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SNOW CONCENTRATION AND EFFECTIVE AIR DENSITY DURING SNOW-FALLS

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ABSTRACT. The mass concentration of falling snow ρ_s can be estimated from the snow-fall rate (accumulation rate) q_v if there is no significant wind. Limited data show only a weak relation between fall velocity u_t and q_v ($u_t \approx 110 q_v^{0.1}$ cm/s with q_v in g/cm^2 h). Consequently there is a strong correlation ($r^2 = 0.97$) between ρ_s and q_v ($\rho_s \approx 2.57 q_v^{0.9}$ g/m^3 with q_v in g/cm^2 h). A simple relation of this kind is of practical value for certain technical purposes, and more data would be welcome.

RÉSUMÉ. *Concentration de neige et densité efficace de l'air au cours des chutes de neige.* On peut estimer la concentration de masse ρ_s de la neige tombante à partir du taux de chute (vitesse d'accumulation) q_v s'il n'y a pas un vent significatif. Des données peu nombreuses montrent seulement une relation faible entre la vitesse de chute u_t et q_v ($u_t = 110 q_v^{0,1}$ cm/s avec q_v en g/cm^2 h). Par conséquent il y a une forte corrélation ($r^2 = 0,97$) entre ρ_s et q_v ($\rho_s = 2,57 q_v^{0,9}$ g/m^3 avec q_v et g/cm^2 h). Une simple relation de ce type a une valeur pratique pour certains usages techniques et plus d'observations seraient les bienvenues.

ZUSAMMENFASSUNG. *Schneekonzentration und effektive Luftdichte bei Schneefällen.* Die Massenkonzentration ρ_s fallenden Schnees kann aus der Schneefallrate (Akkumulation) q_v geschätzt werden, wenn kein starker Wind weht. Begrenzte Daten zeigen eine nur schache Relation zwischen der Fallgeschwindigkeit u_t und q_v ($u_t \approx 110 q_v^{0,1}$ cm/s mit q_v in g/cm^2 h). Folglich besteht eine starke Korrelation ($r_2 = 0,97$) zwischen ρ_s und q_v ($\rho_s \approx 2,57 q_v^{0,9}$ g/m^3 mit q_v in g/cm^2 h). Eine einfache Beziehung dieser Art ist für gewisse technische Zwecke von praktischem Wert; mehr Datenmaterial wäre daher wünschenswert.

IN certain technical problems it is necessary to know the mass concentration of snow in the air ρ_s and the effective air density ρ_{ea} during periods of snow-fall. Defining ρ_s as ice mass per unit volume of snow-filled air (as is done for deposited snow):

$$\rho_{ea} = \rho_a + \rho_s(1 - \rho_a/\rho_i) \approx \rho_a + \rho_s \tag{1}$$

where ρ_i is ice density ($\approx 0.92 \times 10^3$ kg/m^3) and ρ_a is the density of clear air (≈ 1.3 kg/m^3).

In calm weather, the vertical flux of snow q_v is easy to measure, e.g. by weighing the snow collected on a tray over a short time period. Representative fall velocities of snow particles u_t are also fairly easy to measure if the complications of fall velocity variation within the dispersion are ignored. In principle, it is easy to estimate ρ_s, since

$$\rho_s = q_v/u_t. \tag{2}$$

However, while measurement of q_v is routine, corresponding measurements of u_t are seldom made.

At any given location, q_v can vary by two or three orders of magnitude during a winter season (say in the range 0.002 to 2.0 g/cm^2 h). By contrast, u_t is unlikely to change by more than a factor of four for the whole range of snow crystals and snow-flakes. Thus, variations in ρ_s must be controlled mainly by variations of q_v.

Mellor (1966) sampled a range of snow-falls, recording q_v, u_t, ρ_s, and characteristics of the snow crystals. If the values of u_t(cm/s) are plotted against those of q_v(g/cm^2 h), there is a weak correlation (Fig. 1) which can be described by

$$u_t = 110 q_v^{0.104}. \tag{3}$$

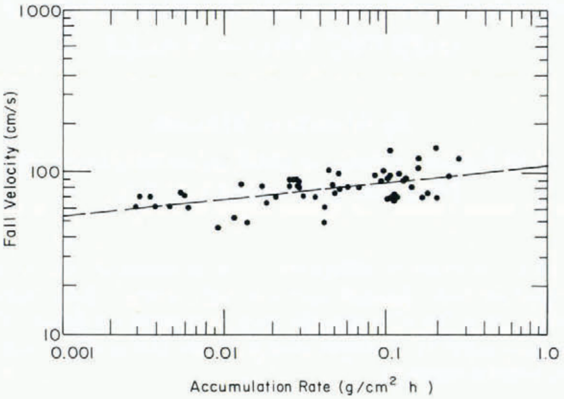

Fig. 1. Fall velocity u_t plotted against accumulation rate q_v.

The coefficient of determination r^2 for the power-relation regression is 0.3. Since u_t does not vary much, there must be a strong correlation between ρ_s and q_v (Fig. 2). The data can be described by

$$\rho_s = 2.566 q_v^{0.899} \approx 2.57 q_v^{0.9} \text{ g/m}^3 \tag{4}$$

where q_v is in g/cm^2 h (which is equivalent to the accumulation rate expressed in centimetres of water per hour). The coefficient of determination r^2 is 0.969. A result that is essentially the same as Equation (4) is obtained by substituting Equation (3) into Equation (2) and adjusting the units.

The most basic quantitative description of a snow-fall is q_v. Knowing q_v, an estimate of ρ_s that is sufficiently accurate for many practical purposes can be obtained from a relation such as Equation (4).

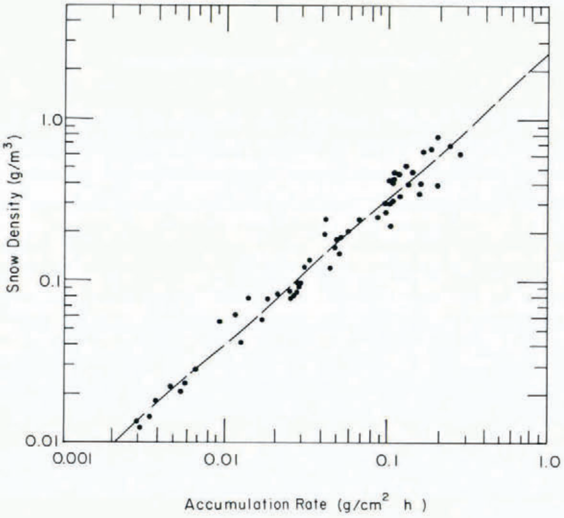

Fig. 2. Snow density ρ_s plotted against accumulation rate q_v.

This is very convenient, and so it would be useful to have more field observations of q_v, u_t, and ρ_s, especially for very heavy snow-falls.

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REFERENCE

Mellor, M. 1966. Light scattering and particle aggregation in snow-storms. *Journal of Glaciology*, Vol. 6, No. 44, p. 237–48.