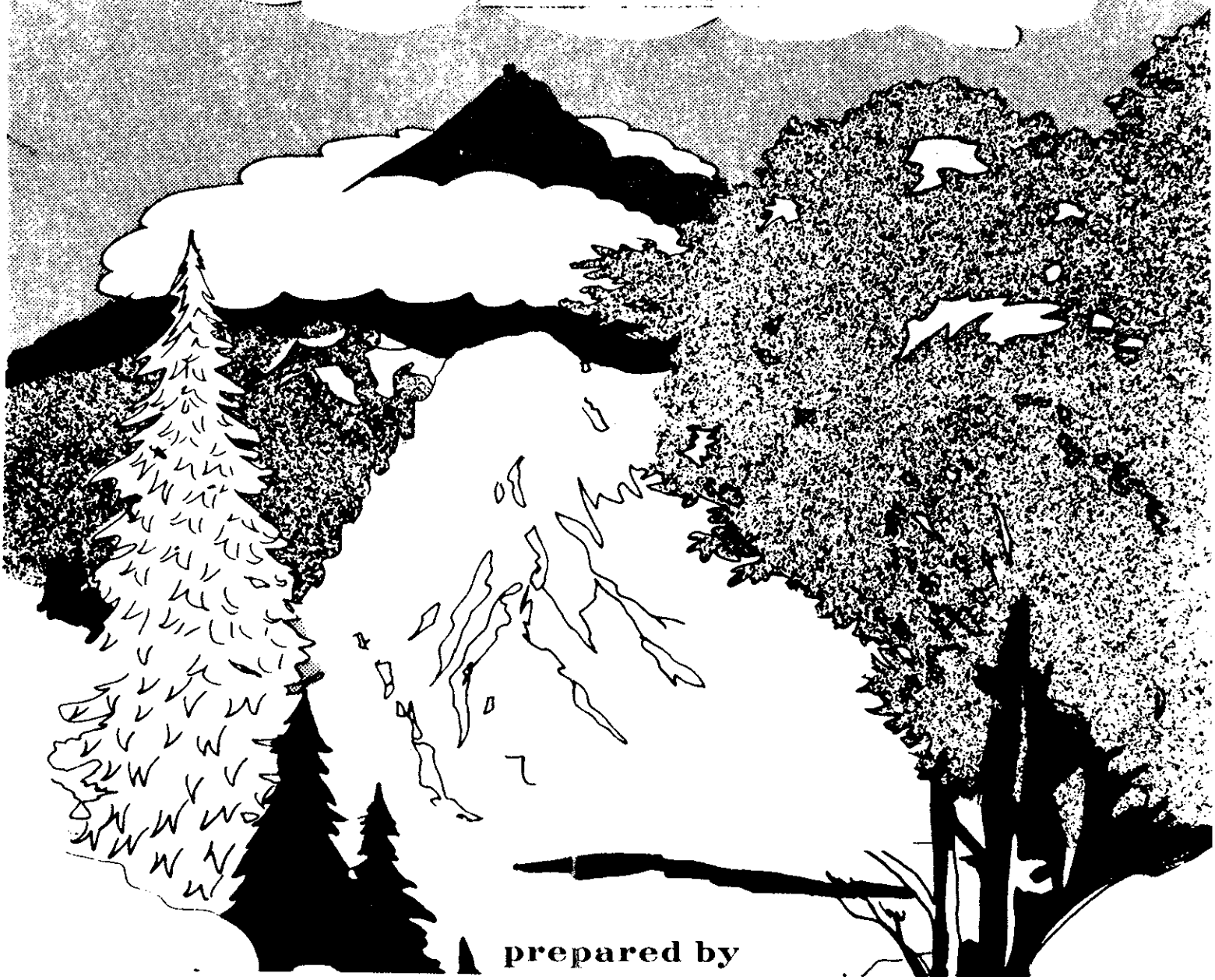
Cloud Chemistry and Meteorological Research at Whiteface Mountain: Summer 1980



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INTRODUCTION

This Final Report of cloud chemistry and meteorological research at Whiteface Mountain during the summer of 1980 contains two contributed articles by staff members of the Atmospheric Sciences Research Center, as well as a compilation of tables and graphs describing nearly all measurements made in the field program. Chapter 1 was written by J. Kadlecek and colleagues and describes the ASRC ground-based and aircraft-mounted cloud water collector systems. Chapter 2, written by P. Falconer, presents an analysis of cloud water and precipitation acidity fluxes, and their variation with airmass at Whiteface Mountain.

These investigations would not have been possible without the help of many dedicated technical assistants. Dr. Douglas Bird designed and maintained the ASRC liquid ion chromatograph. Ms. Debbie Kennedy, Mr. Robert Forman, Mr. Scott McLaren, Mr. Robert Peake, and Dr. Robert Pratt collected and analyzed the cloud water data through the summer season, and otherwise held the program together. Mr. Marc DuBois maintained the MAP3S precipitation network site. And finally, Mr. Andrew Landor of the Department of Atmospheric Science, skillfully constructed and maintained many of the peripheral pieces of equipment associated with this project.

Phillip D. Falconer, Principal Investigator

John A. Kadlecek, Co-Principal Investigator

CHAPTER 1

CLOUD WATER COLLECTION - TECHNIQUES AND COMPOSITION †

I. INTRODUCTION

During recent years, several research projects have been established to investigate possible relationships between anthropogenic pollution sources and the phenomenon of acid precipitation, and/or to determine the deposition of important ions in the rain and snow. The initial controversy about the contribution of these sources to depositions in sensitive areas has given way to an interest in how much emission reduction would be necessary to achieve a noticeable improvement in affected regions for the purpose of assessing appropriate levels of control. Measurements of ion concentrations in precipitation alone are not sufficient either to obtain the correct magnitude of ion deposition to cloud-shrouded mountain ecosystems or to characterize changes in, and possible redistributions of, ion deposition resulting from changes in emissions. As a first step in a program to investigate direct impaction of cloud water to mountain surfaces above cloud base, we began measuring the compositions of ions in cloud water. We have identified what can be a major ion input mechanism to high elevation watersheds. Now, because of the development of aircraft mounted collectors important contributions can be made in validating pollutant transformation and transport models.

This report will discuss the techniques of cloud water collection used in the Atmospheric Sciences Research Center cloud water monitoring program and describe some preliminary results, intended to illustrate the value of these measurements to current research needs.

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†Contributed by J. Kadlecek, V. Mohnen, D. Bird, and P. Falconer.

II. GROUND-BASED CLOUD WATER COLLECTION

Cloud water collected near the ground will include biologically related inputs not found in the free air at higher altitudes. The magnitudes will depend on biological cycles and local meteorology. However, for most measurements of atmospheric chemistry, their importance will diminish if analysis is done essentially in real-time (Kadlecek and Mohnen, 1975).

To permit near real-time analysis on small cloudwater samples (100 µl) we have developed a collection system, patterned loosely on a device used by Tabata, et al. (1953), and shown in Figure 1a (Falconer and Falconer, 1980). Cloud droplets collected by the vertical teflon filaments and support rods are sampled with efficiencies dependent on droplet size and wind speed (Figure 1b). The accumulating water coalesces into millimeter-size droplets which then run down the filaments. The water is collected in a funnel and flows directly into the laboratory for ion chromatograph analysis. If winds exceed approximately 25 knots, the coalesced droplets, which can be blown off the filaments, are then captured by the central rods. Collection rates of a few ml/min are typical.

The site selected for cloud water monitoring was the ASRC field station on the summit of Whiteface Mountain (1500 m) in the Adirondack Mountain Region of New York State. This is the region in the United States where the most noticeable effects have been attributed to acid precipitation (Pfeiffer and Festa, 1980). Rain and snow to this region is monitored by a MAP3S* station located on Whiteface Mountain (600 m). However, the terrain above 900 m is frequently shrouded in clouds which subject the vegetation and exposed surfaces to additional moisture not accounted for by precipitation alone. The amount of

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*Multistate Atmospheric Power Production Pollution Study, a network continuing in operation since 1977, now expanded to include eight wet precipitation collection sites within the northeast quarter of the USA.

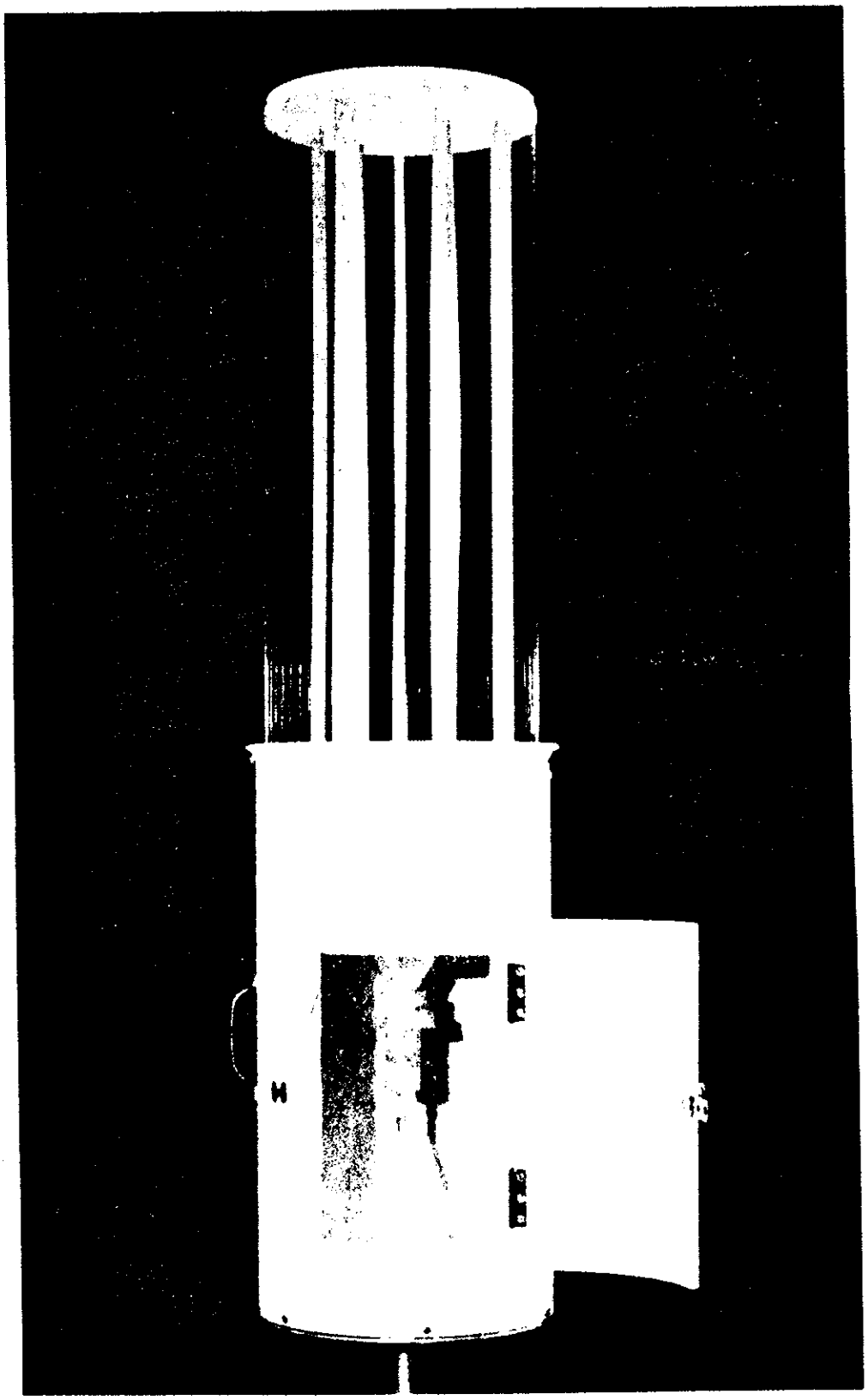

Figure 1a. The ASRC ground-based cloud water collector (Falconer and Falconer, 1980).

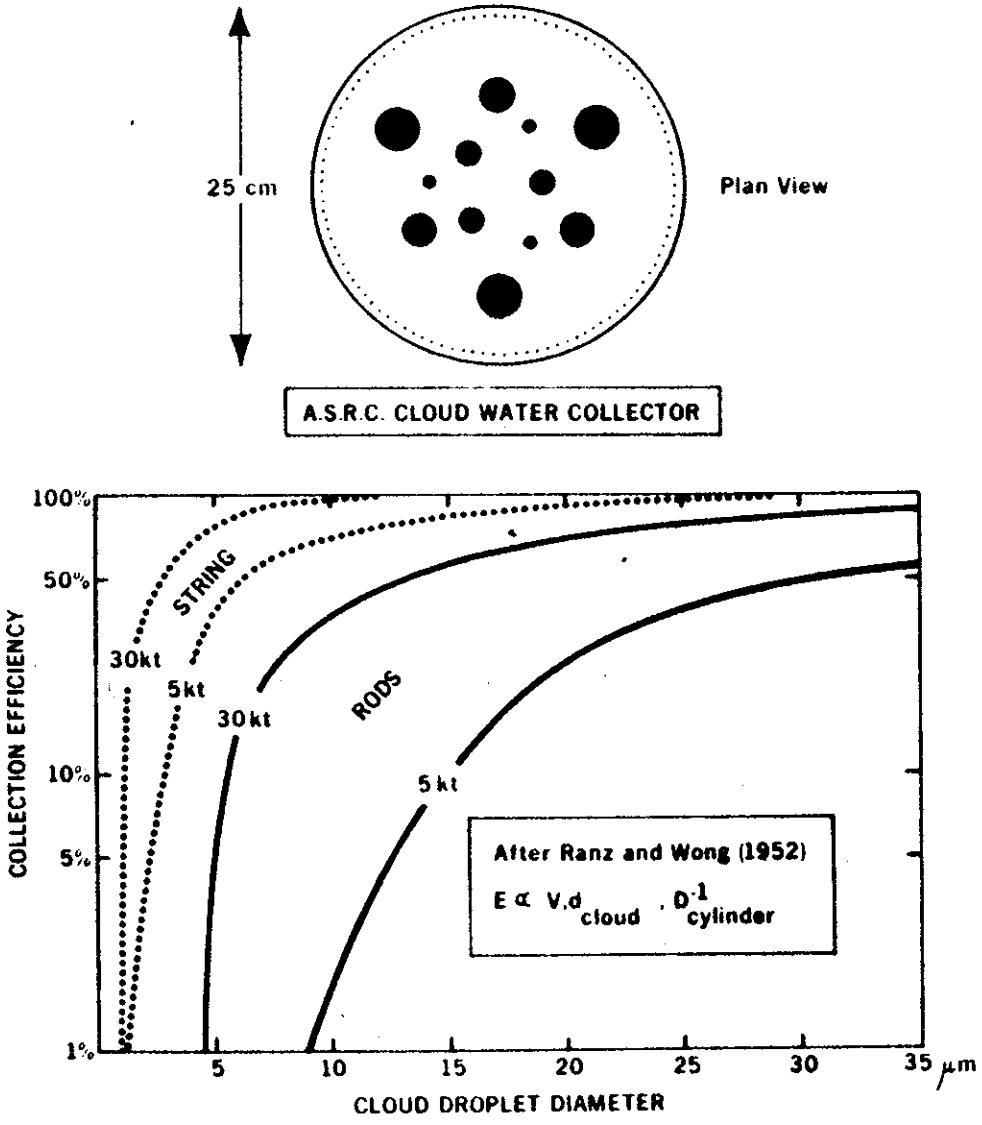

Figure 1b. ASRC Cloud Water Collector design and efficiency curves

water introduced into the watershed by cloud water interception can be significant relative to precipitation.

Only a few measurements of ion concentrations in clouds and fogs have been made with ground-based collectors (Table 1). In all instances, the cloud water was collected in bulk and analyzed for ion concentrations well after the collection was made. In no instances were ion deposition rates specified.

During the summer months of 1979 and 1980, analyses of the inorganic ions ($SO_4^=$, NO_3^-, Cl^-, F^-, H^+, NH_4^+, Na^+, K^+) and solution conductivity were performed as part of our cloud water collection program. The pH and conductivity measurements were recorded continuously, while the concentrations of other ions were determined on a liquid ion chromatograph developed at the Atmospheric Sciences Research Center (Bird, et al., 1979).

Two case studies have been selected to illustrate this approach. Figure 2 shows the temporal behavior of the dominant ions measured in the cloud water during August 29-30, 1979. Figure 3 shows the relative collection rates for water during the same period. The shaded peaks identify periods when the cloud water was diluted with rain blown into the collector. During periods of most intense shower activity, the concentration of all ions dropped by approximately a factor of 5, suggesting that rain originating at higher elevations had substantially lower ion concentrations than clouds collected at 1.5 km. While concentrations of $SO_4^=$ and NO_3^- are typically a few tens of micromoles per liter in precipitation, they can be on the order of hundreds of micromoles per liter in clouds routinely intercepted by mountain vegetation.

In nonprecipitating clouds, the variability observed in ion concentrations is due not only to supersaturation-induced shifts in the cloud droplet mass spectrum, as air flows around and over the mountain, but also to variations in natural and anthropogenic emission source strengths, atmospheric

Investigator	Observation Period	Location	Sampling Method	Range of Ion Concentrations (ppm) pH	$SO_4^=$	NO_3^-	Cl^-	NH_4^+	Na^+
Houghton (1955)	1954	Five sites located in Northeastern U.S.	Cloud water mechanically intercepted on metal screen. Bulk samples.	4.5-7.2[†]	0.2-125[$]	-	0-205[$]	-	-
Frose (1966)	?	Four sites located in German Democratic Republic	Cloud water mechanically intercepted on pervious cloth. Bulk samples.	3.8-5.1[†]	37-159[†]	9-28[†]	7-62[†]	-	7-35[†]
Okita (1968)	(a) July 25-26, 1963 (b) November 20, 1963	(a) Mt. Norikura (b) Mt. Tsukuba Japan	Cloud water mechanically intercepted on copper screen. Bulk samples.	(a) 3.4-4.3[@] (b) 5.6-6.5	11-60[@] 17-99	1.6-10.8[@] 0.3-2.3	2.6-8.1[@] 10-45	2.1-4.7[@] 2-17	1-3.8[@] 4-10
Lazrus et al. (1970)	1967	Pico del Oeste Puerto Rico	Cloud water mechanically intercepted on aluminum screen. Bulk samples.	4.9-5.4[$]	3.4-9.1[$]	-	5-70[$]	-	-
Castillo (1979)	1976	Whiteface Mtn., New York	Cloud water mechanically intercepted on plastic strings and rods. Bulk samples	3.8± .4[○]	1-22[$]	1-15[$]	0.04-0.6[$]	0-3.5[$]	0.01-2[$]
Falconer and Cadlecek	1979-1980	"	"	3.1-4.9[*]	1-43[$]	0.5-22[$]	0.02-0.6[$]	0.07-7[$]	0.03-0.6[$]

[†]Inter-event range of the reported *mean* values. It was not reported whether or not these *mean* values were volume-weighted.
[@]Intra-event range of observed values. It was not reported whether or not these values were volume-weighted.
[$]Inter-event range of observed values. It was not reported whether or not these values were volume-weighted.
[○]Range for all events defined mean pH ± one standard deviation.
[*]Inter-event range of mean, volume-weighted pH values.

Table 1. Summary of pH and dominant, inorganic ion concentrations in fog and cloud water collected at ground level.

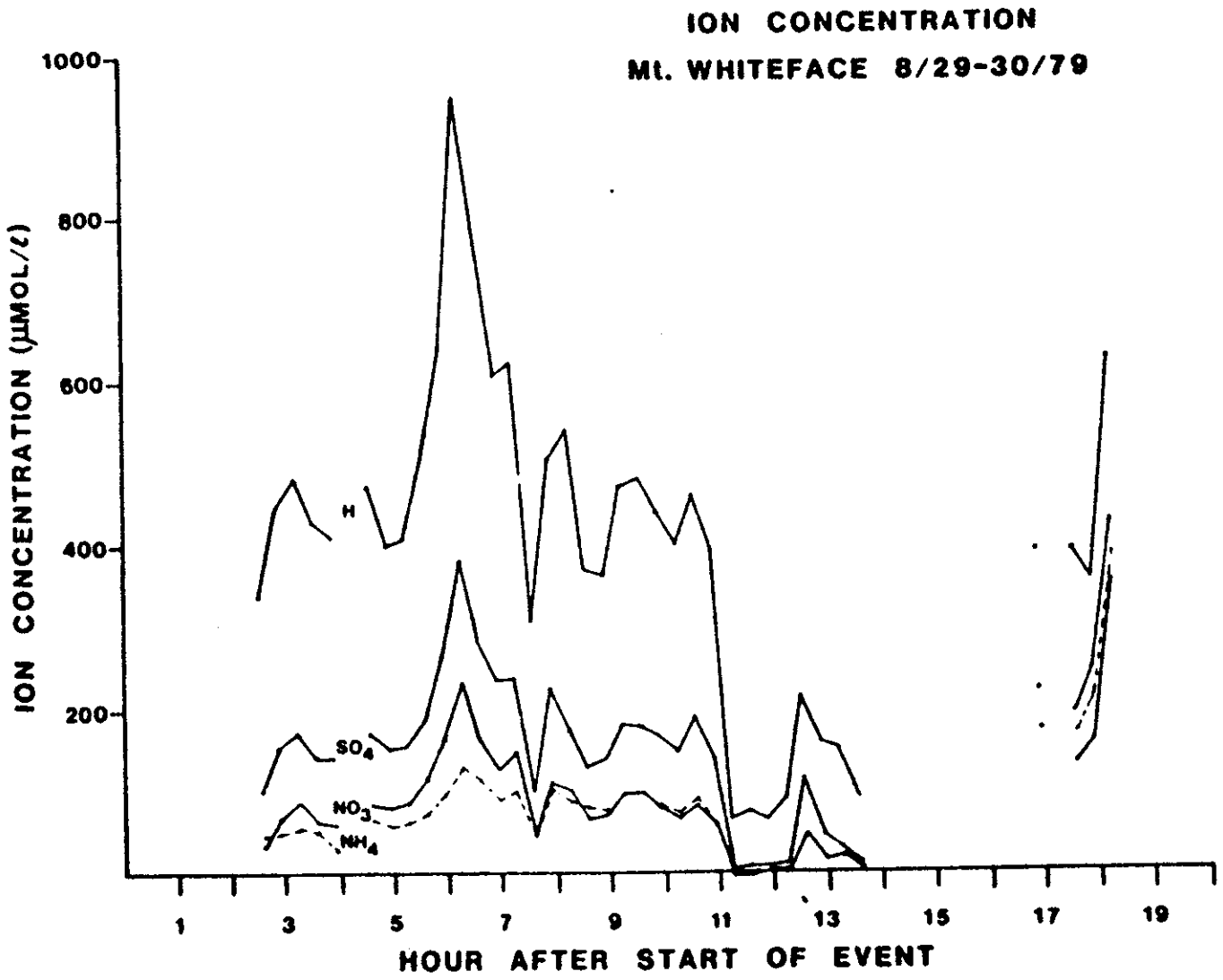

Figure 2. Ion concentrations in cloud water collected at Whiteface Mountain, August 29-30, 1979.

