

METEOROLOGICAL AND DEPOSITION CHEMISTRY MONITORING

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COOPERATORS:

UVM Proctor Maple Research Center (PMRC), VT Dept. of Environmental Conservation (DEC), WCAX-TV staff at Mt. Mansfield transmitter station, National Atmospheric Deposition Program (NADP), US Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), University of Michigan Air Quality Laboratory (UMAQL), Lake Champlain Research Consortium (LCRC), National Weather Service (NWS), and the Electric Power Research Institute (EPRI).

ABSTRACT:

Continuous monitoring of meteorology and wet and dry deposition chemistry has been conducted at the VMC Mansfield site. This work is a fundamental component of the monitoring and research activities there, providing basic information on the physical and chemical environment. Several projects are underway, including (a) basic meteorology at four locations, (b) four precipitation chemistry monitoring programs, and (c) a dry deposition monitoring program. Continuous hourly meteorology data from PMRC (400 m elevation) are available from 1988 to present, and daily temperature and precipitation data from the summit of Mt. Mansfield (1205 m) are available from 1954 to present. In addition, meteorology is monitored within the forest at the canopy research tower and the Nettle Brook gauging station; these are discussed elsewhere in the Annual Report. The National Atmospheric Deposition Program, operating at PMRC since 1984, provides weekly analysis of major ions in precipitation, while the Atmospheric Integrated Research Monitoring Network (AIRMoN), established in January 1993, provides similar data on a daily basis. In addition, atmospheric mercury monitoring in precipitation, gaseous and aerosol phases was established in 1993, and the Vermont Acid Precipitation Monitoring Program provides daily precipitation pH since 1980 (Mount Mansfield summit) and 1983 (PMRC); these projects are also discussed elsewhere in the Annual Report. Finally the Dry Deposition Inferential Measurement system, started mid year in 1992, provides weekly data on dry deposition of nitrogen (HNO_3 vapor) and sulfur (SO_2) compounds.

The main objective of the monitoring activities discussed here is to provide continuous environmental data to VMC cooperators and others. Little detailed assessment of patterns or trends in the data from these projects has been performed at this time, but the data are available from the VMC in various forms, including as Voyager files. (see report on Data Integration). Included in this report are representative data tables, graphs and Voyager views of the data. Also discussed here are plans for the future of these projects.

OBJECTIVES:

Continuous monitoring of meteorological variables and the chemistry of precipitation and dry deposition at several locations at the VMC Mansfield site.

METHODS:

Several monitoring stations and programs were operated at the VMC Mansfield site in Underhill in 1993:

1. Basic meteorology (continuous temperature, dew point, wind speed and direction, standard deviation of wind direction, and precipitation amount) is monitored at the air quality monitoring station at the VMC Mansfield site at the Proctor Maple Research Center (PMRC) at 400 m. elevation. This station has remote (modem) access and has been in continuous operation since June 1988. Data are updated continuously and are stored electronically and as hard copy. Data are available from the VMC as spreadsheets (Lotus, Excel), and in Voyager format. Station supervision is by Tim Scherbatskoy and operated by Joanne Cummings and Carl Waite. Additional meteorological data were collected at the forest canopy research tower and in the Stevensville Brook watershed; these are described in other reports.

2. The National Weather Service (NWS) under NOAA supervises a second weather station at the WCAX-TV transmitter station near the nose of Mt. Mansfield (1205 m), one of 45 NWS cooperative weather stations currently operating in Vermont. This station has monitored temperature (daily minimum, maximum and temperature at time of observation) and precipitation amount (daily rainfall, snowfall and snow depth on the ground) since 1954. Data are collected and stored by the National Climatic Data Center. The VMC does not directly support this station, but has access to the data for this station and all others in Vermont through the NWS. Data are now available from the VMC in Voyager format for the period 1954-1992, as part of the Vermont Coop Network meteorological database.

3. NADP/NTN (National Atmospheric Deposition Program/National Trends Network) maintains a site at the air quality monitoring station at PMRC (400m) for the weekly collection of precipitation for chemical analysis. Precipitation amount, pH and conductivity are measured locally, and the sample is then shipped to the NADP Central Analytical Laboratory in Illinois for analysis of pH, conductivity, Ca, K, Mg, Na, NH₄, NO₃, Cl, SO₄ and PO₄. This station has been operational since 1984, and is part of a national network of over 200 stations including one other in Vermont at Bennington. Data are available from the VMC in Voyager format or in other forms from the NADP Central Analytical Laboratory. The site supervisor is Tim Scherbatskoy, and the site operator is Joanne Cummings with cooperation from Sumner Williams at PMRC.

4. DDIM (Dry Deposition Inferential Measurement) program was started in August 1992 at the forest canopy research tower at the PMRC. This monitoring program uses filterpack technology to collect continuous weekly samples of dry deposition of sulfur (SO_2) and nitrogen (HNO_3 vapor), and also continuous meteorology including temperature, relative humidity, wind speed and direction, surface wetness and precipitation amount. The goal of this program is to measure atmospheric concentrations of these species and model their deposition rates. This station is one of 10 stations in the NOAA network in the eastern US; the data collected are comparable to other dry deposition monitoring programs in the US operated by the EPA. This equipment is located above the forest canopy at 22 m. on the forest research tower. Station operation is by Joanne Cummings with supervision by Tim Scherbatskoy. Filterpack and data analysis are conducted by NOAA, with data returned to the VMC quarterly.

