Climate Forecasting for hydrological extremes in Australia and surrounds

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Australian Bureau of Meteorology

Australian Government
Bureau of Meteorology

Outline

Rainfall and temperature outlook

- How and why: how can we make a seasonal forecast and why do we use one
- Timeline of a service: ENSO, Indian Ocean
- Dynamical models: more accurate, future proofing
- User needs
- The future of seasonal forecasting in Australia

Forecasting for water needs

- Millennium drought
- Streamflow forecasts

Climate variability: strategic context

Important to Australia's economy, society and community

- 5% of GDP ($58B) attributed to annual climate variability
- Bureau can influence Australia's ability to respond effectively
- Potential value of climate forecasts is >$1.5B
- Departures from "normal" are increasing due to global warming

Industry	Potential annual value of forecast A$m	Industry value added A$m	Potential value of forecast as share of industry value added (%)
Agriculture	1 567	21 429	7.31
Construction	192	79 851	0.20
Oil and gas	93	20 363	0.46
Coal mining	68	20 852	0.33
Water supply	28	10 550	0.27
Transport	5	22 824	0.02
Electricity	2.3	16 556	0.01

Note: All values are in Australian dollars at 2012 prices. *Source:* The Centre for International Economics, 2014

From Managing Climate Variability Program

Drought - the costliest (natural) hazard in Australia

2015 El Niño drought likely to cost agriculture $2+ billion

1997-2010 *Millennium* drought

Black Saturday saw 173 deaths

$2 billion in fire damage

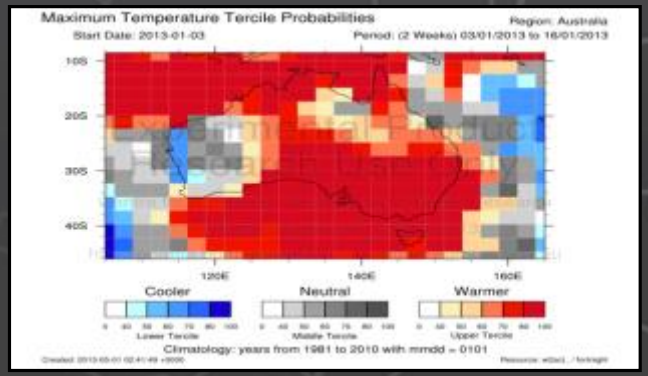
Billions spent to drought *proof* cities

$4 billion in drought payments 2002-2009

What guides our thinking?

- Safety of life and property
- Reduced costs to the economy, society and the environment
- Better decisions across planning, preparation, response and recovery

- Reduced vulnerability to climate change and informing adaptation



What drives wet season rainfall variability?

Weekly time scales

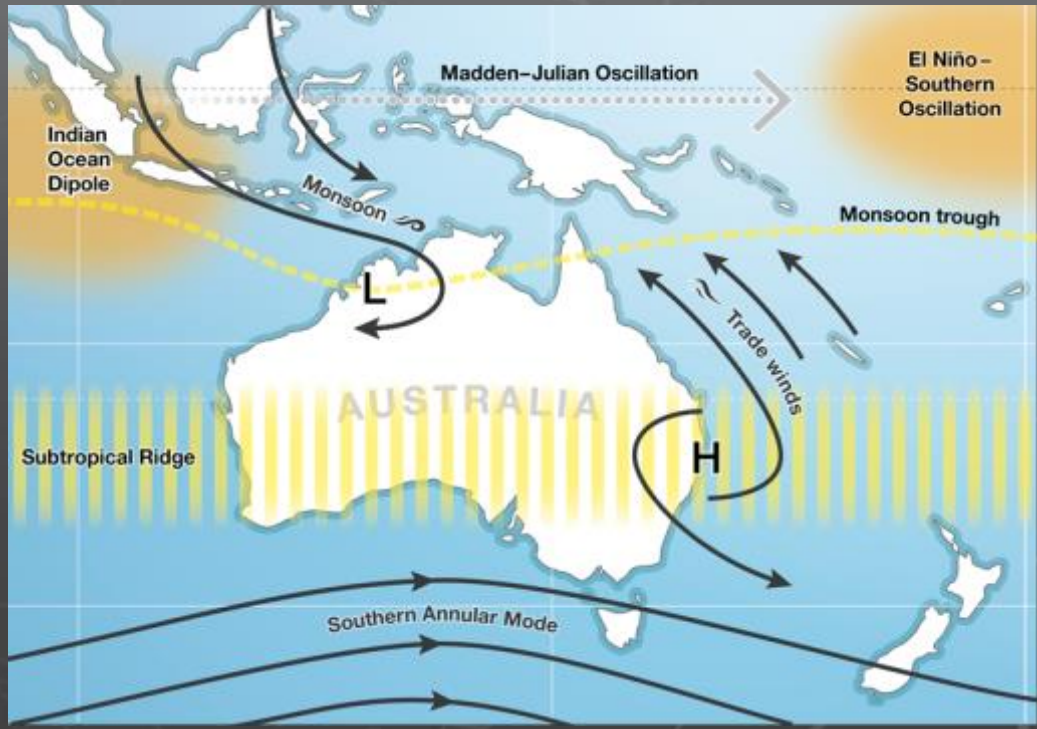
- Strength and position of monsoon trough
- Tropical cyclones

Multi-weekly to monthly

- Madden–Julian Oscillation

Multi-monthly to seasonal

- Indian Ocean Dipole
- El Niño–Southern Oscillation



27 years of the Seasonal Climate Outlook: a continuous improvement model

Bureau of Meteorology

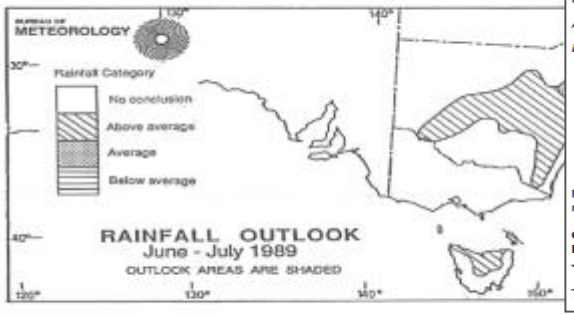
SEASONAL CLIMATE OUTLOOK

SUMMARY

The positive phase of the Southern Oscillation which commenced in autumn 19
peak during the following spring when the highest value of the Southern Oscilla
(SOI) since 1975 was recorded. During summer and early autumn 1989, the SOI
general decrease, but over the last few months has again increased.

Rainfall over the period March to May has generally been well above average o
Australia, consistent with the positive values of the SOI for this period (district
for the period ending 31 May are given at Appendix 1).

The statistical relationship of the April to May SOI with the June to July district
fall provides the basis for the expectation of above average rainfall over parts of
Australia for the June to July period. The figure below shows the general area c
outlook and the predicted rainfall category. Outside the area covered by the out
tical relationships are considered not strong enough for a prediction to be made



Note: This outlook is based on statistical relationships derived from climatic records and is supported by the present understanding of broadscale climatic processes in the atmosphere and oceans. The outlook applies to expected conditions for the total period over the broadly defined area and not to specific locations. It should therefore be interpreted with care.

MEDIA RELEASE - ISSUED 16th JULY 2
Three-month Seasonal Climate Outle

Below average

The latest seasonal rainfa
and southern Australia, a

The chances that total Au
Queensland, together wit
average sea temperature
period, but low reliability e

So with climate patterns li
the country, whilst about

There has been a continu
pattern will continue for th
country during this period

A weekly update of the p

Background Information:

- The Outlook probab
substantially warm
- The Australian imp
- June's value of the
days ending 13th J
- This outlook repres
- Important: Probabili
in the booklet "The

More information on this o
meteorologists in the Nati

Grant Beard on (03) 966
David Jones on (03) 966
Janita Pahalad on (03) 9

THE NEXT ISSUE OF

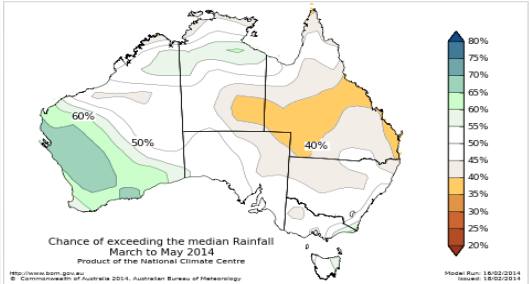
National Seasonal Rainfall Outlook: probabilities for November 2009 to January 2010, issued 23rd October 2009

Mixed rainfall odds for Australia

National rainfall outlook

Issued 24 February 2014

Drier autumn more likely for parts of Queensland, while wetter favoured in the west



Larger view | PDF(2MB) | Wider Australian region | Old colours

Summary

- A drier than normal autumn is more likely for areas of Queensland and southeastern Northern Territory
- A wetter than normal autumn is more likely for southern and western parts of WA
- Outlook accuracy is moderate to high over much of eastern and central Australia, except for some areas near the WA/NT border, southern parts of SA and western parts of WA where the accuracy is low.

Details

The chances of exceeding the median rainfall during autumn are less than 40% over parts of central and western Queensland and the southeast corner of the NT. In other words, the chances of *below* average rainfall are at least 60% over these areas. For every ten autumn outlooks with similar odds to these, about three or four of them would result in above-average rainfall over these areas, while about six or seven would be below average.

Conversely, the chance of exceeding the median rainfall is greater than 60% over the western half of WA, and a small area in northeast of the NT.

Over the rest of the country, there is no significant shift in the odds towards either a wetter or drier than normal autumn.

Climate influences

The El Niño-Southern Oscillation (ENSO) remains neutral, with the majority of atmospheric and oceanic indicators close to their long-term average. Dynamical models surveyed by the Bureau suggest that while ENSO-neutral conditions are likely to persist through autumn, some warming of the central Pacific Ocean is likely. While short of El Niño levels, this warming may still have some impacts upon Australian climate

Ocean temperatures surrounding Australia are generally expected to remain close to their 1981-2010 average, though some cooler than average temperatures around northern and north-eastern coasts early in the season may mean a reduction in evaporation in those areas. Atmospheric pressures may be below average over some southern areas in the first half of the season, which may favour drier westerly winds over some parts of eastern Australia.

The Indian Ocean Dipole is typically too weak to have a significant influence on the Australian climate during the autumn period.

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Seasonal outlooks over time

October 1929 – Hunt (1929) A basis for seasonal forecasting in Australia, Quarterly Journal of the Royal Meteorological Society, **55**, 323-334.

July 1983 – McBride and Nicholls (1983) Seasonal relationships between Australian Rainfall and the Southern Oscillation

June 1989 – first BoM seasonal outlook (SOI rainfall correlation scheme)

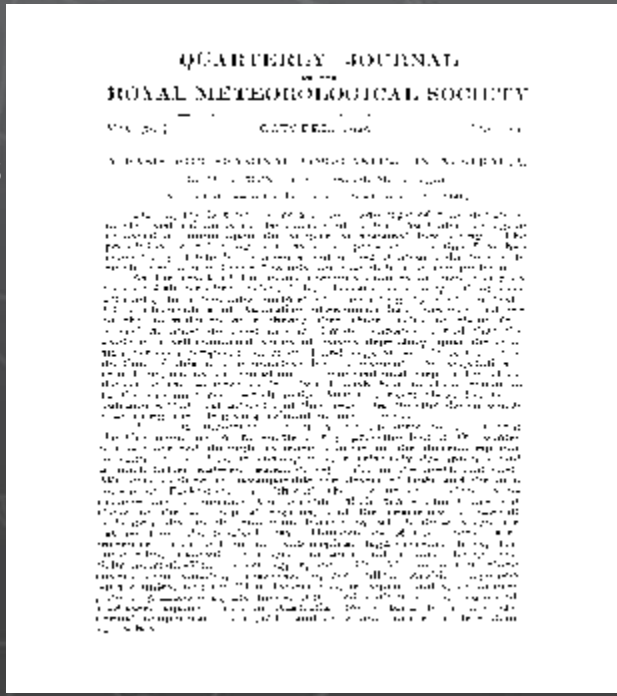
July 1992 – SOI stratified climatology scheme

October 1998 – SST based LDA prediction scheme introduced (Drowsdowsky and Chambers)

July 2008 – last booklet issued

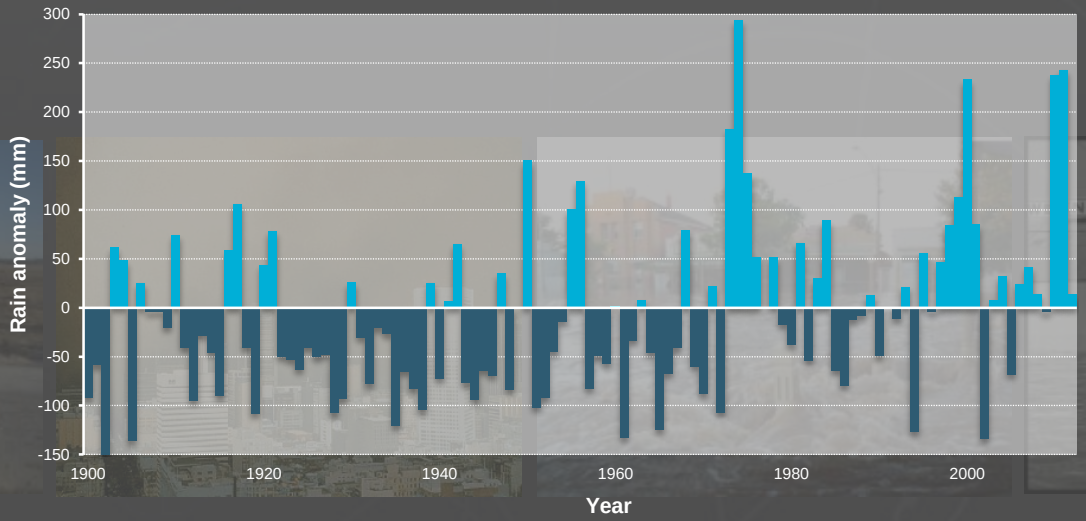
September 2010 – SST1 replaced with NINO34 due to overwhelming trend in data

May 2013 – Move to dynamical modelling system (POAMA)


QUARTERLY JOURNAL
OF THE
ROYAL METEOROLOGICAL SOCIETY

‘…of droughts and flooding rains’

All-Australian rainfall anomalies since 1900
(based on a 30-year climatology 1961-1990)



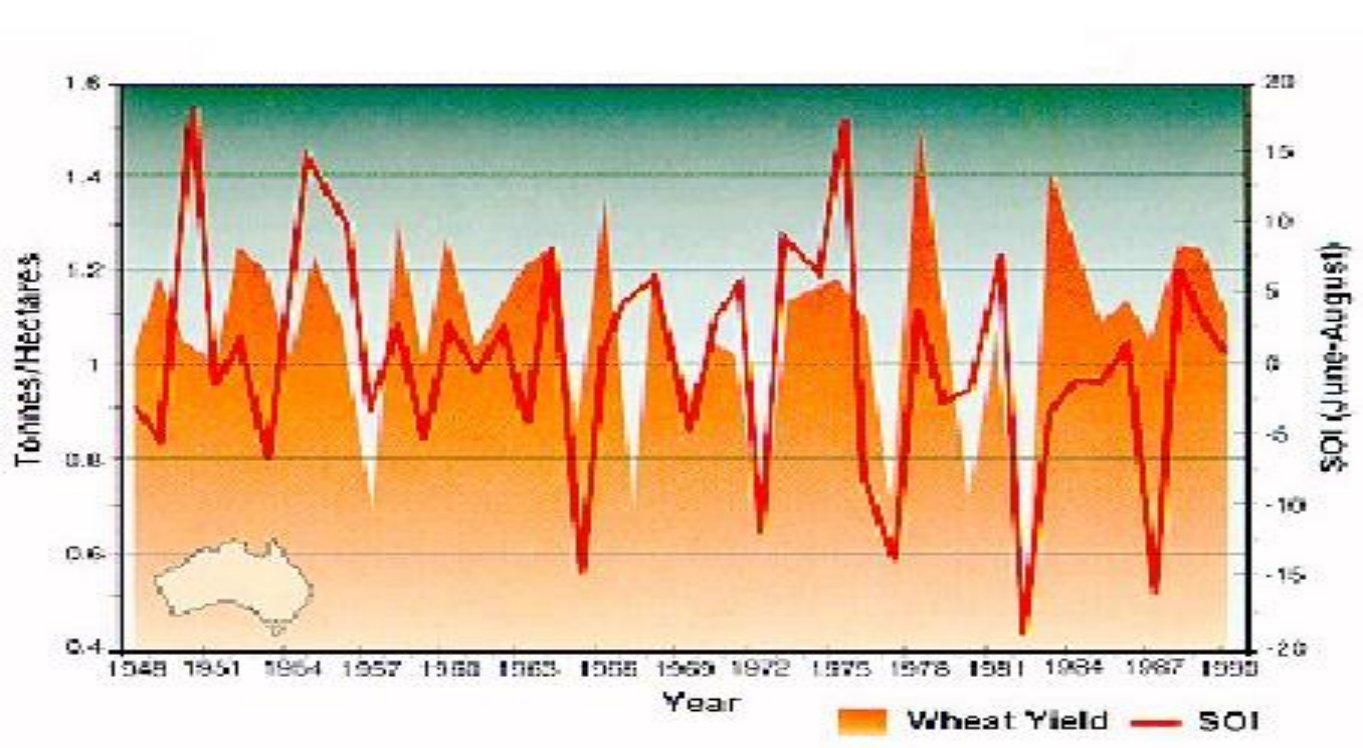
2006 El Niño

1982/83 El Niño

2011 La Niña (Charlton, Mail Times)

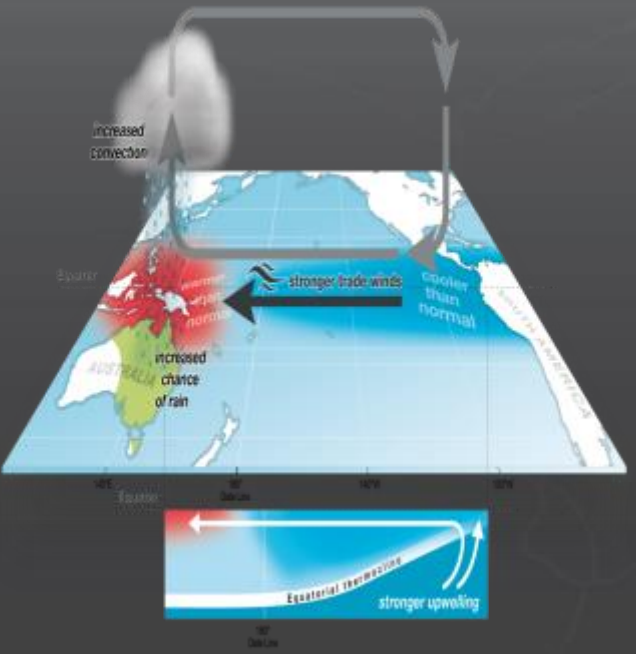
1956 La Niña (Murray River flooding)

Australian Wheat Yields and SOI

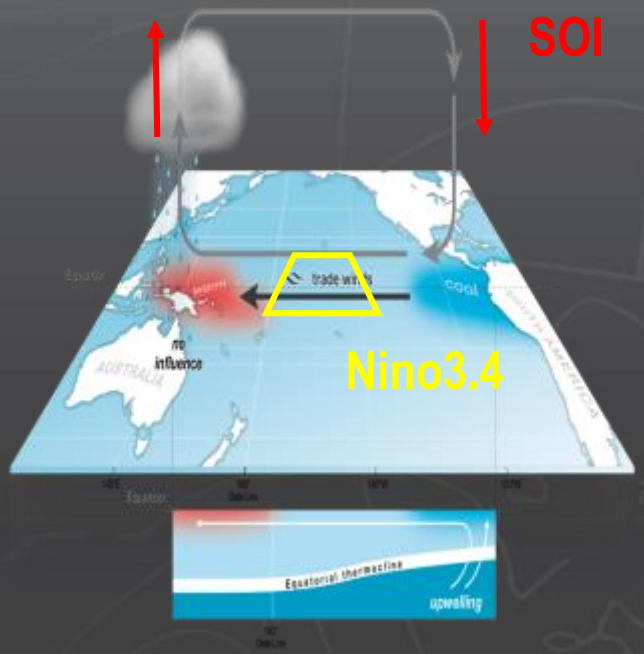


The El Niño-Southern Oscillation

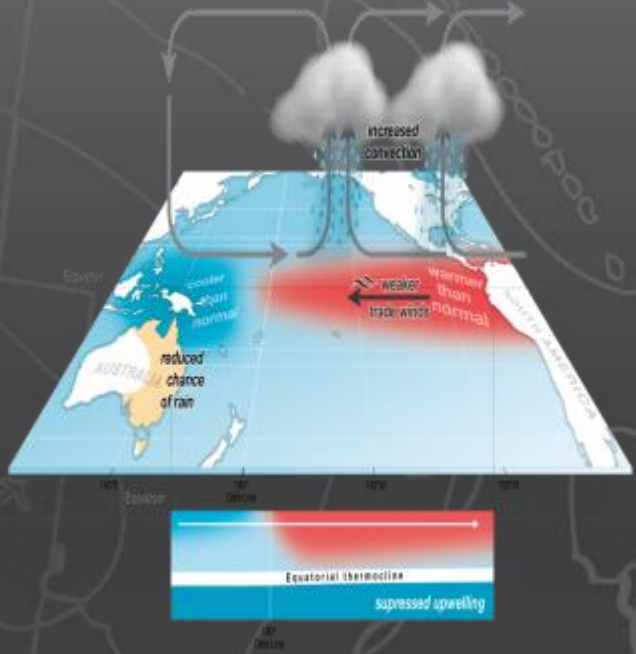
La Niña (2010/11/12)



