Abbreviations

CCAM	Conformal Cubic Atmospheric Model
CMIP5	Coupled Model Intercomparison Project (Phase 5)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EEZ	Exclusive Economic Zone
ENSO	El Niño-Southern Oscillation
GCM	global climate model
GPCP	Global Precipitation Climatology Project
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
PACCSAP	Pacific-Australia Climate Change Science and Adaptation Planning Program
PCCSP	Pacific Climate Change Science Program
RCP	Representative Concentration Pathway
SAM	Southern Annular Mode
SPCZ	South Pacific Convergence Zone
SST	sea-surface temperature
WPM	West Pacific Monsoon

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Executive Summary

About this Report

This report documents the key findings of the science component of the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program (2011–2014). It describes new understanding of large-scale climate processes, variability and extremes in the western tropical Pacific (Figure 1.1), together with new projections for the 21st century based on Coupled Model Intercomparison Project (Phase 5) (CMIP5)-based global climate model (GCM) projections for individual countries. The projections are aligned with greenhouse gas and aerosol concentration scenarios and terminology adopted by the Intergovernmental Panel on Climate Change (IPCC) 2013 report; *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

This new report supplements information from a previous report published jointly by the Australian Bureau of Meteorology and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in 2011 as part of the Pacific Climate Change Science Program (PCCSP), entitled:

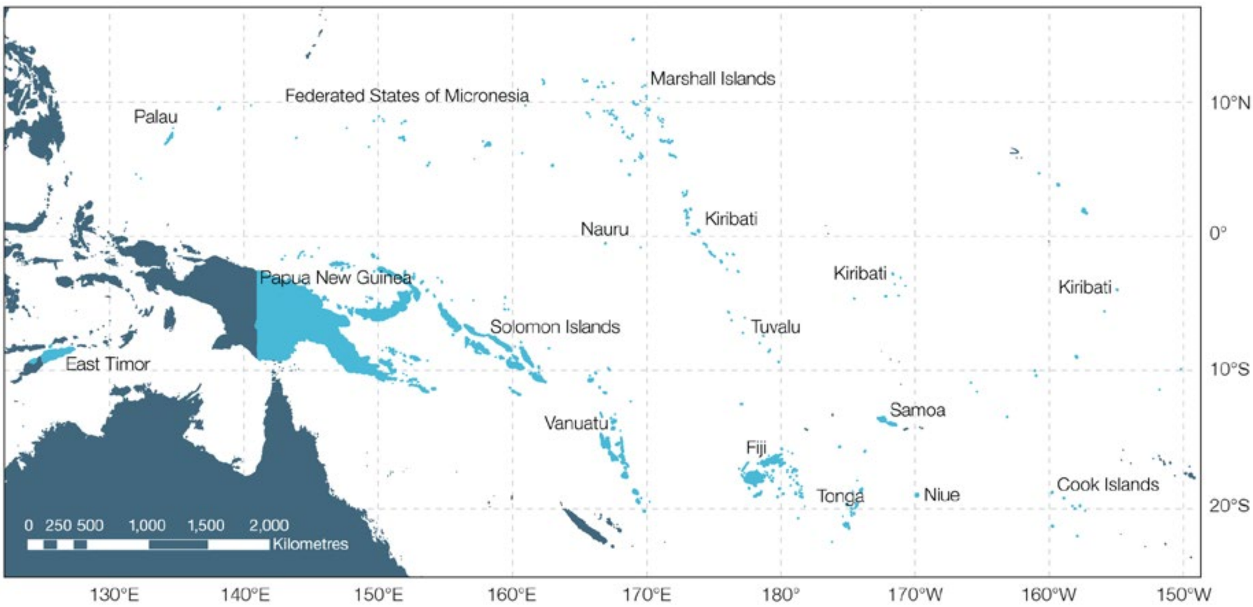
Climate change in the Pacific: Scientific assessment and new research – Volume 1: Regional Overview and Volume 2: Country reports

The previous PCCSP report (Australian Bureau of Meteorology and CSIRO, 2011) provides a general, regional-scale description of large-scale climate processes, variability and extremes and projections based on Coupled Model Intercomparison Project CMIP Phase 3 (CMIP3)-GCMs. This provides context for the latest national-scale climate science findings provided in this new PACCSAP report.

The first chapter provides a general introduction to the content, structure and methods used for each Partner Country report in subsequent chapters, including specific reference to:

- Data availability;
- Seasonal cycles, including wind-driven waves;
- Observed trends over the past 30-60 years, including air temperature, rainfall and tropical cyclones; and
- Climate projections, including how to understand new CMIP5 GCM outputs and emission scenarios, multiple possible futures, natural variability, confidence statements, presentation of projections, and detailed projection methods for relevant climate variables.

Each subsequent Partner Country chapter has five key sections that provide: (1) a current and future climate summary, (2) historical data records, (3) seasonal cycles, (4) observed trends, and (5) projections for atmospheric and oceanic variables. Projections are provided for temperature, rainfall, extreme events (including tropical cyclones, extreme hot days, and heavy rainfall days), sea-surface temperature, ocean acidification and sea-level rise for four future 20-year periods centred on 2030, 2050, 2070 and 2090.



Map showing the western tropical Pacific Partner Countries in this report: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu and East Timor.

Climate Modelling and Performance

While global climate models (GCMs) are presently the best available tool for making climate projections out to 2100, it is not possible to identify a single 'best' scenario or GCM that will accurately forecast the future evolution of greenhouse gas concentrations and our climate.

GCMs produce large-scale projections for computational grid cells that have a horizontal spacing of 70–280 km. This means some results may not incorporate finer-scale but otherwise locally-influential features such as the spatial characteristics of island topography and land cover, inshore bathymetry and local-scale meteorological effects.

Even though all GCMs are based on the same physical laws, they are not perfect representations of the real world because they cannot take into account the things we do not know, e.g. how society will develop and adapt, and what natural climate variability will be experienced in the future. GCMs also differ in how they represent physical processes that occur at spatial scales smaller than that of the grid cells.

Confidence in GCM projections (see About the Projections) is higher for some variables (e.g. temperature) than for others (e.g. rainfall), and it is higher for larger spatial scales and longer averaging periods. On the other hand, confidence is lower for smaller spatial scales, which represents a particular challenge for Partner Country projections in the Pacific, particularly for some of the smaller, low lying atoll nations.

When interpreting projected climate changes throughout this report, it is also important to keep in mind that natural climate variability, such as the state of El Niño–Southern Oscillation (ENSO), strongly affects the climate from one year to the next. The Interdecadal Pacific Oscillation (IPO) can also affect the Pacific climate from one decade to the next.

About the Projections

The science component of the PACCSAP Program has produced climate projections for the western tropical Pacific using up to 26 new GCMs that have been assessed to perform acceptably well over the region. This means there is a range of possible futures generated from these models for each Partner Country. These futures are expressed as a multi-model average change, with a range of uncertainty due to differences between models.

Consistent with the IPCC (2013), the projections use four new greenhouse gas and aerosol concentration emission scenarios, called Representative Concentration Pathways (RCPs): RCP2.6 (very low emissions), RCP4.5 (low emissions), RCP6 (medium emissions) and RCP8.5 (very high emissions). The lowest scenario shows the likely outcome of reducing emissions (mitigation), and the highest scenario shows the impact of a pathway with no climate policy and high emissions. These pathways cover a broader range of possibilities compared with the emission scenarios (B1-low, A1B-medium, and A2-high) used for the previous CMIP3-based projections presented in the 2011 PCCSP report (Australian Bureau of Meteorology and CSIRO, 2011). New analyses included in this latest PACCSAP report, and not previously in the Australian Bureau of Meteorology and CSIRO (2011) report, include trends in extreme air temperature, rainfall and ocean waves.

In practice, results from the CMIP5 projections in this report are very similar to the previous CMIP3 results (Australian Bureau of Meteorology and CSIRO, 2011) when the differences in emission scenarios are taken into account. Another important change between the previous PCCSP work and the new PACCSAP work in this report is the way more advanced and appropriate methods for calculating changes to extremes and drought are used and documented, e.g. using box plots of drought in different categories. Once again, after accounting for the effect of different pathways, the main differences between the previous and new results are mainly reflected in changes to country rainfall projections.

A confidence rating (very high, high, medium, and low) for the direction and magnitude of change is provided with each projection, consistent with the IPCC guidance on confidence assessment. Confidence in the magnitude of change indicates how well the model represents the expected change for a particular scenario. The confidence in the magnitude of change is often lower than the confidence in the direction of change. Confidence is reduced when there are model biases in relevant climate features and where there is a wide range of projections from the models.

