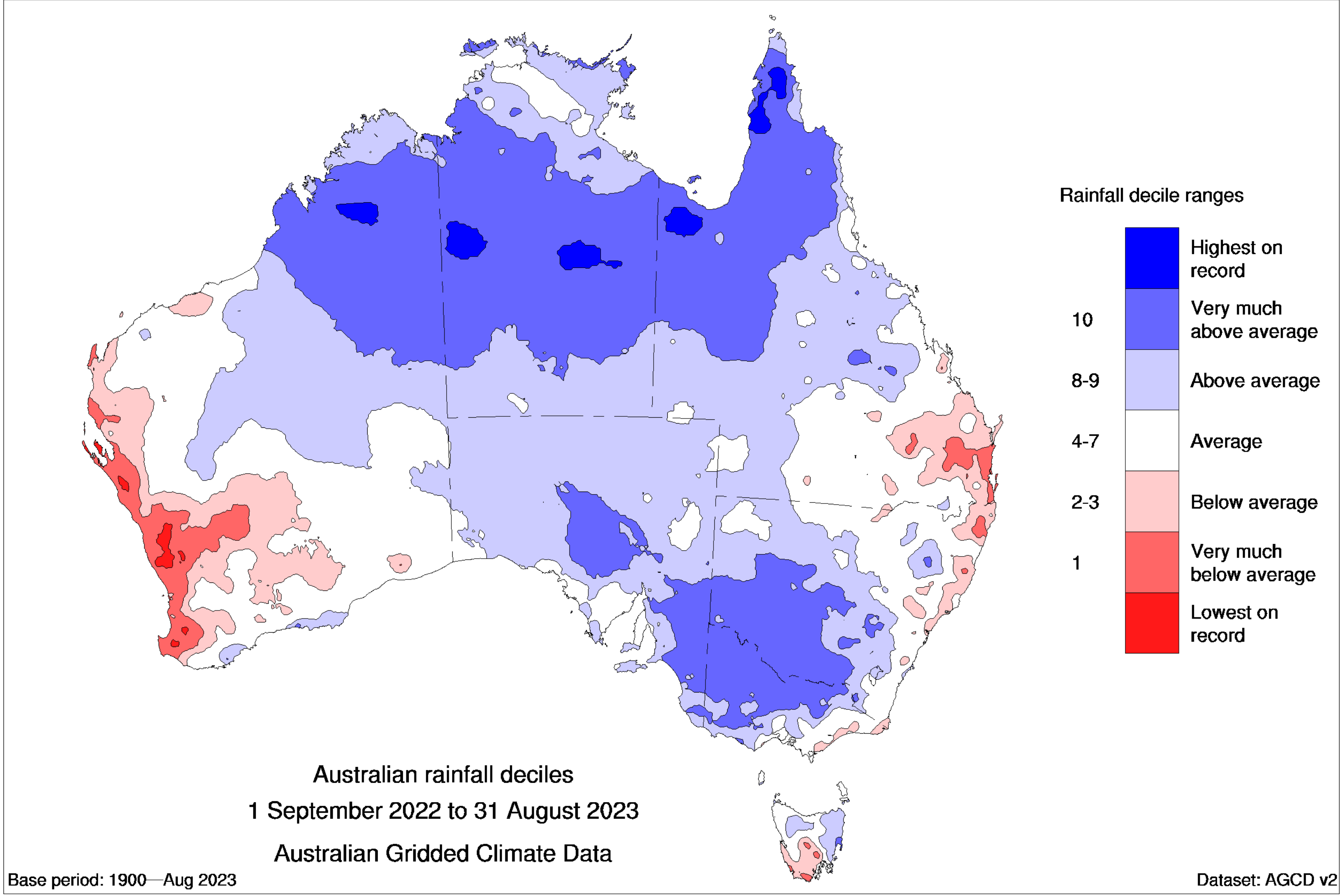
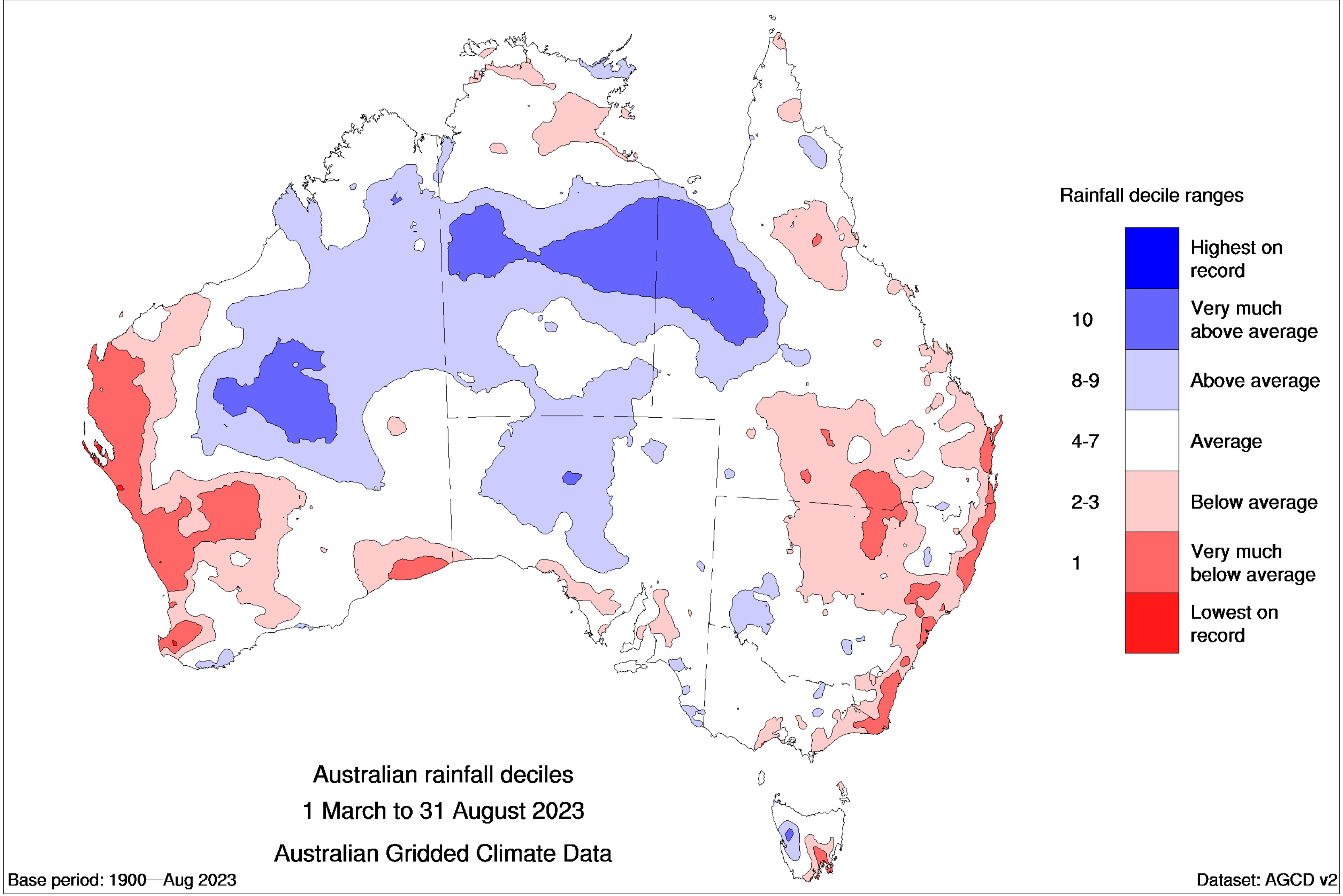
Future precipitation (as far as it's known)

Dr Michael Hewson (Senior Lecturer Geography)

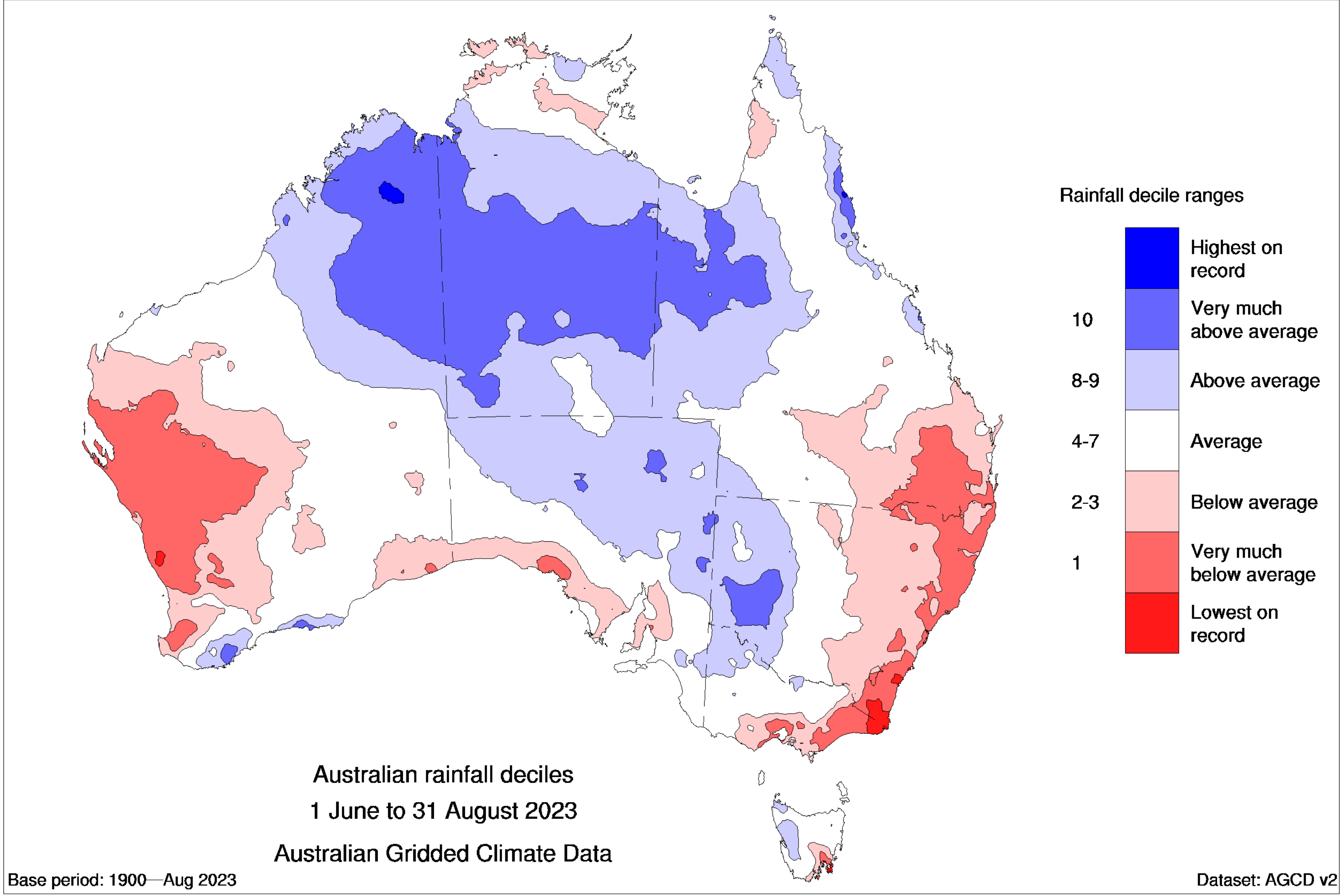
CQUniversity AUSTRALIA



Issued: 31/08/2023

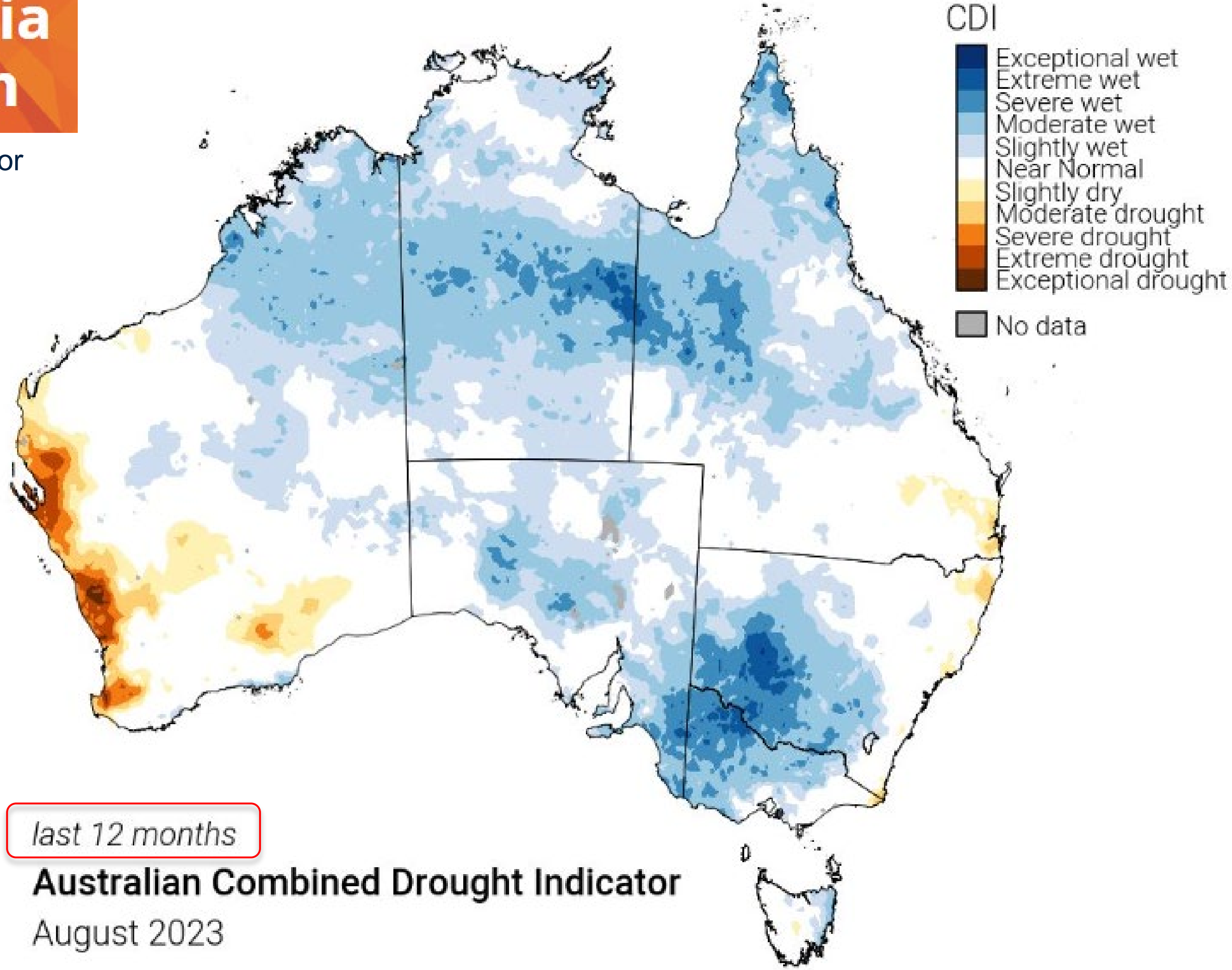


Issued: 31/08/2023


Rainfall decile ranges
Highest on record
10
Very much above average
8-9
Above average
4-7
Average
2-3
Below average
1
Very much below average
Lowest on record
Australian rainfall deciles
1 June to 31 August 2023
Australian Gridded Climate Data
Base period: 1900—Aug 2023
Dataset: AGCD v2
Issued: 31/08/2023

