WIVIS with HIPS Sensor Performance

The current ASOS present weather sensor, the LEDWI, was developed by OSI in the 1980's and became one of the key sensors in the ASOS. This sensor, fielded at over 1100 locations across the United States, continues to meet the original design requirements with a solid track record of high reliability. The capability of LEDWI to differentiate between rain and snow is unmatched by any other sensor or technology. The LEDWI does however have limited drizzle detection sensitivity and limited ability to properly identify hail and ice pellets. With increased concerns over more accurate detection and quick response to all types of hazardous weather, the need for reporting precipitation parameters beyond the original specification has continued to develop.

OSi continued to improve on the original sensor in-house with the development of a commercial series of present weather / visibility sensors. Through the use of hardware design optimization and newer software techniques for algorithm development, OSI has greatly enhanced the commercial sensor's detection sensitivity as well as accuracy. With the asymmetric packaging of the optical head for the new series of WIVIS sensors, the susceptibility to wind-induced vibration was overcome. Through these and other enhancements, OSi has been able to produce a new generation of present weather sensors that greatly improves on the versatility and accuracy of the earlier ASOS LEDWI. These sensors have found widespread use in highway, airport, commercial and international applications.

The WIVIS combines the original scintillation technology used in LEDWI with an addition of an off-axis optical forward scatter channel. It is known that the optical forward scattering is sensitive to small particles such as fog or drizzle. Combining the in-beam scintillation and the off-axis forward scattering, WIVIS is much sensitive to drizzle then its predecessor.

It is extremely difficult if not impossible to reliably discriminate a solid ice particle from a water droplet using optical signal only. However, it is everyone's experience that when an ice particle hit a metal surface, the impact noise is distinguished from that hit by a water droplet. Based on this effect, OSI developed a patented acoustic technology to detect the ice pellets and hail stones. However, it is also known that using only acoustic signal will yield a lot of false identification of ice particle when blowing send hit the metal surface. By combining both the optical signal and the acoustic signal, reliable detection and discrimination of ice particles can be achieved.

In addition, by using advanced algorithm techniques such as artificial intelligence, neural networks and fuzzy logic with these three different but complementary sensing techniques, OSi has developed what is clearly the most advanced present weather sensor available today.

To verify the performance of the WIVIS and HIPS in real field test, three parts of the analyses are included, i.e.,

1. Compare the performance of the WIVIS to that of the LEDWI.
2. Compare the detection sensitivity of WIVIS with or without the off-axis forward scattering channel.
3. Test the detection sensitivity of HIPS for ice pellets.

WIVIS vs. LEDWI Performance Comparison

During 1994 and 1995, a large amount of data was collected and analyzed to compare the performance of the original ASOS LEDWI with the WIVIS at NWS Test and Evaluation Division site at Dulles Airport. It should be noted that for this test, only the in-beam scintillation channel was used for precipitation detection. The off-axis forward scatter channel information was used for visibility measurement but not used for precipitation detection.

The data, collected over a period of several months in winter of 1994 and 1995, is summarized as follows. Looking at the bottom line totals on the following Test Summaries, we can see that the WIVIS is clearly more sensitive and yet more resistant to false alarms. For precipitation detection, WIVIS detected 8% more time with precipitation than that of the LEDWI. WIVIS is also able to discriminate drizzle from rain. For false alarm rate, both WIVIS and LEDWI are extremely low well below the ASOS requirement of 0.2%. Over those years, OSi continued to improve the performance, culminating with the latest WIVIS.

