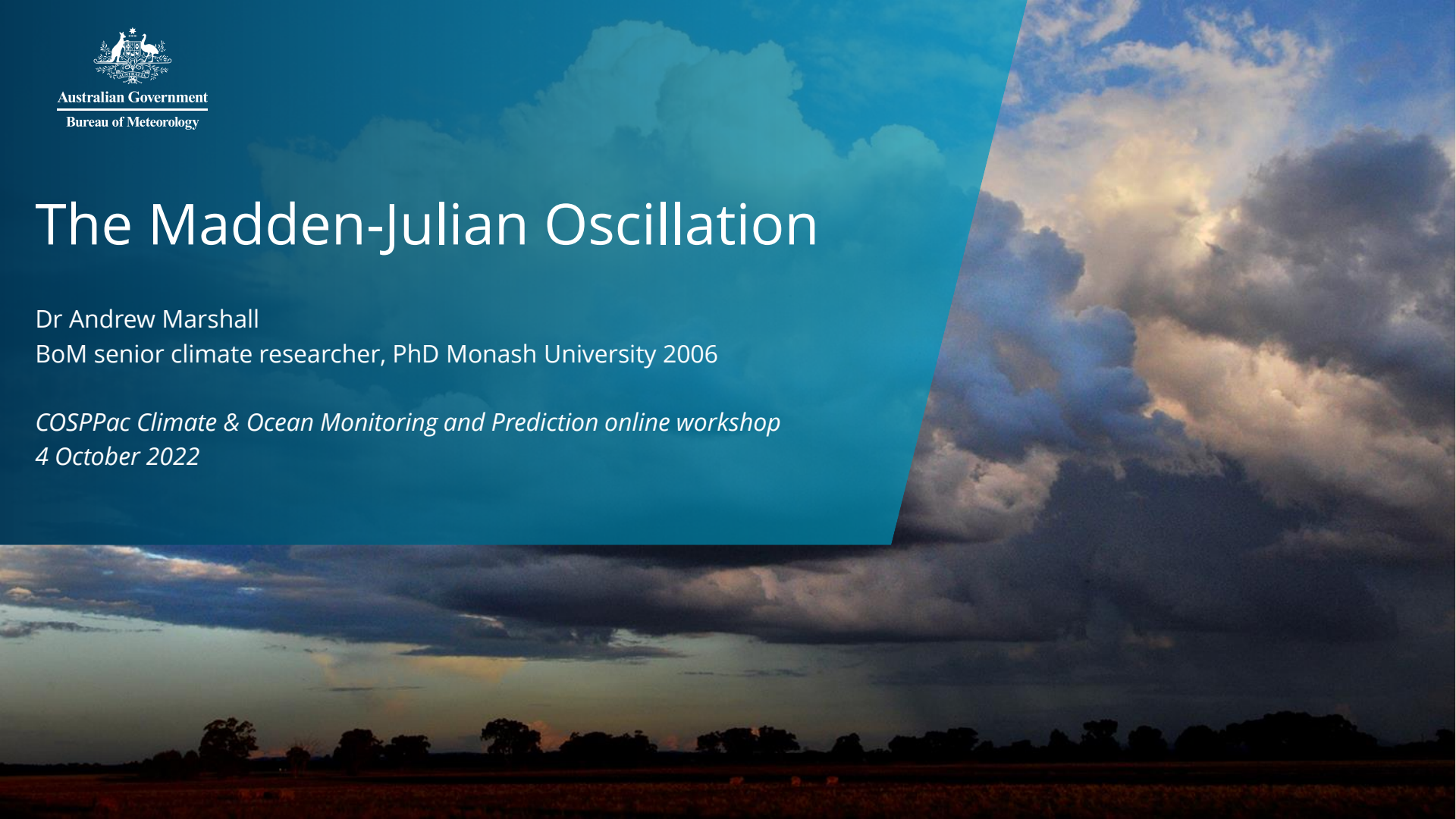
Australian Government
Bureau of Meteorology

The Madden-Julian Oscillation

Dr Andrew Marshall
BoM senior climate researcher, PhD Monash University 2006

COSPPac Climate & Ocean Monitoring and Prediction online workshop
4 October 2022

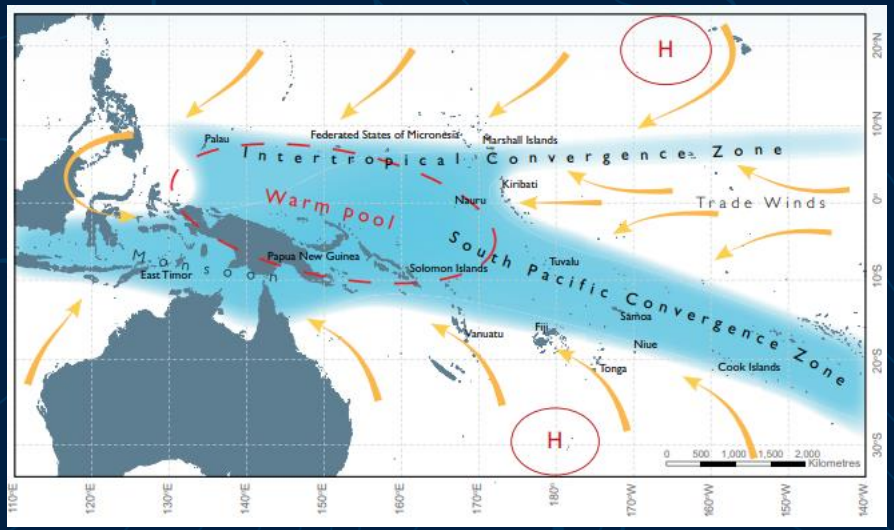


Climate variability timescales

- Days to a week *(weather)*
- Weeks to months *(subseasonal)*
- Seasons to years

  (seasonal, interannual, decadal)

Madden-Julian Oscillation



The Madden-Julian Oscillation (MJO)

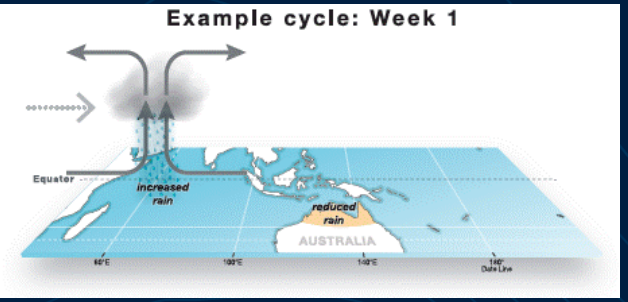
Major fluctuation in tropical weather on weekly to monthly (subseasonal) timescales

Discovered in 1971 (Kiribati) and 1972 (incl. Nauru), an eastward moving ‘pulse’ of cloud and rainfall near the equator, thousands of kilometres across

