

THE INFLUENCE OF BOREAL FOREST COVER ON THE CHEMICAL COMPOSITION OF SNOWCOVER

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ABSTRACT

In the late winter and spring of 1983, a study of precipitation quality on an event basis and a high-frequency time-profile survey of the snowcover were carried out at Laflamme Lake, a boreal forest site, Québec. A comparison of the mean values for ionic species (H^+ , NH_4^+ , Na^+ , K^+ , Ca^{++} , Mg^{++} , $SO_4^{=}$, NO_3^- and Cl^-) in incident precipitation with that at a wooded site showed that, apart from drip zones, the forest canopy did not appreciably influence the composition of the incident precipitation (K^+ excepted) with respect to the variation observed between individual events in open areas. The strong correlation between H^+ and $SO_4^{=}$ concentrations in incident precipitation was not conserved in the snowcover and is due in part to preferential losses of ions during the pre-melt period and suppression of H^+ by large increases in K^+ concentrations in the pack particularly during heavy rains when the pack was saturated. The presence of increased quantities of K^+ is probably due to the physical dissolution and/or microbiological degradation of potassium bound in organic debris deposited from the canopy onto the snowcover during local turbulence. Strong correlations were found for data relating the concentration of ionic species (H^+ , $SO_4^{=}$, NO_3^-) in samples from snowcores to samples of much larger volume from snowpits. No such correlations were found for Ca^{++} , Mg^{++} , K^+ , Na^+ and Cl^- and the differences in the correlation coefficients between the two groups are mainly attributed to the relative origins of ionic species in the snowcover i.e. long range atmospheric transport and local debris from the forest canopy.

INTRODUCTION

The increase in the acidity of atmospheric precipitation in Northeastern America during the last few decades (Likens and Butler, 1981) has been identified as the prevailing factor in the acidification of poorly buffered surface waters in both the Northeastern United States and Eastern Canada (Wright, 1983). Much of the precipitation in Eastern Canada is in the form of snow, which in the shield region covers the ground for 5-9 months of the year. The rapid release during spring melt of acidic pollutants accumulated during the mid-winter period by the snowpack can lead to high acidity values in surface waters and concomitant stress conditions for the aquatic biota (Driscoll et al., 1980).

The degree to which local characteristics of watersheds may influence the acidity in spring meltwaters depends both on the effects of biophysical conditions on the snowcover in winter and soil/subsoil interactions with meltwater during the main melt season in

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spring (Seip et al., 1980). The biophysical characteristic of most watersheds on the southern half of the Canadian shield in Québec is the boreal forest in which conifer stands predominate. Although the influence of conifers on incident precipitation as rain has been well studied (Abrahamsen et al., 1977), the effect of coniferous stands on snow and snowcover is relatively less known. Pierson and Taylor (1983) who compared the chemical quality of snow samples taken from snow courses in open and wooded areas near Peterborough in South-Central Ontario found slightly higher values for Ca^{++} , Mg^{++} and Na^+ in snow taken from under the forest canopy.

A comparison of snowcores taken biweekly in open locations and under coniferous canopies at Sagamore Lake in the Adirondacks permitted Johannes et al. (1981) to conclude that H^+ and NO_3^- concentrations were lower in the woods than in the open area while SO_4^{--} showed no relative loss from one type of location to the other. Evidence for both net losses and preferential losses of ionic species from snowpacks has been reported (Jeffries and Snyder, 1982; Skartveit and Gjessing, 1979). These losses may occur even during cold mid-winter periods (Jeffries and Snyder, 1982) but are usually greatest during spring when the first meltwater discharges from the packs contain relatively high concentrations of H^+ and strong acid anions (Johannessen and Henriksen, 1978; Suzuki, 1982). During these periods it is possible that dry deposition of acidic pollutants, contact between the canopy and incident precipitation (throughfall) and the local deposition of organic debris contribute to the increase or decrease of the acidity of the snowcover. The local deposition of debris from the canopy can be appreciable in the boreal forest and its presence can lead to problems both in sampling procedures and in the interpretation of the data during snow surveys. Jeffries and Snyder (1982) recognizing that litter deposition could possibly influence the quality of snow chose to carry out a survey of snowcover in the Muskoka-Haliburton area of Ontario by sampling the cover in open locations only. In the relatively dense boreal forest found in Southern Québec this type of sampling option however cannot be considered when one needs to estimate the total acidic loading in the snowpack.

During the late winter and spring of 1983 we carried out an intensive snowcover survey at Laflamme Lake, Québec, with the purpose of determining the impact of the coniferous stands on snowpack chemistry both before and during the spring melt. The main objective of this study was to establish criteria for the choice of snow sampling sites which could be considered as representative of the overall mean chemical loading of acidic pollutants [meq m^{-2}] in small watersheds ($< 1 \text{ km}^2$) (Jones et al., 1984a).

Study area

The watershed of Lake Laflamme (0.68 km^2) lies between altitude 777 m (mean lake water level) and altitude 884 at $46^\circ 11' \text{N}$ and $74^\circ 57' \text{W}$ in the Montmorency Forest 80 km to the north of Québec City, Canada (Figure 1). The watershed is completely covered by the dominant mixed spruce and birch forest characteristic of this region of the Precambrian shield. No rock outcrops are visible in the Laflamme watershed as almost the entire surface lies under a cover of till and moraine. Mean annual temperature is 0.2°C (mean minimum, January -15°C ; mean maximum, July 15°C). The mean frost-free period is 40 days and the mean annual precipitation is 1 400 mm of which 34% is snow.

