

## **In-Flight Icing Technical Interchange Meeting (TIM)**

25-26 February 2015 (Day One)

UCAR Ocean Leadership Facility Conference Room

### **Meeting Attendees**

(Roster to be provided by NCAR via ftp website)

### **Agenda**

See attachment – Informational Package

### **Preface**

This is the first In-flight Icing (IFI) TIM type conference. The forum was divided into two days with a wrap-up session at the end of each day. The summary of minutes below is a brief version of the most pertinent statements to keep the comprehensive report to reasonable length. The presentations will be available on NCAR ftp website to allow people to review the slides along with the minutes noted here.

### **Introduction**

There was a round table introduction of all conference attendees. It was announced that Marcia Politovich is retiring at the end of March 2015 after 26+ years at NCAR and 35 years in icing research. There was a high-level description of how the NCAR will restructure their leadership management.

### **Opening Talk: Expectations, Background and Goals of TIM (Dino Rovito)**

**Background:** Icing is a major hazard to aviation especially General Aviation (GA).

**Expectations:** The FAA really appreciates the user community coming together to provide their icing needs and requirements. It was emphasized that the FAA Aviation Weather Research Program (AWRP) was open to all ideas and concerns. All participants were asked to provide ideas and their experiences to help shape and benefit future FAA Research and Development (R&D) that is aligned with Next Generation Air Transportation System (NextGen) requirements and Operational Improvements (OI). It was also emphasized that participant inputs were not just limited to R&D but all icing issues and/or concerns.

**Goals:** Enhance aviation products and services and determine future Levels of Efforts (LOE). Need to minimize weather (Wx) impacts through applied research and development (R&D) in support of the NextGen requirements/OI. Bottom line is there needs to be more common user inputs from the National Airspace System (NAS) domain to enable enhance harmonization of icing information for operators (ATC/planners/users) to effectively utilize. Explore the possibility of increasing the cooperative efforts between government and industry.

There is collaborative work ongoing between FAA and NOAA NWS to transition legacy products and services, and a LOE toward new research products and services to increase aviation safety and operational efficiency.

**FAA Projects:** An explanation was made on FAAAWRP projects to include all Aviation Hazardous Service Providers (AHSP) and assessments. FAA Flight Standards (AFS) is driving R&D via new FAA regulations (new rule issued 04 November 2014) addressing Super-cooled Liquid Droplet (SLD) icing conditions and what the research plan is moving forward. Three major FAA icing weather research areas are ongoing: (1) In-Flight Icing (IFI): improvements to current CIP/FIP High Resolution products; development of a new diagnosis and forecast product for Alaska (Icing Product Alaska); development of an enhanced diagnosis and forecast product which includes Liquid Water Content (LWC), Drop size distribution, and temperature weather parameters; (2) Terminal Area Icing Weather Information for NextGen (TAIWIN): Development of terminal area icing analysis and forecast in hi-resolution from ground De-icing operations extending skyward within the terminal sphere; (3) High Altitude Turbine Engine Icing (HIWC): Investigating root causes into and development of a diagnosis and forecast for engine turbine stall and blade damage from high altitude ice crystal ingestion in areas of deep convection.

### **Perspectives and Overviews Session**

#### **NTSB Safety - Don Eick**

The NTSB looks into man-machine-environment interaction with accidents. An accident was discussed involving freezing rain (FZRA)/mist/fog. The NTSB needs to get into the pilot's head: (1) what the pilot was thinking, (2) how the pilot processed the information he/she knew or was receiving, (3) how the pilot handled the aircraft, and (4), what were the plane's anti-icing equipment capabilities and were those capabilities turned on, etc. Most common cause of fatal accidents is loss of control (LOC), with a significant part occurring in Instrument Meteorological Conditions (IMC). In investigation icing related accident, they look for physical evidence of icing, but this is often lacking upon arrival on the scene of an accident due to splintered and charred wreckage – almost never see icing on airfoil at the scene. NTSB looks at pilot reports to ATC, other pilots operating in the same area and conditions, witness statements, performance analysis and other radar data at that time, and current local weather conditions for favorable conditions for icing.

The NTSB Query System was highlighted. There were ~19,000 accidents from 2000-2011 or about 1,500 on average per year. Part 91 (GA) weather related events accounted for 29% or 435 accidents with icing Wx related incidences only accounting for 3% or 13 accidents. The public can go on the weblink:

<http://www.nts.gov/layouts/ntsb.aviation/index.aspx>

IFI accidents infer carburetor ice, Loss of Control (LOC) (stalled airplane), Pitot tube icing, or control surface icing, etc.

Top-level 2010 icing accidents information was provided with the events involving fatalities critical for investigating what was the bottom line cause for each (some Part 135 and 121). Running totals were shown (events and # of fatalities) from 2010 through 2014 to include some rare Helicopter Emergency Medical Services (HEMS) accidents since they are restricted to operate near suspicious icing conditions. Summertime accidents are usually associated with related weather impacts from thunderstorms. When there are no icing conditions being reported or warnings expected the pilot may not turn on icing detection sensors on-board the aircraft prior to beginning of flight and this could contribute to fatal results later. The number of icing events (2010-2014) were shown among the various aircraft for Public, and Parts 121, 135 and 91.

## **FAA Icing Steering Committee (ISC) – Tom Bond**

The mission of ISC is to assess how the FAA is handling aircraft icing conditions through their icing strategy. Their mission is charged by the FAA Aviation Safety Organization (AVS) and uses a host of various icing experts focusing on current certification issues, policy and guidance for R&D investment to support continued Operational Strategy, Policy and Regulations, Technical Standards, and near and far-term certifications. The next annual ISC meeting is in Washington, DC in May to review winter operations issues and areas of policy and guidance that need coordination.

