Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

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Potential Subseasonal Predictability From the MJO

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Wang, J., et al. (in revision), The potential impacts of improved MJO prediction on the prediction of MJO teleconnections in the UFS global fully coupled model, *Climate Dynamics*.

DeFlorio, M.J., et al.(2024), From California's Extreme Drought to Major Flooding: Evaluating and Synthesizing Experimental Seasonal and Subseasonal Forecasts of Landfalling Atmospheric Rivers and Extreme Precipitation during Winter 2022/23, *Bulletin of the American Meteorological Society*.

Sponsoring Agency: DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA

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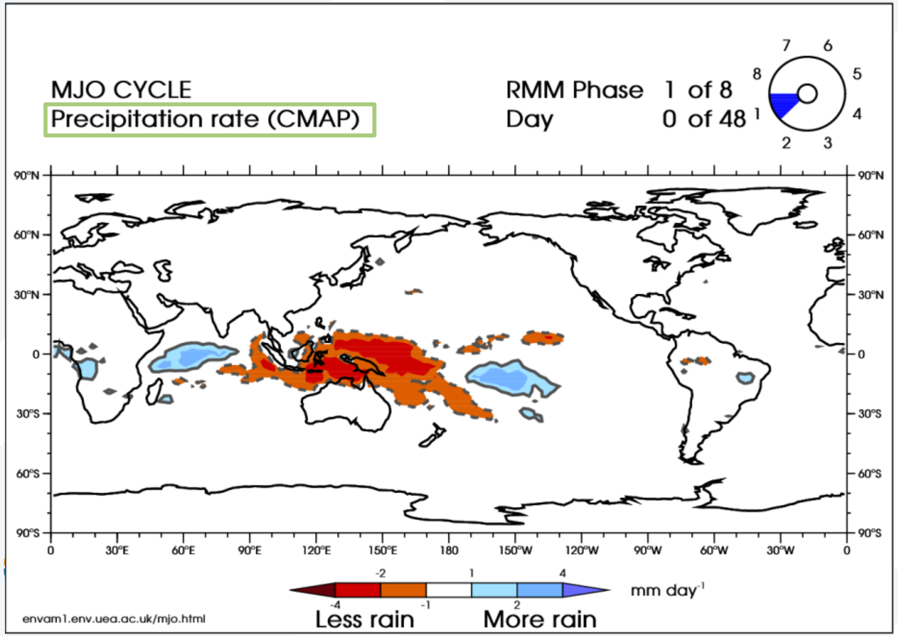
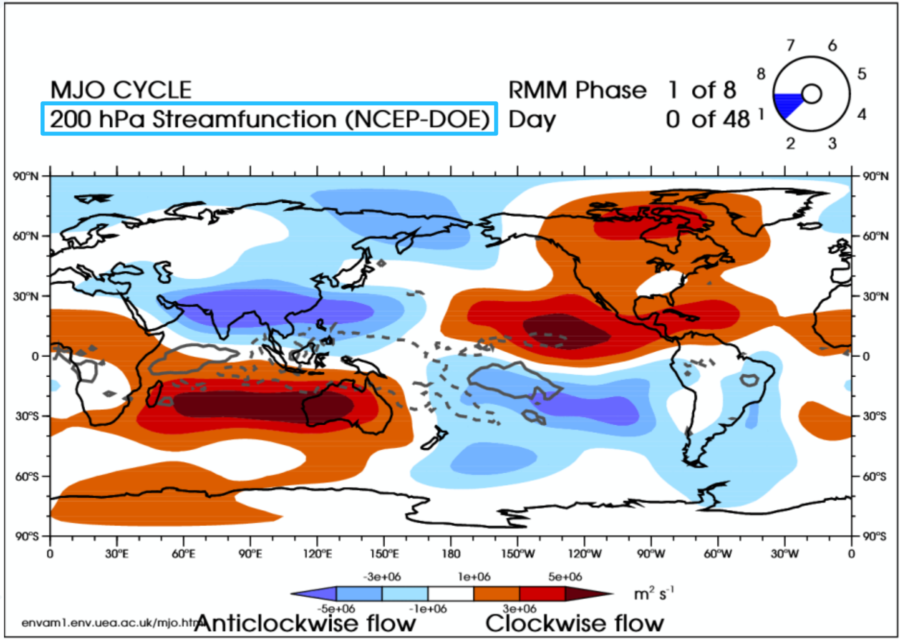
Overview of Madden-Julian oscillation (MJO)

- **MJO is a unique convection-circulation coupled system in the tropics**
- eastward propagation (from the western Indian Ocean to the Pacific)
- planetary scale (large spatial scale; wavenumber 1-3)
- intraseasonal timescale (life cycle approximately 30 to 60 days)

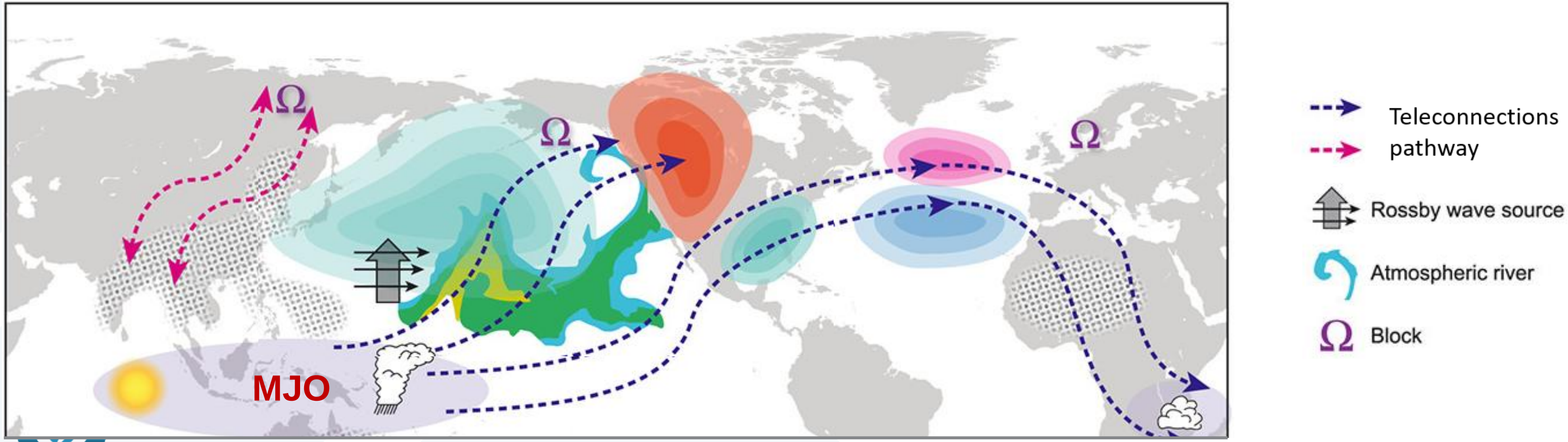




MJO global impacts – MJO teleconnections

- **MJO affects the midlatitudes by generating propagating Rossby waves** (Seo and Lee 2017)
- **Excited MJO teleconnections can modulate**:

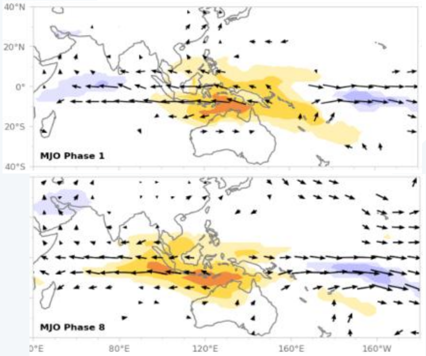
- Climate modes→ Pacific-North American (Mori and Watanabe 2008), North Atlantic oscillation (Cassou 2008)
- Weather events → Blockings (Henderson et al. 2016), Atmospheric Rivers (Mundhenk et al. 2016), precip extremes (Wang et al. 2023)



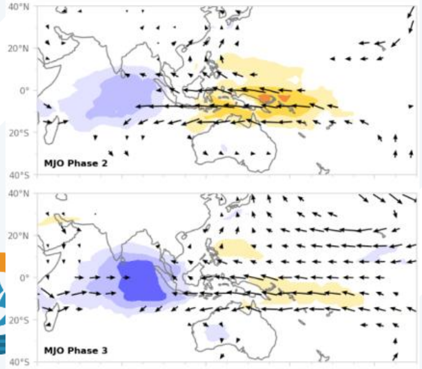
Stan et al. 2017

MJO phase diagram – operational diagnostic tool

MJO Phases 1&8
West. Hem. & Africa

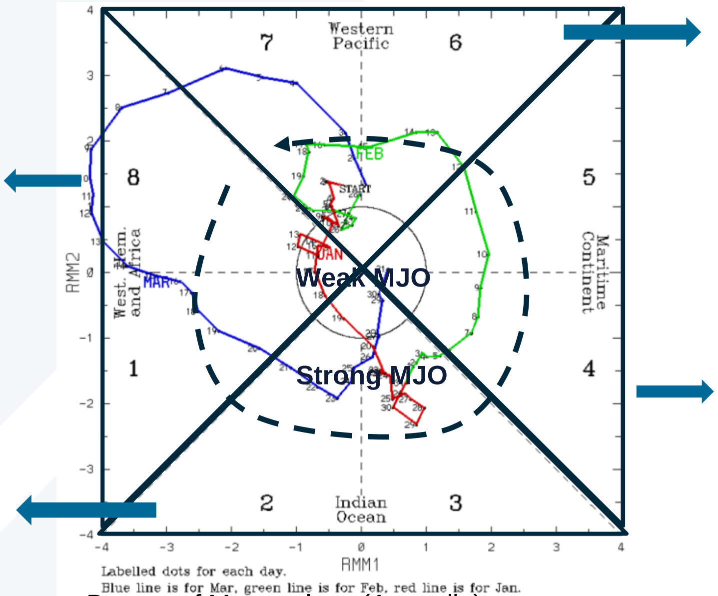


MJO Phases 2&3
Indian Ocean

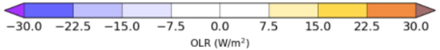


- Each number/date indicates the day and location of MJO convection
- Clockwise: Eastward propagation

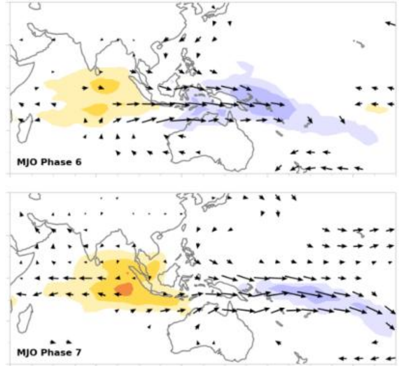
Observed MJO activity during 1 Jan– 31 Mar 2023



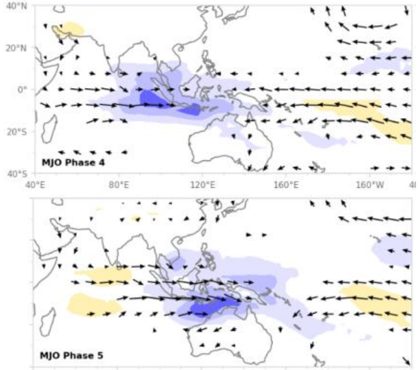
- Bureau of Meteorology (Australia): http://www.bom.gov.au/climate/mjo/#tabs=Phase
- RMM index: Wheeler and Hendon 2004