Neutral phase

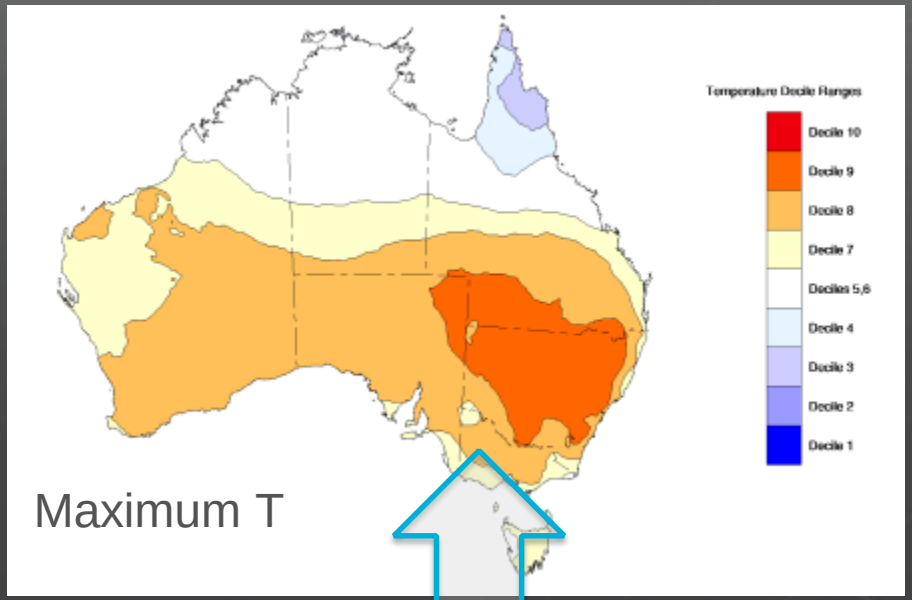


El Niño (this year)



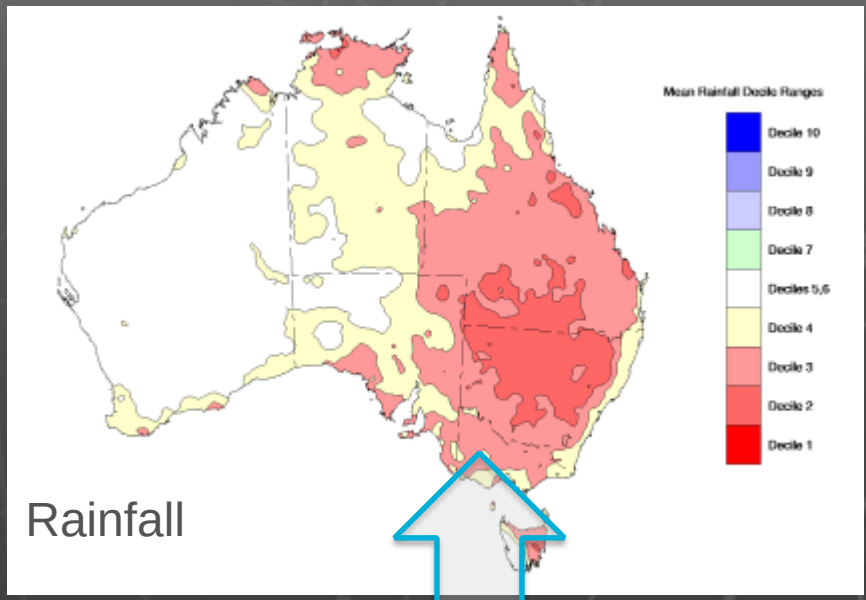
Composite impact of El Niño events

winter/spring rainfall and temperatures → some predictability to our droughts



Maximum T

Plan for decile 8-9



Rainfall

Plan for decile 2-3

Climate Prediction – this is why we can predict

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the… function)
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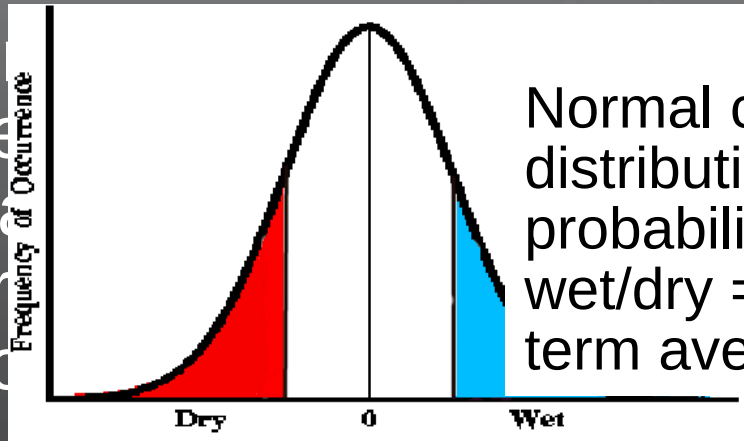
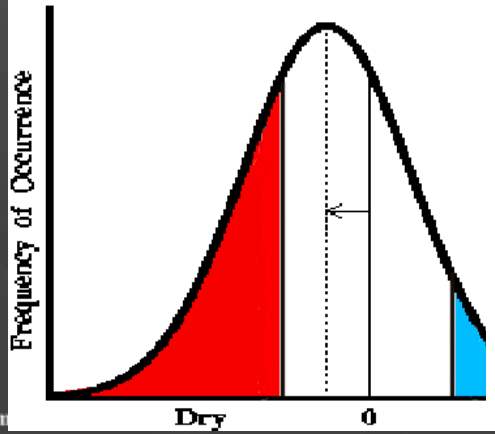
etc…

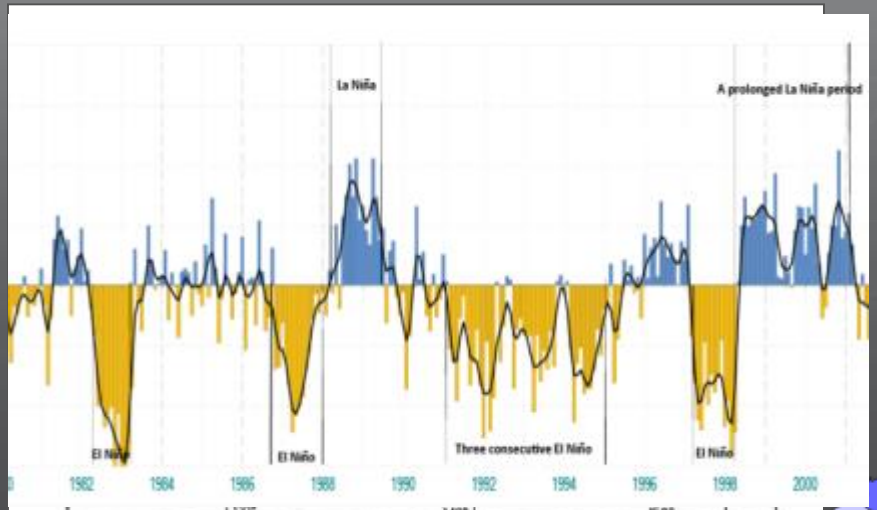


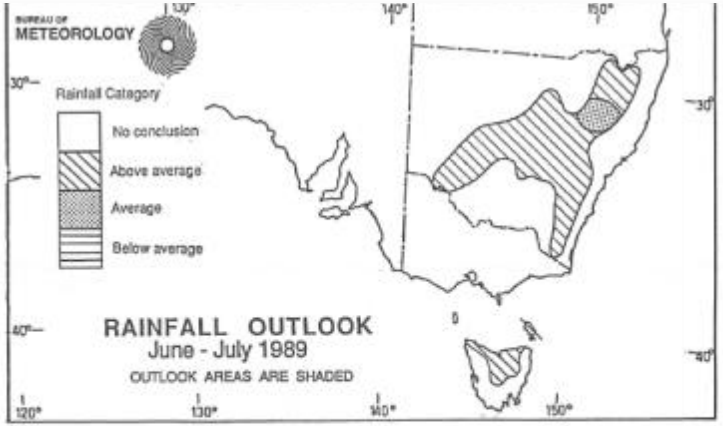
Normal climate distribution – probability of wet/dry = long term average



Conditional climate distribution, for example “El Nino” conditions.

The first issued Outlook





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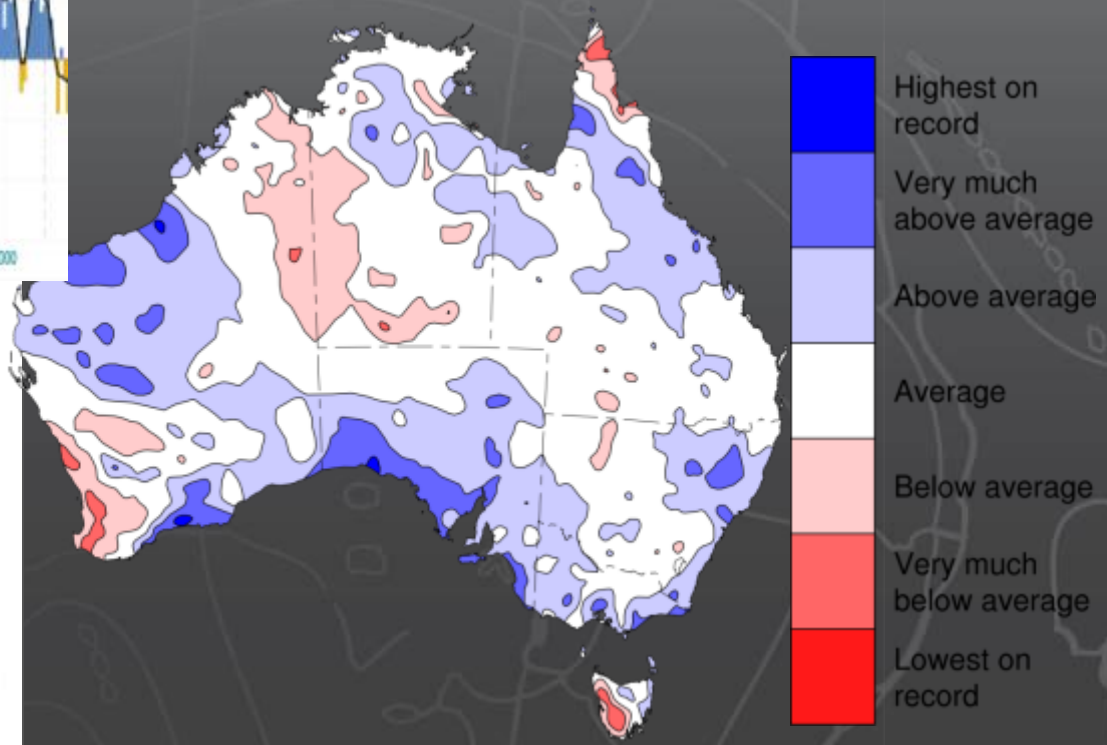
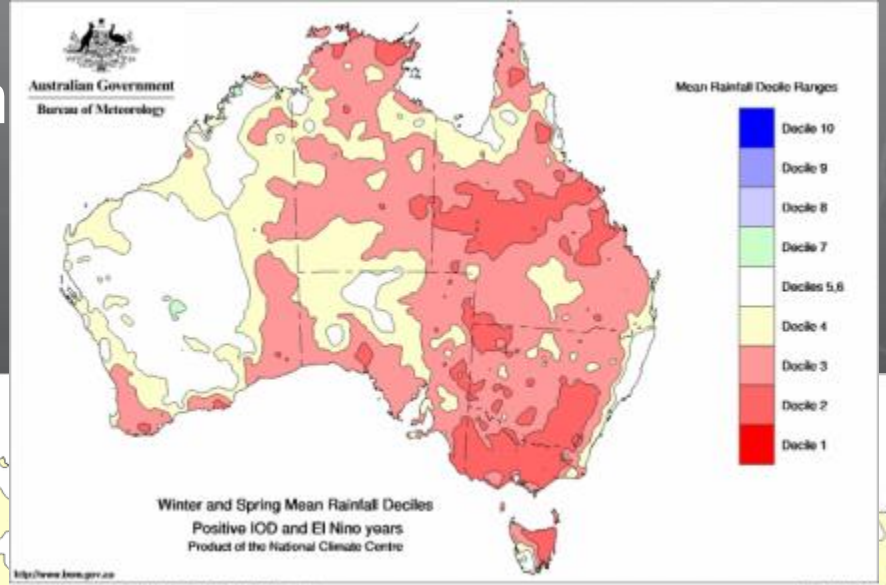
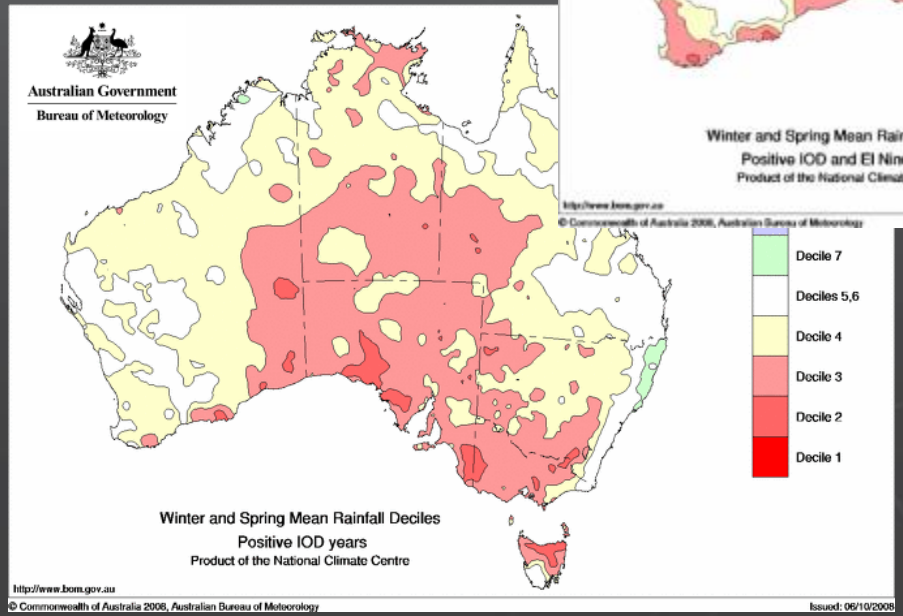
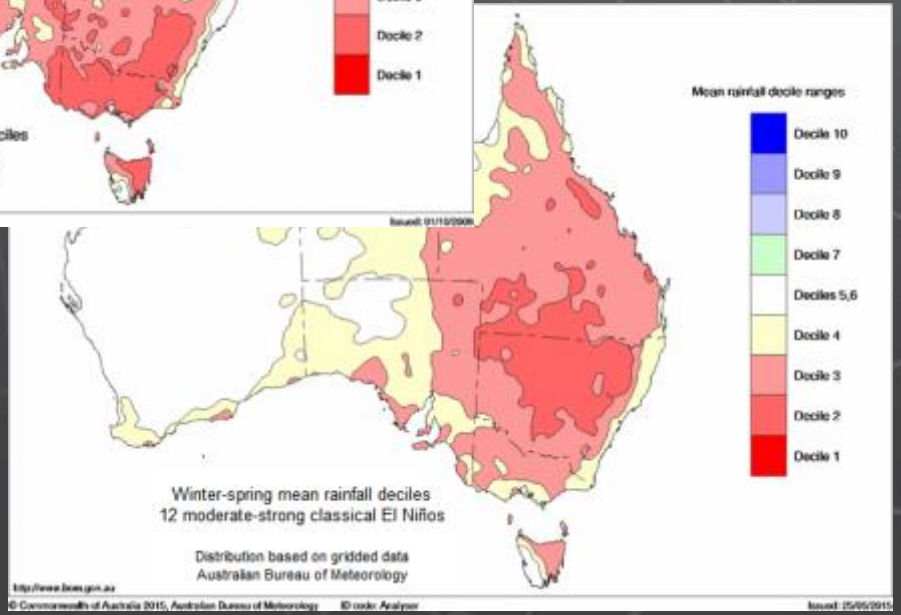


