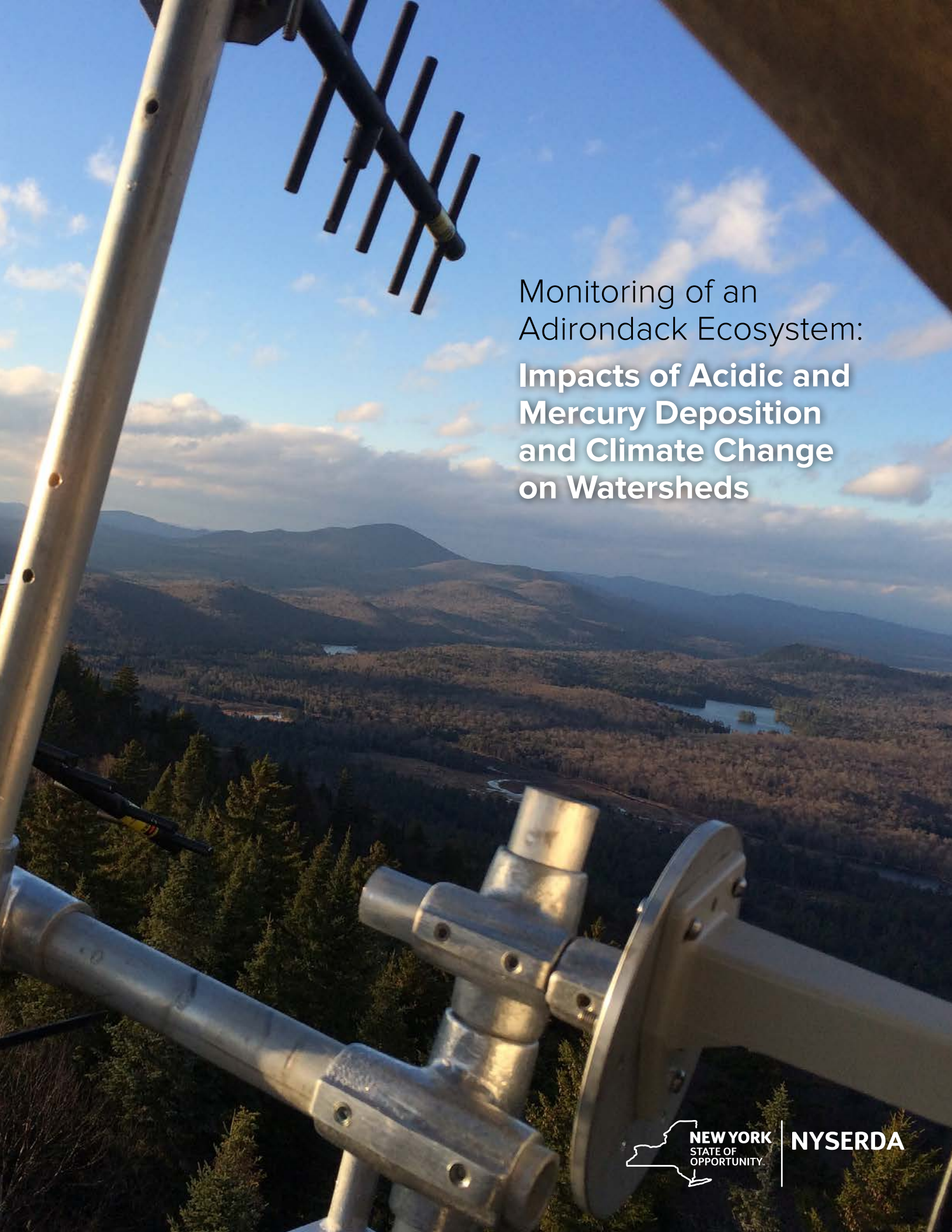

Monitoring of an Adirondack Ecosystem:

Impacts of Acidic and Mercury Deposition and Climate Change on Watersheds

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Cover photograph: View of Arbutus Lake watershed from Goodnow Mountain. Credit: Patrick McHale

Monitoring Brief

EMEP Program Agreement 31250

Monitoring of an Adirondack Ecosystems:
Impacts of Acidic and Mercury Deposition and Climate Change on Watersheds

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Tower at Arbutus Lake Inlet (Archer Creek)
Credit: Patrick McHale

BACKGROUND

Considerable attention has been focused on the Adirondack region or New York State over the past three decades due to the relatively high rates of atmospheric deposition coupled with the associated effects on soil and water quality in the region. For sulfate and nitrate deposition, there have been marked decreases associated with air quality management programs and the recent improvements of terrestrial and aquatic ecosystems. Despite decreases in acid deposition there has been persistent concern about the long-term depletion of available nutrient cations, such as calcium in Adirondack soils, which have been directly linked with forest health of major tree species including sugar maple.

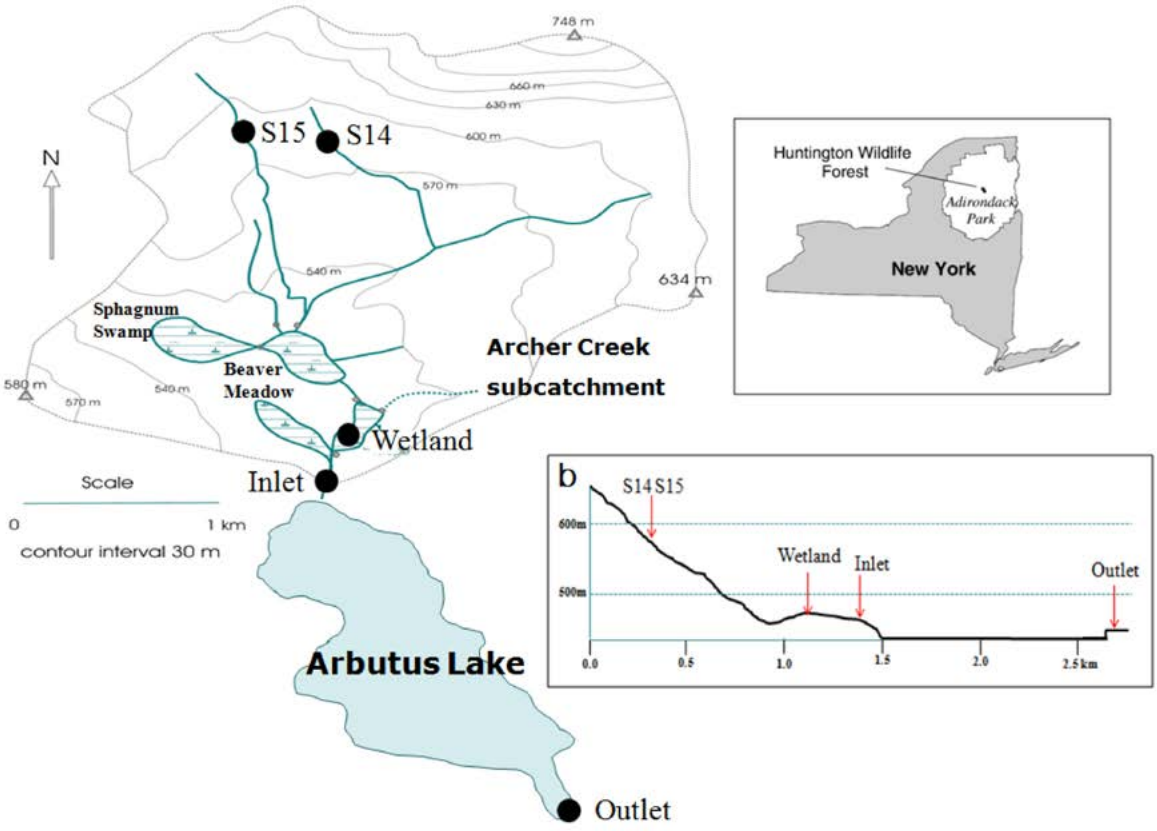
Another aspect of ecosystem effects of air pollution is contamination by atmospheric mercury deposition and subsequent transport of mercury through ecosystems and bioaccumulation of methyl mercury in both aquatic and terrestrial animals. The long-term effects of atmospheric pollutants are concomitantly being influenced by changes in temperature and precipitation that will affect pollutant and nutrient fluxes in forest ecosystems.

A better understanding of how climatic and atmospheric deposition influence ecosystems would aid in understanding the implications of policy on the environment.

