ELECTRICITY SECTOR CLIMATE INFORMATION PROJECT

Climate change data visualisation consultation

Electricity Sector Climate Information (ESCI) Project

Feb 7th 2020

Australian Government
Department of the Environment and Energy

CSIRO

AEMO

Australian Government
Bureau of Meteorology

CSIRO

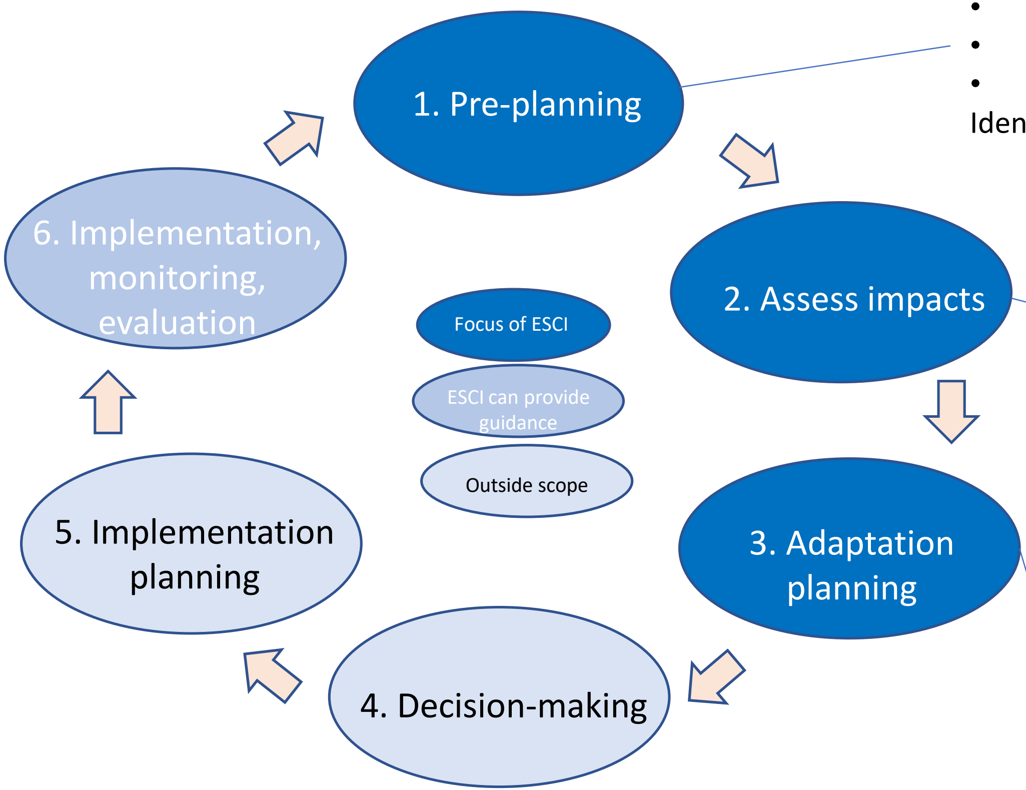
The ESCI Project will provide a framework for using tailored climate information for risk-based decision-making in the electricity sector

Draft Climate-Risk Assessment Framework

Understand decision-making processes:

- Operating risk
- Reliability
- Investment risk

Identify vulnerabilities



Focus of today's consultation

Use tailored climate information to scan for and quantify physical impact:

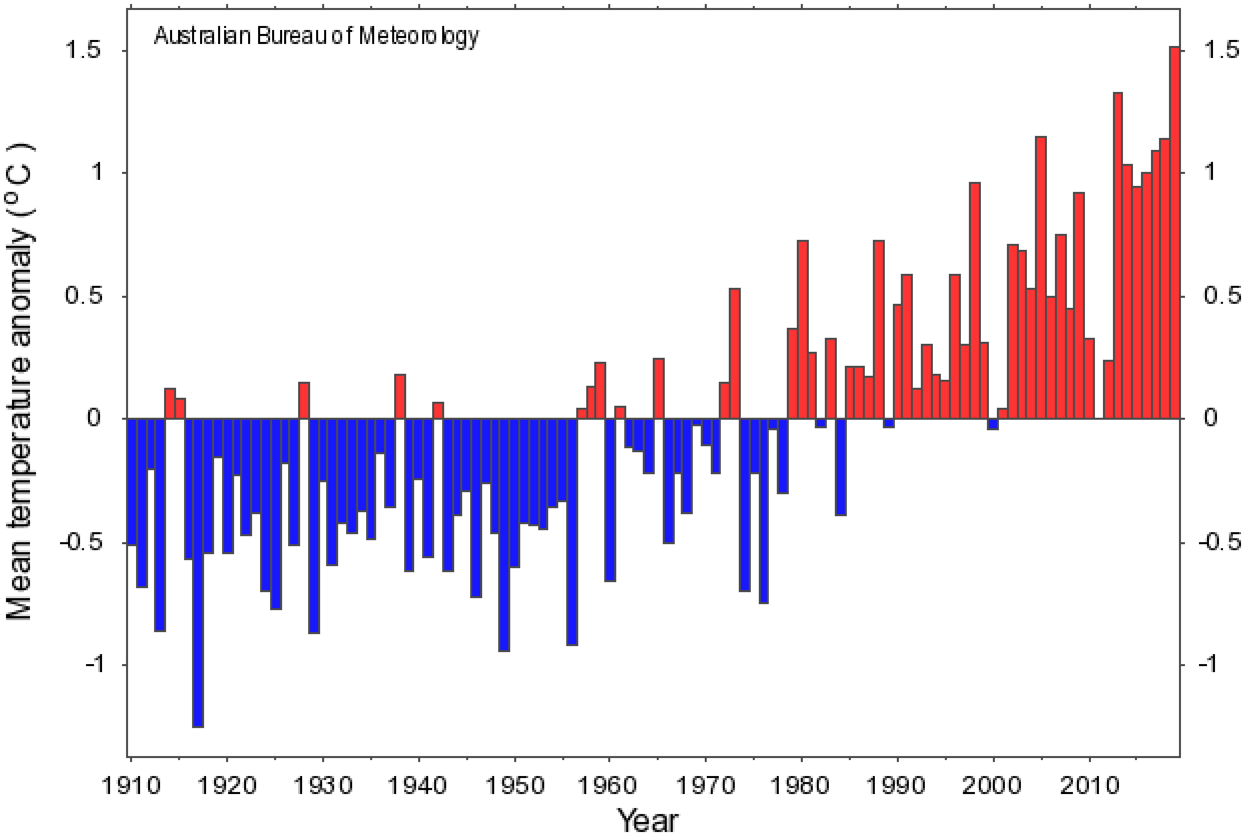
1. Time series of key climate variables driving supply and demand
2. Compound/ extreme weather scenarios to stress test the system
3. Changes in the probability of exceedance of key variables by region over time

- Generate adaptation pathways
- Quantify and evaluate against objectives
- Identify system changes needed

Structure of this consultation
Questions/discussion at the end of each section

- State of the Australian Climate: review of major trends of interest to the electricity sector
- Fundamentals of climate projection, downscaling and sources of uncertainty in the projections
- Discussion of sample data products: preliminary output from the ESCI project

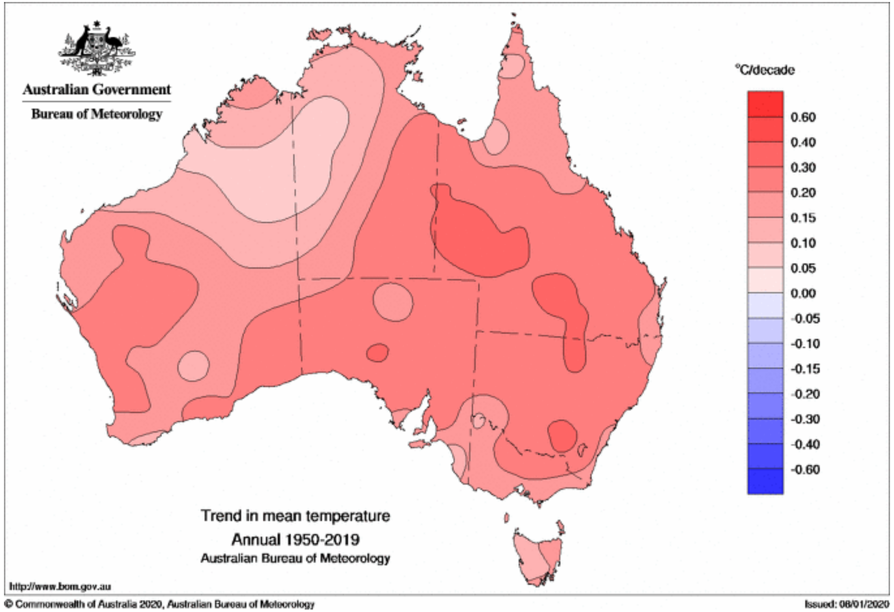
Australia has seen a consistent warming trend in the past 3 decades



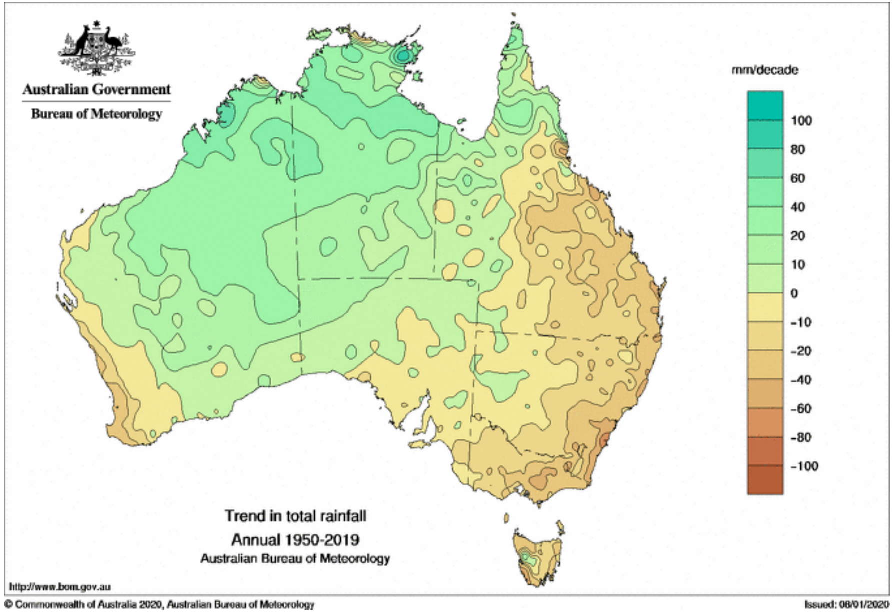
- Warming of 1.1 °C since 1910
- Nine of the ten warmest years have occurred since 2004
- 2019 was the warmest, followed by 2013, 2005 and 2018