The Indian Ocean is important







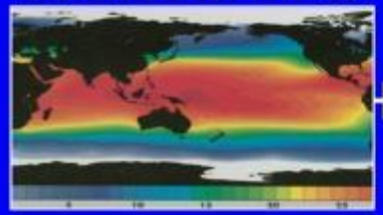
2005

SEA TEMPERATURE (SST) - BASED EMPIRICAL SEASONAL PREDICTION

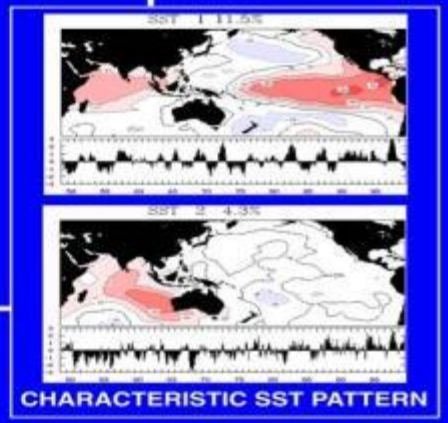
AUSTRALIAN RAINFALL DATA 1949 - 99

AUSTRALIAN TEMPERATURE DATA 1949 - 99

HISTORICAL SST 1949 - 99



STATISTICAL RELATIONSHIPS BETWEEN SST PATTERNS AND AUSTRALIAN TEMPERATURES AND RAINFALL



STATISTICAL PREDICTION SCHEME

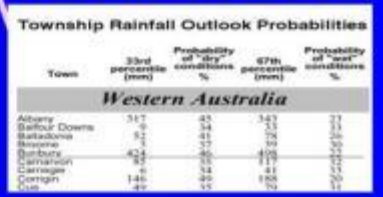
PRINCIPAL COMPONENT ANALYSIS

RECENT SST PATTERNS

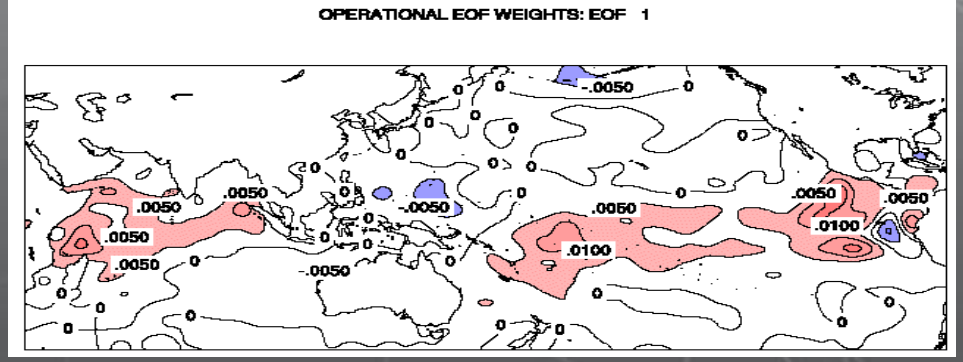
RAINFALL PROBABILITIES

TEMPERATURE PROBABILITIES

PROBABILITY TABLES



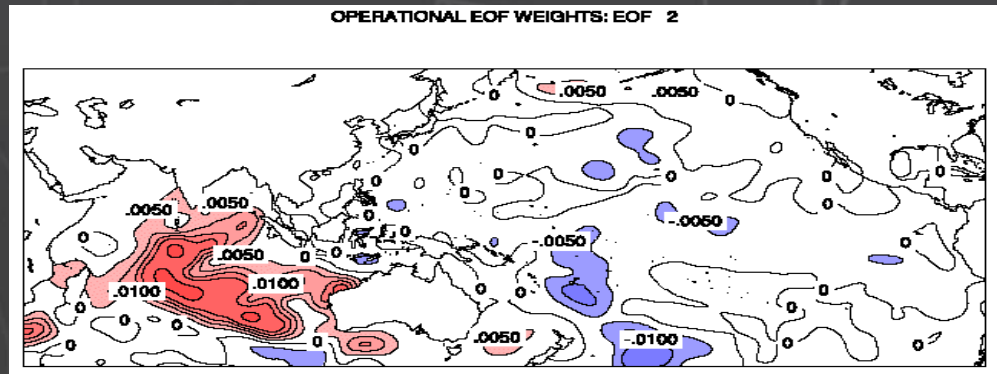
SST Phase scheme –



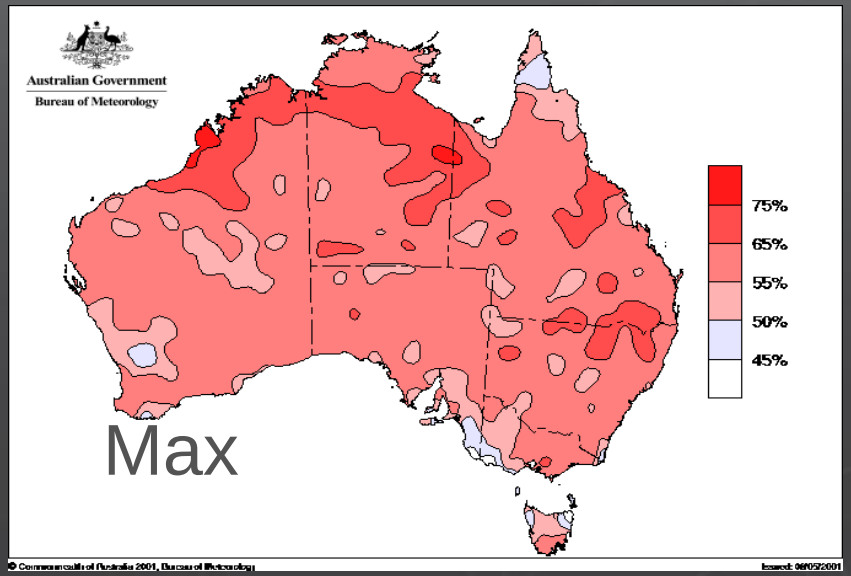
SST1SST2

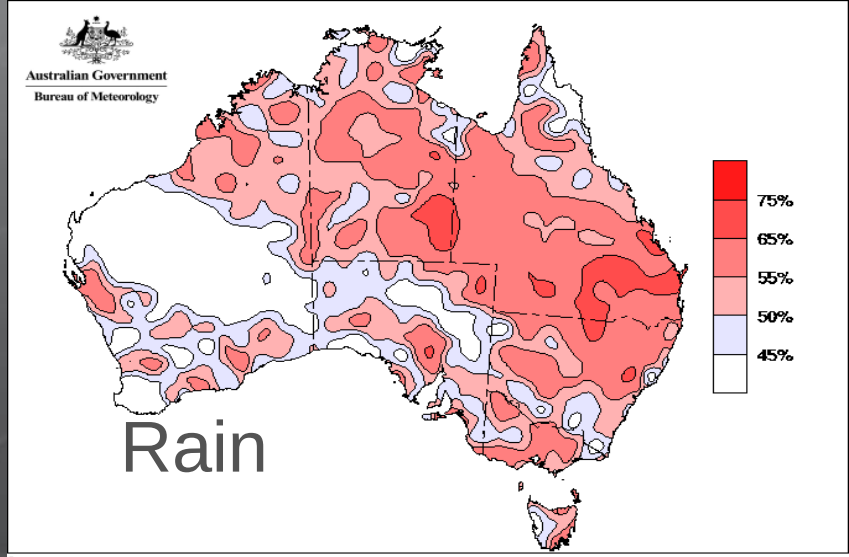
Also looked at the direction of change

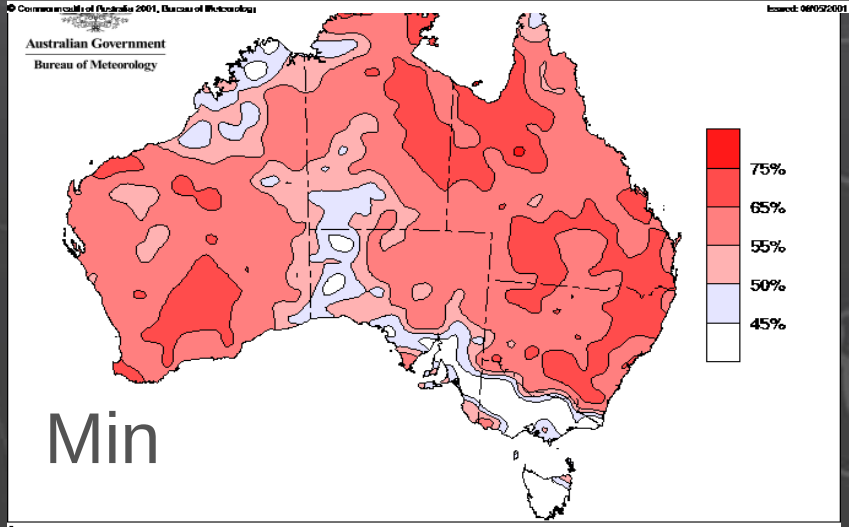
February	+0.904	+0.641	PHASE 9
March	+0.957	+1.037	PHASE 9
April	+1.150	+0.859	PHASE 9

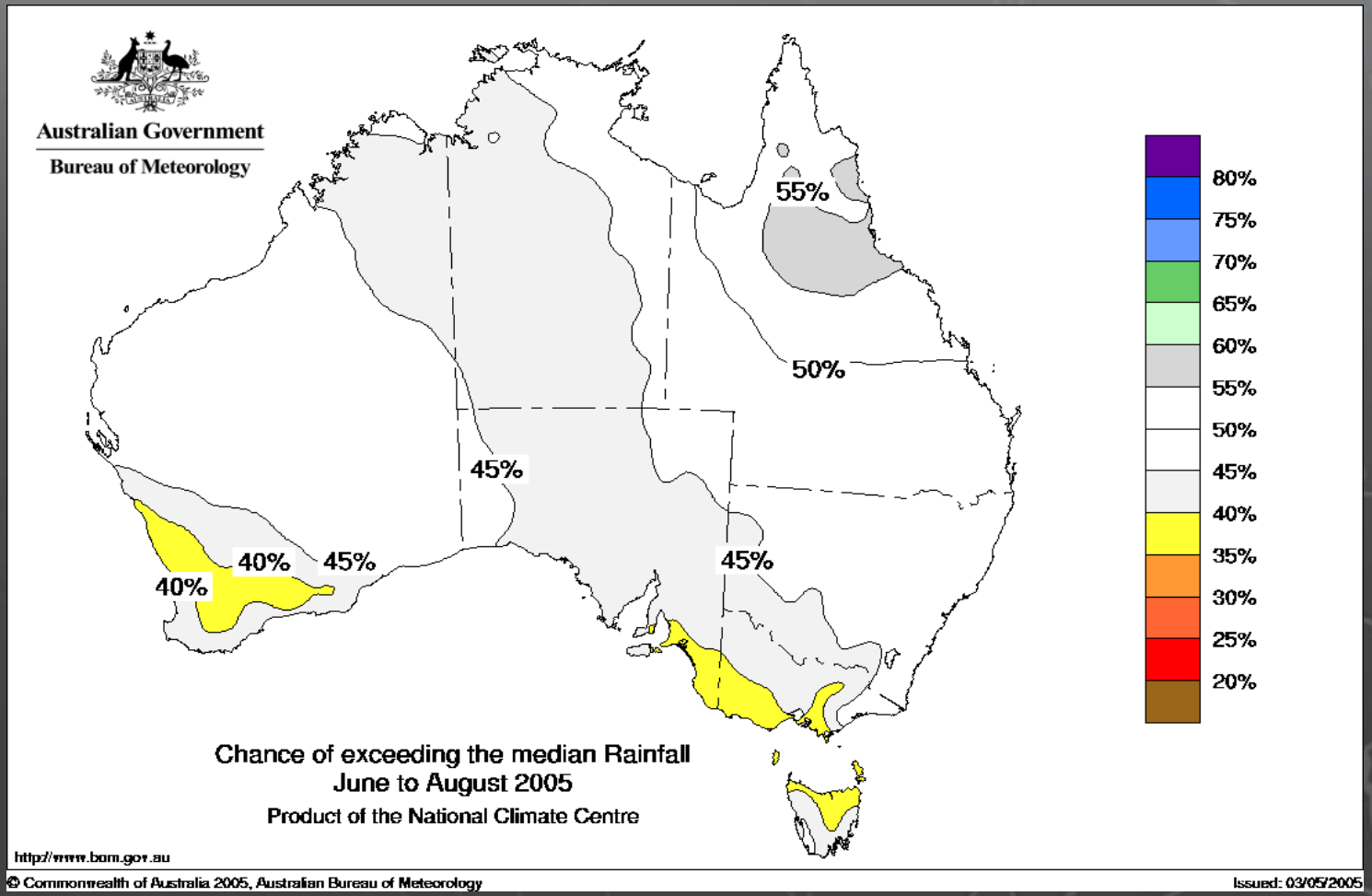


June – August forecast skill





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Bureau of Meteorology
55%
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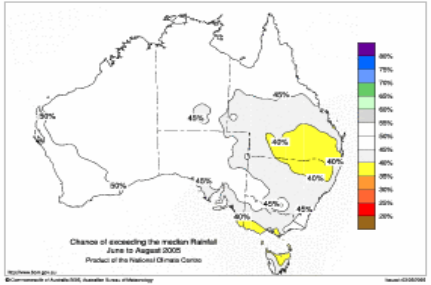
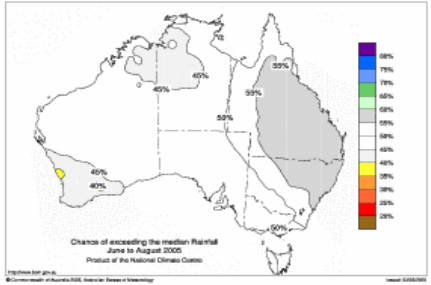
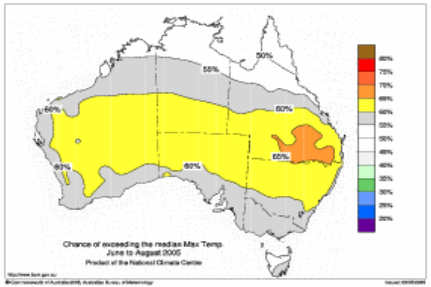
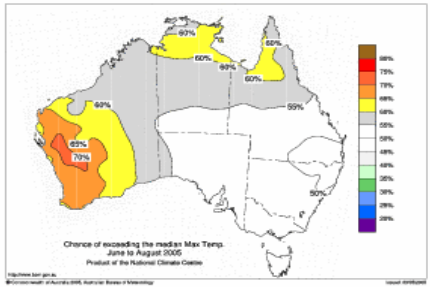
Chance of exceeding the median Rainfall
June to August 2005
Product of the National Climate Centre
http://www.bom.gov.au
© Commonwealth of Australia 2005, Australian Bureau of Meteorology
Issued: 03/05/2005

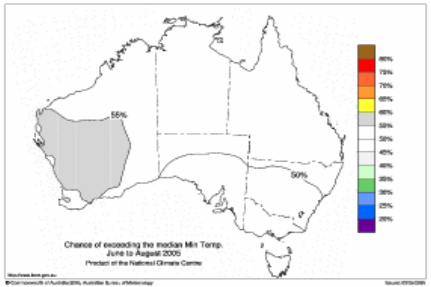
P A C I F I C

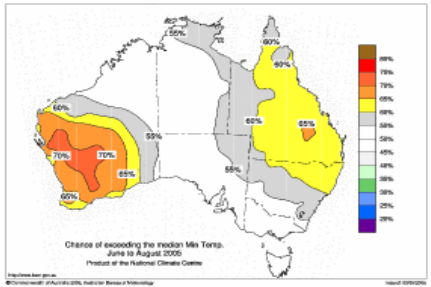












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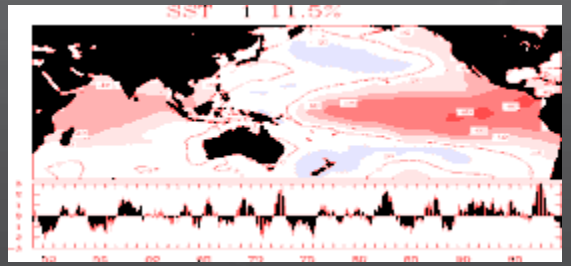
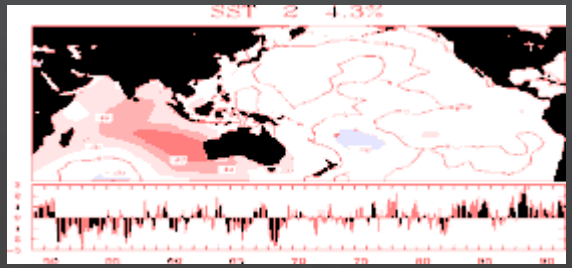
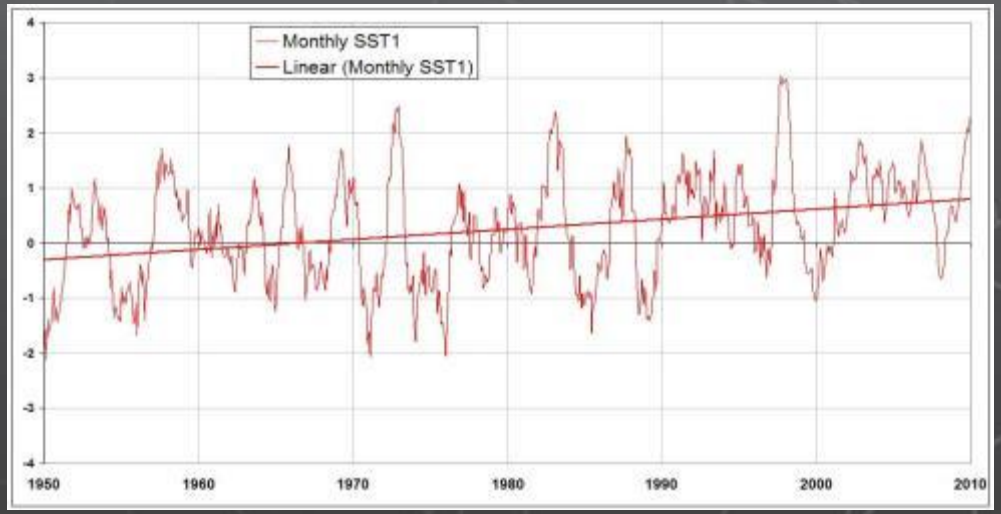
Statistical Model vs Climate Change (Does the past = the future?)



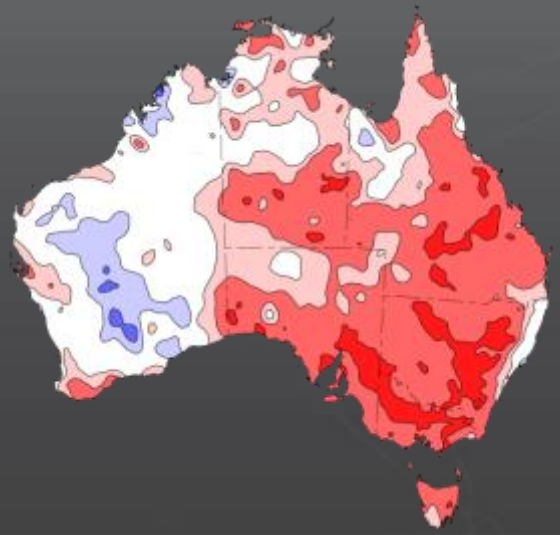




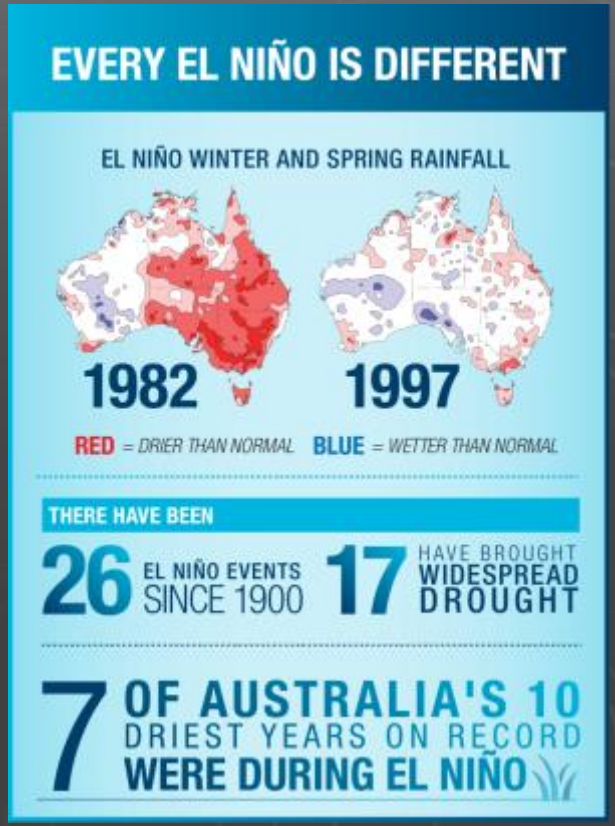
- Ocean temperatures are increasing to the point where the magnitude of the trend is comparable to one standard deviation of the SST predictors
- September 2010 – changed our ocean predictors; but is it enough?

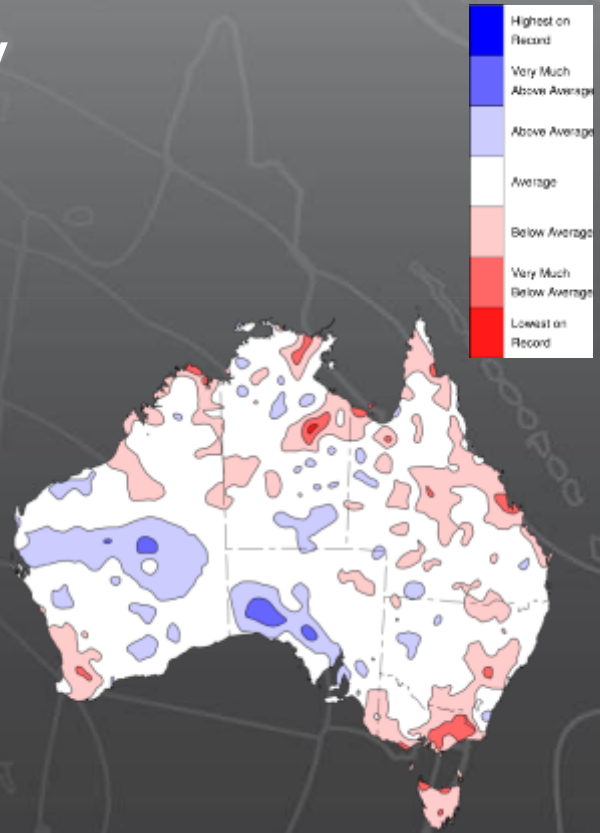
Individual impacts vary

winter/spring rainfall



1982





1997

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POAMA eases ahead

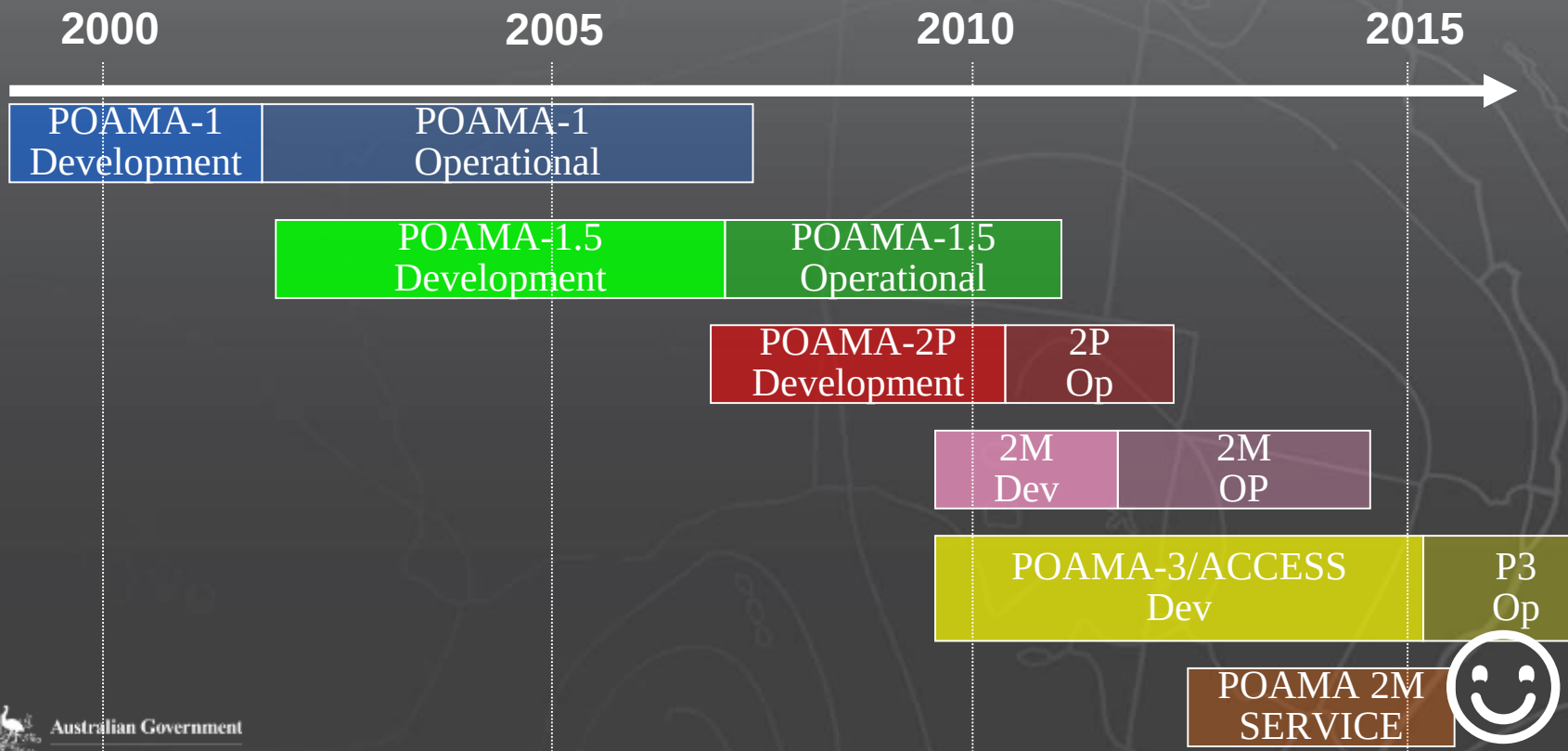
Australia's fortunate/unfortunate position on the globe means we are ENSO dominated; just knowing this means we can make decent outlooks 'cheaply' (McBride and Nicholls 1983)

