FINAL REPORT:
FREEZING DRIZZLE ALGORITHM DEVELOPMENT

WINTER 1998 - 1999

Prepared for

NATIONAL WEATHER SERVICE (W/OSO14x1)

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by

RAYTHEON Information Technology and Scientific Services (RITSS)

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EXECUTIVE SUMMARY

The inability of the Automated Surface Observing System (ASOS) to report freezing drizzle (FZDZ) represents a serious shortfall in support to aviation operations. Reports of FZDZ are among the most important surface weather elements for aviation applications.

> The Federal Aviation Administration (FAA), in coordination with general aviation and airlines, has assigned the highest priority for precipitation reporting to freezing precipitation (including freezing drizzle). (Whatley, 1998)
>
> State-of-the-art in-flight icing models being developed by the National Center for Atmospheric Research (NCAR) and the National Weather Service Aviation Weather Center are especially sensitive to reports of freezing drizzle. The lead scientist in the development of the NCAR Integrated Icing Diagnostic Algorithm has stated (Bernstein, 1999) that "surface observations are the most powerful forecasting tool we have for finding SLD [Supercooled Large Droplet] conditions aloft, and FZDZ observations are our best indicator of the simultaneous occurrence of FZDZ aloft."

This algorithm-development task is a continuation of work that has been in progress since 1995. Previous field investigations indicated that the current ASOS limitation of reporting only freezing rain could be removed by reporting surface icing from sources *other than* freezing rain. This project was intended to confirm that a significant portion of additional icing detected by the ASOS could be accurately and reliably reported as freezing drizzle.

A simple algorithm using the ASOS icing sensor, the precipitation identifier, ceilometer, hygrothermometer, and visibility sensor was demonstrated to provide the ASOS with the ability to report freezing drizzle. The algorithm is based in large part on the sensitivity and reliability of the Rosemount 872C3 icing detector used on the ASOS: in extensive field tests since 1993, involving hundreds of icing events, the sensor *has never falsely indicated ice accretion*. Specific signatures from the sensor clearly and unambiguously indicate ice accretion. (See Section 1.0) The challenge for the algorithm is to assign occurrences of icing to the correct source: freezing rain, freezing drizzle, rime, or hoarfrost.

In 98 case studies covering icing events from around the United States during the winter of 1998-1999, the following statistics were derived (details in Section 5.4):

> Observers reported **20,112** minutes of freezing precipitation (14,616 minutes of FZRA and 5,496 minutes of FZDZ).
>
> At locations where observers were on duty, the proposed ASOS algorithm would have reported **21,346** minutes of freezing precipitation (13,337 minutes of FZRA and 8,009 minutes of FZDZ).

The 1998-1999 Case Studies included an *additional* 17,593 minutes of freezing precipitation reported by the ASOS when no observers were on duty.

Observer freezing precipitation and ASOS freezing precipitation would have been reported coincidentally for 17,090 minutes, which means that the observer and the ASOS were *concurrently* reporting freezing precipitation **85%** of the time.

Of all freezing precipitation reported by observers, 73% was reported as FZRA.
Of all freezing precipitation reported by the ASOS, 62% was reported as FZRA.

Differences between observer and ASOS reports of freezing precipitation are attributed primarily to the limitations imposed on observers by Basic Weather Watch procedures. Observers are not expected to catch every change in precipitation type; observers cannot catch the onset or ending of very light precipitation simply because they are not standing out in the weather, whereas the ASOS is continuously monitoring weather conditions on a minute-to-minute basis. The sensitivity and responsiveness of the ASOS icing detector may well permit the reporting of light freezing precipitation with greater accuracy and reliability than can be expected from an observer.

The proposed algorithm would have allowed the ASOS to report **14,578** minutes (over 240 hours) of freezing drizzle that would have gone un-reported by the current ASOS algorithm. These reports of freezing drizzle all occurred in areas and at times with verified freezing precipitation; there is no reason to consider *any* of these reports to be false alarms.

The Federal Meteorological Handbook Number 1 (FMH-1) requires that the intensity of freezing drizzle is to be determined by *visibility* criteria. However, an alternate definition of freezing-drizzle intensity has been established by the aircraft deicing community through the efforts of the FAA, the Society of Automotive Engineers (SAE), and the National Center for Atmospheric Research (NCAR) (Rasmussen, 1999). The alternate definition of FZDZ intensity is based on ice-accretion rates, and is directly relevant to aircraft ground deicing procedures. It is now possible to compare the two approaches to FZDZ intensity, because the ASOS Preplanned Product Improvement initiative of the National Weather Service Surface Observing Section has developed a procedure (Raytheon ITSS, 1999) to derive actual ice-accretion amounts and rates from ASOS icing sensor data.

Data from the winter of 1998-1999 indicate that there is no correlation between visibility-based FZDZ intensity (as reported in METAR/SPECI) and the rate of ice accretion. In 98 icing events, representing over 240 hours of FZDZ, the use of visibility criteria *failed* to identify about 93 percent of all moderate and heavy FZDZ ice accretion rates, and would have falsely reported “light” FZDZ during more than 100 hours of actual moderate or heavy FZDZ ice accretion rates.

Current deicing holdover timetables do not differentiate among FZDZ intensities; they provide a range of holdover times during periods of freezing drizzle. Some holdover-time ranges may be as large as 65 minutes from the shortest to the longest time (for a given deicing fluid, fluid concentration, and air temperature.) It is our understanding, based on contacts within the aircraft ground deicing community, that many airlines determine specific holdover times by monitoring the reported intensity of precipitation, under the assumption that the reported intensity is representative of the relative rate of ice accretion: if light FZDZ is reported in the METAR/SPECI, the user infers a low rate of ice accretion and selects the longest FZDZ holdover time; if heavy FZDZ is reported, the user infers a high rate of ice accretion and selects the shortest FZDZ holdover time. However, data collected in this project clearly indicate that METAR/SPECI reports of FZDZ intensity, based on visibility, *do not* accurately represent the rate of ice accretion, and they may mislead users into selecting incorrect holdover times.

RECOMMENDATIONS:

1) Because of the critical importance of FZDZ to aviation safety, the results of this report should be immediately forwarded to the ASOS Program Management Committee (APMC) for consideration in adopting the algorithm for operational use.

2) In order for METAR FZDZ reports to be more relevant to aviation operations, the APMC should consider the use of ice-accretion rates as the basis for FZDZ intensity.

3) There are a number of methods currently under review for the determination of FZDZ intensities. However, given the criticality of FZDZ to aviation operations, the APMC should seriously consider the option of always reporting moderate FZDZ intensity rather than delaying the overall implementation of automated FZDZ reporting pending selection of a specific method for determining intensities.

4) The APMC should be made aware of the fact that current METAR/SPECI reports of FZDZ intensity (based on visibility) do not accurately represent ice-accretion rates, and may provide seriously inaccurate guidance to users who rely on METAR/SPECI reports to determine holdover times.

1.0 BACKGROUND

The Rosemount Model 872C3 Sensor (Figure 1) was used in this development project. Within the ASOS, this instrument is known as a "Freezing Rain" sensor; however, because this development project is intended to extend the capabilities beyond freezing rain (FZRA), this sensor will be referred to as the ASOS Icing Sensor. The sensor detects ice accumulation by monitoring the resonant frequency (nominally 40,000 hertz) of a vibrating metal probe. The resonant frequency decreases with increasing ice accretion. Data are acquired from the sensor once each minute and are recorded in a dedicated Data Acquisition System or in the ASOS 12-hour data archive.

Figure 1 ASOS Icing Sensor

Observations during field tests beginning in 1993 indicated that the ASOS icing sensor detects significantly more icing than is indicated by reports of freezing rain. Specific frequency-vs-time signatures from the Rosemount 872C3 icing detector have always provided clear indications of ice accretion. These signatures (Figures 2 - 4), defined by a minimum frequency decrease and a minimum rate-of-change of frequency (for FZRA and freezing drizzle (FZDZ)) or by a minimum frequency decrease alone (for hoarfrost) reliably indicate the formation of ice on the sensor. *There are no instances, in over six years of laboratory and field testing, that these sensor-response signatures could be attributed to anything other than ice accretion.*

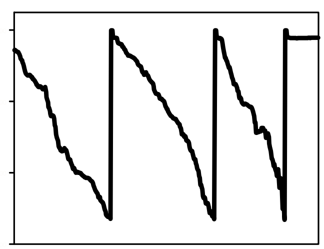

Figure 2 Freezing Rain

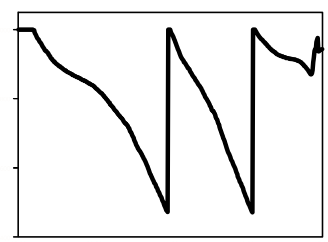

Figure 3 Freezing Drizzle

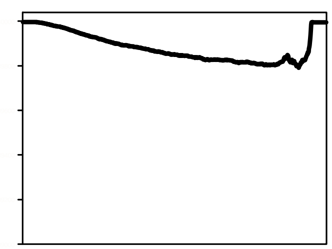

Figure 4 Hoarfrost

Because FZDZ accretion rates may exceed FZRA accretion rates (see Section 5.1), freezing rain and freezing drizzle can be differentiated only by the detectability of the precipitation by the ASOS precipitation sensor, the Light Emitting Diode Weather Identifier (LEDWI): if the precipitation is detectable by the LEDWI, it is reported as FZRA.

