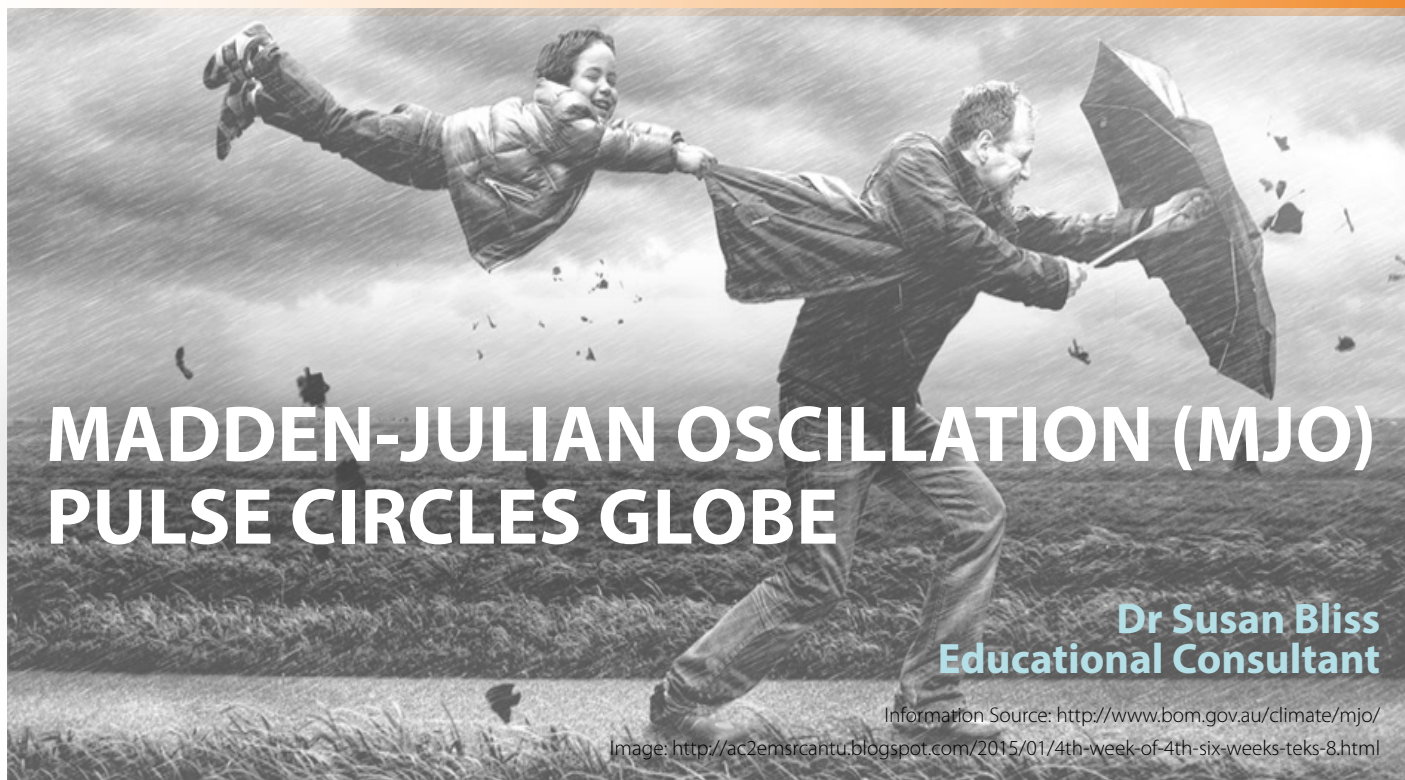


BIOPHYSICAL INTERACTIONS



MADDEN-JULIAN OSCILLATION (MJO) PULSE CIRCLES GLOBE

Dr Susan Bliss
Educational Consultant

Information Source: <http://www.bom.gov.au/climate/mjo/>

Image: <http://ac2emscanttu.blogspot.com/2015/01/4th-week-of-4th-six-weeks-eks-8.html>

CURRICULUM

- **Geographical Skills**-Weather Maps, Satellite Imagery, Diagrams, Graphs and photographs.
- **General Capabilities**-Literacy, Numeracy, Critical Thinking, Work and Enterprise, Information and Communications Technology.
- **Cross Curriculum:** Asia and Australia's Engagement with Asia

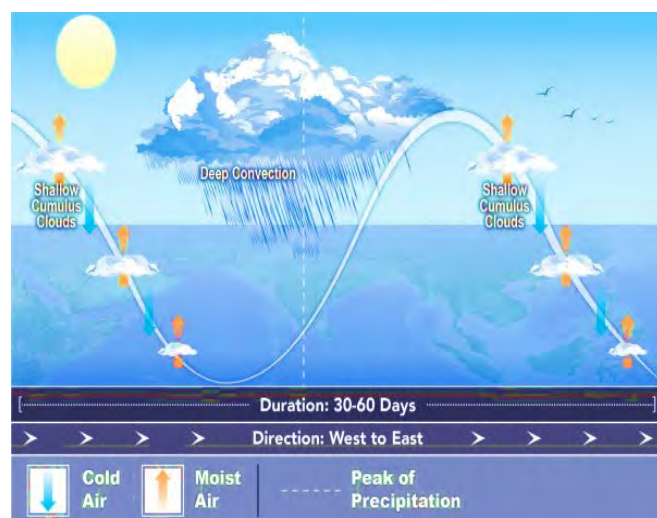
OVERVIEW

Australia's weather and climate varies over time and space. The island continent is affected by monsoons, tropical cyclones, blocking highs, El Nino, La Nina and the Indian Ocean Dipole. However, another important player is the lesser known **Madden-Julian Oscillation** or **MJO**. It is a naturally occurring **oceanic-atmospheric** phenomenon which affects weather across Earth ranging from **Asia, Australia, US** and the **Arctic**. The MJO is the dominant source used to forecast weather and climate in the **sub seasonal range** (3–4 weeks). In fact the **National Oceanic and Atmospheric Administration (NOAA)** produces a weekly update of MJO and a model forecasts MJO daily.

MJO is a **major fluctuation** in **tropical weather** affecting **Australia's northern climate**. It is characterised as an **eastward** moving 'pulse' of cloud and precipitation near the equator that circles Earth approximately every **30–60 days**. Historical weather observations together with the MJO index is used to manage Australia's northern grasslands such as 'best-bet' dates for fire management, weed control, moving stock and planting crops. Interestingly, it also has links with the mid-latitudes such as impacting on precipitation in the southern part of Australia such as NSW.

Recent observations and forecasts of the MJO are available from the Australian Bureau of Meteorology (BoM) website.

Diagram of The Madden-Julian Oscillation



The Madden-Julian Oscillation is a large complex of clouds and rain initiated over the Indian Ocean that slowly progresses around the world along the equator. The MJO has a large effect on tropical monsoons and cyclones, as well as other weather systems outside the tropics. <https://www.pnnl.gov/science/highlights/highlight.asp?id=1032>

BIOPHYSICAL INTERACTIONS: MJO

WHAT ARE THE TWO PHASES OF MJO?

The **Madden-Julian Oscillation (MJO)** also referred to as the 30–60 day oscillation/wave or intra seasonal oscillation, was discovered in the 1970s by Dr. Roland Madden and Dr. Paul Julian when studying tropical wind and pressure patterns.

Due to its slowly evolving nature, the MJO is monitored to assess its position and strength by **NOAA'S geo-stationary and orbiting satellites** and the **global radiosonde network**.

The MJO consists of two **phases** with periods of moderate-to-strong activity followed by periods of little or no activity:

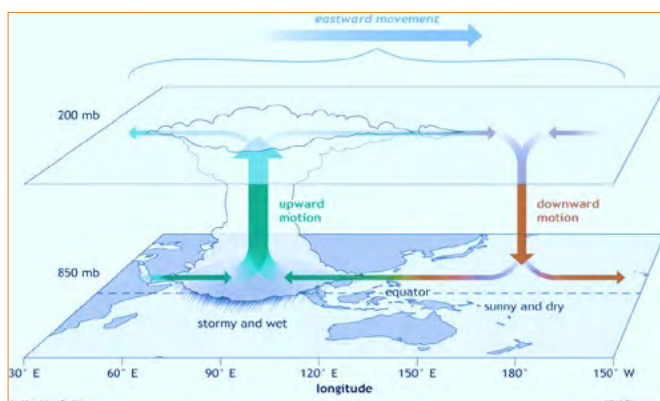
1. **Enhanced rainfall phase** (or convective-active).
2. **Suppressed rainfall phase**.

The MJO brings precipitation in its active phase but suppresses rain before and after its arrival.



