Aircraft Observations of Florida Convective Storm Anvils

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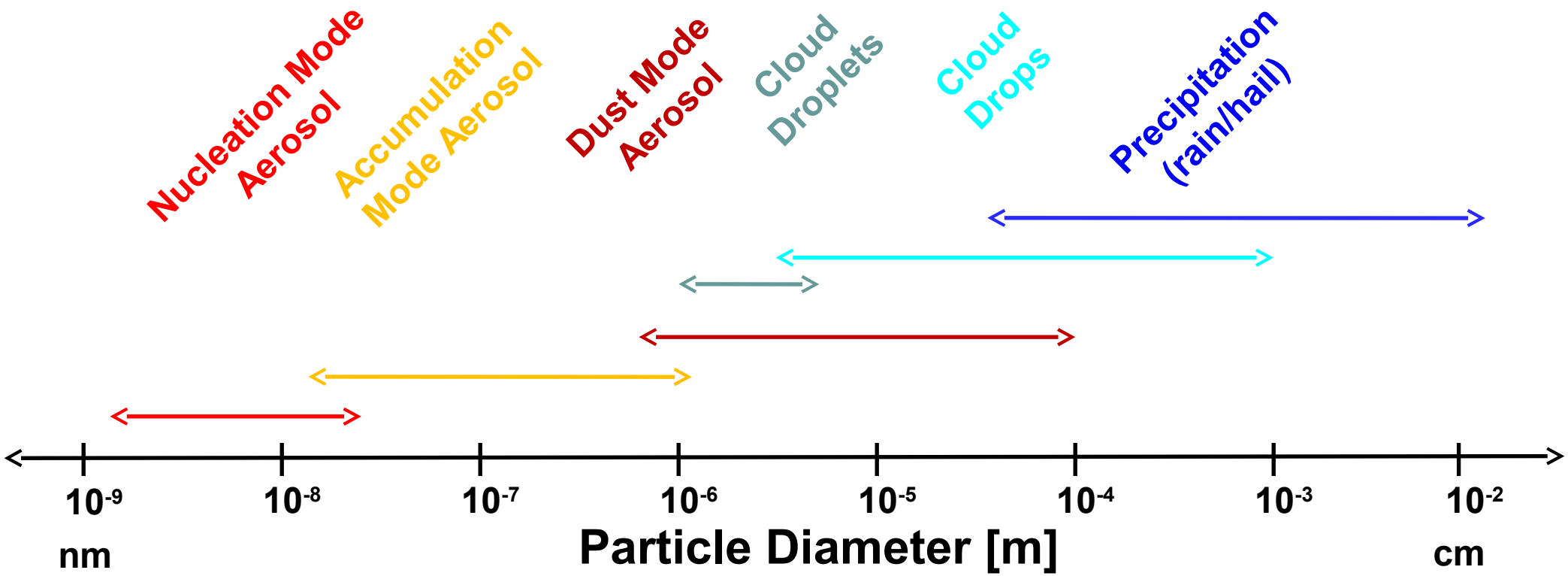
Atmospheric Particle Background

Atmosphere contains particles of all sizes.

- Suspended particles (aerosols) move with the average flow of gas molecules (atmospheric wind).
- Large particles (dust/drops/rain) have sufficient inertia to move independently of the wind.



Objectives

- Compare in-situ measurements with the Mid-Course Radar (MCR) observations.
- Improvements of MCR retrieval algorithms.
- **Model improvement of ice clouds (anvils).**

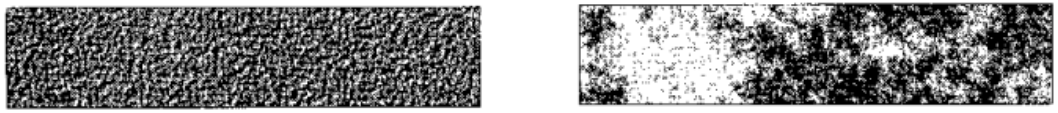
Mid-Course Radar (MCR)

- C-band, Dual-polarization Doppler Radar
- 3 MW Operating Power, 0.22 Degree Beam Width
  - Pulse Volume of 504 m^3 at 12,000 m
  - Box around Citation Research Aircraft has a volume of 1,050 m^3

