INSTITUTE OF ECOSYSTEM STUDIES
ENVIRONMENTAL MONITORING PROGRAM

Summary Report

Precipitation Chemistry (1984-2004); Stream Water Chemistry (1985-2004); Low-Volume Filter Pack Chemistry (Fine Particle Aerosols, SO_2, HNO_3 (1988-2004)

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Introduction

Purpose. The IES Environmental Monitoring Program is a long-term research program. The purpose of the program is to monitor environmental parameters that are important to natural ecosystems. The program includes monitoring of air, precipitation and stream chemistry as well as meteorological, solar radiation and physical stream parameters. IES also hosts sites for two additional programs: The New York State Department of Environmental Conservation Ambient Air Monitoring Program, for ground level ozone; and the National Oceanic and Atmospheric Administration (NOAA), U.S. Climate Reference Network (USCRN), a program designed to provide long-term homogeneous observations of temperature and precipitation that can be coupled to historical observations for the detection and attribution of climate change.

History. The program began in 1984 with collection and chemical analysis of precipitation and stream samples. Equipment to measure stream temperature and height was installed in 1987 although data for most years prior to 1993 are incomplete. Temperature, relative humidity, wind and solar radiation instruments were added to the program in 1987. Air sampling using low-volume filter packs similar to those used in the US EPA CASTnet program began in 1988. The New York State DEC began measuring ground level ozone at IES in 1988. Ultraviolet radiation measurements began in 1999. And the USCRN program began making air temperature, relative humidity, surface temperature, precipitation, wind speed and solar radiation measurements in October 2004. Stream samples were collected from 4 locations on the East Branch of Wappinger Creek on the IES property from 1985 to 1995. Sample collection was reduced to two locations in 1996.

Location. The Institute of Ecosystem Studies is located in the Hudson River Valley near Millbrook, New York, roughly 113 km north of New York City and 24 km east of Poughkeepsie. Data are often compared with a long-term database from Millbrook School, which is 13 km east of IES. The precipitation and air chemistry sampling equipment as well as the meteorological and solar radiation instruments are located in a flat, open field at an elevation of 128 m. GPS coordinates for the site are: N41.785823 W073.741447. The station has a small building (9 ft. x 20 ft.), which is shared with the NYS DEC Ambient Air Monitoring Program. Stream gauging equipment is located on the East Branch of Wappinger Creek in the Fern Glen on the IES property.

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Description of Methods

Precipitation Chemistry. Precipitation samples were collected using the wet side of an automatic wet-dry collector (Aeorchem Metrics model #301). The collector uses a moisture sensor that causes a motor to remove a cover from a clean bucket when it senses precipitated moisture. Samples were collected on an event basis; an event was defined as continuous precipitation that has not been interrupted by more than a 6-hour hiatus. At the end of an event, the sample was collected, weighed, and transferred to a labeled sample bottle. If the sample was frozen, it was allowed to sit at room temperature until the entire sample was melted. After the sample was bottled, it was analyzed at the IES analytical laboratory for pH, SO_4^{-2}, NO_3^-, NH_4^+, PO_4^{-3}, Cl^-, Na^+, Ca^{+2}, Mg^{+2}, and K^+. See Table 1 for analytical methods. If the quantity of sample was insufficient for all of these analyses, as many of the analyses as possible were completed with preference given to pH, SO_4^{-2}, NO_3^-, and NH_4^+ in that order. In 1999 we changed the sample-handling protocol as follows. A 60-ml aliquot of sample was preserved with 2 drops of chloroform and refrigerated. This aliquot was

analyzed for NO_3^-, NH_4^+ and PO_4^{-3}. Comparisons of NO_3^-, NH_4^+ and PO_4^{-3} were made for one year between samples treated with chloroform and samples left untreated. There was no significant difference between treated and untreated samples for NO_3^- and NH_4^+, but PO_4^{-3} was higher in samples treated with chloroform. For estimation of ion balances, volume-weighted mean concentrations and total deposition, values that were below detection limits were replaced with one half of the detection limit. When analyses were completed, an ion balance was calculated as follows:

(anions-cations)/(anions+cations/2)*100 (μeq).

If the cations and anions did not balance within the criteria listed in Table 2, ions that most affected the ion balance (usually H^+, NO_3^- and SO_4^{-2}) were re-analyzed and the average of the first and second readings was used. In addition to the chemistry data, the beginning and ending dates and times of the event, the volume and the type of precipitation (rain, snow or mixed snow and rain) were recorded. The beginning and ending dates and times and the volume of each precipitation event were determined using a universal recording rain gauge (Belfort Instrument Co. Series 5-780). From January to August, 1984 the volume of each event was calculated as the weight of the sample divided by the opening area of the Aerochem Metrics collection bucket.

Total yearly wet deposition and annual and monthly volume-weighted means of all ions are listed in Appendices 1, 2, 3 and 4.

Table 1. Methods of analysis for Environmental Monitoring Program samples at the Institute of Ecosystem Studies as of 2004.

ION	INSTRUMENT	TECHNIQUE
NH_4^+, PO_4^{-3}	Alpkem Flow Solution III OR Lachat QuikChem 8000 FIA	Phenate method (NH_4^+)[1] Phosphomolybdate method (PO_4^{-3})[1]
SO_4^{-2}, NO_3^-, Cl^-	Dionex 500 DX Ion Chromatograph	Ion exchange chromatography, AS4A and AG4A columns, micromembrane supressor[2]
K^+, Na^+	Perkin-Elmer Aanalyst 300 Atomic Absorption Spectrometer	Flame atomization, direct air[3]
Ca^{+2}, Mg^{+2}, SiO_2	Leeman Labs Profile ICP	Emission spectroscopy
PH	Fisher-Accumet AR20 pH meter with Thomas glass electrode, Fisher reference probe (precip. & stream) with Fisher Accu=pHast combination probe (AQ)	Standardization with Fisher 7.00 and 3.00 (precip.), 4.00 (AQ), 10.00 (stream) buffers; samples and buffers at room temperature
Specific Conductivity	Fisher-Accumet AR20 pH/Conductivity Meter	Direct reading

[1] #00578 Standard Alpkem Methods (NH_4^+) #00580 (PO_4^{-3}), 1992,Alplem Corp, Clakamas OR
QuikChem method #10-107-06-1-J (NH4), #10-115-01-1-M (PO4), 2000, Lachat Instruments, Milwaukee, WI
[2] Small, H., Stevens, T.S. and Bauman, W.C. 1975. Anal. Chem. 47:1801-1809.
[3] Slavin, W. Atomic absorption spectroscopy. 1968. Wiley-Interscience, New York.

Table 2. Criteria used for precipitation ion balances for consideration for re-analysis.

ION STRENGTH (μeq)	and ION BALANCE (%)
less than 50	Greater than 40
between 50 and 100	Greater than 20
greater than 100	Greater than 10

East Branch of Wappinger Creek Chemistry, Temperature & Discharge. Stream samples were collected at the end of every month at two sites on the East Branch of Wappinger Creek at IES. Before 1996, samples were collected at four sites. Redundancy in the data and cost of analysis prompted us to discontinue collecting samples at two of the sites. The two remaining sites are Site 2 near the bridge in the Fern Glen on Lovelace Drive and Site 4 near the north bridge on the lowlands loop road. Sample collection began in January 1985 (Site 4) and November 1985 (Site 2). Samples were collected as close to base flow as possible; however, base flow varies seasonally and is higher in winter than summer. The samples were analyzed at the IES Analytical Laboratory for pH, conductivity, NO_3^-, SO_4^{-2}, NH_4^+, PO_4^{-3}, Cl^-, Na^+, Ca^{+2}, Mg^{+2}, K^+ and SiO_2 (see Table 1 for analytical methods). Samples collected between 1985 and 1998 were not preserved and were stored in the light at room temperature before analyses were completed. Beginning with samples collected in January 1999 samples were refrigerated and preserved using filtration (glass fiber filters) and 2 ml sulfuric acid per 250 ml of sample for NO_3^-, NH_4^+, PO_4^{-3} analyses and filtration for SO_4^{-2}, Cl^-, Na^+, Ca^{+2}, Mg^{+2}, K^+ and SiO_2 analyses. SiO_2 analyses were done within 4 days of collection. Conductivity and pH were measured on untreated samples within 4 days of collection.

