

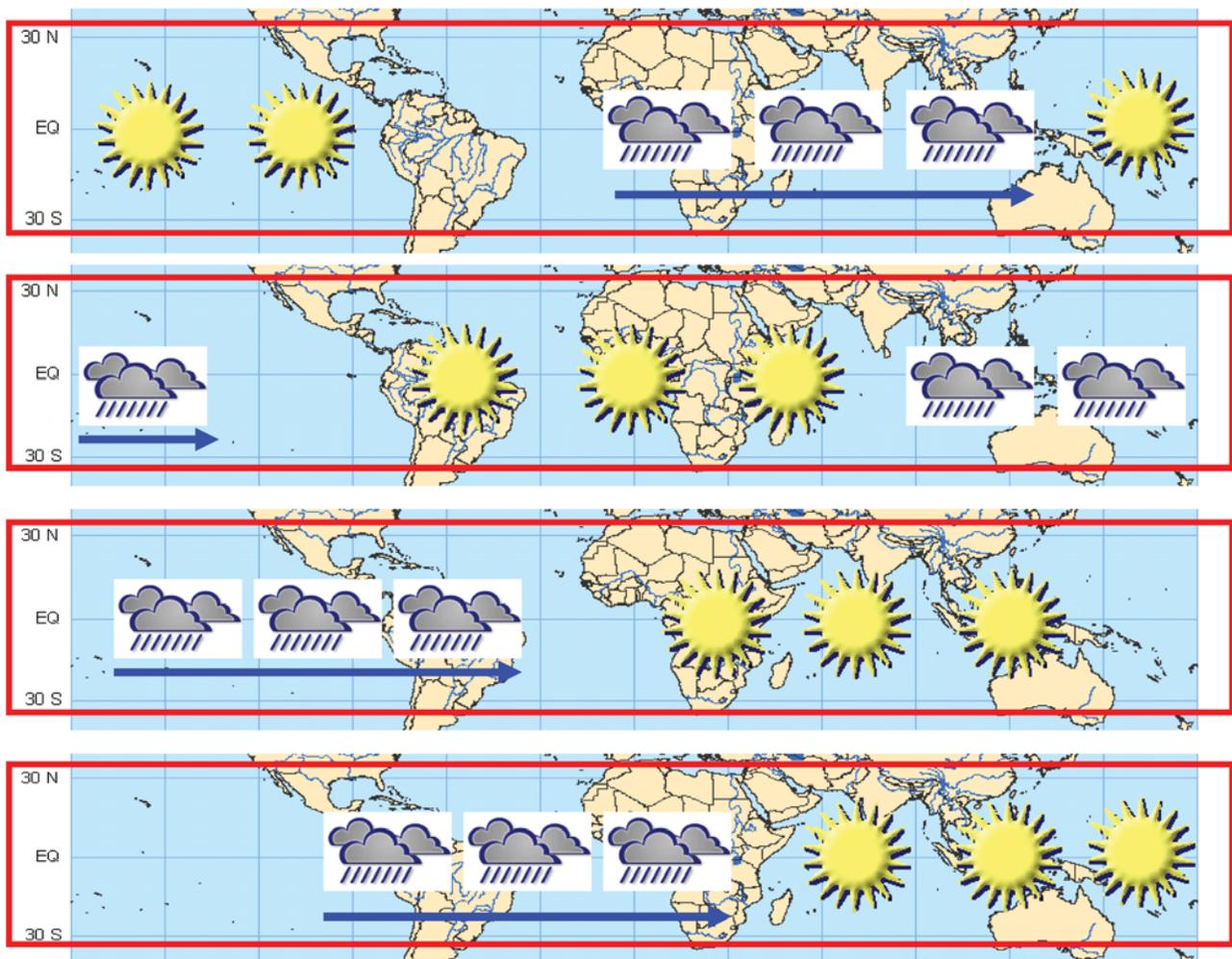
## Meet the MJO

By Jon Gottschalck, NOAA Climate Prediction Center with Andrea Ray, WWA

Recently there has been an upswing in interest among climate and weather scientists in the “Madden-Julian Oscillation” or MJO, a large-scale atmospheric disturbance that strongly alters the pattern and intensity of precipitation across the global tropics. Understanding the MJO has the potential to improve forecasts of heavy precipitation on the West Coast, the monsoon and summer rain in the Southwest, hurricanes and tropical storms, and even the onset or demise of ENSO. The phenomenon is named for Roland Madden and Paul Julian, then at the National Center for Atmospheric Research in Boulder, who first

identified it in data from the Pacific in the early 1970s<sup>1</sup>.