Type of Precip.	**ASOS LEDWI**	**WIVIS**	**Remarks**
Mixed	629	222	WIVIS better – less ambiguous mixed data
Rain	5842	4565	WIVIS better – correctly measures drizzle and sum of drizzle + rain is higher (more sensitive)
Drizzle	0	1557	
Snow	1228	1972	WIVIS able to better detect snow
Total	7699	8316 (108%)	WIVIS is clearly more sensitive – more minutes

Table 1: WIVIS vs. LEDWI Identification Performance Test Summary

WIVIS vs LEDWI Identification Performance Test Results (1994/95)

I. Event Data With Ambient Temperatures Above +38F

	WIVIS					LEDWI				
Date	**Total**	**Mixed**	**Rain**	**Drizzle**	**Snow**	**Total**	**Mixed**	**Rain**	**Drizzle**	**Snow**
01-14-94	20	3	7	10	0	19		19	0	0
01-25-94	298	9	243	46	0	319	5	314	0	0
01-26-94	4	4	0	0	0	4		4	0	0
02-27-95	437	1	436	0	0	422		422	0	0
02-28-95	236	5	219	12	0	215		215	0	0
03-03-95	45	15	0	30	0	0			0	0
03-05-95	129	0	98	31	0	175	11	164	0	0
03-06-95	236	1	176	59	0	287	13	274	0	0
03-08-95	461	2	419	40	0	497	16	481	0	0
Sub-Total	**1866**	**40**	**1598**	**228**	**0**	**1938**	**45**	**1893**	**0**	**0**

II. Event Data With Ambient Temperatures Between +28 and +38F

	WIVIS					LEDWI				
Date	**Total**	**Mixed**	**Rain**	**Drizzle**	**Snow**	**Total**	**Mixed**	**Rain**	**Drizzle**	**Snow**
01-12-94	625	12	608	5	0	628	0	628	0	0
01-14-94	197	42	56	99	0	147	79	64	0	4
01-17-94	404	25	374	5	0	394	0	394	0	0
01-25-94	26	2	15	9	0	32	11	21	0	0
01-26-94	88	8	11	69	0	43	21	22	0	0
01-28-94	216	7	199	10	0	220	4	216	0	0
01-30-94	229	20	0	22	187	188	0	9	0	179
02-08-94	150	3	141	6	0	149	0	149	0	0
02-09-94	321	9	278	34	0	306	11	295	0	0
03-08-95	257	25	20	0	212	258	0	22	0	236
Sub-Total	**2513**	**153**	**1702**	**259**	**399**	**2365**	**126**	**1820**	**0**	**419**

III. Event Data With Ambient Temperatures Below +28F

	WIVIS					LEDWI				
Date	**Total**	**Mixed**	**Rain**	**Drizzle**	**Snow**	**Total**	**Mixed**	**Rain**	**Drizzle**	**Snow**
01-17-94	511	4	149	181	177	491	2	340	0	149
01-19-94	33	0	0	0	33	29	5	7	0	17
01-20-94	633	0	0	0	633	434	1	0	0	433
01-21-94	0	0	0	0	0	15	0	0	0	15
01-26-94	37	19	5	2	11	1	0	1	0	0
01-27-94	929	0	54	399	476	700	249	335	0	116
01-28-94	225	4	130	51	40	201	9	192	0	0
02-08-94	355	2	331	22	0	347	6	341	0	0
02-10-94	192	0	96	62	34	180	15	165	0	0
02-11-94	1022	0	500	353	169	998	171	748	0	79
Sub-Total	**3937**	**29**	**1265**	**1070**	**1573**	**3396**	**458**	**2129**	**0**	**809**
TOTALS	**8316**	**222**	**4565**	**1557**	**1972**	**7699**	**629**	**5842**	**0**	**1228**

Table 2: WIVIS vs. LEDWI Identification Performance Test Results

WIVIS vs LEDWI False Alarm Performance Test Summary

Measured Minutes of Data - 1Q94 Test Period

		WIVIS ---------------		LEDWI ---------------	
DATE	**TOTAL**	**PRECIP**	**FALSE**	**PRECIP**	**FALSE**
01-10-94	819	0	0	0	0
01-11-94	1440	0	1	0	0
01-12-94	1440	625	0	628	0
01-13-94	1440	0	0	0	0
01-14-94	1440	217	0	166	0
01-17-94	1440	915	0	885	0
01-18-94	1440	0	0	0	0
01-19-94	1440	33	0	29	0
01-20-94	1440	633	0	434	0
01-21-94	1440	0	0	15	0
01-22-94	1440	0	0	0	2
01-23-94	1440	0	0	0	0
01-24-94	1440	0	0	0	0
01-25-94	1440	324	0	351	0
01-26-94	1440	129	0	48	0
01-27-94	1440	929	0	700	0
01-28-94	1440	441	0	421	0
01-29-94	1440	0	0	0	0
01-30-94	1440	229	0	188	0
02-08-94	1440	505	0	496	0
02-09-94	1440	321	0	306	0
02-10-94	1440	192	0	180	0
02-11-94	1440	1022	0	998	0
SUB-TOTAL	**32499**	**6515**	**1**	**5845**	**2**

