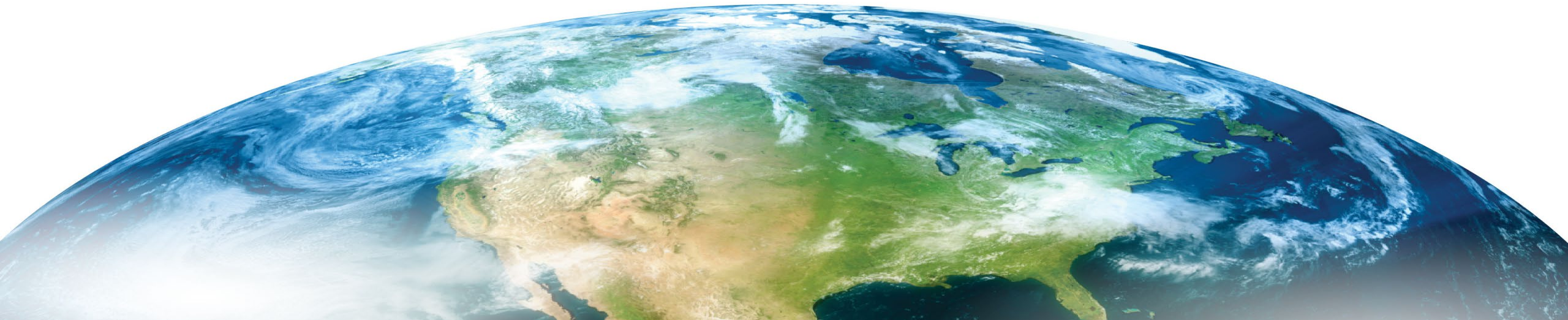




Next**GEN**

Terminal Area Icing Weather Information for NextGen (TAIWIN) User Evaluation Results

Presented to: Aircraft Icing Research Program
By: FAA AWDE Services, ANG-C63
Date: January 2023



Topics

- **Introduction and Background**
- **User Evaluation Objectives and Approach**
- **Participant Summary**
- **Structured Interview Question Results**
- **Conclusions and Recommendations**
- **Acronyms**

Introduction and Background

This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.



Introduction

- The Aircraft Icing Research Program in the Aviation Research Division Propulsion & Aircraft Icing Section (ANG-E282) leads an ongoing effort to develop a diagnostic and forecasting capability that identifies and forecasts **freezing rain (FZRA), freezing drizzle (FZDZ), and small drop icing conditions** in the terminal area, from the surface up to 12,000 feet above ground level (AGL).
- The overarching goal of TAIWIN is to provide pilots with timely and critical **icing and non-icing condition** information to aid in decision-making and operate more safely during flight planning, departure, and landing.
- A User Evaluation was conducted by the Aviation Weather Demonstration and Evaluation (AWDE) Services Team to refine the newly-developed terminal area icing product and gain input on its utility.
- The evaluation focused on gathering feedback from:
 - NATCA Representatives
 - Part 91, Part 107, Part 135, and Helicopter Pilots
 - Meteorologists



Background - Operations

- Currently, FAA Advisory Circular 91-74B contains this caution:

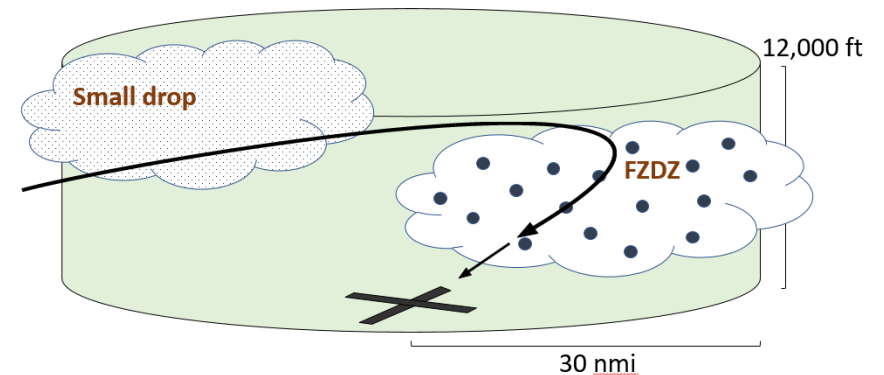
CAUTION: Airplane certification for flight into known icing conditions does not include freezing drizzle and freezing rain. In fact, some airplanes are prohibited from flying into freezing drizzle or freezing rain, regardless of its intensity. These conditions are very dangerous and can cause ice to form behind the protected areas.

- Some future aircraft designs, certified for flight in icing under certification rules introduced in 2015, may include a prohibition on operations in FZDZ and/or FZRA.
- These aircraft designs will also require exiting *all icing conditions* if a prohibited icing condition is encountered.



Background - Product

- The Aircraft Icing Research Program in the Aviation Research Division Propulsion & Aircraft Icing goal was to develop a capability for icing diagnosis and forecasting in the terminal area, with an emphasis on FZDZ and FZRA identification.
- The terminal area was defined as: 30 nmi radius, from the surface to 12,000 ft. AGL.
- A high-resolution gridded icing product was developed, focusing on the terminal area, with a simplified output and display.
- The simplified output and display discriminates between small drop, FZDZ, and FZRA.
 - Small drop: “conventional” icing (e.g., Appendix C)
 - FZDZ & FZRA: supercooled large drop (SLD) icing
Now addressed in a new certification envelope, Appendix O



————— *Drop diameter* —————>



User Evaluation Objectives and Approach

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Objectives

- Determine if the TAIWIN product provides information needed to support decision-making.
 - Does the TAIWIN product provide adequate icing information to aid in decision-making for flight planning, departure, and landing decisions?
 - Is the terminal area domain of icing information (30 nmi; surface to 12,000 ft. AGL) adequate for departure and approach decision-making?
- Determine the usability of the TAIWIN product for decision support.
 - Is the icing information displayed useful?
 - Is the displayed icing information easy to interpret?
 - Is the graphical information easy to understand?