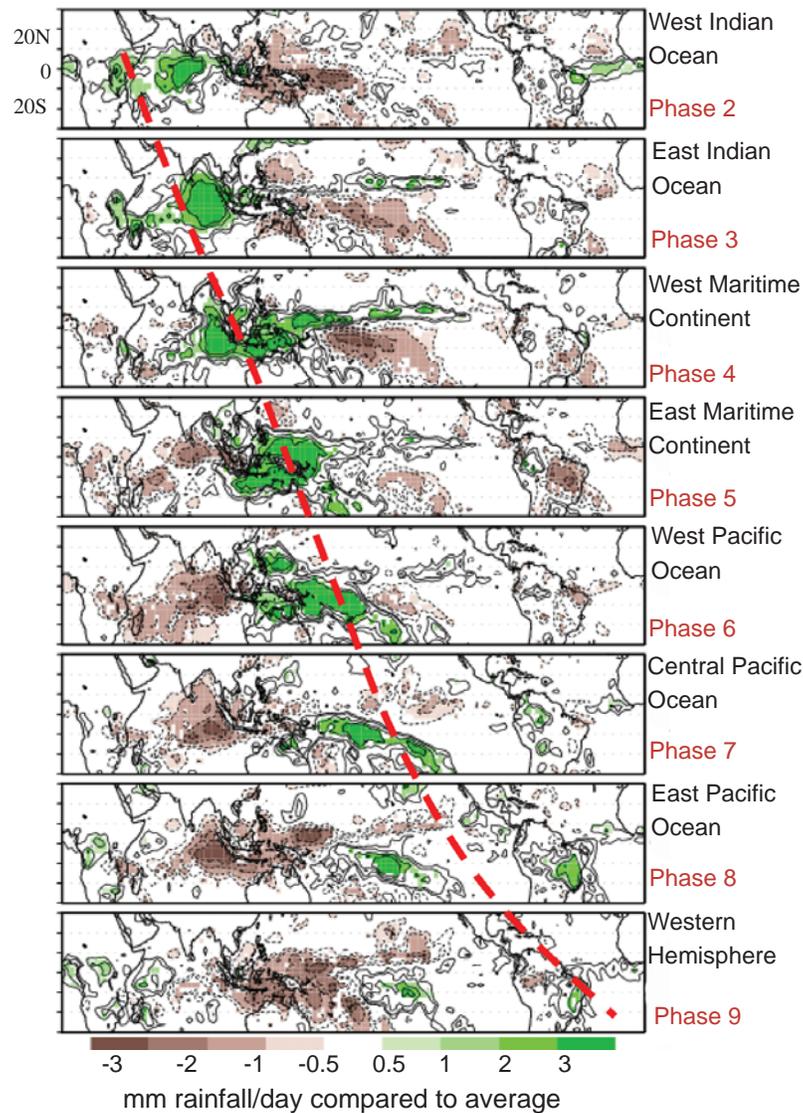
The MJO occurs over time periods of less than 90 days (e.g. the intraseasonal time scale), and it is responsible for the majority of weather variability in the tropics on that timescale. It is a naturally occurring component of our ocean-atmosphere climate system and researchers are beginning to understand its relationship to precipitation in the western U.S. and other parts of the world. This focus page introduces the MJO cycle, its effects on weather variability across the globe (particularly in the western U.S), and its relationship with ENSO.



**Figure 16a:** MJO Spatial Structure and Evolution: a schematic illustrating the large-scale nature and eastward shifting of the MJO over time. The cloud (sun) icons represent the enhanced (suppressed) phase of the MJO respectively and the blue arrows indicate the eastward movement. The period of time for the evolution shown in the figure is typically 30-60 days.

<sup>1</sup>Madden, R.A., and P.R. Julian, 1972: Description of global-scale circulation cells in the tropics with a 40-50 day period. J. Atmos. Sci., 29, 1109-1123.





**Figure 16b:** Global tropics precipitation anomaly composite: precipitation anomaly composite (mm/day) by MJO phase moving from the western Indian Ocean (top row) to Africa (bottom row) based on MJO events in the historical record from 1979-2007 (note that the MJO typically starts with phase 2). The green (brown) areas indicate above (below) average rainfall and the red dashed line shows the eastward propagation.