Sampling sites and methods

The sampling sites (22 base-line stations, 1 main sampling station) were located on the south-facing slope in an area ($45 \text{ m} \times 64 \text{ m}$) lying between 20 m and 84 m from the lakeshore. Biophysical characteristics of each site were determined as described by Jones et al. (1984b).

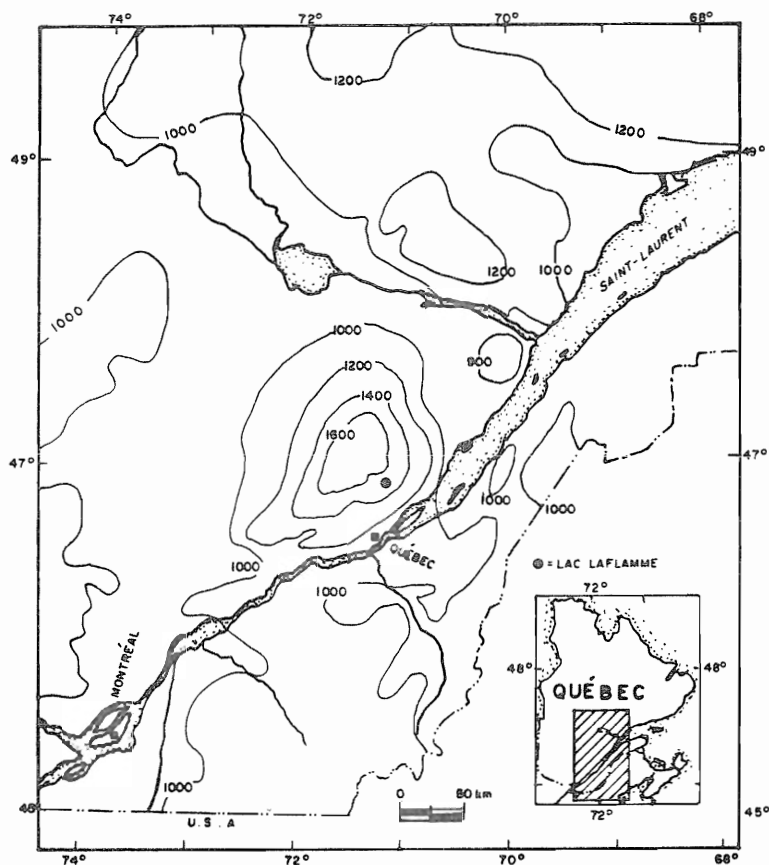


Figure 1: Regional wet deposition, mm; Laflamme Lake, Québec.

Precipitation (snow and rain) were collected on an event basis by means of two Sangamo Type A wet-only collectors. The collectors were installed in two areas representative of the mean forest canopy cover with care being taken to avoid the drip zone of conifers. The distance between the collectors was 11 m.

Samples for the chemical analysis of the snowcover were obtained either by coring with a clear plastic tube (plexiglas 2 m x 7.5 cm ID) (Jeffries and Snyder, 1982; DeWalle et al., 1983) and/or by the progressive cutting of snowpits (Adams et al., 1982; Suzuki, 1982). The snowpits permit a better appreciation of the physical mesostructure of the snow and the removal of separate snow strata by large plastic spatulas (26 x 26 cm). After exposing the face of the snowpits, an integrated cut (horizontal surface area = 338 cm²) of the snow column was taken; immediately following, a snowcore was taken a few centimeters back in from the new face. No special precautions to remove surface debris were taken. The snow from both snowpit cuts and snowcores were placed in plastic bags for the transport and conservation of the samples.

Sampling was initiated in mid-March and terminated on the 12th of May 1983 when the water equivalent of the snowcover was approximately 4 cm. Between 5 and 18 of the base-line stations were sampled at one time every 6 days before the onset of the springmelt (8th April). From the 8th of April to the 11th of May, the base line stations were

sampled every 2-3 days and the main sampling station (L2) every 1-2 days. In the comparative study between the chemical composition of snowcores and snowcuts from snowpits the main station was sampled at 9 hrs and 14 hrs on the same day on 8 separate dates between the 14th of April and the 10th of May. The snowmelt at Laflamme Lake was heavily influenced by rainfall. Two heavy rain events were recorded in April (17, 25) and from the 1st to the 11th of May heavy rain fell continuously except for the 5th and 6th of the month. Free water saturation levels of the pack were estimated according to the method of Anderson (1976).

Analytical procedures

Solid precipitation and snowcover samples were kept at -20°C until melted. The pH and conductivity of the liquid samples were determined by means of a pH meter (Radiometer PHM26), and a conductivity meter (Radiometer CDM) respectively. All samples were filtered through polycarbonate (47 mm, $0.4\ \mu\text{m}$) and analyzed for anions (Cl^- , NO_3^- , SO_4^{2-} , PO_4^{3-}) by ion chromatography (Dionex 12S). Cations were conserved, if necessary, by the addition of nitric acid ($0.5\ \text{ml L}^{-1}$) except for NH_4^+ which was conserved by the addition of concentrated sulfuric acid ($0.2\ \text{ml L}^{-1}$). Ca^{++} , Mg^{++} , Na^+ and K^+ were analyzed by means of atomic adsorption spectrophotometry (Varian 575); and NH_4^+ by colorimetry (Technicon autoanalyzer II, procedure 154-71W).