Measured Minutes of Data - 1Q95 Test Period

		WIVIS ---------------		LEDWI ---------------	
DATE	**TOTAL**	**PRECIP**	**FALSE**	**PRECIP**	**FALSE**
02-27-95	443	437	0	422	0
02-28-95	1440	236	0	215	0
03-01-95	1440	0	0	0	0
03-02-95	1440	0	0	0	0
03-03-95	1440	45	0	0	0
03-04-95	1440	0	0	0	1
03-05-95	1440	129	0	175	0
03-06-95	1440	236	0	287	0
03-07-95	1440	0	0	0	0
03-08-95	1440	718	0	755	0
SUB-TOTAL	**13403**	**1801**	**0**	**1854**	**1**
TEST TOTAL	**45902**	**8316**	**1**	**7699**	**3**

Table 3. WIVIS vs. LEDWI False Alarm Performance Test Summary

WIVIS Detection Sensitivity Using Off-Axis Channel

The WIVIS combines the original scintillation technology used in LEDWI with an addition of an off-axis optical forward scatter channel. It is known that the optical forward scattering is sensitive to small particles such as fog or drizzle. Combining the in-beam scintillation and the off-axis forward scattering, WIVIS is much sensitive to drizzle then its predecessor.

Field test data from October 2002 to March 2003 are listed as follows. From both the Figures and the Tables, The field results indicated that with the addition of the off-axis forward scatter channel (drizzle algorithm), the identification of precipitation increase on all type of precipitation. For rain or snow only, the increase is very minor usually less than 5%. However, for rain or snow with drizzle, the increase of the detection period is substantial up to 80% increase. The data also show that with the drizzle algorithm, even the detection of fine particles of ice pellet increased substantially.

