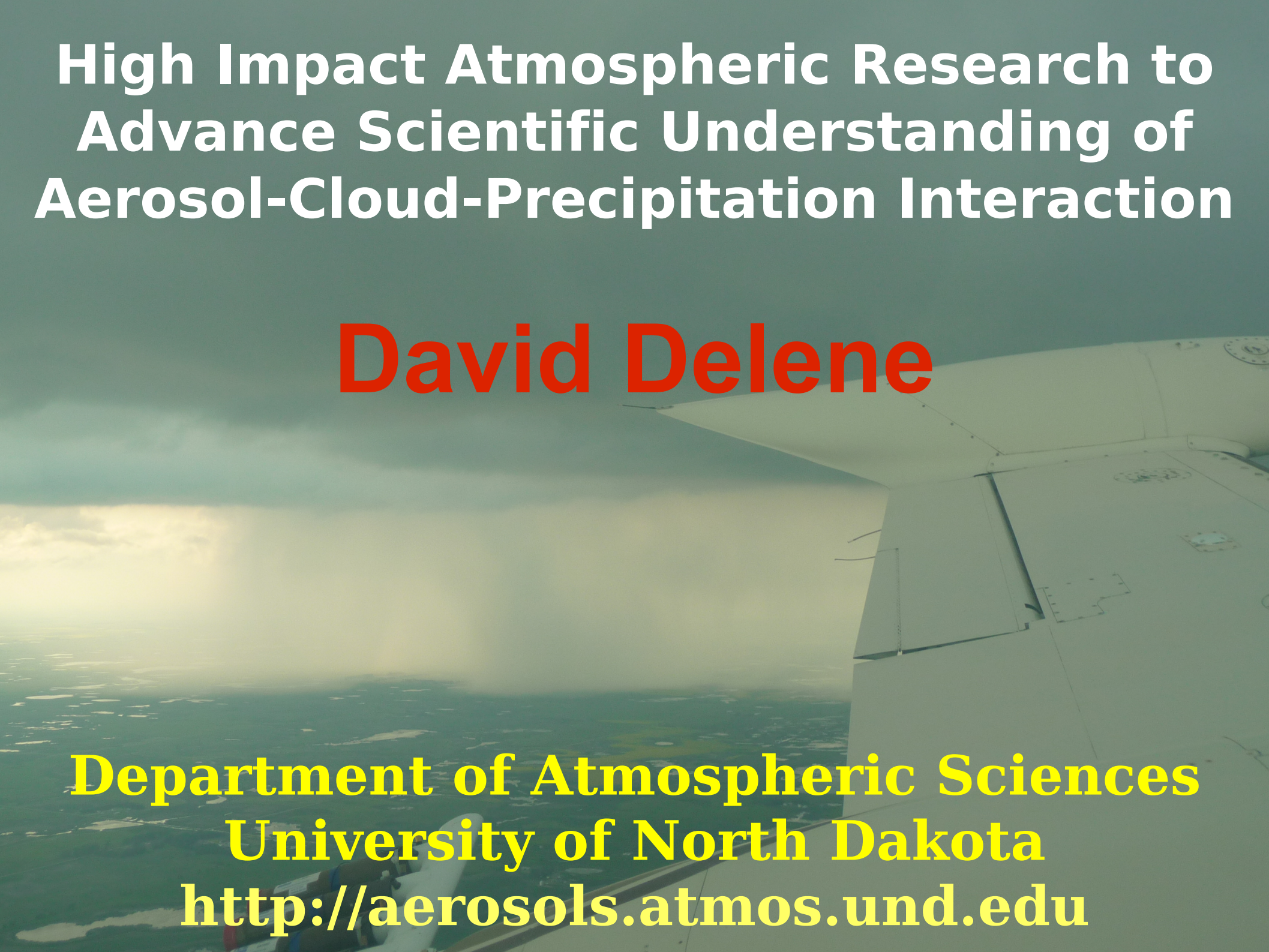


High Impact Atmospheric Research to Advance Scientific Understanding of Aerosol-Cloud-Precipitation Interaction

David Delene

Department of Atmospheric Sciences
University of North Dakota
http://aerosols.atmos.und.edu

Objective

- Illustrate the important of airborne measurement when studying aerosol-cloud-precipitation interactions.
- Provide an overview of my research program and how it is focused on understanding aerosols-cloud-precipitation interaction.

Cloud Deck from Citation Research Aircraft
August 30, 2012

Right Wing of Citation Research Aircraft
September 2, 2012

Societal Significance

The largest issues facing society:

1.) Energy 2.) Water

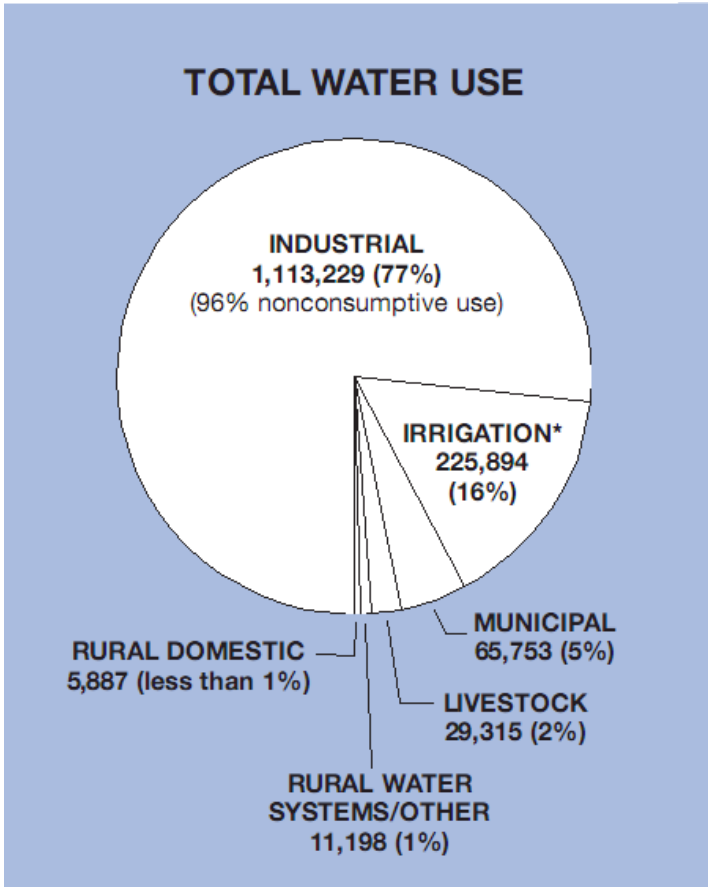
Richard Smalle: Our Energy Challenge

Major PM_{10} Sources in North Dakota

#	COMPANY	SOURCE
1	Great River Energy	Coal Creek Station
2	Basin Electric Power Cooperative	Leland Olds Station
3	American Crystal Sugar Company	Hillsboro Plant
4	American Crystal Sugar Company	Drayton Plant
5	Montana Dakota Utilities Company	RM Heskett Station
6	Great River Energy	Stanton Station
7	Basin Electric Power Cooperative	Antelope Valley Station
8	Minnkota Power Cooperative, Inc.	Milton R. Young Station
9	Otter Tail Power Company	Coyote Station
10	Dakota Gasification Company	Great Plains Synfuels Facility
11	Red Trail Energy, L.L.C.	Richardton Ethanol Plant
12	Tesoro Refining and Marketing Company	Mandan Refinery

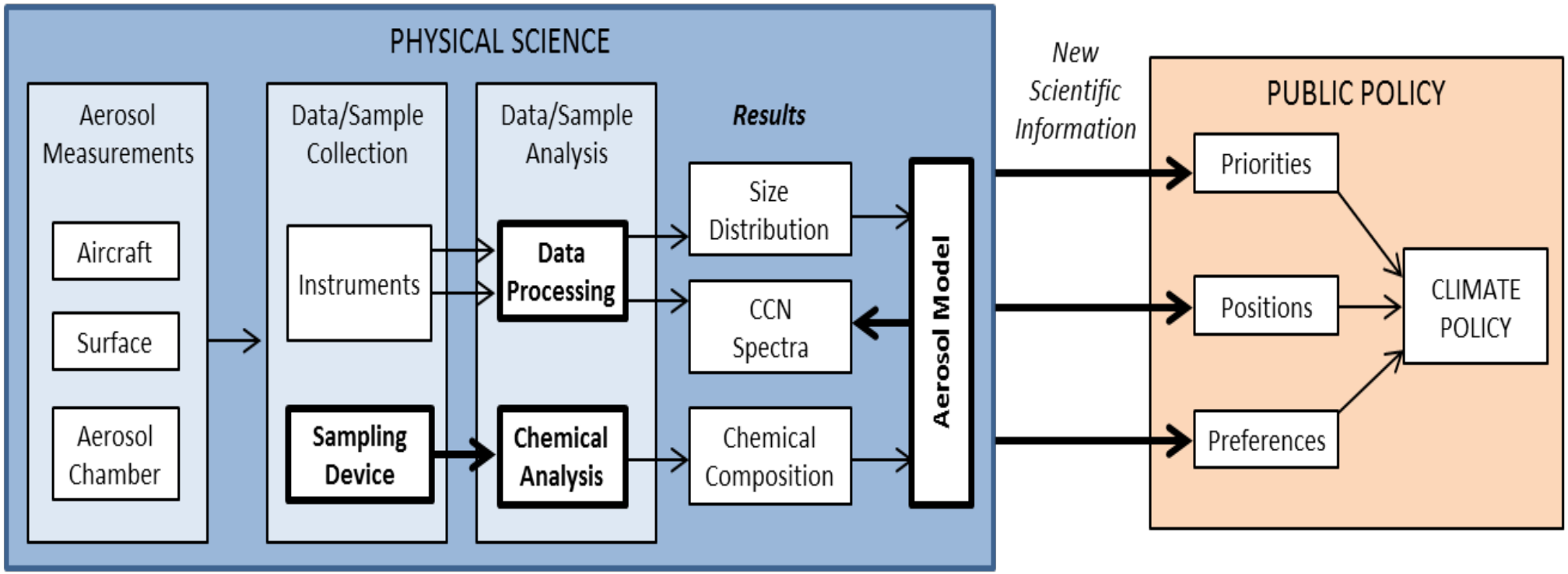
North Dakota Ambient Monitoring Network Plan 2012, Table 9, page 25.

Approximately 77 percent of total water use in North Dakota is for power generation. (ND Water - A Reference Guide)



North Dakota State Wide 2003 Water Use (in acre-feet)

Linking Research to Public Policy



Research framework and tools for the proposed project linking physical science research to public policy research. New capabilities that will be developed are shown in bold.

Physical Science and Public Policy Impact of the Indirect Climate Effects of Organic Aerosols Proposal submitted to the Vice President for Research & Economic Development office at University of North Dakota, December 2012.

Impact of Measurements on Research Progress

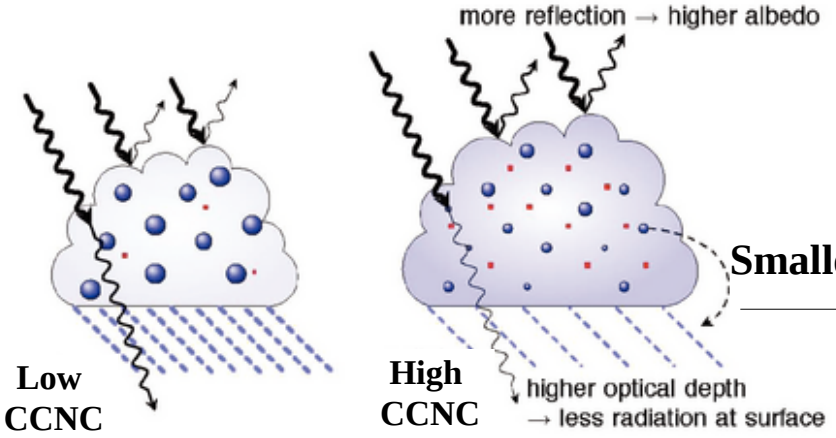
The scientific method consists of **the collection of data through observation** and experimentation, and the formulation and testing of hypotheses - *Merriam-Webster Dictionary*.

"The returns [of science] are so large that it is hardly necessary to justify or evaluate the investment" National Science Foundation. 1957, Basic Research: A National Resource, page 61

"A $3.8 billion investment drove $796 billion in economic impact, create 310,000 jobs and launched the genomic revolution." Economic Impact of the Human Genome Project.

