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THE MADDEN JULIAN OSCILLATION: ITS POTENTIAL FOR WEEK TWO FLOOD OUTLOOKS AND RESERVOIR MANAGEMENT DECISIONS IN CALIFORNIA

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1. INTRODUCTION*

It has been noted (Mo and Higgins, 1998) that tropical influences can have a profound impact on California precipitation. Specifically, hydrologically significant events can occur along the West Coast during the cool season when the negative or convective phase of the intratropical seasonal oscillations (Madden Julian Oscillation or MJO) occur near 120E and eastward. It has been observed that during ENSO neutral years there is a higher frequency of occurrence of the MJO. During this past cool season, a well-defined 30 to 60 day cycle of the MJO began in December, 2003 and has continued up until November, 2004. This paper will highlight what might be an opportunity to provide up to two weeks lead-time to water managers and reservoir operators to potential flooding. However, it will be necessary to improve the confidence of these outlooks before reservoir operators can utilize them to make critical decisions, (e.g., water releases in anticipation of capturing the floodwaters, versus the risk of not refilling the reservoirs if the event fails to materialize).

2. MJO IDENTIFICATION

As stated, during this past cool season, the occurrence of the negative phase of the MJO was closely monitored using NOAA's Climate Prediction Center's (CPC) MJO index page.

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/mjo_index.html

These five-day running mean charts shown on what is called a Hovmoller diagram, allows the forecaster to track the eastward progression of the 200 hPa velocity potential moving out from the Indian Ocean. Figure 1 shows the diagram from May of 2004. This diagram however does not indicate the actual intensity of the convective response to the MJO as this relates to other features such as SSTs. The Climate Diagnostic Center has developed a 3-day filtered running mean of the OLR (Outgoing Longwave Radiation) anomalies which, via the number of contours, indicates the strength of the anomaly and better depicts the convective response to the MJO as it moves eastward, Figure 2. The convective phase of the MJO are shaded in warmer colors. Note that the CDC index quite often shows the convection dissipating near the dateline. This is indicative of the convective response dying off east of the dateline.

The occurrence of the negative (convective) phase of the MJO is not

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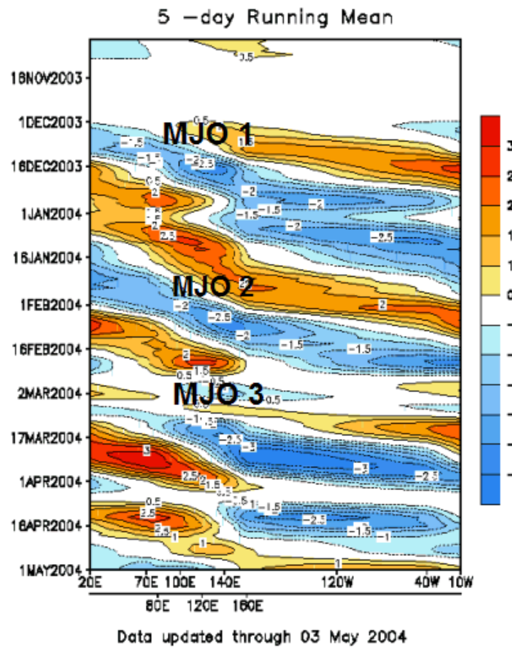

Figure 1 5-day running mean of the MJO Index from CPC. Blue shading denotes negative (enhanced convection) of the MJO cycle. The three cycles during the cool season are noted. The date is along the Y-axis and the longitude is along the X-axis.

