



NASA Glenn Icing Facilities Update

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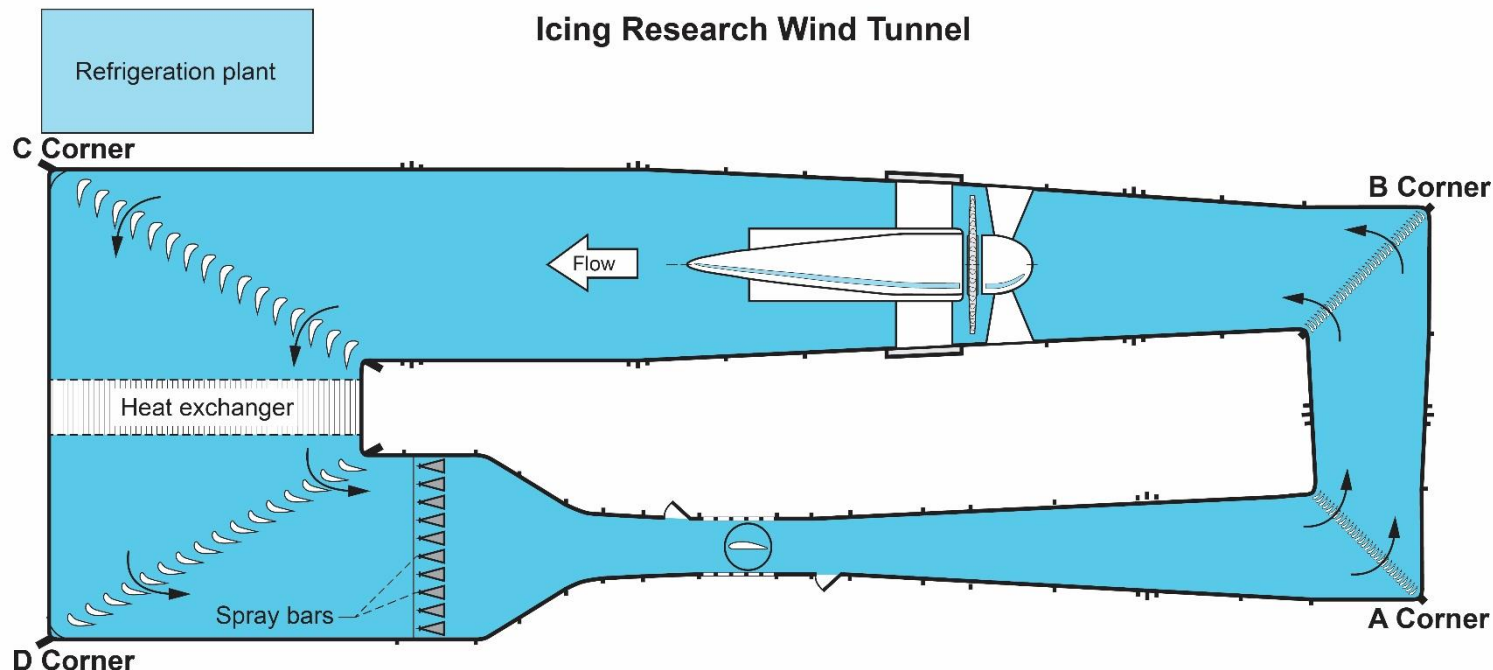
Overview

- Brief description of NASA Glenn's icing facilities
- Icing capabilities at Propulsion Systems Laboratory
 - Past testing
 - Future plans
- Icing Research Tunnel updates
 - Interim calibration results
 - Mod2 cloud development
 - Optical Array Probe comparison studies





Icing Research Tunnel (IRT)



