Analysis of a Parallel Stratiform Mesoscale Convective System during the Midlatitude Continental Convective Clouds Experiment

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Introduction

The parallel stratiform (PS) mode of mesoscale convective systems (MCSs) has received little research attention compared to the trailing stratiform (TS) and leading stratiform modes (Parker 2007).

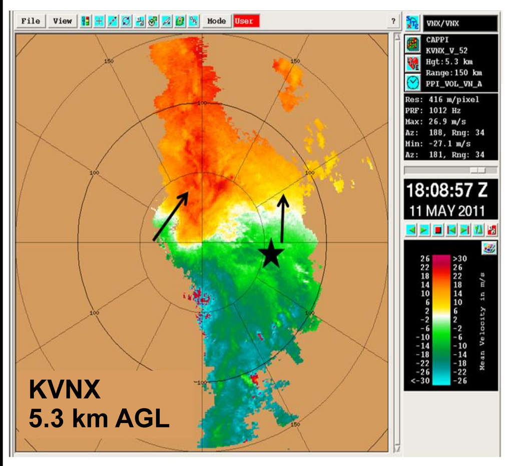
This case study examines the kinematic structure, cold pool effects, and microphysical characteristics of a PS MCS that was sampled during the Midlatitude Continental Convective Clouds Experiment (MC3E) on 11 May 2011.

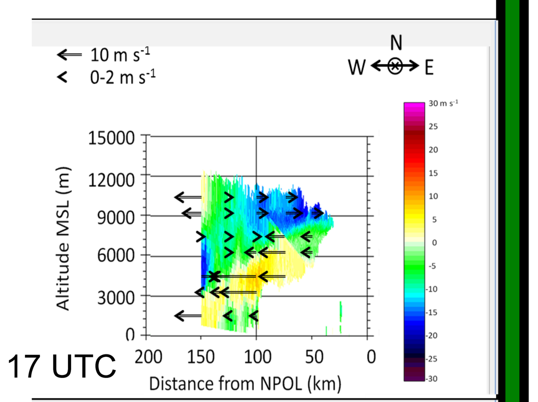
The motivations for this study include:

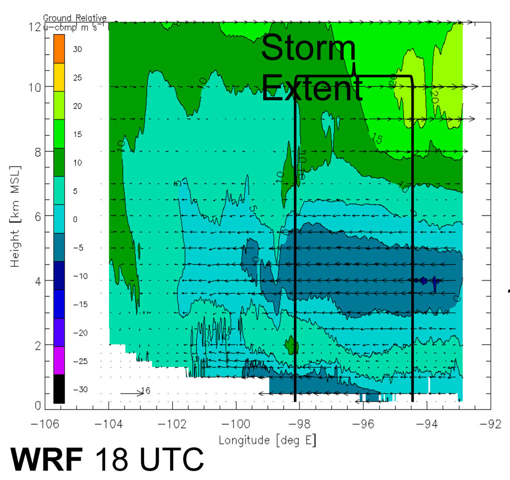
- A lack of in-situ measurements of PS MCSs.
- Uncertainty in the interactions between PS MCS and the cold pool (Bryan et al. 2004; Parker 2007).
- Sensitivity of numerical weather prediction models to variations in microphysical schemes (Li et al. 2009).

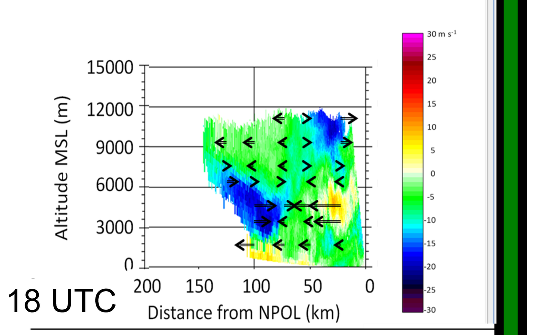
Kinematic Wind Analysis

Subjective analysis of Doppler velocities from the Vance Air Force Base, OK (KVNX), Wichita, KS (KICT), and NASA S-Band Transportable Dual Polarimetric Radar (NPOL) show the approximate kinematic wind structure of this PS MCS. The star on the KVNX CAPPI denotes the position of the Atmospheric Radiation Measurement Program's Southern Great Plains research facility.



