FINAL REPORT

Collecting and Processing of Micrometeorological Data for the Spring, 1967, Cooperative Field Experiment at Davis, California

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1. INTRODUCTION

The cooperative field experiment is under the direction of and sponsored by the Meteorology Department of the U. S. Army Electronics Research and Development Activity, Fort Huachuca, Arizona.

1.1 Objective. The program is a collective and coordinated field study with the objective of gathering together instrumentation for the measurement of momentum, sensible heat and latent heat fluxes in the surface layer of the air, to collect comprehensive sets of data during two or three weeks of concentrated activity and to make comparisons between the results obtained by the several systems.

1.2 Role of the Department of Meteorology, University of Wisconsin. Planning for the Cooperative Field Experiment at Davis, California began after the April 1966 meeting of the contractors for the Meteorology Department (USAERDA). It was decided that the University of Wisconsin, Department of Meteorology would contribute best by making profiles of mean windspeed, wind direction, air temperature and moisture at three sites around the other instruments on the Davis site. One of the purposes would be to determine, if possible, how representative the site actually is.

Additional measurements to be made by the University of Wisconsin, Department of Meteorology would be net radiation and soil heat flux so that the flux of sensible and latent heat to the atmosphere could be determined.

1.3 Theoretical Guidance. Detailed windspeed, wind direction, air temperature and moisture profiles located on a small uniform area lend themselves to analysis in ways which are seldom attempted in micrometeorology. The combination of windspeed and direction profiles at three points allows for the estimation of divergence of velocity and momentum over the small area. If these results should prove reliable then the divergence of sensible and latent heat can be estimated. Only very limited data is available in the literature from which estimates of the divergence of velocity, momentum and sensible and latent heat may be made for small areas.

The modification of the windspeed, air temperature and moisture profile as the air moves over the site from one mast to another can be estimated. This provides a measure of the representativeness of the site.

Other participants in the field experiment would be measuring such items as surface stress, sensible heat flux and latent heat flux. The heat budget would use the Bowen ratio technique for determining the fluxes of sensible and latent heat. The basic heat budget equation at the earth's surface is

$$Ro = So + Qo + Eo + Po$$

where Ro = net radiant energy received at the earth's surface, So = heat conducted into the soil and grass, Qo = sensible heat flux to the air, Eo = latent heat flux to the air and Po = heat flux required for photo chemical processes, which will be neglected. Ro would be measured by net radiometers and So by soil heat flux plates at each mast site. Qo and Eo can be estimated by assuming that the eddy diffusivity for sensible and latent heat are the same. The Bowen ratio Br is equal to Qo/Eo and, if the eddy diffusivities for sensible and latent heat are the same, Br = constant times (dθ/dz) / (dq/dz) where dθ/dz is the potential temperature gradient and dq/dz is the specific humidity gradient at the same height above the surface. The air temperature gradient and specific humidity gradient would be measured at each mast site so that comparisons might be made between the three systems and a more reliable value for the average of Qo and Eo would be available for comparison with other instrument systems.

Estimates of τ_o the surface stress or $V^* = (\tau_o/\rho)^{1/2}$ where V* is the friction velocity and ρ the air density may be obtained from the wind and air temperature profiles. The basis equation to be used is

$$V = V^* k^{-1} (\ln(1+Z/Zo) + \Phi_v)$$

where k = 0.428 the karman constant, z is height above the surface, z_o is the roughness parameter for the surface and Φ_v is the integral diabatic influence function which is a function of stability departures from adiabatic conditions.

From the windspeed, air temperature and moisture profile it is possible to estimate the sensible and latent heat fluxes by the aerodynamic method which will be nearly independent of the heat budget method mentioned above as neither the net radiation or soil heat flux will enter into the equations.

Several wind vanes located on each mast would be used to determine if the wind direction is constant with height over the entire profile so that it can more safely be assumed that V*, Qo and Eo are constant over the profile. The above assumption is essential to the aerodynamic method of estimating V*, Qo and Eo utilizing all levels of profile measurement.

The divergence estimates over the area encompassed by the three masts would yield an estimate of the mean vertical velocity at the top level of the masts. To check this estimate it would be desirable to have an independent measure of the vertical velocity. The vertical momentum transport would also be desirable. Therefore, a supplementary measure of the instantaneous vertical and horizontal velocity would be made at the level of the uppermost anemometer.

2. INSTRUMENTS AND RECORDING

The field sites were located by Mr. Dave Morgan of UCD, Davis, California based on an equilateral triangle 100 meters on a side, oriented so that two masts were 50 m south and north of the Davis 20 m tower and the third mast was directly west of the Davis Tower and 100 m from the other two masts. The

Wisconsin masts were well within the field site, yet enclosed all possible sites for other instruments. Fig. 1 gives the field layout and the corresponding mast numbers which will be referred to in the data.

Space at the University of California, Davis, field site was not available for housing equipment or to serve as a work area. A 7 ft x 9 ft x 7 ft high hutment was obtained which would fit on a 1½ ton stake truck that could be rented from the University of Wisconsin car fleet. The hutment was wired to serve as the recording shelter. A tandem trailer towed by the truck was used to transport equipment to Davis, California.

At Davis, California the hutment was removed from the truck and placed beside an obstruction which was already present on the east edge of the field site, so as to minimize the disturbance to the field. The trailer, which was parked beside the hutment, served both for storage and as a work area during the week of inclement weather present prior to the start of the field experiment.

2.1 Windprofile. The factor limiting profile measurements was that only 29 anemometers were available (including 7 loaned by Dr. C. B. Tanner, Department of Soils, University of Wisconsin). Since three masts were the minimum which would provide an area coverage around other installations, nine levels of wind measurement were made at each mast leaving two anemometers as spares. The heights selected were 20, 40, 80, 120, 160, 200, 240 and 320 cm. The wind vanes were initially installed at 40, 80, 160, 240 and 320 cm.

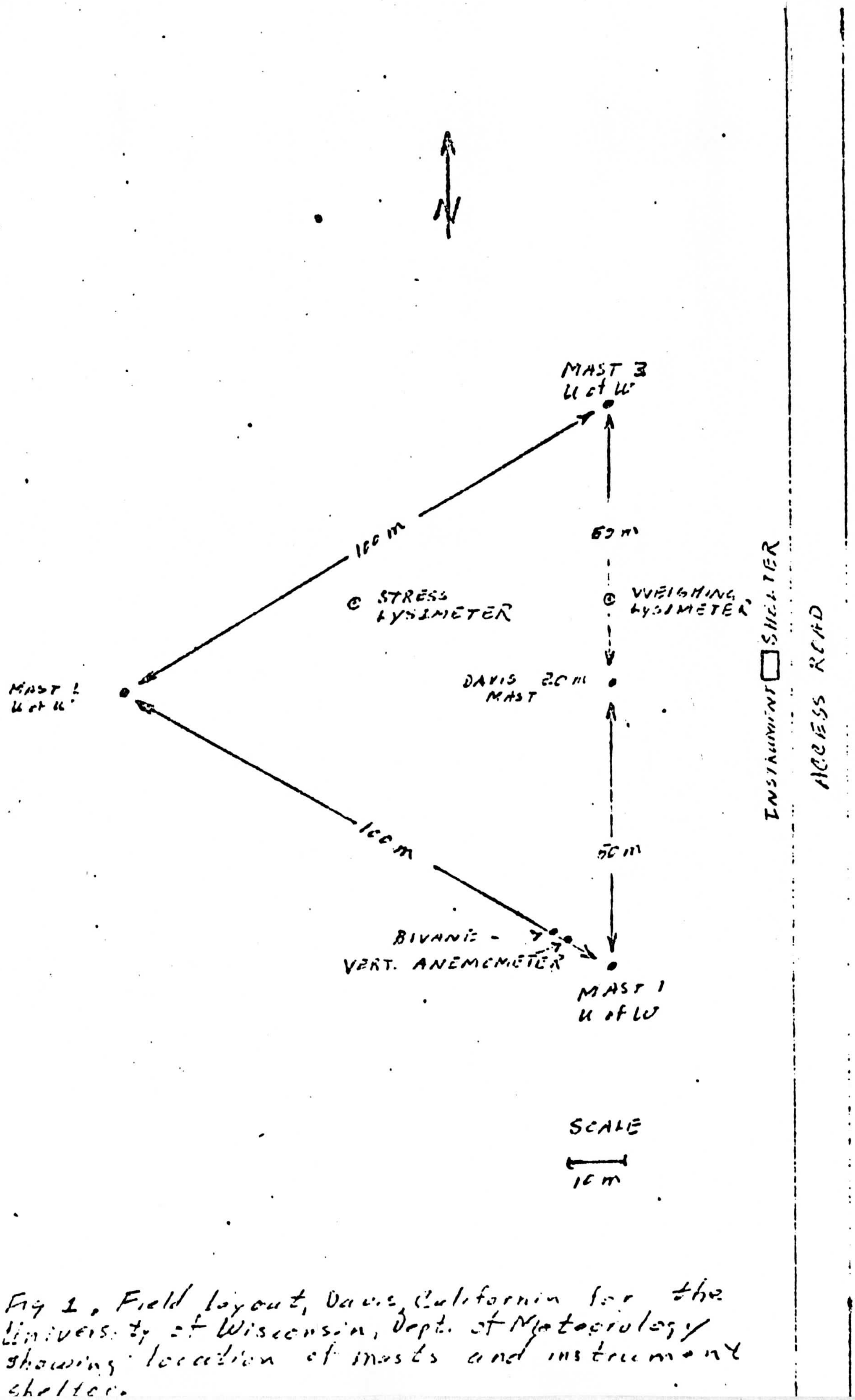

Fig 1. Field layout, Davis California for the University of Wisconsin, Dept. of Meteorology showing location of masts and instrument shelter.

The wind speeds for profiles were measured by 3 cup Thornthwaite anemometers using a recording system described by Stearns (1967). During each revolution of the cup a photo cell is eclipsed from a light bulb by a shutter. The photo cell resistance change is amplified operating an electro-mechanical counter. The counters were photographed once each minute and the counts for 28 minutes out of each 30 minutes were noted commencing one minute after the hour or half hour and stopping one minute before the half hour or hours.

After the field experiment the anemometers were compared to each other in order to establish their relative calibration factors. The anemometers were mounted 12 at a time 50 cm apart on a horizontal bar two meters above the water on Lake Mendota. Comparison runs were made when the wind was within ± 30 degrees of being normal to the bar until 3,000 or more counts had been registered for all anemometers. Then the anemometers were shifted one position along the bar with the anemometer on position 12 removed and one added at position 1 until all anemometers had been run at all positions on the bar. A total of 34 runs were required as occasionally one anemometer was not operating properly. Table 1 presents the resulting correction factor for each anemometer and the standard deviation of the correction factor for the comparison runs.

The average correction factor for each bar position and its standard deviation is presented in Table 2. This was calculated from the correction factor for each anemometer on that position and the average is the average of the correction factors for every anemometer.

2.2 Temperature Profile. Air temperature differences between levels were measured by 10 junction thermopiles. Each thermopile was encased in a 5 mm dia aluminum bulb 10 cm long supported on a stainless steel tube. The bulbs were shielded from direct solar radiation by two concentric tubes covered with aluminized mylar on the outside and painted flat black on the inside (Stearns, 1967). The resulting time constant of the thermopiles was about 2 min when ventilated 5 m/sec by a blower.

The absolute value of the air temperature was determined by measuring the temperature difference from an ice bath to the 20 cm and the 320 cm level with two junction thermopiles. Since this signal normally was more than the amplification range of ± 1 mv could handle, the difference between the thermopile outputs and a milli-volt bias source equivalent to about 18.5°C was amplified and recorded. The temperature at 20 cm and 320 cm was determined by adding the recorded signal to the milli-volt source then the voltage was converted to a temperature difference relative to zero deg C. Then the temperature at the next level was found by adding the temperature difference measured by the 10 junction thermopiles from the previous level. Finally at the 320 cm level two air temperatures were available for comparison: one measured by summing the differences in temperature between each level and the other from the two junction thermopile going from the ice bath to 320 cm taking into account the bias source.

The air temperature data on Mast 1 was recorded once each minute on Mast 2 and 3 twice each minute.

Table 1. Mean and standard deviation of the anemometer correction factor obtained by comparison of 12 anemometers at a time on a horizontal bar two meters above the water of Lake Mendota during June and July, 1967. The standard deviation includes variability due to the differences in bar position.

ANEM. NO.	RUNS	MEAN	STANDARD DEVIATION	ANEM. NO.	RUNS	MEAN	STANDARD DEVIATION
1	11	0.927	0.006	16	12	1.001	0.013
2	12	0.995	0.006	17	12	1.028	0.018
3	12	0.997	0.017	18	12	0.997	0.012
4	12	1.010	0.008	19	12	0.980	0.011
5	12	1.038	0.011	20	12	0.992	0.007
6	12	1.011	0.002	21	12	0.969	0.008
7	12	1.019	0.004	22			
8	12	1.023	0.015	23	11	0.995	0.011
9	9	0.996	0.005	24	10	1.008	0.011
10	12	0.999	0.004	25	11	0.997	0.016
11	12	0.993	0.002	26	11	0.981	0.011
12	11	0.994	0.016	27	11	1.006	0.023
13	11	1.001	0.011	28	10	0.979	0.011
14				29	8	1.006	0.009
15	12	1.026	0.014				

Table 2. The mean and standard deviation of the correction factor for each position on the comparison bar obtained during June and July, 1967 over Lake Mendota. The positions are numbered from right to left facing the wind.

BAR POS.	SAMPLES	MEAN	STANDARD DEVIATION	BAR POS.	SAMPLES	MEAN	STANDARD DEVIATION
1	27	0.992	0.021	7	24	1.004	0.024
2	26	0.994	0.021	8	24	1.007	0.023
3	27	0.998	0.021	9	24	1.005	0.023
4	27	0.999	0.022	10	23	1.007	0.020
5	27	1.001	0.022	11	25	1.000	0.021
6	27	1.006	0.023	12	25	0.990	0.025

2.3 Moisture Profile. The difference between the air temperature and the wet bulb temperature was measured by a two junction thermopile at each of the nine levels on each mast. Two aluminum bulbs 0.5 cm in diameter and 5 cm long were supported on plexiglass tubing. One aluminum bulb was covered with a wick moistened by distilled water fed by capillary action from a 250 cc reservoir. The two junction thermopile measured the temperature difference between the wet and dry bulbs. The unit was located in the supporting pipe for the air temperature probles and ventilated by the same blower.

The output of each wet-bulb-depression thermopile was switched and recorded at nearly the same time as the air temperature at the same level during the first half of each minute.

2.4 Wind Direction. Wind direction in the very lowest layers of the atmosphere has been too often ignored. Although very conservative under lapse conditions, wind directional changes with height during stable conditions are known to be quite significant (Dalrymple, 1967). To remedy this problem, the wind direction was measured at five levels on all three masts to determine if measurable changes in wind direction occur over the profile height.