In 1993, we began continuous collection of stream height and temperature using a Handar, Inc. 570A Data Acquisition System with an incremental shaft encoder (model 436A) and a water temperature sensor (model 433FN). Because daily discharge data were not available for IES for all of 1985-1993, we used published data from the USGS (U.S. Geological Survey Water Resources Data- New York, Water Years 1985-1993) to predict daily average discharge for IES. To predict IES discharge, we regressed daily average discharge on Wappinger Creek at Red Oaks Mill in Wappingers Falls with daily average discharge at IES. Stream temperature was continuously recorded at the same site (1987-2003) using a Weksler, Inc. temperature recorder. Stream height was recorded at Site 2 using a Leupold & Stevens, Inc. total flow meter (model 61R) from 1986-1993 (data are complete only for 1988-1989). Rating curves for the stream were developed in 1987-1988, 1993-1994, 1996, 1997-1998, and 2003-2004. Yearly and monthly mean concentrations are listed in Appendices 5, 6, 7 and 8.

Aerosol Chemistry, HNO_3 & SO_2. Aerosols, HNO_3 and SO_2 were sampled using Teflon filter packs. Three 47 mm filters were placed in each filter pack: a 2 μm Teflon filter for collection of aerosols, a 1 μm nylon filter for collection of HNO_3 vapor and a potassium carbonate coated cellulose filter for collection of SO_2. The cellulose filters were cleaned before coating by rinsing and soaking overnight in double-deionized water. The three filters were placed in line so that the Teflon filter was exposed to incoming ambient air first, the nylon filter second and the carbonate filter last. An inverted stainless steel pot (from 1988 - July 1993 it was an inverted plastic funnel) was suspended over the filter packs on a tower approximately 10 meters above a mowed grass surface. A continuous flow of air was drawn through the filter pack at 3.00 lpm using a Gast, Inc. oil-less

vacuum pump (model 1031, upgraded to model 1531-107B-6288 in 1998), which was regulated by a mass flow controller (Tylan General Inc., model FC280V, upgraded to model FC2604S in 1998 then to Aalborg model GFC171S in September 2002). When the mass flow controller was off line for any reason, either a needle valve or another mass flow controller regulated flow. During this time, flow was measured using a rotameter (Gilmont Instruments, Inc., or Scienceware®), and the flow measurements were corrected for instantaneous temperature and atmospheric pressure. Clean filter packs were exchanged for exposed ones every Tuesday.

Aerosol chemistry was determined from the Teflon filters, which were extracted in 50 ml of double deionized water for 24 hours in the dark at 2 degrees C after sonication for 15 minutes. The solution was then decanted into sample bottles and analyzed at IES for pH, NO_3^-, SO_4^{-2}, NH_4^+, PO_4^{-3}, Cl^-, Na^+, Ca^{+2}, Mg^{+2} and K^+ (see Table 1 for analytical methods). Nitric acid vapor was determined by extracting each nylon filter in 50 ml of a mixture of $NaHCO_3$ (0.28 M) and Na_2CO_3 (0.22 M) diluted 1:100 with double deionized water. The filters were sonicated for 15 minutes and then refrigerated for 24 hours before decanting the solutions and analyzing them for NO_3^- (Table 1). Sulfur dioxide was determined by extracting the carbonate-coated filters in 50 ml of double deionized water with 2 drops of hydrogen peroxide. The filters were sonicated and extracted as described above and the resulting solution was analyzed for SO_4^{-2} (Table 1). Using the total amount of time that each filter was exposed and the average flow rate for the week, concentrations of each chemical species were calculated. From these data, yearly and monthly average concentration of aerosols, HNO_3 and SO_2 were calculated. Hourly deposition velocities were estimated using a multi-layer dry deposition model (Meyers et al., 1998). This model was parameterized with hourly meteorological data collected from a tower adjacent to the air sampling tower, and canopy structure and leaf area data from the nearby forest. Weekly average deposition velocities were combined with weekly concentrations to estimate weekly fluxes. For the purposes of calculating means, all data below analytical detection limits were set to equal one half of that detection limit. Because many of the meteorological data for 2003 were unavailable because of a lightning strike in June of 2003, estimates were made of deposition velocities for June 19 through September 30 for that year. Estimates were made using the means of each hour from the previous 15 years. Contamination of unexposed Zefluor Teflon filters caused us to eliminate all particulate NO_3^- and NH_4^+ data for 2003 from the dataset. Yearly and monthly mean aerosol, HNO_3 and SO_2 concentrations, yearly average deposition velocities and total annual dry deposition of aerosols, HNO_3 and SO_2 are listed in Appendices 9-14.

Related Publications

Kelly, V.R., Lovett, G.M., Weathers, K.C., Likens, G.E. 2005. Trends in Atmospheric Ammonium Concentrations in Relation to Atmospheric Sulfate and Local Agriculture. Environmental Pollution 135(3):363-369.

Kelly, V.R., Lovett, G.M., Weathers, K.C., Likens, G.E. 2002. Trends in atmospheric concentration and deposition compared to regional and local pollutant emissions at a rural site in southeastern New York, USA. Atmospheric Environment 36:1569-1575.

Kelly, V.R. 1999. Environmental Monitoring Program 1988-1998 Summary Report Part I: Meteorology. Occasional Publication of the Institute of Ecosystem Studies, Number 13, May 1999.

Kelly, V.R. 1999. Environmental Monitoring Program 1988-1998 Summary Report Part II: Precipitation Chemistry (1984-1998); Stream Water Chemistry (1985-1998); Aerosol Chemistry, Total Suspended Particulates, SO_2, HNO_3 (1988-1998). Occasional Publication of the Institute of Ecosystem Studies, Number 15, December 1999.

Meyers, T.P., Finkelstein, P., Clarke, J., Ellestad, T.G., Sims, P.F., 1998. A multilayer model for inferring dry deposition using standard meteorological measurements. Journal of Geophysical Research 103:22645-22661.

Appendix

A1. Total annual wet deposition of major ions, inorganic N and SO_4^{-2}-S (kg/ha). Concentrations below detection limits are set to half the detection limit.

Institute of Ecosystem Studies, Millbrook, New York, 1984-2004.

