# MJO Dependency of Summertime California Central Valley Extreme Hot Weather

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## 1. Background and Motivation

➢ The Madden–Julian oscillation (**MJO**) is the dominant tropical intraseasonal variability (Madden and Julian 1994), and its influences weather and climate over the extra-tropics (e.g., Matthews et al. 2004). The MJO may contribute to extreme weather for instance: heavy rainfall and extreme temperature events (Hong and Li 2009, Jones et al. 2011, Matsueda and Takaya 2015). We consider California Central Valley (**CCV**) heat waves.

➢ **Motivation:** Backwards in time trajectories of air arriving at **CCV** at event onset find: many cross the N Pacific, and all sink from mid troposphere before arriving to start the heat wave (Lee and Grotjahn, 2015). Are these motions connected to tropical convection motion? If so, which zonal location of tropical convection is preferable for sinking motion at CCV? **We assess the MJO phase dependency on the occurrence of CCV heat waves.**

## 2. Data and Methods

- **15 NCDC station daily surface Tmax**
- **ERA-Interim:** 6hourly
- **Daily OLR** CDR Product Ver01Rev02
- **MJO index** (Wheeler and Hendon 2004)
- **Data period:** 32 summer seasons (JJAS, 122days), 1979-2010
- **Event detection criteria**
  - MJO events (dur.>=3days, amp.>=1, interval>=10days) for 4 phases
  - 24 CCV heat waves (HWs) (LG2015)

## 3. Tropical signal leads CCV hot weathers?

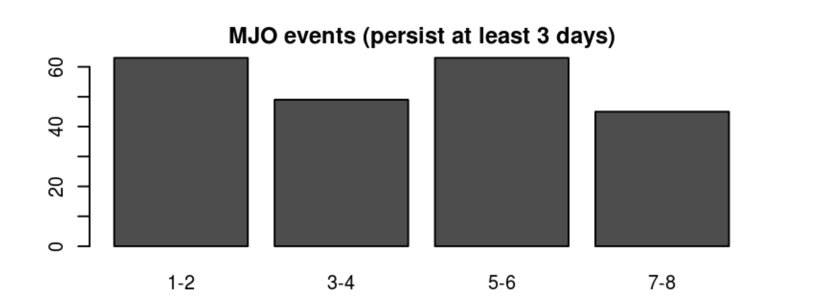


Fig 1. Numbers of MJO events for each pair of MJO phases

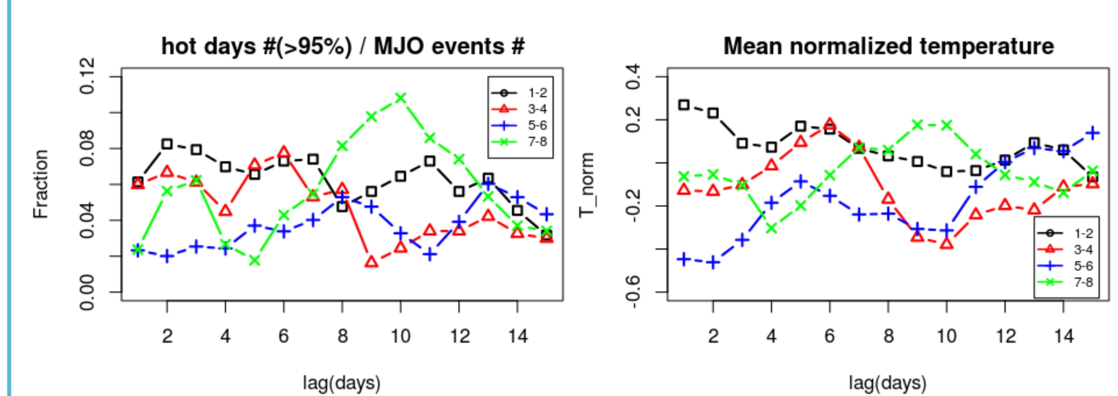


Fig 2. (Left) fraction of 5% hottest days among all event days and (right) mean normalized temperature anomalies for all event days at each lag for 4 MJO phase pairs. Lag measured from end of each MJO event.

