MEASUREMENTS OF EVAPOTRANSPIRATION, SURFACE-ENERGY FLUXES, WEATHER VARIABLES, AND WATER-TABLE DEPTHS IN THE CLOSED BASIN OF THE SAN LUIS VALLEY, ALAMOSA COUNTY, COLORADO, 1985-88

BY DAVID I. STANNARD AND HAROLD L. WEAVER

U.S. GEOLOGICAL SURVEY

Open-File Report 93-639

Denver, Colorado
1995

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
cubic meter (m^3)	35.31	cubic foot
gram (g)	0.03527	ounce
hectare (ha)	2.471	acre
Joule (J)	0.0009486	British thermal unit
kilopascal (kPa)	0.1450	pound per square inch
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
millimeter (mm)	0.03937	inch
square kilometer (km^2)	0.3861	square mile
square meter (m^2)	10.76	square foot

The following terms and abbreviations also are used in this report:

gram per cubic meter (g/m^3)
gram per square meter per second [$(g/m^2)/s$]
hertz (hz)
Joule per gram (J/g)
Joule per gram per degree Celsius [(J/g)/°C]
kilopascal per degree Celsius (kPa/°C)
megajoule per square meter per day [$(MJ/m^2)/d$]
meter per second (m/s)
millimeter per day (mm/d)
minute (min)
second (s)
Watt per square meter (W/m^2)

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5\ (°C) + 32.$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Measurements of Evapotranspiration, Surface-Energy Fluxes, Weather Variables, and Water-Table Depths in the Closed Basin of the San Luis Valley, Alamosa, County, Colorado, 1985-88

By David I. Stannard and Harold L. Weaver

Abstract

A study was conducted to investigate the dependence of wild-land evapotranspiration on environmental factors, and to develop micrometeorological methods for measurement of wild-land evapotranspiration. Micrometeorological measurements of evapotranspiration, net radiation, soil- heat flux, and sensible-heat flux were made at regular intervals during a 3-year period beginning in May 1985 and ending in May 1988 in the closed basin part of the San Luis Valley near Alamosa, Colorado. Evapotranspiration and sensible-heat flux were measured using the eddy-correlation and Bowen-ratio methods. Measurements were made at three sites that had different water-table depths. Continuous weather data were collected during the study period. In this report, flux totals for 24-hour periods, water-table depths, and daily weather summaries are presented. An error analysis indicates that there probably is no significant bias in the measurements of evapotranspiration.

INTRODUCTION

Under provisions of the Rio Grande Compact of 1939, Colorado is required to supply prescribed amounts of water to New Mexico as flow in the Rio Grande each year. The Compact allows debts or credits to accumulate temporarily, to accommodate natural variations in the river flows. During the period 1949 - 1962, Colorado incurred a large water debt to New Mexico. Public Law 92-514, enacted in 1972, authorized the creation of a well field and canal system to pump ground water from a closed basin near Alamosa, Colo., into the Rio Grande. The purpose of the well field was to repay the debt to New Mexico, supply water for recreation and wildlife in the Alamosa area, and help avoid incurring future debts. Water that normally might leave the closed basin by evapotranspiration presumably could be salvaged by lowering the water table, thereby reducing annual evapotranspiration.

In the early 1980's, the U.S. Geological Survey became interested in making micrometeorological measurements of evapotranspiration before and after pumping began in the closed basin. Two goals were to test measurement methods at a relatively flat, extensive, homogeneous site, and to determine the dependence of evapotranspiration on environmental factors. Of particular interest was the dependence of evapotranspiration on a declining water table.

During 1985 and 1986, as the closed-basin project administered by the Bureau of Reclamation was nearing completion, unusually great precipitation caused high flows in the Rio Grande. The water debt to New Mexico was repaid in 1986, eliminating the need for full-scale operation of the well field. Data collection began at a single site (site 1) in the closed basin in May 1985 to obtain measurements of evapotranspiration under predevelopment conditions. In early 1986, when it was decided not to operate the well field at full capacity, two additional sites (sites 2 and 3) with deeper water tables were established. Although naturally deeper water tables were not necessarily comparable to a declining water table, useful information could be obtained from the additional sites.

Purpose and Scope

The purpose of this report is to provide values of evapotranspiration and the environmental variables commonly used to model evapotranspiration. The report presents daily totals of evapotranspiration and surface-energy fluxes, and water-table depths at three sites in the closed basin for selected days between May 1985 and May 1988. The energy-flux and evapotranspiration data were collected by using the eddy-correlation and Bowen-ratio methods. Weather data were collected continuously during the study period, and daily totals of solar radiation and precipitation and daily mean values of air temperature, vapor pressure, and windspeed are presented.

Site Descriptions

The San Luis Valley is a semiarid, high altitude (about 2300 m) rift between the Sangre de Cristo and San Juan mountain ranges in southern Colorado (fig. 1). The relatively flat valley floor is about 145 km long (north to south) and varies between about 30 km and 80 km in width. Soils are sandy. The valley floor is used for irrigated agriculture and for grazing livestock on wild-land vegetation.

About 7600 km^2 of the valley and surrounding mountains north of Alamosa form the closed basin (fig. 1). The floor of the closed basin is used primarily for grazing livestock in the east and irrigated agriculture in the west.

The three study sites are located in the southeast corner of the closed basin, east-northeast of Alamosa, well within the area used for grazing. All three sites are relatively homogenous on a large scale. For example, the vegetation and soil surface are similar from one square kilometer to the next. On a much smaller scale, however, the sites are heterogeneous. For example, one 10-m^2 area is dominated by vegetation, and an adjacent 10-m^2 area is bare soil.

Site 1 was in the NW1/4 SE1/4 sec. 30, T. 38 N., R. 12 E., about 15.7 km east-northeast of Alamosa (fig. 1). The predominant vegetation was greasewood (*Sarcobatus vermiculitus*), rabbitbrush (*Chrysothamnus nauseosus*), and saltgrass (*Distichlis stricta*). The greasewood and rabbitbrush tended to grow on hummocks, which rose as much as 1 m above the surrounding flats. The flats tended to be dominated by saltgrass. The sand comprising the hummocks generally was dry and loose, whereas the surface of the flats was slightly cemented and more moist. During times of little or no precipitation, salt crust formed on much of the flats. On average, the hummocks and flats were about equal in area. Site 1 had the shallowest water table, ranging from about 0.6 m to 1.5 m below mean land surface during the study period. For this report, mean land surface at site 1 is arbitrarily defined to be at an altitude 0.3-m above the salt flat at the site and is discussed further in the section on Water-Table Measurements.

Site 2 was in the NE1/4 NW1/4 sec. 4, T. 37 N., R. 12 E., about 3.7 km southeast of site 1 (fig. 1). The vegetation consisted of the same species as were present at Site 1, but it was sparser. The relief was comparable to that at Site 1, but the low flats were never noticeably salt encrusted. At times, the water table beneath site 2 was affected by a cone-of-depression created by one of the well-field production wells, Salvage Well 3. Water- level measurements ranged from about 3.5 m to 4.2 m below mean land surface during the study period. For this report, mean land surface at site 2 is arbitrarily defined to be at the altitude of the land surface at the piezometer labeled 200-W1. This piezometer was 61.0 m (200 ft) west of Salvage Well 3 and is described further in the section on Water-Table Measurements.

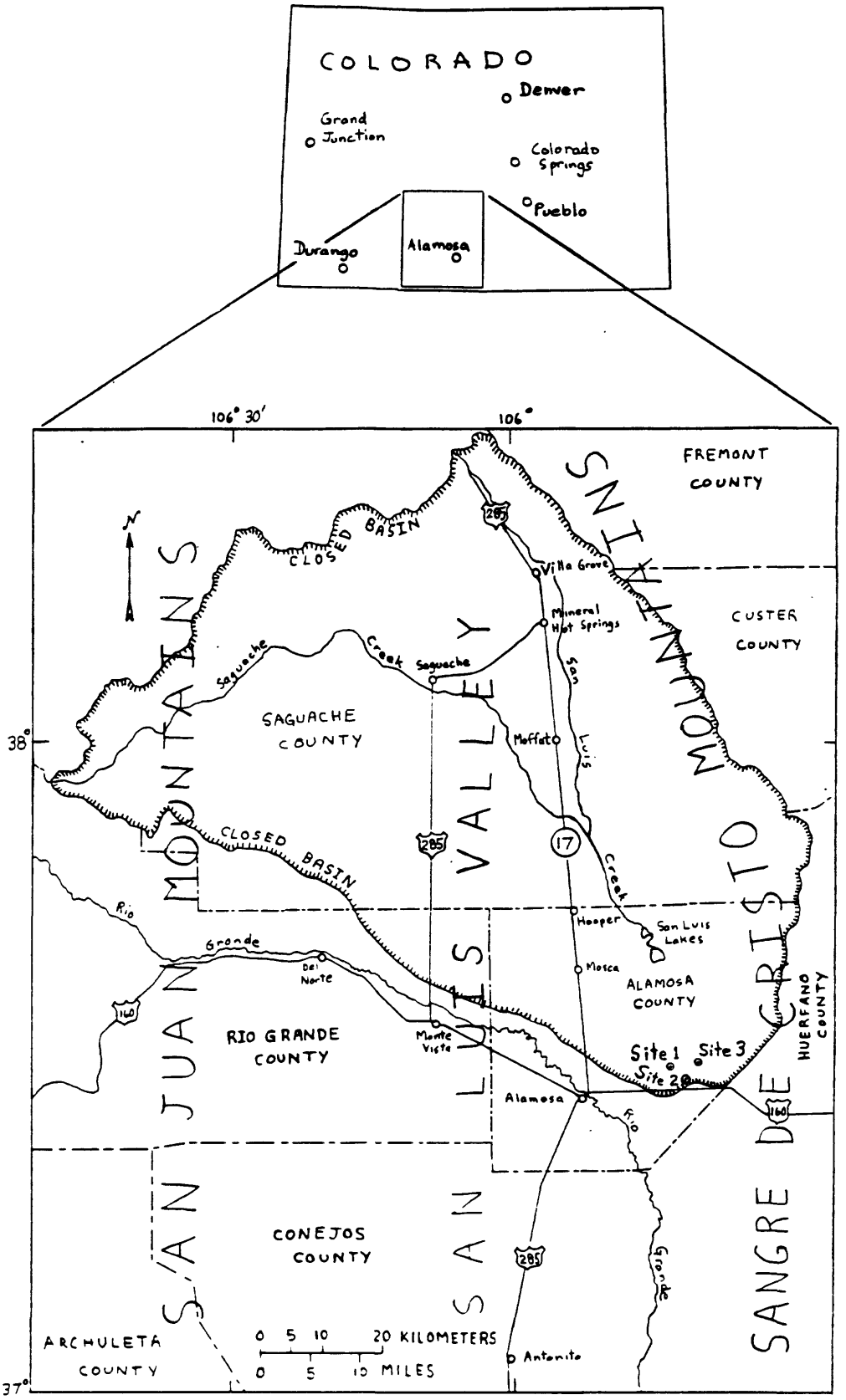

Figure 1.--Location of San Luis Valley, closed basin, and study areas

Site 3 was in the NW1/4 NE1/4 sec. 27, T. 38 N., R. 12 E., about 4.8 km east of site 1 (fig. 1). The predominant vegetation in decreasing order of density at site 3 was saltgrass, rabbitbrush, greasewood, prickly pear (*Opuntia polyacantha*), and blue grama grass (*Bouteloua gracilis*). The vegetation was more sparse than at sites 1 or 2, probably partly because the site was frequently grazed by horses. The soil was loose sand, with no salt flats, and the surface had much less relief than the other two sites. The water table ranged from about 4.4 m to 5.6 m below mean land surface during the study period. For this report, mean land surface at site 3 is arbitrarily defined to be at the altitude of the land surface at the piezometer labeled Observation Well 377. This piezometer was about 20 m northeast of the micrometeorological sensors and is described further in the section on Water-Table Measurements.

DATA COLLECTION METHODS

To simplify the writing of this report (and to be consistent with common micrometeorological usage) calculated flux values are also referred to as flux measurements, although fluxes were not measured directly in the field. The micrometeorological methods of eddy-correlation and Bowen ratio were used to measure sensible- and latent-heat fluxes. Thermopile devices were used to measure net radiation and soil-heat flux. Weather measurements were made with an automated weather station, and water-table depths were measured manually with a steel tape.

Flux Measurements

Evaporation of water requires energy, known as the latent heat of vaporization of water, L:

$$L = 2{,}500.25 - 2.365\ T \tag{1}$$

where L is in J/g, and T is temperature at the evaporation site, in °C (Fritschen and Gay, 1979, p. 130). The energy balance of a vegetated surface can be written:

$$R - G = H + LE \tag{2}$$

where R is net radiation in W/m^2, G is soil-heat flux in W/m^2, H is sensible-heat flux in W/m^2, and E is the evapotranspiration rate in $(g/m^2)/s$ (Campbell, 1977, p. 136). The product LE is known as the latent-heat flux (expressed in W/m^2).

The Bowen-ratio method (BR) uses a rearranged form of the energy- balance equation (eq. 2) to calculate LE as:

$$LE = \frac{R - G}{1 + \beta} \tag{3}$$

where β is the Bowen ratio, or the ratio of H to LE. H is then calculated from the energy-balance equation (eq. 2) directly. Assuming equality between the eddy diffusivities for heat and water-vapor transport just above the plant canopy, β can be measured as (Tanner, 1960):

$$\beta = \frac{\gamma\, \Delta T}{\Delta e} \tag{4}$$

where γ is the psychrometric constant in kPa/°C, ΔT is the time-averaged difference in air temperature between two heights above the plant canopy in °C, and Δe is the time-averaged difference in vapor pressure between the same two heights, in kPa.

The Bowen-ratio method was used to calculate LE and H at the closed basin. R was measured with a net radiometer that was deployed about 1.7 m above the land surface. The device measured the algebraic sum of all incoming and outgoing shortwave and longwave radiation. Prior to May 1986, Micromet Systems Inc. (no model designation) net radiometers were used. From May 1986 until the end of the study, Swissteco, Inc., model S-1 net radiometers were used.

Because the outgoing fluxes of shortwave and longwave radiation from vegetation typically are different than from bare soil, the output from a net radiometer deployed above a sparsely vegetated surface depends on the horizontal location of the net radiometer. For satisfactory results, the net radiometer should be deployed where it will be affected by the different surfaces in the same proportion as they occur at the site. In this study, the selection of a net-radiometer location was made visually. Therefore errors may have occurred in the net-radiation measurement that were caused by the sensor location.