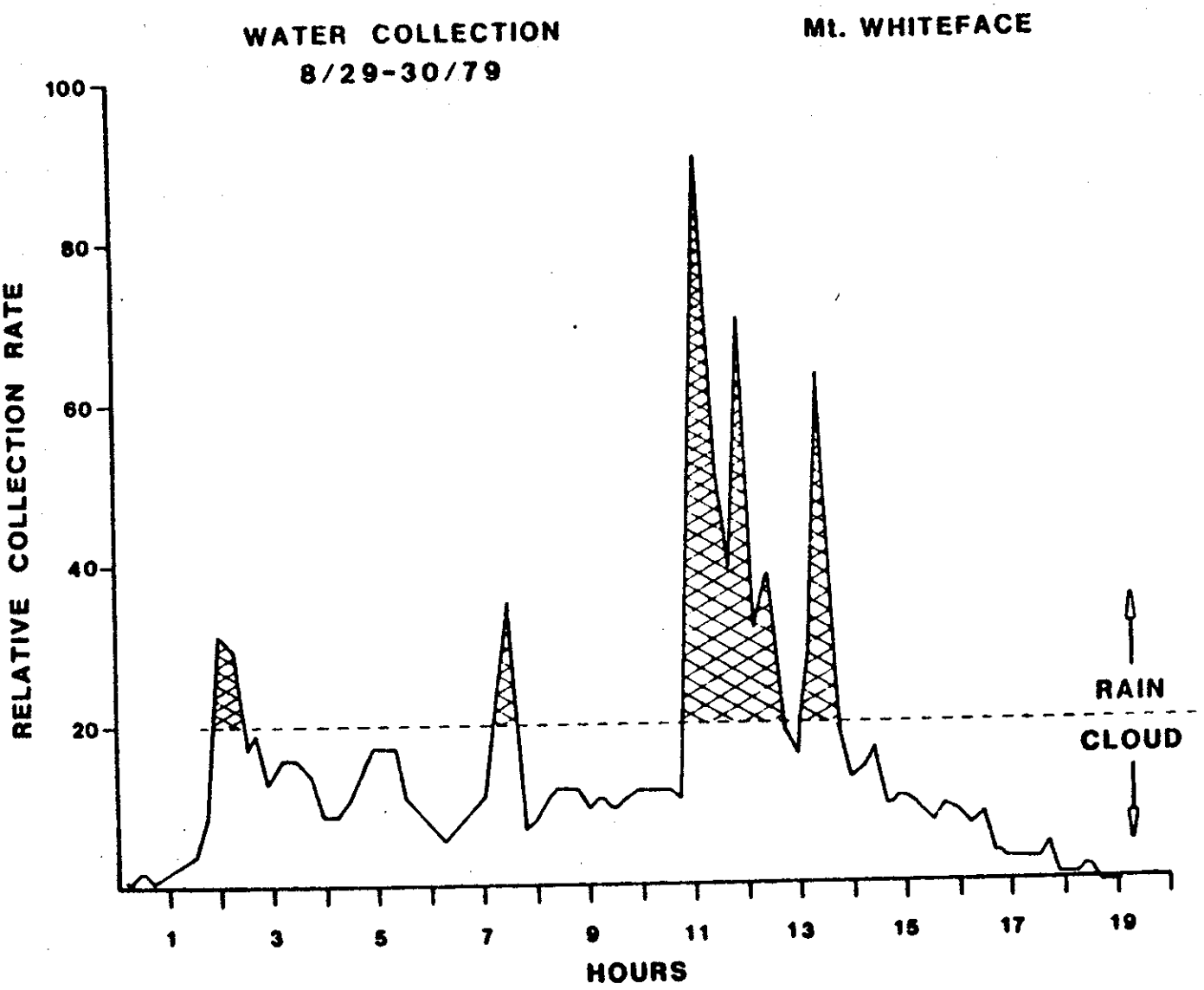

Figure 3. Water collection rate in the ASRC cloud water collector located at the summit of Whiteface Mountain, August 29-30, 1979.

mixing, chemical transformations, and sink mechanisms (all event-specific and not well-known) which have determined the individual air mass parcel's history.

Using trajectories generated by the Atmospheric Transport and Dispersion Model (NOAA--Air Resources Laboratory, Heffter, 1980) we can suggest the approximate regions which are likely to have an influence on the air masses arriving at Whiteface Mountain (Figure 4). The trajectories marked A, B and C describe the air flow history for parcels arriving near the beginning, middle and end of the event. The letters indicate six-hour intervals. As discussed extensively by Pack, et al. (1978), it is not possible to assign an uncertainty to the air mass position vector (relative to Whiteface). However, the apparent uniformity of the air flows suggested by the trajectories, and supported by the 850 mb pressure level winds, indicates that air within which this cloud layer came to Whiteface from the west-southwest to southwest sector.

A second example of time dependent ion concentrations in cloud water (August 12, 1980) is shown in Figure 5. Showers occurred between the hours of 3 a.m. and 6 a.m. (EST) and briefly about 8:30 a.m., associated with the movement of a weak low system passing north of Whiteface across southern Canada. During the remainder of the collection period only cloud water was sampled. Meteorological data tapes for August, 1980 were not yet available for mapping air mass trajectories. However, the flow of air to the summit of Whiteface can be roughly described by the wind velocities measured at the summit and the 850 mb synoptic weather maps prepared at 7 a.m. and 7 p.m. (EST) by the National Weather Service. Preceding the event, these estimated trajectories approached Whiteface from just south of the Great Lakes. By mid-day the low had moved to north of Lake Ontario with the air flow passing over the northern Great Lakes. Except for the first few hours of the event, southern and central

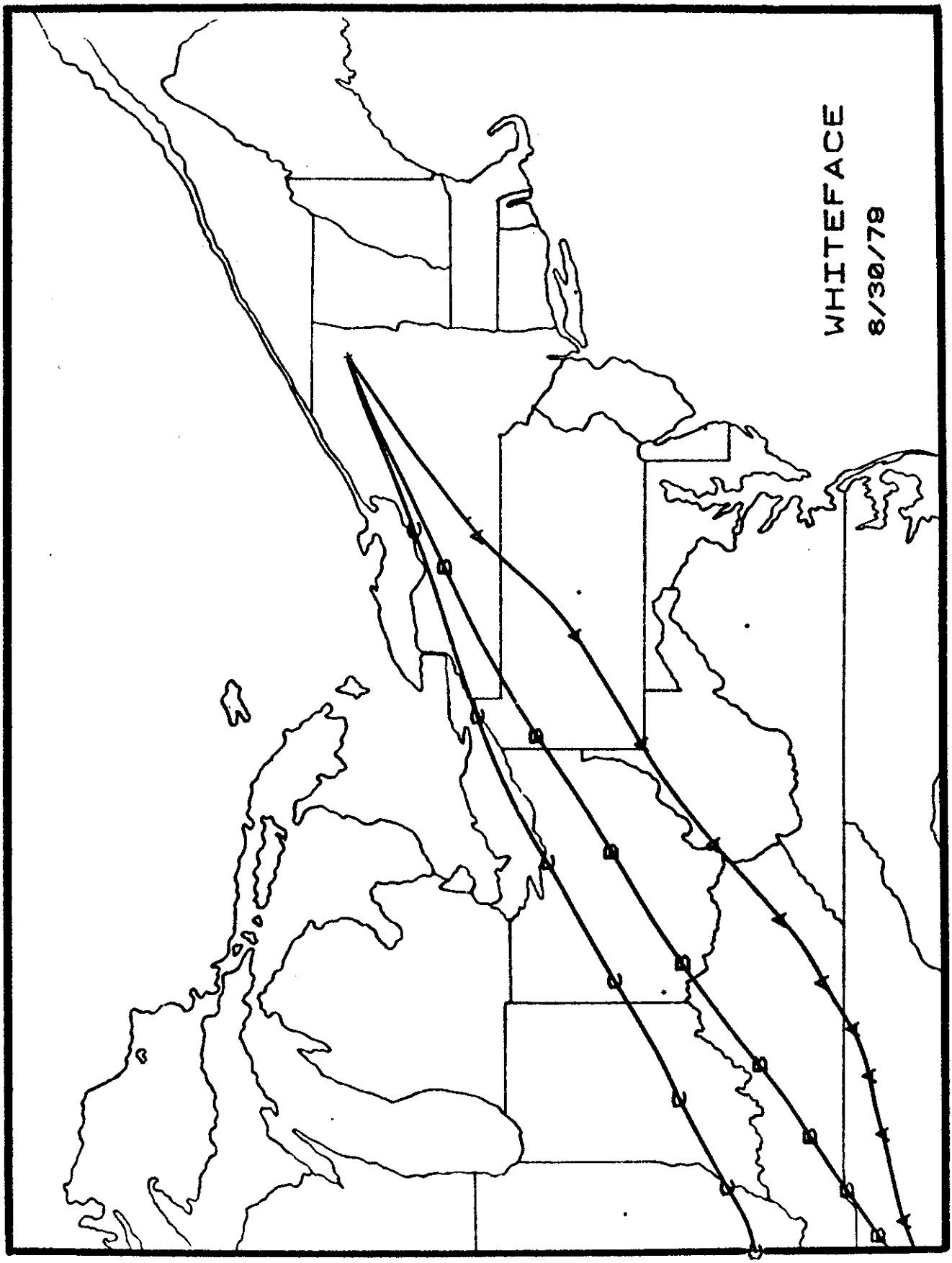

Figure 4. Air parcel trajectories calculated for the August 30, 1979 cloud water collection event at Whiteface Mountain.

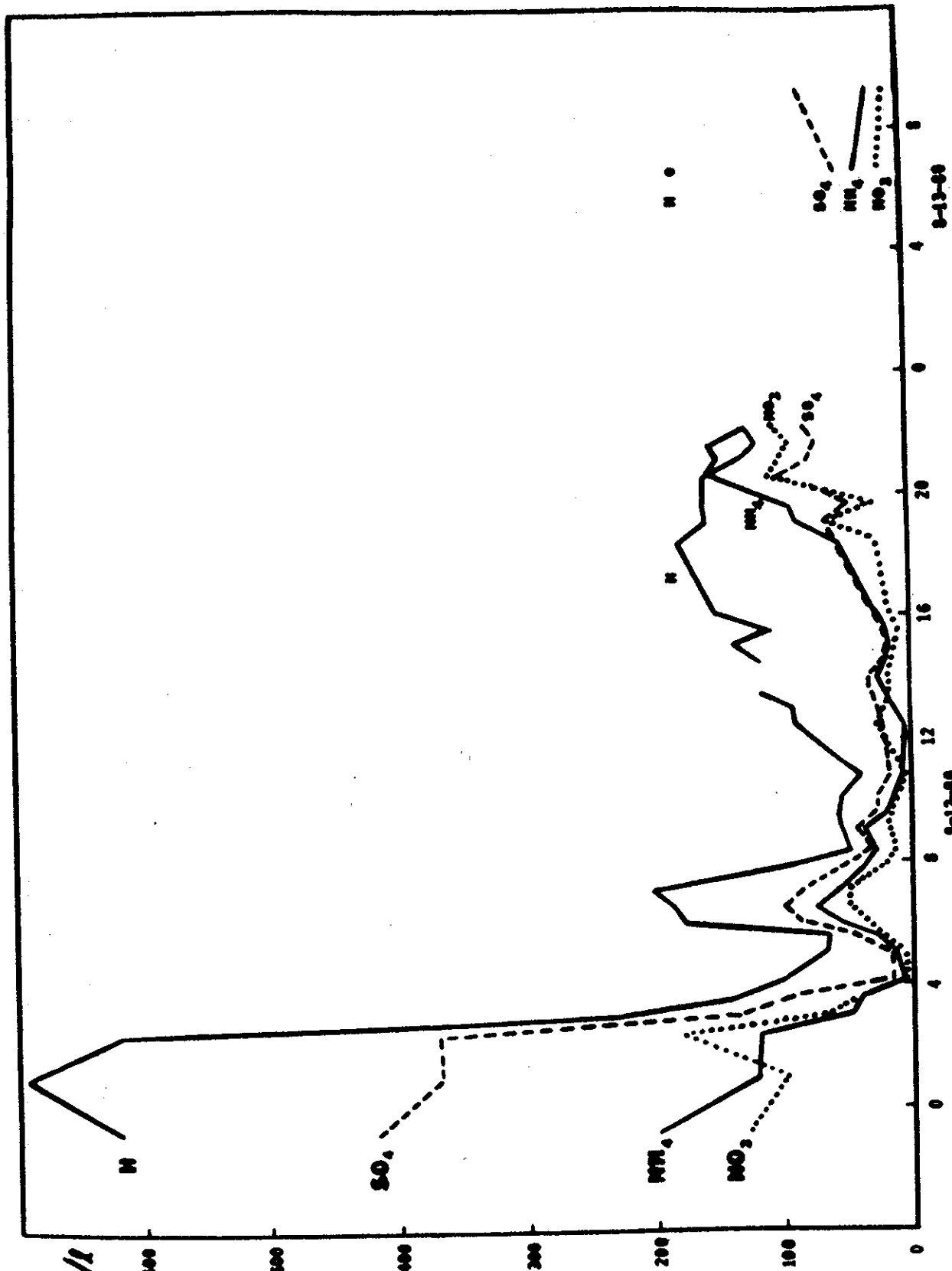

Figure 5. Time variation of the dominant ions in cloud water collected at Whiteface Mountain, August 12, 1980.

Canada would appear to be the region most recently influencing the air mass.

The low ion concentrations observed during most of the event, notably during mid-day, are of particular interest. Normally, clouds tend to be patchy in character, creating the possibility of occasional evaporation of water from the surface of the collector. However, these low concentrations in a relatively light-cloud-density event give confidence to the much higher values observed in most of the other events studied. An air parcel approaching the collector will be forced to rise slightly during the last few kilometers, causing the cloud droplet spectrum to shift to higher masses and perhaps activating additional condensation nuclei. While this has the effect of adjusting concentration values (still applicable to deposition), it also tends to resist evaporation of collected droplets during their few minutes lifetime on the collector. This is consistent with observations of actual droplets, although pre-droplet films on the filaments could not be seen.

Constant elevation collection can, as this data shows, provide time histories of incident cloud compositions suitable for direct deposition studies. Also, classification by direction of wind flow may be more susceptible to interpretation, than has been the case for precipitation (Wilson, et al. 1980), because less complicated atmospheric motions are involved for low level cloud development than for major precipitation events. However, to get improved transport and transformation rates, it becomes necessary to obtain cloud water using aircraft based collectors.

III. AIRBORNE CLOUD COLLECTORS

Mounting cloud water collection devices on aircraft permits access to a wide variety of clouds not accessible to ground-mounted collectors. The principal challenge is to collect sufficient and representative water samples from nonprecipitating warm, supercooled, or glaciated clouds. The collection

efficiency of any device needs be high enough to obtain adequate sample for the desired analysis without sacrificing spatial resolution. Further, a cloud collector should avoid capturing ambient aerosol (radius $\lesssim$ 1 μm). It cannot avoid including some rain or splash, but rain-only collectors in the hands of an experienced observer can be used to identify when rain may be interfering. And finally, the collected and accumulated droplets must not be subjected to condensation or evaporation.

Prototypes using two different collection techniques--centrifugal impaction and forward stagnation--have been built by several investigators and are now being field tested.

Notable designs of the first type are: 1) Kallend (1979), who uses a fixed angled vane system which deflects the air flow causing the droplets to impinge on the wall of a two-inch cylinder. Any accumulated water is removed downstream through an extraction ring. Testing is currently being carried out as part of the Central Electricity Research Laboratories (CERL) European acid rain program; and 2) Scott (1978) who introduced a rotating centriguge ($\sim 10^4$ rpm) to force cloud water to the inside of an outer cone.

A design of the second type, uses an air stagnation zone just in front of a slotted cylinder (Winters, et al., 1979). In this configuration seven cylindrical rods are arranged in two rows perpendicular to the flight direction (Figure 6). The selected dimensions for flight speeds of 50 to 100 m/sec are: rod diameter = 0.476 cm, and slot width = 0.15 cm with total collection area depending upon the length of the slot as well as the number of rods. The ratio of the slot width to the rod radius cannot exceed 0.3, or the flow around the cylinder will be markedly disturbed (Langmuir and Blodgett, 1946). The cloud droplets, captured on the inside walls of the slots, are protected from the passing air aerosols and trace

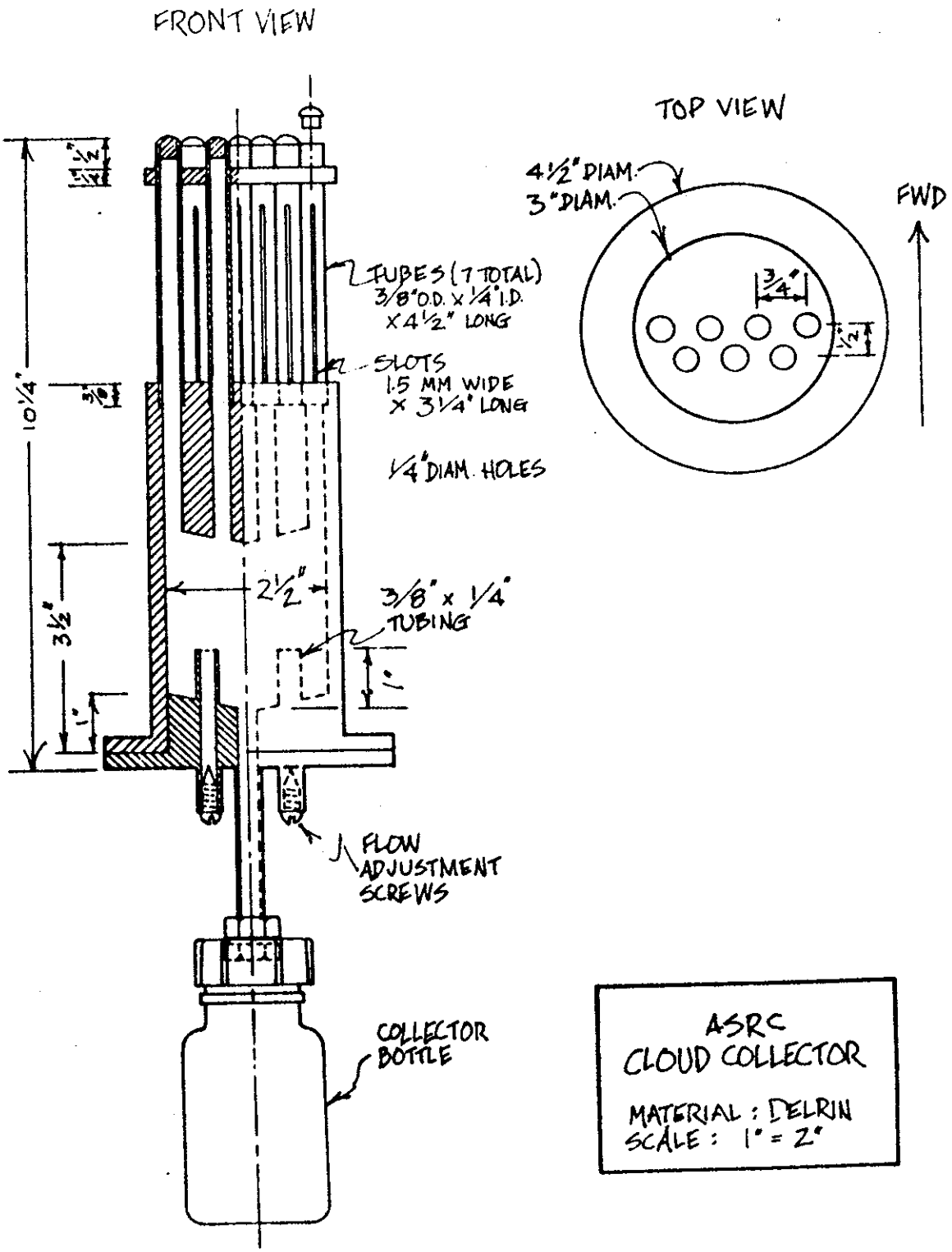
FRONT VIEW
TOP VIEW
4½" DIAM.
3" DIAM.
FWD
3/4"
1/2"
TUBES (7 TOTAL)
3/8" O.D. x 1/4" I.D.
X 4½" LONG
SLOTS
1.5 MM WIDE
X 3¼" LONG
1/4" DIAM. HOLES
10¼"
3½"
2½"
3/8" x 1/4"
TUBING
1"
FLOW
ADJUSTMENT
SCREWS
COLLECTOR
BOTTLE
ASRC
CLOUD COLLECTOR
MATERIAL : DELRIN
SCALE : 1" = 2"

Figure 6

gases and are drawn off to a removable bottle in the airplane through a capillary tube connected to each rod. In the initial flight and wind tunnel tests, this device has been performing particularly well (efficiencies = 85 ± 15% with liquid water content of 0.65 g m^{-3}, speed = 60 m sec^{-1}, and mean droplet diameter of 12 μm; and no measurable evaporation of collected water occurred in the absence of a cloud--Mohnen, 1981). Little impaction of particles below 1 μm radius occurs, and essentially all cloud droplets above 8 μm will pass into the stagnation slot of the cylindrical rods.