**Characteristics of the MJO**

The MJO is characterized by its spatial patterns of enhanced and suppressed rainfall in the tropics, or areas where there is more rainfall than average for that time of year, alternating with areas of less than average rainfall. The “tropics” refers to band of latitude between 30° N and 30° S where precipitation is predominantly convective in nature (i.e., thunderstorms) and winds are predominantly easterly (from the east). These tropical rainfall patterns progress or propagate eastward over time and are highly variable over the year. The MJO is unusual in that it organizes across the whole tropical region, resulting in conditions favorable for enhanced rainfall in half of the tropics, and conditions favorable for suppressed rainfall in the other half. Moreover, as the MJO propagates eastward, any particular area in the tropics experiences alternating periods of enhanced and suppressed rainfall during the lifecycle of an MJO event (Figure 16a).

Interestingly, this eastward movement of the MJO pattern is in the opposite direction of the prevailing easterly tropical wind flow. Anomalous rainfall becomes evident initially over the western Indian Ocean, moves eastward into the equatorial Pacific Ocean, and then into the western hemisphere where the anomalous rainfall pattern becomes less apparent (Figure 16b)<sup>2</sup>.

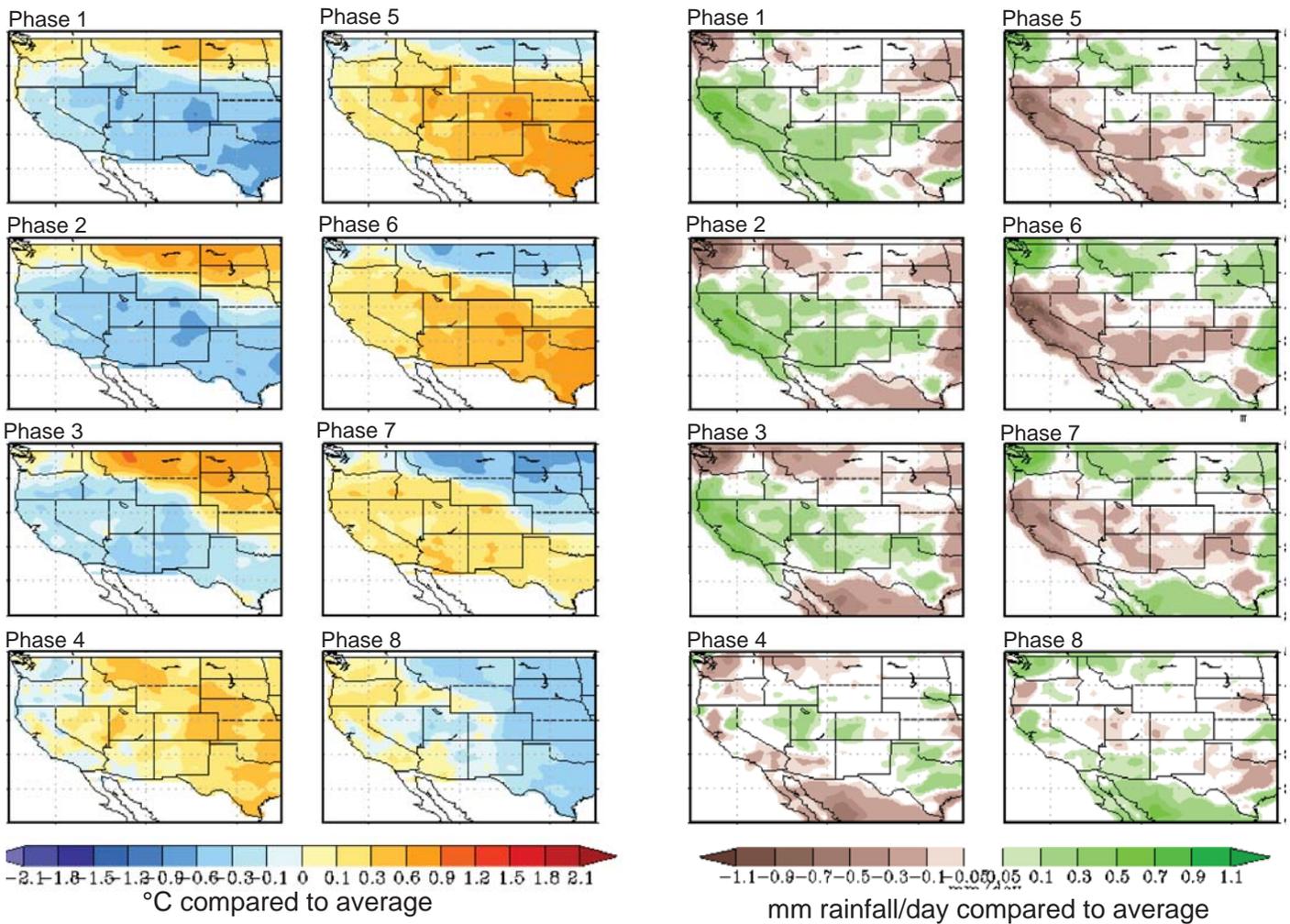
The typical length of the MJO cycle usually lasts between 30-60 days, and the degree of MJO activity is often quite variable. Periods of moderate-to-strong activity are often followed by periods of little or no activity. Typically, MJO activity is greatest during the northern Hemisphere late fall, winter, and early spring and on average there are three active MJO periods each year.