Some confidence ratings have changed from those described previously by PCCSP (Australian Bureau of Meteorology and CSIRO, 2011). This is due to new PACCSAP research showing greater uncertainty in the projection of large-scale climate features and processes. It is also due to a greater range of projections that are produced using CMIP5 compared with CMIP3 models. In particular, some rainfall confidence ratings have been reduced from 'high' to 'medium' or from 'medium' to 'low.'

Regional Climate Observations and Trends

Large-scale Regional Climate Processes

Most of the GCM projections described in this report show increases in Western Pacific Monsoon (WPM) rainfall in a warmer climate, mostly over the wet season, leading to a stronger seasonal rainfall cycle.

They project increases in rainfall within the Inter-Tropical Convergence Zone (ITCZ), particularly in the June to August season, which will amplify the seasonal cycle. This area is projected to expand, in line with these increases, towards the equator.

The average position of the South Pacific Convergence Zone (SPCZ) is not expected to change significantly, although the years when it moves north and merges with the ITCZ will become more frequent. Changes in SPCZ rainfall are uncertain but they are sensitive to sea-surface temperatures not well simulated by many models.

El Niño and La Niña events will continue to occur in the future, but there is little agreement between the climate models on whether these events will change in intensity or frequency.

In general, climate observations and trends across the region for Partner Countries indicate:

Temperature

- On a regional scale, station-based observations show a persistent mean annual warming trend of 0.18°C since 1961, with most of the warmest years on record in the last two decades. There have been significantly more warm days and nights, and fewer cool days and nights.
- Since 1951, the frequency of warm days and nights has increased more than three-fold across the region. Once rare extremes, that used to occur approximately 20 days in a year, are now occurring much more frequently, between 45–80 days in a year.

Rainfall

- Rainfall is highly variable, and over the past 30 years, the southwest and northwest Pacific has become wetter and the central Pacific drier.
- In general, there has been no consistent trend across the region in the long-term for mean and daily extremes of rainfall over the past half century.

Oceans

- Sea surface temperatures have increased, and year-to-year variability is largely due to ENSO.
- Ocean acidification continues to increase in response to human activities.
- As the ocean warms, the risk of coral bleaching (recurrence and severity) increases.
- Sea levels have risen, and vary across the Pacific with large-scale climate processes.
- Extreme sea levels are caused by a combination of long-term sea-level rise from climate change and short-term climate variability factors, such as combined effects of king tides, storm surge and associated wind-wave setup.
- Wind-driven waves that have influence on coastal regions exhibit strong seasonality, and year-to-year variability is largely due to ENSO. The relationship of annual wind-wave properties to ENSO varies regionally.

Tropical cyclones

- An updated analysis of cyclone track data for the South Pacific through to the 2010–11 season shows a slight decrease in the total number of cyclones, with little change in the number of the most intense. As complete records of estimated tropical cyclone intensity are only available from 1981, studies of tropical cyclone trends are limited to this time. Using three different tropical cyclone archives, researchers found contrary trends in the proportion of intense tropical cyclones in the western North Pacific over the past few decades.

Regional Climate Projections

At a regional scale, climate projections that are consistent for Partner Countries across the region in general indicate:

Temperature

Compared to the base period 1986–2005:

- Average temperatures will increase, bringing more extremely hot days and warm nights (by 2030, the projected warming is likely to be around +0.5–1.0°C, regardless of the emissions scenario, and by 2090 a very high emissions scenario could increase temperatures by +2.0–4.0°C).
- Extreme temperatures that occur once every 20 years on average are projected to increase in line with average temperatures by up to +2.0–4.0°C by 2090 under the very high emissions scenario.

Rainfall

- Average annual rainfall will increase with fewer droughts in most areas.
- Extreme rainfall events that occur once every 20 years on average during 1986–2005 are projected to occur once every seven to ten years by 2090 under a very low emissions scenario, and every four to six years by 2090 under a very high emissions scenario.

Other

- Rising sea levels.
- Increasing sea surface temperature.
- Increasing ocean acidification.
- More frequent and longer lasting coral bleaching.
- Changes to wind-driven waves.
- Less frequent but more severe tropical cyclones.

The details of specific projections for rainfall, temperature, drought, waves and other variables vary to some extent between the Partner Countries. All observed climate trends and projections are explained in detail for each Partner Country in Chapters 2-16.