



MADDEN-JULIAN OSCILLATION

GLOBAL CLIMATE INFLUENCER

By James Rohman | February 2014

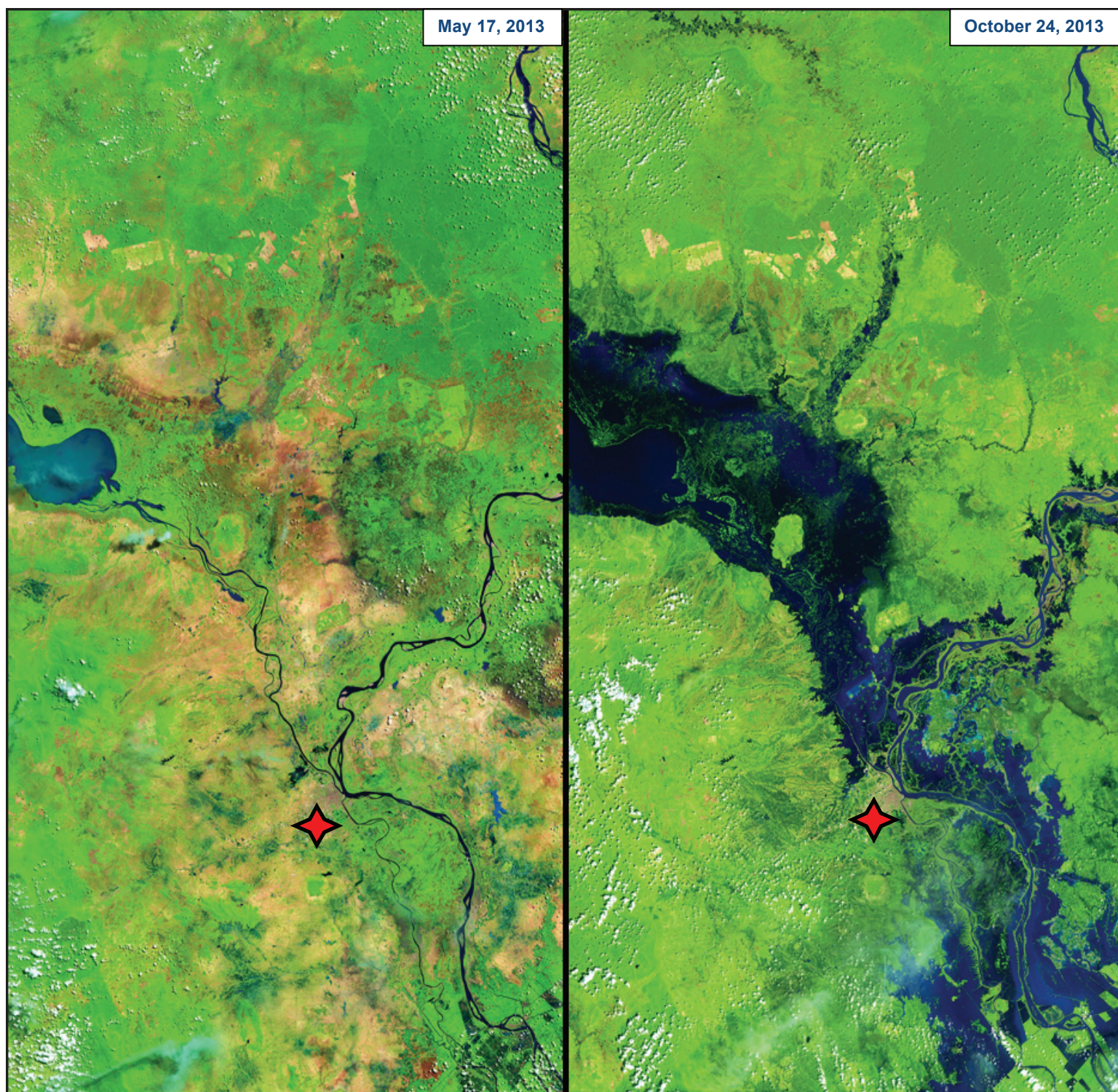


Figure 1. Following heavy rainfall influenced by the Madden-Julian Oscillation, Typhoon Nari caused substantial flooding along the Mekong and Tonlé Sap Rivers in Cambodia. The flood affected more than 500,000 people, and 300,000 hectares of rice fields were destroyed. The capital city of Phnom Penh (with a population 2.2 million) is marked in the image.

