ICE GENESIS
Project Overview

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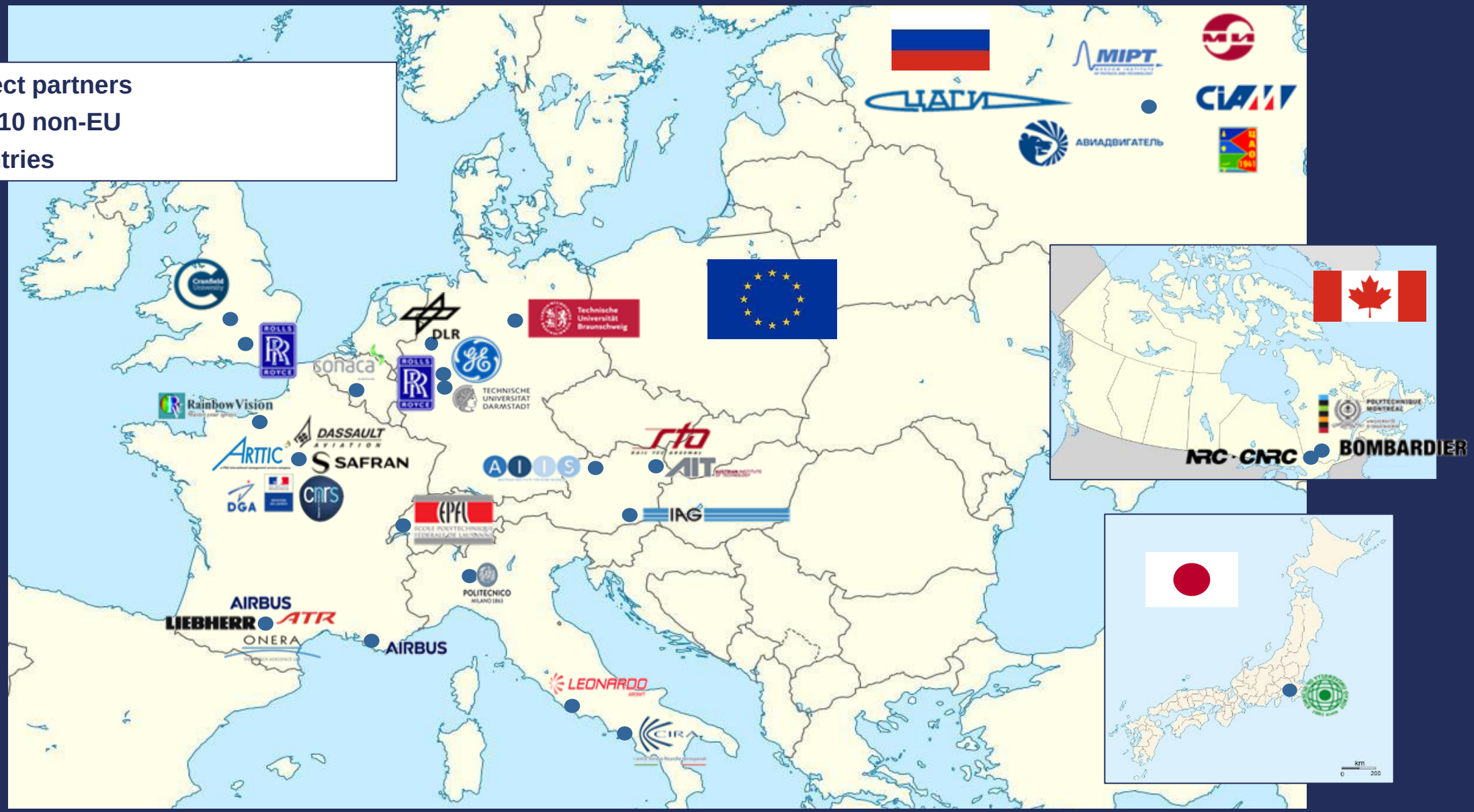
The Consortium

- 37 project partners
- 27 EU / 10 non-EU
- 10 countries



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ICE GENESIS project overview

Creating the next generation of 3D simulation means for icing

- **Duration:** From 1st January 2019 until 31st December 2022
- **Coordinator:** AIRBUS OPERATION SAS

- **Budget:**
  - Max EU Contribution: €11 964 300
  - Total Estimated Project costs: €21 984 549
  - Project effort in Person-months ~ 1858

- **Advisory board:** EASA, FAA, ADSE, AEROTEX,
  AIRBUS Defense&Space, CSTB, DAHER, EMBRAER,PIAGGIO, SAFRAN nacelles

ICE GENESIS project overview

Top level objective

The top level objective of the ICE GENESIS project is to provide the European aeronautical industry with a validated new generation of:

3D icing engineering tools
(numerical simulation and Icing Wind Tunnels capabilities)

addressing

Regulation CS25 Appendix C (well-known icing envionment)

Appendix O (SLD or Supercooled Large Droplet)

and snow conditions,

for safe, efficient and cost effective design and certification of future aircraft and rotorcraft.

Novelties in Europe : 3D ice scanning system
droplet temperature measurement
snow characterization and campaigns

ICE GENESIS project overview

Sub-objectives

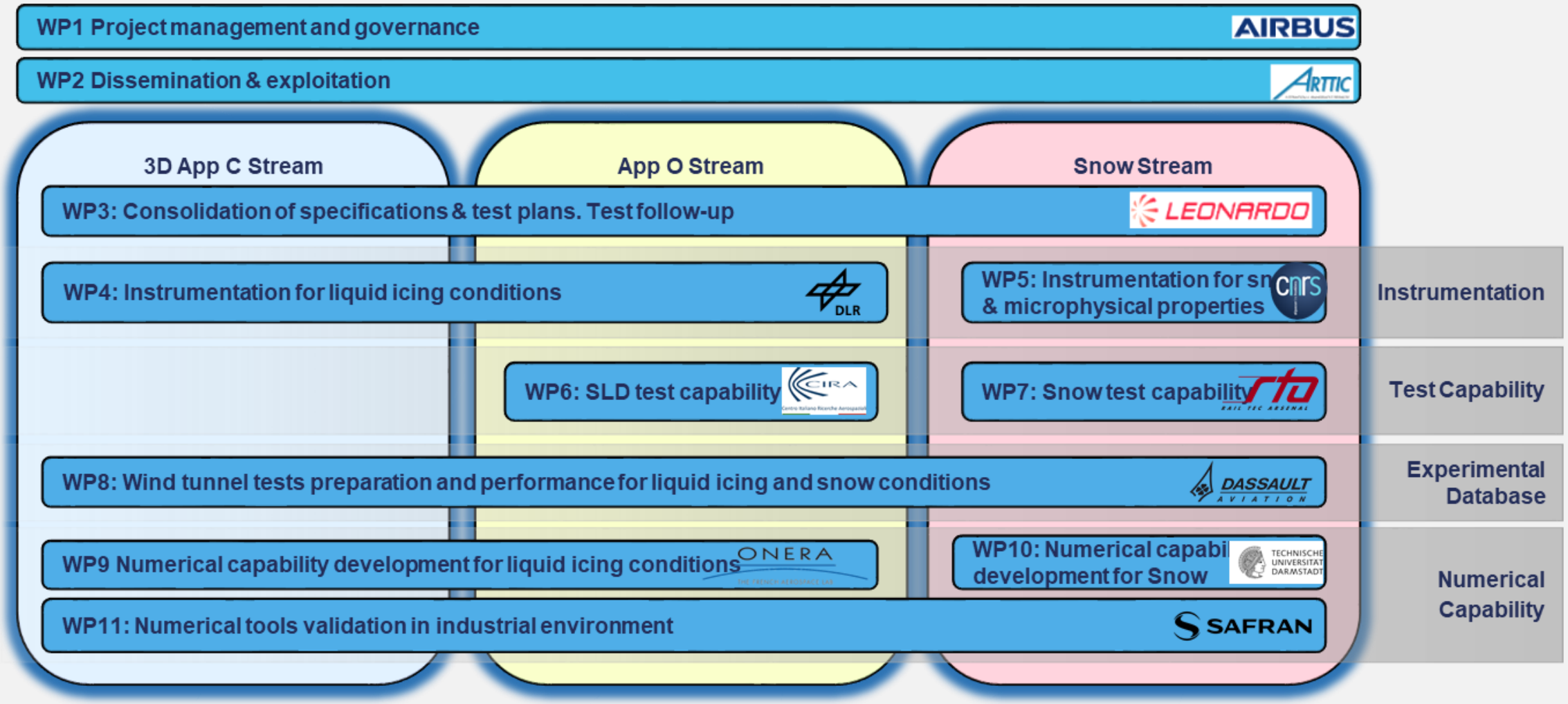
Obj#1: Improve and validate existing **3D numerical tools** to predict ice accretion in Appendix C, Appendix O and Snow conditions.