RESULTS AND DISCUSSION

Precipitation

Mean values for the concentration of inorganic species in both the precipitation and snowcover at the Lake Laflamme watershed are given in Table 1. Precipitation weighted mean values for the open area, a clear cut ($300\ \text{m} \times 300\ \text{m}$), directly adjacent to the watershed were taken from the most recent available CANSAP data (Barrie et al., 1982) while those of the wooded area are calculated from the results of the Sangamo collectors installed under the canopy during the present study. If one considers that the two data sets closely represent the mean mid winter-spring value for the chemical composition of precipitation (snow, rain and mixed) in both the respective areas, then the present differences in ionic content between the two sites are relatively minor (except for K^+) compared to the large fluctuations that are recorded between individual events at the both sites (ex.: H^+ , $0.8 - 139\ \mu\text{eq L}^{-1}$; SO_4^{2-} , $5 - 85\ \mu\text{eq L}^{-1}$). Although interception of snowfall by the canopy can be high for individual events under certain conditions (Laflamme Lake, $< 30\%$), actual physical contact between the total quantity of snow intercepted and the canopy surfaces is only of an appreciable consequence for the chemical composition of snow when the snow is heavily water-laden. Under such conditions snow sliding down into well defined drip zones may show high concentrations of acidic pollutants and nutrients dissolved and/or detached from the canopy surface. In contrast, the effect of conifer canopies on rain fall is more prevalent and can increase chemical loading of SO_4^{2-} by $> 100\%$ from dry deposition washoff, Ca^{++} by $> 500\%$ and K^+ by $> 1\ 500\%$ from physical leaching of the canopy (Abrahamsen et al., 1977). The results in Table 1 indicate that apart from relatively higher K^+ concentrations, the forest canopy had little influence on snowfall or rain showers falling directly on the snowcover sampling sites during the study period. The excess amount of K^+ observed in the Sangamo samples probably comes from wind-borne organic debris detached from the canopy during individual events.

The acidity H^+ of incident precipitation (snow and rain) in the wooded area was more strongly correlated with SO_4^{2-} content ($r^2 = 0.85$) (Figure 2) than that of NO_3^- [$r^2 = 0.18$] during the sampling period.

TABLE 1. Mean values for the concentration ($\mu\text{eq L}^{-1}$) of inorganic species in incident precipitation and snowcover Lake Laflamme

ION	PRECIPITATION ($\mu\text{eq L}^{-1}$)		SNOWCOVER ³ ($\mu\text{eq L}^{-1}$)	
	OPEN AREA ¹	WOODED AREA ²	BEFORE SNOWMELT MARCH-8 APRIL	DURING SNOWMELT 8 APRIL-11 MAY
SO ₄ ⁼	30.15	29.37	24.20	19.76
NO ₃ ⁻	22.30	18.26	26.67	18.40
Cl ⁻	8.06	5.22	11.65	4.59
PO ₄ ⁼	-	-	4.23	6.11
H ⁺	42.50	48.24	33.17	21.68
NH ₄ ⁺	8.81	4.65	5.84	5.29
Na ⁺	5.71	5.16	2.66	2.63
K ⁺	0.10	3.96	5.04	13.85
Ca ⁺⁺	4.17	5.20	3.91	4.32
Mg ⁺	0.47	1.47	1.51	2.09
-ve	60.50	52.85	66.75	48.86
+ve	62.47	68.66	52.13	49.86

¹ CANSAP mean values January-April 1982 calculated from the data of Barrie & Sirois (1982)

² SANGAMO samplers (2) March-May 1983, Jones et al., 1984a

³ Mean values of base-line stations, 1983

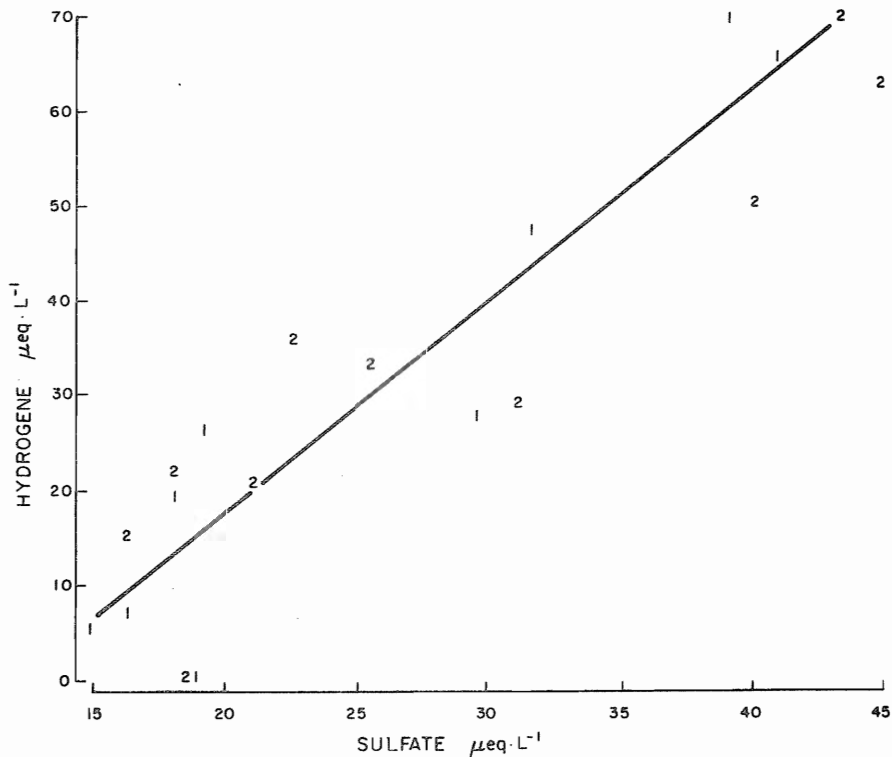


Figure 2: Relationship between $[\text{H}^+]$ concentrations and $[\text{SO}_4^=]$ concentrations in precipitation captured by wet only Sangamo collectors (1 and 2) in wooded area, Laflamme Lake, late winter-spring, 1983.

