The North Dakota Citation Research Aircraft: A Scientific Application Example

David Delene

University of North Dakota

North Dakota Citation Research Aircraft

Modifications

- Two Wing-Tip Pylons with four Particle Measuring Systems (PMS) Cans
- Five Reinforced Fuselage Instrument Mounting Locations
- Six Fuselage Ports for Instruments, such as Electric Field Mills
- Four Side-looking Window Inserts that House Specialized Glass for Lidar Instruments
- Anti-ice Sampling Inlets for Cabin-based Gas and Aerosol Sampling

Citation Research Aircraft Capabilities


CAPE2015 – 2 Aug 2015

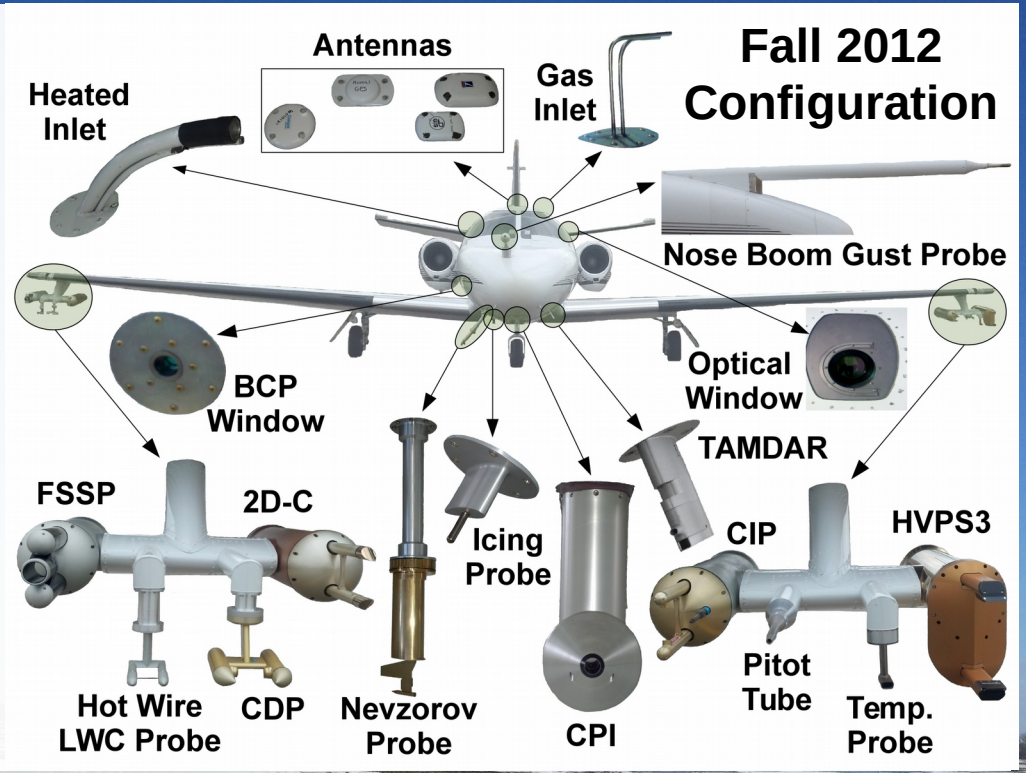
General Aircraft Specifications

Payload	693 – 1147 kg (1,528 – 2,528 lbs)
Range	2,222 km (1,200 nmi)
Ceiling without/with Pylons	13. 1 km (43,000 ft) / 12. 1 km (40,000 ft)
Climb Time	13 min (to 25,000 ft), 24 min (to 35,000 ft)
Endurance	3 to 5 hours
Weather	Known Icing and Storm Penetration
Airspeed Range	150 – 225 knots IAS

Areas of Measurement Focus of the Citation Research Aircraft

Instrument Suite

- Aircraft Icing
- Instrumentation Testing
- Cloud Physics
- Electric Fields
- Atmospheric Chemistry
- Weather Modification



Citation Research Aircraft Resources

Available Power Specifications

Total Available Research Power …… 7,300 W (Below 35,000 ft)

5,400 W (35,000 ft and Above)

Alternating Current Instruments …….. 4,000 W of 110 Volts at 60 Hz

Direct Current Anti-icing Instruments ……..80 Amps of 28 Volts

Direct Current Power Instruments ……...40 Amps of 28 Volts

Data Acquisition System

Science Engineering Associates M300

Real-time Data Acquisition Operating System.

Displays Data in Graphic and Alphanumeric Formats.

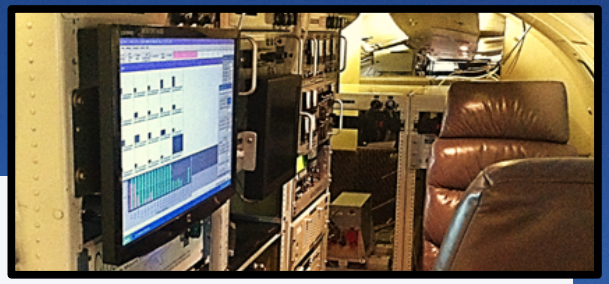
A 12bit, analog to digital 32 channel, is used to acquire voltage measurements at frequencies up to 100 Hz.

Digital data acquisition is available on 25 serial (RS232/RS422) ports at speed of up to 1.8 Mbps, on ARINC-429 ports, and internet ports.

Special M300 interface cards are used to acquire data from Cloud Imaging probes (CAPS, CIP, PIP) and the Applanix System.

Data acquisition configurations and instrument calibration is documented for each field project and incorporated into post-processing software.