Not enough to beat climatology or persistence, a new model needs to beat a good old (statistical) model

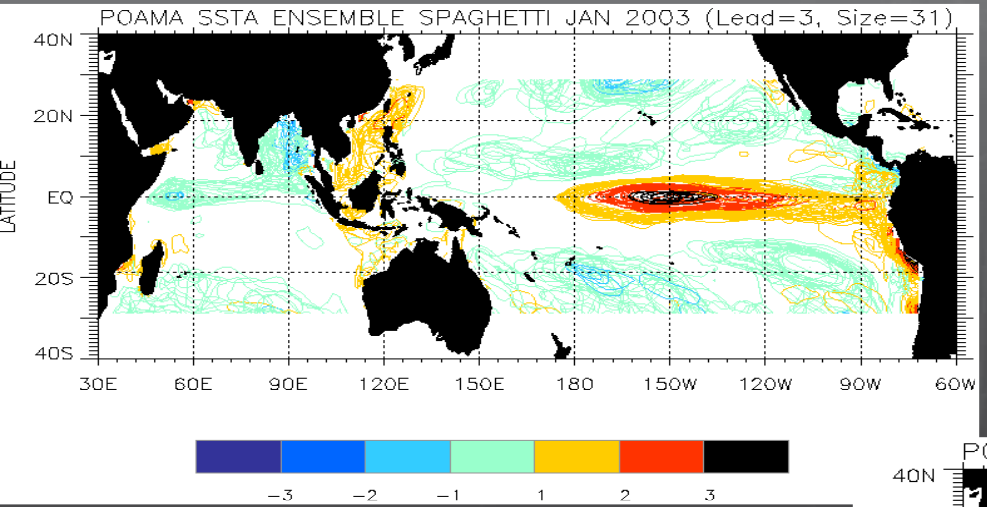
Change to services occurs when research shows a clear improvement over current service

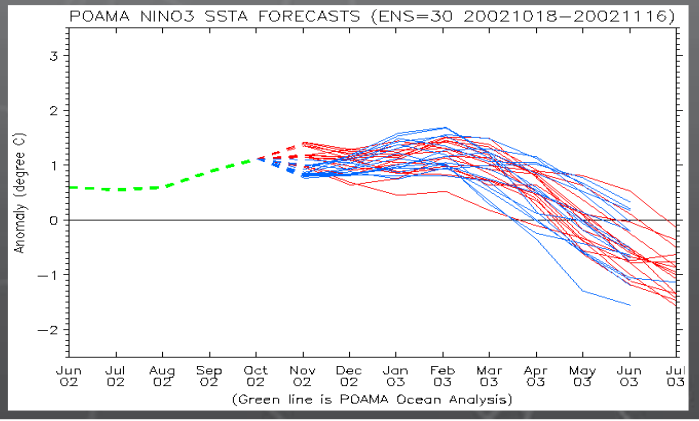
Variable	Hit Rate Statistical	Hit Rate Dynamical (POAMA)
Rainfall	53	56
Maximum Temperature	58	60
Minimum Temperature	59	56

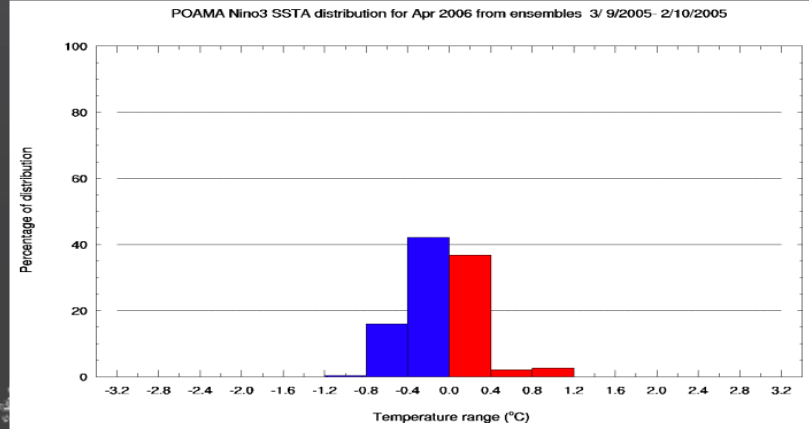
Seasonal outlooks over time

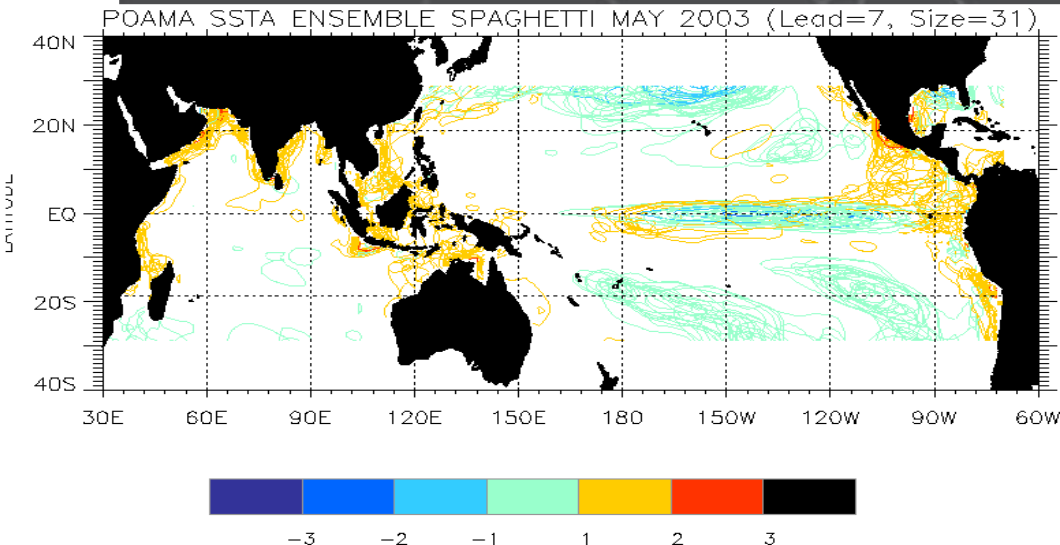


Beginnings of a dynamical forecast system: operational





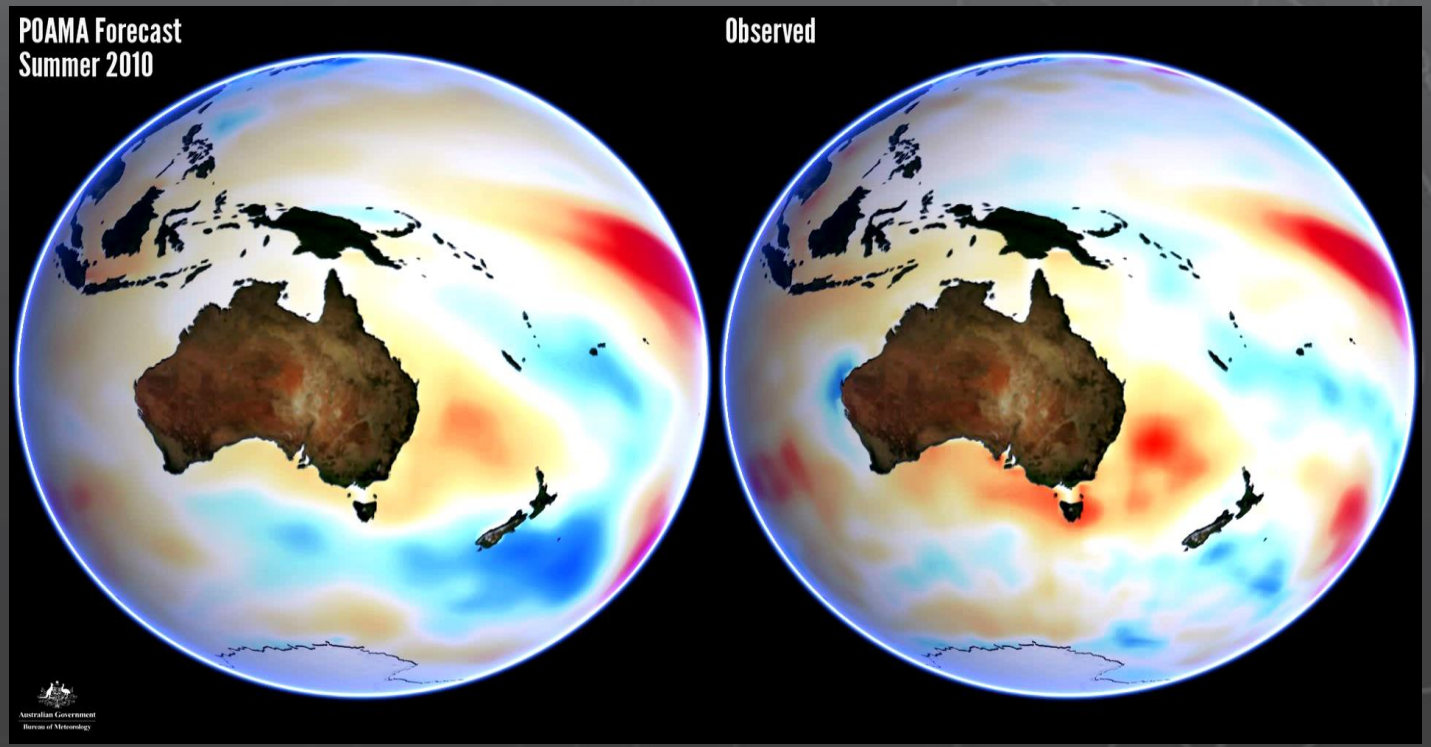




Issues and prospects

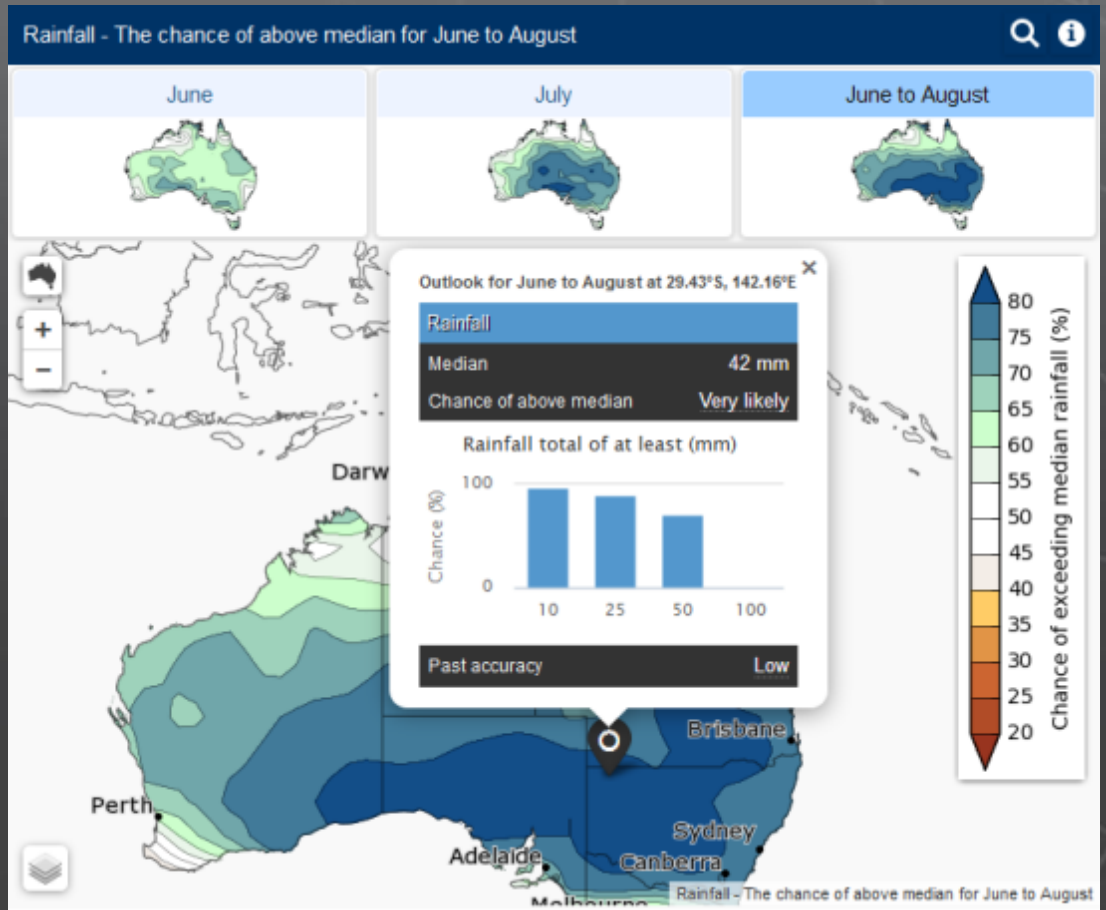
1. Direct and strict comparisons are not possible
2. Dynamical model has year round skill, while statistical model has skill for most standard seasons, but may have no skill for certain seasons
3. Capabilities of dynamical outlook systems are supported by solid and ever improving science and computer technologies
4. Skill has improved, can handle climate change
5. Dynamical systems are full of potential and provide a platform to further develop consistent multi-week to multi-season climate prediction services
6. It’s the future, it is just the beginning!

We know the model (POAMA) world behaves like the real world



Current forecast system

Monthly forecasts for the first two months and a seasonal forecast



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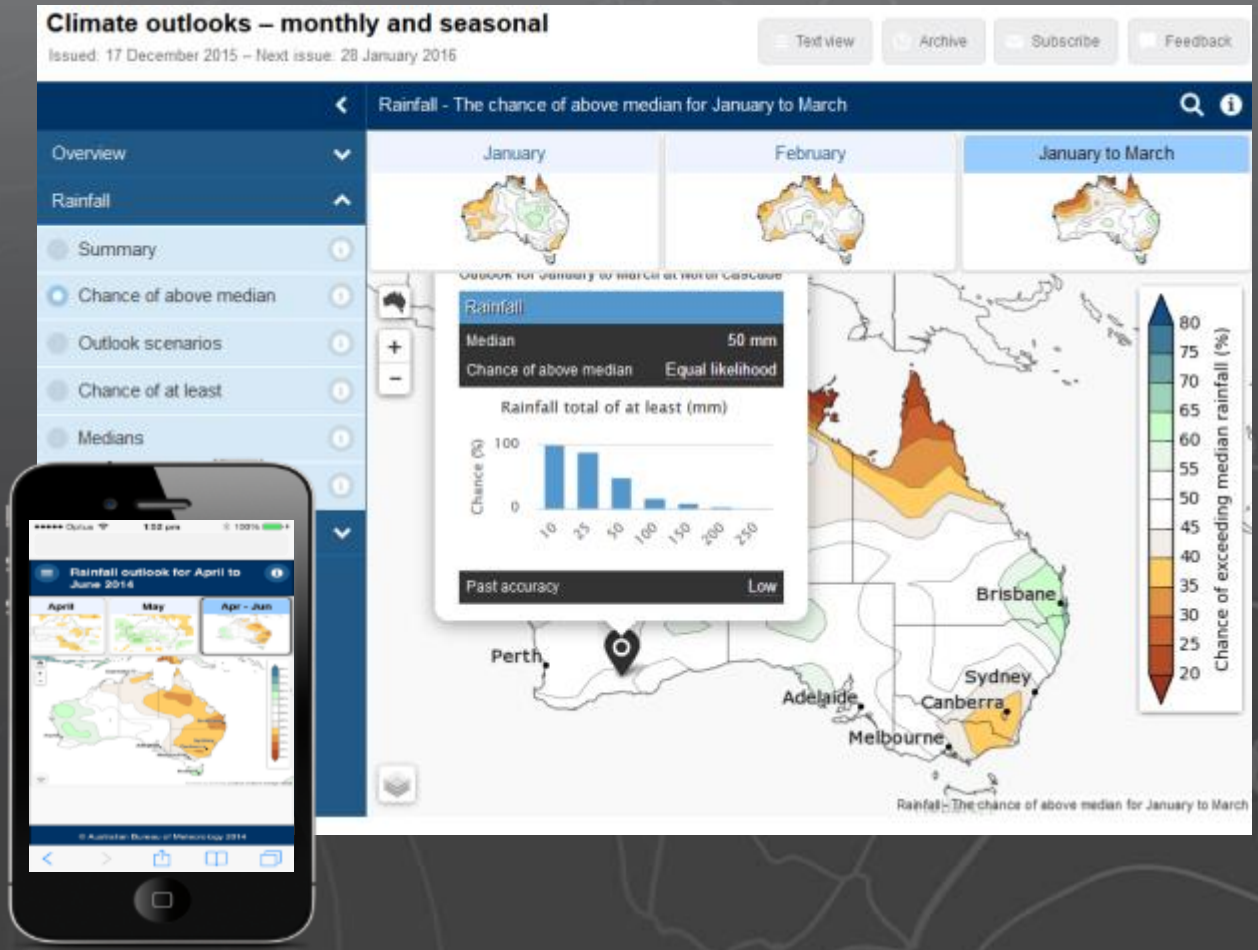
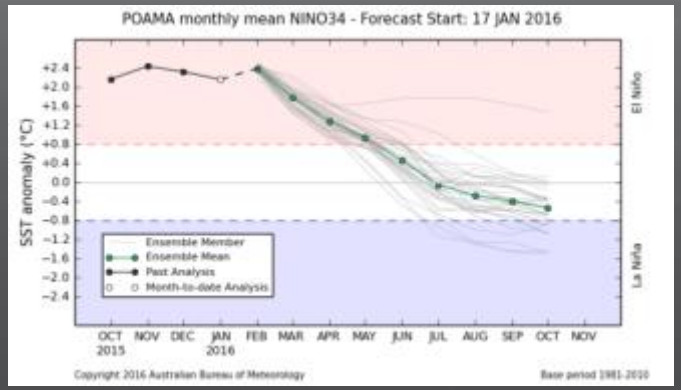
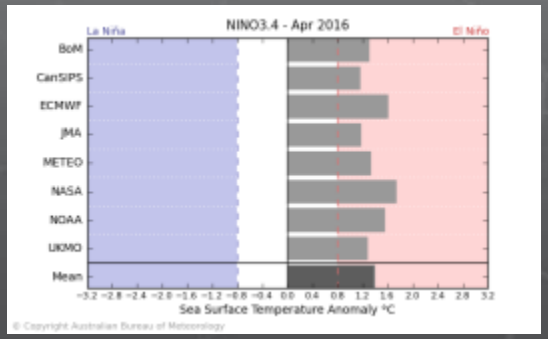
The Climate Outlooks service

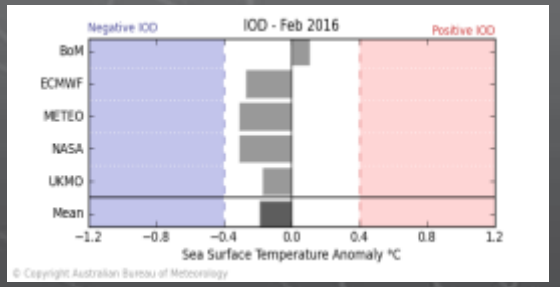
- Monthly and seasonal outlooks
- Temperature and rainfall
- Engaging and intuitive
- Large user base
- Operationally supported

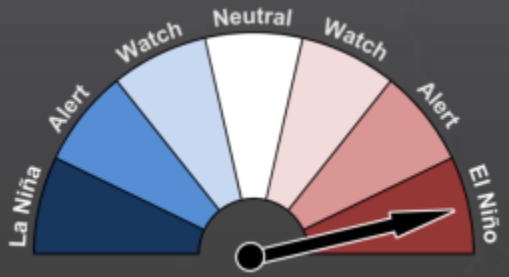


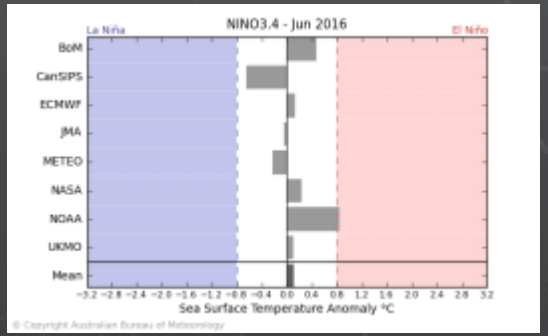
The Climate Outlook service

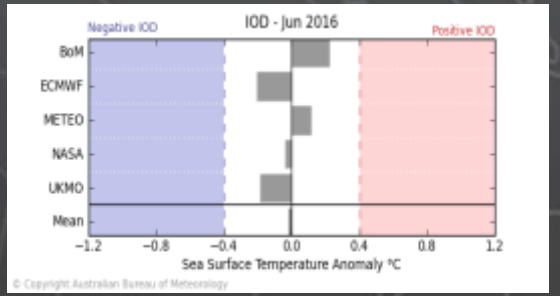












Outlook for drivers including ENSO, IOD, SAM and the MJO

Supporting the outlook service – ENSO wrap

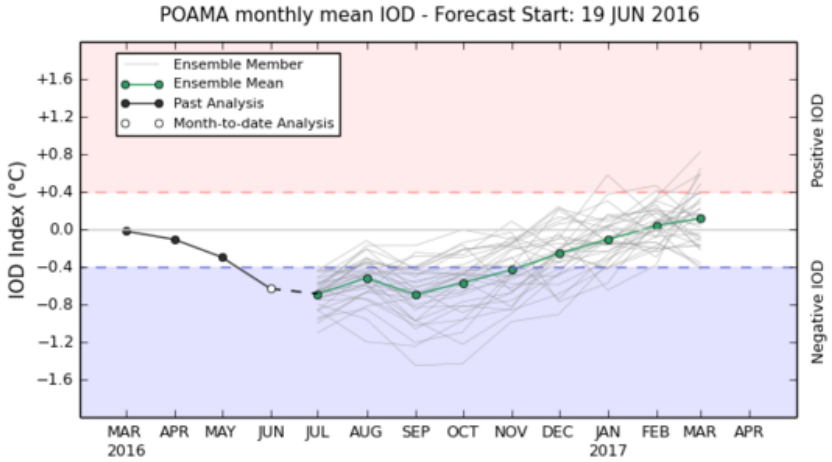
Indian Ocean Dipole outlooks

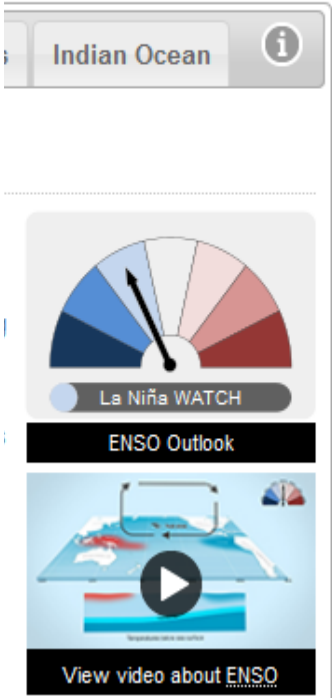
The Indian Ocean Dipole (IOD) index has been below -0.4 °C for the past four weeks, with a latest weekly value of -0.6 °C for the week ending 19 June 2016. To be considered a negative IOD event, it would take several more weeks of IOD index values below the threshold value. International climate models suggest these negative values are likely to persist over the coming months, with all models suggesting a negative IOD event will develop in the winter-spring months.