National Academies (US) Committee on Measuring Economic and Other Returns on Federal Research Investments. Measuring the Impacts of Federal Investments in Research: A Workshop Summary. Washington (DC): National Academies Press (US); 2011. 8, EMERGING METRICS AND MODELS. Available from: https://www.ncbi.nlm.nih.gov/books/NBK83139/

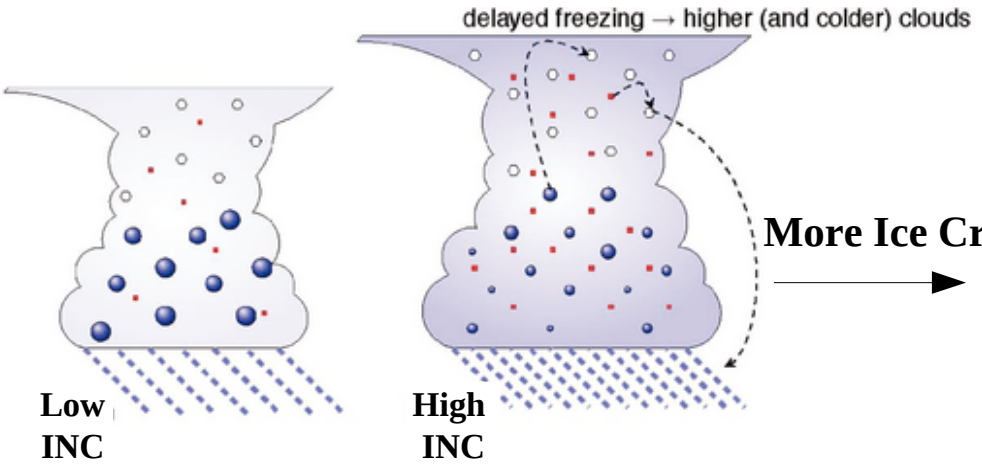
Aerosol-Cloud-Precipiation



Cloud Albedo and Lifetime Effect

Smaller Cloud Particles → Less Precipitation

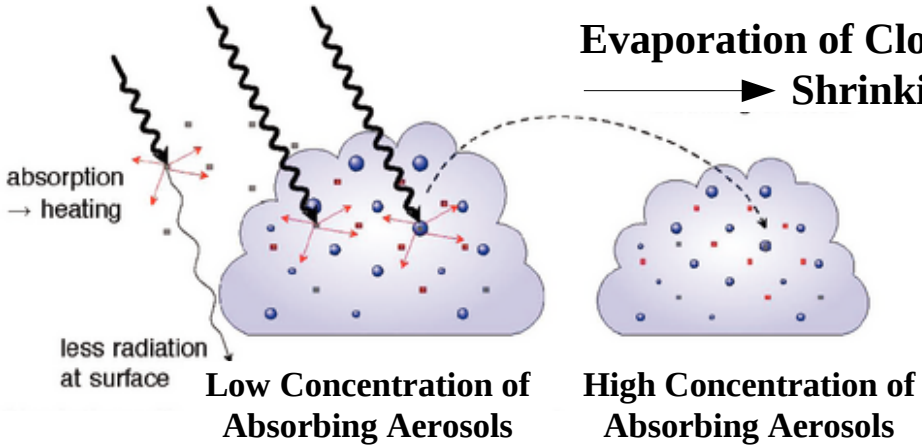
Less Precipitation



Glaciation Effect

More Ice Crystals → More Precipitation

More Precipitation



Semi-direct Effect

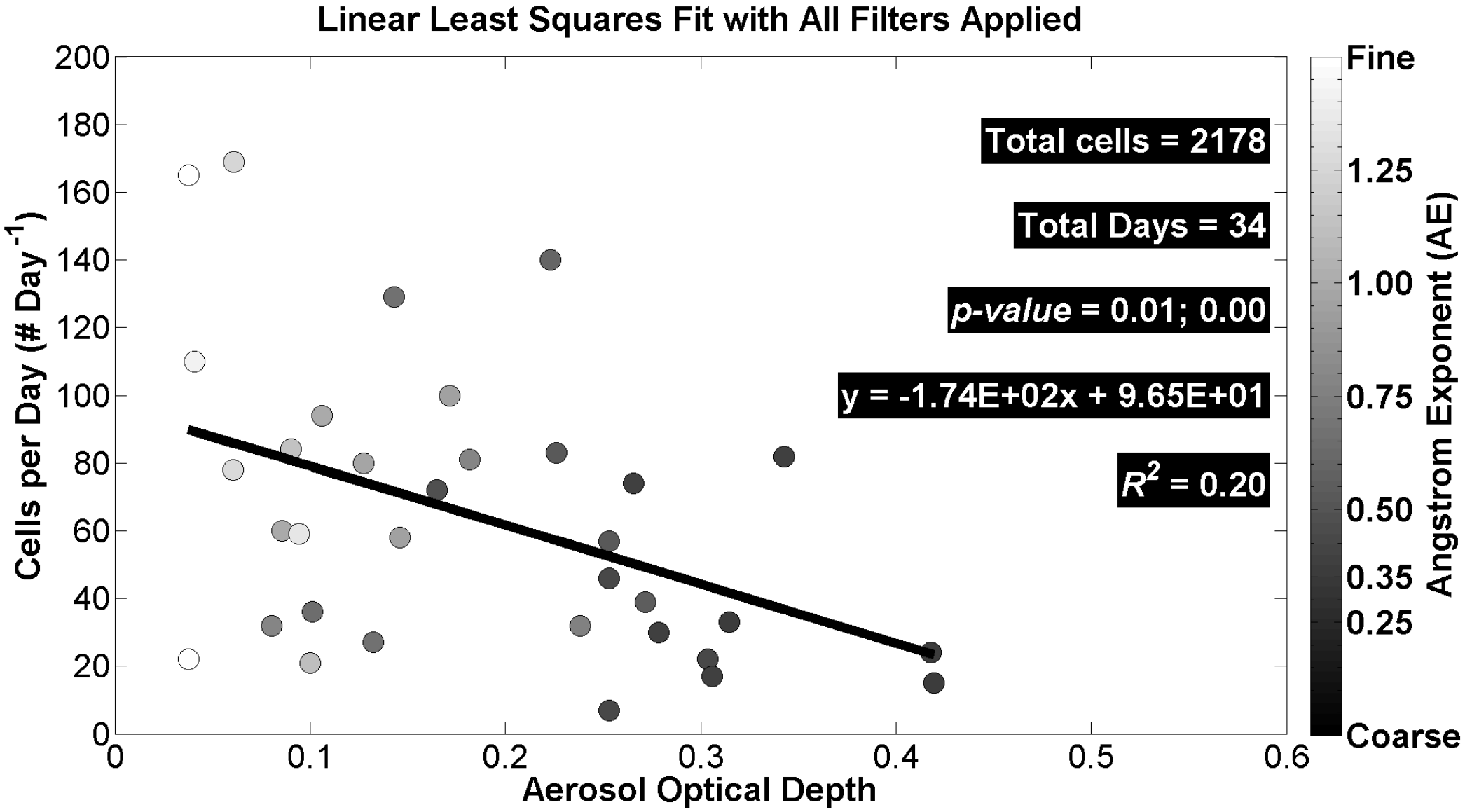
Evaporation of Cloud Droplets → Shrinking of Cloud

Less Precipitation

CCNC – Cloud Condensation Nuclei Concentration
INC – Ice Nuclei Concentration

IPCC Fourth Assessment Report: Climate Change 2007: Working Group 1: The Physical Science Basis, Figure 7.20

Aerosols and Surface-based Convective Cells in Mali, West Africa

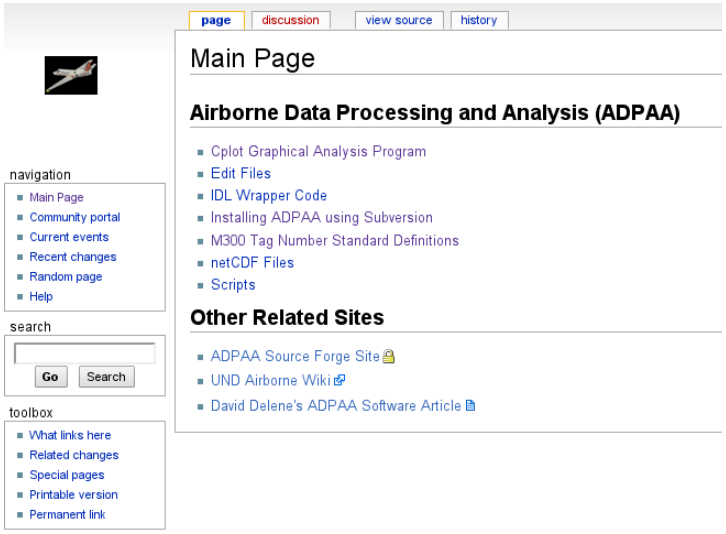


David Keith Thesis entitled "Aerosol Optical Depth and Its Relationship to Radar Derived Precipitation in Mali, West Africa", 2013

ADPAA on Source Forge

http://sourceforge.net/projects/adpaa

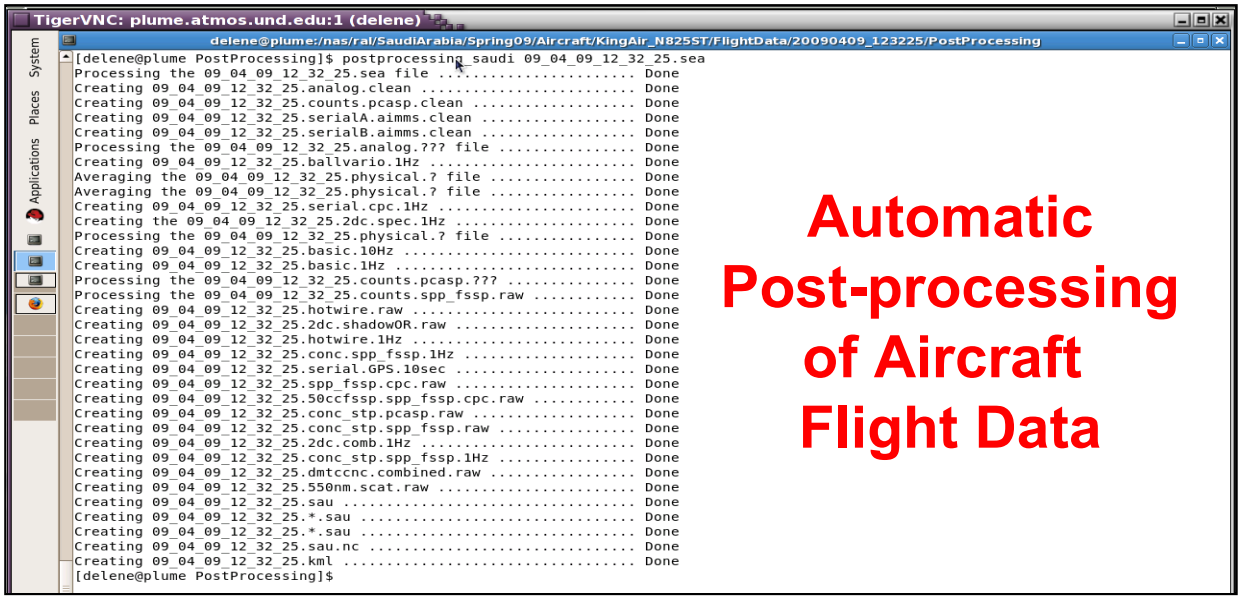
- GNU General Public License, Version 3
- Subversion Source Code Management
  - Sync Code Between Systems
  - Tracking Coding Activity
  - Revert Changes
- Wiki Documentation Site

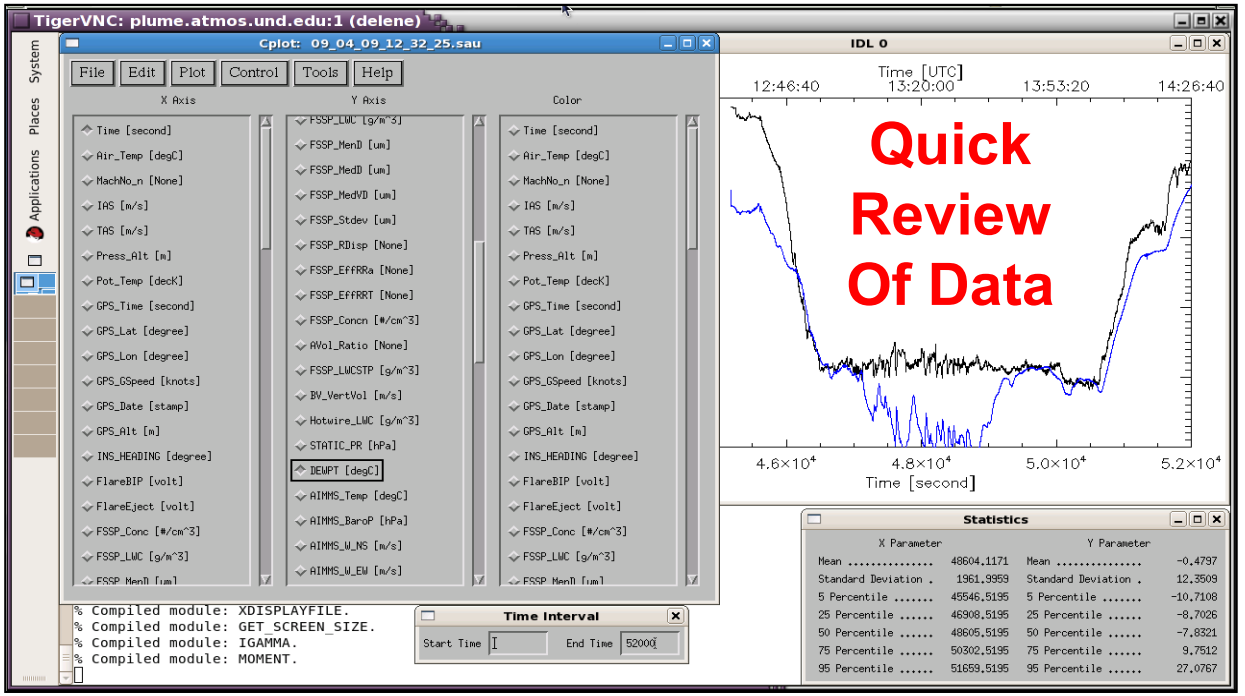


- Feature Requests, Bug Tracker and Forum
- 199,027 lines of code (March 2013) in IDL, Bash/csh Scripts, Perl, FORTRAN, C, and Python

Airborne Data Processing and Analysis (ADPAA) Software Package

- Combining measurement techniques requires robust software.
- Quality control (QC) and quality assurance (QA) of data sets requires a great deal of time.



