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Automating the Observation of Drizzle

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1. Introduction

The modernization of the National Weather Service (NWS) that began in the 1980's has been completed. However, technology continues to evolve and the NWS will continue to look to the future to encourage and exploit technical innovations. In particular, the implementation of Automated Surface Observing Systems (ASOS) nationwide has led to follow-on efforts to enhance its capabilities. The greatest challenge in the ASOS was to automate the visual elements of the observation: sky conditions, visibility, and type of weather. Despite achieving some success in this area, limitations in the reporting capabilities of the ASOS remain and an ongoing effort within the NWS, called Product Improvement, is tasked with investigating new technologies that might be incorporated into the ASOS. As currently configured, the ASOS uses a precipitation identifier (PI) that can identify only two precipitation types, rain and snow. A goal of the Product Improvement program is to replace the current PI sensor with one that can identify additional precipitation types of importance to aviation. Highest priority is being given to implementing capabilities of identifying ice pellets and drizzle. The initial stages of the effort to automate the observation of drizzle are the topic of this paper.

2. Definition of Drizzle

The National Weather Service Handbook No. 7, Surface Weather Observations and Reports (NOAA, 1996) defines drizzle as:

> “Fairly uniform precipitation composed exclusively of fine drops with diameters of less than 0.02 inch (0.5 mm) very close together. Drizzle appears to float while following air currents, although unlike fog droplets, it falls to the ground.”

The definition of drizzle in the Glossary of Meteorology (American Meteorological Society, 1959) is:

> “Very small, numerous, and uniformly dispersed, water drops that may appear to float while following air currents. Unlike fog droplets, drizzle falls to the ground. It usually falls from low stratus clouds and is frequently accompanied by low visibility and fog.
>
> “In weather observations, drizzle is classified as (a) “very light”, comprised of scattered drops that do not completely wet an exposed surface, regardless of duration (b) “light,” the rate of fall being from a trace to 0.01 inch per hour (c) “moderate,” the rate of fall being 0.01-0.02 inch per hour (d) “heavy”, the rate of fall being more than 0.02 inch per hour. When the precipitation equals or exceeds 0.04 inch per hour, all or part of the precipitation is usually rain; however, true drizzle falling as heavily as 0.05 inch per hour has been observed. By convention, drizzle drops are taken to be less than 0.5 mm (500 μm) in diameter”

Whichever definition is used, there is necessarily some subjectivity in the identification of drizzle. It is also difficult to measure the low accumulation rates to determine the intensity based on the rate of accumulation criteria.

3. Human Observations of Drizzle

While the observation of drizzle is obviously difficult to automate, it is generally straightforward for an observer to visually assess when drops are too small to be raindrops. It then becomes a question of whether the drops are suspended in air (fog) or falling (drizzle). This is typically done by determining if the drops can be observed to collect on horizontal surfaces.

Such subjective definitions inevitably cause problems when attempting to develop a specification for an instrument to detect drizzle. It is preferable to have a reference instrument that is accepted by vendors whose products will be evaluated by the government for potential inclusion in the ASOS. Many meteorological measurements can be evaluated in the field against instruments whose calibration is traceable to the National Institutes of Standards and Technology (e.g., temperature). Unfortunately there is no traceable reference for instruments that measure subjective weather elements (sky conditions, visibility, and type of weather).

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4. ASOS Precipitation Identification Sensor

The ASOS PI Sensor is the Optical Scientific Inc. (OSI) Model OWI-240, also called the light emitting diode weather identifier (LEDWI). Its precipitation identification measurement is based on the optical sensing of weather particle-induced scintillations in a partially coherent source (i.e., an infrared light emitting diode). The temporal frequency spectrum of the induced scintillation varies according to the size and velocity of the falling precipitant. By measuring the energy in two frequency bands and comparing their ratios, the state of precipitation (yes/no) and the type (rain/snow) can be identified. An estimate of precipitation intensity is also derived for discriminating the three intensity levels of light, moderate, or heavy. As particle size and/or number decreases, the signal level also decreases and the signal becomes too weak to differentiate from naturally occurring background scintillation which is associated with bright sun and/ or turbulence. However, there is still a detectable signal that could possibly be used to deduce the occurrence of drizzle (Wade, 2000). Wade has developed an algorithm to use these weak signals to detect drizzle occurrence. Section 7 provides examples of how the Wade algorithm can be used to successfully detect drizzle using information derived from the current ASOS PI sensor.

5. Reference Sensor for Drizzle

5.1 *Meteorological Performance Criteria*

The obvious requirements for a reference sensor for drizzle are contained in the definitions cited in section 2. If the number, size, and fall velocity of the atmospheric particles can be measured, it should be possible to differentiate drizzle from rain, fog, or other types of weather. To determine if such technologies existed, the government in 2000 initiated a competitive solicitation to identify any vendors that could provide a sensor that makes the necessary measurements. After a proposal evaluation, a vendor was selected based on the technical merits of their current product line, their technical proposal for supplying a sensor that would meet the government's requirements, and their final cost for delivering the sensor. The successful bidder on this solicitation was Droplet Measurement Technologies, Inc., of Boulder, Colorado, delivering a sensor called the Meteorological Particle Sensor (MPS).

5.2 *Meteorological Particle Sensor*

The MPS is designed to directly measure precipitation shapes, sizes and fall velocities. In post-processing, rainfall rates and statistical data on the intensity of the rainfall can be derived. The Particle Analysis and Collection System (PACS), a graphical user interface at the host computer, provides control of measurement parameters, while simultaneously displaying real-time size distributions.

