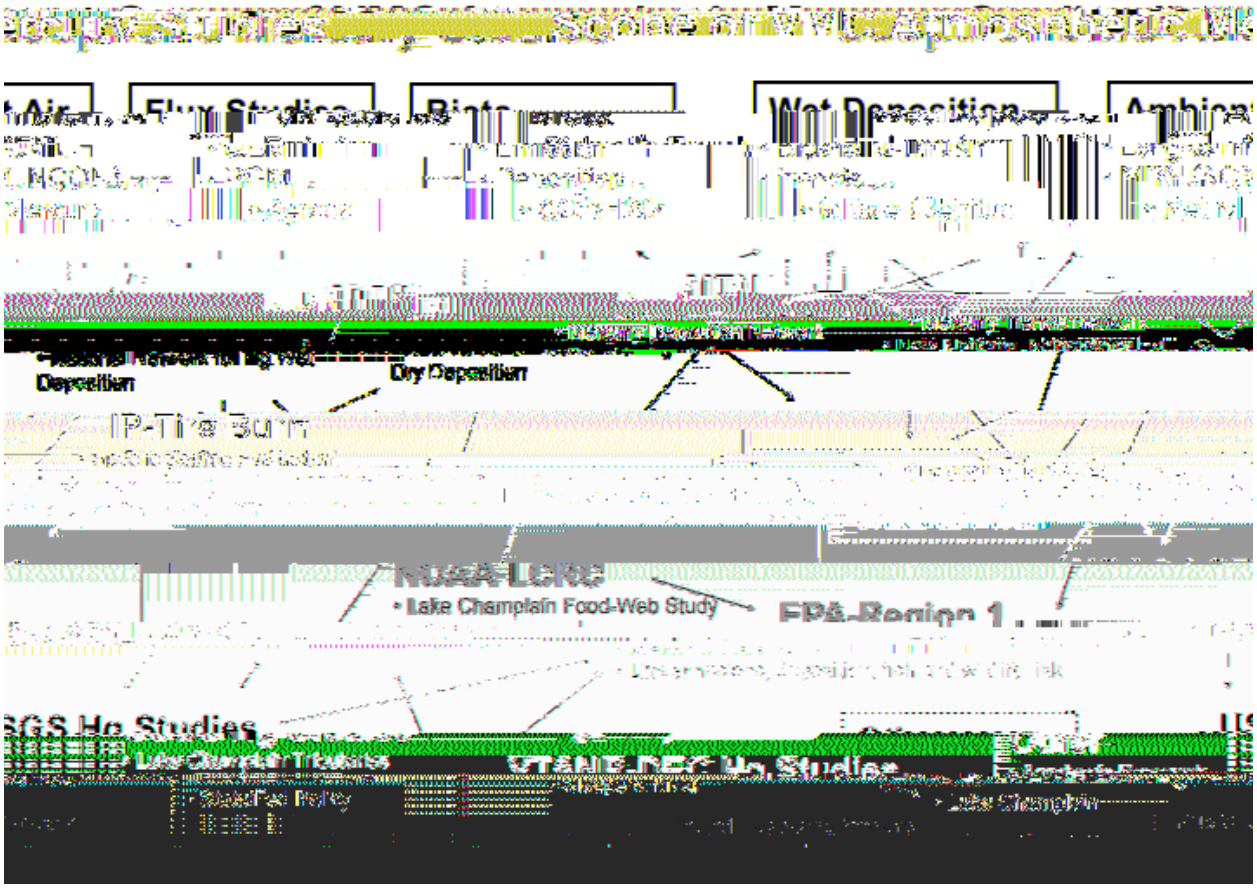


Figure 1. Scope of atmospheric mercury studies coordinated by the Vermont Monitoring Cooperative (VMC) centered on the core EPA-ORD funded atmospheric mercury project (top row of boxes).

