

Supplementary Information

What drives the Mesoamerican Midsummer Drought? Insights from the moist static energy budget

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Climate Dynamics

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1 Gross moist stability

In addition to the bouyancy metric B , we compute two forms of the gross moist stability (GMS), also labelled as Γ , which characterize the efficiency with which the large-scale circulation exports moist static energy from the column [Raymond et al., 2009, Inoue and Back, 2017]. In general, when Γ is negative the circulation imports MSE, favouring convective amplification whereas positive values indicate export with larger positive values indicating efficient MSE export and a more stable, self-limiting convective regime [Inoue and Back, 2017].

The vertical normalized GMS is defined as

$$\Gamma_v = \frac{\left\langle \omega \frac{dh}{dp} \right\rangle}{\left\langle \omega \frac{ds}{dp} \right\rangle}, \quad (1)$$

where the numerator captures the net MSE export by the vertical circulation, while the denominator normalizes by the dry static energy convergence, yielding a dimensionless measure of how effectively vertical motion exports moisture relative to the dry energetic forcing [Neelin and Held, 1987, Raymond et al., 2009, Benedict et al., 2014].

The horizontal normalized GMS is defined as:

$$\Gamma_h = \frac{\langle \vec{u} \cdot \nabla Lq \rangle}{\left\langle \omega \frac{ds}{dp} \right\rangle}, \quad (2)$$

which measures the horizontal advection of moisture by the large-scale flow, normalised by the same dry static energy reference as the vertical GMS [Inoue and Back, 2017]. Large positive values of Γ_h indicate that horizontal winds export moisture from the column, while large negative values reflect moisture import, supporting column moistening and destabilization [Raymond et al., 2009, Inoue and Back, 2017].

References

- James J Benedict, Eric D Maloney, Adam H Sobel, and Dargan MW Frierson. Gross moist stability and mjo simulation skill in three full-physics gcms. *Journal of the Atmospheric Sciences*, 71(9): 3327–3349, 2014.
- Kuniaki Inoue and Larissa E. Back. Gross Moist Stability Analysis: Assessment of Satellite-Based Products in the GMS Plane. *Journal of the Atmospheric Sciences*, 74(6):1819–1837, 2017. ISSN 0022-4928, 1520-0469. doi: 10.1175/JAS-D-16-0218.1. URL <https://journals.ametsoc.org/doi/10.1175/JAS-D-16-0218.1>.
- J David Neelin and Isaac M Held. Modeling tropical convergence based on the moist static energy budget. *Monthly Weather Review*, 115(1):3–12, 1987.
- David J Raymond, Sharon L Sessions, Adam H Sobel, and Željka Fuchs. The mechanics of gross moist stability. *Journal of Advances in Modeling Earth Systems*, 1(3), 2009.