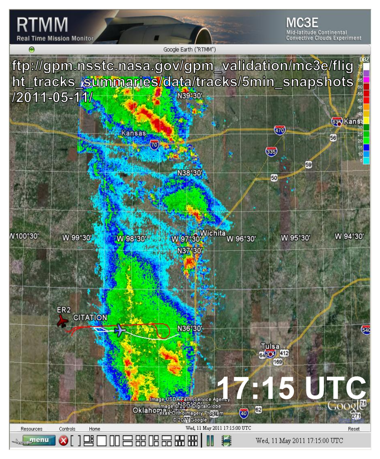


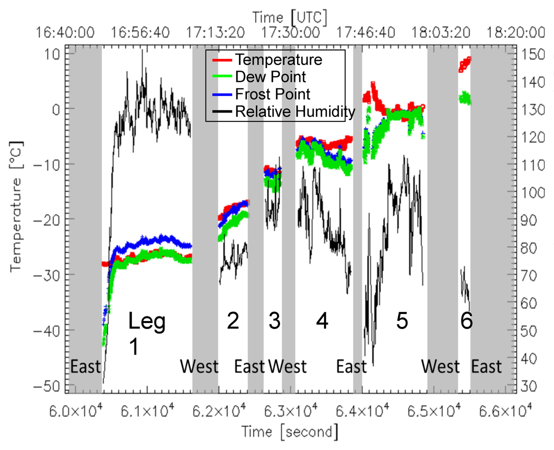




- Southerly storm-relative wind flow above 5 km above ground level (AGL) gave the MCS its PS characteristics.
- NPOL data shows a persistent region of rear inflow, a feature not seen in the WRF model simulation.

Cloud Microphysics





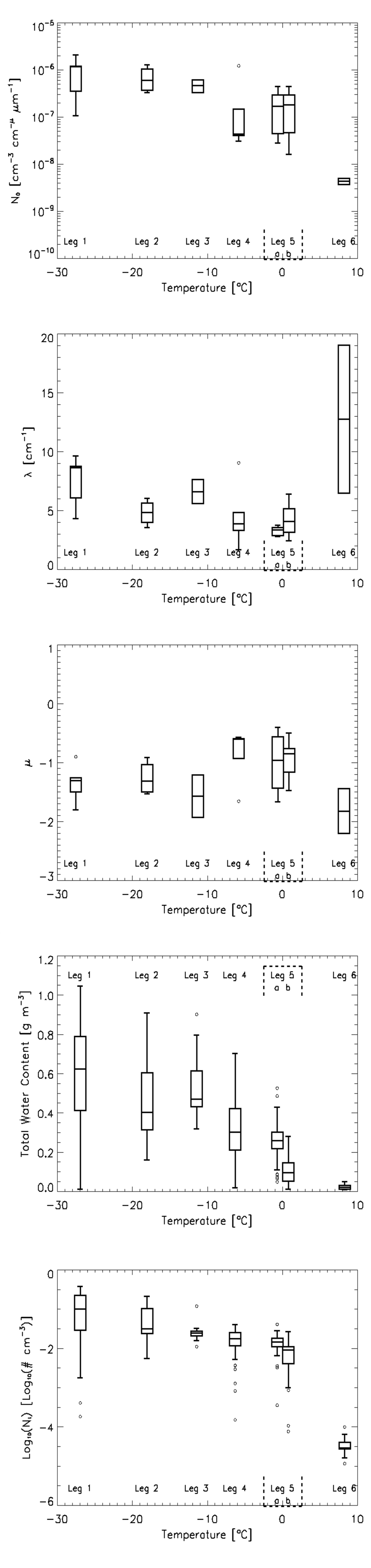
The University of North Dakota Citation II Weather Research Jet was flown on six level flight legs through the PS region of this. Legs 1 through 4 were completely above the melting layer, leg 5 was in the vicinity of the 0 °C isotherm, and the last leg was below the melting layer.

