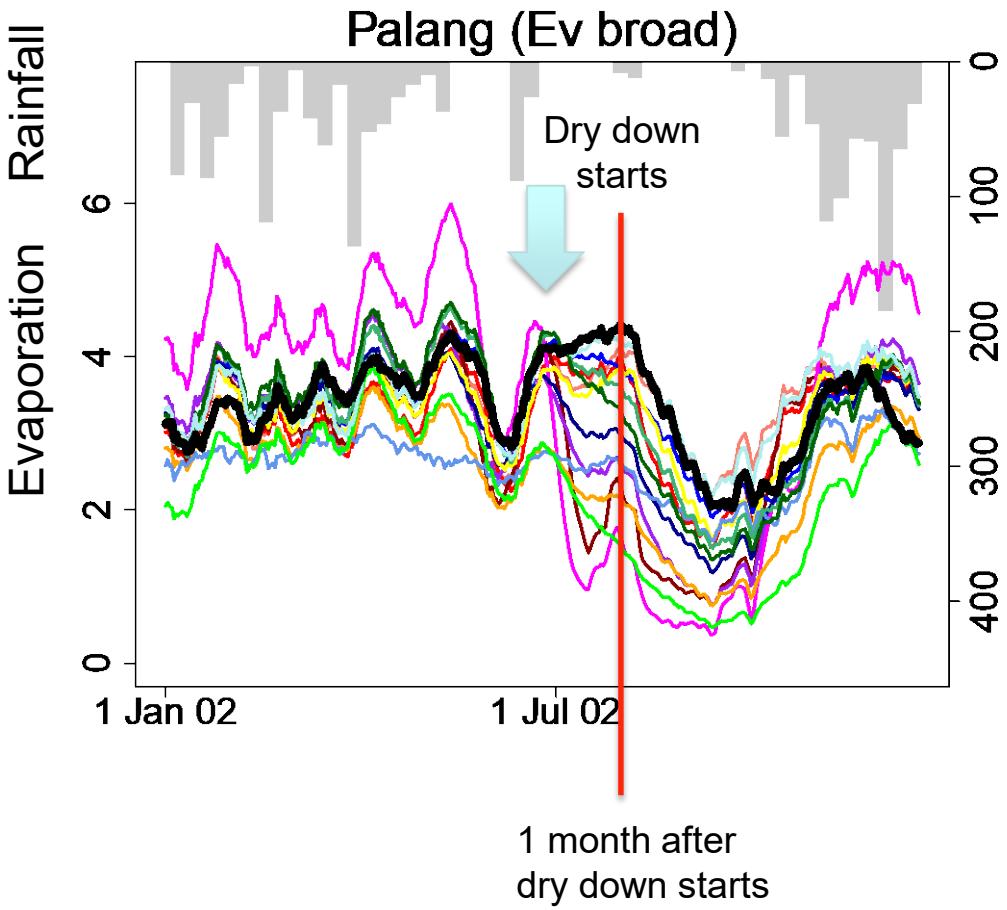
It's a problem of spatial detail – the climate models are simply very coarse

Ability to simulate hail is developing

Summary: Not good

- Major issues with intense rainfall in climate models
- Resolvable, with resolution and improved physics

Simulating drought …



Take the land module from a 15 climate models

Provide the module with observed rain, air temperatures etc

Calculate evaporation during a dry-down

After 1 month observed is 4 mm d^{-1}
Some models close to observed
Some models at 0.5 mm d^{-1}
No model over-predicts evaporation

Conclusion – most models overestimate the magnitude, frequency and duration of drought

Ukkola et al., 2016 Env. Res. Letters

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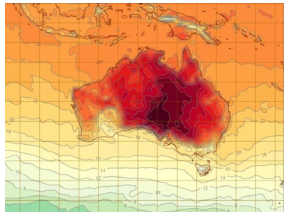
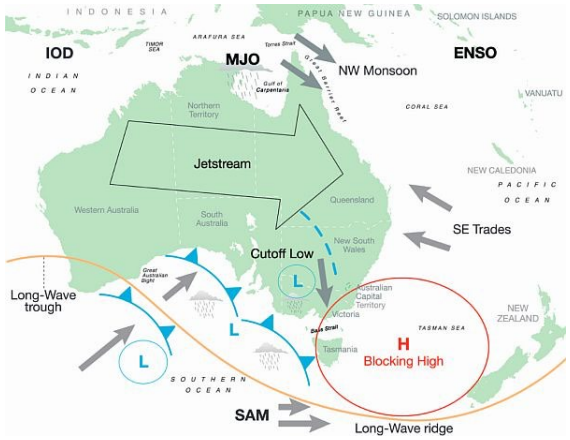
Real climate extremes

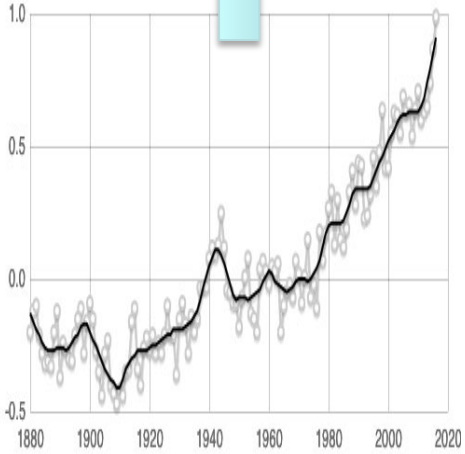
Rainfall

Heatwaves

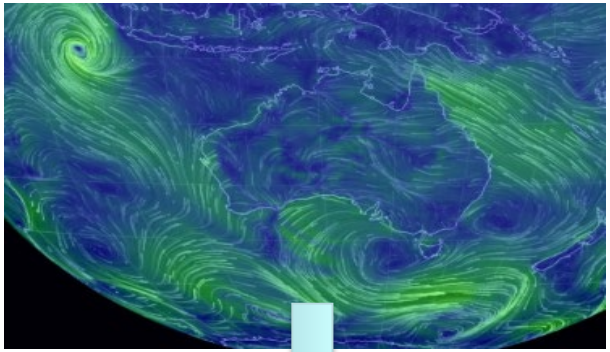


Drought

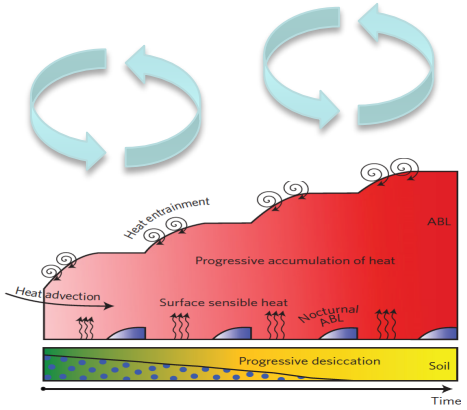




Synoptic scale blocking



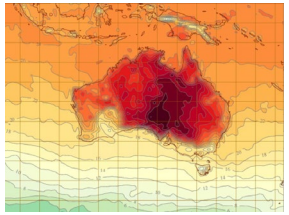
Land – boundary layer intensification



Real climate extremes

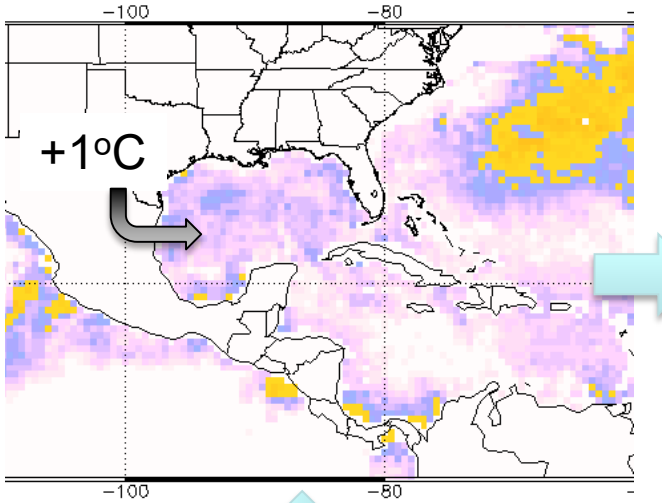
Rainfall

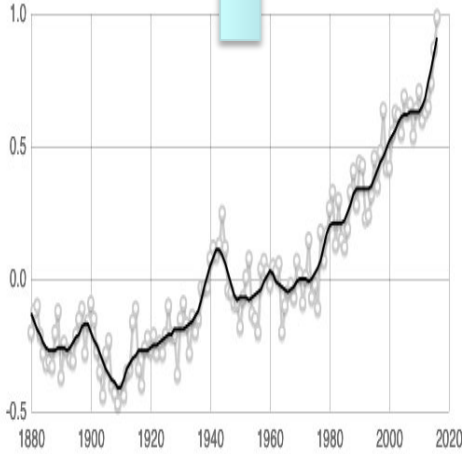
Heatwaves



Drought

14th August. +1°C



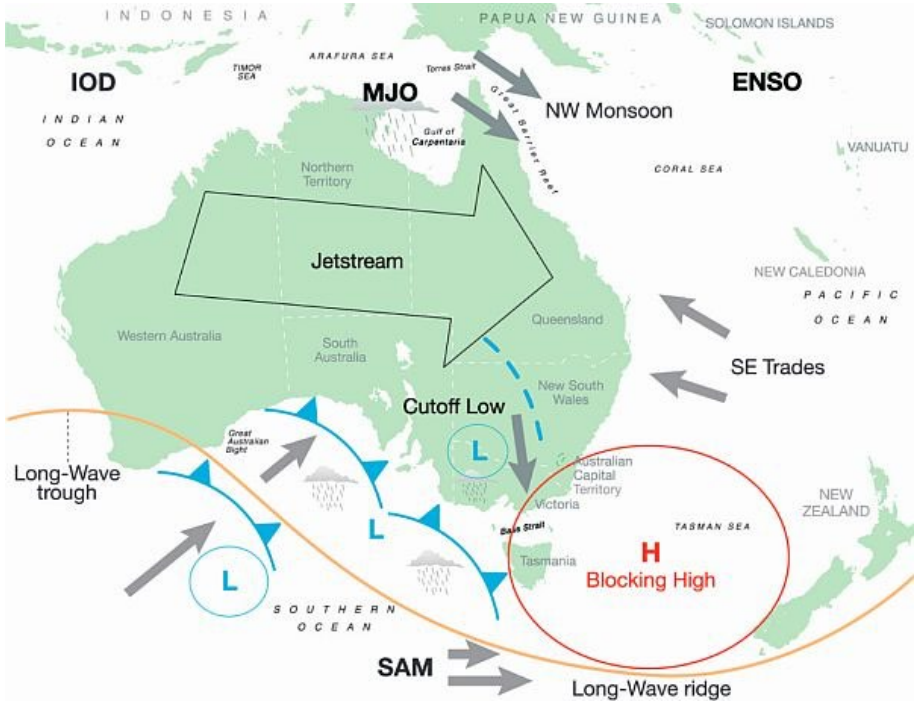


Cyclone Harvey, ~US$180 billion

Stalled – forecast 3 days in advance

Intensity not unusual, stalling very unusual, attribution to climate change will take time

What about droughts



We do not know the sign of the change in future regional drought. Depends on changes in

- Rainfall
- CO_2 and water use efficiency
- Evaporative demand
- How vegetation responds

Traditional view has been drought is linked with modes of variability

To predict droughts would therefore require a model to simulate the modes, their timing, & interdependencies

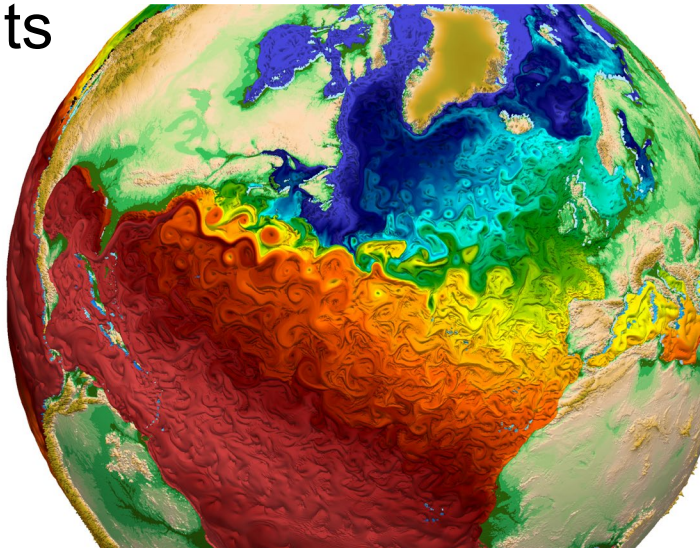
Recent thinking is that Australia is “by default” in drought, broken by major rainfall events

New research will focus on whether we can identify causes for these major rainfall events

It’s not true that higher temperatures lead to drying. It’s true that drying leads to higher temperatures