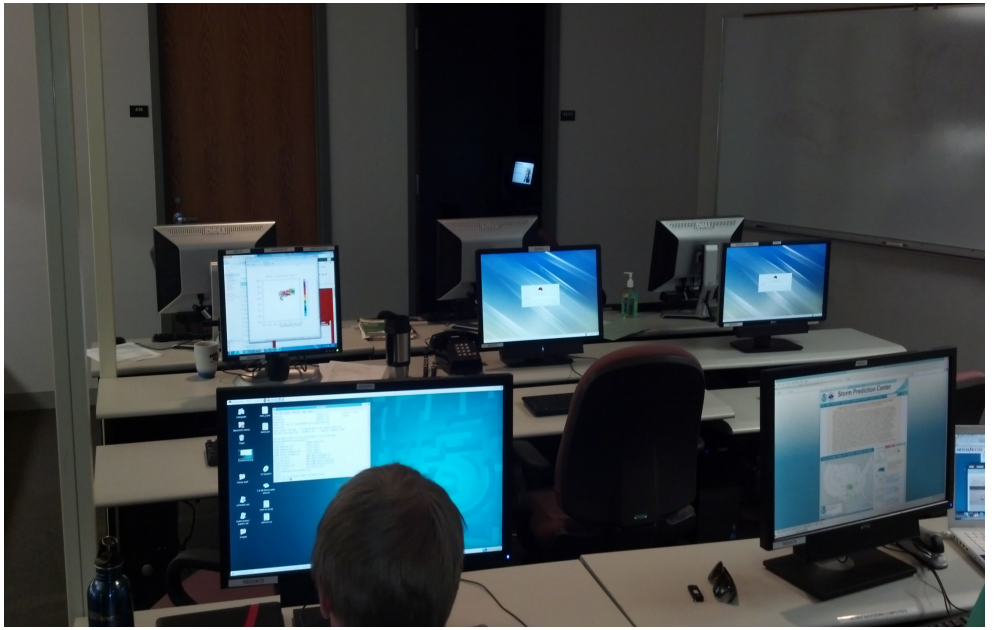


Delene, D. J., Airborne Data Processing and Analysis Software Package, *Earth Science Informatics*, **4**(1), 29-44, 2011, URL: http://dx.doi.org/10.1007/s12145-010-0061-4, DOI: 10.1007/s12145-010-0061-4.

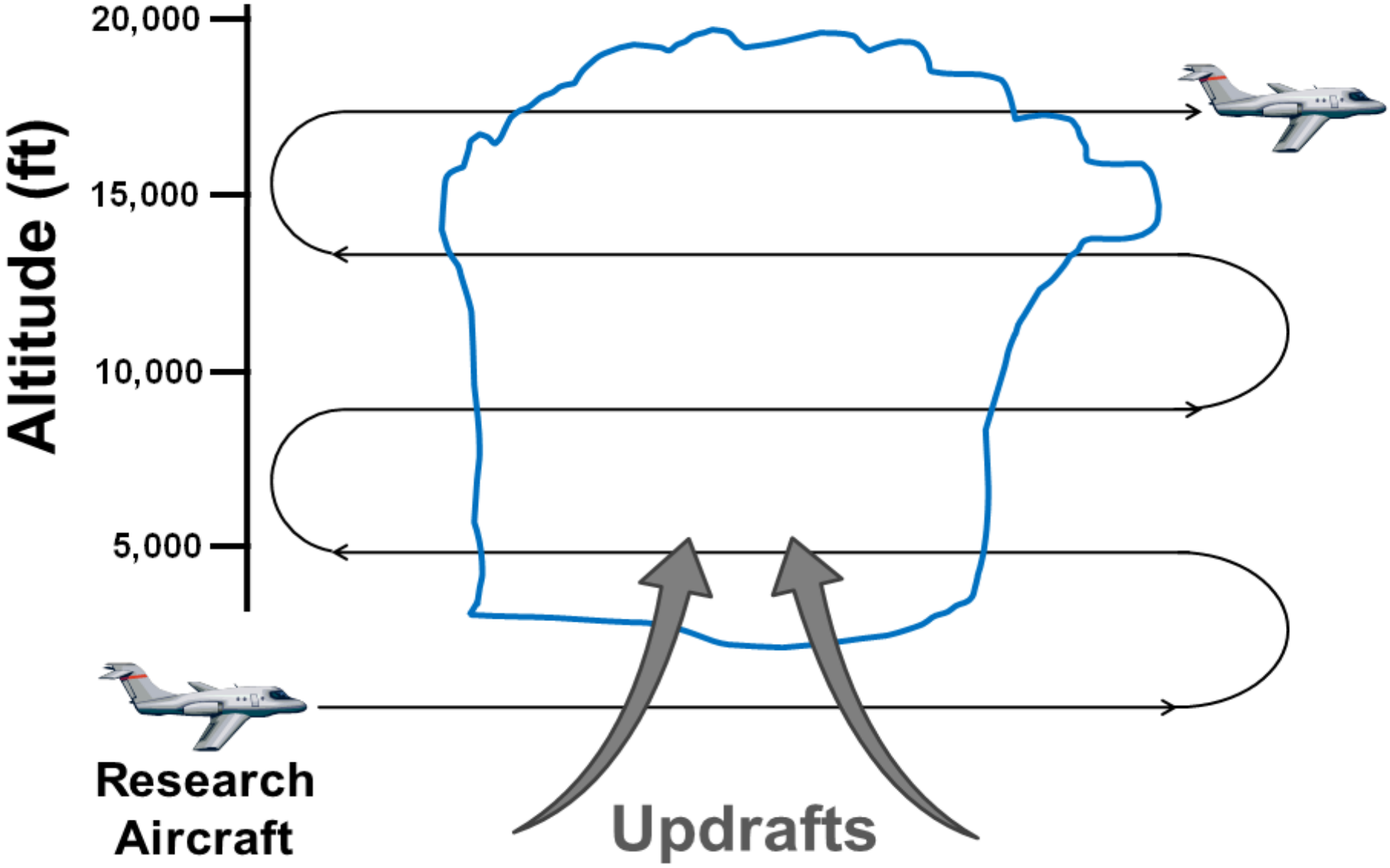
QC/QA

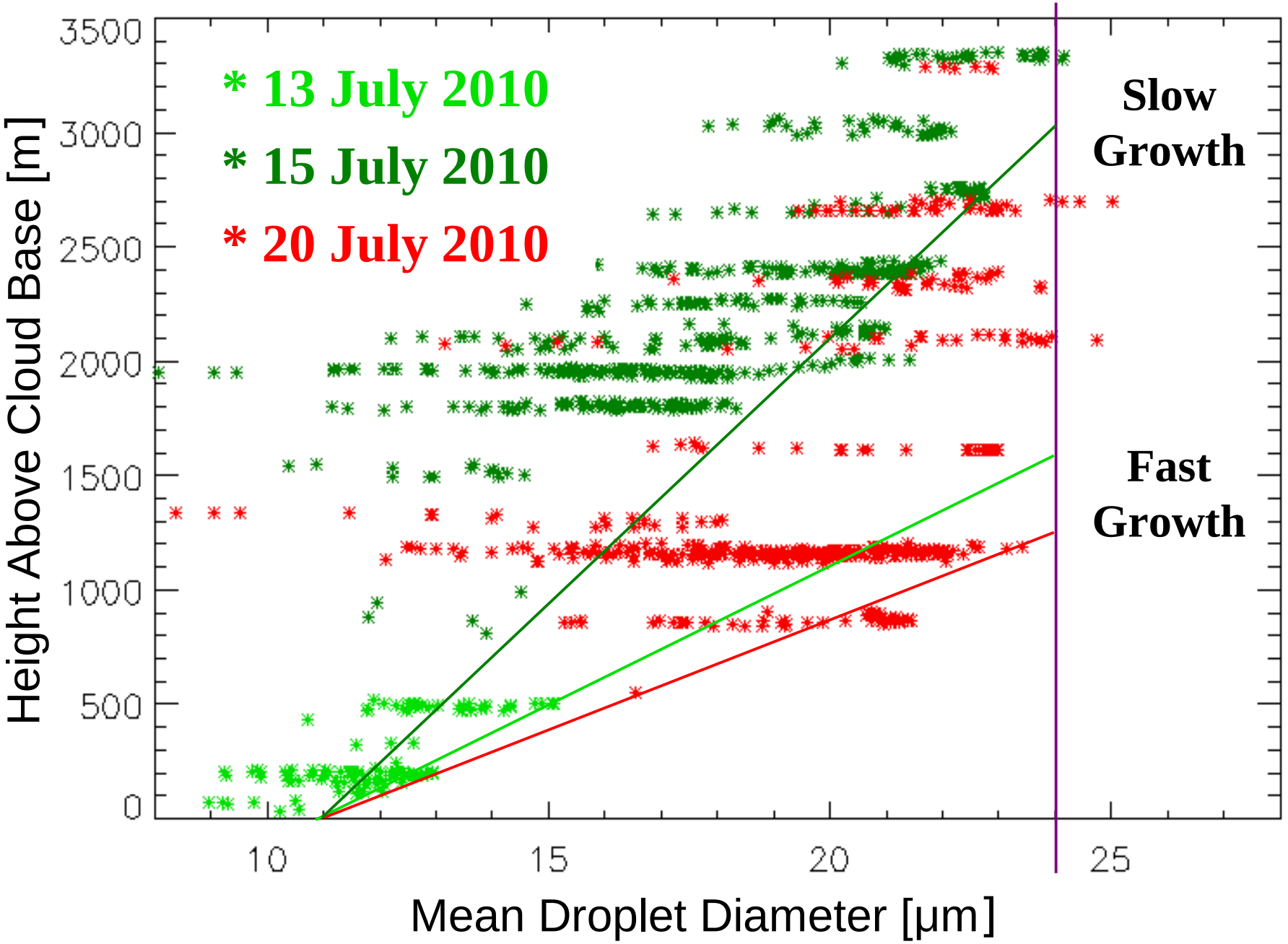
Quality Control (QC) - The process of conducting tests to check that measurements are being made correctly and accurately.

Quality Assurance (QA) The process of reviewing a data set to eliminate (replace with missing value codes) measurements that are invalid due to known problems.



