HIWC Science Team Meeting
conducted at
Centro Italiano Ricerche Aerospaziali (CIRA)
Capua, Italy
05-09 December 2016

Response of the Pilot's Weather Radar to High Ice Water Concentrations

NASA
Steven Harrah
Fred Proctor

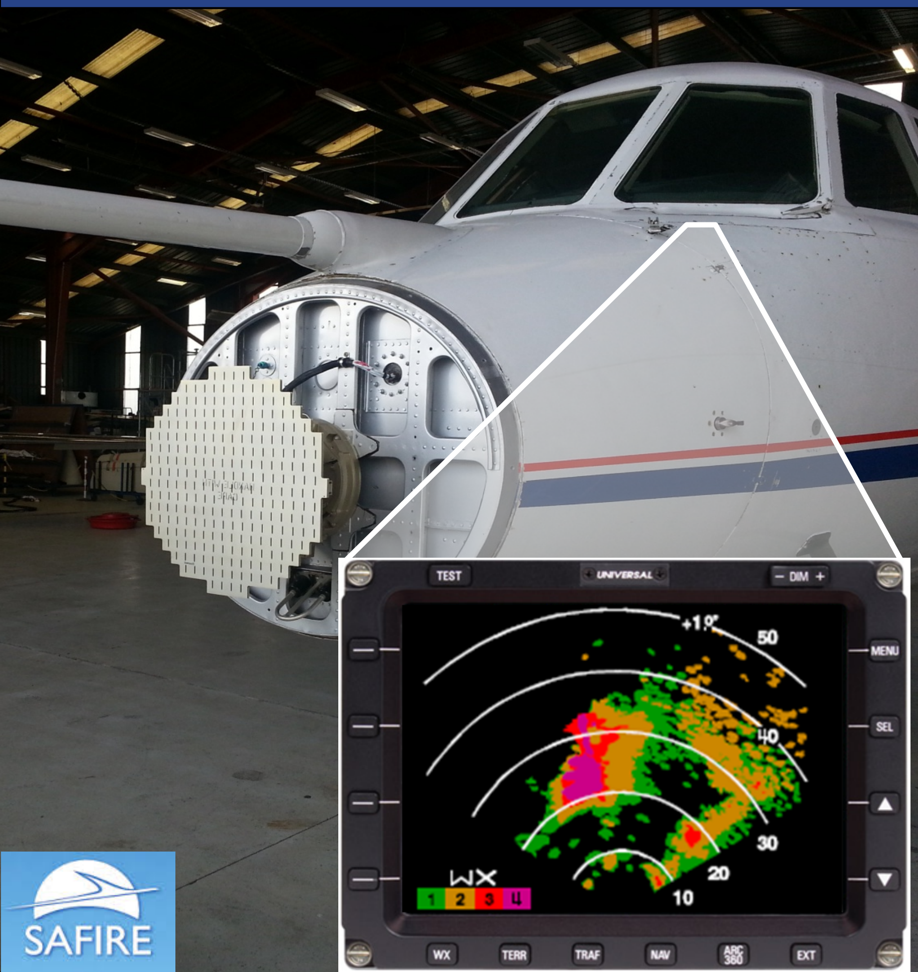
AMA Inc.
Patricia Hunt
Justin Strickland
George Switzer

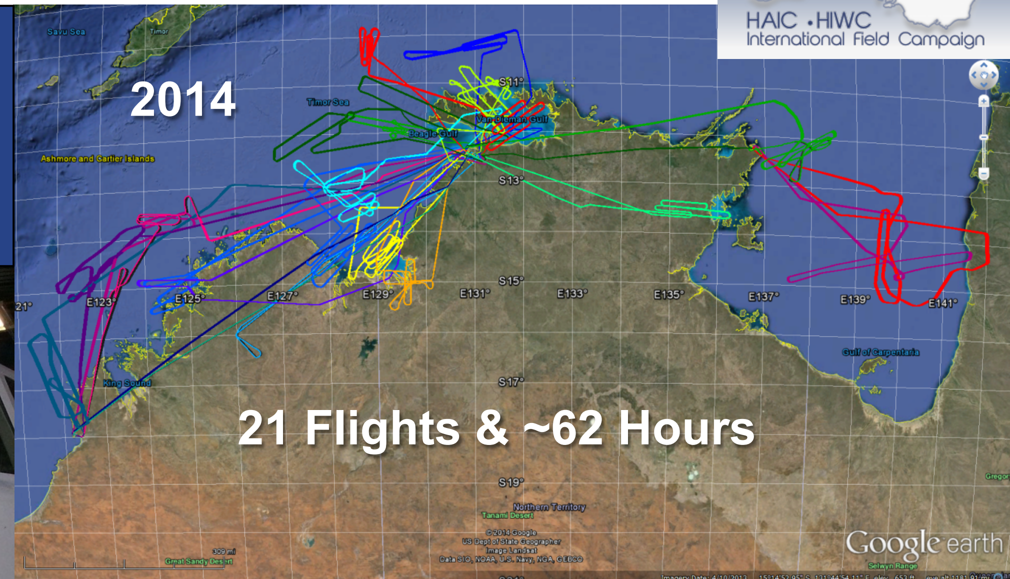
NASA Langley Research Center
Hampton, VA, USA

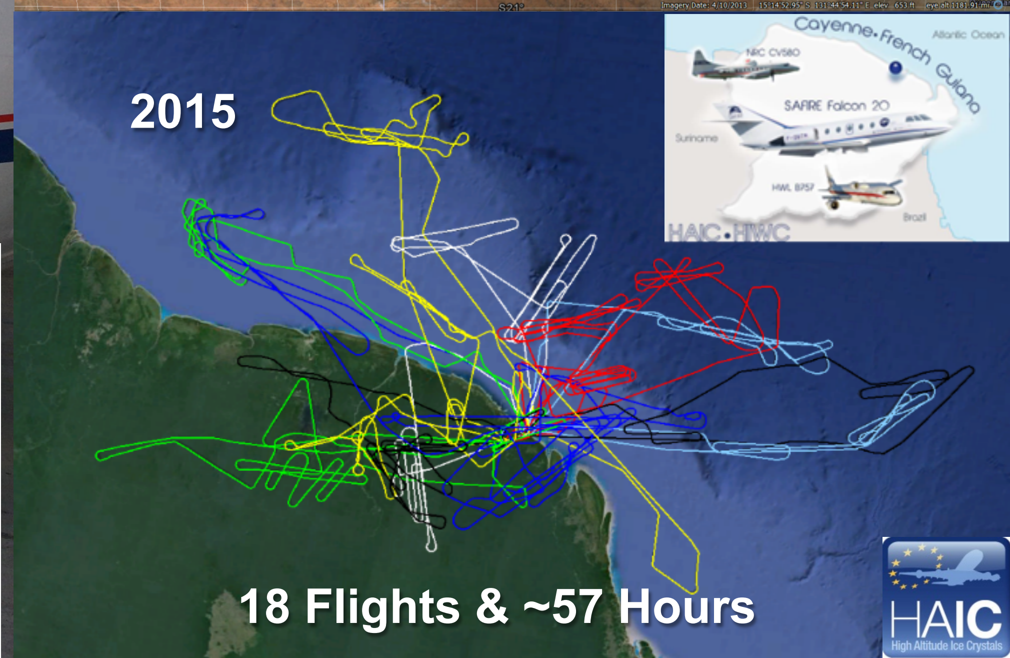
Previous Flight Campaigns

Darwin•Australia
SAFIRE Falcon 20
January – March 2014
HAIC •HIWC
International Field Campaign

Due to space and time limitations, we were ONLY able to record Weather Radar Display Bus (color, gain, az, el, & time) of Honeywell Primus 660 Weather Radar