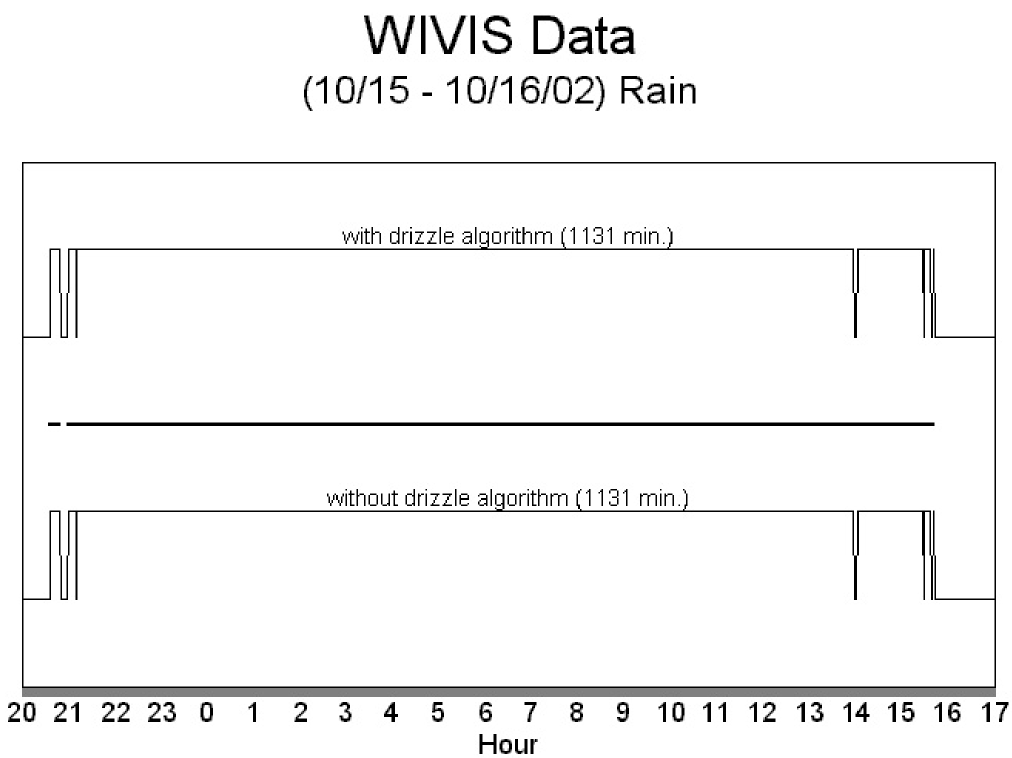

Figure 1: Comparism of WIVIS detection sensitivity with and without the off-axis forward scattering channel (drizzle algorithm) during a rain event.

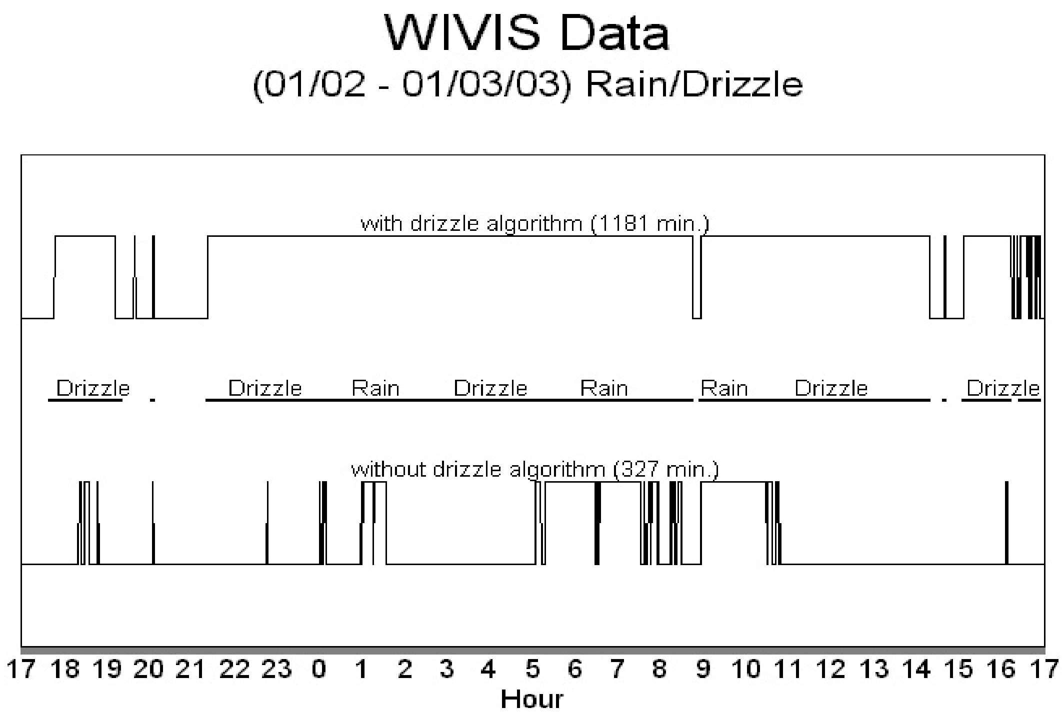

Figure 2: Comparison of WIVIS detection sensitivity with and without the off-axis forward scattering channel (drizzle algorithm) during a rain/drizzle event.