Image: ABC Weather: Kate Doyle <https://www.abc.net.au/news/2020-12-11/madden-julian-oscillation-mjo-the-bearer-of-tropical-rain/12961346>

Diagram of the movement of the MJO



Drawing by Fiona Martin. Source: https://www.climate.gov/sites/default/files/MJO_large.png

The surface and upper-atmosphere structure of the MJO is the **enhanced convective phase** (thunderstorm cloud) is centred across the Indian Ocean and the **suppressed convective phase** is centred over the west-central Pacific Ocean.

Horizontal arrows pointing left represent wind departures from average that are easterly, and arrows pointing right represent wind departures from average that are westerly. The entire system shifts eastward over time, eventually circling the globe and returning to its point of origin.

Source: <https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care>

HOW IS MJO MEASURED?

Statistical methods such as RMM1 and RMM2 (Real-time Multivariate MJO Indexes) measure the strength and location of the MJO. The combination of **clouds** and **winds** at upper and lower levels of the atmosphere constitute the MJO index applied to any location.

WHAT ARE THE EIGHT GEOGRAPHICAL PHASES OF MJO CYCLE?

The MJO phases are grouped into geographically based stages **numbered 1–8**.

- 1 Africa
- 2/3 Indian Ocean e.g. India
- 4/5 Australia falls in the middle of the Maritime Continent
- 7/6 Pacific Ocean
- 8 America

The eight phases of the MJO cycle, move **east** from the Indian Ocean through the Pacific Ocean and into the Western Hemisphere.

This region of enhanced rainfall travels at a speed of ~ 5 m/sec across the Indian Ocean, the Indonesian Archipelago (i.e., the Maritime Continent) and on into the western Pacific Ocean. However, once it reaches the central Pacific Ocean, it speeds up to ~ 15 m/sec and weakens as it moves out over the cooler ocean waters of the eastern Pacific.

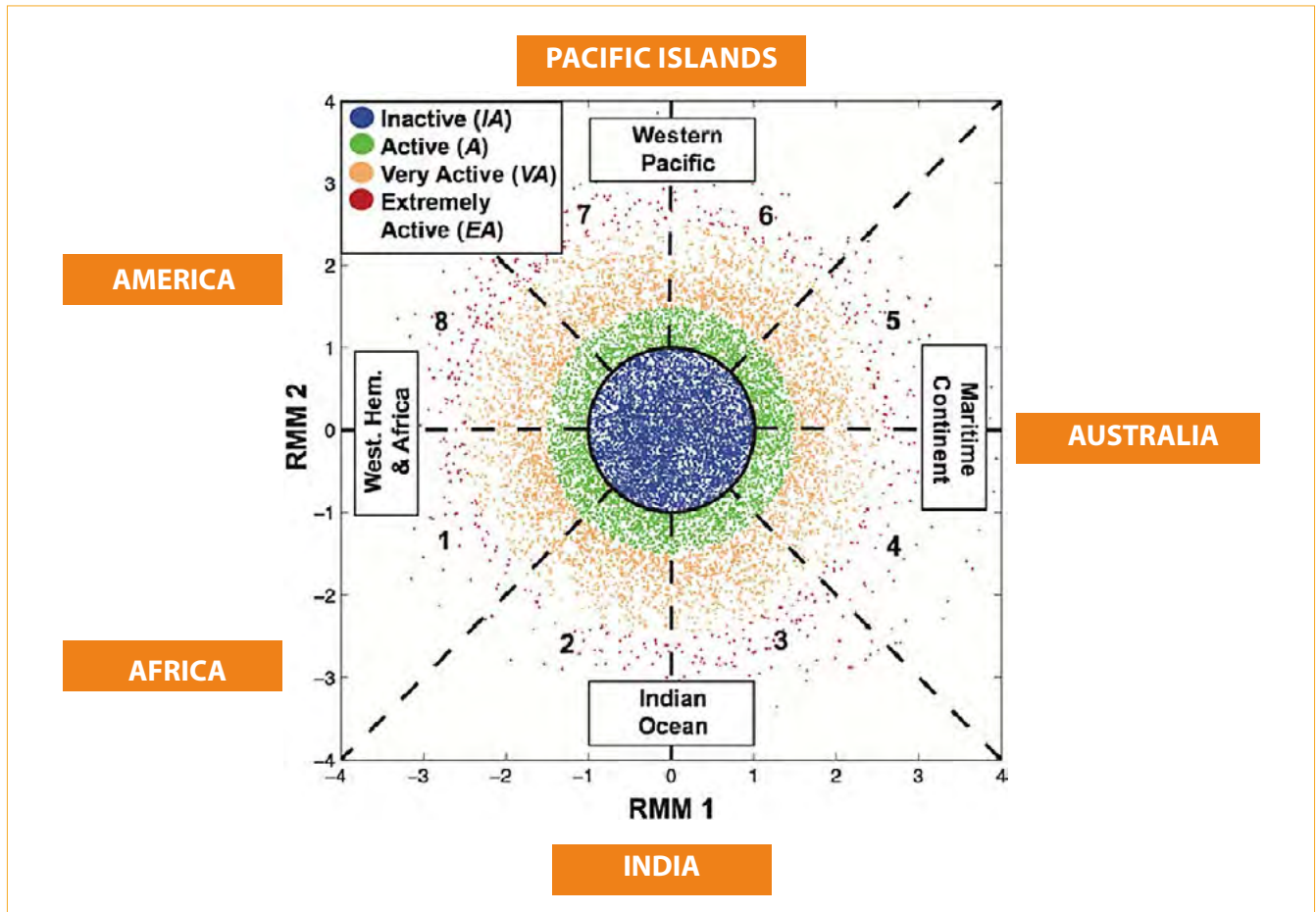
<https://tallbloke.wordpress.com/2018/11/20/ian-wilson-is-the-november-2018-madden-julian-oscillation-mjo-a-possible-trigger-for-an-el-nino/>

BIOPHYSICAL INTERACTIONS: MJO

Eight Phase Diagram

Travelling **anti-clockwise (eastward)** around the equator the diagram indicates that:

- The further the dot (MJO index) from the centre, the stronger the MJO. It is referred to as the **Active Phase**.
- When the dot (MJO index) is within the centre circle of the diagram, the MJO is considered weak. It is referred to as **Inactive/Suppressed Phase**.



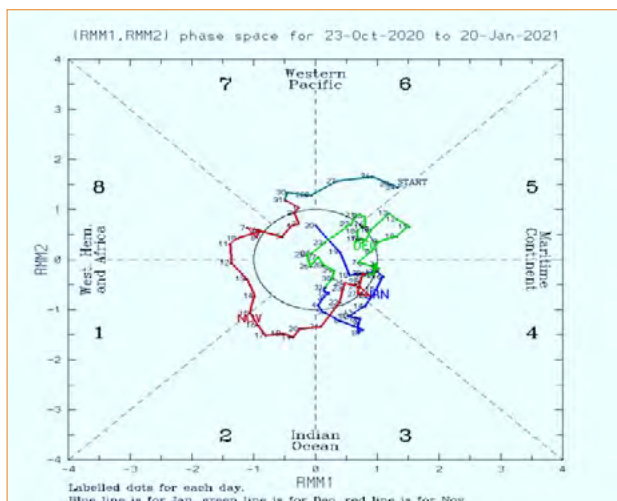
Source: https://www.researchgate.net/figure/Phase-space-diagram-of-the-RMM-index-WH04-showing-daily-phase-quadrant-and-magnitude_fig1_276474259

HOW CAN METEOROLOGISTS TRACK MJO?

Meteorologists track the MJO using a phase diagram that marks the daily location and strength of the 'active MJO phase'. Update these diagrams at the **BoM** site.

