How does the tropical moist margin vary?

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What is the moist margin?

The moist margin is defined as the contour where total column water vapour (TCWV) is 48 kg m^{-2}. Rainfall over the tropical oceans tends to be confined to the region bounded by this margin (Mapes et al. 2018).

Our work examines how and why the moist margin moves across multiple time scales, including the seasonal cycle, synoptic variability and climate modes such as the El Niño Southern Oscillation (ENSO) and the Madden-Julian Oscillation (MJO).

Seasonal cycle

Figure 1 shows the TCWV mean and daily variance for DJF and JJA, where the purple contour shows the moist margin.

- The moist margin includes multiple features such as the tropical warm pool, the intertropical convergence zone (ITCZ), and the South Pacific convergence zone (SPCZ).
- There is a strong seasonal cycle in the margin, particularly in monsoonal regions such as Southeast Asia and northern Australia.
- Variance is largest in the areas straddling outside the margin, suggesting that these areas are ‘hotspots’ for synoptic and longer variability. Variance is smaller inside the margin, suggesting these areas tend to remain moist.
- The diagonal convergence zones (e.g. SPCZ) are clearer as regions of high TCWV variance, rather than high means.

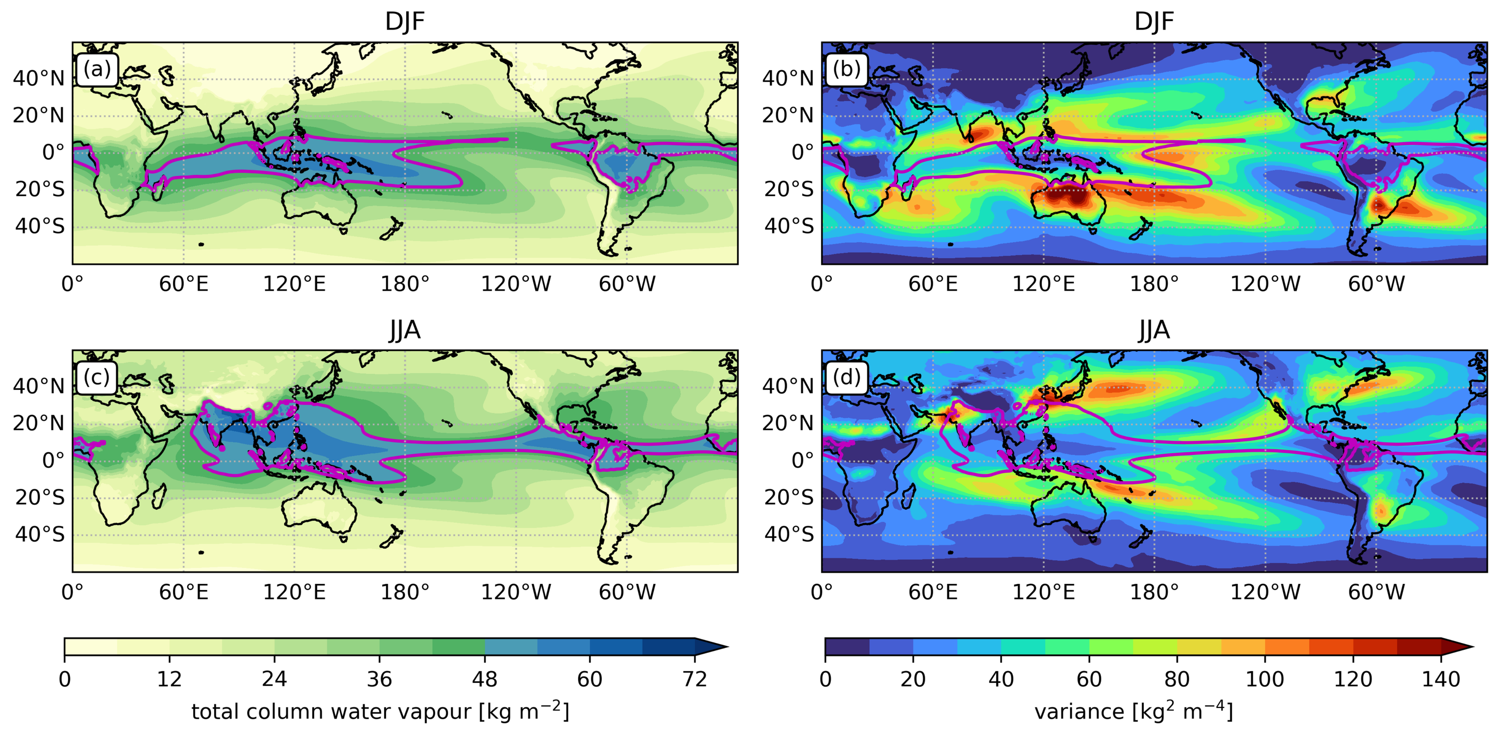

Fig. 1: ERA5 total column water vapour mean (left) and daily variance (right) for DJF (top) and JJA (bottom).