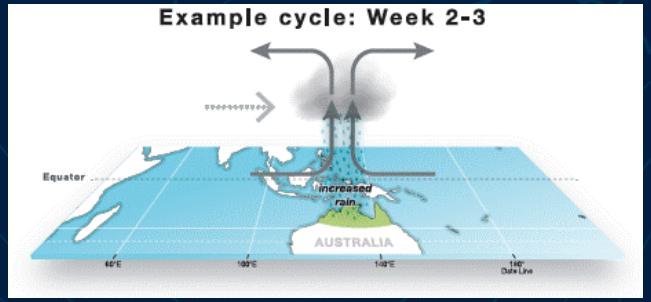
Events recur about every 30 to 80 days

Phases 1 to 8 track the eastward movement of cloud and wind anomalies

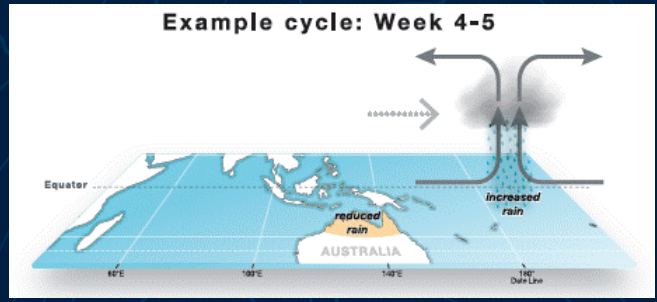
Eastward moving cloud and rainfall



MJO phases 2 & 3

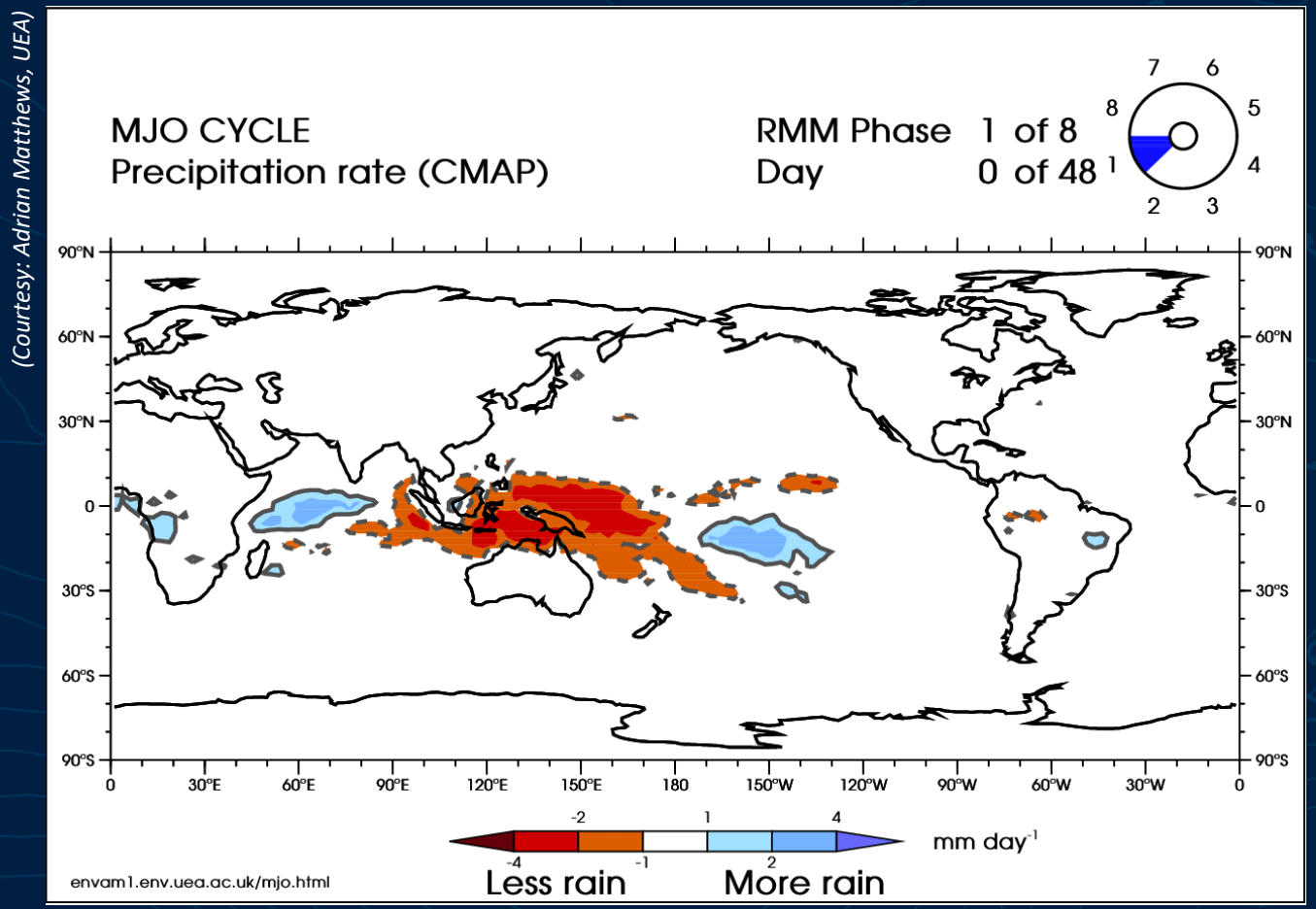


MJO phases 4 & 5



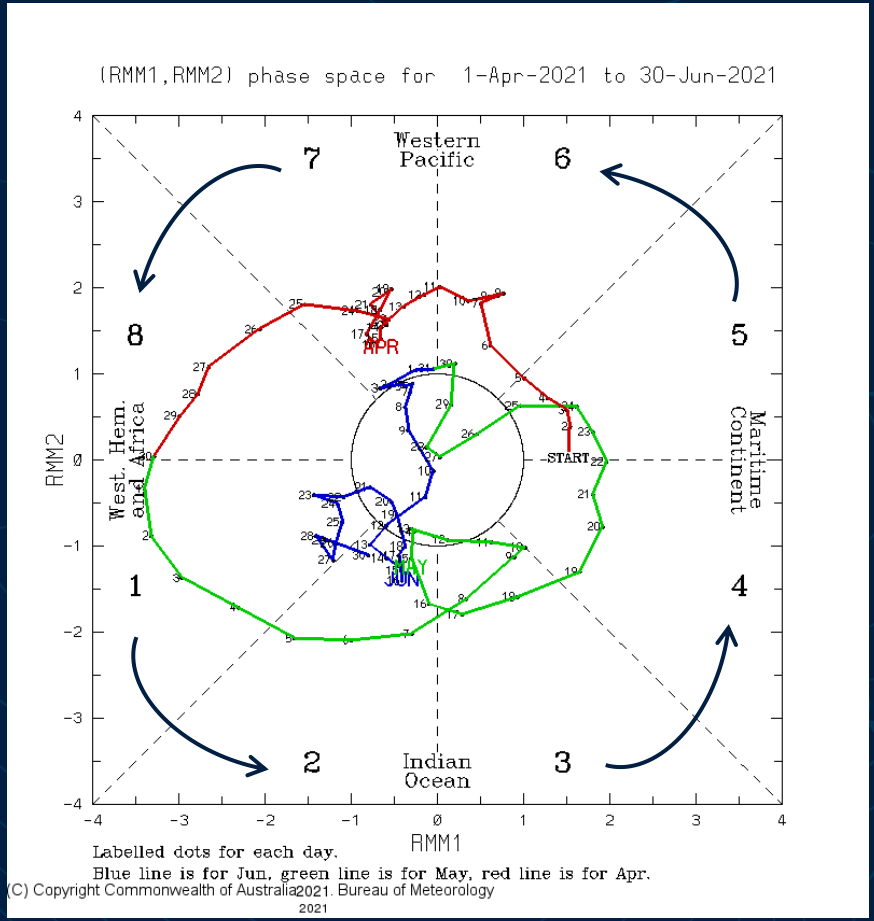
MJO phases 6 & 7

The MJO cycle



MJO monitoring bom.gov.au/climate/mjo

Wheeler and Hendon (2004, Mon Wea Rev)

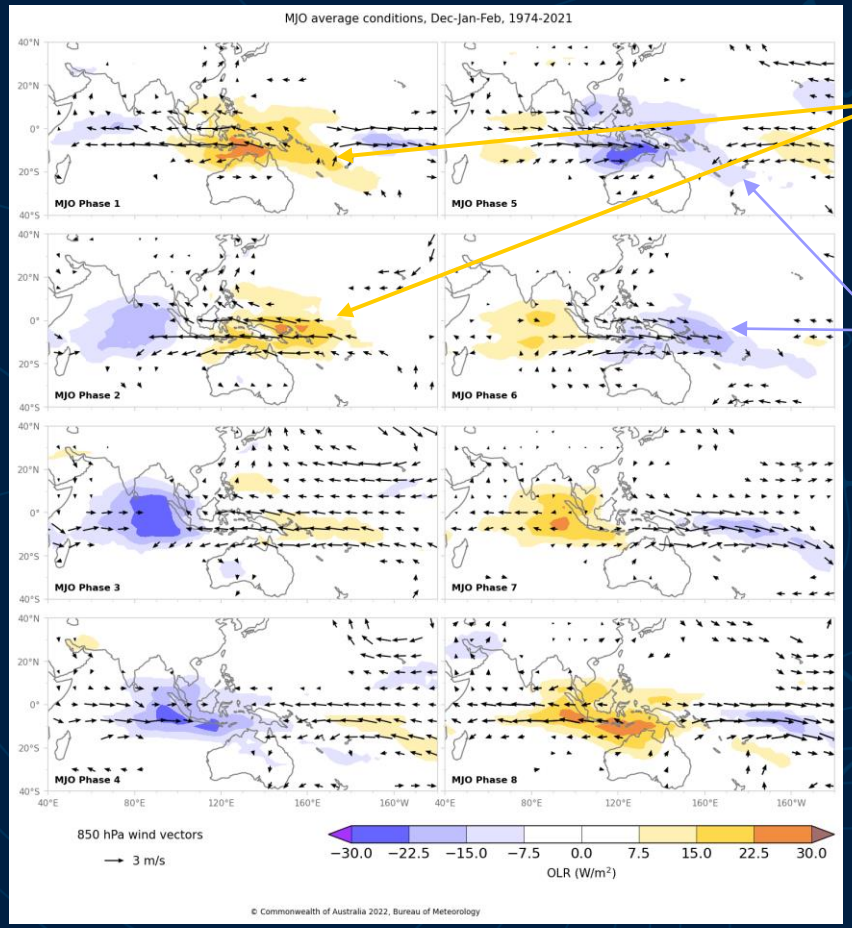


A typical MJO event bom.gov.au/climate/mjo

We can compute what the "average" MJO looks like (example shown for Dec-Feb)

Approximately 6 days per phase

Cowan et al. (2022, J Clim)



