Performance evaluation of a radar-based super-cooled water detection algorithm during the SNOWIE Field Campaign

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Detection of in-flight icing hazard is a priority of the aviation safety community. The 'Radar Icing Algorithm' (RadIA) has been developed at the National Center for Atmospheric Research to detect the presence, phase components, and relative size of super-cooled drops. RadIA has the potential to provide a useful gridded diagnostic of icing hazard in near real-time, but needs to be evaluated with detailed in-situ observations, which are often lacking in icing-prone environments. This paper provides an evaluation of RadIA using in-situ data collected during the 2017 'Seeded and Natural Orographic Wintertime clouds: the Idaho Experiment' (SNOWIE) field campaign, that flew a research aircraft into clouds with known icing.

RadIA uses raw dual-polarization radar moments from an operational National Weather Service WSR-88D S-band radar and a numerical weather prediction model temperature profile. Radar moment values are quality-controlled to exclude clutter, biological targets, anomalous returns and above-freezing regions, and the temperature profile is adjusted based on the detected height of the melting level. Locations that have sub-freezing temperatures and valid radar return then have calculations performed in real-time for every pixel within a given radar's native polar coordinate volume. Previous studies that paired ground-based radar observations with in-situ aircraft measurements have determined relations of spatial moment values to the presence of in-flight icing conditions including super-cooled small-drop, large-drop, mixed-phase and plate-shaped crystals. Radar moment membership functions are defined based on the results of these previous studies, and fuzzy logic is used to combine the output of these functions to create a 0 to 1 interest value output at each radar pixel for each of these micro-physical categories. The interest value output for each of these four categories are the output of RadIA.

During SNOWIE, an array of ground-based meteorological instrumentation were sited in and around the Payette River Basin, just north of Boise, Idaho. The instrument array included six multi-channel passive radiometers, two Doppler X-band radars, one operational S-band radar, multiple precipitation gauges, regular radiosonde releases, and twelve radiosondes coupled with vibrating wire sondes for super-cooled liquid water content profiling. Two instrumented research aircraft flew over one-hundred and thirty combined hours during twenty-four intensive operations periods from January to March of 2017. During this field campaign, a variety of in-flight icing conditions were sampled, including homogeneous small and large drops, mixed-phase, graupel, icing in stratiform and convective environments, and a few null icing cases.

In this study, data from the 2DS particle size/imaging probe on board the University of Wyoming King Air aircraft were categorized as either liquid or solid phase water with a shape classification algorithm and binned by size in 10 micron increments up to 2.5 millimeters in particle diameter. Data from takeoff and approach maneuvers were excluded from the study. Liquid water content (LWC) was calculated from the 2DS particle size distributions and compared with other LWC probes to ensure continuity of measurements. RadIA interest values from 17 cases were matched to statistical measures of the solid/liquid particle size distributions (such as maximum particle diameter) and values of liquid water content from research aircraft flight segments. A statistical analysis will be presented demonstrating how

well the radar-based interest fields correlate to known small-drop, large-drop, and mixed-phase conditions.

Results from one case had over two hours of data divided into 276 periods of 30-second averaged flight data. The 2D-S instrument detected supercooled liquid in 193 periods (70% of the total). 70% of these 193 liquid periods had a RadIA interest value, and 68% of the 193 liquid periods had a RadIA large-drop value above the 0.60 interest threshold for the presence of large supercooled drops. 30% of the liquid periods were missed by RadIA. The 2D-S detected no liquid in 83 30-second average periods (30% of the total periods). RadIA had no interest in 56 of the 83 no-liquid periods (POD-N = 67%) and a corresponding FAR of 33%. The RadIA large drop interest value only explained 8% of the variance in the 99% percentile of supercooled large drop diameter, but correctly identified the presence of these drops in 132 of 134 time periods (98.5%).

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