Soil-heat flux, G, was measured with Peltier-cooler soil-heat-flux plates (Weaver and Campbell, 1985) buried 10 mm below the soil surface, or, toward the end of the study, with soil-heat-flux plates buried 50 mm below the soil surface, combined with thermocouples buried above the plates to measure the change in heat stored in the soil above the plates. In the first method, the change in heat stored in the 10 mm of soil above the plates was not measured, and the heat flux measured by the plates was assumed to be equal to that at the surface. In the second method, the change in heat stored in the 50 mm of soil above the plates was added to the heat flux measured by the plates to obtain the heat flux at the soil surface.

As with the net-radiometer output, the output from soil-heat-flux sensors depends on the horizontal location of the sensors--specifically whether the sensors are buried beneath soil that is shaded or sunlit. For satisfactory results in a sparse canopy, the mean output from multiple sensors is used. In this study, either three or four sensor locations were selected visually, such that the mean output approximated the average soil heating conditions at the site. Because the locations were selected visually, errors may have occurred in the soil-heat-flux measurements that were caused by sensor location.

Temperature and vapor-pressure gradients, ΔT and Δe, were measured using a psychrometer interchange mechanism (Stannard, 1985). Data from two wet-bulb, dry-bulb psychrometers, separated by 1 m in height, were sampled every 2 seconds and the psychrometers were physically interchanged every 5 minutes to remove bias between sensors. Δe was calculated using the Lowe (1977) equation and the standard psychrometric formula (Fritschen and Gay, 1979, p. 133). Corrections to β were made for density effects (Webb and others, 1980). At times near sunrise and sunset, and occasionally during the night, the value of β approaches -1. At these times, small measurement errors in ΔT, Δe, R, or G may cause large errors in the calculated values of H and LE (equations 2 and 3). Because the true values of H and LE are known to be near zero at these times (Tanner, 1960), an alternative method typically is used to calculate H and LE when β approaches -1. In this study, when $-1.3 \leq \beta \leq -0.7$, LE was set equal to zero, and H was still calculated from equation 2.

The eddy-correlation method (EC) uses rapid measurements of vapor density, ρ_v (g/m^3), and vertical windspeed, w (m/s), to calculate the evapotranspiration rate E directly:

$$E = \overline{w'\rho_v'} \tag{5}$$

where prime denotes deviation from mean values and $\overline{w'\rho_v'}$ is the covariance of w with ρ_v (Swinbank, 1951).

Campbell Scientific hygrometers and model A-27T one-dimensional sonic anemometers were used to measure ρ_v

and w at 10 hz. Lyman-alpha hygrometers (no model designation) were used until July 1987, and model KH-20 Krypton hygrometers were used thereafter. Corrections to E were made for density effects (Webb and others, 1980) and for sensitivity of the KH-20 hygrometers to oxygen fluctuations (Tanner and Greene, 1989). The sonic anemometer was equipped with a finewire thermocouple to measure air temperature deviations at 10 hz, and the sensible-heat flux, H, was calculated as:

$$H = \rho C_p \overline{w'T'} \tag{6}$$

where ρ is the air density in g/m^3, C_p is the specific heat of air at constant pressure in (J/g)/°C, and $\overline{w'T'}$ is the covariance of w with T (Swinbank, 1951). The covariances were calculated for 5-min averaging periods before 1987 and for 15-min averaging periods thereafter.

Measurements of R and G were made along with the eddy-correlation measurements so that the accuracy of the measurements could be evaluated by using equation 2. All flux measurements were averaged for 30-min periods, and were recorded on a digital data logger. Occasional short gaps in the eddy-correlation data caused by rain damage to the sonic anemometer or by instrument malfunctions were filled in by using linear interpolation. During 24-hr periods when a hygrometer malfunctioned, LE was computed by using equation 2. This method of calculating LE is referred to as the eddy- correlation energy-balance method (ECEB). During 24-hr periods when a sonic anemometer malfunctioned, H was computed by using the finewire-thermocouple data in a flux variance relation (Weaver, 1990), and LE was computed by using equation 2. This method of calculating LE is referred to as the temperature-variance energy-balance method (TVEB).

On average, the eddy-correlation and Bowen-ratio measurements were representative of about 1 ha of land surface, covering an elliptical area extending about 200 m upwind of the instruments. Flux measurements were made for a few days at a time, approximately once a month during the growing seasons of 1985-87, and less often during the winter. Flux sensors were removed between site visits. One final set of measurements was made in May 1988. Flux totals of R, G, H, LE, and E for selected 24-hr periods are presented in tables 1-3, along with the method used to calculate H or LE or both. Values of E are expressed in mm/d. Whenever possible, 24-hr periods beginning and ending at midnight are presented. However, equipment malfunction or other events often limited the beginning and ending times to other than midnight. Sometimes multiple, overlapping periods are presented for a site in order to coincide or approximately coincide with periods from another site or sites. Half-hourly values of the flux measurements are available upon request.

Table 1.--Flux totals at site 1, San Luis Valley, Colorado, 1985

[Hour, mountain standard time at beginning of 24-hour period (0000 is midnight at beginning of Julian day indicated); R, net radiation; G, soil-heat flux, H, sensible-heat flux, LE, latent-heat flux, E, evapotranspiration; $(MJ/m^2)/d$, megajoules per square meter per day; mm/d, millimeters per day; --, no data]

Julian day	Hour	R	G	Eddy correlation			Bowen ratio		
				H	LE	E	H	LE	E
		[$(MJ/m^2)/d$]				(mm/d)	[$(MJ/m^2)/d$]		(mm/d)
143	0000	11.99	2.09	6.31	2.91	1.18	6.05	3.85	1.56
176	0000	14.44	-0.18	4.92	4.82	1.96	7.72	6.90	2.81
177	0000	15.60	1.12	11.32	7.07	2.87	10.05	4.43	1.80
178	0000	15.80	1.67	9.09	4.62	1.89	10.09	4.04	1.64
204	0000	12.07	1.06	5.00	6.30	2.57	4.72	6.28	2.56
205	0000	12.74	1.78	5.10	5.56	2.27	5.51	5.45	2.22
206	0000	12.85	2.50	5.00	4.88	1.99	5.06	5.30	2.16
240	1100	9.77	0.82	5.78	3.99	1.63	--	--	--
240	2300	11.21	1.21	6.50	4.53	1.86	4.98	5.01	2.05
241	1100	11.36	1.52	6.27	4.74	1.94	--	--	--
274	0000	5.88	0.04	5.58	2.01	0.81	3.56	2.27	0.92
275	0000	2.53	-0.64	3.70	1.43	0.58	1.60	1.56	0.63
311	1200	3.42	-0.26	2.32	1.81	0.73	--	--	--

Table 2. Flux totals at sites 1, 2, and 3, San Luis Valley, Colorado, 1986

[Hour, mountain standard time at beginning of 24-hour period (0000 is midnight at beginning of Julian day indicated); R, net radiation; G, soil-heat flux; H, sensible-heat flux; LE, latent-heat flux; E, evapotranspiration; $(MJ/m^2)/d$, megajoules per square meter per day; mm/d, millimeters per day; EC, eddy correlation; BR, Bowen ratio; ECEB, H determined from EC and LE and E determined from energy balance; TVEB, H determined from temperature variance and LE and E determined from energy balance; --, no data]

	Site 1							Site 2							Site 3						
			R	G	H	LE	E			R	G	H	LE	E			R	G	H	LE	E
Julian day	Hour	Method	[(MJ/m²)/d]				(mm/d)	Hour	Method	[(MJ/m²)/d]				(mm/d)	Hour	Method	[(MJ/m²)/d]				(mm/d)
113	1700	EC	10.85	0.75	6.31	2.32	0.94	--	--	--	--	--	--	--	--	--	--	--	--	--	--
114	1000	BR	13.69	0.36	9.51	3.82	1.55	--	--	--	--	--	--	--	--	--	--	--	--	--	--
141	0000	EC	11.94	2.29	5.51	4.36	1.78	--	--	--	--	--	--	--	--	--	--	--	--	--	--
141	0000	BR	11.94	2.29	4.84	4.81	1.96	--	--	--	--	--	--	--	--	--	--	--	--	--	--
142	0000	EC	13.21	2.58	7.56	5.28	2.15	0000	EC	9.86	2.18	8.82	2.81	1.14	--	--	--	--	--	--	--
142	0000	BR	13.21	2.58	5.82	4.82	1.96	--	--	--	--	--	--	--	--	--	--	--	--	--	--
177	--	--	--	--	--	--	--	0000	TVEB	13.28	2.05	5.98	5.24	2.14	0000	TVEB	13.05	1.52	6.15	5.39	2.20
177	1030	BR	12.67	1.18	5.28	6.21	2.53	0900	TVEB	13.47	2.03	6.76	4.68	1.91	1130	EC	12.58	1.88	6.86	3.82	1.56
204	0000	BR	11.38	0.83	2.85	7.70	3.14	0000	EC	9.82	0.32	5.08	3.93	1.60	--	--	--	--	--	--	--
204	0930	BR	12.91	0.46	4.15	8.30	3.38	1000	EC	12.09	0.53	4.96	4.57	1.86	1000	EC	12.18	0.07	4.48	4.43	1.80
205	0000	BR	13.99	2.22	4.09	7.68	3.13	0000	EC	14.03	2.22	4.27	5.33	2.17	0000	EC	14.63	1.99	3.73	5.45	2.22
205	0930	BR	12.55	2.38	3.15	7.02	2.86	1000	EC	12.53	2.11	4.48	5.01	2.04	1000	EC	12.97	2.17	3.84	5.11	2.08
231	0000	BR	9.84	1.07	4.44	4.34	1.78	0000	EC	8.89	1.73	5.90	1.73	0.71	--	--	--	--	--	--	--
232	0000	BR	8.61	-0.16	5.10	3.68	1.50	0000	EC	8.49	-0.03	5.52	1.05	0.43	0000	ECEB	9.45	-0.05	6.49	3.02	1.23
233	0000	BR	11.51	-0.03	3.68	7.78	3.22	0000	EC	11.30	0.14	3.79	5.37	2.19	0000	ECEB	12.00	-0.01	4.92	7.10	2.90
260	0000	BR	7.66	1.28	3.87	2.51	1.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--
260	0600	BR	7.91	1.21	4.06	2.64	1.07	0730	EC	8.02	1.05	5.59	2.84	1.15	0900	EC	8.44	0.67	4.88	2.63	1.07
261	0000	BR	5.47	0.43	3.28	1.76	0.71	0000	EC	5.14	0.43	4.61	1.76	0.72	0000	EC	5.60	0.29	3.62	1.94	0.79

Table 2. Flux totals at sites 1, 2, and 3, San Luis Valley, Colorado, 1986--Continued

[Hour, mountain standard time at beginning of 24-hour period (0000 is midnight at beginning of Julian day indicated); R, net radiation; G, soil-heat flux; H, sensible-heat flux; LE, latent-heat flux; E, evapotranspiration; (MJ/m^2)/d, megajoules per square meter per day; mm/d, millimeters per day; EC, eddy correlation; BR, Bowen ratio; ECEB, H determined from EC and LE and E determined from energy balance; TVEB, H determined from temperature variance and LE and E determined from energy balance; --, no data]

	Site 1							Site 2							Site 3						
			R	G	H	LE	E			R	G	H	LE	E			R	G	H	LE	E
Julian day	Hour	Method	[(MJ/m^2)/d]				(mm/d)	Hour	Method	[(MJ/m^2)/d]				(mm/d)	Hour	Method	[(MJ/m^2)/d]				(mm/d)
261	0600	BR	5.66	0.79	3.08	1.79	0.73	0730	EC	5.50	0.95	4.57	1.78	0.72	0900	EC	6.06	0.84	3.58	2.01	0.82
288	1200	BR	5.02	0.10	2.84	2.08	0.84	1200	EC	4.62	-0.04	2.31	2.02	0.82	1330	ECEB	5.42	-0.17	2.79	2.80	1.13
289	0000	BR	4.10	-0.24	2.73	1.61	0.65	0000	EC	3.66	-0.44	2.00	1.49	0.60	0000	ECEB	4.76	-0.42	2.64	2.54	1.03
289	1200	BR	4.37	-0.14	2.81	1.70	0.68	1200	EC	3.86	-0.38	2.62	1.34	0.54	1330	ECEB	4.56	-0.56	3.14	1.98	0.80
343	1400	EC	-0.31	-2.94	--	0.22	0.08	--	--	--	--	--	--	--	--	--	--	--	--	--	--
344	1400	EC	-0.71	-3.71	--	0.02	0.01	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 3.--Flux totals at sites 1, 2, and 3, 1987 and 1988

[Hour, mountain standard time at beginning of 24-hour period (0000 is midnight at beginning of Julian day indicated); R, net radiation; G, soil-heat flux; H, sensible-heat flux; LE, latent-heat flux; E, evapotranspiration; $(MJ/m^2)/d$, megajoules per square meter per day; mm/d, millimeters per day; EC, eddy correlation; BR, Bowen ratio; ECEB, H determined from EC and LE and E determined from energy balance; TVEB, H determined from temperature variance and LE and E determined from energy balance; --, no data]

