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MEASUREMENTS OF FALLING ATTITUDES OF SNOWFLAKES USING TWO VIDEO CAMERAS

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Abstract: Falling attitudes of snowflakes were simultaneously photographed by two video cameras from horizontal and vertical directions, and these images were analyzed by an image processor and personal computer. The attitude of each snowflake was measured every 1/30 s from its two images. It is generally found that snowflake images from the top are larger than the ones from the side and some snowflakes rotate during fall.

1. Introduction

To measure the size and velocity of falling snowflakes quantitatively, various methods have been reported (JIUSTO and BOSWORTH, 1971; LANGLEBEN, 1954; MAGONO and NAKAMURA, 1965). We also introduced a system which automatically measures simultaneously the size and falling velocity of snowflakes using a video camera, a personal computer and an image processor (MURAMOTO *et al.*, 1989), but since the video camera shutter speed was set at 1/60 s, the observed images of snowflakes were seen as streaks. Therefore we could not obtain the data about falling attitude of snowflakes.

The present paper describes a system to measure the attitude of individual falling snowflakes in the air. To investigate the difference between side and top images during their falling, two video cameras were used. These 2-D projected images were input to an image processor and analyzed by a personal computer.

2. Measuring System

The measuring system is shown in Fig. 1. In order to protect falling snowflakes from wind and sunlight, naturally falling snowflakes were allowed to fall into a windbreak tower. The photographing space was illuminated by parallel light beams of two halogen lamps (500 W) through slits from two directions. The photographing space was limited to 12 cm(L)$\times$12 cm(W)$\times$12 cm(H). Falling snow-

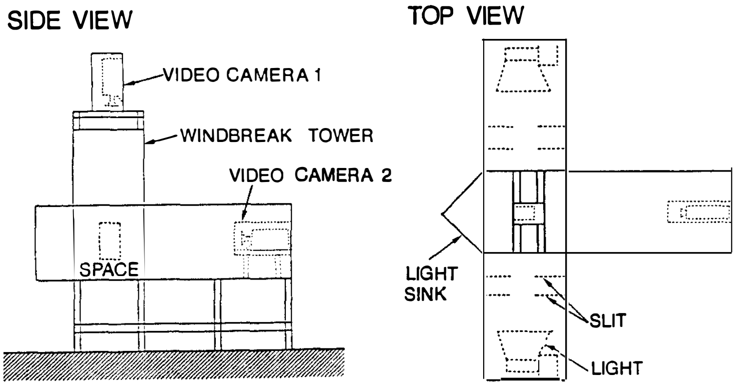

Fig. 1. Configuration of equipment for measuring falling attitude of snowflakes.

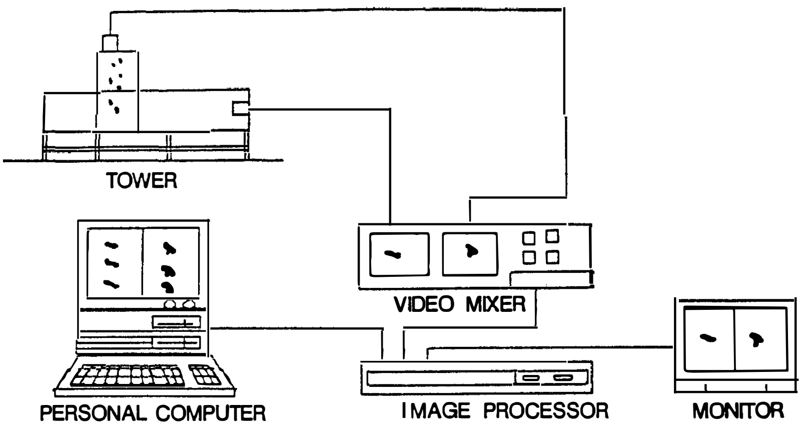

Fig. 2. Schematic diagram of system for measuring falling attitude of snowflakes.

flakes entering this space were simultaneously photographed by two video cameras (the video camera shutter speed was set at 1/1000 s) from horizontal and vertical directions.

As shown in Fig. 2, two images taken from two directions of the same snowflake were combined to one pair of images by a video mixer in order to synchronize timing and were input into an image processor (480×512 pixels). Assuming that the density inside snowflakes was approximately uniform, the snowflake images were binarized by a visually satisfying threshold. Each pair of binary images, therefore, shows horizontal and vertical projections consisting of pixels. Since the image was constructed from arrays of pixels, the number of pixels along both horizontal edges indicates width. The positions of both edges in each row were computed. The details of this method are discussed in a previous paper (MURAMOTO *et al.*, 1989). The characteristics of falling snowflakes, for example, area, change in falling direction and length of image contour of snowflakes, were analyzed every 1/30 s from two binary images of each snowflake.

3. Experimental Results and Discussion

Figure 3 shows four typical examples of the falling snowflakes that consist of

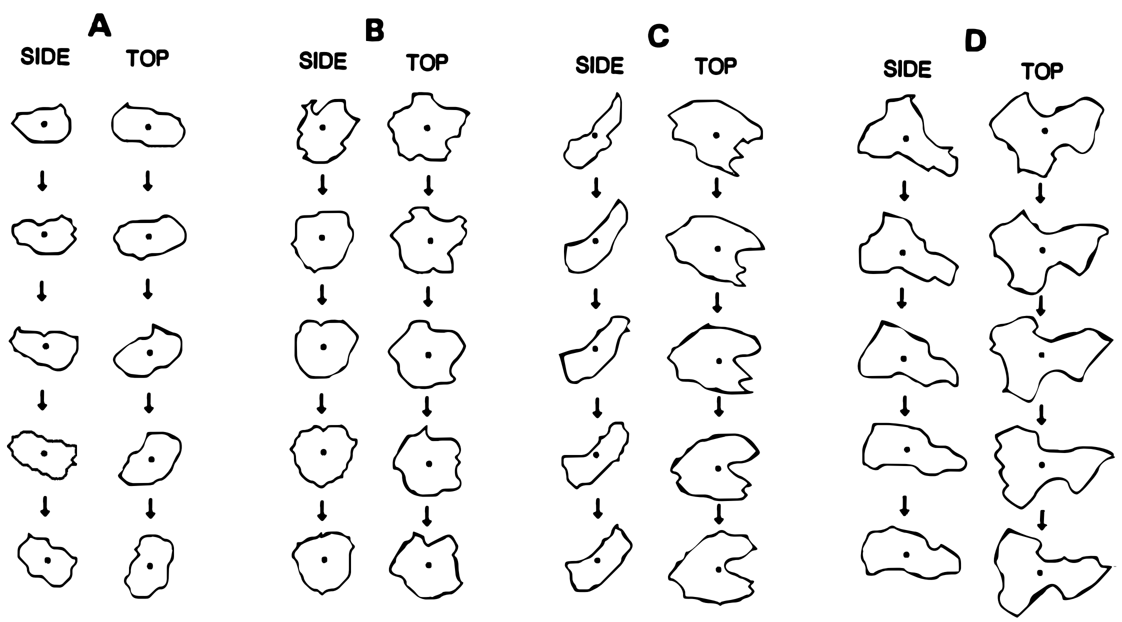

Fig. 3. Examples of image analyzed for typical four snowflakes.

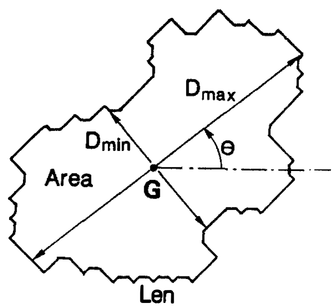

Fig. 4. Geometry of a snowflake image.

five continuous images computed every 1/30 s. It is clear from these examples that the falling snowflake viewed from the top rotates clockwise or counterclockwise.

