Indian Ocean Climate Initiative

Update on IOCI Research: WA Rainfall – What the past can tell us, and what the future may hold

A synthesis of the latest IOCI research

The Indian Ocean Climate Initiative (IOCI) science programme continues to produce insightful new information for Western Australia. This update is the first in a series synthesising details of recent findings from IOCI, Stage 3. The topic of this update is rainfall.

IOCI covers a wide range of topics. New research is revealing a great deal about the variability, drivers and predictability of WA's temperature trends, the tropical cyclones that affect WA, and the extremes that WA can experience. New methods are being developed to produce data and projections at very high resolution across both the north-west and south-west.

We hope you enjoy learning about these new findings and can see how these results can work for you.

IOCI Science Management Team, October 2010

Building on past knowledge

What influences rainfall in WA?

WA covers a broad range of climatic regions extending from the tropics to latitudes influenced by the westerlies or 'roaring forties'.

In the north, rainfall is strongly influenced by tropical cyclones and the intensity of the wet season and monsoon.

In the south-west in winter, rainfall is influenced by the upper level jet and the fronts and high pressure systems that cross the region **(Figure 1)**.

Summer rainfall in the south-west is highly sporadic, and can be associated with the breakdown of tropical cyclones.

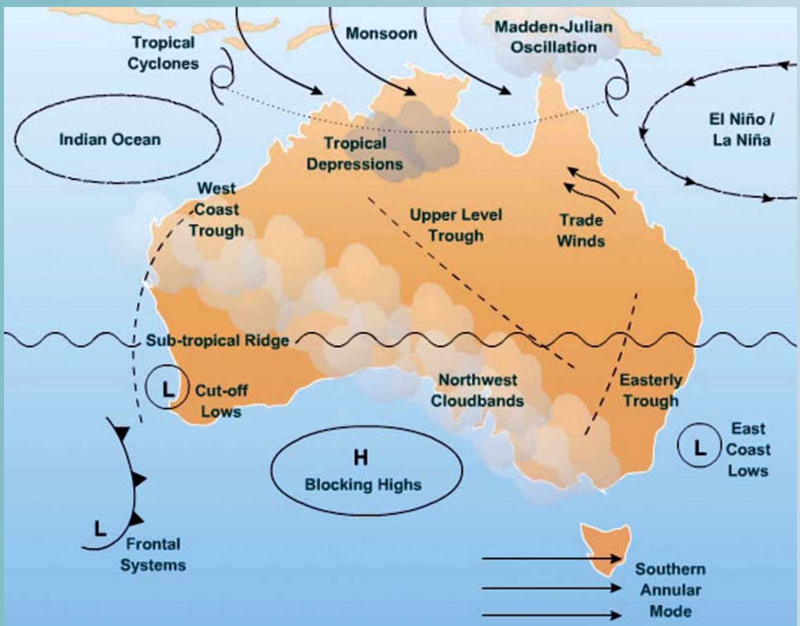

Figure 1 Major influencers of WA's weather (Source: http://www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.shtml

Improved Rainfall Records

Our knowledge of historical rainfall in WA is limited by a lack of good data. One reason for this is the relatively few rainfall observation stations in WA, particularly in the north-west **(Figure 2)**.

One current project has rigorously assessed the quality and availability of daily WA rainfall measurements, resulting in a large increase in the number and distribution of high-quality, long-term records **(Figure 3)**. Some sites were composited to increase record length. This dataset will be soon be available.

