

The filtering effect of snow

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Abstract. Chemical analyses of snow samples from a 10-m snow profile in Queen Maud Land, 1200 m a.s.l., indicate an increase with depth for 14 of the 17 elements. This is explained by the snow acting as a mechanical filter for the particulate content of the air. Due to strong winds the air volume in the snow (30–50 per cent) will constantly be replaced. To test this hypothesis a snow layer was ventilated artificially. This demonstrated that a 1-m snow layer was not a totally effective filter for aerosols.

L'effet filtrant des neiges

Résumé. L'analyse chimique d'échantillons de neige prélevés sur une profondeur de 10 m en Terre de la Reine Maud à 1200 m d'altitude met en évidence un accroissement des teneurs avec la profondeur pour 14 des 17 éléments mesurés. Ceci s'explique par le rôle de filtre mécanique joué par la neige vis à vis des particules présentes dans l'air. A cause des vents forts, le volume d'air dans la neige (30 à 50 pour cent) sera constamment remplacé. Pour vérifier cette hypothèse, une couche de neige a été ventilée artificiellement; cela a montré qu'une couche de 1 m de neige n'était pas un filtre totalement efficace pour les aérosols.

INTRODUCTION

Chemical analyses of snow and ice cores are frequently used to determine the chemical composition of the precipitation and dry deposition.

Snow contains varying quantities of air, and the greater part of this air volume will constantly be replaced due to local changes of air pressure and strong winds above the surface. These ventilation processes are dependent on the snow structure and the snow surface roughness. Any ice layers will seal the snow layers underneath from ventilation processes. It is reasonable to assume that the snow layers will act as a mechanical filter for aerosols so that the air leaving the snow volume is 'clean'. This air exchange between the snow and the atmosphere will consequently contribute to an increase of the ion content of the snow. However, if the filtering effect of snow was so efficient that all the pollutants were absorbed in the uppermost snow layer, say 1 cm thick, the contribution from this filtering effect could hardly be distinguished from the dry deposition at the surface. On the other hand, if the filtering efficiency of snow is not as high, a part of the aerosol content may be transported to deeper layers before it is absorbed or trapped. The chemical composition of a snow layer at a certain depth will then represent the sum of three processes: washout/rainout effect, dry deposition, and filtering of the aerosol content of the circulating air during the time interval since the snow layer had accumulated. The depth to which this aerosol transport will take place and the importance of the process depends on the filtering efficiency of the snow layers and the rate of air exchange between the snow layers and the atmosphere.

STUDY OF THE FILTERING EFFICIENCY OF SNOW

In order to test the filtering efficiency of snow, eight 1-m long tubes of polyethylene (inner cross section 80 cm²) were filled with naturally stratified snow and buried vertically in the snow so that the upper edge levelled with the snow surface. Five of these tubes were ventilated artificially by means of suction pumps connected via flowmeters to the lower end of the tubes. The air flow rates through the tubes were 4 and 7 l. min⁻¹ equivalent to air currents of

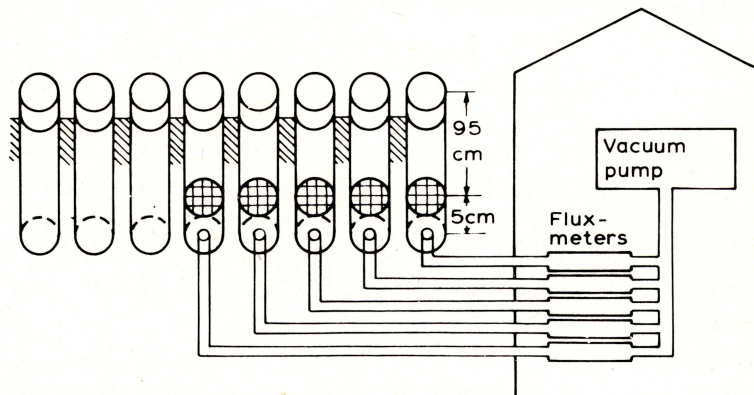


FIGURE 1. Schematic diagram of the snow filtering experiment.

about 1.6 and 2.8 cm s^{-1} . The remaining tubes were not ventilated (Fig. 1). After three test runs of respectively 4, 12 and 18 d, the snow in all the tubes was sampled at every 10 cm and analysed for 10 different components.

