CHEMICAL MIGRATION IN SNOWPACK

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INTRODUCTION:

Chemical precipitation varies with respect to space and time; this variation may be even greater where orographic influences are present. It is inviting to use snowpack sampling as a technique to collect precipitation specimens, and to evaluate chemical precipitation theories or source-receptor pollution transport models with the results of specimen analysis. Such snowpack sampling would allow a posteriori collection of representative samples for analysis, rather than requiring multi-point multi-time collections by several observers, through a long precipitation period.

Warburton and Linkletter [1978], measured chemical profiles in snowpits on the Ross Ice Shelf, Antarctica, and were able to identify major storm systems, from the Na, K and Mg profiles in the snow. Their analysis indicated that riming processes near the coast greatly influenced deposit of both water and sea salt particles, and they inferred exchange and mixing processes on the interior of the shelf. Gjessing [1977, 1984, 1989] examined the chemical composition of polar snow in the Arctic and Antarctic. He accounted for a deficit of SO_4 in coastal Antarctic snow through riming processes. He was able to relate chemical deposition in Arctic snowfields to atmospheric trajectories. Twickler, et al. [1986] found a seasonal deposition pattern of organic carbon in Greenland snow samples collected near DYE3, Greenland (65.01°N, 44.87°W), with higher concentrations observed in the winter/spring period. Schaefer[personal communication] investigated newly fallen snows, and found that the crystal type was preserved for as long as 24 hours allowing application of these snow crystals as aerological sondes.

Hogan, et al. [1985] attempted to synthesize chemical precipitation from analysis of new fallen snow and snowpack. This work differed from that of Cadle, et al. [1984], as new fallen snow was partitioned as a function of meteorological conditions at one observation point, and snow pit collections made in terms of discrete storm strata, rather than by length of core. Additionally, the air temperature remained below freezing at Whiteface through the accumulation of the pack, while several periods of melting occurred at the Michigan site.

Although chemical concentration with respect to water was nearly conserved, when the entire pack is considered at both Whiteface and Michigan, there was considerable exchange of material among strata (or core segments).

This apparent exchange within strata representing a single storm event, or among several strata, confounds any attempt at a posteriori examination of precipitation chemistry as a function of cloud physics. An experiment has been initiated to investigate chemical behavior in snowpack.

INSTRUMENTATION:

Two permanent observatories are maintained at Whiteface Mountain; additional observation and sampling sites have been operated at several levels, seasonally, or in some cases, for a few years. The Schaefer Observatory at the mountain summit (4867 ft ASL, approximately the 850 mb level) is instrumented for cloud physics and cloud chemistry research and is frequently manned by observers, in addition to the recording instruments. Meteorological parameters, aerosol concentration, along with optical properties, and several gas concentrations have been continuously measured for several years. Cloud parameters, and cloud water chemistry are measured when the observatory is immersed in cloud.

The observatory offices and laboratory analytical facilities are located at 1950 ft ASL on the east facing flank of the mountain. Several precipitation collectors, gas, and aerosol samplers (supported by DEC, ENSR and

MAPS3S) are situated in a flat area just above these buildings. Chemical concentration in precipitation and summit cloud water are measured soon after collection at this laboratory; additional collections are forwarded for analysis to the several national precipitation chemistry monitoring programs. The capabilities of the Whiteface observatories are tabulated in Table 1.

This suite of instruments, collectors, and analytical facilities provides an excellent setting for investigating the variation of concentration of components of precipitation from the cloud, into precipitation, and finally in residual snowpack. An instrumented snow field has been established 30M above the precipitation variables. A similar experiment was conducted in February and March of 1986 in an attempt to monitor snow stratigraphy and temperature to follow changes in the distribution of ions in a seasonal snowpack [Arons, personal communication].

A rectangular grid (39m x 18m) was laid out above the precipitation collector area in early winter 1988-89. Four thermistor arrays were placed at the corners. The thermistor arrays sensed temperatures -3, 0, 3, 10, 30 and 60 cm relative heights from the snow-ground interface. The vertical temperature profile is used to determine the instantaneous absolute temperature, and the direction of heat flux within the snowpack. Two radiometers, one oriented vertically, and the other aligned with the slope, measure incoming direct normal and diffuse-sky radiation.

The thermistor and spectral pyranometer outputs are recorded on a Campbell 21X Scientific Data Logger. This data is transferred to personal computer for analysis. Examples of the temperature profiles recorded in the extremely sparse snowpack of 1989 are given in Figures 1, 2, and 3.

Additional to the recording instruments, four bulk precipitation storage collectors are located within the grid. These allow investigation of chemical conservation in a constrained system approximating the environment of the pack.

RESULTS OF EXPERIMENTS:

The temperature histories shown in Figures 1, 2, and 3 indicate the dearth of snowpack maintained at Whiteface in 1989. The shallow snowpack and frequent thaws frustrated accomplishment of the primary experiment.

