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Atmospheric Rivers & The Madden-Julian Oscillation: Key Phenomena for Predicting Western Water Availability and Extremes

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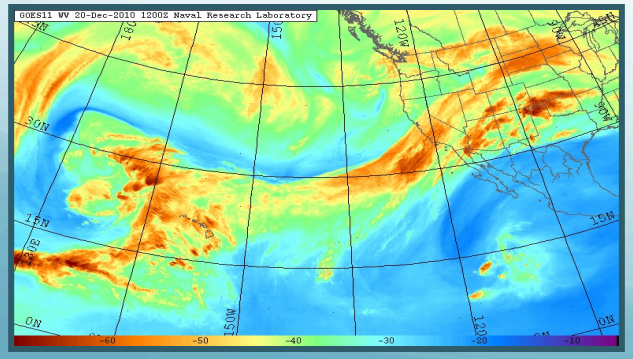
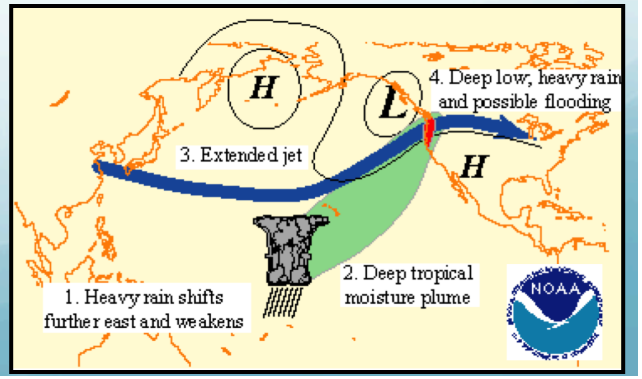


Presentation for
Western States Water Council
Remote Sensing Applications Workshop
August 25-27, 2014



WSWC Policy Resolutions Addressed With These Activities

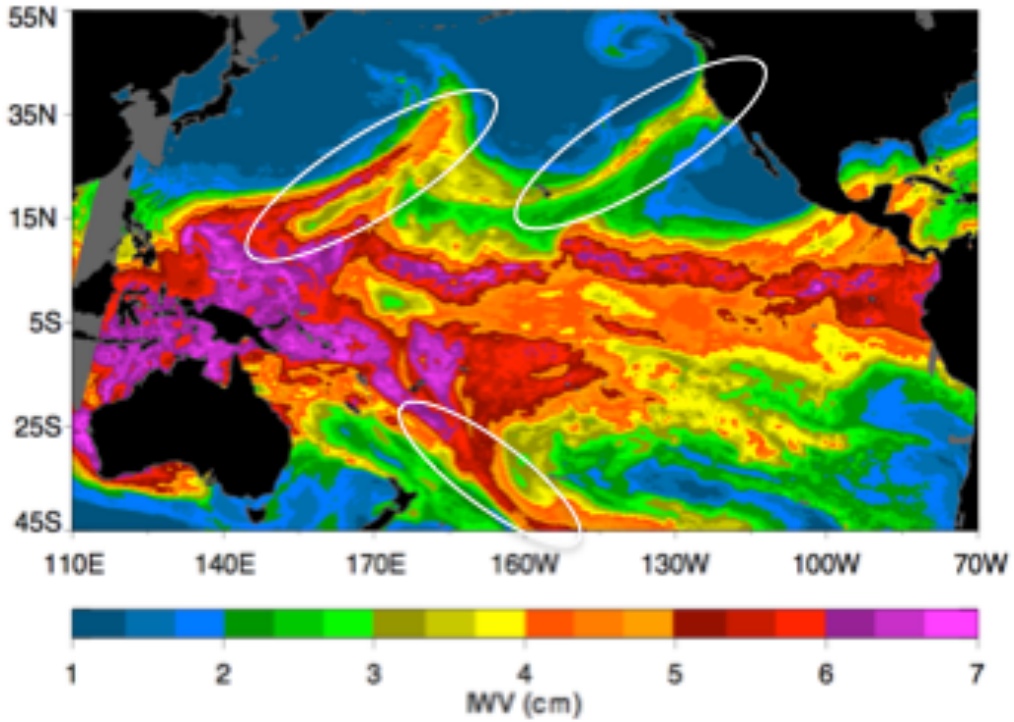
Among others….**Resolution 366 –** July 18, 2014, e.g.

BE IT FURTHER RESOLVED, that the federal government should place a priority on improving subseasonal and seasonal precipitation forecasting capability that would support water management decisions.

BE IT FURTHER RESOLVED, that the Western States Water Council supports development of an improved observing system for Western extreme precipitation events such as atmospheric river storms,…

- The ground-based "Western Observing Systems Vision" (Ralph et al. 2014) led by CW3E.
- In the June 2014 WSWC-sponsored meeting on observing systems, it was recommended the *Vision be extended to include* ***future satellite capabilities***

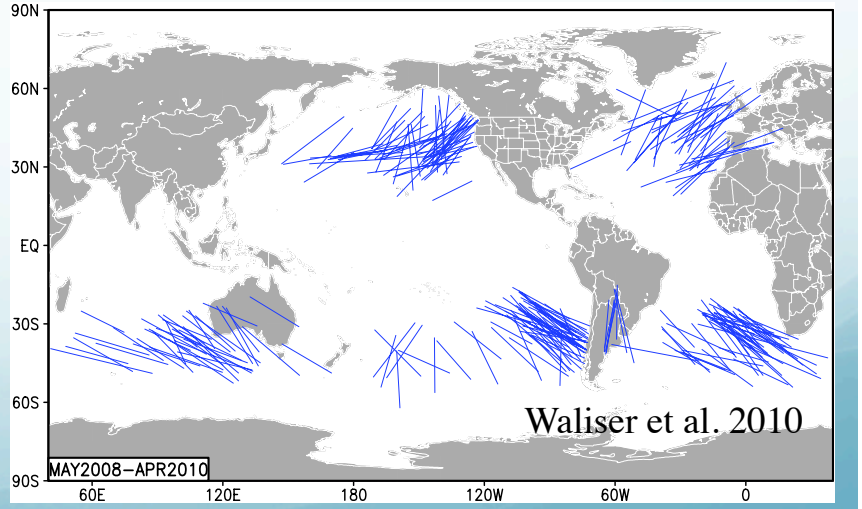
Rivers in the Sky: Key Characteristics of "Atmospheric Rivers"