Less clouds & rainfall

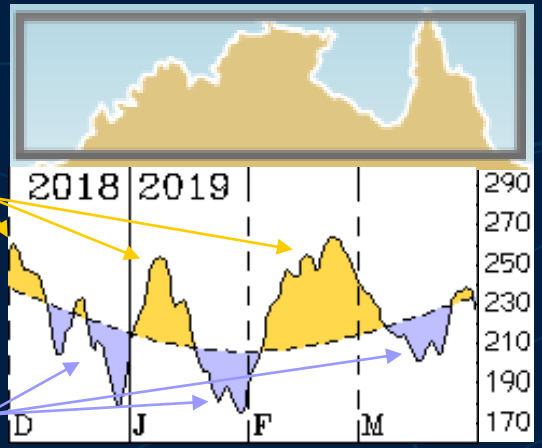
More clouds & rainfall

MJO influence on wet season rainfall for Australia

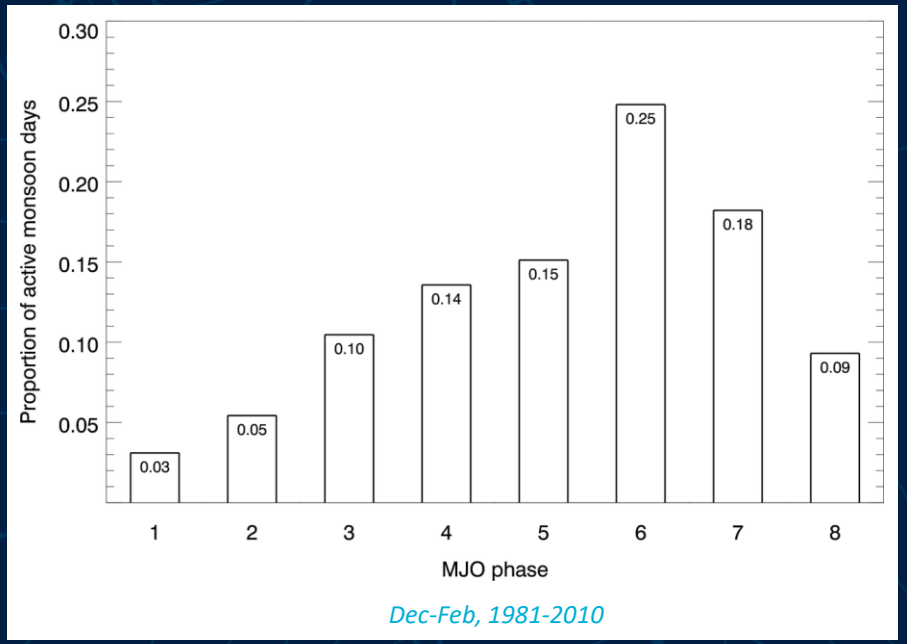
Outgoing longwave radiation (OLR)

Positive OLR: sunnier / drier (breaks)

Negative OLR: cloudier / wetter (bursts)



Marshall and Hendon (2015, GRL)



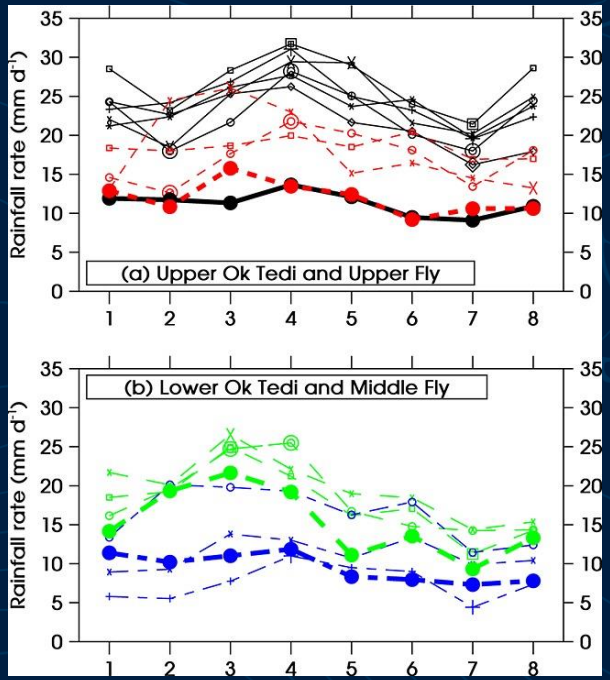
Convective MJO phases 4-7

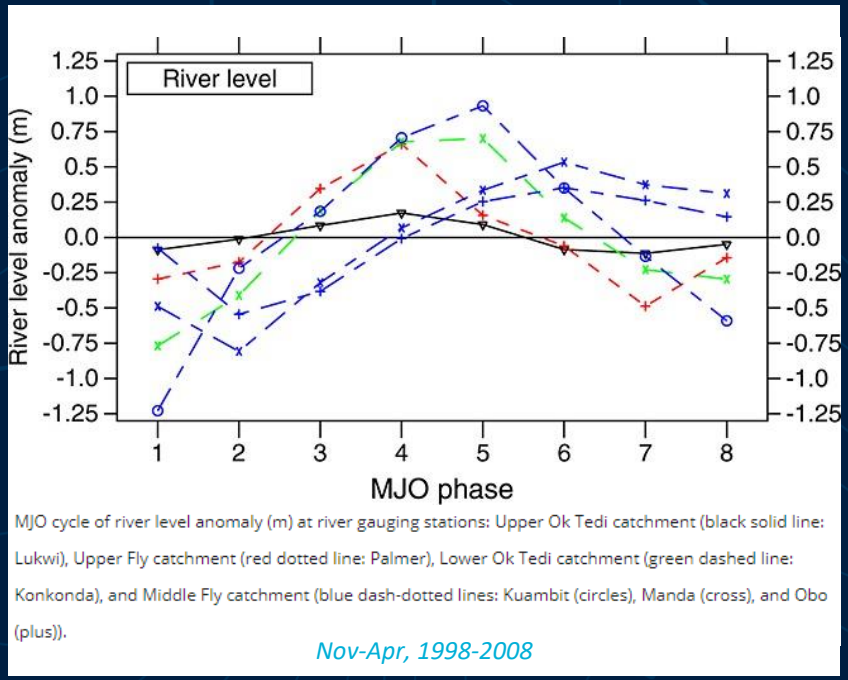
Suppressed MJO phases 8 & 1-3

MJO influence on wet season rainfall for Papua New Guinea

- 40% difference in Fly River rainfall rate between wet and dry MJO
- Fly River levels respond strongly to MJO rainfall

Matthews et al. (2013, JGR-Atmos)





MJO cycle of river level anomaly (m) at river gauging stations: Upper Ok Tedi catchment (black solid line: Lukwi), Upper Fly catchment (red dotted line: Palmer), Lower Ok Tedi catchment (green dashed line: Konkonda), and Middle Fly catchment (blue dash-dotted lines: Kuambit (circles), Manda (cross), and Obo (plus)).

Nov-Apr, 1998-2008

MJO influence on wet season rainfall for Pacific Island countries

www.fijitimes.com.fj/effects-of-the-mjo-pulse

The Fiji Times

Effects of the MJO 'pulse'

DR SUSHIL K SHARMA | 11 April, 2017, 12:00 am

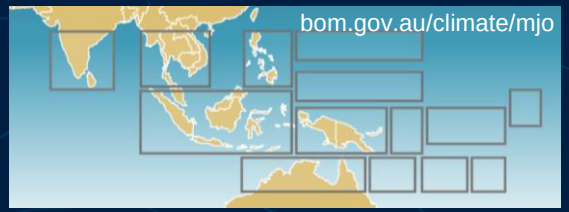
As long as Fiji is still under the active phase of the Madden Julian Oscillation (MJO), we expect the present spate of cloudiness and rains to continue over our region before we notice marked sunshine and dry conditions.

The MJO "pulse" is propagating eastwards over the central and eastern Pacific, which will lead to further activity for a while in our region.

The MJO is not a day-to-day forecasting tool similar to a weather map. Nor would you note it in an upper air atmospheric weather chart analysis.

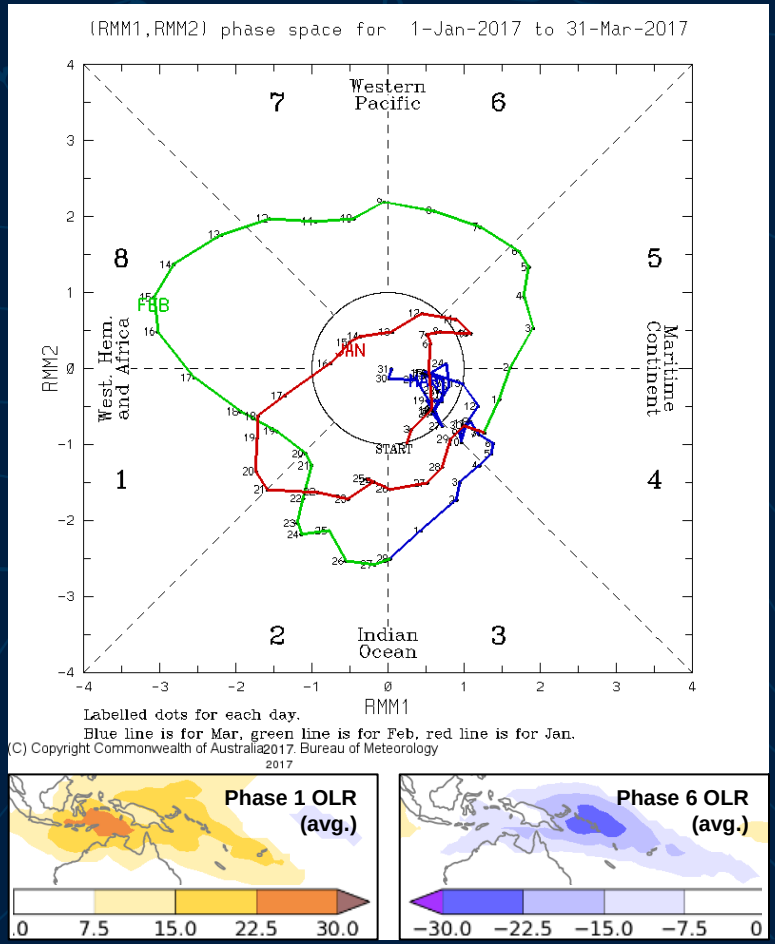
These waves are hemispheric scales with varying amplitudes and frequency, and can only be delineated and understood using general circulation computer models.

