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SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES
FOR SAFER AVIATION IN ICING ENVIRONMENT

Short Range Particulate (SRP)

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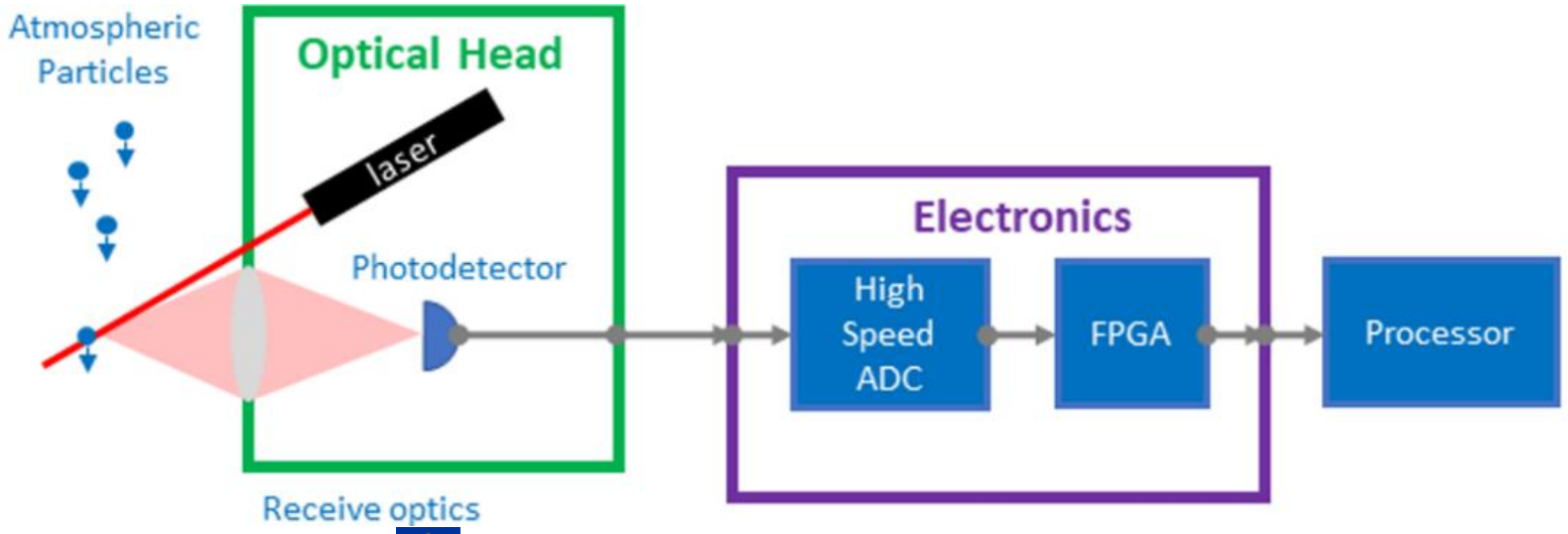
Sensor Description

Short Range Particulate - Overview

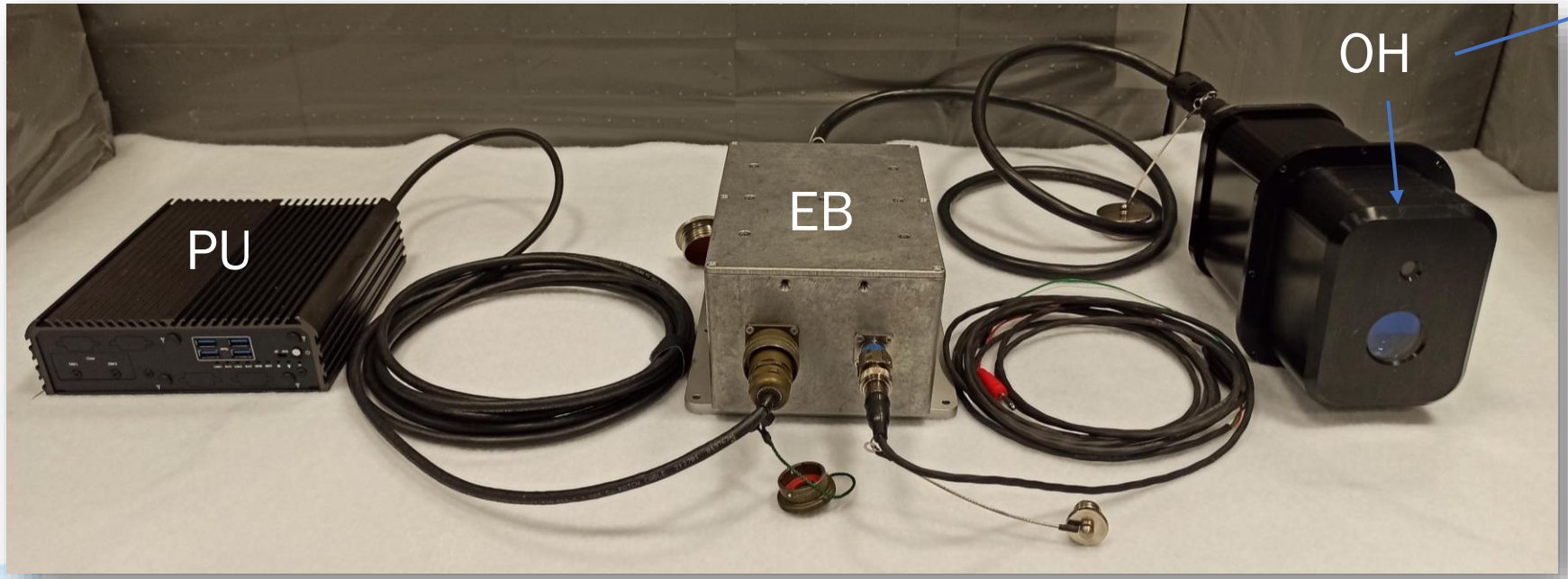
Optical sensor detecting particles through polarized backscatter