MONITORING ACTIVITIES

The current project at the Huntington Forest (HF)/Arbutus Watershed builds on past studies and monitoring at this site and complements other monitoring activities by providing intensive monitoring to better understand the linkages between deposition and ecological effects. The HF/Arbutus Watershed is located in the central Adirondack region of New York State (Figure 1). A wide range of environmental parameters related to air pollutants and climate change are being measured in forested watersheds, with records extending back to the mid-1940s. The current effort is supported by NYSERDA and includes the analytical costs to the National Atmospheric Deposition Program (NADP) for the national trends network (NTN) site at the Huntington Forest (NY20) established in 1978 (one of the oldest NADP/NTN sites), wet-only Mercury Deposition Network (MDN), Litterfall Mercury Monitoring Initiative, the Atmospheric Mercury Network (AMNET), the Passive Ammonia Monitoring network (AMoN) and EPA supported Clean Air Status and Trends network (CASTNET). In addition to this intensive air quality monitoring effort, there is an extensive meteorological, hydrological, and water chemistry collection program that includes the outlet of Arbutus Lake, the major inlet (Archer Creek) of Arbutus Lake, two sub-catchments in the upper reaches of Archer Creek, and a series of ground water wells. This monitoring system (http://www.esf.edu/hss/em/huntington/index.html) provides real-time data on both hydrological and meteorological measurements that are connected via radio transmission to the Internet and are publically available. This intensive monitoring effort at the Huntington Forest is unique to the Adirondacks and serves as an important reference to some of the more extensive monitoring activities in the Adirondacks including the Adirondack Long-Term Lake Monitoring (ALTM) project that began monthly monitoring of water chemistry in 1982 for 17 lakes in the Adirondacks including Arbutus Lake. The project was subsequently expanded to 52 lakes in 1992.

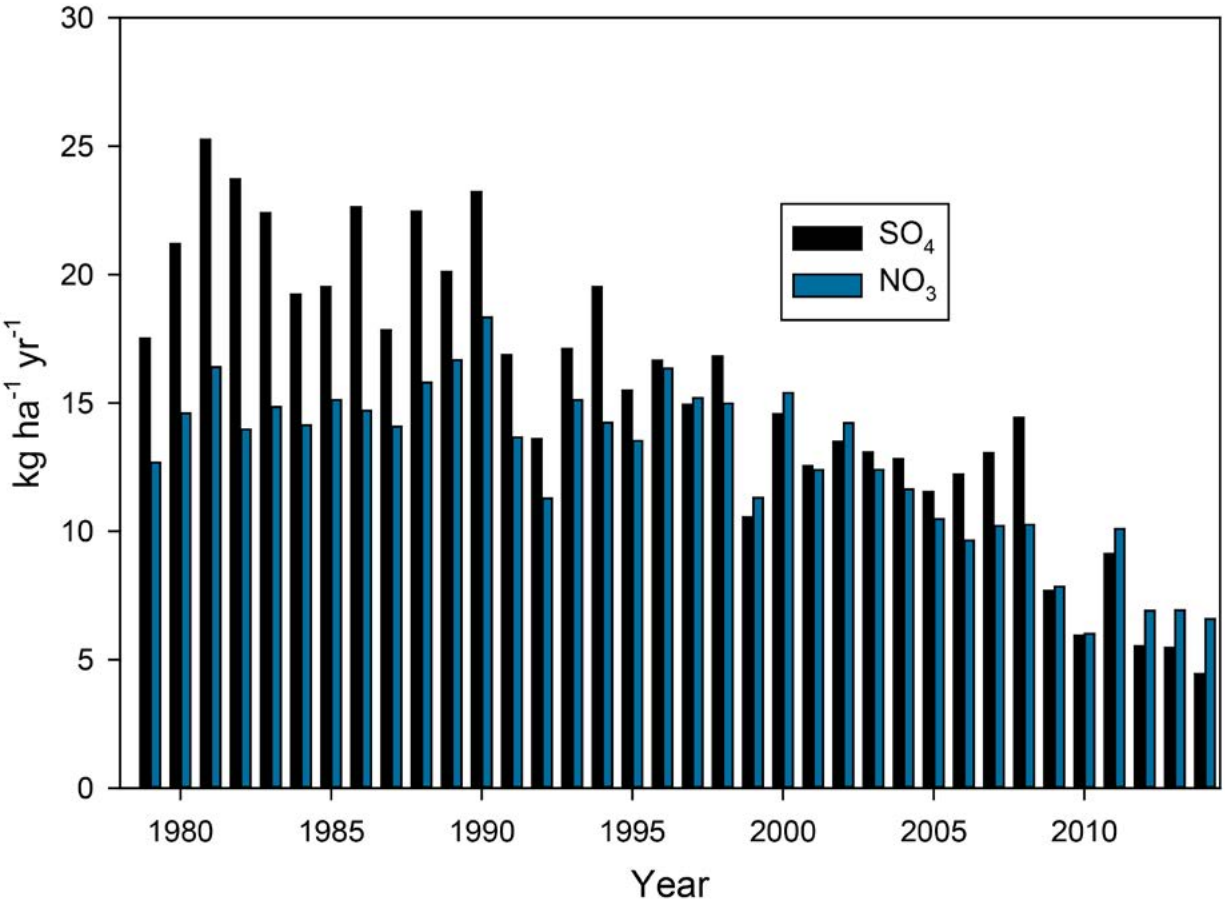
Figure 1. Location of Huntington Forest in the Adirondack Park of New York State and Arbutus Watershed showing surface water sampling locations (From Kang and Mitchell, 2013)



