Report on the Polarimetric Cloud Analysis and Seeding Test 3 (POLCAST3) Field Project

Korey Southerland[1], David Delene[1], Gretchen Mullendore[1], Mariusz Starzec[1], Cedric Grainger[1], Paul Kucera[2], and Darin Langerud[3]

[1]Department of Atmospheric Sciences, University of North Dakota, Grand Forks, North Dakota, USA [2]Research Applications Laboratory, National Center for Atmospheric Research, Boulder, Colorado, USA [3]North Dakota Atmospheric Resource Board, Bismark, North Dakota, USA

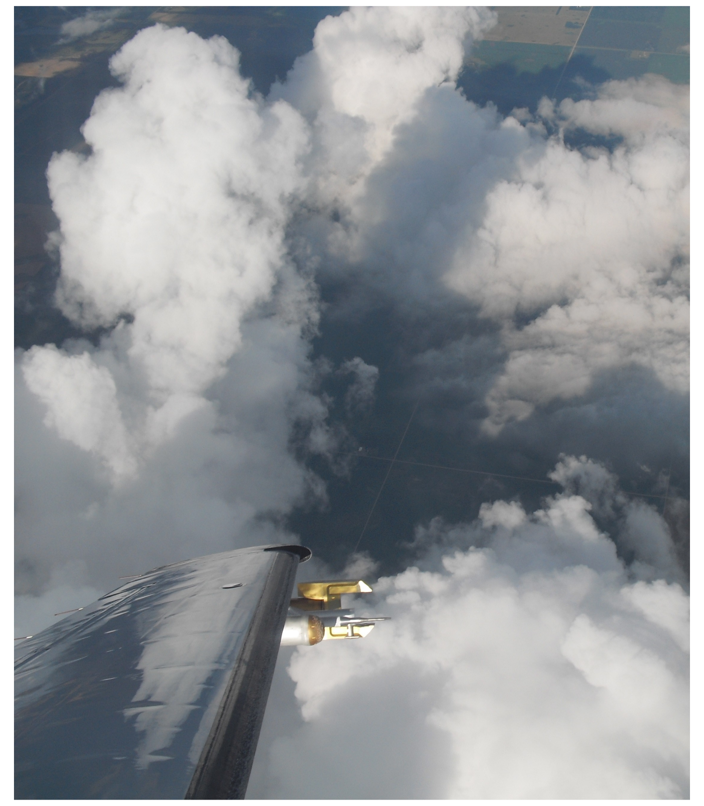
Objectives

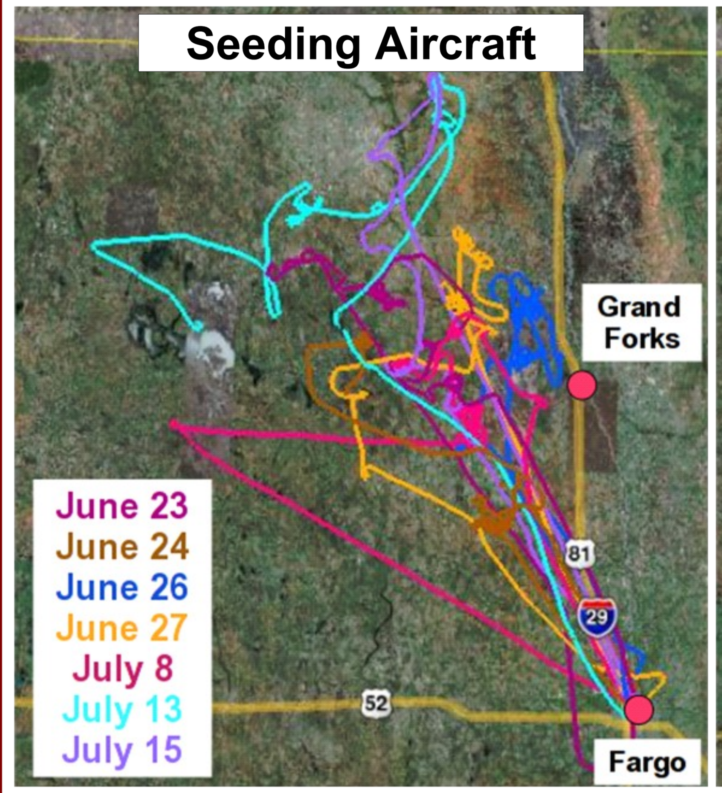
The 2010 field project is a continuation of the POLCAST (Kucera et al., 2008) and POLCAST2 (Delene et al., 2011) programs. The main objective was to better understand the effects of hygroscopic cloud seeding on convective clouds in North Dakota. Specific objectives include:

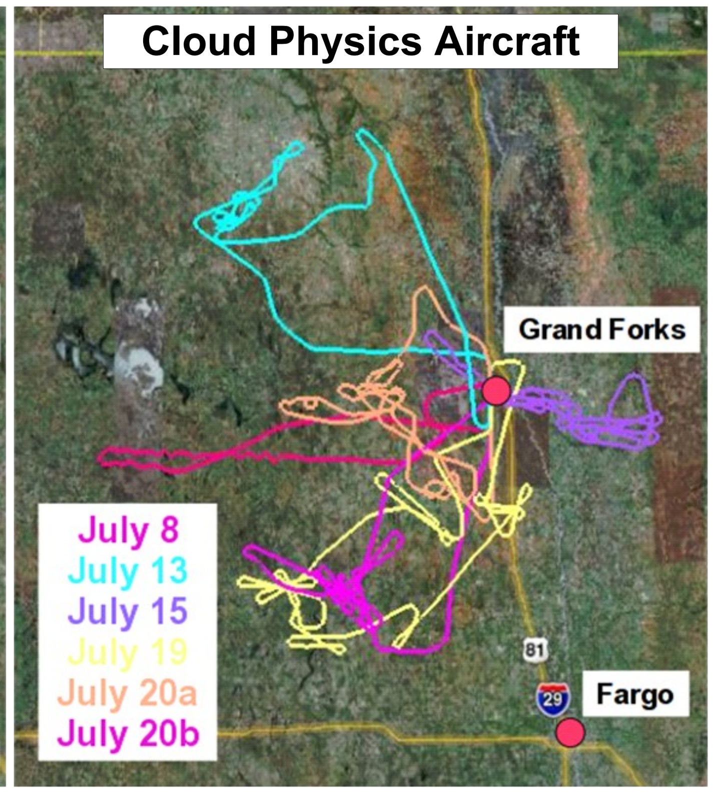
- Determine identifiable signatures of hygroscopic seeding in polarimetric observables or derived fields.
- Determination of hygroscopic seeding effects stratified by aerosol and CCN (cloud condensation nuclei) concentrations.
- Relate aerosol and CCN concentration measured at cloud base to aerosol and CCN concentration measured at the surface and with local weather conditions.
- Relationship of cloud droplet distributions above cloud base for seeded and non-seeded clouds to confirm inferences observed in the polarimetric fields.

Project Overview

POLCAST3 was conducted between June 21 and July 23, 2010. The University of North Dakota's (UND) polarimetric radar, NorthPol, was operated when convective cells existed. A Weather Modification Inc. (WMI) aircraft was used to seed convective cells using hygroscopic flares. The selection criteria for a seeding candidate was a convectively isolated cloud, initial development within 100 km of the radar, seeding in North Dakota, the pilot estimated updraft of at least a 500 ft/min below cloud base, and cloud base temperature of between 4 C and 20 C. After the aircraft crew identified a candidate that met the seeding criteria, a "Seed" or "No Seed" decision was requested by radio from the radar operations center. In situ measurements were made on the seeding aircraft, on a Cloud Physics aircraft and at the surface.