Atmospheric waves in our upper atmosphere moving from the West to East around our globe, with varying amplitudes and frequency, in the form of troughs or ridges, helping with either cyclonic or anti-cyclonic vorticity advection to the lower surface levels, which either help form, enhance or suppress surface high or low pressure and thus good or bad weather

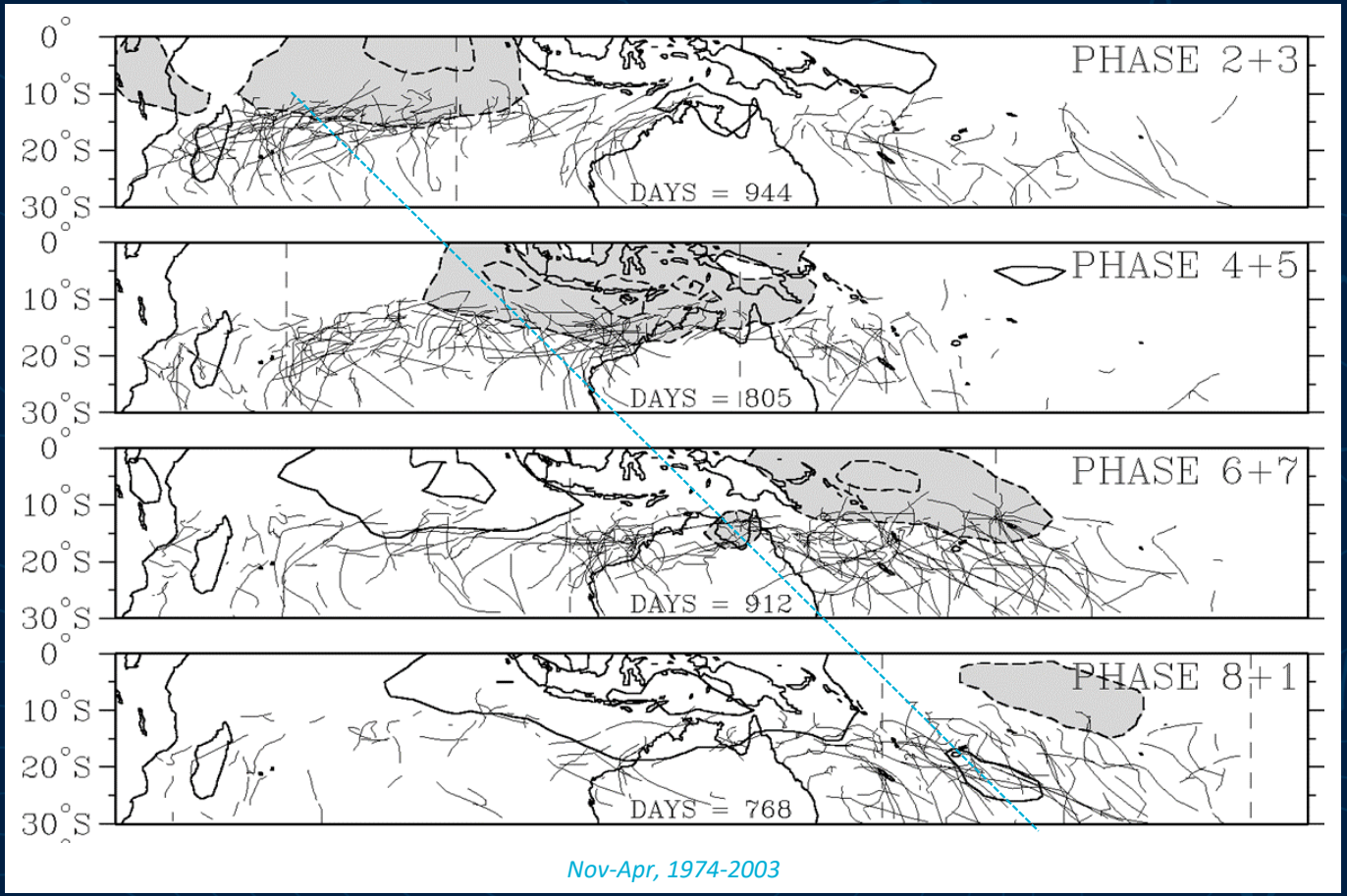


Convective MJO phases 5-7

Suppressed MJO phases 1-3



MJO influence on tropical cyclone activity



Also TC Larry Mar 2006

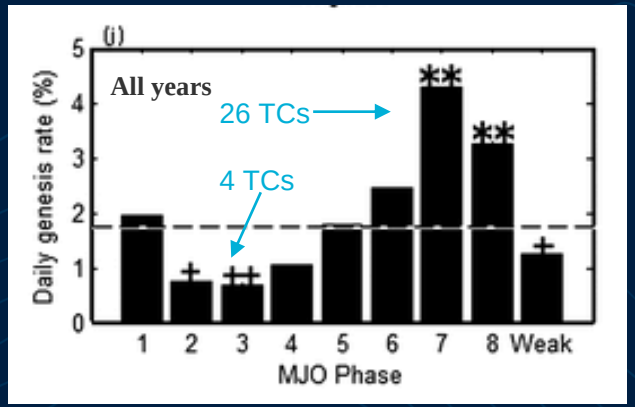
Also TCs Pam (Mar 2015), Ana (Jan 2021) and Seroja (Apr 2021)

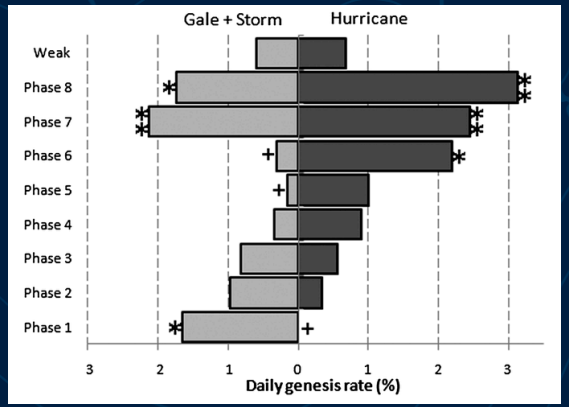
Also TC Yasi Jan-Feb 2011

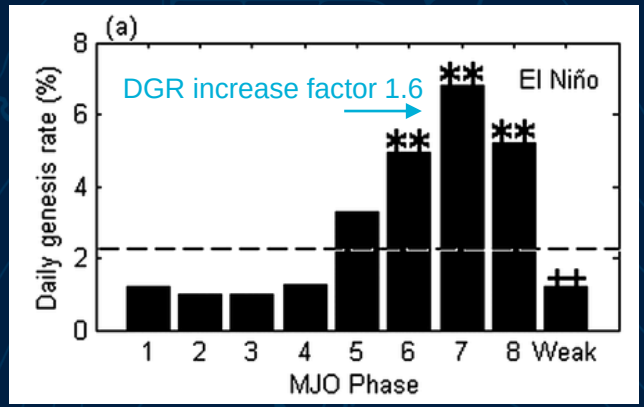
MJO influence on TC activity in Fiji, Samoa and Tonga

- Five times more TCs during active MJO phase than during inactive
- Cyclone category occurrences are increased with MJO convection
- MJO modulation is further strengthened during El Niño periods

Daily genesis rates (DGR): ratio of TC number to the number of MJO days in each phase (Nov-Apr, 1970-2005)







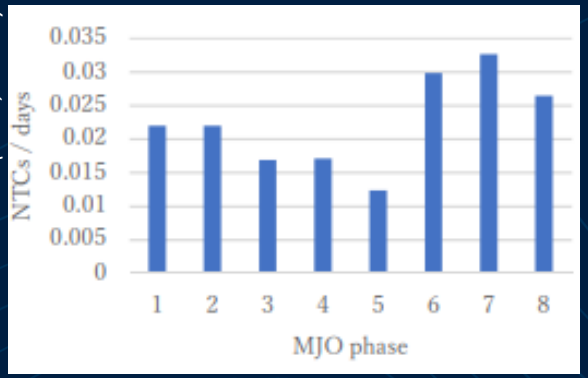
Chand and Walsh (2010, J Clim)

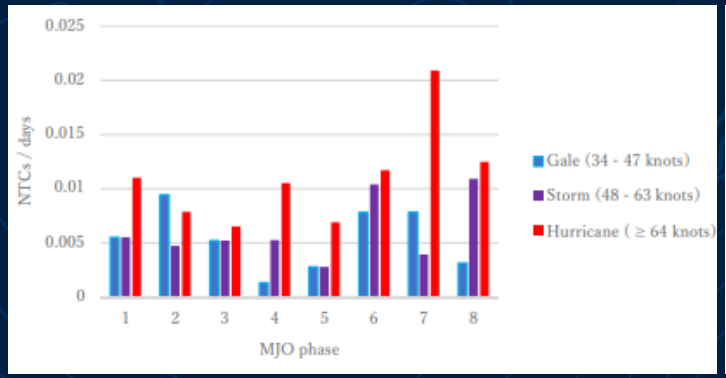
MJO influence on TC activity in Solomon Islands

