Mechanisms behind the occurrence of convective systems in Northwestern South America: results from a cloud-resolving simulation

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Introduction

- Convective Systems (CS) largely contribute to total precipitation in North-Western South America and are associated with high-impact events.
- Convection-permitting (CP) simulations allow to understand processes related to the CS events.
- In this study, we investigated diurnal mechanisms associated with the occurrence of convective systems in different regions of Colombia using a CP simulation.

Data and methods

- A one-month CP (4km) WRF simulation was performed in September-October 2019. Parameterization schemes were based on a previous analysis.
- A CS tracking algorithm was used to identify systems for the analysis and evaluate the model performance against satellite data.
- Days with strong convection and high CS occurrence were selected using an 80th percentile threshold during the rainfall peak.

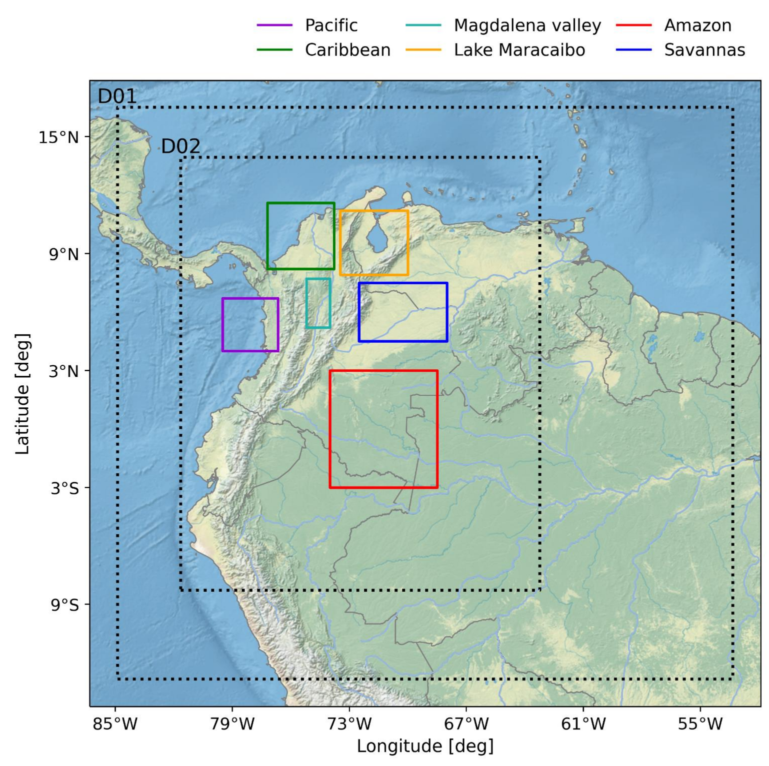

Figure 1. WRF domain configuration and regions of interest. D01: 12 km, D02: 4km.

Model evaluation

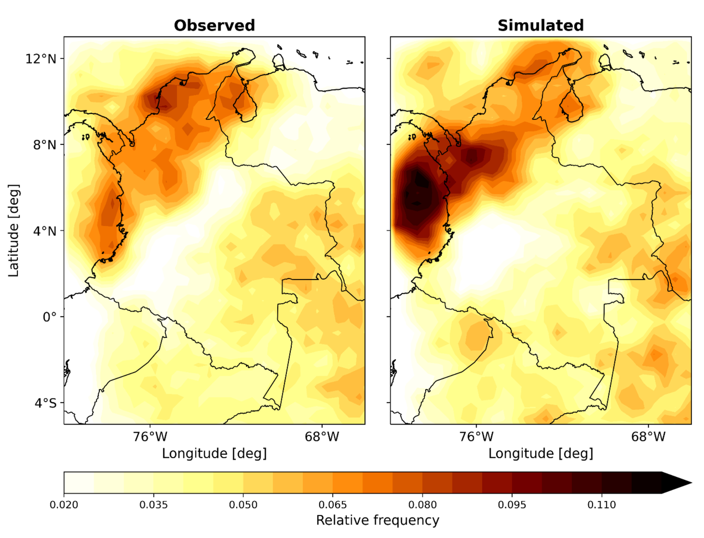

Figure 2. Relative frequency of CS occurrence observed (left panel) and simulated by WRF (right panel) during the study period

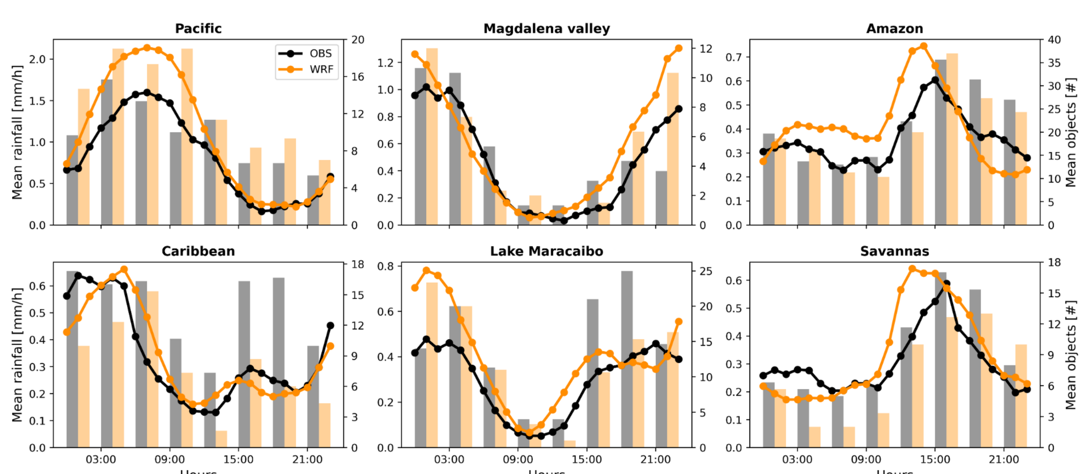

Figure 3. Diurnal cycle of rainfall (lines) and CS objects (bars) averaged in the different regions of interest. Results for the model are depicted in orange, while observations are represented by gray and black colors.

Table 1. Characteristics of CS identified around the diurnal maximum rainfall peak (3 hours prior to 3 hours after) for dry and wet days. The dry and wet days were selected based on a threshold criteria of less than 20th percentile for dry and more than 80th percentile for wet.

Region	Period	Objects (#)	Area (km2)	Prec. (mm/h)	Duration (h)
Pacific	Dry	1	32746.5	11.1	7.0
	Wet	19	65800.9	16.7	9.1
Magdalena valley	Dry	1	15644.7	12.0	7.0
	Wet	16	21326.7	12.0	7.3
Amazon	Dry	3	9899.6	10.7	8.0
	Wet	20	16719.6	12.3	7.5

- Spatial patterns of CS simulated by WRF agree with observations. CS occurred with higher frequency in the northernmost part of the country and the Pacific.
- Regions exhibited differences in the rainfall diurnal cycle. The WRF model captured the variations depending on the region.
- Selected dry and wet periods presented differential CS features around the maximum rainfall peak (following Fig. 3).

Mechanisms

Pacific

- Days with high CS occurrence are characterized by an enhanced low-level moisture flux towards the Andes.
- Updrafts were higher in wet days compared against dry days, with a marked increase 6 hours before the rainfall maxima.
- A higher zonal wind shear was also evidenced, which coincides with other studies in the region. CAPE increased prior to the event and then fell off.