MJO Phases 6&7
Western Pacific



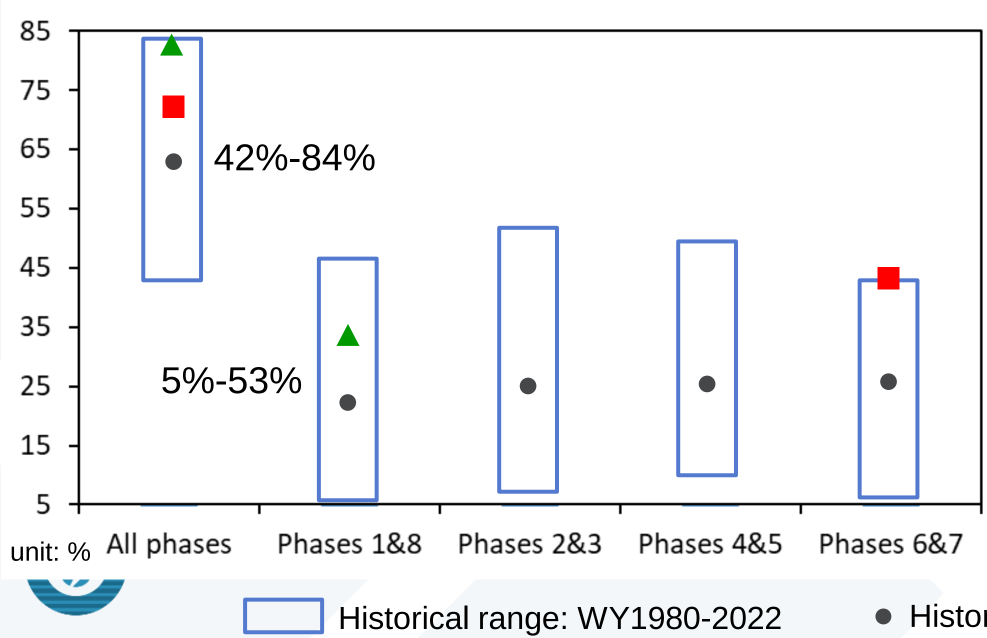
MJO Phases 4&5
Maritime Continent



Historical statistics of strong MJO occurrence

- Number of **active MJO** (RMM amplitude>1) days was **within the top 25% in WY2023** (73%)
- Number of **active MJO** days was the **second most active in WY2024** (83%)

Occurrence frequency of Strong MJO (OCT-MAR)

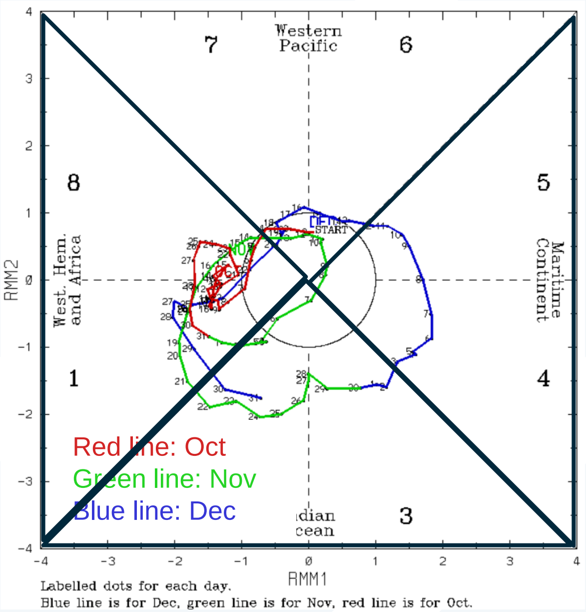


- MJO **Phases 6&7** in **WY2023** had the **highest occurrence frequency** since WY1980
- MJO **Phases 1&8** in **WY2024** had the **above-normal occurrence frequency**
- MJO in those phases is historically linked to wet conditions over CA

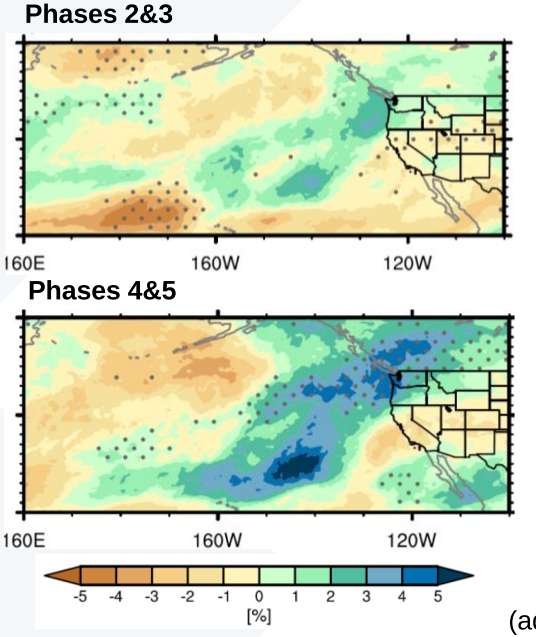
Looking back: Contextualizing WY24 OND MJO activity (Strong El Niño)

- Number of **strong MJO** (RMM amplitude>1) days (83%) is the **second most active MJO year** since WY1980
- Strong MJO was mostly in phases 1&8, 2&3, and 4&5 in OND WY24
- These MJO phases are historically associated with enhanced AR frequency near/over the Pacific Northwest

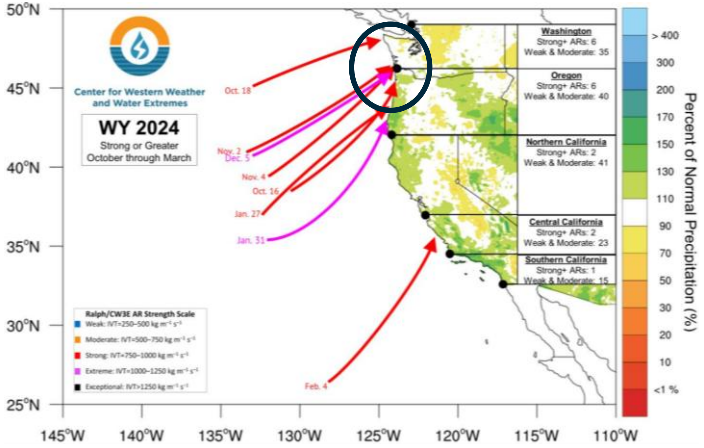
Observed MJO (OND WY24)



