Comparison of Concurrent Radar and Aircraft Measurements of Cirrus Clouds

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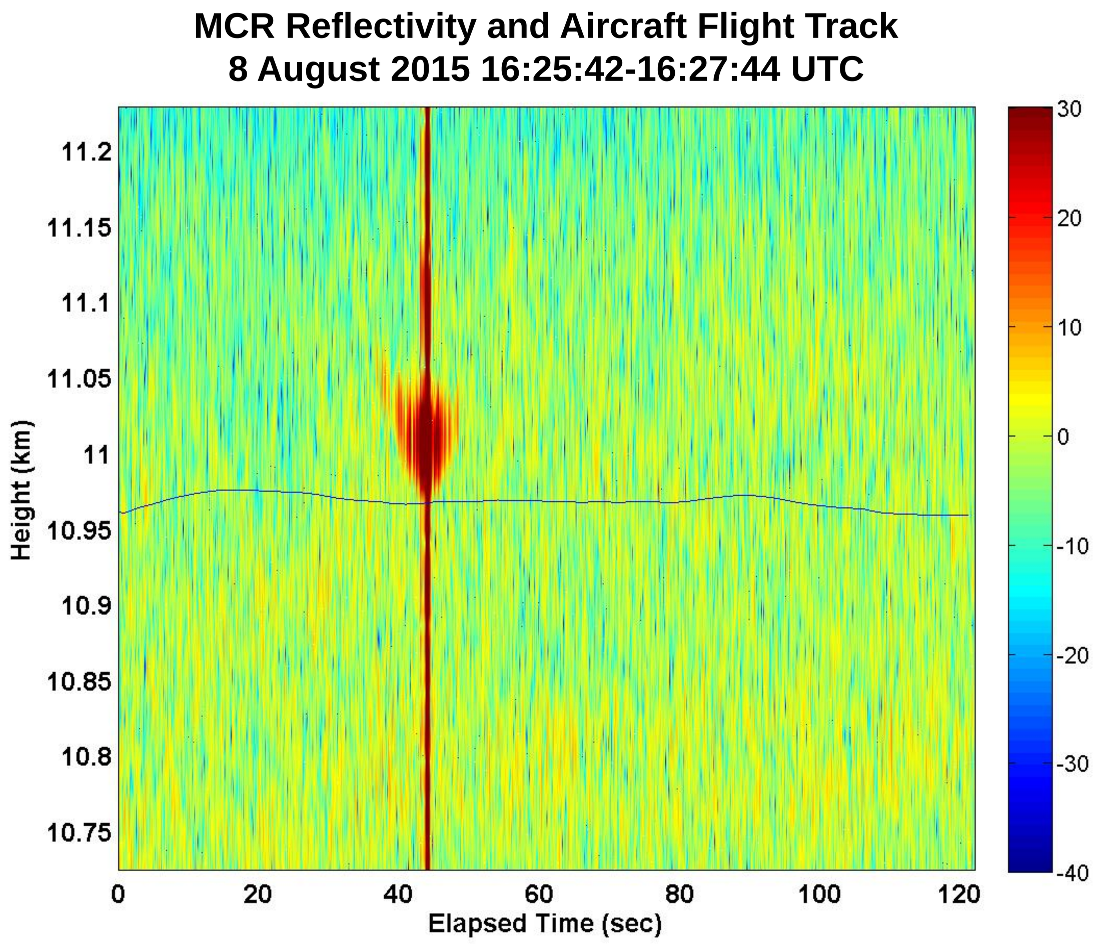
Introduction

The North Dakota Citation Research Aircraft conducted measurements of cirrus cloud particles produced by Florida thunderstorms in 2015 (CAPE2015 field project). Cloud sampling instruments included the two-dimensional stereographic probe (2D-S), and Nevzorov hot wire probe (Nevzorov). Concurrent with the aircraft measurements, remote sensing observations were made by the United States Navy's Mid-Course Radar (MCR). The CAPE2015 field project observed pure ice particles between an altitude of 29,000 ft and 40,000 ft during eight research flights. Comparison between derived reflectivity from in-situ probe data and measured MCR reflectivity is explored and synthesizing missing water content data is discussed.