MJO phase diagram:

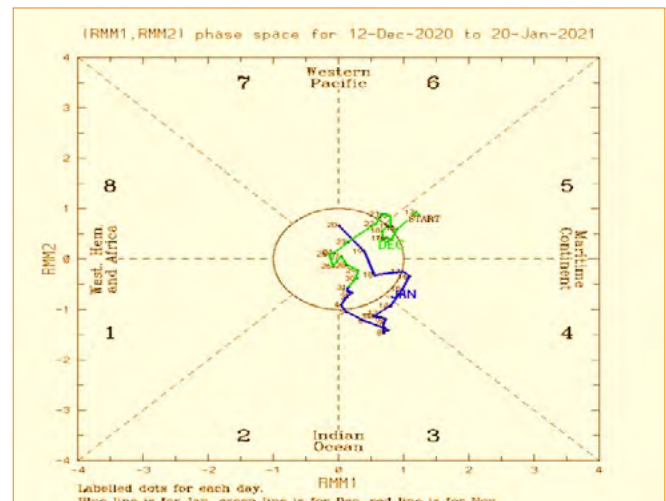
Current phase 90 days 23 October 2020 to 20 January 2021



Source: <http://www.bom.gov.au/climate/mjo/>

MJO phase diagram:

Current phase 40 days 12 December 2020 to 20 January 2021



Source: <http://www.bom.gov.au/climate/mjo/>

BIOPHYSICAL INTERACTIONS: MJO

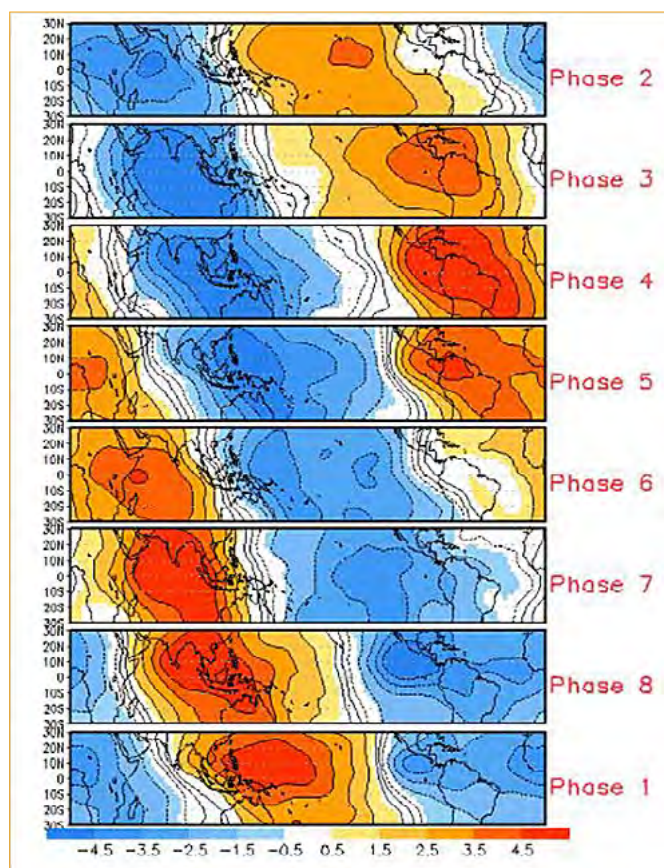
The active monsoon is expected to influence most of tropical Australia in the next fortnight, contributing to widespread heavy rainfall. Eastern parts of tropical Australia, the Coral Sea and the eastern Maritime Continent experience above-average rainfall with an MJO pulse over the western Pacific. During this period, there is an increased risk of a tropical low and cyclone formation over Australian waters.

Details on the MJO over Australia for these graphs are found at <http://www.bom.gov.au/climate/mjo/#tabs=Weekly-note>

HOW IS MJO MAPPED AS IT MOVES EAST?

Map: 200hPa May through September

Note the changes to Australia as MJO moves east



Source: https://www.daculaweather.com/4_mjo_phase_forecast.php



Mekong River, Don Dat Laos. Source: Wikimedia Commons



WHAT ARE THE IMPACTS ON WEATHER ASSOCIATED WITH MJO?

- Moderates the intensity of monsoon systems-timing (onset and end)
- Enhances the intensity and extent of the South Pacific Convergence Zone (Eastern Australia)
- Modulates tropical cyclone activity in the Indian Ocean, Pacific Ocean, Gulf of Mexico, and Atlantic Ocean
- Influences the ENSO cycle. It does not cause El Niño or La Niña, but is able to contribute to the speed of development and intensity of El Niño and La Niña episodes.
- Southern Oscillation, North Atlantic Oscillation and Indian Ocean Dipole affects the MJO.

SE Asia

The MJO is closely related to the **intra seasonal variability** of surface temperature in **East Asia**. Significant **cold surface temperature** anomalies are observed in East Asia during MJO phase 3.

Source: <https://journals.ametsoc.org/view/journals/clim/33/20/jcliD200302.xml>

USA

The MJO influences both **precipitation** and **surface temperature patterns** across **USA**.

The two most significant impacts over USA during the Northern Hemisphere winter are an increase in the frequency and intensity of:

- Heavy **precipitation** along west coast USA.
- **Cold air** outbreaks across eastern USA.

MJO is a major factor in forecasting hurricanes in USA.

Source: <https://cbs12.com/news/local/atlantic-hurricane-season-likely-to-pick-up-due-to-mjo-but-what-is-that>

Global

The MJO influences both the spatial distribution and the occurrence of **extreme weather events (ERE)** over **Southeast Asian regions**. Similarly, over the **East Asia** (Jeong *et al.*, 2008), **China** (Jia *et al.*, 2011), **South America** (Shimizu *et al.*, 2017) and **African regions** (Sossa *et al.*, 2017) as well as **globally** (Jones *et al.*, 2004). The impacts of the MJO on rainfall and ERE are evident.

Source: <https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/met.1901>

BIOPHYSICAL INTERACTIONS: MJO

WHAT ARE THE GLOBAL IMPACTS OF MJO?

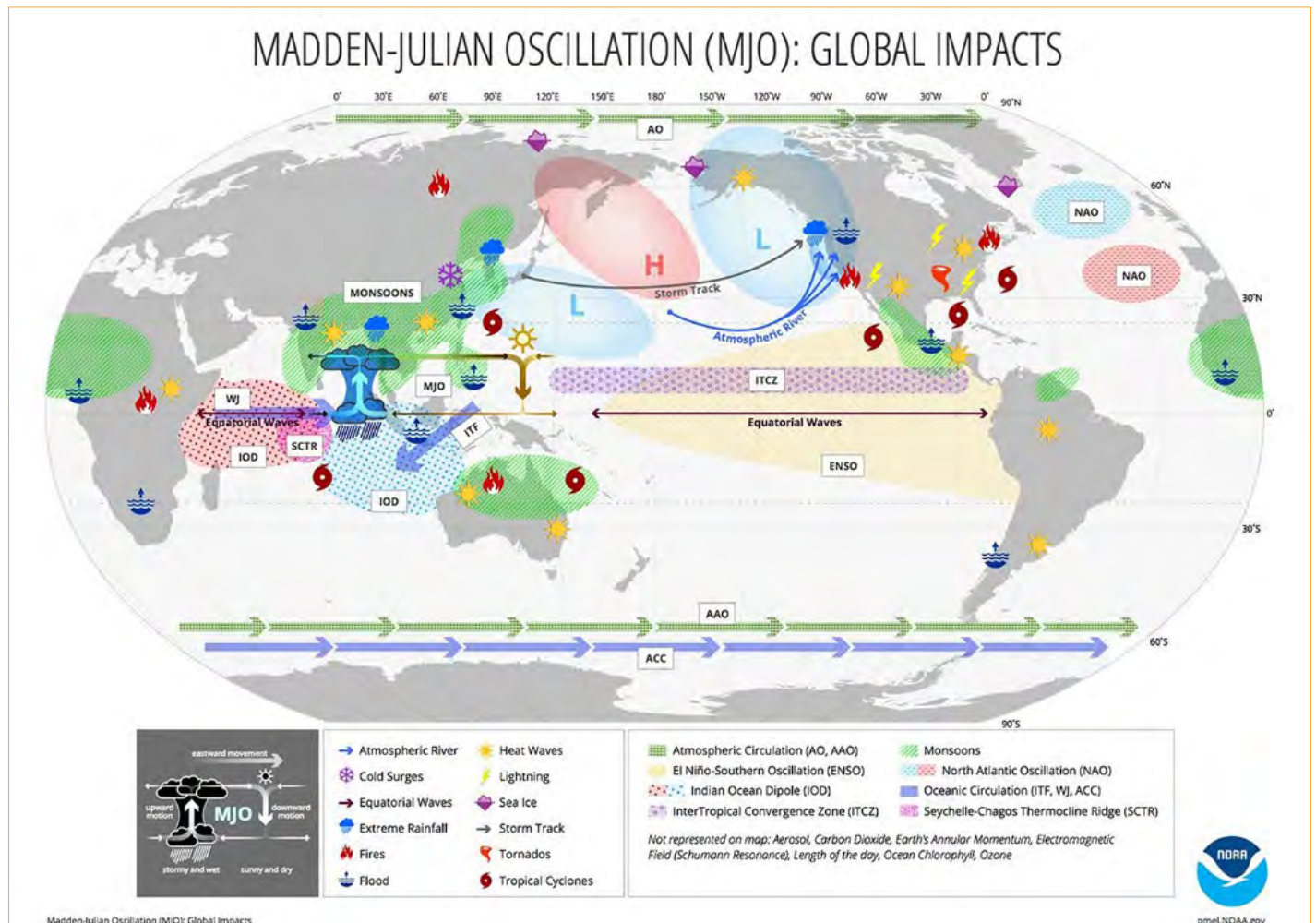
The MJO affects weather and climate globally-not only in tropical areas but also temperate zones and Polar Regions.