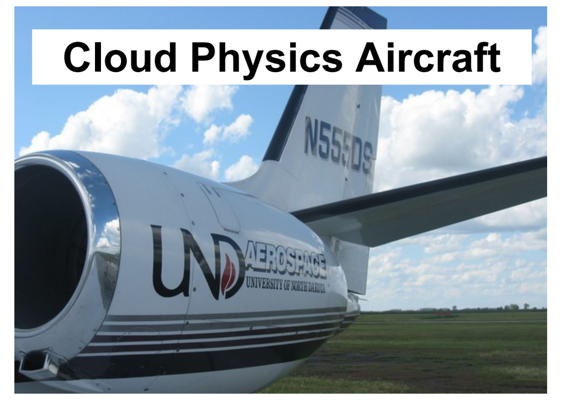


The seeding aircraft flew eleven seeding flights (26.2 hours) and conducted seven days of research measurements. A total of thirteen hygroscopic seeding candidates were found during the POLCAST3 field project.

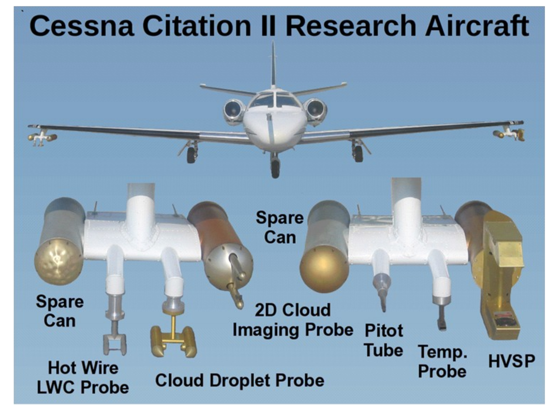
The UND Citation Research Aircraft flew six flights (7.6 hours) to measure cloud properties of seeding candidates above the seeding aircraft.

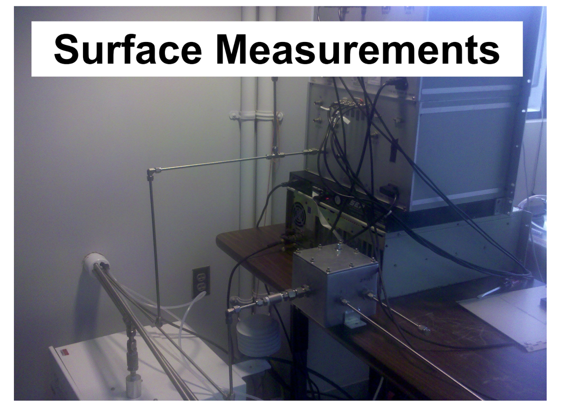
Components of POLCAST3

An instrumented Cessna 340 aircraft was used for cloud seeding and aerosol measurements. Due to engine problems during the project, the last three flights (July 16, 19, and 20) did not have seeding aircraft measurements. The seeding aircraft carried a PMS model 100-SPP200 Passive Cavity Aerosol Spectrometer Probe, a Rosemount Temperature Sensor, a University of Wyoming Cloud Condensation Nuclei (CCN) Counter, a GPS system, pressure transducers, a Science Engineering Associates (SEA) M300 data system, Hygroscopic Cloud Seeding Racks, and a Sulfur Hexafluoride (SF6) Release System.