V-notch weir at sub-catchment 14
Credit: Patrick McHale

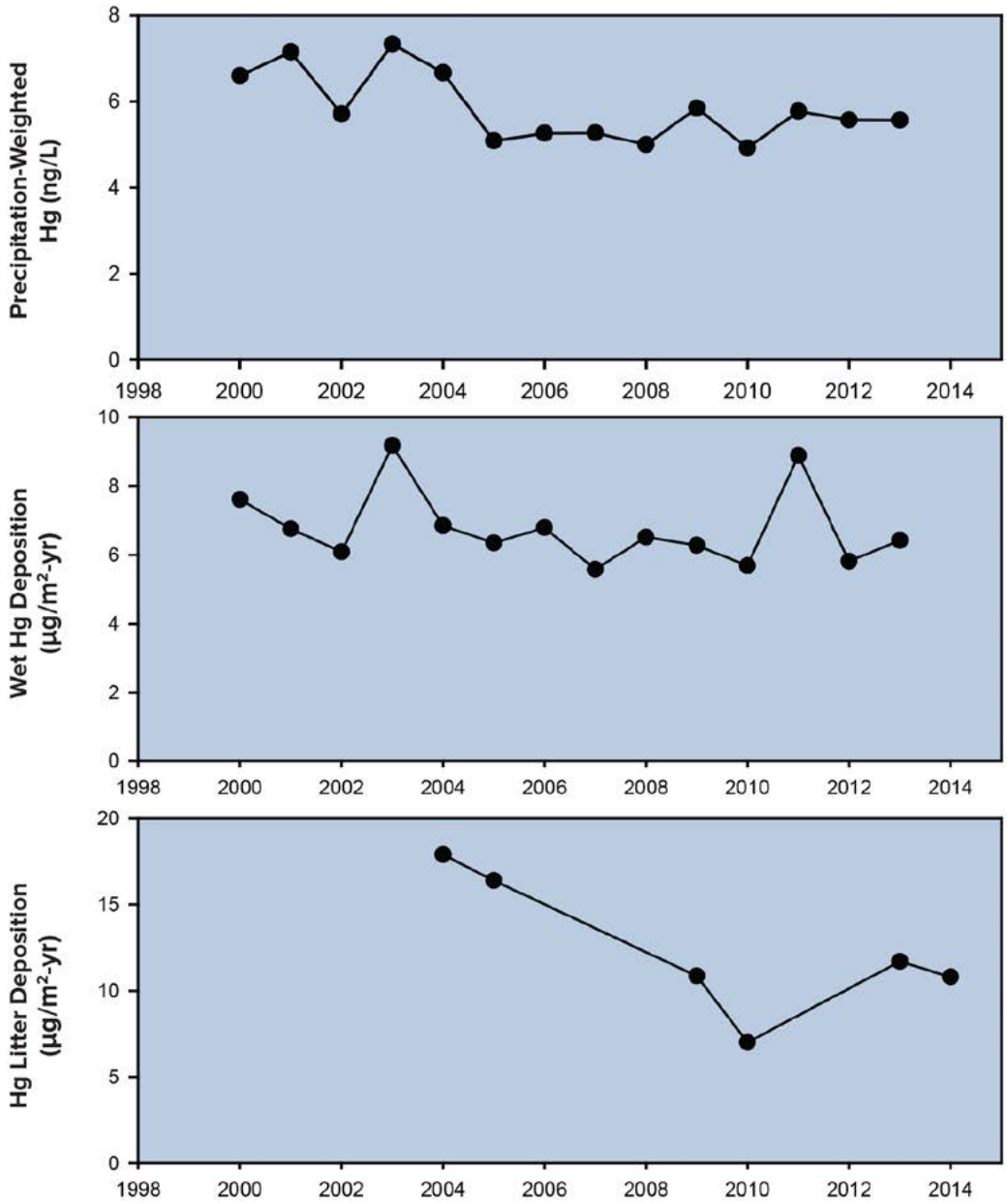
Marked decreases in the atmospheric deposition of some pollutants, including nitrate and sulfate associated with “acid rain,” have been observed at the Huntington NADP/NTN site (Figure 2.) Such changes are consistent with similar changes throughout the Northeast U.S. In June 2012, the HF jointed the AMoN network and has experienced average air concentrations of 0.36 µg NH_3 m^3 (SD=0.19) through January 2015. This mean concentration is substantially less than the mean annual concentrations often found at AMoN sites (http://nadp.sws.uiuc.edu/AMoN/) strongly affected by agricultural activities (>2 µg NH_3 m^3).

Figure 2. Huntington Forest Wet Only Deposition



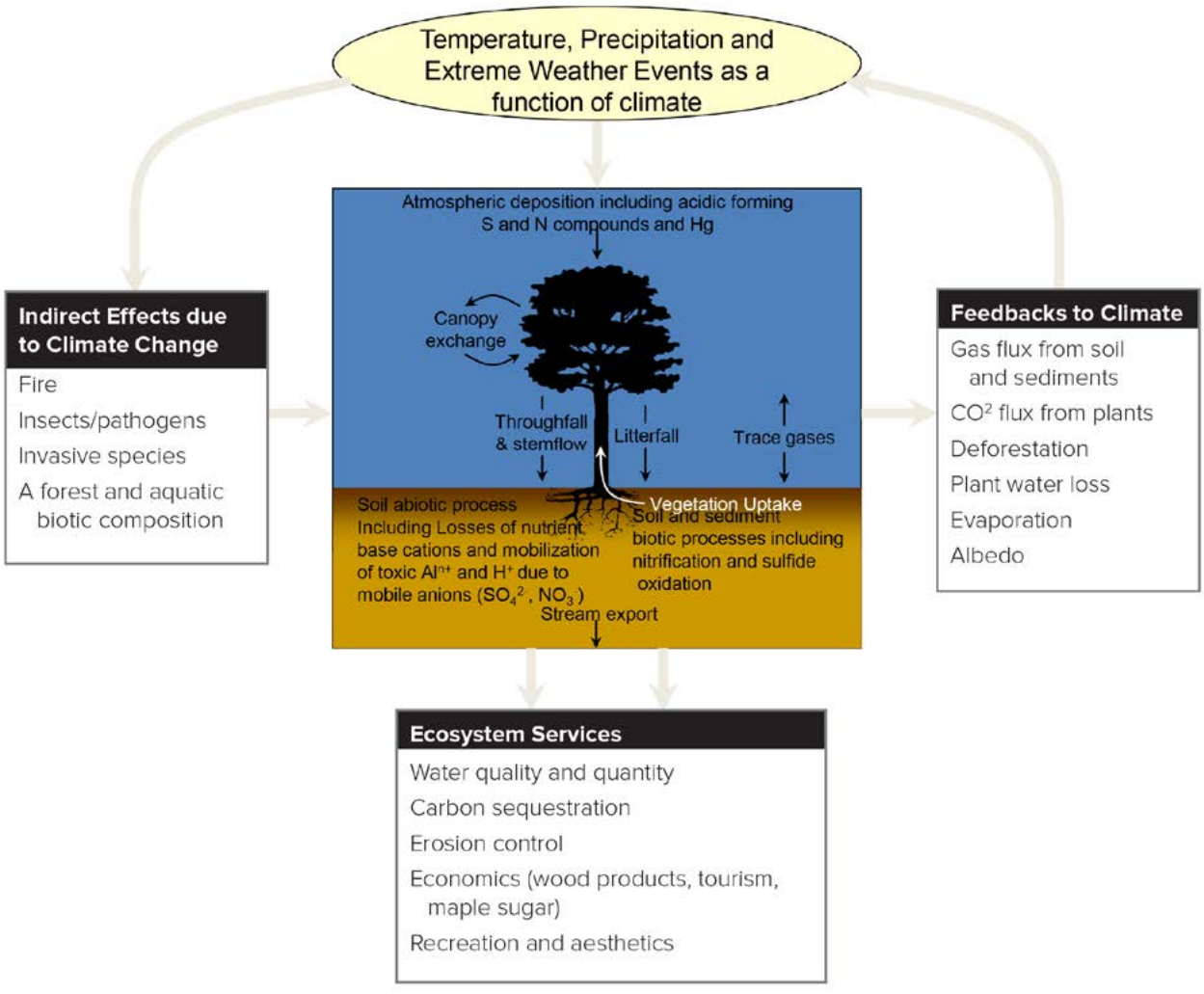
Wet only monitoring of mercury has shown no significant trends in total mercury concentrations or deposition since measurements were initiated in 2000 (Figure 3). Litterfall mercury is thought to be an estimate of dry mercury deposition in forest ecosystems. The combination of wet only mercury inputs plus litter mercury is considered an estimate of total mercury deposition. Using previous measurements of litter mercury for Huntington, there is an extended record of litter mercury deposition. In contrast to the consistent record of wet mercury deposition, it appears that litter mercury may be decreasing. This pattern of decrease in litter mercury deposition appears to be consistent with measurements of declining elemental mercury in the North Atlantic region. As litter mercury is derived from atmospheric elemental mercury, this pattern may reflect decreases in atmospheric mercury deposition to the region.

