INSTANTANEOUS MEASUREMENTS OF SNOWDRIFTS IN SMALL-SCALE MODELING

by

R. A. Schmidt and Robert L. Jairell[1]

ABSTRACT

Side-by-side comparisons of small-scale models in drifting snow can quickly answer questions about efficient drift control. However, measuring snowdrifts simultaneously as they accumulate near paired models requires a faster method than probing each drift with a ruler. We explored computer imaging for a possible alternative. Analyzing photographs of a "rake" of vertical pins pressed into the drift produced promising results. Using the method, we compared trapping efficiency of model tree rows with model snow fences, as an example.

INTRODUCTION

Predicting airflow around buildings and other complex objects is difficult, in spite of progress in computer simulation. This is especially true if the flow problem includes particles, and mapping deposition is required. Often, measurements on small-scale models in wind tunnels or similar facilities provide the only reliable results. Predicting snowdrifts is in this class of problems.

Few materials simulate snow for modeling drifting. The problem is avoided by running the model simulations outdoors (Fig. 1), in snowdrifting at windspeeds just above the threshold for particle movement (Tabler and Jairell, 1980). As in wind-tunnel work, useful results require both accurate models (Jairell and Schmidt, 1987), and proper scaling of wind speed. The key to similitude in outdoor modeling is the auto-scaling of the wind profile (Tabler 1980). Because proper scaling of surface roughness is also critical, we usually work on a frozen lake.

Modeling snowdrift patterns greatly reduces the time to obtain results. Under conditions for dynamic similitude, a 1:30 model scale can simulate the total winter accumulation season in a period of two hours. When only the final, equilibrium drift shape is required, we usually lay a measuring tape along the drift and probe the drift with a metal ruler, using a tape recorder to note the snow depths at various distances along the transect (e.g., see Jairell and Schmidt 1990).

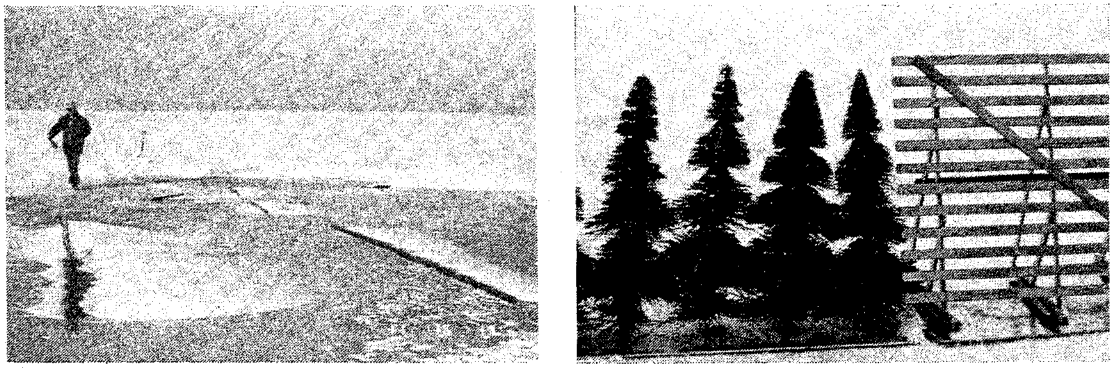

Figure 1. As an example, model experiments (left) compared drifts created by a 12.5-cm snow fence and tree rows, lower left (wind from left). A 6.5-cm snow fence downwind caught drift not trapped by the 12.5-cm models. Photo at right is a closeup of the double-row tree model and 12.5-cm-high snow fence. Models in the background (left photo) are 6.5-cm snow fences with blower or deflector panels upwind (farthest) and without deflectors (nearer).

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[1] Hydrologist and Hydrologic Technician, respectively, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 222 S. 22nd St., Laramie, (307)742-6621, in cooperation with the University of Wyoming. Station headquarters are at Fort Collins, in cooperation with Colorado State University.