5. AIRMoN (Atmospheric Integrated Research Monitoring Network) is an event based precipitation monitoring program established at the end of 1992 to provide high-resolution data on precipitation chemistry to support regional modeling efforts. There are 7 sites in the network, located in the northeastern US. Except for being an event based sampling program, it follows the protocol and measures the variables of the NADP/NTN described in (4) above; the sampler is located at the Air Quality site at PMRC (400 m). Station operation is by Joanne Cummings with supervision by Tim Scherbatskoy. The AIRMoN station was installed in December, 1992.

SIGNIFICANT FINDINGS:

No major analyses of trends and relationships in these projects have been completed at this time. The principle goal of these projects is to provide a high-quality, long-term database on meteorological and chemical deposition for use by VMC cooperators and others. Data are maintained as up-to-date as possible, and are generally available from the VMC in various forms. A major effort is underway to also make these data available as Voyager files (see the Data Integration Project). In addition, periodic reports are made available by the major sponsor of each program (e.g., NADP annual statistical summaries). Overviews, representative data, and/or data summaries are presented in the pages that follow.

1. Basic meteorology

Consolidation of the historic and current basic meteorology data from the VMC Mansfield site is completed, and consists of annual daily and hourly data for all variables. In addition, in 1993 routine quality assurance, maintenance and calibration programs were instituted. Monthly data summaries are produced routinely. These data are available in ASCII text files, spreadsheets, and Voyager workbooks. Table 1 consists of partial spreadsheets exhibiting the monthly means, maximums and minimum 1993 values for meteorological data at the Proctor Maple Research Lab.

Figure 1 displays graphic representation of temperature and precipitation data for 1993 at the PMRC.

Table 1: Basic Meteorology at PMRC; monthly mean, maximum and minimum values for 1993.

	MBP mb	MWD deg	SWD deg	MWS m/s	XWS m/s	XTMP deg C	NTMP deg C	MTMP deg C	MTMP2 deg C	GDD deg C	MDP deg C	MRH %	TRAIN mm
JANUARY													
MEAN	956	209	33.43	1.96	3.42	-2.92	-11.59	-7.05	-7.14	0.60	-12.28	64.43	
MAX	973	307	53.40	3.90	6.20	11.70	1.40	5.80	5.80	5.80	1.60	78.10	15.00
MIN	935	124	23.40	0.90	1.40	-14.60	-26.40	-22.00	-20.50	0.00	-28.30	45.10	0.00
SUM										18.6			51.3
FEBRUARY													
MEAN	950	215	30.98	2.07	3.85	-6.90	-16.14	-11.55	-11.51	0.00	-18.02	56.70	
MAX	965	338	50.40	3.30	8.40	-1.20	-3.90	-3.00	-2.60	0.00	-7.90	78.30	15.50
MIN	929	110	21.80	1.30	2.40	-21.90	-28.40	-26.00	-25.10	0.00	-32.60	38.50	0.00
SUM										0			36.4
MARCH													
MEAN	948	207	33.24	1.95	3.31	1.70	-6.31	-2.10	-2.31	2.08	-10.21	53.33	
MAX	968	317	58.10	4.90	6.70	17.30	9.30	12.90	13.30	12.90	0.70	77.00	13.50
MIN	925	122	18.90	1.00	1.70	-14.40	-23.10	-18.20	-18.70	0.00	-26.30	26.00	0.00
SUM										64.4			43.9
APRIL													
MEAN	949	213	33.83	2.15	3.50	10.26	2.49	6.26	6.38	6.50	-2.73	55.62	
MAX	963	341	52.60	4.60	6.10	20.70	15.10	17.50	17.80	17.50	7.50	84.50	18.00
MIN	935	130	23.90	0.80	1.90	-1.00	-3.90	-3.00	-2.50	0.00	-10.3	22.9	0.00
SUM										195			109.5
MAY													
MEAN	950	201	33.61	2.02	3.54	16.30	8.40	12.31	12.35	12.31	3.14	55.39	
MAX	963	287	49.20	3.90	5.30	24.80	16.10	19.70	19.60	19.70	10.10	79.90	20.30
MIN	938	131	23.50	0.90	1.50	8.70	2.60	6.20	6.40	6.20	-3.10	31.50	0.00
SUM										418.4			91.1
JUNE													
MEAN	948	185	38.26	1.71	3.10	19.79	11.98	15.76	15.89	15.76	8.04	61.78	
MAX	956	291	52.80	2.90	5.20	27.90	17.30	22.30	22.60	22.30	14.90	79.40	16.80
MIN	939	123	29.10	1.00	1.80	10.60	5.10	8.40	8.50	8.40	0.50	37.60	0.00
SUM										472.9			97.8