Additionally, the MJO influences the **physical** characteristics of the atmosphere and oceans, as well as **chemical** and **biological** processes on Earth (Zhang, 2013). For example, frequencies of tropical cyclones, tornados, floods, and heat waves can all change depending on whether the MJO is located over the Indian or Pacific Oceans.

sSource: <https://eos.org/editors-vox/mysterious-engine-of-the-madden-julian-oscillation>

Schematic illustration of global impacts of the MJO.

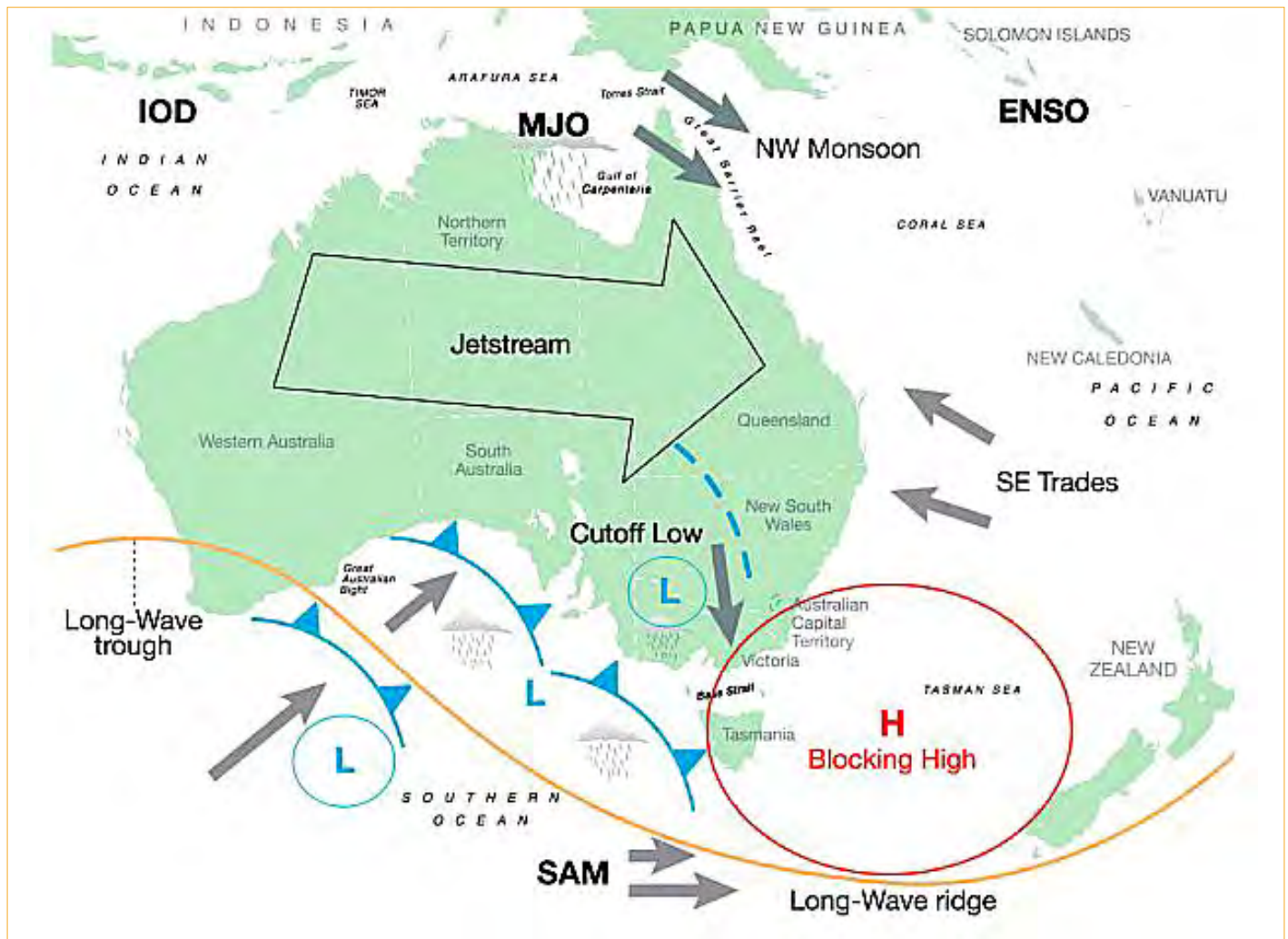
The locations of MJO-affected phenomena are not precise and complete



BIOPHYSICAL INTERACTIONS: MJO

WHAT ARE THE WEATHER SYSTEMS THAT AFFECT AUSTRALIA?

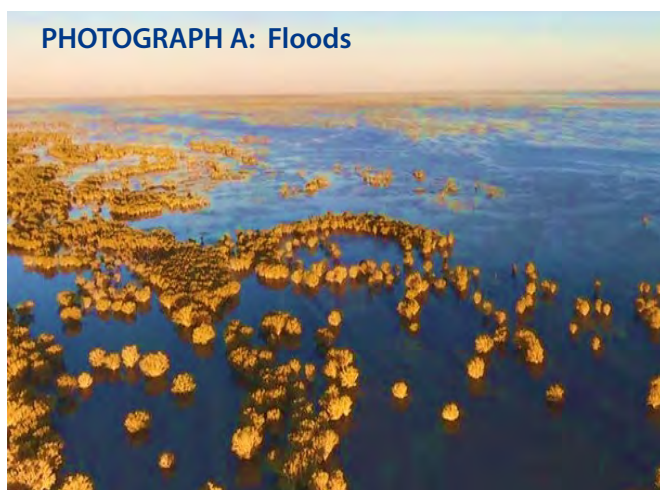
Diagram: Schematic representation of the main drivers of rainfall variability in the Australian region. The dominant features are the Indian Ocean Dipole (IOD), Madden-Julian Oscillation (MJO), and El Niño-Southern Oscillation (ENSO), Southern Annular Mode (SAM), and blocking in the extra tropics.



Source: Risbey et al 2008 <https://www.climatechangeinaustralia.gov.au/en/overview/climate-system/australian-climate-influences/>

MJO is one reason cyclones steered clear of Western Australia in 2019

There was a huge contrast in rainfall around Broome between 2018 photograph A (flooded) and 2019 photograph B (dry).

