Carbon Observations from Cloud Water at Whiteface Mountain New York

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This poster presents observations from the 1994-2010 Whiteface Mountain New York cloud water sampling seasons. The purpose is to understand the relationship of carbon to the ion balance calculation currently used on cloud water samples.

Since 1994 approximately 14% of the clouds collected at Whiteface Mountain fail the established ion balance test. Further, the vast majority of these imbalanced samples are shown to be anion deficient. This ion imbalance may originate from unmeasured organic ions coming from organic acids [*Dukett et. al,* 2011 and *Khwaja et. al.* 1995]. *Inorganic* ions, in relation to acidic deposition, have been thoroughly reported from Whiteface cloud water samples for over 30 years. *Organic* species have also been reported in Whiteface cloud water samples [*Sagona et. al,* 2010], however; the depth of analysis is significantly less in comparison to inorganic ions. As with inorganic acids, organic acids may originate from natural and/or anthropogenic sources.

In 2010, total organic carbon (TOC) analysis was added to a subset of the cloud water samples collected. TOC concentrations determined for 92 samples were observed in the range 0.5-27.9 mg L⁻¹.

Methods

Cloud water is collected from June 1st to September 30th from the roof of the Whiteface Mountain summit observatory building operated and maintained by the SUNY Albany Atmospheric Sciences Research Center. Samples are brought to the Adirondack Lakes Survey Corporation (ALSC) laboratory in Ray Brook for chemical analysis. Meteorological data is down loaded daily at ALSC headquarters in Ray Brook.

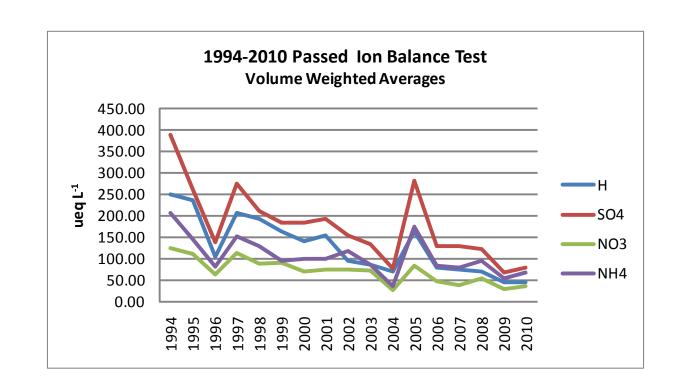
Analysis

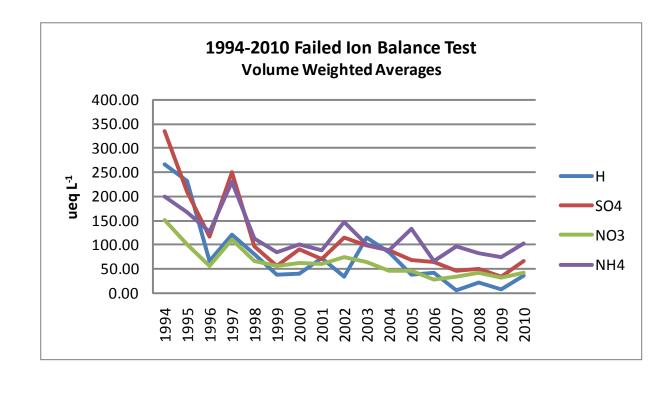
Samples fail the ion balance test [Baumgardner et al., 2003] if either of the following conditions were met:

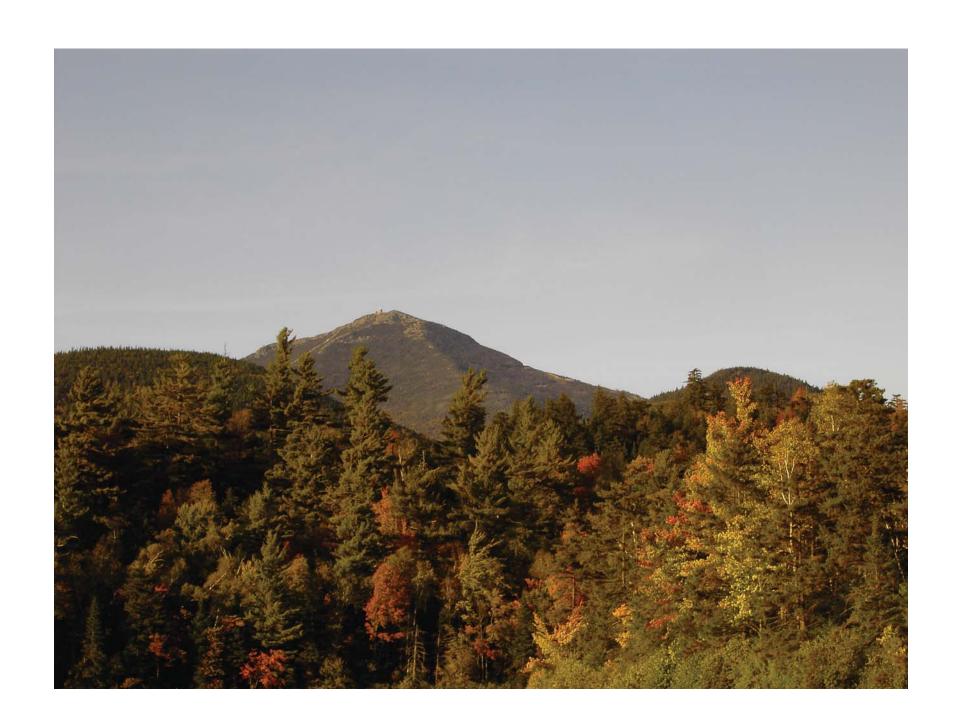
Both the anion and cation sum were $\leq 100 \,\mu\text{eq} \,L^{-1}$ and |RPD| > 100%;

Either the anion sum or the cation sum was $>100~\mu eq~L^{-1}$ and |RPD|>25%

Where relative percent difference, RPD = 100 * (cations - anions) / [(cations + anions) / 2] (3)







This work is made possible from the contributions of:











Conclusions/Results

1994-2010 Cloud water samples

Passed Ion Balance Test ¹							
	n	рН	H+ µeq L-1	SO ₄ ²⁻ µeq L ⁻¹	$NO_3^- \mu eq L^{-1}$	NH ₄ + µeq L-1	
1994-2010	4492	3.95	110.96	153.18	62.23	89.59	

¹volume weighted averages

Failed Ion Balance Test ¹							
n	рН	H⁺ µeq L⁻¹	SO ₄ ²⁻ µeq L ⁻¹	NO ₃ - µeq L-1	NH ₄ + µeq L-1		
1994-2010 712	4.06	87.20	108.47	61.28	116.81		
¹ volume weighted averages							

2010 Cloud water samples with TOC analysis

	Pass						
	n	рН	H+ µeq L-1	SO ₄ ² · µeq L ⁻¹	NO ₃ - µeq L-1	NH ₄ + µeq L-1	TOC mg L-1
2010	83	4.34	45.77	81.67	33.86	65.72	3.52
¹ volume weighted av	erages						
			.				

Failed Ion Balance Test 1,2							
n	рН	H+ µeq L-1	SO ₄ ²⁻ µeq L ⁻¹	NO ₃ - µeq L ⁻¹	NH ₄ + µeq L-1	TOC mg L ⁻¹	
2010 9	4.28	52.32	83.12	42.18	138.25	6.55	
¹ volume weighted averages² All 9 are anion deficient	5						

² All 9 are anion deficient

(1)

- Samples analyzed 1994-2010 (n = 4492), which pass the ion balance test, are on average highest in $[SO_4^{\ 2} \mu eq \ L^{-1}]$.
- Samples analyzed 1994-2010 (n = 712), which fail the ion balance test, are on average highest in $[NH_4^+ \mu eq \ L^{-1}]$.
- 90% of the samples that fail the ion balance test are anion deficient.
- For 2010 samples, higher TOC did not equally translate into failing ion balance. For example, the sample with the highest reported TOC (27.9 mg L⁻¹) also passed the ion balance test, however;
- Relative to $[SO_4^{-2} \mu eq L^{-1}]$, 2010 samples that fail the ion balance are on average both higher in $[NH_4^+ \mu eq L^{-1}]$ and $[TOC \ mg \ L^{-1}]$.

Discussion

Analysis of cloud water from Whiteface Mountain has primarily focused on major inorganic ions [Dukett et. al, 2011]. Our findings show that there are ion imbalances and we suggest that these may be caused by emission sources, and subsequently chemical parameters we are not completely monitoring. Based on our 2010 results, we also find measurable amounts of total organic carbon in cloud water. We suggest that emission sources, which cause NH₄⁺ and TOC to increase significantly in concentration, relative to SO_4^{2-} , are causing an ion imbalance. Further, this suggests that SO₂ sources may have a secondary role in regards to the ion balance for some cloud events that pass over Whiteface Mountain. Therefore, as anthropogenic SO₂ emission sources continue to decline, anthropogenic/ natural sources of carbon may play a larger role in defining the chemical make-up of cloud water in high elevation areas. Finally, quantifying carbon species concentrations in clouds may help improve the level of scientific understanding associated with the role clouds play as a climate driver [The National Academies. 2008 Edition].



References

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