*The signal from the potentiometer was passed through a filter with a 2 min exponential time constant. It was then amplified, digitized and printed on paper tape.

Fifteen small wind vanes were designed by Dabberdt and Stearns and fabricated at the University of Wisconsin Mechanician Shop. The high-aspect-ratio aluminum tail was counter-balanced by a streamlined brass nose. The vertical shaft was mounted in sealed-ball bearings and coupled to a one-turn, high resolution potentiometer.* Although no individual calibrations have as yet been made, the wind speed response threshhold is in the neighborhood of 1 m sec^{-1}.

In the field the vanes were mounted one meter upwind and 50 cm to the left of the vertical mast structure so as to minimize possible interference.

The calibration procedure was as follows: three distant targets were selected the true bearings of which were known; each vane was then sighted on a target for 10 to 15 minutes, recorded, and calibration curves constructed for each wind vane from the three sightings. It was later determined that further refinements were necessary. The assumption was then made that the wind direction was constant with height at each mast during strong lapse conditions. The average departure of the wind direction of each vane from the mean direction over the mast during these periods was used as an additional correction factor.

2.5 <u>Mast Construction</u>. The use of three separate masts for mounting the sensors for windspeed, direction, and air temperature and moisture was rejected in favor of one mast which supported all elements. On a central mast made of a two inch aluminum pipe three meters high a horizontal arm one meter long was mounted at each level which would support the sensors. At the end of the supporting arm a one meter long horizontal cross arm was welded to the arm. On the left end of the crosspiece the wind vanes were mounted and on the right end of the crosspiece the anemometer was mounted. The air temperature and moisture sensors were in the center above the supporting arm. The center of the anemometer cup, the center of the air intake nozzle for air temperature and wet bulb depression, and the center of the wind vane tail are at the same level. The mast was supported on a base by four guy wires and could be turned manually so that the sensors would be directed into the wind.

The height to each level on the mast is given in the program for the reduction of printer output in Appendix B, C and D already corrected for the height error given at zero distance from the mast in Table 4.

2.6 Radiation Measurements. At each mast total shortwave incident radiation was detected by an Eppley pyranometer and recorded once each minute. The net radiometer, due to its short response time, was sampled four times each minute at about 15 sec intervals.

The net radiometer ventilation was balanced by shielding the sensing element from external radiation by a cardboard tube large enough not to restrict the air flow. Then heat was applied to each side of the sensing element while the output was monitored by a D. C. amplifier with meter output. The ventilation was adjusted until the application or removal of the heat did not change the output signal. The radiometer was leveled according to a bubble level placed on the upper sensing surface.

Table 4 Height in cm to be subtracted from zero of mast height to obtain the height of the anemometer above the surface at distances 0 - 9 meters from the mast in the indicated direction. The surface reference is a ½ in. mast screen one foot square resting on the grass.

	Direction	Distance from mast (meters) 0	1	2	3	4	5	6	7	8	9
Mast 1	South	1.1	1.3	4.4	5.4	6.5	10.0	11.0	12.1	12.5	14.3
	Southwest	1.1	-0.1	3.5	4.6	5.7	8.4	11.5	11.3	13.5	14.4
	West	1.3	0.9	4.7	6.5	8.1	9.1	10.7	10.4	11.1	12.0
	Northwest	1.0	0.5	3.8	6.5	6.7	8.9	11.5	12.5	10.5	13.2
Mast 2	South	-1.5	1.6	2.4	6.2	6.3	8.3	7.2	9.0	8.8	10.1
	Southwest	-3.0	-1.3	0.5	0.2	3.7	3.5	5.3	6.1	5.7	12.2
	West	-3.1	-2.3	0.1	3.1	4.7	6.0	11.3	11.9	5.2	3.2
	Northwest	-0.8	-1.1	-0.3	0.9	3.0	4.1	6.2	6.7	13.1	12.9
Mast 3	South	-0.1	2.0	4.6	5.0	4.9	6.0	7.8	8.6	7.4	7.2
	Southwest	0.4	1.0	3.2	4.0	5.6	6.8	9.2	10.2	9.2	11.2
	West	-1.0	0.6	4.2	5.0	6.5	8.0	10.8	10.8	10.2	12.5
	Northwest	1.2	0.0	1.5	2.6	2.9	5.5	8.5	6.0	7.0	8.6

Calibration of the net radiometer was done in comparison to the Eppley pyranometer recorded at the same mast. The pyranometer was shaded for five minutes by a 6" by 12" piece of sheet metal covered with aluminized mylar and mounted on the end of a 10 ft piece of electrical conduit. The conduit was manually held in a vertical position so that the shade shadow would fall on the pyranometer element. After shading the pyranometer, the net radiometer element was shaded in a similar manner for one minute then the shade was shifted slightly, so that the shade shadow was on the ground below the sensing element but not on the element, for one minute so that the effect of the ground shadow on the net radiometer could be determined.

The calibration was carried out whenever the sky was clear and the sun was shining during the latter half of each hour period. The three sets of radiation instruments were calibrated in 30 minutes. During three days only four opportunities were available for calibration of the net radiometers.

2.7 Soil Heat Flux. The soil at the Davis field site was covered with a mat of roots, dead grass and other debris which made a layer of uncertain composition and thickness. There was little point in putting soil flux plates in the soil itself because they obviously would not detect the actual heat flux into the surface. Because of uncertainties about the thermal contact between the litter and the flux plate the calibration of the flux plates in terms of actual soil heat flux will be very uncertain (Philip, 1961), however, the saving feature is that the soil heat flux should be a small portion of the total surface heat budget.

Three 100 junction soil heat flux plates were used at each mast location and recorded separately. The plates were placed in the surface litter by cutting a slit a few centimeters deep, then a horizontal slice was made about 1 cm below what appeared to be the top of the litter and the flux plate was placed in the slice and the litter pressed down. Since the litter was stiff a gallon or so of water was put on the litter over the flux plate so that the litter would be softened and make better thermal contact with the flux plate. Very few actual soil particles were present in the litter.

The three soil heat flux plates at each mast were recorded through the switch-amplifier-digital voltmeter-printer system. After the data was on punch cards the raw values were plotted as a function of time for each of the individual flux plates. Examination showed which plates were operating uniformly in the expected proper phase with respect to the solar forcing function and not exposed to solar radiation filtering through the litter. The flux plates which seemed to be operating properly were used to determine the soil heat flux using a calibration factor of 3.9 mv $ly^{-1}min$. This was arrived at by assuming that the thermal conductivity of the litter was about 0.1 of the flux plate which would mean that the flux plate would indicate about 1.2 times the heat flow that was actually taking place if the thermal contact were perfect. Then it was assumed that the thermal contact was 75% of perfect thermal contact. (Philip, 1961), (Stearns, 1967). The resulting calibration for the soil heat flux plates with 100 thermo-junctions was

3.9 mv ly^{-1}min which was the value used in processing the data for all three masts. It could be in error by as much as ± 25%.

2.8 Soil Heat Flux and Temperature Profile. In view of the effort that was being put forth at Davis, California, it was felt that it would be worth while to make a detailed study of the soil temperature and heat flux at each of the three mast sites. Three systems were constructed for burial at Davis, California, and in March 1967, a trip was made to Davis to bury one system at each of the mast sites. The soil was wet and after one system was rather poorly buried at mast 1 it was believed that it would not be worthwhile to bury the other two systems as they were unlikely to be successful due to the tendency of soil to ball. The installation at mast 1 left much to be desired.

An examination of previous data from the Davis site showed that the amplitude of the diurnal variation of the soil temperature at -32 cm would be about 0.4°C which was selected as the greatest depth at which measurements would be made. The 13 positions available for recording the soil temperature and heat flux profile limited the number of points in the soil to six. The depths selected were -1, -2, -4, -8, -16 and -32 cm. A double system was constructed so that a failure in one side after burial would not cause the experiment to fail. It is very unlikely that both systems would fail at the same level.

Two junction thermopiles were used to measure the temperature difference between adjacent levels. Aluminum tubes one-eighth inch in diameter and 30 cm long were used to house the junctions which were insulated and spaced about three centimeters apart near the midpoint of the tube. Two tubes were used at each depth spaced two inches apart between the inner edges. Thus each row of tubes resulted in a complete temperature profile and were held in place by two plexiglass sheets drilled for the tubes and located at each end of the tubes.

The flux plates were constructed of microscope slides 2" long and ½" wide upon which 60 turns of No. 36 constantan wire were wound. The turns were copper plated to the midpoint of the flat side of the plate resulting in 60 thermojunctions which would measure the temperature difference across the slide. The plated slides were coated with glyptal varnish to improve the thermal contact between the glass plate and the thermo junctions and to insulate the thermo junctions from the soil. Each plate was checked by immersing the plate in water then measuring the resistance between the water and the plate, after leads had been soldered to the outer constantan turn, in order to be sure the plates were well insulated electrically. The flux plates were then glued between the two aluminum tubes housing the thermocouples, so that both soil temperature and heat flux would be at the same level. To partially compensate for the decrease in soil heat flux with depth more individual flux plates were used at greater depths as follows: -1 and -2 cm depth -four plates, -4 and -8 cm depth - 5 plates, -16 and -32 cm depth - six plates. Distribution of the plates along the aluminum tubing was adjusted so that the plates were not aligned in the vertical. It was believed that the staggered distribution plus the small size of the plates would minimize the hinderance to the vertical flow of water. Two separate leads were brought out for each flux plate so that if one plate were broken the complete set of measurements at that level would not be disrupted.

Two thermo junctions were brought out from the -32 cm depth from each side to a reference bulb and similarly from the -1 cm depth so that if there were a complete disruption of the system at one level in temperature it would be possible to work down and up to that level from the two sets of reference junctions.

Prior to recording the soil heat flux and temperature profile, each item was checked to see if it was operational. One set of thermocouples were open but the flux plates all were operating in a reasonable manner except for some leakage to the soil.

The thermopiles from the separate systems at each level were connected in parallel for recording. The flux plates at one level were connected in series for recording.

2.9 Bivane and Vertical Anemometer. A Gill bivane with propeller anemometer was mounted at the 320 cm height near mast 1. About 2 m away a Gill vertical anemometer was mounted at 320 cm together with a set of fine wire thermocouples for air temperature measurement which was referenced to an ice bath less an adjustable bias voltage, which could be changed as the air temperature changes so that the fluctuations only were amplified substantially.

The horizontal and vertical angles of the bivane, the bivane propeller, the vertical anemometer and air temperature were individually amplified to permit range-changing and recorded on a Visecorder 14 Channel oscillograph at a chart speed of 5"/min. A filter of 5 sec exponential time constant was placed in each output in order to smooth out the high frequency components. This would serve to give all systems the same time constant as all are normally quite different.

The outputs will be used to determine the vertical velocity, momentum and sensible heat transport. This will require products which have contributions at frequencys higher than 1/5 hz but this contribution would be lost. The individual time constants are such that the actual contributions of the products would be uncertain if the filter were not used.

2.10 Pressure Gradient Measurement. One term which is always missing in micrometeorological measurements is the horizontal pressure gradient at the earth's surface. An estimate can be made by placing microbarographs tens of kilometers apart but the poor response time of the instruments and their inherent error of ± 0.5 mb in absolute pressure limit their use for determining small scale pressure gradients.

An attempt was made to make a measurement of the horizontal pressure gradient between the three masts at the Davis site. Three snow saucers were mounted on and sealed to a wood base which has a 0.50 inch pipe fitting. Four holes 0.25 inch in diameter were drilled around the saucer dome. One dome was placed in the soil at each mast so that only the dome extended above the soil surface.

Plastic water pipe of 0.50 inch diameter was connected to each dome leading to the recording shelter where a solenoid valve switching arrangement connected the pipes to a Statham differential pressure gauge with a range of $\pm$ 3000 dynes/cm^2 for $\pm$ 10 mv output.

Recording was on a 0 to 2.0 mv Honeywell recording potentiometer. The cycle of the pipe switching was as follows: the pressure difference between mast 1 and 2, mast 2 and 3, mast 1 and 3, and the gauge zero. The switching system for the solenoid switches was triggered every 2.4 sec by the main switch so that 6 cycles were obtained each minute.

2.11 Switching, Amplifying and Recording. At each mast was located a switching and amplifying box which was buried in the ground so as to provide the minimum disturbance to the wind flow plast the mast. The switch was a 24 position eight deck unit arranged so that two decks were used to switch each terminal and two terminals were used (one for each side) for every element which was recorded. The output of each channel was fed to a Sanborn 8875 differential amplifier then to a Hewlett Packard 405 digital voltmeter. Both channels for each mast were recorded on one Hewlett Packard digital printer. Three systems were used, one for each mast. A total of 144 items could be recorded each minute.

All switches were stepped every 2.4 sec by a master clock then 1.8 sec after switching the digital voltmeters were triggered and the digital output was recorded on the printer. After 24 positions had been stepped, the units were quiet for 2.4 sec until the 1 min clock turned the stepping mechanism on for the next cycle. Table 3 gives the recording order.

Table 3 - Recording order for Mast 1, 2, and 3. Wet bulbs, soil heat flux, net and solar radiation were not recorded until May 2, 1967. On May 2 the 40 cm, wind vane was placed at 200 cm and positions 13 to 24, Channel 1, were used for the soil temperature and heat flux profile on Mast 1.

Switch Position	Item - Channel 1	Item - Channel 2
1	0.935 Millivolts ref.	Short
2	Short	0.935 Millivolts ref.
3	Ice bath to 20 cm temp. diff.	Net radiation
4	40 - 20 cm temp. diff.	20 cm wet bulb depression
5	80 - 40 " " "	40 " " " "
6	120 - 80 " " "	80 " " " "
7	160 - 120 " "	120 " " " "
8	200 - 160 " "	160 " " " "
9	240 - 200 " "	Net radiation
10	280 - 240 " "	200 cm wet bulb depression
11	320 - 280 " "	240 " " " "
12	320 cm to icebath tem. diff.	280 " " " "
13	-0.935 Millivolts reference	320 " " " "
14	Short	Solar radiation
15	Ice bath to 20 cm tem. diff.	Net radiation
16	40 - 20 cm temp. diff.	40 cm wind direction
17	80 - 40 " " "	80 " " "
18	120 - 80 " " "	160 " " "
19	160 - 120 " "	240 " " "
20	200 - 160 " "	320 " " "
21	240 - 200 " "	Net radiation
22	280 - 240 " "	Soil flux plate
23	320 - 280 " "	" " "
24	Ice bath to 320 cm tem. diff.	" " "

2.12 Happenings.

Date	Time	Event
4-15-67		Russell Johnson arrives at Davis, Calif. with truck, trailer and hutment.
4-16-67		C. R. Stearns and Tom Frostman arrive at Davis, California, car rented.
4-17-67		Start preparations for field experiment.
4-18-67		Walter Dabberdt arrives at Davis, Calif.
4-24-67		Ken MacKay arrives at Davis, California
4-26-67	1301	Start recording wind profiles
4-26-67	2001-2129	Mast 3, 160 cm anemometer not working. Bulb replaced.
4-26-67	2224	Rain began so recording was stopped.
4-27-67	1131	Recording started.
4-27-67	1201-1301	Mast 1, 240 cm anemometer not working. Bulb replaced.
4-27-67	1231-1259	Started putting wet bulbs on mast 1
4-27-67	1331-1359	Finished putting wet bulbs on mast 1
4-27-67	1701-1959	Mast 2, 200 cm anemometer not operating. Bulb replaced.
4-27-67	1731-1929	Mast 3, 120 cm anemometer not working. Bulb replaced.
4-27-67	1801-1929	Mast 3, 200 cm and 280 cm anemometer not working. Bulbs replaced.
4-27-67	2302-2359	Mast 3, 80 cm anemometer not working. Bulb replaced.
4-28-67	0101-0231	Mast 3, 320 cm anemometer not working. Bulb replaced.
4-28-67	0231-0259	Bias voltage on air temperature reference shorted out. Air temperature had been off scale.