A tracer experiment was attempted using an organic solid (TNT) of vapor pressure

$$\text{Log P (ppbv)} = -5481/T + 19.37$$

[Dionne, et al., 1986]. A few small milligrams of TNT were placed atop 10 cm of snowpack in a covered watch glass on 25 February. Snowfall covered the specimen, and 3-10 cm of snow remained atop the specimen from 4 March through 27 March 1989. Snow samples were collected from the contemporary surface 15 cm from the specimen, on 14 and 24 March, and from the surface 8 cm above the specimen, in new snow 21 March. Analysis of the specimens by D. Leggett showed presence of the tracer, with a variation in concentration of about a factor of two over these distances. This, or a similar organic material may provide a useful tracer for future studies.

CONCLUSIONS:

Sparcity of snowfall and snowpack at Whiteface prevented completion of a comprehensive cloud-precipitation-snowpack chemical precipitation experiment during winter 1988-89. An instrumented snow field was established, and the instrumentation and recording system produced data with sufficient accuracy and time resolution to support the planned experiment. An organic tracer produced a detectable signal after diffusing through the shallow snowpack.

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FIG I. TEMP 3cm BELOW GRND/AIR INTERFACE

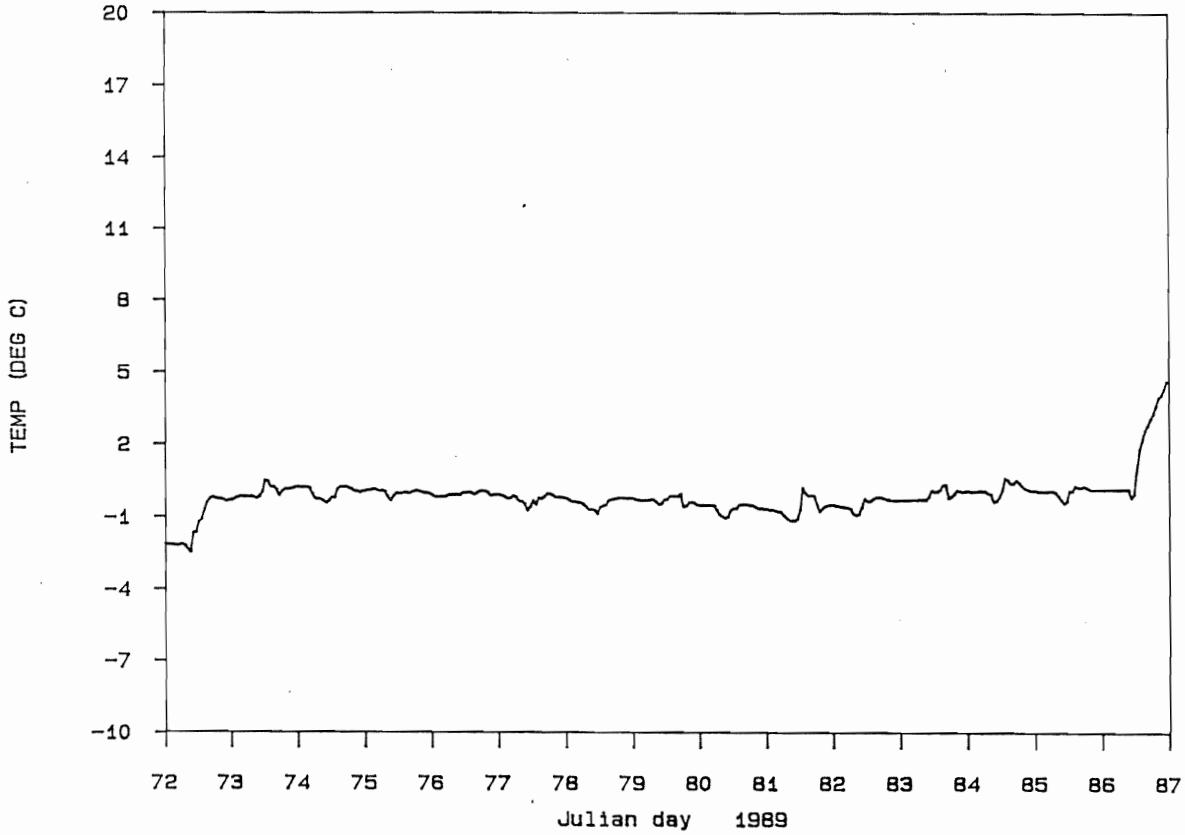


FIG II. TEMP AT GRND/SNOW INTERFACE

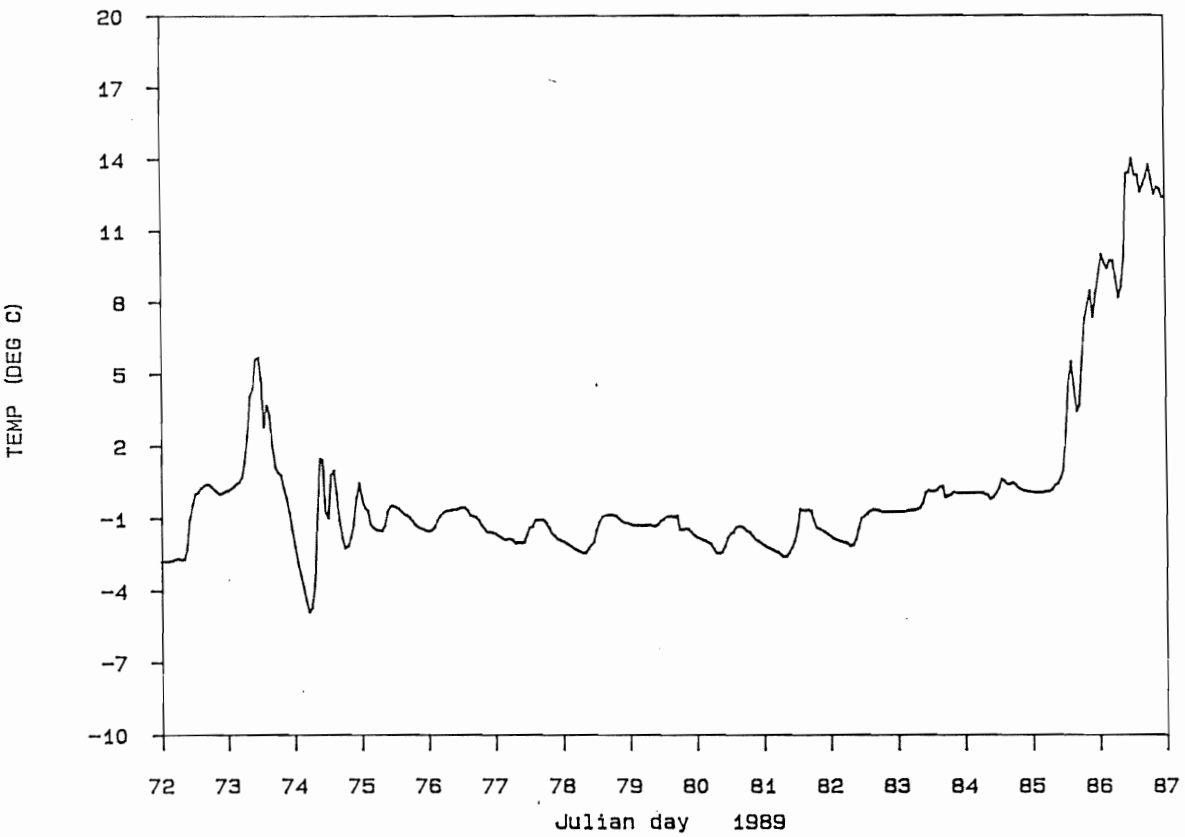
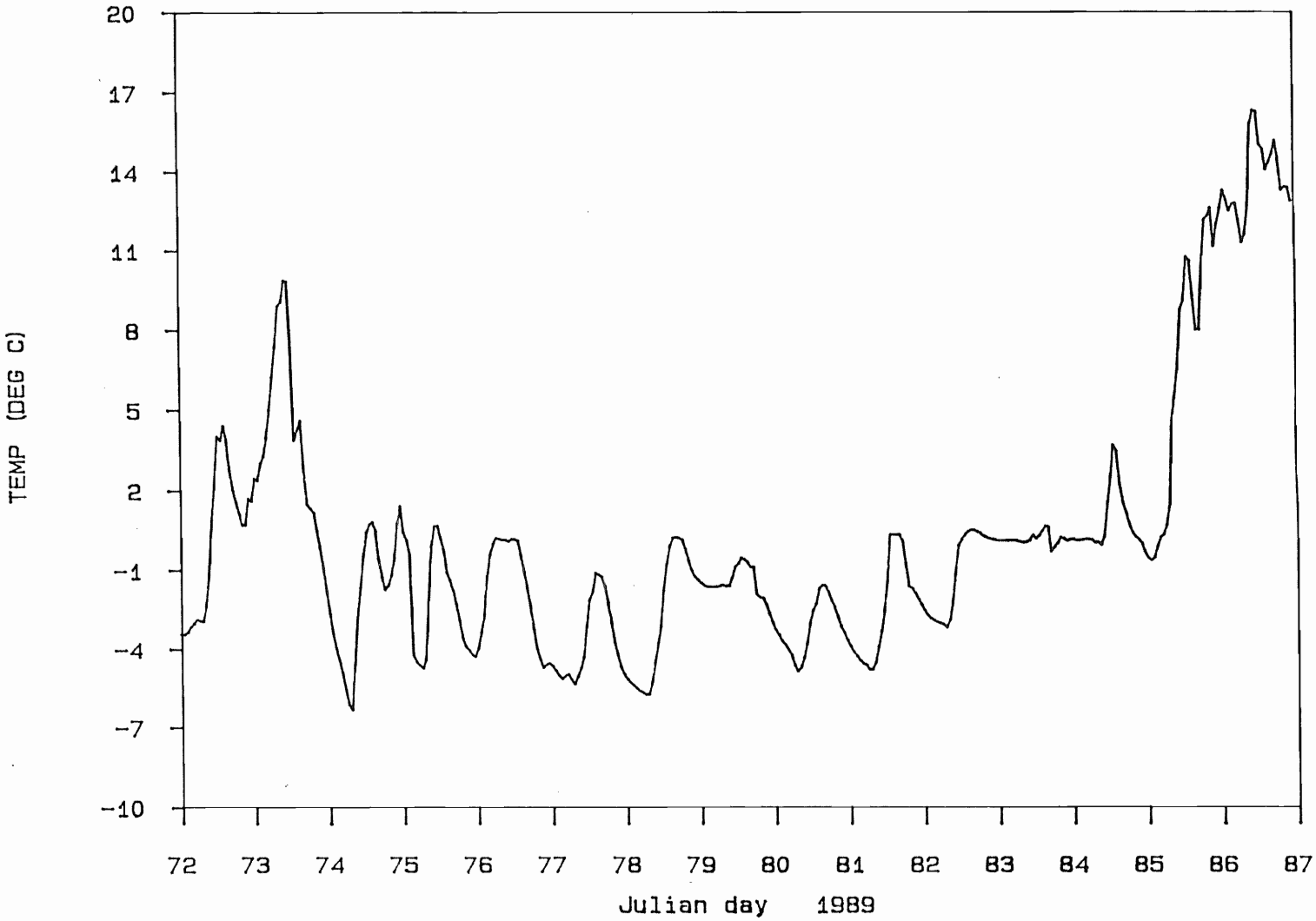