Citation Research Aircraft Flight Crew



Seating Configuration

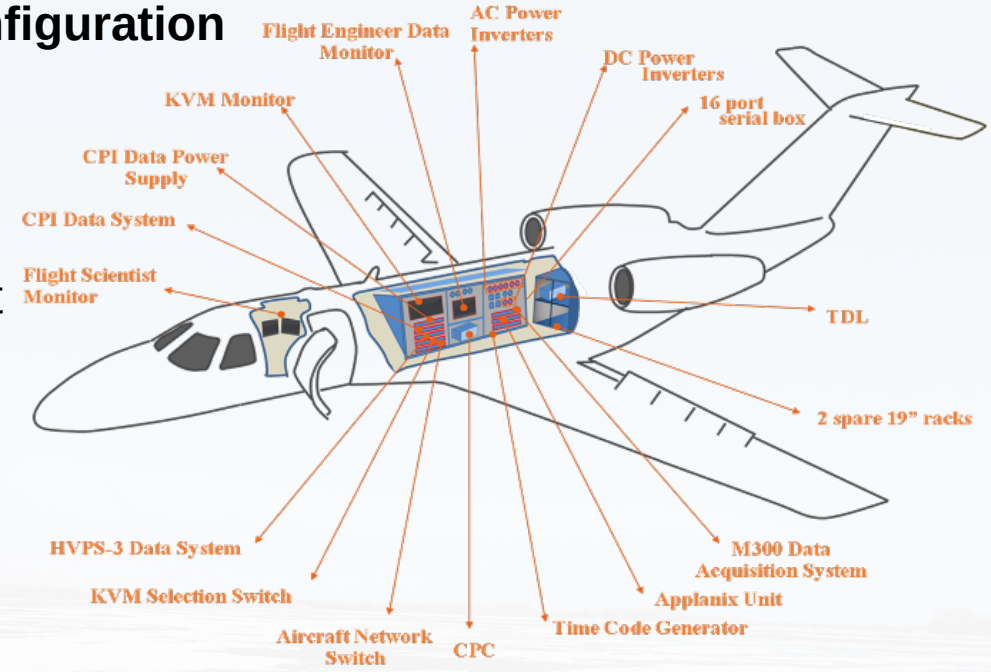
Pilot …….. Front Left Seat

Co-Pilot ……....Front Right Seat

Flight Scientist ....Front Middle Seat

Flight Engineers (2) … Rear Seats

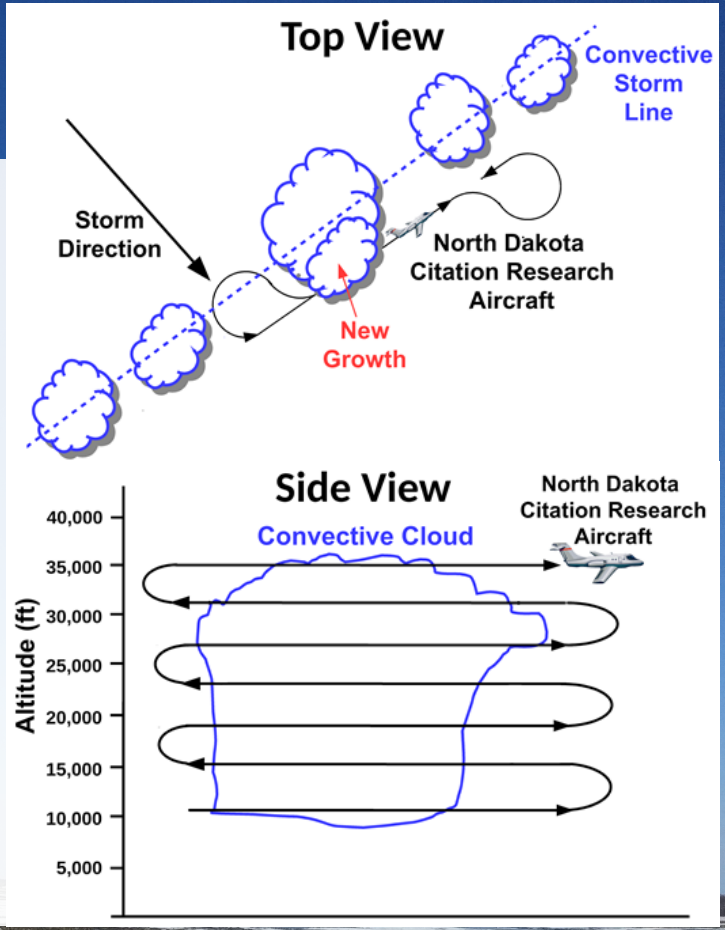
Fall 2012 Configuration



Flight Profiles for Aircraft Sampling

Cumulus Cloud Sampling

- Field projects develop sampling profiles.
- The pilots are responsible for safe operation.
- Flight scientist is responsible obtaining objectives.
- Flight engineers operate the research equipment and monitor instruments using the real-time data displays.
- Detailed checklists are followed.
- Notes are made of interesting observations.

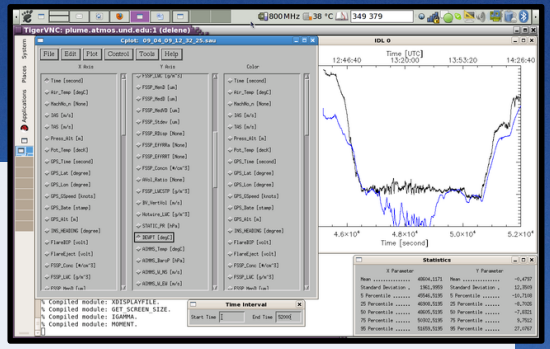


Scientific Software Processing Packages

Package	Availability
ADPAA	svn://svn.code.sf.net/p/adpaa
D2G	Local Team Software, Alexei Korolev
EGADS	https://github.com/eufarn7sp/egads-eufar
OASIS	Droplet Measurement Technologies
SAMAC	https://github.com/StephGagne/SAMAC
SODA	https://github.com/abansemer/soda2
SPEC	http://www.specinc.com/downloads
UIOPS	https://github.com/weiwu5/UIOPS

Software packages presented at the European Facility for Airborne Research (EUFAR) International Conference on Clouds and Precipitation (ICCP) Workshop on Data Processing, Analysis, and Presentation Software.

Community Packages for Airborne Science



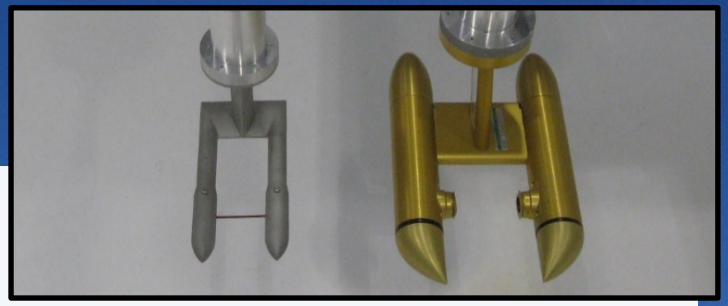
Package	Languages	Summary of Features
ADPAA	IDL, Python, Bash, Perl	Tools for processing instrument data, quality assurance, and visualization.
D2G	Matlab	Process, quality assurance, and visualization of aircraft and radar data.
EGADS	Python	Toolbox for handling meta-data and units for processing data.
OASIS	Igor	Package for OAPs (CIP, PIP/CIP-100, SPEC 2DS and HVPS).
SAMAC	Python	Tools for calculating, displaying and storing segments summaries.
SODA	IDL	Package for OAPs that provides options to derive particle spectra.
SPEC	Matlab, IDL	Tools for SPEC probe data (2D-S, HVPS3, CPI, etc.).
UIOPS	Matlab, C++	University of Illinois analysis package for OAPs.