Historical MJO-AR



Strong or greater AR in WY24

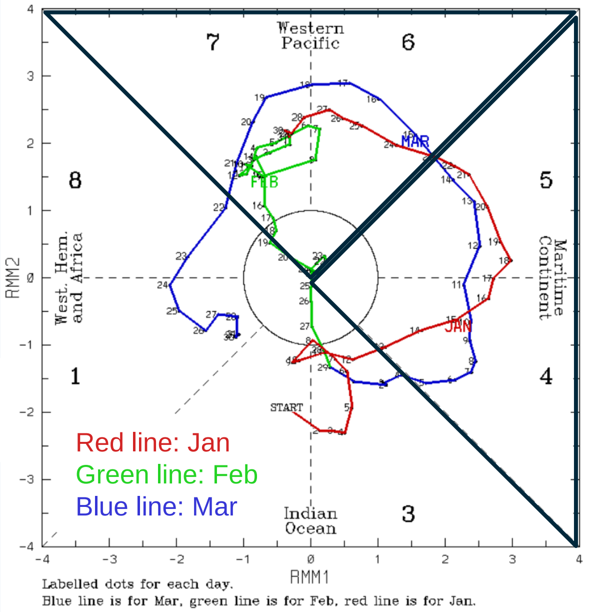


(adapted from Wang et al. 2023)

Looking back: Contextualizing WY24 JFM MJO activity (Strong El Niño)

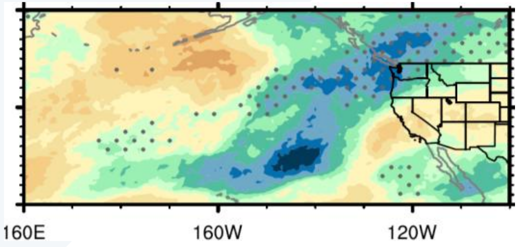
- Number of **strong MJO** (RMM amplitude>1) days (83%) is the **second most active MJO year** since WY1980
- MJO was in phases 4&5 during most of Jan and phases 6&7 in late Jan through mid-Feb
- MJO in those phases is historically linked to transition from dry to wet conditions over CA

Observed MJO (JFM WY24)

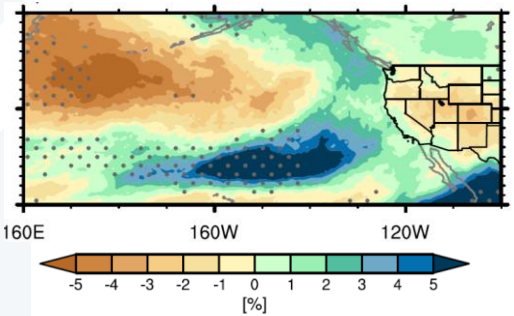


Historical MJO-AR

Phases 4&5



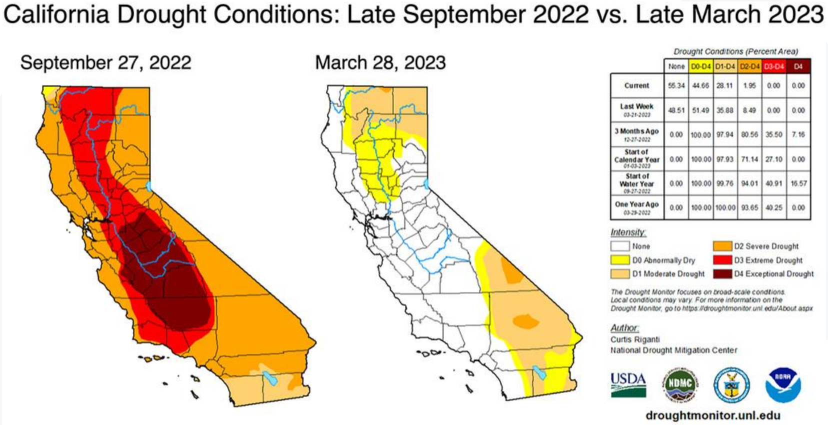
Phases 6&7



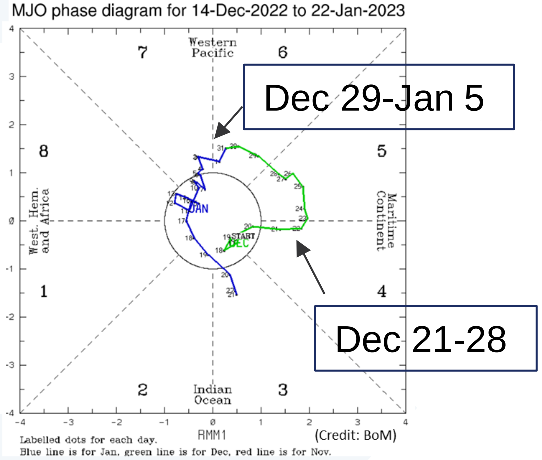
Strong or greater AR in WY24

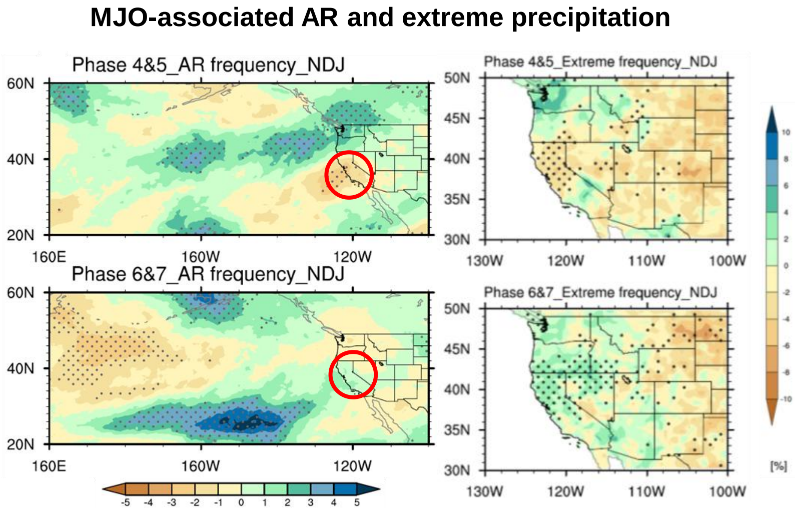
(adapted from Wang et al. 2023)