✓ **Phase 1-2 and 3-4: have more extreme hot weather during 1 to 9 days after MJO events**

✓ **Phase 5-6 and 7-8: their major peaks occurring after lag 10 days**

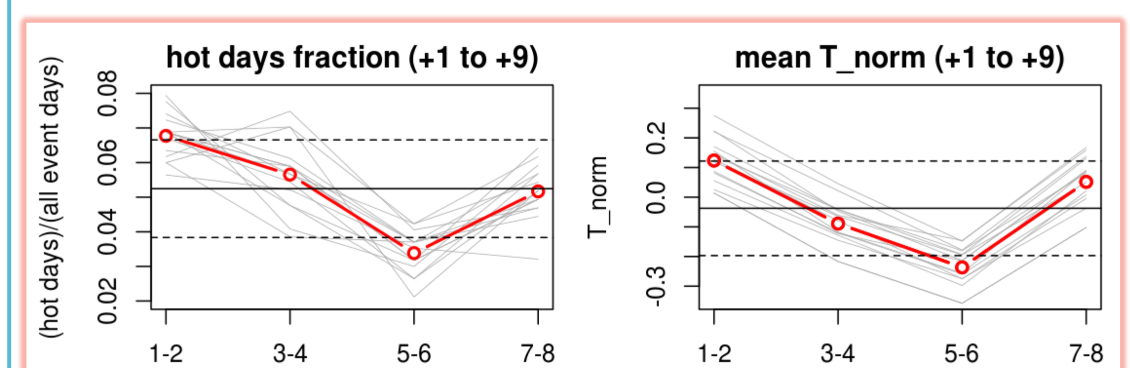


Fig 3. (Left) fraction of 5% hottest days among all event days and (right) mean normalized temperature anomalies for all event days during 1 to 9 days after MJO events. Gray lines are for 15 stations and red is for their average.

✓ **Phase 1-2 MJO (Indian ocean convection) has higher association with subsequent CCV extreme hot days.**

