Characterization of the Convective Environment Over the Western Caribbean and Eastern Pacific Associated with Deep Convection: Goals of OTREC Land-based Observations

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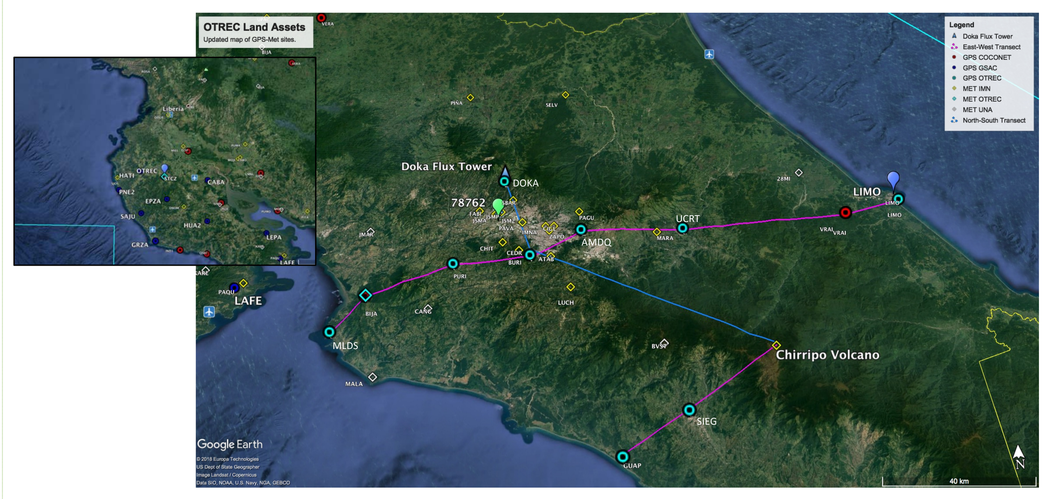
Questions

How does the water vapor environment differ over the western Caribbean Sea and tropical eastern Pacific as deep convection initiates and grows in these regions?

What are the feedbacks between the evolving convection and its environment over water vs land?

How do these interactions affect the trajectories of propagation for these systems?

What is the relative role of low-level moisture vs surface heat and moisture fluxes over tropical ocean and land in supporting the growth of convection?



Abstract

The upcoming Organization of Tropical East Pacific Convection (OTREC) field campaign, scheduled for August-September 2019, is focused on better understanding the controlling mechanisms on atmospheric convection over the western Caribbean and far eastern Pacific. These are very different regimes in terms of both the underlying sea surface temperature, low-level wind speeds, and free tropospheric moisture. Nevertheless, deep convection organized across a range of scales, from mesoscale convective systems to sub-seasonal convectively coupled waves, is observed in both regimes. In addition, convection formed over land in this region experiences upscale growth as it propagates to the surrounding oceans on either side of Central America. We will use dropsondes released from aircraft over the waters east and west of Coast Rica, radiosonde sites on both the east and west coasts of the country, and a network of GPS-Met surface stations across Costa Rica, in addition to a broader pre-existing GPS-Met network throughout northern South America, the Caribbean and up into southern Mexico, to address the main questions for this project. The unique data set to be collected as part of OTREC will allow a more complete understanding of the role of moisture in controlling the growth and organization of tropical convection over both land and ocean regions, as well as the role of the land surface in initiating and/or maintaining propagating convection across Central America - the land bridge between the Caribbean and tropical eastern Pacific.