To examine the falling attitude of snowflakes in detail, the parameters, that is, center of gravity of the plane, length of circumference, inside area surrounded by a contour, diameter through the center of gravity and angle of inclination from the x-axis of the orthogonal coordinates, as shown in Fig. 4, were selected. For a side image, the elevation is the angle measured from a horizontal plane. For the top image, the azimuth is the angle (θ) measured from the direction of the maximum diameter of the first image in five continuous images. Table 1 lists the data of these shape parameters for the four different snowflakes shown in Fig. 3. These data indicate that the size of falling snowflakes viewed from the top is larger than that of the side ones. To confirm this, forty-five falling snowflakes were examined; the results are shown in Figs. 5 and 6. In Fig. 5, the maximum and minimum diameters of falling snowflakes are plotted against coordinates of the side and top diameter. These results show that the top images were somewhat rounder than the side images. Similarly, the areas of the top image were larger than side image (Fig. 6). It is considered

Table 1. Shape parameter data.

	A		B		C		D	
	Side	Top	Side	Top	Side	Top	Side	Top
Area (mm^2)	36	43	54	66	41	81	73	103
Len (mm)	20	22	25	29	24	37	34	44
D_{max} (mm)	8.6	9.6	9.4	10.2	11.8	12.5	13.7	15.3
D_{min} (mm)	4.8	5.4	7.7	8.3	4.3	8.1	6.1	6.0
θ_1 (deg)	−15	−22	−35	−65	52	15	−23	−10
θ_2	−15	−7	−35	−59	52	24	−17	−16
θ_3	−30	11	−32	−56	52	30	−14	−22
θ_4	−45	26	−32	−53	52	33	−11	−28
θ_5	−57	53	−32	−47	52	42	−11	−34
Rotation (deg/s)	315	−563	−23	−135	0	−203	−90	180

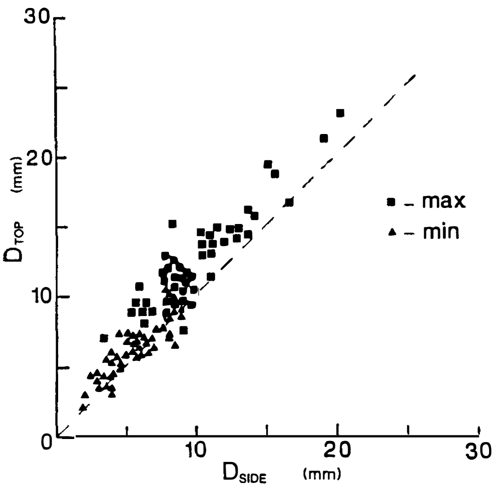

Fig. 5. Maximum and minimum diameters of snowflakes plotted against coordinates of side and top diameter.

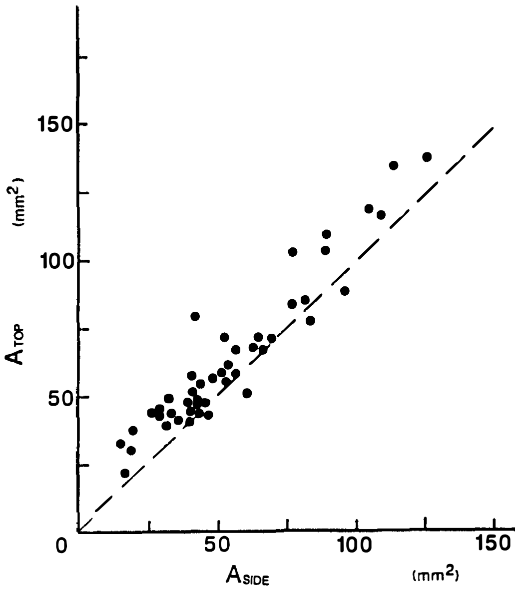

Fig. 6. Areas of the top image plotted against the side image.

that each snowflake receives more resistance from the air toward the upper direction during falling, so the snowflake tends to become disc-shaped.

4. Conclusion

A new measuring system that can observe the falling attitude of snowflakes has been developed using two video cameras from horizontal and vertical directions. The images of snowflakes were automatically analyzed by an image processor and a computer. Present results indicate that snowflake images from the top were larger than the ones from the side, and the images from the top rotated 100–600 degree/s.

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