Earth Systems and Climate Change Hub

National Environmental Science Programme

WORKSHOP REPORT

Climate change impacts on the Gondwana Rainforests of Australia

March 2019

Earth Systems and Climate Change Hub Report No. 8

Australian Government | National Environmental Science Programme

The Earth Systems and Climate Change Hub is supported by funding through the Australian Government's National Environmental Science Program. The Hub is hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and is a partnership between CSIRO, Bureau of Meteorology, Australian National University, Monash University, University of Melbourne, University of New South Wales and University of Tasmania. The role of the Hub is to ensure that Australia's policies and management decisions are effectively informed by Earth systems and climate change science, now and into the future. For more information visit www.nespclimate.com.au.

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Citation

NESP Earth Systems and Climate Change Hub. 2019. *Climate change impacts on the Gondwana Rainforests of Australia (workshop report)*, Earth Systems and Climate Change Hub Report No. 8, NESP Earth Systems and Climate Change Hub, Australia.

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Published: March 2019

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Executive summary

A workshop was convened in Brisbane at the University of Queensland on 8 October 2018 to bring experts from key agencies together to discuss available climate projections and identify specific data needs for ongoing climate change adaptation planning for the Gondwana Rainforests of Australia World Heritage Area.

Gondwana Rainforests

The Gondwana Rainforests of Australia is a serial World Heritage property containing 40 separate reserves within north-east New South Wales and south-east Queensland. Covering more than 366,000 hectares, the rainforests comprise warm temperate, cool temperate, subtropical and dry rainforests similar to those that covered the ancient supercontinent Gondwana. The rainforests are biodiversity hot-spots and are home to many rare and threatened plants and animals.

On-ground management of the Gondwana Rainforests is largely by the NSW National Parks & Wildlife Service (part of the NSW Office of Environment and Heritage) and Queensland Parks & Wildlife Service (part of the Queensland Department of Environment and Science). The Queensland Department of Environment and Science (DES) has developed a Biodiversity and Ecosystems Climate Adaptation Plan, designed to facilitate the adaptation of Queensland's biodiversity and ecosystems to the effects of climate change.

Climate change

Climate change refers to long-term changes in the average pattern of weather that occur over decades to longer timescales. Climate variability, for example, due to the El Niño Southern Oscillation, occurs at shorter timescales of years to decades, while weather occurs on the timescale of hours to days.

Climate change projections are not predictions, but they tell us about the response of the climate system to possible future scenarios of human greenhouse gas emissions. Climate projections for the broader Gondwana Rainforests region include:

- increased average temperatures in all seasons (*very high confidence*).
- more hot days and warm spells with a substantial increase in the temperature reached on hot days, the frequency of hot days, and the duration of warm spells (*very high confidence*).
- uncertain rainfall change with the mean of the models projecting a modest decrease, strongest in winter (*low confidence*). There is a suggestion with a possible modest increase in summer rainfall in the northern part of the region in summer (*low confidence*) but the spread across models from increases to decreases is very large, Irrespective of average rainfall changes, extreme rainfall events will increase in severity.
- higher surface solar radiation (i.e. decreased overall cloud cover), decreased relative humidity (although modest in winter) and higher evapotranspiration in all seasons.

Changes projected generally increase for higher emissions scenarios and for further out in the century.

Detailed climate change projections for Australia are available at www.climatechangeinaustralia.gov.au – Gondwana Rainforests are in the East Coast cluster (both North and South sub-clusters).

Next steps

The ESCC Hub will collaborate with Gondwana Rainforests WHA managers on a case study to assess the impact of climate change on cloud cover in the region covered by the Border Ranges Rainforest Biodiversity Management Plan. The case study will be carried out in 2019–20.

The Gondwana Rainforests Management Committee will continue to investigate adaptation planning for the World Heritage area within their jurisdictions. Opportunities to coordinate and share information and learnings between jurisdictions will be investigated and optimised. Input and advice from the Gondwana Rainforests advisory committees shall be sought as projects and programs are developed, including identifying knowledge gaps along the way.

Background

The Gondwana Rainforests of Australia is a serial World Heritage property containing reserves within north-east New South Wales and south-east Queensland. Inscribed on the World Heritage for the outstanding universal value (OUV) of landforms and biodiversity, it contains numerous relict and endemic species, particularly those associated with rainforests.

Climate change has been identified as a threat to the OUV of the Gondwana Rainforests. Projected changes in temperatures and rainfall are likely to directly affect already restricted cool, moist habitats. Changes in fire regimes and severe storm events, coupled with changes in competition from pest species, are likely to further impact these habitats.[1]

One of the rainforest types which is considered to be under particular threat from climate change is the microphyll fern forests, typically dominated by Antarctic beech (*Nothofagus moorei*).[2] Upland forests, including 'cool temperate rainforests', have been shown to receive significant moisture inputs from cloud and fog.[3]

Research into the potential impacts of climate change on these biotic communities is hampered by a lack of data about the current and projected rainfall and cloud variables. This project focuses on the specific question of how to obtain better data and information on these parameters to assist in adaptation planning.

The ESCC Hub seeks to support governments and communities in adapting to climate change through the provision of climate modelling which meets specific information requirements. Managers of World Heritage at the state and federal level are seeking to develop adaptation plans to protect and conserve World Heritage. This project aims to deliver improved information and data for use by World Heritage managers in the development of these plans.

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[1] Australian National University (2009) Implications of climate change for Australia's World Heritage properties: A preliminary assessment. A report to the Department of Climate Change and the Department of the Environment, Water, Heritage and the Arts by the Fenner School of Environment and Society, Australian National University.

[2] Taylor et al (2005) in Australian National University (2009).

[3] Hutley LB, Doley D, Yates DJ, Boonsaner A (1997) Water balance of an Australian subtropical rainforest at altitude: the ecological and physiological significance of intercepted cloud and fog. *Australian Journal of Botany*, 45(2), 311–329.

About the workshop

A workshop was convened in Brisbane at the University of Queensland on 8 October 2018 to bring experts from key agencies together to discuss available climate projections and identify specific data needs for ongoing climate change adaptation planning.

Specifically, the workshop objectives were to:

- examine the impact of climate change on Queensland cloud caps and cloud forests, including projected change and likelihood of crossing important thresholds under various scenarios
- demonstrate the value of multi-disciplinary and collaborative, 'end-to-end' analysis to address issues of series of steps/aims to achieve this.

This report provides a summary of the information presented at the workshop and identifies possibilities for the next steps, pending agreement and resources.

The workshop program and participant list are included in the appendices of this report.

Gondwana Rainforests – a window into the past

The Gondwana Rainforests of Australia World Heritage Area (Gondwana Rainforests WHA) is a series of 40 separate reserves grouped into eight geographical areas on Australia's east coast (Figure 1). Covering more than 366,000 hectares, the rainforests comprise warm temperate, cool temperate, subtropical and dry rainforests similar to those that covered the ancient supercontinent Gondwana. The rainforests are biodiversity hot-spots and are home to many rare and threatened plants and animals.

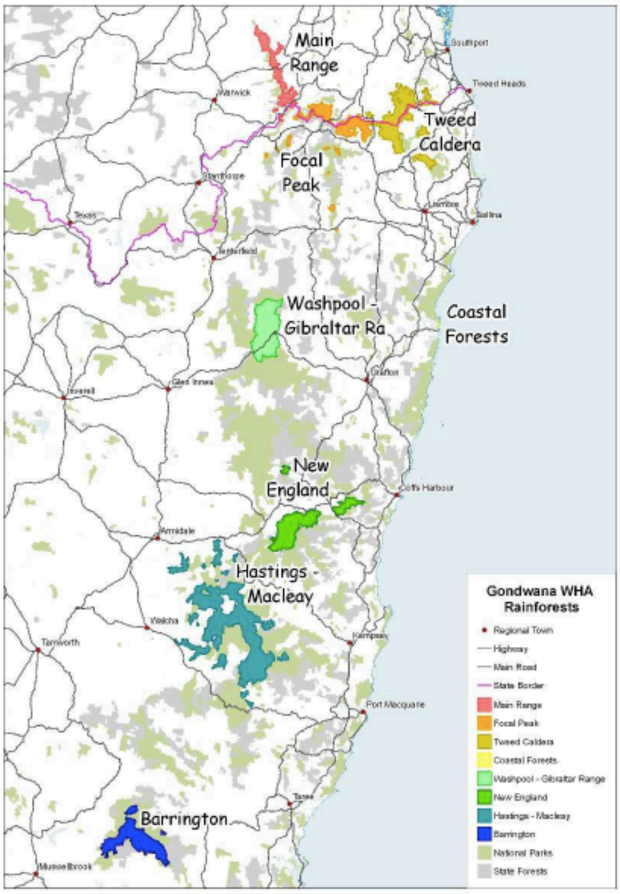

Figure 1. Map showing the eight geographical regions of the Gondwana Rainforests of Australia World Heritage Area (Source: workshop presentation by Tricia Waters)

The mountainous topography typical of the Gondwana Rainforests WHA has both driven the evolution of, and provided refuge for, unique species and communities dependent upon stable, moist microclimates. The high elevation forests in particular provide habitat for a number of narrow-range endemic and threatened species, temperate families and cool temperate rainforest communities which in part define the outstanding universal value (OUV) of the Gondwana Rainforests WHA.

At high elevations, moisture inputs from rainfall are supplemented by cloud and fog intercepted by the forest canopy. Experiments in nearby upland rainforest have shown that fog and cloud-water can contribute moisture inputs equivalent to 40% of annual precipitation.[4] Future warming under climate change and any associated reduction or seasonal change in cloud water inputs could result in a reduction of annual moisture inputs, reduced stream-flows, increased dry-season moisture stress and in turn, threaten the OUV of the property.

World Heritage listing – what this means

The Gondwana Rainforests were first listed as a World Heritage Area in 1986 and were the first serial property to be listed. The original listing was as Australian East Coast Temperate and Subtropical Rainforest Parks. Additions were listed in 1994 and the name changed to Central Eastern Rainforest Reserves of Australia. The name was changed to Gondwana Rainforests of Australia in 2007 to better reflect the values for which it was World Heritage listed.

World Heritage properties are sites of global natural or cultural significance that have been recognised through the World Heritage Convention. The Convention, adopted in 1972 through UNESCO, came into force in 1975. It recognises the need to preserve a balance between World Heritage values and how people interact with nature.

All States Parties signed up to the World Heritage Convention – currently 167 countries (including Australia) – agree to adhere to the Convention and to nominate properties for inclusion on the World Heritage List. They commit to protecting World Heritage values, which includes having management plans in place to protect these values and report on their condition.

There are currently 1092 properties on the World Heritage List – 845 recognised for their cultural value, 209 for their natural value and 38 for both cultural and natural value.

World Heritage properties are to be preserved for the future on the basis of their OUV. Each property has a Statement of OUV (SoOUV) which is:

- the principal reference for all plans and legislation relating to future protection and management of the property
- a point of reference for all monitoring, state conservation reporting and a mandate to maintain the values as per at Listing.

The fundamental concept is passing on the property to future generations with the values/attributes as they are recorded in the SoOUV.

There are 10 criteria for OUV – four natural and six cultural.[5] Gondwana Rainforests WHA meets three of the four natural criteria:

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[4] Hutley LB, Doley D, Yates DJ, Boonsaner A (1997) Water balance of an Australian subtropical rainforest at altitude: the ecological and physiological significance of intercepted cloud and fog. *Australian Journal of Botany*, 45(2), 311–329.

[5] http://whc.unesco.org/en/criteria/

> viii. be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.
>
> ix. be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.
>
> x. contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

World Heritage properties must also meet the conditions of integrity (natural sites) or authenticity (cultural sites) – that is, they must have sufficient protection/management in place to ensure the World Heritage values at Listing are maintained and safeguarded into the future. The IUCN defines the integrity of a World Heritage property as:

> "… a measure of the wholeness and intactness of the natural and/or cultural heritage and its attributes. Examining the conditions of integrity, therefore requires assessing the extent to which the property:
>
> a) includes all elements necessary to express its outstanding universal value;
> b) is of adequate size to ensure the complete representation of the features and processes which convey the property's significance;
> c) suffers from adverse effects of development and/or neglect."[6]

The integrity of the Gondwana Rainforests is considered to be vulnerable to the impacts of climate change. This has been a significant motivation for commencing a systematic evaluation of future climate scenarios and planning for the future.

Gondwana Rainforests of Australia Statement of OUV[7]

Brief synthesis

The Gondwana Rainforests of Australia is a serial property comprising the major remaining areas of rainforest in southeast Queensland and northeast New South Wales. It represents outstanding examples of major stages of the Earth's evolutionary history, ongoing geological and biological processes, and exceptional biological diversity. A wide range of plant and animal lineages and communities with ancient origins in Gondwana, many of which are restricted largely or entirely to the Gondwana Rainforests, survive in this collection of reserves. The Gondwana Rainforests also provides the principal habitat for many threatened species of plants and animals.

Criterion (viii): The Gondwana Rainforests provides outstanding examples of significant ongoing geological processes. When Australia separated from Antarctica following the breakup of Gondwana, new continental margins developed. The margin which formed along Australia's eastern edge is characterised by an asymmetrical marginal swell that runs parallel to the coastline, the erosion of which has resulted in the Great Divide and the Great Escarpment. This eastern continental margin experienced volcanicity during the Cenozoic

[6] https://whc.unesco.org/document/115532
[7] https://whc.unesco.org/en/list/368

Era as the Australian continental plate moved over one of the planet's hot spots. Volcanoes erupted in sequence along the east coast resulting in the Tweed, Focal Peak, Ebor and Barrington volcanic shields. This sequence of volcanos is significant as it enables the dating of the geomorphic evolution of eastern Australia through the study of the interaction of these volcanic remnants with the eastern highlands.