Introduction

The Madden-Julian Oscillation (MJO) is a slow-moving atmospheric pattern that impacts global tropical and sub-tropical weather.

The phenomenon was discovered by Roland Madden and Paul Julian in 1971. They used ten years of pressure records from Kanton Island and Singapore to identify a **40-50 day oscillation of zonal wind anomalies in the tropical Pacific.**

Since then, MJO's recurring pattern of intense rain and thunderstorms followed by an unseasonably dry phase has been identified as occurring every 30-60 days.

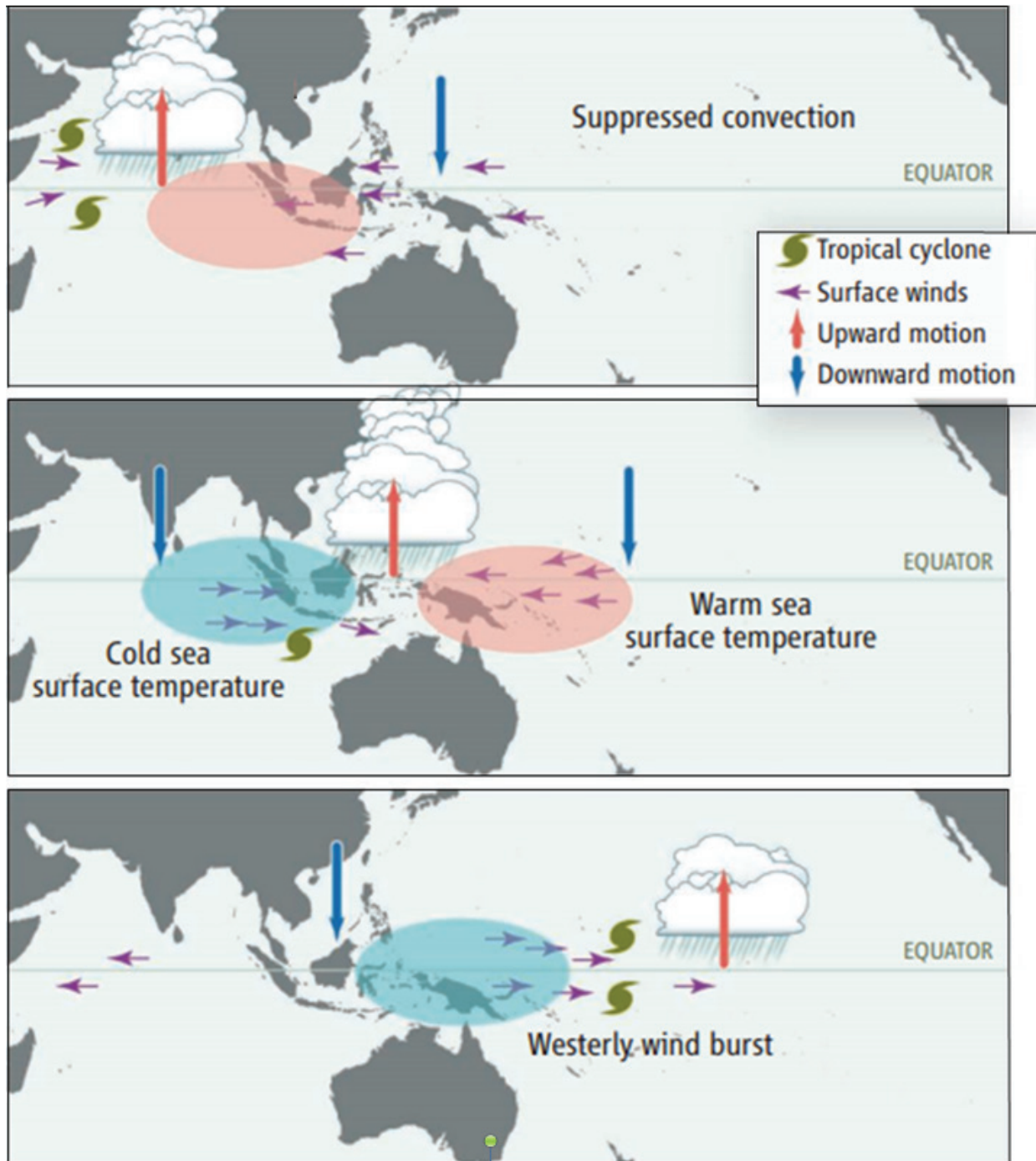
MJO starts in the Indian Ocean as a band of low pressure caused by the Indian Ocean Dipole (IOD). It is a naturally occurring component of the ocean atmosphere. **MJO extracts moisture from the water and then drops rain and tropical cyclones over the Indian, Southeast Asian and Australian regions.** Continuing east, **MJO can kindle weather systems that batter the Pacific Coasts of North and South America with massive rain, heavy winds and flooding.**