Obj#2: Upgrade and calibrate **icing wind tunnels** to allow reproduction of:

- **Supercooled Large Droplets (SLD) in FZDZ (Freezing drizzle) conditions**.
- **Snow conditions**
- Additionally, to **assess the potential of current icing wind tunnels to represent SLD in FZRA (Freezing rain) conditions**.

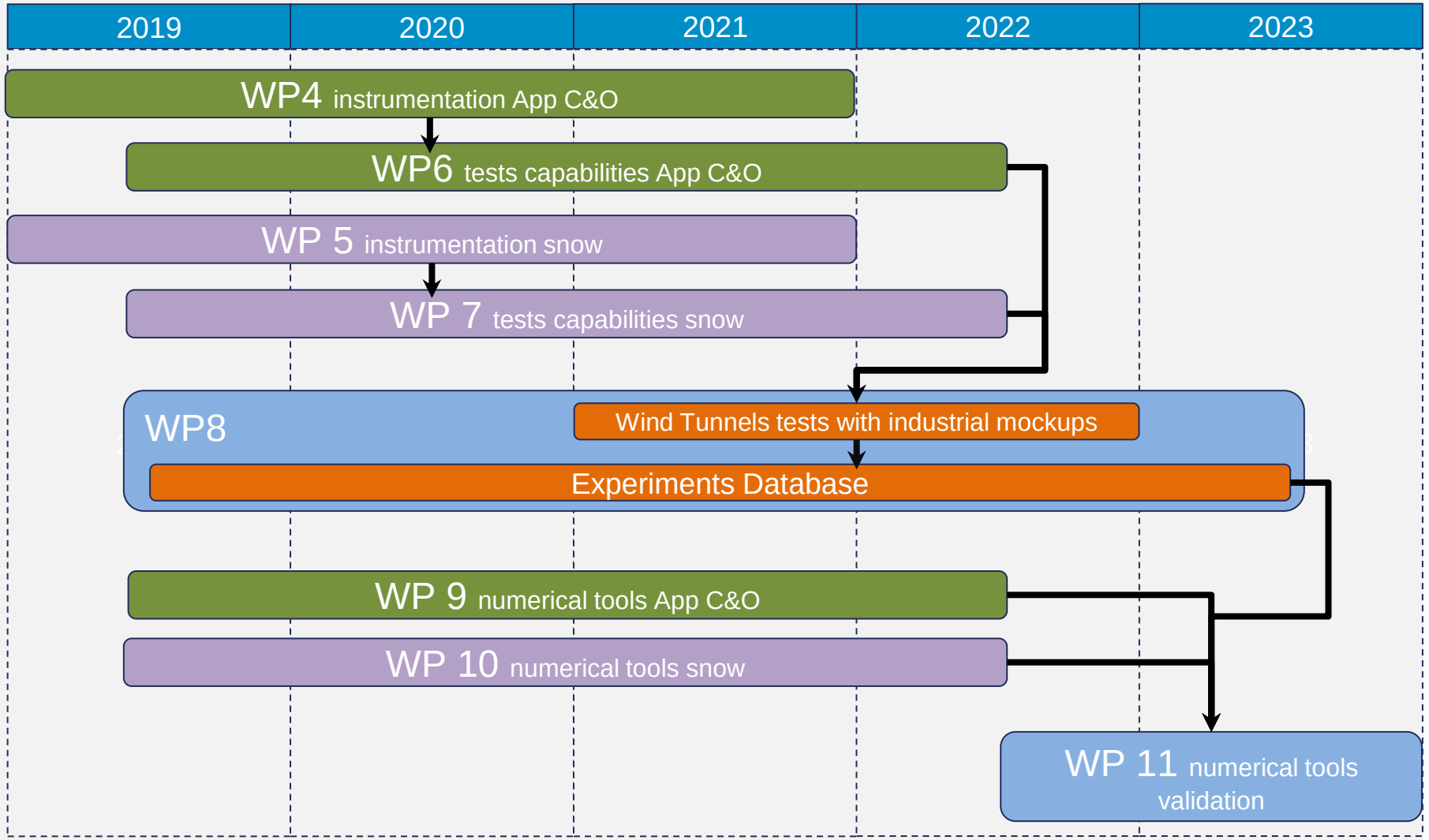
Obj#3: Build a **large scale experimental database** on representative 3D configurations to be used as a solid reference ("ground truth") for future numerical tools validation.

ICE GENESIS Organisation



WP DEPENDENCIES

- Perform wind tunnel tests in liquid icing and snow conditions, in industrial environment (IWT and mockups)
- Provide searchable database of experimental results for validation of numerical tools



Liquid conditions Instrumentation

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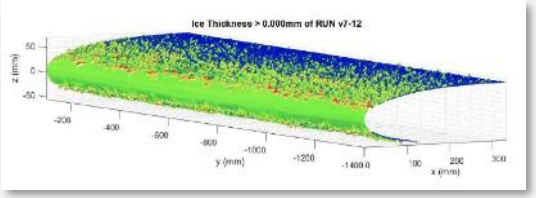
Icing Instrumentation - Objectives



3D-Scanning System

1 - ParticleSize Distribution PSD

Determine MVD for droplet spectra > 40µm

CAPS Cloud and Particle Spectrometer

5 - Ice Shape

Characterize surface roughness and ice density

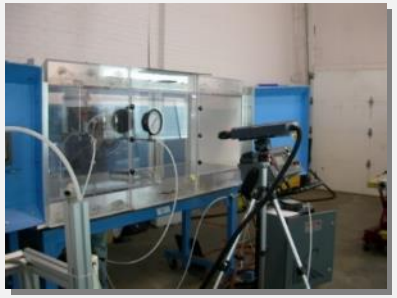
Develop and select the most appropriate instrumentation for experiments in App. C/O icing conditions