MJO - Interruption of ENSO impacts: Example of WY23 (La Niña)



DeFlorio et al. 2024



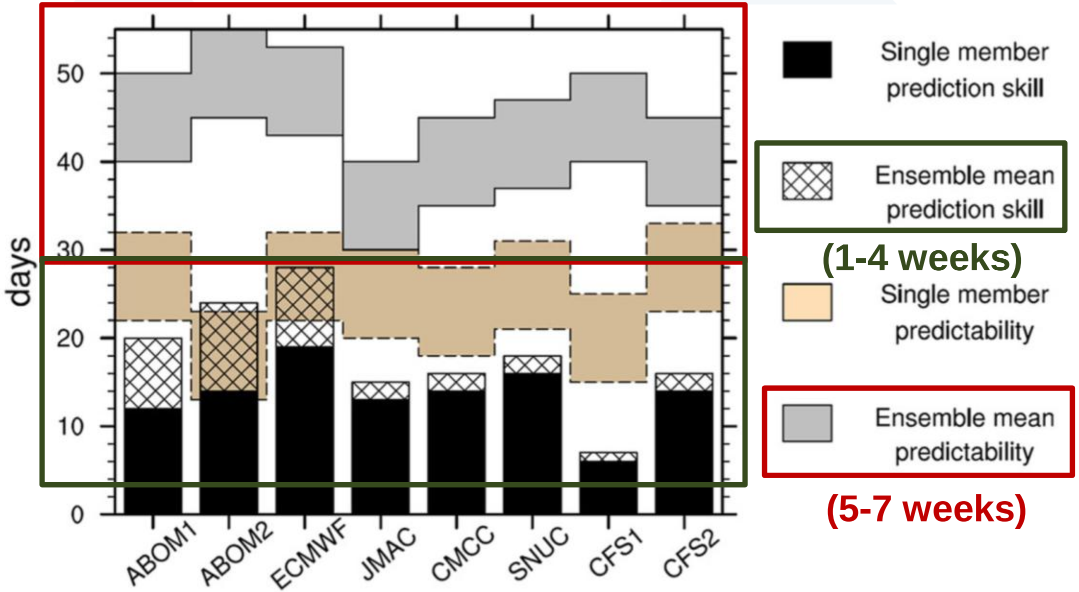


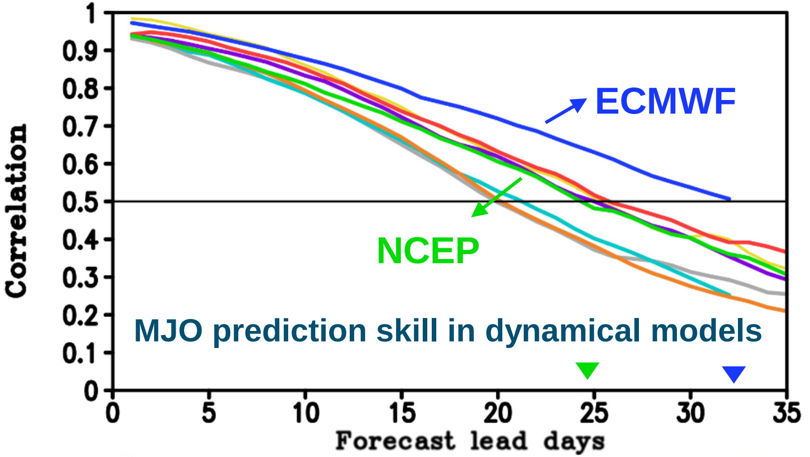
- Phase transition from dry MJO phases 4&5 to wet MJO phases 6&7

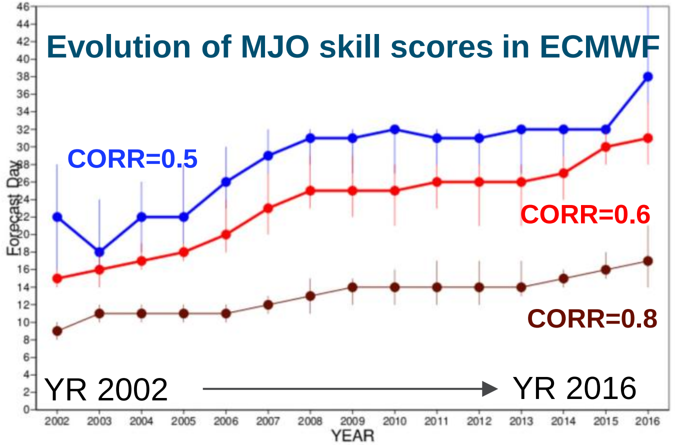
Wet WY23

MJO forecasts: predictability and prediction skills

MJO predictability and prediction skills in dynamical models
(data produced in 2009)





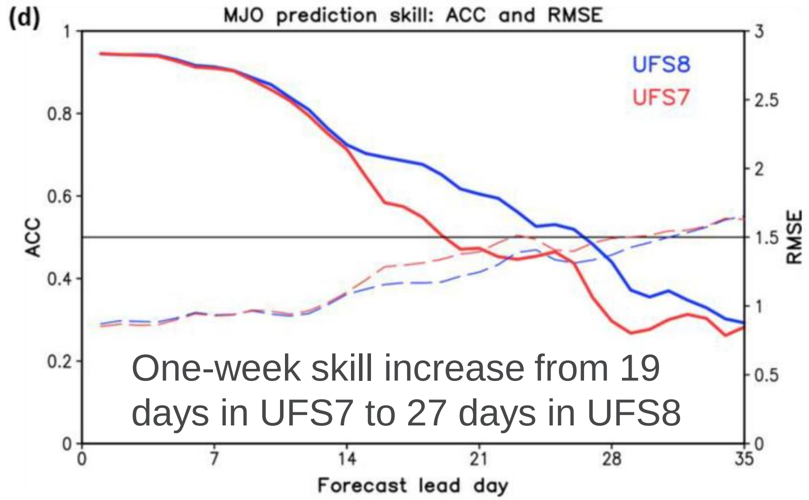


- ➢ MJO prediction skill is about 3 weeks behind its predictability
- ➢ ECMWF has the highest MJO prediction skill at ~ 4-5 weeks
- ➢ The prediction skill has been improving since the last decade for up to 2 weeks