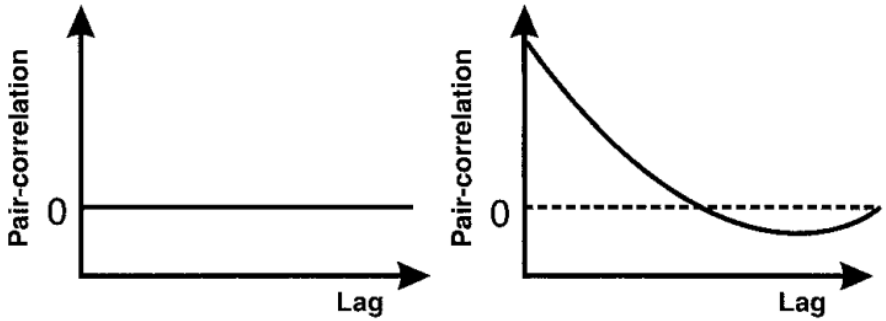
Spatial Distribution of Cloud Particles

POISSON **PATCHY**

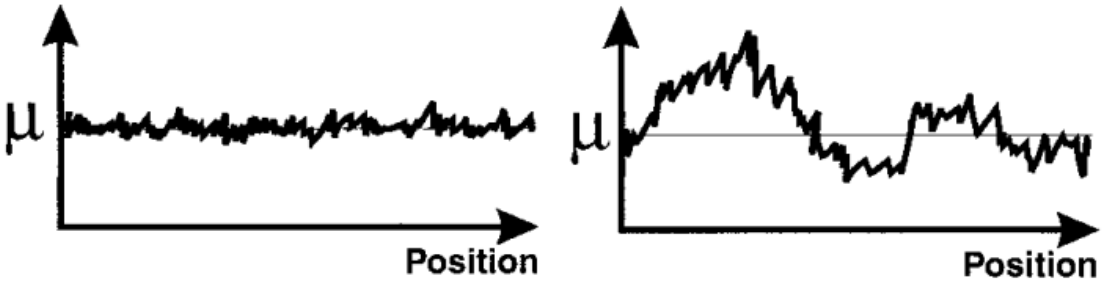
Clouds



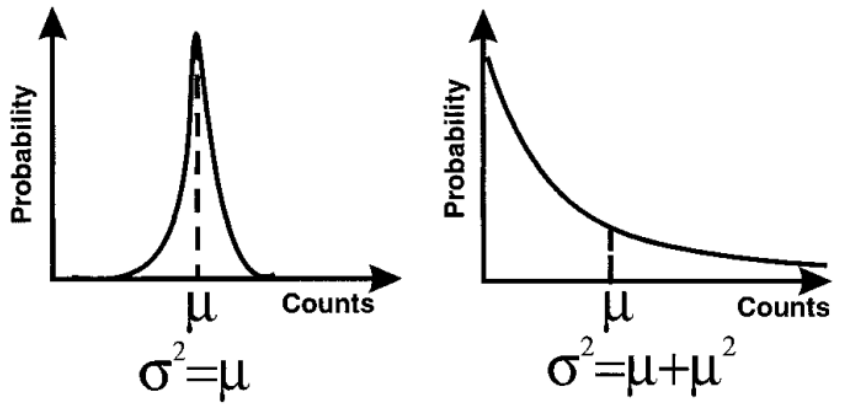
Pair-correlation Function



Counts

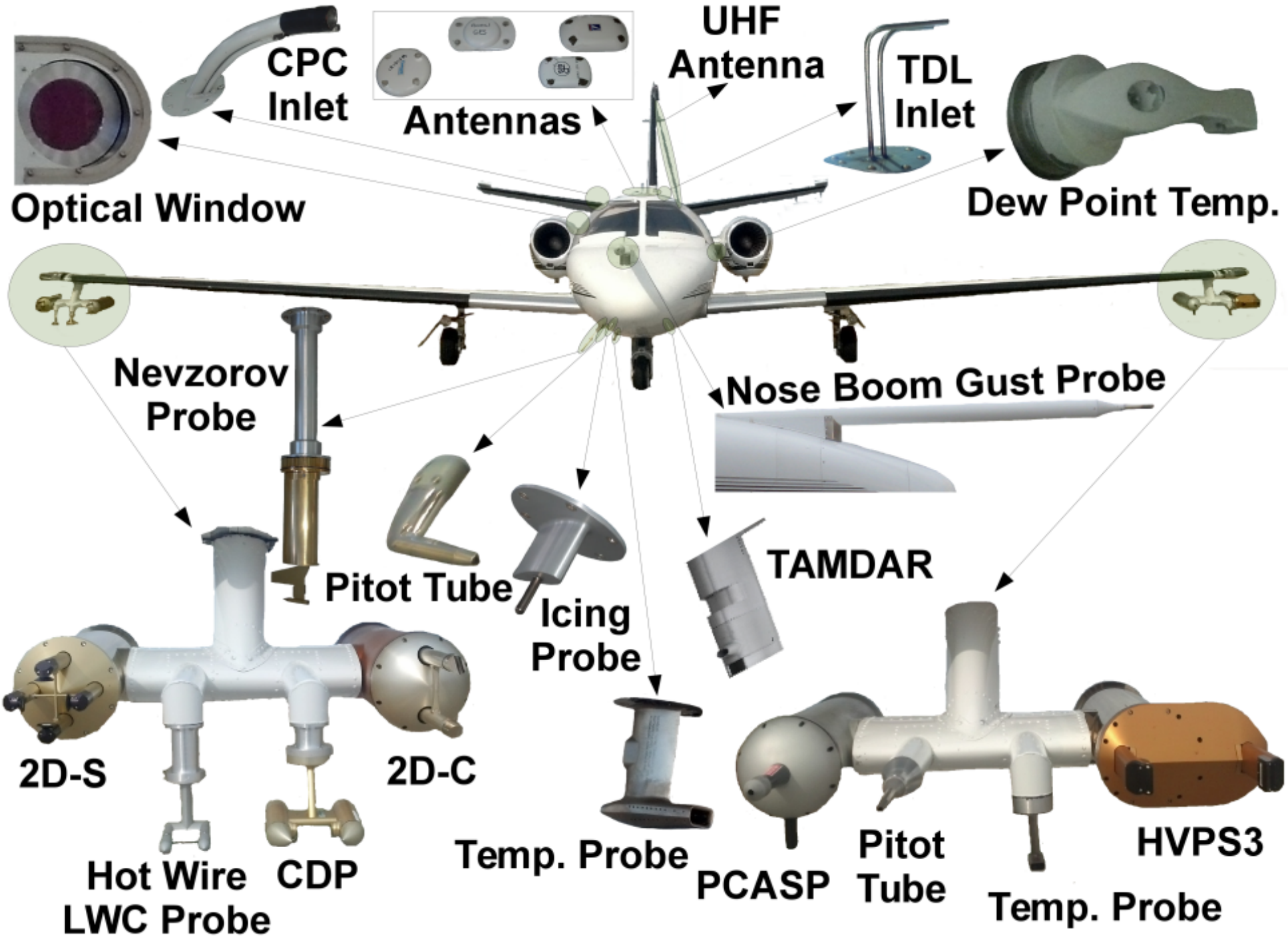


Probability Densities



Adapted from Figure 1 of Kostinski and Jameson, 2000

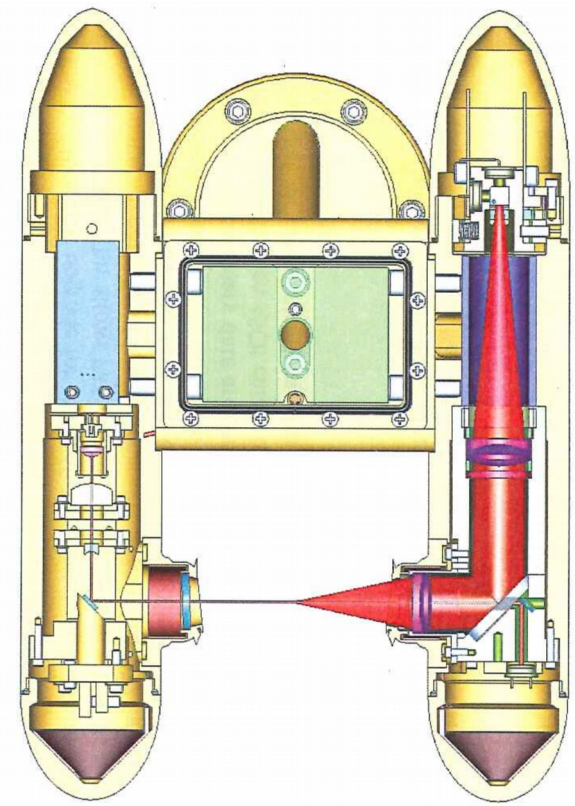
CAPE2015 – Florida, 8 Flights, 21.9 hrs



Cloud Droplet Probe

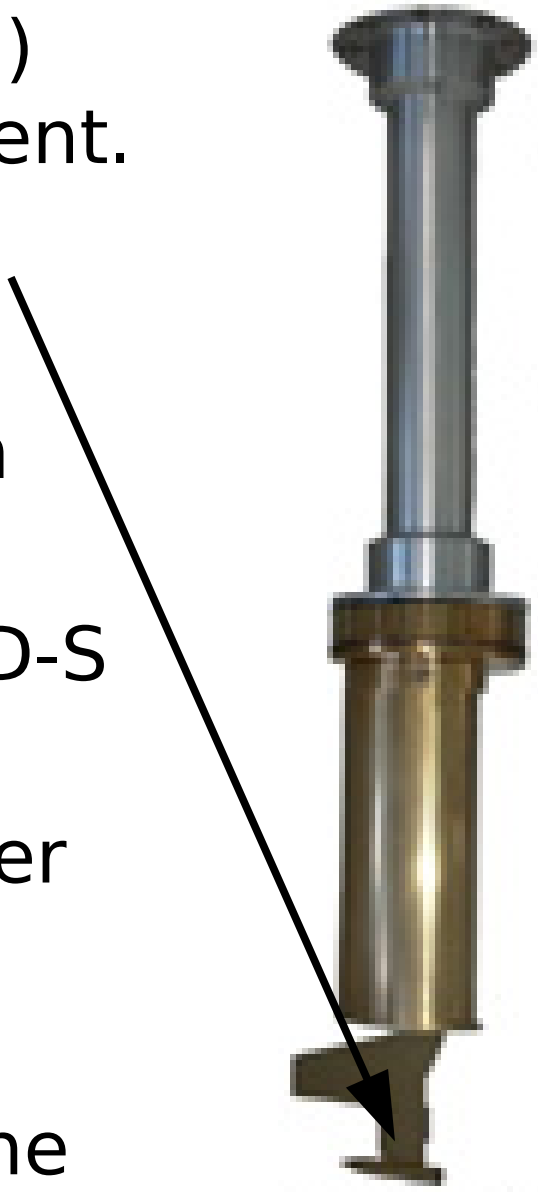
- Measurement of the cloud droplet spectrum in 30 channels between 2 and 50 um diameter.
- Forward scattering between 3-12 degrees.
- Uses Mie scattering to determine particle diameter by assuming spherical water droplets.
- 10 Hz sampling frequency with particle-by-particle information on first 256 particles per sampling interval.
- 0.24 cm^3 sample Volume