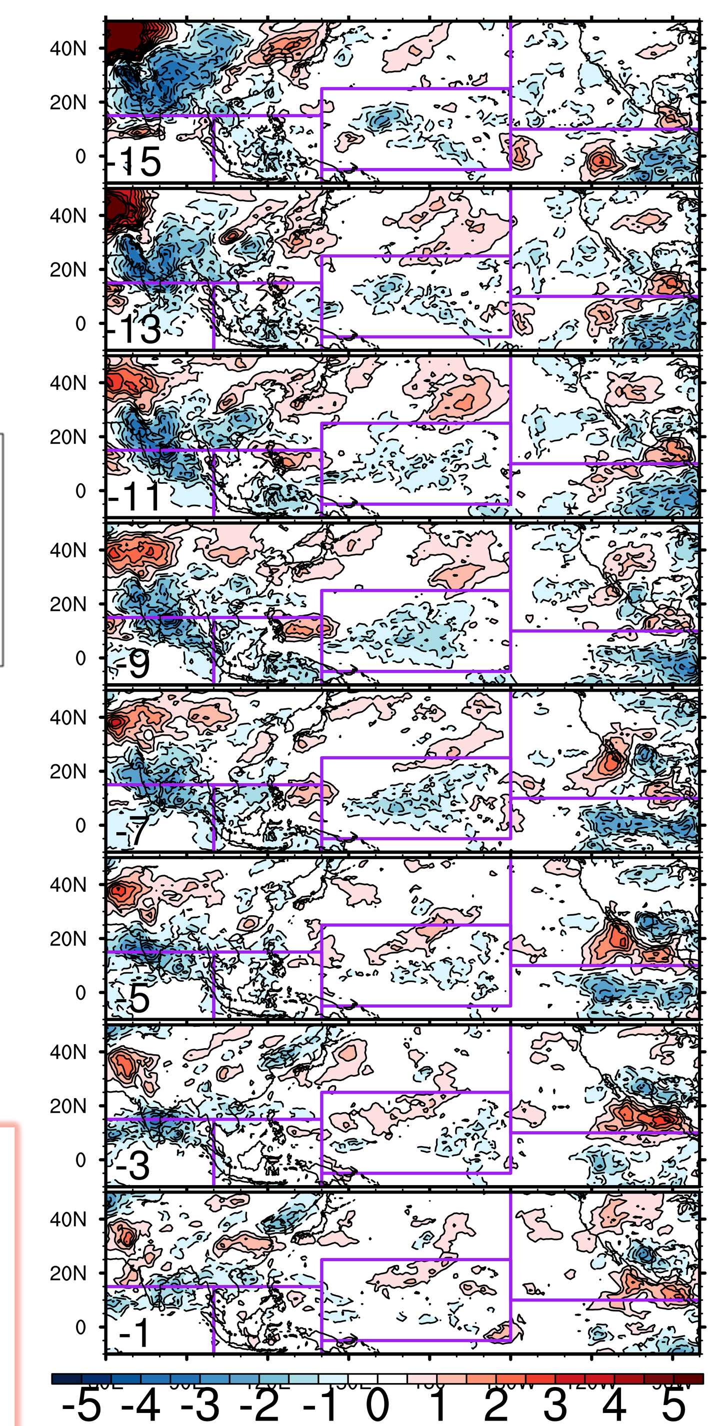

Fig. 4. Lead cross-covariances: OLR anomalies versus 15 CCV stations averaged normalized temperature anomaly time series over 32 summer seasons.

✓ **15 to 11 lead days : strong convection over India & E Asia. Focus on MJO areas**