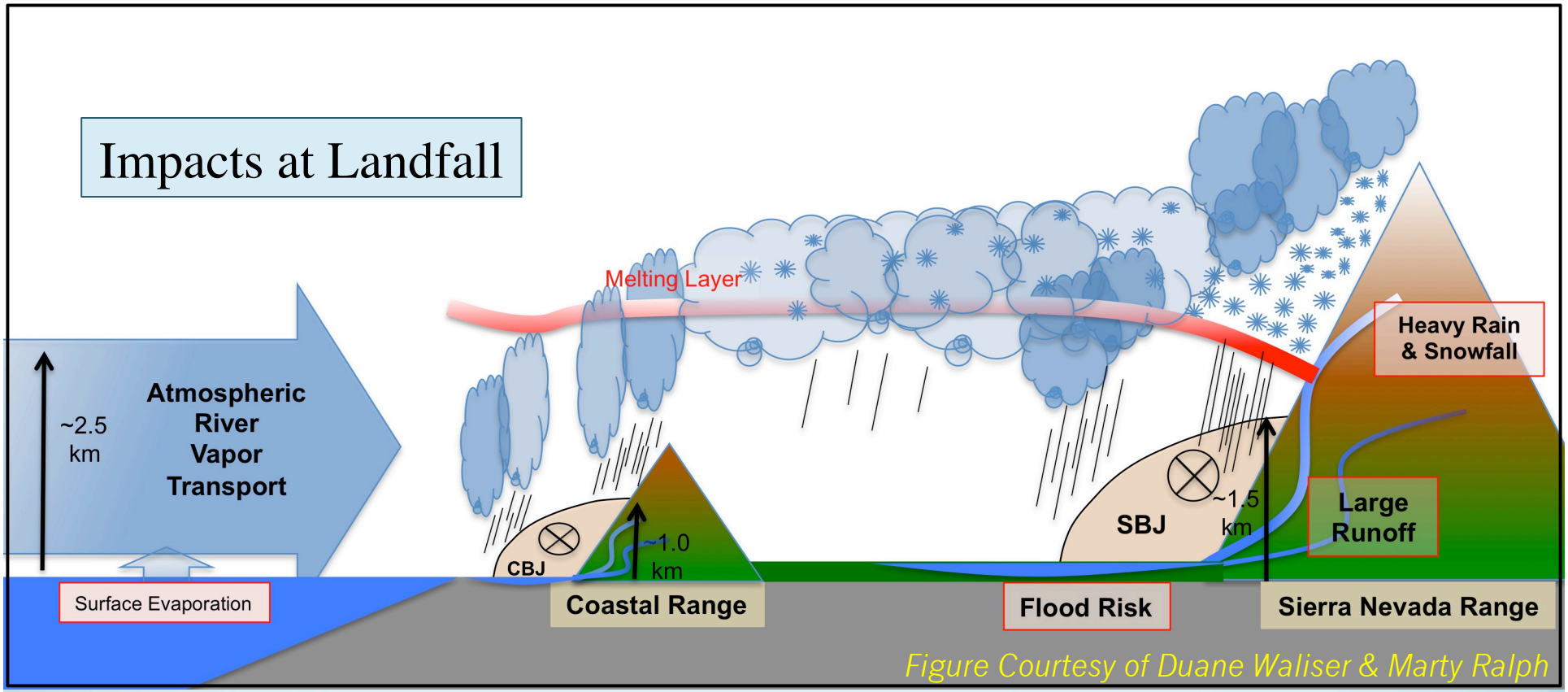
Satellite Measurements of (Total Column) Water Vapor Highlight Streams of Moisture that Transport Water Vapor Poleward & Westward: "Atmospheric Rivers (ARs)"

Occur Globally
Impact West Coasts of Continents
Role in Weather, Water & Hazards

ARs transport as much as 5-10 times the flow of the Mississippi River



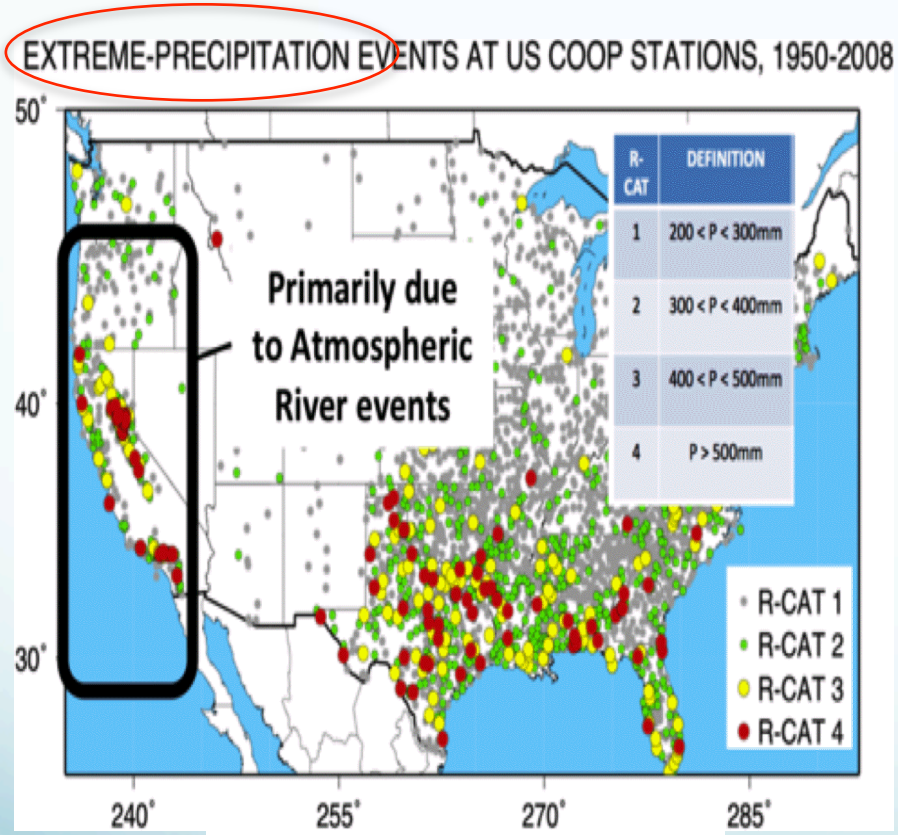
When Atmospheric Rivers Make Landfall Extreme Precipitation Occurs Near Mountains