  (0.024 cm^2 * 100 m/s * 0.1 s)



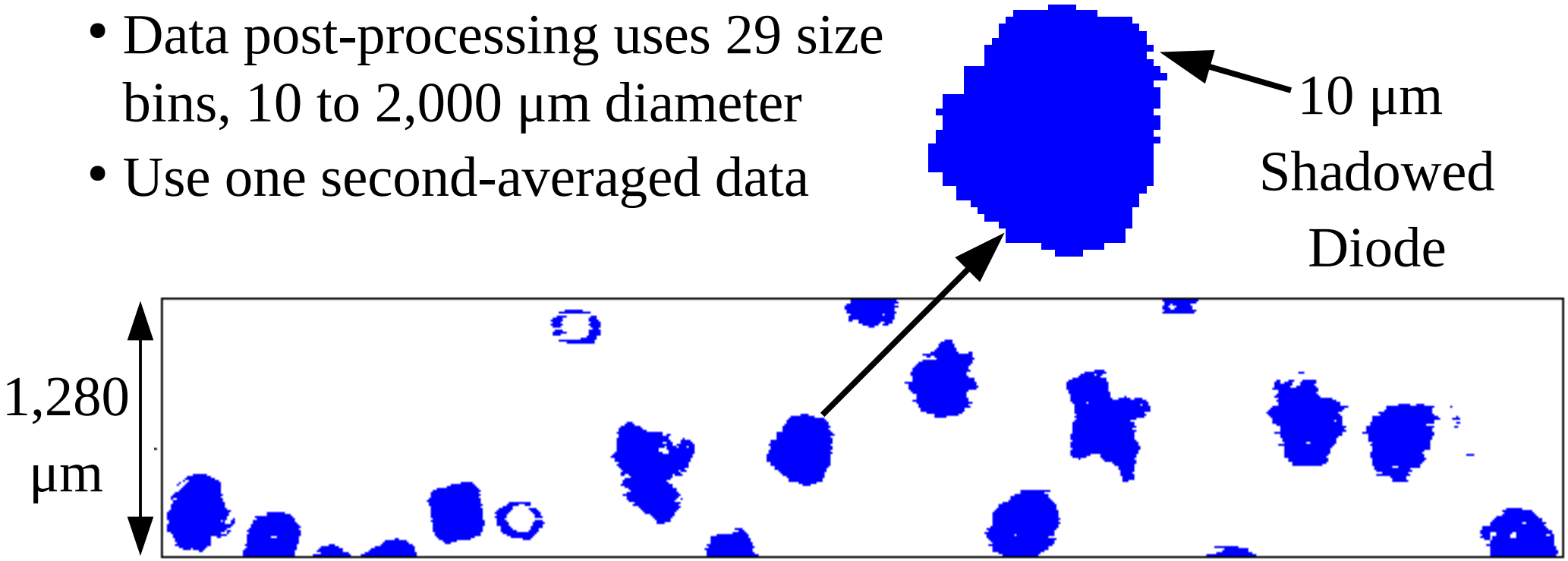
Nevzorov Probe - Water Content

- Measurement of total (ice and liquid) and liquid water content measurement.
- Maintain constant temperature on a hot (125 C) wire sensor head.
- Measure power required to maintain constant temperature.
- Direct measurements to compare 2D-S derived measurements with.
- High altitude clouds so total ice water is used for ice water content measurements.
- Comparison at frequency of up to one second.



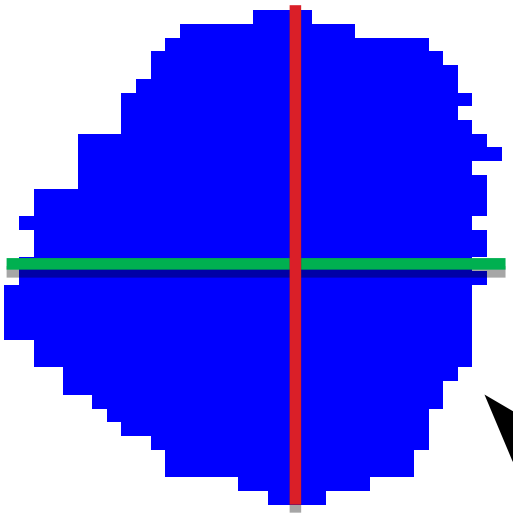
Two-Dimensional Stereographic (2D-S) Probe

- Horizontal and vertically oriented laser.
- 128 Diodes, 10 µm each.
- Captures images of shadows from cloud particles.
  - Data post-processing uses 29 size bins, 10 to 2,000 µm diameter
  - Use one second-averaged data

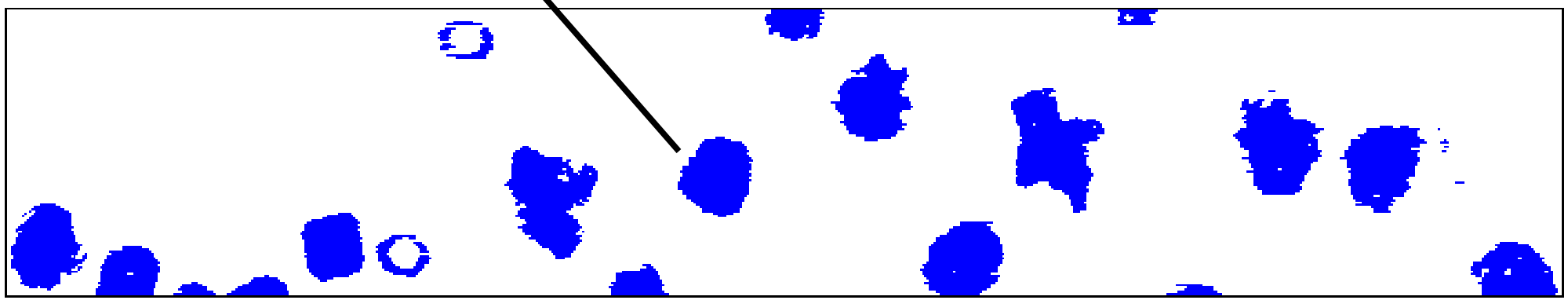


Diameter Size Calculation (Aspect Ratio)