MJO affects the entire tropical troposphere. **Its fluctuating cycle is responsible for most of the weather variability in the tropics** by impacting wind speed and direction, sea surface temperatures (SSTs), rainfall, cloudiness and ocean surface evaporation. As a result, **tropical weather is far less predictable than in the mid-latitudes.**

After passing across North and South America, the pattern of strong tropical rainfall reappears over the tropical Atlantic Ocean and Africa. Variations in tropical rainfall are associated with distinct patterns of lower- and upper-level atmospheric circulation anomalies in the subtropics and tropics.

MJO interacts with the phases of the El Niño Southern Oscillation (ENSO) in the eastern tropical Pacific Ocean. Depending on the phase, **ENSO can increase or decrease the rainfall impact of MJO.**

MJO varies widely from year to year. Periods of strong activity are followed by long periods when MJO is weak or completely absent. This may be due to MJO linkage to the ENSO cycle. Strong MJO activity is often observed 6-12 months before the onset of El Niño, but is almost absent during the maxima of some El Niño episodes. MJO also tends to be more active during La Niña periods.



The Madden-Julian Oscillation. Precipitation first develops in the Indian Ocean and moves eastward with a speed of about 5 m s^{-1} . Surface winds converge under the convection, and a burst of eastward surface winds follows the passage of the heaviest rainfall. This burst is an important driver for ocean dynamics. Each panel is separated by ~ 15 days.

Figure 2. Vertical cross-section of MJO as it propagates from the Indian Ocean to the western and central Pacific.

MJO's Global Impact

Similar to the impacts from each phase of the El Niño Southern Oscillation, the phases of the Madden-Julian Oscillation result in predictable weather patterns

Tropical Cyclones in Eastern Pacific/Gulf of Mexico

MJO strongly modulates tropical cyclones in the eastern Pacific Ocean. During westerly MJO phases, hurricane genesis is four times more likely than during easterly periods, and also tends to occur closer to the Mexican coast. Systems that develop during westerly phases are stronger than tropical systems that develop during easterly phases.

Tropical storm formation in the Gulf of Mexico is also four times more likely during westerly MJO periods than during easterly MJO periods. So is hurricane genesis, and hurricanes that are Category 3 or above have a greater preference to occur during westerly MJO events.

Tropical Cyclones in Indian Ocean/Western Pacific

MJO is known to modulate tropical cyclone activity in the Indian Ocean and western Pacific by providing a large-scale environment favorable to tropical development.

The strongest tropical cyclones develop when MJO favors enhanced precipitation, although it is important to note MJO is just one of many factors that contribute to tropical cyclone development.

Effects on Global Weather

MJO can significantly intensify or weaken monsoon systems in Australia, India, Asia, South America and North America. MJO's westerly phase, linked with enhanced rainfall, can affect a monsoon's timing and intensity. MJO's easterly phase can end monsoon systems early, and even cause breaks in monsoon systems.