BoM (2020)

Climate change in Australia differs by region



Greatest warming in the south and east, with more heat waves and fewer frosts



Less rain in the south and east, more rain in the north-west

BoM – Issued 08/01/2020

Extreme temperature and rainfall events are more common

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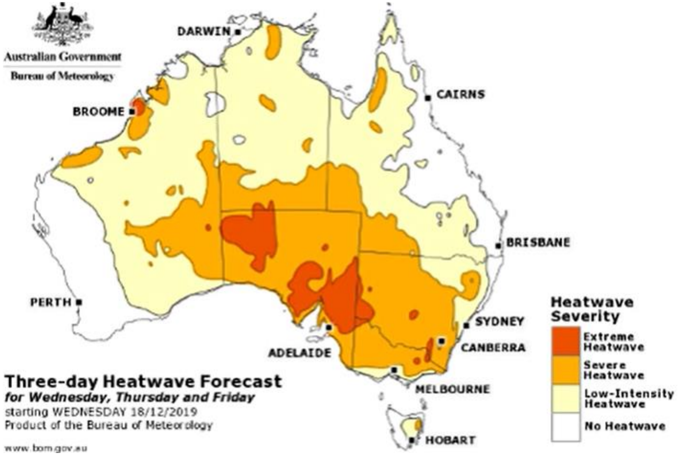
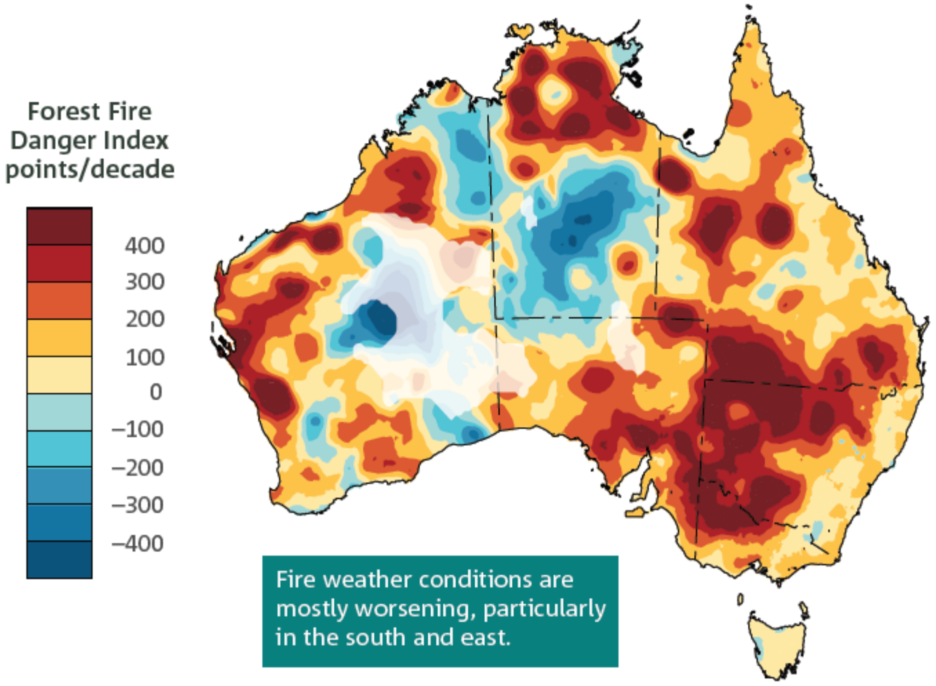


- Heatwaves have increased in duration, frequency and intensity in many regions.
- Very high monthly maximum or minimum temperatures now occur around 12 % of the time (2003–2017) compared with around 2 % of the time in the past (1951–1980)
- Decreases in heavy daily rainfall have tended to occur in southern and eastern Australia, with increases in the north.
- Heavy daily rainfall has accounted for an increased proportion of total annual rainfall since the 1970s

BoM & CSIRO (2018)

Fire season is becoming longer and more intense

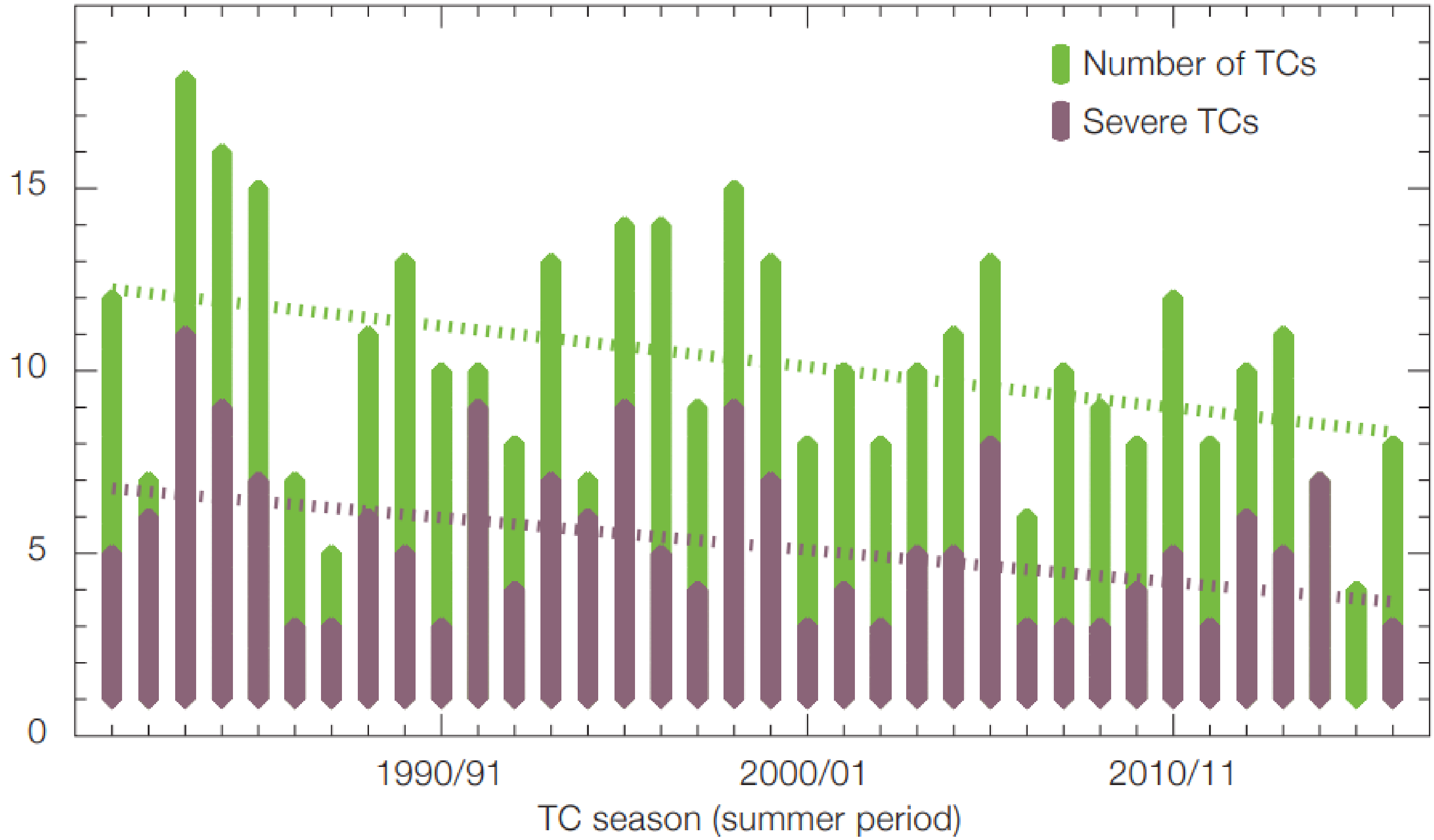


Trend from 1978 to 2017 in the annual sum of daily Forest Fire Danger Index – an indicator of the severity of fire weather conditions.