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A disadvantage of modeling outdoors is (our) lack of control over timing and duration of the proper conditions. We wish to run as many experiments simultaneously as we can adequately record, when conditions are right. In the example experiments described under Figure 1, six drift transects are needed to record each stage of drift growth. Probing each drift requires several minutes. The obstruction of the observer certainly influences deposition. Some method that gives a "snap-shot" measurement of snowdepths, with little disturbance, would improve productivity of the snowdrift modeling technique.

THE RAKE

Figure 2 shows a device we called "the rake". Built in three 1-m sections, each section has welding-rod probes brazed to an electrical conduit top bar. The device was painted black, and distances were marked on the top bar with white, stick-on numerals. Distance between probes was 10 cm except for 5-cm spacing at the ends of each section. Each welding-rod probe extended 19.8 cm from the top bar. A band of orange tape on each probe marked a 5-cm distance from the top bar.

Figure 2. Sections of the rake are joined (left) by conduit couplers, to provide measurements (right) along a transect through the modeled snowdrift.

The rake was easily pushed into a drift, until the probes touched the ice. A model with the rake in place was photographed from one end, using a 35-mm camera with a 55-mm lens and slide film. A data-back printed time on the image. The rake was self-standing in drifts deeper than about 5 cm. Probe spacing of 5 cm at the section ends proved useful for measuring details near our model fences and tree rows, where depth gradients were large. It also helped avoid errors in counting pins to determine distance.

IMAGE EVALUATION

The slides were digitized for storage on compact disk (Kodak PhotoCD*). These images were cropped and converted to 256-level grayscale Tagged Image File Format (TIFF) using a software package by Inset Systems (HiJaak Pro*). The TIFF files were imported into a mapping package (EPPL7*, from Minnesota State Planning Agency), and pin locations were digitized from the enhanced image on the computer monitor. Coordinates of pin intersections with the top bar, and locations where they penetrated the drift, were placed in spreadsheets for conversion to snowdepths (Fig. 3).

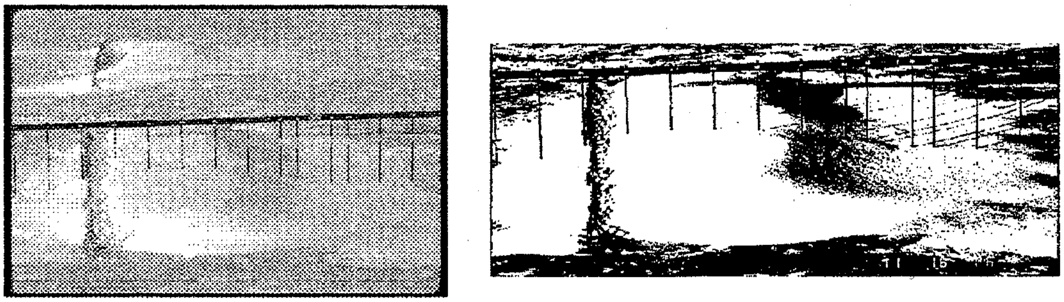

Figure 3. Each digitized slide was converted to a TIFF grayscale file (left), then cropped and reduced to black-and-white (right) for digitizing on the monitor screen. Differences in vertical coordinates of each pin between its intercept with the top bar and the drift were scaled by the coordinate distance of a fully-visible pin. Subtracting corrected estimates of visible pin length from total pin length determined snow depth.

Differences in the vertical coordinates between the top of each pin and its intersection with the snow were adjusted for perspective (ends of rake farther from lens than rake center) using the value 5.22 % (Fig. 4a) for a 55-mm focal length. Corrections when the rake was not parallel to the film plane (Fig. 4b) were computed from differences in horizontal coordinates and the known pin spacing. The estimated visible pin lengths were then subtracted from 19.8 cm, the total pin length, to estimate snow depth.