Year	H^+	Ca^{+2}	Cl^-	K^+	Mg^{+2}	Na^+	NH_4^+-N	NO_3^--N	PO_4^{-3}	SO_4^{-2}	SO_4^{-2}-S	NH_4^+-N + NO_3^--N
1984	0.525	1.1	2.1	0.94	0.40	0.91	3.0	3.6	0.352	21	7.1	6.5
1985	0.720	0.70	2.2	0.17	0.23	0.73	2.2	4.8	0.202	28	9.3	6.9
1986	0.679	0.40	1.9	0.13	0.17	0.56	1.8	3.7	0.162	25	8.2	5.5
1987	0.601	0.33	1.9	0.24	0.21	0.78	1.7	3.1	0.430	20	6.8	4.8
1988	0.939	0.78	2.4	0.20	0.23	0.77	2.8	5.1	0.223	35	12	7.9
1989	0.653	0.58	3.5	0.38	0.22	0.91	2.0	3.9	0.216	23	7.8	6.0
1990	0.694	0.58	2.8	0.23	0.22	1.1	1.9	4.5	0.158	24	8.0	6.4
1991	0.668	0.49	1.5	0.15	0.16	0.55	2.2	4.0	0.157	24	8.1	6.1
1992	0.502	0.36	2.0	0.14	0.16	0.82	1.4	3.2	0.096	18	5.9	4.6
1993	0.565	0.52	2.0	0.17	0.21	0.88	1.5	3.4	0.043	19	6.4	4.8
1994	0.600	0.64	2.0	0.16	0.21	0.85	1.8	3.9	0.044	21	7.1	5.7
1995	0.506	0.63	2.6	0.24	0.25	1.2	1.8	3.9	0.048	18	6.1	5.7
1996	0.599	0.84	3.2	0.22	0.29	1.5	2.1	4.8	0.047	21	7.2	6.9
1997	0.488	0.67	1.6	0.17	0.19	0.74	1.7	3.3	0.030	18	6.1	5.0
1998	0.434	0.58	1.3	0.18	0.20	0.56	1.7	3.0	0.043	16	5.2	4.7
1999	0.387	0.61	2.2	0.17	0.23	1.1	1.2	2.8	0.045	13	4.4	4.0
2000	0.523	0.76	1.8	0.25	0.20	0.85	1.9	3.9	0.089	18	6.1	5.8
2001	0.327	0.52	1.1	0.12	0.13	0.46	1.3	2.4	0.036	13	4.3	3.7
2002	0.378	0.73	1.3	0.62	0.19	0.54	2.6	3.0	0.843	15	5.2	5.6
2003	0.410	0.71	2.7	0.29	0.31	1.4	1.8	3.3	0.277	15	4.9	5.1
2004	0.420	0.53	1.5	0.38	0.20	0.68	2.0	2.7	0.074	16	5.2	4.7
Average	0.532	0.60	2.0	0.25	0.21	0.81	1.8	3.5	0.165	19	6.4	5.3

A2. Monthly average wet deposition of major ions, inorganic N and SO_4^{-2}-S (kg/ha). Concentrations below detection limits are set to half the detection limit. Values are total deposition for every month from 1984-2004 averaged for all years (n=21 years).
Institute of Ecosystem Studies, Millbrook, New York, 1984-2004.

Month	H^+	Ca^{+2}	Cl^-	K^+	Mg^{+2}	Na^+	NH_4^+-N	NO_3^-N	PO_4^{-3}	SO_4^{-2}	SO_4^{-2}-S	NH_4^+-N + NO_3^--N
Jan	0.027	0.023	0.178	0.009	0.013	0.083	0.042	0.196	0.004	0.729	0.243	0.235
Feb	0.027	0.030	0.122	0.010	0.010	0.054	0.060	0.214	0.006	0.794	0.265	0.272
Mar	0.039	0.061	0.238	0.016	0.020	0.110	0.132	0.316	0.008	1.303	0.435	0.447
Apr	0.041	0.084	0.194	0.019	0.022	0.087	0.172	0.307	0.010	1.534	0.512	0.475
May	0.057	0.103	0.174	0.054	0.032	0.056	0.341	0.396	0.028	2.369	0.791	0.737
Jun	0.061	0.063	0.131	0.028	0.017	0.037	0.254	0.366	0.038	2.414	0.806	0.617
Jul	0.107	0.082	0.160	0.029	0.022	0.035	0.314	0.584	0.015	4.050	1.352	0.895
Aug	0.066	0.057	0.142	0.018	0.017	0.042	0.193	0.358	0.008	2.530	0.844	0.551
Sep	0.045	0.041	0.177	0.033	0.018	0.072	0.174	0.285	0.023	1.728	0.577	0.457
Oct	0.029	0.033	0.154	0.028	0.017	0.072	0.111	0.204	0.022	0.999	0.334	0.314
Nov	0.026	0.021	0.216	0.010	0.016	0.111	0.066	0.194	0.005	0.816	0.272	0.261
Dec	0.028	0.025	0.201	0.009	0.015	0.089	0.065	0.215	0.004	0.861	0.287	0.278

A3. Annual volume-weighted mean concentration (mg/L, except pH) and total precipitation amount (cm) of major ions in precipitation. Concentrations below detection limits are set to half the detection limit. Standard deviations are below means.
Institute of Ecosystem Studies, Millbrook, New York, 1984-2004.

Year	H^+	pH	Ca^{+2}	Cl^-	K^+	Mg^{+2}	Na^+	NH_4^+	NO_3^-	PO_4^{-3}	SO_4^{-2}	Amount	# Events	% Volume as Snow
1984	0.051 0.049	4.29	0.11 0.13	0.21 0.25	0.09 0.17	0.04 0.03	0.09 0.15	0.37 0.51	1.56 1.74	0.035 0.051	2.1 2.1	102.6	79	4%
1985	0.070 0.055	4.16	0.07 0.11	0.22 0.27	0.02 0.02	0.02 0.03	0.07 0.14	0.28 0.31	2.07 1.69	0.020 0.015	2.7 2.3	102.9	98	4%
1986	0.071 0.056	4.15	0.04 0.09	0.20 0.23	0.01 0.01	0.02 0.03	0.06 0.13	0.25 0.28	1.73 1.41	0.017 0.018	2.6 2.4	95.8	83	12%
1987	0.061 0.071	4.22	0.03 0.06	0.19 0.35	0.02 0.13	0.02 0.06	0.08 0.19	0.22 0.40	1.42 1.55	0.044 0.324	2.1 2.7	99.1	85	2%
1988	0.085 0.084	4.07	0.07 0.12	0.22 0.19	0.02 0.02	0.02 0.02	0.07 0.10	0.33 0.38	2.08 2.00	0.021 0.020	3.2 3.5	110.1	128	6%
1989	0.056 0.047	4.25	0.05 0.10	0.31 0.32	0.03 0.07	0.02 0.03	0.08 0.16	0.23 0.36	1.52 1.62	0.019 0.053	2.0 2.0	115.9	131	3%
1990	0.053 0.056	4.27	0.04 0.09	0.22 0.29	0.02 0.02	0.02 0.03	0.09 0.15	0.19 0.32	1.54 2.05	0.012 0.012	1.9 2.3	130.0	96	3%
1991	0.067 0.059	4.17	0.05 0.08	0.15 0.14	0.02 0.02	0.02 0.02	0.06 0.07	0.28 0.34	1.79 1.73	0.016 0.013	2.5 2.5	102.8	91	5%
1992	0.057 0.039	4.24	0.04 0.06	0.24 0.30	0.02 0.01	0.02 0.02	0.10 0.17	0.21 0.25	1.67 1.24	0.011 0.009	2.1 1.4	88.2	116	6%
1993	0.057 0.055	4.24	0.05 0.14	0.20 0.36	0.02 0.02	0.02 0.06	0.09 0.20	0.19 0.23	1.53 1.52	0.004 0.005	2.0 2.3	99.5	106	10%
1994	0.052 0.049	4.29	0.06 0.08	0.17 0.15	0.01 0.01	0.02 0.02	0.07 0.16	0.20 0.28	1.50 1.50	0.004 0.005	1.9 2.1	116.1	105	4%
1995	0.047 0.046	4.33	0.06 0.11	0.25 0.27	0.02 0.03	0.02 0.02	0.11 0.16	0.22 0.34	1.61 2.08	0.005 0.009	1.7 1.9	108.0	105	9%
1996	0.042 0.043	4.38	0.06 0.11	0.23 0.32	0.02 0.02	0.02 0.03	0.11 0.18	0.19 0.32	1.51 1.81	0.003 0.004	1.5 1.8	142.9	120	12%
1997	0.051 0.044	4.29	0.07 0.10	0.17 0.20	0.02 0.03	0.02 0.02	0.08 0.11	0.23 0.26	1.53 1.36	0.003 0.004	1.9 1.9	96.2	98	5%
1998	0.044 0.043	4.36	0.06 0.08	0.13 0.16	0.02 0.02	0.02 0.03	0.06 0.08	0.22 0.35	1.37 1.64	0.004 0.005	1.6 1.8	99.8	94	1%
1999	0.037 0.044	4.43	0.06 0.10	0.21 0.47	0.02 0.02	0.02 0.04	0.10 0.27	0.15 0.21	1.19 1.56	0.004 0.008	1.3 1.7	105.2	80	2%
2000	0.045 0.048	4.35	0.07 0.14	0.16 0.19	0.02 0.04	0.02 0.02	0.08 0.10	0.22 0.28	1.50 1.59	0.008 0.038	1.6 2.0	115.9	87	8%
2001	0.041 0.034	4.39	0.07 0.15	0.14 0.13	0.02 0.02	0.02 0.04	0.06 0.07	0.21 0.23	1.38 1.31	0.005 0.006	1.6 1.8	79.7	77	8%
2002	0.034 0.040	4.47	0.07 0.11	0.12 0.15	0.06 0.09	0.02 0.02	0.06 0.08	0.30 0.41	1.21 1.35	0.076 0.190	1.4 1.8	113.4	94	4%
2003	0.030 0.032	4.52	0.05 0.10	0.20 0.31	0.02 0.04	0.02 0.02	0.10 0.17	0.18 0.36	1.07 1.39	0.020 0.128	1.1 1.3	139.7	103	13%
2004	0.038 0.033	4.42	0.05 0.07	0.14 0.15	0.04 0.11	0.02 0.02	0.06 0.08	0.24 0.28	1.13 1.18	0.008 0.030	1.5 1.6	111.0	107	4%
Average	0.051 0.052	4.29	0.06 0.10	0.20 0.27	0.02 0.06	0.02 0.03	0.08 0.15	0.23 0.33	1.51 1.64	0.016 0.086	1.9 2.2	103.9	2083	6%