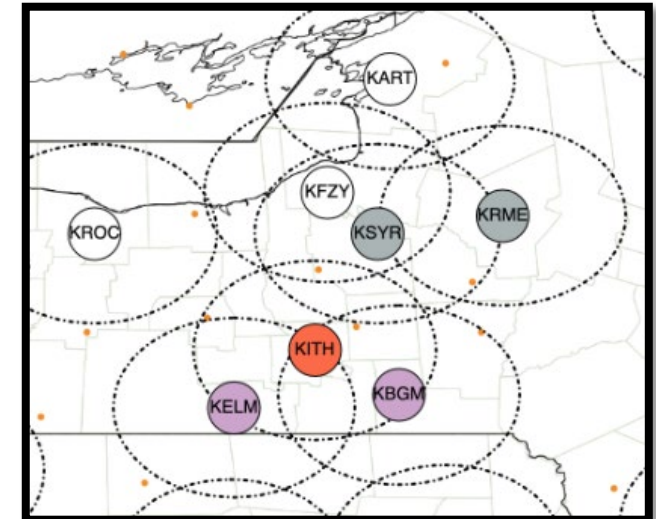
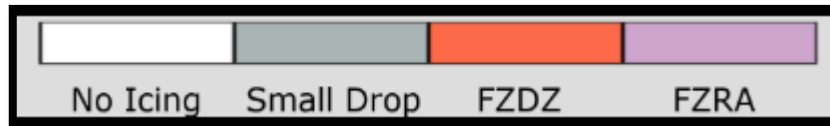
Approach

- All coordination and recruitment was conducted via email, all participants:
 - Completed a demographic form focused on gathering information on experience with icing conditions and flight experience.
 - Received the AWDE TAIWIN Viewer website, username and password, and reviewed the website prior to the interview session.
 - Received a training briefing developed by the AWDE Services and the TAIWIN Team.
- Virtual interviews were conducted one-on-one with each participant via Microsoft Teams. During each session, the AWDE Services Team:
 - Provided an overview of the objectives and procedures.
 - Displayed the TAIWIN Viewer to show three icing scenarios to participants.
 - Asked structured interview questions focusing on determining the suitability for decision-making and usability of the TAIWIN product.
- One participant attended the interview in-person at the William J. Hughes Technical Center AWDE Services Lab.
- TAIWIN team members attended each virtual interview session to provide subject matter expertise (SME) regarding TAIWIN icing scenarios.



TAIWIN Weather Scenarios

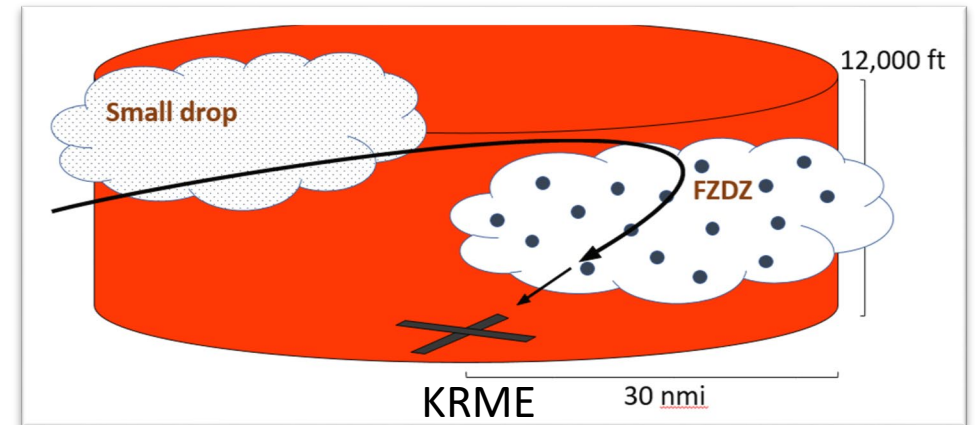
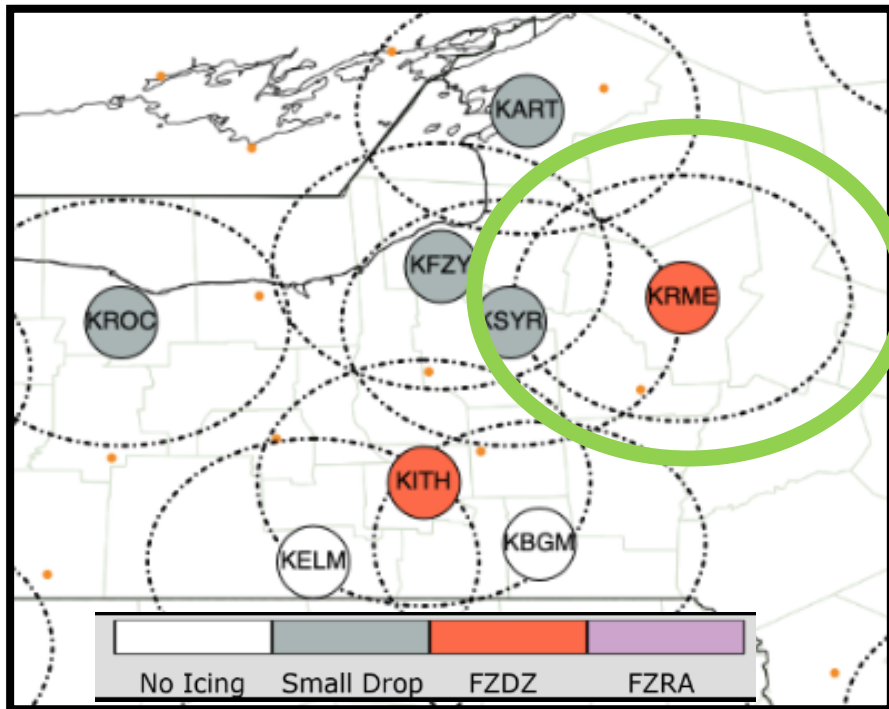
- Participants were asked to consider what decisions would be made during the following phases of flight:
 - Preflight planning - Flight planning operations
 - Departure - Assume ground de-icing already addressed
 - Approach/landing
- Questions were based on:
 - Specified departure airport (provided in the interview session).
 - Three weather scenarios, with simplified TAIWIN output from “now” to +6 hrs for select airports.
- The icing output categories were represented using the colors below:



TAIWIN example with icing information available at specified airports

Interpreting the Simplified Output

- The simplified output indicates only ONE type of icing (*the predominant icing category*) for each terminal area and assigns the predominant icing category to the entire terminal area.
- The predominant icing category is based on 3-D calculations of the likelihood of each icing category and the coverage within the terminal area.
- In the examples below, several terminal areas overlap, where the icing output type for each terminal area is not necessarily identical.



Using KRME (Rome, NY) as an example: FZDZ is identified for KRME. The algorithm has determined FZDZ is the predominant icing category in Rome's terminal area.