- Warmer and drier conditions have increased fire-weather risk
- Annual fire danger index increased across most of Australia since 1978
- Largest increases in spring and autumn
  - Longer fire season and greater overlap with Northern Hemisphere fire seasons
  - Shorter period for fuel-reduction burning
  - More resources needed for fire management

BoM and CSIRO (2018)

Fewer tropical cyclones near Australia since 1981/82



Greenhouse gas concentrations have risen

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	CO_2	CH_4	N_2O
2018 global mean abundance	407.8±0.1 ppm	1869±2 ppb	331.1±0.1 ppb
2018 abundance relative to year 1750*	147%	259%	123%

Greenhouse gases such as water vapour, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have a warming effect

Human activities such as burning fossil fuels, agriculture and land-use change have increased greenhouse gas concentrations

(WMO, 2019)

Human activities have influenced climate change

Human influence has been detected in warming of the atmosphere and the ocean, changes in the global water cycle, reductions in snow and ice, global mean sea level rise, and changes in some climate extremes

It is extremely likely that human influence has been the dominant cause of the observed global warming since the mid-20th century

Intergovernmental Panel on Climate Change (IPCC 2013)

There are three main sources of uncertainty in regional climate projections

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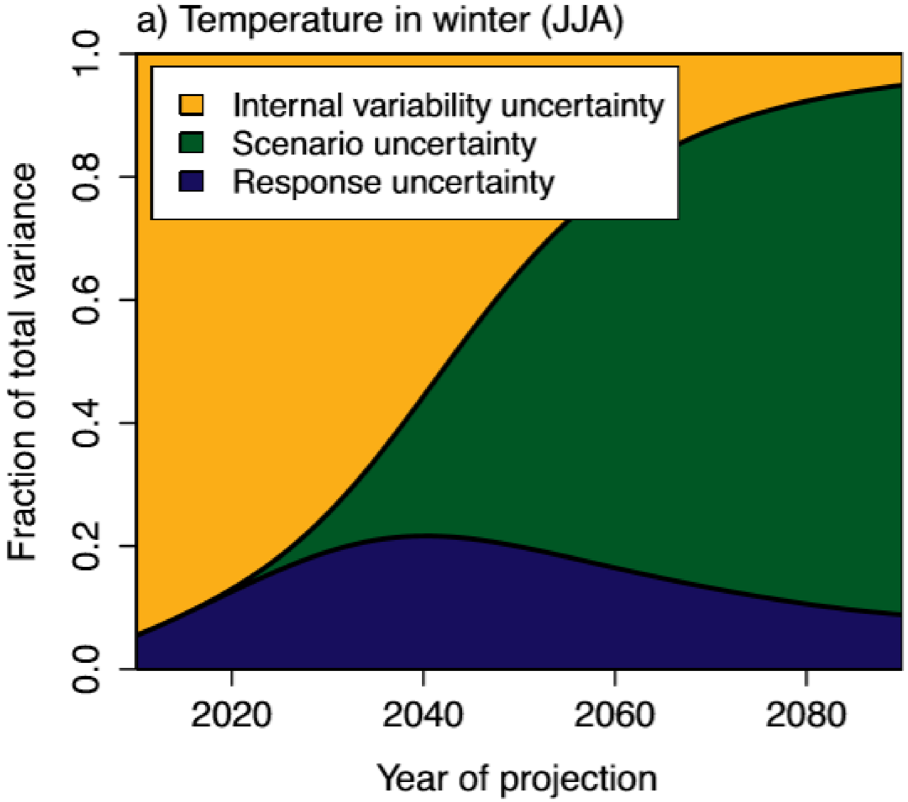
1. Assumptions about future greenhouse gas and aerosol scenarios
2. Regional climate responses to each scenario due to limitations in climate models
3. Internal climate variability



In the short-term, internal climate variability contributes the largest proportion of uncertainty; in the longer-term uncertainty is dominated by scenario uncertainty. Regional climate response uncertainty is fairly constant over time.

CSIRO and BoM (2015)

Future greenhouse gas emission scenarios

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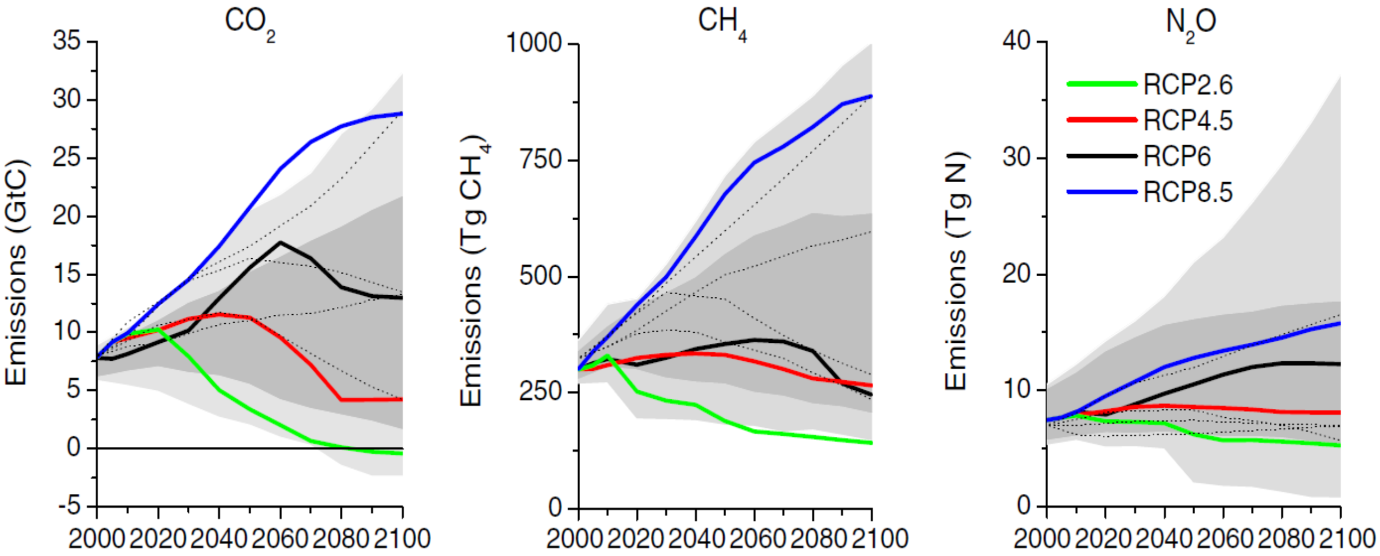


Emission scenarios are based on different assumptions about socio-economic development

Scenarios that avoid 2°C warming by 2100 need global CO_2 emissions to decline rapidly and reach zero emissions after 2050

RCP stands for 'Representative Concentration Pathway'. The four IPCC RCP scenarios range from very high (RCP8. 5) through to very low (RCP2. 6) future concentrations. The numerical values of the RCPs (2.6, 4.5, 6.0 and 8.5) refer to the increase in radiative forcing (Watts per square metre) by the year 2100.

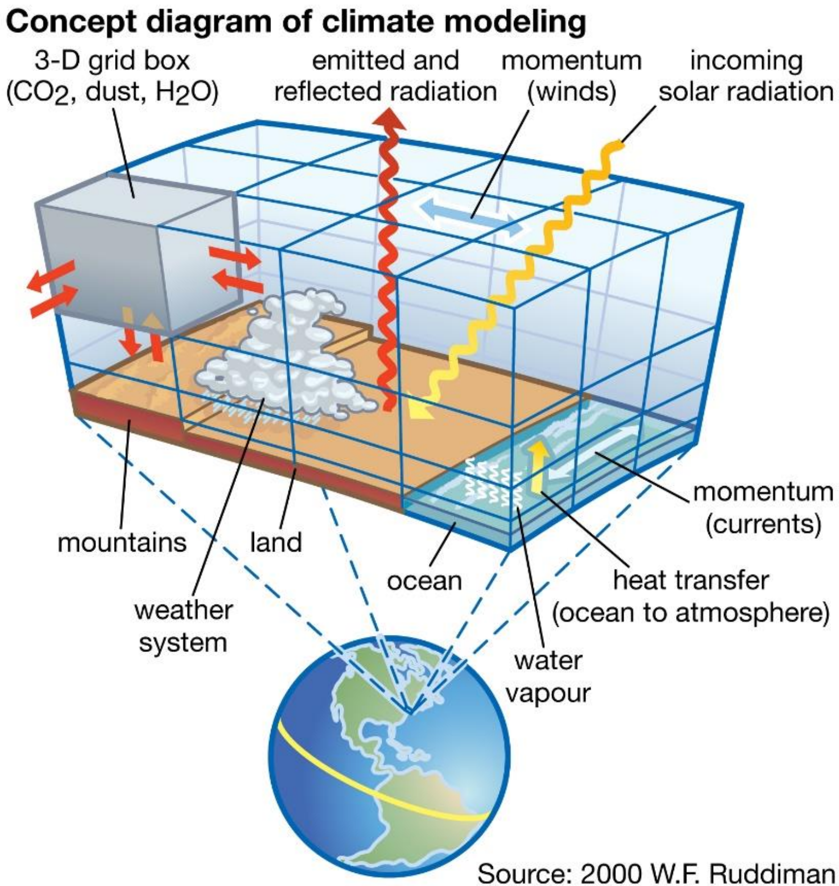
IPCC (2018)

Van Vuuren et al (2011)

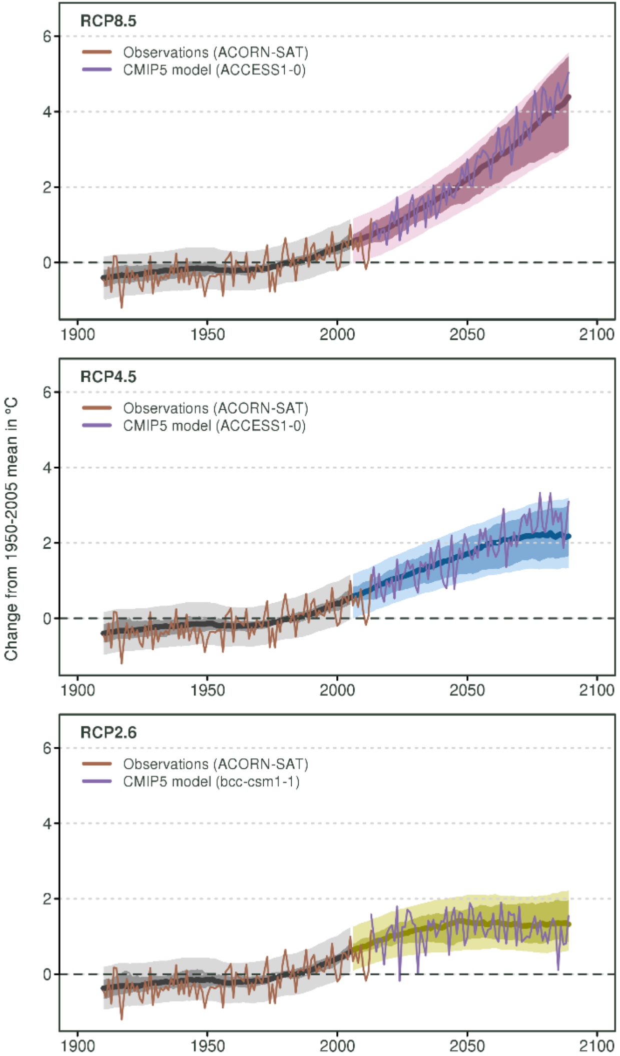
Regional climate responses to each emission scenario can be simulated by global climate models