ISC participants have grown over the last 3-4 years as the R&D has expanded in support of the FAA Icing Strategy. There has been an increase in R&D coordinate from Aviation Safety and NextGen folks to leverage resources in aviation safety icing and support AWRP icing weather R&D. The ISC addresses key issues for: (1) Risks to aviation safety in the current NAS, (2) new rulemaking, revision/updating of advisory materials, and standards development, (3) potential safety hazards, (4) changing operations – NextGen operating capabilities, and (5) preparations for emerging technologies. ISC has a comprehensive vision of into aviation icing issues.

The ISC has closed out the 1996 FAA Icing plan by providing a record of what the FAA did with Alaska (AK) icing activities and issues. A new up-to-date FAA Icing Plan was completed at end of FY 2012. Both the 1996 FAA Icing Plan close out document and the 2012 New FAA Icing Plan are currently available only through e-mail distribution (contact [tom.bond@faa.gov](mailto:tom.bond@faa.gov)) due to the FAA website not being fully functional yet to view the Plan. ISC's current effort is to reorganize and streamline the lengthy 2012 FAA Icing Plan by reducing the content at beginning of plan and go into operational, certification, and R&D details much sooner. This effort is a result of reviewer's comments to change R&D and other task reporting format and make the FAA icing activities (Section 6) and Appendix A format an easier read to track and understand.

Other ISC ongoing work involves Gap Analysis to assess current Icing Plan capabilities and determine if upcoming operational needs are adequately addressed. This includes about half dozen different arenas involving dozens of issues from certification, advisory material and training to operational capabilities, compliance methods, research activities to meet NextGen initial to mid-term requirements partly through Identify current and near-term technology changes and the ability to address their influences on the NAS, and cost concerns.

In summary, the significant areas of R&D in icing weather are focused on improvements to icing conditions and forecast for: (1) Terminal area, (2) addressing Super-cooled Liquid Droplets (SLD) and ice crystal new regulations, and (3) supporting improvements to winter weather operations to maintain/enhance National Airspace System through-put.

## **General Aviation Users - Paul Deres**

AOPA's Air Safety Institute (ASI) was established in 1950. The ASI is a non-profit and charitable division of AOPA foundation. This division offers free safety education to pilots with over 300 videos and other training material. An audience of more than 2M viewers have seen their products and listened to their seminars.

The Institute's purpose is to better educate general aviation aircraft and helicopter operators to reduce fatalities. Statistics from 2003-2012 accidents showed inadequate flight planning, pilots operating in areas of icing without the proper aircraft de-icing equipment, and pilots who did not escape the icing areas once they encountered despite having operating de-icing equipment.

The free education outreach videos ASI offers will hopefully help pilots recognize and improve their skills to take corrective actions. There's an online course funded by NWS on basic theory, icing hazards, tips on avoiding these areas, and exit strategies. Also, there is an "Ice Week" similar to Shark or Hurricane Week where website videos focus on encountering icing scenarios, quizzes, articles and blogs.

An accident case study on airframe icing was briefed. NTSB post-accident analysis of the weather conditions showed the clear likelihood of severe icing conditions. The algorithms used by the NWS Aviation Weather Center to predict icing conditions showed only a low probability of icing in the area, and, in the absence of PIREPs to the contrary, an icing forecast (no AIRMET/SIGMET/PIREP) was not triggered. Despite the pilot's flight briefing fully conformed to Federal Aviation Administration standards and adequately covered the observed and forecast weather conditions, once an operator enters these unexpected conditions better pilot decisions are critical to avoid an accident. This is where this free education is so valuable. NTSB points out in many icing encountered cases the pilot's in-flight loss of control following an inadvertent encounter with un-forecasted severe icing conditions is primary cause of the accident. Many GA accident cases show that the pilots never declared an emergency. It is also interesting to see that even if onboard aircraft have inertial separators, many times the pilots have these sensors turned "off." These inadvertent actions maybe because the pilots do not see any icing in the pre-flight forecast along their route and do not want to take the chance and burn out the separator equipment if they were to forget to turn it off upon landing. This is a sample scenario how AOPA ASI's free education can be a most valuable resource to reach the less experienced pilots that need it most to sharpen their skills on all facets of the aircraft.

There are several factors that could be improved to help out pilots. The NOAA AWC site infrastructure often leads to information overload for most pilots while downloads occur too slowly. A faster download would ease time constraints for pilots to thoroughly complete their checklist. The information is often not filtered enough ahead-of-time for most non-weather savvy pilots to comprehend correctly its intended meaning. All product and service support tools should be converted to local time vice UTC to mitigate pilots misinterpreting critical time oriented forecasts.

Discussions followed concerning the Current Icing Product/Forecast Icing Product (CIP/FIP) displays. NOAA's Current Icing Product is a supplementary weather product that provides a graphical view of the current icing environment. The CIP is updated hourly and displays icing severity in five categories consistent with other weather reports: none, trace, light, moderate, and heavy. Further discussions focused on the CIP displays at the 5K, 7K and 9Kft levels for icing or no icing – PIREPS are always desired to confirm real-time conditions. An Atlanta Center En-route Controller stated they are pushing hard to get PIREPS. An improved CIP/FIP output is critical and research community needs more user feedback. Advance research in dual-pol radar detection for SLD is promising but NOAA/NWS recent report findings shows there is still a notable lack of mountain region icing forecasts, so crucial for GA operations especially in Alaska.