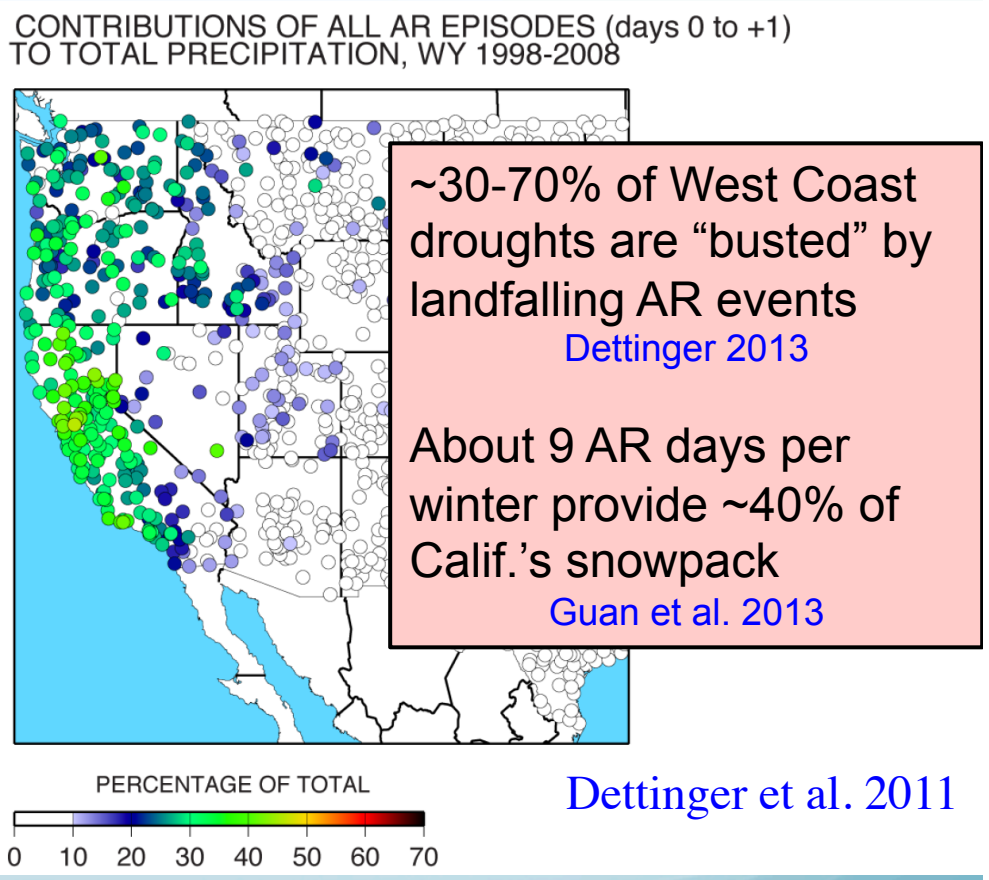
Most flooding / peak streamflow in U.S. coastal states is associated with ARs (e.g. Ralph et al. 2006; Neimen et al. 2011)

Atmospheric Rivers are to the far West What Hurricane Hazards are to the Southeast

Atmospheric Rivers account for 30-40% of the freshwater supply in the far West



Ralph & Dettinger, 2012



~30-70% of West Coast droughts are "busted" by landfalling AR events
Dettinger 2013

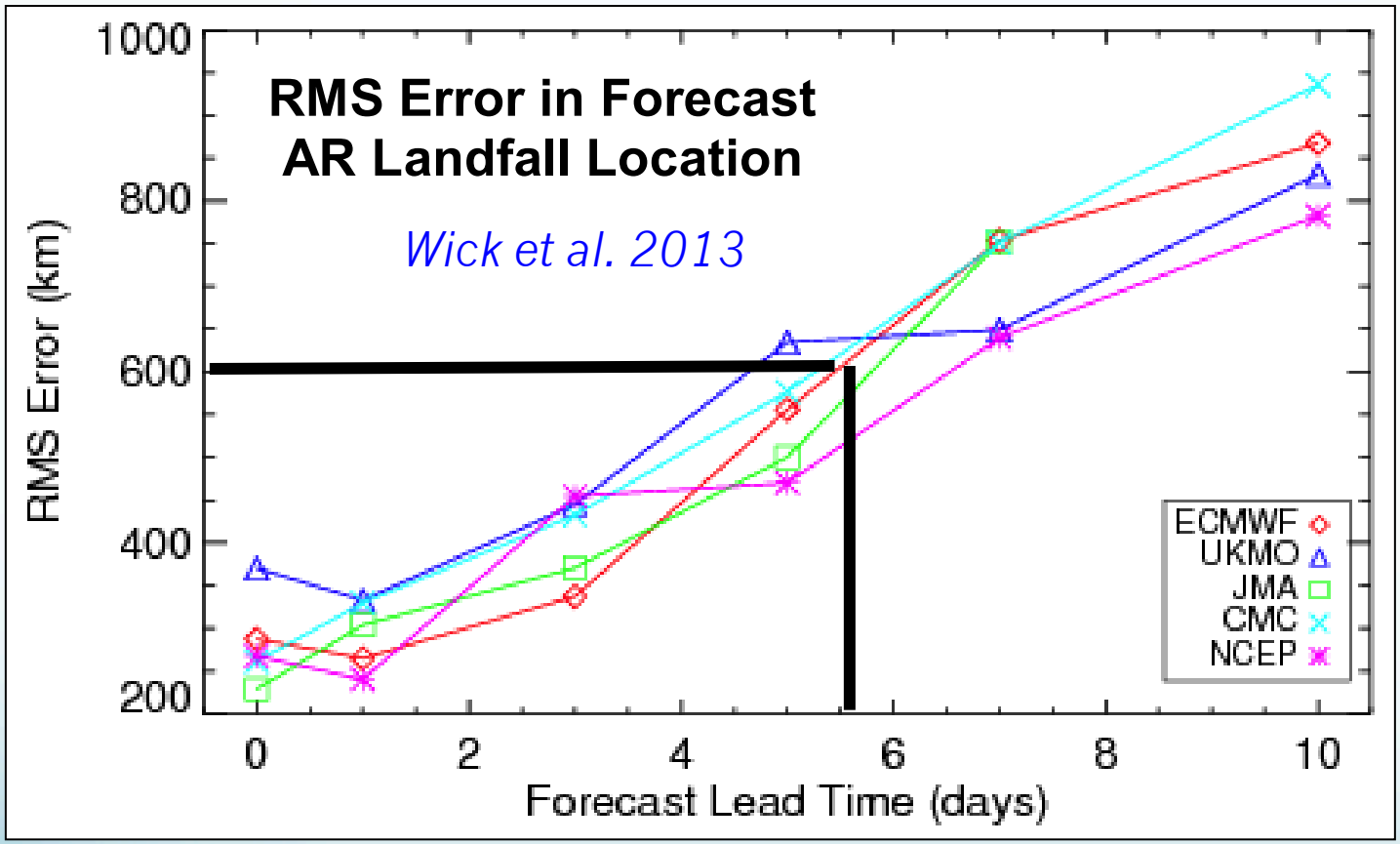
About 9 AR days per winter provide ~40% of Calif.'s snowpack
Guan et al. 2013

Dettinger et al. 2011

Most flooding / peak streamflow in U.S. coastal states is associated with ARs (e.g. Ralph et al. 2006; Neimen et al. 2011)

AR forecasts are Critical for Water and Hazard Support

e.g. Should a reservoir manager release water or not?