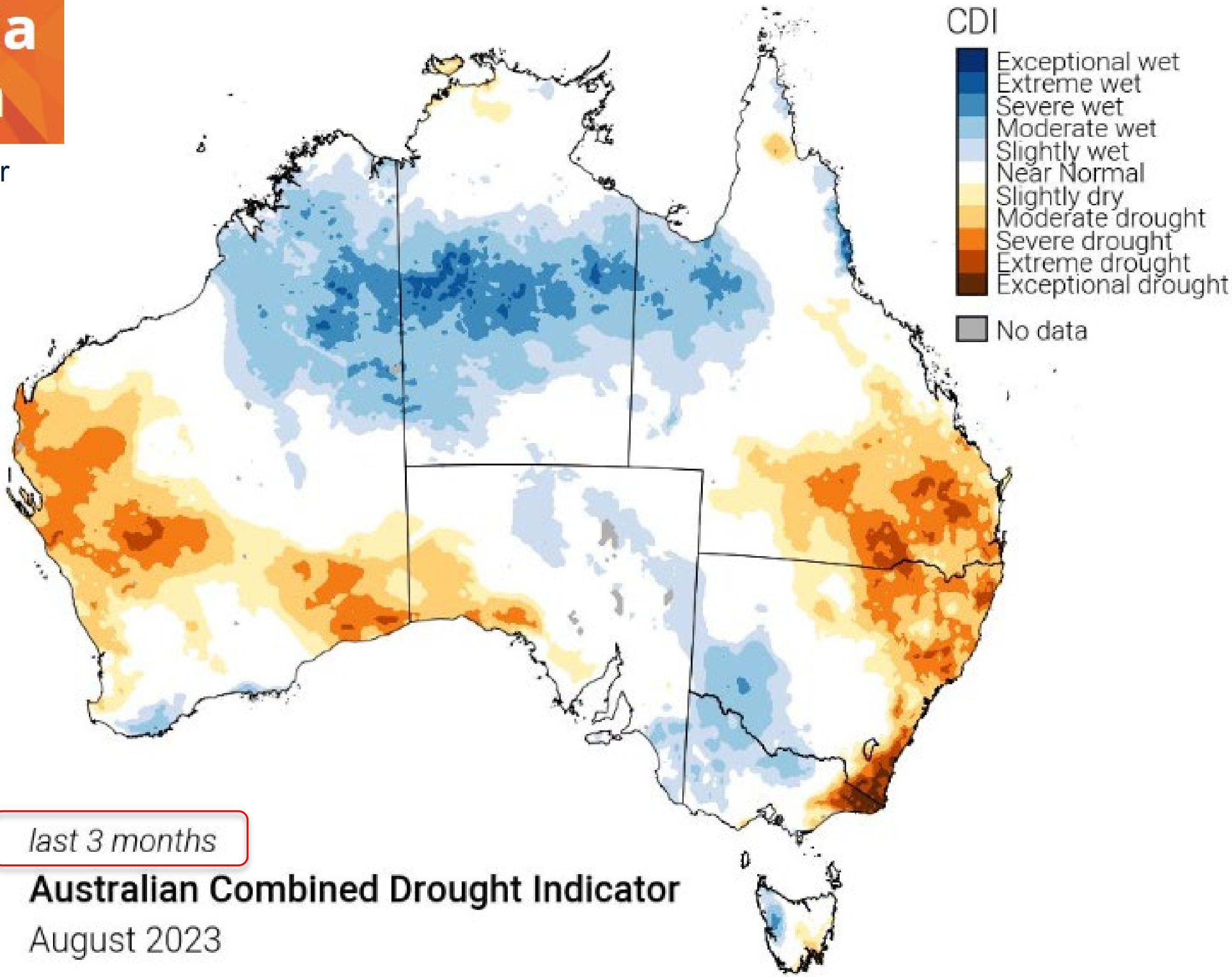
Northern Australia Climate Program

https://www.nacp.org.au/drought_monitor



Northern Australia Climate Program

https://www.nacp.org.au/drought_monitor



last 3 months

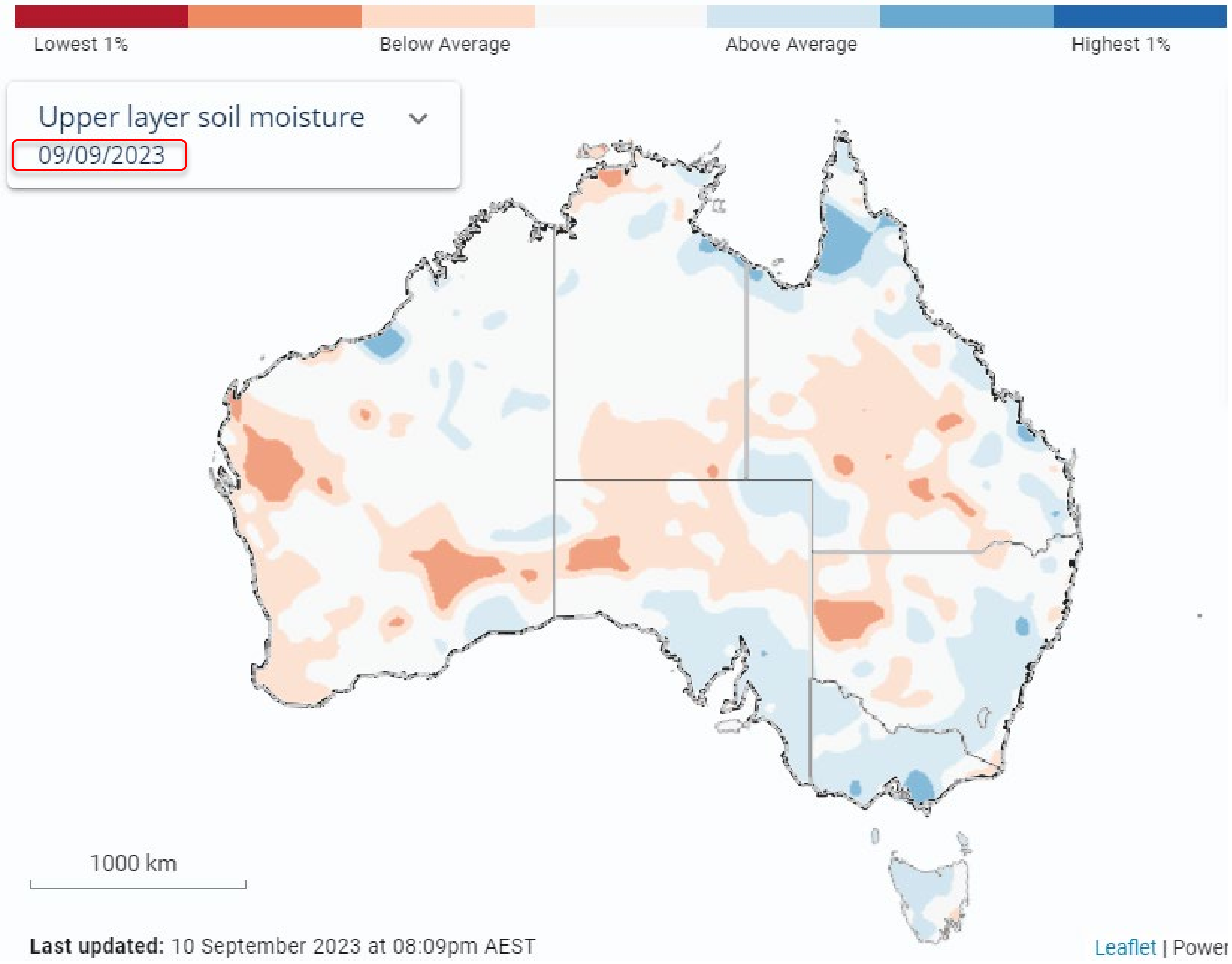
Australian Combined Drought Indicator

August 2023

Australian Government
Bureau of Meteorology

Australian Water Outlook

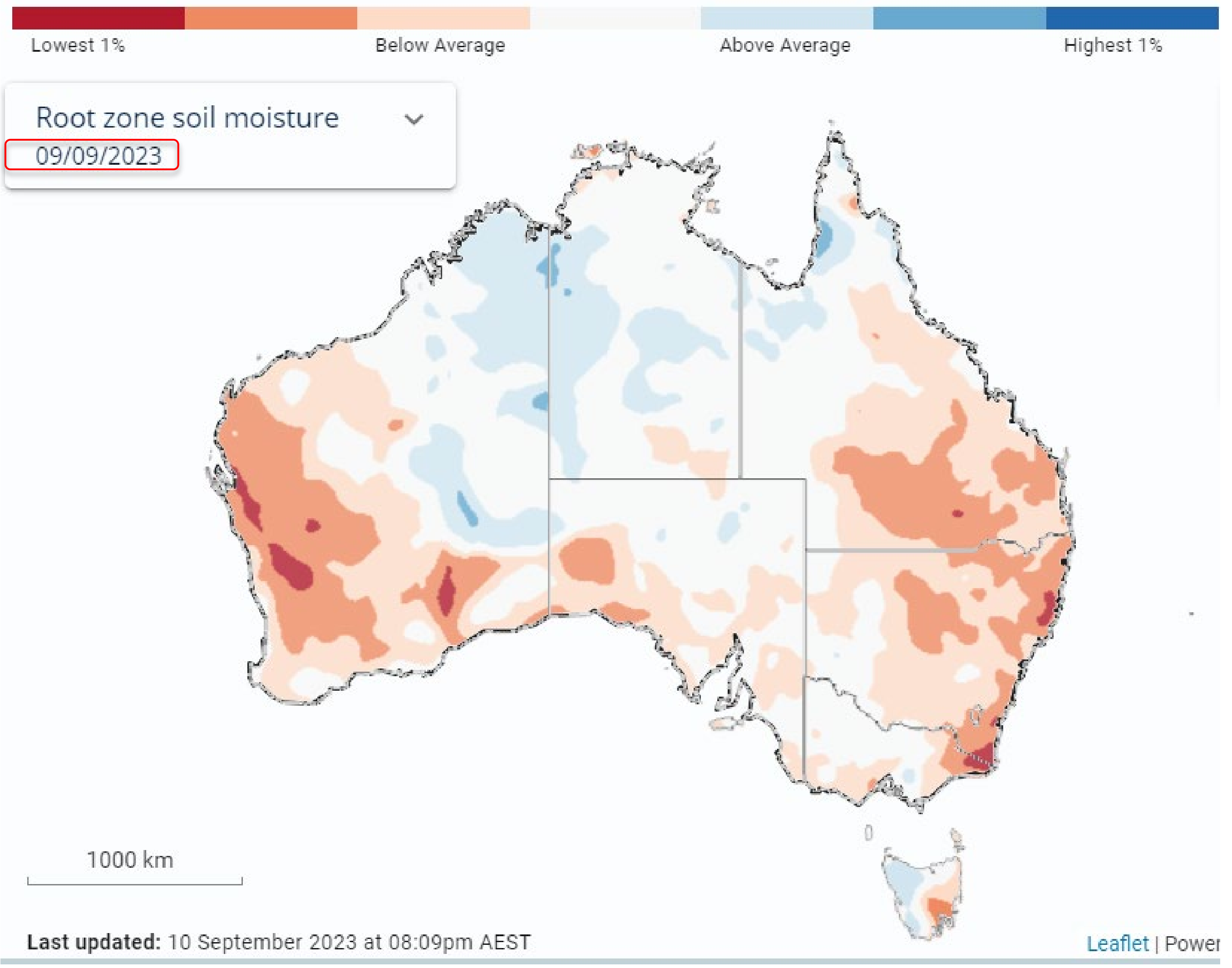
https://awo.bom.gov.au/



Australian Government
Bureau of Meteorology

Australian Water Outlook

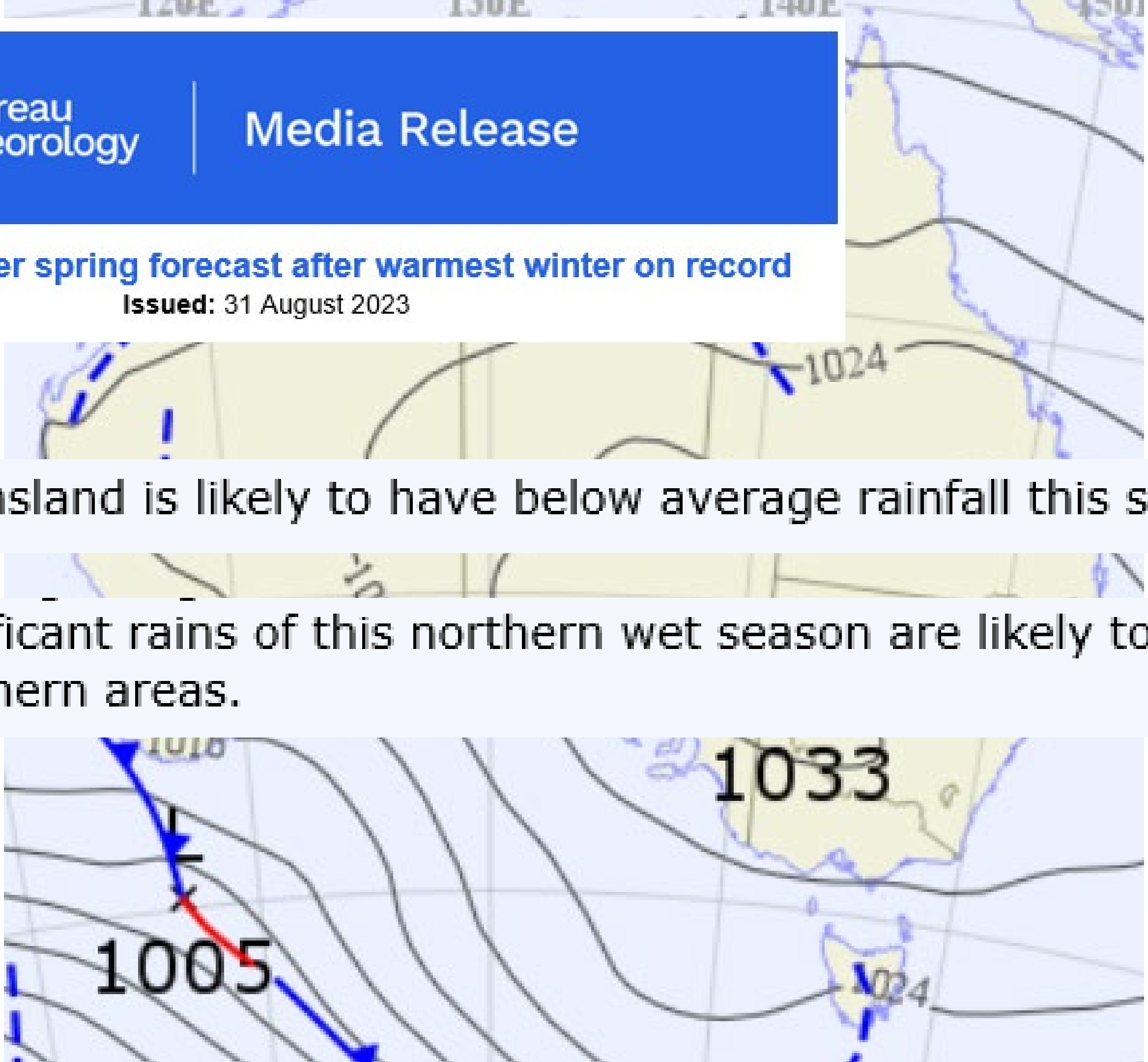
https://awo.bom.gov.au/



The Bureau of Meteorology | Media Release

Warmer and drier spring forecast after warmest winter on record

Issued: 31 August 2023



Most of Queensland is likely to have below average rainfall this spring.

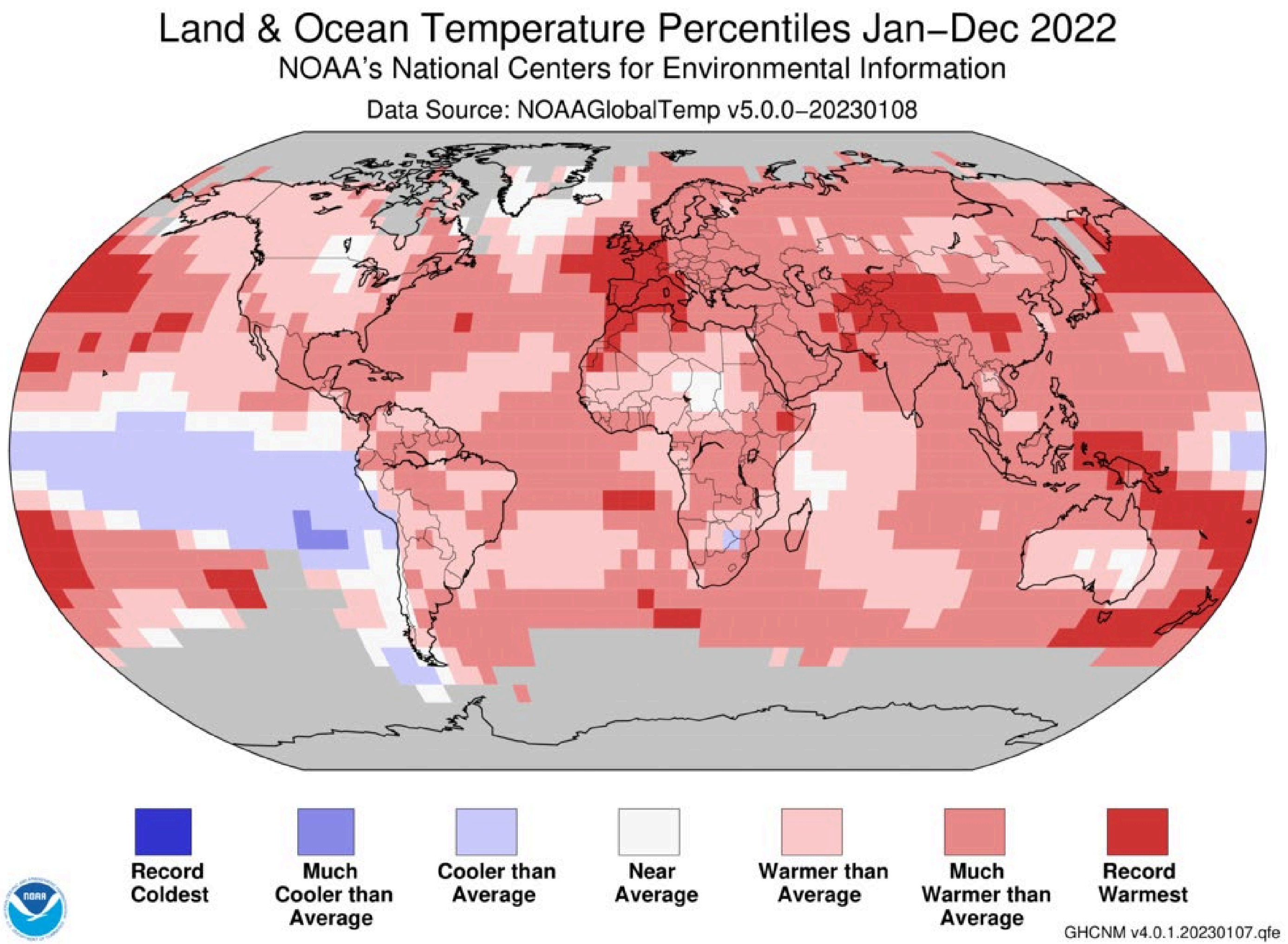
The first significant rains of this northern wet season are likely to be later than usual for northern areas.

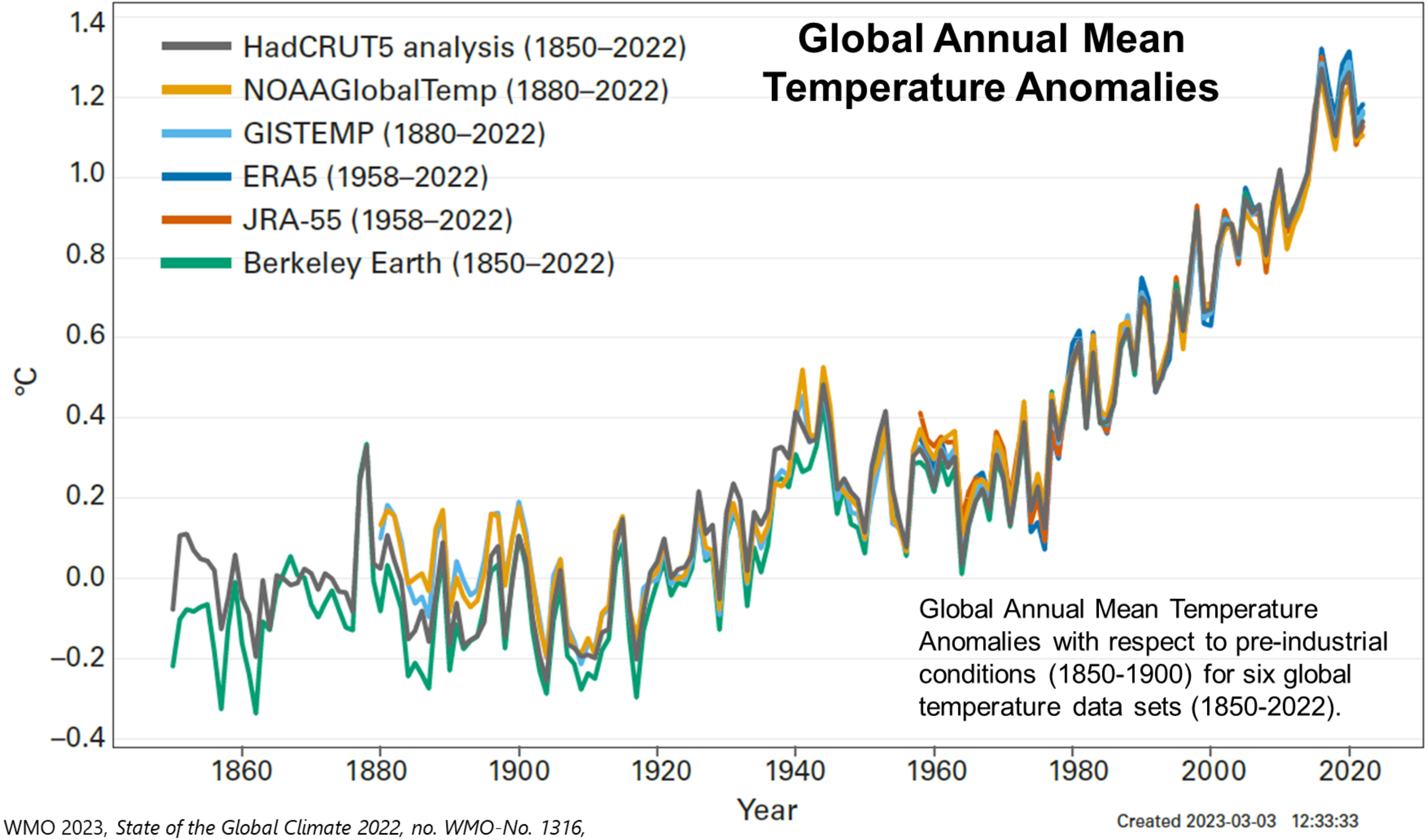
Sixth Assessment Report – August 2021

ipcc

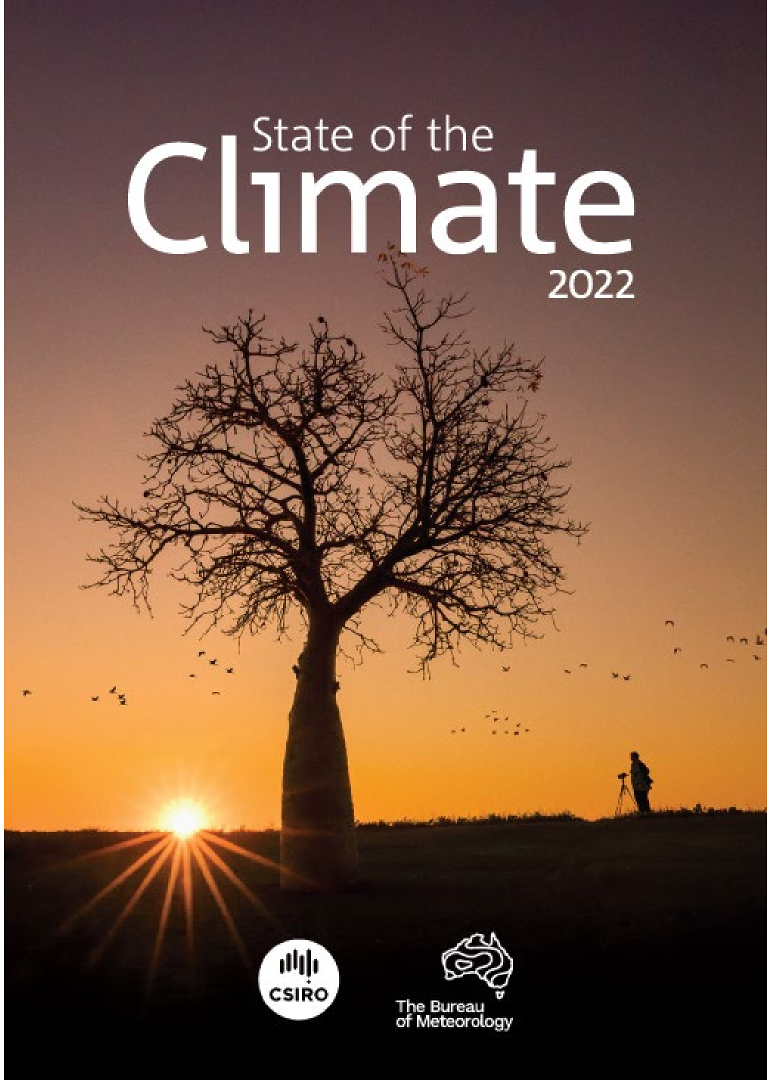
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

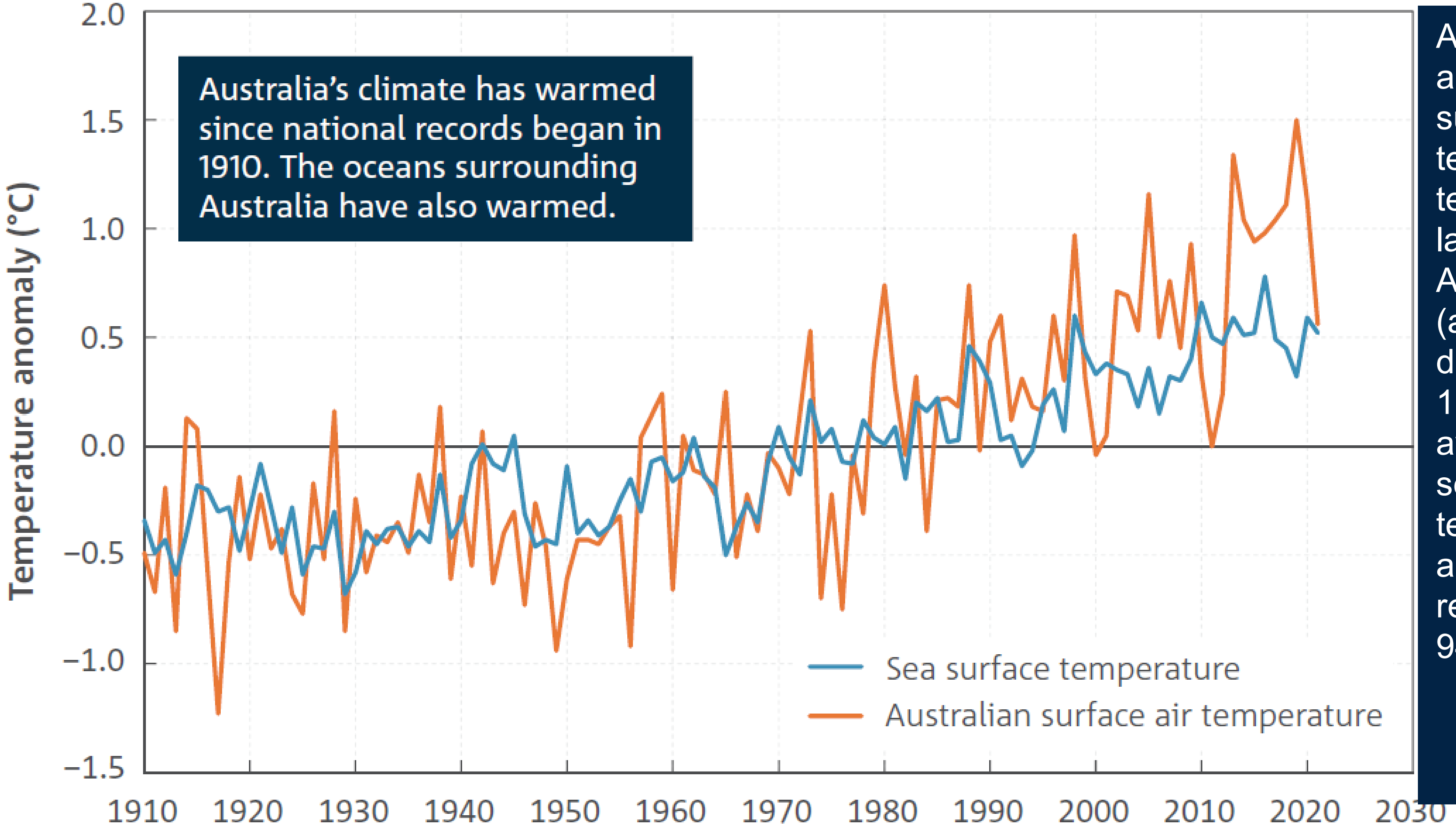

Land & Ocean Temperature Percentiles Jan–Dec 2022
NOAA's National Centers for Environmental Information
Data Source: NOAAGlobalTemp v5.0.0–20230108
Record Coldest
Much Cooler than Average
Cooler than Average
Near Average
Warmer than Average
Much Warmer than Average
Record Warmest
GHCNM v4.0.1.20230107.qfe



WMO 2023, *State of the Global Climate 2022, no. WMO-No. 1316, World Meteorological Organisation, Geneva.*

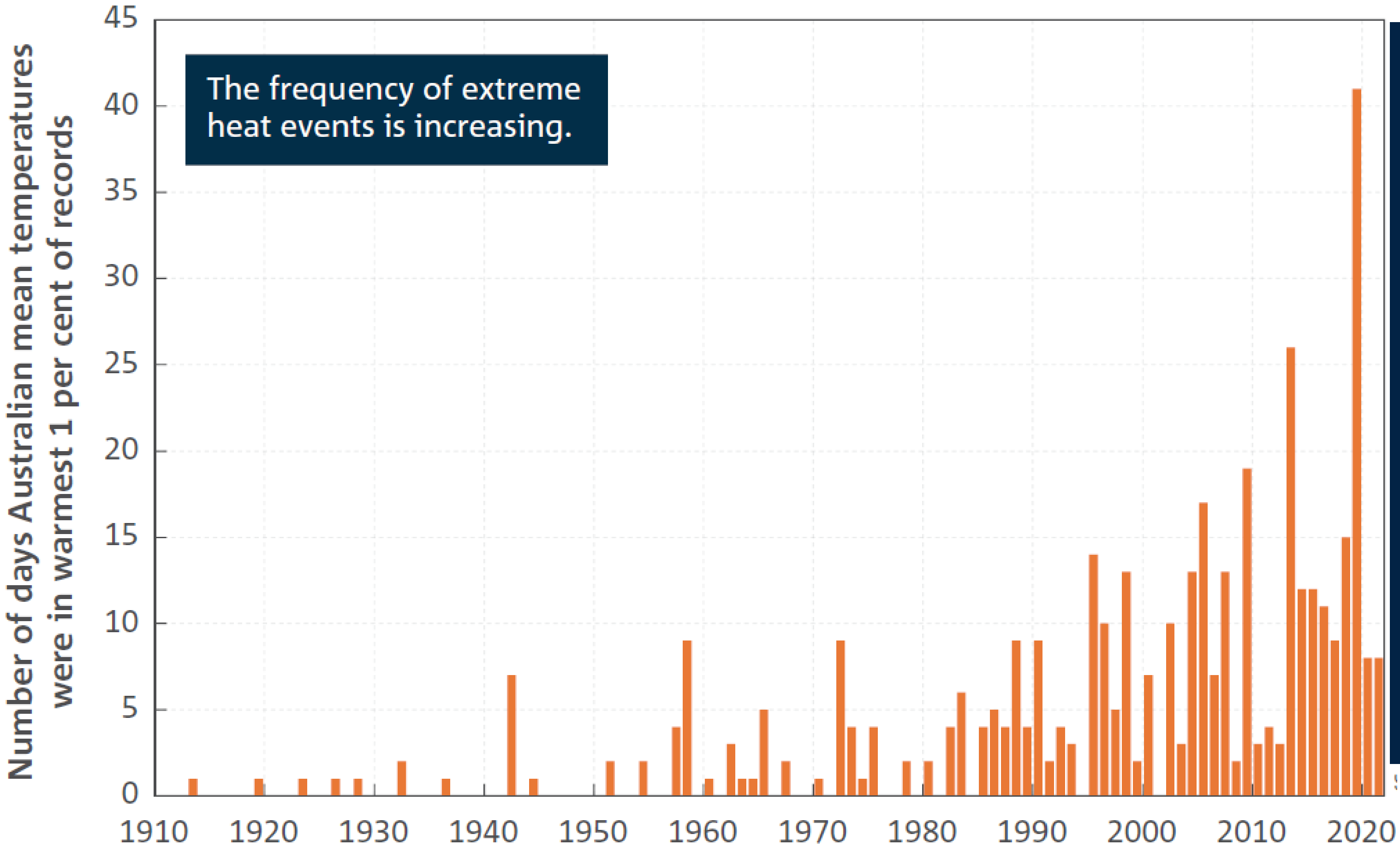

State of the
Climate
2022
CSIRO
The Bureau
of Meteorology

Temperature Trend - Australia



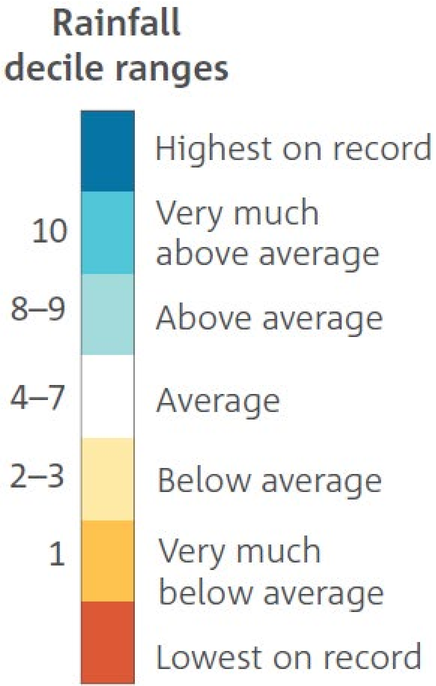
Anomalies in annual mean sea surface temperature, and temperature over land, in the Australian region (anomalies are the departures from the 1961–90 standard averaging period, sea surface temperature values are provided for a region 4–46 ºS and 94–174 ºE).

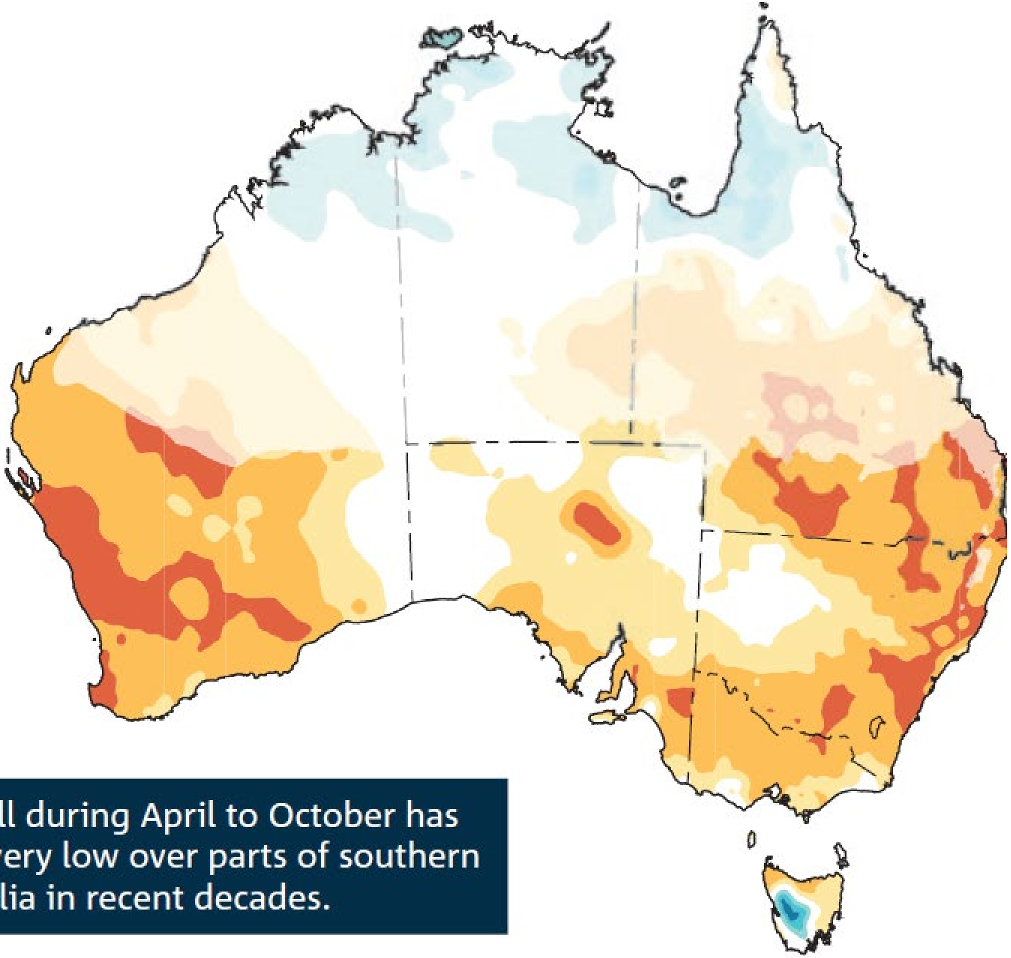
Temperature Trend - Australia



Number of days each year where the Australian area-averaged daily mean temperature for each month is extreme (extremely warm days). Extremely warm days are defined as those where daily mean temperatures are the warmest 1 per cent of days for each month, calculated for the period from 1910–2021.

April to October Rainfall Trends 2000-2022

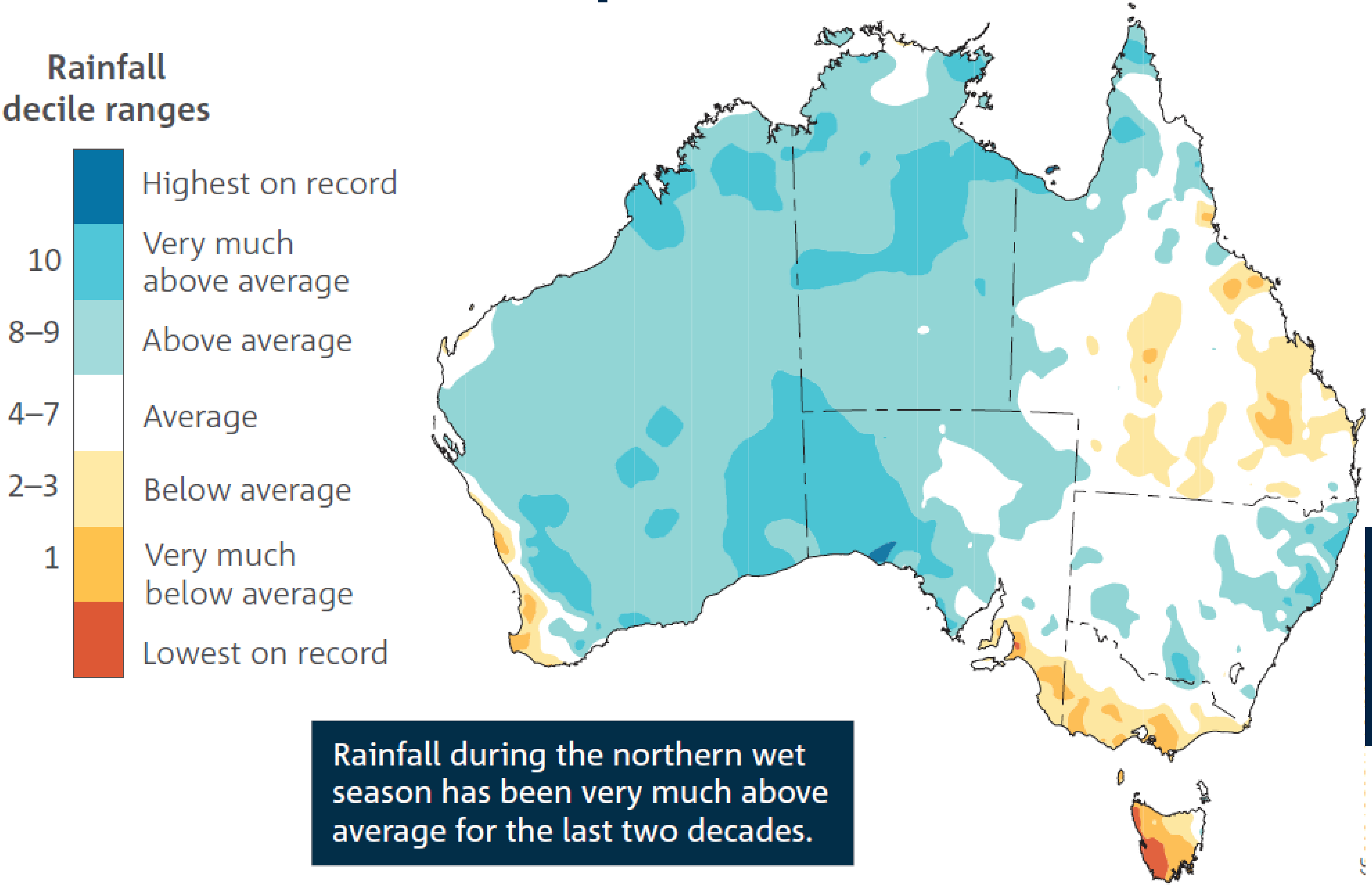




April to October rainfall deciles for the past 22 years (2000–21). A decile map shows where rainfall is above average, average, or below average for this period compared to all years from 1900 (when reliable rainfall records began).

Rainfall during April to October has been very low over parts of southern Australia in recent decades.

October to April Rainfall Trends 2000-2022



Rainfall during the northern wet season has been very much above average for the last two decades.

Northern wet season (October–April) rainfall deciles for the past 22 years (2000–01 to 2021–22).

What we can expect…

National and global temperature rise to continue

Fewer tropical cyclones, but a greater proportion of high-intensity storms with increased rainfall

Sea level rise to continue

Cool season rainfall decline in southern and eastern Australia to continue

Marine heatwaves to be more frequent and intense

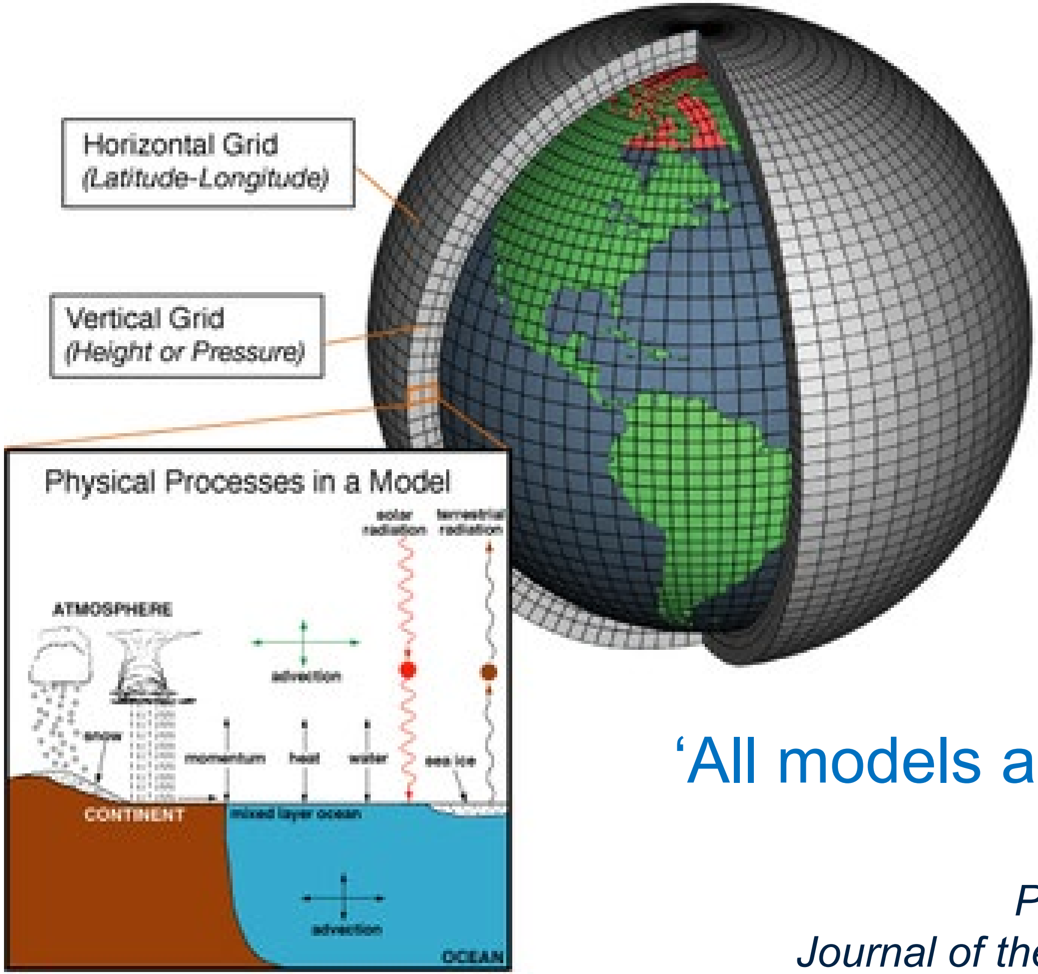
Heavy rainfall to become more intense

Warmer with more heatwaves, fewer cool days

Longer fire season and more dangerous fire weather

Holgate, C.M., Pepler, A.S., Rudeva, I., Abram, N.J., Anthropogenic warming reduces the likelihood of drought-breaking extreme rainfall events in southeast Australia, *Weather and Climate Extremes* (2023).

9% less 'blocking high' and 'intense trough' rain events in SEAu for every 1 degree of warming.



‘All models are wrong: some are useful’

Prof. George Box 1976
Journal of the American Statistical Association

Queensland Government

The Long Paddock

Home | About | Drought Declaration | Drought & Climate Adaptation | Southern Oscillation Index

Home / Queensland Future Climate / Future Climate Dashboard

Queensland Future Climate Dashboard

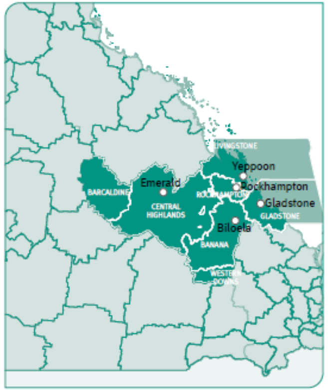
https://www.longpaddock.qld.gov.au/qld-future-climate/dashboard/

Climate change

in the Central Queensland region

VERSION 1

UNDERSTAND | ADAPT



Central Queensland region snapshot

The Central Queensland region extends from the coast to the central highland regions around Emerald and Alpha, and includes Rockhampton and Gladstone. The region occupies 10% of the area of the state, with 5% of the state's population resident there.

How will climate change affect the Central Queensland region?

In the future, the region can expect:

- higher temperatures
- rising sea level
- hotter and more frequent hot days
- more frequent sea-level extremes
- fewer frosts
- warmer and more acidic seas
- more intense downpours

How can we deal with these changes?

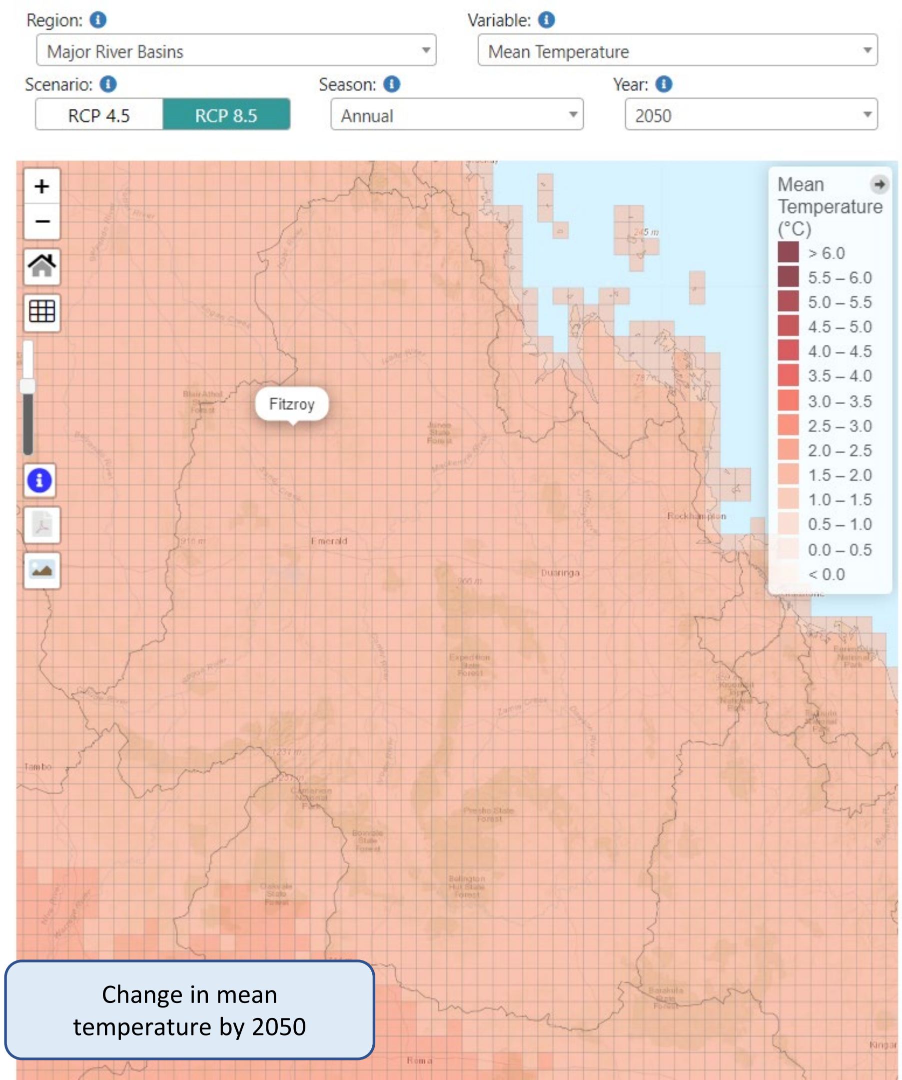
Queensland often experiences climate extremes such as floods, droughts, heatwaves and bushfires. Climate change is likely to exacerbate the frequency and severity of these events. We will increasingly be affected by changes in temperature, rainfall, sea level and extreme weather conditions.

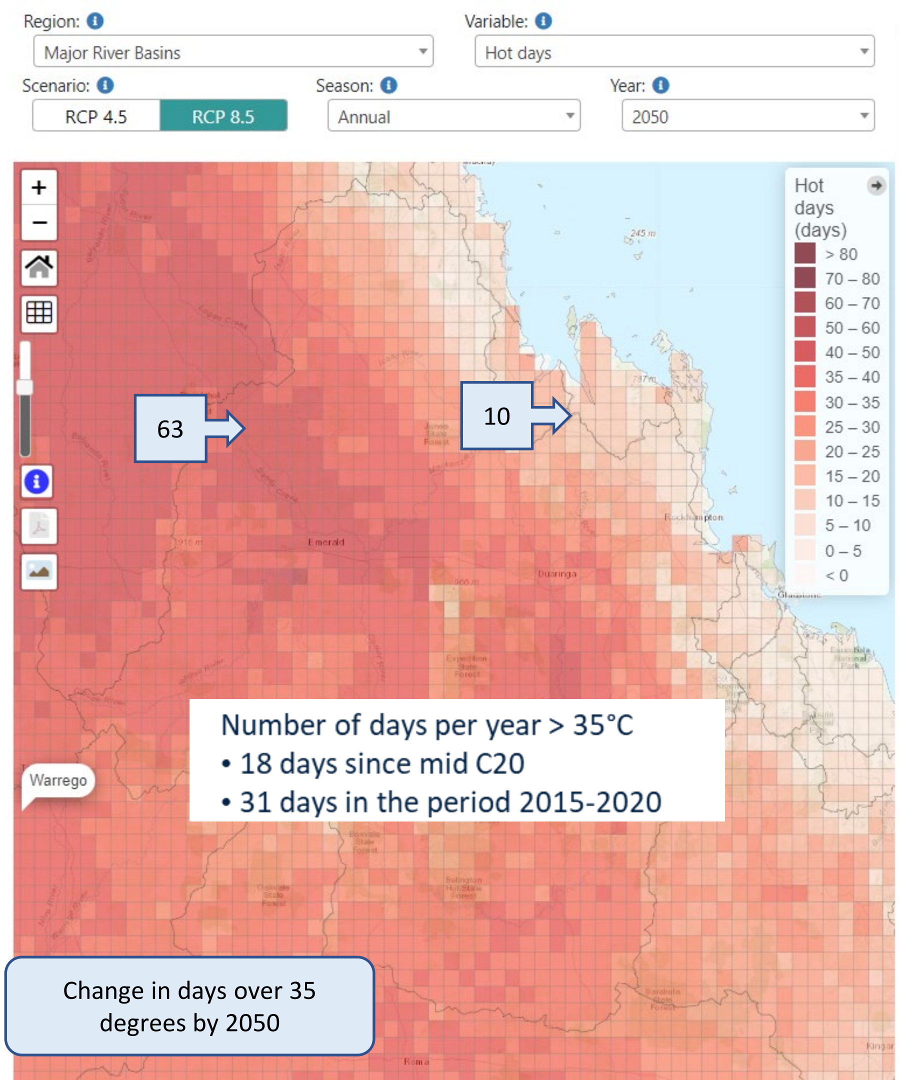
It makes sense to take appropriate action to better manage our climate risks. Well-considered and effective adaptation measures can limit the adverse impacts of climate change on communities, the economy and natural systems. We can achieve more if we act together to plan for and manage current and future climate impacts across different sectors and regions.

The Queensland Government is working with a range of stakeholders, using the best available science to address the risks climate change presents to our economy, environment, infrastructure and communities. This publication presents details of the expected changes to temperature, rainfall and the sea. It highlights the likely impacts on people, businesses and the environment and presents ways to respond. For more information on climate change in Queensland, visit www.qld.gov.au/environment/climate/climate-change.

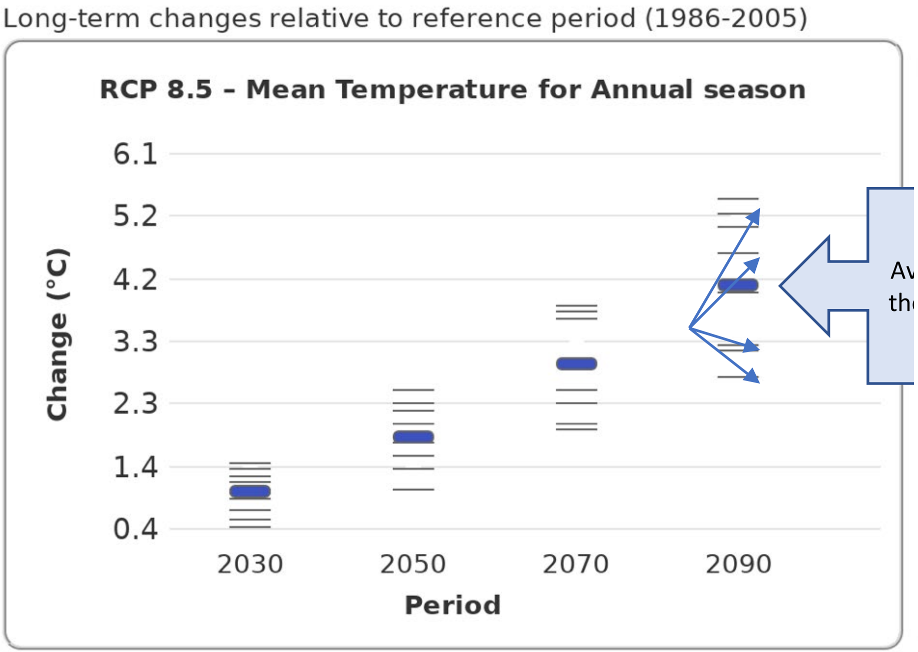
Climate Change

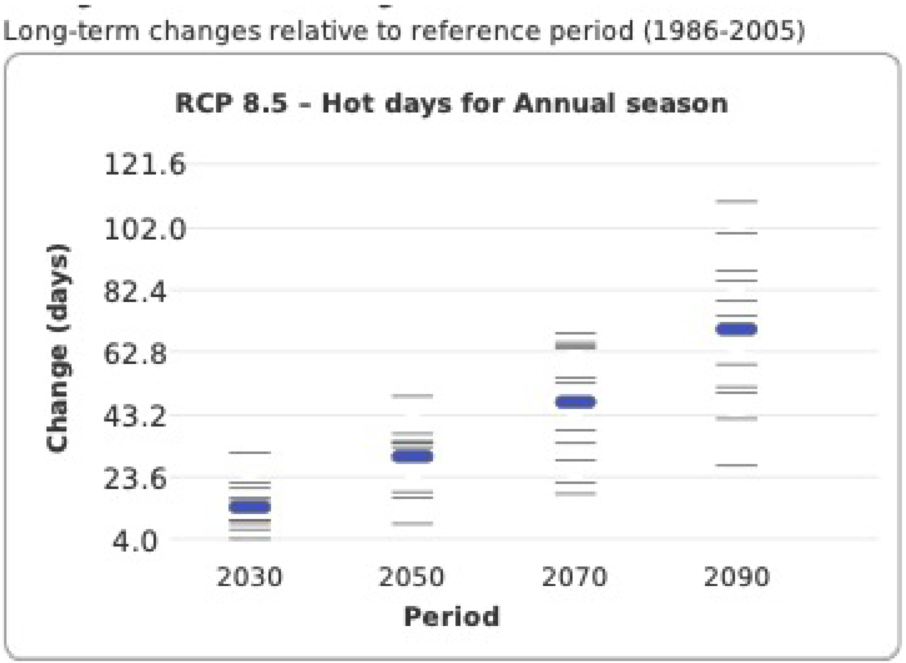
Queensland Government


Region:
Major River Basins
Variable:
Mean Temperature
Scenario:
RCP 4.5
RCP 8.5
Season:
Annual
Year:
2050
Mean Temperature (°C)
> 6.0
5.5 – 6.0
5.0 – 5.5
4.5 – 5.0
4.0 – 4.5
3.5 – 4.0
3.0 – 3.5
2.5 – 3.0
2.0 – 2.5
1.5 – 2.0
1.0 – 1.5
0.5 – 1.0
0.0 – 0.5
< 0.0
Fitzroy
Emerald
Duaringa
Rockhampton
Change in mean temperature by 2050


Region:
Major River Basins
Variable:
Hot days
Scenario:
RCP 4.5
RCP 8.5
Season:
Annual
Year:
2050
Hot days (days)
> 80
70 – 80
60 – 70
50 – 60
40 – 50
35 – 40
30 – 35
25 – 30
20 – 25
15 – 20
10 – 15
5 – 10
0 – 5
< 0
63
10
Emerald
Duaringa
Rockhampton
Warrego
Number of days per year > 35°C
• 18 days since mid C20
• 31 days in the period 2015-2020
Change in days over 35 degrees by 2050

Change in temperature under a high greenhouse gas emission scenario compared to 1986-2005

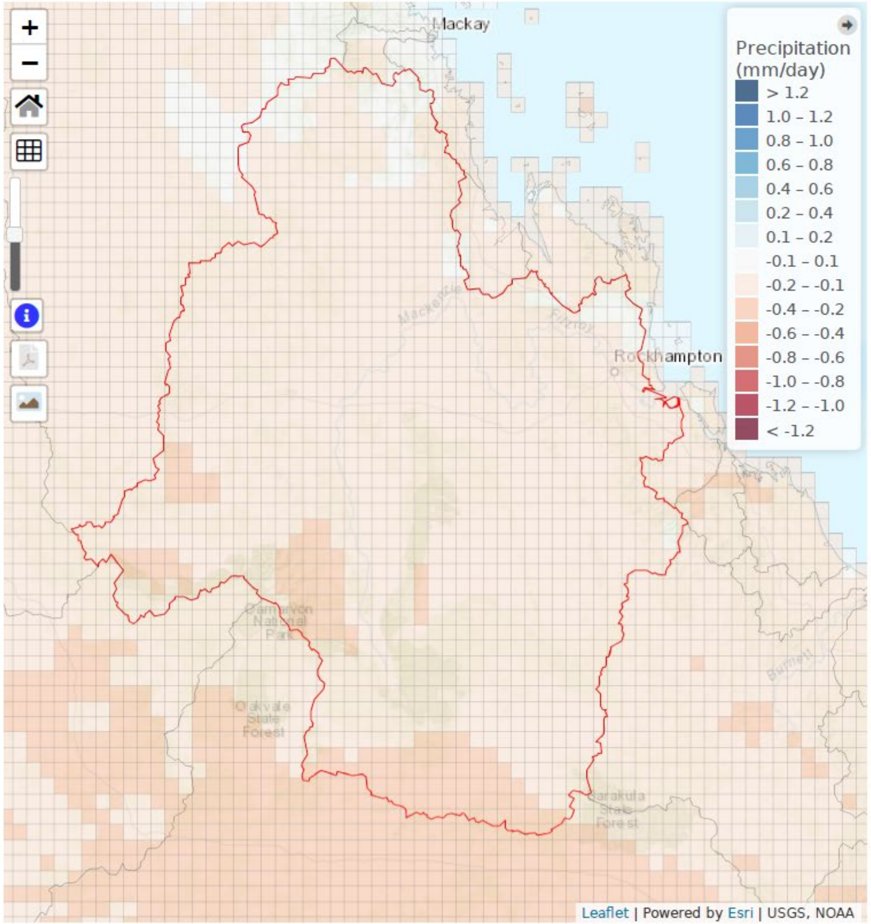




Additional days over 35 degrees

Queensland Future Climate Dashboard

Region: Major River Basins
Variable: Precipitation
Scenario: RCP 4.5 | RCP 8.5
Season: Dry
Year: 2070

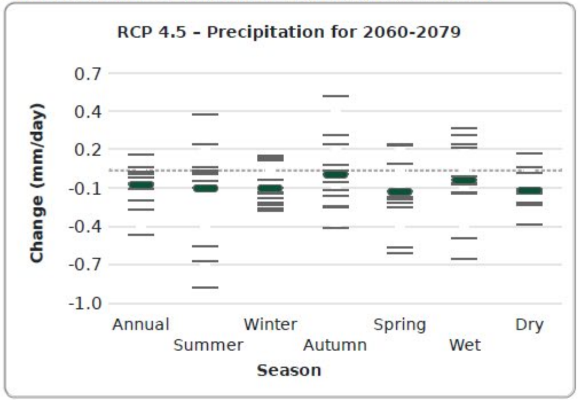


Major River Basins
Fitzroy

On Mean | Off Range | On Models

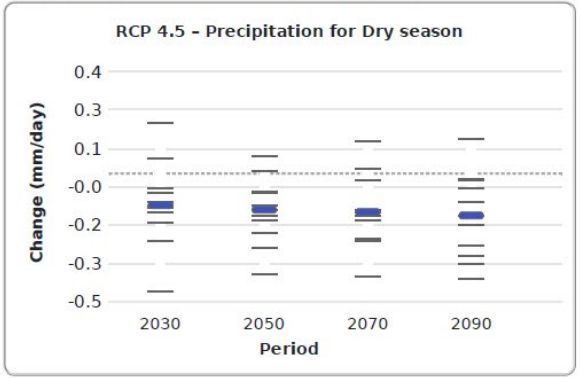
Changes across seasons for regions

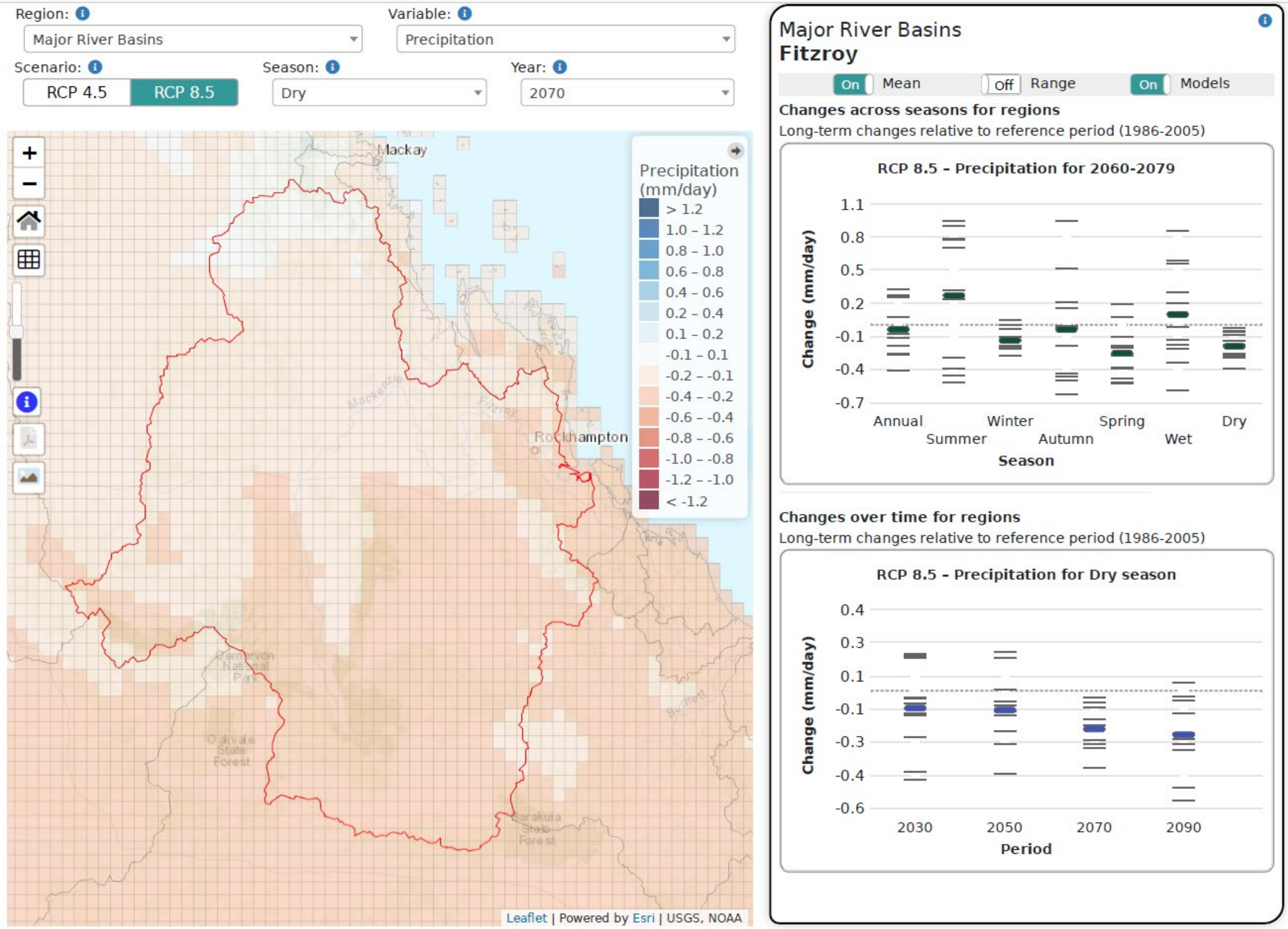
Long-term changes relative to reference period (1986-2005)



Changes over time for regions

Long-term changes relative to reference period (1986-2005)




Region:
Major River Basins
Variable:
Precipitation
Scenario:
RCP 4.5
RCP 8.5
Season:
Dry
Year:
2070
Mackay
Rockhampton
Precipitation (mm/day)
> 1.2
1.0 – 1.2
0.8 – 1.0
0.6 – 0.8
0.4 – 0.6
0.2 – 0.4
0.1 – 0.2
-0.1 – 0.1
-0.2 – -0.1
-0.4 – -0.2
-0.6 – -0.4
-0.8 – -0.6
-1.0 – -0.8
-1.2 – -1.0
< -1.2
Leaflet | Powered by Esri | USGS, NOAA
Major River Basins
Fitzroy
On Mean
Off Range
On Models
Changes across seasons for regions
Long-term changes relative to reference period (1986-2005)
RCP 8.5 - Precipitation for 2060-2079
Change (mm/day)
1.1
0.8
0.5
0.2
-0.1
-0.4
-0.7
Annual
Summer
Winter
Autumn
Spring
Wet
Dry
Season
Changes over time for regions
Long-term changes relative to reference period (1986-2005)
RCP 8.5 - Precipitation for Dry season
Change (mm/day)
0.4
0.3
0.1
-0.1
-0.3
-0.4
-0.6
2030
2050
2070
2090
Period

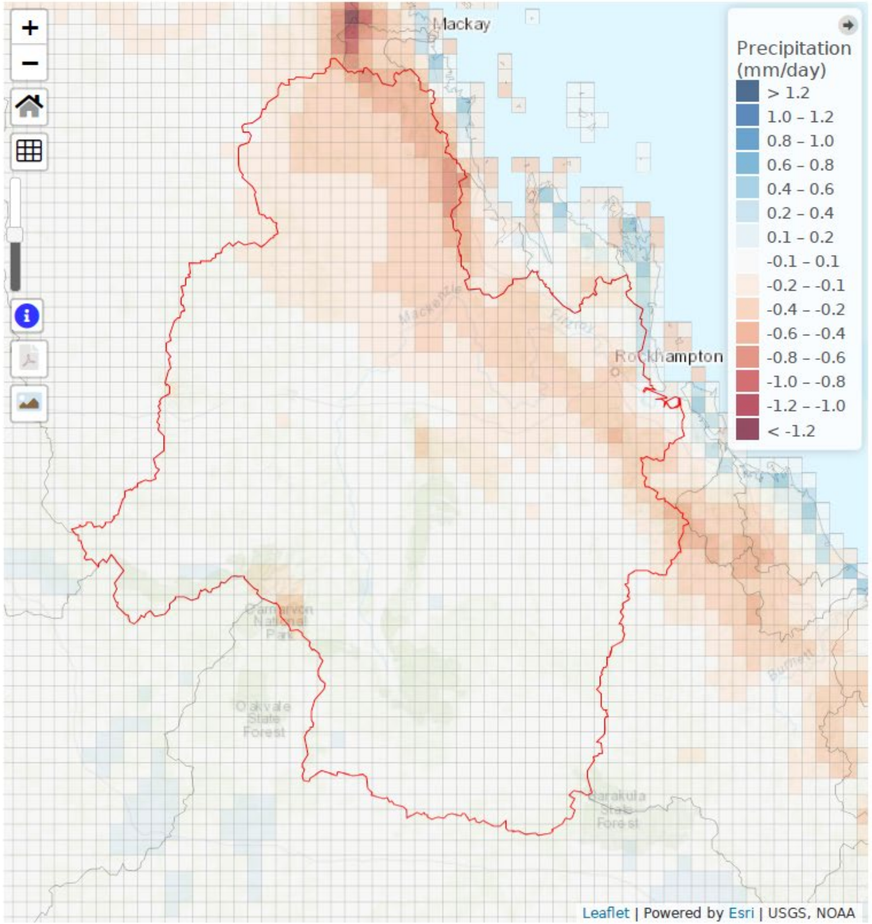
Region: Major River Basins

Variable: Precipitation

Scenario: RCP 4.5 | RCP 8.5

Season: Wet

Year: 2070



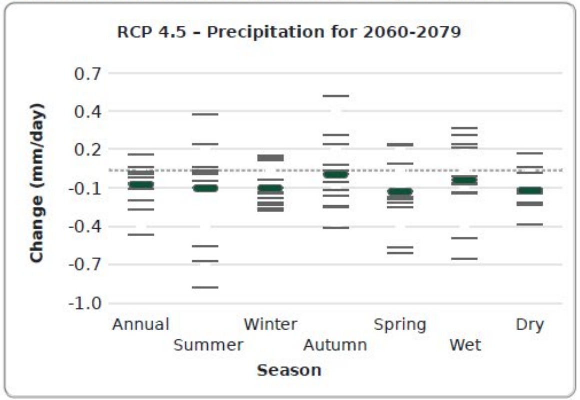
Major River Basins

Fitzroy

On Mean | Off Range | On Models

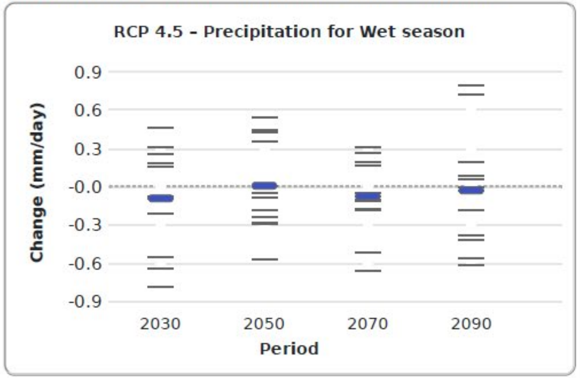
Changes across seasons for regions

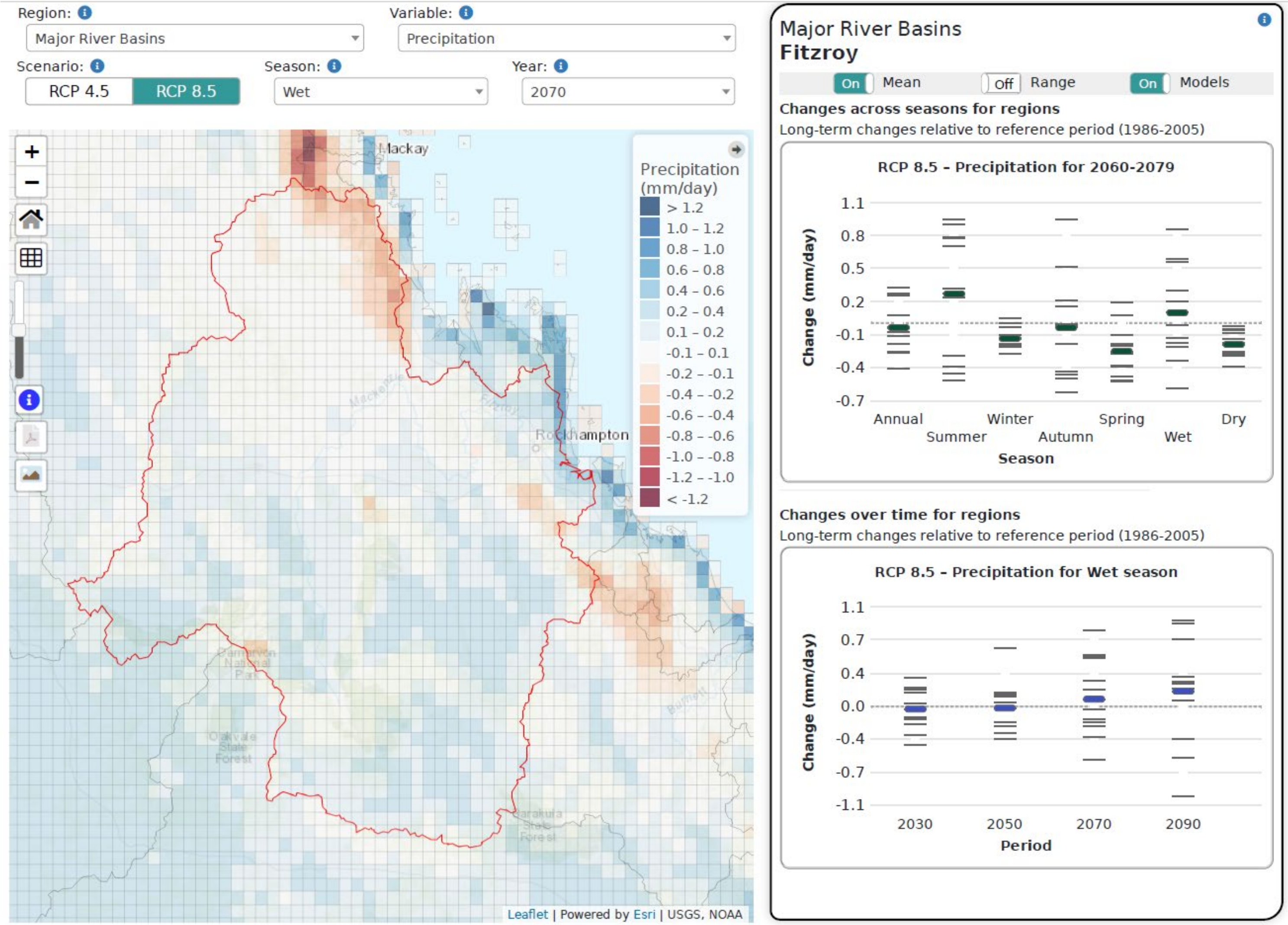
Long-term changes relative to reference period (1986-2005)



Changes over time for regions

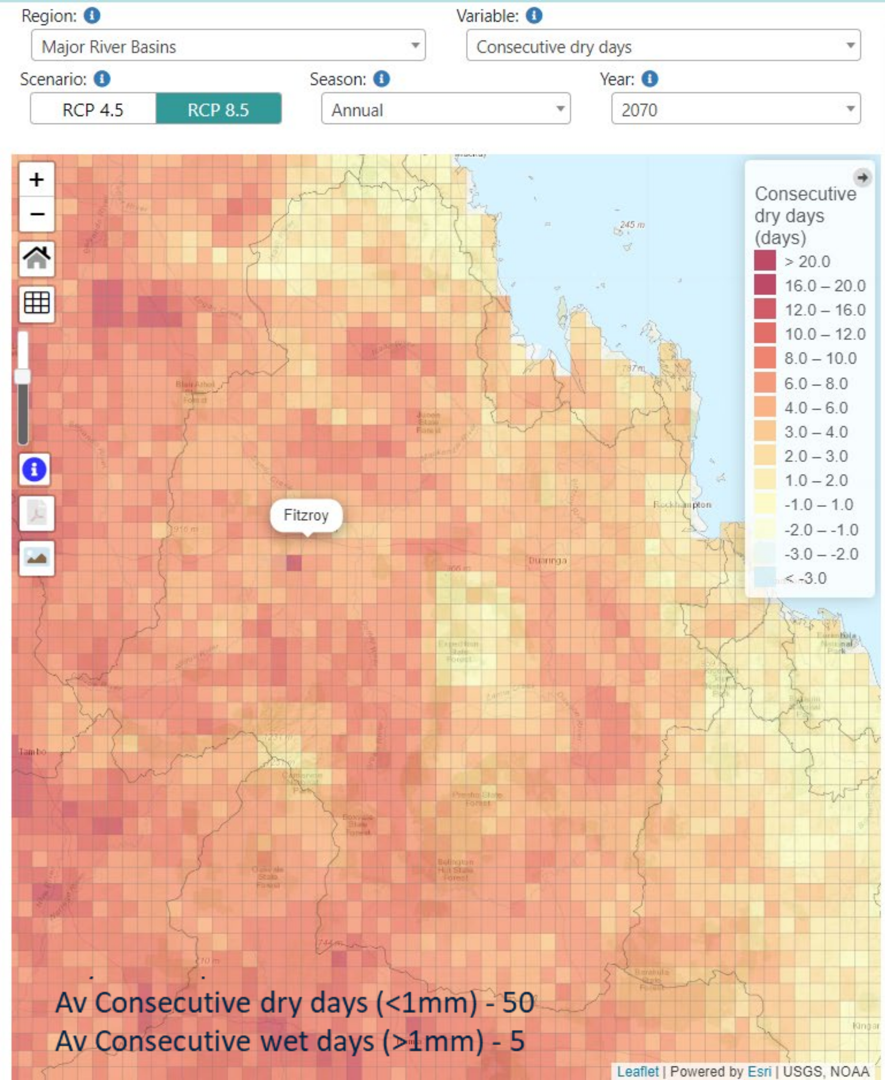
Long-term changes relative to reference period (1986-2005)

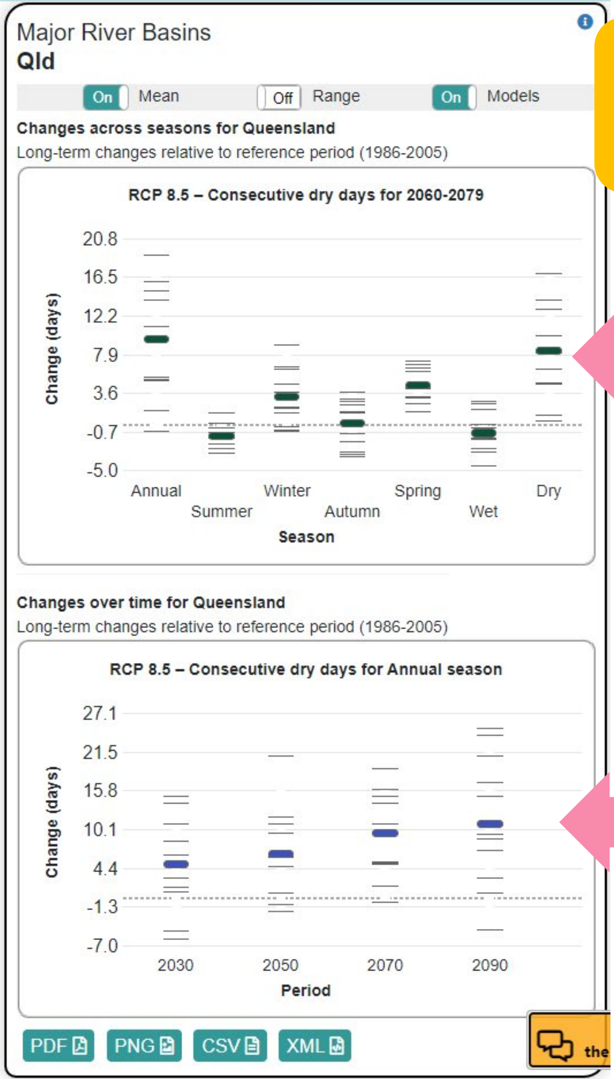




Region:
Major River Basins
Variable:
Precipitation
Scenario:
RCP 4.5
RCP 8.5
Season:
Wet
Year:
2070
Mackay
Rockhampton
Precipitation (mm/day)
> 1.2
1.0 – 1.2
0.8 – 1.0
0.6 – 0.8
0.4 – 0.6
0.2 – 0.4
0.1 – 0.2
-0.1 – 0.1
-0.2 – -0.1
-0.4 – -0.2
-0.6 – -0.4
-0.8 – -0.6
-1.0 – -0.8
-1.2 – -1.0
< -1.2
Leaflet | Powered by Esri | USGS, NOAA
Major River Basins
Fitzroy
On Mean
Off Range
On Models
Changes across seasons for regions
Long-term changes relative to reference period (1986-2005)
RCP 8.5 - Precipitation for 2060-2079
Change (mm/day)
1.1
0.8
0.5
0.2
-0.1
-0.4
-0.7
Annual
Summer
Winter
Autumn
Spring
Wet
Dry
Season
Changes over time for regions
Long-term changes relative to reference period (1986-2005)
RCP 8.5 - Precipitation for Wet season
Change (mm/day)
1.1
0.7
0.4
0.0
-0.4
-0.7
-1.1
2030
2050
2070
2090
Period

Change in number of consecutive dry days

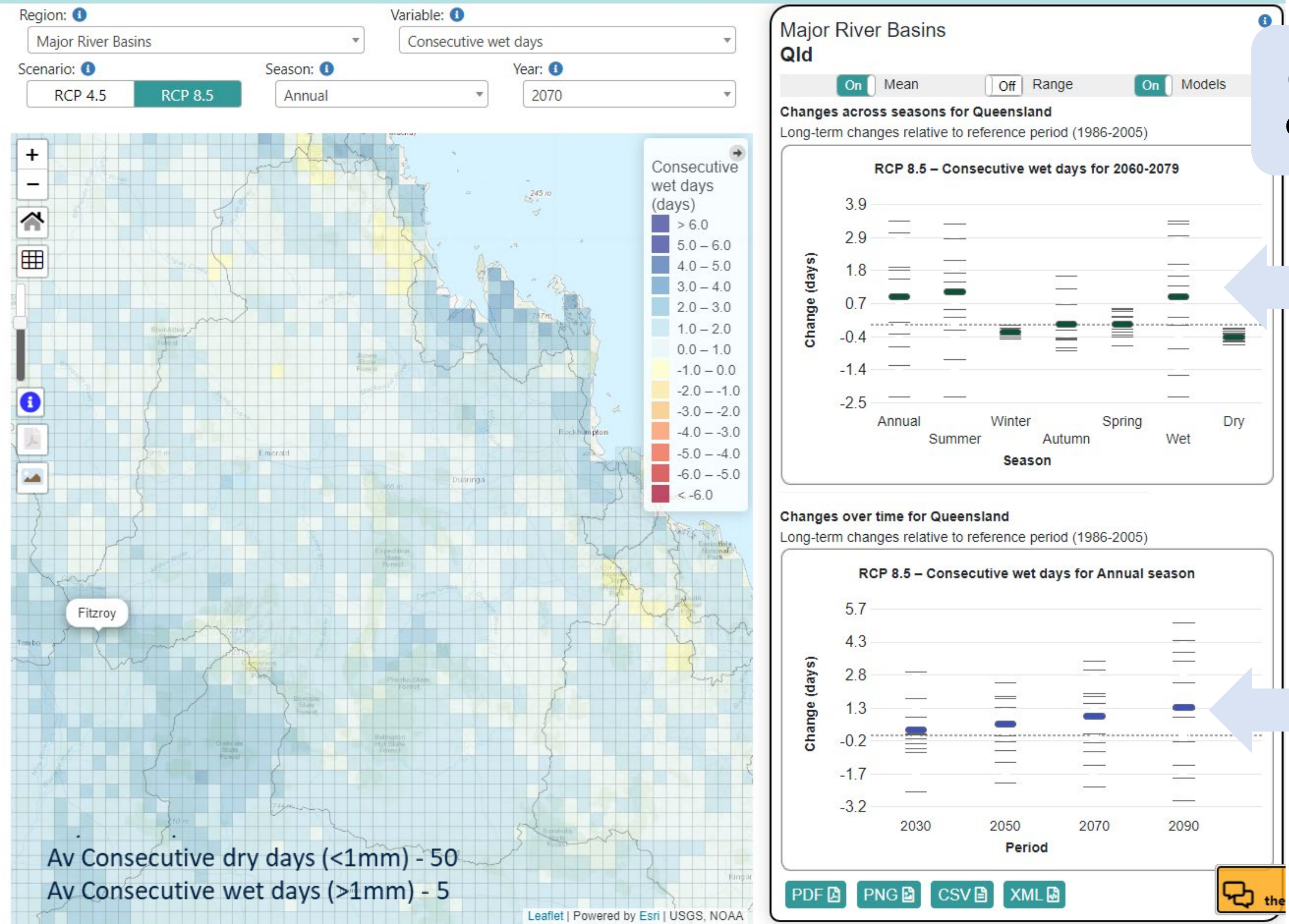




The dry season has longer runs of dry days

The number of dry days in a row will increase

Change in number of consecutive wet days



The wet season has longer runs of wet days

The number of wet days in a row will increase

How will climate change affect the Central Queensland Region?

- Higher temperatures
- Hotter and more frequent hot days
- Fewer frosts
- Harsher fire weather
- More intense downpours

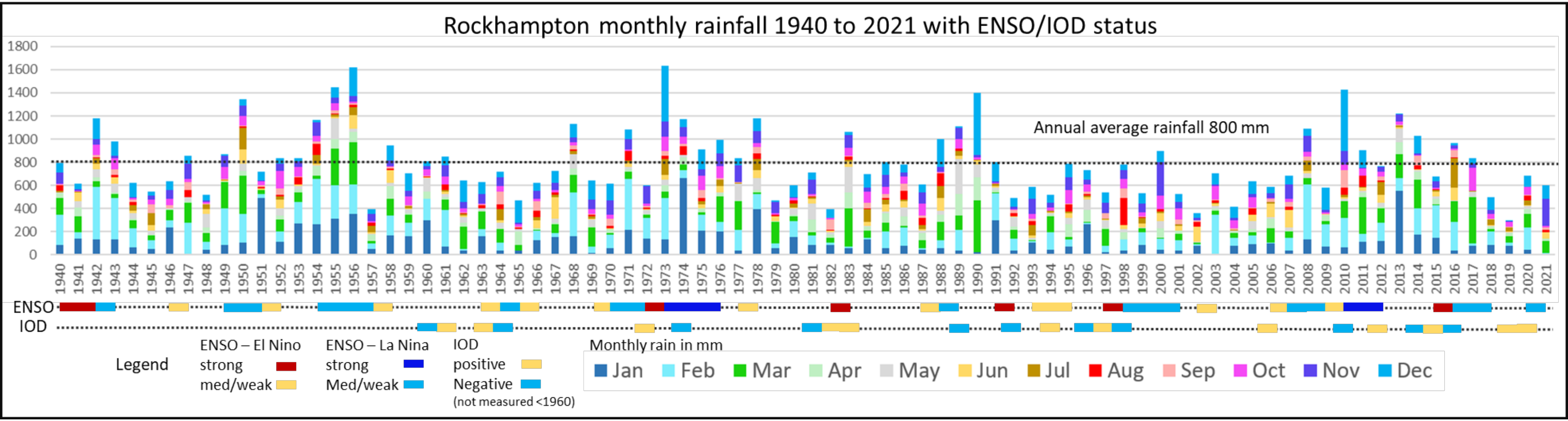
  Inflow season shorter - floods
- Changes to drought are less clear

  Deeper La Nina and El Nino but IOD feedback uncertain

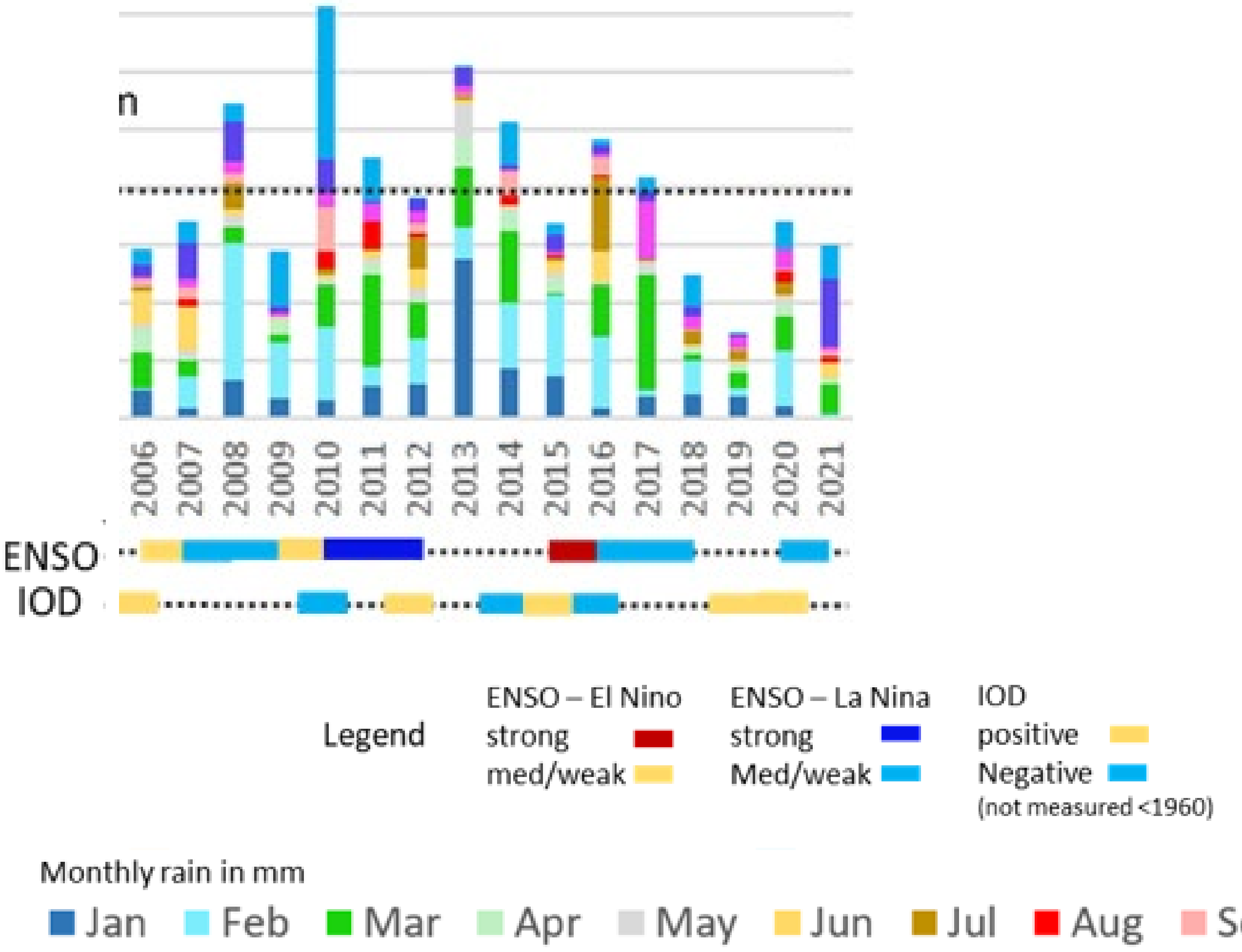
- Sea level will continue to rise
- More frequent sea-level extremes
- Warmer and more acidic ocean

  Less TCs – but more intense

NCCARF
National
Climate Change Adaptation
Research Facility



Rockhampton monthly rainfall 1940 to 2021 with ENSO/IOD status
Annual average rainfall 800 mm
ENSO
IOD
Legend
ENSO – El Nino
strong
med/weak
ENSO – La Nina
strong
Med/weak
IOD
positive
Negative
(not measured <1960)
Monthly rain in mm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



Rockhampton Climate

Average annual rainfall
- Rok 800 mm
- W-Fitzroy Basin 600mm
- E-Fitzroy Basin 900mm

Average Temperatures (max-min)
- Summer 32-22°C
- Winter 23-9°C

Number of days per year > 35°C
- 18 days since mid C20
- 31 days in the period 2015-2020

Wet: Dec-Mar

Dry: Jun-Sep

Av Consecutive dry days (<1mm) - 50

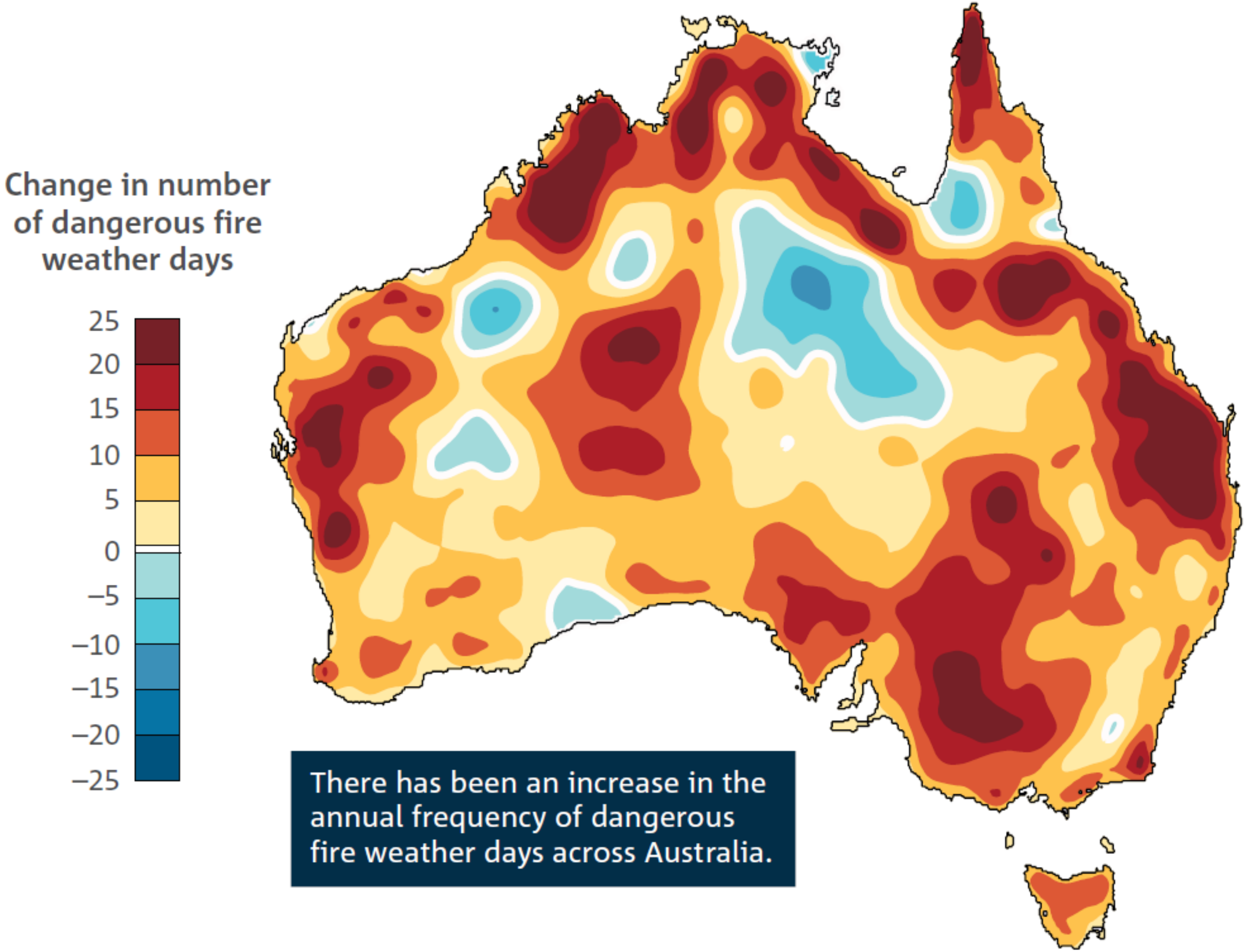
Av Consecutive wet days (>1mm) - 5

Key findings:

- The length of time for the Pacific Walker Circulation to switch between El Niño-like and La Niña-like phases has slowed over the industrial era.
- Multi-year El Niño and La Niña events may become more common as a result.
- Multi-year El Niño and La Niña events can exacerbate the associated risks of drought, fire, rains and floods.
- Aerosol pollution (as distinct from greenhouse gases) may impact the strength of the Pacific Walker Circulation, making La Niña events more likely.
- Volcanic eruptions cause an El Niño-like weakening of the Pacific Walker Circulation.


Dr Michael Hewson
m.hewson@cqu.edu.au
“Climate is what you expect, weather is what you get.”
Andrew John Herbertson 1901

Fire Weather Days



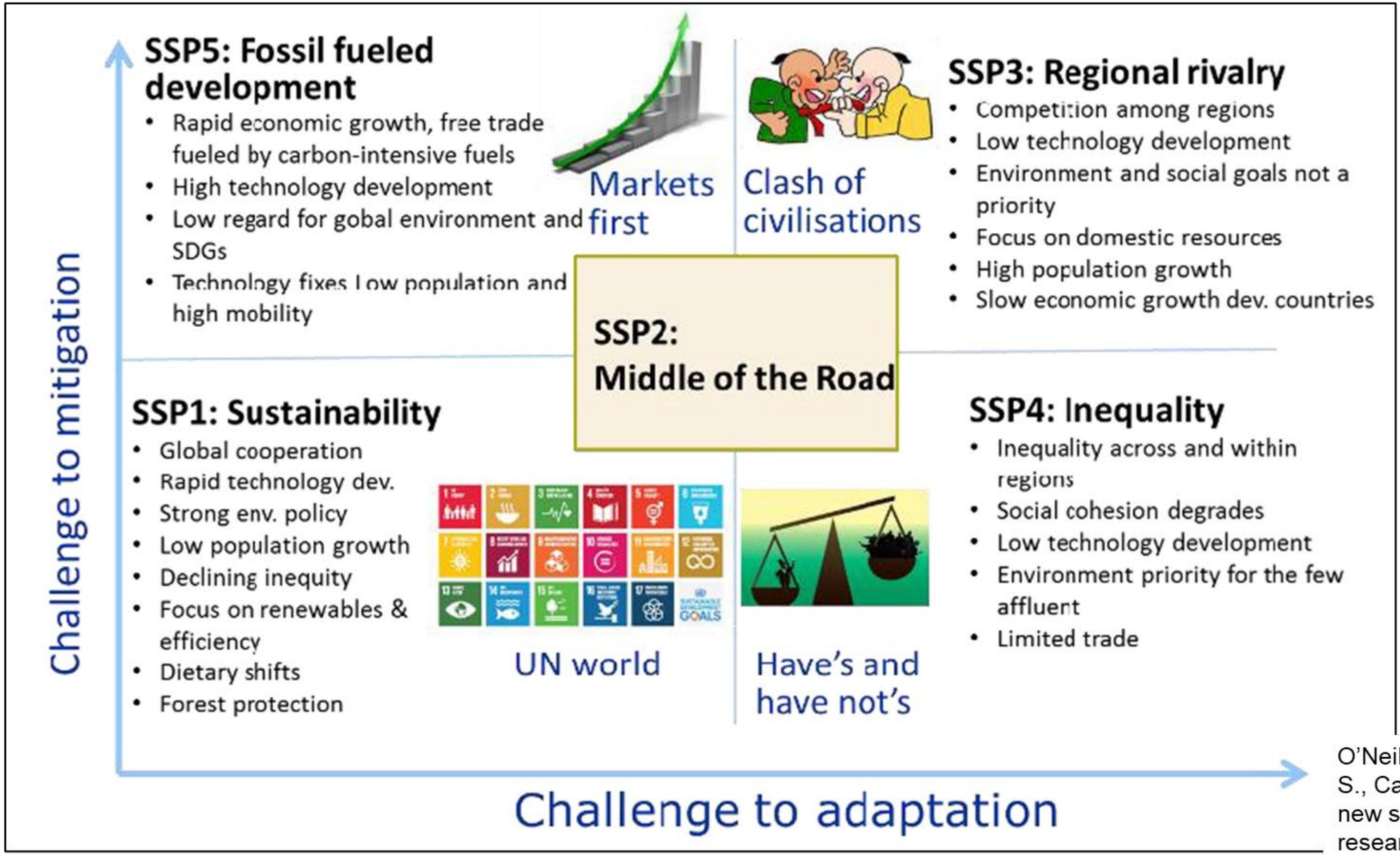
There has been an increase in the annual frequency of dangerous fire weather days across Australia.

