Precipitation type from the Thies disdrometer

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Abstract

This paper describes research done to determine the capabilities and limitations of the disdrometer manufactured by Thies with respect to Present Weather determination. The results show that the disdrometer compares about equally well to an observer as the Vaisala FD12P Present Weather Sensor. The agreement with the observer is about 91% for precipitation phase.

Introduction

Detecting Present Weather, and in particular precipitation type, is done at KNMI with the Vaisala FD12P Present Weather Sensor. Although this sensor generally works quite well, there are some weak points and there is room for improvement. For this reason, new developments in the market in this area are closely monitored. A relatively new instrument is this field is the Laser Precipitation Monitor manufactured by Thies. This instrument is a disdrometer, which can measure size and fall speed of precipitation particles. Also because of an interesting price tag (about €3000, compared to about €15000 for the FD12P) it is worth investigating the performance of this sensor. Unlike the FD12P, the disdrometer does not report visibility.

Experiment

The data used in this investigation were provided by the Deutscher Wetter Dienst. The observations were made at the test site Wasserkuppe, in central Germany (Hessen). This site is situated near the summit of a mountain (hill) at 950 m above sea level. Because of this, the precipitation in summer is mainly rain, and in winter mainly snow, resulting in a good range of precipitation types for Present Weather research. At the site, a variety of Present Weather systems were present. These can be seen in the photo of Figure 1.

Figure 1. The PW sensors at Wasserkuppe, 25 February 2004. 1: Vaisala FD12P, 2: 2 Thies laser precipitation monitors (disdrometers), 3: Parsivel disdrometer (in front), 4: Metek micro rain radar. Also visible 5: Thies precipitation detector.

This work focuses on the Thies Laser Precipitation Monitor (disdrometer) and the Vaisala FD12P Present Weather Sensor. Another important data source at this test site is the reference data which includes observations made by a human observer and data from the Thies precipitation detector. Details of these 3 data sources are given below.

Thies disdrometer

A disdrometer measures the size and fall speed of precipitation. A laser diode and some optics produce a parallel infrared light sheet of 0.75 mm thickness with a detection area of 20 x 228 mm^2. When the precipitation particles fall through this beam, the receiving signal is reduced. The amplitude of the reduction is related to the size of the particles, and the duration of the reduction is related to the fall speed. Precipitation type is then determined from known statistics of particle size and velocity for the different precipitation types. A rough temperature constraint is also used; all precipitation above 9 °C is considered liquid (except hail) and all precipitation below –4 °C is solid. The output consists of many parameters, including 1- minute SYNOP, METAR codes, precipitation intensity and amount, and full particle size and velocity distributions. Theoretically one could even write an own classification algorithm based upon the raw data (velocity – size spectra). However, in the current investigation only the 1-minute PW SYNOP codes produced by the instrument are used. More details on the instrument and its output can be found in the 'Instructions for Use' of the instrument[1].

Figure 2 shows the two Thies disdrometers at Wasserkuppe. The one on the left is an older version, and the one in front is the latest version. This one has lower arms, to prevent spray from the arms into the

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[1] Thies Laser Precipitation Monitor, Instructions for Use: 5.4110.X0.X00, Software version 1.04, 07/2003.

measuring volume. Also, spray from the heads is reduced by means of two small plates. This latter disdrometer is the one that is investigated. Adjustments to the instrument have been made based upon tests at this site, so its performance may be somewhat tuned to the meteorological conditions there. The data used in this investigation is the first data from this improved sensor. Since then, further fine-tuning has been (and is being) done.

Figure 2. The two Thies disdrometers at Wasserkuppe.

Vaisala FD12P

This type of sensor measures the scattering of light of a small volume of the atmosphere. If there are precipitation particles present in this volume, they will lead to peaks in the scattered light. These peaks are related to (the size of) the particles. Separately, the FD12P has a capacitive sensor (DRD 12) that measures the water content of the precipitation. Combining these two quantities leads to a discrimination between large particles with low water content (*i.e.* snow) and small particles with high water content (rain). Fine tuning is done by choosing appropriate limits for, for instance, mixed precipitation, hail and freezing rain. Also, temperature constraints, maximum particle size and a selection algorithm to determine the most significant precipitation type are used. Every minute, an "instant" precipitation type is given (amongst other parameters). This is normally the most popular of the last 5-minute types[2]. More details can be found in the FD12P User's Guide[2]. Figure 3 shows the instrument in use at Wasserkuppe.