Climate modes

ENSO

Figure 2 shows how ENSO affects the moist margin. The largest difference is in the central Pacific, where the margin is continuous during El Niño but separated during La Niña.

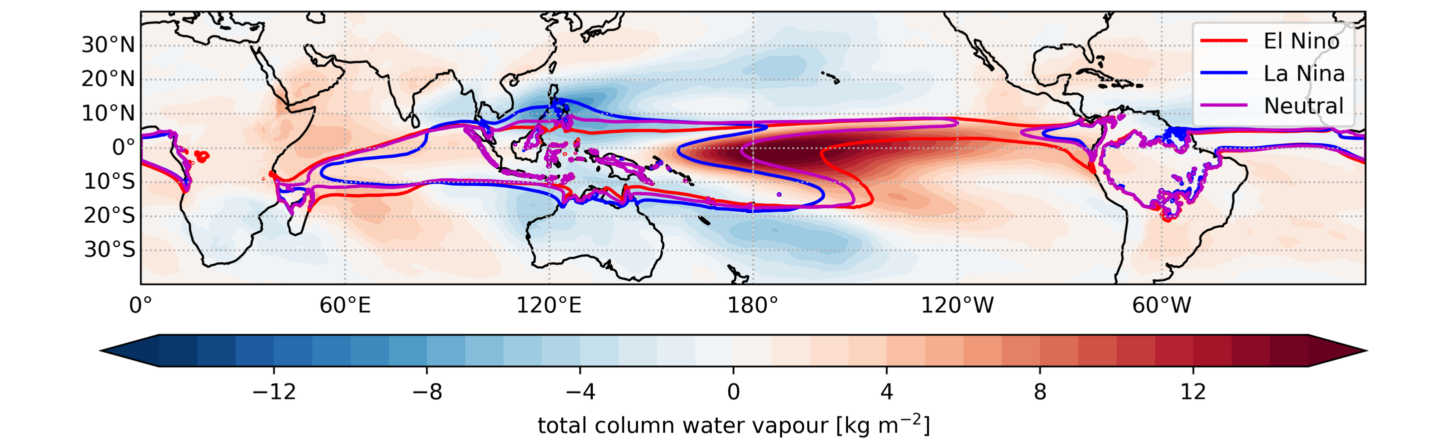

Fig. 2: Moist margin under El Niño months (red), La Niña months (blue) and neutral months (purple) for extended summer NDJFM. Shading shows the mean TCWV difference between El Niño and La Niña.

MJO

Figure 3 shows that the moist margin bulges slightly outward in the active area of the MJO, and inward in the suppressed area. However, TCWV anomalies are small and mostly below 5 kg m^{-2}.

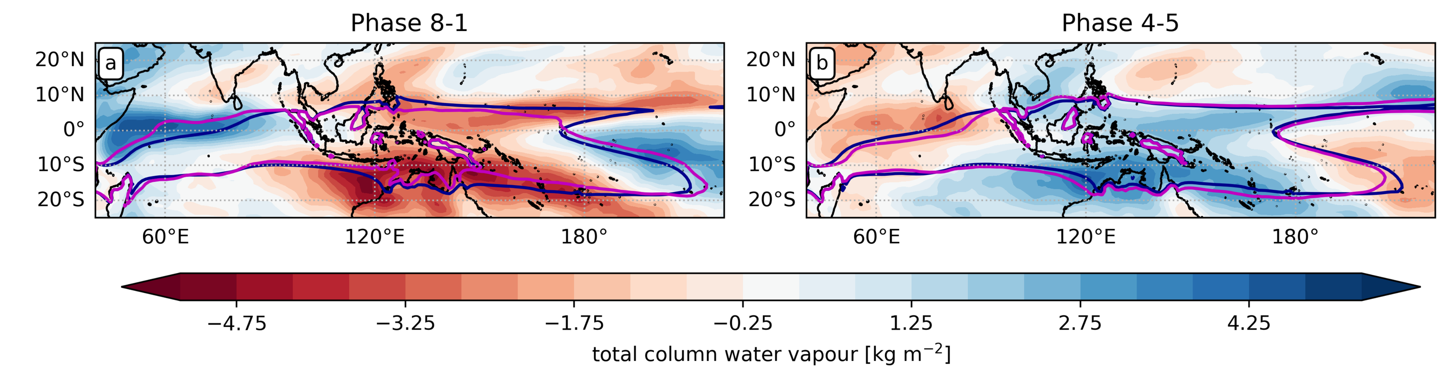

Fig. 3: TCWV anomalies (shading) and moist margin (purple contour) during DJF for MJO phases 8-1 and 4-5. The basic state margin for all MJO phases is in dark blue.