1993 WEATHER DATA SUMMARY FOR PMRC AQ SITE - MONTHLY MEAN, MAXIMUM AND MINIMUM VALUES

	MBP mb	MWD deg	SWD deg	MWS m/s	XWS m/s	XTMP deg C	NTMP deg C	MTMP deg C	MTMP2 deg C	GDD deg C	MDP deg C	MRH %	TRAIN mm
=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
JULY													
MEAN	945	185	37.57	1.55	2.93	23.15	15.94	19.31	19.54	19.31	11.99	63.67	
MAX	954	300	55.60	2.50	4.90	29.80	22.90	25.70	25.70	25.70	17.30	77.70	33.00
MIN	936	126	28.30	1.10	1.80	13.70	11.60	12.70	12.90	12.70	7.40	47.70	0.00
SUM										598.5			127.2
AUGUST													
MEAN	959	158	36.98	1.40	2.49	22.90	15.17	18.72	19.04	18.72	12.63	69.35	
MAX	966	250	54.30	2.00	3.80	28.20	19.80	23.70	23.60	23.70	16.80	82.60	40.90
MIN	951	123	25.30	1.00	1.70	15.20	8.10	11.80	11.90	11.80	3.80	55.80	0.00
SUM										580.4			146.4
SEPTEMBER													
MEAN	957	181	39.63	1.65	2.85	16.31	8.73	12.51	12.52	12.51	7.36	71.89	
MAX	968	276	58.70	2.40	5.10	25.20	19.20	21.90	22.20	21.90	17.40	86.40	23.40
MIN	943	125	27.60	1.10	1.50	7.30	-0.60	2.30	3.30	2.40	-3.30	56.90	0.00
SUM										375.3			119
OCTOBER													
MEAN	955	195	32.60	2.21	3.61	9.57	2.30	5.88	5.93	6.00	-0.55	63.83	
MAX	968	306	46.60	4.00	6.10	19.90	10.30	14.20	15.10	14.20	8.00	87.00	19.80
MIN	942	121	22.20	1.20	1.80	0.90	-4.20	-1.20	-1.00	0.10	-7.20	46.10	0.00
SUM										186.1			
NOVEMBER													
MEAN	961	201	30.42	2.25	3.75	4.91	-2.33	1.26	1.30	2.75	-5.15	63.32	
MAX	974	344	41.40	5.20	7.20	13.70	8.20	10.30	10.80	10.30	7.00	90.20	28.40
MIN	941	138	23.00	1.10	1.70	-7.10	17.40	-11.90	-12.20	0.00	-21.90	19.30	0.00
SUM										82.5			83.8
DECEMBER													
MEAN	957	204	32.08	1.79	3.19	-2.26	-9.05	-5.62	-5.67	0.50	-10.52	67.83	
MAX	981	346	50.40	3.70	7.70	6.30	2.20	4.10	4.20	4.10	-0.40	94.30	25.40
MIN	937	141	20.00	0.90	1.50	16.50	-30.40	-23.20	-23.50	0.00	-30.90	36.20	0.00
SUM										15.6			58.9

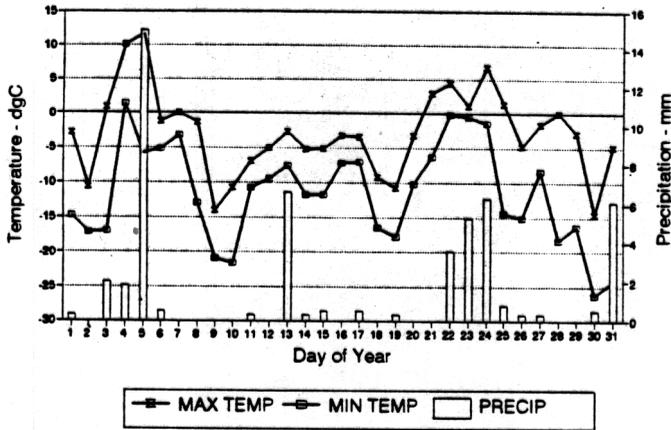
LEGEND

MBP = mean barometric pressure
MWD = mean wind direction
SWD = standard wind deviation
MWS = mean wind speed
XWS = maximum wind speed
XTMP = maximum temperature
NTMP = minimum temperature

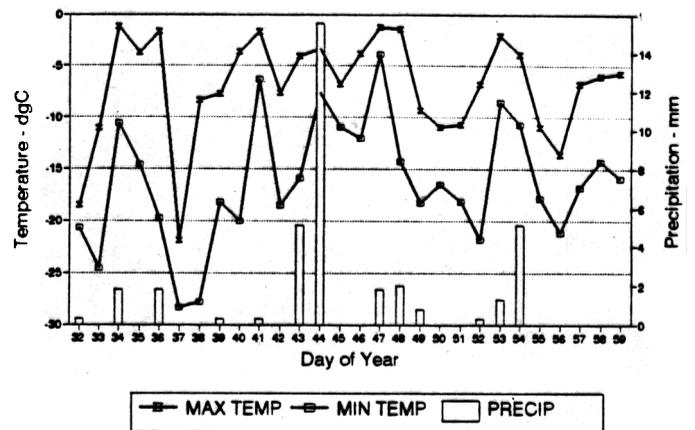
MTEMP = mean temperature (all values for day averaged)
MTEMP2 = mean temperature (max and min temp averaged)
GDD = growing degree day
MDP = mean dew point
MRH = mean relative humidity
TRAIN = total rain

