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FREEZING DRIZZLE (FZDZ) IDENTIFICATION FROM THE AUTOMATED SURFACE OBSERVING SYSTEM (ASOS): STATUS OF THE ASOS MULTI-SENSOR FZDZ ALGORITHM

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1. INTRODUCTION

Requirements for automated identification of freezing drizzle (FZDZ) have been recognized since the initial development efforts of the Automated Surface Observing System (ASOS) in the 1980's. Requirements related to deicing operations have long been established, and a more recent application in support of in-flight icing diagnostic models has been recognized (Bernstein and Brown, 1997; Bernstein, 1999).

Sensor technology has been unable to provide a capability for automated FZDZ reporting. In the mid 1990's, the ASOS Program Office, as a part of its Product Improvement effort, began a development program on surface icing that has delivered two algorithms: (1) an algorithm which provides a quantitative estimate of ice accretion (Ramsay, 1999(2); Ramsay and Ryerson 1998(1) and 1998(2); Ryerson and Ramsay, 1997), and (2) an algorithm which gives the ASOS the capability to identify occurrences of freezing drizzle. The initial development of the multi-sensor FZDZ algorithm has been previously reported (Ramsay, 1999(1); Ramsay and Dover, 2000; Ramsay, 2000) This paper provides a final look at multiple field evaluations of the FZDZ algorithm.

1.1 *The ASOS Icing Sensor and Freezing Rain Algorithm*

The ASOS Rosemount Model 872C3 Icing Sensor (Figure 1) detects ice accumulation by monitoring the resonant frequency of a vibrating metal probe. The resonant frequency decreases with increasing ice accretion. The current ASOS algorithm for freezing precipitation (Table 1) requires suitable temperatures, a report of rain (RA) or unknown precipitation (UP) from the precipitation identification sensor (the Light Emitting Diode Weather Identifier - LEDWI), and a specific ice-accretion response from the ASOS icing sensor. The LEDWI is not used to detect drizzle, and, therefore, the ASOS is allowed to report only freezing rain (FZRA). Currently, freezing drizzle events go unreported unless reports of FZDZ are augmented by on-site observers.

Figure 1. ASOS Icing Sensor

1.2 *Capabilities of the Rosemount Sensor*

Previous field evaluations of the Rosemount sensor (Ramsay, 1997) demonstrated that the reports of ice accretion are highly reliable. The basic criteria for an icing event (Table 1) ensure that the sensor will not issue a false alarm of ice accretion: *only four instances of false freezing rain have been reported in over seven years of*

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monitoring. Three episodes occurred with uncalibrated sensors, and the fourth occurred with one of five collocated test sensors in a unique set of conditions, also at the end of an icing event.

While icing reports from the ASOS icing sensor are highly reliable, users should remain aware that there are icing conditions or portions of icing events which may be *missed* by the sensor: particularly, during an icing event with temperatures near 0EC, the sensor may fail to report ice accretion for up to 30 minutes following a deicing cycle. These periods of missed freezing precipitation occur infrequently, and generally with low amounts and rates of accretion.

2. THE ASOS ALGORITHM FOR FZDZ

The current version of the combined ASOS algorithms for freezing rain and freezing drizzle is presented in Table 1.

TABLE 1. ALGORITHM FOR FZRA / FZDZ

ICE DETECTOR	LEDWI PRESENT WX TYPE	TEMP	VISIBILITY	SKY COVER	PRESENT WEATHER REPORTED
CURRENT ASOS FZRA ALGORITHM: ACCRETION $0.13mm AND 15-MIN ACCRETION RATE $0.2mm/HR	RA, UP	<2.8E C	ANY	ANY	FZRA
	SN	<3.3E C	ANY	ANY	SN *[Note 1]*
ADDED NEW FZDZ ALGORITHM: ACCRETION $0.13mm AND 15-MIN ACCRETION RATE $0.1mm/HR *[Note 2]*	NO PRECIP	# 0E C	ANY	OVC or VV	FZDZ *[Note 3]*
				NOT OVC	NONE *[Note 4]*

Note 1: Snow may adhere to the Rosemount sensor, and can 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 due to snow are ignored: if the LEDWI reports snow, the ASOS will report snow, and the icing indications will be ignored.

Note 2: The 15-minute accretion rate threshold for identification of FZDZ was set at 0.1 mm (0.004 inches) per hour; this lower threshold did *not* generate false reports of FZDZ in any of the 187 case studies with FZDZ analyzed in 1998-2001.

Note 3: 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 1998-2001 indicated that there *may* have been one occurrence of rime icing: 171 minutes of icing at Altoona, Pennsylvania, on February 19, 2000. All other algorithm reports of FZDZ occurred in areas and at times with confirmed glaze ice accretion.