Synoptic variability

To examine synoptic variability in the moist margin, we create objects based on the TCWV compared to its 15-day running mean seasonal climatology. The four categories are:

- Wet perturbations (TCWV currently above 48 kg m^{-2} and below in climatology)
- Dry perturbations (TCWV currently below 48 kg m^{-2} and above in climatology)
- Wet normal (current and climatology TCWV above 48 kg m^{-2})
- Dry normal (current and climatology TCWV below 48 kg m^{-2})

An example of this for 28 Jan 2019 is shown in Figure 4. Features include:

- Tropical Cyclone Riley off northwest Australia
- A monsoon low over northeast Australia
- A frontal structure in the southwest Pacific
- A wet-dry-wet wave-like pattern in the west and central Pacific

Perturbations tend to occur in the shoulder regions of the moist tropics, and are more frequent in the summer hemisphere. Wet perturbations are generally more frequent, larger and stronger than dry perturbations. This is consistent with Figure 1, which shows variance is largest outside the margin.

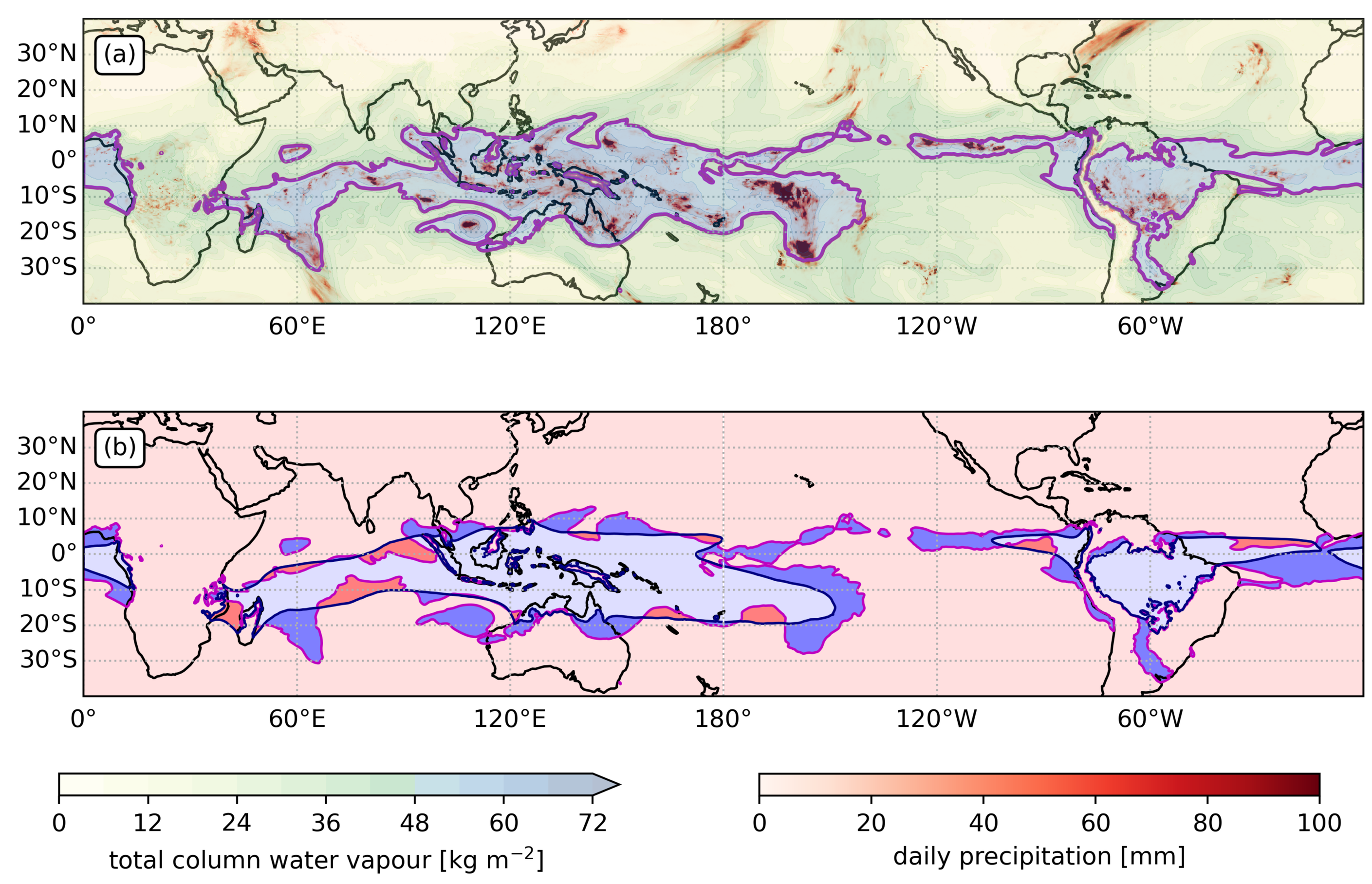

Fig. 4: Daily mean TCWV (shading), moist margin (purple contour), and precipitation (red shading) for 28 Jan 2019 (a). Corresponding categories are shown in the panel b, where the navy contour is the basic state margin. Colours are as in the text.