Inspection and analysis of ASOS data from 1994 through 1997 indicated that it was possible to estimate ice accretion (and accretion rates) from an analysis of raw ASOS sensor data, and that a simple multi-sensor algorithm could be used to infer the source of icing. These potential capabilities were described in a series of reports to the National Weather Service (NWS), and in presentations to the NWS, the FAA, the Meteorology Committee of the Air Transport Association, the American Meteorological Society (AMS), and international workshops on atmospheric icing. (See Attachment 3: Bibliography.)

In July, 1998, the FAA formally provided a prioritized listing of precipitation types to the NWS (Whatley, 1998). After consultation with the aviation industry, the FAA assigned the highest priority to the reporting of freezing precipitation (including FZDZ). The FAA letter stated, in part:

> "... both general aviation and air carriers believe that knowing that freezing precipitation is occurring (type), and the intensity and accumulation of the freezing precipitation is very important to them.
>
> " ... users believed that obtaining information on Freezing Precipitation was either their highest or second highest priority."

In response to that request (and to other requirements stated by NWS Forecast Offices), the ASOS Program Office directed formal evaluation of two ASOS algorithms:

1) an ice-accretion algorithm (Ramsay, 1999(1)) which could provide an estimate of the amount and rate of ice accretion, and

2) an icing-type algorithm (Ramsay, 1999(2)), with focus on occurrences of FZDZ.

The evaluation of the ice accretion algorithm was completed and reported to the NWS (Raytheon ITSS, 1999). As a result of the positive evaluation, the NWS proposed to provide estimates of ice accretion in a METAR/SPECI remark. However, the FAA (Whatley, 1999) did not concur with releasing ice-accretion information to aviation users at this time, citing "unintended, negative operational impacts on the airlines." The NWS is presently investigating alternative methods of disseminating ice-accretion information to NWS users.

The evaluation of the icing-type algorithm is reported in this document. The evaluation was performed on a slightly-modified algorithm from the one presented at the 1999 annual meeting of the AMS. The modified algorithm used in this analysis is described in Section 5.1.

2.0 PURPOSE

The specific question to be answered in this continuation of previous algorithm-development efforts is:

> How effective is the proposed ASOS algorithm in detecting the occurrence of freezing drizzle?

3.0 PERFORMANCE REQUIREMENTS

One of the primary objectives of the ASOS Planned Product Improvement initiative is to enhance ASOS contributions to aviation safety. The inability of the ASOS to report FZDZ represents a serious shortfall in support of aviation operations. Reports of FZDZ are among the most important surface weather elements for aviation applications.

In addition to the requirements stated by the FAA and NWS forecast offices, state-of-the-art in-flight icing models being developed by the National Center for Atmospheric Research and the NWS Aviation Weather Center are especially sensitive to reports of FZDZ. The lead scientist in the development of the Integrated Icing Diagnostic Algorithm (IIDA) has stated (Bernstein, 1999):

> "Surface observations are the most powerful forecasting tool we have for finding SLD [Supercooled Large Droplet] conditions aloft, and FZDZ observations are our best indicator of the simultaneous occurrence of FZDZ aloft.
>
> "Recent aircraft incidents and accidents have clearly identified the importance of determining the locations of FZDZ aloft. In my experience, surface observations are one of the most powerful pieces of information for identifying these potentially hazardous conditions aloft. The lack of surface observations of FZDZ from automated stations makes it more difficult for new SLD diagnostic tools, like IIDA, to find these conditions and to warn pilots and dispatchers of their existence."

The expansion of ASOS present-weather reporting capabilities to include FZDZ would make a major contribution to aviation safety in the United States.

4.0 TEST LOCATIONS AND DATA COLLECTION

Evaluation of this FZDZ algorithm was accomplished in parallel with the evaluation of the ASOS ice accretion algorithm (Raytheon ITSS, 1999). Clinical observations, with full-time dedicated observers, were taken at Sterling, VA, and Johnstown, PA.

Additional detailed data were gathered by NWS staff at Binghamton, NY, and Cleveland, OH; U.S. Army meteorologists at the Corps of Engineers Cold Regions Research and Engineering Laboratory, Hanover and Lebanon, NH; and NWS-certified observers at Mount Washington, NH.

The primary data set used in this FZDZ evaluation was obtained by monitoring weather conditions throughout the United States and downloading ASOS data from areas with freezing precipitation events. ASOS data were processed through the algorithm, and were compared with local reports of icing conditions for 98 icing events (Attachment 1). Fifty-six of the 98 events had significant ice accretion attributable to FZDZ; data for those 56 events are presented in some detail in Attachment 2. Individual case studies were prepared for each of these events, and are available from the NWS Surface Observing Section, W/OSO14x1.