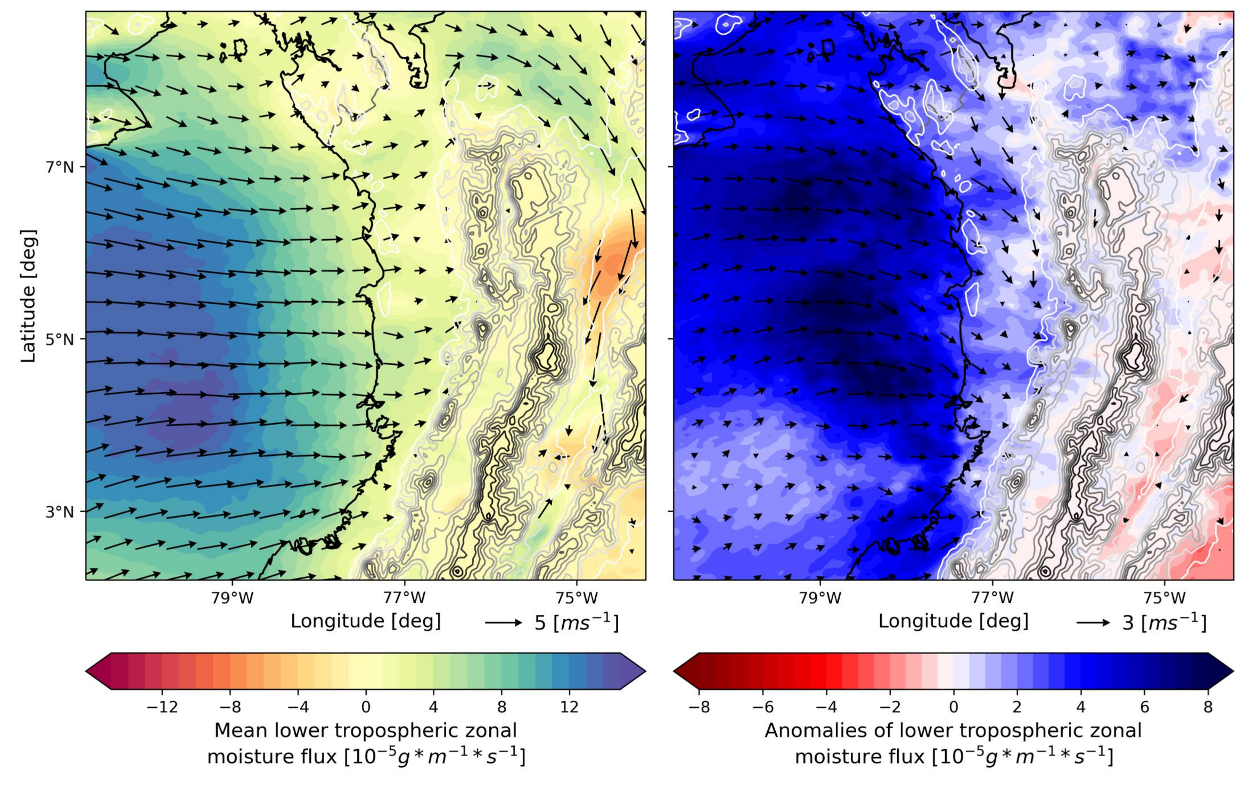

Figure 4. Left panel: lower tropospheric zonal moisture flux (contours) and winds at 925 hPa averaged from 10 to 4 hours before the rainfall peak in the Pacific region. Right panel: anomalies of these fields during the same hours for the wet days.

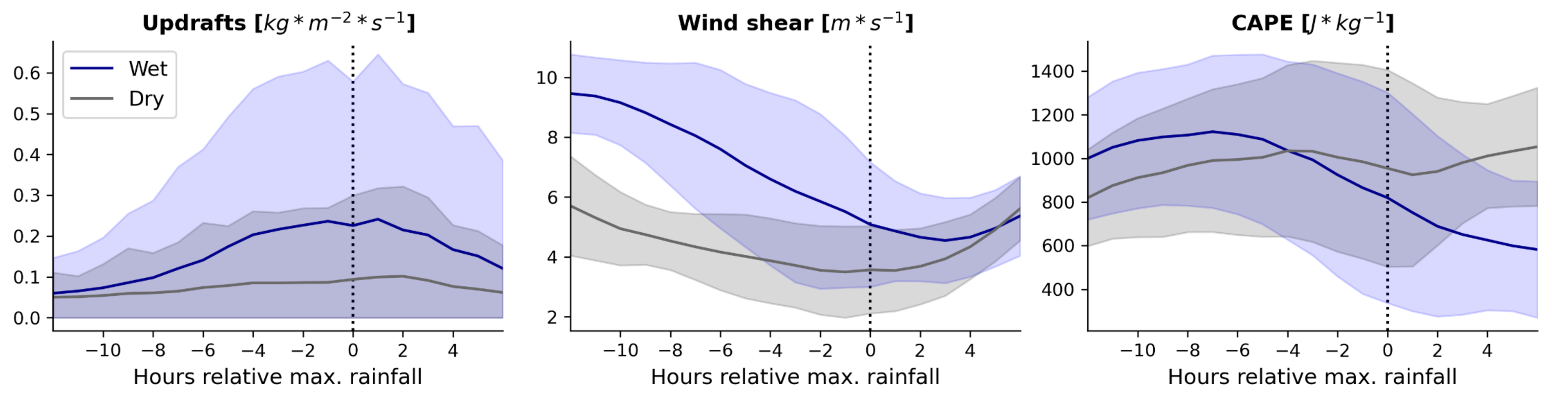

Figure 5. Series relative to the rainfall peak for updrafts (left), 925hPa-700hPa zonal wind shear (center) and Convective Available Potential Energy (CAPE, right) in the Pacific. Series were computed both for dry (gray) and wet (blue) conditions. Shaded areas represent one standard deviation uncertainties..