- Extract data two ways
  - Direct particle by particle measurements (scattering from a single particle)
  - Aggregate particle scatter through shifts in the background signal
- AS5498B App. C and App. O detection and discrimination
- Measures liquid water content (LWC) and median volume diameter (MVD)



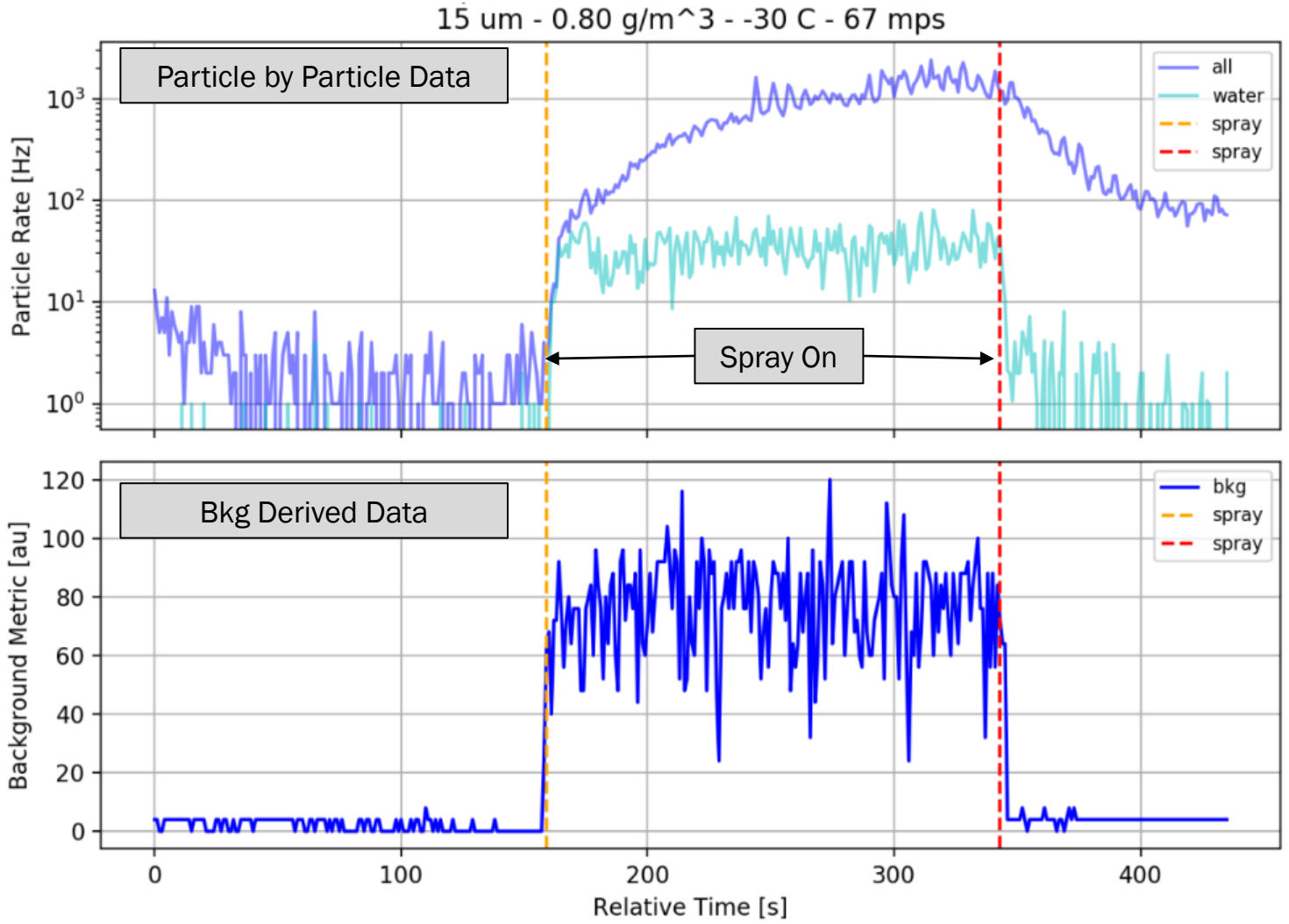
Short Range Particulate - Overview

- (OH) Optical Head
- (EB) Digitalization and Pre-processing
- (PU) RCO-3600 Raw data to Icing Parameters



