MONSOONAL NORTH

CLIMATE CHANGE IN AUSTRALIA

PROJECTIONS FOR AUSTRALIA´S NRM REGIONS

CSIRO

Australian Government
Department of the Environment
Bureau of Meteorology

-20° -10° 0° 10° 20° 30° 40° 50°

CLIMATE CHANGE IN THE MONSOONAL NORTH

THE INTERNATIONAL SCIENTIFIC COMMUNITY ACCEPTS THAT INCREASES IN GREENHOUSE GASES DUE TO HUMAN ACTIVITIES HAVE BEEN THE DOMINANT CAUSE OF OBSERVED WARMING SINCE THE MID-20TH CENTURY. CONTINUED EMISSIONS OF GREENHOUSE GASES WILL CAUSE FURTHER WARMING AND CHANGES IN ALL COMPONENTS OF THE CLIMATE SYSTEM.

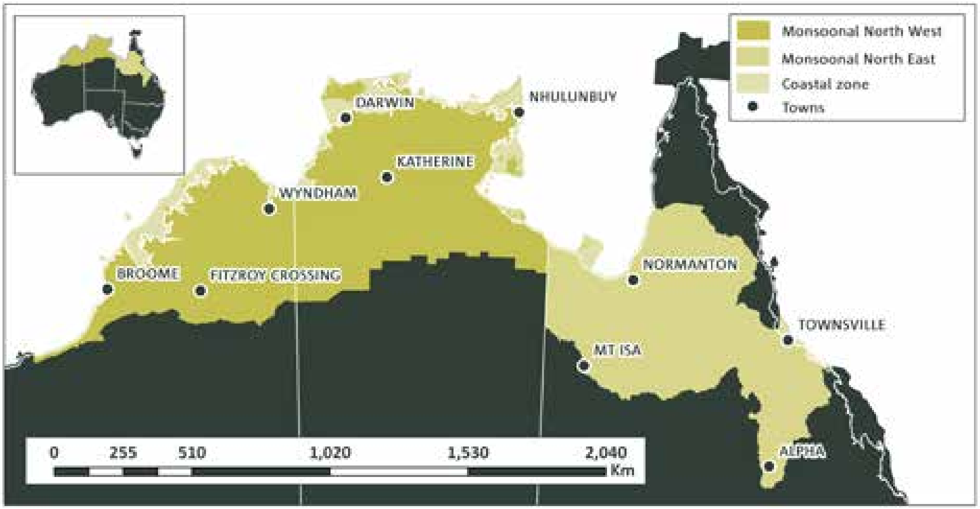
Australia's changing climate represents a significant challenge to individuals, communities, governments, businesses and the environment. Australia has already experienced increases in average temperatures over the past 60 years, with more frequent hot weather, fewer cold days, shifting rainfall patterns, and rising sea levels.

To assist the planning and management of Natural Resource Management (NRM) regions, CSIRO and the Australian Bureau of Meteorology have prepared climate change projections for eight regions of Australia, termed NRM clusters.

This brochure is for the Monsoonal North cluster (Figure 1), comprising NRM regions in Western Australia, Northern Territory and Queensland, commonly known as the tropical 'top end'. This region experiences a pronounced wet and dry season, with differences in the timing between eastern and western parts. In this project, some analysis and reporting of climate change projections for the Monsoonal North is done for two sub-clusters: Monsoonal North-West (MN West) and Monsoonal North-East (MN East).

MN West covers tropical rainforests, wetlands and arid rangelands of the Northern Territory, and the steep mountain ranges of the Ord and Fitzroy River catchments of the Kimberley. MN East covers relatively intact savannah woodland and important rainforest areas as well as the Mitchell, Gilbert, Norman, Burdekin and Staaten River catchments, all of which flow into the Gulf of Carpentaria (except Burdekin).

