WATER EQUIVALENT OF SNOWFALL DERIVED FROM IMAGING DISTROMETER MEASUREMENTS

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1. Introduction

Wave propagation in rain and modeling of rainfall parameters have been widely investigated, comparatively little knowledge exists for snow. Nevertheless knowledge on the structure of snowfall is of considerable importance, as well in radio communications as in remote sensing, especially in radar meteorology. Samples of applications include avalanche and glacier research, and in the field of telecommunication snow certainly has an impact on transmission quality at higher frequencies. In this paper snow data from an imaging distrometer are analysed with emphasis on deriving the snow flakes' water equivalent. Thus a comprehensive knowledge on snow is obtained: front and side contours of the snowflakes, together with their fall velocity and an estimate for their solid fraction, furthermore a highly time resolved record on the size distribution. This is considered to be the first basic step for a comprehensive analysis of wave propagation in snowfall.

2. Relating the snowflakes' solid fraction to their shape and fall velocity

2.1 Type of data

A 2D-Video-Distrometer (2DVD) [1] was used for measuring shape and velocity of snowflakes. Early applications of this imaging distrometer were mainly dedicated to rain investigations. Some minor improvements of the software, using algorithms developed by the Swiss Federal Institute of Technology [2], made the 2D-Video-Distrometer an ideal instrument for measuring snowfall as well. The contours of snowflakes (from front and side) and their fall velocities are recorded, the three-dimensional structure of snowflakes however cannot be resolved. Thus there is no direct measurement of the snowflakes' solid fraction. Fig. 1 gives a

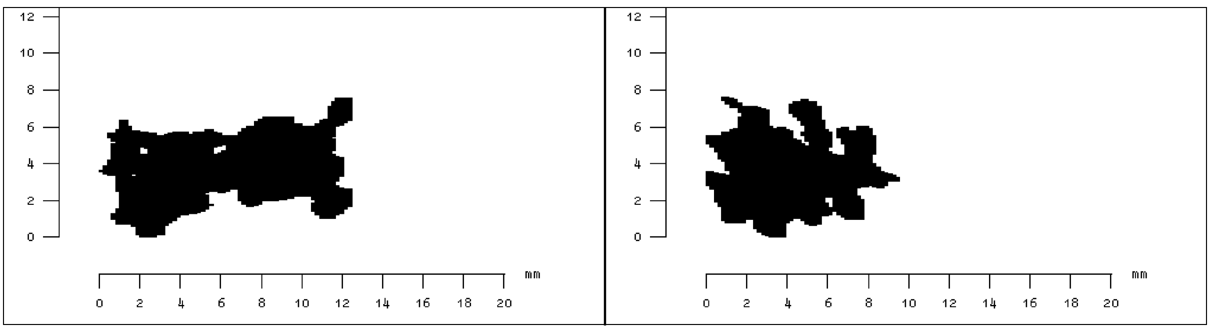

Fig. 1. Front (to the left) and side view (to the right) of snowflake recorded at Mt. Rigi, Switzerland, on March 28, 1997, 12:41:14. Apparent diameter = 8.76 mm, fall velocity = 1.74 m/s.

data sample. The real equivolumetric sphere diameter cannot directly be calculated from such data. Using the same method as for raindrops (summing up elliptical slices) yields a considerable overestimation of the water volume. The resulting diameters are therefore called apparent diameters and, in consequence, the precipitation rate based on apparent diameters overestimates the actual values in the same way. Figure 2 and Fig. 3 give a clear demonstration. Fig. 2 gives a precipitation rate vs. time diagram, the dashed line stands for the 2DVD's apparent precipitation rate, the thick solid line represents a tipping bucket raingauge mounted at the same location. The overestimation is expressed in a comparison factor drawn in Fig. 3, it ranges from 1.51 to 6.62 with a mean of 3.96. This snow period was recorded at Mt. Rigi, Switzerland, in approx. 1620 m M.S.L. It was a relatively calm period with a mean windspeed of 1.90 m/s, mean temperature was -1.94 deg C.