	Site 1							Site 2							Site 3						
			R	G	H	LE	E			R	G	H	LE	E			R	G	H	LE	E
Julian day	Hour	Method		[(MJ/m²)/d]			(mm/d)	Hour	Method		[(MJ/m²)/d]			(mm/d)	Hour	Method		[(MJ/m²)/d]			(mm/d)
55	0000	ECEB	4.36	-0.08	2.20	2.24	0.91	--	--	--	--	--	--	--	--	--	--	--	--	--	--
56	0000	EC	4.47	1.04	1.67	2.03	0.78	--	--	--	--	--	--	--	--	--	--	--	--	--	--
98	0000	EC	9.17	4.30	5.32	1.60	0.65	0000	BR	8.29	3.70	4.02	0.57	0.23	0000	ECEB	9.69	2.66	6.54	0.50	0.19
99	0000	EC	5.34	1.29	3.35	1.26	0.51	0000	BR	4.84	0.74	3.71	0.38	0.16	0000	ECEB	5.07	-0.11	4.15	1.03	0.39
126	0000	EC	10.74	0.72	5.84	6.10	2.47	0000	BR	11.15	1.20	4.21	5.74	2.31	0000	EC	--	0.13	3.60	4.49	1.82
127	0000	EC	12.26	2.16	5.92	3.52	1.43	0000	BR	11.79	2.55	5.25	3.98	1.60	0000	EC	11.66	1.80	5.14	3.84	1.865
167	--	--	--	--	--	--	--	0000	BR	12.16	0.99	8.22	2.95	1.19	--	--	--	--	--	--	--
167	1000	EC	12.14	1.15	6.96	4.83	1.98	0900	BR	11.46	0.80	8.32	2.35	0.95	1100	EC	11.54	1.23	9.02	3.77	1.54
168	0000	EC	12.05	0.64	6.87	4.93	2.02	0000	BR	11.66	1.33	8.29	2.04	0.82	0000	EC	11.96	1.55	9.40	3.70	1.52
168	1000	EC	12.23	1.12	7.09	4.74	1.94	0900	BR	11.56	1.34	8.06	2.17	0.87	1100	EC	11.86	1.55	9.32	3.67	1.50
210	--	--	--	--	--	--	--	0000	BR	10.36	1.17	7.12	2.07	0.84	--	--	--	--	--	--	--
210	0700	EC	12.25	1.64	4.70	4.19	1.72	0700	BR	10.23	1.14	7.07	2.01	0.82	0700	EC	12.70	1.83	8.48	1.39	0.57
211	0000	EC	11.25	1.75	4.28	3.92	1.61	0000	BR	9.63	1.48	6.42	1.73	0.70	0000	EC	12.28	1.64	8.13	1.46	0.60
211	0700	EC	11.22	1.53	4.41	3.91	1.60	0700	BR	9.52	1.28	6.45	1.80	0.73	0700	EC	12.22	1.49	8.18	1.47	0.60
244	0000	EC	7.36	-0.01	2.67	3.18	1.30	--	--	--	--	--	--	--	0000	BR	7.07	0.27	2.93	3.87	1.56
244	0800	EC	8.18	-0.10	3.00	3.27	1.33	0830	EC	7.40	-1.00	--	3.80	1.54	0800	BR	7.61	-0.01	3.77	3.85	1.56
245	0000	EC	8.03	0.09	2.59	2.71	1.10	0000	EC	7.60	-0.33	3.05	4.30	1.75	0000	BR	7.94	0.16	5.20	2.58	1.04
245	0800	EC	7.55	-0.05	2.56	2.48	1.01	0830	EC	7.04	-0.41	3.22	4.07	1.66	0800	BR	7.73	0.27	5.12	2.35	0.95

Table 3.--Flux totals at sites 1, 2, and 3, 1987 and 1988--Continued

[Hour, mountain standard time at beginning of 24-hour period (0000 is midnight at beginning of Julian day indicated); R, net radiation; G, soil-heat flux; H, sensible-heat flux; LE, latent-heat flux; E, evapotranspiration; (MJ/m^2)/d, megajoules per square meter per day; mm/d, millimeters per day; EC, eddy correlation; BR, Bowen ratio; ECEB, H determined from EC and LE and E determined from energy balance; TVEB, H determined from temperature variance and LE and E determined from energy balance; --, no data]

	Site 1							Site 2						Site 3						E
			R	G	H	LE	E			R	G	H	LE	E			R	G	H	LE	(mm/d)
Julian day	Hour	Method		[(MJ/m^2)/d]			(mm/d)	Hour	Method		[(MJ/m^2)/d]			(mm/d)	Hour	Method		[(MJ/m^2)/d]			
300	0000	EC	3.31	-0.65	4.55	0.99	0.40	0000	BR	3.38	-1.18	4.55	0.02	0.01	0000	EC	3.78	-0.97	3.30	0.62	0.25
301	0000	EC	1.99	-0.46	2.86	0.61	0.24	0000	BR	2.14	-0.72	2.35	0.51	0.18	0000	EC	1.98	-0.64	1.93	0.39	0.16
											1988										
138	0900	EC	8.34	0.41	5.76	2.15	0.87	0900	BR	7.69	0.69	4.62	2.37	0.84	--	--	--	--	--	--	--
139	0000	EC	8.15	-1.33	3.70	4.14	1.68	0000	BR	7.56	-1.20	2.11	6.65	2.35	--	--	--	--	--	--	--
139	0900	EC	8.10	-1.22	3.29	3.69	1.50	0900	BR	7.64	-1.18	2.45	6.36	2.25	--	--	--	--	--	--	--

Weather Measurements

Standard weather data collected continuously at site 1 included the following: solar radiation, R_s, or incoming shortwave radiation, in W/m^2, measured with a LiCor LI-200S pyranometer; air temperature, T, in °C, and relative humidity, h, unitless, measured with a shielded, naturally ventilated Campbell Scientific model 207 probe; windspeed, u, at a 2-m height, in m/s, measured with a Met-One model 014A cup anemometer; and precipitation, P, in mm, measured with a Sierra Misco model 2501 tipping-bucket rain gage. The sensors were scanned every 10 seconds, and average values of R_s, T, h, and u, and the total value of P were recorded every hour. The air temperature and relative humidity measurements were of questionable accuracy. Therefore, the air-temperature sensor was calibrated against a finewire thermocouple, and the relative-humidity sensor was calibrated against the Bowen-ratio psychrometers. Short gaps (less than a few hours) in the weather record were filled in by interpolation. Air temperature, T, and relative humidity, h, were used to compute vapor pressure, e, in kPa, for each hour, using the Lowe (1977) equation. The tipping bucket rain gage had a sensitivity of 1 mm. Rainfalls of less than 1 mm that occurred during a site visit were estimated. The gage probably did not indicate accurately the timing and amount of snowfall because the gage was not heated. Daily mean values of air temperature, T, vapor pressure, e, and windspeed, u, and totals of solar radiation, R_s, and precipitation, P, are presented in tables 4-7. Data-logger malfunctions prevented data from being collected on Julian days 354-365 in 1985, Julian days 144-182 in 1986, and Julian days 40-42 in 1988. Hourly values of the weather data are available upon request.

Table 4.--Daily weather data at site 1, San Luis Valley, Colorado, 1985

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, p (mm/d)
136	14.48	9.90	0.802	1.91	1.0
137	26.10	9.74	0.784	2.40	0.0
138	27.31	10.46	0.799	3.34	0.0
139	21.07	8.65	0.795	2.19	0.0
140	24.70	9.61	0.745	2.43	0.0
141	20.95	8.95	0.798	2.80	0.1
142	16.79	8.61	0.788	1.80	0.4
143	24.99	9.60	0.768	2.21	0.0
144	28.64	12.18	0.726	1.85	0.0
145	24.97	12.45	0.766	2.26	0.0
146	30.39	14.46	0.720	3.08	0.0
147	31.84	13.88	0.609	3.56	0.0
148	32.70	15.18	0.607	3.69	0.0
149	26.86	14.49	0.558	4.05	0.0
150	23.05	13.75	0.519	3.56	0.0
151	26.75	12.57	0.724	4.24	0.0
152	31.81	11.94	0.567	3.55	0.0
153	32.44	12.88	0.584	3.25	0.0
154	26.73	12.59	0.585	3.02	0.0
155	25.45	11.61	0.706	3.69	0.0
156	19.68	12.05	0.832	2.14	0.0
157	29.99	15.58	0.898	1.66	0.0
158	29.56	18.16	0.893	1.71	0.0
159	27.79	20.05	0.859	3.29	0.0
160	26.70	19.13	0.911	2.62	1.0
161	23.94	16.34	0.860	4.06	0.0
162	30.91	14.73	0.869	3.01	0.0
163	31.11	15.31	0.843	2.08	0.0

Table 4.--Daily weather data at site 1, San Luis Valley, Colorado, 1985--Continued

(MJ/m^2)/d, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s [(MJ/m^2)/d]	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, p (mm/d)
164	27.59	17.14	0.876	3.79	0.0
165	25.54	16.74	0.783	2.62	0.0
166	32.57	18.73	0.812	2.22	0.0
167	23.52	18.02	0.756	2.42	0.0
168	26.91	17.61	0.878	3.00	0.0
169	27.46	15.30	0.991	2.84	1.0
170	26.32	14.50	0.961	2.94	0.0
171	25.82	17.19	0.868	3.00	0.0
172	25.01	18.46	0.846	3.55	0.0
173	25.52	17.08	0.831	2.36	0.0
174	31.78	20.34	0.855	2.55	0.0
175	24.45	17.95	0.995	3.87	1.0
176	26.03	15.17	1.073	3.43	0.8
177	30.94	11.66	0.579	2.94	0.3
178	32.64	12.74	0.582	1.35	0.0
179	32.46	15.65	0.659	1.61	0.0
180	27.41	16.43	0.685	1.90	0.0
181	23.72	16.07	0.688	1.95	0.0
182	27.77	15.92	0.755	2.79	0.0
183	23.99	14.61	0.844	2.37	0.0
184	31.48	16.84	0.828	1.79	0.0
185	26.79	18.25	0.789	2.47	0.0
186	28.92	18.63	0.764	2.74	0.0
187	28.67	18.87	0.756	2.22	0.0
188	27.12	19.74	0.827	1.96	0.0
189	21.62	19.26	0.914	2.13	0.0
190	20.32	16.70	1.095	1.93	4.0
191	24.65	16.44	1.151	1.80	0.0

Table 4.--Daily weather data at site 1, San Luis Valley, Colorado, 1985--Continued

(MJ/m^2)/d, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s [(MJ/m^2)/d]	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, p (mm/d)
192	30.17	19.23	1.042	1.85	0.0
193	26.16	20.05	1.017	2.83	0.0
194	23.44	19.21	1.145	2.74	0.0
195	27.33	18.80	1.095	2.41	1.0
196	28.40	17.24	1.160	2.73	1.0
197	28.52	18.34	1.171	2.07	0.0
198	25.50	18.96	1.202	2.15	36.0
199	19.62	16.96	1.346	2.12	0.0
200	22.67	17.98	1.349	1.87	1.0
201	26.81	17.66	1.221	2.38	0.0
202	18.54	16.34	1.272	2.35	0.0
203	22.91	16.97	1.304	1.83	2.3
204	21.26	16.46	1.300	2.17	0.0
205	23.69	15.03	1.056	2.20	0.1
206	22.70	15.17	1.037	2.67	0.2
207	27.13	15.90	1.045	1.72	0.0
208	27.91	18.10	1.054	2.02	0.0
209	13.90	14.90	1.146	2.38	8.0
210	13.92	13.65	1.299	1.94	12.0
211	20.16	14.76	1.220	2.06	1.0
212	29.62	17.56	1.114	2.20	0.0
213	15.20	16.01	1.277	2.97	4.0
214	19.92	15.85	1.350	2.19	1.0
215	20.62	16.03	1.283	2.77	0.0
216	28.88	17.73	1.084	1.64	0.0
217	28.63	17.96	0.985	2.11	0.0
218	21.98	17.50	0.937	2.27	1.0
219	25.61	17.42	0.990	1.70	0.0

Table 4.–Daily weather data at site 1, San Luis Valley, Colorado, 1985–Continued

(MJ/m^2)/d, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s [(MJ/m^2)/d]	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, p (mm/d)
220	19.83	16.97	1.122	2.80	2.0
221	24.97	16.46	1.190	2.13	0.0
222	24.29	16.31	1.030	2.50	0.0
223	23.40	15.87	1.085	2.90	0.0
224	28.67	16.16	0.835	2.06	0.0
225	29.01	15.84	0.708	2.10	0.0
226	22.96	14.88	0.767	2.06	0.0
227	27.63	15.60	0.812	2.55	0.0
228	27.15	15.82	0.711	2.14	0.0
229	28.69	17.38	0.696	2.02	0.0
230	24.51	17.34	0.830	2.59	0.0
231	27.17	15.83	0.825	1.64	0.0
232	18.69	16.87	0.975	2.63	0.0
233	26.13	16.64	1.017	1.97	0.0
234	26.59	17.86	0.924	1.83	0.0
235	27.77	17.59	0.804	2.04	0.0
236	26.76	18.09	0.947	2.46	0.0
237	26.42	19.37	0.940	2.47	0.0
238	26.49	19.87	0.818	2.50	0.0
239	21.28	19.17	0.858	2.62	0.5
240	21.95	17.52	0.995	2.44	0.1
241	26.35	18.15	0.902	1.89	0.0
242	23.97	19.22	0.908	2.21	0.0
243	25.98	20.57	0.858	2.62	0.0
244	22.04	17.62	0.897	2.44	0.0
245	18.98	16.19	1.060	3.10	0.0
246	21.05	16.33	1.004	2.60	0.0
247	17.38	15.20	1.040	2.42	0.0

Table 4.--Daily weather data at site 1, San Luis Valley, Colorado, 1985--Continued

(MJ/m^2)/d, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s [(MJ/m^2)/d]	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, p (mm/d)
248	24.97	13.88	0.773	2.53	0.0
249	24.24	12.39	0.583	1.84	0.0
250	20.33	11.43	0.623	3.04	0.0
251	24.78	12.32	0.642	1.83	0.0
252	21.83	13.99	0.579	3.01	0.0
253	15.03	13.22	0.639	1.95	0.0
254	7.92	9.53	0.949	2.99	10.0
255	24.46	11.84	0.684	2.11	0.0
256	24.39	11.87	0.690	1.60	0.0
257	22.78	13.77	0.842	1.75	0.0
258	10.93	12.34	1.065	2.59	2.0
259	17.80	11.77	0.876	1.85	0.0
260	21.18	13.40	0.864	2.64	0.0
261	12.06	11.44	1.032	2.71	10.0
262	22.35	12.43	0.900	3.73	0.0
263	7.53	8.30	0.875	3.18	6.0
264	16.92	7.95	0.823	1.67	2.0
265	9.52	6.62	0.746	2.44	3.0
266	22.28	7.08	0.579	1.72	0.0
267	20.92	9.48	0.497	2.02	0.0
268	21.98	8.63	0.536	2.05	0.0
269	22.02	8.13	0.539	1.61	0.0
270	20.92	10.78	0.560	2.58	0.0
271	10.34	10.18	0.775	4.35	0.0
272	18.35	5.49	0.489	2.64	1.0
273	20.98	6.17	0.390	2.03	1.0
274	20.78	5.42	0.394	1.73	1.0
275	14.72	5.38	0.401	1.44	0.0