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[2] Vaisala, Weather Sensor FD12P, User's Guide, M210296en-A, May 2002.

Figure 3. The Vaisala FD12P Present Weather Sensor at Wasserkuppe.

Reference

The reference at Wasserkuppe contains data from various sources. First of all an observer, located about 100 m from the instruments, reports Present Weather 24 hrs/day with a time resolution of 1 minute. In addition, a number of instruments report precipitation intensity, 2m temperature, 2m relative humidity, 2m wind speed and dew point temperature. Also, two Thies precipitation detectors are logically combined to give a precipitation flag: y/n. All data are given in 1-minute intervals.

Data processing

In order to compare the various quantities, some data processing is necessary. All data are given in synchronously recorded 1-minute intervals, leading to a maximum of 1440 measurements per day. The following processing has been done:

- Because the combined Thies precipitation detectors have a 25 second delay, data are only accepted if the previous minute has the same precipitation indication (y or n).
- If the Thies precipitation detector indicates no precipitation, the PW code of the observer is changed to 00 (clear). This is because it is expected that the detector is quicker in detecting a change (from dry to precipitation, or vice versa) than the observer.
- The (human) observed precipitation type is reported in WMO code 4677 (manual observations). This is changed into code 4680 (automatic observation) to match with the output of the two PW instruments. Next, all PW codes are condensed into the precipitation type possibilities shown in Appendix A.

Averaging. When 10-minute averages are considered, the precipitation type is averaged by taking the maximum PW code in the interval considered. Averaging the FD12P data to 10-minute data is done by taking 10 instant precipitation types, even though these are 5 minute averages. This is because these 5-minute averages are updated every minute and so this way of averaging leads to the best possible (but not perfect) 10-minute average.

Results

All results were obtained using data from12-10-2003 to 31-11-2003, with the exception of 31-10-2003. In this time interval, there was a fair amount of both liquid precipitation (7 % of the time) and solid precipitation (5 % of the time), allowing for a good evaluation of the systems' capabilities.

Precipitation phase

The 10-minute comparison of the PW output of the three sources (observer, Thies disdrometer and FD12P) is shown in the following tables. 10-minute data is used because observers may not note a change in precipitation on a 1-minute time scale. Also, the FD12P "instant" precipitation type is really from the latest 5 minutes. And in normal use, 10-minute averages are used. Shown are the results for the precipitation phase (with freezing rain classified as liquid, and unknown precipitation disregarded).

observer →

Thies ↓

	no precip	**liquid**	**mixed**	**solid**	**total**	**%**
no precip	5077	0	0	0	5077	100.0
liquid	398	339	33	14	784	43.2
mixed	0	0	12	3	15	80.0
solid	89	2	3	230	324	71.0
total	5564	341	48	247	6200	
%	91.2	99.4	25.0	93.1		
total %		91.4				

observer →

FD12P ↓

	no precip	**liquid**	**mixed**	**solid**	**total**	**%**
no precip	5027	13	0	5	5045	99.6
liquid	51	356	29	2	438	81.3
mixed	0	1	8	3	12	66.7
solid	439	21	11	299	770	38.8
total	5517	391	48	309	6265	
%	91.1	91.0	16.7	96.8		
total %		88.6				

FD12P →

Thies ↓

	no precip	**liquid**	**mixed**	**solid**	**total**	**%**
no precip	4722	32	0	329	5083	92.9
liquid	439	514	7	213	1173	43.8
mixed	0	6	4	8	18	22.2
solid	85	2	2	380	469	81.0
total	5246	554	13	930	6743	
%	90.0	92.8	30.8	40.9		
total %		60.0				

Table 1. Comparison of the precipitation phase detected by the Thies disdrometer (Thies), the observer (Obs) and the Vaisala FD12P PWS (FD12P). The numbers are based on 10-minute data. % means the correct identification divided by the total for the column or row in question.