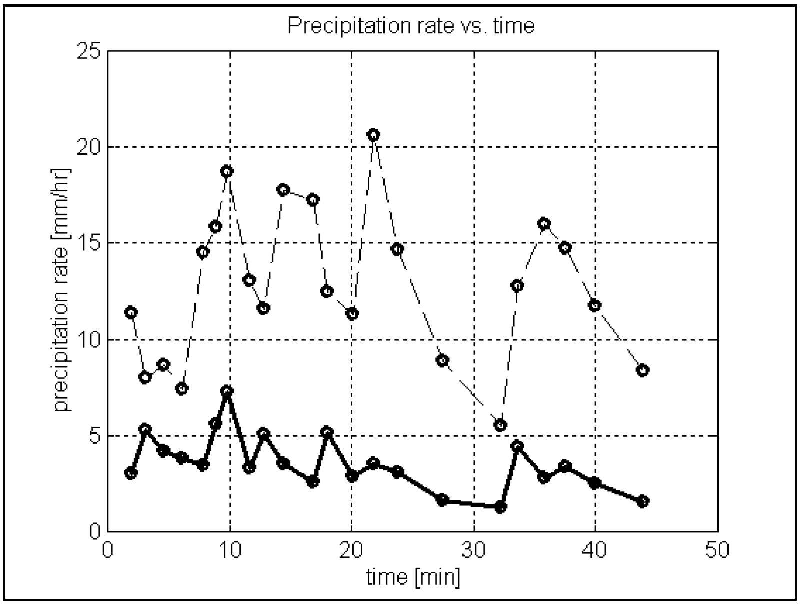

Fig. 2. Precipitation rate vs. time recorded at Mt. Rigi, Switzerland: apparent 2DVD values (thick solid line) and tipping bucket (dashed line). Start time is March 28, 1997, 12:18:52.40

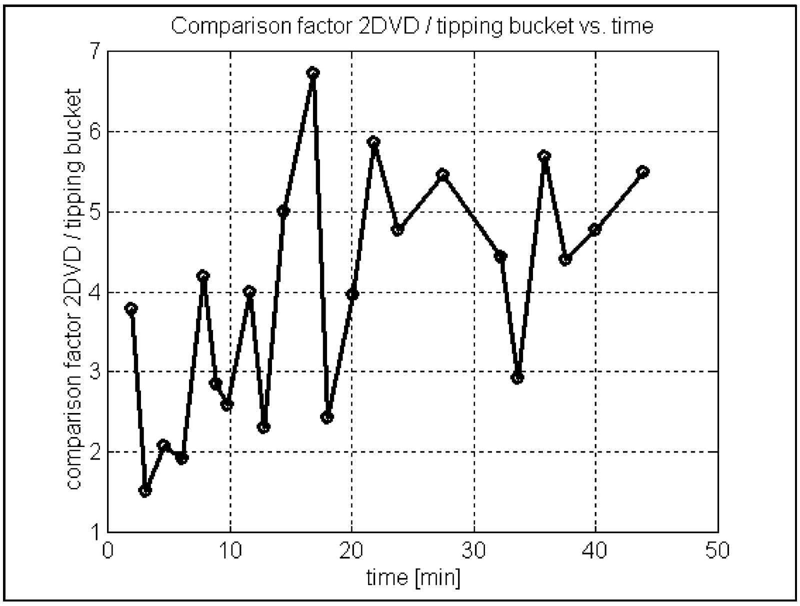

Fig. 3. Comparison factor for precipitation rates by 2DVD and tipping bucket raingauge. Represents data set shown in Fig. 2

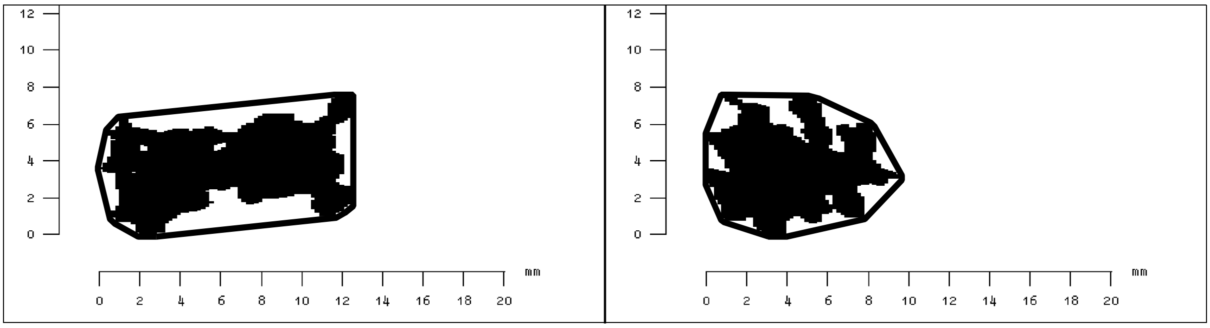

Fig. 4. Same snowflake as shown in Fig. 1. Thick line denotes smallest convex circumferential polygon (schematical drawing). Ratios of actual shadows and corresponding polygons are used for solid fraction estimate.