A4. Monthly volume-weighted mean concentration (mg/L, except pH) of major ions in precipitation. Concentrations below detection limits are set to half the detection limit. Standard deviations are below means.
Institute of Ecosystem Studies, Millbrook, New York, 1984-2004.

Month	H^+	pH	Ca^{+2}	Cl^-	K^+	Mg^{+2}	Na^+	NH_4^+	NO_3^-	PO_4^{-3}	SO_4^{-2}	Avg. # Events
Jan	0.036	4.44	0.03	0.25	0.01	0.02	0.12	0.08	1.21	0.005	1.0	8
	0.029		0.04	0.34	0.01	0.02	0.20	0.10	1.11	0.006	0.8	
Feb	0.044	4.35	0.05	0.20	0.02	0.02	0.09	0.13	1.56	0.010	1.3	6
	0.032		0.08	0.24	0.02	0.02	0.14	0.15	1.46	0.018	1.1	
Mar	0.044	4.36	0.07	0.27	0.02	0.02	0.13	0.19	1.60	0.010	1.5	8
	0.043		0.12	0.40	0.02	0.04	0.22	0.34	2.14	0.014	1.6	
Apr	0.051	4.30	0.11	0.25	0.02	0.03	0.11	0.28	1.75	0.013	2.0	9
	0.034		0.14	0.30	0.02	0.03	0.17	0.29	1.40	0.022	1.4	
May	0.054	4.27	0.10	0.16	0.05	0.03	0.05	0.42	1.66	0.026	2.2	11
	0.043		0.13	0.13	0.07	0.05	0.06	0.42	1.56	0.049	2.0	
Jun	0.069	4.16	0.07	0.15	0.03	0.02	0.04	0.38	1.86	0.044	2.8	10
	0.055		0.12	0.12	0.06	0.02	0.05	0.37	1.53	0.145	2.4	
Jul	0.097	4.01	0.08	0.15	0.03	0.02	0.03	0.37	2.37	0.014	3.7	9
	0.077		0.10	0.11	0.09	0.02	0.04	0.34	1.80	0.018	3.2	
Aug	0.069	4.16	0.06	0.15	0.02	0.02	0.04	0.26	1.66	0.008	2.6	8
	0.066		0.09	0.15	0.03	0.02	0.07	0.28	1.59	0.010	2.7	
Sep	0.038	4.42	0.04	0.15	0.02	0.02	0.06	0.19	1.08	0.017	1.5	7
	0.051		0.08	0.27	0.08	0.02	0.13	0.30	1.47	0.070	2.1	
Oct	0.035	4.46	0.04	0.19	0.03	0.02	0.09	0.17	1.10	0.027	1.2	7
	0.045		0.11	0.26	0.13	0.05	0.14	0.42	1.87	0.259	1.8	
Nov	0.029	4.54	0.02	0.24	0.01	0.02	0.13	0.10	0.96	0.005	0.9	8
	0.032		0.04	0.37	0.01	0.03	0.23	0.14	1.31	0.007	1.0	
Dec	0.034	4.47	0.03	0.25	0.01	0.02	0.11	0.10	1.16	0.004	1.0	7
	0.030		0.06	0.31	0.01	0.03	0.17	0.16	1.30	0.006	1.0	

A5. Annual mean concentration (mg/L, except pH) of major ions and conductivity (μmho) and discharge (m^3/s) for the East Branch of Wappinger Creek, Site 2 (Fern Glen). Concentrations below detection limits are set to half the detection limit. Standard deviations are below means (n=12 months except for 1985, n=2 months). Samples collected prior to 1999 were not preserved. Discharge averages include daily average values for dates on which samples were collected. Institute of Ecosystem Studies, Millbrook, New York, 1985-2004.