## 4. OLR composites & Pattern correlation

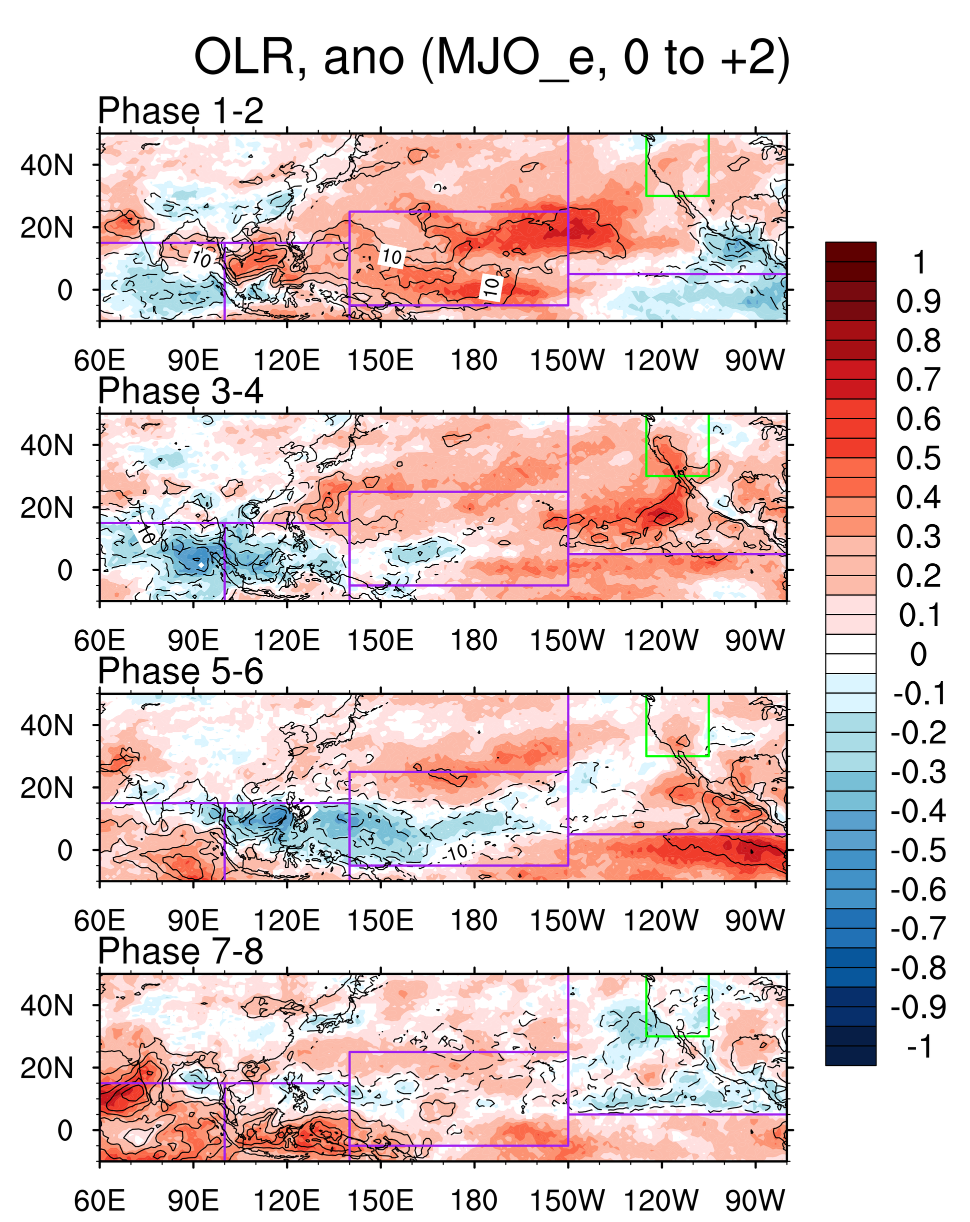


Fig 5. OLR anomaly composites during 0 to 2 days after MJO events onset for 4 pairs of MJO phases. Purple boxes show areas of larger OLR magnitude in 4 MJO phase pairs.

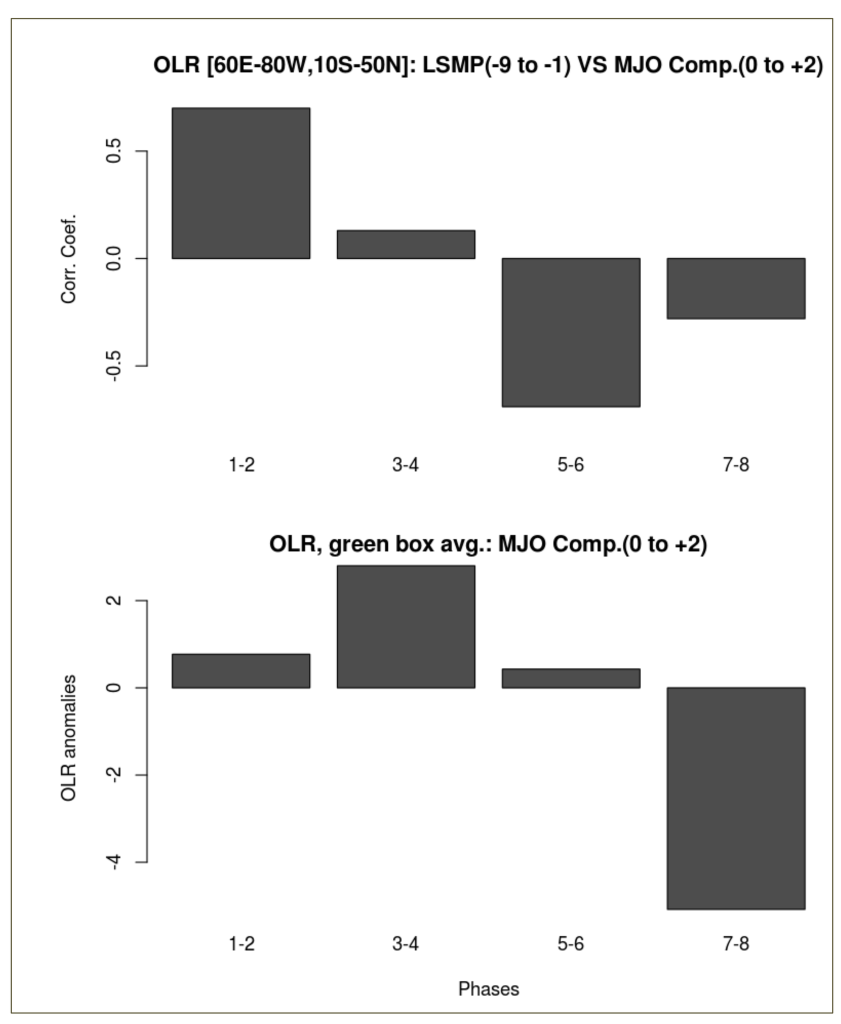


Fig 7. (Top) pattern correlation between the fields of Fig 5 and Fig 6 over the whole domain plotted. (bottom) averages of the OLR anomalies of Fig 5 over green boxed area.