Negative IOD events are more likely to occur during La Niña. Typically a negative IOD brings above average winter-spring rainfall to southern Australia.

More broadly, sea surface temperatures (SSTs) are significantly warmer than average across much of the Indian Ocean. This warmth will likely provide more available moisture to weather systems as they cross the Australian continent.

IOD SST plumes from POAMA forecasts, updated daily





Weekly update of tropical-wave activity – summary via email

e-alert **Weekly Tropical Climate Note**

Australian Government
Bureau of Meteorology

Weekly Tropical Climate Note issued 28 June 2016

The latest Weekly Tropical Climate Note is now available. Below is a summary of tropical weather and climate for the past week. Full details are available on our website.

Indian and South-East Asian monsoons active

- Tropical-wave activity, including a Madden–Julian Oscillation, significantly enhanced weather across the northern Indian Ocean and the western Maritime Continent last week.
- Monsoonal flow has become well established over India and South-East Asia during the last fortnight.

Warm conditions likely to continue across northern Australia

- Last week saw a continuation of the warm conditions which have affected northern Australia for much of the year.
- The Bureau's climate outlooks favour continuing above-median daytime and overnight temperatures over northern Australia.

ENSO Outlook remains at La Niña Watch

- Tropical Pacific Ocean remains in a neutral El Niño-Southern Oscillation (ENSO) state, with the ENSO Outlook at La Niña WATCH.
- Warmer waters in the Indian Ocean to Australia's northwest, relative to waters off the east African tropical coast, indicate a negative Indian Ocean Dipole-like pattern.

http://www.bom.gov.au/climate/tropical-note/

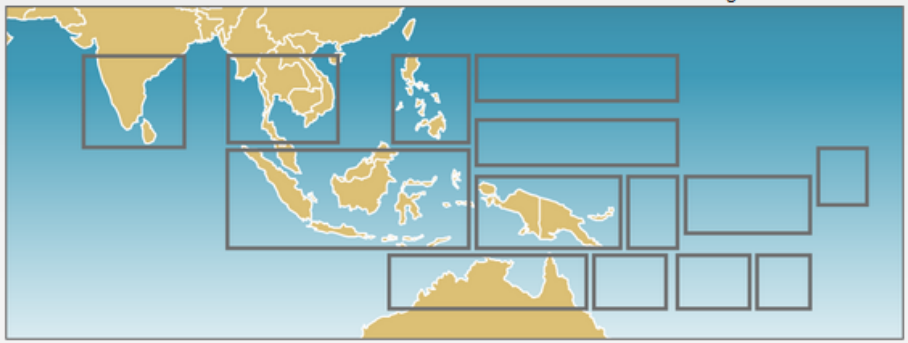
Weekly update o tropical-wave activity – website

http://www.bom.gov.au/climate/mj

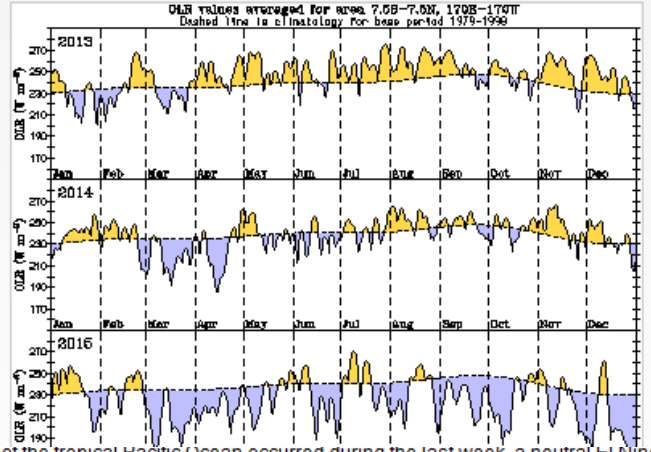
MJO phase | Average conditions | Average OLR | Cloudiness | **Regional cloudiness** | Time longitude | Weekly note

Regional maps of outgoing longwave radiation (OLR)

Click on the boxes to view a timeseries of cloudiness for that region.



Below: OLR totals over the dateline

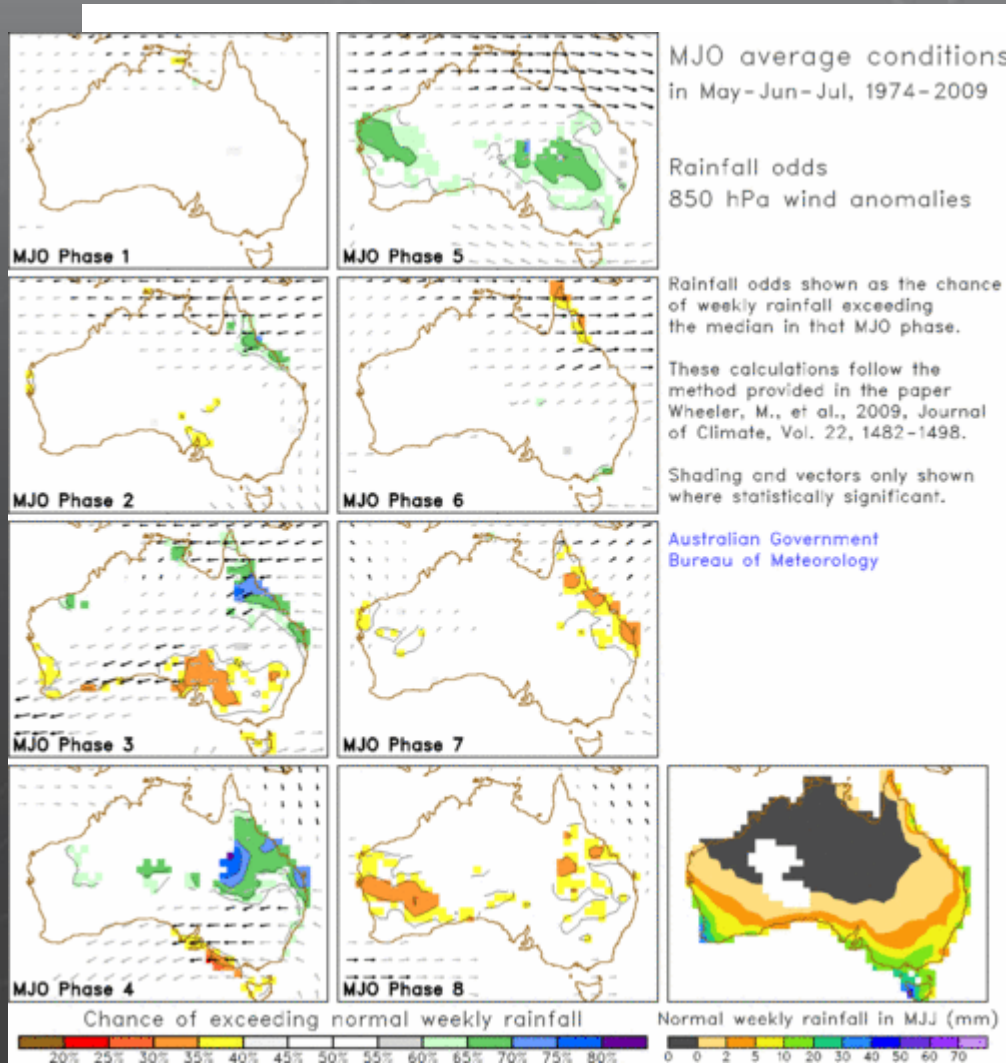


The graphs linked to this map show the OLRs for the different regions within the Darwin RSMC area. The horizontal dashed line represents what is normal for that time of year (based on the 1979 to 1998 period). The coloured curve is the 3-day moving average OLR in W/m². Below normal OLR indicates cloudier than normal conditions in this particular area, and is shown in blue shading. Above normal OLR indicates less cloudy conditions and is shown in yellow shading.

Postscript: Coral Sea Dateline Fiji Guam & Marianas Indochina Malyasia & Indonesia Micronesia Nauru & Tuvalu New Guinea Northern Australia Philippines Solomon Island Southern India & Sri Lanka Vanuatu

While cooling of the tropical Pacific Ocean occurred during the last week, a neutral El Niño–Southern Oscillation (ENSO) continues. The Bureau's *ENSO Outlook* remains at La Niña WATCH, which means

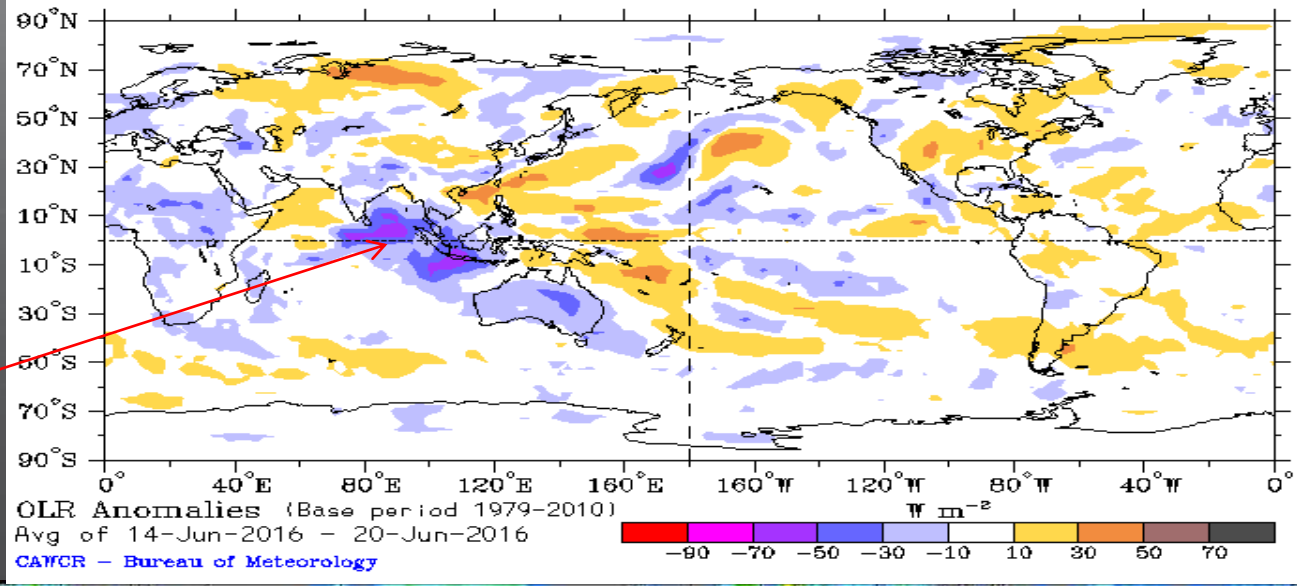
Weekly update of tropical-wave activity – website