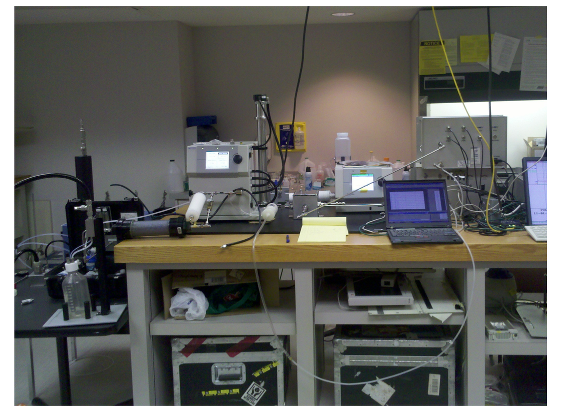


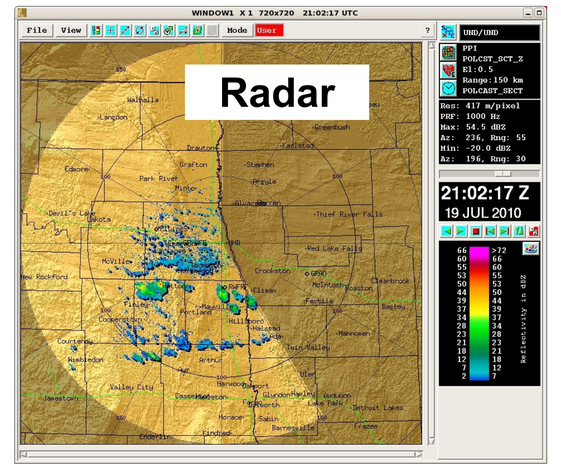
The UND Citation Research Aircraft was equipped with meteorological and cloud physics instruments which included the Droplet Measurement Technologies (DMT) Cloud Droplet Probe (CDP), a Sulfur Hexafluoride Analyzer, the King Hot Wire Liquid Water Probe (LWC), a Two-Dimensional (2D) Cloud Imaging Probe, a SPEC High Volume Precipitation Spectrometer (HVPS) Probe, a Rosemount Temperature Probe, and an Applanix Corporation Position and Orientation System.



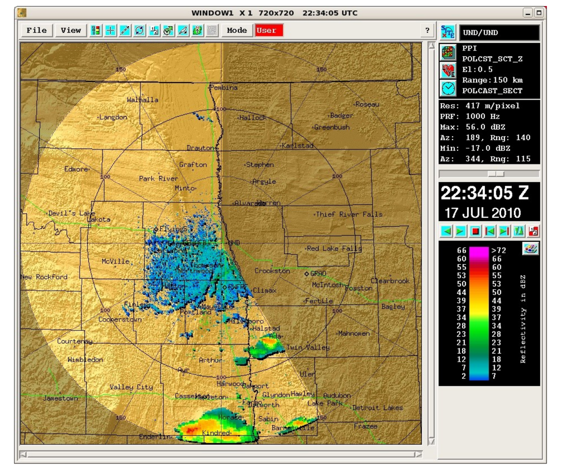


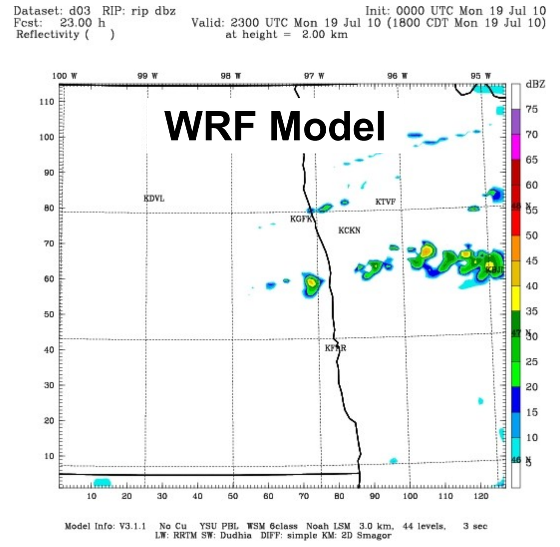
Cloud condensation nuclei measurements were made during POLCAST3 on the top of Clifford Hall at the University of North Dakota to enable comparisons between surface and cloud based concentrations. Additional aerosol measurements include a TSI model 3771 condensation particle counter, a TSI Scanning Mobility Particle Sizer, a Tapered Element Oscillating Microbalance (TEOM), and two sets of PM 2.5 µm filter samplers.



