Carbon Observations from Cloud Water at Whiteface Mountain New York

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Introduction
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 [Duckett 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 Piscataway, N.J. in Ray Brook. 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 ≤100 μeq L⁻¹ and |RPD| > 100% ;
- Either the anion sum or the cation sum was >100 μeq L⁻¹ and |RPD| > 25% ;
- Where relative percent difference, RPD = 100 * (cations - anions) / [(cations + anions) / 2].

Conclusions/Results
1994-2010 Cloud water samples

Passed Ion Balance Test

<table>
<thead>
<tr>
<th>n</th>
<th>H⁺ μeq L⁻¹</th>
<th>SO₄²⁻ μeq L⁻¹</th>
<th>NO₃⁻ μeq L⁻¹</th>
<th>NH₄⁺ μeq L⁻¹</th>
<th>TOC mg L⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994-2010</td>
<td>4492</td>
<td>3.95</td>
<td>110.96</td>
<td>153.18</td>
<td>62.23</td>
</tr>
</tbody>
</table>

*volume weighted averages

Failed Ion Balance Test

<table>
<thead>
<tr>
<th>n</th>
<th>H⁺ μeq L⁻¹</th>
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<th>NH₄⁺ μeq L⁻¹</th>
<th>TOC mg L⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994-2010</td>
<td>172</td>
<td>4.06</td>
<td>51.29</td>
<td>108.94</td>
<td>61.28</td>
</tr>
</tbody>
</table>

*volume weighted averages

2010 Cloud water samples with TOC analysis

Passed Ion Balance Test

<table>
<thead>
<tr>
<th>n</th>
<th>H⁺ μeq L⁻¹</th>
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<th>NH₄⁺ μeq L⁻¹</th>
<th>TOC mg L⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>83</td>
<td>4.34</td>
<td>47.71</td>
<td>87.20</td>
<td>36.67</td>
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*volume weighted averages

Failed Ion Balance Test

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<tr>
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<th>TOC mg L⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>9</td>
<td>4.28</td>
<td>52.32</td>
<td>83.12</td>
<td>42.18</td>
</tr>
</tbody>
</table>

*volume weighted averages

Discussion
Analysis of cloud water from Whiteface Mountain has primarily focused on major inorganic ions [Duckett 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 SO₄²⁻, are causing an ion imbalance. Further, this suggests that SO₄ sources may have a secondary role in regards to the ion balance for some cloud events that pass over Whiteface Mountain. Therefore, an anthropogenic SO₄ 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


This work is made possible from the contributions of: