Aircraft Icing Potential and Ice- and Mixed-phase Cloud Microphysics
Victoria A. Walker and Dorothea Ivanova
Embry-Riddle Aeronautical University, Prescott, AZ 86301

Abstract
Cold cloud interactions with aircrafts that fly through them require knowledge of cloud microphysics. Aircrafts must be designed to fly into supercooled clouds, or they must avoid those clouds in order to prevent problems associated with airframe and engine icing. De-icing or anti-icing systems must be engineered to withstand reasonable extremes in terms of ice water content (IWC), supercooled liquid water content (LWC), ice particle size distributions (SDs), and temperature. The aircraft design or certification envelopes (FAR 25, Appendix C; Federal Aviation Administration, 1999) were developed before the advent of modern cloud physics instrumentation. In the case of ice and mixed-phase clouds, data from the aircraft measurements during recent field campaign suggest that cloud temperature is one of the main parameters governing cloud microstructure, the size distributions, and the current icing potential (CIP). This study may help improve airplane icing prediction through better understanding of the ice microphysical properties.

Introduction
Ice and mixed phase clouds have an important impact on aviation. In-flight icing is a significant threat to aircraft, resulting in loss of lift, reduced airspeed, and, in some cases, loss of control (Bernstein et al. 2005). This threat manifests through a significant number of accidents. Based on recent data, freezing precipitation often forms through nonclassical formation mechanisms, without requiring the formation of a melting layer. However these relationships are still not thoroughly studied. The focus of this research is to help improve our understanding of winter aircraft icing occurrence through parameterizations of the ice microphysical cloud properties. The study explores possible relationships between different ice crystals size distributions, and airplane icing. The study utilizes data for different ice crystal size spectra in winter cold clouds, and data for the corresponding airplane icing occurrences.

Fig.1. Conceptual diagram. Precipitation types: snow (asterisks), rain (large open circles), and freezing drizzle (small gray circles), from Bernstein et al., 2005.

Fig.2. Icing accumulates while in cloud. Photo credit: NASA Glenn Research Center.

Fig.3. After ascending above cloud. Photo credit: NASA Glenn Research Center.

Canadian Research on Aircraft In-Flight Icing and Russian Research on Ground Icing:
- Supercooled large drops (SLD) often coexist with ice crystals in mixed-phase environments. Approximately 80% of SLD observed during the Canadian Freezing Drizzle Experiment (CFDE) were formed without requiring the classical formation mechanism – ice particles falling through a melting layer (Isaac G. A. et al., 2001).
Instrumentation

Fig. 4. a)–h) presents instruments and ice crystal data from several Department of Energy (DoE) – Atmospheric Radiation Measurements (ARM) campaigns. Fig. 4a), b), and c) show a Cloud Droplet Probe (CDP), Cloud Aerosol Precipitation Spectrometer (CAPS), and Cloud Particle Imager (CPI). CDP measures particles from 2 to 50 µm in diameter, CAPS measures particles from 0.35 to 1550 µm in diameter, and CPI provides high-resolution images of ice crystals as particles pass through a sample volume. Fig. 4d) and f) depict various ice crystal distributions. The images were taken using the DRI Automated Replicator System from data collected on April 19th 1994, an Intensive Observation Period (IOP) of the DoE - ARM project. Fig. 4e), g) and h) are pictures of the Citation - ASCII DOE-ARM research aircraft with instruments mounted under the wings.

Fig. 5. Difference between microphysics and size distributions of Mid-latitude and Tropical ice- and mixed-phase cloud as a result of our analysis. Small ice crystals (diameter < 100 micrometers) enhancement with decreasing temperature T for tropical anvil cirrus; Opposite for mid-latitude cirrus. Both ice crystals size distributions schemes are based on 2DC and FSSP instruments in-flight measurements.
Recommendations for Future Research

- Since 80% of the SLD observed in-flight during CFDE were formed through the non-classical mechanism, further research is crucial for understanding the relation between cloud microphysics, size distributions, temperature, and ice water content (IWC) in ice- and mixed-phase clouds.

- Supercooled water can often co-exist with ice crystals in mixed-phase clouds, therefore supercooled drop coalescence is important and needs further studies together with ice crystal aggregation and accretion.

- Aircraft – particle interactions such as collapse, erosion, and structural breakup upon impact should be investigated during ice aggregation, SLD accretion and mixed accretion events.

References


