REGIONAL CLIMATE PROJECTIONS FOR AUSTRALIA: A KEY INPUT INTO NATIONAL ADAPTATION PLANNING

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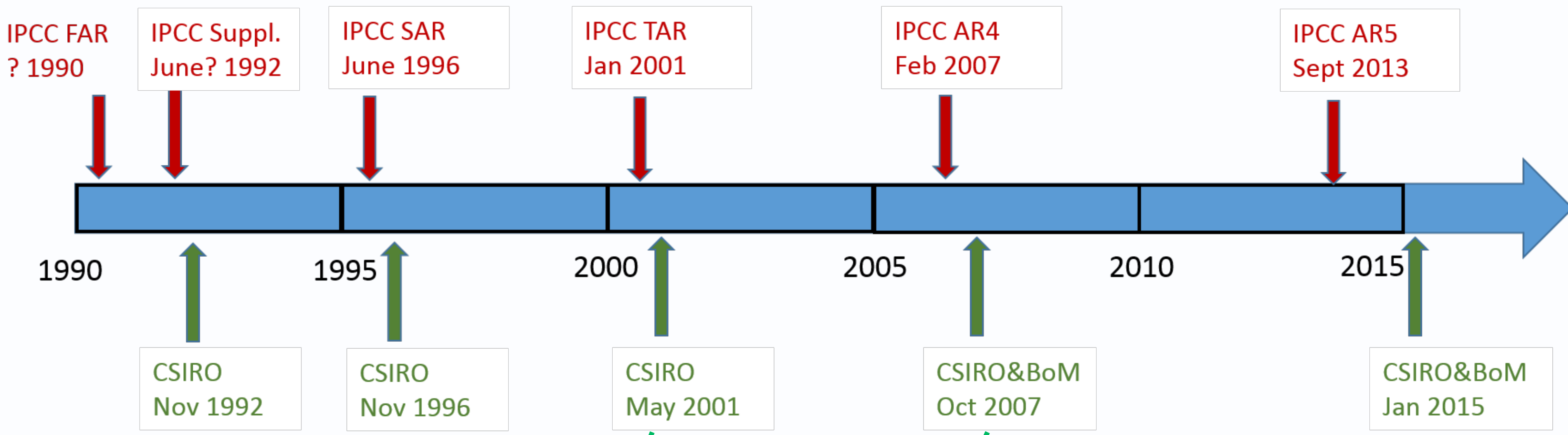
Acknowledgements to NRM Projections Team, CSIRO & BoM

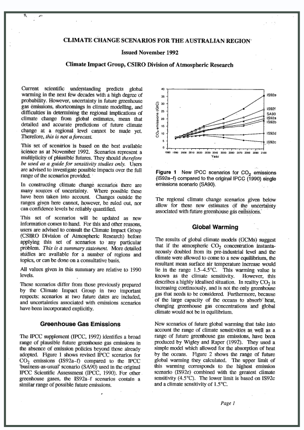
Australian-German Climate and Energy College, 13 April 2016

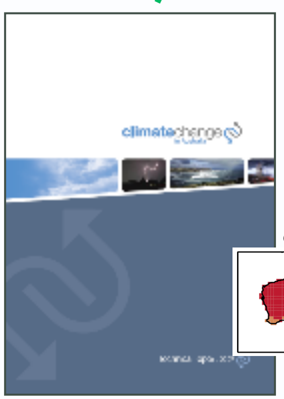
Outline

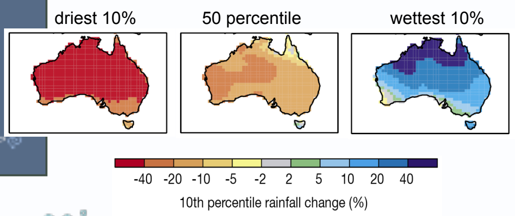
- Background to the new projections release
- The projections project
- Projection methods
- The projections
- Website
- Conclusions

Long history of national projections for Australia



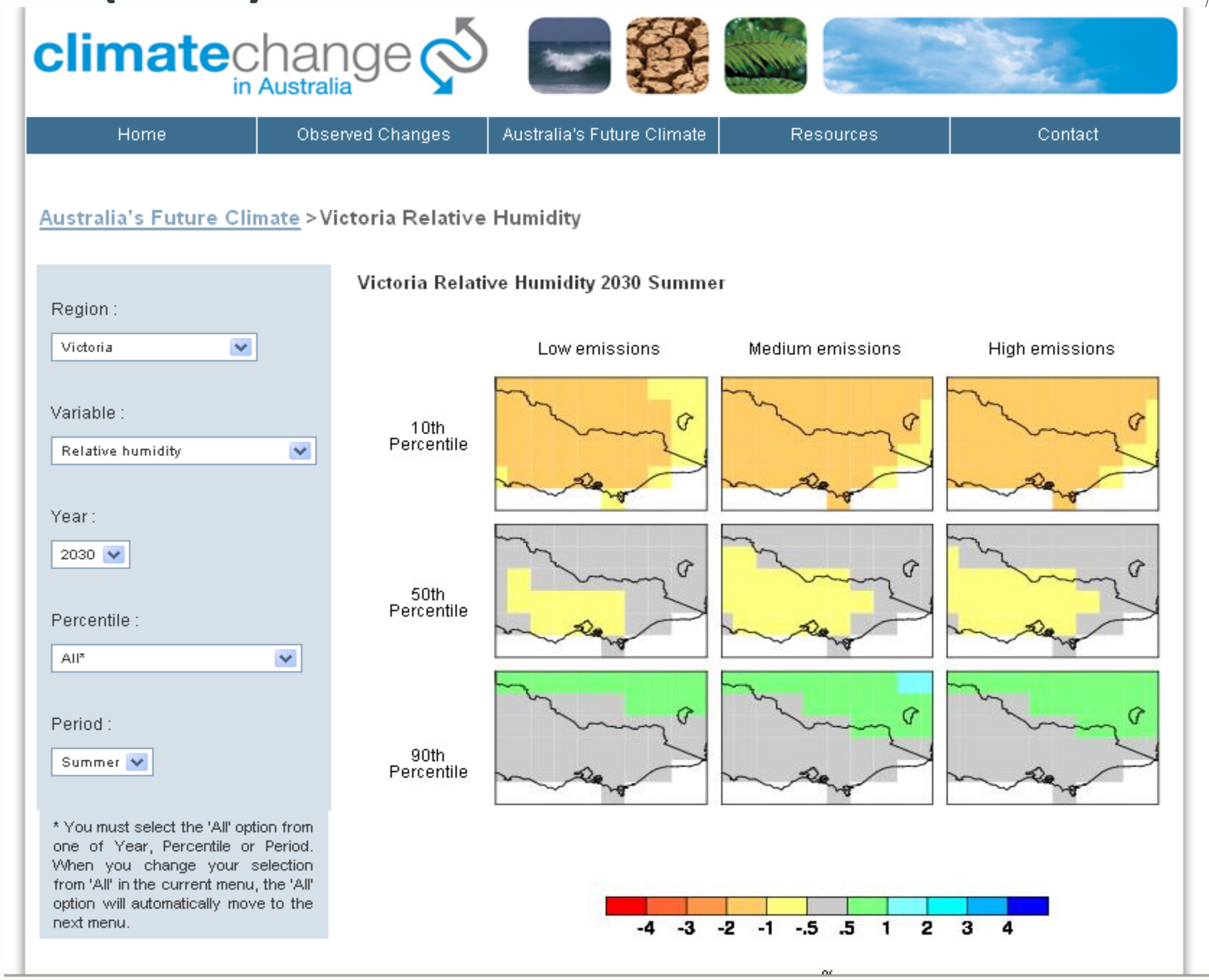






climatechange in Australia

CCIA (2007)



Features of CSIRO projections over the years

Perennial

- Grounded primarily in climate model results
- Strong links to IPCC assessments
- Representation of uncertainty
    - Emission scenarios
    - Multiple climate models

Trends

- Toward use of more models
- Away from various scaling techniques.
- Toward increased scope

Tensions

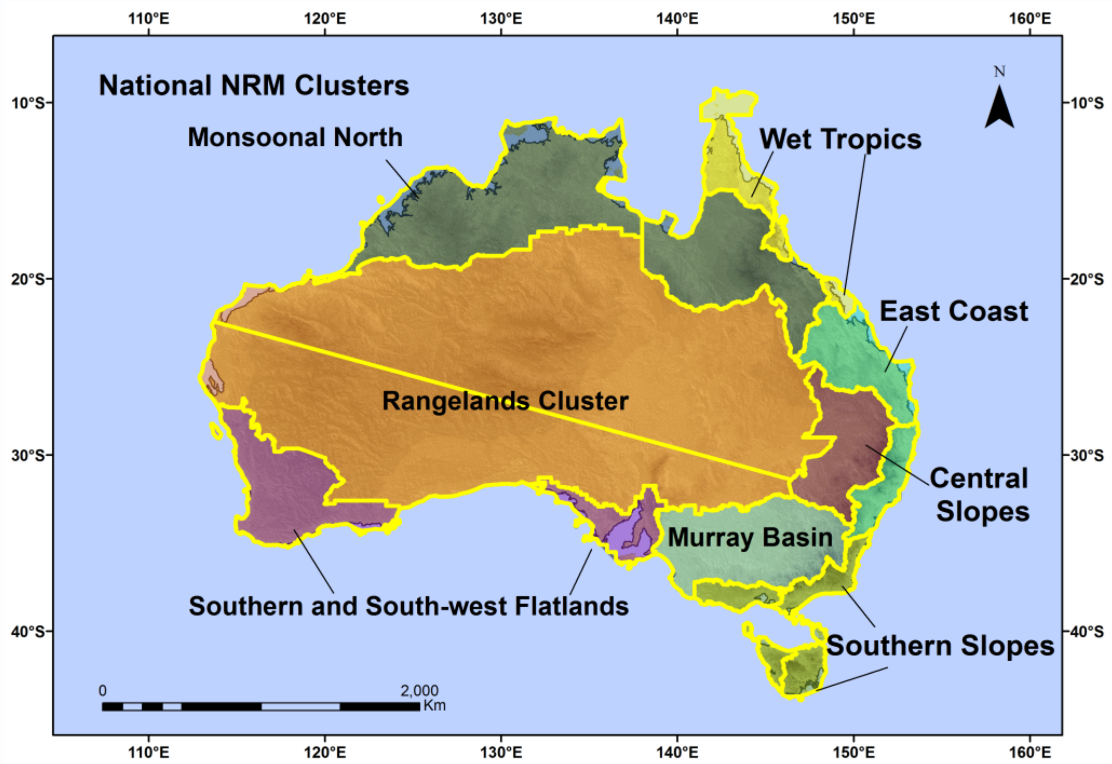
- Simplicity of presentation
- Spatial resolution
- Probabilistic projection information
- Use of model evaluation
- Expert judgment

Used in a broad range of impacts assessment: e.g. water resources

- As a result of reduced precipitation and increasing evaporation, water security problems are projected to intensify by 2030 in southern and eastern Australia
- 0-45% less flow in Victorian catchments by 2030
- 14% less flow in south-western Australia by 2030
- 9% less water in the northern Murray Darling Basin (MDB) by 2030, and 13% less in the southern MDB
- 7-35% less flow into Melbourne dams by 2050

Projections released in 2015

- Focus on serving the needs of natural resource management (+ everyone else)
- Predefined set of regions
- CMIP5-based with some downscaling
- 21 climate variables
- Department of Environment funded
- Knowledge and data
- Projections and scenarios



USER CONSULTATION

NRM user engagement throughout the production process

User Panel

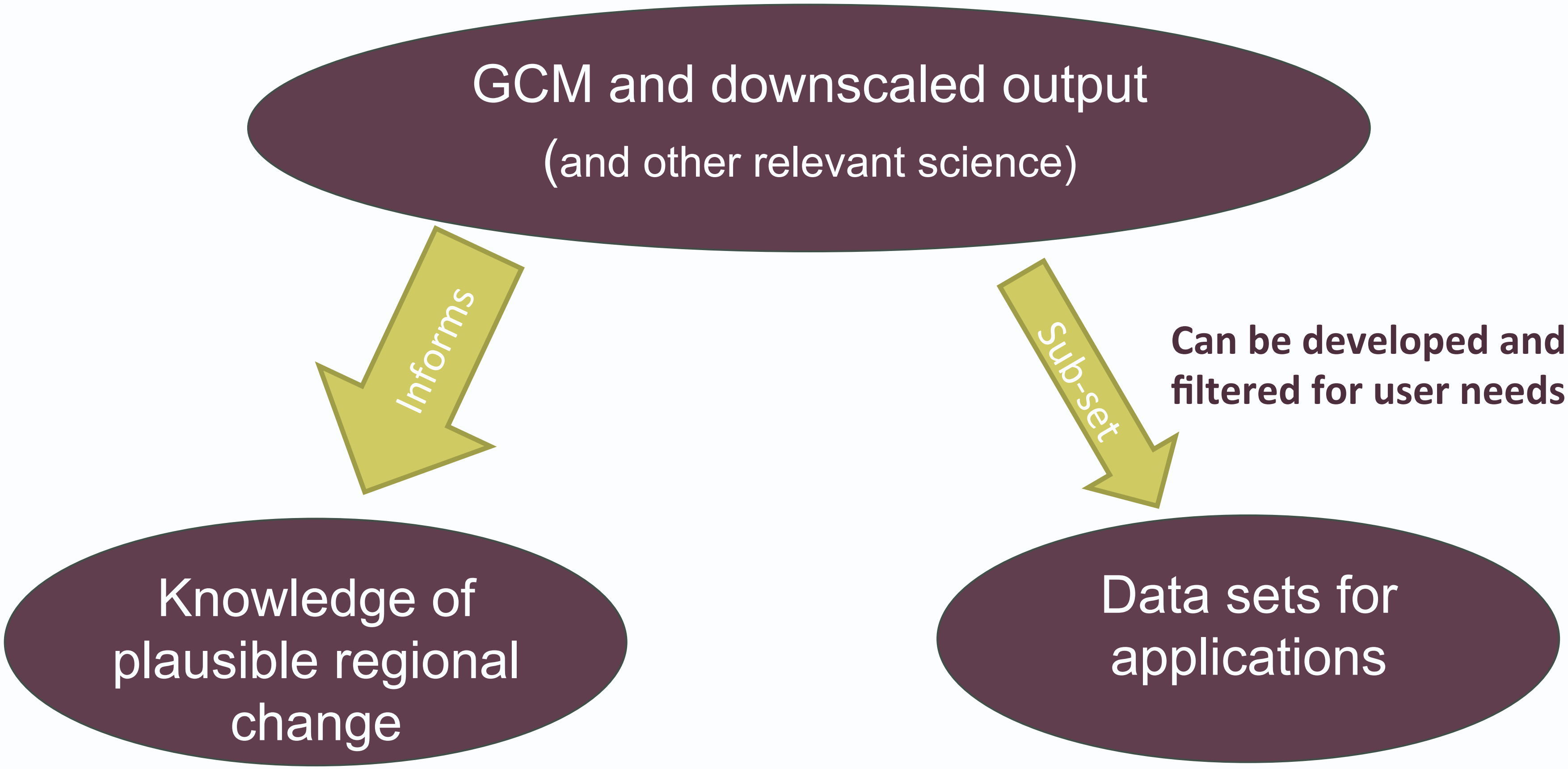
Roadshow

Two basic needs:

- key messages
- application data

Enabled the user communities to better appreciate user needs and scientific limitations, and led to more meaningful projections and better guidance of user expectations.

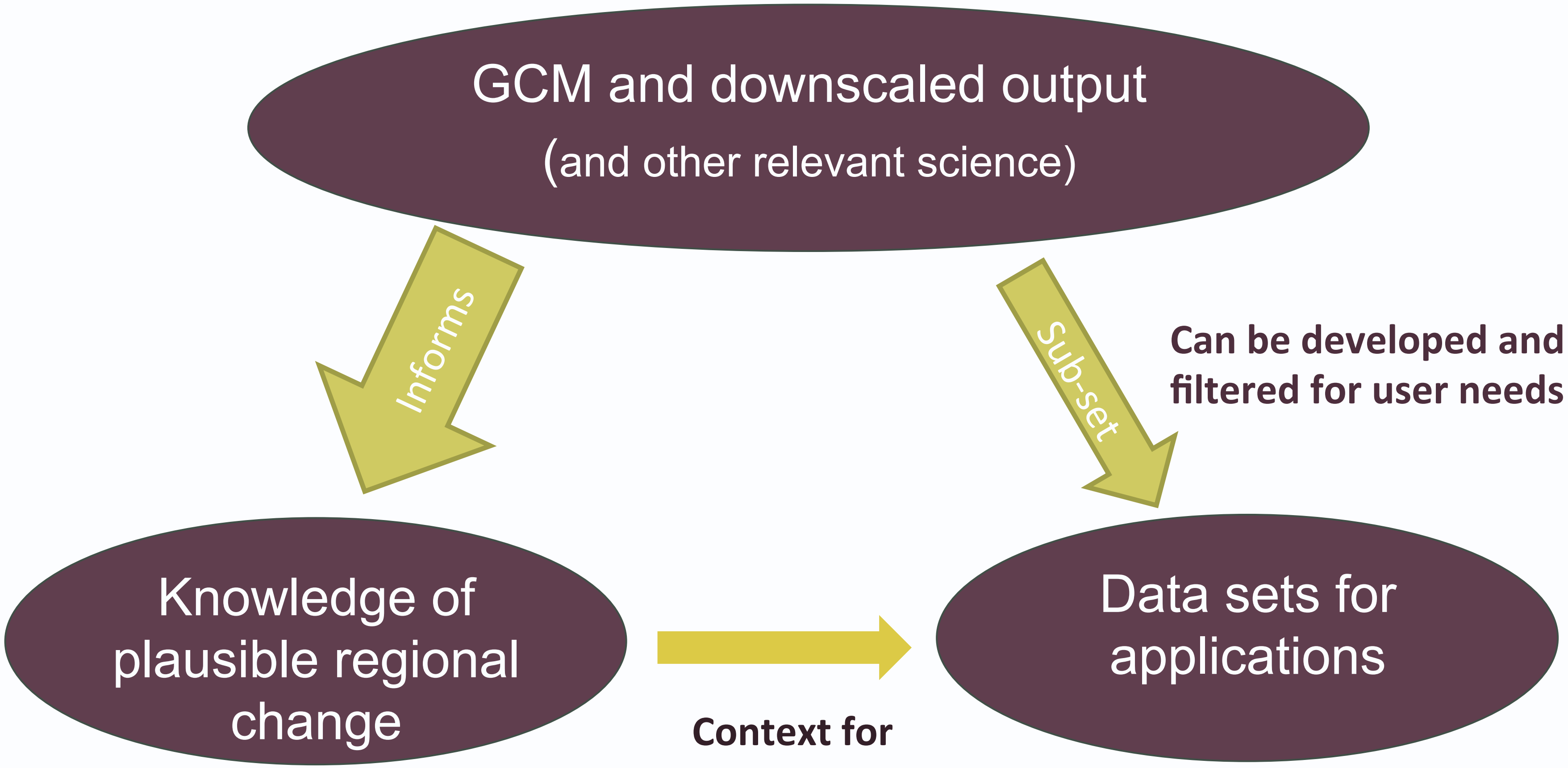
Types of projection information



Ranges of change
Qualitative information

Individual models
(Scenarios)

