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Climate science: informing risk management

Report of the 2011 Indian Ocean Climate Initiative Workshop

Rydges Hotel, Perth
December 5-6, 2011

Prepared by CSIRO on behalf of the Indian Ocean Climate Initiative Stage 3
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Indian Ocean Climate Initiative

Australian Government
Bureau of Meteorology

GOVERNMENT OF WESTERN AUSTRALIA

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About IOCI

The Indian Ocean Climate Initiative (IOCI) is a partnership of the State Government of Western Australia, CSIRO and the Australian Bureau of Meteorology, which was formed by the Western Australian Government to support informed decision-making on climate variability and change in Western Australia.

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Part I Introduction

1.1 About IOCI3

The Indian Ocean Climate Initiative (IOCI) is a strategic climate research partnership of the Western Australian Government, CSIRO and the Bureau of Meteorology. Stage 3 of the Indian Ocean Climate Initiative began in 2008 and ends in June 2012. IOCI's vision, aim and key objective are as follows:

Vision: To empower the State of Western Australia with the best available scientific knowledge for adapting to climate change.

Aim: To establish and maintain state-of-the-art and regionally-specific knowledge of past and projected climate trends in Western Australia and make such knowledge available in a policy ready form and for public information processes.

Key objective: To provide outputs in a useful form to policy-makers and other stakeholders.

1.2 About this report and the IOCI3 Workshop

This report describes the proceedings of an IOCI3 Workshop held at the Rydges Hotel, Perth, on December 5 and 6, 2011. Titled "Climate Science: Informing Risk Management" the aim of this two-day workshop was:

- To update representatives of government agencies and other stakeholder groups on IOCI3 findings in a way that is tailored to "light" & "medium" (Day 1) and "heavy" user groups (Day 2).[1]
- To present this information within the wider context of risk management.

In addition to this event, IOCI3 has held three prior workshops on the following dates:

- 28 August 2008;
- 26–27October 2009;
- 26 October 2010.

[1] "Light" users are defined as having a "general" understanding of the IOCI partnership, climate projection, and major climate changes likely to affect WA, "medium" users a general to detailed understanding, and "heavy" users a detailed understanding of same.

The workshop program

The workshop was introduced and facilitated on both Day 1 and 2 by Mr Paul Holper, CSIRO. The complete Day 1 and Day 2 agendas are provided in Appendix B, and a brief synopsis of the events is provided below.

Day 1 of the workshop began with an opening speech from the Hon Bill Marmion, Minister for Environment; Water. Presentations by IOCI3 scientists during the first session of Day 1 aimed to provide a general overview of IOCI3 research achievements. A further two sessions featured presentations on the use of climate science information in the risk management context. Speakers from industry, the non-profit sector, and governmental agencies provided perspectives on climate risk management from a range of WA sectors.

Day 2 of the workshop opened with a speech by the Hon Carmen Lawrence, Winthrop Professor, University of Western Australia. The main goal of the Day 2 agenda was to provide relatively detailed technical updates of IOCI3 research achievements, with a particular focus on those of the preceding 12 months.

The workshop delegates

Eighty-seven delegates attended the workshop over Days 1 and 2. IOCI3 partner organisations (BoM, CSIRO, and the Government of Western Australia) were well represented, however, the workshop attendance also reflected IOCI's broad range of stakeholders, including delegates from universities, non-governmental organisations and the private sector. A full list of attendees and their organisational affiliations is provided in Appendix C.

Part 2 Summaries of Day 1 Presentations

This section provides summaries of Day 1 speeches and presentations. This includes summaries for morning opening speeches; workshop session 1, "Climate science supporting risk management"; workshop session 2, "Managing climate-related risks on the ground"; and workshop session 3 titled, "Bridging the gap for effective risk management".

1 Morning Opening Speeches

Opening speeches were provided by the Hon Bill Marmion MLA, Minister for Environment; Water; Hon Hendy Cowan, Chair IOCI3; and Mr Robert Atkins, Deputy Director General, Department of Environment and Conservation (DEC). Summaries of their speeches follow.

1.1 Opening address

Hon Bill Marmion MLA, Minister for Environment; Water

"... it was Oscar Wilde who said, 'Conversation about the weather is the last refuge of the unimaginative.' Not so, Oscar, certainly not these days. In fact, we now talk about the weather with far more urgency & importance than ever before."

--Hon Bill Marmion

The Hon Bill Marmion MLA welcomed delegates and attendees. The Minister acknowledged, as an engineer, his professional fondness for empirical proof. He said these principles are also central to IOCI, observing that, "Good science is robust, and like all major issues it's a contest of ideas, ideas that are firstly explored, challenged, and then crystallised into greater certainty. This is the heart of the Indian Ocean Climate Initiative."

He cited IOCI's mission to provide climate information to stakeholders, describing it as an awesome challenge, and quoted IOCI researcher Aloke Phatak (who is a rocket scientist as well as a climate scientist) as saying climate science is much harder than rocket science.

The Minister described how IOCI was launched by Hon Hendy Cowan, who is also a farmer, and how Mr Cowan drew attention at the last workshop to the fact that 2010 was the driest year on record. The Minister emphasised that agriculture and economics are just one facet of climate change impacts, saying, "In effect, outcomes from this initiative will to a significant degree shape the way we live ... how we adapt."

He commended IOCI for communicating its findings to allow government to deliver better policy. He also touched on the fractious nature of the public climate debate, and noted the State Government as being on record as opposing the federal carbon tax. He emphasised the importance of listening in government, and of the virtues of persuasion versus compulsion.

"Your science is challenging, confounding, contesting... and absolutely vital."

--Hon Bill Marmion

Outlining some key State Government achievements, he noted the Kimberley Science & Conservation Strategy, the development of a climate change adaptation and mitigation strategy, strengthened environmental monitoring and compliance, funding of community environment programs, and the encouragement and support of renewable energy through the Low Emissions Energy Development fund. He noted that the government had already delivered all of its key government election promises. He touched on the challenge of balancing socio-economic progress with environmental protection.

He described how prior IOCI stages informed public debate and climate change policy, with special emphasis on water-related policy, such as informing the decision to move into desalination to drought-proof Perth. Turning to IOCI3, he cited the importance of unlocking the mysteries of north-west WA's climate, such as the climate drivers behind the trend of increased rainfall. He said this knowledge is important given that region's role as Australia's economic powerhouse.

The Minster said that IOCI would lead to, "new knowledge and skills, with valuable socio-economic benefits." He acknowledged CSIRO and BoM, and applauded the efforts of DEC staff. Finishing, he quoted Mark Twain's comments about the weather ("climate is what we expect, weather is what we get") and noted that weather these days can be pretty confusing.

1.2 Welcome

Hon Hendy Cowan, Chair, IOCI3

The Hon Hendy Cowan welcomed delegates and speakers, and appealed to the Hon Bill Marmion for his continued support of IOCI research, emphasising its importance to adaptation planning.

Mr Cowan observed how IOCI's influence on cropping decisions has led to increased profitability of the sector. He also cited the role IOCI played in the decision-making process surrounding the first Perth desalination plant.

He gave a brief overview of the morning's upcoming research talks, noting that Day 1 would also include presentations from a diverse range of professionals to address issues surrounding the use of climate science to address climate risk.

Next Mr Cowan summarised results of a June 2011 value-for-money assessment by consultants ACIL Tasman that found IOCI provided robust, independent and objective scientific knowledge. The report stated that IOCI did so while providing good value for money and efficient use of funding. Mr Cowan said that in addition to water resource planning, IOCI's influence extends to health, agriculture, mine safety and planning, and local government sectors. Mr Cowan also described how IOCI's success is demonstrated via its imitation by other regional climate initiatives (e.g., the South Eastern Australian Climate Initiative.)

"The assessment found that IOCI excelled in providing robust, independent and objective scientific knowledge on Western Australia's changing climate. ... The funding provided to IOCI is used more efficiently than that of other, comparable research organisations."

Mr Cowan noted IOCI's recent increased emphasis on communications with the hiring of a full-time communicator. He also noted that IOCI3 projects are entering an exciting phase as they come to a close, and are already influencing policy and decision-making in Western Australia.

1.3 Climate change functions and activities in the Department of Environment and Conservation

Mr Robert Atkins, Deputy Director General, DEC

Mr Atkins began by stressing the importance of climate information like that provided by IOCI to inform management decisions of many DEC activities. After describing the Climate Change Unit's responsibilities and activities, Mr Atkins emphasised how climate change considerations are incorporated into DEC functions and activities, including those related to conservation estates, biodiversity research, the mallee program and Kimberley fire management.

Mr Atkins then outlined the June 2011 *Kimberley Science and Conservation Strategy*, including its centrepiece, 3.5 million hectare Kimberley Wilderness Parks, and highlighted the region's unique biodiversity values, the opportunities these values create, and the threats they are under. He also outlined the *Biodiversity and Cultural Conservation Strategy for the Great Western Woodlands* for the Goldfields area.

"The information provided by the IOCI3 research program will be essential to support decision-making in DEC."

--Mr Robert Atkins

Climate change is a threat to such biodiverse areas, including those of south-west Western Australia (SWWA), a global biodiversity hotspot. IOCI research reveals that warming and drying in this region is likely to continue, posing a threat to SWWA's natural heritage. Mr Atkins described DEC research activities to understand climate change vulnerabilities and develop adaptation options. These include the effects on keystone and iconic species, the role of refugia, and the genetic aspects natural resilience. IOCI3 research information will support these DEC ecological research efforts.

Mr Atkins then highlighted DEC's efforts to improve fire management in the Kimberley, where fire is a major and growing biodiversity threat under changes in climate. He noted IOCI's research on aerosol effects on NWWA rainfall, and the possibility that current rainfall trends could reverse, should aerosol levels drop. He also emphasised the importance of fire management to reduce greenhouse gas (GHG) emissions stemming from savannah fires.

In closing, Mr Atkins emphasised the impacts that further climate change would have on WA's biodiversity. DEC's responsibility, he said, is to implement research on climate change and integrate climate change considerations into its agency-wide functions and activities. As such, IOCI information is essential to support DEC decision-making.

2 Session 1: Climate Science Supporting Risk Management

The first session of Day 1 consisted of presentations of IOCI3 research by Dr Carsten Frederiksen, Dr Pandora Hope, Dr Aloke Phatak, and Dr Debbie Abbs. These presentations aimed to provide a general overview of IOCI3 research findings.

2.1 Observed and projected changes in the Southern Hemisphere circulation, weather systems and WA winter rainfall

Dr Carsten Frederiksen, BoM

Dr Frederiksen began his presentation by stressing the importance of understanding how the systems' atmospheric circulation leads to changes in rainfall. He then described dramatic climatic changes over the past 60 years associated with distinct shifts in rainfall amount in SWWA and related these to large-scale changes in the circulation of the atmosphere. These circulation changes have affected the growth rate, and hence the likely development, of weather systems that affect WA during winter. Dr Frederiksen concentrated on changes during winter and noted that the largest rainfall reductions have occurred in the month of July, with a large negative trend over SWWA.

"There has been reduction in the subtropical jet of nine metres per second —that's an enormous hit on the climate system."

Dr Frederiksen explained that jetstreams are vitally important for the generation of weather in winter. This includes the subtropical jet, which influences weather development in Australia. Wind shear conditions (intense strong winds up high, low winds down below) are necessary for weather systems to "grow". However, in the subtropical jet, the gradient of this wind shear had been reduced because the jetstream has slowed by 9.4 m/s in the region of its maximum strength at an altitude of 12 km and latitude of about 30° S. Dr Frederiksen called this, "an enormous hit on the climate system". This reduction occurred between the 1949-68 period and the 1975-1994 period. Reducing the strength of the jetstream, he observed, results in changes in the nature of the weather systems.

Dr Frederiksen then described the two dominant winter weather systems affecting SWWA, both associated with eastward propagating storms. The first type of weather system (Type 1) had a big impact on SWWA winter rainfall in the early period. However, during the second period, Type 1 and Type 2 weather systems became equally likely to occur. Type 2 weather systems are much less likely to bring rain to SWWA. During the 1997-2006 period the first mode (Type 1) is even more reduced, by about 37%. Consequently there have been progressively fewer July storms that may result in rainfall for SWWA.

The growth rate of weather systems that affect SWWA has continually decreased since the first (1949-1968) period. At the same time, there has been an increasing tendency for storms to form further to the south, over the Southern Ocean.

As noted above, an important factor in the likelihood of storm development is atmospheric instability due to the wind shear. Storms develop when the vertical wind shear exceeds a certain critical value. The Phillips Criterion is a measure of wind shear, and provides an indication of the instability of the atmosphere. Importantly, there is 99% certainty that a (highly significant) downward trend in the Phillips Criterion occurred from 1950-1999 at a latitude of 30° S to 40° S.

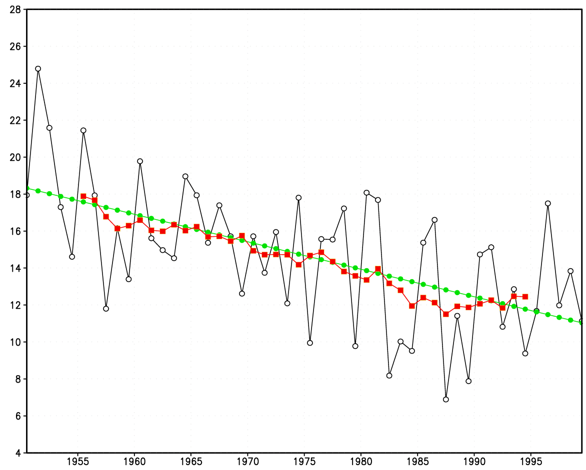


Figure 1 Reduction in the Phillips Criterion at 87° E, 30° S, in metres per second per year, 1950-2000.

Dr Frederiksen emphasised that this change in weather systems is not just a local phenomenon; reduced rainfall has occurred over this whole band of latitude. Conversely there is a band further south where rainfall has increased.

An examination of trends in July rainfall alongside trends for the Phillips Criterion showed that both observations and climate models indicate that a decrease of one metre per second in the Phillips Criterion translates into a six millimetre per month decrease in SWWA rainfall. Some climate scenarios indicate that, in future, continued large reductions in atmospheric instability are likely. This implies further reductions in the growth rate of storm track modes and SWWA rainfall. Some of scenarios indicate that future rates of rainfall reduction will be similar to what has already occurred.

Dr Frederiksen then turned to the topic of north-west cloud bands. An increase in the growth rate of weather systems associated with north-west cloud bands and with intraseasonal oscillations (another type of weather system) is associated with increased winter rainfall over central and north-west WA. Since the 1949-68 period, the growth rate of north-west cloud bands has continually increased: by 28.7% over the 1975-94 period; and 30.6% over the 1997-2006 period.

Dr Frederiksen explained that the various weather systems affecting WA's climate are complex. In the next stage of research he and his colleagues intend to do further work on disentangling the various causes of changes to the weather systems that affect WA.

2.2 Western Australia's changing climate

Dr Pandora Hope, BoM

Dr Hope drew upon results from across a range of IOCI projects to describe WA's climate and how it is changing.

Noting the obvious risks of making decisions based on erroneous climate information, Dr Hope emphasised the need for accurate and reliable observations of WA's climate. There were a limited number of stations from which data were deemed to be of high quality in NWWA. Under IOCI3, the coverage of existing high quality datasets was extended and their data quality improved. These accurate, climate-consistent observations of rainfall, temperature, clouds and tropical cyclones are crucial to establish a baseline against which to assess the risks of a changing climate.

Regarding rainfall, in NWWA there has been an approximately 200 mm increase over the past 50 years (1960-2010). As to the possible causes of this increase, a high proportion of rainfall is associated with tropical cyclone tracks, particularly in the central west. There is also credence to the possibility that aerosols (from the Asian "brown cloud" of pollution) are a driver of rainfall increase. In addition, over part of the North West there has been summer cooling of 1 °C over 50 years, and this could also be linked to changes in rainfall. The causes of rainfall change have important implications for management because if, for example, the Asian brown cloud is cleaned up, the rainfall trend could be reversed. A great deal more work remains to be done on these questions.

"There has been a drying in southern Australia, but also a drying around the hemisphere ... all models agree on drying, it's a signature they all capture well.'

