Observations using slant angle passive radiometry during in-flight icing cases

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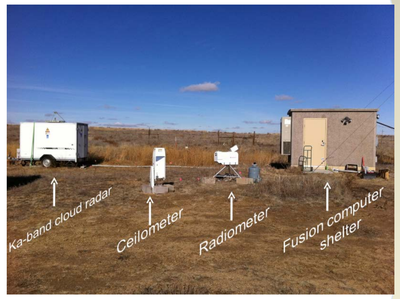
Introduction

- Need for volumetric in-flight icing hazard detection in airport environments

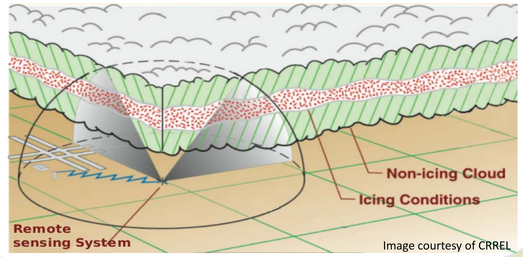
- NASA's Icing Remote Sensing System (NIRSS) is multisensor including:
1. Ka-band cloud radar – defines tops and bases of cloud layers
2. Laser ceilometer – cloud base refinement
3. Radiometer – temperature profile and integrated liquid values (Solheim et al., 1998)
4. Inputs merged and hazard profile derived with fuzzy logic

- NIRSS provides accurate hazard detection with high time resolution (Johnston et al., 2010), but system is currently vertically pointing only



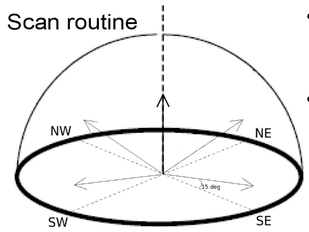
Goal

- Provide airport volumetric icing hazard product.
- First, need to test and understand radiometer functionality in off-zenith slant angle scanning



Method

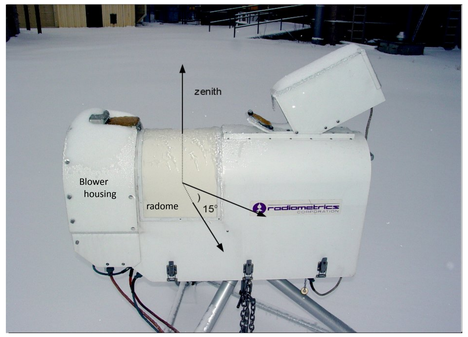
- Want to learn about instrument sensitivity to transient liquid features afforded by slant scanning



- Set up radiometer scan routine (left) to sample 15° elevation at NE,NW, SE and SW azimuths

- At 15°, viewing through equivalent of four atmospheres, ramifications are:
1. channel weighting functions maximize closer to each other in lowest few kms of atmosphere
2. higher resolution in lowest few kms

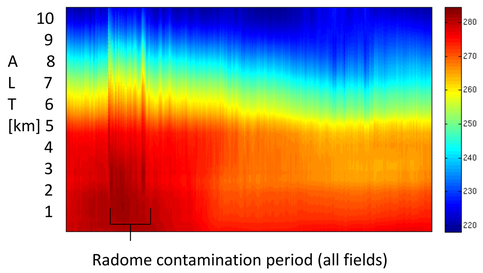
Results



- MP-series Radiometer receiver covered with a radome made with hydrophobic material to keep precipitation out of sensitive electronics

- Blower moves ambient air across the radome to aide in keeping the radome dry, but isn't always effective especially in humid locations

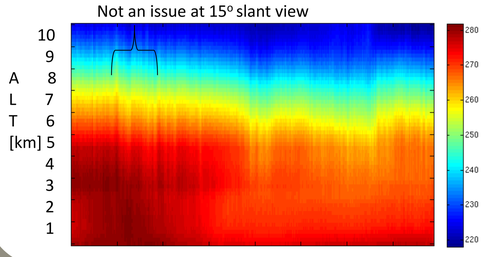
- Liquid or solid precipitation frequently still clings to the radome (left), but much less likely on the nearly vertical sides



- Contamination of the retrieved brightness temperatures, and the derived atmospheric temp, RH, Vapor and Liquid products (left)

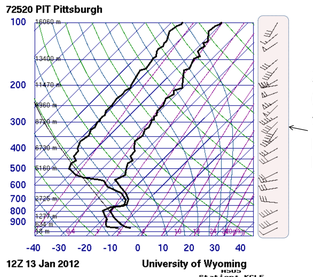
- Contamination periods reduce periods when NIRSS can derive an in-flight icing hazard product