John provided his thoughts on Icing from a pilot's perspective. John is well qualified to do such, a pilot for 49 years with over 23,000 hours of large and small plane flying experience. He brought lively character with his presentation in describing the cockpit panel on the wide-spectrum of aircraft anti-icing equipment: window heating, power test probe, wing anti-icing (heated airfoils) and engine anti-icing. For Cessna 172s' it's whether the Pitot tube heat switch is turned on or more times than not is turned off. Current pilot training is for IFI and ground de-icing not situational maneuvers and procedures when caught within unexpected icing conditions – one initial bad decision leads to another and another which leads to an accident. The challenge is to provide adequate IFI data to all within this flying spectrum for pre-flight planning and inflight updates and assist these pilots to help themselves better when caught in these trouble conditions.

Pilots prefer to have full available engine power during critical climb slope. But when the engine anti-icing equipment is activated there is a huge power to weight ratio constraint that allows for a climb rate out of icing cloud layers of more than 2500ft/minute. But most reasonable pilots flying smaller aircraft would never consider taking off to begin with if icing conditions were a possibility along their flight path. Generally, GA pilot see onboard equipment as expensive, ~\$50K, and if the probes are turned on upon takeoff but not turned off upon landing or over used in-flight they could burn-out and need replacement. It was emphasized that this de-icing equipment is there to help mitigate wing surface icing not resolve the icing conditions of which the aircraft continues to fly within. We will not resolve this today.

John focused on NOAA JAVA tools that he personally views as very useful but under-used and misunderstood. The NOAA AWC ADDS website JAVA flight path tools application is extremely useful but needs to have a faster launch to better serve the aviation community in near real-time to include possible inflight access via ADS-B IN. Better tutorials on how to use ice charts are needed to help pilots improve skills to utilize all the product tools most efficiently; the altitude and time slide rulers to better get a handle on the view of the real-world conditions. The time slider helps to assess a probability of an event and is based upon Zulu time. There is a zoom-in tool capability on specific area of interest as well. Better manipulation of these less used "e- tools" within the webpage would help get provide more details of ice data within layers from overlays, icing condition probabilities and reports to the pilots via ADS-B IN, XM satellite, etc., along with icing PIREPS being available from the ARTCC. All of these capabilities would help paint a more complete picture of the real-time weather picture in 4D (x,y,z,t) to pilots to more easily scan and read the spread of real-time inflight icing condition reports.

The challenge is to bridge the ATC training/support help with the light plane pilot who gets caught flying in areas where they are picking up airfoil icing and asking ATC for help. Often these GA pilots have their Pitot tube heat turned off. The Pitot tube heat needs to be turned on before you get to visible moisture (cloud most of the time) since most small AK aircraft do not have power to weight ratio to overcome establishing airfoil icing.

Though ground De-Icing is outside the purview of this meeting it was mentioned that with existing icing conditions there's ground anti-icing operations and holdover times. The stories of small planes having heated hangers is a fallacy.

Recommended a good book for all pilots to read is "Weather Flying" by Robert Buck (5<sup>th</sup> edition 2013).

#### **Brief Question and Answer Period**

Matt Strahan (NOAA AWC) noted that with JAVA updates there is often derivative malfunctions with other tools, etc. There are unintended consequences to deal with, have to consider “what’s the penalty”, it is a balancing act. Darrell Baumgardner (Droplet Measurement Technologies) stated there are minimal problems with transport planes with de-icing equipment in comparison to small or GA planes where pilots worry about over use of or burning tube wiring up after they forget to turn probe off upon landing. There are 3 heating elements in the Pitot tube but if they are all not working then you are not getting the type of de-icing mechanics and lead into a false sense of safety. Current manufacturers are getting smarter with their design more similar to car headlights going out if engine is shut down to save the battery. Bob Showalter stated there needs to be a better job done to interface with IPAD technology in the cockpit.

## **BREAK**

### **NCEP/AWC: Current and Future Products – Brian Pettegrew presented for Matt Strahan**

There are new products and services (P&S) at AWC. Users are now getting the Collaborative Aviation Wx Statement (CAWS), automated CCFP (convective forecast), Hi-Res AIRMET/SIGMETs that replaced area forecast, better backend ADDS and website. The reason for cessation of the area forecast (FA) was the product was labor intensive and provided low detail. A recent FAA Safety Risk Assessment (SRM) was held for the new Helicopter Emergency Medical Services (HEMS) tool product to allow for a broader audience. The SRM was conducted in December 2014 due to the HEMS converting from java based to Open GeoSpatial. This resulted in a few new requirements for the HEMS Tool prior to its operational release this spring (2015) <http://new.aviationweather.gov/hemst>

These products are displayed on the AWC website and have NWS telecommunications Gateway headers. CAWS starting in early March will be an event driven impact-based product graphics display weather forecast and text format. There will also be a new automated CCFP as an experimental Collaborative Decision Making (CDM) tool for 2, 4, 6 and 8-hr forecast executing with a similar issuing process as before.

CAWS can be distributed or created for aviation operations when the CCFP is not forecasting convective threat in sensible manner (example: possible convection for ORD in next 2-4 hrs) or not in place due to maintenance, etc. The CAWS is focused more on the core 29 terminals especially if needed in place of CCFP at times but can drill down smaller classified terminals. The AWC does have an experimental site setup for viewers to see at <http://www.aviationweather.gov/caws>

In the future there will be upgrades for viewers to participate in chat rooms and can add PERMA a specific link to save settings with bookmarks to access your specific areas of interest and information much faster and can use slider rule to change timeframes for comparison in quick fashion.

