3.2 RECENT SUCCESS STORIES FROM THE INFLIGHT ICING PDT

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I. INTRODUCTION

The FAA's Aviation Weather Research Program (AWRP) supports Product Development Teams (PDTs) addressing a variety of aviation weather hazards. The InFlight Icing PDT (IFIPDT) primarily addresses safety-related issues, but improvements in icing detection and diagnosis will also effect efficiency of the National Airspace System. This paper describes recent successes of the IFIPDT.

2. BACKGROUND

In-flight icing continues to be a cause or factor in numerous fatal aircraft accidents, and creates significant disruption to domestic flight operations. Improvements in detection, diagnosis and forecasting of hazardous icing are coming, and this paper will describe recent successes in this area due to the efforts of the AWRP's IFIPDT.

The roles of the IFIPDT are to provide guidance to the FAA on in-flight icing, prepare annual plans for research and development, monitor progress on the plan and provide reports and briefings to the AWRP and coordinate FAA-sponsored research and development activities with those of other organizations.

The overall goal of the IFIPDT is a gridded depiction of inflight icing with the highest possible temporal and spatial resolution, based on integration of operational model output with real-time sensor data. With increased model resolution, better bandwidth availability, and faster data integration techniques, we expect to achieve a depiction of the actual icing hazard to as fine as 5 km over North America. In data-sparse regions (polar regions, ocean routes, etc.) resolution probably will be degraded depending on available data inputs. Collaboration with the user community, as well as aerodynamicists, is needed to establish the scales required for icing hazard depiction and to determine the appropriate scales based on airplane response to the environment.

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The IFIPDT also identifies potential operational impacts and training/education needs as each icing product enhancement is introduced to end-users. To support product development, the IFIPDT pursues directed research into environmental characterization, storm structure, microphysics, sensor design and response, model improvements, and accretion physics needed to ensure necessary improvement of products.

The IFIPDT is organized into product development and applied research activities. Product development includes model enhancements, algorithms, and special products suited for Alaska. Applied research includes progress in remote sensing techniques (in collaboration with the Advanced Weather Radar Techniques PDT) and in icing physics, which includes cloud and storm structure and characterization. There is considerable interaction with other PDTs, aviation end-users, and organizations responsible for numerical weather prediction model development (such as NCEP and NOAA).

Our primary product is the CIP (Current icing Potential, see Bernstein et al., 2005), founded on the idea that no single piece of information, currently available operationally, can reveal characteristics of inflight icing conditions needed by end-users. Various sources of information yield clues about the icing environment --- where icing does and does not reside, and the expected severity (Fig. 1).

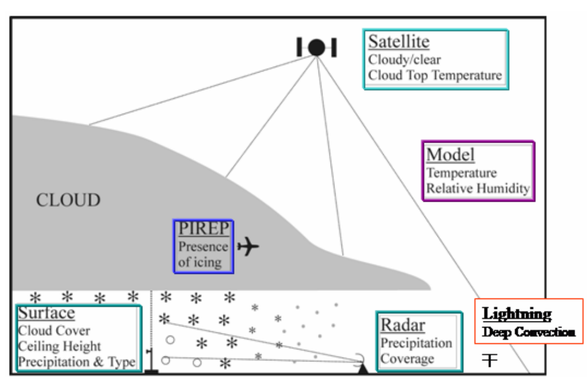


Figure 1: Data sets ingested into CIP.

By understanding the messages conveyed by these bits of information, and combining them intelligently using fuzzy logic techniques, we construct a detailed map of the icing environment. There is a forecast version, FIP (Forecast Icing Potential), which uses model-produced surrogates for the observations, and Alaska versions of both CIP and FIP (CIP-AK and FIP-AK).