2 Supplementary Figures

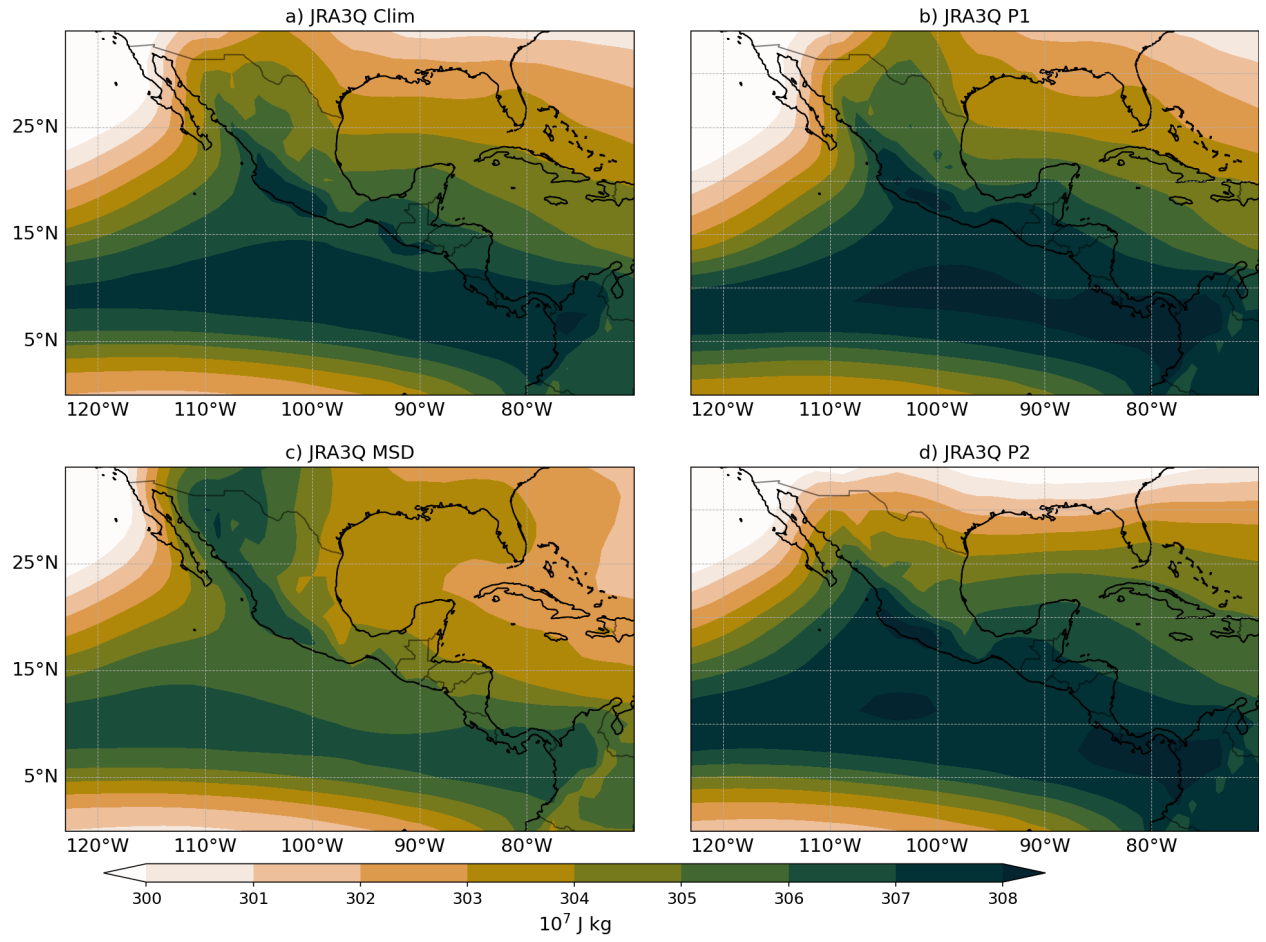


Figure S1: Composites of column-integrated MSE ($\langle h \rangle$ in J kg^{-1}) separated by stage of the rainy season, including the a) rainy season climatology, and during the b) first peak of precipitation, c) the MSD and d) the second peak of precipitation (P2). Data is from JRA3Q.

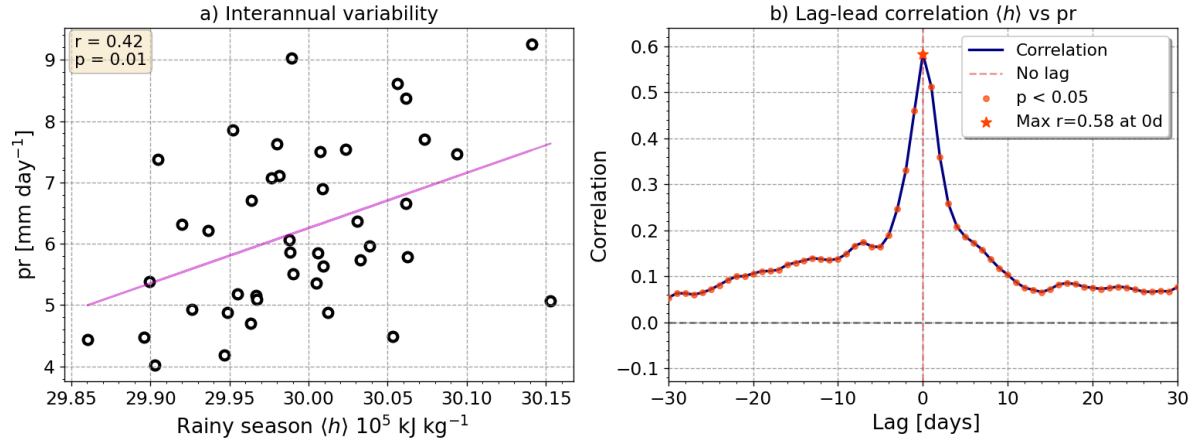


Figure S2: a) Scatterplot of the rainy season mean column-integrated MSE ($\langle h \rangle$ in J kg^{-1}) versus precipitation [mm day^{-1}] per year in ERA5. Each dot represents a season/year. b) Lag-lead correlation of daily column-integrated MSE ($\langle h \rangle$ in J kg^{-1}) versus daily precipitation. The correlations were computed using data from the rainy season (onset to retreat) only.