The MPS is designed to be mounted on a vertical post, and the axis of the projected laser beam is directed parallel to the prevailing wind via a self-contained wind vane. The incident laser beam is focused on particles ranging in size from 50 micrometers to 3100 micrometers, which are magnified by a factor of four, onto a 64 element photo-sensitive diode array (each diode is therefore a 0.05mm width bin). After a sufficient number of particles have been sampled by the sensor, the digital signal processor stores the cumulative number of particles of each size.

6. MPS Algorithm for Drizzle Detection

While the MPS provides key information about the size, number density and fall velocity of particles, an algorithm is needed to use this information to determine if the particles that are falling meet the definition of drizzle. In the early phase of this algorithm development, a simple algorithm, primarily dependent on particle size, was used to post-process the MPS data.

In essence, the algorithm first determines if precipitation is occurring. The assumption is made that most of the particles that are detected by the MPS are large enough to fall. The number of drizzle size particles (N_{dz} # 0.5 mm) and the number of raindrop size particles (N_{ra} > 0.5 mm) are determined. Then the ratio

$$R = N_{dz}/(N_{dz}+N_{ra}) \qquad (1)$$

is used to differentiate drizzle from rain. The higher the percentage, the greater the likelihood that the precipitation type is drizzle (DZ). For the preliminary analysis in the next section, a ratio of greater than 0.95 was chosen as the indicator for drizzle. All other precipitation was considered rain (RA). If no particles were detected, the designation was no precipitation (NP).

An additional objective of this effort is to determine the accumulation rate due to drizzle. Since the MPS sizes all the drops that pass through its sample area, a straightforward computation of the volume of (assumed spherical) drops can be used to determine the cumulative volume of water V_w passing through the sample area A to compute precipitation P for an interval of time (e.g. each minute), whereby:

$$P = V_w/A \qquad (2)$$

The precipitation accumulation derived in this manner can be compared with a high-resolution recording rain gauge (measuring to the nearest 0.025 mm) to assess the accuracy of the method. Again, some early results are presented in the next section.

Since Wade has proposed a method whereby LEDWI information, along with sky conditions and dew point depression, can be used to infer drizzle, results of this approach are also provided in the next section. In both cases the comparison is with the human observer.

7. Results

Table 1 provides a summary of MPS performance in terms of percent comparability with a human observer and percent of derived accumulation compared to a nearby automatic recording rain gauge.

Table 1. MPS performance vs. human observation

Date	Weather (Human minutes)	Percent of correct detection	Percent of measured accum.
1/30/01	DZ(50)	100%	131%
2/14/01	DZ(165) RA(20)	89%	127%
2/15/01	RA(58)	94%	66%
2/16/01	RA(209)	100%	64%
5/21/01	DZ(361)	99%	110%

The detection, even with this very simple algorithm (i.e., are 95% of particles less than or equal to 0.5 mm diameter), is quite good. However, the derived precipitation accumulation is significantly different from the rain gauge in both drizzle and rain. It is evident that the estimate tends to be too high in drizzle and too low in rain. One possible cause for the measurement underestimate in rain is that the MPS detects only particles smaller than 3.2 mm. Larger particles that may contribute significantly to the total accumulation are not counted. The overestimate in drizzle could be caused by multiple counting of the same drop. This would be especially likely for those small drops that float in and out of the beam rather than fall vertically through the beam. It is obvious that further refinements will be required to obtain reasonable precipitation rate and amount estimates from the MPS.

As noted in section 2, the ASOS PI sensor will not report drizzle due to the weak signals received. However, in stable conditions with low background noise, as is common in drizzle conditions, it may be possible to infer drizzle from these weak signals and other information derived by the ASOS, i.e., dew point depression and sky cover. Then performance will improve as shown in Table 2.

Table 2. ASOS PI performance with and without the drizzle algorithm.

Date	Weather (minutes)	Percent of PI sensor correct	Percent Correct with Wade
1/30/01	DZ(50)	0%	88%
2/14/01	DZ(165) RA(20)	3%	24%
2/15/01	RA(58)	85%	58%
2/16/01	RA(209)	95%	40%
5/21/01	DZ(361)	0%	75%

Using the same cases as above, it can be seen that the PI sensor percent detection improves significantly (i.e., from no detection to a significant percentage of correct detections of drizzle). The lower percentage of correct detection for the two pure rain cases is due to some of the LEDWI rain reports being converted to drizzle by the Wade algorithm.

8. Future Work

With early results showing promise for the MPS drizzle detection and accumulation measurement capability, a follow-on effort is now under way. A test plan (NOAA, 2001) has been approved to further evaluate and refine the MPS algorithm for detecting and determining the rate of accumulation of drizzle. Human observations will support this activity. One of the key tasks of the observer will be to use a magnifying glass and reticule to determine the size of the falling particles to the nearest 0.1 mm. Rain rate measurements will also be taken using a high-resolution rain gauge. If the capability of the MPS to identify drizzle and determine its accumulation rate is proven, it will be used as a reference sensor for a follow-on procurement of an enhanced precipitation identifier to replace the current ASOS Precipitation Identifier. In conjunction with the MPS evaluation further evaluation of the Wade algorithm for using the LEDWI to identify drizzle will be conducted.

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