APPENDIX A: Potential Evapotranspiration Calculations.

Potential evapotranspiration was calculated using the Penman equation as modified by Doorenbos and Pruitt (1984) and Pruitt and Doorenbos (1977).

$$ET_p = R_nW + (1 - W)f(U_2)(e_s - e_a) \quad [A1]$$

where R_n is the net radiation in mm, W is a dimensionless weighting factor defined below, $f(U_2)$ is the wind function in mm/kPa, and $(e_s - e_a)$ is the atmospheric vapor pressure deficit in kPa.

Pruitt and Doorenbos (1977) and others have recommended using the Penman and other combination type equations on an hourly or better basis for calculations rather than a daily basis. Use of an hourly basis assures that the wind function and vapor pressure deficit will be more closely synchronized and may eliminate the need for different wind functions for different climates. For hourly calculations Pruitt and Doorenbos (1977) gave a daytime wind function as

$$f(U_2) = 0.030 + 0.0576(U_2) \quad [A2]$$

where U_2 is wind speed in m/s at 2 m height. Wind speeds, which were taken at 3 m height, were corrected to U_2 using the equation

$$U_2 = U_3/(0.1877\ln(3) + 0.87025) \quad [A3]$$

(Gay and Greenberg 1982). The nighttime wind function given by Pruitt and Doorenbos (1977) was:

$$f(U_2) = 0.0125 + 0.0439(U_2) \quad [A4]$$

The daytime wind function was used when solar radiation was greater than zero, otherwise the nighttime wind function was used.

The saturation vapor pressure e_s, kPa, was calculated using Murray's (1967) equation:

$$e_s = 0.61078 \exp(17.2693882\ T/(237.30 + T)) \quad [A5]$$

where T is the average air temperature, °C, over the period of calculation, i.e. 1 hour, 1/2 hour. The actual vapor pressure e_a, kPa, was calculated as

$$e_a = e_s\ (RH/100) \quad [A6]$$

where RH was the percent relative humidity.

The weighting factor W is defined as

$$W = \Delta/(\Delta + \gamma) \quad [A7]$$

where Δ is the slope of the saturation vapor pressure vs. temperature curve, Pa/°C, calculated by

$$\Delta = 44.0381 + 3.08004\ T + 0.05353118\ T^2 + 2.176223E\text{-}03\ T^3 \quad [A8]$$

where T is defined as above and the third order polynomial is a regression fit (r = 0.99995) to data published by Fritschen and Gay (1979, pp. 132-133).

The psychrometric constant, γ [Pa/°C], is defined as

$$\gamma = C_p P/(0.622\ L) \qquad [A9]$$

(Fritschen and Gay 1979) where C_p is the specific heat of dry air (1005 J/kg/°C), L is the latent heat of vaporization (J/kg), and P is the atmospheric pressure, kPa, calculated from

$$P = (101.3)10^{(-h/(18460\ +\ 0.18\ h\ +\ 72\ T))} \qquad [A10]$$

(Conrad and Pollak 1950, p. 334) where h is elevation, m, above MSL, T is defined as above, and the air pressure at MSL is assumed to be 101.3 kPa. The latent heat of vaporization of water, L, is a function of temperature:

$$L = 2500.25 - 2.365\ T \qquad [A11]$$

where T is defined as above.

The values of ET_p calculated periodically were summed for the 24 hour period from midnight to midnight to give daily ET_p estimates.

Since net radiation data were not available for the first two days but solar radiation data were available, a regression analysis was performed relating net to solar radiation for the 10 days for which both values were available on a half-hourly basis. A linear regression resulted in a straight line that described neither the morning nor the afternoon relationship but bisected the two (Figure A-1). Though the R^2 value of 0.964 was high, the hysteresis in the relationship between R_s and R_n clearly required separate equations, one for the morning and one for the afternoon, for good description. Polynomial models of 2nd, 3rd and 4th order were tried along with different times for dividing morning from afternoon. The apparent best relationships are graphed in Figure A-1. For times from midnight through 11:30 AM the equation relating R_n to R_s was

$$R_n = -0.06768897 + 0.7351206(R_s) - 0.07090492(R_s^2)$$
$$R^2 = 0.997 \qquad [A12]$$

For the period from 12:00 PM to midnight the equation was

$$R_n = -0.08696741 + 0.2344109(R_s) + 0.1955146(R_s^2)$$
$$R^2 = 0.994 \qquad [A13]$$

Although the R^2 values for these equations are not much different from that for the single linear regression, the description of the R_n to R_s relationship is qualitatively better. Monteith and Szeicz (1961) found a similar elliptical relationship between R_n and $(1 - \alpha)R_s$ over bare soil.

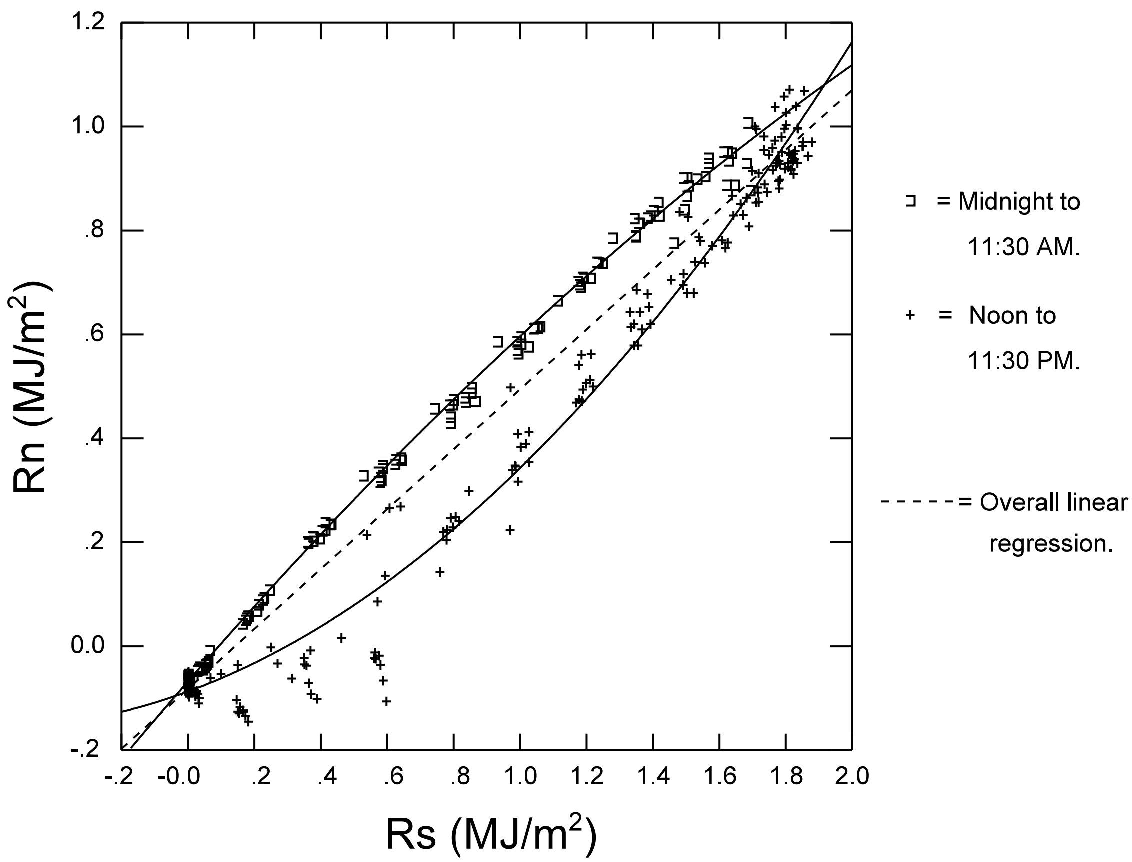

Figure 1-A. Linear and polynomial regressions of net radiation versus solar radiation for 10 days in April, 1985.

APPENDIX B. Comparison of approximate and exact forms of the Stefan-Boltzmann equation.

The energy balance model of Ben-Asher et al. (1983) contained two assumptions for calculation of outgoing longwave radiation. The first was that $(T_o^4 - T_d^4)$ could be approximated by:

$$T_o^4 - T_d^4 = 4\bar{T}_m^3 \Delta T \qquad [B1]$$

where $\Delta T = (T_o - T_d)$. This was shown in Equations 5-16, 5-17 and 5-18 with the resulting approximation for outgoing longwave radiation (Equation 5-19):

$$L_{o,out} - L_{d,out} \doteq \sigma\epsilon 4\bar{T}_m^3 \Delta T \qquad [B2]$$

where T is in °K. The second assumption was that the value of $\bar{T}_m^3$ varied little over the day so that $\bar{T}_m^3$ could be considered constant when Equation 5-23 was integrated. Here these assumptions are evaluated and the amount of error in Equation 5-19 (B2) is shown analytically.

The approximation in B1 can be arrived at by letting:

$$\Delta T = (T_o - T_d) \qquad [B3]$$

and

$$\bar{T}_m = (T_o + T_d)/2 \qquad [B4]$$

so that:

$$T_o = \bar{T}_m + \Delta T/2 \quad [B5]$$

and

$$T_d = \bar{T}_m - \Delta T/2 \quad [B6]$$

Now, expanding $T_o^4 - T_d^4$ using Equations B5 and B6 gives:

$$T_o^4 - T_d^4 = (\bar{T}_m + \Delta T/2)^4 - (\bar{T}_m - \Delta T/2)^4$$

$$T_o^4 - T_d^4 = (\bar{T}_m^2 + \bar{T}_m\Delta T + (\Delta T)^2/4)^2 - (\bar{T}_m^2 - \bar{T}_m\Delta T + (\Delta T)^2/4)^2$$

$$T_o^4 - T_d^4 = 4\bar{T}_m^3\Delta T + \bar{T}_m(\Delta T)^3$$

$$T_o^4 - T_d^4 = 4\bar{T}_m^3\Delta T[1 + (\Delta T)^2/(4\bar{T}_m^2)] \quad [B7]$$

and from Equations 5-14 and B6, an exact expression is:

$$L_{o,out} - L_{d,out} = \sigma\epsilon 4\bar{T}_m^3\Delta T[1 + (\Delta T)^2/(4\bar{T}_m^2)] \quad [B8]$$

Comparing B2 and B8 it is clear that the error in B2 and in 5-19 is:

$$(L_{o,out} - L_{d,out})_{error} = \sigma\epsilon\bar{T}_m\Delta T \quad [B9]$$

Evaluation of the error occurring when 5-19 is integrated over -3 to 9 hours and over -3 to 21 hours was done with a computer program (listed below) that integrated Equations 5-19 and B8 with a 15 minute time step. Soil temperature maxima and minima from day 96 of Experiment 2 (Figure 3-6) were used, and Equation 5-15 was used to predict temperatures (sinusoidal diurnal temperature wave). In the original energy balance model the value of $\bar{T}_m$ was assumed constant. This error was evaluated by defining $\bar{T}_m$ as:

$$\bar{T}_m = (\bar{T}_o + \bar{T}_d)/2 \qquad [B10]$$

where $\bar{T}_o$ and $\bar{T}_d$ were the average daily temperatures of dry and drying soil, respectively.

Two other cases were evaluated. The approximate form for longwave radiation given in Equation B2, but with T_d taking the place of $\bar{T}_m$. And, the case where $\bar{T}_m$ is defined as:

$$\bar{T}_m = \bar{T}_d \qquad [B11]$$

where $\bar{T}_d$ is the average daily drying soil surface temperature.

For integration from -3 to 9 hours the term $(L_o - L_d)$ was under-estimated by 13.7 % when $\bar{T}_m$ was assumed constant over the day and was defined by Equation B10 (Table B1). This was the definition used by Ben-Asher et al. (1983). When $\bar{T}_m$ was assumed constant and was defined by Equation B11 the term $(L_o - L_d)$ was under-estimated by 14.8 %. Equation B2 with T_d taking the place of $\bar{T}_m$ and with $\bar{T}_m = (T_o + T_d)/2$ under-estimated $(L_o - L_d)$ by 2.8 % and 0.01 %, respectively.

For integration from -3 to 21 hours the results were similar (Table B1, Figure B1). Equation 5-19 was a close approximation of the exact form. The assumption that $\bar{T}_m$ is

Table B1.

Program output.

For integration from -3 to 9 hours:

```
Enter the maximum reference dry soil surface temperature, deg. C: ? 53
Enter the maximum drying soil surface temperature, deg. C       : ? 46
Enter the minimum reference dry soil surface temperature, deg. C: ? 8
Enter the minimum drying soil surface temperature, deg. C       : ? 10
Calculate for 12 hours [1] or 24 hours [2]:? ? 1

                                                          Change
                                                        from exact.
Equation B2 with B11 gives          :  1163554  J/m^2.  -14.7973 %
Equation B2 with B10 gives          :  1178104  J/m^2.  -13.7319 %
Equation B2 with Tm = Td gives      :  1327753  J/m^2.   -2.7736 %
Equation B2 with B4 gives           :  1365507  J/m^2.   -0.0090 %
The exact form (Eq. B8 or 5-14) gives:  1365630  J/m^2.

Taking 1 mm of water evaporated as equal to 2.4E06 J/m^2,
Equation B2 with B11 gives          :  .4848143  mm water.
Equation B2 with B10 gives          :  .4908765  mm water.
Equation B2 with Tm = Td gives      :  .5532303  mm water.
Equation B2 with B4 gives           :  .5689612  mm water.
The exact form (Eq. B8 or 5-14) gives:  .5690125  mm water.
```

For integration from -3 to 21 hours:

```
Calculate for 12 hours [1] or 24 hours [2]:? ? 2

                                                          Change
                                                        from exact.
Equation B2 with B11 gives          :  1267456  J/m^2.  -16.9176 %
Equation B2 with B10 gives          :  1283305  J/m^2.  -15.8787 %
Equation B2 with Tm = Td gives      :  1480017  J/m^2.   -2.9841 %
Equation B2 with B4 gives           :  1525404  J/m^2.   -0.0089 %
The exact form (Eq. B8 or 5-14) gives:  1525540  J/m^2.

Taking 1 mm of water evaporated as equal to 2.4E06 J/m^2,
Equation B2 with B11 gives          :  .5281067  mm water.
Equation B2 with B10 gives          :  .5347103  mm water.
Equation B2 with Tm = Td gives      :  .6166735  mm water.
Equation B2 with B4 gives           :  .6355851  mm water.
The exact form (Eq. B8 or 5-14) gives:  .6356418  mm water.
```

constant over the day was clearly unwarranted, resulting in errors of about 15 %, although the absolute error appears to be only about 0.08 mm of water for sunny conditions in April.

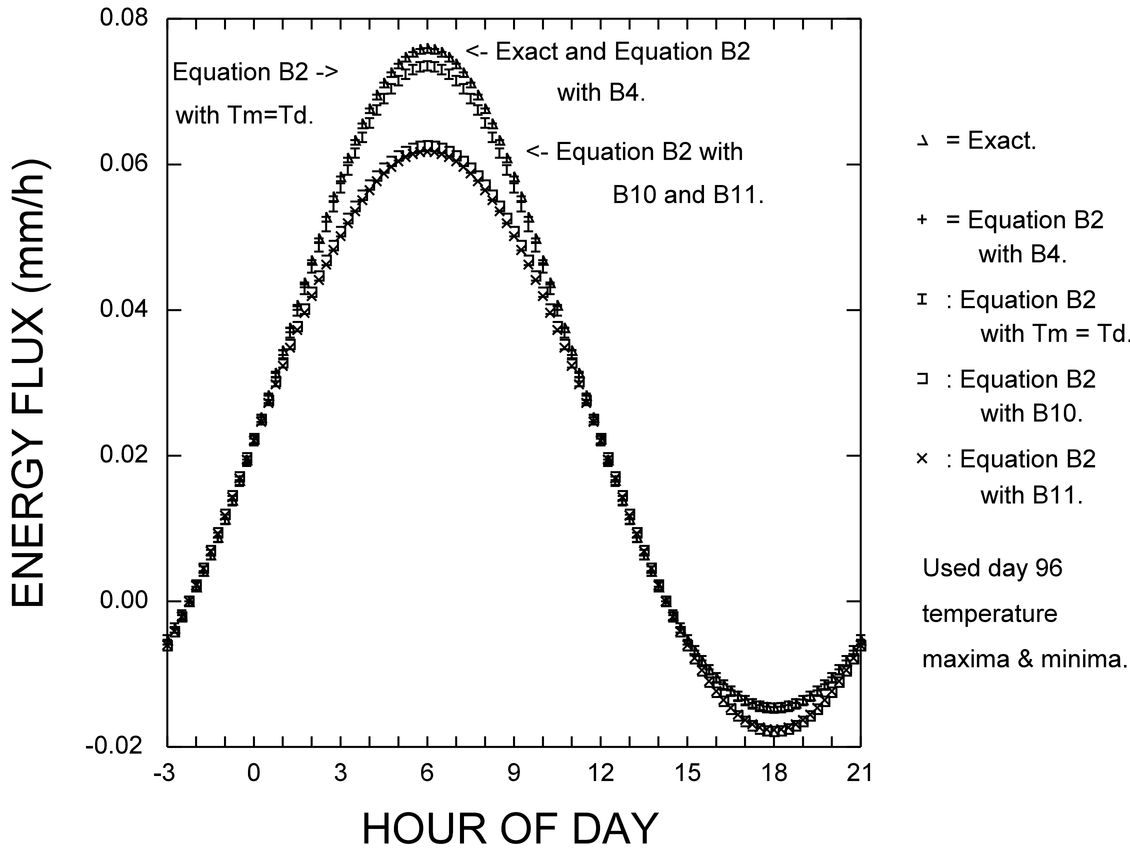

Figure B-1. Comparison of long wave outgoing radiation (mm/s) for the exact form of the Stephan-Boltzmann equation and 4 approximate forms.

Program listing.

```
'Program TEMPER.BAS
CLS : PRINT  'Written in Microsoft (R) QuickBASIC v. 4.0 by  S.R. Evett.
PRINT "   Program TEMPER.BAS tests the difference between 5 equations for"
PRINT "   long wave radiation from a soil surface by numerically integrating"
PRINT "   the equations over the interval -1/8 day to 3/8 day, or over the"
PRINT "   interval -1/8 day to 7/8 day.  The equations are:"
PRINT "   [1]    Lo-Ld = 4*e*s*(Tm)^3*(Tr-Td),         Equation B2 with"
PRINT                                                   Tm defined by B10."
PRINT "   [2]    Lo-Ld = 4*e*s*(Td)^3*(Tr-Td),         Equation B2 with"
PRINT                                                   Tm replaced by Td."
PRINT "   [3]    Lo-Ld = 4*e*s*((Tr+Td)/2)^3*(Tr-Td),  Equation B2 with"
PRINT                                                   Tm = (Tr+Td)/2."
PRINT "   [4]    Lo-Ld = 4*e*s*Tud^3*(Tr-Td),          Equation B2 with"
PRINT                                                   Tm=Tud."
PRINT "   [5]    Lo-Ld = e*s*[(Tr)^4 - (Td)^4],        Exact form (short)."
PRINT
PRINT "   where  e=0.95, is the soil surface emissivity, taken to be constant."
PRINT "          s=5.67E-08 J/s/m^2/(degree K)^4, is the Stefan-Boltzmann"
PRINT "                      constant."
PRINT "        Tr=instantaneous reference dry soil surface temperature, Deg K."
PRINT "        Td=instantaneous drying soil surface temperature, Deg K."
PRINT "        Tm=average of average diurnal dry soil surface temperature and"
PRINT "           average diurnal drying soil surface temperature."
PRINT "        Tud=average drying soil surface temperature, Deg. K."
INPUT "Hit <CR> to continue:", y$: CLS : PRINT
PRINT "   The instantaneous reference dry soil surface temperature"
PRINT "   is estimated using:"
PRINT
PRINT "          Tr = Tuo + dTo*sin(wt)"
PRINT
PRINT "   where  Tuo=(Tomax+Tomin)/2,  is the average surface temperature."
PRINT "          dTo=(Tomax-Tomin)/2,  is the amplitude of the diurnal soil"
PRINT "                                surface temperature wave."
PRINT "   and where Tomax & Tomin are the maximum & minimum diurnal"
PRINT "   reference dry soil temperatures."
PRINT
PRINT "   The instantaneous drying soil surface temperature"
PRINT "   is estimated using:"
PRINT
PRINT "          Td = Tud + dTd*sin(wt)"
PRINT
PRINT "   where  Tud=(Tdmax+Tdmin)/2,  is the average surface temperature."
PRINT "          dTd=(Tdmax-Tdmin)/2,  is the amplitude of the diurnal soil"
PRINT "                                surface temperature wave."
PRINT "   and where Tdmax & Tdmin are the maximum & minimum diurnal "
PRINT "   drying soil temperatures."
PRINT
PRINT "   Also,  w=2pi/1440 min,  is the frequency of the wave."
INPUT "Hit <CR> to continue:", y$: CLS : PRINT
INPUT "   Enter the maximum reference dry soil surface temperature, deg. C: "; Tomax
INPUT "   Enter the maximum drying soil surface temperature, deg. C       : "; Tdmax
INPUT "   Enter the minimum reference dry soil surface temperature, deg. C: "; Tomin
INPUT "   Enter the minimum drying soil surface temperature, deg. C       : "; Tdmin
Redo:
INPUT "   Calculate for 12 hours [1] or 24 hours [2]:? "; Calctime
IF Calctime <> 1 AND Calctime <> 2 THEN GOTO Redo:
IF Calctime = 1 THEN TimeMax = 540 ELSE TimeMax = 1260
   Tuo = (Tomax + Tomin) / 2 + 273.15       'Mean T for ref. dry soil, Deg. K.
   Tud = (Tdmax + Tdmin) / 2 + 273.15       'Mean T for drying soil, Deg. K.
   Tm = (Tuo + Tud) / 2                     'Average of Tuo and Tud, Deg. K.
   dTr = (Tomax - Tomin) / 2                'dT for ref dry soil.
   dTd = (Tdmax - Tdmin) / 2                'dT for drying soil.
   s = 5.67E-08' J/s/m^2/(degree K)^4, is the Stefan-Boltzmann constant.
   e = .95
   w = 2 * 3.141593 / 1440                 'omega in radians per minute.
   OPEN "o", #2, "E:SB.out"
   PRINT #2, "Approx. [1], approx. [2], approx. [3], Exact [4], (all in mm), hours."
   FOR t = -180 TO TimeMax STEP 15
       Td = Tud + dTd * SIN(w * t)      'degrees K.
       Tr = Tuo + dTr * SIN(w * t)
```

```
      dl = e * s * (6 * (Td) ^ 2 * (Tr - Td) ^ 2 + 4 * (Td) ^ 3 * (Tr - Td))
      dl = dl + e * s * ((Tr - Td) ^ 4 + 4 * Td * (Tr - Td) ^ 3)
      dl1 = 4 * e * s * Tm ^ 3 * (Tr - Td) * 900 '900 s in 15 min.
      dl2 = 4 * e * s * Td ^ 3 * (Tr - Td) * 900
      dl3 = 4 * e * s * ((Tr + Td) / 2) ^ 3 * (Tr - Td) * 900
      dl4 = 4 * e * s * Tud ^ 3 * (Tr - Td) * 900
      dl5 = e * s * (Tr ^ 4 - Td ^ 4) * 900
      dl6 = e * s * 4! * ((Tr + Td) / 2!) ^ 3 * (Tr - Td) * 900!
      dl6 = dl6 * (1! + (Tr - Td) ^ 2 / (4! * ((Tr + Td) / 2!) ^ 2))
      dl1sum = dl1sum + dl1
      dl2sum = dl2sum + dl2
      dl3sum = dl3sum + dl3
      dl4sum = dl4sum + dl4
      dl5sum = dl5sum + dl5
      dl6sum = dl6sum + dl6
      'Output energy flux in mm/h:
      PRINT #2, dl1 * 4! / 2400000!, dl2 * 4! / 2400000!;
      PRINT #2, dl3 * 4! / 2400000!, dl4 * 4! / 2400000!;
      PRINT #2, dl5 * 4! / 2400000!, dl6 * 4! / 2400000!, t / 60!
   NEXT t
   CLOSE #2
   PRINT : PRINT "   Output is in file SB.OUT on disk E:\."
PRINT "                                                            Change"
PRINT "                                                          from exact."
   PRINT "   Equation B2 with B11 gives           : "; dl4sum; " J/m^2.  ";
   PRINT USING "###.####"; ((dl4sum - dl5sum) / dl5sum) * 100; : PRINT " %"
   PRINT "   Equation B2 with B10 gives           : "; dl1sum; " J/m^2.  ";
   PRINT USING "###.####"; ((dl1sum - dl5sum) / dl5sum) * 100; : PRINT " %"
   PRINT "   Equation B2 with Tm = Td gives       : "; dl2sum; " J/m^2.  ";
   PRINT USING "###.####"; ((dl2sum - dl5sum) / dl5sum) * 100; : PRINT " %"
   PRINT "   Equation B2 with B4 gives            : "; dl3sum; " J/m^2.  ";
   PRINT USING "###.####"; ((dl3sum - dl5sum) / dl5sum) * 100; : PRINT " %"
   PRINT "   The exact form (Eq. B8 or 5-15) gives: "; dl5sum; " J/m^2.  "
   PRINT
   PRINT "   Taking 1 mm of water evaporated as equal to 2.4E06 J/m^2,"
   PRINT "   Equation B2 with B11 gives           : "; dl4sum / 2400000!; " mm water."
   PRINT "   Equation B2 with B10 gives           : "; dl1sum / 2400000!; " mm water."
   PRINT "   Equation B2 with Tm = Td gives       : "; dl2sum / 2400000!; " mm water."
   PRINT "   Equation B2 with B4 gives            : "; dl3sum / 2400000!; " mm water."
   PRINT "   The exact form (Eq. B8 or 5-14) gives: "; dl5sum / 2400000!; " mm water."
   END
```

APPENDIX C: Program NR.BAS for calculation of apparent diffusivities and positive soil heat flux using the harmonic method of Horton et al. (1983).

