INSTRUMENTATION FOR THE HIGH ICE WATER CONTENT (HIWC) FLIGHT CAMPAIGNS

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Objective

• To Identify, Develop/Modify, and Qualify Cloud Physics Instrumentation for High Ice Water Content Characterization Flight Campaigns

Technical Challenges

HIWC conditions present several technical challenges for cloud physics instruments

• Water Content Measurement:
  - Issues:
    o Saturation: legacy hot-wire probes saturate at 1-2 g/m³ at 200 m/s. HIWC can theoretically reach 9 g/m³
    o Under-sampling: ice and liquid water can bounce, break up and shed from legacy hot-wire probes before fully evaporating, causing measurement to be low
    o Damage: ice impacts on legacy hot-wire probes can deform, erode and break the wires
  - Challenge: Develop water content probes:
    o To measure up to 10 g/m³ at 200 m/s
    o Do not under-sample due to mass loss
    o Robust to the damaging HIWC environment

• Particle Spectra Measurement:
  - Issues:
    o Artifacts: In some types of glaciated conditions, legacy and SDA spectrometers are over-estimating concentrations of small ice particles due to the impact of larger particles on probe tips and inlets and resulting breakup into small fragments
    o Electro-static Discharge: High speed impacts of ice crystals on anodized probes is causing electro-static charge to build up and discharge through the probe ground. This phenomenon temporarily disables the probe electronics.
    o Optics Obscured/Condensation: Spectrometer probes mirrors and optics can get fogged in tropical air after cold soaking at high altitude and descending into high humidity air. Condensation builds up in probe chamber.
  - Challenge: Develop mitigations to:
    o the reduce ice particle artifacts,
    o electro-static build-up
    o optics fogging/condensation build-up

Measurement Type

<table>
<thead>
<tr>
<th>Water Content</th>
<th>Instruments/Probes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRC Isokinetic TWC Evaporator, Hot-wire boom with SEA “robust” probe, Nevisnov LWC/TWC probe, SEA LWC probe, King LWC probe</td>
<td></td>
</tr>
<tr>
<td>PMS Forward Scattering Spectrometer Probe, DMT Cloud Droplet Probe, SPEC 2D-3, SPEC Cloud Particle Imager, PMS Optical Array Probe 20-C, DMT Cloud Imaging Probe, PMS Optical Array Probe 20-P</td>
<td></td>
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<tr>
<td>Atmospheric State</td>
<td>AIMS-20 wind/ndust probe, Goodrich total air temperature (TAT), UK Solid Wire TAT, LIDOR water vapor, Buck Research CH-2 hygrometer, Edgetech Model 137 hygrometer, MayComm TDL open path hygrometer</td>
</tr>
<tr>
<td>Light Extinction</td>
<td>EC Cloud Extinction Probe</td>
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<tr>
<td>Ice Detection</td>
<td>Goodrich D87LM5 Ice detector, Goodrich D831A Ice detector, Stormscope</td>
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<tr>
<td>Remote Sensing</td>
<td>Honeywell RMP-400 point weather radar, Ka-band cloud profiling radar, L3Com WX-500 Stormscope</td>
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<tr>
<td>Imaging &amp; Audio</td>
<td>High Def and Standard Def cameras, video annotator, HD and SD recording decks to capture windscreen, research instruments, engine inlets</td>
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<tr>
<td>Aerosols</td>
<td>TSI Condensation Nuclei (CN) counters, Scanning Mobility Particle Sizer</td>
</tr>
<tr>
<td>Aircraft &amp; Engine Data</td>
<td>Airspeed, altitude, position, heading, roll, pitch angle, vertical acceleration, engine N1, N2, TGT, throttle position</td>
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</tbody>
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Technical Approach: Design, Build, Test

• To address Water Content Measurement challenges:
  - NRC developed an Isokinetic Evaporator Probe to measure Total Water Content to 10 g/m³ at 200 m/s
  - SEA developed a “robust” total water content hot-wire probe to withstand damaging ice impacts
  - EC developed new sensor vanes for Nevisnov LWC/TWC to reduce mass loss / under-sampling
  - New hot-wire boom with new sensors designed for HIWC research aircraft

• To address Particle Spectra Measurement challenges:
  - EC developed new tips and arms for the FSSP, CAP-200C, DMT CDP and CIP: SPEC CPI
  - EC/NRC/NASA identified titanium nitrite (TiN) coating on probes to manage electro-static buildup
  - Dry air purge system defined to keep optics clear; manage condensation within probes

• Wind Tunnel Tests and Flight Tests Conducted to Verify/Quality Instrument Readiness
  - Multiple entries at NRC M-7, NASA ATR, and Cox Icing Tunnel: NRC Convair 580

Results:

• NRC Isokinetic Evaporator Probe:
  - Successfully tested to 9 g/m³ of ice water content; inlet tip icing issue identified and remedied; new controller developed and successfully tested; probe undergoing upgrades for airworthiness.

• SEA Robust Probe:
  - Used for 3 winters at NRC M-7 for TWC mapping without failure;
  - used on Airbus A-340 fight test for HIWC

• New Spectrometer Probe Tips Reduce Ice Particle Artifacts
  - Wind tunnel test and CV-580 test confirmed new tips reduce particle artifacts in measurement area; spectra measurements in glaciated conditions

• TIN Coating Fixes Electro-Static Issues:
  - AIMS-20 test in NRC M-7 tunnel confirmed no-breakup in HIWC conditions
  - TIN coating now being applied to other electro-static sensitive instruments

Conclusions:

• Through collaborations between NASA, the FAA, Environment Canada, National Research Council of Canada, and SEA, issues of operating cloud physics probes in an HIWC environment were identified and remedies were designed, fabricated, and tested.

• As a result, new and improved instruments will be integrated on the HIWC Research Aircraft and flown in the upcoming trial and primary flight campaigns in Darwin, Australia.

• This assures that the highest-possible quality measurements will be made for this important field campaign. The data set will be used for decades to come.