Lifecycle of tropical convection and associated anvil from satellite and radar data

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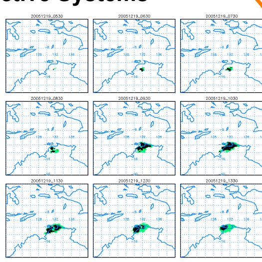
1. Introduction

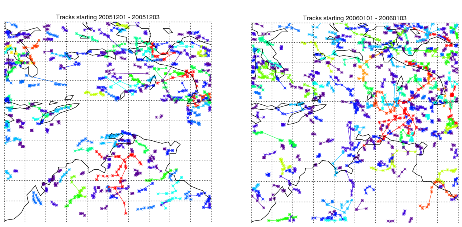
- Tropical convective clouds are important elements of the hydrological cycle and produce extensive cirrus anvils which strongly affect the tropical radiative energy balance; there are large uncertainties in simulating deep convection and its associated anvil in large-scale models.
- Darwin ARM site provides a comprehensive view of convection and anvil cloud from C-Pol precipitation radar, cloud radar (MMCR) and lidar, and satellite (MTSat) datasets.
- Track life cycle of convective systems from satellite data; link to detailed structure and microphysics from ARM data – create database of convective systems for analysis.
- Compare observations of convective systems to results from high-resolution (4 km), large-domain regional model simulations to evaluate model; eventually use regional model to guide parameterization development for climate models .

2. Tracking Convective Systems

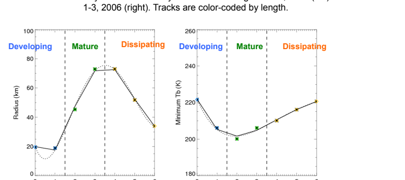
- Hourly MTSat 10.8 um brightness temperatures (Tb) at 5 km resolution
- General methodology (Futyan & Del Genio 2007; Williams & Houze 1987):
  - Identify convective cores and cold anvils as contiguous regions with Tb < 215 K and Tb < 235 K, respectively
  - Track systems in successive images by requiring 50% overlap of core or cold anvil
  - Keep systems > 400 km^2 and > 2 hours long
- Calculate statistics (lifetime, min Tb, radius) of each system
- Define lifecycle stage based on maximum radius and min brightness temperature



Example of tracking a convective system that passed over Darwin. Black pixels are convective cores (Tb < 215 K) and green pixels are cold anvil (215 K < Tb < 235 K).



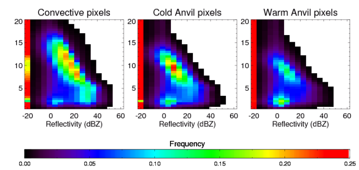
Tracks of convective systems in the analysis domain starting Dec 1-3, 2005 (left) and Jan 1-3, 2006 (right). Tracks are color-coded by length.



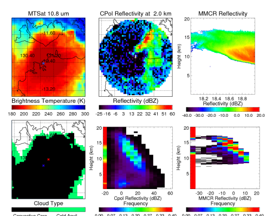
Following Futyan and DelGenio (2007), we define lifecycle stage by fitting polynomials to radius and minimum brightness temperature of system. In 'developing' stage, system has not yet reached minimum brightness temperature; in 'mature' stage, system has reached minimum brightness temperature, but not maximum radius; 'dissipating' stage is after system has reached maximum radius.

3. Linking Satellite & Radar Data

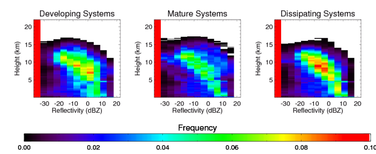
- For each system that crosses Darwin, find corresponding C-Pol and MMCR data:
  - Re-grid C-Pol reflectivity to 5-km resolution of MTSat data to directly compare to Tb
  - Examine MMCR data for one hour centered on satellite overpass
  - Calculate contoured reflectivity by altitude diagrams (CFADs) for each radar
- 74 systems; 892 MTSat images over 3 months
- Separate CFADs for convective, cold anvil, warm anvil pixels by MTSat Tb threshold



C-Pol CFADs for MTSat-identified systems that cross over Darwin. Convective CFADS have highest reflectivity values and more cloud above 10 km; all CFADS show some low cloud.



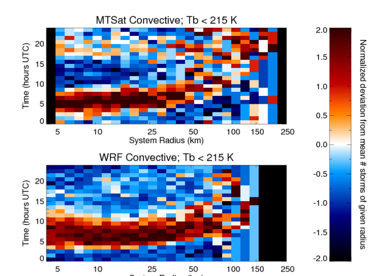
Example of convective system over Darwin from MTSAT (left panels), C-Pol (middle panels), and MMCR (right panels).



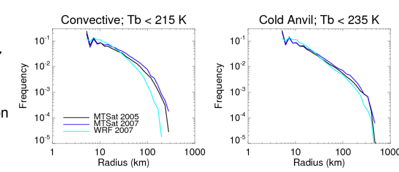
MMCR CFADs for systems that cross over Darwin as a function of lifecycle stage. Mature systems have more ice cloud reflectivities at high values (> 10 dBZ) than developing or dissipating systems.

4. Preliminary Observation/Model Comparisons

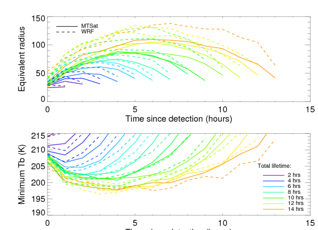
- For preliminary testing of methodology, use existing large-domain, high-resolution WRF v3.1 model run at 4 km resolution (Hagos et al. 2011) and corresponding MTSat data:
  - Subset of WRF run: 10S to 10N; 123 E to 153 E; Oct 2007
  - GFS forecast data for lateral, initial, and surface boundary conditions
  - RRTM, YSU, and WSM-6 schemes; no cu parameterization
  - Convert OLR to 11 um Tb (Yang and Slingo, 2001)
- Apply same cloud identification and tracking methodology



Analysis of diurnal cycle of convective systems following Pearson et al. (JGR, 2010). Each column shows normalized deviation from mean number of storms of that size. Red colors indicate times where there are more systems of that size then average, blue colors when there are fewer. Statistics are noisy for large systems because of small sample sizes. WRF does reasonable job for small systems (< 50 km radius), although underestimates secondary maximum at 18 UTC. WRF has stronger diurnal cycle for large systems than observations.



Frequency distribution of radius of convective systems identified using thresholds of 215 K (left) and 235 K (right) for Oct 2007 WRF simulation and MTSat data from Oct of two different years. WRF has more small systems and fewer large systems than observations.



Average lifecycle of convective systems of different lengths (Pope et al. JGR, 2008) for MTSat (solid) and WRF (dashed). WRF agrees well for minimum Tb, but has steeper slope than observations for radius of system → systems may grow faster in WRF than in observations.

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