YEAR	pH	Ca^{+2}	Cl^{-}	K^{+}	Mg^{+2}	Na^{+}	NH_4^{+}	NO_3^{-}	PO_4^{-3}	SO_4^{-2}	SiO_2	Cond.	Q (m^3/s)
1985	7.74	35.4	25.2	1.37	10.0	8.36	0.01	3.26	0.062	26.0	7.8	295	0.97
		4.2	12.2	0.33	0.1	0.41	0.00	1.69	0.033	4.7	0.3	8	
1986	7.80	32.3	15.8	1.20	9.16	8.03	0.02	3.06	0.066	16.4	6.6	264	1.23
		5.1	1.8	0.34	1.57	0.90	0.02	1.62	0.041	1.9	0.7	42	
1987	7.91	32.8	17.7	1.16	9.34	9.16	0.02	3.83	0.149	16.7	5.5	293	0.92
		4.1	2.4	0.29	1.46	1.33	0.02	1.30	0.119	3.0	1.1	36	
1988	7.89	31.3	18.5	1.21	8.85	9.43	0.01	3.17	0.092	16.1	5.3	268	1.14
		5.1	3.4	0.33	1.60	1.64	0.01	1.47	0.051	1.5	1.7	40	
1989	7.77	29.9	18.0	1.31	8.43	9.62	0.04	3.05	0.090	15.4	4.8	259	1.06
		5.7	2.6	0.39	1.58	1.41	0.09	1.06	0.122	1.7	1.2	44	
1990	8.04	31.0	18.0	1.22	8.69	10.0	0.02	3.33	0.073	14.5	4.9	266	1.10
		4.9	2.6	0.43	1.42	1.3	0.01	1.10	0.049	2.1	1.5	35	
1991	8.09	31.0	17.5	1.17	8.74	10.1	0.02	3.18	0.116	16.3	5.0	265	0.52
		3.3	2.1	0.32	1.17	1.3	0.02	1.04	0.074	2.4	1.0	29	
1992	8.14	33.4	20.3	1.24	9.50	11.1	0.02	3.69	0.122	13.9	4.3	287	0.41
		5.5	2.3	0.44	1.80	1.5	0.01	1.78	0.099	2.1	1.5	48	
1993	7.96	31.9	25.5	1.27	9.23	12.8	0.02	3.11	0.179	16.2	4.0	294	0.76
		6.9	4.9	0.39	2.39	2.9	0.01	1.55	0.341	4.4	1.9	60	
1994	7.96	31.9	24.0	1.13	8.62	12.6	0.01	1.92	0.068	14.1	5.6	284	1.07
		5.4	3.0	0.36	1.61	1.3	0.01	1.20	0.086	2.8	1.4	40	
1995	8.00	33.2	24.4	1.19	8.75	13.7	0.02	1.97	0.120	15.6	3.9	296	1.26
		5.4	5.3	0.49	1.86	3.0	0.03	2.41	0.201	3.1	1.4	49	
1996	8.00	30.4	25.1	0.94	7.94	13.6	0.01	1.02	0.015	13.5	3.0	274	1.22
		5.3	4.4	0.15	1.50	1.7	0.00	1.25	0.018	1.6	2.2	38	
1997	8.07	34.6	27.1	1.26	9.63	15.3	0.01	2.94	0.073	17.4	3.9	313	0.64
		6.5	3.3	0.39	2.38	2.3	0.01	2.36	0.131	5.1	2.6	53	
1998	8.04	37.2	29.8	1.20	9.88	16.6	0.01	3.52	0.142	18.4	4.3	334	0.70
		6.4	5.6	0.41	2.15	3.5	0.00	1.86	0.136	3.5	2.1	57	
1999	8.04	33.0	30.5	1.12	8.70	16.4	0.03	3.88	0.249	18.8	5.8	304	0.79
		6.8	5.7	0.40	1.97	3.2	0.01	3.19	0.250	4.6	1.8	63	
2000	8.04	32.9	28.3	0.96	8.87	16.4	0.03	2.46	0.134	13.9	5.6	304	0.90
		3.9	3.0	0.24	1.35	1.9	0.02	1.09	0.064	2.1	1.1	39	
2001	8.15	38.5	41.9	1.37	10.9	23.6	0.04	5.71	0.346	18.1	5.4	382	0.40
		5.5	10.9	0.51	2.2	7.0	0.05	4.80	0.294	6.7	1.4	66	
2002	8.11	37.9	45.6	1.33	10.2	25.1	0.01	4.05	0.348	18.9	4.8	350	0.37
		6.4	9.2	0.36	2.2	6.9	0.00	3.01	0.259	3.6	1.7	65	
2003	8.04	30.2	36.8	1.20	7.9	20.2	0.04	2.52	0.18	13.1	5.8	300	1.45
		5.5	9.2	0.34	1.5	4.2	0.08	1.24	0.11	2.4	1.6	53	
2004	8.16	33.5	37.3	1.22	9.0	21.4	0.02	2.49	0.21	13.4	5.6	334	0.71
		3.7	4.4	0.28	1.1	2.6	0.01	1.36	0.11	1.6	1.6	36	
Average	8.00	33.0	26.5	1.19	9.08	14.5	0.02	3.10	0.146	15.9	5.0	299	0.93
		5.7	9.9	0.37	1.84	5.8	0.03	2.19	0.179	3.8	1.8	56	

A6. Annual mean concentration (mg/L, except pH) of major ions and conductivity (μmho) for the East Branch of Wappinger Creek, Site 4 (Lowlands). Concentrations below detection limits were set to half the detection limit. Standard deviations are below means (n=12 months). Samples collected prior to 1999 were not preserved. Institute of Ecosystem Studies, Millbrook, New York, 1985-2004.

Year	pH	Ca^{+2}	Cl^{-}	K^{+}	Mg^{+2}	Na^{+}	NH_4^{+}	NO_3^{-}	PO_4^{-3}	SO_4^{-2}	SiO_2	Cond.
1985	7.91	36.2	25.4	1.18	8.71	11.7	0.03	3.66	0.092	23.3	6.4	305
		3.4	6.2	0.17	1.15	1.5	0.03	2.01	0.033	3.0	1.3	31
1986	7.72	33.2	20.5	1.17	8.56	10.4	0.02	3.22	0.044	18.1	6.9	276
		4.6	2.3	0.26	1.41	0.7	0.01	1.54	0.021	1.5	0.4	43
1987	7.94	34.1	21.8	1.11	8.73	11.5	0.02	3.58	0.094	18.4	5.9	293
		4.0	2.4	0.23	1.22	1.4	0.02	1.02	0.032	2.7	1.2	33
1988	7.85	32.9	23.2	1.16	8.30	12.2	0.01	3.42	0.094	18.0	5.8	283
		4.8	3.2	0.25	1.46	1.2	0.01	1.14	0.075	1.3	1.6	37
1989	7.81	31.4	23.4	1.26	7.94	12.5	0.04	3.40	0.043	17.2	5.2	280
		5.2	1.8	0.32	1.36	0.9	0.07	0.85	0.040	1.6	1.4	35
1990	7.99	32.3	23.7	1.19	8.14	13.0	0.02	3.62	0.078	16.5	5.7	276
		4.4	2.1	0.28	1.16	0.9	0.02	1.25	0.098	2.0	1.9	34
1991	8.04	32.3	22.4	1.13	8.08	13.0	0.02	3.39	0.056	18.2	5.5	285
		3.3	2.4	0.20	1.00	1.2	0.02	0.92	0.030	2.0	0.9	26
1992	7.93	34.6	24.1	1.14	8.79	14.1	0.02	3.27	0.055	16.5	5.2	305
		4.7	4.4	0.26	1.51	0.7	0.01	0.99	0.044	1.7	1.0	37
1993	7.78	33.9	31.2	1.22	8.51	15.8	0.02	2.63	0.029	17.8	5.1	316
		6.8	5.5	0.26	1.97	2.6	0.02	1.23	0.031	4.0	1.4	54
1994	7.81	34.0	30.2	1.14	8.06	16.3	0.01	2.18	0.032	16.1	6.1	311
		5.1	4.3	0.30	1.41	1.7	0.01	1.00	0.025	2.5	1.2	38
1995	7.86	34.6	29.3	1.11	8.26	16.2	0.02	1.95	0.037	17.0	3.4	314
		4.3	2.4	0.32	1.48	0.9	0.02	1.44	0.057	2.8	1.8	31
1996	7.93	32.1	30.4	0.98	7.46	16.9	0.01	2.16	0.012	15.2	5.2	299
		4.5	4.3	0.12	1.31	1.4	0.00	1.70	0.017	1.4	1.5	32
1997	8.03	35.3	31.5	1.16	8.74	17.4	0.02	2.27	0.023	17.6	4.8	321
		5.4	3.4	0.27	1.84	1.6	0.01	1.04	0.032	4.0	2.2	36
1998	7.99	37.2	33.1	1.05	8.93	18.5	0.01	2.29	0.053	18.2	4.7	337
		5.0	3.8	0.21	1.64	1.9	0.00	0.83	0.050	2.6	1.9	40
1999	7.98	34.3	35.4	1.01	7.97	19.2	0.02	2.32	0.100	18.6	5.7	328
		6.0	3.7	0.17	1.46	2.0	0.01	0.86	0.059	3.3	1.6	42
2000	8.08	34.4	32.8	0.92	8.41	19.0	0.05	2.43	0.088	14.9	5.9	324
		4.2	5.3	0.17	1.30	3.1	0.04	1.11	0.039	2.2	0.9	37
2001	8.19	39.1	42.7	1.07	9.70	23.1	0.03	3.25	0.125	17.8	6.0	377
		4.4	4.5	0.20	1.55	1.8	0.03	0.90	0.064	4.6	1.2	36
2002	8.12	38.7	48.8	1.11	9.24	25.9	0.01	2.57	0.152	19.4	5.3	359
		4.6	5.8	0.15	1.64	2.6	0.01	0.70	0.058	3.1	1.4	56
2003	8.08	31.8	42.1	1.11	7.41	23.2	0.02	2.59	0.115	14.4	6.2	321
		4.7	8.8	0.29	1.28	3.6	0.04	1.17	0.059	2.1	1.4	45
2004	8.12	34.3	42.2	1.12	8.26	24.2	0.01	2.51	0.141	14.5	6.0	353
		3.2	4.6	0.21	0.92	2.4	0.01	1.12	0.077	1.3	1.5	31
Average	7.94	34.3	30.8	1.12	8.41	16.8	0.02	2.83	0.073	17.4	5.6	313
		5.0	9.0	0.24	1.47	4.8	0.02	1.26	0.063	3.2	1.5	46