Ten-second averaged hydrometeor distributions computed from two-dimensional cloud probe (2DC), cloud imager probe (CIP), and high-volume precipitation spectrometer version 3 (HVPS-3) data were fit with gamma distributions of the form

$$N(D) = N_0 D^{\mu} \exp(-\lambda D)$$

where N(D) is the number concentration; D is the hydrometeor diameter; and N_0, μ, and λ are the intercept, shape, and slope parameters, respectively. These results were compared with the results found in McFarquhar et al. (2007), henceforth known as M07.

Unimodal Distribution Results



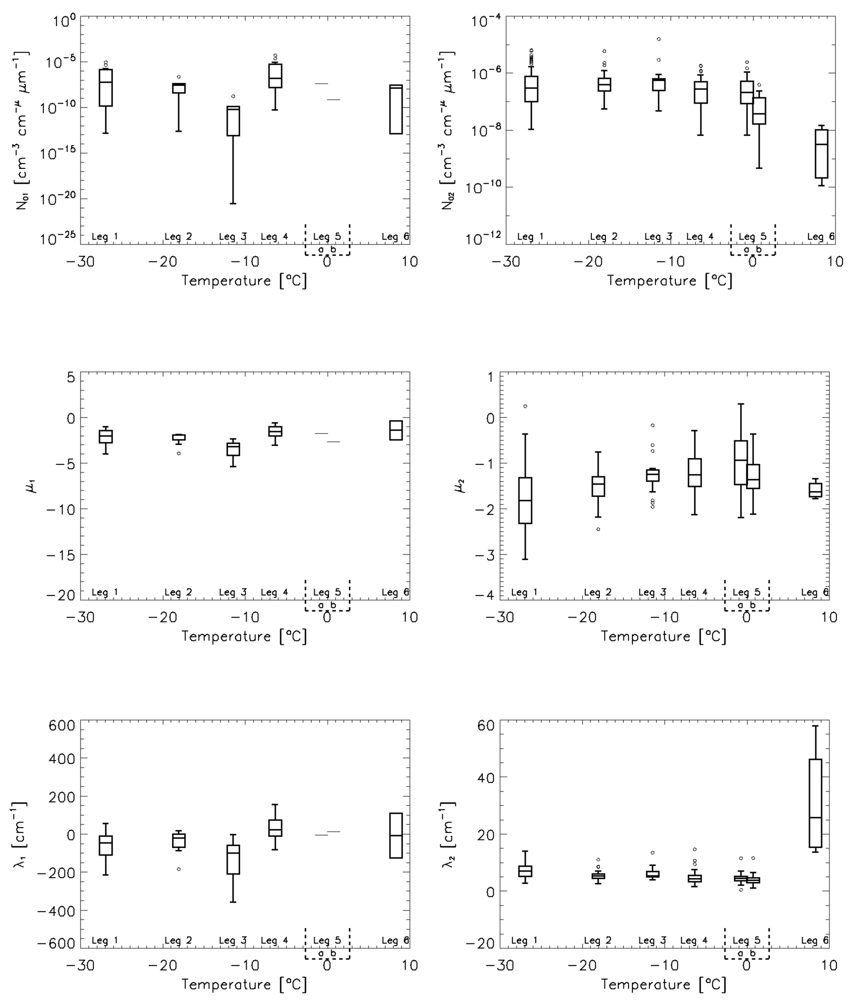
Above the 0°C isotherm, both N_0 and λ decreased with increasing temperature (T), while μ increased with increasing T. This suggests that aggregation was occurring in the stratiform region.