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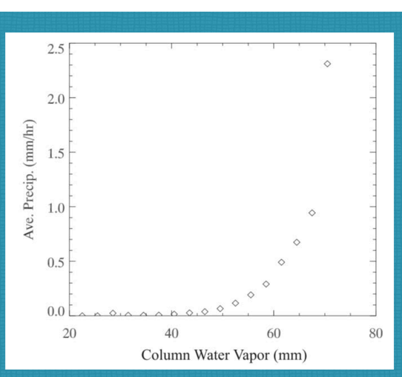
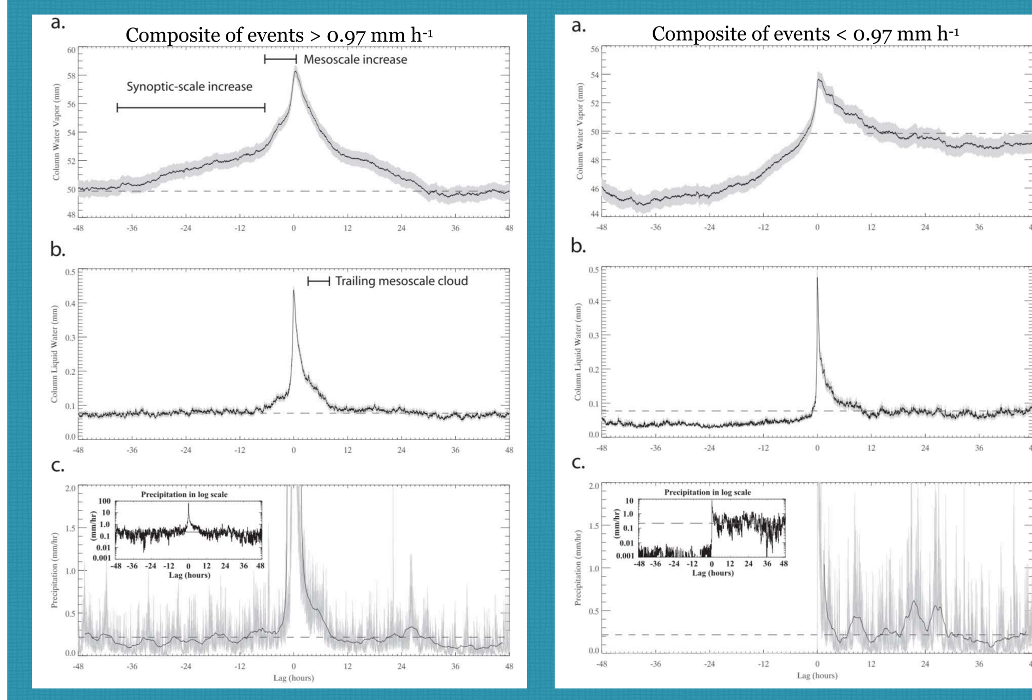
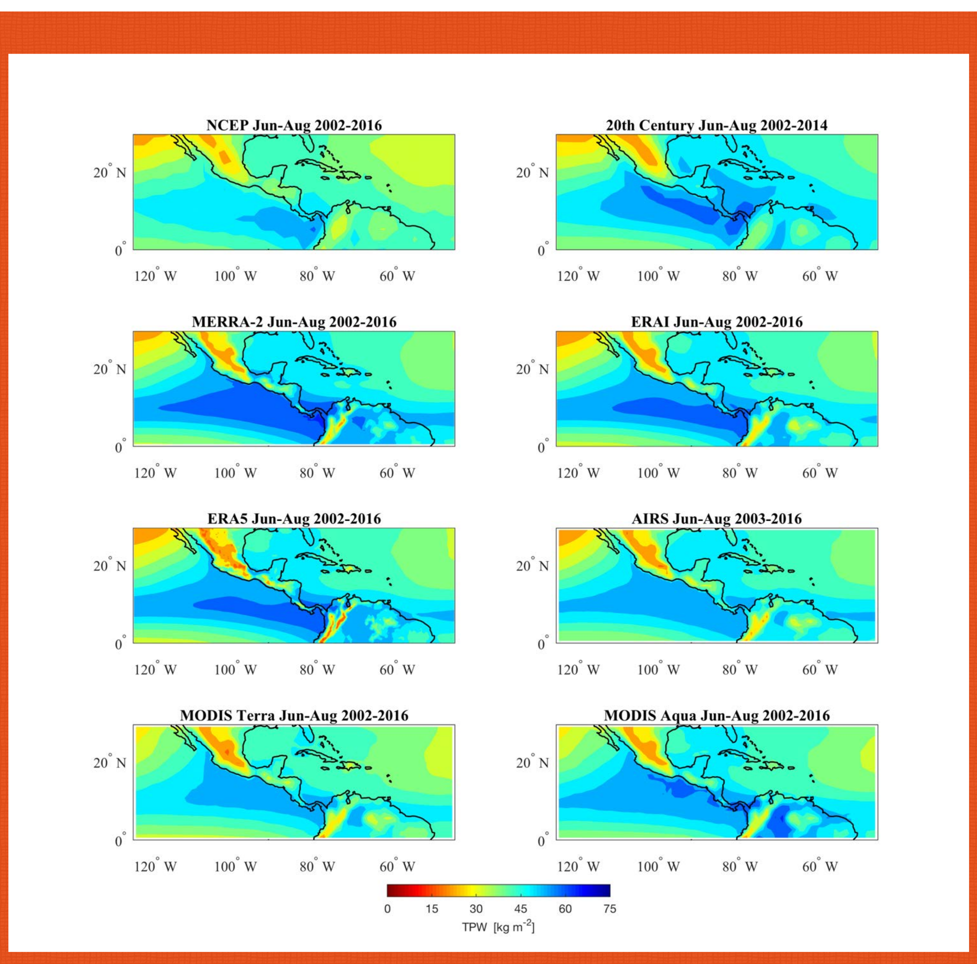




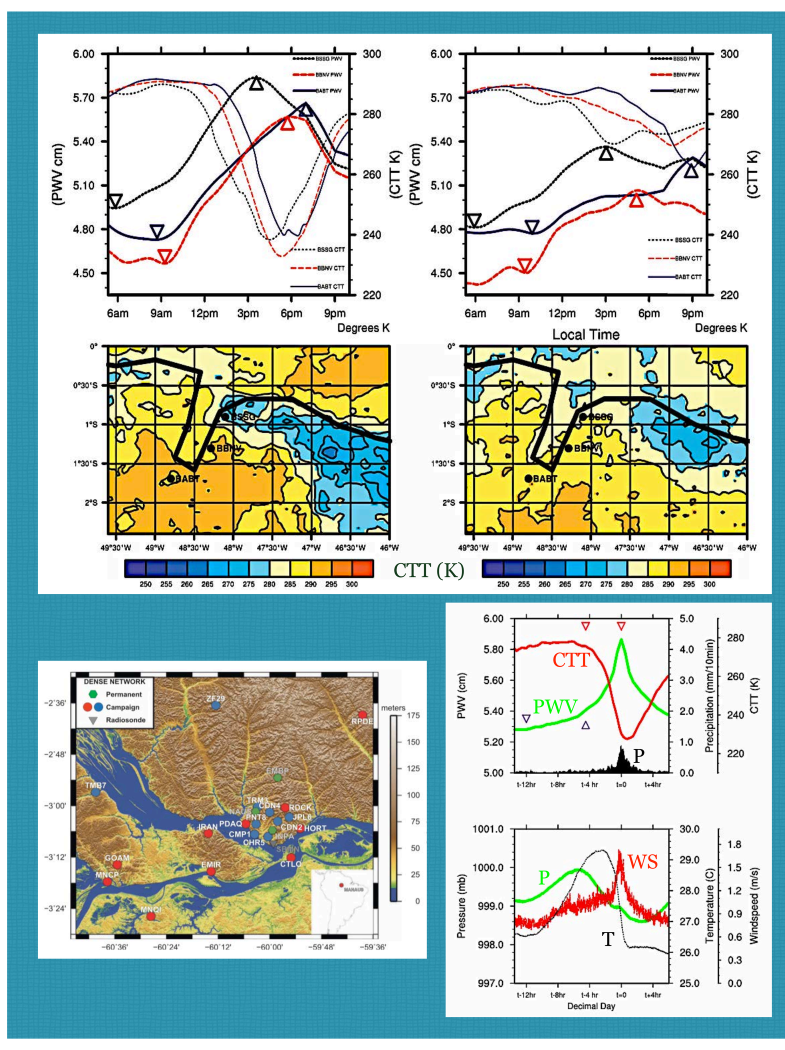
Moisture-Rainfall Relationships Over Tropical Oceans