A7. Monthly mean concentration (mg/L, except pH) of major ions and conductivity (μmho) and discharge (m^3/s) for the East Branch of Wappinger Creek, Site 2 (Fern Glen). Concentrations below detection limits were set to half the detection limit. Standard deviations are below means (n=20 years). Samples collected prior to 1999 were not preserved. Discharge averages include daily average values for dates on which samples were collected.
Institute of Ecosystem Studies, Millbrook, New York, 1985-2004.

Month	pH	Ca^{+2}	Cl^{-}	K^{+}	Mg^{+2}	Na^{+}	NH_4^{+}	NO_3^{-}	PO_4^{-3}	SO_4^{-2}	SiO_2	Cond.	Q (m^3/s)
Jan	7.92	31.3	25.4	1.09	8.53	13.6	0.02	4.00	0.083	17.4	5.7	284	1.66
		6.0	9.1	0.22	1.93	5.3	0.02	1.34	0.094	2.7	1.6	52	
Feb	7.92	30.3	27.6	1.07	8.34	14.5	0.05	3.86	0.092	16.9	5.1	286	1.69
		4.9	10.4	0.28	1.54	5.9	0.07	1.42	0.086	2.1	1.8	53	
Mar	7.87	27.0	24.4	0.92	7.22	12.8	0.01	2.47	0.053	15.2	3.7	252	1.55
		4.4	8.3	0.14	1.47	4.7	0.01	1.06	0.052	2.5	1.5	44	
Apr	8.16	29.7	24.5	0.85	7.86	13.0	0.02	1.45	0.046	14.7	2.6	273	1.15
		3.4	8.8	0.10	0.90	4.6	0.02	0.91	0.039	1.8	1.1	37	
May	8.08	31.5	24.8	0.88	8.44	13.4	0.02	1.72	0.090	13.5	3.7	277	0.86
		4.0	7.4	0.11	1.18	4.3	0.01	1.01	0.068	1.4	1.8	43	
Jun	8.05	34.8	26.5	1.00	9.55	14.5	0.01	2.60	0.163	12.6	4.6	308	0.37
		2.5	7.9	0.16	0.85	4.3	0.01	1.63	0.139	1.8	1.8	32	
Jul	8.05	36.1	29.4	1.21	10.2	16.6	0.01	3.75	0.260	13.7	5.1	333	0.46
		4.4	11.8	0.25	1.4	6.4	0.01	2.26	0.175	2.2	1.9	58	
Aug	8.10	38.1	31.4	1.42	10.5	17.8	0.01	4.41	0.362	15.7	6.1	343	0.21
		3.6	12.5	0.29	1.2	7.6	0.01	2.86	0.345	4.5	0.9	50	
Sep	8.03	37.7	27.5	1.63	10.5	15.4	0.03	2.88	0.190	17.6	5.8	331	0.44
		4.9	10.7	0.30	1.7	6.7	0.06	2.28	0.175	6.0	1.2	41	
Oct	8.02	36.5	27.5	1.76	10.3	15.4	0.01	3.51	0.200	18.0	5.2	327	1.11
		6.2	11.4	0.32	2.2	6.8	0.01	3.66	0.193	4.4	1.3	63	
Nov	7.93	30.9	23.5	1.43	8.65	13.2	0.02	2.90	0.120	17.2	5.5	280	0.84
		4.5	9.5	0.28	1.36	5.9	0.02	2.78	0.169	3.5	1.8	54	
Dec	7.92	32.0	25.3	1.07	8.86	13.5	0.02	3.59	0.090	18.4	5.9	287	1.40
		6.5	9.9	0.22	2.13	5.4	0.02	1.14	0.128	3.9	1.1	62	

A8. Monthly mean concentration (mg/L, except pH) of major ions and conductivity (μmho) for the East Branch of Wappinger Creek, Site 4 (Lowlands). Concentrations below detection limits were set to half the detection limit. Standard deviations are below means (n=20 years). Samples collected prior to 1999 were not preserved.
Institute of Ecosystem Studies, Millbrook, New York, 1985-2004.

Month	PH	Ca^{+2}	Cl^{-}	K^{+}	Mg^{+2}	Na^{+}	NH_4^{+}	NO_3^{-}	PO_4^{-3}	SO_4^{-2}	SiO_2	Cond.
Jan	7.88	32.9	30.9	1.06	8.06	16.8	0.02	4.17	0.069	18.9	6.3	307
		5.2	9.2	0.19	1.61	4.9	0.02	0.98	0.060	2.8	1.0	46
Feb	7.90	32.4	34.9	1.06	7.98	18.4	0.04	4.31	0.063	18.6	5.7	316
		4.8	10.9	0.24	1.39	5.9	0.05	1.46	0.064	2.3	1.1	48
Mar	7.88	28.9	29.7	0.96	6.82	16.0	0.02	2.99	0.045	17.0	4.6	276
		4.2	10.6	0.16	1.24	5.2	0.03	0.89	0.046	2.7	0.9	45
Apr	8.10	31.6	29.6	0.87	7.44	15.8	0.02	2.03	0.032	16.6	3.4	292
		3.4	9.0	0.08	0.82	4.9	0.02	0.99	0.026	2.4	1.0	37
May	8.05	33.0	29.4	0.93	7.90	15.8	0.02	2.08	0.065	15.8	4.8	295
		4.0	8.3	0.11	1.00	4.7	0.02	1.11	0.050	3.5	1.1	44
Jun	7.97	35.8	29.8	1.01	8.80	16.5	0.01	2.37	0.095	14.6	5.4	320
		1.9	8.1	0.10	0.64	4.4	0.01	0.86	0.067	1.9	1.7	31
Jul	7.90	36.6	30.4	1.12	9.12	16.9	0.02	2.42	0.096	15.5	5.7	326
		3.8	9.5	0.14	1.14	5.0	0.02	1.06	0.075	1.9	1.9	52
Aug	7.96	38.6	32.5	1.19	9.47	17.8	0.02	2.66	0.106	16.8	6.3	342
		2.4	8.5	0.09	0.73	5.0	0.01	1.20	0.071	2.9	0.8	31
Sep	7.92	38.5	31.8	1.41	9.62	17.6	0.02	2.22	0.115	18.6	6.3	344
		3.6	8.4	0.21	1.30	4.9	0.03	0.97	0.088	4.4	1.7	28
Oct	7.96	37.4	31.2	1.46	9.34	17.0	0.02	2.25	0.074	18.9	5.7	334
		5.2	8.7	0.21	1.68	4.6	0.02	0.88	0.050	3.3	1.5	44
Nov	7.92	32.8	28.7	1.31	8.12	15.9	0.02	2.66	0.058	18.3	6.2	301
		4.5	7.8	0.21	1.29	4.2	0.01	0.75	0.040	2.9	0.9	44
Dec	7.92	33.1	30.6	1.03	8.15	16.3	0.02	3.74	0.059	19.0	6.4	304
		5.2	9.5	0.11	1.59	4.7	0.02	0.80	0.059	3.1	0.7	51

A9. Annual total dry deposition (kg/ha) of aerosols, HNO_3 vapor and SO_2 from low volume filter packs. Concentrations below detection limits were set to half the detection limit. Institute of Ecosystem Studies, Millbrook, New York, 1988-2004.