RESOLUTION AND ACCURACY

The number of picture elements (pixels) used to represent a distance in the image determines resolution of this method. Kodak's PhotoCD* Standard size is 512-by-768 pixels for a 24 mm-by-36 mm slide frame. If one meter of rake length fills the image width, resolution is 1.3 mm/pix. For 3 m rake length, the resolution is 3.9 mm/pix. Large (1024-by-1536) and Poster (2048-by-3072) sizes are also available from the compact disk files. The 2048-by-3072 file provides 1.3 mm/pix resolution when the full 3-m rake fills the image frame. However, file sizes and processing time are quadrupled for this image size. We conducted our tests using only the 512-by-768 element images. Where two photographs covered sections of a drift, agreement in the overlap region was good (see examples).

We compared depths estimated at the pins with readings to the nearest millimeter on a metal ruler. Uncertainty in depths read from the ruler are at least ±3 mm, caused by drifting snow eroding the surface around the ruler, and irregularities in the underlying ice. All measurements made during the tests at Diamond Lake (Fig. 1) in southeastern Wyoming on 11 February 1993 are plotted in Figure 5. Note 1 (Figs. 5 and 6) points to a digitizing error. Note 2 indicates errors caused by shadows near the model that obscured the pin intersection with the drift.

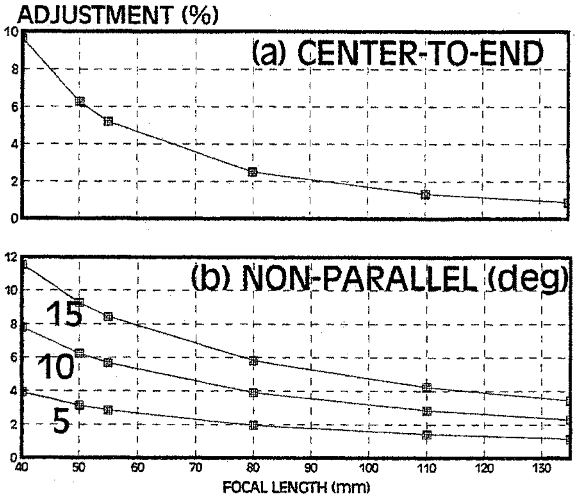

Figure 4. Adjustments for (a) variation in distance from lens, and (b) film plane not parallel to rake, decrease with increasing focal length.

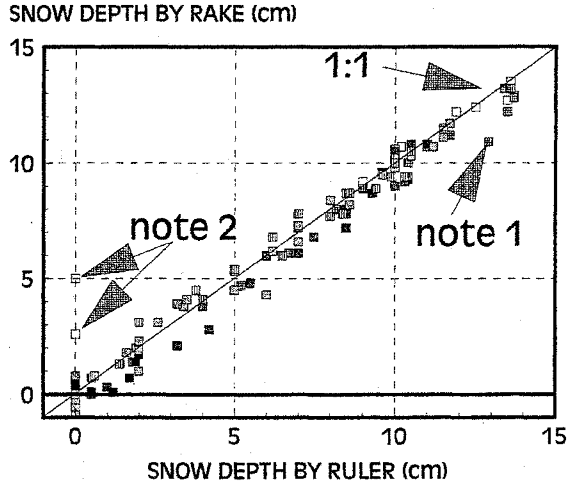

Figure 5. Comparing snow depths measured by image analysis with depths by probing with a ruler showed that the new method gave promising results. (See text on notes 1 and 2.)

EXAMPLES

Figures 6, 7, and 8 show drift results from the experiments described in Figure 1. Conclusions from each experiment are stated in the figure captions. Note that all drifts are at stages less than equilibrium capacity. Rake and ruler depths are those plotted in Figure 5. These promising results from the image measurements could be improved by (1) using a lens with focal length nearer 100 mm, (2) using a tripod or monopod to keep camera height constant, (3) a procedure that assures the film plane is parallel to the rake, and (4) maintaining exposures that don't block detail in the shadows near the models.