Types of projection information



Ranges of change
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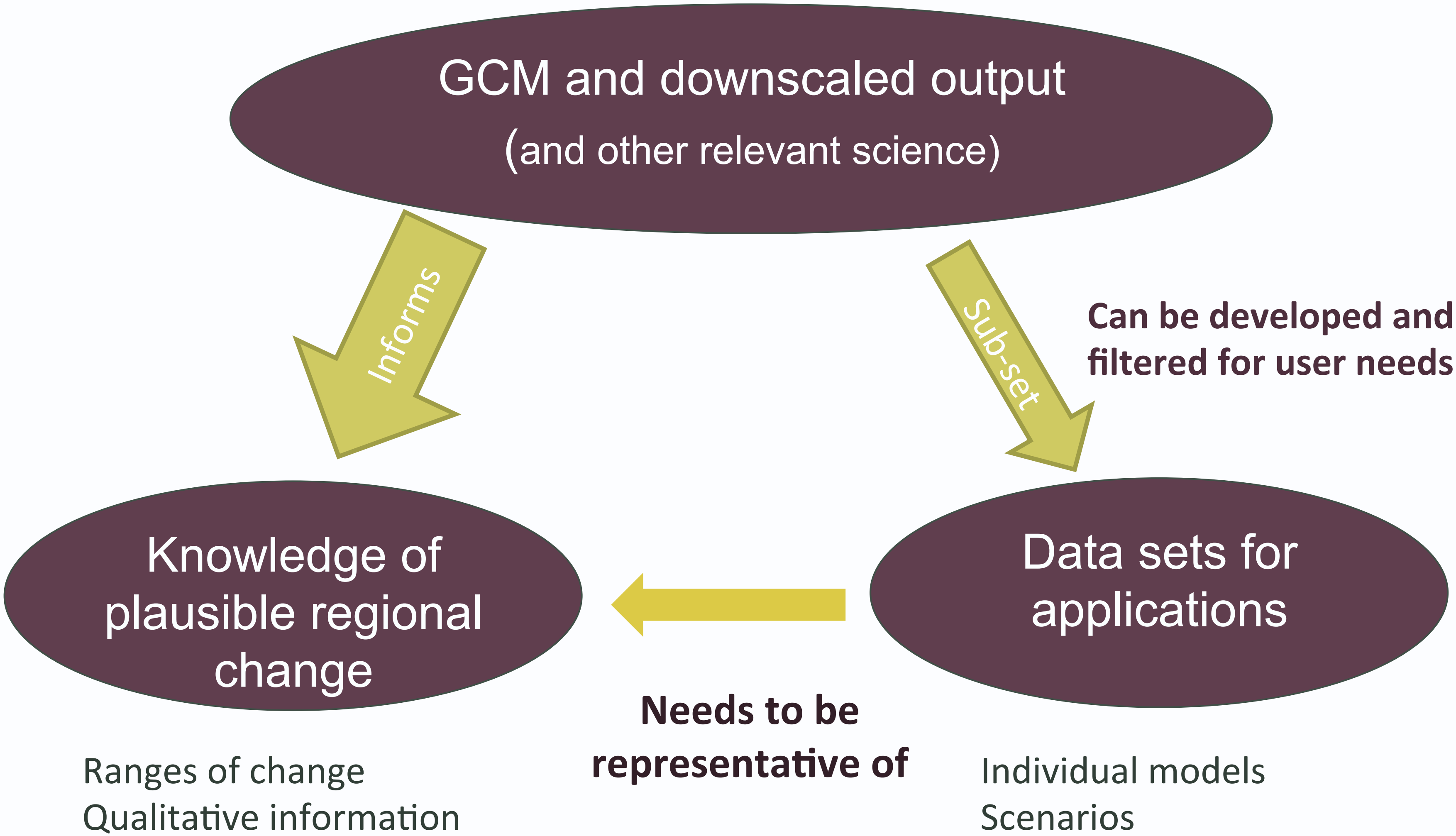


Evaluation of CMIP5 GCMs for use in Climate Projections

Aurel Moise, Jonas Bhend, Ian Watterson, Louise Wilson

CMIP5 models assessed on multiple tests against current climate

Model	Low M-Score for PR and TAS	Low STRMSE	Low score for climate features	Low ENSO – rainfall tele connection	No Monsoon westerlies	Wet season rainfall not good spatially	Rainfall relationship to Blocking not good	IOD spatial variability too low or too high	Simple MJO skill not good	
ACCESS1-0								X		1
ACCESS1-3					X		X			2
BNU-ESM,	X		X			X				3
CanCM4							X			1
CanESM2				X						1
CCSM4,		X								1
CESM1-BGC,		X								1
CESM1-WACCM,	X	X	X							3
CMCC-CESM,	X									1
CMCC-CMS		X								1
CSIRO-Mk3-6-0				X				X		2
GFDL-CM3								X		1
GFDL-ESM2G				X			X		X	3
GISS-E2-H,	X		X		X		X			4
GISS-E2-H-CC,	X		X		X					3
GISS-E2-R			X		X		X			3
HadCM3				X				X		2
HadGEM2-ES									X	1
INMCM4				X	X				X	3
IPSL-CM5A-LR				X	X				X	3
IPSL-CM5A-MR				X	X				X	3
IPSL-CM5B-LR								X		1
MIROC-ESM	X			X	X	X			X	5
MIROC-ESM-CHEM	X				X	X			X	4
MPI-ESM-LR						X				1
MPI-ESM-MR						X				1
MPI-ESM-P						X				1
MRI-CGCM3								X		1
NorESM1-M,		X								1
NorESM1-ME,		X								1

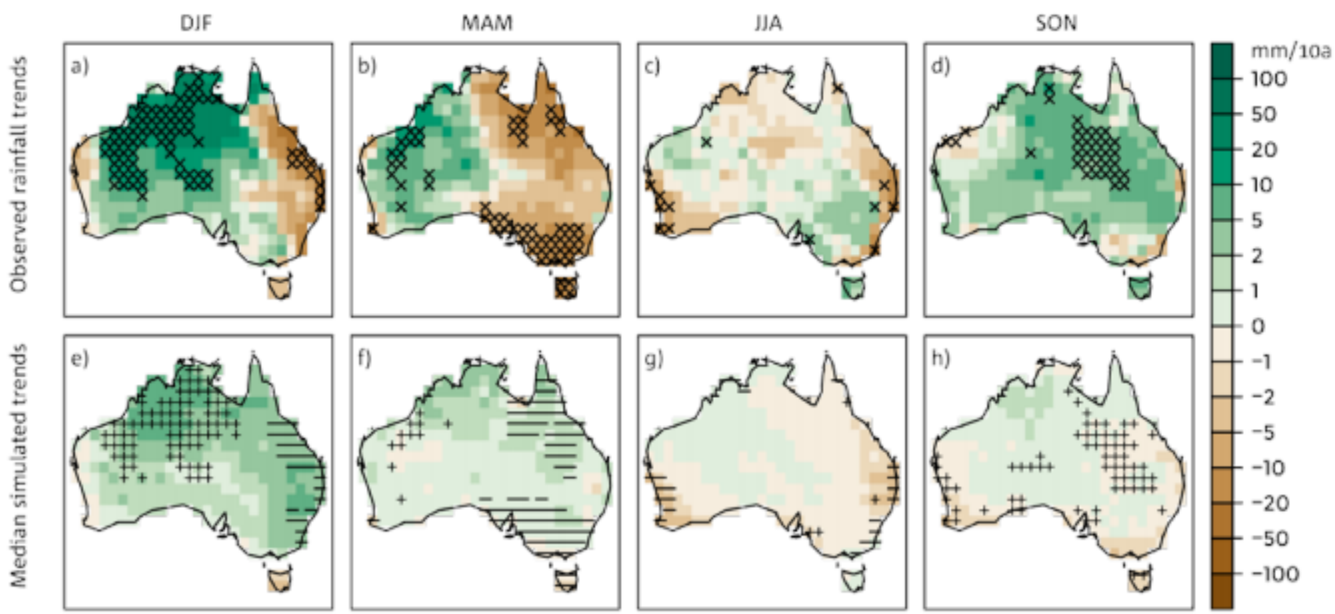
Models scoring low across various test.

BNU-ESM
CESM1-WACCM
GFDL-ESM2G
GISS-E2H
GISS-E2H-CC
GISS-E2R
INMCM4
IPSL-CM5A-LR
IPSL-CM5A-MR
MIROC-ESM
MIROC-ESM-CHEM

Consistency of historical CMIP5 simulations with observed trends: Precipitation

obs

Model median



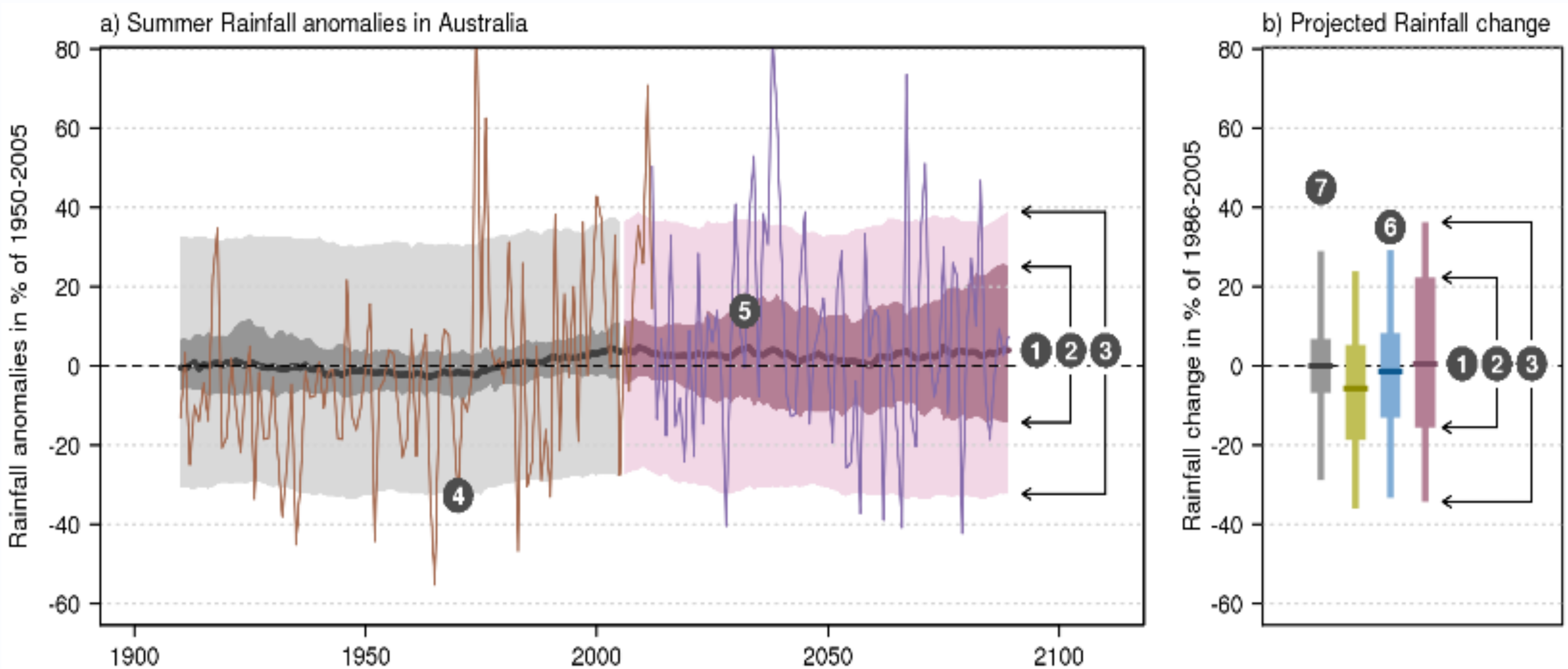
Hatching on model results where fewer than 10% of model runs consistent with observations

Areas of low consistency considered in confidence assessment

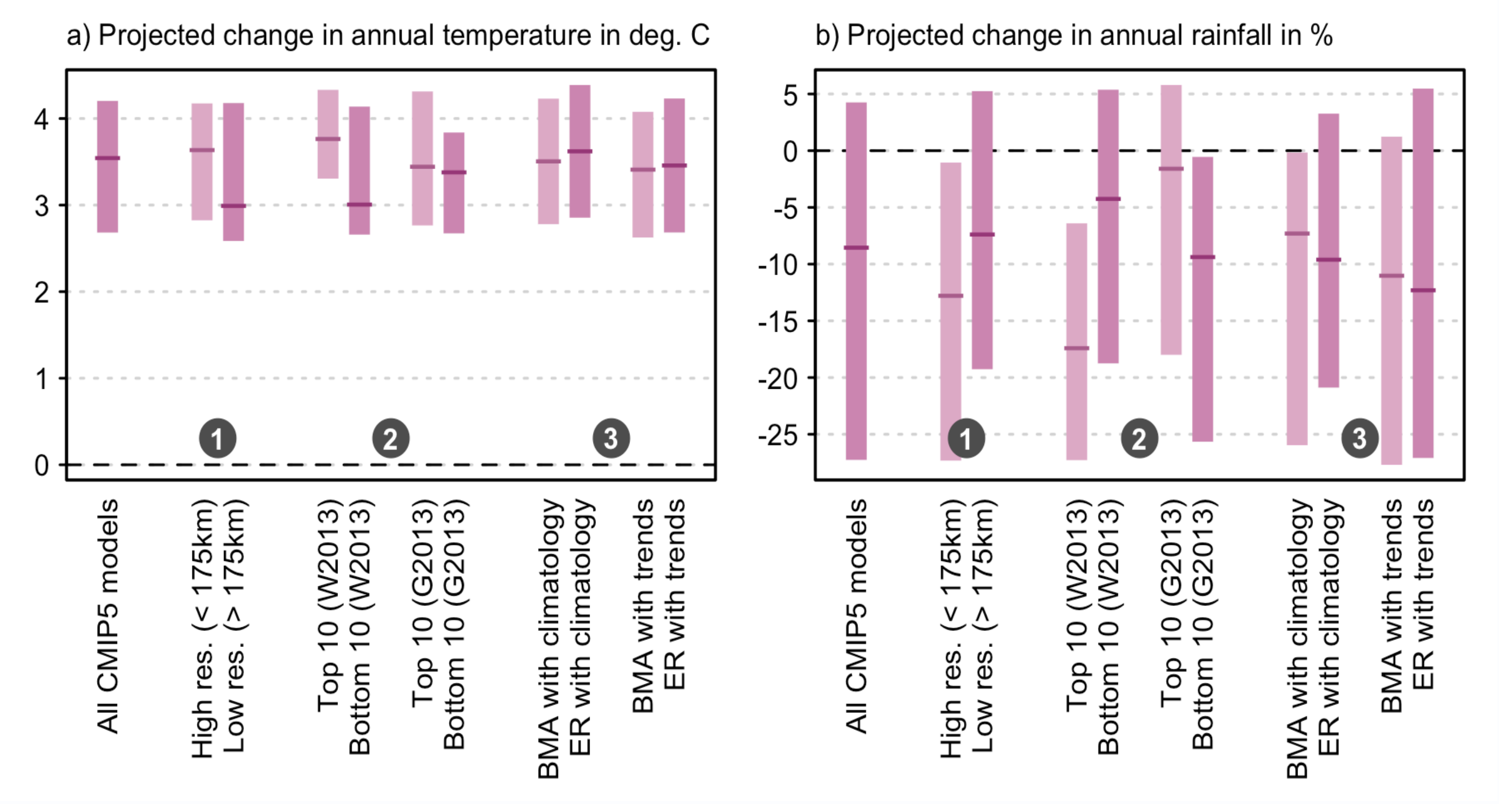
Projection Methods

Jonas Bhend and Ian Watterson

Projection display



Preparing projection range from GCM results
Methods compared



➢ All models, 10th and 90th percentiles of empirical distribution chosen

Temperature projections

Ian Watterson, Tony Rafter, Louise Wilson, Jonas Bhend and Craig Heady

TEMPERATURE

AUSTRALIA WILL WARM SUBSTANTIALLY DURING THE 21ST CENTURY

AUSTRALIA WILL WARM SUBSTANTIALLY DURING THE 21ST CENTURY

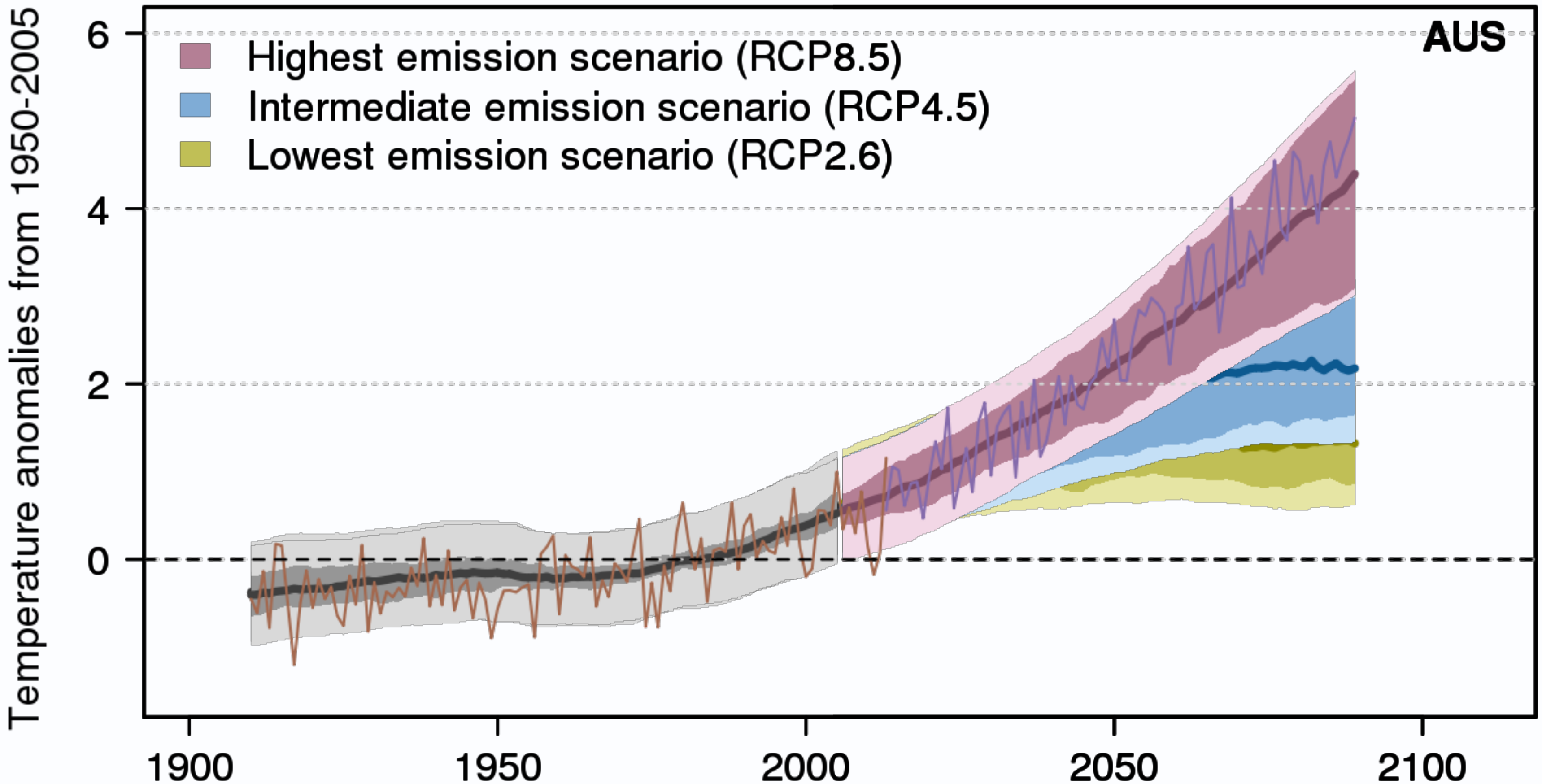
There is *very high confidence* in continued increases of mean, daily minimum and daily maximum temperatures throughout this century for all regions in Australia.