PS-03213-0420

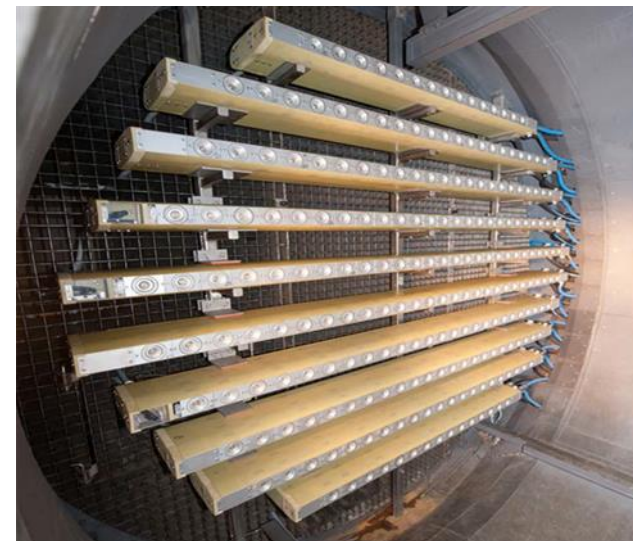
- Test section size: 6 ft. x 9 ft. (1.8 m x 2.7 m)
- LWC & MVD calibration measurements are made in the center of the test section
- LWC uniformity: $\pm 10\%$ for central 4 ft x 6 ft
- Calibrated test section airspeed: 50 –300 kts
- Air temperature: -40°C static to $+10^{\circ}\text{C}$ total
- Calibrated MVD range: 14 –300 μm
- Calibrated LWC range: 0.19 –4.5 g/m^3 (function of airspeed)
- Two types of spray nozzles:
 - Standards = higher water flow rate
 - Mod1 = lower water flow rate



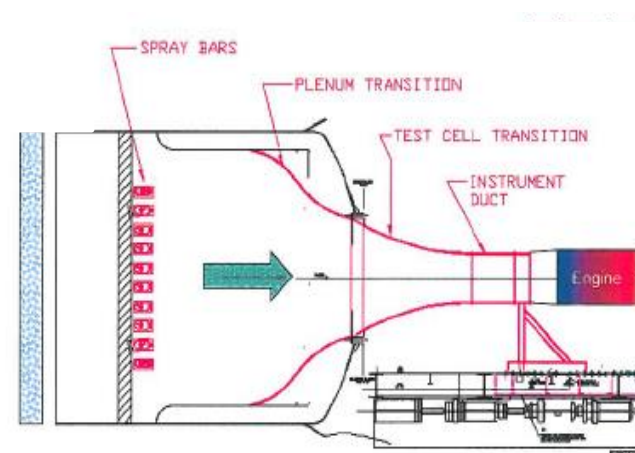


Propulsion Systems Laboratory (PSL)

- NASA's only ground-based test facility that provides true flight simulation for experimental research on air-breathing propulsion systems.
- Recently added the capability to simulate clouds of ice crystals and liquid water droplets.
- PSL-3: Altitude engine icing test cell layout
 - Spray bars: can generate ICI or SCL
 - Transition Duct (s)
 - Instrumentation Duct and Tomography Duct
 - Calibration Instrumentation or a Test Article.



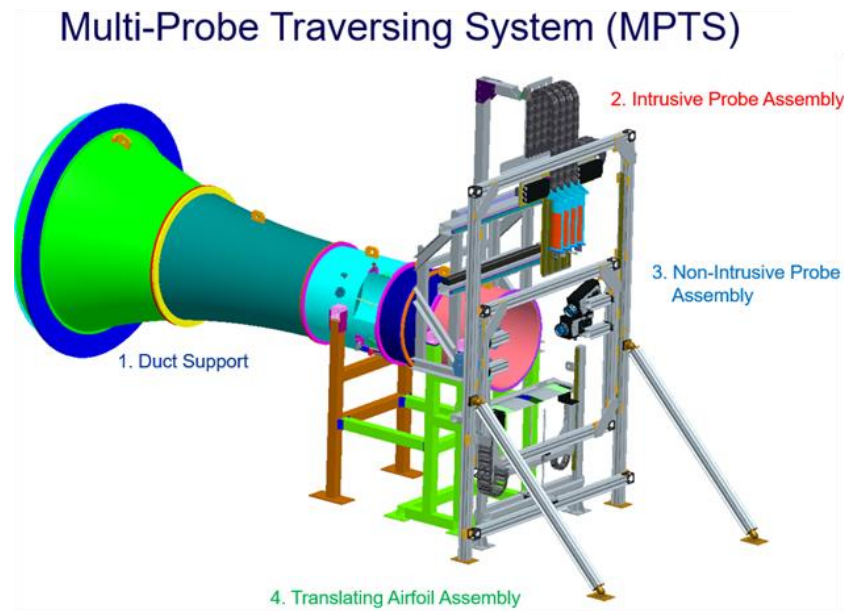
Specified Requirement		
Specification	Minimum	Maximum
Altitude (pressure)	4000 ft	40,000 ft
Inlet Total Temperature	-60°F	15°F
Mach Number	0.15	0.80
Air Flow Rate	10 lbm/sec	330 lbm/sec
IWC (icing water content)	0.5 g/m ³	9.0 g/m ³
MVD (median volumetric diameter)	40μ	60μ
Run Time	Continuous up to 45 minutes	





Past Testing at PSL-3

- Last icing test performed in 2018 – icing spray bars removed for other non-icing test programs
- Preparations for re-establishing icing capabilities at PSL ongoing
- 2018: used Multi-Probe Traversing System (MPTS) for cloud calibration
 - Run test points with instrumentation only (no test article)
 - Install test article, remove instrumentation, rerun same test points with known cloud conditions
 - Observe how cloud affects test article performance



Instrumentation
for Calibration:

- Tomography
Laser Ring
- MPTS
 - Intrusive Probes
 - Non-Intrusive Lasers
 - Airfoil (optional)
- Iso-Kinetic
Translating Probe





Past Testing at PSL-3





Future Testing at PSL-3



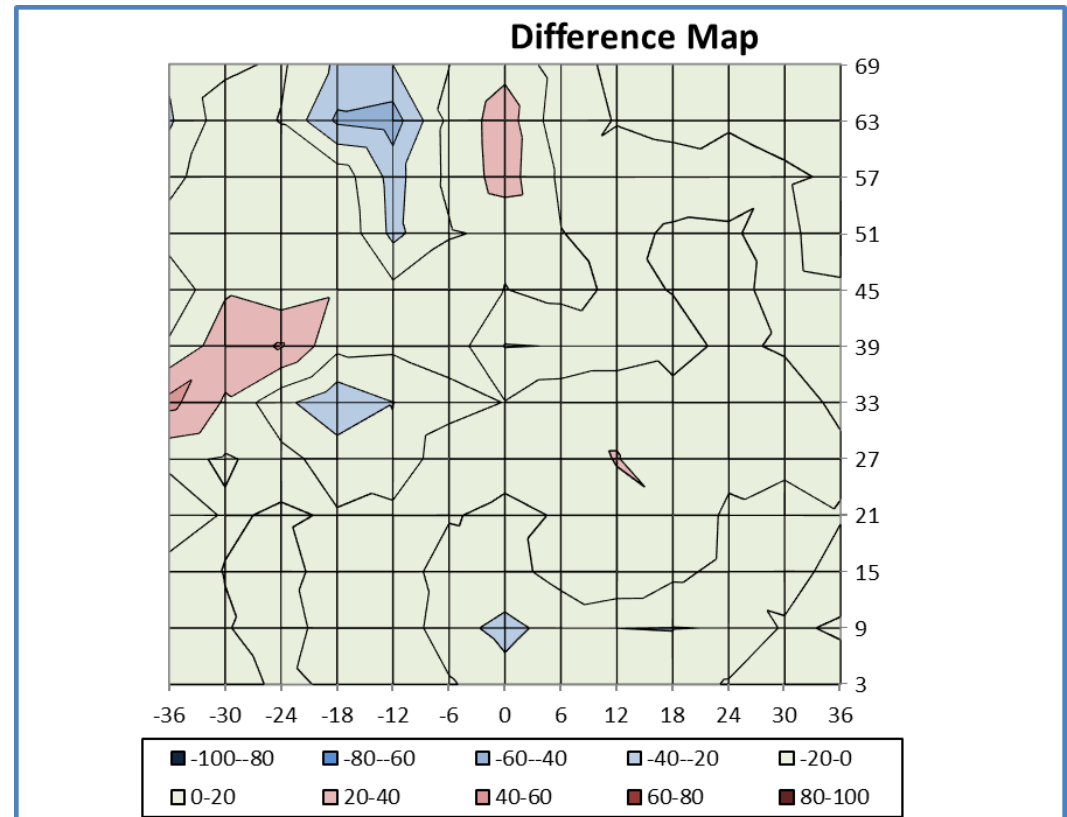
- Request for cloud calibration for larger duct (54" vs 36") which will include expansion of current tomography capabilities
- Redesign MPTS-2 from lessons learned: robustness, more measurement probes, and intentions of MPTS-2 being a more permanent system
- Increased interest in PSL-3 use from industry





IRT Interim Calibration

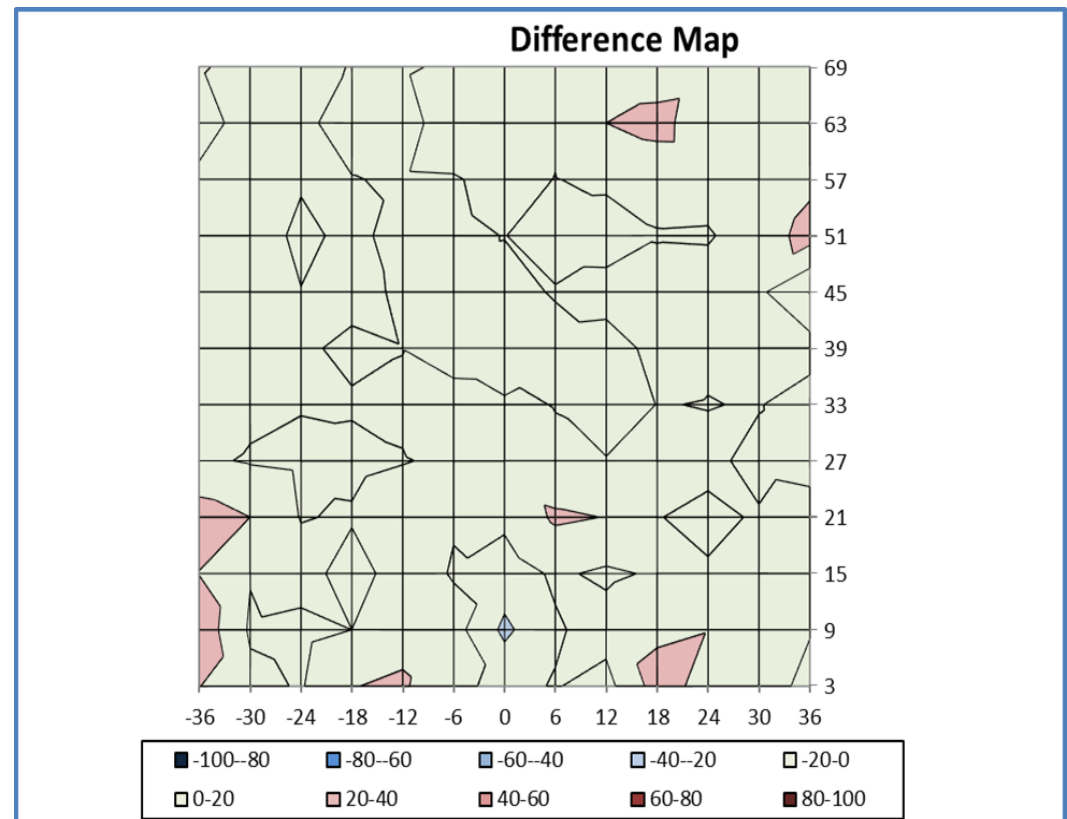
- Performed one year post full calibration per ARP-5905 recommendation
- Uniformity test-to-test repeatability and beginning/end of day repeatability within +/- 10%
- Difference map shown is comparison of Mod 1 nozzle map interim cal uniformity and calibrated uniformity





IRT Interim Calibration

- Difference map shown is comparison of Std nozzle map interim cal uniformity and calibrated uniformity

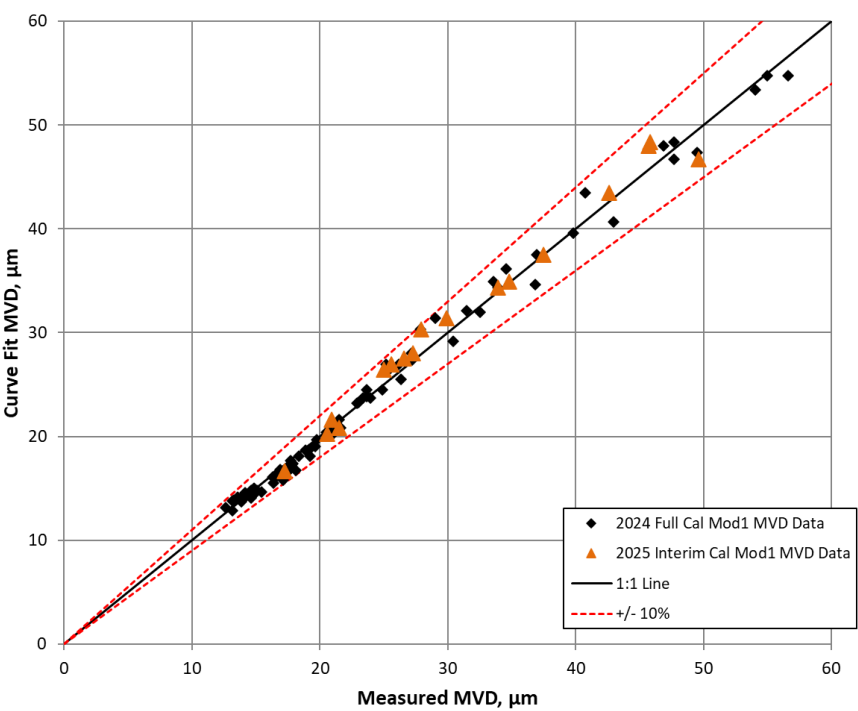




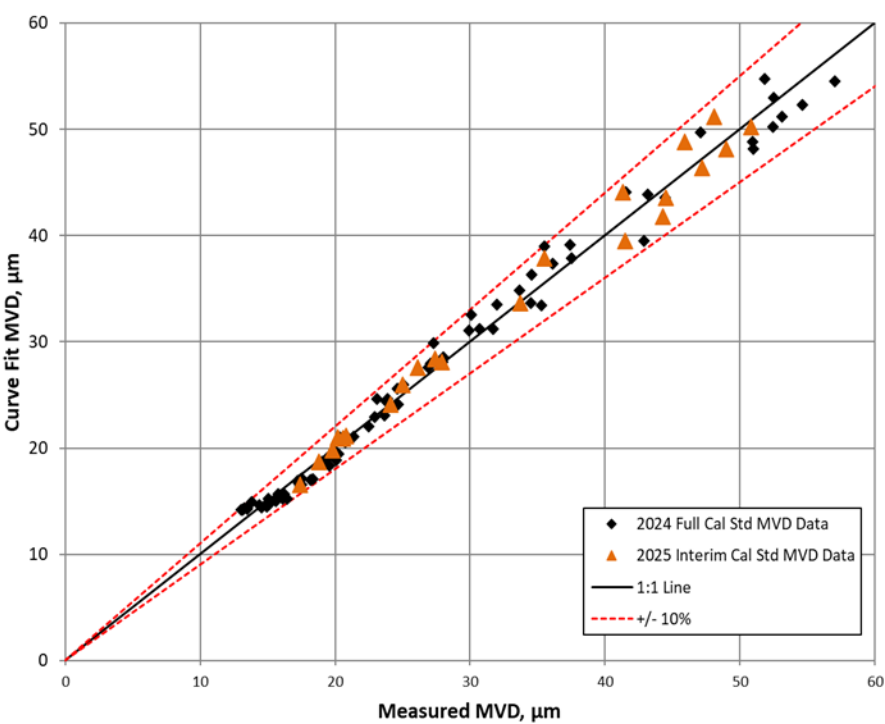