MJO is linked to extreme precipitation in the Pacific Northwest, known as 'Pineapple Express' events. These occur in boreal winter, when the easterly MJO interacts with westward North Pacific mid-latitude patterns (creating heavy flooding such as the 1996-7 winter in California and Pacific Northwest). **For 7-10 days preceding a Pineapple Express event, there are distinct weather anomalies in the Pacific Northwest and subtropical Pacific Ocean.** There is a clear relationship between MJO-related rainfall and extreme west coast precipitation events.

MJO can alter the intensity and extent of the South Atlantic Convergence Zone and the South Pacific Convergence Zone, to enhance rainfall over Southeast Brazil, or Australia and the Philippines, respectively.

MJO's Regional Impacts

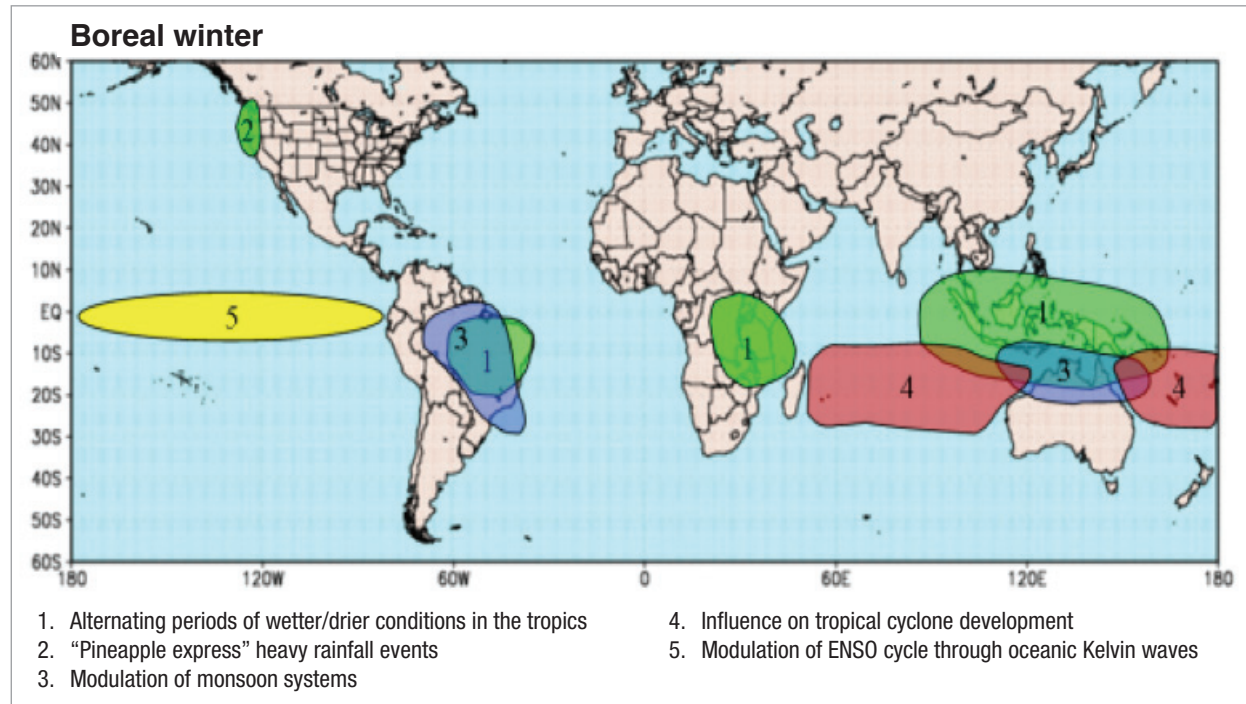


Figure 3. Typical MJO impacts seen during the boreal winter.