5.0 METHODOLOGY AND RESULTS

5.1 Algorithm for FZRA / FZDZ Reporting

The initial algorithm for icing type required input data from the ASOS icing sensor, precipitation-identification sensor, hygrothermometer, visibility sensor, and ceilometer; the algorithm provided a report of icing type: glaze from either freezing rain or FZDZ, rime being deposited from fog, or hoarfrost. This algorithm was to be applied to all available data, and results were to be compared to observer reports of present weather, where available. However, shortly after the start of this field evaluation, the NWS decided that there is no requirement for automated determination of icing type. As a result of this decision, the evaluation was limited to the automated reporting of FZDZ, and the algorithm presented in the 1999 AMS paper was modified accordingly. The modified algorithm is presented in the following table. The major modification is the removal of the visibility criterion which attributes some icing to rime being deposited from fog; in the modified algorithm, all icing with overcast sky cover and no detectable precipitation is attributed to FZDZ.

Table 1. Algorithm for FZRA / FZDZ

ICE DETECTOR	LEDWI PRESENT WX TYPE	TEMP	VISIBILITY	SKY COVER	PRESENT WEATHER REPORTED
ACCRETION $0.13mm (0.005 inches) AND 15-MIN ACCRETION RATE $0.2mm/HR (0.008 inches/HR)	RA, UP	<2.8 C (<37EF)	ANY	ANY	FZRA *[Note 1]*
	SN	ANY	ANY	ANY	SN *[Note 2]*
ACCRETION $0.13mm (0.005 inches) AND 15-MIN ACCRETION RATE $0.1mm/HR (0.004 inches/HR) *[Note 3]*	NO PRECIP	# 0 C (#32EF)	ANY	OVC	FZDZ *[Note 4]*
				NOT OVC	NONE *[Note 5]*
ACCRETION $0.13mm (0.005 inches) *[Note 6]*	NO PRECIP	# 0 C (#32EF)	$7 MILES	CLR or SCT	NONE (FROST not reportable)

Note 1: The values are the standard ASOS criteria for identifying a freezing rain (FZRA) event.

Note 2: Snow may adhere to the Rosemount sensor, and is known to produce decreases in probe frequency. However, “WET SNOW” is not a reportable meteorological phenomenon. Under the current ASOS algorithm, icing signals from the Rosemount sensor are ignored: if the LEDWI reports snow, neither FZRA nor FZDZ will be reported.

Note 3: The 15-minute accretion rate threshold for identification of FZDZ was set at 0.1 mm (0.004 inches) per hour (lowered from the FZRA threshold of 0.2 mm (0.008 inches) per hour); this lower threshold did *not* generate false reports of FZDZ in any of the case studies analyzed in 1998-1999.

Note 4: An analysis of U.S. climatological data for the period 1961 through 1990 indicates that approximately seven percent of all FZDZ may occur with visibility less than 1 kilometer (5/8 miles), and would therefore be reported with FZFG. For this analysis, ice accretion with low visibility was reported as FZDZ, even though there is a possibility that the ice was rime being deposited from fog. Examination of individual cases studies in 1998-1999 indicated that there were no occurrences of rime icing, and that all algorithm reports of FZDZ occurred in areas and at times with confirmed freezing precipitation.

Note 5: In an automated system, allowance must be made for all possible combinations of reports from the various sensors. In the event that ice accretion was detected, but skies were not overcast, it would not be reasonable to report FZDZ with a satisfactory degree of confidence. Therefore, no entry would be made in the METAR present-weather field. In over 650 hours of freezing precipitation analyzed in 1998-1999, there were *no* cases in which the ASOS sky condition was not overcast.

Note 6: This criterion is included in this table for information only: the ASOS icing sensor responds to the formation of hoarfrost. Reports of hoarfrost may be useful to NWS forecasters and to aviation deicing operations. A reported accretion value of 0.13mm (0.005 inches), regardless of the accretion rate, can be used to infer the existence of ice on the probe; if the visibility is unrestricted and if the sky condition is clear or, in rare cases, scattered, a user can reliably infer the existence of hoarfrost. Note that the inference of frost does *not* include a minimum rate of accretion. Significant amounts of frost typically form over a period of hours, and the short-term (15-minute) accretion rate remains low during the entire accretion period.