2 - Liquid Water Content

Cover LWC range:

0.01 – 3 gm^{-3}

Isokinetic Probe



Generalized Scattering Imaging

4 - Cloud Homogeneity

Ensure cloud uniformity in test section

3 - Droplet Temperature

MeasureT of supercooled droplet in test section

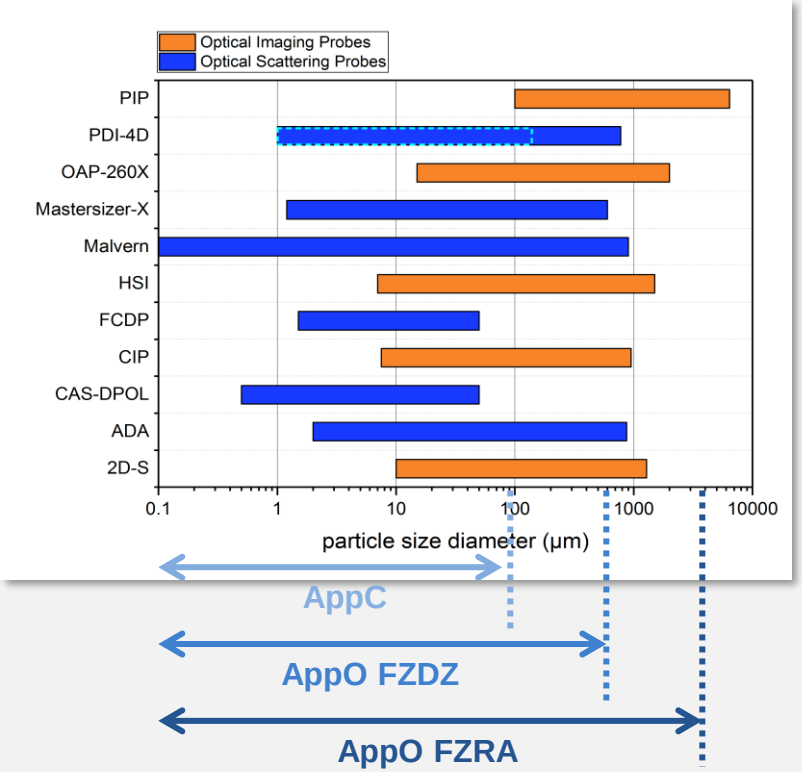
Global Rainbow technique

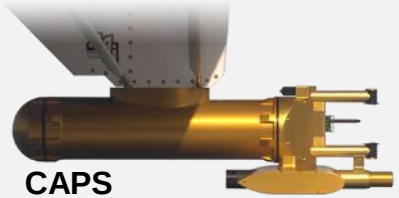
Instrumentation assessment and selection for PSD measurement (1)

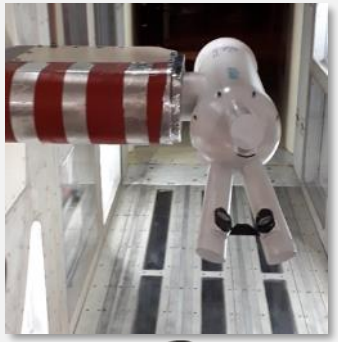
Selection and Calibration of PSD Instrumentation

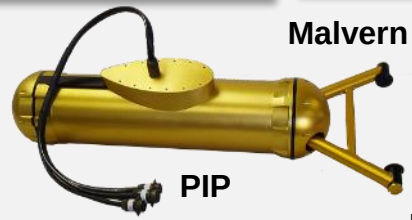
Challenge: → Large size range, correct representation of small and large particles in PSD

→ Better cover critical 50-100 µm size range







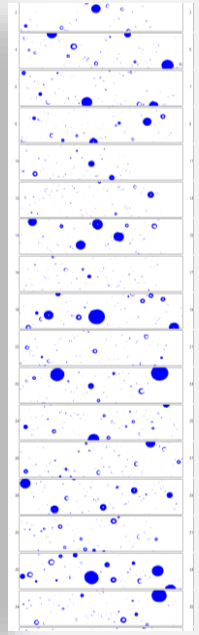


Droplet Generator & Calibration

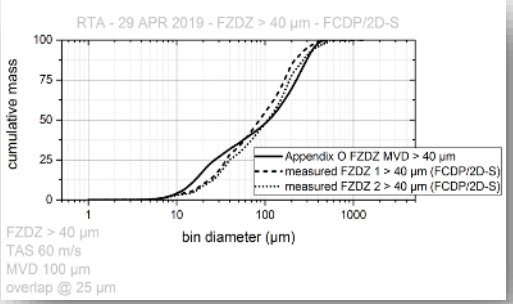
Assessment of PSD instrumentation (1)
2DS/FCDP, PIP, Malvern Spraytec

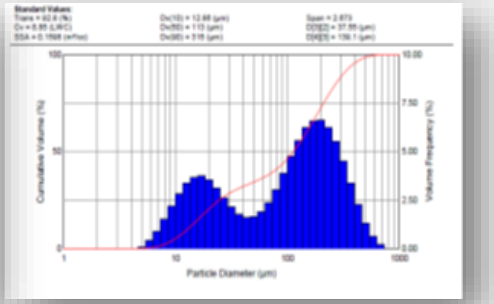
- Assessment & selection of instrumentation for PSD measurement at RTA IWT
  - Comparison of instrumentation (2DS/FCDP, PIP, Malvern Spraytec)
  - Freezing Drizzle and Freezing Rain Conditions

2DS/FCDP in the RTA test section

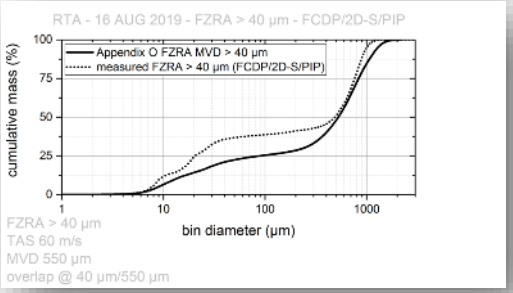


2DS images

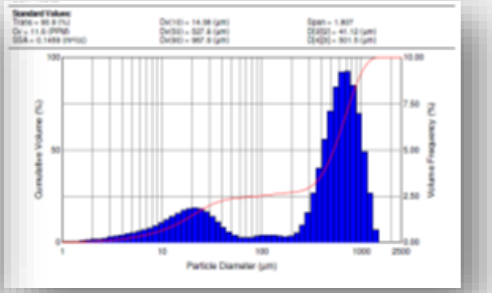




FZDZ conditions



FZRA conditions



FZRA conditions

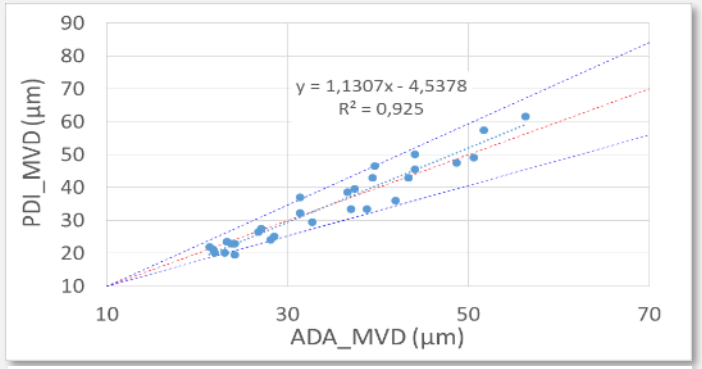
Phase Doppler Interferometer (1)

