The Influence of a Dust Event on Snow Chemistry

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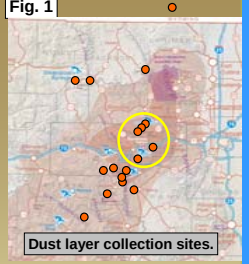
Abstract

In February 2006, windstorms in Arizona and Utah distributed a layer of dust across the surface of the snowpack throughout much of the Colorado Rockies. The 1-2 cm thick deposit formed a distinct stratigraphic layer that remained visible throughout the winter. We studied the influence of the dust event on snowpack chemistry and stratigraphy at multiple sites in northern Colorado. We quantified the dissolved inorganic constituents of snow collected in precipitation collectors during the event, of snow isolated from the dust layer and of cores that sample the dust layer within a composite of the entire snowpack. At the Fraser Experimental Forest, we compare precipitation and snow cores associated with the dust event to fifteen-year precipitation and snow core chemistry records. With the exception of H^+, ion concentrations in dust event precipitation were higher than bulk or wetfall collected before or after the event. Wetfall pH increased by three units to 8.1 during the event, and then declined to pre-event levels. The chemical composition of dust layer snow also differed markedly from snow deeper or shallower in the pack. Typical of clean Rocky Mountain snow, acid neutralizing capacity (ANC) of deep and shallow snow was negative; in contrast, dust layer ANC reached as high as 1176 μeq L^{-1}. The conductivity of dust layer snow was 3.3-fold higher than earlier or later snow on average and pH was 1.8 units higher. The chemical signature of the dust layer was evident in 1m deep cores collected in subalpine and alpine areas at Fraser. For most constituents, post-event cores differed from long-term snow chemistry, however for some anions, differences occurred only in the alpine.

Sampling & Analysis

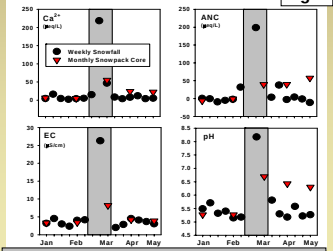
Our study examined 1) *Snow Layer*, 2) *Snowpack*, and 3) *Snowfall* samples. Snow was collected from the dust layer excavated at 17 locations across Colorado and Southern Wyoming. Monthly snowpack cores are collected across an elevation gradient (2750m, 3050m, 3350m) at the USFS Fraser Expt. Forest. We compare chemistry from the 1990 to 2005 record with cores collected during the months after the dust event. Wetfall precipitation is collected weekly at 2750 and 3230m at Fraser. February 2006 samples were compared to those collected before and after the event.

Fig. 1



Dust layer collection sites.

Fig. 2

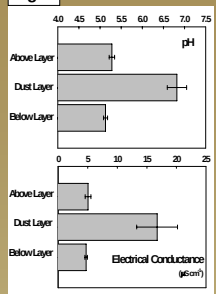


Snowfall & snowpack chemistry at Fraser. The gray bar denotes the dust event.

Thawed, filtered snow samples were analyzed by ion chromatography (Waters Ion Chromatographs with a Dionex AS12 A Separator Anion Column and Waters IC Pak Cation M/D Column). Acid neutralizing capacity (ANC) was measured by Gran titration and pH and conductivity were analyzed with PC Titrate sensors (Man-Tech Co.) on unfiltered samples.

Dust Layer Chemistry

Fig. 3

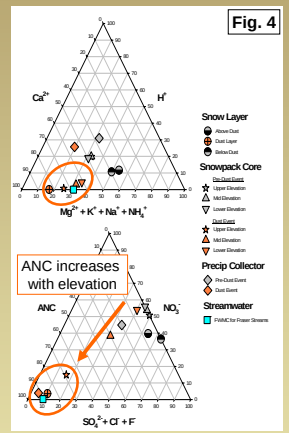


Chemical composition of snow layers sampled at 17 sites across the Colorado and southern Wyoming Rocky Mountains.
Constituent concentrations (μeq / L) were analyzed for the dust layer and samples collected ≥ 20 cm above and below the layer.

Cations	Layer	Mean	Std Dev	Min	Max
H^+	Above	3.06	2.38	0.41	8.71
	Dust	0.21	0.39	0.01	1.32
	Below	4.04	3.11	0.39	10.00
Ca^{2+}	Above	9.05	7.52	2.14	29.72
	Dust	365.13	324.89	3.14	1138.42
	Below	15.02	25.29	1.70	116.91
Mg^{2+}	Above	1.88	1.49	0.52	6.67
	Dust	30.19	26.25	1.44	119.65
	Below	3.06	4.89	0.44	21.84
Na^+	Above	6.69	5.65	1.01	18.00
	Dust	32.48	26.06	3.60	139.22
	Below	10.83	12.99	1.14	47.63
K^+	Above	2.46	2.21	0.05	7.16
	Dust	7.27	6.13	0.48	24.19
	Below	2.00	1.64	0.50	7.45
NH_4^+	Above	3.10	1.47	0.03	5.38
	Dust	4.12	4.06	0.00	15.22
	Below	3.04	1.74	0.10	7.28