--Dr Pandora Hope

Dr Hope then described that as a whole, Western Australia has warmed over the last 60 years, but in both the North and South West, *maximum* summer temperatures have reduced. As mentioned above, this cooling may be linked to shifts in the global circulation that could be transient. Thus it is worthwhile to consider the consequences of increasing temperatures. She illustrated how warming in WA could create conditions that would result not only in more warm spells like those currently experienced, but could also produce warm events that are currently outside our experience.

Regarding SWWA, there has been drying of 150 mm over last 50 years. The year 2010 was very extreme. Looking at Australia as a whole, that was the continent's second-wettest year; the Southern Annular Mode (SAM) was at its highest level on record and had its longest period in that phase. The year 2010 was also the warmest on record. Yet despite the wet conditions elsewhere in Australia, SWWA was at its driest on record. Dr hope asked, "Are we already seeing the conditions that climate models predict in the future?"

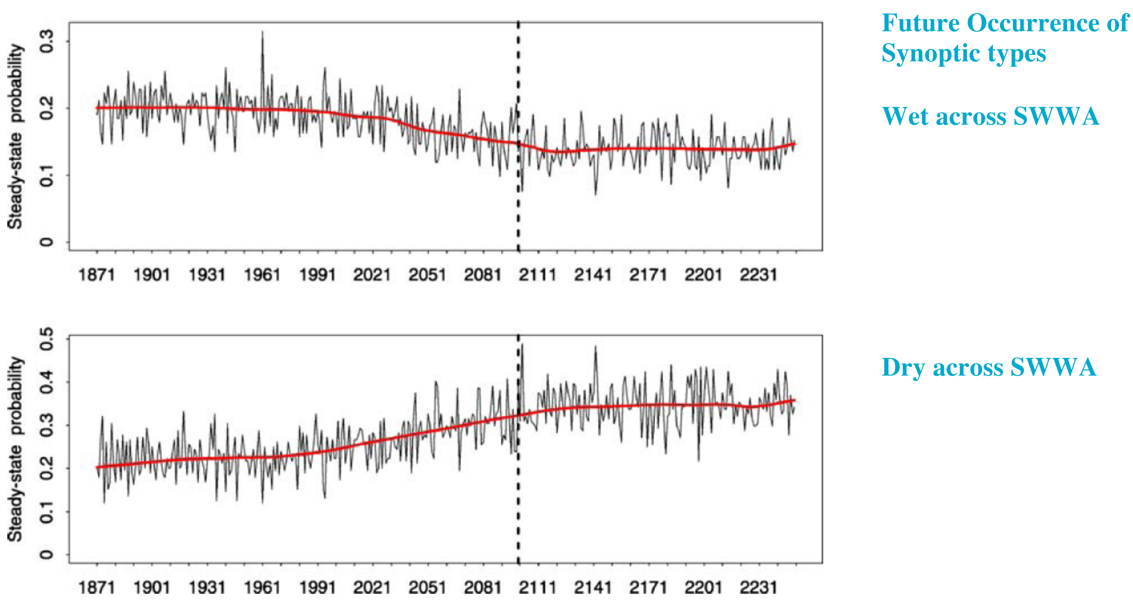


Figure 2 Changes to SWWA weather systems. The probability of synoptic types associated with wet conditions across SWWA is expected to continue to decrease over this century, whilst the probability of those associated with dry conditions is expected to increase. The vertical dashed line marks the year 2100, when forcing from greenhouse gases flattens in this simulation. (The associated climate signal flattens in response). Source: Bates et al. 2008.

Dr Hope also described changes to SWWA weather systems that have occurred over time with the observed drying since the 1960s. This has been due to a decrease in the types of synoptic systems that bring wet weather. Since 2000 the number of synoptic types associated with highs and extensive dry conditions over the region has increased significantly, by 32%. She noted that these historical changes also reflect the findings of the Intergovernmental Panel on Climate Change (IPCC); the observed drying around the Southern Hemisphere is a signature captured very well by climate models.

2.3 Modelling extreme events

Dr Aloke Phatak, CSIRO

Dr Phatak began by citing a Munich Re report which showed that in 2010, 90% of disasters and 65% of associated economic damages were weather and climate related. Although climate change is often described in terms of changes in averages, most of its social and economic costs will arise from shifts in the frequency and severity of extreme events. He emphasized that modelling extreme events is very challenging, and that these challenges need to be considered when projections of extreme events are used.

"Just as they say 'all politics is local', all impacts are local. So what are the local impacts? That's what we're looking at."

—Dr Aloke Phatak

Dr Phatak said that at a global scale the IPCC has stated that the frequency and intensity of extremes have already altered under climate change. According to a recent IPCC report, there has very likely been a decrease in cold extremes (number of cold days and nights), and an increase in warm extremes (number of warm days and nights). However, stakeholders are interested in what's going on in their own neighbourhood, and Dr Phatak remarked that just as 'all politics is local,' so too is the case that 'all impacts local'. For this reason, the work on extremes in IOCI is asking and trying to answer the question: "what are the local impacts of extremes?"

Dr Phatak distinguished between *extreme events,* "those climate events causing extraordinary economic and social (loss of life or livelihood) damage" and *climate extremes*, "the occurrence of climate variables near or beyond the upper [lower] limits of their observed historical values". Regarding extremes, we typically want to know "what is their expected frequency of occurrence?" To answer that question, researchers construct a model and extrapolate into the future to find, on average, how often an extreme event of a certain size or larger might be expected.

Dr Phatak illustrated the modelling of extremes with a simple example, using a roughly 50-year record of daily rainfall at Perth airport. He explained that using only the yearly maximum rainfall, it is possible to construct a return level/return period plot that provides an estimate of the recurrence interval of very extreme events. For example, this simple analysis shows that under the current climate, a daily rainfall of 110 mm would be expected, on average, once every 200 years.

Dr Phatak explained why extremes are hard to model. They are by definition rare events, and there is a paucity of data because only the data at the tails of the distribution are used. Also, in analyzing extreme events in this way, investigators are extrapolating beyond the observed record. For example, they may have only 75 years of data but make projections of, for example, 1-in-200-year events. As Dr Phatak showed, the further we project into the future, the larger the uncertainty becomes.

Dr Phatak provided two examples from the IOCI Projects 2.4 and 3.2, respectively: modelling extreme rainfall in NWWA; and modelling runs of high temperatures.

For extreme rainfall in NWWA, preliminary results providing projections for the current climate and under the A2 emissions scenario for two 40-year periods in the near future (2011-2050 and 2051-2090) are now available for the wet season half of the year. These results are based on a spatial model of extreme rainfall. (Dr Phatak reminded attendees that the climate modelling community is producing updated projections now and these can be used to refine current projections of extremes.) The results highlight projected increases and decreases in 1-in-100-year return levels for extreme 24-hour rainfall in NWWA. Dr Phatak cautioned that thus far the findings are preliminary.

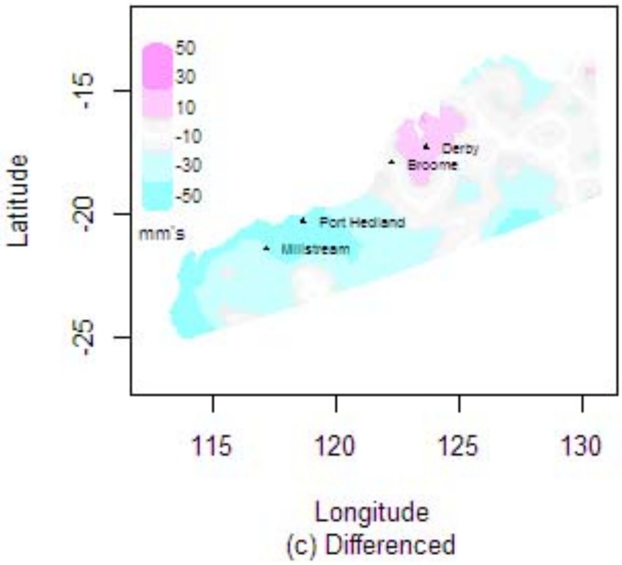


Figure 3 Projected changes to 1-in-100-year return levels of 24-hour rainfall in NWWA by 2030 (projected 2030 levels minus present-day levels). Magenta areas represent an increase in extreme rainfall; blue-green areas represent a decrease.

Dr Phatak also described the work on modelling of hot spells, which aims to examine how the intensity (how hot?), frequency (how many?) and duration (how long do they last?) of hot spells will be affected by climate change. This work is based on data from eight stations in SWWA and seven in NWWA across 50 years of observations. Dr Phatak showed some preliminary results at Perth Airport that show that the duration of hot spells has decreased, but the intensity has remained approximately the same.

In concluding, Dr Phatak said that much more work needs to be done on refining estimates of future extremes, and that additional work has been proposed in the WAWCP. He also emphasized the need for stakeholder feedback in any future research on extremes, participation that would be integral to ensuring the relevance of such research.

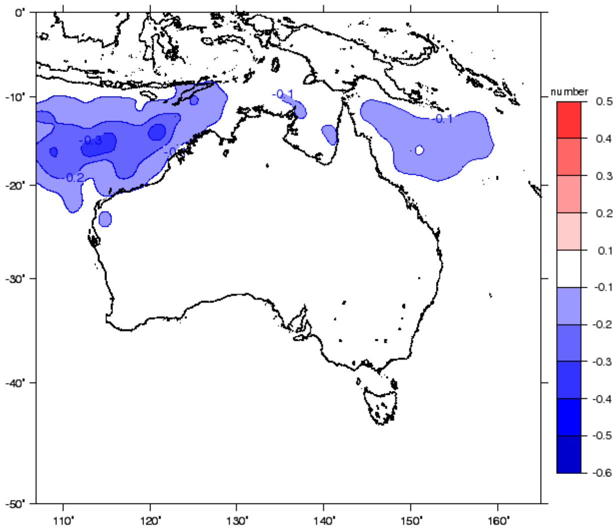
2.4 Tropical cyclones: informing risk management

Dr Debbie Abbs, CSIRO

Dr Abbs acknowledged that her presentation drew on work carried out under several banners to bring together knowledge on tropical cyclones. She began by describing the destructive nature of tropical cyclones (TCs): strong winds, storm surge and flooding. These impacts can result in losses to life and infrastructure, and the lost agricultural and industrial production can be very costly as well. She outlined the impacts under the major TCs Herbie (1988), Bobby (1995) and Monty (2004).

Regarding observational changes, she described rainfall changes over the 1970-2009 period, asking: "how much of the trend in NWWA rainfall is due to tropical cyclones?"

There is a large area of maximum rainfall centred on NWWA from TCs, and there is a large contribution from TCs to the top three rainfall events and extreme rainfalls each year. TCs and other closed low systems account for over 50% of rainfall and extreme rainfall over the majority of Australia, and over north-west Australia this figure is above 70%. Looking at damaging rainfall from TCs there is an increasing trend. Essentially, tropical cyclones are getting wetter, and are accompanied by more rainfall on a per cyclone basis. Over the past 20 years there has been an increase in the precipitation efficiency of TCs, particularly over northern Australia.



"Modelling projects an increase in the likelihood of most extreme cyclonic events, with a marked increase in integrated kinetic energy in future."

--Dr Debbie Abbs

Figure 4 Projected change in tropical cyclone numbers at 2055. There is a strong signal of a decrease in future tropical cyclone numbers in the Australian region, especially in NWWA.

Dr Abbs then outlined the features associated with tropical cyclones. These are low-pressure systems, with distinct cyclonic surface winds and a cloud-free eye. The eye wall is where the strongest precipitation and winds occur, with bands of heavy rainfall. Favourable conditions for TC formation are: low pressure systems over warm (tropical) ocean surface waters of more than 26.5 °C; and unstable atmospheric conditions that allow for large thunder storm complexes, clockwise direction of wind circulation, a small amount of vertical wind shear, and moist mid-troposphere.

Global climate models (GCMs) generally represent the large-scale features important for TC formation (i.e., the monsoon trough). However TCs are generally relatively smaller, and although the grid scale of GCMs (200-300 km) can represent the large-scale features of a TC, this cannot represent the important destructive features associated with the eye, across roughly 50 km. To represent these features of weather and climate of a region, including orographic and coastal effects, dynamical downscaling is frequently used.

Dr Abbs then described the techniques used for projections: the "direct detection technique" and the "empirical technique". In essence, they have developed methods to examine climate model outputs and search for weather features that have the features and behaviour of TCs. They test these methods to determine how well they work by comparing the results with observations.

The resulting projections suggest a decrease in the number of TCs in future, with a substantial decrease in occurrence for the WA region. They also indicate a southward movement in their decay, suggesting TCs will occur further south.

GCMs and 65 km simulation only indicate changes in occurrence and frequency and other "broad brush" projections, but cannot indicate changes in intensity or rainfall. To do this, high-resolution modelling is required that better represents the small-scale features of TCs: wind speed, rainfall, and the eye wall. This high resolution modelling of Australian region TCs uses a five-kilometre grid spacing and picks up the destructive elements of a TC. A good relationship was found between observations and these models for TC Bobby, for example, which helps to illustrate that the system used for downscaling is working.

Importantly, this modelling indicates an increase in the proportion of the most extreme cyclonic events, although the statistical significance of this change still remains to be established. These TCs show an increase in maximum wind speed, but also an increase in integrated kinetic energy of the storm, a measure of TC destructiveness. This suggests an increase in the frequency of larger storms, that is, characterised by a larger radius to gales and larger radius of maximum winds. Results also indicate an increase in precipitation intensity from TCs for both average and extreme rainfall rates.

Going forward, Dr Abbs said there is a need to conduct even finer simulations to get a full representation of the extreme winds associated with TCs.

3 Session 2: Managing Climate-Related Risks

This section provides summaries of the second session of Day 1 presentations by Dr Neil Carroll, Mr Julian Tapp, Ms Irina Cattalini, and Mr Dale Park,

3.1 Evidence based decision making in relation to facing the challenges associated with sea level rise and climate change

Dr Neil Carroll, City of Mandurah

Dr Carroll began by asking, "what would happen if we didn't do anything to intervene?" His approach to the challenge of sea-level rise and climate change has been to use evidence-based decision-making to inform any interventions and management decisions. Evidence-based decision-making derives predominantly from an approach used in clinical medicine and is also widely promoted by the CSIRO Climate Change Adaptation Flagship.[2] This approach entails the conscientious, explicit, and judicious use of current best evidence to assess the risks and benefits of treatments (or even non-treatment).

Dr Carroll provided photos and data for the City of Mandurah across a range of points in time. Concern about beach erosion has intensified in Mandurah; this erosion is real, but it is very hard to quantify the extent to which this problem stems from sea level rise or from normal dynamic coastal processes. Coastal erosion has been observed in Mandurah for decades, with seasonal cycles of low storm activity allowing natural beach recovery. The future impacts of seal level rise are likely to be gradual with increased frequency of severe erosive events.

Importantly, knowledge gained from past events and responses can be used to assist in coping with future change. Dr Carroll commented on long reflective sea walls and their effects. While they usually offer good protection for land and infrastructure behind them, they generally result in severe loss of sediment from the beach in the longer term, which is a poor outcome for beach users.

"Coastal erosion is a long standing and labile process with unpredictable seasonal variations. Historically, beaches have been subject to intermittent severe erosive events.

Knowledge of what has happened in the past can assist with what is likely to happen in future."

--Dr Neil Carroll

He described the importance of a partnership to examine climate change impacts for the whole area, not just a single site. He also emphasized the importance of acquiring local data to calibrate models, and described how acquiring more data can improve the precision of models and therefore future interventions. He said there is also a need to improve scientific data and make this information more site-specific. Dr Carroll expressed surprise at how few people rely on scientific journals in this regard, and illustrated the many relevant journals currently available.

Dr Carroll said that he is involved in the collection of observations about rising water levels and swell direction, and that this information is added to DOT (Department of Transportation) data. The vegetation line is also an important indicator, one that assists in determining the rate of recession, with a definite trend of recession being observed. He noted that the frequency of flooding events of a given magnitude is on the rise.