4-28-67	0231-0430	Mast 3, 20 cm anemometer not operating. Bulb replaced.
4-28-67	0315	Visicorder take up reel plug shorted out tripping circuit breaker 2 cutting power to clock and wind counters. Time thereafter is by Dabberdt's watch.
4-28-67	0731-0831	Mast 3, 40 cm anemometer not operating. Bulb replaced.
4-28-67	0830-0900	Shorts on air temperature bias removed.
4-28-67	1101-11591	Lining up wind vanes on mast 1.
4-28-67	1850	Stopped recording data
4-28-67		H. H. Lettau arrives at Davis, Calif.
4-30-67		H. H. Lettau leaves Davis, Calif.
5-2-67	0630	Start recording
5-2-67	0930-1000	Shaded eppleys and net radiometers on mast 1, 2 and 3.
5-2-67	1000-1030	Rotated masts to the northwest. Aligned wind vanes.
5-2-67	1130-1200	Shaded eppley and net radiometers on mast 1, 2 and 3.
5-2-67	1500-1530	Rotate masts to the southwest and aligned wind vanes.
5-3-67	0930-1000	Shaded eppleys and net radiometers mast 2, 3, and 1. Photographer at mast 1.
5-3-67	1231-1400	Mast 3, 40 cm anemometer missing counts - bulb changed.
5-4-67	0930-1000	Shaded eppleys and net radiometers mast 1, 2, and 3.
5-5-67	0200-0300	Observed mast 2 stepping switch was missing.
5-5-67	0301-0359	Misread mast 2 - 280 cm, Mast 3 - 20, 40, 80, 120, 160, 200 cm anemometers.

5-5-67	0550-0612	Switch off for all masts. Repaired broken micro switch. Now makes 25 steps per minute so every 25th cycle of data will be removed.
5-5-67	1200	Stopped recording.
5-5-67	1201	Started dismantling equipment and loading trailer and truck.
5-6-67		Russell Johnson started return trip to Madison, Wisconsin driving truck with hutment and towing trailer. C. R. Stearns leaves Davis, California

3. DATA REDUCTION

The recording of data commenced at 1130 PCT on April 26, 1967 but the sequence was interupted at 2330 PCT on April 26, 1967 because of light rain showers. Recording commenced again at 1130, April 27, 1967 and continued uninterrupted until 1830, April 28, 1967. The moisture profiles, radiation, soil heat flux and soil temperature and heat flux profiles were not in operation during the above recording periods.

On April 28, 29 and May 1, 1967 the additional items listed in the paragraph above were placed in operation.

Recording commenced again at 0630 PCT, May 2, 1967 and continued with only minor interruptions until 1200 PCT, May 5, 1967. On the afternoon of May 5 the equipment was dismantled, the truck and trailer were loaded. On the morning of May 6, 1967, the truck started for Madison, Wisconsin.

Data was recorded for about 120 hrs. resulting in about 6,000 28 minute windspeeds, 1,000,000 three digit numbers on printed paper tape, 25 rolls of Visicorder paper with five traces which potentially represent 2,000,000 three digit numbers, 10 rolls of Brown recorder paper representing another 173,000 potential three digit numbers. The wind profiles were photographed once each minute and this data represents a potential 195,000 three digit numbers. If all the data is utilized in the maximum desired detail then about 3.4 x 10^6 three digit numbers were collected at Davis, California by the Department of Meteorology, University of Wisconsin.

3.1 Windprofile Data Reduction. The wind counts for 28 minutes were recorded in a notebook every 30 minutes. The two minute time period allowed for reading the counters was insufficient to allow for resetting the counters so it was necessary to subtract the previous reading from the present reading in order to obtain the anemometer counts for the recording period. This operation was carried out after the data was recorded providing a check on the operation of all anemometers. Light bulbs burned out several times and these were corrected usually in the next hour. The missing data was filled in by the ratio of the counts for the anemometer above and below the missing anemometer for the period of missing data to the period before and after when all three anemometers were operating. Checks had shown that this method would duplicate the missing data within 1% of the actual value. The list of events gives times and location when anemometer counts had to be estimated.

The date, time of start, time of stop, mast number and anemometer counts for the period were recorded on punch cards. The correction factors for each anemometer given in Table 1 were used in the program "Fast Air" in Appendix A for the initial processing of the data. The program converted the anemometer counts to cm/sec then computed V*, Z_o and the displacement height assuming that the wind profile was adiabatic. Often a solution could not be found because the bottom anemometer would be below the ground level so the program prints out "The______ th iteration. Try other initial guesses." In other cases a solution would be found at displacement heights hundreds of meters above the surface which should be considered ridiculous. If the displacement height is ± 10 cm and a solution is obtained then the V* and z_o value should be reasonable.

The program takes the value of V*, z_o and D calculates a smooth windspeed profile, the speed difference between the smoothed speed and the observed speed, and the ratio of the smoothed speed to the observed speed printing out the results.

During the period April 26 to 28 the anemometers remained in the same position, then for the period May 2 to 5 the anemometers previously on mast 1 were placed at the same levels on mast 2 and so forth.

Since slight differences in mounting may alter an anemometer calibration it would be desirable to correct an anemometer while mounted on the profile mast. From the initial pass at the wind profile data using the correction factors given in Table 1, ten profiles were selected under lapse conditions and ten under inversion conditions for which there were solutions with reasonable displacement heights. The average of the ratio of the smooth speed to the observed speed was obtained for each anemometer for the 20 profiles for the periods April 26 to 28 and May 2 to 5. Table 5 gives the initial correction factor for the anemometer, the correction based on the smooth speed to the observed speed and the final correction factor for each anemometer. The final correction factor is based on the assumption that the 20 profiles were adiabatic and the correction factor could force the profile towards the adiabatic profile. However, the correction factor for lapse and inversion conditions was generally of the same sign and magnitude while the departures from the adiabatic wind profile for lapse and inversion condition should be of the opposite sign. The program used for the wind profiles is given in Appendix A.

The program "Fast Air" punches a card containing the mast number in column 2, the number 1 in column 4 which is an identifier for windspeed, the date, time of start, time of stop and the windspeed at nine levels on the mast in order of ascending height.

3.2 Printed Tape Data Reduction. Air temperature, wet bulb depression, wind vane angle, solar radiation, net radiation and soil heat flux were recorded through the switch-amplifier-digital voltmeter-printer system at one minute intervals.

The mast number, card number, date and time, then 24 values of printer output were placed on one card. Since 48 values were recorded on each printer each minute two cards were required, hence the card number. For ease in puching, alternate channels were entered serially on the card as they were side by side on the printed tape.

It was necessary to scan the data punched from printed tape for errors in recording and punching. Recording errors were relatively easily corrected during the initial inspection of the tape when one minute times marks were indicated. The punching error which was most bothersome and difficult to correct for was the mispunching of, for example, a 1 instead of a 4. Some errors are still present in the data and as they are corrected an errata sheet will be provided with the corrected values.

A computer program was written which would scan the data and look for a significant departure of a one minute value for each item from the previous and next minute. If a departure was detected, the position of the data point on the card would be indicated. All errors detected in this manner were checked to see if the departure were real, or a punching or printing mistake. If either, the card was corrected. The variability of some data, such as net radiation, was so large that it was not possible to make corrections for printing errors.

Once the data was on tab cards and scanned for obvious printing and punching errors it was possible to do the actual calculations on the data and serch for errors in measurements. Each mast was considered separately, resulting in three separate programs which are basically the same. Examples of differences between programs: one air temperature gradient might be reversed in sign on one mast or the recording order might be different. These errors had to be found before final computations could be made. Wiring errors are revealed in the programs in Appendix B, C and D.

The nominal heights of each level are given initially and the geometric mean heights are computed. At statement 100 the mean values are initially set to zero. The first card is read in, checked to see if it is the first card for the one minute sequence of two cards, and, if it is the second card for that minute, is read into the computer. A check is made to see that both cards are for the same mast, day and time. The electrical zero is subtracted from each reading and the reading is adjusted to the value of the reference voltage which is recorded once each cycle.

The first item computed is air temperature. A check is made to see if the bias voltage of 1.516 mv in the reference (ice bath) to 20 cm and to 320 cm level is shorted out. Once decided the air temperature at successive levels is computed. On mast 1 only, the second sampling of air temperature on May 2, 3, 4, and 5, 1967 has been deleted so that the soil temperature and heat flux profile could be recorded. The air temperature sum TM(J) and the sum of the squares TMV(J) are made.

The date and mast number for one minute values are written together with the heights for each level. The difference between the two measured temperatures at 320 cm is computed along with the 320-20 cm temperature difference. The air temperature data is printed on one line labeled "air temperature (deg C)" under the appropriate height. On the right hand side is printed first the difference between the two temperatures measured at 320 cm and the difference in temperature between 320 and 20 cm.

Wet bulb depression, radiation and soil heat flux were not measured before May 2, 1967 so the program skips to wind direction prior to May 2. On and after May 2 solar radiation, net radiation and soil heat flux are computed. The one minute values of solar radiation, net radiation, soil heat flux and the remainder from net radiation and soil heat flux are printed. Sums of each item are formed for the computation of the average.

The wet bulb depression is added to the air temperature at the same level, then the vapor pressure is determined at each level. In some cases a wet bulb did not seem to be operating properly so the average wet bulb depression for the level above and below was used for the wet bulb depression. On other occasions the wet bulb was dry which is obvious in the data as one minute values of the wet bulb are printed, and, if the wet bulb and air temperature are within 0.2°C then it is safe to assume that the wet bulb at that level was dry. The profile of the wet bulb temperature does not vary smoothly either, if one wick is dry.

Specific humidity in gm/kg is computed from the vapor pressure at each level and printed at one minute intervals. Sums are formed for the mean and the standard deviation.

The Bowen ratio is computed between the 40-20, 80-40, 160-80, 240-120 and 320-160 cm levels. From the Bowen ratios and the residue of the net radiation and soil heat flux, the latent and sensible heat flux to the air are computed for each Bowen ratio. The mean value of the sensible and latent heat flux are determined from the values at the five levels above. The five levels and mean value of sensible and latent heat flux in ly/min are printed for each minute. Sums are formed for computing the mean value.

Upon reaching either a 30 minute or hour time the program forms means from the time that a mean was last formed. The heading is printed which includes the date, mast number, the time of the first minute and the last minute in the mean together with the number of minutes used to form the mean. Heights of the levels of measurement are printed.

The mean air temperature at each level, the difference between the two mean temperatures at 320 cm and the temperature difference from 320 to 20 cm temperature are computed and printed. A card is punched which is dated, timed for start and stop, identified (a 2 in column 4 for air temperature), then the air temperature at each level is punched in ascending order. The standard deviation of air temperature at each level is computed and printed.

If the date is prior to May 2, 1967, the program skips to wind direction, otherwise the mean and standard deviation of specific humidity are computed and printed. A card is punched as for air temperature except the identifier in column 4 is 3 for specific humidity. The printed values for specific humidity are punched in ascending order.

Mean values of solar radiation, net radiation, soil heat flux and the residue from net radiation and soil heat flux are printed.

The mean values of the sensible and latent heat flux determined at one minute intervals for each level and the mean of all levels are computed and printed. Then the Bowen ratio is determined from the mean air temperature and specific humidity at five level pairs. From the residue of mean net radiation and soil heat flux another set of sensible and latent heat flux values are obtained at the above level pairs, the mean of the five levels determined and the results printed for comparison to the previous method of determining mean values of sensible and latent heat flux.

A card is now punched identified by a 5 in column 4 containing heat flux data. The punching order is solar radiation, net radiation, soil heat flux, mean sensible heat flux formed from one minute values of sensible heat flux at five levels, mean sensible heat flux determined from the mean air temperature and specific humidity over the five pair of levels, the mean latent heat flux determined from one minute values at five level pairs, and the mean latent heat flux calculated at five level pairs from the mean air temperature and specific humidity using the mean Bowen ratios. All units are ly/min.

The heights at which wind directions were measured are printed, then the mean wind direction at each level and the mean of all levels are printed. The standard deviation for each level and the difference from the mean are printed. A card with identifier 5 in column 4 is punched with the wind direction at each level and the mean of all levels in order of ascending height with the mean of all levels last.

Table 6 lists the symbols used in the programs for the air temperature, moisture and heat budget. The programs are listed in Appendix B, C and D.

4. CONCLUSIONS

The accuracy of all measurements is open to question. The windspeed is based on calibration data supplied by the manufacturer of the anemometers. The absolute value of the air temperature is dependent upon the gain of an amplifier and the value of a bias voltage, if present. The air temperature differences between adjacent levels are dependent on the gain of the amplifier as is the wet bulb depression, radiation and soil heat flux. The amplifier gain was checked by a reference

Table 6 List of Program Symbols, Mast 1, 2, 3.