Long-term record of event-based precipitation mercury and identification of potential mercury wet-deposition sources

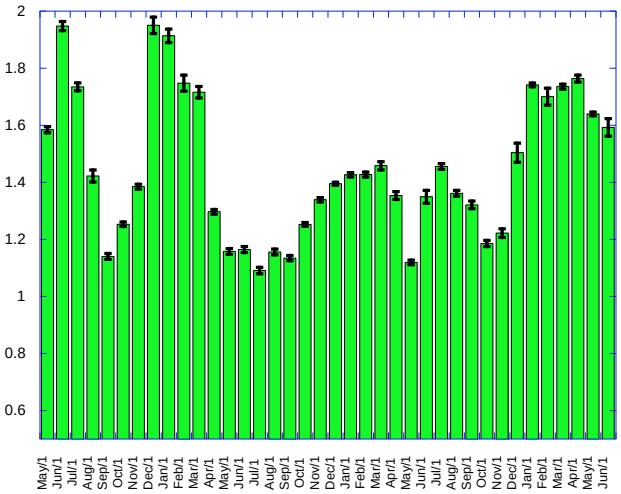
Event-based wet deposition sampling at Underhill, VT was continued for the project duration and continues uninterrupted, maintaining the longest, continuous record of event-based atmospheric mercury deposition *in the world.* We conducted an intensive comparison of collector systems and protocols used for the measurement of mercury in precipitation. The results of this study were used to transition the long-t-2 (e)0 Tm/F5.0 1 Tf [(t) -2 (-2 W n) -2 (pa) 3 (r) -7 (i) -2 (s) 8 (on)-10 (o (eT Q Q q 9.3) 3 (i

annual deposition were located to the south and west in areas with high densities of coal-fired electric generating units (EGUs) (Figure 3). In contrast to estimated total mercury emissions, estimated EGU emissions have been flat during the period of observation. Variation in precipitation amounts at

and 7.9% of annual deposition during the methyl mercury sampling period 2005-2007), methyl mercury concentration was positively linearly correlated with total mercury concentration (r

aerosols at moderate RH. The dependence of HGP on the water vapor mixing ratio may relate to HGP source regions and accompanying seasonal variations in water vapor.

The concentrations of the three mercury species exhibited strong seasonal patterns that were slightly out of phase with each other (Figure). GEM concentrations peak in winter and spring with an early fall minimum, HGP concentrations peak in late winter and RGM concentrations peak in spring (Figure 4). The wintertime peak in HGP may be due, in part, to increased local combustion for home heating. However, trajectory analysis (discussed below) also indicates major out-of-region sources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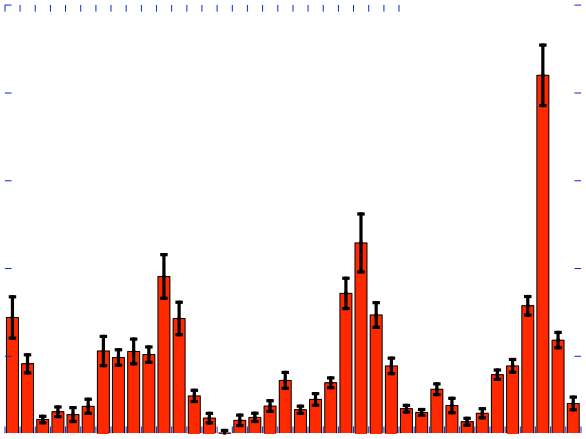

concentration arriving at the receptor attributable to a given source field. It is noteworthy that very large and very distant sources (NE Texas, base-metal smelter in Manitoba are indicated as potential sources by the CPSC map for mean RGM concentration. Additional CPSC maps shown in the full report (FR-sec3a-AmbHgSpec-2009-01-16.pdf) further serve to pinpoint the contribution of specific sources to the highest concentration events or "plume hits".

CPSC maps were prepared for HGP and GEM and identify the different spatial distribution and intensities of anthropogenic HGP and GEM emissions. These analyses demonstrate that out-of-region and even very distant sources are significant contributors to the mercury burdens in New England's terrestrial and aquatic ecosystems. These observations and source identification analyses will assist the air-quality modeling community in improving emissions transport models. Air-quality planners will make use of the information to target specific sources for emissions reductions.