Program listing.

```
'30 August88.  Written in Microsoft QuickBASIC version 4.0 by Steve Evett.
'Program NR.BAS employs an iterative procedure to find the diffusivity
'at 15 minute intervals over a 24 hour period.  Input are the coefficients
'for a Fourier series representation of the surface temperature wave.
'Procedure was based on reduction of sum of squared error between predicted
'and actual temperature at a given depth as published by Horton et al. 1983
'Soil Sci. Soc. Am. J., 47:25-32.
'Changed 11 Aug. 88 to use average thermistor temperatures from files 9?t.ave
'and 10?t.ave on disk 45.

DIM a(15), c0(15), phi0(15), t(18, 97), hour(97), t1(8), t2(8)
d = 15            'Initialize diffusivity.

LPRINT "Date: "; DATE$; ".   Time: "; TIME$
WHILE y$ <> "4"
    CLS : PRINT
    PRINT "Program NR.BAS employs a sum of squares based iterative search"
    PRINT "to find the diffusivity at 15 minute intervals over a 24 hour period. "
    PRINT "Procedure was based on reduction of sum of squared error between"
    PRINT "predicted and actual temperature at a given depth as published by"
    PRINT "Horton et al. 1983. Soil Sci. Soc. Am. J., 47:25-32."
    PRINT "Input are the coefficients for a Fourier series representation of"
    PRINT "the surface temperature wave, thermistor based temperatures at one"
    PRINT "depth, and the soil volumetric water content."
    PRINT "A bulk density of 1.48 is assumed."
    PRINT
    PRINT "Files needed are:"
    PRINT "   9?DRY.cof, 9?FLD.cof, 9?SO0.cof, etc. with Fourier series "
    PRINT "from SAS, see disk 43 for surface wave and disk 31 for subsurface."
    PRINT "   93t.ave, 95t.ave, etc. with average thermistor measured "
    PRINT "sub-surface soil temperatures, see disk 45."
    PRINT
    PRINT "   Enter 1 to estimate thermal diffusivity."
    PRINT "   Enter 2 to calculate temperature at a given depth."
    PRINT "   Enter 3 to calculate soil heat flux."
    PRINT "   Enter 4 to quit: ";
    LOCATE , , 1
    y$ = INPUT$(1)
    IF y$ = "1" THEN GOSUB CalcD
    IF y$ = "2" THEN GOSUB CalcT
    IF y$ = "3" THEN GOSUB CalcG
WEND
END

CalcD:
CLS : PRINT
PRINT "   Enter input file name for Fourier series coefficients "
INPUT "      for the surface temperature wave: "; infile$
OPEN "i", #2, infile$
LINE INPUT #2, id1$
LPRINT : LPRINT "   1st line of file "; infile$; ":"
LPRINT id1$
LPRINT "   The input coefficients are:"
i = 0
'a(0) is the average temperature, a(1) is the amplitude of 'thefirst sine term, a(2)
is the amplitude of the firstcosine 'term, a(3) is the amplitude of the second sine
term, etc.
WHILE NOT EOF(2)
    INPUT #2, a(i): LPRINT USING "      ###.######"; a(i)
    i = i + 1
```

```
WEND
CLOSE #2
nc = i: m = (nc - 1) / 2        'nc is no. of coefficients. m is no. of terms.
LPRINT "   Number of terms in Fourier series was"; m; "."
FOR i = 1 TO nc - 1 STEP 2
    'Convert amplitudes from sine + cosine series to amplitude and phase
    'coefficients for sine series:
    phi0((i + 1) / 2) = ATN(a(i + 1) / a(i))
    c0((i + 1) / 2) = a(i + 1) / SIN(phi0((i + 1) / 2))
NEXT i
F$ = LEFT$(infile$, INSTR(infile$, "."))
out$ = LEFT$(infile$, INSTR(infile$, ".")) + "pof"
OPEN "o", #3, out$
LPRINT "   The amplitude and phase coefficients are: "
PRINT #3, "   Amplitude (deg C) and phase (radians) coefficients for: " + out$
FOR i = 1 TO m
     LPRINT USING "      ###.######"; c0(i), phi0(i)
     PRINT #3, c0(i), phi0(i)
NEXT i
CLOSE #3
INPUT "   Enter the depth, z [cm], at which to estimate d and temp.   : "; z
INPUT "   Enter the input file name for temperatures at depth, z: "; infile$
INPUT "   Enter the column for temperatures at depth, z.        : "; col
period = 24   'Period set to 24 hours.

'Read temperature data and compute average:
OPEN "i", #2, infile$
LINE INPUT #2, id$
i = 0: tsum = 0
WHILE NOT EOF(2)
   i = i + 1
   INPUT #2, day, hour(i)
   FOR k = 3 TO 18
       INPUT #2, t(k, i)
       IF k = col THEN tsum = tsum + t(k, i)
   NEXT k
WEND
CLOSE #2
a(0) = tsum / i    'Compute average temperature.
PRINT "   Average temperature at"; z; "cm was"; a(0)
PRINT "      If this is incorrect then"
INPUT "      enter the average temperature at this depth           : "; aveT$
IF aveT$ <> "" THEN a(0) = VAL(aveT$)
LPRINT : LPRINT "   Temperatures at depth"; z; "cm were from file: "; infile$;
LPRINT ", column "; col; "."
LPRINT "   The period was 24 h.  The average temperature at"; z; "cm was"; a(0)
w = 2 * 3.141592653# / period

'For each time estimate temperature at depth, z, and find squared deviation.
PRINT : PRINT "   Wait while processing ........";
ssybf = 10000: flag = 0: count = 0: dbest = 0
d = .01: dbf = d     'Initial estimate of diffusivity.
OPEN "o", #3, "e:difsse.out"
PRINT #3, "Sum of squared errors vs. values of diffusivity at depth" + STR$(z) + " "
+ id1$
jcount = 0
D1st:
PRINT " 4 ";
FOR j = 1 TO 20
    jcount = jcount + 1
    d = d - .001: sy = 0: ssy = 0
    IF d < 0 AND flag = 0 THEN PRINT "Negative diffusivity!": END
    IF d < 0 AND flag = 1 THEN EXIT FOR
    FOR i = 1 TO 96
        temp = t(col, i)
        time = hour(i)
        GOSUB FindT
        sy = (temp - tzest) ^ 2
        ssy = ssy + sy
```

```
    NEXT i
    PRINT #3, d, ssy
    IF ssy > ssybf THEN
        IF flag = 0 THEN
            flag = 1: LPRINT
            LPRINT "   Diffusivity (1st approx.) = ";
            LPRINT USING "#.######"; dbf
            LPRINT "        sum of squared error = ";
            LPRINT USING "#.######"; ssybf
            IF jcount < 3 THEN
               PRINT "Error 1.  SSE not minimized."
               PRINT "Upper bound of"; dbf; " too low."
               END
            END IF
            dbest = dbf
        ELSE
            count = count + 1: IF count = 10 THEN EXIT FOR
        END IF
    END IF
    ssybf = ssy: dbf = d
NEXT j
IF dbest = 0 THEN flag = 0: ssybf = ssy: dbf = d: GOTO D1st
CLOSE #3
'Now get closer approximation.
IF dbest = 0 THEN PRINT "1st approx. of d was zero.": END
dincrement = .0001: flag = 0
d = dbest + .001: ssybf = 1000000
PRINT "3 ";
GOSUB D2nd
dincrement = .00001: flag = 0
d = dbest + .0001: ssybf = 1000000
PRINT "2 ";
GOSUB D2nd
dincrement = .000001: flag = 0
d = dbest + .00001: ssybf = 1000000
PRINT "1";
GOSUB D2nd
Dflag = 1
RETURN

D2nd:
dbest = 0
jcount = 0
D3rd:
FOR j = 1 TO 20
    jcount = jcount + 1
    d = d - dincrement: sy = 0: ssy = 0
    IF d < 0 THEN PRINT "Negative diffusivity!": END
    FOR i = 1 TO 96
        temp = t(col, i)
        time = hour(i)
        GOSUB FindT
        sy = (temp - tzest) ^ 2
        ssy = ssy + sy
    NEXT i
    IF ssy > ssybf THEN
        LPRINT "   Diffusivity    = ";
        LPRINT USING "#.######"; dbf;
        LPRINT " to within +/-"; dincrement
        LPRINT "        sum of squared error =";
        LPRINT USING "###.###"; ssybf
        IF jcount <= 2 THEN
            PRINT "Error 2.  SSE not minimized. Upper bound too low."
            INPUT "Hit <CR>:"; y$: END
        END IF
        dbest = dbf
        EXIT FOR
    END IF
    ssybf = ssy: dbf = d
```

```
NEXT j
IF dbest = 0 THEN flag = 0: ssybf = ssy: dbf = d: GOTO D3rd
RETURN

CalcT:
'For each time estimate temperature at depth, z.
'IF dbest = 0 THEN PRINT "1st approx. of d was zero.": END
d = dbest              'Set diffusivity value.
PRINT : PRINT
IF Dflag <> 1 OR d <= 0 THEN
    PRINT "   Thermal diffusivity (cm^2/s) must be found before temperatures"
    PRINT "   can be estimated.   Use choice #1 at Main Menu."
    PRINT "   Hit any key to continue:"
    y$ = INPUT$(1)
    RETURN
END IF
Dflag = 0
INPUT "   Enter two letter identifier for output file: "; type$
PRINT "   Temperature values for "; z; " cm depth are in file";
PRINT " E:" + LTRIM$(STR$(day)) + "tem" + type$ + "." + LTRIM$(STR$(z))
LPRINT : LPRINT "   Temperature values for "; z; " cm depth are in file";
LPRINT " E:" + LTRIM$(STR$(day)) + "tem" + type$ + "." + LTRIM$(STR$(z))
OPEN "o", #3, "e:" + LTRIM$(STR$(day)) + "tem" + type$ + "." + LTRIM$(STR$(z))
PRINT #3, "Time, temperature & estimated temp. at depth" + STR$(z) + " " + id1$
FOR i = 1 TO 96
    temp = t(col, i)
    time = hour(i)
    GOSUB FindT
    PRINT #3, time, temp, tzest
NEXT i
CLOSE #3
RETURN

FindT:
'Estimate temperature at depth, z, given the diffusivity, d.
'Calculate terms not including d
FOR n = 1 TO m
    t1(n) = c0(n) * (z / 2) * SQR(n * w / (2 * 3600))
    t2(n) = n * w * time + phi0(n)
NEXT n
dT = 0: tzest = 0     'Initialize dT and estimated T.
FOR n = 1 TO m
    t3 = z * SQR(n * w / (2 * d * 3600))
    t4 = EXP(-t3)
    sind = SIN(t2(n) - t3)
    cosd = COS(t2(n) - t3)
    dT = dT + t1(n) * d ^ -1.5 * t4 * (sind + cosd)
    tzest = tzest + c0(n) * t4 * sind
NEXT n
tzest = tzest + a(0)   'Add average T to complete estimated T calc.
RETURN

CalcG:
CLS
PRINT "Subroutine computes the soil heat flux at a depth, z, using"
PRINT "equation 10 from Horton et. al. 1983. Estimating the soil heat"
PRINT "flux from observations of soil temperature near the surface."
PRINT "Soil Sci. Soc. Amer. J. 47:14-20."
PRINT "   For "; F$; "..."
INPUT "   Enter the soil volumetric water content [m^3/m^3]: "; c
'Calculate volumetric heat capacity in J/cm^3/K:
c = 2.01 * 1.48 / 2.65 + 4.19 * c
PRINT "   Enter the soil thermal diffusivity [cm^2 s^-1]."
INPUT "      Hit <CR> to use value from diffusivity estimation: "; d
IF d = 0 THEN d = dbest
IF d = 0 THEN
    PRINT
    PRINT "   Diffusivity was zero.  You may estimate diffusivity by"
    PRINT "   taking choice #1 at the Main Menu.  Hit a key to continue:"
```

```
    y$ = INPUT$(1)
    RETURN
END IF
IF z = 0 THEN
    PRINT "   Enter depth at which diffusivity was calculated,"
    INPUT "   or hit <CR> to return to Main Menu: "; depth
    IF depth = 0 THEN RETURN
ELSE
    depth = z         'Set depth equal to z in subroutine CalcD.
END IF
INPUT "   Enter two letter identifier for output file: "; type$
INPUT "   Enter the depth, z, at which to estimate soil heat flux: "; z
period = 24               'Set period equal to 24 hours.
w = 2 * 3.141592653# / period
PRINT "   Enter the file name for amplitude and phase coefficients. "
INPUT "      Hit <CR> to use name assigned in diffusivity estimation: "; infile$
IF infile$ = "" THEN infile$ = out$
LPRINT
LPRINT "   The soil heat capacity was "; c; " J/cm^3/K."
LPRINT "   The soil thermal diffusivity was ";
LPRINT USING "#.######"; d;
LPRINT " cm^2 s^-1."
LPRINT "   Soil heat flux was computed for a depth of "; z; " cm."

OPEN "i", #2, infile$
LINE INPUT #2, id1$
LPRINT "   1st line of file "; infile$; ":"
LPRINT id1$
i = 0
WHILE NOT EOF(2)
        i = i + 1
        INPUT #2, c0(i), phi0(i)
WEND
CLOSE #2
m = i       'nc is no. of coefficients. m is no. of terms.
LPRINT "   Number of terms in Fourier series was"; m; "."
pi = 3.141592653#

'For each time estimate the soil heat flux, G.
PRINT "   Soil heat flux vs. time is in file";
PRINT " E:" + LTRIM$(STR$(day)) + type$ + LTRIM$(STR$(depth)) + ".";
PRINT LTRIM$(STR$(z))
LPRINT "   Soil heat flux vs. time is in file";
LPRINT " E:" + LTRIM$(STR$(day)) + type$ + LTRIM$(STR$(depth)) + ".";
LPRINT LTRIM$(STR$(z))
F$ = "e:" + LTRIM$(STR$(day)) + type$ + LTRIM$(STR$(depth)) + "."
F$ = F$ + LTRIM$(STR$(z))
OPEN "o", #3, F$
PRINT #3, "Time and estimated flux (MJ/m^2/s) at" + STR$(z) + " cm. " + id1$
gsum = 0: gallsum = 0
FOR i = 1 TO 96
    time = (i - 1) * .25
    GOSUB FindG
    'Convert heat flux from J/cm^2/s to MJ/m^2/s.
    g1 = -g / 100!
    IF g > 0 THEN gsum = gsum + g / 100!  'Total heat flux into soil.
    gallsum = gallsum + g / 100!          'Total heat flux in and out of soil.
    PRINT #3, time, g1
NEXT i
CLOSE #3
LPRINT : LPRINT "   Positive heat flux was: ";
LPRINT USING "####.###"; gsum * .25 * 3600; : LPRINT " MJ/m^2."
h2o = gsum * .25 * 3600     'MJ/m^2.
'2.442 MJ/kg of H2O translates to 1 mm of water since 1 kg/m^2 is 1 mm:
h2o = h2o / 2.442                     'kg/m^2=mm water.
LPRINT "   Equivalent latent heat flux as depth of water is: ";
LPRINT USING "##.###"; h2o; : LPRINT " mm."
LPRINT : LPRINT "   Total 24 hour heat flux was: ";
LPRINT USING "####.###"; gallsum * .25 * 3600; : LPRINT " MJ/m^2."
```

```
h2o = gallsum * .25 * 3600    'MJ/m^2.
h2o = h2o / 2.442                    'kg/m^2=mm water.
LPRINT "   Equivalent latent heat flux as depth of water is: ";
LPRINT USING "##.###"; h2o; : LPRINT " mm."
RETURN

FindG:
'Estimate soil heat flux at depth, z, given the diffusivity, d.
'Calculate terms not including d
g = 0           'Set g equal to zero.
FOR n = 1 TO m
    t1 = c0(n) * c * SQR(n * w * d / 3600)'Factor of 3600 converts to s.
    t3 = z * SQR(n * w / (2 * d * 3600))  'Factor of 3600 converts to seconds.
    t2 = n * w * time + phi0(n) + pi / 4 - t3
    t4 = EXP(-t3)
    sind = SIN(t2 - t3)
    'g is in J/cm^2/s if d is in cm^2/s and c is in J/cm^3/K:
    g = g + t1 * t4 * sind
NEXT n
RETURN
```

APPENDIX D: Program IMPLIC2.BAS, a Crank-Nicolson type finite difference solution to one dimensional heat flow in a homogeneous medium with surface and bottom boundary conditions consisting of temperature known as a discrete function of time. Net and positive heat flux are computed.

Program listing.

```
'ProgramIMPLIC2.BAS.
'Written 1 September 1988 in Microsoft QuickBASIC (R) by S.R. Evett.
'Basic program for computing soil temperature and soil heat flux using an
'implicit (Crank-Nicolson) finite difference scheme.

KEY OFF: CLS
PRINT "Program IMPLIC2.BAS.  Program for computing soil temperature and net"
PRINT "soil heat flux.  Written in QuickBasic v. 4.0 by S.R. Evett,"
PRINT "September 1988.  Uses actual soil temperatures"
PRINT "for surface and 30 cm boundary conditions, and ouputs net and"
PRINT "positive soil heat fluxes."
PRINT
PRINT "For validation purposes the surface temperature is a "
PRINT "sine function of time, t, in hours:"
PRINT "    T(0) = 20 + 15 sin(w(t - 6))"
PRINT "where 20 is the average and 15 the amplitude of the diurnal wave,"
PRINT "temperature is zero and increasing at 6 AM, and w = 2 pi/24. "
PRINT "The temperature at 30 cm is taken as constant and equal to the"
PRINT "average surface temperature.  The volumetric water content is"
PRINT "taken to be 0.21 and thermal conductivityis calculated
print "by Campbell's (1985) method."
PRINT "Otherwise the surface and 30 cm temperatures are taken"
PRINT "from the input files 9?t.ave and theta is from file Theta85.ave."
PRINT
PRINT "Hit any key to continue..."
y$ = INPUT$(1)
CLS : PRINT
PRINT "Files needed:"
PRINT "    92t.ave, 93t.ave, ... ,100t.ave, disk 45,"
PRINT "      (or Valid.dat, disk 45, for validation run.)"
PRINT "    Theta85.ave, disk 45."
PRINT "    Diff85.ave, disk 45, unless diffusivities are calculated"
PRINT "       in program."
PRINT
INPUT "   Do validation (Y or N): "; v$
IF v$ = "y" THEN v$ = "Y"
PRINT "   Use diffusivity values in file Diff85.ave to calculate thermal"
INPUT "      conductivity (1), or use Campbell's method (0): "; DiffFlag
INPUT "   Enter time step in seconds: "; DT
INPUT "   Enter Element depth in m  : "; dx
INPUT "   Enter number of elements  : "; m
LPRINT DATE$; " "; TIME$; "                         Program IMPLIC2.BAS"
LPRINT "Time step [s] was"; DT
LPRINT "Element depth [m] was"; dx
LPRINT "Number of elements was"; m

n0col = 4: n30col = 14 'Columns for surface and 30 cm field soil temperatures.
n15col = 9

DIM gam(m + 1)   'Holding variable used in Gaussian elimination.
DIM W(m + 1)     'Not used.
DIM T(m + 1)     'Old temperature at node i, set to TN(i) at end of each loop.
DIM TN(m + 1)    'New temperature at node i, calculated for each time step.
DIM k(m + 1)     'Element conductance at each node, i.
```

```
DIM CP(m)        'Element heat storage at node, i.
DIM a(m + 1)     'Lower diagonal element.
DIM b(m)         'Diagonal element.
DIM c(m)         'Upper diagonal element.
DIM d(m)         'Vector element.
DIM z(m + 1)     'Depth [m].
DIM day(14)       'Holds julian days to be modeled.
DIM SurfTemp(96) 'Holds surface soil temperatures from file.
DIM Temp30(96)   'Soil temperatures at 30 cm from file.
DIM hour(96)     'Holds time in hours from file.
DIM ThetaV(14)   'Water content for each day.
DIM diffu(14)    'Diffusivity from harmonic analysis for each day [cm^2/s]

day(0) = 91
day(1) = 92: day(2) = 93: day(3) = 94: day(4) = 95: day(5) = 96: day(6) = 97
day(7) = 98: day(8) = 99: day(9) = 100
day(10) = 101: day(11) = 102: day(12) = 103: day(13) = 104

BD = 1.48         'Bulk density [Mg/m^3] found in 30 cm ML's.
k(0) = 20        'Boundary layer conductance [W/(m^2 K)].

'Calculate depths of layers and initialize temperature of each layer
'to temperature at begining:
IF v$ = "Y" THEN
    Temp30(1) = 20
    Temp15 = 23
    SurfTemp(1) = 19.589
ELSE
    da = 0
    GOSUB GetTimeTemp      'Get temperatures for day 91.
END IF
FOR i = 0 TO m
    z(i + 1) = z(i) + dx   'Depth [m], Z(0)=0, Z(10)=.3 m.
    'Initial temperatures are linearly interpolated between inital surface,
    '15 cm and 30 cm temperatures from file:
    IF z(i) < m * dx / 2! THEN
        T(i) = SurfTemp(1) + (Temp15 - SurfTemp(1)) * z(i) / (m * dx / 2!)
    ELSE
        T(i) = Temp15
     T(i) = T(i) + (Temp30(1) - Temp15) * (z(i) - m * dx / 2!) / (m * dx / 2!)
    END IF
    PRINT i, z(i), T(i)
NEXT
LPRINT "Depth of slab was"; z(m); " m."

'Set temperature of outer nodes to temperature at begining.
T(m) = Temp30(1)           'Old temperature.
T(0) = SurfTemp(1)             ' "
TN(m) = T(m)     'New temperature.

'Initialize variables.
  da = 0          'Day number.

'Calculate constants for thermal conductivity equation [W/m/K] for a
'typical low-quartz, mineral soil, after Campbell, Soil Physics with BASIC:
  MC = .31            'Clay fraction for Pima clay loam.
  'Equation 4.27:
  C1 = .65 - .78 * BD + .6 * BD * BD
  'Equation 4.25.  Theta-v is missing here. Should it be???
  C2 = 1.07 * BD
  'Equation 4.28.
  C3 = 1 + 2.64 / SQR(MC)
  'Equation 4.22.  First constant is 0.03 in text not 0.3. Which is correct???
  C4 = .03 + .1 * BD * BD
```

```
'Input water content for each day:
    OPEN "i", #2, "E:theta85.ave"
    LINE INPUT #2, in$
    PRINT "First line of file E:theta85.ave was:"
    PRINT in$
    i = 0
    DO
        IF NOT EOF(2) THEN INPUT #2, d, ThetaV(i) ELSE EXIT DO
        PRINT d, ThetaV(i)
        i = i + 1
    LOOP
    CLOSE #2

'Get diffusivities if desired:
IF DiffFlag > 0 THEN
    OPEN "i", #2, "E:diff85.ave"
    LINE INPUT #2, in$
    PRINT "First line of file E:diff85.ave was:"
    PRINT in$
    i = 0
    DO
        IF NOT EOF(2) THEN INPUT #2, d, diffu(i) ELSE EXIT DO
        PRINT d, diffu(i)
        i = i + 1
    LOOP
    CLOSE #2
END IF

'Loop for number of days.
IF v$ = "Y" THEN
   lowlim = 0: hilim = 13
ELSE lowlim = 0
   hilim = 13
END IF
FOR da = lowlim TO hilim
   LPRINT
   IF v$ = "Y" THEN LPRINT "Validation day"; da ELSE LPRINT "Day"; day(da)
   Ti = 0    'Start at time = zero and go for 24 hours.
   GOSUB FindCPandK          'Calculate element heat capacity and conductance.
   flip = 0                  'Set flag for begin & end times of positive flux.
   soilfluxsum = 0: posflux = 0           'Initialize fluxes to zero.
   Time1 = 0: Time2 = 0                   'Initialize times to zero.
   IF v$ = "Y" THEN
       OPEN "o", #3, "E:Valid" + LTRIM$(STR$(da)) + ".out"
       PRINT #3, "Day, hour, flux [W/m^2]. Validation run."
   ELSE
       OPEN "o", #3, "E:" + LTRIM$(STR$(day(da))) + "flux.out"
       PRINT #3, "Day, hour, flux [W/m^2]"
   END IF
   IF v$ <> "Y" THEN GOSUB GetTimeTemp
   FOR kk = 1 TO INT(24! * 3600! / DT)
       IF da = 0 AND Ti = 11 THEN GOSUB FindCPandK
       IF da = 10 AND Ti = 13 THEN GOSUB FindCPandK
       GOSUB Calc
       Ti = Ti + DT / 3600!            'Time [h] based on incrementing by DT.
   NEXT kk
   IF v$ = "Y" THEN PRINT #3, "Validation day"; da ELSE PRINT #3, "Day"; day(da);
"."
   PRINT #3, "Sum of positive soil heat flux is: ";
   PRINT #3, posflux * DT; " J/m^2"
   PRINT #3, "or an equivalent depth of water of";
   PRINT #3, posflux * DT / 2442000!; " mm."
   PRINT #3,
   PRINT #3, "Begin and end times of positive flux were"; Time1; " and";
   PRINT #3, Time2; " hours."
```

```
   PRINT #3,
   PRINT #3, "Sum of soil heat flux is: "; soilfluxsum * DT; " J/m^2"
   PRINT #3, "or an equivalent depth of water of";
   PRINT #3, soilfluxsum * DT / 2442000!; " mm."
   CLOSE #3
   LPRINT "   Sum of positive soil heat flux is: ";
   LPRINT posflux * DT; " J/m^2"
   LPRINT "   or an equivalent depth of water of";
   LPRINT posflux * DT / 2442000!; " mm."
   LPRINT "   Begin and end times of positive flux were"; Time1; " and";
   LPRINT Time2; " hours."
   LPRINT "   Sum of soil heat flux is: "; soilfluxsum * DT; " J/m^2"
   LPRINT "   or an equivalent depth of water of";
   LPRINT soilfluxsum * DT / 2442000!; " mm."
NEXT da
END

Calc:
'New temperatures at surface and at 30 cm, from sine wave or from file:
  IF v$ = "Y" THEN
      'PRINT "Validation ";
      TN(0) = 20 + 15 * SIN(.261799 * (Ti - 6))
      TN(m) = 20  'Average temperature of surface = temperature at bottom.
  ELSE
      'Interpolate linearly to get temperature at time Ti:
      lEnd = INT(Ti / .25): tEnd = lEnd + 1
      ydif = SurfTemp(tEnd) - SurfTemp(lEnd)
      xdif = .25
      xinc = Ti - lEnd * .25
      TN(0) = SurfTemp(lEnd) + (ydif / xdif) * xinc
      ydif = SurfTemp(tEnd) - SurfTemp(lEnd)
      TN(m) = Temp30(lEnd) + (ydif / xdif) * xinc
      T(m) = Temp30(lEnd) + (ydif / xdif) * xinc
  END IF

'Calculate R.H.S.:
   d(1) = Rm * T(1) + r * T(2) + r * T(0) + r * TN(0)
   FOR i = 2 TO m - 2
       d(i) = r * T(i - 1) + Rm * T(i) + r * T(i + 1)
   NEXT i
   d(m - 1) = r * T(m - 2) + Rm * T(m - 1) + r * T(m) + r * TN(m)

'Calculate diagonal terms in L.H.S.:
   FOR i = 1 TO m - 1
       'c() is the upper diagonal term and equals the lower diagonal a().
       c(i) = -r: a(i + 1) = -r
       b(i) = Rp
   NEXT i

'Do elimination:
   bet = b(1)
   TN(1) = d(1) / bet
   FOR i = 2 TO m - 1
       gam(i) = c(i - 1) / bet
       bet = b(i) - a(i) * gam(i)
       IF bet = 0 THEN PRINT "Error": y$ = INPUT$(1)
       TN(i) = (d(i) - a(i) * TN(i - 1)) / bet      'TN(m-1) is OK as is.
   NEXT i

'Find new temperatures by back substitution, TN(m-1) already calculated above:
   FOR i = m - 2 TO 1 STEP -1
       TN(i) = TN(i) - gam(i + 1) * TN(i + 1)
   NEXT i

'Soil heat flux is combination of conductance through 1st layer and
```

```
'storage in 1st layer:
 'soilflux = (Ki / DX) * (T(0) - T(1))             'Flux in W/m^2.
 'soilflux = soilflux + CPi * DX * (T(0) - T(1))   'Flux in W/m^2.
 avetemp = ((T(0) - T(1)) + (TN(0) - TN(1))) / 2  'Time averaged deltaT.
 soilflux = (Ki / dx) * avetemp                   'Flux in W/m^2.
 soilflux = soilflux + CPi * dx * avetemp         'Flux in W/m^2.
 IF soilflux > 0 AND flip = 0 THEN flip = 1: Time1 = Ti
 IF soilflux < 0 AND flip = 1 THEN flip = 0: Time2 = Ti
 IF soilflux > 0 THEN posflux = posflux + soilflux  'Sum positive flux.
 soilfluxsum = soilfluxsum + soilflux                    'Sum total flux.
 FOR i = 0 TO m
     T(i) = TN(i)            'Old temperatures set to new temperatures.
 NEXT
 IF Ti MOD 900 = 0 THEN
     IF v$ = "Y" THEN PRINT #3, da; Ti;  ELSE PRINT #3, day(da); Ti;
     PRINT #3, soilflux
 END IF
RETURN

GetTimeTemp:
file$ = "e:" + LTRIM$(STR$(day(da))) + "t.ave"
OPEN "i", #2, file$
LINE INPUT #2, in$
PRINT
PRINT "First line of file " + file$ + " is:"
PRINT in$
i = 0
WHILE NOT EOF(2)
    i = i + 1
    INPUT #2, Jday, hour(i)
    FOR ii = 1 TO 16
         INPUT #2, x
         IF ii = n15col - 2 AND i = 1 THEN Temp15 = x'Get 15 cm temp. at start.
         IF ii = n0col - 2 THEN SurfTemp(i) = x
         IF ii = n30col - 2 THEN Temp30(i) = x
    NEXT ii
WEND
CLOSE #2
RETURN

FindCPandK:
   'Use actual water content for all runs.
   wv = ThetaV(da)
   'Set theta to .26 before irrigation on first day:
   IF da = 0 AND Ti < 11 THEN wv = .236
   'Set theta to .3 after irrigation on 11th day:
   IF da = 10 AND Ti = 13 THEN wv = .3
   PRINT "Day"; da; ", theta="; wv
   LPRINT "   Volumetric specific heat is";
   CPi = (2010000! * BD / 2.65 + 4180000! * wv) / 1000000!
   LPRINT CPi; " MJ/(m^3 K)."
   LPRINT "   Thermal conductivity is    ";
   IF DiffFlag = 0 THEN
       'Use Campbell's method for calculating thermal conductivity:
       Ki = (C1 + C2 * wv - (C1 - C4) * EXP(-(C3 * wv) ^ 4))
   ELSE
       'Use diffusivity values from harmonic analysis and CPi to calculate Ki:
PRINT "Used diffusivity values from harmonic analysis and CPi to calculate Ki:"
       Ki = (diffu(da) / 10000!) * CPi * 1000000!
   END IF
   LPRINT Ki; " J/(s m K)."
   LPRINT "   Diffusivity is             "; Ki / (CPi * 1000000!); " m^2/s."
   r = (Ki / (CPi * 1000000!)) * DT / (dx * dx)
   Rm = 2 - 2! * r: Rp = 2 + 2! * r
   LPRINT "   r is "; r
```

```
   IF v$ = "Y" THEN
     'Calculate analytical solution:
     sa = SQR(2) * CPi * 1000000!
     sa = sa * SQR(2 * (Ki * 86400 / (CPi * 1000000! * 6.2831853#)))
     sa = sa * 15 / 2442000     'Amplitude of sine wave is 15 Deg. C.
     LPRINT "Analytical solution is"; sa; " mm."
   END IF
RETURN
```

APPENDIX E: Model for least squares linear regression analysis using dummy variables for the ML treatments.