The Tweed Shield erosion caldera is possibly the best preserved erosion caldera in the world, notable for its size and age, for the presence of a prominent central mountain mass (Wollumbin/Mt Warning), and for the erosion of the caldera floor to basement rock. All three stages relating to the erosion of shield volcanoes (the planeze, residual and skeletal stages) are readily distinguishable. Further south, the remnants of the Ebor Volcano also provides an outstanding example of the ongoing erosion of a shield volcano.

Criterion (ix): The Gondwana Rainforests contains outstanding examples of major stages in the Earth's evolutionary history as well as ongoing evolutionary processes. Major stages represented include the 'Age of the Pteridophytes' from the Carboniferous Period with some of the oldest elements of the world's ferns represented, and the 'Age of Conifers' in the Jurassic Period with one of the most significant centres of survival for Araucarians (the most ancient and phylogenetically primitive of the world's conifers). Likewise the property provides an outstanding record of the 'Age of the Angiosperms'. This includes a secondary centre of endemism for primitive flowering plants originating in the Early Cretaceous, the most diverse assemblage of relict angiosperm taxa representing the primary radiation of dicotyledons in the mid-Late Cretaceous, a unique record of the evolutionary history of Australian rainforests representing the 'golden age' of the Early Tertiary, and a unique record of Miocene vegetation that was the antecedent of modern temperate rainforests in Australia. The property also contains an outstanding number of songbird species, including lyrebirds (Menuridae), scrub-birds (Atrichornithidae), treecreepers (Climacteridae) and bowerbirds and catbirds (Ptilonorhynchidae), belonging to some of the oldest lineages of passerines that evolved in the Late Cretaceous. Outstanding examples of other relict vertebrate and invertebrate fauna from ancient lineages linked to the break-up of Gondwana also occur in the property.

The flora and fauna of the Gondwana Rainforests provides outstanding examples of ongoing evolution including plant and animal taxa which show evidence of relatively recent evolution. The rainforests have been described as 'an archipelago of refugia, a series of distinctive habitats that characterise a temporary endpoint in climatic and geomorphological evolution'. The distances between these 'islands' of rainforest represent barriers to the flow of genetic material for those taxa which have low dispersal ability, and this pressure has created the potential for continued speciation.

Criterion (x): The ecosystems of the Gondwana Rainforests contain significant and important natural habitats for species of conservation significance, particularly those associated with the rainforests which once covered much of the continent of Australia and are now restricted to archipelagos of small areas of rainforest isolated by sclerophyll vegetation and cleared land. The Gondwana Rainforests provides the principal habitat for many species of plants and animals of outstanding universal value, including more than 270 threatened species as well as relict and primitive taxa.

Rainforests covered most of Australia for much of the 40 million years after its separation from Gondwana. However, these rainforests contracted as climatic conditions changed and the continent drifted northwards. By the time of European settlement rainforests covered only 1% of the landmass and were restricted to refugia with suitable climatic conditions and protection from fire. Following European settlement, clearing for agriculture saw further loss of rainforests and only a quarter of the rainforest present in Australia at the time of European settlement remains.

The Gondwana Rainforests protects the largest and best stands of rainforest habitat remaining in this region. Many of the rare and threatened flora and fauna species are rainforest specialists, and their vulnerability to extinction is due to a variety of factors including the rarity of their rainforest habitat. The Gondwana Rainforests also protects large areas of other vegetation including a diverse range of heaths, rocky outcrop communities, forests and woodlands. These communities have a high diversity of plants and animals that add greatly to the value of the Gondwana Rainforests as habitat for rare, threatened and endemic species. The complex dynamics between rainforests and tall open forest particularly demonstrates the close evolutionary and ecological links between these communities.

Species continue to be discovered in the property including the re-discovery of two mammal species previously thought to have been extinct: the Hastings River Mouse (*Pseudomys oralis*) and Parma Wallaby (*Macropus parma*).

Integrity

The Gondwana Rainforests contains the largest and most significant remaining stands of subtropical rainforest and Antarctic Beech (*Nothofagus moorei*) cool temperate rainforests in the world, the largest and most significant areas of warm temperate rainforest and one of only two remaining large areas of Araucarian rainforest in Australia.

Questions related to the small size of some of the component parts of the property, and the distance between the sites for the long-term conservation and continuation of natural biological processes of the values for which the property was inscribed have been raised. However, noting that the serial sites are in reasonable proximity and are joined by corridors of semi-natural habitats and buffers, compensation for small size and scattered fragments is being made through intensive management consistent with approved management plans and policy.

Since inscription, there have been significant additions to the protected area estate in both New South Wales and Queensland in the region encompassing the Gondwana Rainforests. These areas have undergone a rigorous assessment to determine their suitability for inclusion in the property and a significant extension of the property is planned as indicated by the addition of the property extension to Australia's Tentative List in May 2010. In relation to ongoing evolution, the level of legislative protection provided for World Heritage properties will minimise direct human influence and enable the continuation of natural biological processes.

Protection and management requirements

Institutional arrangements for the protection and management of Gondwana Rainforests are strong. The property is made up of 41 reserves, almost all of which are within the protected area estate, and primarily managed by the Queensland Parks and Wildlife Service and the New South Wales National Parks and Wildlife Service. Both States have legislation relating to protected areas and native flora and fauna that provide protection for the values of the Gondwana Rainforests.

In 1993, Governments agreed to establish a Coordinating Committee, comprised of on-ground managers from these agencies and the Australian Government, to facilitate the cooperative management of the property at an operational level. A Technical and Scientific Advisory Committee and a Community Advisory Committee have also assisted with management advice since their establishment in 2002.

In 1994 when the property was extended, the World Heritage Committee requested the Australian authorities to complete the management plans of individual sites, particularly those within Queensland. Management plans have been produced for the majority of individual reserves within the property, and are in draft form or planned for the remainder.

In 2000 a Strategic Overview for Management for the Central Eastern Rainforest Reserves of Australia (now Gondwana Rainforests) World Heritage Area was published. This overarching document is a major element in guiding cooperative management by the three Governments in relation to the identification, protection, conservation, rehabilitation and presentation of the Gondwana Rainforests.

All World Heritage properties in Australia are 'matters of national environmental significance' protected and managed under national legislation, the *Environment Protection and Biodiversity Conservation Act 1999*. This Act is the statutory instrument for implementing Australia's obligations under a number of multilateral environmental agreements including the World Heritage Convention. By law, any action that has, will have or is likely to have a significant impact on the World Heritage values of a World Heritage property must be referred to the responsible Minister for consideration. Substantial penalties apply for taking such an action without approval. Once a heritage place is listed, the Act provides for the preparation of management plans which set out the significant heritage aspects of the place and how the values of the site will be managed.

Importantly, this Act also aims to protect matters of national environmental significance, such as World Heritage properties, from impacts even if they originate outside the property or if the values of the property are mobile (as in fauna). It thus forms an additional layer of protection designed to protect values of World Heritage properties from external impacts.

On 15 May 2007, the Gondwana Rainforests of Australia was added to the National Heritage List; National Heritage is also a matter of national environmental significance under the EPBC Act.

The impacts of climate change and high levels of visitation, undertaking effective fire management, and mitigating the effects of invasion by pest species and pathogens present the greatest challenges for the protection and management of Gondwana Rainforests. Climate change will impact particularly on those relict species in restricted habitats at higher altitudes, where particular microclimatic conditions have enabled these species to survive. Management responses include improving the resilience of the property by addressing other threats such as inappropriate fire regimes and invasion by pest species, and trying to increase habitat connectivity across the landscape.

Management of Gondwana Rainforests WHA

On-ground management of the Gondwana Rainforests WHA is largely by the:

- NSW National Parks & Wildlife Service (part of the NSW Office of Environment and Heritage)
- Queensland Parks & Wildlife Service (part of the Queensland Department of Environment and Science).

Queensland Biodiversity and Ecosystems Climate Adaptation Plan

At the workshop, Queensland's Department of Environment and Science (DES) provided workshop participants with an overview of its work underway with partners representing the Biodiversity and Ecosystems 'sector' in Queensland to develop a sector adaptation plan, under its Queensland Climate Adaptation Strategy (Q-CAS) 2017–2030. The plan, the Biodiversity and Ecosystems Climate Adaptation Plan (B&E CAP) is designed to facilitate the adaptation of Queensland's biodiversity and ecosystems to the effects of climate change.

DES relayed the context to development of the B&E CAP in terms of Q-CAS and in terms of the issues facing the sector. Indeed, Queensland, as NSW, is facing a future of increasing biodiversity loss and decline in ecosystem integrity and function. Contributing to this are climate factors such as human-induced changes in temperature and rainfall, and scenarios of increasingly impactful intermittent extreme weather events and climate hazards like heatwaves, droughts, fires, cyclones and floods. As well as their direct impacts, changes such as these are likely to compound the impacts of non-climate factors such as habitat loss, pollution and invasive species.

DES informed participants that it had engaged the National Climate Change Adaptation Research Facility (NCCARF) and Cath Moran Ecological Consultancy to lead development of the B&E CAP and its identification of priority measures for the management of climate change impacts on Queensland's unique biodiversity and ecosystems.

DES relayed that the B&E CAP (launched on 9 November 2018) would be the sixth sector adaption plan to be launched under Q-CAS.

DES also highlighted that, beyond release of the B&E CAP, it would be looking to partner with the sector, ideally on a matched-funding basis, to develop and deliver pilot projects aligned to the recommendations of the B&E CAP. DES highlighted that World Heritage areas were considered a priority under the B&E CAP, and that it would look to pilot projects within a Queensland National Park that forms part of one of its four terrestrial World Heritage areas.

Climate change

All climate and climate change figures in this report are from presentations by ESCC Hub researchers at the workshop.

Weather, climate, climate variability and climate change

Weather is how we experience climate, but weather and climate are not the same thing. Weather refers to atmospheric conditions and events that occur over short periods of time, typically hours to days. Climate is the average pattern of weather over an extended period of time. Baseline climate features would ideally be derived from very long periods (traditionally around 30 years) so that they capture the 'average' climate as well as the intrinsic variability around this average. However, a rapidly changing climate means that we may need to reassess the appropriate length of such periods to sample when we define 'climate'.

Climate is what you expect, weather is what you get. — Robert A. Heinlein

The climate is not uniform, but varies over months, years and decades (Figure 2). These variations are due to natural processes. On a timescale of months, climate varies due to seasonal cycles. On a timescale of years, phenomena such as the El Niño–Southern Oscillation[8] causes variations in climate, while climate variability at a decadal timescale is influenced by processes such as the Interdecadal Pacific Oscillation (sometimes called the Pacific Decadal Oscillation[9]).

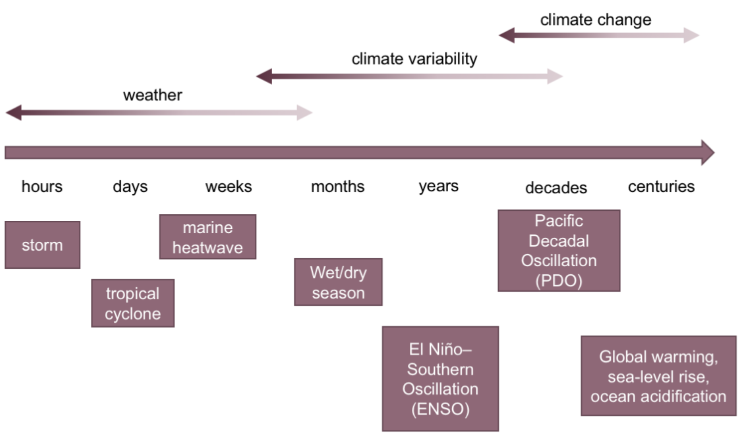

Figure 2. Climate and weather time scales

Climate change refers to long-term changes in the average pattern of weather that occur over decades or. Since industrialisation, rapidly increasing concentrations of greenhouse gases in the atmosphere have resulted in global warming. As the climate becomes warmer, other climate processes also change.