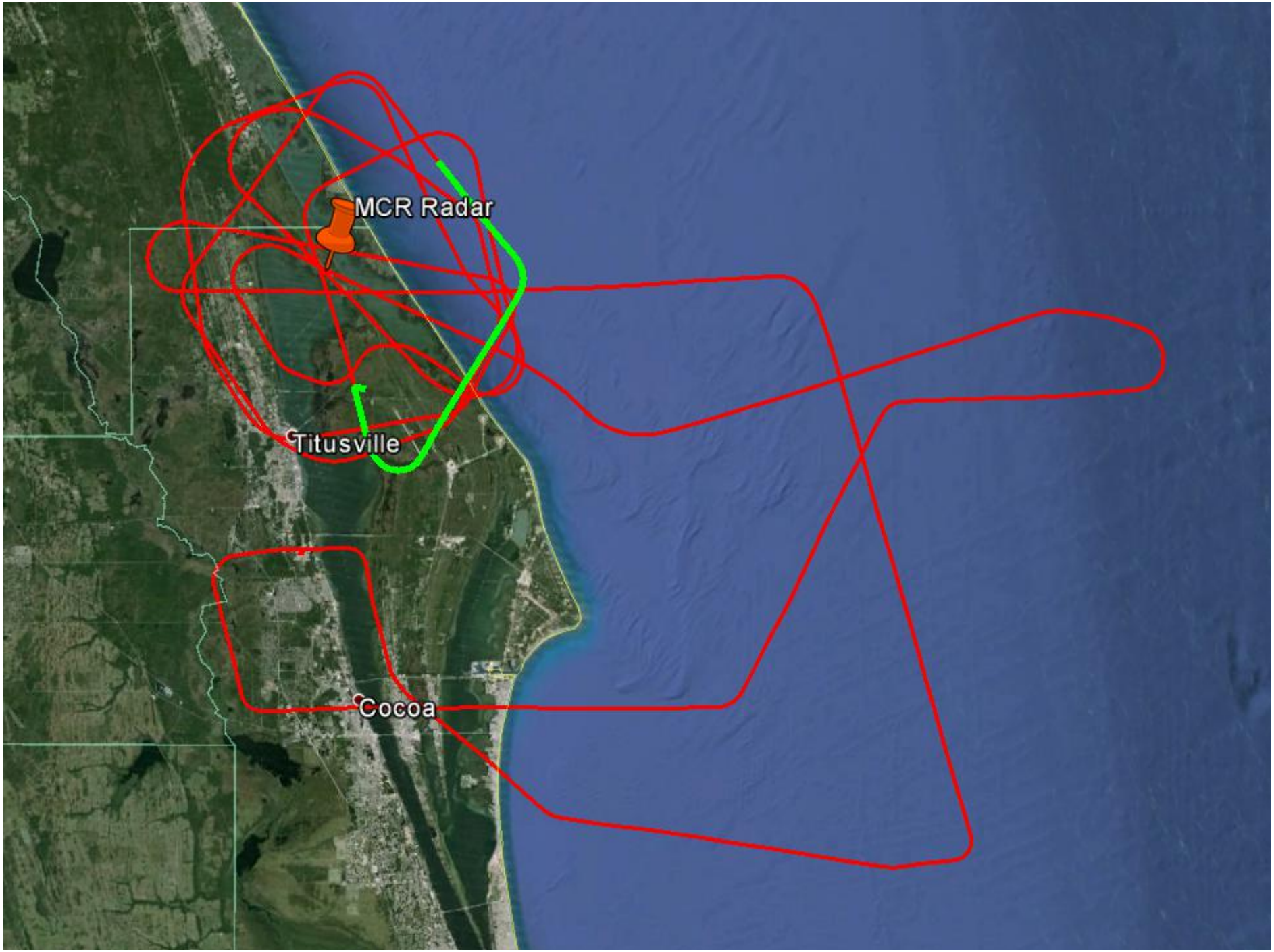
- Calculated during data post-processing using the SODA code from NCAR.
- How circular (spherical) are particles?



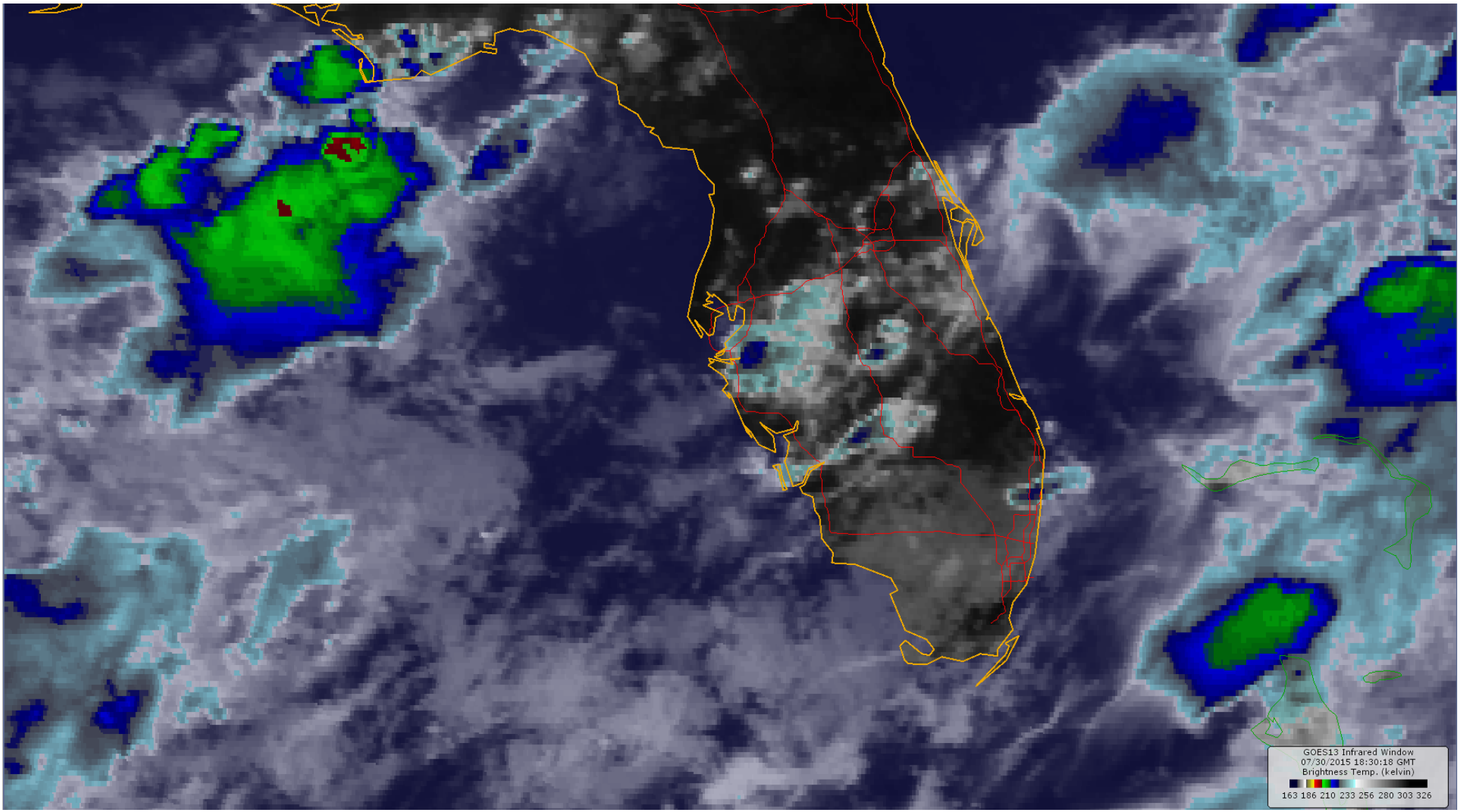
$$\text{Aspect Ratio} = \frac{\text{Horizontal Width}}{\text{Vertical Width}}$$