For example: at 5-6 day lead time, global weather forecasts cannot determine if AR will hit L.A. or San Francisco

Timing, Location & Intensity of AR Landfall Forecasts are Targets for Improvement

The Unusually Snowy Winter of 2010/2011

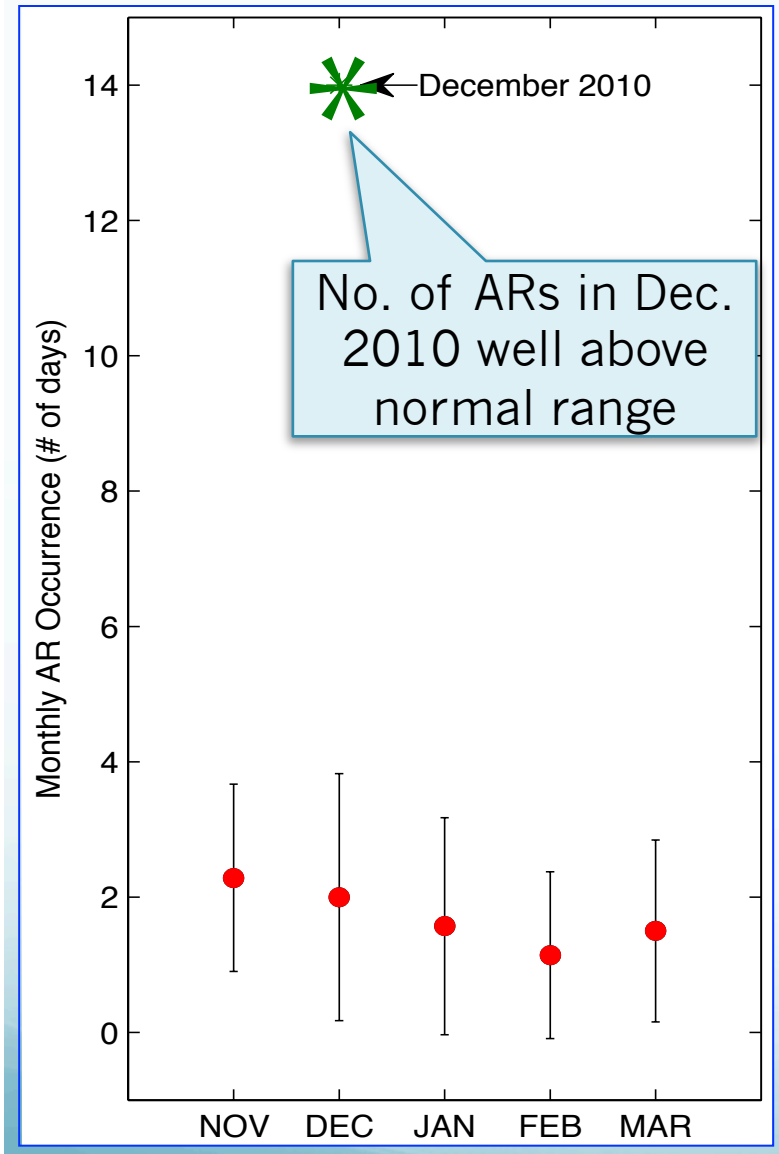


Figure Courtesy
B.Guan UCLA/JPL

Typical Year in CA

9 AR days occur over entire winter and contribute ~40% total snow

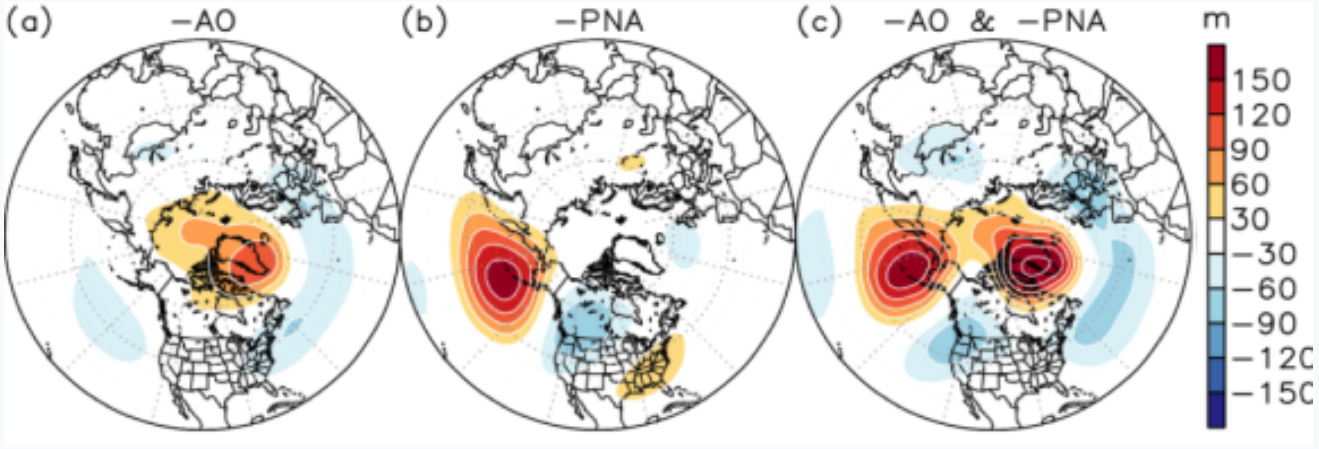
2010/2011 Winter

- Largest total seasonal snow in previous 14 Years (~170% of normal)
- Largest # of AR days (twice normal)

Dec 18 to 22

- Five Straight Days of AR
- >13 feet of snow in the Sierras
- >6 inches of rain in LA and >21 inches in nearby foothills