Anions	Layer	Mean	Std Dev	Min	Max
ANC	Above	1.15	12.80	-33.23	21.06
	Dust	351.52	361.92	4.12	1176.22
	Below	-0.86	13.16	-15.05	38.27
SO_4^{2-}	Above	4.21	3.01	0.07	12.14
	Dust	30.24	25.94	0.58	86.16
	Below	4.83	3.52	0.83	17.20
NO_3^-	Above	7.37	4.52	0.10	17.02
	Dust	14.58	9.98	0.56	30.53
	Below	7.59	3.64	1.01	15.39
Cl^-	Above	5.63	4.23	0.11	17.36
	Dust	11.78	11.60	2.21	46.98
	Below	8.22	10.79	1.07	41.88
F^-	Above	0.17	0.36	0.00	1.55
	Dust	0.48	1.01	0.05	5.61
	Below	0.20	0.41	0.00	1.72

Fig. 4



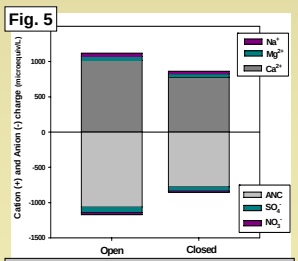
Percent total μeq/L for anions & cations.

Dust layer ion concentrations exceeded the mean (and in most cases the maximum) ion concentrations of snow collected above and below the dust layer. Ca^{2+} and ANC (largely HCO_3^-) increased by 10^2. Mg^{2+} increased 7-fold and the concentrations of most other ions doubled. The hydrogen ion concentration declined by about 10^{-1}, equivalent to a 1.5 pH unit increase. Electrical conductance of dust snow was 10^1 higher than the other layers; that indicator of ionic strength paralleled the 14- and 22-fold greater sums of cation and anion charge in dust layer snow.

The snow below the dust layer had higher ionic concentration than that collected above the layer, indicating downward elution through the snowpack.

The high Ca^{2+} and HCO_3^- concentrations of the aeolian deposit dominated the charge balance of dust layer snow. These compounds represented more than 80% of ionic composition of dust layer snow, similar to the Ca^{2+}/Bicarbonate type streamwater typical of the Fraser Expt. Forest and the Upper Colorado River basin. In contrast, in non-dust snow ANC contributes no anion charge and Ca^{2+} represents 30-50% of the cation charge.

Fig. 5



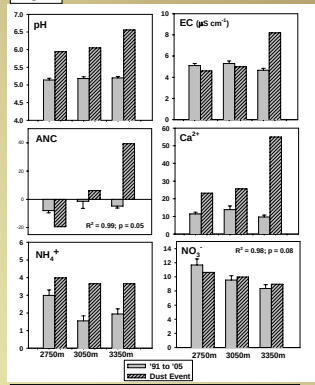
Dust layer sampled in a regenerating clear cut and adjacent closed-canopy forest at Fraser Expt. For.

Forest Canopy Influence

Dust layer snow collected in open forest had significantly higher ANC, Ca^{2+}, Na^+, SO_4^- and NO_3^- concentrations ($\alpha = 0.05$), and higher total anion and cations than adjacent closed-canopy forest ($n = 3$ subsamples per site). Averaged across snow layer sample sites, EC, NO_3^- and H^+ concentrations in non-dust snow were higher below forest canopy ($\alpha \leq 0.1$); there was no general canopy effect on dust layer snow.

Elevation Gradients

Fig. 6



Fraser long-term snowpack vs dust-event chemistry.

Concentrations of several individual ions and the sums of cations and anions were higher at the upper elevation snowpack collection site (Fig 6). ANC increased and NO_3^- decreased linearly across the sites (Fig 4 and 6). Nitrate concentrations also declined linearly with the elevation of the dust layer sample sites ($R^2 = 0.28$; $p = 0.004$).

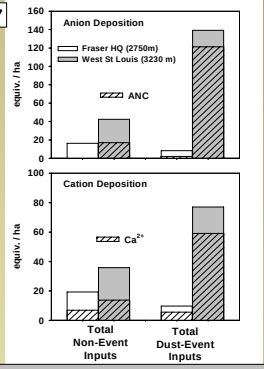
At the upper Fraser snowfall collection site, the ion load received during the dust event was more than twice that deposited during twelve weeks of non-event precipitation (Fig. 7). At the lower elevation site, total anion and cation inputs during the dust event did not surpass those received during the balance of the snowfall season.

Regional Patterns

Ion concentrations in the dust layer were elevated relative to surrounding snow at sites from central Colorado to the Wyoming border (Fig 1). At the most northerly sites for example, dust layer pH was 1.4 units higher, EC was 5-fold higher, and so on.

Dust layer EC, Ca^{2+}, ANC and SO_4^- concentrations and the sums of cations and anions were significantly higher ($p < 0.05$) in the central portion of the dust regional (see yellow circled area in Fig. 1) compared to either the northern or southern extent of the area receiving dust.

Fig. 7



Snowfall ion load at Fraser wetfall precipitation collectors.

Key Points

- The dust event affected snow chemistry at all sample sites.
- The 1-3cm dust layer altered the chemistry of entire 1-2m snowpack cores; the degree of these changes is unprecedented in the 15-yr Fraser snowpack chemistry record.
- ANC & Ca^{2+} were elevated most dramatically; the ionic composition of dust layer snow was comparable to streamwater.
- Anion & cation deposition during the event exceeded total winter ion loads at an upper elevation site. Lower sites were affected less by the dust event.
- At one paired site, dense forest canopy reduced concentrations of most ions relative to an adjacent open forest.

Acknowledgement

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