Table 4.–Daily weather data at site 1, San Luis Valley, Colorado, 1985–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, p (mm/d)
276	20.64	9.38	0.503	1.73	0.0
277	20.37	10.12	0.524	2.54	0.0
278	20.28	8.73	0.508	1.62	0.0
279	18.16	10.00	0.491	3.31	0.0
280	18.46	10.61	0.658	6.61	0.0
281	9.76	8.80	0.617	5.15	0.0
282	14.53	10.37	0.733	3.48	0.0
283	16.36	9.68	0.779	2.96	10.0
284	13.98	6.51	0.724	3.57	3.0
285	18.83	6.14	0.599	1.84	0.0
286	15.78	7.12	0.648	2.81	0.0
287	15.49	3.60	0.508	1.77	0.0
288	18.60	3.45	0.414	1.63	0.0
289	14.64	5.25	0.565	2.33	0.0
290	5.72	5.42	0.755	1.45	3.0
291	12.93	6.72	0.719	1.88	3.0
292	13.55	6.17	0.692	1.69	0.0
293	16.24	5.84	0.626	1.79	0.0
294	14.30	7.31	0.676	2.32	0.0
295	14.07	7.24	0.539	4.24	0.0
296	14.93	5.72	0.494	1.54	0.0
297	16.75	5.61	0.472	1.11	0.0
298	15.20	7.93	0.545	1.97	0.0
299	15.62	8.52	0.585	1.52	0.0
300	16.09	7.42	0.544	1.68	0.0
301	15.24	7.63	0.615	1.86	0.0
302	12.11	5.16	0.608	2.43	0.0
				1.42	0.0

Table 4.--Daily weather data at site 1, San Luis Valley, Colorado, 1985--Continued

(MJ/m^2)/d, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s [(MJ/m^2)/d]	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, p (mm/d)
304	7.60	5.23	0.644	2.60	3.0
305	14.85	0.42	0.460	0.94	3.0
306	14.80	2.17	0.503	1.53	0.0
307	15.13	3.08	0.537	1.41	0.0
308	12.36	3.68	0.500	1.21	0.0
309	12.05	7.10	0.575	2.91	0.0
310	15.85	3.37	0.364	3.35	0.0
311	14.57	1.28	0.334	1.61	0.0
312	11.30	5.00	0.416	3.99	0.0
313	13.23	6.09	0.414	6.40	0.0
314	12.94	5.68	0.387	5.14	0.0
315	11.82	6.70	0.524	5.28	0.0
316	12.28	4.61	0.585	5.27	0.0
317	10.41	-2.13	0.295	3.48	0.0
318	6.02	-5.92	0.319	1.58	0.0
319	13.61	-10.63	0.200	1.50	0.0
320	13.71	-11.72	0.175	0.86	0.0
321	9.95	-5.26	0.354	3.19	0.0
322	12.92	-4.08	0.323	4.13	0.0
323	13.49	-9.20	0.156	2.84	0.0
324	13.35	-6.37	0.193	3.03	0.0
325	12.73	-3.27	0.310	5.03	0.0
326	11.66	-1.49	0.294	4.27	0.0
327	12.39	1.57	0.413	3.61	0.0
328	10.20	2.60	0.448	3.30	0.0
329	9.13	3.88	0.624	4.83	0.0
330	6.04	3.47	0.660	1.99	0.0
331	11.32	0.25	0.444	1.83	0.0

Table 4.–Daily weather data at site 1, San Luis Valley, Colorado, 1985–Continued

(MJ/m^2)/d, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s [(MJ/m^2)/d]	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, p (mm/d)
332	9.28	-0.19	0.444	3.08	0.0
333	8.12	2.01	0.569	5.15	0.0
334	8.65	0.75	0.440	3.74	0.0
335	11.60	-0.41	0.383	1.86	0.0
336	6.64	1.49	0.394	3.85	0.0
337	11.52	1.61	0.438	2.27	0.0
338	11.66	-0.84	0.325	1.76	0.0
339	10.49	-4.03	0.297	0.93	0.0
340	9.75	-2.47	0.333	1.16	0.0
341	9.36	-1.98	0.359	1.73	0.0
342	11.36	-0.41	0.351	3.39	0.0
343	8.92	-1.96	0.327	3.01	0.0
344	8.23	-9.68	0.242	3.37	0.0
345	7.64	-13.05	0.155	1.19	0.0
346	9.59	-16.53	0.109	1.27	0.0
347	11.37	-16.91	0.104	1.66	0.0
348	11.36	-15.47	0.121	1.14	0.0
349	11.34	-15.06	0.130	1.17	0.0
350	11.33	-13.93	0.141	1.39	0.0
351	9.61	-12.71	0.153	1.37	0.0
352	10.05	-9.06	0.213	1.45	0.0
353	11.16	-9.32	0.216	1.21	0.0

Table 5.--Daily weather data at site 1, San Luis Valley, Colorado, 1986

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
1	11.26	-8.60	0.230	0.97	0.0
2	8.92	-7.09	0.250	1.37	0.0
3	9.03	-6.15	0.268	1.37	0.0
4	10.50	-6.38	0.197	2.17	0.0
5	9.06	-10.08	0.174	1.32	0.0
6	9.33	-5.02	0.310	1.86	0.0
7	11.56	-4.93	0.283	2.46	0.0
8	11.97	-9.43	0.197	0.92	0.0
9	11.79	-7.22	0.240	1.26	0.0
10	12.09	-4.84	0.305	1.33	0.0
11	11.93	-4.87	0.307	1.09	0.0
12	12.14	-4.57	0.314	1.24	0.0
13	12.33	-5.74	0.280	1.12	0.0
14	11.56	-6.02	0.272	0.97	0.0
15	12.11	-2.65	0.337	1.77	0.0
16	11.25	-2.41	0.350	1.78	0.0
17	11.87	-1.04	0.375	1.87	0.0
18	11.73	-0.12	0.404	2.14	0.0
19	12.83	-1.98	0.352	1.25	0.0
20	12.48	0.19	0.356	2.71	0.0
21	12.76	-1.46	0.270	2.79	0.0
22	11.39	-4.45	0.277	1.12	0.0
23	12.85	0.07	0.324	2.02	0.0
24	12.94	-0.12	0.257	3.42	0.0
25	13.63	-2.33	0.214	3.36	0.0
26	13.58	-4.41	0.232	1.59	0.0
27	13.86	-2.85	0.280	1.60	0.0

Table 5.–Daily weather data at site 1, San Luis Valley, Colorado, 1986–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
28	14.08	-1.86	0.302	1.59	0.0
29	13.99	2.19	0.346	2.51	0.0
30	13.24	3.97	0.370	2.63	0.0
31	11.63	3.89	0.506	2.66	0.0
32	12.93	0.43	0.403	1.57	0.0
33	11.34	2.55	0.443	1.55	0.0
34	12.89	0.31	0.370	3.25	0.0
35	14.91	-3.56	0.247	1.96	0.0
36	14.79	-4.48	0.242	1.72	0.0
37	10.78	-3.67	0.257	4.28	0.0
38	12.50	-5.58	0.266	3.24	0.0
39	13.08	-5.98	0.275	3.15	0.0
40	6.75	-8.06	0.266	2.52	0.0
41	14.82	-9.6	0.186	2.08	0.0
42	14.52	-7.58	0.206	2.72	0.0
43	15.52	-3.84	0.268	2.81	0.0
44	11.46	0.44	0.445	3.93	0.0
45	15.86	1.28	0.393	1.84	0.0
46	6.16	3.84	0.577	5.55	0.0
47	15.28	1.54	0.433	3.34	0.0
48	16.28	3.05	0.454	3.23	0.0
49	14.00	5.72	0.564	4.35	0.0
50	11.96	6.69	0.593	5.73	0.0
51	15.63	3.78	0.453	4.40	0.0
52	14.93	-1.04	0.302	2.04	0.0
53	17.31	-0.62	0.264	1.50	0.0
54	16.13	2.29	0.368	2.84	0.0
55	16.85	5.27	0.466	1.84	0.0

Table 5.--Daily weather data at site 1, San Luis Valley, Colorado, 1986--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
56	19.04	5.36	0.426	2.11	0.0
57	18.59	6.31	0.442	2.47	0.0
58	19.15	3.38	0.401	2.39	0.0
59	19.77	0.57	0.297	1.33	0.0
60	19.92	3.17	0.330	1.62	0.0
61	19.00	3.94	0.338	2.03	0.0
62	19.23	5.50	0.431	2.30	0.0
63	19.48	3.55	0.381	1.24	0.0
64	20.05	4.00	0.343	2.28	0.0
65	20.82	3.78	0.301	1.40	0.0
66	17.46	3.62	0.333	1.56	0.0
67	15.31	6.27	0.407	3.26	0.0
68	14.61	3.27	0.405	4.79	0.0
69	9.08	-0.13	0.397	3.78	0.0
70	15.99	1.42	0.451	2.09	0.0
71	14.39	0.66	0.420	2.00	0.0
72	16.81	-1.35	0.355	1.61	0.0
73	14.42	-0.15	0.394	2.02	0.0
74	19.16	1.03	0.339	1.99	0.0
75	18.48	1.93	0.356	3.36	0.0
76	11.54	1.10	0.432	3.78	0.0
77	16.19	-3.37	0.378	2.11	0.0
78	19.57	-3.31	0.329	1.74	0.0
79	22.87	2.19	0.416	1.89	0.0
80	23.54	3.30	0.406	1.68	0.0
81	22.48	5.21	0.381	1.77	0.0
82	20.69	5.97	0.403	1.67	0.0
83	15.65	7.63	0.366	3.22	0.0

Table 5.–Daily weather data at site 1, San Luis Valley, Colorado, 1986–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
84	22.65	7.63	0.354	2.52	0.0
85	24.47	7.35	0.423	1.91	0.0
86	24.56	8.97	0.441	1.77	0.0
87	24.58	8.61	0.420	1.48	0.0
88	21.21	8.58	0.459	1.60	0.0
89	20.02	8.05	0.555	2.58	0.0
90	18.69	8.18	0.678	2.32	0.0
91	7.76	5.01	0.731	4.22	0.0
92	12.48	3.32	0.648	4.90	0.0
93	14.00	0.18	0.527	2.10	0.0
94	26.16	1.92	0.481	1.65	0.0
95	25.41	3.51	0.511	2.11	0.0
96	23.04	7.00	0.555	2.11	0.0
97	23.73	9.49	0.629	4.24	0.0
98	20.88	8.06	0.634	3.78	0.0
99	26.42	7.45	0.510	3.73	0.0
100	26.12	7.36	0.418	2.18	0.0
101	20.10	7.09	0.512	2.10	0.0
102	24.01	6.77	0.553	3.17	0.0
103	23.96	4.93	0.395	6.49	0.0
104	26.05	4.42	0.308	2.72	0.0
105	25.07	8.88	0.404	2.63	0.0
106	13.83	7.86	0.614	4.73	0.0
107	25.06	3.93	0.462	5.02	0.0
108	20.07	2.23	0.447	2.42	0.0
109	26.50	4.89	0.471	3.09	0.0
110	27.66	8.91	0.485	3.13	0.0
111	25.81	11.08	0.623	2.59	0.0

Table 5.--Daily weather data at site 1, San Luis Valley, Colorado, 1986--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
112	22.32	10.72	0.710	2.30	0.0
113	24.13	9.21	0.593	3.48	0.0
114	23.02	8.49	0.660	3.61	5.3
115	14.59	6.68	0.620	3.94	0.0
116	12.88	4.02	0.557	4.77	0.0
117	28.21	3.52	0.348	4.18	0.0
118	28.89	8.50	0.512	4.02	0.0
119	26.65	11.66	0.495	4.29	0.0
120	29.39	11.65	0.490	2.26	0.0
121	28.33	12.46	0.535	2.59	0.0
122	21.01	13.21	0.756	3.87	0.0
123	26.96	12.84	0.765	3.10	0.0
124	28.72	13.61	0.662	6.12	0.0
125	30.33	8.82	0.385	2.85	0.0
126	28.97	10.66	0.413	4.98	0.0
127	28.83	8.66	0.442	4.98	0.0
128	21.93	2.97	0.481	2.37	0.0
129	26.53	4.87	0.488	4.27	0.0
130	30.78	7.22	0.473	2.01	0.0
131	31.18	11.31	0.457	3.40	0.0
132	31.42	10.71	0.435	3.02	0.0
133	30.51	10.60	0.459	2.39	0.0
134	28.59	10.27	0.451	2.74	0.0
135	14.44	9.95	0.492	2.76	0.0
136	22.22	9.33	0.519	4.09	0.0
137	28.50	5.43	0.569	2.29	0.0
138	28.62	9.58	0.564	1.78	0.0
139	29.10	12.44	0.599	1.75	0.0

Table 5.–Daily weather data at site 1, San Luis Valley, Colorado, 1986–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
140	25.71	13.39	0.622	1.97	0.0
141	27.49	13.54	0.577	2.73	0.0
142	30.91	14.26	0.537	3.12	0.0
143	27.49	13.54	0.577	2.73	0.0
183	25.92	18.44	1.001	2.46	0.0
184	24.39	18.76	1.035	2.32	0.0
185	27.53	18.67	1.115	3.27	0.0
186	18.96	16.14	1.236	2.72	0.0
187	32.50	16.23	1.039	2.24	0.0
188	20.20	14.80	1.129	2.07	1.0
189	18.72	15.87	1.251	2.82	3.0
190	19.81	14.63	1.205	1.68	1.0
191	19.57	14.08	0.979	1.75	0.0
192	29.87	17.01	0.885	1.78	0.0
193	24.11	18.17	0.911	2.30	1.0
194	25.63	18.00	0.904	2.45	0.0
195	26.08	17.18	1.014	2.01	0.0
196	30.27	18.84	1.122	3.04	0.0
197	22.14	16.52	1.194	3.82	0.0
198	26.79	17.28	1.102	2.49	0.0
199	20.56	16.10	1.205	2.22	0.0
200	19.71	14.70	1.102	2.49	4.0
201	11.73	12.89	1.237	1.82	5.0
202	13.49	13.74	1.257	1.80	0.0
203	26.19	14.67	1.154	2.44	0.0
204	24.56	14.69	1.180	2.70	1.6
205	28.04	15.29	0.960	1.76	0.0
206	30.33	16.04	0.887	2.01	0.0

Table 5.--Daily weather data at site 1, San Luis Valley, Colorado, 1986--Continued