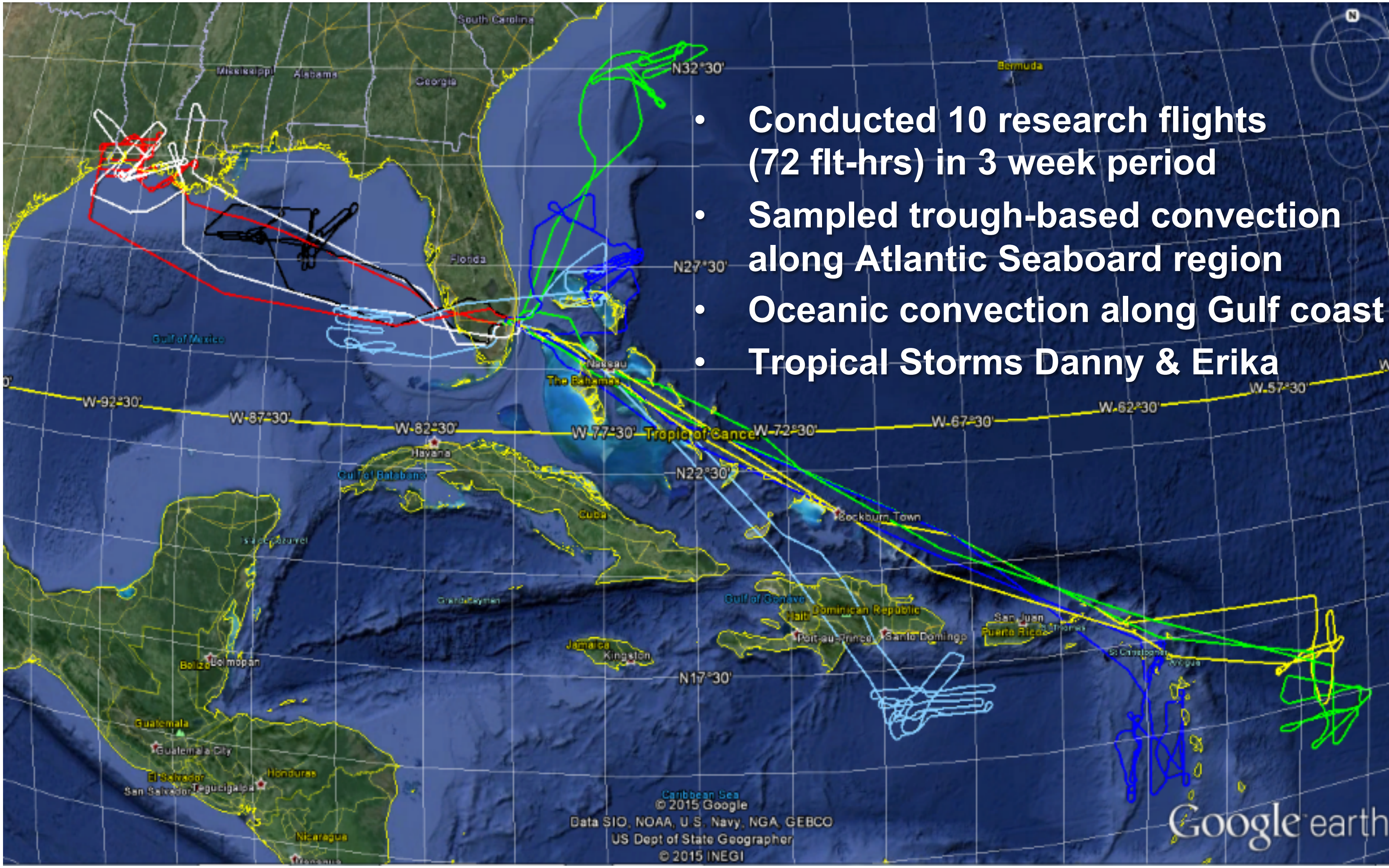


SAFIRE

HAIC
High Altitude Ice Crystals

NASA HIWC Radar Flight Campaign

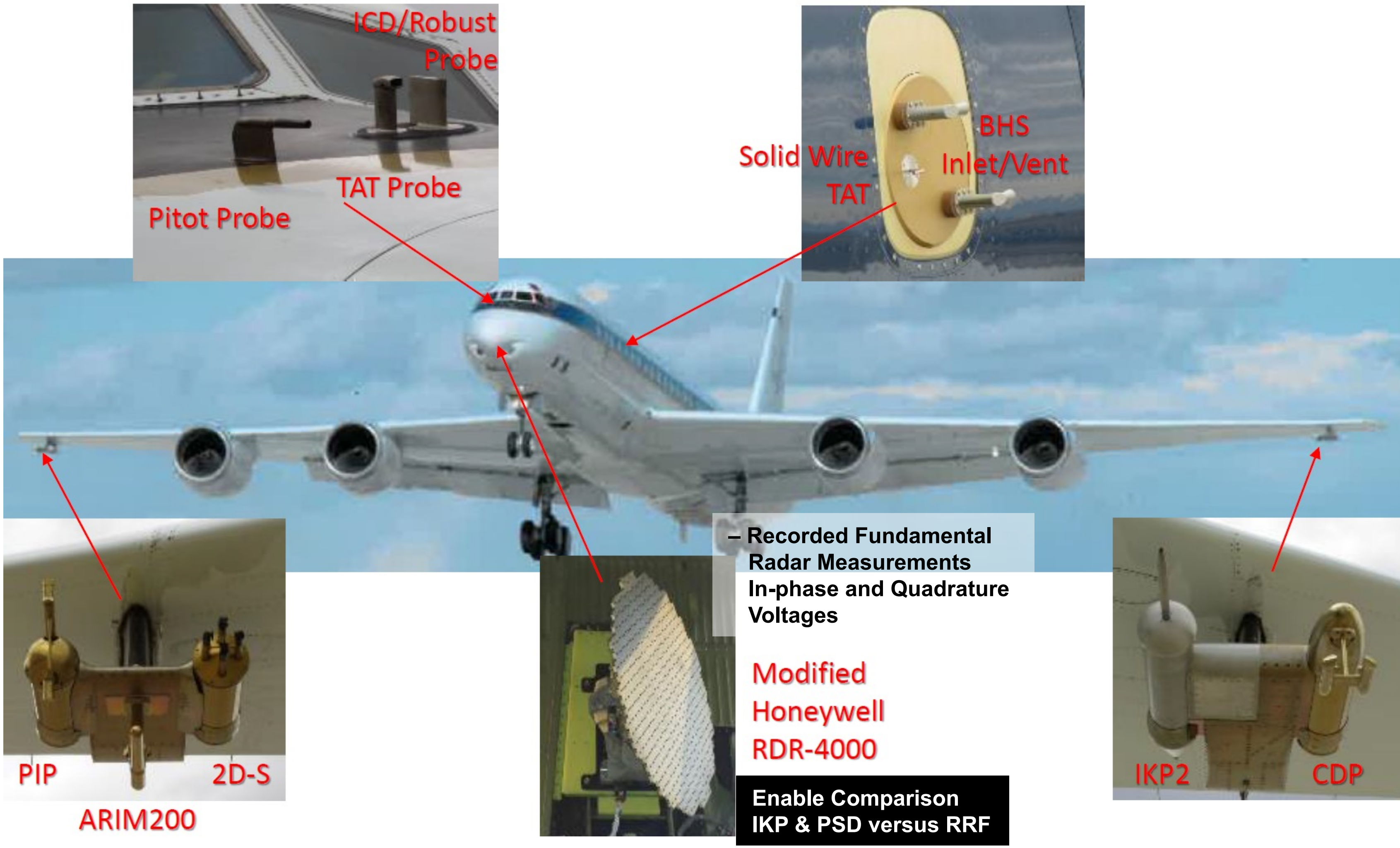
- Conducted 10 research flights (72 flt-hrs) in 3 week period
- Sampled trough-based convection along Atlantic Seaboard region
- Oceanic convection along Gulf coast
- Tropical Storms Danny & Erika



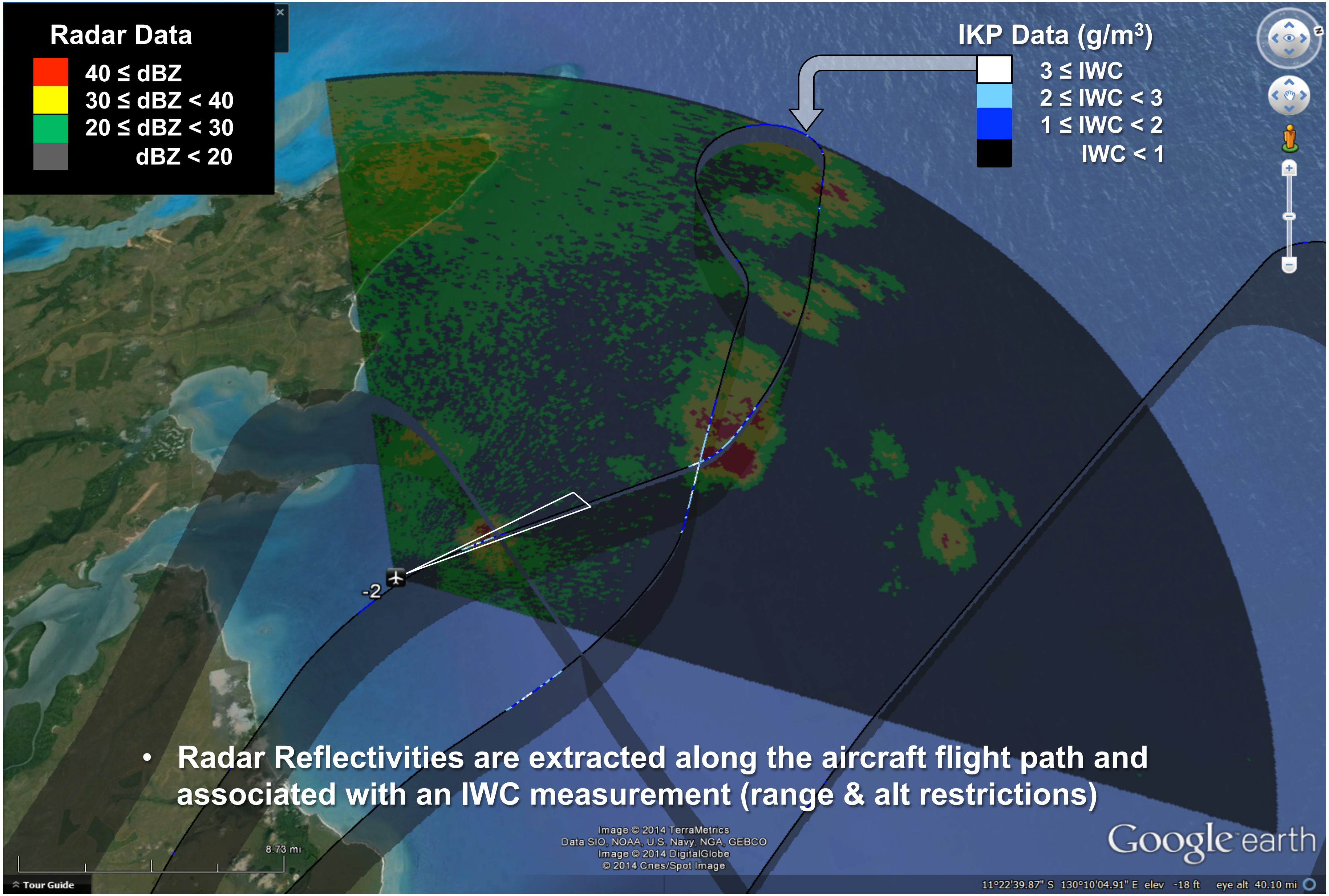
Flight Instruments

National Aeronautics and Space Administration

2015 NASA HIWC Radar Flight Campaign

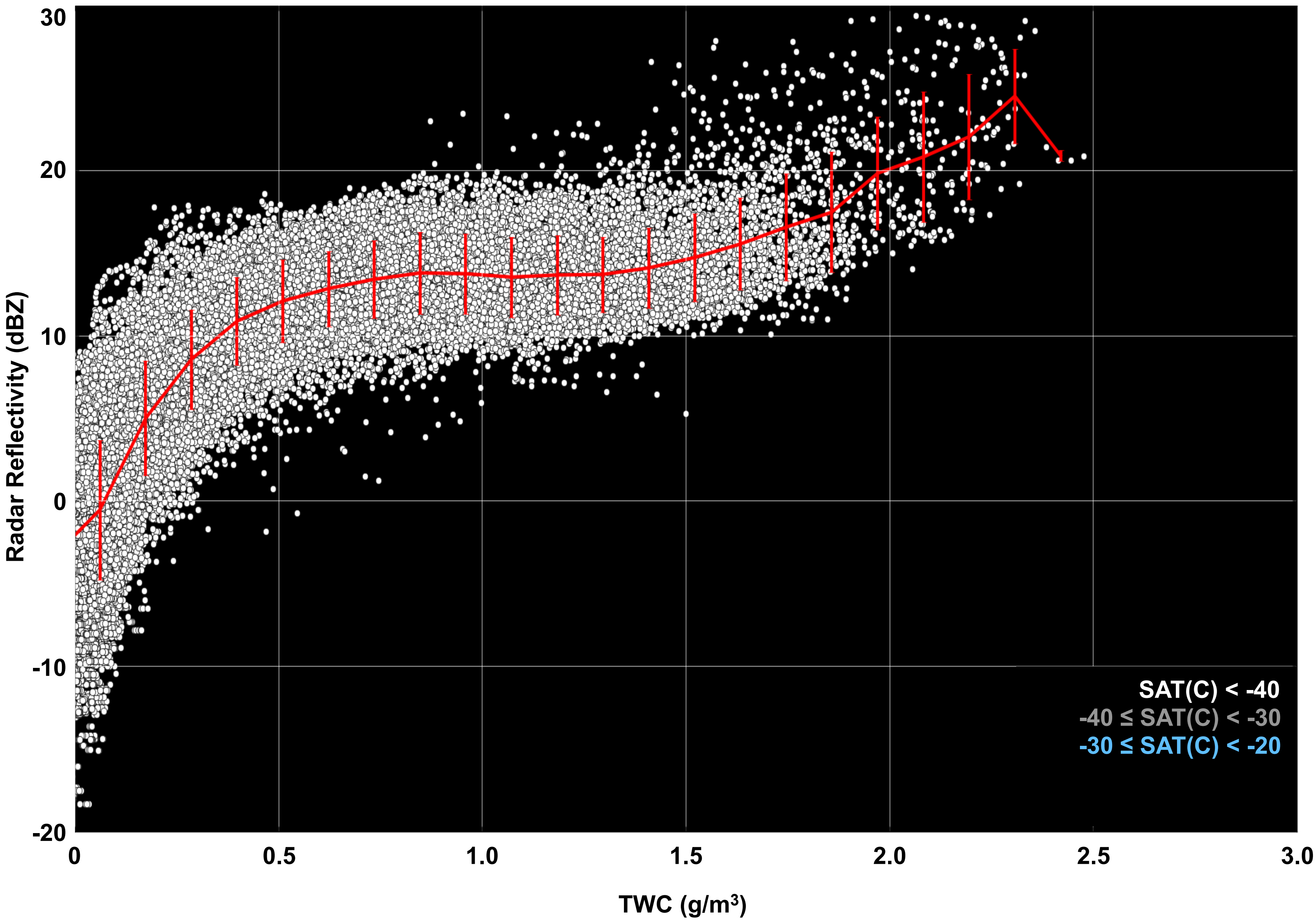


Extracting RRF for Comparison

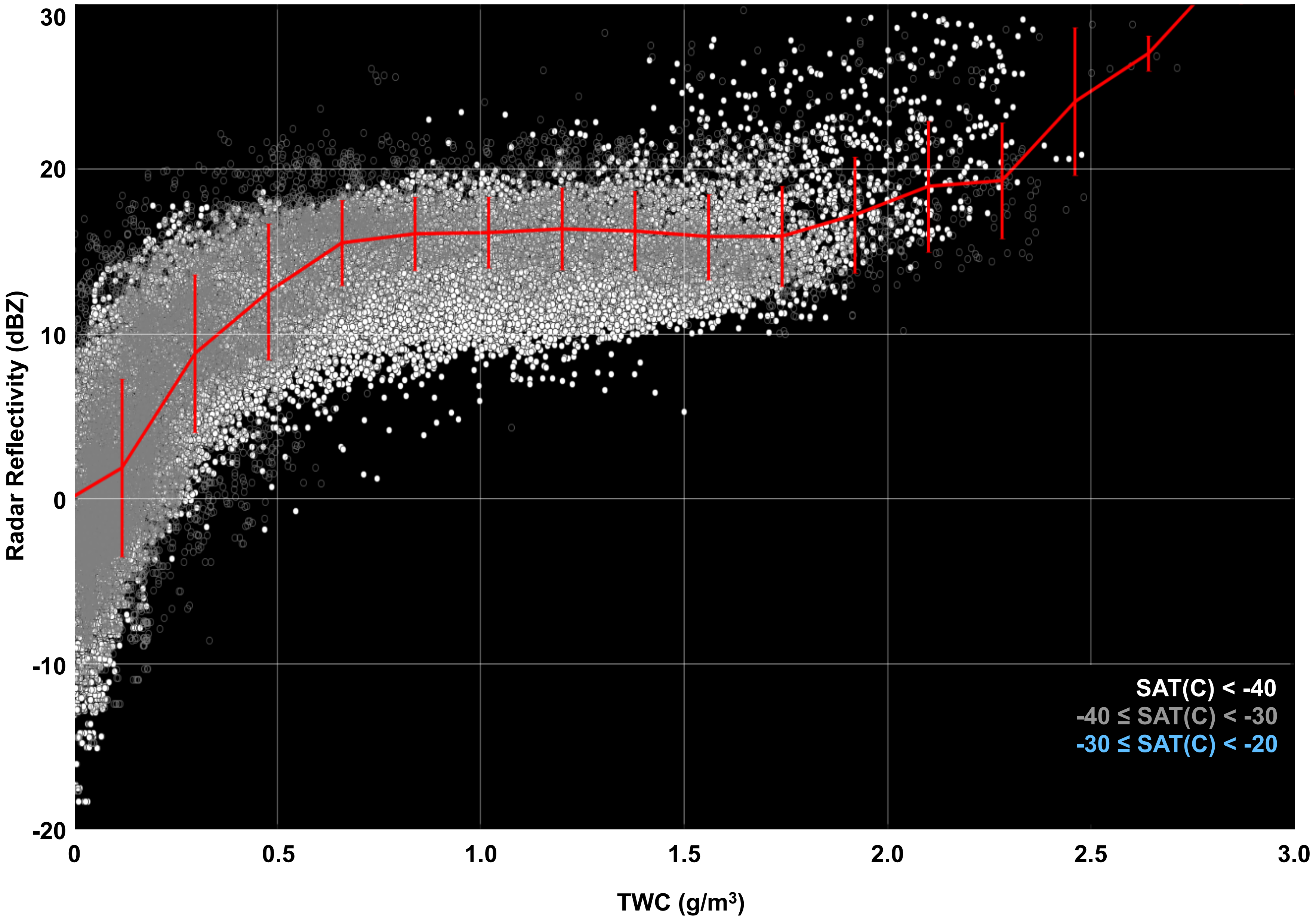


- Radar Reflectivities are extracted along the aircraft flight path and associated with an IWC measurement (range & alt restrictions)