Magdalena

- Prior to the peak, down-valley dry winds prevailed and moisture downwards increased.
- Easterly winds at 500 hPa weakened during days with enhanced rainfall.
- CAPE was even lower than dry days before the rainfall peak and then presented lower values.

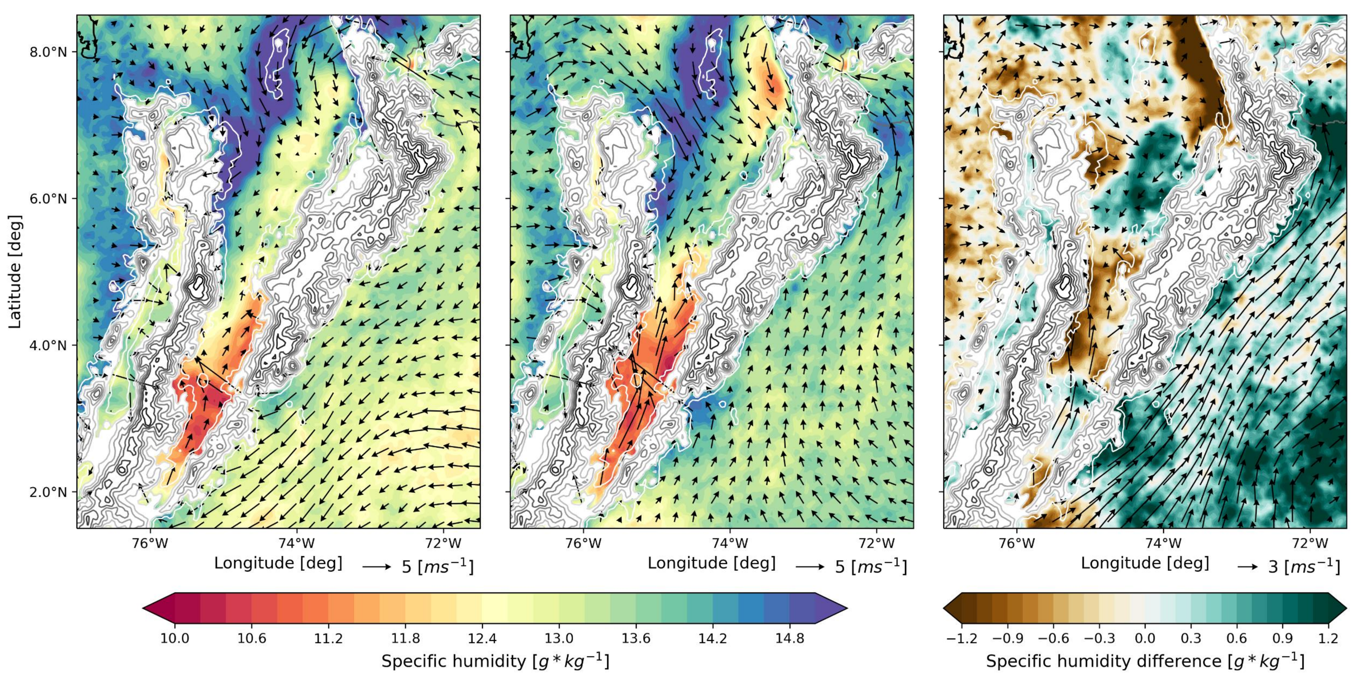

Figure 6. Left panel: composites of 850 hPa specific humidity (contours) and winds at 850 hPa calculated from 8 to 4 hours before the diurnal rainfall peak during dry days for the Magdalena valley region. The center panel shows the same but for wet days. Right panel: differences between the wet and dry fields (center minus left).