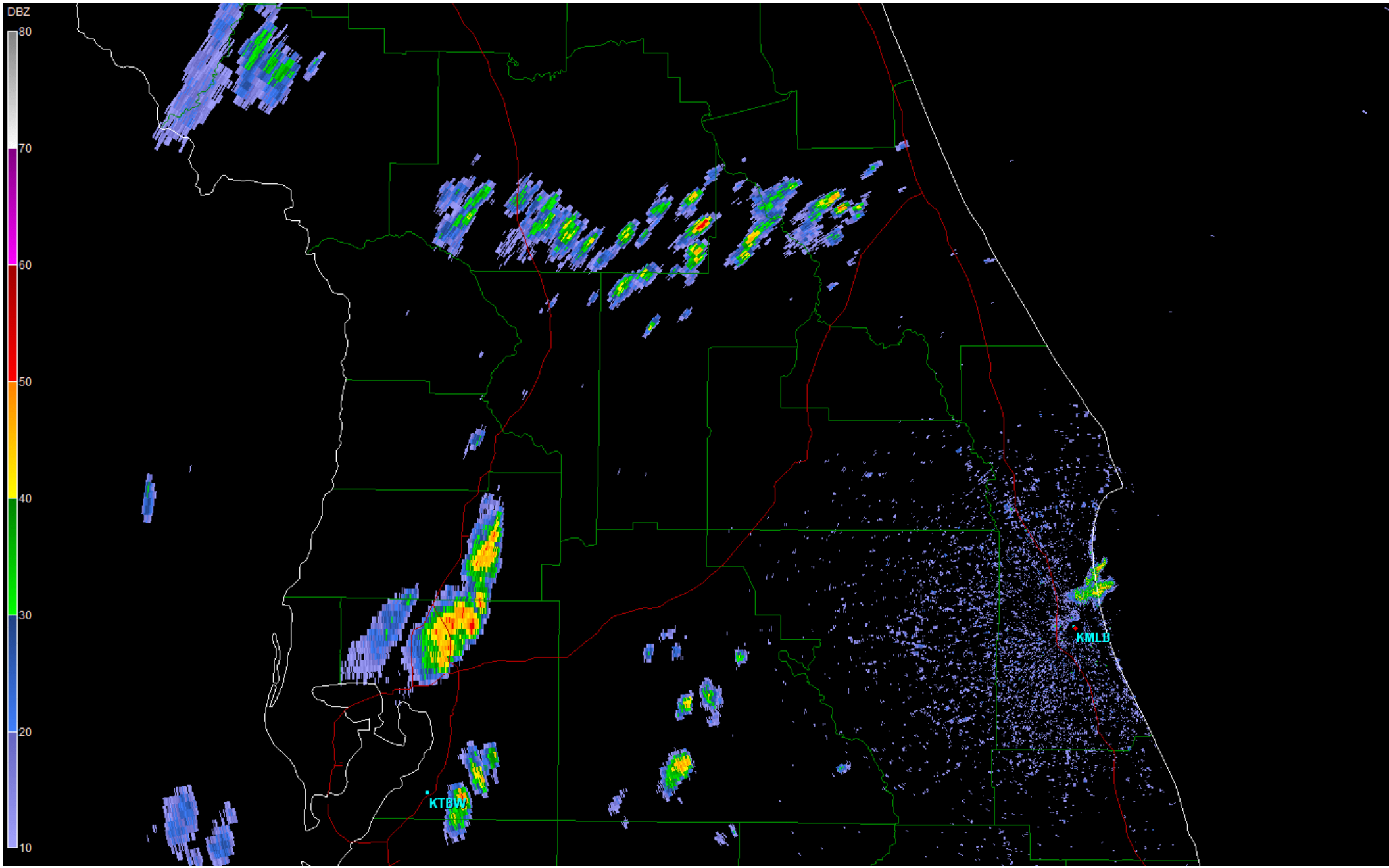
July 30, 2015 Flight: 66,000-66,360 sfm



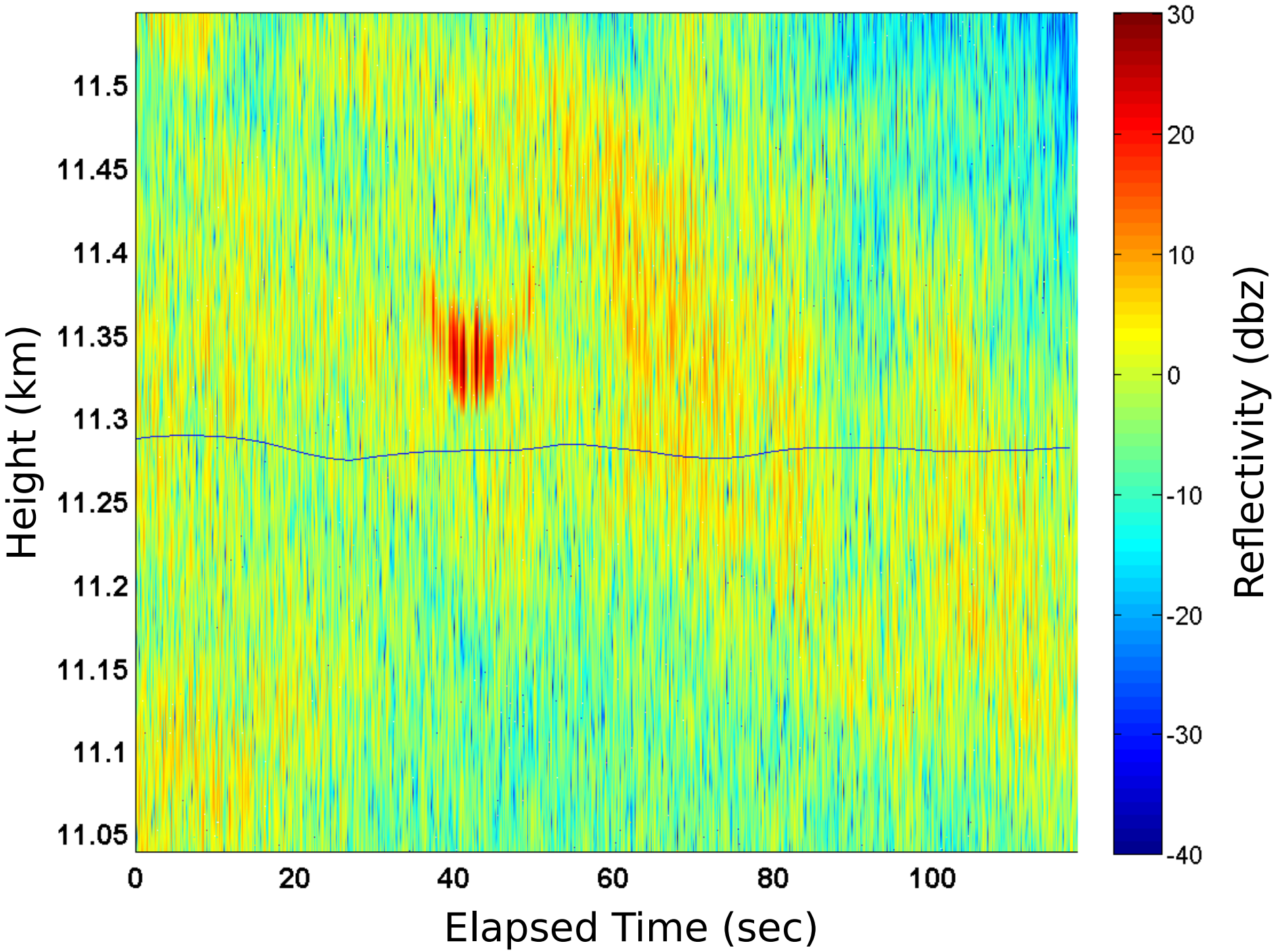
GOES 13 IR Channel
July 30, 2015: 18:30:18 UTC