Comparing these results with M07:

- As in M07, the total water content (TWC) and total particle concentrations (N_t) decreased with increasing T.
- Values of μ and λ fall within the ranges of μ and λ reported in M07.
- Above and in the melting layer, values of N_t fall within the range reported in M07.
- Both N_0 and TWC are lower than the N_0 and total mass content reported in M07.
- There were more bimodal spectra than in M07, which is another indication of aggregation.

These results suggest that there are similarities in the microphysical processes occurring in this PS MCS and the processes occurring in TS MCSs.

Bimodal Distribution Results



Bimodal distributions are fit to a piecewise gamma distribution

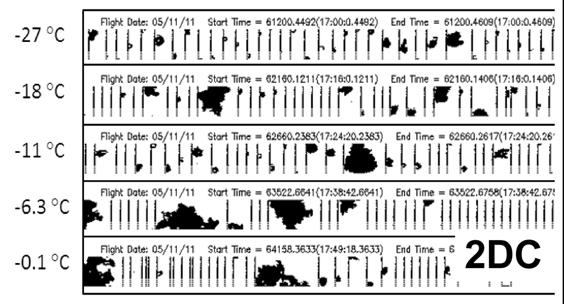
$$N(D) = \begin{cases} N_{01} D^{\mu_1} \exp(-\lambda_1 D) & D < D^* \\ N_{02} D^{\mu_2} \exp(-\lambda_2 D) & D \geq D^* \end{cases}$$

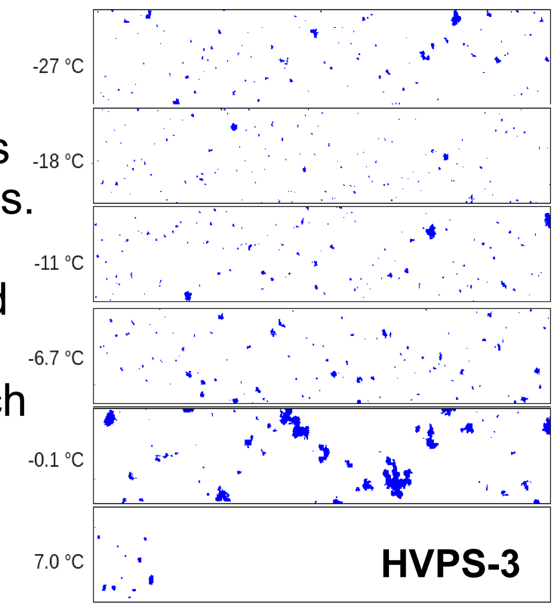
where D* is the smallest diameter of the second mode.

N_{01}, μ_1, and λ_1 show little dependence on temperature. This may be due to limited sample sizes.

μ_2 increased with increasing T and there were indications of λ_2 decreasing with increasing T, which suggests that aggregation was occurring in the stratiform region.

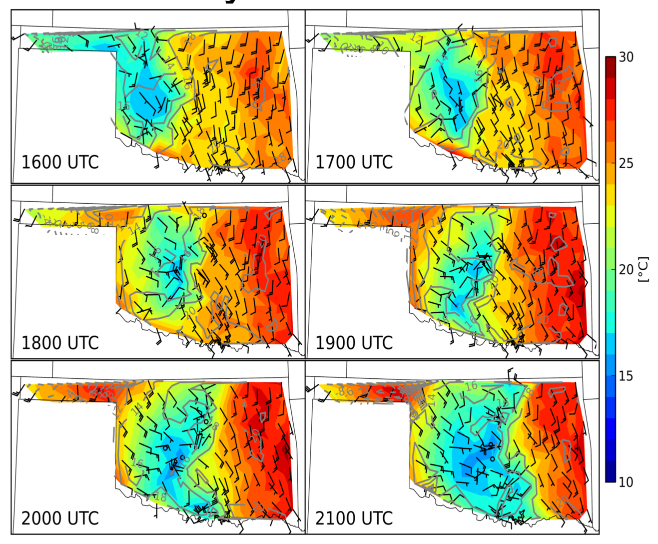
Particle images from the 2DC and the HVPS-3 show that aggregation was occurring in the PS region.