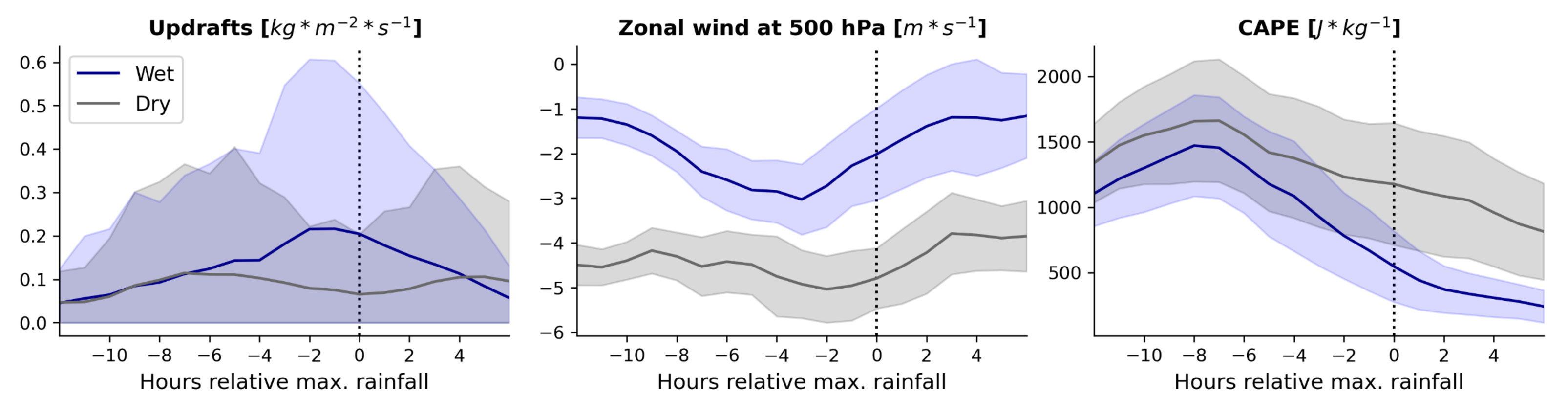

Figure 7. Series relative to the rainfall peak for updrafts (left), zonal wind at 850hPa (center) and CAPE (right) in the Magdalena valley. Series were computed both for dry (gray) and wet (blue) conditions. Shaded areas represent uncertainties of one standard deviation.

Amazon

- Wet days were associated with enhanced moisture flux from the Amazon rainforest and the Orinoco LLJ. This enhanced the convergence and thus convection in the region.
- The updrafts were stronger for wet days, especially a couple of hours prior to the rainfall peak.
- Events developed in a most sheared environment, which is associated with an increment in 700 hPa zonal winds.