In general samples from rain events showed high values of $\text{SO}_4^{=}$ than snow (rain $37.2 \mu\text{eq L}^{-1}$, snow $19.0 \mu\text{eq L}^{-1}$), relative H^+ concentrations were $20.2 \mu\text{eq L}^{-1}$ (snow) and $59.3 \mu\text{eq L}^{-1}$ (rain) while NO_3^- concentrations ($\approx 19 \mu\text{eq L}^{-1}$) differed little between the two forms of precipitation. Although the quantity and quality of the precipitations captured by the two Sangamo collectors varied according to the intensity of the rain episodes and concomitant atmospheric turbulence the correlation coefficient between the data relating the rainfall (mm) ($r^2 = 0.95$; $n = 42$) captured by each collector was the same as that between the data relating the acidity of the incident rainfall sampled from each collector ($r^2 = 0.95$; $n = 42$).

Snowcover

The density of forest cover influences the quantitative distribution of snow on the forest floor. In the type of closed boreal forest that one finds at Lake Laflamme, forest density and tree species, and not wind distribution, are the predominant control factors in the variability of the amount of snow distributed throughout the watershed (Jones et al., 1984b). In order to calculate a mean value for the total chemical loading for the study area at any one time a mean value for the water equivalent of the snowcover was calculated from the data of the base-line stations (17 sampling dates between the 24th of March and the 11th of May) representing the whole range of site biophysical characteristics (open area \rightarrow completely closed canopy). The standard deviations around the mean value for the water equivalent (snowcores, Figure 3) represent the result of all data (pertinent to the sampling date) from the complete range of study sites in the watershed. The individual water equivalent values for the main station (snowcores, 8 April - 12 May) are shown for comparison during this latter period. The main sampling station generally underestimated the mean water equivalent of snowcover (-1% ; extreme values = $-14\%/+21\%$) as compared to the cores taken at the base-line stations. The 1st discharge of snowmelt from the pack was observed on the 8th of April but only really became appreciable on the 17th of the month during heavy rain at which time the pack became saturated. The mean water equivalent of the pack, fluctuated slightly between the 11th and the 17th of the month; on the latter date the water equivalent rose due to pack saturation and remained fairly constant until the 25th of April when heavy rains caused massive discharge from the snowcover. The whole pack then rapidly declined under the influence of rain being saturated on the 25-27 April, 1-5 May and 7-11 May.

Concentrations values of $\text{SO}_4^{=}$ for both the base-line stations and main sampling station closely followed the same trend (Figure 4). Contrary to the results of the data obtained for the water equivalent of the snowcover, no significant correlation was consistently observed between forest density and the concentration of $\text{SO}_4^{=}$ (or any other chemical parameter) at the base-line stations. From a steady value of $\approx 24 \mu\text{eq L}^{-1}$ during the stable phase (March - 8 April) the concentration declined appreciably to $\approx 17 \mu\text{eq L}^{-1}$ on the 19th. The first part of the decline (8 April - 17 April) indicates a loss of $\approx 30\%$ of the $\text{SO}_4^{=}$ content of the pack although very little meltwater was lost. This type of preferential ionic loss from snowcover during initial melt periods has been well documented in laboratory studies (Johannessen and Henriksen, 1978; Colbeck, 1981) and has been also observed in the field under certain conditions (Johannes et al., 1981; Suzuki, 1982; Jeffries and Semkin, 1983). On the 17th April the pack became saturated and the concentration of $\text{SO}_4^{=}$ in the pack was approximately that of the incident precipitation. Subsequent to the 19th of April the $\text{SO}_4^{=}$ concentration in the snowcover did not decline in a progressive fashion to the end of the melt but fluctuated around a mean value of $\approx 20 \mu\text{eq L}^{-1}$. The relative $\text{SO}_4^{=}$ concentrations of individual rain episodes (25 April, $36 \mu\text{eq L}^{-1}$; 3 May, $25 \mu\text{eq L}^{-1}$; 4 May, $66 \mu\text{eq L}^{-1}$; 9 May, $22 \mu\text{eq L}^{-1}$) became, during this period, the predominant factors in raising or lowering the $\text{SO}_4^{=}$ concentrations in the pack while the intermittent dry warm periods were accompanied by a lowering of $\text{SO}_4^{=}$ concentrations. This is in contrast to the effect of rain events on snowcover reported by Jeffries and Semkin (1983). The reason for the difference between the rapid decline in ionic content of the pack in 1982 recorded by these authors and the results we obtained at Laflamme Lake in 1983 is the persistent heavy rain of May 1983 which in effect hit new records for wet deposition in the region. The $\text{SO}_4^{=}$ loading deposited by the heavy rains