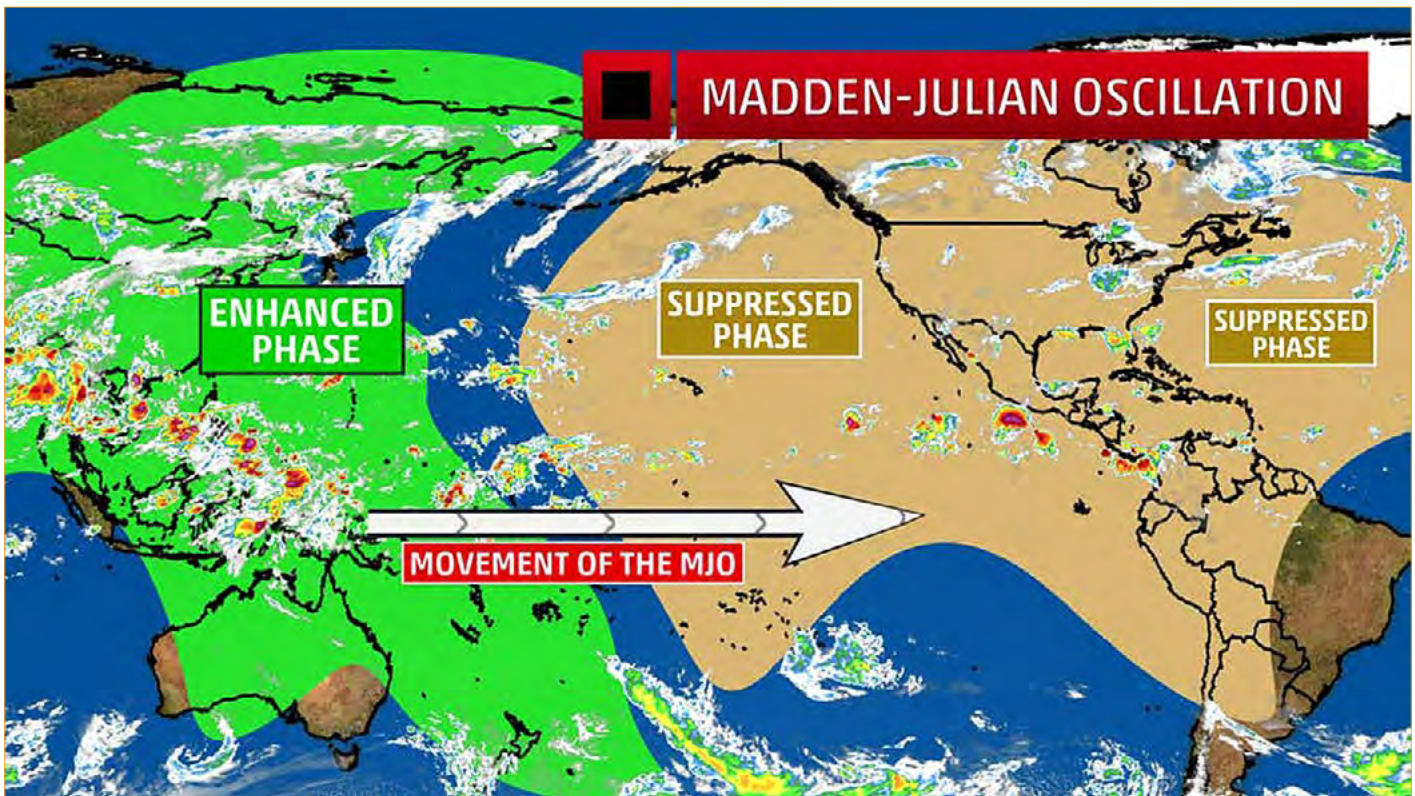


Images: <https://www.abc.net.au/news/2019-03-03/madden-julian-oscillation-causing-wa-cyclones-to-vanish/10855032?nw=0>

BIOPHYSICAL INTERACTIONS: MJO

WHAT ARE THE IMPACTS OF MJO ON AUSTRALIA?

Diagram: Movement of MJO across Australia



Source: <https://weather.com/storms/hurricane/news/2018-08-21-west-pacific-typhoon-atlantic-hurricane-relationship>

IMPACTS OF MJO ON WEATHER IN AUSTRALIA

Wind

An active MJO generates a westerly wind pattern across Australia

Precipitation

MJO is able to increase or decrease precipitation depending on its location.

An active MJO generates a wetter summer season than normal across Australia (generally from October to April.)

Temperature

MJO can increase or decrease the average temperature depending on its location

Monsoon

MJO can drive surges and cessations in monsoon precipitation

El Niño

MJO is capable of triggering the MJO

WHAT ARE THE IMPACTS OF MJO ON AUSTRALIA DURING EIGHT PHASES?

The following maps show average weekly rainfall probabilities and expected 850hPa (approximately 1.5 km above sea level) wind anomalies for each of the eight MJO phases.

Colour:

- **Green and blue** shading indicates higher than normal rainfall is expected.
- **Red and orange** shading indicates lower than normal rainfall is expected.

The chance of weekly rainfall exceeding the median increases for northern Australia during Phase 5 and 6 of the MJO when it passes to the north of the continent.

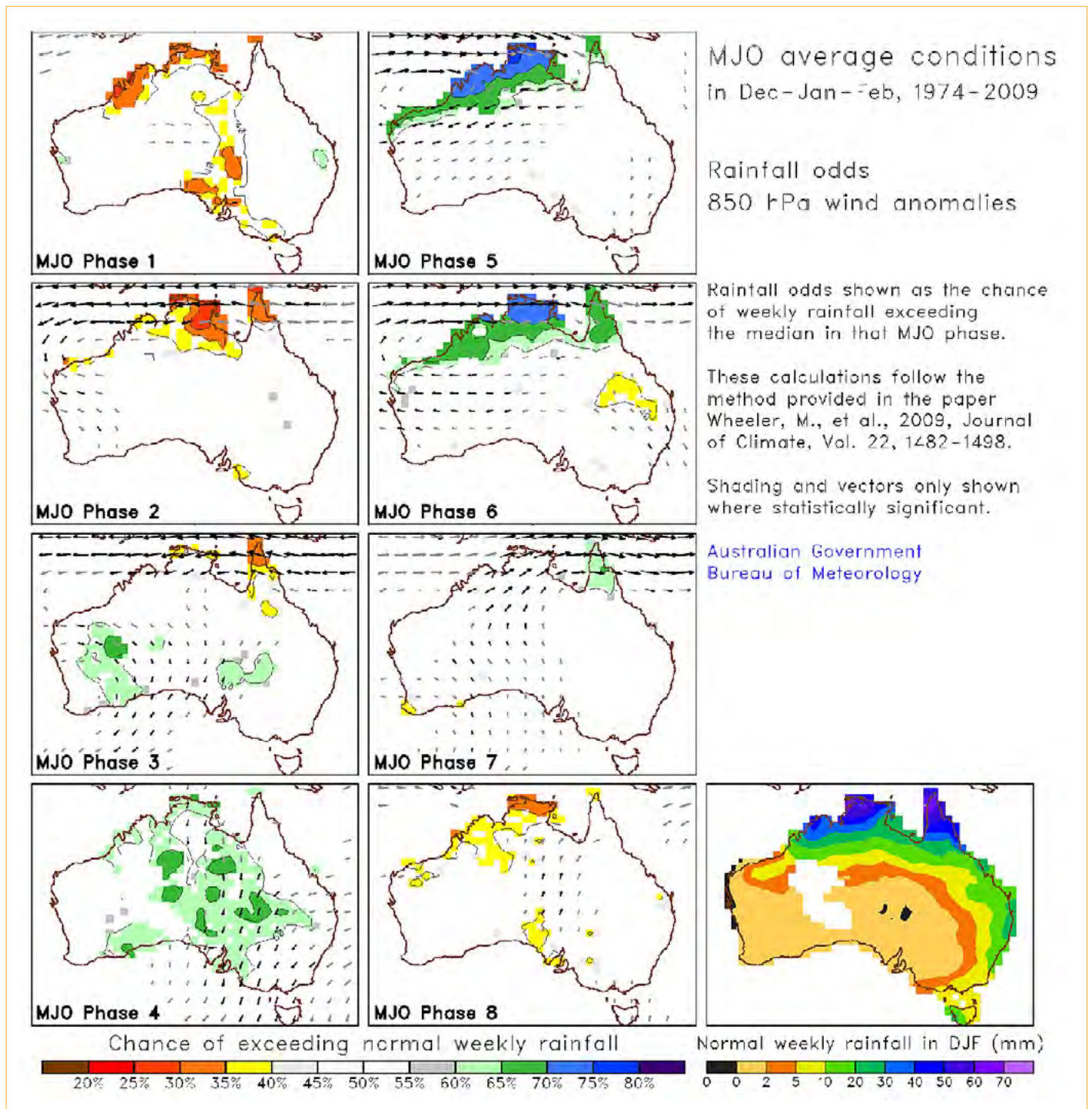
Direction and length of the arrows:

- Indicates the direction and strength of the wind anomaly.
- The darker the arrow, the more reliable the information.

BIOPHYSICAL INTERACTIONS: MJO



The relationship of the MJO with Australian rainfall and winds changes with seasons can be observed at the following website. <http://www.bom.gov.au/climate/mjo/#tabs=Average-conditions>



Maps: <http://www.bom.gov.au/climate/mjo/#tabs=Average-conditions>

BIOPHYSICAL INTERACTIONS: MJO

The Bureau of Meteorology track the influence of the Madden Julian Oscillation as it passes across the north of Australia using a range of tools including a radiosonde, launched here by Dr Matthew Wheeler off the coast of northern Australia. Source: Bureau of Meteorology.

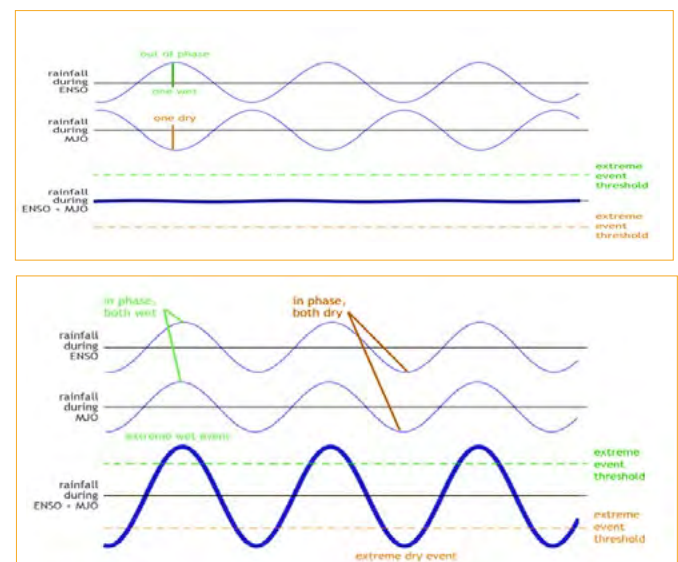


<http://www.climatekelpie.com.au/index.php/2020/08/10/what-goes-around-may-bring-rain-to-northern-australia/>

- The MJO atmospheric disturbance is distinct from ENSO, which once established, is associated with persistent features that last several seasons or longer over the Pacific Ocean basin.
- There can be multiple MJO events within a season, and so the MJO is best described as ***intra-seasonal*** tropical climate variability (i.e. varies on a week-to-week basis).
- *MJO can block or enhance the effects of the La Niña in the western Pacific.