Figure 1: PMRC Monthly temperature and precipitation data for 1993

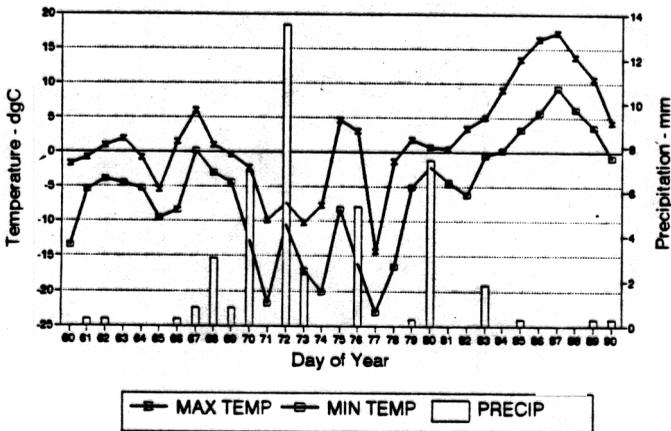
**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - JANUARY 1993**



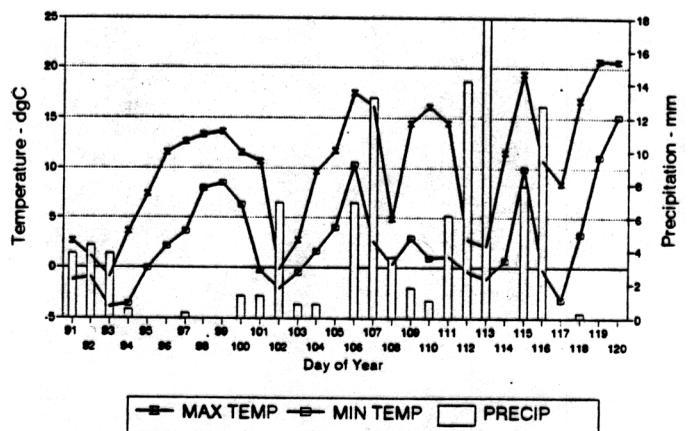
**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - FEBRUARY 1993**



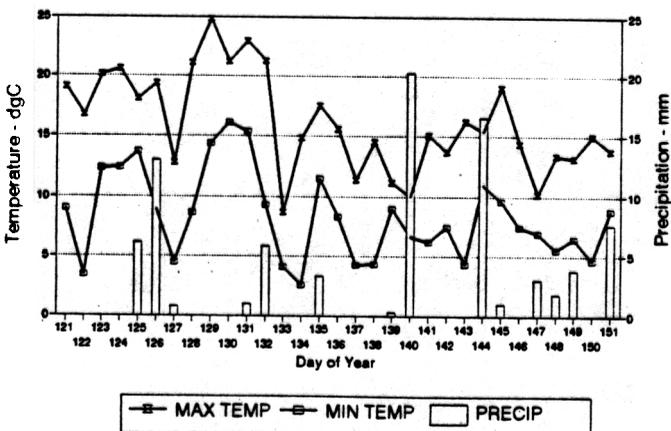
**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - MARCH 1993**



**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - APRIL 1993**



**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - MAY 1993**



**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - JUNE 1993**

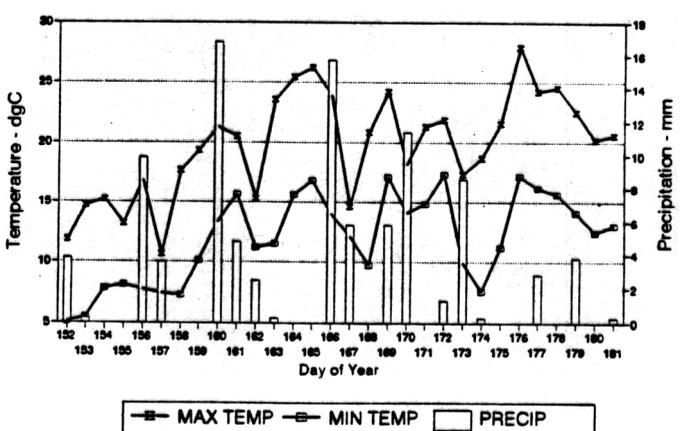
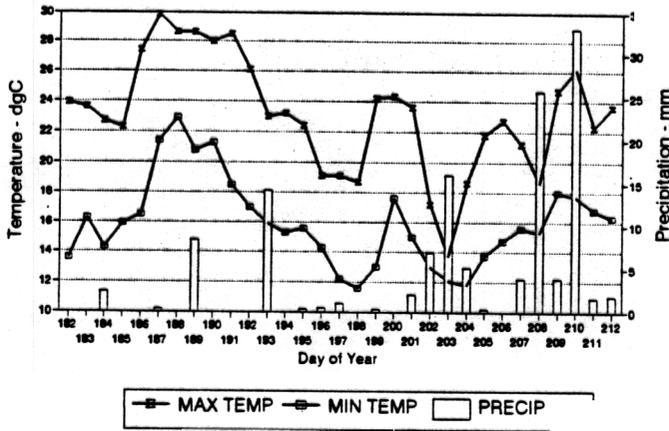
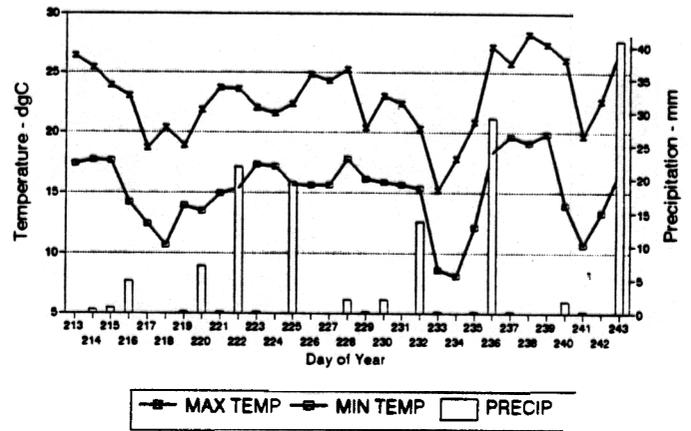