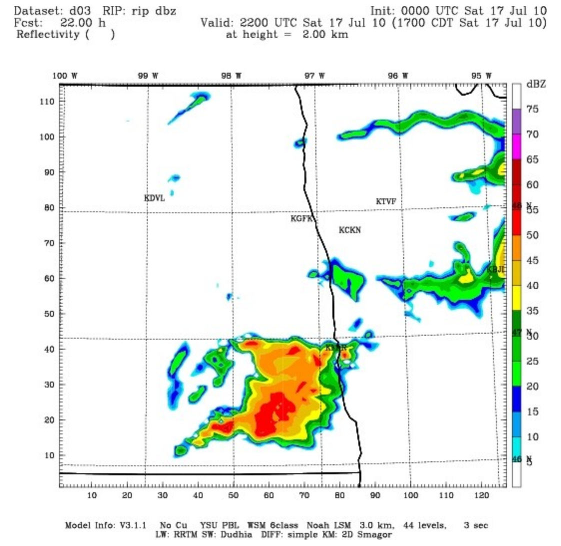


The UND radar was used to analyze the characteristics of clouds in the study region and for assessing the potential hygroscopic seeding effects. The data was collected by IRIS (Interactive Radar Information System). The IRIS software was used to create real time display products that were then posted to the UND POLCAST web-page. The radar data along with the flight tracks were incorporated in the Thunderstorm Identification Tracking Analysis and Nowcasting (TITAN) software packages for real time display and post field project analysis.