Common Climate Modes Linked to Atmospheric River Frequency

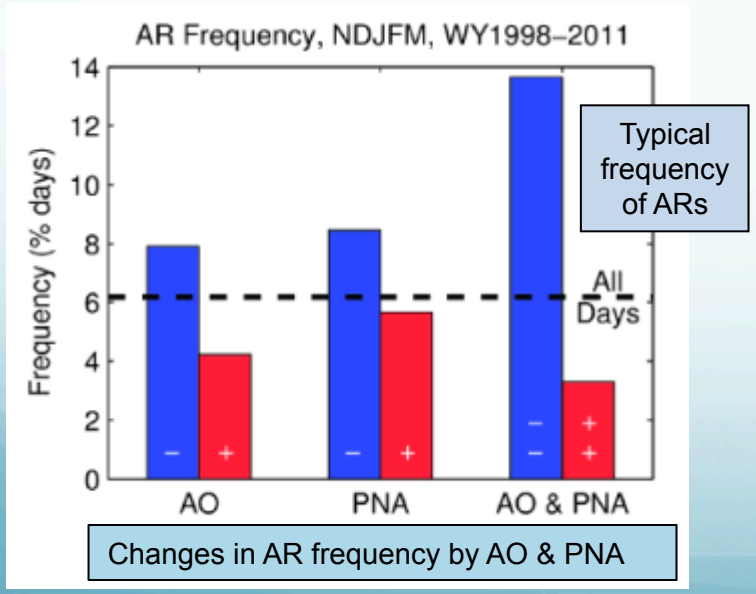


500 mb Geopotential Height Anomalies

"Arctic Oscillation" (AO)

"Pacific North American" (PNA)

Circulation anomaly when both PNA and AO in "negative" phase



Changes in AR frequency by AO & PNA

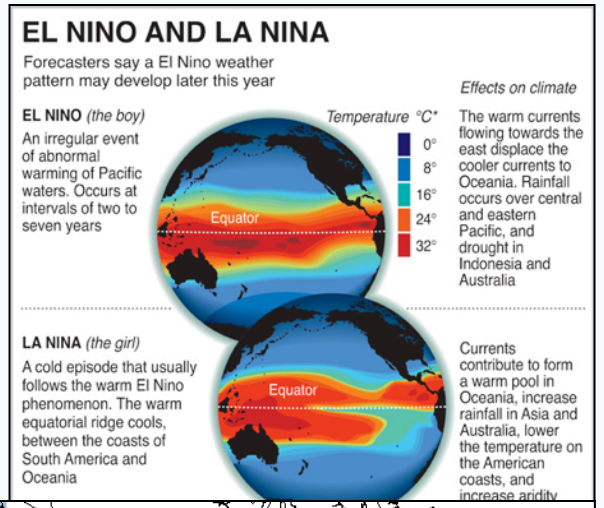
- When PNA & AO are in "negative" phases, there is a doubling of the frequency of ARs.
- This "double negative" occurred in 2010-11.
- Since PNA&AO exhibit some long-lead predictability, it may be possible to provide long-lead predictions of high/low AR periods

Guan et al. (2104)

A Forecast Gap

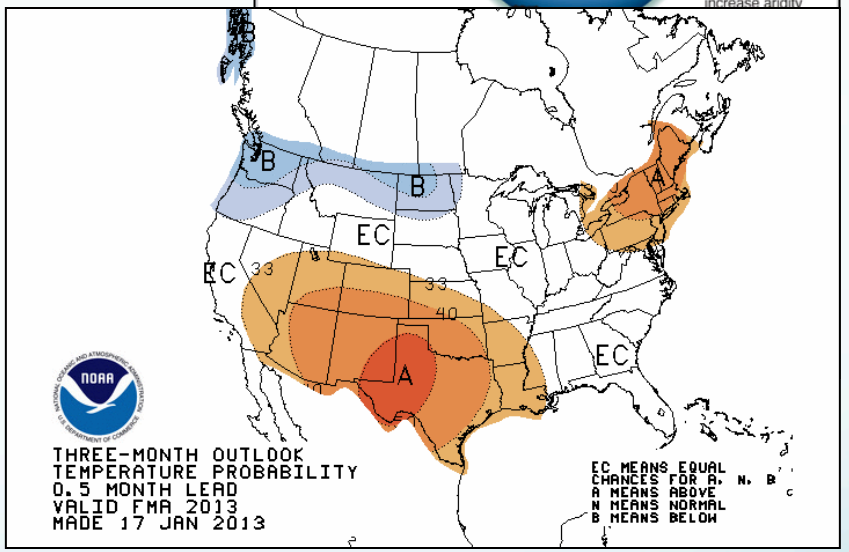
Screen shot of typical 7 day weather forecast as it would appear on the web or on TV.

AR Event



Weather Forecasts ~ O (10 Days)

(Mid-Latitude Baroclinic Instability & Cyclone Lifetime)



Seasonal Forecasts ~ O (100 Days)

(ENSO Phenomena & Local/Remote Circulation Impacts)

What about forecast information between "weather" and "climate"?

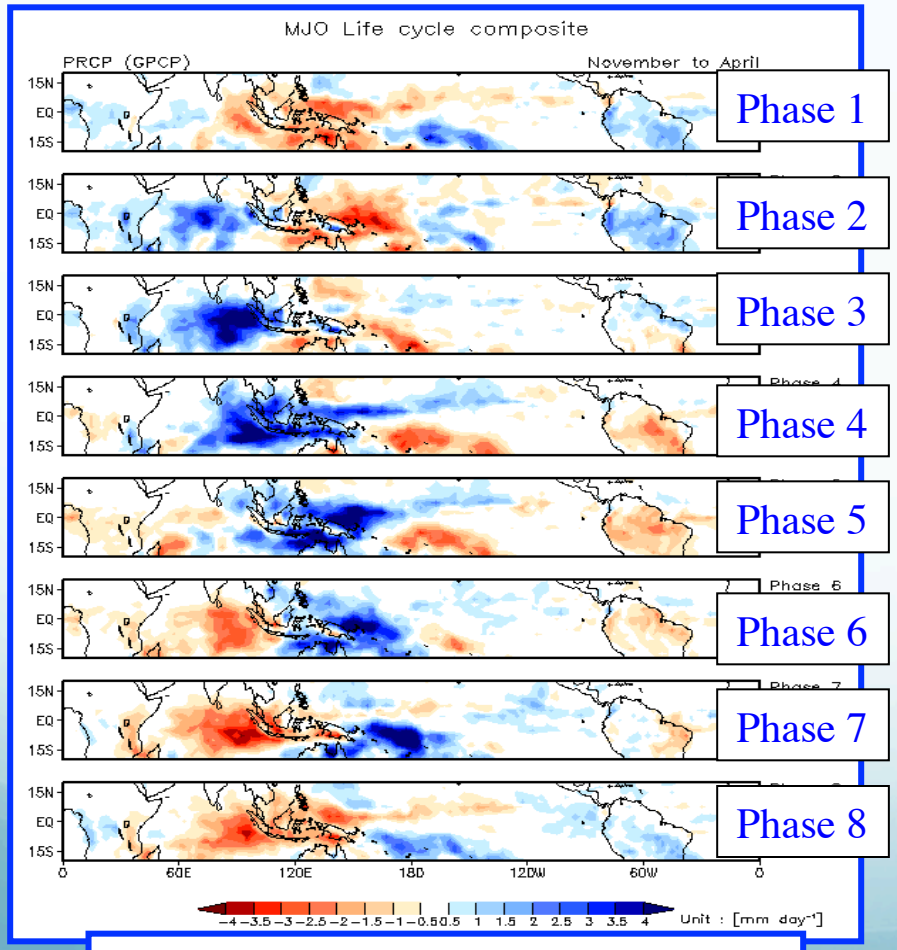
Newly, emerging opportunities from the so-called "MJO"

The dominant "subseasonal" variation of the atmosphere – provides unique long-lead prediction potential!