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[2] http://www.csiro.au/files/files/p123g.pdf

If a protective wall is placed in front of a property, he observed that the local residents could assume this will effectively spell the demise of their beach. Dr Carroll said it helps to explain this possible outcome to residents when it comes to decision-making. With regard to erosion, those in charge of management need to know where sand is being redistributed, and move it back.

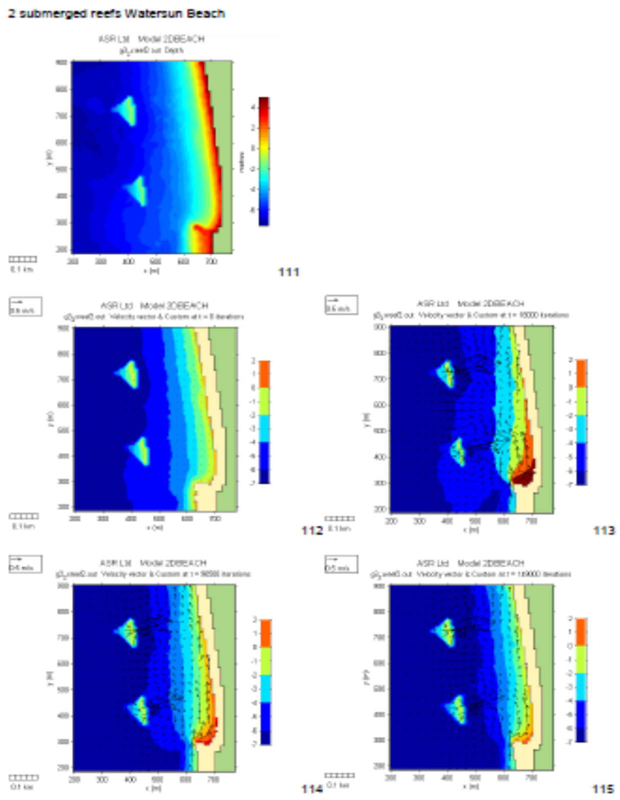

Figure 5 Beach evolution modelling at Watersun Beach, including two submerged reefs.

In managing all this, there is a need to bring the community along by showing them good quality data, and by showing them that observational evidence from the past has been examined, to allow for better predictions of the future. It is also possible to achieve solutions that increase social amenity. There is no "one glove fits all" solution — there is a need to be flexible. For example, zones with natural protection may not actually require new protection.

Dr Carroll said that with each approach it is likely that someone has tried it before. He emphasized the need for "softer technology", an approach still in its infancy. Highlighting new technologies, he said sea level rise would not be stopped by interventions so there is a need to make structures that will float and adapt to a climate. There is a need to become more innovative than simply resorting to "putting up brick walls".

Dr Carroll emphasised the need for careful observation, and the need to budget and plan for sea level rise, with contingency plans built in. Furthermore, one must be prepared to make decisions on what to defend. When the decision is made not to intervene, there will be losses, because we cannot — and do not want — to protect everything.

3.2 Industry perspective: changing extreme weather events and potential impacts for our projects

Mr Julian Tapp, Fortescue Metals Group (FMG)

Mr Tapp began by saying that it is important to understand what it is that they are seeking to protect. Fortescue's main mine is a huge flat sheet of iron ore, about 200 km long and 8 km wide. The resulting mine excavations are shallow troughs much more susceptible to filling up with rain. Regarding risks to machinery, for crusher machinery there is some risk from extreme events. Mr Tapp also described train unloaders. This machinery is typically situated in a pit 15 m under ground and is vulnerable to flooding; once flooded, expelling water is difficult.

Mr Tapp described a review performed by his company to assess exposure to climate change. They examined potential risks out to the year 2030, and restricted the scope to critical infrastructure. They sought to address the possible effect on existing and planned operations. He noted that planning on a timescale of 20-30 years limits the company's risk exposure.

Figure 6 At mine sites, rain that persists over days carried the highest risk rating to operations because this may disrupt production, with serious economic consequences if this disruption persists for two days or more. This type of event is expected to occur at least once per year.

Mr Tapp described the railway infrastructure that services mine sites. These lines are typically approximately one metre above ground. It is vital to know where to locate a bridge for these rail lines, so that water can bypass the barrier created by the raised track. One critical concern is that some rail line culverts may not be able to cope with rain. If water builds up behind the railway line embankment, it may accumulate until it passes over a dip in the railway, taking out the track and the railway. Water flowing over these embankments is therefore a large risk. There is also concern about low levels of rainfall that occur over a long time period, because this causes roads to become muddy and prevents transport vehicles from reaching their destinations. Mr Tapp made the observation that two days' disruption could mean approximately 100 million dollars coming out of production.

Mr Tapp emphasised that water is a critical area of concern; substantial money is involved in moving water around to permit these mines to operate. For tailings dams, which are essentially holes in the ground, this question is not as critical.

FMG have examined climate risks and are planning for adaptation. They also recognise a need to continue examining this plan to assess how it will require modification in future. Mr Tapp furthermore emphasised the need to look at the consequences of catastrophic failure. It is vitally important to assess the worst outcome, and layer that onto what is going to happen in terms of the climate.

"Changes in extreme events are more important to us than averages."

--Mr Julian Tapp

Mr Tapp said that changes in extremes are more important than changes in averages. FMG are very interested in the implications of climate change impacts on cyclones and also need to know more about storm surges. They are most interested in regional data and finer-scale models. They need to know about patterns of rainfall, not just cyclones. Changes in rainfall intensity pose the greatest potential risk but also have a very high level of uncertainty.

3.3 Vulnerability and resilience: a community service perspective

Ms Irina Cattalini, Western Australian Council of Social Service (WACOSS)

Ms Cattalini began by providing background on WACOSS and on WA's social services sector in general. She noted that climate stresses associated with housing affordability are a major problem for a proportion of the population. She described the climate change risks associated with this stress (poor thermal quality of homes, their location and connection to public transport, and locational risks associated with extreme weather events). She also noted the climate risks related to homelessness (increased incidence of extreme weather events, and the spread of vector-borne/mosquito-borne diseases). She observed that WA has the second highest rate of homelessness, this problem being greatest among 12-24 year olds, older women and Indigenous people.

Ms Cattalini said energy affordability is another challenge to consider with regard to climate change adaptation. Given the increasing cost of power, she emphasised the need, under climate change policies, to consider the costs of basic essential services. There is also an equity perspective: she said that it would be undesirable to leave out lower-income groups because they can't afford energy technology upgrades. She further noted that these groups must spend a greater proportion of their income on power.

"We don't know what tips people over the edge into extreme risk for fuel poverty, for example."

--Ms Irina Cattalini

Ms Cattalini also outlined the disadvantages related to climate change for people affected by mental illness, noting that drought and extreme weather can contribute to mental illness, as can the anxiety of an uncertain future under climate change.

She noted Australia's changing demographics, with the expected aging of the population and concomitant increase in the proportion of people with disabilities, and observed that these trends will interact with climate change risks. She said it is important to consider how these people would be affected by heatwaves, for example, or by the underutilisation of energy, or how their lack of mobility or social isolation could increase their vulnerability under extreme weather events.

Another area of concern for economically disadvantaged groups is food access and affordability, and the effect of carbon price on food affordability. Challenges could also arise around accessibility to food if, for example, flooding cuts off food supplies.

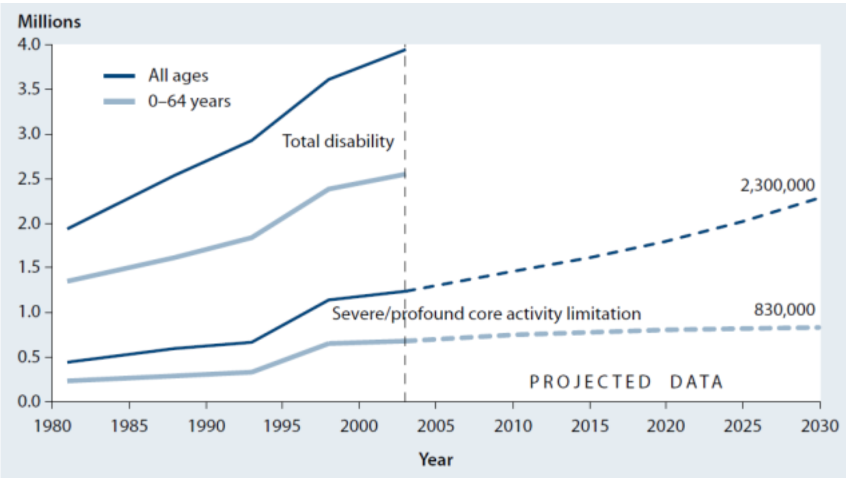

Figure 7 Demographic changes in disabilities will interact with climate change risks. By 2030 the number of Australians living with severe disability will increase to 2.3 million because of population growth and aging.

Source: The Australian Government 2010 Intergenerational Report

Regarding equity and social outcomes, Ms Cattalini observed that the more equitable a society is, the more resilient that society will be. For example, it is not known what tips people over the edge into extreme risk for fuel poverty. Addressing social inequity builds community resilience and capacity to respond and adapt to challenges such as climate change. Ms Cattalini looked at issues of complexity that arise as the different risks/risk groups combine (heat stress, aging and disabled populations, poor quality housing, increasing energy costs, bushfire risk, poor mobility and social isolation).

For example, living in poorly designed and poorly heated homes affects physical and mental health, especially amongst young children and the elderly. Links also exist between household temperatures and cardiovascular and respiratory illness, and death. Therefore, if climate change adaptation is to be successful, there is a need to improve energy efficiency and affordability of housing stock, and to overcome social isolation. Good measurement and reliable information based on real experience are also important requirements toward the goal of adaptation.

Ms Cattalini also emphasised the role of community social services in prevention and preparedness for disasters and extreme weather, and in support of communities through to recovery. Community services are grossly under-resourced to deal with shocks such as the Queensland Floods. More services must be engaged and made aware of the risks such shocks pose to their clients, and informed as to where these risks are likely to occur.

Future directions include the need to better understand at-risk populations, and to understand how complex needs interact under climate change and our adaptation to it. Ms Cattalini said there is also a need to better determine and support community service organisations' role in climate change adaptation and disaster preparedness.

3.4 Managing climate-related risks from a farmer's perspective

Mr Dale Park, Western Australian Farmers Federation

Mr Park's presentation aimed to outline farmers' attitudes and their research priorities, i.e., what this stakeholder group wants from climate researchers in the future. He began by observing that views on climate change are quite polarised within the farming community.

He then provided an overview of WA agriculture, stating that it is very much an export-oriented industry; and furthermore that since 2002–03 almost 70% of exports have been to Asia. He observed that farmers tend to be incurring progressively more debt, that they are doing more and more with less investment, and with a low return on capital. Lower equity levels are a problem. Moreover, WA loses a third of its farmers with each generation.

"Research is an answer, not a popularity contest. Politics is what we're going to do about the problem."

--Mr Dale Park

On the "up side", there are opportunities. A growing middle class in Asia could spell an increase in demand, which is good for farmers. Farmers would need to adapt to an altered climate but could also take advantage of mitigation opportunities and reduce CO_2 equivalents per output. Studies show that mitigation is cheaper than adaptation. The federal Carbon Farming Initiative, for example, can make farmers part of the solution.

With regard to climate change, Mr Park noted that in the farming community, there is a dialectic of research versus speculation. However, he stressed that research results related to climate change should be treated as an answer to a question, not the subject of a "popularity contest". Politics, on the other hand, is what we're going to do about the problem.

He emphasised that, for farmers, short-term economic imperatives tend to overshadow long-term issues of climate change. There is also the challenge of understanding uncertainty, given that localised effects of climate change are in many cases still uncertain. In addition, there is the challenge of distinguishing between change and variability. Farmers are very dependent on weather and short-term effects. Trends are not always borne out at a local level, and local effects may mask climate trends in some cases.

Looking at rainfall variability, he asked, what do the averages really mean for farmers? Summer rainfall can be good on land with heavy soil because it can store soil moisture. However, in sandy landscapes farmers really need the winter rain. In 1969 the first really big drought occurred in Western Australia after 20 years of reasonable rainfall, and 2010 was the worst year on record. Yet farmers have adapted to reductions in rainfall with the help of better technology, and have learned how to live with this challenge.

Coming into the 1990s, it emerged that price risk associated with harvests became less of a risk than production risk. That is, if farmers had pre-sold their harvest and could not actually come up with the product, they had to go and find this supply. As a result of this shift in vulnerability to risk, the practise of forward selling has declined.

Research priorities for farmers include preparedness for risk management, changes to core business, the need for income diversity ("it's not just about wheat and sheep"), the Carbon Farming Initiative, and dependence on external factors. Other research priorities centre on the type of enterprise farmers conduct, its rainfall dependence and how extreme events, frosting, water supply, and infrastructure and approvals affect it.

"It's all about risk management. It's about keeping farmers on the land."

--Mr Dale Park

For example, a farmer effectively risks his farm every year in order to put a crop in. Farmers need not wait for rain, thanks for modern machinery that plants into hard ground. But if rain does not eventuate, Mr Park said a farmer is "in deep" because the costs of putting the crop in exceed the value of the farm. He said farmers are the best parties to work out where and what to farm; he argued that right-to-farm legislation does not work.

In terms of forecasting for agriculture, Mr Park said it would be most desirable to have the ability to predict six months in advance what the season is going to be like. This would allow farmers to asses whether or not it would be worth sowing a crop. "It's all about risk management," Mr Park said, "It's about keeping farmers on the land." He observed that rainfall predictions have improved significantly over the last few years.

Mr Park summed up with the observation that farmers require an understanding of predictions but also of the uncertainties inherent in these predictions; it cannot be assumed that what is predicted will actually happen. He said broad climate impacts are understood, but less so at the local level. Improving the understanding of the difference between change versus variability is a challenge. Research is needed to assist farmers to produce in this new environment; and research must provide income/food production opportunities for farmers.

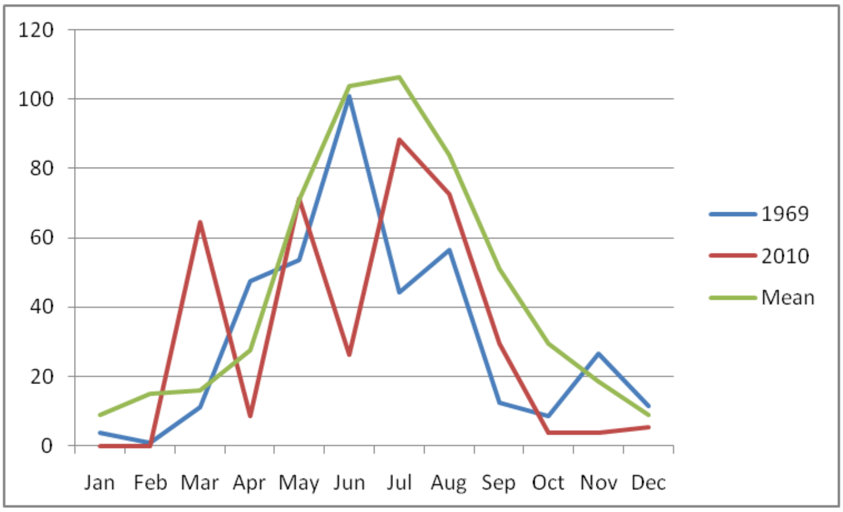

Figure 8 Annual rainfall for Badingarra (mm).

4 Session 3: Bridging the Gap for Effective Risk Management

This section contains summaries of presentation from the third session of workshop Day 1, provided by Dr Kieren Moffat, Prof. John McAneney, Dr Ailbhe Travers. It also summarises the closing comments made by Dr Bryson Bates.

4.1 Social dimensions of managing climate risks and climate adaptation processes

Dr Kieren Moffat, CSIRO

Dr Moffat provided an overview of the Science in Society Group (SISG) and its contribution to research under CSIRO Climate Adaptation Flagship Themes 1 (Pathways to Adaptation) and 4 (Adaptive Primary Industries). He presented work conducted by SISG regarding adaptation of the mining industry, and its attendant communities, to climate variability and change. This is work being conducted in partnership with the CSIRO Minerals Down Under Flagship.

"... critically, we have also demonstrated the important role that sound and trusted information plays in these social processes – but that information alone is not enough to help people and industries make good decisions."