Perturbations create anomalous rainfall

Figure 5 shows that wet perturbations produce over 50% more rainfall compared to normal, and this value increases up to 800% in higher latitudes. Similarly, dry perturbations reduce the rainfall by over 60% for most of the tropics.

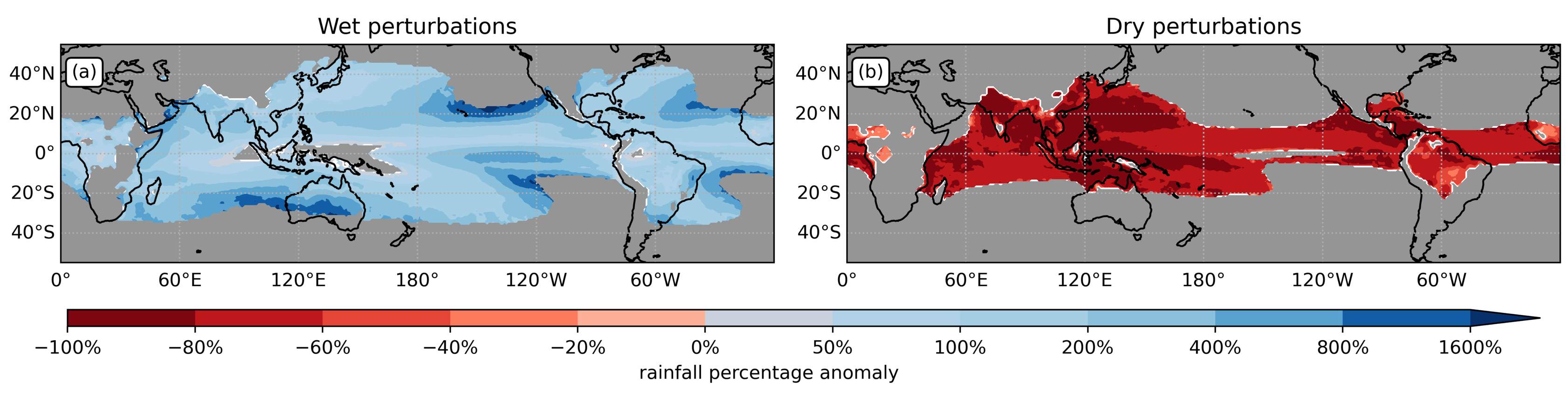

Fig. 5: Percentage anomaly of rainfall compared to climatology for wet perturbations (left) and dry perturbations (right).

Large-scale controls for perturbations

Advection of mid-level moisture

The largest difference in moisture between wet and dry perturbations is in the mid-troposphere. Along with moisture budget analysis, this implies that the advection and convergence of mid-level moisture is key for pushing the atmosphere into a wet or dry perturbation.

Role of sea surface temperature

Sea surface temperatures have minimal effect on TCWV anomalies on daily time scales. However, there is a stronger positive correlation on monthly time scales, reflecting the influence of processes such as ENSO.

References

Mapes, B. E. et al. (2018). The Meandering Margin of the Meteorological Moist Tropics. *Geophysical Research Letters* 45.2, pp. 1177–1184.

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