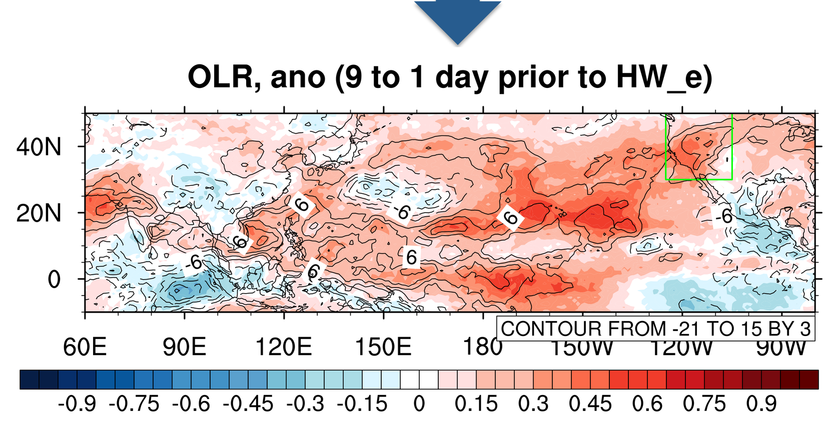


Fig 6. OLR anomaly composite during 9 to 1 days prior to the onset of the 24 CCV heat wave events

✓ **Phase 1-2 MJO (Indian ocean convection) OLR pattern is most similar to the OLR composite prior to heat waves events.**

✓ **Although phase 3-4 MJO (western Pacific convection) sinking pattern over CCV is stronger than other pairs and matches best the CCV values before the onset, the rest of the 3-4 MJO OLR pattern does not match the CCV OLR composite so, it hardly induces hot days occurrence.**