--Dr Kieren Moffat

Climate change is a physical problem that entails a social challenge. The research into these social dimensions will help inform sound decision making to be taken by individuals, groups, industries and regions. Dr Moffat noted that risk is a social construct, and likewise our responses to it are informed by existing beliefs about climate change; understanding of issues, risks, and adaptive capacity; and drivers of decision-making processes.

Speaking to the problem of inactivity on climate adaptation in the mining and minerals sector, he noted results from industry and local government surveys that pointed to the following reasons for inaction: waiting for someone else (government, others in the value chain) to act; organisational culture that doesn't support change; a lack of information and resources; and a degree of scepticism about climate change.

For example, survey respondents from mining companies were generally less likely to believe in climate change, and reported uncertainty regarding the likely relevant impacts of climate change. On the other hand, local government respondents reported stronger beliefs in climate change but lacked the resources to adapt. Both of these types of entities are not doing a great deal about preparing for climate change — but evidently for quite different reasons.

How can these deficits best be dealt with to move forward? One way Dr Moffat's group explores this question is through workshops. For mining, it is likely that future climate change and extreme weather events will have impacts through the mining value chain, by causing lost revenue to mine operations and lost work to contractors; through damage to utility infrastructure (e.g., power and water), rail operators, and ports that may see less throughput; and damage from cyclones in some regions.

For local and state governments the concerns for local community health and wellbeing, social infrastructure and planning for recovery after extreme weather events will be critical. There is also the very real threat that the effects of impacts on mining operations will flow through to local communities -- as was the case during the 2008 flooding of the Ensham mine in Queensland, which resulted in release of untreated water into local watercourses, downstream impacts, and subsequent tightening of water release regulation for the industry.

The workshop process allows all potentially affected members of the mining value chain (i.e., companies, local and state government, utility providers, contractors, academics and climate scientists) to come together to explore risks and implications of regional climate information products at different time scales, and to examine how the resources and capacities of these different groups may support collaborative adaptation planning.

Dr Moffat also discussed the decision making process that groups and individuals go through in response to the risks and implications of future climate change. He presented a model developed by CSIRO colleagues reflecting decision making that leads to incremental or transformational change, currently being tested in two Victorian rural communities. Incremental change is typified by small adjustments to behaviour and activities in response to current changes in climate and attitudes toward the issue of climate change. Transformational change reflects a more dramatic response to perceived future climate risks and opportunities. Dr Moffat provided the example of transformational change by the peanut industry in Queensland that had made the decision to move, in large part, to areas in north Australia where the climate is expected to become wetter in the future. An example of a more incremental type of change would include a switch in the type of wheat farmed.

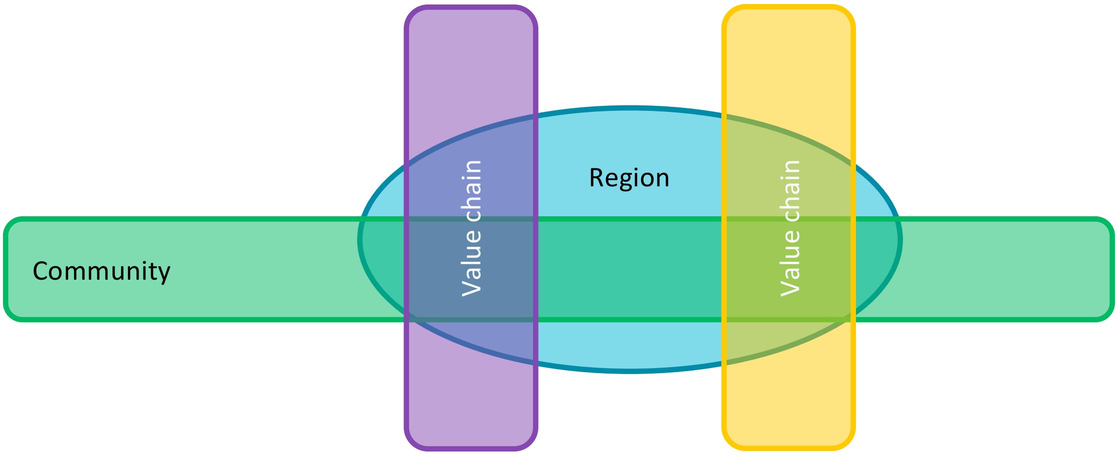

Figure 9 Regional contexts are complex, especially in mixed land use contexts where resource contests (e.g., for water or energy) between industries may be exacerbated under climate change. Here a regional response makes sense: crosscutting value chains, industries, and communities explore issues that are spatially located.

Results to date from research testing this model in Victoria revealed that in viticulture, drivers for change include awareness of climate change, and tying water availability and temperature change to future success. Drivers for change also included success in prior adaptation strategies and trusted information. Constraints on decision making included a level of uncertainty about climate change, and co-occurring social issues, such as aged care, health and well being of community, and access to education, issues which were seen to be higher priorities in strategic planning processes for the region and community.

The next step toward decision-making on adaptation is to consider the regional context. This is important because, in reality, these issues are embedded in regions where mixed land use and multiple interests may contend. Constraints on scarce resources such as water could bring about inter-group conflicts if scarcity is exacerbated under climate change. But the picture is complicated by strongly held identities in some regions which may not allow the accommodation of multiple, different roles; for example, being a vintner and driving a coal truck may be psychologically incompatible. Forces that threaten or challenge deeply held identities will be resisted. We need to think about how these different value chains and groups intersect, on a regional level in the same geographic space, and how communities interact with them all.

Dr Moffat ended his presentation by referring to the Hunter Valley in New South Wales as one obvious Australian regional location where industrial land use and community values around future development intersect and provoke conflict. In a future climate-constrained world, how is it possible to bring premium wine industry, coal mines, coal seam gas and strongly held community values around sense of place to collaborate, resolve conflicts, and adapt? The solutions will be human ones, although technical information will support negotiation and decisions.

Dr Moffat said such socially complex regions emphasise the importance of comprehensive and well-thought-through social processes to inform, engage and enable people to work together to adapt.

4.2 Climate change, natural disaster losses and insurance implications

Prof. John McAneney, Risk Frontiers

Prof. McAneney began by describing Risk Frontiers which, amongst its other goals, provides an independent and local capability to research natural hazards and develop catastrophe loss models for the insurance sector.

Prof. McAneney pointed out that the main concern with natural disasters is the accumulation of wealth in disaster-prone areas. This is the most important driver of future economic disaster damage. Risk is not simply a function of climate, and risk managers, underwriters, emergency managers, and governments need to acknowledge this fact. They also need to think more about big events possible under our existing climate and how these may affect their businesses or constituents. If we are serious about reducing disaster losses, he says, then we need risk-informed land-use planning.

While we know that air temperatures are going up, and that sea level is rising, we know very little about how global warming will influence local weather extremes, e.g. extreme rainfall and flooding, hailstorms and tropical cyclones.

> *"The accumulation of wealth in disaster-prone areas is, and will always remain, by far the most important driver of future economic disaster damage."*
>
> **--Prof. John McAneney**

The latest annual assessment of global economic losses due to natural disasters from Munich Re shows 2011 to be the highest on record. This cost includes those arising from the Tohoku earthquake and tsunami and the Christchurch earthquakes. In most years, it is weather-related disasters including hurricanes that account for most of the damage and these costs have also been escalating. However, Prof. McAneney asserts that the key issue here is the placement of the number and value of assets in hazard-prone areas and that the increasing property losses are not due to an increase in the frequency and magnitude of natural perils.

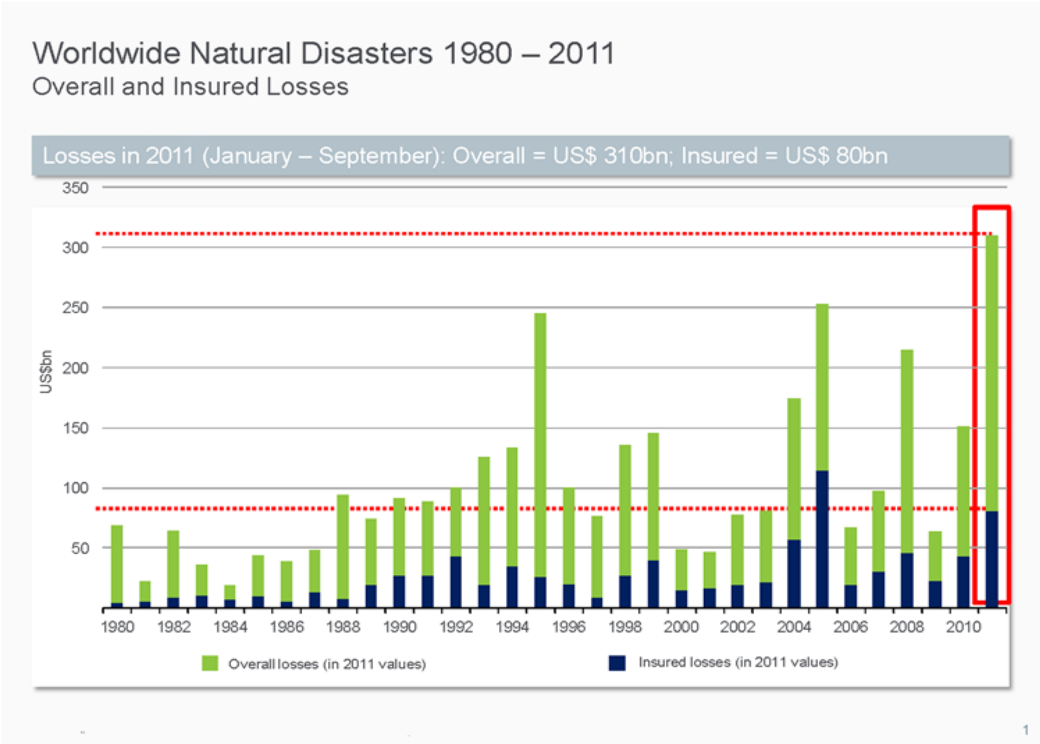

Figure 10 Overall natural disaster losses exceeded US$300 billion in 2011.

Source: Munich Re

For example, the rising losses caused by hurricanes since the 1970s cannot be explained by an increase in the number and intensity of land falling events. Prof. McAneney described the normalisation process that is widely used now to capture the influence of known increases in coastal population, wealth, and inflation on such disaster costs. He illustrated this with an image of radical growth in development in Miami Beach, Florida, that has occurred since 1926.

A plot of normalised insured losses for Australian weather-related events provides an estimate of the losses as if all events had impacted upon 2006 exposure; it shows good evidence of El Niño Southern Oscillation (ENSO) cycles but no obvious trend over time. This is also the case for normalised Australian bushfire property losses since 1925. The international peer-reviewed literature now reports similar results for some 30 other studies on various perils and in other jurisdictions.

The clear conclusion is that societal factors are driving the increase in disaster losses: where people live and how they build. Prof. McAneney considers that insurance premiums could provide a market signal to encourage better land use planning practices. The corollary to this is that unless homeowners are charged risk-adjusted premiums, then changes in land-use planning or investments in mitigation measures are unlikely, and the cost of natural disasters will continue to grow.

Given that no climate change signal is yet apparent in the disaster losses, Prof. McAneney then explored how long it might be until a climate change signal is detectable. He used U.S. hurricane losses as the example. According to a new paper by Ryan Crompton at Risk Frontiers and others, this timeframe will be somewhere between 120 to 550 years. This estimate is based on a projected 81% increase in category 3 and above TC activity in 80 years, and an emergence timescale in the basin-wide cyclone activity of 60 years. Among the assumptions and caveats for these timeframes is that only one emission scenario was employed, and future sea level rise and related adaptation were ignored. The wide variation in the emergence timescale for the signal arises from the different climate change models used to set the boundary conditions in the hurricane activity modelling that was undertaken by the Geophysical Fluid Dynamics Laboratory at Princeton University.

Prof. McAneney summed up by restating the importance of better land-use planning as the key to reducing the impact of disasters. He said risks need to be reduced well in advance of emergency situations, and that it is unwise to rely on risk communication, early warnings, and new technology as a panacea to achieve reductions in vulnerability. The loss of life in the 2009 Victorian bushfires stands out as an example of what is possible even with near perfect weather forecasts.

4.3 Stepping stones across rapids: building a bridge between climate science and users

Dr Ailbhe Travers, Coastal Zone Management

Dr Travers spoke to the workshop about her practical experience as a climate change consultant engaged in vulnerability and adaptation assessment work in Western Australia. She began with a brief overview of the variety of projects her company, AdaptiveFutures, undertakes locally, nationally and internationally dealing with differential climate change data availability and integrity. She explained that it is important to understand that the various "contexts" in which climate change adaptation decisions are made require information at different spatial scales and degrees of accuracy.

Dr Travers went on to outline the sources of climate data that AdaptiveFutures commonly use in the risk assessment process within Australia. She said that the CSIRO/BoM 2007 Climate Change in Australia report was the key source of climate projections used in their work. However, she explained that the continued emergence of climate change science and the need for expert interpretation meant that personal communications with climate change scientists was vital. Many of the experts consulted locally are currently involved with the IOCI program.

After providing a brief overview of the risk assessment process adopted through the Australian Federal Government's Local Adaptation Pathways Program (LAPP I & II), Dr Travers went on to discuss the issues that clients (largely local governments) encounter when trying to apply available climate science within this framework. Firstly, a lack of consensus on an appropriate sea level rise figure for planning at a local level has been a difficulty. She noted that this should be less of an issue in the future given the recent release of the State Government's updated coastal planning policy. She explained that local governments wanted direction on what "numbers" they should be using across the board as well as appropriate timeframes within which they should conduct their assessments. While they recognize that it is not a simple case of providing "black and white" figures, there is a need for a position statement with respect to directions of likely future change and the magnitude of this change. Dr Travers said she realized the paradox in the requests for "more information and more accurate information" as well as the statement that "we can not wait for science to provide us with the answers – we have to act now".

> *"Science products are often disconnected from the reality of risk decision frameworks."*
>
> **--Dr Ailbhe Travers**

This led Dr Travers to discuss the role of the climate change consultant in the "middle ground" between climate scientists and end users who want to make "good" adaptive decisions (most often governments and international organisations). She stressed that this could be a difficult position as end users (clients) are requesting information on future projections that are useable, credible and understandable while scientists are largely unable to provide "quick fix answers" to these client requests due to requirements to ensure their work is rigorous.

In summarizing existing difficulties in using available climate science in an effective adaptation decision-making, Dr Travers said there is no doubt a disconnect exists between data products from scientists and what is needed to make a balanced decision. She cautioned that climate scientists should remain mindful of decision drivers and that science products may often not align with the decision risk framework of many users, in which climate is just one factor.

She noted that businesses and governments have always made decisions under uncertainty, and it is important to remember that climate change is really nothing new in this regard. Importantly, Dr Travers said that in her experience, climate science is "invisible" to most end-users. In light of this, she emphasised the need for end-user driven, actionable science into the future, and stressed the need for an appropriate translation of the good science already available. Ultimately effective decisions with respect to climate change adaptation will only eventuate if users drive the science being done, instead of simply being made aware of it once it is complete. This entails a two-way relationship between scientists and stakeholders that may lead to research questions that might not otherwise have been asked.

4.4 Closing comments

Dr Bryson Bates, CSIRO

Dr Bates closed the day's presentations by expressing his appreciation for the Hon Bill Marmion's talk, which he said highlighted the history of climate science, climate forecasts, and the importance of these to planning for desalination plants in the South West. Mr Hendy Cowan talked about the importance of climate science communication, and of lobbying upwards to support climate science research. He noted that the ACIL Tasman report demonstrated how IOCI has provided value for money. Mr Robert Atkins described climate change and related bushfire impacts on biodiversity, and the importance of risk management.

In the first session, Dr Frederiksen emphasized that the changes we are seeing in WA are part of a hemispheric phenomenon. Dr Hope's talk highlighted the importance of high-quality data, the role of aerosols, and touched on WA's changing weather systems. In his talk on extremes, Dr Phatak explained why these aspects of climate and weather are so hard to model, and described intensity-frequency-duration relationships. Dr Abbs' talk described results, so far based on one climate model, outlining a possible increase in the destructive potential of tropical cyclones in future, and an observed increase in the precipitation efficiency of tropical cyclones.