Z(9)	Height (cm) of sensor levels
ZZ(8)	geometric height (cm) between adjacent sensor levels
L1	Mast number first card
L2	Card number - must be 1 for first card of minute
L3	Date 26,27,28,2,3,4,5
L4	Time hours (1 to 24)
L5	Time tens of minutes (0 to 6)
L6	Time minutes (0 to 9)
M1	Mast number, second card
M2	Card number - must be 2 for second card of minute
M3	Date (26, 27, 28, 2, 3, 4, 5)
M4	Time hours (1 to 24)
M5	Time tens of minutes (0 to 6)
M6	Time minutes (0 to 9)
A(48)	Data on cards 1 and 2 minute consisting of 48- three digit numbers
P	number of minutes read in to be used to obtain the number of samples for the mean value over a period of time ending on the hour or 30 minutes after the hour
K	Index for time-numerically equal to P
M4, L4	are converted to time in hours and minutes
IT(K)	The time of all cards read in for a given period such as 30 minutes
REF 1	Value of reference voltage on channel 1
REF 2	Value of reference voltage on channel 2
B(48)	Data on cards minus electrical zero corrected for recorded value of reference voltage
T(10)	Air temperature computed for 1 minute period.
TM(10)	Sum of air temperature
TMV(10)	Sum of air temperature squared
DD	Air temperature difference at 320 cm
DDT	Air temperature difference between 320 and 20 cm
RS	Short wave radiation

Table 6 Continued

RO	Net radiation
SO	Soil heat flux
RSS	Sum of short wave radiation
ROS	Sum of net radiation
SOS	Sum of soil heat flux
S	Difference between net radiation and soil heat flux
TW(9)	Wet bulb temperature
ES(9)	Saturation vapor pressure of wet bulb temperature
E(9)	Vapor pressure of the air
SP(9)	Specific humidity of air
SPM(9)	Sum of specific humidities
SPMV(9)	Sum of specific humidities squared
BR(5)	Bowen ratio
EO(6)	Latent heat flux
QO(6)	Sensible heat flux
EOS(5)	Sum of latent heat flux
EOSV(5)	Sum of latent heat flux squared
QOS(5)	Sum of sensible heat flux
QOSV(5)	Sum of sensible heat flux squared
W(5)	Wind direction
ZW(5)	Height of wind vanes
WM	Mean wind direction
WD(5)	Wind direction difference from mean
WW(5)	Sum of wind direction
WWV(5)	Sum of wind direction squared
DDQ	Specific humidity difference between 320 and 20 cm
DT(5)	Mean temperature gradient
DQ(5)	Mean specific humidity gradient
QOM	Sensible heat flux computed from mean air temperature and specific humidity
EOM	Latent heat flux computed from mean air temperature and specific humidity

voltage during each data cycle but the reference voltage may also be in error. Net radiation should be questioned seriously as the calibrations left much to be desired. A recheck of the net radiometer calibration will be made which may result in changes of as much as ± 20%.

Occasionally a wet bulb was dry so these points should be eliminated from the output. The decision is simple but was omitted from the program.

The correction of the basic data and altering of the program will continue under Grant No. DA-AMC-28-043-66-624. The corrected results will be forwarded to the Meteorology Department, Fort Huachuca, Arizona.

Several items which were recorded are not mentioned. The soil heat flux and temperature profiles are not yet ready for presentation. The soil temperature profile is excellent for differences between levels but there is some doubt about the absolute value of the temperature. The soil heat flux profile is erratic and at this time the results are doubtful.

The vertical velocity, bivane and air temperature data at 320 cm is being read from the charts onto punch cards at the present time. The pressure gradient measurements is the least likely of all data to be useful but selected periods will be evaluated to determine if the scheme was measuring any thing meaningful.

The data will be supplied as magnetic tape containing the one minute data and the 30 minute means, and punch cards containing 30 minute means of the data necessary for further computations.

5. PERSONNEL

5.1 Personnel participating in the field experiment at Davis, California.

Russell Johnson - electronic technician

Walter Dabberdt - graduate student

Kenneth MacKay - graduate student

Thomas Frostman - graduate student

Charles Stearns - Assistant Professor

Heinz Lettau - Professor

5.2 Personnel participating in the data reduction.

Walter Dabberdt - graduate student

Jack Kittridge - project assistant

Mary Schumacher - hourly help

Helen Tuten - hourly help

Ruby Turner - hourly help

Phoebe Winterbottom - hourly help

Janet Ledin - hourly help

5.3 Data Analysis in Progress.

Allen Worcester - The temperature gradient vector and modification of the air as it moves over the surface.

George Fredericks - Divergence of wind velocity.

Walter Dabberdt - Variation of wind direction in the vertical.

Charles R. Stearns - Determination of displacement height, roughness length and shearing velocity.

6.0 REFERENCES

Philip, J. R. (1961), "The theory of heat flux meters", J. Geoph. Res., 66, 571-579.

Stearns, C. R. (1967), "Micrometeorological studies in the coastal desert of southern Peru", Ph.D. Thesis, Department of Meteorology, University of Wisconsin, Madison, Wisconsin.

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APPENDIX A

Fortran program for processing the wind profile data.

```
1COOP,21023327?5?STEARNS,O7HD1/E/2=50,20,00000/0000,  s
1PLEASE MOUNT TAPE DAVIS WIND AS LUN 1 .
TFTN,L,P,F,
C       COMPUTATION OF WIND PROFILE PARAMETERS ZO,V STAR,DEU
C
        PROGRAM  FAST AIR                                                    9.1
C
        DIMENSION Z(3,9),          GZ(8),ZO(8),DEU(7)
        DIMENSION  ZL(3,9),ZZ(3,8),ZZZ(3,7)
        DIMENSION  A(3,9),B(9),D(9),E(9)
        DIMENSION V(9),VD(9),VR(9)
C
C..DEFINITIONS
C       A(J,I)=ANEM.CORRECTION FACTOR
C       Z(J,I)=ANEM.HEIGHT
C       J=TOWER NUMBER
C       I=LEVEL
C       A(I)=WIND COUNTS IN THE PERIOD TE-TS FOR THE J PROFILE
C       D(I)=WIND VELOCITY (CM/SEC)
200     DO 1 L=1,3
         READ (2,51) J,(A(J,I),I=1,9)
         WRITE (1,51) J,(A(J,I),I=1,9)
 51      FORMAT(I2,9F6.2)
         READ(2,50) J,(Z(J,I),I=1,9)
   1     WRITE(1,50) J,(Z(J,I),I=1,9)
 50      FORMAT(I2,9F6.1)
100     DO 4 L=1,3
         READ (2,52) J,JAY,TS,TE,(B(I),I=1,9)
 52      FORMAT(I1,I2,11F4.0)
        IF(J) 999,200,201
201     IF(J-1)200,108,120
108     WRITE(1,59)
  59    FORMAT (1H1)
120      DT=TE-TS
         IF (DT-60.) 130,121,121
121       DT=DT-40.
130      IF (L-1) 999,131,14
131       IF (JAY-10) 135,133,133
133        WRITE (1,56) JAY,TS,TE
 56        FORMAT (///6H APRIL,I3,6H, 1967,10X,5HSTART,F6.0,10X,4HSTOP,F6.0)
           GO TO 140
135        WRITE (1,57) JAY,TS,TE
 57        FORMAT (///4H MAY,I3,6H, 1967,12X,5HSTART,F6.0,10X,4HSTOP,F6.0)
140     WRITE (1,55) J
 55     FORMAT(1H0,30X,5HTOWER,I5)
        DO 2 I=1,9
         C=A(J,I)*B(I)/DT
   2     D(I)=2.518*C-.000198*C*C+13.93
 530    FORMAT (11H0HEIGHT(CM), 6X,9F10.2)
         WRITE (1,530) (Z(J,I),I=1,9)
 54     FORMAT (14H WIND VELOCITY,3X,9F10.2)
        WRITE (1,54) (D(I),I=1,9)
       L2=1
       L3=TS
       L4=TE
599    FORMAT(2I2,I3,2I5,9F7.2)
       PUNCH 599,J,L2,JAY,L3,L4,(D(I),I=1,9)
       DO=10.
       DN=5.
       T=.01
       SV=0.0
```

```
      S2V=0.0
      K=0
      DO 600I=1,9
      SV=SV+D(I)
600   S2V=S2V+D(I)**2
      S=0.
      DM=D0
601   SX=0.
      S2X=0.
      SVX=0.
      SB=0.
      SVB=0.
      SXB=0.
      DO 602 I=1,9
      Y=Z(J,I)+DM
      IF(Y) 611,611,610
611   WRITE(1,561) K
561   FORMAT(1H0,10HERROR AT    ,I4,39HTH ITERATION. TRY OTHER INITIAL GUE
     1SSES)
      GO TO 4
610   X=LOGF(Y)
612   SX=SX+X
      S2X=S2X+X**2
      SVX=SVX+X*D(I)
      B=1./Y
      SB=SB+B
      SVB=SVB+B*D(I)
602   SXB=SXB+X*B
      G=(SVX-SV*SX/9.)*(SXB-SX*SB/9.)-(S2X-SX**2/9.)*(SVB-SV*SB/9.)
      IF(S) 603,604,603
604   S=1.
      G0=G
607   DM=DN
      GO TO 601
603   GN=G
      K=K+1
      DP=(D0*GN-G0*DN)/(GN-G0)
      IF(ABSF(DP-DN)-T)605,605,606
606   D0=DN
      G0=GN
      DN=DP
      DM=DN
      IF(K-100) 601,605,605
605   VST=(SVX-SV*SX/9.)/(S2X-SX**2/9.)
      ZNT=EXPF((SX-SV/VST)/9.)
      R2=(S2V-SV**2/9.)-VST*((2.*SVX-VST*S2X)-SX*(2.*SV-VST*SX)/9.)
562   FORMAT(1H0,I4,12HTH ITERATION,9H  V STAR=,E15.6,4H  D=,E15.6,9H  Z
     1 ZERO=,E15.6,17H  SUM OF SQUARES=,E15.6)
      VST=VST*0.428
       WRITE(1,562) K,VST,DP,ZNT,R2
        WRITE (1,530) (Z(J,I),I=1,9)
      DO 410 I=1,9
      V(I)=VST/0.428*LOGF((Z(J,I)+DP)/ZNT)
      VD(I)=V(I)-D(I)
410   VR(I)=V(I)/D(I)
540   FORMAT(17H SMOOTH VELOCITY  ,9F10.2)
      WRITE(1,540) (V(I),I=1,9)
541   FORMAT(17H VELOCITY DIFF     ,9F10.2)
      WRITE(1,541) (VD(I),I=1,9)
542   FORMAT(17H VELOCITY RATIO    ,9F10.4)
      WRITE(1,542) (VR(I),I=1,9)
```

```
C       COMPUTE DEACON NO FOR WIND PROFILE
        DO 831 I=1,8
831     ZZ(J,I)=SQRTF((Z(J,I)+DP)*(Z(J,I+1)+DP))
        DO 832 I=1,7
832     ZZZ(J,I)=SQRTF(ZZ(J,I)*ZZ(J,I+1))
        DO 8 I=1,7
        S=(D(I+1)-D(I))/(D(I+2)-D(I+1))
        IF(S)81,81,82
81      DEU(I)=0.0
        GO TO 8
82      DEU(I)=LOGF(S)/LOGF(ZZ(J,I+1)/ZZ(J,I))
8       CONTINUE
520     FORMAT(1H0,6HHEIGHT,10X,7F10.1)
        WRITE(1,520) (ZZZ(J,I),I=1,7)
521     FORMAT(1H ,10HDEACON NO.,6X,7F10.3)
        WRITE(1,521) (DEU(I),I=1,7)
      4 CONTINUE
        GO TO 100
C..GRAPHS..D(I) VS ZL(J,I)
C               VST(I) VS ZZ(J,I)
C               ZO(I) VS ZZ(J,I)
C               DEU(I) VS ZZZ(J,I)
C
999     END FILE 1
        END OF HOT AIR
        END
             FINIS
*EXECUTE
 1   .937   .998 1.001 1.007   .976 1.026 1.025 1.022 1.004          APRIL
 1   18.7   38.7   79.3 119.3 159.8 200.5 240.9 280.5 320.8
 2 1.005   .994   .989   .999   .997 1.034 1.013 1.028   .988        APRI
 2   20.8   40.9   80.9 122.2 162.2 201.9 244.3 283.6 322.4
 3   .966 1.000   .997 1.004   .999 1.003 1.002 1.006   .996         APRI
 3   19.1   38.9   79.1 119.1 159.4 199.0 239.6 280.3 319.8
```