Figure 3. Time-series of annual volumeweighted concentrations in precipitation, wet deposition of total mercury and litter mercury deposition at Huntington Forest



The extensive monitoring of atmospheric deposition, meteorology, water chemistry and hydrology at the HF/Arbutus Watershed has resulted in various studies that have evaluated a wide spectrum of environmental effects in the Adirondacks. For example, it has been demonstrated that the spring snowmelt period is responsible for a large proportion of nitrate being exported to surface waters (e.g. Kurian et al. 2013; Park et al. 2005). The infrastructure within the HF/Arbutus watershed has served as a basic platform to evaluate a broad range of environmental issues to the region. For example, work on two sub-catchments of the Arbutus Watershed has shown the importance of nutrient (including calcium) availability in altering the forest vegetation and biotic recycling processes that are critical for forest health (Page et al. 2008). The effect of calcium availability is a key factor in the health of important tree species, especially sugar maple. Calcium availability has also been shown to influence the forest fauna (Beier et al. 2012). Research at the HF/Arbutus watershed has shown there are important interactions among climate change, atmospheric deposition, surface water chemistry landscape components (Kang and Mitchell, 2013; Vidon et al. 2014) and the emission of trace gases that contribute to global warming. These factors, as summarized in Figure 4, need to be evaluated concomitantly to understand how current and future environmental factors are affecting environmental health not only for the Adirondacks but for other regions of North America and the World.

Figure 4. Interactions between acidic deposition and climate change in affecting forested watersheds including other extrinsic factors important for forest ecosystem process such as ecosystem services