Participant Summary

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Participant Summary

User Group	# of Participants Demographic	# of Participants Interview Sessions
Part 91 Pilots	24	8
Part 107 Pilots	1	1
Helicopter Pilots	6	3
NATCA Representatives	3	2
Meteorologists	2	3
Total	36	17

Note: Of the 36 participants who completed the demographic form, 17 also participated in an interview session. The following six slides pertain only to the demographic form. Not all demographic form questions were answered by each participant. The full demographic form results can be found in the TAIWIN Final Report.



Demographic Form

What aircraft weight class do you fly most frequently?

N=31	Small	Medium	Large Commuter	Large Jet	B757	Heavy	Rotorcraft- Helicopter
Part 91 Pilots	21	2		1	1		
Part 107 Pilots	1						1
Part 135 Pilots							
Helicopter Pilots	2	2					
Total	24	4	0	1	1	0	1



Demographic Form

Part 91, 107, 135, Helicopter Pilot Questions

N=31

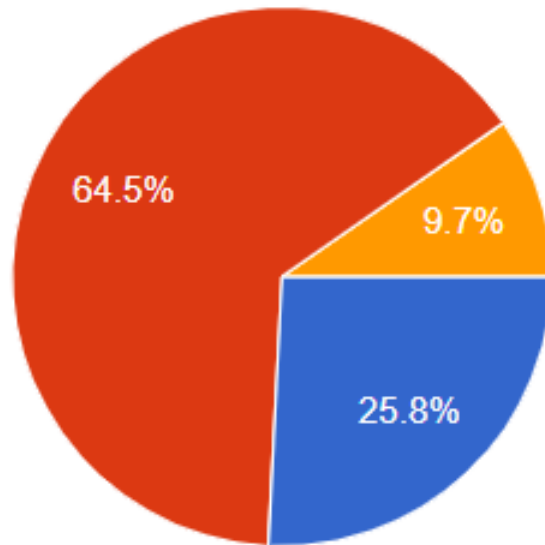
Which products do you typically use to assess icing in the terminal area?	
AIRMETs	PIREPs
AWC Website Icing Product	Progression Charts
CIP/FIP	SIGMETs
ForeFlight	Sirius XM
GOES Satellite	Skew-T Diagrams
Graphical Forecasts	SkyVector
HRRR Model	TAFs
METARs	Windy
NEXRAD	



Demographic Form

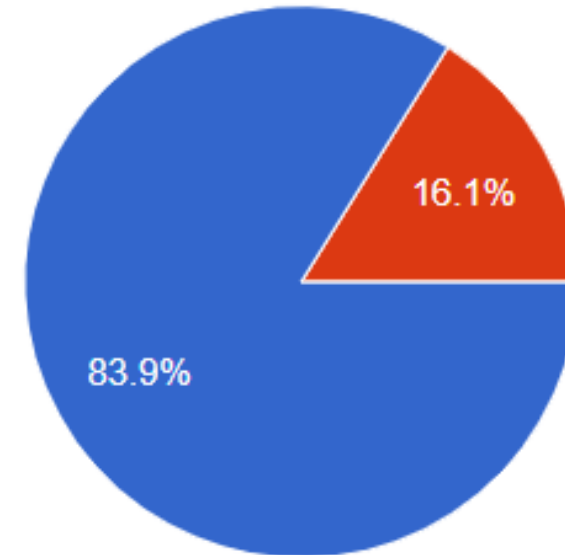
Part 91, 107, 135, Helicopter Pilot Questions N=31

Have you flown an aircraft certified to fly into freezing rain or freezing drizzle?



20 pilots have never flown an aircraft certified to fly into FZRA/FZDZ, 8 pilots have, and 3 pilots were unsure about flying into FZRA/FZDZ conditions.

Have you flown an aircraft certified to fly into icing conditions?



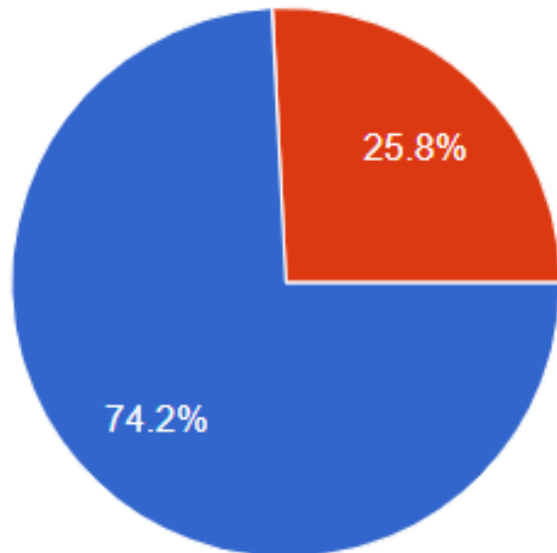
26 pilots have flown an aircraft certified to fly into icing conditions while 5 have not.



Demographic Form

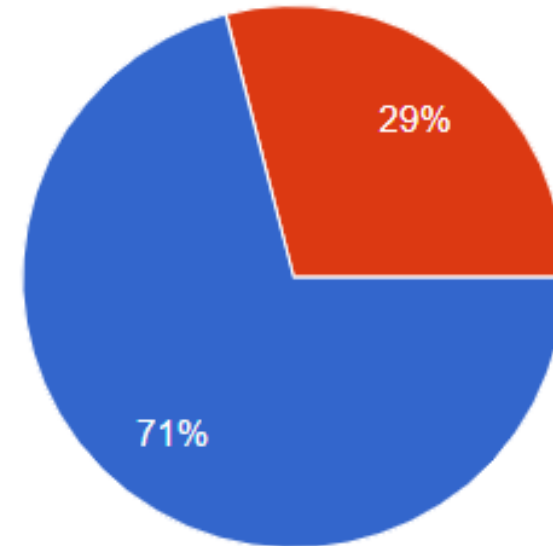
Part 91, 107, 135, Helicopter Pilot Questions N=31

Have you experienced a situation where you inadvertently encountered icing conditions?



23 pilots have encountered unexpected icing conditions while 8 pilots have not.

Have you experienced a situation where you needed to exit icing conditions?



22 pilots have experienced a situation exiting icing conditions while 9 pilots have not.