Not an issue at 15° slant view

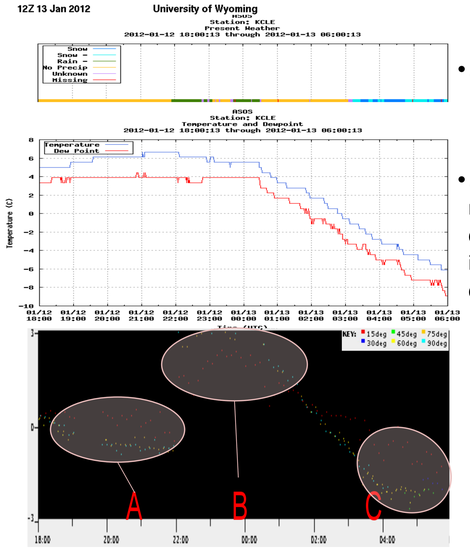


- Contamination much less likely on nearly vertical sides of radome where 15° elevation scan is viewing (left)

- Therefore, much more continuously usable time periods for detection of in-flight icing hazards with low elevation angle radiometer scanning



Zonal flow (west-to-east) through full profile behind front

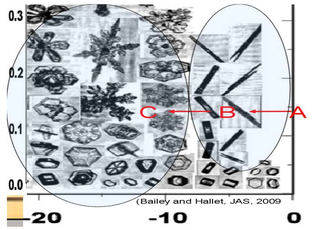


- Look at a simplest possible icing scenario and test the sensitivity of the slant viewing to advecting pockets of supercooled liquid water (SLW)

- Examined Jan 2012 case, cold frontal passage through Cleveland, Ohio:
1. many Pilot Reports of icing, and
2. flow was zonal through depth of atmosphere, may be able to track feature passage (sounding at left)

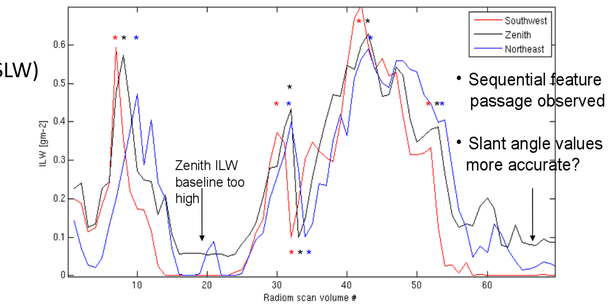
- At surface, ASOS detected surface rain changing to snow (left) and steady temperature drop behind front (below left)

- At Cleveland, also had a scanning 1° beamwidth radiometer with multi-frequency Ka-band for deriving integrated liquid water (ILW) and integrated 89 GHz polarized receiver (more discussion below)



- 89 GHz V-H signal (above left) is viewing three particle habits (upper right):
A. Signal near zero = round particles, which are liquid near freezing
B. Signal large positive = vertically oriented rods or needles
C. Signal large negative = horizontally oriented plates or dendrites

- **Future work?** Utilize 89V-H signal, radiometer temperature profile and radiometer derived saturation vapor pressure to aid in detecting supercooled liquid water



- Sequential feature passage observed

- Slant angle values more accurate?

- As the front passed NIRSS, we examined the MP-series radiometer derived ILW traces (above) from the southwest (red), zenith (black) and the northeast (blue) viewing directions

- Found consistent order in ILW relative maxima and minima of southwest then zenith then northeast (color coded stars)

- Indicates slant angle scanning is very sensitive to the discrete pockets of SLW that are advecting zonally across radiometer's field of view

- Observed that the zenith ILW values were high biased outliers compared to slant angle values > slant values more accurate?

Conclusion

Slant angle radiometry can improve detection of in-flight icing by:

1. Allowing for airport volumetric hazard coverage
2. Reducing time periods lost to radome contamination by precipitation
3. Providing higher resolution output in lowest few kilometers than zenith
4. Allowing sequential supercooled liquid feature tracking across radiometer field-of-view in cases with zonal flow proves sensitivity
5. Slant angle ILW product more accurate in low ILW?
6. Particle species information from 89 GHz V – H signal

References

i) Bailey, M. and Hallet, J., A comprehensive habit diagram for atmospheric ice crystals: confirmation from the laboratory, AIRSS II and other field studies, *J. Atmos. Sci.,* **66,** pp. 2888-2899, 2009.

ii) Johnston, C., Serke, D., Adriaansen, D., Reehorst, A., Politovich, M. K., Wolff, C. and McDonough, F., Comparison of in-situ, model and ground based in-flight icing severity, NASA/TM-2011-217141, 2011.

iii) Solheim, F., Godwin, J., Westwater, E., Han, Y., Keihm, S., Marsh, K. and Ware, R., Radiometric profiling of temperature, water vapor and cloud liquid water using various inversion methods, Rad. Sci., 33, pp. 393-404, 1998.