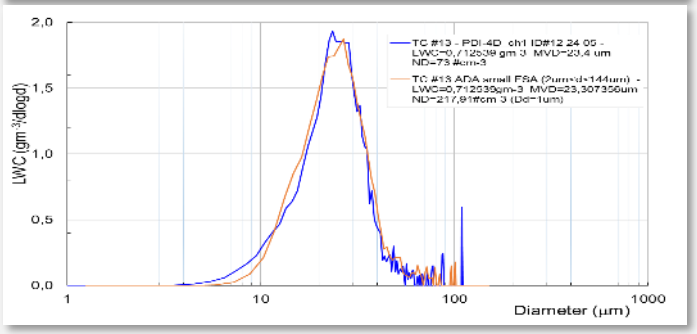
Calibration of Phase Doppler Instrumentation in CIRA Wind Tunnel

to better cover critical 50 µm – 100 µm size range

- New phase Doppler PDI-4D probe with four detectors configuration
- Standard ADA probes with new processors for signal analysis

- Airflow 140 ms-1
- Air T -5 °C
- 24 cloud conditions (sea level)
- 13 & 18 conditions (3 & 6 km)



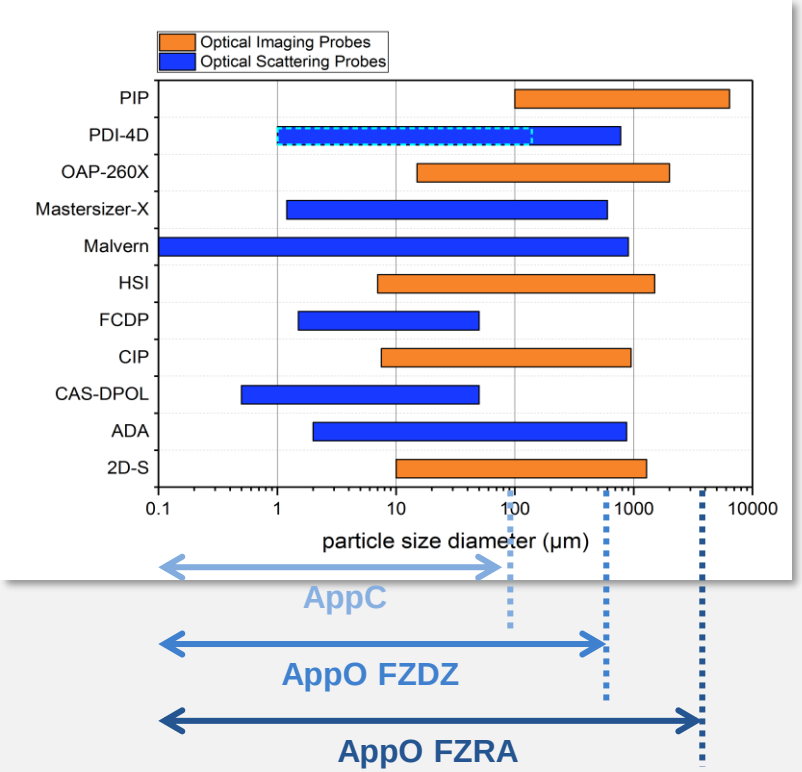


Instrumentation assessment and selection for PSD measurement (1)

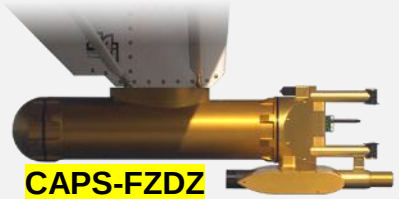
Selection and Calibration of PSD Instrumentation

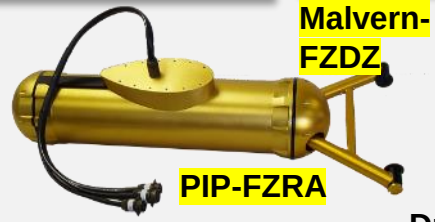
Challenge: → Large size range, correct representation of small and large particles in PSD

→ Better cover critical 50-100 µm size range



Recommendations





Droplet Generator & Calibration

Instrumentation assessment and selection for LWC measurement (2)

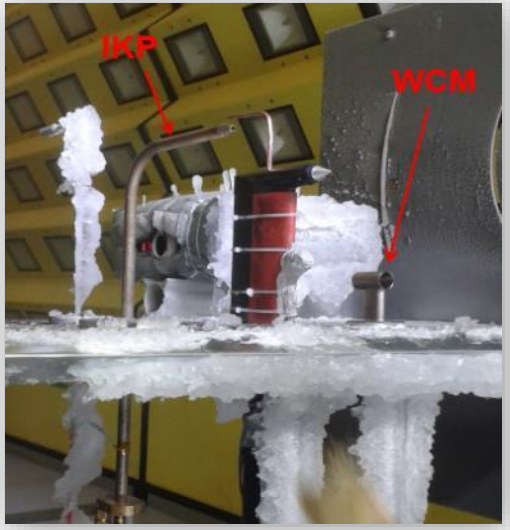
Selection and Calibration of LWC Instrumentation

- Challenge: Wide LWC range < 3 g m-3 (App.C) and low LWC << 0.4 g m-3 (App. O)
- Bulk measurements require corrections for collection efficiency for small and large droplets
- Accurate water vapor measurement needed for isokinetic probe data evaluation at low LWC

Isokinetic Probe (CU-IKP)