Figure 1: PMRC Monthly temperature and precipitation data for 1993

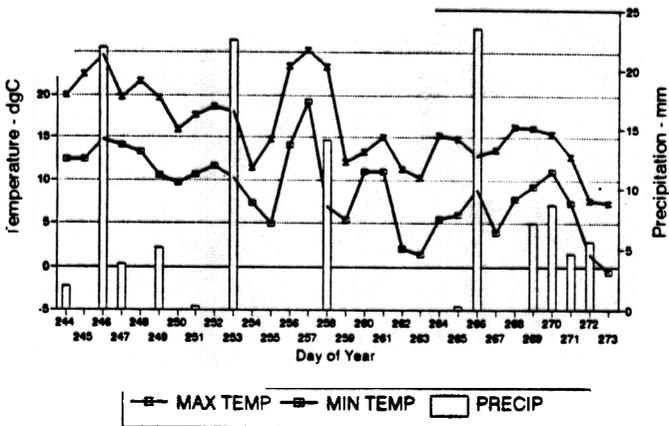
**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - JULY 1993**



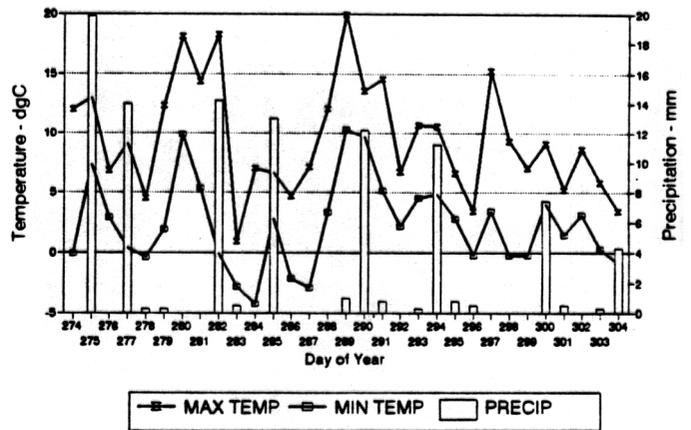
**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - AUGUST 1993**



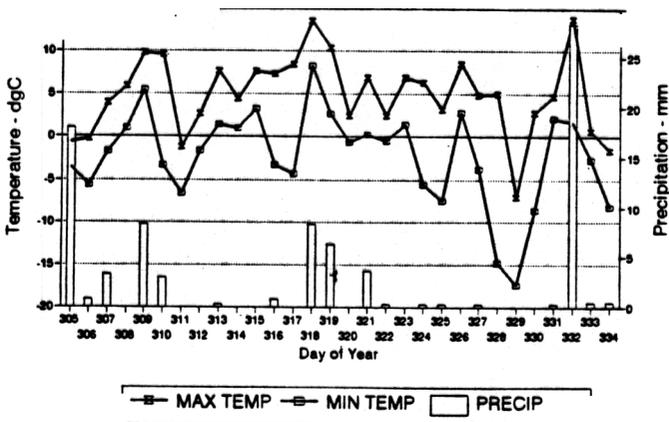
**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - SEPTEMBER 1993**



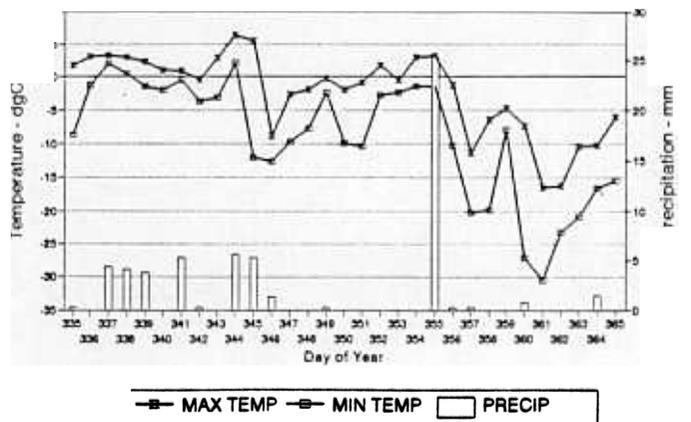
**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - OCTOBER 1993**



**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - NOVEMBER 1993**



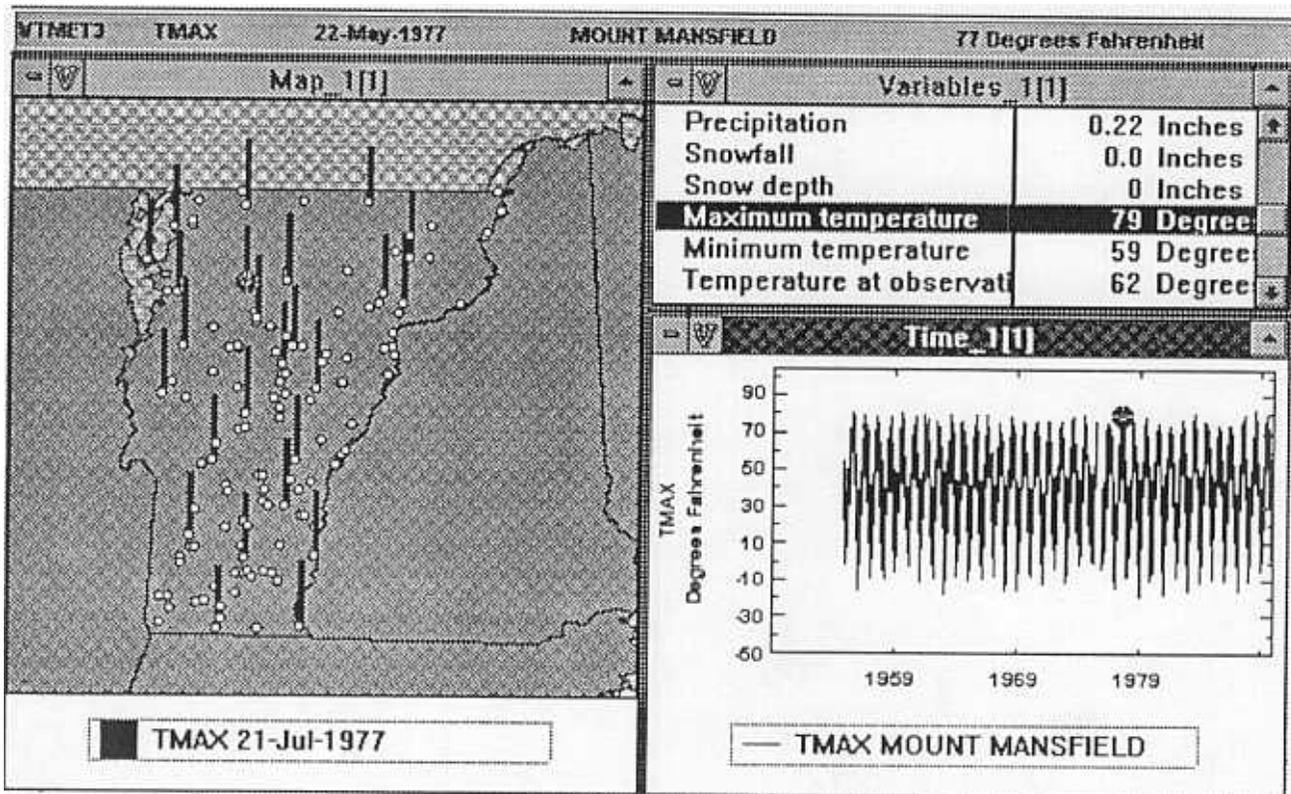
**MEAN DAILY TEMPERATURE & PRECIPITATION
PMRC - DECEMBER 1993**



2. National Weather Service data

Due to the time lag in obtaining data from the National Climatic Data Center, the 1993 data from the Mt. Mansfield weather station will not be available until May 1994. Current data is complete through 1992. Representative data, as a Voyager view, are shown in Figure 2.

Figure 2: NWS Cooperating stations in Vermont: Voyager view showing the Vermont map view and a time view for the Mt. Mansfield summit weather station.