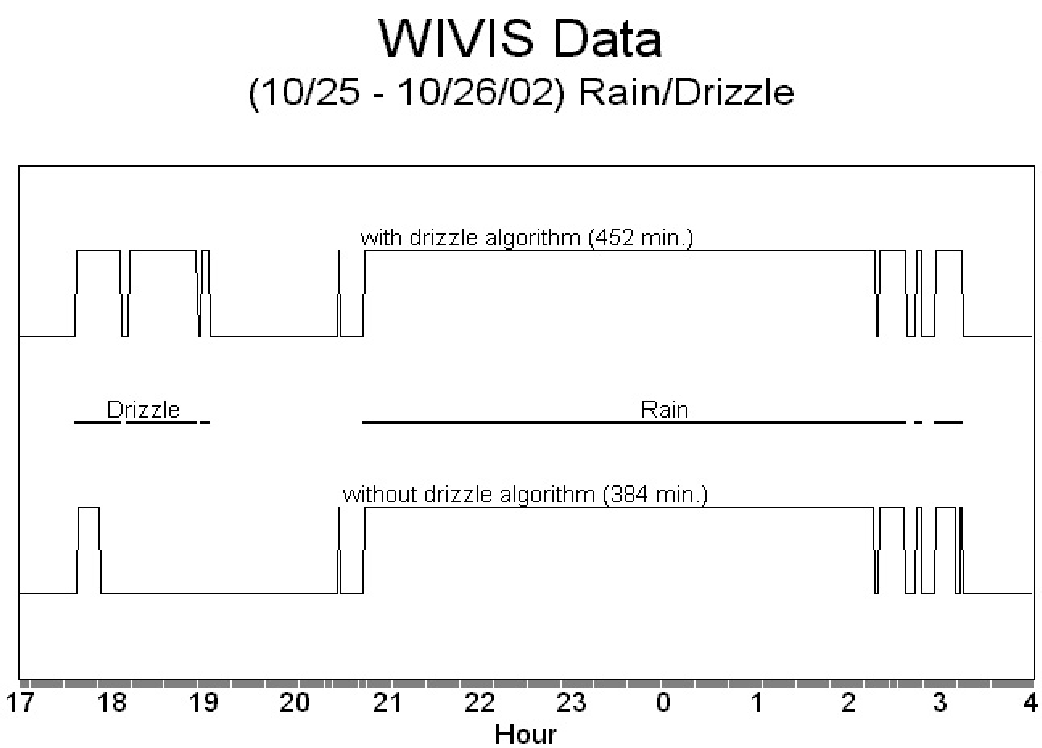

Figure 3: Comparison of WIVIS detection sensitivity with and without the off-axis forward scattering channel (drizzle algorithm) during a rain/drizzle event.