Demographic Form

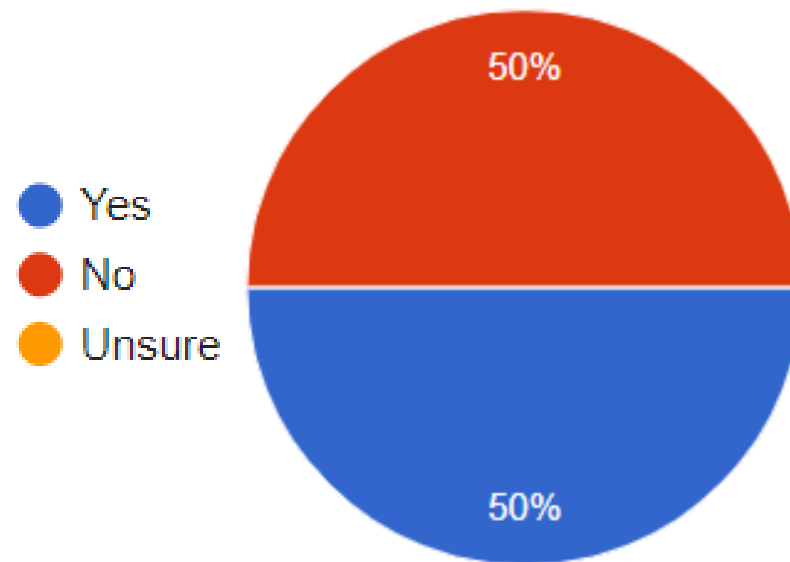
Meteorologist Questions

N=2

How many hours out do you focus on when assessing weather conditions?

N=1	N=1
3-4 hours	6+ hours

Have you ever needed to assist a pilot in avoiding or exiting an icing encounter?



1 Meteorologist did need to assist a pilot in avoiding or exiting an icing encounter while 1 did not.

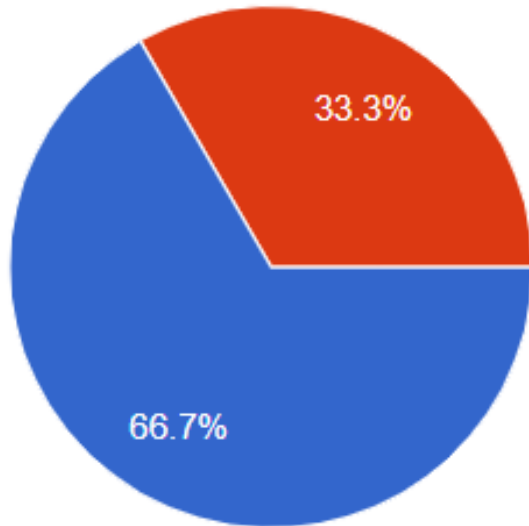


Demographic Form

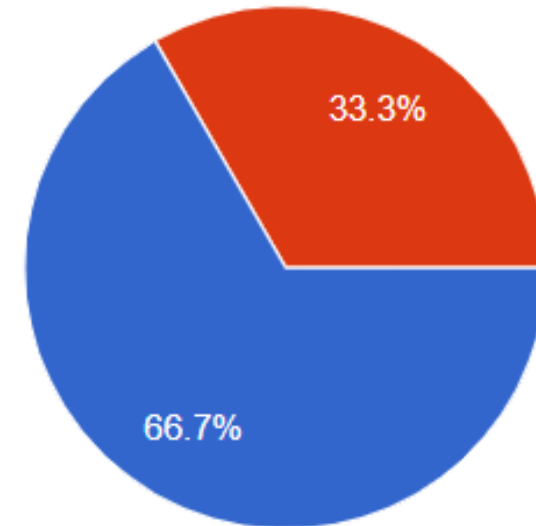
NATCA Representative Questions

N=3

Have you ever assessed icing conditions in the terminal area?



Have you ever needed to assist a pilot in avoiding or exiting an icing encounter?



- Yes
- No
- Unsure

2 of the 3 NATCA representatives have assessed icing conditions in the terminal area and assisted a pilot in avoiding or exiting an icing encounter.



Structured Interview Question Results

Note: Number of participant interviews differ from the number of people who completed the demographic form. Some questions were worded differently per user group.

Q1. Which decisions would you make depending on the icing category (freezing rain, freezing drizzle, small drop, none) observed or forecasted in a departure/destination airport? How would you use this information?

- Part 91 Pilots (N=8)
 - All Part 91 Pilots would not depart or fly in FZDZ/FZRA conditions; if small drop icing was observed or forecasted the conditions would not impact the departure decisions.
 - The icing categories would be used in addition to other icing tools (i.e., CIP and FIP) to aid in determining the need to delay/cancel a flight, specifically if FZDZ/FZRA was observed or forecasted.
 - The “no icing” category helps build confidence in flight plans by determining FZDZ/FZRA conditions are not observed or forecasted in the terminal area.
- Part 107 Pilot (N=1)
 - The four icing categories would help determine go-no-go decisions dependent upon the Uncrewed Aircraft System (UAS) aircraft certifications for icing.
 - Small drop icing information is not critical for UAS flights because small drop does not impact the aircraft as much as FZDZ/FZRA.
 - FZDZ/FZRA areas would be avoided because the faster ice accretion rates would affect the UAS aircraft.
 - The forecast would help determine if a flight should be canceled, delayed, or rerouted to avoid the FZDZ/FZRA conditions.



Q1. Which decisions would you make depending on the icing category (freezing rain, freezing drizzle, small drop, none) observed or forecasted in a departure/destination airport? How would you use this information?

- Helicopter Pilots (N=3)
 - The observed and forecasted icing conditions would aid in making go-no-go decisions because flights will be canceled if FZDZ/FZRA is observed or forecasted.
 - The TAIWIN product would aid pilots to determine departure times by using small drop or no icing categories because of the time slider and forecast features.
 - Pilots need the capability to assess FZDZ/FZRA conditions along a flight path to make better decisions about avoiding impacted areas instead of canceling the flight.



Q1. Which decisions would you make depending on the icing category (freezing rain, freezing drizzle, small drop, none) observed or forecasted in your region? How would you use this information?

- Meteorologists (N=3)
 - No-go decision would be recommended based on any FZDZ/FZRA conditions observed or forecasted.
 - Forecasts would be based on the growth/decay of weather conditions and if the icing categories were changing over time.
 - TAIWIN product would be used to increase confidence in a forecast due to having the capability to assess small drop, FZDZ, and FZRA icing conditions.
 - The FZDZ/FZRA icing information would be used to inform airlines that an alternate route or extra fuel may be needed for a flight due to the need to reroute around areas having FZDZ/FZRA conditions.
 - To aid in decision-making, training is suggested to ensure pilots understand the icing categories and how each icing type may impact the aircraft.
- NATCA Representatives (N=2)
 - The TAIWIN product would be used for situation awareness by providing information on the icing categories and where the icing is occurring.
 - Air Traffic Control can brief the TAIWIN product icing information to pilots; however, the pilot determines go-no-go decisions or if deviations are needed based on possible impacts to the aircraft.