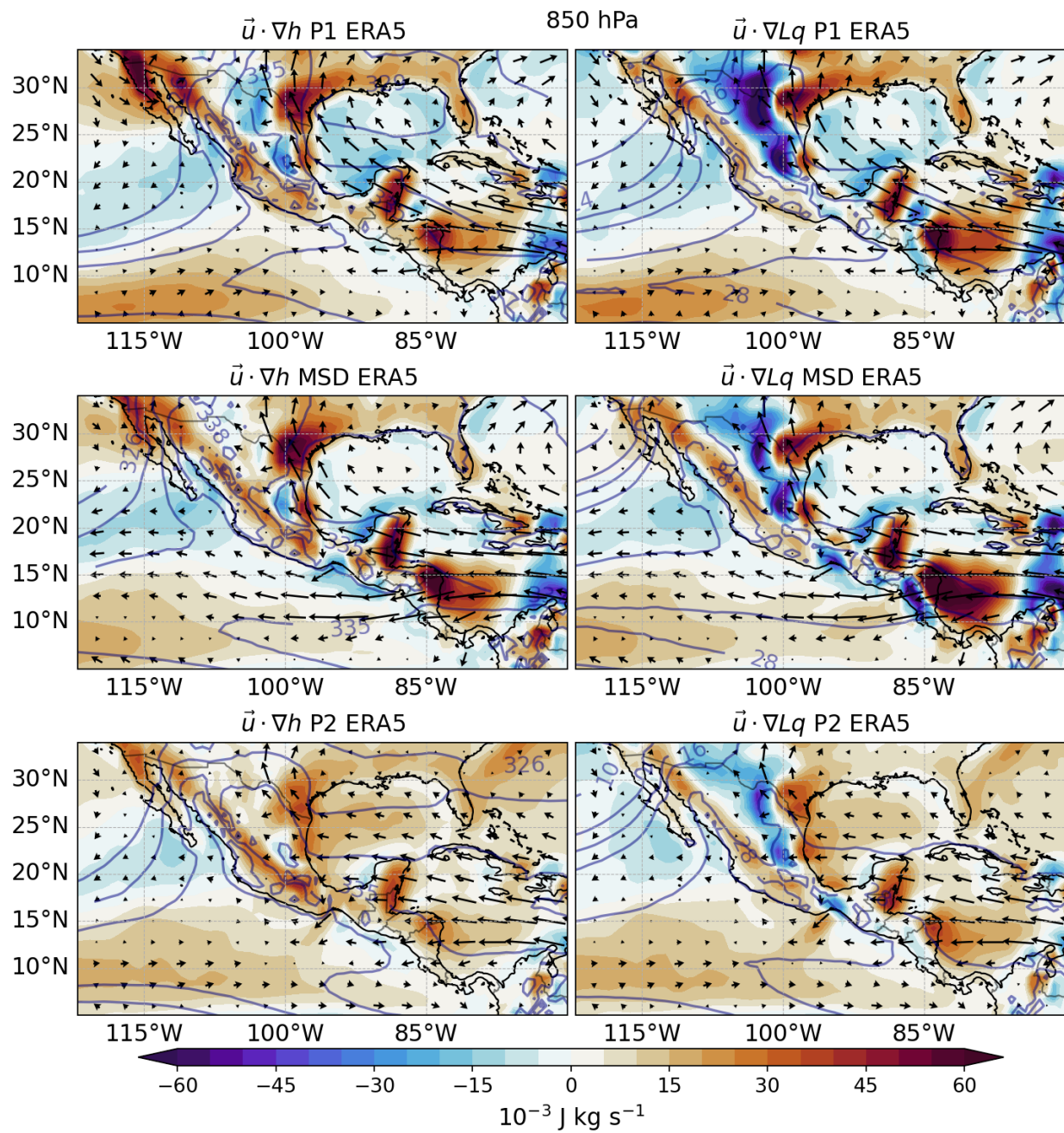


Figure S3: Composites of 850-hPa average horizontal advection of (left) MSE $\vec{u} \cdot \nabla h$ and (right) and latent energy term $\vec{u} \cdot \nabla Lq$ from ERA5. The vectors show the wind speed and direction, whereas the blue contour lines show the (left) MSE and (right) Lq absolute values [10^3 kJ] at the same 850-hPa level.

