Rainfall projections for the Adelaide region

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4 April 2024

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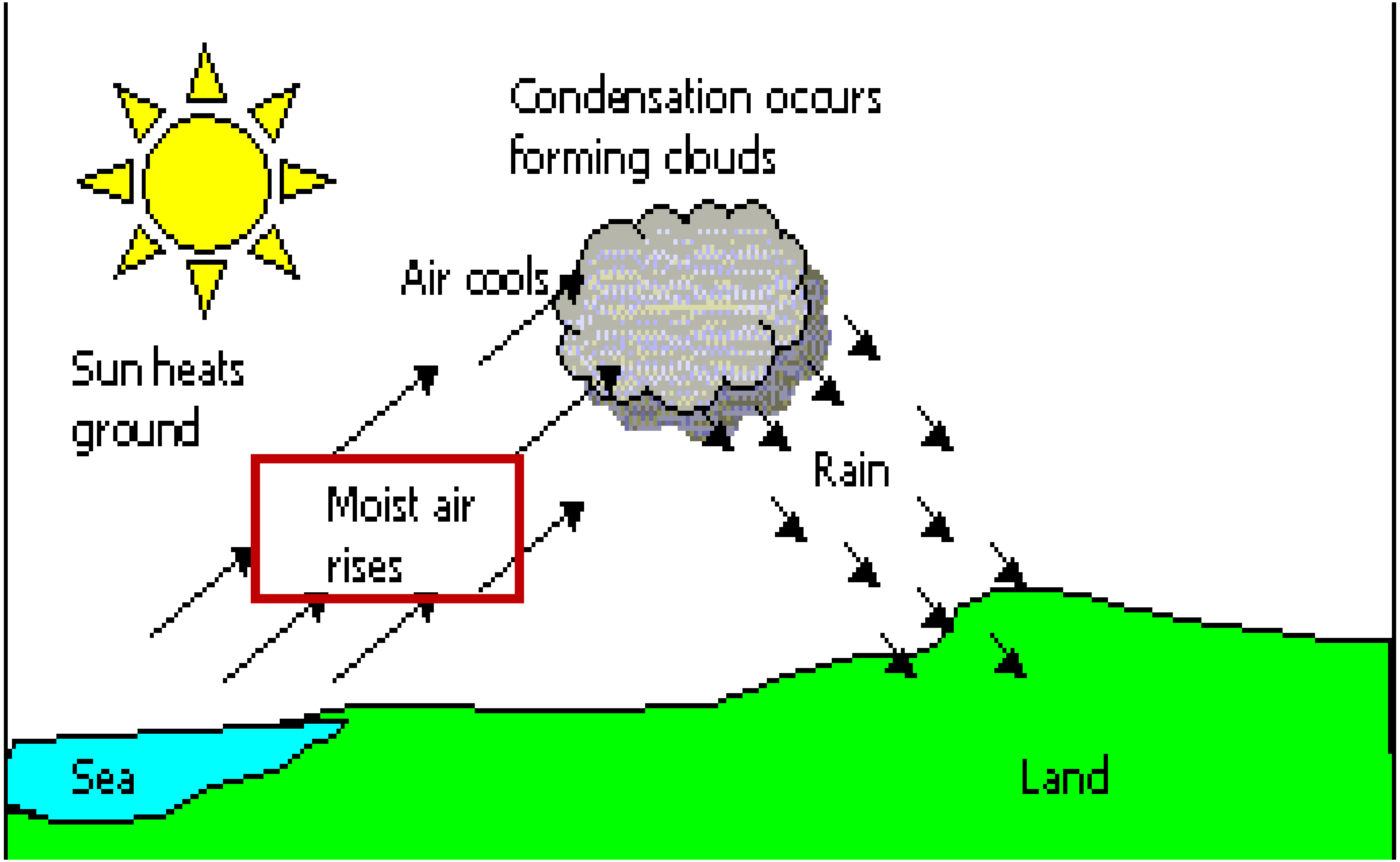
Rain 101

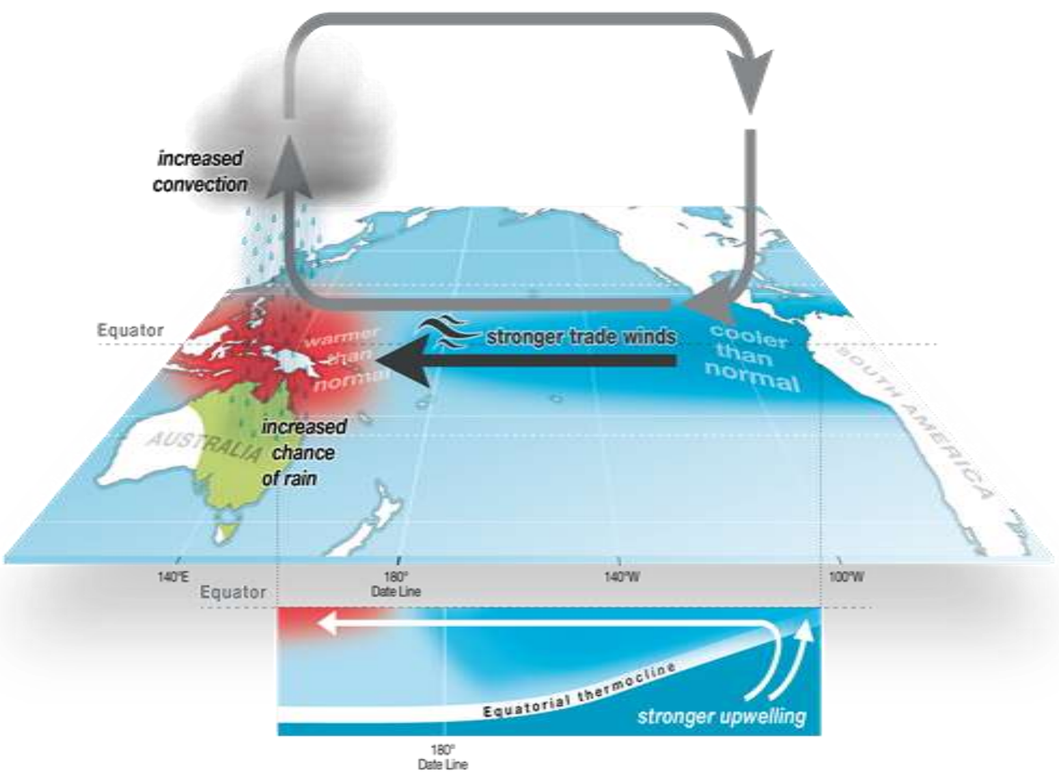
Two key ingredients for rain

- Moist air
- Rising up



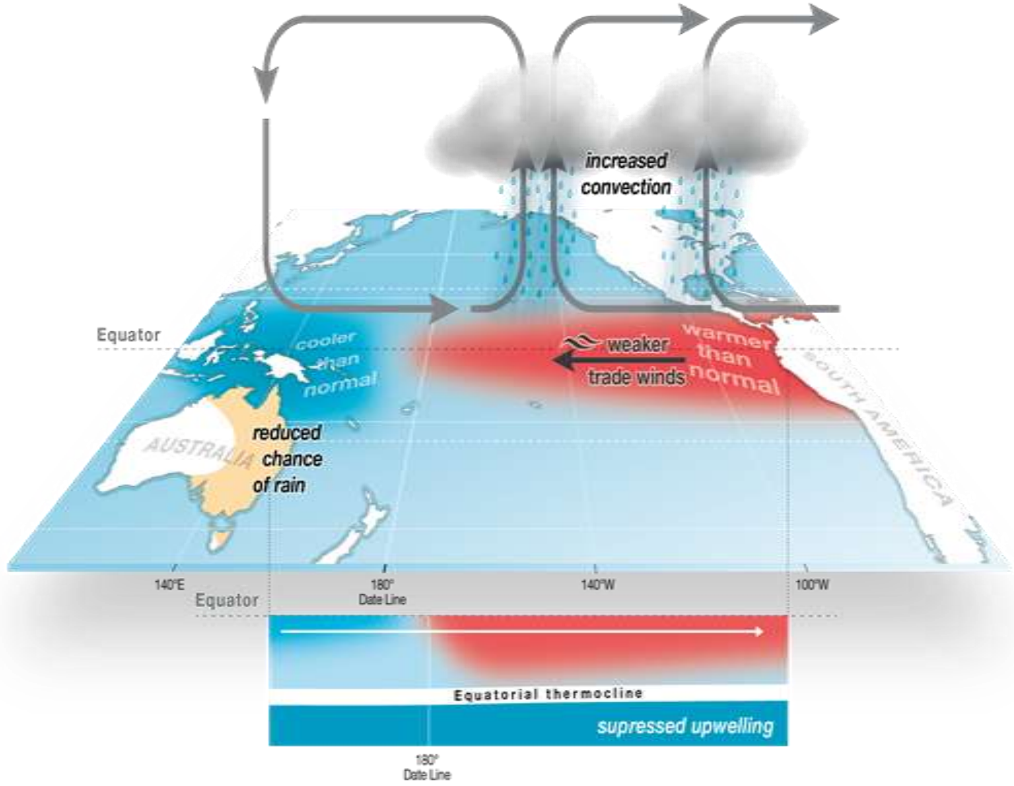
ENSO: La Nina / El Nino

La Niña



2020,2021,2022

El Niño



2015,2023

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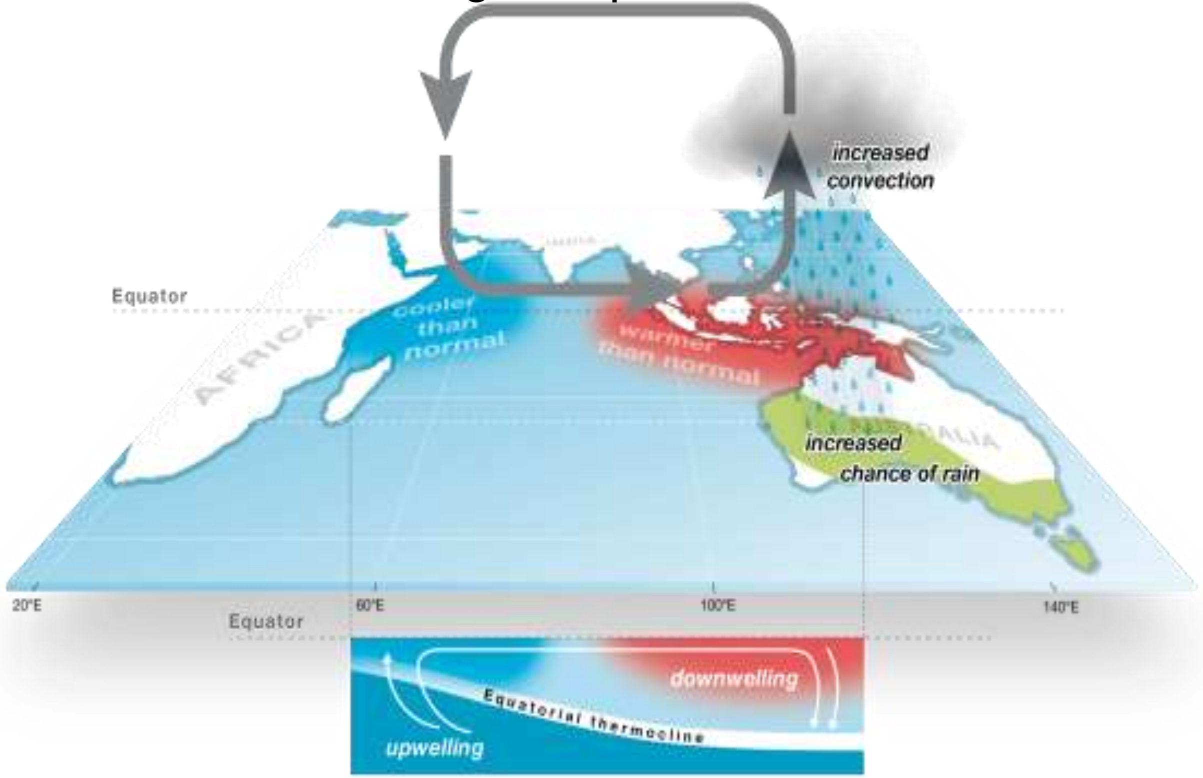
Year to year variability influencing <u>moisture availability</u> and <u>atmospheric circulation</u>

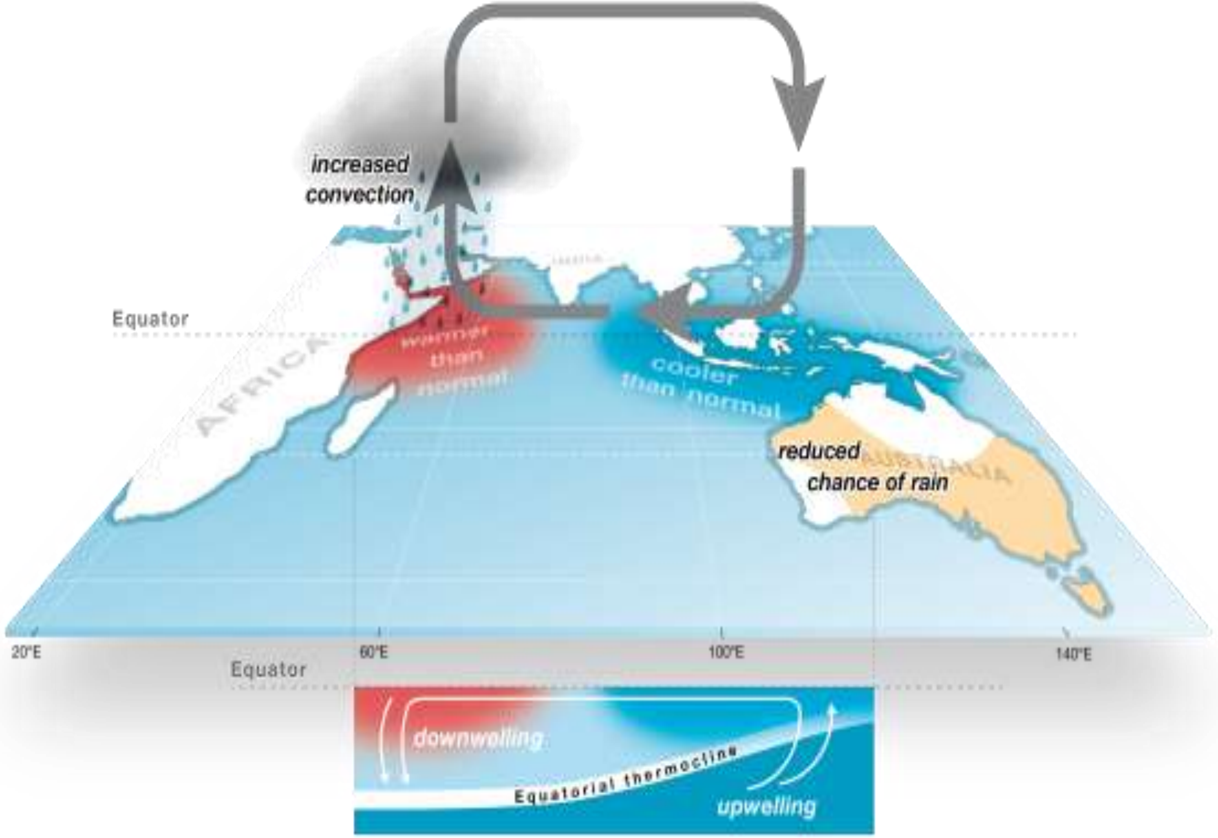
Indian Ocean Dipole (IOD)