Short Range Particulate - Overview

- Sample data from icing wind tunnel test (IWT)
- Sensor channels:
  - Direct particle measurements (top) signals large droplets
  - Shifts in background signal (bot) indicate smaller droplets
- Water/Ice discrimination based on polarization discrimination



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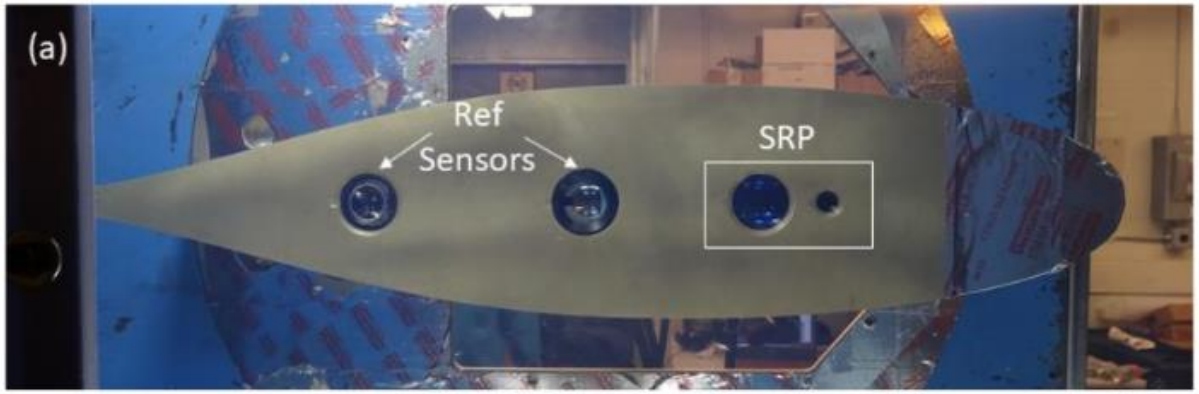
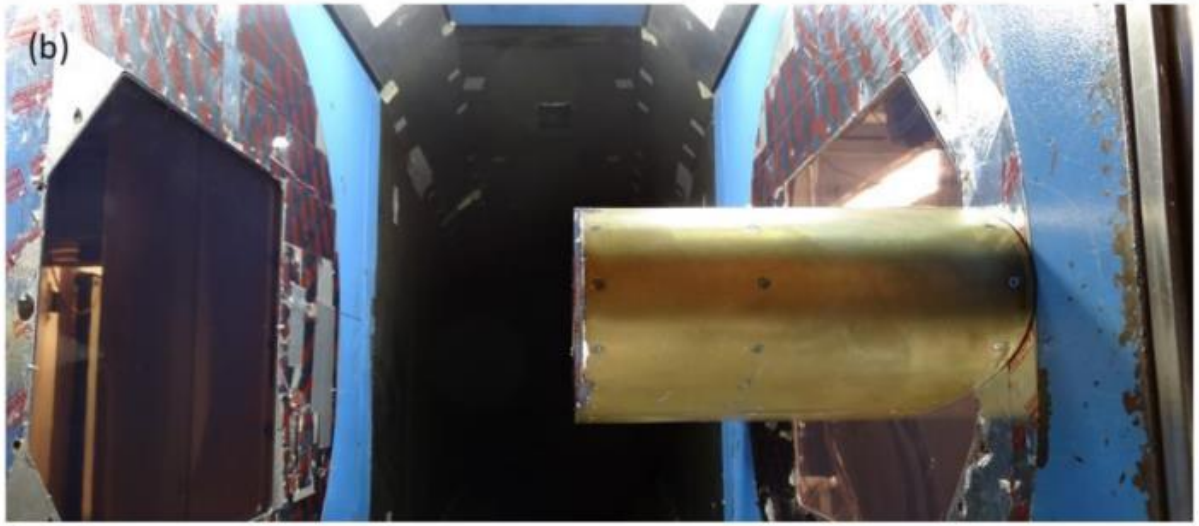
Icing Wind Tunnel Test