Future risk of compound events

- Compound events are expressions of weather that translate a large-scale climate trend into simultaneous weather events
- Can be catastrophic
- Not represented in existing modelling technologies



nature climate change

PERSPECTIVE

https://doi.org/10.1038/s41558-018-0156-3

Future climate risk from compound events

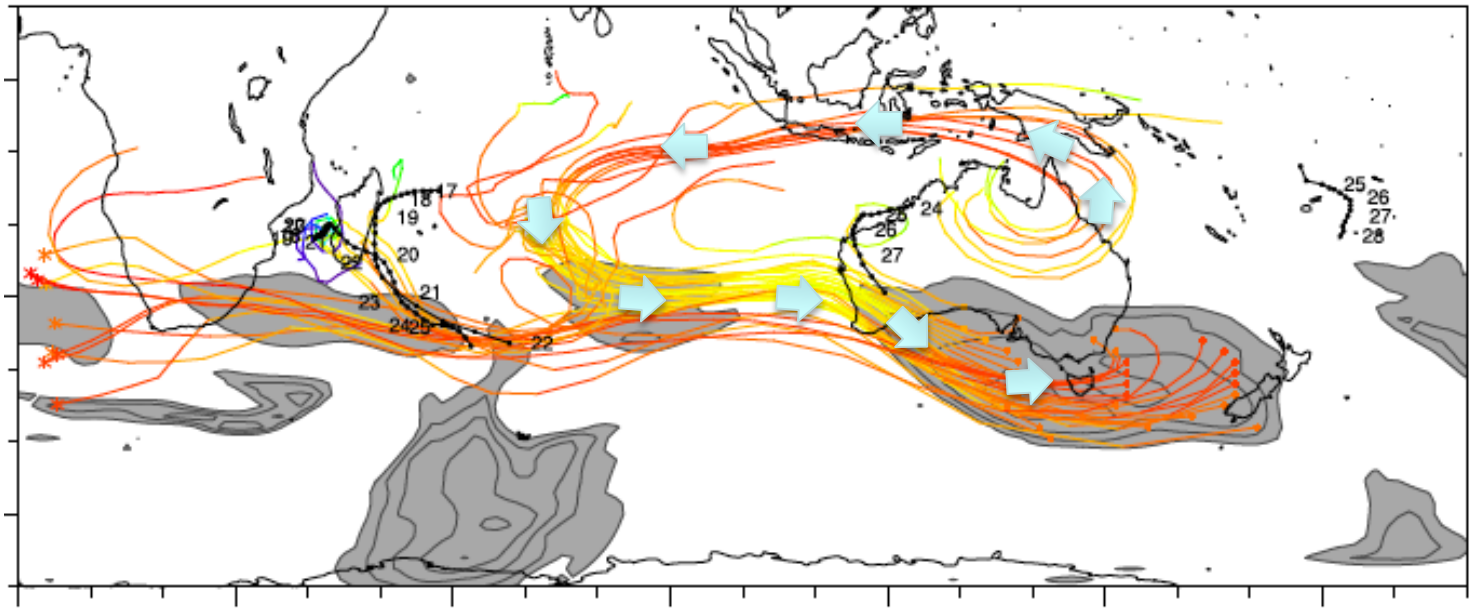
Jakob Zscheischler[1*], Seth Westra[2], Bart J. J. M. van den Hurk[3,4], Sonia I. Seneviratne[1], Philip J. Ward[4], Andy Pitman[5], Amir AghaKouchak[6], David N. Bresch[7,8], Michael Leonard[2], Thomas Wahl[9] and Xuebin Zhang[10]

Compound events

- Events that might individually be manageable, but in combination are beyond a system's resilience
  - Flood - storm surge – high tide
  - Cyclone – heatwave – fire
  - Heatwave – infrastructure – health
  - Heatwave - flooding
- Joint probabilities unknown, but black swans appear rather too common
- Not incorporated into risk associated with losses, supply lines, markets and so on.

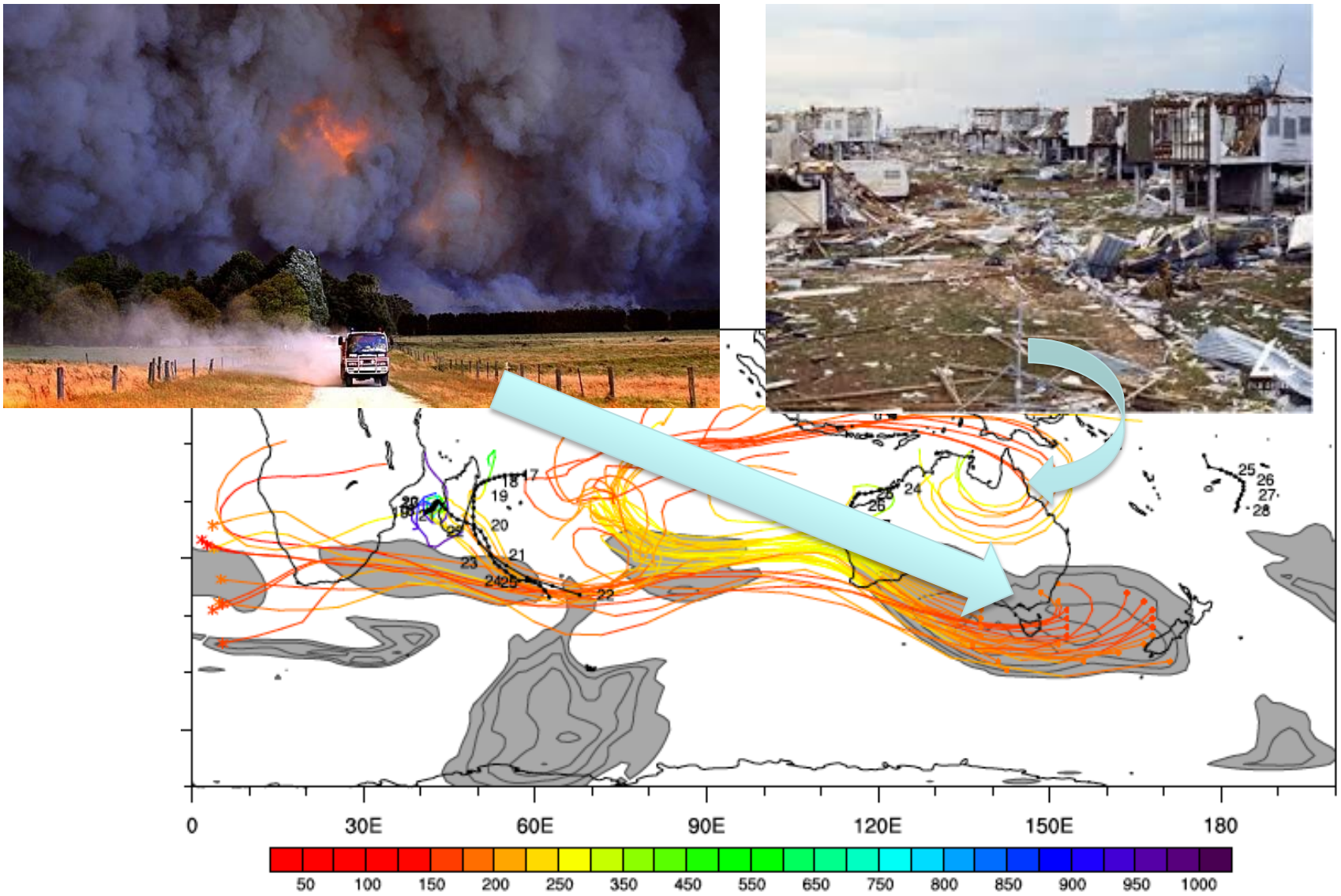
Compound events – Victorian heatwaves

- Link between cyclones in the Australian tropics and heatwaves over Victoria
- Linked with potential vorticity (PV) anomalies
- Likely not just cyclones – broader to include tropical convection



