Icing Risk Detection and Avoidance

Supercooled liquid water freezes on contact, presenting serious icing hazards to drones, helicopters and other aircraft. As a consequence, military and commercial flights are often curtailed or precluded from flying in weather conditions when the risk of actual or potential icing risk can impact the asset. The lack of icing data causes mission stoppage even in cases where the risk of icing is low. Better measurements will reduce uncertainty allowing for higher mission completion rates and more productive use of assets. We discuss recent ground and aircraft-based microwave radiometer observation and analysis and its potential for icing risk identification at 20 mile or more standoff distance.

Microwave Radiometry

Microwave radiometers detect thermal radiation emitted by the atmosphere. The atmospheric absorption spectrum (emission spectrum equivalent) for 24 °C air with 15 and 0.1 gm⁻³ of water vapor and liquid, is shown in Figure 1. Liquid emission is ~30X stronger than ice emission, allowing cloud liquid (icing risk) vs. ice (no icing risk) discrimination.

Airborne Sensor

An airborne side-looking radiometer observing multiple 170 to 183 GHz (G-band) frequency channels is shown in Figure 2. Effective range of clear air radiometer frequencies near the 183 GHz molecular absorption peak are roughly 1 km, extending to roughly 30 km for the 170 GHz frequency channel¹. Broad effective range variability with channel frequency provides passive ranging capability.

Ground-Based Observations

Temperature and liquid water density retrievals from ground-based G-band radiometer observations of a Colorado upslope winter storm are shown in Figures 3 and 4. Liquid water density up to 0.6 gm⁻³ at temperatures as low as -8 °C is seen, identifying moderate to heavy icing risk².

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¹ Effective range for a given frequency depends on air humidity, temperature and pressure.
² Supercooled liquid density up to 1 gm⁻³ can occur.
Flight Observations in Cloud

For ground and flight observations, liquid water in the radiometer field of view\(^3\) compresses Tb’s toward the liquid water physical temperature, providing liquid water density and temperature information. Liquid water standoff distance can be estimated from multiple frequency Tb measurements and temperature lapse rate information\(^4\), a topic for further study.

Side-looking flight observations of subfreezing liquid and ice cloud, and flight altitudes, are shown in Figures 5 and 6. Temperature was \(\sim 15 \, ^\circ C\) on the runway during takeoff (3:05) and landing (4:45), and \(\sim -4 \, ^\circ C\) during level flight (3:25-4:25). The radiometer looked upward during right turns and downward during left turns at the indicated elevation angles.

The first 10° right bank shows warmer Tb’s, identifying higher icing risk than the second. Colder Tb’s for the first 20° right bank identifies lower icing risk than the second. Level flight fields of view identifying low icing risk (expanded Tb) are marked by green arrows, with higher risk (compressed Tb) marked by red arrows.

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\(^3\) The G-band radiometer has a one degree beamwidth.

\(^4\) Temperature lapse rates are available from flight path data and numerical weather models.
Figure 5. In flight side-looking ambient (Tamb) and brightness (Tb) temperatures. Moderate and low icing risk flight paths are identified by red and green arrows.

Figure 6. Flight altitude.

Downward looking left bank Tb’s for the lower frequency channels would show ground temperature (~15 °C) with no liquid in the field of view. Instead, they converge at 0 °C identifying liquid water near freezing and associated icing risk in the field of view.

Additional aircraft-based G-band radiometer observations of supercooled cloud liquid and ice, complemented by wing camera images, were previously reported\(^5\).

References


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\(^5\) Ware et al, 2017.