IRT Interim Calibration

MVD within +/- 10% for Mod1 and Standard nozzles

Mod1 MVD Measured vs Curve Fit Calculated



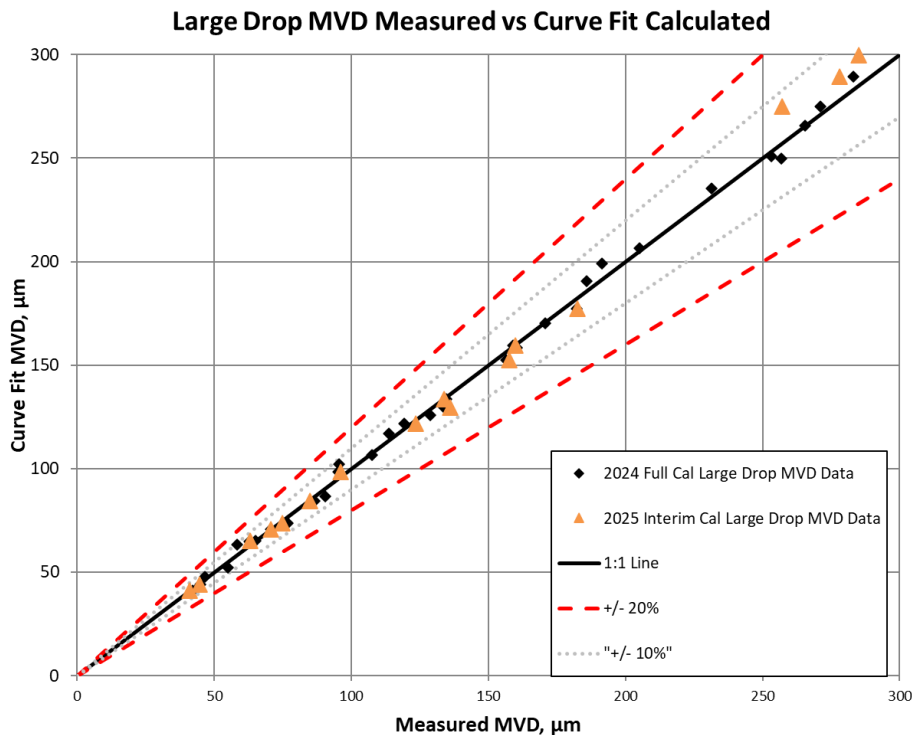
Standard MVD Measured vs Curve Fit Calculated