Parker et al., 2013, GRL

Compound events – Victorian heatwaves



Parker et al., 2013, GRL

Outline

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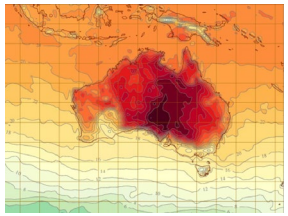
Future extremes

These are all weather scales. What do the weather sciences tell us?

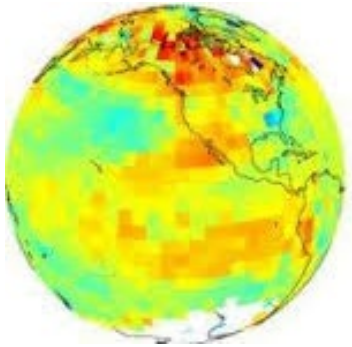
Rainfall

Poor deep convection,
Poor resolution of frontal dynamics
Cyclones not resolved well

Heatwaves

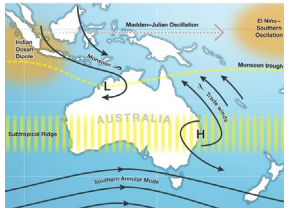


Weak persistence, Poor blocking



Drought

Modes poorly teleconnected to provide long-term variability. No multi-year droughts



Variability

Cannot synchronize modes

~300, ~200, ~100 km pixels

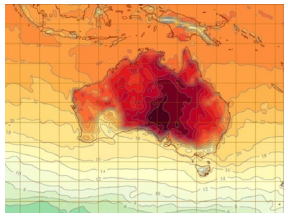
Future extremes

The weather sciences tell us we need global models at ~20 km

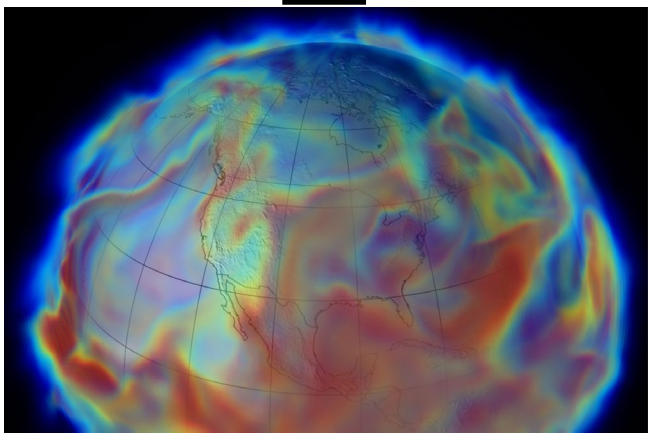
Rainfall

Explicitly resolve deep convection, Simulate frontal dynamics

Heatwaves

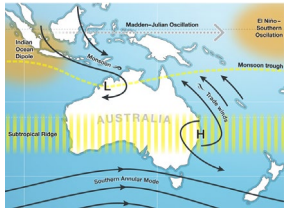


Persistence and blocking resolved



Drought

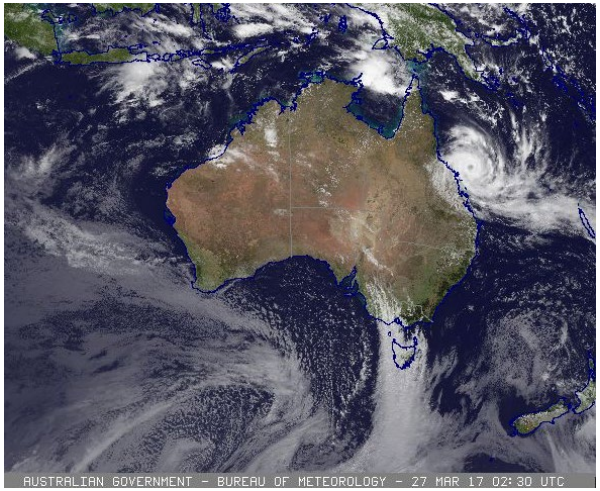
Modes provide long-term variability
Multi-year droughts simulated?



Variability

Marine heatwaves resolved

The “weatherfiction of climate models



Computationally *almost* impossible - exascale

Data management *almost* impossible

But … we are giving it a go !

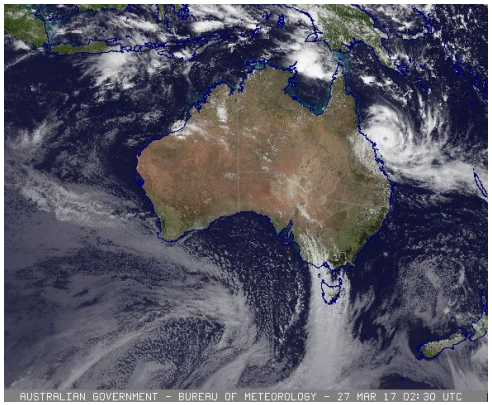
Major national effort to reengineer Australia’s weather and climate model

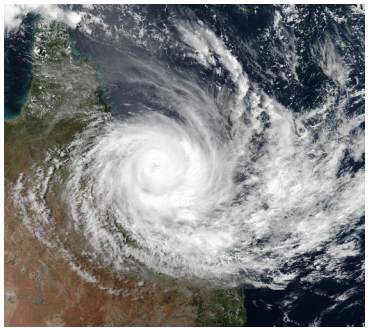
- Called for in NCRIS roadmap, scoping study via Dept Education and Training
- Supported by key Universities, Dept Environment, BoM, CSIRO, AAD,
- To fund 5-10 year effort to software engineer the model for weather and climate research
- Enable new questions to be asked, flexibly, quickly and reproducibly
- To build new capability

Future extremes

Climate under climate change

Weather under climate change





Direct simulation of the actual extremes that threaten society

Summary

- Warming of 2^{o}C is almost certain. Changes in the frequency, magnitude and duration of some extremes is inevitable
- Compound events are emerging as a real threat to society, businesses and investors. Poorly understood, climate models do not capture them
- Next generation climate modelling must use ~20 km globally to properly reflect synoptic scale weather
- These models will help assess risk of extremes and may enable assessment of some compound events

AMOS 2020
Fremantle, Western Australia
10-14 February 2020

Theme IV. Extreme events
Session ID: 38

Session announcement

Compound Events – an Australian perspective

We invite researchers analysing Compound Events to present findings, research methods, and stakeholder engagement practices to support the growth of the Australian Compound Events research community.