Methodology

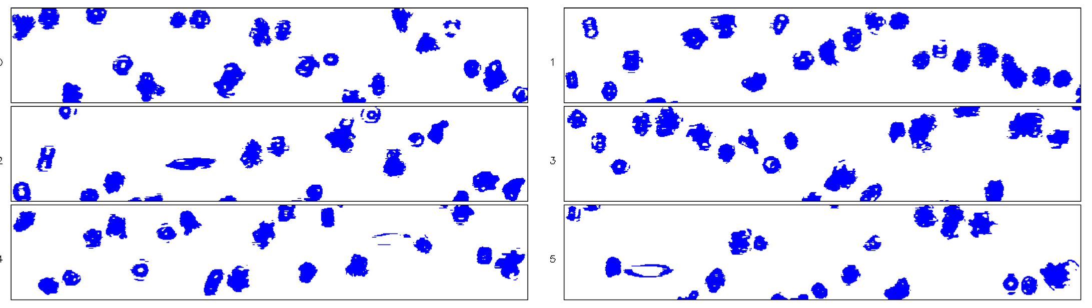
UND's Cessna Citation II Research Aircraft is used to conduct 21.86 hours of research measurements during eight flights. Ice water content and reflectivity are derived assuming spherical ice particles from measurements taken by the 2D-S and Nevzorov probe onboard the aircraft (Delene, 2011). The MCR is a C-band, dual-polarization radar that operates at 3 MW and alternates transmissions between two wave forms with a range resolution of 37 m or 0.546 m (Schmidt et al. 2012). The aircraft position is downlinked in real-time to the MCR which enables the aircraft to be located and followed by the beams of the MCR, ensuring concurrent measurements. Data analysis includes data from the 2D-S and Nevzorov to derive radar reflectivity for a direct comparison to the narrowband reflectivity from the MCR. The average ice density during flight legs with constant temperature is evaluated to determine relationship between ice crystal density and temperature. The temperature-density relation is used for the 8 August 2015 flight when Nevzorov data is not available.