APPENDIX B

Fortran program for processing the air temperature, moisture and wind direction profile data and the heat flux data for Mast 1.

```
*CODP,2102,3275/STEARNS,I/HD270/HD1,30,99999/9999,        ,
*PLEASE MOUNT TAPE MAST I-OUTPUT 1/2 THEN2/2 IF NECESSARY AS LUN 1.
*FTN,L,P,F.
      PROGRAM  AIR T 1
C     TOWER 1 TEMPERATURE, MOISTURE, RADIATION, WIND DIRECTION         STEA
      DIMENSION A(48),B(48),T(10),TW(9),Z(9),ZZ(8),ZZZ(7),W(5),WD(5),ES(
     1 9),E(9),SP(9),RR(8),TM(10),TMV(10),WW(5),WWV(5),SPM(9),SPMV(9)
      DIMENSION DET(7),DEH(7),ZL(9),ZW(5),ID(6),DT(8),DQ(8),IT(100)
      DIMENSION EO(6),QO(6),EOSV(6),QOSV(6),EOS(6),QOS(6)
      Z(1)=18.7
      Z(2)=38.7
      Z(3)=79.3
      Z(4)=119.3
      Z(5)=159.8
      Z(6)=200.5
      Z(7)=240.9
      Z(8)=280.5
      Z(9)=320.8
      DO 116 J=1,8
  116 ZZ(J)=SQRTF(Z(J)*Z(J+1))
      ZZ(3)=SQRTF(Z(5)*Z(3))
      ZZ(4)=SQRTF(Z(7)*Z(4))
      ZZ(5)=SQRTF(Z(9)*Z(5))
  105 READ(2,51) L1,L2,L3,L4,L5,L6
      IF(L3-4) 105,106,105
  106 L4=L4*100+L5*10+L6
      IF(L4-0700) 105,107,107
  107 IF(L2-2)105,100,105
  100 P=0.0
      K=0
      DO 101 J=1,6
      EOS(J)=0.0
      EOSV(J)=0.
      QOSV(J)=0.
  101 QOS(J)=0.0
      DO 102 J=1,5
      WW(J)=0.0
  102 WWV(J)=0.0
      RSS=0.0
      SOS=0.0
      RUS=0.0
      DO 113 J=1,10
      TM(J)=0.0
  113 TMV(J)=0.0
      DO 114 J=1,9
      SPM(J)=0.0
  114 SPMV(J)=0.
51    FORMAT(2I1,2I2,2I1,24F3.3)
1     READ(2,51) L1,L2,L3,L4,L5,L6,(A(J),J=1,24)
      IF(L2-1)99,2,1
2     READ(2,51) M1,M2,M3,M4,M5,M6,(A(J),J=25,48)
      P=P+1.
      K=K+1
      M4=M4*100+M5*10+M6
      L4=L4*100+L5*10+L6
      IT(K)=M4
      IF(L1-M1)99,3,99
3     IF(M2-L2-1)99,4,99
4     IF(M3-L3)99,5,99
5     IF(M4-L4)99,6,99
C     COMPUTE MILLIVOLTS
```

```
6     REF1=(A(3)-A(1))*2.0
      REF2=(A(2)-A(4))*2.0
      DO 7 J=5,47,2
    7 B(J)=(A(J)-A(1))/REF1*.935
      DO 8 J=6,48,2
8     B(J)=(A(J)-A(4))/REF2*.935
      IF(L3-5) 600,604,600
600   IF(B(6)+.1)601,601,602
602   IF(L4-900)604,604,603
603   IF(L4-1800)601,601,604
601   T(1)=B(6)*25.+12.5*1.516
      GO TO 610
604   T(1)=B(6)*25.
610   IF(L3-5)609,614,609
609   IF(B(24)+.1)611,611,612
612   IF(L4-900)614,614,613
613   IF(L4-1800)611,614,614
611   T(10)=B(24)*25.+12.5*1.516
      GO TO 615
614   T(10)=B(24)*25.
615   IF(L3-25)1001,1002,1002
1001  T(2)=T(1)+B(8)* 5.
      T(3)=T(2)+B(10)*5.
      T(4)=T(3)+B(12)*5.
      T(5)=T(4)-B(14)*5.
      T(6)=T(5)+B(16)*5.
      T(7)=T(6)+B(18)*5.
      T(8)=T(7)+B(20)*5.
      T(9)=T(8)+B(22)*5.
      GO TO 1003
1002  T(2)=T(1)+(B(8)+B(32))*2.5
      T(3)=T(2)+(B(10)+B(34))*2.5
      T(4)=T(3)+(B(12)+B(36))*2.5
      T(5)=T(4)-(B(14)+B(38))*2.5
      T(6)=T(5)+(B(16)+B(40))*2.5
      T(7)=T(6)+(B(18)+B(42))*2.5
      T(8)=T(7)+(B(20)+B(44))*2.5
      T(9)=T(8)+(B(22)+B(46))*2.5
1003  DO 401 J=1,10
      TM(J)=TM(J)+T(J)
401   TMV(J)=TMV(J)+T(J)**2
      IF(L3-25) 801, 802, 802
566   FORMAT(6HOTOWERI4,25X,4HMAY I4,6H, 1967I6,5X,6HREF. 1F6.3,9H     REF
     1. 2F6.3)
801   WRITE(1,566) L1,L3,L4,REF1,REF2
      GO TO 803
802   WRITE(1,565) L1,L3,L4,REF1,REF2
803   WRITE(1,538) (Z(J),J=1,9),Z(9)
53    FORMAT(24H AIR TEMPERATURE (DEG C),12F8.3)
      DD=T(9)-T(10)
      DDT=T(9)-T(1)
      WRITE(1,53) (T(J),J=1,10),DD,DDT
565   FORMAT(6HOTOWERI4,25X,4HAPR.I4,6H, 1967I6,5X,6HREF. 1F6.3,9H     REF
     1. 2F6.3)
      IF(L3-25)13,13,14
13     RS=B(27)*3.35
      RO=-(B(5)+B(17)+B(29)+B(41))*3.42/4.
      SO=B(47)*2.0/3.0
      S=RO-SO
      RSS=RSS+RS
      ROS=ROS+RO
```

```
   61 W(1)=182.3+(B(31)+.033)/1.647*1000.
      W(1)=W(1)+0.23
      W(2)=182.3+(B(33)+.069)/1.634*1000.
      W(2)=W(2)+1.903
      W(3)=182.3+(B(35)+.054)/1.660*1000.
      W(3)=W(3)-1.147
      W(4)=182.5+(B(37)+.049)/1.647*1000.
      DAB=(((212.5-W(4))*(1.05/70.))-0.3)
      IF(DAB-0.3)56,56,58
   56 IF(DAB+1.75)57,57,59
   57 DAB=-1.75
      GO TO 59
   58 DAB=0.30
   59 W(4)=W(4)-DAB
      W(5)=182.5+(B(39)+.065)/1.634*1000.
      W(5)=W(5)-0.773
      ZW(1)=40.
      ZW(2)=80.
      ZW(3)=160.
      ZW(4)=240.
      ZW(5)=320.
      GO TO 69
60    IF(L3-2)62,62,67
62    IF(LA-1000)64,64,65
65    IF(LA-1500)66,66,67
   64 W(1)=182.3+(B(33)+.135)/3.154*1000.
      W(1)=W(1)+1.903
      W(2)=182.3+(B(35)+.108)/3.198*1000.
      W(2)=W(2)-1.147
      W(3)=182.3+(B(31)+.065)/3.154*1000.
      W(4)=182.3+(B(37)+.097)/3.176*1000.
      DAB=(((212.5-W(4))*(1.05/70.0))-0.3)
      IF(DAB-0.3)156,156,158
  156 IF(DAB+1.75)157,157,159
  157 DAB=-1.75
      GO TO 159
  158 DAB=0.3
  159 W(4)=W(4)-DAB
      W(5)=182.3+(B(39)+.131)/3.220*1000.
      W(5)=W(5)-0.773
      GO TO 68
   66 W(1)=275.5+(B(33)+.192)/3.154*1000.
      W(2)=275.5+(B(35)+.161)/3.432*1000.
      W(3)=275.5+(B(31)+.122)/3.371*1000.
      W(4)=275.5+(B(37)+.154)/3.412*1000.
      W(5)=275.5+(B(39)+.187)/3.412*1000.
      GO TO 68
   67 W(1)=275.5+(B(33)-.110)/3.154*1000.
      W(1)=W(1)+1.22
      W(2)=275.5+(B(35)-.141)/3.198*1000.
      W(2)=W(2)-0.25
      W(3)=275.5+(B(31)-.120)/3.154*1000.
      W(3)=W(3)+0.50
      W(4)=275.5+(B(37)-.149)/3.176*1000.
      IF(W(4)-165.0)201,205,205
  201 DAB=-1.00
      GO TO 210
  205 IF(W(4)-225.0)207,208,208
  208 DAB=0.8
      GO TO 210
  207 DAB=-0.4+(W(4)-165.0)*0.02
```

```
      SOS=SOS+SO
C     COMPUTE WET BULB TEMPERATURE
   12 ESO=LOGF(6.105)
      TW(1)=T(1)-B(7)*25.
      TW(2)=T(2)+B(9)*25.
      TW(3)=T(3)+B(11)*25.
      TW(4)=T(4)+B(13)*25.
      TW(5)=T(5)+(B(13)-B(19))*12.5
      TW(6)=T(6)-B(19)*25.
      TW(7)=T(7)+B(21)*25.
      TW(8)=T(8)-B(24)*25.
      TW(9)=T(9)+B(25)*25.
   54 FORMAT(21H WET BULB TEMPERATURE,3X,9F8.3)
      WRITE(1,54) (TW(J),J=1,9)
C     COMPUTE SPECIFIC HUMIDITY
      DO 18 I=1,9
      ES(I)=ESO+25.22*TW(I)/(TW(I)+273.)-5.31*LOGF((TW(I)+273.)/273.)
      ES(I)=EXPF(ES(I))
   17 E(I)=ES(I)-.00066*(1.+.00115*TW(I))*1000.*(T(I)-TW(I))
      SP(I)=0.622*E(I)
      SPM(I)=SPM(I)+SP(I)
   18 SPMV(I)=SPMV(I)+SP(I)**2
   57 FORMAT (18H SPECIFIC HUMIDITY,6X,9F8.3)
      WRITE(1,57) (SP(J),J=1,9)
C     COMPUTE BOWEN RATIO
      BR(1)=0.4*(T(2)-T(1))/(SP(2)-SP(1))
      BR(2)=0.4*(T(3)-T(2))/(SP(3)-SP(2))
      BR(3)=0.4*(T(5)-T(3))/(SP(5)-SP(3))
      BR(4)=0.4*(T(7)-T(4))/(SP(7)-SP(4))
      BR(5)=0.4*(T(9)-T(5))/(SP(9)-SP(5))
   78 FORMAT(12H BOWEN RATIO,12X,5F8.3)
      WRITE(1,98) (BR(I),I=1,5)
      X=0.0
      DO 212 J=1,5
      IF(BR(J))209,211,209
  209 IF(BR(J)+1.)213,211,213
