Simulations to Establish Design Requirements for Forward-Looking Millimeter-Wave Radiometers on Airborne Platforms for Detection of Super-Cooled Liquid Water in Clouds

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Super-cooled liquid water in clouds has been recognized for decades as posing a serious threat to aviation through aircraft icing. Specifically, super-cooled liquid water can condense on airplane wings and helicopter rotors, causing a change in wing geometry and increasing the probability of unintended aerodynamic behavior. Such potential behavior includes loss of lift, increased drag, uncontrolled pitch and yaw in an aircraft as well as stalling of aircraft and helicopters. In this context, we consider small aircraft and helicopter operations when preventive treatment with de-icing fluids is not practical or possible. To prevent harmful effects of aircraft icing, currently the standard practice for helicopters is to avoid flying in weather conditions where clouds with super-cooled liquid water may be present. This often creates no-fly zones over large areas where super-cooled liquid water in clouds might not necessarily be present. This also leads to an inefficient use of resources, and access to some of these areas needing helicopter service is unavailable.

An improved solution requires increased knowledge of the presence or absence of super-cooled liquid water in clouds. To accomplish this, we propose deployment of forward-looking millimeter-wave radiometers on aircraft or helicopter platforms. Millimeter-wave radiometers are particularly well suited for airborne remote sensing applications due to their small form factors, low power consumption and small antenna apertures, as compared to those at lower microwave frequencies. Millimeter-wave radiometers, along with appropriate processing algorithms, are proposed to predict the presence or absence of super-cooled liquid water in clouds, as well as to estimate the distance of these clouds from the airborne platform. In this way, knowledge provided in near real-time by the sensor could direct the airborne platform to avoid clouds that may contain super-cooled liquid water as well as to continue flying in cases where super-cooled liquid water is not present. This could potentially increase access to large swaths of airspace that are currently inaccessible to helicopters and small aircraft. To design the proposed millimeter-wave radiometer, it is necessary to determine the requirements for channel frequencies, bandwidths, sampling time and radiometric resolutions for such a forward-looking sensor.

To model various atmospheric scenarios and estimate the best radiometer frequency ranges and requirements based on their sensitivity to super-cooled liquid water in clouds, radiative transfer models are constructed using the Atmospheric Radiative Transfer Simulator (ARTS). These models simulate observed brightness temperatures, which can be used to determine the capability of such a millimeter-wave radiometer to distinguish between harmful super-cooled liquid water droplets and relatively harmless ice particles, as well as to estimate the distance to the cloud of interest. These simulations are optimized to approximate realistic atmospheric conditions, which may include a mixture of water droplets and ice particles of different shapes, as well as a variety of water droplet and ice particle size distributions.