Observations of Melting-Layer Microphysical Processes in MC3E

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BACKGROUND

Microphysical factors controlling cold pool evolution are uncertain and lead to considerable uncertainty in simulations of aerosol effects on organized deep convection. In particular, microphysical processes in stratiform rain regions of mesoscale convective systems are not well understood, especially within and above the melting layer. In an effort to reduce these uncertainties we have analyzed in-situ observations of cloud particle size distributions and particle shape during the Mid-latitude Continental Convective Clouds Experiment (MC3E), with particular focus on aircraft spiral ascent/descents through the melting layer during stratiform and convective trailing stratiform events over the SGP ARM/CART site.

Of the 23 spiral ascents/descents performed by the University of North Dakota Citation during MC3E, five of them measured the melting layer transition within precipitation. The improved image quality from the newly-developed SPEC High Volume Particle Spectrometer (HVPS-3) allows us to see the melting processes in more detail than was previously possible by analyzing the shape of the particles over a wide size range in addition to measuring the size and area of the particles. The spiral examples to the right show the differences in the melting process for a saturated, sub-saturated, and strongly sub-saturated environment. An additional challenge in the melting layer is the choice of a mass-size parameterization in an environment where particle density is changing very rapidly. Mass-size parameterizations in ice usually take the form of a power law:

$$m = aD^b \qquad (1)$$

Where D is the particle diameter in centimeters and the factors a and b are determined experimentally as in Heymsfield et al., 2010 (a=0.0053, b=2.1). A simple mass-size parameterization in liquid water is:

$$m = \rho_w(\pi/6)D^3 \qquad (2)$$

We have used the area ratio (roundness) parameter from the HVPS-3 to guide the choice between an ice mass-size relationship (1) and a liquid water mass-size relationship (2) for each individual particle size bin. Computations of the mass flux, which includes fall velocity, mass, and number concentration, now show realistic transitions in the melting layer. Computation of other mass-related bulk parameters such as condensed water content and radar reflectivity also benefit from this approach.

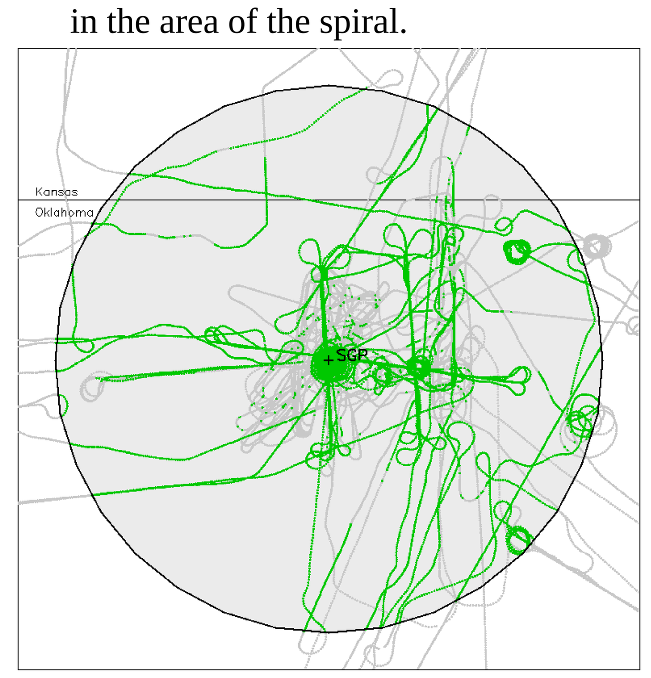
We gratefully acknowledge the crew and scientists of the University of North Dakota Citation research aircraft who collected the data used in this study.

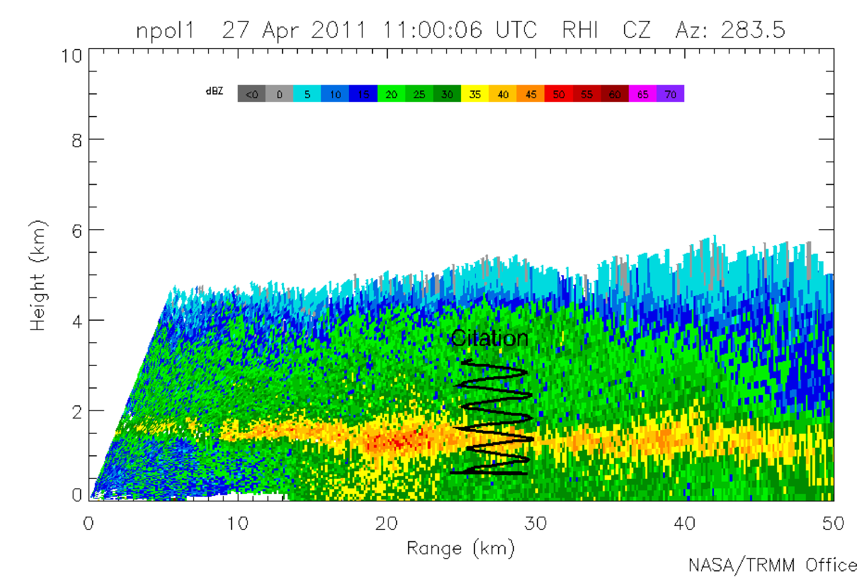
References:

Improved Representation of Ice Particle Masses Based on Observations in Natural Clouds. Andrew J. Heymsfield, Carl Schmitt, Aaron Bansemer, Cynthia H. Twohy. Journal of the Atmospheric Sciences Volume 67, Issue 10 (October 2010) pp. 3303-3318

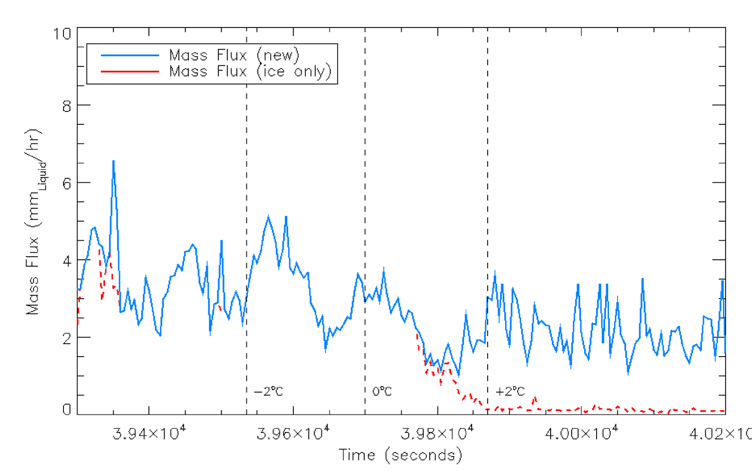
Saturated Stratiform Melting Layer

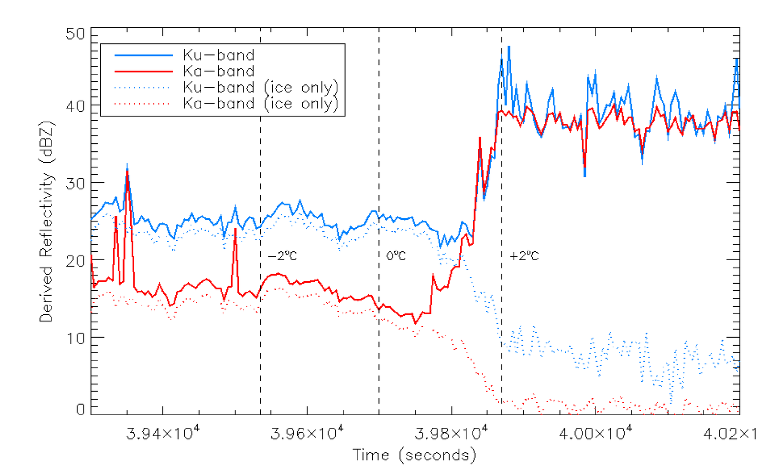
An overview of all 23 spirals in the MC3E project (left), and the spiral descent near the SGP/ARM site in Oklahoma on April 27th, 2011. The NPOL radar shows a clear bright band in the area of the spiral.