Madden-Julian Oscillation (MJO)

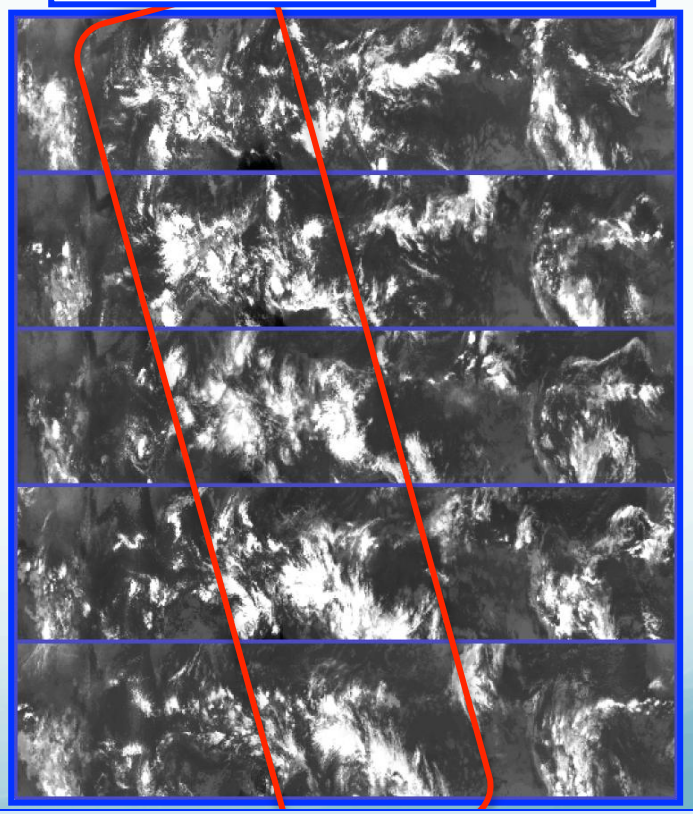
Discovered by
Madden & Julian, 1972

Average MJO Life Cycle ~50 Days



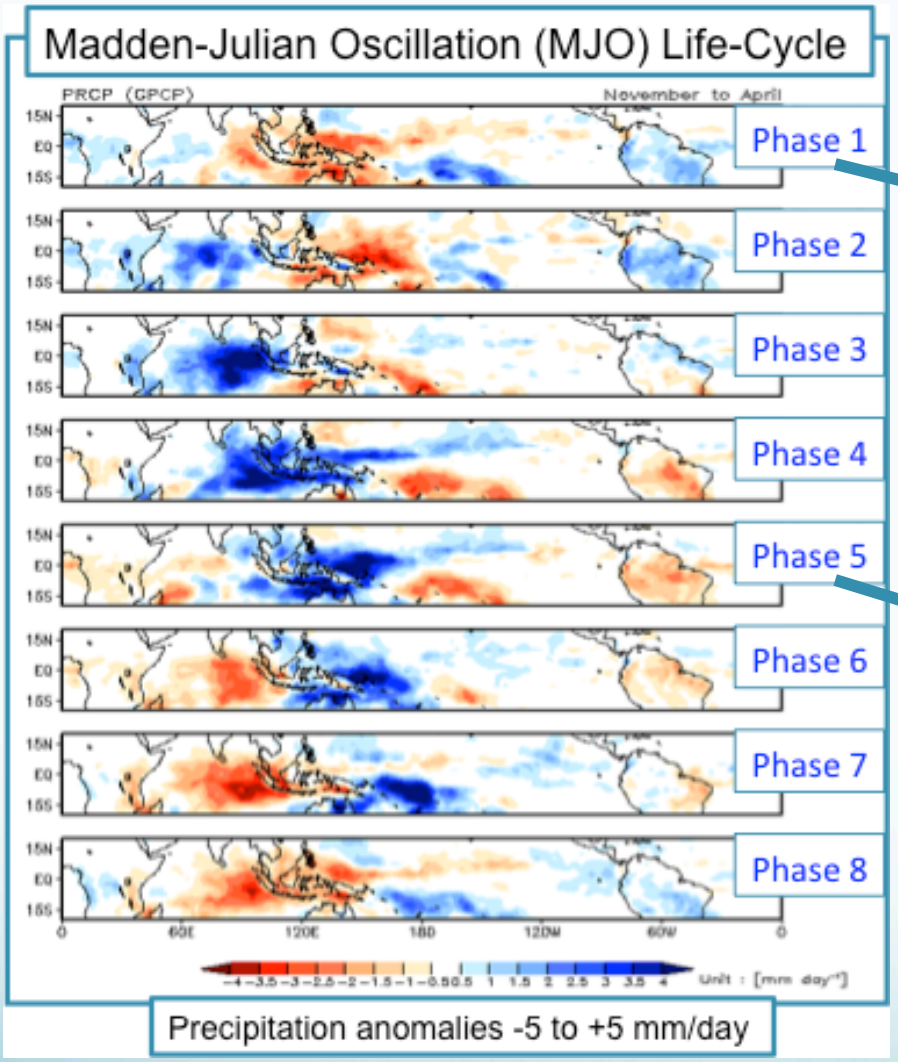
Precipitation anomalies -5 to +5 mm/day

Actual MJO Event in 1987

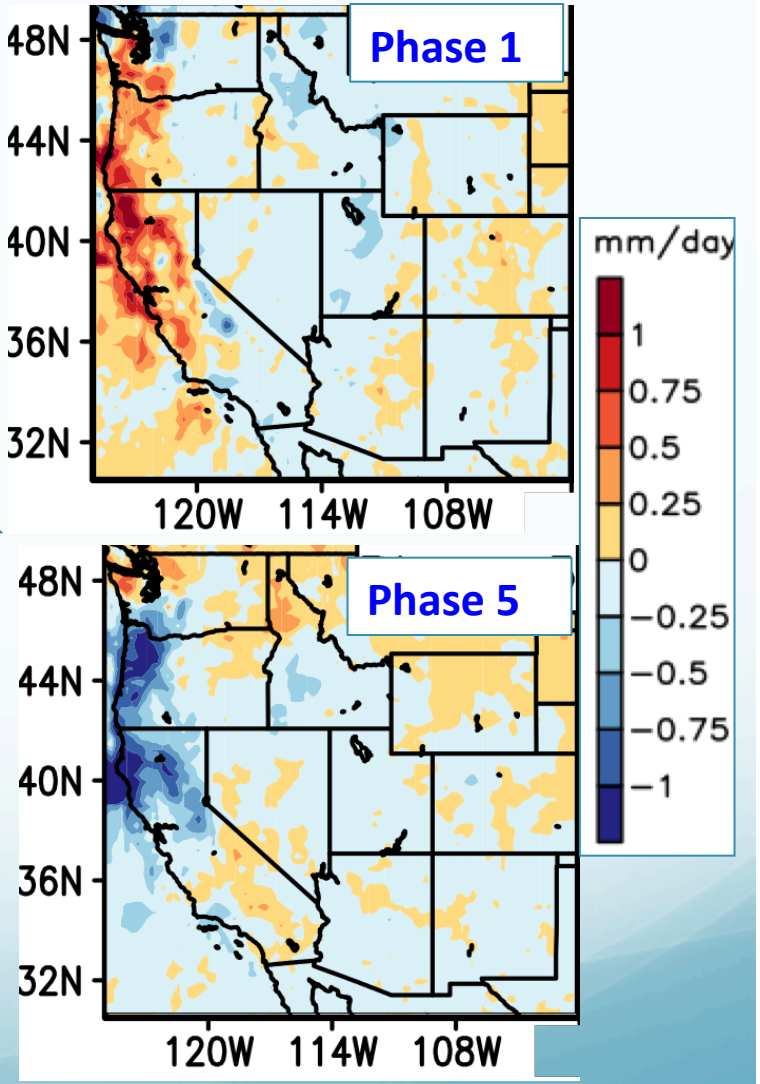