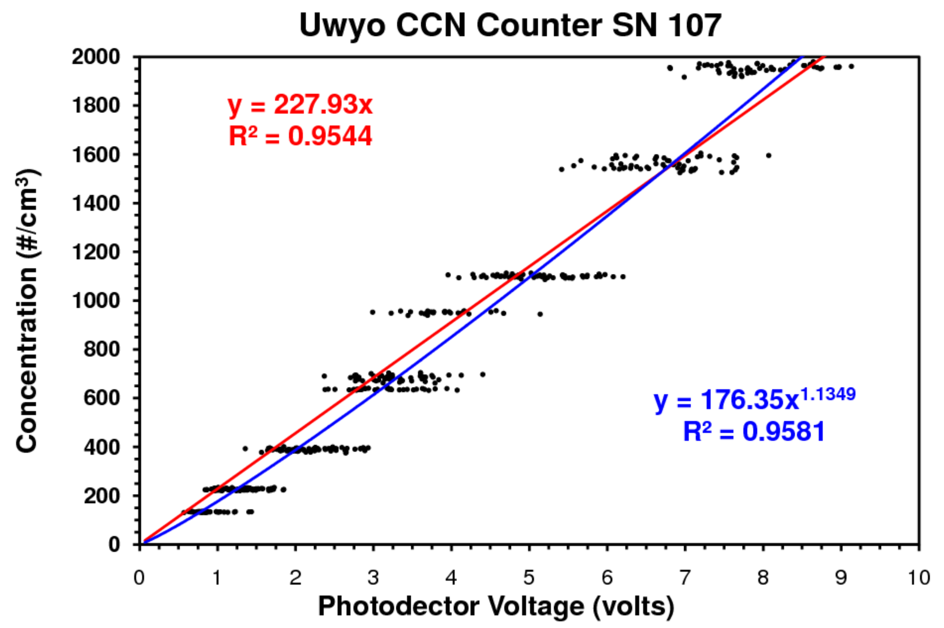


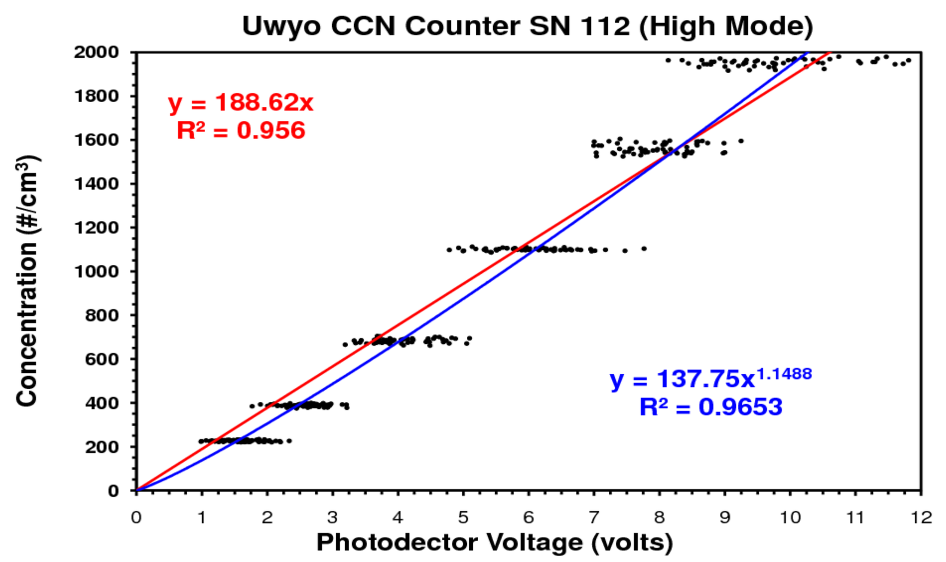


The Weather and Research Forecasting (WRF) model ran twice daily from the NAM 212 00 UTC and 12 UTC output. The 36-hour forecasts were run as nested domains with horizontal domain spacing of 27, 9, and 3 km, and 45 vertical levels (grid stretched). Output was saved at 3-hour intervals for the 27- and 9-km domains and at 1-hour intervals for the 3 km domain. Forecast fields were posted to the web during the field project. Posted fields included composite reflectivity, relative humidity at 850 MB, water vapor mixing ratio at 2 km, and a simulated sounding at the Grand Forks airport.



CCN Counter Calibrations





Both of the CCN counters used during POLCAST3 were calibrated at the UND after the completion of the field project. An Electrostatic Classifier (TSI Model 3080) was used to size select 100 nm diameter particles from a poly-dispersed, ammonium sulfate, aerosol size distribution generated with a nebulizer and dried using a diffusional dryer. The 100 nm particles were sampled from a mixing chamber concurrently by the two CCN counters (SN 107 and SN 112) and a TSI Model 3775 Condensation Particle Counter (CPC). Measurement of the CCN counter's photodector voltage peak were related to the 30 s average CPC concentration to obtain calibration equations at an instrument selected supersaturation of 1%. Pre-project calibrations were y=156.69x (SN107) and y=137.75x (SN112).

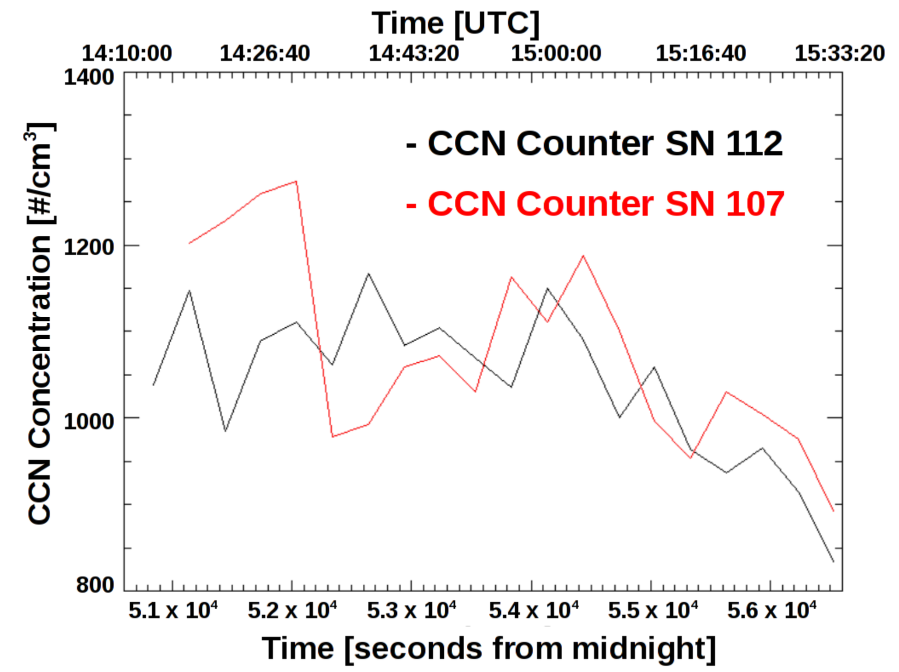
Acknowledgments: This research is supported by the North Dakota Atmospheric Resource Board (NDARB). Ice Crystal Engineering donated the hygroscopic flares. Dennis Afseth and Kelly Bosch did an excellent job installing research instruments on the seeding aircraft. On the Citation aircraft, Aaron Ness installed instruments and Runjun Li helped with the SF_6 Analyzer. Chris Theisen and Pavle Kirilov helped greatly with operation of the UND radar. Haewoo Jeong helped with the lab set up for the CCN counter calibrations. Dan Brothers was the project's lead forecaster. We would like to thank pilots Jody Fisher, Hans Ahlness, Jason Newham, and Wayne Schindler for safe and effective flying. UND students David Keith, Andrea Neumann, Christopher Kruse, Miranda Hilgers, and Emily Danielson helped with the field project.