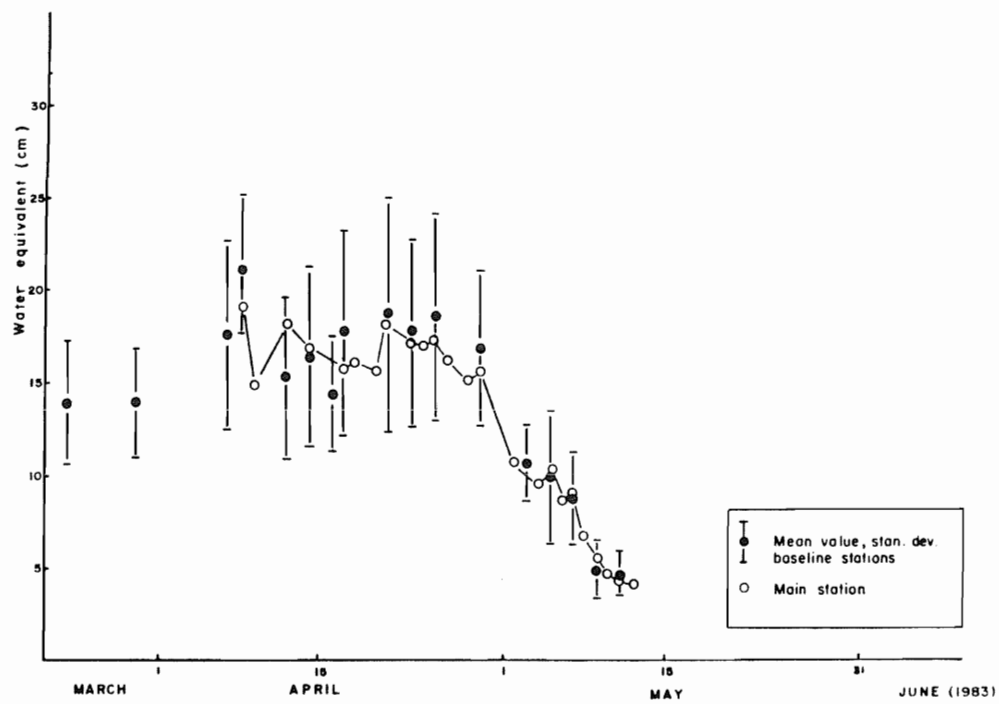


Figure 3: Water equivalent of snow cover, Laflamme Lake, late winter-spring, 1983.

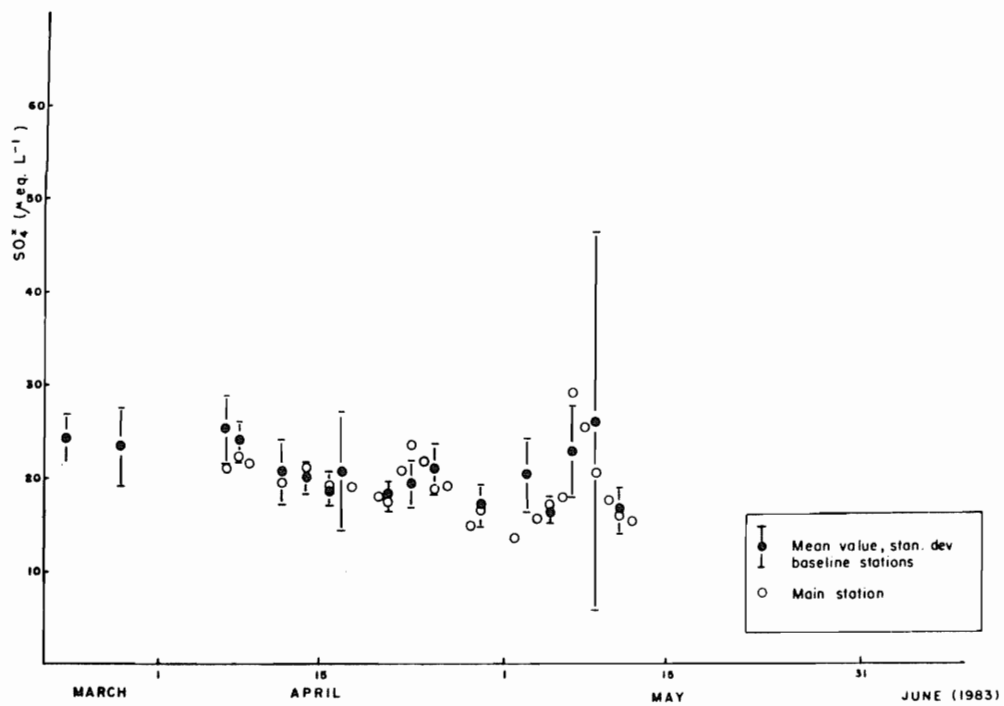


Figure 4: SO₄⁼ concentration of snow cover, Laflamme Lake, late winter-spring, 1983.

during the whole snowmelt period would, in effect, have considerably outweighed the inputs from any other source of $\text{SO}_4^{=}$ to the snowcover such as loading from dry deposition (Dovland and Eliassen, 1977; Ibrahim et al., 1983); any change in the chemical composition of snow due to this latter phenomena is thus neglected in the following discussion.

As stated above, no consistent correlation was observed between the spatial distribution of $\text{SO}_4^{=}$ concentrations and the biophysical characteristics of the sites. However, the data on samples obtained during heavy rain episodes (17, 25 April, 3, 7, 9 May) generally led to much larger standard deviations about the mean values which we associate with the heterogenous nature of water retention in, and water flow through, the snow cover (Suzuki, 1982). The nature of the forest cover at Laflamme Lake gives rise to pipeflow conditions of meltwaters during heavy discharge periods (Jones et al., 1984b).