Available Aircraft Data Sets

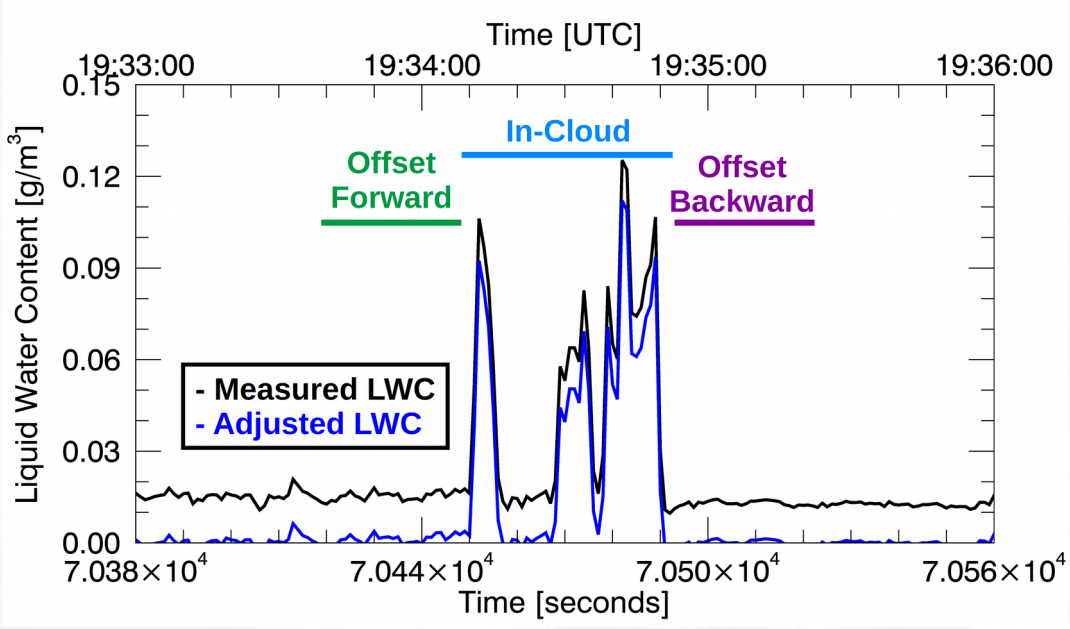
20 Years of Airborne Data

- Several field projects have been done for companies to test airborne instruments (Ophir, UT Corp, Goodrich, and TAMDAR projects).
- Field project conducted for natural icing studies (Sikorsky and L3Com).
- The main government sponsor recently has been NASA.
- The data sets are readily available for further scientific analysis since the raw data was recorded on an 8 mm tape (before 2005) or directly to a hard drive (2005 onward).
- Several data sets (e.g., NASA GPM data sets) are available in open repositories, with ongoing work devoted to archiving additional data sets.

Liquid Water Content Data Processing



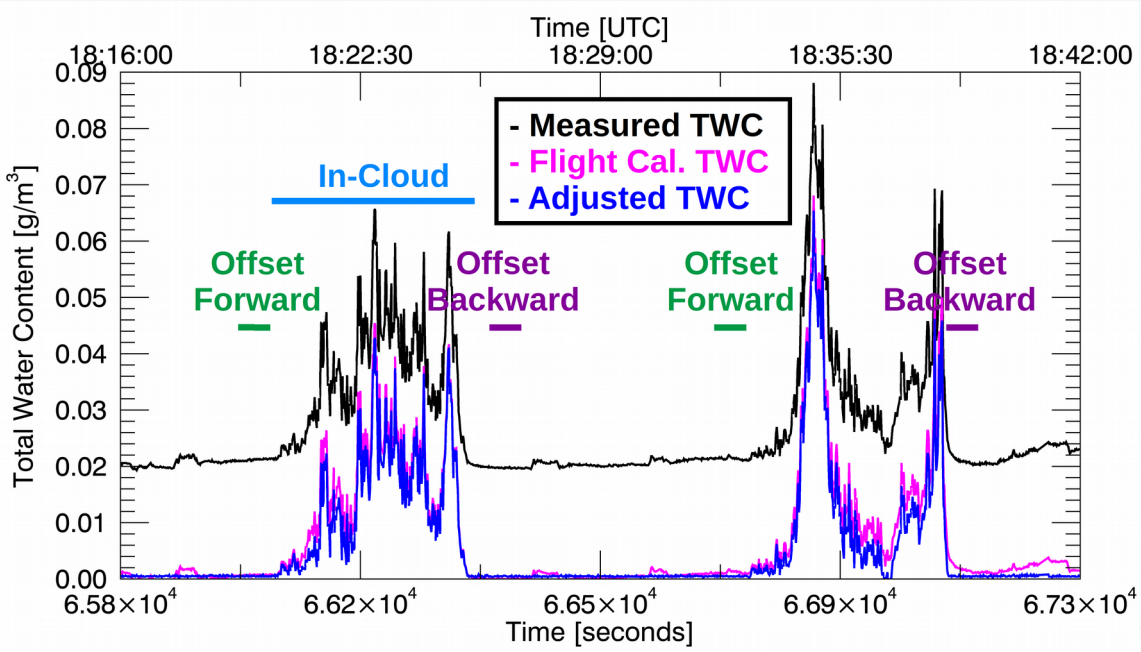
Automatic Offset Adjustment



Cloud penetration on 9 March 2004 showing an offset of ~0.015 g/m^3 being applied to the measured liquid water content (LWC) to obtain the Adjusted LWC. The Adjusted LWC is obtained by linear interpolation of the average measured LWC during the “Offset Forward” segment and the “Offset Backward” segment.