As indicated in Fig. 2 the ion concentrations in the ventilated tubes were considerably higher than for the unventilated ones at all levels. It should be mentioned that no melting occurred during the experiment.

The experiments were carried out at Gullsvik (150 m a.s.l.), a small village about 100 km west of Oslo, and at Finse (1200 m a.s.l.), a typical mountain area without any main anthropogenic sources within some 100 km distance.

In Fig. 3 the mean ion concentration in the tubes *versus* volume of ventilated air is shown. Both the mean ion concentration increase per unit volume of ventilated air and the ion concentration of the unventilated tubes were markedly higher in Gullsvik compared to the mountain area. The explanation to this is evidently differences in background aerosol concentrations.

After passing the 90-cm snow column the air was analysed in a photoelectric

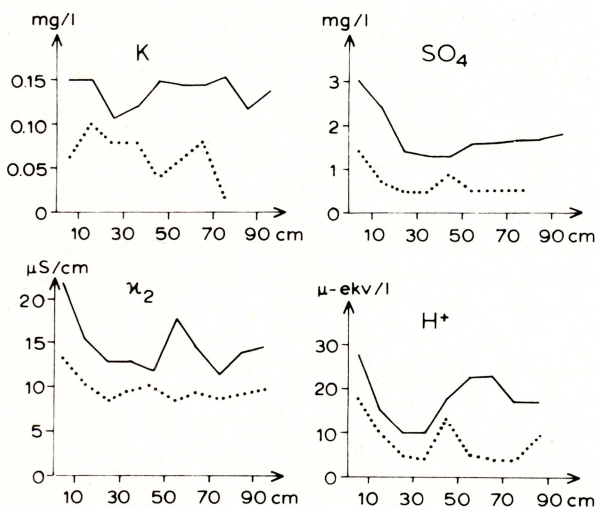


FIGURE 2. Ion concentration of the snow in the tubes as a function of depth. no ventilation; — ventilated tubes.

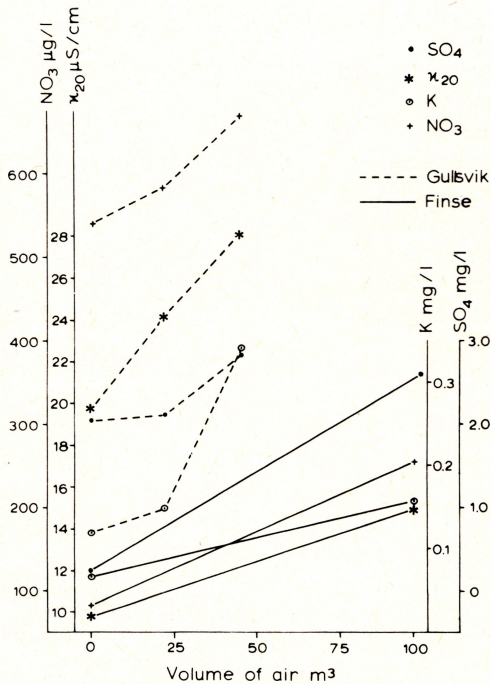


FIGURE 3. Mean concentration of some of the ions as a function of the air volumes that had passed through the snow layer.

condensation nuclei counter. These measurements showed that a 90-cm snow layer was not a 100 per cent effective filter for condensation nuclei in the air.

NATURAL SNOW FILTERING EFFECT

An essential question is whether the amount of natural air exchange between a snow layer and the atmosphere is sufficient for the significant increases of ion concentration in snow to be due to the filtering effect. If we assume that 50 cyclones pass per year giving variations in air pressure of 50 mb and these act on a 10-m snow layer, a rough estimate of the pumping effect gives only some $100 \text{ l. year}^{-1} \text{ dm}^{-2}$ surface. This effect alone is not sufficient to explain any increases in the ion content. However, small-scale pressure gradients near the snow surface due to sastrugies and marked wind shear will also contribute to air exchange between the snow volume and the atmosphere.