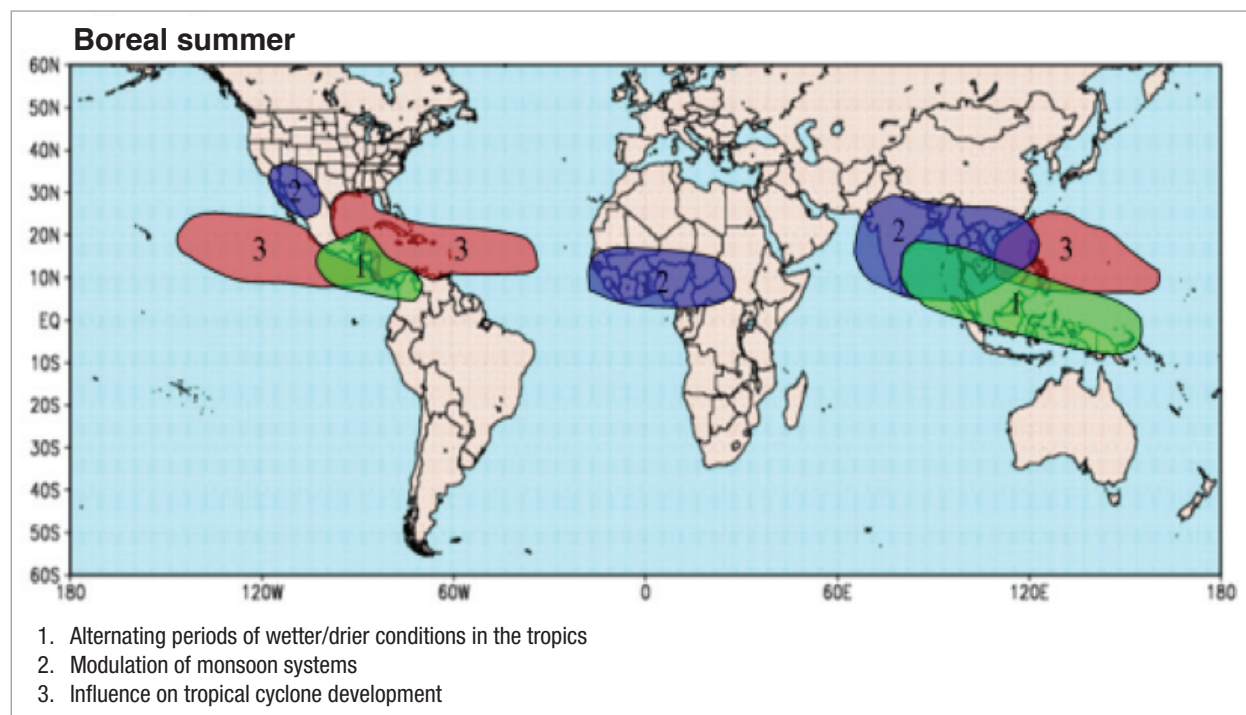


Figure 4. Typical MJO impacts associated with the boreal summer.

Monitoring & Predicting MJO

Due to MJO's impact on tropical weather, it is imperative to track and predict its development, movement and impact. **Over the past ten years, NOAA has developed mathematical models to predict MJO**, using a variety of analysis techniques and data. **NOAA's polar orbiting and geostationary satellites generate data on strong tropical convective activity and regional rainfall anomalies.** These 'departures-from-normal' are a main diagnostic tool used to monitor and predict the global schematic of MJO.

The global radiosonde network also provides useful information on moisture, temperature, atmospheric winds and pressure at multiple altitudes. Twice daily the dataset is integrated into dynamic weather prediction models to drive climate analysis and numerical weather prediction.