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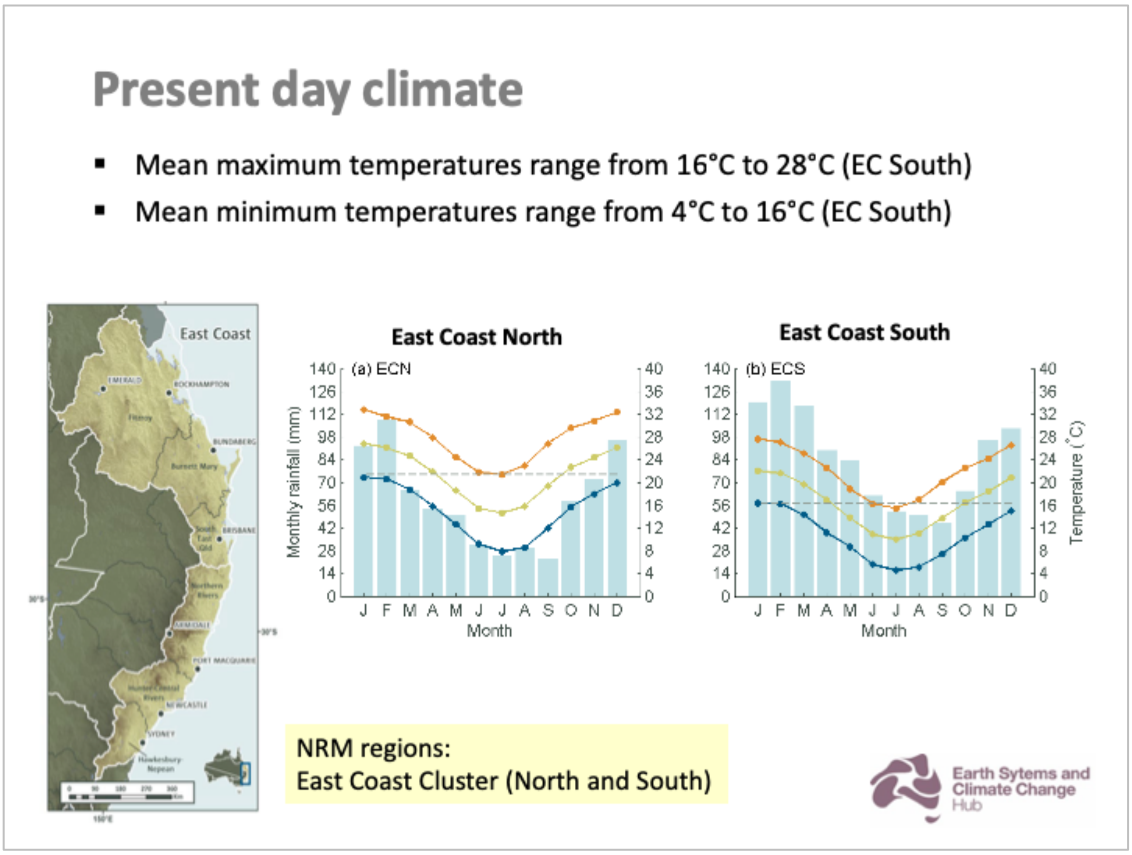
[8] http://www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.shtml?bookmark=enso
[9] https://www.metoffice.gov.uk/videos/5580792782001

Present day climate of the Gondwana Rainforests WHA region



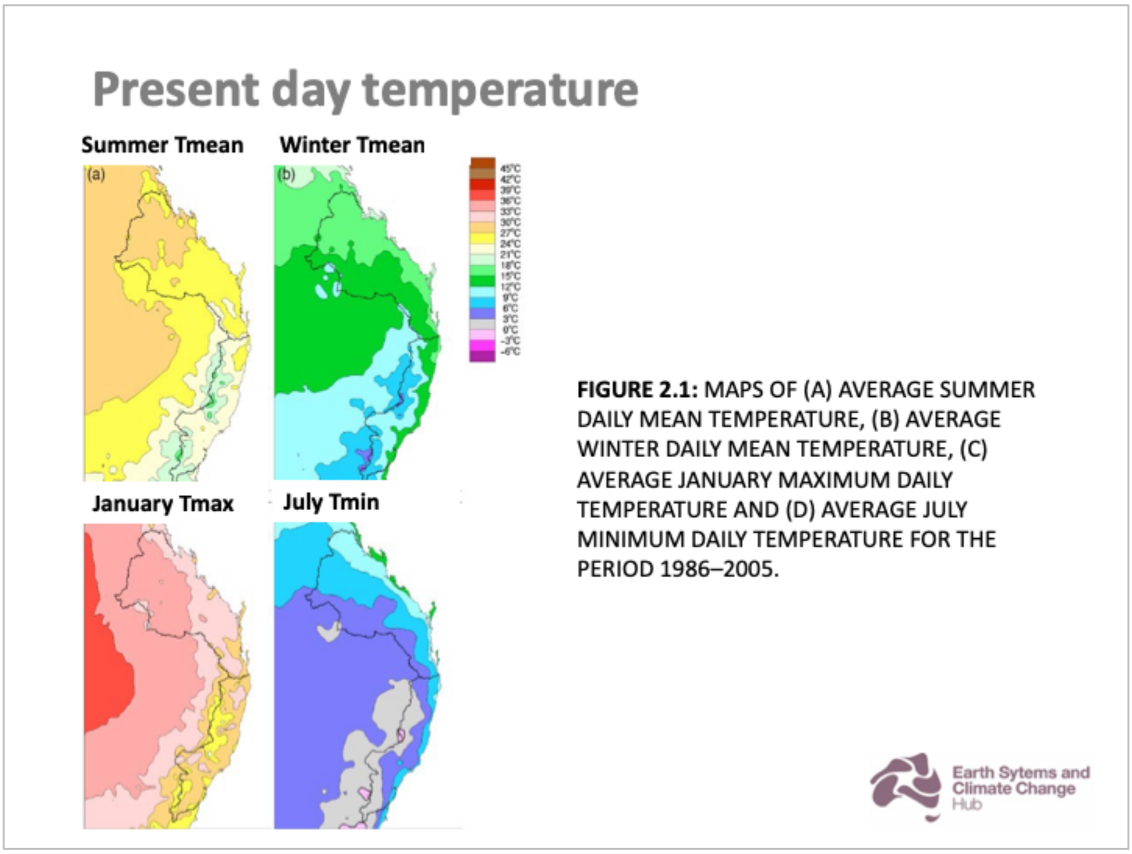


FIGURE 2.1: MAPS OF (A) AVERAGE SUMMER DAILY MEAN TEMPERATURE, (B) AVERAGE WINTER DAILY MEAN TEMPERATURE, (C) AVERAGE JANUARY MAXIMUM DAILY TEMPERATURE AND (D) AVERAGE JULY MINIMUM DAILY TEMPERATURE FOR THE PERIOD 1986–2005.

Present day rainfall

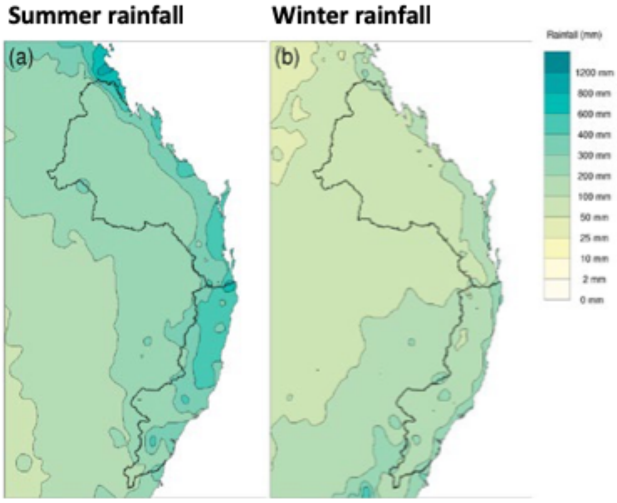


FIGURE 2.3: FOR THE 1986–2005 PERIOD, AVERAGE RAINFALL FOR (A) SUMMER (DECEMBER, JANUARY AND FEBRUARY) AND (B) WINTER (JUNE, JULY AND AUGUST)

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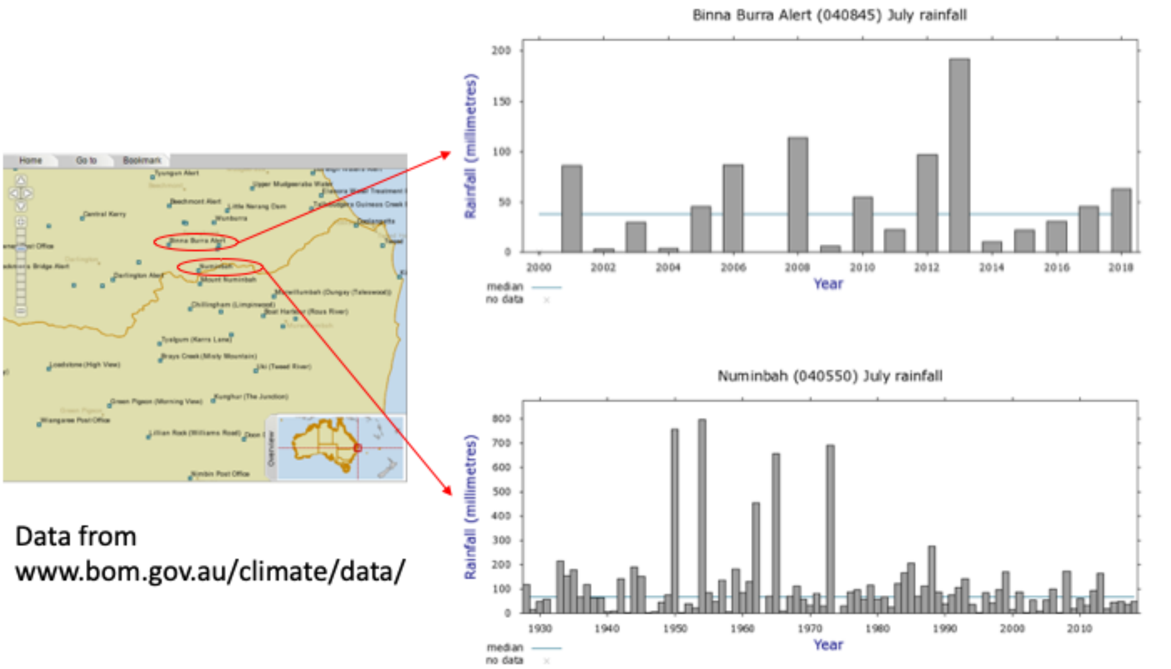
Winter rainfall is highly variable



Data from
www.bom.gov.au/climate/data/

Climate Data Online, Bureau of Meteorology
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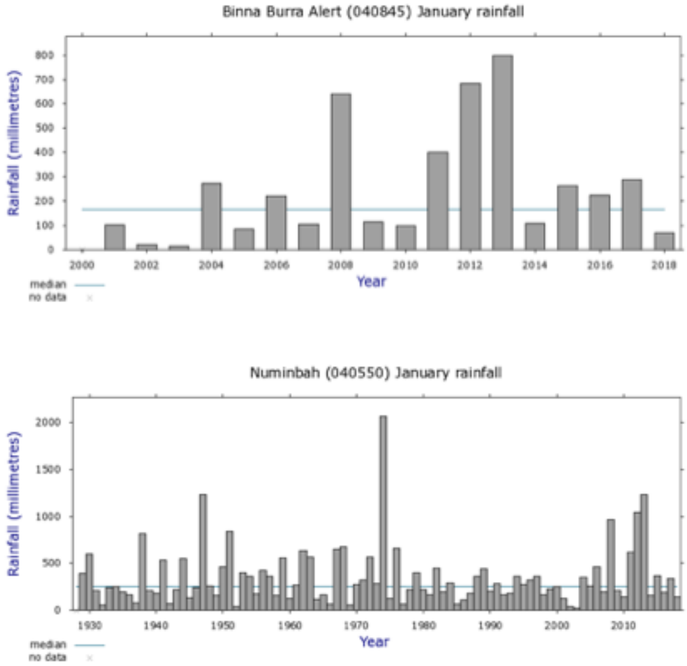
Summer rainfall is also highly variable