The unit is held in place by a support panel mounted on the fuselage of the airplane and can be exchanged during flight within seconds from inside the airplane. If the cloud should be supercooled, the full surface of the rod exposed to the oncoming airstream will act as a collector and will ice over. In this case, the collector has to be exchanged until the sample can be removed by melting.

Shown in Figure 7 is a scaled-up version of the same collection concept to collect rain. The cylindrical rod is now sufficiently large to exclude cloud droplets and only the more massive rain drop will enter the slot, and will then flow into a bottle below. This gives the investigator the capability of separating rain from the cloud--a most valuable tool in studying atmospheric liquid phase chemistry.

The ASRC Cloud collector was in flight tested during the APEX (Acid Precipitation Experiment) August 8, 1980 flights down wind of Buffalo, N.Y. The concentrations obtained in cumulus clouds at 6000 ft. are shown in Table II along with values obtained from clouds at Whiteface Mountain during the same event.

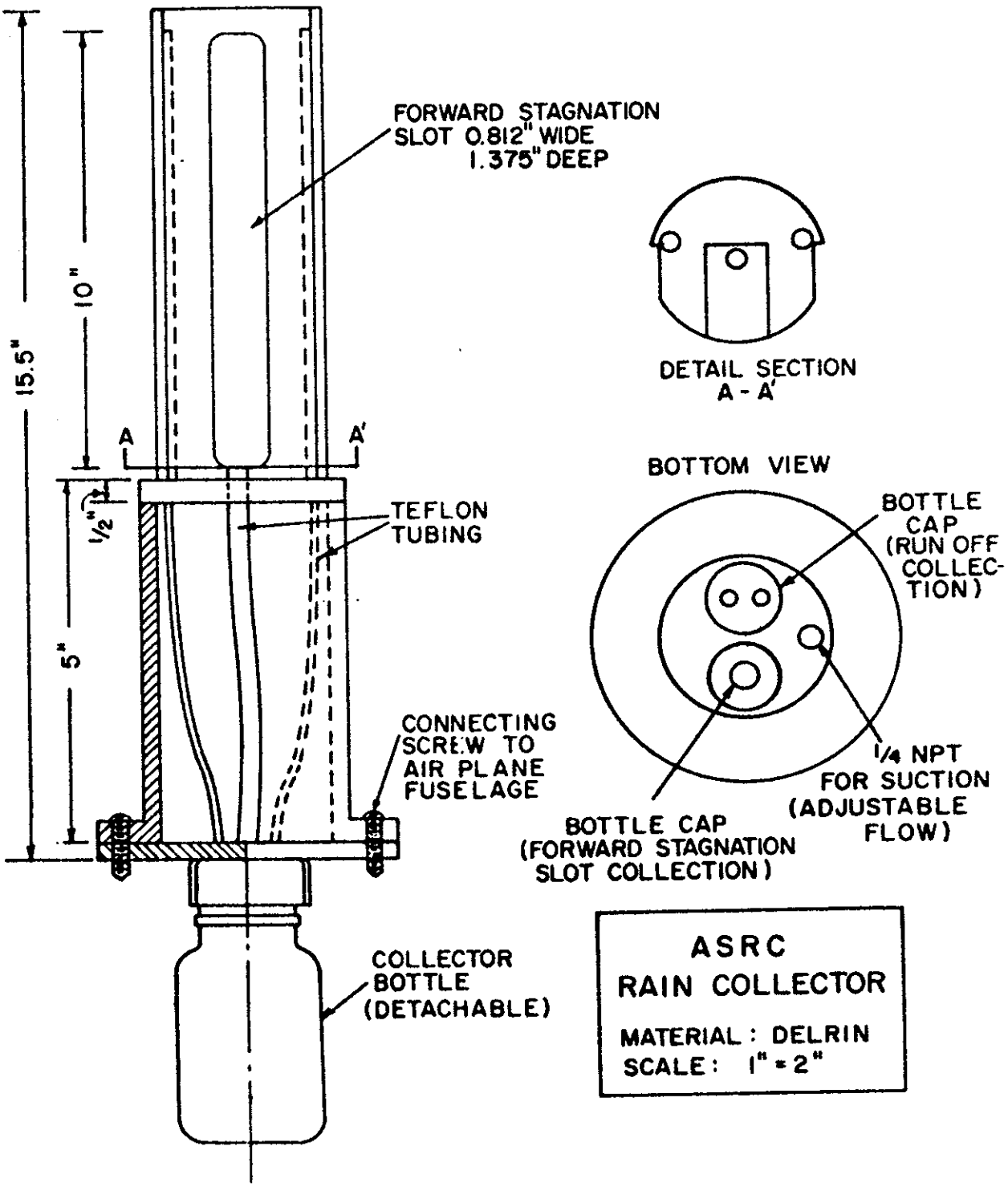
FORWARD STAGNATION
SLOT 0.812" WIDE
1.375" DEEP
15.5"
10"
A
A'
1/2"
5"
TEFLON
TUBING
CONNECTING
SCREW TO
AIR PLANE
FUSELAGE
COLLECTOR
BOTTLE
(DETACHABLE)
DETAIL SECTION
A - A'
BOTTOM VIEW
BOTTLE
CAP
(RUN OFF
COLLEC-
TION)
1/4 NPT
FOR SUCTION
(ADJUSTABLE
FLOW)
BOTTLE CAP
(FORWARD STAGNATION
SLOT COLLECTION)
ASRC
RAIN COLLECTOR
MATERIAL : DELRIN
SCALE: 1" = 2"

Figure 7

DOWNWIND OF BUFFALO AT 6,000 FEET (CUMULUS)

	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	NH_4^{+}	$SO_4^{=}$	NO_3^{-}	Cl^{-}	$PO_4^{\equiv}$	pH
meq/liter	0.90	0.17	0.044	0.26	0.21	0.65	0.38	0.20	0.003	5.42

WHITEFACE MOUNTAIN SUMMIT-BASED CLOUD COLLECTOR

	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	NH_4^{+}	$SO_4^{=}$	NO_3^{-}	Cl^{-}	$PO_4^{\equiv}$	pH
meq/liter	0.025	0.008	0.003	0.004	0.10	0.27	0.10	0.005	-	3.67

Table II. Comparison of two clouds during August 8, 1980. Analysis performed by G. Likens, Cornell University, with the cooperation of A. Lazrus, NCAR.

Even though the Buffalo cloud contained the greater anion concentrations, neutralization provided by relatively local emissions were sufficient to dominate cation chemistry. As this data shows, regional plume studies, investigations into the variability of transformation rates, and pollutant transport are now possible with improved sensitivity and reliability.

Acknowledgements

We wish to gratefully acknowledge the thoughtful advice of A. Hogan, and the dedication and sustained effort in the field displayed by D. Kennedy, S. McLaren, and R. Pratt.

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CHAPTER 2

THE FLUX OF ACIDITY DUE TO CLOUDS AND PRECIPITATION IN THE ADIRONDACK MOUNTAINS OF NEW YORK STATE[†]

I. INTRODUCTION

In a previous paper, Falconer and Kadlecek (1980) pointed out that the scavenging of certain fogs and low-lying stratus clouds by exposed surfaces, particularly trees, shrubs and other vegetative cover, along mountain slopes should be of considerable importance to the water economy of Whiteface Mountain in the northeastern Adirondack Mountains of New York State. Similar lines of reasoning, based upon actual field measurements in the Northeast had already shown that the amount of moisture added directly to the ecosystem by the horizontal interception of cloud or fog droplets could equal, or exceed that amount contributed by precipitation (Vogelmann, et al., 1968; Schlesinger and Reiners, 1974). A new, and important, aspect of this deposition phenomenon is that it probably represents a major pathway for the transfer of trace pollutants, including those ions associated with cloud and precipitation acidity, from the atmosphere to the upper portions of the mountain ecosystem.

In this paper, we shall attempt to compare the flux of hydrogen ion (H^+, also the "free acidity") in cloud water samples collected at the summit of Whiteface Mountain (1500 msl) and in precipitation collected (concurrently) at the MAP3S observation site* located on the eastern shoulder of Whiteface Mountain at the ASRC Field Station (610 msl). As far as can be determined, these analyses are unique in North America and could serve to underscore the importance of cloud water acidity deposition relative to that associated with the phenomenon of acid

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[†]Contributed by P.D. Falconer, Research Associate, A.S.R.C.

*Maintenance of the MAP3S site is financially-supported by the U.S. Department of Energy (EY76022986A003).

precipitation in high altitude ecosystems of the Northeast.

II. METHODS OF COLLECTION

(a) Cloud Water Collection, pH Determination, and Flow Rate Characterization

In keeping with recently recommended design criteria for collectors used in precipitation chemistry measurements programs (Galloway and Likens, 1978), the ASRC cloud water collector is constructed entirely of plastic, as shown in Figure 1. The collector consists of two polypropylene discs of diameter, d, equal to 0.25 m, separated, and supported, by several polypropylene rods of diameters 9-, 12-, and 22 mm, each 1.0 m in length. A continuous strand of Teflon FEP-fluorocarbon fiber (d = 0.4 mm) was strung back and forth between the discs, every 3 mm apart, along their periphery. A plastic funnel was secured to the base of the collector so as to direct the intercepted cloud water indoors, into the laboratory pH sensor, through pre-cleaned Teflon tubing. The interface between the pH probe of sensor unit (Markson Electro Mark) and the intake line is an assembly of polypropylene blocks (each 1.6 cm x 7 cm x 12 cm) which, through a succession of chambers, permit a controlled flow of water from the inflow to outflow ports, across the pH probe. The water flow through the blocks is regulated to maintain approximately 20 ml of fresh sample at any one time at the probe. The voltage output from the pH probe is recorded continuously.

Prior to operation, the collector is thoroughly acid rinsed, washed, and covered. As clouds, or rain, develop at the summit, the collector is mounted on a telescoping tower which can be raised to 3 m above the ASRC Summit Observatory. At this height rain splash from the roof is eliminated.

In order to monitor the cloud water collection rate, a duplicate collector was erected on the roof of the observatory. All water intercepted by the second unit passes through a tipping bucket mechanism beneath the funnel. For each passage of 7.95 ml of water, the balance of the tipping buckets is disturbed, causing the momentary closure of an electrical contact. Each contact closure

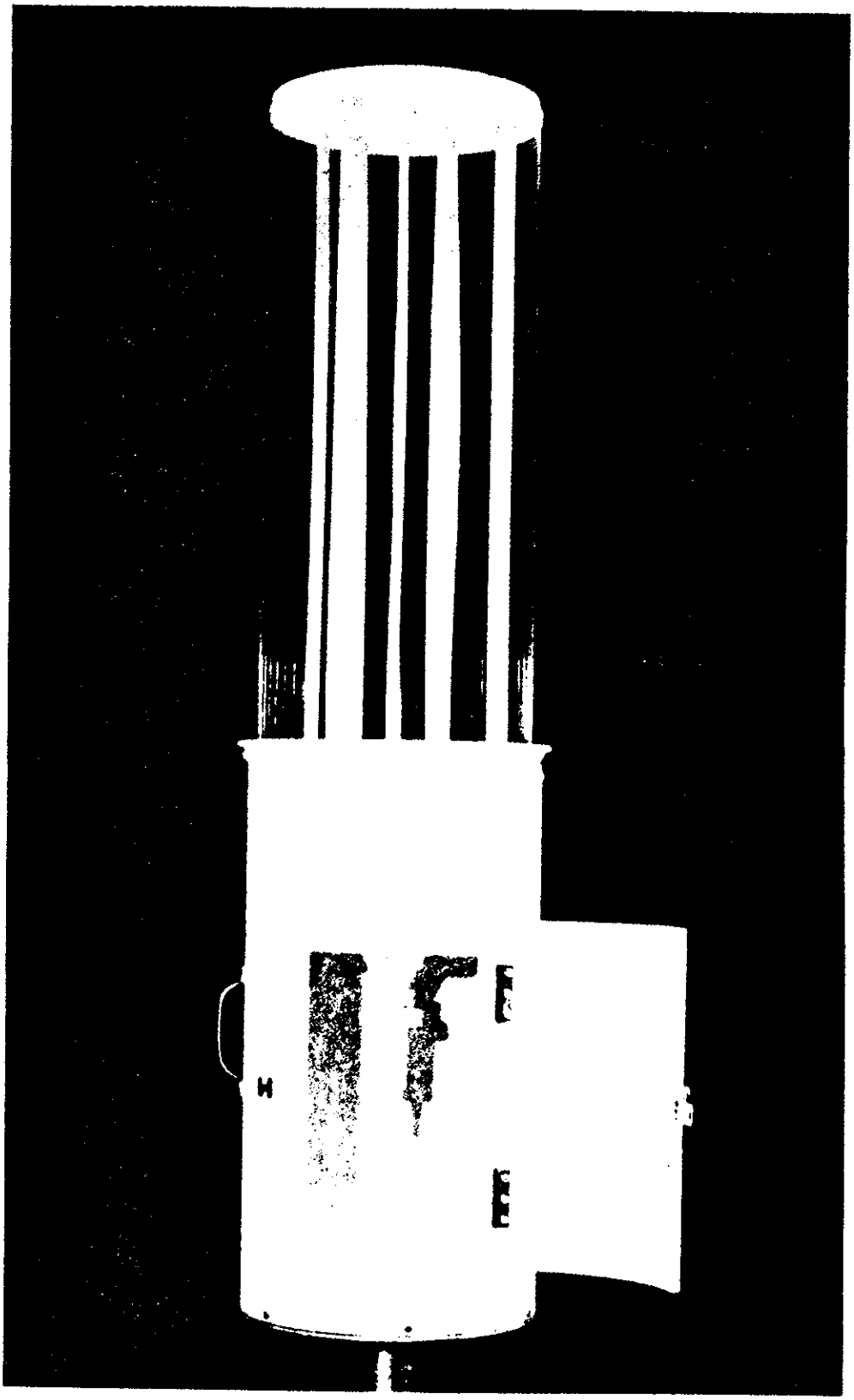

Figure 1. The ASRC ground-based cloud water collector.

provides a pulsed, electrical signal to a recorder in the summit laboratory. From the total number of signals recorded over a period of time, the volume of water which passed through a unit vertical area can be calculated to a high degree of approximation.†

(b) Precipitation Collection and pH Determination

A special-purpose rain gauge, designed by Battelle-Pacific Northwest Laboratory for the MAP3S program, is located at the ASRC Field Station at Whiteface. The details of its construction and the protocol for collecting and handling precipitation samples is described elsewhere (Pacific Northwest Laboratory, 1980). For the purposes of this special study, it is instructive to point out that the pH measurement made in the field at the time of collection is used in preference to the laboratory pH measurement. Kadlecek and Mohnen (1975), among others, have pointed out that pH readings avoid the recurrent problem of time changes in the acidity of stored precipitation samples.

III. CALCULATION OF THE FLUX OF ACIDITY DUE TO CLOUDS AND PRECIPITATION

The basic set of cloud water and precipitation data was assembled from the June-August 1980 period, using only those events where cloud collection at the summit and rain collection at the Field Station occurred contemporaneously, from the same synoptic scale weather system. Seventeen such paired events were identified (Table 1).

Although the H+ concentration in rain water (H_R^+) is specified directly from the single field measurement of pH through the relationship $H_R^+ (\mu ML^{-1}) = 10^{6-pH_R}$, the corresponding event average of cloud water acidity ($\bar{H}_c^+$) is derived by first converting the recorded pH_c measurement to H_c^+ concentrations at intervals of 7½ minutes, and then to weight, by volume, these successive H_c^+ concentrations. The method of calculation is straightforward, namely

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†Cloud droplets of diameters less than approximately 5-10 μm are collected with increasingly reduced efficiencies. However, their contribution to the mass of any given cloud element is generally small.

$\bar{H}_c^+$ (μML^{-1}) = (1/n) (Σ H_c^+ x n), where n is the volume of cloud water collected in the 7½ minute interval following the pH_c reading. The value $\bar{H}_c^+$ is directly analogous to H_R^+.

The flux of H^+ in cloud water and in precipitation is expressed in terms of milligrams H^+ per square meter (mgm^{-2}), where it is understood that the "square meter" referred to is oriented vertically in the case of clouds and horizontally in the case of rain. In general, the flux of acidity (F) will be calculated for each cloud or MAP3S rain event as follows:

$$F = \underbrace{\frac{\mu m}{L}}_{\bar{H}_c^+ \text{ or } H_R^+} \times \underbrace{0.001 \frac{mg}{\mu M}}_{\text{conversion factor for } H^+} \times \underbrace{\text{sample volume}}_{\text{liters per } m^2, \text{ where magnification factor (M) is 13.33 for cloud collector and 20.41 for rain gauge.}} \times M$$

IV. RESULTS

Nineteen cloud water collection periods and seventeen rain sampling periods between June 18-19 and August 23-24 were used in computing the total flux of H^+. Table 1 summarizes the results, which lead to several points of interest:

(1) The cumulative transport of cloud water* across a (vertical) square meter surface at the summit of Whiteface Mountain (1650 Lm^{-2}) is nearly 7.5 times greater than that delivered by precipitation further down the mountain (223 Lm^{-2}). It must be remembered, however, that the surface area of Whiteface Mountain affected by direct cloud wetting during these months is significantly smaller, perhaps by an order of magnitude, than the total area of Whiteface Mountain impacted by rainfall. Accordingly, it is not unreasonable to expect that the *potential* contri-

*over the seventeen events listed in Table 1.

bution of water volume by clouds and by precipitation to the *entire* mountain system is roughly comparable. At higher altitude clouds are the primary source of moisture to the ecosystem while, at lower levels, the input due to rainfall prevails.

(2) The volume-weighted average hydrogen ion concentration of clouds (179.8 μML^{-1}), including both precipitating and non-precipitating varieties, is nearly twice as great as that calculated for precipitation collected at the MAP3S site (99.2 μML^{-1}). This difference is significant at the 5% level, using Student's t-test, consistent with observations made at Whiteface Mountain during prior summer field experiments (Castillo, 1979; Falconer and Falconer, 1980).

(3) Because of the greater acidity of, and water volume transported by, clouds along the upper slopes of Whiteface, the total flux of H^+ in cloud water far exceeds that due to precipitation at the MAP3S site. Nearly 90% of the paired collection events analyzed in this study show a $F_c : F_R$ ratio in excess of 2.5:1 and 10% of the ratios exceed 50:1.

In order to further explore the nature of acid transport in clouds and rainfall, we segregated collection periods according to airmass trajectory sector (derived from NOAA-Air Resources Laboratories trajectory model output) and by airmass type (loosely following the classification scheme of Bryson (1966)). The NOAA-ARL regional transport and dispersion trajectory model (Heffter, 1980) has been widely used and accepted as a tool by which the recent history of a parcel of air within the planetary boundary layer may be calculated. For the purposes of these analyses, the ARL trajectories, in conjunction with surface weather maps and 850 millibar height field depictions, were used in distinguishing between those airmass types listed in Table 2.