[(MJ/m^2)/d, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s [(MJ/m^2)/d]	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
207	28.78	16.68	0.869	2.72	0.0
208	30.40	16.51	0.714	2.76	0.0
209	31.08	16.71	0.645	2.06	0.0
210	30.43	17.25	0.689	1.91	0.0
211	30.46	18.25	0.783	2.01	0.0
212	29.42	18.98	0.752	2.61	0.0
213	19.30	18.00	0.785	3.34	0.0
214	25.28	15.62	0.813	2.70	0.0
215	23.10	16.57	0.858	2.22	0.0
216	16.80	14.80	0.867	2.49	0.0
217	22.22	14.59	0.965	2.24	0.0
218	28.09	17.05	0.917	2.37	0.0
219	24.81	16.01	0.834	2.51	0.0
220	25.90	16.08	0.913	2.33	0.0
221	29.06	18.05	0.866	3.40	0.0
222	20.53	15.45	0.944	2.66	0.0
223	25.47	15.52	0.913	2.16	0.0
224	21.70	16.61	1.026	2.23	0.0
225	26.50	16.55	1.036	1.84	0.0
226	19.11	15.89	0.888	1.84	0.0
227	28.58	16.09	0.763	1.63	0.0
228	28.55	18.17	0.719	1.88	0.0
229	25.85	18.78	0.815	2.66	0.0
230	25.75	19.62	0.899	2.81	0.0
231	26.22	20.02	0.870	2.22	0.0
232	22.51	17.30	0.939	2.90	0.0
233	24.32	16.95	1.141	2.19	0.9
234	24.26	15.84	1.031	1.81	0.0

Table 5.–Daily weather data at site 1, San Luis Valley, Colorado, 1986–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
235	16.88	15.35	1.256	2.10	0.0
236	16.24	15.36	1.239	1.99	0.0
237	21.46	15.70	1.198	2.04	0.0
238	18.40	15.01	1.162	1.95	0.0
239	23.07	16.90	1.057	2.90	0.0
240	22.47	15.38	0.893	1.92	0.0
241	16.73	14.38	1.092	2.29	0.0
242	23.61	15.55	1.064	1.94	0.0
243	20.45	14.45	0.910	1.86	0.0
244	16.98	13.58	1.028	1.54	1.0
245	21.01	10.69	0.838	1.94	0.0
246	25.69	12.31	0.732	1.68	0.0
247	22.14	14.37	0.792	2.26	0.0
248	24.89	14.72	0.770	1.84	0.0
249	24.58	15.00	0.773	2.83	0.0
250	17.05	13.43	1.031	3.73	2.0
251	16.15	11.68	1.061	1.79	0.0
252	17.28	12.02	0.999	2.94	0.0
253	7.46	7.39	0.890	2.11	1.0
254	24.55	8.74	0.733	1.74	14.0
255	23.23	11.74	0.702	2.13	0.0
256	16.65	11.78	0.948	2.77	7.0
257	21.66	12.84	0.795	2.98	9.0
258	21.85	13.68	0.737	2.76	0.0
259	17.92	12.41	0.867	3.09	0.0
260	23.05	12.39	0.644	2.67	3.0
261	18.17	11.99	0.568	3.52	1.0
262	22.57	13.94	0.599	3.73	2.0

Table 5.--Daily weather data at site 1, San Luis Valley, Colorado, 1986--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
263	22.42	13.99	0.569	4.22	0.0
264	18.66	13.62	0.602	3.29	0.0
265	17.40	12.60	0.621	2.49	0.0
266	11.67	11.98	0.716	2.99	0.0
267	14.67	6.85	0.614	5.26	0.0
268	22.05	7.47	0.577	5.61	0.0
269	16.73	7.27	0.628	4.12	0.0
270	20.95	8.94	0.574	4.02	0.0
271	18.95	10.09	0.523	3.61	0.0
272	10.51	6.05	0.688	2.36	0.0
273	15.79	5.53	0.564	2.08	0.0
274	20.92	9.46	0.529	3.21	0.0
275	19.88	10.12	0.478	3.43	0.0
276	11.49	6.39	0.647	3.30	0.0
277	20.80	4.74	0.417	1.64	0.0
278	19.72	7.00	0.503	3.05	0.0
279	14.55	8.80	0.705	2.06	0.0
280	17.66	9.57	0.689	1.85	0.0
281	16.22	9.47	0.577	1.59	0.0
282	19.52	8.86	0.611	2.21	0.0
283	9.93	8.13	0.834	3.37	0.0
284	5.99	0.52	0.540	4.51	0.0
285	8.10	-1.65	0.450	2.08	0.0
286	18.65	-0.22	0.435	1.63	0.0
287	18.94	2.24	0.459	1.06	0.0
288	18.83	4.03	0.468	1.22	1.0
289	16.04	4.65	0.466	1.18	0.0
290	16.69	5.32	0.439	1.53	0.0

Table 5.–Daily weather data at site 1, San Luis Valley, Colorado, 1986–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
291	12.84	6.28	0.501	2.40	0.0
292	11.22	7.26	0.653	2.83	0.0
293	6.92	3.61	0.676	2.31	1.0
294	10.69	2.06	0.561	1.22	0.0
295	16.42	2.89	0.517	1.55	0.0
296	14.65	4.09	0.532	1.15	0.0
297	16.52	3.99	0.548	1.18	0.0
298	16.45	3.97	0.443	1.73	0.0
299	16.63	3.08	0.406	1.57	0.0
300	14.65	3.71	0.399	1.28	0.0
301	16.10	4.29	0.426	1.57	0.0
302	13.75	6.93	0.491	2.12	0.0
303	15.07	7.52	0.496	2.60	0.0
304	10.12	7.57	0.546	4.03	0.0
305	7.42	4.83	0.696	3.80	0.0
306	4.50	2.31	0.626	1.29	0.0
307	7.42	4.04	0.613	1.94	0.0
308	10.02	2.22	0.508	1.79	0.0
309	14.75	0.71	0.457	1.52	0.0
310	13.47	2.99	0.505	3.19	0.0
311	9.64	-1.33	0.347	3.97	0.0
312	13.75	-3.97	0.238	3.92	0.0
313	14.83	-4.82	0.202	1.64	0.0
314	13.90	-3.24	0.224	2.15	0.0
315	14.12	-2.00	0.240	1.62	0.0
316	13.85	-0.29	0.330	2.22	0.0
317	9.34	-3.10	0.360	1.91	0.0
318	9.18	-1.78	0.408	1.19	0.0

Table 5.--Daily weather data at site 1, San Luis Valley, Colorado, 1986--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
319	13.29	0.42	0.364	1.75	0.0
320	12.34	2.83	0.401	2.35	0.0
321	13.07	4.26	0.448	2.92	0.0
322	11.52	3.87	0.520	3.43	0.0
323	10.02	5.81	0.604	3.12	0.0
324	12.89	1.83	0.457	1.47	0.0
325	12.88	1.21	0.469	1.37	0.0
326	5.44	-0.28	0.511	2.22	0.0
327	12.49	-3.74	0.341	1.40	0.0
328	11.13	-5.18	0.302	0.96	0.0
329	11.78	-1.56	0.386	2.03	0.0
330	7.02	-1.60	0.432	1.29	0.0
331	11.07	-3.85	0.354	0.94	0.0
332	12.00	-2.02	0.372	0.87	0.0
333	10.14	-0.43	0.400	1.73	0.0
334	7.83	-0.04	0.391	3.85	0.0
335	11.77	-2.24	0.279	2.01	0.0
336	11.71	-3.34	0.299	0.90	0.0
337	11.54	-2.41	0.332	0.90	0.0
338	11.48	-1.01	0.335	1.18	0.0
339	9.20	0.31	0.394	1.48	0.0
340	3.60	1.38	0.551	3.21	0.0
341	8.00	0.69	0.496	2.35	0.0
342	9.13	-3.06	0.354	1.30	0.0
343	6.89	-5.57	0.321	2.96	3.7
344	11.26	-14.89	0.124	1.01	0.0
345	11.17	-11.51	0.180	0.96	0.0
346	10.58	-8.30	0.221	1.11	0.0

Table 5.--Daily weather data at site 1, San Luis Valley, Colorado, 1986--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
347	8.42	-7.71	0.251	1.22	0.0
348	11.16	-8.81	0.211	0.99	0.0
349	10.58	-8.30	0.221	1.11	0.0
350	8.42	-7.71	0.251	1.22	0.0
351	5.93	-6.66	0.273	0.73	0.0
352	6.79	-4.38	0.342	0.95	0.0
353	9.72	-5.38	0.299	1.14	0.0
354	8.42	-7.71	0.251	1.22	0.0
355	9.48	-6.45	0.267	1.16	0.0
356	9.32	-7.26	0.232	1.11	0.0
357	9.78	-7.45	0.243	0.89	0.0
358	7.11	-7.51	0.224	1.11	0.0
359	9.78	-7.45	0.243	0.89	0.0
360	7.11	-7.51	0.224	1.11	0.0
361	9.72	-7.73	0.209	1.20	0.0
362	11.02	-8.55	0.189	1.37	0.0
363	11.29	-9.31	0.177	1.33	0.0
364	10.64	-9.33	0.155	0.91	0.0
365	11.36	-9.81	0.148	1.21	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
1	10.64	-9.33	0.155	0.91	0.0
2	10.62	-7.83	0.187	1.22	0.0
3	9.86	-9.61	0.170	1.26	0.0
4	10.62	-7.13	0.199	1.25	0.0
5	10.91	-3.46	0.277	1.96	0.0
6	10.91	-3.30	0.280	1.92	0.0
7	8.92	-4.31	0.320	1.48	0.0
8	10.91	-3.30	0.280	1.92	0.0
9	8.92	-5.00	0.310	1.42	0.0
10	11.40	-10.81	0.150	1.05	0.0
11	12.06	-9.17	0.167	0.98	0.0
12	10.62	-7.13	0.199	1.25	0.0
13	12.41	-6.00	0.248	1.09	0.0
14	9.64	-4.78	0.248	2.22	0.0
15	11.40	-6.93	0.251	1.08	0.0
16	11.77	-4.49	0.323	1.78	0.0
17	13.95	-2.92	0.341	1.52	0.0
18	12.86	-4.16	0.353	1.22	0.0
19	10.97	-3.31	0.354	1.33	0.0
20	11.36	-4.66	0.299	1.23	0.0
21	11.77	-4.49	0.323	1.78	0.0
22	13.95	-2.92	0.341	1.52	0.0
23	12.86	-4.16	0.353	1.22	0.0
24	10.97	-3.31	0.354	1.33	0.0
25	8.64	-2.68	0.373	1.11	0.0
26	15.08	-2.79	0.316	1.32	0.0
27	15.30	-4.72	0.261	1.28	0.0

Table 6.–Daily weather data at site 1, San Luis Valley, Colorado, 1987–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
28	15.56	-4.66	0.266	1.29	0.0
29	10.88	-5.35	0.276	1.24	0.0
30	11.40	-6.93	0.248	1.10	0.0
31	11.77	-4.49	0.323	1.78	0.0
32	13.95	-2.92	0.341	1.52	0.0
33	12.86	-4.16	0.353	1.22	0.0
34	10.97	-3.31	0.354	1.33	0.0
35	8.64	-2.68	0.373	1.11	0.0
36	15.08	-2.79	0.316	1.32	0.0
37	15.30	-4.72	0.261	1.28	0.0
38	15.56	-4.66	0.266	1.29	0.0
39	11.27	-4.56	0.300	1.06	0.0
40	13.92	-3.89	0.323	1.08	0.0
41	14.30	-2.62	0.340	1.15	0.0
42	14.94	-0.56	0.418	1.51	0.0
43	9.02	0.79	0.524	1.46	0.0
44	12.71	1.13	0.494	1.81	0.0
45	10.29	1.96	0.511	4.19	0.0
46	14.23	0.21	0.380	2.31	0.0
47	8.20	-0.92	0.438	2.22	0.0
48	12.92	-1.60	0.383	1.34	0.0
49	14.03	-2.05	0.351	1.77	0.0
50	8.61	-4.24	0.287	2.92	2.0
51	14.73	-7.10	0.230	1.41	2.0
52	17.62	-8.23	0.214	1.39	0.0
53	15.58	-6.62	0.255	1.46	2.0
54	15.31	-4.55	0.291	2.42	0.0
55	15.30	-2.07	0.340	4.18	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
56	12.48	-0.64	0.407	4.02	1.4
57	10.89	-1.76	0.401	4.51	0.0
58	15.71	-5.81	0.232	2.62	0.0
59	19.40	-6.54	0.219	2.38	0.0
60	19.74	-6.22	0.234	1.27	0.0
61	18.12	-3.43	0.287	1.34	0.0
62	19.80	-1.76	0.322	1.37	0.0
63	19.92	-0.61	0.344	1.48	0.0
64	20.47	0.61	0.369	1.26	0.0
65	20.74	1.45	0.390	1.19	0.0
66	20.77	2.73	0.417	1.38	0.0
67	13.59	2.75	0.529	2.17	0.0
68	16.70	2.36	0.493	1.59	0.0
69	15.63	2.21	0.494	1.71	0.0
70	13.99	1.71	0.463	2.71	0.0
71	21.73	2.12	0.398	1.55	0.0
72	19.52	3.77	0.382	2.54	0.0
73	21.22	3.94	0.307	2.61	0.0
74	12.40	4.10	0.376	4.13	0.0
75	18.61	-0.32	0.414	2.37	0.0
76	21.41	0.17	0.366	3.50	0.0
77	22.73	2.60	0.346	2.45	0.0
78	21.74	4.10	0.397	5.04	0.0
79	22.14	-0.27	0.316	5.34	0.0
80	21.65	-0.36	0.308	3.13	0.0
81	7.48	-0.79	0.456	2.95	0.0
82	23.41	-0.59	0.320	3.48	0.0
83	22.60	-0.93	0.275	1.73	0.0