Note 4: 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 any degree of confidence. Therefore, no entry would be made in the METAR present-weather field. In over 2800 hours of freezing precipitation analyzed in 1998-

2001, there were *no* cases in which the ASOS sky condition was not overcast.

METAR/SPECI reports of FZRA and FZDZ must contain a value of precipitation intensity. The intensity of FZRA is obtained directly from the ASOS precipitation identification sensor, the LEDWI. At the present time, instructions to observers on FZDZ intensity require that intensity be determined from surface visibility: FZDZ is 'light" if the surface visibility is greater than 1/2 statute mile; FZDZ is "moderate" if the surface visibility is greater than 1/4 and less than or equal to 1/2 statute mile; and FZDZ is "heavy" if the surface visibility is less than or equal to 1/4 statute mile. Data from the ASOS icing sensor permit the estimation of actual ice accretion rates, and it has been shown (Ramsay, 2000) that surface visibility is very poorly correlated with surface icing rates. The NWS and the FAA have agreed that automated reports of FZDZ should have intensities derived from ASOS-estimated icing rates: "light" for rates less than 0.25 mm (0.01 inches) per hour, "moderate" for rates between 0.25 (0.01 inches) and 0.5 mm (0.02 inches) per hour; and "heavy" for rates greater than 0.5 mm (0.02 inches) per hour.

3. ALGORITHM PERFORMANCE

Raytheon ITSS completed case studies for 323 icing events throughout the United States during the winters of 1998-1999, 1999-2000, and 2000-2001. The 323 cases covered 2838 hours of freezing precipitation. Raw ASOS sensor (one-minute) data were downloaded directly from the systems during icing events, and were processed through the proposed FZDZ algorithm. ASOS precipitation reports from the proposed algorithm were compared to either manual observations from collocated observers or (where no observers were present) to automated precipitation reports from the current ASOS operational algorithm. When no observers were present, reports from the new ASOS FZDZ algorithm were validated by reference to reports of precipitation type from surrounding stations. This paper presents results of a subset of those case studies (i.e., 187 cases which involved at least five minutes of FZDZ identified by the new algorithm), and represents ASOS performance in over 1730 hours of icing conditions.

A perfect "match" between manual and automated observations is not to be expected, especially when the majority of manual observations are taken under Basic Weather Watch criteria. The identification of freezing precipitation by an observer is necessarily a subjective activity, and depends on many non-meteorological factors, including the temperature, mass, thermal conductivity, orientation and shape, exposure, etc., of the surfaces being monitored for ice accretion (Makkonen, 1997).

Table 2 is a summary of all precipitation reports for the 187 icing events with freezing drizzle analyzed in 1998-2001. These data represent a total accumulation of over 35 inches of ice (28 inches from FZRA, 7 inches from FZDZ), estimated using the ASOS ice-accretion algorithm (Ramsay, 1997).

TABLE 2. COMPARISON OF PRECIPITATION REPORTS:
187 EVENTS WITH FREEZING DRIZZLE, 1998-2001

		HOURS OF PRECIPITATION TYPE						
		CLASSIFIED BY THE ASOS FZRA / FZDZ ALGORITHM						HUMAN TOTAL
		FZRA	FZDZ [Note 1]	UP	RA	SN	NP	
HUMAN	FZRA	310.6	80.6	9.5	16.5	3.9	19.1	440.2
	FZDZ	43.6	125.3	1.9	5.4	3.6	56.6	236.4
	PL	11.1	0.3	1.3	8.3	- -	3.0	24.0
	UP [Note 2]	3.3	0.9	0.9	3.5	3.1	0.3	12.0
	RA	16.0	1.6	5.8	28.6	0.6	3.5	56.1
	DZ	1.9	6.6	1.9	0.3	- -	3.6	14.3
	SN [Note 3]	5.4	10.7	2.7	3.6	45.0	14.0	81.4
	NP	10.5	106.9	1.1	0.3	0.2	0.2	119.2
ALGORITHM SUBTOTAL		402.4	333.9	25.1	66.5	45.2	100.3	973.4
HUMAN NA [Note 4]		340.2	204.0	10.3	77.8	62.5	62.5	757.3
ALGORITHM TOTAL		742.6	537.9	35.4	144.3	107.7	162.8	1730.7

Note 1: None of the occurrences of FZDZ would have been reported by the current ASOS algorithm; all reports would have appeared in the no-precipitation (NP) column.

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.

3.1 *Over-All Performance*

Comparing automated and manual observations is always a risky business, especially when the manual observations are made by personnel with other (sometimes higher priority) duties. For observers "trapped" in a control tower, accurately detecting the onset and cessation of FZDZ is extremely difficult.

The following statistics are derived from the over-all summary of precipitation reports (Table 2).