FIGURE 1: MAP OF THE MONSOONAL NORTH CLUSTER



CLIMATE CHANGE PROJECTIONS

Projections for the Monsoonal North are based on the outputs of a set of 40 global climate models (GCMs) developed by Australian and international scientists. Climate models are based on established laws of physics and are rigorously tested for their ability to reproduce past climate. These projections draw on the full breadth of available data and peer-reviewed literature to provide a robust assessment of the potential future climate.

Projections for the Monsoonal North are based on four Representative Concentration Pathways (RCPs) underpinned by emission scenarios. More information on climate models and RCPs can be found inside this brochure.

FOR MORE COMPREHENSIVE INFORMATION ABOUT THE MONSOONAL NORTH, READ THE CLUSTER REPORT AVAILABLE ON THE CLIMATE CHANGE IN AUSTRALIA WEBSITE: WWW.CLIMATECHANGEINAUSTRALIA.GOV.AU

PAST TEMPERATURE TRENDS

Temperatures have increased over the past century. Mean temperature increased between 1910 and 2013 by around 0.9 °C. One area of north-west Australia has seen a decrease in mean temperature since 1960 due in part to increases in rainfall and cloudiness. In the eastern sub-cluster daily minimum temperatures have increased more than daily maximums.

TEMPERATURE PROJECTIONS

Average temperatures will continue to increase in all seasons (*very high confidence*).

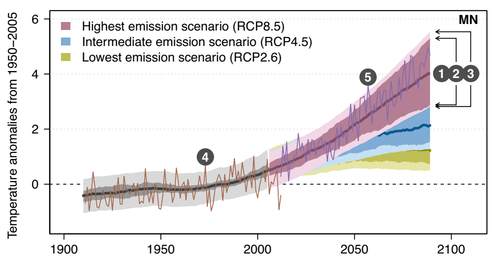
There is *very high confidence* in continued substantial increases in projected mean, maximum and minimum temperatures in line with our understanding of the effect of further increases in greenhouse gas concentrations.

For the near future (2030), the annually averaged warming across all emission scenarios is projected to be around 0.5 to 1.3 °C above the climate of 1986–2005. By late in the century (2090), for a high emission scenario (RCP8.5) the projected range of warming is 2.8 to 5.1 °C (Table 1 and Figure 2). Under an intermediate scenario (RCP4.5) the projected warming is 1.3 to 2.7 °C.

TABLE 1: PROJECTED TEMPERATURE CHANGE (°C), COMPARED TO 1986–2005, FOR 20-YEAR PERIODS (CENTRED ON 2030 AND 2090) AND THREE RCPs. THE MEDIAN PROJECTION ACROSS THE MODELS IS SHOWN, WITH THE 10TH TO 90TH PERCENTILE RANGE OF MODEL RESULTS IN BRACKETS.

	RCP2.6 Low emissions	RCP4.5 Intermediate emissions	RCP8.5 High emissions
2030	0.8 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.0 (0.7 to 1.3)
2090	0.9 (0.5 to 1.6)	1.8 (1.3 to 2.7)	3.8 (2.8 to 5.1)

FIGURE 2: SIMULATED HISTORICAL AND PROJECTED TEMPERATURE (°C) TIME-SERIES FOR THE MONSOONAL NORTH CLUSTER, SHOWN AS DIFFERENCES FROM THE 1950–2005 AVERAGE. (SEE EXPLANATION BELOW).



EXPLANATION OF THE TEMPERATURE TIME-SERIES:

1. The projected multi-model median temperature. Half the models have projections above, and half below, this line.
2. 10th to 90th percentile of projected 20-year average climate. 80 per cent of model results lie in this range.
3. 10th to 90th percentile of individual years (taking into account year to year variability). 80 per cent of years lie in this range.
4. The observed time-series for 1910–2013 is overlaid on the simulated climate for the corresponding period (grey line and shading as per 1–3).
5. One climate model is shown to illustrate how the warming future may unfold. Note that models simulate realistic variability in annual temperature.