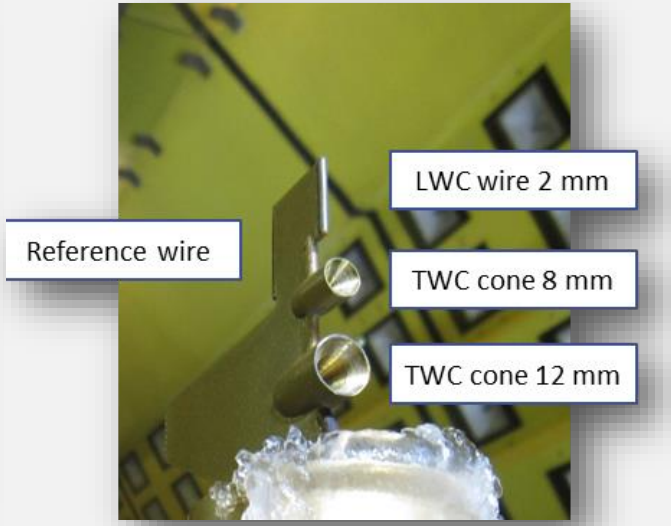
WCM 2000

Tests at RTA/TUBS WT



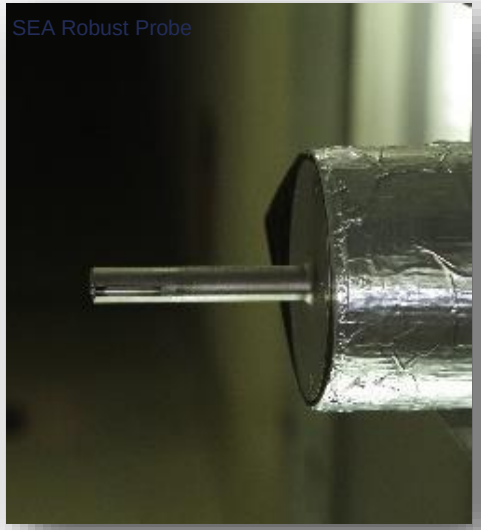
Nevzorov Probe

Tests at RTA / TUBS IWT



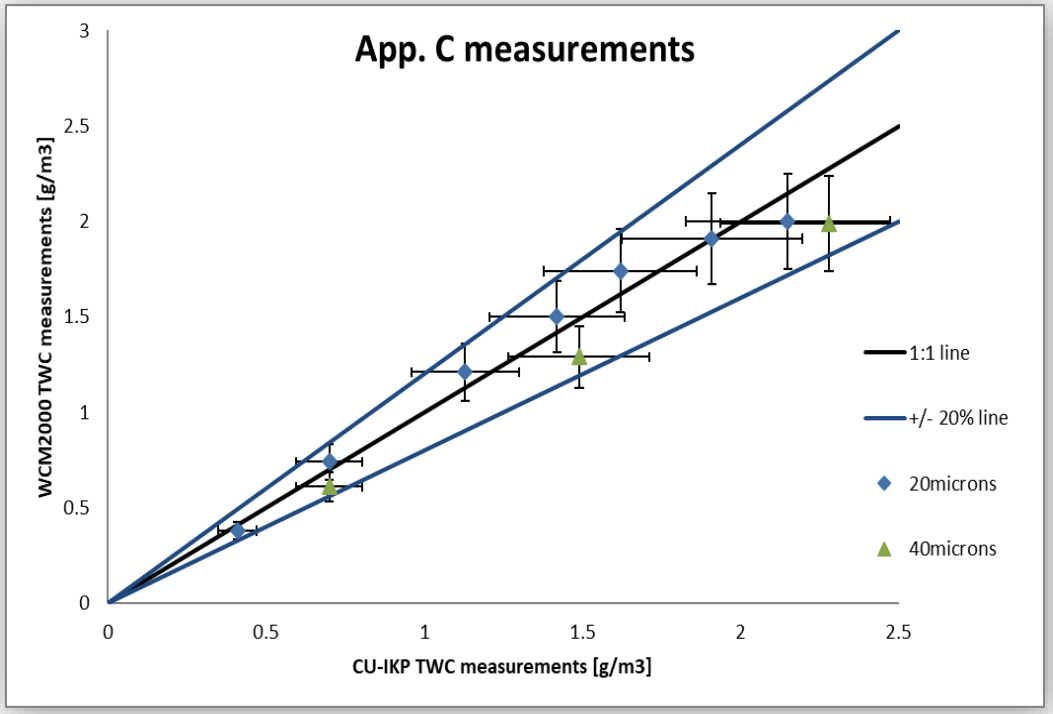
Robust probe

Tests CIRA IWT



Instrumentation assessment and selection for LWC measurement (2)

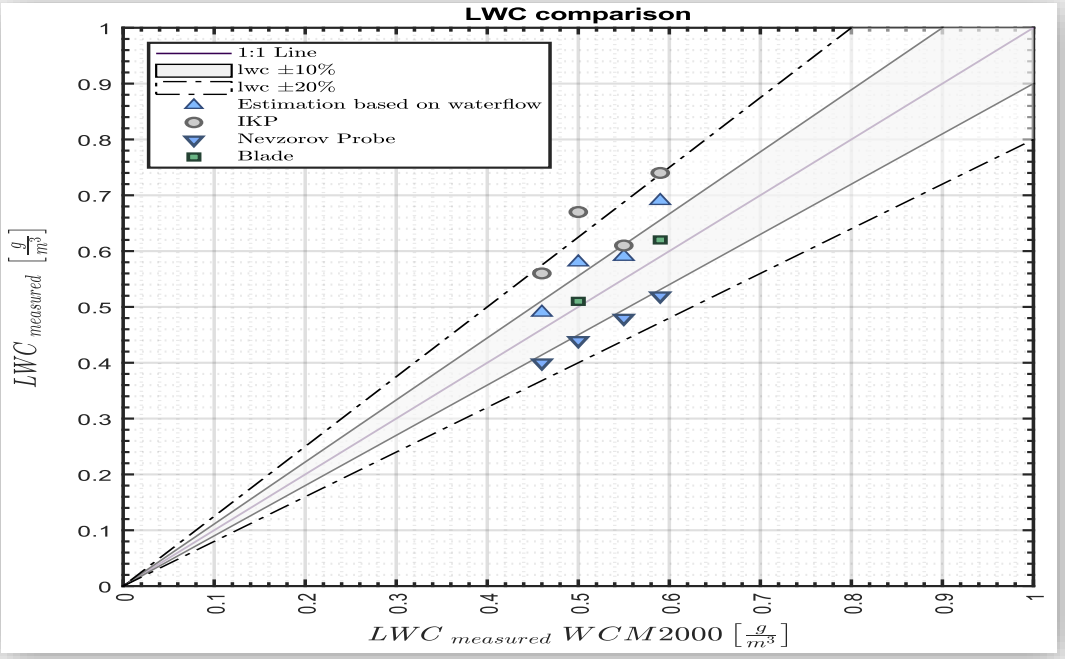
Selection and Calibration of LWC Instrumentation App. C, MVD < 40µm



Good agreement between CU-IKP and WCM2000 < 10% in RTA IWT

Instrumentation assessment and selection for LWC measurement (2)

Selection and Calibration of LWC Instrumentation App. O Freezing Drizzle, MVD~100µm



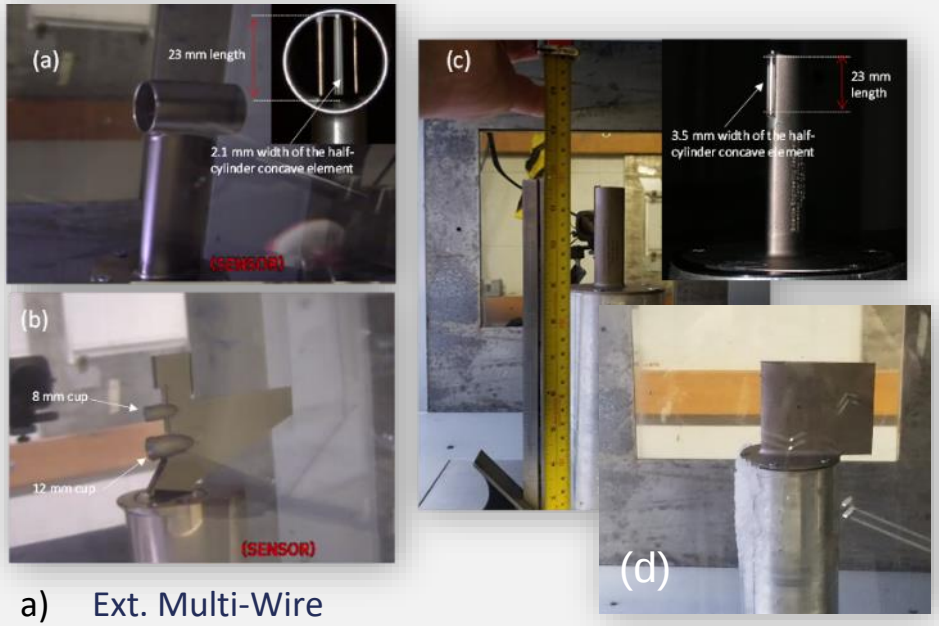
Comparison of LWC from several instruments to mean LWC from WCM2000 in RTA IWT
Agreement between WCM2000, Nevzorov TWC8 cup and Icing Blade < 10%, IKP < 20%