  213 EO(J)=S/(1.+BR(J))
      QO(J)=S/(1.+1./BR(J))
      EOS(J)=EOS(J)+EO(J)
      QOS(J)=QOS(J)+QO(J)
      EOSV(J)=EOSV(J)+EO(J)**2
      QOSV(J)=QOSV(J)+QO(J)**2
      X=X+1.
      GO TO 212
  211 BR(J)=0.0
      EO(J)=0.0
      QO(J)=0.0
  212 CONTINUE
      EO(6)=EO(1)+EO(2)+EO(3)+EO(4)+EO(5)
      QO(6)=QO(1)+QO(2)+QO(3)+QO(4)+QO(5)
      EO(6)=EO(6)/X
      QO(6)=QO(6)/X
  548 FORMAT(19H SENSIBLE HEAT FLUX,5X,6F8.3)
      WRITE(1,548) (QO(J),J=1,6)
  549 FORMAT(17H LATENT HEAT FLUX,7X,6F8.3)
      WRITE(1,549) (EO(J),J=1,6)
  546 FORMAT(1H ,16HSOLAR RADIATION,F8.3,6X,13HNET RADIATION,F8.3,6X,14H
     1SOIL HEAT FLUX,F8.3,6X,25HLATENT PLUS SENSIBLE HEAT,F8.3)             545
      WRITE(1,546) RS,RO,SO,S
C     COMPUTE WIND DIRECTION-TOWER ONE
   16 IF(L3-25)60,60,61
```

```
210 W(4)=W(4)+DAR
    W(5)=275.5+(B(39)-.115)/3.220*1000.
    W(5)=W(5)-1.50
68  ZW(1)=50.
    ZW(2)=160.
    ZW(3)=200.
    ZW(4)=240.
    ZW(5)=320.
 69 WM=(W(1)+W(2)+W(3)+W(4)+W(5))/5.
    DO 403   J=1,5
    WD(J)=W(J)-WM
    WW(J)=WW(J)+W(J)
403 WWV(J)=WWV(J)+W(J)**2
58  FORMAT(24H WIND DIRECTION (DEG)    ,6F8.2)
    WRITE( 1,58) (W(I),I=1,5),WM
    IF(LG)300,301,300
300 IF(LA-9)1,305,1
303 IF(LS-3)305,304,305
305 WRITE (1,59)
59  FORMAT(1H1)
    GO TO 1
301 IF (LS)303,304,303
511 FORMAT(6H1TOWERI4,15X,4HMAY I4,6H, 1967,6H STARTI6,5H STOPI6,F8.0)
501 FORMAT(6H1TOWERI4,15X,4HAPR.I4,6H, 1967,6H STARTI6,5H STOPI6,F8.0)
304 IF(L3-25) 125,125,124
124 WRITE(1,501)L1,L3,IT(1),IT(K),P
    GO TO 126
125 WRITE(1,511)L1,L3,IT(1),IT(K),P
538 FORMAT(1H 510HHEIGHT(CM),13X,10F8.1)
126 WRITE(1,538) (Z(J),J=1,9),Z(9)
C   COMPUTE MEANS AND STANDARD DEVIATION FOR AIR TEMPERATURE
    DO 700 J=1,10
    TMV(J)=SQRTF((TMV(J)-TM(J)**2/P)/(P-1.))
700 TM(J)=TM(J)/P
    DD=TM(9)-TM(10)
    DDT=TM(9)-TM(1)
520 FORMAT(1H0,16HMEAN TEMPERATURE,7X,12F8.3)
    WRITE(1,520) (TM(J),J=1,10),DD,DDT
    PUNCH 59
    L2=2
    PUNCH599,L1,L2,L3,IT(1),IT(K),(TM(J),J=1,9)
521 FORMAT(1H ,18HSTANDARD DEVIATION,5X,10F8.3)
    WRITE(1,521) (TMV(J),J=1,10)
    IF(L3-25)131,133,133
131 RSS=RSS/P
    ROS=ROS/P
    SOS=SOS/P
    S=ROS-SOS
C   COMPUTE MEANS AND STANDARD DEVIATION FOR SPECIFIC HUMIDITY
    DO 710 J=1,9
    SPMV(J)=SQRTF((SPMV(J)-SPM(J)**2/P)/(P-1.))
710 SPM(J)=SPM(J)/P
    DDQ=SPM(9)-SPM(1)
530 FORMAT(1H0,13HMEAN HUMIDITY,10X,10F8.3)
    WRITE(1,530) (SPM(J),J=1,9),DDQ
    L2=3
    PUNCH599,L1,L2,L3,IT(1),IT(K),(SPM(J),J=1,9)
599 FORMAT(2I2,I3,2I5,9F7.3)
531 FORMAT(1H ,18HSTANDARD DEVIATION,5X,9F8.4)
    WRITE(1,531) (SPMV(J),J=1,9)
547 FORMAT(1H0,15HSOLAR RADIATION,F8.3,6X,13HNET RADIATION,F8.3,6X,14H
```

```
     1SOIL HEAT FLUX,F8.3,6X,25HLATENT PLUS SENSIBLE HEAT,F8.3)
      WRITE(1,547) RSS,ROS,SOS,S
C     COMPUTE BOWEN RATIO FROM MEANS
589   FORMAT(1H0,15HGEOM.HEIGHT(CM),14X,8F8.1)
      WRITE(1,589) (ZZ(J),J=1,5)
      DO 221 J=1,5
      EOSV(J)=SQRTF((EOSV(J)-EOS(J)**2/P)/(P-1.))
      QOSV(J)=SQRTF((QOSV(J)-QOS(J)**2/P)/(P-1.))
      QOS(J)=QOS(J)/P
221   EOS(J)=EOS(J)/P
      EOS(6)=(EOS(1)+EOS(2)+EOS(3)+EOS(4)+EOS(5))/5.
      QOS(6)=(QOS(1)+QOS(2)+QOS(3)+QOS(4)+QOS(5))/5.
      WRITE(1,551) (QOS(J),J=1,6)
      WRITE(1,552) (EOS(J),J=1,6)
      DT(1)=(TM(2)-TM(1))/( Z(2)-Z(1))
      DT(2)=(TM(3)-TM(2))/(Z(3)-Z(2))
      DT(3)=(TM(5)-TM(3))/(Z(5)-Z(3))
      DT(4)=(TM(7)-TM(4))/(Z(7)-Z(4))
      DT(5)=(TM(9)-TM(5))/(Z(9)-Z(5))
      DQ(1)=(SPM(2)-SPM(1))/(Z(2)-Z(1))
      DQ(2)=(SPM(3)-SPM(2))/(Z(3)-Z(2))
      DQ(3)=(SPM(5)-SPM(3))/(Z(5)-Z(3))
      DQ(4)=(SPM(7)-SPM(4))/(Z(7)-Z(4))
      DQ(5)=(SPM(9)-SPM(5))/(Z(9)-Z(5))
      QOM=0.0
      EOM=0.0
      X=0.0
      DO 733 J=1,5
      BR(J)=0.4*DT(J)/DQ(J)
      IF(BR(J)) 732,731,73
732   IF(BR(J)+1.)730,731,730
731   EO(J)=0.0
      QO(J)=0.0
      GO TO 733
730   EO(J)=S/(1.+BR(J))
      QO(J)=S/(1.+1./BR(J))
      EOM=EOM+EO(J)
      QOM=QOM+QO(J)
      X=X+1.
733   CONTINUE
      QOM=QOM/X
      EOM=EOM/X
      WRITE(1,550) (BR(J),J=1,5)
550   FORMAT(1H ,21HBOWEN RATIO,18X,9F8.2)
551   FORMAT(1H ,18HSENSIBLE HEAT FLUX,11X,6F8.3)
      WRITE(1,551) (QO(J),J=1,5),QOM
552   FORMAT(1H ,16HLATENT HEAT FLUX,13X,6F8.3)
      WRITE(1,552) (EO(J),J=1,5),EOM
      L2=4
      PUNCH 599,L1,L2,L3,IT(1),IT(K),RSS,ROS,SOS,QOS(6),QOM,EOS(6),EOM
  153 DO 720 J=1,5
      WWV(J)=SQRTF((WWV(J)-WW(J)**2/P)/(P-1.))
720   WW(J)=WW(J)/P
543   FORMAT (1H010HHEIGHT(CM),20X,5F8.1)
      WRITE (1,543) (ZW(J),J=1,5)
      WM=(WW(1)+WW(2)+WW(3)+WW(4)+WW(5))/5.
540   FORMAT(1H ,14HWIND DIRECTION,16X,6F8.1)
      WRITE(1,540) (WW(J),J=1,5),WM
      L2=5
      PUNCH599,L1,L2,L3,IT(1),IT(K),(WW(J),J=1,5),WM
541   FORMAT(1H ,18HSTANDARD DEVIATION,12X,5F8.1)
```

```
61 W(1)=182.3+(B(31)+.033)/1.647*1000.
   W(1)=W(1)+0.23
   W(2)=182.3+(B(33)+.069)/1.634*1000.
   W(2)=W(2)+1.903
   W(3)=182.3+(B(35)+.054)/1.660*1000.
   W(3)=W(3)-1.147
   W(4)=182.5+(B(37)+.040)/1.647*1000.
   DAB=(((212.5-W(4))*(1.05/70.))-0.3)
   IF(DAB-0.3)56,56,58
56 IF(DAB+1.75)57,57,59
57 DAB=-1.75
   GO TO 59
58 DAB=0.30
59 W(4)=W(4)-DAB
   W(5)=182.5+(B(39)+.065)/1.634*1000.
   W(5)=W(5)-0.773
   ZW(1)=40.
   ZW(2)=80.
   ZW(3)=160.
   ZW(4)=240.
   ZW(5)=320.
   GO TO 69
60 IF(L3-2)62,62,67
62 IF(L4-1000)64,64,65
65 IF(L4-1500)66,66,67
64 W(1)=182.3+(B(33)+.135)/3.154*1000.
   W(1)=W(1)+1.903
   W(2)=182.3+(B(35)+.105)/3.198*1000.
   W(2)=W(2)-1.147
   W(3)=182.3+(B(31)+.065)/3.154*1000.
   W(4)=182.3+(B(37)+.097)/3.176*1000.
   DAB=(((212.5-W(4))*(1.05/70.0))-0.3)
   IF(DAB-0.3)156,156,158
156 IF(DAB+1.75)157,157,159
157 DAB=-1.75
   GO TO 159
158 DAB=0.3
159 W(4)=W(4)-DAB
   W(5)=182.3+(B(39)+.131)/3.220*1000.
   W(5)=W(5)-0.773
   GO TO 69
66 W(1)=275.5+(B(33)+.192)/3.154*1000.
   W(2)=275.5+(B(35)+.161)/3.432*1000.
   W(3)=275.5+(B(31)+.122)/3.371*1000.
   W(4)=275.5+(B(37)+.158)/3.412*1000.
   W(5)=275.5+(B(39)+.187)/3.412*1000.
   GO TO 68
67 W(1)=275.5+(B(33)-.110)/3.154*1000.
   W(1)=W(1)+1.22
   W(2)=275.5+(B(35)-.141)/3.198*1000.
   W(2)=W(2)-0.25
   W(3)=275.5+(B(31)-.180)/3.154*1000.
   W(3)=W(3)+0.50
   W(4)=275.5+(B(37)-.149)/3.176*1000.
   IF(W(4)-165.0)201,205,205
201 DAB=-1.00
   GO TO 210
205 IF(W(4)-225.0)207,208,208
208 DAB=0.8
   GO TO 210
```

```
      WRITE(1,541) (WWV(J),J=1,5)
      DO 721 J=1,5
  721 WW(J)=WW(J)-WM
  542 FORMAT(1H ,15HWIND DIFFERENCE,15X,5F8.1)
      WRITE(1,542) (WW(J),J=1,5)
      WRITE(1,99)
      GO TO 100
   99 END FILE 1
       STOP
      END
      END
         FINIS
*EXECUTE
```