Radar Measurements

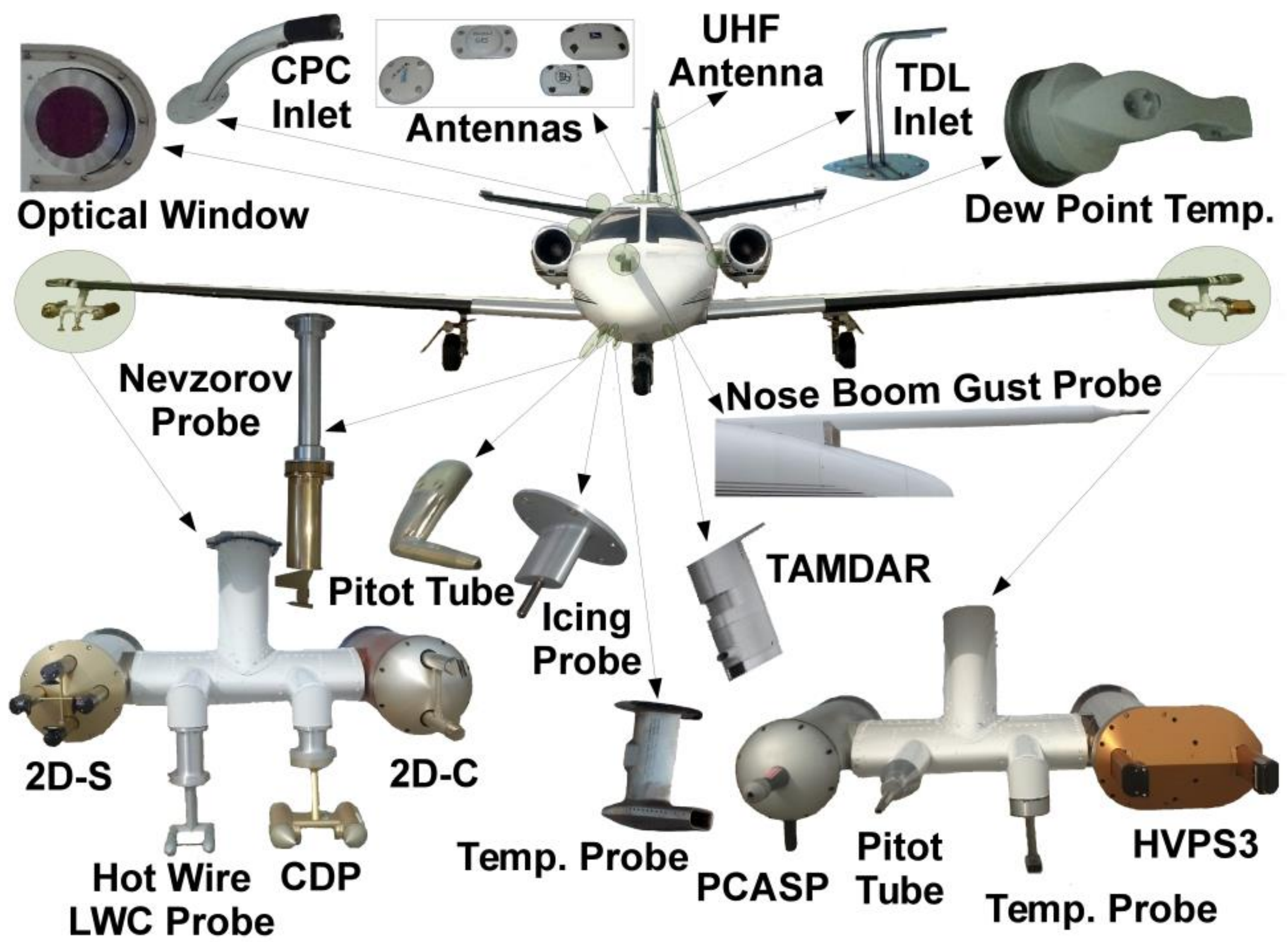


A volume scan from the MCR showing reflectivity (shading, values in dBZ) and the track of UND's Cessna Citation II Research Aircraft (blue line) on a time-height plot. The maximum in the MCR reflectivity is the aircraft as it passes over the MCR. Differences in height between the MCR and aircraft is due to an issue with the range gate spacing on the MCR.

Aircraft Measurements

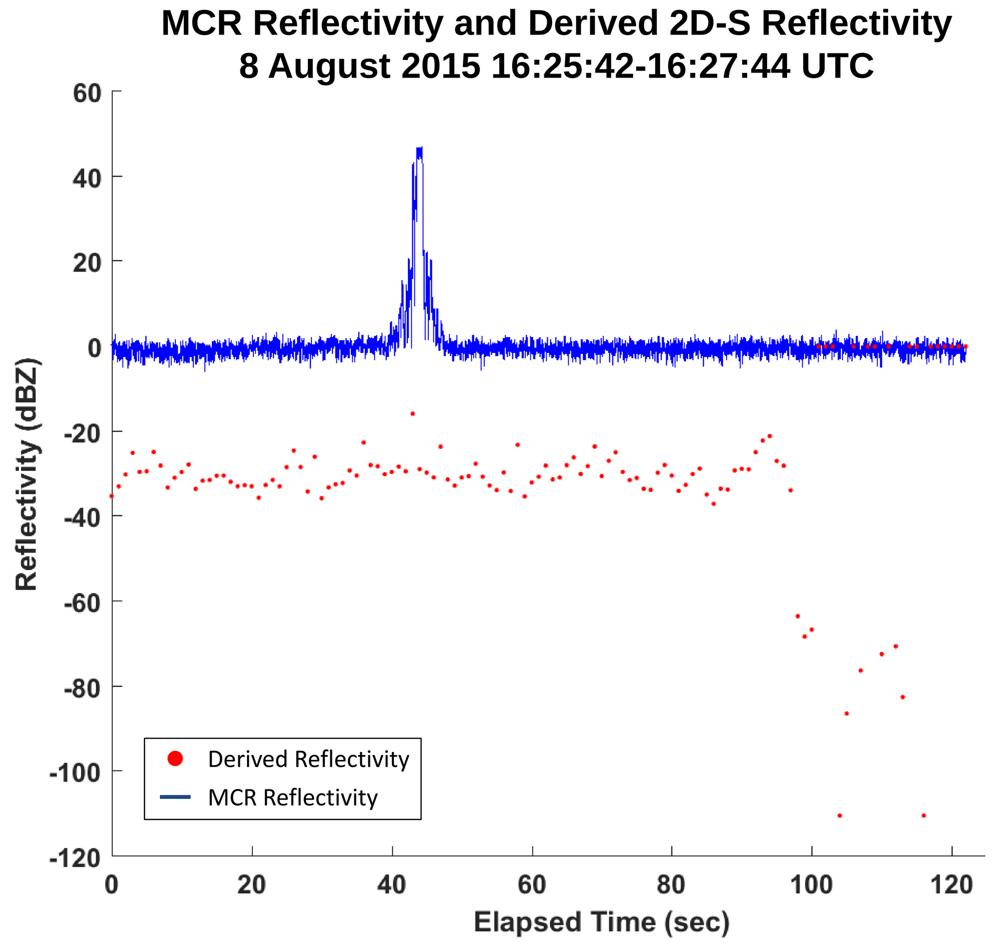


Representative images of cirrus particles taken by the 2D-S on 30 July 2015.