Table 6.–Daily weather data at site 1, San Luis Valley, Colorado, 1987–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
84	19.67	-1.44	0.288	1.76	0.0
85	19.38	0.25	0.324	1.60	0.0
86	14.31	-2.37	0.281	3.29	0.0
87	16.67	-5.19	0.204	2.77	0.0
88	16.60	-6.33	0.238	1.91	0.0
89	25.02	-2.01	0.222	2.98	0.0
90	25.29	2.37	0.302	1.96	0.0
91	22.33	3.78	0.360	2.68	0.0
92	26.01	2.07	0.308	2.24	0.0
93	25.10	5.21	0.362	2.72	0.0
94	11.47	3.06	0.326	3.24	0.0
95	10.57	0.10	0.466	1.50	0.0
96	23.75	1.65	0.369	2.30	0.0
97	23.22	1.89	0.328	1.89	0.0
98	25.92	5.57	0.408	2.44	0.0
99	17.79	4.68	0.381	2.48	0.0
100	26.27	5.79	0.350	3.14	0.0
101	17.48	6.76	0.390	2.75	0.0
102	10.81	3.01	0.500	3.55	0.0
103	25.60	-0.61	0.345	2.71	0.0
104	27.84	4.29	0.384	1.78	0.0
105	27.16	8.74	0.452	2.19	0.0
106	27.94	10.41	0.479	1.84	0.0
107	27.94	10.39	0.466	1.84	0.0
108	24.22	10.03	0.431	3.06	0.0
109	27.36	10.64	0.405	5.04	0.0
110	28.57	4.49	0.280	2.32	0.0
111	28.89	4.51	0.348	1.79	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
112	29.24	10.02	0.424	2.57	0.0
113	29.80	11.13	0.456	2.19	0.0
114	25.96	12.71	0.475	3.01	0.0
115	18.04	10.46	0.538	2.90	2.0
116	25.78	10.78	0.540	2.18	0.0
117	16.76	10.06	0.668	2.53	0.0
118	24.79	11.16	0.660	1.93	0.0
119	24.04	11.21	0.647	2.84	0.0
120	19.85	9.21	0.686	1.79	0.0
121	21.25	10.15	0.665	1.80	0.0
122	14.27	6.33	0.582	2.82	0.0
123	7.97	3.96	0.640	2.47	0.0
124	22.40	7.48	0.631	2.25	0.0
125	16.84	7.13	0.656	1.94	1.8
126	22.27	8.75	0.680	2.63	1.7
127	28.78	9.93	0.579	2.38	0.0
128	29.73	11.81	0.605	2.29	0.0
129	19.62	10.73	0.628	2.30	0.0
130	28.30	10.78	0.678	2.05	0.0
131	19.92	10.17	0.694	2.56	0.0
132	20.66	11.45	0.830	2.54	1.0
133	29.70	13.20	0.767	2.42	0.0
134	16.88	12.14	0.911	2.18	0.0
135	22.55	11.47	0.858	2.09	0.0
136	24.92	12.97	0.783	2.83	0.0
137	28.54	14.05	0.697	2.66	0.0
138	28.91	13.08	0.699	2.65	0.0
139	12.02	10.37	0.746	1.91	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
140	26.00	11.47	0.664	3.14	0.0
141	26.52	10.53	0.603	4.33	0.0
142	26.16	10.82	0.610	3.12	0.0
143	22.85	10.48	0.686	3.35	0.0
144	18.58	7.97	0.686	2.61	0.0
145	25.96	8.84	0.521	3.22	0.0
146	31.19	9.59	0.450	4.24	0.0
147	31.99	8.14	0.360	3.52	0.0
148	18.17	6.60	0.512	2.23	2.0
149	27.60	8.47	0.517	2.65	0.0
150	28.52	10.01	0.528	1.89	0.0
151	32.22	12.27	0.562	1.98	0.0
152	31.23	14.99	0.553	2.17	0.0
153	32.86	15.23	0.556	1.90	0.0
154	31.47	14.77	0.690	2.52	0.0
155	26.59	14.27	0.759	2.71	0.0
156	30.64	15.19	0.662	2.19	0.0
157	30.19	17.11	0.716	3.00	0.0
158	27.17	15.88	0.772	3.07	0.0
159	15.65	13.06	0.935	2.45	0.0
160	19.98	13.45	0.999	2.16	0.0
161	27.60	13.82	0.745	2.11	0.0
162	31.29	16.26	0.730	1.78	0.0
163	30.46	17.75	0.747	2.15	0.0
164	30.79	17.40	0.711	2.55	0.0
165	32.16	17.95	0.707	2.29	0.0
166	24.01	17.67	0.735	2.43	0.4
167	31.75	16.46	0.750	2.75	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
168	33.27	14.94	0.593	2.33	0.0
169	33.13	15.42	0.559	2.70	0.0
170	32.97	16.99	0.586	1.94	0.0
171	32.33	16.37	0.577	2.48	0.0
172	32.16	17.42	0.621	2.21	0.0
173	32.21	17.97	0.619	2.08	0.0
174	29.81	16.84	0.611	2.29	0.0
175	26.11	17.79	0.674	2.04	0.0
176	32.19	18.32	0.827	2.07	0.0
177	24.00	18.37	0.850	3.42	0.0
178	28.63	17.25	0.773	2.26	0.0
179	21.19	16.81	0.771	2.51	0.0
180	22.94	14.55	0.836	2.60	0.0
181	24.18	13.27	0.816	1.58	0.0
182	28.06	16.38	0.742	1.70	0.0
183	32.90	17.14	0.680	2.81	0.0
184	33.09	16.18	0.561	2.76	0.0
185	30.50	16.03	0.521	2.90	0.0
186	32.83	16.86	0.617	1.99	0.0
187	32.07	17.03	0.558	2.80	0.0
188	30.25	17.23	0.629	2.05	0.0
189	29.25	17.36	0.707	2.11	0.0
190	30.42	18.06	0.655	2.98	0.0
191	28.44	17.15	0.589	3.09	0.0
192	27.60	17.58	0.587	3.23	0.0
193	23.94	15.50	0.741	2.34	0.0
194	31.32	15.23	0.719	2.03	0.0
195	32.19	19.05	0.817	3.30	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
196	26.99	17.67	0.716	2.77	0.0
197	26.30	19.29	0.741	3.75	0.0
198	18.07	14.38	0.912	2.62	0.0
199	31.87	14.13	0.591	3.28	0.0
200	31.77	15.85	0.579	2.72	0.0
201	25.32	15.96	0.633	2.57	0.0
202	28.82	18.93	0.868	3.75	0.0
203	29.20	20.37	0.925	2.44	0.0
204	31.26	22.16	0.865	2.77	0.0
205	22.69	20.10	0.841	2.50	0.0
206	26.69	19.75	0.883	3.12	0.0
207	25.52	19.23	0.957	2.60	1.0
208	27.75	19.47	0.926	2.91	0.0
209	27.75	19.97	0.973	3.16	0.9
210	29.49	20.95	0.989	3.18	0.0
211	28.83	21.09	0.947	2.53	0.0
212	30.42	20.56	0.904	2.38	0.0
213	27.77	18.76	1.028	2.06	0.0
214	22.76	16.98	1.021	1.70	0.0
215	18.15	15.96	1.087	1.87	0.0
216	26.30	15.77	0.983	2.13	0.0
217	26.91	18.33	0.920	2.51	0.0
218	27.71	19.26	0.929	2.45	0.0
219	18.67	16.90	1.112	1.92	0.0
220	22.43	17.85	0.945	2.24	0.0
221	24.37	18.60	0.931	2.60	0.0
222	24.06	17.78	0.935	2.06	0.0
223	20.76	18.40	0.986	2.11	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
224	16.97	15.34	0.983	2.73	0.0
225	27.70	15.43	0.962	1.80	0.0
226	25.17	15.04	0.762	2.74	0.0
227	28.92	15.43	0.645	2.88	0.0
228	28.91	15.63	0.584	2.13	0.0
229	28.84	16.31	0.600	1.67	0.0
230	28.77	16.47	0.605	1.80	0.0
231	28.49	16.96	0.674	1.45	0.0
232	25.91	20.22	0.699	3.55	0.0
233	23.92	18.94	0.838	2.47	0.0
234	18.39	16.16	1.001	2.10	0.0
235	13.83	14.13	1.036	2.44	0.0
236	19.66	14.19	1.034	3.89	0.0
237	17.32	12.27	0.872	1.57	0.0
238	22.28	12.16	0.764	2.40	0.0
239	17.72	12.42	0.751	2.09	0.0
240	19.52	10.74	0.737	1.64	0.0
241	25.02	12.30	0.641	1.90	0.0
242	25.16	14.42	0.660	1.75	0.0
243	26.55	16.35	0.718	2.40	0.0
244	22.31	16.34	0.763	2.39	1.2
245	21.67	14.18	0.734	1.84	0.0
246	20.21	13.60	0.684	1.55	0.0
247	15.15	11.93	0.744	2.05	0.0
248	19.60	10.92	0.655	1.38	0.0
249	18.14	10.94	0.585	1.81	0.0
250	21.19	11.39	0.619	1.75	0.0
251	20.73	9.73	0.606	1.46	0.0

Table 6.–Daily weather data at site 1, San Luis Valley, Colorado, 1987–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
252	19.62	9.66	0.575	1.86	0.0
253	23.26	10.64	0.561	1.53	0.0
254	19.30	10.71	0.535	2.02	0.0
255	21.36	11.51	0.531	1.79	0.0
256	22.59	13.18	0.576	2.40	0.0
257	20.87	10.26	0.564	2.33	0.0
258	18.90	8.43	0.473	2.24	0.0
259	22.49	11.62	0.509	1.81	0.0
260	18.18	11.46	0.459	1.78	0.0
261	23.41	10.66	0.475	1.34	0.0
262	23.01	11.24	0.473	1.70	0.0
263	22.41	11.43	0.516	1.94	0.0
264	22.42	12.28	0.532	1.93	0.0
265	22.20	11.30	0.513	1.40	0.0
266	22.73	12.98	0.521	1.63	0.0
267	20.01	13.79	0.487	2.18	0.0
268	14.30	10.78	0.461	1.89	0.0
269	21.87	12.03	0.562	1.65	0.0
270	14.88	8.95	0.545	2.24	0.0
271	21.10	9.53	0.501	1.37	0.0
272	21.63	10.22	0.467	1.92	0.0
273	21.35	11.08	0.468	1.67	0.0
274	21.40	12.15	0.488	1.70	0.0
275	20.96	11.64	0.427	1.63	0.0
276	20.79	12.22	0.459	1.85	0.0
277	20.48	11.11	0.413	1.44	0.0
278	20.26	11.27	0.410	1.52	0.0
279	20.35	9.71	0.405	1.23	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
280	19.06	8.40	0.388	1.03	0.0
281	17.94	11.15	0.417	1.91	0.0
282	18.93	10.47	0.435	2.20	0.0
283	18.78	11.51	0.426	2.14	0.0
284	19.27	9.93	0.408	1.41	0.0
285	13.44	10.92	0.453	1.44	0.0
286	10.58	11.16	0.601	2.86	0.0
287	14.18	7.85	0.565	3.22	0.0
288	14.63	6.75	0.458	1.52	0.0
289	18.62	4.89	0.373	1.31	0.0
290	18.48	6.67	0.374	1.40	0.0
291	18.16	6.12	0.337	1.42	0.0
292	17.95	5.63	0.325	1.59	0.0
293	17.97	3.27	0.305	1.39	0.0
294	17.80	4.10	0.318	1.32	0.0
295	17.32	4.72	0.290	1.25	0.0
296	14.58	6.54	0.353	1.33	0.0
297	11.03	8.09	0.531	2.65	0.0
298	12.03	7.63	0.535	2.69	0.0
299	16.55	4.54	0.388	1.34	0.0
300	16.64	4.70	0.356	1.30	0.0
301	12.19	5.29	0.328	1.26	0.0
302	13.26	7.80	0.452	1.93	0.0
303	13.84	7.13	0.495	2.99	0.0
304	14.50	5.80	0.399	1.88	0.0
305	9.49	8.02	0.638	3.28	0.0
306	14.83	5.45	0.505	3.31	0.0
307	12.85	3.54	0.446	0.96	0.0

Table 6.–Daily weather data at site 1, San Luis Valley, Colorado, 1987–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
308	15.29	4.86	0.403	1.28	0.0
309	13.41	5.23	0.486	2.32	0.0
310	10.68	5.79	0.541	3.22	0.0
311	8.69	2.07	0.378	1.80	0.0
312	14.67	2.02	0.313	1.93	0.0
313	14.67	-0.08	0.276	1.17	0.0
314	13.78	1.66	0.288	1.79	0.0
315	12.62	1.72	0.302	1.75	0.0
316	13.92	-0.41	0.273	1.04	0.0
317	12.28	1.74	0.276	1.60	0.0
318	10.41	3.81	0.340	3.90	0.0
319	3.39	-2.44	0.344	1.65	0.0
320	13.93	-5.33	0.224	1.18	0.0
321	13.92	-0.41	0.273	1.04	0.0
322	13.42	-7.13	0.176	1.45	0.0
323	13.36	-5.91	0.190	1.36	0.0
324	12.73	-3.12	0.238	1.20	0.0
325	12.81	-2.13	0.245	1.87	0.0
326	12.73	-3.12	0.238	1.20	0.0
327	9.06	-3.89	0.242	0.77	0.0
328	12.74	-3.86	0.225	1.41	0.0
329	11.98	-4.32	0.247	0.96	0.0
330	10.36	-3.01	0.281	1.43	0.0
331	11.63	-2.70	0.204	2.03	0.0
332	11.37	-4.19	0.201	1.78	0.0
333	10.58	-2.22	0.256	1.90	0.0
334	11.18	1.53	0.288	3.17	0.0
335	11.55	-8.81	0.158	1.06	0.0

Table 6.--Daily weather data at site 1, San Luis Valley, Colorado, 1987--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
336	11.31	-5.24	0.202	1.75	0.0
337	12.73	-3.12	0.238	1.20	0.0
338	10.78	-4.45	0.251	0.85	0.0
339	7.79	-2.04	0.305	1.03	0.0
340	11.07	-3.25	0.275	0.86	0.0
341	10.36	-3.01	0.281	1.43	0.0
342	11.63	-2.70	0.204	2.03	0.0
343	11.37	-4.19	0.201	1.78	0.0
344	10.58	-2.22	0.256	1.90	0.0
345	11.18	1.53	0.288	3.17	0.0
346	11.40	-4.19	0.182	1.29	0.0
347	10.90	-6.77	0.169	1.99	0.0
348	9.50	-10.63	0.128	1.32	0.0
349	11.19	-14.40	0.089	1.13	0.0
350	8.43	-10.56	0.113	0.95	0.0
351	9.14	-5.29	0.184	1.18	0.0
352	5.67	-2.80	0.306	1.51	0.0
353	5.22	-3.70	0.287	1.60	0.0
354	8.07	-6.77	0.215	0.88	0.0
355	9.29	-9.90	0.159	1.04	0.0
356	9.66	-6.09	0.198	3.05	0.0
357	11.30	-0.55	0.249	4.69	0.0
358	5.84	-7.39	0.200	2.90	0.0
359	6.93	-9.64	0.165	1.69	0.0
360	3.91	-10.87	0.144	1.23	0.0
361	2.13	-13.56	0.112	1.34	0.0
362	5.60	-7.82	0.195	1.46	0.0
363	9.47	-3.71	0.218	2.57	0.0