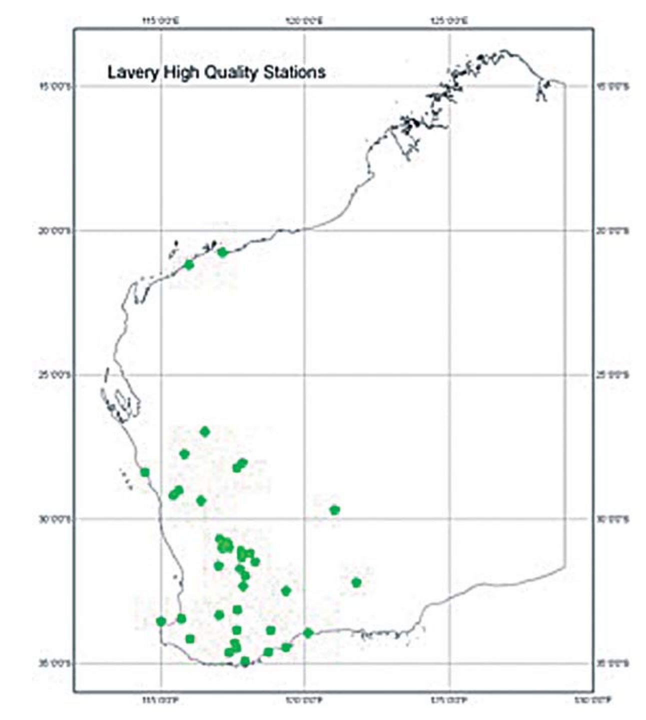

Figure 2 Figure 2 Former network of high-quality daily rainfall stations across WA (following Lavery et al. 1992)

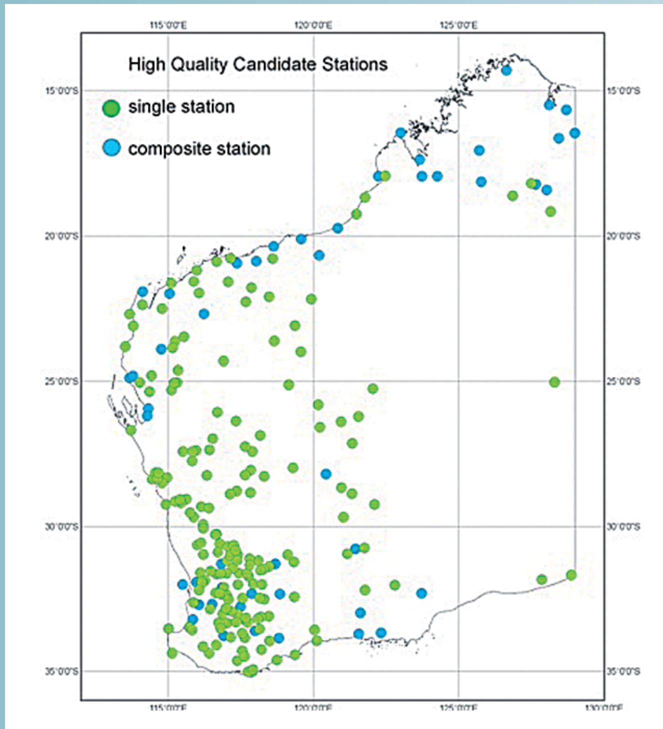

Figure 3 New network of high quality rainfall stations across WA, showing a dramatic increase in data suitable for climate research

Changes in rainfall

Any change to rainfall – the total amount, variability or the pattern of occurrence – has major implications for WA communities and industries. It is therefore important to understand past changes to rainfall patterns and how the patterns we see today may change in the future.

IOCI researchers have found that for the past six decades, rainfall trends have been dramatic both in the north and south west **(Figure 4)**.

In the south-west of WA – once considered Australia's most reliable wheat growing region – rainfall during winter has been declining since the late 1960s. **Figure 5** shows that since that time, there has consistently been below average rainfall in the months from May to July. In recent years, this increase in aridity has also expanded spatially **(Figure 6).**

This information about declining rainfall is useful for climate dependent sectors and industries, particularly the water sector. The reduction in run-off in the south-west has been substantial. The changes in the south-west also mean that decision makers cannot rely on historical data alone to guide them, as the future climate is likely to be very different from the past.