**Tropical Impacts**

The MJO impacts two other important tropical features – tropical cyclone and monsoon activity across the globe. The enhanced rainfall phase of the MJO results in more frequent tropical cyclone activity, and the suppressed rainfall phase of the MJO generally results in reduced tropical cyclone activity in these areas. The enhanced rainfall phase of the MJO can also initiate the onset of monsoon seasons around the globe; monsoons often result in brief periods (1-2 weeks) of intense rainfall. The suppressed rainfall phase can delay monsoon onset, result in a break in activity, or end a monsoon season prematurely.

<sup>2</sup>Recall that the hemispheres are defined from an arbitrary 0° longitude in Greenwich, England; the “western” hemisphere extends to the “dateline” which is both 180°E and 180°W in the mid-Pacific. Although it may be spatially counterintuitive at first, the western Pacific is in the eastern hemisphere and one can move east towards the eastern Pacific in the western hemisphere!





**Figure 16c:** U.S. temperature and precipitation anomaly composites: temperature (left; °C) and precipitation (right; mm/day) anomaly composites for the western US by MJO phase for MJO events during the November through March portion of the year. The phase numbers refer to those shown in Figure 2.

**Impacts on mid-latitudes**

The MJO also effects weather and climate outside the tropics, in particularly in the mid-latitudes between 40° and 70° in both hemispheres where the prevailing winds are westerly (from the west) and the atmospheric flow pattern is highly variable with alternating low and high pressure systems. The impacts occur in both hemispheres, but especially across the northern hemisphere Pacific and North America, and may include heavy precipitation or cold outbreaks over time periods of 1-2 weeks

The MJO impacts the western U.S. through “teleconnections,” a term that refers to climate anomalies having a relationship between each other at large distances (typically thousands of kilometers). For example, rainfall in the Indian Ocean associated with the MJO is often related to cooler and wetter weather in the western U.S. The impacts of ENSO on U.S. temperature and precipitation are also considered teleconnections. The time of the year when MJO related impacts are the greatest in

the northern hemisphere is during the months from November through March. When the enhanced rainfall phase of the MJO is in the eastern hemisphere and over the Indian Ocean, there is a teleconnection with the mid-latitudes that favors more frequent periods of wetter and cooler conditions for California, the Southwestern U.S and parts of the interior west (Figure 16c, phases 1-3). As the MJO and associated enhanced rainfall shifts eastward across Indonesia and into the western Pacific Ocean, it is more likely that these areas of the U.S. will experience drier and warmer than average conditions (phases 5-7).

Another important mid-latitude response of the eastward shift enhanced rainfall is the extension of the East Asian-Pacific jet stream further out into the Pacific Ocean (Figure 16d). A consequence of this Pacific jet stream extension is often extreme precipitation events along the US west coast, sometimes called a “pineapple express.” The jet extension occurs as the enhanced rainfall shifts into the western Pacific, but the impacts on the



U.S. typically don't occur until up to 7-10 days later.

The MJO also influences summer precipitation in California and the U.S. southwest. It influences tropical cyclone activity in the eastern Pacific Ocean, which may result in anomalous tropical moisture and heavy precipitation in parts of southern California, Arizona, and New Mexico. During strong MJO activity, the MJO phase may also influence the North American monsoon resulting in above or below average monsoon precipitation.

### Relationship with ENSO

The strength of the MJO varies year-to-year and some of this variability is linked to ENSO. Overall, the MJO tends to be most active during neutral and weak ENSO years. MJO activity is often absent during strong El Niño events while the level of MJO activity is highly variable during strong La Niña periods. The very active MJO during late 2007 and early 2008 occurred during strong La Niña conditions, activity that was unusual but not unprecedented.