Installation

- IWT Collins Facility (2021), App. C&O conditions





Procedure

Icing Wind Tunnel Test Procedures – Most Points

- Start data recording and record data for 1 min in clear air
- Start the icing cloud
- Run for several minutes with the icing cloud – total exposure varies depending on specific condition being tested
  - In most cases, a minimum of 3 min of icing exposure was tested
- Stop the icing cloud, record minimum of 1 min of data

Icing Wind Tunnel Test Procedures – Repeat Points

- For a few test conditions, the procedure was repeated three times without de-icing or other intervention

Performance Summary

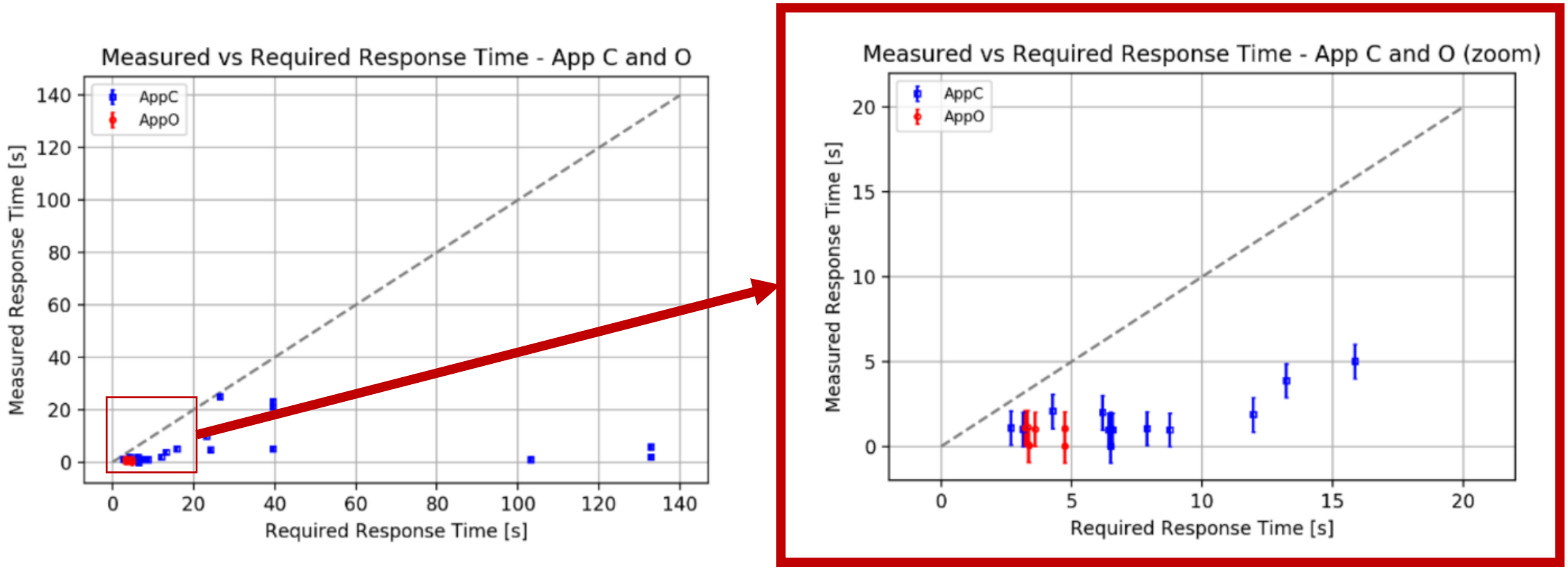
- Excellent performance on response time metric across both icing appendices
- Parameter measurement accuracy differed between the two appendices
  - Good match with tunnel values for App. C
  - Higher Error for App. O – discussed in subsequent slide

Test	Test Points Detected within Response Time [%]	Average MVD Error [%] *	Average LWC Error [%] *
Appendix C Test Points	100%	14%	28%
Appendix C Repeat Points	100%	15%	27%
Appendix O Test Points	100%	41%	67%
Appendix O Repeat Points	100%	24%	59%

* $Error = 100 * \sqrt{\Sigma\left(1 - \frac{meas}{truth}\right)^2 / n}$

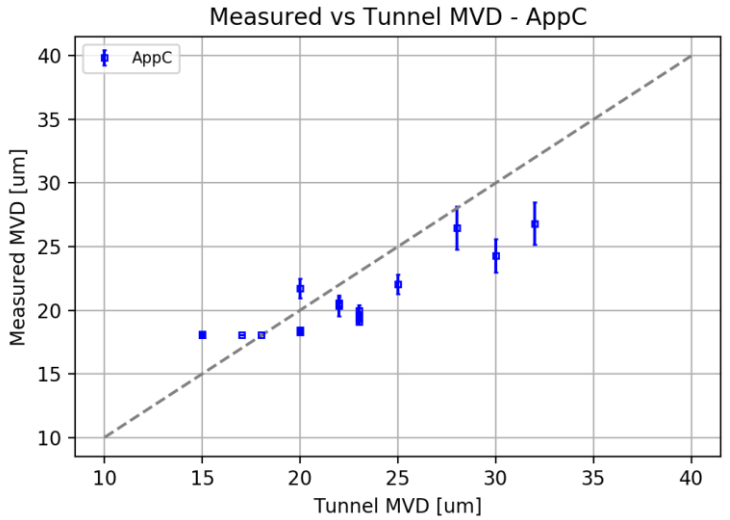
Response Time

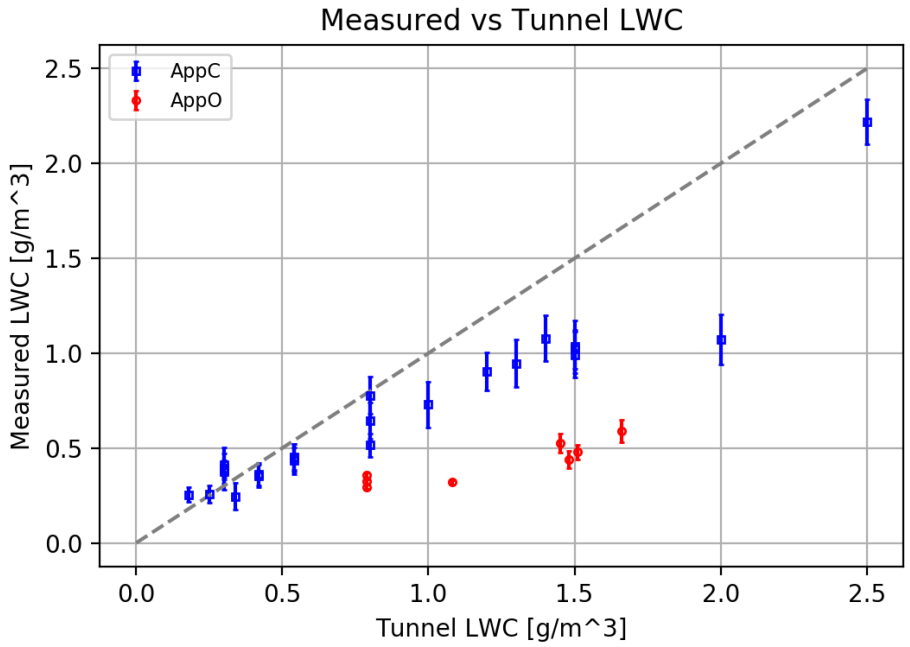
- Sensor meets SAE AS5498B (or equivalently ED-103B from EUROCAE) requirements on response time

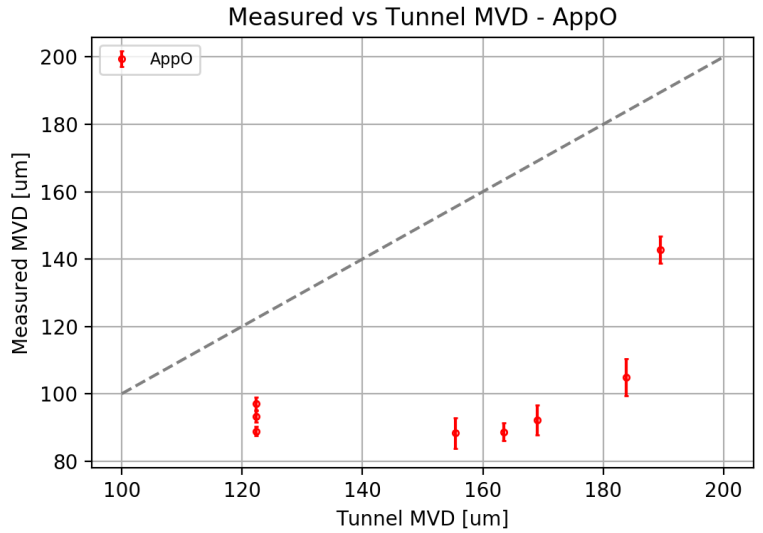


MVD/LWC Measurements

- Appendix C tracks well for both MVD and LWC
- Larger errors in Appendix O resulting from loss of signal in IWT vs lab calibration
  - Believe window fogging to be core issue – mitigations being developed