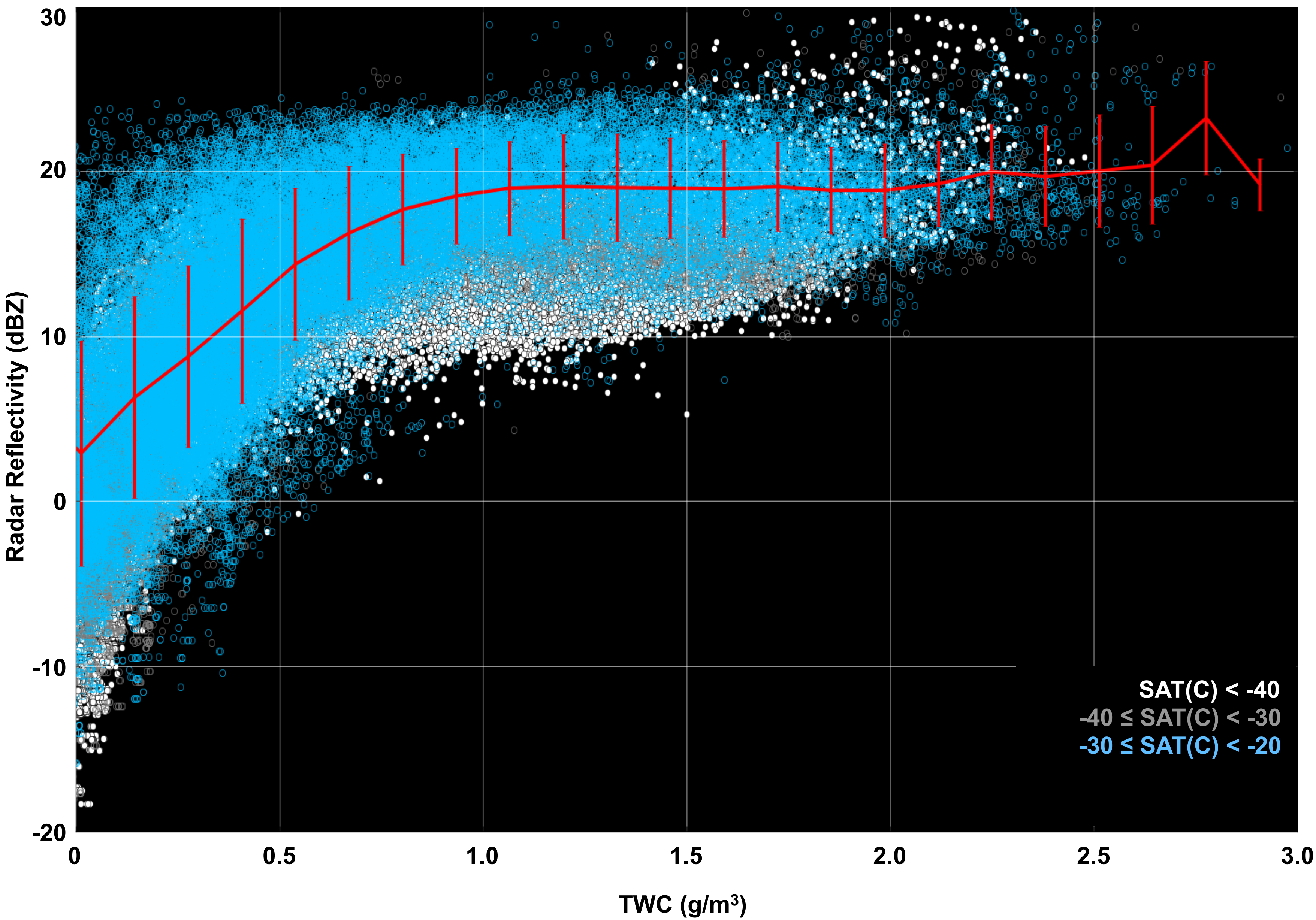
Radar Reflectivity v Ice Water Content (1 of 3)



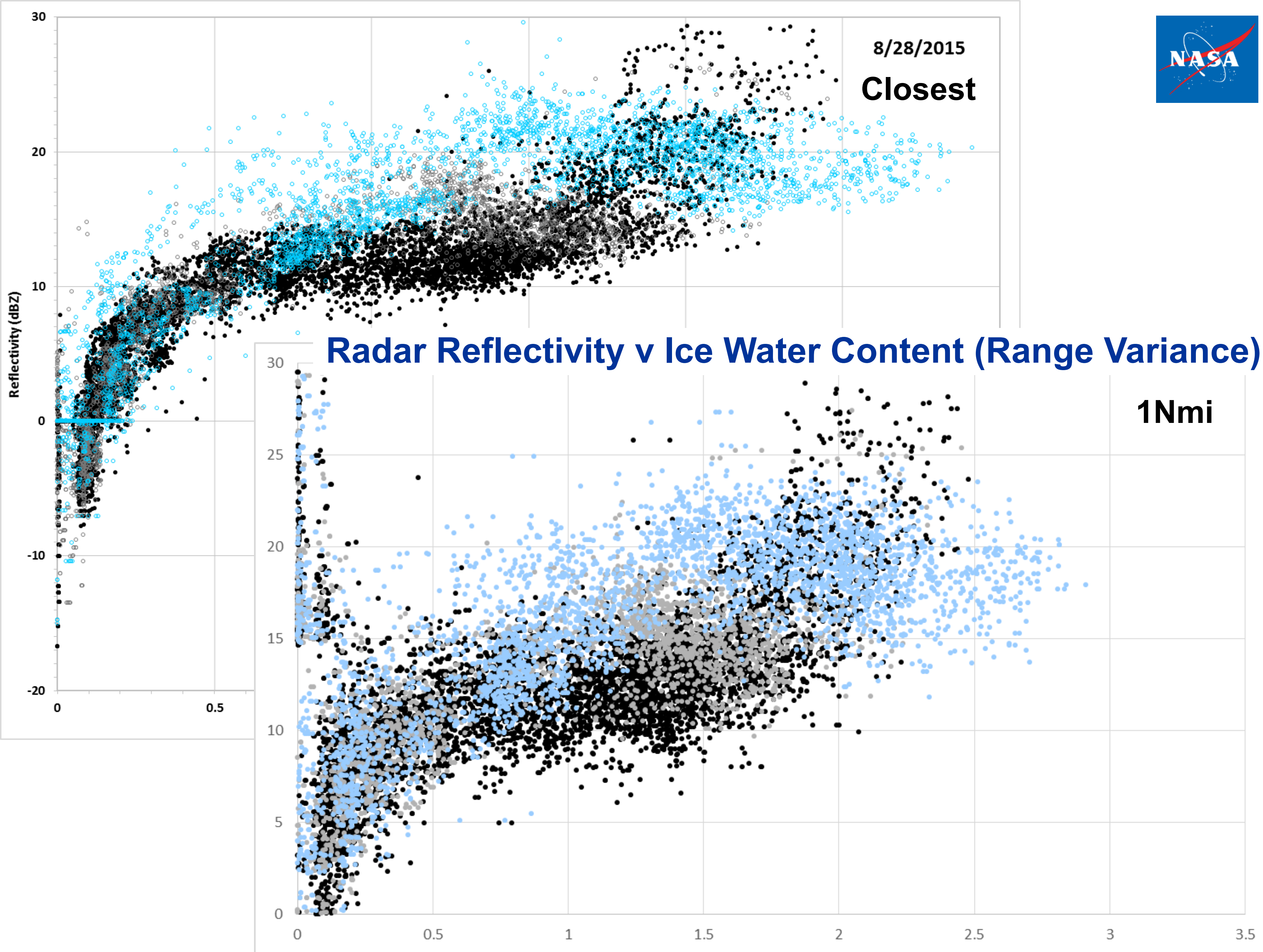
Radar Reflectivity v Ice Water Content (2 of 3)



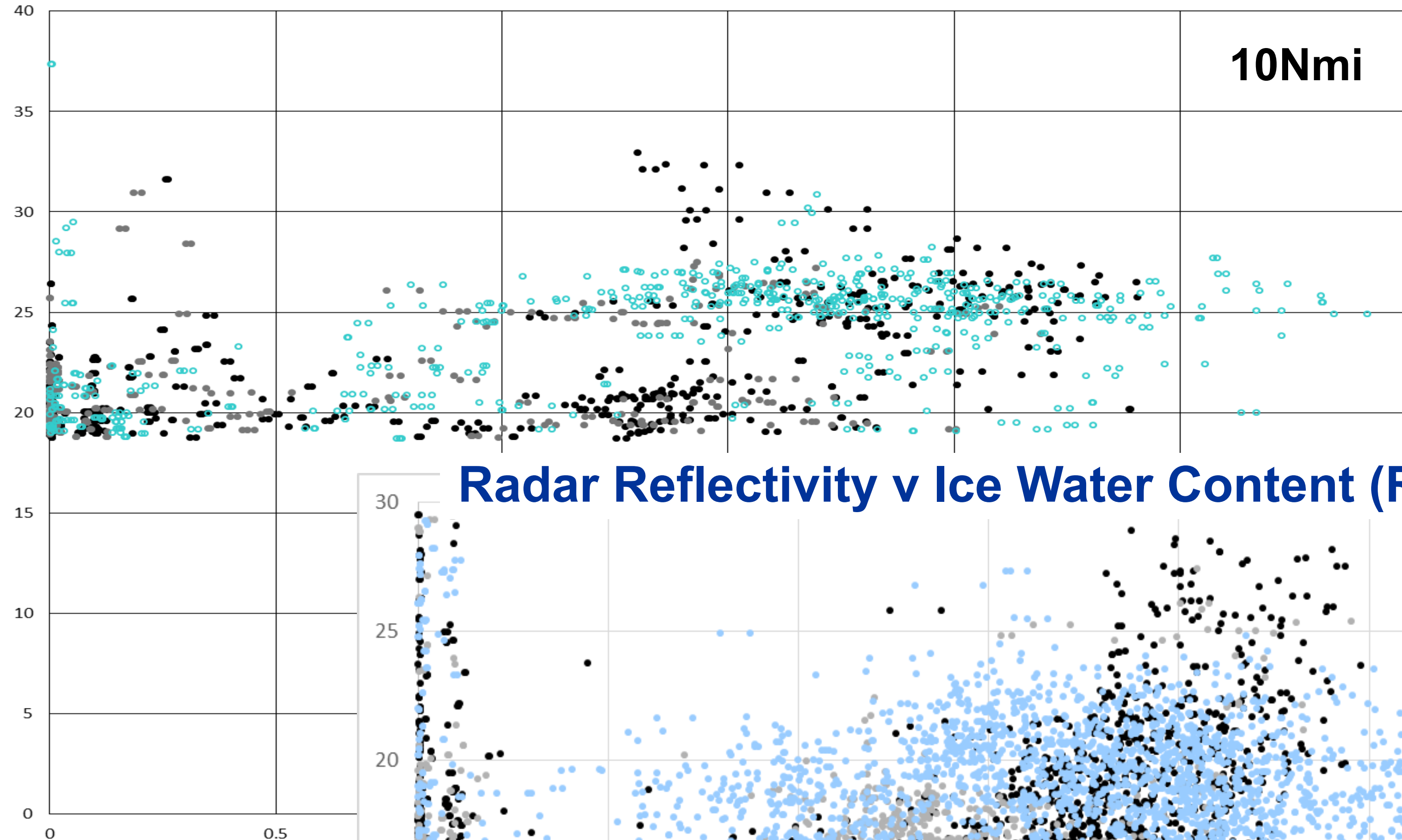
Radar Reflectivity v Ice Water Content (3 of 3)

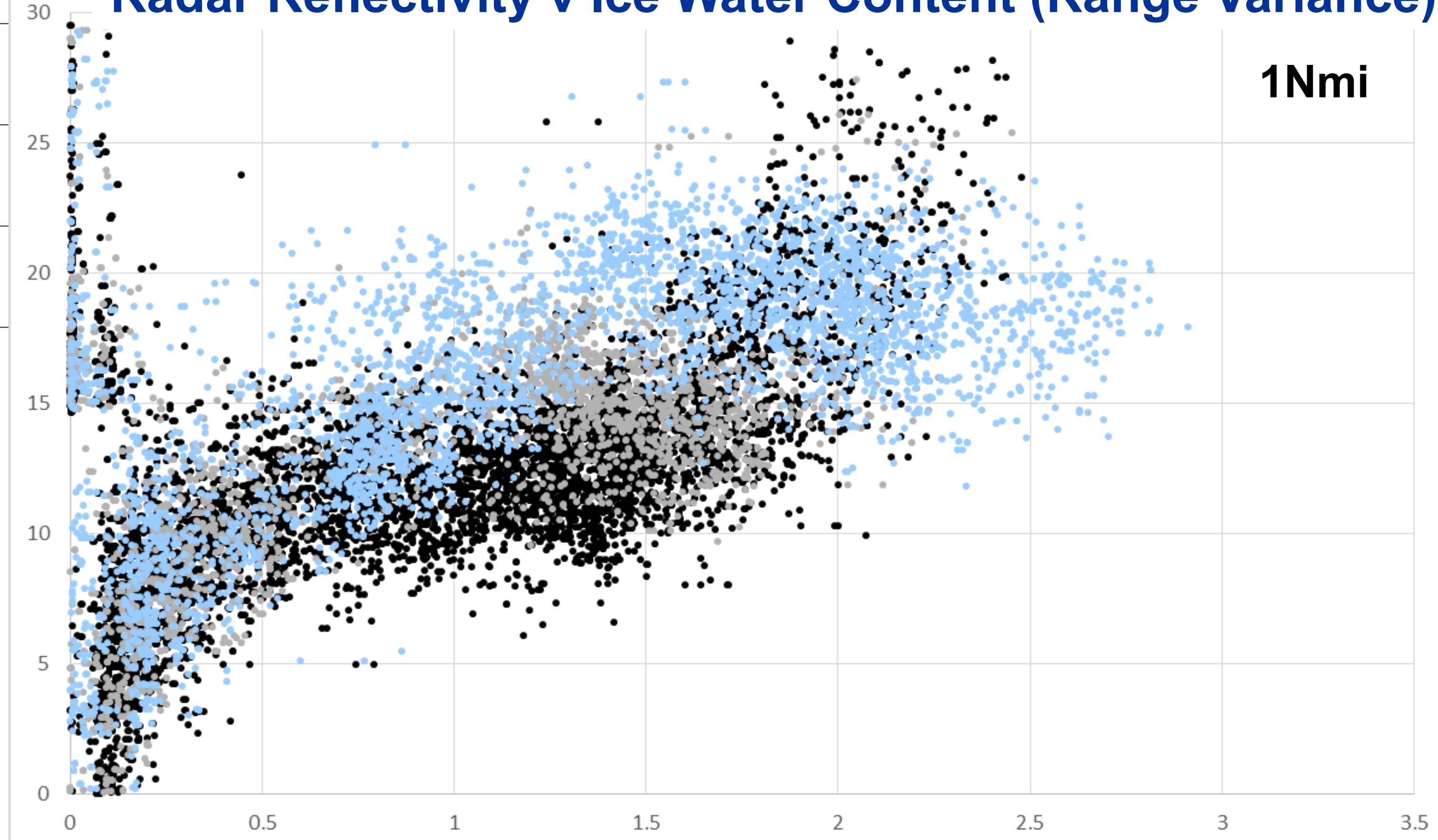


Radar Reflectivity v Ice Water Content (Range Variance)

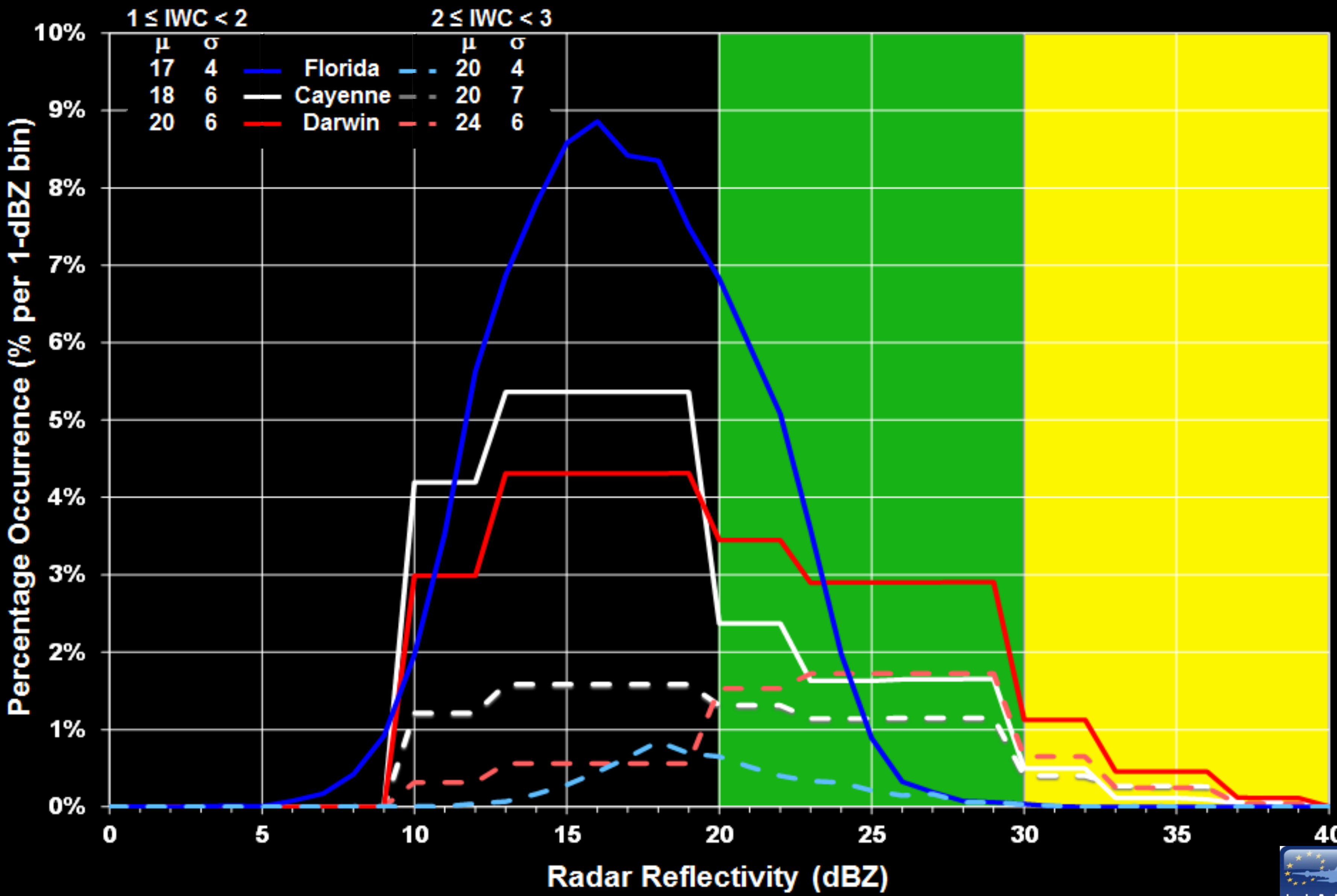


Radar Reflectivity v Ice Water Content (Range Variance)

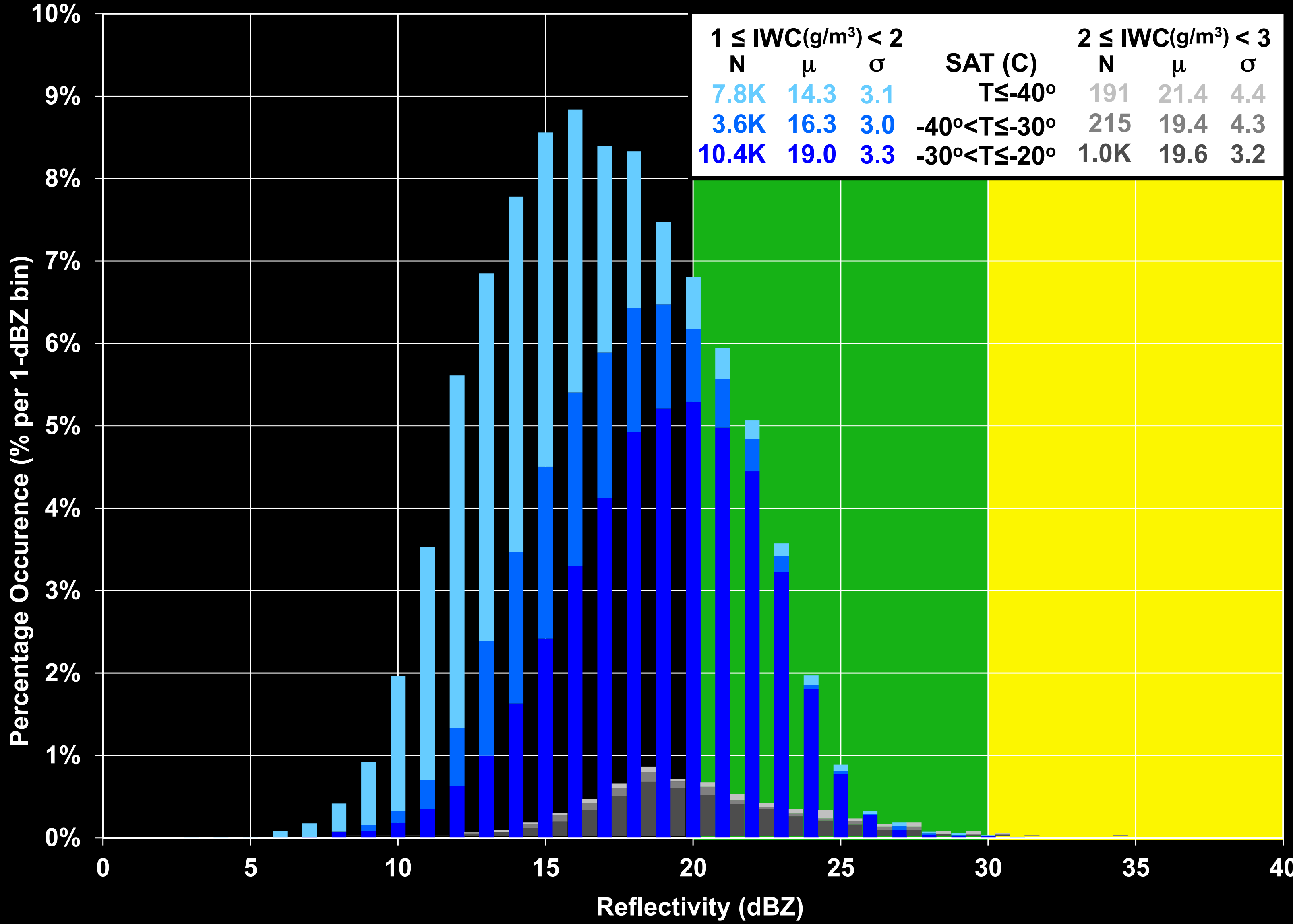




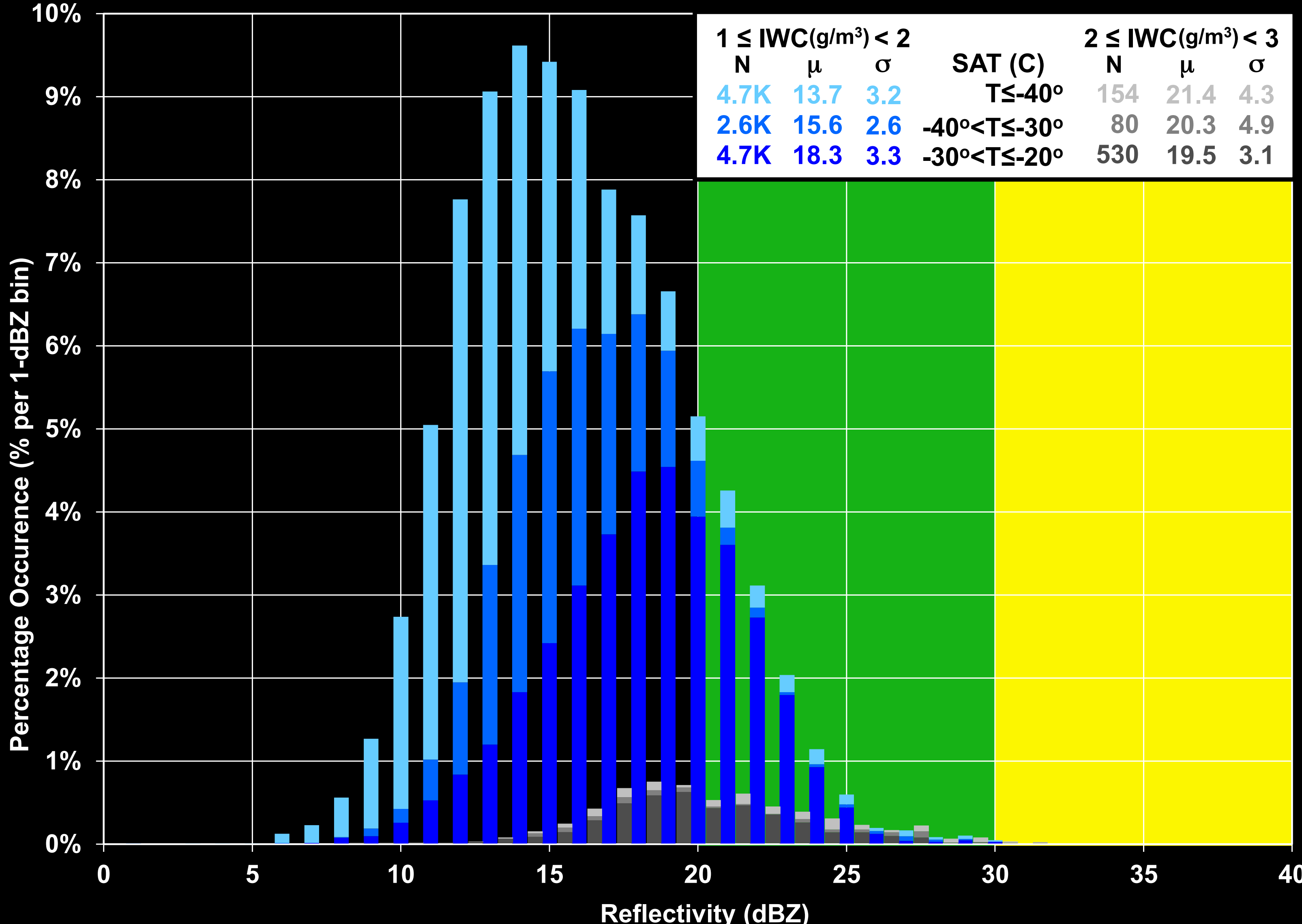
RRF Comparison from Flight Campaigns



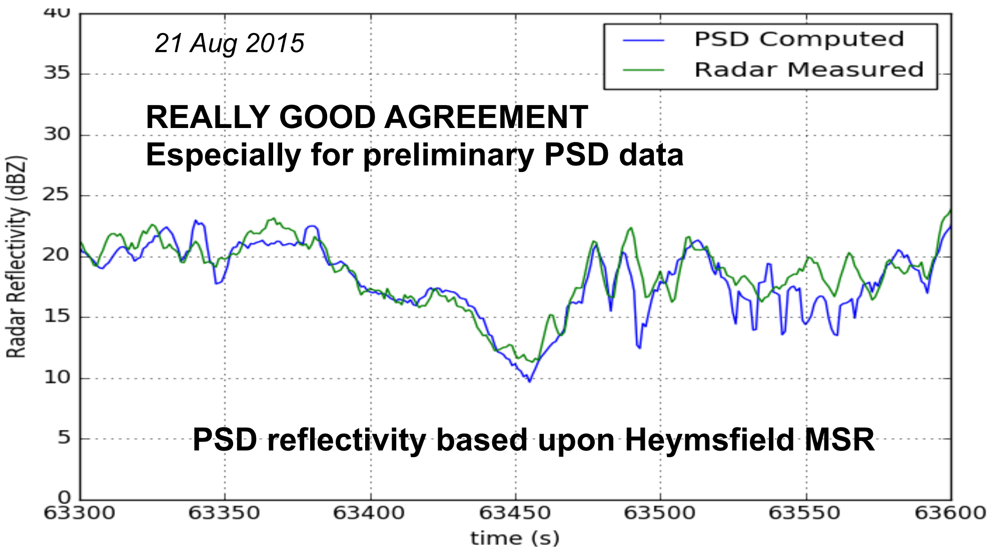
RRF Summary – NASA 2015 - ALL Flights



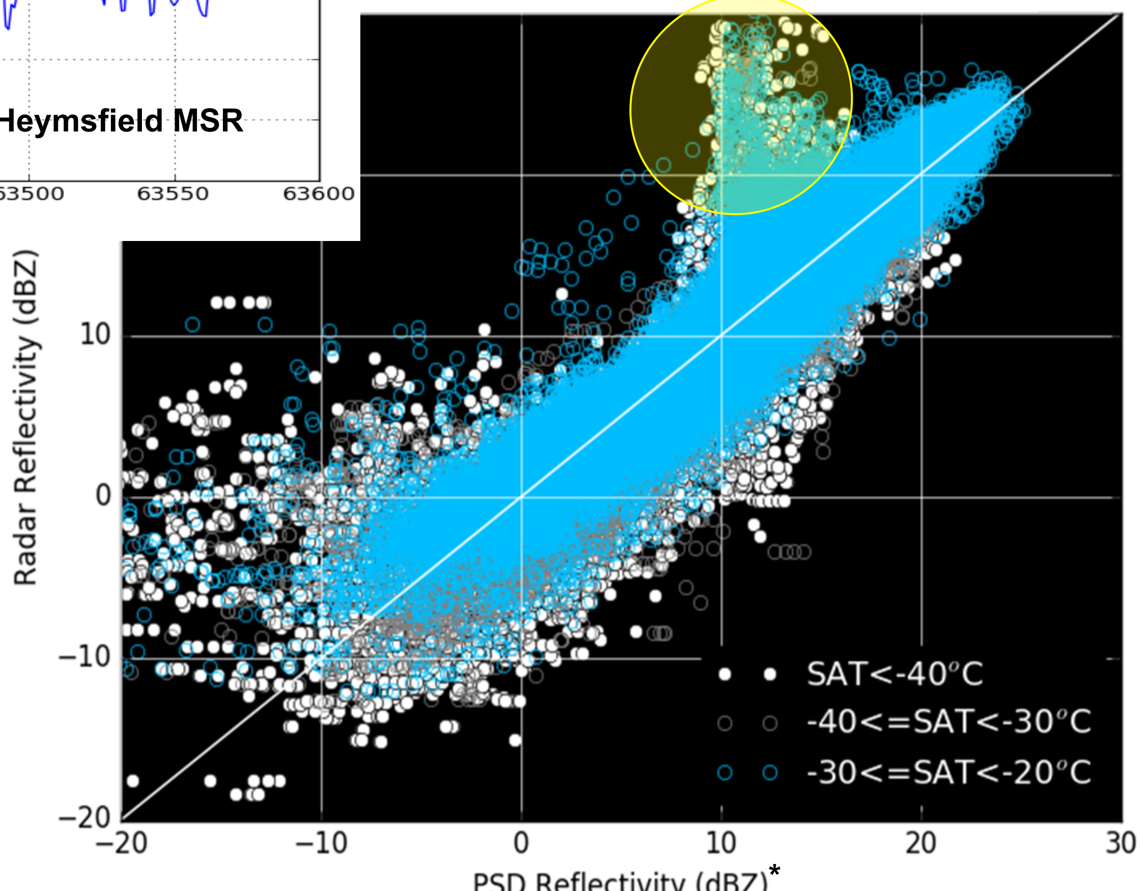
RRF Summary – NASA 2015 - TS Flights



PSD Reflectivity Estimate v Radar Reflectivity Measurement



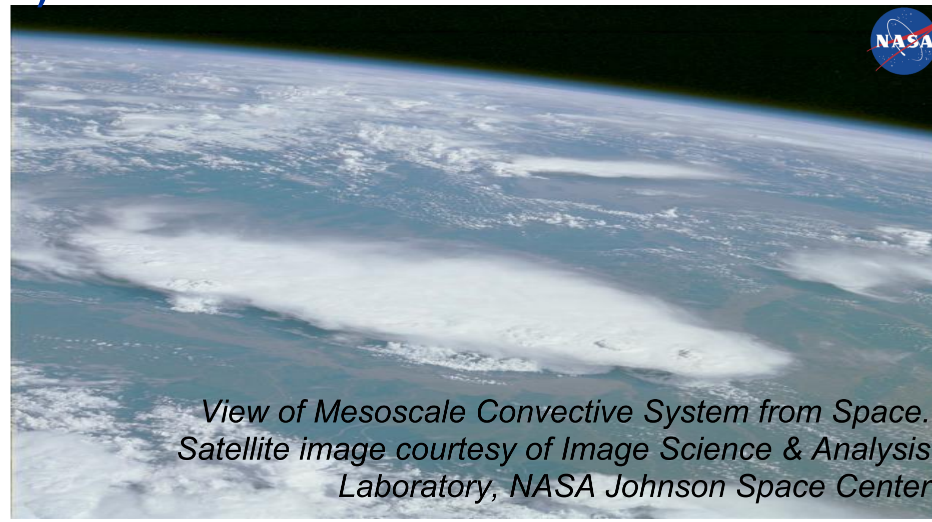
Under-reported PSD-Reflectivity
Due to Spherical Particles
- no longer an issue
- proper D^3 MSR results in data along LoA



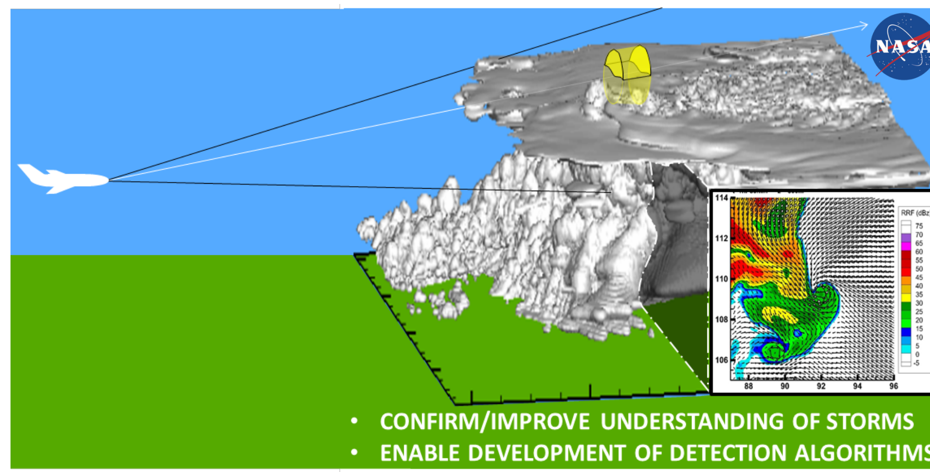
*** Based on Preliminary Data – Official PSD Release NOV 2016**

Modelling Objectives
(Details and Results in Proctor Presentation)

- Characterize HIWC events through numerical modeling studies
  - Size, duration, elevations of event
  - Ice water contents
  - Time evolution of ice water fields
  - Location of hazard areas relative to convective cloud system
  - Relationship to environment
- Data for Radar simulation
  - Generate realistic numerical data sets for Radar detection studies
  - Represent three-dimensional HIWC convective system as it evolves within different environments
  - Extract three-dimensional sub-volumes sequenced in time during the evolution of a HIWC event
  - Provide as input for Radar simulator studies
  - Post-analysis of extracted data provides "truth" for Radar simulation studies



View of Mesoscale Convective System from Space. Satellite image courtesy of Image Science & Analysis Laboratory, NASA Johnson Space Center