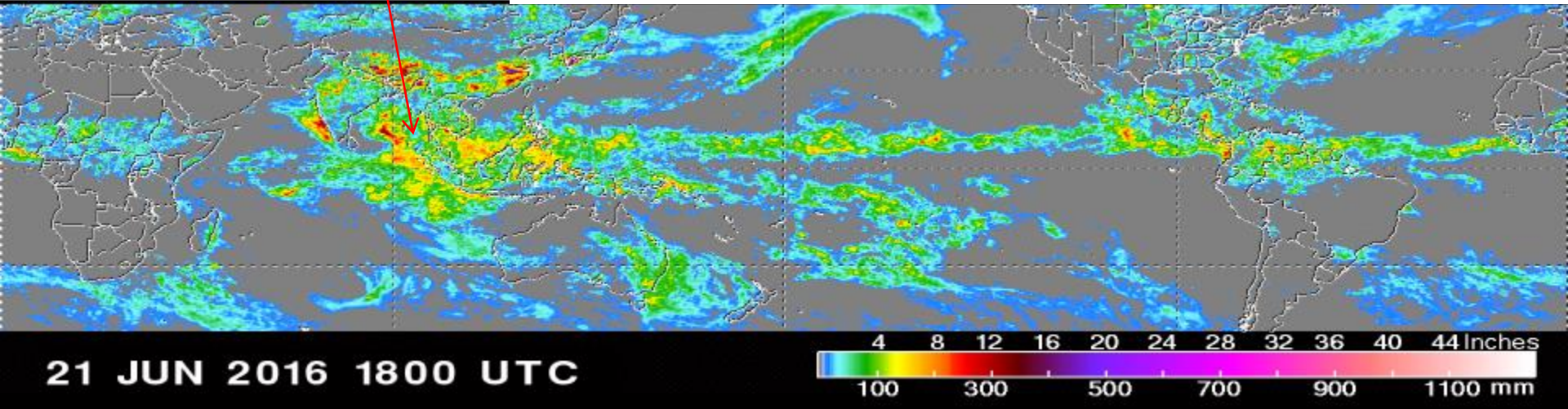
Latest weekly OLR anomaly

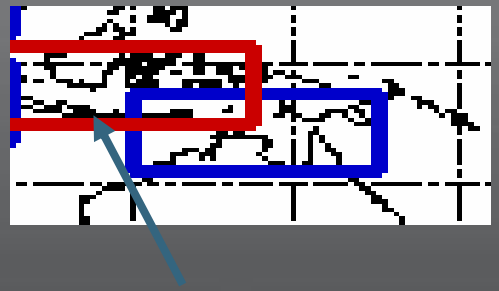
14 – 20 June

Indian and East Asia monsoons active

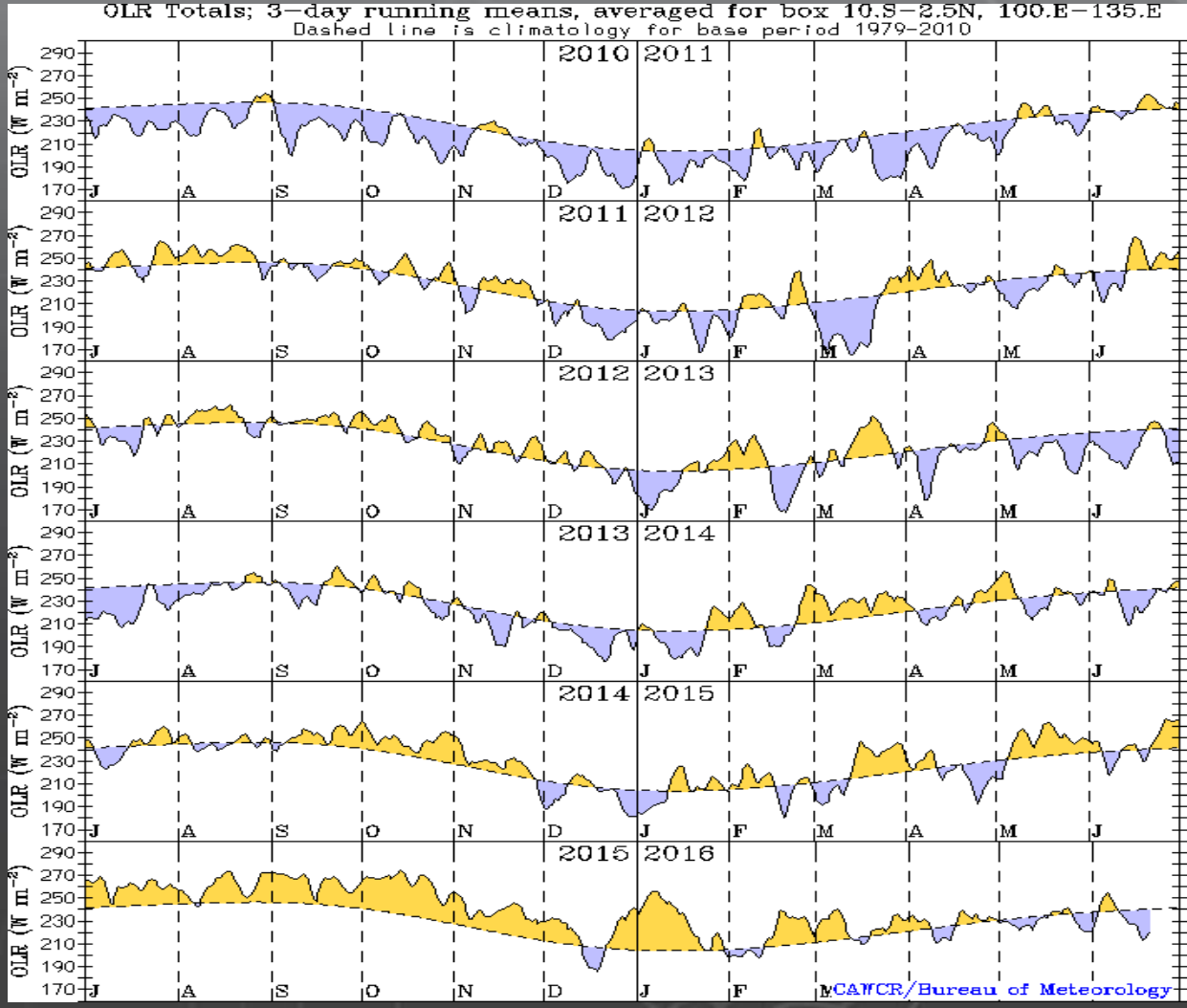


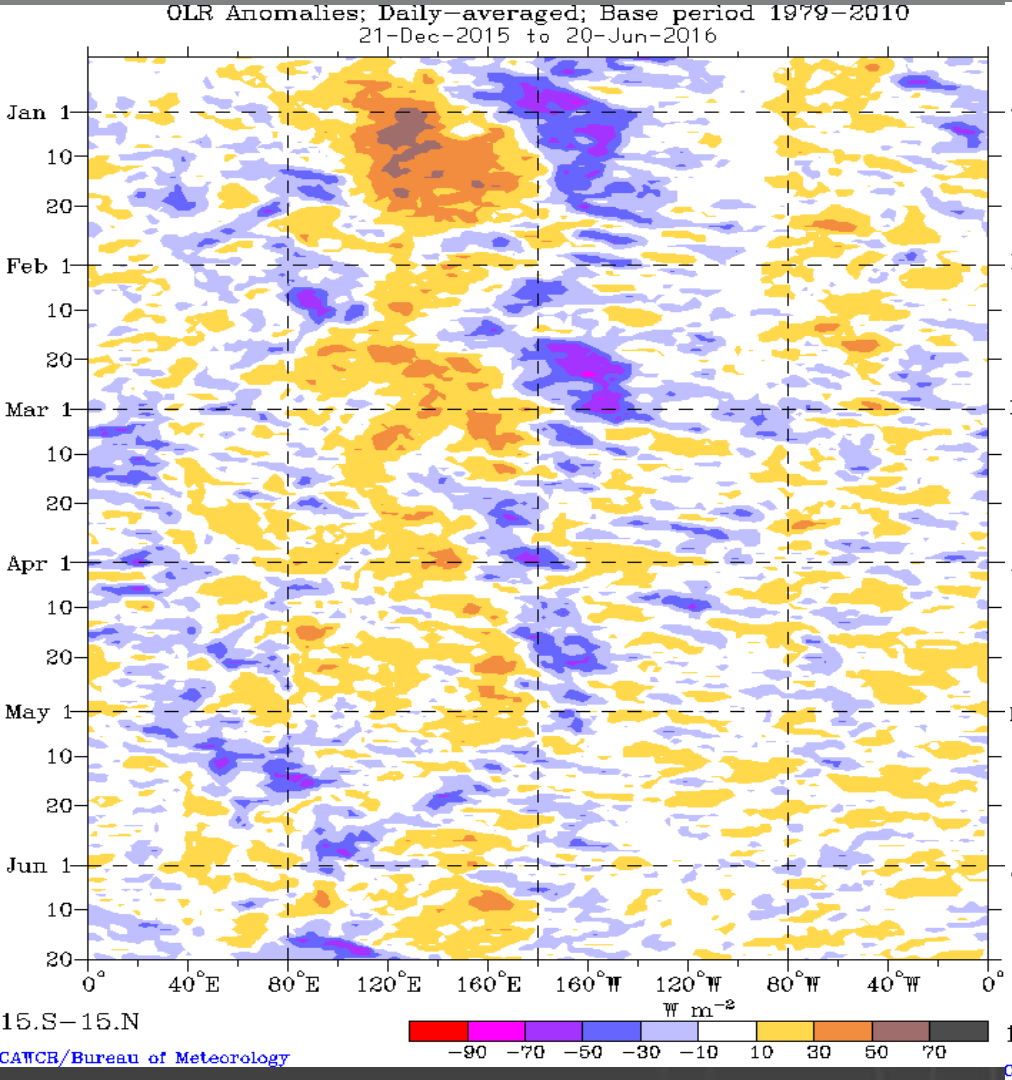
7-day precip total

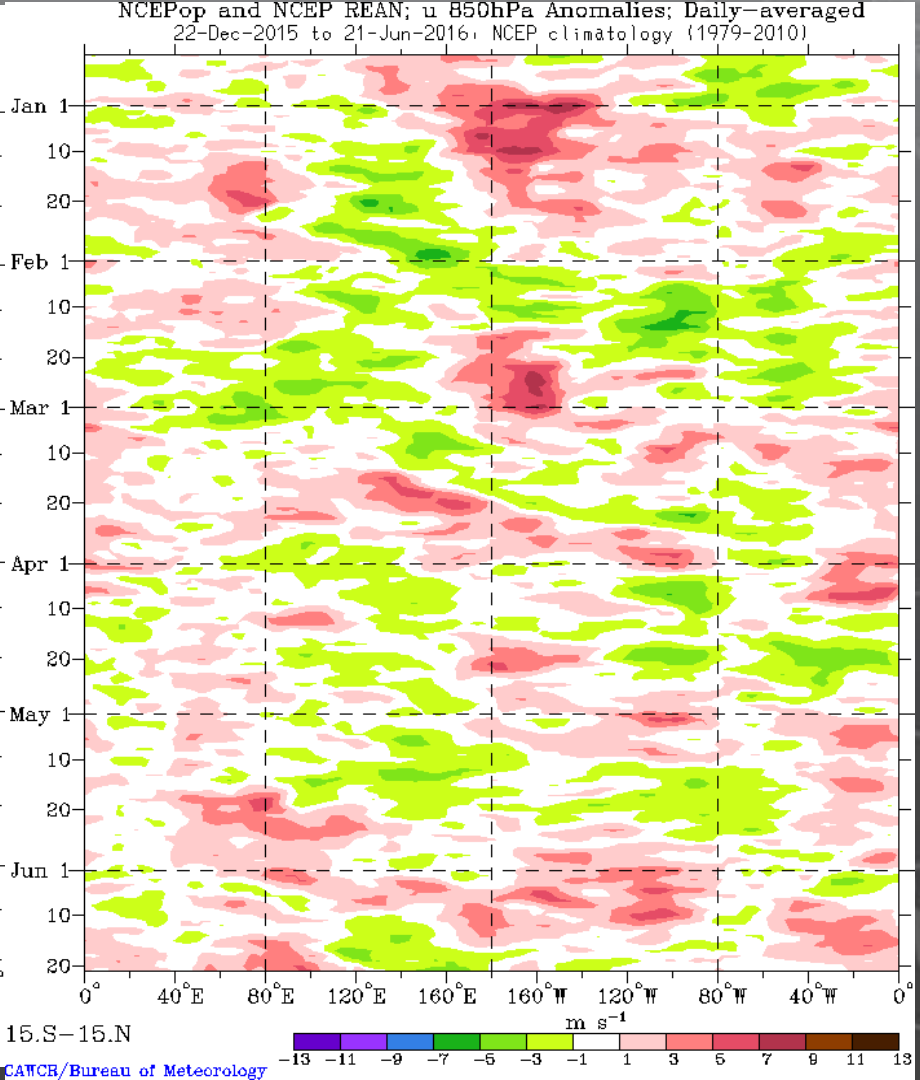


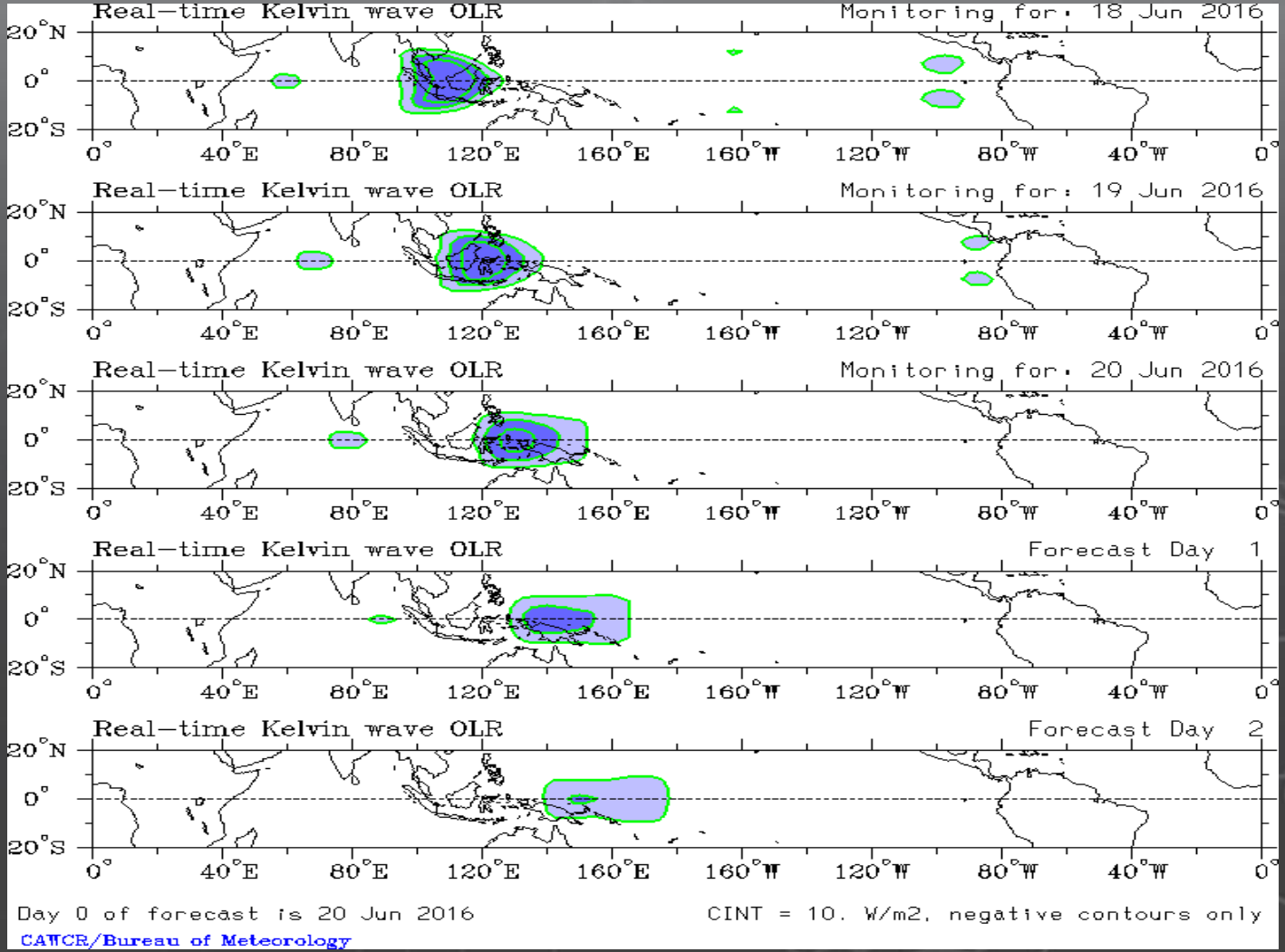


Convection (OLR) in western Maritime Continent




OLR Anomalies; Daily-averaged; Base period 1979-2010
21-Dec-2015 to 20-Jun-2016
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
0° 40°E 80°E 120°E 160°E 160°W 120°W 80°W 40°W 0°
W m-2
-90 -70 -50 -30 -10 10 30 50 70
15.S-15.N
CAWCR/Bureau of Meteorology


NCEPop and NCEP REAN; u 850hPa Anomalies; Daily-averaged
22-Dec-2015 to 21-Jun-2016, NCEP climatology (1979-2010)
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
0° 40°E 80°E 120°E 160°E 160°W 120°W 80°W 40°W 0°
m s-1
-13 -11 -9 -7 -5 -3 -1 1 3 5 7 9 11 13
15.S-15.N
CAWCR/Bureau of Meteorology



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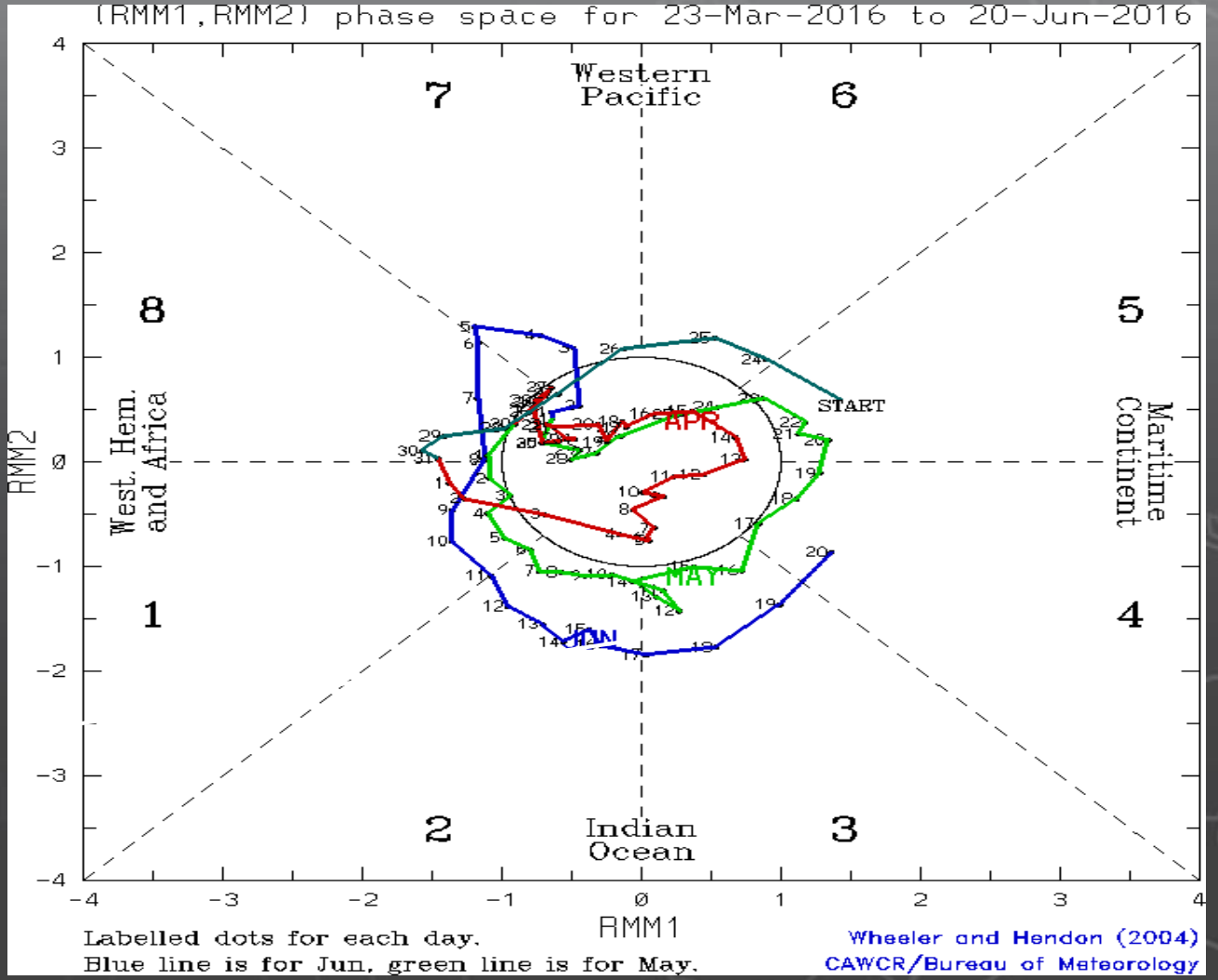
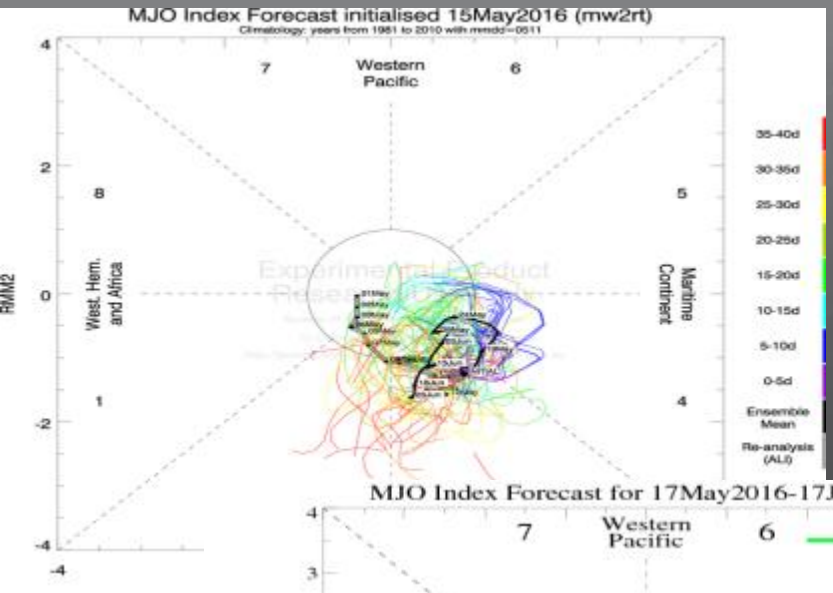
MJO index