	CLOUD DATES (EST)	MAP3S DATES (EST)*	AIRMASS	VOLUME COLLECTED (m^{-2}) RAIN	VOLUME COLLECTED (m^{-2}) CLOUD	AVERAGE H^+ (pH) RAIN	AVERAGE H^+ (pH) CLOUD	TOTAL H^+ FLUX RAIN	TOTAL H^+ FLUX CLOUD	COMMENTS
1.	6/18-19 (19/00-03)	6/16-19 (18/20-19/04)	cP via Great Lakes	2.63L	3.82L	257μML^{-1} (3.59)	960μML^{-1} (3.02)	0.676$\frac{mg}{m^2}$	3.66$\frac{mg}{m^2}$	No apparent precipitation accompanied cloud cover at summit.
2.	6/20-21 (20/06-21/16)	6/19-21 (19/15-21/11)	mT_c until 21/1300 shifting to AP	7.53	296.9	100 (4.00)	85.4 (4.07)	0.753	25.34	No apparent precipitation accompanied cloud cover at summit. 75% of rain collected at MAP3S site fell during cloud water collection period.
3.	6/27 (27/0000-1530)	6/24-27 (27/10-14)	Briefly mT, but progressing to NR to CR to cP	0.71	110.6	177 (3.77)	208.7 (3.68)	0.126	23.10	No apparent precipitation accompanied cloud cover at summit
4.	6/30-7/1 (30/13-1/02)	6/27-7/1 (30/14-1/00)	cP	40.04	30.15	71 (4.15)	244.7 (3.61)	2.84	7.40	Embedded precipitation at summit on 30/13-20 EST.
5.	7/8 (8/07-1345)	7/7-9 (8/06-15)	CR via Great Lakes	24.98	27.34	71 (4.15)	41.8 (4.38)	1.77	1.14	Primarily precipitation from stratiform overcast during AM.
6.	7/12 (12/1600-2345)	7/9-13 (10/02-03 and 12/20-22)	CR on the 10th but cP throughout collections of the 12th.	1.51	47.16	83 (4.08)	14.9 (4.83)	0.125	0.700	Fifteen minute shower at summit on 12/1915-1930. 71% of rain collected at MAP3S site fell during cloud water collection period.
7.	7/15-16 (15/21-16/09)	7/13-16 (16/00-02)	MT	4.29	92.5	112 (3.95)	328.7 (3.48)	0.480	30.41	Embedded precipitation, heavy at times, within cloud cover on 16/00-03 EST.
8.	7/17 (17/08-2115)	7/16-18 (17/16-19)	MT_c	14.14	57.3	78 (4.11)	196.0 (3.71)	1.103	11.23	Embedded precipitation, heavy at times, at summit on 17/00-02 EST.
9a.	7/20-21 (20/1530-21/12)	7/18-21 (20/1200-21/11)	MT	13.57	60.19	123 (3.91)	217.3 (3.66)	1.67	13.09	No apparent precipitation accompanied cloud cover at summit.
** 9b.	7/21-22 (21/12-22/19)	7/21-22 (22/02-22/19)	modified NR and mT	21.72	135.01	78 (4.11)	159.6 (3.80)	1.69	21.55	Very light, intermittent rain showers at summit.
9c.	7/22-24 (22/19-24/0645)	7/22-24 (23/11-17)	CR via Great Lakes	5.72	195.42	63 (4.20)	139.3 (3.86)	0.360	27.21	No apparent precipitation accompanied cloud cover at summit.
10.	7/26-27 (26/1952-27/0530)	7/24-27 (26/00-27/08)	mT, progressing to mT_c	7.04	23.42	100 (4.00)	280.0 (3.55)	0.704	6.56	Embedded precipitation at summit on 26/21-22 EST. 75% of MAP3S sample volume had fallen by cloud collection time on 26th.
11.	7/29-30 (29/05-30/0315)	7/27-30 (29/06-30/11)	mT_c	13.55	137.98	76 (4.12)	209.8 (3.68)	1.030	28.95	Embedded precipitation at summit on 29/13-18 EST.
12.	8/6 (6/0225-13)	8/4-6 (5/18-6/00)	mT	22.08	25.85	141 (3.85)	379 (3.42)	3.113	9.797	No apparent precipitation accompanied cloud cover at summit. Notice that these clouds developed 2 ½ hrs. after shower activity at MAP3S site.
13.	8/8-9 (8/0145-9/11)		modified mT and NR		116.37		261.9 (3.58)		30.487	No apparent precipitation accompanied cloud cover at summit.
14.	8/11-13 (11/2152-13/1030)	8/6-12 (12/02-11)	cP via Great Lakes	21.82	202.25	105 (3.98)	164.6 (3.78)	2.291	33.30	Embedded shower activity at summit on 12/0300-0600 EST.
15.	8/14-15 (14/16-21)	8/12-15 (14/16-18)	modified mT and NR	17.06	11.56	135 (3.87)	240.4 (3.62)	2.303	2.778	Embedded shower activity at summit, occasionally heavy, on 14/1600-1800 EST.
16.	8/18-19 (18/23-19/12)	8/16-19 (16/12-19/12)	modified mT and NR	4.35	52.14	240 (3.62)	309.9 (3.51)	0.704	16.16	Brief period of rain on 19/0400-0500 EST.
17.	8/23-24 (23/2130-24/0930)		mT_c		24.27		161.3 (3.79)		3.92	Apparent cap cloud.

*MAP3S date/times indicate when precipitation occurred, rather than how long sample bottle remained in the field
**continuous cloud water collection and analyses of pH was made between 20 and 24 July.

Table 1. Chronology of cloud water and precipitation event registered at Whiteface Mountain during the summer of 1980. The volume of water collected per unit area, the average H^+ concentrations, and the total H^+ flux per event due to clouds and precipitation were calculated as described in the text.

Abbreviation	Name	Remarks
mT_c	maritime Tropical$_{coastal}$	warm, moist airflow confined to east of Appalachian Ridge
mT	maritime Tropical	standard definition, mostly from Gulf of Mexico in broad northeasterly sweep
NR	Northern Rockies Pacific	crosses the Rockies in Montana and through the Wyoming gap
CR	Canadian Rockies Pacific	crosses the Rockies into Alberta, especially in the Edmonton-Calgary area
cP	continental Polar	standard definition, mostly from the interior of Canada
AP	Atlantic Polar	cool, moist fetch circulated inland from the Atlantic, north of 40°N latitude.

Table 2. Airmass classification scheme used in this report.

In many instances, a change in airmass type may occur during the time when the precipitation or cloud water collector is exposed. This is particularly true whenever clouds or rain are initiated prior to, and during, the passage of weather fronts. In other circumstances, this fact would complicate the matter of assigning the ion chemistry of a given *bulk* precipitation sample to one airmass or the other, or of prorating the *continuous* measurements of ion and cloud water fluxes according to different airmass source regions. However, for the purposes of this study, we have collected the various airmass types of Table 2 into three categories of importance to contemporary studies of the acid precipitation phenomenon--Canadian interior (CR and cP), Midwestern (NR and mT), and Coastal (mT_c and AP). In most instances, there was little ambiguity in specifying to which of these three categories a cloud water or precipitation event belonged. Consequently, a sufficient number of cloud and rain event measurements of H^+ concentrations,

sample volumes collected, and the computed event total H^+ fluxes, were available from each category to develop tests for the statistical significance of these inter-airmass variations during the summer field experiments.

Cloud and precipitation measurements of average H^+ concentrations (in μML^{-1}); total H^+ flux (mgm^{-2} per event); and total sample volume collected (Lm^{-2}) were segregated according to the three genetic airmass types described above - Canadian, Midwestern, and Coastal. The average values of each of these three values were computed and the results are summarized in Table 3.

AIRMASS CATEGORY			PARAMETERS WHOSE MEAN VALUE HAVE BEEN CALCULATED
Midwestern	Coastal	Canadian	
138.2 (pH=3.86)	84.7 (pH=4.07)	118.1 (pH=3.93)	Precipitation Acidity (μML^{-1})
1.66	0.96	1.17	Acidity Flux (mgm^{-2} per event)
13.85	11.74	13.92	Sample Volume Collected (Lm^{-2})
271.0 (pH=3.57)	163.1 (pH=3.79)	135.7 (pH=3.87)*	Cloud Water Acidity (μML^{-1})
17.75	17.36	15.48*	Acidity Flux (mgm^{-2} per event)
70.52	129.11	102.15*	Sample Volume Collected (Lm^{-2})

Table 3. Average values of precipitation and cloud water acidities, sample volumes collected, and the computed acidity fluxes from data obtained at Whiteface Mountain during June-August 1980. (*Cloud collection period of June 18-19, 1980 has been eliminated from the Canadian data base because it was viewed as an abnormally rare occurrence. This is a justifiable grounds for elimination, as pointed out by Wilson (1952).)

The significance of differences in the averages of acidity concentrations, acidity fluxes, and volumes of water collected between airmass source regions was established by application of the Student t-test (Adler and Roessler, 1977). This test procedure assumes that the variables involved (H^+, F or volume collected) are drawn from independent and normally distributed populations (associated with distinct airmasses), each with a certain mean value. The Student t-test permits us to determine whether or not these mean values are truly different at some

assigned level of confidence, here 95%, given the relatively small number of observations involved. Table 4 below summarizes the results of the significance tests for the inter-airmass comparisons of cloud and precipitation chemistry attributes derived from the three month program at Whiteface Mountain.

AIRMASS CATEGORY PAIRS			PARAMETERS WHOSE MEAN VALUES ARE COMPARED
Midwestern-Coastal	Coastal-Canadian	Canadian-Midwestern	
Not significant (ν=7)	Not significant (ν=8)	Not significant (ν=11)	Precipitation Acidity
Not significant (ν=7)	Not significant (ν=8)	Not significant (ν=11)	Acidity Flux
Not significant (ν=7)	Not significant (ν=8)	Not significant (ν=11)	Sample Volume Collected
significant (ν=9)	Not significant (ν=8)	*significant* (ν=11)	Cloud Water Acidity
Not significant (ν=9)	Not significant (ν=8)	Not significant (ν=11)	Acidity Flux
Not significant (ν=9)	Not significant (ν=8)	Not significant (ν=11)	Sample Volume Collected

Table 4. Results of statistical testing of airmass differences in acidity, acidity flux and sample volume size collected due to clouds and precipitation at Whiteface Mountain during June-August 1980. Using the Student t-distribution, any inter-airmass differences in the mean values of those attributes which exceed the 95% confidence limits are reported as significant.

It is striking to note that, except for the differences in mean cloud water acidity (H_c^+) between airstreams of Canadian and Midwestern origins (135.7 μML^{-1} and 271.0 μML^{-1}, resp.), and between those of Midwestern and Coastal origins (271.0 μML^{-1} and 163.1 μML^{-1}, resp.), all remaining inter-airmass differences in the average acidities, acidity fluxes, and sample volume size cannot be considered significantly distinguishable. Unfortunately, there are no comparable cloud water and precipitation data from other locations in the Northeastern U.S.. Therefore, it is impossible to determine whether the observed airmass independence of average cloud and precipitation physico-chemical characteristics is a regional-scale phenomenon.

For the sake of completeness, and in order to provide the proper perspective on the issue of *total* acid deposition and cloud or rain water deposition, rather than their *event average* values, we have constructed Table 5, which displays the inter-airmass variability of these two important parameters.

AIRMASS CATEGORY

Midwestern	Coastal	Canadian	
9.96	2.88	8.19	Total Precipitation Acidity Flux (mgm^{-2})
83.10	35.22	97.44	Total Precipitation Sample Volume (Lm^{-2})
124.25	69.44	92.88	Total Cloud Water AcidityFlux (mgm^{-2})
493.64	516.44	612.9	Total Cloud Water Sample Volume (Lm^{-2})

Table 5. Cumulative total precipitation and cloud water acidity fluxes (mgm^{-2}) and sample volume collected for the June-August 1980 period at Whiteface Mountain, segregated according to the prevailing airmass type.

V. CONCLUSIONS

The cloud water and precipitation chemistry data base developed at Whiteface Mountain during the June-August 1980 field experiments have been used to identify any systematic differences in the average acidity (H^+, in μML^{-1}), average acidity fluxes (F, in mgm^{-2} per event), and volume of water collected (Lm^{-2}) between clouds and rain and between broad airmass source regions. No attempt was made to distinguish between non-precipitating and precipitating cloud types even though it has been shown (Falconer and Falconer, 1980) that the cloud water pH and collection rates for non-precipitating clouds are easily distinguished from clouds with embedded precipitation. It has been shown that the cumulative (approx. 3 mo.) transport of cloud water across the upper slope of Whiteface Mountain (1650 Lm^{-2}) was nearly an order of magnitude greater than that due to rain (223 Lm^{-2}); that the acidity of cloud water ($\bar{H}_C^+$ = 179.8 μML^{-1}) was almost twice that of rain sampled at the MAP3S site ($\bar{H}_R^+$ = 99.2 μML^{-1}); and that the resultant total flux of acidity due to clouds was substantially greater than that due to precipitation. It was pointed out, however, that the impact of acid depositon due to cloud water interception would be confined to a relatively small area at higher altitudes along the mountain slopes.

No dependence of mean precipitation acidities, acidity fluxes, and precipitation volumes upon airmass type was revealed in the statistical tests developed

in this report. Neither do event-averaged cloud water acidity fluxes nor total cloud water collection volumes seem to show any relationship to recent airmass history. The differences in mean cloud water acidities attributable to Canadian and Midwestern airmasses, and to Midwestern and Coastal airmasses, are large enough to warrant the conclusion that a significant airmass dependence exists. Our measurements indicate that clouds produced in association with weather systems arriving from the Canadian interior (CR and cP) are least acidic (135.7 μML^{-1} or pH = 3.87); those of recent eastern seaboard influence of slightly greater acidity (163.1 μML^{-1} or pH = 3.79); and finally, those of midwestern origin, often referred to as "Ohio Valley" air, the most acidic (271 μML^{-1} or pH = 3.57). These results are certainly consistent with those reported by Falconer and Falconer (1980), based upon earlier field measurements at the summit of Whiteface Mountain.

The *average* H^+ fluxes associated with clouds moving along the upper slopes of Whiteface Mountain are not significantly different between weather systems of differing origin. However, the *cumulative total* H^+ deposition favors airstreams of midwestern origin, followed by Canadian and coastal systems in the approximate proportions of 1.8 : 1.4 : 1. Total (potential) H^+ deposition cannot be uniquely related to the total volume of water collected, since it may be shown that cloud-producing weather systems from the Canadian sector contributed the greatest proportion of the cloud water collected during the summer, followed by coastal and midwestern airmass systems (38%, 32%, and 30%, resp.). These results are certainly consistent with the concept of a well mixed, atmospheric reservoir (the regional "superbowl" concept of Wilson, et al., (1980)) within which the average cloud water acidity fluxes remain comparable. Cumulative H^+ fluxes from June through August favored events that had recent transit over the midwestern states, primarily due to the combined effects of higher H^+ concentrations and high sample volumes collected during these times.

The inter-airmass differences of mean precipitation fluxes of acidity were

too small, based upon the limited number of samples collected, to be of significance. The 3-month total H^+ depositions show, on the other hand, an airmass dependence which, upon close scrutiny seems strongly modulated by the precipitation volume. It is of particular interest to note that, in contrast to the summers of 1978 and 1979, the contribution which CR and cP airmass precipitation events make to the 1980 precipitation totals is 39%. This compares with 18% and 24% for the years 1978 and 1979, respectively. Thus, it is conceivable that the apparent impact of precipitation from weather systems migrating southward out of Canada has been overemphasized based upon our 1980 field program results. However, we are inclined to believe that the apparent contributions of Canadian, Coastal, and Midwestern summer rainfall patterns at Whiteface Mountain to total H^+ deposition are comparable, dependent, for the most part, upon the inter-annual variability of precipitation amounts.

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APPENDIX A

Chronology of Cloud Water Collection Events
June - August 1980

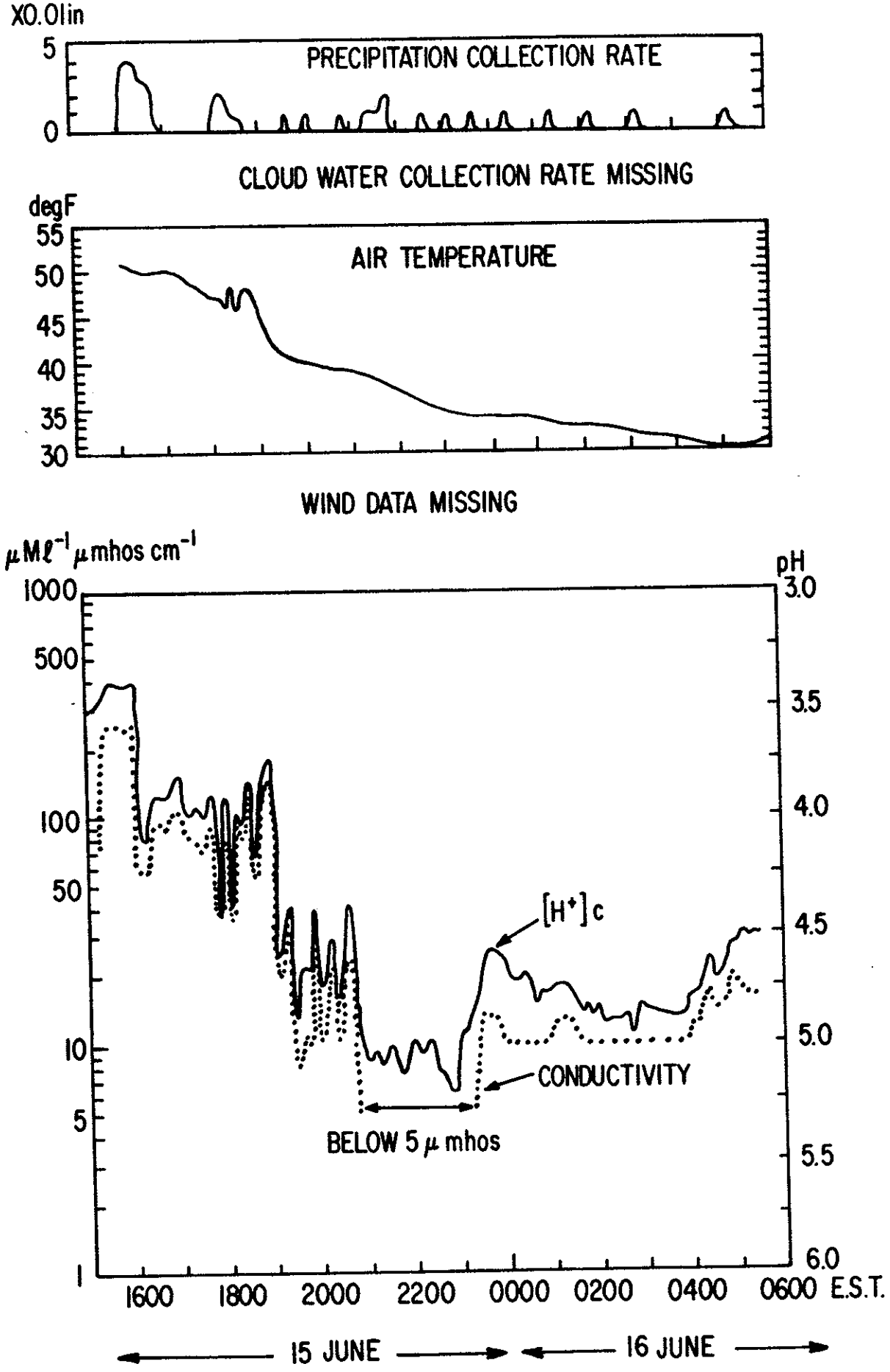
CLOUD CHEMISTRY DATA LOG

1980

DATE \ DATA	pH_C $Cond_C$ pH_R	Cloud Rate	Rain Rate	Cloud Anions	Cloud Cations	LWC	Lodge pH_R	Cloud Ion Dep.
June 7-8	X	-	-	-	-	-	-	
15-16	X	X	-	-	-	-	-	
18-19	X	X	X	-	-	-	-	
20-21	X	X	X	X	X	-	-	X
27	X	X	X	X	X	-	-	
29	X	X	-	X	X	-	-	
June 30-July 1	-	X	X	X	X	-	-	X
July 5-6	X	-	X	X	X	-	-	
8-9	X	X	X	X	X	-	-	
11	X	X	X	X	X	-	-	
12	X	X	X	X	X	-	-	
15-16	X	X	X	X	X	-	-	
17	X	X	X	X	X	-	-	
20-24	X	X	X	X	X	-	-	X
26	-	-	-	X	X	-	-	
27	-	-	-	X	X	-	-	
29-30	-	X	X	X	X	-	X	
August 1	X	X	X	X	X	-	X	
3	(X)	-	-	-	-	-	X	
5-6	X	X	X	X	X	-	X	X
8-9	X	X	X	X	X	X	X	X
11-13	X	X	X	X	X	X	X	
14-15	X	X	X	X	X	X	X	
19-21	X	X	X	X	X	X	X	