PAST RAINFALL TRENDS

The Monsoonal North experienced an overall slight increase in rainfall during the 20th century, which includes prolonged periods of drying as well as above average rainfall. The strongest increases have been across north-western regions during recent decades. Year to year variability is strongly influenced by the El Niño Southern Oscillation.

RAINFALL PROJECTIONS

Providing confident rainfall projections for the Monsoonal North cluster is difficult because global climate models offer diverse results, and models have shortcomings in resolving some tropical processes. Natural climate variability is projected to remain the major driver of rainfall changes in the next few decades.

By late in the century, rainfall projections have *low confidence*. Potential summer rainfall changes are approximately -15 to +10 per cent under an intermediate emission scenario (RCP4.5) and approximately -25 to +20 per cent under a high scenario (RCP8.5). Per cent changes are much larger in winter in some models, but these changes are less reliable because average winter rainfall is very low.

Impact assessment in this region should consider the risk of both a drier and wetter climate.

Changes to rainfall are possible but unclear. For the near future the natural variability in the climate system will mask any projected trends due to human influence.

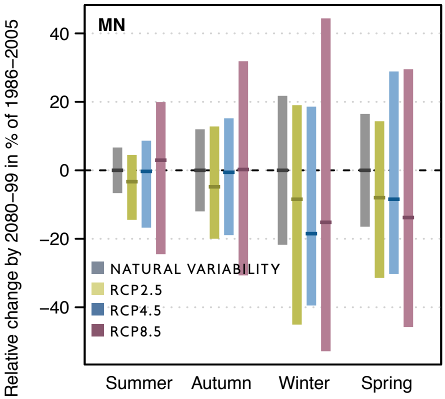
CONSULT THE MONSOONAL NORTH CLUSTER REPORT FOR MORE DETAILED DESCRIPTIONS OF THE RESULTS USING DIFFERENT MODELLING METHODS (E.G. DOWNSCALING).

TABLE 2: PROJECTED RAINFALL DIFFERENCES (PER CENT), COMPARED TO 1986–2005, FOR 20-YEAR PERIODS (CENTRED ON 2030 AND 2090) AND THREE RCPs. THE 10TH TO 90TH PERCENTILE RANGE OF MODEL RESULTS IS SHOWN. FOR 2030, RESULTS FOR ALL RCPs ARE SIMILAR SO ONLY RCP4.5 VALUES ARE SHOWN.

	RCP4.5 2030	RCP2.6 2090	RCP4.5 2090	RCP8.5 2090
ANNUAL	-10 to +5	-14 to +4	-15 to +7	-24 to +24
SUMMER	-7 to +9	-14 to +4	-17 to +9	-24 to +20
AUTUMN	-19 to +9	-20 to +13	-19 to +15	-31 to +32
WINTER	-31 to +19	-45 to +19	-39 to +19	-53 to +44
SPRING	-26 to +18	-31 to +14	-30 to +29	-46 to +30

MEDIAN RESULTS ARE NOT SHOWN HERE BECAUSE MODELS DO NOT ALWAYS AGREE ON THE DIRECTION OF CHANGE.

FIGURE 3: PROJECTED RAINFALL DIFFERENCES (PER CENT) FOR THREE RCPs FOR THE MONSOONAL NORTH FOR 20 YEARS CENTRED ON 2090 (2080–2099 PERIOD) COMPARED TO 1986–2005. BARS INDICATE THE 10TH TO 90TH PERCENTILE RANGE OF MODEL RESULTS. THE HORIZONTAL LINE INDICATES THE MEDIAN.