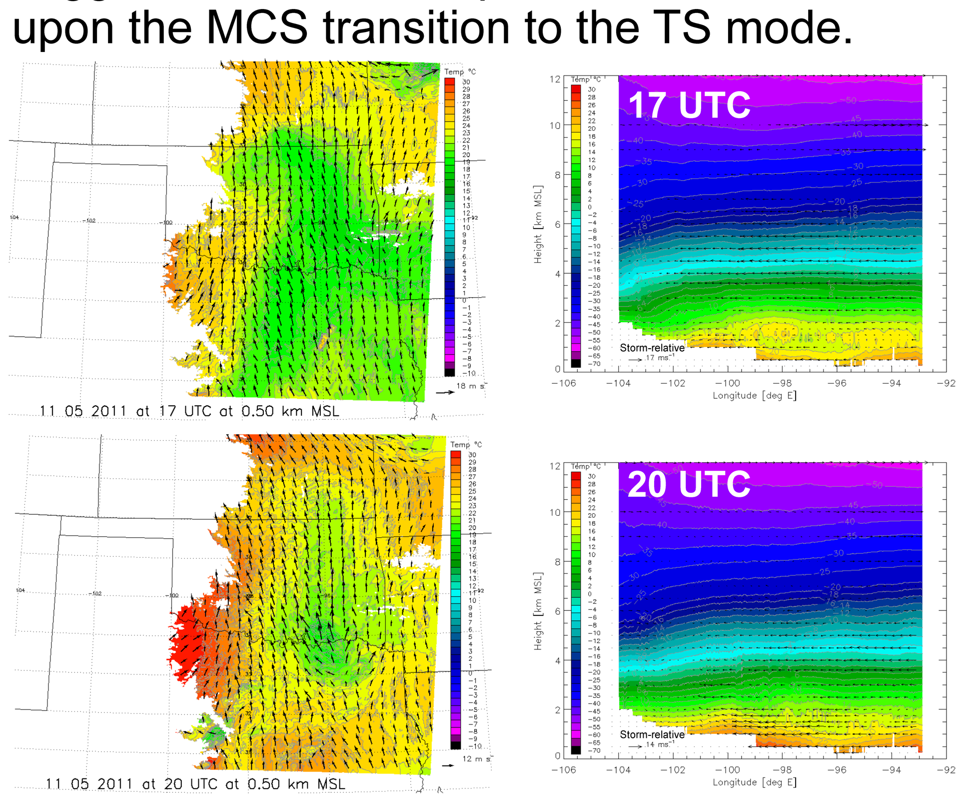


Cold Pool Analysis

To determine the effect of the cold pool upon the MCS, a mesoscale community Weather Research and Forecasting (WRF) model simulation is analyzed. The WRF simulation is also compared to Oklahoma Mesonet surface data to determine how well the model simulated the convection that occurred on 11 May 2011.



- The temperature difference between the center of the cold pool and the pre-storm environment in the model simulation is similar to that of the actual storm.
- Both model data and the Mesonet data show there was very little outflow extending ahead of the MCS from 16 to 21 UTC.
- There is an increase in the easterly component of the low-level storm-relative wind between 17 and 20 UTC, during which the MCS transitioned from PS to TS mode. This suggests that the cold pool did have an effect upon the MCS transition to the TS mode.



Conclusions

- The pre-storm wind profile and storm evolution were similar to those observed in in previous studies of PS MCSs.
- The presence of bimodal spectra, decreasing N_0, decreasing λ, and increasing μ with respect to increasing temperature indicate that aggregation was occurring in the stratiform precipitation region.
- The microphysical processes in this MCS are similar to processes found in TS MCSs.
- A WRF simulation of this event suggests that the growth of a cold pool has an effect upon the low-level wind flow.

Acknowledgments

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