Least squares linear regression, with dummy variables defined for the k treatments, can be used to perform one multiple linear regression which generates regression coefficients (intercepts and slopes) for all k treatments (Nie et al. 1975, pp. 372-382). This procedure has the advantage of separating treatment effects from the effect of the independent variable while maximimizing the error degrees of freedom and thus the general level of significance of the regression. While k separate regressions could be performed, using the data from only one treatment for each regression, the individual regressions would have only (N/k)-2 error degrees of freedom (where the number of samples is evenly divided among the k treatments and there are N samples overall) whereas the single regression with dummy variables would have N-2k degrees of freedom. The correlation coefficients for the individual regressions would generally be lower than that for the multiple regression and would not be good indicators of the overall effect of the independent variable.

The general linear model with dummy variables for k different treatments can be written:

$$Y_j = b_0 + \sum_{i=1}^{k-1} b_i x_{ij} + b_k X_j + \sum_{i=1}^{k-1} b_{ik} x_{ikj} + \epsilon_j \qquad [E1]$$

where Y is the dependent variable and X is the independent variable, and where the dummy variables x_{ij} are defined by

$$x_{ij} = 1, \text{ if treatment number } = i, \quad = 0, \text{ otherwise.} \qquad [E2]$$

Also, the dummy variables x_{ikj} are defined by

$$x_{ikj} = 1(X_j), \text{ if treatment number } = i, \quad = 0, \text{ otherwise.} \qquad [E3]$$

For the ith treatment Equation E1 reduces to

$$Y_j = b_0 + b_i + b_k X_j + b_{ik} X_j + \epsilon_j \qquad [E4]$$

Note that x_{ij} and x_{ikj} are not defined for i=k in Equation E1. So, for the kth treatment Equation E1 reduces to

$$Y_j = b_0 + b_k X_j + \epsilon_j \qquad [E5]$$

Thus it is clear that k equations are defined, one for each of the k treatmments.

At this point it should be clear that the model is nothing more than a special case of the general model for multiple linear regression (Montgomery 1976, p. 316)(Neter and Wasserman 1974, pp.297-338). Minimizing the least squares function will be easier if the intercept term is redefined as (following Montgomery 1976)

$$b'_0 = b_0 + b_k\bar{X} + \sum_{i=1}^{k-1} b_{ik}\bar{x}_i \qquad [E6]$$

Where $\bar{X}$ is the average of all X and $\bar{x}_i$ is the average of X for the ith treatment. This procedure also makes computer calculations easier since it reduces the tendency for overflow to occur. The redefined model is now

$$Y_j = b'_0 + \sum_{i=1}^{k-1} b_i x_{ij} + b_k(X_j - \bar{X}) + \sum_{i=1}^{k-1} b_{ik}(x_{ikj} - \bar{x}_i) + \epsilon_j \qquad [E8]$$

Any one of the k equations defined for the k treatments is identical to the equation that would be generated if a linear regression were performed using the data from that treatment alone. This is obvious in the case of Equation E5 and will be clear for Equation E4 if the intercept terms, b_0 and b_i, are combined and if the slope terms, b_k and b_{ik}, are combined.

In matrix form, the model represented by Equation E8 is

$$\mathbf{y} = \mathbf{X}\beta + \epsilon \qquad [E9]$$

where **y** is the vector containing the N dependent variable values, **X** is the N by 2k matrix containing the independent and dummy variables, β is the vector containing the 2k coefficients, and ϵ is the vector containing the N error terms. As an example these matrices are shown below for a model with dummy variables for 6 treatments.

$$\mathbf{y} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ \cdot \\ \cdot \\ \cdot \\ Y_N \end{bmatrix} \qquad \beta = \begin{bmatrix} \beta'_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \\ \beta_{16} \\ \beta_{26} \\ \beta_{36} \\ \beta_{46} \\ \beta_{56} \end{bmatrix} \qquad \epsilon = \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \cdot \\ \cdot \\ \cdot \\ \epsilon_N \end{bmatrix}$$

and

$$\mathbf{X} = \begin{bmatrix}
1 & 1 & 0 & 0 & 0 & 0 & (X_1 - \bar{X}) & (X_1 - \bar{x}_1) & 0 & 0 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 0 & (X_2 - \bar{X}) & 0 & (X_2 - \bar{x}_2) & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 0 & (X_3 - \bar{X}) & 0 & 0 & (X_3 - \bar{x}_3) & 0 & 0 \\
1 & 0 & 0 & 0 & 1 & 0 & (X_4 - \bar{X}) & 0 & 0 & 0 & (X_4 - \bar{x}_4) & 0 \\
1 & 0 & 0 & 0 & 0 & 1 & (X_5 - \bar{X}) & 0 & 0 & 0 & 0 & (X_5 - \bar{x}_5) \\
1 & 1 & 0 & 0 & 0 & 0 & (X_6 - \bar{X}) & (X_6 - \bar{x}_1) & 0 & 0 & 0 & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
1 & 0 & 0 & 0 & 0 & 1 & (X_N - \bar{X}) & 0 & 0 & 0 & 0 & (X_N - \bar{x}_5)
\end{bmatrix} \qquad \text{[E10]}$$

Squaring the error term in Equation E9 gives $\epsilon'\epsilon$ which is the sum of squared error terms. Minimizing $\epsilon'\epsilon$ results in the normal equations in matrix form (Montgomery 1976)

$$\mathbf{X}'\mathbf{X}\hat{\beta} = \mathbf{X}'\mathbf{y} \qquad [E11]$$

where $\hat{\beta}$ is the vector of regression coefficients. Multiplying both sides of Equation E11 by $(\mathbf{X}'\mathbf{X})^{-1}$ results in

$$\hat{\beta} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{y} \qquad [E12]$$

Solution of Equation E12 can be accomplished on a personal computer using the SAS, SPSS or other statistical programs. The user must provide the dummy variables in the data set or, alternatively, direct the program to construct them using user -specified equations. Note that the first column in **X**, above, is filled with ones. This dummy variable is associated with the intercept and is automatically created by most statistical programs, thus the user need not create it.

In the following example evaporation, E, was the dependent variable and the midday temperature depression, $(T_{o,max} - T_{d,max})$, was the independent variable. There were 6 treatments so 5 dummy variables associated with the intercept are defined, x_1 through x_5; and 5 dummy variables associated with the slope were defined, x_{16} through x_{56}. The treatments were designated as T1, T2, T3, T4, and T5. No dummy variable was necessary for treatment number 6.

$$\text{Model:}\quad E = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6(T_{o,max} - T_{d,max}) + b_{16}x_{16} + b_{26}x_{26} + b_{36}x_{36} + b_{46}x_{46} + b_{56}x_{56} \qquad [E13]$$

where: x_1 = 1, if length=10 cm and wall type is steel, T1,
= 0, otherwise,
x_2 = 1, if length=10 cm and wall type is plastic, T2,
= 0, otherwise,
x_3 = 1, if length=20 cm and wall type is steel, T3,
= 0, otherwise,
x_4 = 1, if length=20 cm and wall type is plastic, T4,
= 0, otherwise,
x_5 = 1, if length=30 cm and wall type is steel, T5,
= 0, otherwise,
x_{16} = $1(T_{o,max} - T_{d,max})$, if length=10 cm and wall type is steel, T1,
= 0, otherwise,
x_{26} = $1(T_{o,max} - T_{d,max})$, if length=10 cm and wall type is plastic, T2,
= 0, otherwise,
x_{36} = $1(T_{o,max} - T_{d,max})$, if length=20 cm and wall type is steel, T3,
= 0, otherwise,
x_{46} = $1(T_{o,max} - T_{d,max})$, if length=20 cm and wall type is plastic, T4,
= 0, otherwise,
x_{56} = $1(T_{o,max} - T_{d,max})$, if length=30 cm and wall type is steel, T5,
= 0, otherwise. [E14]

This model was analyzed using the SAS statistical programs on an IBM PC compatible. In the following output the variables are defined as OBS = sequential observation number; TRT = treatment number; E_mm = actual evaporation in mm; Tdepress = $(T_{o,max} - T_{d,max})$; X1 through X5 are the dummy variables x_i and X16 through X56 are the dummy variables x_{i6}.

Output from SAS.

Eactual (mm) = (To,max - Td,max) w/ dummys for treatments.

OBS	TRT	E_MM	X1	X2	X3	X4	X5	TDEPRESS	X16	X26	X36	X46	X56
1	4	4.98	0	0	0	1	0	26.47	0.00	0.00	0.00	26.47	0.00
2	3	5.92	0	0	1	0	0	28.41	0.00	0.00	28.41	0.00	0.00
3	5	6.97	0	0	0	0	1	28.57	0.00	0.00	0.00	0.00	28.57
4	6	5.75	0	0	0	0	0	28.07	0.00	0.00	0.00	0.00	0.00
5	1	4.01	1	0	0	0	0	24.52	24.52	0.00	0.00	0.00	0.00
6	2	5.18	0	1	0	0	0	26.49	0.00	26.49	0.00	0.00	0.00
7	3	4.53	0	0	1	0	0	27.65	0.00	0.00	27.65	0.00	0.00
8	4	3.83	0	0	0	1	0	27.29	0.00	0.00	0.00	27.29	0.00
9	1	3.14	1	0	0	0	0	26.40	26.40	0.00	0.00	0.00	0.00
10	4	2.49	0	0	0	1	0	25.21	0.00	0.00	0.00	25.21	0.00
11	5	3.83	0	0	0	0	1	25.94	0.00	0.00	0.00	0.00	25.94
12	6	1.73	0	0	0	0	0	26.34	0.00	0.00	0.00	0.00	0.00
13	1	3.48	1	0	0	0	0	24.89	24.89	0.00	0.00	0.00	0.00
14	2	1.34	0	1	0	0	0	25.78	0.00	25.78	0.00	0.00	0.00
15	3	1.92	0	0	1	0	0	26.37	0.00	0.00	26.37	0.00	0.00
16	4	1.53	0	0	0	1	0	27.46	0.00	0.00	0.00	27.46	0.00
17	2	0.96	0	1	0	0	0	27.78	0.00	27.78	0.00	0.00	0.00
18	4	3.26	0	0	0	1	0	12.36	0.00	0.00	0.00	12.36	0.00
19	3	1.39	0	0	1	0	0	12.46	0.00	0.00	12.46	0.00	0.00
20	5	0.87	0	0	0	0	1	13.90	0.00	0.00	0.00	0.00	13.90
21	6	0.96	0	0	0	0	0	13.46	0.00	0.00	0.00	0.00	0.00
22	1	1.57	1	0	0	0	0	12.64	12.64	0.00	0.00	0.00	0.00
23	2	1.73	0	1	0	0	0	11.70	0.00	11.70	0.00	0.00	0.00
24	3	2.09	0	0	1	0	0	12.83	0.00	0.00	12.83	0.00	0.00
25	4	3.64	0	0	0	1	0	11.03	0.00	0.00	0.00	11.03	0.00
26	1	1.74	1	0	0	0	0	13.70	13.70	0.00	0.00	0.00	0.00
27	4	2.30	0	0	0	1	0	10.46	0.00	0.00	0.00	10.46	0.00
28	5	4.01	0	0	0	0	1	14.90	0.00	0.00	0.00	0.00	14.90
29	6	2.49	0	0	0	0	0	11.37	0.00	0.00	0.00	0.00	0.00
30	1	1.05	1	0	0	0	0	12.08	12.08	0.00	0.00	0.00	0.00
31	2	1.53	0	1	0	0	0	11.07	0.00	11.07	0.00	0.00	0.00
32	3	1.57	0	0	1	0	0	11.81	0.00	0.00	11.81	0.00	0.00
33	4	0.96	0	0	0	1	0	10.45	0.00	0.00	0.00	10.45	0.00
34	2	1.73	0	1	0	0	0	9.30	0.00	9.30	0.00	0.00	0.00
35	4	3.26	0	0	0	1	0	11.31	0.00	0.00	0.00	11.31	0.00
36	3	1.39	0	0	1	0	0	11.63	0.00	0.00	11.63	0.00	0.00
37	5	0.87	0	0	0	0	1	12.63	0.00	0.00	0.00	0.00	12.63
38	6	0.96	0	0	0	0	0	12.48	0.00	0.00	0.00	0.00	0.00
39	1	1.57	1	0	0	0	0	11.71	11.71	0.00	0.00	0.00	0.00
40	2	1.73	0	1	0	0	0	10.06	0.00	10.06	0.00	0.00	0.00
41	3	2.09	0	0	1	0	0	13.06	0.00	0.00	13.06	0.00	0.00
42	4	3.64	0	0	0	1	0	10.59	0.00	0.00	0.00	10.59	0.00
43	1	1.74	1	0	0	0	0	12.70	12.70	0.00	0.00	0.00	0.00
44	4	2.30	0	0	0	1	0	10.63	0.00	0.00	0.00	10.63	0.00
45	5	4.01	0	0	0	0	1	12.33	0.00	0.00	0.00	0.00	12.33
46	6	2.49	0	0	0	0	0	9.33	0.00	0.00	0.00	0.00	0.00
47	1	1.05	1	0	0	0	0	10.15	10.15	0.00	0.00	0.00	0.00
48	2	1.53	0	1	0	0	0	10.04	0.00	10.04	0.00	0.00	0.00
49	3	1.57	0	0	1	0	0	11.88	0.00	0.00	11.88	0.00	0.00
50	4	0.96	0	0	0	1	0	10.88	0.00	0.00	0.00	10.88	0.00
51	2	1.73	0	1	0	0	0	8.63	0.00	8.63	0.00	0.00	0.00
52	4	-0.96	0	0	0	1	0	6.75	0.00	0.00	0.00	6.75	0.00
53	3	1.05	0	0	1	0	0	7.62	0.00	0.00	7.62	0.00	0.00
54	5	0.17	0	0	0	0	1	9.34	0.00	0.00	0.00	0.00	9.34
55	6	0.77	0	0	0	0	0	8.30	0.00	0.00	0.00	0.00	0.00

OBS	TRT	E_MM	X1	X2	X3	X4	X5	TDEPRESS	X16	X26	X36	X46	X56
56	1	0.70	1	0	0	0	0	7.13	7.13	0.00	0.00	0.00	0.00
57	2	0.77	0	1	0	0	0	6.37	0.00	6.37	0.00	0.00	0.00
58	3	1.05	0	0	1	0	0	8.05	0.00	0.00	8.05	0.00	0.00
59	4	1.34	0	0	0	1	0	6.64	0.00	0.00	0.00	6.64	0.00
60	1	1.22	1	0	0	0	0	7.86	7.86	0.00	0.00	0.00	0.00
61	4	0.96	0	0	0	1	0	5.62	0.00	0.00	0.00	5.62	0.00
62	5	1.39	0	0	0	0	1	7.21	0.00	0.00	0.00	0.00	7.21
63	6	2.11	0	0	0	0	0	6.12	0.00	0.00	0.00	0.00	0.00
64	1	1.22	1	0	0	0	0	7.03	7.03	0.00	0.00	0.00	0.00
65	2	0.77	0	1	0	0	0	5.58	0.00	5.58	0.00	0.00	0.00
66	3	1.05	0	0	1	0	0	6.78	0.00	0.00	6.78	0.00	0.00
67	4	1.15	0	0	0	1	0	6.72	0.00	0.00	0.00	6.72	0.00
68	2	0.77	0	1	0	0	0	3.74	0.00	3.74	0.00	0.00	0.00
69	4	1.34	0	0	0	1	0	6.33	0.00	0.00	0.00	6.33	0.00
70	3	1.05	0	0	1	0	0	7.06	0.00	0.00	7.06	0.00	0.00
71	5	1.05	0	0	0	0	1	8.24	0.00	0.00	0.00	0.00	8.24
72	6	2.68	0	0	0	0	0	7.21	0.00	0.00	0.00	0.00	0.00
73	1	0.70	1	0	0	0	0	6.73	6.73	0.00	0.00	0.00	0.00
74	2	1.34	0	1	0	0	0	3.76	0.00	3.76	0.00	0.00	0.00
75	3	1.39	0	0	1	0	0	5.80	0.00	0.00	5.80	0.00	0.00
76	4	1.53	0	0	0	1	0	4.62	0.00	0.00	0.00	4.62	0.00
77	1	0.70	1	0	0	0	0	6.33	6.33	0.00	0.00	0.00	0.00
78	4	1.15	0	0	0	1	0	4.36	0.00	0.00	0.00	4.36	0.00
79	5	0.52	0	0	0	0	1	5.85	0.00	0.00	0.00	0.00	5.85
80	6	0.19	0	0	0	0	0	4.04	0.00	0.00	0.00	0.00	0.00
81	1	1.22	1	0	0	0	0	4.81	4.81	0.00	0.00	0.00	0.00
82	2	1.15	0	1	0	0	0	4.75	0.00	4.75	0.00	0.00	0.00
83	3	0.17	0	0	1	0	0	6.16	0.00	0.00	6.16	0.00	0.00
84	4	1.53	0	0	0	1	0	6.33	0.00	0.00	0.00	6.33	0.00
85	2	1.34	0	1	0	0	0	4.20	0.00	4.20	0.00	0.00	0.00
86	4	2.68	0	0	0	1	0	7.88	0.00	0.00	0.00	7.88	0.00
87	3	1.39	0	0	1	0	0	9.01	0.00	0.00	9.01	0.00	0.00
88	5	3.31	0	0	0	0	1	11.00	0.00	0.00	0.00	0.00	11.00
89	6	-0.77	0	0	0	0	0	8.66	0.00	0.00	0.00	0.00	0.00
90	1	1.74	1	0	0	0	0	8.36	8.36	0.00	0.00	0.00	0.00
91	2	0.38	0	1	0	0	0	5.11	0.00	5.11	0.00	0.00	0.00
92	3	0.52	0	0	1	0	0	6.69	0.00	0.00	6.69	0.00	0.00
93	4	0.96	0	0	0	1	0	6.06	0.00	0.00	0.00	6.06	0.00
94	1	1.05	1	0	0	0	0	8.12	8.12	0.00	0.00	0.00	0.00
95	4	0.38	0	0	0	1	0	4.94	0.00	0.00	0.00	4.94	0.00
96	5	2.09	0	0	0	0	1	8.42	0.00	0.00	0.00	0.00	8.42
97	6	2.49	0	0	0	0	0	5.02	0.00	0.00	0.00	0.00	0.00
98	1	0.52	1	0	0	0	0	7.26	7.26	0.00	0.00	0.00	0.00
99	2	1.15	0	1	0	0	0	6.09	0.00	6.09	0.00	0.00	0.00
100	3	1.22	0	0	1	0	0	7.45	0.00	0.00	7.45	0.00	0.00
101	4	0.77	0	0	0	1	0	7.08	0.00	0.00	0.00	7.08	0.00
102	2	0.58	0	1	0	0	0	4.37	0.00	4.37	0.00	0.00	0.00
103	4	1.15	0	0	0	1	0	7.39	0.00	0.00	0.00	7.39	0.00
104	3	1.05	0	0	1	0	0	8.17	0.00	0.00	8.17	0.00	0.00
105	5	-0.17	0	0	0	0	1	9.38	0.00	0.00	0.00	0.00	9.38
106	6	1.73	0	0	0	0	0	7.88	0.00	0.00	0.00	0.00	0.00
107	1	0.52	1	0	0	0	0	7.55	7.55	0.00	0.00	0.00	0.00
108	2	0.77	0	1	0	0	0	6.20	0.00	6.20	0.00	0.00	0.00
109	3	0.52	0	0	1	0	0	6.73	0.00	0.00	6.73	0.00	0.00
110	4	0.00	0	0	0	1	0	5.85	0.00	0.00	0.00	5.85	0.00
111	1	0.70	1	0	0	0	0	7.58	7.58	0.00	0.00	0.00	0.00
112	4	0.77	0	0	0	1	0	4.99	0.00	0.00	0.00	4.99	0.00
113	5	0.52	0	0	0	0	1	6.92	0.00	0.00	0.00	0.00	6.92
114	6	0.38	0	0	0	0	0	5.30	0.00	0.00	0.00	0.00	0.00
115	1	1.05	1	0	0	0	0	7.18	7.18	0.00	0.00	0.00	0.00

OBS	TRT	E_MM	X1	X2	X3	X4	X5	TDEPRESS	X16	X26	X36	X46	X56
116	2	0.58	0	1	0	0	0	5.42	0.00	5.42	0.00	0.00	0.00
117	3	1.22	0	0	1	0	0	8.34	0.00	0.00	8.34	0.00	0.00
118	4	0.77	0	0	0	1	0	7.28	0.00	0.00	0.00	7.28	0.00
119	2	0.96	0	1	0	0	0	5.26	0.00	5.26	0.00	0.00	0.00
120	4	0.77	0	0	0	1	0	4.51	0.00	0.00	0.00	4.51	0.00
121	3	-0.17	0	0	1	0	0	5.78	0.00	0.00	5.78	0.00	0.00
122	5	0.87	0	0	0	0	1	6.96	0.00	0.00	0.00	0.00	6.96
123	6	0.77	0	0	0	0	0	5.45	0.00	0.00	0.00	0.00	0.00
124	1	0.70	1	0	0	0	0	5.52	5.52	0.00	0.00	0.00	0.00
125	2	0.96	0	1	0	0	0	4.13	0.00	4.13	0.00	0.00	0.00
126	3	1.39	0	0	1	0	0	5.23	0.00	0.00	5.23	0.00	0.00
127	4	0.77	0	0	0	1	0	4.50	0.00	0.00	0.00	4.50	0.00
128	1	0.87	1	0	0	0	0	6.14	6.14	0.00	0.00	0.00	0.00
129	4	0.96	0	0	0	1	0	3.75	0.00	0.00	0.00	3.75	0.00
130	5	0.87	0	0	0	0	1	5.76	0.00	0.00	0.00	0.00	5.76
131	6	1.15	0	0	0	0	0	4.10	0.00	0.00	0.00	0.00	0.00
132	1	1.22	1	0	0	0	0	5.45	5.45	0.00	0.00	0.00	0.00
133	2	0.96	0	1	0	0	0	4.62	0.00	4.62	0.00	0.00	0.00
134	3	0.87	0	0	1	0	0	6.96	0.00	0.00	6.96	0.00	0.00
135	4	1.73	0	0	0	1	0	6.25	0.00	0.00	0.00	6.25	0.00
136	2	1.15	0	1	0	0	0	4.25	0.00	4.25	0.00	0.00	0.00
137	4	-0.19	0	0	0	1	0	5.27	0.00	0.00	0.00	5.27	0.00
138	3	0.87	0	0	1	0	0	7.12	0.00	0.00	7.12	0.00	0.00
139	5	0.00	0	0	0	0	1	8.50	0.00	0.00	0.00	0.00	8.50
140	6	0.77	0	0	0	0	0	7.28	0.00	0.00	0.00	0.00	0.00
141	1	0.70	1	0	0	0	0	6.67	6.67	0.00	0.00	0.00	0.00
142	2	0.58	0	1	0	0	0	4.57	0.00	4.57	0.00	0.00	0.00
143	3	-0.17	0	0	1	0	0	6.68	0.00	0.00	6.68	0.00	0.00
144	4	0.38	0	0	0	1	0	5.53	0.00	0.00	0.00	5.53	0.00
145	1	0.35	1	0	0	0	0	6.14	6.14	0.00	0.00	0.00	0.00
146	4	0.38	0	0	0	1	0	4.01	0.00	0.00	0.00	4.01	0.00
147	5	-0.17	0	0	0	0	1	4.86	0.00	0.00	0.00	0.00	4.86
148	6	-0.19	0	0	0	0	0	2.58	0.00	0.00	0.00	0.00	0.00
149	1	0.17	1	0	0	0	0	3.67	3.67	0.00	0.00	0.00	0.00
150	2	0.77	0	1	0	0	0	3.29	0.00	3.29	0.00	0.00	0.00
151	3	-0.52	0	0	1	0	0	5.81	0.00	0.00	5.81	0.00	0.00
152	4	0.00	0	0	0	1	0	4.74	0.00	0.00	0.00	4.74	0.00
153	2	0.19	0	1	0	0	0	1.95	0.00	1.95	0.00	0.00	0.00