Instrumentation assessment and selection for LWC measurement (2)

Selection and Calibration of LWC Instrumentation App. O FZDZ/FZRA

- Measurements at NRC-AIWT
- NRC-AIWT, NRC-FRL, SEA, CIRA-Metanalytics, DLR, international cooperation

	Test point	VTAS	Static T	LWC	MVD
		m/s	°C	g/m3	microns
LWC sweep at 20 microns	2	80	-5	0,5	20
	3	80	-5	1	20
	4	80	-5	1,5	20
	5	80	-5	2	20
	6	80	-5	2,5	20
	7	80	-5	3	20
LWC sweep at 100 microns	13	80	-5	0,25	100
	14	80	-5	0,5	100
	15	80	-5	0,75	100
	16	80	-5	1	100
LWC sweep at 250 microns	20	80	-5	0,25	250
	21	80	-5	0,5	250
	22	80	-5	0,75	250
	23	80	-5	1	250
MVD sweep at LWC 0.5	1	80	-5	0,5	15
	8	80	-5	0,5	28
	9	80	-5	0,5	40
	10	80	-5	0,5	60
	11	80	-5	0,5	55
	12	80	-5	0,5	81
	17	80	-5	0,5	126
	18	80	-5	0,5	187
	19	80	-5	0,5	236
	24	80	-5	0,5	314
40 m/s	S4I 13 CM	40	-5	0,42	20
	S4I 18 IM	40	-5	1,2	28
100 m/s	FRL 16	100	-5	0,7	10
	FRL 27	100	-5	0,2	30
	FRL 25	100	-5	0,2	200
	FRL 26	100	-5	0,2	max

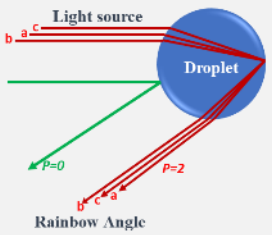


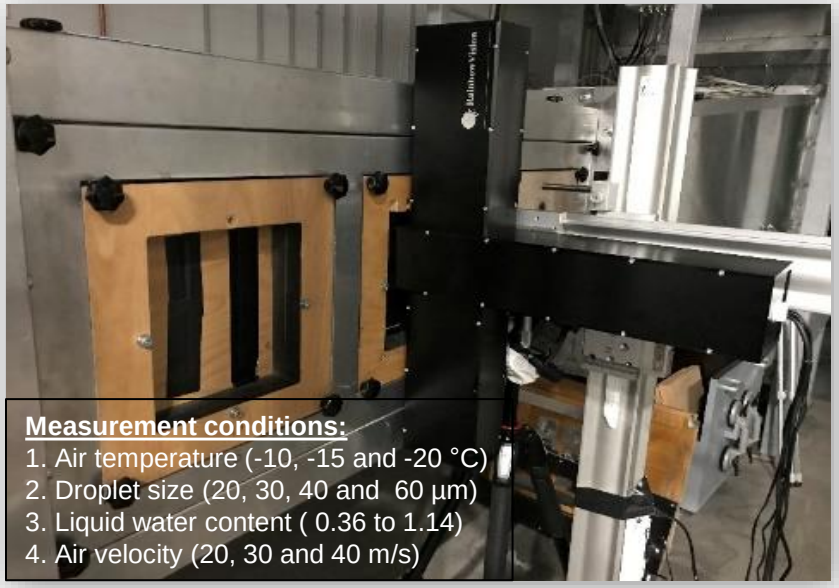
a) Ext. Multi-Wire
b) Nevzorov 2-cup,
c) Nevzorov
d) Robust probe, Ice Crystal Detector

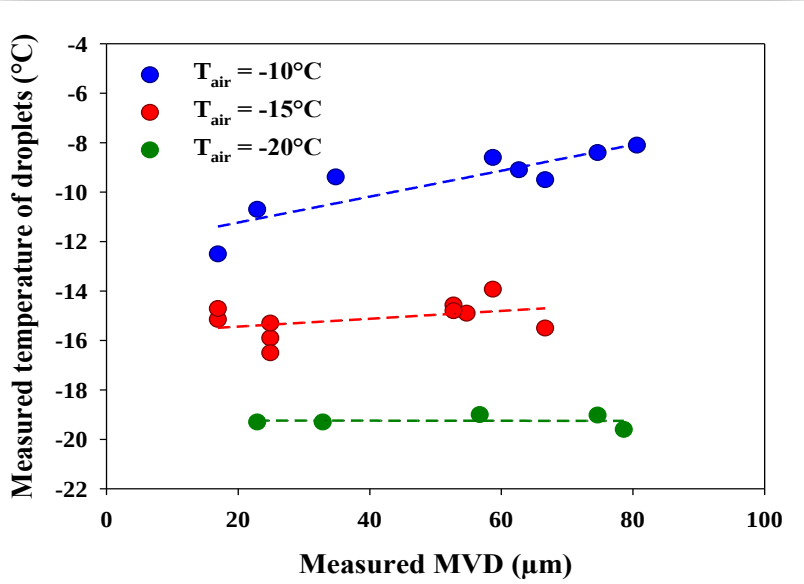
Temperature Measurement (3)

Innovation: Global Rainbow Technique for T measurement

- Successful droplet temperature measurement at TUBS IWT.
- Extension of GRT technique to SLD developed, inversion code validated by numerical simulations.
- **Challenges**: Define uncertainties. Prevent icing on window, Measurements in large IWT





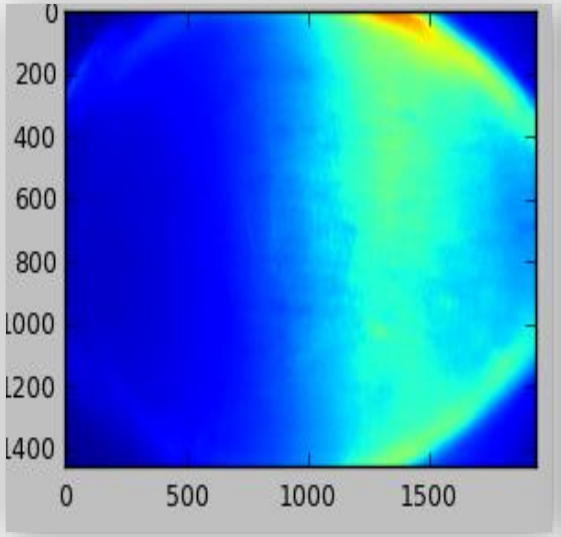


Temperature Measurement (3)