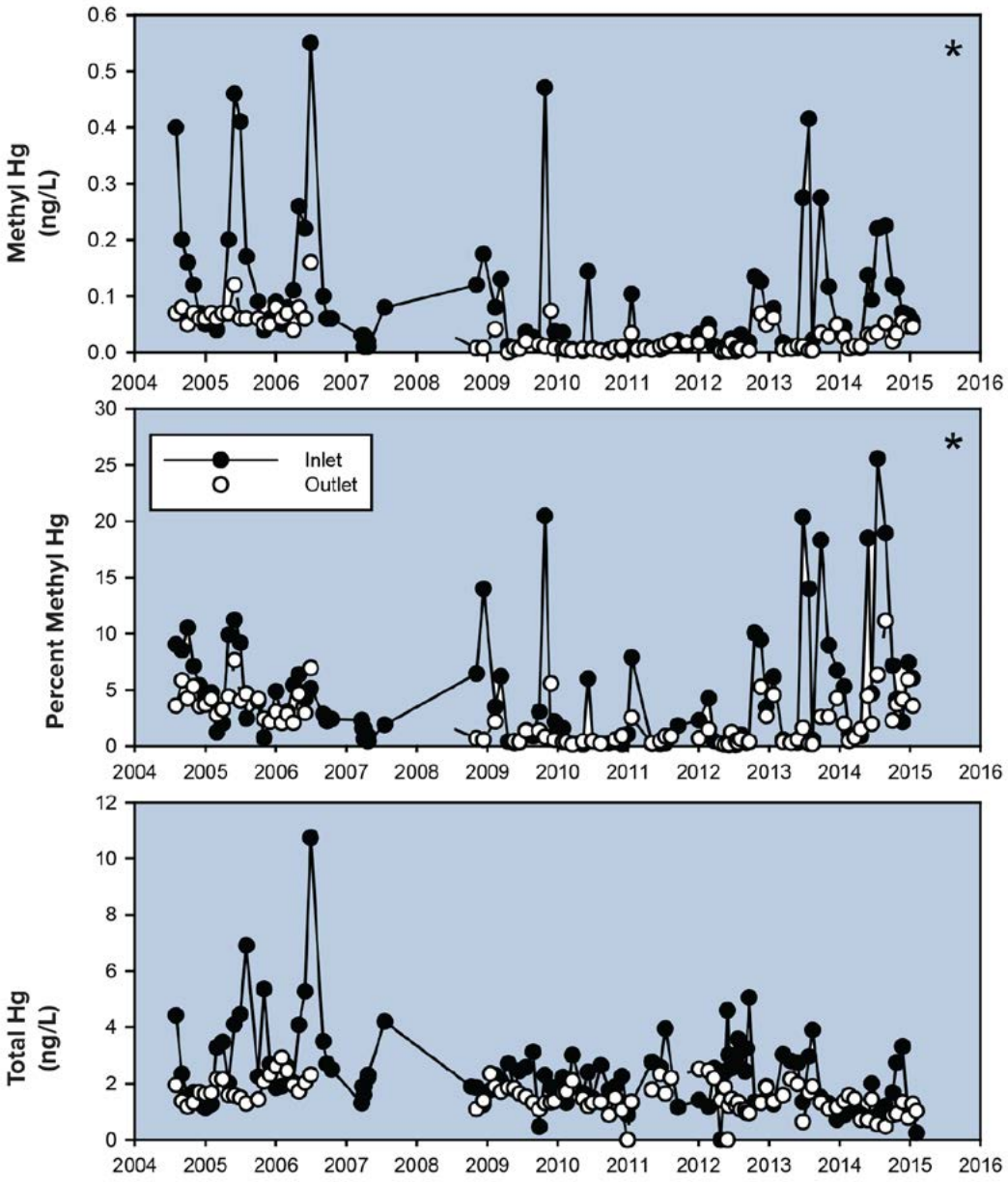
We expect the HF/Arbutus Watershed will continue to serve as the premier monitoring site for the Adirondacks. The detailed information available at the HF/Arbutus Watershed has been extrapolated and used in the evaluation of environmental patterns throughout the Adirondacks including changing patterns of climate (Ito et al. 2002), nitrogen budgets (Ito et al. 2005) and sulfur budgets (Mitchell et al. 2013). The HF/Arbutus watershed has also been used extensively in regional comparisons with particular focus on the Northeast U.S. and Southeast Canada (Campbell et al. 2009; Kerr et al. 2012; Mitchell et al. 2011). The HF/Arbutus watershed is also part of the Phenocam network (Figure 5). The PhenoCam Network was developed to provide automated, near-surface remote sensing of canopy phenology across the Northeast United States and Southeast Canada (http://phenocam.sr.unh.edu/webcam/).

The HF/Arbutus Watershed has been utilized in the comparison of environmental impacts of air pollution and climate effects for sites on a global basis (Mitchell 2011; Shibata et al. 2015; Watmough et al. 2005). These local and regional analyses are used in developing legislation and rules for wide range of air pollutants including the impact of carbon dioxide on climate change (http://www3.epa.gov/climatechange/EPAactivities/regulatory-initiatives.html)

Figure 5. Overview of Arbutus Watershed from one of the cameras used in the Phenocam Network

In addition to mercury deposition measurements, concentrations of total and methyl mercury have been measured in the inlet and outlet of Arbutus Lake. Between 2004 and 2015, the inlet and outlet of Arbutus Lake had statistically significant differences in mercury concentrations (Figure 6). Average concentrations of total mercury and methylmercury were higher at the inlet (2.35 ng/L for total mercury, 0.086 µg/L for methylmercury) compared to the outlet (1.54 ng/L for methylmercury, 0.032 µg/L for total mercury). Consequently, the percentage of mercury occurring as methylmercury was higher at the inlet (4.4%) compared to the outlet (2.4%). Time-series analysis shows that there have been significant decrease in the concentrations of total mercury in the lake outlet and of methyl mercury in the inlet and outlet. Methylmercury and total mercury fluxes for Arbutus Lake were also greater at the inlet (0.06 µg/m^2 – yr) for methylmercury, 1.89 µg/m^2 –yr) for total mercury) compared to the outlet (0.02 µg/m^2 – yr)

Figure 6. Time-series of concentrations of methylmercury, the percent of total mercury as methyl mercury and total mercury in the inlet and outlet of Arbutus Lake at Huntington Forest



for methylmercury, 1.03 µg/m^2 –yr) for total mercury) (Figure 7). Based on this mass balance, the lake is retaining inputs of total mercury and methylmercury with an average of 60.3% total mercury and 57.6% methylmercury retained. A time-series analysis of indicates significant decreases in the fluxes of total mercury and methyl mercury in the lake inlet, but not the lake outlet over the monitoring period. These patterns may suggest that the lake-watershed system is responding to decreases in mercury deposition.