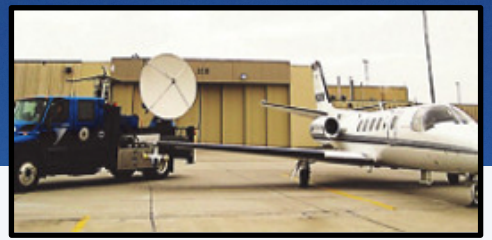
Total Water Content Processing

Nevzorov Probe Measurements



Cloud penetration by the Citation Research Aircraft on 30 July 2015. The Adjusted TWC is obtained by a linear interpolation of the average measured TWC during the “Offset Forward” segment and the “Offset Backward”.

Platform



Themes:

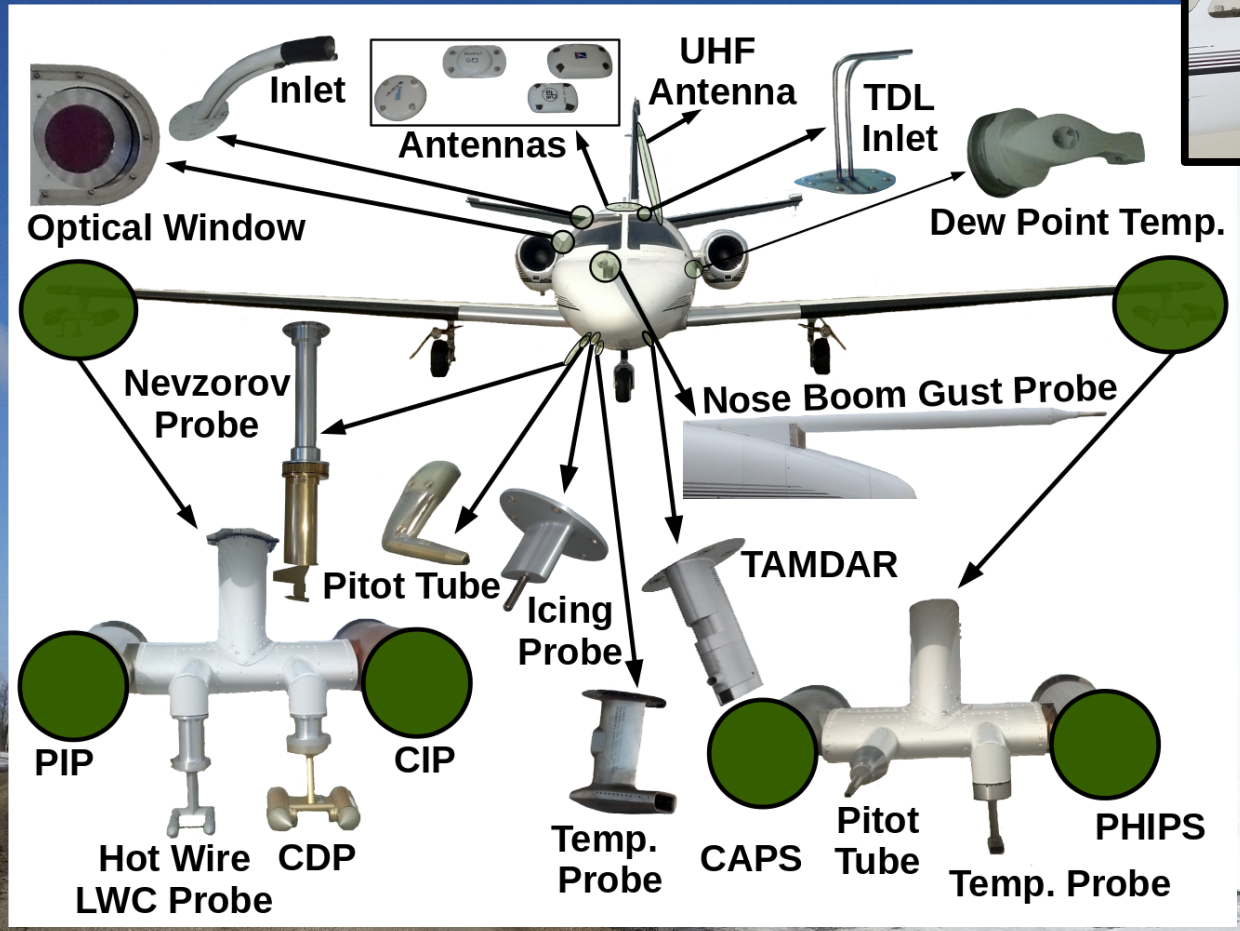
- One theme is the use of aircraft for observing properties of flight environments (icing, turbulence, etc.) and the instrumentation used to measure that environment. This requires consideration of calibration and performance issues of the selected instruments.
- Theme two is the need for open source software for data processing and the need to build a community that tests the quality of its software.
- Theme three is a history of past research projects, the creation/availability of aircraft data sets, and what the near future will bring.
- Overall, the correct aircraft platform, with the correct instrumentation, software and people, is necessary for obtaining required observations.

Future Field Projects

Next 20 Years

- The future is bright for utilization of North Dakota Citation Research Aircraft platform.
- The first joint UND/WMI field project (CapeEx19) utilizing the North Dakota Citation Research Aircraft is scheduled for July and August 2019.
- Instrumentation Advancements: 10 µm cloud imaging resolution, anti-shattering probe tips, and polar scattering measurements
- Instrumentation advances with more robust software allows us to effectively address topics of interest that have existed for a long time.

CapeEx19 Field Project Objectives



Obtain in-situ measurements of hydrometers in the upper layer (bottom to the top) of convective storms near the convective core to the cloud edge concurrent with Mid-Course Radar (MCR) observations.