Model: MODEL3
Dependent Variable: E_MM

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	11	141.90230	12.90021	16.841	0.0001
Error	141	108.00623	0.76600		
C Total	152	249.90853			

Root MSE	0.87522	R-square	0.5678
Dep Mean	1.40320	Adj R-sq	0.5341
C.V.	62.37269		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|	Type I SS	Type II SS
INTERCEP	1	0.285019	0.35555430	0.802	0.4241	301.253569	0.492226
X1	1	-0.396673	0.48292145	-0.821	0.4128	0.456643	0.516824
X2	1	0.288298	0.44206706	0.652	0.5154	1.662800	0.325789
X3	1	-0.699147	0.47806914	-1.462	0.1458	0.723456	1.638270
X4	1	0.048791	0.43501984	0.112	0.9109	0.222222	0.009636
X5	1	-1.248569	0.54812277	-2.278	0.0242	0.575069	3.974654
TDEPRESS	1	0.123300	0.03013265	4.092	0.0001	124.099746	12.825699
X16	1	0.017259	0.04125610	0.418	0.6763	0.008201	0.134049
X26	1	-0.046909	0.03867380	-1.213	0.2272	6.335601	1.126979
X36	1	0.045775	0.03982909	1.149	0.2524	0.260140	1.011795
X46	1	0.001731	0.03738744	0.046	0.9631	2.166818	0.001643
X56	1	0.117614	0.04433187	2.653	0.0089	5.391604	5.391604

Variable	DF	Standardized Estimate	Tolerance	Variance Inflation
INTERCEP	1	0.00000000	.	0.00000000
X1	1	-0.11832157	0.14771813	6.76964959
X2	1	0.08599488	0.17628303	5.67269582
X3	1	-0.20854489	0.15073197	6.63429252
X4	1	0.01619364	0.14703293	6.80119733
X5	1	-0.31475999	0.16053109	6.22932280
TDEPRESS	1	0.63571371	0.12699213	7.87450369
X16	1	0.06137588	0.14239259	7.02283730
X26	1	-0.15815800	0.18028207	5.54686345
X36	1	0.17244918	0.13614108	7.34532151
X46	1	0.00683807	0.14056103	7.11434722
X56	1	0.38653305	0.14439883	6.92526382

Covariance of Estimates

COVB	INTERCEP	X1	X2	X3	X4	X5
INTERCEP	0.1264188634	-0.126418863	-0.126418863	-0.126418863	-0.126418863	-0.126418863
X1	-0.126418863	0.2332131306	0.1264188634	0.1264188634	0.1264188634	0.1264188634
X2	-0.126418863	0.1264188634	0.1954232836	0.1264188634	0.1264188634	0.1264188634
X3	-0.126418863	0.1264188634	0.1264188634	0.2285501055	0.1264188634	0.1264188634
X4	-0.126418863	0.1264188634	0.1264188634	0.1264188634	0.1892422627	0.1264188634
X5	-0.126418863	0.1264188634	0.1264188634	0.1264188634	0.1264188634	0.3004385665
TDEPRESS	-0.008726157	0.0087261571	0.0087261571	0.0087261571	0.0087261571	0.0087261571
X16	0.0087261571	-0.016617643	-0.008726157	-0.008726157	-0.008726157	-0.008726157
X26	0.0087261571	-0.008726157	-0.013612878	-0.008726157	-0.008726157	-0.008726157
X36	0.0087261571	-0.008726157	-0.008726157	-0.015799901	-0.008726157	-0.008726157
X46	0.0087261571	-0.008726157	-0.008726157	-0.008726157	-0.01323735	-0.008726157
X56	0.0087261571	-0.008726157	-0.008726157	-0.008726157	-0.008726157	-0.020516068

COVB	TDEPRESS	X16	X26	X36	X46	X56
INTERCEP	-0.008726157	0.0087261571	0.0087261571	0.0087261571	0.0087261571	0.0087261571
X1	0.0087261571	-0.016617643	-0.008726157	-0.008726157	-0.008726157	-0.008726157
X2	0.0087261571	-0.008726157	-0.013612878	-0.008726157	-0.008726157	-0.008726157
X3	0.0087261571	-0.008726157	-0.008726157	-0.015799901	-0.008726157	-0.008726157
X4	0.0087261571	-0.008726157	-0.008726157	-0.008726157	-0.01323735	-0.008726157
X5	0.0087261571	-0.008726157	-0.008726157	-0.008726157	-0.008726157	-0.020516068
TDEPRESS	0.0009079763	-0.000907976	-0.000907976	-0.000907976	-0.000907976	-0.000907976
X16	-0.000907976	0.001702066	0.0009079763	0.0009079763	0.0009079763	0.0009079763
X26	-0.000907976	0.0009079763	0.0014956627	0.0009079763	0.0009079763	0.0009079763
X36	-0.000907976	0.0009079763	0.0009079763	0.0015863563	0.0009079763	0.0009079763
X46	-0.000907976	0.0009079763	0.0009079763	0.0009079763	0.0013978205	0.0009079763
X56	-0.000907976	0.0009079763	0.0009079763	0.0009079763	0.0009079763	0.0019653148

Correlation of Estimates

CORRB	INTERCEP	X1	X2	X3	X4	X5
INTERCEP	1.0000	-0.7363	-0.8043	-0.7437	-0.8173	-0.6487
X1	-0.7363	1.0000	0.5922	0.5476	0.6018	0.4776
X2	-0.8043	0.5922	1.0000	0.5982	0.6574	0.5217
X3	-0.7437	0.5476	0.5982	1.0000	0.6079	0.4824
X4	-0.8173	0.6018	0.6574	0.6079	1.0000	0.5302
X5	-0.6487	0.4776	0.5217	0.4824	0.5302	1.0000
TDEPRESS	-0.8145	0.5997	0.6551	0.6058	0.6657	0.5283
X16	0.5949	-0.8341	-0.4785	-0.4424	-0.4862	-0.3859
X26	0.6346	-0.4672	-0.7962	-0.4720	-0.5187	-0.4117
X36	0.6162	-0.4537	-0.4956	-0.8298	-0.5036	-0.3997
X46	0.6564	-0.4833	-0.5280	-0.4882	-0.8139	-0.4258
X56	0.5536	-0.4076	-0.4453	-0.4117	-0.4525	-0.8443

CORRB	TDEPRESS	X16	X26	X36	X46	X56
INTERCEP	-0.8145	0.5949	0.6346	0.6162	0.6564	0.5536
X1	0.5997	-0.8341	-0.4672	-0.4537	-0.4833	-0.4076
X2	0.6551	-0.4785	-0.7962	-0.4956	-0.5280	-0.4453
X3	0.6058	-0.4424	-0.4720	-0.8298	-0.4882	-0.4117
X4	0.6657	-0.4862	-0.5187	-0.5036	-0.8139	-0.4525
X5	0.5283	-0.3859	-0.4117	-0.3997	-0.4258	-0.8443
TDEPRESS	1.0000	-0.7304	-0.7791	-0.7565	-0.8060	-0.6797
X16	-0.7304	1.0000	0.5691	0.5526	0.5887	0.4964
X26	-0.7791	0.5691	1.0000	0.5895	0.6280	0.5296
X36	-0.7565	0.5526	0.5895	1.0000	0.6097	0.5142
X46	-0.8060	0.5887	0.6280	0.6097	1.0000	0.5478
X56	-0.6797	0.4964	0.5296	0.5142	0.5478	1.0000

End of SAS ouput.

The parameter estimates in the SAS output were the regression coefficients b_0, b_i and b_{ik} as follows

b_0	0.285019
b_1	-0.396673
b_2	0.288298
b_3	-0.699147
b_4	0.048791
b_5	-1.248569
b_6	0.123300
b_{16}	0.017259
b_{26}	-0.046909
b_{36}	0.045775
b_{46}	0.001731
b_{56}	0.117614

Following Equation E5, the regression equation for the 6th treatment was:

$$Y = b_0 + b_6X = 0.285 + 0.123\ X$$

where $X = (T_{o,max} - T_{d,max})$. For the 1st treatment the regression equation was (following Equation E4):

$$y = b_0 + b_1 + b_6X + b_{16}X$$

$$y = 0.2850 - 0.3967 + 0.1233\ X + 0.0173\ X$$

and subsituting $X = (T_{o,max} - T_{d,max})$:

$$y = -0.112 + 0.141(T_{o,max} - T_{d,max})$$

The other equations were found in the same way.

APPENDIX F: Analysis of Covariance.

The analysis of covariance (ANCOVA) on microlysimeter (ML) data in Chapter 4 was complicated by the fact that one of the independent variables (length) was quantitative. Even though the levels of length were fixed, it was desirable to handle it as quantitative in the ANCOVA since the actual values were different for steel and plastic ML's. The SAS program for statistical analysis on the IBM PC computer provides the GLM (General Linear Model) Procedure for ANCOVA when one or more of the independent variables is quantitative (a covariate) (SAS Institute Inc. 1985, p. 183). Non-quantitative variables are called class variables or factors and are assigned levels such as A, B and C or 1, 2 and 3. These levels are handled by the use of dummy (indicator) variables in the regression analysis which preceeds the ANCOVA.

The microlysimeter experiment was set up with two class variables, one called walltype with two levels (steel and plastic) and the other being the blocks (call them A and B). There was also one covariate, length. This was a randomized block design which can be modeled for ANCOVA as (Neter and Wasserman 1974, Eqtn. 23.29):

$$y_{ij} = \mu_{..} + \alpha_i + \tau_j + \delta(x_{ij} - \bar{X}_{..}) + \epsilon_{ij} \qquad [F1]$$

$i = 1$ and 2; $j = 1$ and 2

where y_{ij} is the dependent variable (evaporation), $\mu_{..}$ is the mean response, the α_i are the block effects (α_1 for block A and α_2 for block B), the τ_j are the walltype effects (τ_1 for plastic and τ_2 for steel), δ is the regression coefficient for the covariate term $(x_{ij} - \bar{X}_{..})$, $\bar{X}_{..}$ is the overall mean length, x_{ij} is the covariate, length, and ϵ_{ij} is the error term. Letting:

$$X_{ij} = x_{ij} - \bar{X}_{..} \qquad [F2]$$

and substituting into F1 gives the ANCOVA model:

$$y_{ij} = \mu_{..} + \alpha_i + \tau_j + \delta X_{ij} + \epsilon_{ij} \qquad [F3]$$

The corresponding regression model is (following Neter and Wasserman 1974, Eq. 23.31):

$$y_{ij} = b_0 + b_1 x_{ij1} + b_2 x_{ij2} + b_3 X_{ij} + \epsilon_{ij} \qquad [F4]$$

where

y_{ij} is the dependent variable (evaporation in mm)

x_{ij1} = 1, if the block is A
= 0, otherwise

x_{ij2} = 1, if walltype is plastic
= 0, otherwise

$X_{ij} = (x_{ij} - \bar{X}_{..})$, where x_{ij} is the length in cm.

and ϵ_{ij} is the error term. Variables x_{ij1} and x_{ij2} are called indicator or dummy variables. The regression model in matrix form is:

$$\mathbf{y} = \mathbf{X}\beta + \epsilon \qquad \text{[F5]}$$

where **y** is the vector matrix containing the response variable y_{ij} (evaporation in mm). The rectangular matrix, **X**, contains actual values of the independent variable X_{ij}; the indicator variables, x_{ij1} and x_{ij2}, representing the class variables; and an indicator variable, consisting of a column of ones, representing the intercept term, b_0, in Equation F2. The vector matrix, ϵ, contains the error terms and the vector, β, contains the coefficients to be estimated.

For the first ANCOVA performed, matrix **X** would be (using data from Table 3-1):

$$\mathbf{X} = \begin{array}{cccc} \mu & \text{length} & \text{block} & \text{walltype} \end{array} \left[\begin{array}{cccc} 1 & 0.89 & 1 & 1 \\ 1 & 1.49 & 1 & 0 \\ 1 & 11.49 & 1 & 0 \\ 1 & 10.89 & 1 & 1 \\ 1 & -8.51 & 1 & 0 \\ 1 & -9.11 & 1 & 1 \\ 1 & 1.49 & 1 & 0 \\ 1 & 0.89 & 1 & 1 \\ 1 & -8.51 & 0 & 0 \\ 1 & 0.89 & 0 & 1 \\ 1 & 11.49 & 0 & 0 \\ 1 & 10.89 & 0 & 1 \\ 1 & -8.51 & 0 & 0 \\ 1 & -9.11 & 0 & 1 \\ 1 & 1.49 & 0 & 0 \\ 1 & 0.89 & 0 & 1 \\ 1 & -9.11 & 0 & 1 \end{array}\right] \qquad \text{[F6]}$$

The vector **y** would be:

$$\mathbf{y} = \begin{bmatrix} 14.95 \\ 13.76 \\ 14.46 \\ 14.19 \\ 11.84 \\ 12.84 \\ 12.37 \\ 11.88 \\ 11.32 \\ 10.73 \\ 13.06 \\ 10.73 \\ 11.67 \\ 9.58 \\ 9.58 \\ 9.58 \\ 9.01 \end{bmatrix} \qquad [F7]$$

Vector β would be:

$$\beta = \begin{bmatrix} b_0 \\ b_1 \\ b_2 \\ b_3 \end{bmatrix} \qquad [F8]$$

Squaring the error term in Equation F5 gives $\epsilon'\epsilon$ which is the sum of squared error terms. Minimizing $\epsilon'\epsilon$ results in the normal equations in matrix form (Montgomery 1976)

$$\mathbf{X}'\mathbf{X}\hat{\beta} = \mathbf{X}'\mathbf{y} \qquad [F9]$$

where $\hat{\beta}$ is the vector of regression coefficients. Multiplying both sides of Equation F6 by $(\mathbf{X}'\mathbf{X})^{-1}$ results in the solution for the regression coefficients:

$$\hat{\beta} = (\mathbf{X'X})^{-1}\mathbf{X'y} \qquad [F10]$$

Multiple linear regressions of this sort may be done easily using Procedure GLM (SAS Institute Inc. 1985. p. 246).

To illustrate the procedure and to show that the result is the same as that produced by the SAS statistical package, the ANCOVA shown in Table 4-1 will be performed here using the regression approach (Neter and Wasserman 1974. p. 755) which requires that the regression model parameters be known in terms of the ANCOVA parameters. Correspondences between the ANCOVA and regression model parameters may be established by writing the ANCOVA model for observations from each level of each factor and writing the corresponding forms of the regression model. Since the dependent variable y_{ij} is the same in both cases the right hand sides of these equations may be equated yielding new equations giving regression coefficients in terms of ANCOVA model parameters. For example if an observation is from block B and the walltype is steel then the indicator variables are 0 and the regression equation is:

$$y_{22} = b_0 + b_3X_{22} + \epsilon_{22} \qquad [F11]$$

while the corresponding ANCOVA model is:

$$y_{22} = \mu_{..} + \alpha_2 + \delta_2 + \eta X_{22} + \epsilon_{22} \qquad [F12]$$

Equating the R.H.S. of F11 and F12 gives:

$$b_0 + b_3X_{22} = \mu_{..} + \alpha_2 + \delta_2 + \eta X_{22} \qquad [F13]$$

Since b_0, b_3, $\mu_{..}$, α_2, δ_2, and η_1 are all constants, taking the derivative of F13 with respect to X_{22} gives:

$$b_3 = \eta \qquad [F14]$$

Substituting F14 into F13 and subtracting like terms gives:

$$b_0 = \mu_{..} + \alpha_2 + \delta_2 \qquad [F15]$$

Similarly if the observation is from block B and walltype is plastic then the indicator variables are zero and and one. The regression equation is then:

$$Y_{21} = b_0 + b_2 + b_3X_{21} + \epsilon_{21} \qquad [F16]$$

and the ANCOVA model is:

$$y_{21} = \mu_{..} + \alpha_2 + \delta_1 + \eta X_{21} + \epsilon_{21} \qquad [F17]$$

Equating the R.H.S. of F16 and F17, substituting F14 and subtracting like terms gives:

$$b_0 + b_2 = \mu_{..} + \alpha_2 + \delta_1 \qquad [F18]$$

Substituting F15 and subtracting like terms gives:

$$b_2 = \delta_1 - \delta_2 \quad [F19]$$

Similarly we can find that:

$$b_1 = \alpha_1 - \alpha_2 \quad [F20]$$

Equations F14, F15, F19 and F20 are a full set of correspondences between the parameters of the regression model and those of the ANCOVA model.

Testing of hypotheses concerning treatment effects requires fitting of the full regression model (Equation F4) and then fitting of a reduced model corresponding to the hypothesis to be tested. The test statistic is (Neter and Wasserman 1974, Eqtn. 3.66):

$$F^* = \frac{SSE(R) - SSE(F)}{df_{eR} - df_{eF}} \div \frac{SSE(F)}{df_{eF}} \quad [F21]$$

where SSE(R) and SSE(F) are the error sum of squares for the reduced and full models, respectively; and df_{eR} and df_{eF} are the error degrees of freedom for the reduced and full models, respectively.

Fitting the full model (Equation F4) to the data in F6 and F7 gave an error sum of squares (SSE(F)) of 16.3591 with df_{eF} of 13 (Table F1). The COSTAT statistical package was used for the multiple regression analysis (CoHort Software 1988). To test for block effects, the null and alternative hypotheses were:

H_1: $\alpha_1 = \alpha_2 = 0$

H_2: not all α_i are zero,

and we must construct the reduced model under H_1 (F21 is true under H_1). From correspondence F20 we see that for the reduced model b_1 is zero so the reduced regression model is:

Table F1.

```
MULTIPLE REGRESSION - Full model.
Using: C:\COPLOT\ANCOVA1.DT
Regression equation:
E_mm = 10.991433849
  + 0.0776405019*length
  + 2.4942252197*block
  + -0.5842421345*walltype

R^2 =  0.7004220733
```

Source	SS	df	MS	F	P	
Total	54.607211765	16				
Regression	38.248096484	3	12.749365495	10.131461793	.0010	**
length	10.406126726	1	10.406126726	8.2693742975	.0130	*
block	26.401483593	1	26.401483593	20.980308581	.0005	***
walltype	1.4404861651	1	1.4404861651	1.1447024992	.3041	ns
Error	16.359115281	13	1.2583934831			

$$y_{ij} = b_0 + b_2 x_{ij2} + b_3 X_{ij} + \epsilon_{ij} \qquad [F22]$$

Fitting of F22 resulted in an SSE for the reduced model of 42.0579 with df_{eR} of 14 (Table F2). Equation F21 now yields:

$$F^* = \frac{42.0579 - 16.3591}{14 - 13} \div \frac{16.3591}{13} = 20.42 \qquad [F23]$$

The test statistic F^* is distributed as $F(1-p,(df_{eR} - df_{eF}),df_{eF})$ and for the 10 % probability level we have F(90 %, 1, 13) = 3.14 so we decide that the effects of blocking are significant at the 10 % level (blocking is still significant at the 0.001 % level, see Table 4-1).

Table F2.

```
MULTIPLE REGRESSION - Reduced model testing block effects.
Using: C:\COPLOT\ANCOVA1.DT
Regression equation:
E_mm = 12.232656785
  + 0.1017667173*length
  + -0.7116853329*walltype

R^2 =  0.2298104819
```

Source	SS	df	MS	F	P
Total	54.607211765	16			
Regression	12.549309653	2	6.2746548263	2.08867212	.1608 ns
length	10.406126726	1	10.406126726	3.4639334546	.0838 ns
walltype	2.143182927	1	2.143182927	0.7134107854	.4125 ns
Error	42.057902112	14	3.0041358652		

To test for walltype effects, the null and alternative hypotheses are:

H_1: $\delta_1 = \delta_2 = 0$

H_2: not all δ_i are zero,

and we must again construct the reduced model under H_1. From correspondence F19 we see that for the reduced model b_2 is zero so the reduced regression model is:

$$y_{ij} = b_0 + b_1 x_{ij1} + b_3 X_{ij} + \epsilon_{ij} \quad [F24]$$

Fitting of F24 resulted in an SSE for the reduced model of 17.7996 with df_{eR} of 14 (Table F3). Equation F21 now yields:

$$F^* = \frac{17.7996 - 16.3591}{14 - 13} \div \frac{16.3591}{13} = 1.14 \qquad [F25]$$

The test statistic F^* is distributed as $F(1-p,(df_{eR} - df_{eF}),df_{eF})$ and for the 10 % probability level we have F(90 %, 1, 13) = 3.14 so we decide that the effects of walltype are not significant at the 10 % level.

Table F3.

```
MULTIPLE REGRESSION - Reduced model testing walltype effects.
Using: C:\COPLOT\ANCOVA1.DT
Regression equation:
E_mm = 10.667777698
  + 0.0785099022*length
  + 2.5247221358*block

R^2 =  0.6740430271
```

Source	SS	df	MS	F	P	
Total	54.607211765	16				
Regression	36.807610319	2	18.403805159	14.475227044	.0004	***
length	10.406126726	1	10.406126726	8.1847773165	.0126	*
block	26.401483593	1	26.401483593	20.765676772	.0004	***
Error	17.799601446	14	1.2714001033			

To test for length effects, the null and alternative hypotheses are:

H_1: η = 0

H_2: η is not zero,

and we must again construct the reduced model under H_1. From correspondence F14 we see that for the reduced model b_3 is zero so the reduced regression model is:

$$y_{ij} = b_0 + b_1x_{ij1} + b_2X_{ij2} + \epsilon_{ij} \qquad [F26]$$

Fitting of F26 resulted in an SSE for the reduced model of 22.1175 with df_{eR} of 14 (Table F4). Equation F21 now yields:

$$F^* = \frac{22.1175 - 16.3591}{14 - 13} \div \frac{16.3591}{13} = 4.58 \qquad [F27]$$

The test statistic F^* is distributed as $F(1-p,(df_{eR} - df_{eF}),df_{eF})$ and for the 10 % probability level we have F(90 %, 1, 13) = 3.14 so we decide that the effects of walltype are significant at the 10 % level.

Table F4.

```
MULTIPLE REGRESSION - Reduced model testing length effects.
Using: C:\COPLOT\ANCOVA1.DT
Regression equation:
E_mm = 10.923552632
  + 2.6678947368*block
  + -0.6103947368*walltype

R^2 =  0.5949713211

Source                      SS    df            MS             F      P
-----------------------------------------------------------------------------
Total              54.607211765    16
Regression         32.489724923     2  16.244862461  10.282726789 .0018 **
  block            30.916602042     1  30.916602042  19.569693053 .0006 ***
  walltype         1.5731228801     1  1.5731228801  0.9957605255 .3353 ns
Error              22.117486842    14  1.5798204887
```

Note that the F values that we calculated for the effects of blocks, walltype and length are the same as those for type

III sum of squares generated by Procedure GLM (Table F5) and given in Table 4-1. Note also that the R^2 value of 0.7004 from regression analysis of the full model is the same as that from Procedure GLM (Table F5).

Table F5.

Output from SAS Procedure GLM.

SAS 14:12 Monday, May 29, 1989 1

General Linear Models Procedure
Class Level Information

Class	Levels	Values
BLOCK	2	0 1
WALLTYPE	2	0 1

Number of observations in data set = 17

SAS 14:12 Monday, May 29, 1989 2

General Linear Models Procedure

Dependent Variable: E_MM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	38.24809648	12.74936549	10.13	0.0010
Error	13	16.35911528	1.25839348		
Corrected Total	16	54.60721176			

R-Square	C.V.	Root MSE	E_MM Mean
0.700422	9.461813	1.121781	11.8558824

SAS 14:12 Monday, May 29, 1989 3

General Linear Models Procedure

Dependent Variable: E_MM

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	1	30.91660204	30.91660204	24.57	0.0003
WALLTYPE	1	1.57312288	1.57312288	1.25	0.2838
LENGTH	1	5.75837156	5.75837156	4.58	0.0520

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	1	25.69878683	25.69878683	20.42	0.0006
WALLTYPE	1	1.44048617	1.44048617	1.14	0.3041
LENGTH	1	5.75837156	5.75837156	4.58	0.0520

APPENDIX G: Program MOD19J.BAS for estimation of evaporation on a half-hourly basis using EBM1, EBM2 or EBM3. The program code is self-documenting.