Regional climate simulations are available from up to 40 global climate models (GCMs)

- GCMs mathematically represent physical processes over a three-dimensional grid of points across the globe, including the surface, oceans and atmosphere
- Calculations are made for hundreds of climate variables over thousands of grid-points, over hundreds of years
- The computer-intensive nature of this activity limits the horizontal resolution of most global climate models to about 100 km.
- Results match well with historical observations



Source: 2000 W.F. Ruddiman



Projected Australian warming relative to 1986-2005

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2030: 0.5-1.3°C for low emissions (RCP2.6) and 0.7 to 2.0°C for high emissions (RCP8.5)

2090: 0.6 to 1.7°C for low emissions (RCP2.6) and 2.8 to 5.1°C for high emissions (RCP8.5)

Greater rise in maximum temperature than minimum temperature in southern Australia

CSIRO and BoM (2015)

Annual-average number of days over 35°C

THRESHOLD 35 °C	1995	2030 RCP4.5	2090 RCP2.6	2090 RCP4.5	2090 RCP8.5
ADELAIDE[1]	20	26 (24 to 29)	28 (24 to 31)	32 (29 to 38)	47 (38 to 57)

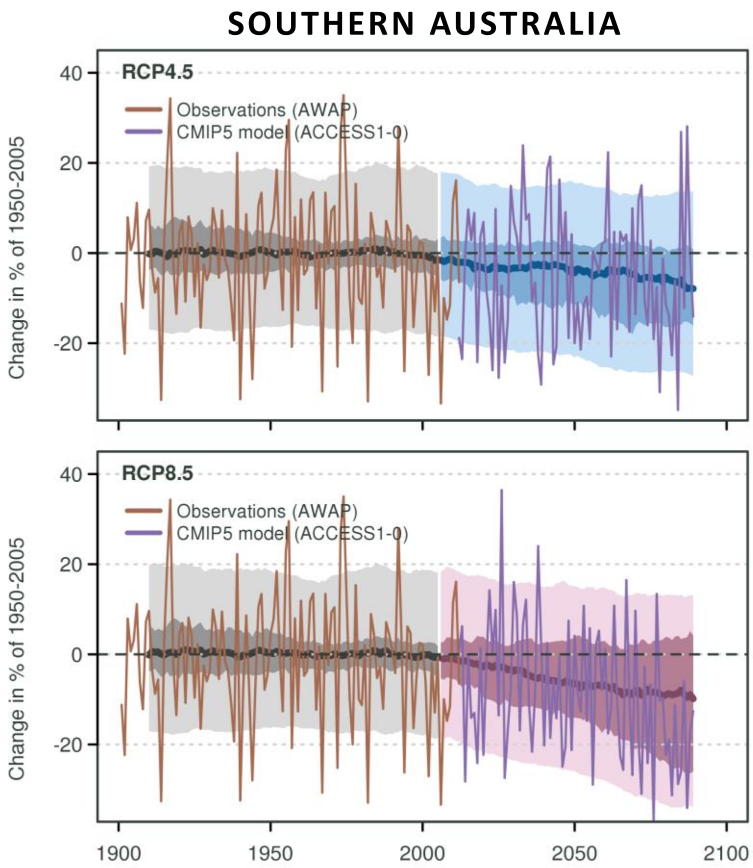
CSIRO and BoM (2015)

Natural climate variability is significant for rainfall projections

Over Southern Australian, there is large natural variability in rainfall from year to year

In future, this variability will be superimposed on a drying trend

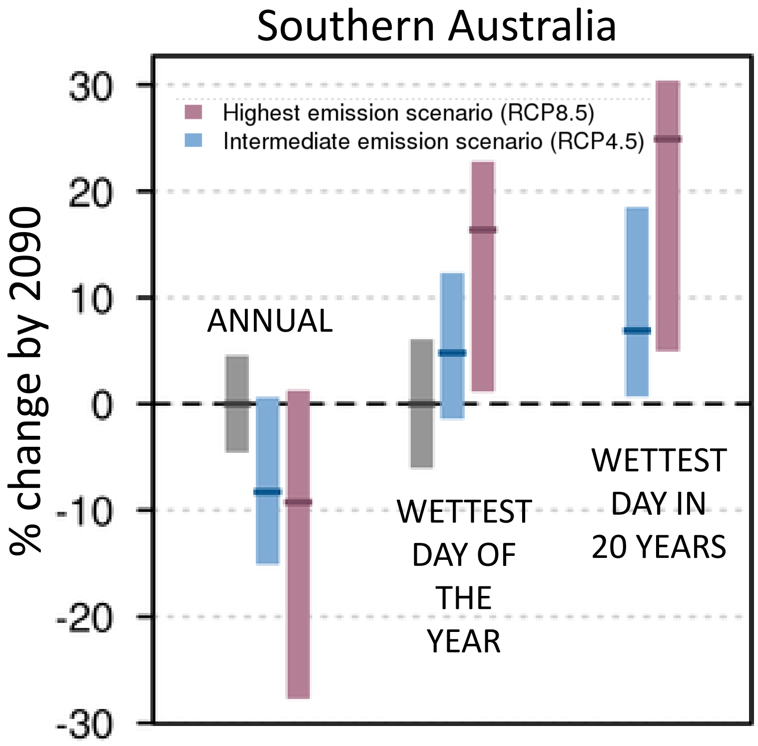
The rate of drying depends on the greenhouse gas emission scenario and climate model simulation



CSIRO and BoM (2015)

Extreme rainfall intensity will increase

Annual average rainfall decreases, but extreme rainfall events (wettest day of the year and wettest day in 20 years) are projected to increase in intensity



CSIRO and BoM (2015)

Detailed information about regional climate change and extreme weather events requires ‘downscaling’ from GCMs

- **Dynamical or statistical downscaling** methods can provide climate data on a grid of less than 25 km
    - This can reveal new information about regional climate change and extreme weather events, especially in areas of complex topography, e.g. mountains and coasts
- **Dynamical downscaling** uses the output from a GCM to drive a regional climate model (RCM) over a small region at high spatial resolution
- **Statistical downscaling** uses statistical relationships between regional climate and local climate, along with GCM or RCM regional climate projections, to infer local climate projections

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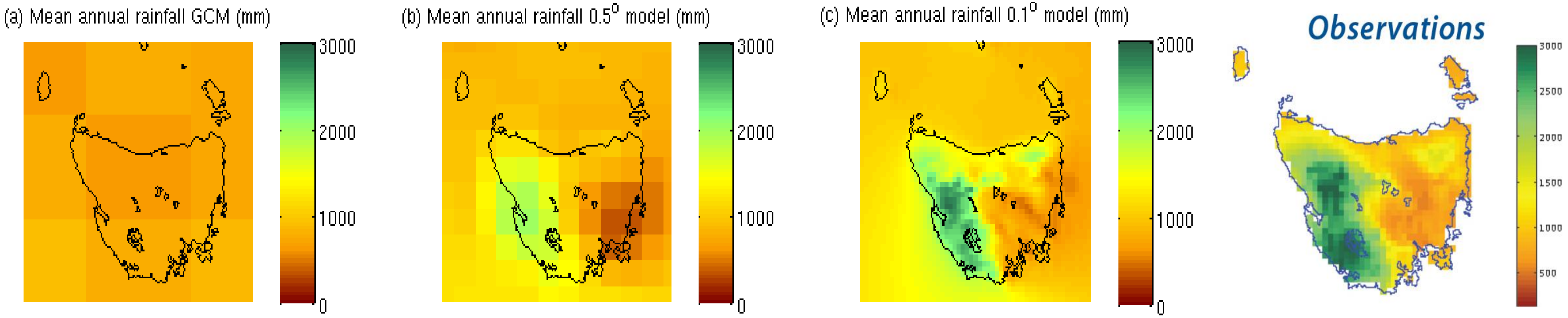
Questions on the review of the state of the Australian climate?

New downscaled climate projection datasets

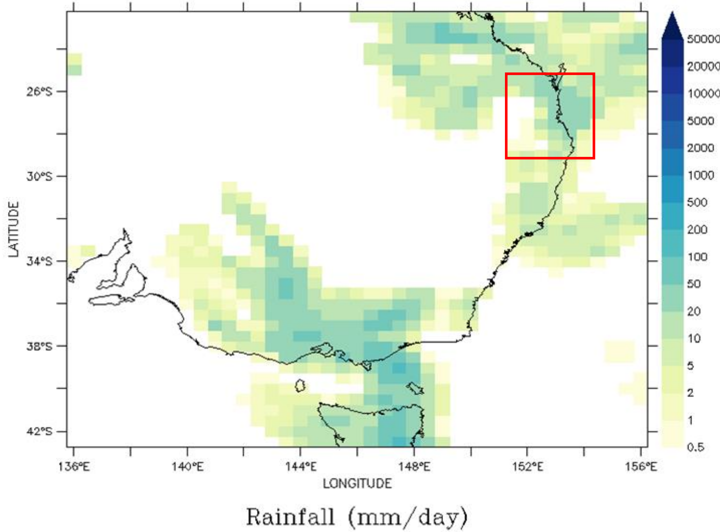
- The ESCI project is employing 'downscaled' projection datasets.
- To ensure the results are robust, we are drawing on a range of different modelling techniques.