3. TECHNOLOGY TRANSFER

The IFIPDT's main path to implementation is through AWC via the Aviation Weather Technology Transfer (AWTT) process. This process involves the AWTT Board, with membership chosen from FAA, NWS, and other interested organizations. The Board approves aviation weather products under development for three levels of use: test (D2, very limited availability); experimental (D3, prototype products publicly available for user comment); and operational (D4, publicly available to all aviation decision-makers). The process is described by Knapp et al. (2002). The calendar for future upgrades and approvals of IFIPDT-developed products is shown in Table 1.

Table 1: AWTT Board Decision Timetable for IFIPDT Products

AWTT DECISION	D3	D4
CIP	Nov'00	Dec'01
FIP	May'01	Jun'03
CIP-SLD	Jun'02	Jun'02
FIP-SLD	Nov'04	May'05
CIP Severity	May'04	Aug'06
FIP Severity	May'05	Aug'07
CIP-AK	Nov'03	Nov'06
FIP-AK	Nov'04	FY07
Terminal CIP	May'04	FY08

Some users desire different outputs than AWC is currently able or planning to generate. This is particularly pertinent for those end-users who want either route-or aircraft-specific products, or finer time and space scales than provided by either the current AIRMETs or the 20-km resolution of the CIP/FIP. The Aviation Digital Data Service (ADDS) team is working on Jade (a revision of Java) applets that will allow users to designate and store multiple routes; this will solve the problem of tedious route input into the Flight Path Tool every time they need a forecast for a route they routinely fly. Airlines may also generate their own products in-house, or be provided products the IFIPDT on a test and evaluation basis. Weather product vendors may enter into the distribution system by reformatting and/or redistributing the products available on ADDS (they may also produce their own in-house products independently). These products may also be tailored for in-cockpit use by various datalinking programs planned or underway.

4. SUCCESS!

4.1 High-Resolution CIP

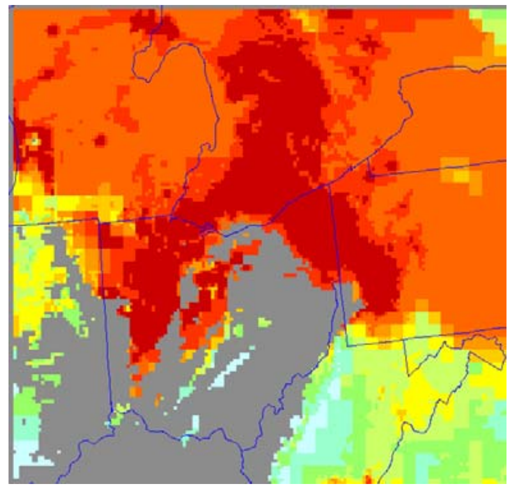


Figure 2: Example of HRCIP composite product for 1700 UTC, 2 Dec'04. Scale indicates likelihood of icing from light blue (low) through red (high).

From January through April 2005, the IFIPDT ran a high resolution version of CIP, or HRCIP, over the Great Lakes area (Fig. 2). This grid was available every 15-30 min and had 5-km horizontal spacing, taking greater advantage of the increased resolution available from satellite and radar data sets. The location was chosen to cover the area flown by the NASA Glenn Research Center Twin Otter, and to cover most of the TAMDAR (Moninger et al., 2003) Great Lakes Fleet Experiment.

The results were encouraging in demonstrating the value of a higher resolution product. Details of winter storm structure conducive to icing were more readily visible to developers. The runs also form a solid basis for testing improvements to CIP by inclusion of better radar data sets (NEXRAD Level 2, NSSL 3-D mosaic, vendor layer-averaged reflectivity products) and improved satellite-derived cloud products being developed at NASA Langley, and the TAMDAR icing reports.

4.2 Remote Sensing Hardware

The IFIPDT has supported the design and construction of two new remote sensing systems for inflight icing detection. GRIDS, the Ground-based Remote Icing Detection System, was supported by FAA and NOAA. The system consists of a K_a-band radar in a fixed-staring mode at at 40^o elevation angle. GRIDS is based on a 45^o slantwise polarization which was found (through previous field studies, see Reinking et al., 2000) to have optimal capability for discriminating between freezing drizzle and snow. For icing conditions not related to freezing drizzle, data from a dual-channel radiometer is incorporated and used, with the cloud radar, to estimate likely areas of icing conditions.