By regrouping the $\text{SO}_4^{=}$ data for the snowcover to within two periods i.e. before snowmelt (March - 8 April) and during snowmelt (8 April - 11 May; Table 1) it can be seen that the $\text{SO}_4^{=}$ content in the stable pack represents approximately 80% of that observed in the incident precipitation. This apparent loss of $\text{SO}_4^{=}$ from stable packs has been noted by Skartveit and Gjessing (1979) and Jeffries and Snyder (1982). The preferential loss of $\text{SO}_4^{=}$ compared to NO_3^{-} (Table 1) has also been reported by Jeffries and Snyder. The reasons for such preferential losses of ions from snow are not clear but may be related to both physical (metamorphism) and microbiological activity in the snowcover (Jones et al., 1984a).

From the close relationship between H^{+} and $\text{SO}_4^{=}$ concentrations in the precipitation one would expect a similar relationship to exist in the snowcover as the forest canopy had little influence on precipitation falling directly on the sampling sites. Although the general trend of mean H^{+} concentrations in the pack (Figure 5) approximates that of $\text{SO}_4^{=}$ (Figure 4), no significant correlation was found between H^{+} and $\text{SO}_4^{=}$ for cores taken at the main sampling station ($r^2 = 0$, $n = 40$) or at the base-line stations ($r^2 = 0.06$, $n = 152$). Better, although albeit weak, correlations were found between data relating H^{+} and NO_3^{-} concentrations in the snowcover; this is similar to other studies on the chemical content of snowcover in Northeastern America (DeWalle et al., 1983). Standard deviations about the mean value for H^{+} in the snowcover (Figure 5) were generally much larger than those for $\text{SO}_4^{=}$, while the mean value of H^{+} itself in snowcover, both before and during snowmelt, is lower than would be expected from the concentrations of the strong acid anions (Table 1). These results are conciliatory with the neutralization of H^{+} in snowcover by the presence of cations distributed, however, in a heterogenous fashion throughout the pack. K^{+} is the only cation to show any significant increase in the snowcover during the snowmelt period (Table 1) but its distribution, as indicated by extremely large values of standard deviations around the mean value, is extremely heterogenous (Figure 6) during the rain episodes.

When the pack is saturated during heavy rain episodes there is a significant rise in the K^{+} concentrations of the snowcover (Figure 6). From the results of the Sangamo precipitation collectors, and our analytical procedures (i.e. filtered samples) we conclude that the potassium is solubilized on, or within, the pack. The ionic species must originate from the physical dissolution and/or the possible microbiological degradation of the canopy debris (needles, bark, twigs and epiphytic lichens) which litter the snowcover. Thus the differences between the increases or decreases in concentration with time and the spatial distributions of $\text{SO}_4^{=}$ and K^{+} may be related to their respective origins in the snow. $\text{SO}_4^{=}$ possesses a more homogeneous distribution in snow associated with its incorporation mode into ice crystals in the atmosphere. Relative concentrations with time are dependent on both general meltwater losses from the pack and the $\text{SO}_4^{=}$ concentration in rain when the pack is saturated. In contrast, K^{+} is released from organic debris which is generally of a larger size than snow grains and has been transported onto the snow by low-level turbulence in a more heterogeneous manner. As H^{+} concentrations may vary with both strong acid anions and cationic input, the behavior of H^{+} (mean values and standard deviations (Figure 5) in the snowcover is intermediate between that of $\text{SO}_4^{=}$ and that of K^{+} .

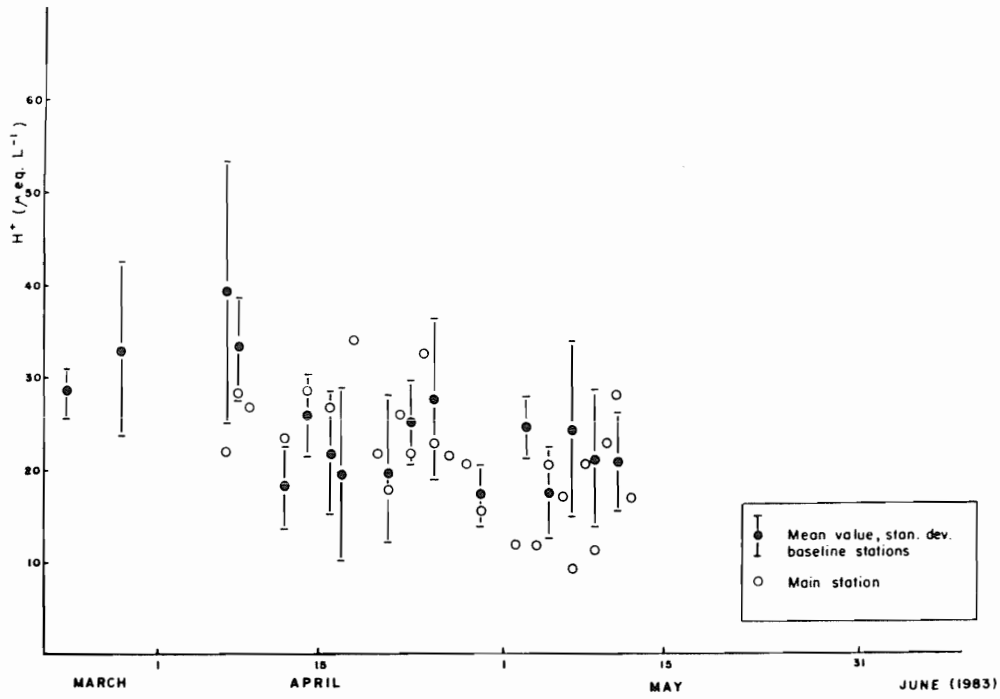


Figure 5: H^+ concentration of snow cover, Laflamme Lake, late winter-spring, 1983.