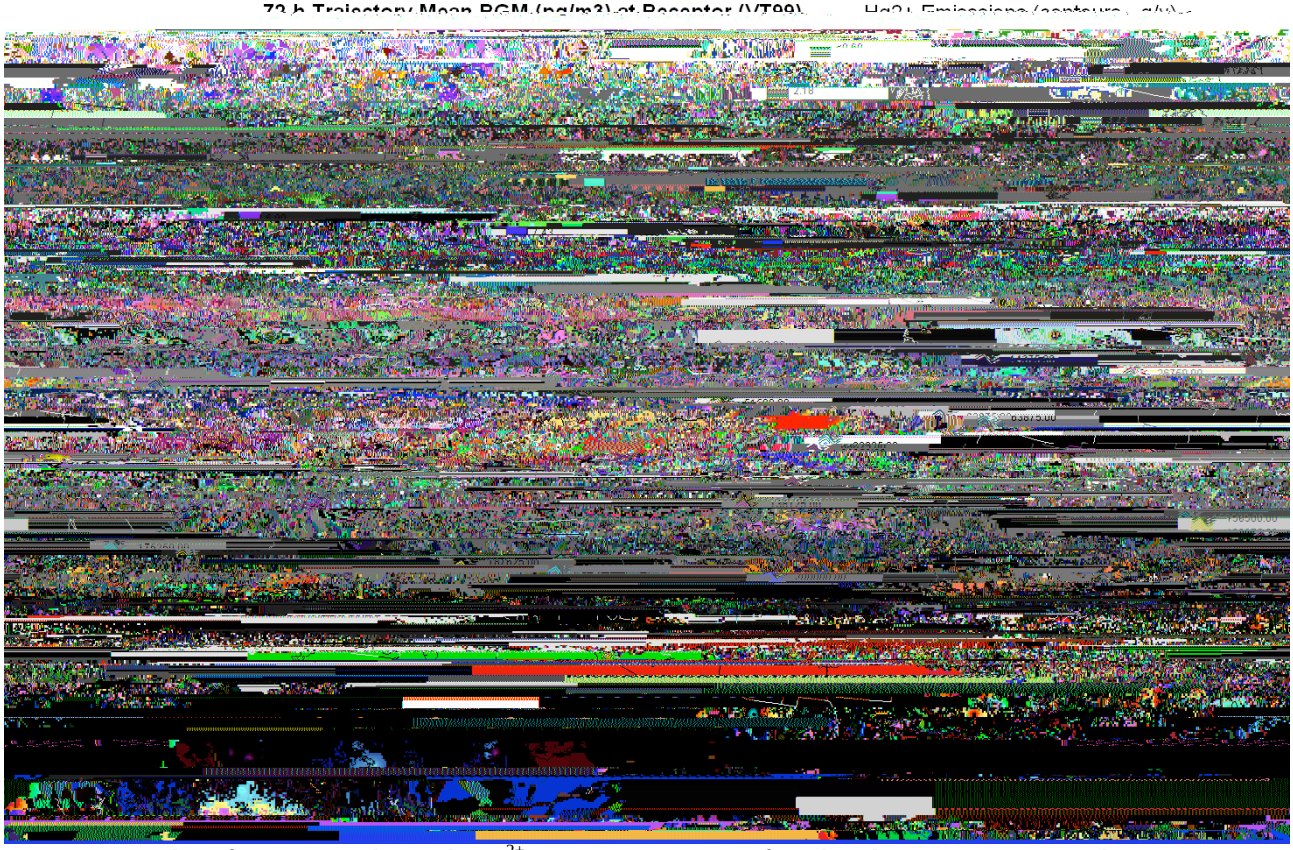

Figure 6. Overlay of 1999 US and Canada Hg^{2+} emissions (courtesy of Mark Cohen(e) 3 (s) 8 ( )-10 (de) 3 (m) -2 (ons) 8 (t) -2 (r) -7 (a)

Several potential "natural process[2]" sources are also indicated by the analysis, but cannot be compared with emissions data as the anthropogenic sources can. An example is the significant marine source of RGM in the western Atlantic Ocean east of Cape Cod. High halogen concentrations enhance the production of RGM in the marine boundary layer and this potential source location is consistent

Figure 7. (Left) Example of diurnal and multi-day pattern of above-canopy mercury gradient. Positive values indicate emission of GEM and negative values indicated deposition to the forest canopy. (Right) Frequency distribution of fluxes.