The New York State Department of Environmental Conservation has listed 128 lakes in the Adirondacks as impaired due to elevated acidity. Investigation of acid deposition and surface water chemistry help to inform the recovery of surface waters from acidification effects. Mercury contamination is a critical and dynamic environmental issue in New York State and globally. Exposure to mercury largely occurs through consumption of fish. There are currently 104 fish consumption advisories due to mercury for specific waters in New York, many of these are in the Adirondacks. For most Adirondacks watersheds, atmospheric deposition dominates mercury inputs. This monitoring program helps inform changes in atmospheric mercury deposition and changes in watershed and lake response to these changes. Long-term meteorological and atmospheric deposition measurements provides valuable information that is used as input to hydrochemical models to project the response of Adirondack watersheds to changes in acid deposition and climate change.

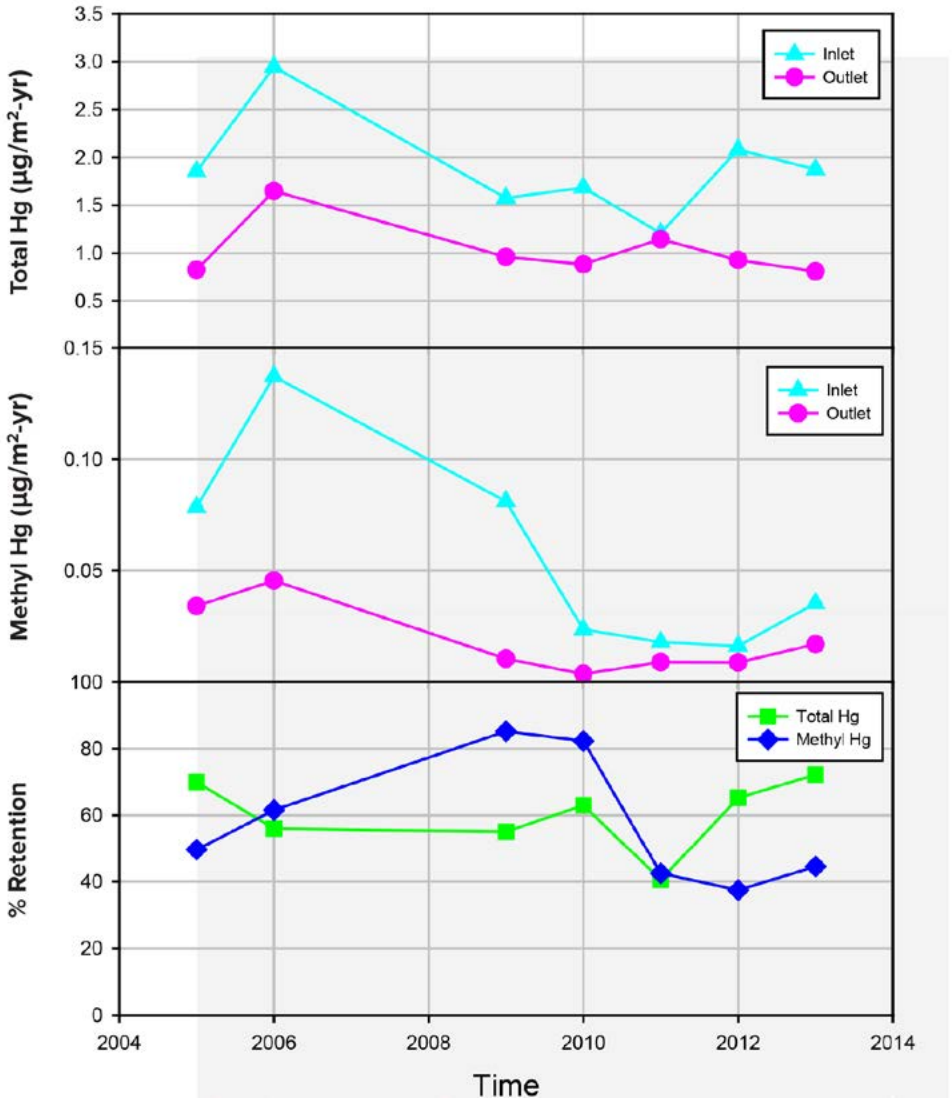


Figure 7. Time-series of fluxes of methylmercury and total mercury in the inlet and outlet of Arbutus Lake at Huntington Forest

Tower at Ackerman Clearing, upper Arbutus watershed
Credit: Patrick McHale

Instrumentation cabin at the Adirondack Ecological Center's NTN site (NY20)
Credit: Patrick McHale

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