Literature concerning natural air currents in snow is rather scarce. Dubrovin (1961) found at Lazarev Ice Shelf that the mean speed of the air flow within the upper 5-m snow layer amounted to 1/2000 of the wind speed at the 2-m level. Consequently, a mean annual wind velocity of say 10 m s^{-1} (fresh breeze) and a 40 per cent free air volume in the 5-m layer, correspond to a mean air flow per square decametre of some $600 \text{ m}^3 \text{ year}^{-1}$. This is 6–10 times the air exchange in the filtering experiments. A mean exchange component of say 1/10 of the horizontal flow should result in the air exchange being of the same order of magnitude as in our filtering experiments.

If the assumption is made that the mean aerosol concentration has been constant in an area for, say, the last decade, and that the ventilation process decreased with depth, the concentration of the different pollution elements in

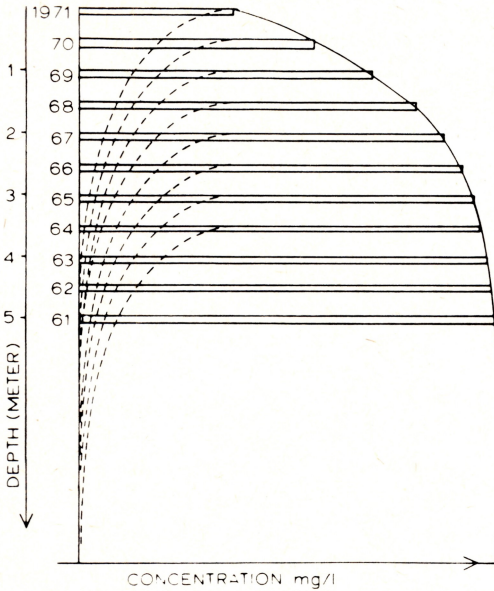


FIGURE 4. Schematic diagram to show the additional concentration due to the ventilation and the filtering effect of snow. ----- increase for one year; ——— integrated values for a 10-year period

snow would, due to the filtering effect, increase with depth and approach a maximum value asymptotically. It should be emphasized that this refers to areas without any impermeable hard layers in the snow. In Fig. 4 this mechanism is outlined.

Figure 5 shows some results from chemical analyses of a 10-m snow layer in the mountains in Queen Maud Land (Antarctica), 1200 m a.s.l. (Gjessing and Gjessing, 1973). This snow layer, without any hard summer layers, represents about 25 years accumulation. Snow samples were taken every 30 cm in this layer and mean values for each 2.5 m for some of the components are given in Fig. 5. It is seen that the concentrations increase with depth for all elements except for the SO₄-content. The chemical analysis covered 17 different components and the

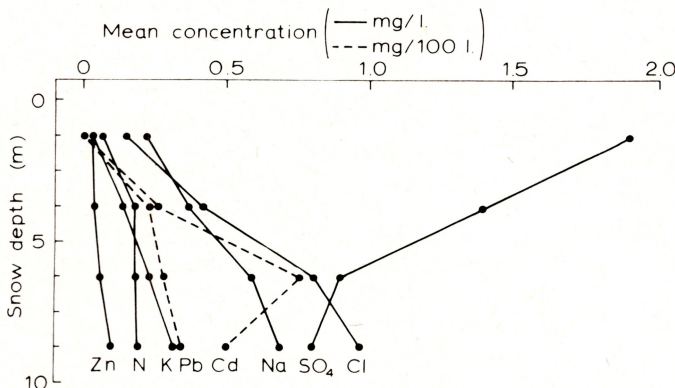


FIGURE 5. Mean concentration of some of the components as a function of depth. Each dot represents the mean of eight observations.

concentration of 14 of these elements increased with depth (two elements were constant). Thus, this study supports the considerations given above.

It should, however, be mentioned that the ion concentrations found in the Antarctic study were considerably higher than the concentrations found in more recent investigations from this area (Boutron and Lorius, 1977). The probable explanation is that our sampling technique cannot be considered as completely free of contamination.

REFERENCES

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