Application deadline: Sunday **22 September 2019 (11:00pm AEST)**

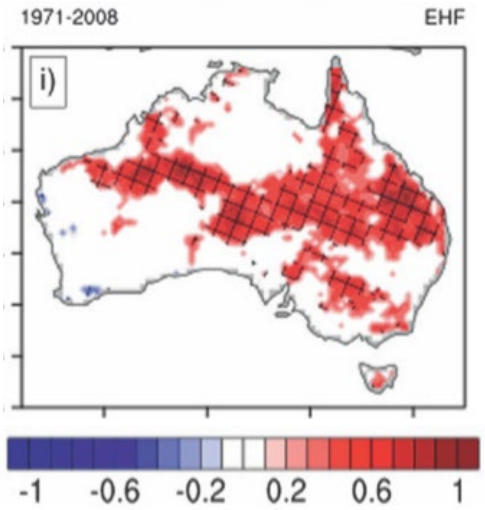
https://amos.currinda.com/register/event/2

We are looking forward to your submissions and an informative and fruitful session!

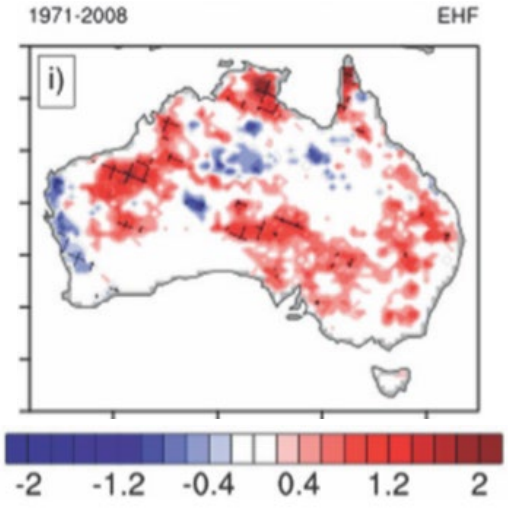
SPARE SLIDES

Over just Australia: temperature

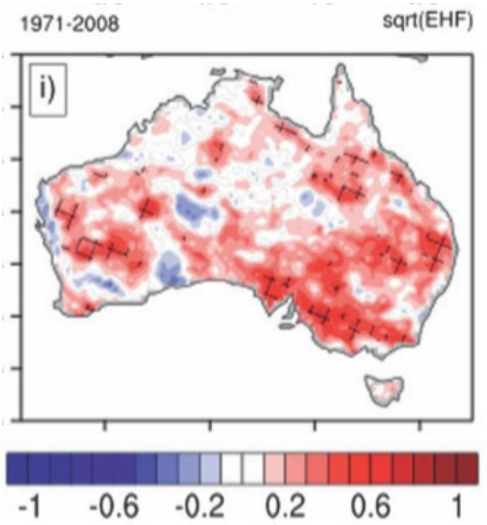
Number of heatwaves



Length of heatwaves