5.2 Algorithm for Ice Accretion Rate and FZDZ Intensity

It is a relatively simple matter to derive ice-accretion rates from ASOS sensor data on a minute-to-minute basis (Ramsay, 1999(1) and Raytheon ITSS, 1999). Each minute, an accretion rate was calculated from the mean rate of change of the frequency-vs-time curve over the preceding 10 minutes. The 10-minute averaging period is in accordance with recommendations of the World Meteorological Organization Commission for Instruments and Methods of Observation (CIMO, 1997). The validity of the derived accretion rates is confirmed by the fact that, if the accretion-rate values are integrated over an entire icing event, the estimated total ice accretion is highly correlated with measurements of ice mass and thickness at those locations where measurements are available. (Raytheon ITSS, 1999)

The distribution of 98 event mean ice-accretion rates for FZDZ and FZRA are shown in Figure 5. The mean accretion rate for all periods of FZDZ was 0.014 inches per hour, while the mean accretion rate for all periods of FZRA was 0.038 inches per hour. Note the significant overlap of FZDZ and FZRA accretion rates.

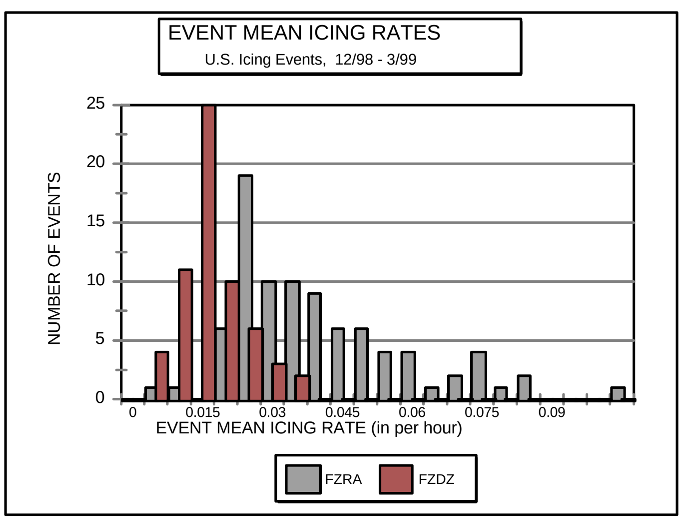

Figure 5 Distribution of FZDZ and FZRA Icing Rates

Two sets of rules for determining FZDZ intensity were applied to the entire FZDZ data set: one set of rules based on prevailing visibility, as stated in Federal Meteorological Handbook 1 (FMH-1), and another set based strictly on rates of ice accretion (which it is believed would have more direct operational relevance to aircraft icing issues.) The accretion-rate criteria are equivalent to those developed by the National Center for Atmospheric Research for use in determining deicing holdover times (Rasmussen, 1999). The "intensity" criteria are compared in the following table:

Table 2. Criteria for Determining FZDZ Intensity

Intensity	FMH-1 Criteria for Drizzle Occurring Alone [1]	FZDZ Accretion-Rate Criteria [2]
Light	Visibility > ½ mile	Rate # 0.01 inches per hour
Moderate	Visibility > ¼ mile but # ½ mile	Rate > 0.01 inches per hour but # 0.02 inches per hour
Heavy	Visibility # ¼ mile	Rate > 0.02 inches per hour

Note 1: Both the NWS and the FAA require that, when drizzle is occurring with other phenomena, the reported intensity shall be no greater than that determined using visibility.

Note 2: Accretion-rate criteria are equivalent to those used by the FAA, Society of Automotive Engineers, and National Center for Atmospheric Research in tests of aircraft deicing fluids. FAA/SAE/NCAR accretion rates are expressed in units of grams per decimeter squared per hour: 0.01 in/hour = 2.54 grams/dm^2/hr.

These criteria were applied to over 240 hours of FZDZ, with the following results:

Table 3. Comparison of FZDZ Intensities From VISIBILITY or ICE ACCRETION RATE

MINUTES OF FZDZ INTENSITIES, 1998 - 1999		Intensity Determined by VISIBILITY			Total Determined by Accretion Rate
		Light	**Moderate**	**Heavy**	
Intensity Determined by ACCRETION RATE	**Light**	7412	78	7	7497
	Moderate	4464	197	4	4665
	Heavy	2135	131	150	2416
Total Determined by VSBY		14011	406	161	14578

It is clear that visibility-based criteria provide little or no information on the intensity of ice accretion from FZDZ. The visibility-based criteria correctly identified (reported moderate *or* heavy FZDZ) only 482 minutes (about 7 percent) of the 7081 total minutes of moderate or heavy FZDZ accretion rates. Nearly half of the visibility-based "light" intensities would have occurred with actual moderate or heavy FZDZ accretion rates.

