Feasibility study of a Microwave Radiometer for Aviation Safety - MRAS

Marian Klein[1*], Vladimir Irisov[1], Albin J. Gasiewski[2]

(1) Boulder Environmental Sciences and Technology, http://www.boulderest.com
(2) University of Colorado, Center for Environmental Technology, Boulder, CO

Aircraft icing is a hazardous meteorological process resulting from the near-instantaneous freezing of supercooled liquid (SCL) droplets upon their impact with either an airframe, propeller, or rotor surface. The presence of SCL along a flight path, particularly large drops that are more prone to contact with the aircraft, results in a high risk of life and assets due to loss of aerodynamic lift, increased drag, and reduced power. Boulder Environmental Sciences and Technology (BEST) has completed key analyses and basic design studies of a practical airborne passive microwave sensor for detection and avoidance of hazardous aircraft icing conditions.

In order to develop an ensemble of realistic cases of atmospheric states with supercooled liquid (SCL) conditions, an extensive set of diverse profiles from the European Centre for Medium-Range Weather Forecasts (ECMWF) numerical weather model (ECMWF, 2014) were used. A total of 4049 profiles containing SCL were found among 5000 profiles of the data set containing cloud condensate. These profiles were used for evaluation of the sensitivity of simulated microwave radiometer observations to the presence of the SCL in the atmosphere over 59 preselected radiometric channels between 6 and 234 GHz.

Additional analysis was focused on optimal channel selection using a scattering-based radiative transfer model and statistically realistic cloud profiles containing either cloud ice (which is benign for flight) or SCL. The model results along with SWaP-C limitations on the radiometer yielded a set of 16 channels suitable for the BEST MRAS sensor operating within three radiometric bands (~70, ~150, and ~230 GHz). Using a large number of permuted subsets of these channels an optimal binary inverse covariance detection algorithm was developed based on a likelihood ratio test to determine the probabilities of detection and false alarm, along with the receiver operating characteristics for icing detection. This analysis further narrowed the range of useful channel sets through quantitative ranking of their detection performances. Initial evaluation of the addition of a single frequency radar band to MRAS for primarily providing range information was also studied.

The results confirm the ability of the 16-channel MRAS set and several subsets to provide adequate advance warning of in flight icing conditions under a typical flight scenario, and that an added radar band would both provide range information and further improve detection. The effort identified a practical design suitable for use on platforms such as helicopters, tilt rotorcraft, and turbo propeller aircraft operating in critical missions or military and commercial platforms. The primary conclusion of the detection study is that most reliable information about aircraft icing hazard potential derives from the polarization signal observed using a passive microwave sensor.