Data from
www.bom.gov.au/climate/data/



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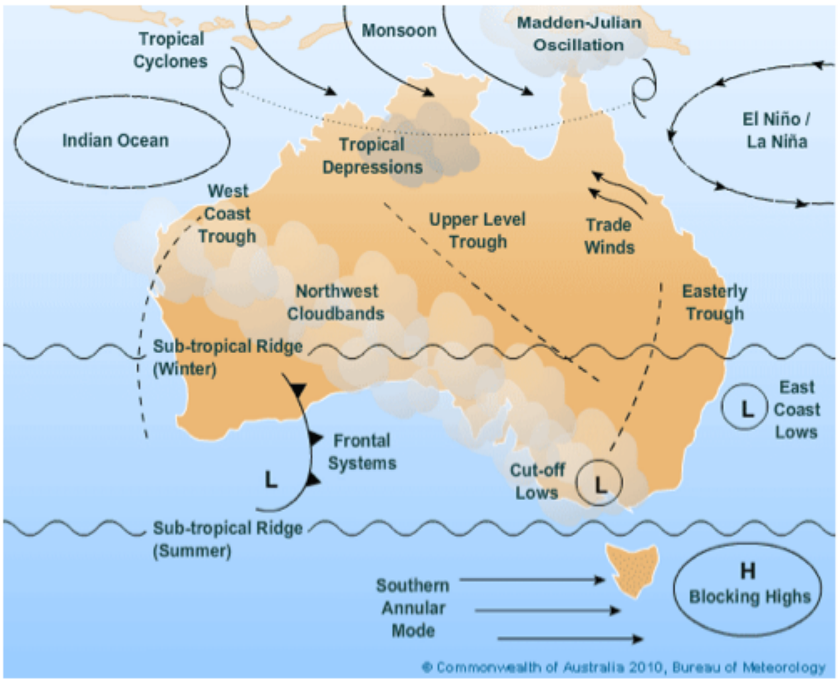
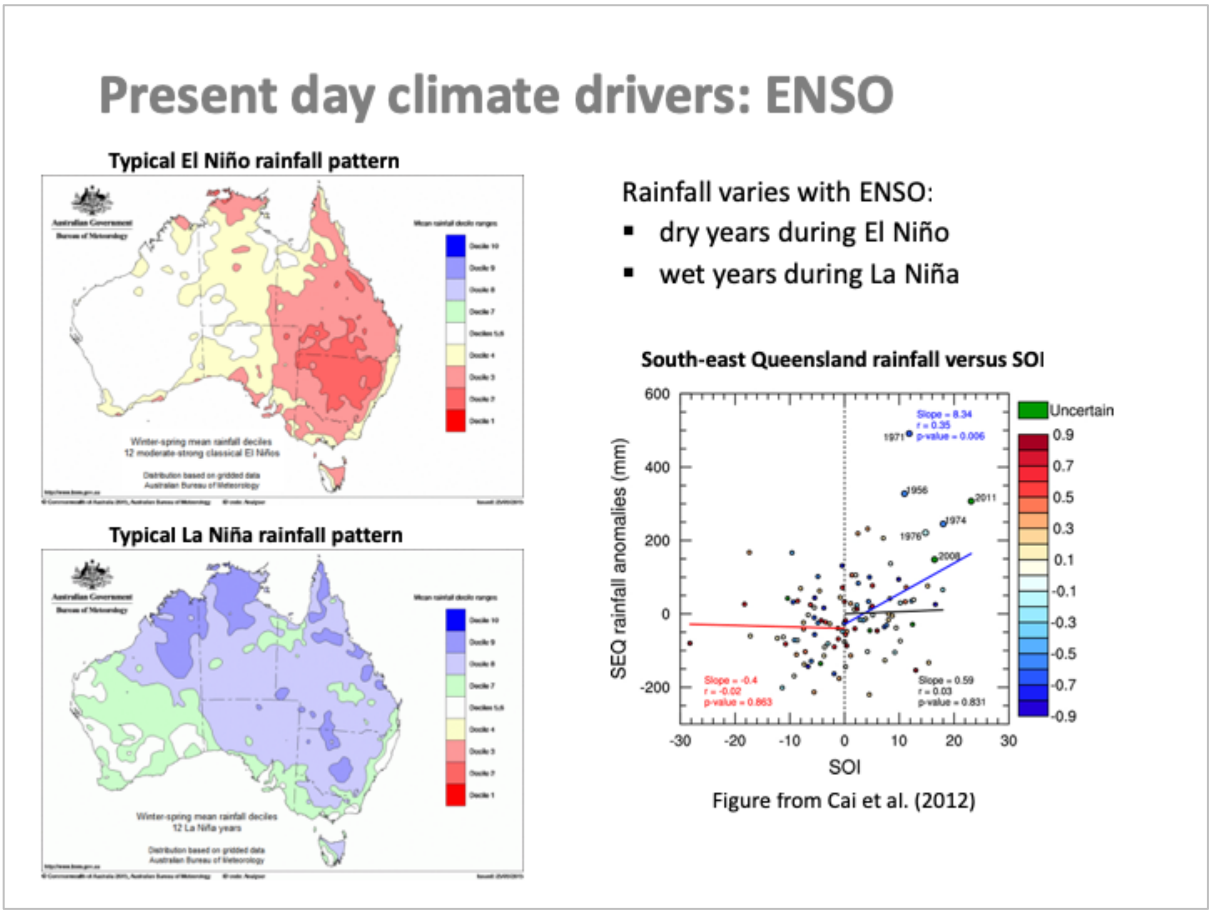
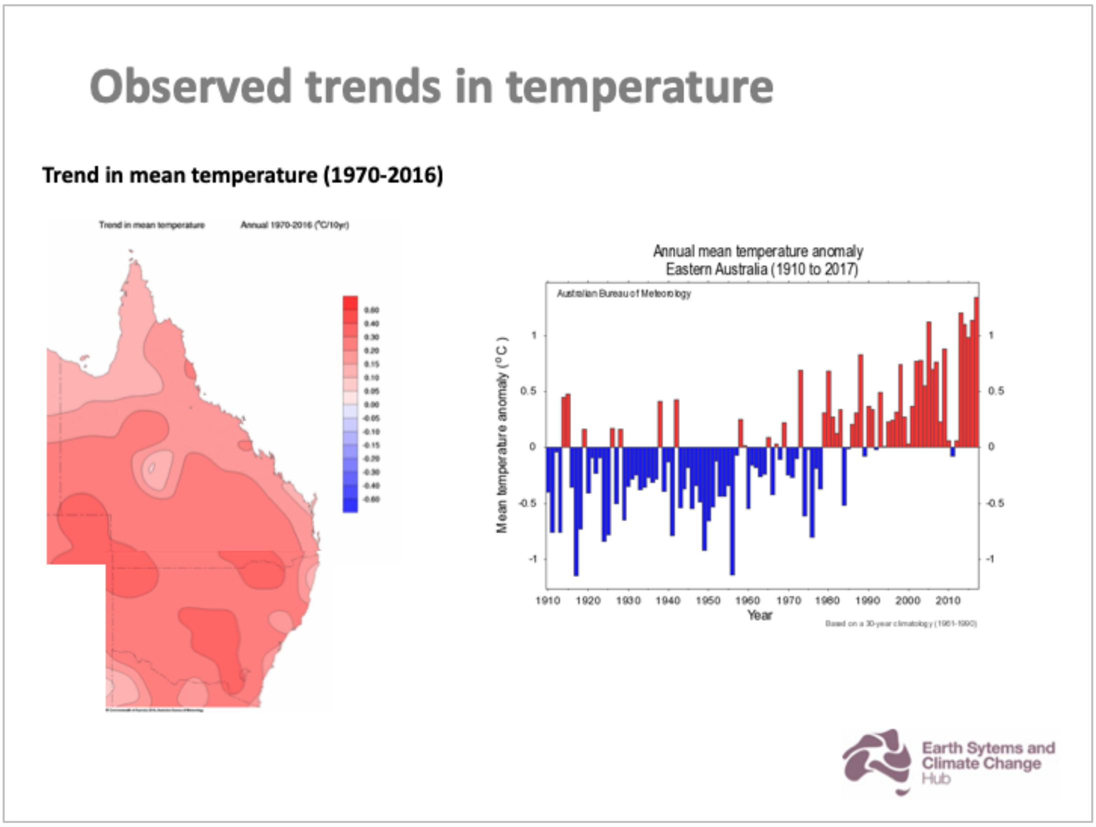
Present day climate drivers

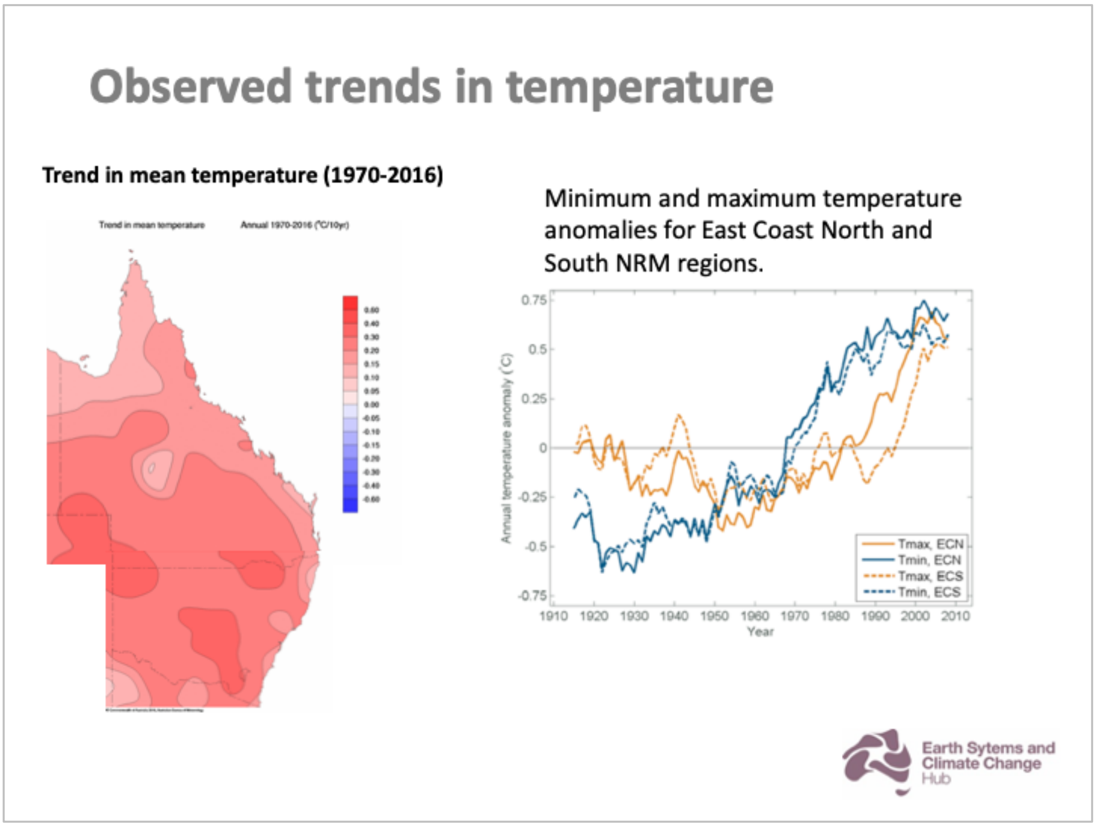



Present day climate drivers: ENSO
Typical El Niño rainfall pattern
Winter-spring mean rainfall deciles
12 moderate-strong classical El Niños
Typical La Niña rainfall pattern
Winter-spring mean rainfall deciles
12 La Niña years
Rainfall varies with ENSO:
dry years during El Niño
wet years during La Niña
South-east Queensland rainfall versus SOI
SEQ rainfall anomalies (mm)
SOI
Uncertain
Slope = 8.34
r = 0.35
p-value = 0.006
Slope = -0.4
r = -0.02
p-value = 0.863
Slope = 0.59
r = 0.03
p-value = 0.831
Figure from Cai et al. (2012)