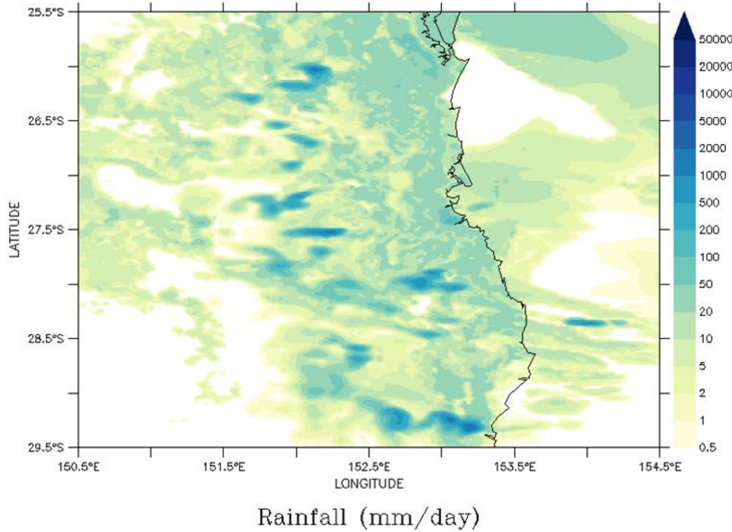


Rainfall simulation results at various spatial resolution from Climate Futures for Tasmania

Why downscale?

- Higher resolution does not necessarily imply higher accuracy. However, it can help provide additional insights.
- Useful features of downscaling include:
    - Better resolving of extreme weather (e.g., storms, cyclones, etc)
    - Better representation of sub-daily variability (e.g., solar ramp rates)
    - Accounting for urban heat island
    - Accounting for complex terrain and coastlines (e.g., rainfall over catchment regions and mountain ranges)

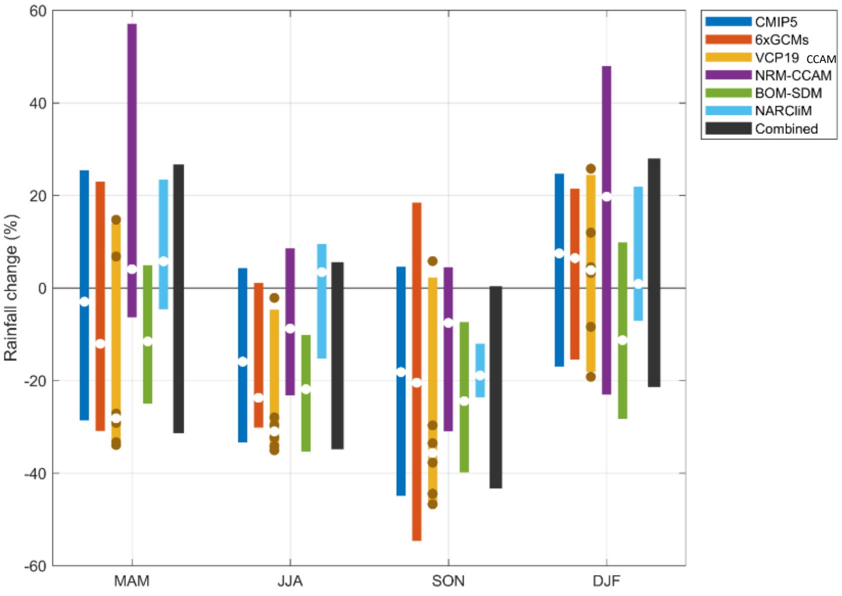




Example of simulated extreme rainfall over SE Queensland at 50 km and 2 km resolution

Multi-model approach

- There are several ways to generate the downscaled data including:
  - Delta-scaling
  - Quantile-scaling
  - Statistical downscaling
  - Dynamical downscaling
- New datasets are being developed for ESCI based on the delta-scaling and dynamical downscaling.
- However, existing datasets based on other techniques are still valid and useful.



Example of the projected change in rainfall for the Ovens-Murray region (VCP19 Technical Report)

New projection datasets

- The ESCI project is funding development of new climate projection datasets based on:
  - Delta-scaling
  - Bureau of Meteorology Atmospheric Regional Projections for Australia (BARPA)
  - Conformal Cubic Atmospheric Model (CCAM)
- We also employ the latest NSW and ACT Regional Climate Modelling (NARCliM) v1.5 regional climate modelling (NSW DPIE).
- Datasets are expected to be consistent across the NEM, with a focus on National datasets.

Developing climate projection datasets for ESCI

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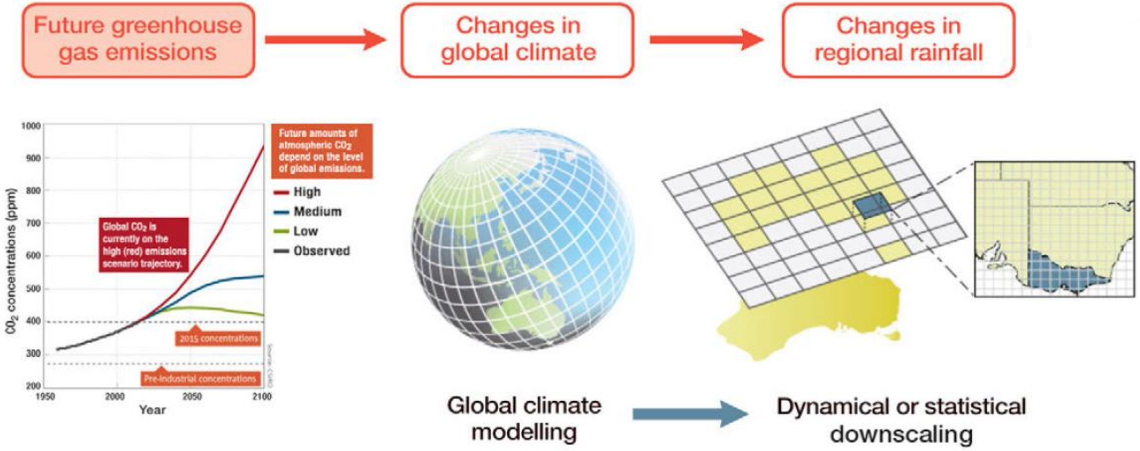
- The downscaling process is linked to the choice of emission scenario and the choice of host Global Climate Model.
- Since there is no ‘perfect’ global climate model, we need to downscale an ensemble of climate models.



Host CMIP5 GCM ensemble

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SELECTED MODEL	CLIMATE FUTURES	BARPA	CCAM	NARCLIM	Delta
ACCESS1.0	Maximum consensus for many regions.	☑	☑	☑	☑
ACCESS1.3				☑	
CESM1-CAM5	Hotter and wetter, or hotter and least drying				?
CNRM-CM5	Hot /wet end of range in Southern Australia		☑		?
GFDL-ESM2M	Hotter and drier model for many clusters		☑		?
HadGEM2-CC	Maximum consensus for many regions.				?
CanESM2			☑	☑	?
MIROC5	Low warming wetter model		☑		?
NorESM1-M	Low warming wettest representative model		☑		?

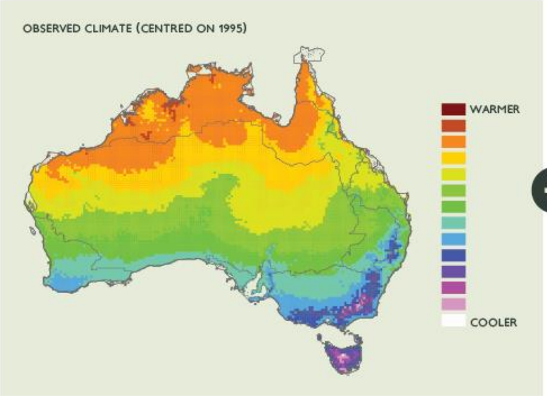
- The large number of climate projection datasets can be overwhelming.
- Climate Change in Australia recommends a sub-set of GCMs that represent the range of the broader CMIP5 ensemble.
- GCMs are selected on quality, independence and relevance.

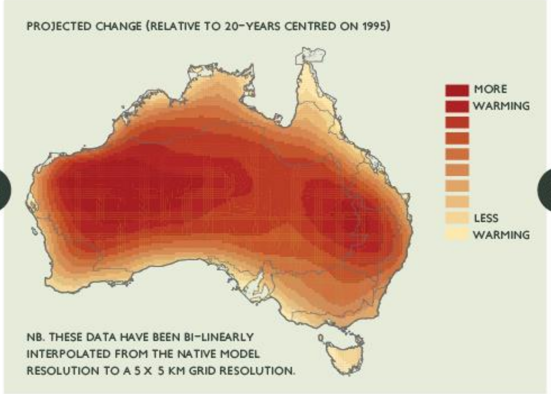
☑Completed or underway

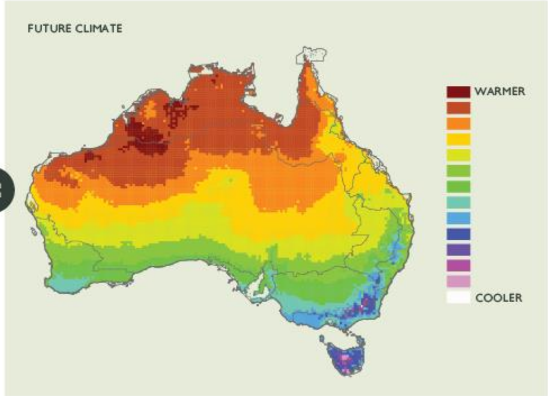
? Planned

Delta-scaling datasets

- Delta-scaling applies the change predicted by a global climate model to observed data.
- The method is accessible to most stakeholders, although depends on access to relevant historical records.
- ESCI is modifying the technique to accommodate 30 min intervals.