Negative phase



2016, 2020, 2021, 2022

Positive phase



2015, 2019, 2023

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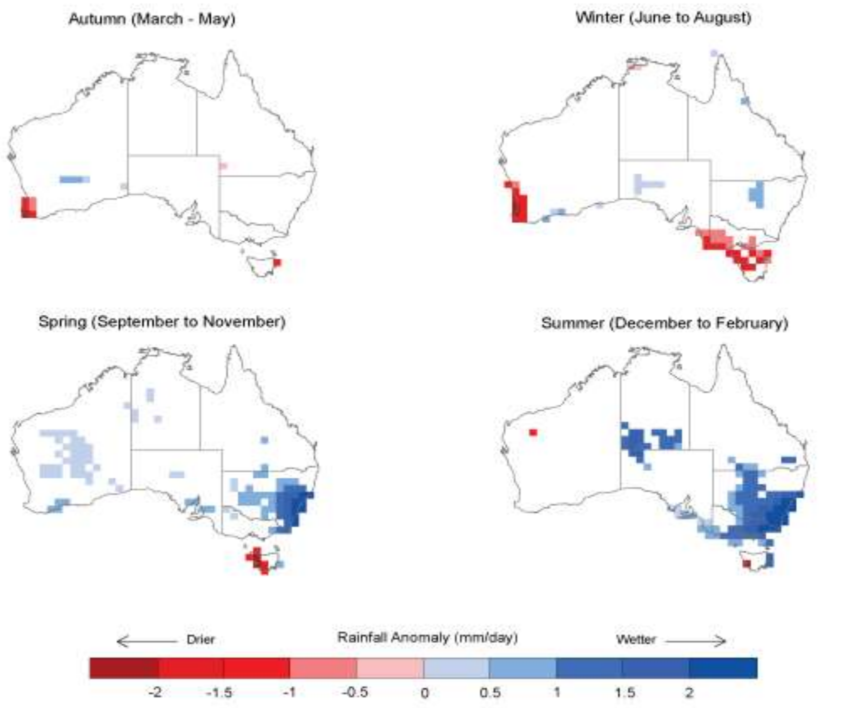
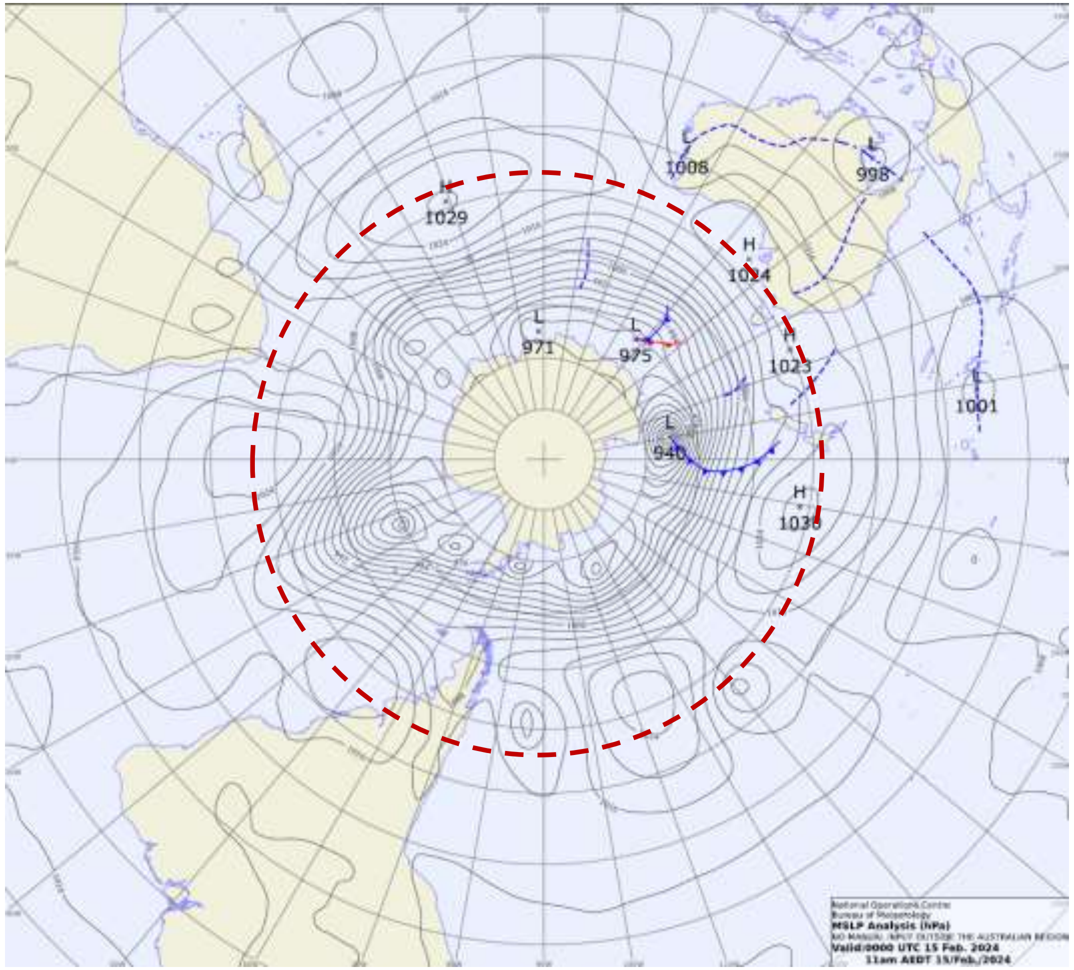
Year to year variability influencing moisture availability and atmospheric circulation

Southern Annular Mode (SAM)

- Measure of the winds and weather patterns around the Southern Hemisphere mid-latitudes



Average impact of the Southern Annular Mode ("positive" phase) on rainfall in Australia
(Composite over multiple events based on data from 1979-2005)



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Influenced by ozone depletion and volcanic events as well as GHG's

Geophysical Research Letters

Research Letter | Free Access

Observational Evidence of Increasing Global Radiative Forcing

Ryan J. Kramer, Haozhe He, Brian J. Soden, Lazaros Oreopoulos, Gunnar Myhre, Piers M. Forster, Christopher J. Smith

First published: 25 March 2021 | https://doi.org/10.1029/2020GL091585 | Citations: 31

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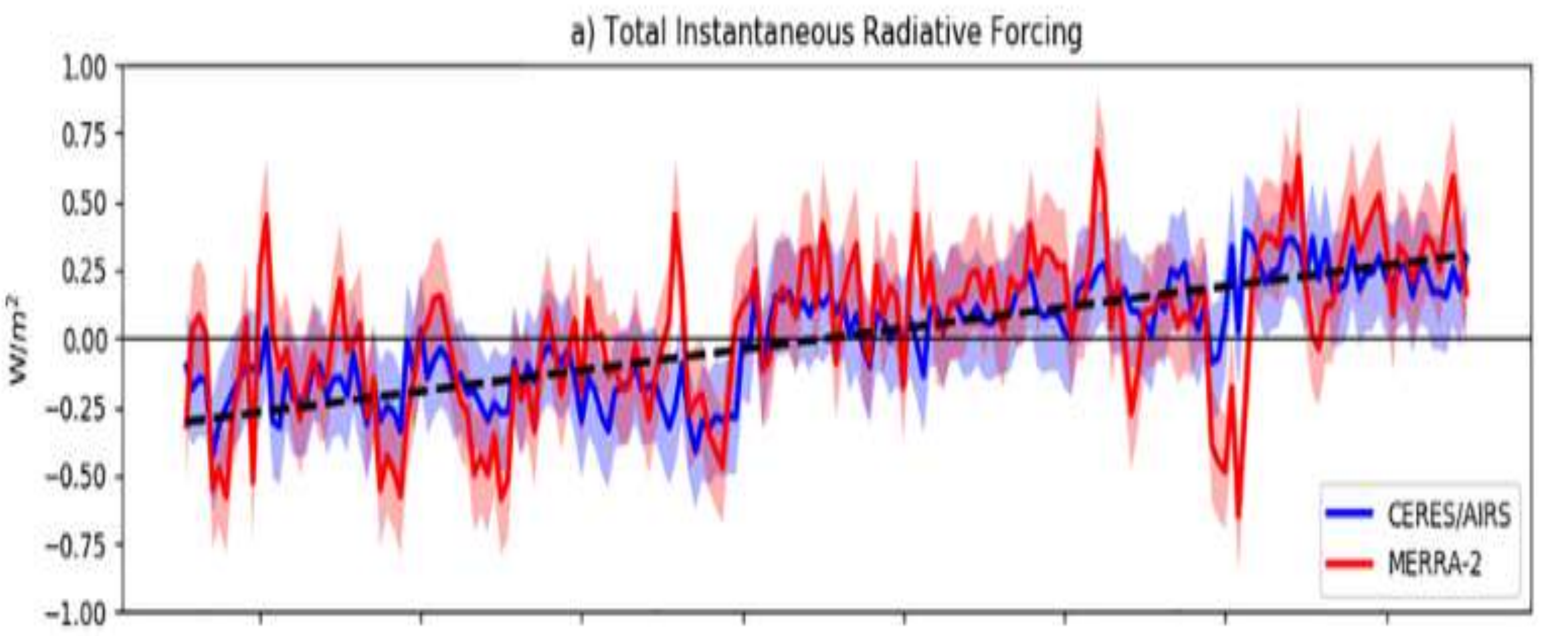
Abstract

Changes in atmospheric composition, such as increasing greenhouse gases, cause an initial radiative imbalance to the climate system, quantified as the instantaneous radiative forcing. This fundamental metric has not been directly observed globally and previous estimates have come from models. In part, this is because current space-based instruments cannot distinguish the instantaneous radiative forcing from the climate's radiative response. We apply radiative kernels to satellite observations to disentangle these components and find all-sky instantaneous radiative forcing has increased 0.53 ± 0.11 W/m^2 from 2003 to 2018, accounting for positive trends in the total planetary radiative imbalance. This increase has been due to a combination of rising concentrations of well-mixed greenhouse gases and recent reductions in aerosol emissions. These results highlight distinct fingerprints of anthropogenic activity in Earth's changing energy budget, which we find observations can detect within 4 years.



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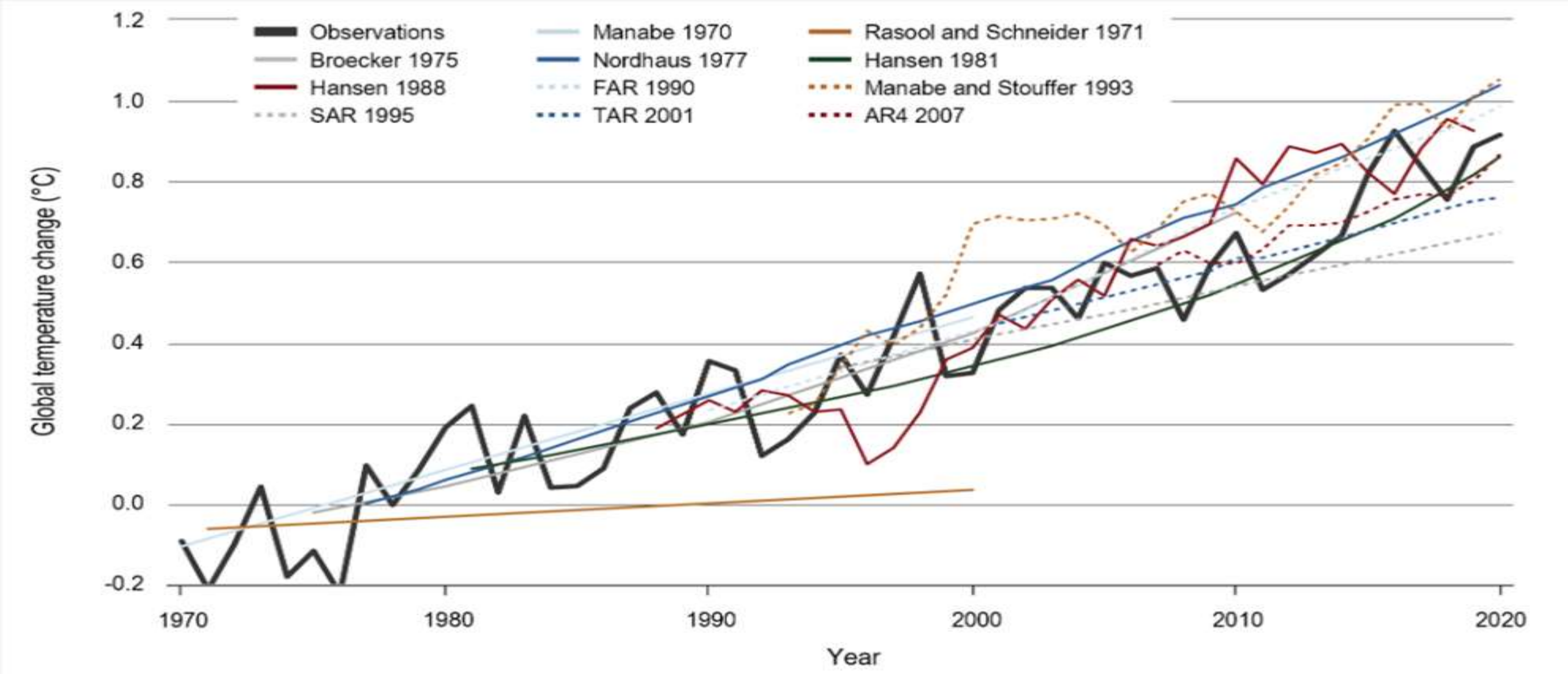
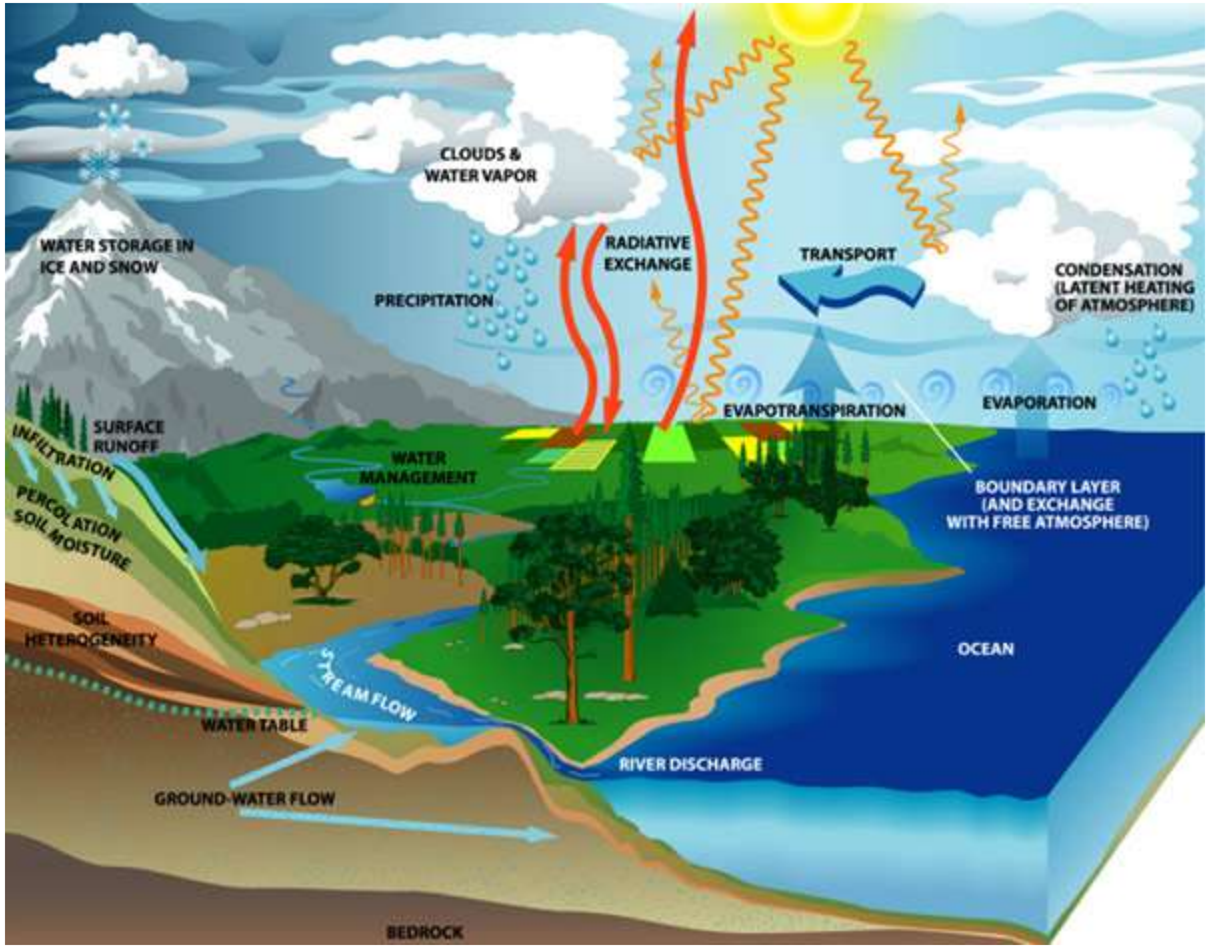
Direct observational evidence from satellite and surface data of the impacts of increasing greenhouse gases in the atmosphere

