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A comparison of fine particle and aerosol strong acidity at the interface zone (1540 m) and within (452 m) the planetary boundary layer of the Great Gulf and Presidential-Dry River Class I Wildernesses on the Presidential Range, New Hampshire USA

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ABSTRACT

Mount Washington, NH in the White Mountain National Forest, is flanked to the north-northeast and south by two Class I Wilderness areas, the Great Gulf and Presidential Range-Dry River Wildernesses, respectively. The Clean Air Act protects Class I Area natural resource values from air pollution. Aerosol sulfate, a fine particulate component that is often transported long distances, is a known contributor to visibility degradation and acidic deposition. We examined summertime fine particulate aerosol mass and sulfate, strong acidity and ammonium concentrations from 1988 to 2007 on Mount Washington at two elevations, 452 and 1540 m (msl). The former site is often within, and the latter at the interface of, the planetary boundary layer. Comparisons of sampling interval durations (10 and 24 h) and site vs. site are made. We also examine the extent to which aerosol sulfate is neutralized.

Ten hour (daytime) compared to 24 h samples have higher mass and aerosol sulfate concentrations, however paired samples are well correlated. Fine mass concentrations compared between the 452 m and 1540 m sites (standard temperature and pressure corrected) show a weak positive linear relationship with the later being approximately 32% lower. We attribute the lack of a strong correlation to the facts that the 1540 m site is commonly at the interface of and even above the regional planetary boundary layer in summer and that it can intercept different air masses relative to the 452 m site. Sulfate is ~18% lower at the higher elevation site, but comprises a greater percentage of total fine mass; 42% compared to 37% for the high and low elevation site, respectively. Aerosol strong acidity was found to increase with increasing sulfate concentrations at both sites. Further the ratio of hydrogen to sulfate ion was greater in 24 h than 10 h samples at the higher elevation site likely due to overnight transport of fresh acidic aerosols.

1. Introduction

In the 1977 amendments to the Clean Air Act (CAA), the US Congress designated existing National Parks greater than 6000 acres and federal Wilderness and wildlife refuge lands greater than 5000 acres as "Class I Areas" (Section 162 (a)) and provided protections against degradation of air quality under the Prevention of Significant Deterioration (PSD) provisions. The PSD program has a permit process for major new and modified emission sources to determine if they will cause an "adverse impact" on the Air Quality Related Values (AQRVs) of Class I Areas. Those values are established by the federal land manager and can include scenic, cultural, biological, and recreational resources. Visibility, an AQRV, was also singled out by Congress not only to prevent future degradation through the PSD program but to improve conditions back to natural conditions.

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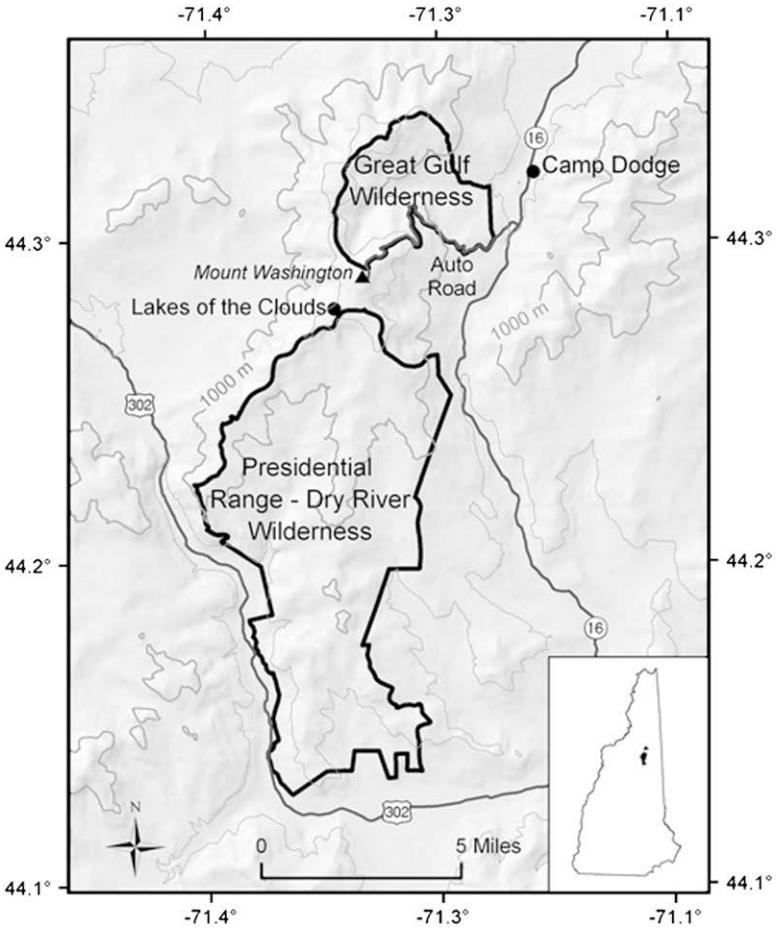