In the day's second session, Dr Carroll emphasized that erosion is part of a natural cycle, and highlighted the importance of asset management. Mr Tapp described how top risks to FMG's mining operations are storm surge and changes in rainfall patterns. Ms Cattalini revealed how poverty makes Western Australians more vulnerable — whether it is from thermal stress, bushfire risk or disease risk. And in the final talk of this session, Mr Park described the research interests of farmers, including lead times for seasonal forecasts.

In the third and final session, Dr Moffat described how climate change adaptation needs to be a negotiated process. Dr McAneney made some good points about attribution of climate related risks. And Dr Travers pointed out that there needs to be a discussion about scenarios used. Dr Bates noted that initiatives like Climate Futures can help address this disconnect between scientists and users. He acknowledged that it is important to remember climate change is only one of many risks people need to consider.

Dr Bates thanked the speakers and said he ranked the day as a success. He noted the thoughtful questions, and the high level of engagement and interest participants showed in the day's presentations.

Part 3 Summaries of Day 2 Presentations

This section provides summaries of speeches and presentations from the second day of the IOCI3 workshop. This includes summaries of morning opening speeches, two sessions of detailed updates of IOCI3 research, and a final session that included a presentation on IOCI3 communications.

1 Morning Opening Speeches

Mr Holper opened Day 2 of the conference by introducing the Hon Carmen Lawrence, who has done valuable work on the interplay between human behaviour, climate science and climate scepticism. The Hon Hendy Cowan and Dr Bryson Bates gave additional opening presentations.

1.1 Opening address: What do we need to know about human behaviour to reduce CO_2 emissions?

The Hon Carmen Lawrence, University of Western Australia

Dr Lawrence stated that her work addresses the gap between science and politics. She said that whilst it is often assumed that if the facts were laid before people they would act on them, this is not the case. Efforts to promote behaviour change and attitude change are therefore also critical. She also noted the many drivers of environmental degradation, including rising consumption.

Dr Lawrence said that debunking myths is required. Some people have the view that if they accept climate science, they will be threatened. And whereas most people agree they are concerned about climate change, if you push harder you find that addressing this problem is quite low on their order of priorities. Many people tend to assume someone else will pay the necessary price to do so.

There is also an ethical question involved: the developed world uses most of the world's resources, yet we are asking developing countries to adapt while continuing to burn fossil fuels ourselves. There will probably be an acceleration of greenhouse gas emissions, but acting later will cost us more than acting now.

"The challenge of climate change calls for the practical application of social science ..."

--**Hon Carmen Lawrence**

Dr Lawrence observed that surprisingly few people actually understand what carbon dioxide is, and one study showed that only 30% actually understand how it relates to climate change. This creates a problem when one proposed solution is a carbon tax. Many who thought it was "okay" to say they want action do not understand the association between climate change and carbon emissions. So when it no longer appeared so socially desirable to support this solution, people backed off.

Dr Lawrence noted the recently released work on the debunking of climate myths by Stephan Lewandowsky of the University of Western Australia. This work outlines which methods of communication will work and which will backfire. She observed that the literature on attitude and behaviour change is not yet systematically applied, and not applied by policy makers.

What do we know, and how can it improve? She observed that, even when people are well informed, if one looks at what they actually do, there is still a big behaviour gap. Dr Lawrence said that it is possible to use social influence and ideas about citizenship. Many persuasive arguments have been focussed on costs, for example, the costs of a carbon tax. But what about the benefits? For example, the benefits related to reducing emissions include not spending time sitting in cars and reducing particulate pollution (greater freedom and clean air). Another approach is to say, "This is a good citizen here who is pulling their weight". This also puts the focus on the positive outcomes of action instead of the burdens.

Dr Lawrence noted that local state authorities tend not to make is easy to sign up to green power. But what if this status quo bias (inertia) were reversed and people were signed up automatically? The proportion of subscribers could be flipped simply by changing the default option. In California for example, people consume 40% less power than the U.S. average. Utilities get paid to reduce power use, a policy that was prompted by brownouts. She said utilities were compelled to go out and ask people to use less energy, and ran a "Flex Your Power" campaign. Some people also reduced energy use because it was “the right thing to do”.

Dr Lawrence emphasized that there is not nearly enough dialogue about how we relate to one another in this space. The challenge of climate change calls for the practical application of social science, that is, people who understand cognition and behaviour change. She argued that one should always include psychologists and social scientists in climate change communication.

1.2 Welcome

Hon Hendy Cowan, Chair, IOCI3

Mr Cowan welcomed delegates and speakers, with a special welcome to the Hon Carmen Lawrence. He touched on the main points of the previous day's presentations and introduced upcoming presentations. He then outlined the history of IOCI, which was initially begun to investigate early winter rainfall declines in SWWA. He described how IOCI has linked these changes to large-scale circulation changes that have led to a shift in SWWA's weather systems, and noted that further rainfall declines may be expected. Mr Cowan said this information has been vitally important to assist water managers as they implement adaptive measures. He then outlined the broadened scope of IOCI3, which has sought to analyse both rainfall and temperature variability and change across the whole state, including NWWA. The number of stakeholders for IOCI has also dramatically increased.

"IOCI is a robust and independent organisation that can provide independent scientific knowledge."

--**Hon Hendy Cowan**

Mr Cowan outlined some research accomplishments of IOCI, including papers in scientific journals and reports to be made available on the IOCI website. He also outlined the positive results of a value-for-money assessment of IOCI carried out by ACIL Tasman in June 2011.

Mr. Cowan outlined the day's upcoming presentations, and commended the scientists, saying, "As I have shown, your work is held in the highest regard by your peers and will no doubt assist our stakeholders to effectively adapt to the changes that may take place in Western Australia’s climate."

1.3 Overview of the science program of IOCI3

Dr Bryson Bates, CSIRO

Dr Bates provided a brief overview of IOCI3's role, objectives, study areas and themes. He noted with pleasure the results of the ACIL Tasman review of IOCI, and outlined its major findings: IOCI's good return on investment, the large body of knowledge it has built up on SWWA's climate, and the notable uptake of this information in the water and agriculture sectors, and some uptake in other sectors such as mine safety. He noted that IOCI has been emulated by similar initiatives in other states, and acknowledged that more effort is required under IOCI in the area of communication.

Dr Bates outlined observed changes in WA's climate, noting that these are not merely local effects; rather these changes appear due to a combination of local and hemisphere-wide effects. These include a more stable atmosphere over SWWA; increased frequency of north-west cloud bands during winter; fewer deep low-pressure systems since the 1970s, and more high-pressure systems since 2000.

In terms of rainfall decline, Dr Bates outlined the decline in the number of wet days in SWWA, the rainfall amounts, and the year-to-year rainfall variability. Over the past five to ten years, the May-July rainfall decline has intensified and expanded.

Turning to explanations for SWWA rainfall declines at the regional scale, he noted that a winter increase in mean sea level pressure, and a decline in atmospheric moisture in winter and spring are important. Dr Bates noted that after three generations of climate models, the direction of projected change is still the same for SWWA, with these models indicating that similar or larger declines in winter rainfall will occur in future.

Outlining other IOCI3 findings, Dr Bates noted that summer maximum temperatures have cooled over the last 60 years in eastern SWWA. He also outlined IOCI's provision of high-quality datasets for WA on daily rainfall, temperature, cloudiness and solar radiation.

He described provisional results implicating aerosols in the observed rainfall increase in NWWA. He suggested that future trends could differ markedly from those of the recent past if aerosol concentrations change in future, since their influence appears to mask the greenhouse gas signal. He also outlined work on tropical cyclones showing that although there is not yet evidence of a historical trend in tropical cyclone intensity, the destructive potential of these storms is projected to increase in future, even as the overall number of tropical cyclones is expected to decline.

Turning to some of his own analysis of the SWWA climate, Dr Bates described a statistical analysis of the annual inflows into Integrated Water Supply Scheme (IWSS) dams, which have decreased over time. His analysis shows that there is no coherent baseline for annual inflows — rather, there is a long-term, nonlinear trend.

"After three generations of climate models, the direction of projected change is still the same for the South West."

--**Dr Bryson Bates**

Dr Bates finished by saying that IOCI has a justifiably proud record of international and national leadership in the provision of regionally specific and policy-relevant climate research. Ultimately this research will help to guide adaptation strategies.

2 Summaries of Session 1 Presentations

This section provides summaries of presentations from the first session of workshop Day 2, including those of Dr Carsten Frederiksen, Dr Pandora Hope, Ms Doerte Jakob, and Dr Leon Rotstayn.

2.1 Detection and attribution of changes to weather systems and large scale circulation drivers (IOCI3 Project 1.1)

Dr Carsten Frederiksen, BoM

Dr Frederiksen's talk built on his more general presentation of the previous day, with a focus on mid-latitude storms. He began by describing the Phillips Criterion, a measure of atmospheric instability. In the subtropics, the most unstable region is at a latitude of 30° S. This baroclinic instability (vertical shear in atmospheric winds) plays an important role in the formation of storms that affect SWWA. Dr Frederiksen's results demonstrate a systematic change in the Phillips Criterion in the recent past, alongside a reduced growth rate of storms.

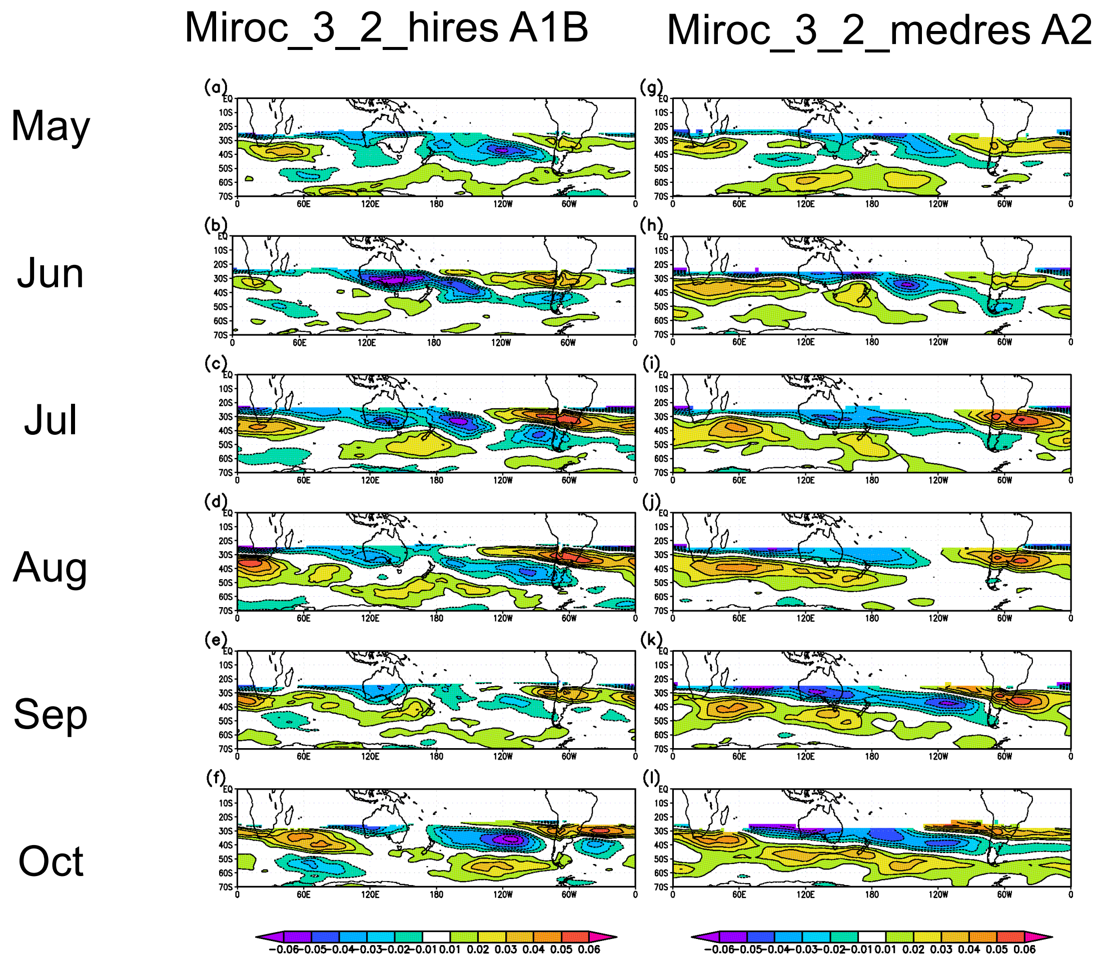

Figure 11 Future trends in the Phillips Criterion, according to climate modelling, for the years 2001-2100 (in metres per second per year). Blue-green to purple colours indicate a trend of reduction in the Phillips Criterion, which is a measure of the atmospheric instability associated with storm tracks and the growth of storms.

Dr Frederiksen showed changes in the Phillips Criterion in all months across three time periods, and also demonstrated the impact this has had on mid-latitude storm tracks.

During the first period (1949-68), Dr Frederiksen observed that in the month of July there was typically instability at a latitude of 30° S. Over time, during the second period studied (1975-1994), this baroclinic instability diminished. There was also a marked reduction in SWWA rainfall over the 1997-2007 period.

Atmospheric instability changes from month to month. During summer, most unstable air lies far south of Australia, but as we progress into winter instability increases at 30° S. Over time, however, there has been a negative trend in the Phillips Criterion where it was formerly at its strongest; that is, the atmosphere is becoming more stable. These findings are highly significant (at the 99th percentile).

The resulting change in storm tracks is the important issue. In the recent period, there has been a preference for these storms to grow further south, particularly in winter (see Part 2, Section 2.1 above). For example, in summer (January) there has been a pole-ward shift in the location of the dominant mid-latitude storms. Unlike the situation during winter, however, the reduction in the summer growth rate (i.e., likelihood) of these storms is only modest for recent periods (1975-1994 and 1997-2006) compared to (1949-1968).

Regarding autumn (April) storms, during the first period there were two predominant storm types (Type 1 and Type 2), both of which had very similar growth rates and were equally likely to occur. Type 2 had more impact on SWWA rainfall than Type 1. However, during the second period (1975-1994), Type 1 came to predominate, whilst the growth rate of Type 2 storms declined. Furthermore, since the 1949-68 period the preferred region for growth of storms in autumn (May) has shifted from the subtropical jet to the polar jet. This shift was accompanied by an approximately 10% reduction in growth rate.

"In the latter period the reduction in equator to pole temperature gradient has resulted in fewer storms affecting SWWA."

--**Dr Carsten Frederiksen**

During spring (October) the structure of the dominant mid-latitude storms is quite different across the three periods studied. The growth rate of these storms in this season has undergone only a modest reduction since 1949-1968.

In future, as atmospheric carbon dioxide concentrations increase, progressively larger reductions in baroclinic instability may be expected in the subtropics, especially over the Australian region. Whereas there is a general trend of wetting for 40° S and below, a drying trend is underway above this latitude. This is a global trend -- a global signal that affects rainfall throughout the entire Southern Hemisphere.

Turning to the attribution of these changes, Dr Frederiksen said it is necessary to know how weather systems can impact on the climate, and to find the fingerprint of forcing. Obtaining a comprehensive understanding of these complex dynamics is a challenge. The climate of the Southern Hemisphere (and global) circulation is affected by both external forcing and the eddy fluxes related to weather systems.

Dr Frederiksen observed that weather systems are essentially "trying to break down", or reduce, the temperature gradient between the equator and the pole. This gradient is generated by the preferential heating of the tropics compared to the higher latitudes and through thermal wind balance and gives rise to the jetstream. However, in recent times this gradient has been reduced dramatically and has resulted in fewer weather systems that are associated with the stormtracks affecting SWWA.

2.2 Drivers of climate variability of the South West — by season (ICOI3 Project 1.2)

Dr Pandora Hope, BoM

Dr Hope's talk described synoptic-scale weather systems that directly influence the climate of SWWA. Shifts in these systems have accompanied the significant changes in climate observed in this region over the past few decades.