2.2 Improved precipitation rate results by use of fall velocity and contour information

The analyses of 2DVD data shown in Fig. 2 and Fig. 3 clearly need to be improved. On the one hand the particles' fall velocity may be used for. From a snowflakes' apparent diameter the fall velocity of a raindrop with that size may be obtained after well known models (e.g. as given in [3]). The smaller mass of the snowflake at same or even bigger air resistance is the reason for its smaller fall velocity. In a first approach the apparent water volume of a snowflake is divided by the ratio of the before mentioned velocities. In Fig. 5 the resulting comparison factor (with the tipping raingauge) is shown as the dashed line. The comparison factor improved to a mean of 1.31, with a minimum of 0.69 and a maximum of 2.26. On the other hand the contour information should be integrated as well for further improvements. The following method was chosen to quantify the degree of branching in the front and side views: The actually shadowed area is related to that of the smallest convex circumferential polygon. Fig. 4 shows a schematical drawing for illustration. The thick black line represents the smallest convex circumferential polygon. All corner points of the polygon are corner points in the actual contour (but not vice versa). Thus two area ratios are obtained, one for the front and one for the side view, both of them are # 1. They are formed to a product by which the drops' estimated water equivalent is multiplied. This considers the fact that the more branched a particle's structure is, the less water it will contain. The resulting precipitation rate's comparison factor (with the tipping bucket raingauge) is given in Fig. 5 as well (thick line). The mean further improved to 0.93, the minimum

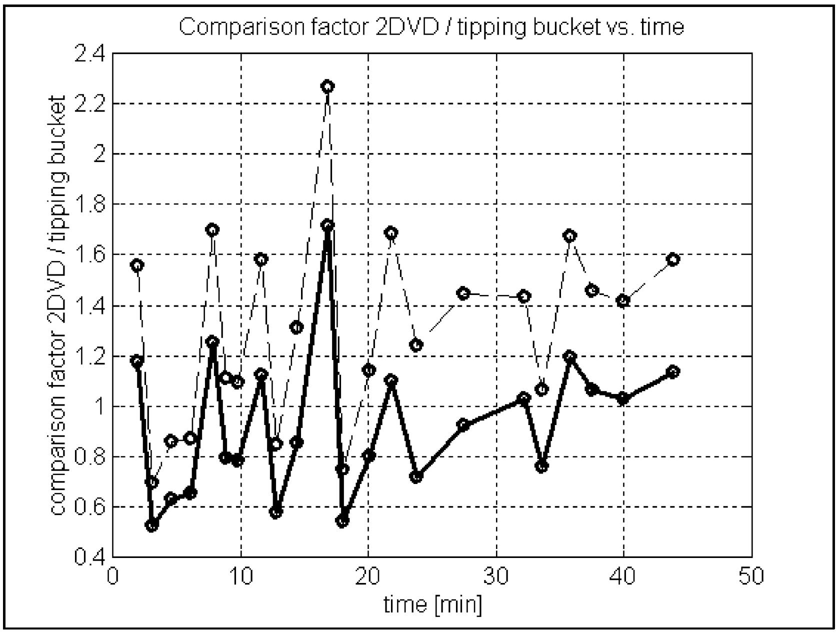

Fig. 5. Same comparison factor as in Fig. 3, but 2DVD's precipitation result improved by fall velocity (dashed line) and by fall velocity plus contour information (thick solid line).

is 0.52, the maximum 1.71. It should explicitly be pointed out, that this discussion is based on a single event only, no general rules may be derived from. More examples and detailed descriptions are given in [4]. Future work should clarify if integration of temperature and wind parameters would allow further improvements in the precipitation rate result.

3. Conclusion and Outlook

On basis of a unique data set an empirical relationship between snowflakes' contours, their fall velocity and their water equivalent was established. Verification was done via comparison factors with a tipping bucket raingauge. Presently the analysis is based on data of a single event only, future work should provide a statistically significant basis. Further analyses should be extended from purely empirical considerations to applying relevant theoretical models. Such investigations and their results will be of considerable value for obtaining improved quality in remote sensing and other radiowave propagation applications affected by snowfall.

4. References

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