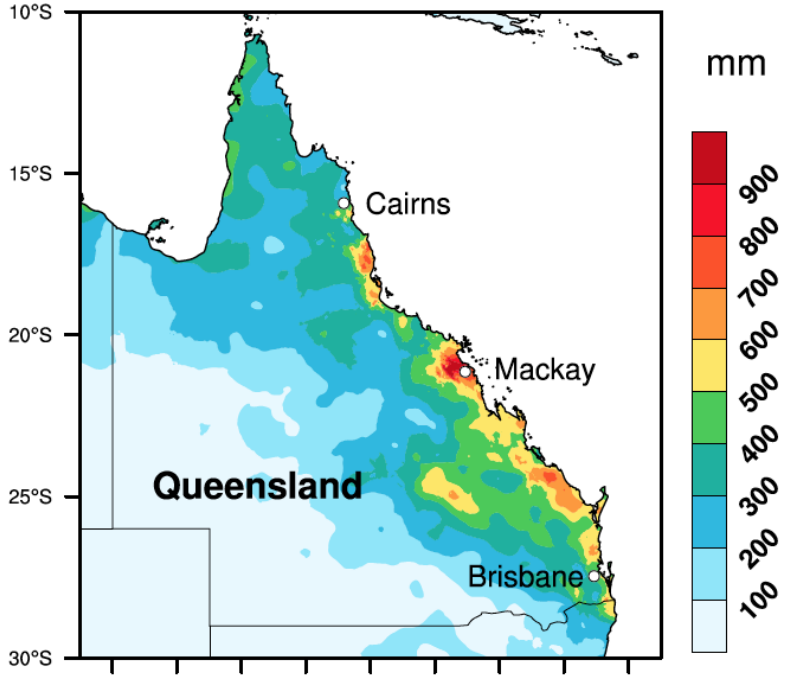
Hottest heatwaves

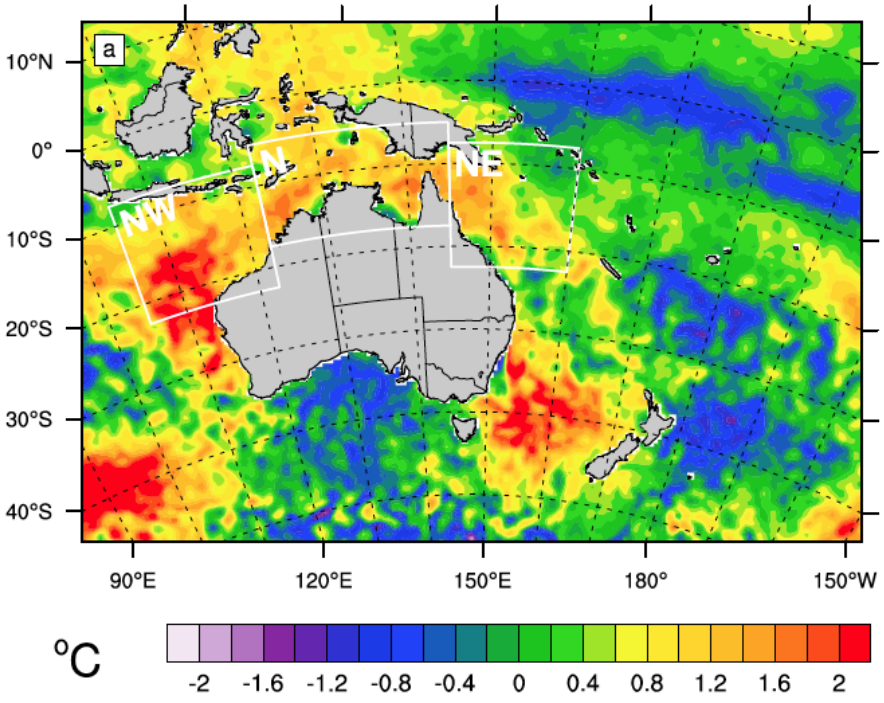


- Hotter over most of Australia
- Heatwaves – bigger, commoner, longer
- Strong link to health, agriculture, infrastructure risk

Other extremes

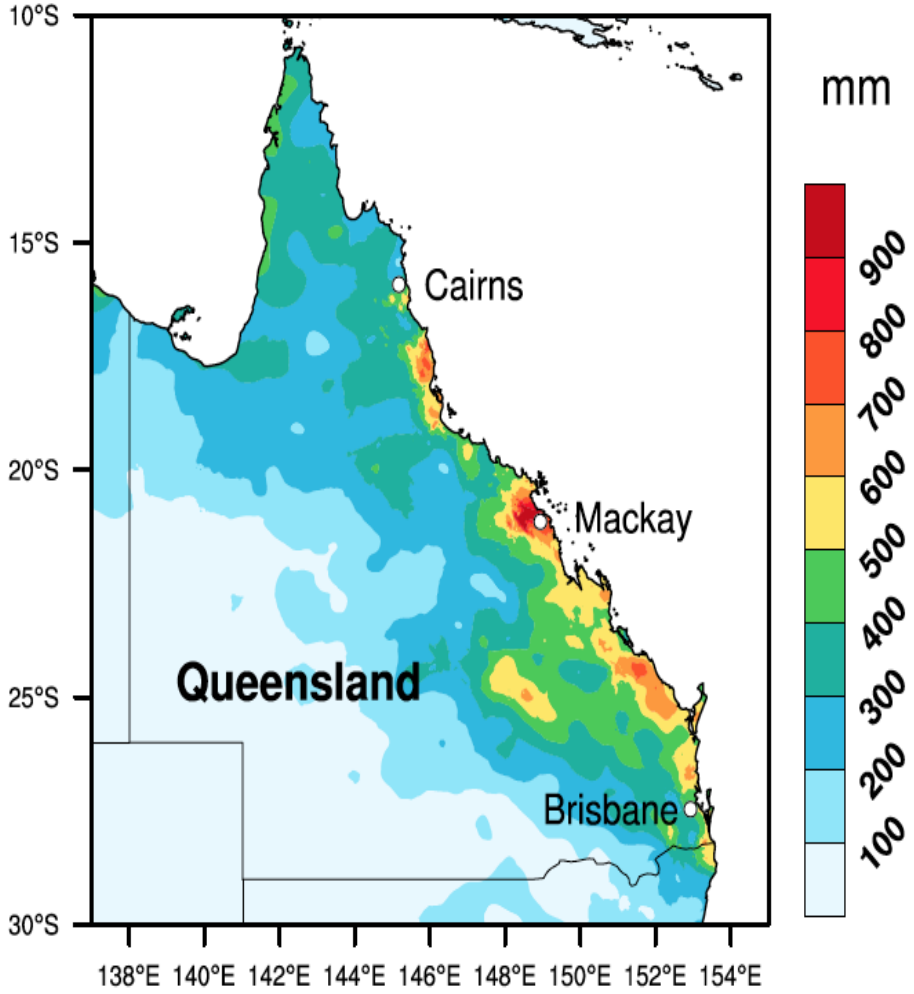
- Extreme rainfall …
- You cannot attribute a single event to global warming
- … is a myth [it just takes lots of work and 12 months]