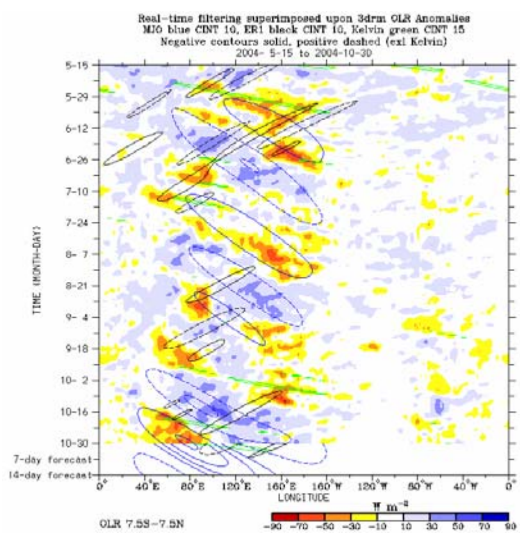

Figure 2 CDC 3-Day running OLR filtered anomaly with a 7 to 14 day forecast. The contours suggest the strength of the anomaly. The green, black and brown lines indicate convectively coupled equatorial waves. see http://www.cdc.noaa.gov/map/clim/olr_modes/hovEa.html for further discussions.

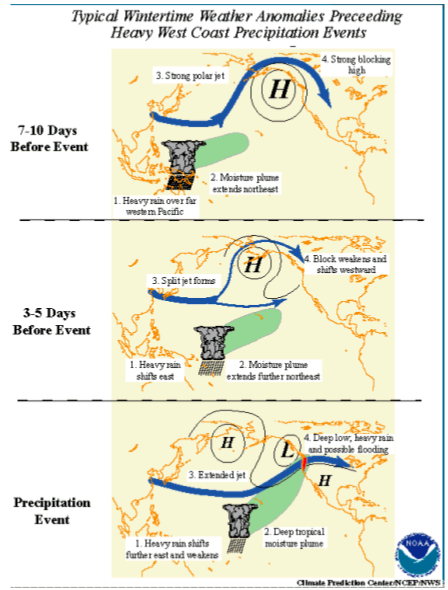

Figure 3 conceptual patterns of large scale flow field and a scenario that would allow the MJO to enhance rainfall to potentially extreme amounts along the West Coast. Taken from CPC MJO Tutorial.

sufficient by itself to cause flooding along the West Coast. As CPC has noted, there appears to be a favored large-scale synoptic pattern, Pacific North American or PNA, that, when in the positive phase, Figure 4, provides a favored flow pattern for the MJO to increase the mid-latitude westerly flow or jet stream into the West Coast. This is shown conceptually in Figure 3 from CPC's web site.

3.0 APPLICATION OF THE MJO TO WEEK TWO FORECASTS

For this past cool season, the MJO index was monitored closely along with the

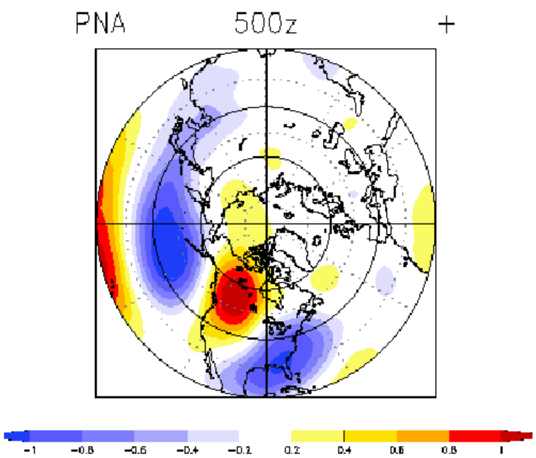

Figure 4 Positive Phase of the PNA pattern as depicted at 500 mb. Red areas denote positive height anomalies and blue areas denote negative height anomalies.

output from the Global Forecast Model or GFS and its ensembles. Since the GFS and its ensembles are now run out to 15 days it is possible to analyze the model output with respect to the pattern identified in Figure 3 to determine whether, when the MJO negative phase approaches 120E longitude, there could be potential heavy rain 7 to 14 days later in California. Note in Figure 3 that the below normal height anomalies in the northern Pacific and the above normal height anomalies in the tropical and sub-tropical Pacific infer a strong zonal jet stream over the central Pacific. It is the enhancement of this jet by the tropical convection associated with the MJO out near the dateline that allows the jet to undercut the ridge over western North America, and hence slam the jet into California with enhanced moisture content through entrainment of the tropical to sub-tropical moisture.