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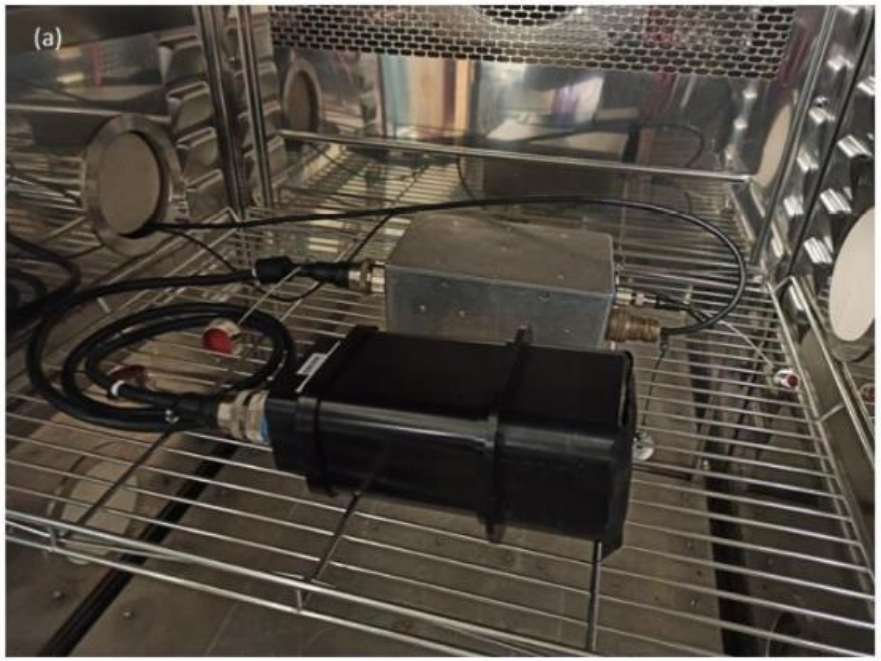
Flight Test Campaign

Preparations

- Flight test campaign executed late Feb - early Mar in North America
- Prior to flight test, sensor went through flight worthiness
  - Qualified against a subset of DO-160G tests, including temperature, vibration / shock, power input, lightning, and ESD



Flight test execution

Embraer‘s Phenom 300 optical sensor integration

- Communication issue between sensor & aircraft was resolved without any impact on the campaign

Flight Test Campaign

- Eight flights for which reference data were successfully measured
- Appendix C and Appendix O conditions encountered multiple times
- Optical sensor data collection successful

Sensor data analysis and preliminary results

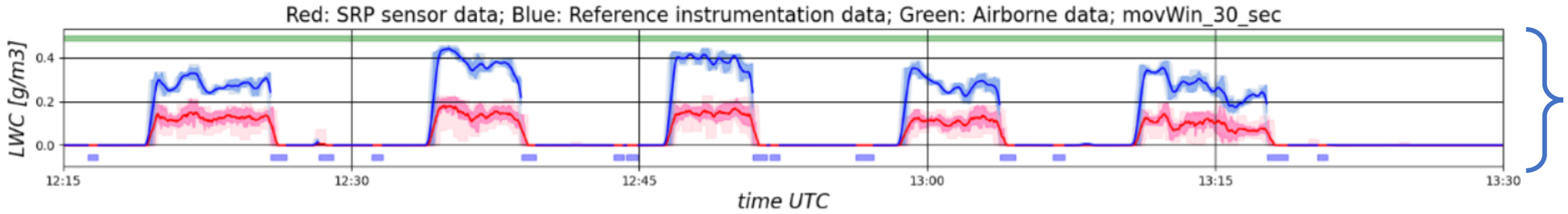
- Performance compared with reference data provided by DLR
- Good results for events in which particulate MVD > 25 microns
- Sensor underestimates TWC for events in which particulate MVD < 15-20 microns
- Detailed results provided for flights 1476 and 1481