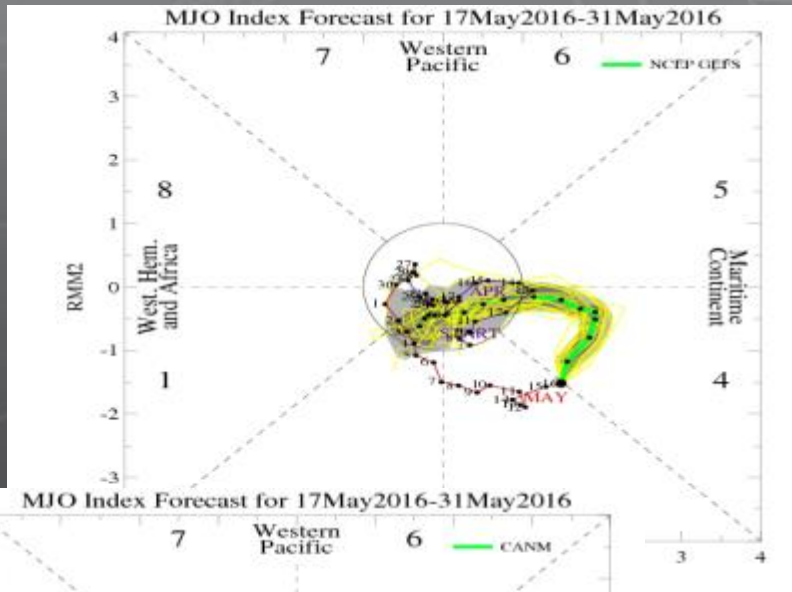
Latest 90 days

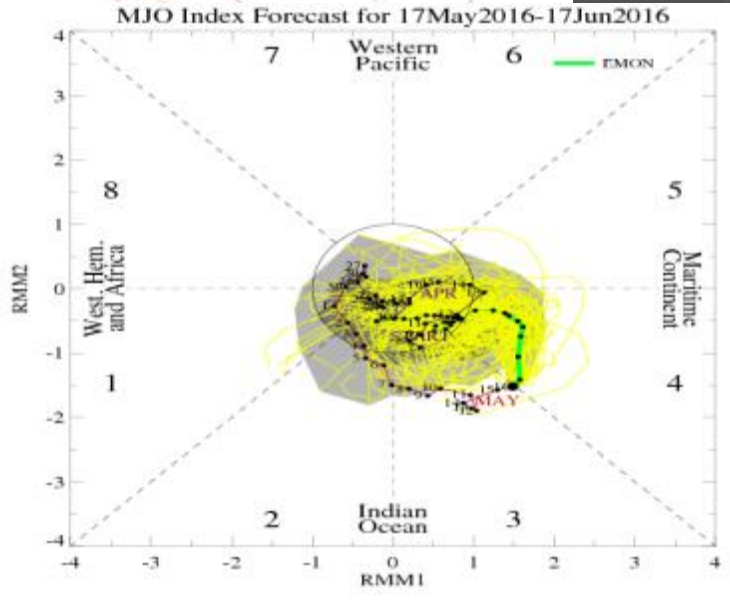
Recently 'Moderate' in strength

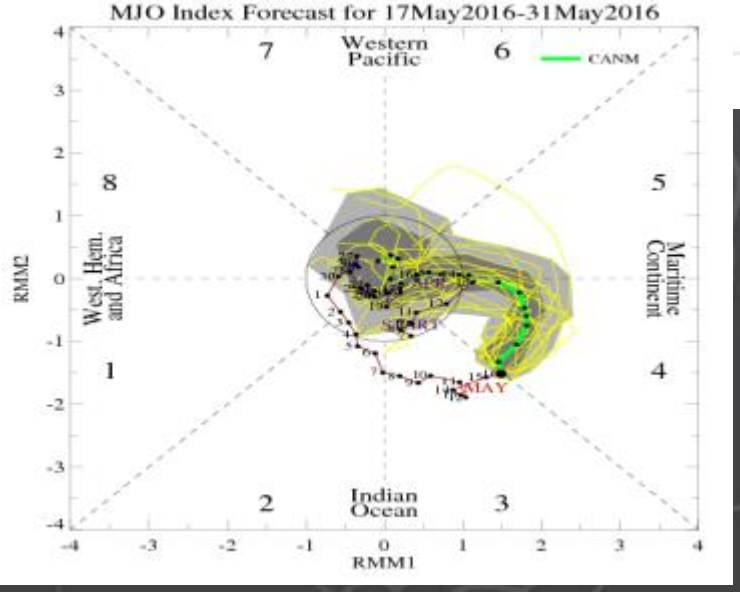


MJO forecasts from last month

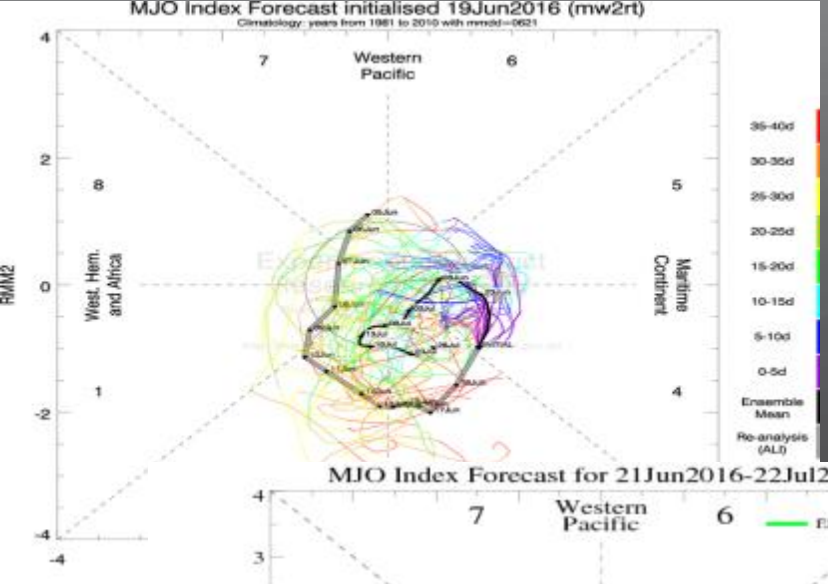


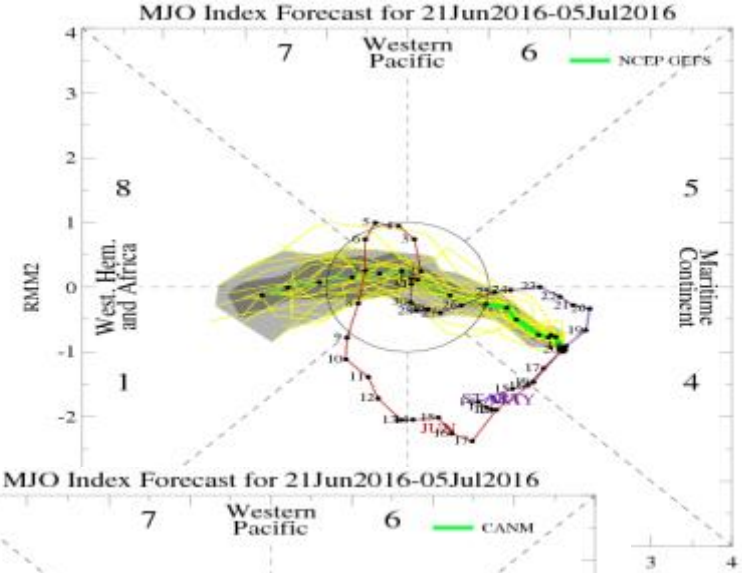


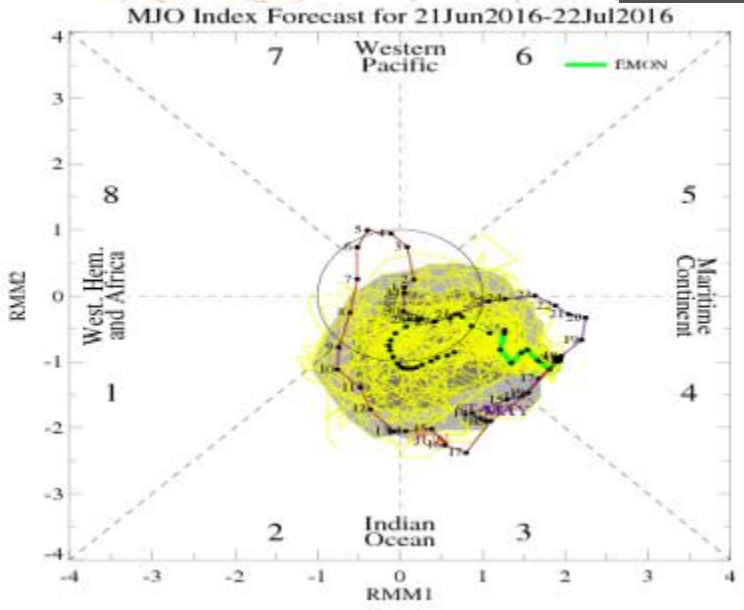


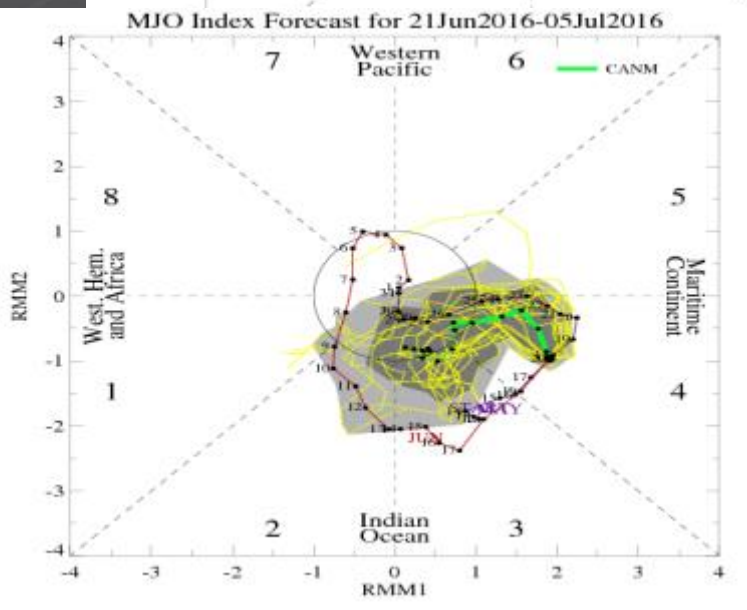


Current MJO forecasts



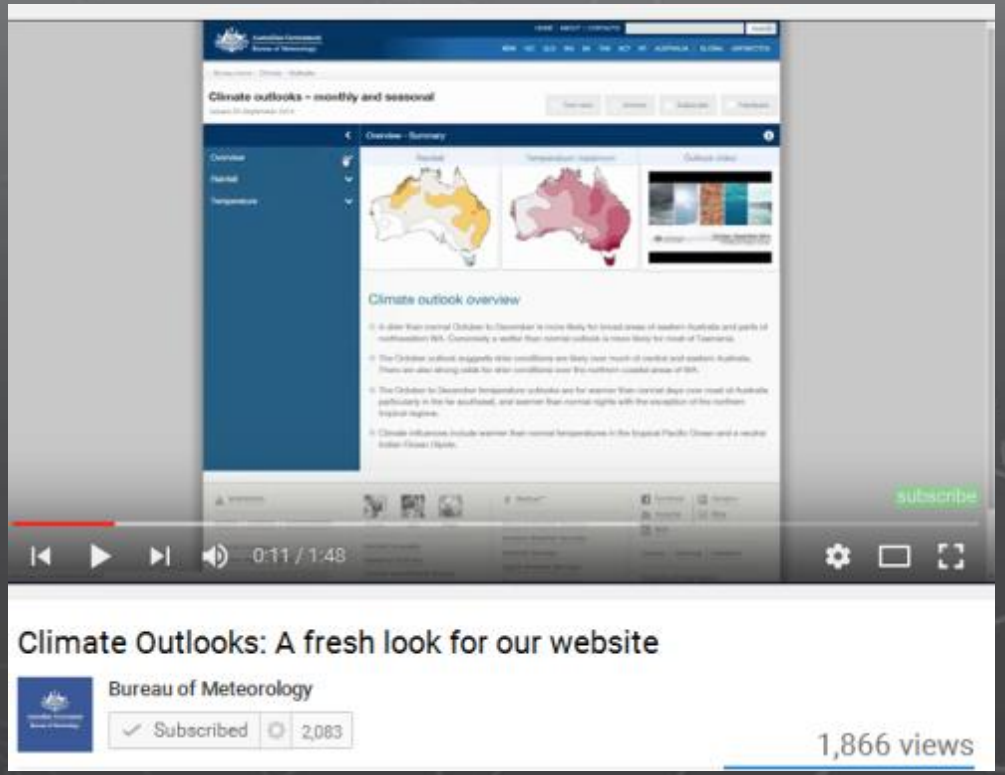






The Climate Outlooks service

Communicating forecasts: Type of forecast, language of forecast



https://www.youtube.com/watch?v=-bkMtPeyW_0&list=PLbKuJrA7Vp7mYDUe6o1CtVskn8xeKcNrb

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Feedback - Simple and Advanced Needs

User needs range from a simple map overview, to data that can be entered into complex decision models, e.g., crop models

"I just want a map I can glance at to get a snapshot of what's going on, then I can decide whether to drill deeper."

"I want climate outlook information in a form I can enter into a decision-support model."

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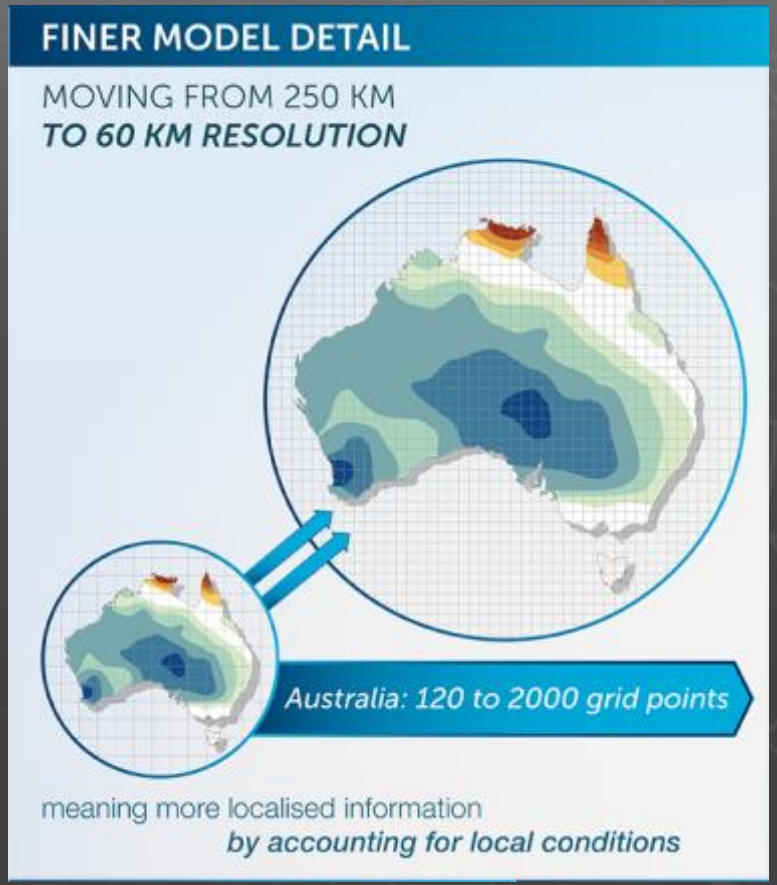
Feedback - Accuracy and resolution

- Users want greater accuracy, and information specific to their location

"Specific and accurate information for our location not just for the region."



"Spatial resolution remains a problem"

"It's very good but I would like a more detailed 0 to 3 week forecast over a smaller grid."

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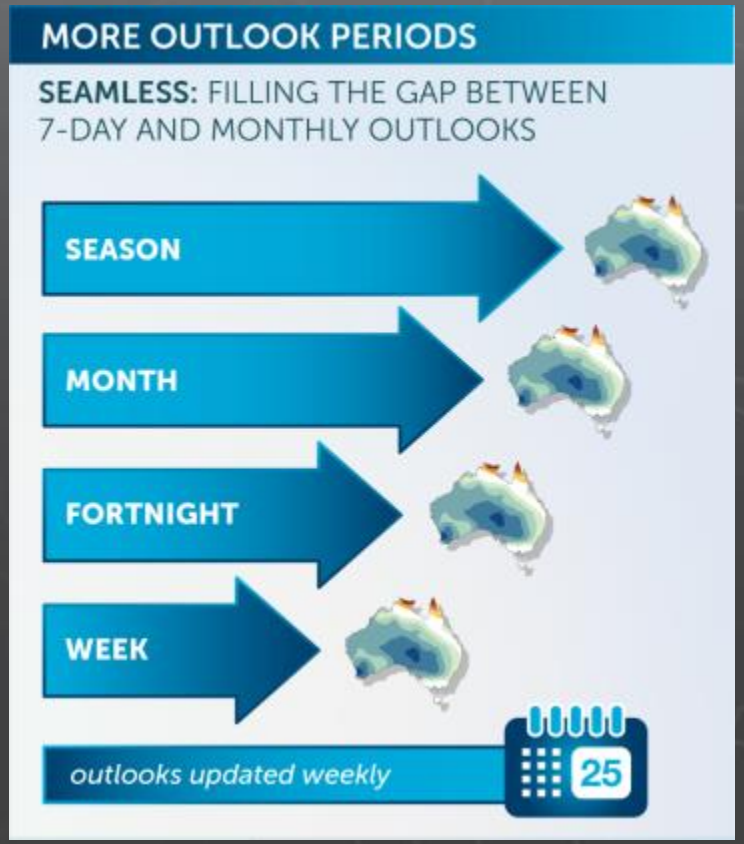
Feedback - Timescales

- Multi-week outlooks will be valued highly by users
- More frequent updates will be useful



"Current products are useful, but there is scope to improve service through greater focus on timescales of 1-4 weeks."

"Having more regular updates and plugging the forecasting gap between 7 days and 1 month will also be highly valued. "

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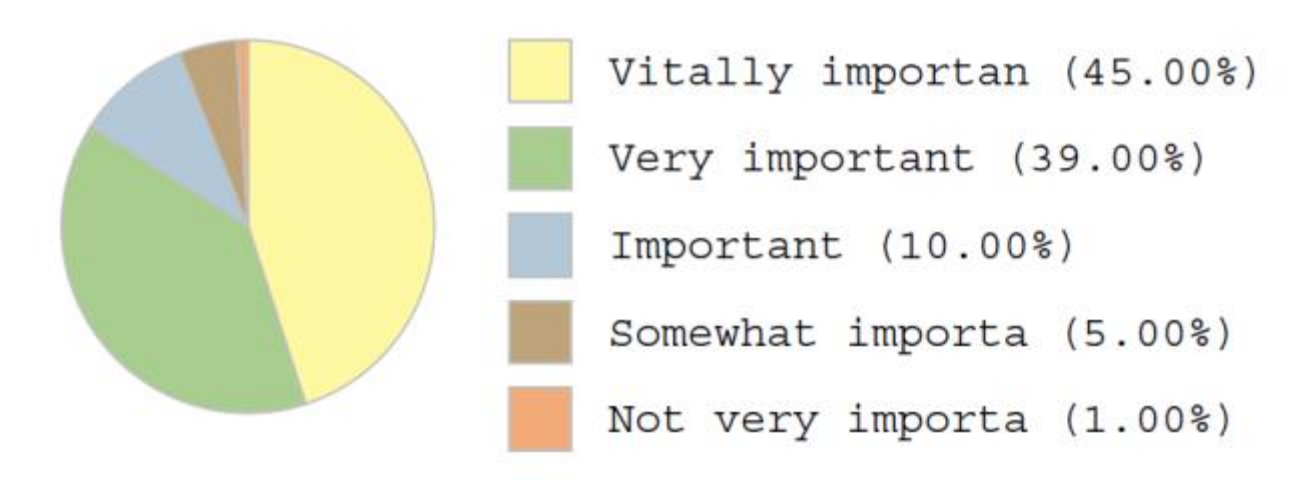
User satisfaction

- Almost 85% of survey respondents said that climate outlooks information is either vitally important or very important to them



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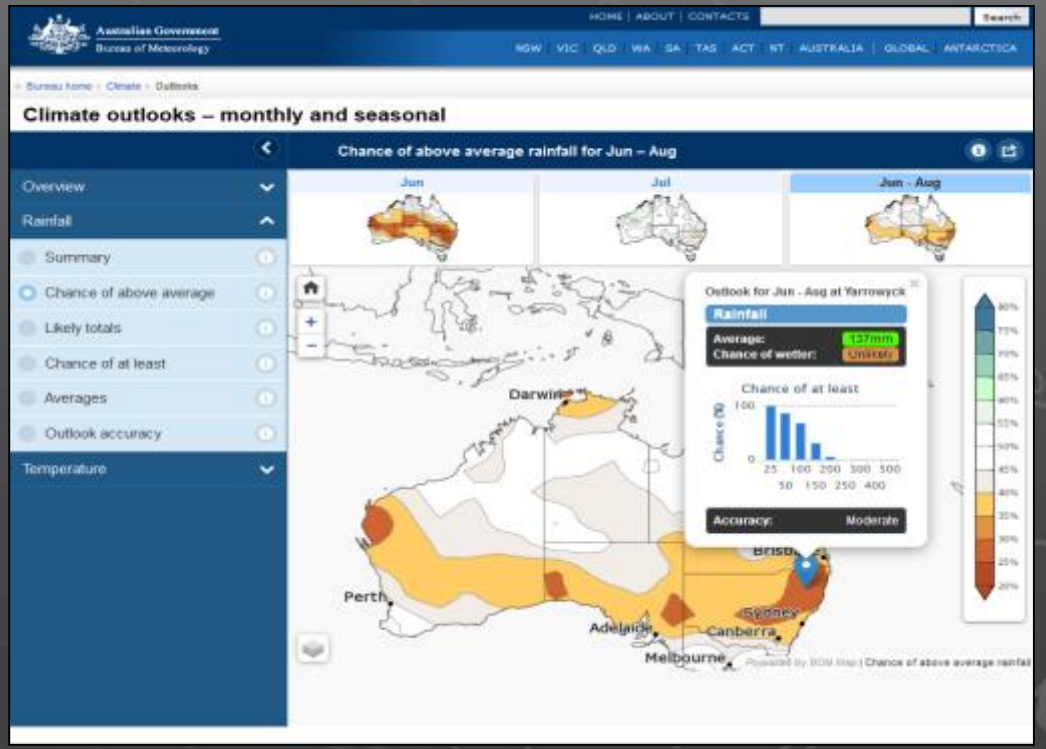
A new Climate Outlooks service

- Monthly and seasonal outlooks
- Update twice monthly percentages, probability of exceedence, anomaly
- 166 member super ensemble
- Contextual information and short videos
- Familiar interface



Useful options for decision-making

- Overlay different information (e.g. accuracy maps)
  - extremely or very useful for 80 of 98 people

- Zoom in closer to your location
  - extremely or very useful for 84 of 99 people

- Connection from climate outlooks directly to other Bureau information
  - 66 of 98 people said this would be extremely or very useful

Week/fortnight beyond 7 day forecast

Rainfall:

- Chance of receiving (at least) a specific amount of rain
  - 74 of 100 people said this would be extremely or very useful
- Chance of extreme heavy rainfall
  - 72 of 100 people said this would be extremely or very useful

Temperature:

- Likelihood of extremely high temperatures
  - 65 of 97 people said this would be extremely or very useful
- Chance of specific selectable temperature threshold
  - 50 of 98 (and 53 of 100 for minimum temperature*) people said this would be extremely or very useful

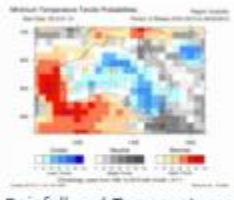
Current operational and experimental products:

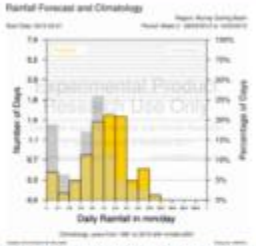
- sub-seasonal
- Applied forecasts

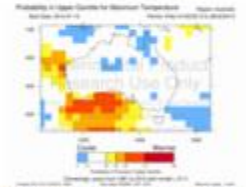
Seamless Multi-Week to Seasonal Products

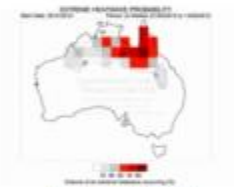
POAMA-2 seamless products span time scales from weeks to seasons. Forecasts are updated twice per week based on the last ensemble set of forecast. A 33-member ensemble of forecasts is produced twice per week. Weekly and multi-week products are based on a 66-member ensemble using the last two sets of forecasts. Monthly forecasts are based on a 99-member ensemble using the forecasts from the last three forecasts. Seasonal forecasts are based on a 165-member ensemble using the forecasts generated from the last 5 sets of forecasts generated over the last two weeks.

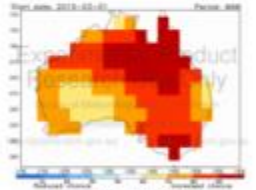

SST Indexes

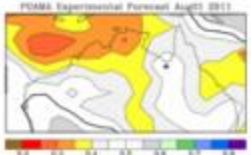

Rainfall and Temperatures

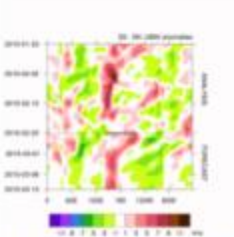

Rainfall and Temperatures Histograms

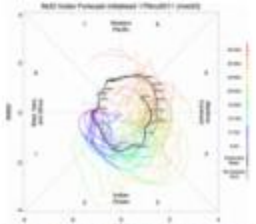

Extreme Temperature Forecasts


Heatwaves (EHF)


Extreme Heat Days

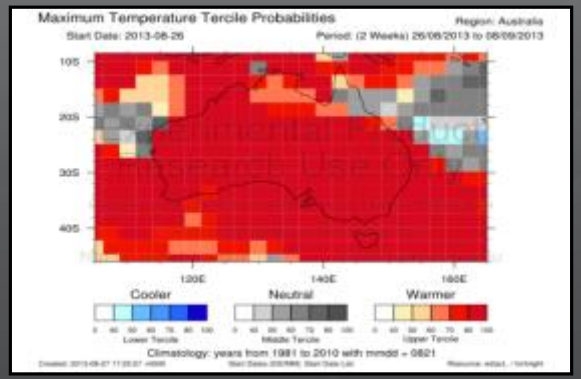

North Australian Wet Season Onset


Equatorial zonal wind anomaly Hovmoller


MJO (Madden-Julian Oscillation)

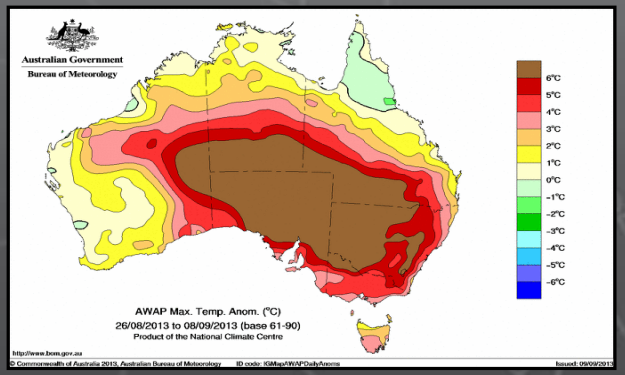
Australian Government
Bureau of Meteorology

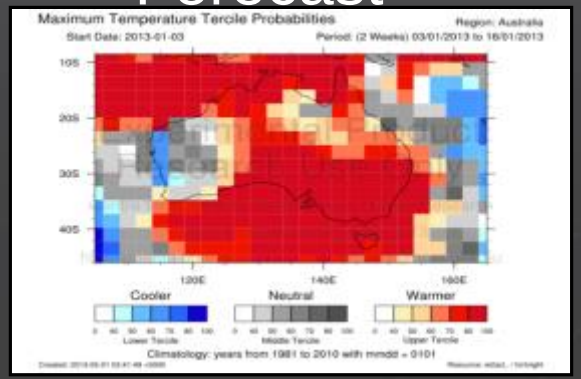
Predicting extremes: POAMA 2 week forecasts