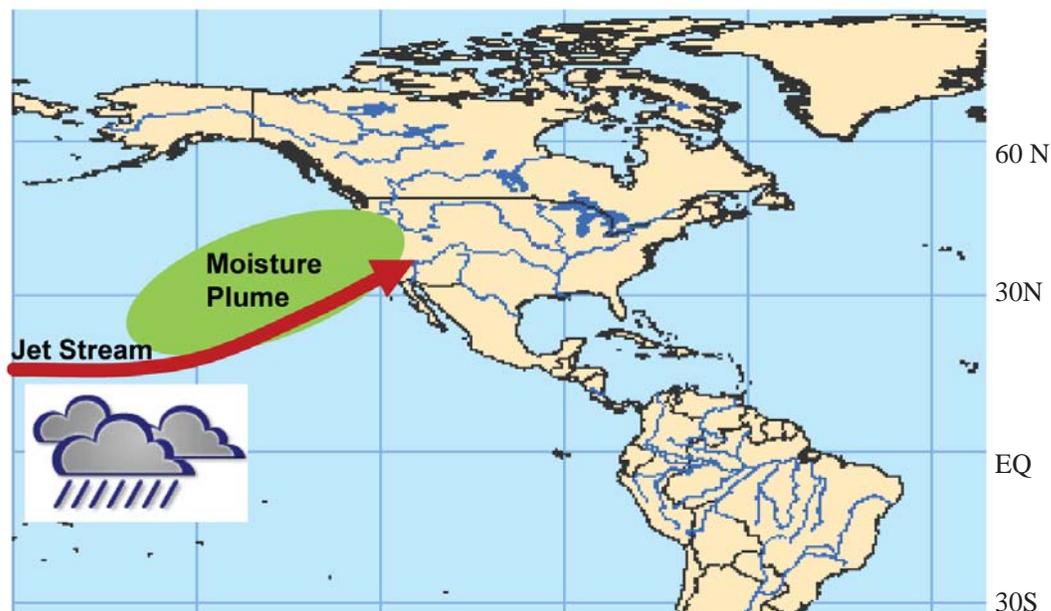
There is also evidence that the MJO influences the ENSO cycle. It does not cause El Niño or La Niña, but can contribute to the speed of development and intensity of El Niño and La Niña episodes by significantly altering the low-level wind field that in turn, can result in variations in the ocean sub-surface conditions and later sea surface temperature.

### The influence of the MJO during the winter of 2007-2008

The MJO was very active beginning in mid-November 2007 and lasting through mid-February 2008. During this period, the MJO exhibited two complete cycles through the global tropics and resulted in some important weather impacts across the western US. These impacts were linked to changes in the mid-latitude circulation set in motion by the strong MJO activity during the period. For example, there were several bouts of heavy rainfall and associated flooding in the areas of the southwest US during November and December. This rainfall was quite noteworthy because very dry conditions are typical across this region during La Niña conditions. A second example is the extratropical storminess further north along the west coast during the winter. An intense cyclone slammed into the central California coast on January 3-4, 2008 resulting in heavy rainfall and flooding with heavy snowfall in the higher elevations.

In conclusion, the MJO is a natural phenomenon that causes alternating periods of enhanced and suppressed precipitation across the global. Climate scientists and forecasters are beginning to gain a better understanding of MJO, its predictability, and its influence on weather in other parts of the world. Strong MJO activity during the past winter is believed to have modulated the La Niña resulting in atypical La Niña impacts in in the western U.S.

**Figure 16d:** East-Asian Pacific jet extension: a schematic illustrating the extension of the East-Asian-Pacific jet stream (red line) when enhanced tropical rainfall associated with the MJO crosses the western Pacific Ocean. Often these events can lead to a surge of tropical moisture (green area) from the tropics to the western US.



### On the Web

Please contact the author with any questions: [Jon.Gottschalck@noaa.gov](mailto:Jon.Gottschalck@noaa.gov).

- MJO page from NOAA Climate Prediction Center, click on Educational Material: <http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml>
- MJO Primer from NOAA Earth System Research Laboratory: <http://www.cdc.noaa.gov/MJO/MJOprimer/>
- MJO Animation from the University of East Anglia – United Kingdom: <http://envam1.env.uea.ac.uk/mjo.html>