Source: <https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care>

Line graphs: Two climate signals interfering (i.e., combining) with each other. Bold blue curve sketches the result of the combination. Horizontal bars indicate conceptual thresholds for occurrence of extremely wet and dry events.



Animation adapted by Climate.gov <http://www.acs.psu.edu/drussell/Demos/superposition/superposition.html>. Source: <https://www.climate.gov/news-features/blogs/enso/catch-wave-how-waves-mjo-and-enso-impact-us-rainfall>

How does MJO differ from ENSO? How does MJO impact on ENSO?

- Imagine **ENSO** as a person riding a **stationary** exercise bike in the middle of a stage all day long. His unchanging location is associated with the persistent changes in **tropical rainfall** and winds that we have **previously described** as being linked to ENSO.
- Now imagine another bike rider entering the stage on the left and pedalling slowly across the stage, passing the stationary bike (ENSO), and exiting the stage at the right. This bike rider we will call the **MJO** and he/she may cross the stage from left to right several times during the show.
- So, unlike ENSO, which is stationary, the MJO is an **eastward moving** disturbance of clouds, rainfall, winds, and pressure that traverses the planet in the tropics and returns to its initial starting point in 30 to 60 days, on average.

HOW WILL GLOBAL WARMING AFFECT MJO?

ARTICLE 1

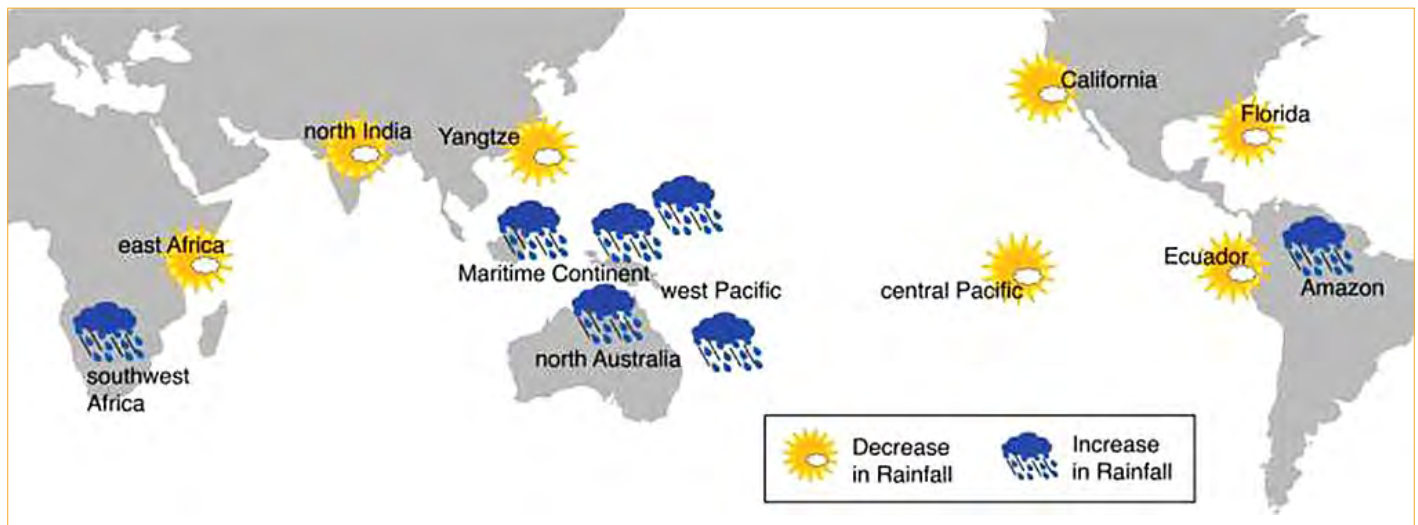
The MJO travels 12,000–20,000 km over **tropical oceans**, mainly the **Indo-Pacific warm pool** which has ocean temperatures generally warmer than 28 °C.

This **Indo-Pacific warm pool** has been warming rapidly, altering the **residence time** of MJO over tropical oceans. While the total lifespan of MJO remains in the 30–60 day timescale, its **residence time has shortened over the Indian Ocean** by 3–4 days (from an average of 19 days to 15 days) and **residence time increased** by 5–6 days over the West Pacific (from an average of 18 days to 23 days). **This change in the residence time of MJO has altered the rainfall patterns across the globe.**

Source: https://en.wikipedia.org/wiki/Madden%E2%80%93Julian_oscillation

BIOPHYSICAL INTERACTIONS: MJO

Indo-Pacific Ocean warming is changing global rainfall patterns and altering the MJO



Map Source: <https://phys.org/news/2019-11-indo-pacific-ocean-global-rainfall-patterns.html>

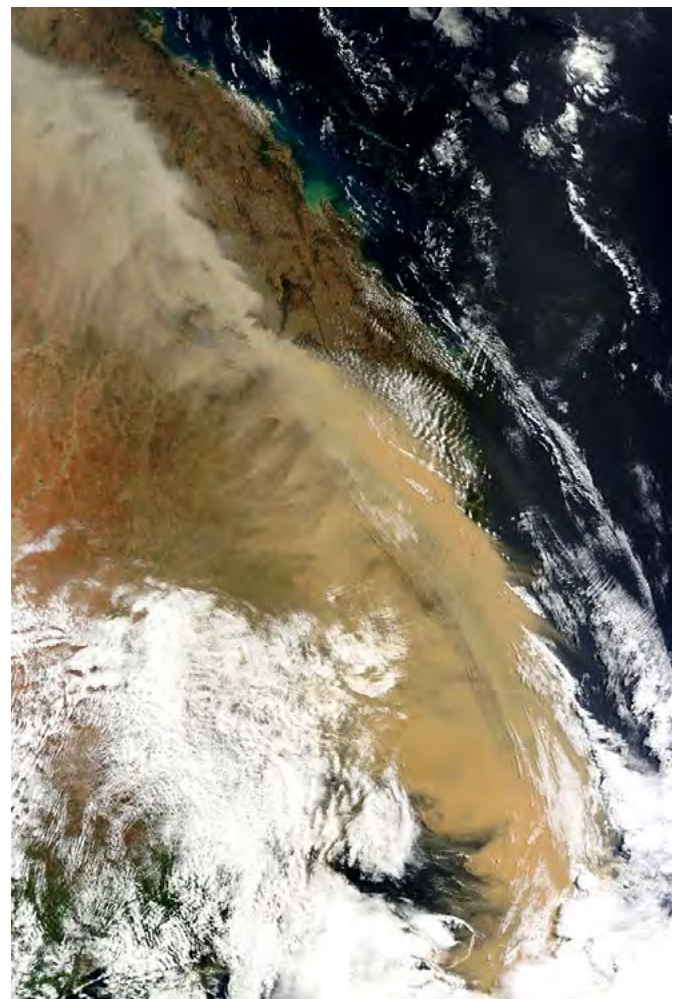
ARTICLE 2

Atmospheric scientists have studied how the MJO modulates **extreme weather events** across the globe, from hurricanes to floods and droughts.