Dr Hope began by noting that 2010 was the driest year on record, despite wetting in the east of Australia and a La Niña event; it was also the year of the Southern Annular Mode's strongest and most extended high phase.

Dr Hope explained the methodology of Self Organising Maps, wherein one studies weather conditions once or twice a day to examine the continuum of weather types over time. She explained how low-pressure systems are generally associated with wet conditions, high-pressure systems with dry conditions.

Regarding winter rainfall, in SWWA during the late 1960s, observed declines in rainfall amount were driven by a decrease in wet synoptic types, that is, there were fewer days with low-pressure systems. In recent years a different type of shift has occurred. Whereas in the early period the occurrence of dry synoptic types did not increase much, the rainfall decline since the late 1990s has been due to the persistence of high pressure systems. Although low-pressure systems are still crossing the South West and bringing rain, the prevalence of high-pressure systems has become more marked since 2000.

"It is the May weather types that are driving the autumn rainfall change. However, April rainfall is growing in its contribution to the total."

--**Dr Pandora Hope**

Turning to the topic of autumn rainfall, Dr Hope noted that totals in this season have decreased by 15% in SWWA since 2000. The changes in the frequency of weather types that occur in May are driving the overall autumn rainfall change; May rainfall declined 25% post-2000. As with winter systems, the May rainfall decline is now largely driven by an increase in high-pressure systems. However, the contribution of April rainfall to the autumn total has increased during the last 10 years, thus the changes in April weather types may become more important to total autumn rainfall. This may be a signature of a shift to a more even distribution of rainfall throughout the year.

Dr Hope then provided an example of how Self Organising Maps can be applied to answer other important research questions, in this case how climate might contribute to the observed decline since 2006 of rocklobster settlement (that is, low returns of puerulus, the larvae of western rocklobsters, *Panulirus cygnus*). The reasons for this decline could be numerous, including weather system changes. The preliminary results link reduced puerulus returns with a weather type characterised by strong offshore winds. This suggests one possible reason for the low returns could be very strong winds that push these larvae back out to the ocean, away from inshore sites where they settle.

This data is now being used by the Department of Fisheries to complement their study of the full range of factors that influence rock lobster numbers. However, Dr Hope noted that whilst oceanic conditions were favourable for settlement in 2011, larvae still did not show good returns. This study is continuing in collaboration with the WA Department of Fisheries.

Regarding temperature tends, Dr Hope outlined how summer maximum temperatures cooled in the eastern reaches of the South West over the 1960-2010 period. This trend is mirrored by a growing occurrence of a weather pattern that enhances cooler conditions across the east of SWWA and also by the observed upward trend in the Southern Annular Mode in summer.

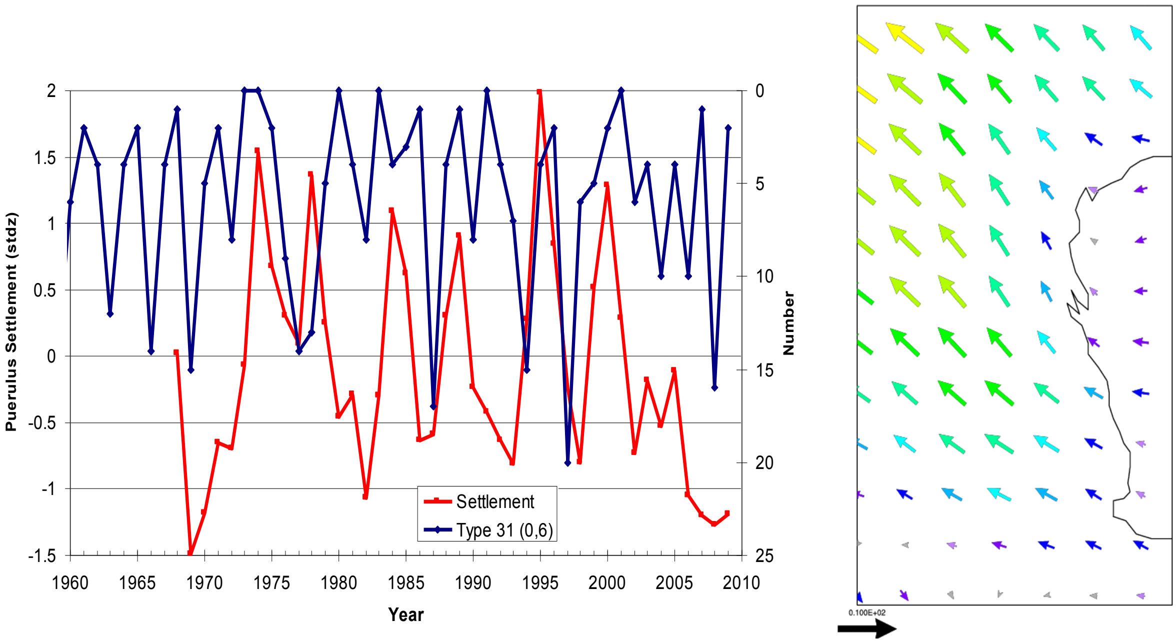

Figure 12 The Self Organising Map methodology is applied to the problem of low puerulus (rocklobster larvae) return since 2006. The weather type most typical of periods of low return was characterised by strong offshore winds (see arrows in diagram on right).

The upward trend in SAM in summer is linked to increasing levels of greenhouse gases and the Antarctic ozone hole. As the ozone hole recovers through this century, the SAM may return to less elevated values, and maximum temperatures may again begin to climb. Further studies of climate model results are required to identify how these large-scale drivers impact on the local weather systems that are cooling the maximum temperatures in this region.

2.3 Regionally specific climate data & monitoring for WA (IOCI3 Project 1.4)

Ms Doerte Jakob, BoM

The brief of Project 1.4 was to provide regionally specific climate data for WA. The top two reasons for this are: first, the need for historical information for climate models to show how well they replicate the past climate; and second, the need to look back over time to provide an understanding of climate variability.

Ms Jakob explained what climatologies are: the average monthly rainfall and temperature, as well as the variability and extremes. There is a temporal component, showing change over time, as well as a spatial component of maps/gridded data.

She then explained that, for high-quality data sets, there is a need to remove artefacts due to changes in instrumentation and other non-climatic factors. Equally, however, there is also a need to avoid introducing errors when conducting this clean-up process.

She discussed the high-quality precipitation dataset, which now extends back to 1900 at some sites, and to 1920 or earlier for most sites, with improved coverage in the South West and North. Ms Jakob acknowledged the major role Dr Marco Marinelli played in this work. For this dataset, automated quality control was used to compare daily rainfall to neighbouring data to check for consistency, whilst flagging those values that appear suspicious. The second step is to manually examine some outliers. But these outliers that are investigated could be present due to isolated local events like thunderstorms. The last thing one would want to do is exclude valid data like this. She stressed that the maxim to obey here is, "do no harm".

The temperature dataset, previously limited to 1957-2009, has been extended to 1910-2009 and to six new stations in WA. Referred to as the ACORN-SAT dataset (Australian Climate Observations Reference Network – Surface Air Temperature), it features rigorous and consistent quality control and homogenisation of data. Developed by Dr Blair Trewin, it has also been internationally reviewed to positive feedback. Looking forward, there have been recommendations that funding be made for a small number of additional sites to fill remaining gaps.

"We need historical information to show how well climate models replicate past climate.

Looking back also helps us understand variability."

--Ms Doerte Jakob

Ms Jakob described homogeneity testing: statistical tests are used to identify break points; then metadata is used to validate these break points. Ms Jakob provided an example for Albany, showing how a site move may affect minimum temperature (i.e., this station was moved from the town centre to the airport). Unadjusted data would have led to a downward step of about 2 °C in the record. Instead, through the approach used by this project, the earlier part of the record is adjusted so it now has continuity with incoming observations.

Turning to work under this project on heat stress climatologies currently being carried out by Ms Agata Imielska of BoM, Ms Jakob described how the shading used on the maps she presented indicates the intensity of heat stress for a particular region. This integrated excess heat factor is a measure that encompasses two perspectives: our own human capacity to adjust to heat; and how unusual the actual heat event is from a climatological perspective.

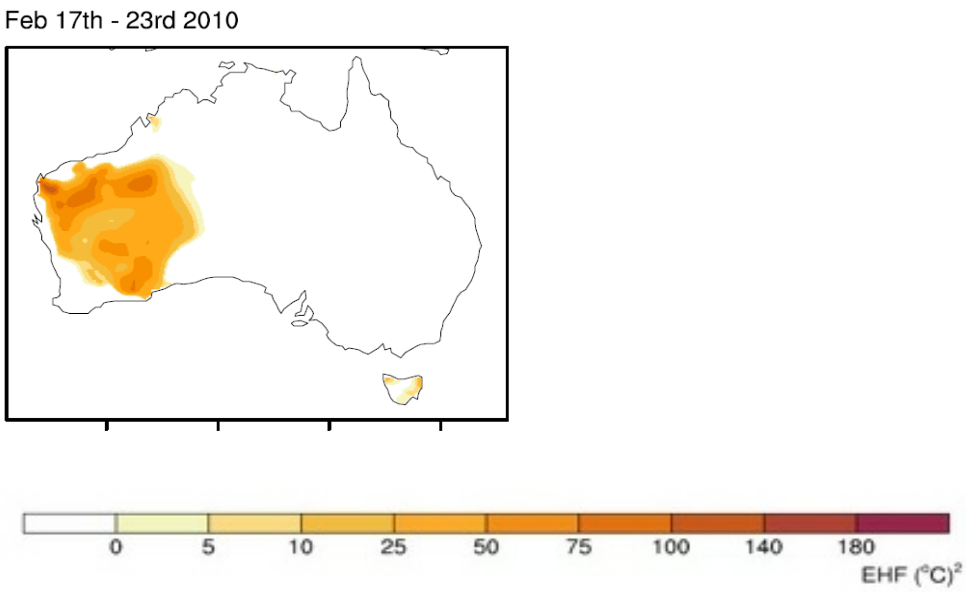

Figure 13 Integrated excess heat factor. This index integrates information on the human capacity to adjust to a heat event with the statistical significance of an event from a climatological perspective (i.e., how unusual is that event?) Deeper orange areas indicate a higher score on the index, that is, a more severe heat wave from February 17-23rd, 2010.

Another sector-relevant climatology is fire danger, which may be indicated by the Grassland Fire Danger Index. This index aims to provide information to assess fire danger, to facilitate warnings and preparedness. The index entails assumptions for fuel load and curing, and incorporates temperature, relative humidity and wind speed. A major challenge is the high sensitivity of the index to wind speed.

Next Ms Jakob turned to work on a high-quality surface solar radiation dataset and a newly developed high-quality cloud dataset. Satellite-based estimates of surface solar radiation are now being provided in real time and at daily resolution on a 0.05° grid. Solar radiation data are important for the renewable energy sector.

Ms Jakob noted that monitoring clouds differs from other weather variables in that it entails a human observer looking at the sky and estimating the proportion covered by cloud. Because this implies a degree of subjectivity, quality control work was undertaken; this confirmed the quality of the surface observations.

Turning to the final part of this IOCI3 project, Ms Jakob described the homogenised tropical cyclone database. This was required to establish whether tropical cyclones are becoming more frequent and/or intense. Clean data was needed to undertake this scientific research. The results have been documented in a scientific paper, and reveal that so far, no significant trends have been found in tropical cyclone frequency and intensity for the south Indian Ocean and south Pacific (see presentation below).

2.4 Effects of different forcing agents on simulated rainfall trends over the North West (IOCI3 Project 2.1)

Dr Leon Rotstayn, CSIRO

Dr Rotstayn began by describing observed rainfall trends, noting the large and significant increase in summer rainfall in north-west Australia, even as rainfall has decreased in Australia's east. So, he asked, will these trends continue or be reversed in future?

The challenge we must grapple with is that climate models tend not to agree on these changes in the North West. In fact, the majority of models -- but not all -- simulate drying in response to increasing greenhouse gases. Pollution aerosols may be contributing to increased rainfall in the North West, but this aerosol influence is expected to decrease in future. This issue is important: future rainfall trends in the North West depend on whether the cause of recent increases is long-term (such as increasing greenhouse gases) or short-term (such as aerosols).

"Why is this work [on aerosols] important? Aerosols may be influencing rainfall in the North West but this influence is expected to decrease."

--Dr Leon Rotstayn

Dr Rotstayn said it is also important to recognise other possible causes of these rainfall changes, such as the influence of Antarctic ozone depletion (from which a recovery has begun). Ozone depletion is thought to contribute to reduced rainfall in SWWA. However, new modelling suggests it may also cause increased summer rainfall across the Southern Hemisphere. The (short-term) natural variability that is ubiquitous in Australia could also be exerting some of the observed effects.

Dr Rotstayn then explained how aerosols might influence the climate. This haze of fine particulates or droplets from pollution blocks solar radiation but also affects cloud properties. It produces a strong regional cooling effect that can mask greenhouse warming and change wind patterns. Moreover, Australia is close to Asia, which is now the "epicentre" of these effects.

Dr Rotstayn used the metaphor of a "four-legged dog" to explore the following four drivers: the effects of greenhouse gases, ozone, aerosols and land-use change. The best way to explore the effects of these different "forcings" is to use a model to turn each forcing on, in turn. To do this, he and his colleagues at the Queensland Climate Change Centre of Excellence have done a very large number of modelling runs, and this has helped to separate out the signal from the climate noise. Dr Rotstayn noted that if aerosol pollution did not mask the warming effects of greenhouse gases, the world would be very different today.

Dr Rotstayn then described the CSIRO-Mk3.6 Global Climate Model, a coupled atmospheric-ocean model that includes a detailed, interactive aerosol scheme he has developed. This model can examine most of the major human-induced and natural climate forcing agents identified by the Intergovernmental Panel on

Climate Change. This makes Mk3.6 a flexible tool for exploring the effects of the forcings. Mk3.6 can treat long-lived greenhouse gases, aerosols, ozone, solar and volcanic forcing (but not land-use change).

Turning to the modelling results, Dr Rotstayn found that greenhouse gas forcing simulates a big decrease in rainfall. He explained why GHG forcing looks very different from the "all forcing" historical runs. The model suggests that ozone and aerosols may have masked effects of increasing greenhouse gases on rainfall changes in Australia. Greenhouse gas forcing also projects a strong drying trend over Australia in future. But this could be an overly pessimistic model.

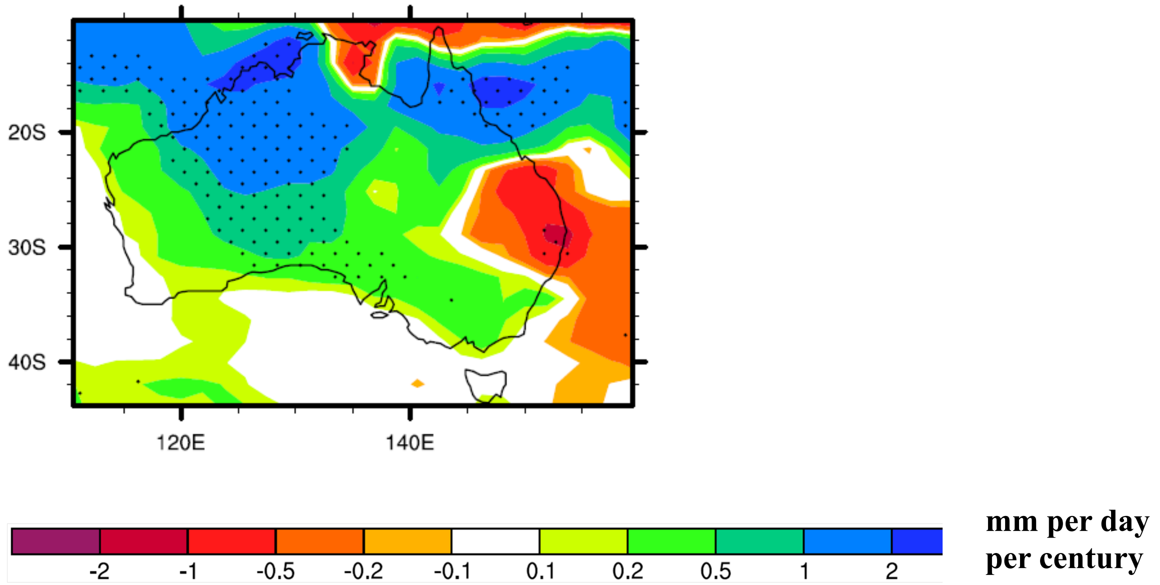

Figure 14 This simulation of historical rainfall (1951-2010) indicates the possible effects of aerosols on summer (December through March) rainfall trends, showing an increase in rainfall (green through blue areas), especially in the North West. This result was obtained with the CSIRO-Mk3.6 model using "all forcings" minus "all except anthropogenic aerosol" in order to isolate the possible effects of aerosols on rainfall.