For this past cool season, December 03 to March 04, it was possible, by analyzing the charts noted above, to begin an open discussion among the West Coast forecasters some ten days ahead that a major pattern change was possible and could lead to flooding. The 120E longitude line was used as a threshold to begin these discussions. Since the MJO moves on average of about 7 degrees longitude per day a rather specific date could be given as to the pattern change. Additionally, the numerical models do not usually handle the breakdown of the large West Coast ridge patterns very well. One reason for this is the models do poorly in simulating the MJO and its impacts. Thus in situations when the models are continuing what would be a dry pattern in 7 to 10 days, the forecaster, by recognizing the pattern, can have more confidence that the models could be in error at this time frame and can add significant value to the forecast process by forecasting a breakdown of the ridge and a turn to potentially much wetter conditions.

Twice during the past cool season this scenario was followed. The first event came in December of 2003. The second event occurred in February of 2004. Referring back to Figure 1, this would be what was called MJO #1 and MJO #2. Figure 5 shows a hydrograph for the Napa River at St Helena for a period running from 1 December, 2003 through 19 February, 2004. The red line denotes the flood stage for the Napa River. Annotated on the chart are the dates when the negative phase of the MJO was noted at 120E longitude.

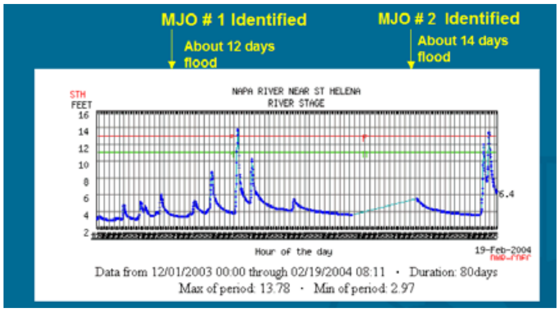

Figure 5 Hydrograph for the Napa River at St Helena in the north San Francisco Bay Area showing two periods of flooding believed to be correlated with the MJO's identified some 12 to 14 days earlier.

Figure 6 shows the 500 mb height field for 10 February, 2004. This is indicative of a positive PNA pattern. This pattern as referenced earlier is more conducive to the impacts of the MJO on precipitation in California.

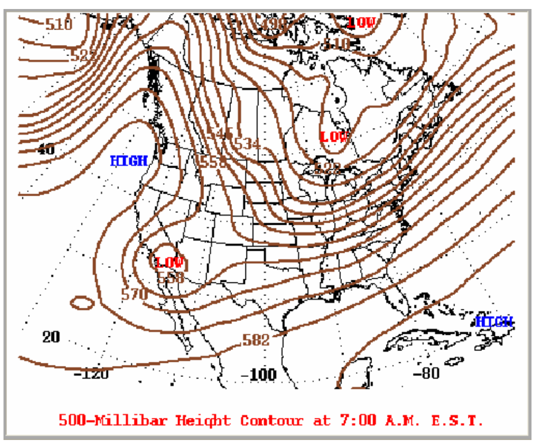

Figure 6 500 mb height field for 10 February, 2004. This pattern is indicative of a positive PNA pattern.

Figure 7 shows the hydrograph for the Russian river at Guerneville. This is the largest river in the San Francisco hydrologic service area. Note that for the February MJO, flood stage was attained on the 17th.

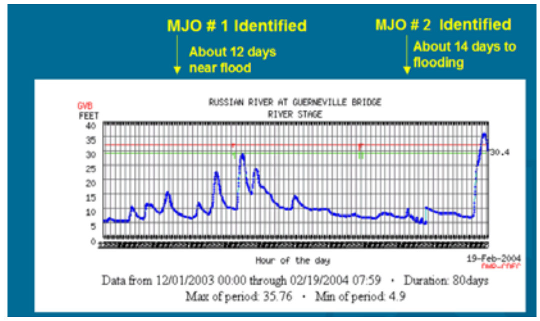

Figure 7 Hydrograph for the Russian river at Guerneville for the period December 1 through February 19, 2004. The red line indicates flood stage.

