The isotopic composition of water vapor during the Madden-Julian Oscillation: a comparison between satellite retrievals and isotope-enabled GCMs

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Summary:

Changes in isotopic composition of water vapor during the MJO should reveal shifts in the fluxes of water "types" into the system and provide information on precipitation efficiency and convective processes

An analysis of the isotopic composition of mid-tropospheric water vapor from TES using a 5-year composite of MJO events confirm the MJO leaves a strong isotopic footprint.

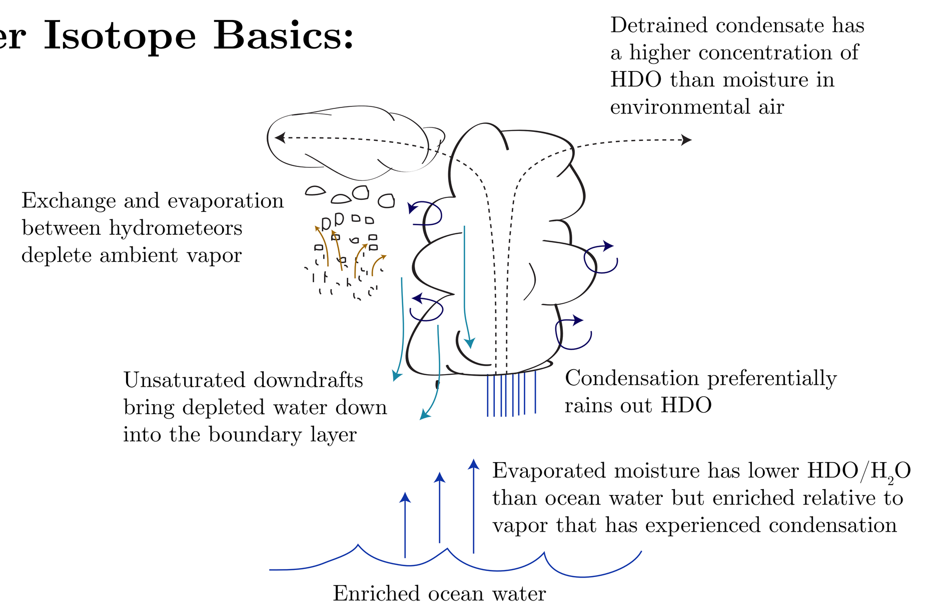
Using the joint-distribution of H_2O and HDO, it is shown that the onset of the MJO is associated with a strong evaporative flux, which is also persistent during the peak of the event. Additionally we identify critical moisture sources incuding that from rainfall re-eavporation and from convergence by way of westward-propagating Rossby waves.

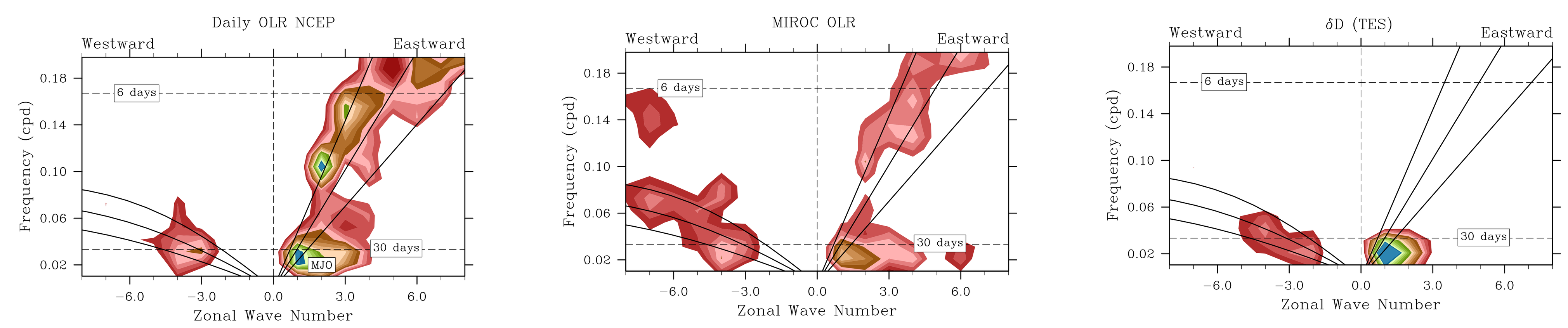
A series of similar isotopic diagnostics are performed on GCMs that include isotope tracers. These models have been nudged to Reanalysis fields thus, we ask if after the synoptic circulation is corrected towards "reality", are the moist processes during the MJO events comaparable to observations?