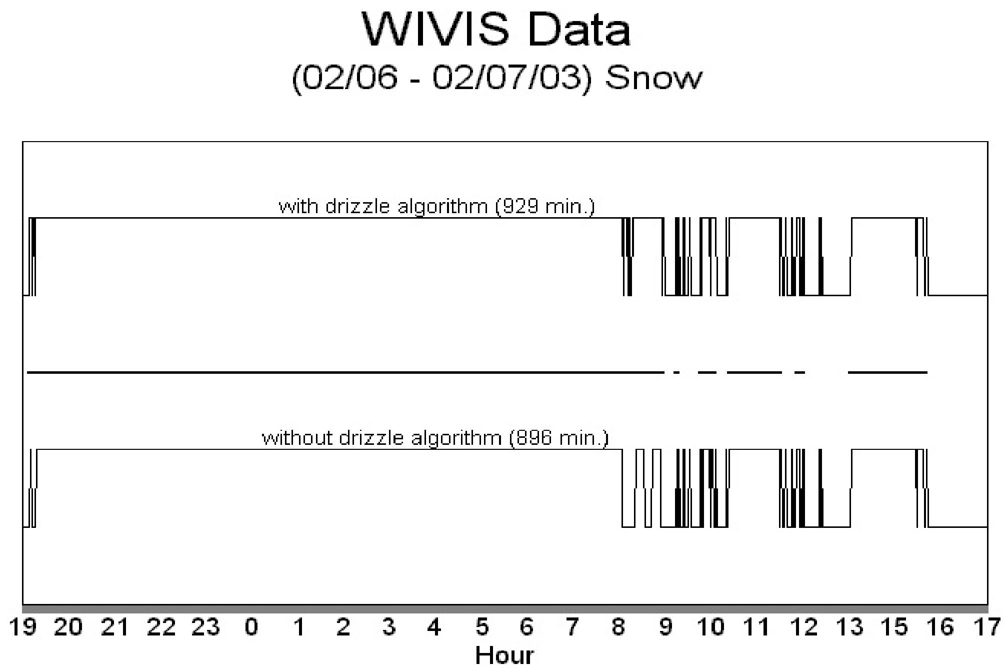

Figure 4: Comparison of WIVIS detection sensitivity with and without the off-axis forward scattering channel (drizzle algorithm) during a snow event.

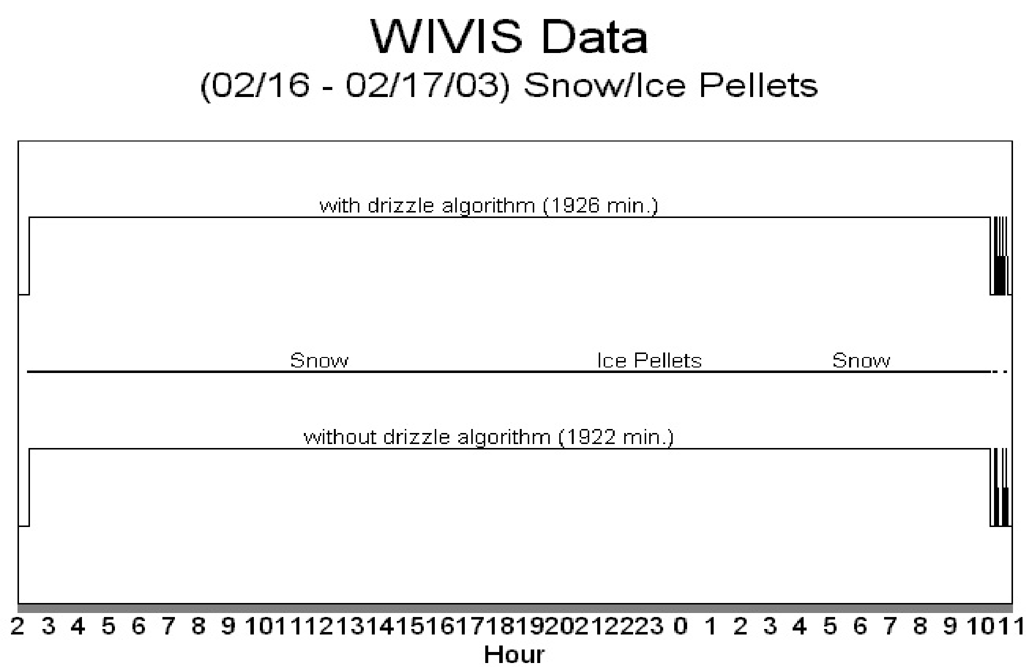

Figure 5: Comparison of WIVIS detection sensitivity with and without the off-axis forward scattering channel (drizzle algorithm) during snow/ice pellet event.