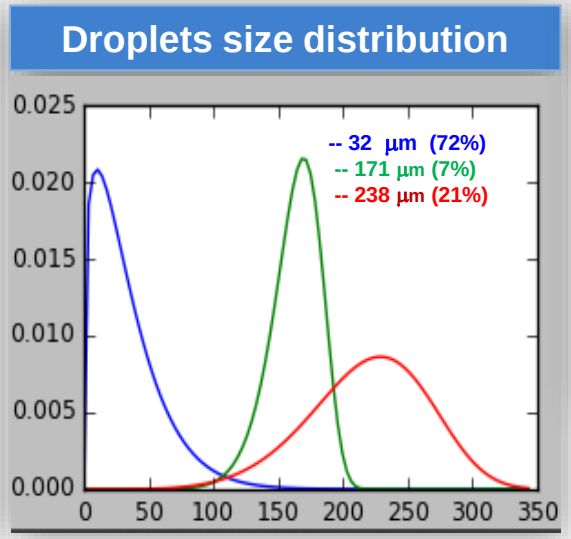
The General Rainbow Technique for droplet T measurements in large IWT

- Droplet temperature measurement campaign at RTA IWT
- Development of GRT technique for large IWT with SLD

Example of validated signal



Measurement results

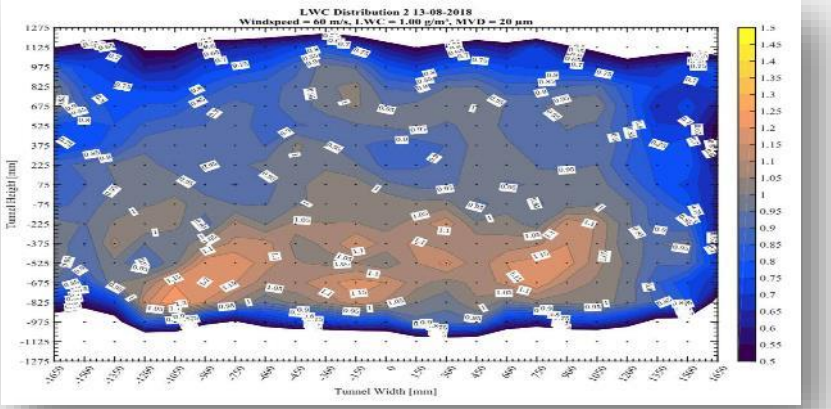


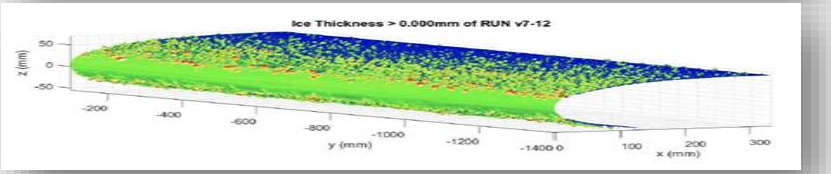
+ Droplets temperature = - 4,1°C

Homogeneity measurement (4)

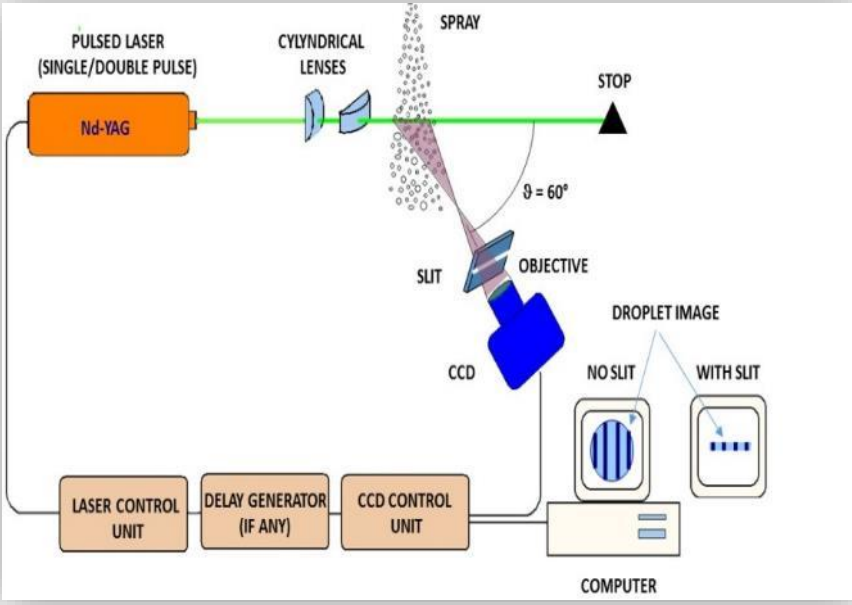
Instrumentation for cloud homogeneity characterisation

Ice Accretion Grid in FRDZ in RTA IWT as first check of cloud uniformity, ice accretion tests on NACA0012 to evaluate cloud homogeneity, validation of codes





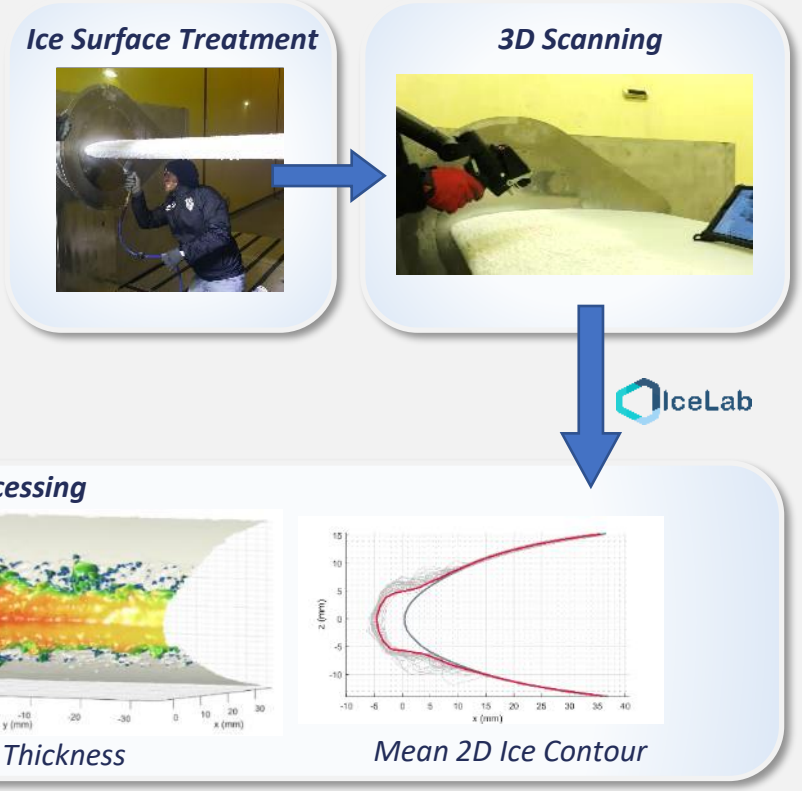
General Scattering Imaging optical configuration in the laboratory for cloud homogeneity assessment in CIRA-IWT