B&W "Photo" of whole tropics every 6 days

The MJO & West Coast Winter Precipitation



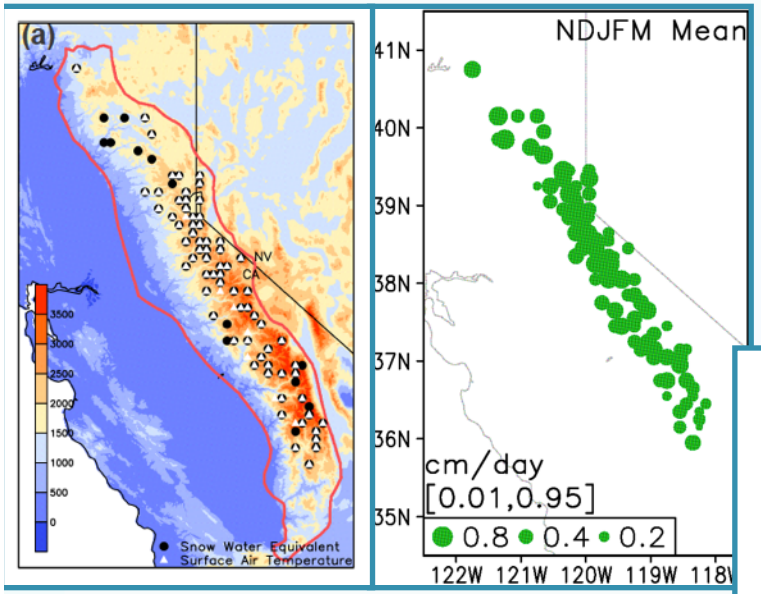
Typical Impact of MJO on West Coast Precipitation

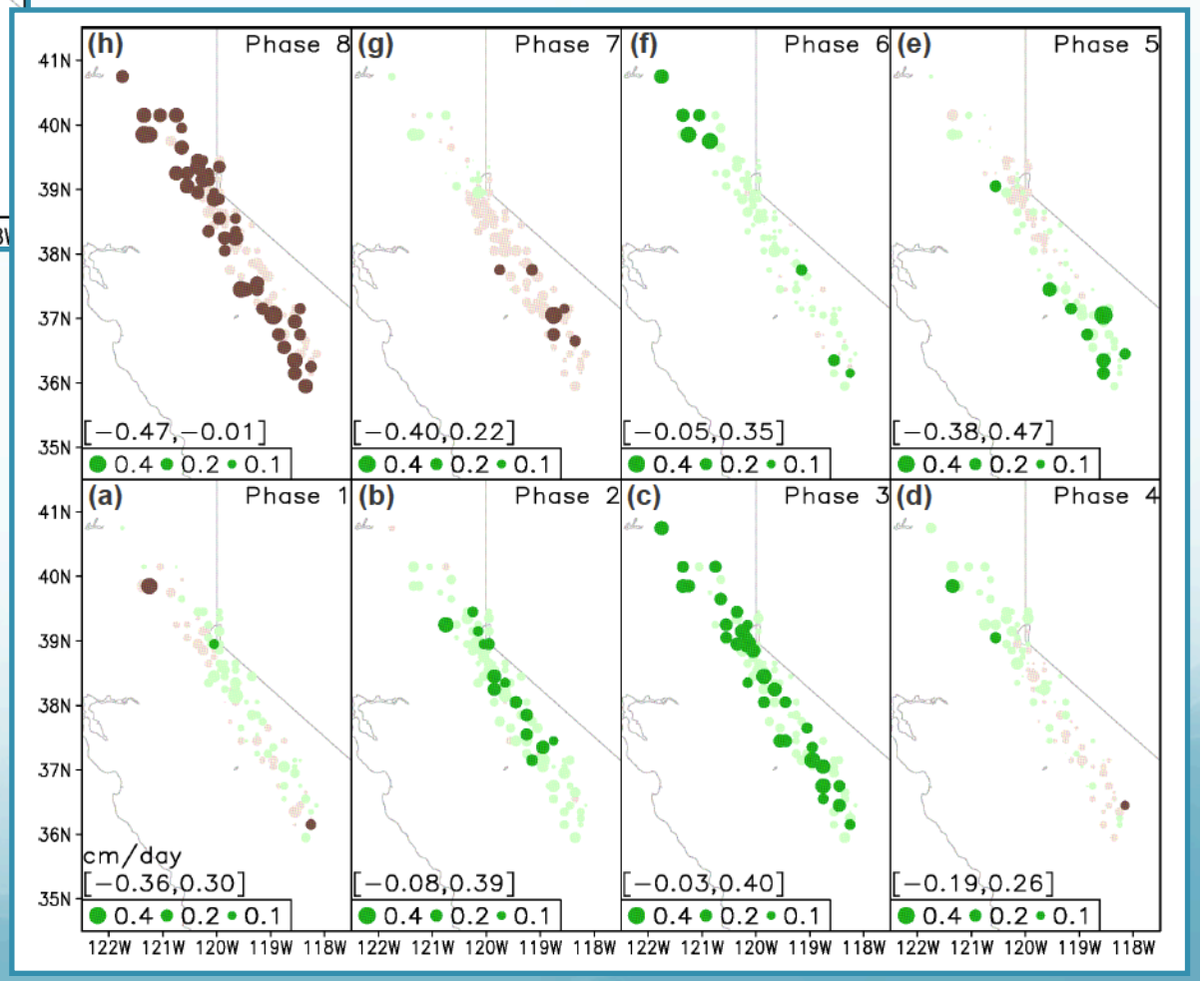


Typical Wintertime
Precipitation Rates ~2-6 mm/day (not shown);
MJO Modulation ~ +/- 1 mm/day (~25-50%)