1st gen. optical sensor
direct ptcl. sensing: 2 - 42 um

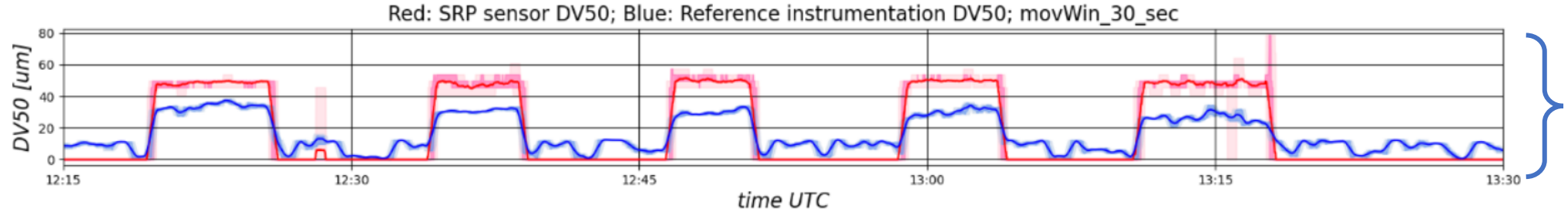
2nd gen. optical sensor
direct ptcl. sensing: 50 - 1000 um
background signal sensing: 5 – 50 um

Optical sensor data analysis: Flight 1476

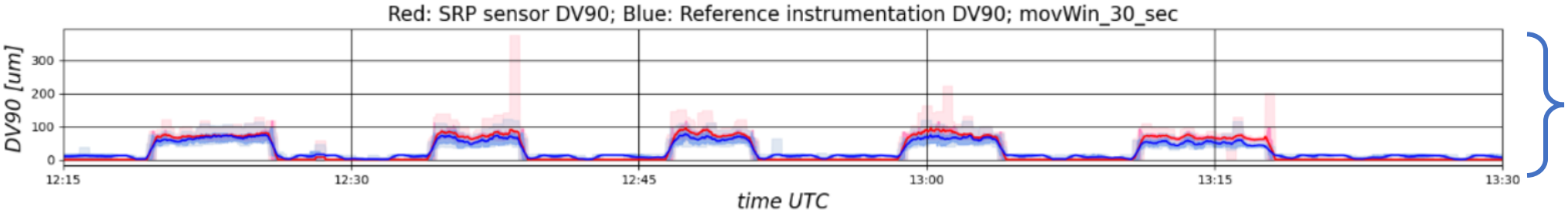
No collection efficiency corrections applied, sensor non-linearities corrections not applied, better results are expected



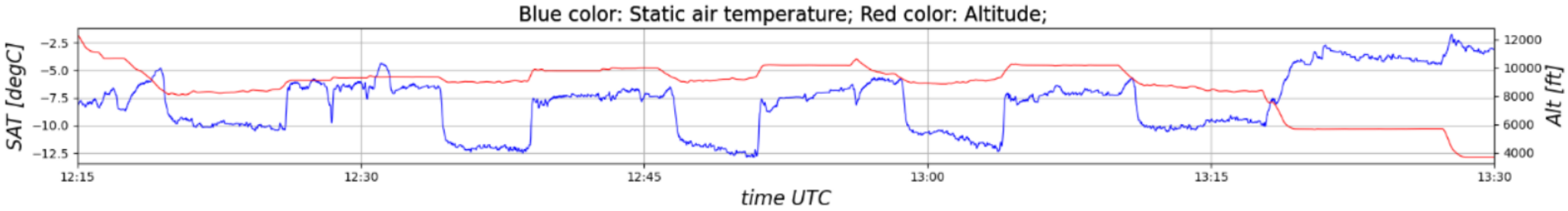
High correlation between reference and optical sensor data



