The Short and the Long of Storms: Tracing a Deep Convective System's Life in the Midlatitude

Research Highlight

Deep convective systems (DCSs) consist of intense convective cores (CC), large stratiform rain (SR) regions, and extensive nonprecipitating anvil clouds (AC). This research aims at improving the fundamental understanding of the processes responsible for the evolution of these components associated with midlatitude continental DCSs. Many aspects of deep convection are poorly represented in current global climate models. By statistically analyzing satellite, ground radar, and reanalysis data sets, and by providing long-term statistics from these observations, this study highlights the importance of the environment favorable for mesoscale convective organization and provides observational constrains for cloud-resolving model simulations, ultimately leading to improving representations of deep convection in climate models.

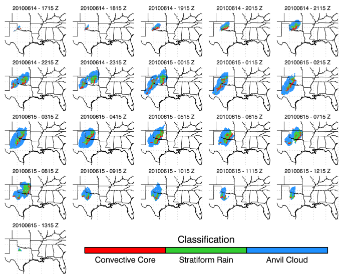
In this study, an automated satellite tracking method was used in conjunction with a new multi-sensor hybrid classification to analyze the life cycle of precipitation and cloud structures associated with midlatitude DCSs in a Lagrangian framework (Figure 1) during two warm seasons (May–August 2010 and 2011) over the central United States. On average, the frequency of occurrence for all DCSs tracked by the automated satellite tracking method is ~43/day during the study period. The average DCS cloud fraction accounts for 25% of total clouds as observed by the GOES satellite, with 8% of total clouds from precipitating deep clouds. The majority of the tracked systems have lifetimes shorter than 14 hours. The number of systems decreases exponentially with increasing lifetime, and ~51% of the systems have a lifetime of 3 hours or longer. Anvil clouds (AC) dominate the DCS area, covering an area about three times that of the stratiform rain (SR) area and an order of magnitude larger that of the convective core (CC). SR accounts for 72% of the precipitation area, similar to the tropics-wide average SR area fraction reported in other studies.

Composite analysis from 4221 tracked DCSs shows that maximum system size correlates with lifetime, and longer-lived DCSs have more extensive SR and AC. For short to medium systems (lifetimes <6 hours), the lifetime is mainly attributed to the intensity of the initial convection. Systems that last longer than 6 hours are associated with up to 50% higher midtropospheric relative humidity and up to 40% stronger middle to upper tropospheric wind shear (Figure 2). Such environments allow continuous growth of detrained hydrometeors by deposition, supporting further development of the SR and AC region, as indicated by the increased staggered timing between stratiform clouds and peak convective intensity, thus prolonging the system lifetime beyond 6 hours. Regression analysis shows that the areal coverage of thick AC is strongly correlated with the size of CC, updraft strength, and SR area. Ambient upper tropospheric wind speed and wind shear also play an important role for convective AC production, where for systems with large AC (radius >120 km) they are 24% and 20% higher, respectively, than those with small AC (radius = 20 km).

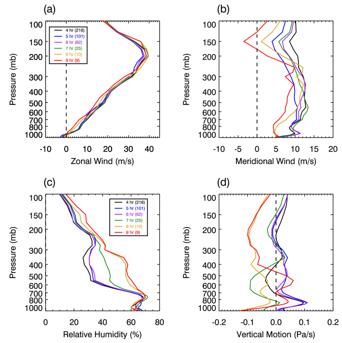
Analyses performed in this study provide a framework for comparison with long-term large-scale cloud-resolving model (CRM) simulations to systematically evaluate their performance in simulating convections at various scales. Classification and automated cloud tracking can be applied on proxy observation data sets from model output fields, allowing comparison of precipitation and cloud structure statistics directly with observations in the Lagrangian framework. The evolution of the CC/SR/AC, their lifetime and associated environments, and factors that impacts AC production found in this study should also be compared with more CRM-simulated cases to diagnose the mechanisms responsible for transition from CC to SR and AC, and provide guidance for parameterizing these processes in global climate models.

Reference(s)

Feng Z, X Dong, B Xi, S McFarlane, A Kennedy, B Lin, and P Minnis. 2012. "Life cycle of midlatitude deep convective systems in a Lagrangian framework."



The life cycle of a convective system tracked by the automated tracking algorithm in the study domain. Time increases from the top left to the bottom right, and each image represents an hour. The colors represent regions given by the hybrid classification.



Composite NARR atmospheric state profiles as a function of system lifetimes. The profiles are obtained during developing and mature stages of each system and averaged within the convective and stratiform rain region.

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Cloud Life Cycle