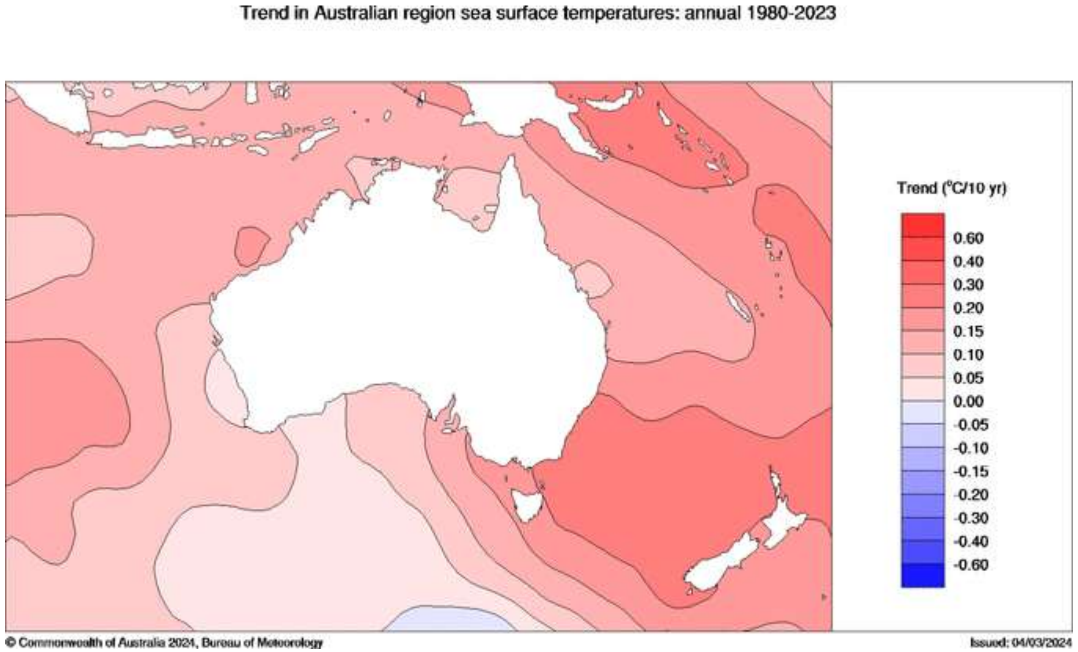


Global climate models have been capturing the broad global response to climate forcings quite well for decades.

This is strong evidence that the general response of the climate to increasing greenhouse gases is well understood

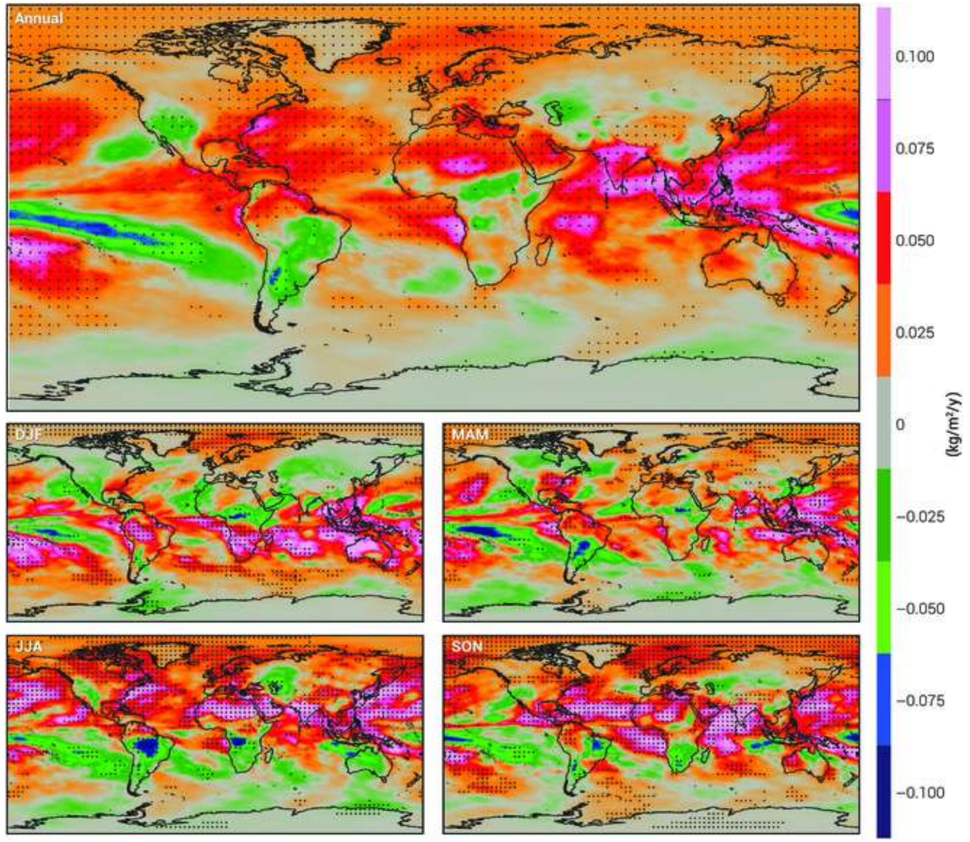
Hydrological cycle intensification

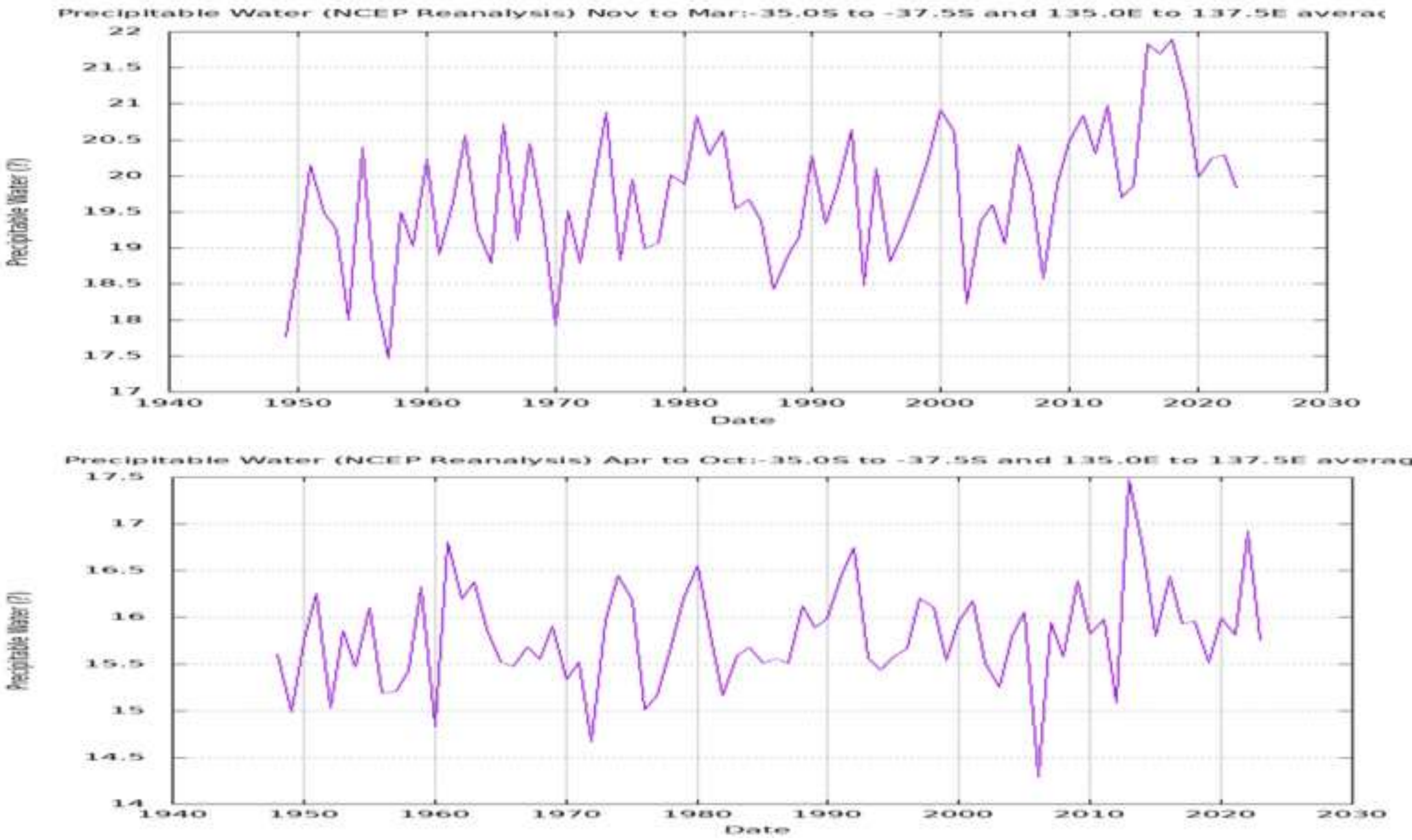




- Warming oceans around Australia to enhance moisture availability

Atmosphere is holding more moisture





[Patel and Kuppitturath (2023)]

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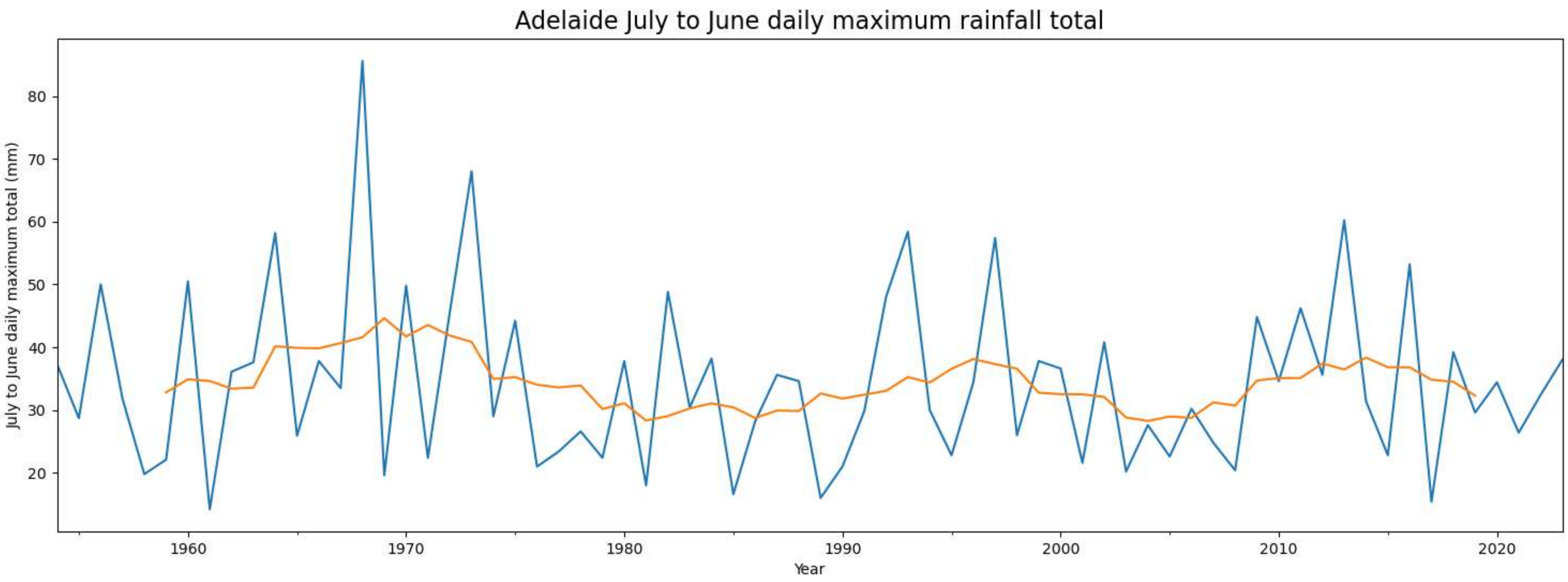
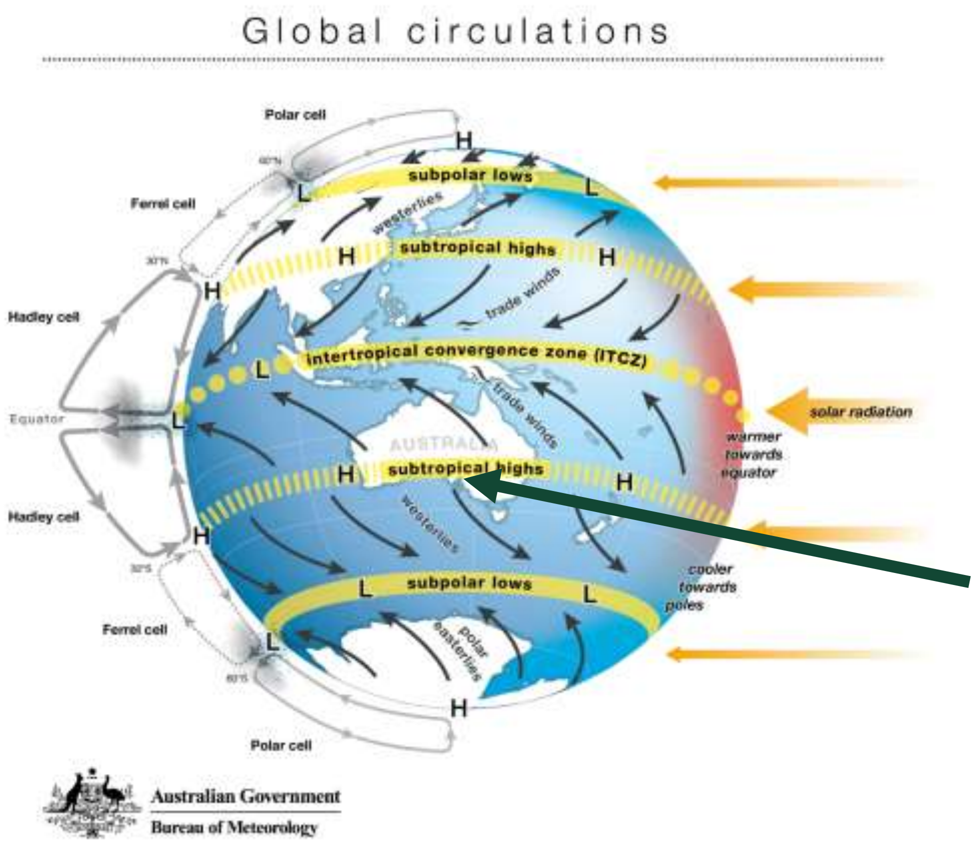
- More moisture available in spring/summer from the Pacific Warm Pool