VERMONT METEOROLOGICAL DATA

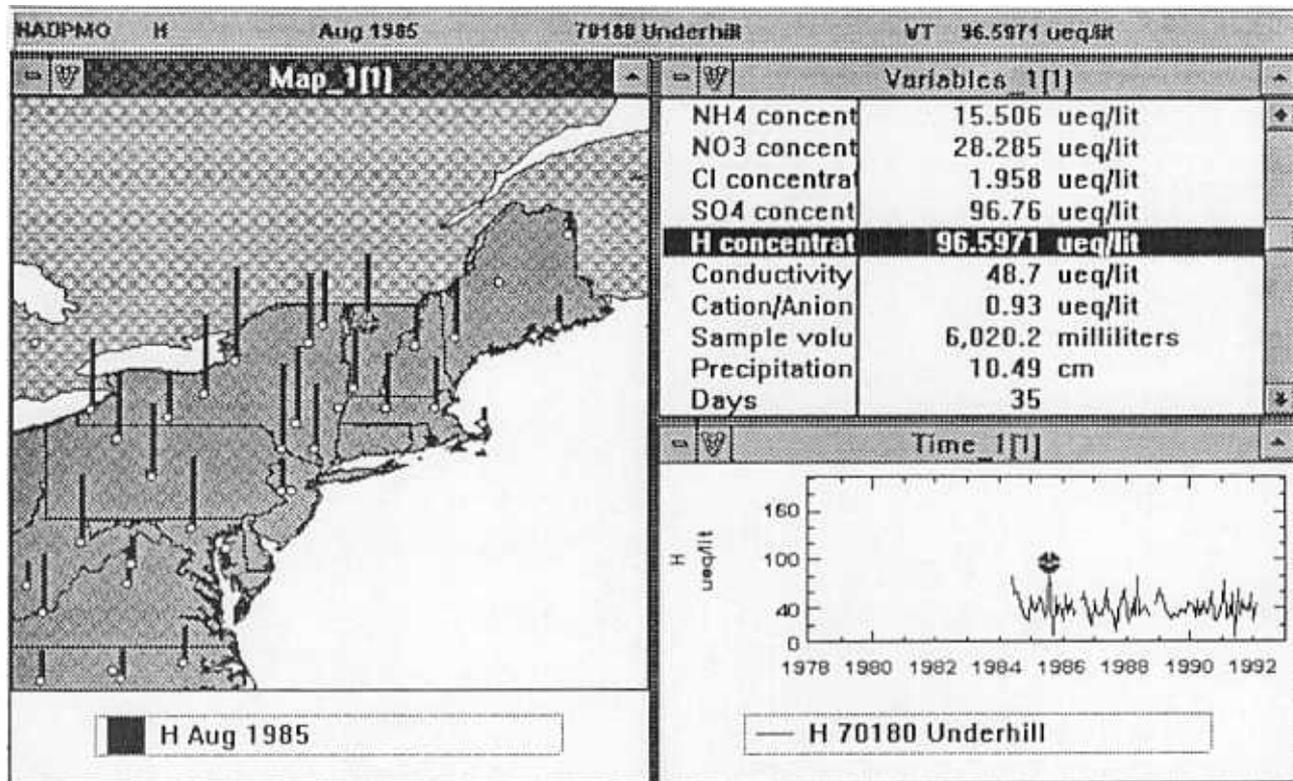
Contributors: National Weather Service

Compiled: October 10, 1993 by Don Hay, Carl Slenk and Ian Martin

This data set contains daily weather data from all National Weather Service cooperating weather stations in Vermont for their entire period of record. The most recent data available is through December 1990, at which time there were 45 active stations. Due to the large size of this database, it is only available as a Voyager file and workbook, or as an ASCII file of variable (40 Mb) or fixed (90 Mb) length records. The only known problem with these data may be an erroneous extreme value (easy to identify) for at least one station for temperature (e.g., 500 deg F) and precipitation (e.g., 1,000 inches).

Variables: Daily precipitation amount (inches), snowfall (inches), snow-depth (inches), maximum, minimum and time-of-observation temperature (deg. F), and numerous categories of weather conditions (sleet, blowing snow, lightning, dust, etc.).

Figure 3: NADP program data: Voyager view showing map view for the eastern United States and a time view of data for the VMC station in Underhill.



NADP PRECIPITATION CHEMISTRY AVERAGES

Contributors: National Atmospheric Deposition Program / National Trends Network
 Compiled: September 11, 1992 by Lantern Corp.

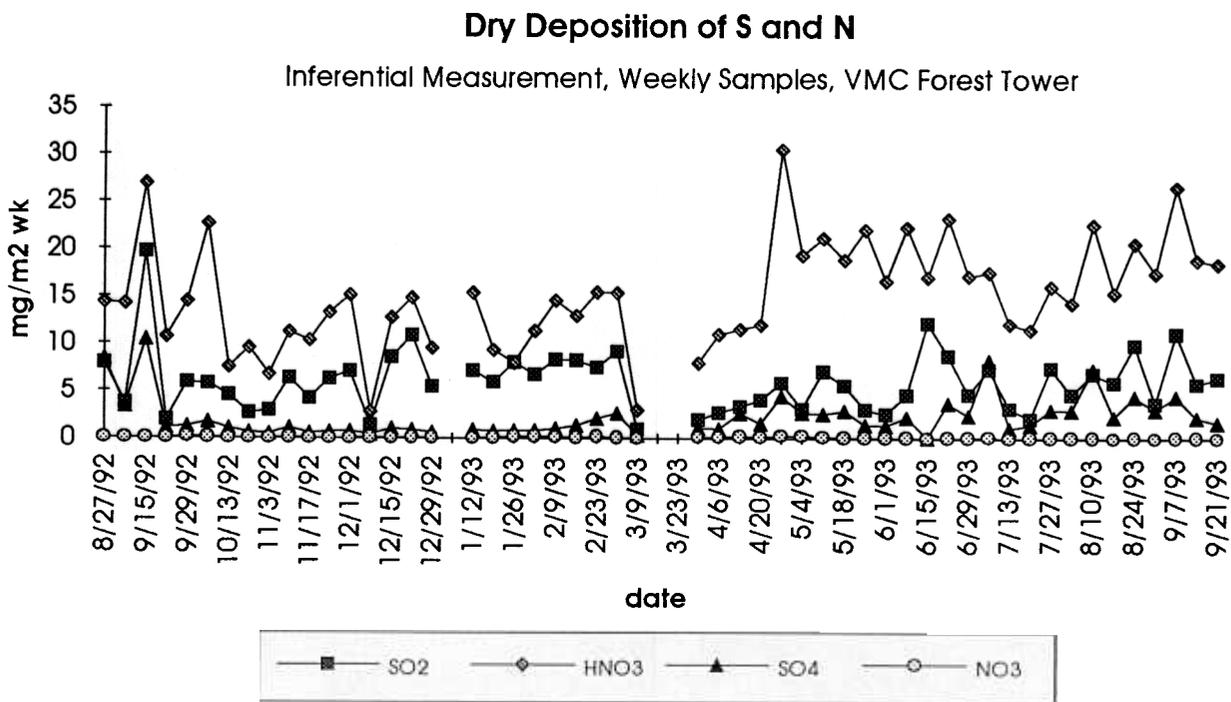
This data set contains monthly averaged data from all U.S. NADP/NTN stations (206 sites in 47 states) from July 1978 through February 1992. There may be in the data at least one erroneous very extreme (easy to identify as erroneous) value for some variables; there are no other known problems.