APPENDIX C

Fortran program for processing the air temperature moisture and wind direction profile data on the heat flux data for Mast 2.

```
7COOP,2102,3275/STEARNS,I/HD2/O/HD1,30,09999/9999,
*PLEASE MOUNT TAPE MAST I-OUTPUT 1/2 THEN2/2 IF NECESSARY AS LUN 1.
*FTN,L,P,F.
      PROGRAM  AIR T 1
C     TOWER I TEMPERATURE, MOISTURE, RADIATION, WIND DIRECTION          STEA
      DIMENSION A(48),B(48),T(10),TW(9),Z(9),ZZ(8),ZZZ(7),W(5),WD(5),ES(
     1 9),E(9),SP(9),AR(8),TM(10),TMV(10),WW(5),WWV(5),SPM(9),SPMV(9)
      DIMENSION DET(7),DEH(7),ZL(9),ZW(5),ID(6),DT(8),DQ(8),IT(100)
      DIMENSION EO(6),QO(6),EOSV(6),QOSV(6),EOS(6),QOS(6)
      Z(1)=19.7
      Z(2)=38.7
      Z(3)=79.3
      Z(4)=119.3
      Z(5)=159.8
      Z(6)=200.5
      Z(7)=240.9
      Z(8)=280.5
      Z(9)=320.8
      DO 116 J=1,8
116   ZZ(J)=SQRTF(Z(J)*Z(J+1))
      ZZ(3)=SQRTF(Z(5)*Z(3))
      ZZ(4)=SQRTF(Z(7)*Z(4))
      ZZ(5)=SQRTF(Z(9)*Z(5))
105   READ(2,51) L1,L2,L3,L4,L5,L6
      IF(L3-4) 105,106,105
106   L4=L4*100+L5*10+L6
      IF(L4-0700) 105,107,107
107   IF(L2-2)105,100,105
100   P=0.0
      K=0
      DO 101 J=1,6
      EOS(J)=0.0
      EOSV(J)=0.
      QOSV(J)=0.
101   QOS(J)=0.0
      DO 102 J=1,5
      WW(J)=0.0
102   WWV(J)=0.0
      RSS=0.0
      SOS=0.0
      ROS=0.0
      DO 113 J=1,10
      TM(J)=0.0
113   TMV(J)=0.0
      DO 114 J=1,9
      SPM(J)=0.0
114   SPMV(J)=0.
51    FORMAT(2I1,2I2,2I1,24F3.3)
1     READ(2,51) L1,L2,L3,L4,L5,L6,(A(J),J=1,24)
      IF(L2-1)99,2,1
2     READ(2,51) M1,M2,M3,M4,M5,M6,(A(J),J=25,48)
      P=P+1.
      K=K+1
      M4=M4*100+M5*10+M6
      L4=L4*100+L5*10+L6
      IT(K)=M4
      IF(L1-M1)99,3,99
3     IF(M2-L2-1)99,4,99
4     IF(M3-L3)99,5,99
5     IF(M4-L4)99,6,99
C     COMPUTE MILLIVOLTS
```

```
    7 B(J)=(A(J)-A(1))/REF1*.935
      DO 8 J=5,48,2
 8    B(J)=(A(J)-A(4))/REF2*.935
      IF(L3-5) 600,604,600
600   IF(B(6)+.1)601,601,602
602   IF(L4-900)604,604,603
603   IF(L4-1800)601,601,604
601   T(1)=(B(6)+B(30))*12.5+12.5*1.508
      GO TO 610
604   T(1)=(B(6)+B(30))*12.5
610   IF(L3-5)609,614,609
609   IF(B(24)+.1)611,611,612
612   IF(L4-900)614,614,613
613   IF(L4-1800)611,614,614
611   T(10)=(B(24)+B(48))*12.5+12.5*1.508
      GO TO 615
614   T(10)=(B(24)+B(48))*12.5
615   T(2)=T(1)+(B(8)+B(32))*2.5
      T(3)=T(2)+(B(10)+B(34))*2.5
      T(4)=T(3)+(B(12)+B(36))*2.5
      T(5)=T(4)+(B(16)+B(40))*2.5
      T(6)=T(5)+(B(14)+B(38))*2.5
      T(7)=T(6)+(B(18)+B(42))*2.5
      T(8)=T(7)+(B(20)+B(44))*2.5
      T(9)=T(8)+(B(22)+B(46))*2.5
1003  DO 401 J=1,10
      TM(J)=TM(J)+T(J)
401   TMV(J)=TMV(J)+T(J)**2
      IF(L3-25) 801, 802, 802
566   FORMAT(6HOTOWERI4,25X,4HMAY I4,6H, 1967I6,5X,6HREF. 1F6.3,9H     REF
     1. 2F6.3)
801   WRITE(1,566) L1,L3,L4,REF1,REF2
      GO TO 803
802   WRITE(1,565) L1,L3,L4,REF1,REF2
803   WRITE(1,538) (Z(J),J=1,9),Z(9)
53    FORMAT(24H AIR TEMPERATURE (DEG C),12F8.3)
      DD=T(9)-T(10)
      DDT=T(9)-T(1)
      WRITE(1,53) (T(J),J=1,10),DD,DDT
565   FORMAT(6HOTOWERI4,25X,4HAPR.I4,6H, 1967I6,5X,6HREF. 1F6.3,9H     REF
     1. 2F6.3)
      IF(L3-25)13,13,14
13    RS=B(27)*2.64
      RO=(B(5)+B(17)-B(29)+B(41))*3.46/4.
      SO=(B(43)-B(45))/3.0
      S=RO-SO
      RSS=RSS+RS
      ROS=ROS+RO
      SOS=SOS+SO
C     COMPUTE WET BULB TEMPERATURE
   12 ESO=LOGF(6.105)
      TW(1)=T(1)-B(7)*25.
      TW(2)=T(2)-B(9)*25.
      TW(3)=T(3)+(B(13)-B(9))*12.5
      TW(4)=T(4)+B(13)*25.
      TW(5)=T(5)-B(15)*25.
      TW(6)=T(6)+B(19)*25.
      TW(7)=T(7)-B(21)*25.
      TW(8)=T(8)+(B(25)-B(21))*12.5
      TW(9)=T(9)+B(25)*25.
54    FORMAT(21H WET BULB TEMPERATURE,3X,9F8.3)
```

```
      WRITE(1,54) (TW(J),J=1,9)
C     COMPUTE SPECIFIC HUMIDITY
      DO 18 I=1,9
       ES(I)=ES0+25.22*TW(I)/(TW(I)+273.)-5.31*LOGF((TW(I)+273.)/273.)
      ES(I)=EXPF(ES(I))
17    E(I)=ES(I)-.00066*(1.+.00115*TW(I))*1000.*(T(I)-TW(I))
      SP(I)=0.622*E(I)
      SPM(I)=SPM(I)+SP(I)
   18 SPMV(I)=SPMV(I)+SP(I)**2
57    FORMAT (18H SPECIFIC HUMIDITY,6X,9F8.3)
      WRITE(1,57) (SP(J),J=1,9)
C      COMPUTE BOWEN RATIO
      BR(1)=0.4*(T(2)-T(1))/(SP(2)-SP(1))
      BR(2)=0.4*(T(3)-T(2))/(SP(3)-SP(2))
      BR(3)=0.4*(T(5)-T(3))/(SP(5)-SP(3))
      BR(4)=0.4*(T(7)-T(4))/(SP(7)-SP(4))
      BR(5)=0.4*(T(9)-T(5))/(SP(9)-SP(5))
58    FORMAT(12H BOWEN RATIO,12X,5F8.3)
      WRITE(1,58) (BR(I),I=1,5)
      X=0.0
      DO 212 J=1,5
      IF(BR(J))209,211,209
 209  IF(BR(J)+1.)213,211,213
213   EO(J)=S/(1.+BR(J))
      QO(J)=S/(1.+1./BR(J))
      EOS(J)=EOS(J)+EO(J)
      QOS(J)=QOS(J)+QO(J)
      EOSV(J)=EOSV(J)+EO(J)**2
      QOSV(J)=QOSV(J)+QO(J)**2
      X=X+1.
      GO TO 212
211   BR(J)=0.0
      EO(J)=0.0
      QO(J)=0.0
212   CONTINUE
      EO(6)=EO(1)+EO(2)+EO(3)+EO(4)+EO(5)
      QO(6)=QO(1)+QO(2)+QO(3)+QO(4)+QO(5)
      EO(6)=EO(6)/X
      QO(6)=QO(6)/X
548   FORMAT(19H SENSIBLE HEAT FLUX,5X,6F8.3)
      WRITE(1,548) (QO(J),J=1,6)
549   FORMAT(17H LATENT HEAT FLUX,7X,6F9.3) .
      WRITE(1,549) (EO(J),J=1,6)
544   FORMAT(1H ,16HSOLAR RADIATION,F8.3,6X,13HNET RADIATION,F8.3,6X,14H
     1SOIL HEAT FLUX,F8.3,6X,25HLATENT PLUS SENSIBLE HEAT,F8.3)         545
      WRITE(1,546) RS,RO,SO,S
C     COMPUTE WIND DIRECTION-TOWER ONE
14    IF(L3-25)60,60,61
   61 W(1)=(173.1-(B(31)-.044)/1.673*1000.)
      W(2)=(173.1-(B(33)-.043)/1.620*1000.)
      W(3)=(173.1-(B(35)+.098)/1.746*1000.)
      W(4)=(173.1-(B(37)-.038)/1.678*1000.)
      W(5)=(173.1-(B(39)-.034)/1.690*1000.)
C     CORRECTION FACTORS FOR TOWER TWO FOR PERIOD ONE WITH ABSOLUTE VALUES CO
      W(1)=W(1)-0.271     +0.3
       W(2)=W(2)-2.421    +0.3
      IF(W(3)-190.)270,265,265
  265 IF(W(3)-260.)266,266,271
  266 W(3)=W(3)-((260.-W(3))*3./70.)+3.0    +0.3
      GO TO 273
  270 W(3)=W(3)          +0.3
```

```
      GO TO 273
  271 W(3)=W(3)+3.0     +0.3
  273 CONTINUE
      W(4)=W(4)-1.350    +0.3
      IF(W(5)-200.)280,275,275
  275 IF(W(5)-250.)276,276,281
  276 W(5)=W(5)-((W(5)-200.)/20.)+3.5   +0.3
      GO TO 285
  280 W(5)=W(5)+3.5     +0.3
      GO TO 285
  281 W(5)=W(5)+1.0      +0.3
  285 CONTINUE
      ZW(1)=40.
      ZW(2)=80.
      ZW(3)=160.
      ZW(4)=240.
      ZW(5)=320.
      GO TO 69
60    IF(L3-2)62,62,67
62    IF(L4-1000)64,64,65
65    IF(L4-1500)66,66,67
   64 W(1)=(173.1-(B(33)-.070)/3.111*1000.)
      W(2)=(173.1-(B(35)+.177)/3.432*1000.)
      W(3)=(173.1-(B(31)-.084)/3.371*1000.)
      W(4)=(173.1-(B(37)-.073)/3.412*1000.)
      W(5)=(173.1-(B(39)-.064)/3.412*1000.)
C      CORRECTION FACTORS FOR PERIOD TWO ON TOWER TWO
      W(1)=W(1)-0.271     +0.3
      W(2)=W(2)-2.421    +0.3
      IF(W(3)-190.)170,165,165
  165 IF(W(3)-260.)166,166,171
  166 W(3)=W(3)-((260.-W(3))*3./70.)+3.0        +0.3
      GO TO 173
  170 W(3)=W(3)            +0.3
      GO TO 173
  171 W(3)=W(3)+3.0      +0.3
  173 CONTINUE
      W(4)=W(4)-1.350     +0.3
      IF(W(5)-200.)180,175,175
  175 IF(W(5)-250.)176,176,181
  176 W(5)=W(5)-((W(5)-200.)/20.)+3.5    + 0.3
      GO TO 185
  180 W(5)=W(5)+3.5       +0.3
      GO TO 185
  181 W(5)=W(5)+1.0   +0.3
  185 CONTINUE
      GO TO 68
   66 W(1)=(276.8-(B(33)-.132)/3.111*1000.)
      W(2)=(276.8-(B(35)+.108)/3.432*1000.)
      W(3)=(276.8-(B(31)-.154)/3.371*1000.)
      W(4)=(276.8-(B(37)-.142)/3.412*1000.)
      W(5)=(276.8-(B(39)-.133)/3.412*1000.)
      GO TO 68
   67 W(1)=(276.8-(B(33)+.147)/3.111*1000.)
      W(2)=(276.8-(B(35)+.410)/3.432*1000.)
      W(3)=(276.8-(B(31)+.148)/3.371*1000.)
      W(4)=(276.8-(B(37)+.160)/3.412*1000.)
      W(5)=(276.8-(B(39)+.169)/3.412*1000.)
C     CORRECTION FACTORS FOR PERIOD FOUR   FOR 80,200,240CM LEVELS
C     NO CORRECTIONS CAN BE SAFELY ASCERTAINED FOR 160 AND 320CM LEVELS
      W(1)=W(1)+4.329      -7.2
```

```
      W(2)=W(2)           -7.2
      W(3)=W(3)-0.833         -7.2
      W(4)=W(4)-2.477        -7.2
      W(5)=W(5)          -7.2
 68   ZW(1)=90.
      ZW(2)=160.
      ZW(3)=200.
      ZW(4)=240.
      ZW(5)=320.
   69 WM=(W(1)+W(2)+W(3)+W(4)+W(5))/5.
      DO 403    J=1,5
      WD(J)=W(J)-WM
      WW(J)=WW(J)+W(J)
 403  WWV(J)=WWV(J)+W(J)**2
 55   FORMAT(24H WIND DIRECTION (DEG)      ,6F8.2)
      WRITE( 1,55) (W(I),I=1,5),WM
      IF(L6)300,301,300
 300  IF(L6-5)1,305,1
 303  IF(L5-3)305,304,305
 305  WRITE (1,59)
 59   FORMAT(1H1)
      GO TO 1
 301  IF (L5)303,304,303
 519  FORMAT(6H1TOWERI4,15X,4HMAY I4,6H, 1967,6H STARTI6,5H STOPI6,F8.0)
 501  FORMAT(6H1TOWERI4,15X,4HAPR,I4,6H, 1967,6H STARTI6,5H STOPI6,F8.0)
 304  IF(L3-25) 125,125,124
 124  WRITE(1,501)L1,L3,IT(1),IT(K),P
      GO TO 126
 125  WRITE(1,519)L1,L3,IT(1),IT(K),P
 538  FORMAT(1H ,10HHEIGHT(CM),13X,10F8.1)
 126  WRITE(1,538) (Z(J),J=1,9),Z(9)
C     COMPUTE MEANS AND STANDARD DEVIATION FOR AIR TEMPERATURE
      DO 700 J=1,10
      TMV(J)=SQRTF((TMV(J)-TM(J)**2/P)/(P-1.))
 700  TM(J)=TM(J)/P
      DD=TM(9)-TM(10)
      DDT=TM(9)-TM(1)
 520  FORMAT(1H0,16HMEAN TEMPERATURE,7X,12F8.3)
      WRITE(1,520) (TM(J),J=1,10),DD,DDT
      PUNCH 59
      L2=2
      PUNCH599,L1,L2,L3,IT(1),IT(K),(TM(J),J=1,9)
 521  FORMAT(1H ,18HSTANDARD DEVIATION,5X,10F8.3)
      WRITE(1,521) (TMV(J),J=1,10)
      IF(L3-25)131,133,133
  131 RSS=RSS/P
      ROS=ROS/P
      SOS=SOS/P
      S=ROS-SOS
C     COMPUTE MEANS AND STANDARD DEVIATION FOR SPECIFIC HUMIDITY
      DO 710 J=1,9
      SPMV(J)=SQRTF((SPMV(J)-SPM(J)**2/P)/(P-1.))
 710  SPM(J)=SPM(J)/P
      DDQ=SPM(9)-SPM(1)
 530  FORMAT(1H0,13HMEAN HUMIDITY,10X,10F8.3)
      WRITE(1,530) (SPM(J),J=1,9),DDQ
      L2=3
      PUNCH599,L1,L2,L3,IT(1),IT(K),(SPM(J),J=1,9)
 599  FORMAT(2I2,I3,2I5,9F7.3)
 531  FORMAT(1H ,18HSTANDARD DEVIATION,5X,9F8.4)
      WRITE(1,531) (SPMV(J),J=1,9)
```

```
547   FORMAT(1H0,16HSOLAR RADIATION,F8.3,6X,13HNET RADIATION,F8.3,6X,14H
     1SOIL HEAT FLUX,F8.3,6X,25HLATENT PLUS SENSIBLE HEAT,F8.3)           5
      WRITE(1,547) RSS,ROS,SOS,S
C     COMPUTE BOWEN RATIO FROM MEANS
583   FORMAT(1H0,15HGEOM.HEIGHT(CM),14X,8F8.1)
      WRITE(1,583) (ZZ(J),J=1,5)
      DO 221 J=1,5
      EOSV(J)=SQRTF((EOSV(J)-EOS(J)**2/P)/(P-1.))
      QOSV(J)=SQRTF((QOSV(J)-QOS(J)**2/P)/(P-1.))
      QOS(J)=QOS(J)/P
221   EOS(J)=EOS(J)/P
      EOS(6)=(EOS(1)+EOS(2)+EOS(3)+EOS(4)+EOS(5))/5.
      QOS(6)=(QOS(1)+QOS(2)+QOS(3)+QOS(4)+QOS(5))/5.
      WRITE(1,551) (QOS(J),J=1,6)
      WRITE(1,552) (EOS(J),J=1,6)
      DT(1)=(TM(2)-TM(1))/( Z(2)-Z(1))
      DT(2)=(TM(3)-TM(2))/(Z(3)-Z(2))
      DT(3)=(TM(5)-TM(3))/(Z(5)-Z(3))
      DT(4)=(TM(7)-TM(4))/(Z(7)-Z(4))
      DT(5)=(TM(9)-TM(5))/(Z(9)-Z(5))
      DQ(1)=(SPM(2)-SPM(1))/(Z(2)-Z(1))
      DQ(2)=(SPM(3)-SPM(2))/(Z(3)-Z(2))
      DQ(3)=(SPM(5)-SPM(3))/(Z(5)-Z(3))
      DQ(4)=(SPM(7)-SPM(4))/(Z(7)-Z(4))
      DQ(5)=(SPM(9)-SPM(5))/(Z(9)-Z(5))
      QOM=0.0
      EOM=0.0
      X=0.0
      DO 733 J=1,5
      BR(J)=0.4*DT(J)/DQ(J)
      IF(BR(J)) 732,731,73
732   IF(BR(J)+1.)730,731,730
731   EO(J)=0.0
      QO(J)=0.0
      GO TO 733
730   EO(J)=S/(1.+BR(J))
      QO(J)=S/(1.+1./BR(J))
      EOM=EOM+EO(J)
      QOM=QOM+QO(J)
      X=X+1.
733   CONTINUE
      QOM=QOM/X
      EOM=EOM/X
      WRITE(1,550) (BR(J),J=1,5)
550   FORMAT(1H ,11HBOWEN RATIO,18X,9F8.2)
551   FORMAT(1H ,18HSENSIBLE HEAT FLUX,11X,6F8.3)
      WRITE(1,551) (QO(J),J=1,5),QOM
552   FORMAT(1H ,16HLATENT HEAT FLUX,13X,6F8.3)
      WRITE(1,552) (EO(J),J=1,5),EOM
      L2=4
      PUNCH 599,L1,L2,L3,IT(1),IT(K),RSS,ROS,SOS,QOS(6),QOM,EOS(6),EOM
133   DO 720 J=1,5
      WWV(J)=SQRTF((WWV(J)-WW(J)**2/P)/(P-1.))
720   WW(J)=WW(J)/P
543   FORMAT (1H010HHEIGHT(CM),20X,5F8.1)
      WRITE (1,543) (ZW(J),J=1,5)
      WM=(WW(1)+WW(2)+WW(3)+WW(4)+WW(5))/5.
540   FORMAT(1H ,14HWIND DIRECTION,16X,6F8.1)
      WRITE(1,540) (WW(J),J=1,5),WM
      L2=5
      PUNCH599,L1,L2,L3,IT(1),IT(K),(WW(J),J=1,5),WM
```

```
541     FORMAT(1H ,19HSTANDARD DEVIATION,12X,5F8.1)
        WRITE(1,541) (WWV(J),J=1,5)
        DO 721 J=1,5
  721   WW(J)=WW(J)-WM
542     FORMAT(1H ,15HWIND DIFFERENCE,15X,5F8.1)
        WRITE(1,542) (WW(J),J=1,5)
        WRITE(1,59)
        GO TO 100
99      END FILE 1
         STOP
        END
        END
            FINIS
•EXECUTE
```