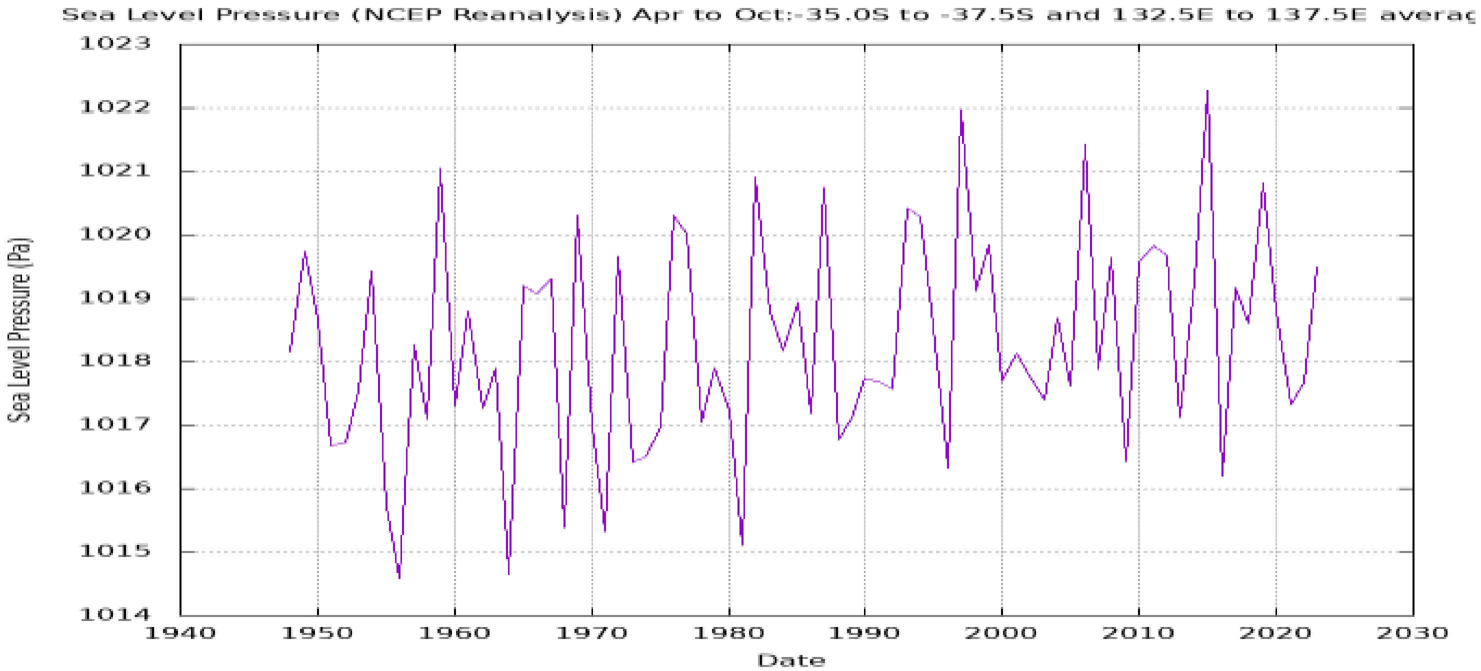
Observed daily scale rainfall extremes



- Multi-decadal variability on a slight decreasing trend?

So what's happening?





In the mid-latitudes, atmospheric changes are opposing the increasing moisture levels

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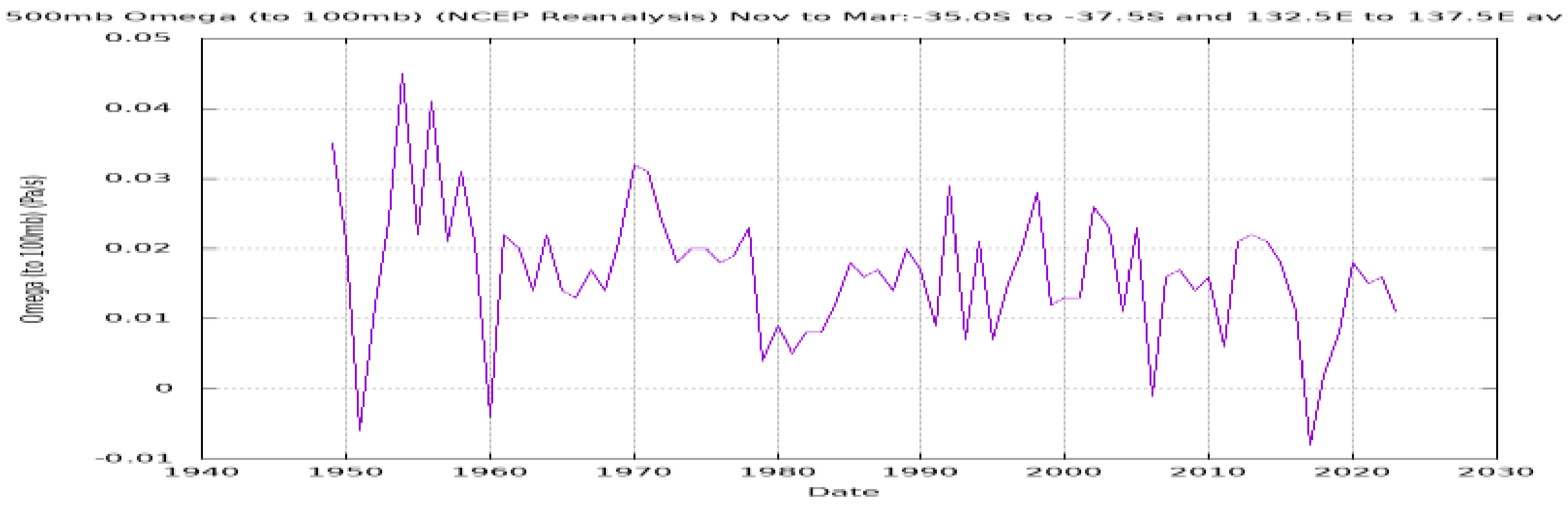
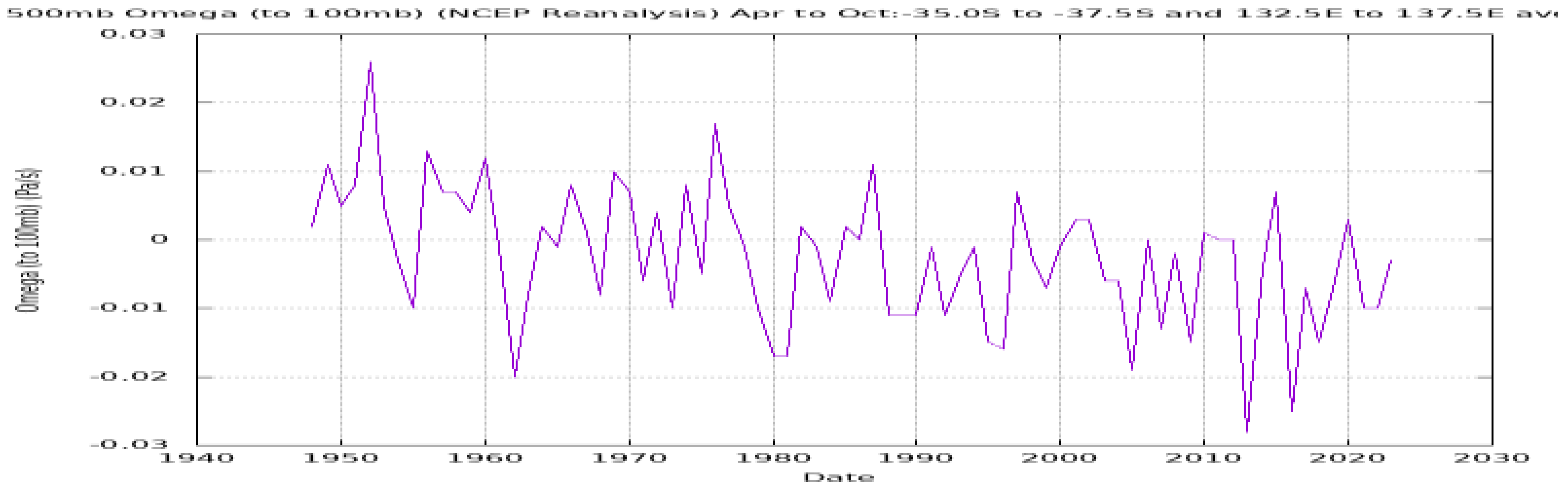
Atmosphere in the mid-latitudes is sinking down more, opposing rainfall formation

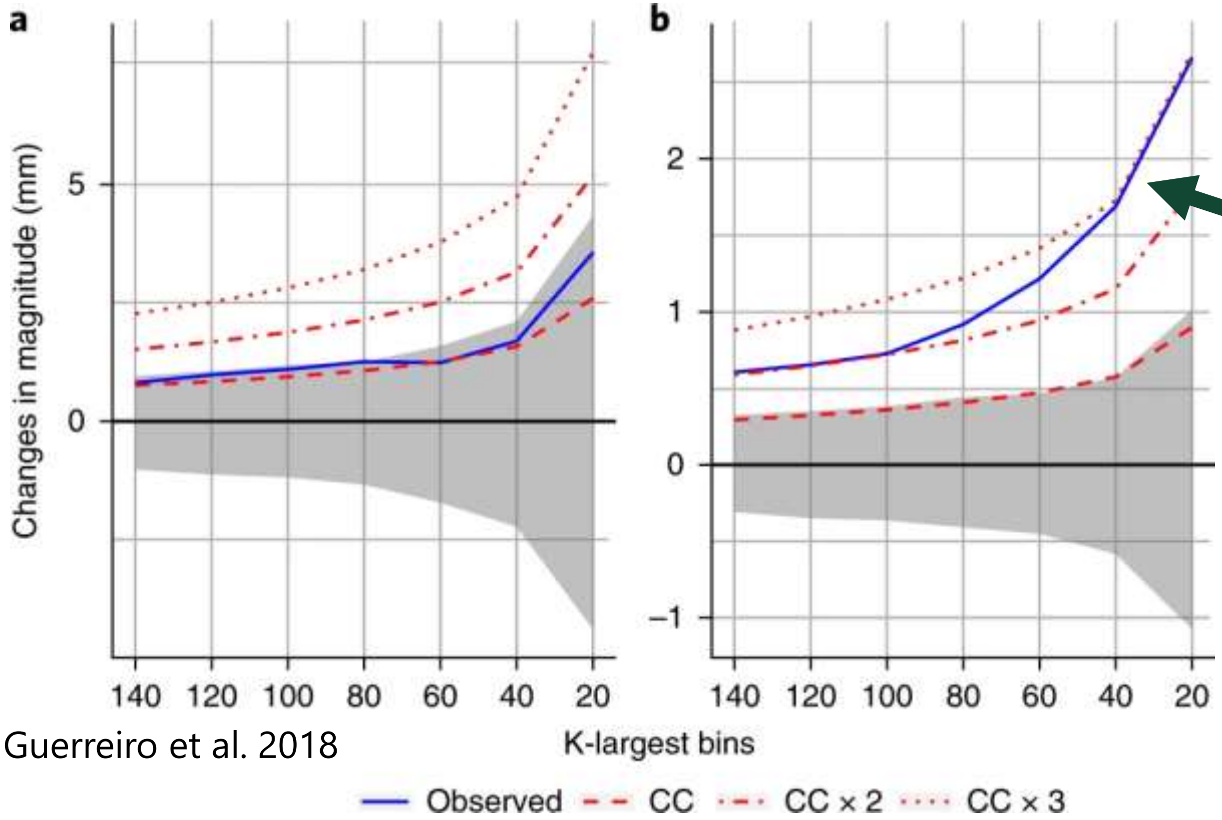




Thunderstorms are driven by local scale convection and generate intense hourly or less rain events

Daily scale

Hourly scale



Guerreiro et al. 2018

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Science

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HOME > SCIENCE > VOL. 378, NO. 6620 > INTENSIFICATION OF SUBHOURLY HEAVY RAINFALL

REPORT | RAINFALL EXTREMES

Intensification of subhourly heavy rainfall

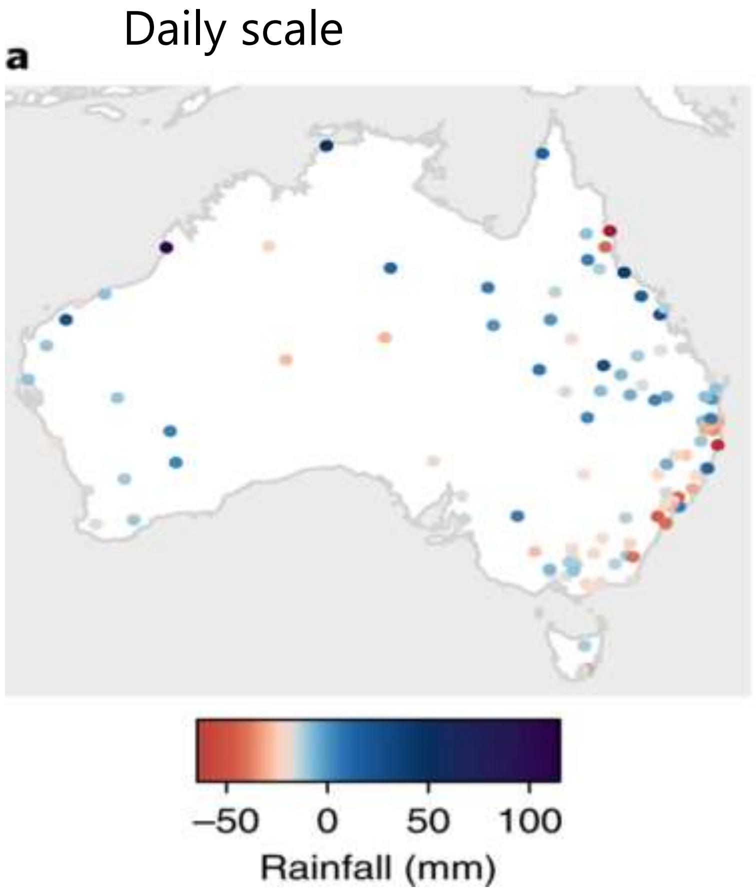
HOOMAN AYAT, JASON P. EVANS, STEVEN C. SHERWOOD, AND JOSHUA SODERHOLM Authors Info & Affiliations