Fig. 1. Location of the aerosol $PM_{2.5}$ and chemistry sample sites and NH Class I Areas.

The Great Gulf (2247 ha) and Presidential Range-Dry River (8094 ha[1]) Wildernesses (Fig. 1) on the Presidential Range, NH in the White Mountain National Forest (WMNF) are such designated Class I Areas. The AQRVs for these areas include visibility, vegetation health, and water and soil chemistry as it relates to watershed health. The WMNF is one of the most visited of federal lands in the US, seeing more than 6 million visitors annually. The Great Gulf and Presidential Range-Dry River Wildernesses also comprise part of the largest alpine ecosystem in the eastern US (Kimball and Weihrauch, 2000).

Suspended fine particulates, $\leq$2.5 μm in size ($PM_{2.5}$), cause visibility degradation by absorbing and scattering light (Malm et al., 2004). Additionally, they are a regulated air pollutant under the National Ambient Air Quality Standards (NAAQS) provisions of the CAA (Section 109) for human health and welfare protections. Adverse human health effects of $PM_{2.5}$ include difficulty breathing, decreased lung function, aggravated asthma and even premature death in people with heart or lung disease (EPA, 2005). Ozone, $PM_{2.5}$ and strong aerosol acidity exposure were associated with declines in lung function in vigorously exercising hikers in a study on the Presidential Range (Korrick et al., 1998). Korrick et al. (1998) found that the effects of $PM_{2.5}$ and strong aerosol acidity persisted after adjustment for ozone and were of the same magnitude as the ozone related impacts. $PM_{2.5}$, when deposited on vegetation and other surfaces, contributes to acid loading of ecosystems, resulting in loss of important nutrients and mobilization of toxins such as aluminum (Driscoll et al., 2001).

Interagency Monitoring of Protected Visual Environments (IMPROVE) compliance monitoring for visibility protections in Class I Areas in the northeast occurs at lower elevations well within the planetary boundary layer (BL), due to sampling and electrical power infrastructure needs. Unlike the four other designated Class I Areas in the northeastern US, the Great Gulf and Presidential Range-Dry River Wilderness areas occupy much higher topography, from 268 to 1770 m, putting them within and above the regional BL. Summer mixed-layer height of the atmosphere in the northeast typically ranges from 1100 to 1500 m (Freedman et al., 2001). Our monitoring program for $PM_{2.5}$ using the MST Area Sampler[2] (herein referred to as the "Harvard Impactor") at two elevations, which bracket the elevational range of the NH Wilderness areas was initiated in 1988. An IMPROVE sampler was co-located at our low elevation site in 1995 however comparison with this sampler is not the subject of this paper and will be examined elsewhere.

It has been well established using airborne observations that air pollutant concentrations can differ with altitude and that above vs. within the BL air masses can have different origins, composition and chemistry (Tanner et al., 1984; Taubman et al., 2004a; Peltier et al., 2007). However, little long-term work has been done at

[1] Presidential Range-Dry River Wilderness area was expanded in 1984–11,080 ha but the new additional area is designated Class II.

[2] Specification by manufacturer: http://www.airdiagnostics.com/indoor_samp_equip.html.