APPENDIX D

Fortran program for processing the air temperature, moisture and wind direction profile data and the heat flux data for Mast 3.

```
 COOP,2102,3275/STEARNS,1/HD2/0/HD1,50,99999/9999,
 PLEASE MOUNT TAPE MAST III-DATA AS LUN 2/
 PLEASE MOUNT TAPE MAST III-OUTPUT 1/4 THEN 2/4 THEN 3/4 THEN 4/4 IF NECESSAR
 AS LUN 1.
 FTN,L,P,F.
C       TOWER 3 TEMPERATURE, MOISTURE,RADIATION, SOIL HEAT FLUX,            STEA
        PROGRAM  AIR T 3
        DIMENSION A(48),B(48),T(10),TW(9),Z(9),ZZ(8),ZZZ(7),W(5),WD(5),ES(
       * 9),E(9),SP(5),BR(8),TM(10),TMV(10),WW(5),WWV(5),SPM(9),SPMV(9)
        DIMENSION DET(7),DEH(7),ZL(9),ZW(5),ID(6),DT(8),DQ(9),IT(100)
        DIMENSION EO(6),QO(6),EOSV(6),QOSV(6),EOS(6),QOS(6)
         Z(1)=19.7
        Z(2)=39.0
        Z(3)=79.1
        Z(4)=119.1
        Z(5)=159.4
        Z(6)=199.0
        Z(7)=239.6
        Z(8)=280.2
        Z(9)=319.8
        DO 116 J=1,8
  116   ZZ(J)=SQRTF(Z(J)*Z(J+1))
        ZZ(2)=SQRTF(Z(6)*Z(3))
        ZZ(4)=SQRTF(Z(7)*Z(4))
        ZZ(6)=SQRTF(Z(9)*Z(5))
  100 P=0.0
        K=0
        DO 101 J=1,6
        EOS(J)=0.0
        EOSV(J)=0.
        QOSV(J)=0.
  101   QOS(J)=0.0
        DO 102 J=1,5
        WW(J)=0.0
  102   WWV(J)=0.0
         RSS=0.0
        SOS=0.0
        ROS=0.0
        DO 113 J=1,10
        TM(J)=0.0
  113   TMV(J)=0.0
        DO 114 J=1,9
        SPM(J)=0.0
  114   SPMV(J)=0.
   51   FORMAT(2I1,2I2,2I1,24F3.3)
    1   READ(2,51) L1,L2,L3,L4,L5,L6,(A(J),J=1,24)
        IF(L2-1)99,2,1
    2   READ(2,51) M1,M2,M3,M4,M5,M6,(A(J),J=25,48)
        P=P+1.
        K=K+1
        M4=M4*100+M5*10+M6
        L4=L4*100+L5*10+L6
        IT(K)=M4
        IF(L1-M1)99,3,99
    3   IF(M2-L2-1)99,4,99
    4   IF(M3-L3)99,5,99
    5   IF(M4-L4)99,6,99
C       COMPUTE MILLIVOLTS
    6   REF1=(A(3)-A(1))*2.0
        REF2=(A(2)-A(4))*2.0
        DO 7 J=5,47,2
```

```
    7 B(J)=(A(J)-A(1))/REF1*.935
      DO 8 J=6,48,2
    8 B(J)=(A(J)-A(4))/REF2*.935
      IF(L3-5) 600,604,600
  600 IF(B(6)+.1)601,601,602
  602 IF(L4-900)604,604,603
  603 IF(L4-1800)601,601,604
  601 T(1)=(B(6)+B(30))*12.5+12.5*1.492
      GO TO 610
  604 T(1)=(B(6 +B(30))*12.5
  610 IF(L3-5)609,614,609
  609 IF(B(24)+. )611,611,612
  612 IF(L4-900)614,614,613
  613 IF(L4-1800)611,614,614
  611 T(10)=(B(24)-B(48))*12.5+12.5*1.492
      GO TO 615
  614 T(10)=(B(24) B(48))*12.5
  615 T(2)=T(1)+(B(8)+B(32))*2.5
      T(3)=T(2)+(B(10)+B(34))*2.5
      T(4)=T(3)+(B(12)+B(36))*2.5
      T(5)=T(4)+(B(14)+B(38))*2.5
      T(6)=T(5)+(B(16)+B(40))*2.5
      T(7)=T(6)+(B(18)+B(42))*2.5
      T(8)=T(7)+(B(20)+B(44))*2.5
      T(9)=T(8)+(B(12)+B(46))*2.5
 1003 DO 401 J=1,10
      TM(J)=TM(J)+T(J)
  401 TMV(J)=TMV(J)+T(J)**2
      IF(L3-25) 801, 802, 802
  565 FORMAT(6HOTOWER I4,25X,4HMAY I4,6H, 1967I6,5X,6HREF. 1F6.3,9H    REF
     1. 2F6.3)
  801 WRITE(1,566) L1,L3,L4,REF1,REF2
      GO TO 803
  802 WRITE(1,565) L1,L3,L4,REF1,REF2
  803 WRITE(1,539) (Z(J),J=1,9),Z(9).
   53 FORMAT(24H AIR TEMPERATURE (DEG C),12F8.3)
      DD=T(9)-T(10)
      DDT=T(9)-T(1)
      WRITE(1,53) (T(J),J=1,10),DD,DDT
  565 FORMAT(6HOTOWERI4,25X,4HAPR. I4,6H, 1967I6,5X,6HREF. 1F6.3,9H    REF
     1. 2F6.3)
      IF(L3-25)13,13,1.
   13 RS=B(37)*2.83
      RO=(B(5)+B(17)+B(29)+B(41))*4.89/4.0
      SO=(B(47)-B(45))*3.9
      S=RO-SO
      RSS=RSS+RS
      ROS=ROS+RO
      SOS=SOS+SO
C     COMPUTE WET BULB TEMPERATURE
   12 ES=LOGF(6.105)
      TW(1)=T(1)-B(7)*25.
      TW(2)=T(2)-B(9)*25.
      TW(3)=T(3)+B(11)*25.
      TW(4)=T(4)+B(13)*25.
      TW(5)=T(5)+B(15)*25.
      TW(6)=T(6)+B(19)*25.
      TW(7)=T(7)+B(21)*25.
      TW(8)=T(8)+(B(21)-B(25))*12.5
      TW(9)=T(9)+B(25)*25.
   54 FORMAT(21H WET BULB TEMPERATURE,3X,9F8.3)
```

```
      WRITE(1,54) (TW(J),J=1,9)
C     COMPUTE SPECIFIC HUMIDITY
      DO 18 I=1,9
       ES(I)=ESO+25.22*TW(I)/(TW(I)+273.)-5.31*LOGF((TW(I)+273.)/273.)
      ES(I)=EXPF(ES(I))
17    E(I)=ES(I)-.00066*(1.+.00115*TW(I))*1000.*(T(I)-TW(I))
      SP(I)=0.622*E(I)
      SPM(I)=SPM(I)+SP(I)
   18 SPMV(I)=SPMV(I)+SP(I)**2
57    FORMAT (18H SPECIFIC HUMIDITY,6X,9F8.3)
      WRITE(1,57) (SP(J),J=1,9)
C      COMPUTE BOWEN RATIO
      BR(1)=0.4*(T(2)-T(1))/(SP(2)-SP(1))
      BR(2)=0.4*(T(3)-T(2))/(SP(3)-SP(2))
      BR(3)=0.4*(T(5)-T(3))/(SP(5)-SP(3))
      BR(4)=0.4*(T(7)-T(4))/(SP(7)-SP(4))
      BR(5)=0.4*(T(9)-T(5))/(SP(9)-SP(5))
58    FORMAT(12H BOWEN RATIO,12X,5F8.3)
      WRITE(1,58) (BR(I),I=1,5)
      X=0.0
      DO 212 J=1,5
      IF(BR(J))209,211,209
 209  IF(BR(J)+1.)213,211,213
213   EO(J)=S/(1.+BR(J))
      QO(J)=S/(1.+1./BR(J))
      EOS(J)=EOS(J)+EO(J)
      QOS(J)=QOS(J)+QO(J)
      EOSV(J)=EOSV(J)+EO(J)**2
      QOSV(J)=QOSV(J)+QO(J)**2
      X=X+1.
      GO TO 212
211   EO(J)=0.0
      QO(J)=0.0
      BR(J)=0.0
212   CONTINUE
      EO(6)=EO(1)+EO(2)+EO(3)+EO(4)+EO(5)
      QO(6)=QO(1)+QO(2)+QO(3)+QO(4)+QO(5)
      EO(6)=EO(6)/X
      QO(6)=QO(6)/X
548   FORMAT(19H SENSIBLE.HEAT FLUX,5X,6F8.3)
      WRITE(1,548) (QO(J),J=1,6)
549   FORMAT(17H LATENT HEAT FLUX,7X,6F8.3)
      WRITE(1,549) (EO(J),J=1,6)
546   FORMAT(1H ,16HSOLAR RADIATION,F8.3,6X,13HNET RADIATION,F8.3,6X,14H
     1SOIL HEAT FLUX,F8.3,6X,25HLATENT PLUS SENSIBLE HEAT,F8.3)          5454
      WRITE(1,546) RS,RO,SO,S
C     COMPUTE WIND DIRECTION-TOWER ONE
16    IF(L3-25)60,60,61
   61 W(1)=(181.9+(B(31)+.036)/1.666*1000.)
      W(2)=(181.9+(B(33)+.046)/1.653*1000.)
      W(3)=(181.9+(B(35)+.041)/1.653*1000.)
      W(4)=(181.9+(B(37)+.045)/1.653*1000.)
      W(5)=(181.9+(B(39)+.059)/1.655*1000.)
C     CORRECTION CARDS FOR TOWER THREE FOR PERIOD ONE
      W(1)=W(1)+0.775             +4.7
      W(2)=W(2)-0.569             +4.7
      W(3)=W(3)+0.206             +4.7
      W(4)=W(4)-0.388             +4.7
      W(5)=W(5)+4.7
      ZW(1)=40.
      ZW(2)=80.
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      ZW(3)=160.
      ZW(4)=240.
      ZW(5)=320.
      GO TO 69
60    IF(L3-2)62,62,67
62    IF(L4-1000)64,64,65
65    IF(L4-1500)66,66,67
   64 W(1)=(181.9+(B(33)+.098)/3.258*1000.)
      W(2)=(181.9+(B(35)+.087)/3.234*1000.)
      W(3)=(181.9+(B(31)+.075)/3.258*1000.)
      W(4)=(181.9+(B(37)+.096)/3.283*1000.)
      W(5)=(181.9+(B(39)+.124)/3.258*1000.)
C     CORRECTION CARDS FOR TOWER THREE FOR PERIOD TWO
      W(1)=W(1)+0.775            +4.7
      W(2)=W(2)-0.569            +4.7
      W(3)=W(3)+0.206            +4.7
      W(4)=W(4)-0.388             +4.7
      W(5)=W(5)+4.7
       GO TO 68
   66 W(1)=(274.2+(B(33)+.092)/3.258*1000.)
      W(2)=(274.2+(B(35)+.072)/3.234*1000.)
      W(3)=(274.2+(B(31)+.060)/3.258*1000.)
      W(4)=(274.2+(B(37)+.080)/3.283*1000.)
      W(5)=(274.2+(B(39)+.108)/3.258*1000.)
      GO TO 68
   67 W(1)=(274.2+(B(33)-.195)/3.258*1000.)
      W(2)=(274.2+(B(35)-.205)/3.234*1000.)
      W(3)=(274.2+(B(31)-.217)/3.258*1000.)
      W(4)=(274.2+(B(37)-.197)/3.283*1000.)
      W(5)=(274.2+(B(39)-.169)/3.258*1000.)
C     CORRECTION CARDS FOR TOWER THREE FOR PERIOD FOUR
      W(1)=W(1)-1.122            -3.0
      W(2)=W(2)+0.528            -3.0
      W(3)=W(3)+0.434            -3.0
      W(4)=W(4)+0.279            -3.0
      W(5)=W(5)-0.116            -3.0
68    ZW(1)=80.
      ZW(2)=160.
      ZW(3)=200.
      ZW(4)=240.
      ZW(5)=320.
   69 WM=(W(1)+W(2)+W(3)+W(4)+W(5))/5.
      DO 403    J=1,5
      WD(J)=W(J)-WM
      WW(J)=WW(J)+W(J)
403   WWV(J)=WWV(J)+W(J)**2
55    FORMAT(24H WIND DIRECTION (DEG)     ,6F8.2)
      WRITE( 1,55) (W(I),I=1,5),WM
      IF(L6)300,301,300
300   IF(L6-5)1,305,1
303   IF(L5-3)305,304,305
305   WRITE (1,59)
59    FORMAT(1H1)
      GO TO 1
301   IF (L5)303,304,303
510   FORMAT(6H TOWERI4,15X,4HMAY I4,6H, 1967,6H STARTI6,5H STOPI6,F8.0)
50    FORMAT(6H TOWERI4,15X,4HAPR. I4,6H, 1967,6H STARTI6,5H STOPI6,F8.0)
304   IF(L3-25) 125,125,124
124   WRITE(1,510)L1,L3,IT(1),IT(K),P
      GO TO 126
125   WRITE(1,50)L1,L3,IT(1),IT(K),P
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538   FORMAT(1H ,10HHEIGHT(CM),13X,10F8.1)
126   WRITE(1,529)  (Z(J),J=1,9),Z(9)
C     COMPUTE MEANS AND STANDARD DEVIATION FOR AIR TEMPERATURE
      DO 700 J=1,10
      TMV(J)=SQRTF((TMV(J)-TM(J)**2/P)/(P-1.))
700   TM(J)=TM(J)/P
      DD=TM(9)-TM(10)
      DDT=TM(9)-TM(1)
520   FORMAT(1H0,16HMEAN TEMPERATURE,7X,12F8.3)
      WRITE(1,520)  (TM(J),J=1,10),DD,DDT
      PUNCH 59
      L2=2
      PUNCH599,L1,L2,L3,IT(1),IT(K),(TM(J),J=1,9)
521   FORMAT(1H ,18HSTANDARD DEVIATION,5X,10F8.3)
      WRITE(1,521)  (TMV(J),J=1,10)
      IF(L3-25)131,133,133
131   RSS=RSS/P
      ROS=ROS/P
      SOS=SOS/P
      S=ROS-SOS
C     COMPUTE MEANS AND STANDARD DEVIATION FOR SPECIFIC HUMIDITY
      DO 710 J=1,9
      SPMV(J)=SQRTF((SPMV(J)-SPM(J)**2/P)/(P-1.))
710   SPM(J)=SPM(J)/P
      DDQ=SPM(9)-SPM(1)
530   FORMAT(1H0,13HMEAN HUMIDITY,10X,10F8.3)
      WRITE(1,530)  (SPM(J),J=1,9),DDQ
      L2=3
      PUNCH599,L1,L2,L3,IT(1),IT(K),(SPM(J),J=1,9)
599   FORMAT(2I2,I3,2I5,9F7.3)
531   FORMAT(1H ,18HSTANDARD DEVIATION,5X,9F8.4)
      WRITE(1,531)  (SPMV(J),J=1,9)
547   FORMAT(1H0,14HSOLAR RADIATION,F8.3,6X,13HNET RADIATION,F8.3,6X,14H
     1SOIL HEAT FLUX,F8.3,6X,25HLATENT PLUS SENSIBLE HEAT,F8.3)          54
      WRITE(1,547) RSS,ROS,SOS,S
C     COMPUTE BOWEN RATIO FROM MEANS
583   FORMAT(1H0,15HGEOM.HEIGHT(CM),14X,8F8.1)
      WRITE(1,583)  (ZZ(J),J=1,5)
      DO 221 J=1,5
      EOSV(J)=SQRTF((EOSV(J)-EOS(J)**2/P)/(P-1.))
      QOSV(J)=SQRTF((QOSV(J)-QOS(J)**2/P)/(P-1.))
      QOS(J)=QOS(J)/P
221   EOS(J)=EOS(J)/P
      EOS(6)=(EOS(1)+EOS(2)+EOS(3)+EOS(4)+EOS(5))/5.
      QOS(6)=(QOS(1)+QOS(2)+QOS(3)+QOS(4)+QOS(5))/5.
      WRITE(1,551)  (QOS(J),J=1,6)
      WRITE(1,552)  (EOS(J),J=1,6)
      DT(1)=(TM(2)-TM(1))/( Z(2)-Z(1))
      DT(2)=(TM(3)-TM(2))/(Z(3)-Z(2))
      DT(3)=(TM(5)-TM(3))/(Z(5)-Z(3))
      DT(4)=(TM(7)-TM(4))/(Z(7)-Z(4))
      DT(5)=(TM(9)-TM(5))/(Z(9)-Z(5))
      DQ(1)=(SPM(2)-SPM(1))/(Z(2)-Z(1))
      DQ(2)=(SPM(3)-SPM(2))/(Z(3)-Z(2))
      DQ(3)=(SPM(5)-SPM(3))/(Z(5)-Z(3))
      DQ(4)=(SPM(7)-SPM(4))/(Z(7)-Z(4))
      DQ(5)=(SPM(9)-SPM(5))/(Z(9)-Z(5))
      QOM=0.0
      EOM=0.0
      X=0.0
      DO 733 J=1,5
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      BR(J)=0.4*DT(J)/DQ(J)
      IF(BR(J)) 732,731,73
      IF(BR(J)+1.)730,731,730
      FO(J)=0.0
      QO(J)=0.0
      GO TO 733
730   FO(J)=S/(1.+BR(J))
      QO(J)=S/(1.+1./BR(J))
      FOM=FOM+FO(J)
      QOM=QOM+QO(J)
      X=X+1.
733   CONTINUE
      QOM=QOM/X
      FOM=FOM/X
      WRITE(1,550) (BR(J),J=1,5)
550   FORMAT(1H ,11HBOWEN RATIO,18X,9F8.2)
551   FORMAT(1H ,18HSENSIBLE HEAT FLUX,11X,6F8.3)
      WRITE(1,551) (QO(J),J=1,5),QOM
552   FORMAT(1H ,16HLATENT HEAT FLUX,13X,6F8.3)
      WRITE(1,552) (EO(J),J=1,5),EOM
      L2=4
      PUNCH 899,L1,L2,L3,IT(1),IT(K),RSS,ROS,SOS,QOS(6),QOM,EOS(6),EOM
 133  DO 720 J=1,5
      WWV(J)=SQRTF((WWV(J)-WW(J)**2/P)/(P-1.))
720   WW(J)=WW(J)/P
 543  FORMAT (1H0)10HHEIGHT(CM),20X,5F8.1)
      WRITE (1,543) (ZW(J),J=1,5)
      WM=(WW(1)+WW(2)+WW(3)+WW(4)+WW(5))/5.
540   FORMAT(1H ,14HWIND DIRECTION,16X,6F8.1)
      WRITE(1,540) (WW(J),J=1,5),WM
      L2=5
      PUNCH899,L1,L2,L3,IT(1),IT(K),(WW(J),J=1,5),WM
541   FORMAT(1H ,18HSTANDARD DEVIATION,12X,5F8.1)
      WRITE(1,541) (WWV(J),J=1,5)
      DO 721 J=1,5
  721 WW(J)=WW(J)-WM
542   FORMAT(1H ,15HWIND DIFFERENCE,15X,5F8.1)
      WRITE(1,542) (WW(J),J=1,5)
      WRITE(1,59)
      GO TO 100
99    END FILE 1
       STOP
      END
      END
         FINIS
*EXECUTE
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