Figure 8 shows an image of the total precipitable water from the SSMI instrument on the NOAA polar orbiter satellite. It shows a narrow plume of high PWs extending back to the tropical pacific near Hawaii. It has been noted in the past that very heavy rains in California have what has been coined a "pineapple connection" (relating to the extension of clouds back to near the Hawaiian Islands).

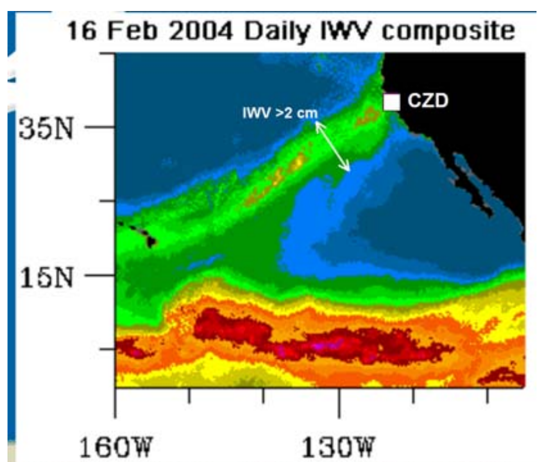

Figure 8 SSMI total precipitable water image for 16 February, 2004. The location called CZD is located in the Russian river watershed. IWV here stands for Integrated Water Vapor.

The December and February cases stand out as excellent cases where identifying the MJO out near 120E, and identifying that the synoptic regime might be more conducive to the influence of the MJO may provide a week two heads up to water managers.

As you can see from Figure 1 there was a third MJO in March. However there was no impact on California rainfall from this MJO. One possible reason for this is that the large-scale flow regime was not representative of the positive PNA pattern. Figure 9 is the 500 mb chart for March 12, 2004. It indicates that the westerlies have receded north in Canada and that there is no full latitude West Coast ridge representative of the positive PNA pattern.

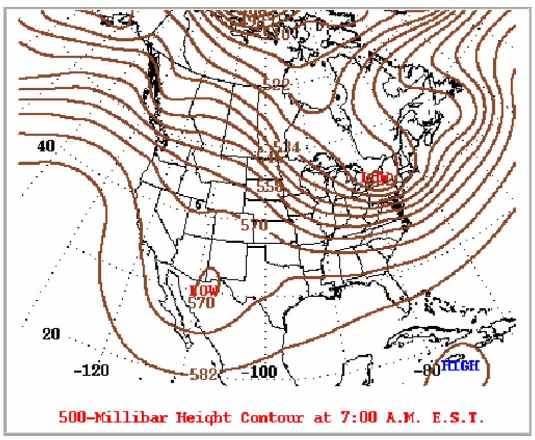

Figure 9 500 mb chart for March 12, 2004. This pattern is not representative of the positive phase of the PNA pattern.

4.0 **SUMMARY**

NOAA's Climate Prediction Center has outlined a set of circumstances whereby the negative phase of the MJO can interact with the mid- latitude westerlies to produce heavy to extreme rainfall in Central and Northern California. The more extreme of these events have been coined the "pineapple connection" in reference to a tap to the deep tropical moisture near and south of Hawaii. As part of the National Weather Service's new Climate Services Program (NWS, 2003), this study is an attempt to develop a climate-weather connection that can be used in a weather forecast office to provide up to two weeks notice of a potential significant hydrologic event. One can think of this as similar to the identification of a strong EL Nino such as those of 1982-83 and 1997-98 that had profound influences on California's precipitation. The MJO however provides a more specific time frame then do the seasonal El Nino forecasts such that if confidence is sufficient, water managers may be able to utilize this information to more efficiently manage reservoir operations to both benefit flood control, hydro power generation, and water supply needs. However it is anticipated that a much better understanding of the interactions of the MJO with the mid-latitudes is needed before confidence can be raised to a level that reservoirs can be more efficiently managed. The hope in this paper is to stimulate further studies by the research and climate communities that may help the operational forecaster have more confidence in issuing week two flood outlooks that in turn can be used by water managers to take action.