IRT Interim Calibration

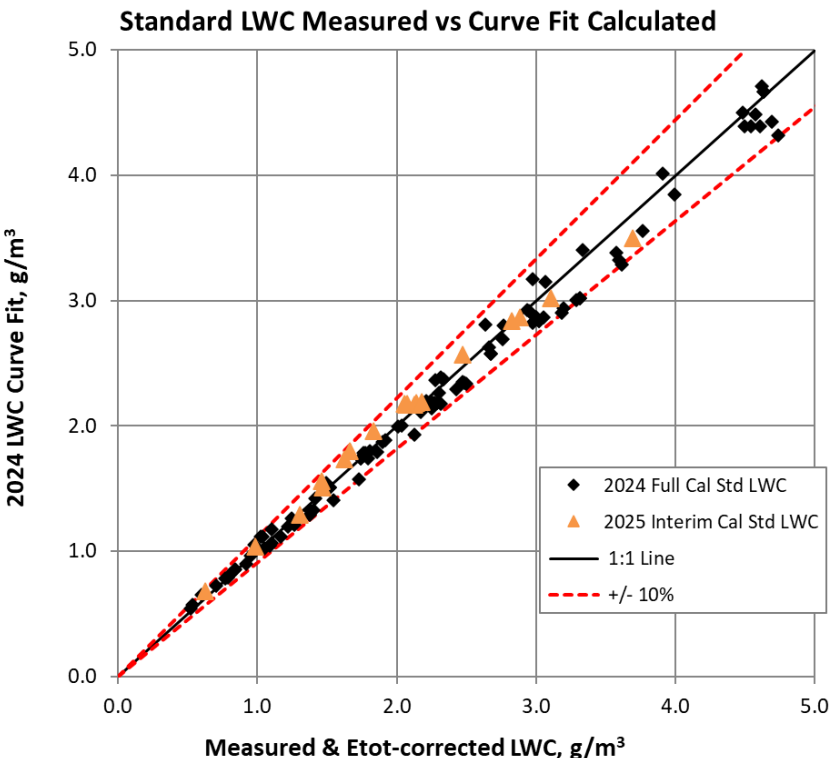
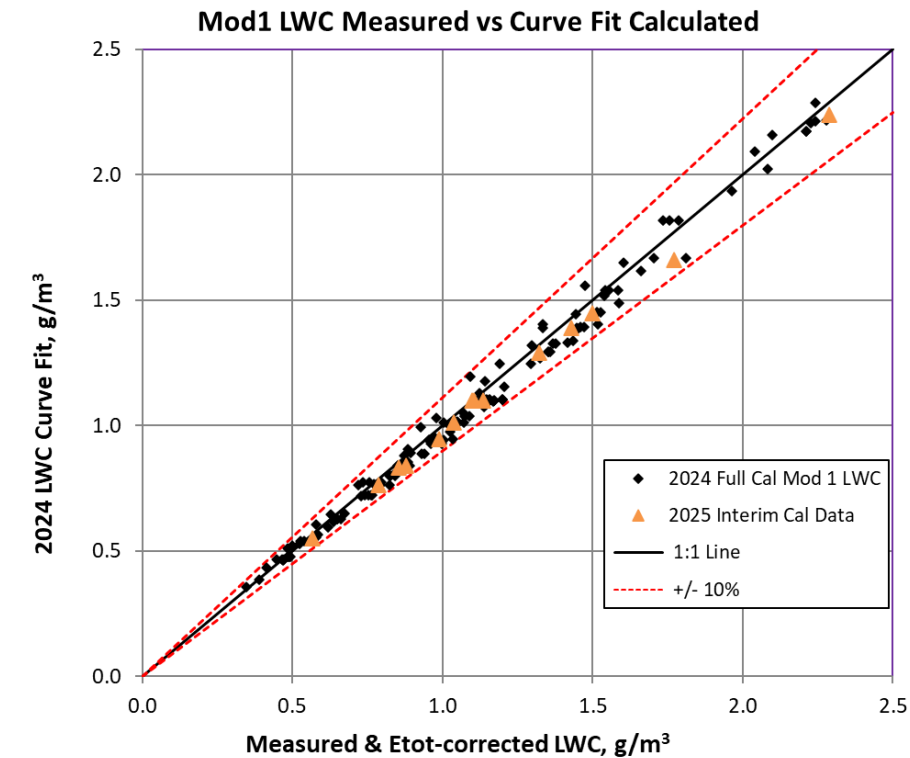
MVD within +/- 20% for large drop conditions (actually within +/- 10%)