It is clear that the Thies performs quite well, especially in the case when the observer reports liquid precipitation (99 %). In case of solid precipitation, the FD12P performs somewhat better (97 %) than Thies (93 %). For all precipitation phases, the performance of the Thies is 91 % and the FD12P 89 %. When the Thies reports liquid precipitation, quite often the observer reports no precipitation. This may indicate that the Thies is not very good as a precipitation detector and should really be used as a precipitation *type* detector only, or that the Thies is more sensitive than the combined observer/Thies precipitation detector. This will be investigated further. Also, the same seems to hold for the FD12P in case of solid precipitation. Mixed-phase precipitation remains a weak point for both sensors. Interestingly, the Thies and the FD12P each agree better with the observer individually, than with each other (lower table of Table 1).

Verification scores

From the above tables, the verification scores can be derived. These are defined using the following results for a particular precipitation phase (e.g. liquid):
a: the observer and the instrument both report the precipitation phase
b: the observer reports the phase, and the instrument reports another phase or no precipitation
c: the instrument reports the phase, and the observer reports another phase or no precipitation
d: both the observer and the instrument do not report the phase

The verification scores are then defined as:

Probability Of Detection (POD): a/(a+b)
False Alarm Rate (FAR): c/(a+c)
Heidke Score Skill (HSS): (ad-bc)/((ad-bc)+ ½n(b+c)), with n the total number of events
* indicates that only the precipitation type is considered when the observer reports precipitation[3]

The range of the POD is between 0 and 1, with 1 the perfect score. The FAR range is also between 0 and 1, and here of course 0 is the perfect score, meaning no false alarms have occurred. HSS has a range between –1 and 1. 1 is the perfect score and 0 means random guessing.

This leads to the following results for the disdrometer (Table 2) and the FD12P (Table 3).

phase	POD	FAR	FAR*	HSS	HSS*
liquid	0.99	0.57	0.12	0.57	0.84
mixed	0.25	0.2	0.2	0.38	0.36
solid	0.93	0.29	0.02	0.80	0.93

Table 2. Verification scores for the Thies disdrometer. For the definition of the scores, see text.

phase	POD	FAR	FAR*	HSS	HSS*
liquid	0.91	0.18	0.08	0.84	0.82
mixed	0.17	0.33	0.33	0.26	0.24
solid	0.97	0.61	0.10	0.52	0.89

Table 3. The verification scores for the FD12P. For the definition of the scores, see text.

Again, there is a clear indication that the sensors report too much precipitation and/or that the observer reports too little. But aside from that, the HSS* for the FD12P and the Thies disdrometer are very similar.
Previous research on the FD12P done at KNMI[4] resulted for liquid precipitation in a POD of 0.71 with a FAR of 0.24. Solid precipitation had a POD of 0.63 and a FAR of 0.14 (mixed precipitation was not considered). The different manual observing methods (1 minute vs. 10 minutes, the use of the precipitation detector) and/or the different climatology may be responsible for the difference with the current results.

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[3] This is equivalent to regarding the instruments as a precipitation *TYPE* detectors only. Cases where the observer reports no precipitation are disregarded.

[4] Wauben, W.M.F., Automation of visual observations at KNMI; (I) comparison of present weather, paper no. J3.1, AMS annual conference, 2002.

Conclusions

In conclusion, the Thies Laser Precipitation Monitor (or disdrometer) performs quite well in distinguishing precipitation type. The results of the available data show that this instrument compares about equally to the current Present Weather Sensor in use at KNMI, the Vaisala FD12P. The agreement with the observations is 91 % if precipitation phase is considered (and 89 % for the FD12P for the same data set).
Based on these results, and the favourable price tag of the disdrometer compared to the FD12P, KNMI has purchased a Thies disdrometer for testing so that we can gain experience with the instrument and see how it performs in Dutch weather conditions. If these tests are successful, this instrument may be used on the smaller automatic weather stations to better inform the meteorologists regarding precipitation type.

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Appendix A: Present Weather codes

All the weather codes in this paper are used according to the table below.

PW code	**NWS code**	**Precipitation type**
00	‘C’	no precipitation
40	‘P’	precipitation (unknown)
50	‘L’	drizzle
55	‘ZL’	freezing drizzle
57	‘RD’	drizzle and rain
60	‘R’	rain
65	‘ZR’	freezing rain
67	‘RS’	rain and snow
70	‘S’	snow
75	‘IP’	ice pellets
77	‘SG’	snow grains
78	‘IC’	ice crystals
87	‘SP’	snow pellets
89	‘A’	hail