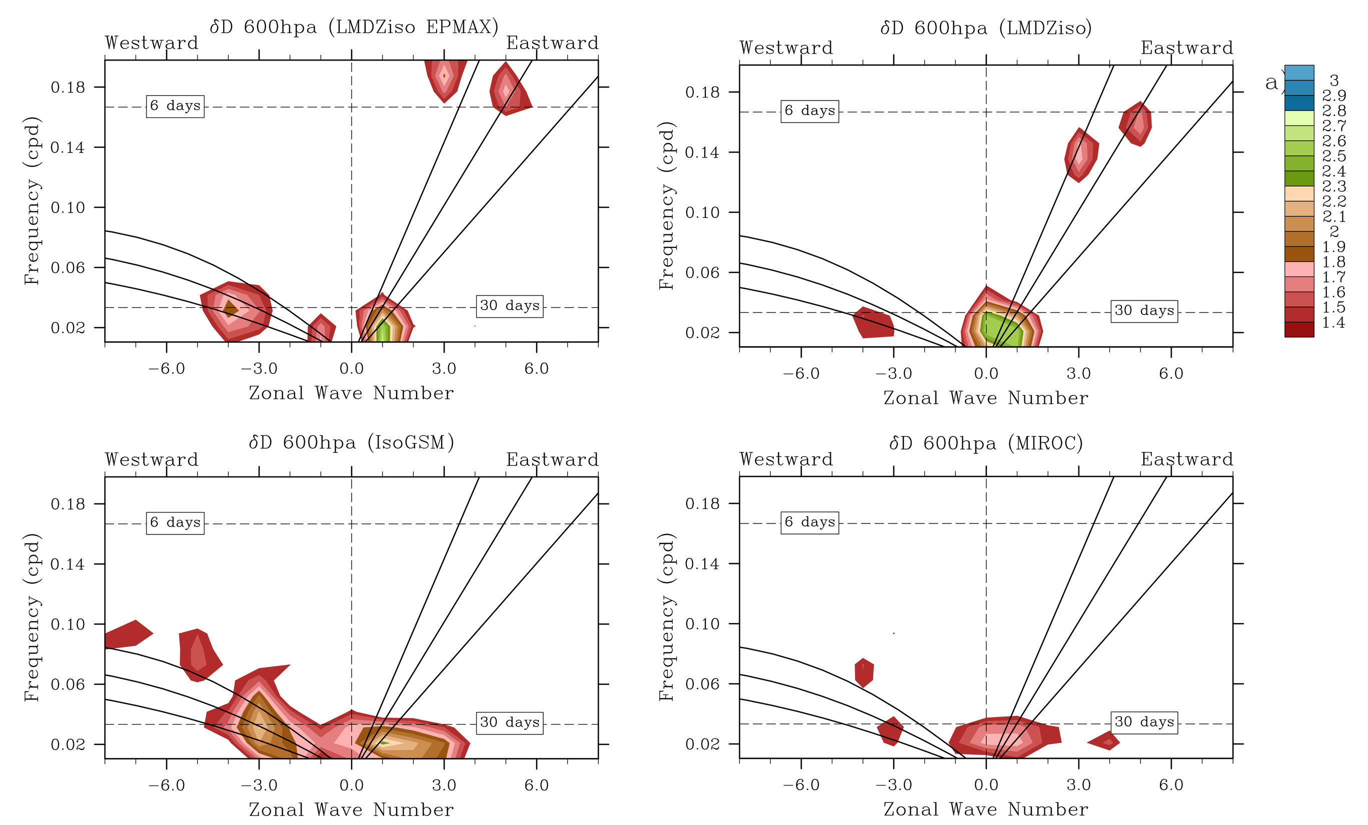
The isoGCMs all show a clear mid-tropospheric isotopic signature associated with the MJO but the footprint is typically weaker than observed.

All the GCMs show an isotopic depletion and moistening during the MJO lifecycle. However, unlike observations, the trajectory falls along a straight line with a negative slope. Therefore, the GCMs fail to capture discrete shifts in moisture sources during the MJO lifecycle. Notably, there is an absence of an evaportive flux during the peak of the MJO, which Cloud Resolving Models have shown to be critical to the moisture-convection feedbacks that sustain the MJO.