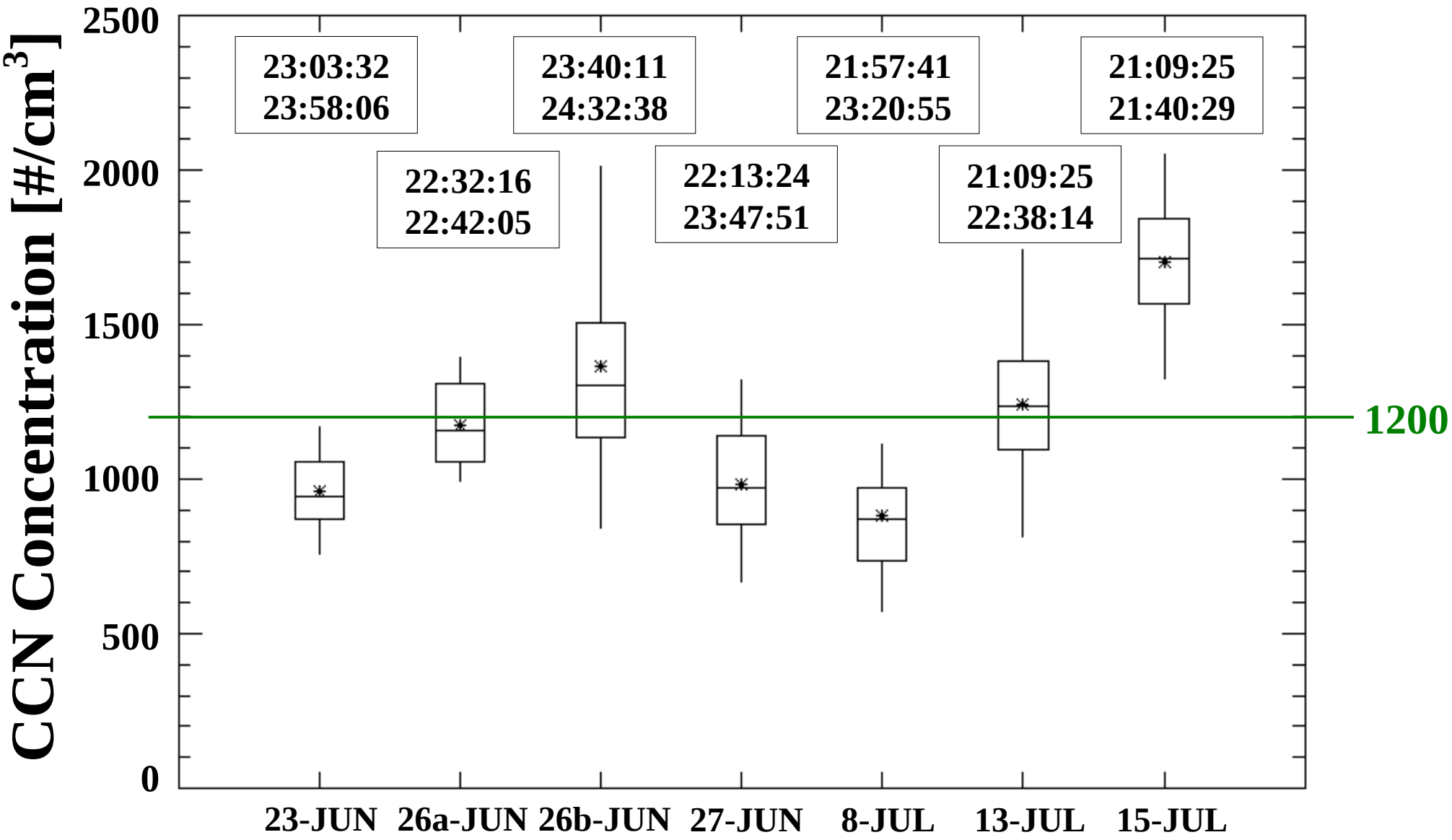
Surface Based Convective Cloud





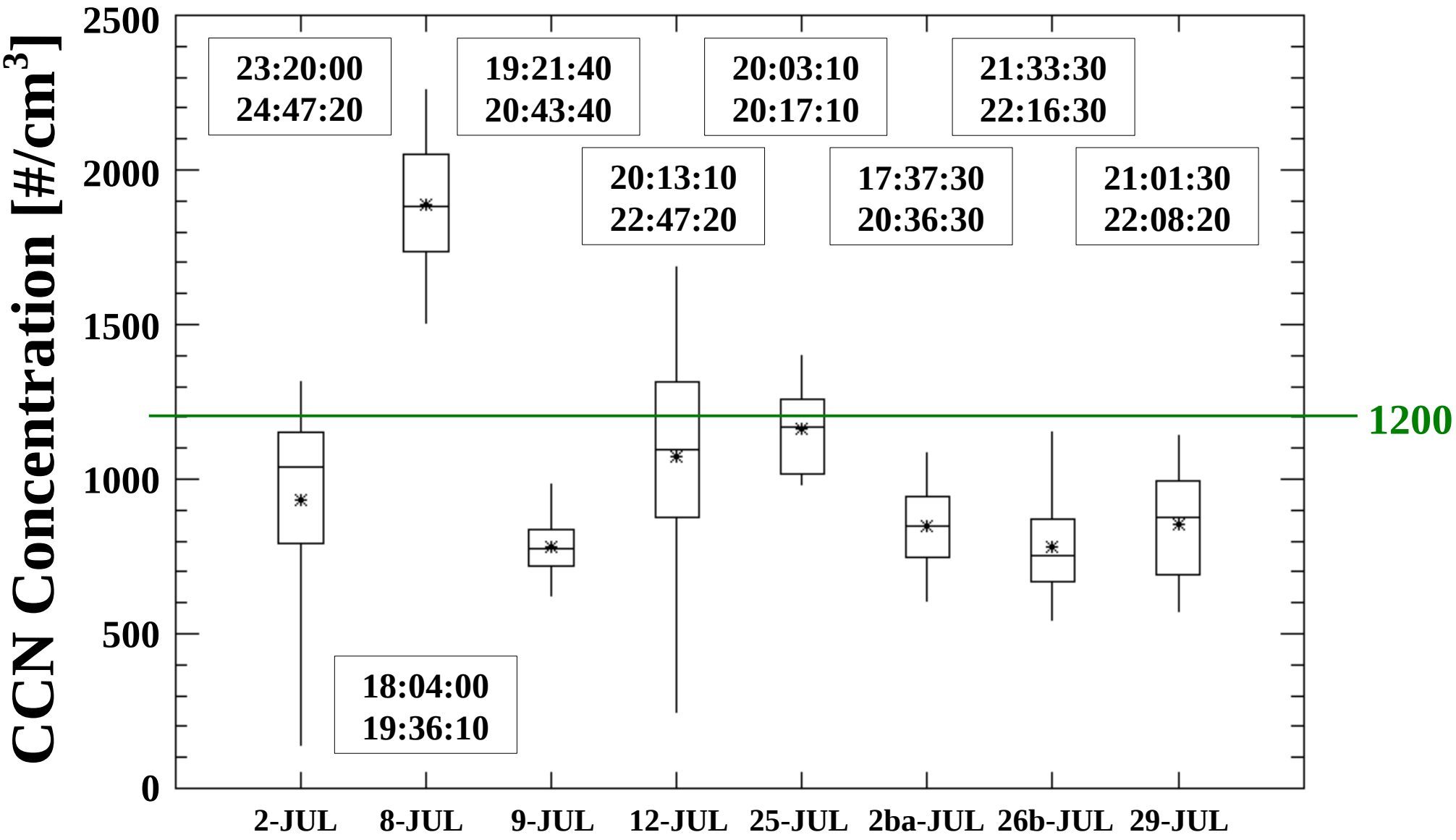
The Cloud Droplet Probe (CDP) mean droplet diameter versus the height above cloud base for aircraft flights during POLCAST3 near Grand Forks, North Dakota. Only measurements with CDP concentrations about 140 cm^{-3} are presented.

Cloud Base: 2010



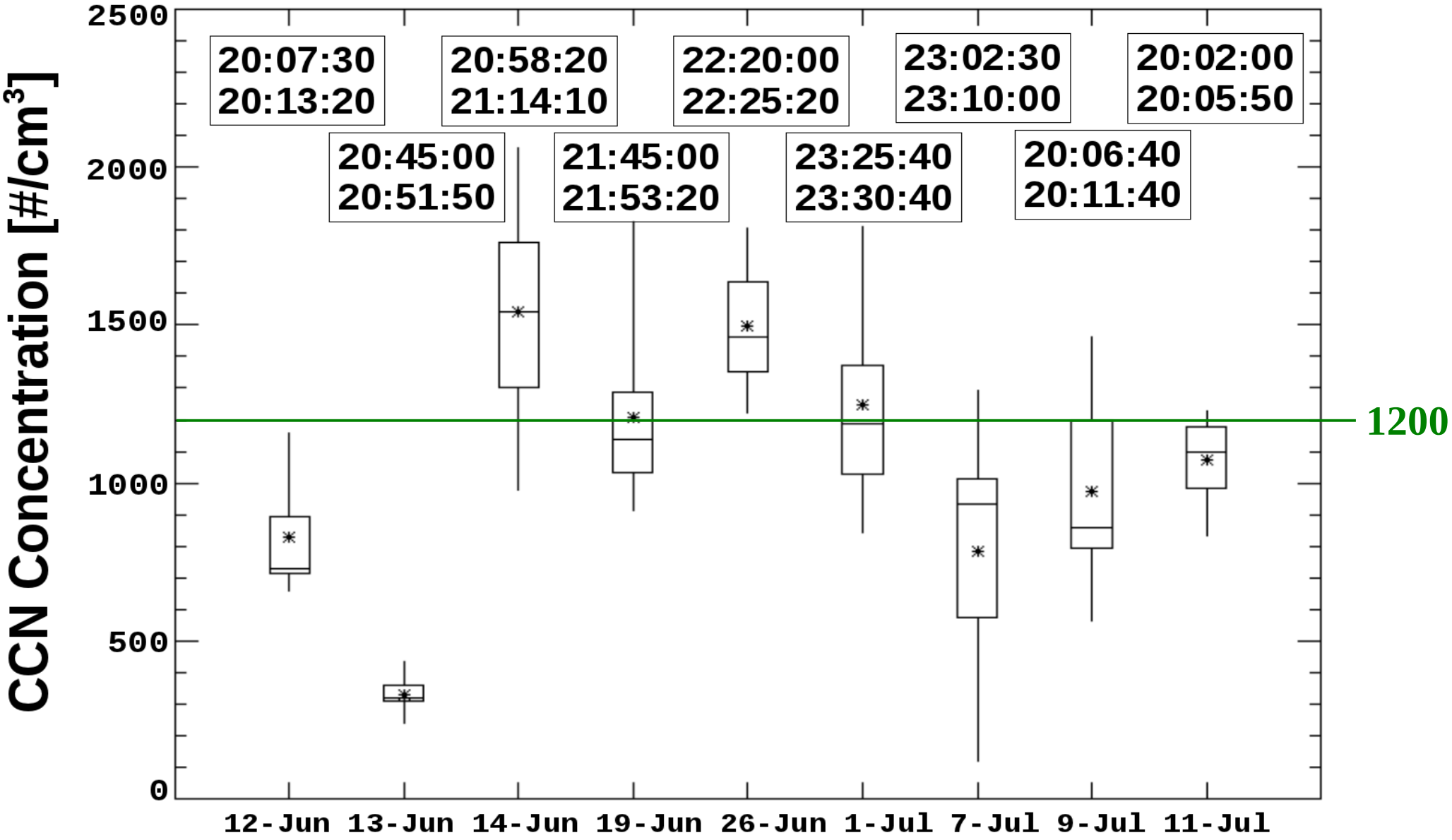
Statistical distributions near cloud base of 30 s 1 % supersaturation (counter's theoretical value) Cloud Condensation Nuclei (CCN) adjusted to standard temperature and pressure during the 2010 POLCAST3 field project. The solid circle is the mean value, the horizontal line is the 50th percentile, the top of the box is the 75th percentile, the bottom is the 25th percentile, and the top and bottom of the whiskers are the 95th and 5th percentiles, respectively.

Cloud Base: 2012



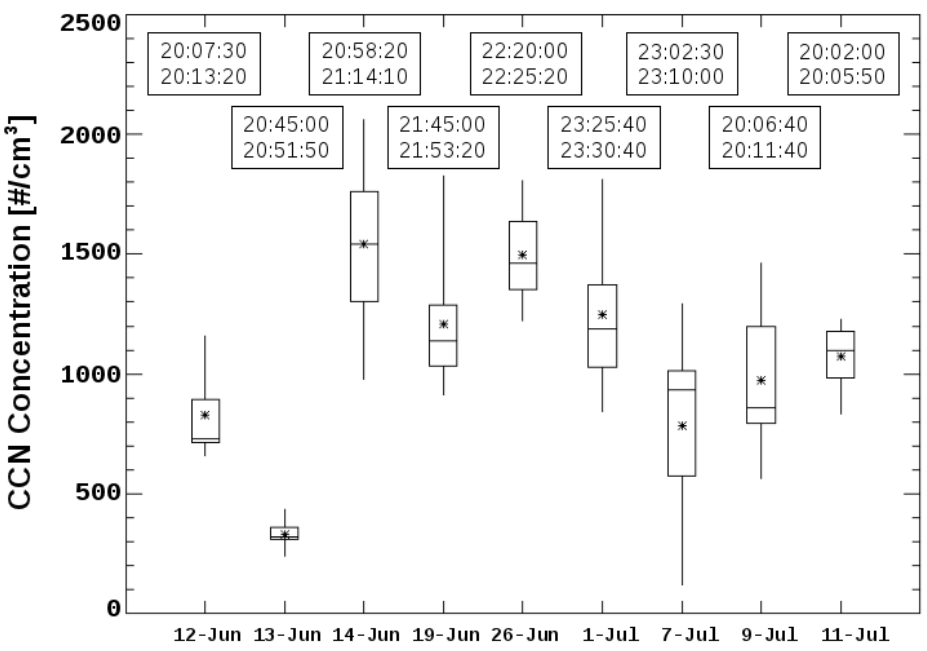
Statistical distributions near cloud base of 30 s 1 % supersaturation (counter's theoretical value) Cloud Condensation Nuclei (CCN) adjusted to standard temperature and pressure during the 2010 POLCAST3 field project. The solid circle is the mean value, the horizontal line is the 50th percentile, the top of the box is the 75th percentile, the bottom is the 25th percentile, and the top and bottom of the whiskers are the 95th and 5th percentiles, respectively.