Q1a. If your aircraft was certified to fly in freezing rain and/or freezing drizzle conditions in the future, how would this affect your decisions?

- Part 91 Pilots (N=8)
 - 1 Part 91 Pilot stated the TAIWIN product information would be used to help stay within the icing limitations of a new aircraft certification.
 - 7 Part 91 Pilots would delay or cancel departure and would not fly into FZDZ/FZRA conditions regardless of aircraft certification changes, because of the dangers associated with flying in FZDZ/FZRA conditions.
- Part 107 Pilot (N=1)
 - Decisions would be mission dependent on the capability of the UAS, as various sizes of the aircraft can withstand different ice accretion rates.
 - The TAIWIN product would be used to identify safer landing locations that have less severe icing conditions.
- Helicopter Pilots (N=3)
 - 1 Helicopter Pilot stated the decision would still be a no-go, regardless of the icing certification because flying in FZDZ/FZRA conditions is dangerous for any helicopter.
 - The FZDZ/FZRA categories should be related to the icing severity levels (trace, light, medium, heavy) for pilots to understand how the aircraft would be affected, standardized icing terms would be helpful for better communication between pilots.
 - Icing conditions above “trace” would still be avoided, regardless of the certification.



Q1a. Considering in the future there may be aircraft certified to fly in freezing rain and/or freezing drizzle conditions, and aircraft with limitations explicitly stated in their flight manual related to those conditions, how would this affect your decisions?

- Meteorologists (N=3): A change in aircraft certification would not affect decisions because meteorologists provide the observations and forecast information, however most pilots would still avoid FZDZ/FZRA conditions.
- NATCA Representatives (N=2): The icing information would still be briefed to the pilots; however, the pilot determines go-no-go decisions or if deviations are needed based on possible impacts to the aircraft.



Q2. Does the TAIWIN product provide adequate freezing rain, freezing drizzle, and small drop information to aid in decision-making for flight planning operations?

- Part 91 Pilots (N=8)
 - All Part 91 Pilots stated the TAIWIN product provides an adequate “big picture” overview of observed and forecasted icing conditions for flight planning.
 - During flight planning, the FZDZ/FZRA observation and forecast provides critical icing information needed to determine the need to cancel/delay a flight due to safety concerns.
 - Pilot Reports (PIREPs) would be used with TAIWIN product information to make final departure decisions to verify the location of the icing conditions along a flight path.
 - Training is needed to understand what each icing category represents and how each icing category impacts the aircraft.
- Part 107 Pilot (N=1)
 - The TAIWIN product provides a “big picture” overview of icing conditions for flight planning.
 - Adding icing category probabilities would provide more confidence for UAS Pilots to determine locations within the terminal area to depart or land.
- Helicopter Pilots (N=3)
 - The TAIWIN product provides adequate icing information and forecasts needed to support flight planning and increase safety during flight.
 - The TAIWIN product would provide the capability to make go-no-go decisions based on assessing observed and forecasted FZDZ/FZRA conditions.
 - Adding historical icing information to the TAIWIN product would be helpful to show weather trends for flight planning.




Q2a. Does the TAIWIN product provide adequate freezing rain, freezing drizzle, and small drop information to aid in decision-making for departure operations into terminal airspace?

- Part 91 Pilots (N=8)
 - 2 of the 8 Part 91 Pilots stated the TAIWIN product provides adequate icing information for departure operations.
 - 6 of the 8 Part 91 Pilots stated the TAIWIN product would not be used during departure unless TAIWIN was available on a tablet/iPad, ADS-B, Sirius XM weather, and/or ForeFlight.
 - 2 of the 8 Part 91 Pilots stated needing historical icing information and altitude layers to identify improving/worsening icing conditions and where the icing conditions are occurring within the terminal area during departure operations.
 - PIREPs would be used with the TAIWIN product information to make final departure decisions to provide more confidence in the icing conditions observed/forecasted by TAIWIN in addition to providing more specific icing location information.
- Part 107 Pilot (N=1)
 - UAS do not typically depart from airports, so Part 107 Pilots need the ability to overlay multiple airports to fill in gaps to help pinpoint locations that have less severe icing conditions.
 - Small UAS operations would benefit from viewing multiple icing categories, instead of the most severe icing category, within the terminal area to aid in identifying departure locations.
- Helicopter Pilots (N=3)
 - Helicopters cannot depart if FZDZ/FZRA conditions are present; therefore, using TAIWIN to determine the forecasted time of FZDZ/FZRA conditions is critical to make go-no-go decisions.
 - Currently, tablets are put in airplane mode during departure so the TAIWIN product would be unavailable to use during departure operations.



Q2b. Does the TAIWIN product provide adequate freezing rain, freezing drizzle, and small drop information to aid in decision-making for approach/landing operations?

- Part 91 Pilots (N=8)
 - The TAIWIN product would help determine if a deviation or descent to a different altitude is needed upon approach if FZDZ/FZRA was observed.
 - 6 of the 8 Part 91 Pilots stated TAIWIN cannot be used during approach/landing unless the product is available on a tablet/iPad, ADS-B, Sirius XM weather, and/or ForeFlight.
 - 2 of the 8 Part 91 Pilots stated the need to assess icing conditions at specific altitudes to determine more precisely where the icing conditions are occurring.
 - Part 107 Pilot (N=1)
 - The TAIWIN product would be used as a tactical tool to aid in determining the need to divert due to FZDZ/FZRA conditions being observed, especially within 15 minutes prior to landing.
 - More precise locations of icing information within the 30 nmi radius would be useful for landing operations, especially because UAS's do not typically land at airports.
 - Helicopter Pilots (N=3)
 - Arrival times would be adjusted based on the type of icing category forecasted.
 - The TAIWIN product FZDZ/FZRA icing information is critical for landing operations because a helicopter is unable to land at a location if FZDZ/FZRA are present.
 - The TAIWIN product information would be unavailable during landing operations because tablets are in airplane mode.
 - To use TAIWIN during approach/landing the information needs to be available via an electronic flight bag, www.aviationweather.gov, and/or another portable device or tablet.
- 

Q2. Does the TAIWIN product provide adequate icing information to enable you to provide relevant information for your region/area? How would you want to receive this type of icing information?