Table 6.–Daily weather data at site 1, San Luis Valley, Colorado, 1987–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; wind speed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
364	11.87	-3.99	0.236	3.47	0.0
365	12.05	-3.98	0.238	1.28	0.0

Table 7.–Daily weather data at site 1, San Luis Valley, Colorado, 1988

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; -99.99, missing data; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
1	12.31	-11.91	0.098	-99.99	0.0
2	11.89	-18.05	0.069	-99.99	0.0
3	12.34	-15.34	0.086	-99.99	0.0
4	8.90	-12.12	0.111	-99.99	0.0
5	9.98	-3.83	0.252	-99.99	0.0
6	10.53	-5.59	0.220	-99.99	0.0
7	8.17	-7.26	0.210	-99.99	0.0
8	7.92	-17.73	0.081	-99.99	0.0
9	9.77	-17.53	0.079	-99.99	0.0
10	11.41	-16.72	0.081	-99.99	0.0
11	10.46	-10.32	0.164	-99.99	0.0
12	12.31	-11.91	0.098	-99.99	0.0
13	11.89	-18.05	0.069	-99.99	0.0
14	12.34	-15.34	0.086	-99.99	0.0
15	8.90	-12.12	0.111	-99.99	0.0
16	9.98	-3.83	0.252	-99.99	0.0
17	10.53	-5.59	0.220	-99.99	0.0
18	7.82	-4.06	0.252	-99.99	0.0
19	12.40	-9.94	0.133	-99.99	0.0
20	13.19	-19.47	0.059	-99.99	0.0
21	9.01	-17.98	0.066	-99.99	0.0
22	13.11	-18.48	0.067	-99.99	0.0
23	13.01	-12.93	0.104	-99.99	0.0
24	13.62	-10.96	0.100	-99.99	0.0
25	13.44	-16.20	0.075	-99.99	0.0
26	13.78	-13.93	0.098	-99.99	0.0
27	13.81	-12.94	0.110	-99.99	0.0

Table 7.--Daily weather data at site 1, San Luis Valley, Colorado, 1988--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; -99.99, missing data; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
28	13.19	-12.70	0.116	-99.99	0.0
29	11.03	-10.51	0.141	-99.99	0.0
30	14.27	-2.47	0.250	-99.99	0.0
31	11.94	-5.08	0.194	-99.99	0.0
32	11.41	-1.03	0.272	-99.99	0.0
33	10.98	-0.19	0.369	-99.99	0.0
34	10.04	-1.37	0.307	-99.99	0.0
35	12.11	-9.86	0.137	-99.99	0.0
36	15.50	-13.48	0.102	-99.99	0.0
37	15.64	-12.64	0.107	-99.99	0.0
38	14.66	-12.90	0.107	-99.99	0.0
39	16.14	-10.01	0.133	-99.99	0.0
43	15.46	-8.58	0.143	1.23	0.0
44	16.64	-6.84	0.145	3.12	0.0
45	16.81	-6.97	0.127	2.55	0.0
46	16.35	-8.52	0.127	1.38	0.0
47	17.01	-7.36	0.148	1.47	0.0
48	15.75	-5.55	0.160	1.81	0.0
49	14.81	-8.63	0.129	1.21	0.0
50	17.13	-8.50	0.132	1.45	0.0
51	17.96	-6.51	0.151	2.05	0.0
52	18.30	-5.97	0.162	1.31	0.0
53	18.33	-5.10	0.171	1.54	0.0
54	18.73	-4.75	0.175	1.26	0.0
55	18.35	-5.07	0.170	1.18	0.0
56	18.67	-4.30	0.182	1.10	0.0
57	18.50	-3.11	0.200	0.98	0.0
58	18.30	-1.07	0.232	1.09	0.0

Table 7.--Daily weather data at site 1, San Luis Valley, Colorado, 1988--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; -99.99, missing data; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
59	16.32	1.62	0.280	1.40	0.0
60	16.49	0.20	0.280	1.38	0.0
61	19.59	2.48	0.293	1.79	0.0
62	16.88	0.38	0.248	1.85	0.0
63	15.60	-0.22	0.250	1.42	0.0
64	18.91	0.76	0.245	1.96	0.0
65	19.54	0.04	0.209	1.77	0.0
66	20.52	1.81	0.250	2.18	0.0
67	7.93	-1.07	0.181	4.55	0.0
68	21.03	-2.97	0.160	2.59	0.0
69	20.69	1.01	0.226	1.72	0.0
70	18.40	-1.01	0.182	5.03	0.0
71	14.17	-4.02	0.147	2.83	0.0
72	18.07	-4.27	0.158	1.80	0.0
73	19.83	-5.63	0.147	2.90	0.0
74	22.56	-4.43	0.152	1.77	0.0
75	21.88	1.36	0.215	3.63	0.0
76	14.78	-0.72	0.196	4.26	0.0
77	20.18	-4.58	0.156	2.31	0.0
78	22.17	-2.08	0.178	2.45	0.0
79	23.40	1.40	0.227	1.67	0.0
80	23.84	3.14	0.267	1.45	0.0
81	24.11	4.64	0.291	1.79	0.0
82	21.61	6.32	0.300	2.37	0.0
83	23.85	6.30	0.315	2.75	0.0
84	23.63	3.13	0.237	4.46	0.0
85	24.35	4.88	0.278	2.56	0.0
86	24.80	7.29	0.323	1.83	0.0

Table 7.--Daily weather data at site 1, San Luis Valley, Colorado, 1988--Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; -99.99, missing data; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
87	24.73	10.63	0.375	5.38	0.0
88	24.34	3.24	0.241	5.46	0.0
89	25.36	-0.62	0.193	2.79	0.0
90	18.37	3.75	0.249	5.73	0.0
91	9.24	-1.24	0.189	4.34	0.0
92	11.16	-0.97	0.193	2.07	0.0
93	24.42	4.29	0.280	2.86	0.0
94	25.59	5.67	0.306	1.98	0.0
95	20.87	7.31	0.318	3.31	0.0
96	26.56	7.33	0.308	4.11	0.0
97	26.72	8.16	0.342	1.69	0.0
98	26.96	10.87	0.390	2.38	0.0
99	21.88	9.49	0.358	3.86	0.0
100	25.77	2.33	0.233	2.26	0.0
101	27.50	1.69	0.238	1.94	0.0
102	27.48	5.42	0.302	1.59	0.0
103	27.58	9.10	0.364	1.59	0.0
104	23.76	11.42	0.403	2.56	0.0
105	18.67	9.15	0.350	3.42	0.0
106	16.84	9.45	0.402	2.54	0.0
107	7.92	3.68	0.346	2.34	0.0
108	15.97	2.02	0.318	1.42	0.0
109	19.11	4.34	0.333	1.62	0.0
110	26.19	7.65	0.357	2.35	0.0
111	26.65	8.80	0.347	3.41	0.0
112	22.29	6.76	0.307	4.35	0.0
113	16.37	3.25	0.254	3.43	0.0
114	25.42	4.22	0.270	2.85	0.0

Table 7.–Daily weather data at site 1, San Luis Valley, Colorado, 1988–Continued

[$(MJ/m^2)/d$, megajoules per square meter per day; °C, degrees Celsius; kPa, kilopascals; m/s, meters per second; mm/d, millimeters per day; -99.99, missing data; windspeed measured at 2-meter height]

Julian day	Solar radiation, R_s $[(MJ/m^2)/d]$	Air temperature, T (°C)	Vapor pressure, e (kPa)	Windspeed, u (m/s)	Precipitation, P (mm/d)
115	18.76	3.30	0.246	2.96	0.0
116	27.96	5.61	0.299	3.66	0.0
117	29.44	8.05	0.323	2.76	0.0
118	28.63	9.38	0.361	1.64	0.0
119	23.03	10.55	0.381	2.60	0.0
120	26.96	11.43	0.441	2.31	0.0
121	27.44	12.52	0.431	4.23	0.0
122	22.77	9.10	0.341	5.34	0.0
123	26.91	4.44	0.259	5.94	0.0
124	27.94	6.87	0.307	2.26	0.0
125	27.50	9.82	0.370	3.42	0.0
126	23.04	11.41	0.394	3.96	0.0
127	28.05	9.26	0.338	7.54	0.0
128	31.43	6.38	0.294	4.09	0.0
129	24.96	6.27	0.292	2.62	0.0
130	30.60	9.67	0.363	1.76	0.0
131	27.38	10.04	0.371	2.28	0.0
132	31.08	10.81	0.411	2.05	0.0
133	31.07	14.65	0.476	2.22	0.0
134	27.68	15.33	0.491	2.98	0.0
135	25.68	15.26	0.489	2.26	0.0
136	31.41	15.80	0.513	2.35	0.0
137	25.41	15.02	0.480	3.09	0.0
138	22.72	13.85	0.486	2.35	0.8
139	17.60	10.59	0.491	2.45	0.4

Water-Table Measurements

Selected piezometers were used to measure the water-table depth at the three sites, although the schedule and selection were somewhat erratic. Therefore, to supplement the piezometer measurements, some data are presented that were obtained from randomly located soil-sampling holes that penetrated the water table and from two tensiometers that were sometimes below the water table at site 1.

Because the piezometers and tensiometers used at site 1 were in locations that had different land-surface altitudes, a description of their locations is necessary to determine the mean water-table depth for the site at any point in time. The U.S. Bureau of Reclamation (BOR) installed three volumetric lysimeters at site 1 prior to 1985. Each lysimeter was equipped with a nearby piezometer that penetrated the water table as much as 2 m. The lysimeters enclosed either bare soil, saltgrass, or greasewood. The piezometer next to the lysimeter that enclosed bare soil (BS) and the piezometer next to the lysimeter that enclosed saltgrass (SG) were located in a salt flat, where the land-surface altitude was very near the minimum for the site. Therefore the water-table depths indicated by these piezometers probably were very near the minimum for the site. The piezometer next to the lysimeter that enclosed greasewood (GW) was located on a hummock, where the land surface was approximately 0.6 m above the salt flat. Tensiometer #1 was located in the salt flat and, therefore, probably indicated very near the minimum water-table depth for the site. Tensiometer #2 was located on one of the highest-altitude hummocks at the site, where the land surface was approximately 1.0 m above the salt flat. Therefore the water-table depth indicated by this tensiometer probably was very near the maximum for the site.

Because the hummocks and salt flats were, on average, about equal in area at site 1, and because the highest-altitude hummocks were about 1.0 m above the salt flats, the mean altitude of the land surface was less than 0.5 m above the salt flats. In this report, mean land-surface altitude is arbitrarily taken to be 0.3 m above the salt flats, and 0.7 m below the land-surface altitude at tensiometer #2. Therefore the mean water-table depth is taken to be about 0.3 m greater than the water-table depth at BS, SG, or tensiometer #1, about 0.3 m less than the water-table depth at GW, and about 0.7 m less than the water-table depth at tensiometer #2. Care was taken to define the relation between the mean water-table depth and the various water-table measurements at site 1 because the topographic relief is large and the water table is shallow at that site, and because no one piezometer or tensiometer at the site was measured during every site visit. Water table depths at site 1 are presented in tables 8-10.

Table 8.–Water-table depths at site 1, San Luis Valley, Colorado, 1985
[All depths in meters below land surface]

Julian day	Tensiometer #1	Tensiometer #2	Soil-sampling hole
135	--	--	0.45
136	--	--	0.11
136	--	--	0.30
143	--	--	1.20
178	0.81	--	--
179	--	1.84	--
204	0.86	--	--
242	1.10	--	--
275	1.03	--	1.68
275	--	--	1.14
275	--	--	1.73
311	--	--	1.50
312	0.82	1.80	--

Table 9.–Water-table depths at sites 1, 2, and 3, San Luis Valley, Colorado, 1986
[BS, piezometer next to lysimeter enclosing bare soil; GW, piezometer next to lysimeter enclosing greasewood; T1, tensiometer #1; T2, tensiometer #2; SH, soil-sampling hole; 25-W2, piezometer 7.6 m west of Salvage Well 3; 200-W1, piezometer 61.0 m west of Salvage Well 3; OW-377, Observation Well 377; all depths in meters below land surface; --, no data]

	Site 1					Site 2			Site 3
Julian day	BS	GW	T1	T2	SH	25-W2	200-W1	SH	OW-377
113	--	--	--	--	0.65	--	--	--	--
115	0.50	1.10	0.42	1.45	--	--	--	--	--
141	--	--	--	--	--	--	--	2.6	--
142	0.6	1.25	--	--	--	2.76	--	--	--
143	--	--	0.59	1.59	--	--	--	--	--
176	0.78	1.40	--	--	--	2.86	--	--	4.42
178	--	--	0.82	1.80	--	--	--	--	--
206	--	--	1.00	--	--	--	--	--	--
225	--	--	--	--	--	--	--	--	4.42
233	1.25	1.5	1.10	--	--	[1]6.5	[1]4.0	--	--
254	--	--	--	--	--	--	--	--	4.5
261	1.10	1.50	1.10	--	--	--	--	--	--
295	0.92	1.58	--	--	--	--	--	--	--
297	--	--	--	--	--	--	--	4.1	--

[1]Salvage Well 3 was being pumped at time of measurement.

Table 10.--Water-table depths at sites 1, 2, and 3, San Luis Valley, Colorado,1987 and 1988

[BS, piezometer next to lysimeter enclosing bare soil; GW, piezometer next to lysimeter enclosing greasewood; SG, piezometer next to lysimeter enclosing saltgrass; T1, tensiometer #1; T2, tensiometer #2; SH, soil- sampling hole; 25-W2, piezometer 7.6 m west of Salvage Well 3; 100-W1, piezometer 30.5 m west of Salvage Well 3; 200-W1, piezometer 61.0 m west of Salvage Well 3; OW-377, Observation Well 377; all depths in meters below land surface; --, no data]

	Site 1					Site 2			Site 3
Julian day	BS	GW	SG	T1	T2	25-W2	100-W1	200-W1	OW-377
					1987				
55	1.27	1.53	--		--	--	--	--	--
99	0.60	1.16	0.52	--	--	[1]5.24	[1]4.76	[1]4.18	5.11
126	0.54	1.14	--	--	--	--	3.8	3.5	5.0
127	--	--	--	0.56	1.54	--	--	--	--
168	0.92	1.48	0.85	0.87	--	[1]4.83	[1]4.40	[1]3.84	5.21
210	--	--	--	--	--	[1]4.92	[1]4.48	[1]3.91	5.33
211	1.34	1.90	1.24	120	--	--	--	--	--
244	--	--	--	--	--	[1]4.95	[1]4.54	[1]4.01	--
245	--	--	--	--	--	--	--	--	5.43
246	1.47	2.02	1.35	1.25	--	--	--	--	--
300	1.39	1.92	1.27	1.23	--	--	--	--	--
301	--	--	--	--	--	[1]7.33	[1]6.24	[1]5.23	5.55
					1988				
139	1.22	1.40	1.16	1.06	--	--	--	--	5.49
140	--	--	--	--	--	5.56	5.13	4.58	--

[1]Salvage Well 3 was being pumped at time of measurement.