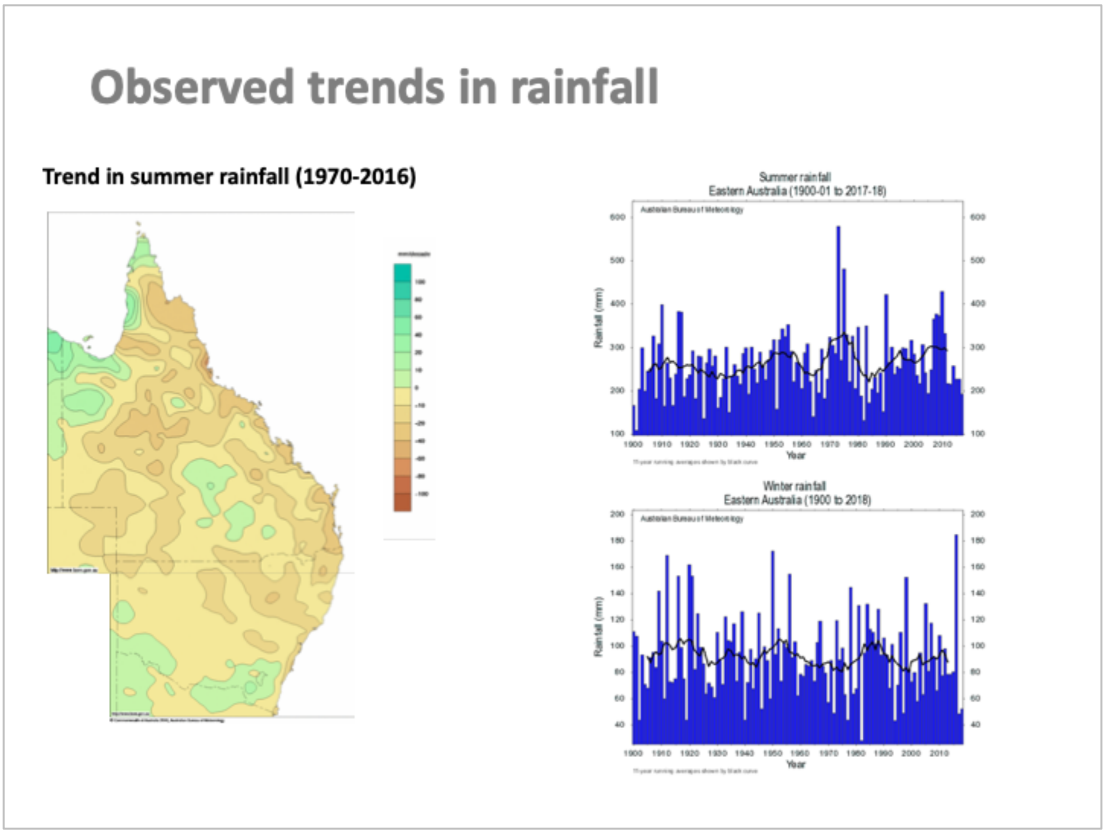
Observed climate trends

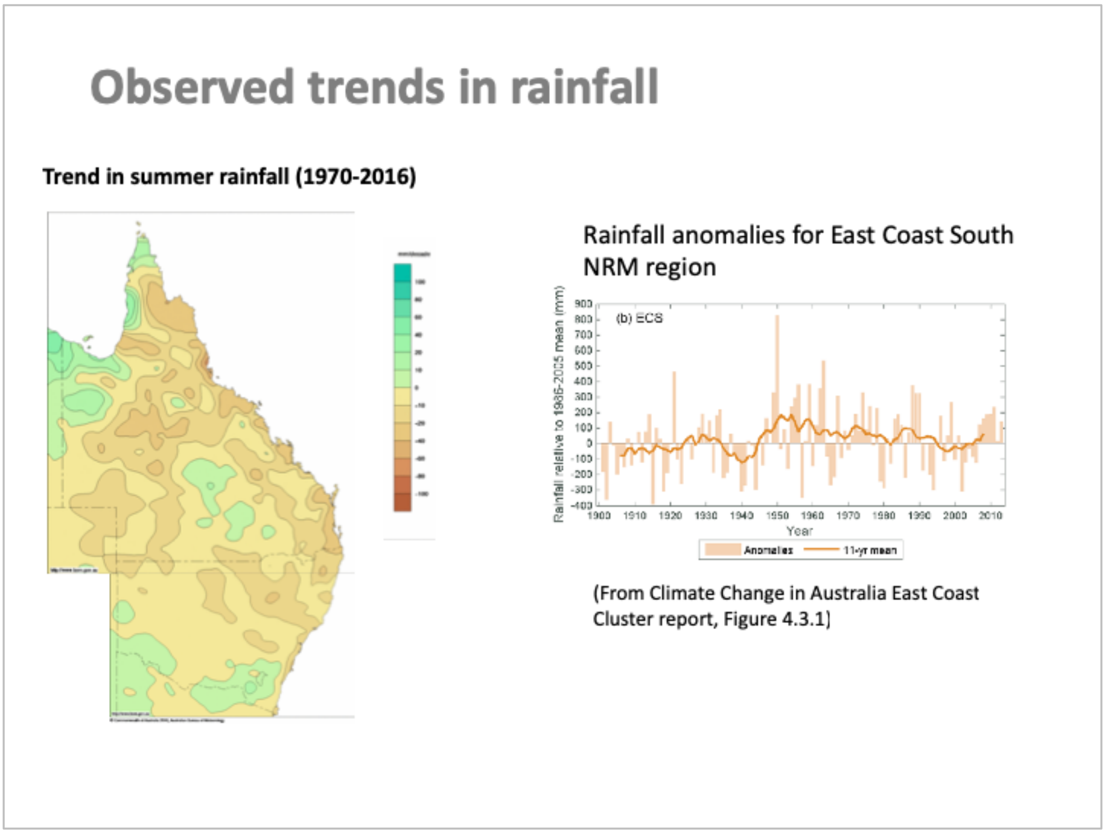
Temperature



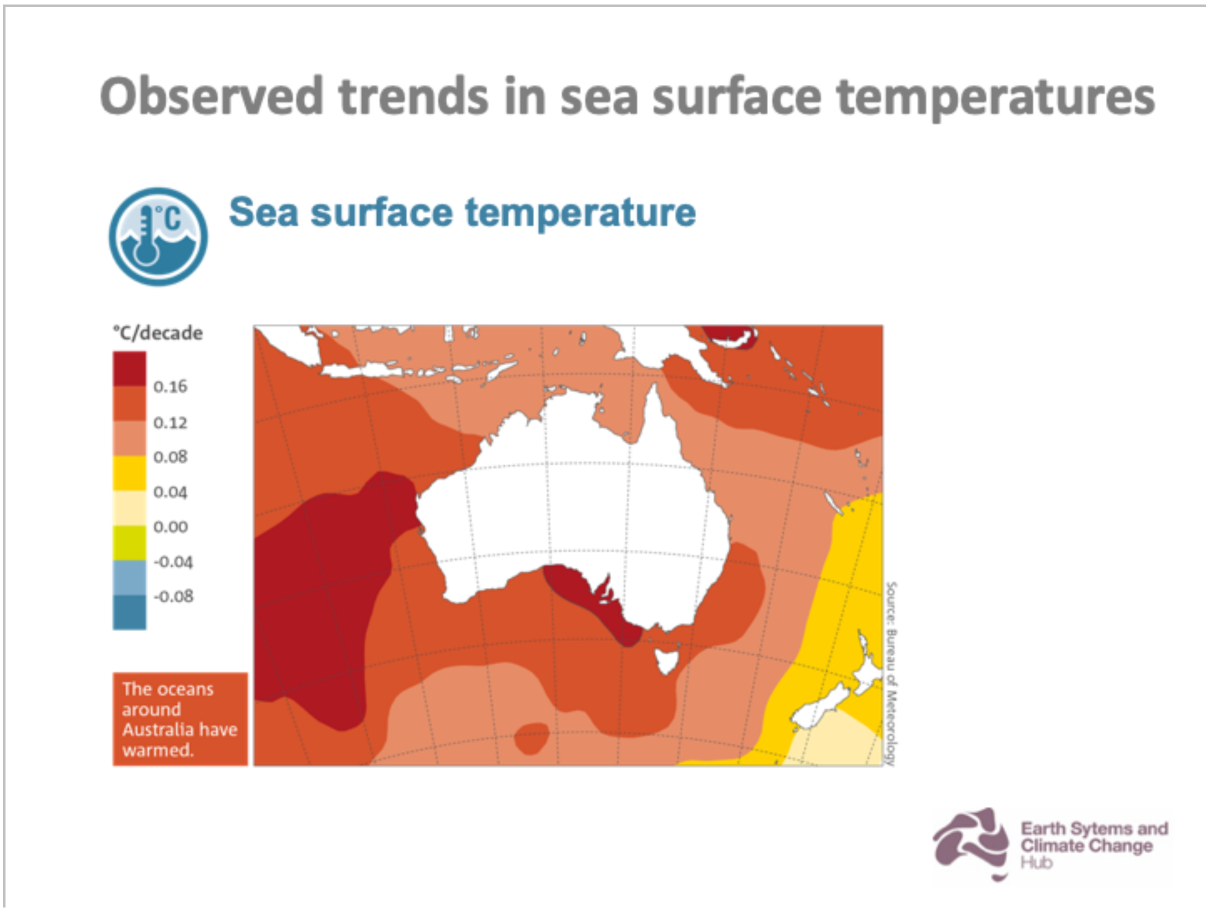


Rainfall


Observed trends in rainfall
Trend in summer rainfall (1970-2016)
Summer rainfall
Eastern Australia (1900-01 to 2017-18)
Rainfall (mm)
Year
Winter rainfall
Eastern Australia (1900 to 2018)
Rainfall (mm)
Year


Observed trends in rainfall
Trend in summer rainfall (1970-2016)
Rainfall anomalies for East Coast South NRM region
(b) ECS
Rainfall relative to 1986-2005 mean (mm)
Year
Anomalies
11-yr mean
(From Climate Change in Australia East Coast Cluster report, Figure 4.3.1)

Sea surface temperature



Climate change projections

With the past no longer being a good indicator of what we can expect in the future, climate projections are useful tools for planning ahead. Climate projections are developed using global climate models, which simulate the future climate based on emissions scenarios (see *Representing emissions*, next page). They can be from an individual model, or the mean of many models (known as the multi-model mean). Projections are typically presented as averages over 20-year periods. For convenience they are referred to by the central year in the period, so projections for 2070 actually cover 2060–2079. Projections are relative to a baseline time period (e.g. 1986–2005), so if a projection was for a 2°C increase in temperature, it is relative to the baseline period and can be presented as the change between the historic and the future (e.g. an increase of 2°C), or change applied to an observational dataset (e.g. mean annual temperature of 30°C).

Climate projections are not predictions. A prediction estimates a sequence of events in the future, including the effect of climate change and variability. Given the timescale and uncertainties (such as emissions concentrations) associated with climate change, predictions are not possible. Instead, we use projections, which tell us about the response of the climate system to a possible future scenario. Climate projections do not tell us the climate of a particular day or month or predict a specific series of events, but rather how the probabilities of climate conditions (including the changing odds of extremes) may change in our changing climate.

Global climate models

Global climate models (GCMs) are mathematical representations of the climate system based on the laws of physics. They take into account interacting processes that shape the global climate, including atmospheric dynamics and physics, oceans and sea ice, land surface processes, and aerosols, and some Earth system models also represent carbon and biogeochemical cycles. The models are very complex and run on powerful supercomputers.

GCMs have been developed in many centres around the world and are continually being improved. A global project – the Coupled Model Intercomparison Project (CMIP) – coordinates experiments and data archiving of climate model simulations. The most recent phase of this project, CMIP5, contains simulations from up to 50 models from 28 modelling centres (including ACCESS, Australia's national climate model).[10]

GCMs are tested for their ability to reproduce past climate, including mean values; seasonal cycle; major processes (e.g. ENSO). The better they are at reproducing the past, the more confidence we have in their simulations of the future.

Representing emissions

GCMs are comprised of various sub-models that interact to predict rates of global warming for different concentrations of greenhouse gases and aerosols. While the laws of physics govern the climate system, they cannot tell us about social, political and economic aspects of the future, which will have a bearing on emissions. Instead, the science community defined a set of four future scenarios called representative concentration pathways (RCPs) that represent a range of economic, technological, demographic, policy and institutional futures (Table 1).

Table 1. Summary of representative concentration pathways (RCPs)

	At the end of the century (2100)		
RCP	**CO_2 concentration***	**Radiative forcing****	**Warming*****
2.6 (low emissions)	420 ppm	2.6 W m^{-2}	0.3°C to 1.7°C
4.5	540 ppm	4.5 W m^{-2}	1.1°C to 2.6°C
6.0	660 ppm	6.0 W m^{-2}	1.4°C to 3.1°C
8.5 (high emissions)	940 ppm	8.5 W m^{-2}	2.6°C to 4.8°C

* 2018 CO_2 concentration is 407 ppm
** Radiative forcing is a measure of the energy absorbed and retained in the lower atmosphere; more forcing = more warming.
*** Global mean surface warming for 2081–2100 relative to 1986–2005.

10 https://pcmdi.llnl.gov/mips/cmip5/availability.html

Because of natural variability in the climate and inertia in the climate system, results from the different emissions scenarios are quite similar to 2030 – after this time, the higher the emissions, the more climate change signal is evident by 2100.

It is worth noting that these RCPs were developed prior to the Paris Agreement, so they do not align directly with the Paris targets of 1.5°C and 2.0°C (relative to pre-industrial) by 2100. However, RCP2.6 *could* be regarded as a trajectory that would arrive at around 1.5°C by 2100 – but this change is relative to 1986–2005.

Confidence in projections

Our confidence in climate change projections is determined by considering climate model results along with our physical understanding of the climate system and past observations. Confidence is higher for some projections (e.g. temperature) than others (e.g. rainfall).

It is important to recall that variability will continue, and the temperature or rainfall, say, in a particular year will be a result of climate variability, superimposed on the underlying climate trend (see figure below). In effect this means variability will be sometimes reinforcing and sometime opposing climate change. The internal variability of rainfall changes is particularly large over most Australian regions (including the Gondwana rainforests region) so it may take many years for the climate change 'signal' to emerge clearly from the year to year variability.

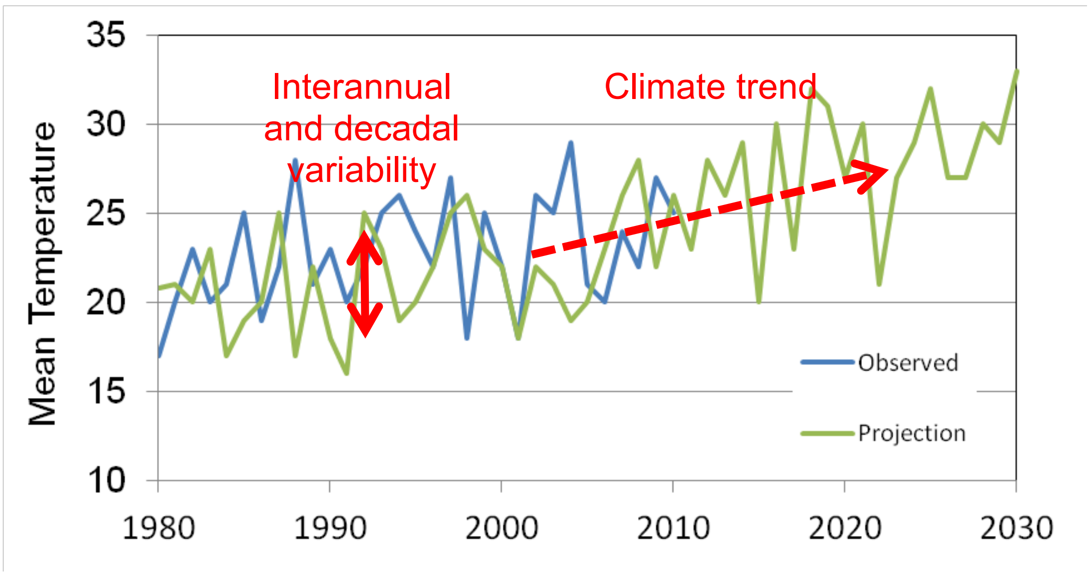
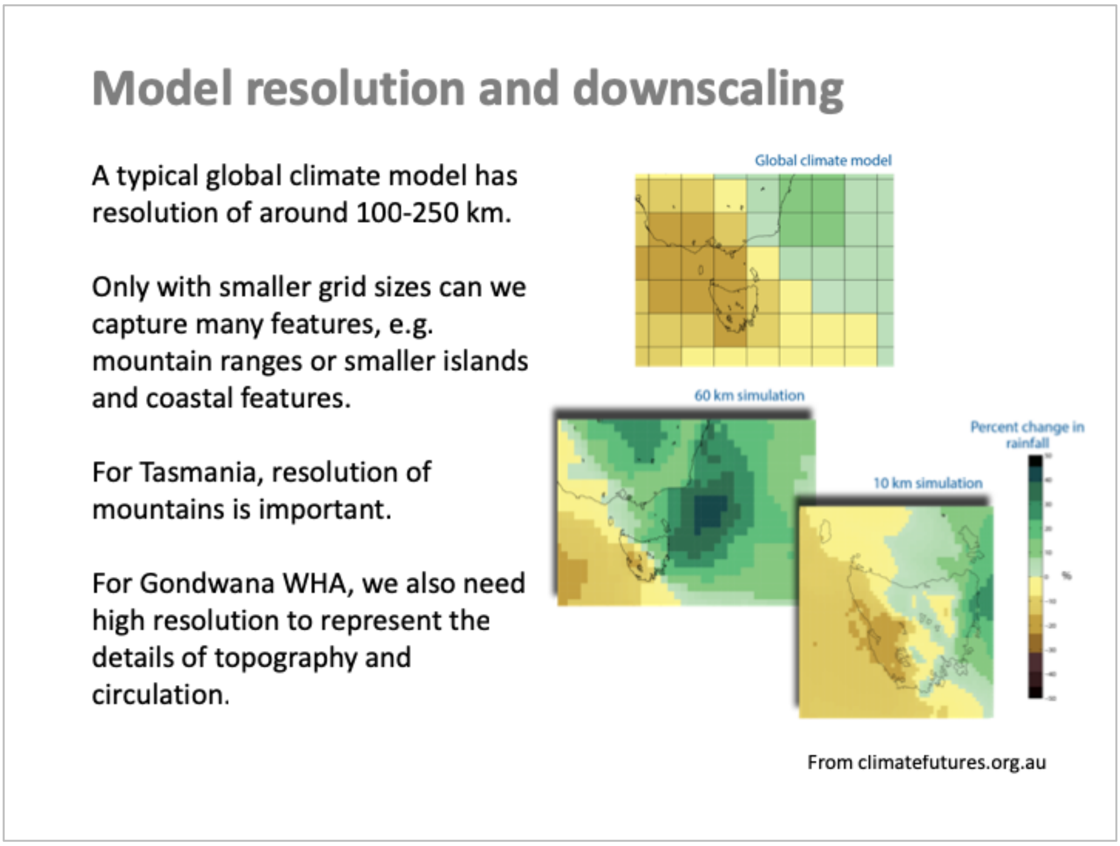