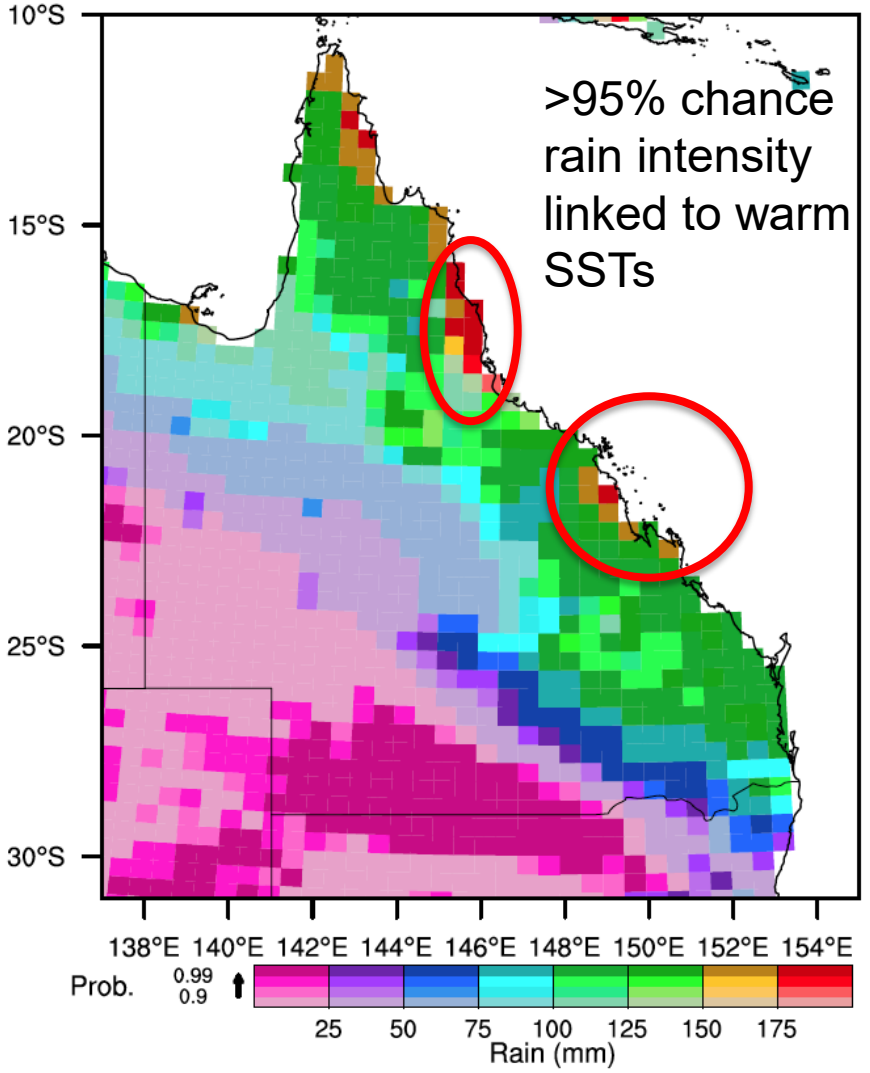




Source: Evans and Boyer-Souchet, 2012

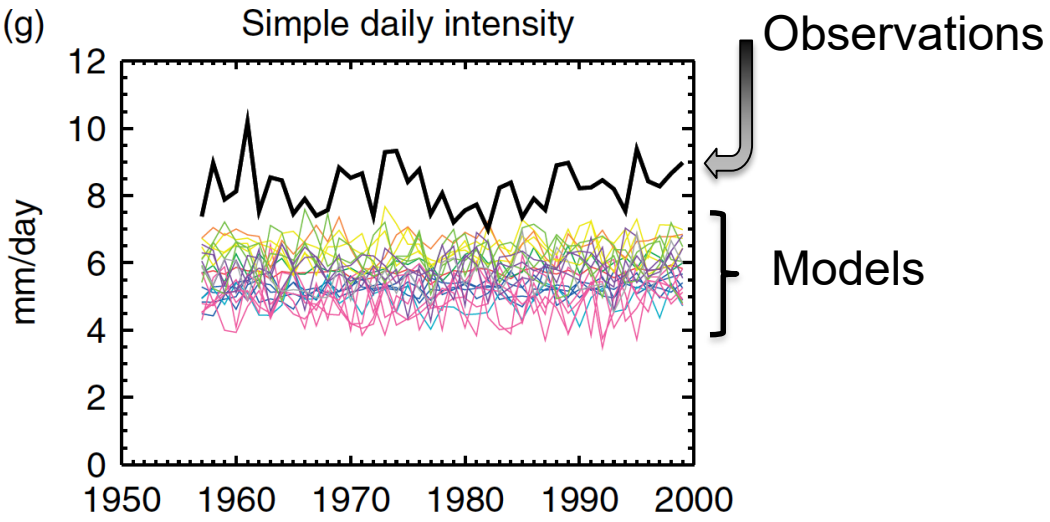
Other extremes



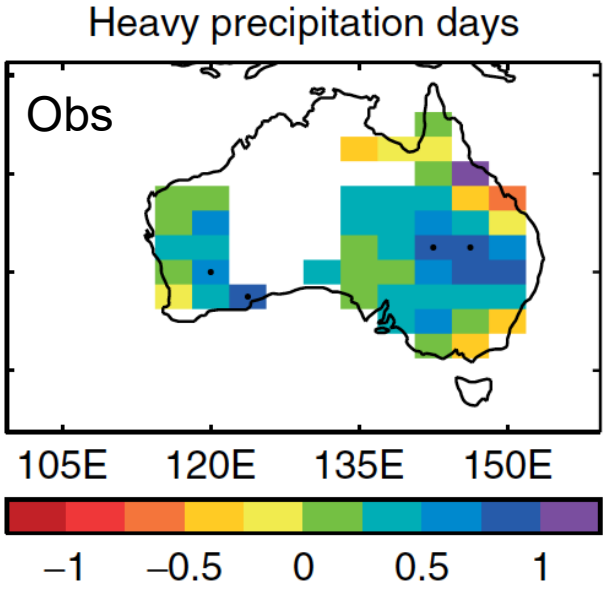


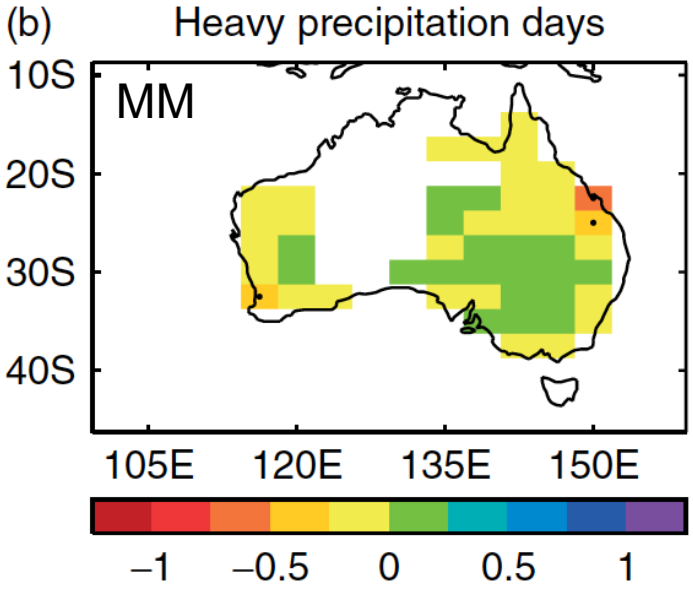
Source: Evans and Boyer-Souchet, 2012

Can we simulate extremes ?