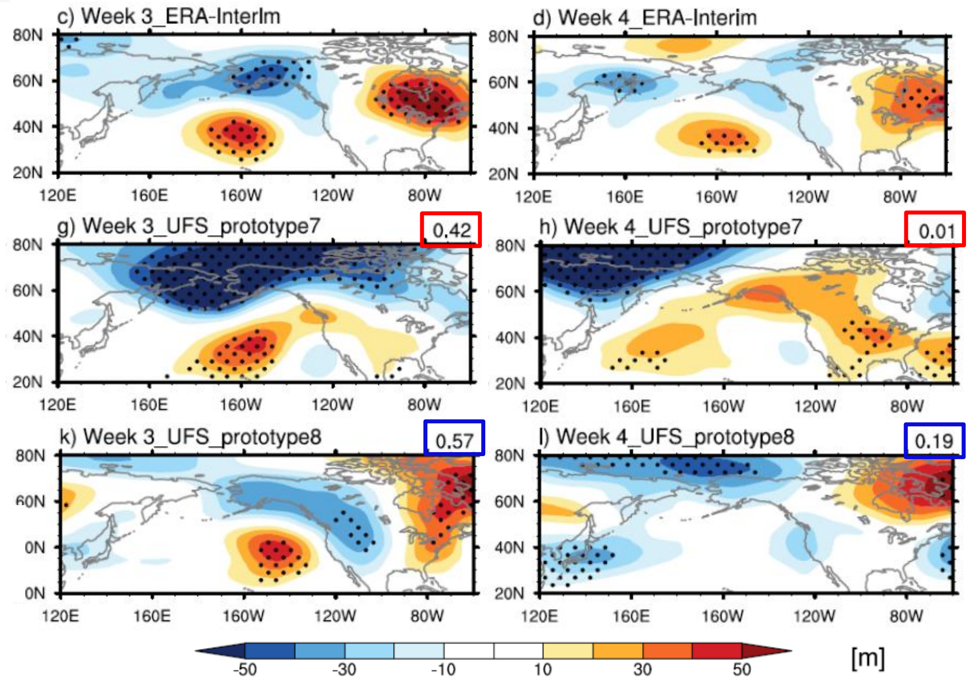
(Kim et al. 2019)

How does improved MJO prediction influence Z500 prediction?

Development towards fully-coupled GEFSv13 (MJO in UFS7 vs. UFS8)



Z500a after MJO phases 2&3 in UFS7 vs. UFS8

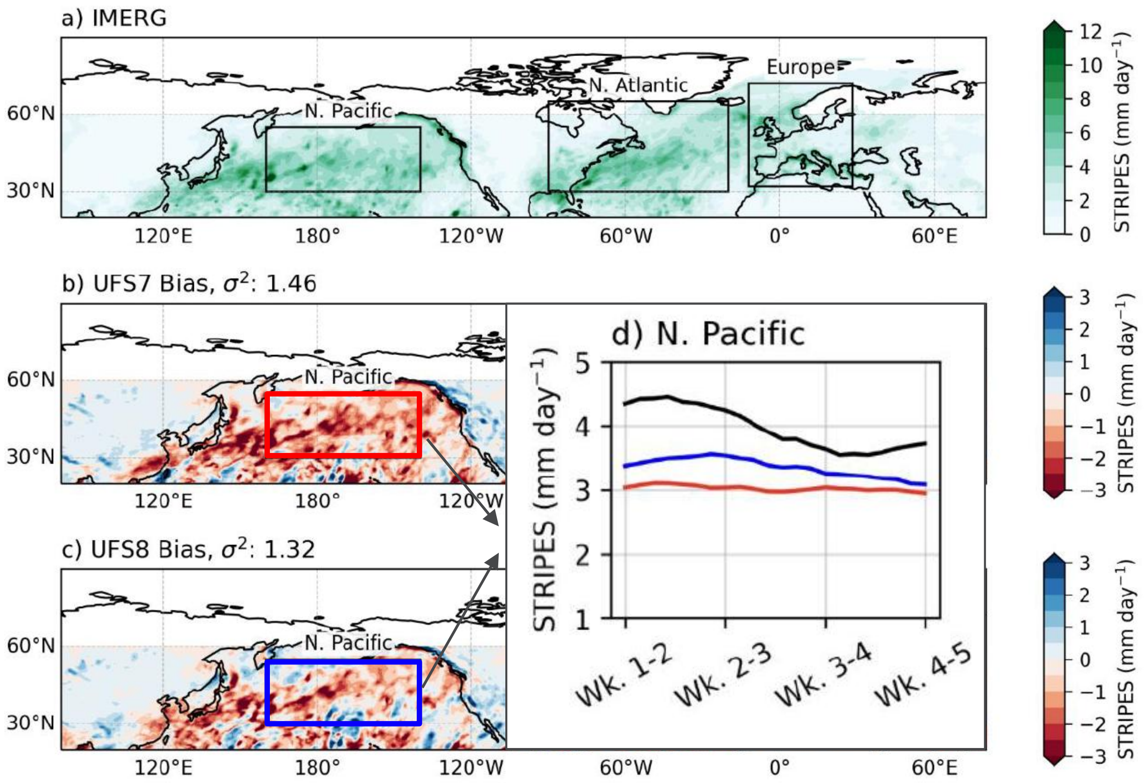


- ➢ Models struggle to predict the Week 4 PNA pattern
- ➢ UFS8 better predicts PNA-like pattern evolvement in Weeks 3-4 (0.01 → 0.19 in Week 4)

(Wang et al. in revision)

How does improved MJO prediction influence precipitation prediction?