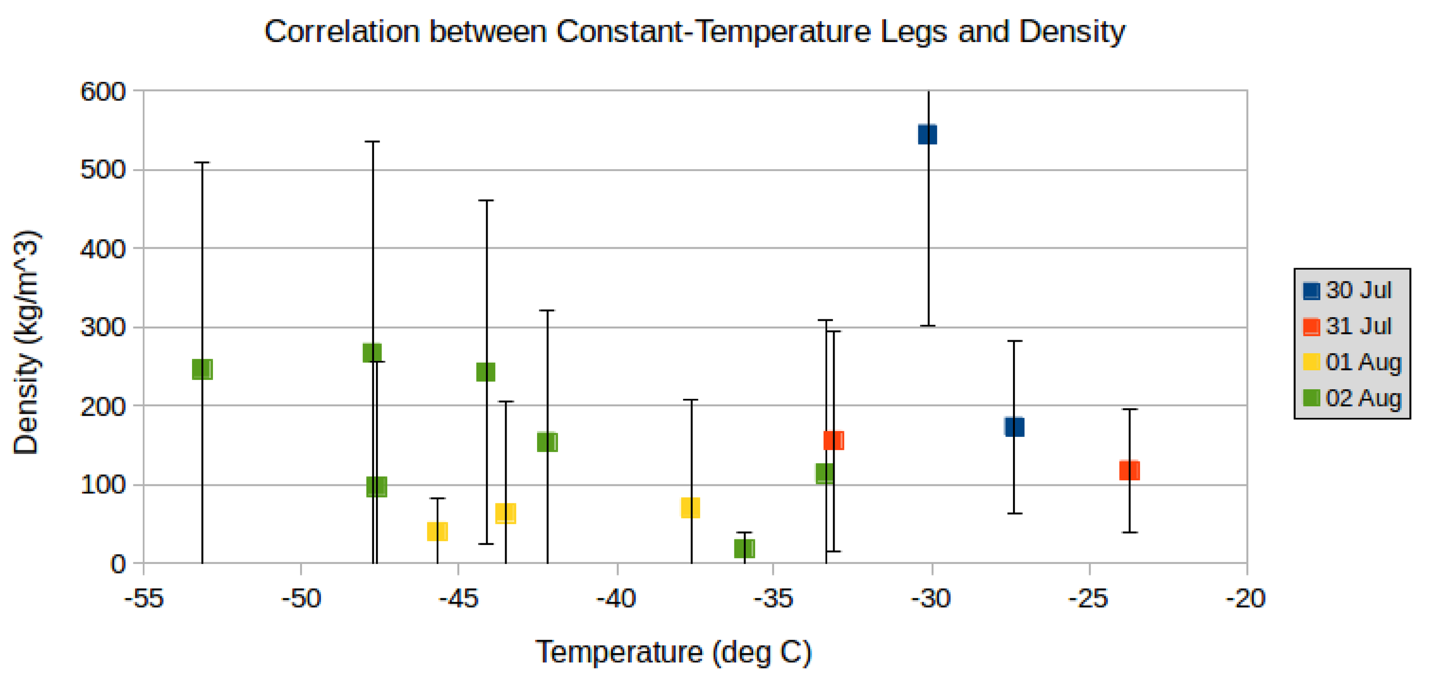
Locations of external instruments onboard the Citation Research Aircraft are shown above. The 2D-S probe provides two-dimensional images of particles using 128 10-um diode lasers with one laser oriented horizontally and one oriented vertically. The Nevzorov Probe measures total and liquid water using hot wire sensors and provides highly accurate total particle mass after processing using routines from the Airborne Data Processing and Analysis software package (Delene, 2011).