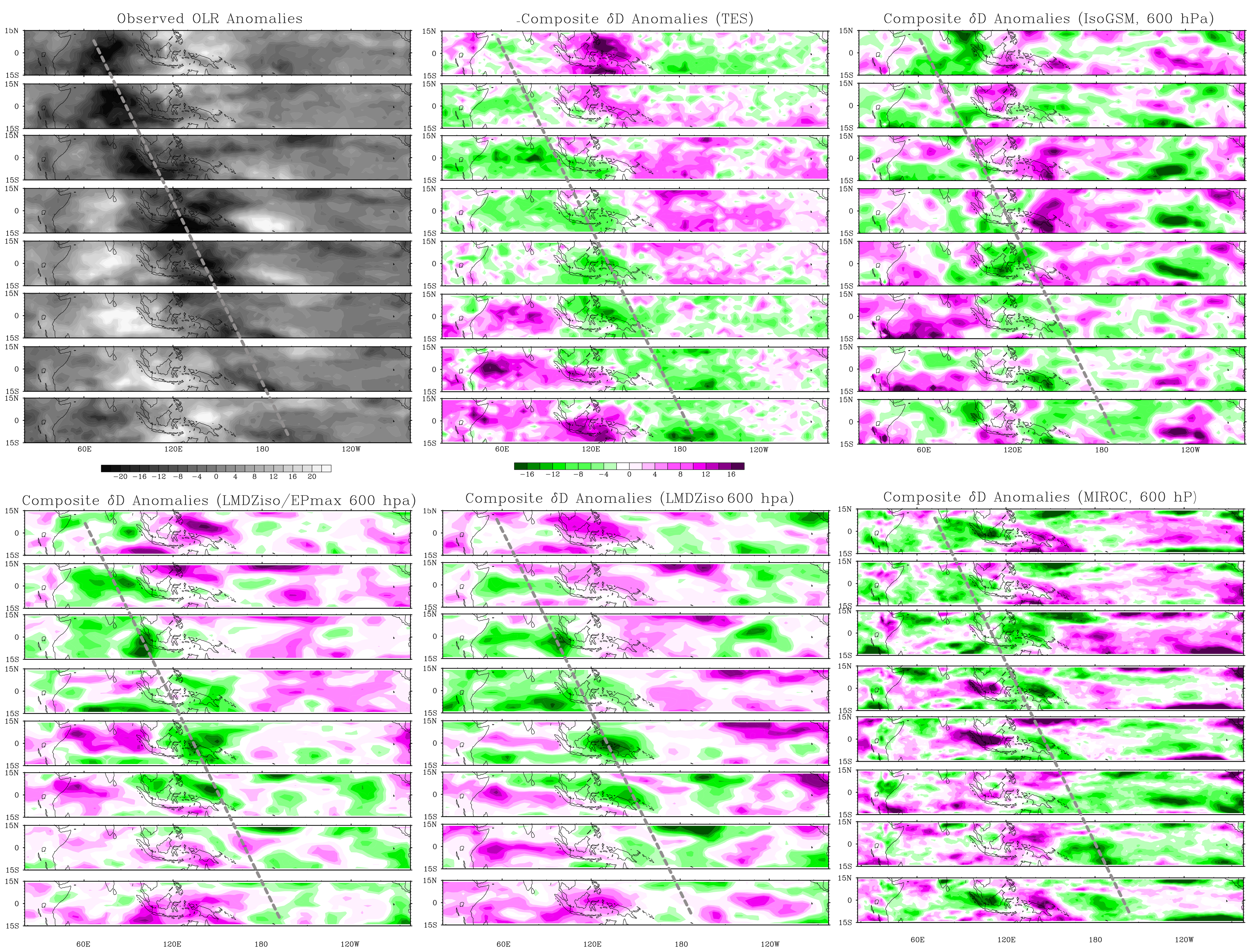
Water Isotope Basics:



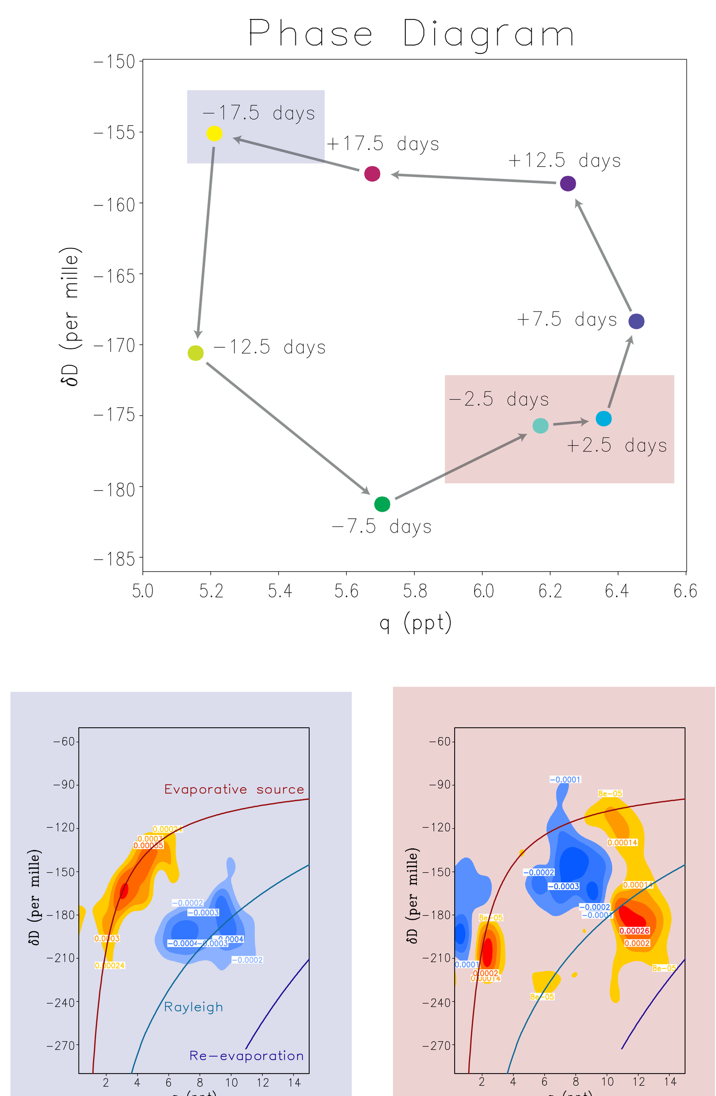


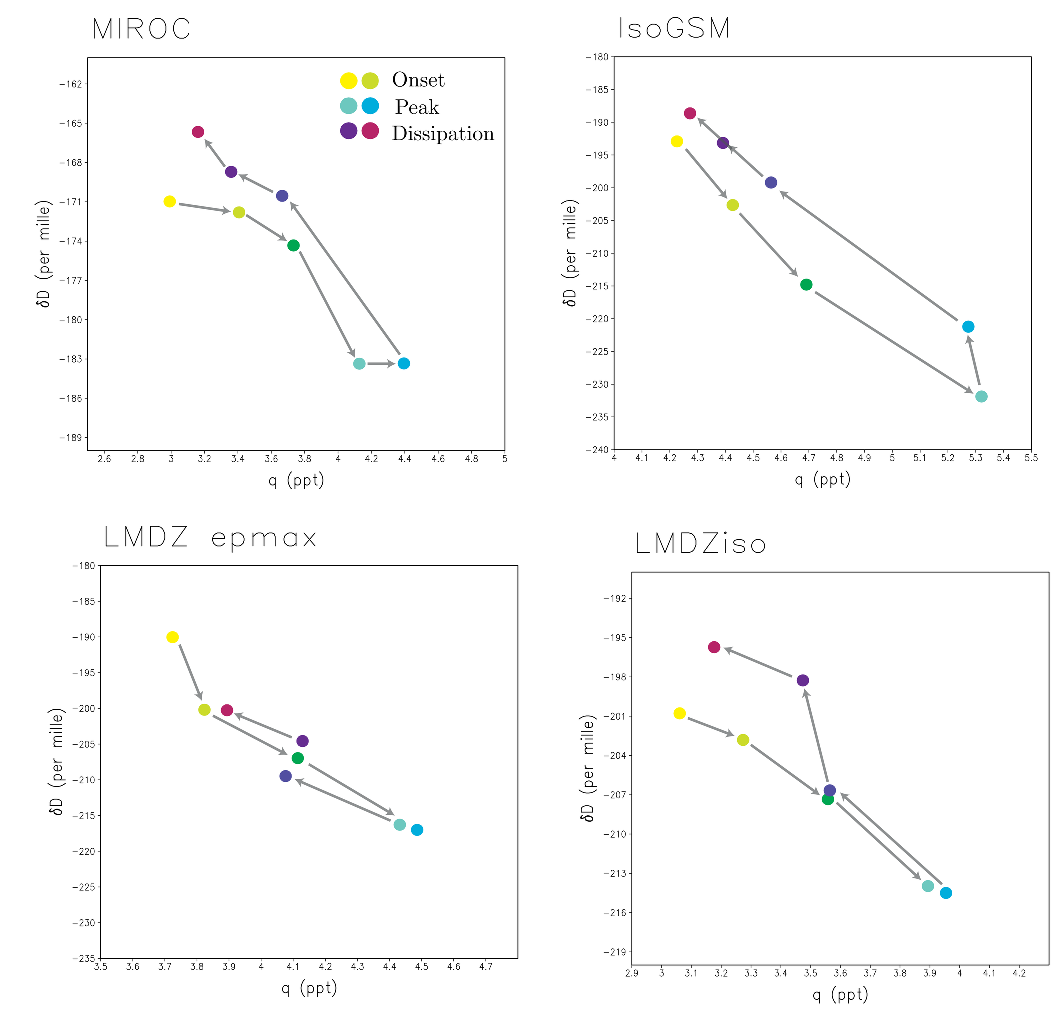


Space-time spectral analysis is used to determine power of different wave types. The power spectrum of OLR from observations and a nudged model show a clear signature of the MJO as well as Kelvin and Rossby waves (top left). Mid-tropospheric δD from TES shows clear MJO signal and Rossby but lacks Kelvin (top left). Comparable analysis on GCMs show similar features though with overall weaker power. This is particularly true in the MIROC model (bottom right). All values plotted on same logPower scale and the technique follows that of:
Wheeler and Kiladis 1999.



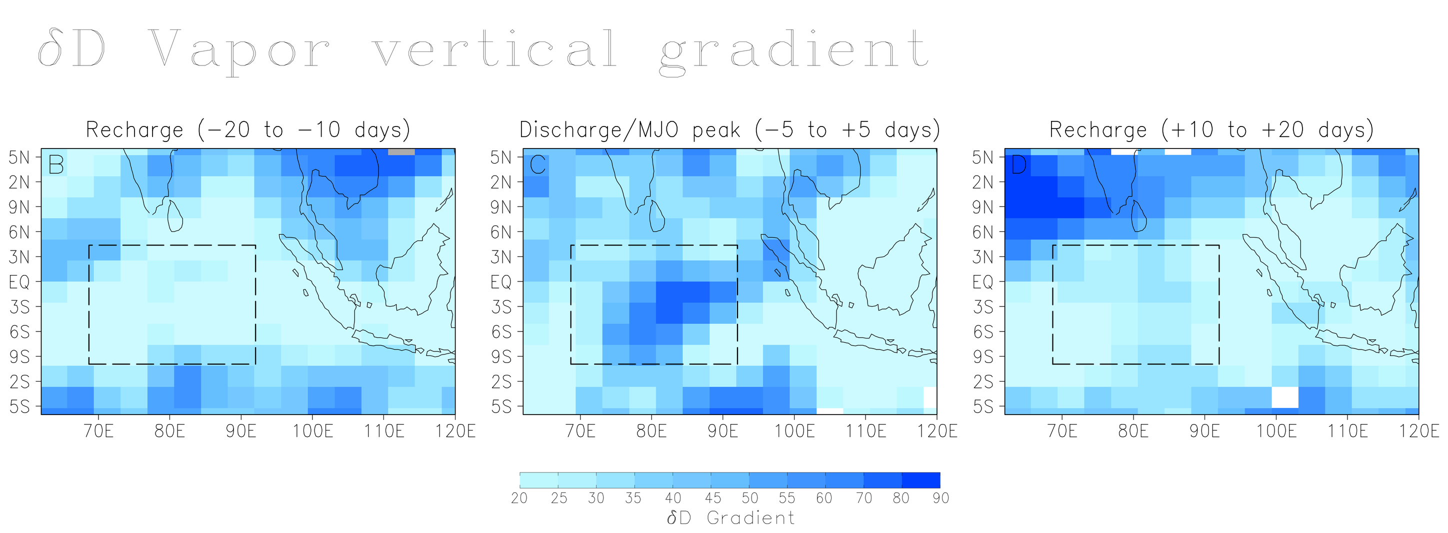
MJO Composite maps for 2005-2009 made by projecting anomalies of a given field onto the EOF-derived MJO strength. Clockwise starting top left: observed OLR, TES δD (~600 hpa), δD 600 hpa IsoGSM (Yoshimura et al., 2008), δD 600 hpa LMDZ (Risi et al., 2010) with enhanced entrainment rates, δD LMDZ and δD MIROC (Kurita et al., 2011). All isotopic anomalies are plotted on a common scale with dotted line indicating MJO progress.