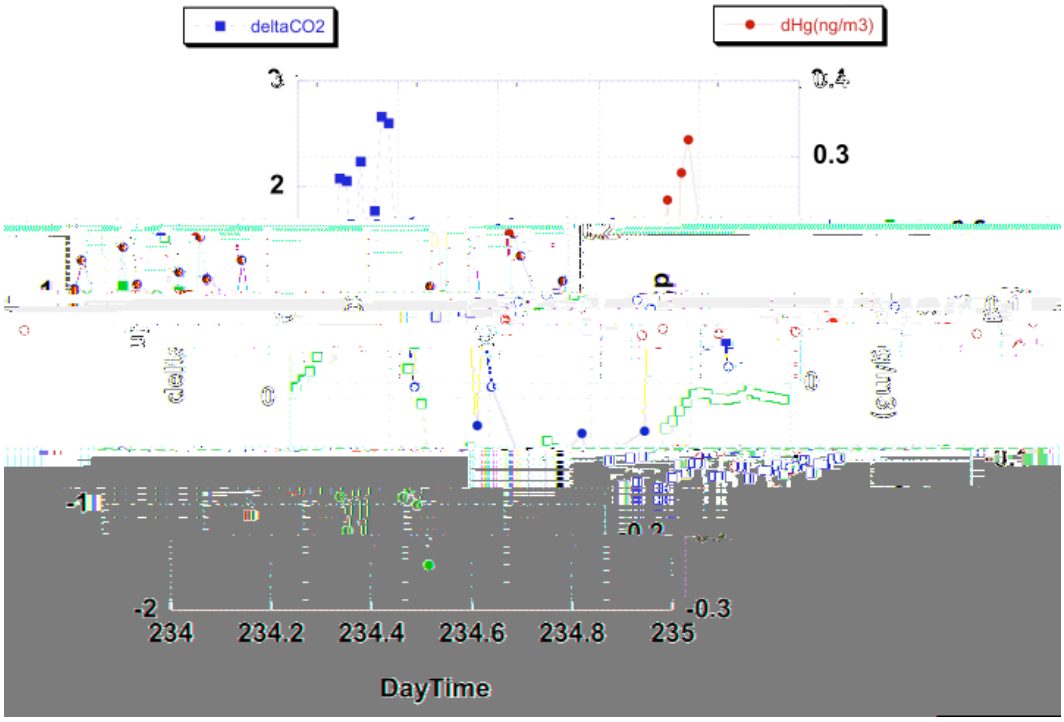

Figure 8. Example diurnal cycle of GEM and CO_2 gradients measured above the forest canopy. GEM deposition is indicated by the negame