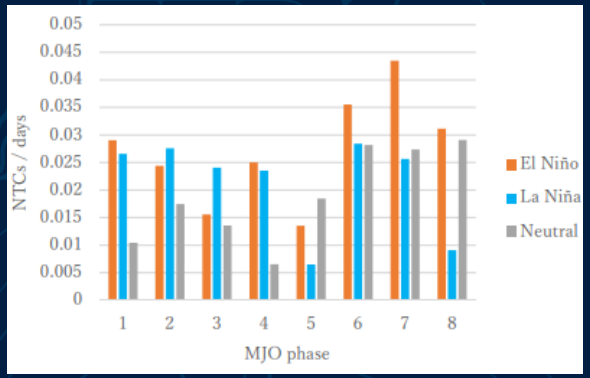
- TC genesis occurs most frequently in MJO phases 6-8
- Influenced by strong upper level divergence and lower level vorticity
- TC genesis occurs least frequently in MJO phase 5 (weak vorticity)

Daily genesis rates (DGR): ratio of TC number to the number of MJO days in each phase (Nov-Apr, 1986-2015)

Maru et al. (2018, Atmos)





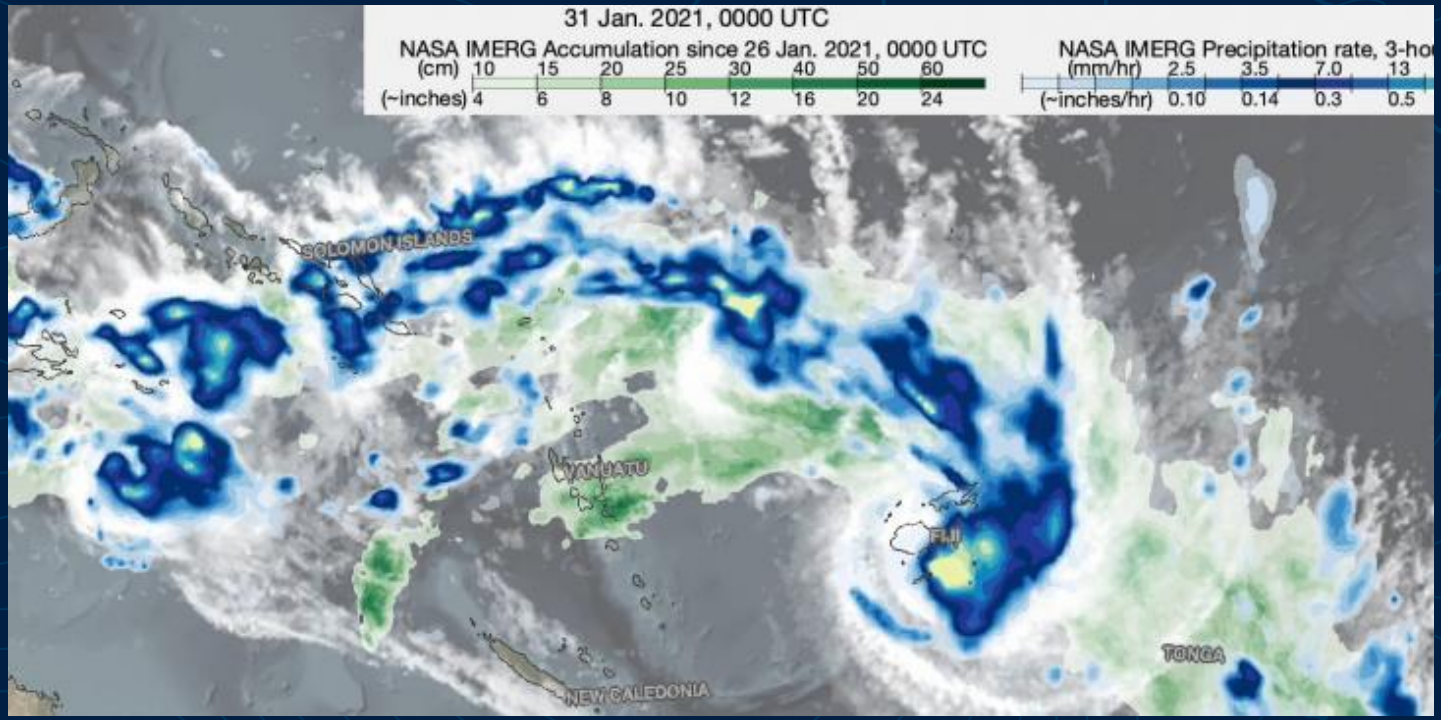


MJO influence on TC Ana in Fiji

Also affected: Vanuatu and Solomon Islands

- MJO stalled in phases 6 and 7, late Jan to early Feb 2021

Rainfall rates (blue/yellow), rainfall accumulations (green) and cloudiness (white/grey)

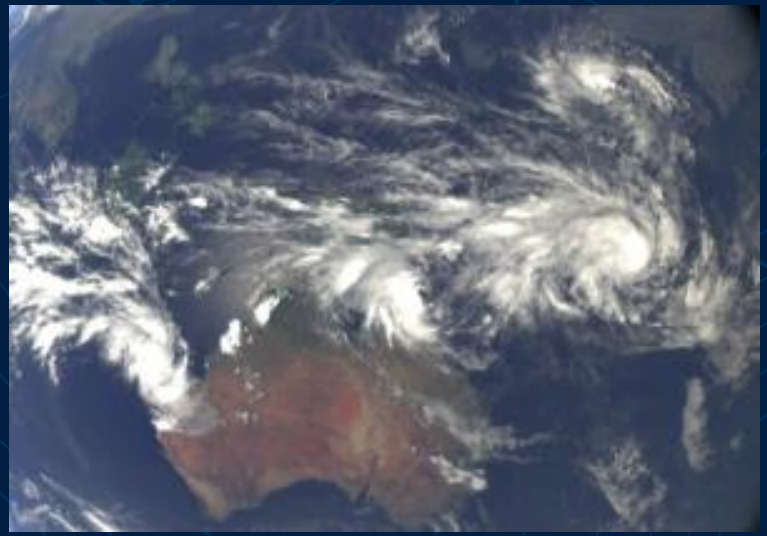


MJO influence on TC Pam in Vanuatu

Also affected: Fiji, Tuvalu, Solomon Islands, Kiribati, Papua New Guinea

- TC Pam hit Vanuatu at a devastating 250 km/h on 13 March 2015
- Four TCs occurred together in one week – a rare event
- Occurred with the strongest MJO on record (ph 6-7) at El Niño onset…

TC PAM (Cat 5) was connected to three other major TCs in association with a record strong MJO



MJO relationship to ENSO a two-way feedback

- Record MJO event of March 2015 promoted by the developing El Nino
- Sensitivity experiments:

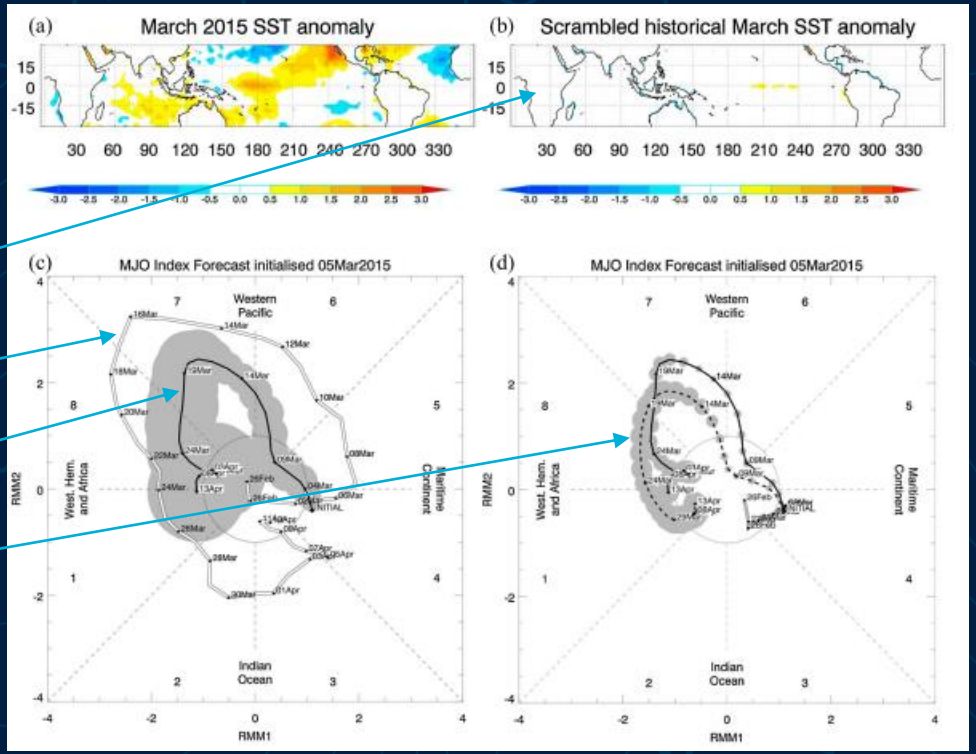
Observed SSTa

Scrambled ocean SSTa

Observed MJO

Control forecast MJO

Scrambled ocean MJO

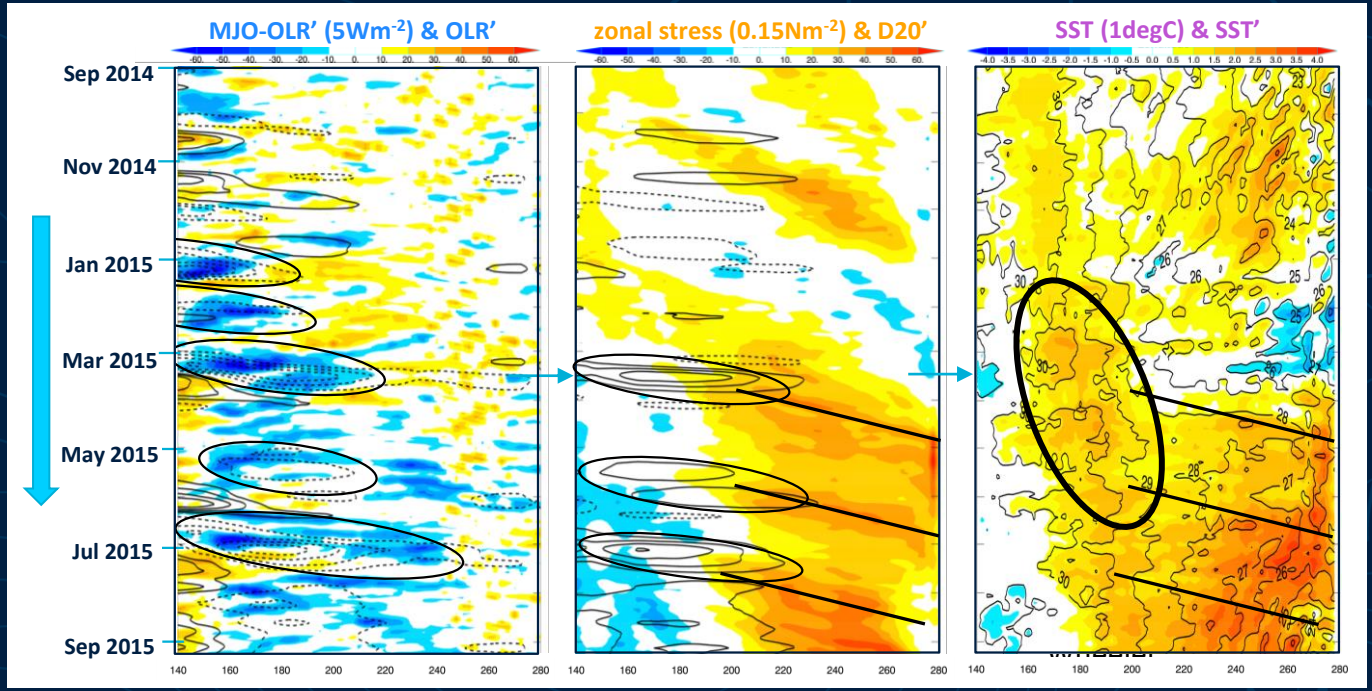


Marshall et al. (2016, GRL)

MJO growth increased by 20 %

MJO relationship to ENSO a two-way feedback

- MJO westerlies and oceanic Kelvin waves may contribute to El Niño
- MJO activity extends eastward along with the edge of the warm pool



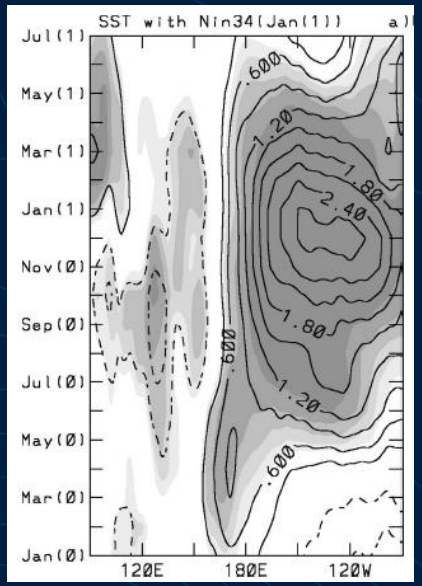
Successive MJO events: westerlies and Kelvin waves warm east Pacific & expand warm pool, convection into east Pacific

MJO relationship to ENSO a two-way feedback

2015 reminiscent of historical MJO-ENSO relationship:

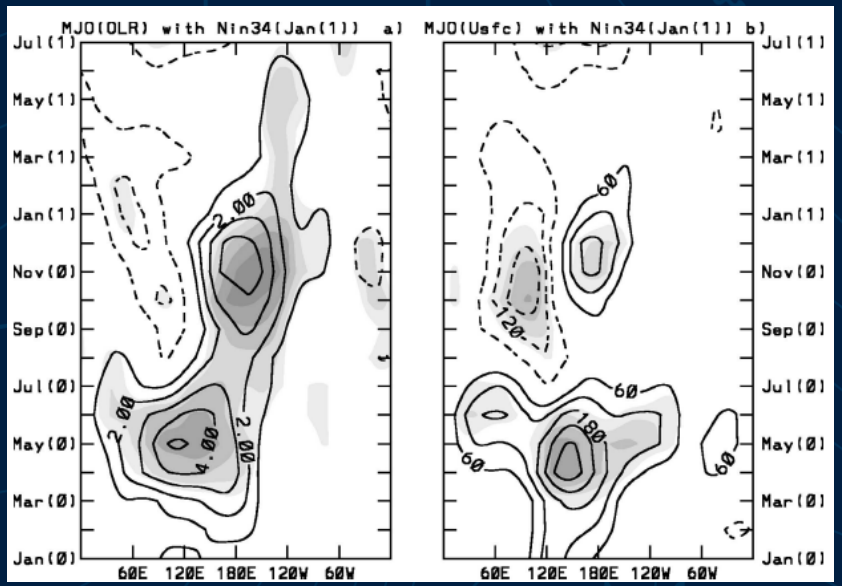
Enhanced western Pacific MJO in autumn precedes El Niño development

SST



MJO-OLR variance

MJO-Usfc variance



MJO relationship to ENSO a two-way feedback

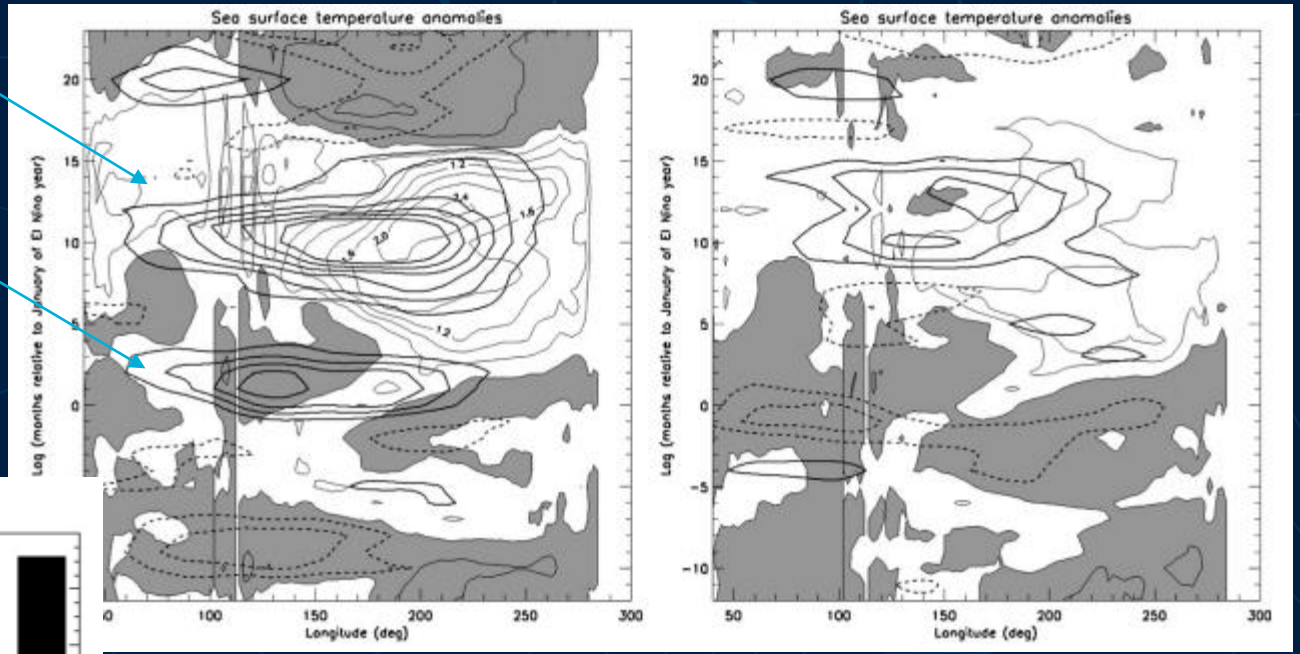
in the Bureau's 2005 atmosphere (BAM3) – ocean (ACOM2) coupled model

Enhanced MJO activity (bold contours) shifts eastward as warm pool expands

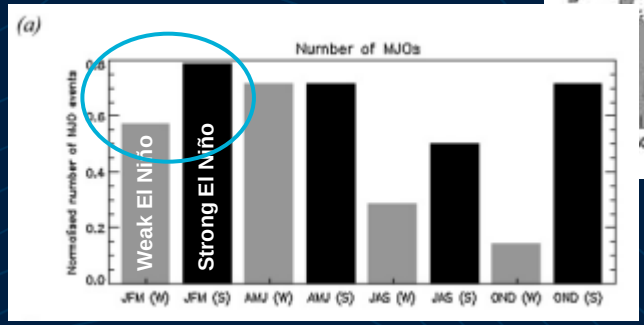
Enhanced MJO activity at the onset precedes the development of strong El Niño events but not weak events

Strong El Niño events

Weak El Niño events



Marshall et al. (2009, J Atmos Sci)