	Aerosols								Gases			
Year	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	NH_4^{+}	NO_3^{-}	SO_4^{-2}	HNO_3	SO_2	Total N	Total S
1988	0.07	0.03	0.07	0.03	0.02	0.56	0.04	0.73	5.3	8.1	5.9	8.5
1989	0.07	0.02	0.07	0.03	0.02	0.52	0.03	0.76	5.6	8.4	6.2	9.2
1990	0.07	0.02	0.07	0.02	0.01	0.43	0.05	0.63	4.6	8.0	5.1	8.6
1991	0.07	0.02	0.05	0.02	0.00	0.58	0.03	0.73	4.9	7.8	5.5	8.2
1992	0.06	0.02	0.07	0.02	0.01	0.44	0.04	0.60	4.8	5.0	5.3	5.6
1993	0.05	0.02	0.07	0.02	0.02	0.37	0.03	0.52	4.8	4.4	5.2	5.0
1994	0.06	0.02	0.06	0.02	0.02	0.46	0.04	0.66	5.0	5.2	5.5	5.9
1995	0.06	0.02	0.07	0.02	0.02	0.37	0.04	0.54	4.3	ND	4.6	ND
1996	0.05	0.02	0.08	0.02	0.02	0.36	0.04	0.51	4.1	ND	4.4	ND
1997	0.05	0.02	0.06	0.03	0.01	0.34	0.03	0.46	3.7	3.2	4.1	3.6
1998	0.05	0.02	0.05	0.02	0.01	0.30	0.05	0.39	3.5	4.3	3.8	4.7
1999	0.04	0.01	0.05	0.01	0.01	0.26	0.02	0.35	2.7	3.2	2.7	3.6
2000	0.05	0.01	0.06	0.03	0.02	0.36	0.04	0.48	3.9	3.0	4.1	3.5
2001	0.08	0.02	0.07	0.02	0.01	0.40	0.03	0.58	4.1	3.1	4.4	3.4
2002	0.07	0.02	0.08	0.02	0.02	0.42	ND	0.50	3.8	3.2	4.0	3.7
2003	0.04	0.01	0.06	0.02	0.02	ND	ND	0.32	3.9	3.0	ND	3.3
2004	0.04	0.01	0.06	0.01	0.02	0.26	0.04	0.32	2.7	3.5	3.0	3.8
Average	0.06	0.02	0.06	0.02	0.02	0.40	0.04	0.53	4.2	4.6	4.6	5.0

ND = no data

A10. Monthly average deposition (kg/ha) of aerosols, HNO_3 vapor and SO_2 from low volume filter packs. Concentrations below detection limits were set to half the detection limit. Values are total deposition for every month from 1988-2004 averaged for all years (n=17 years).

Institute of Ecosystem Studies, Millbrook, New York, 1988-2004.

	Aerosols								Gases	
Month	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	NH_4^{+}	NO_3^{-}	SO_4^{-2}	HNO_3	SO_2
Jan	0.003	0.001	0.008	0.001	0.003	0.016	0.005	0.019	0.190	0.611
Feb	0.003	0.001	0.008	0.001	0.003	0.019	0.006	0.024	0.225	0.452
Mar	0.006	0.002	0.009	0.002	0.001	0.030	0.006	0.040	0.388	0.400
Apr	0.007	0.002	0.007	0.002	0.001	0.032	0.004	0.043	0.431	0.287
May	0.007	0.002	0.006	0.003	0.001	0.042	0.003	0.058	0.551	0.348
Jun	0.006	0.002	0.004	0.003	0.001	0.050	0.002	0.069	0.472	0.407
Jul	0.006	0.002	0.003	0.003	0.001	0.068	0.001	0.086	0.478	0.443
Aug	0.005	0.002	0.004	0.002	0.001	0.052	0.001	0.075	0.474	0.456
Sep	0.004	0.001	0.004	0.002	0.001	0.036	0.001	0.048	0.331	0.340
Oct	0.004	0.001	0.004	0.002	0.001	0.027	0.003	0.034	0.328	0.362
Nov	0.003	0.001	0.003	0.001	0.001	0.018	0.004	0.021	0.227	0.410
Dec	0.002	0.001	0.004	0.001	0.001	0.011	0.002	0.014	0.134	0.408

A11. Annual mean concentrations ($\mu g/m^3$) of aerosols, HNO_3 vapor and SO_2 from low volume filter packs. Concentrations below detection limits were set to half the detection limit. Standard deviations are below means, n=approximately 52 weeks.
Institute of Ecosystem Studies, Millbrook, New York, 1988-2004.