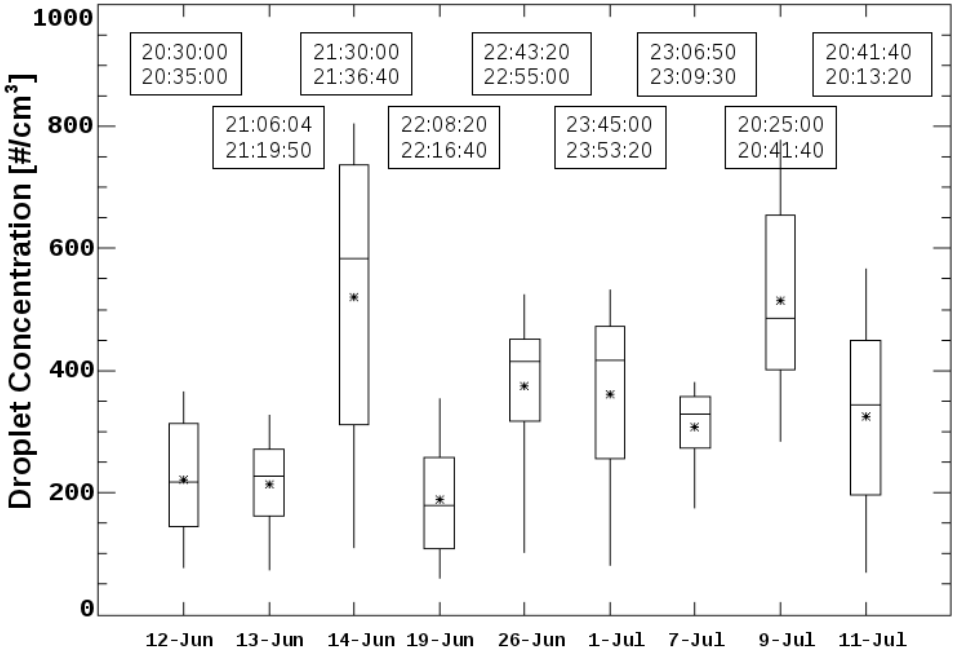
Cloud Base: 2008

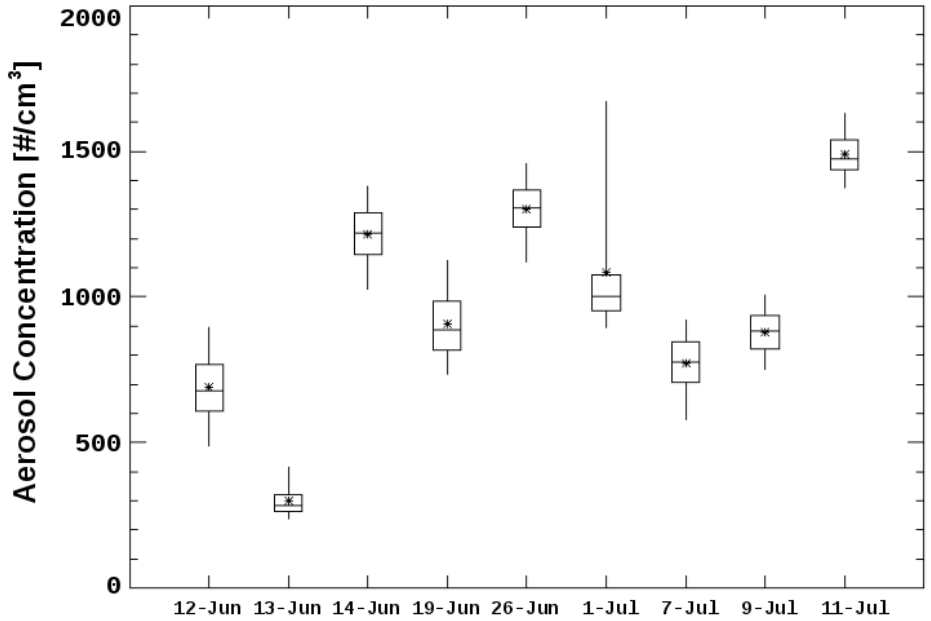


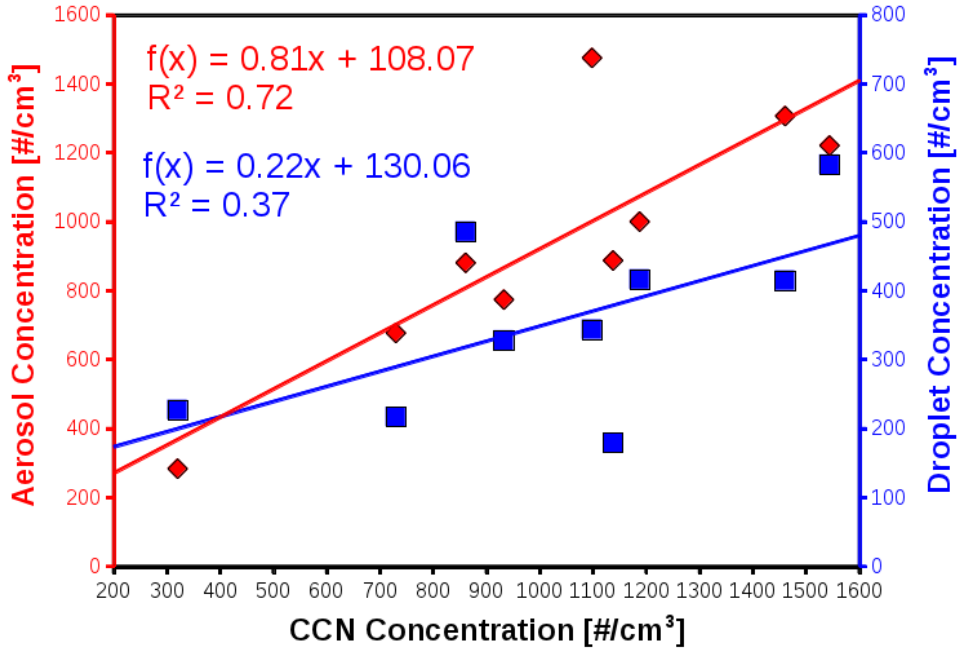
Statistical distributions near cloud base of 30 s 1 % supersaturation (counter's theoretical value) Cloud Condensation Nuclei (CCN) adjusted to standard temperature and pressure during the 2008 POLCAST2 field project. The solid circle is the mean value, the horizontal line is the 50th percentile, the top of the box is the 75th percentile, the bottom is the 25th percentile, and the top and bottom of the whiskers are the 95th and 5th percentiles, respectively.

North Dakota: CCN and Cloud Droplet



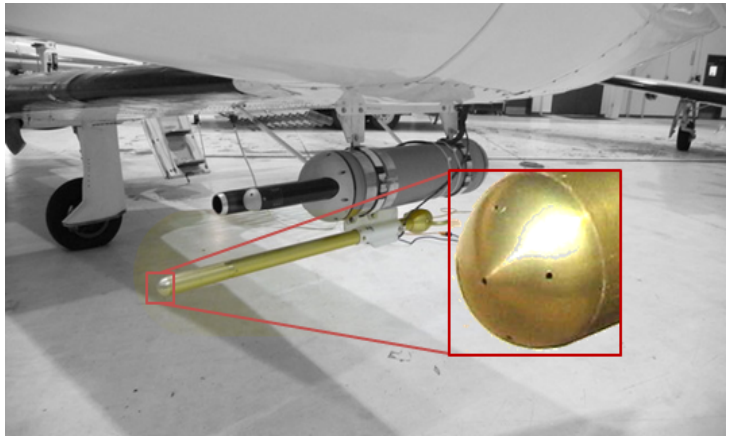


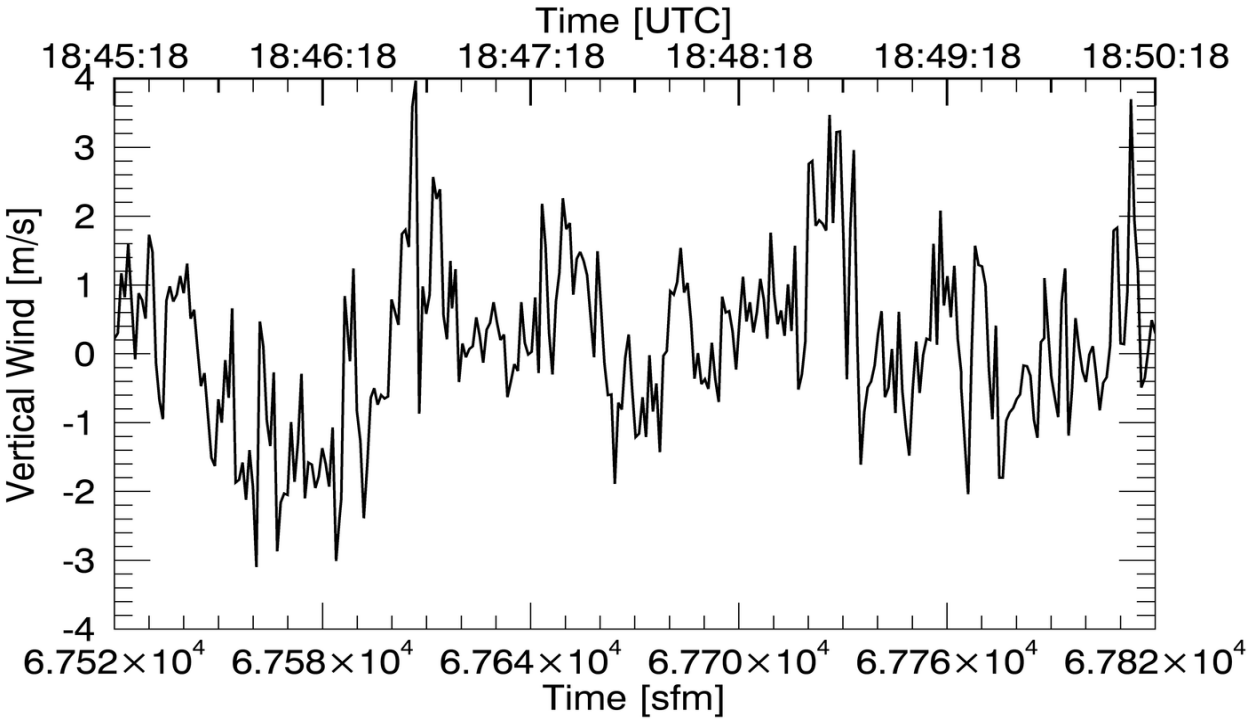


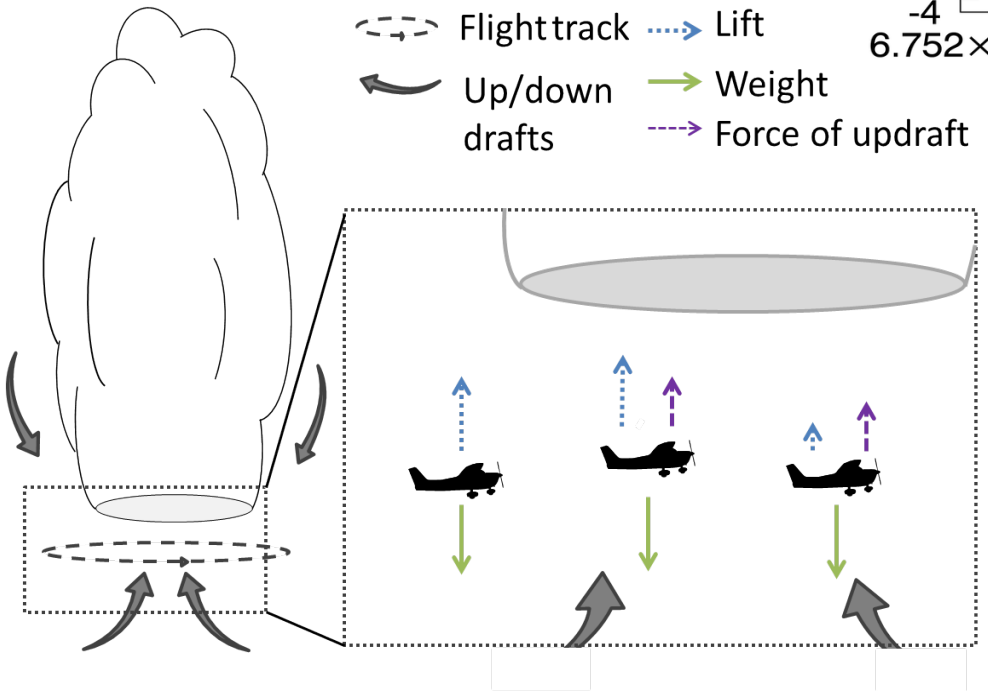


Delene, D. J., C. Grainger, P. Kucera, D. Langerud, M. Ham, R. Mitchell, and C. Kruse, The Second Polarimetric Cloud Analysis and Seeding Test, *Journal of Weather Modification*, 43, 14-28, 2011.