APPENDIX B

Cloud Water Collection Event Summary of Anions and Cations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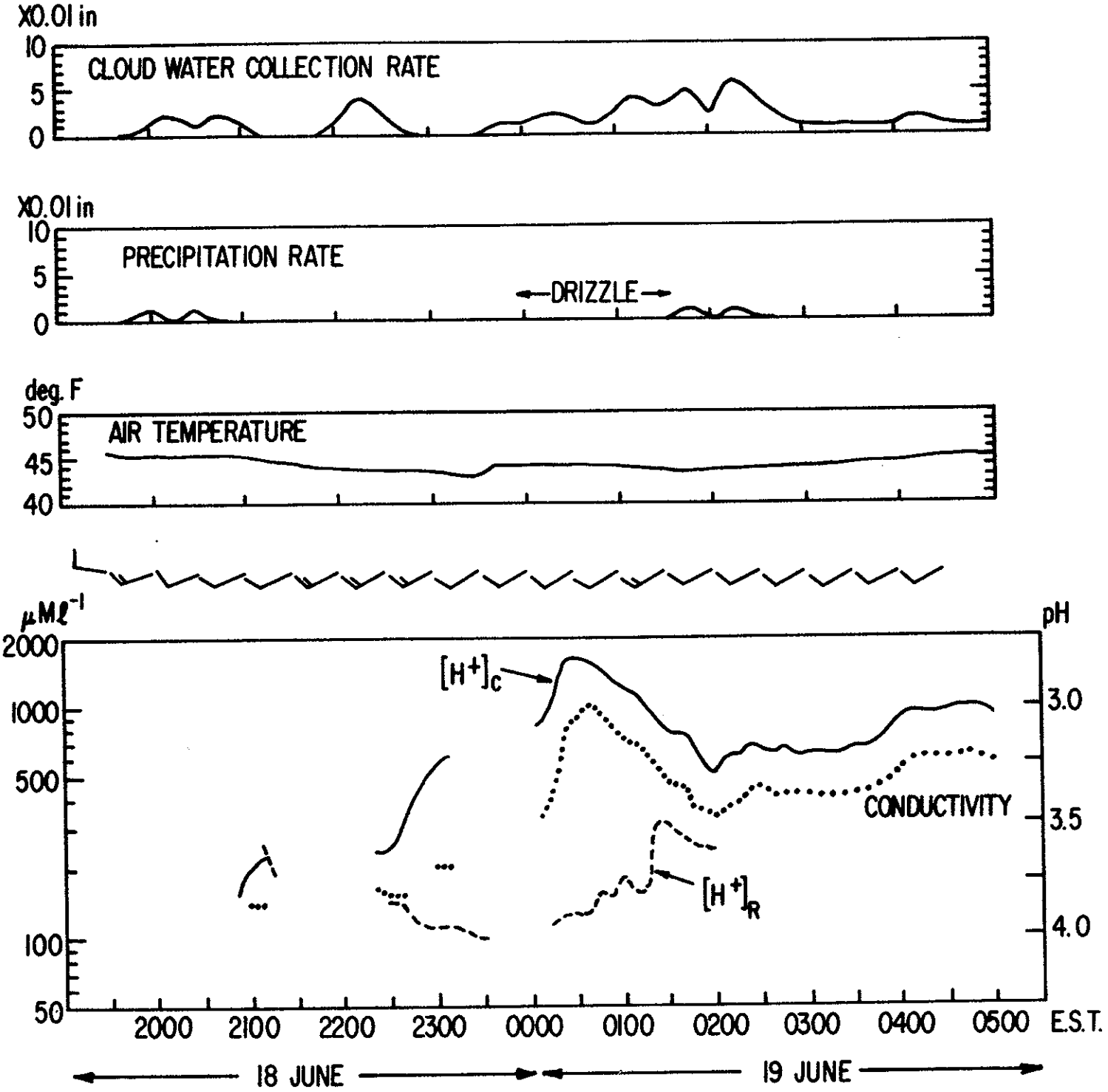
PRECIPITATION COLLECTION RATE
CLOUD WATER COLLECTION RATE MISSING
degF
55
50
45
40
35
30
AIR TEMPERATURE
WIND DATA MISSING
μMℓ⁻¹ μmhos cm⁻¹
1000
500
100
50
10
5
1
pH
3.0
3.5
4.0
4.5
5.0
5.5
6.0
[H⁺]c
CONDUCTIVITY
BELOW 5 μ mhos
1600
1800
2000
2200
0000
0200
0400
0600 E.S.T.
15 JUNE
16 JUNE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DRIZZLE
deg. F
50
45
40
AIR TEMPERATURE
μMℓ⁻¹
2000
1000
500
100
50
pH
3.0
3.5
4.0
[H+]C
[H+]R
CONDUCTIVITY
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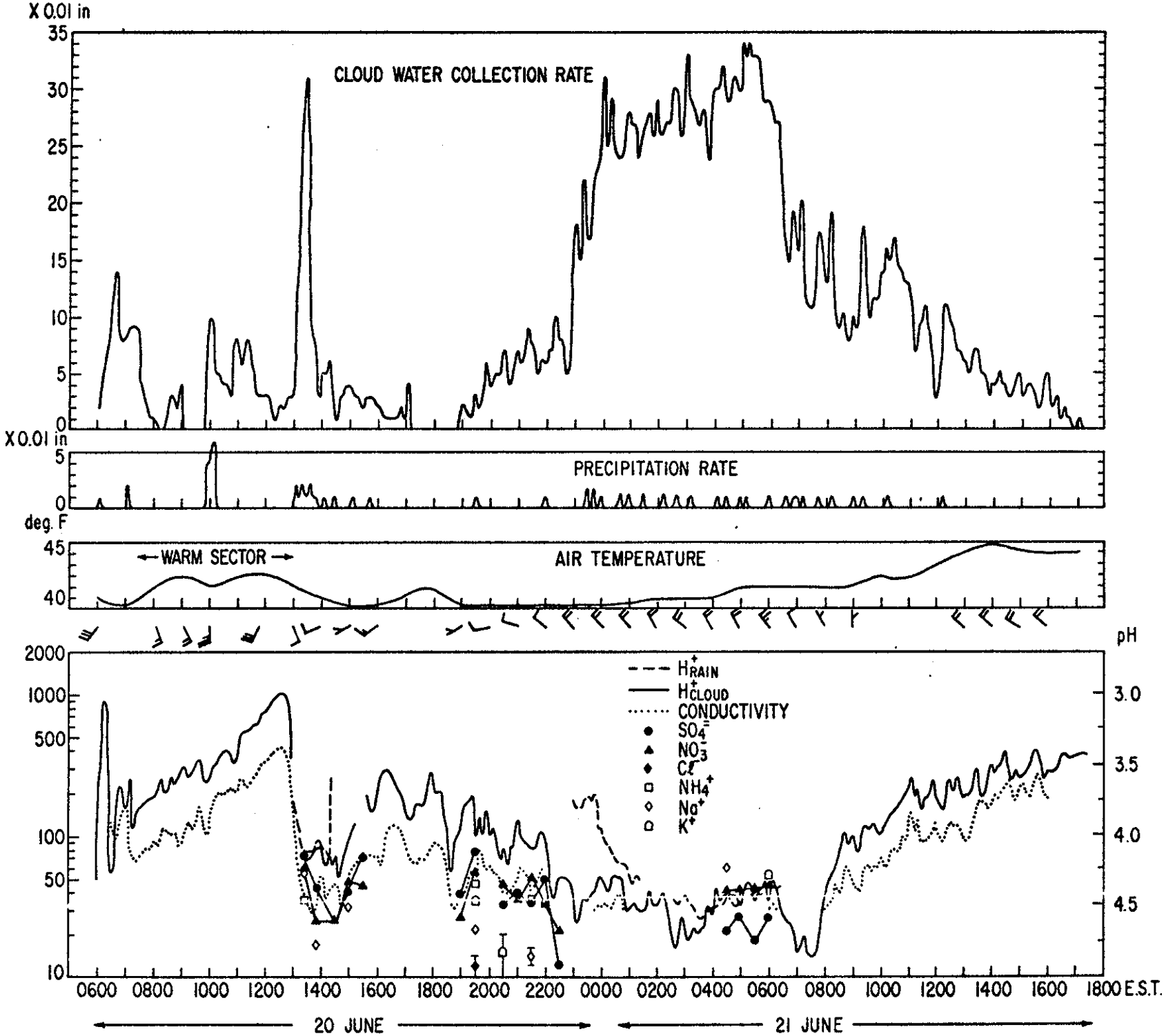
2100
2200
2300
0000
0100
0200
0300
0400
0500
E.S.T.
18 JUNE
19 JUNE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30
25
20
15
10
5
0
CLOUD WATER COLLECTION RATE
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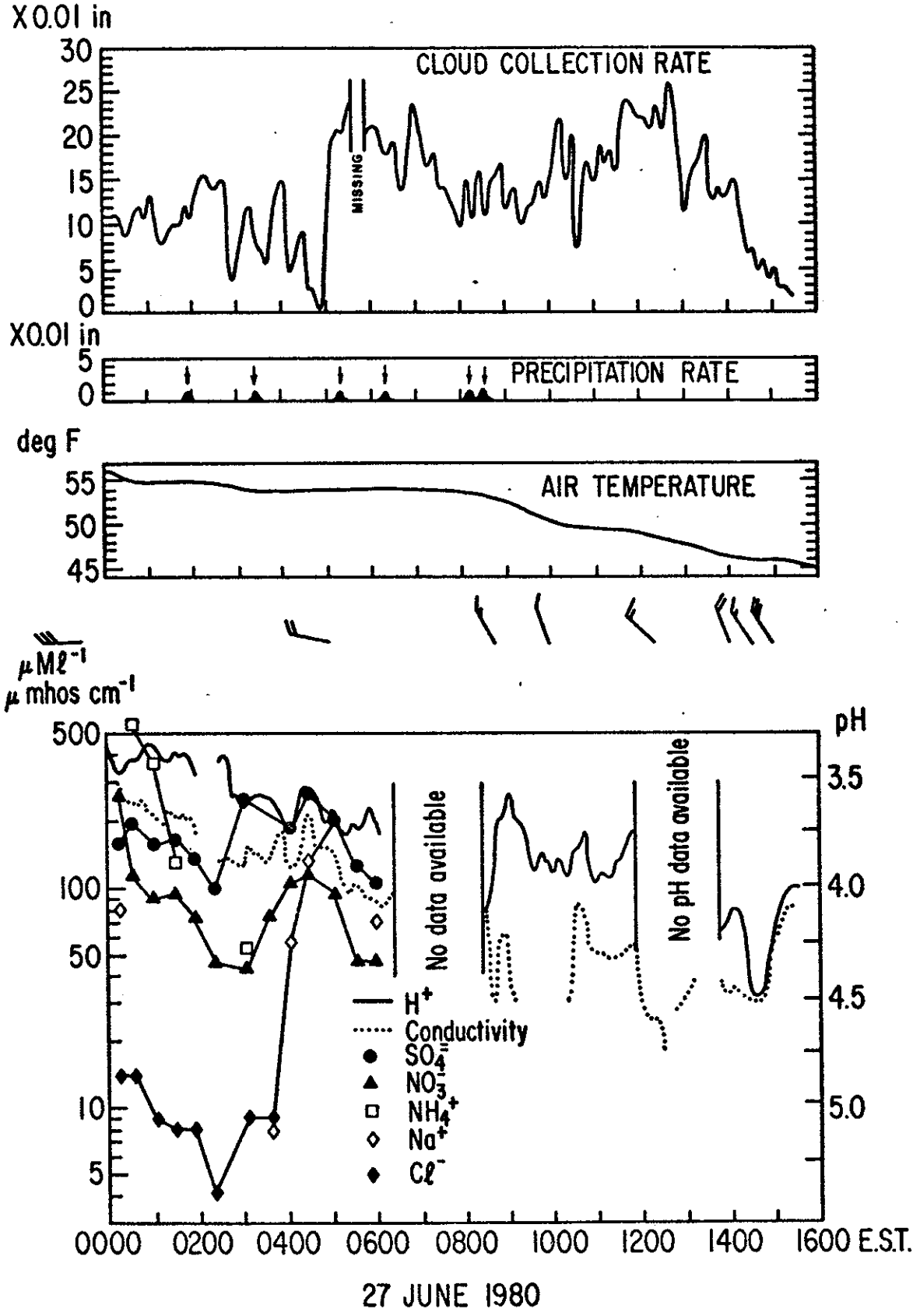
PRECIPITATION RATE
deg. F
45
40
← WARM SECTOR →
AIR TEMPERATURE
pH
2000
1000
500
100
50
10
3.0
3.5
4.0
4.5
H^+_{RAIN}
H^+_{CLOUD}
CONDUCTIVITY
$SO_4^=$
NO_3^-
Cl^-
NH_4^+
Na^+
K^+
0600 0800 1000 1200 1400 1600 1800 2000 2200 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 E.S.T.
20 JUNE
21 JUNE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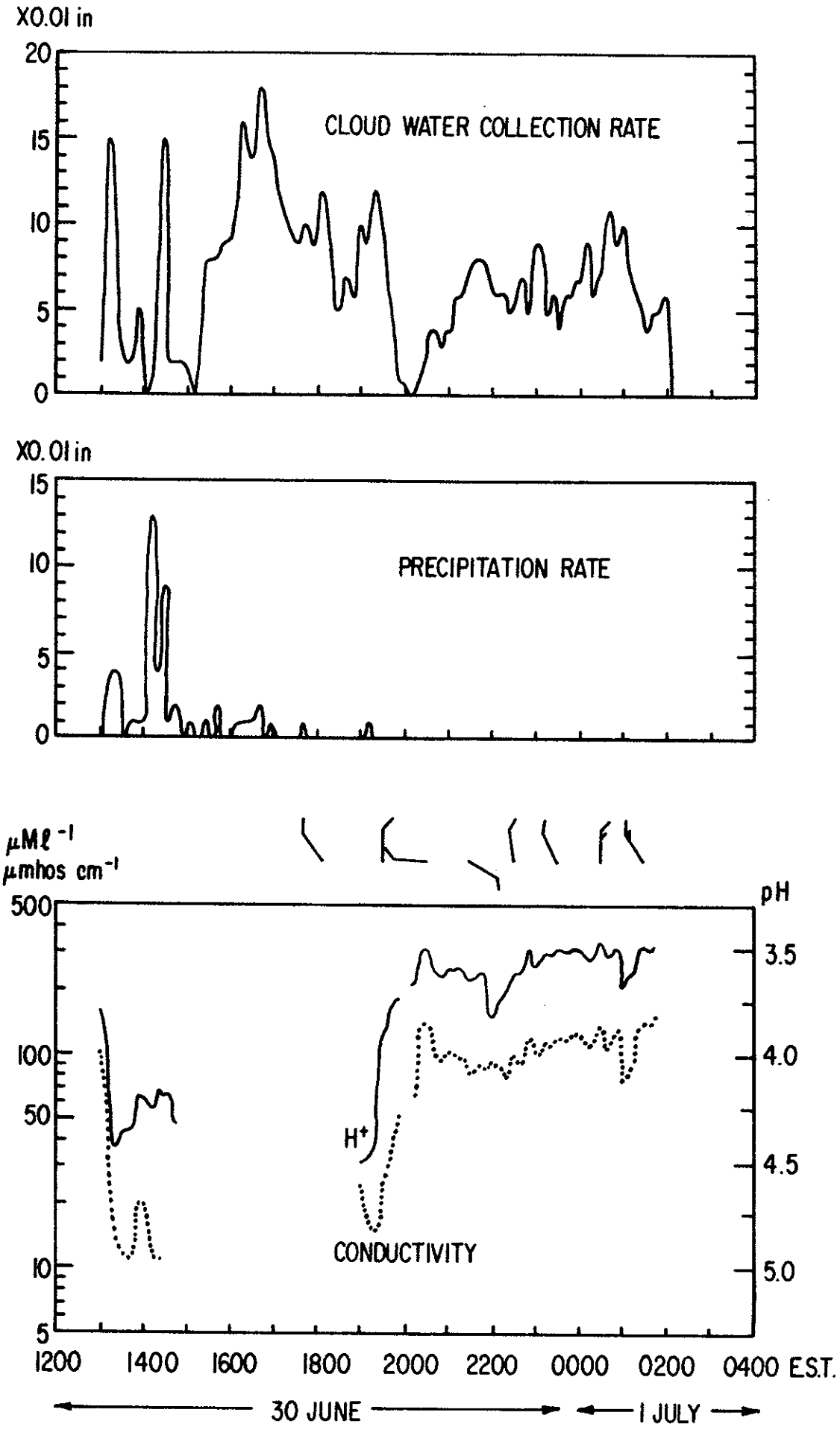
30
25
20
15
10
5
0
CLOUD COLLECTION RATE
MISSING
X0.01 in
5
0
PRECIPITATION RATE
deg F
55
50
45
AIR TEMPERATURE
μMℓ⁻¹
μ mhos cm⁻¹
500
100
50
10
5
pH
3.5
4.0
4.5
5.0
No data available
No pH data available
H⁺
Conductivity
SO₄⁼
NO₃⁻
NH₄⁺
Na⁺
Cℓ⁻
0000
0200
0400
0600
0800
1000
1200
1400
1600 E.S.T.
27 JUNE 1980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XO.01 in
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10
5
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μMℓ⁻¹
μmhos cm⁻¹
500
100
50
10
5
pH
3.5
4.0
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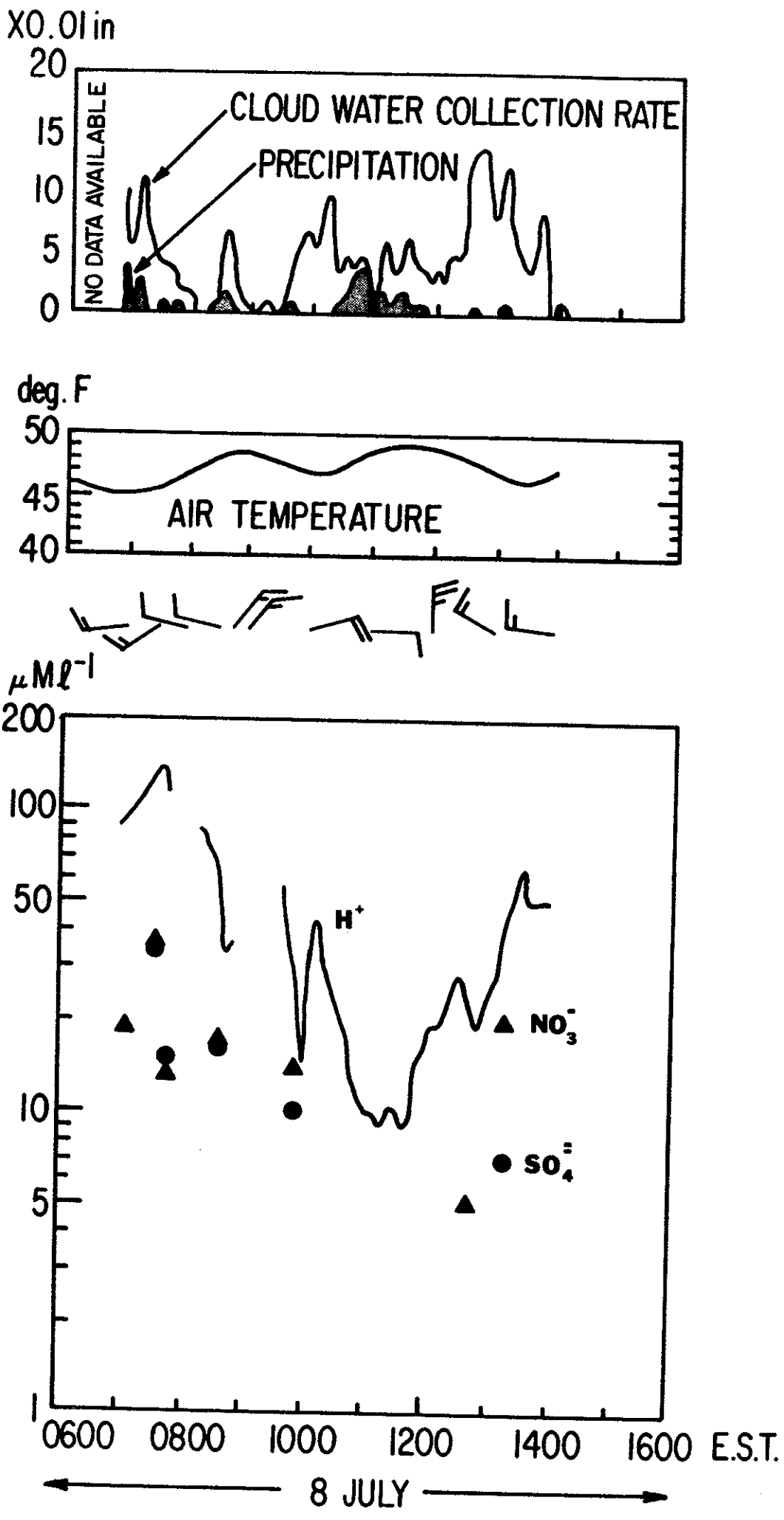
H+
CONDUCTIVITY
1200
1400
1600
1800
2000
2200
0000
0200
0400 E.S.T.
30 JUNE
1 JULY

5-8 July 1980

Sample	ANIONS						CATIONS					
	Collected EST	Analyzed EST	F^-	Cl^-	NO_3^-	$SO_4^=$	Analyzed EST	Conductivity	pH	Na^+	NH_4^+	K^+
Cloud	5/1800-1807	8/1245	44 μML^{-1}	11 μML^{-1}	116 μML^{-1}	267 μML^{-1}	8/0830		3.49	8 μML^{-1}	230 μML^{-1}	-
Cloud	5/1907-1919	8/1315	51	13	158	305	8/0845		3.36	10	264	-
Cloud	5/2000-2005	8/1345	54	15	174	322	8/0900		3.47	6	310	-
Cloud	5/2300-2305	8/1410	39	8	79	162	8/0930		3.58	-	195	-
Cloud and Rain	6/0100-0105	8/1430	7	4	8	24	8/1000		3.35	-	25	-
Cloud and Rain	6/0700-0705	8/1900	-	5	19	-	8/1015		4.00	5	20	-
Rain	6/0730-0735	9/0810	22	15	36	35	8/1045		3.89	41	84	27 μML^{-1}
Rain	6/0744-0749	9/0830	9	7	13	15	8/1100		3.93	4	31	3
Rain	6/0832-0837	9/0900	7	-	17	16	8/1115		4.12	5	47	-
Cloud	6/0945-0955	9/0930	8	-	14	10	8/1330		4.60	-	-	-
Rain	6/1025-1030		-	-	-	-	8/1345		4.60	2	10	-
Rain	6/1315-1320	9/1315	10	3	20	7			4.43	-	-	-
Cloud and Rain	6/1241-1249	9/1345	6	5	5	-			4.75	-	-	-
Cloud and Rain	9/0450-0500	9/1415	25	7	25	50			3.77	-	61	-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15
10
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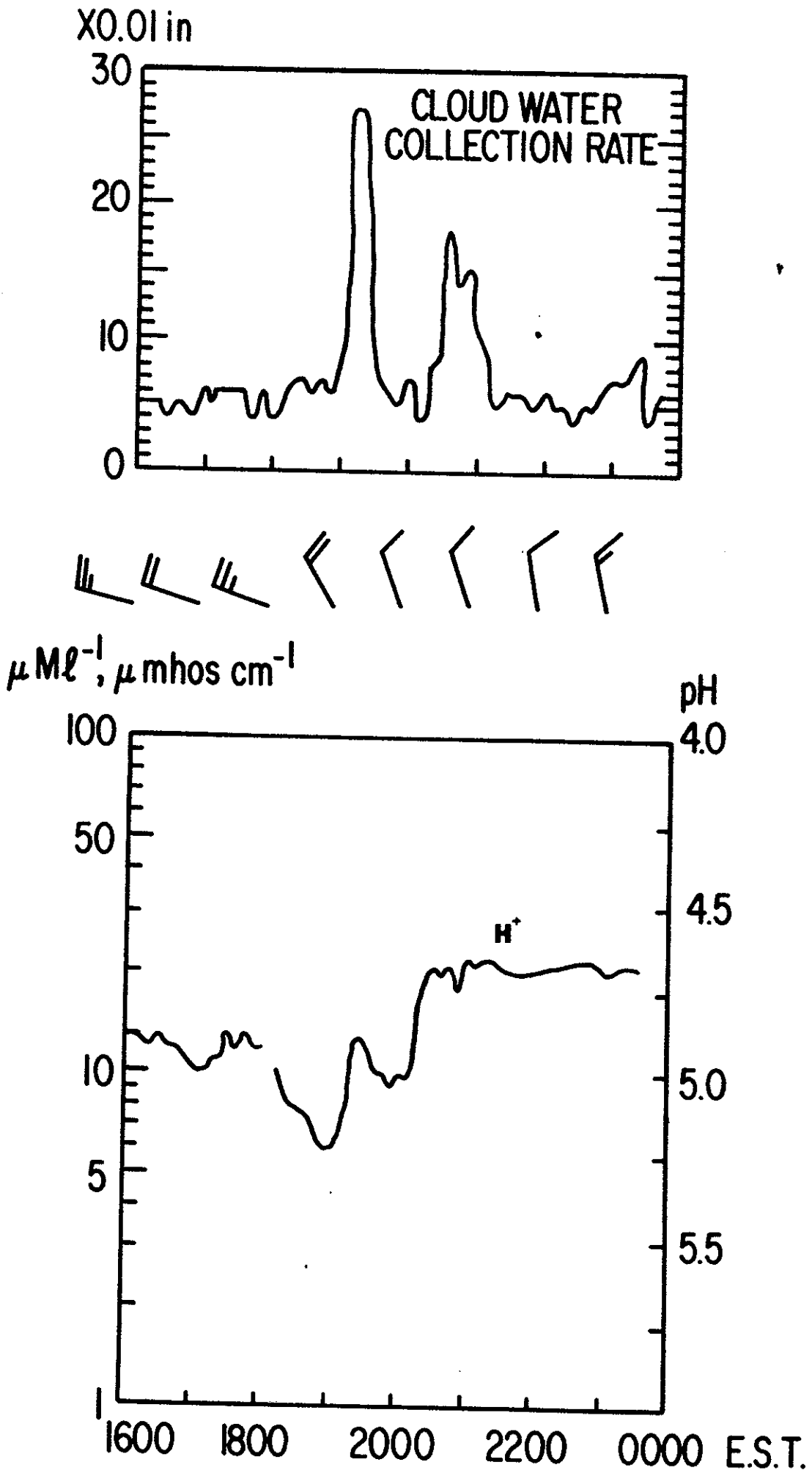
PRECIPITATION
deg. F
50
45
40
AIR TEMPERATURE
μMℓ⁻¹
200
100
50
10
5
1
H⁺
NO₃⁻
SO₄⁼
0600
0800
1000
1200
1400
1600 E.S.T.
8 JULY