- Observers reported **676** hours of freezing precipitation (440 hours of FZRA; 236 hours of FZDZ).

- At locations where observers were on duty, the ASOS FZRA / FZDZ algorithm would have reported **736** hours of freezing precipitation (402 hours of FZRA; 334 hours of FZDZ).

‘ Observer freezing precipitation and ASOS freezing precipitation would have been reported coincidentally for 560 hours, which means that ASOS algorithms agreed with the observer on the occurrence of freezing precipitation about **83%** of the time.

‘ The 1998-2001 Case Studies included an *additional* **544** hours of freezing precipitation (340 hours of FZRA; 204 hours of FZDZ) that would have been reported by the ASOS when no observers were on duty (during non-observing hours at Service Level C locations, and for all hours at Service Level D locations.)

3.2 *Performance At Sites With Service Levels A and B*

The NWS and the FAA have established four levels of meteorological service for ASOS sites (FAA, 2000). Service Levels A and B *require* observers to augment ASOS reports whenever FZDZ is occurring, and therefore provide a particularly interesting set of comparisons between observer and automated reports.

For the 187 events with freezing drizzle, observers at Level A/B sites reported 176 hours of freezing precipitation (113 hours of FZRA, 63 hours of FZDZ.) The ASOS algorithm would have reported 194 hours of freezing precipitation (98 hours of FZRA, 97 hours of FZDZ.) However, 21 hours of automated FZDZ would have been reported when the observer was reporting “no precipitation.” Detailed analyses of sensor data provide highly reliable evidence of ice accretion at the ASOS while observers were reporting no precipitation; the additional hours of FZDZ provided by the algorithm could have alerted the observer of icing occurrence. The 12% increase in detected freezing precipitation would be significant, especially in light of the fact that Level A and B sites are hub airports or special airports that have worse-than-average weather conditions. This evaluation demonstrated that implementation of this ASOS algorithm at Level A/B sites could provide more accurate information to observers, and could thereby enhance their ability to provide accurate observations to their customers.

3.3 *Example of Algorithm Performance*

One event observed in early 2001 illustrates both the power of the freezing drizzle algorithm and one of the issues that the algorithm raises. This event (at Kansas City International Airport - KMCI - on February 23, 2001) had low total ice accretion (less than 1/4 inch), but is significant in that it illustrates the performance of the ASOS FZDZ algorithm in a case of “freezing mist.”

In this event, the ASOS freezing drizzle algorithm would have reported freezing drizzle for over eight hours before the observer. The event is illustrated in Figure 2, which provides comparative timelines of observer and automated reports. Raw sensor (frequency) values clearly show ice accretion at the ASOS beginning as early as 0700 UTC. (The sharp vertical lines in the frequency data indicate times when the sensor was deiced in accordance with the ASOS algorithms.)

‘ The duty observer reported that the conditions were primarily “very fine mist” - very small particles that could be detected on his glasses when he faced into the wind. He noted that KMCI had 10-15 knot easterly winds all morning. He confirmed that there was a very light film of ice on some surfaces, and that the ice was glaze rather than rime.

‘ Officials at the NWS Central Region reported that cars in the Kansas City suburbs had a thin coating of ice that morning.

‘ Southwest Airlines reported that they had conducted minimal deicing activities for originating flights that morning. They noted “a very thin layer of ice,” and decided to deice aircraft to ensure safe operations.

The ASOS FZDZ algorithm performed as designed: it reported a total of ten hours of freezing drizzle associated with ice accretion at the ASOS. However, only about 90 minutes of FZDZ coincided with freezing-precipitation reports from the observer. Some of the discrepancy could be attributed to the separation between the ASOS and the observer, and the possible effects of the terminal heat-island around the observer. However, in this case, the discrepancy most probably lies in the FMH-1 definition of precipitation and drizzle: droplets must reach the ground in order to be reported as precipitation. The very small particles seen at KMCI were visible on the observer’s glasses, but were carried horizontally by the 10-15 knot winds. The horizontal flux of liquid particles produced light glaze on objects (witness Southwest Airlines' deicing activities), but may well *not* have met the criteria for reporting precipitation. Note that it required many hours of this very low particle flux to deposit ice on surfaces; the estimated mean icing rate between 0700 and 1600 UTC would have been about 0.3 mm (0.012 inches) per hour.

This event raised the issue: is it acceptable for the ASOS to report freezing drizzle in order to advise users that ice accretion is occurring, even though an observer does not report freezing drizzle? The NWS and FAA decision to adopt the automated FZDZ algorithm indicates that both agencies accept the premise that reports of ice accretion are important to aviation safety, regardless of the semantics surrounding the source of the icing.