Date	Type	Detected Minutes		Improvements	
		Without Drizzle Algorithm	With Drizzle Algorithm	Minutes	%
10/15/02	Rain	194	194	0	
10/16/02	Rain	937	937	0	
10/17/02	Rain	180	180	0	
10/19/02	Rain	29	29	0	
10/24/02	Rain	155	160	5	
10/26/02	Rain	176	181	5	
10/28/02	Rain	146	151	5	
11/16/02	Rain	1259	1293	34	
11/19/02	Rain	87	87	0	
11/26/02	Rain	275	276	1	
11/27/02	Rain	88	98	10	
11/30/02	Rain	69	72	3	
12/20/02	Rain	297	343	46	
01/01/03	Rain	731	787	56	
Sub-total		4623	4788	165	3.57%
10/25/02	Rain / Drizzle	211	274	63	
10/29/02	Rain / Drizzle	612	848	236	
10/30/02	Rain / Drizzle	324	905	581	
10/31/02	Drizzle	15	80	65	
11/17/02	Rain / Drizzle	878	1076	198	
11/18/02	Drizzle	2	21	19	
11/21/02	Rain / Drizzle	322	392	70	
11/22/02	Rain / Drizzle	29	234	205	
12/01/02	Drizzle	4	14	10	
12/11/02	Rain / Drizzle	566	661	95	
12/13/02	Rain / Drizzle	532	682	150	
12/14/02	Rain / Drizzle	74	236	162	
12/19/02	Drizzle	0	37	37	
01/02/03	Rain / Drizzle	16	248	232	
01/03/03	Rain / Drizzle	311	947	636	
01/04/03	Drizzle	10	18	8	
01/29/03	Rain / Drizzle	55	76	21	
01/30/03	Rain / Drizzle	21	64	43	
01/31/03	Rain / Drizzle	92	514	422	
02/01/03	Rain / Drizzle	141	315	174	
02/19/03	Drizzle	1	10	9	
02/21/03	Rain / Drizzle	394	505	111	
02/22/03	Rain / Drizzle	556	1044	488	
02/23/03	Rain / Drizzle / Snow	139	329	190	
03/01/03	Drizzle	3	7	4	

03/02/03	Rain / Drizzle	162	216	54	
Sub-total		5470	9753	4283	78.30%
01/06/03	Snow / Drizzle	338	542	204	
01/14/03	Snow / Drizzle	43	187	144	
01/15/03	Snow / Drizzle	12	42	30	
01/21/03	Snow / Drizzle	301	387	86	
02/10/03	Snow / Drizzle	292	359	67	
02/17/03	Snow / Ice Pellets / Drizzle	717	800	83	
02/18/03	Snow / Drizzle	318	441	123	
02/26/03	Snow / Ice Pellets / Drizzle	743	972	229	
02/27/03	Snow / Drizzle	623	678	55	
02/28/03	Snow / Drizzle	364	419	55	
Sub-total		3751	4827	1076	28.69%
12/05/02	Snow / Ice Pellets	898	965	67	
01/05/03	Snow	533	545	12	
01/16/03	Snow	271	299	28	
01/17/03	Snow	80	102	22	
01/19/03	Snow	12	12	0	
01/20/03	Snow	29	30	1	
02/06/03	Snow	285	290	5	
02/07/03	Snow	611	642	31	
02/11/03	Snow	17	21	4	
02/12/03	Snow	24	28	4	
02/14/03	Snow	7	7	0	
02/15/03	Snow	854	892	38	
02/16/03	Snow / Ice Pellets	1299	1299	0	
03/03/03	Snow	24	24	0	
Sub-total		4944	5156	212	4.29%
Total		18788	24524	5736	30.53%

Table 4: WIVIS Drizzle Algorithm Improvements Summary (By Precipitation Type)

Date	Type	Measured Minutes	False Minutes			False
			Without Drizzle Algorithm	With Drizzle Algorithm	Difference	%
10/18/02	No Precipitation	1440	1	1	0	
10/20/02	No Precipitation	1440	0	0	0	
10/23/02	No Precipitation	1440	1	1	0	
10/27/02	No Precipitation	1440	1	1	0	
11/20/02	No Precipitation	1440	0	0	0	
11/28/02	No Precipitation	1440	0	0	0	
11/29/02	No Precipitation	1440	0	0	0	
12/04/02	No Precipitation	1440	0	0	0	
12/12/02	No Precipitation	1440	1	1	0	
12/21/02	No Precipitation	1440	0	0	0	
12/31/02	No Precipitation	1440	1	1	0	
01/07/03	No Precipitation	1440	1	1	0	
01/13/03	No Precipitation	1440	0	0	0	
01/18/03	No Precipitation	1440	0	0	0	
01/22/03	No Precipitation	1440	0	0	0	
01/28/03	No Precipitation	1440	0	0	0	
02/02/03	No Precipitation	1440	0	0	0	
02/05/03	No Precipitation	1440	0	0	0	
02/08/03	No Precipitation	1440	0	0	0	
02/09/03	No Precipitation	1440	0	0	0	
02/13/03	No Precipitation	1440	0	0	0	
02/20/03	No Precipitation	1440	0	0	0	
02/24/03	No Precipitation	1440	0	0	0	
02/25/03	No Precipitation	1440	0	0	0	
Sub-total		34560	6	6	0	0.017 %