Total column water vapor relationship with rainfall exhibits a synoptic followed by a mesoscale buildup prior to and surrounding rainfall events in the Tropics. There also appears to be a threshold total column water vapor value, above which precipitation occurs. These results, reported by Holloway and Neelin (2010), point to water vapor as a strong controlling factor for deep convection and are a strong motivation for the GPS-met surface network in Costa Rica as part of OTREC.



Uncertainty in Tropical Moisture

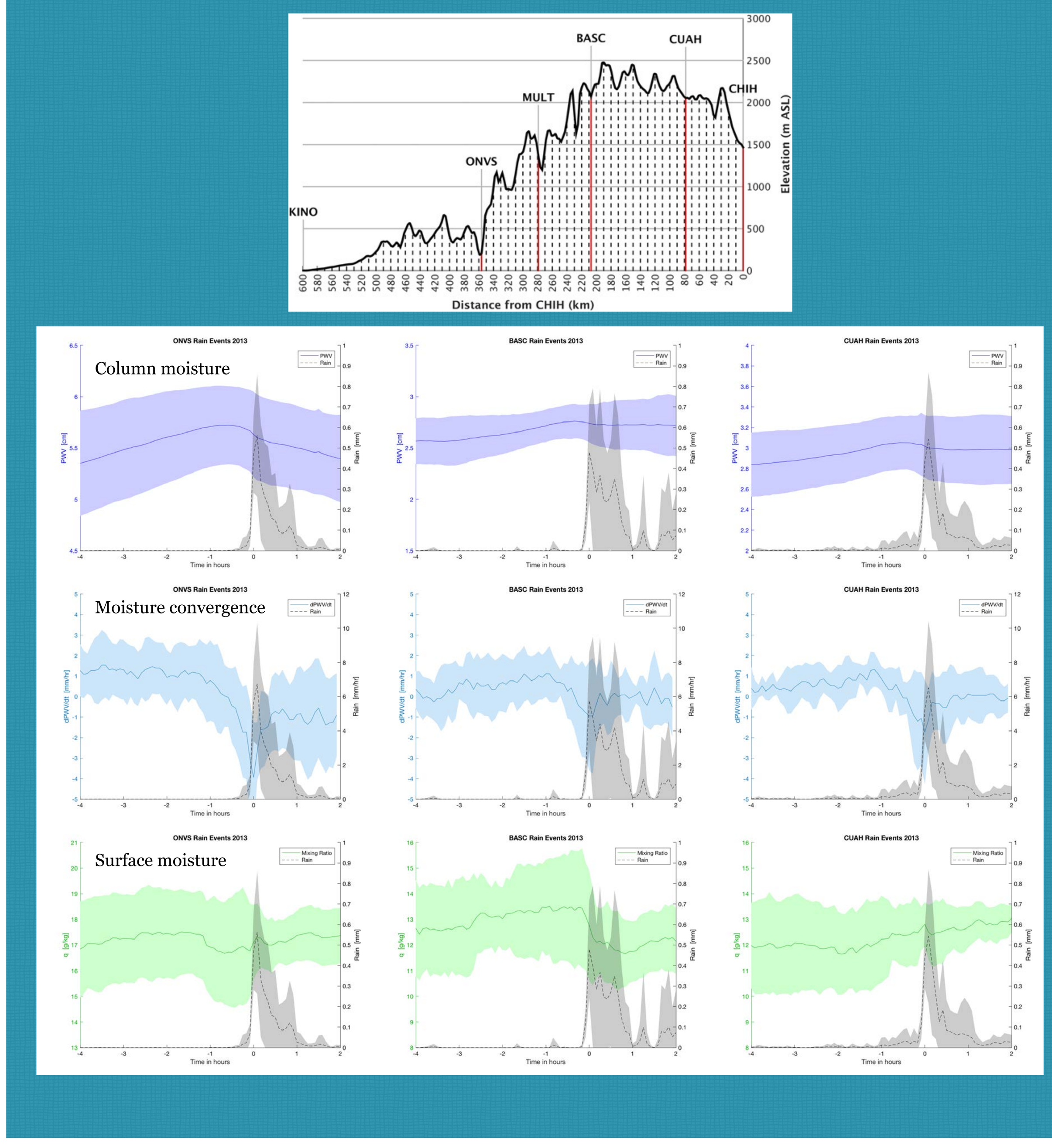
Uncertainty in total column water vapor, not even considering the vertical structure of moisture in the atmosphere, is significant, with differences on the order of 10s of kg m^{-2} across the tropical western hemisphere. We assert that better observations of total column water vapor with higher accuracy and precision such as those being collected as part of OTREC will permit deeper understanding of the mechanisms of moisture controls on tropical convection going forward.