Figure 3. Confidence in climate change projections is based on the direction and size of the long-term trend, not the year-to-year variability.

Model resolution and downscaling



Future climate for Gondwana Rainforests WHA

While we do not know exactly how the future will unfold in the decades out to 2100, we can draw on climate change science to tell us what the future climate might be like.

We can use science-based climate change information to provide the evidence for developing 'climate smart' policies and plans for sectoral adaptation and disaster risk management.

Using the latest climate science and modelling, climate projections can help us plan for a smaller range of options by narrowing down the range of possible future climates.

Australia's national climate change projections

Australia's national climate change projections[11] were developed by CSIRO and the Bureau of Meteorology in 2015 for the Commonwealth Natural Resource Management funded projections project. They are reported on the basis of clusters, which correspond to the broadscale climate and biophysical regions of Australia (Figure 4). The reserves of the Gondwana Rainforests are in the East Coast cluster (both North and South sub-clusters).

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[11] Climate Change in Australia, www.climatechangeinaustralia.gov.au

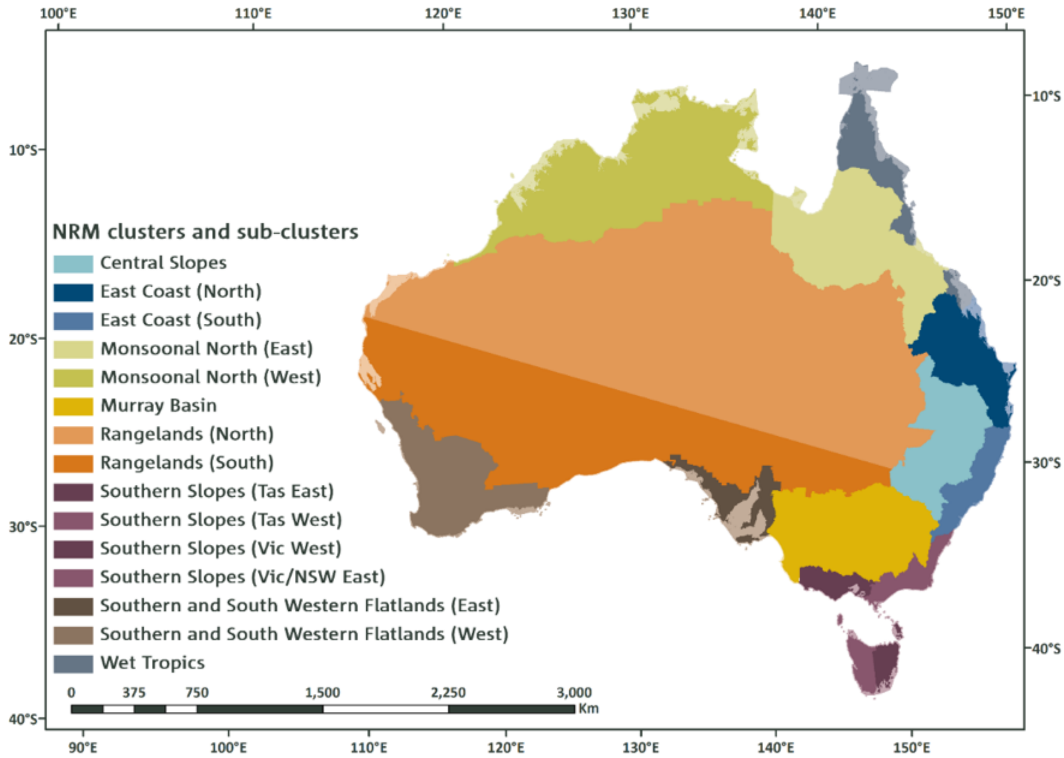
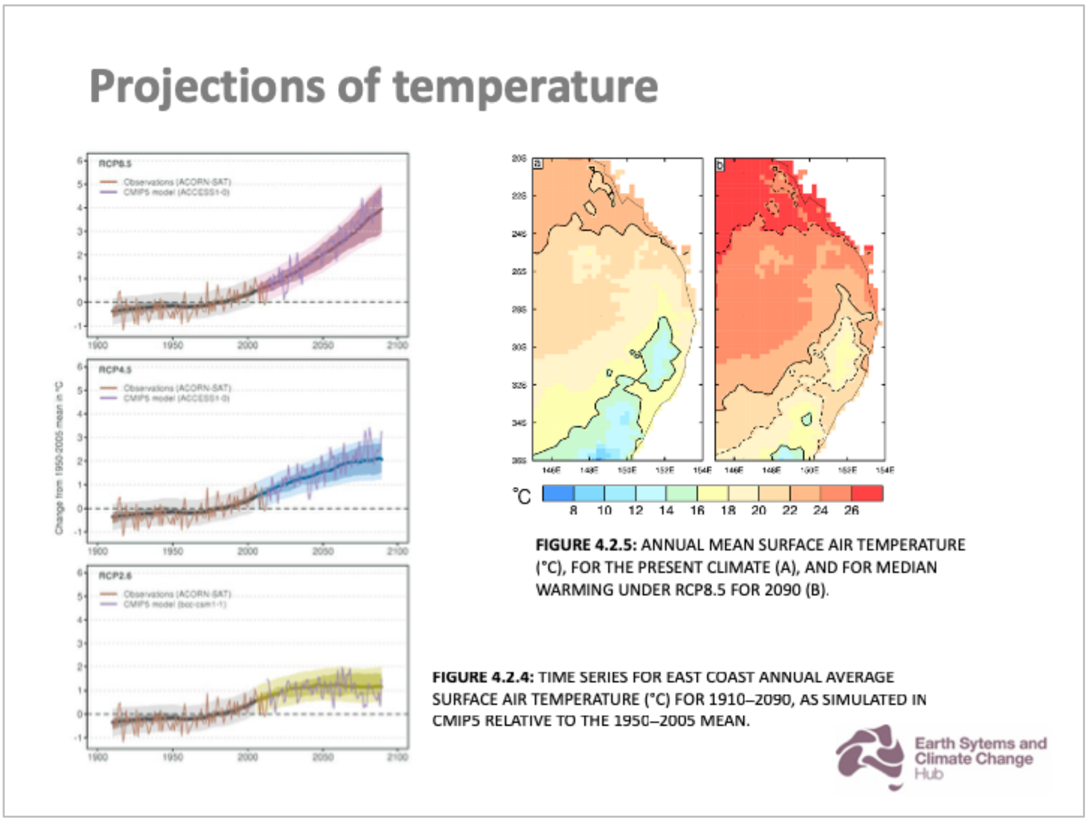


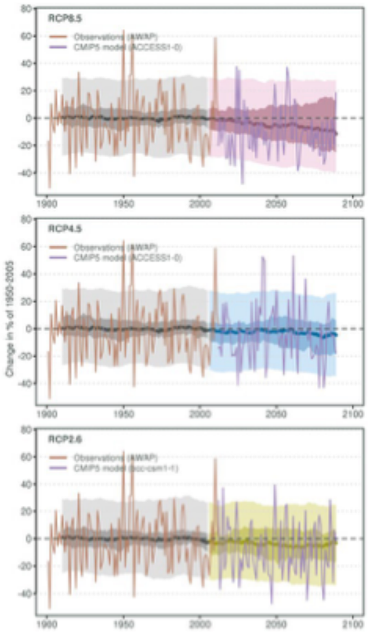
Figure 4. Clusters and sub-clusters used in Climate Change in Australia

Temperature



Rainfall

Projections of rainfall



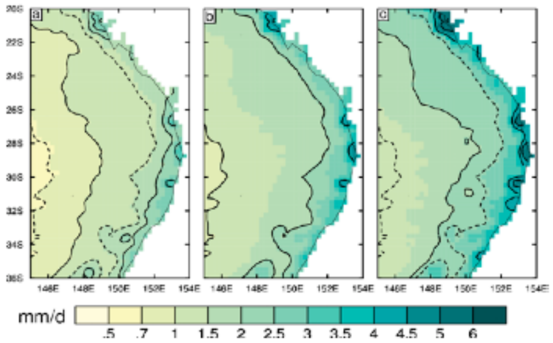


FIGURE 4.3.4: ANNUAL MEAN RAINFALL (MM/DAY), FOR THE PRESENT CLIMATE (B), AND FOR DRIER END OF THE PROJECTED MODEL RANGE (A) AND WETTER END OF THE PROJECTED MODEL RANGE (C).

FIGURE 4.3.3: TIME SERIES FOR EAST COAST ANNUAL RAINFALL FOR 1910–2090, AS SIMULATED IN CMIP5 MODELS, EXPRESSED AS A PERCENTAGE RELATIVE TO THE 1950–2005 MEAN.THE CENTRAL LINE IS THE MEDIAN VALUE, AND THE SHADING IS THE 10TH AND 90TH PERCENTILE RANGE OF 20-YEAR MEANS (INNER) AND SINGLE YEAR VALUES (OUTER).

Projections of rainfall

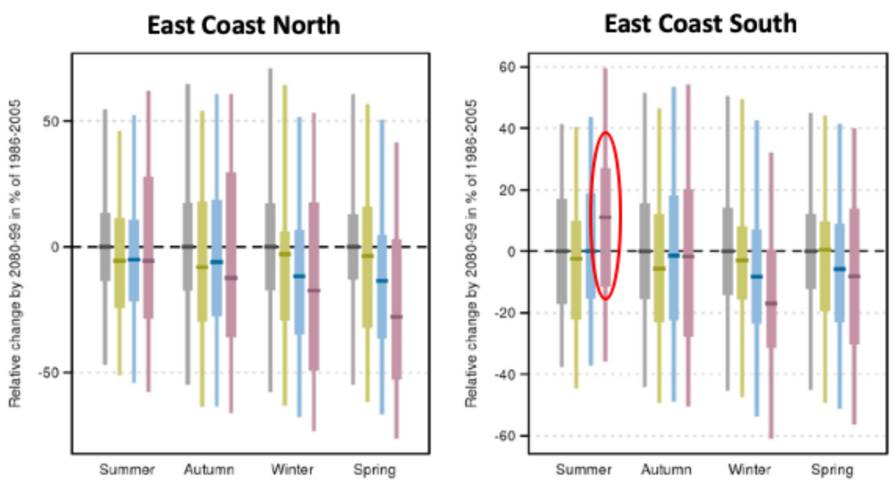


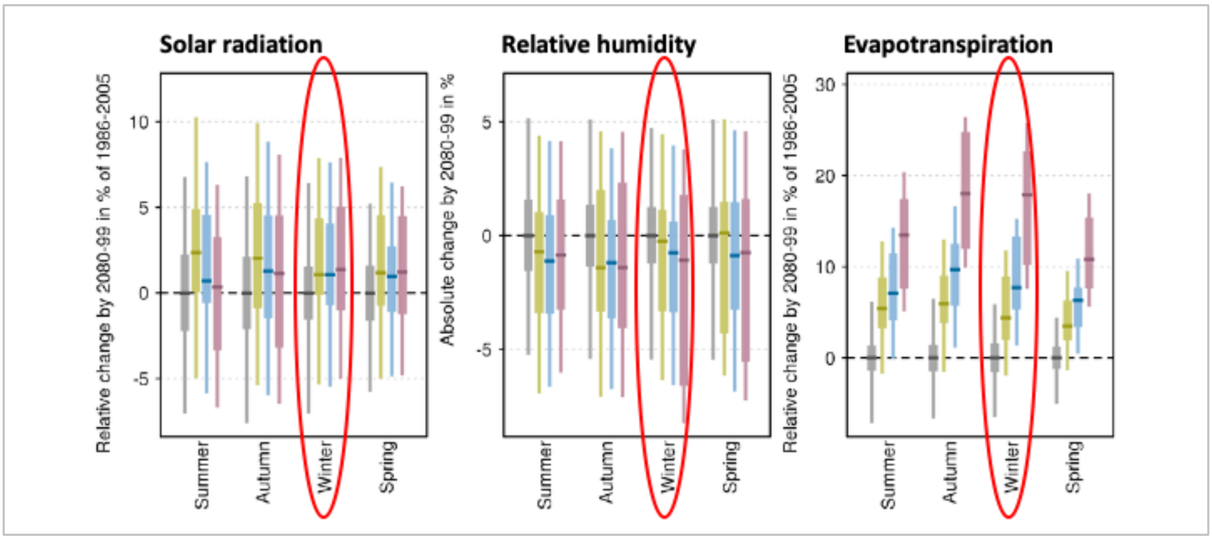
FIGURE 4.3.5: PROJECTED SEASONAL RAINFALL CHANGES. RAINFALL ANOMALIES ARE GIVEN IN PER CENT WITH RESPECT TO THE 1986–2005 MEAN UNDER RCP2.6 (GREEN), RCP4.5 (BLUE) AND RCP8.5 (PURPLE) FOR 2090.NATURAL CLIMATE VARIABILITY IS REPRESENTED BY THE GREY BAR.

