Recent Cloud Chemistry Measurements at Whiteface Mountain, NY

Nenad Aleksic, Karen Roy and Gopal Sistla, New York State Department of Environmental Conservation, Albany NY 12233
James Dukett, Nathan Houck and Paul Casson, Adirondack Lakes Survey Corporation, Ray Brook NY 12977

Abstract

Cloud water deposition is thought to be one of the principal causes of the forest decline at elevations between 800 meters and tree line. In recent years, many cloud water studies have been undertaken to study it. A routine cloud water chemistry measurement program operational during the summer season was established in 1994 under the auspices of the Mountain Acid Deposition Program (MADPro) at the summit of Whiteface Mountain located in the northeastern quadrant of the Adirondack Park at an elevation of 1483 meters. Even though the MADPro monitoring program was terminated in 2000, the cloud chemistry program was continued utilizing the same equipment and measurement procedures by the Adirondacks Lakes Survey Corporation (ALSC). In this presentation we summarize the objectives, methods, cloud water chemistry and conclusions of cloud water monitoring at Whiteface Mountain, New York conducted June - September from 1994 to 2003.

Cloudwater ion concentrations are dominated by sulfate (SO_4^{2-}) and nitrate (NO_3^-) in the anion category, while hydrogen (H^+) and ammonium (NH_4^+) dominate cations. Concentrations are found to be considerably higher in the cloud samples than in rain. While analysis of individual cloud events shows considerable variability between events, on an overall basis the cloud chemistry data shows a decrease in the concentration levels of the measured ions with time.

References

Anderson, J.B., R.E. Baumgardner, V A. Mohnen and J.J. Bowser, 1999: Cloud chemistry in eastern United States, as sampled from three high-elevation sites along the Appalachian Mountains. Atmospheric Environment, 33, 5105-5114

Baumgardner, R., S. Isil, T.F. Lavery, C.M. Rogers, and V.A. Mohnen, 2003:Estimates of Cloud Water Deposition at Mountain Acid Deposition Program Sites in the Appalachian Mountains. J. Air. & Waste Manage. Assoc., 53, 291-308

Isil, S., V. Mohnen, G. Lovett, E. Miller, J. Anderson, T.F. Lavery and R. Baumgardner, 2000: Mountain Acid Deposition Program (MADPro): Cloud Deposition to the Appalachian Mountains, 1994-1999. Report EPA/600/R-01/016. U.S. Environmental Protection Agency (EPA), Office of Research and Development, Washington, D.C.

1. Continue the work started in1994 by MADPro.
2. Discuss and summarize cloud frequency and liquid water content.
3. Analyze major and minor ions from within the cloud water matrix.
4. Analyze cloud water in comparison to rainwater.
5. Examine the variability between the chemistry of individual cloud events.
6. Examine for trends as associated with cloud water ions and pH.

Methods

Cloud water is collected from the collector shown to the right. The apparatus sits atop the roof of the summit observatory building. Clouds that pass through the sensors are collected when the following criteria are established:

1. A heated grid rain sensor confirms no rain is present;
2. A Gerber Continuous Particle Volume Monitor(PVM) detects cloud with a liquid water content (LWC) value equal or greater than 0.05 g/m3;
3. The temperature is 2 degrees Celsius or greater; and
4. The wind speed is 2 meters/second or greater.

Rain water is sampled at 600m near the base of Whiteface Mountain as part of NYSDEC's Acid Deposition Monitoring Network.

Cloud Water Chemistry

Ion concentrations can differ significantly from one cloud event to another. Figure 1 illustrates this for the hydrogen ion. Cloud observations are considered to be from the same event if they were within 90 min of each other.

Cloud water is found to be much more acidic than the rainwater. Figure 2 shows the comparison of average July pH for both rainwater and cloudwater samples.

Major ions (H^+, SO_4^{2-}, NO_3^-, NH^{4+}) on average contribute 92.8 percent [Figure 3] of the total ions present when compared with minor ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, NO_2^-) [Figure 4].

Figures 5 and 6 show a decreasing trend in conductivity and an increase in pH from 1994-2003.

Year to year changes of cloud frequency do not have any particular pattern, but Liquid Water Content (LWC) appears to have decreased [Figure 7].

Figure 1. H+ Concentrations for All Cloud Events by Year

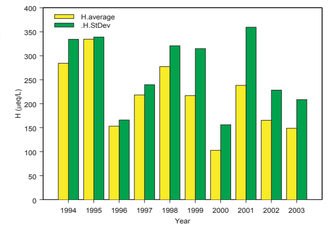


Figure 2. Comparison of Average July pH for Rain and Cloud water

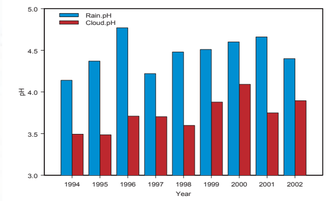


Figure 3. Average Major Ion Concentrations 1994 - 2003

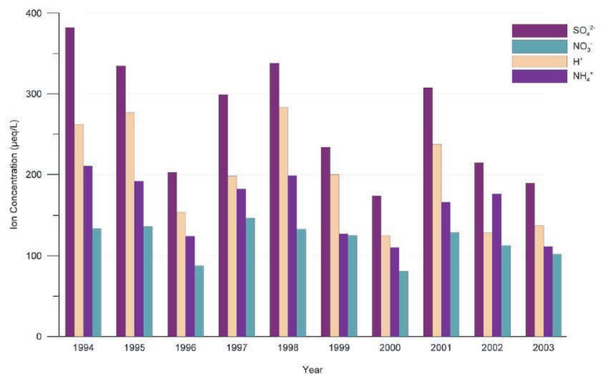


Figure 4. Average Minor Ion Concentrations 1994 - 2003

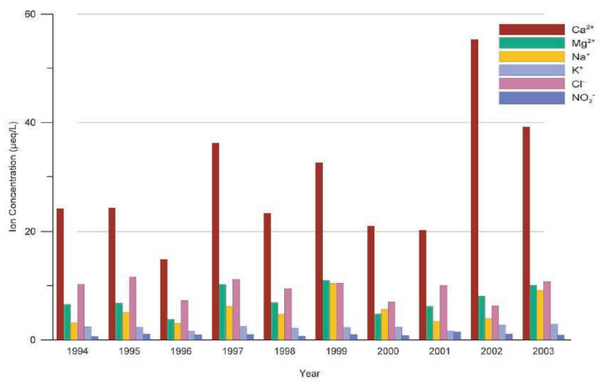


Figure 5. Cloudwater Conductivity 1994-2003.

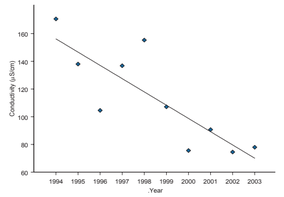


Figure 6. Cloudwater pH 1994-2003.

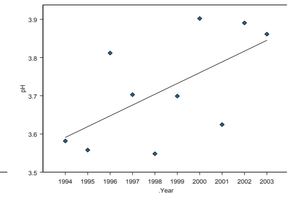
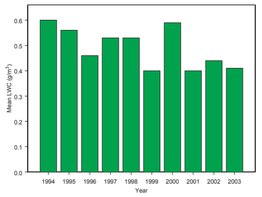


Figure 7. Cloudwater LWC 1994-2003



Conclusions

- Cloud water ion concentrations are dominated by hydrogen, sulfate, nitrate and ammonium.
- There is considerable variability between chemistry of individual cloud events.
- Recent observations appear to show a decrease in liquid water content, a downward trend in ion concentrations and an increase in cloud water pH.
- Cloud water is more acidic than the rainwater.
- Acid deposition from non-precipitating cloud water greatly exceeds rain deposition during summer months. For example, July 2001 observations for sulfate show cloud water deposition is 24.9 kg/ha versus 0.63 kg/ha for that of rain water. Likewise, nitrate cloud water deposition for the same period was 10.9 kg/ha compared to 0.38 kg/ha for rain water deposition. Cloud water observations are converted to depositions using Lovett model (Atmos. Environ.,1984, 361-371)

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