Warming will be large compared to natural variability in the near future (2030) *(high confidence)* and very large compared to natural variability late in the century (2090) under high emissions (*very high confidence*).

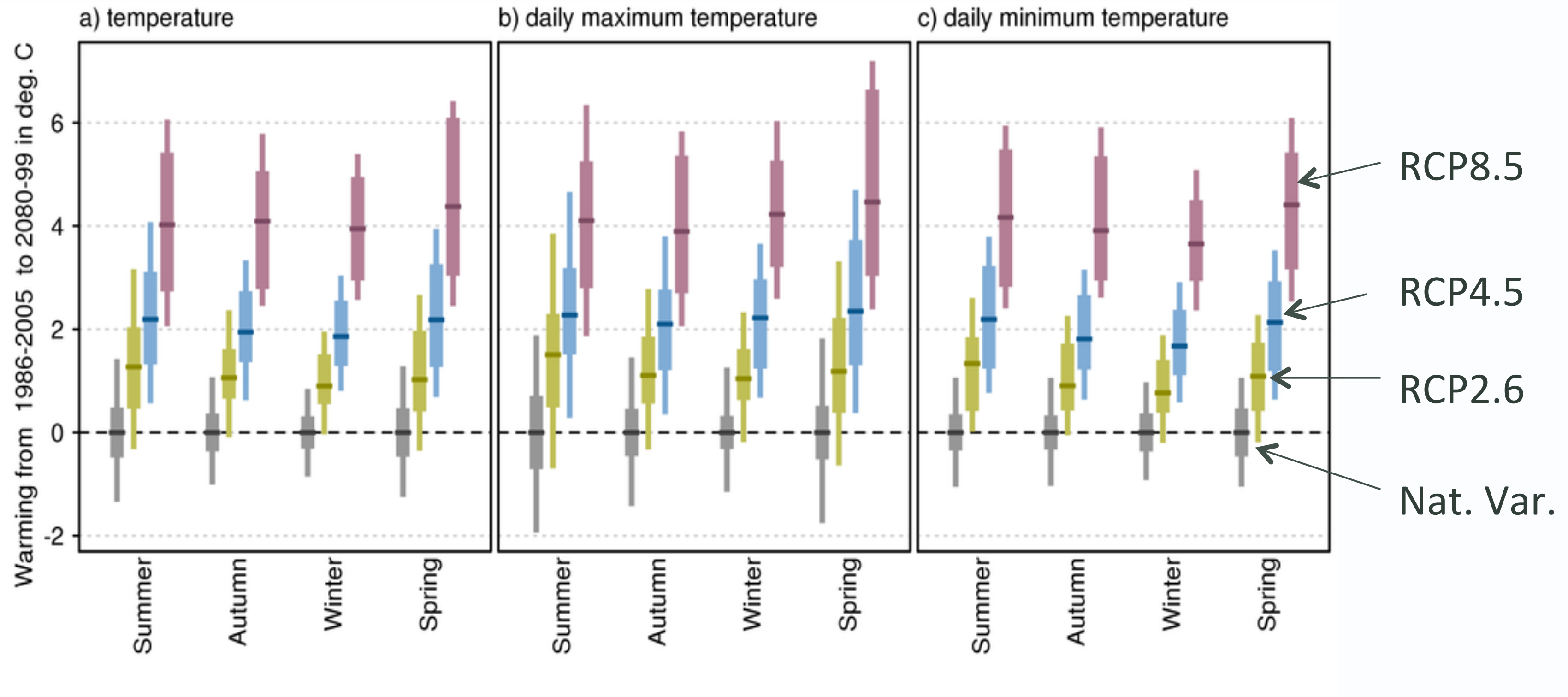
More frequent and hotter hot days (*very high confidence*).

Fewer frost days are projected (*high confidence*)

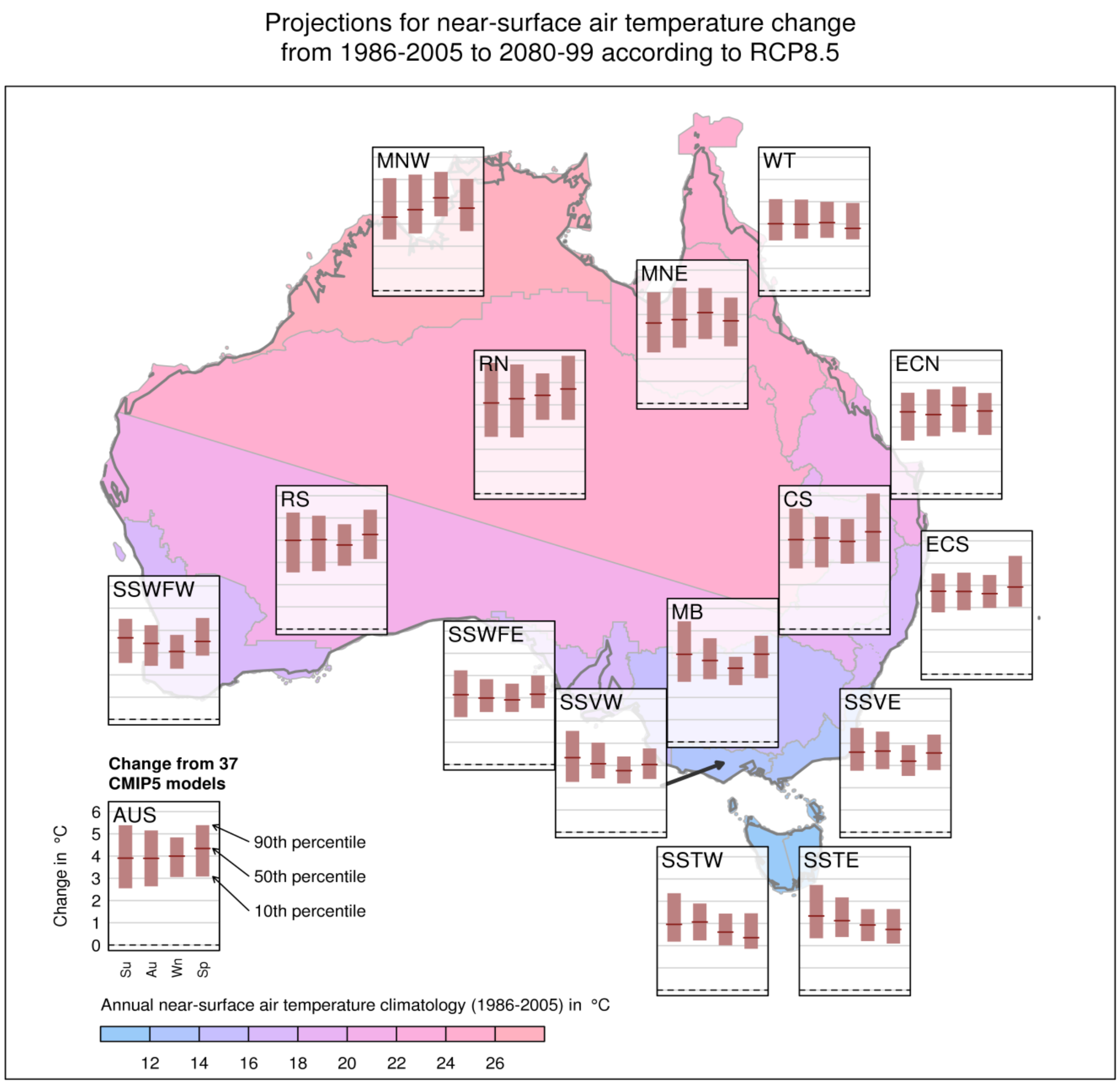
AUSTRALIA WILL WARM SUBSTANTIALLY DURING THE 21ST CENTURY



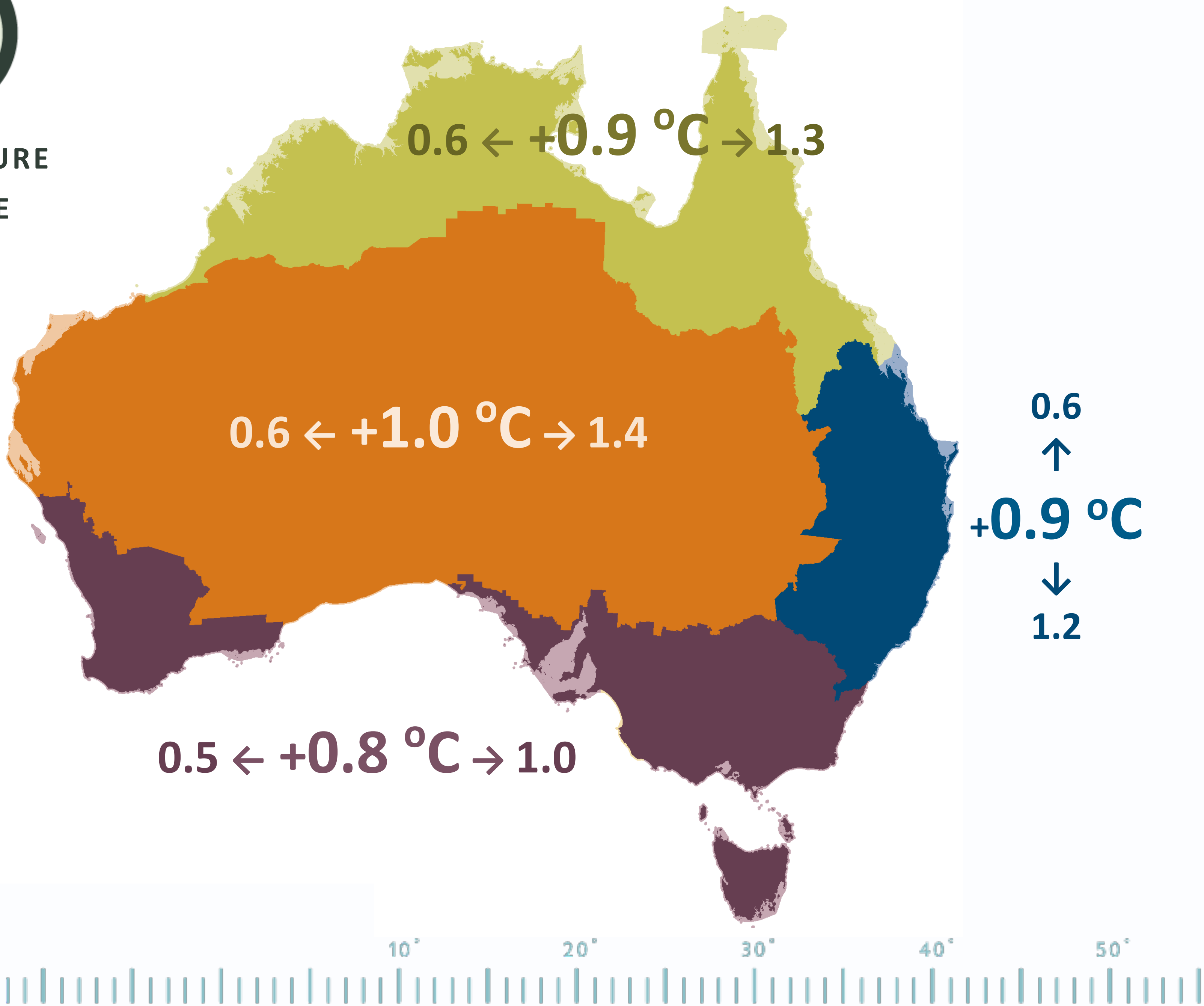
Projected temperature change (mean, min and max) for Central Slopes in 2090



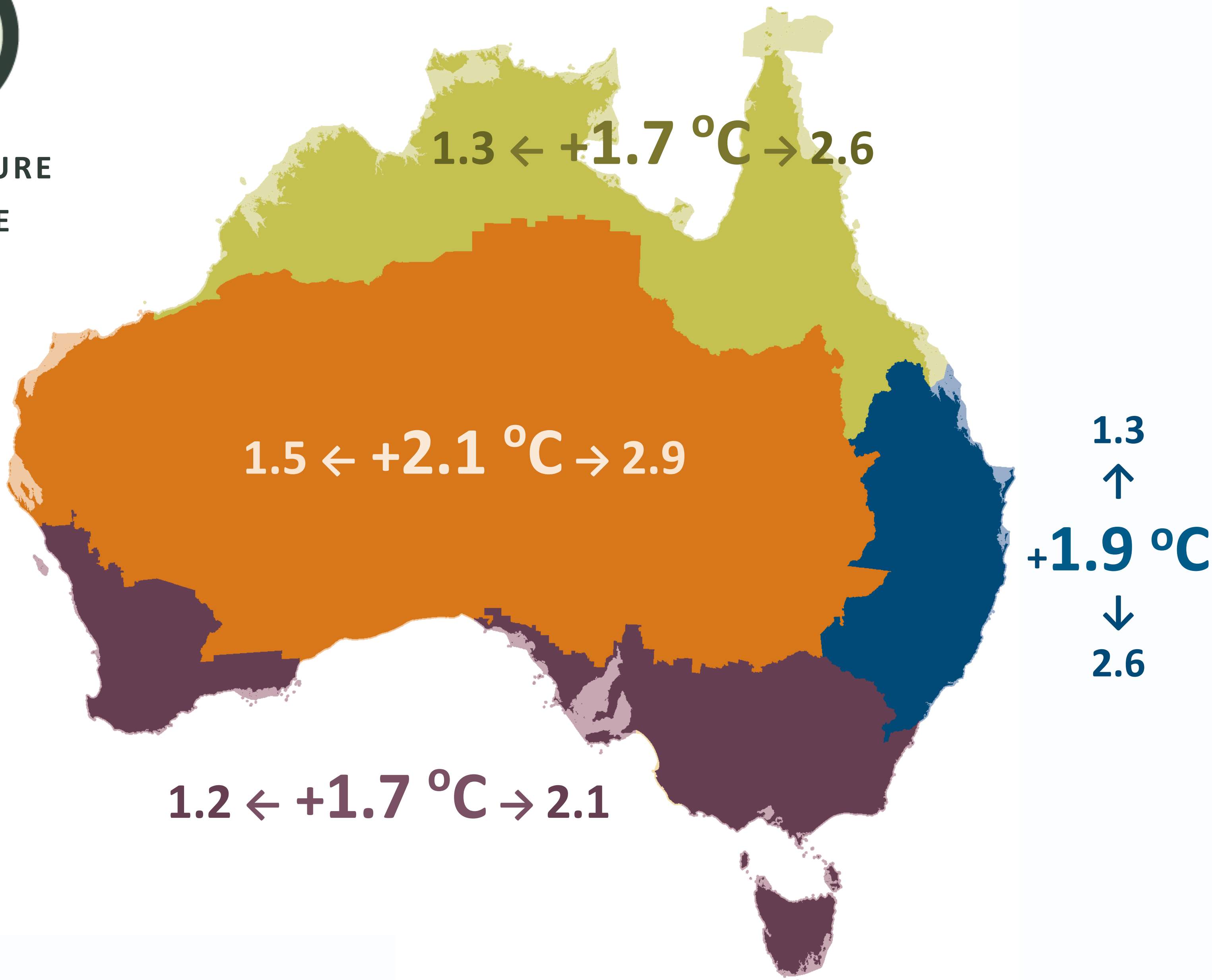
Projected temperature change : 2090, RCP8.5



TEMPERATURE INCREASE 2030 RCP4.5

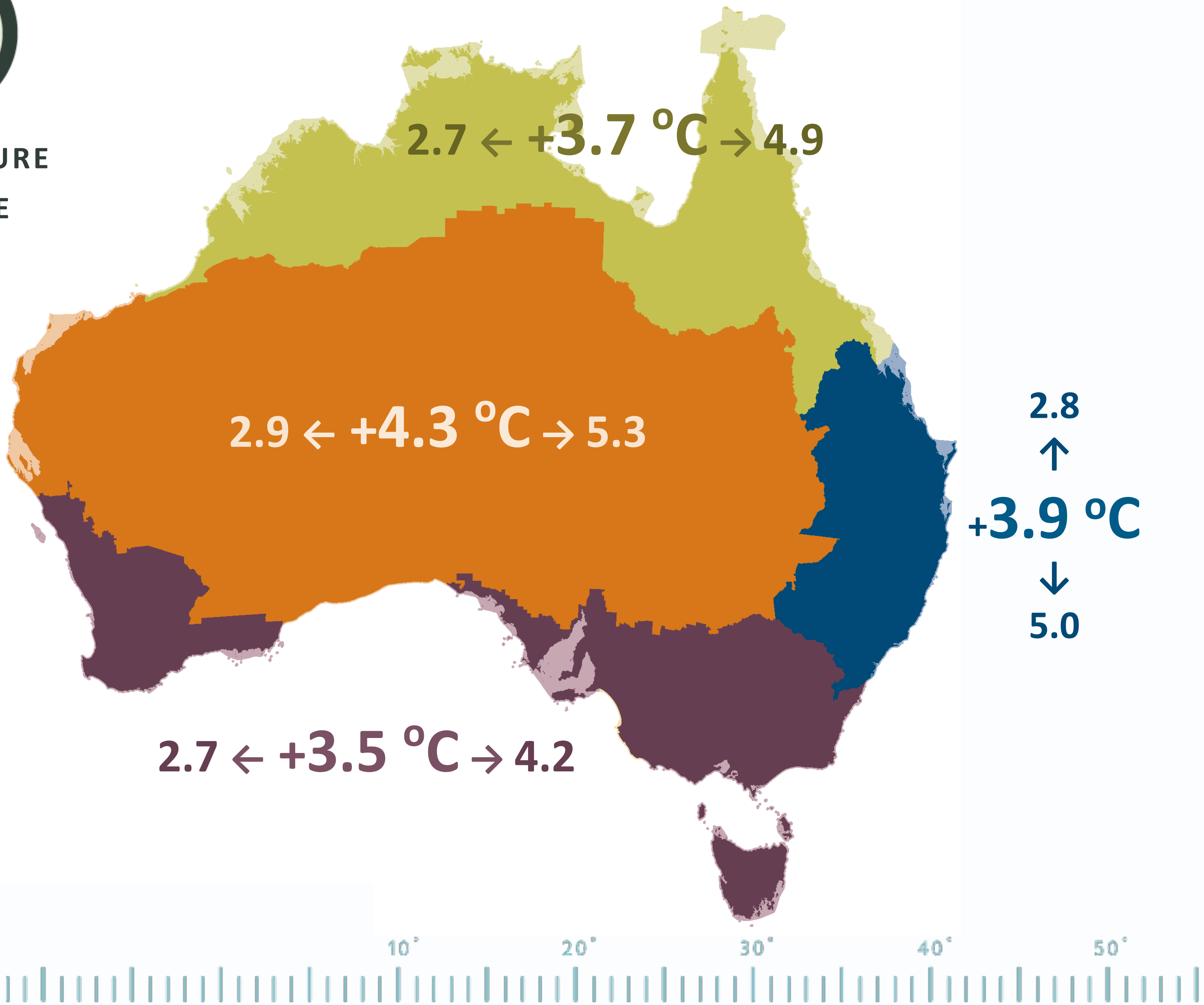


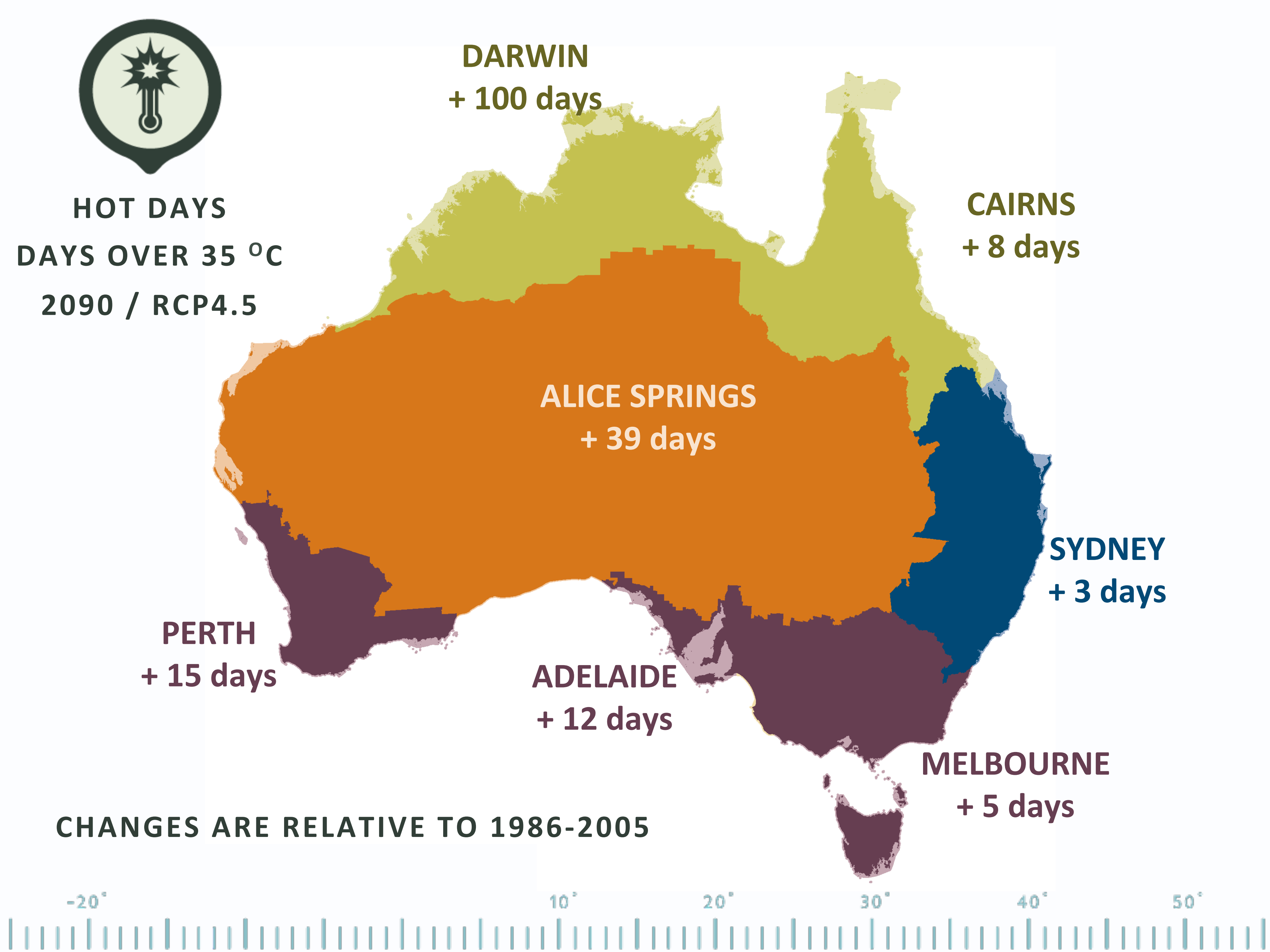
TEMPERATURE INCREASE
2090
RCP4.5



-20° 10° 20° 30° 40° 50°

TEMPERATURE INCREASE
2090
RCP8.5




HOT DAYS
DAYS OVER 35 °C
2090 / RCP4.5
DARWIN
+ 100 days
CAIRNS
+ 8 days
ALICE SPRINGS
+ 39 days
SYDNEY
+ 3 days
PERTH
+ 15 days
ADELAIDE
+ 12 days
MELBOURNE
+ 5 days
CHANGES ARE RELATIVE TO 1986-2005
-20°
10°
20°
30°
40°
50°

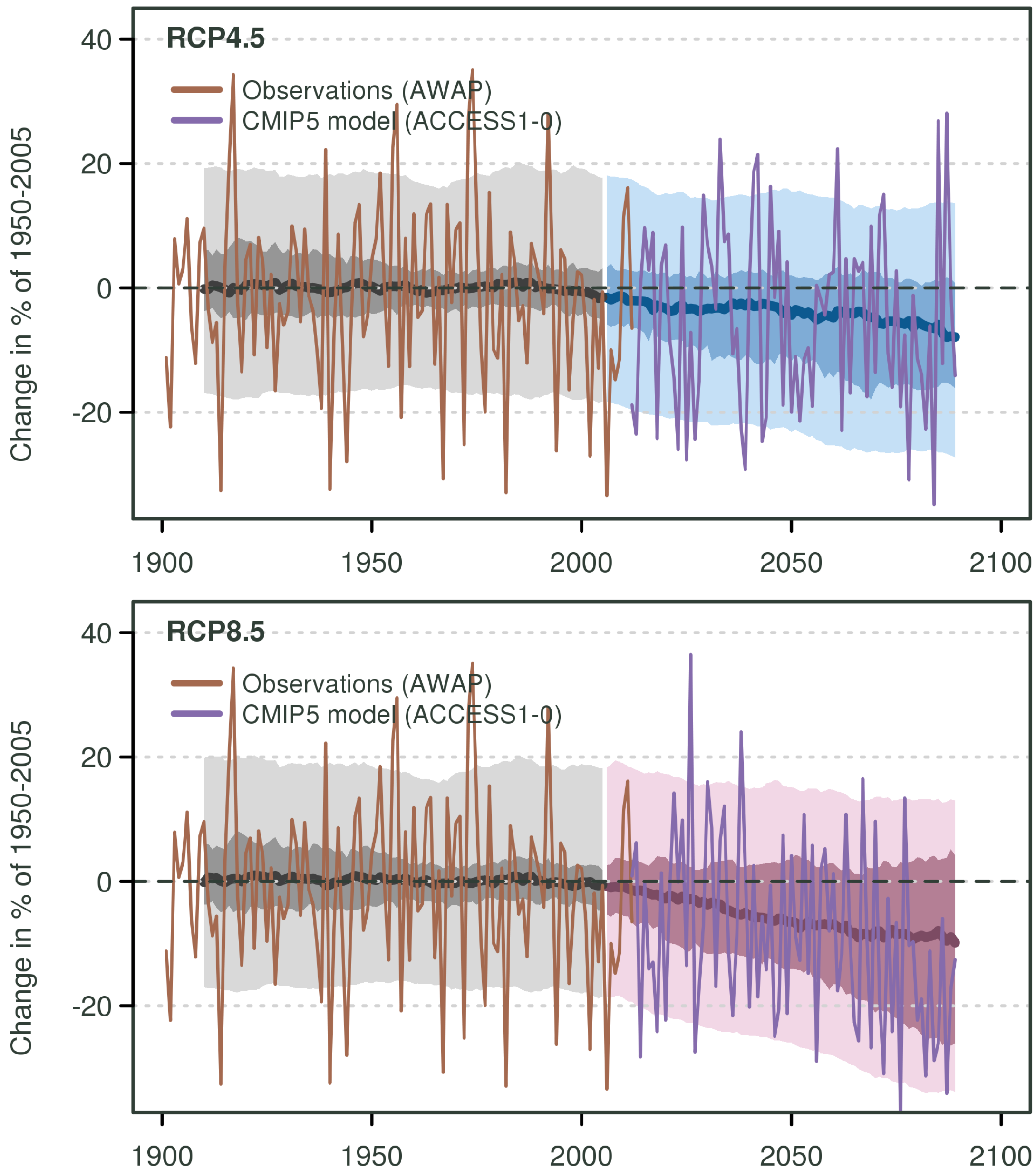
Rainfall projections

Penny Whetton, Aurel Moise, Dewi Kirono, Tony Rafter, Louise Wilson, Kevin Hennessy, Jonas Bhend, Pandora Hope, Bertrand Timbal, Andrew Dowdy, Ian Watterson, Michael Grose and Janice Bathols

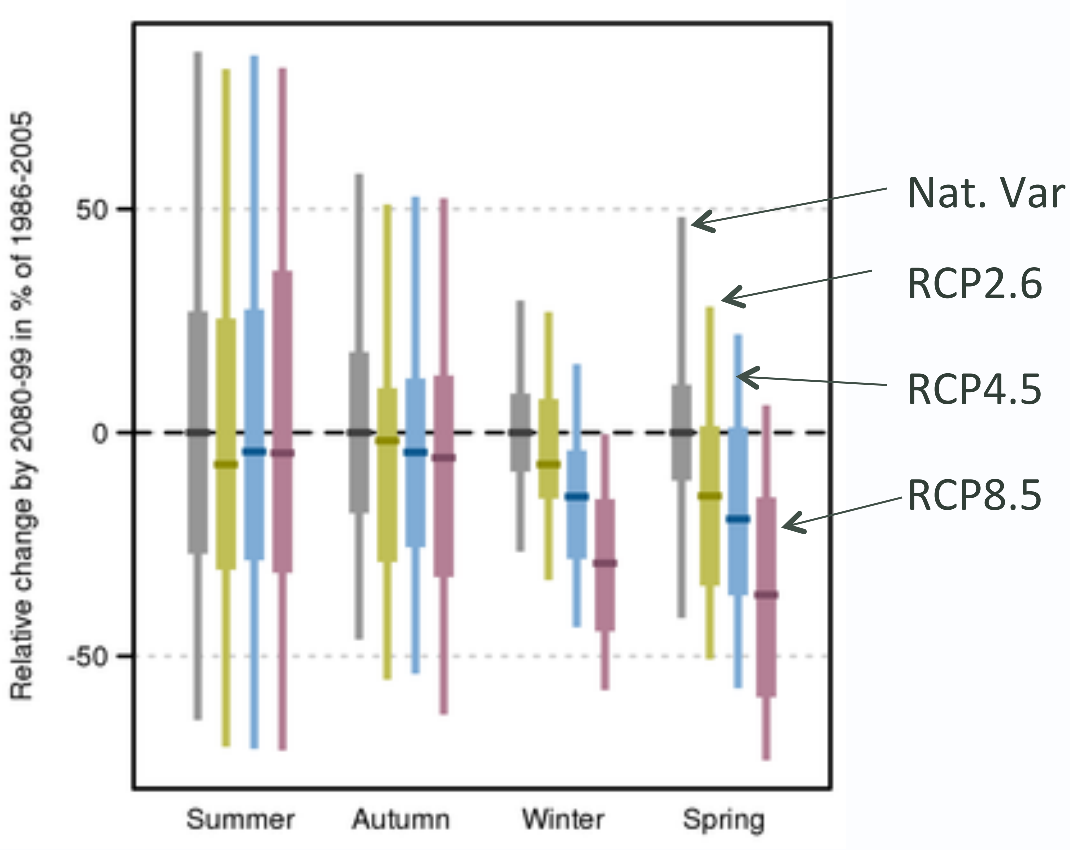

RAINFALL
WINTER/SPRING RAINFALL IS PROJECTED TO DECLINE IN SOUTHERN AUSTRALIA
INCREASES OR DECREASES ARE POSSIBLE ELSEWHERE & IN OTHER SEASONS

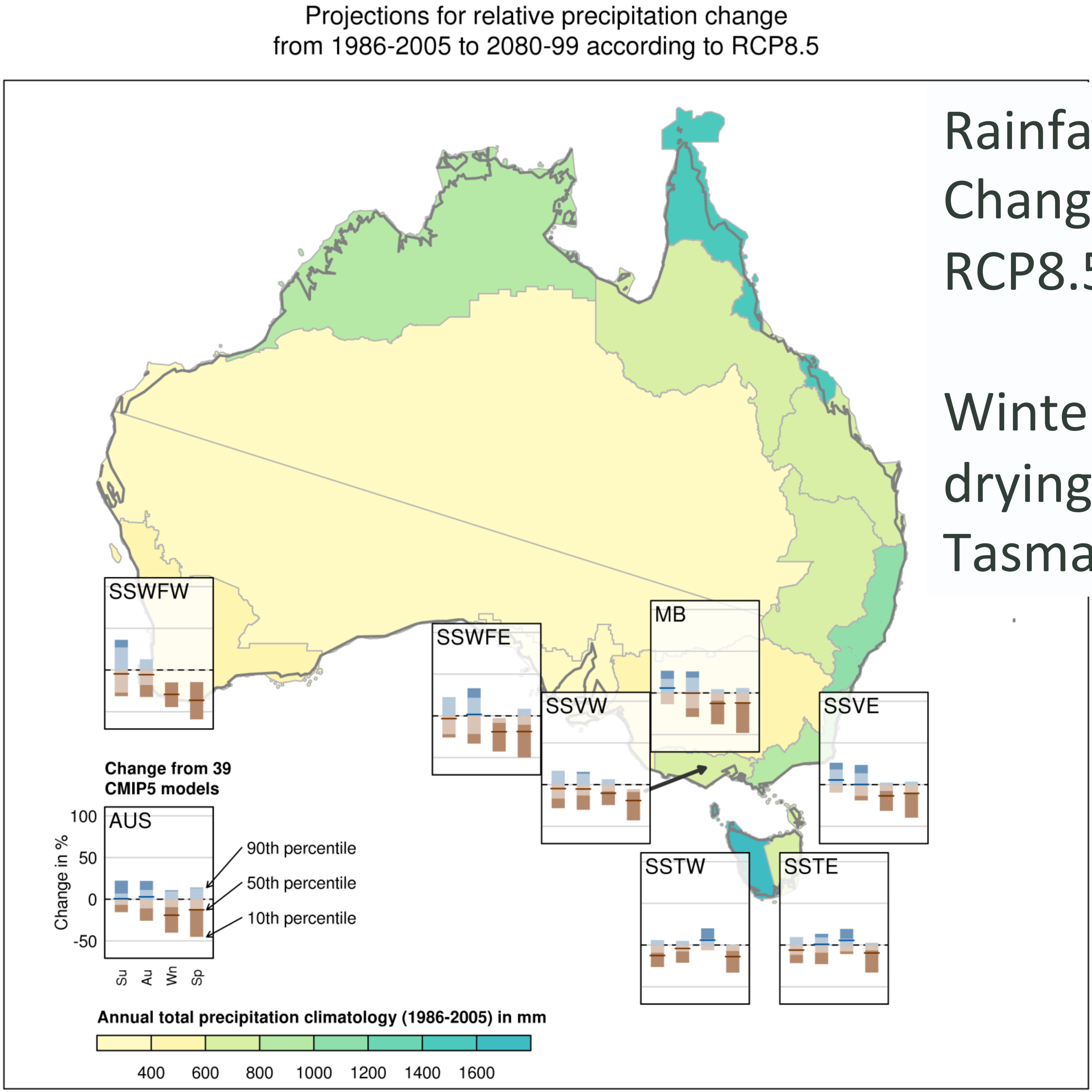
SOUTHERN AUSTRALIA

RAINFALL VARIABILITY VERSUS CHANGE



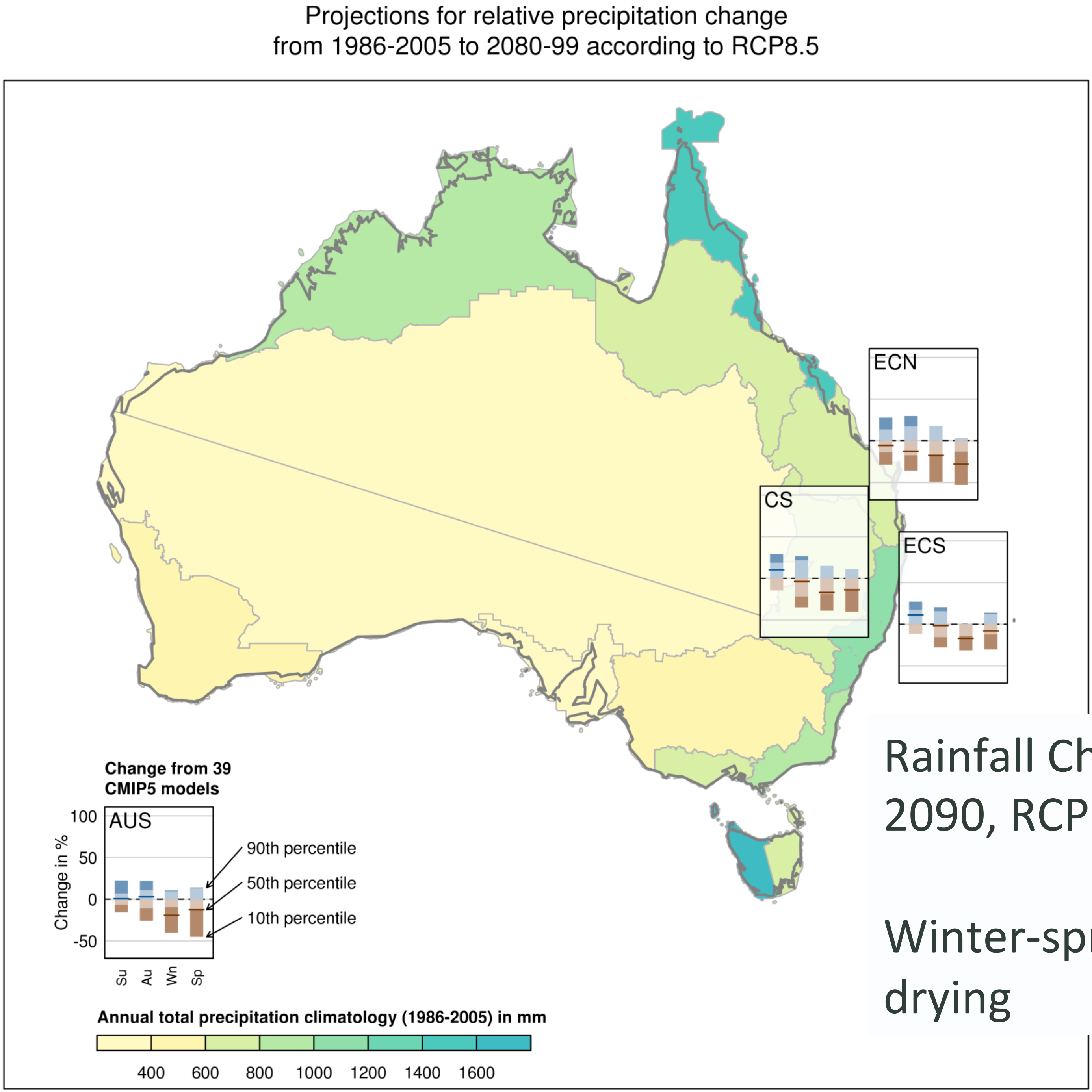
Projected precipitation change (%) for SW WA in 2090





Rainfall Change 2090, RCP8.5

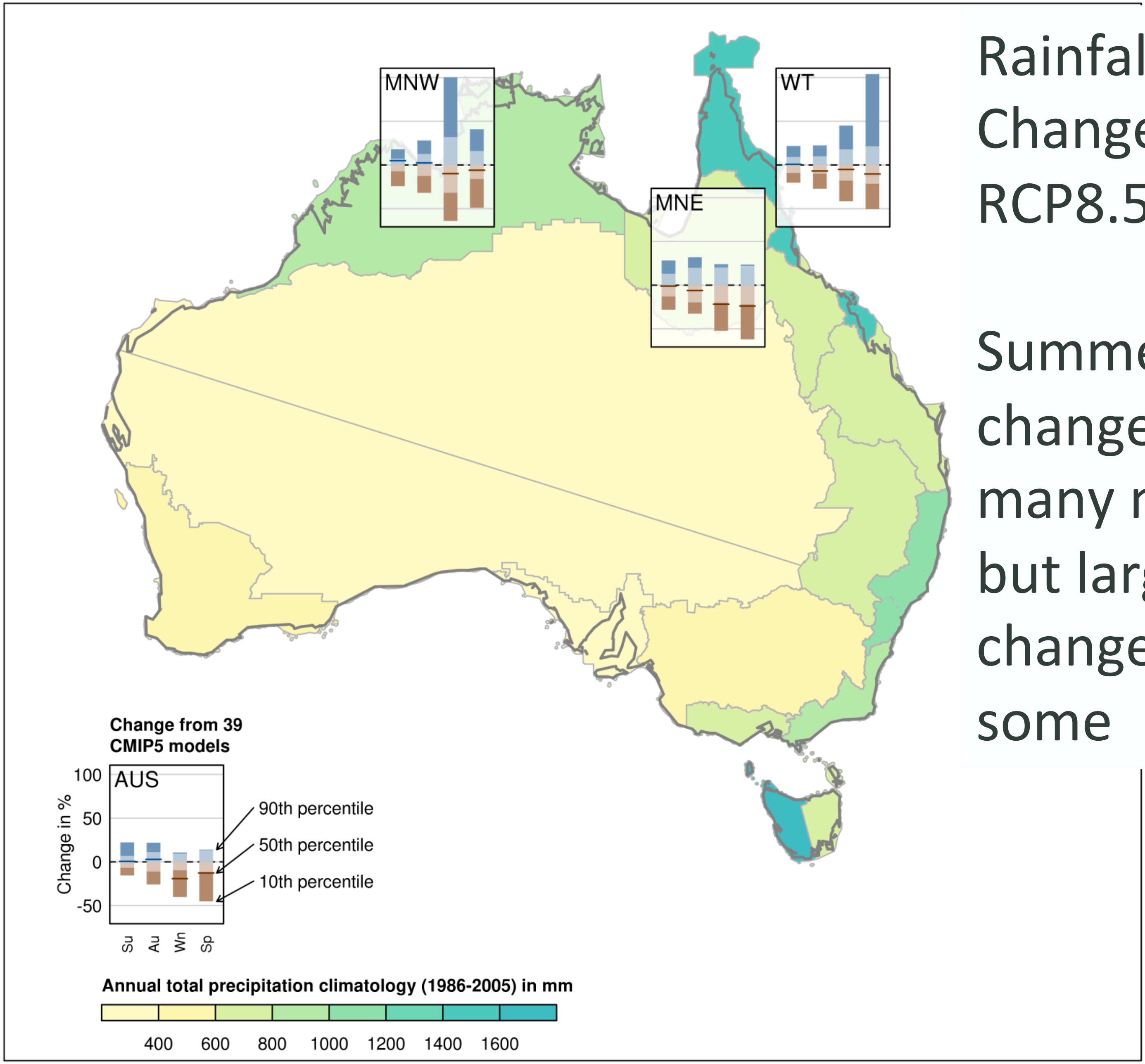
Winter- spring drying (not Tasmania)



Rainfall Change 2090, RCP8.5

Winter-spring drying

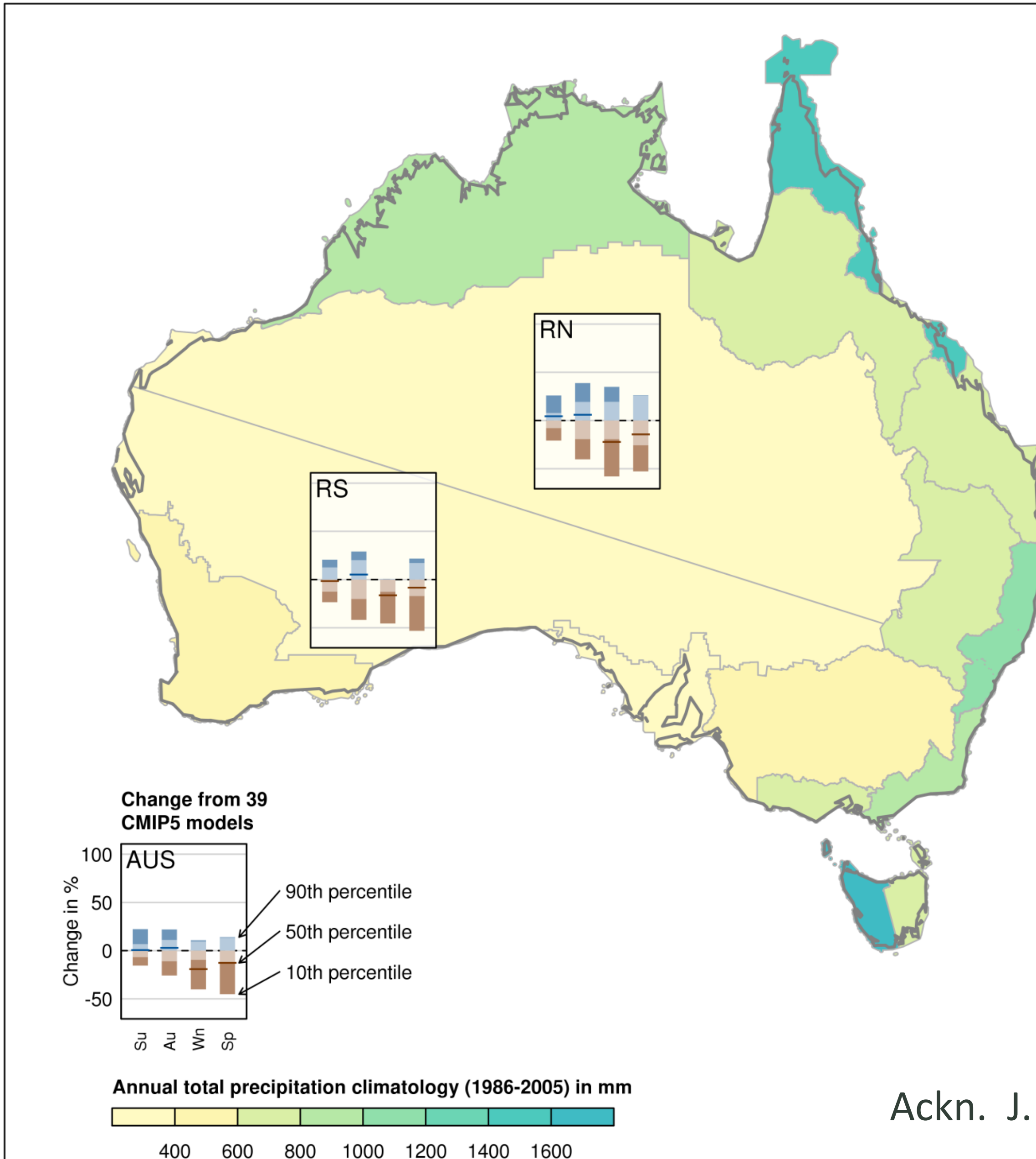
Projections for relative precipitation change
from 1986-2005 to 2080-99 according to RCP8.5



Rainfall Change 2090, RCP8.5

Summer: little change in many models, but larger changes in some

Projections for relative precipitation change
from 1986-2005 to 2080-99 according to RCP8.5

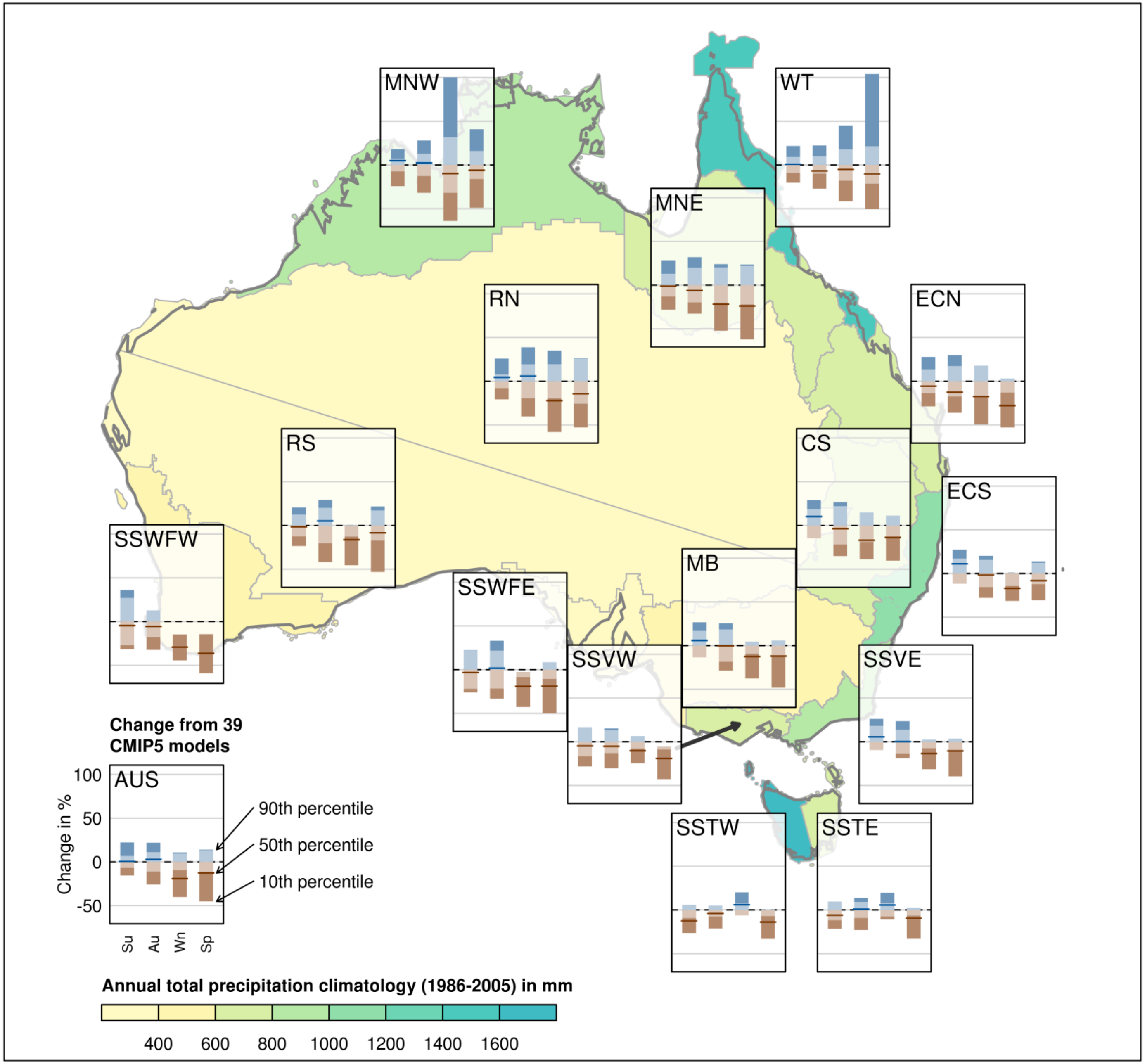


Rainfall Change 2090, RCP8.5

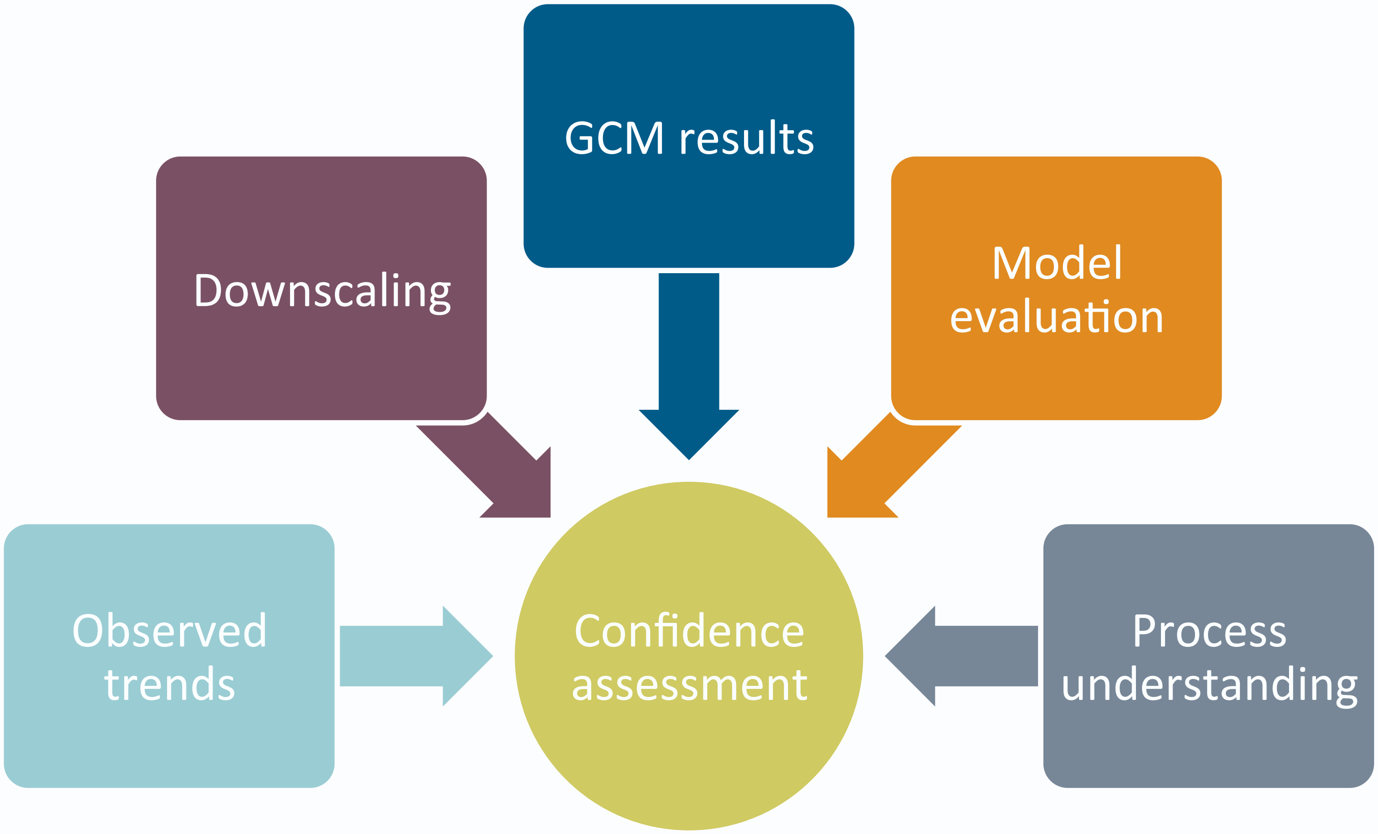
Winter-spring decrease in the south, summer uncertain

Ackn. J. Bhend

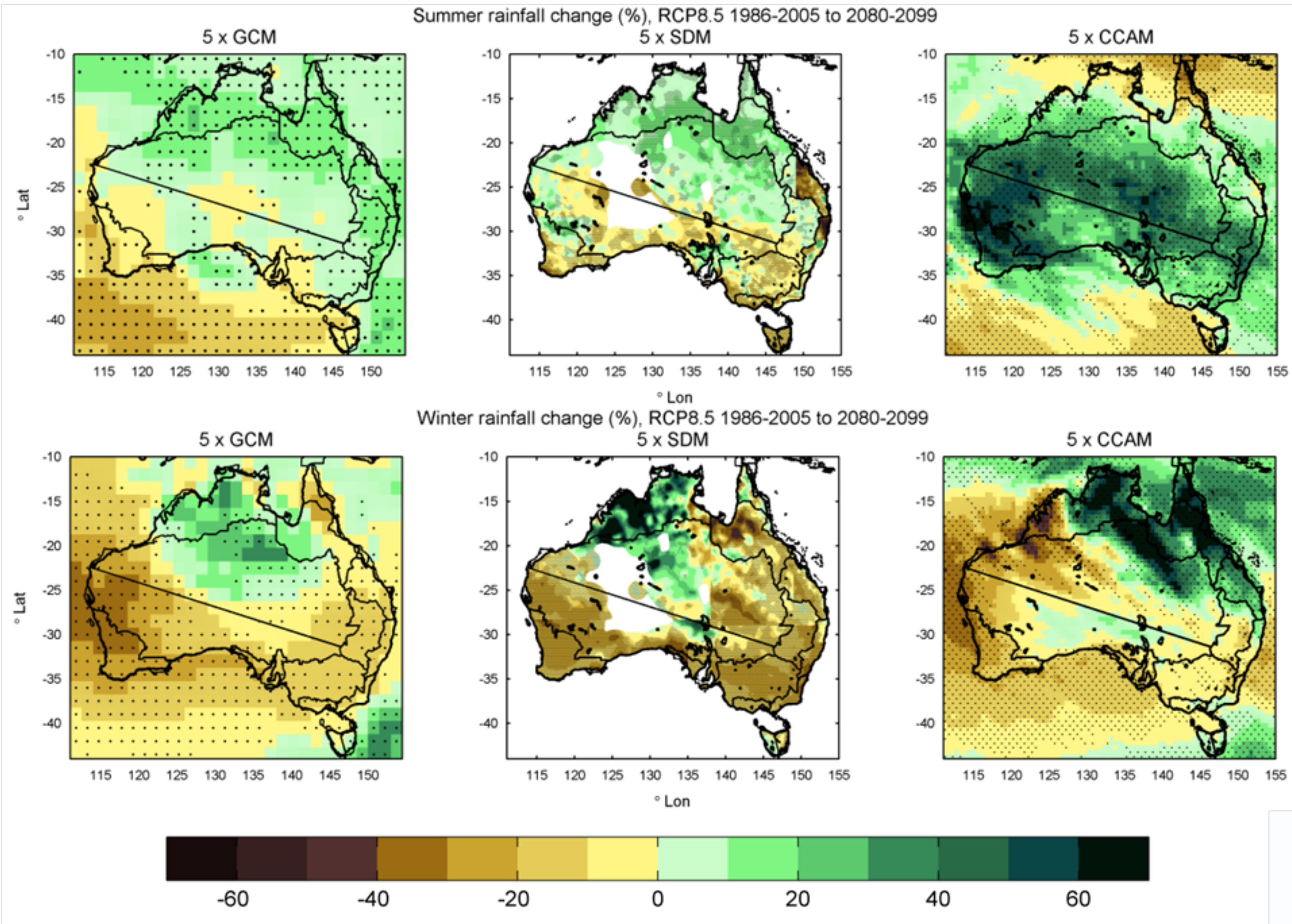
Projections for relative precipitation change
from 1986-2005 to 2080-99 according to RCP8.5



ASSESSING CONFIDENCE IN PROJECTIONS



Benefit of downscaling depends on region
RCP8.5 2090 rainfall change



Setting confidence drawing on multiple lines of evidence

Season	Subregional exceptions	2090, RCP85 CMIP5 range of change (%)	2090, RCP8.5 CMIP5 Model agreement	Additional evidence: Downscaling/consistency with observed trends with GCMs	Additional evidence: Plausible processes/model reliability	Agreement of multiple lines of evidence	Summary statement with confidence	Is the GCM range (regional and subregional) a good guide for projected change?
Southern Australia								
Annual		-26 to +4	***Medium agreement in substantial decrease*** (69%)	Downscaling generally agrees, obs. trend not inconsistent	Related to cool season circulation change, e.g. well supported southward shift of westerlies, strengthening of sub-tropical ridge. Relevant GCM processes reasonable	Good	Medium confidence in substantial decrease	A good guide
DJF		-13 to +16	***High agreement in little change*** (71%), but also substantial increase (18%) & decrease (11%).	Downscaling generally agrees, obs. trend not inconsistent	Balance of tropical and mid-latitude influences not certain	Good, but process understanding less certain	Medium confidence in little change	Possibly too narrow, less relevant for Western Tasmania
	Western Tasmania (SSTW)	-26 to +6	***Medium agreement in substantial decrease*** (63% of models).	Downscaling generally agrees, obs. trend not inconsistent	Region well exposed to SAM-related weakening westerlies Likely difference between east and west Tasmania	Good	Medium confidence in substantial decrease	A good guide
MAM		-25 to +13	***Medium agreement in little change*** (57%), but also substantial decrease (28%) & increase (15%).	Downscaling decrease stronger in many subregions. Obs decrease stronger in some regions and inconsistent in SW Vic.	Strength of cool season processes uncertain. Downscaling suggests stronger influence of cool season trend than in GCMs.	Some disagreement	Low confidence in direction of change	OK, but high end probably less likely
	South-western Victoria (SSVW)	-30 to +15	***Medium agreement in little change*** (52%), but also substantial decrease (35%) & increase (12%).	Downscaling decrease stronger in SW Vic and more consistent with observed drying	Predominance of cool season southward shift of westerlies and increasing intensity of sub-tropical ridge	Some disagreement	Medium confidence in decrease	Downscaling projections preferable [give SDM range]
JJA		-32 to -2	***High agreement in substantial decrease*** (80%).	Downscaling generally agrees, obs. trend not inconsistent	Related to cool season circulation change, e.g. well supported southward shift of westerlies and related storms. Relevant GCM processes reasonable	Good	High confidence in a substantial decrease	A good guide, except in Tasmania
	Western Tasmania	-6 to +20	***Medium agreement in increase*** (64% of models).	Downscaling generally agrees, obs. trend not inconsistent	Related to strengthening and moistening of westerlies at this latitude (reasonable evidence)	Good	Medium confidence in increase	A good guide

Winter and spring rainfall is projected to decrease (*high confidence*), though increases are projected for Tasmania in winter (*medium confidence*).

The direction of change in summer and autumn rainfall in southern Australia cannot be reliably projected, but there is *medium confidence* in a decrease in south-western Victoria in autumn and in western Tasmania in summer.

SOUTHERN AUSTRALIA

Range of change in % for 2090	Summer	Autumn	Winter	Spring
RCP4.5	-13 to +8	-19 to +9	-19 to +2	-23 to 0
RCP8.5	-13 to +16	-25 to +13	-32 to -2	-44 to -3

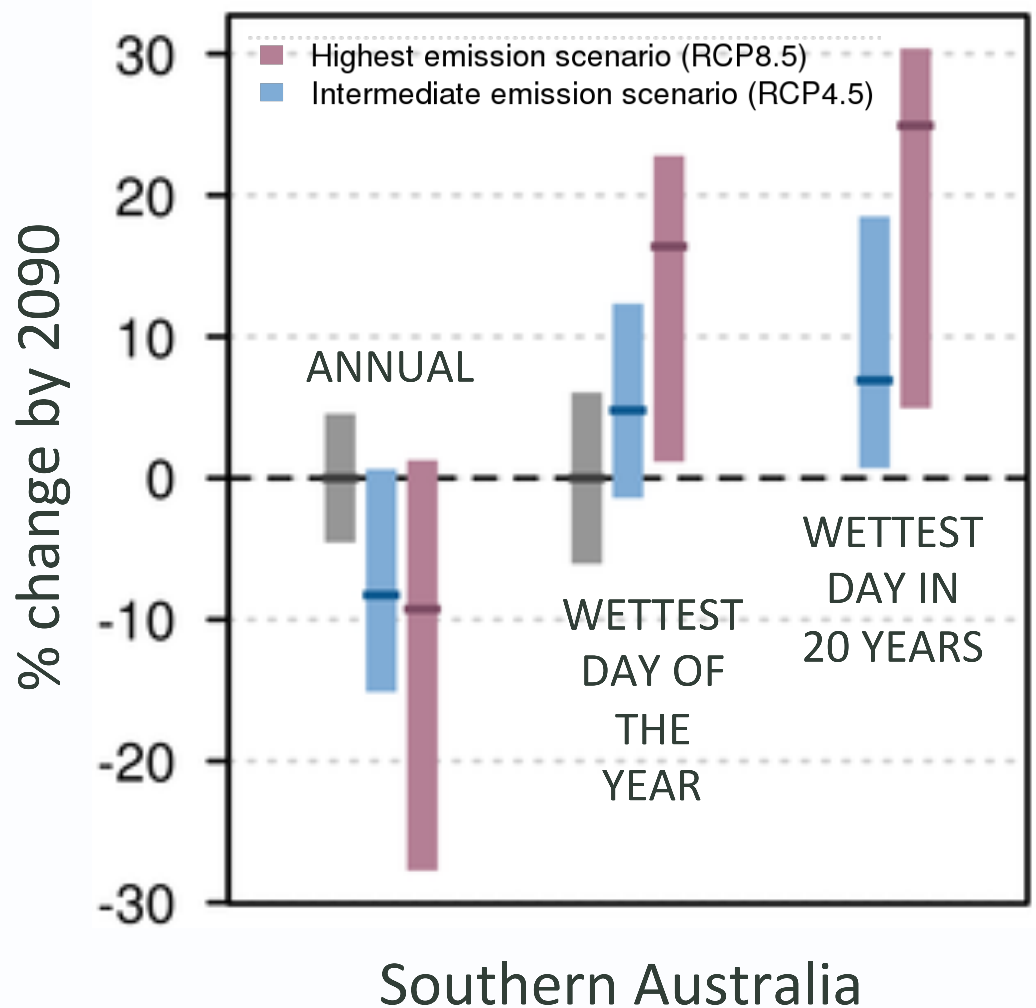
Extreme rainfall

Tony Rafter, Louise Wilson, Jonas Bhend, Ian Watterson, Penny Whetton


m
2
1.8
1.6
1.4
1.2
1
0.8
EXTREME
RAINFALL
EXTREME RAIN EVENTS ARE
PROJECTED TO BECOME
MORE INTENSE

EXTREME RAINFALL

Throughout most of Australia, extreme rainfall events (wettest day of the year and wettest day in 20 years) are projected to increase in intensity with *high confidence*



Drought, runoff, potential evaporation, wind, humidity, radiation snow & fire

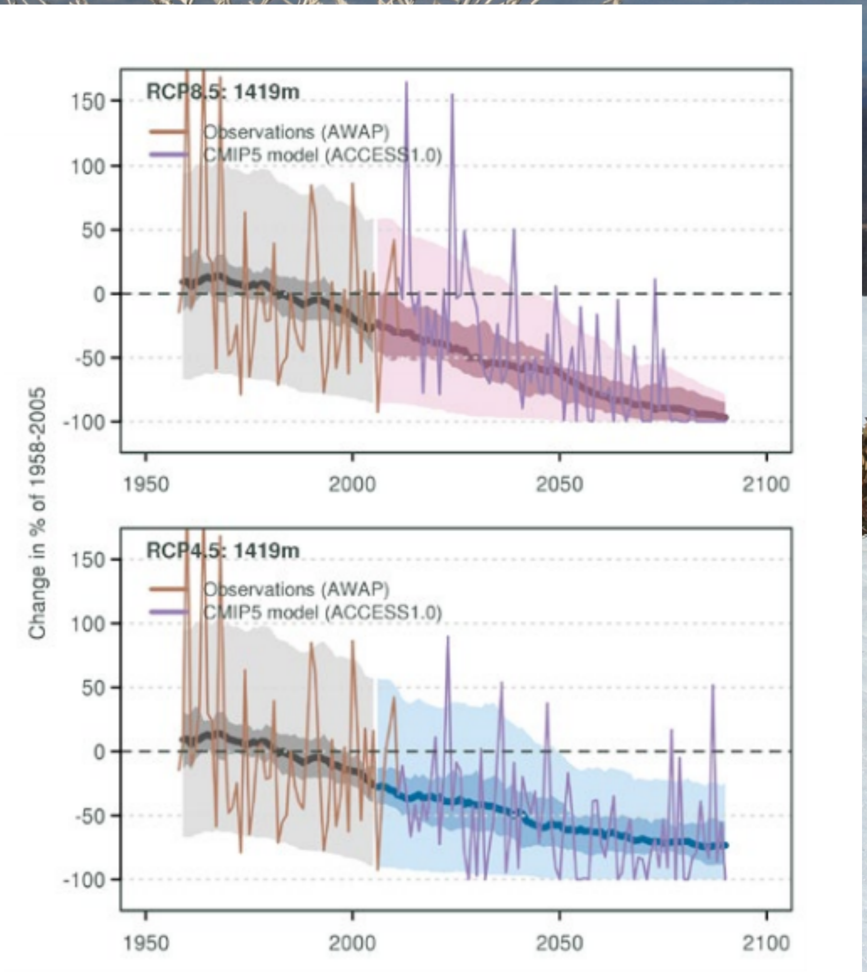
Dewi Kirono, Kathy McInnes, Aurel Moise, Debbie Abbs, Bertrand Timbal, Andrew Dowdy, Pandora Hope, Jonas Bhend, Chris Lucas, Ian Watterson, Freddie Mpelasoka &Francis Chiew

DROUGHT

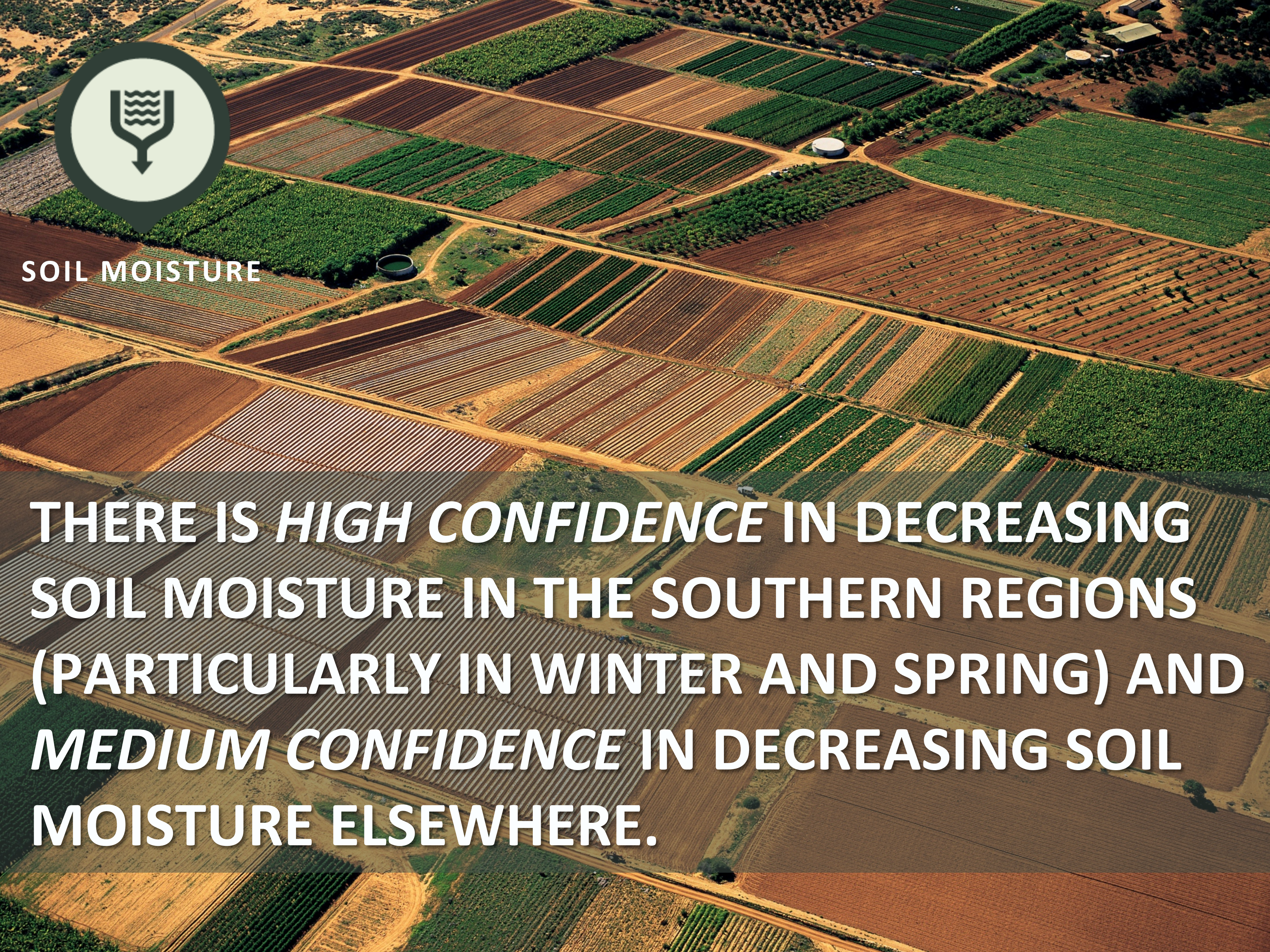
TIME IN DROUGHT IS PROJECTED TO INCREASE IN SOUTHERN AUSTRALIA

HIGHER EVAPORATION RATES

SNOWFALL IN THE AUSTRALIAN ALPS IS PROJECTED TO DECREASE, ESPECIALLY AT LOW ELEVATIONS



SNOW


SOIL MOISTURE
THERE IS *HIGH CONFIDENCE* IN DECREASING SOIL MOISTURE IN THE SOUTHERN REGIONS (PARTICULARLY IN WINTER AND SPRING) AND *MEDIUM CONFIDENCE* IN DECREASING SOIL MOISTURE ELSEWHERE.


SOUTHERN AND EASTERN AUSTRALIA ARE PROJECTED TO EXPERIENCE HARSHER FIRE WEATHER
CHANGES ELSEWHERE ARE LESS CERTAIN
FIRE WEATHER

Coastal and marine projections

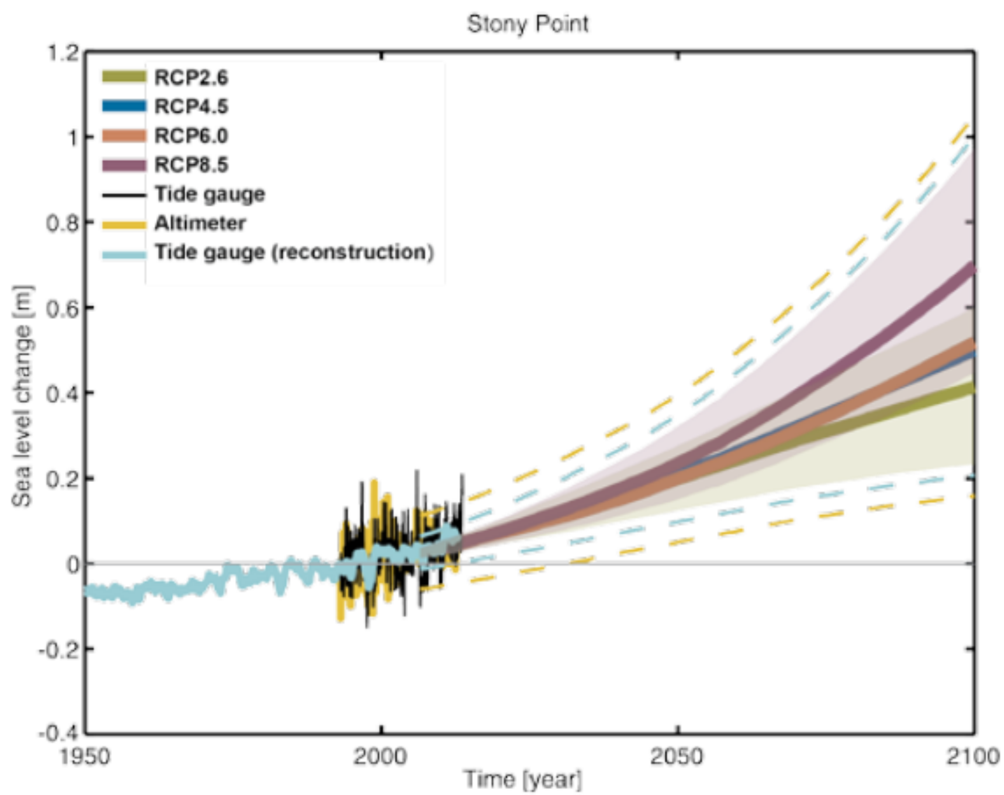
Mean sea level and extremes, SST, salinity and acidification

John Church, Didier Monselesan, Kathy McInnes, Andrew Lenton, and Julian O'Grady

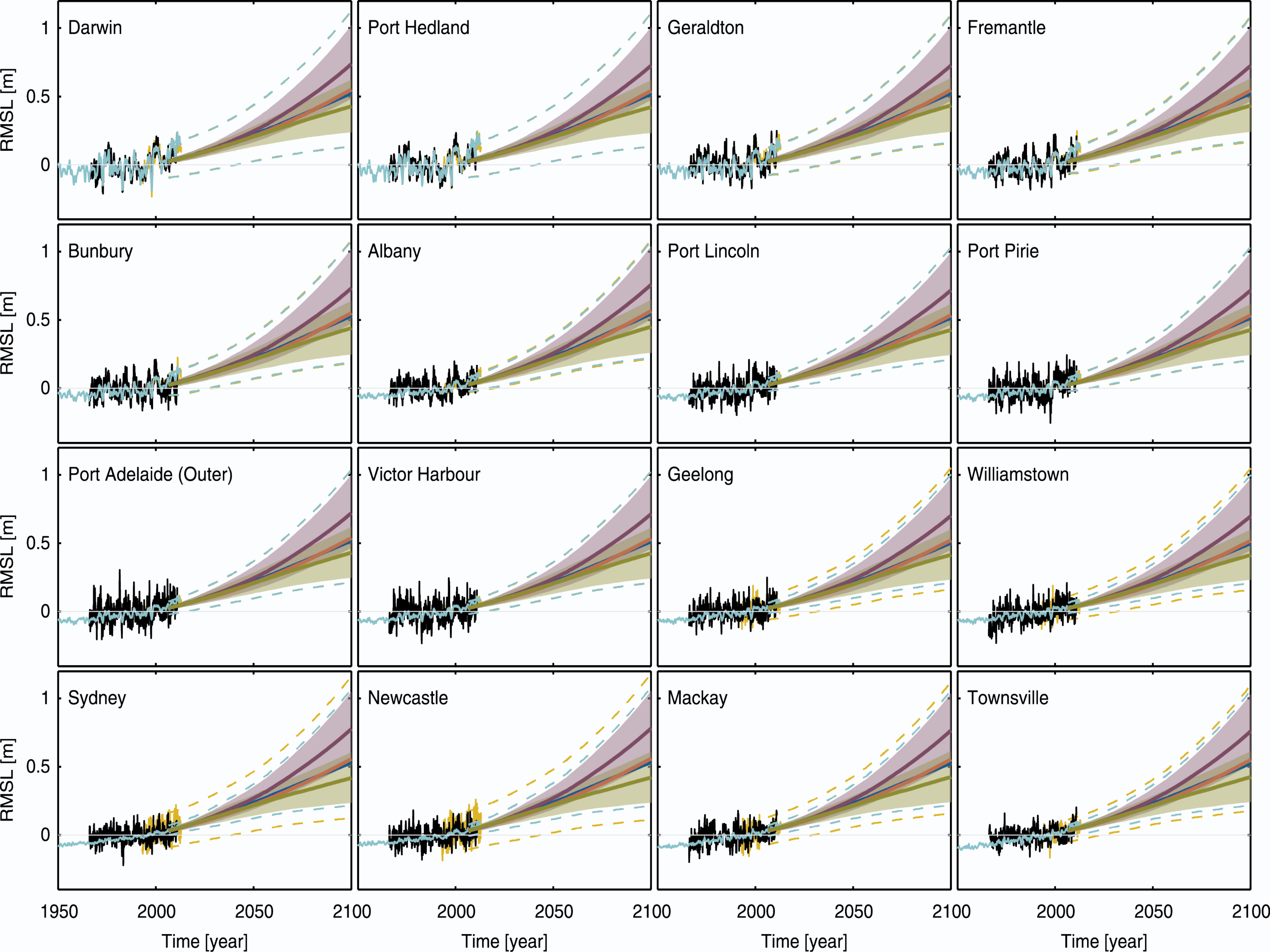

SEA LEVEL RISE
SEA LEVELS WILL CONTINUE TO RISE THROUGHOUT THE 21ST CENTURY AND BEYOND
EXTREME SEA LEVELS WILL ALSO RISE

SEA LEVEL RISE

In line with global mean sea level, Australian sea levels are projected to rise through the 21st century (*very high confidence*), and are very likely to rise at a faster rate during the 21st century than over the past four decades, or the 20th century as a whole, for the range of RCPs considered (*high confidence*)



CHANGES ARE RELATIVE TO 1986-2005



Darwin
Port Hedland
Geraldton
Fremantle
Bunbury
Albany
Port Lincoln
Port Pirie
Port Adelaide (Outer)
Victor Harbour
Geelong
Williamstown
Sydney
Newcastle
Mackay
Townsville
RMSL [m]
1
0.5
0
1950
2000
2050
2100
Time [year]

SEA LEVEL RISE

PROJECTED CHANGES IN MEAN SEA LEVEL AT STONY POINT

Allowance is the height needed to raise structures to maintain current risk of flooding

	2030 RCP4.5	2030 RCP8.5	2090 RCP4.5	2090 RCP8.5
Mean SLR	0.11 (0.07-0.16)	0.12 (0.08-0.17)	0.44 (0.27-0.62)	0.59 (0.38-0.81)
Allowance	0.12	0.13	0.51	0.70

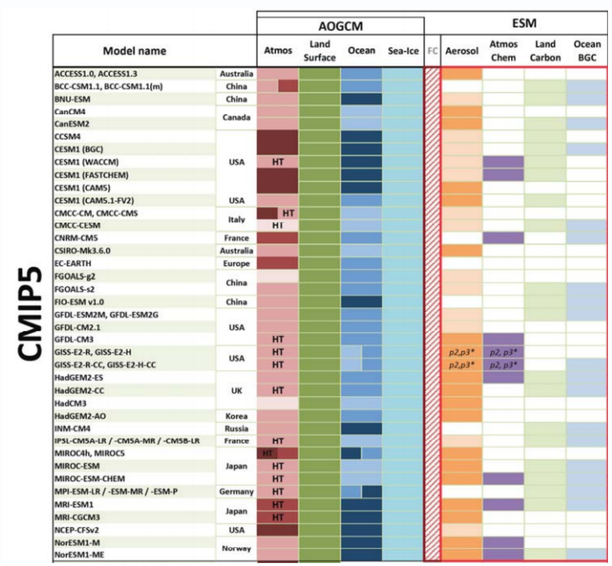
CHANGES ARE RELATIVE TO 1986-2005

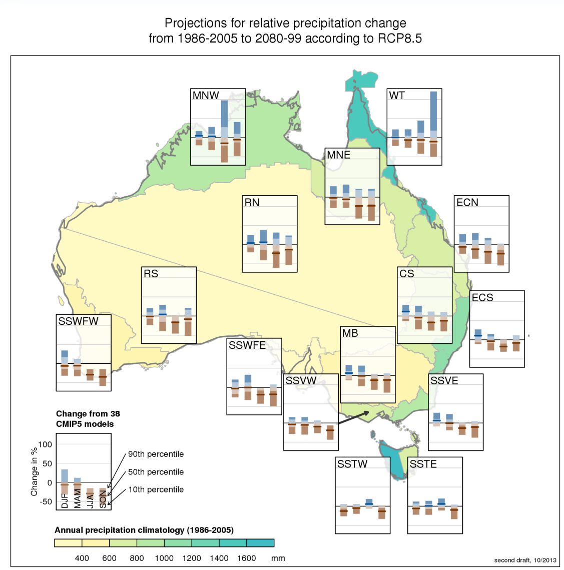
Where is the science? Methods versus assessment

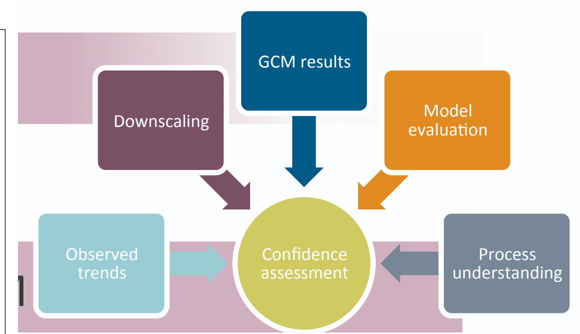
Model data sets
- Existing ensemble
- Generate new ensemble
- Downscaling
- Model evaluation

Analysis
- Production of projection results
- Statistical tools
- PDFs

Assessment
- Other lines of evidence
- Model evaluation
- Process understanding
- Assigning confidence







By late in the century, less rainfall is projected during the cool season, with *high confidence*. There is *medium confidence* that rainfall will remain unchanged in the warm season.

Special issue of Australian Meteorological and Oceanographic Journal, Vol 65, No 1, 2015

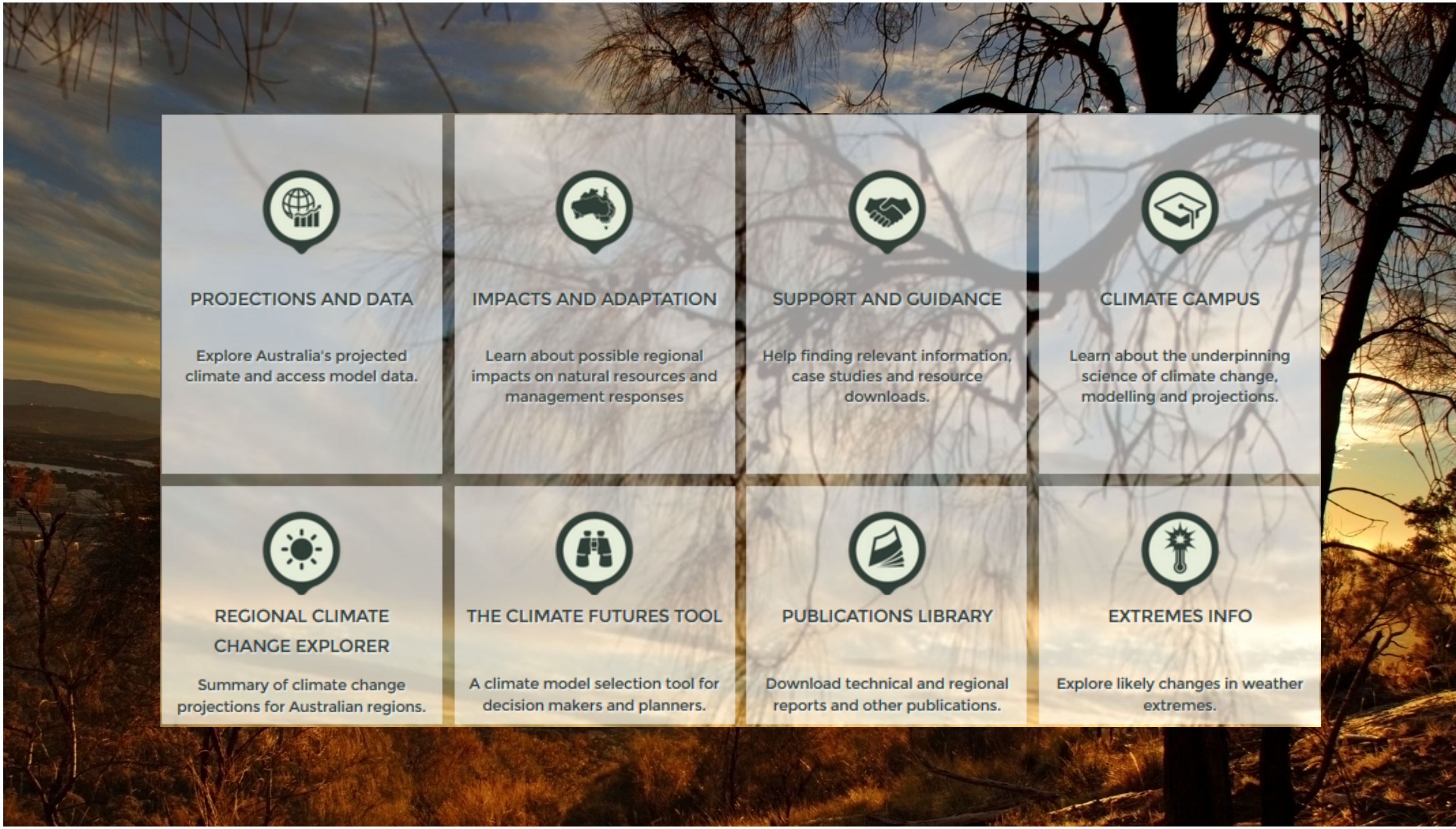
Data delivery and website

Kevin Hennessy, Leanne Webb, John Clarke, Chris Gerbing, Tim Erwin, Tim Bedin, Paul Holper, Yun Li

COMMUNICATION – REPORTS / BROCHURES

- Peer-reviewed journal papers
- Technical Report
  - The underpinning science behind all projections
- 8 x Cluster Reports
  - Focus on regional areas with distinct future climates
- 8 x Cluster Brochures
  - Easy to understand key messages about regional climate change
- Data Delivery Brochure
  - Info on climate model data availability

WEBSITE, DATA DELIVERY AND SUPPORT



REGIONAL CLIMATE EXPLORER

About | **Future climate** | Explore data | Climate Futures Tool | Climate analogues | Coastal & marine | Sign-In/Register

Home » Climate projections » Future climate » Regional Climate Change Explorer » Super Clusters » Clusters » **Murray Basin**

Super Clusters

Sub Clusters

MURRAY BASIN PROJECTION SUMMARIES

RAINFALL

MURRAY BASIN

The Murray Basin cluster comprises NRM regions across New South Wales, Victoria and South Australia. The cluster extends from the flatlands of inland New South Wales to the Great Dividing Range along the southern and eastern boundaries and includes Australia's highest mountain; Mt Kosciusko, at 2228m.

The cluster is relatively dry and temperate, with a warm and dry grassland climate in the north-west ranging to temperate with hot summers further east.

KEY MESSAGES

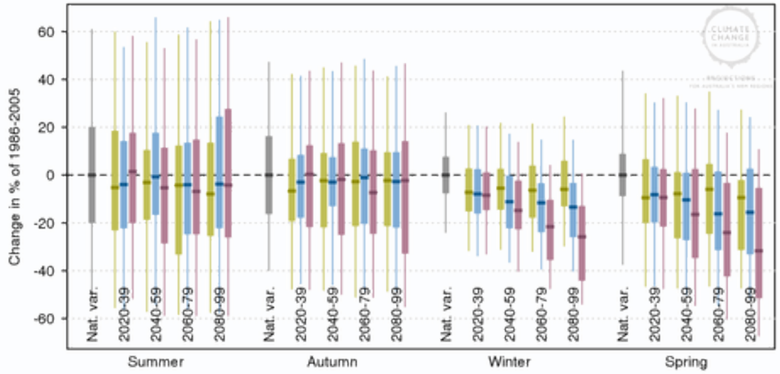
- Average temperatures will continue to increase in all seasons (*very high confidence*).
- More hot days and warm spells are projected with *very high confidence*. Fewer frosts are projected with *high confidence*.
- By late in the century, less rainfall is projected during the cool season, with *high confidence*. There is *medium confidence* that rainfall will remain unchanged in the warm season.
- Even though mean annual rainfall is projected to decline, heavy rainfall intensity is projected to increase, with *high confidence*.
- Mean sea level will continue to rise and height of extreme sea-level events will also increase (*very high confidence*).
- A harsher fire-weather climate in the future (*high confidence*).
- On annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human induced trend, particularly in the next 20 years and for rainfall.

SUMMARY DATA EXPLORER

Home » Climate Projections » Explore Data » **Summary Data Explorer**

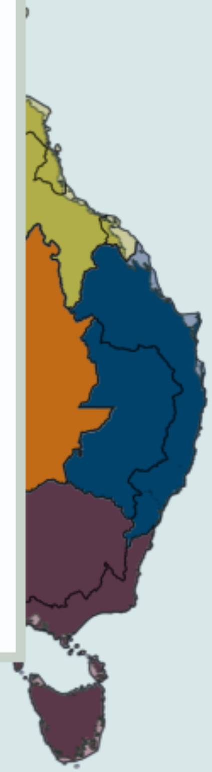
SOUTHERN AND SOUTH-WESTERN FLATLANDS

- [Temperature]
- [Maximum Temperature]
- [Minimum Temperature]
- [Rainfall]
- [Solar Radiation]
- [Evapotrasporation]
- [Wind Speed]
- [Humidity]



Data: CSV Image: PNG 1800x900

Projected change in seasonal precipitation for 2080-99 with respect to 1986-2005 according to different scenarios. The bars show the 10th to 90th percentile range of the CMIP5 results, the horizontal line indicates the median. The scenarios from left to right are: Natural variability only, RCP2.6, RCP4.5, RCP8.5



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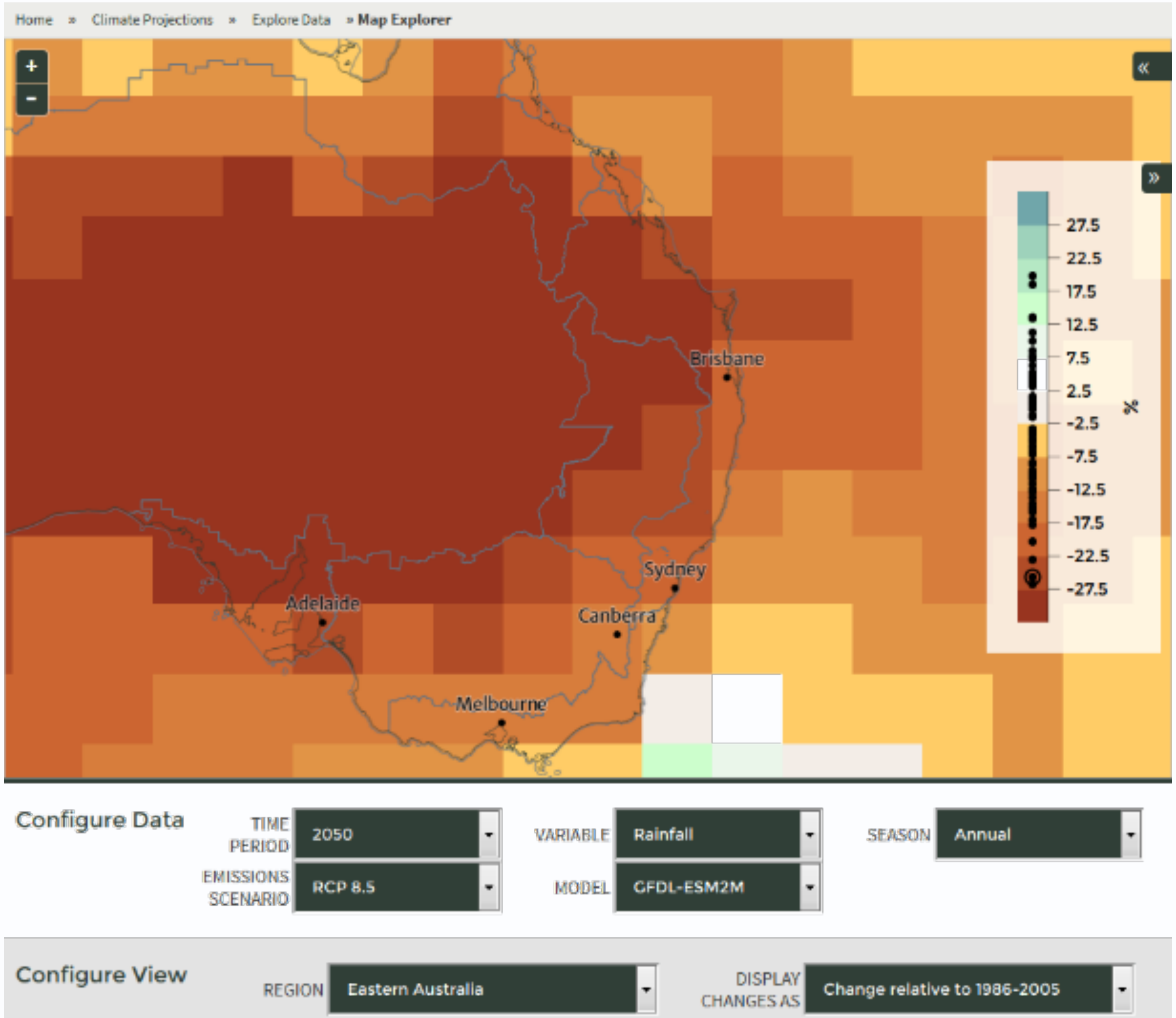
MAP EXPLORER



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Climate futures tool

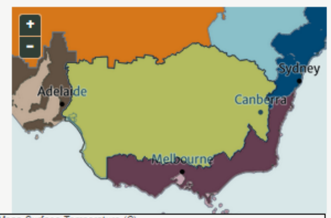
Home » Climate projections » Climate Futures Tool » **Detailed Projections**