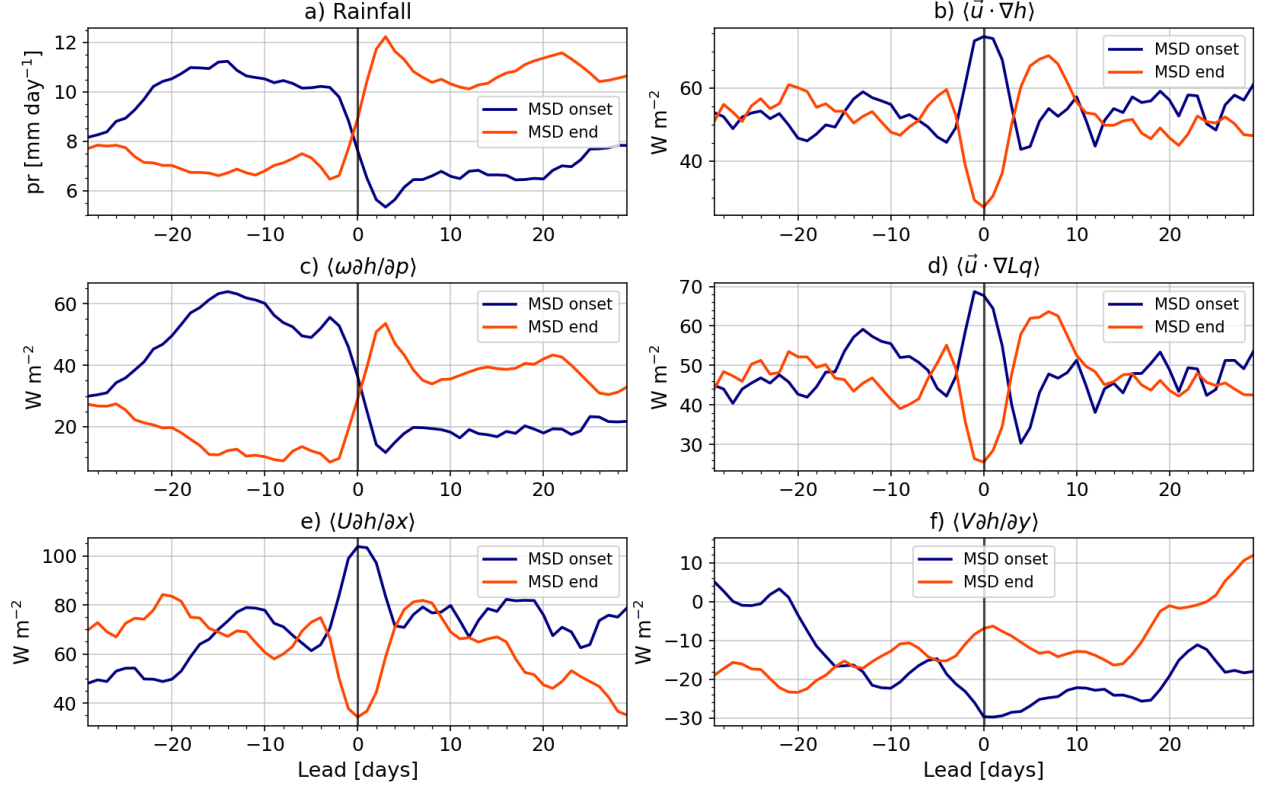


Figure S4: Lag-lead composites of rainy-season daily mean horizontal advection terms including a) precipitation, b) $\langle \vec{u} \cdot \nabla h \rangle$, c) the vertical MSE advection, d) the moisture advection $\langle \vec{u} \cdot \nabla Lq \rangle$, and the MSE advection split by e) zonal and f) meridional components. Lag-0 represents the dates of MSD onset or end as labelled in the legend. Data is from the blend of observational precipitation for panel a) and ERA5 for the rest of the panels.

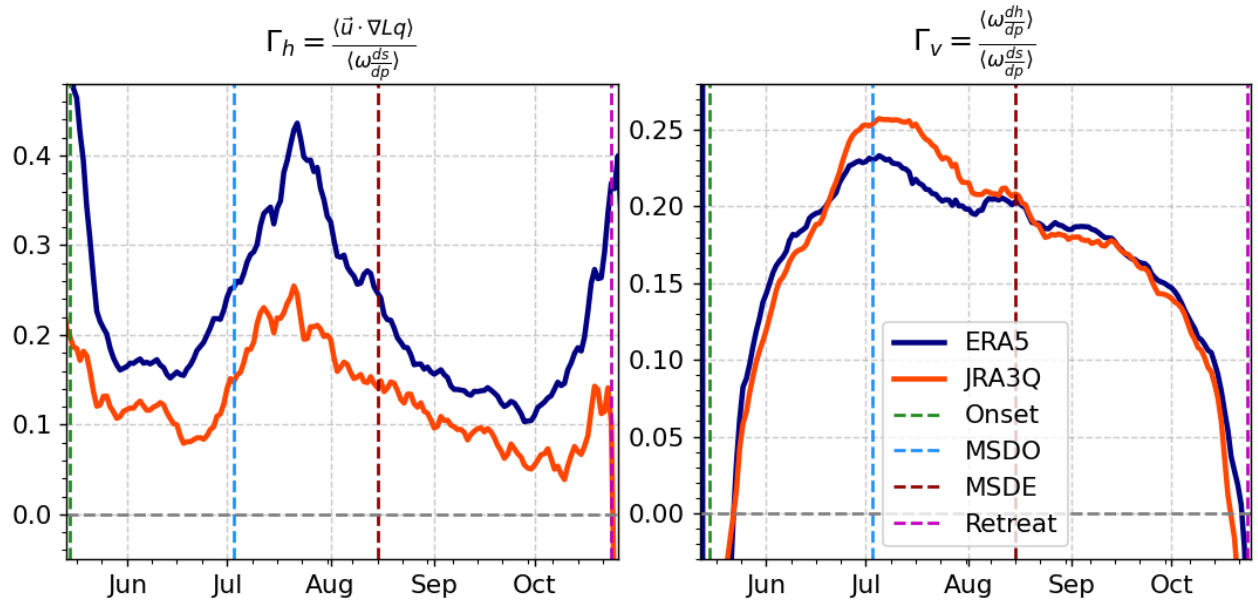


Figure S5: Seasonal cycle of the gross moist stability over land split into the a) horizontal Γ_h and b) vertical components Γ_v .