<u>Program Listing</u>.

```
'Program MOD19J.BAS
'Written by Steve Evett, 19 June 1989 in MicroSoft QuickBASIC (R) ver. 4.0b.
'Program calculates latent heat flux using EBM1, EBM2 or EBM3
'and Experiment 1 data.
'Different formulas may be used to calculate
'the transfer coefficient for sensible heat flux.
'Latent heat flux (estimated evaporation) is calculated on a 30 minute basis.

DECLARE SUB Regress (estE(), aE(), b(), r2, np%, sse)

'All temperature variables are in degrees C:
DIM estE(136)        'Estimated evaporation [mm].
DIM aE(136)          'Measured evaporation [mm].
DIM b(3)             'Regression coefficients.
DIM FieldT(196, 9)   'Field soil surface temperature at 15 minute interval.
DIM DryT(196, 9)     'Dry soil surface temperature at 15 minute interval.
DIM cd(17, 9)        'Code number for each microlysimeter (ML).
DIM Tr(17, 9)        'Code number for ML treatment.
DIM ToMax(17, 9)     'Maximum daily reference dry soil temperature (IR).
DIM ToMin(17, 9)     'Minimum daily reference dry soil temperature (IR).
DIM TdMax(17, 9)     'Maximum daily drying soil temperature (IR).
DIM TdMin(17, 9)     'Minimum daily drying soil temperature (IR).
DIM Ea(17, 9)        'Measured evaporation (mm).
DIM d(11)            'Julian day.
DIM Wind(96, 9)      'Wind speed at 3 m measured at 1/2 h intervals.
DIM Time(96, 9)      'Time of weather station measurements.
DIM Tair(96, 9)      'Air temperature [Deg.C].
DIM estD(136)        'Estimated evaporation.
DIM FLmaxT(9)        'Maximum field soil temperature measured by thermistor.
DIM FLminT(9)        'Minimum field soil temperature measured by thermistor.
DIM DryMaxT(9)       'Maximum reference dry soil temperature by thermistor.
DIM DryMinT(9)       'Minimum reference dry soil temperature by thermistor.

rho = 1.21           'air density, 1.21 kg/m^3.
Cp = 1005            'specific heat of air, 1005 J/kg/(degree K).
emis = .95           'emissivity of soil, taken to be 0.95.
s = 5.67E-08         'Stefan-Boltzmann constant, J/s/m^2/(degree K)^4.

CLS : PRINT
PRINT "   Program MOD19J.BAS calculates latent heat flux using Equation 40c."
PRINT "   Program calculates latent heat flux using different formulas"
PRINT "   to calculate the transfer coefficient for sensible heat flux."
PRINT
PRINT "   These files must be placed on disk E:"
PRINT "       maxt1.dat, disk 95"
PRINT "       92t.dat to 101t.dat, disk 95"
PRINT "       92w.dat to 101w.dat, disk 95."
PRINT
PRINT "Hit any key to continue...": SLEEP

GOSUB InputDir       'Get program parameters and choices from keyboard.
PRINT : PRINT DATE$, TIME$


'Define Julian days for which Experiment 1 data exists.
d(1) = 92: d(2) = 93: d(3) = 94: d(4) = 95: d(5) = 96: d(6) = 97
d(7) = 98: d(8) = 99: d(9) = 100
```

```
'IR temperature and actual evaporation data for each
'microlysimeter on each day are in this file:
    temfile$ = "E:maxt1.dat"

'Get IR temperature, evaporation and weather data for each day:
kk = 0
FOR j = 1 TO 9
    day = d(j)
    GOSUB GetTempTime
NEXT j
PRINT "There were"; kk; " actual evaporation values."

'Get temperature, evaporation and weather data for each 48 hour period.
PRINT "GOT TO 1"
FOR j = 1 TO 9
    day = d(j)
  'Get wind speed, air temperature and time on the half-hour for day:
    windfile$ = "e:" + LTRIM$(STR$(day)) + "w.dat"
    houre = 0: k = 0
    GOSUB GetWind
    windfile$ = "e:" + LTRIM$(STR$(day + 1)) + "w.dat"
    GOSUB GetWind
  'Get actual field soil surface thermistor temperature & max. and min.:
    file$ = "e:" + LTRIM$(STR$(day)) + "t.dat"
    GOSUB GetFieldT1
    file$ = "e:" + LTRIM$(STR$(day + 1)) + "t.dat"
    GOSUB GetFieldT2
NEXT j
PRINT "Thermistor max. & min. temperatures (Deg. C):"
PRINT "Field max., Field min., Dry max., Dry min."
FOR j = 1 TO 9
    PRINT FLmaxT(j), FLminT(j), DryMaxT(j), DryMinT(j)
NEXT j

Main:
IF TranFlag = 3 THEN GOTO Main2  'Go search for best coeffcients for Dh,o.
Main1:
'Main program loop #1.
PRINT "GOT TO Main-1."
count% = 0
OPEN "a", #3, outfile$
FOR j = 1 TO 9
    day = d(j)
    'Do numerical integration for E for each day and all ML's:
    IF day <> 94 THEN GOSUB NumerInt
NEXT j
CALL Regress(estD(), aE(), b(), r2, count%, sse)
PRINT "Regression coefficients:";
PRINT USING "##.##### "; r2, b(0), b(1);
PRINT count%, sse
CLOSE #3
PRINT "Hit any key to continue: ": SLEEP
GOSUB InputDir1  'Decide what to do now.
GOTO Main



Main2:
'Main program loop #2.
PRINT "GOT TO Main-2."
count% = 0
Endb0 = 1 + ABS(b0Start - b0End) / ABS(b0Inc)
Endb1 = 1 + ABS(b1Start - b1End) / ABS(b1Inc)
FOR jj = 1 TO Endb0
    PRINT : COLOR 0, 7: PRINT jj; : COLOR 7, 0: PRINT
```

```
    b0 = b0Start + (jj - 1) * b0Inc
    FOR kj = 1 TO Endb1
        b1 = b1Start + (kj - 1) * b1Inc
        PRINT kj, b0, b1, TIME$
        FOR j = 1 TO 9
            day = d(j)
            'Do numerical integration for E for each day and all ML's:
            IF day <> 94 THEN GOSUB NumerInt
        NEXT j
        CALL Regress(estD(), aE(), b(), r2, count%, sse)
        OPEN "a", #3, outfile$
        PRINT #3, USING "##.##### "; b(0), b(1);
        PRINT #3, USING "#.####### "; r2;
        PRINT #3, USING "###.## "; sse;
        PRINT #3, USING "#.#####"; b0;
        PRINT #3, USING "##.####"; b1
        CLOSE #3
        count% = 0
    NEXT kj
NEXT jj
GOSUB InputDir1  'Decide what to do now.
GOTO Main

NumerInt:
w = 2 * 3.141593 / 24
'Air temperature was measured at 1.5 m so calculate part of equation for
'transfer coefficient for neutral conditions:
logz2 = .16 * (LOG(150 / .03)) ^ -2
'Calculate estimated evaporation (mm) for each microlysimeter.
FOR k = 1 TO 17
    'Numerical integration of estimated evaporation (mm) for this ML.
    StartFlag = 0           'Set flag for integration to zero.
    IntCnt% = 0             'Initialize integration period counter to zero.
    Eest = 0: EestD = 0
IF k = 0 THEN LPRINT "day, i, FieldT(i*2+1,j), DryT(i*2+1,j), time(i, j), RefT,
MLT, Wind(i, j), Tair(i, j); ED"
    FOR i = 1 TO 96
        ED = 0  'Initialize evaporation for this time step to zero.
        'Decide if it's time to start integration:
        IF Time(i, j) >= StartTime THEN StartFlag = 1
        IF StartFlag = 0 THEN GOTO EndInt
        'Increment counter for period of integration:
        IntCnt% = IntCnt% + 1
        'End integration if period is over:
        IF IntCnt% > IntPeriod * 2 THEN EXIT FOR

        'Correct wind speed from 3 m to 1.5 m reference height:
        U1 = Wind(i, j) * .879     'See Appendix A for formula.
        IF U1 <= 0 THEN
            PRINT "Error.  Wind speed ="; U1; " m/s for time"; Time(i, j);
            PRINT " Day"; d(j)
            U1 = .00001   'Set wind speed to arbitrarily low value.
        END IF
        'Calculate ML temperature, MLT, from field temp. & IR:
        GOSUB FindMLT
        'Calc. Dry soil temp. from dry soil thermistor temp. & IR:
        GOSUB FindDryT
        'Calculate transfer coefficient for sensible heat flux
        'using formulas of Kreith and Sellers:
        Dm = U1 * logz2: DhML = Dm
        'Calculate transfer coefficient for sensible heat flux from dry soil:
        DhDry = b0 * U1 ^ b1              'Dh in m/s.
        'If TranFlag=-1 then use Ben-Asher formula instead:
        IF TranFlag = -1 THEN DhML = DhDry
        dTML = MLT - Tair(i, j)    'ML - air temperature difference.
```

```
        dTDry = RefT - Tair(i, j)  'Dry soil - air temperature difference.
        IF TranFlag = -2 THEN
            'Use stability corrected terms.
            IF dTML >= 0 THEN
                DhML = Dm * (1 + 14 * dTML / U1 ^ 2) ^ .33333
            ELSE
                DhML = Dm * (1 - 14 * dTML / U1 ^ 2) ^ -.33333
            END IF
            IF dTDry >= 0 THEN
                DhDry = Dm * (1 + 14 * dTDry / U1 ^ 2) ^ .33333
            ELSE
                DhDry = Dm * (1 - 14 * dTDry / U1 ^ 2) ^ -.33333
            END IF
        END IF
        'Calc. LE flux based on (To - Td) estimated from field temp's. & IR.
        'LED is latent heat flux density in kW/m^2
        'using thermistor & IR based (To - Td):
        T4 = (RefT + 273.15) ^ 4 - (MLT + 273.15) ^ 4
        Hterm = rho * Cp * (DhDry * dTDry - DhML * dTML) 'use in MOD13J.BAS.
        LED = (Hterm + emis * s * T4) / 1000
        'ED is evaporation in mm for 1/2 hour. kg/m^2=mm water.
        ED = LED * .5 * 3600 / 2442
        'Do not sum if only positive values are to be summed and evap. is neg:
        IF ED < 0 AND PosOnly = 1 THEN GOTO EndInt
        'Eest is total evaporation for day in mm.
        'If day is 92 then only integrate from time of 1st weighing.
        IF day = 92 THEN
            GOSUB PartDay  'Decide to sum or not.
        ELSE
            EestD = ED + EestD  'Go ahead and sum.
        END IF
EndInt:
    IF k = 0 THEN
      LPRINT USING "## "; day; i;
      LPRINT USING "##.# "; Time(i, j);
     LPRINT USING "##.#### "; FieldT(i * 2 + 1, j); DryT(i * 2 + 1, j); RefT; MLT;
      LPRINT Wind(i, j); Tair(i, j); ED
    END IF
    NEXT i
    'Put Eest in array for use in regression.
    count% = count% + 1
    estD(count%) = EestD
    'Print day, Code, treatment, est. evaporation (mm), & actual evap. (mm).
    IF TranFlag <> 3 THEN PRINT #3, day, cd(k, j), Tr(k, j), EestD, aE(count%)
NEXT k
RETURN



FindMLT:
IF Time(i, j) < SplitTime THEN
    'For this day. Use minimum therm. and IR temp. from this AM.
    fslope = (TdMax(k, j) - TdMin(k, j)) / (FLmaxT(j) - FLminT(j))
    intercept = TdMax(k, j) - fslope * FLmaxT(j)
ELSE
    'For rest of period use minimum therm. & IR temp. from tomorrow AM.
    IF j < 9 THEN
        fslope = (TdMax(k, j) - TdMin(k, j + 1))
        fslope = fslope / (FLmaxT(j) - FLminT(j + 1))
        intercept = TdMax(k, j) - fslope * FLmaxT(j)
    ELSE
        'For 6.5 hours of day 101 use same day 100 temps.
        fslope = (TdMax(k, j) - TdMin(k, j)) / (FLmaxT(j) - FLminT(j))
        intercept = TdMax(k, j) - fslope * FLmaxT(j)
    END IF
```

```
END IF
'Calc. ML temp. from field temp.:
MLT = intercept + fslope * FieldT(i * 2 + 1, j)
RETURN

FindDryT:
IF Time(i, j) < SplitTime THEN
    'For this day.
    dslope = (ToMax(k, j) - ToMin(k, j)) / (DryMaxT(j) - DryMinT(j))
    intercept = ToMax(k, j) - dslope * DryMaxT(j)
ELSE
    'For next day.
    IF j < 9 THEN
        dslope = ToMax(k, j) - ToMin(k, j + 1)
        dslope = dslope / (DryMaxT(j) - DryMinT(j + 1))
        intercept = ToMax(k, j) - dslope * DryMaxT(j)
    ELSE
        'For 6.5 hours of day 101 use same day 100 temps.
        dslope = (ToMax(k, j) - ToMin(k, j)) / (DryMaxT(j) - DryMinT(j))
        intercept = ToMax(k, j) - dslope * DryMaxT(j)
    END IF
END IF
'Calc. Dry soil temp. from dry soil thermistor temp. & IR:
RefT = intercept + dslope * DryT(i * 2 + 1, j)
RETURN

GetWind:  'Get wind and time for 6 to 24 hours for a day.
'Get half-hourly wind speed in m/s at 3 m height, and time.
OPEN "i", #2, windfile$
LINE INPUT #2, id$
WHILE NOT EOF(2)
    k = k + 1
    houre = houre + .5
    Time(k, j) = houre
    'Get wind at 3 m (m/s).  Get air temperature [Deg.C]:
    INPUT #2, x, h, Tair(k, j), Wind(k, j)
WEND
CLOSE #2
nwind% = k
PRINT "   There were"; nwind%; " variables from file "; windfile$
RETURN




GetTempTime:
'Get temperatures and actual evaporation for each microlysimeter for day:
OPEN "i", #2, temfile$
LINE INPUT #2, id$
PRINT id$
k = 0
DO WHILE NOT EOF(2)
    INPUT #2, thisday, Code, trt, pmt, amt, maxtdry, mintdry, Emm, U3
    IF thisday = day THEN
        k = k + 1
        cd(k, j) = Code        'Code for each microlysimeter.
        Tr(k, j) = trt         'Treatment number.
        TdMin(k, j) = amt     'Minimum drying soil surface temperature, Deg.C.
        TdMax(k, j) = pmt      'Maximum drying soil surface temperature, Deg.C.
        ToMax(k, j) = maxtdry    'Maximum dry soil surface temperature, Deg.C.
        ToMin(k, j) = mintdry 'Minimum dry soil surface temperature, Deg.C.
        Ea(k, j) = Emm         'Actual evaporation for each ML in mm, Deg.C.
        IF day <> 94 THEN kk = kk + 1
        IF day <> 94 THEN aE(kk) = Emm
    END IF
```

```
    IF thisday > day THEN EXIT DO
LOOP
CLOSE #2
nML% = k
PRINT "   There were"; nML%; " variables in file "; temfile$
RETURN

PartDay:
    SELECT CASE cd(k, j)
    CASE 25
        IF Time(i, j) > 9.25 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 26
        IF Time(i, j) > 9.5 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 27
        IF Time(i, j) > 9.75 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 28
        IF Time(i, j) > 10! THEN Eest = E + Eest: EestD = ED + EestD
    CASE 29
        IF Time(i, j) > 10.25 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 210
        IF Time(i, j) > 10.5 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 211
        IF Time(i, j) > 10.75 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 212
        IF Time(i, j) > 11! THEN Eest = E + Eest: EestD = ED + EestD
    CASE 15
        IF Time(i, j) > 13.25 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 16
        IF Time(i, j) > 13.5 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 17
        IF Time(i, j) > 14! THEN Eest = E + Eest: EestD = ED + EestD
    CASE 18
        IF Time(i, j) > 14.25 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 19
        IF Time(i, j) > 14.25 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 110
        IF Time(i, j) > 14.5 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 111
        IF Time(i, j) > 14.75 THEN Eest = E + Eest: EestD = ED + EestD
    CASE 112
        IF Time(i, j) > 15! THEN Eest = E + Eest: EestD = ED + EestD
    CASE 113
        IF Time(i, j) > 15.25 THEN Eest = E + Eest: EestD = ED + EestD
    CASE ELSE
        PRINT "ERROR.  First day code not found.  Sum not performed."
    END SELECT
    RETURN

'Get field & dry soil surface temperature for this day.
GetFieldT1:
OPEN "i", #2, file$
LINE INPUT #2, id$
k = 0
FLminT(j) = 60
FLmaxT(j) = 0
DryMinT(j) = 60
DryMaxT(j) = 0
WHILE NOT EOF(2)
    k = k + 1
    INPUT #2, x, h, DryT(k, j), FieldT(k, j)
    IF FieldT(k, j) > FLmaxT(j) THEN FLmaxT(j) = FieldT(k, j)
    IF FieldT(k, j) < FLminT(j) THEN FLminT(j) = FieldT(k, j)
    IF DryT(k, j) > DryMaxT(j) THEN DryMaxT(j) = DryT(k, j)
    IF DryT(k, j) < DryMinT(j) THEN DryMinT(j) = DryT(k, j)
WEND
```

```
CLOSE #2
ntdep% = k
PRINT "   There were"; ntdep%; " variables in file "; file$
RETURN

GetFieldT2:  'Get temperatures for next day.
OPEN "i", #2, file$
LINE INPUT #2, id$
WHILE NOT EOF(2)
    k = k + 1
    INPUT #2, x, h, DryT(k, j), FieldT(k, j)
WEND
CLOSE #2
ntdep% = k
PRINT "   There were"; ntdep%; " variables in file "; file$
RETURN

InputDir1:
CLS
INPUT "[Q]uit, [S]hell to DOS, or [R]un again: "; q$
IF q$ = "Q" OR q$ = "q" THEN END
IF q$ = "S" OR q$ = "s" THEN SHELL: GOTO InputDir1
IF q$ <> "R" AND q$ <> "r" THEN GOTO InputDir1
InputDir:
CLS : PRINT
PRINT "The transfer coefficient for neutral stability, Dm, is normally used"
PRINT "for sensible heat flux from the drying soil.  You may choose to use"
PRINT "Dm for dry soil also (Choice 0), or use the function used by Ben-Asher"
PRINT "et al. (1983) for both soils (Choice -1).  Or, you may use the"
PRINT "stability corrections of Kreith and Sellers (Choice -2). "
PRINT "Choices 1, 2 & 3 allow the transfer coefficient for dry soil to be"
PRINT "changed while that for drying soil is Dm."
PRINT
PRINT "   Use stability correction for Dm for both soils    [-2],"
PRINT "   Use Dh = 1/(126 u^-.96)  (Ben-Asher et al. 1983)  [-1],"
PRINT "   Use transfer coefficient, Dm for neutral stability [0],"
PRINT "      or use that plus Dh,o = 0.00313 u^0.41          [1],"
PRINT "      or input coefficients for Dh,o                  [2],"
INPUT "      or search for coefficients for Dh,o             [3]:"; TranFlag
IF TranFlag = -1 THEN b0 = .00794: b1 = .96
IF TranFlag = 0 THEN b0 = .002205: b1 = 1   'For wind speed at 1.5 m.
IF TranFlag = 1 THEN b0 = .00313: b1 = .41
IF TranFlag = 2 THEN INPUT "Enter b0: "; b0: INPUT "Enter b1: "; b1
IF TranFlag = 3 THEN
    INPUT "Enter begining value for b0: "; b0Start
    INPUT "Enter ending value for b0:   "; b0End
    INPUT "Enter increment for b0:      "; b0Inc
    INPUT "Enter begining value for b1: "; b1Start
    INPUT "Enter ending value for b1:   "; b1End
    INPUT "Enter increment for b1:      "; b1Inc
END IF
PRINT
PRINT "   Define period of interest. Evaporation will be found only for this"
PRINT "   period of the day. Values are in hours starting at midnight = 0 h."
INPUT "   Enter starting time (hours): "; StartTime
Redo:
PRINT "   Period of integration plus starting time must be less than 31 h."
PRINT "   Ending time cannot be later than 7 AM on next day."
INPUT "   Enter period of integration (hours): "; IntPeriod
PRINT "Starting time will be"; StartTime; " hours."
EndTime = IntPeriod + StartTime
IF EndTime > 31 THEN PRINT : PRINT "Start time:"; StartTime; " h.": GOTO Redo
IF IntPeriod + StartTime > 24 THEN EndTime = IntPeriod + StartTime - 24
PRINT "Integration will end at"; EndTime; " hours;"; IntPeriod;
PRINT " hours after start."
```

```
PRINT
PRINT "   Enter time in hours to change base for temperature calculations: ";
INPUT SplitTime
PRINT "   Sum only positive values of evaporation [1] or all values [0]: ";
INPUT PosOnly
'Output will be in this file:
FileNum = FileNum + 1
    outfile$ = "E:evap" + LTRIM$(STR$(FileNum)) + ".out"
    OPEN "o", #3, outfile$
PRINT #3, "Output from Mod19j.bas. "; DATE$; " "; TIME$; "."
PRINT #3, "Starting time was"; StartTime; "hours."
PRINT #3, "Integration ended at"; EndTime; " hours;"; IntPeriod;
PRINT #3, "hours after start."
PRINT #3, "Base for temperature calculations changed at"; SplitTime; "hours."
IF PosOnly = 1 THEN PRINT #3, "Summed only positive values of evaporation."
IF TranFlag = -2 THEN
    PRINT #3, "Using transfer coefficient, Dm, for neutral stability ";
    PRINT #3, "with stability corrections."
END IF
IF TranFlag = -1 THEN
    PRINT #3, "Using Dh = 1/(126 u^-.96)  (Ben-Asher et al. 1983)."
END IF
IF TranFlag = 0 THEN
    PRINT #3, "Using transfer coefficient, Dm, for neutral stability."
END IF
IF TranFlag = 1 THEN PRINT #3, "Using Dh,d = Dm & Dh,o = 0.00313 u^0.41."
IF TranFlag = 2 THEN
    PRINT #3, "Using Dh,d = Dm and Dh,o = b0 u^b1 w/ b0="; b0; " and b1="; b1
END IF
IF TranFlag = 3 THEN
    PRINT #3, "Using Dh,d = Dm & finding best coefficients for Dh,o = b0 u^b1."
END IF
IF TranFlag <> 3 THEN PRINT #3, "Hour, est. E (mm) w/ estimated To-Td, Actual E."
IF TranFlag = 3 THEN PRINT #3, "Regression b0, b1 & r^2, SSE, transfer function b0
& b1."
    CLOSE #3
RETURN

SUB Regress (estE(), aE(), b(), r2, np%, sse)
' ++++++++++++++++++++++++++++++++   Calculate linear regression.
   sumx = 0: sumxx = 0: sumy = 0: sumyy = 0: sumxy = 0
   FOR i% = 1 TO np%: sumx = sumx + estE(i%): sumy = sumy + aE(i%): NEXT i%
   avex = sumx / np%: avey = sumy / np%
   FOR i% = 1 TO np%
          sumxx = sumxx + (estE(i%) - avex) ^ 2
          sumyy = sumyy + (aE(i%) - avey) ^ 2
          sumxy = sumxy + (estE(i%) - avex) * aE(i%)
   NEXT i%
   varx = sumxx / (np% - 1)
   vary = sumyy / (np% - 1)
   IF sumxx <> 0 THEN
       b(1) = sumxy / sumxx
       ELSE
       b(1) = 0
       PRINT "   There is only 1 value of X, regression cannot be calculated."
   END IF
   b(0) = avey - b(1) * avex
   b(2) = 1
   sse = sumyy - b(1) * sumxy
   IF sumxx <> 0 THEN
       ssr = b(1) * sumxy
       IF np% > 2 THEN
           varyhat = sse / (np% - 2)
           IF varyhat > 0 THEN f0 = ssr / varyhat
           r2 = ssr / sumyy
```

```
       ELSE
           PRINT "   There are only 2 data pairs.  Variance of the estimate,"
         PRINT "   correlation coefficient and F statistic cannot be computed."
       END IF
   END IF
END SUB
```

Appendix H. Tables of linear and Spearman correlations for Chapter 8.

The following tables contain linear correlations and Spearman rank-order correlations on data discussed in Chapter 8. The linear correlations were performed on the data after it was transformed to relative differences using Equation 8-3. Tables of linear correlations present, from top to bottom, the correlation coefficient, r, the intercept, the slope, the probability that the slope equals 0 (probability that data were not correlated between days), and the probability that the slope equals 1 (probability that Equation 8-4 is confirmed).

The Spearman correlation tables present, from top to bottom, the correlation coefficient, the probability that ranks were uncorrelated between days, and the number of data pairs included in calculations. The number of data pairs was the same for both linear and Spearman correlations.

Table 8-4.

Correlations on relative differences of daily profile water contents, Experiment 2, all irrigations.

	Irrigation 1						Irrigation 2	
Day\Day	80	81	82	83	85	90	92	93
77	0.9179	0.9312	0.9401	0.9463	0.9443	0.9521	0.9422	0.9369
	0.000	-0.003	0.000	0.000	0.000	0.000	0.000	-0.005
	0.986	0.997	1.003	1.015	1.023	1.046	1.053	1.012
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.9033	.9794	.9816	.9015	.8449	.6980	.6623	.9239
79 Irrigation 1		----------	----------	----------	----------	----------	----------	----------
80		0.9985	0.9969	0.9948	0.9888	0.9802	0.9755	0.9748
		-0.002	-0.000	-0.000	-0.000	0.000	-0.000	-0.002
		0.997	0.990	0.993	0.998	1.004	1.015	0.986
		.0000	.0000	.0000	.0000	.0000	.0000	.0000
		.9772	.9275	.9505	.9848	.9740	.8877	.9001
81			0.9991	0.9982	0.9927	0.9859	0.9800	0.9792
			0.003	0.003	0.003	0.003	0.003	0.000
			0.995	1.001	1.006	1.013	1.024	0.993
			.0000	.0000	.0000	.0000	.0000	.0000
			.9661	.9953	.9568	.9035	.8284	.9504
82				0.9993	0.9937	0.9878	0.9821	0.9803
				0.000	0.000	0.000	0.000	-0.003
				1.004	1.010	1.018	1.029	0.997
				.0000	.0000	.0000	.0000	.0000
				.9664	.9295	.8691	.7916	.9811
83					0.9935	0.9891	0.9829	0.9815
					-0.000	0.000	-0.000	-0.003
					1.004	1.014	1.025	0.993
					.0000	.0000	.0000	.0000
					.9693	.8969	.8219	.9488
85						0.9946	0.9898	0.9883
						0.000	0.000	-0.003
						1.009	1.021	0.989
						.0000	.0000	.0000
						.9333	.8459	.9206
90							0.9884	0.9875
							-0.000	-0.004
							1.005	0.974
							.0000	.0000
							.9615	.8020
91 Irrigation 2		----------	----------	----------	----------	----------	----------	----------
92								0.9866
								-0.003
								0.958
								.0000
								.6832

Continued on next page.

Table 8-4 (cont.)

Day\Day	Irrigation 2 94	95	96	98	100	Irrigation 3 102	103	105
77	0.9534	0.9536	0.9552	0.9559	0.9631	0.9540	0.9596	0.9390
	0.000	0.000	0.000	0.001	-0.003	-0.008	0.005	0.005
	1.042	1.036	1.041	1.042	1.067	1.049	1.094	1.032
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.7272	.7588	.7279	.7288	.5789	.6841	.4427	.7982
79	Irrigation 1							
80	0.9813	0.9811	0.9797	0.9789	0.9772	0.9716	0.9714	0.9500
	-0.000	-0.000	-0.000	0.001	-0.003	-0.006	0.009	0.005
	0.999	0.993	0.995	0.994	0.978	1.002	1.021	0.959
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.9893	.9496	.9619	.9586	.8320	.9884	.8449	.7109
81	0.9862	0.9863	0.9850	0.9845	0.9831	0.9770	0.9784	0.9555
	0.003	0.003	0.003	0.004	-0.000	-0.004	0.011	0.008
	1.007	1.002	1.003	1.003	0.991	1.010	1.032	0.969
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.9494	.9830	.9751	.9769	.9333	.9318	.7737	.7805
82	0.9886	0.9885	0.9878	0.9872	0.9858	0.9799	0.9820	0.9595
	0.000	0.000	0.000	0.001	-0.002	-0.007	0.008	0.005
	1.013	1.007	1.010	1.009	1.003	1.015	1.039	0.976
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.9073	.9458	.9288	.9331	.9745	.8927	.7197	.8288
83	0.9892	0.9895	0.9890	0.9884	0.9875	0.9818	0.9840	0.9622
	-0.000	-0.000	-0.000	0.001	-0.002	-0.006	0.008	0.006
	1.008	1.003	1.006	1.005	1.001	1.012	1.035	0.975
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.9404	.9769	.9576	.9621	.9918	.9119	.7442	.8200
85	0.9959	0.9958	0.9953	0.9951	0.9945	0.9894	0.9905	0.9686
	0.000	0.000	-0.000	0.000	-0.003	-0.007	0.008	0.006
	1.004	0.999	1.001	1.002	0.991	1.005	1.026	0.969
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.9689	.9914	.9891	.9879	.9292	.9641	.8039	.7767
90	0.9961	0.9963	0.9962	0.9966	0.9964	0.9915	0.9935	0.9730
	-0.000	-0.000	-0.000	0.001	-0.002	-0.007	0.008	0.006
	0.990	0.985	0.988	0.988	0.983	0.993	1.012	0.957
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.9239	.8866	.9088	.9123	.8723	.9474	.9102	.6893
91	Irrigation 2							
92	0.9921	0.9923	0.9916	0.9917	0.9902	0.9882	0.9876	0.9646
	-0.000	0.000	-0.000	0.001	-0.002	-0.008	0.009	0.005
	0.970	0.965	0.967	0.968	0.956	0.969	0.983	0.935
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.7667	.7299	.7480	.7532	.6606	.7586	.8684	.5366
93	0.9916	0.9912	0.9913	0.9902	0.9895	0.9880	0.9861	0.9649
	0.003	0.003	0.003	0.004	0.002	-0.005	0.013	0.010
	0.999	0.994	0.997	0.996	0.990	0.998	1.018	0.969
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.9929	.9530	.9787	.9743	.9265	.9860	.8675	.7786

Continued on next page.