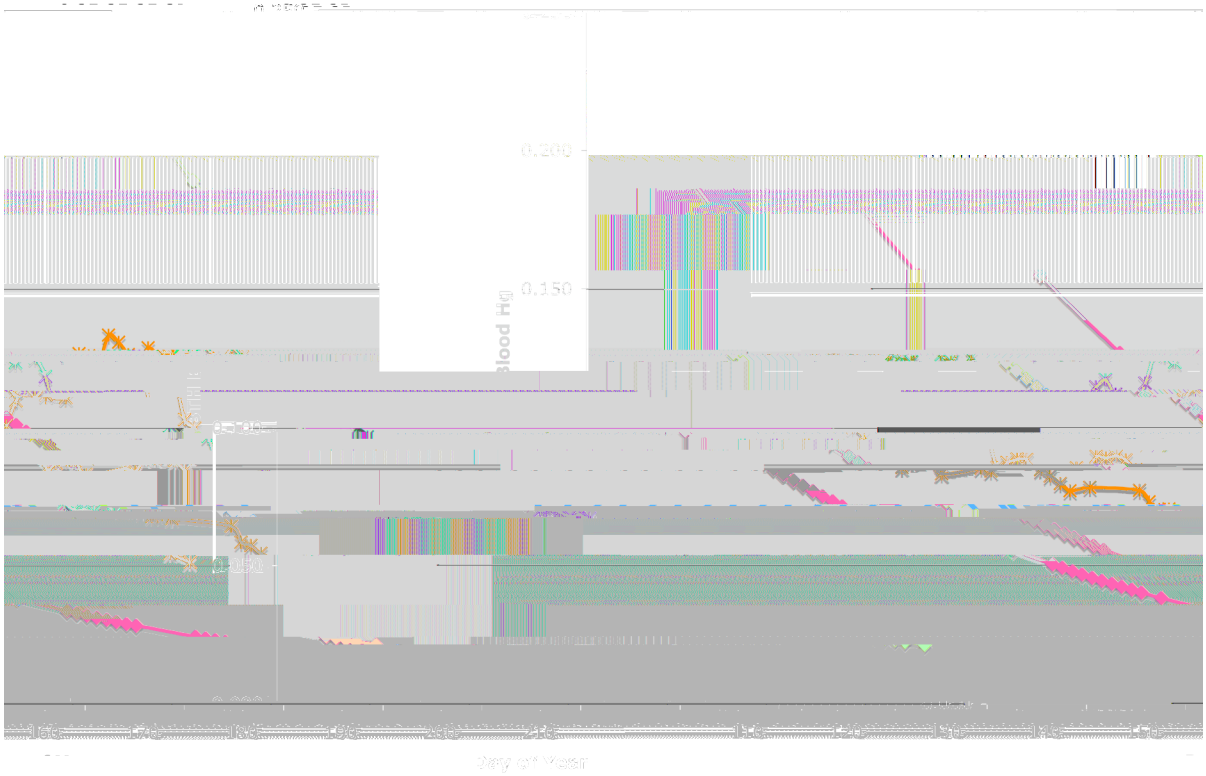

Figure 10. Exponential decay model (light blue) of the dissipation of wintering ground Hg burden and observations (purple) of Hg blood concentrations (ug/g) on the breeding ground in Bicknell's thrush. Due to the fluctuations in number of birds captured and sampled daily, the observed blood levels are presented as the 10-day moving average. Bicknell's thrush blood Hg initially increased after reaching the breeding ground. A decline in blood Hg levels began about mid-June.

Figure 11.

Coordination with national, regional, and state mercury research

The project personnel successfully coordinated with other mercury research efforts at local, regional and national levels. We used the new Hg information from the Underhill site and this project to estimate mercury deposition not only to the forested watersheds of Vermont, but also specifically to Lake Champlain in collaboration with researchers supported by the NOAA funded, Lake Champlain Research Consortium. More broadly, Drs. Miller and Keeler participated in the Northeast Mercury Research Group, a regional research group funded by the USDA Forest service (www.briloon.org/mercury). The three-way, west-east (WA-VT), precipitation mercury collector intercomparison was a collaboration designed to inform the national MDN program on potential improvements to collector design as well as to facilitate Underhill's transition from the UMAQL to the MDN system.

Observations and analyses of mercury concentrations and fluxes at Underhill are providing benefits to several mercury research groups working to model emissions-transport-deposition cycles at regional, national and global scales. The results of our trend analysis (no trend detected) for wet deposition and our source identification efforts for wet and dry deposition have informed state, regional, national, and international air-quality planning bodies about the identity of sources contributing mercury to the biologically sensitive New England region. Our pioneering assessment of mercury in a terrestrial food-web has highlighted the need for expanded consideration of the risks posed by atmospheric mercury deposition to terrestrial environments.

Dr. Miller participated in the technical working group designing protocols and operations standards for the proposed MTN (Mercury Trends Network), a new mercury dry deposition network being established by NADP. Dr. Miller provided detailed information on our operating procedures and data management process for use in developing the network SOP. Underhill served as demonstration site for the network and we hosted a field trip for NADP personnel to observe our operations in 2007. The Underhill site was one of the initial four sites funded by EPA-OAR-CAMD for start-up of the network in January of 2008.

Scientific communication and public outreach

In addition to the research coordination activities described above project personnel made numerous presentations about project activities and results at regional and national meetings. Dr. Miller produced a public-outreach overview document describing mercury research activities at Underhill in conjunction with the VMC. Interviews were granted to print and radio media to convey project results to the public. Several peer-reviewed scientific publications were prepared, accepted and published that made use of project data. Additional manuscripts are currently being prepared for submission by the project team. The final results of the project (which are the subjects of these manuscripts) will be presented at national meetings and communicated to the air-quality management community.

Organization of the Final Report and document file names

Section 0 – **Executive Summary** – "FR-sec0-ExecSum-2009-01-16.pdf"

Section 1 – **Introduction** – "FR-sec1-Introduction-2009-01-16.pdf"

Section 2a – **Event-Based Wet Deposition** – "FR-sec2a-Event-Wet-2009-01-16.pdf"

Section 2b – **Collector Comparison Manuscript** – "FR-sec2b-Collector-Comparison-2009-01-16.pdf"

Section 2c – **Long-Term Wet Deposition Manuscript** – "FR-sec2c-Long-Term-Record-2009-01-16.pdf"

Section 3a – **Ambient Air Mercury Speciation Studies** – "FR-sec3a-AmbHgSpec-2009-01-16.pdf"

Section 3b –