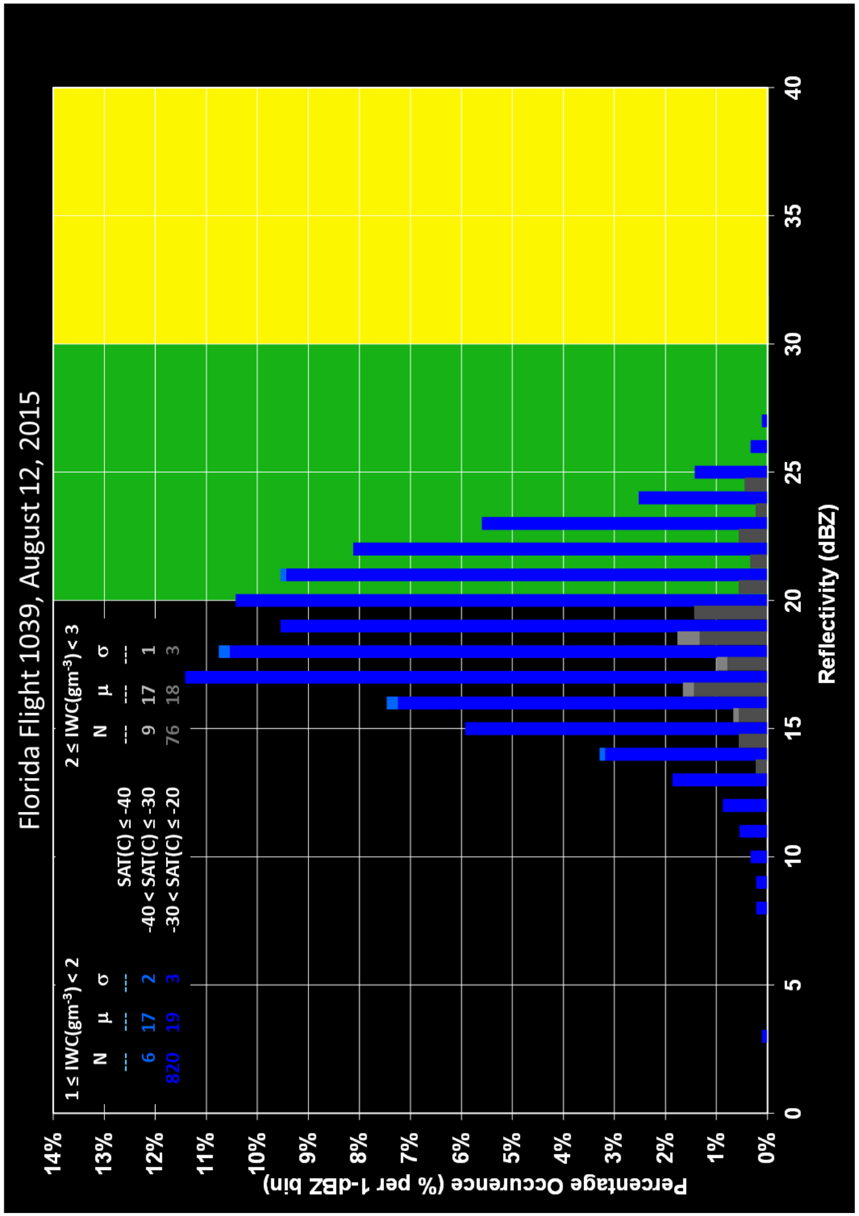


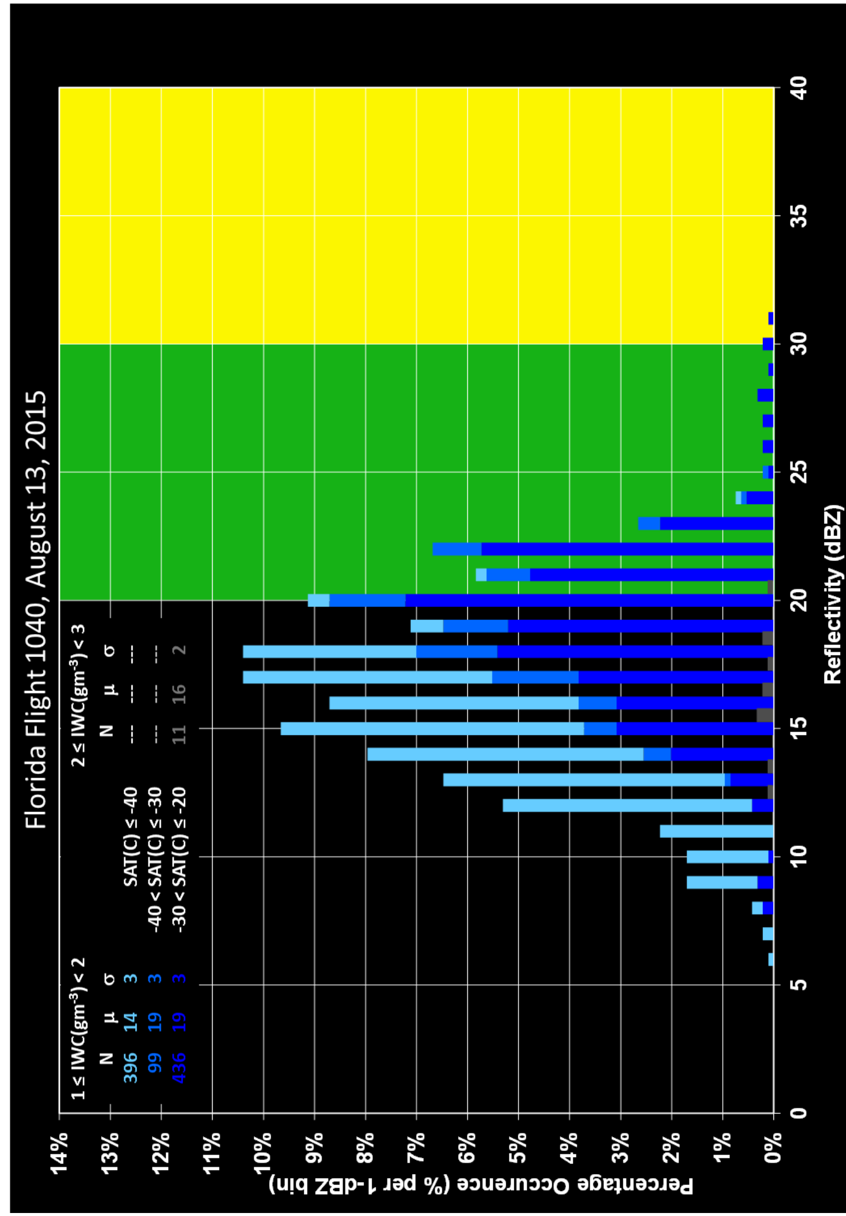
CONCLUSIONS & FUTURE – PILOT'S WEATHER RADAR

- We've come a long way in our understanding of the HIWC condition and the environment that produces it.
- We now understand what needs to be measured and why conventional weather radar hasn't been showing these areas as hazardous.
- Existing weather radar can see (detect) HIWC but discerning the difference between hazardous and benign conditions appears to require information (measurements) beyond the information contained in the existing radar echoes.
- Multi-Frequency Radar and Polarimetric Radar techniques offer additional information that appear promising at providing this added information.
- In 2017, NASA and FAA are planning to conduct HIWC Radar II Flight Campaign focused on remote detection (collaborative with radar manufacturers) exploring detection capabilities.
- In 2018, perform analyses and detection performance assessment.
- In 2019, if there are remaining HIWC detection issues, NASA could conduct HIWC Radar III Flight Campaign (as part of a larger assessment of convective weather).
- We will continue to develop our understanding of HIWC detection processes and defining Minimum Operational Performance Standards for future commercial radars (including updating RTCA DO-220 as information is refined).

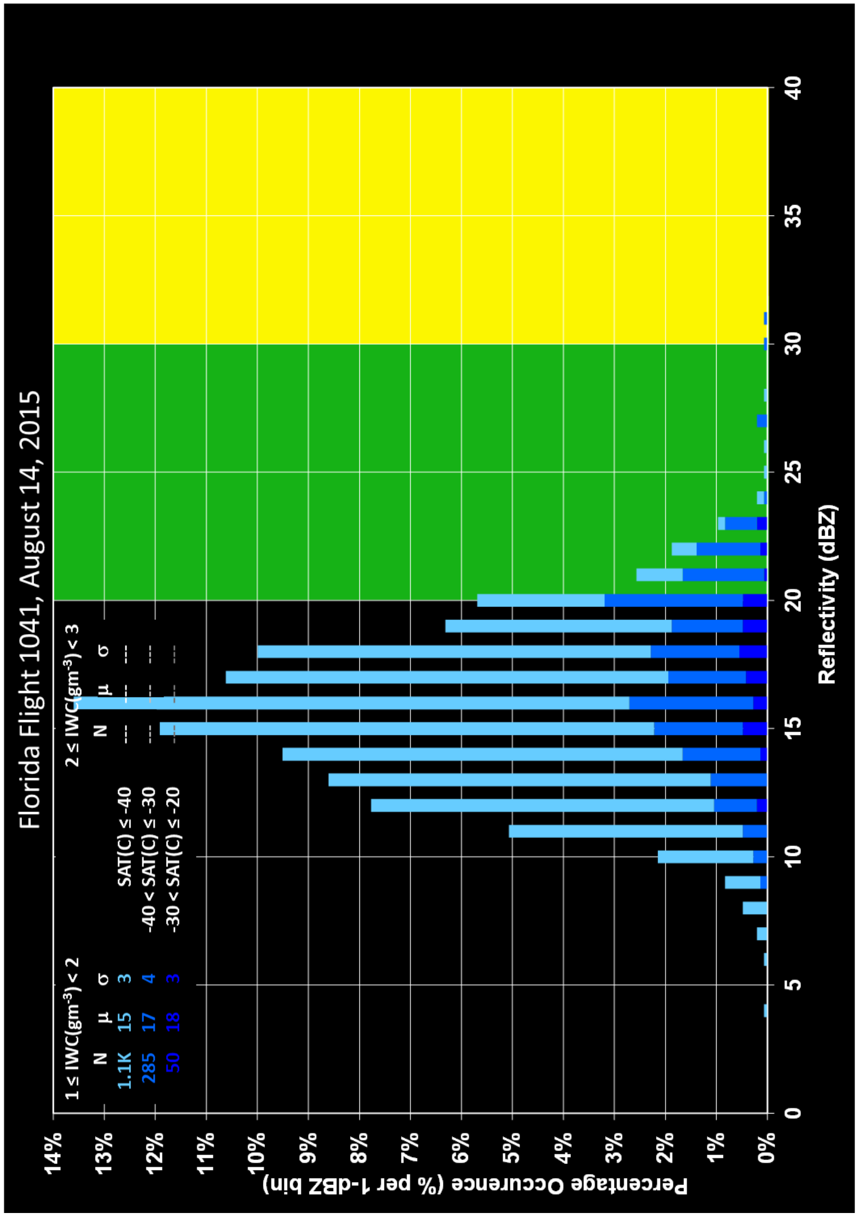
Additional / Backup Slides

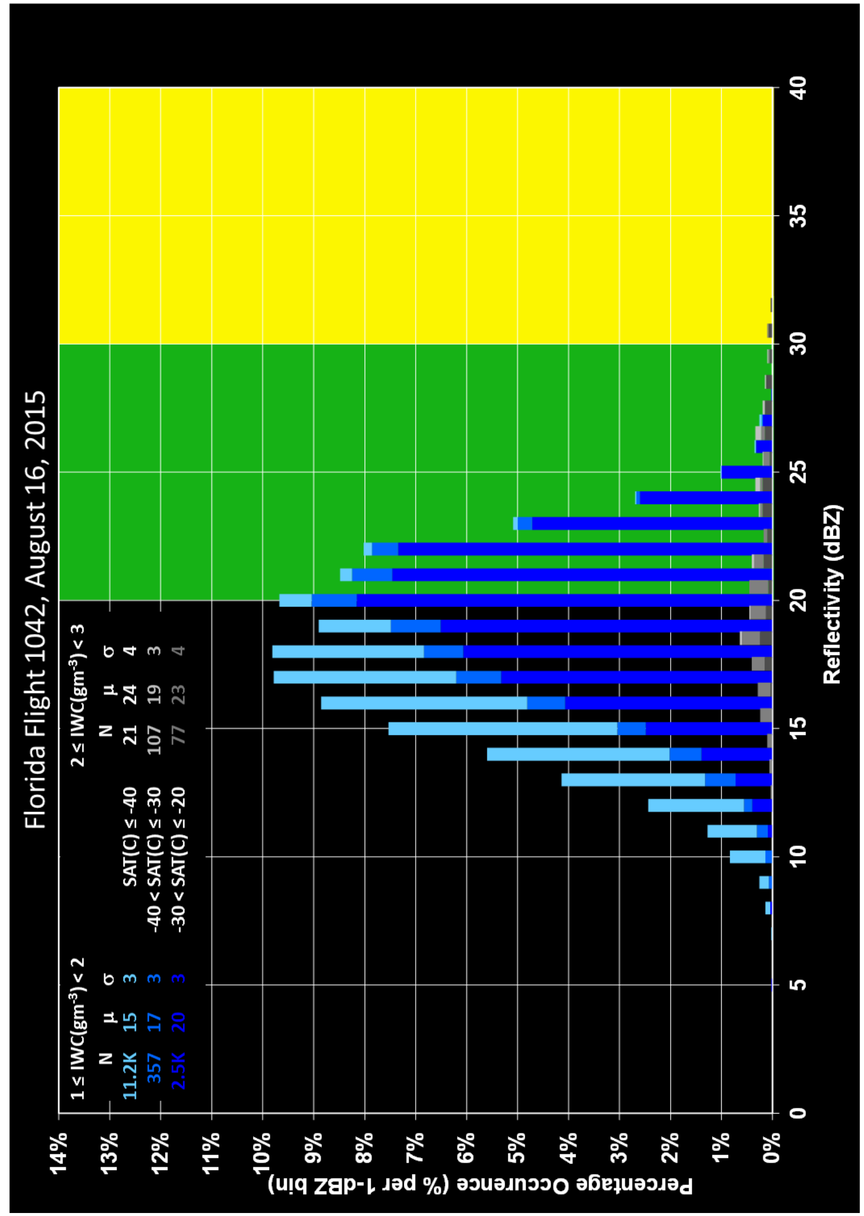
Daily RRF Distributions (1&2 of 10)