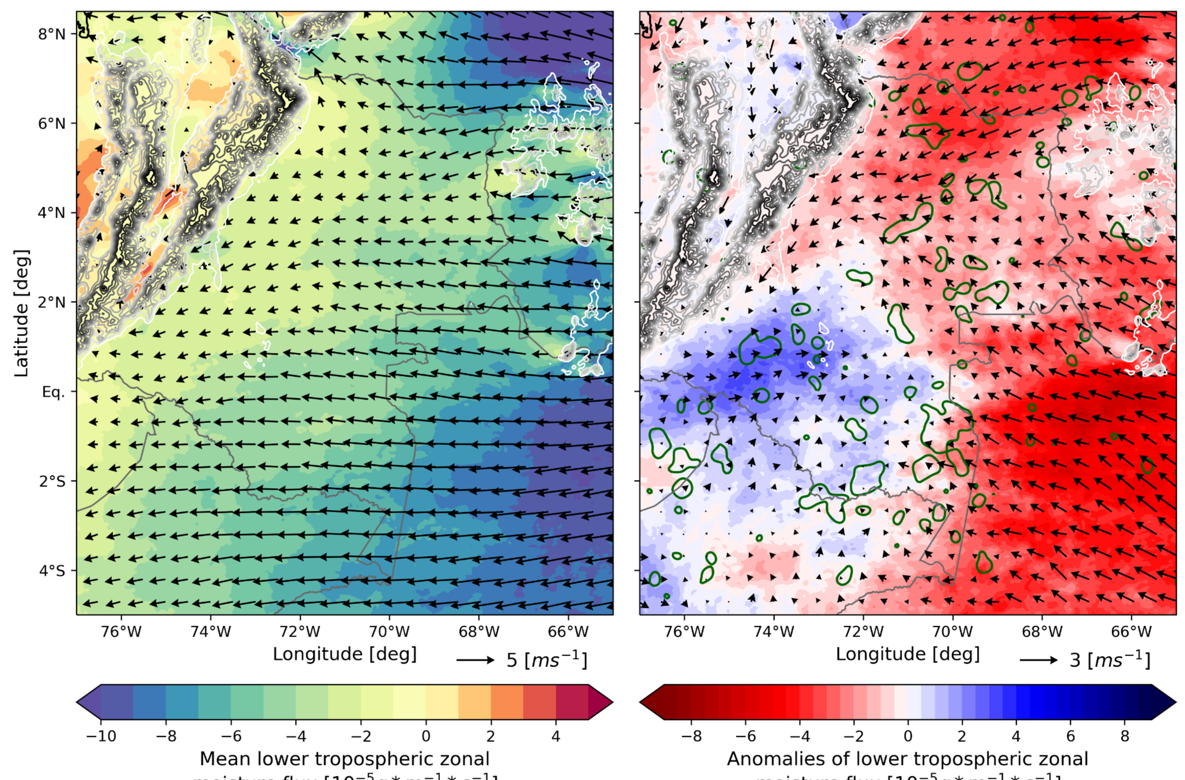

Figure 8. Left panel: lower tropospheric zonal moisture flux (contours) and winds at 850 hPa averaged from 12 to 4 hours before the rainfall peak in the Amazon region. Right panel: anomalies of these fields during the same hours for the wet days. Anomalies of 8 cm/s vertical velocity are represented in green contours.

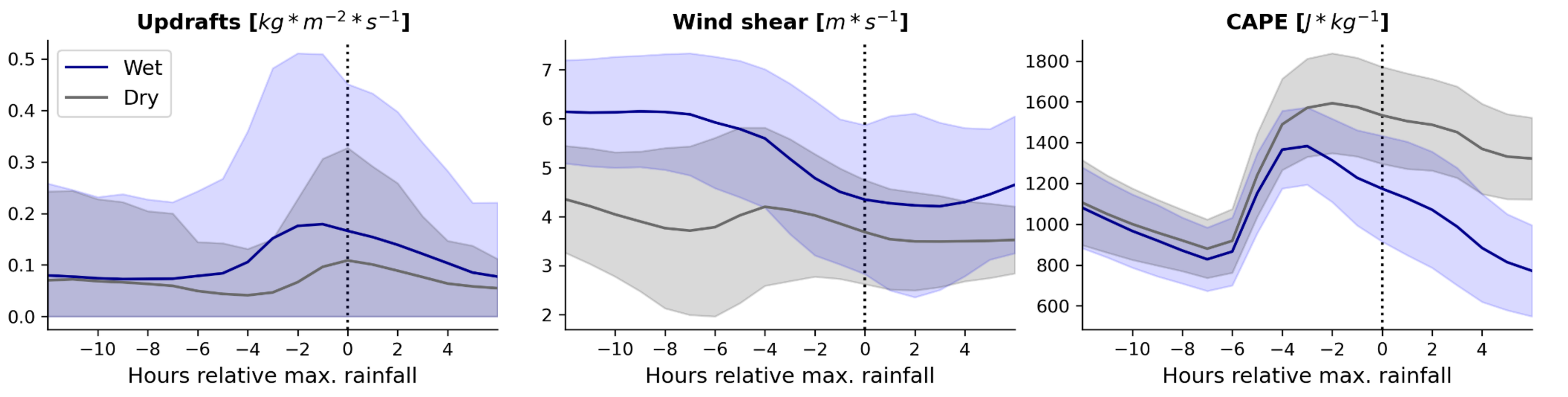

Figure 9. Series relative to the rainfall peak for updrafts (left), 925hPa-700hPa zonal wind shear (center) and CAPE (right) in the Amazon. Series were computed both for dry (gray) and wet (blue) conditions. Shaded areas represent uncertainties of one standard deviation.

Conclusions

- The WRF model was able to represent the main spatial and diurnal patterns of convective systems for the different regions. Besides, the selected dry and wet periods showed different CS features. The three selected regions exhibited differential patterns during convection-enhanced days.
- In the Pacific, an increase in zonal moisture flux towards the range favors the development of the systems. Intra-valley dynamics are determinant for the development of the convection in the Magdalena, also medium-level patterns seem to be relevant. Finally, convection is related to an increase in low-level moisture fluxes in the Amazon region, while CAPE was not decisive.
- Future work will be focused on the assessment for other seasons, analyzes of other regions of the country, and linking these mechanisms to the organization of convection.

Acknowledgments

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