Updraft Measurements to Determine Supersaturation





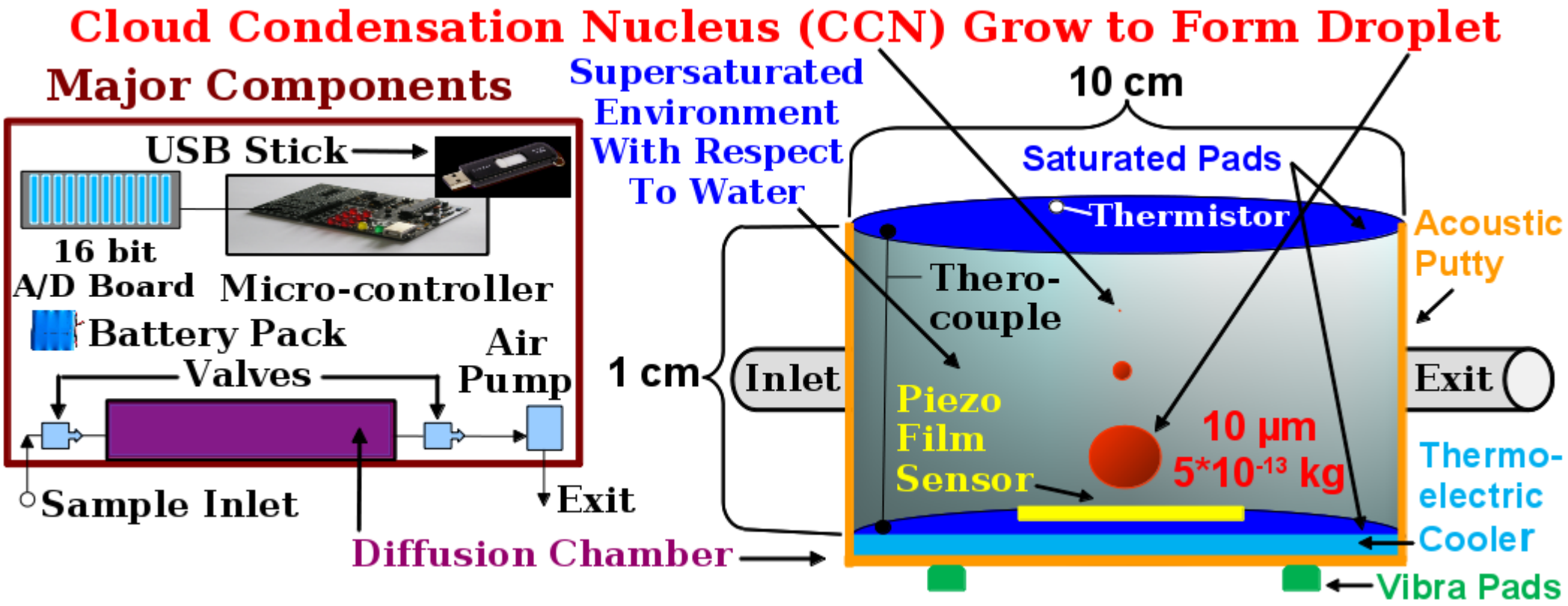


Vertical wind velocity measured at a frequency of 1.0 Hz by the Aircraft Integrated Meteorological Measurement System (AIMMS) during the first flight on 26 July 2012. Time period is the first five minutes (67,518-67,818 seconds from midnight (sfm) of sampling for target case 1.

Simelane, P. S., D. J. Delene, H. Ahlness, and D. Langerud, Evaluation of Pilot Estimated Updrafts Using Aircraft Integrated Meteorological Measurment Systems (AIMMS) Measurements, Journal of Weather Modification, 45, in press, 2013.

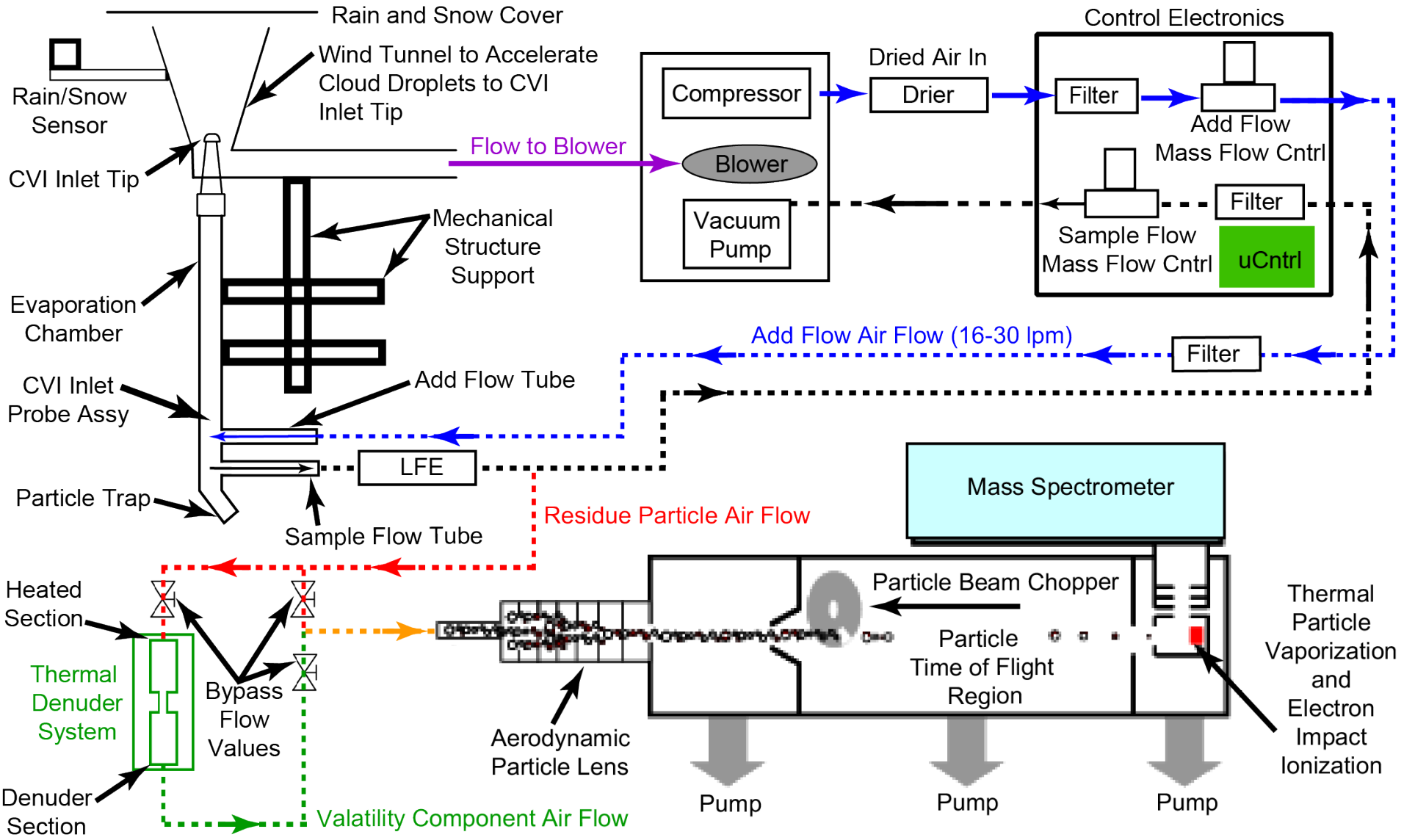
New Measurement Techniques

Miniaturized Cloud Condensation Nucleus Counter



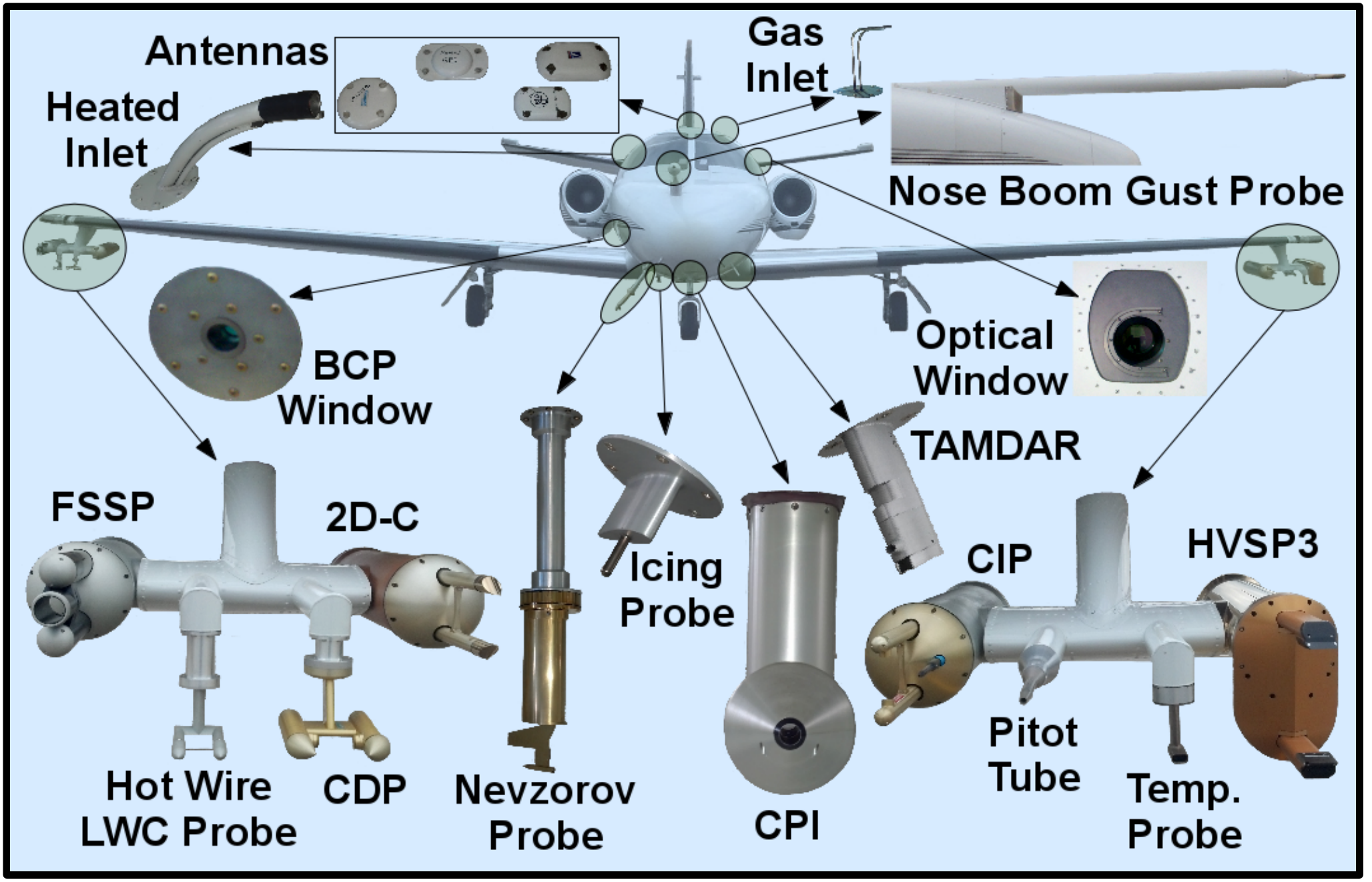
NSF Proposal: Collaborative Research: NORCIS - Northern Plains Convective Initiation Study Proposal

Counterflow Virtual Impactor, Thermal Denuder, High Resolution, Time-of-Flight, Aerosol Mass Spectrometer (CVI-TD-HR-ToF-AMS)