	Aerosols									Gases	
Year	H^+	Ca^{+2}	Mg^{+2}	Na^+	K^+	Cl^-	NH_4^+	NO_3^-	SO_4^{-2}	HNO_3	SO_2
1988	0.023	0.20	0.07	0.22	0.07	0.05	1.9	0.58	5.7	3.1	15.3
	0.043	0.09	0.03	0.17	0.04	0.66	4.3	0.08	1.4	1.3	9.9
1989	0.020	0.17	0.06	0.18	0.08	0.04	1.6	0.39	5.4	3.0	14.8
	0.019	0.07	0.02	0.17	0.05	0.36	3.1	0.08	1.0	1.4	9.6
1990	0.020	0.18	0.06	0.20	0.06	0.02	1.5	0.63	5.0	2.6	15.0
	0.023	0.09	0.03	0.23	0.04	0.72	3.1	0.03	0.9	1.1	13.2
1991	0.016	0.16	0.06	0.14	0.07	0.02	1.9	0.39	5.6	3.0	14.7
	0.013	0.06	0.03	0.09	0.03	0.30	5.9	0.03	2.8	1.2	10.2
1992	0.016	0.13	0.05	0.16	0.06	0.03	1.4	0.45	4.4	2.5	8.7
	0.021	0.06	0.02	0.16	0.03	0.52	2.6	0.07	0.7	1.2	5.9
1993	0.009	0.13	0.05	0.18	0.04	0.04	1.2	0.37	3.9	2.7	8.0
	0.010	0.04	0.02	0.17	0.03	0.33	2.2	0.08	0.6	1.2	4.7
1994	0.011	0.15	0.05	0.17	0.05	0.06	1.4	0.50	4.6	2.7	9.5
	0.019	0.07	0.02	0.16	0.02	0.38	3.2	0.08	0.9	1.2	11.0
1995	0.004	0.15	0.05	0.18	0.05	0.06	1.1	0.42	3.7	2.3	ND
	0.004	0.05	0.02	0.14	0.04	0.32	2.4	0.07	0.7	1.1	
1996	0.008	0.13	0.05	0.20	0.05	0.04	1.2	0.42	4.0	2.1	ND
	0.013	0.06	0.02	0.18	0.02	0.44	2.5	0.06	0.7	1.2	
1997	0.003	0.14	0.04	0.16	0.08	0.04	1.1	0.41	3.6	2.0	7.1
	0.003	0.05	0.02	0.14	0.06	0.28	1.7	0.05	0.5	1.0	5.9
1998	0.005	0.14	0.05	0.14	0.05	0.04	1.1	0.68	3.2	2.1	8.4
	0.008	0.07	0.02	0.13	0.03	0.80	2.5	0.05	0.6	1.2	7.3
1999	0.003	0.14	0.04	0.18	0.04	0.07	1.1	0.42	3.1	2.0	7.2
	0.003	0.06	0.02	0.13	0.03	0.26	1.7	0.07	0.6	0.9	5.0
2000	0.002	0.13	0.04	0.17	0.08	0.05	1.2	0.49	3.7	2.1	5.4
	0.003	0.05	0.02	0.16	0.10	0.58	2.0	0.08	0.6	1.1	4.3
2001	0.004	0.18	0.05	0.19	0.05	0.03	1.3	0.40	4.5	2.3	7.8
	0.004	0.12	0.03	0.15	0.03	0.39	2.9	0.03	0.9	1.2	5.0
2002	0.009	0.15	0.05	0.20	0.06	0.05	1.2	ND	3.3	1.9	6.5
	0.006	0.09	0.02	0.14	0.04	0.10	0.7		2.0	1.3	5.8
2003	0.007	0.11	0.04	0.21	0.06	0.06	ND	ND	3.0	2.5	6.3
	0.004	0.06	0.22	0.24	0.07	0.10			1.8	1.4	5.7
2004	0.007	0.12	0.04	0.18	0.04	0.07	1.0	0.62	2.9	1.7	6.6
	0.005	0.07	0.02	0.17	0.03	0.14	0.6	0.63	2.0	1.0	4.4
Average	0.010	0.15	0.05	0.18	0.06	0.04	1.3	0.50	4.1	2.4	9.4

ND=no data

A12. Monthly mean concentrations ($\mu g/m^3$) of aerosols, HNO_3 vapor and SO_2. Concentrations below detection limits were set to half the detection limit. Standard deviations are below means, n=17 years.
Institute of Ecosystem Studies, Millbrook, New York, 1988-2004.

Month	H^+	Ca^{+2}	Mg^{+2}	Na^+	K^+	Cl^-	NH_4^+	NO_3^-	SO_4^{-2}	HNO_3	SO_2
Jan	0.006	0.13	0.04	0.33	0.06	0.12	1.0	1.00	2.9	1.6	18.9
	0.005	0.06	0.02	0.20	0.04	0.14	0.4	0.68	1.2	0.8	12.7
Feb	0.008	0.15	0.05	0.35	0.05	0.12	1.1	1.02	3.3	2.1	15.8
	0.010	0.05	0.02	0.16	0.02	0.13	0.4	0.69	1.3	1.0	10.4
Mar	0.006	0.17	0.05	0.26	0.05	0.04	1.2	0.82	3.5	2.5	10.2
	0.006	0.08	0.03	0.16	0.04	0.04	0.6	0.75	1.8	1.1	7.1
Apr	0.006	0.18	0.05	0.16	0.04	0.03	1.0	0.50	3.3	2.6	6.0
	0.009	0.09	0.03	0.14	0.02	0.04	0.5	0.42	1.5	1.3	4.6
May	0.011	0.16	0.05	0.13	0.06	0.02	1.3	0.34	4.0	3.0	5.2
	0.022	0.09	0.02	0.10	0.05	0.03	0.6	0.24	2.0	1.3	3.5
Jun	0.015	0.16	0.05	0.10	0.08	0.03	1.7	0.22	5.4	3.0	6.2
	0.030	0.09	0.02	0.10	0.06	0.06	0.9	0.17	3.2	1.2	5.0
Jul	0.020	0.16	0.05	0.09	0.09	0.02	2.3	0.13	6.9	3.2	7.0
	0.023	0.06	0.03	0.09	0.07	0.02	2.3	0.10	4.9	1.1	6.0
Aug	0.021	0.15	0.05	0.11	0.06	0.02	2.0	0.13	6.7	3.2	7.2
	0.023	0.07	0.03	0.10	0.03	0.01	1.2	0.11	3.9	1.1	6.0
Sep	0.012	0.12	0.05	0.13	0.06	0.02	1.5	0.20	4.6	2.4	5.9
	0.018	0.06	0.03	0.12	0.03	0.02	0.9	0.14	3.1	1.2	5.0
Oct	0.007	0.14	0.04	0.14	0.06	0.02	1.0	0.48	3.2	2.2	7.1
	0.008	0.07	0.02	0.18	0.06	0.02	0.6	0.56	2.1	1.2	5.1
Nov	0.004	0.14	0.04	0.13	0.05	0.03	0.92	0.63	2.6	1.7	10.4
	0.004	0.08	0.02	0.12	0.03	0.06	0.37	0.55	1.2	0.9	7.5
Dec	0.004	0.12	0.04	0.22	0.04	0.07	0.83	0.61	2.5	1.2	13.9
	0.004	0.05	0.02	0.19	0.02	0.09	0.27	0.37	1.0	0.6	9.2

A13. Annual mean deposition velocities (cm/s) for aerosols, HNO_3 vapor and SO_2. Standard deviations are below means, n=approximately 52 weeks. Institute of Ecosystem Studies, Millbrook, New York, 1988-2004.

Year	Particulate vd	HNO_3 vd	SO_2 vd
1988	0.13	2.72	0.40
	0.04	0.50	0.10
1989	0.13	2.70	0.40
	0.04	0.43	0.10
1990	0.13	2.55	0.39
	0.05	0.75	0.12
1991	0.13	2.51	0.39
	0.07	1.08	0.14
1992	0.13	2.74	0.39
	0.04	0.55	0.11
1993	0.12	2.57	0.38
	0.04	0.50	0.09
1994	0.13	2.59	0.41
	0.04	0.48	0.11
1995	0.13	2.66	0.39
	0.04	0.48	0.10
1996	0.12	2.61	0.36
	0.04	0.76	0.09
1997	0.12	2.54	0.36
	0.05	0.73	0.11
1998	0.10	2.25	0.36
	0.04	0.69	0.12
1999	0.09	1.98	0.33
	0.04	0.90	0.14
2000	0.12	2.62	0.39
	0.04	0.44	0.10
2001	0.13	2.67	0.29
	0.05	0.56	0.08
2002	0.13	2.65	0.34
	0.04	0.56	0.07
2003	0.11	2.32	0.37
	0.03	0.39	0.09
2004	0.10	2.13	0.37
	0.03	0.41	0.10
Average	0.12	2.52	0.37

A14. Monthly mean deposition velocities (cm/s) for aerosols, HNO_3 vapor and SO_2, n=62-70.
Institute of Ecosystem Studies, Millbrook, New York, 1988-2004.

Month	Particulate vd	HNO_3 vd	SO_2 vd
Jan	0.08	2.16	0.26
Feb	0.10	2.28	0.26
Mar	0.13	2.73	0.31
Apr	0.16	3.06	0.39
May	0.16	3.06	0.47
Jun	0.15	2.81	0.50
Jul	0.14	2.63	0.47
Aug	0.12	2.44	0.46
Sep	0.12	2.40	0.43
Oct	0.12	2.47	0.37
Nov	0.09	2.24	0.29
Dec	0.07	1.95	0.24