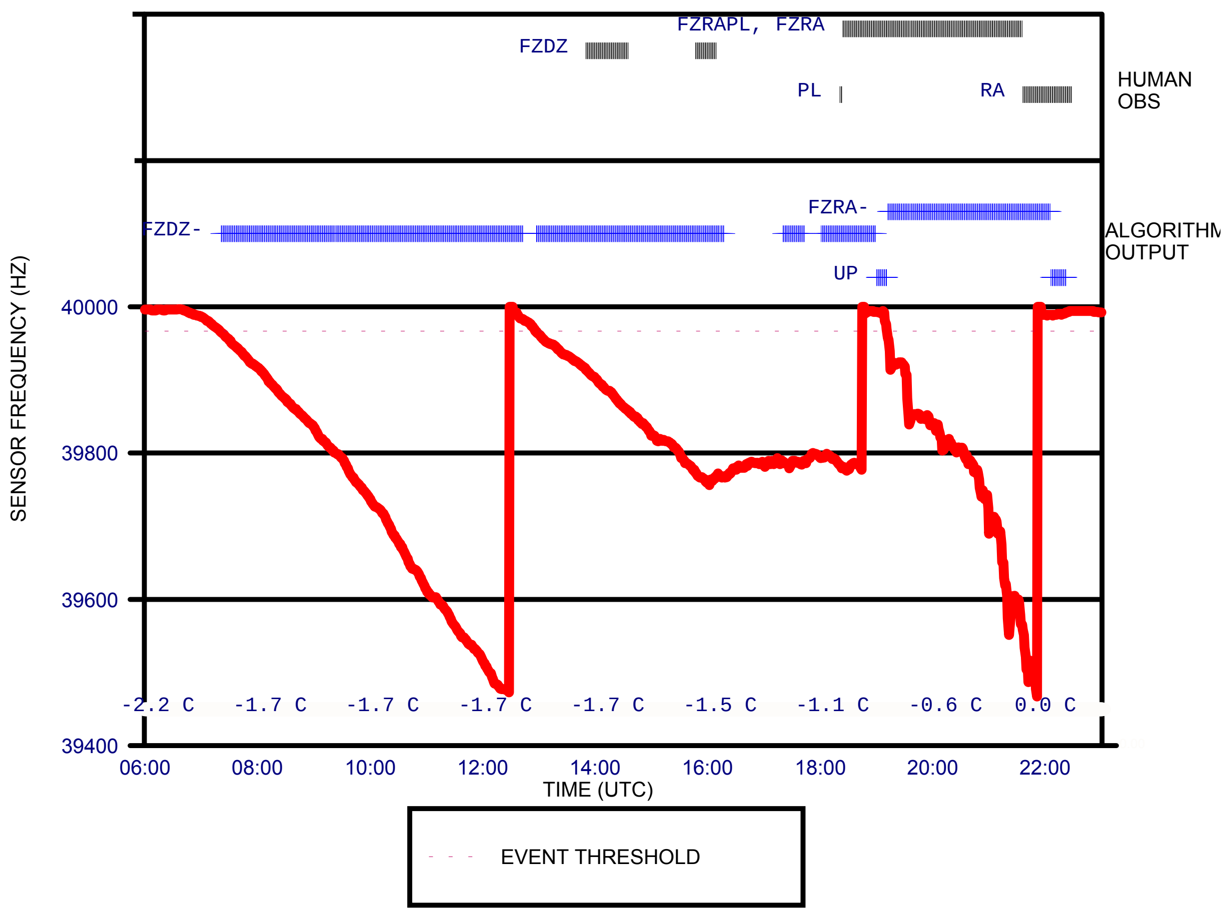

Figure 2. ASOS Icing Event at Kansas City International Airport (KMCI), February 23, 2001

4. CONCLUSION

The National Weather Service and the Federal Aviation Administration completed their reviews of the FZDZ algorithm in the spring of 2001, and both agencies have officially endorsed its implementation throughout the ASOS.

ASOS management intends to implement the FZDZ algorithm in software version 3.0, which is not expected to be released before 2003. The timing of the release is not firm, because of a number of issues which must be addressed before the new algorithm can be incorporated in ASOS code. These issues include the installation of high-priority sensor hardware (i.e., a new dewpoint sensor, new ice-free wind sensor) and a major upgrade of the central processor. Another important factor in the implementation process will be to ensure that the algorithm is turned on simultaneously at all ASOS locations so that users in the aviation community will not have to wonder whether or not a given location is capable of identifying FZDZ.

The ASOS freezing drizzle algorithm would have added over 300 hours of surface icing conditions which went unreported by the aviation weather system in the United States during the three winters of 1998-2001. The author believes that implementation of this algorithm will significantly enhance meteorological support to the aviation industry.

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