Current deicing holdover timetables (FAA, 1998) do not differentiate among FZDZ intensities; they provide a range of holdover times during periods of freezing drizzle. Some holdover-time ranges may be as large as 65 minutes from the shortest to the longest time (for a given deicing fluid, fluid concentration, and air temperature.) It is our understanding, based on contacts within the aircraft ground deicing community (Rasmussen, 1999), that many airlines determine specific holdover times by monitoring the reported intensity of precipitation, under the assumption that the reported intensity is representative of the relative rate of ice accretion: if light FZDZ is reported in the METAR/SPECI, the user infers a low rate of ice accretion and selects the longest FZDZ holdover time; if heavy FZDZ is reported, the user infers a high rate of ice accretion and selects the shortest FZDZ holdover time. However, data collected in this project clearly indicate (Table 3) that METAR/SPECI reports of FZDZ intensity, based on visibility, *do not* accurately represent the rate of ice accretion, and they may mislead users into selecting incorrect holdover times.

5.3 Ice Accretion Rates from FZDZ and FZRA

Data in the following table indicate that the distribution of ice accretion rates in freezing rain, as derived from the ASOS icing sensor, does not agree with the distribution of freezing-rain intensities reported by the LEDWI[1]. There is no reason to question the freezing-rain intensities reported by the LEDWI. The small fraction of moderate ice-accretion rates and the total lack of heavy ice-accretion rates from the ASOS icing sensor can be explained by examining the likely response of the icing sensor to large drops. The ASOS sensor reports ice accretion on a small (1" X 1/4" diameter) vertical rod, which does not provide a large area for ice collection. If drops do not freeze *immediately* on impact with the ASOS sensor, the liquid water runs to the bottom of the probe before freezing, and the ice is not detectable. Extensive field observations indicate that large drops which occur in moderate and heavy rain may require some seconds - or even minutes - to change state from liquid to solid; the time delay gives the drops enough time to run off the bottom of the probe, thereby making them undetectable to the icing sensor.

[1] Both FZRA and ice-accretion intensities were established using one set of thresholds: #0.01 inches per hour for light FZRA, >0.01 to #0.03 inches per hour for moderate FZRA, and >0.03 inches per hour for heavy FZRA.

Table 4. Comparison of FZRA Intensities From LEDWI or ICE ACCRETION RATE

MINUTES OF FZRA INTENSITIES, 1998 - 1999		**FZRA Intensity Determined by LEDWI**			**Total Determined by Accretion Rate**
		Light	**Moderate**	**Heavy**	
FZRA Intensity Determined by ACCRETION RATE	**Light**	19000	3640	1162	23802
	Moderate	76	230	253	559
	Heavy	0	0	0	0
Total Determined by LEDWI		19076	3870	1415	24361

One unplanned outcome from this project is the ability to construct a "climatology" of ice accretion rates for the 650 hours of icing observed during the winter of 1998-1999. The observed distribution of the 10-minute mean ice-accretion rates is shown in Figures 6 and 7, below; the data are presented with two different units of measure: inches per hour for the use of NWS forecasters, and grams per decimeter squared per hour for the aviation deicing community.

The two most notable features of the accretion-rate statistics are:

1) the low frequency (about 1.4 percent) of accretion rates greater than 0.1 inches per hour or 25 grams per decimeter squared per hour (equivalent to moderate rain), and

2) the significant overlap in accretion rates attributed to FZDZ or to FZRA. The definition of FZDZ in this project is based on the ability (or, more precisely, the *inability*) of the ASOS precipitation identifier (the LEDWI) to detect liquid precipitation. The LEDWI is believed to respond in some manner to particles smaller than the design value of greater than or equal to approximately 1000 microns, but no detailed information is available about the sensitivity of the sensor to the smaller particles. It is, therefore, possible that some of the icing attributed to FZDZ in this project could actually have occurred from undetectable rain particles in the 500-1000 micron range.