CapeEx19 Field Project - 2019

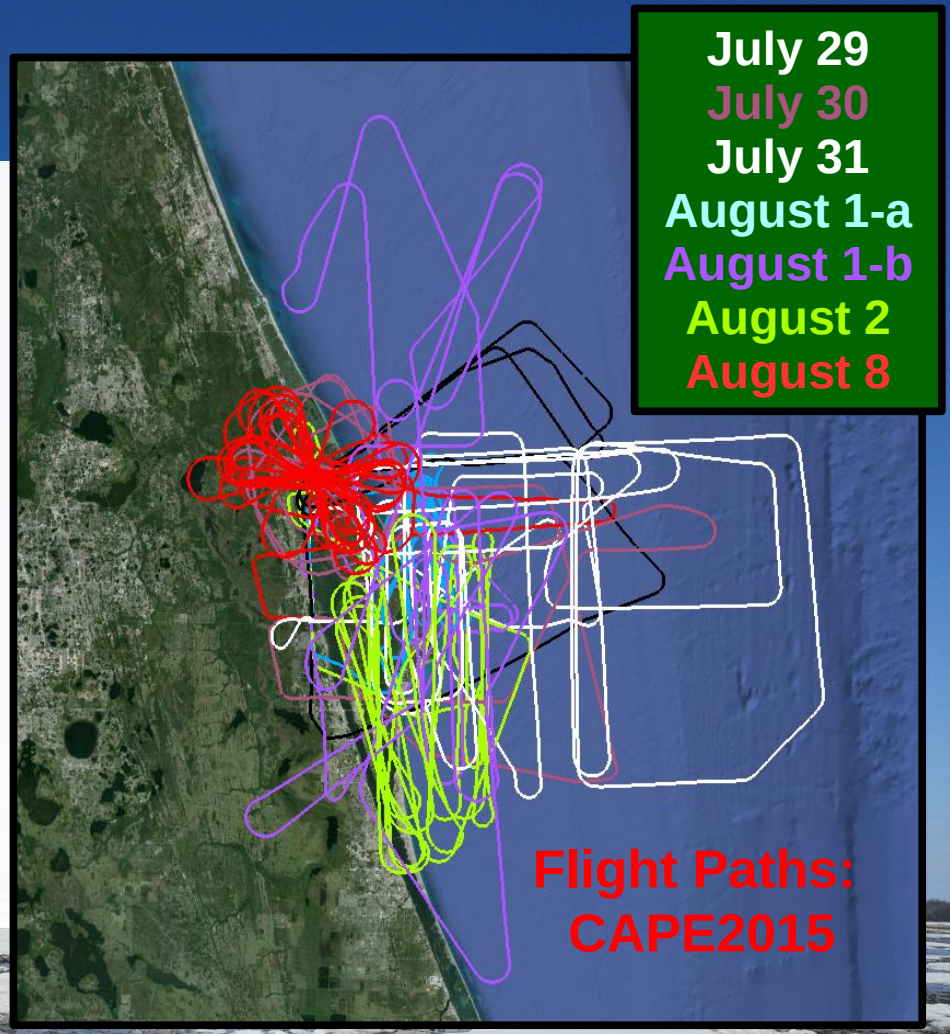
Institutional Participants

- Naval Surface Warfare Center Dahlgren Division
- Marine Meteorology Division, Naval Research laboratory (NRL)
- University of North Dakota (Aircraft)
    - Weather Modification International
    - University of Alabama Huntsville
- L3Com (Radar)
- Scripps Institution of Oceanography, University of California (Surface)
- AECOM (Robert D. Yates)