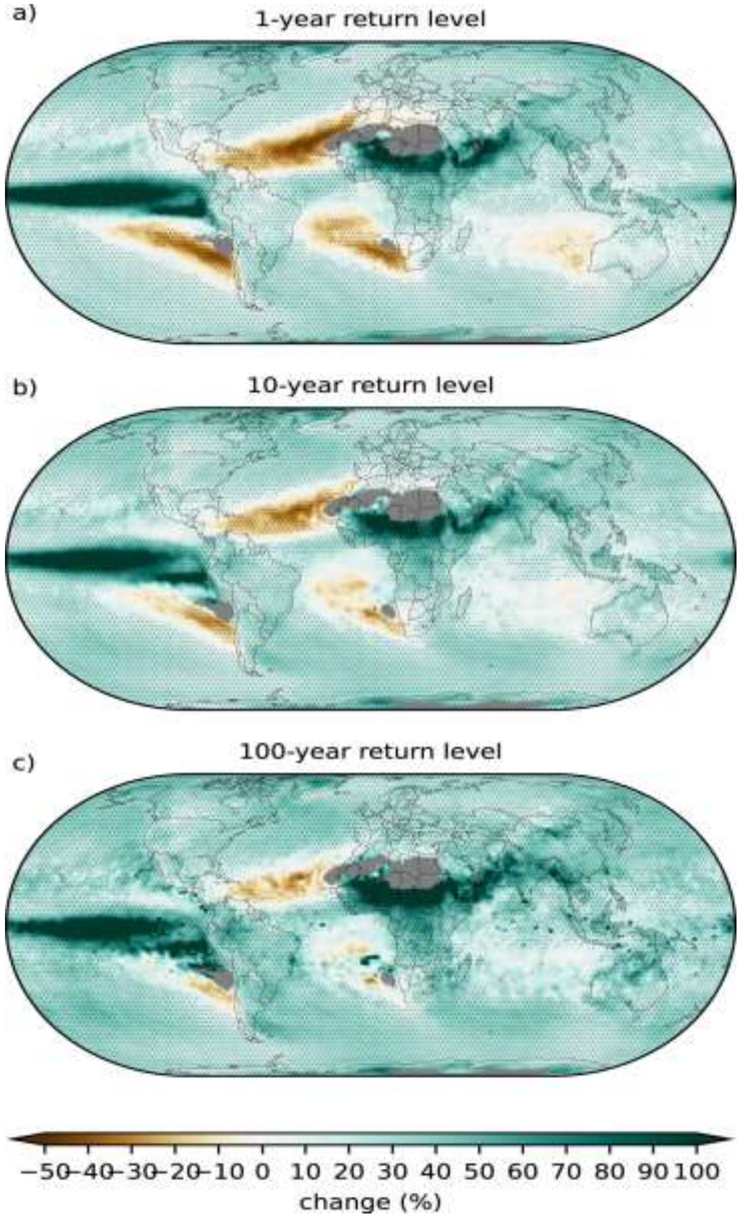
SCIENCE • 10 Nov 2022 • Vol 378, Issue 6620 • pp. 655-659 • DOI: 10.1126/science.abn8657

A hard rain is falling

Short-duration, extreme rainfall can cause dangerous flash flooding, threatening life, infrastructure and the landscape. Studies of this type of event have focused mainly on daily rain totals, not considering how precipitation might vary on shorter time scales. Ayat *et al*. analyzed subhourly rainfall extremes near Sydney, Australia, over 20 years and found that they are increasing much faster than those over longer periods. Better understanding of such extremes is vital for effective climate adaptation and to reduce the vulnerability of populated regions. —HJS

Changes in daily scale events





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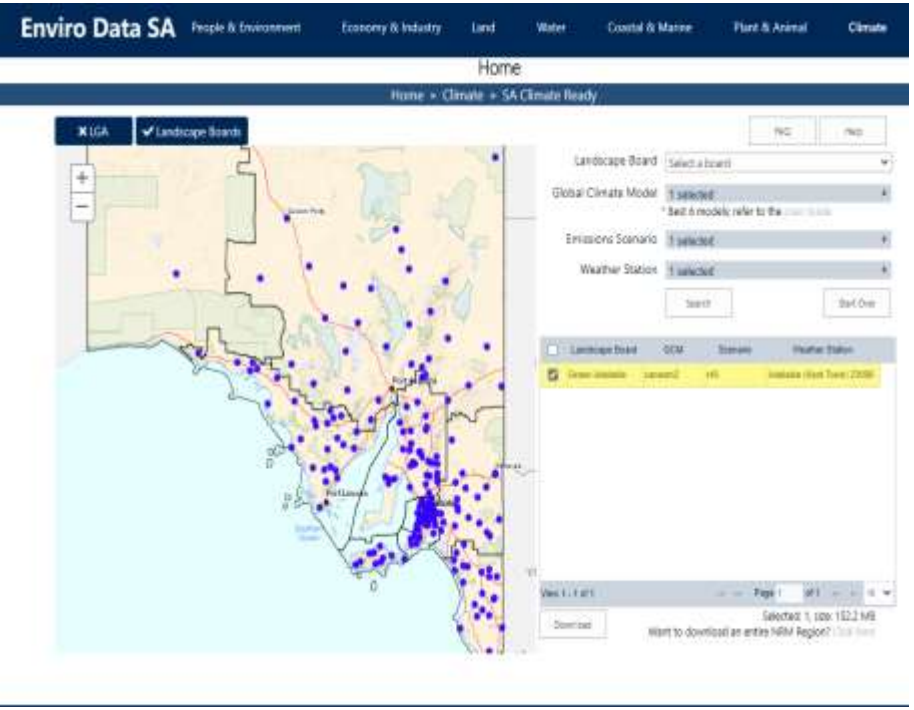
Grundemann et al. 2022

NARCLiM1.5 downscaled projections for South Australia

Goyder
- Statistically downscaled
- Good for hydrological projections
- Not mappable

NARCLIM1.5
- Regional climate model downscaling
- Mappable, more parameters
- Fully <u>daily</u> values 1951-2100
- 6 GCM/RCM combinations



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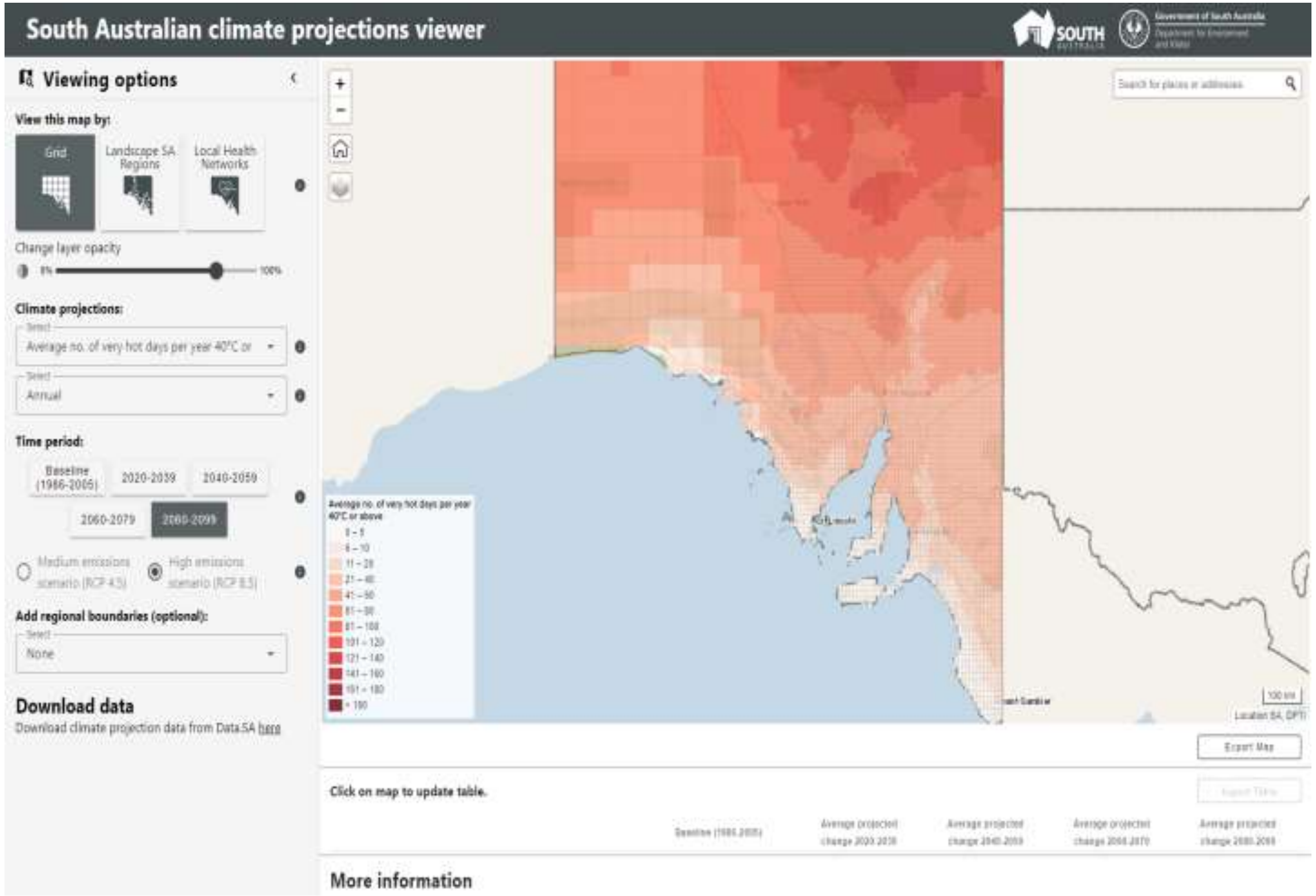
South Australia projections viewer

- NARCLiM1.5 10km resolution east of Streaky Bay/ 50km elsewhere
- 1950 to 2100 at daily scale
- 6 global to regional downscaling model combinations
- NARCLiM2.0 4km resolution projections coming
- No rainfall extremes on there yet



https://environment.sa.gov.au/climate-viewer/details/

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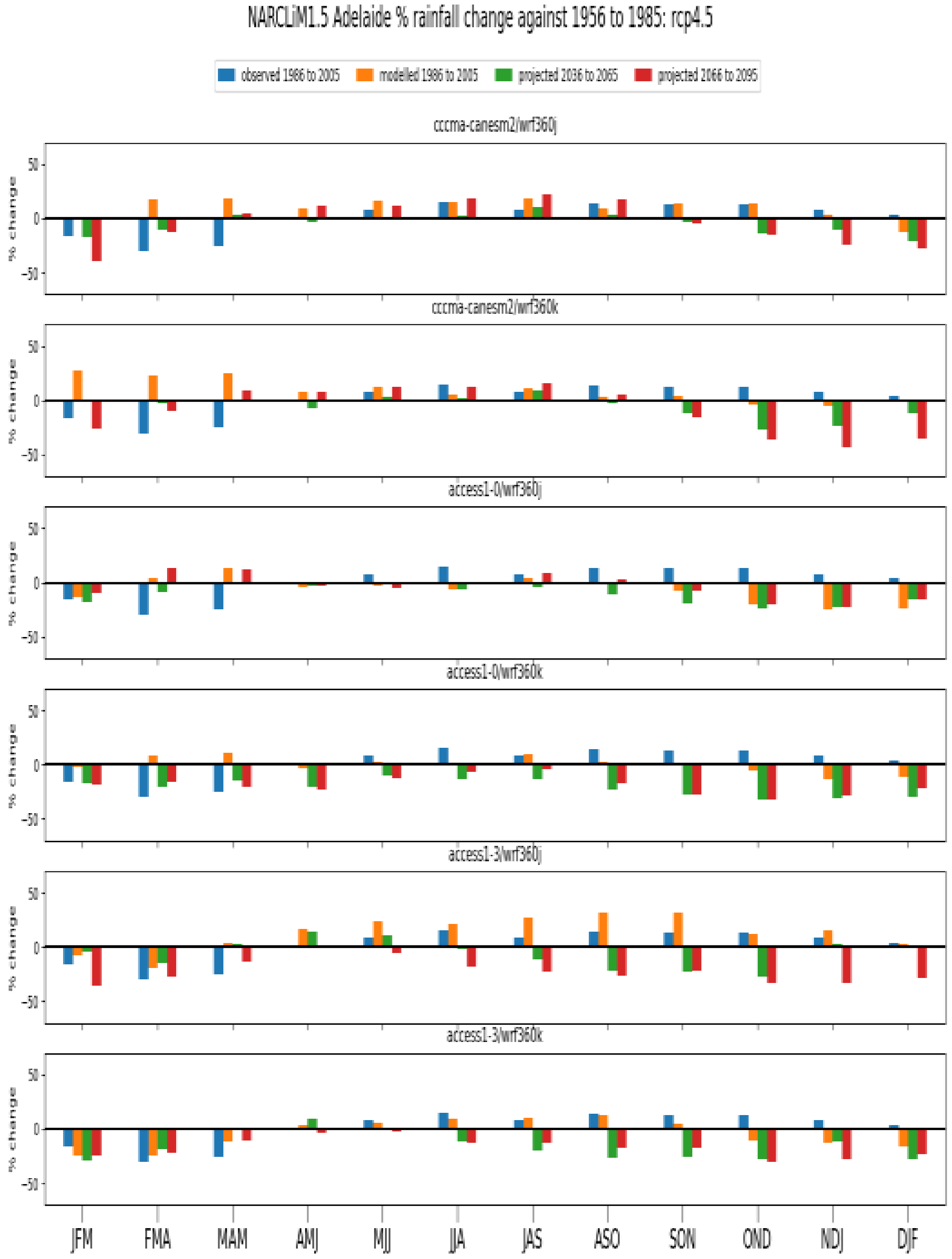
Average rainfall change

These projections suggest that the positive trend in SAM from both spring/early summer ozone depletion, and increased GHG's has influenced rainfall trends for Adelaide