Modelling results that aim to simulate the historical trend show significant rainfall decreases when only GHG forcing is used, similar to those for future projections (which are strongly driven by GHG forcing). This provides further confirmation that non-GHG forcings have had a “masking” effect.

Dr Rotstayn then touched on the possible mechanism by which aerosols may be affecting Australia's climate. Aerosols may affect winds, with the model suggesting that aerosols induce a cyclonic (clockwise) circulation off north-west Australia. This circulation carries more moisture from the Indian Ocean towards north-west Australia.

He went on to say that Coupled Model Intercomparison Project Phase 5 (CMIP5) will provide a unique, first-time opportunity to compare this model with a range of international models. CMIP5 provides the climate modelling input for the IPCC 5th Assessment Report, and all the participating models attract major scrutiny from climate analysts around the world.

3 Summaries of Session 2 Presentations

This sub-section provides summaries of presentations from the second session of Workshop Day 2, including those of Dr Pandora Hope, Dr Debbie Abbs, Mr Mark Palmer, Dr Yun Li, and Dr Steve Charles.

3.1 Tropical cyclones of the North West (IOCI3 Project 2.2)

Dr Hope presented extensive new work on the understanding of tropical cyclones for Dr John McBride, who recently retired from BoM. This included work on Tropical observations, which showed that no significant trends have been detected yet in TC intensity or frequency. The rainfall contribution of tropical cyclones was also discussed. Important new work on the relationship between tropical cyclones and climate variables such as sea surface temperatures was covered. Finally, Dr Hope described collaborative work on improved tropical cyclone forecasts.

3.2 Dynamical downscaling of tropical cyclones for the NW (IOCI3 Project 2.4)

Dr Deborah Abbs, CSIRO

Dr Abbs began her talk by outlining some key questions about the ability to model tropical cyclones, and the impacts of climate change on tropical cyclone characteristics in the region. She outlined her approach to modelling tropical cyclones.

By way of background, Dr Abbs said that the El Niño - Southern Oscillation affects where cyclones are generated and occur. She described the conditions for favourable environments for TC formation: warm ocean surface waters; a potentially unstable atmosphere; a moist mid-troposphere; a pre-existing near surface disturbance with established spin and convergence; and a small amount of vertical wind shear.

Turning to climate modelling of tropical cyclones, she said that global climate models generally capture TC's broad-scale features (at a grid spacing of 200-300 km), but they don't capture the damaging features of tropical cyclones. This is why dynamical downscaling is frequently used to get the resolution down to a scale that allows investigators to examine coastal effects and TC features, such as the eye walls (which cause damage) or the eye of the cyclone, which may be 50 km in diameter.

Dr Abbs described the direct detection technique used, which examines model outputs, to search for and identify weather systems that look like a TC (i.e., share their features and behaviour). Then she described the empirical techniques used that tie cyclogenesis to environmental conditions; these compute effects like thermodynamic characteristics, wind shear, tropospheric moisture and spin. To assess how well the models capture reality (validation), they compare the results with observations. They can then apply them to future output.

"There is an increase in the precipitation intensity of tropical cyclones, for both average and extreme rainfall rates."

--Dr Debbie Abbs

Dr Abbs noted that the models do not capture enough tropical-cyclone-like vortices. They only capture 60% of the expected number (i.e. 60% of those observed). In addition, the spatial characteristics of ENSO were captured, but too weakly. However, the researchers determined that the modelling is probably up to the task of the downscaling.

Turning to projected changes, a strong signal of a decrease in tropical cyclone numbers in the Australian region is indicated (from GCMs and 65-km simulations that provide "broad brush" projections). There is a strong consensus on this effect between the various modelling simulations (12 simulations).

However, turning to the high-resolution modelling results (which allows small-scale features to be identified), Dr Abbs said these indicate a strong increase in the damage potential of tropical cyclones, due to an increase in wind speed and size, or areas affected by the damaging winds. The shift to more intense storms is indicated by integrated kinetic energy (IKE). This is a measure of the amount of energy contained in the air rotating around the storm. Her results showed that the increase in storm size was indicated by an increase in features including the "radius to gales" and the "radius to maximum wind speed".

Dr Abbs said that they are seeking to examine whether, in future, the most intense TCs will also be the largest. There is also a need to conduct even finer simulations to get a full representation of the extreme winds associated with TCs.

Turning to rainfall changes, models also indicate that there will generally be increases in average rainfall intensity and maximum rainfall intensity.

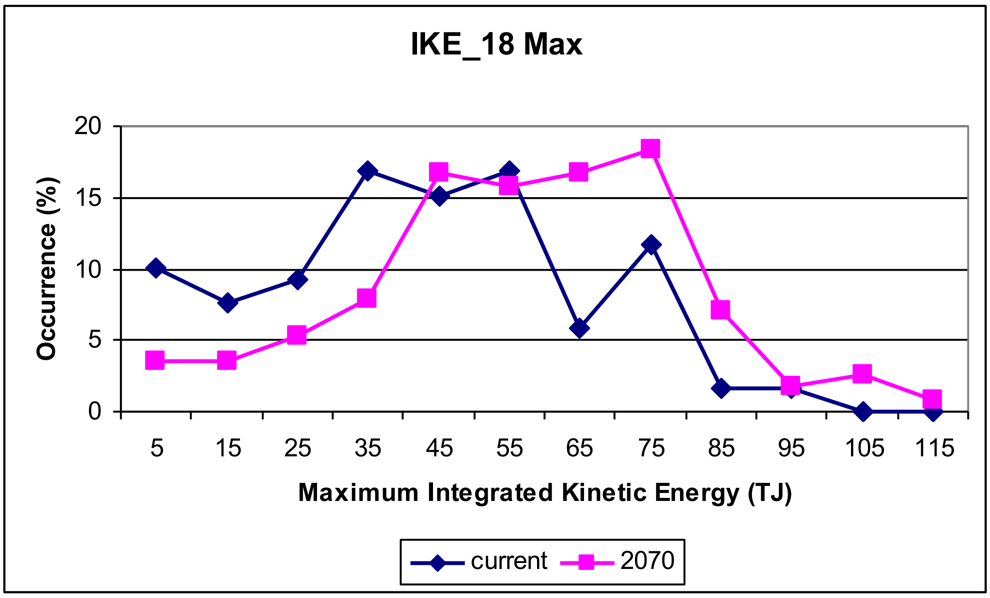

Figure 15 Wind speed alone does not fully explain a cyclone's potential to cause damage, particularly via wave or storm surge, so an additional measure was used. Called integrated kinetic energy, this measure accounts for both wind speed and the overall area covered by a cyclone's strong winds. Importantly, Dr Abbs' research shows this measure also indicates a distinct shift toward more destructive cyclones.

3.3 High resolution climate change scenarios for rainfall extremes (IOCI3 Projects 2.4 and 3.2)

Mr Mark Palmer, CSIRO

Mr Palmer began by explaining that an understanding of changes to rainfall extremes is important for engineering design, such as that for culverts, roads and dams. There is a need to know whether these rainfall extremes are becoming more or less extreme, and, if so, by how much.

This research aims to use statistical modelling to provide scenarios on how rainfall intensity, frequency and duration will be affected by climate change. If climate change affects extremes, then the intensity-frequency-duration (IFD) curves would be expected to change. The distribution of the maximum value of a sample (i.e., of rainfall) is modelled by a generalised extreme value (GEV) distribution. Any changes in this distribution should be manifested by changes in the parameters of the GEV. It is possible to estimate return levels and IFD curves from fitted GEVs.

This work essentially combines the deliverables for projects 2.4 (for NWWA) and 3.2 (for SWWA). Mr Palmer said there is a need to infill to make up for a lack of data (data gaps) in NWWA. Data is sourced from BoM, DAFWA, DWA (all rainfall stations), and modelling is used to infill missing data, in particular for the North West for the 1961-2000 period.

In SWWA, there has been a trend of generally decreasing rainfall extremes. These are correlated with total dam inflow and seasonal rainfall. Mr Palmer said they are currently exploring what variables are driving these changes.

Modelling is used to develop scenarios for the future, for the periods 2011-50 and 2051-90. Extreme events are extracted from this modelled data and GEV's are fitted to these. The GEV characteristics are input into models to examine where the return levels of studied regions have increased, where they have not changed, and where they have decreased.

Mr Palmer then summarised what is currently possible with regard to predicting extreme events. Using regional climate models, they are able to produce climate change scenarios for extreme rainfall in the form of return levels or differences in them. The results indicate that some regions are projected to have increasing extreme rainfall. It is also possible to produce measures of variability to go with this output.

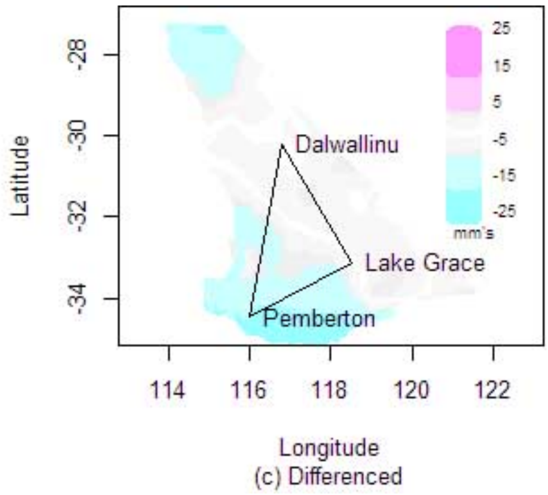

Figure 16 Projected changes in SWWA 24-hour extreme rainfall at 2030 showing regions of increase (magenta) and decrease (blue-green) for 100-year return levels (see Figure 3 above for the corresponding results for NWWA).

Figure 16 shows the areas of expected increase and decrease in extreme rainfall for SWWA at 2030. The modelling can also produce IFD curves for future periods (centred on 2030 and 2070).

Mr Palmer cautioned that the model linking the output from the regional climate model and the spatial model requires further refinement. Improved linkages would allow for more accurate measures of variability. It is anticipated that higher resolution climate models would allow for better projections.

3.4 Two new climate drivers and their influence on the variability and trends in rainfall and temperature extremes in SWWA and NWWA (IOCI3 Projects 2.4 and 3.2)

Dr Yun Li, CSIRO

Dr Li began began by describing possible climate mechanisms for the observed south-west drying trend and the north-west wetting trend in Western Australia. They have observed that SWWA undergoes strong seasonality in its annual rainfall cycle, and exhibits an atmospheric circulation feature which they have termed the south-west Western Australian circulation (SWAC). They also hypothesised that changes in the tropical Atlantic may exert a remote influence on NWWA's summer (December-March) rainfall.

Dr Li then reviewed the high-quality data temperature stations in SWWA and north-west Australia (1957-Present), noting that the North West has a very limited number of stations.

They found that north-west Australia's summer (December-March) rainfall variability and wetting trend are influenced by a mid-latitude teleconnection pattern associated with enhanced atmospheric ascending motion in the tropical Atlantic.

Turning to the topic of hot spells, he explained that these events can be defined as a number of consecutive days with a maximum temperature above a certain threshold. Dr Li described the statistical modelling of hot spells using extreme value theory, which takes into account variables including hot spell frequency, duration, and intensity. This method can incorporate climate change by modelling the influence of large-scale climate drivers on hot spells.

Dr Li described the data distributions of frequency, duration and intensity of hot spells in Perth (defined in this particular location as consecutive days with daily maximum temperature greater than 37 °C). He described how the number of hot spells in Perth has increased significantly since 1958, but that the duration of these hot spells has significantly decreased. He noted that there is no trend in the intensity of hot spells in Perth with a maximum temperature of greater than 37 °C.

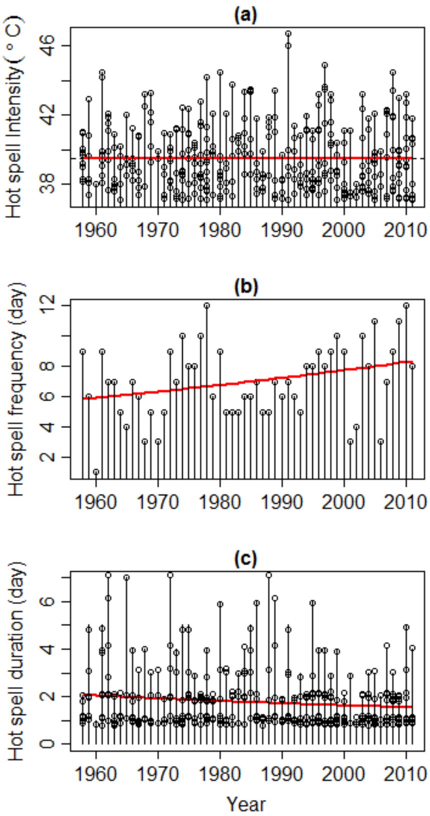

Figure 17 Hot spell trends for Perth. This figure illustrates that there is no trend in the intensity of hot spells in Perth since the 1958 (a), that the frequency (number) of hot spells has increased (b), but that their duration (length) has decreased over the same period (c).

Turning to SWWA in general, Dr Li noted that the number of hot spells has increased in the north of SWWA, but decreased in the south of SWWA. He proposed the possibility that the weakening summer south-west Australian circulation is linked to the increased frequency of Perth hot spells.

3.5 Statistical downscaling for the North West and South West (IOCI3 Projects 2.3 & 3.1)

Dr Steve Charles, CSIRO

Dr Charles began by acknowledging the collaborators on this work. He then described the rationale for statistical downscaling: to relate weather on a local scale to large-scale atmospheric forcing (whether this forcing is observed or modelled). In this way climate models with their gridded output at a spatial resolution of 100-200 km can be regionally downscaled to the resolution of individual stations.

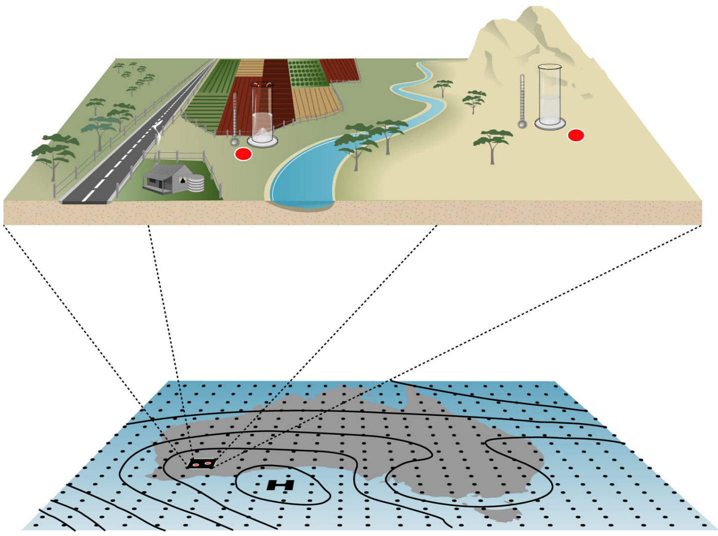

Figure 18 Statistical downscaling relates weather on a local scale to large-scale atmospheric forcing.

Dr Charles also outlined the data requirements and statistical methodology. His research chooses not to use rainfall outputs from the global climate models because of their biases (GCMs overestimate the number of wet days and concurrently underestimate the intensity rainfall). Instead this project uses non-homogeneous hidden Markov models (NHMMs) to link large-scale atmospheric processes (well reproduced by GCMs) with local scales. The stochastic nature of the NHMM allows the generation of multiple realisations of rainfall and temperature conditional on observed (i.e., reanalysis) or modelled (i.e., GCM) large-scale forcing.