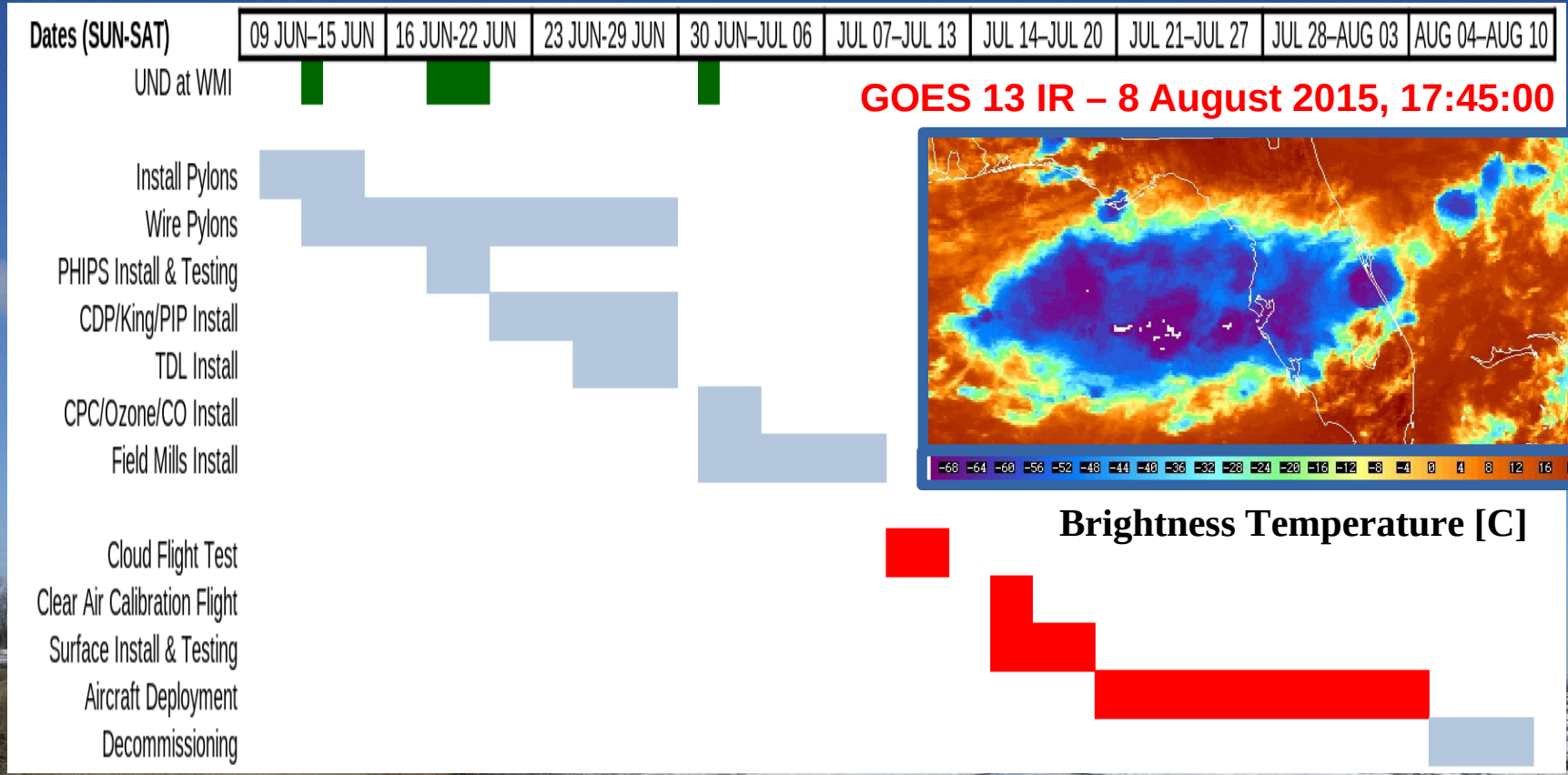
CapeEx19 Field Project - 2019

Area of Study

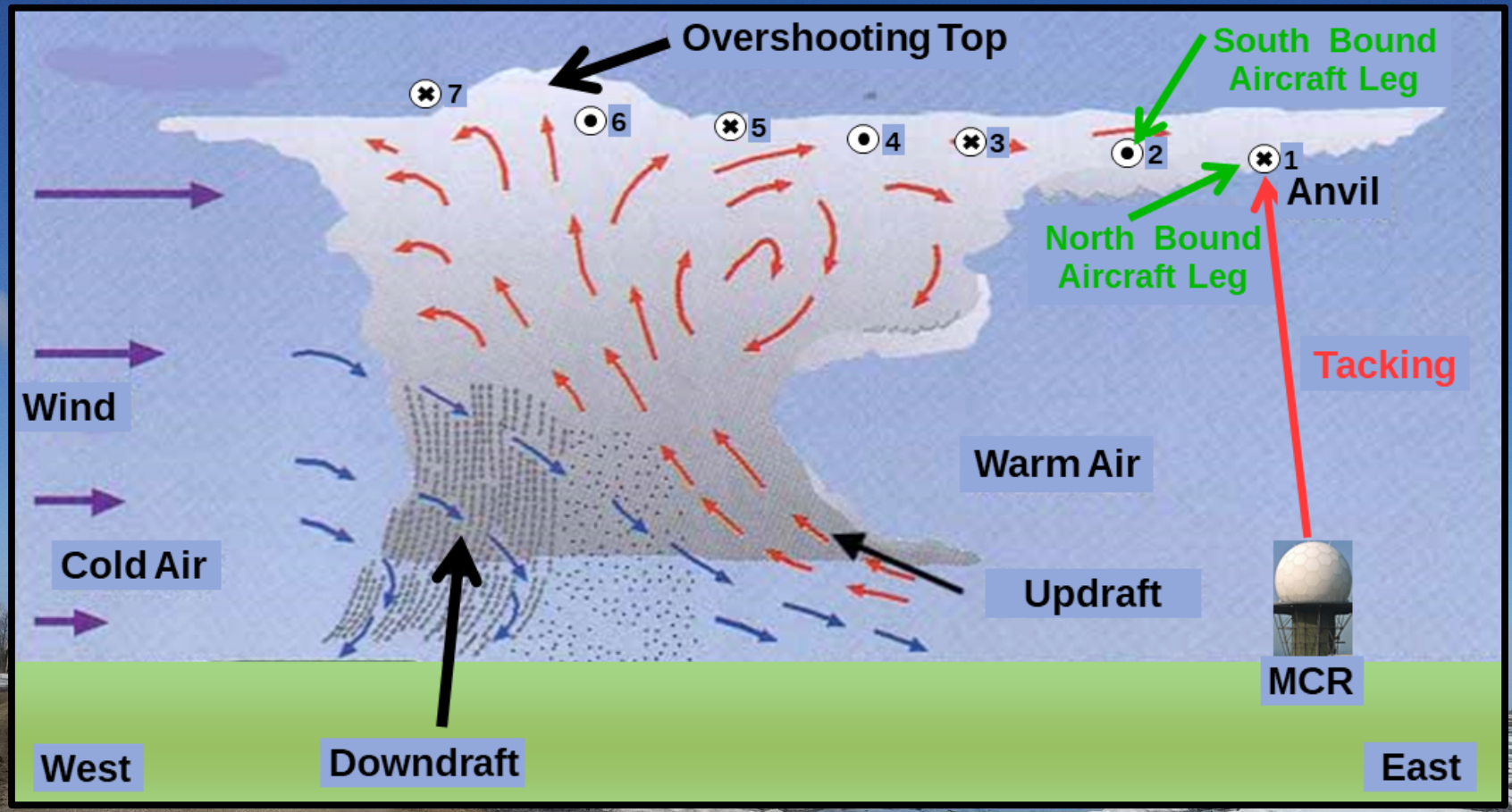
- Study region is centered on Mid-Course Radar (MCR) at latitude of 28.7550265 and longitude of 80.7743669.
- The Citation Research Aircraft will be based at Space Coast Jet Center (7003 Changer Ave, Titusville, FL, 83780, phone 321-267-8355) at Space Coast Regional Airport (KTIX).