MURRAY BASIN CLIMATE FUTURES

Go back

Change scenario: RCP 8.5

Change time period: 2090



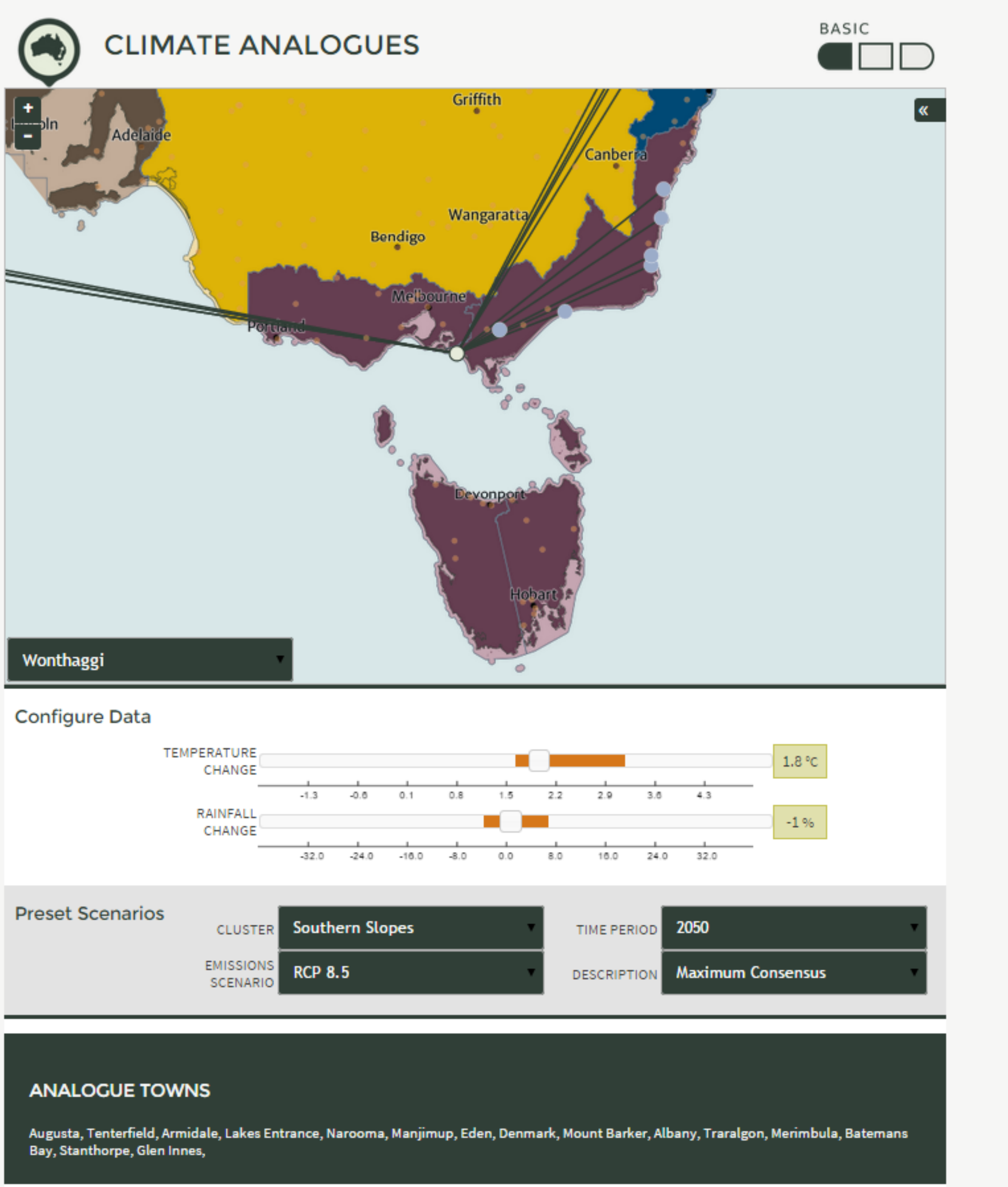
		Annual Mean Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Wetter > 15.00			+ 1 of 48 (2%)	+ 1 of 48 (2%)
	Wetter 5.00 to 15.00			+ 4 of 48 (8%)	+ 4 of 48 (8%)
	Little Change -5.00 to 5.00			+ 2 of 48 (4%)	+ 11 of 48 (23%)
	Drier -15.00 to -5.00			+ 3 of 48 (6%)	+ 9 of 48 (19%)
	Much Drier < -15.00				+ 13 of 48 (27%)

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

A projection classification and selection tool for developing a small representative set of individual model–based scenarios, tailored for decision making contexts

- Populated with, CMIP3, CMIP5 and downscaled data
- Additional model ensembles can be added

ANALOGUES EXPLORER



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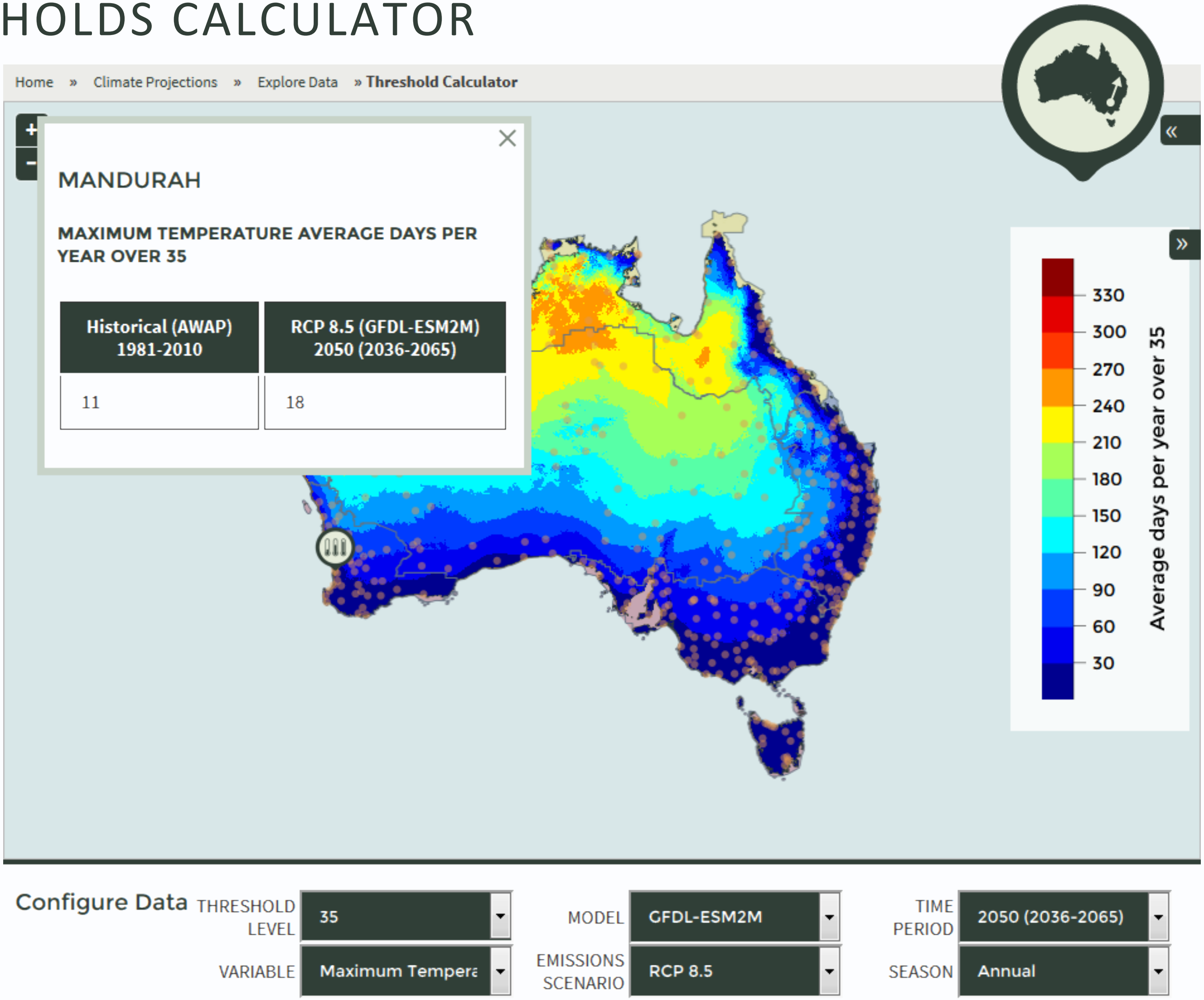
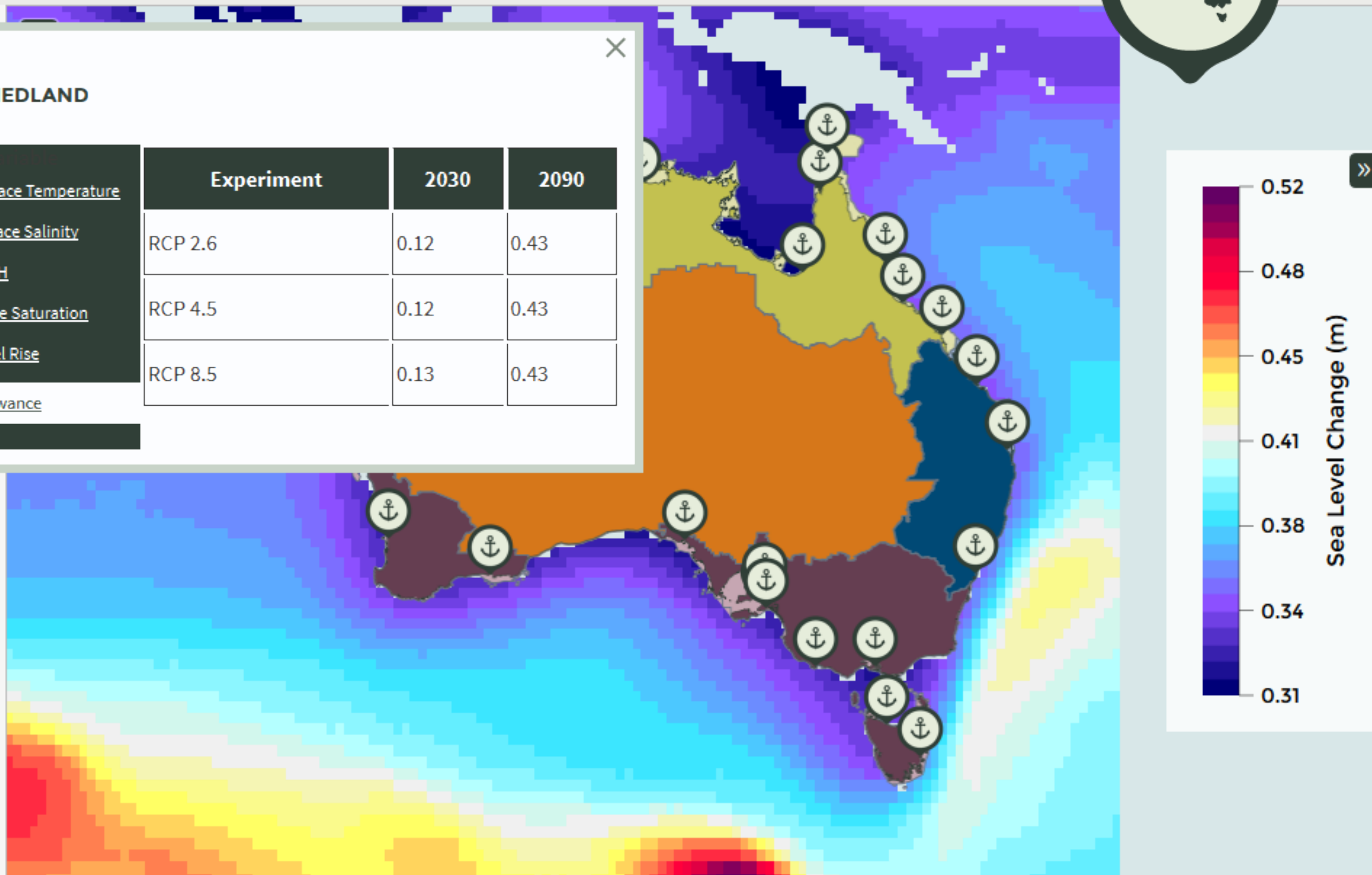
THRESHOLDS CALCULATOR



MARINE EXPLORER

Home » Climate Projections » Coastal & Marine » **Marine Explorer**



PORT HEDLAND

- Sea Surface Temperature
- Sea surface Salinity
- Ocean pH
- Aragonite Saturation
- Sea Level Rise
- Sea allowance

Experiment	2030	2090
RCP 2.6	0.12	0.43
RCP 4.5	0.12	0.43
RCP 8.5	0.13	0.43

Configure Data

TIME PERIOD: 2050

VARIABLE: Sea Level

EMISSIONS SCENARIO: RCP 8.5

PERCENTILE: HIGH (90th percent

SEASON: Annual

AUTO SCALE LEGEND: ☑

-20° -10° 0° 10° 20° 30° 40° 50°

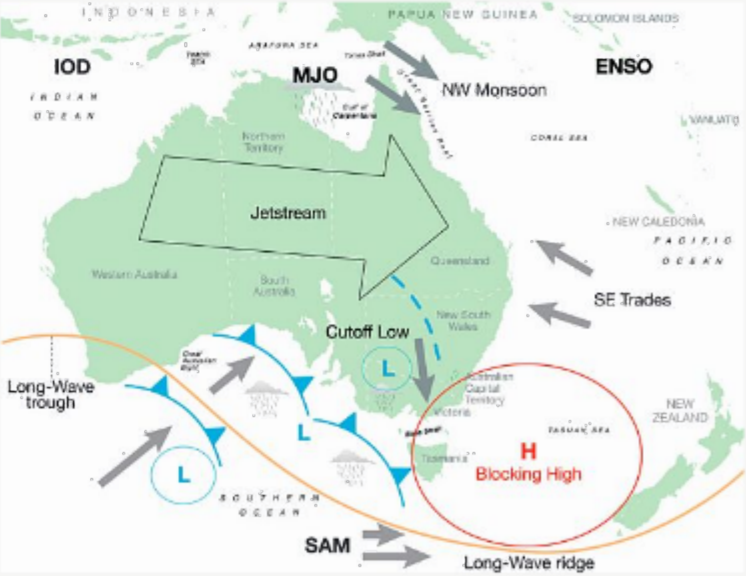
AUSTRALIAN CLIMATE INFLUENCES

Australia is affected by many different weather systems. Our climate can vary greatly from one year to the next. This climate variability is driven by many significant climate features that will have varying levels of impact in different regions at different times.

Important climate drivers in Australia include El Niño-Southern Oscillation, the Indian Ocean Dipole, the Australian monsoon and the Madden-Julian Oscillation, and the Southern Annular Mode. These drivers have varying levels of influence on rainfall in Australia over different regions and seasons.

The term **El Niño** refers to the extensive warming of the central and eastern tropical Pacific Ocean which leads to a major shift in weather patterns across the Pacific Ocean. El Niño conditions generally result in below average rainfall over much of eastern Australia. The (ENSO) is the term used to describe the oscillation between the El Niño phase and the La Niña, or opposite, phase. La Niña, generally leads to above average rainfall over much of Australia.

The Indian Ocean also affects Australian climate. Higher than average Indian Ocean sea surface temperatures near Australia (known as a negative Indian Ocean Dipole) may enhance our rainfall. Lower than average temperatures near Australia (positive Indian Ocean Dipole) can result in below average rainfall from western to south-east Australia.



The Australian monsoon is created by the summer heating of the Australian continent and the resulting change in temperature between the land and the sea. The monsoon is responsible for the tropical wet summer and dry winter. The monsoon can be in either an 'active' or an 'inactive' phase. The active phase is usually associated with cloud and rain. Transitions from active to inactive phases may be associated with the Madden-Julian Oscillation, a large-scale slow-moving band of increased cloudiness that travels eastwards in the tropics.

The northern wet season is also the tropical cyclone season in Australia. Most tropical cyclones occur between November and April, with an average of 11 affecting the Australian continent each year. Southern Australia is also affected by a more large-scale circulation climate influence, the sub-tropical ridge. The sub-tropical ridge straddles a belt of high pressure that encircles the mid-latitudes of the globe. The position of the sub-tropical ridge plays an important part in the way our weather varies from season to season.

For a fun take on the drivers of Australian rainfall view the Victorian Government's Climate Dogs animations.

USAGE STATISTICS 11 NOVEMBER 2015

Website

	Since Phase 1 Jan 2015	Since Phase 2 May 2015	Last 30 days
Unique Users	142,314	118,971	9,797
Unique sessions	110,739	94,423	7,150

Manual requests

Client Category	Since Phase 1	Since Phase 2
Consultants	16	15
CSIRO	10	8
Federal Government	1	1
International Researchers	1	1
Local Government	1	1
Media	2	2
NRM	26	18
Private Sector	2	1
Schools	1	1
State Government	3	3
Universities	24	23
(blank)	3	3
Grand Total	90	77

Application Category	Since Phase 1	Since Phase 2
Agriculture	5	5
Biodiversity	2	2
Carbon Sequestration	1	1
Coastal Engineering	1	1
Fire modelling	4	4
Flood Risk	1	1
General Adaptation Planning	6	6
Infrastructure Planning	4	3
Media	2	2
NRM	30	18
Outreach	1	1
Primary Production	1	1
Unknown	24	24
Water Supply	8	8
Grand Total	90	77

-20° -10° 0° 10° 20° 30° 40° 50°

KEY MESSAGES

- FURTHER INCREASES IN GREENHOUSE GASES WILL CAUSE MORE CLIMATE CHANGE
- MORE HOT DAYS, FEWER COLD DAYS & LESS SNOW
- DRIER IN THE SOUTH
- MORE EXTREME DAILY RAIN AND FIRE WEATHER
- SEA LEVEL RISE
- OCEAN ACIDIFICATION
- FEWER BUT MORE INTENSE TROPICAL CYCLONES
- REAFFIRMS PREVIOUS PROJECTIONS BUT SOME UNCERTAINTIES REMAIN

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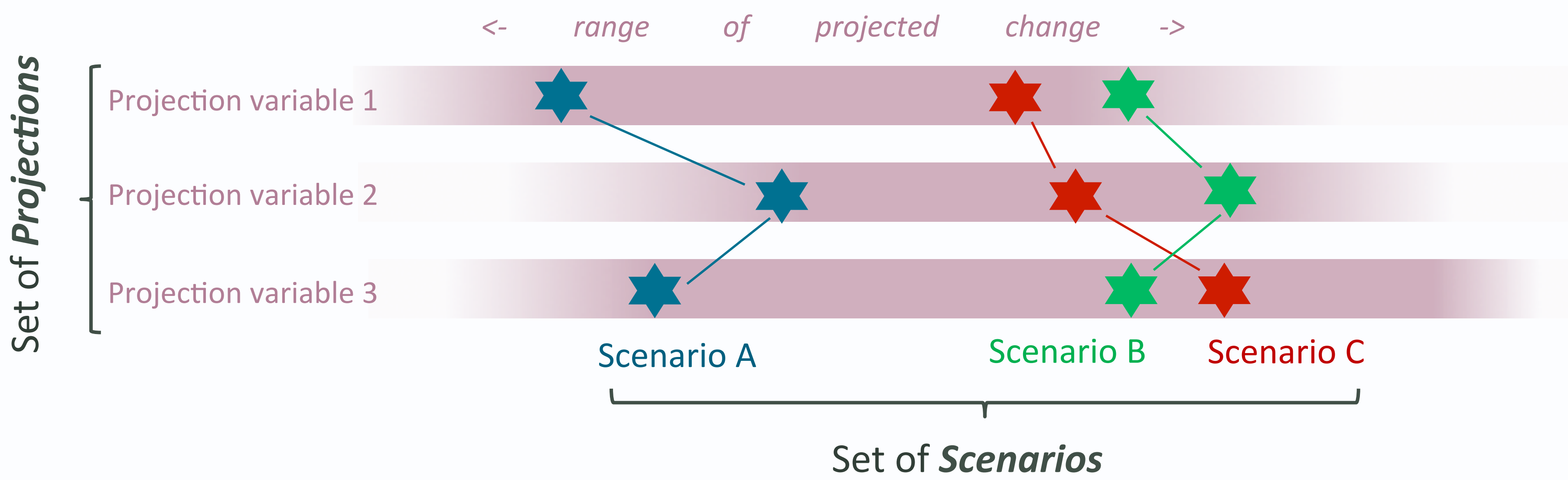
Scenarios and projections



- Scenarios are multivariate individual cases (usually for technical applications)
- Scenarios are usually based on individual model results
- Challenge is for a set of scenarios to be representative, relevant and few in number