3D Ice scanning system (5)

Development of an approach for 3D documentation and analysis of ice shapes, generated in icing wind tunnel tests

1. Assessment and optimization of 3D scanning system in harsh IWT environments
2. Evaluation of 3D scanning accuracy
3. Software analysis of 3D ice shape data and development of evaluation methods
4. Definition of a whole process for ice shape documentation and evaluation



3D Ice scanning system (5)

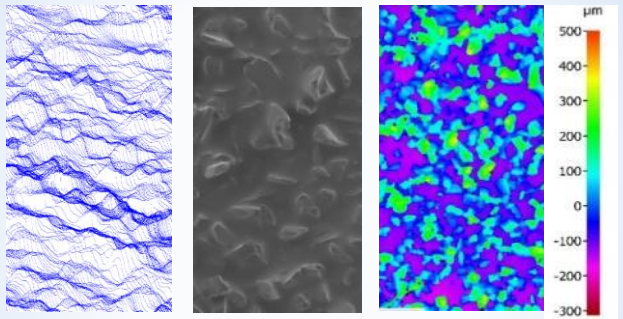
Main achievements and innovations

First in-depth analysis and comparison of existing 3D scanning techniques in terms of roughness accuracy

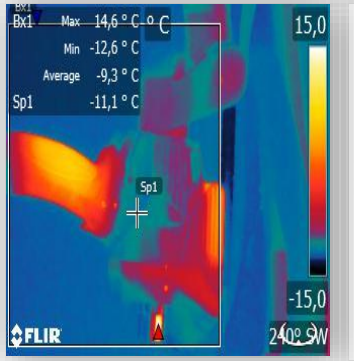
- Quantitative assessment via sandpaper/scanning electron microscopy
- Selection of a line-laser scanning technique and adaptation for IWT environment

Evaluation of system accuracy

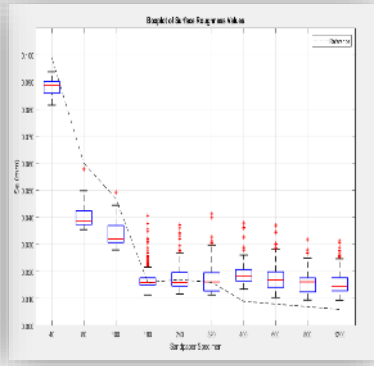
- Overall ice shape scan accuracy 28 µm (2σ)
- Roughness detection accuracy up to sandpaper grade P320
- Thermal investigation showed 3D scan accuracy independence at 20 °C to -10 °C



3D Scan Result *Electron microscopy* *Optical profilometry*



Thermal investigation in climatic chamber



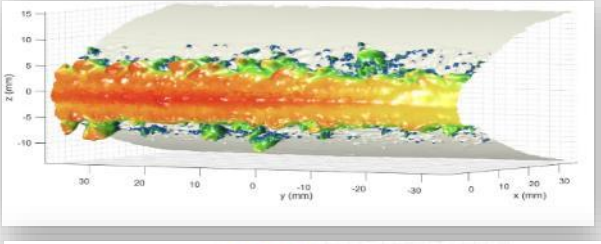
Evaluation of roughness scan accuracy

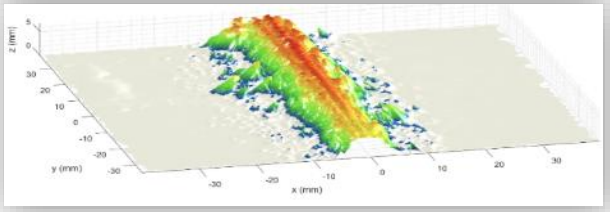
Adapted RS5 scanner performs well at shape and roughness scanning at temperatures and environments relevant for IWT testing in ICE GENESIS

3D Ice scanning system (5)

Development of 3D ice shape data evaluation tool

Main achievements and innovations





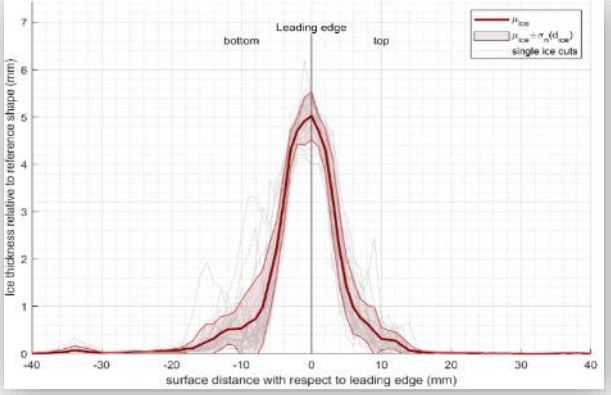
Ice thickness analysis and shape unfolding

3D ice shape evaluation

- Determination of ice shape geometry and volume
- Calculation of mean ice shapes and geometries

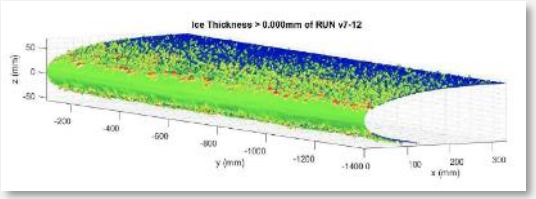
3D surface roughness evaluation

- A topological grid is averaged over the projected ice surface via neural network Self-Organizing Maps. The amount of data scattering about the nodes of the neural network represent the local roughness.
- First adaptive 2D and 3D roughness evaluation via automatic roughness vector spacing



Mean unfolded ice shape and gaussian inclusion limits

Icing Instrumentation - Objectives



3D-Scanning System

1 - ParticleSize Distribution PSD

Determine MVD for droplet spectra > 40µm

CAPS Cloud and Particle Spectrometer

5 - Ice Shape

Characterize surface roughness and ice density

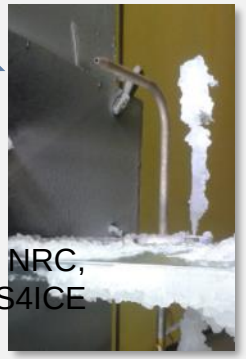
Develop and select the most appropriate instrumentation for experiments in App. C/O icing conditions

2 - Liquid Water Content

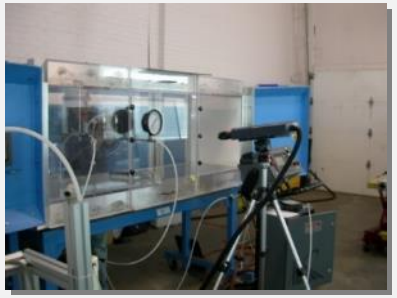
Cover LWC range:

0.01 – 3 gm^{-3}

Int. Coop. NRC, Link:SENS4ICE



Isokinetic Probe



Generalized Scattering Imaging

4 - Cloud Homogeneity

Ensure cloud uniformity in test section

3 - Droplet Temperature

MeasureT of supercooled droplet in test section

Global Rainbow technique

THANK YOU FOR YOUR INTEREST

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