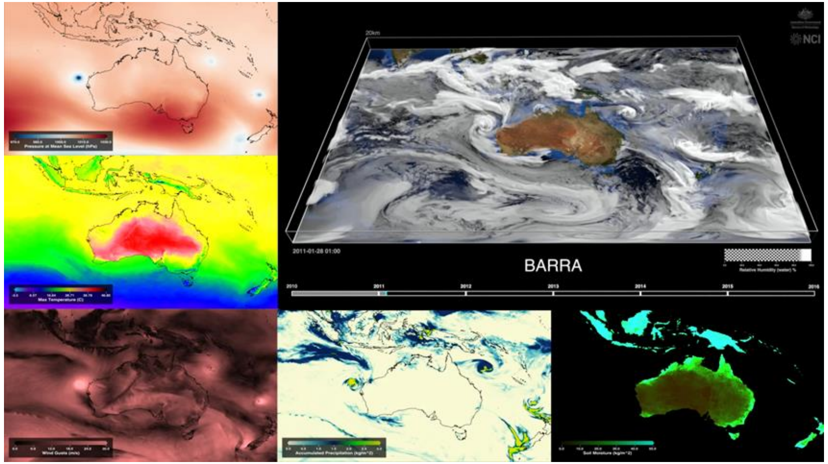






Dynamical downscaling

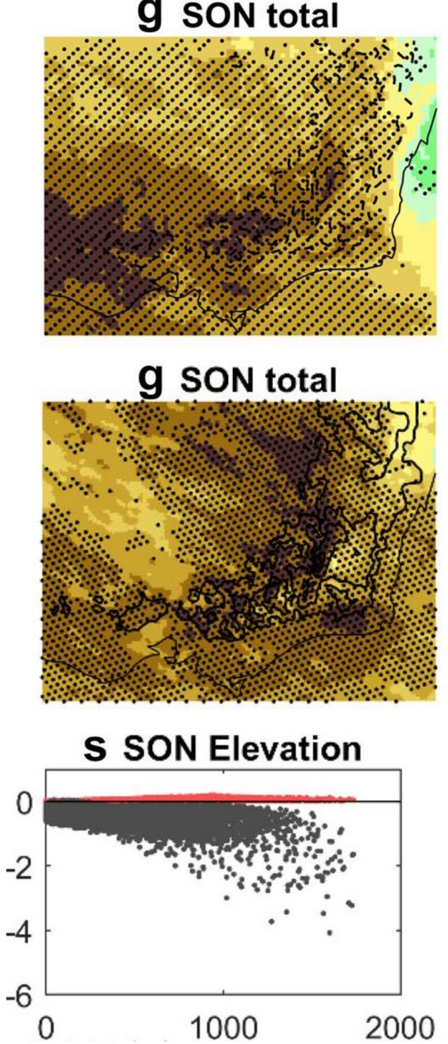
- We are also employing projections from multiple regional climate models:
  - New BARPA simulations (BoM)
  - New CCAM simulations (CSIRO)
  - The latest NARCLiM v1.5 projections (NSW DPIE)
- The regional models maintain the meaningful physical relationships between variables in space and time.
- The output has also been modified to provide additional information for solar and wind generators.



Examples from the BARRA regional climate simulations developed at BoM

Example: Elevated drying

- An example of how the dynamic models may add value is with elevated drying.
- In this case CCAM and NARCLiM both indicated an enhanced drying effect as a relationship with terrain height.
- As well as the prediction of an additional reduction in rainfall, the results also suggest increases in the number of dangerous fire days.



Projected change in average annual rainfall between 1980-1999 and 2080-2099 at 5km resolution over Victoria after downscaling with NARCLiM (top) and CCAM (middle). Bottom shows the change in rainfall as a function of elevation

There is a range of data products depending on the downscaling technique

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Resolution/location

- Point data for various locations
- Regional average data for NRM clusters
- Gridded national datasets:
  - 50 km for various models from 1950-2100 with RCP4.5 and RCP8.5
  - 12 km ESCI simulations from 1980-2099 (+ selected summers) for RCP8.5
  - 10 km NARCLiM data for NSW, VIC, southern QLD and eastern SA
- 30 min and 1 hour data, as well as daily and monthly averages

Variables

- Standard climate variables include:
  - 2m air temperature (dry bulb)
  - 2m dew point temperature
  - 2m relative humidity
  - Precipitation
  - Surface pressure
  - Global Horizontal Irradiance (GHI)
  - 10m wind speed and direction
  - Forest Fire Danger Index
- Some additional variables include:
  - Direct Normal Irradiance (DNI), 150m & 250m wind speed & direction

Questions on the fundamentals of climate projection, downscaling and sources of uncertainty?

Priority Climate Information for the electricity sector

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Focus of today's consultation

- Temperature (average, maximum & heatwave)
  - Generator and network capacities, rates of deterioration and failure rates
  - Customer demand for cooling load
- Bushfire
  - Threat to all assets, with particular smoke impacts on transmission lines
  - Design specifications
- Wind (average and gust)
  - Wind generation output and design
  - Network capacity, design specifications and failure rates

Risk frameworks will also provide guidance on risk assessment for other vulnerabilities.
E.g. coastal inundation, extreme precipitation events & flooding.

Consultation questions

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- What applications could you/ would you use this information for?
- What specifications would be most useful?
- How would you prefer to access the data, and which formats would be most desirable?
- What guidance and support would your organisation require to effectively use this information?

Questions can be posted in the chat.

Live questions at the end.

Sample spatial visualisations of climate information. Days over threshold for history & 4 climate models.

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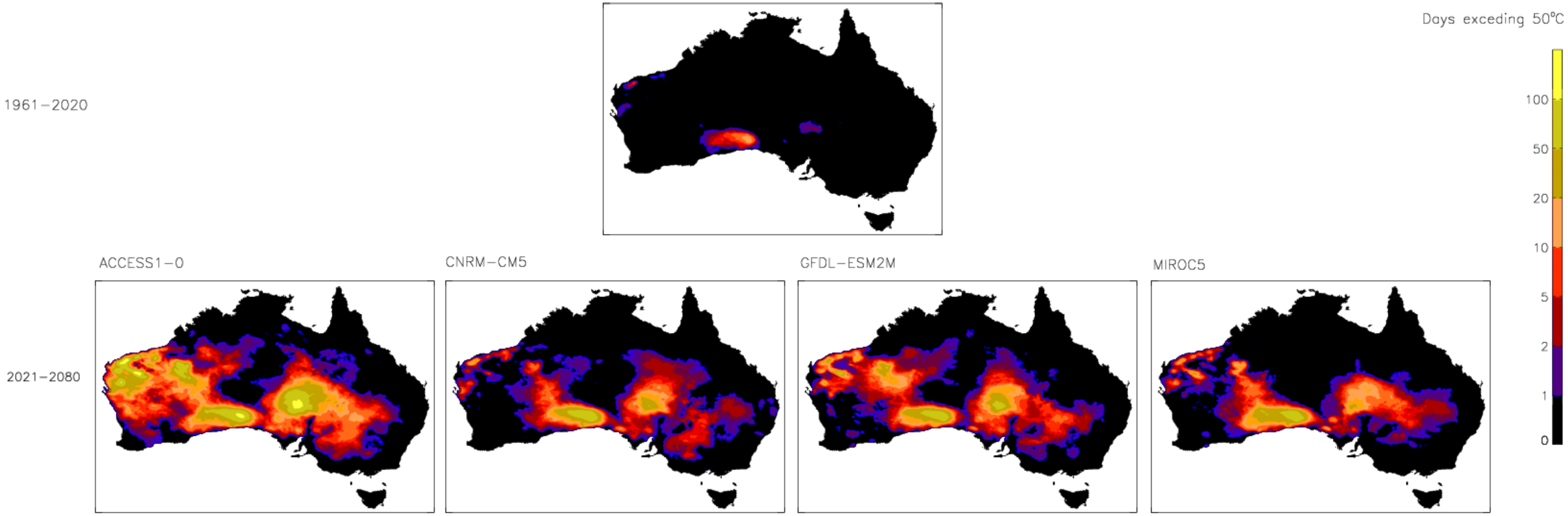
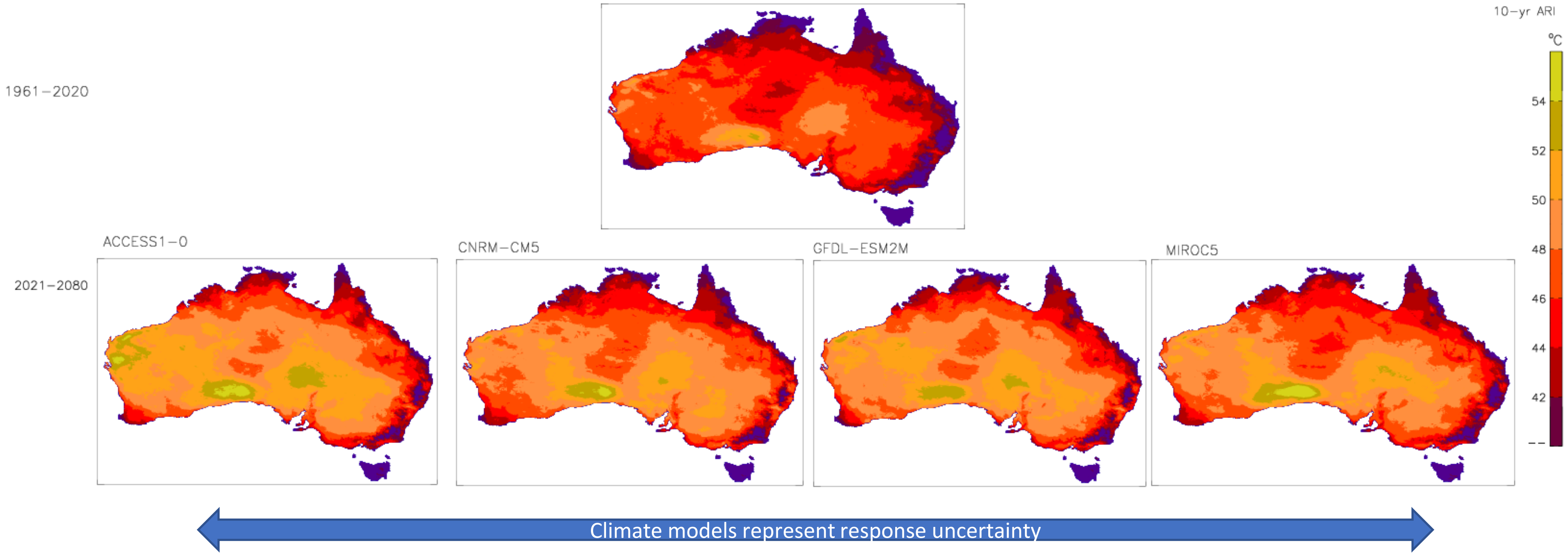