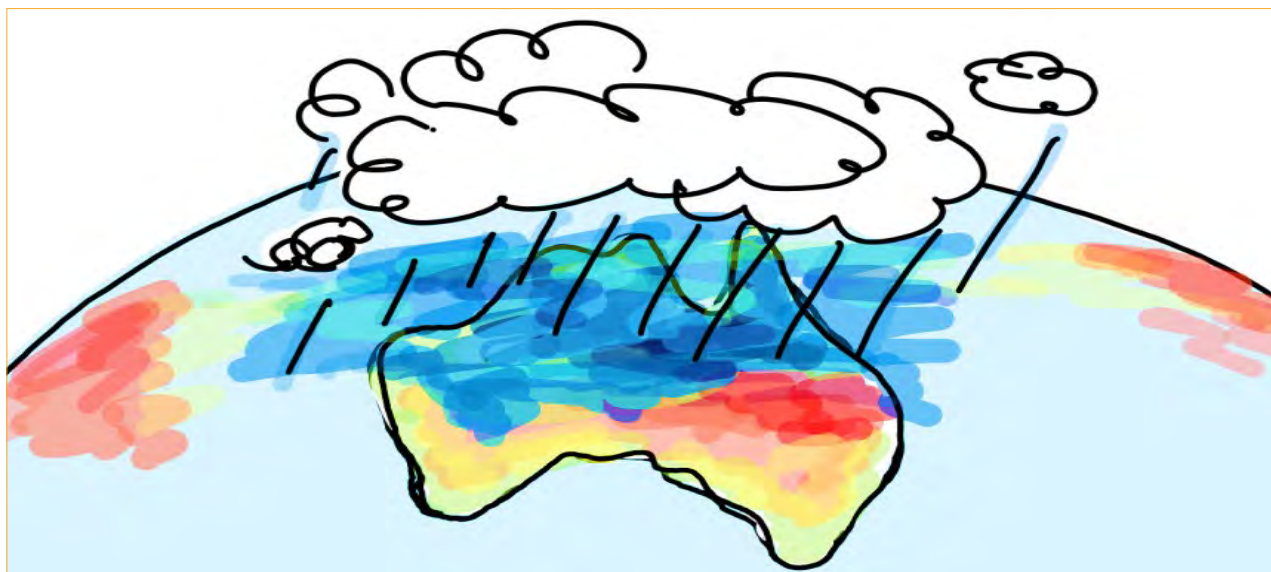
As **human activities** cause the Earth's temperature to increase, weather patterns like the MJO will also change. Eric Maloney, professor in the Department of Atmospheric Science, Colorado State University led a study published in *Nature Climate Change* that **attributes future changes in the behaviour of the MJO to anthropogenic global warming**. Maloney and co-authors used data from six climate models to synthesise current views of such changes projected for the years **2080–2100**.

Read the full article, "Reliable tropical weather pattern to change in a warming climate." https://engr.source.colostate.edu/reliable-tropical-weather-pattern-to-change-in-a-warming-climate/?utm_source=newsletter&utm_medium=email&utm_campaign=t0103-19

Additional article: "Prof. Maloney leads study on how global warming will affect MJO" <https://www.atmos.colostate.edu/2019/01/prof-maloney-leads-study-on-how-global-warming-will-affect-mjo/>



Dust storm over eastern Australia, NASA image Source: https://commons.wikimedia.org/wiki/File:Dust_storm_over_eastern_Australia_-_MODIS_Terra_250m_-_23_Sept_2009.jpg



The Madden-Julian Oscillation, ABC Weather: Drawing by Kate Doyle
Source: <https://www.abc.net.au/news/2020-12-11/madden-julian-oscillation-mjo-the-bearer-of-tropical-rain/12961346>

STUDENT ACTIVITIES

Before you start the questions check YouTube to gain a better understanding of the topic.

Understanding the MJO:

- YouTube video – https://www.youtube.com/watch?v=UsWHHE_jkGE
- ABC: MJO the bearer of tropical rain – <https://www.abc.net.au/news/2020-12-11/madden-julian-oscillation-mjo-the-bearer-of-tropical-rain/12961346>
- Weatherview – <https://weatherview.in/madden-julian-oscillation/>
- ABC: MJO causing WA cyclones – <https://www.abc.net.au/news/2019-03-03/madden-julian-oscillation-causing-wa-cyclones-to-vanish/10855032?nw=0>
- BOM summer 2020-21 climate and water outlook – <https://www.abc.net.au/news/2020-12-11/madden-julian-oscillation-mjo-the-bearer-of-tropical-rain/12961346>

Refer to the article, YouTube and websites on the Madden-Julian Oscillation (MJO) to complete the following sentences. – <http://www.bom.gov.au/climate/mjo/>

1. MJO is a pulse of, enhanced cloud and rainfall that cycles.....around the globe near the
2. MJO is a global feature of the..... atmosphere.
3. MJO is the.....fluctuation in tropical weather onto monthly timescales.
4. MJO can forecast weather (Timescale) in advance.
5. MJO recurs every.....todays
6. MJO is associated with variations in....., cloudiness, and.....
7. MJO effects are most evident over the..... Ocean and equatorial Pacific.
8. MJO influences the timing, development and strength of the major global monsoon patterns, including theand.....Monsoons.

STUDENT ACTIVITIES

9. MJO can be monitored by using measurements.
10. The area most affected by the MJO in Australia is in northern or southern Australia during summer or winter?.....
11. MJO can have an effect on the timing and intensity of “active” monsoon periods in northern Australia. Explain this statement
.....
12. Describe an example of the active MJO in Australia in 2006.
Include weather map and satellite image.
 - a. The satellite image showed increased convective activity (.....) over Australia during an active phase of the MJO.
 - b. Explain the impacts of this event
.....
.....
13. Describe the current situation of the MJO. <http://www.bom.gov.au/climate/tropical-note/>.
.....
.....
14. Refer to the current MJO phase diagram for the next 40 days.
Summarise its conclusions <http://www.bom.gov.au/climate/mjo/>
.....
.....
15. Indicate True or False to the following statements:
 - [] Tropical cyclones are less likely when the MJO is active.
 - [] El Nino can be triggered by MJO.
 - [] An active MJO results in increased precipitation in northern Australia in summer.
 - [] There is evidence that the MJO influences the ENSO cycle. It does not cause El Niño or La Niña, but contributes to the speed of development and intensity of El Niño and La Niña periods.



A storm preluding an MJO event over the tropical Indian Ocean. Credit: Yuji Kashino, RIGC/JAMSTEC Source: <https://eos.org/editors-vox/mysterious-engine-of-the-madden-julian-oscillation>

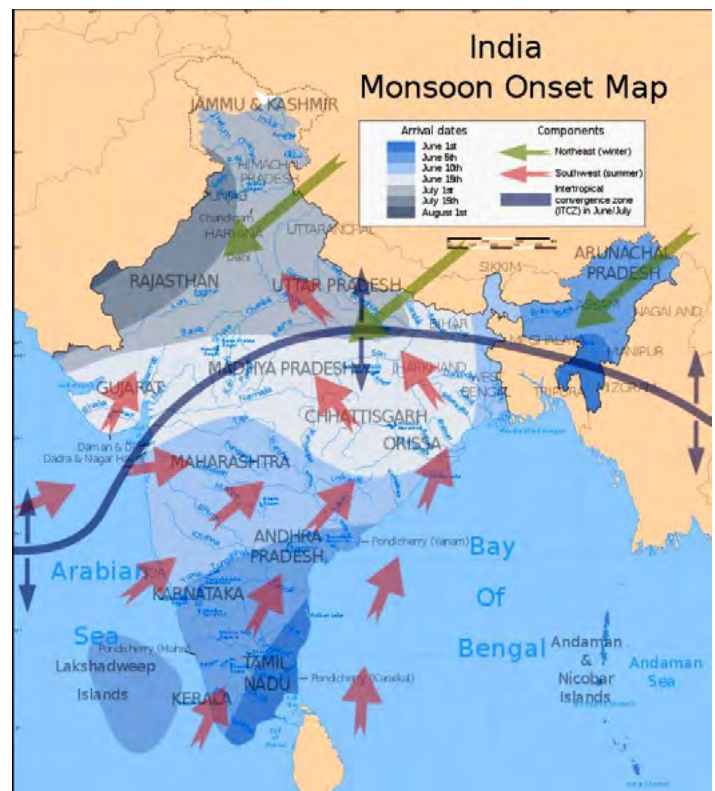
EXTENSION ACTIVITIES

Monsoon India

- In groups research the link between the MJO and the onset of the summer monsoon in India.
- Present as an oral report supported using ICT.

<https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/met.1901>

https://www.researchgate.net/publication/304345025_Linkages_between_MJO_and_summer_monsoon_rainfall_over_India_and_surrounding_region



Map https://en.wikipedia.org/wiki/Madden%E2%80%93Julian_oscillation#/media/File:India_southwest_summer_monsoon_onset_map_en.svg

Pineapple Express USA

- In pairs describe the Pineapple Express and its impacts on North American weather patterns.
- Discuss the links between MJO and the Pineapple Express.

https://en.wikipedia.org/wiki/Madden%E2%80%93Julian_oscillation#/media/File:Mjo_north_america_rain.png