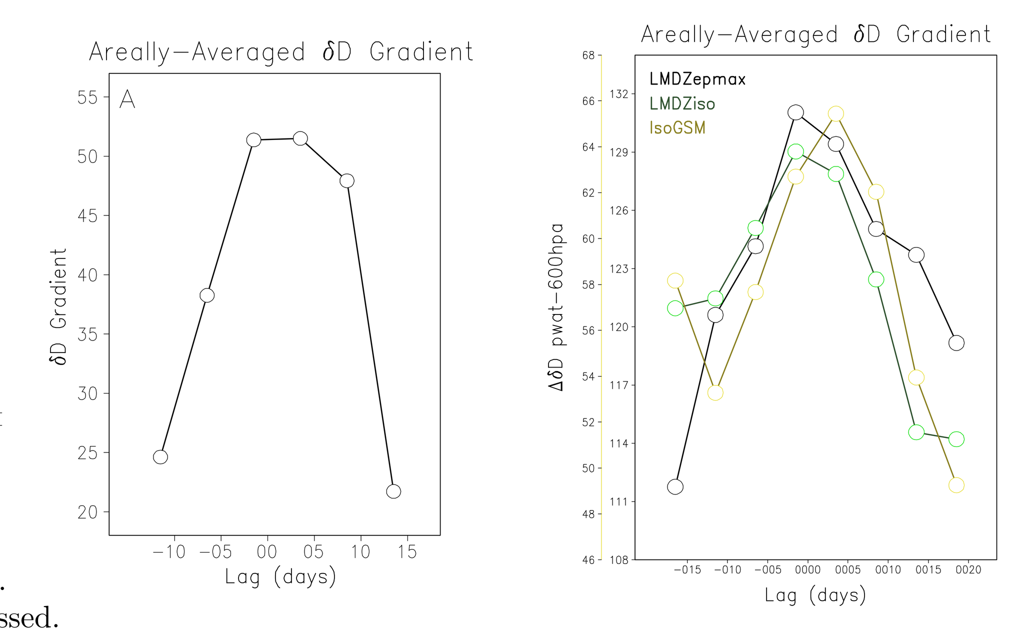




Isotopic phase diagram of the MJO as a function of joint changes in δD and q. Top left shows the trajectory for TES alongside joint pdf anomaly maps of onset and MJO peak. This indicates the clear evaporative source and that derived from rainfall evaporation. Trajectories for MIROC, IsoGSM and LMDZ are shown and reveal that all the GCMs produce a similar pattern through one that differs from the observations. This suggests the GCMs are not producing the correct moisture source transitions.

δD Vapor vertical gradient





The vertical gradient of δD is useful in understanding precipitation efficiency and different moisture sources as a function of altitude. We use 600hpa-precipitable water δD as an indicator of isotopic "lapse". This value increases systematically during the onset of MJO and rapidly relaxes after the system has passed. This feature is nicely replicated by all of the models. Note, the absolute vertical scale is not the same for all models but the amplitude is similar.

References:

LMDZ: Risi, C., S. Bony, F. Vimeux, and J. Jouzel (2010), Water-stable isotopes in the LMDZ4 general circulation model: Model evaluation for present-day and past climates and applications to climatic interpretations of tropical isotopic records, Journal of Geophysical Research

TES: Worden, J., D. Noone, K. Bowman, and T. E. Spect (2007), Importance of rain evaporation and continental convection in the tropical water cycle, Nature, 445 (7127)

IsoGSM: Yoshimura, K., Kanamitsu, M., Noone, D., & Oki, T.(2008). Historical isotope simulation using reanalysis atmospheric data. Journal of Geophysical Research-Atmosphere

MIROC: Kurita, N., D. Noone, C. Risi, G. Schmidt, H. Yamada, and K. Yoneyama (2011), Intraseasonal isotopic variation associated with the Madden-Julian Oscillation, Journal of Geophysical Research.

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