Table 5: WIVIS Drizzle Algorithm False Alarm Summary

HIPS Ice Pellet Detection Sensitivity

The HIPS sensor has been tested extensively by ASOS/NWS under the field test of Enhanced-LEDWI program during 2 winters from 1997 to 2000. The ASOS/NWS Test Report [16] stated, which tested the addition of an acoustic sensor, a temperature sensing probe, and enhanced algorithms, a premature conclusion that the efforts did not offer enough improvement. However, independent analysis of these enhancements and the findings, along with investigation into other algorithm enhancements were conducted by Charles Wade of NCAR. The NCAR published report [24], found that the earlier conclusions were indeed premature and that the addition of the acoustic sensing and other algorithms enhancements could meet the requirements for hail and ice pellet sensing and could also improve drizzle performance. A direct quote from Reference [24] is as follows:

> *The theory behind the acoustic sensor was that ice pellets and hail would be detectable by the increased sound that they would make compared to rain and snow. The NWS evaluated the sensor over 2 winters at their research facilities at Sterling, VA and Johnstown, PA, and concluded that the enhanced LEDWI (ELEDWI) with the acoustic sensor "showed no significant improvement" in precipitation identification over the LEDWI sensor that is currently being used operationally at nearly 900 ASOS stations. Thus, the acoustic sensor is no longer being considered as an upgrade to ASOS stations, and the NWS is continuing to search for an enhanced precipitation identification sensor that is capable of detecting ice pellets and hail.*
>
> *A reanalysis of the data collected during this period has shown that the acoustic sensor, in fact, works quite well at detecting ice pellets and hail, and can even distinguish snow pellets from snow. The statistics provided by the NWS in their reports summarizing the performance of the enhanced LEDWIs show that the 8 sensors tested correctly identified ice pellets 82% of the time on an average, with one sensor correctly identifying ice pellets 96% of the time. While these numbers are below the 97% acceptance criteria established by the NWS, they are considerably better than the 0% identified by the current LEDWIs. In fact the ELEDWI ice pellet identification is sufficiently good that one might wonder about the circumstances surrounding the misidentifications that occurred. Might a slight modification to the identification algorithm improve the statistics? Were the human observations of precipitation type correct every minute? How does one handle the problem whereby only one precipitation type can be reported when mixed types are occurring? For example, if only 20% of the precipitation is in the form of ice pellets (IP) and 80% is freezing rain (ZR), the observer might report mixed ZR and IP, but the ELEDWI algorithm might report rain. Is this a case of erroneous identification?*
>
> *This paper will discuss these issues using examples from ELEDWI data collected at Sterling and Johnstown during 1997-1998. The paper will argue that, with minor modifications to the precipitation identification algorithm, the addition of an acoustic sensor will allow ASOS to report ice pellets, snow pellets, and hail with an accuracy equal to or better than the human observer.*

The field test results of several events are shown in the following figures. By taking the difference of the high channel of the in-beam scintillation signal to that of the acoustic channel, it gives a clear discrimination of the ice particles and the water droplets. For more detailed information, a copy of Charles Wade's presentation material [24] is attached as an appendix. From the field test results, it is clear that by adding an acoustic channel to the Enhanced Precipitation Identification Sensor, it will provide the capability of reliably discriminating ice pellets and hail stones from rain, snow, and drizzle. The acoustic channel will provide the information no other optical sensor can mach for the detection and discrimination of ice pellets.

From the above data, it is clear that by adding an acoustic channel to the Enhanced Precipitation Identification Sensor, it will provide the capability of reliably discriminating ice pellets and hail stones from rain, snow, and drizzle. The acoustic channel will provide the information no other optical sensor can mach for the detection and discrimination of ice pellets.