Optical sensor underestimates volume/mass of small particles

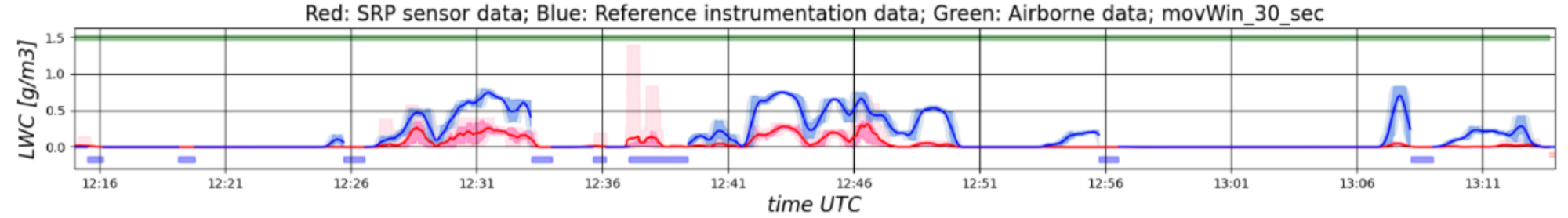


DV90 values are well matched with reference instrumentation data

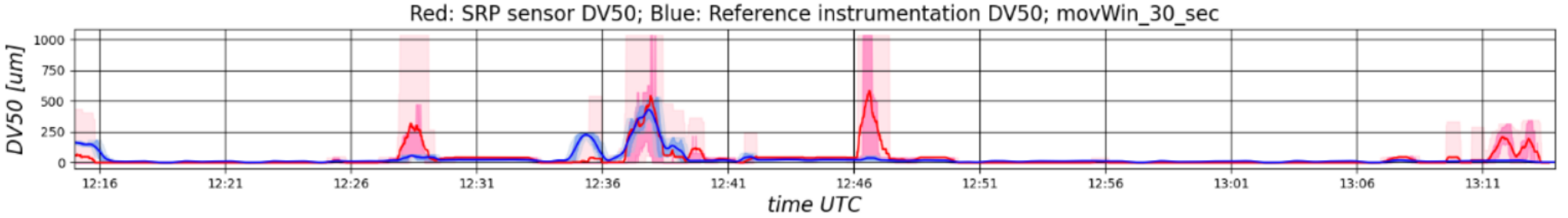


Optical sensor data analysis: Flight 1481

No collection efficiency corrections applied, sensor non-linearities corrections not applied, better results are expected



High correlation between reference and optical sensor data



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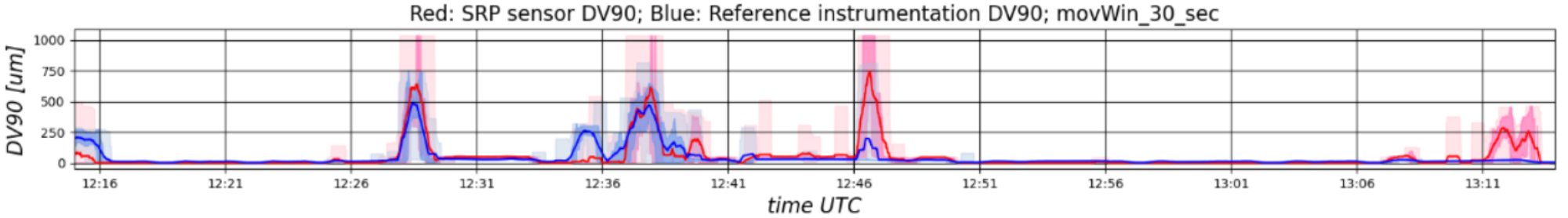

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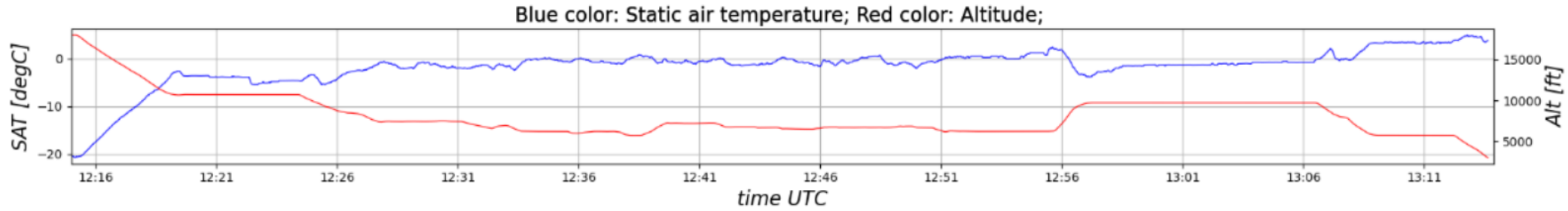

Conclusions & Next Steps

Conclusions

- High measurement performance for events in which particulate MVD > 25 microns
- Small particulate detection successfully evaluated under previous program (1st gen. optical head)

Next gen. optical sensor development

- Design single sensor covering icing appendixes C, D, O
- Develop ash / dust / sand sensing functionality

Use-cases

- Safety, autonomy, situation awareness
- Reduce fuel consumption, reduce CO_2 emissions
- Predictive health maintenance

Acknowledgment

- Thank you to Embraer, DLR and all SENS4ICE partners for US flight test preparations and execution

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