## 5. Velocity Potential Composite & Pattern Correlation

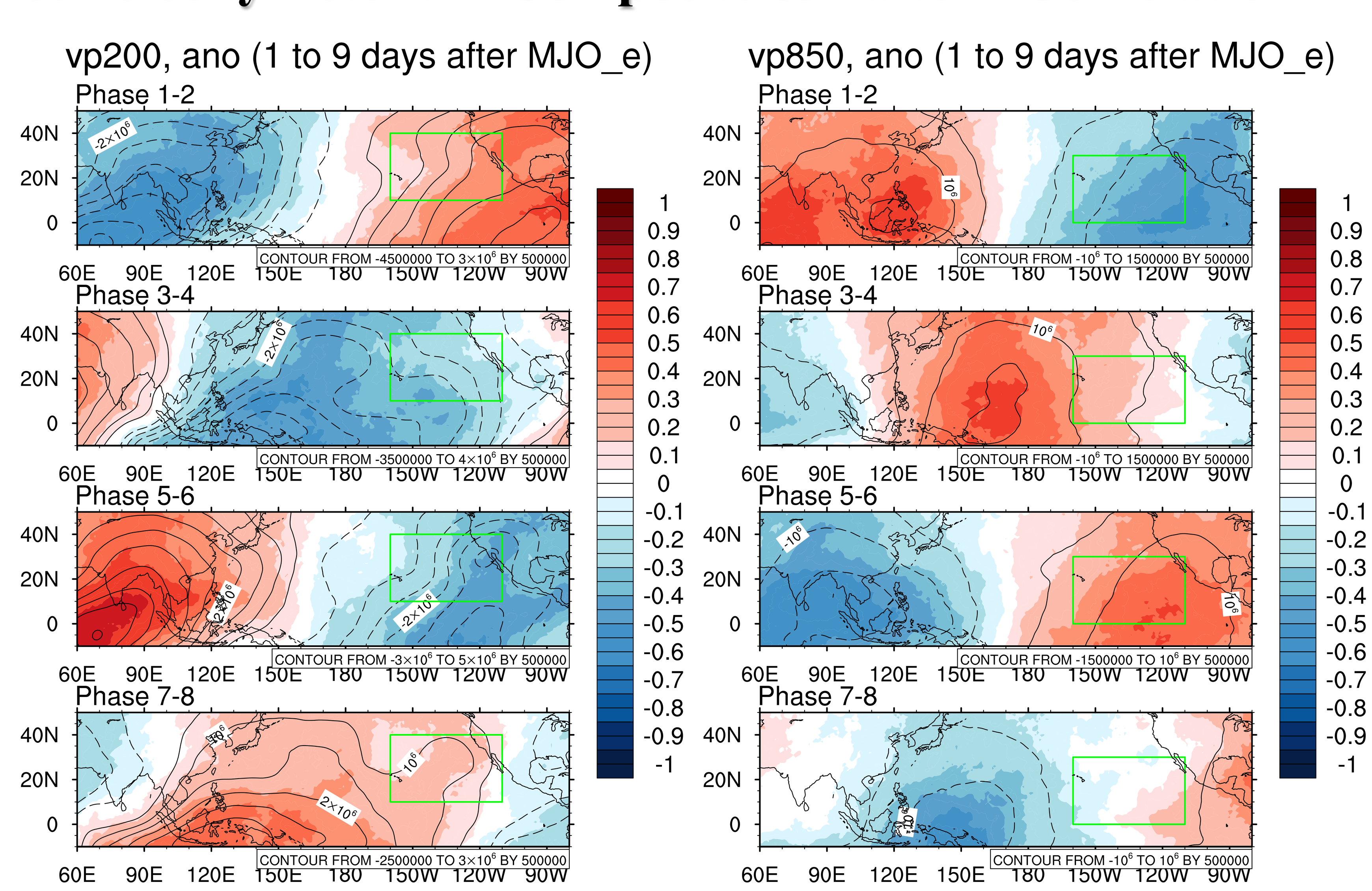


Fig 8. Velocity potential anomaly composite during 1 to 9 days after MJO events at 200 hPa (left) and 850 hPa (right) for 4 pairs of MJO phases. (>0 for convergence; <0 for divergence)

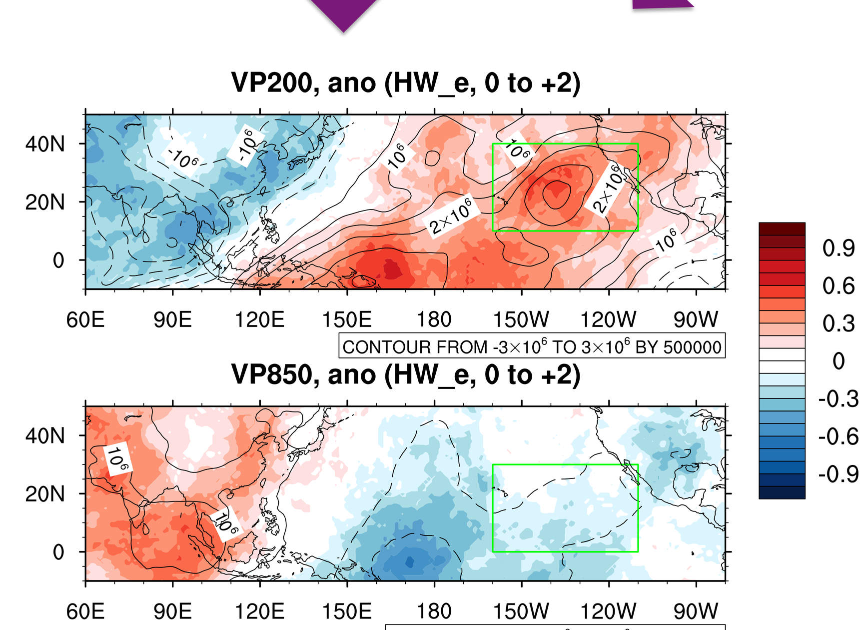


Fig 9. Velocity potential anomaly composites during 0 to 2 days after the onset of the 24 CCV heat wave events