REPRESENTATIVE CONCENTRATION PATHWAYS

- Future changes in greenhouse gases, aerosols (suspended particles in the atmosphere) and land use depend on human behaviour.
- The scientific community defined a set of four scenarios, called Representative Concentration Pathways (RCPs) for the *Fifth Assessment Report* of the Intergovernmental Panel on Climate Change.
- The RCPs reflect plausible trajectories of future greenhouse gas and aerosol concentrations to the year 2100 and represent a range of economic, technological, demographic, policy, and institutional futures.
- Climate projections are available from model simulations using four RCPs: RCP8.5 (high emissions), RCP6.0 and RCP4.5 (intermediate scenarios resulting from moderate emissions reduction, with differing timing of peak emissions) and RCP2.6 (low emissions; ambitious and sustained global emissions reduction). RCPs are named in accordance with the level of influence these gases have on the Earth's energy balance.
- Not every combination of RCP and climate variable is available for all GCMs in the projections presented here.
- Projections for RCP6.0 are not presented in this brochure, but are available on the website.

EXTREME TEMPERATURE

Extreme temperatures are projected to increase at a similar rate to mean temperature, 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*).

For Darwin and Broome, for example, days with temperatures over 35 °C could be experienced for around a third of the year under an intermediate emission scenario (RCP4.5) by late in the century (Table 3).

More hot days and warm spells are projected with *very high confidence*.

CALCULATE THE FREQUENCY OF DAYS EXCEEDING SELECTED TEMPERATURE THRESHOLDS ON THE WEBSITE THRESHOLD CALCULATOR.

TABLE 3: AVERAGE ANNUAL NUMBER OF DAYS ABOVE 35 AND 40 °C FOR DARWIN (NT) AND BROOME (WA) FOR THE 30-YEAR PERIOD CENTRED ON 1995 (1981–2010) AND FOR FUTURE 30-YEAR PERIODS (CENTRED ON 2030 AND 2090).

THRESHOLD	DARWIN (NT)				BROOME (WA)			
	1995	2030 RCP4.5	2090 RCP4.5	2090 RCP8.5	1995	2030 RCP4.5	2090 RCP4.5	2090 RCP8.5
OVER 35 °C	11	43 (25 to 74)	111 (54 to 211)	265 (180 to 322)	56	87 (72 to 111)	133 (94 to 204)	231 (173 to 282)
OVER 40 °C	0	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.2)	1.3 (0.2 to 11)	4	7.2 (6.0 to 9.3)	11 (7.7 to 22)	30 (17 to 61)

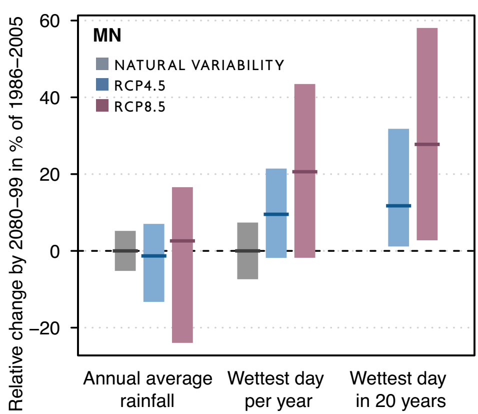
EXTREME RAINFALL & DROUGHT

Despite uncertainty in future projections of total rainfall for the Monsoonal North cluster, an understanding of the physical processes that cause extreme rainfall, coupled with modelled projections (Figure 4), indicate with *high confidence* a future increase in the intensity of extreme rainfall events. However, the magnitude of the increases cannot be confidently projected.

Drought will continue to be a feature of the regional climate variability, but projected changes are uncertain.

Increased intensity of extreme rainfall events is projected, with *high confidence*.

FIGURE 4: MODELLED DIFFERENCES (PER CENT) IN ANNUAL AVERAGE RAINFALL, RAINFALL ON THE WETTEST DAY PER YEAR, AND RAINFALL ON THE WETTEST DAY IN 20 YEARS FOR 2080–2099 COMPARED TO 1986–2005. (BARS AS PER FIGURE 3).



MARINE AND COASTAL PROJECTIONS

For 1966 to 2009, the average rate of relative sea-level rise for Australia, from observations along the coast, was 1.4 mm/year.