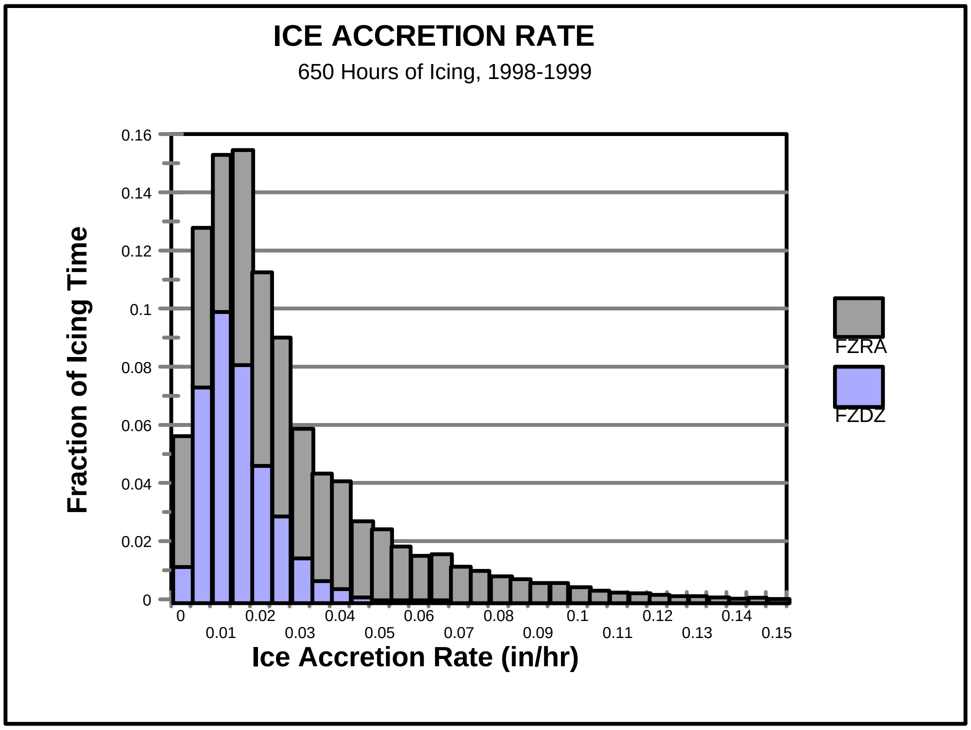

Figure 6 Ice Accretion Rates in Inches per Hour

5.4 Metrics

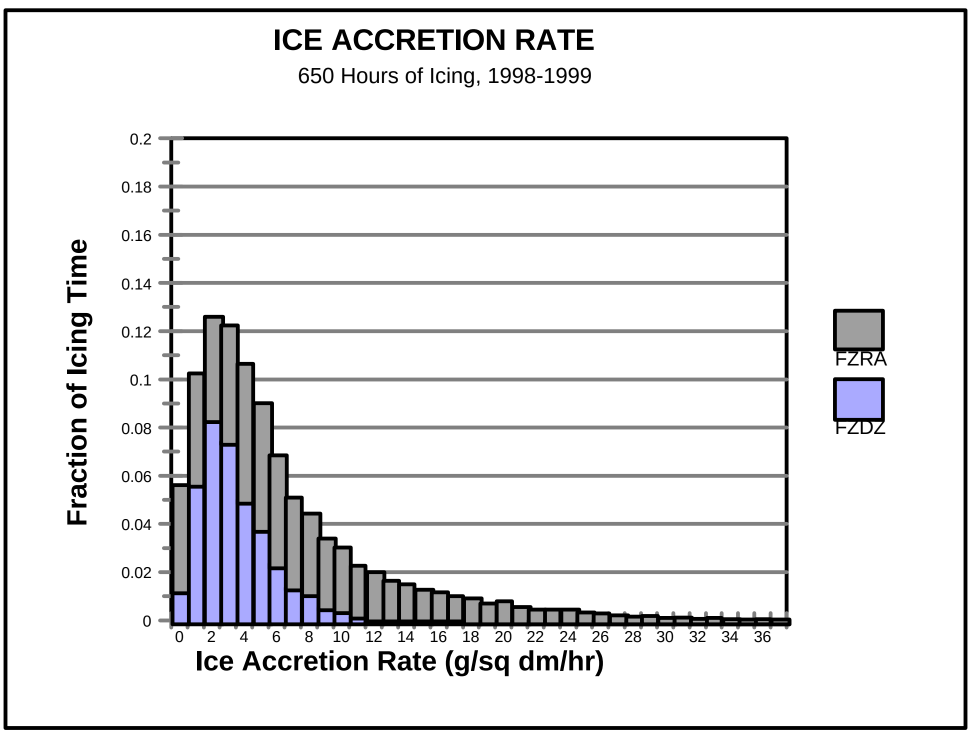

Figure 7 Ice Accretion Rates in Grams per Decimeter Squared per Hour

5.4 Metrics

The performance of the freezing drizzle algorithm was measured by comparing the number of minutes of freezing precipitation, minutes of freezing rain, and minutes of FZDZ reported by an on-site observer or by the current ASOS algorithm (V2.40 to 2.60) with the number of minutes reported by the proposed ASOS algorithm. When no observers were present, the ASOS algorithm reports were evaluated with reference to reports of precipitation type from surrounding stations.

5.5 Results

Case studies were prepared for 98 individual icing events, from December 1998 through March 1999. Summary statistics for the 98 freezing-precipitation events are presented in Attachment 1. Copies of individual case studies are available from W/OSO14x1. The case studies consisted of:

(1) descriptions of weather conditions;

(2) a graphical timeline of manual observations and ASOS precipitation-type reports, and sensor frequency; and

(3) a table of precipitation reports, comparing observer and automated reports.