X0.01 in
30
20
10
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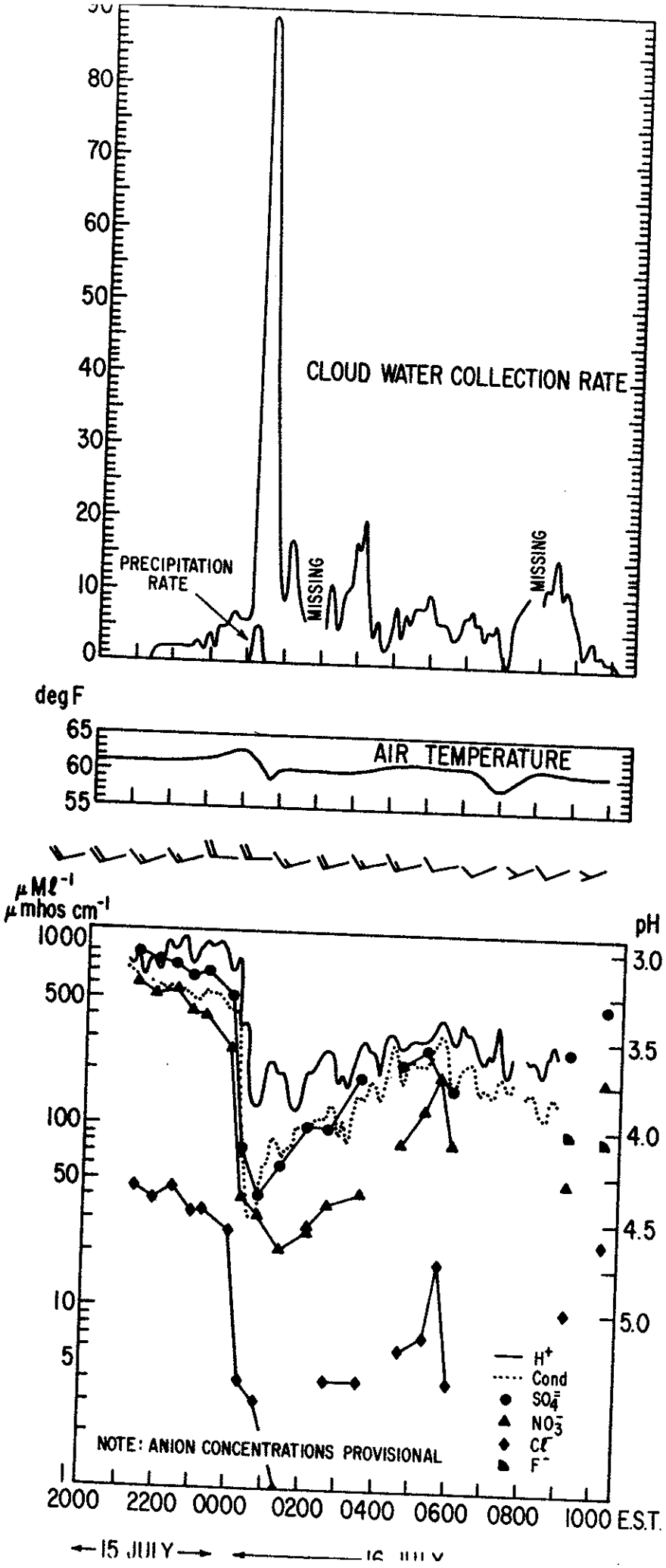
CLOUD WATER
COLLECTION RATE
μMℓ⁻¹; μmhos cm⁻¹
pH
100
50
10
5
1
4.0
4.5
5.0
5.5
H⁺
1600
1800
2000
2200
0000 E.S.T.

12 JULY 1980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70
60
50
40
30
20
10
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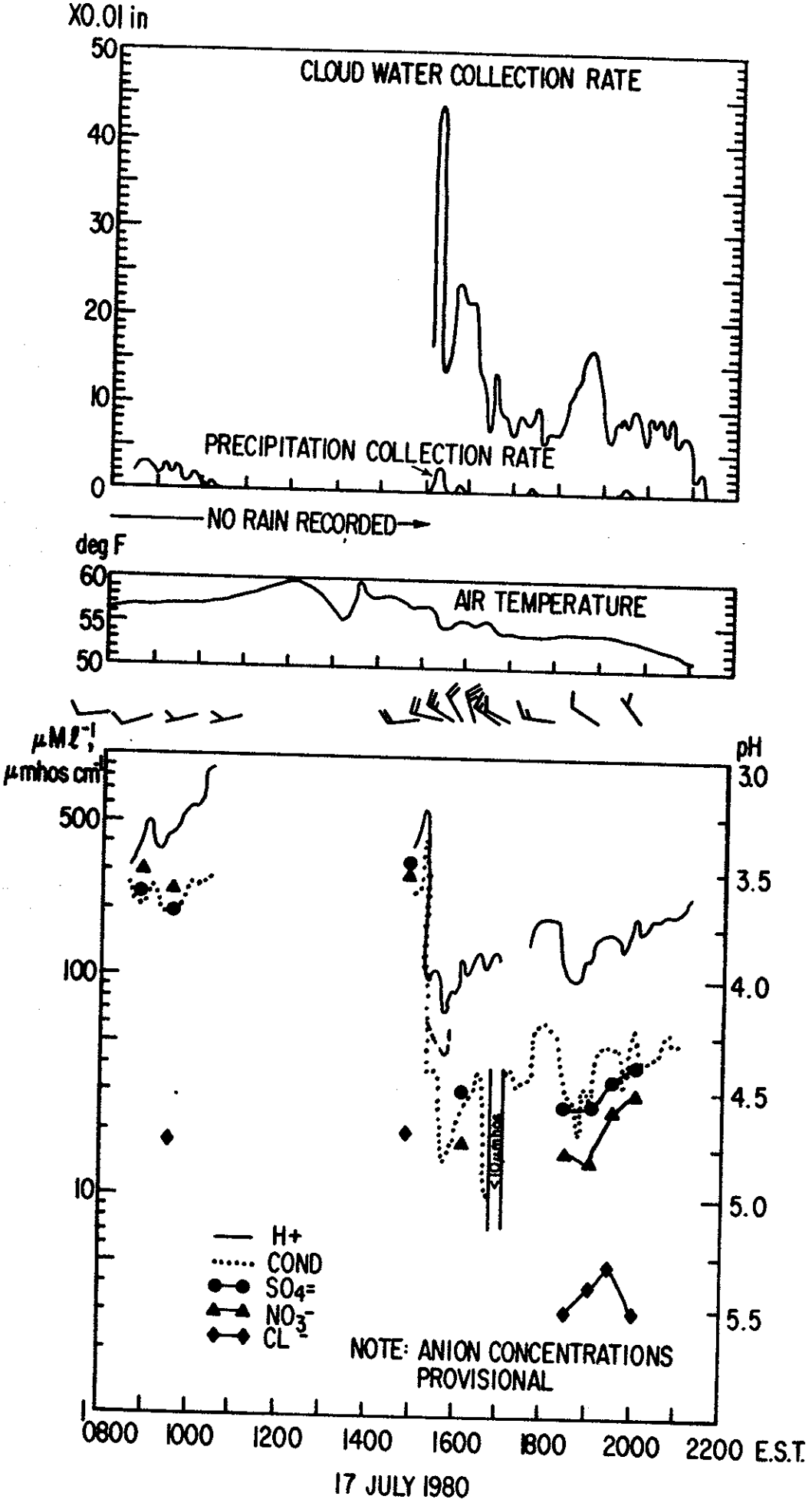
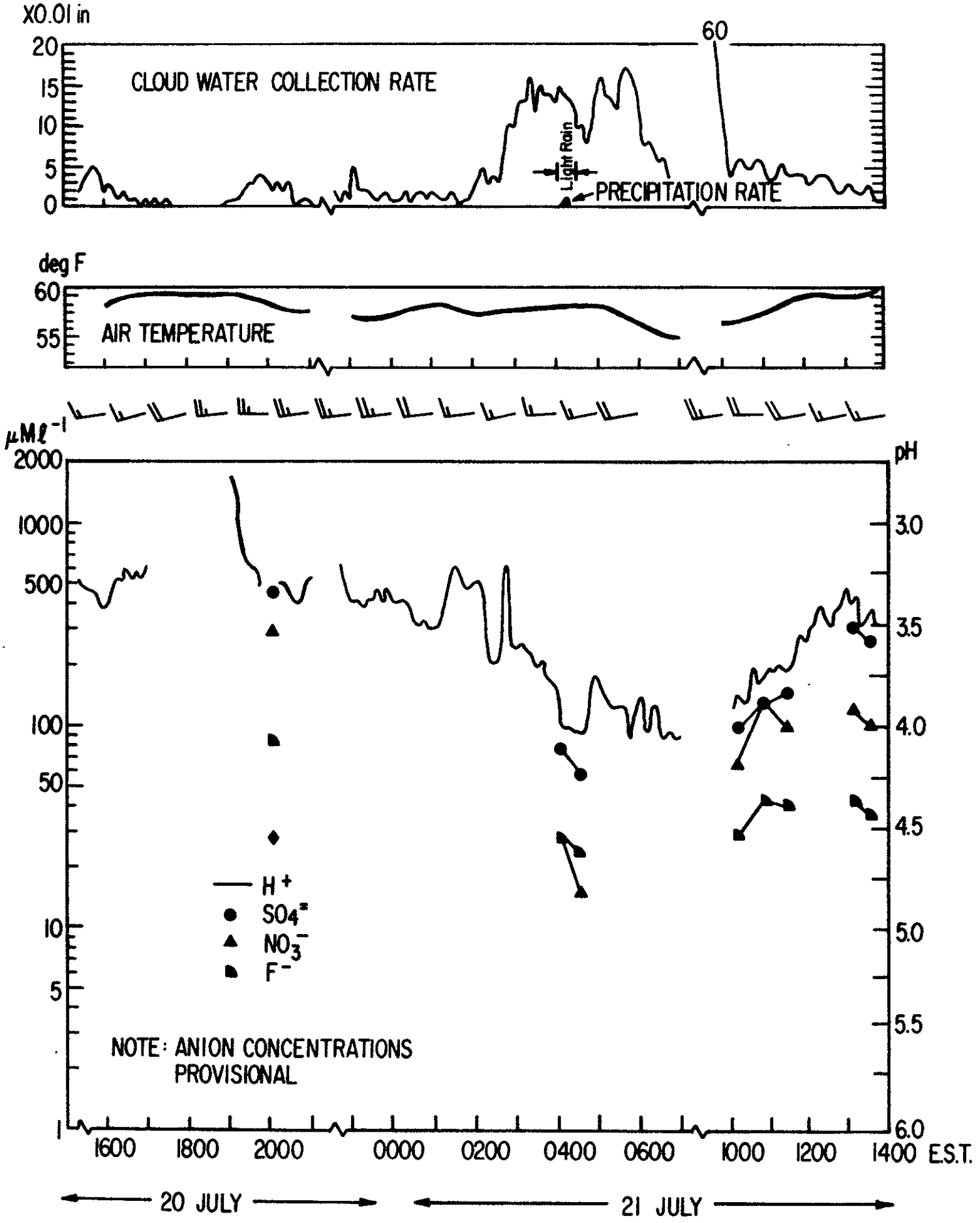
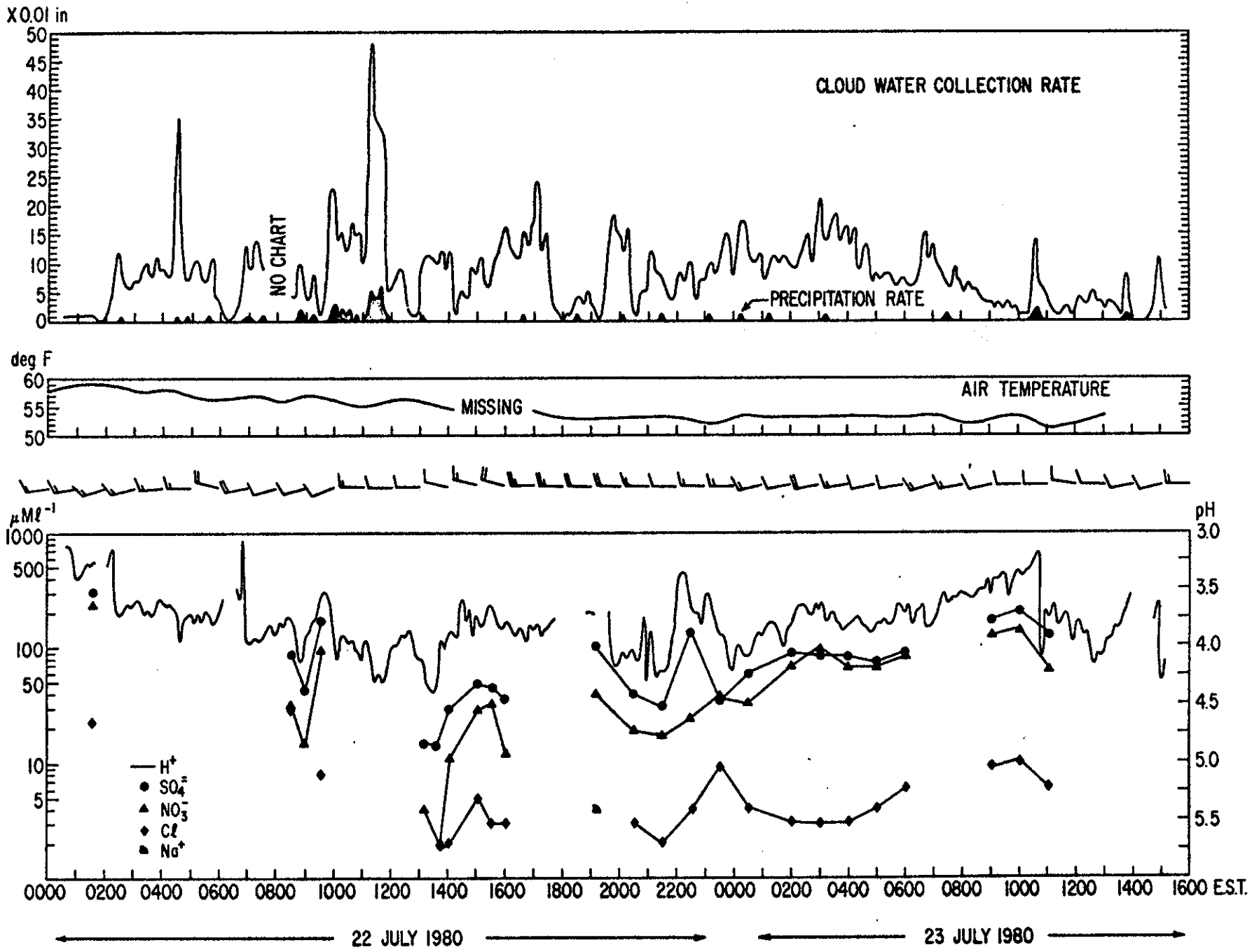
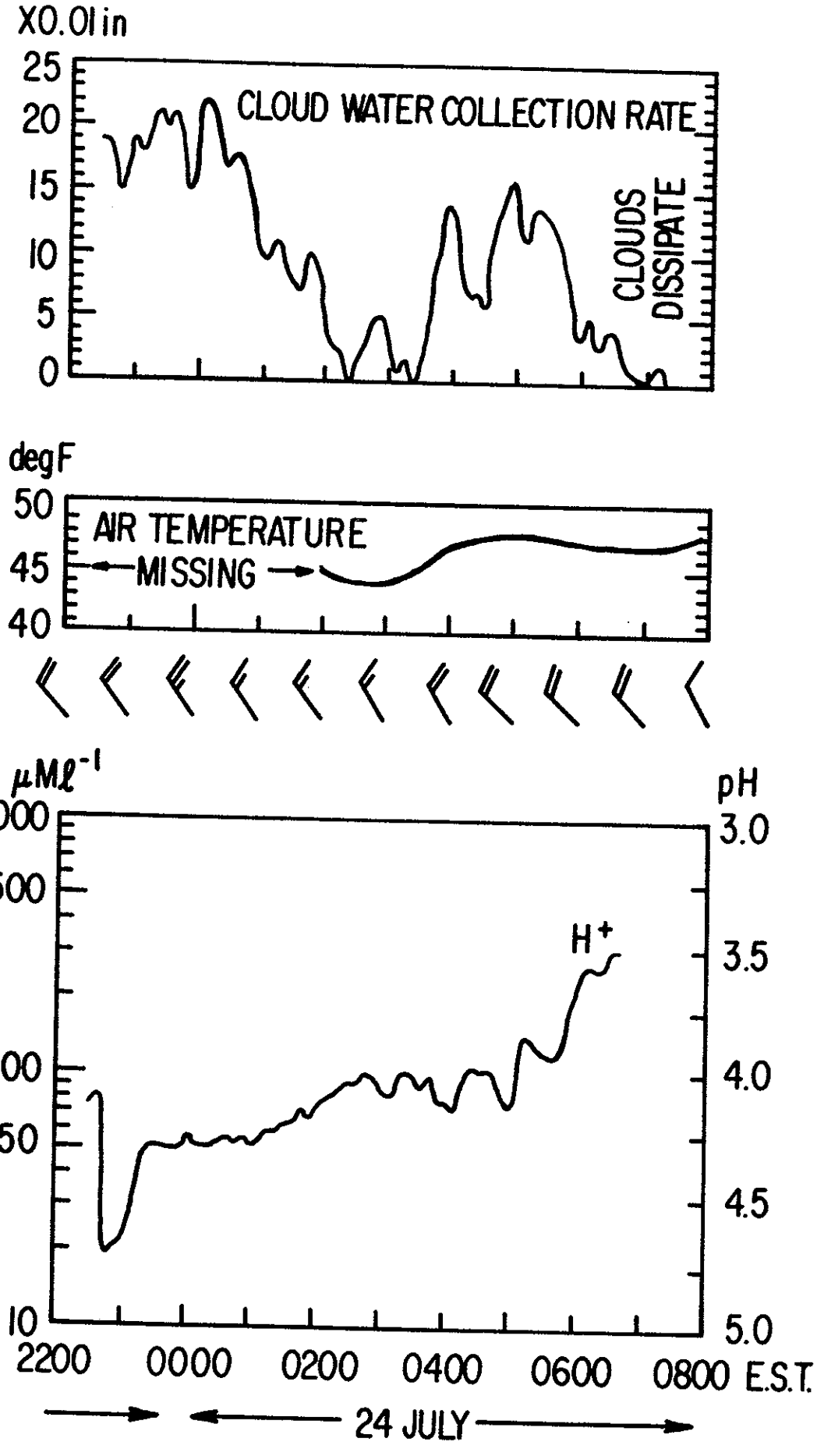
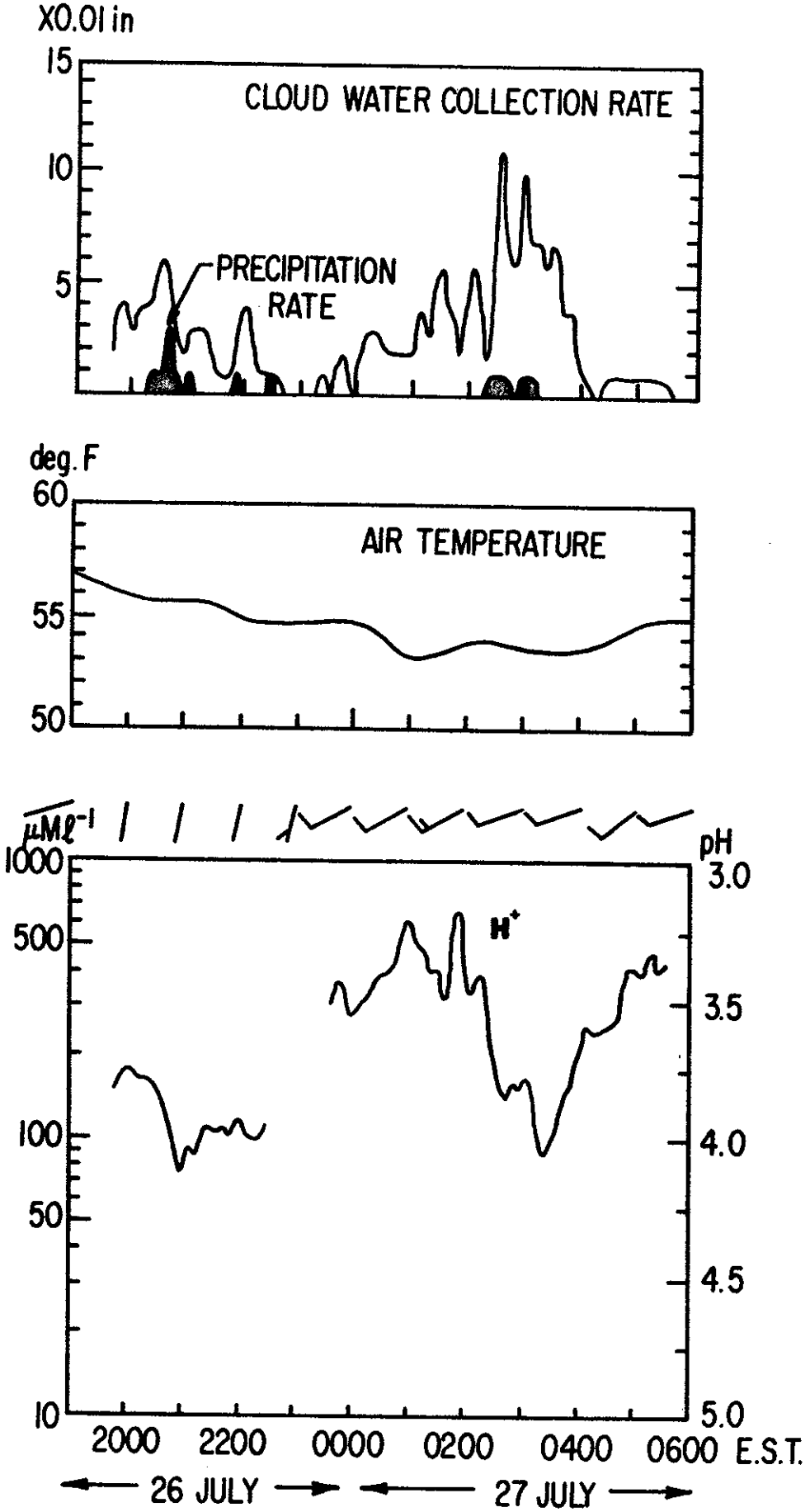
PRECIPITATION RATE
MISSING
MISSING
deg F
65
60
55
AIR TEMPERATURE
μMℓ⁻¹
μmhos cm⁻¹
1000
500
100
50
10
5
1
pH
3.0
3.5
4.0
4.5
5.0
H⁺
Cond
SO4=
NO3⁻
Cℓ⁻
F⁻
NOTE: ANION CONCENTRATIONS PROVISIONAL
2000
2200
0000
0200
0400
0600
0800
1000 E.S.T.
15 JULY
16 JULY