At site 2, one of the BOR production wells, Salvage Well 3, was located about 20 m northeast of the flux-measurement sensors. It was pumping during one visit in 1986 and during all but one visit in 1987 (tables 9 and 10). Three piezometers installed by BOR (labeled 25-W2, 100- W1, and 200-W1) were used to measure the water-table depth at various times. Piezometer 25-W2 was 7.6 m (25 ft) west of Salvage Well 3 and was 13.7 m deep. Piezometer 100-W1 was 30.5 m (100 ft) west of Salvage Well 3 and was 23.8 m deep. Piezometer 200-W1 was 61.0 m (200 ft) west of Salvage Well 3 and was about 24 m deep. As indicated in the section on Flux Measurements, the Bowen-ratio and eddy-correlation measurements of LE and H are representative of about 1 ha of land upwind of the instruments, known as the source area. For the prevailing southwest wind direction the water table underlying this source area at site 2 probably was affected very little by the cone of depression surrounding Salvage Well 3. Because the water table at piezometer 200-W1 also probably was affected very little, the water-table depth at this piezometer is assumed to be the mean water-table depth at site 2. The water-table at piezometers 25-W2 and 100-W1 was significantly affected by Salvage Well 3 at times. Water-table depths at site 2 are presented in tables 9 and 10.

At site 3, micrometeorological sensors were located about 20 m southwest of a piezometer labeled Observation Well 377, installed by BOR approximately 0.4 km south of Salvage Well 26. Total depth was 6.0 m below land surface. Because the relief at this site was much less than at sites 1 and 2 (on the order of 0.2 m), the water-table depth indicated by this piezometer is assumed to be the mean water-table depth at the site. Water- table depth at site 3 is presented in tables 9 and 10.

ACCURACY OF FLUX MEASUREMENTS

Under ideal conditions, standard errors of R, G, H, and LE (s_R, s_G, s_H, and s_{LE}) are considered to be between 5 and 10 percent of the measured values (Shuttleworth and others, 1988) if H and LE are measured using eddy correlation. The standard errors of the measurements presented here probably exceed this range for several reasons. First, the heterogeneity of the vegetated surface made measurement errors in R and G dependent on sensor location. Second, the unevenness of the land surface and vegetation could cause the mean vertical windspeed, $\overline{w}$, at the sonic anemometer to be slightly non-zero, whereas the measurements of w were made by assuming that $\overline{w} = 0$. Non-zero values of $\overline{w}$ would cause errors in the values of LE and H measured using the eddy-correlation method. Third, the eddy-correlation sensors were occasionally obstructed because the wind direction was somewhat variable. Instrument orientation was based on the prevailing wind direction; but, if the direction changed such that the instrument supports were upwind of the sensors, errors could be caused in the measured values of LE and H.

In this study, 56 24-hr periods of flux measurements (using eddy-correlation values of H and LE) were used with the energy-balance equation (eq. 2) to estimate the errors in the measurements. These periods were selected from tables 1-3, using periods that began at midnight whenever possible, and avoiding the use of overlapping periods. For each 24-hr period, a value of the energy-balance closure, B, was computed as: $B = R - G - H - LE$. A histogram of B (fig. 2) indicates that values of B were approximately normally distributed about zero. The mean value of B was 0.003 $(MJ/m^2)/d$. The coefficients of variation of each of the energy- balance components were assumed to be equal: $s_R/|R| = s_G/|G| = s_H/|H| = s_{LE}/|LE| = C_1$. This assumption is a reasonable first approximation in view of the uncertainties in the measurements of each of the energy-balance components. It was also assumed that measurement errors in R, G, H, and LE were randomly distributed, and that the mean error in each was zero. The fact that the mean value of B was near zero [0.003 $(MJ/m^2)d$] is consistent with this assumption, although it does not necessarily imply that the assumption is correct. (That is, there may be compensating non-zero mean errors in two or more of the energy balance terms, leading to a near-zero value of B.) With these assumptions, a

method of moments (Mood and others, 1974, p. 274) was used to compute C_1 as (B.M. Troutman, U.S. Geological Survey, written commun., 1991):

$$C_1 = \{1/\left[(\overline{R^2} + \overline{G^2} + \overline{H^2} + \overline{LE^2})/s_B^2 - 1\right]\}^{1/2} \quad (7)$$

where s_B^2 is the variance of B, and overbars denote 56-day means. The calculated value of C_1 was 0.142, indicating that the standard error of each of the daily-flux totals was about 14 percent.

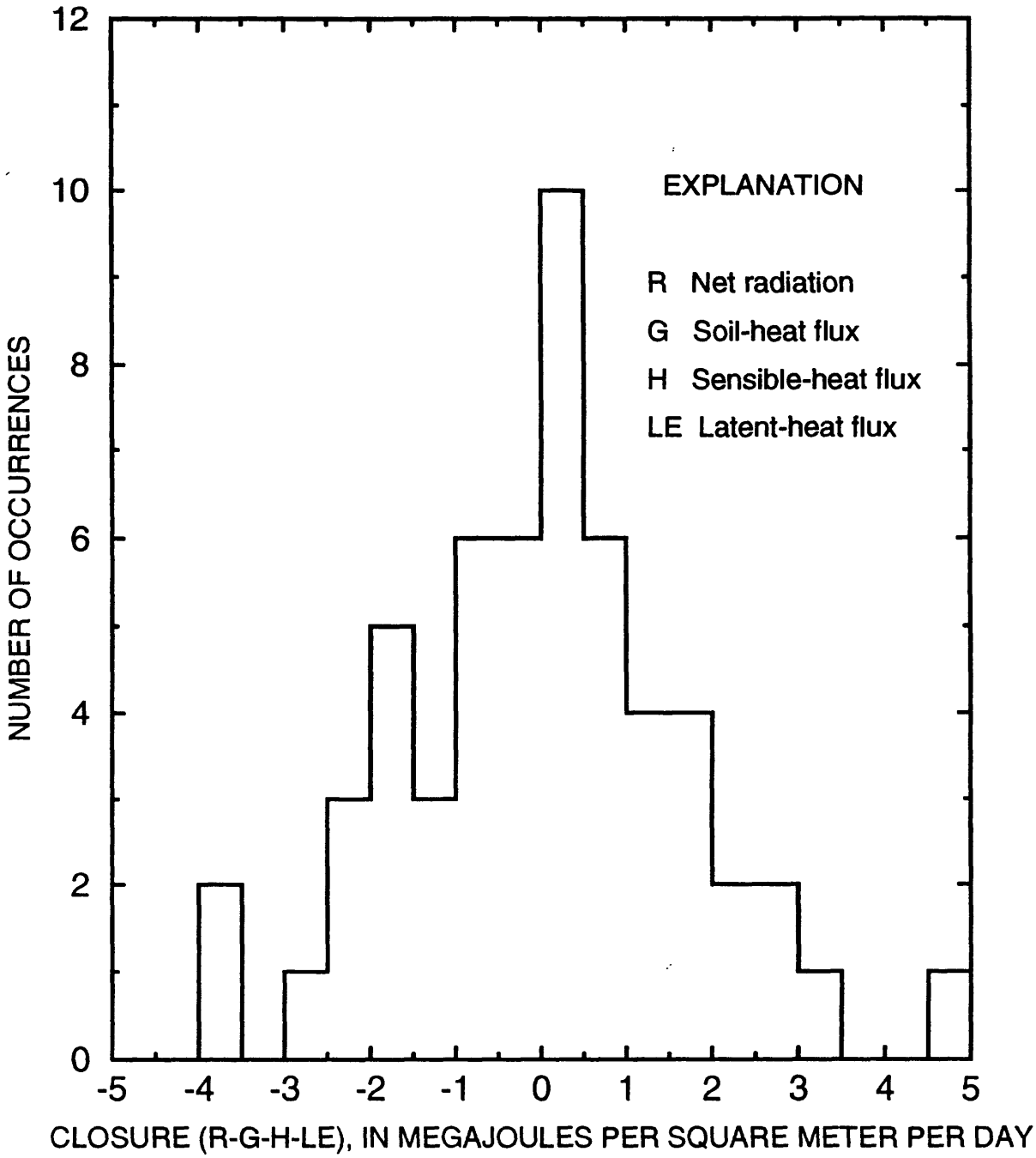

Figure 2.--Histogram of the energy-balance closure at sites 1, 2, and 3 in the San Luis Valley, Colorado

The energy-balance approach could not be used to estimate errors in the Bowen-ratio values of LE and H because the energy-balance closure, B, is always equal to zero when using the Bowen-ratio method. Another possible approach is to estimate the magnitudes of the errors in the variables and assumptions used to calculate LE and H (eqs. 2-4), and to use a propagation- of-errors procedure to estimate the magnitudes of the resulting errors in LE and H. This approach was not used because it was difficult to estimate the magnitudes of the errors in ΔT and Δe and the error inherent in the assumption that the eddy diffusivities for heat and water-vapor transport were equal. Instead, periods of simultaneous operation of eddy-correlation and Bowen-ratio sensors at the same site (site 1) were used to estimate the magnitudes of the errors in the Bowen-ratio values of LE and H. All of these Bowen-ratio measurements (tables 1 and 2) were made before Julian day 177, 1986, and because of a data-logger programming error, they were based on instantaneous rather than mean temperature gradients. That is, the wet- and dry-bulb temperature data were sampled only once at the end of each 5-min interval, rather than being averaged over the interval. Therefore the values of H and LE calculated for the period before June 1986 using the Bowen-ratio method had a greater degree of random error than the values for the remainder of the study, but there is no reason to believe that these values would be biased. Assuming that measurement errors in the eddy-correlation and Bowen-ratio measurements of H and LE were randomly distributed and that the mean errors were zero, a method of moments (Mood and others, 1974, p. 274) was used to calculate the coefficient of variation of LE as measured by the Bowen-ratio method as (B.M. Troutman, U.S. Geological Survey, written commun., 1991):

$$C_2 = (\{2 + C_1^2 [1 - (\overline{LE_{EC}^2} + \overline{LE_{BR}^2})/s_{LE}^2]\}/[(\overline{LE_{EC}^2} + \overline{LE_{BR}^2})/s_{LE}^2 - 1])^{1/2} \quad (8)$$

and the coefficient of variation of H as measured by the Bowen-ratio method as:

$$C_3 = (\{2 + C_1^2 [1 - (\overline{H_{EC}^2} + \overline{H_{BR}^2})/s_H^2]\}/[(\overline{H_{EC}^2} + \overline{H_{BR}^2})/s_H^2 - 1])^{1/2} \quad (9)$$

where C_2 is the coefficient of variation of LE_{BR}, LE_{EC} is the eddy-correlation measurement of LE, LE_{BR} is the Bowen-ratio measurement of LE, s_{LE}^2 is the variance of the quantity ($LE_{EC} - LE_{BR}$), C_3 is the coefficient of variation of H_{BR}, H_{EC} is the eddy-correlation measurement of H, H_{BR} is the Bowen-ratio measurement of H, s_H^2 is the variance of the quantity ($H_{EC} - H_{BR}$), and overbars denote means. The mean value of the quantity ($LE_{EC} - LE_{BR}$) was -0.079 $(MJ/m^2)/d$, and the mean value of the quantity ($H_{EC} - H_{BR}$) was 0.466 $(MJ/m^2)/d$. The calculated value of C_2 was 0.174 and the calculated value of C_3 was 0.161. The values of C_2 and C_3 are appropriate for only those Bowen-ratio measurements that were made before Julian day 177, 1986, and were based on instantaneous temperature gradients. Gradients measured after Julian day 176, 1986 were calculated from mean temperatures, so those measurements of H and LE were more accurate, and had smaller coefficients of variation than the above analysis would indicate. Because simultaneous comparisons between fluxes calculated from mean gradients and eddy- correlation fluxes are not available, the coefficients of variation for the Bowen-ratio measurements of H and LE made after Julian day 176, 1986 cannot be calculated directly. Instead, the values of C_2 and C_3 calculated for data collected before Julian day 177, 1986 are presented as upper limits of the coefficients of variation for data collected after Julian day 176, 1986.

SUMMARY

Micrometeorological measurements of net radiation (R) soil-heat flux (G) sensible-heat flux (H) and latent-heat flux (LE) were made at sites within a closed basin in the southeastern part of the San Luis Valley, Colo., from May 1985 to May 1988. Latent-heat flux is the energy flux used to sustain the evapotranspiration rate, E. R, G, H, and LE are related to each other through an energy-balance equation. These flux measurements were made at only one site during 1985, and at two additional sites beginning in 1986. Vegetation consisted of wild shrubs, grasses, and cacti. Measurements were made for a few days at a time, about once a month during the growing season, and less frequently during the winter. Eddy-correlation and Bowen-ratio methods were used to measure H and LE.

An automated weather station located at the first site was used to measure solar radiation (R_s) air temperature (T) relative humidity (h) windspeed (u) and precipitation (P) continuously during the study period. Water-table depths were measured manually during site visits.

This report presents daily summaries of the flux measurements (including evapotranspiration) and weather data, and measurements of water- table depth. The weather variables and water-table depths are known to affect evapotranspiration rates, and are commonly used in evapotranspiration models.

Use of an energy-balance equation indicates that flux-measurement errors were randomly distributed and that mean errors were near zero. Daily totals of flux measurements were used with a method of moments to estimate standard errors of the flux measurements. The estimated standard error of R and G and of eddy-correlation measurements of H and LE was about 14 percent. The estimated standard error of the Bowen-ratio measurements of H was 16 percent or less, and of LE was 17 percent or less.

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