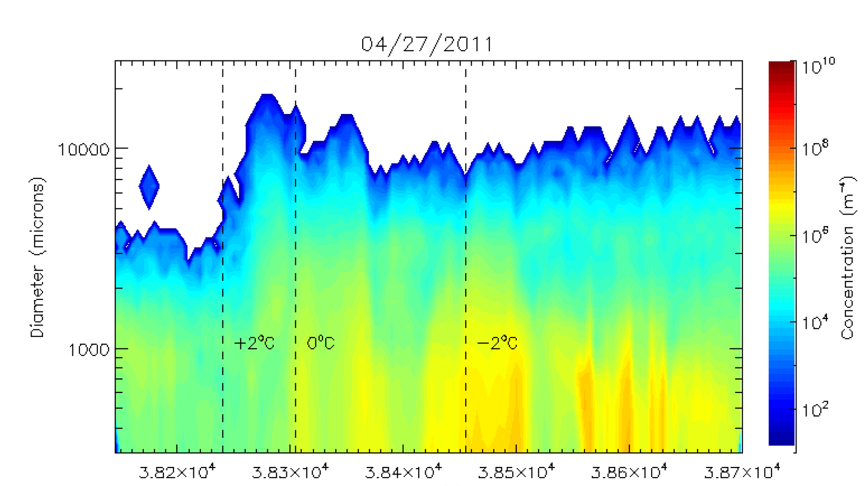


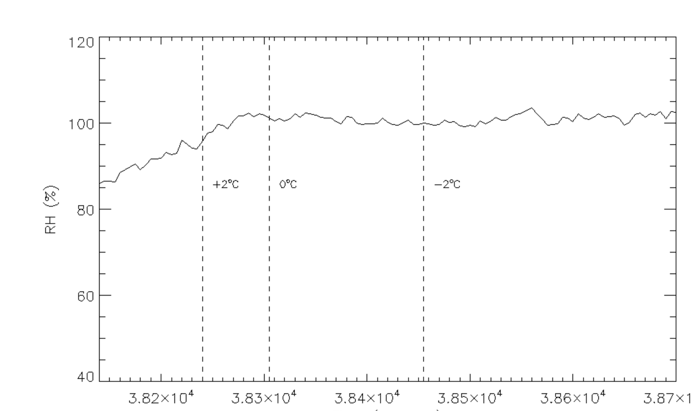
Use of the flexible mass-size parameterization as described in the text results in more realistic mass flux and radar reflectivity computations in the melting layer (results are for Spiral #2).

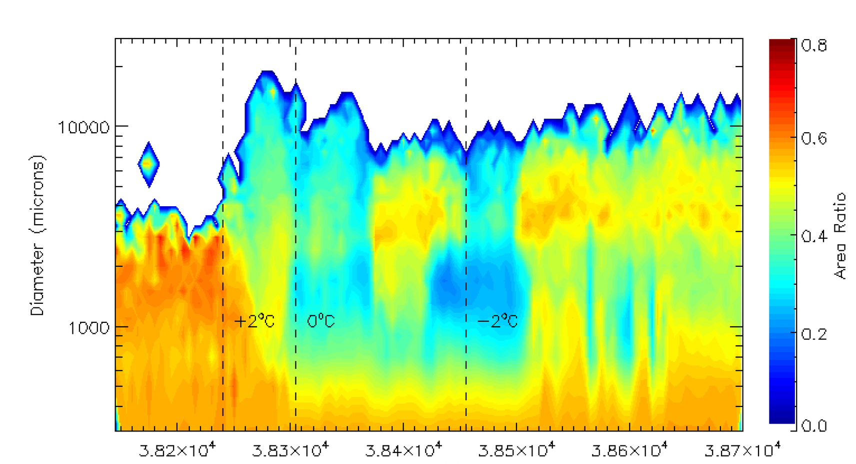


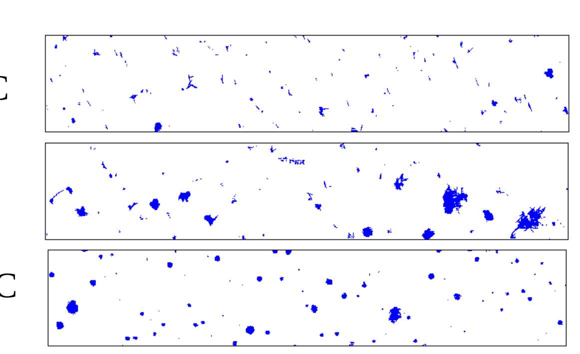


Spiral #1: Particle size distributions recorded by the HVPS-3 show particle growth to about +1C. The particles become smaller as they melt at warmer temperatures. The area ratio of the particles can be used to determine shape. Circular particles are shown in orange/red on the lower plot. Note that small particles melt first starting around 0C. Large particles do not completely melt until warmer than +2C