Futures plans for operational ADDS includes a transition of the algorithm code over to the new more computational powerful Weather and Climate Operational Supercomputing System (WCOSS) running at NCEP. This major advance in computational efficiency has many benefits such as direct access to input data form the source of the model run vice relying on the data flow from NCEP to AWC to retrieve such data. Other products coming on line in WCOSS include the turbulence product GTG going through implementation test trial in April, followed by a 30-day real-time evaluation in May toward a 15 June

operational implementation. The CIP/FIP v1.2 product will be the next product for WCOSS implementation through the summer months.

Scott Dennstaedt (Foreflight, Inc.) pointed out that there is a need to increase the resolution of cloud top heights (currently too vague). He believes the pilots need cloud height resolution every 2kft vice only every 5kft above 5000 ft. GA pilots need to understand the primary aspects: (1) need to know the dangers ahead of flying in what seems to be in clear air over top of building convective cumulus clouds – icing can occur on airfoil surfaces rapidly, and (2) need to understand the operational input and capability required for AWC to distribute these products onto websites or over telecommunications lines, etc.

#### **Appendix O – Roger Sultan**

The science of Appendix O and its impact on aircraft icing needs to be simplified to understand it better. Roger sited the 1994 American Eagle accident near RoseLawn, Indiana dealing with Super-cooled Large Drop (SLD) (freezing rain (FZRA) and freezing drizzle (FZDZ)) environments. The new Part 25 §25.1420 rule captures this for aircraft less than or equal to 60,000 lbs or aircraft having reversible controls. Three parts to the rule were explained:

- §25.1420 (a) (1): Detect SLD conditions as defined in Appendix O and operate safely while exiting all icing conditions, or
- §25.1420 (a) (2): Operate safely in a selected portion of SLD conditions as defined in Appendix O, detect when the airplane is operating in conditions that exceed the selected portion, and then operate safely while exiting all icing conditions, or
- §25.1420 (a) (3): Operate safely in all the SLD conditions as defined in Appendix O.

All the current aircraft designs which are currently certified for flight in icing and/or have begun the icing certification process for Appendix C will not be subject (grandfathered in) to the new rule despite vulnerabilities and will follow different rules. Based on certification a statement will be placed in the Limitations section of the Airplane Flight Manual (AFM). There will be two more lengthy statements added for international flights. This presentation will not get much in Part 23 vice the Part 25 discussed here.

For Part 91 aircraft, §91.9 states that no person may operate a civil aircraft without complying with the operating limitations specified in the approved Airplane or Rotorcraft Flight Manual, markings, and placards, or as otherwise prescribed by the certificating authority of the country of registry.

Part 25 Appendix O impacts will undertake a thorough investigation into the weather P&S if flying one of these newer aircraft – the percentage of these aircraft falling under this new rule compared to the total number of aircraft out there now is tiny.

TAIWIN is a new FAA endeavor to improve P&S terminal area icing condition analysis and forecast. The SLD rule will impact terminal area icing operations with the consequence of the new rule limiting takeoff and landing in freezing drizzle and/or freezing rain conditions for aircraft that are not certificated to operate in all SLD icing conditions. This will require major changes in identifying freezing precipitation in the terminal area and determining operational capabilities or limitations for these conditions. This leads to operational control for air carriers involving weather minimums, flight planning, airworthiness of aircraft, aircraft loading (weight), fuel requirements (weight balancing against cargo/people) acting in accordance with 121.55 and 122.553 as applicable.

FAA is struggling to determine how to handle pre-dispatch flight planning concerning alternate terminals for aircraft divers. Does the alternate airport need to be outside Appendix O conditions to meet compliance of the AFM or POH limitations and operational specifications applicable to new rule? A decision needs to be made with user feedback toward determining a specified approach distance for pilots to choose between their primary destination or an alternate destination. John Hazlet (RAAC) stated there's precision and non-precision approaches. What happens if suddenly there's icing condition occurring within the approach decision point(s)? Currently, if operating in Part 135 can a pilot continue to IFR approach with updated weather report? Yes, but Roger stated this needs to be addressed. Rick Heuwinkel inquired whether we need to assign additional responsibilities to ATC when these types of situations pop-up within the approach distance criteria. Air Traffic Routing (ATR) limitations try to provide governing guidelines for approaching aircraft types that falling into this distance grey zone within the terminal control arena.

The future plan is for the FAA AFS to continue their support of TAIWIN and coordinate with AFS leadership on pathway forward include drafting an Air Circular (AC) guidance on the operational impacts of §25.1420 and Appendix O. Don Eick (NTSB) stated there needs to be Dispatcher Inspector involved in this process. Roger stated that there is now a qualified Dispatcher (AFS-200) involved.

#### **Question and Answer Period**

Darrell Baumgardner (Droplet Measurement Technologies) asked if pilots can use guidance to tell the difference between ice specific types developing on the wing. Steve Green (FAA Flight Observation Research) stated there are meteorologists working on dual-pol science to detect ice types in clouds. Dual-pol research is also focusing on ground icing within the terminal sphere. The Cessna 208 has built-in airframe design in 4 areas but not where its anti-icing boot equipment is located (OEM - Operational Equipment Manufacturer perspective). There was more discussion on reading the AFM and/or POH to understand and know more on the alternative maneuvering options. Pilots need to be careful and more aware of not flying unintentionally into icing conditions and stay within stable environments that can lead to slower icing accretion rates before they realize such aircraft icing is ongoing, and their required escape route may be an extended distance with similar ice accretion rates leading to significant amounts beyond the wing anti-icing capability to resolve.

Scott Densdaedt asked why terminal (TAF) forecast does not include IFI conditions similar to what Don Eick stated earlier about ICAO and the military providing non-detailed information on altitude and cloud thickness? ICAO does not do this, however the DOD does Icing and turbulence SFC-10K in their TAFs. It was noted that the NWS would need a format change. For the NWS to do this, TIME, MONEY AND TRAINING would be required etc. It would not be a small feat, better to use new guidance that is out their such as the FIP. But the main issue is the TAF would then be ICAO non-compliant. Steve Albersheim (FAA AWD International) responded yes, but this is a tough issue to solve in determining where the correct informational balance and training is needed and provided.

Matt Strahan (NOAA AWC) asked whether NCEP is running an un-calibrated GFS model with CIP/FIP on the global domain vice domestic. This model is running with the icing climatology used from the 2005 format also not calibrated to the new model. Jim Riley (FAA ARD) asked Marcia Politovich (NCAR) whether this new model is still based upon the 2005 format (only using TAMDARs and PIREPS)? For the

global model NCAR does not use TAMDAR data because they do not run the climo model, and they found the model forecast for them does not make a difference for their needs. Steve Abelman stated this was a good discussion topic and this issue will be added to the list of topics for the Panel Discussion on Forecasting Thursday afternoon.

## LUNCH

### Related R&D Efforts Session

#### **High Ice Water Content (HIWC) – Tom Bond**

An international partnership formed in 2005-2006 the HIWC project consisting of 10 organizations/countries. HIWC is an international collaboration and field campaign with the European High Altitude Icing Condition (HAIC) to study ice and convective storm forecast. The first field campaign was conducted in Darwin, Australia during their Monsoon season and spent the first 3-4 years addressing ice crystal environments with aircraft performing hi-speed sampling, probe tip effects and relative humidity (RH) issues. It took several years to work out the bugs to get reliable observations collected up to 42kft and have enough descent results to base possible aircraft design upon. These campaigns will lead to the development of icing weather tools later.

The French Falcon 20 aircraft flew research missions from Darwin for 2-months (mid-January thru mid-March 2014). The target was 150 flight hours in Ice Crystal Icing (ICI) conditions. 20 sensors were outfitted on the aircraft to include an isokinetic probe. Weather conditions were hot/humid, 6 days on one day off. The daily schedule involved the current Wx observation data/forecast models, pre-flight Wx briefing, post-flight science team debriefing, and post-flight pilot and crew debriefs. There were lots of maintenance issues to resolve to keep instrumentation properly calibrated daily. There were additional challenges with erosion damage from grapple/hail on radome, wing tips and LWC sensors. A lightning strike on the rose boom trailing out from the leading edge of the IKP was caused by static electrical buildup with ice, graupel, etc. bouncing off the boom. The Falcon 20 does not have the fuel capacity or flight time (3.5hrs) vice 6+ hours normally to fly long distances and loiter for research. Therefore, the forecast to go or no go from meteorologists (team of 8 PhDs) was critical. They never all agreed, not an easy task but did good job. It would be interesting to see this case scenario from an engineer's perspective. Gulf of Carpentaria was too far to fly unless there was no alternate and there was definite good conditions to go there with only 1-hour to loiter. This was done many times but worth it in the end.

The HAIC-HIWC campaign ended early with aircraft engine problems unrelated to 23 R&D and calibrated flights – used 72 of the 150 flight hrs. The French have been gracious enough to let the remaining hours not used in Darwin to be used again during May 2015 in the Cayenne, French Guiana Campaign while using a 2<sup>nd</sup> CONVAIR 580 aircraft to capture low-level altitude data. Research on the Darwin data is ongoing but will not be completed until COB FY15 due to the efforts now focused on the Cayenne Campaign. The future plan is to eventually compare these data results to Appendix D in 2016.

To date, ten plus years of engine power loss and damage event rate statistics from 5 engine types have been compiled, from these efforts a science plan and operational documents were developed and worked expanded to address ice ingestion and facility capable weather tools to achieve high altitude icing detection methods. The A330 accident was cited as one example of engine power loss from high altitude ice crystal concentration. It was noted that when the A330 probes froze up if the pilot(s) had

strictly followed the Air Flow Management (AFM) instructions to escape to above freezing temperatures the probe's icing would have melted and started working again.

There were specifications formulated from previous field campaigns that were then taken to various companies in 2012 to configure an aircraft. The chosen company ended up going bankrupt and that stopped additional work on the partially configured aircraft until late in 2013; that's when the Europeans joined the group. Through the generosity and logistical support an isokinetic probe was developed on a tight time constraint schedule to provide reliable measurements of the Icing Water Content (IWC). The acquired benchmark for the atmospheric reflectivity (DB) environment was matched up against those conditions causing the engine probe and air sensor failures. These conditions were placing a strain on aviation industry threatening air transportation safety. This was a major breakthrough toward isolating the causes of high-altitude icing aircraft accidents over the past decade from engine power loss or damage from ice crystal concentration. An Engine Harmonization Working Group (WG) proposed new certification criteria from their investigation of high-altitude icing with HIWC ice crystal concentrations in the compression engine stage and engine failure. This led to the FAA Notice for proposed rulemaking to develop new regulations for certification to address ice crystal ingestion into the engine. There was a change made as well to the 2009 envelope of Appendix D (mixed phased precipitation) considered to be too conservative.