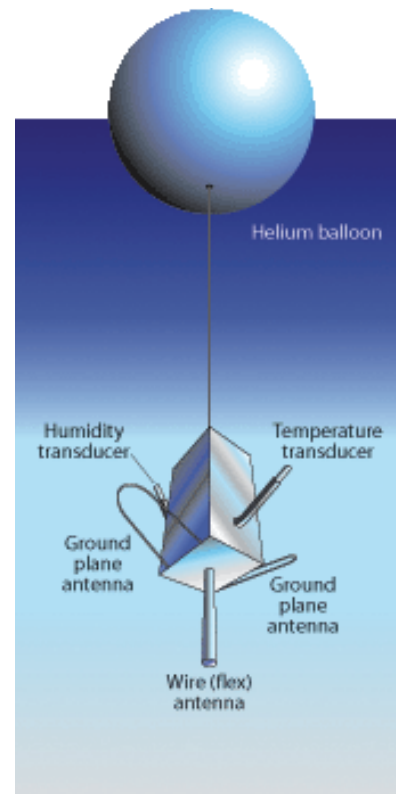


Figure 5. Radiosonde unit used to measure various atmospheric parameters.

The satellite and radiosonde data allow meteorologists to monitor and assess MJO and its evolution.

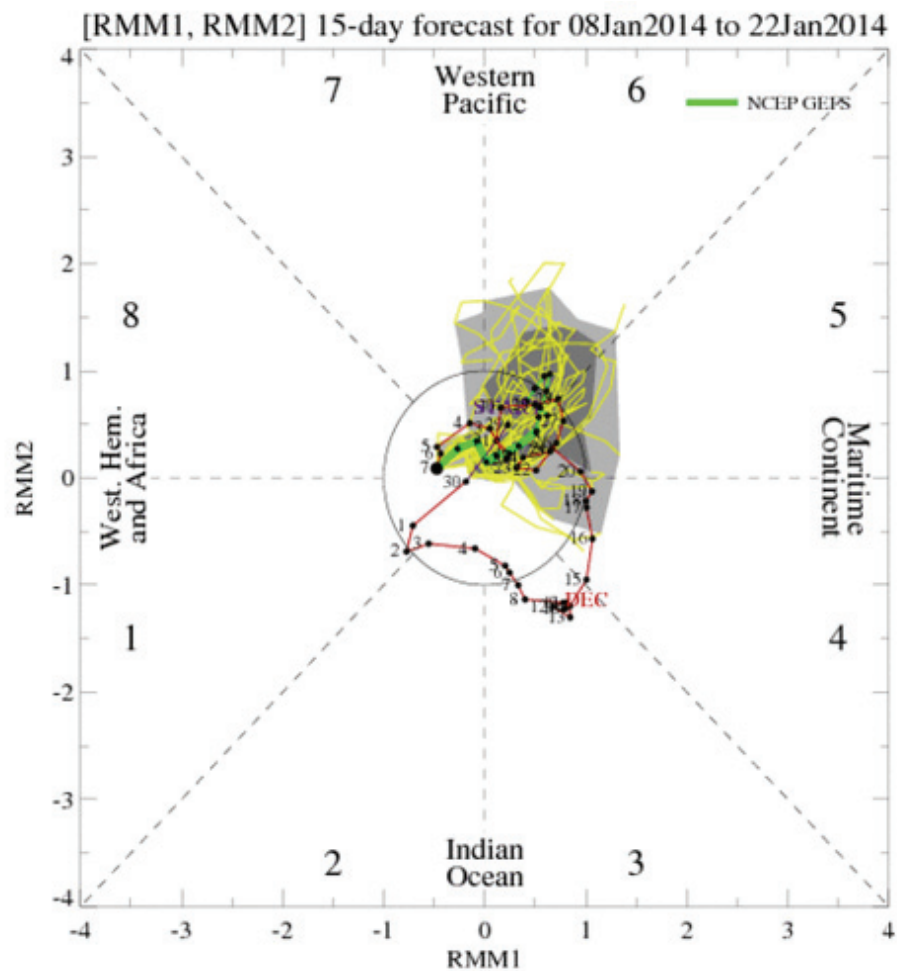


Figure 6. A recent example from the MJO Dynamic Model Forecast.

NOAA has a working group that creates MJO diagnostics. Their **Index Forecast**, as displayed in Figure 6, **gives two week predictions for MJO**.