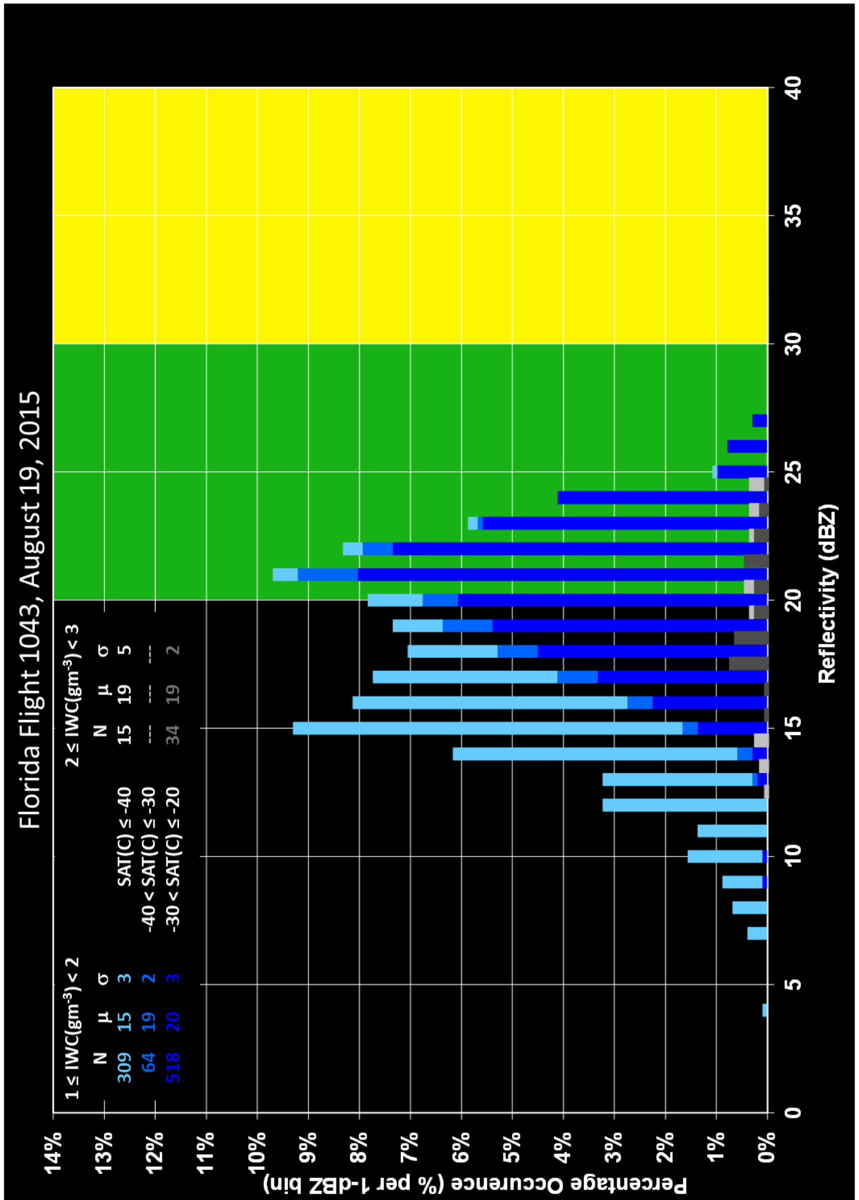


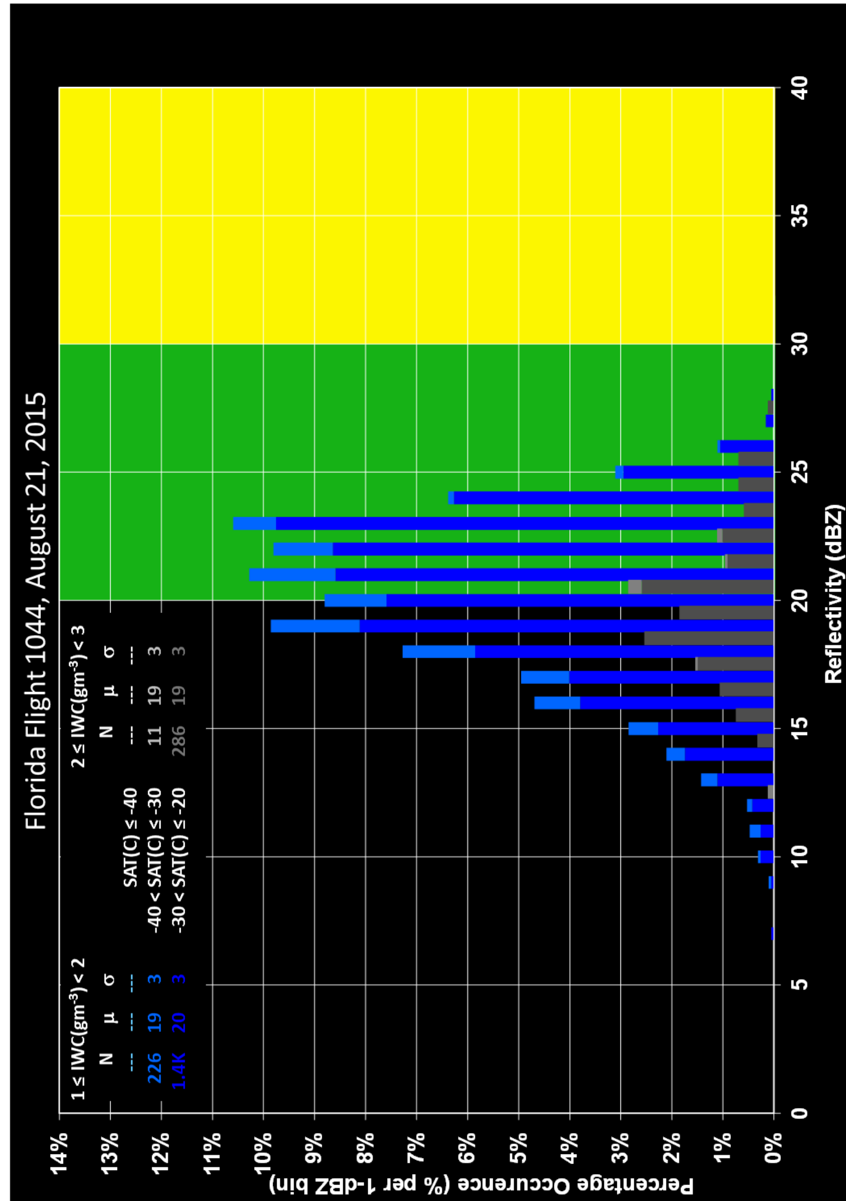
Daily RRF Distributions (3&4 of 10)



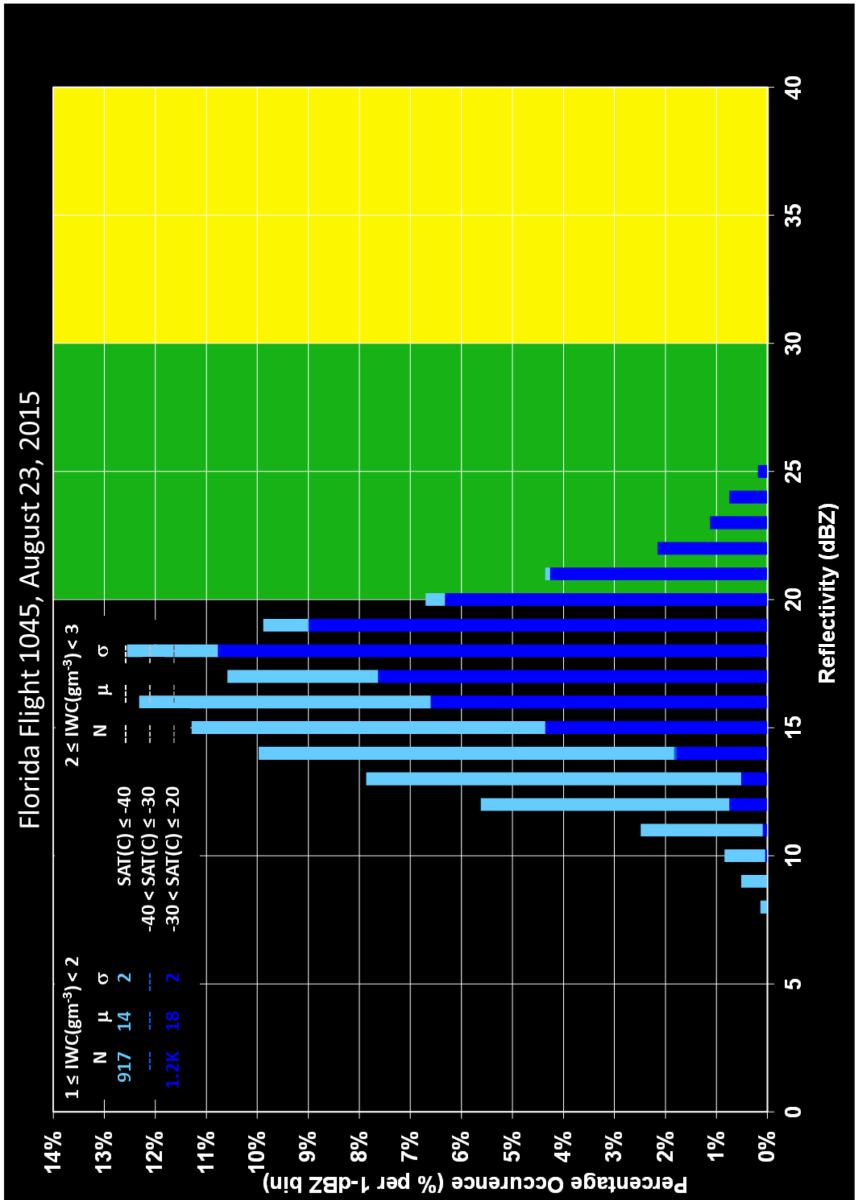


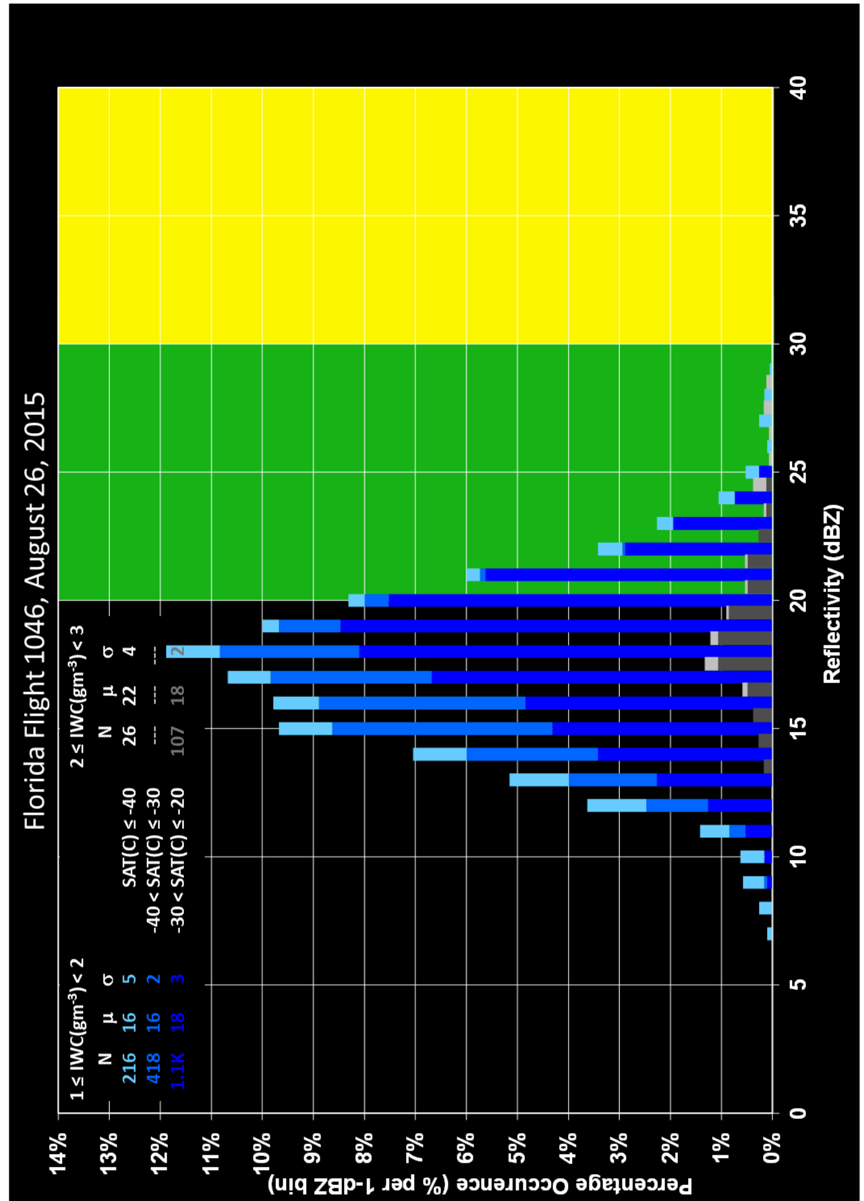
Daily RRF Distributions (5&6 of 10)