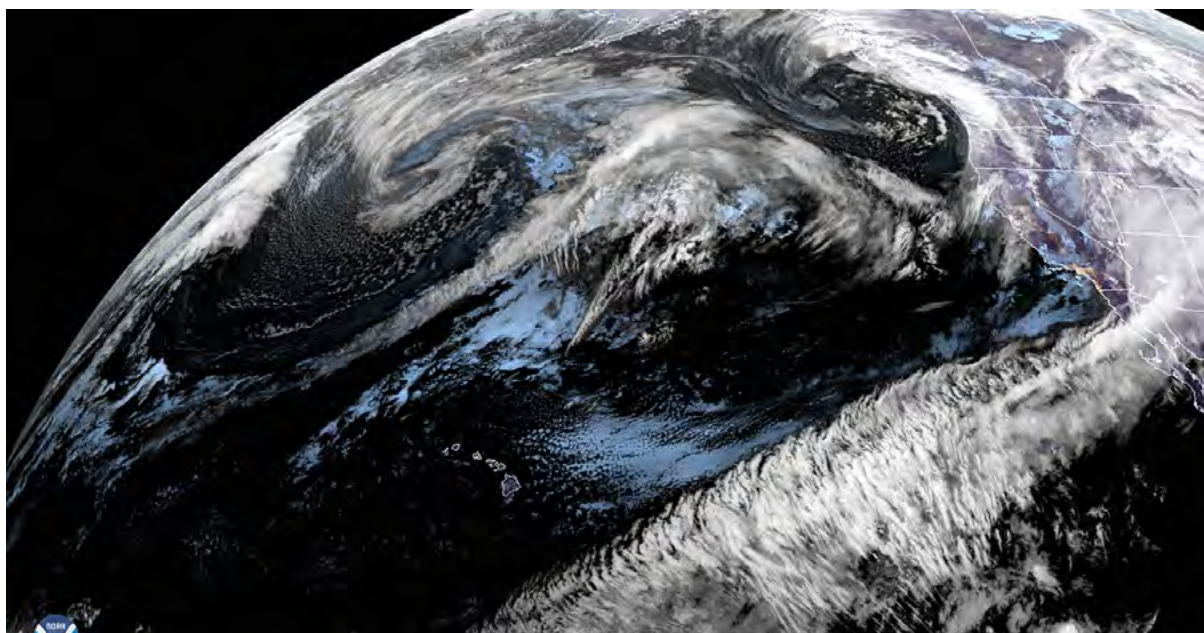
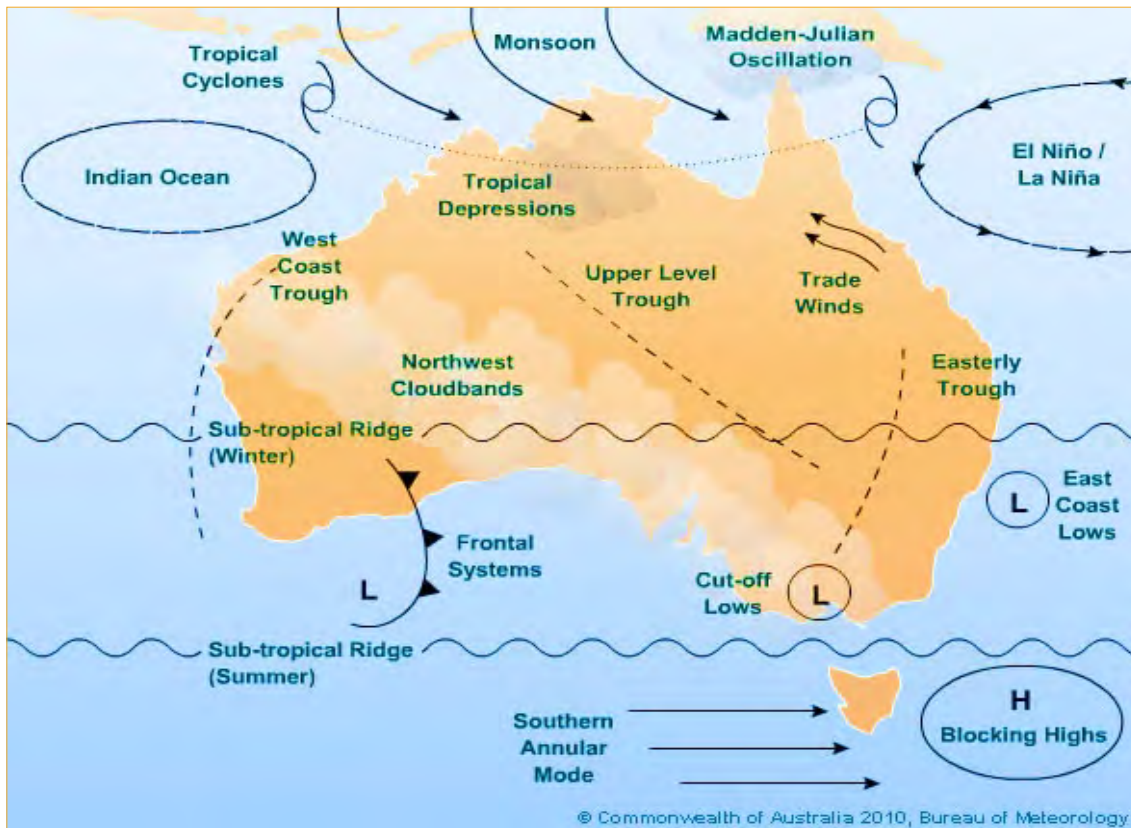


Image: The Pineapple Express brings precipitation to Western USA. January 2020.

EXTENSION ACTIVITIES



A strong flow of moisture streaming across the Pacific toward the western coast of USA. This phenomenon, colloquially known as the "Pineapple Express", brings deep atmospheric moisture from around the Hawaiian Islands to the Pacific coastline Source: <https://www.nesdis.noaa.gov/content/pineapple-express-brings-precipitation-western-us>

Climate and weather influences on Australia

- In pairs select one climate and weather influences on Australia from the list below

Australian climate and weather influenced by the following:

- | | |
|--------------------------|--------------------------|
| 1. Blocking Highs | 12. Tropical Depressions |
| 2. Cut-off Lows | 13. Upper Level Trough |
| 3. East Coast Lows | 14. West Coast Trough |
| 4. Easterly Trough | |
| 5. Frontal Systems | |
| 6. Northwest Cloud bands | |
| 7. Southern Annular Mode | |
| 8. Sub-tropical Ridge | |
| 9. Monsoon | |
| 10. Trade Winds | |
| 11. Tropical Cyclones | |

Include in your investigation:

- What is it?
- When does it occur?
- Where does it occur?
- How long does it occur?
- Provide an example
- Map
- Latest update <http://www.bom.gov.au/climate/mjo/>

- Present investigation as a short response using ICT.

WANT TO LEARN MORE?



Image: <https://www.abc.net.au/news/2020-12-11/madden-julian-oscillation-mjo-the-bearer-of-tropical-rain/12961346>

The Bureau of Meteorology has great resources for learning more about climate

- The three phases of the El Niño–Southern Oscillation (ENSO)
<http://www.bom.gov.au/climate/enso/history/In-2010-12/three-phases-of-ENSO.shtml>
- Indian Ocean influences on Australian climate
<http://www.bom.gov.au/climate/iod/>
- The Southern Annular Mode (SAM)
<http://www.bom.gov.au/climate/enso/history/In-2010-12/SAM-what.shtml>
- Subtropical ridge leaves us high and dry this June
<http://www.bom.gov.au/climate/updates/articles/a025.shtml>
- About East Coast Lows <http://www.bom.gov.au/nsw/sevwx/facts/ecl.shtml>
- Madden-Julian Oscillation (MJO) <http://www.bom.gov.au/climate/mjo/>
- Impacts of the Madden-Julian Oscillation on Australian Rainfall and Circulation (Journal Article)
<https://journals.ametsoc.org/view/journals/clim/22/6/2008jcli2595.1.xml>



Image: <https://www.bcg.org.au/old-dog-new-tricks-new-look-climate-kelpie-website-unveiled-at-cotton-conference/>

Resources – ICT

- Current Hunt: Madden-Julian Oscillation (MJO)
<http://currenthunt.com/2019/05/madden-julian-oscillation-mjo/>
- An All-Season Real-Time Multivariate MJO Index
http://www.atmos.albany.edu/daes/atmclasses/atm421/Reference_Material_files/WheelerHendon_2004.pdf
- Madden-Julian Oscillation: The bearer of tropical rain
<https://www.abc.net.au/news/2020-12-11/madden-julian-oscillation-mjo-the-bearer-of-tropical-rain/12961346>
- The Madden–Julian Oscillation (MJO)
https://www.daculaweather.com/4_mjo_phase_forecast.php
- MJO Model Forecasts
<https://trackthetropics.com/mjo-model-forecasts/>
- Catch a wave: how waves from the MJO and ENSO impact US rainfall
<https://www.climate.gov/news-features/blogs/enso/catch-wave-how-waves-mjo-and-enso-impact-us-rainfall>
- Prediction of the Madden–Julian Oscillation: A Review
<https://journals.ametsoc.org/view/journals/clim/31/23/jcli-d-18-0210.1.xml>
- MJO Climate Prediction Centre
<https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml>
 - Current Conditions
 - Forecasts
 - MJO Task Force Dynamical Model MJO Forecasts
 - Additional MJO Products
 - Expert Discussions
 - Composites
 - Educational Material
 - Publications
- MJO detailed information
https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/MJO_summary.pdf

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