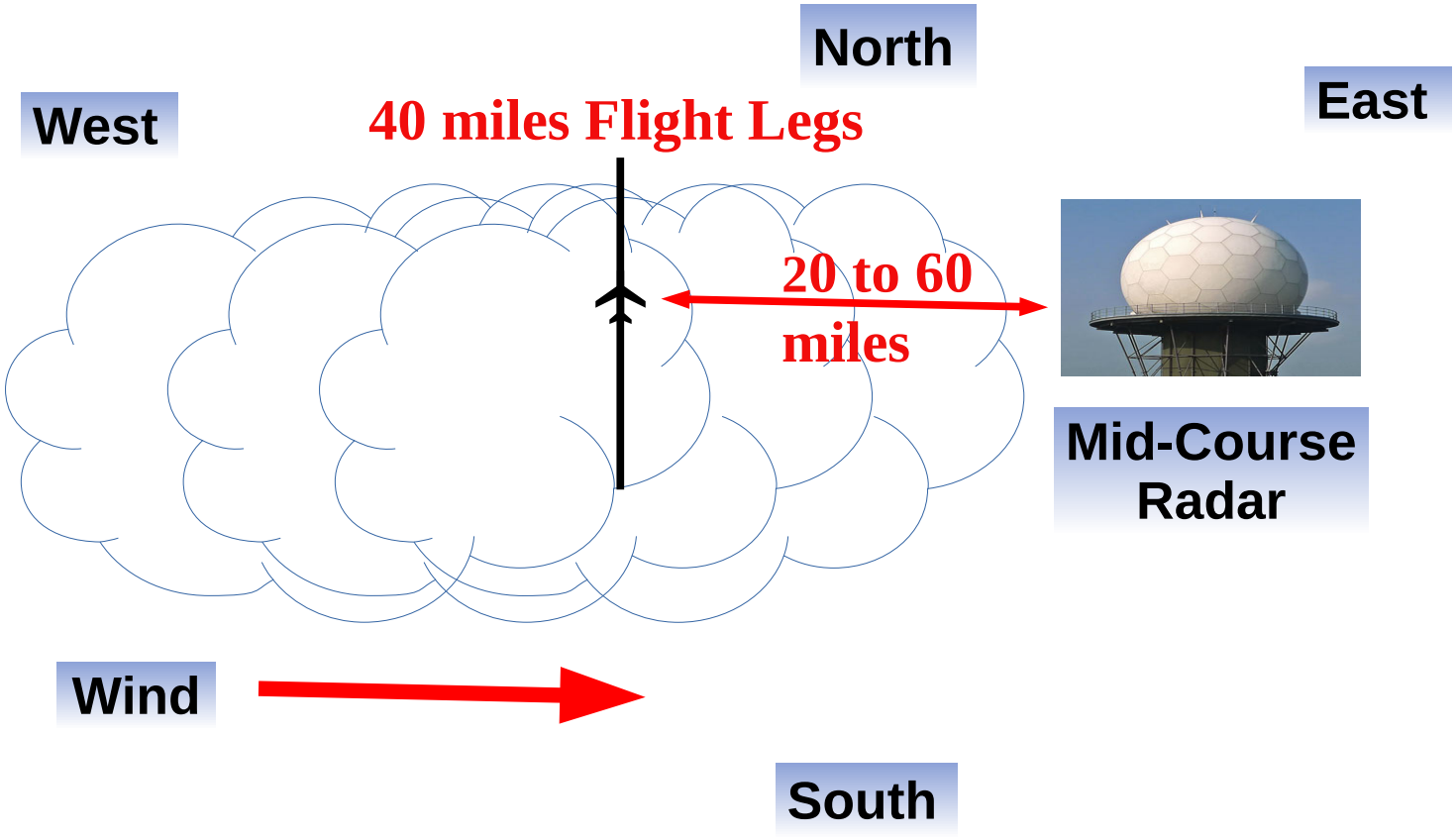
CapeEx19 Field Project Schedule



CapeEx19 Field Project Flight Profile – Relative to Cloud

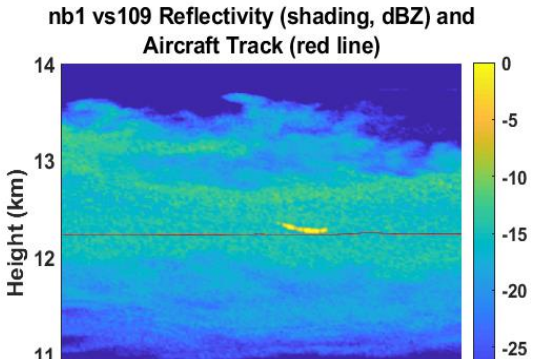


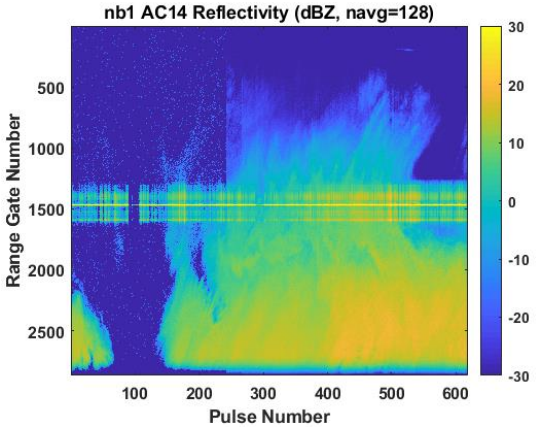
CapeEx19 Field Project Flight Profile – Relative to Ground