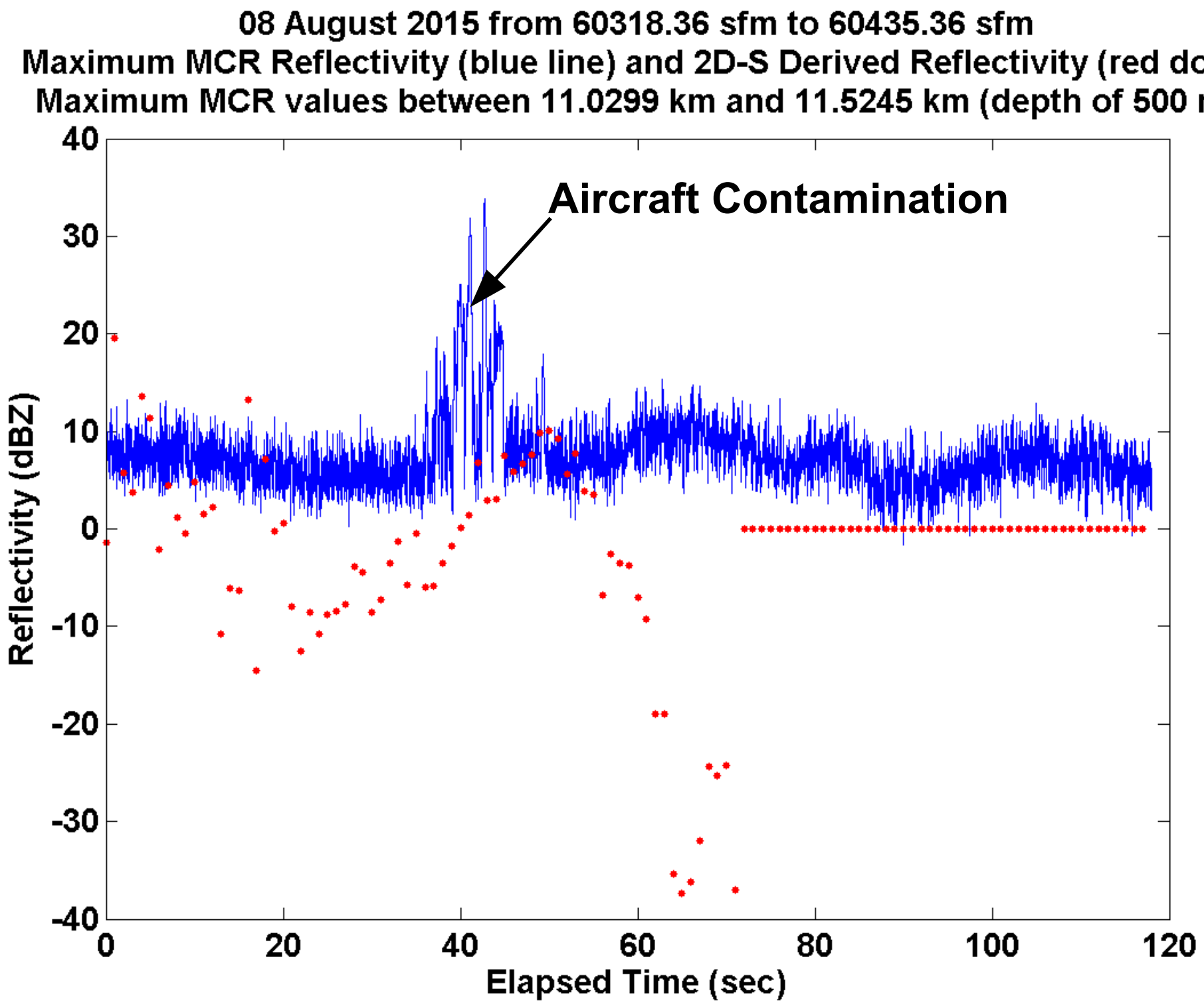


Melbourne Radar
July 30, 2015 - 16:19:06 - 20:42:52 UTC

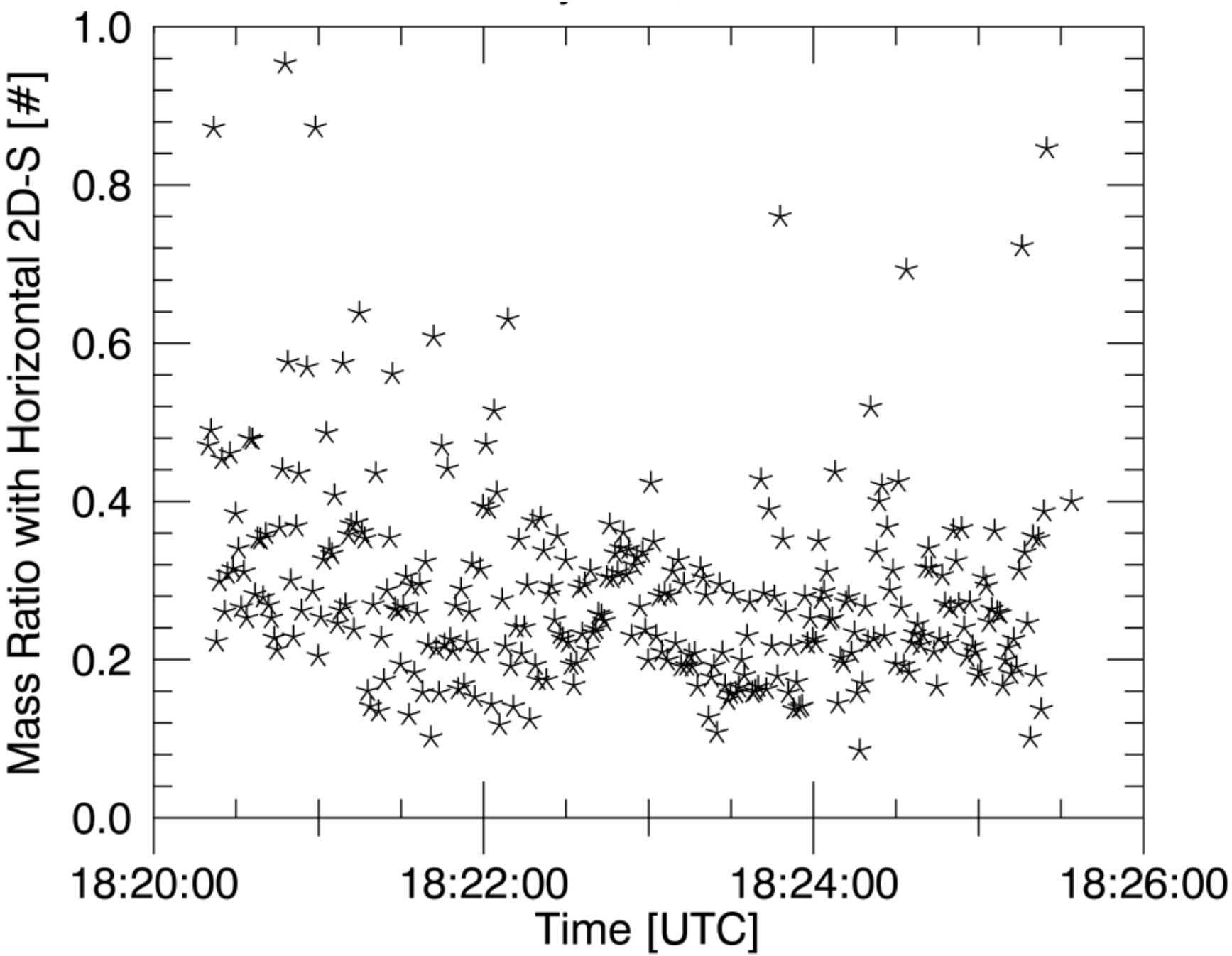


Track (Blue Line) 08 August 2015 60,318 to 60,435 sfm

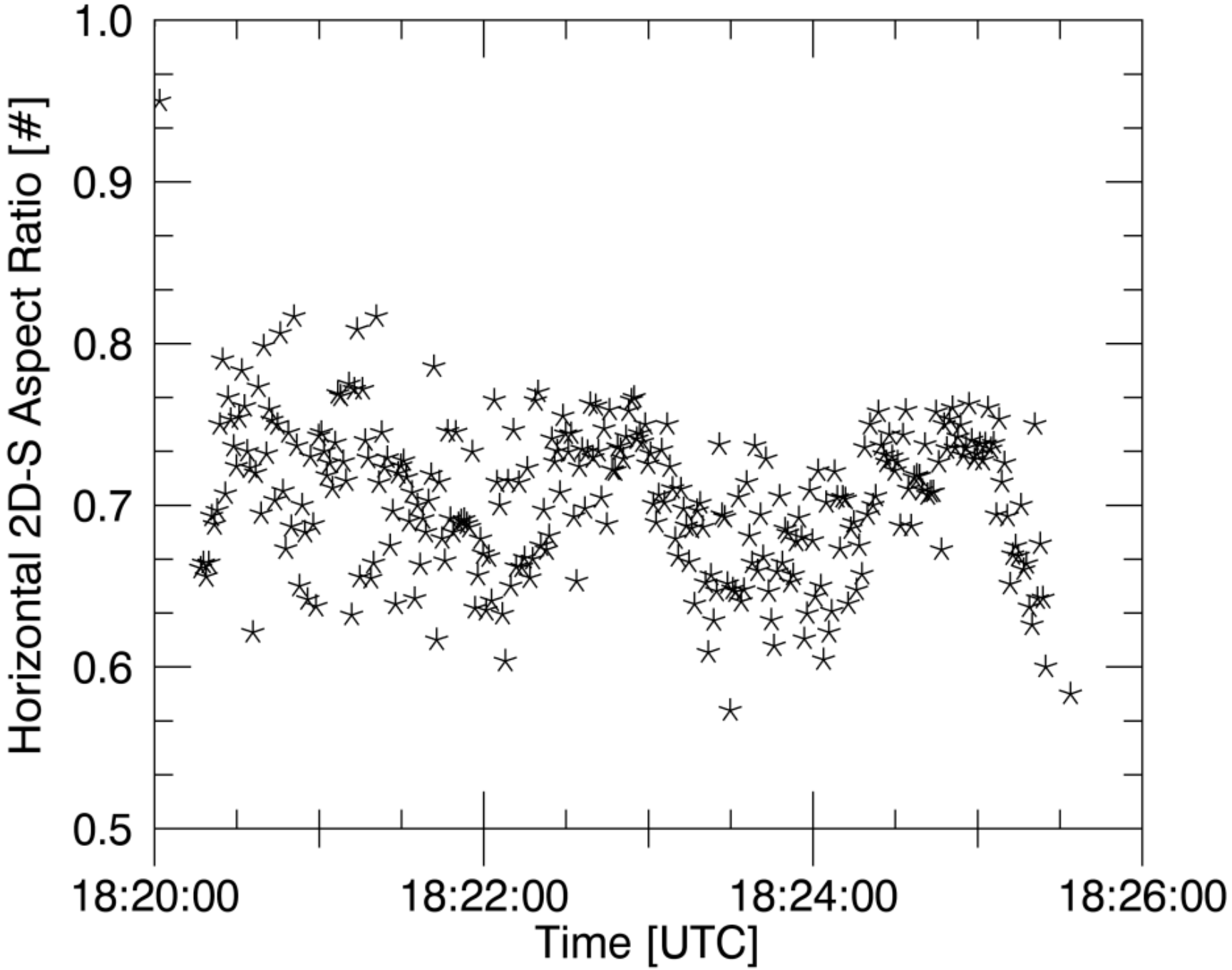



08 August 2015 from 60318.36 sfm to 60435.36 sfm
Maximum MCR Reflectivity (blue line) and 2D-S Derived Reflectivity (red dots)
Maximum MCR values between 11.0299 km and 11.5245 km (depth of 500 m)
Aircraft Contamination
Reflectivity (dBZ)
Elapsed Time (sec)
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120