Other variables

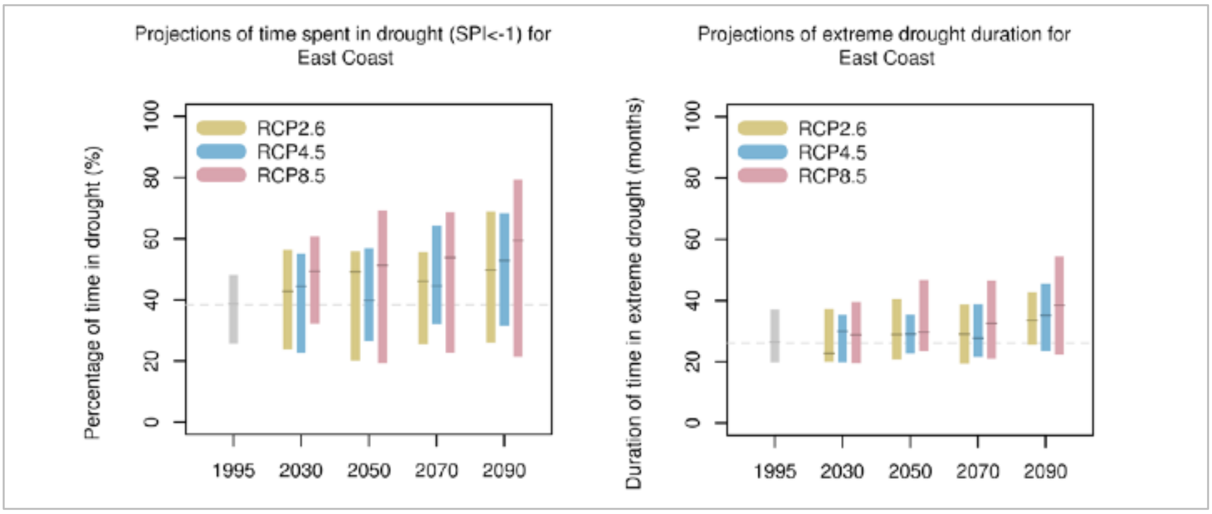
Higher surface **solar radiation** (i.e. decreased overall cloud cover)

Decreased **relative humidity** (although modest in winter)

Higher **evapotranspiration**



Increased frequency of **drought**, and longer drought duration



Climate drivers

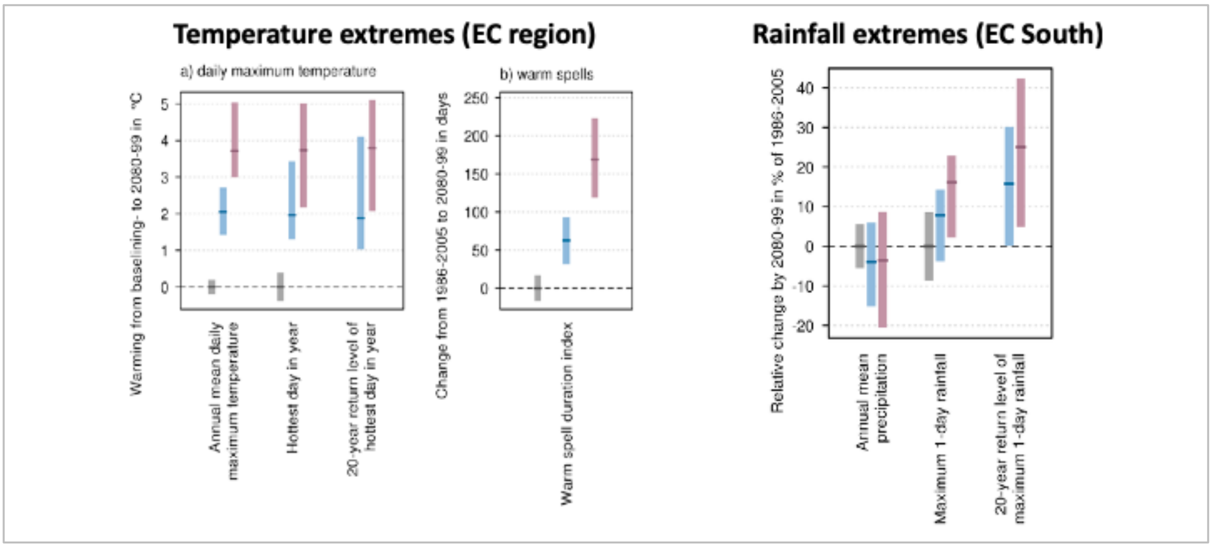
Climate models can be used to investigate how climate drivers will change in future.

Monsoons: models generally agree that rainfall variability will increase across a broad range of timescales (from daily to interannual).

Extremes

Models agree on an increase in **temperature** of the hottest days, the frequency of hot days and warm spell duration.

Heavy **rainfall** events will become more intense (even with reduction in annual mean rainfall).



Tropical cyclones are projected to occur less often, but with a greater proportion of high intensity storms (stronger winds and greater rainfall).

East coast lows are projected to occur less often but potentially be more intense when they do occur.[12]

Winter mid latitude storm systems will shift southward (hence fewer winter storms affecting the East Coast region).

Clouds

Observations and trends

Surface observer stations (Figure 5) have estimated cloud in 'octas' for many decades but:

- Station network is sparse (and the stations are some distance from the various Gondwana Rainforests reserves)
- Coverage estimate has a subjective component
- Record is incomplete
- Separate altitudinal data (high/mid/low) is not generally available.

[12] Dowdy AJ, Mills GA, Timbal B, Wang Y (2014) Fewer large waves projected for eastern Australia due to decreasing storminess. *Nature Climate Change*, 4, 283–286.

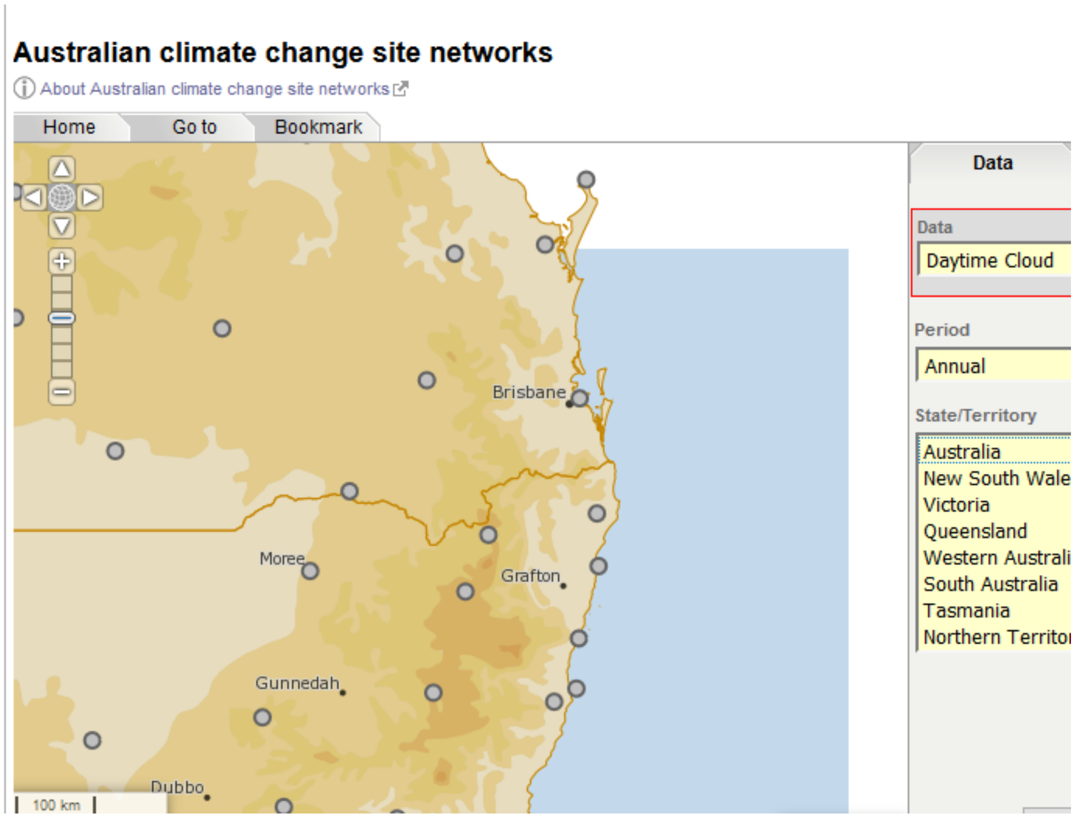


Figure 5. Surface observer stations

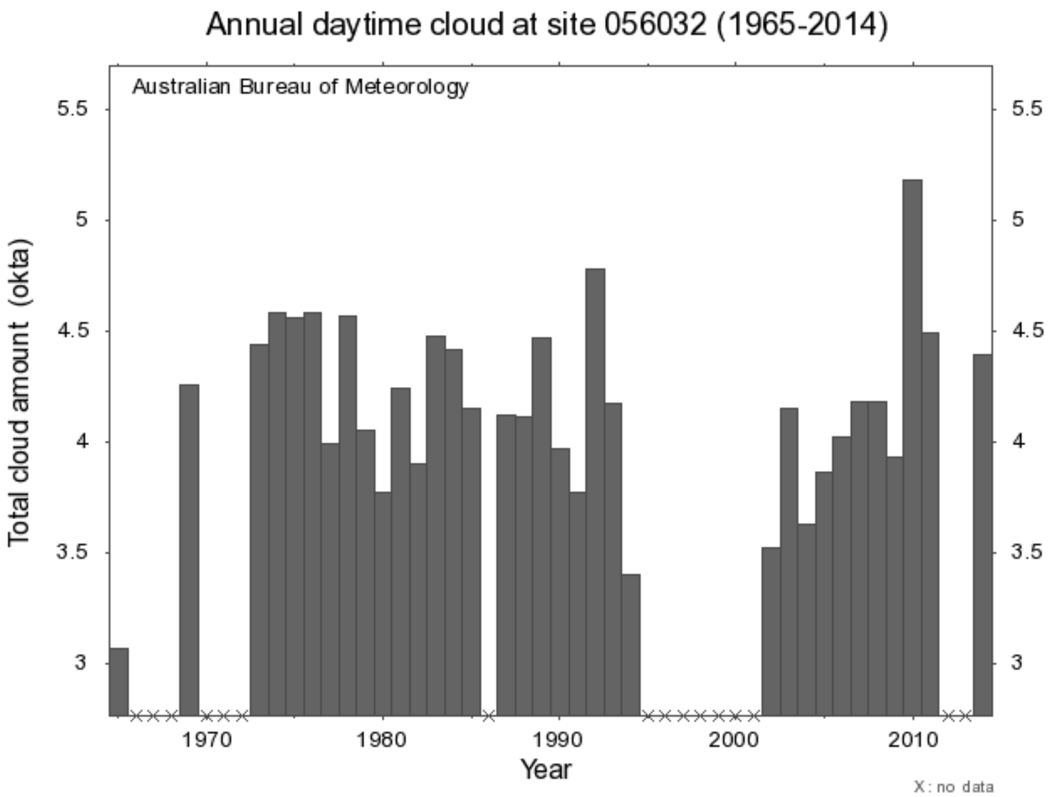


Figure 6. Annual daytime cloud at Tenterfield for the period 1965–2014.

Satellite observations also available but:

- the record is relatively short (since ~mid-1980s)
- the satellite record has issues of drifts in calibration, changes in satellites, orbital drifts, day/night
- low clouds can be obscured by higher-level clouds.