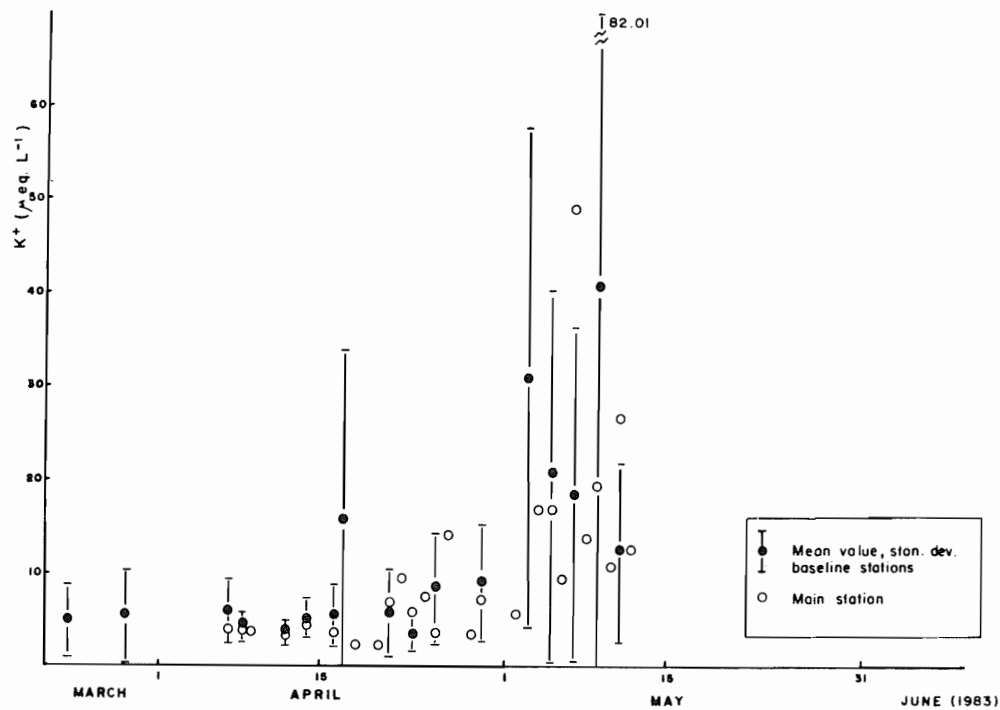


Figure 6: K^+ concentration of snow cover, Laflamme Lake, late winter-spring, 1983.

That K^+ does have some influence in reducing the acidity of the snowcover may be indicated by the weak negative correlation coefficient for data relating H^+ to K^+ concentrations for snowcores at the main sampling station ($r^2 = 0.30$; $S = 0.001$; $n = 40$). At the base-line stations however no such relationship was evident ($r^2 = 0.02$; $S = 0.05$; $n = 152$). The influence that locally transported debris (K^+ source) may exert in suppressing the acidity of snowpack in the boreal forest can be considered analogous to the same phenomena reported by DeWalle et al. (1983) on local particulate matter (Ca^{++} source) in the snowpacks of Pennsylvania.

In a solid matrix such as snow the definition of homogeneous and heterogeneous distribution of chemical constituents is fundamentally related to the volume of the samples and to the number of sources of each constituent per unit volume within the matrix. A greater number of sources per unit size should give a more significant correlation coefficients for the data relating the concentration of an ionic species between samples of differing volume than for the data relating the concentration of species which have relatively few sources per unit volume. As discussed above one should thus expect to find for concomitant samples of different volumes that atmospheric chemical constituents (H^+ , NH_4^+ , Na^+ , SO_4^{--} , NO_3^- , Cl^-) which are associated with the formation or deposition of small ice crystals will be distributed consistently throughout the snowcover in a more homogeneous fashion than locally transported constituents (K^+ , Ca^{++} , Mg^{++} , debris) associated with large particulate matter.

The mean correlation coefficients for the concentration of an ionic species in samples obtained from snowpits by square cuts and those obtained by snowcores (ratio, volume snowpit sample/volume snowcore = 7,7:1) on eight separate occasions during the snowmelt are shown in Table 2. Only H^+ , NO_3^- , SO_4^{--} and total anions showed any significant correlation between the two sampling methods. All other ions had very weak correlation coefficients and the similarity of Ca^{++} , Mg^{++} , Na^+ and Cl^- to K^+ would suggest that the major input of these particular ionic species to the snowcover may well be either local transportation direct from the source i.e. road salt or capture of air particulates by the canopy i.e. dust with subsequent distribution of organic debris onto the pack.

Snowcores taken during the melt period underestimated the water equivalent of the snowcover as determined by cuts from the snowpit by a mean value of 20% (extreme values of 0-44%). Relative mean concentrations of individual ionic species as determined by the two methods however were much closer. The snowcore underestimated $[H^+]$ mean concentration by 2% and SO_4^{--} and NO_3^- by 5% and 4% respectively. As a result the error in the estimations of total acid loading by snowcores (mean H^+ , -13%; SO_4^{--} , -21%; NO_3^- , -21%) is due more to the underestimation of the water equivalent in the snowcover rather than to that of the H^+ concentration.