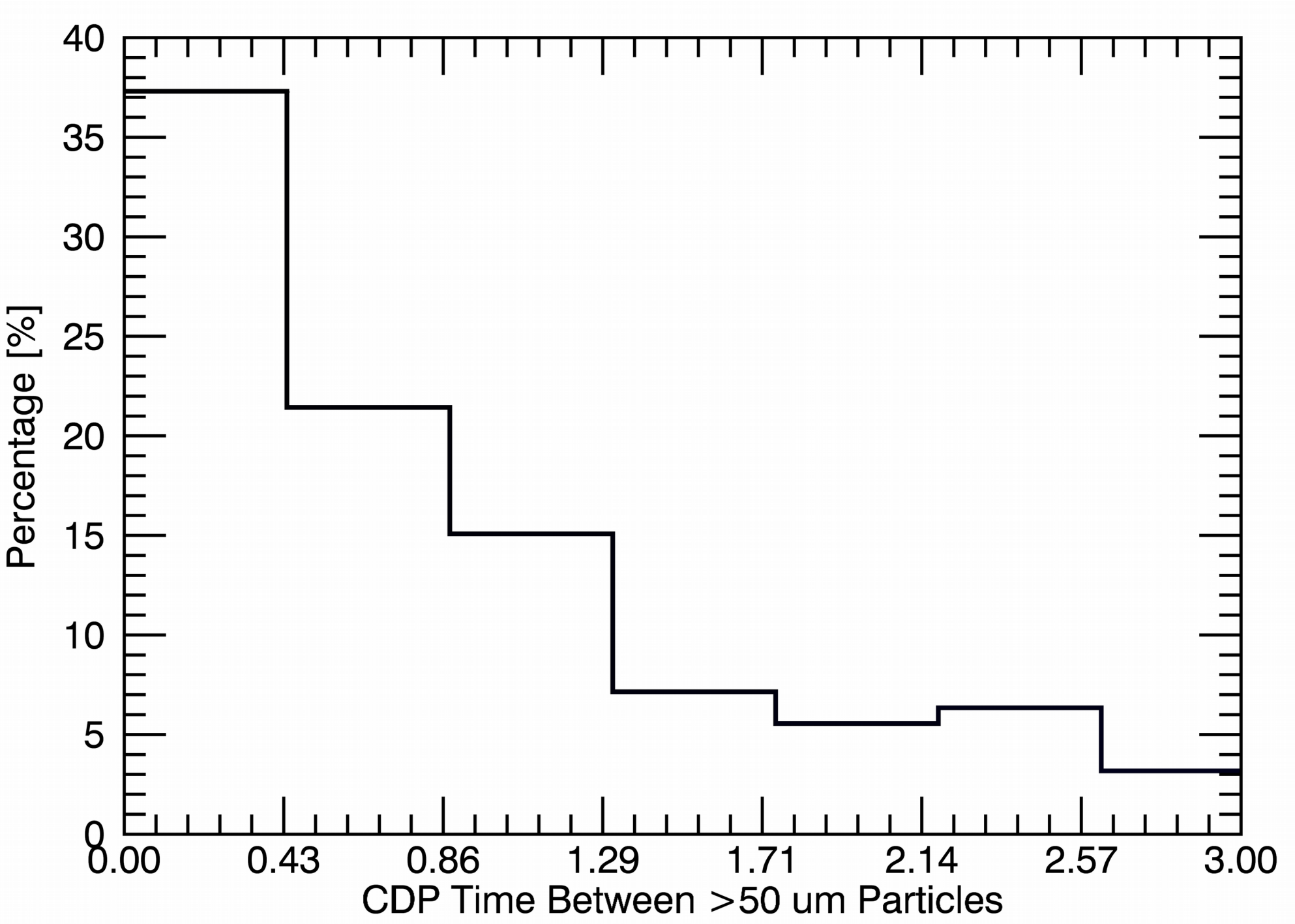
July 30, 2015: 9,400 m (31,000 ft)



July 30, 2015: 9,400 m (31,000 ft)



August 8, 2015 17:46:56-17:49:22: 12,560 m

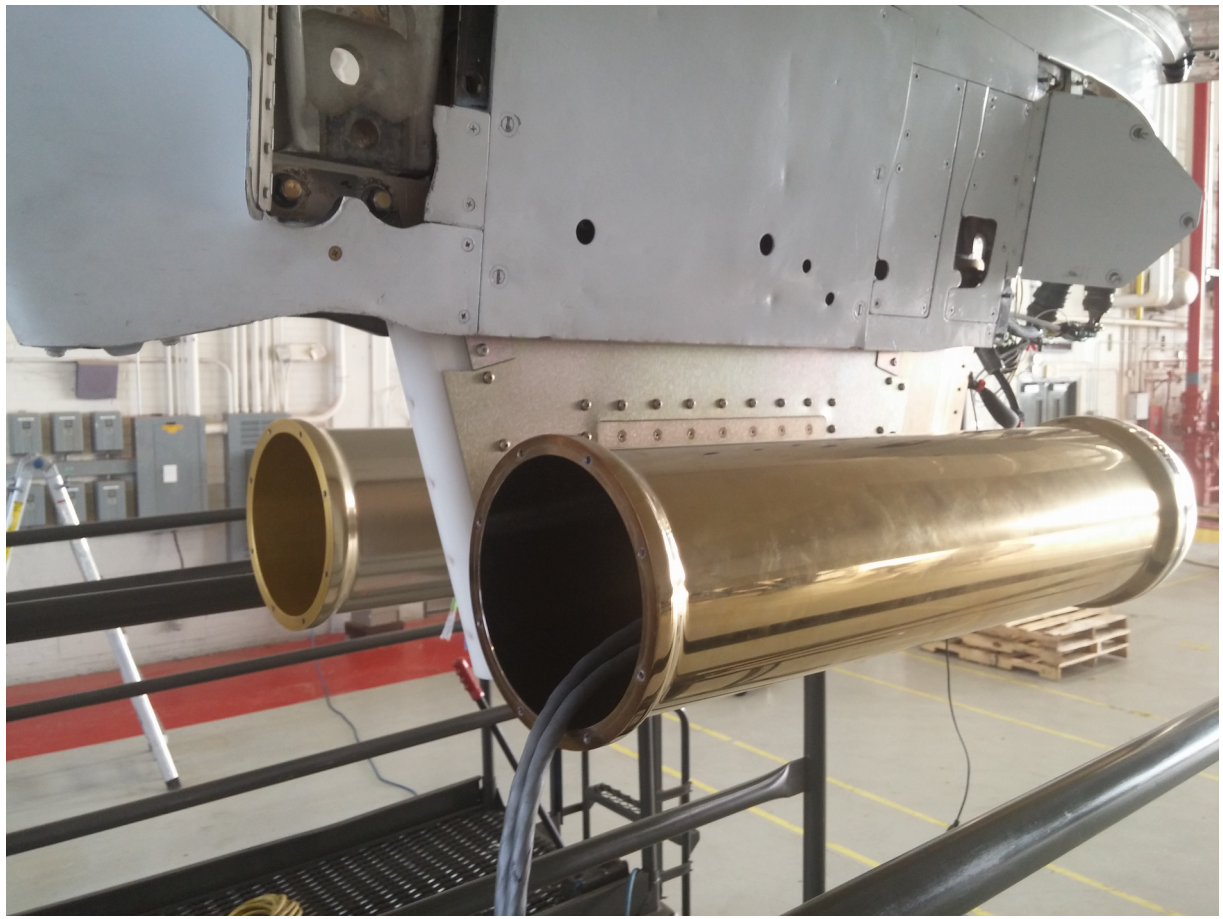


Conclusion

- Cloud core reflect ivies of -10 to 10 dbz.
- Aspect ratios of 0.7 – 0.8.
- Mass ratios of 0.1 to 0.4.
- Observed Cirrus Clouds are Patchy.

Future Work: NASA ORACLES

- **O**bseRvations of Aerosols above CLouds and their intEractionS
- Aerosol-cloud Interaction Study in Southern Atlantic Ocean.



References

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- Kostinski, A. B., and A. R. Jameson, 2000: On the Spatial Distribution of Cloud Particles. J. Atmos. Sci., 57, 901–915, doi:10.1175/1520-0469(2000)057<0901:OTSDOC>2.0.CO;2.
- Rinehart, R. E., 2010: Radar for Meteorologists. Rinehart Publications, 482 pp.
- J. M. Schmidt, and Co-Authors, 2012: Radar observations of individual rain drops in the free atmosphere. PNAS, 109, 9293-9298, doi: 10.1073/pnas.1117776109.More complex equations for reflectivity calculations.

Reflectivity Calculations

- Calculate reflective to compare with MCR using 2D-S number size distribution.

$$z = \sum_{i=1}^{n} N_i D_i^6 \, |K|^2$$

  - Ice Dielectric constant of 0.197 (Rinehart, 2010).
  - Summed over all 29 size bins.
  - Convert to logarithmic units (dBZ).

$$Z = 10 \log_{10} \left(\frac{z}{1 \, mm^6/m^3} \right)$$

Processing Codes:

- twods_conc2bulk_ice.py
- twods_conc2bulk_liquid.py