The forecast is divided into octants. When MJO is in a particular octant it will enhance convective development in a corresponding part of the world. For example, when MJO is in phases 1, 2 and strong in phase 3, there will be enhanced rainfall across Mexico and the Caribbean and an increased chance for tropical cyclone development during the tropical season across the East Pacific, Gulf of Mexico and Caribbean. **There are corresponding forecasts for each part of the globe.**

The circle in the center of the graphic gives a sense of the intensity. **MJO becomes stronger as the forecast moves away from the center of the concentric circle.** Plotted points within the circle indicate a very weak or minimal MJO signal.

Summary of Conditions

Table 1. Summary of conditions expected from the phases of MJO.

Phase of MJO	Region	Expected Forecast
Westerly	Tropical Atlantic	Tropical storm genesis is four times more likely. Hurricanes of Cat 3 or greater have a preference to occur.
	Tropical Eastern Pacific	Hurricane genesis is four times more likely. Systems tend to track closer to Mexican coast.
	Tropical Western Pacific	Favors tropical cyclone development.
	Southeast Brazil	Most intense rainfall events occur when a strong MJO interacts with a preexisting South Atlantic Convergence Zone.
Easterly	Tropical Atlantic	Less opportunity for tropical cyclone genesis due to increased wind shear.
	Tropical Eastern Pacific	Same as in Tropical Atlantic.
	Tropical Western Pacific	There will be less convective weather due to drier atmospheric patterns.
	Pacific Northwest	Increased opportunity for Pineapple Express events to bring significant rainfall anomalies to Pacific Coast of United States.

The Future

Why is it important?

MJO's 30-60 day oscillation is the largest element of variability in weather throughout the global tropics. The diagnostics give an **indication of the position of convection and tropical storms in equatorial countries.**

What does it mean?

From its genesis in the Indian Ocean to its final dissipation over the Atlantic, MJO exhibits distinct atmospheric behavior. Through **Westerly and Easterly phases, MJO either increases or decreases the potential for extreme weather in tropical ocean basins.**

The location and phase of the lower-level and upper-level atmospheric circulation anomalies **influence weather patterns in North America, Central America, South America, Africa, Asia and Australia**, where dense populations and heavily insured values reside.

Developing a greater understanding of the science of the Madden-Julian Oscillation can therefore assist insurance underwriters in understanding regional weather patterns and their subsequent impact on insured exposures.

Glossary

Boreal - Of or relating to the Northern hemisphere.

Convection – Upward flowing air currents that create clouds. Convection is directly associated with rainfall patterns.

Easterly MJO- The ‘drier’ and ‘calmer’ phase of MJO.

El Niño - Anomalously warm phase of ENSO cycle.

El Niño Southern Oscillation (ENSO) – The 2-5 year Pacific Ocean cycle between El Niño and La Niña conditions that affects 60% of global weather.

Indian Ocean Dipole (IOD) – Also known as the Indian Nino, IOD is an irregular oscillation of sea surface temperatures in which the western Indian Ocean alternates between anomalously warm and cold phases.

La Niña- Anomalously cold phase of ENSO.

Pineapple Express- The non-technical term used to describe the meteorological phenomenon whereby heavy precipitation is dumped along the Pacific Coast, anywhere from Vancouver to Los Angeles.

Madden-Julian Oscillation (MJO) – A slow-moving atmospheric pattern that impacts global tropical and sub-tropical weather. It is an intraseasonal wave (30-60 days) that creates large-scale variability in tropical weather.

MJO Index Forecast- A dynamic forecast for MJO that incorporates global databases to create a two-week prediction.

Radiosonde- A piece of equipment used on weather balloons used to measure various atmospheric parameters.

South Atlantic Convergence Zone (SACZ) - An elongated string of clouds, precipitation and convergent winds oriented across Brazil into the Atlantic Ocean. It is a monsoon trough that helps define Brazil’s rainy season.

South Pacific Convergence Zone (SPCZ) – Similar to the SACZ, SPCZ is a band of low pressure that extends from the west Pacific into French Polynesia.

Westerly MJO- Phase of MJO that favors tropical development and extreme convective precipitation.

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Citations

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