During this coming cool season, the CPC and CDC MJO indices will continue to be monitored. In addition one can monitor the forecast of the PNA pattern using the CPC web site that displays various time ranges of the PNA pattern out to day 14. http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/new.pna_index_ensm.html

Figure 10 is an example of using the GFS ensembles to denote the pattern currently existing and expected to develop.

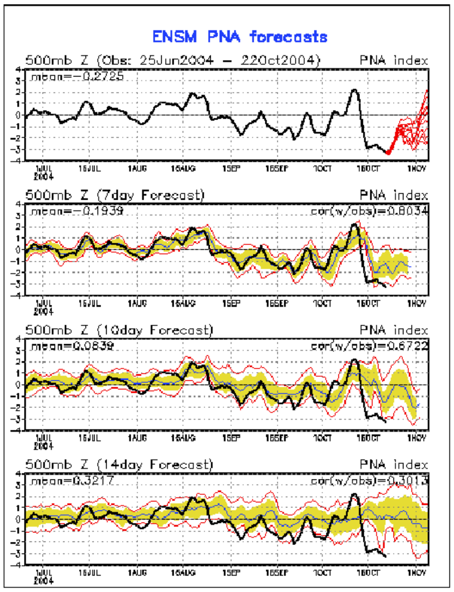

Figure 10 Ensemble observed and forecast phase of the Pacific North American pattern as per Figure 3.

A forecaster should look for a positive PNA pattern near the time the MJO is near 120E with a forecast to shift to a negative phase of the PNA indicating the models agree with a breakdown in the ridge and the westerlies pushing into California. In summary it can be said that not all floods in California occur with an MJO and not all MJO's induce flooding. There are certainly seasonal variations of the impacts of MJO on mid-latitude circulations as noted by Bond and Vecchi (2003).

Figure 11 shows a comparison of the CDC Multivariate ENSO Index (MEI) of Wolter and Timlin (1998) (positive El Nino, negative La Nina), and MJO activity using the MJO multivariate index following Wheeler and Hendon, (2004) for the past 30 years. As noted earlier one can see that the MJO is most active when ENSO is near neutral.

Several other noteworthy features are that the last two major statewide floods in California, February 1986 and January 1997 both occurred during active periods of the MJO. Secondly the two strongest El Nino events, 1982-83 and 1997-98, were both preceded by active MJO years. McPhaden (2004) suggests that frequent westerly wind reversals in the tropics brought about by the MJO can accelerate or initiate El Nino.

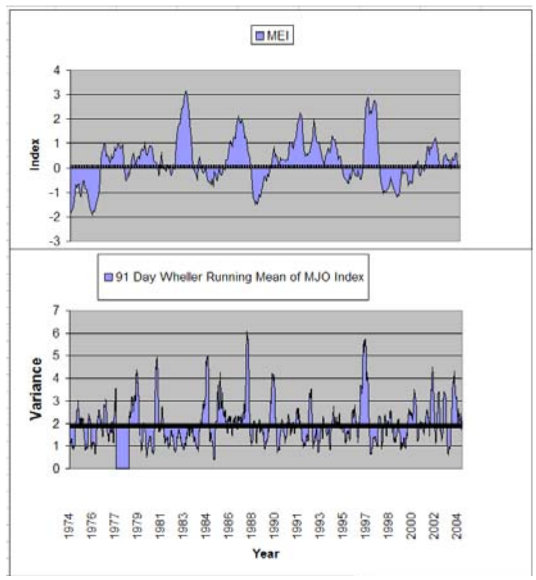

Figure 11 Plot of MJO activity (Wheeler and Hendon, 2004) per year with the regions above 2 indicating active MJO years.

5.0 **REFERENCES**

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