There has been an increase in the number of days with dangerous weather conditions for bushfires.
The map shows the change in the annual (July to June) number of days that the FFDI exceeds its 90th percentile between the two periods: July 1950 to June 1986 and July 1986 to June 2022.
The FFDI is an indicator of dangerous fire weather conditions for a given location.

UNITED NATIONS
PARIS CLIMATE AGREEMENT
SIGNING CEREMONY
22 APRIL 2016

Scenario	Effort to curb emissions	Energy generation	New technology	Transport	Representative Concentration Pathway	Temperature 2080–2099 (average increase relative to 1986-2005)	Sea level 2081–2100 (average rise relative to 1986-2005)	Extreme weather 2081–2100	Adaptation required
Business as usual	Low	Coal-fired power		Cars, trucks	RCP 8.5	4.1 °C	0.63 m	Large increase	High level at high cost
	Medium	Mix		Mix	RCP 6.0	1.9 °C	0.48 m	Moderate increase	Medium level at medium cost
Low emissions scenario	Medium	Renewable		Mix	RCP 4.5	1.0 °C	0.47 m	Moderate increase	Medium level at medium cost
A brave new world	High	Renewable	Emissions capture	Bicycles, public transport	RCP 2.6	0.9 °C	0.4 m	Small increase	Low level at low cost

IPCC 6th Annual Report - RCPs to SSPs…



The five illustrative scenarios are referred to as SSPx-y, where 'SSPx' refers to the ***Shared Socio-economic Pathway*** or 'SSP' describing the socio-economic trends underlying the scenario, and 'y' refers to the approximate level of radiative forcing (in watts per square metre, or W m–2) resulting from the scenario in the year 2100.

O'Neill, B., Kriegler, E., Riahi, K., Ebi, K., Hallegatte, S., Carter, T., Mathur, R., van Vuuren, D., 2014. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Clim. Change 122, 387–400.

Observed Australian Climate Change

Australia's climate has warmed by an average of 1.47 ± 0.24 ºC since national records began in 1910.

There has been an increase in extreme fire weather and a longer fire season across large parts of the country since the 1950s.

There has been a decrease in the number of tropical cyclones observed in the Australian region.

Observed Australian Climate Change

There has been a decline of around 15 per cent in April to October rainfall in the southwest of Australia since 1970. Across the same region, May to July rainfall has seen the largest decrease, by around 19 per cent since 1970.

In the south-east of Australia, there has been a decrease of around 10 per cent in April to October rainfall since the late 1990s.

There has been a decrease in streamflow at most gauges across Australia since 1975.

Rainfall and streamflow have increased across parts of northern Australia since the 1970s.

Snow depth, snow cover and number of snow days have decreased in alpine regions since the late 1950s.

Observed Australian Climate Change

Sea surface temperatures have increased by an average of 1.05 ºC since 1900. This has led to an increase in the frequency of extreme heat events over land and sea.

Oceans around Australia have continued to become more acidic, with changes happening faster in recent decades.

Sea levels are rising around Australia, including more frequent extremes that are increasing the risk of inundation and damage to coastal infrastructure and communities.

What we can expect…

Continued warming, with more extremely hot days and fewer extremely cool days.

A further decrease in cool season rainfall across many south and east regions.

Continued drying in the southwest of Western Australia, especially during winter and spring.

Longer periods of drought on average in the south and east.

A longer fire season for the south and east, and an increase in the number of dangerous fire weather days

What we can expect…

More short-duration heavy rainfall events leading to complex streamflows, associated flood and erosion risks.

Fewer tropical cyclones, but a greater proportion of high intensity - the intensity of associated rainfall will increase - higher sea levels will amplify coastal flooding.

Fewer east coast lows, particularly during the cooler months.

Ongoing sea level rise through this century and beyond, at a rate that varies by region.

Recent research on potential ice loss from the Antarctic ice sheet suggests that a scenario of larger and more rapid sea level rise can't be ruled out.

What we can expect…

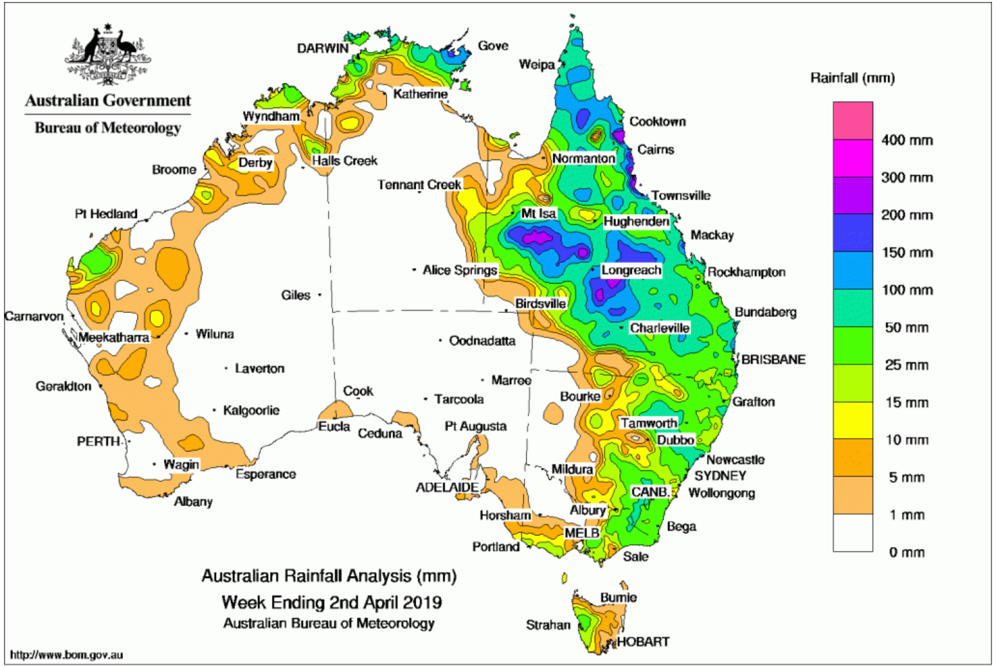
Sea level rise to cause coastal inundation and erosion.

Continued warming and acidification of oceans with consequent impacts on biodiversity and ecosystem processes.

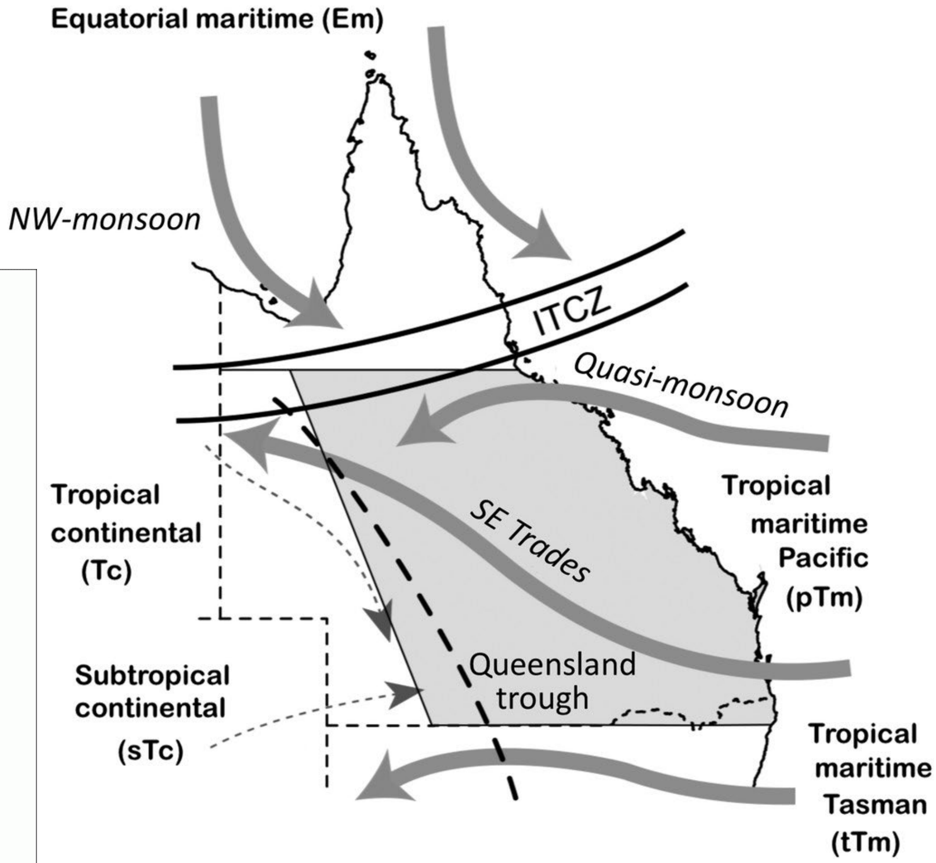
Increased and longer-lasting marine heatwaves, which will further stress marine environments, such as kelp forests, and increase the likelihood of more frequent and severe bleaching events in coral reefs around Australia, including the Great Barrier Reef and Ningaloo Reef.

An increase in the risk of natural disasters from extreme weather, including ‘compound extremes’, where multiple extreme events occur together or in sequence, thus

CQ trough location to 2100?

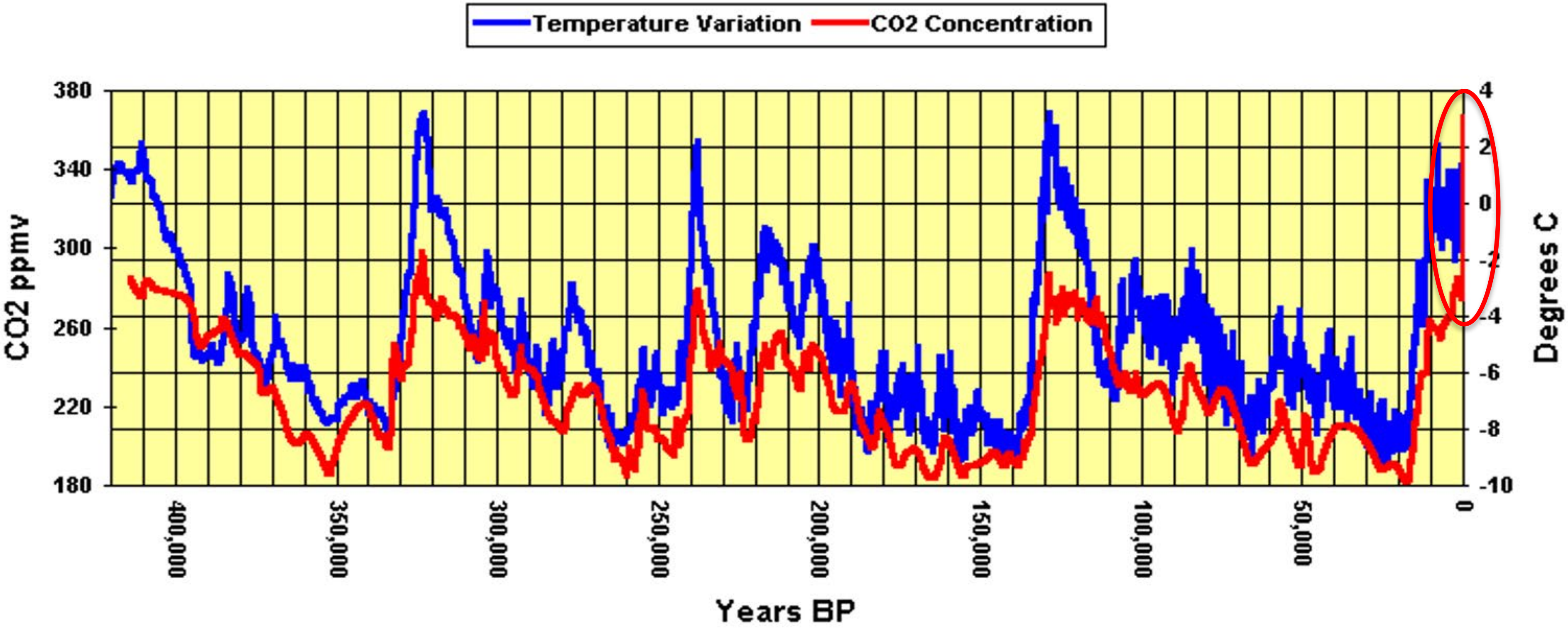


Issued: 02/04/2019



Day, K. A., & McKeon, G. M. (2018). An Index of Summer Rainfall for Queensland's Grazing Lands, *Journal of Applied Meteorology and Climatology*, *57*(7), 1623-1641.

Antarctic Ice Core Data 1



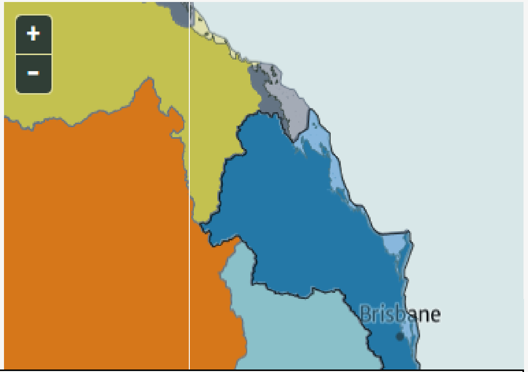
(Source Petit et. al. 1999)

EAST COAST CLIMATE FUTURES

Go back

Change scenario: RCP 2.6

Change time period: 2090



Consensus	Proportion of models
Not projected	No models
Very Low	< 10%
Low	10% - 33%
Moderate	33% - 66%
High	66% - 90%
Very High	> 90%

		Annual Mean Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Wetter > 15.00				
	Wetter 5.00 to 15.00	+ 1 of 29 (3%)	+ 3 of 29 (10%)		
	Little Change -5.00 to 5.00	+ 2 of 29 (7%)	+ 7 of 29 (24%)	+ 1 of 29 (3%)	
	Drier -15.00 to -5.00		+ 7 of 29 (24%)		
	Much Drier < -15.00		+ 6 of 29 (21%)	+ 2 of 29 (7%)	

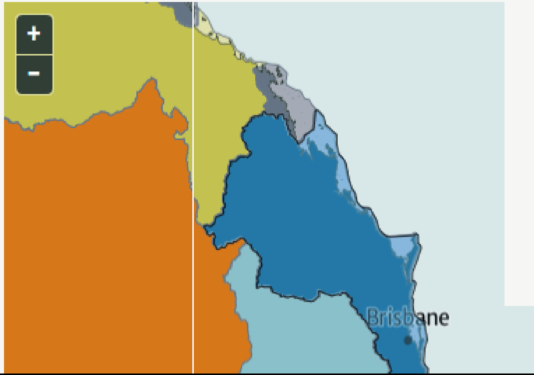
https://www.climatechangeinaustralia.gov.au

EAST COAST CLIMATE FUTURES

Go back

Change scenario: RCP 4.5

Change time period: 2090



Consensus	Proportion of models
Not projected	No models
Very Low	< 10%
Low	10% - 33%
Moderate	33% - 66%
High	66% - 90%
Very High	> 90%

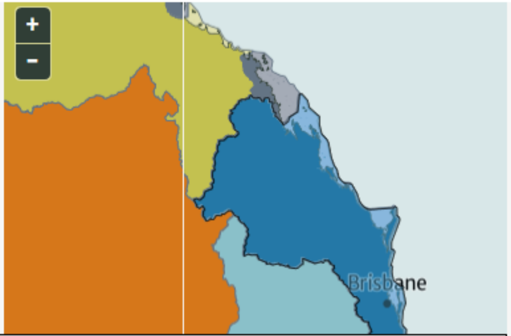
		Annual Mean Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Wetter > 15.00				
	Wetter 5.00 to 15.00		+ 3 of 46 (7%)	+ 6 of 46 (13%)	
	Little Change -5.00 to 5.00		+ 4 of 46 (9%)	+ 10 of 46 (22%)	
	Drier -15.00 to -5.00		+ 6 of 46 (13%)	+ 9 of 46 (20%)	
	Much Drier < -15.00			+ 8 of 46 (17%)	

EAST COAST CLIMATE FUTURES

Go back

Change scenario: RCP 8.5

Change time period: 2090



	Consensus	Proportion of models
	Not projected	No models
	Very Low	< 10%
	Low	10% - 33%
	Moderate	33% - 66%
	High	66% - 90%
	Very High	> 90%

		Annual Mean Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Wetter > 15.00			+ 3 of 48 (6%)	+ 1 of 48 (2%)
	Wetter 5.00 to 15.00				+ 5 of 48 (10%)
	Little Change -5.00 to 5.00			+ 1 of 48 (2%)	+ 10 of 48 (21%)
	Drier -15.00 to -5.00			+ 4 of 48 (8%)	+ 8 of 48 (17%)
	Much Drier < -15.00			+ 2 of 48 (4%)	+ 14 of 48 (29%)

The Bureau of Meteorology | Climate Outlooks

Issued Thursday 31 August 2023

The latest Climate Outlooks are now available on our website.

Overview

- For September to November, below median rainfall is likely to very likely (60% to greater than 80% chance) for most of Australia.
- For September to November, above median maximum temperatures are very likely (greater than 80% chance) for almost all of Australia.
- For September to November, warmer than median minimum temperatures are likely (60 to 80% chance) to very likely for most of western and southern Australia.
- The long-range forecast is influenced by several factors, including likely El Niño development and positive Indian Ocean Dipole development, and record warm oceans globally.