SPolKa was developed jointly by the FAA and Naitonal Science Foundation. It is based on the NSF's SPol radar, an S-band fully polarized Doppler radar used for cloud physics research. A K_a-band radar was attached to the S-band antenna and adjusted to have the same viewing angle and similar beamwidth to the S-band radar. The K_a-band signal is attenuated by liquid water in its path (see Martner et al., 1993 and Vivekanandan et al., 2001) whereas the S-band signal is not; thus in the fully-scanning system a map of liquid water content should be achievable with corrections for Mie scattering.

GRIDS was included as part of the Alliance Icing Research Study field effort (AIRS-2) near Montreal, Canada, in late 2003. Both GRIDS and SPolKa were tested during WISP04 near Boulder, CO. Results from both deployments showed promise in determining locations of icing conditions and estimating severity (Schneider et al., 2004).

4.3 Model Microphysics Parameterizations

The IFIPDT has a major role in upgrading microphysics parameterizations in the MM5. These are subsequently transferred to operations via incorporation into the RUC, and in the future, the WRF models. The last RUC release, RUC-13, in spring 2005, included new microphysics and mixing parameterizations that already appear to have improved cloud fields; these are described by Thompson et al. (2004).

IFIPDT investigators are currently analyzing aerosol and cloud physics data from recent IMPROVE and AIRS-2 field campaigns. These data sets are being used to improve the size distributions of hydrometeors in the models to better predict both precipitation and the cloud water that remains and poses an icing hazard.

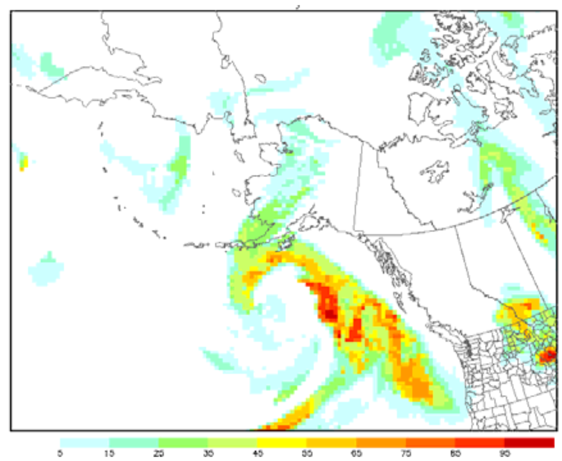
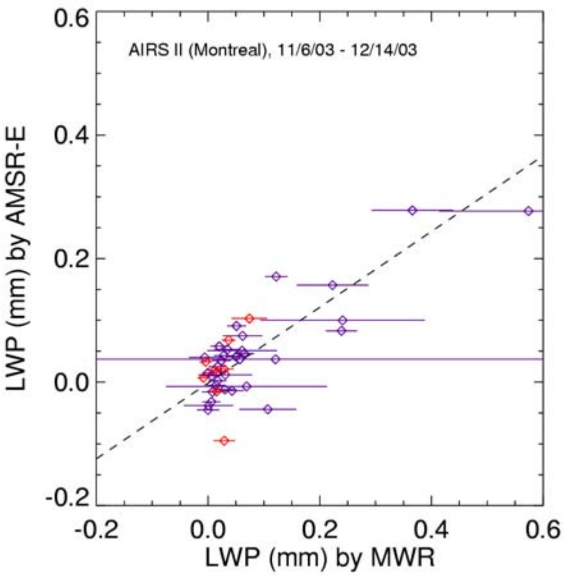


Figure 3: CIP-AK for 1900 UTC, 20 Oct 2005 at 12,000 ft MSL. Color scale at bottom is uncalibrated icing potential.