The goal is to (1) validate new aircraft design and develop certification standards for Appendix D, (2) develop HIWC for onboard, ground-based, and space-based detection methods, and provide diagnosis and forecast weather tools to avoid this threat, (3) develop engine ice models/simulation techniques as guidelines for future experimental research activities, and (4) understand fundamental cloud microphysics processes that caused HIWC scenarios in order to improve icing forecasts. Ice Crystal Icing (ICI) reactive detection is easier than forecasting it but the problem with that is the ice has already formed on the turbine blade. The goal here is to have pilots avoid these icing areas completely despite having onboard anti-icing equipment – do not knowingly fly into this environment. The end game is to enable remote aircraft sensors to detect HIWC hazardous conditions 60-80nm away. The target is to deliver a nowcasting/forecast tools that will identify HIWC areas in 2018+. To date, the progress is leading to new type of engine designs and regulations, onboard detection sensors for the current and future fleet, and improved Wx forecast tools that have resulted in an overall reduction in engine power loss and damage event rate statistics since 2010. This is primarily due to better training and becoming more aware of these threats from this research. Elizabeth Krajewski (WSI) mentioned that manufacturers were only looking at this icing risks for 2-3 engine types vice across the broader number of engines? Discussions revealed the 2003-2010 statistical increase in these icing accidents were probably due to 5 engine types evaluated in the larger number of over flights exposed to the right type of icing atmospheric conditions in conjunction with a historic lack of pilot knowledge at that time.

#### **Current State of Aviation Weather Research Program and other Research – Marcia Politovich**

This presentation looked at the perspective on aircraft icing weather research. The rest of Day #1 of this conference will be on R&D. The dream goal is to have widge sensors that detect icing ahead of the pilot and allows the pilot to steer away and stay out of icing environments. The reality is there is no such instrumentation nor numerical modeling that can achieve this and likely never will but research continues to make improvements to analyzing and forecasting weather, improved models, sensors and is fusing these better capabilities together. There's a cautious optimism on running a 3km model for

cloud/rain droplets. The optimism will be measured when models get close to real-world in real-time forecasting LWC and droplet sizes.

The next 7 presentations slides were toolbox snapshots of current and future plans information sources on icing: NWP models, in-situ sensors (on planes and on ground), and remote sensors (on plane, on ground and in-space). Currently, icing detection and forecast are pretty darn good using AMDAR, TAMDAR, and other icing sensors but there's lots of room to improve.

But there are multiple future goals for in-situ and remote sensors mentioned above. One goal is to use multi-use sensors to gain better access to measure icing with real-time downlink observational data from icing sensors on the detail droplet size analysis for improving diagnosis and forecast of icing conditions in hi-spatial and temporal resolution. Another goal is to improve METARs (ASOS/AWOS) delineating precipitation types, especially for FZDZ and FZRA from mobile Precipitation Near-the-Ground (mPING). It is paramount to increase the onboard remote sensor capabilities on aircraft that are not always good. Future radar capability needs to employ passive sensing with polarization and dual-pol radar capabilities in real-time into the cockpit and transmit this radar capability to the ground. Current research is increasing dual-pol NEXRAD data updates to terminal towers across airfield proper. The future plans is employing a Hydrometeor Classification Algorithm (HCA) for water precipitation, Terminal Doppler Weather radar in terminal areas, Multi-phased Array Radars (MPARS - radars without antennas), and Radiometers integrated into bigger Wx systems. The current capabilities for in-space remote sensing includes the GOES and POES relevant satellite parameters and cloud-satellite (CLDSat) radar. The future plans are to fly GOES-R series of satellites that will supersede all current onboard technologies to include real-time CLDSAT.

Climate or Climatology (Climo) was not within the scope of this conference. But the thought was expressed on whether Climo will change the severity (up or down) of icing conditions. In any case, the governmental research community will continue to try and increase their collaboration and leverage expertise from the DoD, academia, aviation industries and other commercial agencies.

Today, the aviation community just does not have good database of verification results on research aircraft in-situ data. In summary, R&D atmospheric instrumentation and NWP models have brought science good icing forecast to date. There will be more presentations forthcoming from two perspectives: (1) from users and agencies of what kind of information is desired and needed, and (2) where icing P&S stand now and how the far-term technological milestones stack-up, and what limitations will the industry be facing.

Tom Carty (FAA AWD Tech Center) stated that the NextGen Surface Observing Capability (NSOC) program is working to discriminate all precipitation types at 2 sites: (1) Marshall, CO (NCAR) and Volpe Otis (near Falls River, MA) this past winter but expecting to survey 4-6 site next season involving the NextGen Surface Operational Capability (NSOC).

#### **Radar Detection of Icing – Dave Serke**

In the past it was too hard to do R&D on IFI detection with polarized NEXRADs but now technology delivers dominate detection frequencies through point momentum values (reflectivity factor - ~D6 level and RadIA). Technique applies polarization to freezing detection and SLD algorithms (icing conditions)

and apply RadIA output threshold hazard values and rules after masking out radar data (rain above freezing), clutter and other known identified objects. The NASA Icing Remote Sensing system (NIRSS) looked at repeated reflectivity signatures of RadIA detected in 2010 field campaign. Several incidences of embedded freezing droplet (ZDR) bands were observed not associated with the freezing layer. RadIA was broken down into polar and non-polarized to see if it would work operationally with the non-polar S-band (SP) radar and dual-pol (DP) NEXRAD. NIRSS and PIREPS provide icing/non-icing case verification for examining DP against SP. Compared the DP algorithm to the SP radar with temperature and reflectivity algorithm. The RadIA short-comings involved not detecting tiny homogeneous size FZDZ droplets (< -5dbz) in more stable conditions, no icing detection outside of its radar volume (36km diameter), probable detection capability degradation beyond ~100km from NEXRAD, and particle canting effects due to electrification.

Progress in 3 areas in 2014: (1) Adjustment made for elevated freezing droplets in formerly non-polarized 'Freezing Drizzle Algorithm' reduces FZDZ area of interest significantly, (2) Cleveland SLW-sonde detected ice supersaturated growing hexagonal plates (very large ZDR from plates) via the plate crystal detection algorithm that reduced the icing hazard area of interest a lot, and (3) mixed phase radar detection of two types of microphysics mechanisms (water saturation or growing dendrites with light rimming) is a great leap forward that will improve CIP/FIP forecast and help improve future flight planning.