Delene D. J., Grainger C., Kucera P., Langerud D., Ham M., Mitchell R., and Kruse C., The Second Polarimetric Cloud Analysis and Seeding Test, Journal of Weather Modification, Submitted, January 2011.

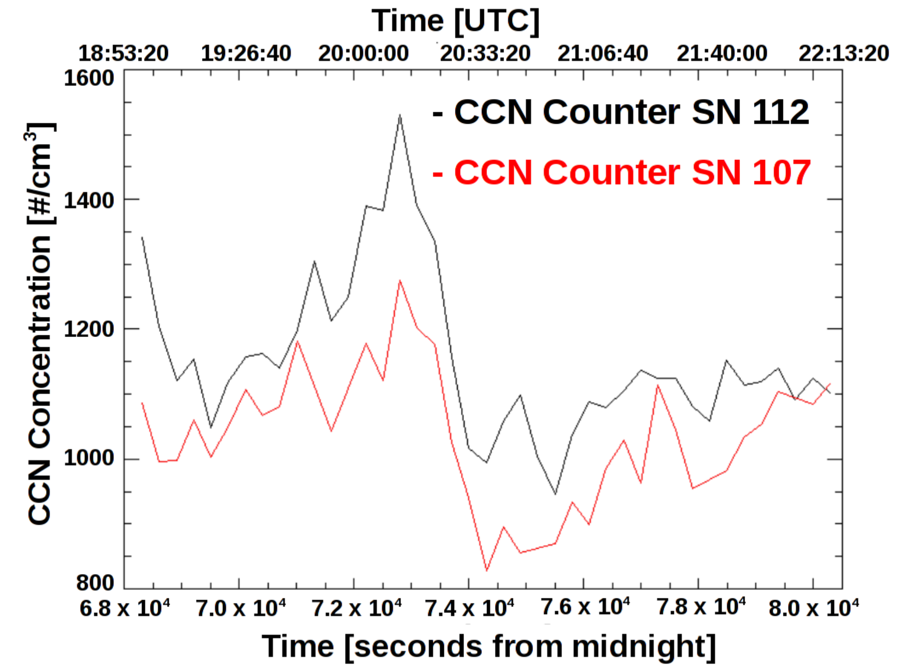
Kucera, P. A., Theisen, A., and Langerud, D., 2008: Polarimetric Cloud Analysis and Seeding Test (POLCAST). J. Wxmod, 40, 64-76.

Surface CCN Counters Comparison

October 14, 2010



October 7, 2010



Future Work

The data set collected will be analyzed to determine summary statistics of aerosol and cloud properties for the North Dakota region. CCN concentrations are an important parameter for precipitation development. The cloud base CCN concentrations and surface measurements will be compared to determine if, and under what conditions, surface CCN measurements can be used to infer cloud base concentration. Preliminary evaluations between the WRF model and the radar data is encouraging and an in-depth analysis has been started. Simulated reflectivity forecasted by the model will be compared with observed reflectivity using the WRF-Model Evaluation Tools (MET) package. Using object-based verification tools, convective forecasting can be tested while allowing for spatial and/or temporal shifts.