Table 8-4 (cont.)

	Irrigation 2					Irrigation 3		
Day\Day	94	95	96	98	100	102	103	105
94		0.9995	0.9994	0.9993	0.9988	0.9968	0.9979	0.9732
		0.000	-0.000	0.001	-0.002	-0.008	0.009	0.005
		0.994	0.997	0.997	0.991	1.002	1.022	0.968
		.0000	.0000	.0000	.0000	.0000	.0000	.0000
		.9564	.9796	.9808	.9280	.9831	.8294	.7674
95			0.9996	0.9994	0.9989	0.9968	0.9980	0.9730
			-0.000	0.001	-0.002	-0.008	0.009	0.005
			1.003	1.003	0.996	1.008	1.024	0.973
			.0000	.0000	.0000	.0000	.0000	.0000
			.9794	.9787	.9694	.9422	.8148	.8059
96				0.9995	0.9994	0.9971	0.9984	0.9746
				0.001	-0.002	-0.008	0.008	0.005
				1.000	0.995	1.004	1.023	0.971
				.0000	.0000	.0000	.0000	.0000
				.9986	.9579	.9670	.8255	.7917
98					0.9993	0.9970	0.9986	0.9734
					-0.003	-0.008	0.008	0.004
					0.994	1.005	1.022	0.968
					.0000	.0000	.0000	.0000
					.9557	.9604	.8302	.7699
100						0.9966	0.9986	0.9721
						-0.006	0.010	0.006
						1.010	1.029	0.968
						.0000	.0000	.0000
						.9269	.7798	.7644
101	Irrigation 3 ----------							
102							0.9975	0.9710
							0.016	0.012
							1.007	0.962
							.0000	.0000
							.9461	.7253
103								0.9690
								-0.003
								0.944
								.0000
								.5803

Table 8-5.

Spearman rank-order correlation coefficients on daily profile water contents, Irrigations 1, 2 and 3, Experiment 2. From top to bottom numbers are correlation coefficient, probability that ranks are not preserved, and number of samples.

	Irrigation 1						Irrigation 2	
Day/Day	80	81	82	83	85	90	92	93
77	0.91788	0.92925	0.93350	0.93901	0.93661	0.94043	0.92507	0.93175
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	56	57	57	57	57	57	55
79 Irrigation 1								
80	1.00000	0.99658	0.99566	0.99313	0.98393	0.97725	0.97180	0.96198
	0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	56	57	57	57	57	57	55
81		1.00000	0.99713	0.99727	0.98715	0.98113	0.97526	0.96699
		0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		56	56	56	56	56	56	54
82			1.00000	0.99695	0.98879	0.98114	0.97498	0.96558
			0.0	0.0001	0.0001	0.0001	0.0001	0.0001
			57	57	57	57	57	55
83				1.00000	0.98503	0.98094	0.97096	0.96472
				0.0	0.0001	0.0001	0.0001	0.0001
				57	57	57	57	55
85					1.00000	0.99138	0.98956	0.98110
					0.0	0.0001	0.0001	0.0001
					57	57	57	55
90						1.00000	0.98820	0.98175
						0.0	0.0001	0.0001
						57	57	55
91 Irrigation 2								
92							1.00000	0.98759
							0.0	0.0001
							57	55

	Irrigation 2					Irrigation 3		
Day/Day	94	95	96	98	100	102	103	105
77	0.94024	0.94108	0.94128	0.93780	0.94365	0.94026	0.95267	0.93042
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	57	57	56	55	55	53	52
79 Irrigation 1								
80	0.97744	0.97576	0.97375	0.97628	0.97338	0.97063	0.97250	0.95245
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	57	57	56	55	55	53	52

Continued on next page.

Table 8-5 (cont.).

	Irrigation 2					Irrigation 3		
Day/Day	94	95	96	98	100	102	103	105
81	0.98038	0.97990	0.97683	0.97951	0.97698	0.97461	0.97678	0.94968
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	56	56	56	55	54	54	52	51
82	0.98101	0.98010	0.97790	0.98072	0.97713	0.97569	0.97766	0.95569
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	57	57	56	55	55	53	52
83	0.97770	0.97796	0.97556	0.97772	0.97576	0.97294	0.97525	0.95612
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	57	57	56	55	55	53	52
85	0.99410	0.99268	0.99112	0.99262	0.99098	0.98773	0.98839	0.96730
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	57	57	56	55	55	53	52
90	0.99306	0.99378	0.99293	0.99392	0.99488	0.99026	0.99065	0.97123
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	57	57	56	55	55	53	52
91 Irrigation 2								
92	0.99520	0.99417	0.99255	0.99234	0.99026	0.99149	0.98984	0.96209
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	57	57	56	55	55	53	52
93	0.98824	0.98586	0.98629	0.98277	0.98516	0.98766	0.98139	0.95419
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	55	55	55	54	53	53	52	50
94	1.00000	0.99806	0.99656	0.99768	0.99668	0.99531	0.99573	0.97055
	0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	57	57	57	56	55	55	53	52
95		1.00000	0.99896	0.99904	0.99747	0.99610	0.99702	0.97191
		0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		57	57	56	55	55	53	52
96			1.00000	0.99809	0.99812	0.99610	0.99702	0.97362
			0.0	0.0001	0.0001	0.0001	0.0001	0.0001
			57	56	55	55	53	52
98				1.00000	0.99779	0.99619	0.99693	0.97240
				0.0	0.0001	0.0001	0.0001	0.0001
				56	54	54	52	51
100					1.00000	0.99532	0.99656	0.97128
					0.0	0.0001	0.0001	0.0001
					55	53	51	50
101 Irrigation 3								
102						1.00000	0.99683	0.96792
						0.0	0.0001	0.0001
						55	51	50
103							1.00000	0.96884
							0.0	0.0001
							53	48

Table 8-6.

Correlations on relative difference of midday ($T_{o,max}$ - $T_{d,max}$), Experiment 2, all irrigations.

	Irrigation 1							Irrigation 2	
Day\Day	81	82	83	84	85	86	87	92	93
80	0.2683	0.1172	0.0079	-.1659	0.1210	0.3882	0.3492	0.0770	0.1053
	-0.001	-0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000
	0.070	0.028	0.002	-0.020	0.043	0.101	0.122	0.016	0.018
	.0520	.3989	.9548	.2308	.3835	.0037	.0097	.5803	.4486
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
81		0.8464	0.6115	-.0067	0.3000	0.4712	0.5386	0.6064	0.6675
		-0.004	-0.002	-0.000	-0.001	-0.002	-0.001	-0.006	-0.003
		0.849	0.739	-0.003	0.452	0.524	0.789	0.511	0.466
		.0000	.0000	.9610	.0247	.0002	.0000	.0000	.0000
		.0171	.0059	.0000	.0009	.0000	.0421	.0000	.0000
82			0.7934	-.1598	0.3621	0.6159	0.5979	0.5223	0.6338
			0.000	0.000	0.000	0.000	0.000	0.000	-0.000
			0.970	-0.086	0.556	0.695	0.896	0.403	0.443
			.0000	.2353	.0056	.0000	.0000	.0000	.0000
			.6370	.0000	.0040	.0021	.2674	.0000	.0000
83				0.0149	0.5515	0.4283	0.5414	0.3561	0.3945
				-0.000	0.000	-0.000	-0.000	-0.000	-0.000
				0.007	0.693	0.395	0.664	0.225	0.226
				.9124	.0000	.0009	.0000	.0065	.0024
				.0000	.0000	.0000	.0000	.0000	.0000
84					0.4813	-.5332	-.0517	-.2588	-.3175
					0.000	0.000	0.000	0.000	0.000
					1.372	-1.116	-0.144	-0.371	-0.412
					.0002	.0000	.7025	.0519	.0161
					.2350	.0000	.0041	.0000	.0000
85						0.1846	0.6051	-.0306	0.0235
						-0.000	-0.000	-0.000	-0.000
						0.136	0.590	-0.015	0.011
						.1695	.0000	.8215	.8624
						.0000	.0000	.0000	.0000
86							0.6821	0.2243	0.4097
							0.000	0.000	0.000
							0.906	0.153	0.254
							.0000	.0934	.0016
							.0001	.0000	.0000
87								0.2536	0.2782
								0.000	-0.000
								0.131	0.130
								.0570	.0362
								.0000	.0000

Continued on next page.

Table 8-6 (cont.)

Day\Day		93
91	Irrigation 2	--
92		0.7865
		-0.000
		0.713
		.0000
		.0044

	Irrigation 2							Irrigation 3		
Day\Day	94	95	96	97	98	99	100	102	103	104
80	0.1407	0.0606	0.1660	0.1531	0.2368	0.1277	0.0952	0.1405	0.2580	0.0042
	-0.000	-0.000	0.000	-0.000	-0.001	-0.000	0.001	-0.001	-0.001	-0.000
	0.048	0.010	0.027	0.031	0.054	0.026	0.014	0.019	0.052	0.001
	.3152	.6636	.2351	.2692	.0847	.3577	.5020	.3158	.0596	.9762
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
81	0.5435	0.4579	0.5270	0.6383	0.4962	0.5735	0.4635	0.3381	0.6804	0.4762
	-0.004	-0.005	-0.000	-0.005	-0.004	-0.003	0.003	0.001	-0.005	-0.004
	0.727	0.341	0.370	0.555	0.480	0.481	0.287	0.165	0.568	0.356
	.0000	.0004	.0000	.0000	.0001	.0000	.0004	.0124	.0000	.0002
	.0104	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
82	0.5141	0.5450	0.5293	0.6448	0.5916	0.6463	0.5236	0.2382	0.6108	0.4208
	0.000	0.000	0.003	0.000	0.000	0.000	0.005	0.007	0.000	0.000
	0.693	0.360	0.351	0.537	0.539	0.538	0.313	0.119	0.484	0.301
	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0829	.0000	.0011
	.0097	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
83	0.3672	0.4207	0.2970	0.5277	0.4730	0.5693	0.4037	0.3004	0.4749	0.3287
	0.000	-0.000	0.002	0.000	0.000	0.000	0.004	0.001	-0.000	-0.000
	0.405	0.227	0.162	0.360	0.352	0.388	0.200	0.128	0.308	0.192
	.0054	.0011	.0262	.0000	.0002	.0000	.0022	.0273	.0002	.0126
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
84	-.1333	-.1775	0.1425	-.0772	-.4106	-.1838	-.1437	-.0155	-.0038	0.2297
	-0.003	0.000	-0.003	0.000	0.000	0.000	0.006	-0.003	0.000	0.000
	-0.332	-0.218	0.177	-0.119	-0.694	-0.284	-0.158	-0.016	-0.006	0.305
	.3276	.1866	.2951	.5680	.0015	.1714	.2954	.9115	.9774	.0856
	.0004	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002
85	0.1021	0.2025	0.3124	0.3344	0.1798	0.3228	0.1609	0.0455	0.2218	0.2577
	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000	0.004	0.001	-0.000	-0.000
	0.089	0.087	0.137	0.181	0.107	0.175	0.062	0.016	0.114	0.120
	.4541	.1312	.0191	.0110	.1811	.0143	.2408	.7441	.0975	.0529
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
86	0.2205	0.2570	0.2285	0.2909	0.4429	0.3282	0.1992	-.1154	0.1941	-.1096
	0.000	0.000	0.001	0.000	0.000	0.000	-0.002	0.008	0.000	0.000
	0.264	0.151	0.136	0.215	0.358	0.242	0.109	-0.055	0.136	-0.070
	.1027	.0536	.0903	.0281	.0006	.0127	.1451	.4063	.1482	.4172
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Continued on next page.

Table 8-6 (cont.)

Day\Day	Irrigation 2 94	95	96	97	98	99	100	Irrigation 3 102	103	104
87	0.2842	0.3460	0.4831	0.4427	0.4293	0.3695	0.3404	0.0626	0.3290	0.1560
	0.001	0.000	0.001	0.000	0.000	0.000	0.003	0.004	0.000	0.000
	0.255	0.153	0.217	0.246	0.261	0.205	0.136	0.022	0.174	0.075
	.0337	.0084	.0002	.0006	.0009	.0047	.0110	.6531	.0124	.2469
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
91 Irrigation 2										
92	0.7996	0.8394	0.6646	0.7693	0.8191	0.6885	0.7879	0.6373	0.8299	0.7279
	-0.002	0.000	0.003	0.000	0.000	0.000	0.001	0.011	0.000	0.000
	1.394	0.719	0.575	0.831	0.967	0.743	0.623	0.326	0.852	0.675
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0021	.0032	.0001	.1271	.7686	.0280	.0001	.0000	.1561	.0021
93	0.8324	0.6915	0.5834	0.7913	0.6952	0.7469	0.5642	0.4397	0.7723	0.6750
	-0.006	0.000	0.002	0.000	0.000	0.000	0.004	0.000	0.000	0.000
	1.565	0.653	0.561	0.942	0.905	0.890	0.489	0.318	0.875	0.691
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0009	.0000	.0000
	.0001	.0022	.0003	.6441	.4933	.3860	.0000	.0000	.3032	.0099
94		0.7841	0.6888	0.8337	0.7226	0.6637	0.7094	0.5379	0.8240	0.7515
		0.000	0.002	0.001	-0.000	0.001	0.001	-0.000	0.001	0.001
		0.384	0.344	0.517	0.489	0.411	0.321	0.196	0.485	0.401
		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
		.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
95			0.7381	0.8211	0.8873	0.7207	0.8630	0.6259	0.7968	0.7386
			0.004	0.000	0.000	0.000	0.002	0.008	0.000	0.000
			0.743	1.035	1.223	0.909	0.786	0.396	0.955	0.800
			.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
			.0299	.7911	.1050	.5082	.0425	.0000	.7281	.1064
96				0.7948	0.6372	0.5376	0.7799	0.3697	0.7589	0.7568
				-0.003	-0.004	0.000	-0.003	0.007	-0.003	-0.002
				0.994	0.881	0.665	0.712	0.271	0.901	0.808
				.0000	.0000	.0000	.0000	.0064	.0000	.0000
				.9666	.4369	.0240	.0084	.0000	.4470	.1152
97					0.7706	0.7779	0.7468	0.5890	0.8902	0.8239
					0.000	0.000	0.007	-0.001	-0.000	-0.000
					0.843	0.778	0.528	0.340	0.846	0.708
					.0000	.0000	.0000	.0000	.0000	.0000
					.1311	.0269	.0000	.0000	.0900	.0015
98						0.7658	0.8333	0.5518	0.7239	0.5719
						0.000	0.000	0.004	-0.000	-0.000
						0.700	0.562	0.275	0.630	0.450
						.0000	.0000	.0000	.0000	.0000
						.0010	.0000	.0000	.0001	.0000
99							0.5901	0.4611	0.7339	0.6482
							0.007	0.002	-0.000	-0.000
							0.420	0.272	0.698	0.557
							.0000	.0004	.0000	.0000
							.0000	.0000	.0029	.0000

Continued on next page.

Table 8-6 (cont.)

	Irrigation 2							Irrigation 3		
Day\Day	94	95	96	97	98	99	100	102	103	104
100								0.6915 -0.012 0.558 .0000 .0000	0.7868 -0.011 1.112 .0000 .4686	0.7454 -0.011 0.944 .0000 .6986
101	Irrigation 3 ---									
102									0.7448 0.028 1.314 .0000 .1156	0.6708 0.039 0.992 .0000 .9617
103										0.8773 -0.000 0.793 .0000 .0275

Table 8-7.

Spearman rank correlation coefficients for daily midday ($T_{o,max}$ - $T_{d,max}$), Irrigations 1, 2 and 3, Experiment 2.

	Irrigation 1								Irrigation 2	
Day/Day	80	81	82	83	84	85	86	87	92	93
79 Irrigation 1	------									
80	1.0000	0.1877	0.1158	0.0638	-0.2424	0.1183	0.4030	0.3142	0.2227	0.1152
	0.0	0.1783	0.4042	0.6467	0.0774	0.3939	0.0025	0.0207	0.1055	0.4068
	54	53	54	54	54	54	54	54	54	54
81		1.0000	0.8059	0.5767	-0.0857	0.2191	0.3835	0.4939	0.4558	0.6360
		0.0	0.0001	0.0001	0.5299	0.1046	0.0035	0.0001	0.0004	0.0001
		56	56	56	56	56	56	56	56	56
82			1.0000	0.8019	-0.2444	0.3101	0.6267	0.6362	0.4868	0.6739
			0.0	0.0001	0.0669	0.0189	0.0001	0.0001	0.0001	0.0001
			57	57	57	57	57	57	57	57
83				1.0000	-0.0460	0.4996	0.4706	0.5992	0.2983	0.4582
				0.0	0.7337	0.0001	0.0002	0.0001	0.0242	0.0003
				57	57	57	57	57	57	57
84					1.0000	0.4466	-0.6487	-0.1153	-0.4476	-0.3521
					0.0	0.0005	0.0001	0.3929	0.0005	0.0072
					57	57	57	57	57	57
85						1.0000	0.1608	0.6052	-0.0120	0.0383
						0.0	0.2320	0.0001	0.9291	0.7770
						57	57	57	57	57
86							1.0000	0.6469	0.4614	0.4774
							0.0	0.0001	0.0003	0.0002
							57	57	57	57
87								1.0000	0.3344	0.3069
								0.0	0.0110	0.0202
								57	57	57
91 Irrigation 2	------	------	------	------	------	------	------	------	------	------
92									1.0000	0.6782
									0.0	0.0001
									57	57

	Irrigation 2							Irrigation 3		
Day/Day	94	95	96	97	98	99	100	102	103	104
80	0.2054	0.0608	0.1669	0.1708	0.2412	0.0787	0.0922	0.0198	0.3582	-0.0419
	0.1399	0.6622	0.2320	0.2168	0.0788	0.5712	0.5113	0.8867	0.0078	0.7633
	53	54	53	54	54	54	53	54	54	54
81	0.5896	0.3006	0.4893	0.6023	0.3594	0.4505	0.2099	0.0977	0.6190	0.4179
	0.0001	0.0243	0.0001	0.0001	0.0065	0.0005	0.1240	0.4737	0.0001	0.0013
	55	56	55	56	56	56	55	56	56	56

Continued on next page.

Table 8-7 (cont.).

Day/Day	Irrigation 2							Irrigation 3		
	94	95	96	97	98	99	100	102	103	104
82	0.5880	0.5335	0.4901	0.6656	0.5940	0.5896	0.3961	0.2406	0.6432	0.3405
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0025	0.0714	0.0001	0.0095
	56	57	56	57	57	57	56	57	57	57
83	0.4526	0.4556	0.2405	0.5770	0.5234	0.5562	0.3583	0.3831	0.5543	0.2882
	0.0005	0.0004	0.0742	0.0001	0.0001	0.0001	0.0067	0.0033	0.0001	0.0297
	56	57	56	57	57	57	56	57	57	57
84	0.1418	-0.1782	0.1083	-0.1557	-0.3750	-0.1300	-0.1411	-0.0144	-0.1227	0.3938
	0.2970	0.1845	0.4266	0.2473	0.0040	0.3350	0.2996	0.9152	0.3631	0.0024
	56	57	56	57	57	57	56	57	57	57
85	0.2163	0.2337	0.2833	0.3613	0.1775	0.2908	0.1686	0.0949	0.2460	0.3413
	0.1093	0.0801	0.0344	0.0058	0.1864	0.0282	0.2141	0.4826	0.0650	0.0094
	56	57	56	57	57	57	56	57	57	57
86	0.3265	0.3345	0.2200	0.4002	0.4828	0.3257	0.2040	-0.0185	0.3204	-0.2244
	0.0141	0.0110	0.1031	0.0020	0.0001	0.0134	0.1315	0.8911	0.0151	0.0932
	56	57	56	57	57	57	56	57	57	57
87	0.4123	0.3650	0.5059	0.5500	0.4233	0.3677	0.3318	0.1315	0.3808	0.1163
	0.0016	0.0052	0.0001	0.0001	0.0010	0.0049	0.0125	0.3292	0.0035	0.3888
	56	57	56	57	57	57	56	57	57	57
91 Irrigation 2										
92	0.5847	0.6260	0.3742	0.5616	0.7616	0.6281	0.4330	0.3248	0.5176	0.2314
	0.0001	0.0001	0.0045	0.0001	0.0001	0.0001	0.0009	0.0137	0.0001	0.0832
	56	57	56	57	57	57	56	57	57	57
93	0.7140	0.5955	0.4208	0.7114	0.6159	0.7144	0.2667	0.2655	0.6783	0.4713
	0.0001	0.0001	0.0012	0.0001	0.0001	0.0001	0.0469	0.0459	0.0001	0.0002
	56	57	56	57	57	57	56	57	57	57
94	1.0000	0.7006	0.6000	0.7607	0.6607	0.5779	0.4902	0.3586	0.7423	0.5562
	0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0066	0.0001	0.0001
	56	56	55	56	56	56	55	56	56	56
95		1.0000	0.5287	0.7151	0.8721	0.6755	0.6611	0.4680	0.5592	0.4766
		0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002
		57	56	57	57	57	56	57	57	57
96			1.0000	0.6668	0.4732	0.3600	0.5230	0.2206	0.5376	0.5550
			0.0	0.0001	0.0002	0.0064	0.0001	0.1023	0.0001	0.0001
			56	56	56	56	55	56	56	56
97				1.0000	0.7113	0.6968	0.5065	0.4220	0.7787	0.5634
				0.0	0.0001	0.0001	0.0001	0.0011	0.0001	0.0001
				57	57	57	56	57	57	57
98					1.0000	0.7217	0.7079	0.4865	0.6470	0.3627
					0.0	0.0001	0.0001	0.0001	0.0001	0.0056
					57	57	56	57	57	57
99						1.0000	0.4117	0.4314	0.6705	0.5128
						0.0	0.0016	0.0008	0.0001	0.0001
						57	56	57	57	57

Continued on next page.

Table 8-7 (cont.).

	Irrigation 2							Irrigation 3		
Day/Day	94	95	96	97	98	99	100	102	103	104
100							1.0000	0.5081	0.4697	0.3906
							0.0	0.0001	0.0003	0.0029
							56	56	56	56
101 Irrigation 3										
102								1.0000	0.4832	0.4190
								0.0	0.0001	0.0012
								57	57	57
103									1.0000	0.6248
									0.0	0.0001
									57	57

Table 8-8.

Correlations on relative difference for midday ($T_{o,max} - T_{d,max}$), Experiment 3, Irrigations 1 and 2.

Day\Day	305	308	309	311	312	313	314	315	316	317	318	319
303	Irrigation 1.											
304	0.7241	0.4179	0.6221	0.0986	0.6443	0.5384	0.5516	0.5374	0.5059	0.5419	0.4741	0.6403
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.000
	0.375	1.187	0.993	0.427	0.984	0.748	0.825	0.975	0.628	0.133	0.573	1.093
	.0000	.0014	.0000	.4697	.0000	.0000	.0000	.0000	.0001	.0000	.0002	.0000
	.0000	.5884	.9717	.3157	.9312	.1576	.3551	.9100	.0232	.0000	.0084	.6588
305		0.4603	0.3674	0.0068	0.5362	0.5461	0.5216	0.5082	0.6638	0.6010	0.3446	0.5748
		0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	-0.000
		2.522	1.131	0.057	1.579	1.463	1.504	1.777	1.589	0.284	0.803	1.891
		.0004	.0053	.9604	.0000	.0000	.0000	.0001	.0000	.0000	.0093	.0000
		.0339	.7490	.4091	.1392	.1940	.1886	.0936	.0654	.0000	.5301	.0416
308			0.6003	0.5141	0.5579	0.5394	0.5739	0.6709	0.6526	0.3230	0.4866	0.4677
			-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
			0.337	0.783	0.300	0.264	0.302	0.428	0.285	0.028	0.207	0.281
			.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0152	.0001	.0003
			.0000	.0038	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
309				0.5432	0.7940	0.7413	0.7464	0.7138	0.5465	0.3512	0.7658	0.7450
				-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
				1.472	0.759	0.645	0.699	0.811	0.425	0.054	0.580	0.796
				.0000	.0000	.0000	.0000	.0000	.0000	.0079	.0000	.0000
				.0313	.0265	.0008	.0061	.1305	.0000	.0000	.0000	.0859
311					0.5530	0.5171	0.4900	0.5888	0.3897	0.1631	0.5959	0.5091
					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
					0.195	0.166	0.169	0.247	0.112	0.009	0.167	0.201
					.0000	.0000	.0001	.0000	.0030	.2300	.0000	.0001
					.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
312						0.8734	0.8436	0.7872	0.6920	0.4324	0.7865	0.8693
						-0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000
						0.795	0.826	0.935	0.563	0.070	0.623	0.972
						.0000	.0000	.0000	.0000	.0009	.0000	.0000
						.0478	.1140	.6105	.0000	.0000	.0002	.8107
313							0.9128	0.8480	0.7646	0.4671	0.7508	0.8092
							-0.000	-0.000	0.000	0.000	0.000	-0.000
							0.983	1.107	0.684	0.083	0.654	0.994
							.0000	.0000	.0000	.0003	.0000	.0000
							.8849	.4472	.0044	.0000	.0016	.9673
314								0.8760	0.6979	0.3212	0.7546	0.6943
								-0.000	0.000	0.000	0.000	-0.000
								1.063	0.579	0.053	0.610	0.793
								.0000	.0000	.0158	.0000	.0000
								.6201	.0001	.0000	.0002	.1130

Continued on next page.

Table 8-8 (cont.)