4.4 Alaska

Our Alaskan versions of CIP and FIP, CIP/FIP-AK, run hourly on the 45-km Eta model (Fig. 3). They incorporate METARs, GOES-10 satellite imagery and PIREPs but at this time they are not using local NEXRAD or polar orbiter satellite data. The products are designated experimental and may be viewed on experimental ADDS. NCEP has plans to replace this version of the Eta in Spring 2006 with a new mesoscale model to cover all of North America, and eventually the WRF-RR (Weather Research and Forecast Rapid Refresh) model will cover approximately the same domain. This highlights an opportunity (or problem) for the IFIPDT: to keep the diagnosis and forecast algorithms in step with model upgrades. While these upgrades are intended to improve forecasts of relevant parameters such as temperature, humidity and precipitation, the changes effect the final algorithm output. A nearly continuous development and verification process is required for all our products to keep them current.



4.5 POES

Figure 4. Comparisons of all AMSR-E and MWR LWP retrieval results for 6 Nov – 14 Dec 2003 during AIRS-2. Error bars for MWR retrieval results indicate LWP variability over a two-hour period around the time of the AMSR-E overpass.

Retreival of liquid water path (LWP) over water surfaces is a relatively easy problem. The IFIPDT has produced reasonable results for LWP retrieval over land, which has varying transmissivity and is a more difficult retrieval. Comparisons of retrieved LWP with ground-based measurements look promising (Fig. 4). This information has potential for inclusion into CIP for estimating total liquid amounts in clouds.

4.6 User Training = Smarter Users

We believe that training users both in basic principles of icing weather and in use of new products will enhance aviation safety. NASA Glenn Research Center recently completed several training modules for pilots and dispatchers focusing on SLD and tailplane icing (see http://icebox.grc.nasa.gov for details). IFIPDT members contributed meteorological background for these modules. One of the team members also has participated in pilot classroom training at University of Tennessee Space Sciences Institute, and we hope to continue these efforts in the future.

4.7 Forecast Support = Smarter Forecasters

IFIPDT members have supplied forecasts of icing conditions for various field projects, most recently the Alliance Icing Research Study (AIRS-2) and NASA Glenn icing flight missions (Fig 5). These exercises keep our skills fresh, introduce us to new products and help us learn how to use them, as well as provide a service to the icing community. In turn we receive immediate feedback on our prediction skills, and the data sets from the research aircraft and other instruments assist our product development. The most recent example of forecaster/researcher experience being translated into an improved algorithm is our new CIP Severity algorithm, described by Bernstein et al. (2006).

Figure 5: The NASA Glenn Twin Otter Research Aircraft after a successful icing mission.

4.8 Icing Climatology

Due to a lack of regular, direct measurements, little information is available about the frequency, spatial and temporal distribution of icing conditions aloft, including supercooled large drops (SLD). Research aircraft provide in-situ observations of these conditions, but the sample set is small and can be biased. Other techniques must be used to create a more unbiased climatology. The presence and absence of icing and SLD conditions can be inferred using surface weather observations in conjunction with vertical profiles of temperature and moisture. Such climatologies were created for both North America and Europe using ~15 years of coincident, 12-h surface weather reports and balloon-borne soundings. Over North America, icing conditions were found to be most common along the Pacific coast from Alaska to Oregon, and in a large swath from the High Plains to the Canadian Maritimes. For SLD, the western maximum was more pronounced, but a secondary maximum was found in the east. The primary European icing and SLD maxima were found over the United Kingdom, Iceland, western Scandinavia and around northern Germany. Prime locations migrated seasonally. Most SLD events appeared to occur <4km MSL, were <1km deep and were formed via the collision-coalescence process.

5. SUMMARY

The IFIPDT has made substantial progress in product development, from applied weather research through dissemination of user-friendly products. We have also enjoyed our many collaborations with fellow icing weather researchers around the world.

ACKNOWLEDGEMENTS

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