There is *very high confidence* in future sea-level rise. By 2030 the projected range of sea-level rise is 0.06 to 0.17 m above the 1986–2005 level, with only minor differences between emission scenarios. As the century progresses, projections are sensitive to concentration pathways. By 2090, the intermediate emissions case (RCP4.5) is associated with a rise of 0.28 to 0.65 m and the high case (RCP8.5) a rise of 0.38 to 0.85 m. Under certain circumstances, sea-level rises higher than these may occur (see Table 4 caption).

Late in the century warming of the Monsoonal North coastal waters poses a significant threat to the marine environment through biological changes in marine species, including local abundance, community structure, and enhanced coral bleaching risk. Sea surface temperature is projected to increase in the range of 2.2 to 4.1 °C by 2090 under a high scenario (RCP8.5). The sea will also become more acidic, with acidification proportional to emissions growth.

Mean sea level will continue to rise and height of extreme sea-level events will also increase (*very high confidence*).

TABLE 4: PROJECTED SEA-LEVEL CHANGE (METRES) FOR TWO MONSOONAL NORTH SITES, COMPARED TO 1986–2005, FOR 20-YEAR PERIODS (CENTRED ON 2030 AND 2090) AND THREE RCPs. THE MEDIAN PROJECTION ACROSS THE MODELS IS SHOWN, WITH THE RANGE OF MODEL RESULTS IN BRACKETS. THESE RANGES OF SEA LEVEL RISE ARE CONSIDERED 'LIKELY'. HOWEVER, IF A COLLAPSE IN THE MARINE BASED SECTORS OF THE ANTARCTIC ICE SHEET WERE INITIATED, THESE PROJECTIONS COULD BE SEVERAL TENTHS OF A METRE HIGHER BY LATE IN THE CENTURY.

SEA-LEVEL CHANGE	BROOME (WA)		KARUMBA (Qld)	
	2030	2090	2030	2090
RCP2.6	0.12 (0.07 to 0.16)	0.38 (0.22 to 0.55)	0.11 (0.06 to 0.15)	0.35 (0.19 to 0.51)
RCP4.5	0.12 (0.07 to 0.16)	0.46 (0.30 to 0.64)	0.11 (0.07 to 0.15)	0.44 (0.28 to 0.61)
RCP8.5	0.12 (0.08 to 0.17)	0.61 (0.40 to 0.84)	0.11 (0.07 to 0.16)	0.59 (0.38 to 0.81)

TROPICAL CYCLONES

Tropical cyclones are projected to become less frequent, but the proportion of the most intense storms is projected to increase (*medium confidence*).

With *medium confidence*, fewer but more intense tropical cyclones are projected.

FIRE WEATHER

The primary determinant of bushfire in the Monsoonal North is fuel availability, which varies mainly with rainfall. In regions where abundant rain falls (Top End and the Kimberley), climate change is not expected to change the frequency of fire (*high confidence*). In more southerly locations, changes to future rainfall will be the determining factor of change to fire frequency. When fire does occur, there is *high confidence* that fire behaviour will be more extreme.

OTHER VARIABLES

HUMIDITY: There is little change projected in relative humidity until later in the century under a high greenhouse scenario (RCP8.5), where a decrease in relative humidity is projected (*medium confidence*).

EVAPORATION: Potential evapotranspiration is projected to increase in all seasons as warming progresses (*high confidence*).

WWW.CLIMATECHANGEINAUSTRALIA.GOV.AU

This website provides comprehensive information about the future climate and its impacts, and how communities, in particular the NRM sector, can adapt to these projected changes.

A number of interactive tools allow exploration of a range of climate variables up to late in the 21st century.

A full report for the cluster can be found on the site, as well as specific impacts and adaptation information.

KEY MESSAGES FOR THE MONSOONAL NORTH

- Average temperatures will continue to increase in all seasons.
- More hot days and warm spells.
- Changes to rainfall are possible but unclear.
- Increased intensity of extreme daily rainfall events.
- Mean sea level will continue to rise. Height of extreme sea-level events will also increase.
- Fewer but more intense tropical cyclones.
- 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.

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