Day\Day	305	308	309	311	312	313	314	315	316	317	318	319
315									0.7556 0.000 0.517 .0000 .0000	0.4043 0.000 0.055 .0020 .0000	0.7616 0.000 0.508 .0000 .0000	0.6693 0.000 0.630 .0000 .0006
316										0.6643 -0.000 0.131 .0000 .0000	0.6037 -0.000 0.588 .0000 .0013	0.7272 -0.000 1.000 .0000 .9986
317											0.4751 -0.000 2.340 .0002 .0478	0.6634 -0.000 4.613 .0000 .0003
318												0.7703 -0.000 1.087 .0000 .5939

Day\Day	320	321	329	330	331	332	333	334	335	336	337	338
304	0.6104 0.000 1.203 .0000 .3975	0.6985 -0.000 1.355 .0000 .1291	0.1482 -0.001 0.449 .2758 .1692	0.0320 -0.000 0.075 .8152 .0054	0.2062 -0.001 0.333 .1276 .0028	0.3460 -0.001 0.506 .0090 .0118	0.3978 -0.001 0.547 .0024 .0137	0.2790 -0.001 0.468 .0373 .0183	0.3250 -0.000 0.496 .0145 .0140	0.2751 -0.000 0.647 .0402 .2472	0.3286 -0.001 0.507 .0134 .0170	0.4587 -0.000 0.643 .0004 .0519
305	0.4964 0.000 1.887 .0001 .0779	0.6755 -0.000 2.527 .0000 .0023	0.3478 -0.006 2.031 .0086 .1781	0.1139 -0.001 0.518 .4035 .4347	0.2482 -0.002 0.772 .0651 .5858	0.3090 -0.002 0.870 .0205 .7314	0.3682 -0.002 0.976 .0052 .9464	0.2399 -0.002 0.776 .0749 .6064	0.2527 -0.000 0.744 .0602 .5179	0.0719 -0.000 0.326 .5985 .2766	0.3924 -0.002 1.167 .0028 .6729	0.4786 -0.001 1.294 .0002 .4133
308	0.5755 -0.000 0.399 .0000 .0000	0.6158 -0.000 0.420 .0000 .0000	0.4151 -0.001 0.442 .0015 .0000	0.2930 -0.000 0.244 .0284 .0000	0.3483 -0.001 0.198 .0085 .0000	0.4289 -0.000 0.221 .0010 .0000	0.3620 -0.000 0.175 .0061 .0000	0.2359 -0.000 0.139 .0801 .0000	0.5026 -0.000 0.270 .0001 .0000	0.2130 -0.000 0.176 .1152 .0000	0.4331 -0.000 0.235 .0009 .0000	0.4300 -0.000 0.212 .0009 .0000
309	0.8523 0.000 1.052 .0000 .6693	0.7488 -0.000 0.910 .0000 .4803	0.3147 -0.002 0.597 .0182 .0732	0.1020 -0.000 0.151 .4546 .0001	0.2174 -0.001 0.220 .1078 .0000	0.2800 -0.001 0.256 .0366 .0000	0.3033 -0.001 0.261 .0231 .0000	0.1349 -0.000 0.142 .3216 .0000	0.4071 -0.000 0.389 .0018 .0000	0.4049 -0.000 0.597 .0020 .0224	0.1695 -0.000 0.164 .2120 .0000	0.2945 -0.000 0.259 .0276 .0000
311	0.5845 0.000 0.266 .0000 .0000	0.5076 0.000 0.228 .0001 .0000	0.2825 -0.001 0.198 .0349 .0000	0.2406 -0.000 0.131 .0740 .0000	0.3138 -0.000 0.117 .0185 .0000	0.3723 -0.000 0.126 .0047 .0000	0.3203 -0.000 0.102 .0161 .0000	0.2720 -0.000 0.105 .0425 .0000	0.4879 -0.000 0.172 .0001 .0000	0.3988 -0.000 0.217 .0023 .0000	0.3635 -0.000 0.130 .0059 .0000	0.3544 -0.000 0.115 .0074 .0000

Continued on next page.

Table 8-8 (cont.)

	Irrigation 1		Irrigation 2									
Day\Day	320	321	329	330	331	332	333	334	335	336	337	338
312	0.9151	0.8556	0.3359	0.1323	0.2919	0.3805	0.3987	0.1832	0.4364	0.4490	0.2927	0.4101
	0.000	-0.000	-0.002	-0.000	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
	1.181	1.087	0.666	0.205	0.308	0.364	0.359	0.201	0.436	0.692	0.296	0.377
	.0000	.0000	.0114	.3312	.0290	.0038	.0023	.1767	.0008	.0005	.0286	.0017
	.1548	.5003	.1525	.0002	.0000	.0000	.0000	.0000	.0000	.0881	.0000	.0000
313	0.8310	0.8036	0.3851	0.2059	0.3173	0.3606	0.3510	0.1579	0.3777	0.3614	0.2732	0.3533
	0.000	-0.000	-0.002	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
	1.179	1.122	0.840	0.350	0.369	0.379	0.348	0.191	0.415	0.612	0.303	0.357
	.0000	.0000	.0034	.1282	.0172	.0063	.0080	.2455	.0041	.0062	.0416	.0076
	.2345	.4156	.5252	.0041	.0001	.0000	.0000	.0000	.0001	.0641	.0000	.0000
314	0.8250	0.7291	0.3645	0.1329	0.2293	0.3759	0.3275	0.1371	0.3599	0.3321	0.2330	0.2799
	0.000	-0.000	-0.002	-0.000	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
	1.088	0.946	0.738	0.210	0.247	0.367	0.301	0.154	0.367	0.523	0.240	0.263
	.0000	.0000	.0057	.3291	.0891	.0043	.0137	.3139	.0064	.0124	.0840	.0367
	.5198	.7003	.2643	.0003	.0000	.0000	.0000	.0000	.0000	.0154	.0000	.0000
315	0.7724	0.7324	0.4560	0.2492	0.3444	0.4385	0.3867	0.2585	0.5108	0.3746	0.4474	0.4455
	0.000	-0.000	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.001	-0.000
	0.839	0.783	0.761	0.324	0.306	0.353	0.293	0.239	0.430	0.486	0.380	0.344
	.0000	.0000	.0004	.0639	.0093	.0007	.0032	.0544	.0001	.0045	.0005	.0006
	.1349	.0485	.1652	.0001	.0000	.0000	.0000	.0000	.0000	.0011	.0000	.0000
316	0.6788	0.7754	0.4366	0.2773	0.4609	0.4743	0.4942	0.2890	0.4973	0.3391	0.4431	0.5794
	-0.000	-0.000	-0.003	-0.001	-0.002	-0.001	-0.001	-0.001	-0.000	-0.000	-0.001	-0.000
	1.078	1.212	1.065	0.527	0.599	0.558	0.547	0.391	0.611	0.643	0.550	0.654
	.0000	.0000	.0008	.0385	.0004	.0002	.0001	.0307	.0001	.0106	.0006	.0000
	.6699	.2294	.8174	.0535	.0163	.0041	.0020	.0009	.0138	.1334	.0056	.0162
317	0.3889	0.5577	0.3038	0.1742	0.3752	0.2571	0.2934	0.1678	0.2320	0.2096	0.3088	0.5662
	0.000	-0.000	-0.011	-0.003	-0.007	-0.003	-0.004	-0.003	-0.001	-0.001	-0.003	-0.002
	3.123	4.408	3.748	1.675	2.467	1.530	1.644	1.147	1.443	2.010	1.940	3.235
	.0031	.0000	.0228	.1995	.0044	.0558	.0282	.2165	.0853	.1212	.0206	.0000
	.0533	.0020	.1009	.6049	.1026	.5121	.3981	.8740	.6001	.4374	.2715	.0050
318	0.8063	0.6991	0.3654	0.1897	0.3722	0.4091	0.2989	0.1173	0.4414	0.4364	0.2686	0.3803
	0.000	-0.000	-0.003	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.001	-0.000	-0.000
	1.315	1.122	0.915	0.370	0.497	0.494	0.340	0.163	0.557	0.849	0.343	0.441
	.0000	.0000	.0056	.1617	.0047	.0017	.0252	.3894	.0007	.0008	.0453	.0038
	.0864	.5113	.7774	.0158	.0044	.0018	.0000	.0000	.0074	.5228	.0002	.0004
319	0.8883	0.9170	0.4271	0.1863	0.3824	0.3022	0.3223	0.1768	0.4030	0.4124	0.3147	0.5111
	0.000	-0.000	-0.002	-0.000	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
	1.026	1.042	0.758	0.258	0.362	0.259	0.260	0.174	0.360	0.569	0.284	0.420
	.0000	.0000	.0010	.1693	.0036	.0236	.0154	.1927	.0021	.0016	.0181	.0001
	.8103	.6890	.2044	.0001	.0000	.0000	.0000	.0000	.0000	.0084	.0000	.0000
320		0.9128	0.4254	0.1955	0.3409	0.3900	0.3776	0.1980	0.4630	0.4306	0.2937	0.4200
		-0.000	-0.002	-0.000	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
		0.898	0.654	0.234	0.279	0.289	0.263	0.169	0.359	0.514	0.230	0.299
		.0000	.0011	.1490	.0101	.0030	.0041	.1438	.0003	.0009	.0280	.0013
		.2243	.0296	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0000	.0000

Continued on next page.

Table 8-8 (cont.)

	Irrigation 1		Irrigation 2									
Day\Day	320	321	329	330	331	332	333	334	335	336	337	338
321			0.4522	0.1758	0.3531	0.3765	0.3989	0.2330	0.4244	0.2900	0.3746	0.5222
			-0.002	-0.000	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
			0.706	0.214	0.294	0.284	0.283	0.202	0.334	0.352	0.298	0.377
			.0005	.1951	.0076	.0042	.0023	.0839	.0011	.0301	.0044	.0000
			.0625	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
328 Irrigation 2.												
329				0.5375	0.5165	0.2057	0.2225	0.2380	0.3824	0.2174	0.3543	0.4421
				0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
				0.420	0.275	0.100	0.101	0.132	0.194	0.170	0.181	0.206
				.0000	.0000	.1249	.0965	.0746	.0033	.1045	.0068	.0006
				.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
330					0.8632	0.6202	0.4981	0.5168	0.5705	0.5193	0.4892	0.5277
					-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
					0.589	0.385	0.290	0.367	0.370	0.519	0.321	0.315
					.0000	.0000	.0001	.0000	.0000	.0000	.0001	.0000
					.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
331						0.7955	0.6969	0.5960	0.7435	0.6896	0.6398	0.7672
						0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
						0.723	0.596	0.621	0.708	1.011	0.614	0.671
						.0000	.0000	.0000	.0000	.0000	.0000	.0000
						.0078	.0001	.0024	.0076	.9389	.0009	.0014
332							0.8918	0.6543	0.7956	0.6423	0.6335	0.7102
							0.000	-0.000	0.000	-0.000	-0.000	0.000
							0.839	0.750	0.833	1.036	0.670	0.683
							.0000	.0000	.0000	.0000	.0000	.0000
							.1303	.0614	.1598	.8309	.0097	.0064
333								0.7386	0.8186	0.6809	0.6362	0.7507
								-0.000	0.000	-0.000	-0.000	-0.000
								0.900	0.911	1.168	0.715	0.768
								.0000	.0000	.0000	.0000	.0000
								.4705	.4828	.3566	.0355	.0559
334									0.6736	0.5725	0.5974	0.5687
									0.000	0.000	0.000	0.000
									0.615	0.806	0.551	0.477
									.0000	.0000	.0000	.0000
									.0004	.1933	.0001	.0000
335										0.7991	0.6583	0.7983
										-0.000	-0.000	-0.000
										1.231	0.664	0.733
										.0000	.0000	.0000
										.1183	.0054	.0126
336											0.4976	0.6373
											0.000	0.000
											0.326	0.380
											.0001	.0000
											.0000	.0000

Continued on next page.

Table 8-8 (cont.)

	Irrigation 1		Irrigation 2									
Day\Day	320	321	329	330	331	332	333	334	335	336	337	338
337												0.7475 0.000 0.680 .0000 .0032

Table 8-9.

Spearman rank order correlations on midday ML surface temperatures, Irrigations 1 and 2, Experiment 3, 1986.

Day/Day	305	308	309	311	312	313	314	315	316	317	318	319
303 Irrigation 1 ---												
304	0.4933 0.0001 56	0.3754 0.0044 56	0.7281 0.0001 56	0.1438 0.2901 56	0.6631 0.0001 56	0.4924 0.0001 56	0.4775 0.0002 56	0.4691 0.0003 56	0.4465 0.0006 56	0.5079 0.0001 56	0.5487 0.0001 56	0.7239 0.0001 56
305	1.0000 0.0 56	0.4711 0.0002 56	0.3337 0.0119 56	-0.0409 0.7642 56	0.4273 0.0010 56	0.3702 0.0050 56	0.3000 0.0246 56	0.4847 0.0002 56	0.6338 0.0001 56	0.7140 0.0001 56	0.3227 0.0153 56	0.5554 0.0001 56
308		1.0000 0.0 56	0.5181 0.0001 56	0.4216 0.0012 56	0.5636 0.0001 56	0.5214 0.0001 56	0.5290 0.0001 56	0.6477 0.0001 56	0.6180 0.0001 56	0.2495 0.0636 56	0.3818 0.0037 56	0.5027 0.0001 56
309			1.0000 0.0 56	0.4879 0.0001 56	0.8161 0.0001 56	0.7751 0.0001 56	0.7664 0.0001 56	0.7030 0.0001 56	0.5165 0.0001 56	0.2849 0.0333 56	0.7399 0.0001 56	0.7750 0.0001 56
311				1.0000 0.0 56	0.4429 0.0006 56	0.5190 0.0001 56	0.5046 0.0001 56	0.5918 0.0001 56	0.2866 0.0322 56	-0.0471 0.7303 56	0.4734 0.0002 56	0.3740 0.0045 56
312					1.0000 0.0 56	0.8512 0.0001 56	0.7922 0.0001 56	0.7296 0.0001 56	0.6426 0.0001 56	0.3528 0.0076 56	0.7410 0.0001 56	0.8782 0.0001 56
313						1.0000 0.0 56	0.8595 0.0001 56	0.8130 0.0001 56	0.7048 0.0001 56	0.3766 0.0042 56	0.7415 0.0001 56	0.8074 0.0001 56
314							1.0000 0.0 56	0.8426 0.0001 56	0.6081 0.0001 56	0.2510 0.0620 56	0.7944 0.0001 56	0.6799 0.0001 56
315								1.0000 0.0 56	0.7554 0.0001 56	0.3936 0.0027 56	0.7384 0.0001 56	0.6944 0.0001 56
316									1.0000 0.0 56	0.6078 0.0001 56	0.5480 0.0001 56	0.6896 0.0001 56
317										1.0000 0.0 56	0.3886 0.0031 56	0.5961 0.0001 56
318											1.0000 0.0 56	0.7544 0.0001 56

Continued on next page.

Table 8-9 (cont.).

	Irrigation 1		Irrigation 2									
Day/Day	320	321	329	330	331	332	333	334	335	336	337	338
304	0.6673	0.7019	-0.0575	0.0045	0.1531	0.2592	0.2367	0.1119	0.1910	0.2821	0.1819	0.3292
	0.0001	0.0001	0.6738	0.9733	0.2599	0.0537	0.0789	0.4115	0.1584	0.0352	0.1797	0.0132
	56	56	56	56	56	56	56	56	56	56	56	56
305	0.4083	0.6100	0.2890	0.0146	0.2224	0.2573	0.3117	0.2024	0.1438	0.0527	0.4588	0.4591
	0.0018	0.0001	0.0307	0.9148	0.0994	0.0555	0.0193	0.1346	0.2901	0.6993	0.0004	0.0004
	56	56	56	56	56	56	56	56	56	56	56	56
308	0.5435	0.6492	0.3203	0.0168	0.0415	0.2491	0.2746	0.0605	0.3313	0.0331	0.3968	0.3056
	0.0001	0.0001	0.0161	0.9021	0.7610	0.0641	0.0405	0.6573	0.0126	0.8081	0.0025	0.0220
	56	56	56	56	56	56	56	56	56	56	56	56
309	0.8811	0.7901	0.0877	-0.0044	0.0458	0.1808	0.1531	-0.0390	0.2969	0.3148	0.1223	0.1751
	0.0001	0.0001	0.5202	0.9739	0.7373	0.1822	0.2599	0.7754	0.0263	0.0181	0.3692	0.1968
	56	56	56	56	56	56	56	56	56	56	56	56
311	0.4999	0.4252	0.0769	0.1888	0.1277	0.3063	0.2779	0.0399	0.3905	0.2462	0.2927	0.2077
	0.0001	0.0011	0.5732	0.1635	0.3482	0.0217	0.0381	0.7703	0.0029	0.0674	0.0286	0.1245
	56	56	56	56	56	56	56	56	56	56	56	56
312	0.8994	0.8385	0.1472	-0.0519	0.1279	0.2785	0.2556	-0.0016	0.3354	0.3400	0.1718	0.2681
	0.0001	0.0001	0.2790	0.7038	0.3475	0.0376	0.0573	0.9903	0.0115	0.0103	0.2055	0.0457
	56	56	56	56	56	56	56	56	56	56	56	56
313	0.8498	0.7703	0.2094	0.0459	0.1837	0.2846	0.2707	0.0213	0.3384	0.3025	0.1685	0.2462
	0.0001	0.0001	0.1213	0.7369	0.1752	0.0335	0.0436	0.8758	0.0107	0.0234	0.2142	0.0674
	56	56	56	56	56	56	56	56	56	56	56	56
314	0.8228	0.6894	0.1851	-0.0165	0.0558	0.2619	0.2229	0.0342	0.3155	0.2569	0.1228	0.1612
	0.0001	0.0001	0.1720	0.9037	0.6827	0.0511	0.0987	0.8024	0.0178	0.0559	0.3672	0.2351
	56	56	56	56	56	56	56	56	56	56	56	56
315	0.7626	0.7380	0.2977	0.0835	0.1930	0.3854	0.3728	0.1422	0.4507	0.2646	0.4006	0.3818
	0.0001	0.0001	0.0258	0.5403	0.1540	0.0034	0.0047	0.2957	0.0005	0.0487	0.0022	0.0037
	56	56	56	56	56	56	56	56	56	56	56	56
316	0.6343	0.7466	0.2973	0.0547	0.3599	0.4271	0.4433	0.1458	0.4442	0.2335	0.3643	0.5017
	0.0001	0.0001	0.0260	0.6885	0.0064	0.0010	0.0006	0.2836	0.0006	0.0833	0.0058	0.0001
	56	56	56	56	56	56	56	56	56	56	56	56
317	0.3171	0.4776	0.1006	0.0702	0.2956	0.2275	0.2894	0.0783	0.1420	0.1359	0.2617	0.5169
	0.0173	0.0002	0.4606	0.6070	0.0270	0.0916	0.0305	0.5660	0.2963	0.3180	0.0513	0.0001
	56	56	56	56	56	56	56	56	56	56	56	56
318	0.7945	0.6882	0.1520	0.1265	0.2641	0.3597	0.2807	-0.0238	0.3823	0.3474	0.2039	0.2734
	0.0001	0.0001	0.2634	0.3526	0.0491	0.0065	0.0361	0.8612	0.0036	0.0087	0.1316	0.0415
	56	56	56	56	56	56	56	56	56	56	56	56
319	0.8878	0.8972	0.1597	0.0059	0.2298	0.2755	0.2412	-0.0205	0.3142	0.2965	0.2255	0.3705
	0.0001	0.0001	0.2396	0.9655	0.0883	0.0398	0.0733	0.8803	0.0183	0.0265	0.0947	0.0049
	56	56	56	56	56	56	56	56	56	56	56	56

Continued on next page.

Table 8-9 (cont.).

	Irrigation 1		Irrigation 2									
Day/Day	320	321	329	330	331	332	333	334	335	336	337	338
320	1.0000	0.9072	0.2419	0.0519	0.1908	0.3027	0.2560	0.0433	0.3535	0.3119	0.1926	0.2663
	0.0	0.0001	0.0724	0.7039	0.1588	0.0233	0.0568	0.7508	0.0075	0.0193	0.1550	0.0472
	56	56	56	56	56	56	56	56	56	56	56	56
321		1.0000	0.2160	-0.0227	0.1824	0.3044	0.2692	0.0345	0.2969	0.1346	0.3170	0.3570
		0.0	0.1098	0.8681	0.1784	0.0225	0.0448	0.8007	0.0263	0.3224	0.0173	0.0069
		56	56	56	56	56	56	56	56	56	56	56
328 Irrigation 2												
329			1.0000	0.3645	0.2779	0.1744	0.1748	0.1356	0.2737	0.0640	0.2055	0.1908
			0.0	0.0053	0.0363	0.1944	0.1932	0.3145	0.0393	0.6357	0.1251	0.1549
			57	57	57	57	57	57	57	57	57	57
330				1.0000	0.7202	0.5579	0.4941	0.3712	0.4620	0.3965	0.2924	0.2864
				0.0	0.0001	0.0001	0.0001	0.0045	0.0003	0.0023	0.0273	0.0307
				57	57	57	57	57	57	57	57	57
331					1.0000	0.8639	0.8123	0.5285	0.6999	0.6280	0.4360	0.6420
					0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0007	0.0001
					57	57	57	57	57	57	57	57
332						1.0000	0.9382	0.5883	0.7836	0.6290	0.5751	0.7132
						0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
						57	57	57	57	57	57	57
333							1.0000	0.5884	0.7837	0.6264	0.5973	0.7894
							0.0	0.0001	0.0001	0.0001	0.0001	0.0001
							57	57	57	57	57	57
334								1.0000	0.4982	0.4697	0.4515	0.4071
								0.0	0.0001	0.0002	0.0004	0.0017
								57	57	57	57	57
335									1.0000	0.7476	0.5160	0.7357
									0.0	0.0001	0.0001	0.0001
									57	57	57	57
336										1.0000	0.2752	0.5173
										0.0	0.0383	0.0001
										57	57	57
337											1.0000	0.6038
											0.0	0.0001
											57	57

Table 8-10.

Correlations on relative differences of evaporation from ML's, Irrigations 1 and 2, Experiment 3.

Day\Day	305	308	309	311	312	313	314	315	316	317	318	319
304	0.7523	0.5151	0.6983	0.5582	0.6905	0.6642	0.6431	0.5940	0.6546	0.7243	0.2694	0.1623
	0.003	0.005	0.005	-0.003	0.004	0.002	0.003	0.006	0.003	0.003	-0.000	0.001
	0.402	1.093	0.916	1.716	0.939	0.671	0.801	0.860	1.140	1.076	0.338	0.293
	.0000	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0467	.2366
	.0000	.7352	.6256	.0641	.7291	.0170	.2282	.4630	.5331	.6938	.0003	.0054
305		0.3339	0.6307	0.3805	0.7959	0.8431	0.8365	0.7367	0.7236	0.6707	0.2965	0.4557
		-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
		1.303	1.540	2.180	2.015	1.597	1.946	1.971	2.353	1.864	0.697	1.531
		.0119	.0000	.0038	.0000	.0000	.0000	.0000	.0000	.0000	.0265	.0004
		.5623	.1013	.1225	.0036	.0209	.0032	.0080	.0024	.0221	.3427	.2391
308			0.8065	0.7570	0.6165	0.4884	0.4982	0.5496	0.5876	0.5673	0.3605	0.2894
			-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000	-0.000	0.000
			0.505	1.111	0.400	0.237	0.297	0.377	0.490	0.404	0.217	0.249
			.0000	.0000	.0000	.0001	.0001	.0000	.0000	.0000	.0063	.0305
			.0000	.4113	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
309				0.7228	0.8324	0.7457	0.7553	0.7590	0.7470	0.6818	0.4269	0.3877
				-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				1.695	0.863	0.578	0.719	0.831	0.995	0.776	0.411	0.533
				.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0010	.0032
				.0103	.2912	.0001	.0234	.2224	.9732	.1228	.0000	.0110
311					0.6261	0.5117	0.5218	0.5026	0.5771	0.6476	0.3810	0.2071
					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
					0.277	0.169	0.212	0.235	0.328	0.314	0.156	0.121
					.0000	.0001	.0000	.0001	.0000	.0000	.0038	.1259
					.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
312						0.9005	0.8952	0.8826	0.7935	0.6840	0.3537	0.5195
						0.000	0.000	0.000	0.000	0.000	0.000	0.000
						0.674	0.823	0.933	1.019	0.751	0.328	0.689
						.0000	.0000	.0000	.0000	.0000	.0075	.0000
						.0011	.1254	.6049	.9021	.0753	.0000	.0685
313							0.9293	0.8972	0.8229	0.7230	0.4447	0.4902
							-0.000	-0.000	-0.000	0.000	-0.000	-0.000
							1.141	1.267	1.413	1.061	0.552	0.869
							.0000	.0000	.0000	.0000	.0006	.0001
							.3681	.1381	.0585	.7456	.0083	.5703
314								0.9287	0.8599	0.7737	0.4977	0.5890
								0.000	0.000	0.000	-0.000	-0.000
								1.068	1.202	0.925	0.503	0.850
								.0000	.0000	.0000	.0001	.0000
								.6313	.2375	.6144	.0004	.4132
315									0.8498	0.7552	0.5583	0.5950
									-0.000	0.000	-0.000	-0.000
									1.033	0.785	0.491	0.747
									.0000	.0000	.0000	.0000
									.8210	.0982	.0000	.1095

Continued on next page.

Table 8-10 (cont.)