Moisture-Convection Relationships Over Tropical Land

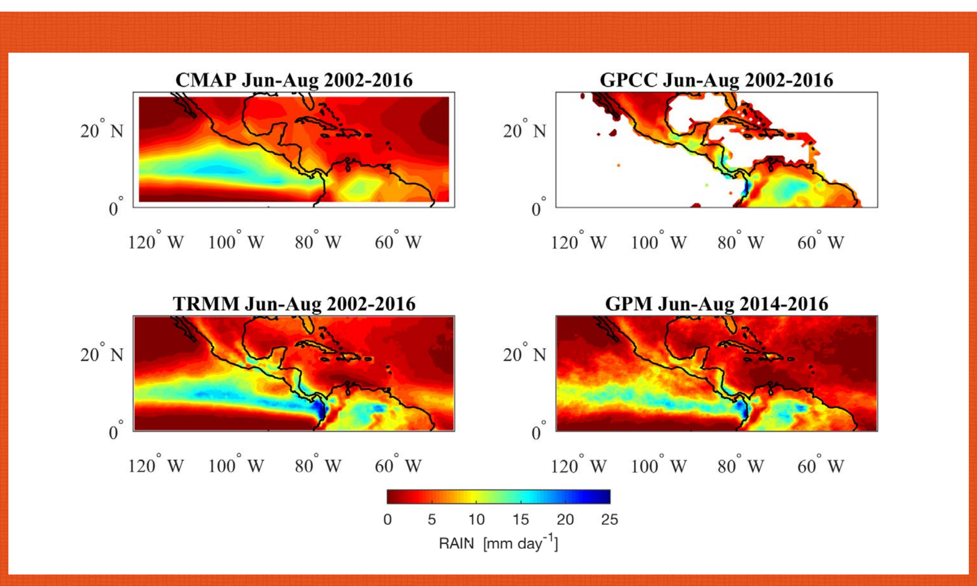
Sea-breeze regime: Using a GPS-met network installed in Amazonia, Brazil, Adams et al. (2015) are able to capture propagation of convection associated with squall lines formed over the Atlantic that moved southwestward over the stations along the Amazon River (top left). These results can be contrasted to non-convective days, when convection dissipates rather than builds and propagates inland (top right). Also evident in these composites is the characteristic buildup of total column water vapor on convective days like that seen in Holloway and Neelin (2010) at the small island site in the tropical Pacific (above).

Tropical forest regime: As over the tropical Pacific Ocean, Adams et al. (2013) show that total column water vapor increases over several hours prior to the onset of deep convection for inland sites in the Amazon forest near Manaus (bottom). On average, total column water vapor returns to its background state several hours following convective onset over these sites. This contrasts the non-convective ocean regime and convective coastal regime, where background column water vapor increases following convection.



Moisture-Rainfall Relationships Over Complex Terrain

In the North American monsoon region total column water vapor and rainfall exhibit different relationships depending on whether the rain occurs on the eastward (dry) or westward (wet) slopes of the Sierra Madre Occidental mountain range in northwest Mexico. Total column water vapor tends to return to its pre-convective value within 2 hours of peak rainfall at lower elevations (ONVS), while higher elevations see an increase in column water vapor following peak rainfall (BASC, CUAH). The changes in column moisture are not necessarily related to changes in low-level moisture, as surface moisture is similar on the western slopes (ONVS, BASC) before and after convection, while lower on the eastern slope (CUAH). In the context of studies by Yasunaga and Mapes (2012a,b; 2013), we hypothesize that convection on the western slopes of the Sierra Madre Occidental is in the form of mesoscale convective systems with large stratiform regions that tend to form in the presence of a moist troposphere, while those on the eastern slopes is more in the form of isolated deep convection that forms primarily from non-local dynamics and results in moistening the environment following the convection. Understanding these relationships between convection and its environment under different background conditions (geographic, dynamic) is a main goal of OTREC.



Uncertainty in Tropical Rainfall

Precipitation is one of the most difficult branches of the water cycle to quantify. While ocean surfaces are simpler than land surfaces for satellite retrieval algorithms of rainfall, deep clouds and limited sampling complicate matters. Over land, accurate direct measurement of rainfall from gauges, disdrometers, and other capable instruments is offset by a lack of spatial coverage, particularly in complex terrain. The colocated rainfall and total column water vapor measurements during OTREC will permit examination of the water vapor-rainfall relationship from convective (<1 hour) to synoptic (days) time scales.

Summary

The OTREC field campaign, 5 August to 30 September 2019, will explore questions related to what controls deep convection over the western Caribbean and far tropical eastern Pacific. A major contribution of OTREC will be the co-located, all-weather, high time resolution observation of total column water vapor, surface meteorology and rainfall across the land bridge between the western Caribbean and far eastern Pacific, a main pathway for the propagation of easterly waves from the Atlantic into the Pacific, as well as a main source of mesoscale convective systems over these basins from propagating diurnally driven topographic convection. This presentation highlights previous studies which suggest that total column water vapor is an important controlling mechanism for tropical convection and that the phasing of column moisture with rainfall may be used to distinguish rainfall events produced by isolated deep convection from those produced by mesoscale convective systems. These results lead to some hypotheses relevant to the questions listed above, such as does isolated diurnally driven topographic deep convection over the mountains of Central America moisten the environment and permit upscale growth and/or maintenance of propagating convection from the western Caribbean into the far eastern Pacific associated with, for example, easterly waves? Does this isolated diurnally driven topographic convection experience upscale growth over the western Caribbean or far eastern Pacific when the moisture over these waters exceeds a critical threshold? While surface fluxes of heat and moisture are not the focus of this presentation, the role of these parameters over land will also be explored using flux tower observations and water isotopes collected during OTREC at various locations across Costa Rica, shedding light on local vs non-local sources of total column water vapor in association with the formation of deep convection. The expected outcomes of this study have applications to the following important issues:

- **Representation of tropical convection across sub-seasonal time scales in global models;**
- **Representation of tropical convection and its propagation across the land bridge of Central America in global models;**
- **Understanding of the role of convection over the land bridge and northwestern South America in generating pre-cursors to tropical cyclones and easterly waves in the far eastern Pacific;**
- **Understanding the impacts of the projected large-scale shift in easterly wave tracks and the ITCZ (Serra and Geil 2017) on the nature of convection over the western Caribbean and far eastern Pacific under a warming climate.**

References

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