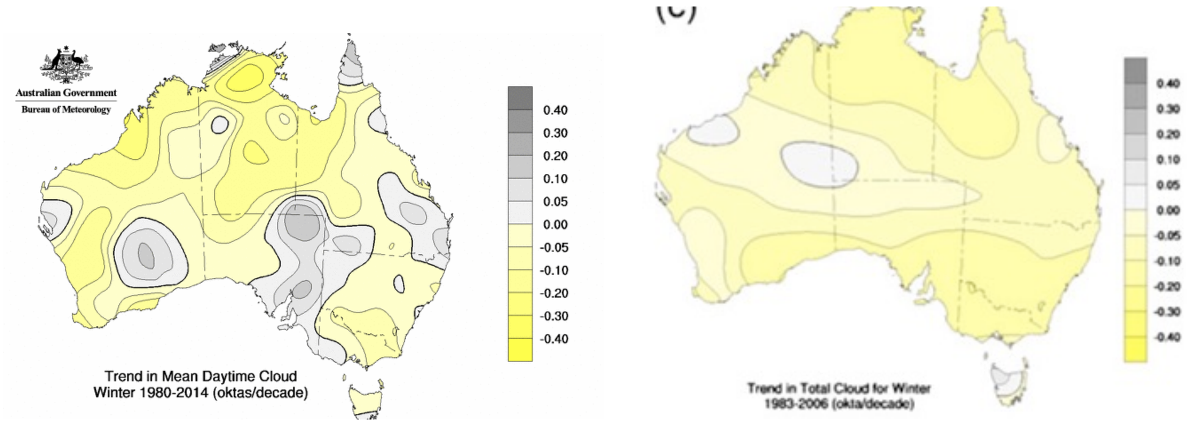


Figure 7. Cloud trends based on surface observations (left) and satellites (right)

Cloud caps

Cloud caps are caused by moist air lifting over mountains. The cloud base forms around height of lifting condensation level (LCL). Low cloud is also caused by other processes (e.g. boundary layer mixing), some of which is poorly understood.

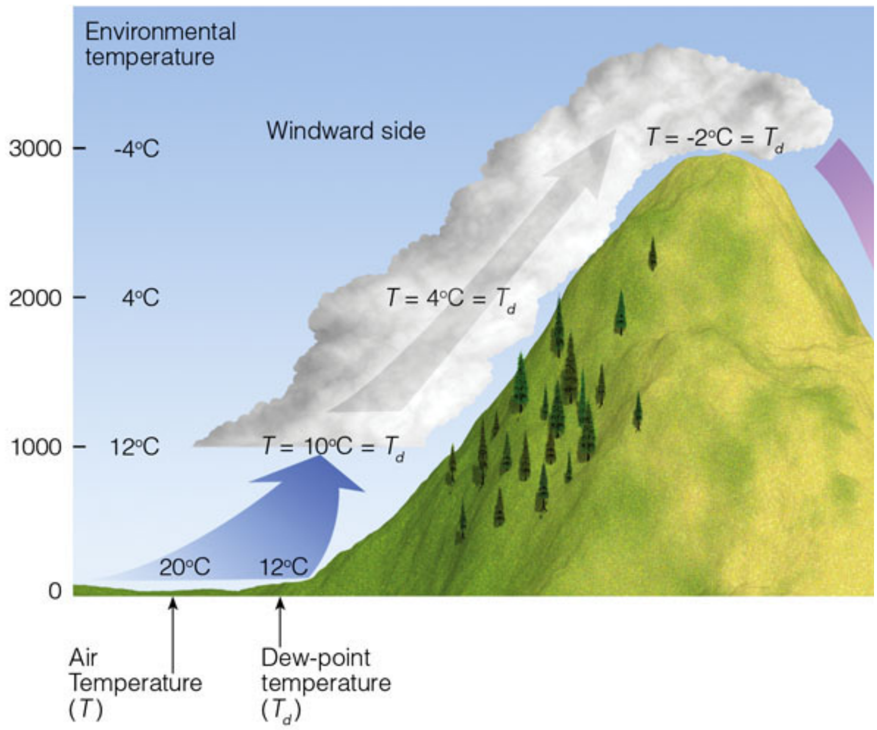


Figure 8. Cloud cap formation

Low cloud projections

Clouds are one of the key uncertainties in climate model simulations and projections. Low cloud projections in particular contain significant uncertainties because:

- clouds are not explicitly represented ('resolved') in climate models as they are too small to be 'seen' by the grid (~100 km across) – this means they must be represented indirectly from large scale temperature, moisture and wind fields ('parametrisations')
- mountain ranges such as the Great Dividing Range are also only coarsely represented in global models (as the mountains are too low and broad)
- cloud formation processes are still not well understood (observations are difficult, and clouds vary in complex ways on small scales).

This makes it difficult to configure parametrisations in the first place, and to then evaluate them. We have more trust in:

- large-scale processes in models, like 'synoptic' scale circulations (e.g. monsoon circulations, trade winds, mid-latitude highs and lows, locations of high and low pressure, regions of large-scale convergence)
- processes driven by physics that is well understood (e.g. increased water holding capacity of warmer air, land/sea surface differences, energy constraints on the system)
- changes where the various models show strong agreement (i.e. despite their different formulations and parametrisations) – this includes some broad scale cloud changes.

→ Cloud changes *partially* fall into these categories.

What do projections suggest for low cloud changes?

Models generally indicate:

- reduced low clouds in the tropics and subtropics – although very widely found, this is still not well understood as no single process dominates changes in cloud formation → *confidence only limited*
- reduced relative humidity over land – due to land warming faster than oceans. This is universally found in models and relatively well understood → *confidence high, but regional details will matter, e.g. close to the coast the effect is smaller as it warms less than inland.*

→ This suggests decreases in low cloud fraction, and increased cloud base height.

Some additional factors

Will the clouds that do form have higher moisture content as the air is warmer?

Intuitively yes, but the evidence from models and observations is mixed, suggesting this may not be a strong effect

Will wind strength changes occur, and will this impact on clouds?

A general slowing of tropical/sub-tropical circulations is expected. However, the impact on cloud caps is unknown

What about local effects such as sea-breezes, local circulations, etc?

These are not 'resolved' by climate models, so high resolution modelling (downscaling) is needed. There is currently relatively little information on this

What will happen to ENSO and its effects on the region?

Not certain. We know ENSO will continue, but changes to its frequency, strength or impacts are less clear. This is the subject of ongoing study.

Will evapotranspiration change?

Yes, evaporative demand increases in a warmer climate, but evaporation also depends on stability, water availability, wind speed and humidity – confidence very high of increase, but projected range varies

Will fire regimes change?

Increased bushfire risk due to higher temperatures and lower rainfall (30% increase in summed FFDI by 2090 under RCP8.5)

Have international climate assessments (e.g. IPCC) considered cloud cap/cloud base changes and their impacts?

Very little. The focus has been on oceanic cloud because of its strong impact on global energy balance.

Climate change information

Climate change information needs for the Gondwana Rainforests WHA

Gaps in the existing projections

- Current projections are not specific to the Gondwana Rainforests WHA (the East Coast North/South clusters are too large and do not cover homogenous climate region)
- Existing downscaled projections disagree on sign of rainfall changes
- Some of the relevant climate variables for changes in Gondwana Rainforests forest conditions are not available e.g. cloud base height, although it may be possible to infer cloud base height from other variables – for example lifting condensation level may be approximated from large scale variables of relative humidity and temperature.

What more could be done?

- (Updated) projections information specific to the Gondwana Rainforests WHA
- Additional specific process-related variables and understanding e.g. relating to LCL, rainfall, cloud cover and cloud base
- Targeted downscaling to provide high resolution projections
- Additional variables could be obtained for e.g. vegetation modelling
- Consider projections in terms of likelihood of crossing certain key thresholds for given emissions scenarios.

Climate information available for impact assessment

Discussions at the workshop made it clear that stakeholders/managers want information about how cloud base height and moisture transport associated with horizontal (occult) rainfall will change in future, as this is crucial to the diversity of flora and fauna in the upland rainforests. Today, there is an important threshold around 700–900 m above sea level associated with the current level of the cloud base.[13]

The ESCC Hub already has some climate projections data that is suitable to explore climate change impacts on the montane rainforests of the World Heritage Area. Additional data and information should be available by the end of 2020, after additional research and evaluation has been undertaken.

[13] Laidlaw MJ, McDonald WJF, Hunter RJ, Putland DA and Kitching RL (2011) The potential impacts of climate change on Australian subtropical rainforest. *Australian Journal of Botany*, 59, 440–449.

Currently available

Projections of seasonal means for air surface temperature and rainfall under a high (RCP8.5) and lower (RCP4.5) emissions scenario for a region covering the Tweed caldera.

This information would be from global climate model data (where grid cells are 200 km across).

Available by December 2020

Lifting condensation level (LCL) projections

LCL is a critical variable for cloud caps and can potentially serve as a proxy for cloud base height. Unlike the temperature and rainfall data, which are 'simply' extracted from datasets, LCL is a derived variable that will require some processing and research.

Cloud cover projections

Cloud cover (i.e. fraction) throughout the vertical column can be extracted directly from global climate models (with some processing to allow for differences in the way different models define cloud levels, and for a smaller number of models than for other fields). There are limitations on the confidence in representing clouds in models, and the processes determining low clouds are different in GCMs from the 'lifted parcel' cloud caps that occur in the real world are critical in the Gondwana Rainforests. This is because GCMs do not represent the mountains of the Great Divide well, and cloud processes contain uncertainties and approximations. Nevertheless, it may be worth examining the cloud changes in the bottom layers (e.g. 1000 hPa to 850 hPa layer) of the models, to at least (i) quantify what the GCMs project and (ii) determine the consistency with other fields. Preliminary work suggests that on average the GCMs project a decrease in cloudiness in the lower layers. More research is needed to deliver these, and climate models need to be evaluated.

Downscaled projections

Downscaled data allows for projections across smaller grid cells (i.e. higher resolution) and also has the potential to reveal regional details, such as the effects of mountain ranges. However, downscaled projections require more resources (computer and human) to produce than projections using GCM data. Downscaled data for the region of interest is available, but it is yet to be fully assessed and evaluated.

Next steps

ESCC Hub case study

In February 2019 the Hub met with representatives from the managing agencies for the Gondwana Rainforests WHA to determine the scope for ongoing collaboration between the Hub and the Gondwana Rainforests WHA managers.

The needs of the Gondwana Rainforests WHA were discussed in light of the available data, and it was decided there was value in carrying out a case study to assess the impact of climate change on cloud caps and cloud forests in the Gondwana Rainforests WHA. At this meeting it was noted that cloud projections generated in the case study would also be of benefit to the agriculture sector on the tablelands along the length of the eastern seaboard.

The case study will focus on the region covered by the Border Ranges Rainforest Biodiversity Management Plan. The Hub will provide projections for temperature, rainfall and LCL for 2030 (2020–2039)[14], 2050 (2040–2059) and 2070 (2060–2079) under high (RCP8.5) and lower (RCP4.5) emissions scenarios.

Dry season moisture stress is another variable of interest to the Gondwana Rainforests WHA. Projections for this variable may fall outside the scope of this case study.

Adaptation planning

The Gondwana Rainforests Management Committee will continue to investigate adaptation planning for the World Heritage area within their jurisdictions. Opportunities to coordinate and share information and learnings between jurisdictions will be investigated and optimised. Input and advice from the Gondwana Rainforests advisory committees shall be sought as projects and programs are developed, including identifying knowledge gaps along the way.

[14] Noting that current values-based planning for reserves is on a 5–10-year time horizon.

Appendix 1: Workshop agenda

AGENDA

Monday, 8 October 2018

University of Queensland
Global Change Institute, Level 2, Building 20, Staff House Rd
St Lucia, QLD 4067

Item	Description	Responsible	Time (mins)	Start
1.	Welcome: Introductions	Chair: Mandy Hopkins Roundtable	30	09.30
2.	QLD Government – Climate Change	Moira Rice	30	10.00
3.	Overview of the Gondwana Rainforests of Australia World Heritage area and the outstanding universal values	Tricia Waters	30	10.30
	Morning tea break		30	11.00
4.	The potential impacts of climate change on Australian subtropical rainforest	Melinda Laidlaw	30	11.30
5.	Title to be confirmed	Andrew Baker/Di Fisher TBC	30	12.00
6.	Title to be confirmed	Ian Gynther TBC	30	12.30
	Lunch		30	13.00
7.	Climate Change in the region and the outcomes of the literature review	Jo Brown – ESCC Hub	30	13.30
8.	Downscaled projection data	Jozef Sytkus	30	14.00
9.	Discussion and next steps for the case study	Led by Rob Colman and Jo Brown	90	14.30
	Working afternoon tea – get up stretch get a coffee			15.00
10.	Meeting close			16.00

Appendix 2: Workshop participants

NAME	ORGANISATION	EXPERTISE
Dr Rob Colman	NESP ESCC Bureau of Meteorology	Climate Scientist
Dr Jo Brown	NESP ESCC Bureau of Meteorology	Climate Scientist
Ms Mandy Hopkins	NESP ESCC CSIRO	Knowledge Broker
Mr John Clarke	NESP ESCC CSIRO	Team Leader – Regional Projections
Ms Tricia Waters	Gondwana Rainforests of Australia World Heritage Area	Executive officer
Dr Melinda Laidlaw	Queensland Herbarium	Senior Ecologist
Dr Di Fisher	University of Queensland	
Dr Jozef Syktus	University of Queensland	Regional Projections
Dr Ralph Trancoso	University of Queensland	Regional Projections
Dr Michael Mahoney		
Dr Bill MacDonald		
Dr Ian Gynther		

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