Climate models represent response uncertainty

Sample spatial visualisations of climate information.
1 in 10 year return temperature for history and 4 climate models



Sample spatial visualisations of climate information.
Temperature over thresholds – single climate model

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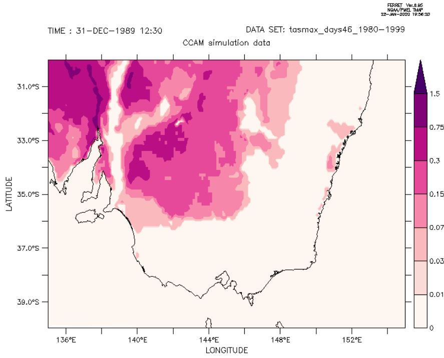
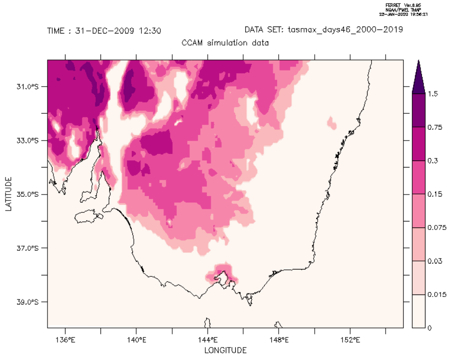
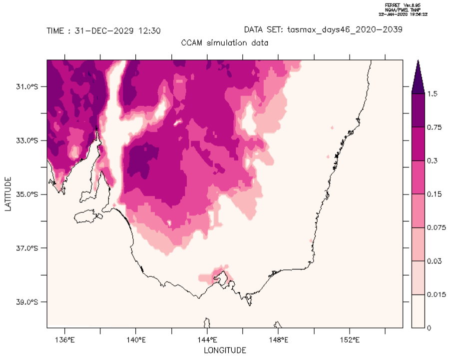


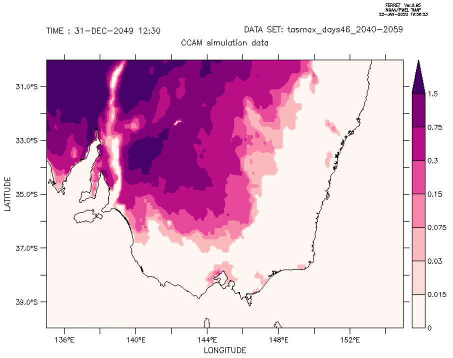
Days per year exceeding 46 C for 1980 to 1999



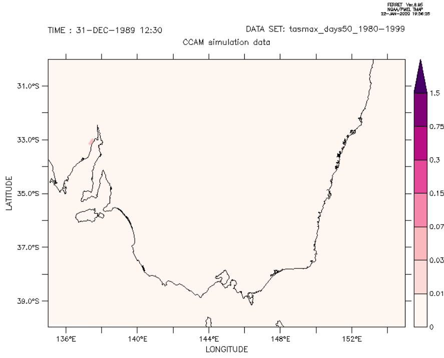
Days per year exceeding 46 C for 2000 to 2019



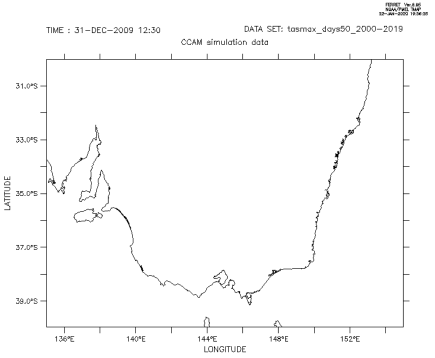
Days per year exceeding 46 C for 2020 to 2039



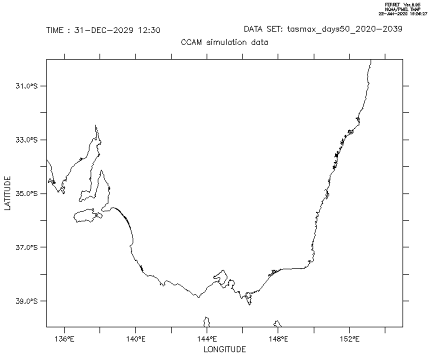
Days per year exceeding 46 C for 2040 to 2059



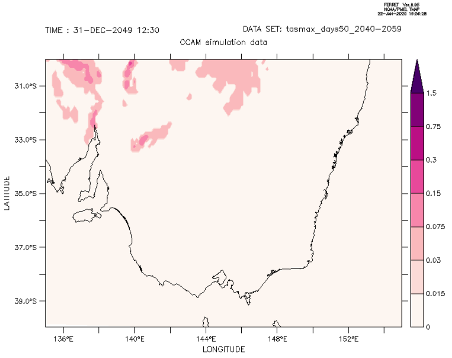
Days per year exceeding 50 C for 1980 to 1999



Days per year exceeding 50 C for 2000 to 2019



Days per year exceeding 50 C for 2020 to 2039



Days per year exceeding 50 C for 2040 to 2059

Sample spatial visualisations of climate information.
1 in 20 year return temperature – single climate model

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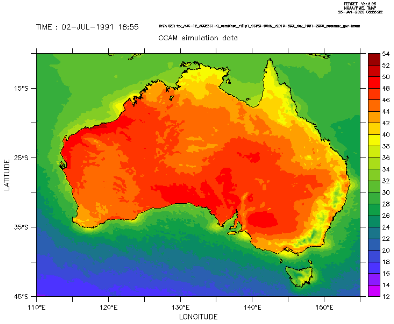
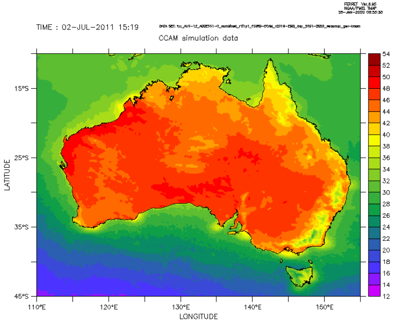
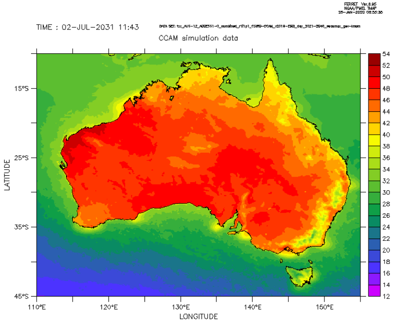


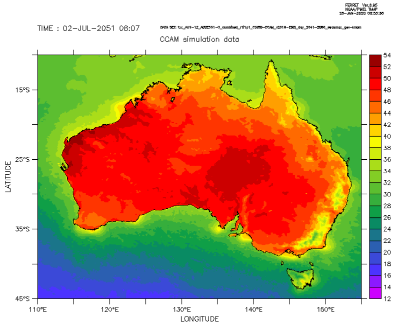
1-in-20 ARI for 1981 to 2000



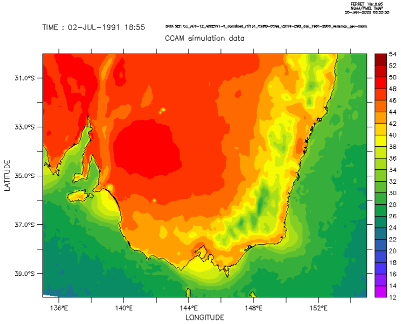
1-in-20 ARI for 2001 to 2020



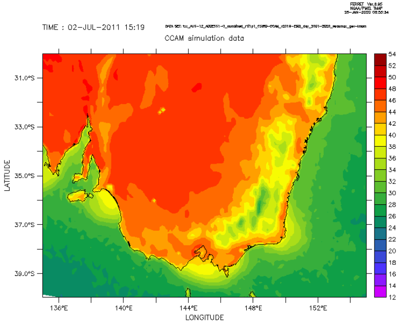
1-in-20 ARI for 2021 to 2040



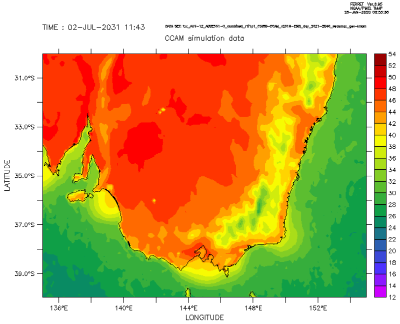
1-in-20 ARI for 2041 to 2060



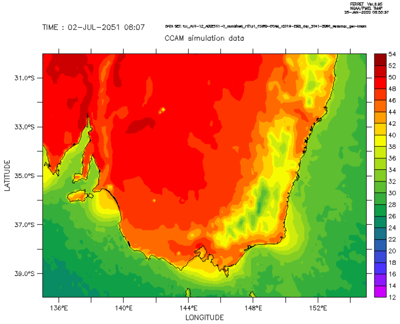
1-in-20 ARI for 1981 to 2000



1-in-20 ARI for 2001 to 2020



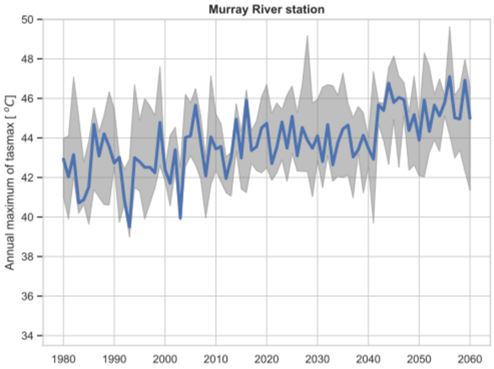
1-in-20 ARI for 2021 to 2040



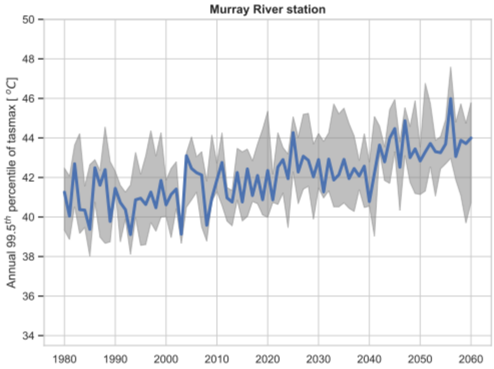
1-in-20 ARI for 2041 to 2060

Sample temporal visualisations of climate information for a single location

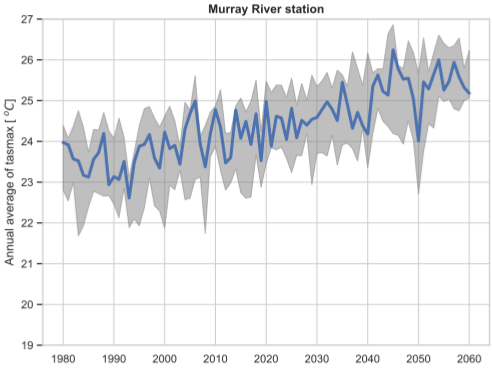
ELECTRICITY SECTOR CLIMATE INFORMATION PROJECT



Annual maximum temperature

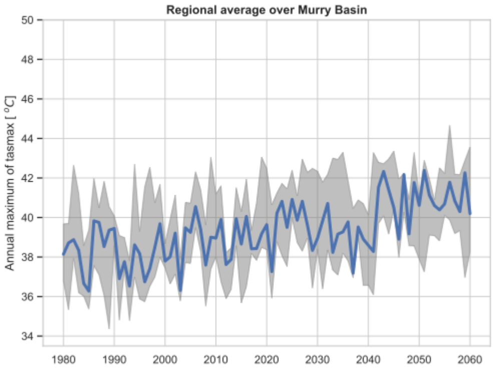


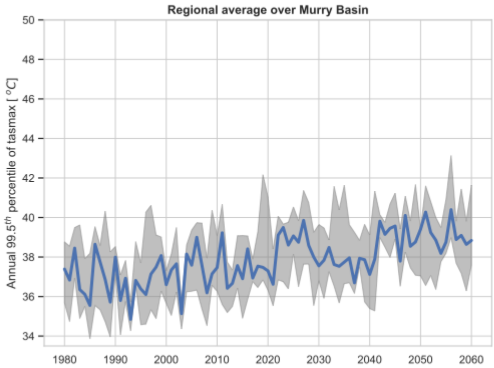
Annual 99.5th pctl daily max

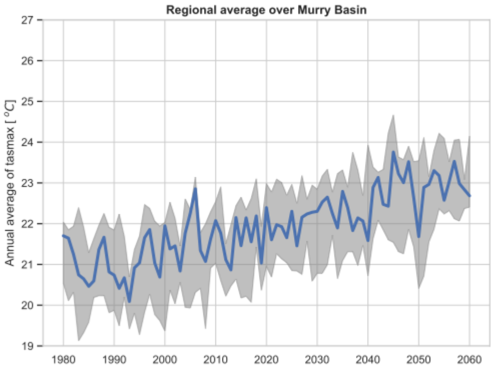


Annual average daily max

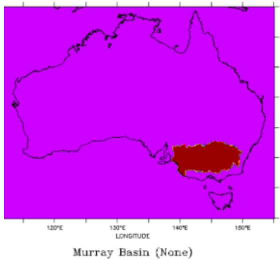
Murray River
(Red Cliffs Substation)





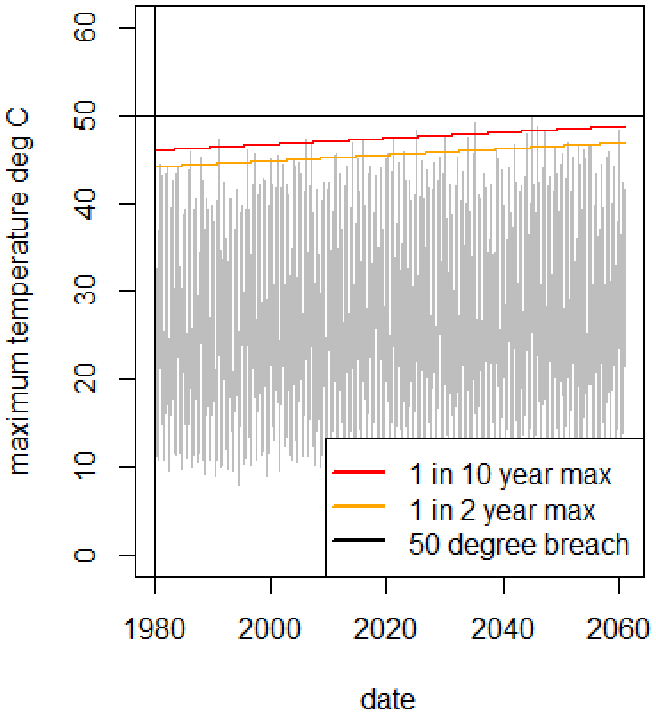


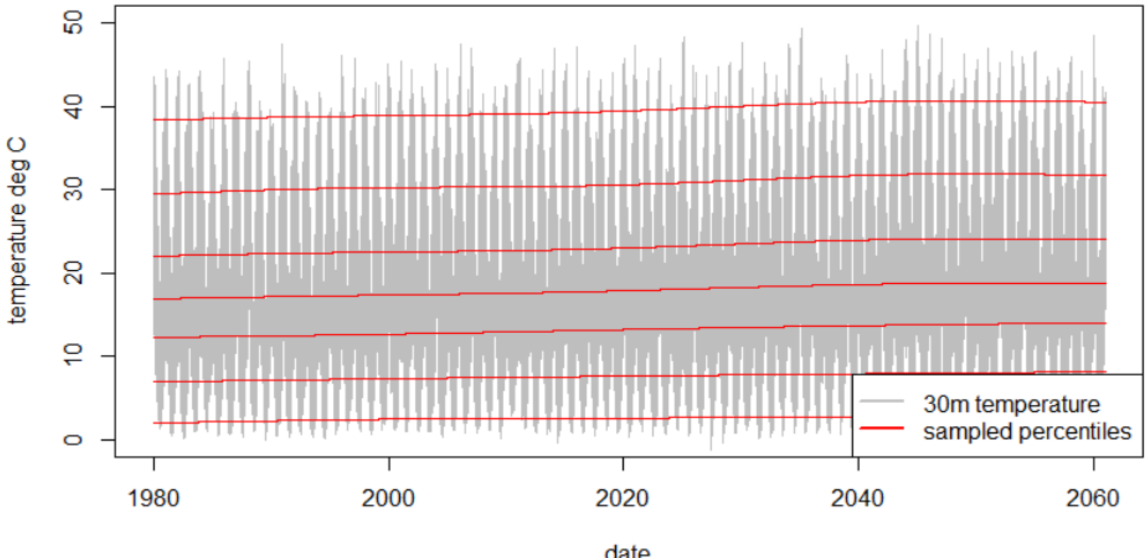
Murray Basin
Region



Sample temporal visualisations of climate information for a single location

ELECTRICITY SECTOR CLIMATE INFORMATION PROJECT





Consultation questions

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- What applications could you/ would you use this information for?
- What specifications would be most useful?
- How would you prefer to access the data, and which formats would be most desirable?
- What guidance and support would your organisation require to effectively use this information?

Close

- Very short evaluation survey (on survey monkey)
- Consultation response template sent this morning with the slide pack – please review and return by Friday February 14th to:

  Judith.Landsberg@BoM.gov.au

THANK YOU

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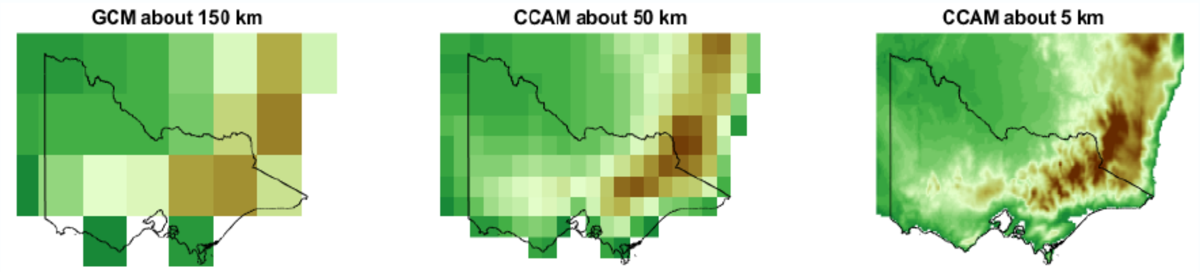
Additional slides

Regional Climate modelling is relatively accurate, and provides additional information

Dynamical downscaling example



Victorian Climate Projections 2019 (VCP19)

Higher resolution projections can be obtained from the GCMs through downscaling

- Statistical interpolation of boundary conditions can quickly provide localised data
- Running specialised models at high resolution can add value in complex areas of particular interest, e.g. mountains, coastal areas.

Climate Change in Australia

- Existing datasets based on the CMIP5 ensemble of global climate models can be obtained from Climate Change in Australia.
- This includes changes in many climate variables (e.g., daily temperature, precipitation, etc) averaged over National Resource Management Clusters (NRM) as well as for various weather stations at point locations.

Example of National Resource Management (NRM) clusters from Climate Change in