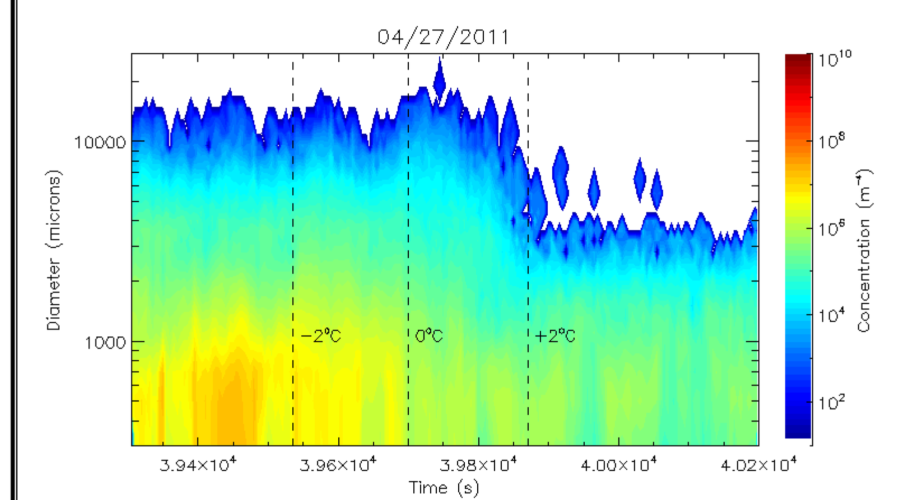


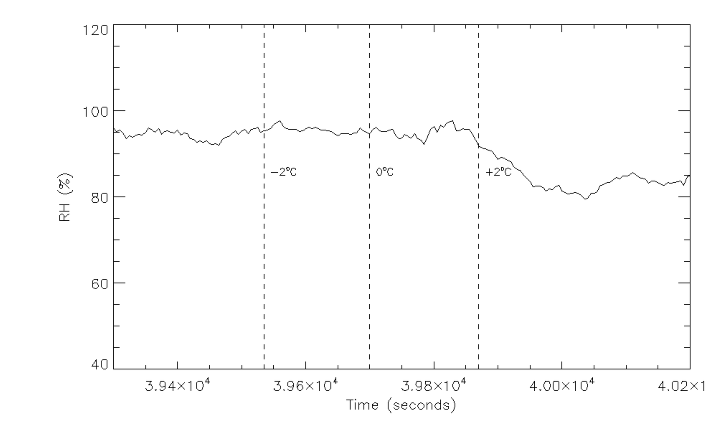


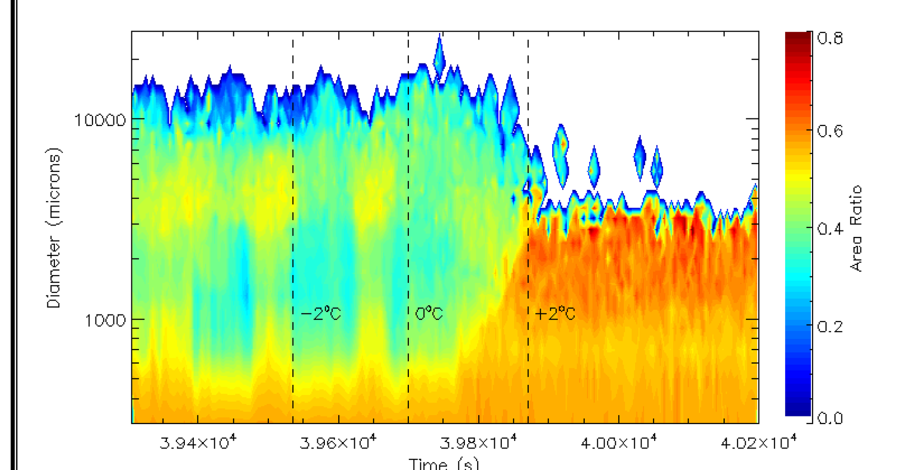


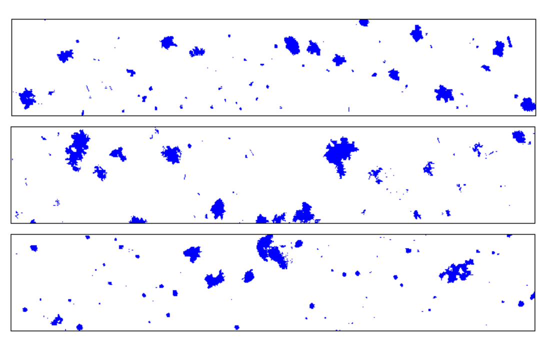
Subsaturated Trailing Stratiform

Spiral #2: In a slightly sub-saturated environment particle size distributions show particle growth to about +1C. Note that small particles melt first starting around +1C. Large particles do not completely melt until above +2C









Spiral #3: This spiral descent on May 20th, 2011 occurred in a more strongly sub-saturated environment. Large particles are maintained up to +2C where the melting process begins. Melting is not complete until well above +3C.