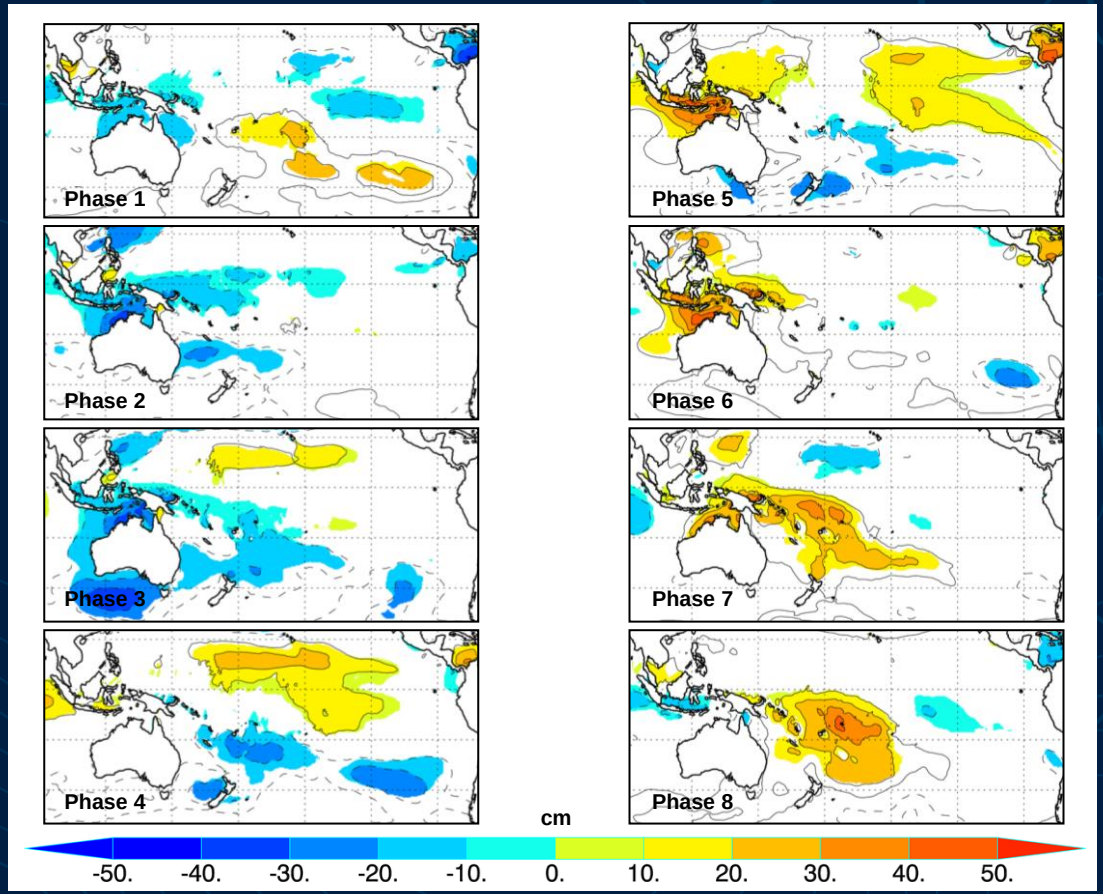


An increase in the amount of MJO activity leads to stronger ENSO warming, which then feeds back to enhance MJO activity during peak warming

MJO influence on significant ocean wave height

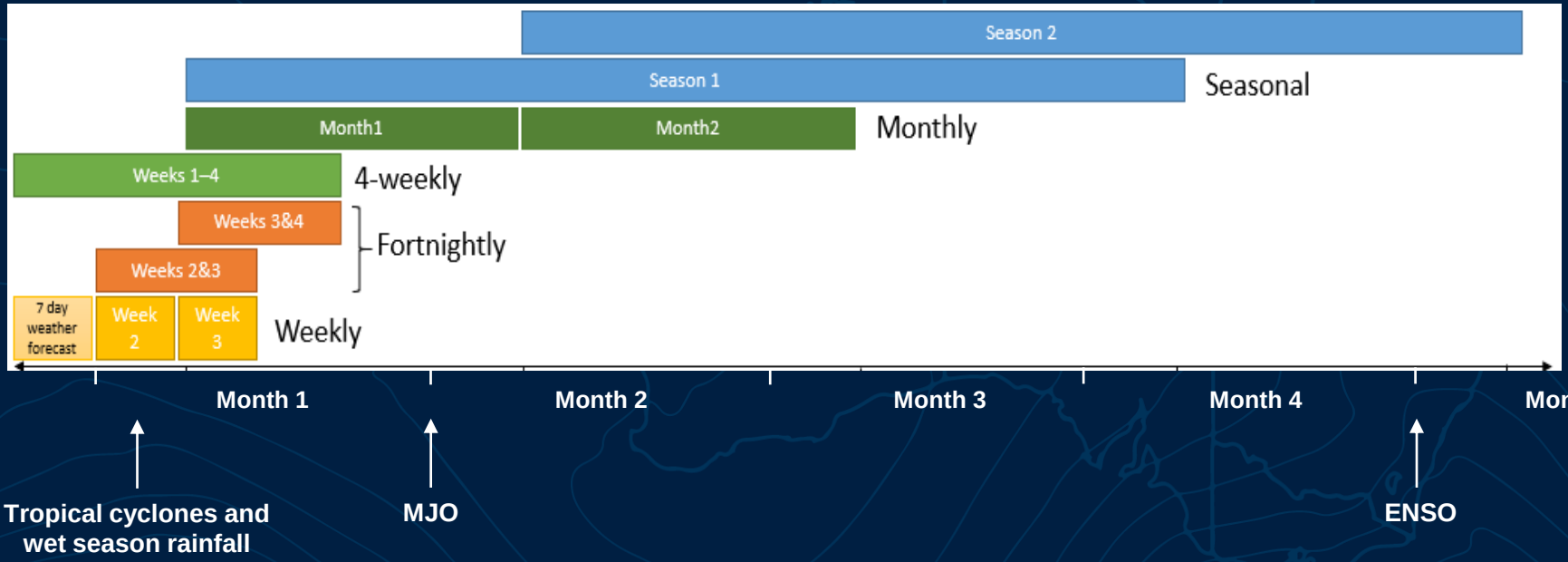
(Average height of the highest third of ocean waves)

Marshall et al. (2015, Ocean Mod)



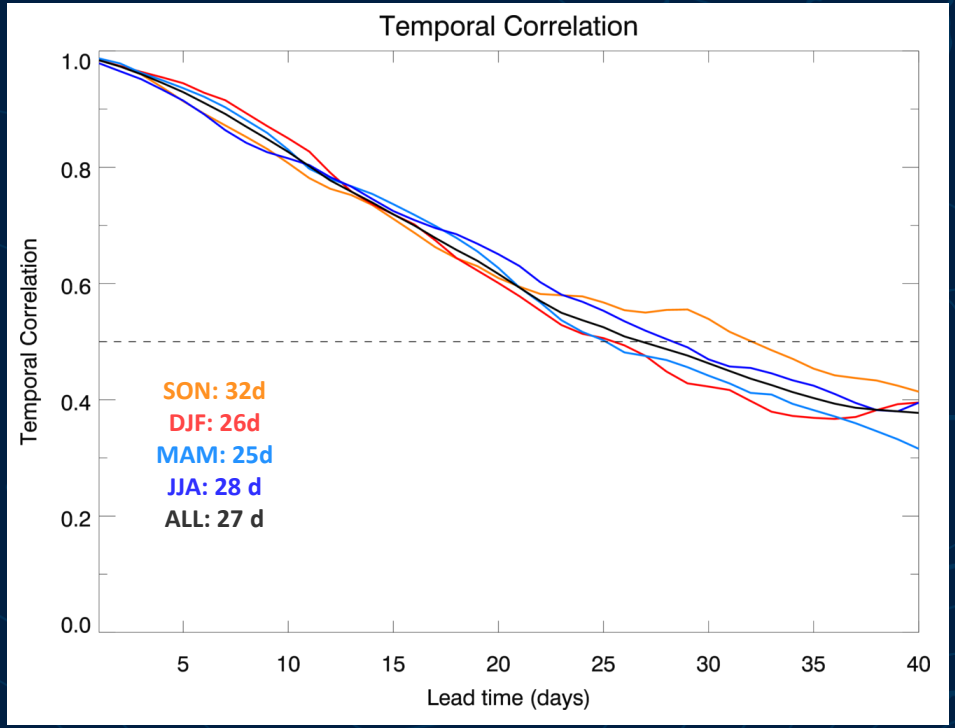
Wave height variations of up to 0.5 m

Climate prediction timescales



MJO prediction timescales

ACCESS-S2 RMM bivariate correlation skill (1981-2018)

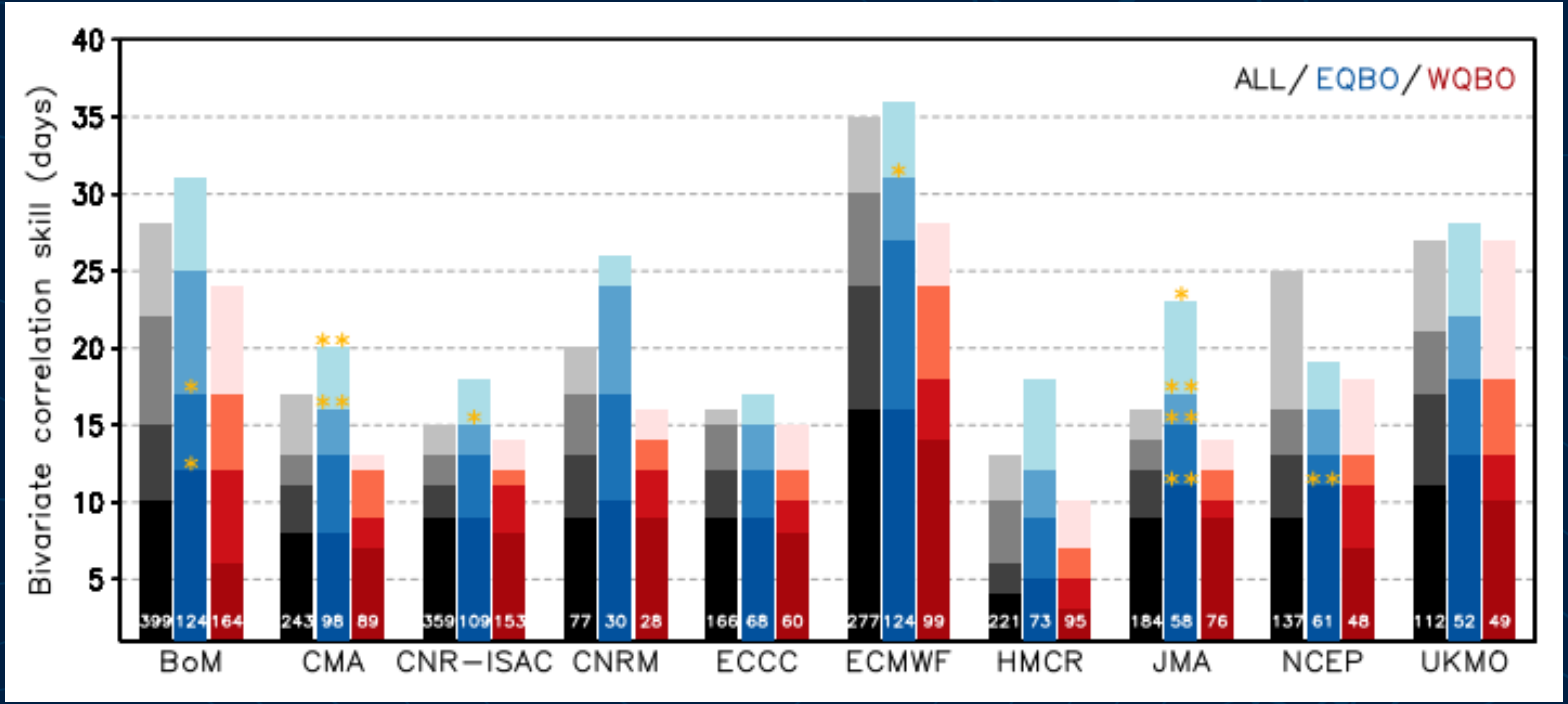


- ACCESS-S produces skilful MJO forecasts out to 32 days lead time in SON

MJO prediction timescales

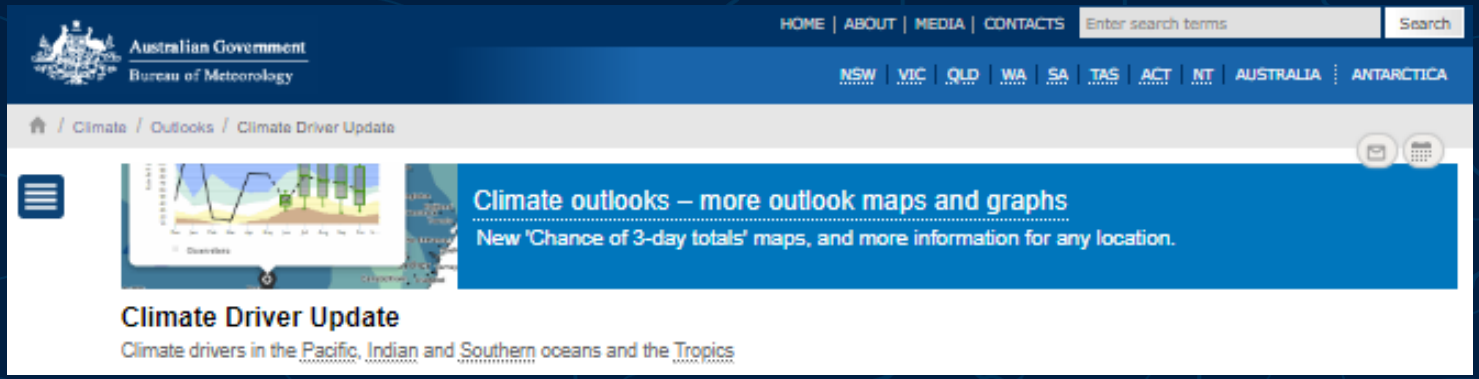
RMM bivariate correlation skill in DJF: relationship to the Quasi-Biennial Oscillation easterly (EQBO) and westerly (WQBO) phases

Lim et al. (2019, Clim Dyn)



- The MJO is stronger with higher predictability during **EQBO** than during **WQBO**

MJO prediction at the Bureau bom.gov.au/climate



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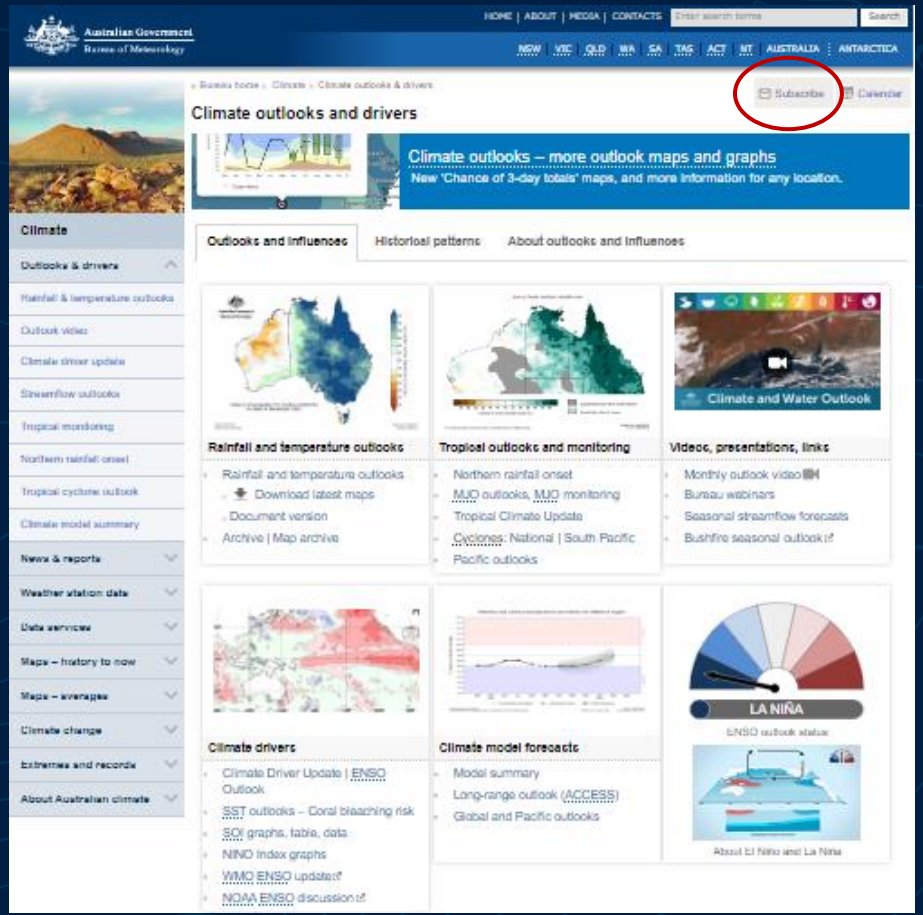

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  Emailed 2–6 times per year
- [ ] **Water Information**
  Emailed 6–10 times per year
- [ ] **Weather Calendar Updates**
  Emailed 4–8 times per year

Weather, climate and water outlooks and forecasts

- [ ] **Climate Driver Update**
  Overview of the current state of the Pacific, Indian and Southern oceans and the tropics, emailed every 2 weeks
- [ ] **Climate Outlooks**
  Rainfall and temperature outlooks for the coming 3 months, emailed monthly
- [ ] **Drought Statement**
  Discussion of severe rainfall deficiencies in Australia, emailed monthly
- [ ] **Seasonal Streamflow Forecasts**
  Streamflow forecasts for the coming 3 months, emailed monthly
- [ ] **Tropical Climate Update**
  Climate commentary for northern Australia and the Asia-Pacific region, emailed every 2 weeks
- [ ] **Weekly Rainfall Update**
  Rainfall commentary and highest totals for the past week, emailed weekly

Take-home points

- MJO: largest mode of subseasonal variability in the tropics with period 30-80 days

- RMM index phases 1 to 8 track its eastward propagation around the globe

- MJO is a major driver of climate variations for Pacific Island countries, including
  - Wet season rainfall
  - Tropical cyclone activity
  - Modulating ENSO activity (a two-way feedback)
  - Ocean wave conditions

- MJO is a valuable source of subseasonal predictability of these climate variations
  - Skill extends out to about a month in ACCESS-S2 (varies by season)
  - Is improved by about a week during EQBO, compared to WQBO
  - Subscribe to Bureau of Meteorology tropical climate updates at bom.gov.au/climate/ahead