The Significance of Multilayer Cloud Systems in Tropical Convection

Contributors

Graeme L. Stephens, *Colorado State University*

Research Highlight

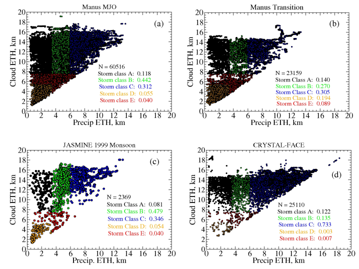
Cumulus convection is an essential part of the feedback mechanisms that modulate climate. Representing cumulus convection in global models has been a long-standing challenge to the modeling community. The parameterization schemes used to produce convection in global models are often highly sensitive to key parameters and crude assumptions about complex microphysical processes. Comparing these schemes against observations is difficult, partly because convection parameterizations are formulated in terms of parameters that have not been adequately observed and partly because the schemes lack information about parameters that are more directly observable.

Millimeter wavelength radar (MWR) observations, while not traditionally used to study convective precipitating cloud systems, show some promise in evaluating these parameterizations. This study applied a large set of tropical MWR observations (largely ARM millimeter cloud radar [MMCR] observations) to relate MWR reflectivity patterns to other properties of convective systems. A clustering analysis was used to categorize radar reflectivity patterns into distinct "storm classes," based on cloud and precipitation echo top heights, cloud layering, and the presence of precipitation.

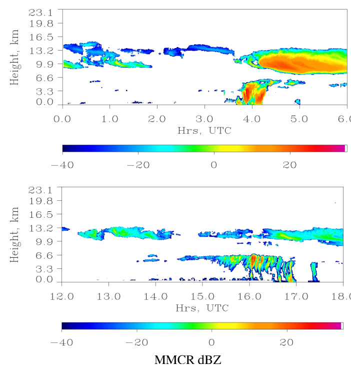
The frequency of occurrence of these storm classes under different large-scale forcing regimes (for example, the different phases of the monsoon and Madden-Julian Oscillation [MJO]) was determined.

The classes were then related to other observable characteristics of convection, such as precipitation amounts and surface energy fluxes. The structure of these individual storm classes were similar under each of the different convective regimes. What changed between the regimes was the relative frequency of occurrence of the different storm classes (Figure 1). Precipitation, rather than occurring in deep convective systems, was more commonly associated with multi-layered structures, often consisting of higher altitude cirrus overlying lower-level cumulus congestus-like convection (Figure 2). The majority of water accumulated (53% to 62%) over each of the active monsoon, active MJO and transitional MJO periods fell from these multi-layered cloud systems (Figure 3).

The structures revealed by these radar data suggests a fundamental revision of what we have typically thought of as the modes of precipitation from convection. The study suggests that significant portions of the total precipitation that falls to the surface (greater than 40%) is from convection that penetrates only to the melting layer or slightly above. In contrast, models predominantly represent this precipitation as deriving from penetrating deep convection with a heating structures similarly spread throughout the troposphere. The implications to tropical dynamics and the medium range prediction of tropical variability are profound. The validity of the findings of this



Storm classifications (derived from k-means clustering analysis) applied to MWR observations from (a) Manus during MJO, (b) Manus during MJO transition, (c) Indian Ocean (JASMINE experiment) during monsoon, and (d) tropical convection off the Florida coast (CRYSTAL-FACE experiment) of cloud and precipitation echo top heights. The relative frequencies of occurrence for the five storm classes are also shown in (a)-(d).



Representative time-height cross section of MWR reflectivity profiles from Manus during the MJO, illustrating instances of congestus underlying cirrus.

	Manus MJO			Manus Transition		
	Freq.	Total	Precip	Freq.	Total	Precip.
		precip.	fraction		precip.	fraction
Stormclass		mm			mm	
Single	0.5455	304.9	0.470	0.4931	64.82	0.384
Multi	0.4544	344.3	0.530	0.5069	103.97	0.616

	JASMINE Monsoon			JASMINE All		
	Freq.	Total	Precip.	Freq.	Total	Precip.
		precip.	fraction		precip.	fraction
Stormclass		mm			mm	
Single	0.4885	57.72	0.429	0.470	81.44	0.452
Multi	0.5117	76.78	0.571	0.530	98.70	0.548

Table of single- and multi-layered storm class statistics, showing for each the frequency of occurrence, total amount of associated precipitation, and the relative fraction of the total precipitation.

study is based on surface observations restricted to a few radar observation sites in the tropics. However, the robustness of the conclusions has since been confirmed more broadly by CloudSat measurements.

Reference(s)

Stephens, GL, and NB Wood. 2007. "Properties of tropical convection observed by millimeter-wave radar systems." Monthly Weather Review 135: 821-842.

Working Group(s)

Cloud Properties