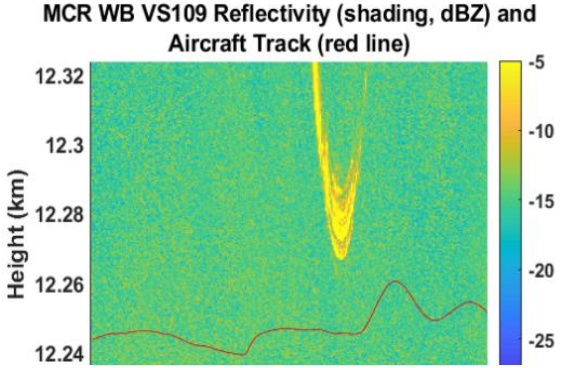
Radar Scanning Strategies

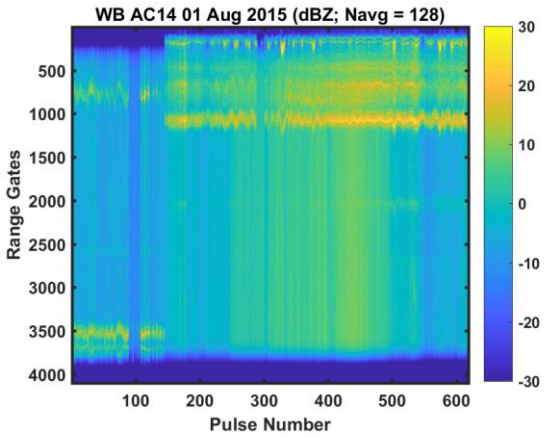
Narrowband





Wideband

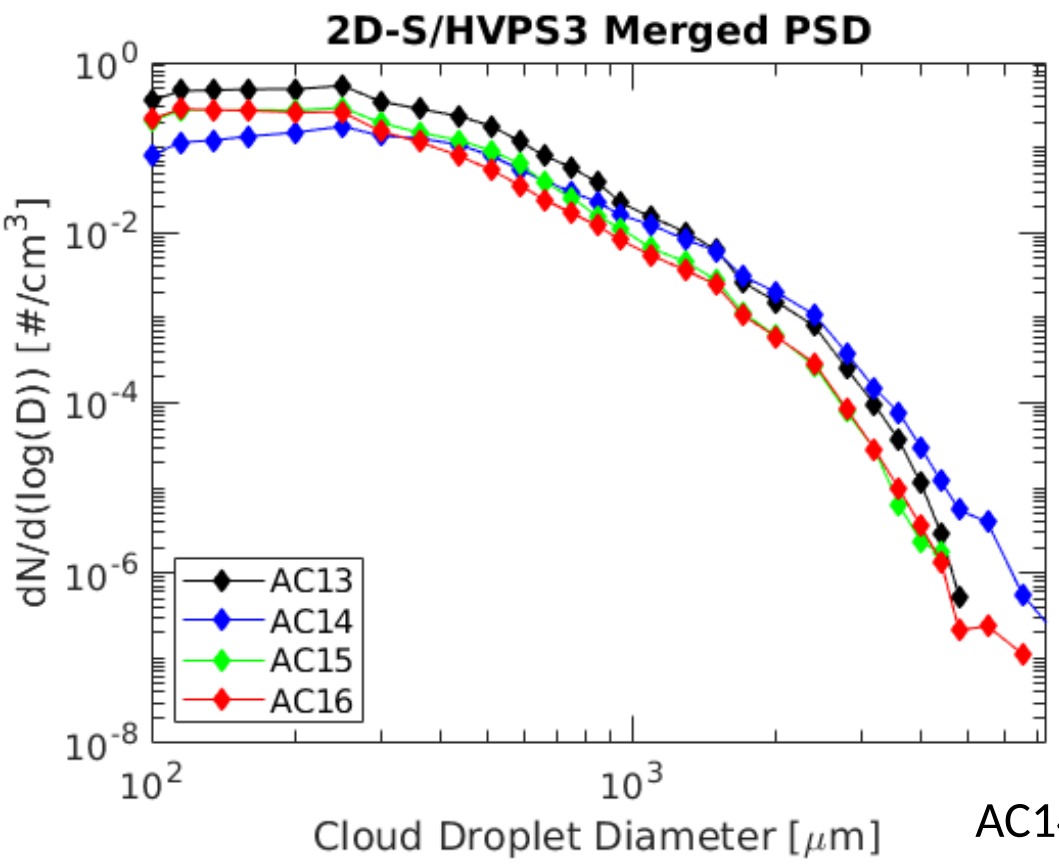




Vertical Stare

Aircraft Tracking

01 August 2015 – Aircraft Tracking



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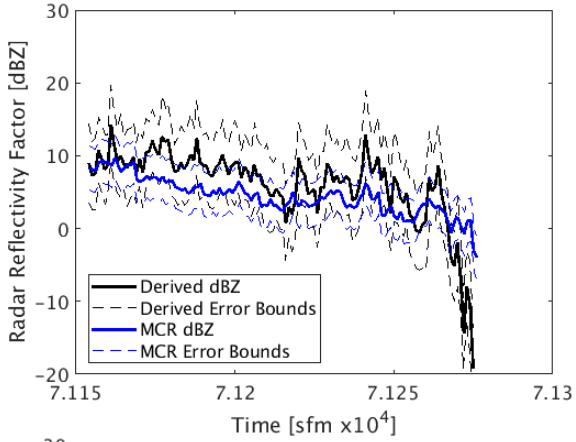
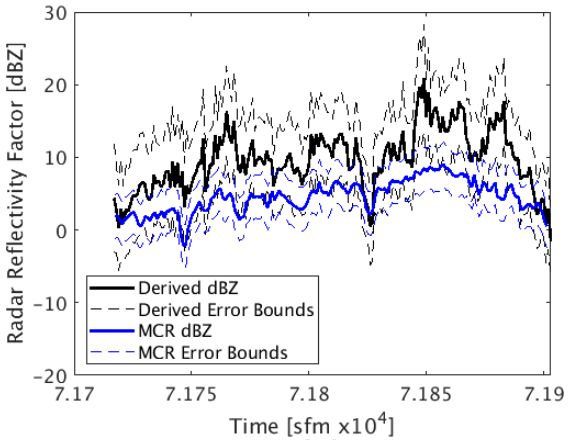
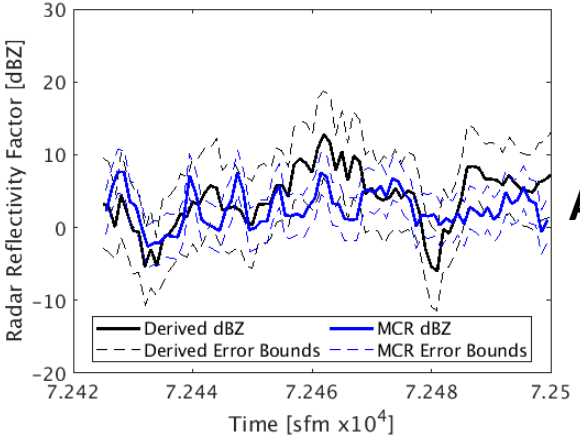
01 August 2015 – Aircraft / MCR Comparison



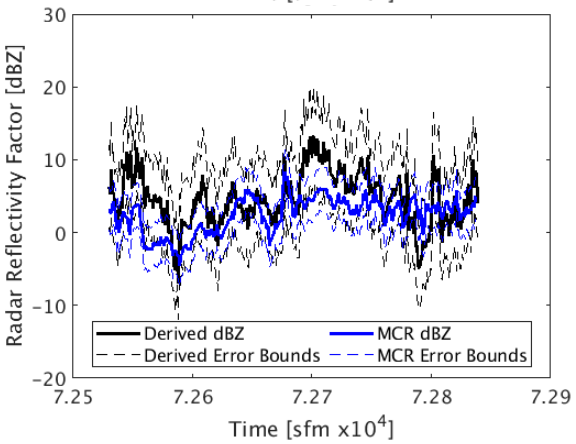
AC13



AC14



AC15



AC16

Conclusion and Current Work

- Overview Paper – BAMS (Accepted)
  - Schmidt, Jerome M., Piotr J. Flatau, Paul R. Harasti, Robert D. Yates, David J. Delene, Nicholas J. Gapp, William J. Kohri, Jerome R. Vetter, Jason E. Nachamkin, Joshua D. Hoover, Mark J. Anderson; Seth Green, and James E. Bennett, Radar Detection of Individual Raindrops, Bulletin of the American Meteorological Society, in press, 2019. [Preparation 09/27/2018, Submitted 12/03/2018, Major Revision Submitted 04//24//2019, Accepted 05/22/2019]
- Aircraft/Radar Comparison Case Study Paper
  - Gapp, Nicholas, David J. Delene, Matthew Gilmore, Jerome Schmidt, and Paul Harasti, Comparison of Concurrent Radar and Aircraft Measurements of Cirrus Clouds, Journal of Atmospheric Science, in preparation, 2019. [Preparation 01/16/2019]

Future Work

- Conduct CapeEx19 Field project
  - July 21 – August 4
- Conduct Quality Assurance
- Software Development (NetCDF4 Image Data and Uncertainty Optimized Combined Spectrum)
- Aircraft/Radar Comparison CAPE2015 and CapeEx19 Projects
- Aircraft/Model Comparison