Precipitation response to MJO in UFS7 vs. UFS8



STRIPES index (Jenney et al. 2019)

- Quantifies the strength of teleconnection response to the entire life cycle of the MJO
- A larger value indicates stronger MJO teleconnection response

- ➢ Strongest precipitation response falls within the North Pacific and North Atlantic storm track regions
- ➢ Models underestimate the response over the ocean, and overestimate the response over much of North America
- ➢ The underestimation is improved with better predicted MJO over the North Pacific throughout Week 5

(Wang et al. in revision)

Summary

- The MJO is considered a prominent source of subseaonal predictability because of its pronounced impacts on extratropical weather and its potential predictability at S&S lead times
- Seasonality of MJO activity and its impacts on CA precipitation: Example of WY24
- The MJO can interrupt the canonical ENSO-precipitation relationship: Example WY23
- Better predicted MJO may lead to better prediction in large-scale circulation over the Pacific and North America but has less impact on downstream weather over the Atlantic and Europe

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S&S website:
https://cw3e.ucsd.edu/s_and_s_forecasts/

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Seasonality of MJO-precipitation relationship

In OND, compared to JFM, we found:

Westward-retreated weaker MJO & Northwestward displaced weaker jet

↓

Weak trough vs. strong ridge over North America

↓

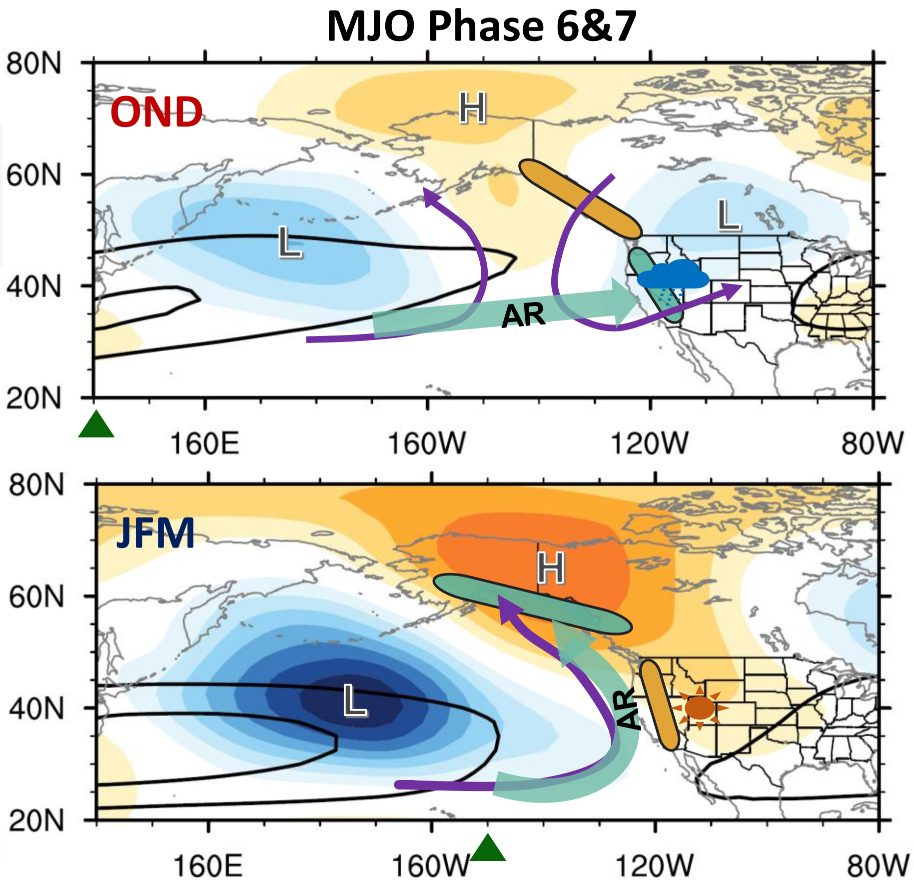
Eastward moisture transport to the West Coast vs. poleward transport

↓

Increased AR activity over the western U.S.