Recently, a dedicated RadIA server has been acquired at NCAR. Real-time RadIA output for Cleveland now exists with 5 minute resolution. It is unfortunate that the NASA Twin Otter aircraft was not available this winter season but RadIA data was compared to NIRSS, NCAR's RadIA, NCAR's CIP/MICRO algorithm (near-future), ~50 wired vibrating SLW sonde launches and any available PIREPs. RadIA goals beyond 2015: (1) Real-time RadIA for NEXRADs near NSOC test sites, (2) Ingest satellite fields to assist in cloud-but-no-precip scenarios, (3) Journal papers on field campaign findings, (4) Improve the flexibility of RadIA's freezing level detection algorithm, and (5) port RadIA into NSSL's MRMS through NWS platform

### **NCEP Model Development – Brad Ferrier for Geoff DiMego**

The NCEP production suite is the most complex operational system in the world. The NWS is on a pathway going from “model of the day” thinking to probabilistic guidance from ensemble systems. Currently, the 12-km, 60-layer North American Mesoscale (NAM) modeling system runs out to 84 h, and it has 5 different higher-resolution grids, including a small 1.33-km nest that varies in location depending on fire weather and high-impact weather events. The 13-km, 50-layer Rapid Refresh(RAP) runs 24 times a day out to 18hrs, and the 3-km, 50-layer High-Resolution Rapid Refresh (HRRR) is also run every hour out to 15 hrs.

The benefits of higher resolution models (HRRR 3km, 4-km NAM CONUS nest) for aviation operation are also apparent by running closer to the scale of storm cells, providing more accurate storm structure and evolution, and therefore an estimate of permeability for aircraft to more effectively navigate around thunderstorms. Radar data assimilation methods are used to derive improved estimates of latent heating and diabatic temperature tendencies for convective cell growth or decay tendencies at the start of the forecasts. Another aviation forecast tool is to employ the Short-Range Ensemble Forecast (SREF) system, comprised of many models running simultaneously to provide forecast mean and probabilistic

(spread, uncertainty) guidance out to 87 hrs. The current operational SREF with 21 members (16 km, 35 layers) is being compared against a parallel SREF running at NCEP with 26 members (16 km, 40 layers) and greater diversity in physics and initial conditions.

Future plans are to implement the NAM Rapid Refresh (NAMRR), in which the upgraded NAM system (12-km parent, increased resolution to 3-km nests over CONUS, Alaska, plus the other nests) will be run hourly out to 18 h. The NAMRR, RAP, and HRRR will form the basis for the next generation set of rapidly updated regional and high-resolution ensemble systems. The High-Resolution Ensemble Forecast (HREF) system will run multiple NAMRR nests and HRRR runs (all at 3 km) using different physics at hourly intervals out to 18-24 h (TBD) over CONUS and Alaska, with extended forecasts out to 60 h every 6 h at 00, 06, 12, 18 UTC. The Short-Range Ensemble Forecast (SREF) system will run the NAM (12 km) and RAP (13 km) at coarser resolution over North American at hourly intervals out to 18-24 h (TBD), with extended guidance out to 84 h every 6 h at 00, 06, 12, and 18 UTC. This guidance will be used to improve aviation products of convective echo tops (ETs), cloud ceiling heights, and visibility provided by AWC, as well as hazardous weather forecasts provided by the Severe Storms Prediction Center (SPC). Improved products will delineate between discrete thunderstorm cells and squall lines, whether the convection is super-cellular, as well as overall storm evolution and time tendencies (growth or decay). An icing cross-section was shown from the 1.33-km Fire-Weather nest for a recent winter weather event, in which the degree of ice riming was used to discriminate between unrimmed snow, rimed snow, graupel, and sleet precipitation types.

Global models are now being run at resolutions comparable to coarser resolution regional models. The Global Forecast System (GFS) is run at 13 km, 64 layers out to 10 days, and at 33-km resolution for days 11-16. The upcoming Global Ensemble Forecast System (GEFS) upgrade will run 20 members at 27 km with 64 layers out to 8 days, and at 33 km for days 9 to 16. The goal over the next 5 years (2019) is for the Next Generation Global Prediction System (NGGPS) to be run at higher resolutions, providing skillful forecasts out to 30 days.

#### **Satellite Detection of Icing – Pat Minnis and Bill Smith**

The application's objective is to produce well-characterized consistent regional & global cloud and surface property using Low-Earth Orbiting (LEO) and Geostationary (GEO) Satellites for global cloud and surface property datasets at all times and space scales with minimal lag times. Future satellites will employ INSAT, Himawari-8 & GOES-R series. NASA LaRC is working with researchers and operations to use data for weather research & applications. Assimilated data would be used in an analysis for various aircraft applications to include icing.

Satellite channels for standard cloud/radiation parameters using Primary frequency channels for atmospheric lapse rates and secondary channels for cloud mask and snow retrievals. Future technology capabilities will improve night-time displays for multi-layered cloudiness and examined cloud layer heights in a domain from 60N to 60S latitude using different domains across Alaska (6km run hourly), North America (8km run hourly) and CONUS(4km run every 30min).

Bill Smith briefed icing techniques to determine icing threats. A major issue is poor initialization of models to accurately predict clouds & their impacts with numerical models when few or no clouds

observations are assimilated. Nowcasting and forecasting clouds and their impacts (e.g. icing) require accurate observations.