Next Dr Charles described the goals of projects 2.3 and 3.1: to use statistical downscaling to link circulation drivers to the behaviour of historical rainfall and temperature at spatial and temporal scales suitable for management and planning. A second goal is to assess atmospheric predictors of climate models and compare the time series of observed weather states with those obtained from downscaling of forced GCMs. Finally, a third major goal is to produce high-resolution climate change scenarios that can be used for impact and vulnerability assessments.

Dr Charles provided findings for the Kimberley and the Pilbara for the summer half-year and for south-west WA for the winter half-year. These results show the change in median annual rainfall relative to a 1981-2000 baseline for the 2046-2065 and 2081-2100 time periods. He also illustrated the projected change in maximum and minimum temperatures over these periods.

"Although statistical downscaling provides plausible local-scale projections they cannot remove inherent, potentially irreducible, uncertainty."

--Dr Steve Charles

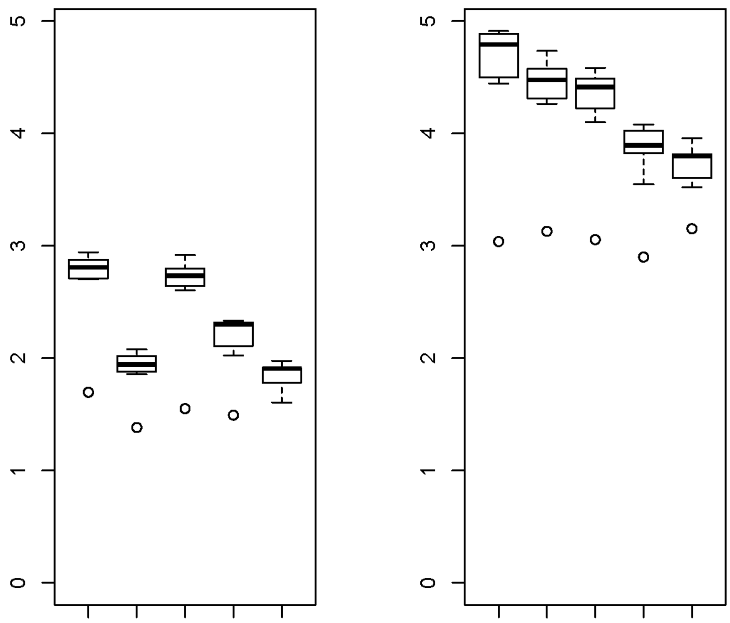

Figure 19 Kimberley change in maximum temperature relative to 1981-2000 baseline (°C). Left: 2046-2065 period. Right: 2080-2100 period. Downscaled results from five GCMs: Each boxplot shows the range of projected changes across the nine stations. The thick line is the median, the boxes are the interquartile range (i.e. 25th to 75th percentile), the whiskers (dashed lines) extend up to 1.5 times the length of the box, with any outliers shown as individual points (open circles).

The NHMM reproduces both NW and SW overall at-site rainfall characteristics (for example, it depicts that SWWA had a very dry year in 2010), accounting for the large-scale drivers of rainfall variability on a regional and seasonal basis. The method provides multiple realisations of multi-site daily rainfall and temperature. Dr Charles noted that confidence in statistical downscaling projections depends on GCM performance: much of the range in the projections is due to the differences between different GCMs. He also cautioned that the level of uncertainty is undoubtedly larger than presented here, given that only five GCMs were used.

Dr Charles finished his presentation by noting that it was important to remember that statistical downscaling projections are scenario planning under inherent, potentially irreducible, uncertainty.

4 Summaries of Session 3 Presentations

This section summarises the presentations from the third and final session of Workshop Day 2.

4.1 Toward bridging the climate science communication gap

Ms Janice Wormworth

Ms Wormworth began by outlining public attitudes about climate change, noting that there was a major gap between public opinion and the scientific consensus. Part of this gap is due to the challenge of communicating climate science. These challenges stem from the complexity of climate science, the gradual nature of climate change, lags in the climate system, public confusion about the implication of uncertainties in climate science, a lack of understanding about climate extremes, and a tendency for variability to be confused with long-term change in the minds of the public.

However, and importantly in this context, this communication gap also extends to those who must use climate science to address climate-related risks. Ms Wormworth quoted John D. Stermann (Sloan School of Management at MIT) who stated, "Risk communication is now a major bottleneck preventing science from playing an appropriate role in climate policy".

"For IOCI, the wide range of stakeholder needs presents a communication challenge. Currently we need to provide more summary-style information to bridge this gap."

--Ms Janice Wormworth

She then provided some examples of good climate science communication, including the CSIRO/BoM State of the Climate report, Climate Dogs (an initiative which portrays complex climate information using animation), and flood maps (which translate abstract data into concrete visuals experience).

Moving on to specifically communicating IOCI climate science, Ms Wormworth noted that the IOCI communication role sits between IOCI scientists and the initiative's many and diverse stakeholders; moreover, IOCI's stakeholders have many and diverse stakeholders of their own. IOCI stakeholders have widely varying needs in terms of climate information. However, she noted that more summary-style information is currently needed.

Ms Wormworth then outlined upcoming communication plans. This includes an IOCI synthesis report, which must be useable by a wide range of stakeholders, and will summarise the main findings for all of IOCI Stage 3. She noted that more "push" information (i.e. email updates) is required to make stakeholders aware of IOCI materials. The IOCI website has been revised to allow for more frequent updates and greater currency. She also noted that generally increasing the profile of IOCI climate science information would assist stakeholders who face challenges in acceptance of policy because their stakeholders are not convinced that shifts, such as drying trends, are examples of long-term climate change (rather than short-term variability).

4.2 Overview of a future climate research program

Ms I-Lyn Loo

Ms Loo stated that a proposal for a future climate research program to replace the IOCI program has been prepared and submitted to the Government for consideration. The proposal builds on the knowledge from IOCI, addresses cross-government priorities on climate research and has a strong focus on communication and engagement with stakeholders.

4.3 Closing comments

Ms Sarah McEvoy, WA DEC

Ms Sarah McEvoy thanked the speakers for their presentations. She then thanked the organisers, and brought the workshop to a close.

Appendix A Abbreviations Used in This Report

ACORN-SAT	Australian Climate Observations Reference Network – Surface Air Temperature
BoM	Bureau of Meteorology
CCU–DEC	Climate Change Unit, Department of Environment and Conservation, Western Australia.
CO_2	Carbon dioxide
CSIRO	Commonwealth Scientific and Industrial and Research Organisation
DAFWA	Western Australian Department of Agriculture and Food
DEC	Western Australian Department of Environment and Conservation
DoF	Western Australian Department of Fisheries
DTF	Western Australian Department of Treasury and Finance
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Authority
FMG	Fortescue Metals Group
GCM	Global climate model
GEV	Generalised extreme value
GHG	Greenhouse gas
IFD	Intensity Frequency Duration
IKE	Integrated Kinetic Energy
IOCI	Indian Ocean Climate Initiative
IPCC	Intergovernmental Panel on Climate Change
IWSS	Integrated Water Supply Scheme
LAPP	Local Adaptation Pathways Program
NHMM	Non-homogeneous hidden Markov models
SOM	Self Organising Map
TC	Tropical cyclone
WA	Western Australia
WACOSS	Western Australian Council of Social Service
WAMSI	Western Australian Marine Science Institution

Appendix B Workshop Agenda

The Day 1 IOCI3 2011 workshop agenda follows.

Monday, 5 December 2011		
Time	**Agenda**	**Speaker**
8:30 – 9:00 am	Registration	
9:00 – 9:15 am	Opening address	**Hon Bill Marmion, MLA** Minister for Environment; Water
9:15 – 9:30 am	Welcome	**Hon Hendy Cowan** Chair, IOCI3 Board
9:30 – 9:50 am	Climate change functions and activities in the Department of Environment and Conservation	**Mr Robert Atkins** Deputy Director General, DEC
9:50 – 10:15 am	Morning tea	
Session 1: Climate science supporting risk management		
10:15 – 10:45 am	Observed and projected changes in the Southern Hemisphere circulation, weather systems and WA winter rainfall	**Dr Carsten Frederiksen** BoM
10:45 – 11:15 am	WA's changing climate	**Dr Pandora Hope** BoM
11:15 – 11:45 am	Modelling extreme events	**Dr Aloke Phatak** CSIRO
11:45 am – 12:15 pm	Tropical cyclones	**Dr Debbie Abbs** CSIRO
12:15 – 1:00 pm	Lunch	
Session 2: Managing climate-related risks on the ground		
1:00 – 1:30 pm	Evidence based decision making in relation	**Dr Neil Carroll**

	to facing the challenges associated with sea level rise and climate change	City of Mandurah
1:30 – 2:00 pm	Industry perspective: Changing extreme weather events and potential impacts for our projects	**Mr Julian Tapp** Fortescue Metals Group
2:00 – 2:30 pm	Vulnerability and resilience: A community service perspective	**Ms Irina Cattalini** WACOSS
2:30 – 3:00 pm	Managing climate-related risks from a farmer's perspective	**Mr Dale Park** WA Farmers Federation
3:00 – 3:20 pm	Afternoon tea	
Session 3: Bridging the gap for effective risk management		
3:20 – 3:50 pm	Social dimensions of managing climate risks and climate adaptation processes	**Dr Kieren Moffat** CSIRO
3:50 – 4:20 pm	Climate change, natural disaster losses and insurance implications	**Prof. John McAneney** Risk Frontiers
4:20 – 4:50 pm	Stepping stones across rapids: Building a bridge between climate science and users	**Dr Ailbhe Travers** Coastal Zone Management
4:50 – 5:05 pm	Close	**Dr Bryson Bates** CSIRO

Day 2 IOCI3 2011 workshop agenda follows.

Tuesday, 6 December 2011		
Time	**Agenda**	**Speaker**
8:30 – 9:00 am	Registration	
9:00 – 9:20 am	What do we need to know about human behaviour to reduce CO2 emissions?	**Hon Carmen Lawrence,** Winthrop Professor School of Psychology, UWA
9:20 – 9:35 am	Welcome	**Hon Hendy Cowan** Chair, IOCI3 Board
9:35 – 10:00 am	Overview of the science program of IOCI3	**Dr Bryson Bates** CSIRO
10:00 – 10:30 am	Morning tea	
10:30 – 11:00 am	Detection and attribution of changes to weather systems and large scale circulation drivers (Project 1.1)	**Dr Carsten Frederiksen** BoM
11:00 – 11:30 am	Drivers of climate variability of the south-west - by season (Project 1.2)	**Dr Pandora Hope** BoM
11:30 am – 12:00 pm	Regionally specific climate data & monitoring for WA (Project 1.4)	**Ms Doerte Jakob** BoM
12:00 – 12:30 pm	Effects of different forcing agents on simulated rainfall trends over the North West (Project 2.1)	**Dr Leon Rotstayn** CSIRO
12:30 – 1:15 pm	Lunch	
1:15 – 1:45 pm	Tropical cyclones of the North West (Project 2.2)	**Dr Pandora Hope** BoM
1:45 – 2:15 pm	Dynamical downscaling of tropical cyclones for the NW (Project 2.4)	**Dr Deborah Abbs** CSIRO

2:15 – 2:55 pm	High resolution climate change scenarios for rainfall extremes Two new climate drivers and their influence on the variability and trends in rainfall and temperature extremes in SWWA and NWWA (Project 2.4 and 3.2)	**Dr Mark Palmer** CSIRO **Dr Yun Li** CSIRO
2:55 – 3:25 pm	Statistical downscaling for the North West and South West (Projects 2.3 and 3.1)	**Dr Steve Charles** CSIRO
3:25 – 3:50 pm	Afternoon tea	
3:50 – 4:15 pm	Toward bridging the climate science communication gap	**Ms Janice Wormworth** IOCI3 Communications Advisor
4:15 – 4:30 pm	Overview of the future climate research proposal	**Ms I-Lyn Loo** Technical Specialist, DEC
4:30 – 4:45 pm	Close	**Ms Sarah McEvoy** Asst Director, DEC

Appendix C List of Workshop Delegates

First name	Surname	Organisation
Debbie	Abbs	CSIRO
Robert	Atkins	DEC
Melanie	Bainbridge	WA Local Government Association
Mohammed	Bari	Bureau of Meteorology
Ben	Bassett	Dept of Planning
Bryson	Bates	CSIRO
Chris	Beaton	City of Cockburn
Tom	Beer	CSIRO
Mike	Bergin	Bureau of Meteorology
Charlie	Bicknell	Dept of Transport
Steve	Blake	WAMSI
Anne	Braithwaite	Office of Energy
Mark	Canny	Northern Agricultural Catchment Council
Nick	Caputi	Dept of Fisheries
Neil	Carroll	City of Mandurah
Irina	Cattalini	WACOSS
Steve	Charles	CSIRO
Glenn	Cook	Bureau of Meteorology
Hendy (Hon)	Cowan	Chairman, IOCI Board
Brett	Crabtree	Dept Environment & Cons
Fleur	Crowe	Emerson Stewart Consulting
Miles	Dracup	WA Water Corp
James	Duggie	Dept Environment & Cons
Jacqueline	Durrant	Dept of Water
Anna	Evers	BMW, DTF
Imma	Farre	Dept of Agriculture and Food WA
Ming	Feng	CSIRO
Ian	Foster	Dept Agriculture & Food
Carsten	Frederiksen	Bureau of Meteorology
Ray	Froend	Edith Cowan University
Stephen	Fry	Shire of Bruce Rock
Pauline	Grierson	UWA
Joel	Hall	Dept of Water

Lisa	Harry	Dept Environment & Cons
Ed	Hauck	Dept of Water
Shirene	Hickman	Dept Environment & Cons.
Alan	Hill	WA Farmers Federation
Paul	Holper	CSIRO
Pandora	Hope	Bureau of Meteorology
Agata	Imielska	Bureau of Meteorology
Doerte	Jacob	Bureau of Meteorology
Phillip	Kalaitzis	Dept of Water
Dianne	Katscherian	Department of Health
Christine	Kershaw	South West Catchment Council
Carmen (Hon)	Lawrence	UWA
Stephen	Lewandowsky	WA Climate Group, UWA
Yun	Li	CSIRO
I-Lyn	Loo	Office of Climate Change, DEC
Joanne	Ludbrook	City of Mandurah
Tom	Lyons	Murdoch University
Bill (Hon)	Marmion	Min. Environment; Water
Marco	Marinelli	Bureau of Meteorology
Carolyn	Marshall	BMW, DTF
Anne	Mathews	Dept Environment & Cons
John (Prof.)	McAneney	Risk Frontiers
Greg	McAuliffe	Dept Regional Development and Lands
Sarah	McEvoy	Dept Environment & Cons
Greg	McLennan	Dept Sport and Recreation
Keiran	McNamara	Dept Environment & Cons
Judith	Mitchley	Santos Ltd
Kieren	Moffat	CSIRO
Karen	Murphy	CSIRO
Mark	Palmer	CSIRO
Vivienne	Panizza	Dept of Planning
Dale	Park	WA Farmers Federation
Jackson	Parker	Dept Agriculture & Food
Craig	Perry	City of Mandurah
Aloke	Phatak	CSIRO
Sue	Phillips	CSIRO
Ro	Richardson	Dept Environment & Cons.
Leon	Rotstayn	CSIRO
Brian	Sadler	

Tim	Sparks	Dept of Water
Shelley	Spriggs	Northern Agricultural Catchment Council
Carmel	Staniland	Dept of Mines and Petroleum
David	Stephens	Dept of Agriculture and Food
Laura	Stocker	Curtin University
Geoff	Stoneman	Dept Environment & Cons
Julian	Tapp	Fortescue Metals Group
Ailbhe	Travers	Coastal Zone Management
Paul	Vanderwal	Water Corporation
Doug	Vickery	City of Cockburn
Sam	Wilkinson	Fortescue Metals Group
Don	Woodcock	Guest of Hendy Cowan
Janice	Wormworth	CSIRO
Karl-Heinz	Wyrwoll	UWA
Jens	Zinke	UWA

Numbering is included in the style (Appendix A, Appendix B).

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FOR FURTHER INFORMATION ABOUT IOCI

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