Left Figure CLIVAR MJO Working Group
Right Figure Courtesy B.Guan, JPL/UCLA

MJO Modulation of Sierra-Nevada Snow Pack





- The MJO impart a strong modulation of CA snowfall.
- Phase 3 -> + 30-50%
- Phase 8 -> - 30-50%

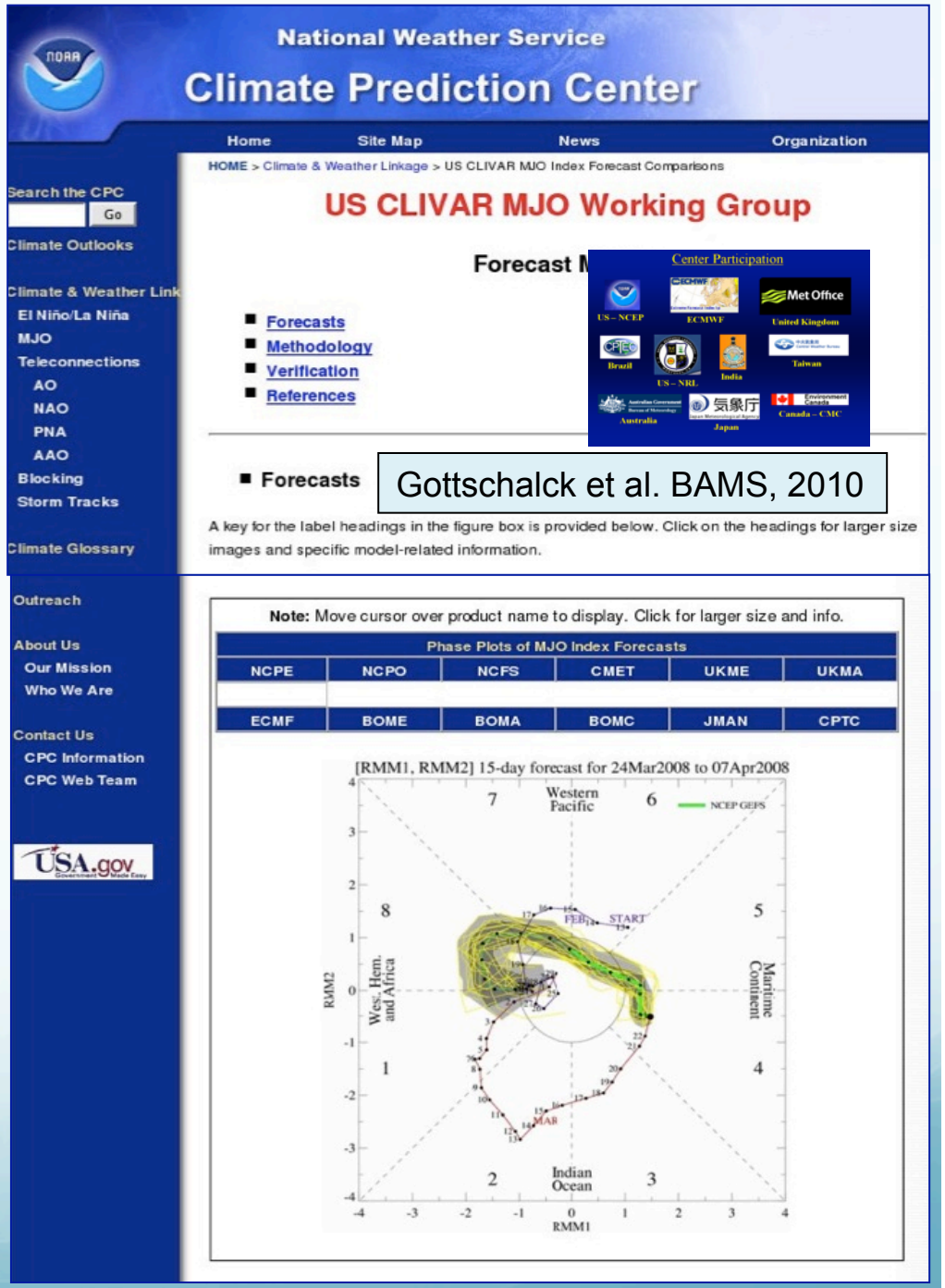
Guan et al. (2012)

Operational MJO Forecasts

This has been a GREAT challenge, but many operational weather prediction centers now routinely produce useful MJO predictions

JPL/NASA has teamed with the global weather & climate forecast communities to enable and improve MJO forecasts.

Note: Only a few MJO events per year - as with ENSO, the MJO represents a "forecast of opportunity"



http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml

AR & MJO Summary

- Atmospheric Rivers are important to climate, weather, and water – and in particular weather and water extremes in the west.
- Advancing our ability to forecast ARs for weather, water and hazard decision-support requires additional airborne/satellite observations and improved weather/climate models.

- The Madden-Julian Oscillation impacts global climate and weather, including west coast precipitation and snowpack.
- MJO forecasting has become operational and useful with lead-times of 3-4 weeks – providing a source of predictability at longer lead times typical of weather and shorter than ENSO/climate varability.

To capitalize on ARs and the MJO, better predictions & targeted decision-support tools are needed.

JPL and CW3E Collaborative Actions

- **Observations**
  - ✓ Airborne Field Experiments Funded (CalWater-2) and proposed (EV-2 AREX)
  - ✓ Satellite observations to better characterize rain/snow level & partition (e.g. CloudSat & GPM)
  - ✓ Satellite observations (SMAP) to relate soil moisture & flood potential.

- **Forecasts and Products**
  - ✓ Improving 2 week to 2 month weather/climate forecasts via a number national/international activities
  - ✓ Characterize relations between ARs/MJOs and climate variability
  - ✓ Work with DWR (and SPU) to develop tailored water/weather forecast products based on ARs/MJOs