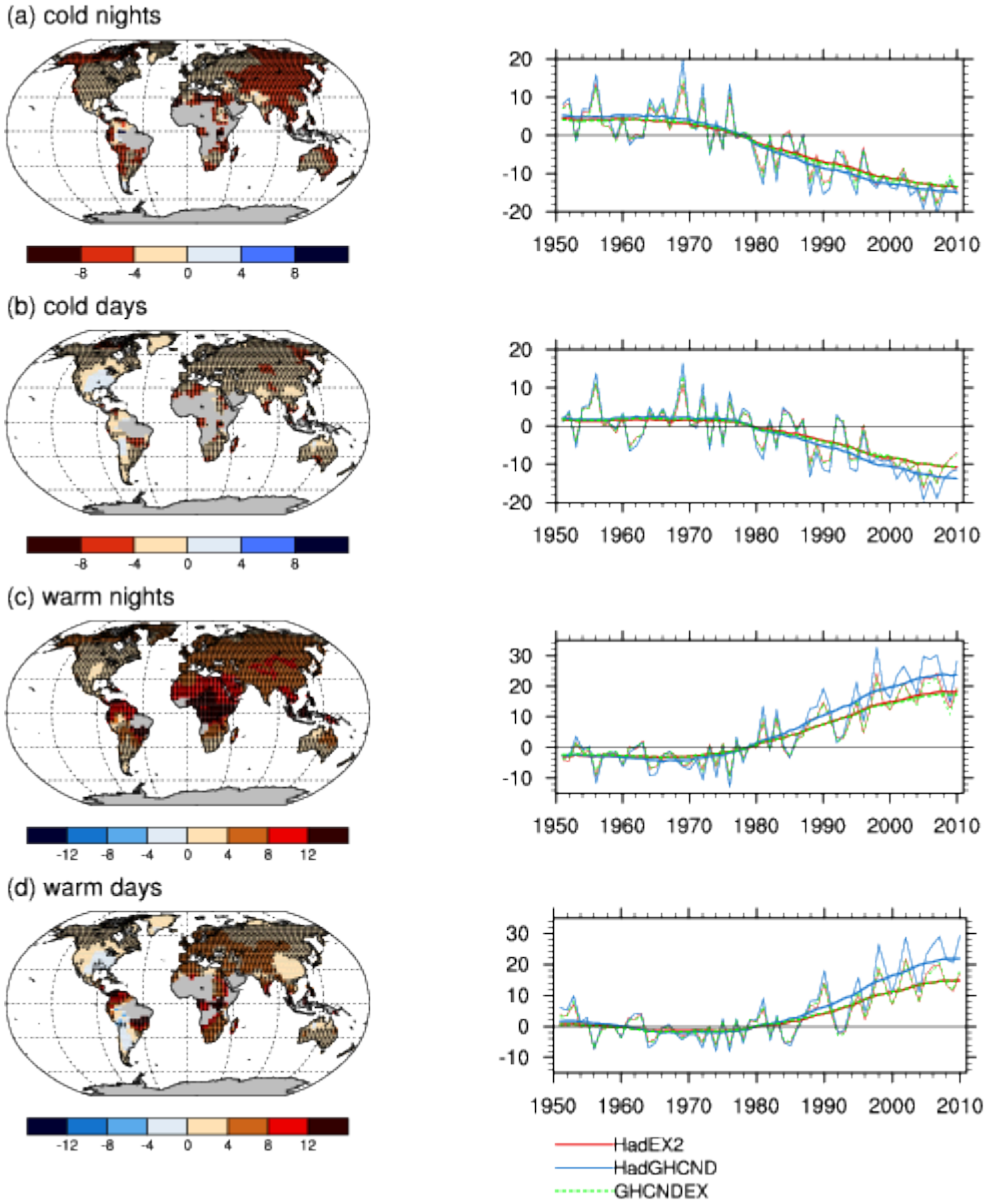


Trend in heavy rainfall



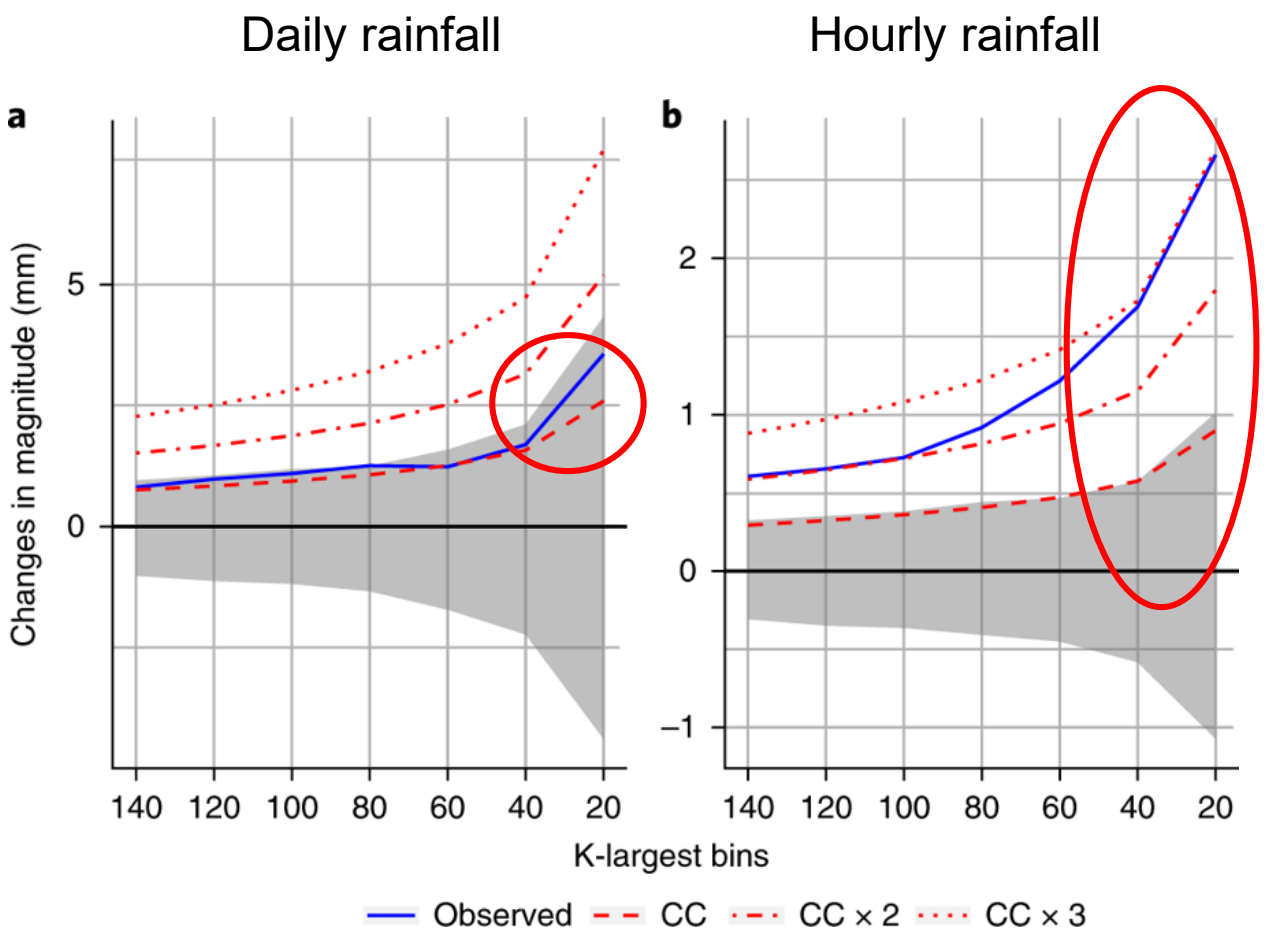


Global changes in temperature extremes



It is *very likely* that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased globally since about 1950

Over just Australia: extreme rainfall



Suggests most extreme rainfall is intensifying a lot

- Evidence of most extreme rainfall intensifying (by more than theory predicts) – should scale by Clausius–Clapeyron = ~6.5% $^{o}C^{-1}$

Westra et al., Nature CC., 2018