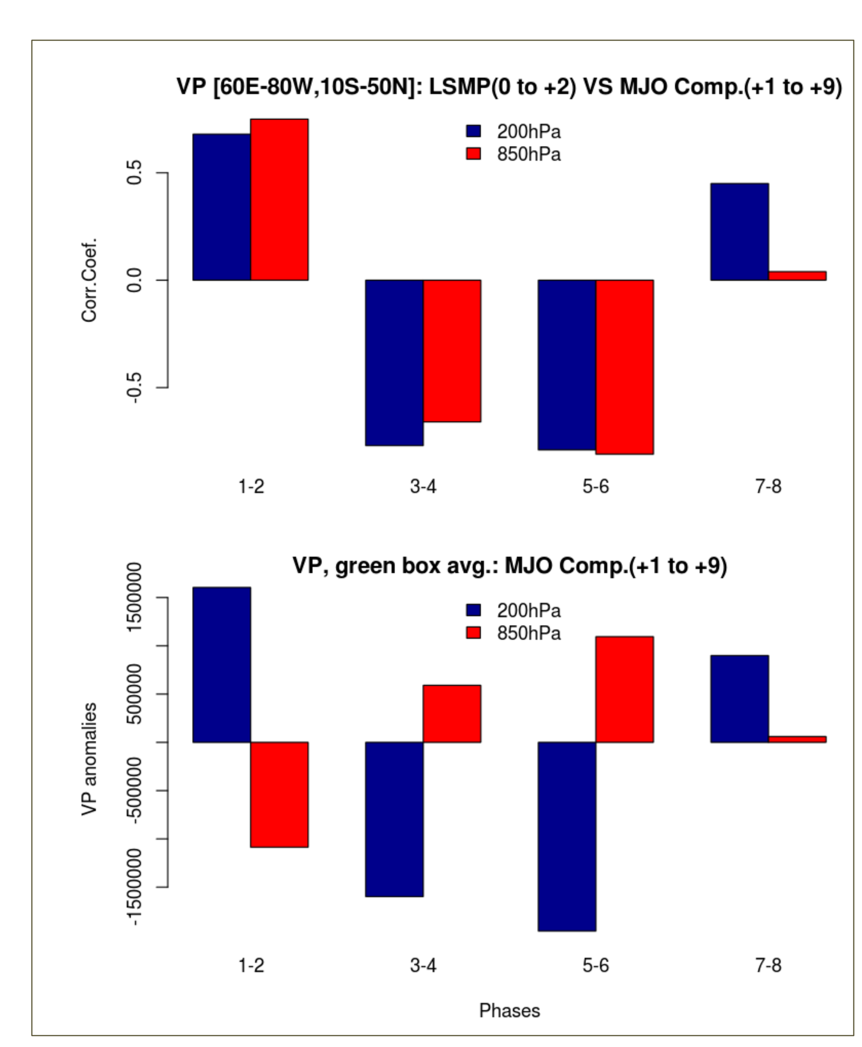


Fig. 10. (Top) pattern correlation between the fields of Fig 8 and Fig 9 and (bottom) averaged velocity potential anomalies of Fig 8 over green boxed area for (dark blue) 200 hPa and (red) 850 hPa.

✓ **Phase 1-2 MJO (Indian ocean convection): VP pattern 1 to 9 days after MJO events is most similar to the VP composite of heat waves events for both levels.**

✓ **Phase 3-4 and 5-6 MJO: upper level divergence and lower level convergence (not preferable for sinking motion, hence cooler temperatures in fig. 3)**

## 6. Conclusions

✓ **Cross covariance and two normalized temperature anomalies metrics show that MJO events lead CCV heat waves (HWs) by about 1 to 9 days particularly for phase 1-2 and 3-4 [figs. 2 & 4].**

✓ **It's hard to separate the impact of tropical and extratropical convection to CCV hot weather for 10 or more days before CCV hot days [fig. 4]. To focus on tropical contribution, this study mainly considers the period of 1 to 9 days after MJO events or the period of 9 to 1 days prior to heat wave events onset.**

✓ **Indian Ocean tropical convection leads extreme (5% hottest) hottest days more frequently than other phases [fig. 3], consistent with the largest pattern correlation of OLR & velocity potential anomalies between MJO phases and HWs [fig. 7 & 10].**

✓ **Indian Ocean tropical convection (phases 1-2) leads upper level (200 hPa) convergence and lower level (850 hPa) divergence near west coast of N. America [fig. 10] causing sinking there; such sinking is needed to create the CCV HW.**

✓ **Hence phases 1-2 of MJO are most consistent with subsequent CCV HWs.**

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