- Meteorologists (N=3)
 - Probabilistic icing information would be more beneficial than deterministic to increase the Meteorologists' confidence in providing the likelihood of each type of icing in a forecast to pilots and airlines.
 - The TAIWIN icing information should be incorporated into other available icing products (i.e., CIP, FIP, and GAIRMETs) to decrease workload by having fewer icing products to analyze.
 - All Meteorologists stated needing the capability to view and assess specific altitudes within the surface to 12,000-ft. terminal domain to help provide pilots safe altitudes for flight.



Q2a. Does the TAIWIN product provide adequate icing information to enable you to provide support for departure/approach/landing operations? How would you want to receive this type of icing information?

- NATCA Representatives (N=2)
 - The TAIWIN product needs to provide icing conditions at specific altitudes to support flight operations.
 - Different decisions would be made regarding the altitude at which the icing was occurring. The icing would have a more severe impact at lower altitudes during departure/landing operations than at 12,000 ft. or higher, where de-icing equipment can be used.
 - If the TAIWIN product is web-based, only supervisors would have access to the product. To support air traffic controllers, TAIWIN would have to be integrated into the Information Display System (IDS) or Enterprise Information Display System (E-IDS).



Q3. How frequently should the TAIWIN product information be updated for flight planning decisions?

- Part 91 Pilots (N=8)
 - All Part 91 Pilots stated a 15-minute product update would be adequate for flight planning decisions.
 - 1 Part 91 Pilot stated a faster update rate, such as 5 minutes, would be helpful because icing conditions can change rapidly.
- Part 107 Pilot (N=1): 30-60 minute updates would be adequate for flight planning.
- Helicopter Pilots (N=3)
 - All Helicopter Pilots stated a 15-minute update rate would be adequate for flight planning.
 - 2 Helicopter Pilots stated a 5-minute update rate would be useful because icing conditions change quickly and would allow more confidence in flight planning decisions.



Q3a. How frequently should the TAIWIN product information be updated for departure decisions?

- Part 91 Pilots (N=8)
 - 5 Part 91 Pilots stated a 15-minute product update would be adequate for departure decisions.
 - 2 Part 91 Pilots stated a faster update rate, such as 5 minutes, would be helpful because icing conditions can change rapidly.
 - 1 Part 91 Pilot stated the update rate is not critical during departure because the web-based TAIWIN product cannot be accessed during this phase of flight.
- Part 107 Pilot (N=1): The Part 107 Pilot preferred the TAIWIN product information updated at the same rate as other diagnostic products, such as the 5-minute update rate currently available on ADS-B.
- Helicopter Pilots (N=3): A 5-minute update rate would be useful because icing information is assessed before takeoff and the most current icing information is needed for departure decisions.



Q3b. How frequently should the TAIWIN product information be updated for approach/landing decisions?

- Part 91 Pilots (N=8)
 - 4 Part 91 Pilots stated a 15-minute product update would be adequate for approach decisions.
 - 3 Part 91 Pilots stated a faster update rate, such as 5 minutes, would be more helpful in making quick decisions upon approach and landing.
 - 1 Part 91 Pilot stated the update rate is not critical during approach/landing because the web-based TAIWIN product cannot be accessed during this phase of flight.
- Part 107 Pilot (N=1): The Part 107 Pilot preferred the TAIWIN product information updated at the same rate as other diagnostic products, such as the 5-minute update rate currently available on ADS-B.
- Helicopter Pilots (N=3)
 - All Helicopter Pilots stated a 15-minute update rate would be adequate for decision-making.
 - Update rates under 15 minutes would be more beneficial for helicopter pilots because they are traveling slower and need more time to change routes or altitudes.



Q3. How frequently should the TAIWIN product information be updated to support your decision-making responsibilities?

- Meteorologists (N=3)
 - All Meteorologists stated a 15-minute update is adequate for more precise forecasting.
 - 1 Meteorologist stated a 5-minute update rate would be most useful to brief more accurate icing information to pilots en route, especially if the TAIWIN product information were available through FIS-B.
- NATCA Representatives (N=2)
 - The 15-minute update rate would be adequate to support decision-making.
 - The product information should be updated in real-time so the most current icing conditions can be given to pilots.



Q4. What is the maximum forecast length needed for decision-making? What time increments would be adequate for decision-making?

- Part 91 Pilots (N=8)
 - 7 Part 91 Pilots stated a 6-hour forecast is adequate for decision-making for flights within the Continental US. A 16-hour forecast is needed for decision-making if the TAIWIN product becomes available for international flights because of the longer flight times.
 - 1 Part 91 Pilot stated a 12-18 hour forecast would be beneficial to notify customers of flight cancelations or changes in departure times.
 - All Part 91 Pilots stated 15-minute time increments would be adequate for decision-making.
- Part 107 Pilot (N=1)
 - The maximum forecast time needed for UAS operations is dependent on the type of aircraft being flown and how long the aircraft can fly.
 - If a UAS aircraft can fly between 1-6-hours, then a 6-hour forecast would be needed.
 - If a UAS aircraft can fly 6-10 hours, then a 10-hour forecast would be needed.
 - 15-minute time increments are adequate for decision-making.
- Helicopter Pilots (N=3)
 - The maximum forecast time needed for decision-making for helicopter pilots is 6 hours.
 - 1 Helicopter Pilot stated the 15-minute time increment was adequate for decision-making.
 - 2 Helicopter Pilots stated smaller update increments of 5 minutes or less would be more effective due to quick planning decisions due to emergency medical services flights.



Q4. What is the maximum forecast length needed for decision-making? What time increments would be adequate for decision-making?

- Meteorologists (N=3)
 - Meteorologists stated a need for a 12-24 hour forecast for adequate time to assess then brief airlines and pilots.
 - 15-minute time increments are adequate for decision-making.
- NATCA Representatives (N=2)
 - The 6-hour forecast is adequate for decision-making.
 - A 2-hour forecast would suit the needs of terminal controllers.



Q5. Is the domain of icing information (30 nmi radius; surface to 12kft.) adequate for departure and approach decision-making? If not, what domain size would you need?

- Part 91 Pilots (N=8)
 - All Part 91 Pilots stated the 30 nmi radius was adequate for departure and approach decision-making.
 - 6 out of 8 Part 91 Pilots stated the surface to 12kft. domain was adequate for decision-making.
 - 2 out of 8 Part 91 Pilots stated an extended domain from the surface to 15kft. would provide coverage for additional altitudes where icing information may be needed to help improve safety.
- Part 107 Pilot (N=1)
 - The 30 nmi radius may be larger than needed for small UAS because of the shorter missions.
 - The altitude information is adequate for decision-making.
- Helicopter Pilots (N=3)
 - 2 Helicopter Pilots stated the 30 nmi radius would be adequate for departure and approach decisions.
 - 1 Helicopter Pilot stated a 50 nmi radius would provide better coverage because helicopters have alternate departure and landing locations than other aircraft. The 50 nmi radius would allow pilots to select multiple airports and gain icing information over a large area.
 - The ability to choose and assess specific altitudes between surface to 12,000 ft. would be helpful to avoid icing conditions present in certain altitudes.