Satellite cloud retrievals can help improve diagnosis and forecast, to diagnosis icing potential directly and an input into other diagnosis products (CIP) mainly through improved cloud initialization. Many NASA LaRC satellite algorithm slides showing cloud property retrievals provide quantitative information. This would lead to a better low-level cloud algorithm on the location for SLW in the atmosphere and in low-level cloud tops observed directly, and on the droplet size distribution or ice over water clouds (multi-layers Cirrus over Stratus clouds) that could infer embedded icing (icing potential). The thick ice over water algorithm employs a cloud water content profiling technique (fully constrained with satellite cloud retrievals) to estimate the embedded super-cooled LWC(z) which is then used to infer the icing potential. Satellite method provides early warning and improved resolution of the icing threat not captured in current forecasting techniques and reduces over-warning. Examples were shown of current satellite icing products showed cross-section 3D icing potential GOES potential with PIREPS potential >90% POD. Case studies were shown to capture heavy icing scenarios where overcast liquid clouds over lower level icing potential clouds and verification.

Satellite analysis involves icing layer top altitude for potential SLW thresholds (cloud type dependent) tuned with PIREPS and icing layer base altitude for cloud base or freezing level. PIREPS are a prime triggering piece of information used to issue for severe icing conditions (SIGMETs). PIREPS are a valuable resource! It was shown that icing detection beneath ice clouds also has skill almost as accurate as that for unobscured low-level liquid clouds Intensity accuracy similar for liquid and ice clouds. It was shown that there was too much MOG icing depicted (higher %) by satellite vs PIREPs for low clouds. In summary satellite clouds retrievals are not perfect and needs the uncertainties be more understood, incorporate new channels, refine the methods, package these information most appropriately for users, and acquire feedback, all part of the potential path toward research-to-operations (R2O).

#### **Onboard Icing Sensors (Panasonic Weather Services - PWS) – Jamie Braid for Robert Fuschino**

An overview of the PWS global weather system detailing application to Inflight Icing for forecasts, detection, and reporting while collaborate with Industry Stakeholders. The weather system has 300+ sensor-equipped commercial aircraft, the Iridium data-link communications system, and their Super Computers (Data Processing and Exploitation) of hi-Res forecast model and customized weather products. Between all the government observations plus 30-40k daily PWS observations PWS is the only commercial company to initialize model from scratch to get proprietary output. Onboard TAMDAR icing detection system uses dual redundant icing probe triggers to calculate LWC. PWS ice-accretion rate process was shown. FlightLink TAMDAR-edge unmanned aircraft (UAS) sensor is small, lightweight and requires low power and flies on NASA's Predator to collect measure data to ingest into their icing potential model. This effort is just getting started to use and generate output.

Icing wind tunnel testing was investigated looking at the 4-dimensional (4D) vs 3D proprietary data assimilation AirDat Data Center (ADC) slopes while changing the LWC values to simulate different icing intensities. Initial testing has been limited but future wind tunnel testing is desired.

## **Sensors/Programs for Inflight/Engine Icing–Darrel Baumgardner (Droplet Measurement Technologies)**

The In-service Aircraft for a Global Observing System (IAGOS) backscattering cloud probe (BCP-100) instrument was passed around the conference audience. The IAGOS is mounted flush to airfoil skin with a focal plan sensor sticking out ~4cm and similar to other sensor/probes. The sensor is described as a dual-polarized probe use for routine measurements of cloud microphysical proprieties from commercial aircraft as well as to look at other phenomena (i.e., ice mass or Ash Plumes engine loading, etc.). High Ice Crystal impact on aircraft sensor is critical to pilot decisions that has been primary cause for accidents vice icing itself. An illustration showed how this sensor operated for impact on temperature measurements (anomalies) and impact on airspeed measurements (Pitot-Static Tube) to indicate airspeed loss. High Ice Crystal concentrations and sensor anomalies are not isolated phenomena. Potential applications involve enhanced TAMDAR measured data complemented with other icing measurements can be refined with mass size distribution differentiated by liquid/ice and closure between icing and size distribution measurements improve fidelity of the information. This information serves another purpose to alert flight crews that the temperature and airspeed sensors could be degraded from the presence of high ice crystal concentrations alerts. This complementary information could help improve forecasts of the Current Icing Potential (CIP).

The challenges they are facing: (1) cost of integration on aircraft (STC, Interface with satellite link, data format, etc.), (2) acceptance by aircraft industry, (3) modification of models to assimilate and utilize cloud measurement information, and (4) sensor maintenance.

Tom Bond wanted to know if the drop size (10um) were validated based upon 2004 Clinton Bedick paper? This question extends from the briefing information of most of the ice crystals in cloud were very small and would produce a very weak signal return from aircraft weather radar. High Ice Crystal concentrations and sensor anomalies are not isolated phenomena. The data from the sample flight measurements from Luana, Angola to Frankfurt Flight showed >300,000 particles per liter with a temperature anomaly of 35<sup>0</sup> C in the high altitude cloud.

### **Question and Answer – ReCap by Tom Carty (FAA AWD Tech Center)**

Tom Carty provided a summary of what was heard on Day 1. There were several web links provided along with GA pilot experiences on icing, radar and airborne sensor detection ongoing research and future visions that will help improve the skills of icing current and forecast icing potential. There was information provided about new icing rules and policy to go along with aircraft certification standards in HIWC. The human-element perspective piece kept coming up in the AM sessions and this is the interface that is paramount and cannot be resolved easily.

Technology is a great thing and satellite inferred data is one piece of that advanced science of icing potential in clouds, etc., but without this information being displayed in a user friendly format for the aviation community the benefit is minimized and never utilized as it was meant due to a lack of misunderstanding and misinterpretation. The next step would be to allow these user friendly format products and services to be effectively tailored into temporal and spatial relevant data for real-time outputs.

**End of Day One**