Radar Analysis

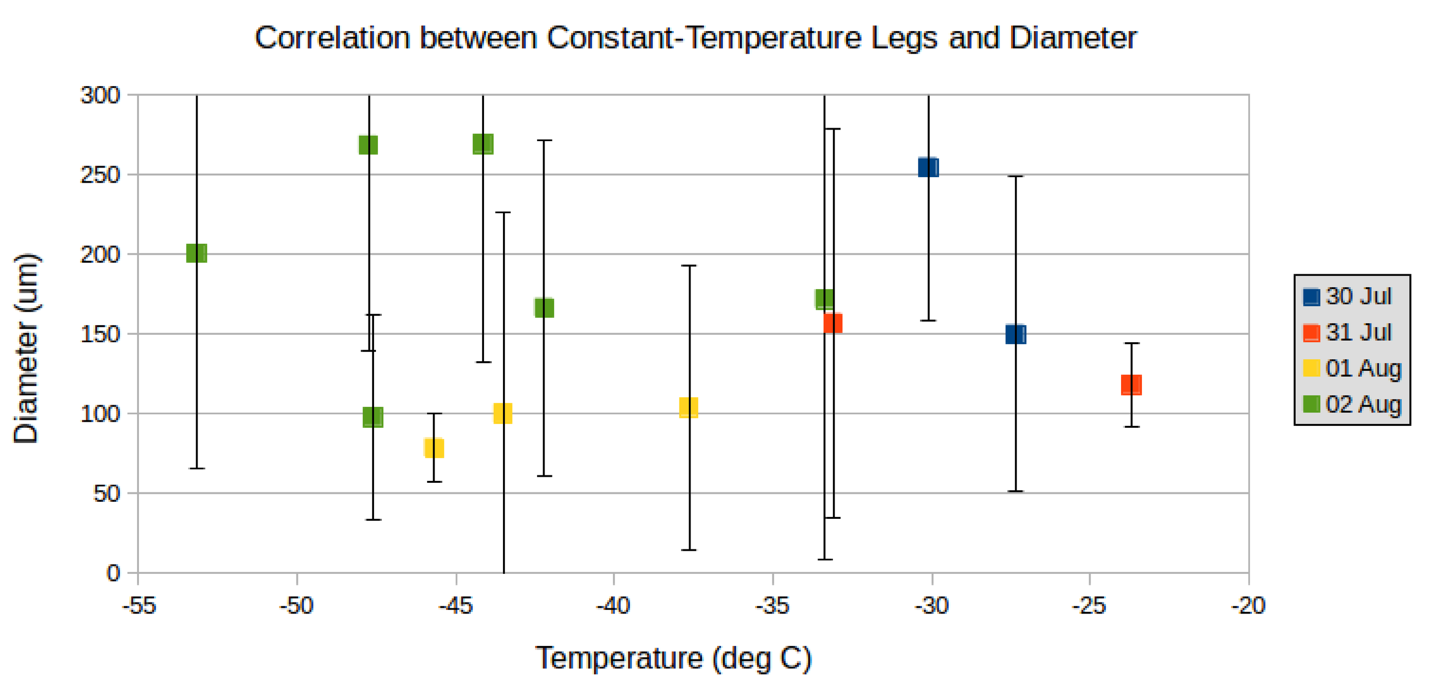


A case where the comparison between the derived aircraft reflectivity and the measured MCR reflectivity shows a difference of 30 dBZ. The MCR reflectivity is averaged over a 500 m column surrounding the aircraft's mean altitude. The spike in MCR reflectivity (about 45 s) is due to contamination of the signal by the aircraft. Generally, the measured MCR reflectivity ranges from -20 to 40 dBZ and aircraft derived reflectivity ranges from -50 to 10 dBZ.

Cirrus Anvil Temperature Relationship



Plot showing the average bulk ice density from 14 flight legs during four CAPE2015 research flights where the temperature remained constant below -20 °C. Error bars show high variability in the density data. Since no correlation is found between temperature and density, the average value is used for synthesizing Nevzorov mass for calculation of reflectivity data for the 8 August 2015 case day.



Plot showing average liquid-equivalent diameter from the same flight legs and criterion as above.

Future Work

- Compare MCR and aircraft probability distribution functions.
- Compare MCR wideband reflectivity to derived aircraft reflectivity.
- Incorporate the area ratio of sampled cloud particles into reflectivity calculation instead of assuming spherical particles.
- Determine a reasonable out-of-cloud threshold to apply to the aircraft data to reduce measurement variability.

References

Delene, D. J., 2011: Airborne data processing and analysis software package. Earth Sci. Inform., 4, 29–44, doi:10.1007/s12145-010-0061-4.

Schmidt, J. M., and Coauthors, 2012: Radar observations of individual rain drops in the free atmosphere. PNAS, **109**, 9293-9298, doi: 10.1073/pnas.1117776109.

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