The results of this survey showed how both site characteristics of the boreal forest and sampling methods (pit vs core) can influence the estimation of total chemical loading over any area as small as the Lake Laflamme watershed. On any one date the main sampling station could have overestimated or underestimated the H^+ loading as +37.3% or -57.9% respectively of the mean value for the base-line stations (all stations sampled by the snowcore method). If in addition we consider the underestimation of chemical loading (see above) in the snowcover due to the sampling procedure used (pit vs core) it becomes difficult to interpret the evolution of the calculated acid load with time at any one site. As a result, we have relied more on the values obtained from the base-line stations at a sampling frequency of approximately 2-3 days during the springmelt than on those from the main sampling station at a frequency of 1-2 days in our analysis of the snowmelt and the discharge of ionic species from the snowcover into the surface waters of Lake Laflamme.

The H^+ loading in the snowpack for 13 dates during the snowmelt period is reproduced in Figure 7; a maximum value of 5.1 meq m^{-2} was recorded on the 25 April during heavy rain. With the successive events of heavy rains concentrations of ionic species,

TABLE 2. Correlation coefficients between data relating ionic concentrations, ionic loading, conductivity and water equivalent in snowpit samples to those in snowcores, main sampling station, Lake Laflamme, spring 1983.

IONIC SPECIES	CORRELATION COEFFICIENT (r^2) SNOWCORE VS SNOWPIT (n=16)	
	CONCENTRATION	TOTAL LOADING
H ⁺	0.43*	0.50**
NH ₄ ⁺	0.50	0.72
Na ⁺	0.07	0.02
K ⁺	0.00	0.04
Mg ⁺⁺	0.02	0.17
Ca ⁺⁺	0.00	0.25
Cl ⁻	0.23	0.19
NO ₂ ⁻	0.71***	0.70***
SO ₄ ²⁻	0.42*	0.65***
Σ-ve	0.31*	0.57**
Σ+ve	0.05	0.31
Conductivity	0.48**	-
Water equivalent	-	0.57**

* significant at the 0.01 level
 ** significant at the 0.001 level
 *** significant at the 0.0001 level

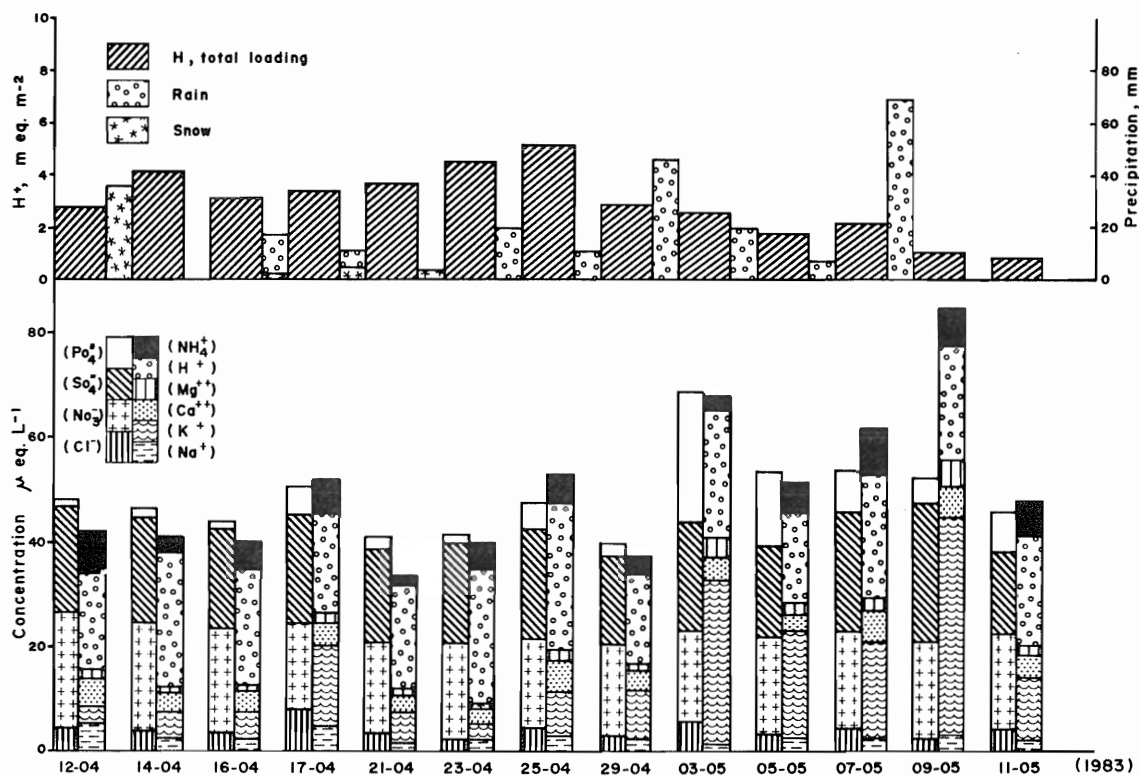


Figure 7: Precipitation, H⁺ loading and ionic composition of snowcover during the springmelt, Laflamme Lake, 1983.

particularly K^+ and PO_4^{3-} , rose sharply. The PO_4^{3-} ion which may originate from microbiological activity or animal excrement shows the same local heterogeneous distribution in the snowcover as K^+ and may, on certain dates (May 3, May 5), have compensated for the increase in K^+ . However, the overall release of soluble K^+ into the pack structure is greater than that of the PO_4^{3-} and K^+ is thought to play an important role in the suppression of H^+ in the pack at this particular time.

It is hoped that the results from these surveys and the future work at Lake Laflamme will allow us to determine criteria for the choice of representative stations for snowcover study analogous to those discussed by Barrie and Sirois (1982) or NADP (1981) for incident precipitation networks.

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