Day\Day	305	308	309	311	312	313	314	315	316	317	318	319
316										0.7804	0.6699	0.6368
										0.000	-0.000	-0.000
										0.667	0.484	0.658
										.0000	.0000	.0000
										.0019	.0000	.0078
317											0.5464	0.4178
											-0.000	-0.000
											0.462	0.505
											.0000	.0014
											.0000	.0022
318												0.3651
												0.000
												0.522
												.0057
												.0125

	Irrigation 1		Irrigation 2									
Day\Day	320	321	329	330	331	332	333	334	335	336	337	338
304	0.3998	0.2688	0.2255	0.0750	0.1713	0.3626	0.3703	0.2543	0.3415	0.1079	0.3874	0.4057
	0.002	-0.002	-0.005	-0.000	-0.001	-0.003	-0.003	-0.001	-0.004	-0.001	-0.002	-0.001
	0.792	0.391	0.866	0.221	0.345	0.663	0.637	0.532	0.662	0.318	0.745	0.710
	.0025	.0472	.0982	.5863	.2115	.0065	.0054	.0610	.0107	.4329	.0035	.0021
	.4273	.0030	.7908	.0564	.0191	.1682	.1162	.0987	.1919	.0914	.3184	.2133
305	0.2679	0.3708	0.2762	0.0570	0.1824	0.2891	0.3397	0.2225	0.2187	-.0071	0.3801	0.4049
	-0.000	-0.000	-0.006	-0.001	-0.002	-0.002	-0.003	-0.002	-0.000	0.000	-0.002	-0.001
	0.992	1.006	1.956	0.314	0.688	0.987	1.092	0.873	0.781	-0.039	1.371	1.328
	.0459	.0049	.0393	.6768	.1786	.0307	.0104	.0995	.1056	.9587	.0039	.0020
	.9866	.9874	.3101	.3632	.5417	.9783	.8312	.8101	.6491	.1715	.4431	.4564
308	0.4880	0.3884	0.2630	0.0919	0.0952	0.0612	0.0771	0.0445	0.1485	0.1729	0.1429	0.0849
	0.000	0.000	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	0.463	0.270	0.477	0.130	0.092	0.054	0.064	0.045	0.136	0.244	0.132	0.071
	.0001	.0031	.0502	.5006	.4856	.6541	.5722	.7447	.2748	.2028	.2937	.5342
	.0000	.0000	.0188	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000
309	0.5522	0.3810	0.3397	0.0130	0.0864	0.0927	0.1631	0.0666	0.1901	0.1662	0.1245	0.2487
	0.000	0.000	-0.003	-0.000	-0.000	-0.000	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
	0.837	0.423	0.985	0.029	0.134	0.130	0.215	0.107	0.278	0.374	0.184	0.334
	.0000	.0038	.0104	.9242	.5265	.4971	.2299	.6257	.1608	.2210	.3608	.0646
	.3918	.0002	.9658	.0025	.0001	.0000	.0000	.0001	.0005	.0387	.0001	.0004
311	0.5142	0.3009	0.3699	0.1109	0.0561	0.1243	0.0838	-.0377	0.1135	-.0280	0.1064	0.0857
	0.000	0.000	-0.001	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000
	0.332	0.142	0.457	0.107	0.037	0.074	0.047	-0.026	0.071	-0.027	0.067	0.049
	.0001	.0242	.0050	.4159	.6815	.3615	.5393	.7826	.4049	.8375	.4354	.5301
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
312	0.5522	0.3910	0.3523	0.0948	0.1743	0.2422	0.2826	0.1495	0.2344	0.1275	0.2133	0.2606
	0.000	0.000	-0.003	-0.000	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000
	0.808	0.419	0.985	0.207	0.260	0.327	0.359	0.232	0.331	0.277	0.304	0.337
	.0000	.0029	.0078	.4871	.1991	.0721	.0348	.2717	.0820	.3492	.1148	.0524
	.2940	.0001	.9656	.0085	.0004	.0004	.0003	.0005	.0007	.0148	.0005	.0003

Continued on next page.

Table 8-10 (cont.)

	Irrigation 1		Irrigation 2									
Day\Day	320	321	329	330	331	332	333	334	335	336	337	338
313	0.5044	0.3993	0.3104	0.1015	0.1462	0.2348	0.2358	0.1244	0.1755	0.0688	0.2300	0.2530
	0.000	-0.000	-0.003	-0.000	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.001	-0.000
	0.986	0.572	1.160	0.296	0.291	0.423	0.400	0.258	0.331	0.200	0.438	0.438
	.0001	.0023	.0199	.4567	.2823	.0815	.0802	.3610	.1959	.6146	.0881	.0600
	.9552	.0269	.7362	.0763	.0102	.0194	.0103	.0099	.0102	.0454	.0301	.0175
314	0.5677	0.4458	0.3868	0.1667	0.2225	0.2551	0.2588	0.1413	0.1943	0.1029	0.2450	0.3109
	0.000	0.000	-0.003	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.001	-0.000
	0.903	0.520	1.177	0.395	0.361	0.375	0.358	0.238	0.298	0.243	0.380	0.438
	.0000	.0006	.0032	.2198	.0995	.0577	.0541	.2990	.1516	.4505	.0687	.0197
	.6287	.0025	.6331	.0575	.0042	.0021	.0009	.0013	.0011	.0198	.0036	.0035
315	0.6103	0.4726	0.3069	0.1788	0.2601	0.2898	0.2975	0.1591	0.2279	0.2194	0.2048	0.2618
	0.000	-0.000	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000
	0.844	0.479	0.812	0.369	0.367	0.370	0.357	0.233	0.304	0.451	0.276	0.321
	.0000	.0002	.0214	.1876	.0529	.0303	.0260	.2417	.0912	.1045	.1303	.0513
	.3612	.0002	.5650	.0224	.0011	.0004	.0001	.0002	.0002	.0430	.0001	.0001
316	0.6415	0.5551	0.3840	0.2410	0.3506	0.3529	0.3292	0.2120	0.3165	0.1627	0.3281	0.4166
	0.000	0.000	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000
	0.730	0.463	0.836	0.409	0.407	0.371	0.326	0.256	0.347	0.275	0.364	0.420
	.0000	.0000	.0035	.0735	.0081	.0076	.0132	.1171	.0175	.2310	.0136	.0014
	.0493	.0000	.5157	.0079	.0002	.0000	.0000	.0000	.0000	.0017	.0000	.0000
317	0.6174	0.4861	0.3954	0.3254	0.3004	0.3752	0.2955	0.1333	0.3194	0.1422	0.3329	0.3558
	0.000	-0.000	-0.003	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.001	-0.000
	0.822	0.474	1.007	0.646	0.408	0.461	0.342	0.188	0.410	0.281	0.432	0.420
	.0000	.0001	.0026	.0144	.0245	.0044	.0270	.3276	.0164	.2961	.0122	.0071
	.2761	.0001	.9812	.1586	.0013	.0012	.0001	.0001	.0008	.0077	.0012	.0003
318	0.5850	0.4247	0.3284	0.1808	0.2655	0.1545	0.1187	0.0002	0.1276	0.1196	0.2198	0.2509
	0.000	0.000	-0.003	-0.001	-0.001	-0.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.000
	0.921	0.490	0.989	0.424	0.426	0.225	0.162	0.000	0.194	0.280	0.337	0.350
	.0000	.0011	.0135	.1827	.0480	.2556	.3839	.9986	.3489	.3802	.1038	.0622
	.6888	.0013	.9764	.0662	.0084	.0002	.0000	.0001	.0002	.0241	.0018	.0008
319	0.2980	0.4546	0.3274	0.2375	0.3096	0.2049	0.2151	0.1768	0.2022	0.1492	0.1916	0.2617
	0.000	0.000	-0.002	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	0.328	0.367	0.690	0.390	0.348	0.208	0.206	0.206	0.215	0.244	0.206	0.255
	.0257	.0004	.0138	.0780	.0202	.1300	.1116	.1926	.1353	.2727	.1575	.0514
	.0000	.0000	.2171	.0048	.0000	.0000	.0000	.0000	.0000	.0008	.0000	.0000
320		0.1946	0.1246	0.0692	0.1391	0.2326	0.1036	-.1206	0.1817	0.1622	0.0705	0.1370
		-0.000	-0.001	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.000
		0.143	0.238	0.103	0.142	0.215	0.090	-0.128	0.175	0.241	0.069	0.121
		.1509	.3602	.6122	.3068	.0845	.4473	.3760	.1804	.2326	.6055	.3141
		.0000	.0031	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000
321			0.4166	0.2278	0.2865	0.1370	0.1876	0.2067	0.2189	0.2245	0.1321	0.2849
			-0.003	-0.001	-0.001	-0.000	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000
			1.088	0.464	0.398	0.173	0.222	0.299	0.288	0.456	0.176	0.344
			.0014	.0913	.0323	.3141	.1665	.1266	.1054	.0964	.3320	.0333
			.7757	.0448	.0015	.0000	.0000	.0005	.0001	.0415	.0000	.0001

Continued on next page.

Table 8-10 (cont.)

	Irrigation 1		Irrigation 2									
Day\Day	320	321	329	330	331	332	333	334	335	336	337	338
328	Irrigation 2.											
329				0.5375	0.5165	0.2057	0.2225	0.2380	0.3824	0.2174	0.3543	0.4421
				0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
				0.420	0.275	0.100	0.101	0.132	0.194	0.170	0.181	0.206
				.0000	.0000	.1249	.0965	.0746	.0033	.1045	.0068	.0006
				.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
330					0.8632	0.6202	0.4981	0.5168	0.5705	0.5193	0.4892	0.5277
					-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
					0.589	0.385	0.290	0.367	0.370	0.519	0.321	0.315
					.0000	.0000	.0001	.0000	.0000	.0000	.0001	.0000
					.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
331						0.7955	0.6969	0.5960	0.7435	0.6896	0.6398	0.7672
						0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
						0.723	0.596	0.621	0.708	1.011	0.614	0.671
						.0000	.0000	.0000	.0000	.0000	.0000	.0000
						.0078	.0001	.0024	.0076	.9389	.0009	.0014
332							0.8918	0.6543	0.7956	0.6423	0.6335	0.7102
							0.000	-0.000	0.000	-0.000	-0.000	0.000
							0.839	0.750	0.833	1.036	0.670	0.683
							.0000	.0000	.0000	.0000	.0000	.0000
							.1303	.0614	.1598	.8309	.0097	.0064
333								0.7386	0.8186	0.6809	0.6362	0.7507
								-0.000	0.000	-0.000	-0.000	-0.000
								0.900	0.911	1.168	0.715	0.768
								.0000	.0000	.0000	.0000	.0000
								.4705	.4828	.3566	.0355	.0559
334									0.6736	0.5725	0.5974	0.5687
									0.000	0.000	0.000	0.000
									0.615	0.806	0.551	0.477
									.0000	.0000	.0000	.0000
									.0004	.1933	.0001	.0000
335										0.7991	0.6583	0.7983
										-0.000	-0.000	-0.000
										1.231	0.664	0.733
										.0000	.0000	.0000
										.1183	.0054	.0126
336											0.4976	0.6373
											0.000	0.000
											0.326	0.380
											.0001	.0000
											.0000	.0000
337												0.7475
												0.000
												0.680
												.0000
												.0032

Table 8-11.

Spearman rank correlations for daily ML evaporation, Irrigations 1 and 2, Experiment 3, 1986.

Day/Day	305	308	309	311	312	313	314	315	316	317	318	319
303 Irrigation 1 ---												
304	0.6568 0.0001 55	0.5826 0.0001 55	0.7373 0.0001 55	0.6482 0.0001 55	0.7355 0.0001 55	0.6549 0.0001 55	0.6073 0.0001 55	0.5684 0.0001 55	0.6152 0.0001 55	0.6968 0.0001 55	0.1872 0.1711 55	0.1900 0.1645 55
305	1.0000 0.0 56	0.4692 0.0003 56	0.6702 0.0001 56	0.5591 0.0001 56	0.7615 0.0001 56	0.7654 0.0001 56	0.8040 0.0001 56	0.6981 0.0001 56	0.7937 0.0001 56	0.7278 0.0001 56	0.3595 0.0065 56	0.5595 0.0001 56
308		1.0000 0.0 56	0.8333 0.0001 56	0.7522 0.0001 56	0.7292 0.0001 56	0.6958 0.0001 56	0.6237 0.0001 56	0.6530 0.0001 56	0.6165 0.0001 56	0.5419 0.0001 56	0.3339 0.0119 56	0.3066 0.0215 56
309			1.0000 0.0 56	0.7539 0.0001 56	0.8748 0.0001 56	0.8602 0.0001 56	0.8135 0.0001 56	0.8124 0.0001 56	0.7671 0.0001 56	0.6842 0.0001 56	0.4298 0.0009 56	0.4077 0.0018 56
311				1.0000 0.0 56	0.7191 0.0001 56	0.6699 0.0001 56	0.6333 0.0001 56	0.5779 0.0001 56	0.6103 0.0001 56	0.6386 0.0001 56	0.3656 0.0056 56	0.2232 0.0982 56
312					1.0000 0.0 56	0.8898 0.0001 56	0.8739 0.0001 56	0.8634 0.0001 56	0.8125 0.0001 56	0.6866 0.0001 56	0.3878 0.0031 56	0.4941 0.0001 56
313						1.0000 0.0 56	0.8810 0.0001 56	0.8991 0.0001 56	0.8961 0.0001 56	0.7403 0.0001 56	0.5507 0.0001 56	0.5103 0.0001 56
314							1.0000 0.0 56	0.9020 0.0001 56	0.8747 0.0001 56	0.7744 0.0001 56	0.5302 0.0001 56	0.6182 0.0001 56
315								1.0000 0.0 56	0.8451 0.0001 56	0.6990 0.0001 56	0.5417 0.0001 56	0.6097 0.0001 56
316									1.0000 0.0 56	0.7309 0.0001 56	0.5995 0.0001 56	0.6292 0.0001 56
317										1.0000 0.0 56	0.4525 0.0005 56	0.4420 0.0006 56
318											1.0000 0.0 56	0.3178 0.0170 56

Continued on next page.

Table 8-11 (cont.).

	Irrigation 1		Irrigation 2									
Day/Day	320	321	329	330	331	332	333	334	335	336	337	338
304	0.4237	0.2091	0.0671	0.0851	0.0893	0.1890	0.1379	0.1846	0.3196	0.2301	0.2065	0.2582
	0.0013	0.1254	0.6395	0.5365	0.5165	0.1669	0.3151	0.1900	0.0196	0.0974	0.1303	0.0570
	55	55	51	55	55	55	55	52	53	53	55	55
305	0.3648	0.4996	0.1407	0.1563	0.2178	0.3184	0.2588	0.2602	0.3272	0.1538	0.2681	0.1940
	0.0057	0.0001	0.3197	0.2500	0.1067	0.0167	0.0541	0.0599	0.0157	0.2665	0.0457	0.1519
	56	56	52	56	56	56	56	53	54	54	56	56
308	0.4791	0.3566	0.1775	0.0501	-0.0060	0.0216	-0.0305	-0.0267	0.1150	0.0015	0.0352	0.0827
	0.0002	0.0070	0.2081	0.7136	0.9649	0.8743	0.8229	0.8494	0.4075	0.9912	0.7965	0.5442
	56	56	52	56	56	56	56	53	54	54	56	56
309	0.5670	0.3833	0.1902	0.0504	0.0080	0.0823	0.0480	0.0747	0.1814	0.0305	0.1305	0.0693
	0.0001	0.0035	0.1767	0.7122	0.9530	0.5462	0.7252	0.5949	0.1891	0.8262	0.3376	0.6116
	56	56	52	56	56	56	56	53	54	54	56	56
311	0.5002	0.2760	0.1833	-0.0161	-0.0565	0.0154	-0.0388	-0.0101	0.1417	-0.1051	0.1783	0.0756
	0.0001	0.0395	0.1932	0.9059	0.6789	0.9101	0.7761	0.9424	0.3065	0.4493	0.1885	0.5794
	56	56	52	56	56	56	56	53	54	54	56	56
312	0.6145	0.4641	0.1720	0.0750	0.0799	0.1828	0.1138	0.1594	0.1776	0.1497	0.0660	0.1321
	0.0001	0.0003	0.2225	0.5825	0.5580	0.1774	0.4036	0.2540	0.1988	0.2797	0.6288	0.3315
	56	56	52	56	56	56	56	53	54	54	56	56
313	0.6276	0.5258	0.2264	0.0619	0.0479	0.1359	0.0499	0.1212	0.1687	0.0851	0.0806	0.0750
	0.0001	0.0001	0.1065	0.6504	0.7256	0.3177	0.7149	0.3873	0.2226	0.5403	0.5548	0.5826
	56	56	52	56	56	56	56	53	54	54	56	56
314	0.6539	0.5342	0.2435	0.1741	0.1354	0.1924	0.1341	0.1363	0.1846	0.0869	0.1011	0.1351
	0.0001	0.0001	0.0819	0.1994	0.3195	0.1554	0.3243	0.3304	0.1813	0.5320	0.4581	0.3207
	56	56	52	56	56	56	56	53	54	54	56	56
315	0.6726	0.5385	0.2172	0.1605	0.1468	0.2142	0.1411	0.1952	0.1737	0.1264	0.0837	0.1052
	0.0001	0.0001	0.1218	0.2371	0.2801	0.1128	0.2995	0.1612	0.2090	0.3624	0.5396	0.4401
	56	56	52	56	56	56	56	53	54	54	56	56
316	0.6504	0.5430	0.1923	0.2284	0.2076	0.2557	0.1827	0.2170	0.2680	0.1732	0.1983	0.1931
	0.0001	0.0001	0.1720	0.0904	0.1247	0.0571	0.1776	0.1185	0.0500	0.2103	0.1427	0.1539
	56	56	52	56	56	56	56	53	54	54	56	56
317	0.5809	0.4394	0.2041	0.1266	0.1403	0.2198	0.1545	0.1634	0.3125	0.1298	0.2388	0.2487
	0.0001	0.0007	0.1466	0.3523	0.3023	0.1036	0.2556	0.2422	0.0214	0.3494	0.0763	0.0645
	56	56	52	56	56	56	56	53	54	54	56	56
318	0.5452	0.3658	0.2350	0.0380	0.0404	0.0559	0.0711	0.1426	0.1170	-0.0616	0.2605	0.0822
	0.0001	0.0056	0.0935	0.7809	0.7673	0.6823	0.6024	0.3081	0.3995	0.6577	0.0525	0.5470
	56	56	52	56	56	56	56	53	54	54	56	56
319	0.3174	0.4355	0.1919	0.3285	0.2594	0.2788	0.2285	0.2348	0.1732	0.0875	0.1865	0.2091
	0.0171	0.0008	0.1728	0.0134	0.0535	0.0375	0.0903	0.0904	0.2102	0.5290	0.1686	0.1219
	56	56	52	56	56	56	56	53	54	54	56	56

Continued on next page.

Table 8-11 (cont.).

Day/Day	Irrigation 1 320	321	Irrigation 2 329	330	331	332	333	334	335	336	337	338
320	1.0000	0.1953	0.0914	0.1130	0.1031	0.1593	0.1143	0.0865	0.1681	0.1417	0.0956	0.0550
	0.0	0.1491	0.5192	0.4067	0.4494	0.2408	0.4015	0.5379	0.2241	0.3065	0.4834	0.6868
	56	56	52	56	56	56	56	53	54	54	56	56
321		1.0000	0.2212	-0.0114	0.0359	0.0609	0.0747	0.1016	0.0283	0.0422	0.0403	0.1034
		0.0	0.1151	0.9331	0.7923	0.6555	0.5842	0.4691	0.8387	0.7618	0.7680	0.4482
		56	52	56	56	56	56	53	54	54	56	56
328 Irrigation 2												
329			1.0000	0.4342	0.3216	0.2762	0.2699	0.2916	0.1122	0.2552	0.1328	0.3008
			0.0	0.0012	0.0189	0.0452	0.0506	0.0399	0.4330	0.0707	0.3431	0.0286
			53	53	53	53	53	50	51	51	53	53
330				1.0000	0.8947	0.7587	0.6588	0.5910	0.5552	0.5959	0.3510	0.5836
				0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0074	0.0001
				57	57	57	57	54	55	55	57	57
331					1.0000	0.9237	0.8665	0.7963	0.7179	0.7392	0.5024	0.7139
					0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
					57	57	57	54	55	55	57	57
332						1.0000	0.9375	0.9221	0.8518	0.8136	0.6411	0.7996
						0.0	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
						57	57	54	55	55	57	57
333							1.0000	0.9167	0.8560	0.7581	0.7233	0.8142
							0.0	0.0001	0.0001	0.0001	0.0001	0.0001
							57	54	55	55	57	57
334								1.0000	0.8243	0.8048	0.7072	0.8287
								0.0	0.0001	0.0001	0.0001	0.0001
								54	52	52	54	54
335									1.0000	0.6808	0.7858	0.8182
									0.0	0.0001	0.0001	0.0001
									55	54	55	55
336										1.0000	0.3888	0.7441
										0.0	0.0033	0.0001
										55	55	55
337											1.0000	0.6433
											0.0	0.0001
											57	57

REFERENCES

Aase, J.K., and S.B. Idso. 1975. Solar radiation interactions with mixed prairie rangeland in natural and denuded conditions. Arch. Met. Geoph. Biokl., Ser. B, 23, 255-264.

Benjamin, J.R., and C.A. Cornell. 1970. Probability, statistics and decision for civil engineers. McGraw-Hill, New York.

Ben-Asher, J., A.W. Warrick, and A.D. Matthias. 1984. Bare-soil evaporation determined in-situ by infrared thermometry. J. of Hydrology 69:325-334.

Ben-Asher, J., A.D. Matthias, and A.W. Warrick. 1983. Assessment of evaporation from bare soil by infrared thermometry. Soil Sci. Soc. Am. J. 47:185-191.

Boast, C.W., and T.M. Robertson. 1982. A "micro-lysimeter" method for determining evaporation from bare soil: description and laboratory evaluation. Soil Sci. Soc. Am. J. 46:689-696.

Bowers, S.A., and R.J. Hanks. 1965. Reflection of radiant energy from soils. Soil Sci. 100(2):130-138.

Campbell, G.S. 1977. An introduction to environmental biophysics. Springer-Verlag, New York, p.94.

Campbell, G.S. 1985. Soil physics with BASIC. Elsevier, Amsterdam.

CoHort Software. 1988. CoStat Statistical Software. P.O. Box 1149, Berkeley, CA 94701.

Cressie, N. 1985. When are relative variograms useful in geostatistics? Math. Geol. 17(7):693-702.

deVries, D.A. 1975. Heat transfer in soils. In deVries, D.A. and N.H. Afgan. Heat and mass transfer in the biosphere, part 1. John Wiley and Sons, New York.

Doorenbos, J., and W.O. Pruitt. 1984. Crop water requirements, FAO Irrigation and Drainage Paper 24. FAO, Rome.

Englund, E., and A. Sparks. 1988. GEO-EAS (Geostatistical environmental assessment software) user's guide. U.S. Environmental Protection Agency report EPA600/4-88/033.

Fritschen, L.J., and L.W. Gay. 1979. Environmental Instrumentation. Springer. 216 pp.

Gay, L.W., and R.J. Greenberg. 1982. A RPN program for the generalized Penman equation. Hydrology and Water Resources in Arizona and the S.W. 12:17a-17g.

Hillel, D. 1982. Introduction to soil physics. Academic Press, New York. 365 pp.

Horton, R., P.J. Wierenga, and D.R. Nielsen. 1983. Evaluation of methods for determining the apparent thermal diffusivity of soil near the surface. Soil Sci. Soc. Am. J. 47:25-32.

Idso, S.B., R.J. Reginato, R.D. Jackson, B.A. Kimball, and F.S. Nakayama. 1974. The three stages of drying of a field soil. Soil Sci. Soc. Amer. J. 38(5):831-837.

Idso, S.B., R.D. Jackson, R.J. Reginato, B.A. Kimball, and F.S. Nakayama. 1975. The dependence of bare soil albedo on soil water content. Applied Meteoroly, 14(1):109-113.

Kachanoski, R.G., and E. De Jong. 1988. Scale dependence and the temporal persistence of spatial patterns of soil water storage. Water Resour. Res. 24(1):85-91.

Kohl, R.A. 1972. Sprinkler precipitation gage errors. Trans. Amer. Soc. Agric. Eng. pp. 264-265 and 271.

Kreith, F., and W.D. Sellers. 1975. General principles of natural evaporation. In, deVries, D.A., and N.H. Afgan (eds.). Heat and mass transfer in the biosphere, part 1. John Wiley & Sons. New York. pp. 207-227.

Matthias, A.D., and A.W. Warrick. 1987. Simulation of soil temperatures with sparse data. Soil Sci. 144(6):394-402.

Monteith, J.L. 1973. Principles of environmental physics. Edward Arnold Publishers, London.

Monteith, J.L., and G. Szeicz. 1961. The radiation balance of bare soil and vegetation. Quart. J. Roy. Meteorol. Soc., S7, 372, 159-170.

Montgomery, D.C. 1976. Design and analysis of experiments. John Wiley and Sons, New York. P. 316.

Mulla, D.J. 1988. Estimating spatial patterns in water content, matric suction and hydraulic conductivity. Soil Sci. Soc. Amer. J. 52:1547-1553.

Murray, F.W. 1967. On the computation of saturation vapor pressure. J. Appl. Meteorol. 6:203-204.

Neter, J., and W. Wasserman. 1974. Applied linear statistical models. Richard D. Irwin, Inc., Homewood IL. Pp. 297-338.

Nie, N.H., D.H. Hull, J.G. Jenkins, K. Steinbrenner, and D.H. Bent. 1975. SPSS, statistical package for the social sciences, 2nd edition. McGraw-Hill Book Co., New York.

Ozisik, M.N. 1980. Heat conduction. John Wiley and Sons, New York.

Post, D.F., D.M. Hendricks, and O.J. Pereira. 1978. Soils of the University of Arizona experiment station: Marana. College of Agriculture, University of Arizona, Tucson.

Press, W.H., B.P. Flannery, S.A. Teukolsky, and W.T. Vetterling. 1986. Numerical recipes, the art of scientific computing. Cambridge University Press, Cambridge.

Pruitt, W.O., and J. Doorenbos. 1977. Empirical calibration, a requisite for evapotranspiration formulae based on daily or longer mean climatic data? The International Round Table Conference on "Evapotranspiration", The Hungarian National Committee, International Commission on Irrigation and Drainage.

Rosenberg, N.J. 1974. Microclimate: The biological environment. John Wiley & Sons, New York.

Rosenberg, N.J., B.L. Blad, and S.B. Verma. 1983. Microclimate, the biological environment. John Wiley and Sons, New York.

Salehi, R. 1984. Micro-lysimeter and thermometric measurements of soil evaporation near a point source emitter. M.S. thesis, Dept. of Soils, Water and Engineering, University of Arizona.

SAS Institute Inc. 1987. SAS technical report P-171, changes and enhancements to base SAS software for personal computers, release 6.03. Cary, N.C.

Shawcroft, R.W., and H.R. Gardner. 1983. Direct evaporation from soil under a row crop canopy. Agric. Meteorol. 28:229-238.

Touloukian, Y.S., R.W. Powell, C.Y. Ho, and P.G. Klemens. 1970. Thermophysical properties of matter. IFI/Plenum, New York. Vol. 1, page 1113 and Vol. 2, page 953.

Vachaud, G., A. Passerat De Silans, P. Balabanis, and M. Vauclin. 1985. Temporal stability of spatially measured soil water probability density function. Soil Sci. Soc. Am. J. 49:822-828.

Vauclin, M., S.R. Viera, R. Bernard, and J.L. Hatfield. 1982. Spatial variability of surface temperature along two transects of a bare soil. Water Resour. Res. 18:1677-1686.

Viera, S.R., J.L. Hatfield, D.R. Nielsen, and J.W. Biggar. 1983. Geostatistical theory and application to variability of some agronomic properties. Hilgardia. 51(3):1-75.

Walker, G.K. 1983. Measurement of evaporation from soil beneath crop canopies. Can. J. Soil Sci. 63:137-141.

Warrick, A.W., D.E. Myers, and D.R. Nielsen. 1986. Geostatistical methods applied to soil science. Chapter 3 In Methods of soil analysis. Part 1. A. Klute (ed.). Amer. Soc. Agron. Inc., Soil Sci. Soc. Amer. Inc., Madison, Wisconsin.

Yates, S.R., and A.W. Warrick. 1987. Estimating soil water content using cokriging. Soil Sci. Soc. Amer. J. 51:23-30.

Yates, S.R., A.W. Warrick, A.D. Matthias, and S. Musil. 1988. Spatial variability of remotely sensed surface temperatures at field scale. Soil Sci. Soc. Amer. J. 52:40-45.