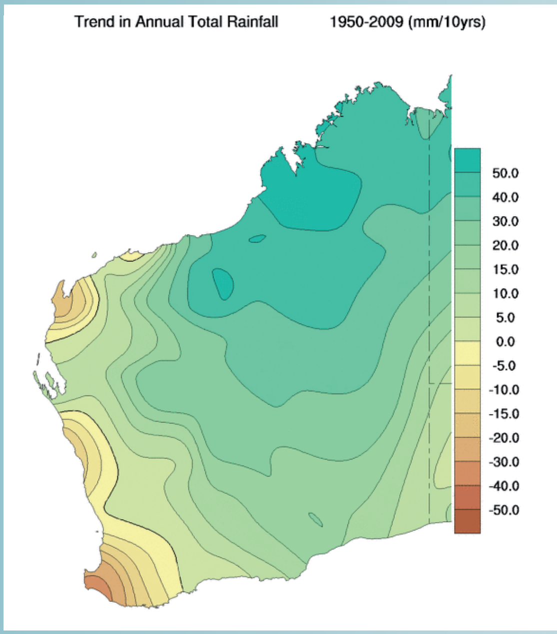

Figure 4 Trends in total annual rainfall for WA from 1950-2008 (mm/10 years). This figure shows where the rainfall has decreased sharply (brown shading) in the south west and increased dramatically in the north (darker green shading). (Source: http://www.bom.gov.au/climate/change/)

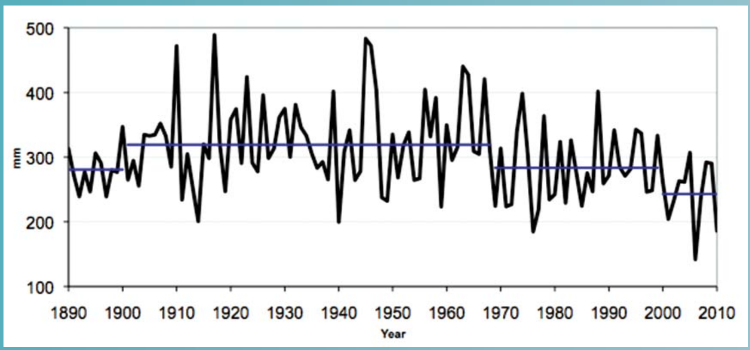

Figure 5 Average rainfall for May to July for far south-west WA. Horizontal lines are the mean between each statistical breakpoint

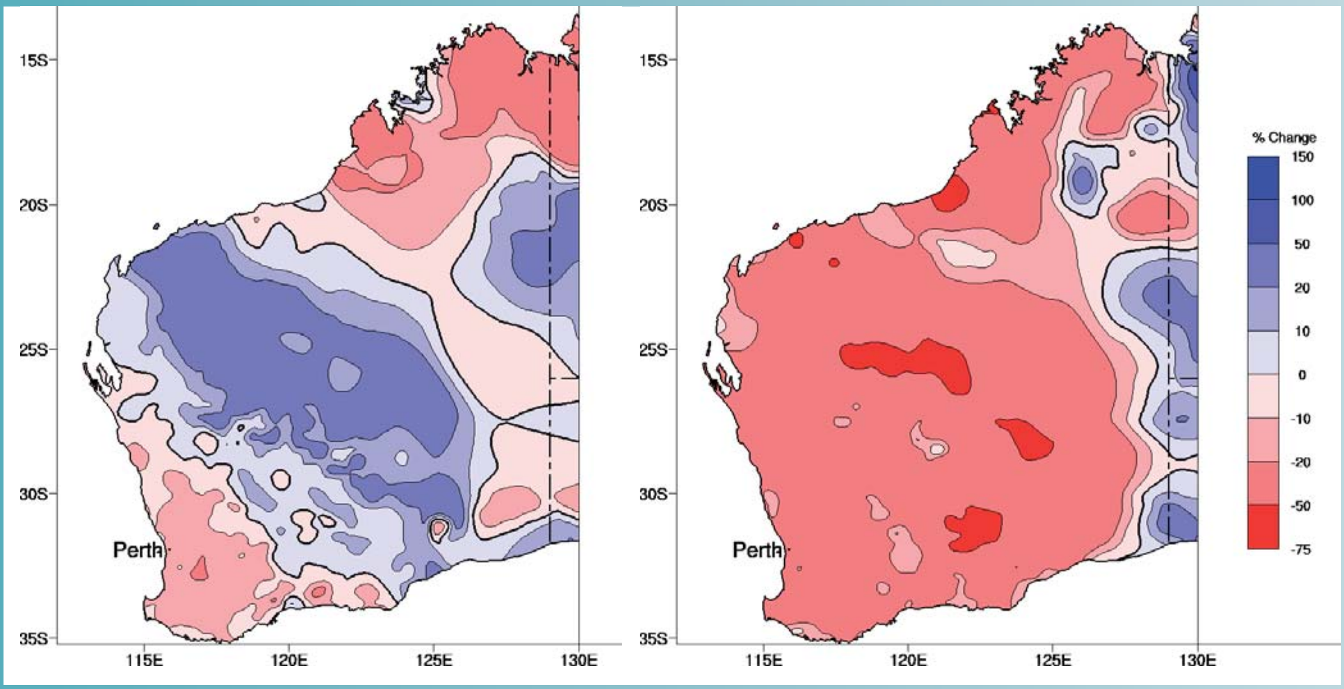

Figure 6 (left) The percentage change in average 1969–1999 May to July rainfall from the 1910–1968 mean. (right) The percentage change in average 2000–2008 May to July rainfall from the 1910–1968 mean

Changing weather systems

Understanding the underlying weather conditions behind rainfall trends will help explain their cause and help us to best interpret climate model data and hence what the future may hold.

There have been opposing shifts in the north and the south of the state. However, IOCI research has shown that changes in the types of weather systems that impact WA are related to larger hemispheric-scale shifts in atmospheric circulation.

In early winter in the south-west, atmospheric conditions have become more stable. There have been fewer low pressure systems, more prevalent high pressure systems and, since 2000, the rainfall associated with each system has decreased. The changes that have already being experienced in the south-west are projected to continue at the same rate over the next century under increasing levels of atmospheric greenhouse gases.

Fine-scale rainfall data from climate models

Climate models produce data on a scale of approximately 200 km. IOCI scientists are using their understanding of the large-scale weather systems that drive rainfall to produce finer-scale rainfall information from this relatively coarse data. In the south-west our understanding of rainfall processes is excellent, and new methods are now being used to provide faster results from more sites. These data will become available towards the end of 2011.

In the north, new IOCI research is revealing the range of weather systems that drive the day-to-day variability of summer wet season rainfall. These large-scale weather systems are better represented in climate models and will allow for site-specific future projections to be made.

The pattern of rainfall variability across the Kimberley was used to determine the weather associated with wet and dry conditions. Five different patterns describe the variability during the summer half-year. **Figure 7** shows the weather patterns associated with very wet conditions across the north-west (State 2) and very dry conditions (State 3).

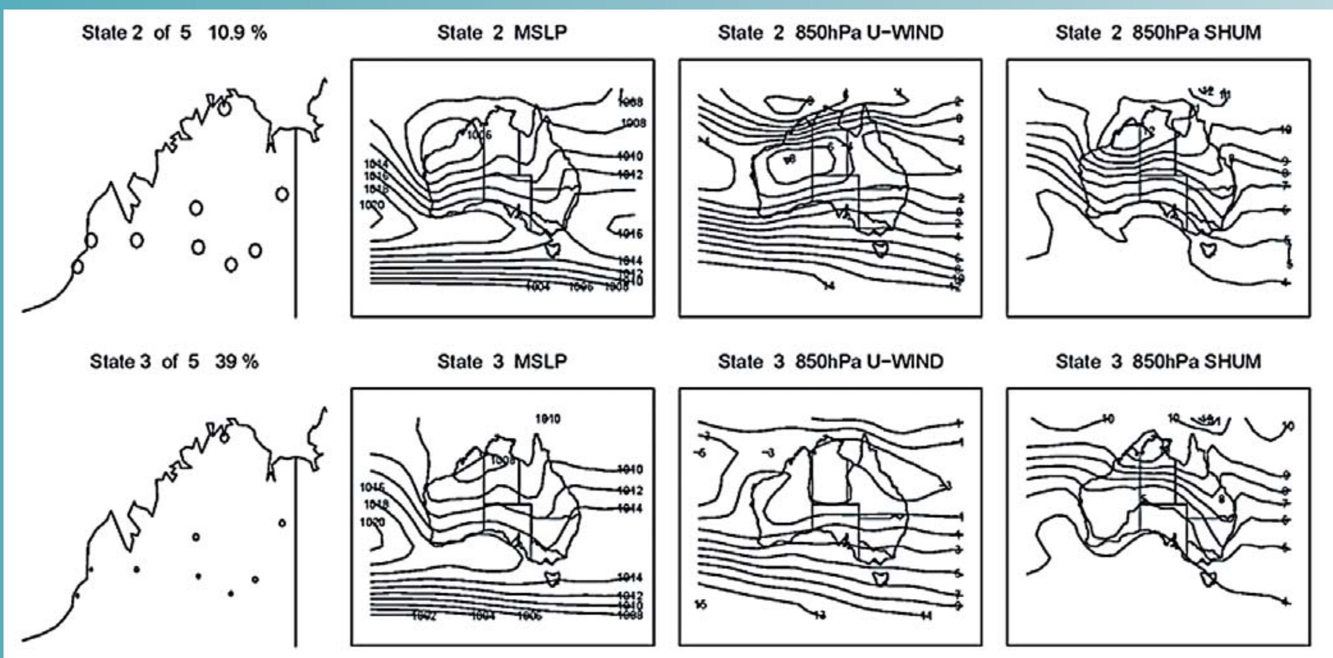

Figure 7 Kimberley November-April rainfall weather patterns associated with wet (State 2) or dry (State 3) conditions. MSLP: Mean Sea-Level Pressure, 850hPa U-WIND: low level east-west wind, SHUM: low level moisture levels

Figure 8 shows that over the last 50 years, State 2 (very wet conditions throughout the Kimberley) is becoming more common, while State 3 (very dry conditions) is becoming less common. This new understanding of the weather systems associated with observed rainfall will produce more realistic, fine-scale, rainfall information from climate model projections.

Improving our knowledge of the future

Predictability of rainfall

Many WA industries and community services depend heavily on climate, and hence being able to predict what lies ahead for the future, as well as the coming season, is vital for their long term viability. Being able to determine what the likely rainfall will be over the early winter months of May to July is particularly useful for agriculture, food and wine industries. In the south-west, as dry years follow dry, seasonal forecasts also have a growing importance for water resources and health and emergency services.

In the past there has been only limited success in seasonal predictions of winter rainfall across the south-west. IOCI3 has explored if there is potential for predictability on a seasonal timescale using new theoretical estimates. This is a good example of how, in some instances, the delivery of practical information may stall until there is further development of theory.

The result of this research can be explained through **Figure 9**. This shows the estimated potential predictability of WA rainfall for each of twelve three month seasons, expressed as a fraction of the interannual variance in the rainfall. If the fraction is high (red) there is more chance of being able to successfully predict the total seasonal rainfall a month or more ahead of the season.

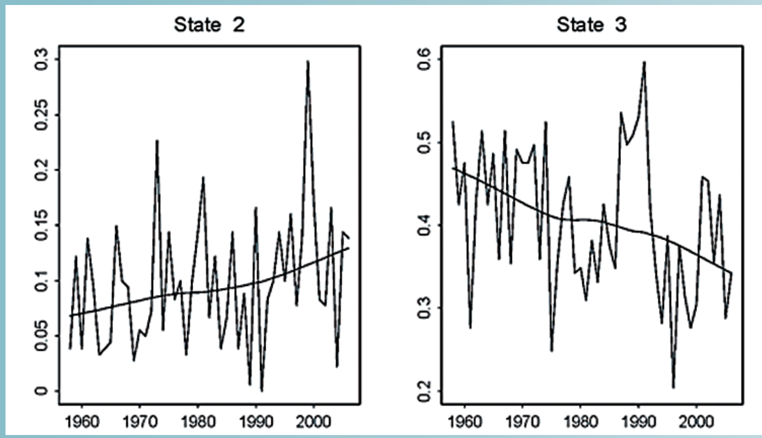

Figure 8 Five states explain the rainfall and weather variability in the Kimberley. State 2 is the wettest, and it is becoming increasingly common. State 3 is very dry and has become far less common over the last 50 years.

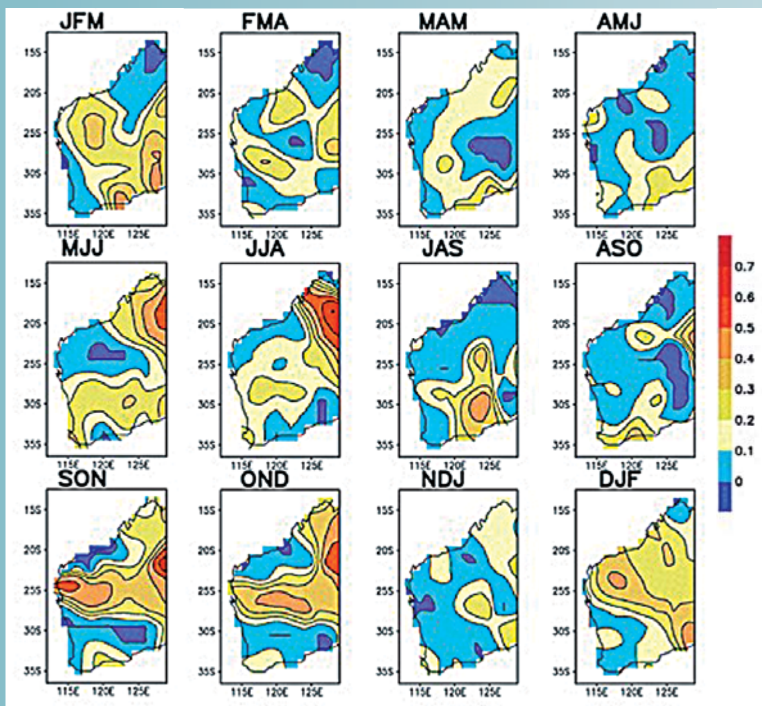

Figure 9 Estimated potential predictability of WA rainfall – red areas have high potential for predictability

- Northern WA: this is the area of largest predictability (as high as 70%) during May to July (MJJ), June to August(JJA), September to December (SOD) and October to December (OND).
- Central WA: this area, including near the coast, has substantial predictability during spring – September to November (SON) and October to December – (OND).
- South-west WA: predictability during MJJ and JJA ranges between 20-30%, indicating that there is some potential for long range skilful seasonal prediction during these seasons. During the rest of the year there is very low predictability over the south-west WA

These results suggest that there is limited scope for using traditional methods to predict winter rainfall across the south-west. Under the current stage of the IOCI, no further work is scheduled to explore seasonal prediction. However, elsewhere new approaches are being explored, with some success for the south-east.

Improving the power of climate models

Climate models traditionally simulate the highs and lows in the westerlies reasonably well. More than 90% of climate models agree that there will be winter drying across the south-west at the end of the century compared to the end of last century **(Figure 10a)**.

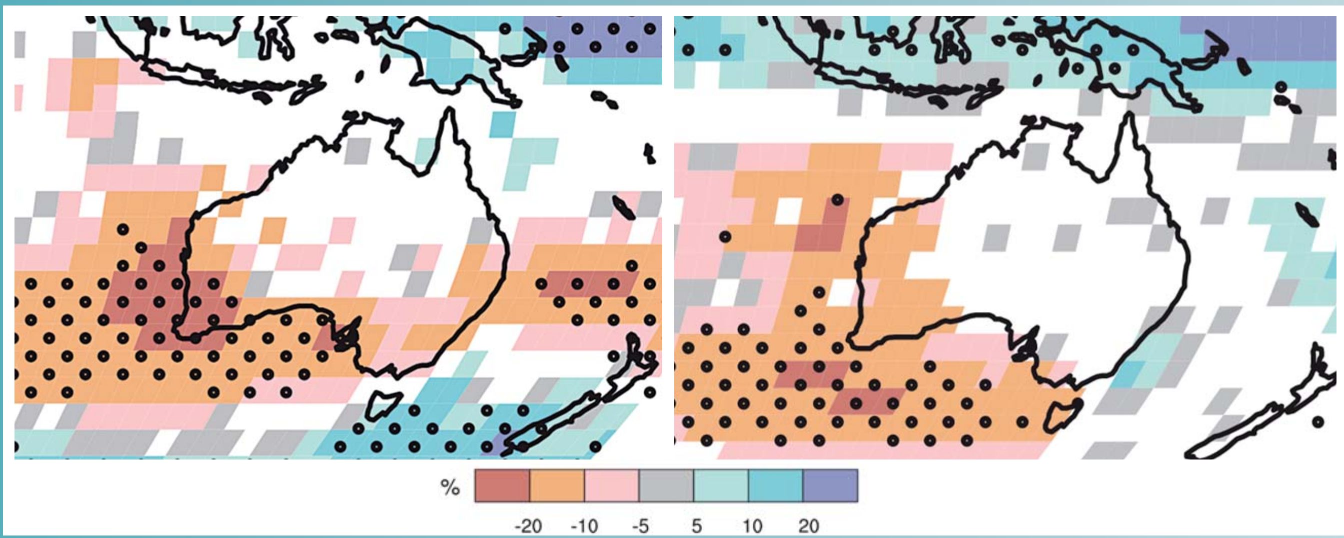

Figure 10 Projected Rainfall % Change at 2090-99 from 1980-99 for a mid-range future emission scenario. a) Winter, b) Summer. The results are the mean from more than 20 climate models. White regions indicate that less than two thirds of the models agree on the direction of change. Stippling is where more than 90% agree. (From: IPCC Assessment Report 4, Summary for Policy Makers - www.ipcc.ch)

In contrast, climate models do not agree on the direction of change in the north-west **(Figure 10b)**. Historically, climate models have not simulated the tropics very well and hence this is currently a vigorous and active area of research.

The observed dramatic increase in summer rainfall across the north-west provides a test-bed for improving both our understanding of the climate system and improving our climate models. At present, the underlying cause of the rainfall increase in the north-west is not clear.

IOCI scientists have improved the representation of dust, aerosols and tropical processes in the CSIRO climate model. This new model better captures the extent and influence of the Asian Brown Cloud and the El Niño-Southern Oscillation (ENSO). The model is far better placed to explore the dramatic rainfall increase in the north-west.

As one of the few countries in the tropics that has a number of high quality weather observing sites and its own dynamical climate models, Australia (and IOCI) is well placed to advance the world's understanding of the drivers of tropical climate. Understanding the dramatic trends in WA's tropical rainfall, and how it may change into the future, will greatly assist the climate adaptation of communities and industries in the north of the state.

* Note: All figures not otherwise attributed were sourced from the first two IOCI3 milestone reports. To use any of these results, please contact the science management team.

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