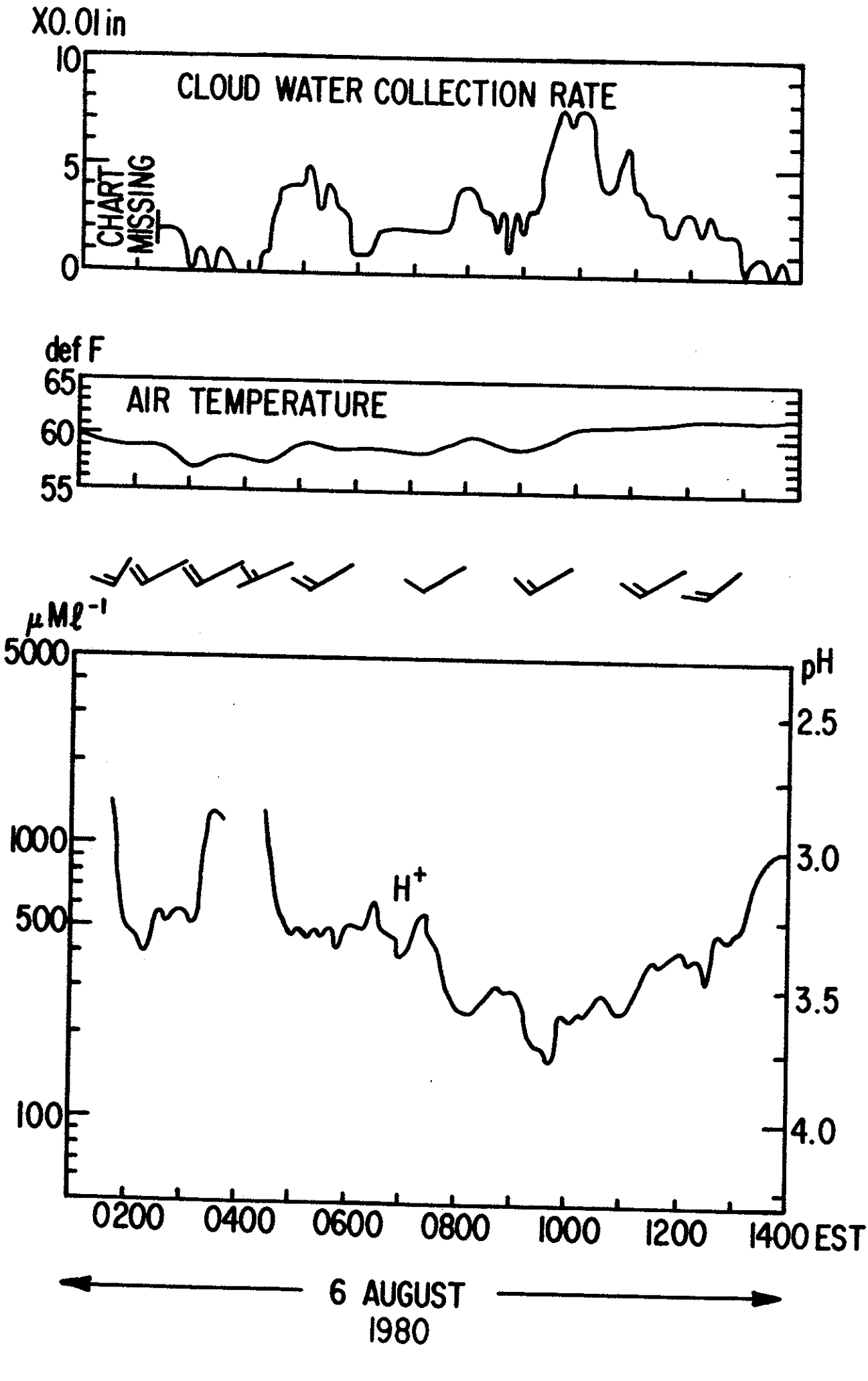

X0.01 in
CLOUD WATER COLLECTION RATE
PRECIPITATION COLLECTION RATE
NO RAIN RECORDED
deg F
AIR TEMPERATURE
μM ℓ⁻¹
μmhos cm⁻¹
pH
H+
COND
SO4=
NO3⁻
CL⁻
NOTE: ANION CONCENTRATIONS PROVISIONAL
0800
1000
1200
1400
1600
1800
2000
2200 E.S.T.
17 JULY 1980

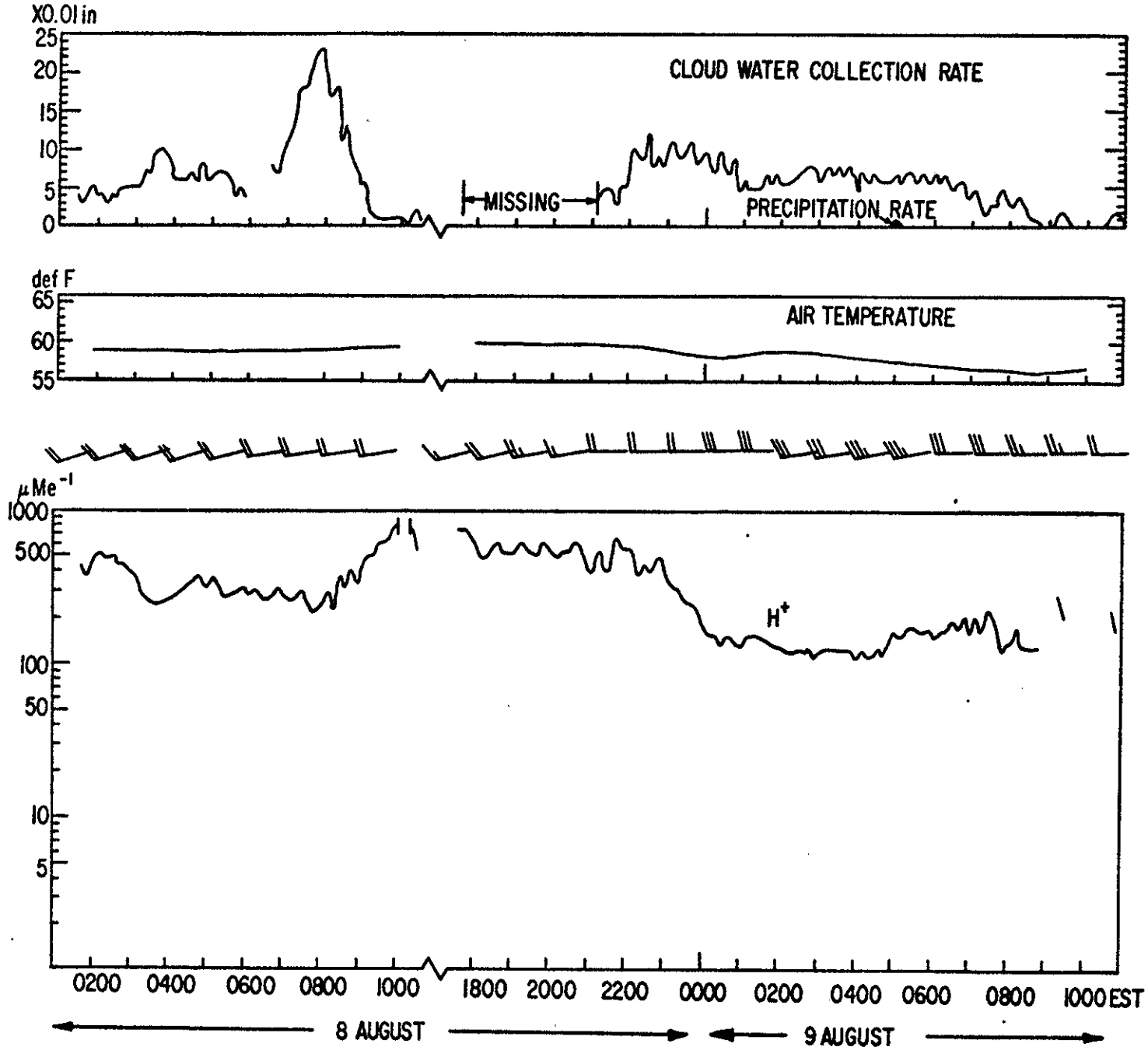

X0.01 in
20
15
10
5
0
60
CLOUD WATER COLLECTION RATE
Light Rain
PRECIPITATION RATE
deg F
60
55
AIR TEMPERATURE
μMℓ⁻¹
2000
1000
500
100
50
10
5
1
pH
3.0
3.5
4.0
4.5
5.0
5.5
6.0
H⁺
SO4⁼
NO3⁻
F⁻
NOTE: ANION CONCENTRATIONS PROVISIONAL
1600
1800
2000
0000
0200
0400
0600
1000
1200
1400
E.S.T.
20 JULY
21 JULY


X0.01 in
50
45
40
35
30
25
20
15
10
5
0
CLOUD WATER COLLECTION RATE
NO CHART
PRECIPITATION RATE
deg F
60
55
50
MISSING
AIR TEMPERATURE
μMℓ⁻¹
1000
500
100
50
10
5
pH
3.0
3.5
4.0
4.5
5.0
5.5
H+
SO4=
NO3-
Cℓ-
Na+
0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 0000 0200 0400 0600 0800 1000 1200 1400 1600 E.S.T.
22 JULY 1980
23 JULY 1980


X0.01 in
25
20
15
10
5
0
CLOUD WATER COLLECTION RATE
CLOUDS DISSIPATE
degF
50
45
40
AIR TEMPERATURE
MISSING
μMℓ⁻¹
1000
500
100
50
10
pH
3.0
3.5
4.0
4.5
5.0
H+
2200
0000
0200
0400
0600
0800 E.S.T.
24 JULY


X0.01 in
15
10
5
CLOUD WATER COLLECTION RATE
PRECIPITATION RATE
deg. F
60
55
50
AIR TEMPERATURE
μMℓ⁻¹
1000
500
100
50
10
pH
3.0
3.5
4.0
4.5
5.0
H+
2000
2200
0000
0200
0400
0600
E.S.T.
26 JULY
27 JULY


X0.01 in
10
5
0
CLOUD WATER COLLECTION RATE
CHART MISSING
def F
65
60
55
AIR TEMPERATURE
μMℓ⁻¹
5000
1000
500
100
H+
pH
2.5
3.0
3.5
4.0
0200
0400
0600
0800
1000
1200
1400 EST
6 AUGUST
1980

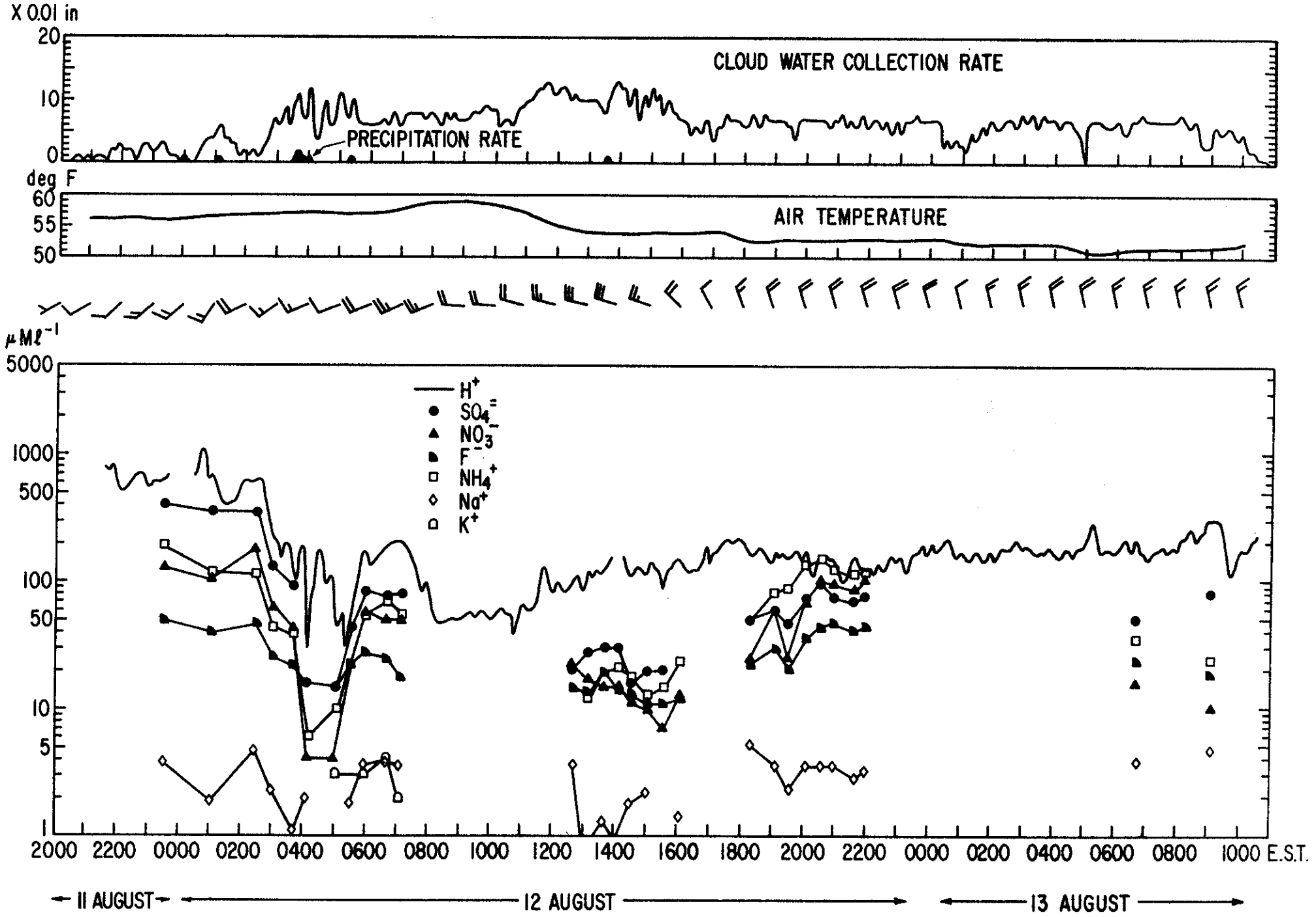

X0.01 in
25
20
15
10
5
0
CLOUD WATER COLLECTION RATE
MISSING
PRECIPITATION RATE
def F
65
60
55
AIR TEMPERATURE
μMe⁻¹
1000
500
100
50
10
5
H+
0200
0400
0600
0800
1000
1800
2000
2200
0000
0200
0400
0600
0800
1000 EST
8 AUGUST
9 AUGUST

11-12 August 1980

Sample	ANIONS						CATIONS					
	Collected EST	Analyzed EST	F^-	Cl^-	NO_3^-	$SO_4^=$	Analyzed EST	Conductivity	pH	Na^+	NH_4^+	K^+
Cloud	11/2300-2325	12/0835	50 μML^{-1}	11 μML^{-1}	129 μML^{-1}	403 μML^{-1}	12/0835	-	3.23	3.8 μML^{-1}	197 μML^{-1}	-
Cloud	12/0050-0105	12/0910	40	7	101	358	12/0910	-	3.16	1.9	119	-
Cloud	12/0210-0225	12/1000	46	14	180	360	12/0955	-	3.21	4.7	115	-
Cloud and Rain	12/0300-0305	12/1020	26	5	61	133	12/1020	-	3.65	2.3	44	-
Cloud and Rain	12/0330-0340	12/1035	22	4	44	91	12/1035	-	3.85	1.1	38	-
Cloud and Rain	12/0405-0410	12/1050	16	2	4	16	12/1050	-	4.00	2.0	6	-
Cloud and Rain	12/0500-0503	12/1115	15	2	4	15	12/1100	-	4.18	-	10	3 μML^{-1}
Cloud	12/0530-0535	12/1200	22	4	22	44	12/1110	-	4.20	1.8	23	-
Cloud	12/0550-0600	12/1225	28	5	56	86	12/1200	-	3.76	3.6	54	3
Cloud	12/0630-0638	12/1240	25	4	48	77	12/1215	-	3.74	3.8	70	4
Cloud	12/0705-0710	12/1300	18	4	46	81	12/1230	-	3.70	3.6	55	2
Cloud	12/1230-1237		15	1	23	21		30 $\mu mhos\ cm^{-1}$	4.06	3.6	4	1
Cloud	12/1300-1306		14	1	17	28		33	4.05	0.6	12	-
Cloud	12/1330-1337		20	2	15	30		37	3.95	1.3	20	-
Cloud	12/1400-1408		14	2	15	31		28	3.71	0.7	21	-

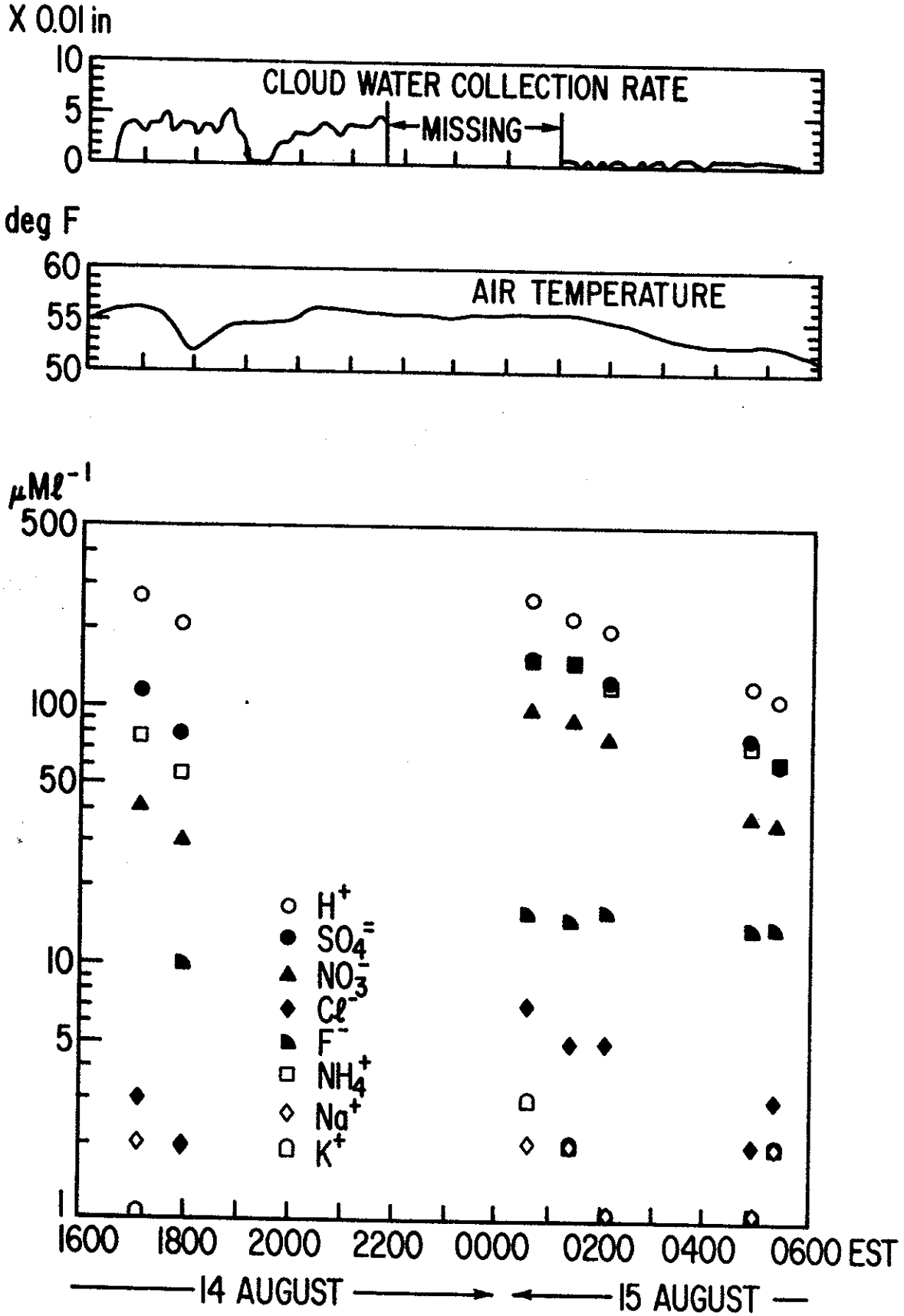
11-12 August 1980 (continued)