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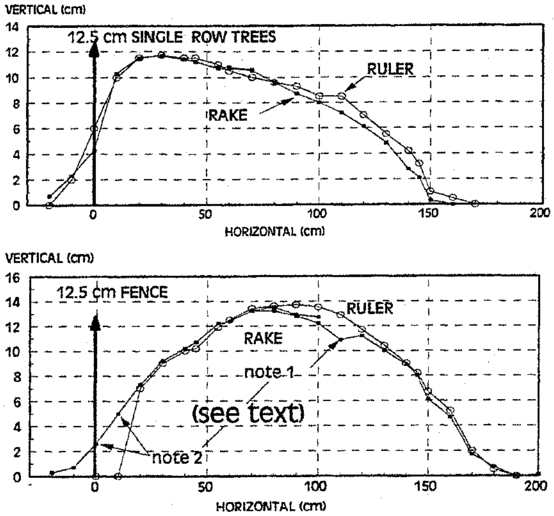

Figure 6. The drift from a single row of trees begins upwind and does not extend downwind as far as the drift behind a snow fence, at this stage of deposition.

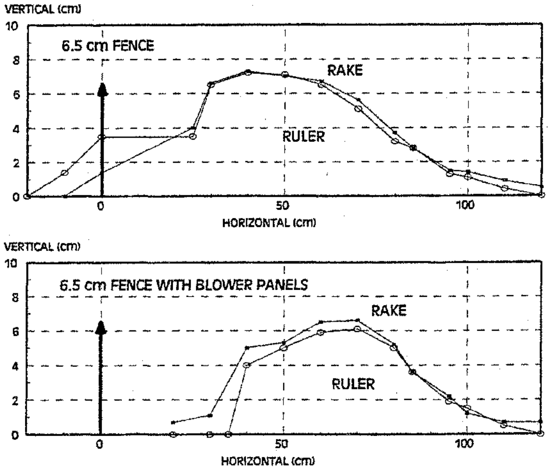

Figure 7. Blower panels that guide drift into a fence produced a smaller drift, farther downwind than the drift behind a fence without the lead-in panels.

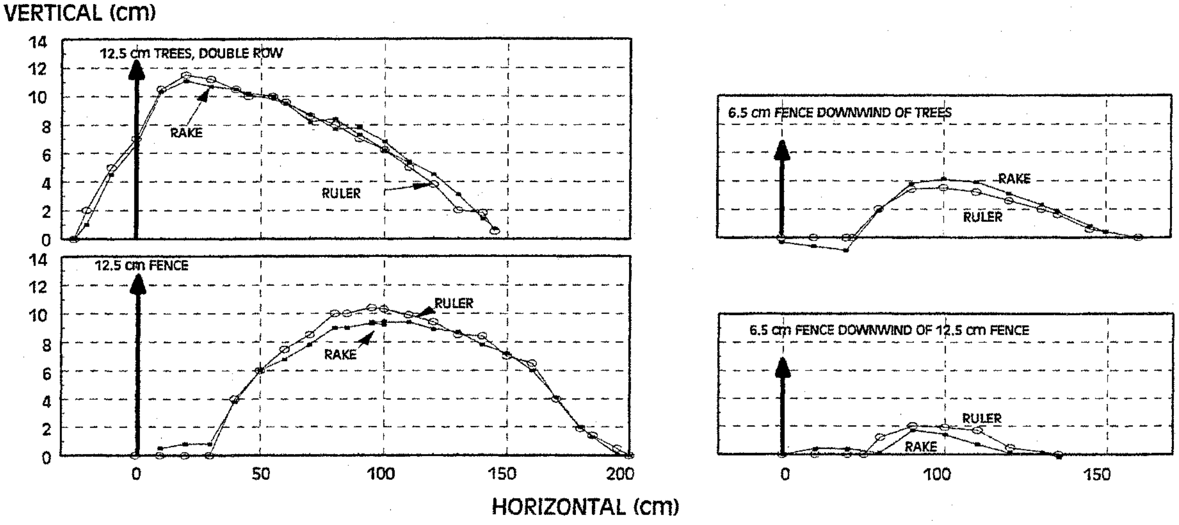

Figure 8. Drift partly buried the double-row tree model, while the fence remained free. Catch at the downwind 6.5-cm fence indicated the 12.5-cm fence was more efficient than the tree model, up to this stage of deposition.

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