IRT Interim Calibration

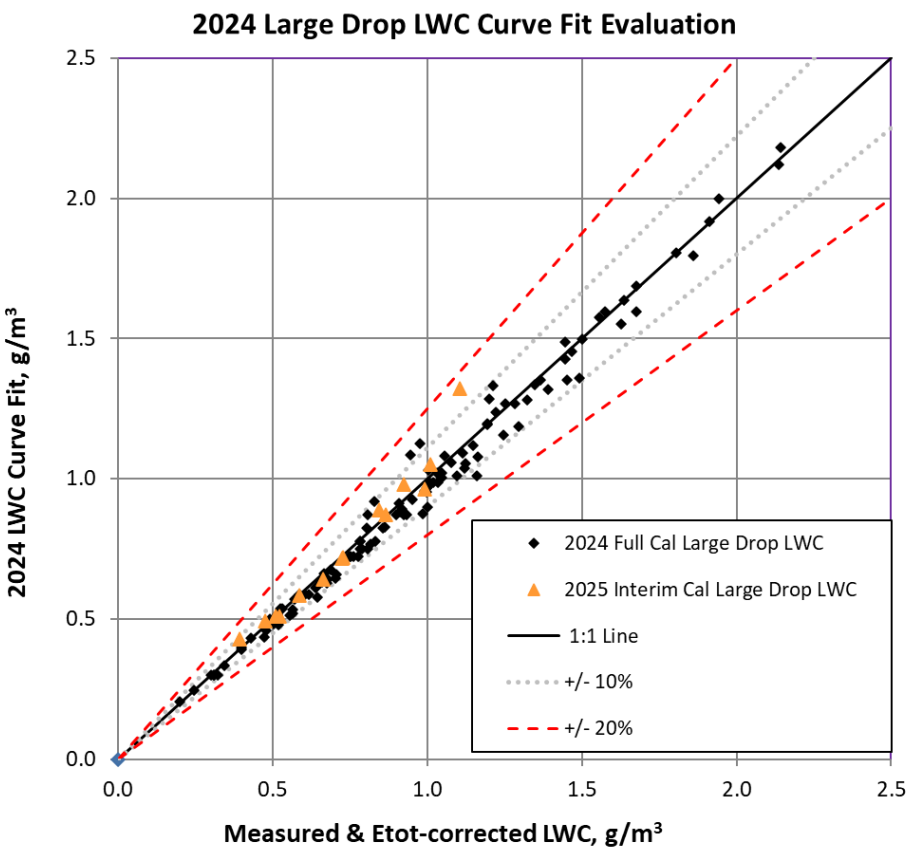
LWC within +/- 10% for Mod1 and Standard nozzles





IRT Interim Calibration

LWC within +/- 20% for large drop conditions





Lower Water Content Cloud

- Mod2 nozzles
 - Lower flow rate than Mod1
 - Average coefficient of flow of Mod1 = 0.0045
 - Mod2 = 0.0015
- Developed uniformity with 89 spraying nozzles
 - Mod1 cloud has 101 spraying nozzles
 - Vertical gradient +/- 10% LWC variation (follows ARP-5905 recommendations)
- Measured drop size and water content and developed preliminary curve fits
 - Appendix C – high confidence in development
 - Started on large drops ($MVD > 50\mu m$)
 - Need to collect more data for further conclusions
 - Appendix C initial results show an average reduction in water content of 65%
- Currently processing large drop data that was collected in December 2024 and preparing for ice shape comparison tests





Drop Size Probes Comparison Tests

- Implementation of OAP-1D2DY as trusted calibration instrument
 - OAP-230Y is aging and reliability decreases over time
 - Development work with SEA, Inc., CIRA, NCAR, and other contractors
 - Data processing methods with SODA
 - Crossover regions
 - Data acquisition modes
 - MUA team at NASA Glenn doing repeatability studies and statistical analysis

Paper to be presented at 2025 AIAA-Aviation in Las Vegas





Questions?