↓

Increased frequency in wet extremes

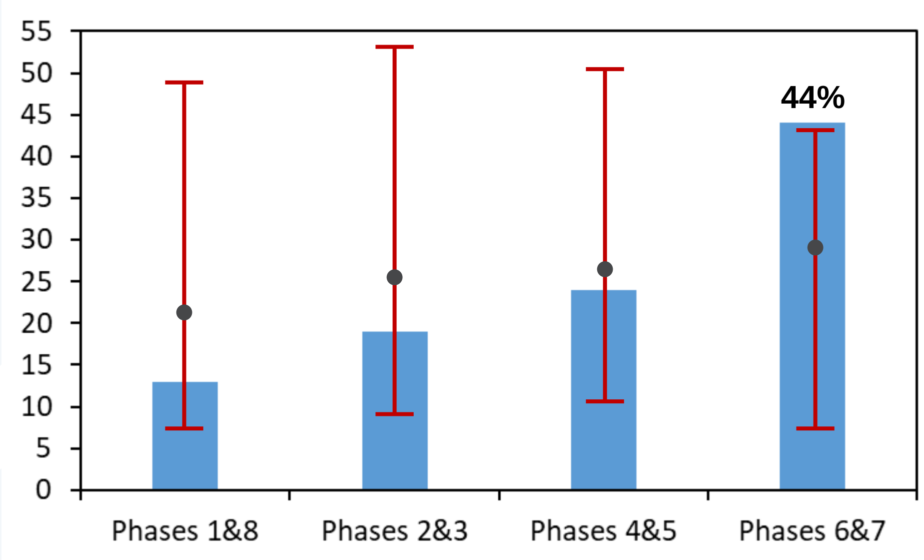


MJO - Interruption of ENSO impacts: Example of WY23

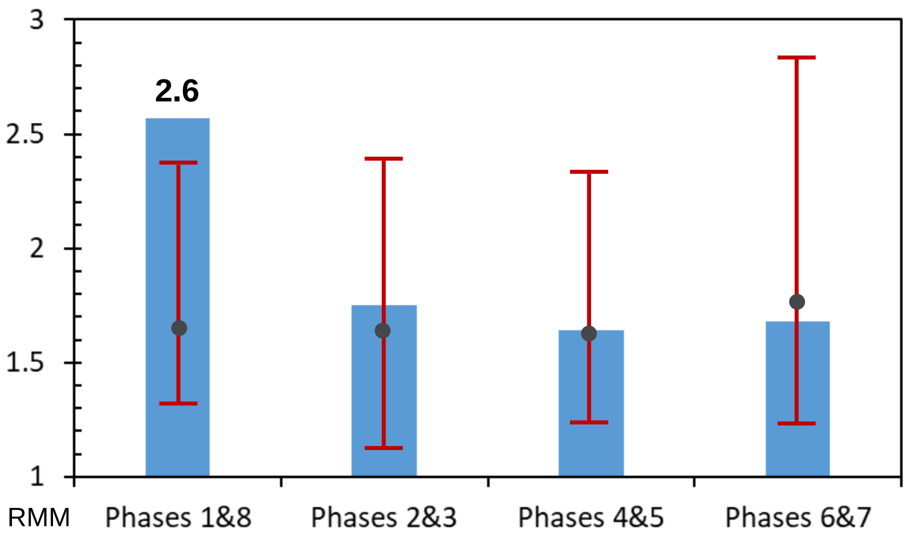
- Number of **strong MJO** (RMM amplitude > 1) days (73%) is within the **top 25th percentile** of all past WYs
- MJO **Phases 6&7** in WY23 had the **highest occurrence frequency** since WY1980
- MJO **phases 1&8** in WY23 had the **largest average amplitude** since WY1980

Wet WY23

Occurrence frequency of each MJO phase combination



Average amplitude of each MJO phase combination

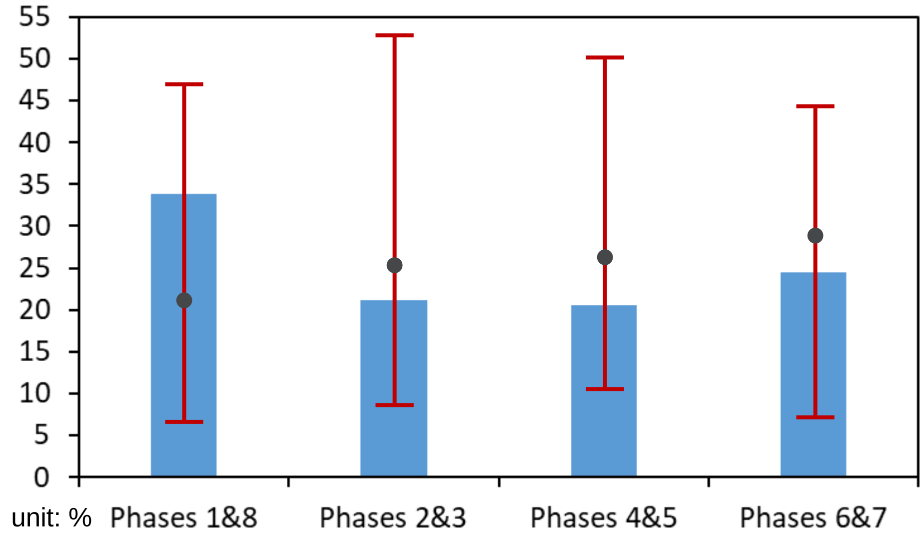


- Historical context: WY 1980-2022 (43 yrs)
- Blue bars: WY23
- Percentiles lines: Historical range
- Black dots: Historical mean

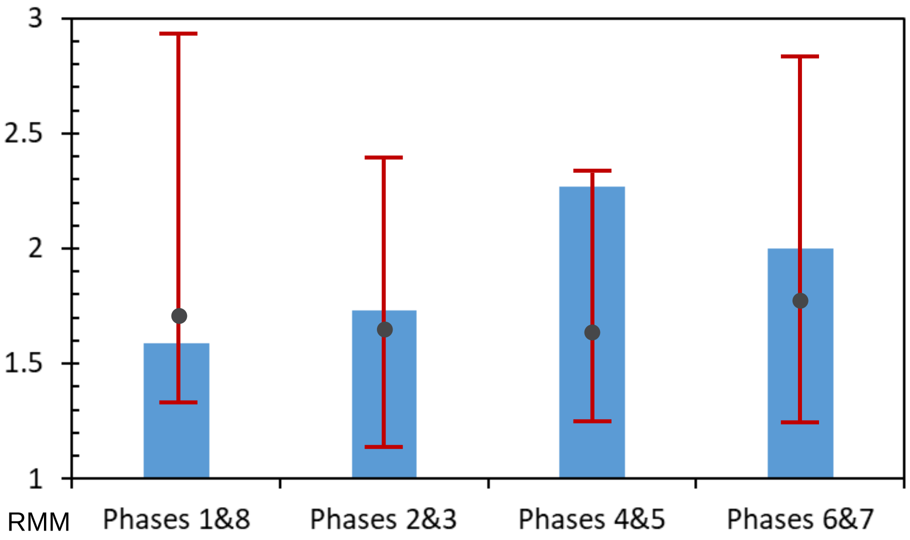
Looking back: Contextualizing WY24 MJO activity (Strong El Niño)

- Number of **strong MJO** (RMM amplitude>1) days (83%) is the **second most active MJO year** since WY1980
- MJO **Phases 1&8** in WY24 had the **above-normal occurrence frequency**
- MJO **phases 4&5 and 6&7** in WY24 had the **above-normal amplitude**

Occurrence frequency of each MJO phase combination



Average amplitude of each MJO phase combination



- Historical context: WY 1980-2023 (44 yrs)
- Blue bars: WY24
- Percentiles lines: Historical range
- Black dots: Historical mean