Q5. Is the domain of icing information (30 nmi radius; surface to 12kft.) adequate for departure and approach decision-making? If not, what domain size would you need?

- Meteorologists (N=3)
 - The 30 nmi is adequate for decision-making; however, the National Weather Service defines the terminal area as 5 statute miles (4.34 nmi), so more consistent terms would be helpful.
 - Surface to 18kft is adequate because some aircraft are still climbing at 18kft.
- NATCA Representatives (N=2)
 - The 30 nmi radius domain is adequate for decision-making.
 - For the towers, there is a need to choose and assess specific altitudes between surface to 3,000 ft.
 - An extended domain of surface to 15kft would be helpful for TRACONs, where controllers are working with aircraft departing or approaching from these altitudes.



Q6. Is the TAIWIN product icing information easy to interpret? Are the colors easy to distinguish?

- Part 91 Pilots (N=8)
 - All Part 91 Pilots stated the TAIWIN product icing information was easy to interpret.
 - The Part 91 Pilots stated the icing category colors should be standardized with other icing products (i.e., CIP/FIP).
 - The color red should indicate the most severe icing condition because red typically indicates areas that should be avoided.
 - A legend needs to be provided to define each icing category.
- Part 107 Pilot (N=1): The Part 107 Pilot stated the TAIWIN product icing information was easy to interpret.
- Helicopter Pilots (N=3)
 - 2 Helicopter Pilots found the colors easy to understand and interpret.
 - 1 Helicopter Pilot stated shades of blue or purple would be more beneficial to distinguish the icing categories, similar to flight categories, because the colors are easily perceived.



Q6. Is the TAIWIN product icing information easy to interpret? Are the colors easy to distinguish?

- Meteorologists (N=3)
 - All Meteorologists stated the TAIWIN product icing information was easy to interpret.
 - Red should be used to represent the most severe icing conditions (FZDR) because red gives an indication to the user the area must be avoided.
 - Shapes (i.e., circles, squares, or triangles) could be used to represent icing categories for color-blind users.
- NATCA Representatives (N=2): The NATCA Representatives stated the TAIWIN product icing information was easy to interpret.



Q6. (cont.) Are there any improvements or changes that would help improve the usability?

Part 91 Pilots	Part 107 Pilot	Helicopter Pilots	Meteorologists	NATCA
Display probabilities associated with icing categories.	Colors matching flight categories (i.e., blue, red purple).	Icing terminology should align with existing pilot equipment (i.e., trace, light, mod, heavy icing severities).	Ability to select and view specific altitudes.	Ability to filter altitudes.
Add a route tool which allows users to input a route and view icing conditions along the route.	Percentage probability of each icing category.	Integrate the TAIWIN product into an existing product, such as ForeFlight.	Provide a gridded output to view specific information on the location, time, and movement of weather.	Ability to zoom.
FZDZ should be red or orange to indicate danger to aircraft.	Intensity of icing categories (i.e., trace, light, mod, heavy).	Include a notice (using words or red boarder) to indicate the product is unavailable.	Ability to change domain radius.	Extend vertical limits for TRACONs from surface to 15kft.
Provide icing confidence levels for locations where two terminal areas overlap.	Include looping to track the movement of the weather.	Provide all observed/forecasted icing categories within each terminal area.	Provide probabilities of each icing category.	Allow towers to select and assess altitudes from surface to 3,000 feet.
Available on an iPad.		Add confidence levels for each of the icing categories.	Use color scheme such as red, yellow, and green to indicate probabilities of each icing category.	
Provide information on the movement of the weather.		Provide 3-6 hours of historical data.		
Provide 3-6 hours of historical data.				

Q7. (Based on the future capability image) Is the graphical information easy to understand? Would this be useful to you? Do you suggest any changes?

- Part 91 Pilots (N=8): All Part 91 Pilots found the future capability information easy to understand and stated the 3D view provides the capability to easily identify routes with FZDZ/FZRA which enables the pilots to make better decisions about rerouting.
- Part 107 Pilot (N=1): The future capability image provides more precise information about the location of icing which allows pilots to navigate around the icing areas.
- Helicopter Pilots (N=3): All Helicopter Pilots agreed the 3D view provided in the future capability image was easy to understand and provided a useful visual tool for making quick decisions by displaying where icing is occurring.



**Q7. (Based on the future capability image) Is the graphical information easy to understand?
Would this be useful to you? Do you suggest any changes?**

- Meteorologists (N=3)
 - All Meteorologists stated the information was easy to understand; however, could be improved with the addition of a looping capability to see how the icing will develop or change in the future.
 - 1 Meteorologist stated being concerned that pilots may not understand how to use the graphical information correctly, resulting in overconfidence in taking routes too close to the icing conditions, which could be dangerous.
- NATCA Representatives (N=2)
 - The future capability image would be difficult to use in real-time because the image is difficult to correlate with real-time air traffic.
 - Air Traffic Controllers need a quick, easy-to-use product, and the future capability image could increase workload by needing to identify the location of the icing and convey the information to a pilot.



**Q7. (Based on the future capability image) Is the graphical information easy to understand?
Would this be useful to you? Do you suggest any changes?**

Future Capability Image Suggested Changes	Part 91 Pilots N=8	Part 107 Pilot N=1	Helicopter Pilots N=3	Meteorologists N=3	NATCA Representatives N=2
Add ability to select specific altitudes to view cross section.	X	X	X	X	X
Add a time slider.	X	X	X	X	
Add ability to turn on/off specific icing categories.	X				
Add a legend.	X	X	X	X	X
Add routes to view traffic.				X	X
Incorporate AIRMETs and freezing level line.			X		
Add a hover capability to display the icing conditions.				X	
Include the ability to zoom into areas.				X	X
Add a line graph to display how the icing is trending over time.				X	
Provide the ability to re-play events.					X

Q8. Is the TAIWIN product providing unique and useful information when compared to other icing products?

- All participants agreed TAIWIN provides unique icing category information, including FZDZ/FZRA, not found in other icing products.
- Part 91 Pilots (N=8): All Part 91 Pilots agreed TAIWIN provides unique and valuable low-level icing information within the terminal area that other icing products do not provide.
- Part 107 Pilot (N=1): The Part 107 Pilot stated the TAIWIN product provides specific icing categories beyond what is included in a Terminal Aerodrome Forecast (TAF) for the terminal area.
- Helicopter Pilots (N=3)
 - All Helicopter pilots stated the TAIWIN product helps determine the movement of the icing to identify departure times.
 - The TAIWIN product provides locations where no icing is occurring to help identify safer routes.
- Meteorologists (N=3): The TAIWIN product provides a comprehensive look at FZDZ/FZRA, which is not provided by other products.
- NATCA Representatives (N=2): The NATCA Representatives agreed TAIWIN provides unique icing category information.



Q9. How would you make decisions based on conflicting icing information from multiple products?

- **Part 91 Pilots (N=8)**
 - The Part 91 Pilots would search for recent PIREPs to confirm current conditions to determine more accurate icing information.
 - The Part 91 Pilots would contact meteorologists for help with go-no-go decisions.
 - The Part 91 Pilots would view additional observation information from Automated Surface Observing Systems (ASOS), Meteorological Aerodrome Forecasts (METARs), and Skew-T diagrams to help make decisions.
- **Part 107 Pilot (N=1)**
 - The Part 107 Pilot stated the most severe icing information would be used to ensure confidence and safety.
 - The product with the most trust and confidence would be used for decision-making.
 - The Part 107 Pilot would compare the TAIWIN product with other sources, including CIP/FIP, prognostic charts, TAFs, and wind information.
- **Helicopter Pilots (N=3)**
 - Helicopter Pilots use the most conservative icing information and combine that information with the probability of icing conditions occurring and the confidence in the product.
 - Helicopter Pilots would view historical information (out to 3-6 hours) to view the trends and movement of the icing conditions.
 - Helicopter Pilots would view additional tools, such as prognostic charts, the aviation weather discussion, TAFs, and wind information.



Q9. How would you make decisions based on conflicting icing information from multiple products?

- Meteorologists (N=3)
 - The Meteorologists would view additional weather information, such as Significant Meteorological Information (SIGMETs), Graphical Airman's Meteorological Information (GAIRMETs), Skew-T diagrams, satellite, and radar information, to check for consistency among products to make decisions.
 - The Meteorologists would provide probability information to pilots and airlines based on confidence in the products.
- NATCA Representatives (N=2): Air Traffic Controllers would provide the pilots with all available icing information, including recent PIREPs, and the pilots use that information to make the final decisions.



Conclusions and Recommendations

This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.



Objective 1: Determine if the TAIWIN product provides information needed to support decision-making.

- Overall, the TAIWIN product provides the information needed to support decision-making.
 - The observed and forecasted icing conditions would aid in making go-no-go decisions because a flight will be delayed or canceled if FZDZ/FZRA is observed or forecasted; if small drop icing was observed or forecasted the conditions would not severely impact the departure or arrival decisions.
 - The TAIWIN product provides unique icing category information, including FZDZ/FZRA, not found in other icing products.
 - Participants stated a need to view multiple icing categories observed/forecasted in the terminal area, not just the predominant icing category.
 - The TAIWIN product provides an adequate “big picture” overview of observed and forecasted icing conditions for flight planning.
 - The TAIWIN product would help determine if a diversion or descent to a different altitude is needed upon approach if FZDZ/FZRA was observed.
 - The 15-minute product update is adequate for flight planning, departure, and approach decisions; however, a 5-minute update rate would be helpful because icing conditions can change rapidly.
 - The 6-hour forecast is adequate for decision-making. A 12-24 hour forecast would be beneficial to notify customers of flight cancelations or changes in departure times.
 - The TAIWIN product domain of icing information is adequate for departure and approach decision-making. Participants stated a need to choose and assess icing conditions at specified altitudes.



Objective 2: Determine the usability of the TAIWIN product for decision support.

- Overall, the TAIWIN product is easy to use, and the information is easy to understand for decision support.
 - The TAIWIN product icing information was easy to interpret.
 - The future capability image was easy to understand and provided a useful visual tool for making quick decisions by displaying where icing is occurring.
- The TAIWIN product could be improved by:
 - Add the ability to view icing conditions at select altitudes.
 - Display probabilities associated with each icing category.
 - Integrate the TAIWIN product into existing products, such as ForeFlight or CIP/FIP.
 - Add a routing tool allows users to view icing conditions along a specified route.
 - Use red or orange to indicate the most severe icing category, as those colors typically indicate danger to aircraft.
 - Provide 3-6 hours of historical data to assess weather trends.
 - Use colors, such as blue and purple, similar to those found in other icing products (i.e., CIP/FIP).



Recommendations

- Based on participant feedback, recommendations include:
 - Provide the capability to filter altitudes to aid in assessing icing impacts to support flight operations.
 - Integrate the TAIWIN product on displays available to all users, including tablet/iPad, ADS-B, Sirius XM weather, and/or ForeFlight.
 - Provide the TAIWIN icing information into other available icing products (i.e., CIP, FIP, and GAIRMETs) to decrease workload by having fewer icing products to analyze.
 - Provide a 12-24 hour forecast to aid in strategic planning to adequately determine how the weather may impact traffic and communicate the impacts to other facilities and pilots.
 - Provide probabilistic icing information to display the likelihood of each type of icing in a forecast to pilots and airlines.
 - Provide training to users to understand the four icing categories and the impacts on aircraft.
 - Provide additional zoom levels when zooming in/out of a specific region on the map to aid in more accurately identifying weather locations.



Acronyms

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Acronyms

ADDS	Aviation Digital Data Service
ADS-B	Automatic Dependent Surveillance - Broadcast
AGL	Above Ground Level
AIRMET	Airman's Meteorological Information
ASOS	Automated Surface Observing System
AWC	Aviation Weather Center
AWDE	Aviation Weather Demonstration and Evaluation
CIP	Current Icing Product
FIP	Forecast Icing Product
FZDZ	Freezing Drizzle
FZRA	Freezing Rain
GAIRMET	Graphical Airman's Meteorological Information
METAR	Meteorological Aerodrome Forecast
NATCA	National Air Traffic Controllers Association
NMI	Nautical Miles
PIREP	Pilot Reports
SIGMET	Significant Meteorological Information
SLD	Supercooled Large Drops
SME	Subject Matter Expert
TAIWIN	Terminal Area Icing Weather Information for Nextgen
TAF	Terminal Aerodrome Forecast
TRACON	Terminal Radar Approach Control Facility
UAS	Uncrewed Aircraft System