Variables: Ca, Mg, K, Na, NH4, NO3, Cl, SO4, H, conductivity, cation/anion ratio, volume, precip amount, # days, # valid samples, date on, date off, and data completeness.

4. Dry Deposition Inferential Measurement System

All meteorological data (on tape) and filter packs are sent to NOAA-ATDD weekly. Data are generally returned to the VMC quarterly, although this was slow in occurring in 1993. Quality assurance checks of monitoring equipment on the tower are made weekly, and an annual site audit is done by NOAA-ATDD staff. Missing meteorological data (due to equipment malfunction) can be supplied from the VMC meteorological measurements also taken at the tip of the tower. A summary of the modeled deposition flux data is currently available and presented in Figure 4.

Figure 4: DDIM station dry deposition data in graphic form



5. Atmospheric Inferential Research Monitoring Network

Data reports are now being generated for this project and are available through the NADP/AIRMoN network. Table 3 displays a portion of this summary for 1993.

Table 3: AIRMoN program data: representative data for a portion of 1993 (May - June)

PRELIMINARY PRINTOUT
DATE: 03/18/94

NADP/AIRMoN CENTRAL ANALYTICAL LABORATORY - ILLINOIS STATE WATER SURVEY

SAMPLE ID	LAB TYPE	DATE ON	TIME ON	DATE OFF	TIME OFF	CONCENTRATIONS(MICROEQUIVALENTS/LITER)										FIELD LAB FIELD LAB			
						CA	MG	K	NA	NH4	NO3	CL	SO4	PO4	COND.	COND.	PH	PH	
AA0658L	VT99	W	051993	1005	052093	0930	.50	.08	.10	.13	3.3	10.5	.8	15.6	.00	10.0	10.6	4.58	4.62
AA0659L	VT99	W	052093	0930	052193	0915	.65	.33	.10	.17	12.8	11.5	.6	29.4	.00	14.0	14.8	4.50	4.51
AA0660L	VT99	W	052193	0915	052593	0925	3.69	1.32	.28	.26	16.1	23.2	1.7	62.1	.00	35.0	32.4	4.20	4.15
AA0672L	VT99	W	052593	0925	052893	0905	17.32	4.36	1.07	1.04	33.8	36.3	2.0	53.9	.00	26.0	25.1	4.37	4.42
AA0673L	VT99	W	052893	0905	052993	0910	6.29	1.40	1.30	2.17	61.0	63.1	4.5	98.1	.00	54.0	54.3	4.05	4.01
AA0674L	VT99	W	052993	0910	053093	0915	10.98	3.87	2.40	1.48	24.9	9.2	2.5	14.8	.00	7.0	6.7	5.30	5.80
AA0675L	VT99	W	053093	0915	060193	0920	2.05	.66	1.02	.39	6.7	13.9	1.1	24.8	.00	19.0	19.2	4.42	4.42
AA0688L	VT99	W	060193	0920	060293	0920	1.90	.58	.77	.91	8.3	4.2	1.4	18.7	.00	6.0	8.4	4.80	4.81
AA0689L	VT99	W	060293	0920	060693	0915	1.05	.25	.59	.52	4.4	13.2	1.1	14.2	.00	10.0	11.5	4.55	4.61

FUNDING:

1. Basic meteorology: The weather station is maintained with funds from the VMC base budget, the University of Vermont, and the VT Dept. of Environmental Conservation (DEC); this amounts to approximately \$2,500 for utilities, maintenance and data management. During its first two years this station was funded and operated by EPRI as part of the Operational Evaluation Network.

2. National Weather Service: Data collection and station operations are supported by the NOAA National Weather Service and WCAX-TV. VMC activity and funding was used for initial acquisition of the data (approximately \$600) and data processing (approximately \$1,500). Involvement of University students seeking research experience has reduced costs of data management. Access to future updates of the data is anticipated to be provided at no charge by the Vermont State Climatologist.

3. NADP/NTN: The overall program is funded by several federal agencies; operation of the VMC station is supported by the US Geological Survey (\$3,700). Chemical analysis and data management are supported by the USGS, at a cost of about \$5,000 per year.

4. DDIM: The overall program as well as the VMC station at the forest research tower is supported by the National Oceanic and Atmospheric Administration (NOAA). Site operations and logistical support cost about \$1,000 per year; data management, sampling equipment and chemical analysis are paid for by NOAA at a cost of \$10,000 per year.

5. AIRMoN: This program is also supported by NOAA. Annual costs for analysis and coordination for the VMC station in the network are about \$22,000 for operation, plus \$4,000 for local field technical and logistical support.

FUTURE PLANS:

All of these stations will continue to operate in 1994. Updates for the Mt. Mansfield weather station (as well as all other National Weather Service Vermont stations) will be obtained in May of 1994.

The State of Vermont Air Pollution Control Division will be adding a station at the Proctor Maple Research Center. The PMRC field station will continue operation for at least one year as a calibration for the APCD station, and while we work out plans for data acquisition through APCD.

The VMC will purchase NOAA data from the summit station on Mt. Mansfield to update our data (1991 - 1993). Tim Scherbatskoy will acquire and format the data. This will become part of the complete VT meteorological database containing data for all cooperative NWS stations, through 1993, formatted for Voyager.

The VMC Data Manager (new position, starting in June 1994), will receive processed data from all VMC meteorological stations to reformat for VMC and individuals user's needs.