Projected spring/late summer rainfall changes may be from ozone recovery

But modelling of this is currently not great



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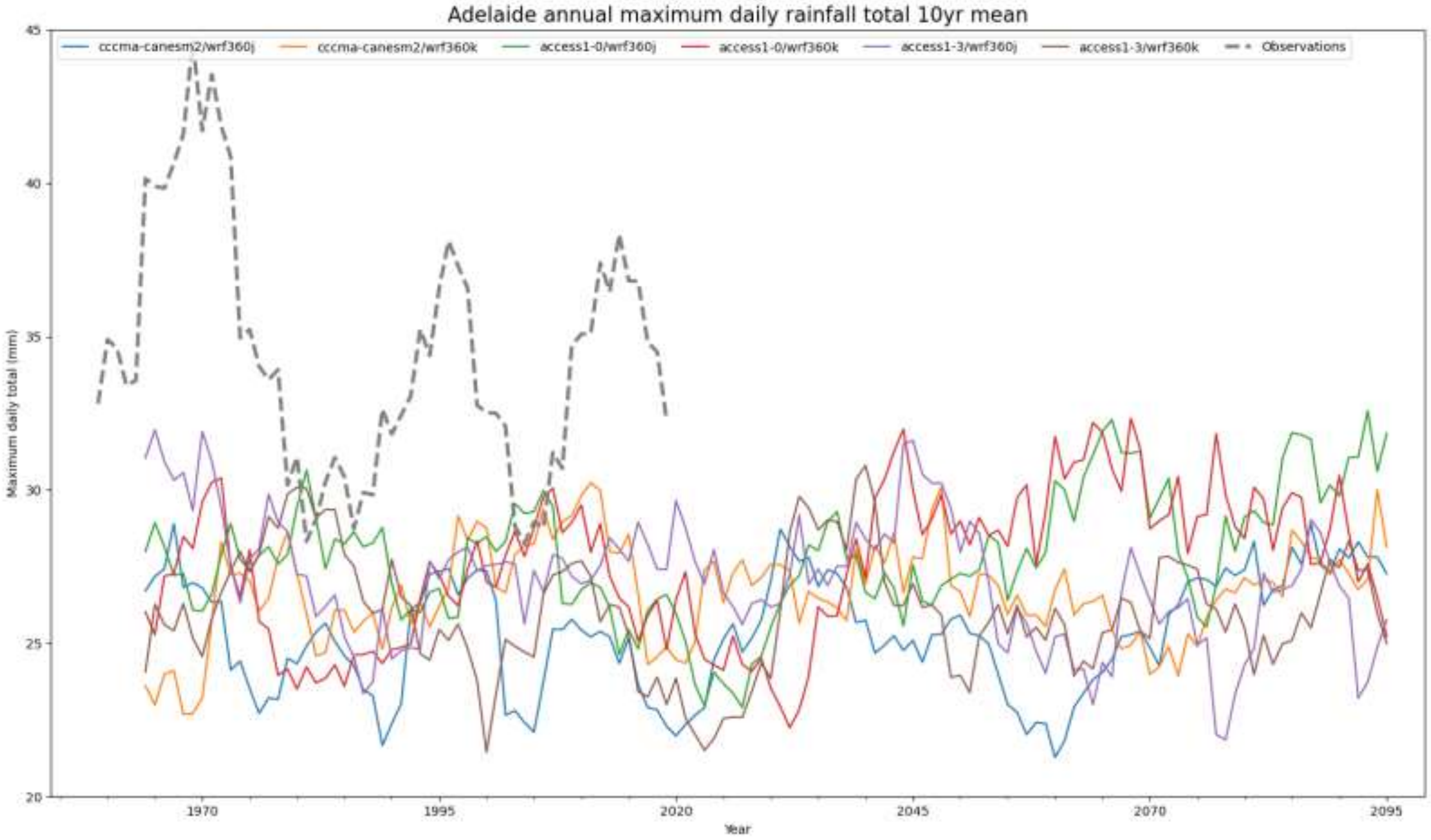
Projected daily rainfall extremes

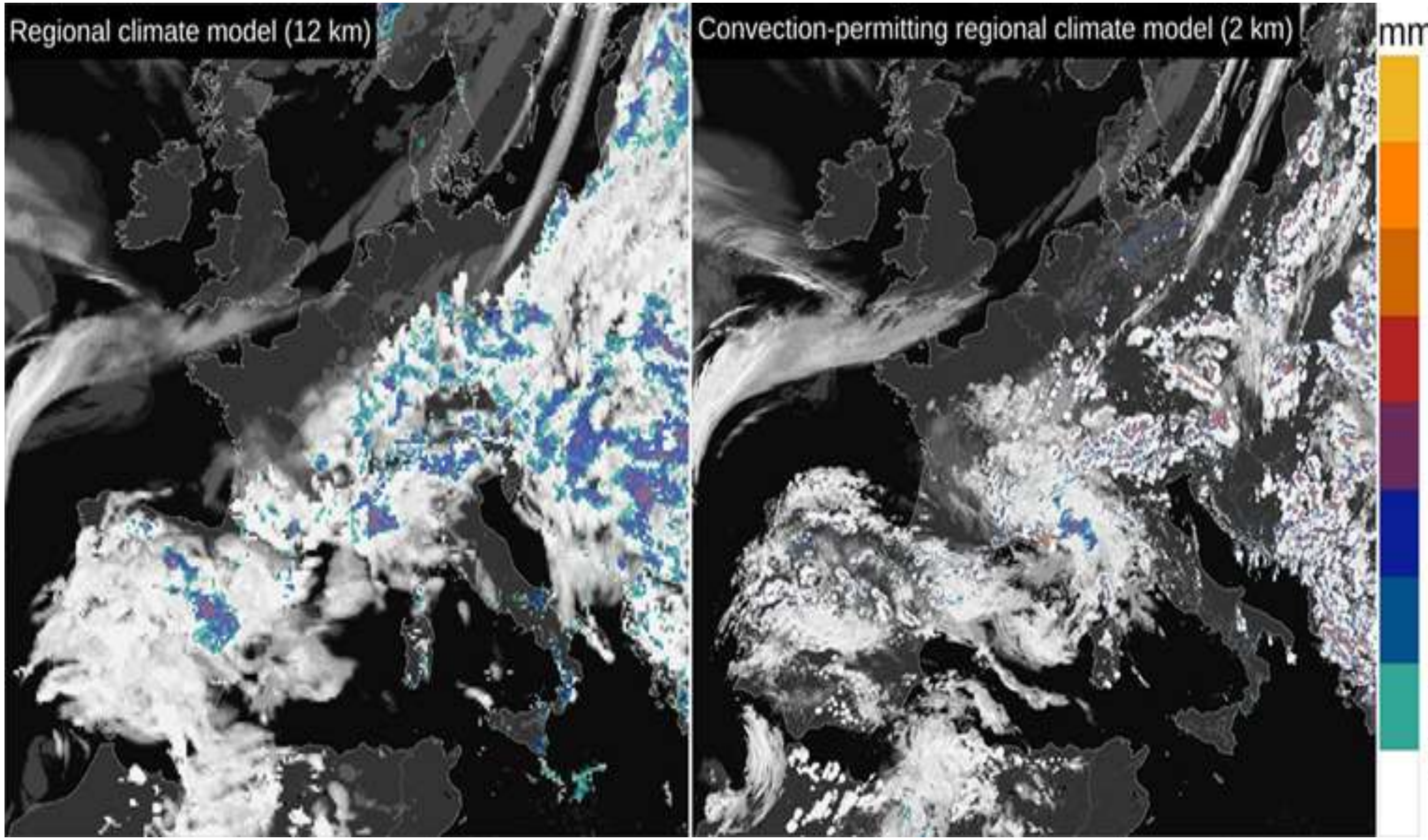
Multi-decadal variability in the observations is bigger than any projected change

Models underdoing the size of the extreme rainfall



Convection permitting modelling

- Need to be modelling at ~2km scale to capture thunderstorms properly
- Rainfall extremes are better represented in CP models [Fosser et al. 2024]
- GCM used still is a big influence



Lucas-Picher et al. 2021

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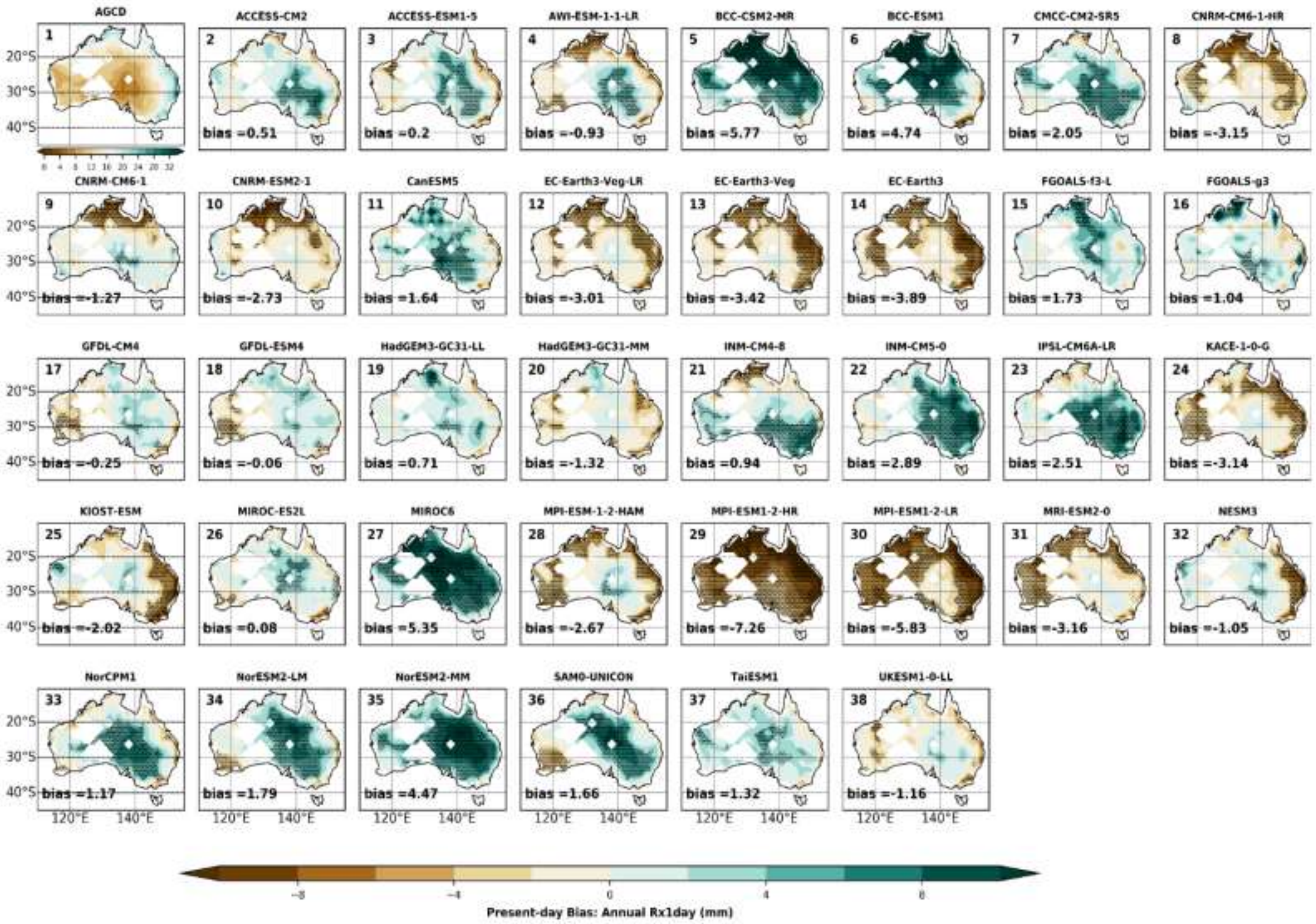
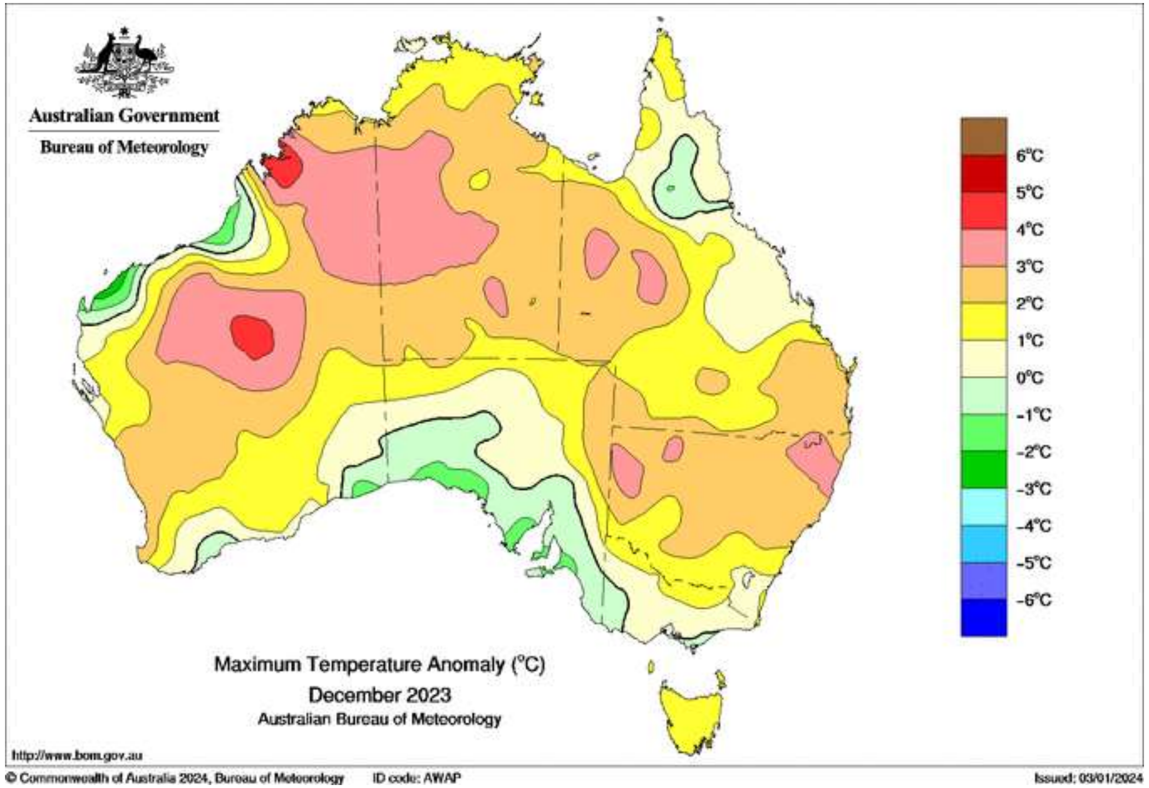
NARCLiM2.0

- 4km for eastern SA and 20km elsewhere
- Available this time in 2025
- Will improve the depiction of rainfall, but still some way to go

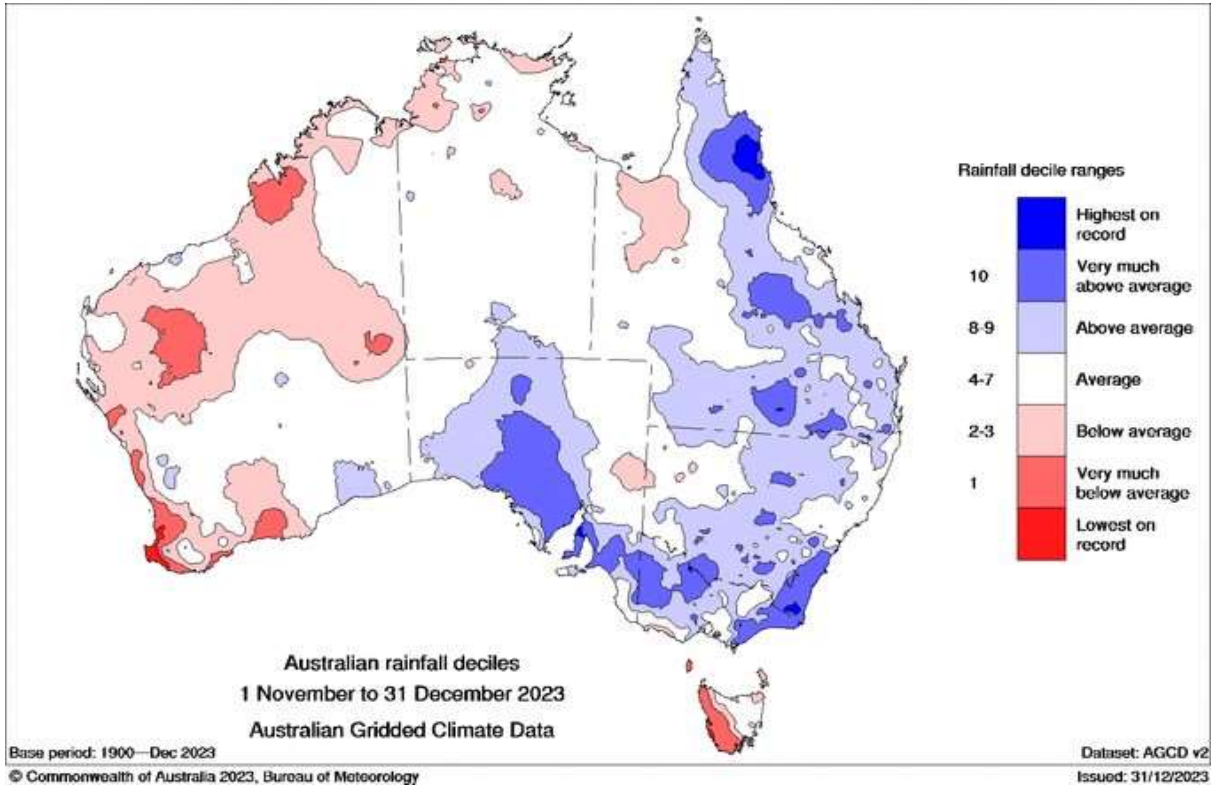


Just to complicate the picture further…

Maximum temperature



Rainfall



What happened to the 2023/24 El Nino?

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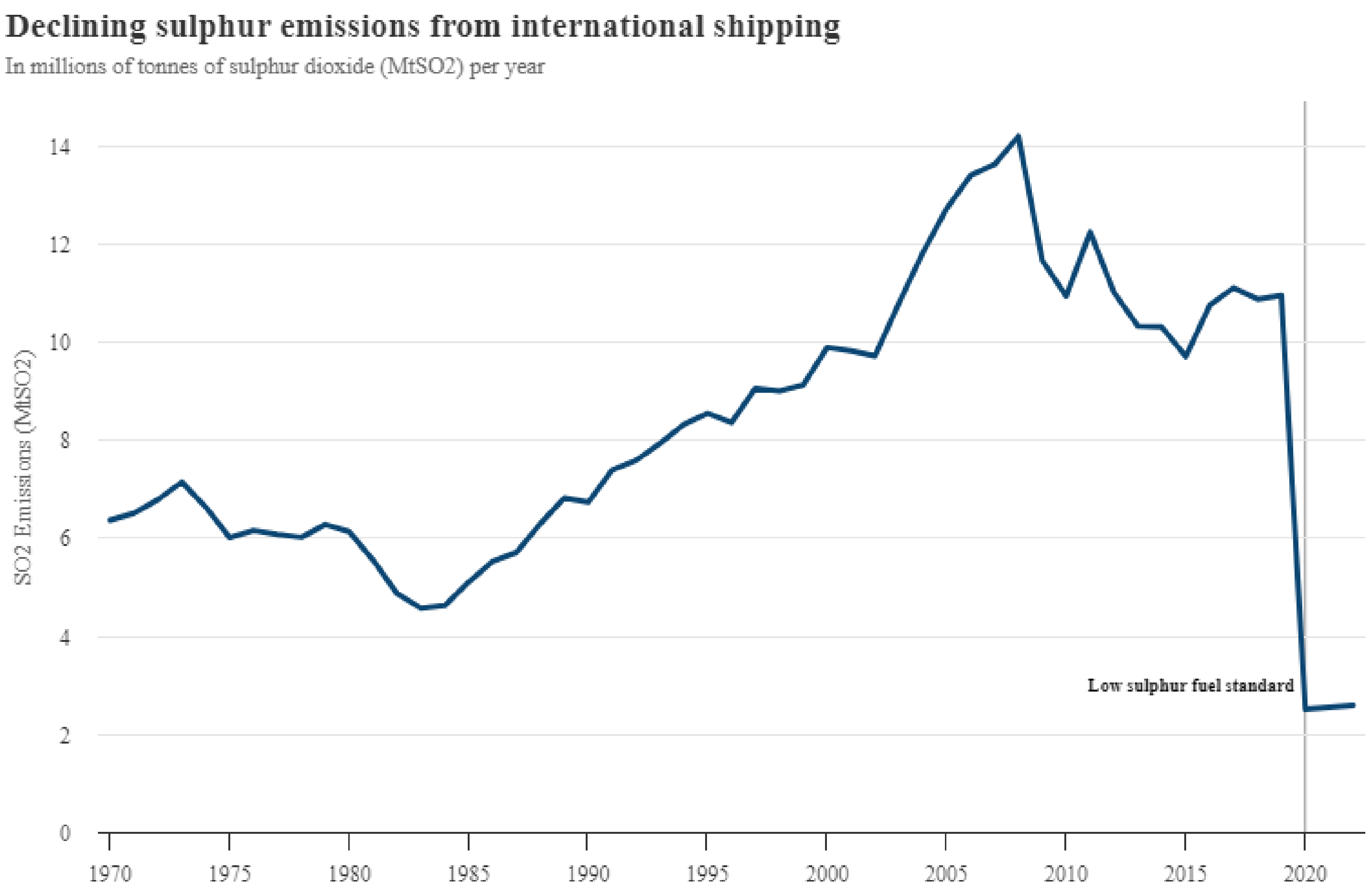
Shipping pollution changes?

- Reduced sulphur in shipping fuels reduces aerosol pollution over the oceans
- Likely to be a contributor to recent warm ocean conditions



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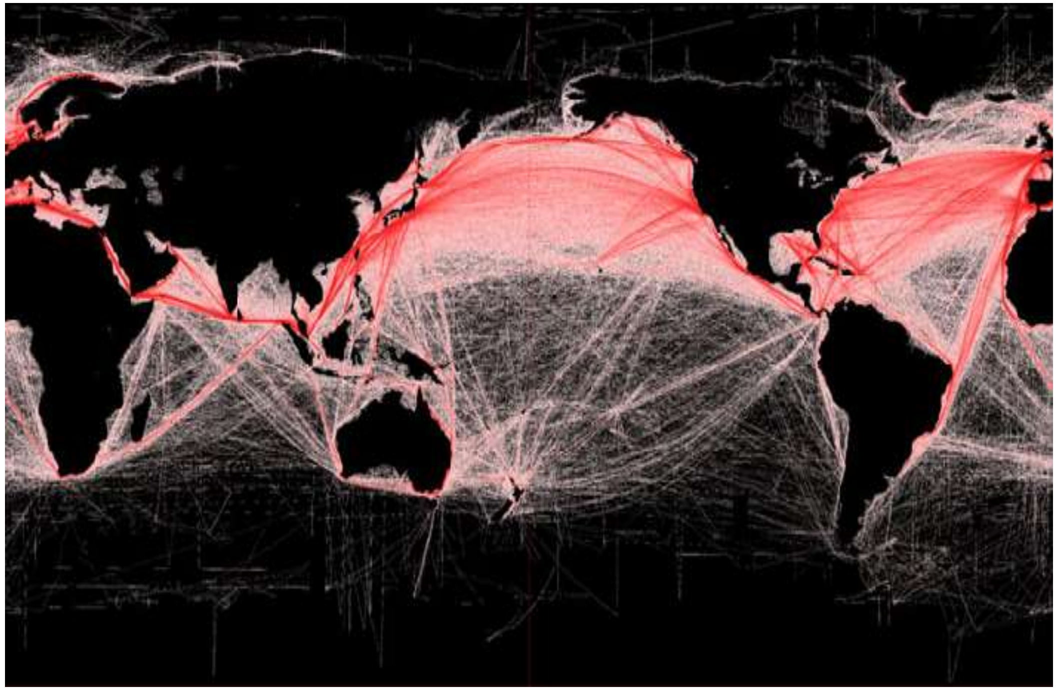
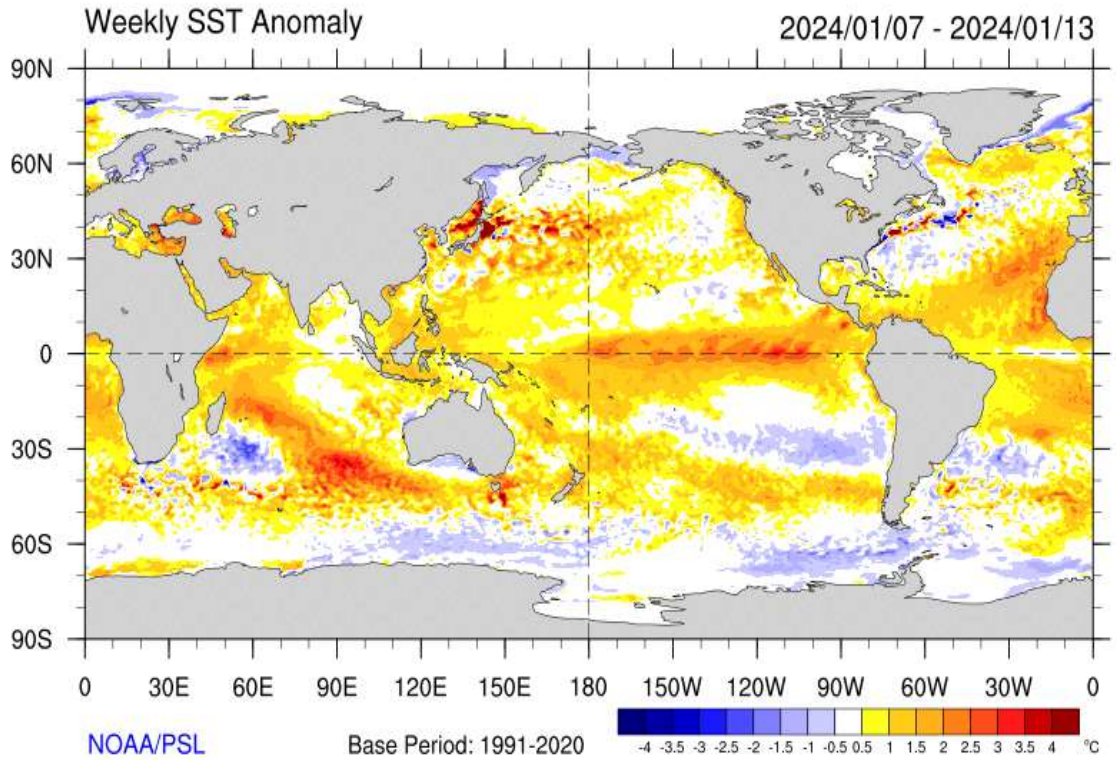
Shipping pollution?