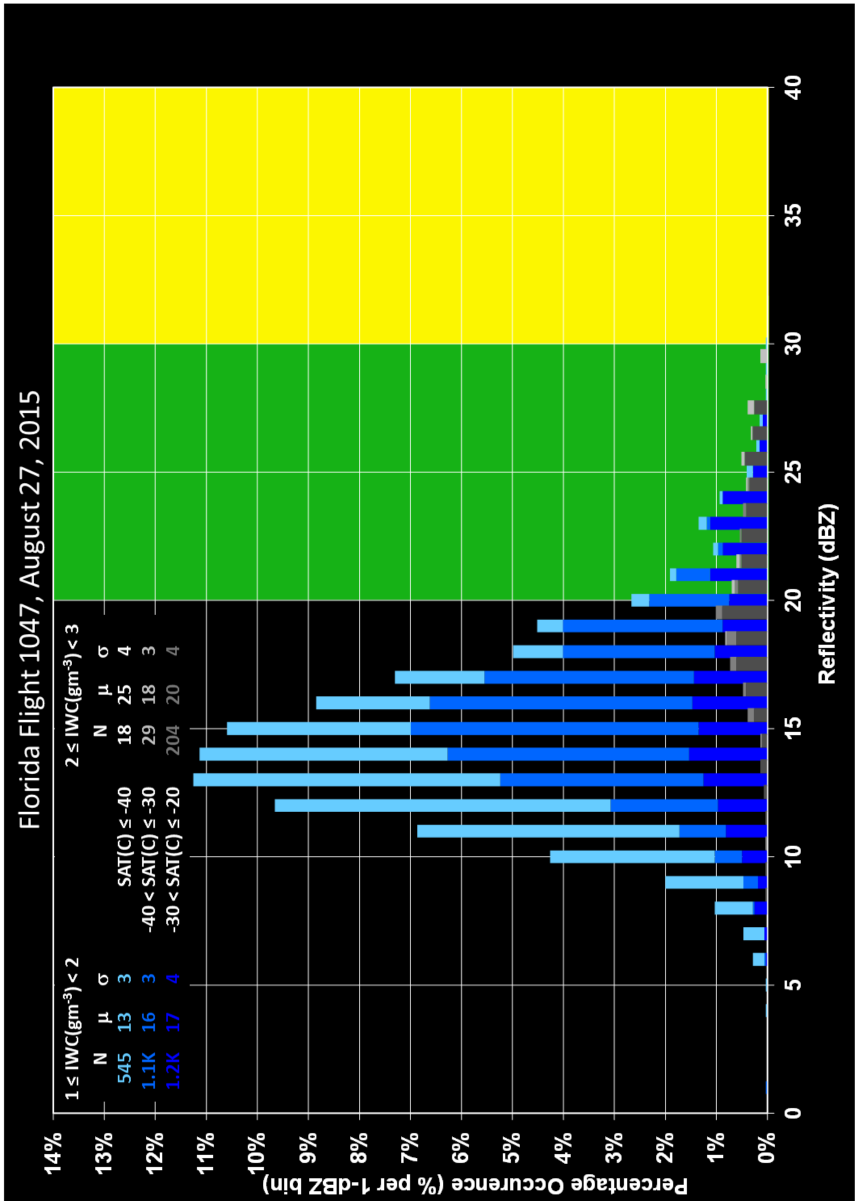


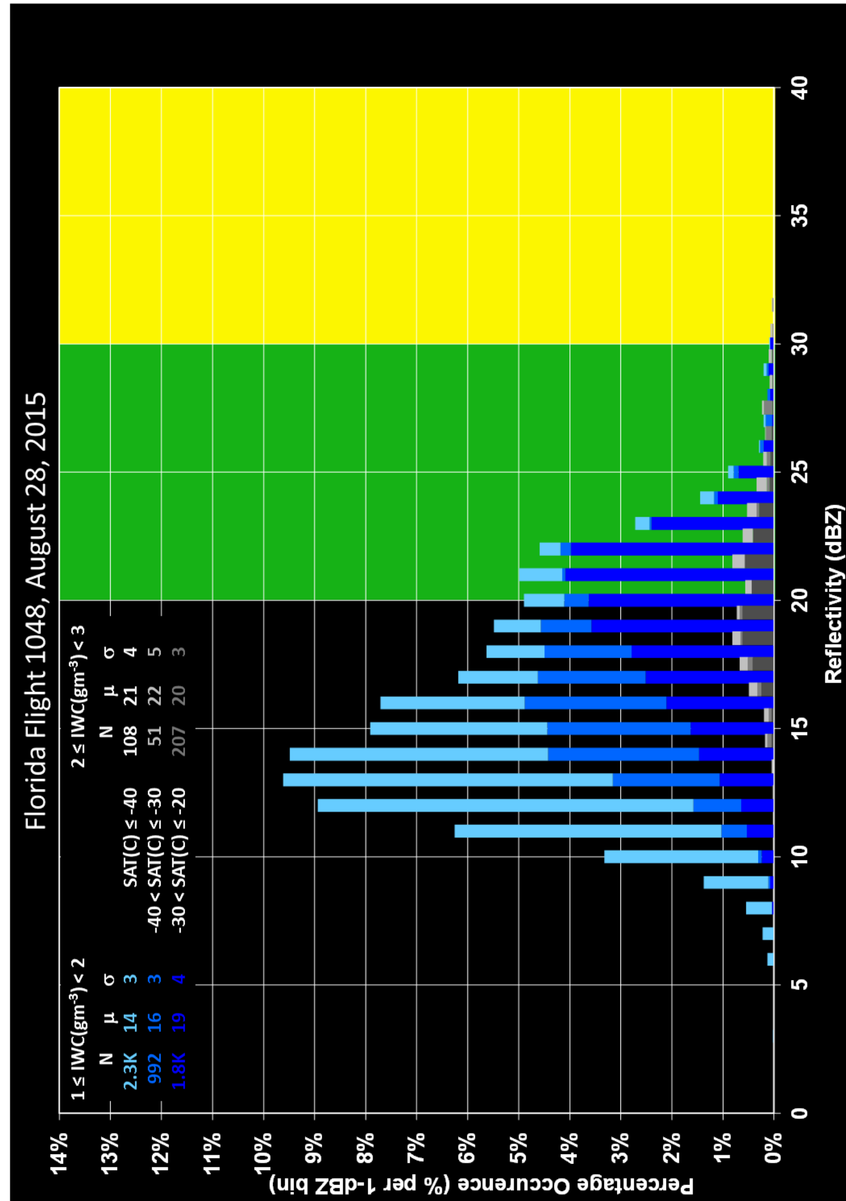
Daily RRF Distributions (7&8 of 10)





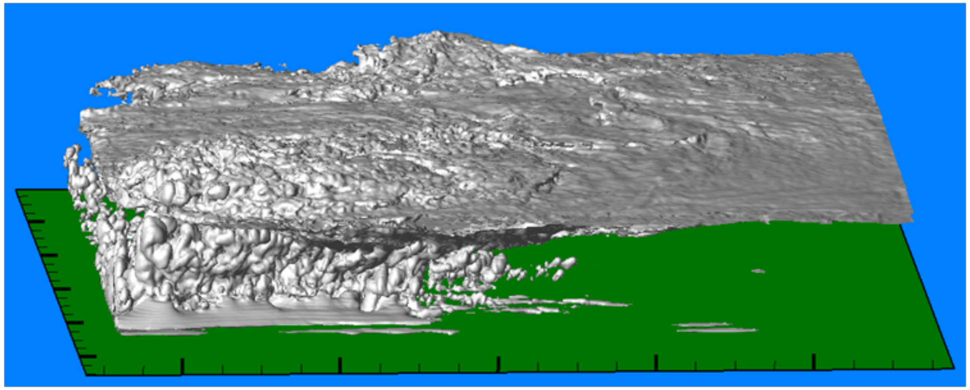
Daily RRF Distributions (9&10 of 10)





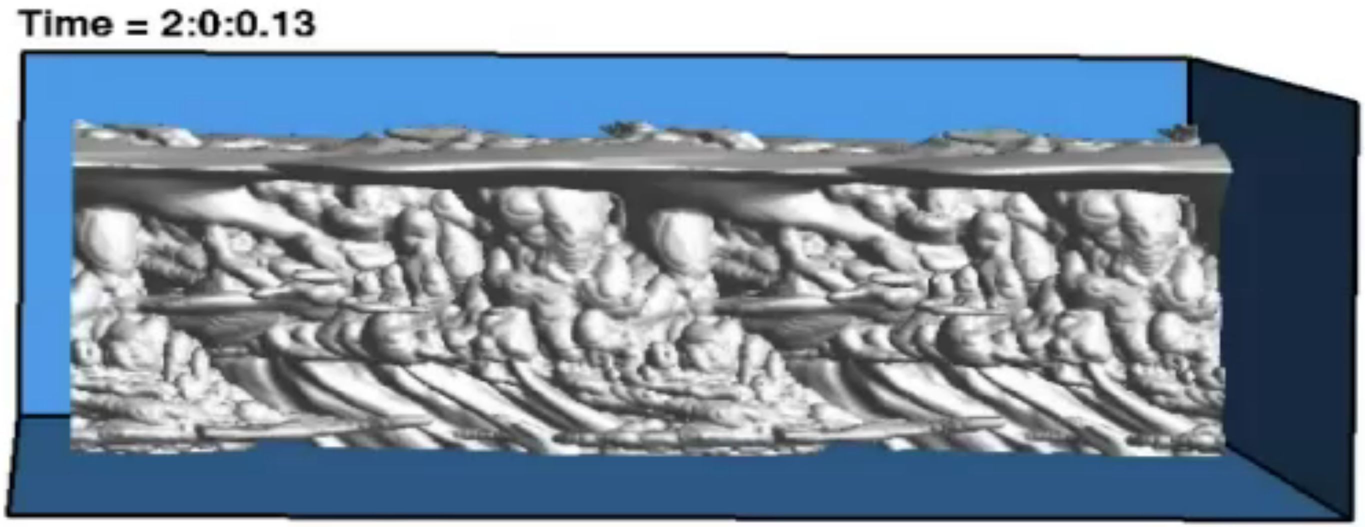
Terminal Area Simulation System (TASS)

- **Time-dependent, 3-D, Large Eddy Simulation (LES) Model**
- **Meteorological Framework**
- **Prognostic Equations for:**
  - 3-Components of Velocity - Pressure
  - Potential Temperature - Rain
  - Water Vapor - Snow
  - Liquid Cloud Droplets - Hail / Graupel
  - Cloud Ice Crystals - Dust / Insects



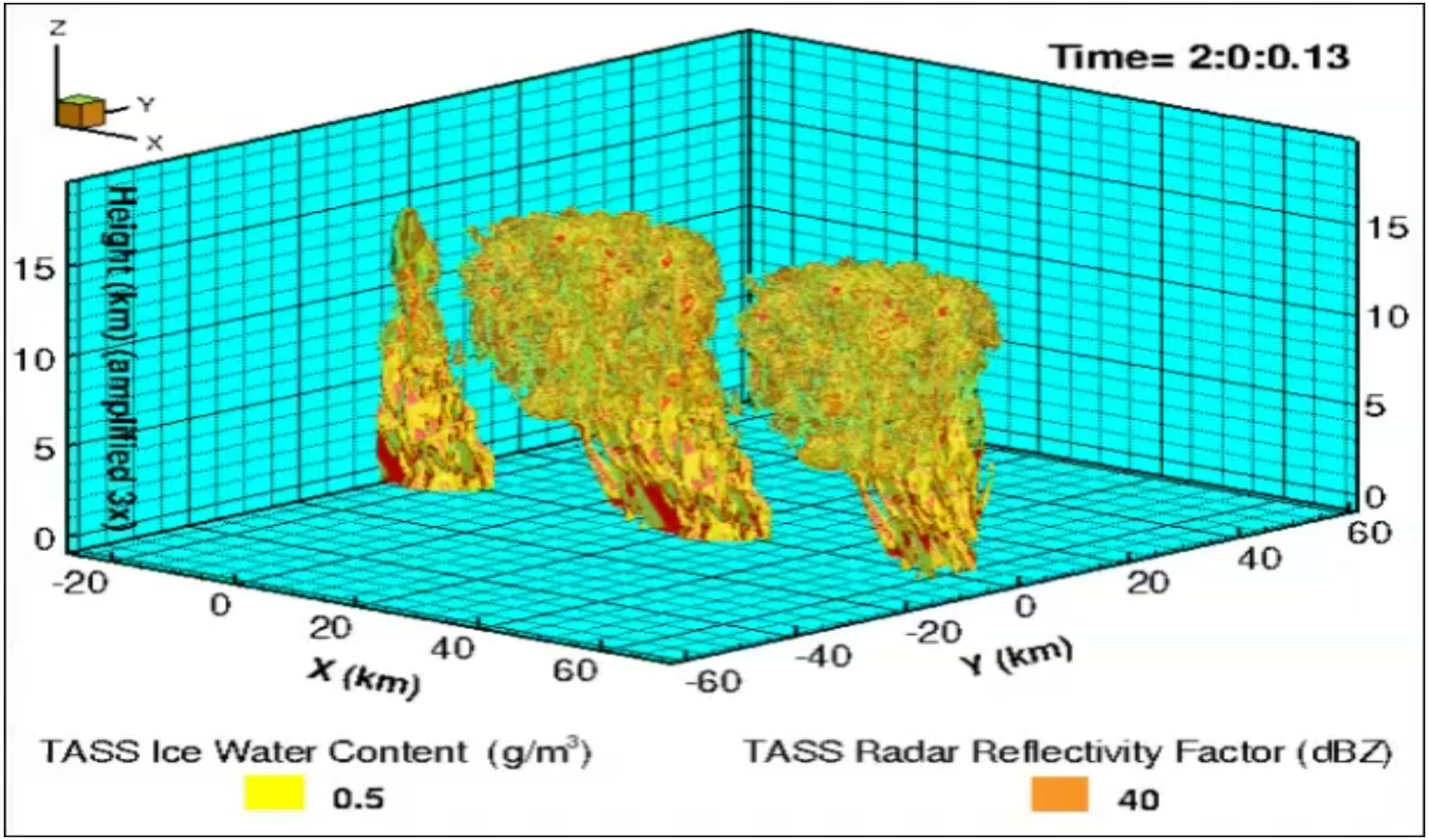
- **Subgrid-scale turbulence parameterized with modifications for stratification and flow rotation**
- **Numerics are accurate, highly efficient*, and* essentially free of numerical diffusion**
- **Contains roughly 60 bulk cloud microphysics submodels**
- **Initialization modules for simulation of convective storms, microbursts, atmospheric boundary layers, turbulence, and aircraft wake vortices**
- **Software modifications and re-coding have occurred to take advantage of paradigm shifts in computing platforms**
- **User's guide, version 10.0: NASA TM-2014-218150**

TASS Darwin Simulation:
Animation of 3-D Cloud System (2 hr – 4.5 hr)



- Viewed from South
- Multiple pulsing convective cells feed canopy overhang
- Overhanging cloud canopy much larger than active cells

TASS Darwin Simulation:
Animation of 3-D Cloud System (2 hr – 4.5 hr)



- **Viewed from South East**
- **RED - RRF > 40 dBZ**
- **Yellow – IWC > 0.5 *g m*$^{-3}$**