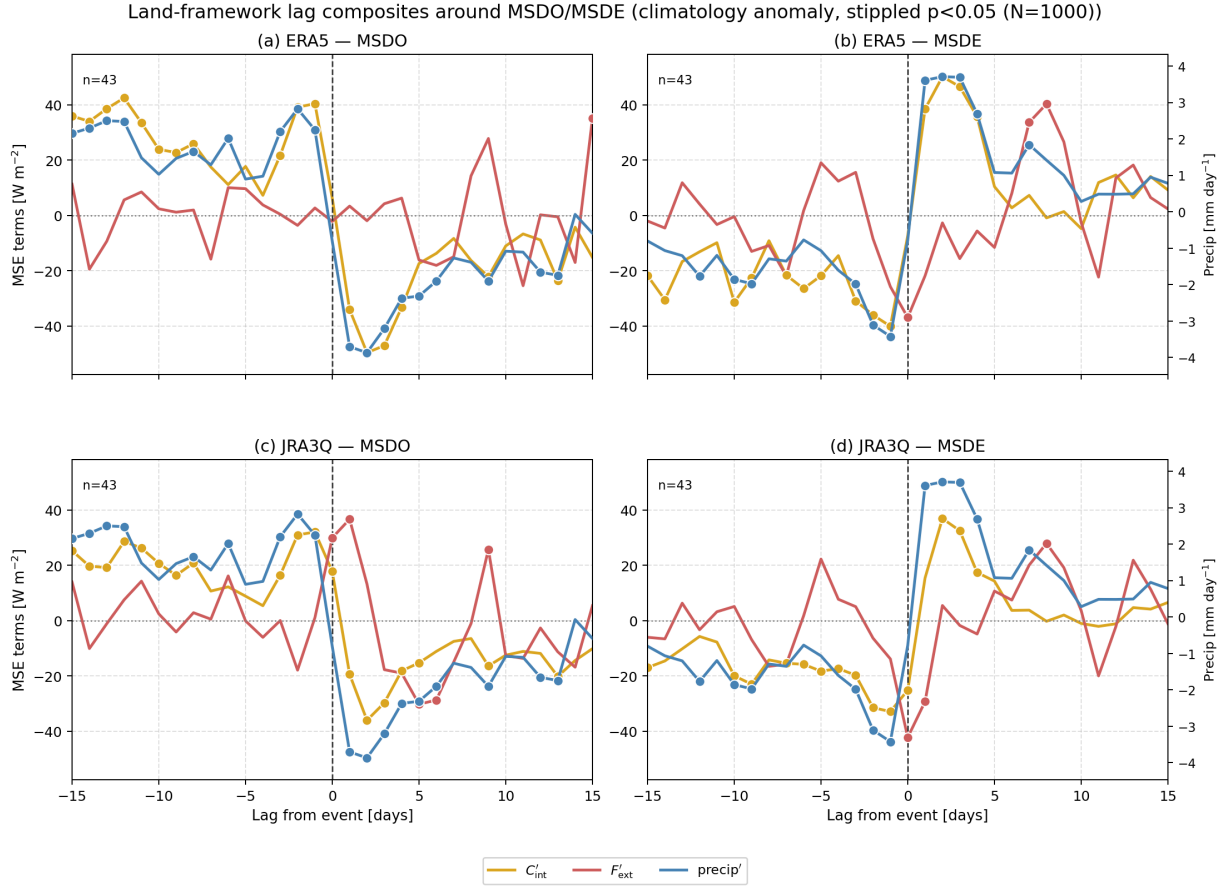


Figure S6: Lag lead anomaly composites averaged with respect to each year's dates of a-c) MSDO and b-d) MSDE for both reanalysis datasets. Plotted are the composites of the column process and external forcing processes, as well as precipitation.