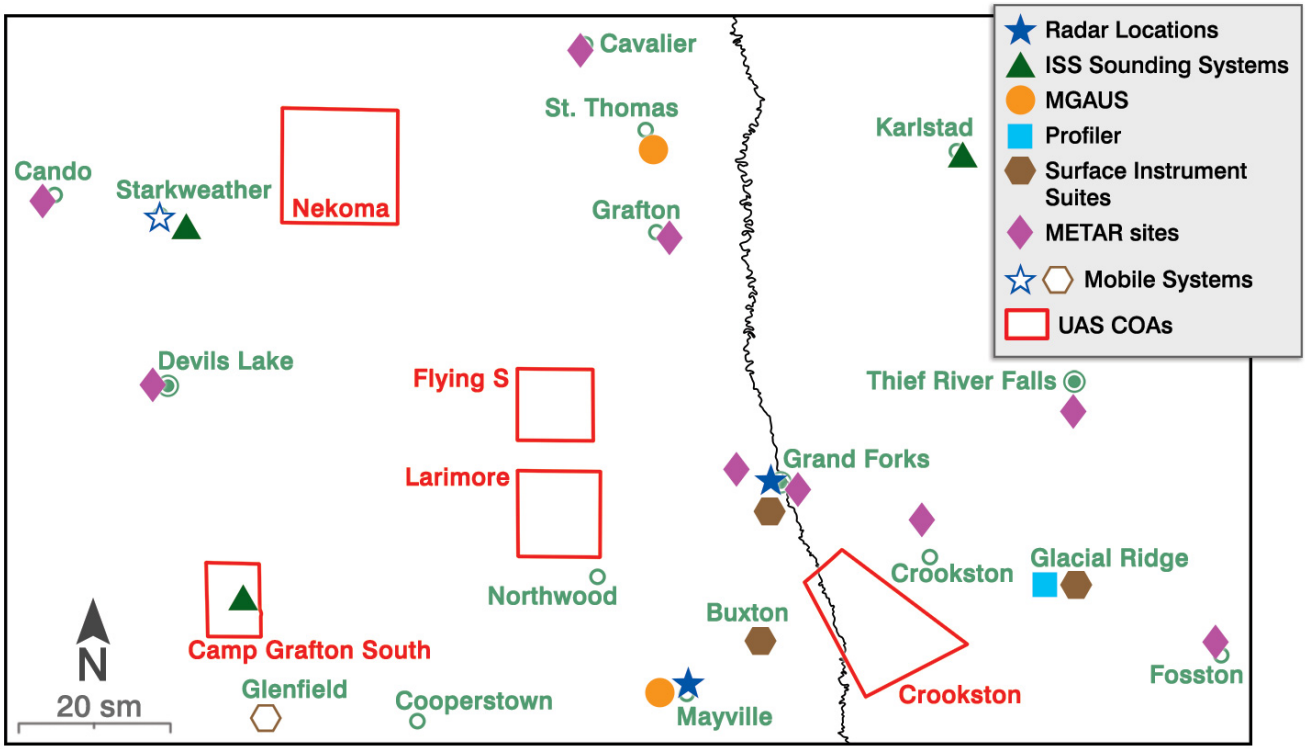
NSF Proposal: Major Research Instrumentation: Acquisition of an Aerosol Mass Spectrometer

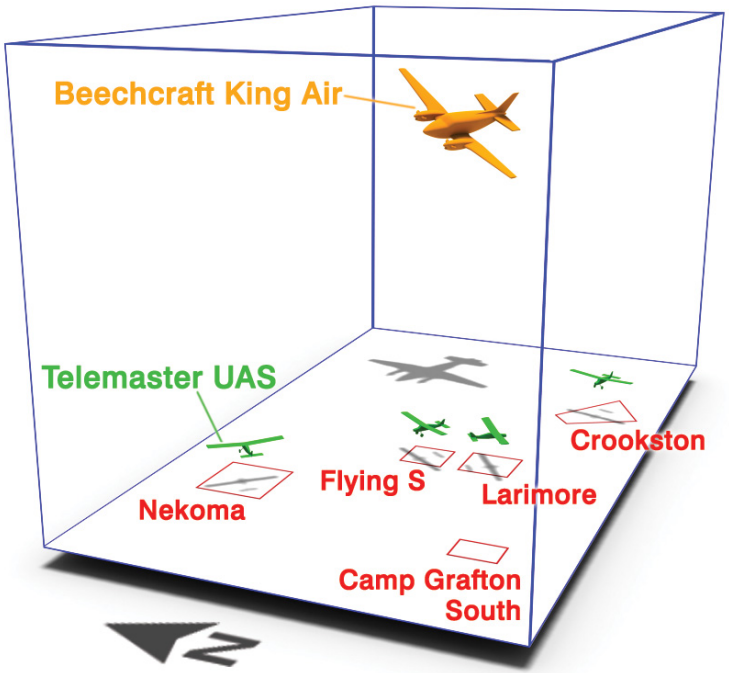
Advanced Instrument on Airborne Platforms for Field Projects



Field Projects using New Instrumentation

Northern Plains Convective Initiation Study





The open star represents the OU mobile X-band radar, at a possible deployment location; the open brown circle indicates the UMB MARS-1 system, which includes a profiling radiometer and a Doppler wind lidar. The green triangles are for the Integrated Sounding System (ISS) which is a self contained meteorological observing system at the Earth Observing Laboratory (EOL) of the National Center for Atmospheric Research (NCAR). The ISS consists of a wind profiler radar, radiosonde sounding system, a 10 m meteorological tower, solar radiation and other sensors. The orange circles is for the mobile GPS Advanced Upper-Air Sounding (MGAUS) systems from EOL.

NSF Proposal: Collaborative Research: NORCIS - Northern Plains Convective Initiation Study Proposal

Proposals

Project Title: Polarimetric Cloud Analysis & Seeing Test 4, **Supporting Agency:** North Dakota Atmospheric Research Board, **Principal Investigator:** David Delene, **Co-Principal Investigator:** Gretchen Mullendore and Jeffrey Tilley **Investigator Support:** 3.0 months, **Project Dollar Value:** $128,473 **Project Duration:** April 16, 2012 - May 31, 2014.

Proposal Title: Physical Science and Public Policy Impact of the Indirect Climate Effects of Organic Aerosols, **Funding Agency:** Seed/Planning Grant for Collaborative Research solicitation from the Vice President for Research & Economic Development office at University of North Dakota, **Proposal Submitted:** December 3, 2012, **Proposed Project Period:** January, 2013 to December 31, 2013, **Total Funds Requested:** $75,000, **Principal Investigator:** David Delene, Alena Kubatova, Frank Bowman, and Bo Wood

Project Title: Collaborative Research: NORCIS - Northern Plains Convective Initiation Study, **Supporting Agency:** National Science Foundation **Principal Investigator:** David Delene, **Co-Principal Investigator:** Leon Osborne and William Semke, **Co-Investigator:** John Nordlie, Investigator Support: 4.0 months per year, **Project Dollar Value:** $1,327,333, **Project Duration:** June 1, 2013 - May 31, 2016.

Project Title: Major Research Instrumentation: Acquisition of an Aerosol Mass Spectrometer: Acquisition of an AMS, **Supporting Agency:** National Science Foundation Principal Investigator: Frank Bowman, **Co-Principal Investigator:** David Delene, Alena Kubatove, Steve Benson, Wayne Seames, **Investigator Support:** 0.0 months per year, **Project Dollar Value:** $717,478, **Project Duration:** September 1, 2013 - August 31, 2016.

Conclusions

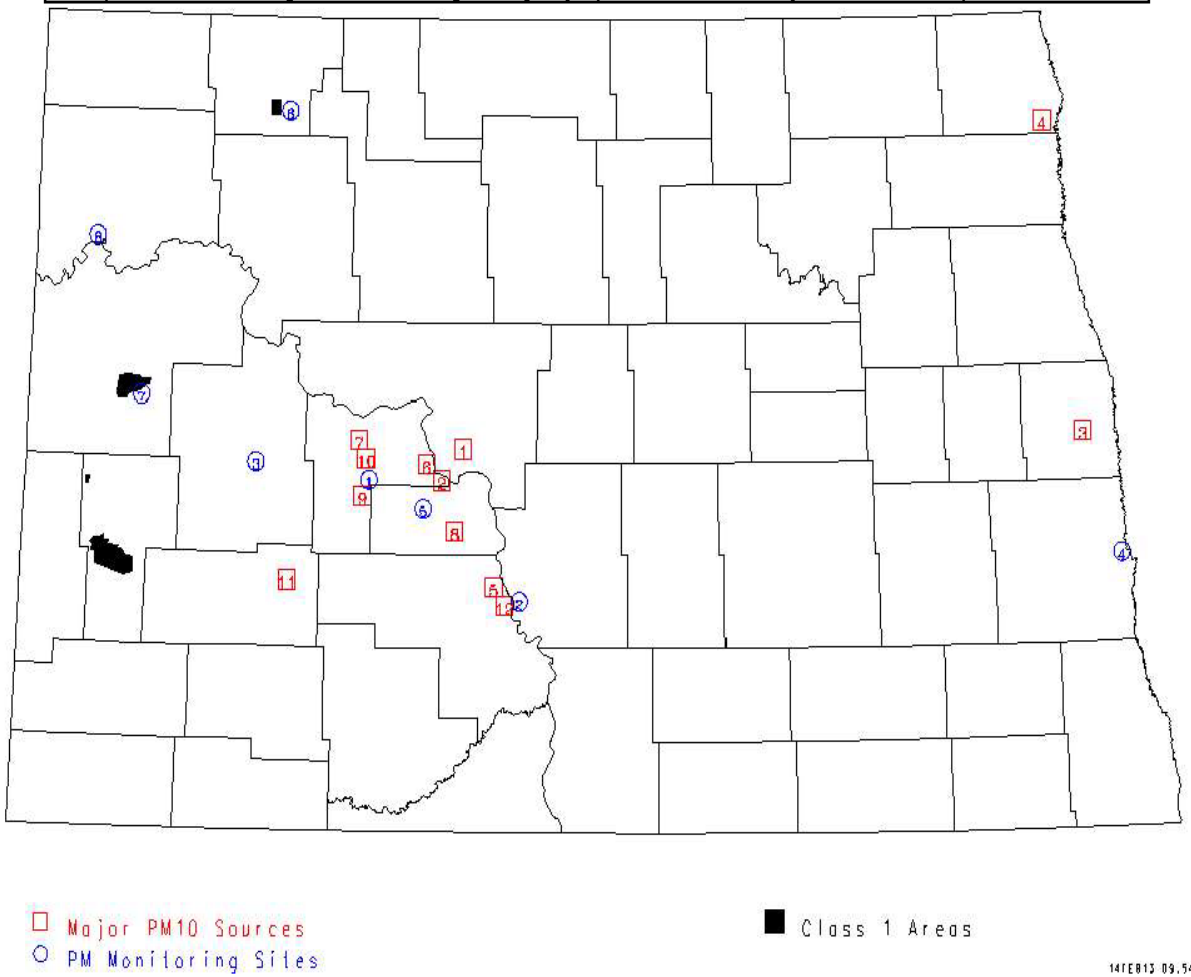
- Measurements are expensive.
  - Requires Robust Software
  - Need Quality Controlled and Quality Assured Data from Advanced Instruments.
  - Range of Sampling Scales
- Measurements have a large impact on advancing scientific understanding.
  - Only measurements tell you what CCN concentration really are at cloud base.


If your in the Fog
Ask Questions


Hopefully things are a little clearer.
Thanks for listing.