Forecast

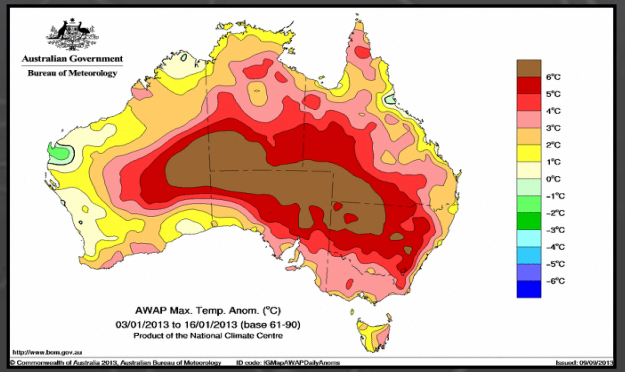
Record warm start to Spring 2013





Record hot January 2013

Observed



Latest Australian Forecasts | Advanced Forecast Options

Dimension:

Daily Rainfall	Australia	Tercile Probabilities
Daily Max Air Temperature	Global	Anomaly
Daily Min Air Temperature	Asia/Pacific Tropics	Probability Above Median

StartDate: < 2016 > < Jun > < 16 >

Forecast for: < Week 2 >

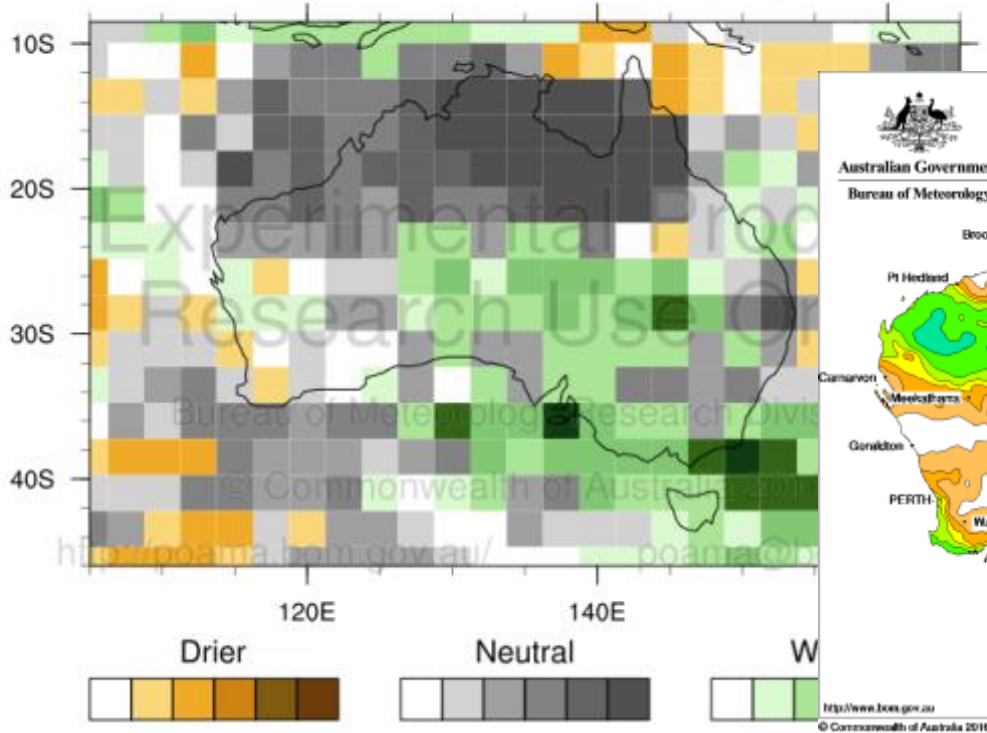
Hindcast / Realtime

Precipitation / Rainfall Tercile Probabilities

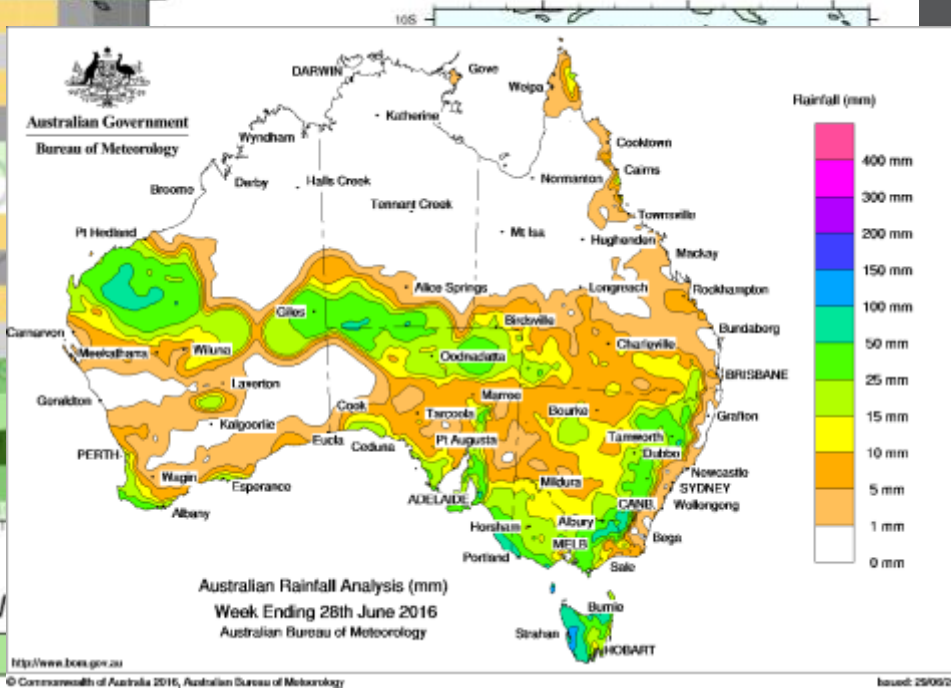
Region: Australia

Start Date: 2016-06-16

Period: (Week) 23/06/2016 to 29/06/2016



Average Rainfall Skill for this period



Drivers for future services

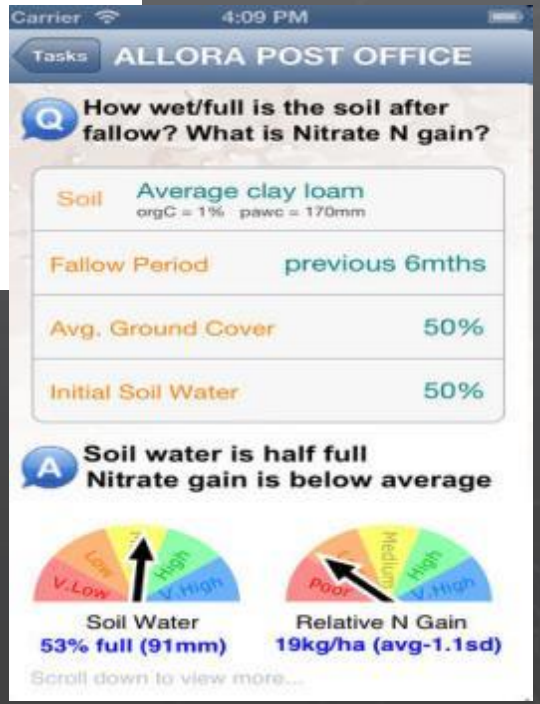
User pull → being informed by engagement and feedback

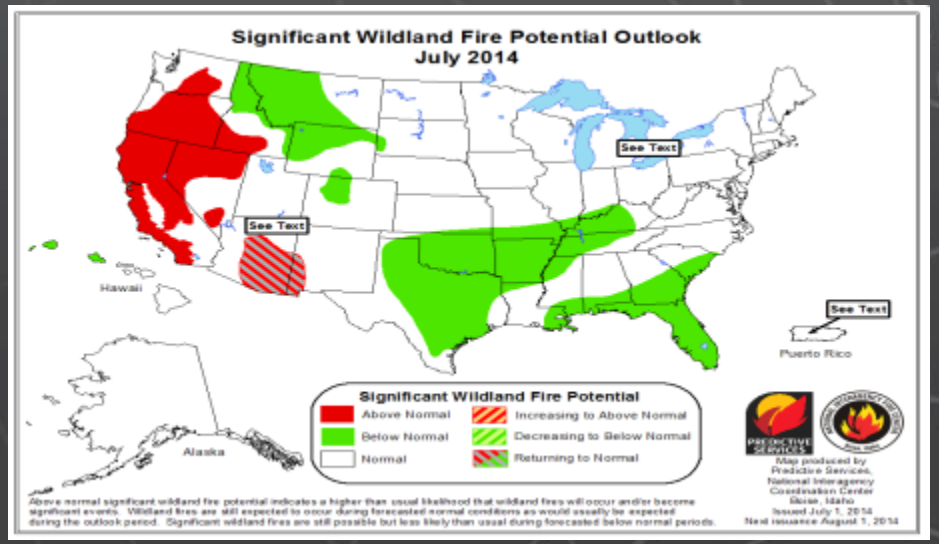
Technology push, allowing new and better information services

Growing sophistication of down stream tools (the next users, rather than the end users?)

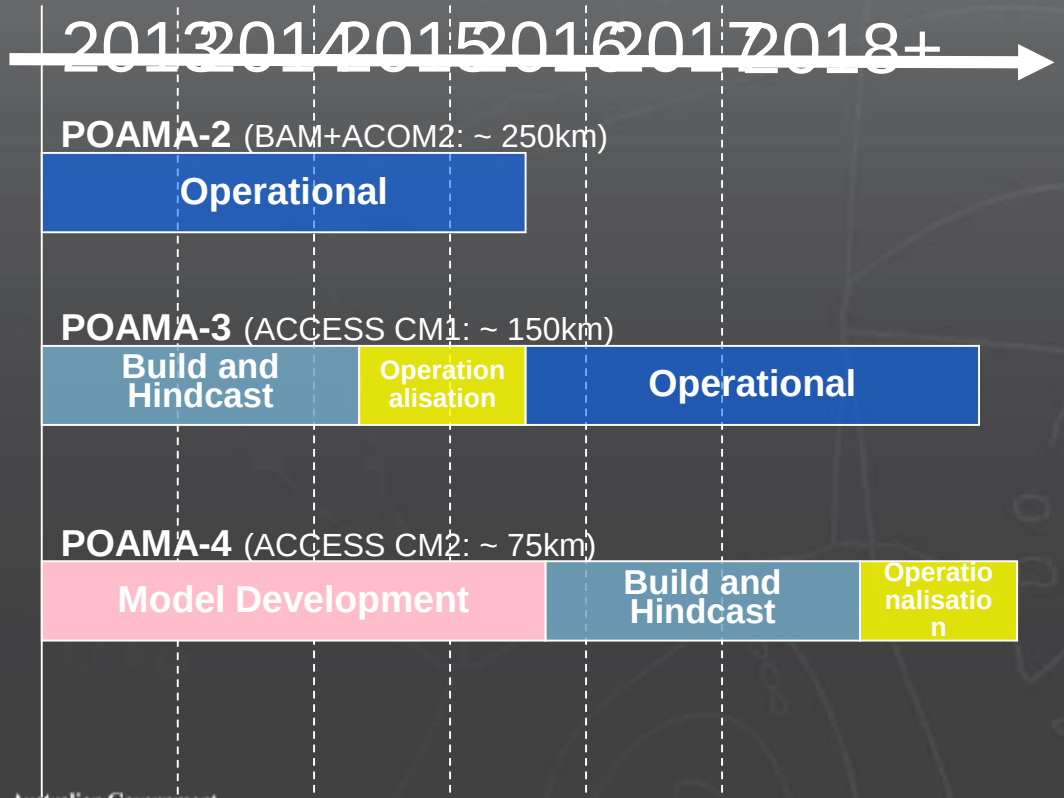
Climate (and other) change making past practices no longer viable

Interfacing with decisions





Better models: POAMA development pipeline



POAMA phases

Model+Assim development

Develop new coupled model, New physics, tune for seasonal, part of larger modelling effort

Build and Hindcast

Bring components together, build system, Ensemble strategy, Skill and product evaluation

Operationalisation

Complete comprehensive hindcast, re-analyses up to date, transition to operations.

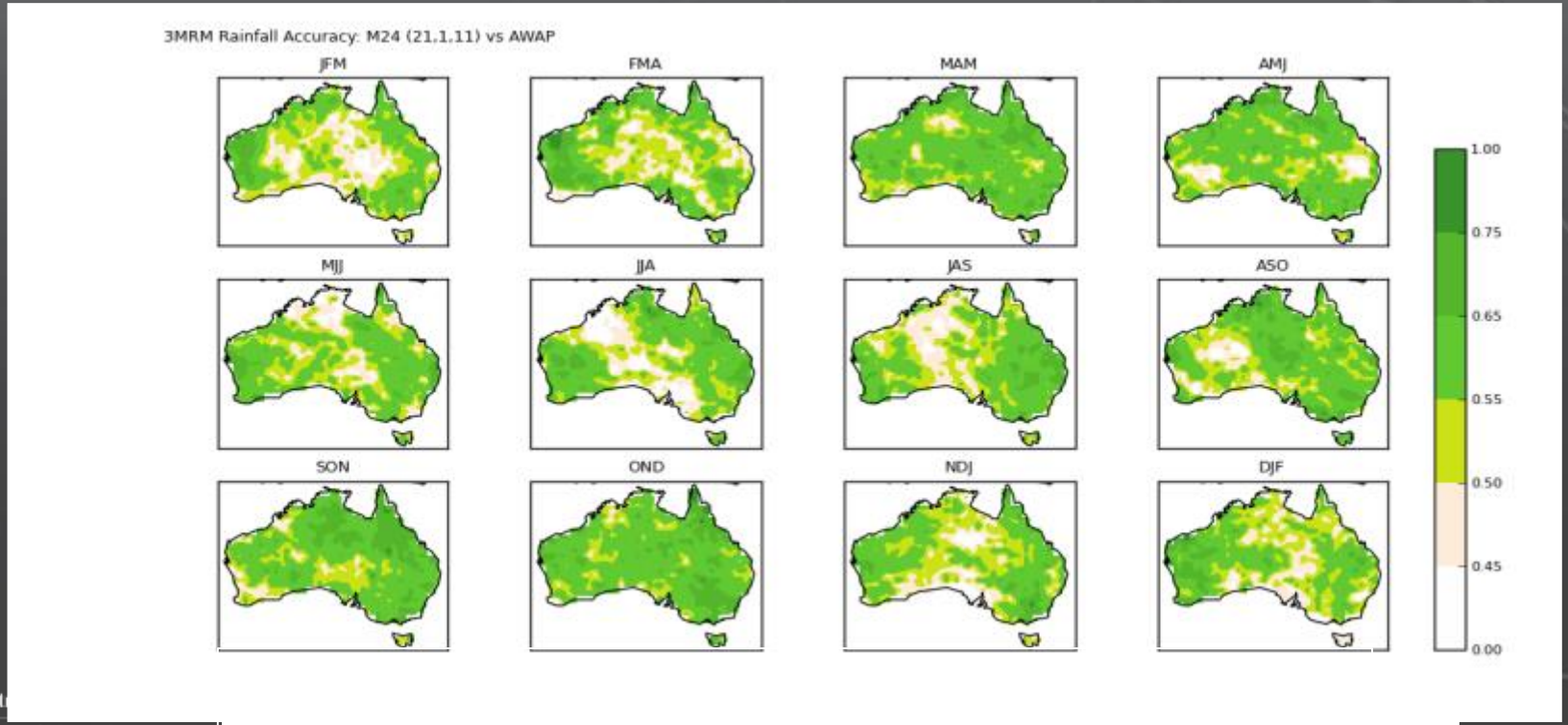
NMOC/Services support,

evaluation, monitoring,

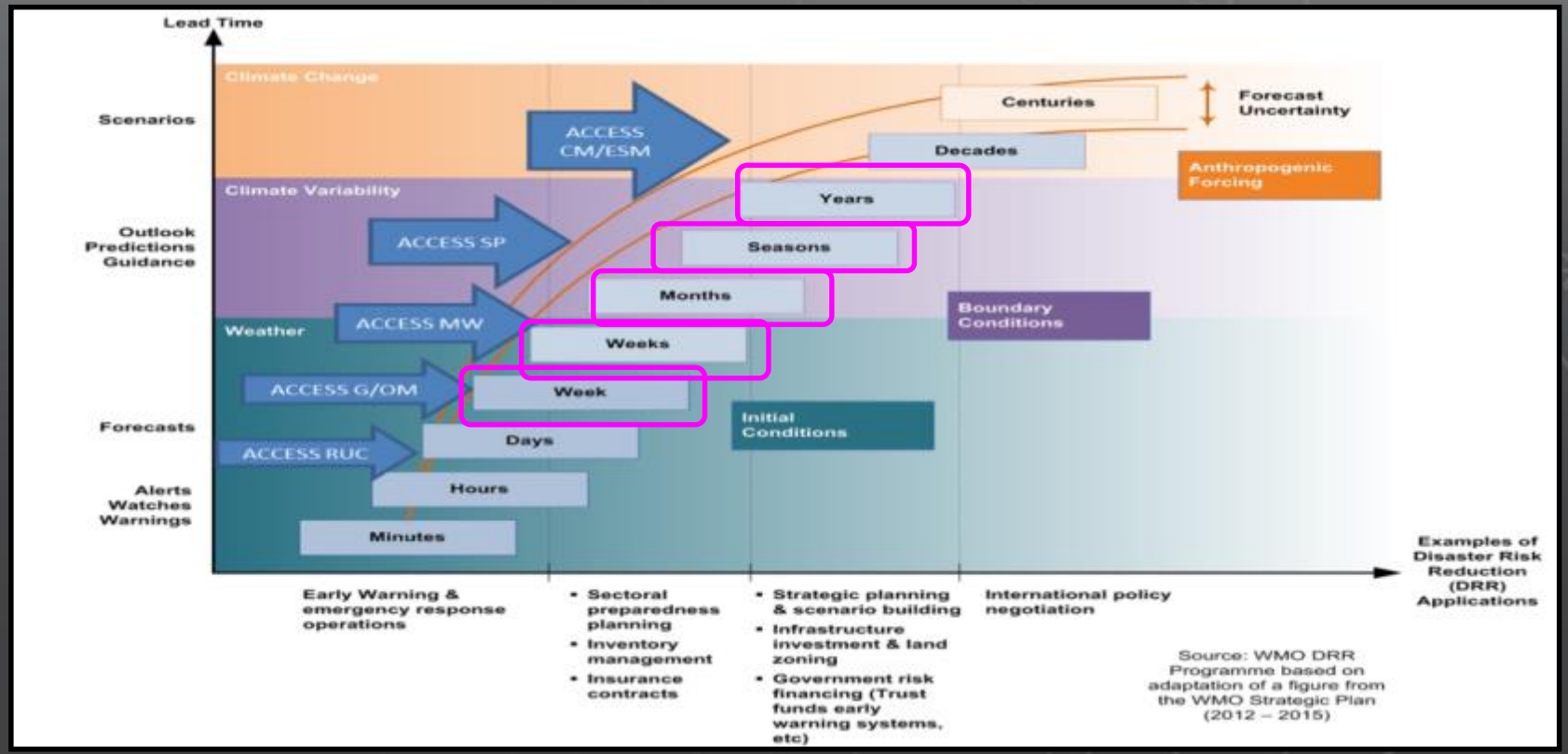
case studies, new products,

interface to applications, etc

The value of R&D for better models: Increased forecast skill



Responding to climate variability Seamless forecasts



Providing consistent services across all time scales.

New Climate Outlooks website – coming soon

Increasing value of the Seasonal Climate Outlook by improving communication and engagement

Enhanced usability and comprehension through better design

Helping people work with probabilities

And also…

- Who uses it?
- What for?
- Do they understand it?
- Are they making the right decisions?

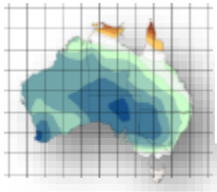
Australian Government
Bureau of Meteorology

BETTER SEASONAL OUTLOOKS

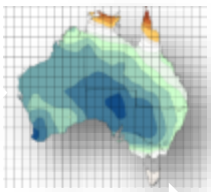
Finer model detail

Moving from

250 km to 60 km resolution



Australia:120 to 2000 grid points



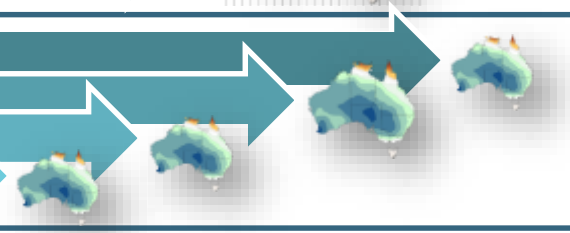
meaning
more localised information *by accounting for local conditions*

More outlook periods

Seamless: filling the gap between

7-day and monthly outlooks

Season
Month
Fortnight
Week



Outlooks updated weekly

Higher outlook skill

Likely 10% improvement in outlook accuracy

meaning
the best outlooks for Australia

of all international models

World class service

+

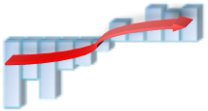
meaning
information is clear, concise and available when and where you need it

More intelligence possible:

- Evaporation
- Drought
- Wind
- Extremes

Not only rainfall and temperature

Bigger user returns



Reduce losses: agricultural production lost from 2010-11 La Niña:

More than **$2 billion**

Potential **value of improved** seasonal forecasts:

Centre for International Economics 2014

More than **$1 billion** **per year**