FIG III. TEMP 10cm ABV GRND/SNOW INTERFCE



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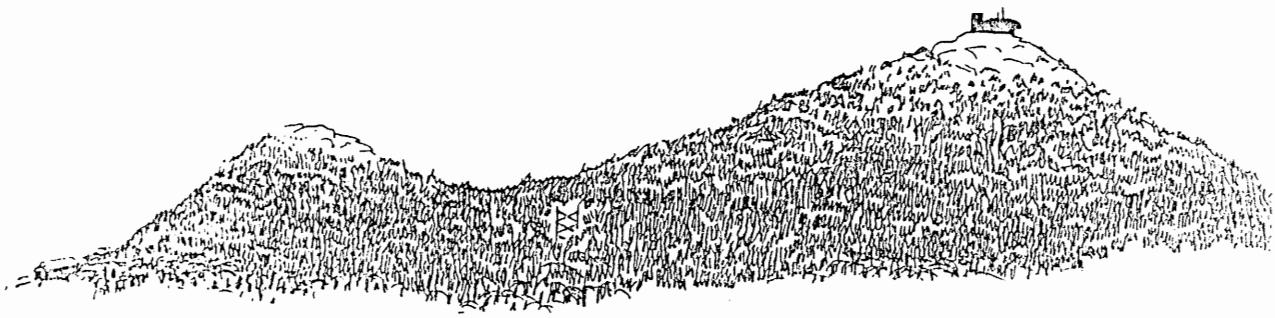

Base (600m)	Tower (1000m)	Summit (1483m)
Ozone	Ozone	Ozone
Meteorological	Meteorological	Meteorological
wind speed	wind speed	wind speed
wind direction	wind direction	wind direction
temperature	temperature	temperature
solar radiation	solar radiation	
relative humidity	relative humidity	
barometricpressure		barometric pressure
Filter (tripack)	Filter (tripack)	Filter (high-volume)
aerosols	aerosols	aerosols
nitric acid	nitric acid	nitric acid
sulfur dioxide	sulfur dioxide	sulfur dioxide
		Gaseous
		sulfur dioxide
		nitrous oxides
Dry deposition (NOAA/ADTL)	Dry deposition	
Precipitation as:	Precipitation as:	Precipitation as:
wet-only (MAPS3S,NADP)	wet-only	
	cloudwater	cloudwater
	rime ice	rime ice
	throughfall	
	stemflow	
Condensation nuclei (summer)		Condensation nuclei (summer)
		Hydrogen Peroxide

Table 1. Whiteface 1989 Atmospheric Experiment Program