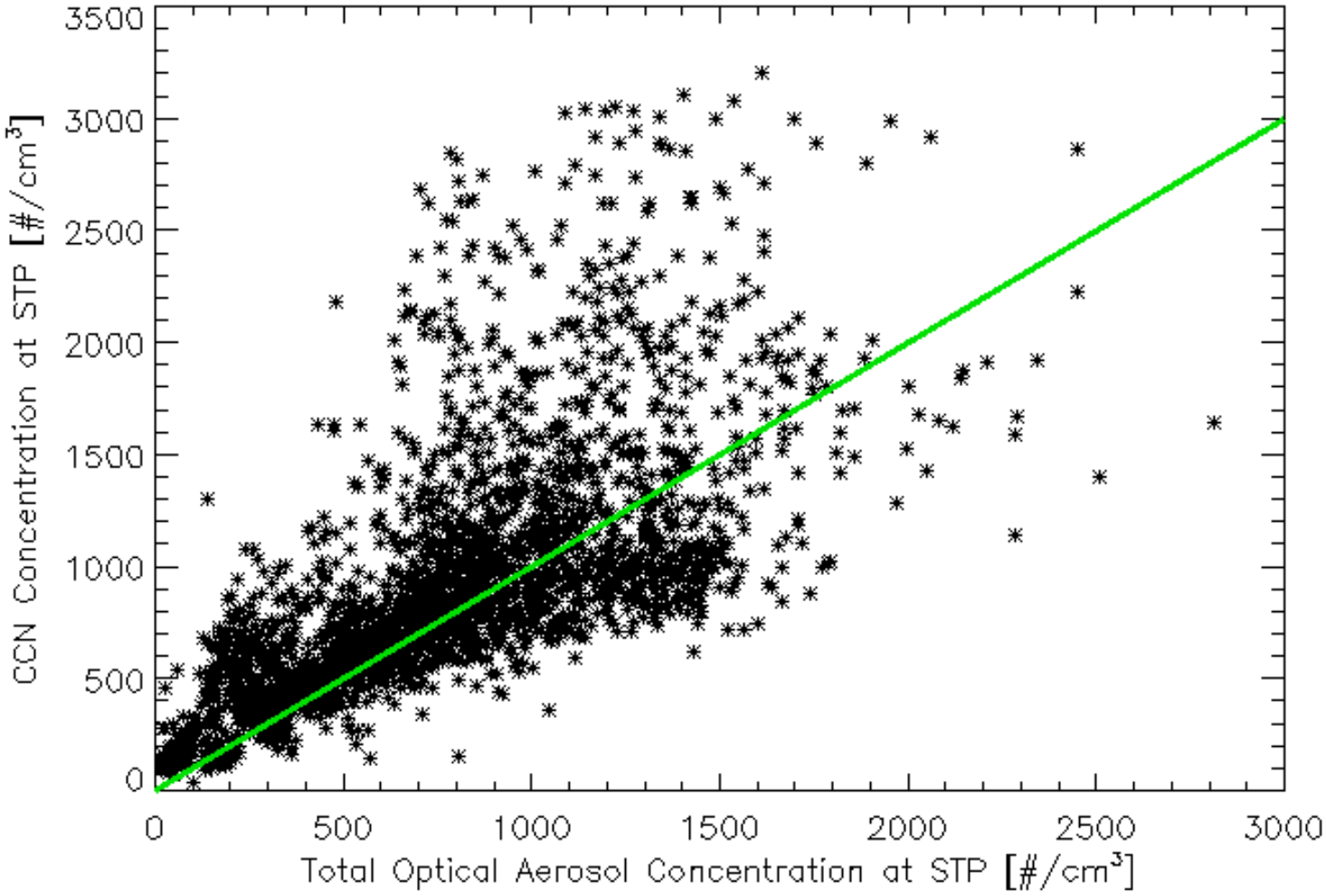
Major PM10 Sources

#	COMPANY	SOURCE	Facility ID
1	Great River Energy	Coal Creek Station	3805500017
2	Basin Electric Power Cooperative	Leland Olds Station	3805700001
3	American Crystal Sugar Company	Hillsboro Plant	3809700019
4	American Crystal Sugar Company	Drayton Plant	3806700003
5	Montana Dakota Utilities Company	RM Heskett Station	3805900001
6	Great River Energy	Stanton Station	3805700004
7	Basin Electric Power Cooperative	Antelope Valley Station	3805700011
8	Minnkota Power Cooperative, Inc.	Milton R. Young Station	3806500001
9	Otter Tail Power Company	Coyote Station	3805700012
10	Dakota Gasification Company	Great Plains Synfuels Facility	3805700013
11	Red Trail Energy, L.L.C.	Richardton Ethanol Plant	3808900058
12	Tesoro Refining and Marketing Company	Mandan Refinery	3805900003



North Dakota Ambient Monitoring Network Plan 2012, Table 9 and Figure 10, page 25.

Quality Assured Data

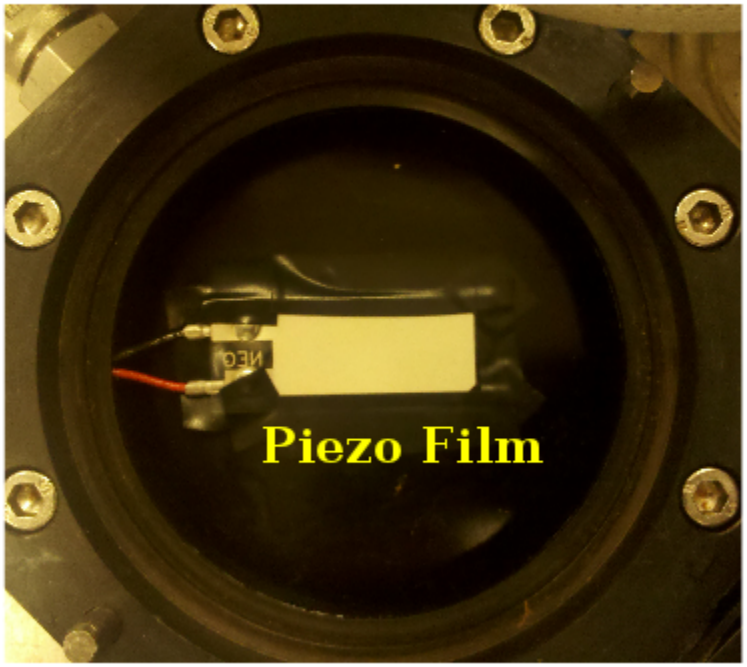


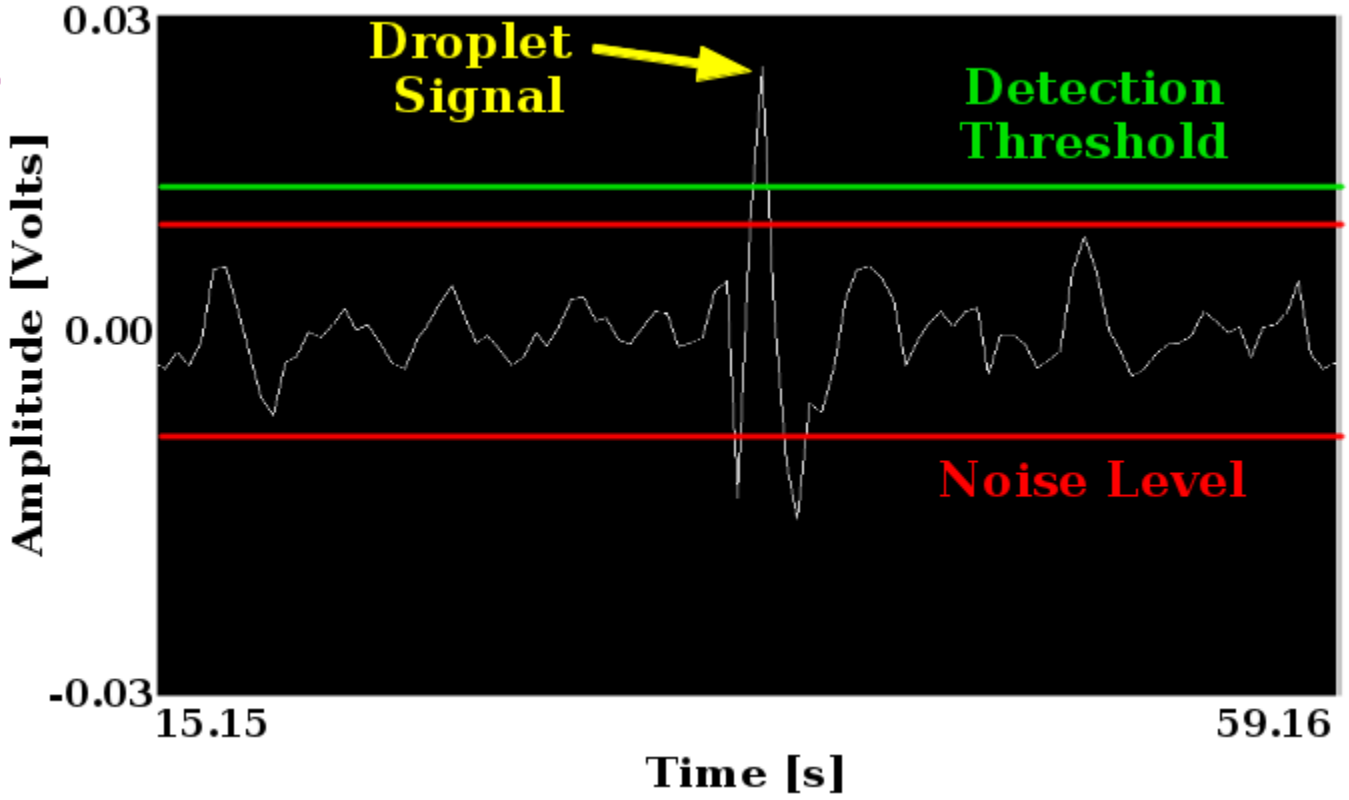
The 1 Hz averaged total (0.1 – 3.0 μm in diameter) aerosol concentration measured by the Passive Cavity Aerosol Spectrometer Probe (PCASP) at the time corresponding to samples made be the University of Wyoming Cloud Condensation Nuclei (CCN) counter (1% Supersaturation). The solid green line is the one-to-one line. All valid out of cloud measurements (FSSP total number concentration less than 50 # cm^{-3}) obtained during the POLCAST2 field project are presented. Both the PCASP and CCN Counter concentrations have been adjusted to standard temperature and pressure.

New Measurement Techniques

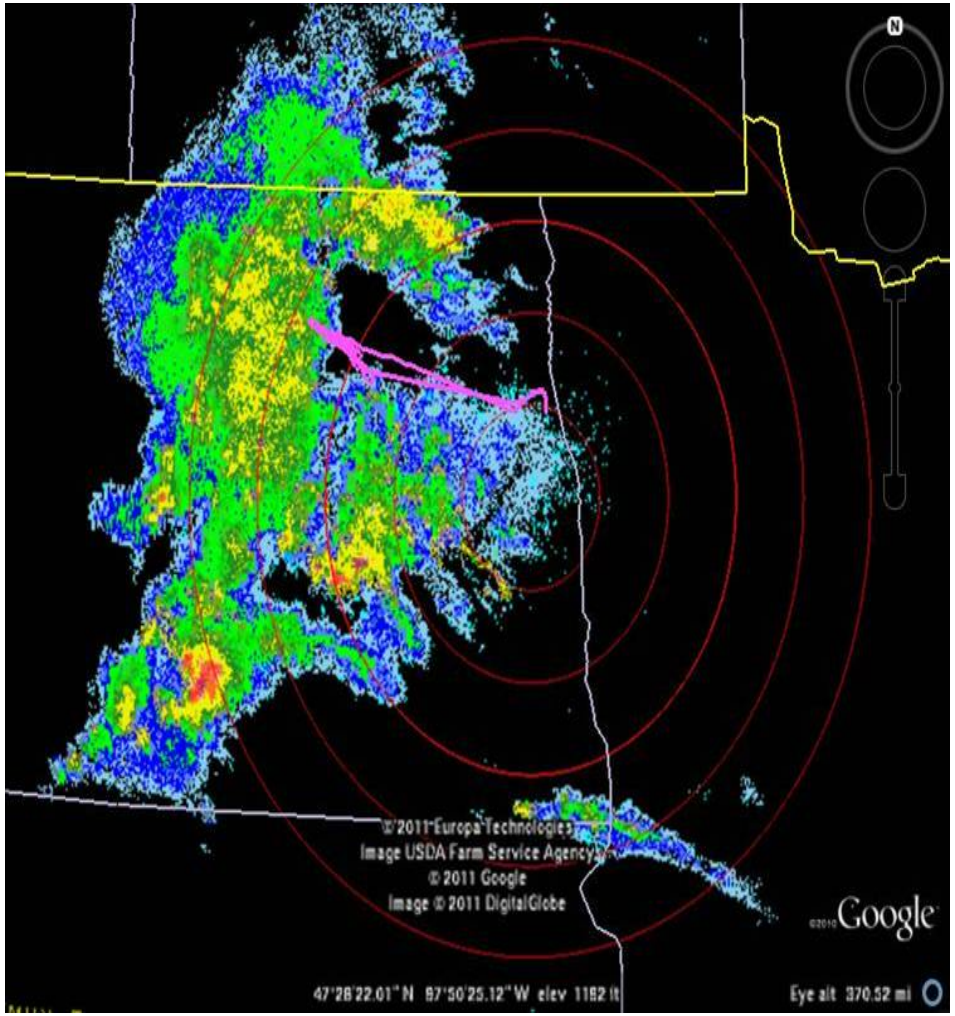
Miniaturized Cloud Condensation Nucleus Counter

Top View of the UWYO CCN Counter Diffusion Chamber





Combining Measurements



Radar reflective at 01:03:22 Z on 09 July 2011. The Citation Research Aircraft flight track is in violet. (Bart and Delene, 2011)

Relevant Papers

Bart, N. and D. J. Delene, The use of Geographical Information Systems to Interpret Research Aircraft Measurements, Poster presented by Nicole Bart at UND Fall Undergraduate Research Forum, 18 November 2011, in Grand Forks, North Dakota.

Delene, D. J., Airborne Data Processing and Analysis Software Package, *Earth Science Informatics*, 4(1), 29-44, 2011, URL: http://dx.doi.org/10.1007/s12145-010-0061-4, DOI: 10.1007/s12145-010-0061-4.

Delene, D. J., C. Grainger, P. Kucera, D. Langerud, M. Ham, R. Mitchell, and C. Kruse, The Second Polarimetric Cloud Analysis and Seeding Test, Journal of Weather Modification, 43, 14-28, 2011.

C. Kruse, D. J. Delene, C. Grainger, T. Krauss, and A. S. Ghulam, Evaluation of Two Calibration Methods for the Aventech Aircraft Wind System, JTECH, In preparation, 2013.

Simelane, P. S., D. J. Delene, H. Ahlness, and D. Langerud, Evaluation of Pilot Estimated Updrafts Using Aircraft Integrated Meteorological Measurment Systems (AIMMS) Measurements, Journal of Weather Modification, 45, in press, 2013.