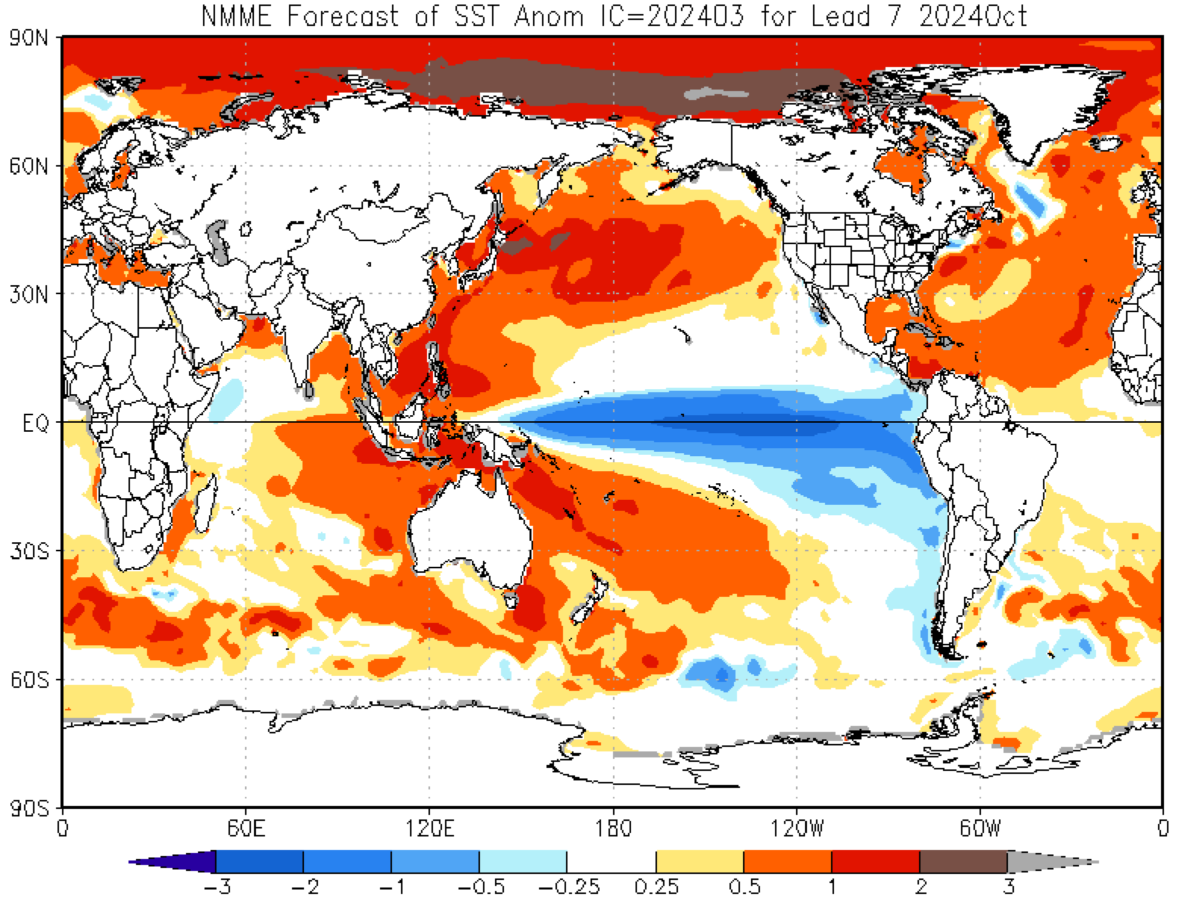


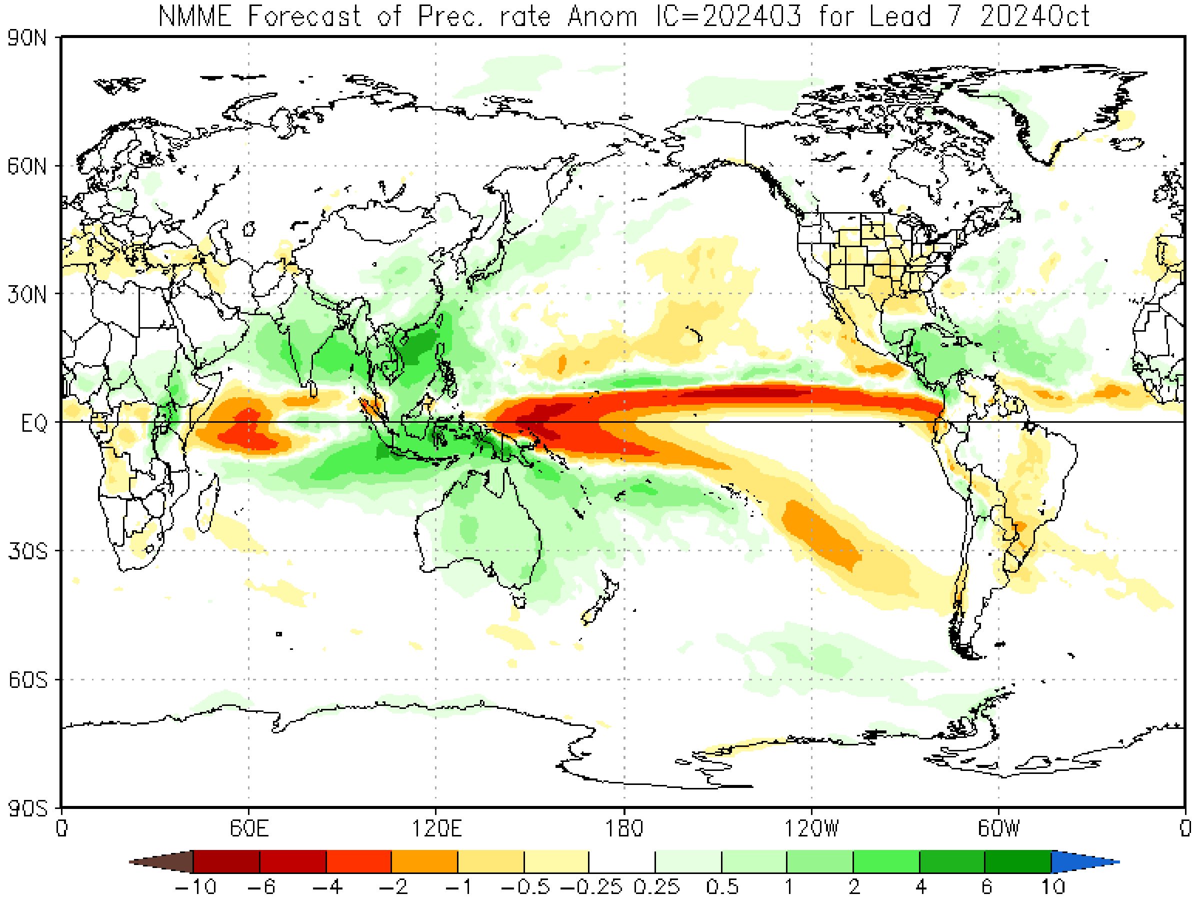
Shipping routes



Difference from average of ocean surface temperature

La Niña, -IOD, and record flooding in second half 2024?





- The possibility of a combination of record ocean temperatures and La Niña from mid 2024 present a high risk of flooding this year

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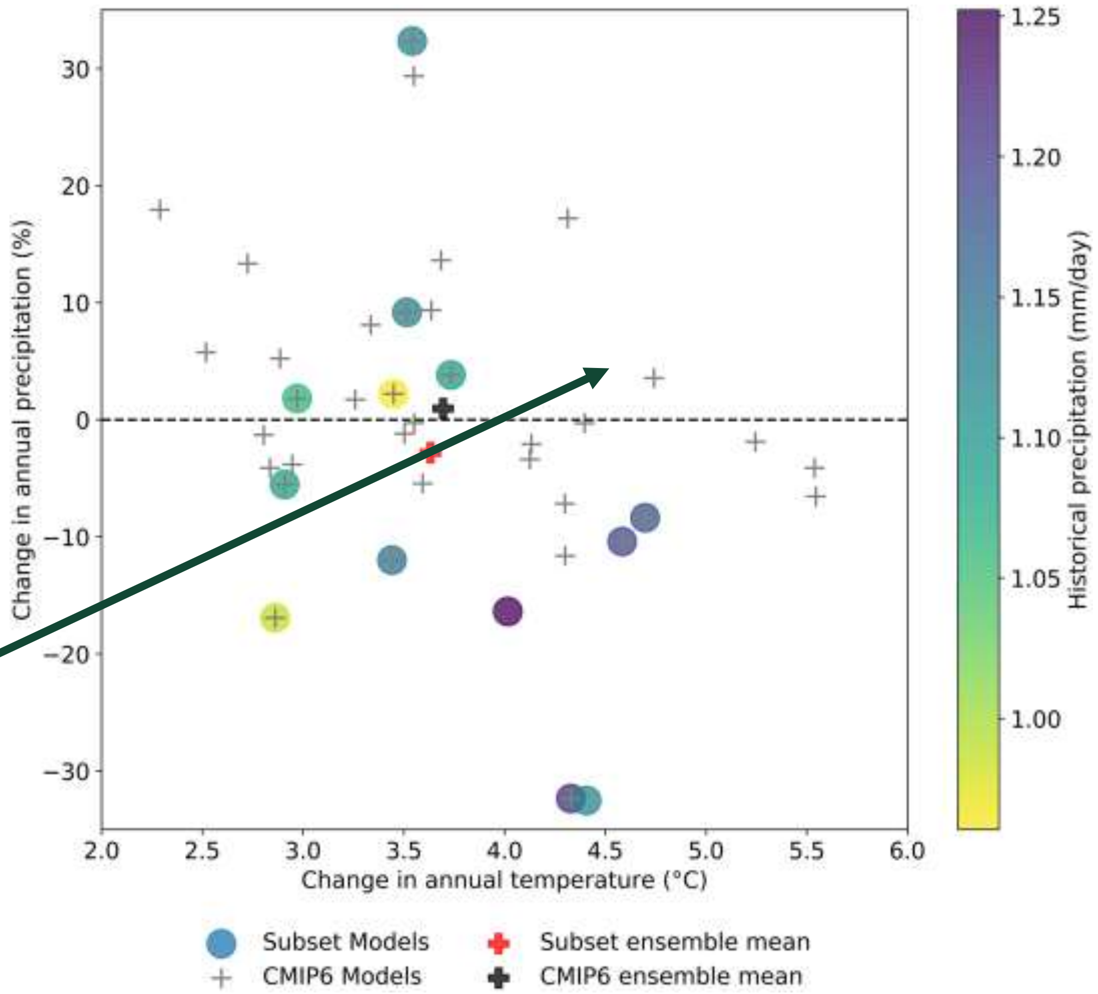
Ocean shutdown impacts on Australia?

- AMOC ocean circulation shutdown looking more likely during the 21stC
- Could lock in La Niña conditions with a strong increase in temperatures (hot/wet scenario)
- Not necessarily captured well in the modelling



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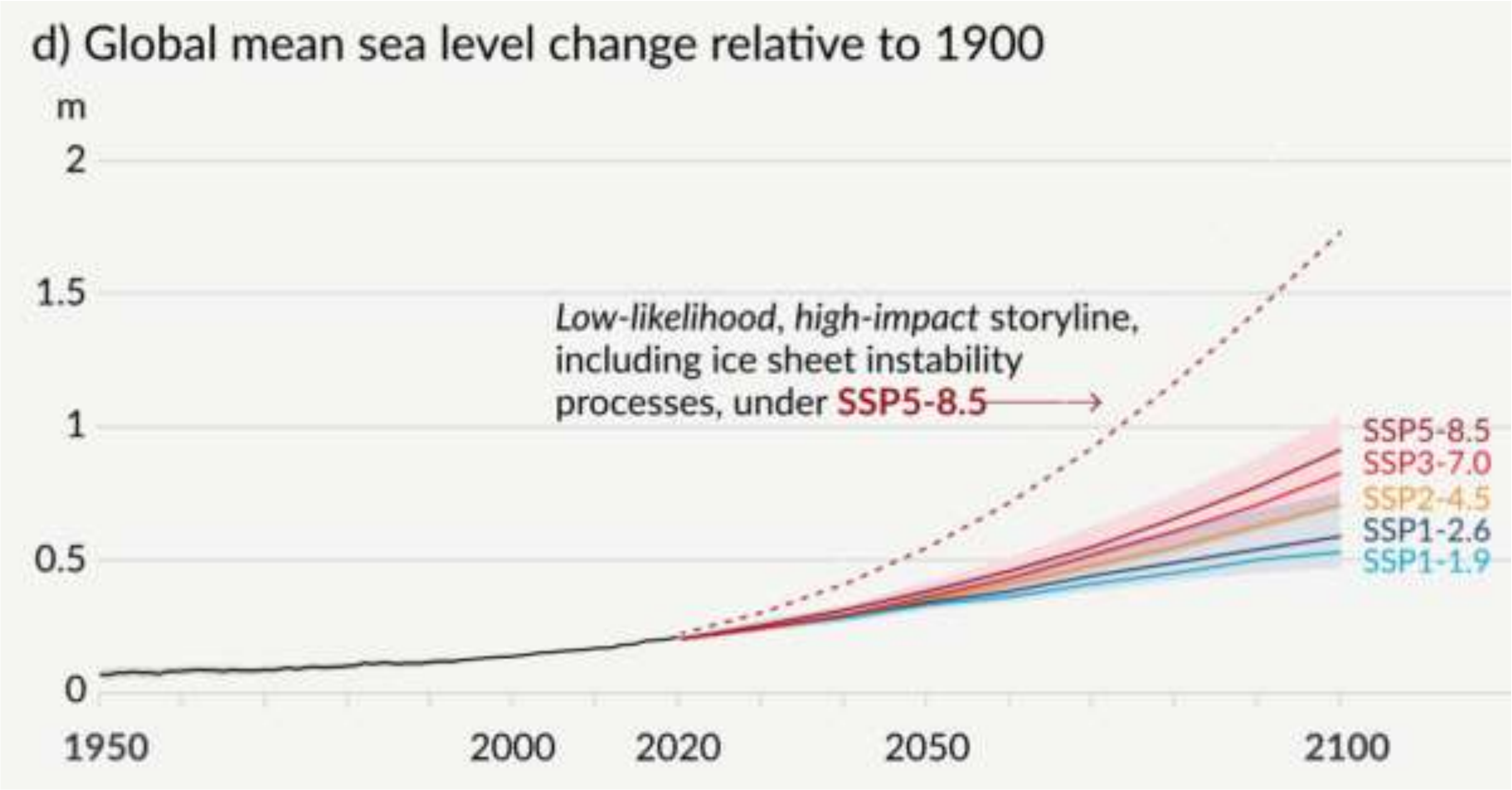
Sea level rise and coastal infrastructure



- Recent work on icesheets in Greenland and West Antarctica indicates high sensitivity
- The IPCC AR6 low-likelihood high impact sea level rise scenario is starting to look more likely

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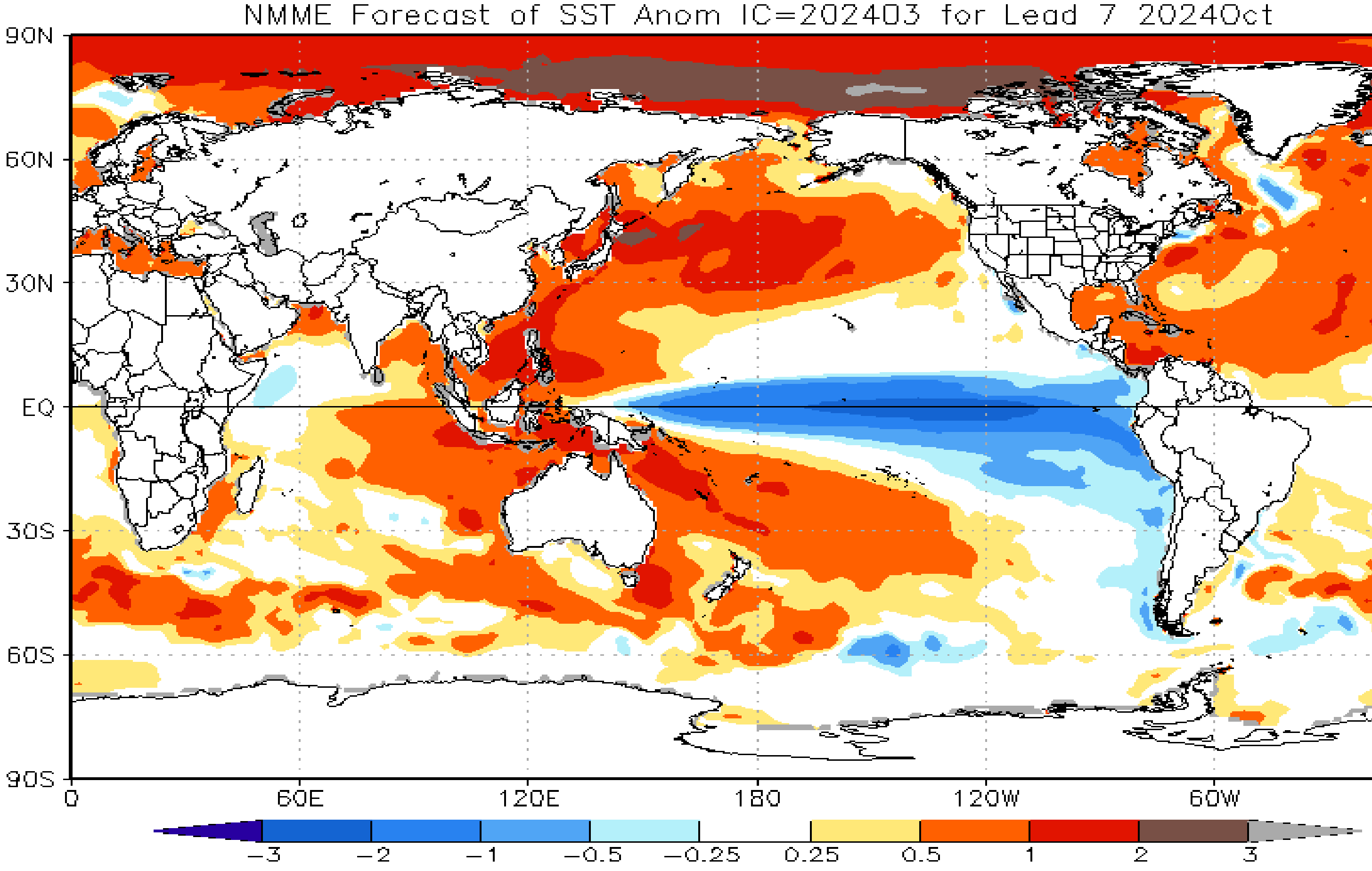
Summary

- Clear evidence of ocean warming and increased moisture availability for rainfall
- Daily rainfall extremes are increasing in <u>tropical areas</u>
- Sub-daily rainfall totals are strongly increasing in many areas
- Adelaide daily rainfall extremes show no strong trend- some multi-decadal variability - despite increased atmospheric moisture
- Atmosphere is opposing the increased moisture
- Drying is projected for average rainfall – though some recovery in winter may occur
- Projections of rainfall extremes are difficult – need convective modelling

Wet in second half of 2024?



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