Attachment 2 contains excerpts from 56 case studies with at least 0.01" of ice deposited from FZDZ, as estimated from the ASOS ice accretion algorithm (Ramsay, 1999(1)). Attachment 2 is included in this report primarily to allow a reader to establish confidence in the validity and reliability of this algorithm through a review of the graphs and tables.

The following table is a summary of all precipitation reports for 98 case studies prepared in 1998-1999. These data represent a total estimated accumulation of 18.7 inches of ice (15.3 inches from FZRA, 3.4 inches from FZDZ).

Table 5. Precipitation Type for 98 Case Studies, 1998-1999

		MINUTES OF PRECIPITATION TYPE						
		CLASSIFIED BY THE PROPOSED ASOS ALGORITHM						HUMAN TOTAL
		FZRA	FZDZ[1]	UP	RA	SN	NP	
HUMAN	FZRA	10639	2440	57	832	180	468	14616
	FZDZ	989	3042	36	161	175	1093	5496
	PL	468	13	49	413	212	19	1174
	UP [2]	66	22	188	56		3	335
	RA	773	90	21	1456	23	118	2481
	DZ		60	12	16		17	105
	SN [3]	143	267	141	219	2021	347	3138
	NP	259	2075	23	84	12	4881	7334
	NA [4]	11024	6569	439	3669	2553	4767	29021
ALGORITHM TOTAL		24361	14578	966	6906	5176	11713	63700

Note 1: None of the minutes of FZDZ would have been reported by the current ASOS algorithm
Note 2: "Human UP" may occur when an automated report of UP is not edited by the observer on duty.
Note 3: Includes reports of snow grains and snow pellets.
Note 4: "NA" indicates that there were no observers on duty.

Key statistics derived from the summary of precipitation reports:

Observers reported **20,112** minutes of freezing precipitation (14,616 minutes of FZRA and 5,496 minutes of FZDZ).

At locations where observers were on duty, the proposed ASOS algorithm would have reported **21,346** minutes of freezing precipitation (13,337 minutes of FZRA and 8,009 minutes of FZDZ).

(The 1998-1999 Case Studies included an *additional* 17,593 minutes of freezing precipitation reported by the ASOS when no observers were on duty.)

Observer freezing precipitation and ASOS freezing precipitation would have been reported coincidentally for 17,090 minutes, which means that the observer and the ASOS were *concurrently* reporting freezing precipitation **85%** of the time.

Of all freezing precipitation reported by observers, 73% was reported as FZRA.
Of all freezing precipitation reported by the ASOS, 62% was reported as FZRA.

Differences between observer and ASOS reports of freezing precipitation are attributed primarily to the limitations imposed on observers by Basic Weather Watch procedures. Observers are not expected to catch every change in precipitation type; observers cannot catch the onset or ending of very light precipitation simply because they are not standing out in the weather, whereas the ASOS is continuously monitoring weather conditions on a minute-to-minute basis. Even though the ASOS icing sensor is known to miss some occurrences of freezing precipitation (Ramsay, 1997), the sensitivity and responsiveness of the ASOS icing detector may well permit the reporting of freezing precipitation with greater accuracy and reliability than can be expected from an observer.

The proposed algorithm would have allowed the ASOS to report 14,578 minutes (over 240 hours) of FZDZ that would have gone un-reported by the current ASOS algorithm. These reports of FZDZ all occurred in areas and at times with verified freezing precipitation from surrounding stations; there is no reason to consider *any* of these reports to be false alarms.

There were eight icing events consisting *only* of freezing drizzle. These events represented over 46 hours of freezing drizzle, with an estimated total ice accretion of nearly 0.74 inches of glaze ice. None of these events would have been reported by the current ASOS algorithm.

6.0 RECOMMENDATIONS

The freezing drizzle algorithm should be referred to the ASOS Program Management Committee (APMC) for consideration of adopting the algorithm for operational use.

- Because of its impact on aviation safety, the FAA and the aviation industry have assigned the highest precipitation-identification need to freezing precipitation - including FZDZ.
- The ASOS currently does not report FZDZ.
- This algorithm provides accurate and reliable reports of the occurrence of FZDZ.

In order for METAR/SPECI FZDZ reports to be more relevant to aviation operations, the APMC should consider the use of ice-accretion rates as the basis for FZDZ intensity.

There are a number of methods currently under review for the determination of FZDZ intensities. However, given the criticality of FZDZ to aviation operations, the APMC should seriously consider the option of always reporting moderate FZDZ intensity rather than delaying the overall implementation of automated FZDZ reporting pending selection of a specific method for determining intensities.

The APMC should be made aware of the fact that current METAR/SPECI reports of FZDZ intensity (based on visibility) do not accurately represent ice-accretion rates, and may provide seriously inaccurate guidance to users who rely on METAR/SPECI reports to determine holdover times.