Sample	Collected EST	Analyzed EST	ANIONS F^-	Cl^-	NO_3^-	$SO_4^=$	Analyzed EST	CATIONS Conductivity	pH	Na^+	NH_4^+	K^+
Cloud	12/1432-1435		13 μML^{-1}	1 μML^{-1}	11 μML^{-1}	16 μML^{-1}		23 $\mu mhos\ cm^{-1}$	3.95	1.8 μML^{-1}	18 μML^{-1}	-
Cloud	12/1500-1503		11	-	10	20		18	3.88	2.2	13	-
Cloud	12/1530-1533		11	1	7	20		15	3.97	-	15	-
Cloud	12/1600-1605		12	2	13	25		25	3.83	1.4	24	-
Cloud	12/1815-1820	13/0815	22	2	25	52	13/0815	-	3.75	5.2	50	-
Cloud	12/1900-1907		30	4	61	62		-	3.81	3.6	82	-
Cloud	12/1930-1934		21	2	25	46		-	3.80	2.3	87	-
Cloud	12/2000-2006		36	4	72	73		-	3.80	3.6	133	-
Cloud	12/2030-2035		44	5	103	97		-	3.80	3.6	151	-
Cloud	12/2100-		46	4	96	76		-	3.83	3.6	125	-
Cloud	12/2130-2138		41	4	88	69		-	3.82	2.9	113	-
Cloud	12/2200-		44	4	101	76		-	3.91	3.2	120	-
Cloud	13/0635-0645		24	4	16	51		-	3.75	3.8	35	-
Cloud	13/0900-0910		19	3	10	81		-	3.50	4.7	24	-
Cloud	13/0910-0922		-	-	-	-		-	3.55	3.8	24	-


X 0.01 in
20
10
0
CLOUD WATER COLLECTION RATE
PRECIPITATION RATE
deg F
60
55
50
AIR TEMPERATURE
μMℓ⁻¹
5000
1000
500
100
50
10
5
1
H+
SO4=
NO3−
F−
NH4+
Na+
K+
2000 2200 0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 0000 0200 0400 0600 0800 1000 E.S.T.
11 AUGUST
12 AUGUST
13 AUGUST

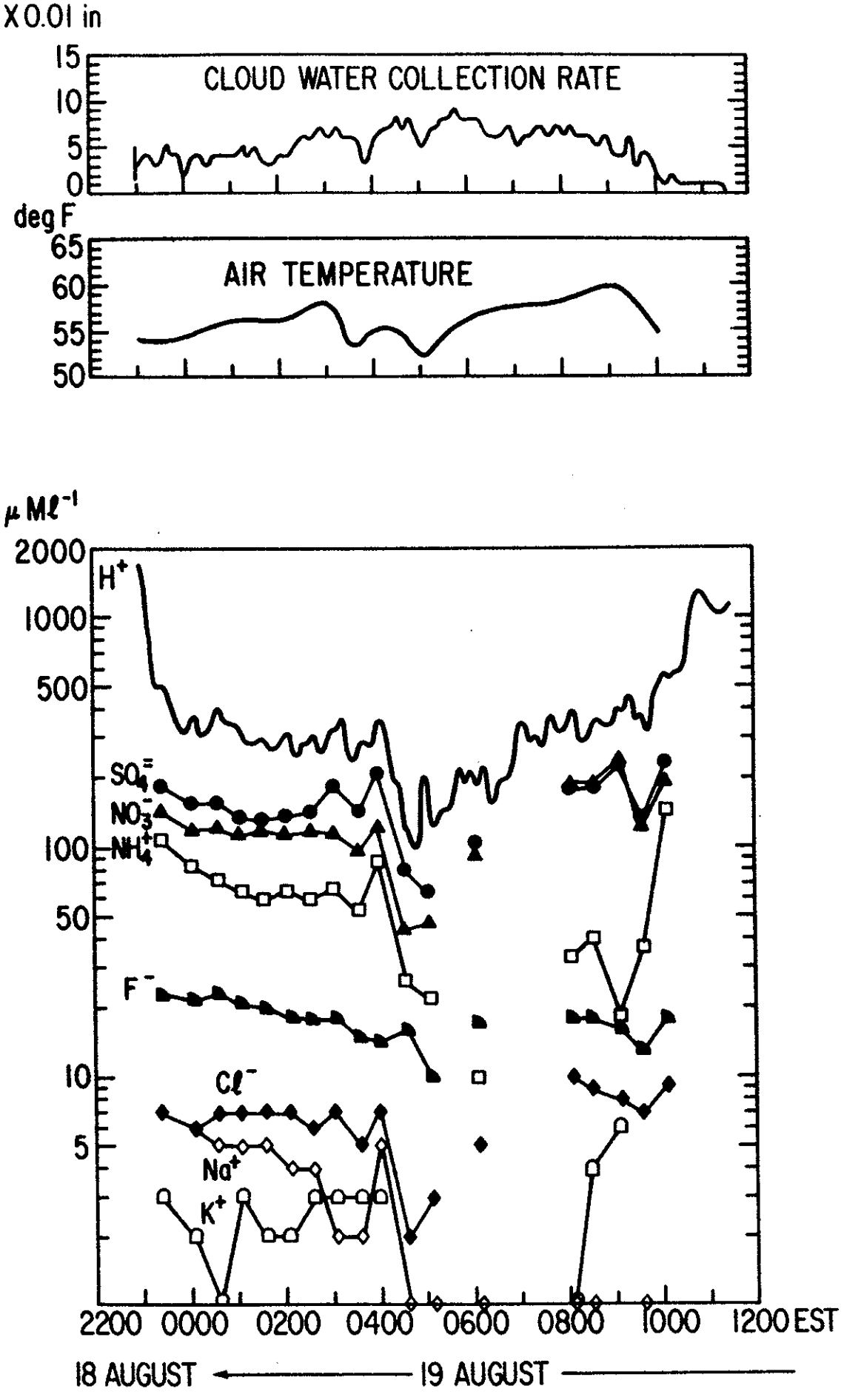
14-16 August 1980

Sample	ANIONS						CATIONS					
	Collected EST	Analyzed EST	F^-	Cl^-	NO_3^-	$SO_4^=$	Analyzed EST	Conductivity	pH	Na^+	NH_4^+	K^+
Cloud and Rain	14/1705-1715	15/0750	-	3 μML^{-1}	41 μML^{-1}	117 μML^{-1}	15/0750	105 $\mu mhos\ cm^{-1}$	3.57	2 μML^{-1}	76 μML^{-1}	-
Cloud and Rain	14/1750-1800	15/0815	10 μML^{-1}	2	30	78	15/0810	70	3.68	2	55	-
Cloud	15/0035-0040	15/0835	16	7	99	156	15/0825	155	3.57	2	155	3 μML^{-1}
Cloud	15/0120-0130	15/0855	15	5	90	153	15/0845	121	3.65	2	153	2
Cloud	15/0200-0210	15/0925	16	5	76	125	15/0910	115	3.69	1	122	1
Cloud	15/0445-	15/0950	14	2	38	78	15/0930	54	3.91	1	72	1
Cloud	15/0520-0525	15/1010	14	3	36	61	15/0945	52	3.97	2	64	2
Cloud	15/0550-0600	15/1035	11	2	28	82	15/1000	56	3.96	1	64	1
Cloud	15/0600-0610	15/1140	11	4	25	80	15/1015	55	3.95	55	64	2
Cloud	15/0900-0930		13	3	21	44	15/1315	-	-	2	82	3
Cloud	15/0930-1000		20	4	27	43	15/1325	-	-	2	59	3


X 0.01 in
10
5
0
CLOUD WATER COLLECTION RATE
MISSING
deg F
60
55
50
AIR TEMPERATURE
μMℓ⁻¹
500
100
50
10
5
1
H+
SO4=
NO3-
Cℓ-
F-
NH4+
Na+
K+
1600
1800
2000
2200
0000
0200
0400
0600 EST
14 AUGUST
15 AUGUST

18-19 August 1980

	ANIONS						CATIONS					
Sample	Collected EST	Analyzed EST	F^-	Cl^-	NO_3^-	$SO_4^=$	Analyzed EST	Conductivity	pH	Na^+	NH_4^+	K^+
Cloud	18/2320-2330	19/0750	23 μML^{-1}	7 μML^{-1}	145 μML^{-1}	188 μML^{-1}	19/0750	-	3.35	7 μML^{-1}	109 μML^{-1}	3 μML^{-1}
Cloud	19/0000-0008	19/0820	22	6	117	153	19/0805	180 $\mu mhos\ cm^{-1}$	3.50	6	81	2
Cloud	19/0030-0038		23	7	122	157	19/0820	185	3.51	5	73	1
Cloud	19/0100-0110		21	7	112	135	19/0835	168	3.55	5	64	3
Cloud	19/0130-0138		20	7	119	132	19/0845	161	3.56	5	60	2
Cloud	19/0200-0210		18	7	113	137	19/0910	175	3.52	4	65	2
Cloud	19/0230-0237		18	6	117	142	19/0925	166	3.54	4	60	3
Cloud	19/0300-0305		18	7	114	181	19/0935	168	3.52	2	65	3
Cloud	19/0330-0340		15	5	96	145	19/0950	154	3.54	2	54	3
Cloud	19/0355-0405		14	7	122	207	19/1005	188	3.48	5	87	3
Cloud and Rain	19/0430-0435		16	2	44	80	19/1040	66	3.93	1	26	-
Cloud and Rain	19/0500-0505		10	3	47	64	19/1055	110	3.73	1	22	-
Cloud	19/0600-0605		17	5	91	107	19/1100	120	3.69	1	10	-
Cloud	19/0800-0810		18	10	188	179	19/1200	220	3.44	1	33	1
Cloud	19/0830-0837		18	9	189	189	19/1215	209	3.39	1	40	4
Cloud	19/0905-0910		16	8	187	177	19/1235	-	3.46	-	18	6
Cloud	19/0930-0940		13	7	125	132	19/1250	188	3.48	1	37	-
Cloud	19/1000-1010		18	9	192	236		-	3.50	-	144	-


X 0.01 in
15
10
5
0
CLOUD WATER COLLECTION RATE
deg F
65
60
55
50
AIR TEMPERATURE
μ Mℓ⁻¹
2000
1000
500
100
50
10
5
H+
SO4=
NO3-
NH4+
F-
Cℓ-
Na+
K+
2200 0000 0200 0400 0600 0800 1000 1200 EST
18 AUGUST
19 AUGUST

APPENDIX C

Time Plots and Weather Synopsis of Cloud Water Collection Events at Whiteface Mountain June - August 1980

20-21 June 1980

0600 EST, 6/20 - 1800 EST, 6/21

Preceding 12 hours (1800 EST 6/19 - 0600 EST 6/20)

An upper level, short-wave propagates around a large trough over Eastern Canada. Closed low develops at 850 mb over Wisconsin when the short wave overtakes a slowly moving cold front stretching from New York State westward to lower Michigan and Kansas. Surface low develops in Northern Illinois and moves to the NE over the Saint Lawrence Valley, passing NW of Whiteface at 0600 EST 6/20 (start of data). The original cold front moves northward over Whiteface as a warm front as the low approaches.

Event (0600 6/20 - 1800 EST 6/21)

Low center is most intense at 0500 EST on the 20th as it passes to the NW. Passage of the warm sector corresponds to an interval of elevated temperature at the summit (0800-1200 EST), followed by a 3°F drop, wind shift from light southerly to southwesterly, and rainfall (.12"). Eleven hours later (2300 EST) rain and cloud collection increases to its event maximum rate.

27 June 1980

0000 - 1500 EST

Preceding 12 hours

Surface cold front forms in Southern Canada, running ENE to WSW and starts moving SE slowly. 850 mb winds are weak from W and WSW, with closed low to the NE. Surface air from S and SW. Possible moist Atlantic inflow available to Whiteface from surface low over North Carolina. High clouds above summit at 2100 with breaks; first intermittent clouds appear at summit by 22:30 EST.

Event

850 mb wind swings to the NW halfway thru the event (0800 EST) and cold advection associated with front reaches Whiteface. Surface chart indicates cold front passage @ 0400 EST.

11 - 13 August 1980

1930 EST, 8/11 → 0930 EST, 8/13

Previous 12 hours

Low center develops on weak front lying from Texas panhandle eastward to Virginia. A frontal wave appears at 1300 EST on 8/11 with the low center over Michigan. A secondary low center is indicated briefly in surface analyses over Souther New York State but is gone by the 0100 EST analysis of 8/12. Broad 850 mb flow exists from the WSW until an 850 mb low develops along with a surface disturbance.

Event

Surface low passes almost over Whiteface about 0600 EST 8/12 and is approaching occlusion stage. 850 mb trough passes at about 0800 EST on 8/12 as summit winds shift from 260° to 320°. Periods of rain were observed as the warm front and low center approached, ceasing at 0800 EST. Well into the cold sector (1300 EST), rain ceases and periodic bright spots are observed at the summit. High surface dewpoints (in the 60's) in the cold sector, which probably result from marine air circulating around the low, along with the 850 mb trough, contribute to maintaining non-precipitating cloud and cap cloud at the summit through the evening until 1100 on the 13th. Clouds persisted until surface dewpoints fell below 60°F.

14-15 August 1980

0220 EST, 8/14 → 1200 EST, 8/15

Previous 12 hours

A nearly stationary occluded low over Minnesota starts moving eastward rapidly, eroding an 850 mb ridge and surface high over Whiteface. A cloud deck ahead of the occluded/warm front lowers in the evening of the 13th, as the associated 850 mb trough develops into a broad closed low.

Event

Light rain from above and clouds blowing upslope are experienced from 0200 - 0300 on the 14th. A non-precipitating, overcast cloud deck continues to 1000 EST, at which time it lowers to summit. Summit is in intermittent cloud until 1600 EST when rain showers, thickening cloud, and lightning are observed as warm front approaches. After a period of clearing, steady, moderate cloud collection resumes at 0030 EST on 8/15 in the warm sector (temperature rises 8°F). The surface low passes 100-200 miles to the NW of Whiteface, and a temperature drop at the summit at 0900 EST on 8/15 indicates passage of the cold (moist) air. Clouds become variable and finally lift by 1100 EST as surface dewpoints at surrounding stations drop below 60°F. The 850 mb closed low passes to the N of Whiteface at about 0600 EST 8/15.

19-21 August 1980

2300 EST, 8/19 → 0630 EST, 8/21

Previous 12 hours

A slowly moving occluded frontal system over the Great Lakes begins to bring high cloudiness after a day of clear, dry weather. Surface dewpoints rose through the day on the 18th with weak onshore flow from a surface high off the coast of Virginia. A narrow 850 mb ridge moved toward the east away from Whiteface with the approach of the system.

Event

As the occluded system approaches, the occluded part of the front dissipates, leaving a weak and slowly moving ripple on an air mass boundary which lies over the Ohio Valley and Virginia. Intermittent rain begins at summit at 0300 EST on 8/19 as the temperature rises. Bright spots in clouds are observed shortly after the passage of the 850 mb trough at 0700 EST on 8/19, with a summit wind shift to WNW. Clouds break at the summit by 1330 EST on 8/19 (shutdown). With surface dewpoints in the mid-sixties and the lingering stationary front to the south, haze and scattered valley clouds persist. Cloud water collection resumes at 2000 EST on 8/19, accompanied by moderate rain. This corresponds to the passage of a very weak trough on the surface analysis. Summit winds remain light and variable.

In the following hours, a low center intensifies off the Virginia coast and an 850 mb cutoff low develops from the trough, to the SE of Whiteface. The resulting easterly flow produces solid undercast at dawn, which rises to engulf the summit in constant cloud until about 1500 EST on 8/20. The very thick fog and haze in the valleys clear up by sunset, leaving persistent cap cloud above about 4000' on the summit in otherwise very clear air. Conductivity as low as 8 μmho is measured around midnight (pH = 4.1). Summit winds increase to 25 mph maximum, from the SE. Cloud collection decreases after 0000 EST on 8/21 and skies become cloudless although hazy at sunrise on the 21st.

APPENDIX D

Cloud Hours at Whiteface Mountain

STATE OF WYOMING

ATMOSPHERIC SCIENCES RESEARCH CENTER

DATA SHEET; HOURLY RECORDS

Station Whiteface Summit June 1980 **Data** Cloud hours, ending at the indicated E.S.T.*

Date	A. M.												P. M.												Sum	Mean	Date
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Midn't			
1																											1
2																											2
3																											3
4																											4
5																											5
6																											6
7																											7
8																											8
9																											9
10																											10
11																											11
12																											12
13							BEGIN DATA RECORDS																				13
14																											14
15																											15
16																									0		16
17																									0		17
18																				0.5	0.9	--	0.5	0.1	2.0		18
19	1	1	1	1	0.8					0.1					0.2										5.1		19
20						0.2	1	1	0.8	0.2	1	1	1	1	1	1	1	0.1	0.1	1	1	1	1	1	15.4		20
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.1	0	0	0	0	0	0	17.1		21
22																											22
23																											23
24																									0		24
25																									0		25
26																								0.5	0.5		26
27	1	1	1	1	0.8	1	1	1	1	1	1	1	1	1	1	0.5									15.3		27
28																									0		28
29							1	1	1															1	4.0		29
30	1	0.5	0.3	0.5	1	0.5	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21.8		30
31																											31
Sums																									59.5		Sums
Means																											Means

*Cloud occurrence is registered whenever the flow rate through the collector system is ≥ 8ml per 15 min.

ATMOSPHERIC SCIENCES RESEARCH CENTER

DATA SHEET; HOURLY RECORDS

Station Whiteface Summit - July 1980 **Data** Cloud hours ending at the indicated E.S.T.*

Date	A. M.												P. M.												Sum	Mean	Date
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Midn			
1																			0.5	1.0	1.0	0.6	--	--	3.1		1
2	--	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3	--	--	--	--	--	--	--	15.0		2
3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			3
4																											4
5																											5
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			6
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			7
8	--	--	--	--	--	0.1	1.0	1.0	0.5	0.5	1.0	1.0	1.0	0.6	--	--	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	14.0		8
9	1.0	1.0	0.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.5		9
10																											10
11																											11
12																											12
13																											13
14																											14
15																			0.5	1.0	1.0	1.0	1.0	1.0	5.5		15
16	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	--	--	MRI tipping bucket removed												9.5		16
17																											17
18																											18
19																											19
20																0.5	1.0	0.6	0.1	0.9	--	--	0.5	1.0	4.6		20
21	1.0	1.0	1.0	1.0	1.0	1.0	0.8	--	--	0.4	1.0	1.0	1.0	1.0											11.2		21
22	0.5	0.8	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	0.9	1.0	1.0	1.0	1.0	22.6		22
23	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.2							1.0	1.0	14.7		23
24	1.0	1.0	0.9	0.9	1.0	1.0	0.9	0.2																	6.9		24
25																											25
26																				0.6	1.0	1.0	0.7	0.8	4.1		26
27	1.0	1.0	1.0	1.0	0.9	0.5																			5.4		27
28																											28
29																											29
30																											30
31																											31
Sums																											Sums
Means																											Means

*Cloud occurrence is registered whenever the flow rate through the collector is ≥ 8ml per 15 min.

STATE UNIVERSITY OF NEW YORK

ATMOSPHERIC SCIENCES RESEARCH CENTER

DATA SHEET; HOURLY RECORDS

Station Whiteface Summit - August 1980 Date Cloud hours ending at the indicated E.S.T.*

Date	A.M. 1	2	3	4	5	6	7	8	9	10	11	Noon	P.M. 1	2	3	4	5	6	7	8	9	10	11	Mid't	Sum	Mean	Date
1																											1
2																											2
3									NO DATA RECORDS																		3
4																											4
5																											5
6																											6
7																											7
8																											8
9																											9
10															0	0	0	0	0	0	0	0	0	0.2	0.2		10
11																											11
12	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	24.0		12
13	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	11.5		13
14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0	0	0	0	0.4	1.0	1.0	0.5	1.0	1.0	1.0	1.0	7.9		14
15	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	1.0	1.0	1.0	12.2		15
16	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.6		16
17	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0	0	0	0	0	0	0	0	0	0		17
18	1.0	1.0	1.0	1.0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2		18
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.8		19
20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4	0	0	0	0	0.8	0.5	0	0	0.5	1.0	0.3	0	20.2		20
21	0	0	0	0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8		21
22	1.0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.7	0	0	0	0	0		22
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		23
24	1.0	0.4	0.6	0	0	0.9	1.0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	1.0	1.0	1.0	1.0	9.2		24
25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.5		25
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		26
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	1.0	1.0	1.0	1.0	0.7	0.4	1.0	0.2	0.5	7.4		27
28																											28
29									NO DATA RECORDS																		29
30																											30
31																											31
Sums																											Sums
Means																											Means

*Cloud occurrence is registered whenever the flow rate through the collector is ≥ 8ml per 15 min.