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# An Empirical Surface Temperature Model

Alan E. Krusinger

September 1988

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Based on long-term radiometric, temperature, and meteorological measurements, made at instrumented test sites, the U.S. Army Engineer Topographic Laboratories (USAETL) has developed an empirical surface temperature prediction model. The model has simple inputs, with no measurements, for use by the field Army. The model uses analogous climates and type-days, or composite days, of relatively unique weather conditions. Model inputs of climate, season, sky cover, and surface soil wetness produce diurnal temperature curves for various backgrounds, for each type-day. The temperate climate, summer season model is presented in this report.

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# PREFACE

The work reported herein was performed under DA Project 4A161102B52C, Task 0C, Work Unit 004, "Radiation Backgrounds."

The work was performed during the period 1984 to 1987 under the supervision of Dr. Jack N. Rinker, Team Leader, Center for Remote Sensing, and Mr. Lawrence A. Gambino, Director, Research Institute, U.S. Army Engineer Topographic Laboratories.

Colonel David F. Maune, EN, was Commander and Director, and Mr. Walter E. Boge was Technical Director of the U.S. Army Engineer Topographic Laboratories during the report publication preparation.


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# AN EMPIRICAL SURFACE TEMPERATURE MODEL

## INTRODUCTION

**Background.** Thermal infrared (IR) surface temperature models are necessary to deal with the challenge of automatic, or Assisted Target Recognition (ATR), false target discrimination, and forward-looking infrared (FLIR) imager manual settings. Passive thermal infrared is a proven sensor that is used for many tactical systems at the present time. Multisensor, or two-color, target locator systems will probably be used in the future to take advantage of temperature and shape information. As a result, IR will probably be one of the sensors.

In a thermal infrared image, the camouflaging effect of background clutter is a difficult problem. The background may be the same temperature or warmer than all, or parts, of a military target. Vehicles can successfully hide thermally in the right background, at the right time of day.

Current attempts to predict surface and target temperatures have resulted in complex, *first-principles* models of the energy budget type. This complexity has been necessary because of the lack of good empirical data and because of the perceived need, with an empirical model, of measuring everything at all times. The nature of the energy budget analysis is necessarily complex, and it requires many assumptions that are not realized, such as one-dimensional heat flow, laminar air flow, and infinite extent of surfaces. The inputs to these models may exceed 30 types of data, with multiple entries of several types (soil, temperature, profile), as in the models by Balick, *et al.*[1] Many of these inputs are complex measurements and/or constants not available to the field Army. Examples of these data inputs are condition (flux or temperature) of the soil system bottom boundary and shortwave adsorptivity. In actuality, the models rely on several empirical relations to estimate critical input values that cannot be measured realistically, in the manner of Geiger[2] and Sellers[3]. Examples of these empirical relations in the *first-principles* models are the Haurwitz equation, based upon empirical cloud cover and type factors, used to adjust computations for insolation; the Brunt equation, based upon empirical constants, used to estimate atmospheric thermal infrared radiation; and other empirical factors, based on subjective cloud cover and type observations, used to adjust atmospheric infrared radiation.

---

[1] Balick, L. K., L. E. Link, R. K. Scoggins and J. L. Solomon, 1981. Thermal Modeling of Terrain Surface Elements. Technical Report EL-81-2, prepared by the Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, in collaboration with Mississippi State University, for the U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss., pp. 13-14.

[2] Geiger, R., 1965. The Climate Near the Ground. Harvard University Press, Cambridge, Mass., pp. 13,26.

[3] Sellers, W. D., 1965. Physical Climatology. University of Chicago Press, Chicago, pp. 58-61.

Other current models, or tactical decision aids (TDA's), like those done by Higgins[4] and Higgins, et al.;[5] are of a very restricted type, using "snapshot" data of a few days' duration. They, too, have an extensive list of inputs (5 system, 5 target/background, 26 site/meteorological). Because these models are not usable outside of a carefully measured and calibrated field site, they cannot be simplified for tactical use.

## INVESTIGATION

**Approach.** Previous work by the U.S. Army Engineer Topographic Laboratories (ETL) in this area involved the effect of various meteorological variables on the radiometric temperature of natural surfaces.[6] This work indicated the great complexity of the modeling problem, exhibited by the *first-principles* models. Consequently, this work was undertaken to find an interim solution to simplify model inputs and fill the void of useful models.

Because the model evolved from the data, the model is empirical. The model is based upon "type-days" of relatively unique weather conditions and the premise that in certain weather conditions, for example, a clear day, the meteorological variables would be repeatable, within a certain range. Therefore, in a given climate, in a given season, on a given type-day, backgrounds would have repeatable diurnal temperature curves.

Meteorological, radiometric, and temperature data have been collected, around the clock, for several years at a temperate climate site in Northern Virginia. In addition, our agency (ETL) has been cooperating with the Department of the Interior, Geological Survey, Geologic Division, Astrogeology Branch, Flagstaff, Arizona, in collection of data in New Mexico. This report will use the Virginia data for the temperate climate model. Similar models for the semi-arid climate of New Mexico, as well as several other climates of the world that are of interest to the Army will be addressed in future models.

---

[4] Higgins, G. J., 1984. Users Guide for the Operational Tactical Decision Aid (OTDA) for Infrared (8-12um) Systems - Mark III Computer Version, Report No. AFGL-TR-84-0164, Scientific Report No. 18, by Systems and Applied Sciences Corporation (SASC) for the Air Force Geophysics Laboratory, Air Force Systems Command, U.S.A.F.

[5] Higgins, G. J., J. M. Freni, P. F. Hilton, T. J. Keegan, B. A. Mareiro, M. A. Mickelson, C. N. Touart and R. F. Wachtmann, 1987. Mark I Tactical Decision Aids for Microcomputer Systems, Report No. AFGL-TR-87-0057, Scientific Report No. 32, by ST Systems Corporation for the Air Force Geophysics Laboratory, Air Force Systems Command, U.S.A.F.

[6] Krusinger, A. E., 1984. Some Factors Affecting Vehicle/Background Thermal IR Contrast. Technical Memo, unpublished. U.S. Army Engineer Topographic Laboratories (ETL), Fort Belvoir, Va., 22060-5546.

**Description of the Work.** The work entailed making composites of days of similar weather conditions and doing a regression computation on the values for background temperature through the diurnal cycle.

The annual cycle was initially separated into four seasons of three months each, as shown in table 1. As yet, only the summer season has been addressed.

**Table 1.**

Seasons with Included Days of the Year

| | | |
|---|---|---|
| Summer | 1 June - 31 August | Days 152-243 |
| Fall | 1 September - 30 November | Days 244-334 |
| Winter | 1 December - 28 February | Days 335-365<br>Days 1- 59 |
| Spring | 1 March - 31 May | Days 60-151 |

The seven "type-days" selected for the temperate climate are listed in table 2. Originally, there were two partly cloudy conditions, but this created too many type-days to start with, making computations difficult and the number of observations small in some categories.

**Table 2.**

The Seven Type-Days

| | | |
|---|---|---|
| 1. | Clear, | Dry Surface Soil |
| 2. | Clear, | Wet Surface Soil |
| 3. | Partly Cloudy, | Dry Surface Soil |
| 4. | Partly Cloudy, | Wet Surface Soil |
| 5. | Overcast, | Dry Surface Soil |
| 6. | Overcast, | Wet Surface Soil |
| 7. | Overcast, Rain, | Wet Surface Soil |

The backgrounds, target, and temperature differences that were available are listed in table 3.

**Table 3.**

Backgrounds, Target, and Temperature Differences

| | |
|---|---|
| 1. Cut Grass (1) | Temperature (drier, thin cover) |
| 2. Bare Soil | Temperature (silty sand) |
| 3. Uncut Grass/Weeds | Temperature |
| 4. Cut Grass (2) | Temperature (wetter, thicker cover) |
| 5. Gravel | Temperature |
| 6. M114 Armored Reconnaissance Vehicle | Temperature |
| 7. M114 - Cut Grass (1) | Temperature Difference |
| 8. M114 - Bare Soil | Temperature Difference |
| 9. M114 - Uncut Grass | Temperature Difference |
| 10. M114 - Cut Grass (2) | Temperature Difference |
| 11. M114 - Gravel | Temperature Difference |

The temperature differences were included in order to have an accurate value and not have to subtract one regression curve from another to determine thermal contrasts when using the model. All temperatures used in the study are degrees Celsius. No emissivities were determined for the backgrounds or the target, but an emissivity of 1 was assumed. Since emissivities could not be measured practically, effective blackbody temperatures were used throughout, just as a tactical system would do.

In this first attempt, days and parts of days were subjectively sorted from our 33,750 records from 1984 and 1985 into the seven type-days. The variables used to sort with are shown in table 4.

**Table 4.**

Meteorological Variables Used to Sort Type-Days

1. Short-Wave Incoming Radiation
2. Long-Wave Incoming Radiation
3. Air Temperature
4. Dew Point Temperature
5. Bare Soil Surface Radiometric Temperature
6. Precipitation
7. Wind Speed
8. Soil Moisture near the Surface

Data were recorded every half hour at the Remote Sensing Test Facility, located at ETL, Fort Belvoir, Virginia. Fast changing data, like wind speed and radiometric temperature, were averaged 15 times over a 5-minute period, twice an hour, and other data, like barometric pressure and soil temperature, were measured once each half hour.

Surface soil moisture affects surface temperature greatly and had to be addressed. Since it was not expected that the field Army would be measuring soil moisture, the model input for soil moisture was either *dry* or *wet*, a simple observation of the bare surface soil.

Daytime periods were sorted mostly on the basis of the shape of the short-wave incoming radiation curve. Nighttime periods were sorted using plot radiometric temperature, air temperature, dew-point temperature, and long-wave incoming radiation. A malfunctioning long-wave incoming radiation sensor created problems in sorting nighttime periods, as will be discussed later.

Observation numbers of stored data for the sorted days were determined, and 20 temperatures, temperature differences, and meteorological variables were re-stored, with the time of day of the observation. All the observations for days fitting into a given type-day were placed in a separate file. The files were shuffled to put the observations into chronological order through the 24-hour diurnal cycle. The data were separated into three parts, with overlaps, to develop polynomial regression curves for each part, since a single polynomial curve would not be suitable. Subsequently, a Fourier series was used. Polynomial regressions were computed for each third of each 24-hour period, for each of 11 background temperatures and temperature differences, for each type day. Altogether, 231 regression curves were developed for the summer season. The plots of the three regression curves, for each background, were overlaid together on a light table to find the match points. The two match points and the regression coefficients constituted files for use in the model.

The partly cloudy type-days had a considerable temperature spread because of the variability of conditions contained in this category. A top and bottom envelope was developed for each partly cloudy background by digitizing imaginary curves going through the top, or bottom-most, data points and computing regression curves for those points. These envelopes should represent the maximum (sunlit) and minimum (shaded) conditions inherent in the partly cloudy type-day. Future refinements should subdivide this type-day category. A partly cloudy and a mostly cloudy condition should be used in the next attempt.

## RESULTS

The results of the effort have been incorporated in a graphics program. This program takes the model inputs (see appendix A) and selects a data statement to read match points and polynomial regression coefficients (see appendix B). The three merged polynomial equations are computed, and the curve is plotted. The form of the polynomial regression equations is shown in table 5. Six orders were used for the equations to allow for certain cases, but typical curves were third order on the ends and fourth order in the middle.

**Table 5.**

Form of Polynomial Regression Equations

$$y = b_0 + b_1 x + b_2 x^2 + b_3 x^3 + \ldots + b_n x^n$$

Basic Code

```
READ C(*)          REM Match points & coefficients read from data
                       statements and entered into a 23-item array.
FOR I=0 TO C(1) STEP .01
PLOT I,C(3)+C(4)*I+C(5)*I^2+C(6)*I^3+C(7)*I^4+C(8)*I^5+C(9)*I^6
NEXT I
FOR I=C(1) TO C(2) STEP .01
PLOT I,C(10)+C(11)*I+C(12)*I^2+C(13)*I^3+C(14)*I^4+C(15)*I^5+C(16)*I^6
NEXT I
FOR I=C(2) TO 1.00 STEP .01
PLOT I,C(17)+C(18)*I+C(19)*I^2+C(20)*I^3+C(21)*I^4+C(22)*I^5+C(23)*I^6
NEXT I
```

The curves for the various backgrounds, the target, and the thermal contrast between target and backgrounds are plotted with the data used to form the composite days, and they are in appendix C. The data points were plotted using symbols for three day periods to allow us to see what data might not belong in a particular type-day and whether the variation of the data within the season was unreasonable.

An additional program compares the predicted model curve with raw data from the data base for selected days, and plots or tabulates both the measured and predicted temperature curves. This program was used to test the model, using 1987 data (see figures 1-7). Figure 1 shows a clear, dry condition in late August. Figure 2 is a clear, dry condition in mid-June that had persisted for several days, with rising humidity and rising long-wave radiation (also haze) that elevated plot temperature by the greenhouse effect. Figure 3 is a clear, wet condition, 25 mm of rain having occurred the previous day (see figure 6). The wet ground is indicative of the previous rainfall that cleaned the air, leaving a true clear sky. Some clouds after midnight raised plot temperature, and clouds in midmorning reduced plot temperature. Figure 4 is an overcast dry

condition with some partly cloudy periods that raised plot temperature. Figure 5 is an overcast dry condition with some clouds in the early morning that lowered plot temperature by shading. Figure 6 is the overcast raining condition that occurred previous to tne day in figure 3, with 25 mm of rain occurring in the early afternoon. Sharp drops in all temperatures and long-wave incoming radiation indicate passage of a cold front. This was not typical of the data making up the composite, and model prediction errors occurred. Figure 7 represents an overcast raining condition with light rain.

Validation of the model was further accomplished with another program that computed the root mean square (rms) of the differences between model predictions and temperature observations made at this site in 1986 and 1987. In comparing "apples to apples," the 1986-87 data was automatically classified into type-days by a newer routine and the type-day data was used as a basis of comparison with this model, made from 1984-85 data. The rms was computed for five backgrounds and the results are shown in table 6.

**Table 6.**

Rms Values of Differences between Actual 1986-87 Temperature Measurements and Model Prediction Temperatures

| Type-Day | Bare Soil | Uncut Grass | Cut Grass | Gravel | M114 ARV |
|---|---|---|---|---|---|
| Clear, Dry | 6.65 | 7.11 | 7.01 | 6.98 | 7.06 |
| Clear, Wet | 6.94 | 5.05 | 3.76 | 5.42 | 4.90 |
| Partly Cloudy, Dry | 5.30 | 4.47 | 4.60 | 4.64 | 4.67 |
| Partly Cloudy, Wet | 4.57 | 3.83 | 3.55 | 3.61 | 4.10 |
| Overcast, Dry | 4.14 | 3.41 | 3.87 | 4.47 | 5.20 |
| Overcast, Wet | 2.35 | 2.33 | 2.59 | 2.99 | 3.42 |
| Overcast, Rain | 3.77 | 4.15 | 4.42 | 4.38 | 5.18 |

## DISCUSSION

The model comes directly from the data, and requires no estimates of critical factors needed to compute the model. The inputs to the model are simple, requiring no measurements. For all the simplicity of the inputs, the model does a good job of temperature prediction, and illustrates the feasibility of this empirical approach.

The observations that went into the composite days were subjectively selected, without quantitative limits, and this has led to variation because of

the inclusion of some observations in a type-day when they didn't belong there. The method of sorting of nighttime periods was difficult and subject to error. It relied heavily on long-wave incoming radiation data, but the long-wave incoming radiation measurements for most of 1984-1985 were bad, in that they had slowly drifted up too high. A sufficient quantity of data was always a problem, and even given several years of data, it was difficult to assemble hundreds of observations for a given type-day, except partly cloudy days. More type-days were desirable, but the more type-days there were to be separated, the less data there were available to composite and the more computations there were to do.

Because these results can be applied only to a temperate climate, data need to be collected for models of other climatic areas. As a result, ETL has established two more instrumented test sites in collaboration with other federal agencies. A subhumid instrumented site went on line in 1986 via the Geostationary Operational Environmental Satellite (GOES) system. The site is located on the Jornada Experimental Range near Las Cruces, New Mexico, and the work is a collaborative effort between ETL, the U.S. Geological Survey's (USGS) Desert Studies Group at Flagstaff, Arizona, and the U.S. Department of Agriculture's Agricultural Research Service station at the University of New Mexico in Las Cruces. In 1988, an arid instrumented test site went on line, via the GOES system. This site is near Yuma, Arizona, and is a cooperative effort between ETL and the USGS Desert Studies Group. The collaborative work on the instrumented desert sites resulted from the 1984 Workshop on Desert Processes.[7] We are planning to install instrumented test sites in a hyperarid region and in a tropical area.

## CONCLUSIONS

1. The long-time continuous collection of measurements at instrumented sites is a reliable way, and perhaps the only way, of establishing data bases that have the quantity and quality of information needed for the following purposes:

   a. Testing and validating radiation models.
   b. Deriving empirical models for the field Army in the form of Tactical Decision Aids (TDA) and target/background thermal contrast predictions.
   c. Supporting Assisted Target Recognition (ATR).
   d. Deriving mathematical models.

2. The empirical model derived from the ETL Radiation Data Base-Temperate provides reasonable predicted values for various background temperatures, a target temperature, and meteorological variables for typical days.

3. The data base itself is an excellent means of establishing characteristics of typical days, i.e. what they are versus what you think they are.

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[7] McCauley, J. F. and J. N. Rinker, 1987. A Workshop on Desert Processes, September 24-28, 1984. U.S. Geological Survey Circular 989. AD A184 599.

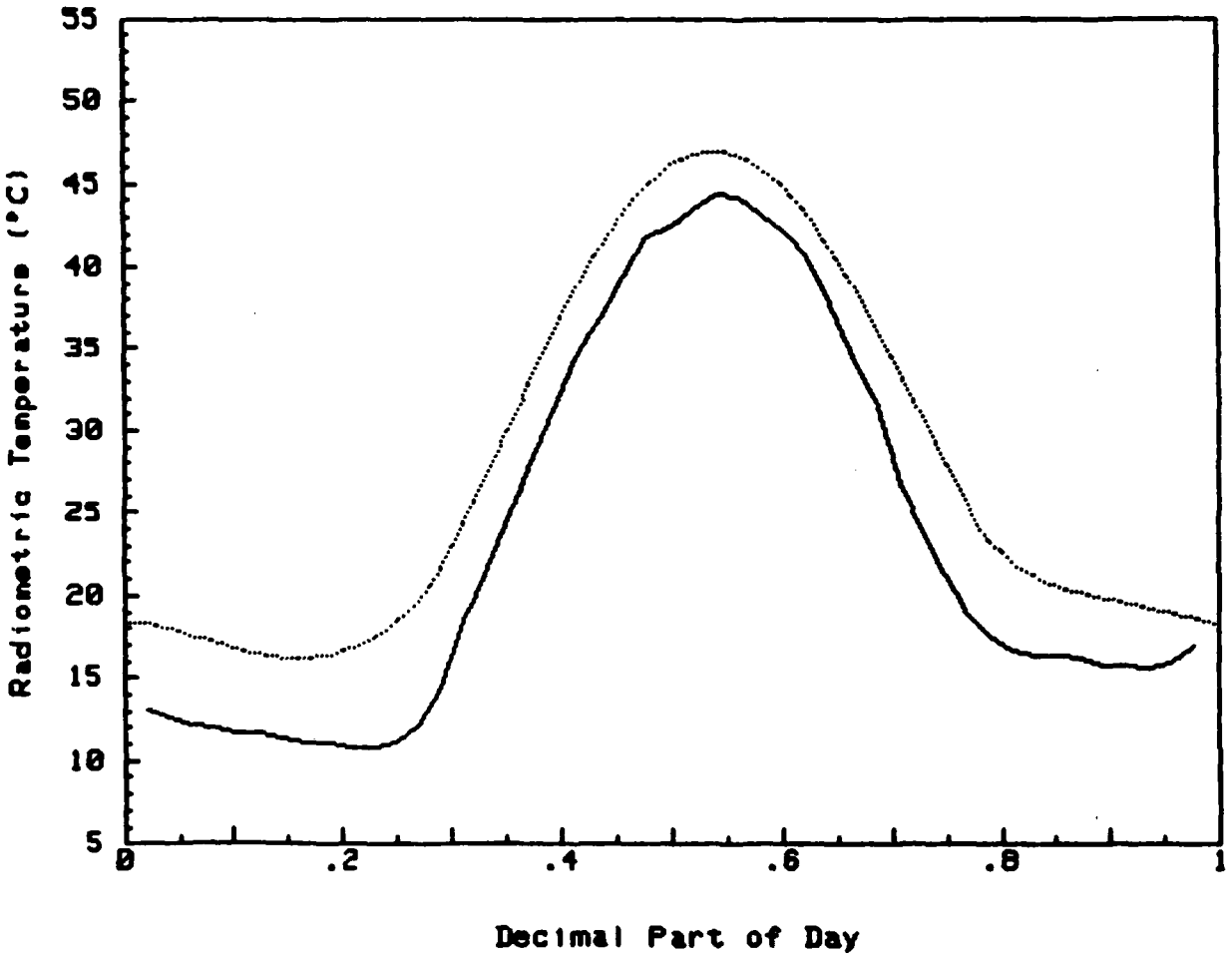


Figure 1. Measured (solid line) and predicted (dotted line) effective blackbody temperatures for a clear, dry summer day (30 August 1987).

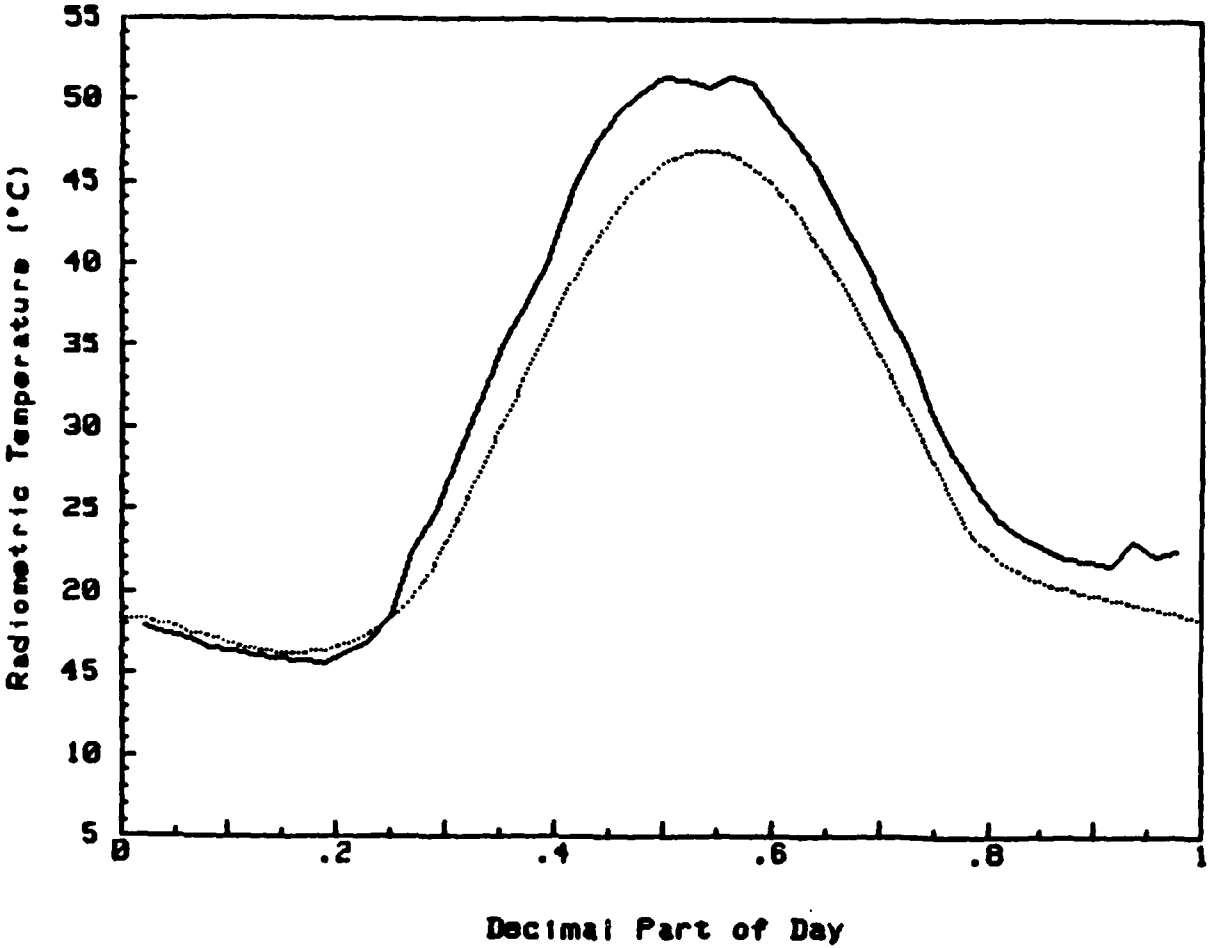


Figure 2. Measured (solid line) and predicted (dotted line) effective blackbody temperatures for a clear, dry summer day (19 June 1987).

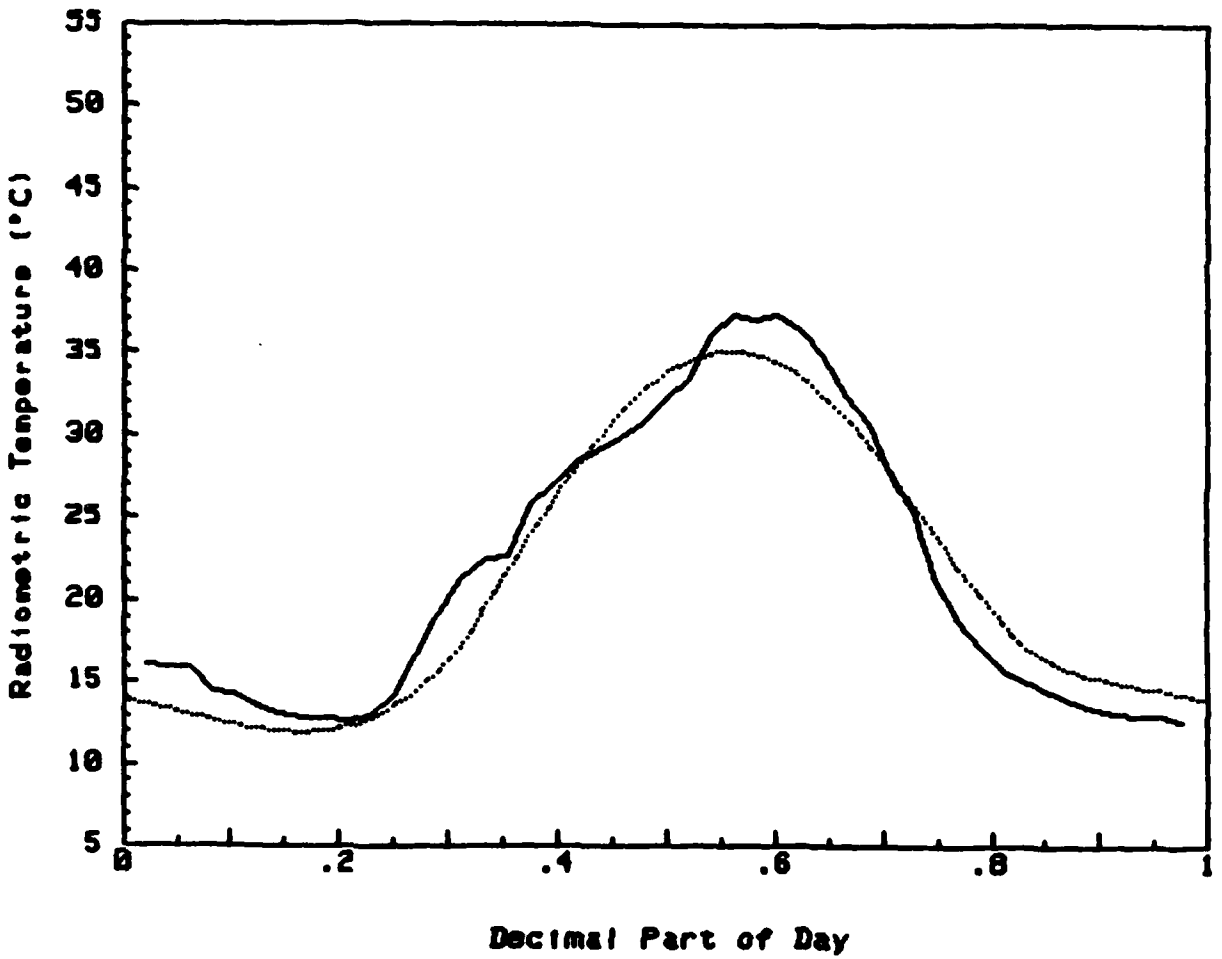


Figure 3. Measured (solid line) and predicted (dotted line) effective blackbody temperatures for a clear, wet summer day (5 June 1987).

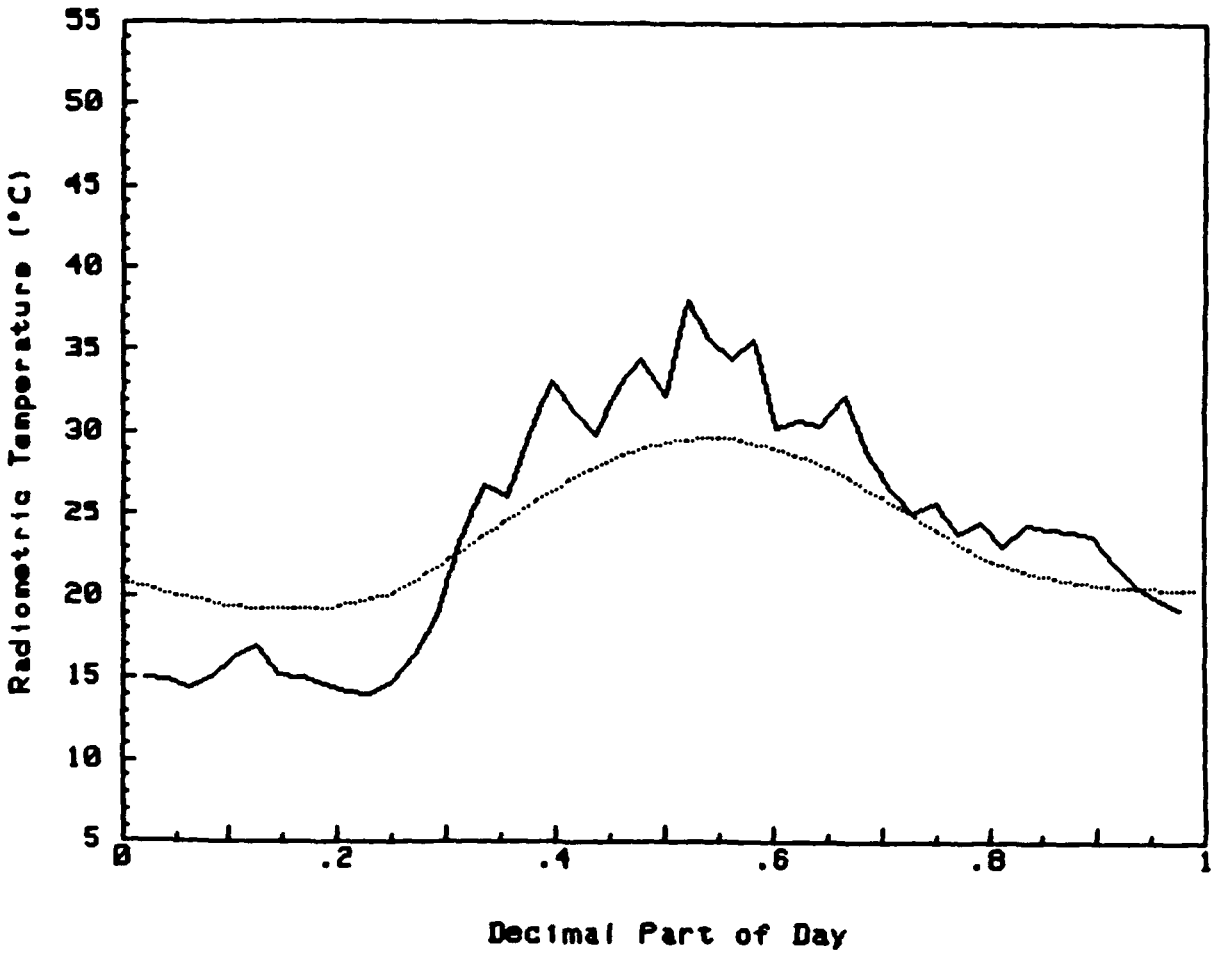


Figure 4. Measured (solid line) and predicted (dotted line) effective blackbody temperatures for an overcast, dry summer day (31 August 1987).

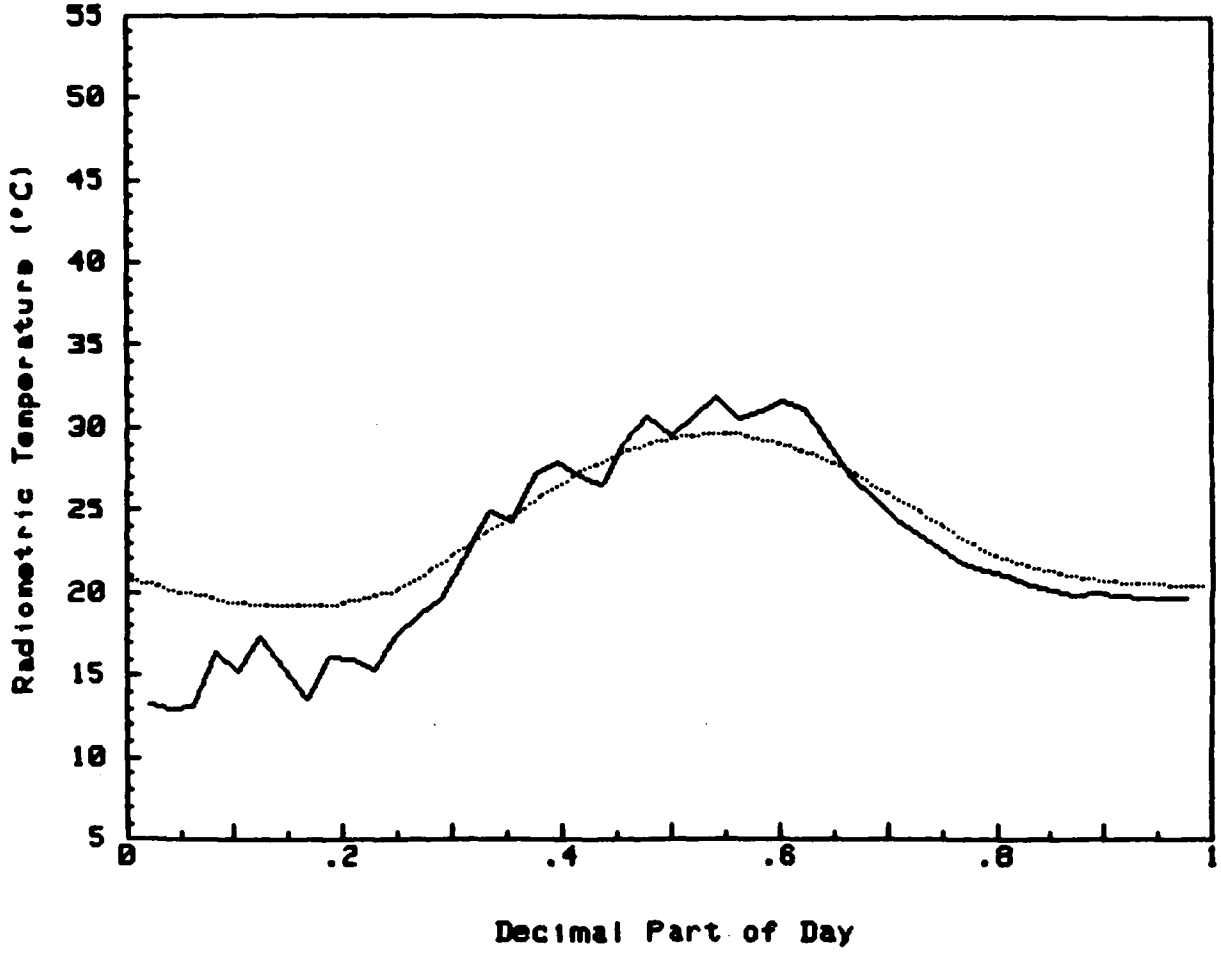


Figure 5. Measured (solid line) and predicted (dotted line) effective blackbody temperatures for an overcast, dry summer day (25 August 1987).

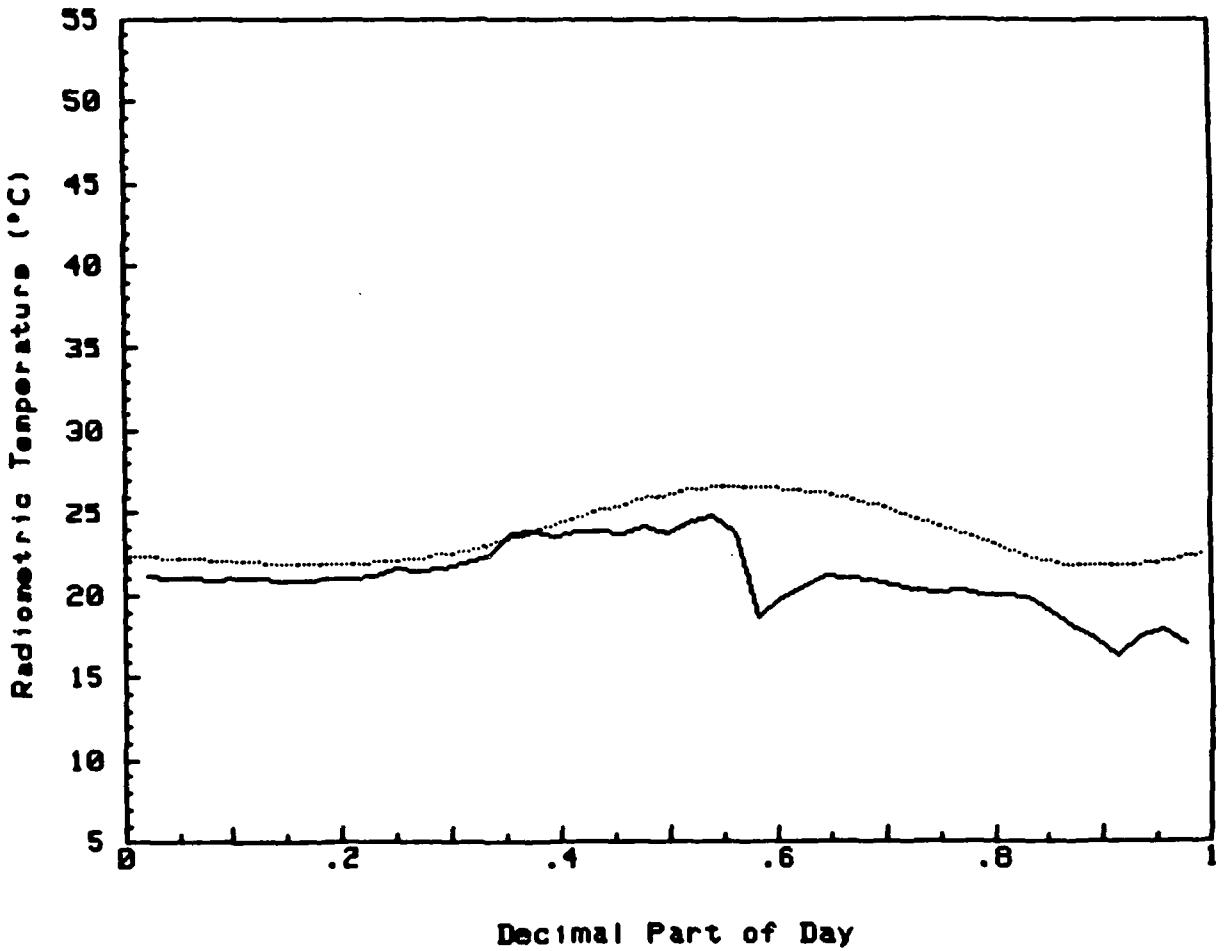


Figure 6. Measured (solid line) and predicted (dotted line) effective blackbody temperatures for an overcast, rainy summer day (4 June 1987).

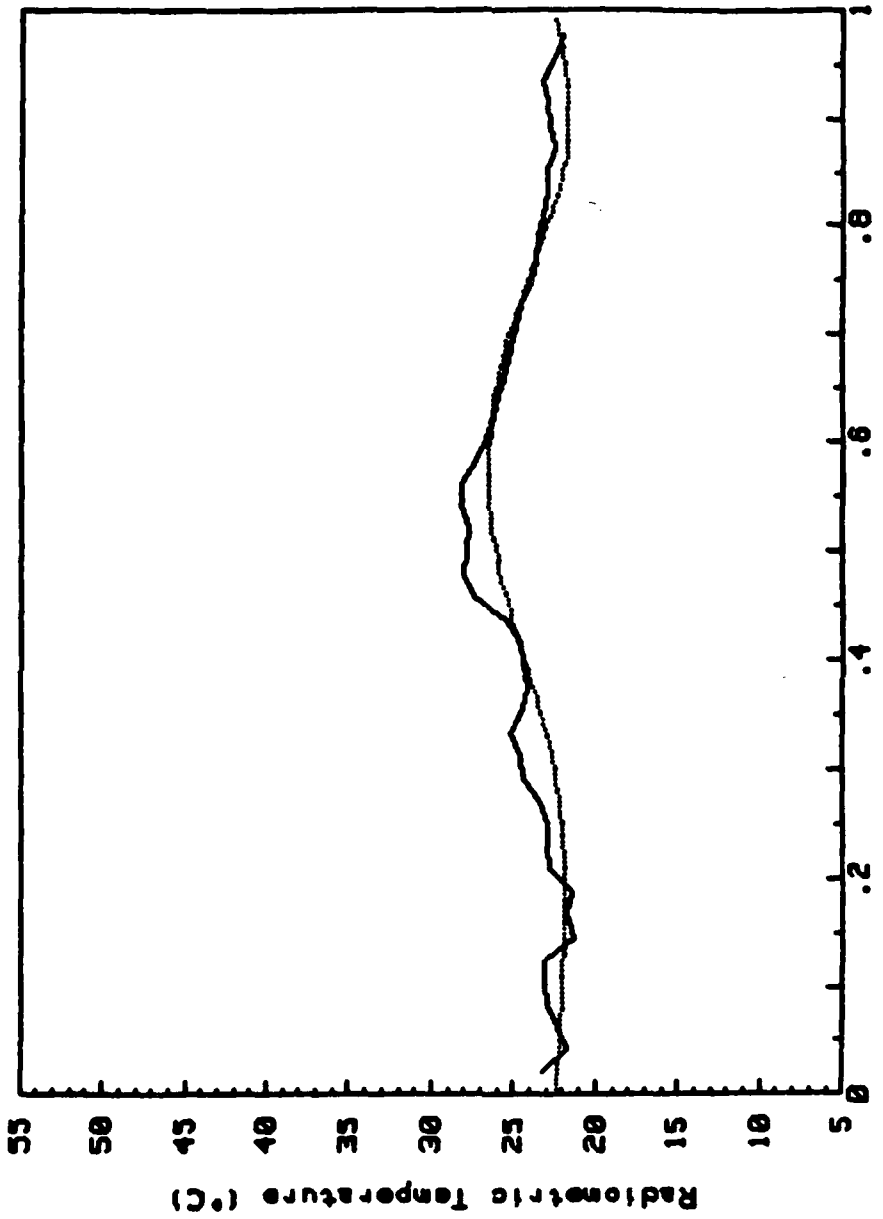


Figure 7. Measured (solid line) and predicted (dotted line) effective blackbody temperatures for an overcast, rainy summer day (22 August 1987).

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Higgins, G.J., J.M. Freni, P.F. Hilton, T.J. Keegan, B.A. Mareiro, M.A. Mickelson, C.N. Touart and R.F. Wachtmann, 1987. *Mark I Tactical Decision Aids for Microcomputer Systems*, Report No. AFGL-TR-87-0057, Scientific Report No. 32, by ST Systems Corporation for the Air Force Geophysics Laboratory, Air Force Systems Command, U.S.A.F.

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# APPENDIX A. Model Inputs

## Inputs To USAETL Surface Temperature Model

### Season

Summer
Fall
Winter
Spring

### Sky Conditions And Surface Soil Moisture

| | |
|---|---|
| Clear, | Dry |
| Clear, | Dry |
| Partly Cloudy, | Dry |
| Partly Cloudy, | Dry, Upper Envelope |
| Partly Cloudy, | Dry, Lower Envelope |
| Partly Cloudy, | Wet |
| Partly Cloudy, | Wet, Upper Envelope |
| Partly Cloudy, | Wet, Lower Envelope |
| Overcast, | Dry |
| Overcast, | Wet |
| Overcast, Rain, | Wet |

### Background Or Thermal Contrast

Cut Grass
Bare Soil
Uncut Grass
Gravel
M114 Armored Reconnaissance Vehicle
M114-Cut Grass
M114-Bare Soil
M114-Uncut Grass
M114-Gravel

# APPENDIX B.

**Polynomial Match Points & Coefficients in Basic Code**

The Following Abbreviations Are Used for the Type-Days:

Clear, Dry Summer. . . . . .Cdsu

Clear, Wet Summer. . . . . .Cwsu

Partly Cloudy, Dry Summer . . . . . .Pcdsu

Partly Cloudy, Wet Summer . . . . . .Pcwsu

Overcast, Dry Summer . . . . . .Odsu

Overcast, Wet Summer . . . . . .Owsu

Overcast, Rain Summer. . . . . .Orsu

```
  630 !
  640 SELECT Season
  650 CASE 1  !******************      SUMMER      ****************************
  660  SELECT Conditions
  670   CASE 1  !--------------------------      Cdsu    ---------------------
  680    SELECT Bkgd
  690     CASE 1                                                 ! Cut Grass (1)
  700      RESTORE 710
  710      DATA .27,.80,17.785,-29.698,3.8081,549.31,0,0,0,73.793,-796.80,3433.
8,-5138.9,2482.4,0,0,1417.9,-4637.8,5118.9,-1882.5,0,0,0
  720      GOSUB Line_type
  730     CASE 2                                                 ! Bare Soil (2)
  740      RESTORE 750
  750      DATA .29,.78,18.490,-7.0193,-167.46,779.28,0,0,0,104.11,-1045.7,4078
.4,-5796.2,2715.7,0,0,2993.4,-12516,19772,-13881,3649.9,0,0
  760      GOSUB Line_type
  770     CASE 3                                                 ! Uncut Grass (3)
  780      RESTORE 790
  790      DATA .28,.84,16.930,-37.751,102.10,269.64,0,0,0,62.077,-630.64,2684.
0,-3969.8,1895.8,0,0,1097.8,-3553.2,3895.5,-1424.2,0,0,0
  800      GOSUB Line_type
  810     CASE 4                                                 ! Cut Grass (4)
  820      RESTORE 830
  830      DATA .27,.73,16.881,-40.150,93.047,377.86,0,0,0,57.935,-639.46,2886.
0,-4395.1,2137.5,0,0,1366.2,-4467.8,4926.9,-1809.8,0,0,0
  840      GOSUB Line_type
  850     CASE 5                                                 ! Gravel (5)
  860      RESTORE 870
  870      DATA .27,.80,17.273,.92250,-282.44,1117.3,0,0,0,98.864,-1054.5,4246.
7,-6090.1,2852.6,0,0,1392.0,-4472.7,4870.9,-1773.0,0,0,0
  880      GOSUB Line_type
  890     CASE 6                                                 ! M114 ARV (6)
  900      RESTORE 910
  910      DATA .27,.78,18.962,-22.392,-91.548,683.79,0,0,0,73.338,-743.34,3040
.4,-4327.0,1996.3,0,0,701.68,-2059.4,2091.7,-714.95,0,0,0
  920      GOSUB Line_type
  930     CASE 7                                                 ! M114-Cut Grass (1)
  940      RESTORE 950
  950      DATA .23,.87,1.1766,7.3060,-95.356,134.48,0,0,0,-.45517,53.459,-393.
41,811.94,-486.11,0,0,-716.18,2578.4,-3027.2,1167.6,0,0,0
  960      GOSUB Line_type
  970     CASE 8                                                 ! M114-Bare Soil (2)
  980      RESTORE 990
  990      DATA .24,.83,.47439,-15.484,76.793,-97.261,0,0,0,84.208,-1331.3,8130
.6,-24588,38949,-30795,9565.9,-440.25,1623.4,-1946.4,764.15,0,0,0
 1000      GOSUB Line_type
 1010     CASE 9                                                 ! M114-Uncut Grass (3)
 1020      RESTORE 1030
 1030      DATA .30,.87,2.4252,-6.3980,58.085,-578.00,1251.1,0,0,138.74,-1771.2
,8835.4,-22267,30454,-21498,6113.4,-396.12,1493.8,-1803.8,709.26,0,0,0
 1040      GOSUB Line_type
 1050     CASE 10                                                ! M114-Cut Grass (4)
 1060      RESTORE 1070
 1070      DATA .42,.89,2.0862,17.535,-182.84,302.38,0,0,0,23.882,-180.66,394.5
9,-241.94,0,0,0,-664.55,2408.5,-2835.1,1094.9,0,0,0
```

```
1080       GOSUB Line_type
1090      CASE 11                                          ! M114-Gravel (5)
1100       RESTORE 1110
1110       DATA .20,.82,1.6740,-22.685,185.93,-423.52,0,0,0,-25.526,311.11,-120
6.2,1763.1,-856.28,0,0,-690.32,2413.3,-2779.2,1058.1,0,0,0
1120       GOSUB Line_type
1130     END SELECT
1140    CASE 2  !-------------------------     Cwsu     ----------------------
1150     SELECT Bkgd
1160      CASE 1                                           ! Cut Grass (1)
1170       RESTORE 1180
1180       DATA .30,.82,11.256,-7.7079,305.84,-4738.6,22333,-29130,0,13.769,-19
3.11,1205.7,-1962.3,954.20,0,0,829.35,-2556.1,2668.5,-929.72,0,0,0
1190       GOSUB Line_type
1200      CASE 2                                           ! Bare Soil (2)
1210       RESTORE 1220
1220       DATA .33,.825,13.911,-8.2763,-114.99,567.17,0,0,0,73.946,-713.81,270
7.9,-3724.1,1685.0,0,0,703.24,-2150.5,2249.3,-788.07,0,0,0
1230       GOSUB Line_type
1240      CASE 3                                           ! Uncut Grass (3)
1250       RESTORE 1260
1260       DATA .32,.83,11.031,-14.329,380.69,-4964.0,22163,-28352,0,7.8721,-12
4.76,928.04,-1561.7,766.47,0,0,584.94,-1744.9,1772.1,-600.43,0,0,0
1270       GOSUB Line_type
1280      CASE 4                                           ! Cut Grass (4)
1290       RESTORE 1300
1300       DATA .32,.84,10.030,.84325,116.42,-3362.3,18486,-25301,0,8.8746,-168
.95,1177.8,-1974.4,974.28,0,0,831.88,-2563.8,2670.1,-927.26,0,0,0
1310       GOSUB Line_type
1320      CASE 5                                           ! Gravel (5)
1330       RESTORE 1340
1340       DATA .33,.82,12.686,34.913,-1505.1,18996,-111939,305320,-300047,96.3
62,-1036.0,4067.6,-5724.0,2637.3,0,0,1242.0,-3905.4,4156.2,-1479.8,0,0,0
1350       GOSUB Line_type
1360      CASE 6                                           ! M114 ARV (6)
1370       RESTORE 1380
1380       DATA .24,.845,14.028,-18.209,-123.15,720.15,0,0,0,48.359,-514.77,216
1.6,-2999.5,1320.1,0,0,396.54,-902.57,649.65,-129.02,0,0,0
1390       GOSUB Line_type
1400      CASE 7                                           ! M114-Cut Grass (1)
1410       RESTORE 1420
1420       DATA .23,.85,1.7538,64.083,-2215.0,25372,-130530,303540,-259020,34.5
90,-321.66,955.96,-1037.2,365.88,0,0,-432.81,1653.5,-2018.9,800.70,0,0,0
1430       GOSUB Line_type
1440      CASE 8                                           ! M114-Bare Soil (2)
1450       RESTORE 1460
1460       DATA .29,.82,.11645,-9.9329,-8.1633,152.97,0,0,0,286.51,-4011.2,2182
3,-59464,86589,-64284,19091,-306.70,1247.9,-1599.6,659.06,0,0,0
1470       GOSUB Line_type
1480      CASE 9                                           ! M114-Uncut Grass (3)
1490       RESTORE 1500
1500       DATA .27,.79,2.8256,-24.704,273.51,-1545.0,2642.1,0,0,40.486,-390.02
,1233.6,-1437.8,553.60,0,0,-4465.2,21143,-37100,28689,-826[illegible].1,0,0
1510       GOSUB Line_type
1520      CASE 10                                          ! M114-Cut Grass (4)
1530       RESTORE 1540
1540       DATA .22,.83,3.6920,-30.194,371.06,-2046.0,3246.5,0,0,39.484,-345.82
```

```
,983.84,-1025.2,345.80,0,0,-435.34,1661.3,-2020.5,798.24,0,0,0
  1550       GOSUB Line_type
  1560      CASE 11                                          ! M114-Gravel (5)
  1570       RESTORE 1580
  1580       DATA .29,.83,1.0027,-20.405,153.57,-338.25,0,0,0,81.660,-1316.3,8366
.2,-26334,42719,-34048,10540,-845.46,3002.8,-3506.5,1350.8,0,0,0
  1590       GOSUB Line_type
  1600     END SELECT
  1610    CASE 3   !-------------------------    Pcdsu   ----------------------
  1620     SELECT Bkgd
  1630      CASE 1                                           ! Cut Grass (1)
  1640       RESTORE 1650
  1650       DATA .26,.80,19.660,-18.670,-2.6735,376.06,0,0,0,36.227,-320.83,1574
.8,-2462.3,1209.0,0,0,787.20,-2517.6,2755.2,-1005.2,0,0,0
  1660       GOSUB Line_type
  1670      CASE 2                                           ! Bare Soil (2)
  1680       RESTORE 1690
  1690       DATA .275,.775,20.484,3.9021,-184.41,661.88,0,0,0,75.503,-677.72,265
4.9,-3769.0,1760.8,0,0,641.88,-1998.8,2155.8,-777.87,0,0,0
  1700       GOSUB Line_type
  1710      CASE 3                                           ! Uncut Grass (3)
  1720       RESTORE 1730
  1730       DATA .25,.82,19.032,-21.424,37.882,241.68,0,0,0,29.510,-226.79,1145.
6,-1790.1,871.39,0,0,689.04,-2191.7,2394.1,-872.33,0,0,0
  1740       GOSUB Line_type
  1750      CASE 4                                           ! Cut Grass (4)
  1760       RESTORE 1770
  1770       DATA .25,.83,19.126,-24.327,43.239,292.45,0,0,0,31.425,-271.44,1391.
9,-2203.1,1084.8,0,0,834.75,-2686.7,2950.8,-1079.8,0,0,0
  1780       GOSUB Line_type
  1790      CASE 5                                           ! Gravel (5)
  1800       RESTORE 1810
  1810       DATA .27,.79,19.625,8.9145,-273.23,951.37,0,0,0,77.701,-760.25,3092.
7,-4456.1,2093.6,0,0,877.11,-2750.7,2958.3,-1064.3,0,0,0
  1820       GOSUB Line_type
  1830      CASE 6                                           ! M114 ARV (6)
  1840       RESTORE 1850
  1850       DATA .26,.78,20.677,1.7210,-207.17,743.27,0,0,0,66.865,-598.58,2374.
4,-3326.0,1519.9,0,0,490.41,-1403.5,1414.6,-480.10,0,0,0
  1860       GOSUB Line_type
  1870      CASE 7                                           ! M114-Cut Grass (1)
  1880       RESTORE 1890
  1890       DATA .22,.80,1.8200,-21.063,269.16,-1498.9,2357.0,0,0,30.638,-277.75
,799.59,-863.72,310.95,0,0,-296.79,1114.1,-1340.5,525.11,0,0,0
  1900       GOSUB Line_type
  1910      CASE 8                                           ! M114-Bare Soil (2)
  1920       RESTORE 1930
  1930       DATA .25,.785,.44101,-9.8372,25.697,0,0,0,0,6.3284,-55.434,135.83,-8
9.780,0,0,0,29.201,-48.703,19.609,0,0,0,0
  1940       GOSUB Line_type
  1950      CASE 9                                           ! M114-Uncut Grass (3)
  1960       RESTORE 1970
  1970       DATA .38,.835,2.4232,-17.019,213.86,-1306.5,2283.6,0,0,80.260,-858.4
3,3293.5,-5658.6,4551.6,-1411.7,0,-198.63,788.17,-979.44,392.23,0,0,0
  1980       GOSUB Line_type
  1990      CASE 10                                          ! M114-Cut Grass (4)
  2000       RESTORE 2010
```

```
  2010       DATA .38,.82,2.4736,-21.581,293.80,-1693.3,2708.1,0,0,79.425,-826.03
,3099.2,-5349.4,4436.4,-1447.3,0,-344.34,1283.2,-1536.1,599.74,0,0,0
  2020       GOSUB Line_type
  2030      CASE 11                                          ! M114-Gravel (5)
  2040       RESTORE 2050
  2050       DATA .27,.88,1.0524,-7.1935,66.061,-208.09,0,0,0,-33.543,419.23,-181
1.1,3312.0,-2639.3,747.15,0,-386.69,1347.2,-1543.7,584.23,0,0,0
  2060       GOSUB Line_type
  2070     END SELECT
  2080    CASE 4  !--------------------------    Pcdsu  Upper Envelope --------
  2090     SELECT Bkgd
  2100      CASE 1                                           ! Cut Grass (1)
  2110       RESTORE 2120
  2120       DATA .375,.76,23.427,-24.730,12.406,521.72,0,0,0,65.770,-663.49,3038
.8,-4661.8,2276.3,0,0,517.47,-1477.5,1468.8,-485.30,0,0,0
  2130       GOSUB Line_type
  2140      CASE 2                                           ! Bare Soil (2)
  2150       RESTORE 2160
  2160       DATA .39,.76,24.918,-26.393,26.577,390.59,0,0,0,76.199,-706.84,2974.
1,-4372.0,2081.4,0,0,378.95,-1025.9,994.67,-322.73,0,0,0
  2170       GOSUB Line_type
  2180      CASE 3                                           ! Uncut Grass (3)
  2190       RESTORE 2200
  2200       DATA .27,.77,22.942,-17.021,43.054,308.20,0,0,0,49.644,-439.00,2072.
2,-3184.9,1543.5,0,0,432.35,-1203.3,1175.8,-381.69,0,0,0
  2210       GOSUB Line_type
  2220      CASE 4                                           ! Cut Grass (4)
  2230       RESTORE 2240
  2240       DATA .26,.76,22.832,-21.972,30.201,445.28,0,0,0,37.812,-380.52,2075.
5,-3383.5,1698.4,0,0,418.24,-1169.7,1151.4,-376.95,0,0,0
  2250       GOSUB Line_type
  2260      CASE 5                                           ! Gravel (5)
  2270       RESTORE 2280
  2280       DATA .28,.67,23.865,-29.052,42.235,432.11,0,0,0,75.914,-743.71,3210.
5,-4760.8,2271.1,0,0,485.45,-1339.8,1299.0,-420.69,0,0,0
  2290       GOSUB Line_type
  2300      CASE 6                                           ! M114 ARV (6)
  2310       RESTORE 2320
  2320       DATA .29,.75,25.330,-20.430,11.984,77.031,809.77,0,0,160.92,-1703.6,
7309.0,-13186,10568,-3118.2,0,374.32,-984.95,933.01,-297.12,0,0,0
  2330       GOSUB Line_type
  2340      CASE 7                                           ! M114-Cut Grass (1)
  2350       RESTORE 2360
  2360       DATA .32,.87,3.0566,-6.4999,-.76484,-302.28,970.69,0,0,97.232,-1063.
2,4149.4,-7171.0,5748.0,-1762.3,0,56.747,-93.578,39.750,0,0,0,0
  2370       GOSUB Line_type
  2380      CASE 8                                           ! M114-Bare Soil (2)
  2390       RESTORE 2400
  2400       DATA .35,.83,1.7142,-12.108,26.173,61.470,0,0,0,10.428,-119.74,459.7
7,-581.70,230.57,0,0,47.459,-80.956,35.178,0,0,0,0
  2410       GOSUB Line_type
  2420      CASE 9                                           ! M114-Uncut Grass (3)
  2430       RESTORE 2440
  2440       DATA .39,.82,3.8171,-7.2363,-8.9889,-246.00,1077.6,0,0,243.22,-3163.
9,15771,-38721,50822,-34342,9402.9,60.609,-100.39,43.378,0,0,0,0
  2450       GOSUB Line_type
  2460      CASE 10                                          ! M114-Cut Grass (4)
```

```
  2470       RESTORE 2480
  2480       DATA .31,.89,4.1879,-10.325,-.33437,-294.83,1115.7,0,0,153.90,-1789.
3,7586.6,-14548,13059,-4481.2,0,59.966,-94.268,38.842,0,0,0,0
  2490       GOSUB Line_type
  2500      CASE 11                                          ! M114-Gravel (5)
  2510       RESTORE 2520
  2520       DATA .32,.81,1.9725,-2.8241,27.641,-62.232,0,0,0,-16.727,200.86,-725
.57,1032.9,-498.37,0,0,-1030.2,4404.6,-6933.5,4783.2,-1222.4,0,0
  2530       GOSUB Line_type
  2540     END SELECT
  2550    CASE 5  !--------------------------    Pcdsu  Lower Envelope   -------
  2560     SELECT Bkgd
  2570      CASE 1                                           ! Cut Grass (1)
  2580       RESTORE 2590
  2590       DATA .24,.86,15.166,-3.7303,28.760,132.70,0,0,0,-.029356,59.388,157.
68,-469.69,267.72,0,0,392.20,-1141.7,1144.9,-380.04,0,0,0
  2600       GOSUB Line_type
  2610      CASE 2                                           ! Bare Soil (2)
  2620       RESTORE 2630
  2630       DATA .28,.80,16.966,-10.686,12.003,190.46,0,0,0,41.020,-334.69,1416.
4,-2052.2,953.48,0,0,388.16,-1115.7,1114.2,-369.59,0,0,0
  2640       GOSUB Line_type
  2650      CASE 3                                           ! Uncut Grass (3)
  2660       RESTORE 2670
  2670       DATA .31,.80,15.113,-8.9492,-81.006,401.29,2309.2,-5863.4,0,-48.202,
624.54,-2286.7,4357.6,-4180.1,1556.1,0,331.80,-950.98,945.91,-312.00,0,0,0
  2680       GOSUB Line_type
  2690      CASE 4                                           ! Cut Grass (4)
  2700       RESTORE 2710
  2710       DATA .32,.79,14.874,-.25840,-127.44,304.83,3126.7,-6574.5,0,-53.598,
707.83,-2808.5,5925.3,-6210.0,2471.7,0,489.34,-1454.1,1468.5,-489.49,0,0,0
  2720       GOSUB Line_type
  2730      CASE 5                                           ! Gravel (5)
  2740       RESTORE 2750
  2750       DATA .25,.79,16.433,-12.242,2.8588,105.52,576.51,0,0,45.769,-452.28,
2016.3,-3003.7,1424.2,0,0,429.82,-1221.4,1202.6,-394.52,0,0,0
  2760       GOSUB Line_type
  2770      CASE 6                                           ! M114 ARV (6)
  2780       RESTORE 2790
  2790       DATA .23,.82,17.881,-14.277,-93.406,91.886,3155.2,-5538.3,0,42.935,-
364.46,1511.3,-2124.4,956.94,0,0,298.08,-789.82,748.44,-239.27,0,0,0
  2800       GOSUB Line_type
  2810      CASE 7                                           ! M114-Cut Grass (1)
  2820       RESTORE 2830
  2830       DATA .24,.80,.55402,-3.7057,40.543,-223.39,-605.85,1623.7,0,-35.845,
541.96,-2856.9,6302.1,-6104.0,2157.9,0,-542.90,2307.0,-3597.6,2455.0,-620.9,0,0
  2840       GOSUB Line_type
  2850      CASE 8                                           ! M114-Bare Soil (2)
  2860       RESTORE 2870
  2870       DATA .37,.83,-.94930,-2.9195,8.1437,-105.68,0,0,0,-62.871,808.24,-38
50.1,8092.5,-7692.1,2711.2,0,6.6441,-8.9711,1.4461,0,0,0,0
  2880       GOSUB Line_type
  2890      CASE 9                                           ! M114-Uncut Grass (3)
  2900       RESTORE 2910
  2910       DATA .34,.83,1.1775,-2.7886,-13.651,-168.77,444.41,0,0,29.059,-267.7
7,771.01,-856.74,325.43,0,0,15.618,-22.376,7.8449,0,0,0,0
  2920       GOSUB Line_type
```

```
  2930      CASE 10                                              ! M114-Cut Grass (4)
  2940       RESTORE 2950
  2950       DATA .24,.83,1.0151,.34897,-20.328,-329.52,694.99,0,0,-15.203,306.89
,-1924.9,4694.3,-4846.0,1789.8,0,22.862,-36.774,14.772,0,0,0,0
  2960       GOSUB Line_type
  2970      CASE 11                                              ! M114-Gravel (5)
  2980       RESTORE 2990
  2990       DATA .27,.67,-.37996,4.8349,9.5487,-200.28,0,0,0,-27.161,355.03,-151
0.4,2292.2,-1129.8,0,0,-1030.3,4313.1,-6702.9,4584.5,-1165.1,0,0
  3000       GOSUB Line_type
  3010     END SELECT
  3020    CASE 6  !-------------------------     Pcwsu   ----------------------
  3030     SELECT Bkgd
  3040      CASE 1                                               ! Cut Grass (1)
  3050       RESTORE 3060
  3060       DATA .26,.79,18.875,-5.5998,36.666,148.19,0,0,0,27.764,-178.99,933.1
6,-1424.9,657.20,0,0,387.02,-1087.3,1064.4,-345.08,0,0,0
  3070       GOSUB Line_type
  3080      CASE 2                                               ! Bare Soil (2)
  3090       RESTORE 3100
  3100       DATA .30,.79,19.999,-11.353,34.549,136.96,0,0,0,51.845,-391.96,1550.
4,-2160.8,973.86,0,0,292.92,-782.59,747.87,-238.13,0,0,0
  3110       GOSUB Line_type
  3120      CASE 3                                               ! Uncut Grass (3)
  3130       RESTORE 3140
  3140       DATA .25,.80,18.103,-4.2015,39.778,98.542,0,0,0,-.15112,100.87,-56.1
71,-47.204,0,0,0,338.71,-943.45,920.60,-297.54,0,0,0
  3150       GOSUB Line_type
  3160      CASE 4                                               ! Cut Grass (4)
  3170       RESTORE 3180
  3180       DATA .25,.78,18.049,-4.0876,40.405,141.66,0,0,0,-5.0108,126.12,-62.7
89,-70.199,0,0,0,429.10,-1222.3,1203.9,-392.34,0,0,0
  3190       GOSUB Line_type
  3200      CASE 5                                               ! Gravel (5)
  3210       RESTORE 3220
  3220       DATA .30,.72,19.274,-17.477,28.420,287.77,0,0,0,72.323,-665.75,2670.
1,-3810.1,1773.0,0,0,467.01,-1300.7,1256.6,-403.73,0,0,0
  3230       GOSUB Line_type
  3240      CASE 6                                               ! M114 ARV (6)
  3250       RESTORE 3260
  3260       DATA .32,.725,20.463,-17.052,52.426,149.44,0,0,0,65.602,-539.22,2080
.1,-2880.6,1309.3,0,0,311.32,-786.28,706.18,-210.87,0,0,0
  3270       GOSUB Line_type
  3280      CASE 7                                               ! M114-Cut Grass (1)
  3290       RESTORE 3300
  3300       DATA .42,.865,1.5570,-4.7482,8.1966,-231.34,566.58,0,0,71.985,-773.8
0,3044.5,-5596.1,4970.2,-1730.8,0,34.376,-57.041,24.198,0,0,0,0
  3310       GOSUB Line_type
  3320      CASE 8                                               ! M114-Bare Soil (2)
  3330       RESTORE 3340
  3340       DATA .33,.82,.44016,-.41074,11.911,-170.98,446.92,0,0,56.800,-668.57
,2921.7,-5938.8,5778.4,-2181.7,0,40.755,-76.398,35.965,0,0,0,0
  3350       GOSUB Line_type
  3360      CASE 9                                               ! M114-Uncut Grass (3)
  3370       RESTORE 3380
  3380       DATA .40,.76,2.3242,-5.0923,3.8957,-218.26,655.68,0,0,55.053,-537.44
,1791.3,-2347.9,1065.9,0,0,43.695,-74.075,32.550,0,0,0,0
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 3390       GOSUB Line_type
 3400      CASE 10                                              ! M114-Cut Grass (4)
 3410       RESTORE 3420
 3420       DATA .40,.77,2.3798,-5.6044,3.6175,-247.56,622.01,0,0,49.744,-465.16
,1470.0,-1863.5,834.53,0,0,-117.78,436.07,-497.69,181.46,0,0,0
 3430       GOSUB Line_type
 3440      CASE 11                                              ! M114-Gravel (5)
 3450       RESTORE 3460
 3460       DATA .25,.75,1.2013,-2.2753,27.053,-44.626,-228.28,0,0,-6.7203,126.5
3,-589.99,929.54,-463.74,0,0,-155.69,514.45,-550.47,192.86,0,0,0
 3470       GOSUB Line_type
 3480     END SELECT
 3490    CASE 7  !--------------------------   Pcwsu   Upper Envelope -------
 3500     SELECT Bkgd
 3510      CASE 1                                              ! Cut Grass (1)
 3520       RESTORE 3530
 3530       DATA .28,.775,21.872,-12.035,46.227,232.49,0,0,0,76.059,-674.44,2761
.1,-4014.6,1896.5,0,0,366.48,-991.29,947.60,-300.88,0,0,0
 3540       GOSUB Line_type
 3550      CASE 2                                              ! Bare Soil (2)
 3560       RESTORE 3570
 3570       DATA .30,.66,22.184,-13.819,71.725,140.23,0,0,0,77.180,-652.30,2575.
7,-3656.4,1697.0,0,0,289.75,-722.68,647.39,-192.27,0,0,0
 3580       GOSUB Line_type
 3590      CASE 3                                              ! Uncut Grass (3)
 3600       RESTORE 3610
 3610       DATA .28,.79,20.882,-9.1537,58.686,117.63,0,0,0,57.471,-456.85,1892.
5,-2755.1,1298.6,0,0,268.34,-687.09,633.66,-193.98,0,0,0
 3620       GOSUB Line_type
 3630      CASE 4                                              ! Cut Grass (4)
 3640       RESTORE 3650
 3650       DATA .28,.68,21.030,-8.0824,57.020,173.92,0,0,0,66.679,-577.01,2414.
5,-3537.2,1672.6,0,0,518.65,-1502.4,1508.8,-503.65,0,0,0
 3660       GOSUB Line_type
 3670      CASE 5                                              ! Gravel (5)
 3680       RESTORE 3690
 3690       DATA .28,.78,21.544,-20.511,68.564,311.61,0,0,0,80.604,-759.77,3157.
4,-4588.9,2155.5,0,0,497.13,-1361.8,1296.3,-409.97,0,0,0
 3700       GOSUB Line_type
 3710      CASE 6                                              ! M114 ARV (6)
 3720       RESTORE 3730
 3730       DATA .31,.80,22.362,-27.284,94.587,208.41,0,0,0,142.61,-1485.0,6384.
1,-11594,9434.3,-2862.2,0,239.29,-514.96,397.34,-99.303,0,0,0
 3740       GOSUB Line_type
 3750      CASE 7                                              ! M114-Cut Grass (1)
 3760       RESTORE 3770
 3770       DATA .31,.73,2.2619,-11.843,10.990,-87.513,447.32,0,0,38.501,-404.07
,1403.2,-1816.4,787.77,0,0,48.394,-78.777,32.543,0,0,0,0
 3780       GOSUB Line_type
 3790      CASE 8                                              ! M114-Bare Soil (2)
 3800       RESTORE 3810
 3810       DATA .27,.85,1.2921,-12.704,22.949,135.26,0,0,0,5.7443,-111.95,568.6
1,-857.80,398.88,0,0,160.11,-446.83,421.10,-133.01,0,0,0
 3820       GOSUB Line_type
 3830      CASE 9                                              ! M114-Uncut Grass (3)
 3840       RESTORE 3850
 3850       DATA .33,.73,3.0644,-19.221,34.753,101.91,0,0,0,40.730,-435.76,1579.
```

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6,-2111.4,940.20,0,0,55.527,-90.409,37.974,0,0,0,0
  3860       GOSUB Line_type
  3870      CASE 10                                          ! M114-Cut Grass (4)
  3880       RESTORE 3890
  3890       DATA .31,.80,3.3172,-11.753,11.847,-170.45,627.45,0,0,38.454,-388.94
,1318.8,-1662.9,702.63,0,0,-8.7127,111.07,-168.68,69.546,0,0,0
  3900       GOSUB Line_type
  3910      CASE 11                                          ! M114-Gravel (5)
  3920       RESTORE 3930
  3930       DATA .28,.72,2.2353,-4.7596,33.493,-91.043,0,0,0,-91.415,1321.0,-722
2.4,19583,-28161,20652,-6094.1,8664.3,-59444,167250,-247160,202570,-87417,15534
  3940       GOSUB Line_type
  3950     END SELECT
  3960    CASE 8  !--------------------------   Pcwsu   Lower Envelope -------
  3970     SELECT Bkgd
  3980      CASE 1                                           ! Cut Grass (1)
  3990       RESTORE 4000
  4000       DATA .23,.84,15.896,-1.5871,53.425,22.894,0,0,0,-5.1718,146.12,-210.
67,82.276,0,0,0,158.32,-395.63,365.40,-111.88,0,0,0
  4010       GOSUB Line_type
  4020      CASE 2                                           ! Bare Soil (2)
  4030       RESTORE 4040
  4040       DATA .38,.88,18.007,-.95211,-42.567,-89.504,2092.4,-3171.9,0,11.140,
-12.604,301.57,-564.26,282.70,0,0,-966.39,4488.4,-7471.4,5409.9,-1443.1,0,0
  4050       GOSUB Line_type
  4060      CASE 3                                           ! Uncut Grass (3)
  4070       RESTORE 4080
  4080       DATA .23,.68,14.861,-1.9897,63.240,0,0,0,0,-4.5783,133.94,-185.16,66
.871,0,0,0,144.67,-355.22,324.64,-98.746,0,0,0
  4090       GOSUB Line_type
  4100      CASE 4                                           ! Cut Grass (4)
  4110       RESTORE 4120
  4120       DATA .30,.83,15.575,-1.0667,-90.971,231.14,2949.2,-6428.2,0,6.5037,1
9.899,233.82,-528.34,283.18,0,0,223.08,-619.75,616.01,-204.02,0,0,0
  4130       GOSUB Line_type
  4140      CASE 5                                           ! Gravel (5)
  4150       RESTORE 4160
  4160       DATA .39,.775,17.049,-8.7113,-61.729,63.518,2807.6,-5097.6,0,17.148,
-119.40,777.11,-1285.9,634.82,0,0,53.995,-37.407,-23.577,23.737,0,0,0
  4170       GOSUB Line_type
  4180      CASE 6                                           ! M114 ARV (6)
  4190       RESTORE 4200
  4200       DATA .28,.77,17.482,-15.773,51.779,102.49,0,0,0,37.365,-285.69,1213.
1,-1734.0,792.97,0,0,224.09,-565.53,520.42,-161.27,0,0,0
  4210       GOSUB Line_type
  4220      CASE 7                                           ! M114-Cut Grass (1)
  4230       RESTORE 4240
  4240       DATA .32,.82,.11350,-10.138,0,0,0,0,0,140.87,-1950.1,10498,-28674,41
791,-30807,9007.3,-3303.5,17214,-35571,36507,-18632,3785.4,0
  4250       GOSUB Line_type
  4260      CASE 8                                           ! M114-Bare Soil (2)
  4270       RESTORE 4280
  4280       DATA .42,.84,-1.0204,-4.6139,9.3450,-46.311,0,0,0,129.41,-1947.5,113
10,-32819,49929,-37922,11329,-611.59,2552.2,-3938.2,2668.0,-671.54,0,0
  4290       GOSUB Line_type
  4300      CASE 9                                           ! M114-Uncut Grass (3)
  4310       RESTORE 4320
```

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  4320       DATA .35,.75,.80745,-11.665,4.5559,55.286,0,0,0,15.912,-169.59,552.9
1,-668.45,271.38,0,0,-14.294,79.562,-103.50,38.985,0,0,0
  4330       GOSUB Line_type
  4340      CASE 10                                          ! M114-Cut Grass (4)
  4350       RESTORE 4360
  4360       DATA .40,.725,.65590,-11.656,0,0,0,0,0,174.09,-2506.5,14187,-40801,6
2504,-48322,14791,-348.35,1442.3,-2164.5,1408.9,-338.00,0,0
  4370       GOSUB Line_type
  4380      CASE 11                                          ! M114-Gravel (5)
  4390       RESTORE 4400
  4400       DATA .35,.66,-.51933,-2.5327,84.211,-154.16,-2088.0,3913.0,0,-47.189
,559.44,-2226.5,3236.7,-1543.3,0,0,-1062.6,4257.3,-6337.9,4159.8,-1016.9,0,0
  4410       GOSUB Line_type
  4420     END SELECT
  4430    CASE 9  !--------------------------    Odsu    ------------------------
  4440     SELECT Bkgd
  4450      CASE 1                                           ! Cut Grass (1)
  4460       RESTORE 4470
  4470       DATA .35,.83,20.245,-23.844,60.658,122.11,0,0,0,20.055,-90.209,569.9
6,-954.14,479.53,0,0,364.05,-1101.1,1172.5,-416.16,0,0,0
  4480       GOSUB Line_type
  4490      CASE 2                                           ! Bare Soil (2)
  4500       RESTORE 4510
  4510       DATA .25,.80,20.870,-17.643,15.106,180.69,0,0,0,37.242,-240.47,1014.
3,-1475.9,693.04,0,0,279.22,-796.38,820.07,-282.56,0,0,0
  4520       GOSUB Line_type
  4530      CASE 3                                           ! Uncut Grass (3)
  4540       RESTORE 4550
  4550       DATA .27,.80,20.022,-29.172,106.92,0,0,0,0,19.000,-65.480,423.00,-70
4.54,350.07,0,0,96.297,-167.76,90.534,0,0,0,0
  4560       GOSUB Line_type
  4570      CASE 4                                           ! Cut Grass (4)
  4580       RESTORE 4590
  4590       DATA .35,.83,20.347,-35.161,131.44,0,0,0,0,18.103,-70.789,496.74,-85
1.55,431.35,0,0,345.44,-1041.8,1107.3,-392.12,0,0,0
  4600       GOSUB Line_type
  4610      CASE 5                                           ! Gravel (5)
  4620       RESTORE 4630
  4630       DATA .36,.78,20.359,-15.774,-22.966,323.26,0,0,0,38.364,-289.69,1288
.3,-1920.5,914.55,0,0,394.45,-1161.4,1206.2,-419.42,0,0,0
  4640       GOSUB Line_type
  4650      CASE 6                                           ! M114 ARV (6)
  4660       RESTORE 4670
  4670       DATA .36,.85,21.030,-17.385,-21.229,276.30,0,0,0,37.119,-243.83,1010
.5,-1418.4,638.15,0,0,323.79,-906.59,911.46,-308.90,0,0,0
  4680       GOSUB Line_type
  4690      CASE 7                                           ! M114-Cut Grass (1)
  4700       RESTORE 4710
  4710       DATA .34,.87,1.3381,-8.5877,10.173,0,0,0,0,17.064,-153.62,440.51,-46
4.21,158.62,0,0,24.167,-36.002,12.172,0,0,0,0
  4720       GOSUB Line_type
  4730      CASE 8                                           ! M114-Bare Soil (2)
  4740       RESTORE 4750
  4750       DATA .28,.84,.15969,.25806,-36.335,95.606,0,0,0,51.287,-733.48,4086.
4,-11529,17509,-13568,4193.3,28.746,-53.629,24.324,0,0,0,0
  4760       GOSUB Line_type
  4770      CASE 9                                           ! M114-Uncut Grass (3)
```

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  4780       RESTORE 4790
  4790       DATA .31,.87,1.2234,5.9242,-92.283,216.22,0,0,0,18.119,-178.35,587.4
7,-713.82,288.07,0,0,41.925,-75.020,34.228,0,0,0,0
  4800       GOSUB Line_type
  4810      CASE 10                                          ! M114-Cut Grass (4)
  4820       RESTORE 4830
  4830       DATA .315,.87,.91093,11.574,-114.72,212.75,0,0,0,19.016,-173.04,513.
73,-566.80,206.80,0,0,28.341,-43.658,16.090,0,0,0,0
  4840       GOSUB Line_type
  4850      CASE 11                                          ! M114-Gravel (5)
  4860       RESTORE 4870
  4870       DATA .31,.85,.50280,2.9725,-26.706,0,0,0,0,-30.958,391.55,-1780.4,35
62.9,-3219.7,1077.5,0,-4.2672,17.347,-13.245,0,0,0,0
  4880       GOSUB Line_type
  4890     END SELECT
  4900    CASE 10  !--------------------------   Owsu    ----------------------
  4910     SELECT Bkgd
  4920      CASE 1                                          ! Cut Grass (1)
  4930       RESTORE 4940
  4940       DATA .29,.76,21.640,15.753,-134.46,351.04,0,0,0,56.261,-391.82,1484.
8,-2089.0,974.70,0,0,460.98,-1438.2,1571.0,-572.23,0,0,0
  4950       GOSUB Line_type
  4960      CASE 2                                          ! Bare Soil (2)
  4970       RESTORE 4980
  4980       DATA .34,.78,22.071,15.233,-127.45,307.57,0,0,0,54.883,-353.73,1284.
8,-1757.5,804.00,0,0,295.17,-872.70,934.36,-334.59,0,0,0
  4990       GOSUB Line_type
  5000      CASE 3                                          ! Uncut Grass (3)
  5010       RESTORE 5020
  5020       DATA .33,.81,20.995,11.515,-94.673,252.66,0,0,0,46.873,-293.08,1109.
6,-1551.0,716.98,0,0,392.05,-1205.0,1305.5,-471.64,0,0,0
  5030       GOSUB Line_type
  5040      CASE 4                                          ! Cut Grass (4)
  5050       RESTORE 5060
  5060       DATA .30,.78,21.216,14.419,-114.54,310.40,0,0,0,54.740,-377.50,1432.
5,-2013.6,937.34,0,0,496.58,-1558.5,1704.5,-621.35,0,0,0
  5070       GOSUB Line_type
  5080      CASE 5                                          ! Gravel (5)
  5090       RESTORE 5100
  5100       DATA .35,.80,20.980,29.689,-238.55,551.31,0,0,0,83.270,-654.09,2326.
5,-3140.9,1424.0,0,0,551.46,-1715.5,1859.4,-673.73,0,0,0
  5110       GOSUB Line_type
  5120      CASE 6                                          ! M114 ARV (6)
  5130       RESTORE 5140
  5140       DATA .29,.83,22.286,-6.2621,95.836,-625.93,1346.0,0,0,63.018,-445.46
,1588.4,-2099.3,921.90,0,0,279.28,-737.71,708.05,-227.44,0,0,0
  5150       GOSUB Line_type
  5160      CASE 7                                          ! M114-Cut Grass (1)
  5170       RESTORE 5180
  5180       DATA .27,.87,.46750,-7.0092,13.455,0,0,0,0,-21.440,268.90,-1277.9,27
72.1,-2705.5,964.64,0,-181.70,700.47,-862.91,344.78,0,0,0
  5190       GOSUB Line_type
  5200      CASE 8                                          ! M114-Bare Soil (2)
  5210       RESTORE 5220
  5220       DATA .27,.81,-.40742,5.6016,-65.982,161.50,0,0,0,-11.996,138.55,-682
.66,1644.7,-1776.0,688.71,0,-15.886,134.99,-226.31,107.14,0,0,0
  5230       GOSUB Line_type
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  5240      CASE 9                                          ! M114-Uncut Grass (3)
  5250       RESTORE 5260
  5260       DATA .30,.81,.66867,9.3194,-98.756,216.41,0,0,0,16.146,-152.38,478.7
5,-548.31,204.92,0,0,-112.77,467.30,-597.44,244.20,0,0,0
  5270       GOSUB Line_type
  5280      CASE 10                                         ! M114-Cut Grass (4)
  5290       RESTORE 5300
  5300       DATA .28,.68,.44759,6.4158,-78.887,158.66,0,0,0,9.2030,-76.359,182.1
9,-119.68,0,0,0,-217.30,820.80,-996.46,393.90,0,0,0
  5310       GOSUB Line_type
  5320      CASE 11                                         ! M114-Gravel (5)
  5330       RESTORE 5340
  5340       DATA .40,.74,.68337,-8.8550,45.116,-82.247,0,0,0,62.997,-971.47,5863
.0,-17630,27757,-21794,6722.9,-272.18,977.80,-1151.3,446.29,0,0,0
  5350       GOSUB Line_type
  5360     END SELECT
  5370    CASE 11  !-------------------------    Orau   ------------------------
  5380     SELECT Bkgd
  5390      CASE 1                                          ! Cut Grass (1)
  5400       RESTORE 5410
  5410       DATA .35,.725,21.615,-4.7186,3.6909,68.353,0,0,0,36.417,-168.58,622.
75,-838.21,369.59,0,0,234.83,-642.44,634.02,-204.71,0,0,0
  5420       GOSUB Line_type
  5430      CASE 2                                          ! Bare Soil (2)
  5440       RESTORE 5450
  5450       DATA .36,.87,22.424,-2.6949,-18.421,97.508,0,0,0,40.102,-190.18,663.
22,-864.36,374.03,0,0,98.600,-170.34,94.368,0,0,0,0
  5460       GOSUB Line_type
  5470      CASE 3                                          ! Uncut Grass (3)
  5480       RESTORE 5490
  5490       DATA .35,.85,20.942,-4.2214,6.1227,53.291,0,0,0,31.379,-121.23,453.8
8,-608.32,264.21,0,0,100.64,-178.16,98.647,0,0,0,0
  5500       GOSUB Line_type
  5510      CASE 4                                          ! Cut Grass (4)
  5520       RESTORE 5530
  5530       DATA .38,.86,21.527,-11.140,45.696,0,0,0,0,33.721,-146.65,558.23,-76
1.42,336.86,0,0,118.79,-219.88,122.62,0,0,0,0
  5540       GOSUB Line_type
  5550      CASE 5                                          ! Gravel (5)
  5560       RESTORE 5570
  5570       DATA .35,.85,21.968,-2.8287,-23.937,120.08,0,0,0,43.955,-232.41,796.
43,-1015.7,428.70,0,0,282.18,-800.10,814.19,-274.63,0,0,0
  5580       GOSUB Line_type
  5590      CASE 6                                          ! M114 ARV (6)
  5600       RESTORE 5610
  5610       DATA .38,.86,21.685,-5.6181,-13.012,107.87,0,0,0,40.566,-199.75,664.
08,-792.38,303.90,0,0,249.82,-667.50,648.28,-209.21,0,0,0
  5620       GOSUB Line_type
  5630      CASE 7                                          ! M114-Cut Grass (1)
  5640       RESTORE 5650
  5650       DATA .38,.72,.19771,-4.6716,6.9209,0,0,0,0,4.0487,-30.192,37.997,50.
481,-67.942,0,0,12.265,-15.353,2.7829,0,0,0,0
  5660       GOSUB Line_type
  5670      CASE 8                                          ! M114-Bare Soil (2)
  5680       RESTORE 5690
  5690       DATA .36,.87,-.70579,-3.9127,11.605,0,0,0,0,-28.327,320.72,-1416.0,2
927.5,-2793.8,990.99,0,24.792,-45.804,20.065,0,0,0,0
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  5700       GOSUB Line_type
  5710      CASE 9                                                ! M114-Uncut Grass (3)
  5720       RESTORE 5730
  5730       DATA .31,.84,.74323,-1.3967,-19.135,54.583,0,0,0,-17.571,228.19,-110
4.2,2461.8,-2480.8,915.83,0,22.751,-37.979,15.785,0,0,0,0
  5740       GOSUB Line_type
  5750      CASE 10                                               ! M114-Cut Grass (4)
  5760       RESTORE 5770
  5770       DATA .48,.85,.34318,.02947,-24.309,50.328,0,0,0,-14.312,189.38,-933.
07,2059.8,-2024.1,723.25,0,4.6056,3.7354,-8.1897,0,0,0,0
  5780       GOSUB Line_type
  5790      CASE 11                                               ! M114-Gravel (5)
  5800       RESTORE 5810
  5810       DATA .40,.86,-.32187,-1.6241,3.6268,0,0,0,0,-9.4563,102.37,-432.00,8
28.67,-703.64,211.16,0,7.1758,-8.5524,1.0369,0,0,0,0
  5820       GOSUB Line_type
  5830     END SELECT
  5840   END SELECT
```

# APPENDIX C.

**Diurnal Curves and Data Points for All**

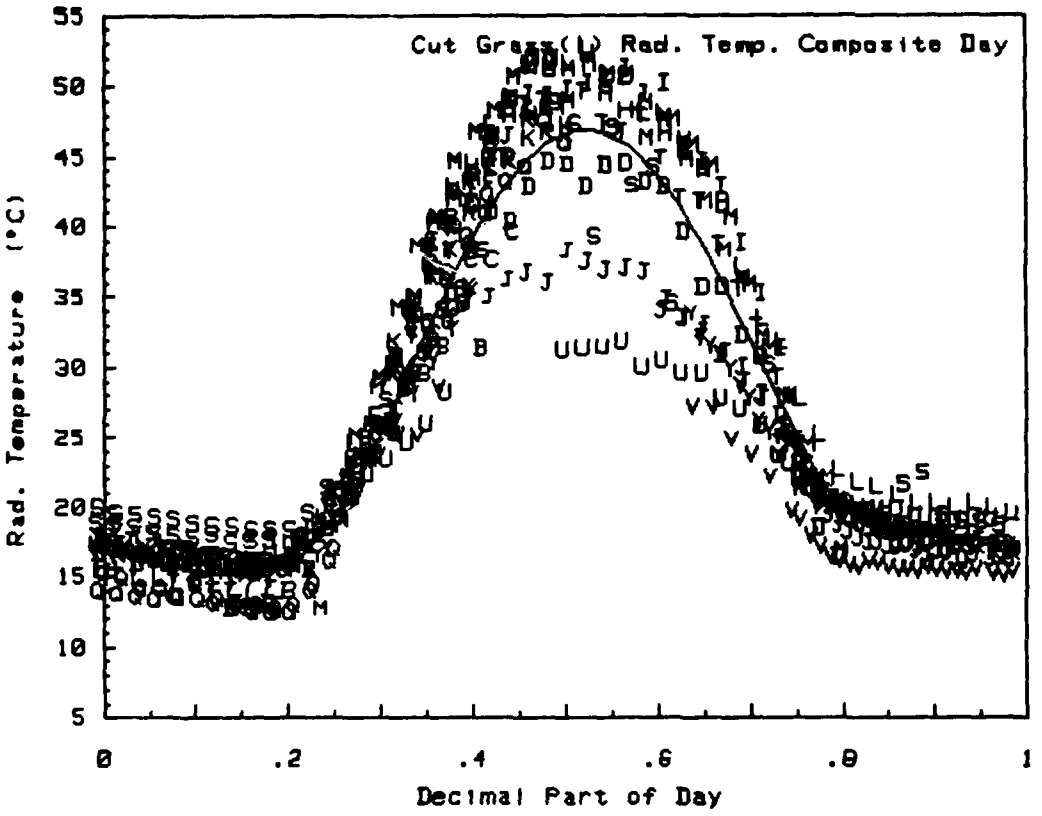
**Backgrounds, the Target, and Thermal Contrasts**

**For All Seven Type-Days, for the Summer Season**

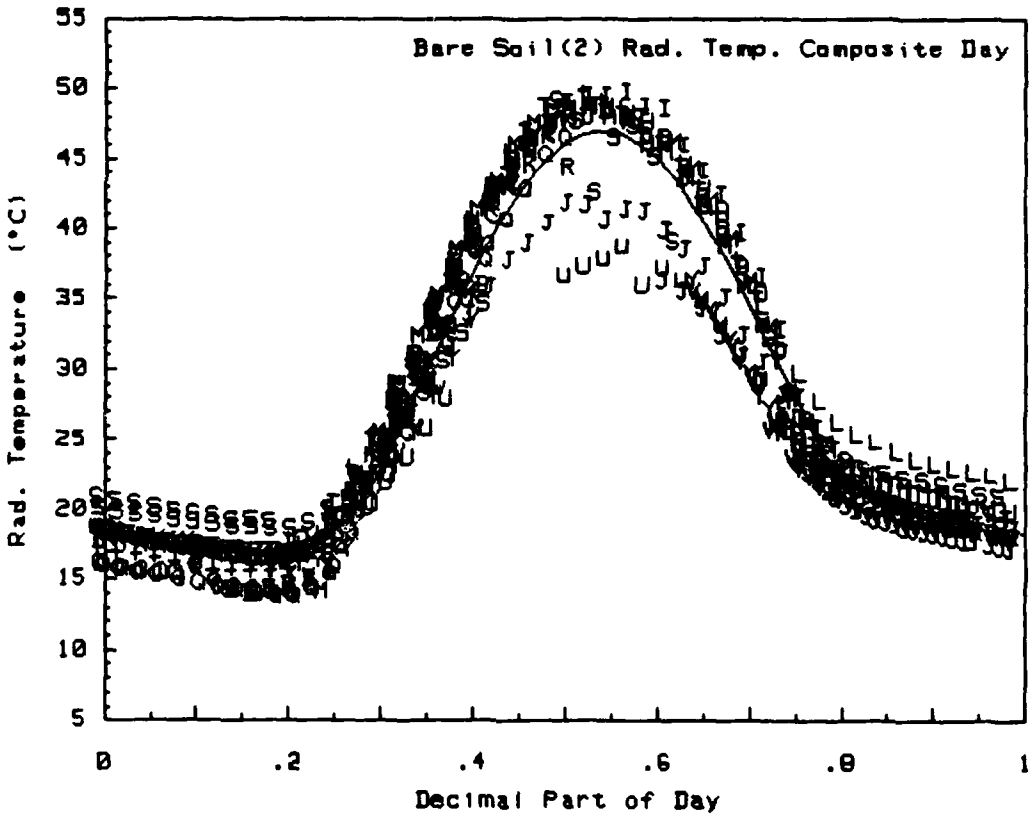
## CLEAR SKY: SUMMER: DRY SURFACE SOIL

**Diurnal Plots of All Backgrounds and Differences**

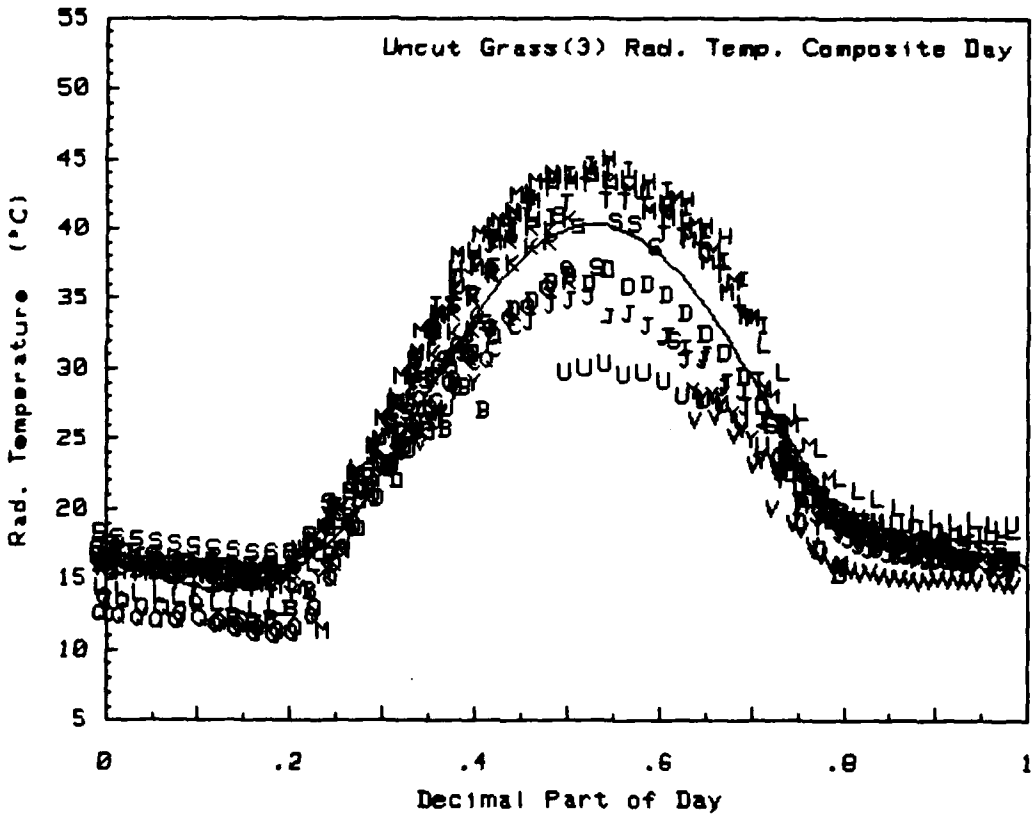
**with Regression Curves**



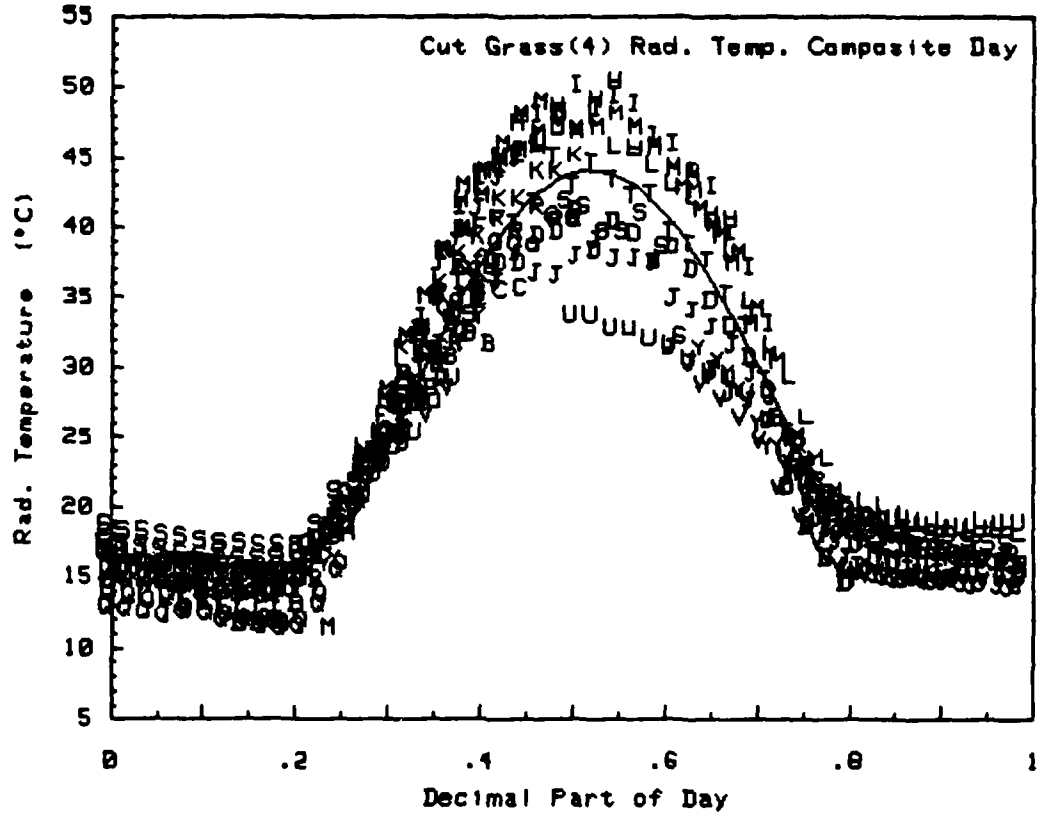

Plot 1 Cut Grass
Summer Clear Dry
1984-5 Composite
Records 1
Records 1-712
1/13/87



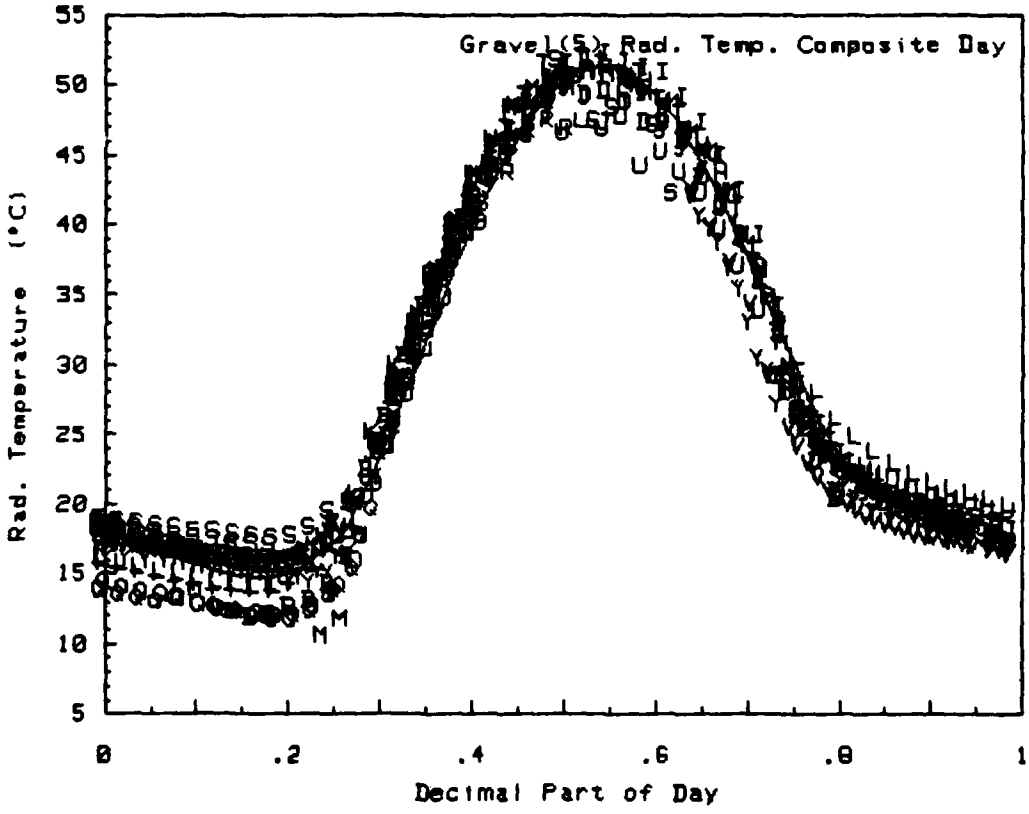

Summer Clear Dry
1984-5 Composite
Records 1-712
1/15/87



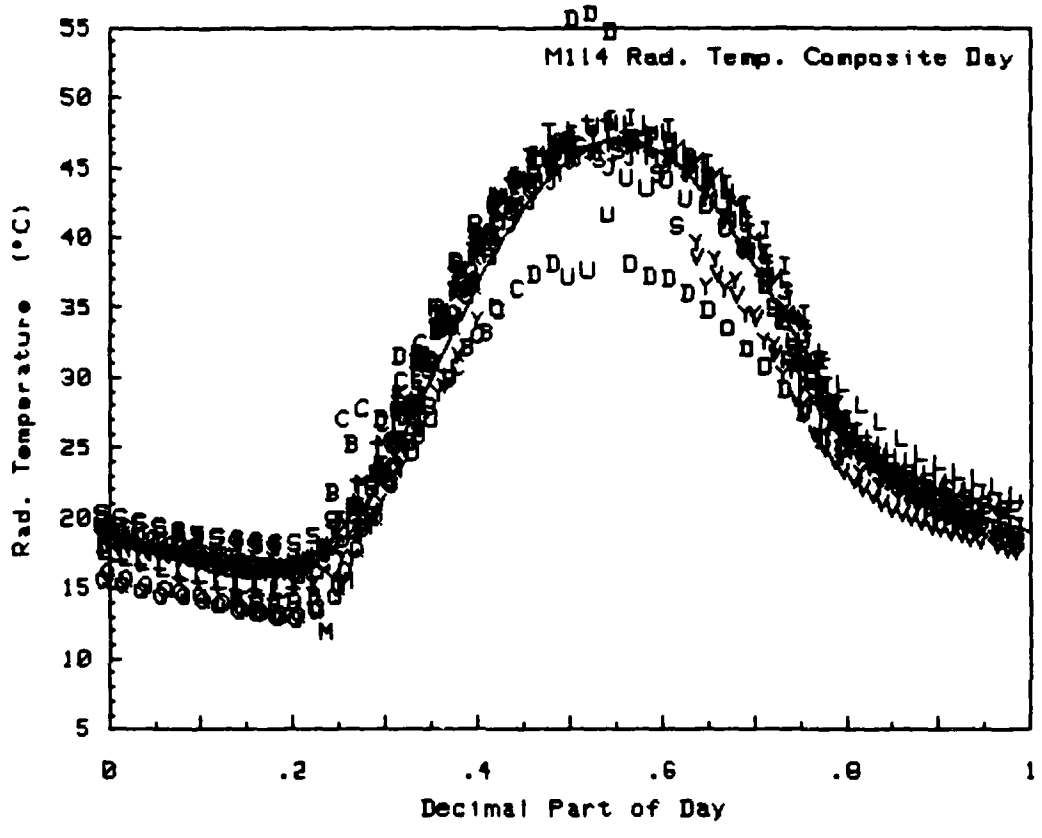

Plot 3 Uncut Grass
Summer Claer Dry
1984-5 Composite
Records 1-712
1/13/87



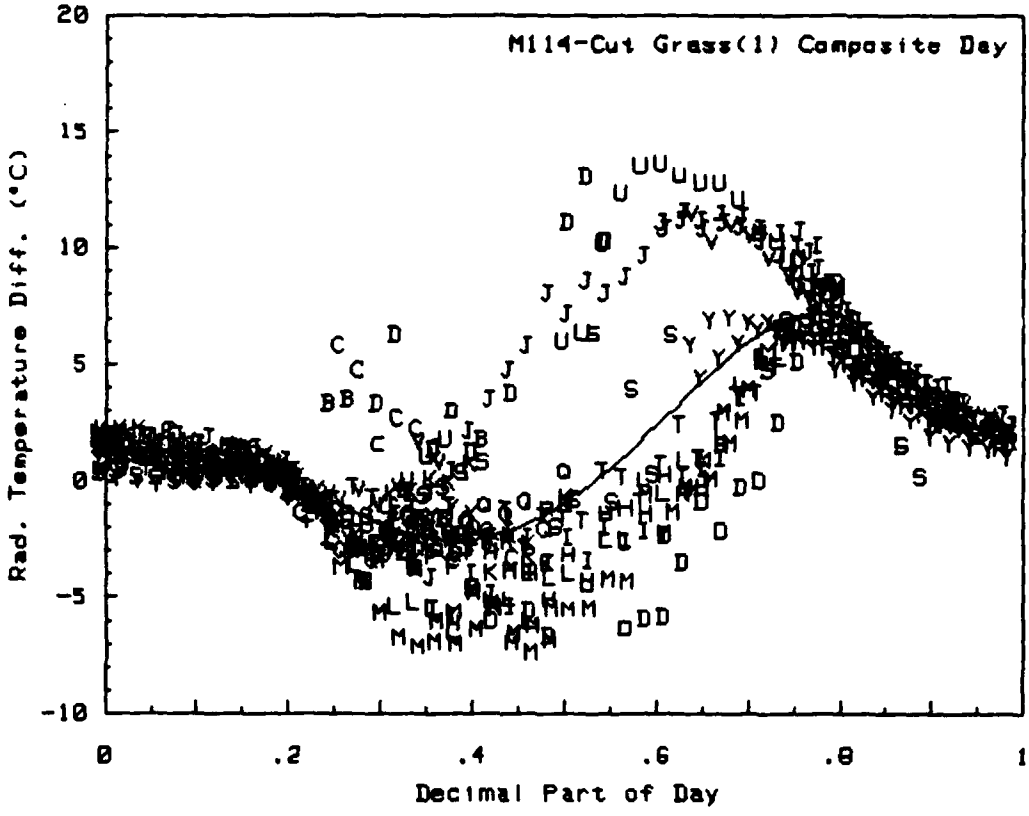

Plot 4 Cut Grass
Summer Clear Dry
1984-5 Composite
Records 1-712
1/13/87



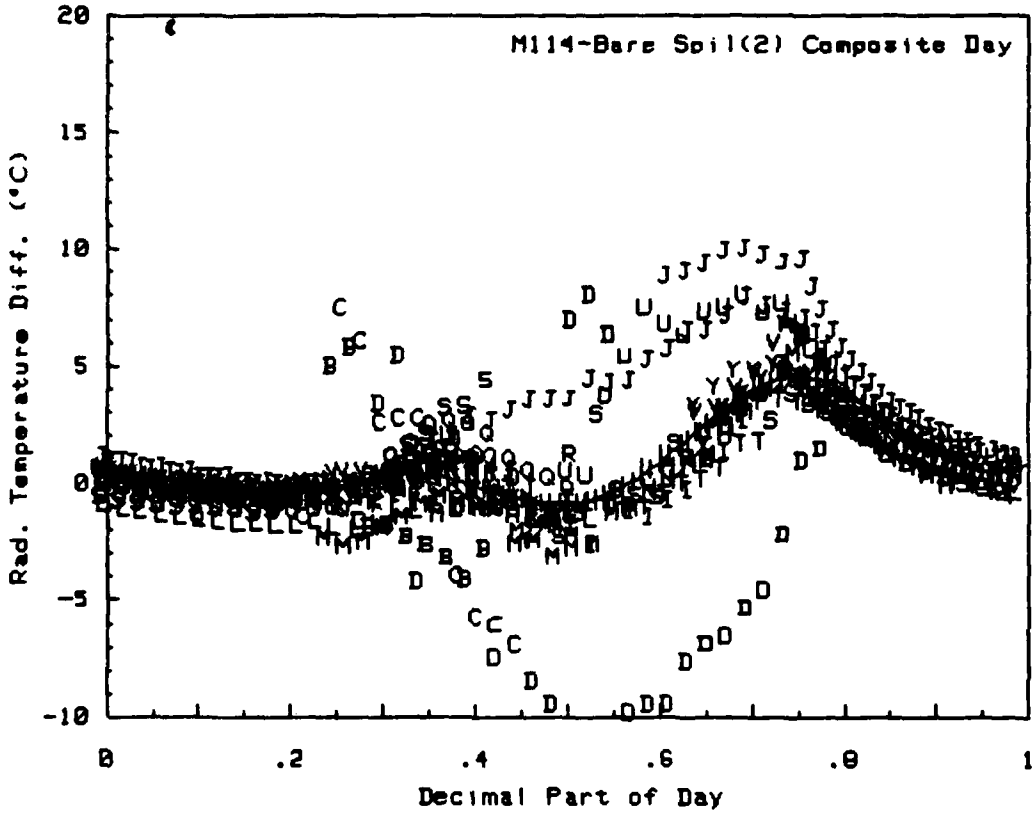

Summer Clear Dry
1984-5 Composite
Records 1-712
1/15/87



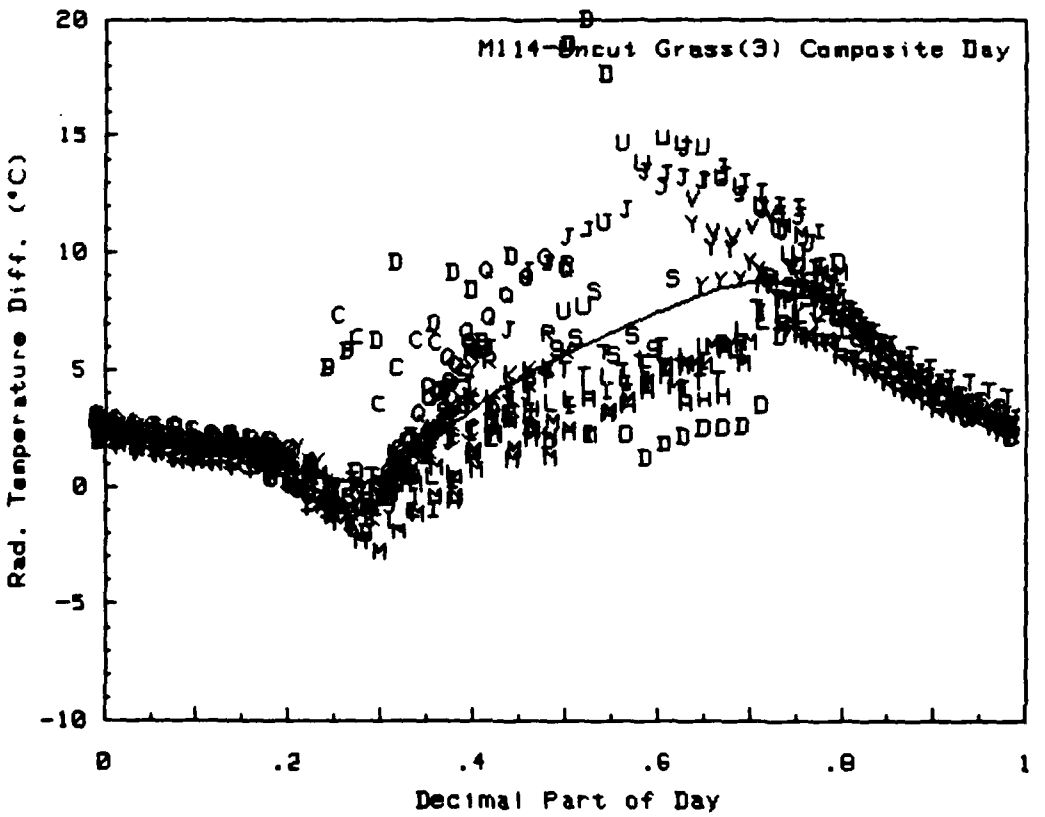

M114 ARV
Summer Clear Dry
1984-5 Composite
Records 1-712
1/13/87



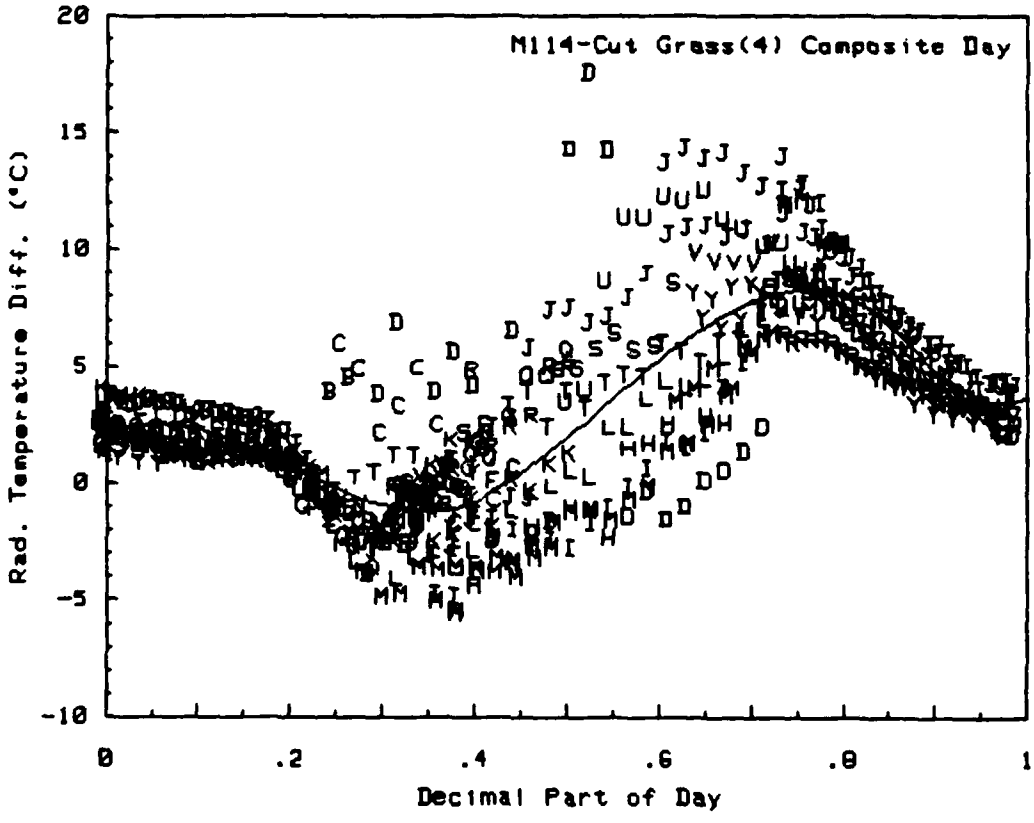

M114-Cut Grass(1)
Summer Clear Dry
1984-5 Composite
Records 1-712
1/13/87



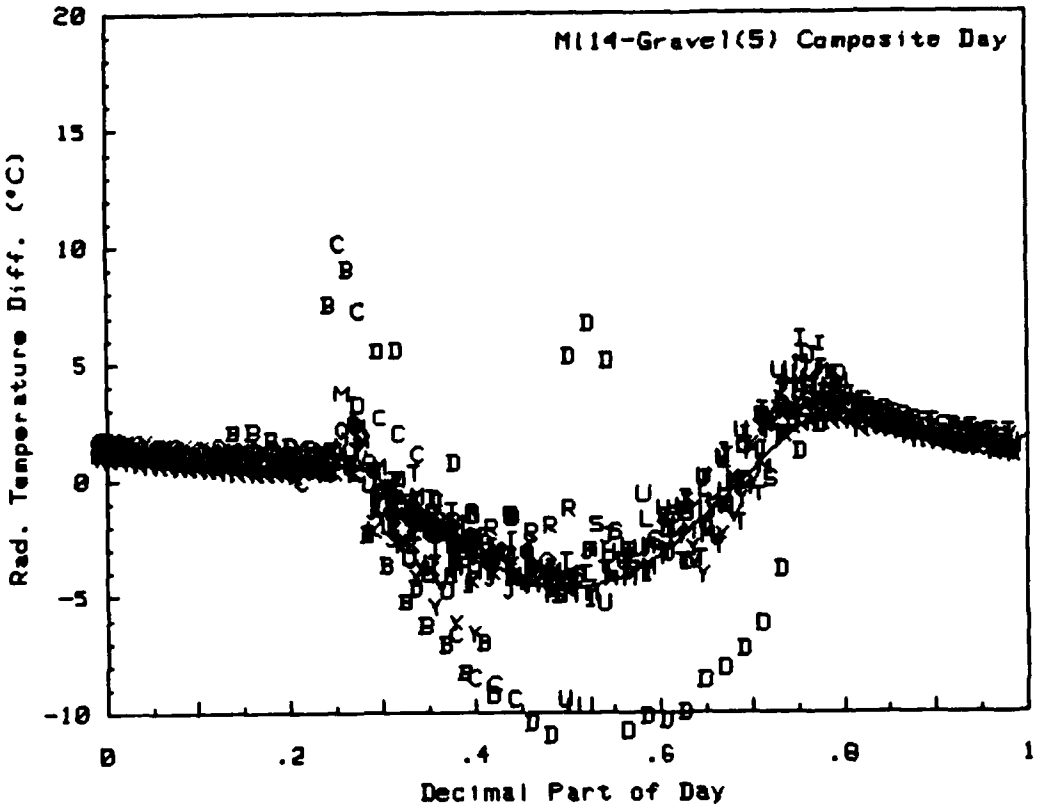

M114- Bare Soil(2)
Summer Clear Dry
1984-5 Composite
Records 1-712
1/13/87




Summer Clear Dry
1984-5 Composite
Records 1-712
1/15/87




M114- Cut Grass(4)
Summer Clear Dry
1984-5 Composite
Records 1-712
1/13/87

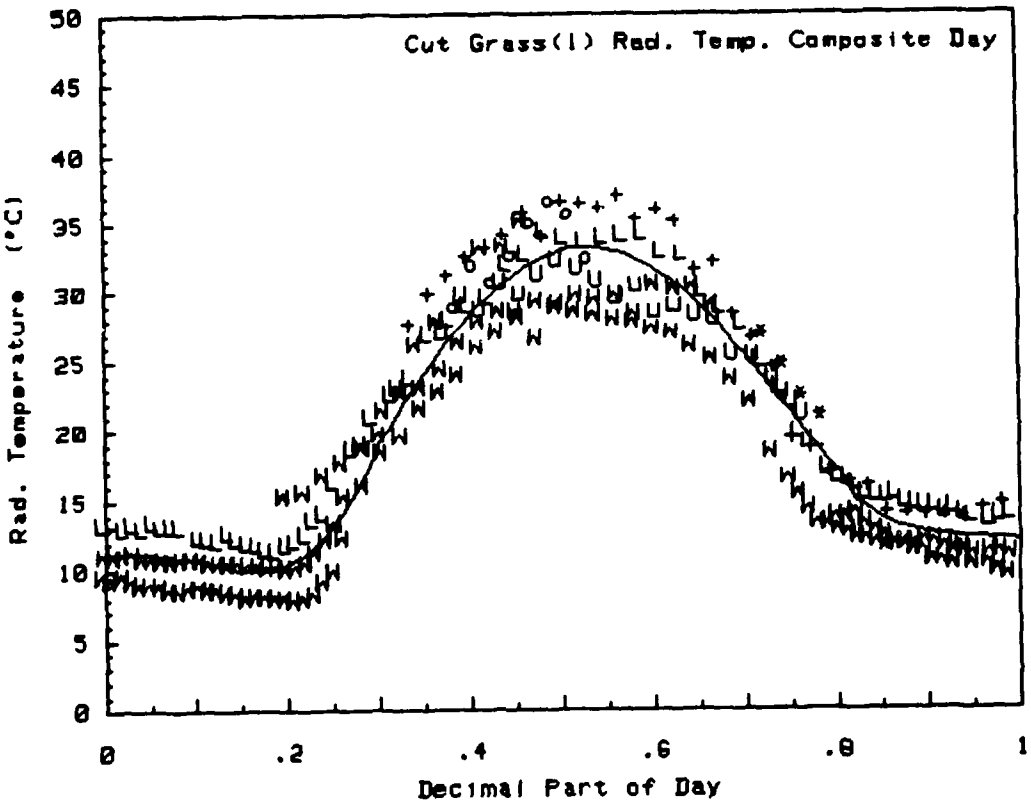



Summer Clear Dry
1984-5 Composite
Records 1-712
1/15/87

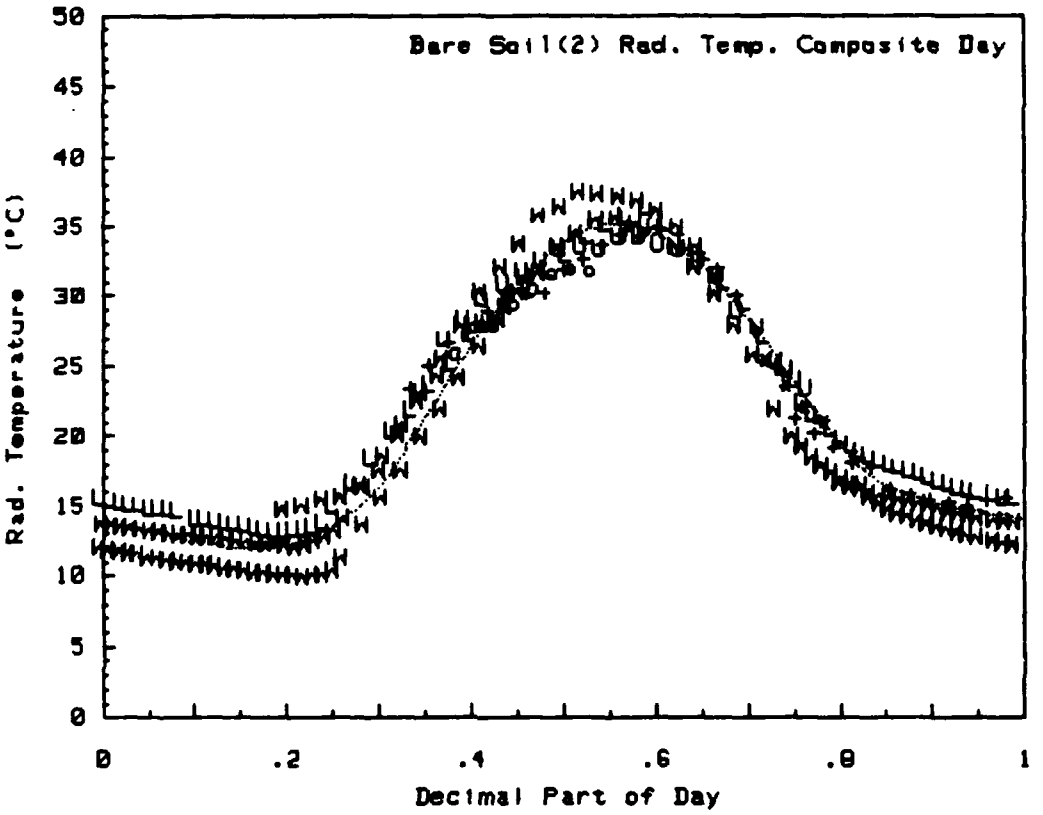
## CLEAR SKY: SUMMER: WET SURFACE SOIL

**Diurnal Plots of All Backgrounds and Differences**

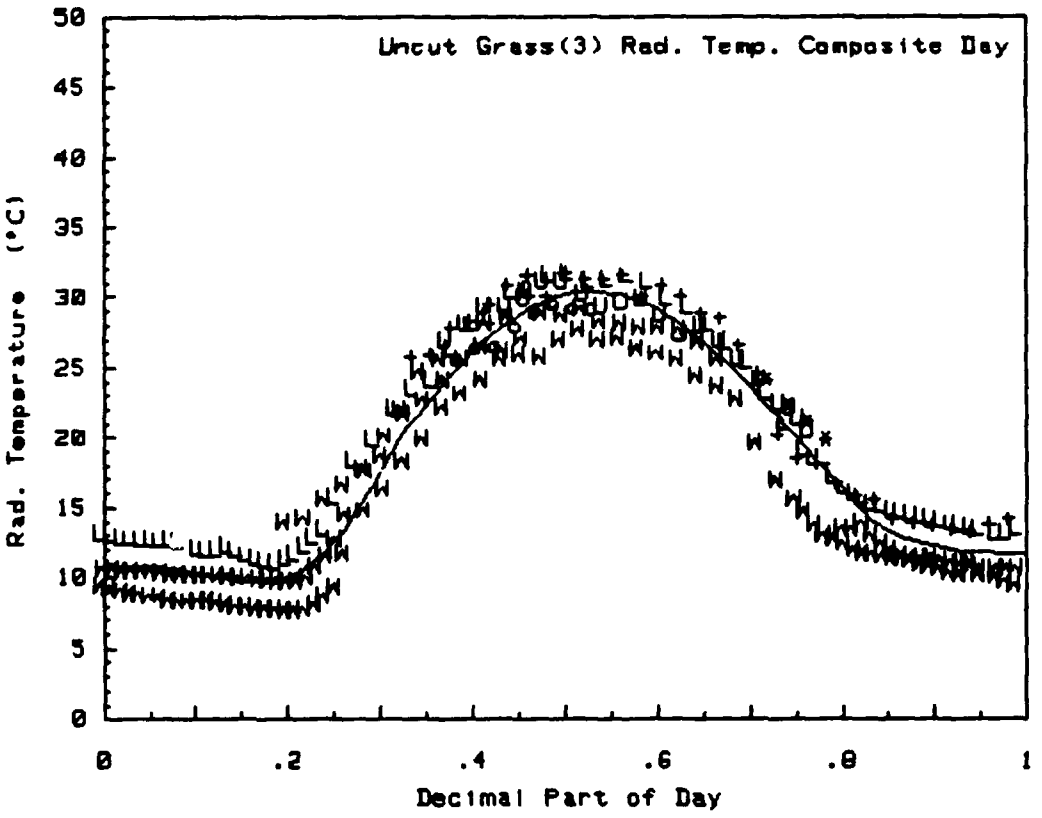
**with Regression Curves**



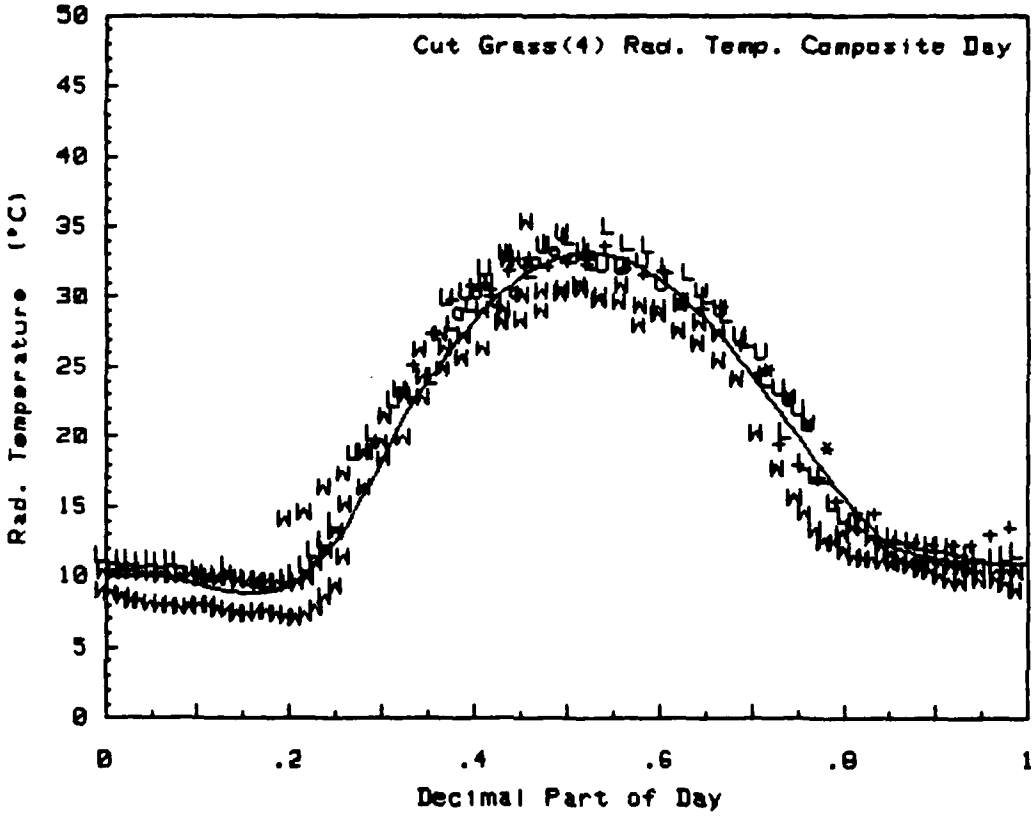

Plot 1 Cut Grass
Summer Clear Wet
1984-5 Composite
Records 1-282
1/13/87



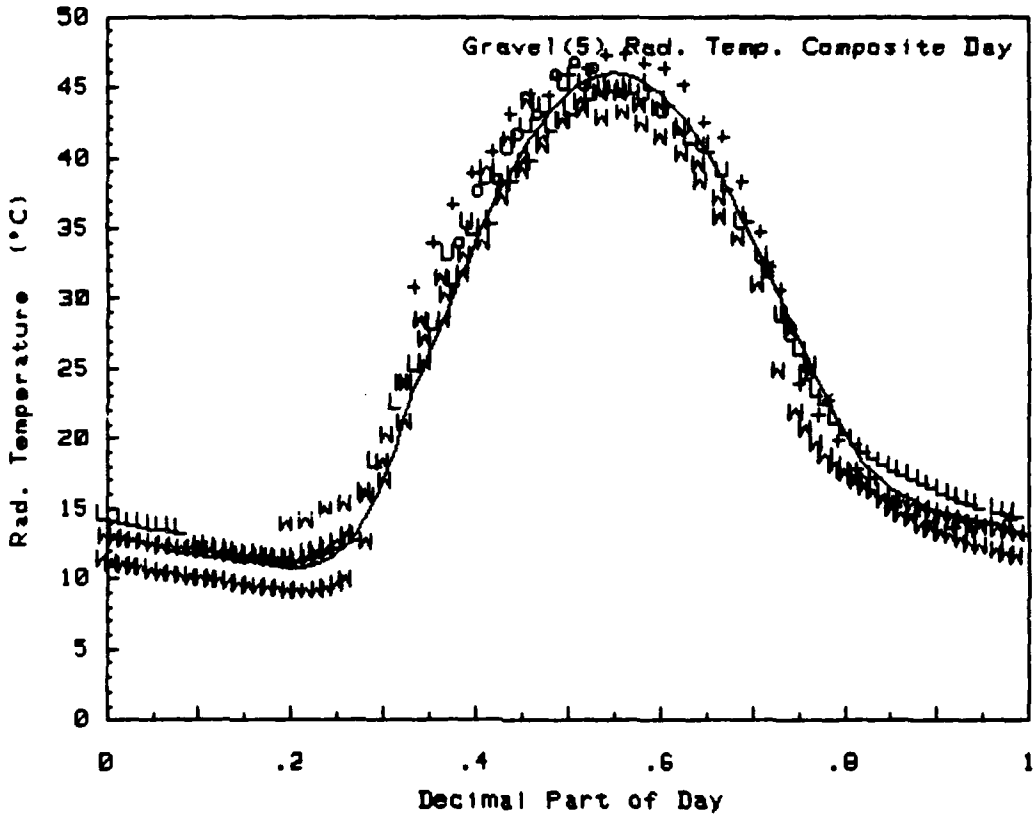

Plot 2 Bare Soil
Summer Clear Wet
1984-5 Composite
Records 1-282
1/13/87



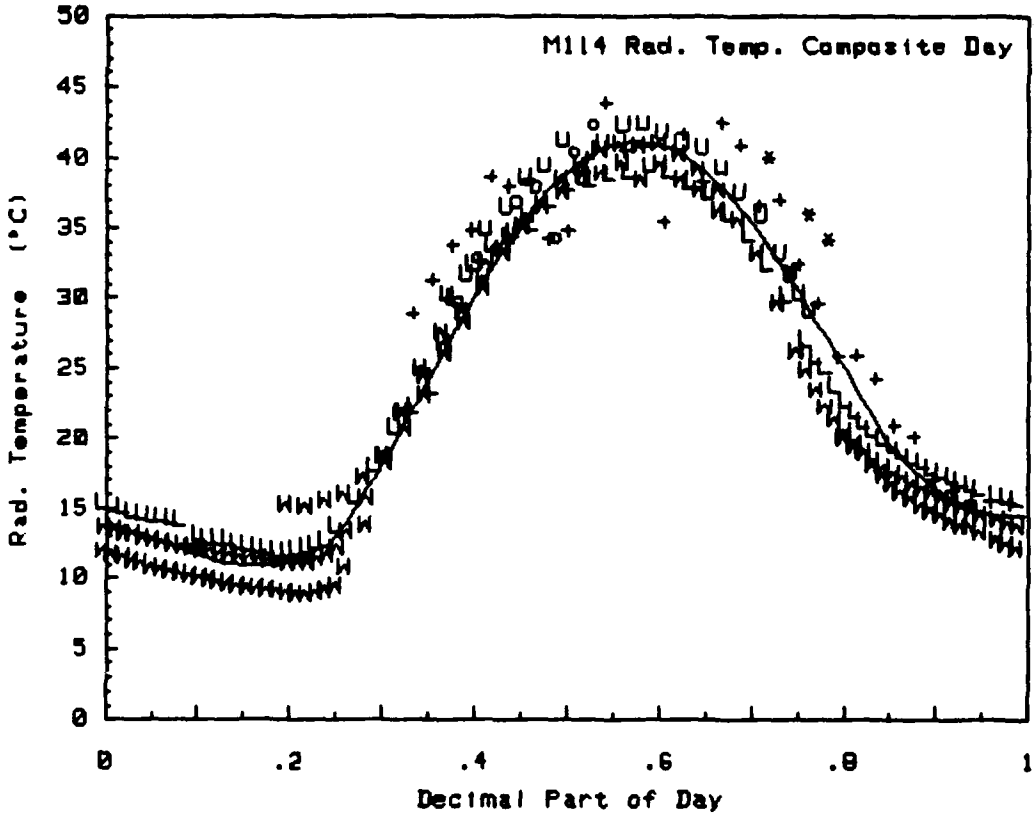

Plot 3 Uncut Grass
Summer Clear Wet
1984-5 Composite
Records 1-282
1/13/87



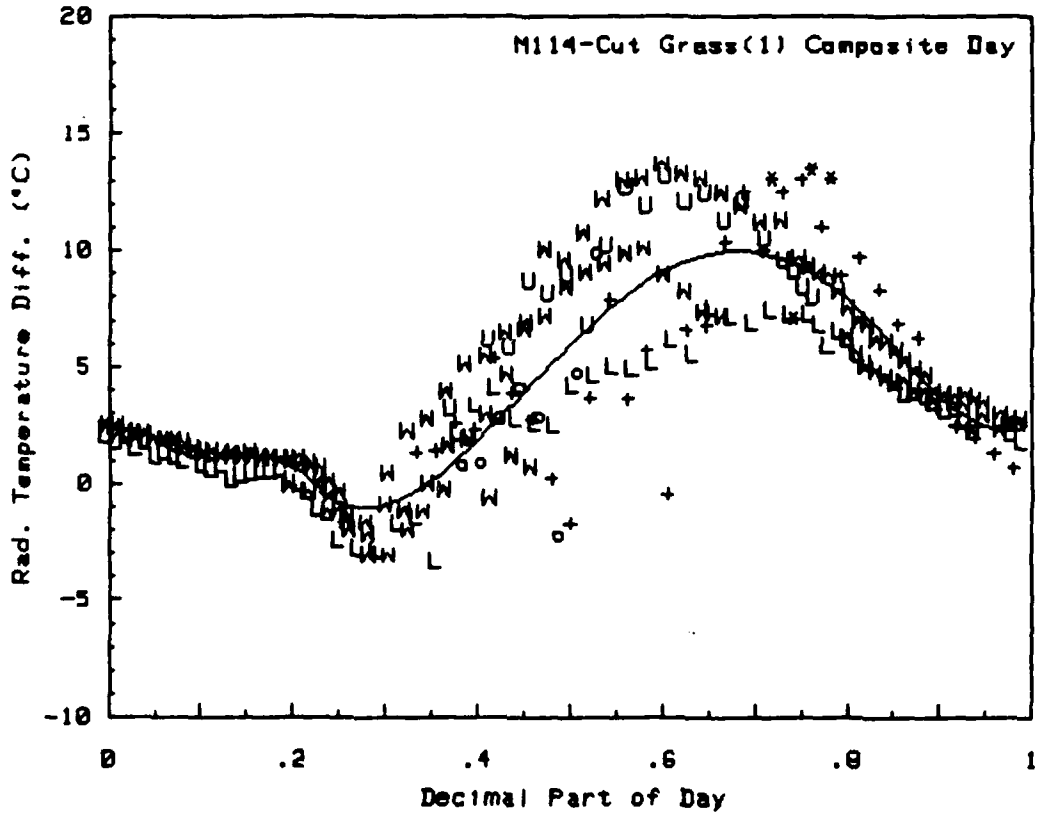

Plot 4 Cut Grass
Summer Clear Wet
1984-5 Composite
Records 1-282
1/13/87



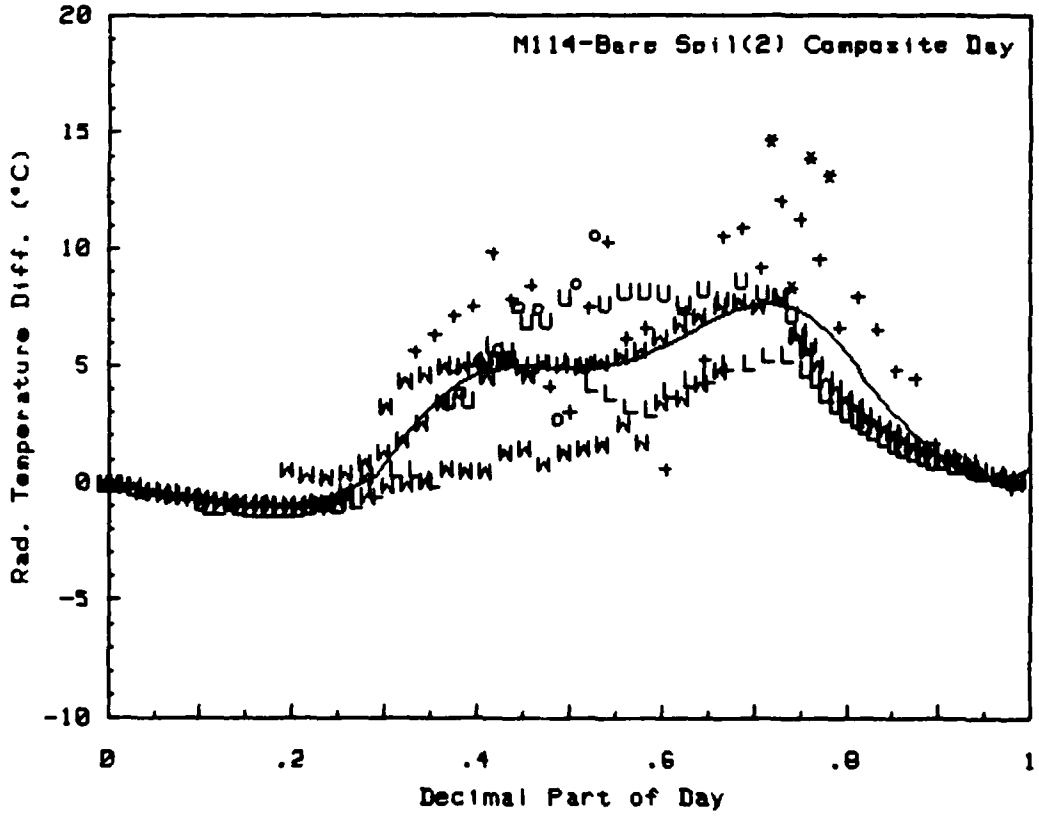

Plot 5 Gravel
Summer Clear Wet
1984-5 Composite
Records 1-282
1/13/87



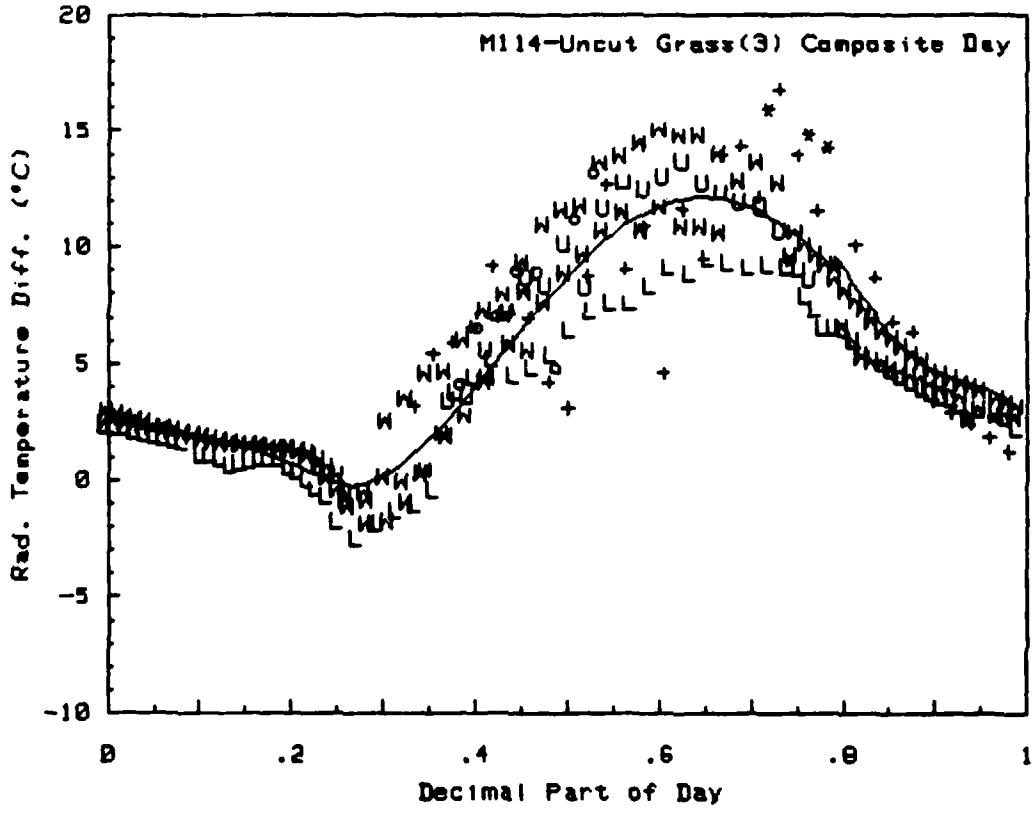

M114 ARV
Summer Clear Wet
1984-5 Composite
Records 1-282
1/13/87



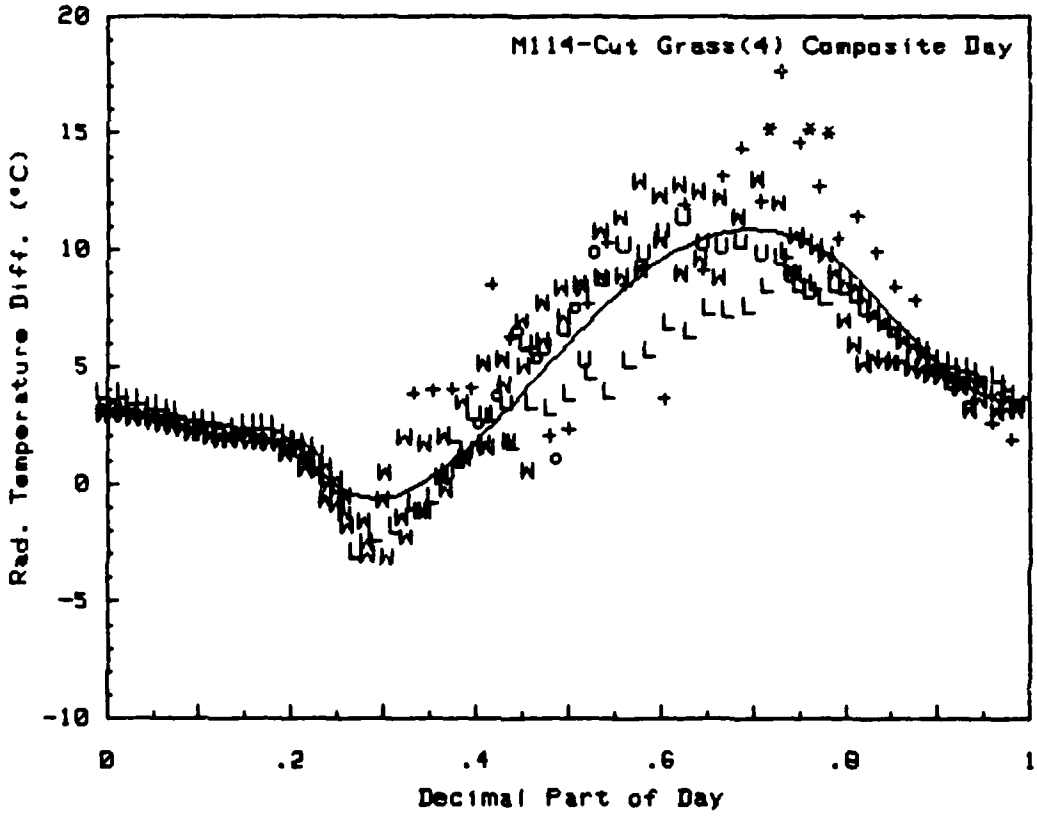

Summer Clear Wet
1984-5 Composite
Records 1-282
1/14/87



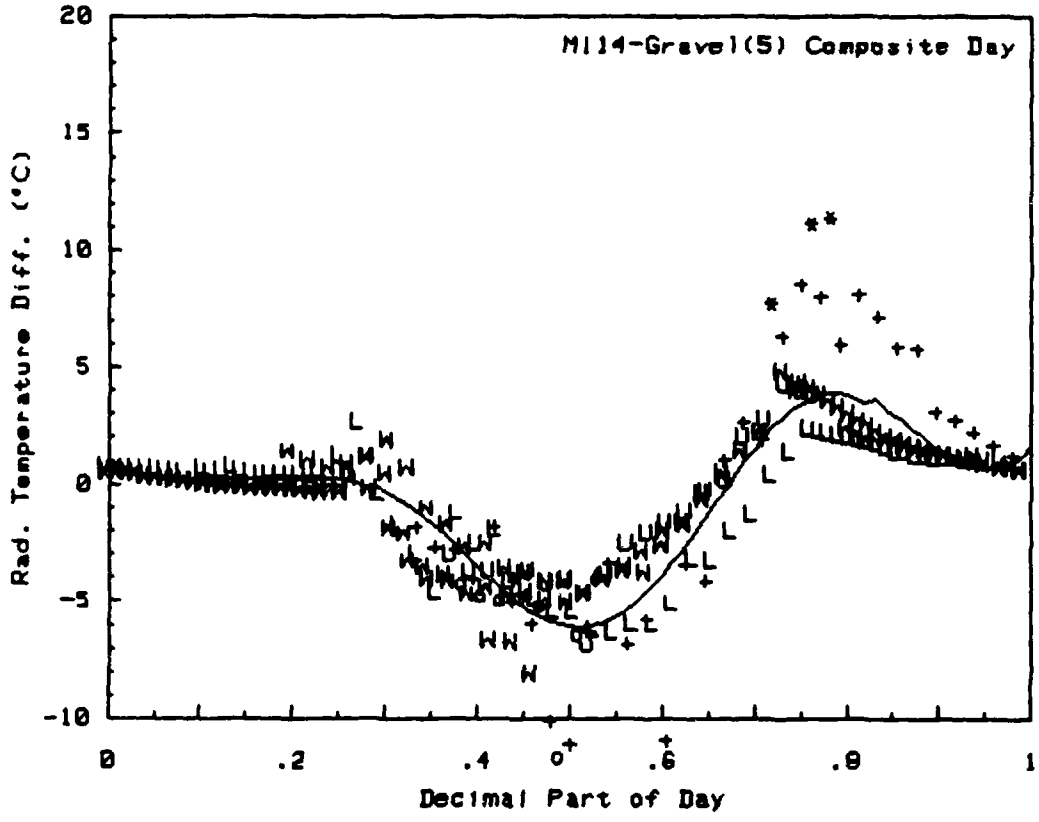

Summer Clear Wet
1984-5 Composite
Records 1-282
1/14/87




Summer Clear Wet
1984-5 Composite
Records 1-282
1/14/87




Summer Clear Wet
1984-5 Composite
Records 1-282
1/14/87

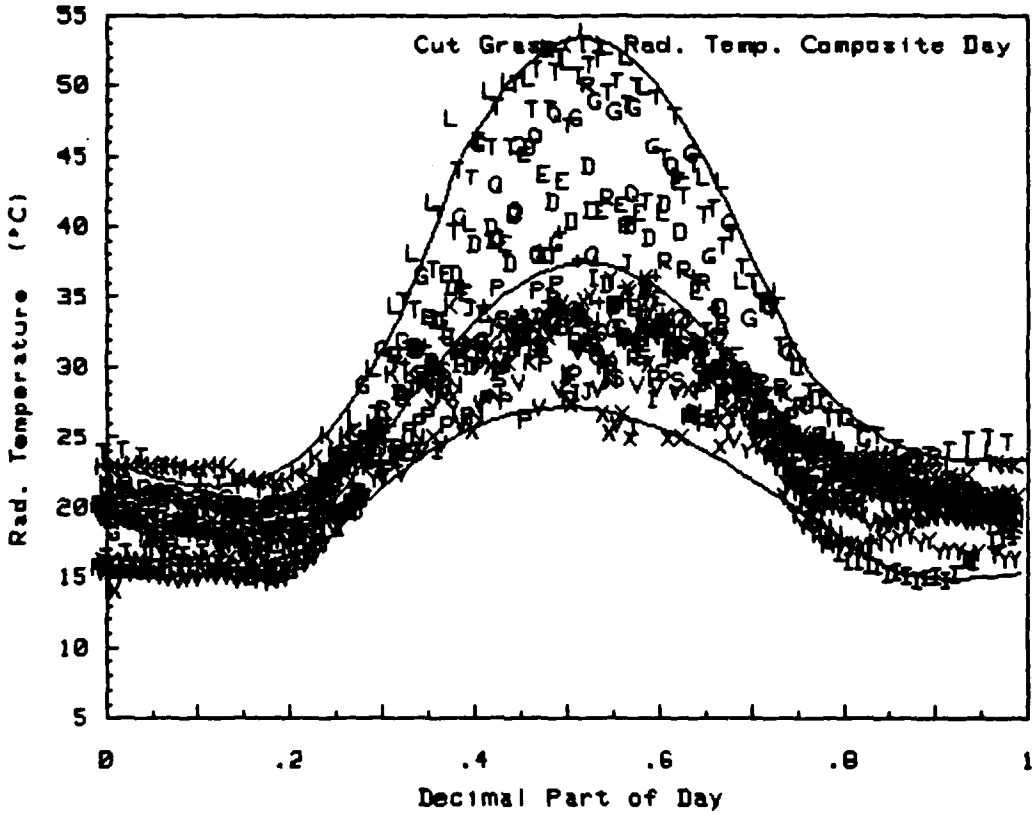



Summer Clear Wet
1984-5 Composite
Records 1-282
1/14/87

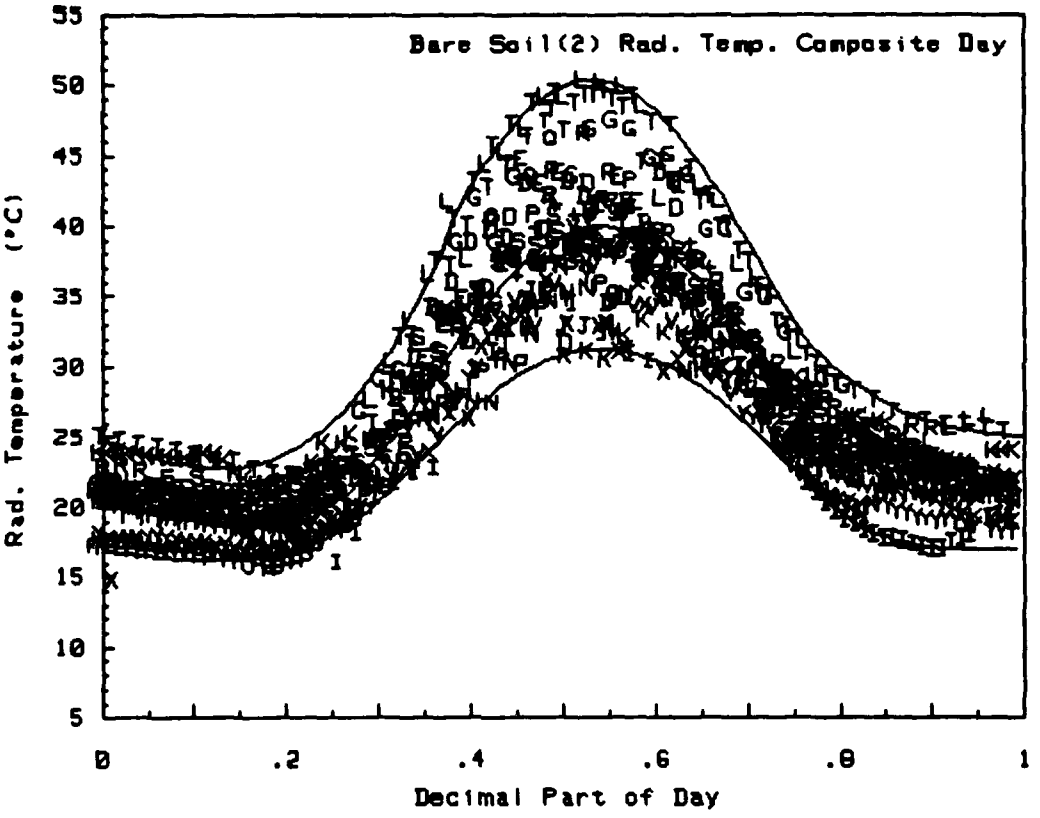
## PARTLY CLOUDY SKY: SUMMER: DRY SURFACE SOIL

### Diurnal Plots of All Backgrounds and Differences

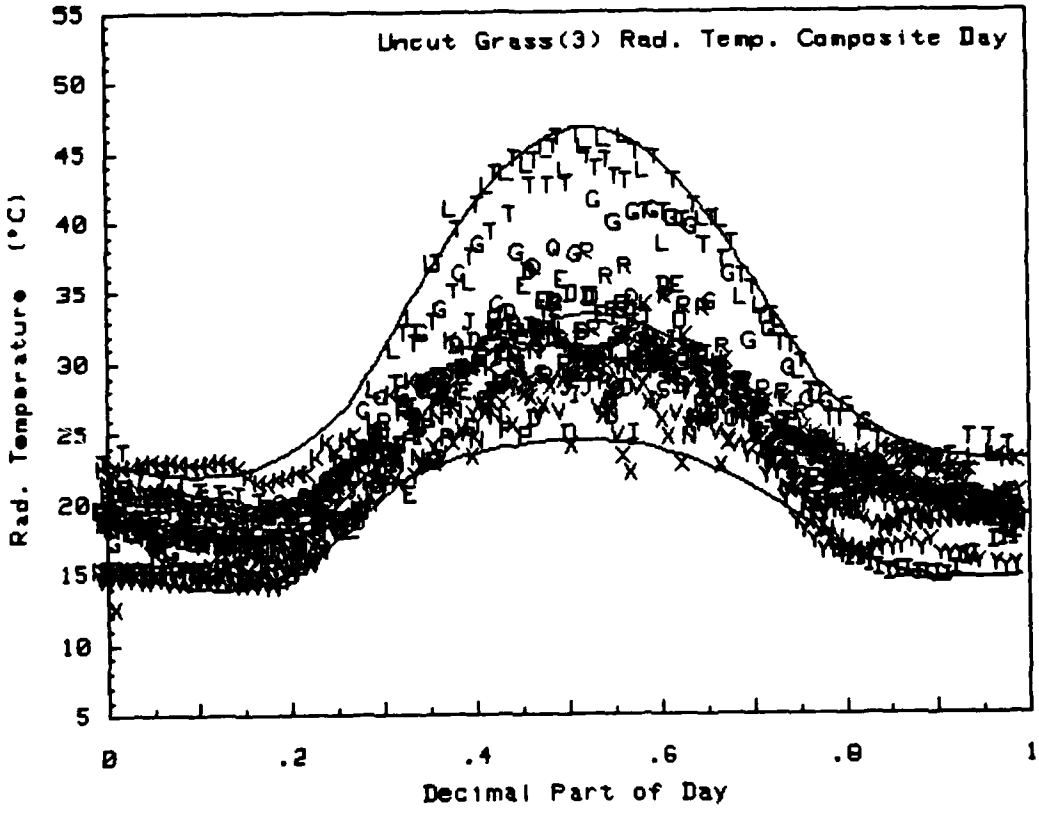
### with Regression Curves



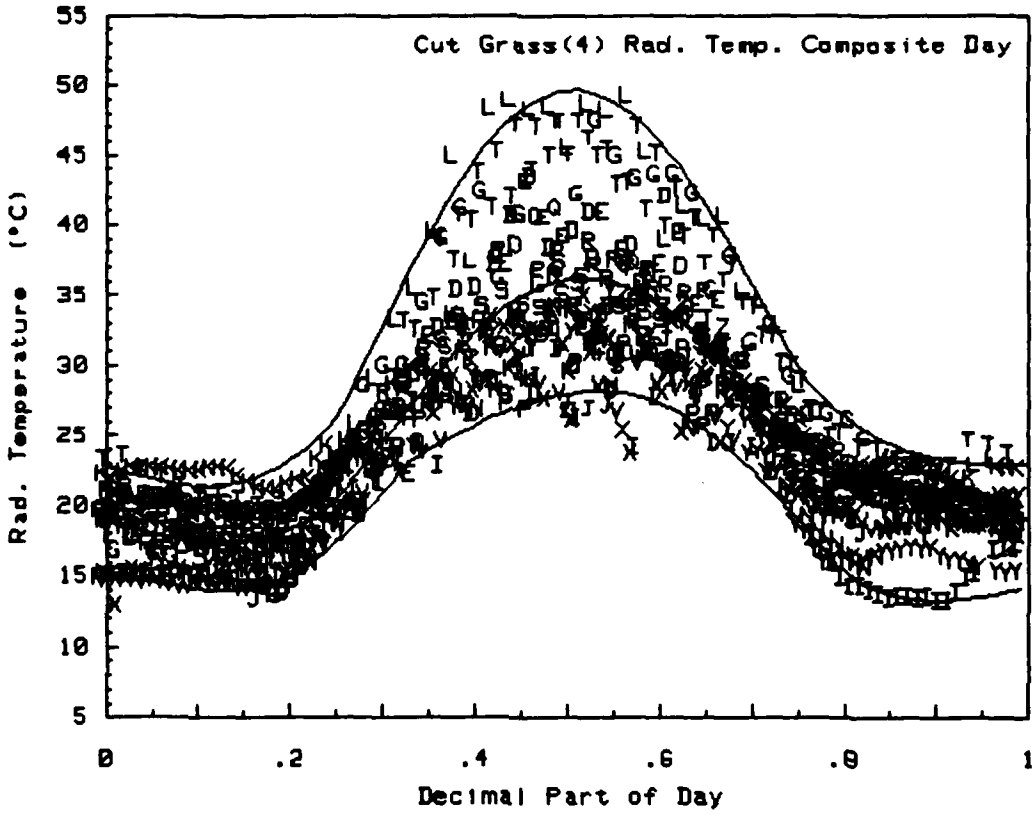

Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113

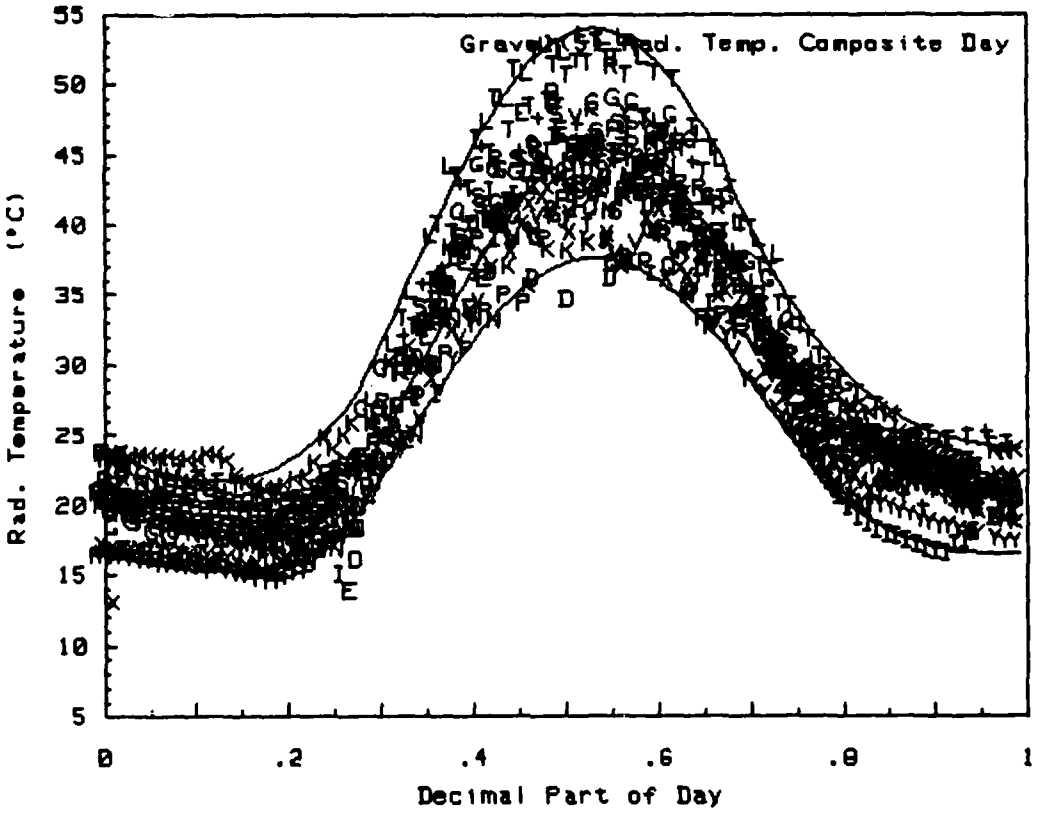



Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113

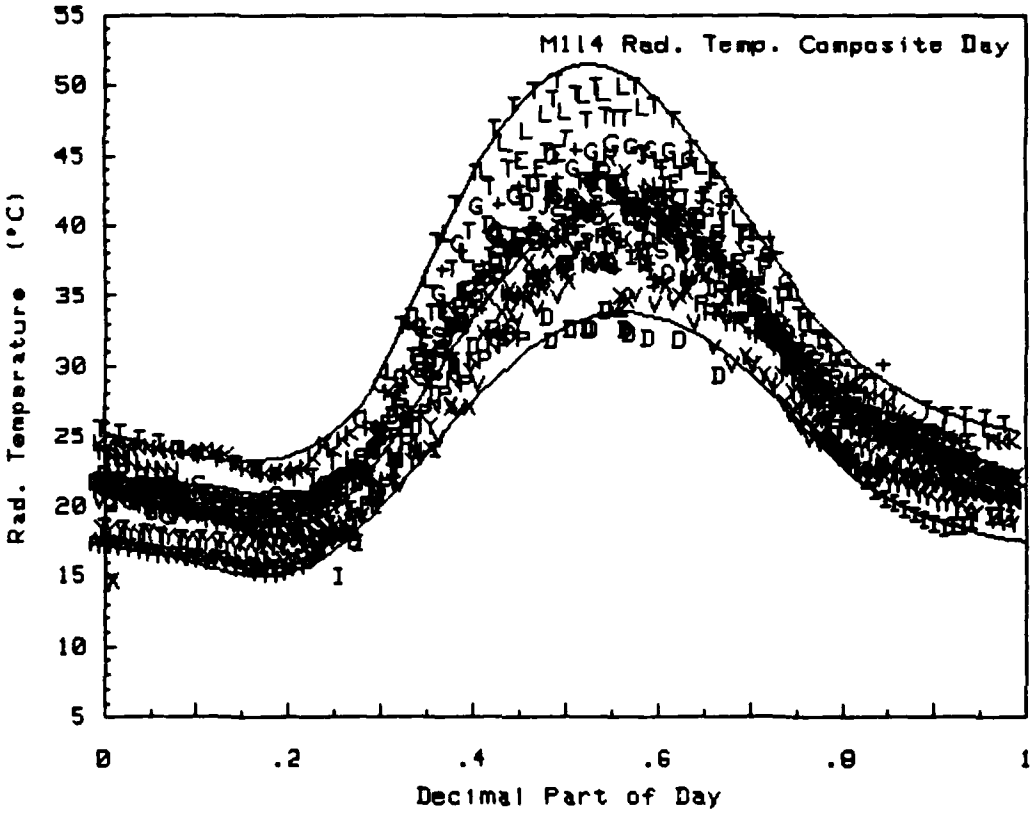



Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113

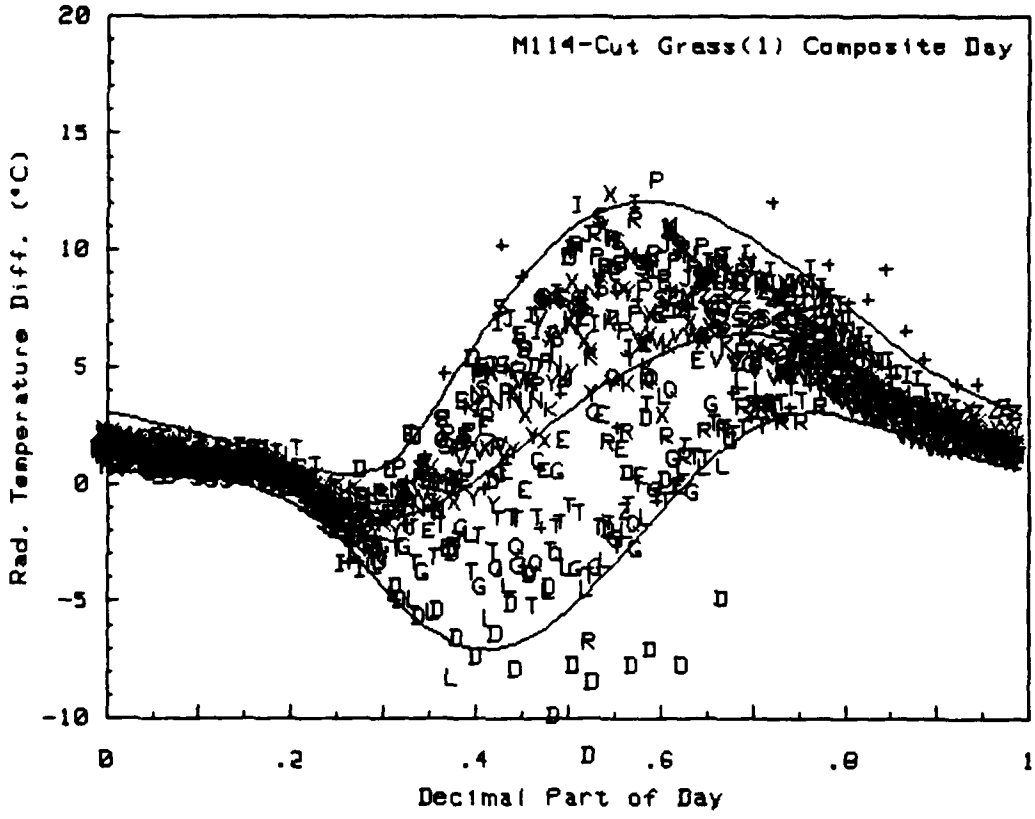

Cut Grass(4) Rad. Temp. Composite Day
Rad. Temperature (°C)
55
50
45
40
35
30
25
20
15
10
5
0
.2
.4
.6
.8
1
Decimal Part of Day



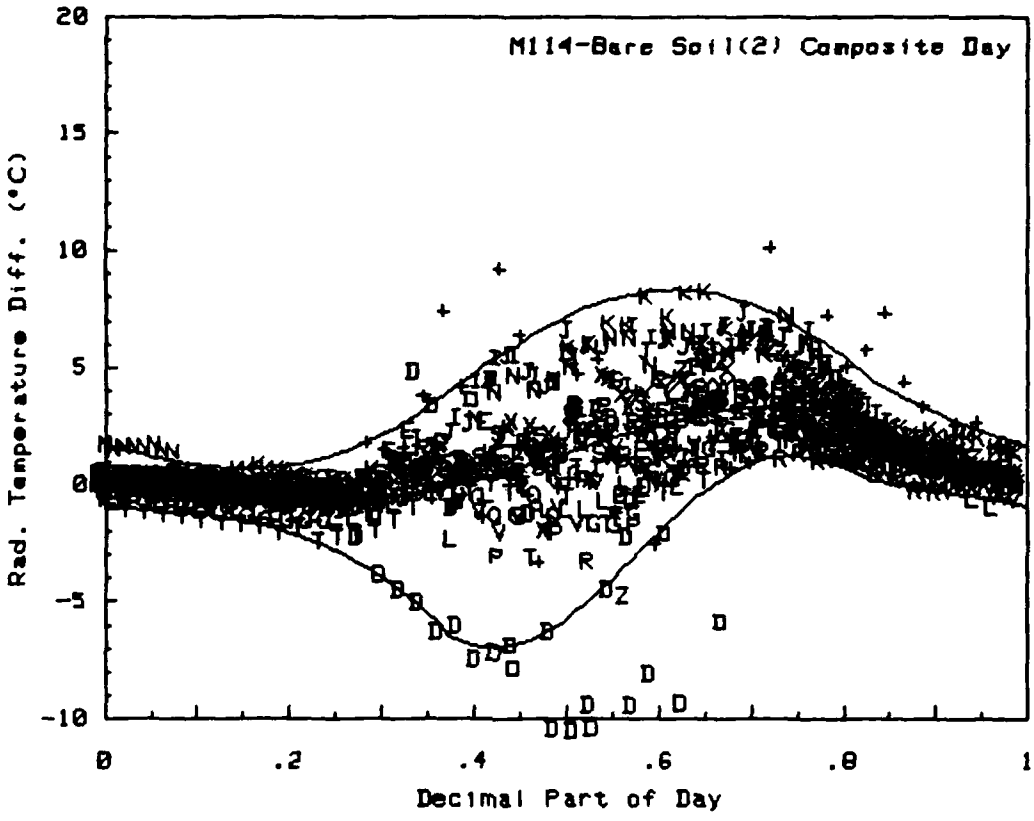

Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113



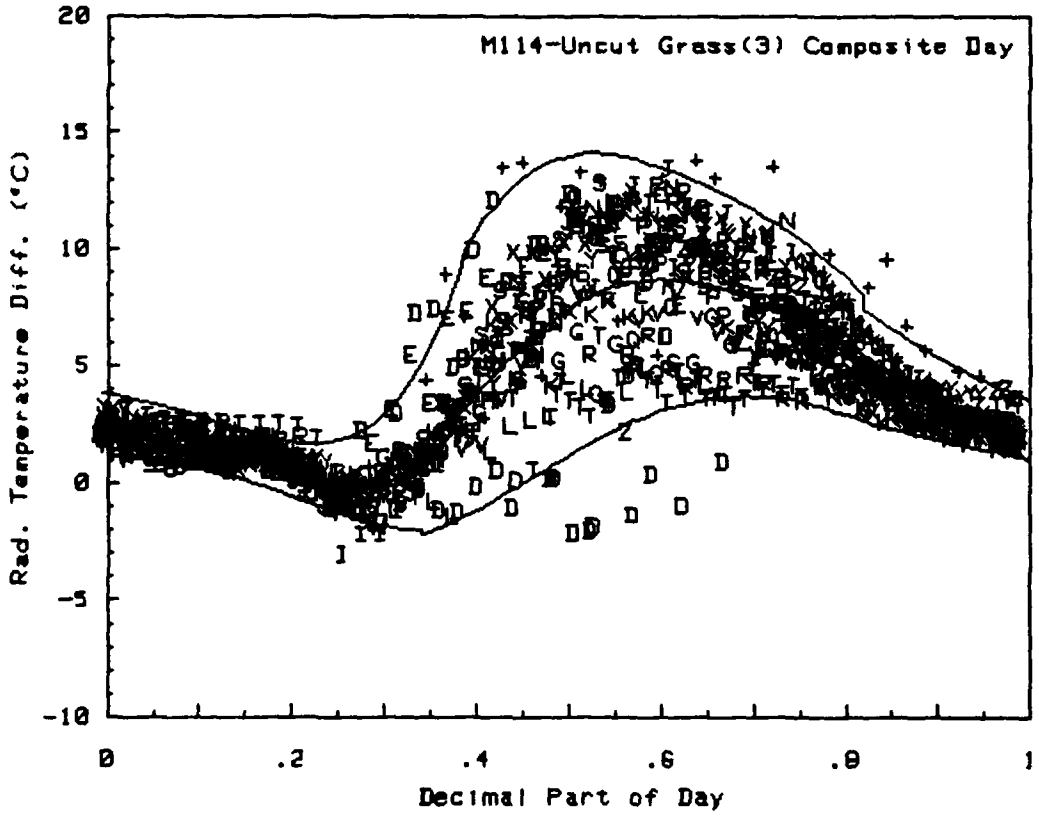

Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113



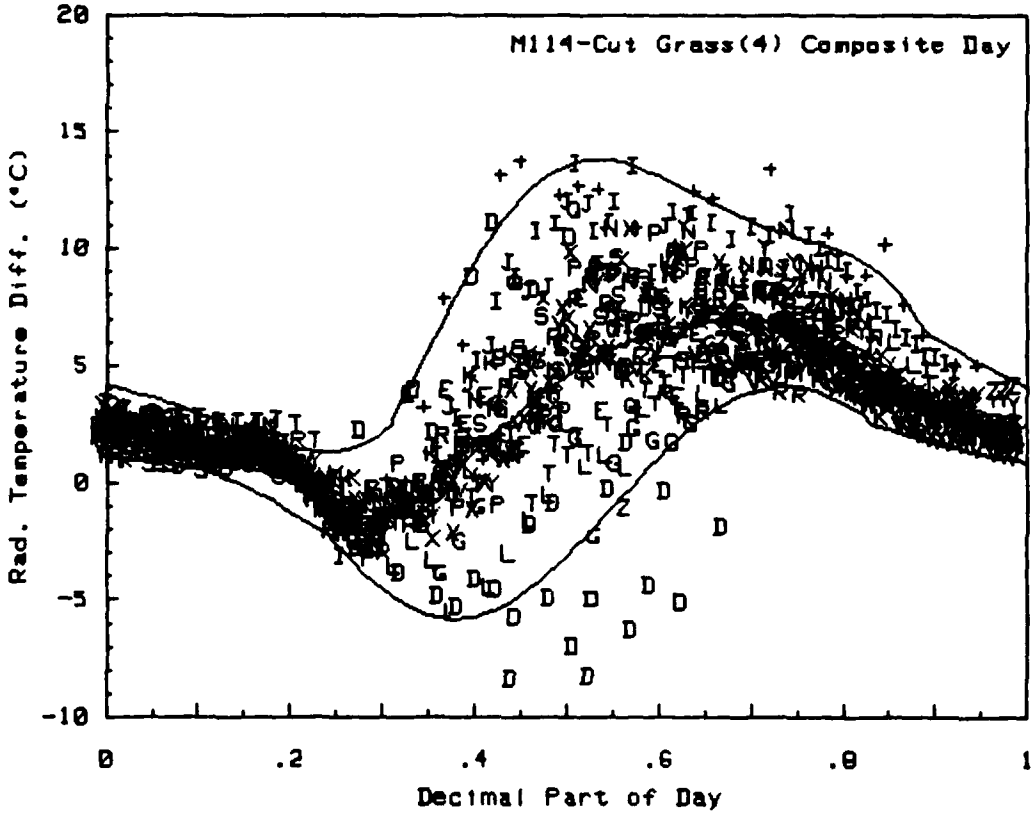

Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113



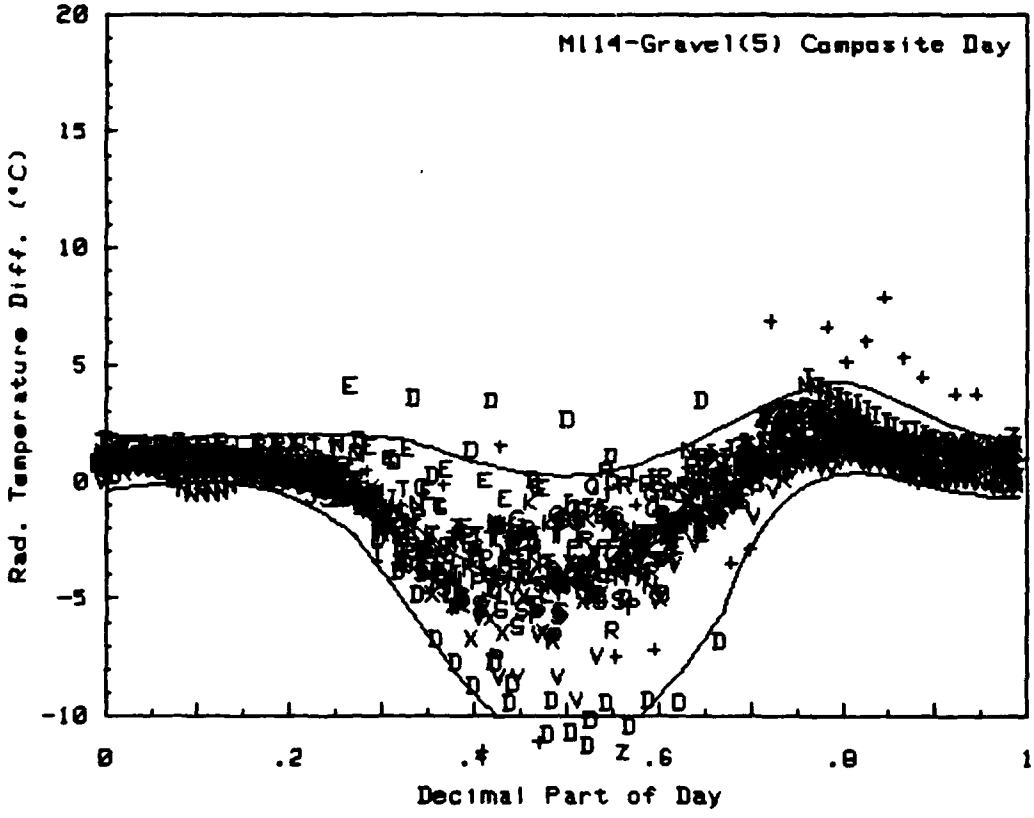

Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113




Summer Partly Cloudy Dry
1984-85 Composites Records 1-1113




Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113

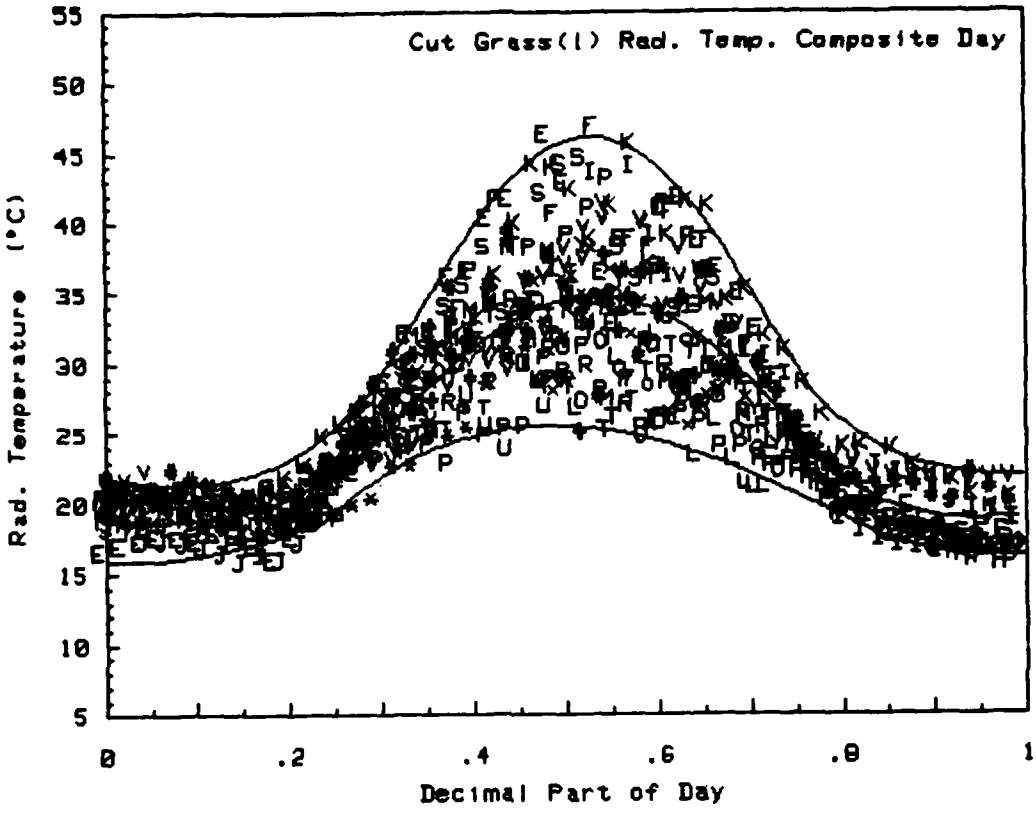



Summer Partly Cloudy Dry
1984-85 Composite: Records 1-1113

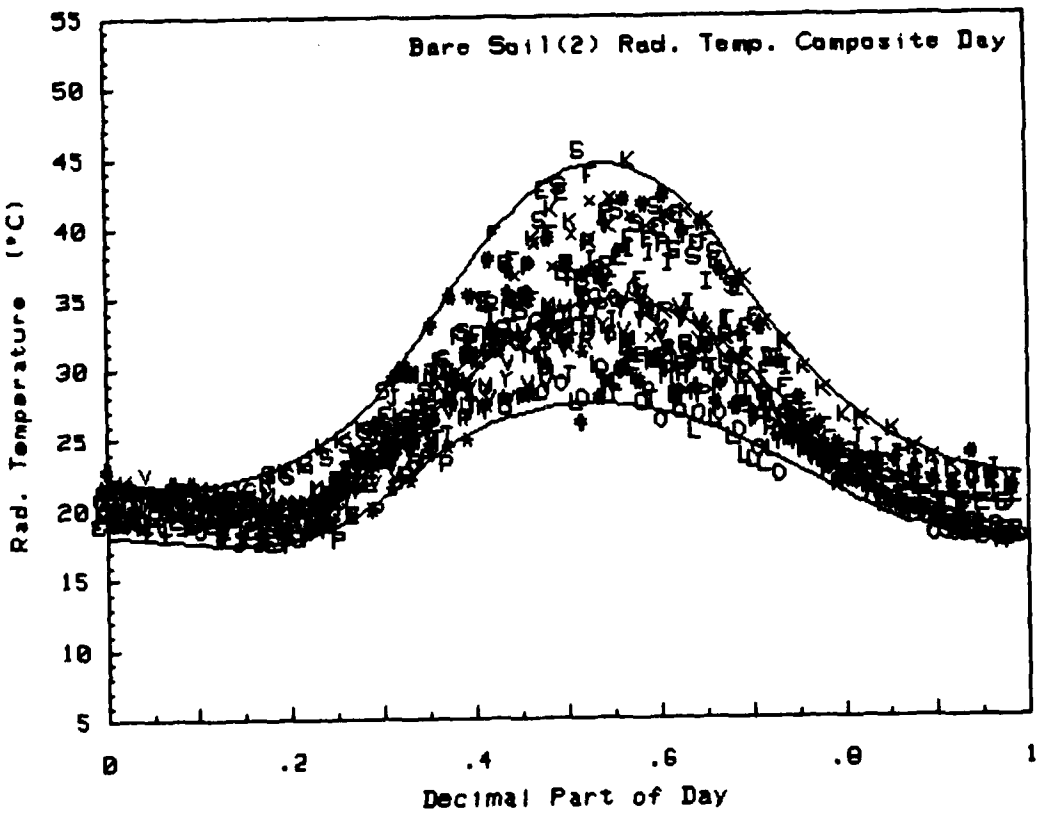
## PARTLY CLOUDY SKY: SUMMER: WET SURFACE SOIL

**Diurnal Plots of All Backgrounds and Differences**

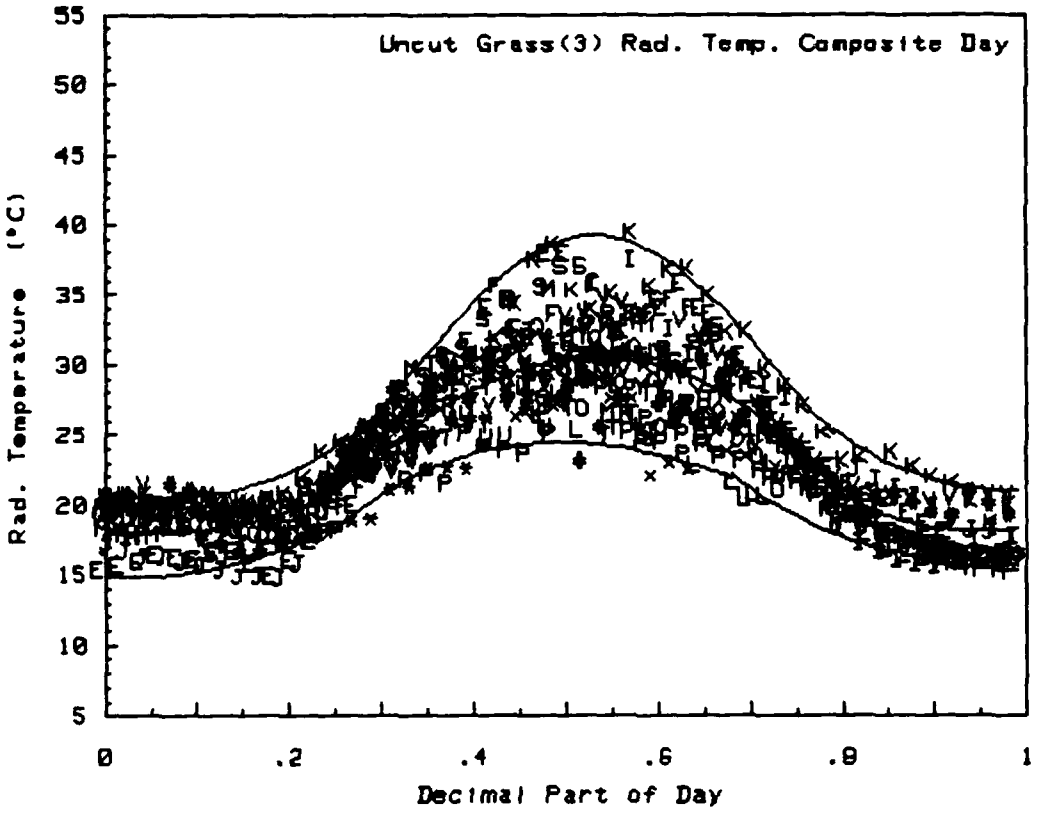
**with Regression Curves**



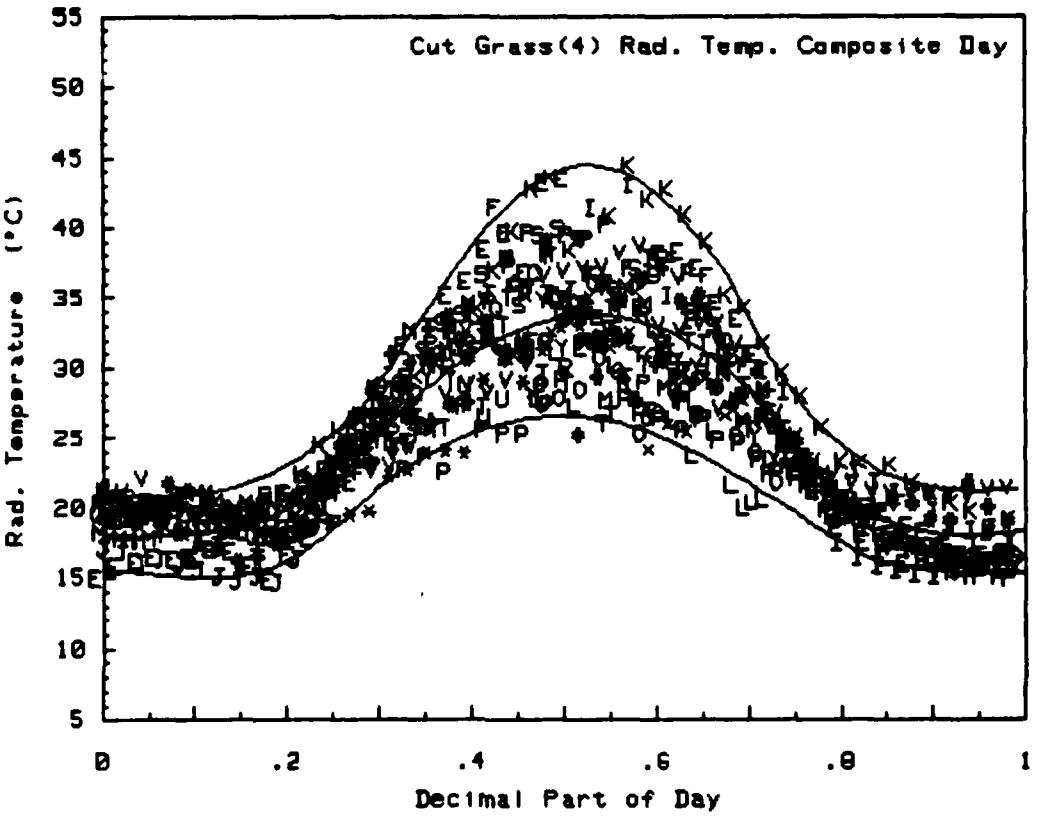

Summer Partly Cloudy Wet
1984-85 Composite: Records 1-781



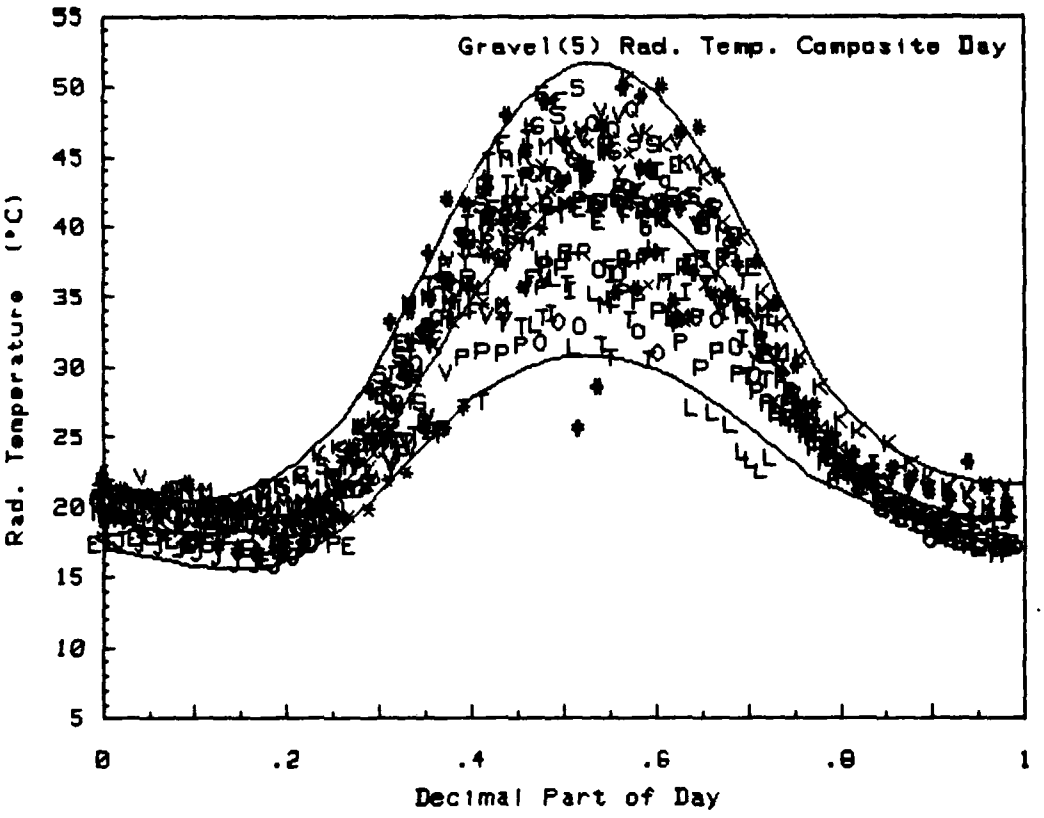

Summer Partly Cloudy Wet
1984-85 Composites Records 1-781



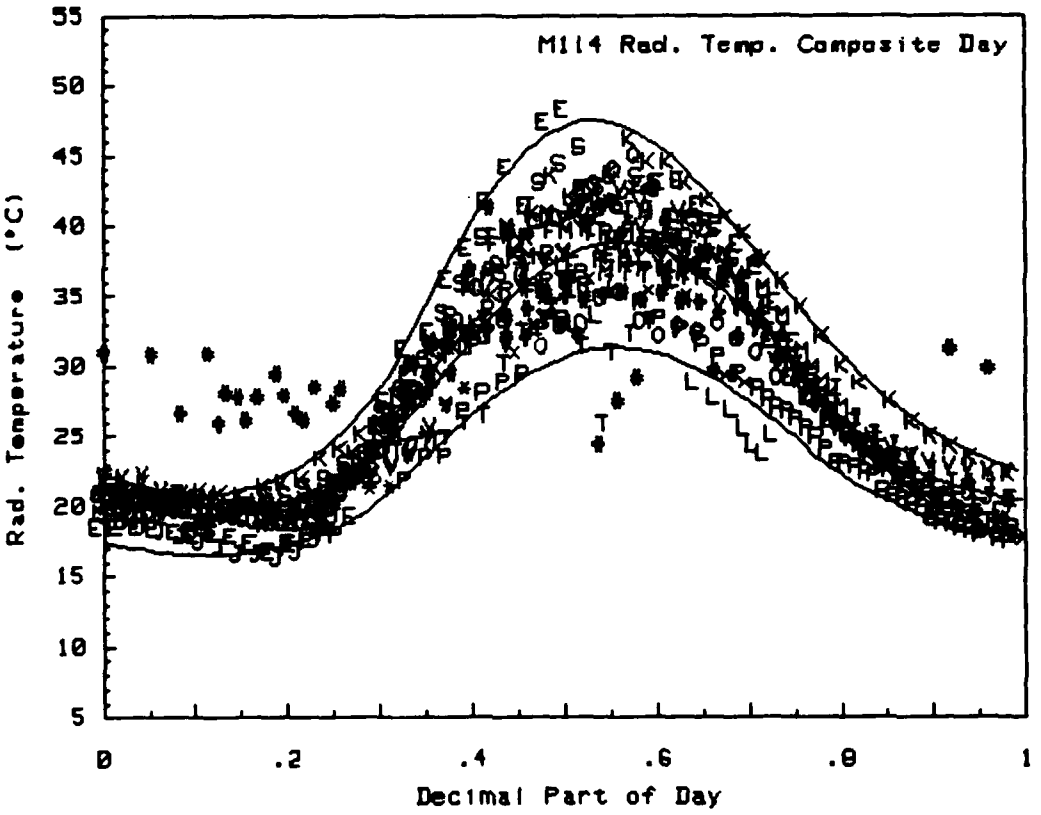

Summer Partly Cloudy Wet
1984-85 Composite: Records 1-781



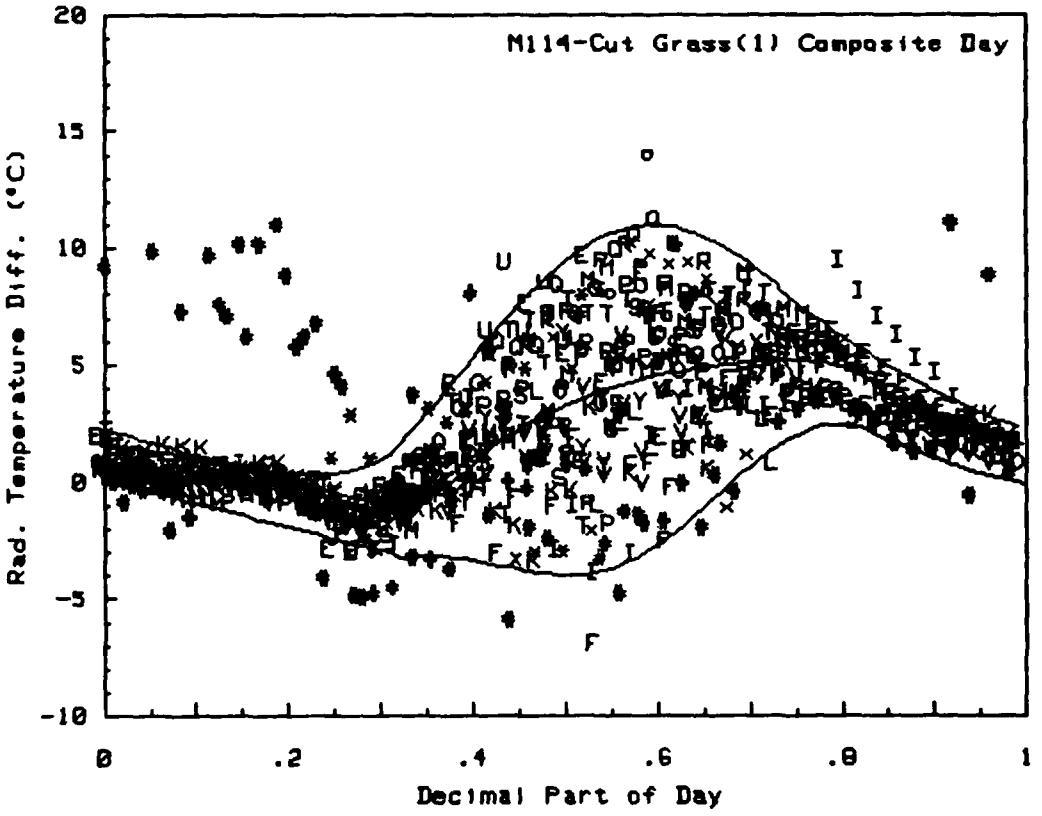

Summer Partly Cloudy Wet
1984-85 Composite: Records 1-781



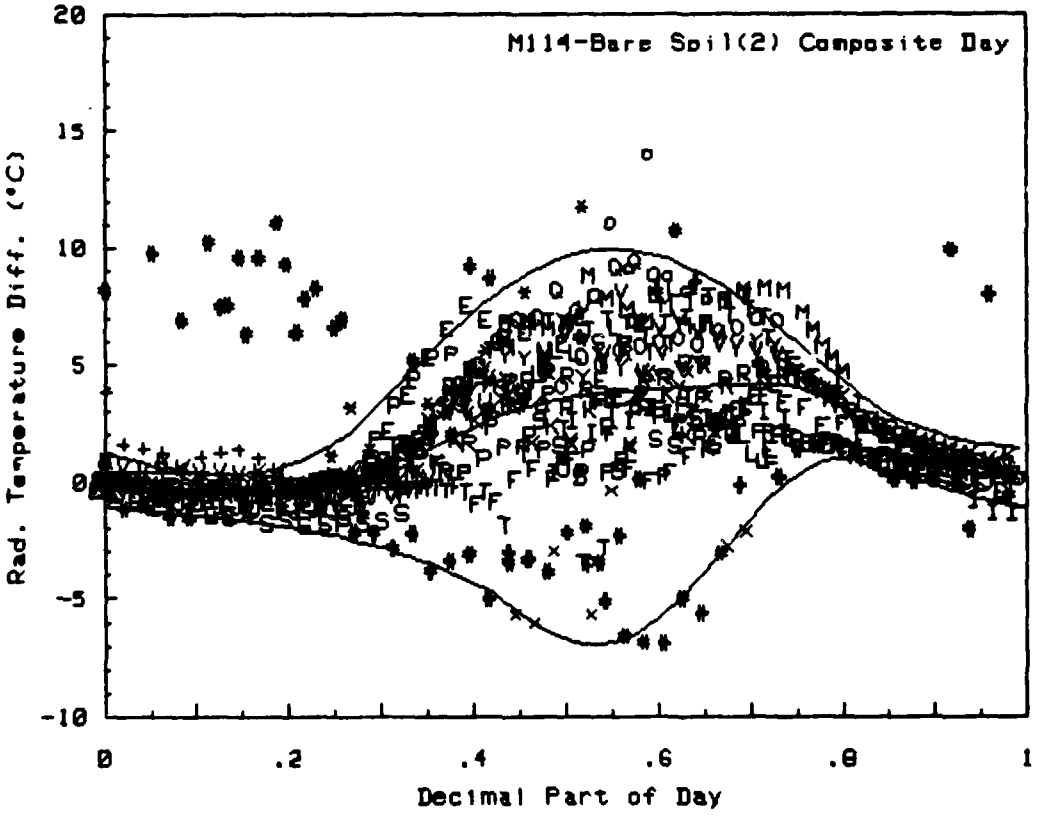

Summer Partly Cloudy Wet
1984-85 Composite: Records 1-781



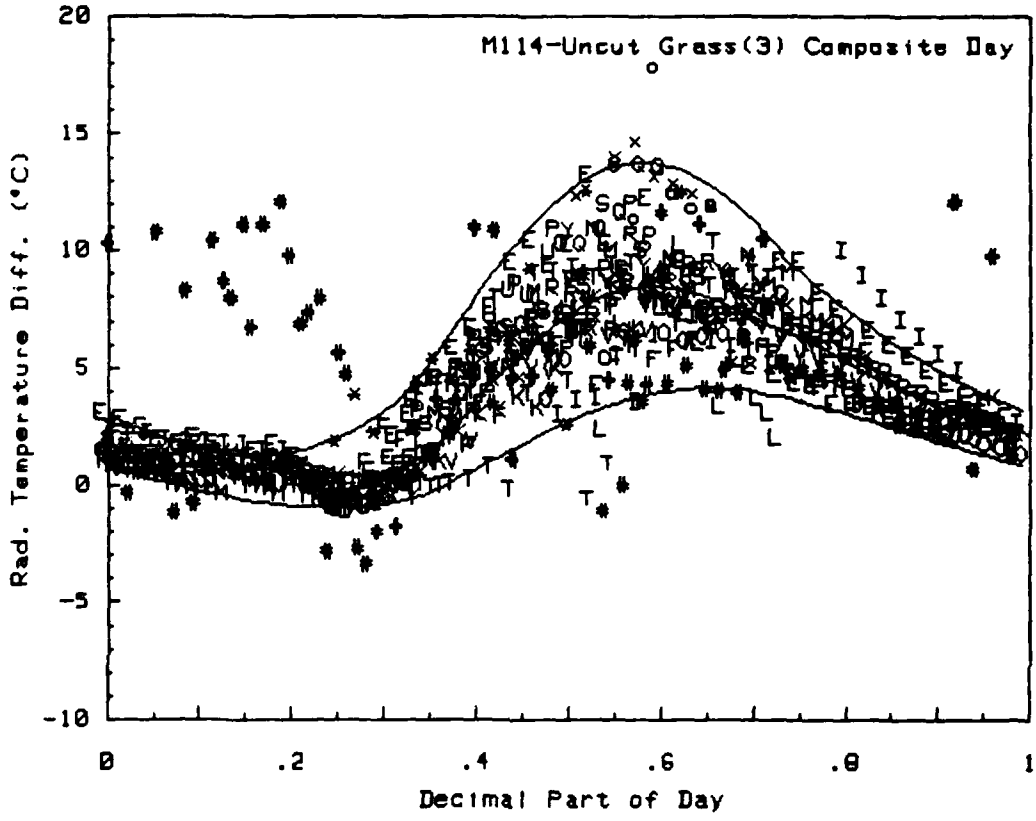

Summer Partly Cloudy Wet
1984-85 Composites Records 1-781



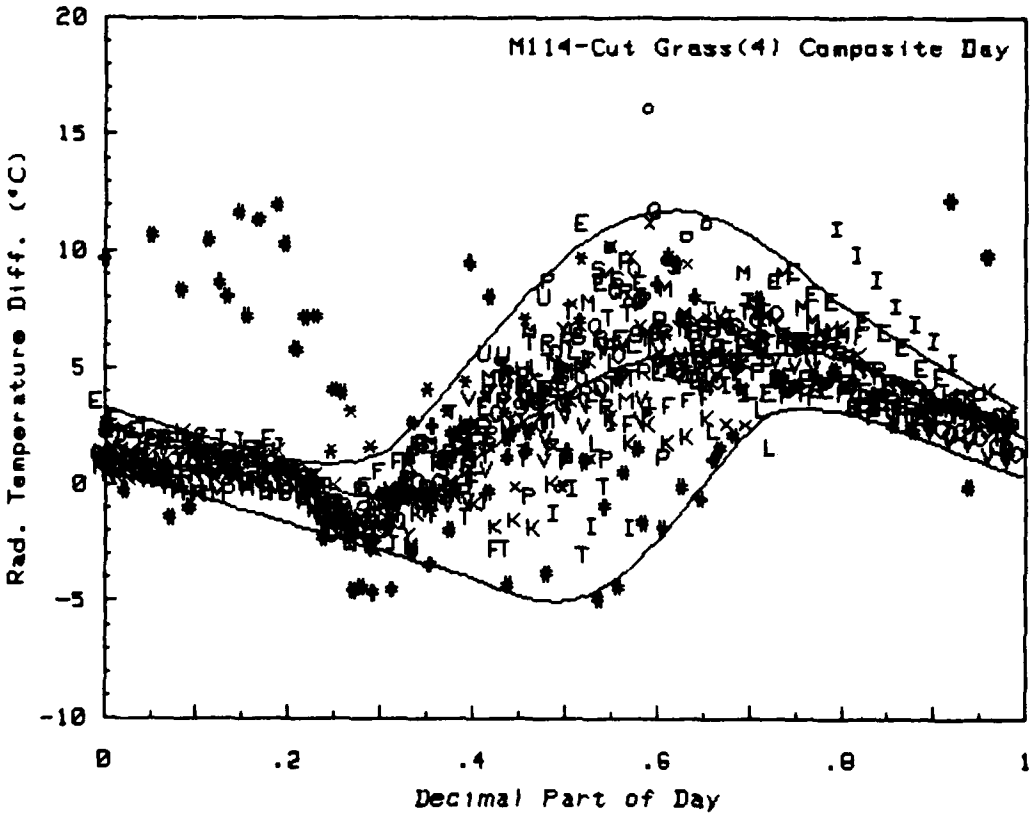

Summer Partly Cloudy Wet
1984-85 Composites Records 1-781



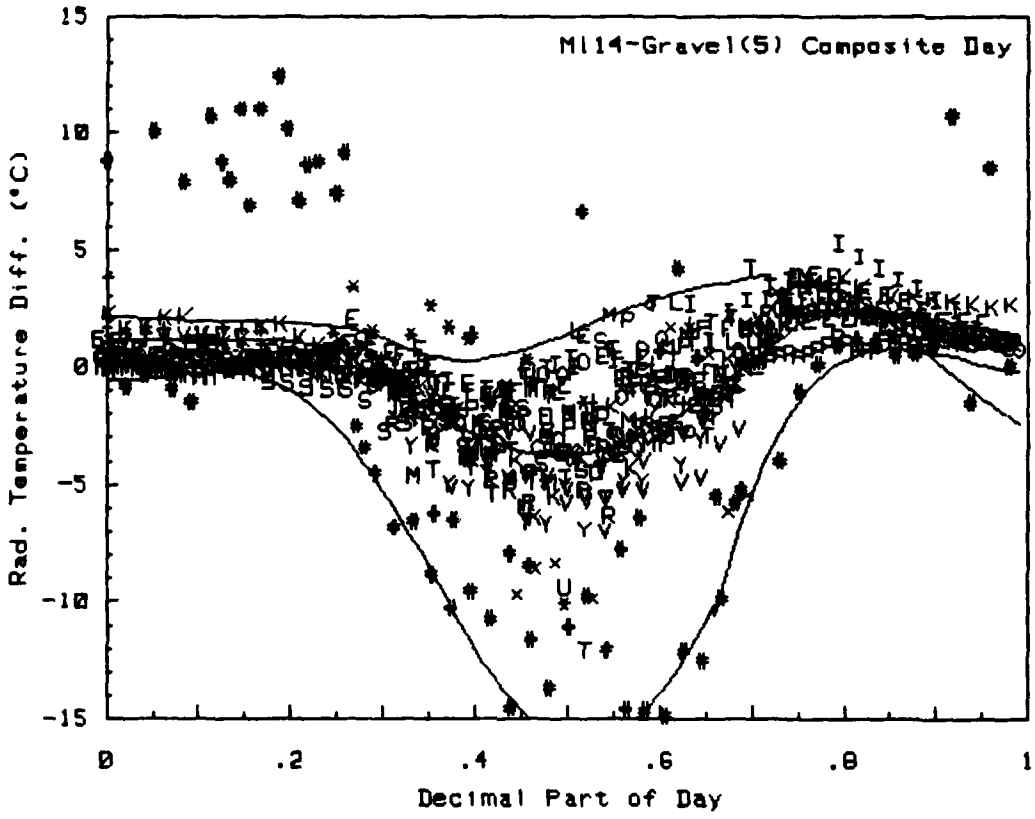

Summer Partly Cloudy wet
1984-85 Composite: Records 1-781




Summer Partly Cloudy Wet
1984-85 Composite: Records 1-781




Summer Partly Cloudy Wet
1984-85 Composite: Records 1-781

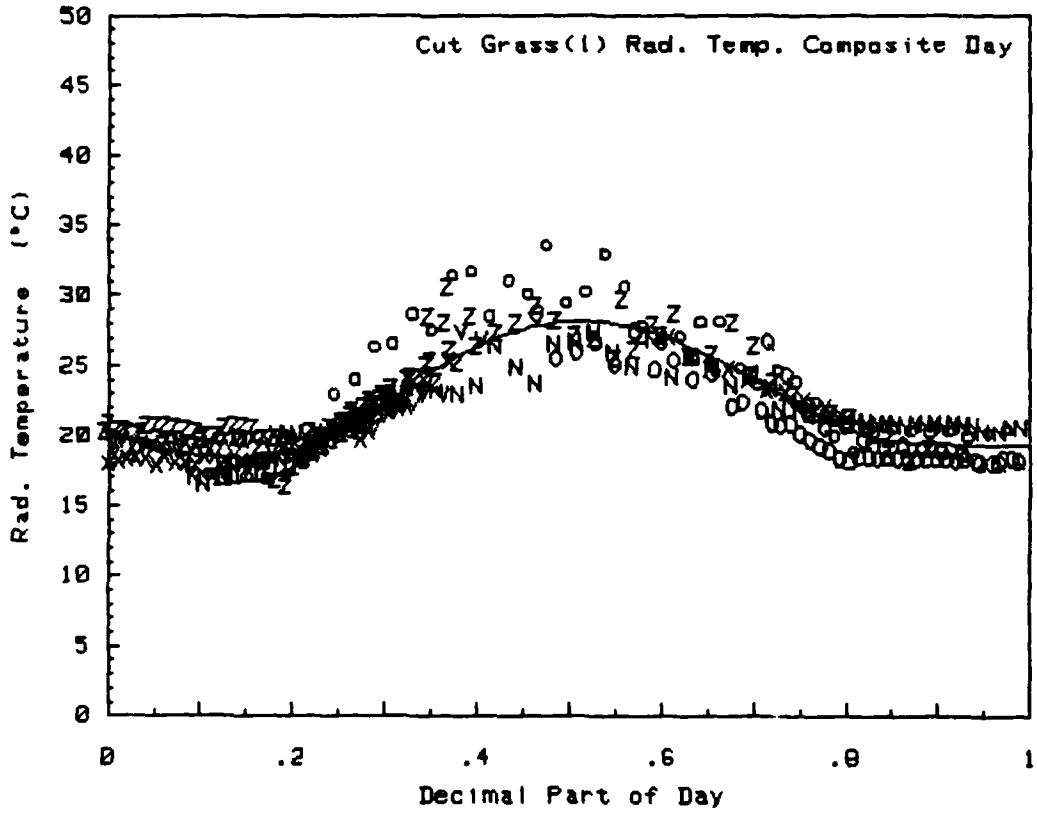



Summer Partly Cloudy Wet
1984-85 Composites Records 1-781

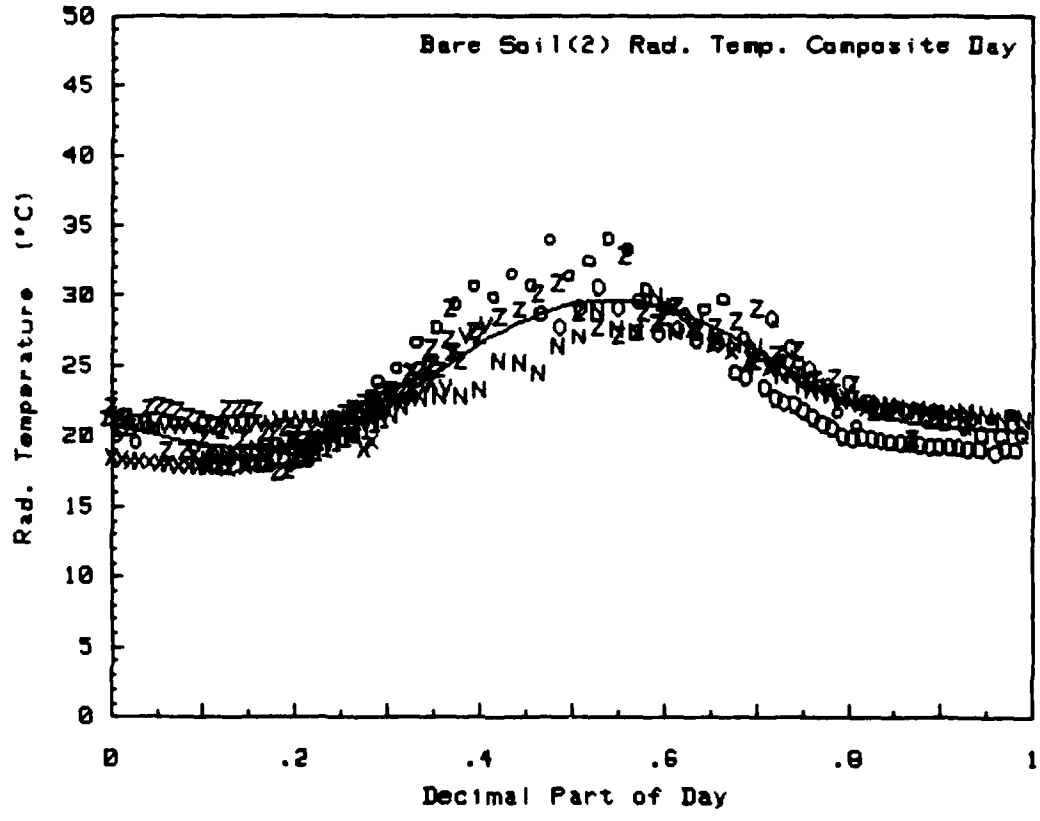
## OVERCAST SKY: SUMMER: DRY SURFACE SOIL

**Diurnal Plots of All Backgrounds and Differences**

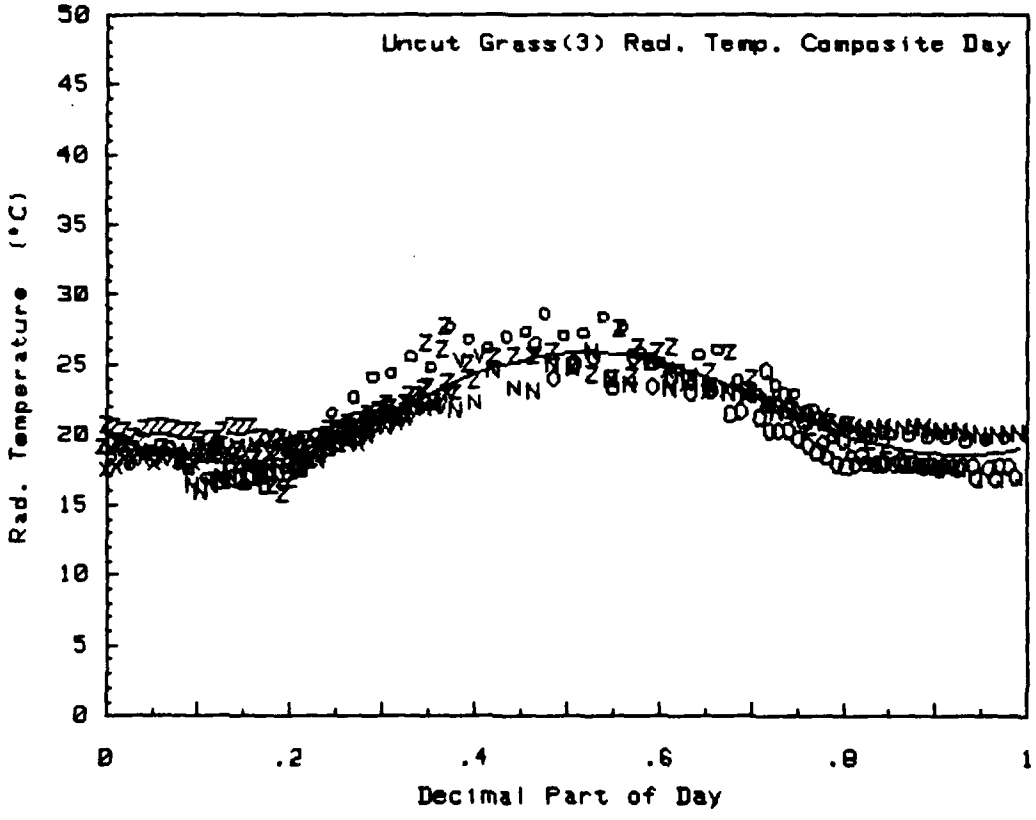
**with Regression Curves**



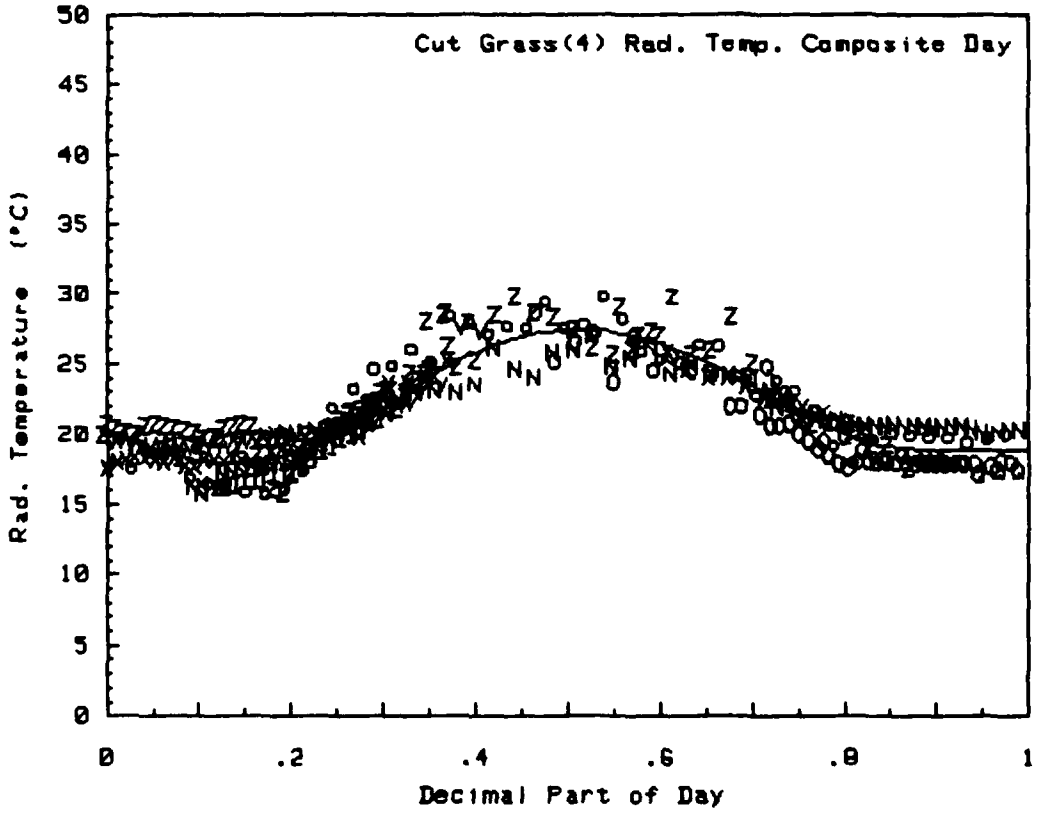

Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87



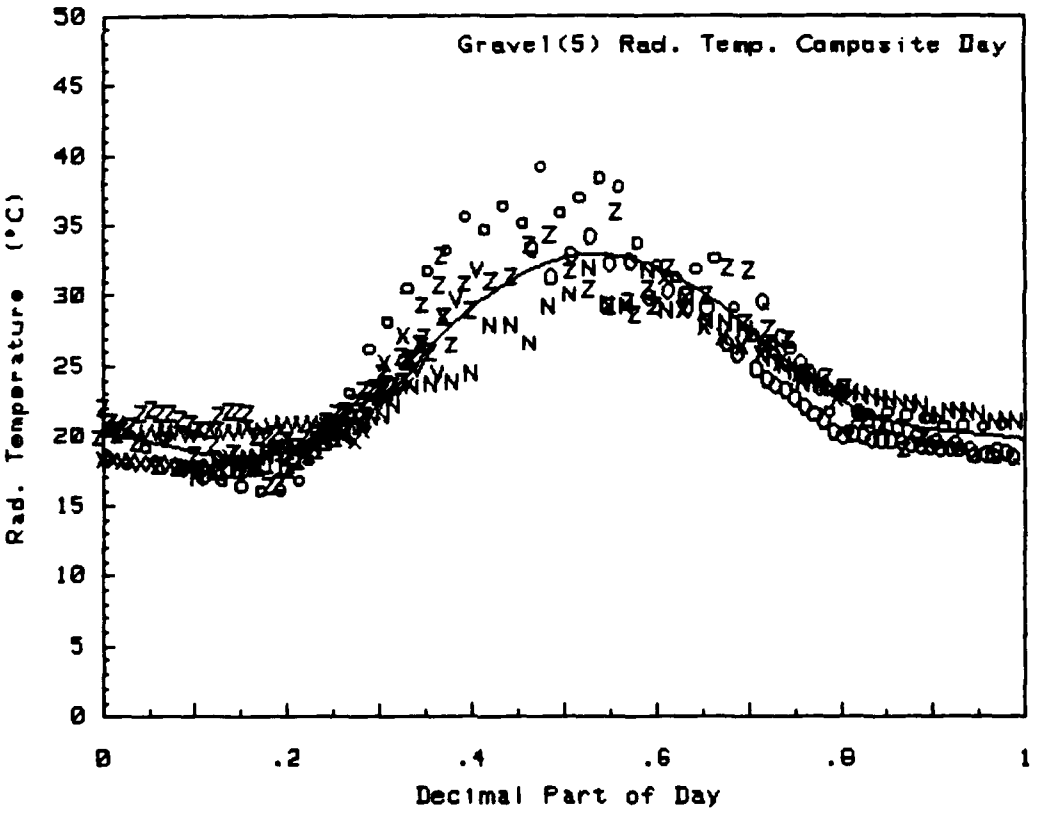

Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87



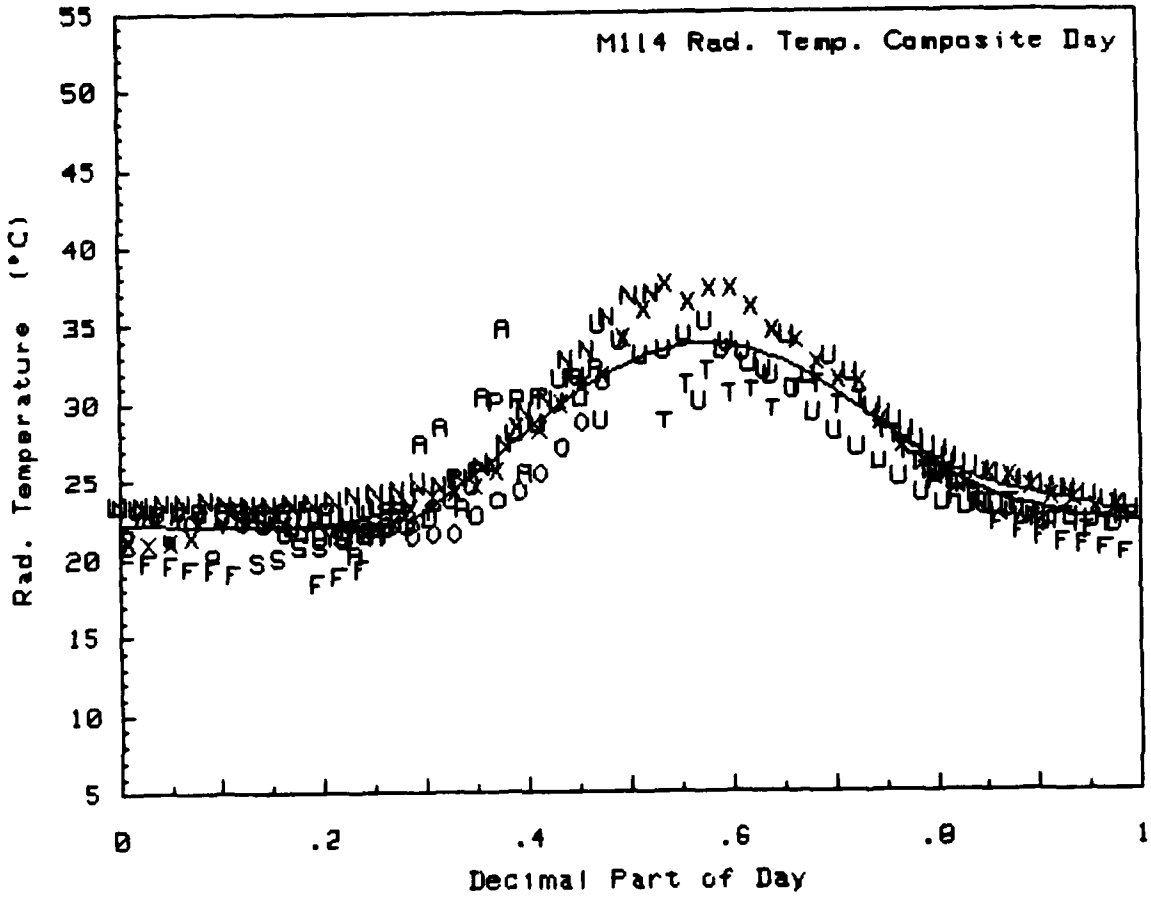

Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87



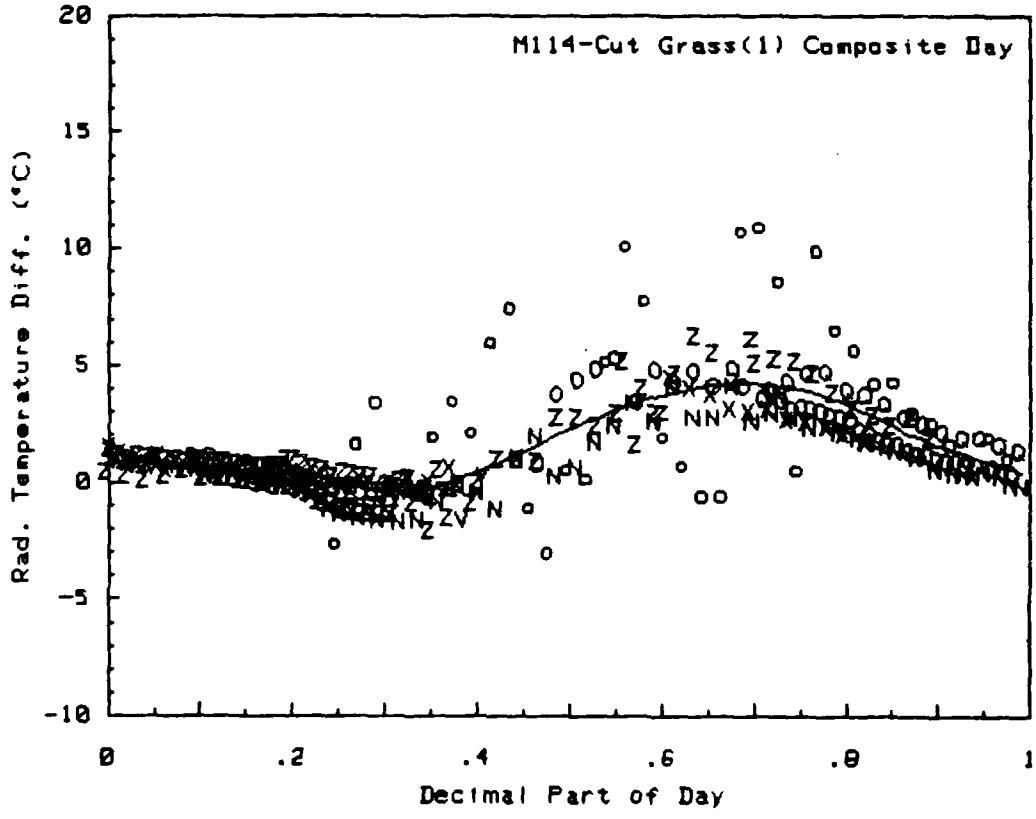

Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87



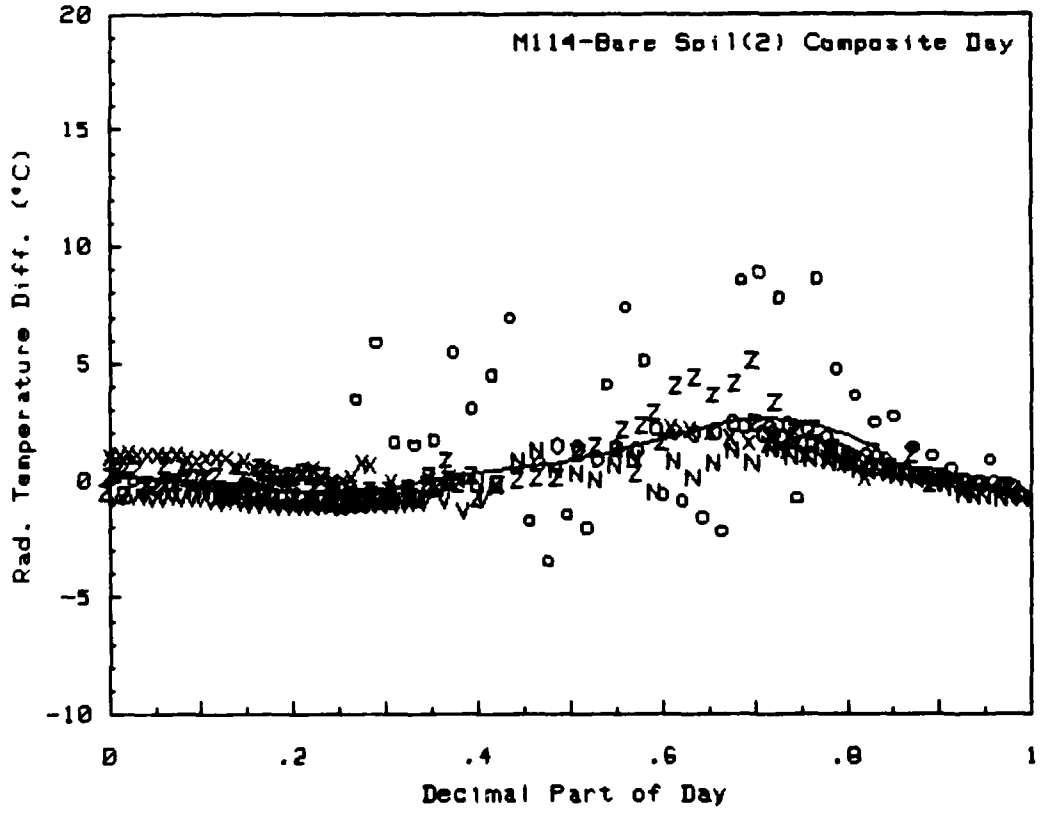

Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87



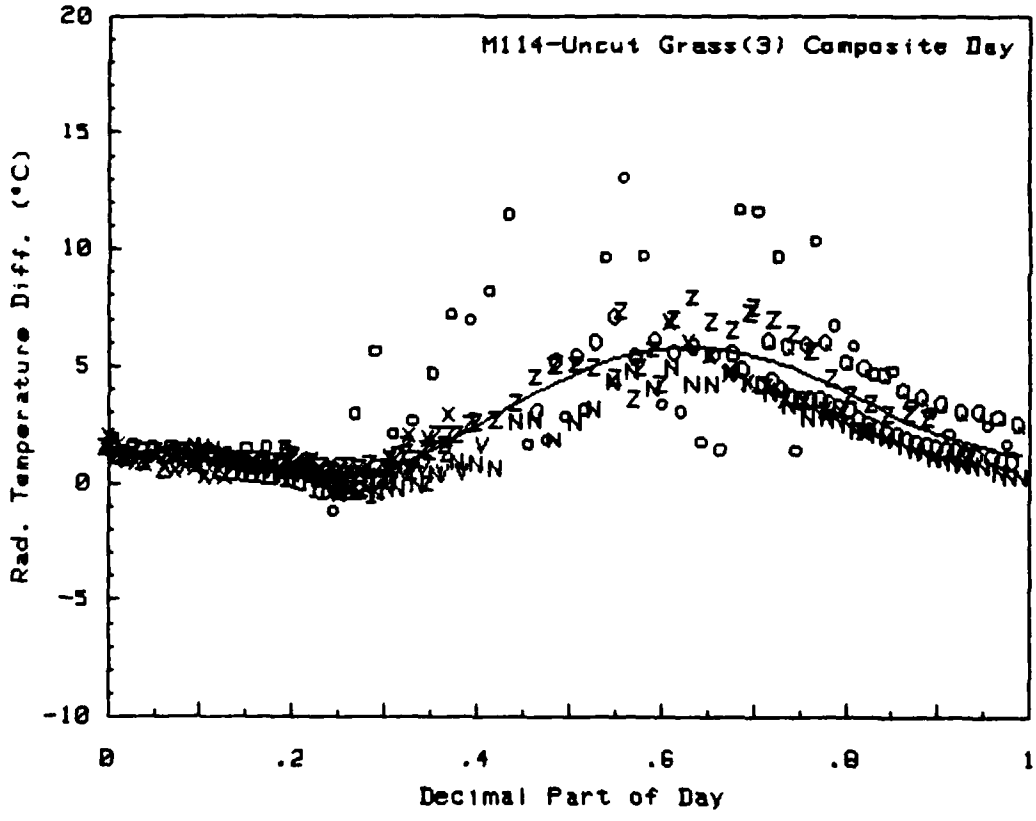

Summer Wet Overcast
1984-85 Composite: Records 1-290



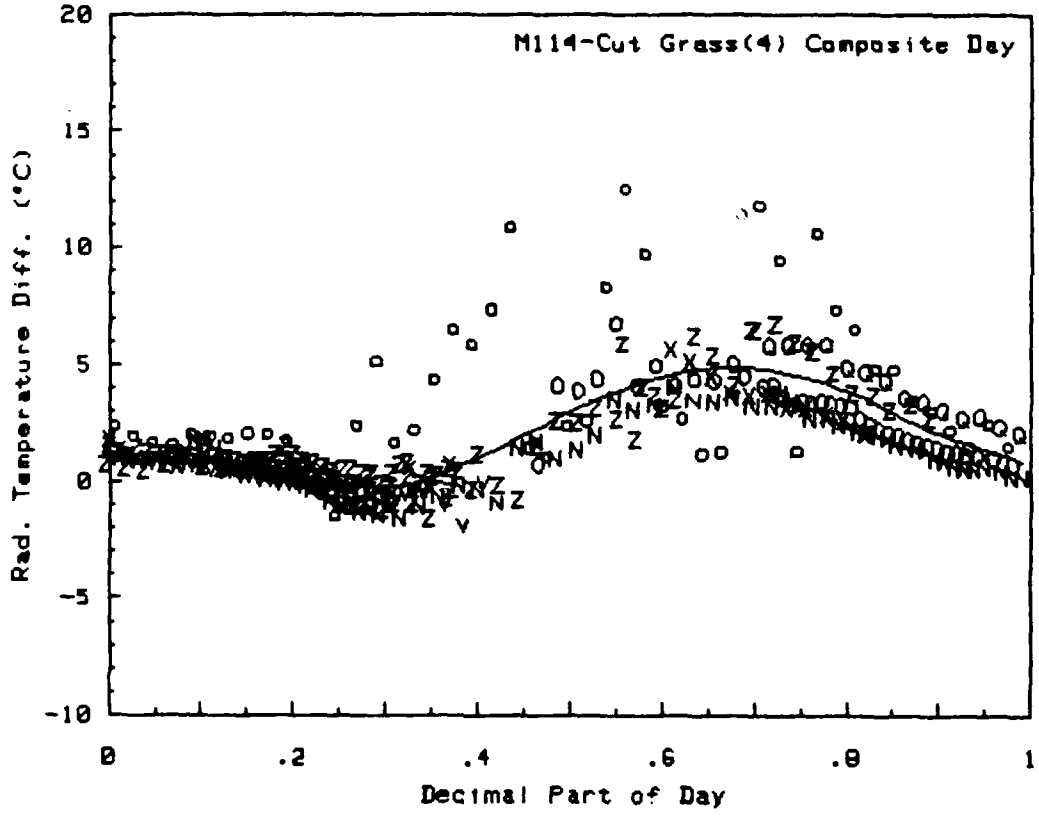

Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87



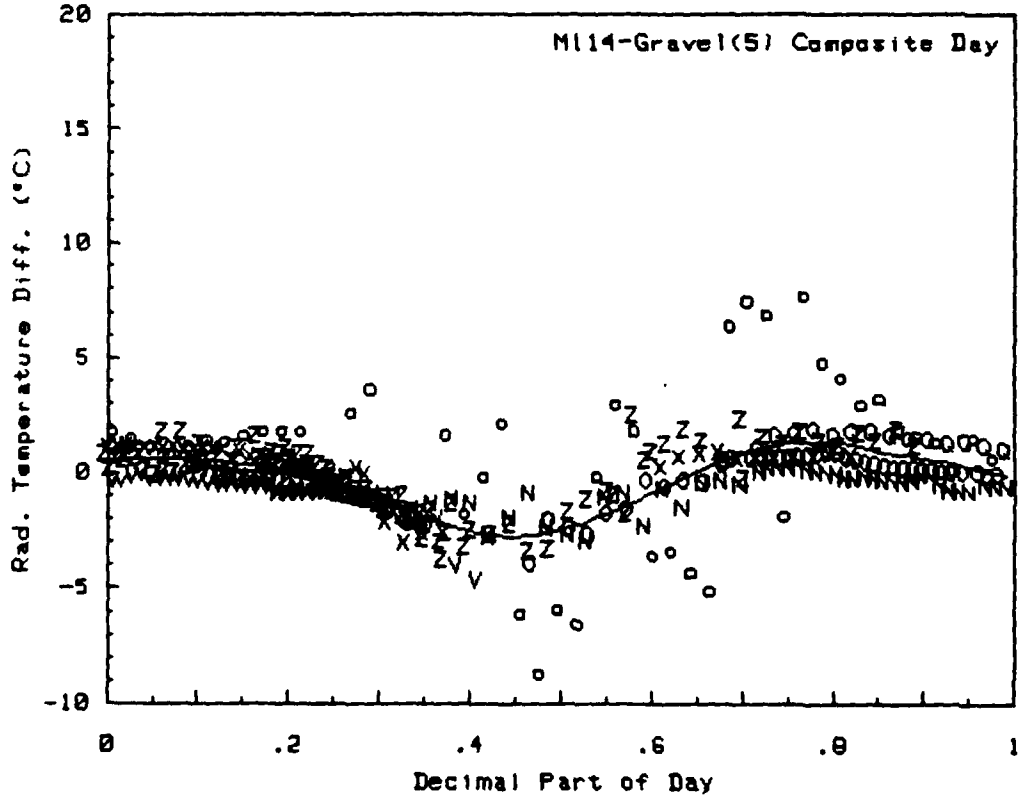

Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87




Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87




Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87

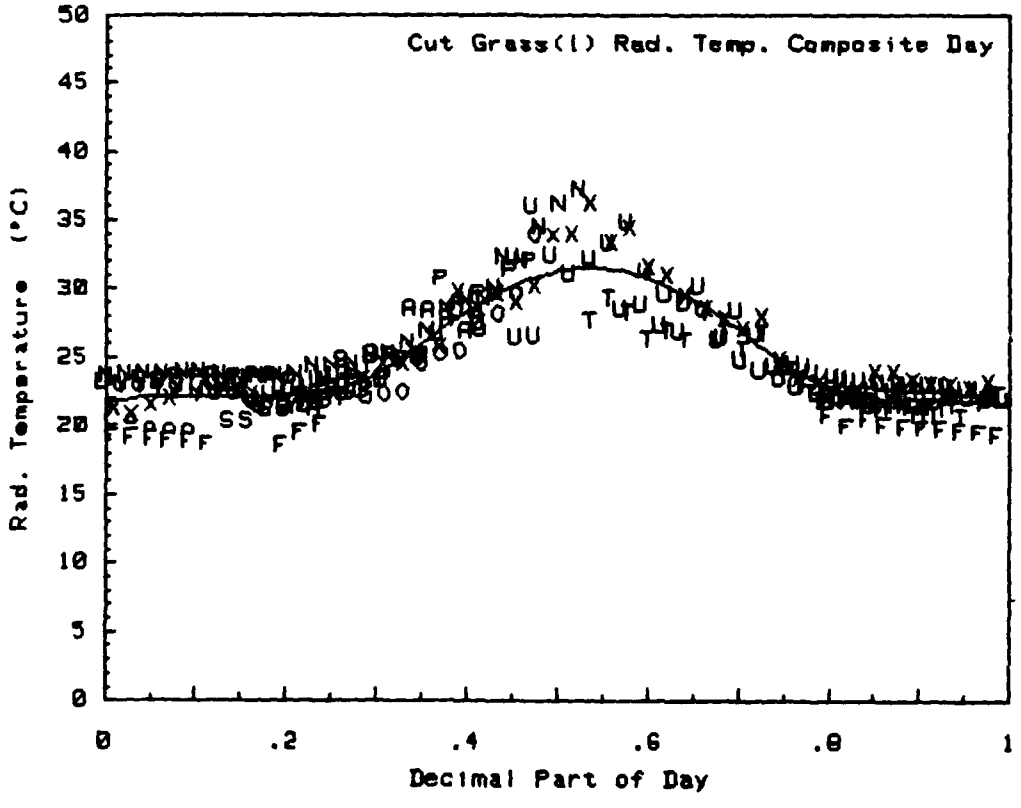



Summer Dry
Overcast
1984-5 Composite
Records 1-365
1/14/87

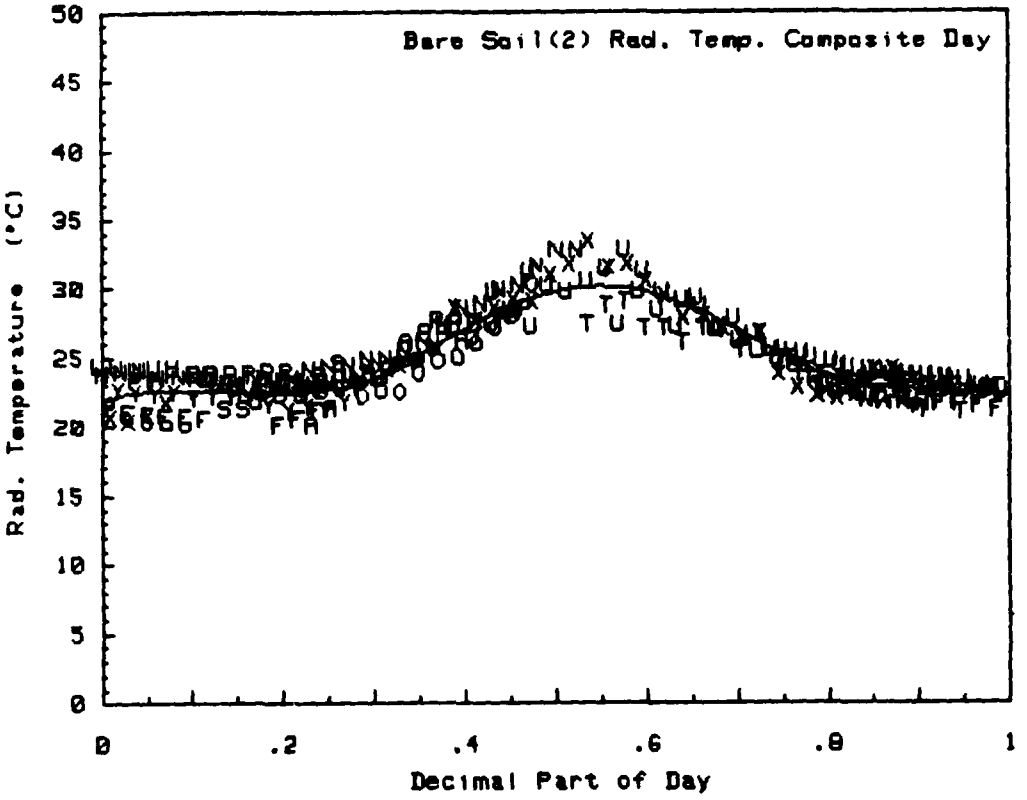
## OVERCAST SKY: SUMMER: WET SURFACE SOIL

**Diurnal Plots of All Backgrounds and Differences**

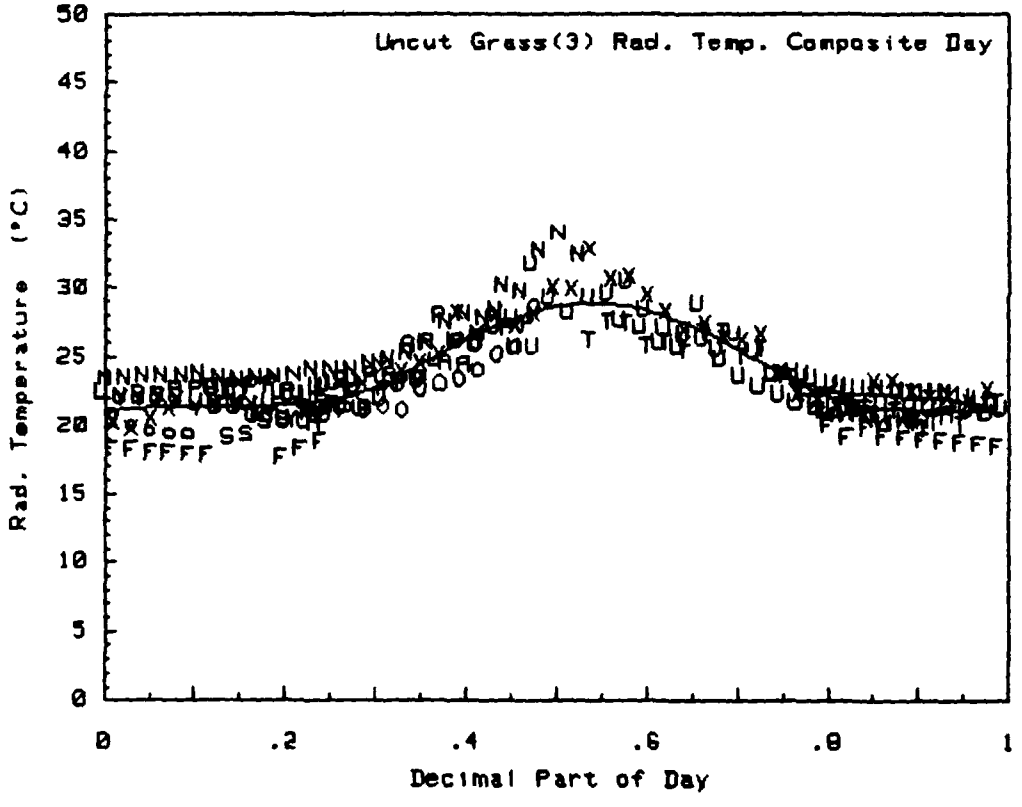
**with Regression Curves**



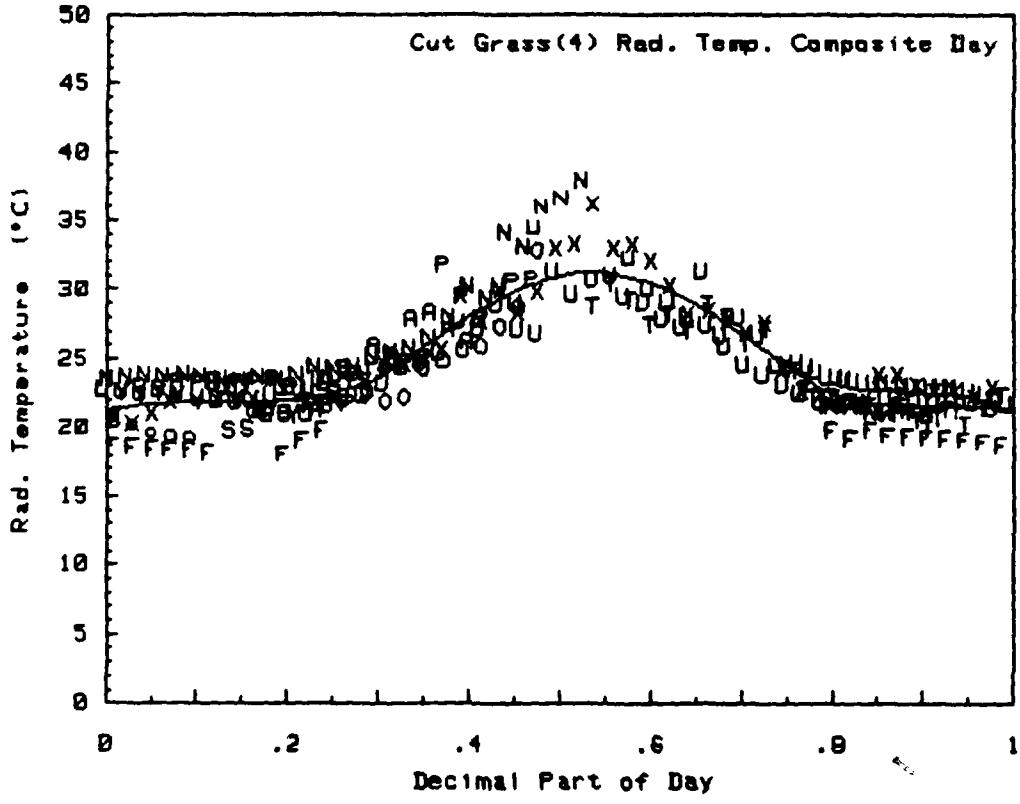

Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87



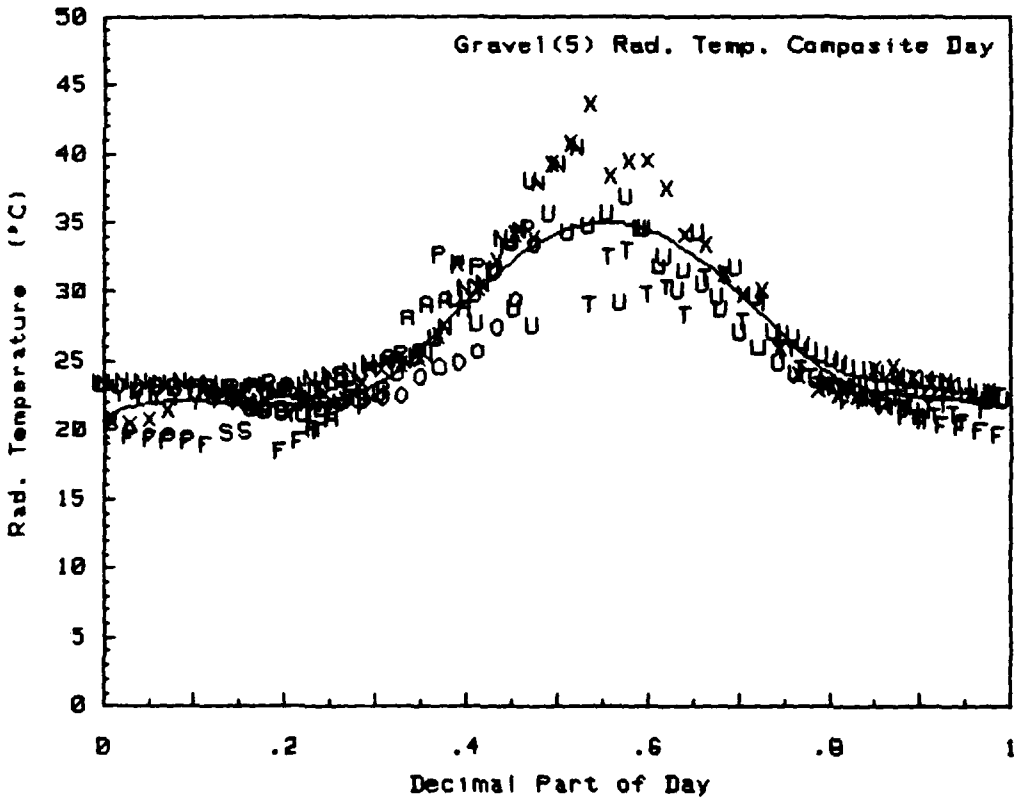

Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87



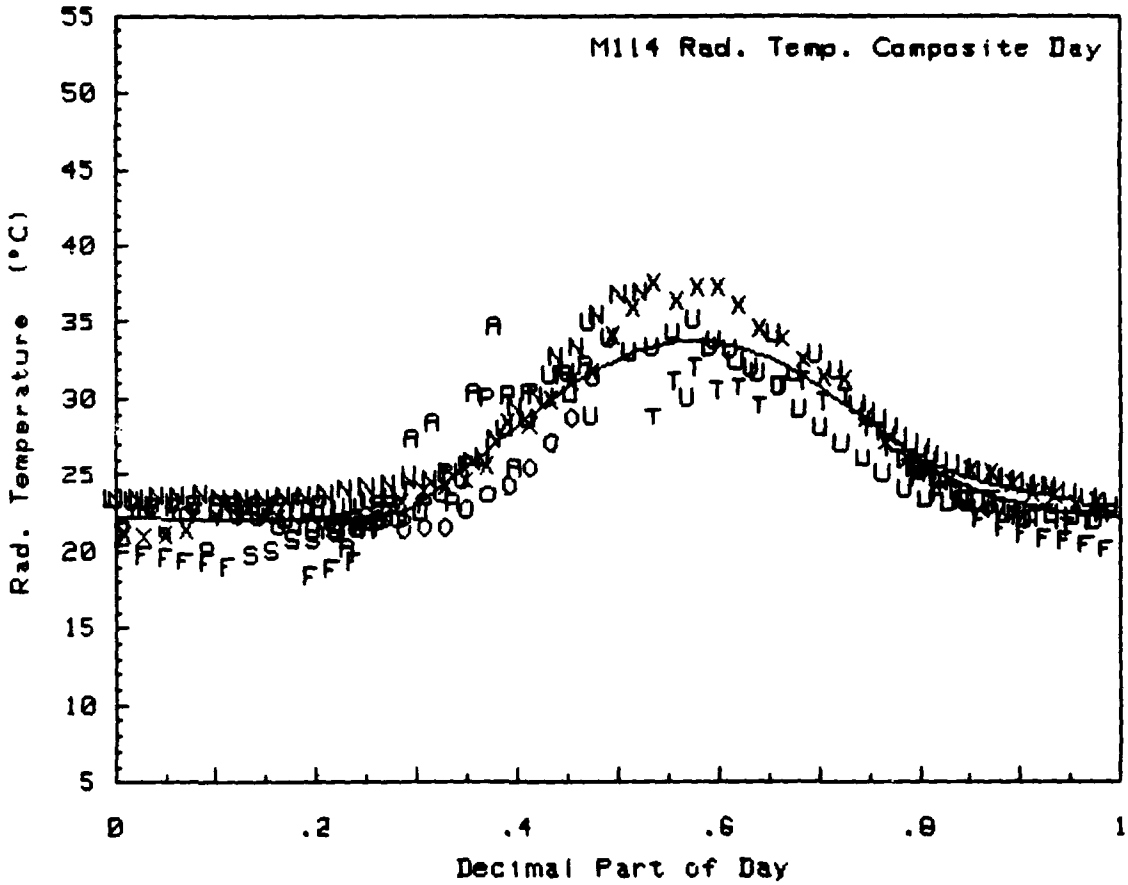

Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87



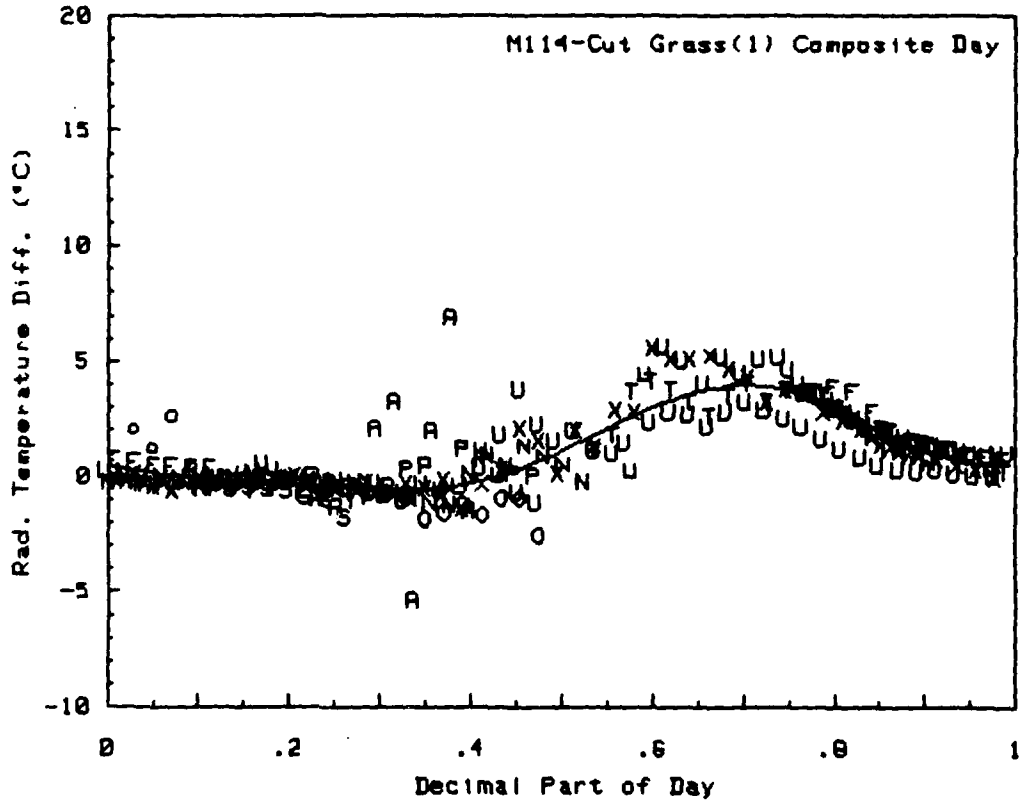

Summer Wet
Overcast
1984-5 Composite
Records 1-298
1/14/87



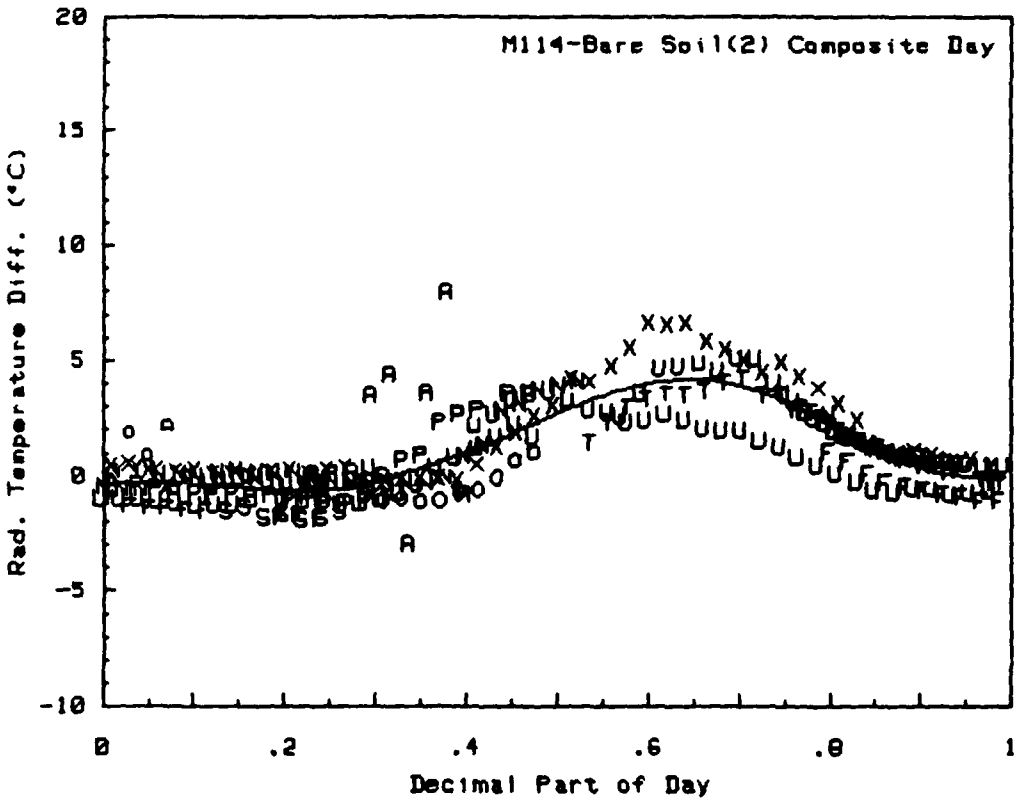

Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87



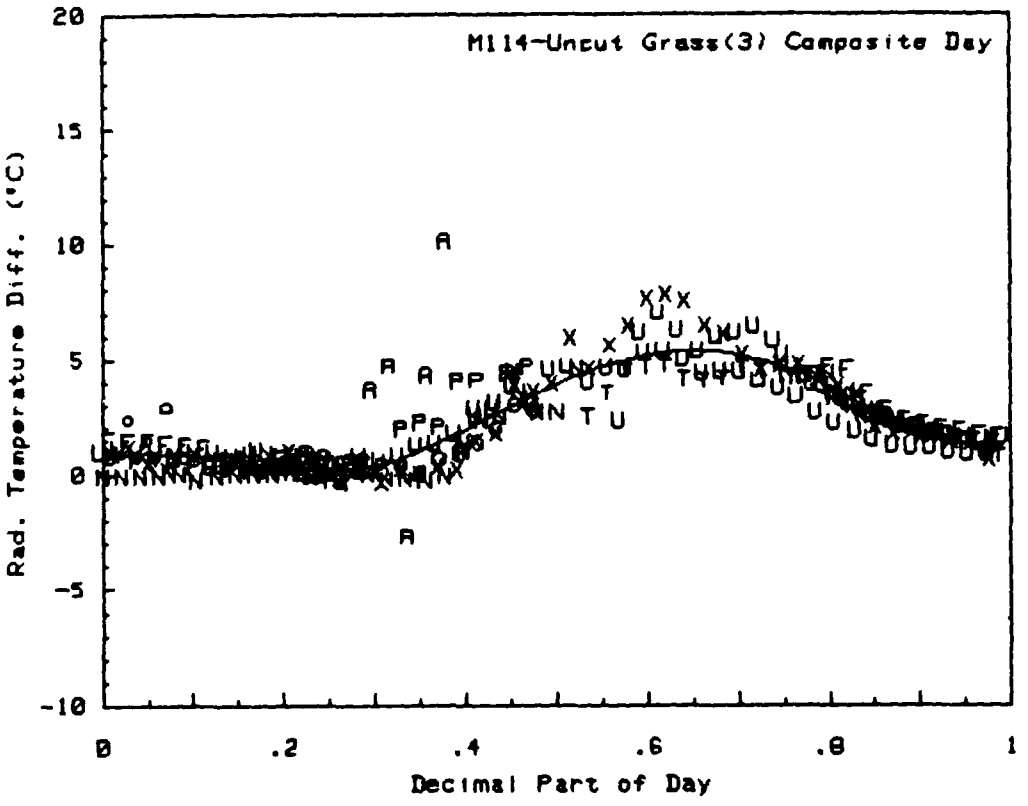

Summer Wet Overcast
1984-85 Composite: Records 1-290



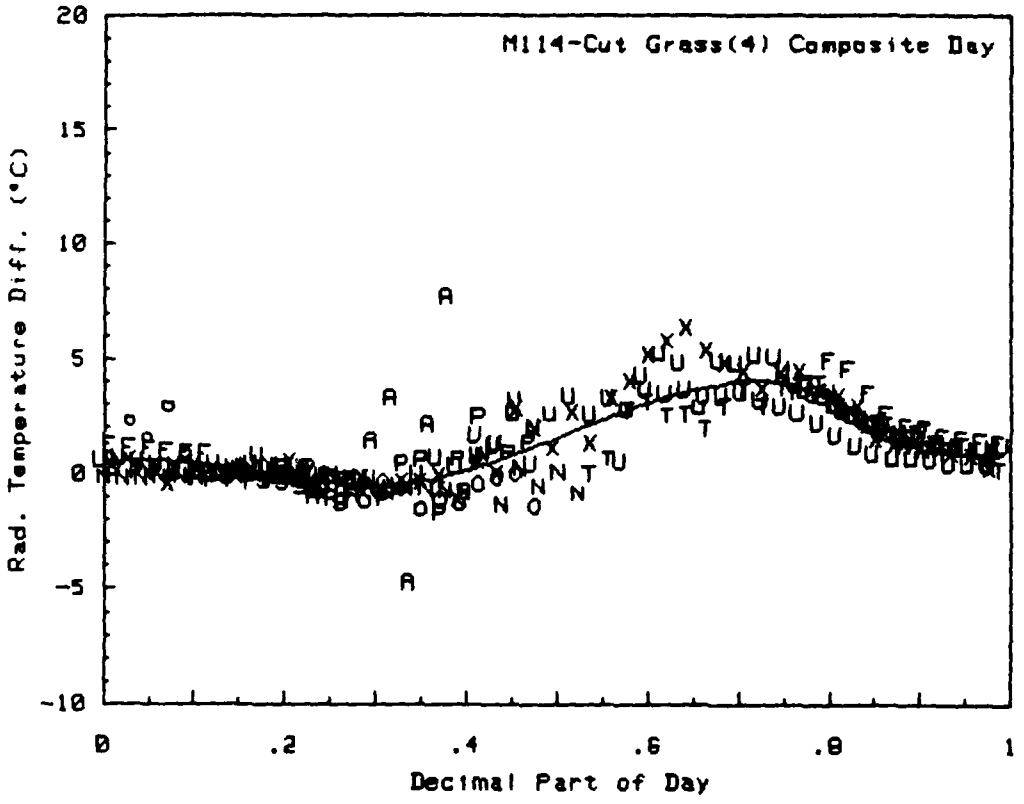

Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87



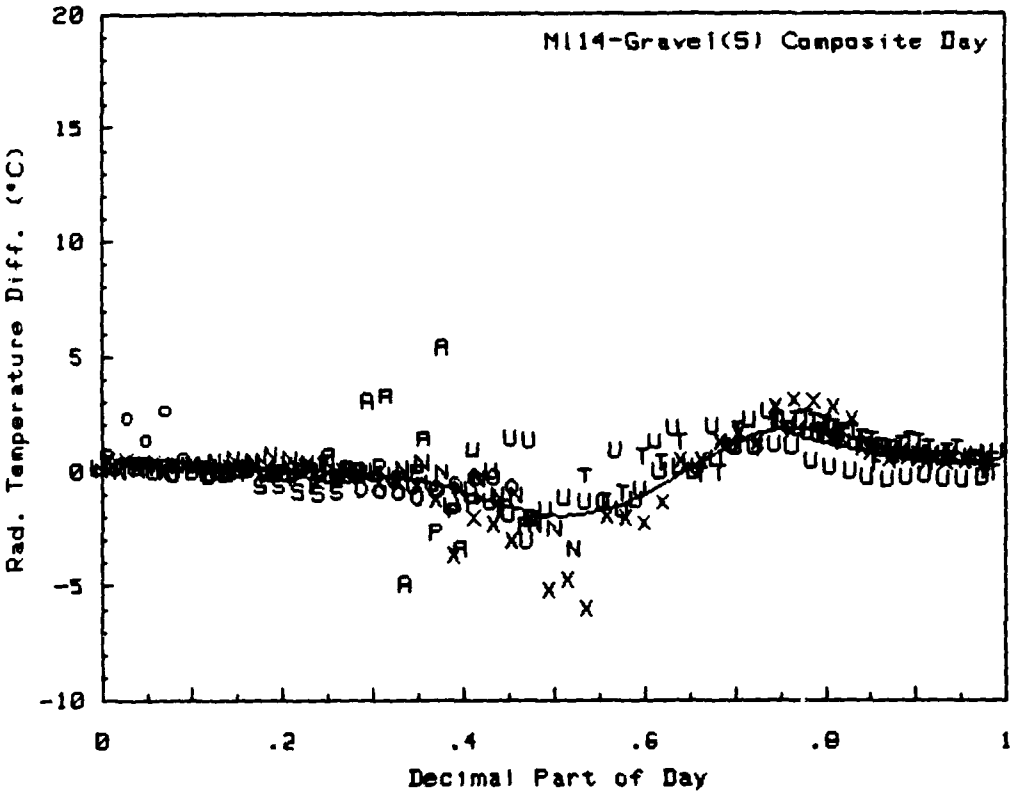

Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87




Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87




Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87

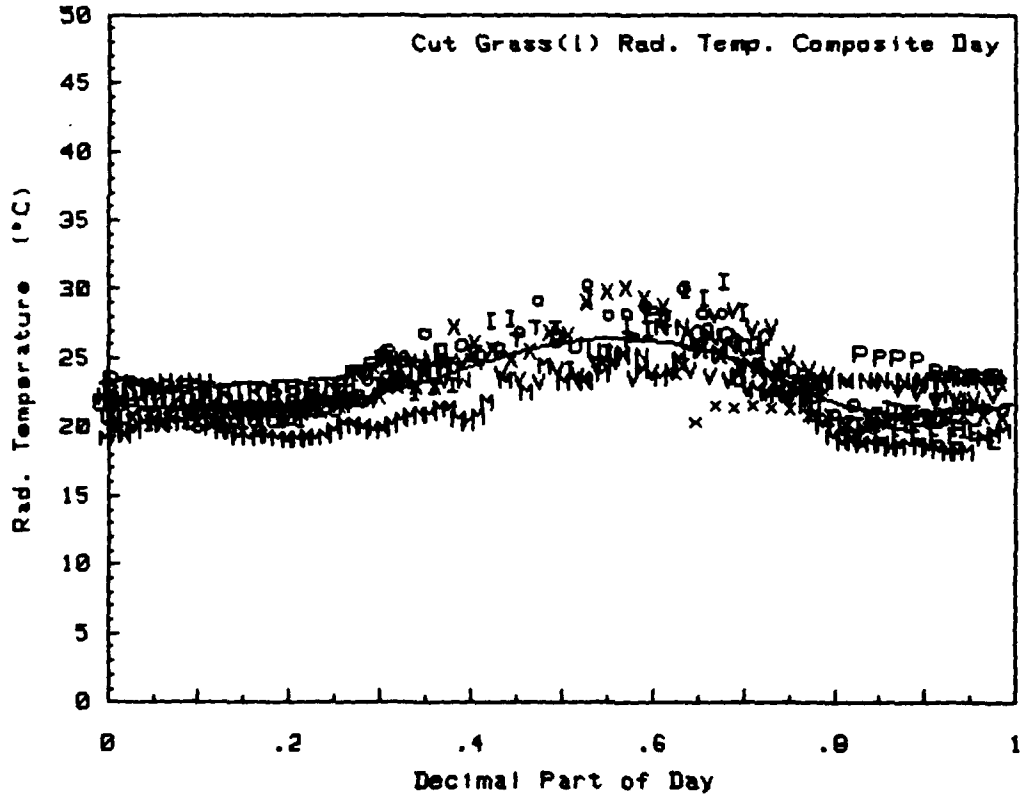



Summer Wet
Overcast
1984-5 Composite
Records 1-290
1/14/87

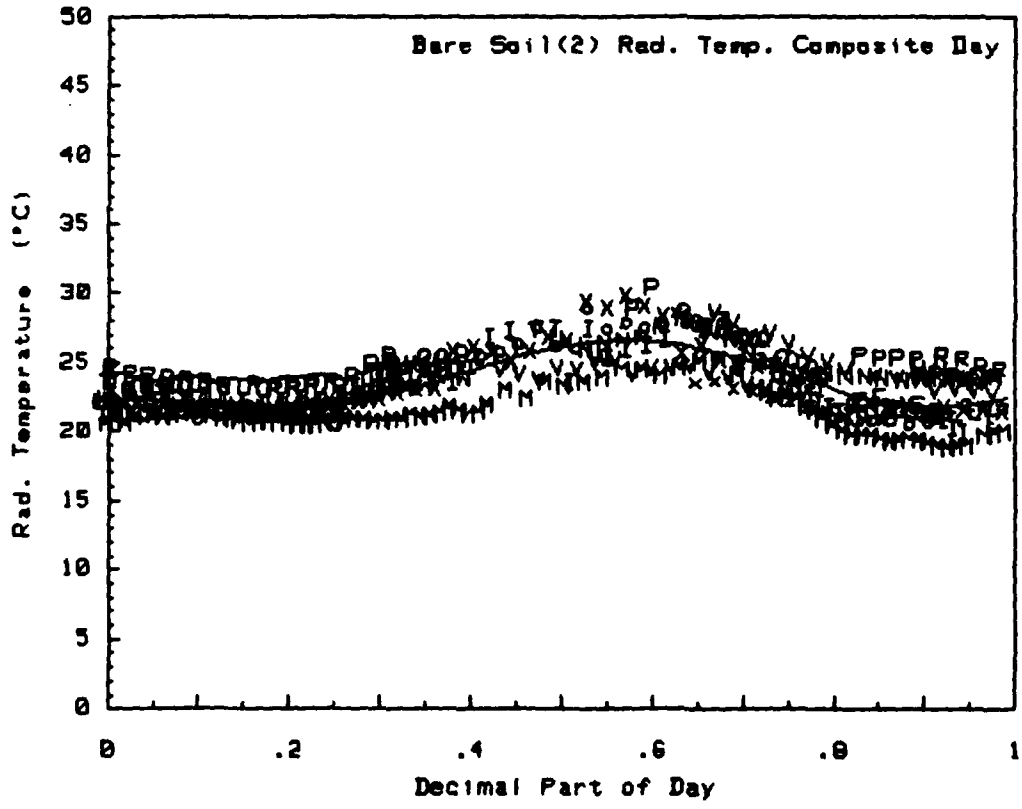
## OVERCAST SKY: SUMMER: RAINING: WET SURFACE SOIL

**Diurnal Plots of All Backgrounds and Differences**

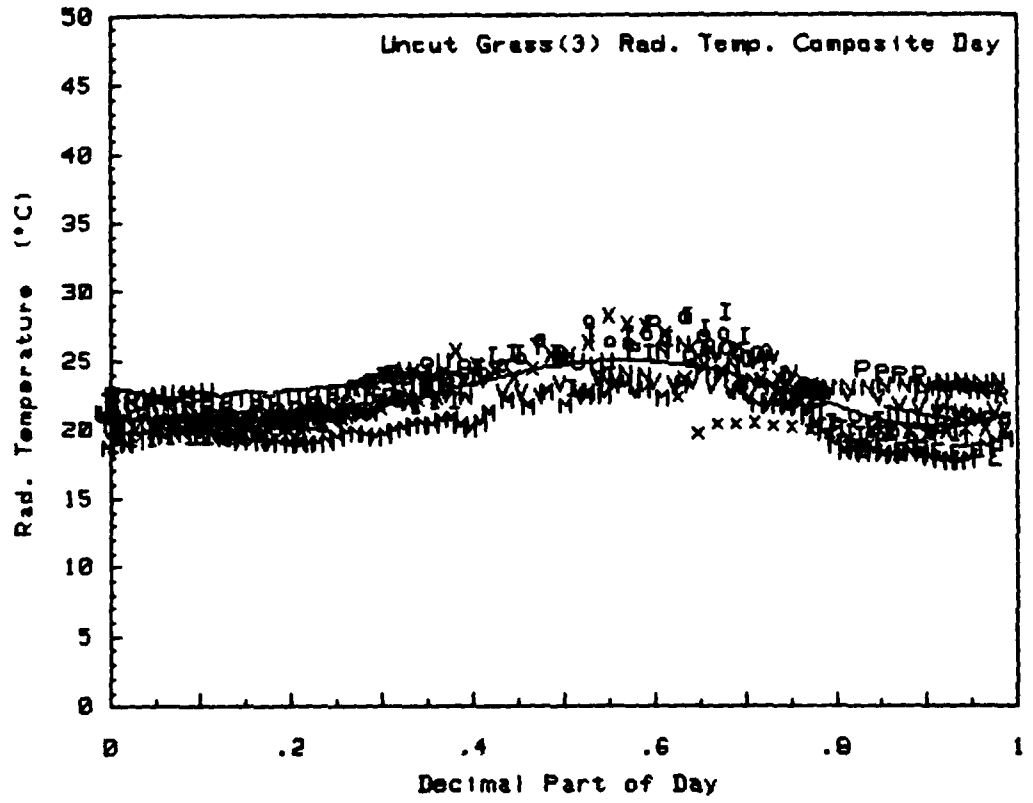
**with Regression Curves**



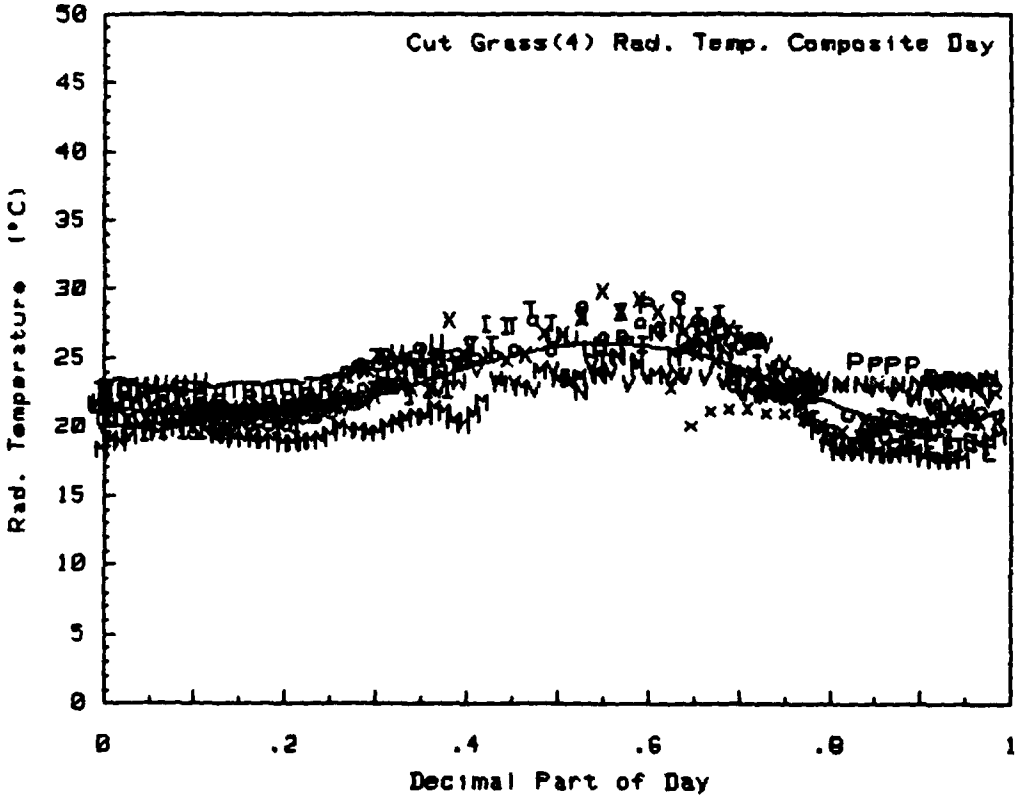

Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87



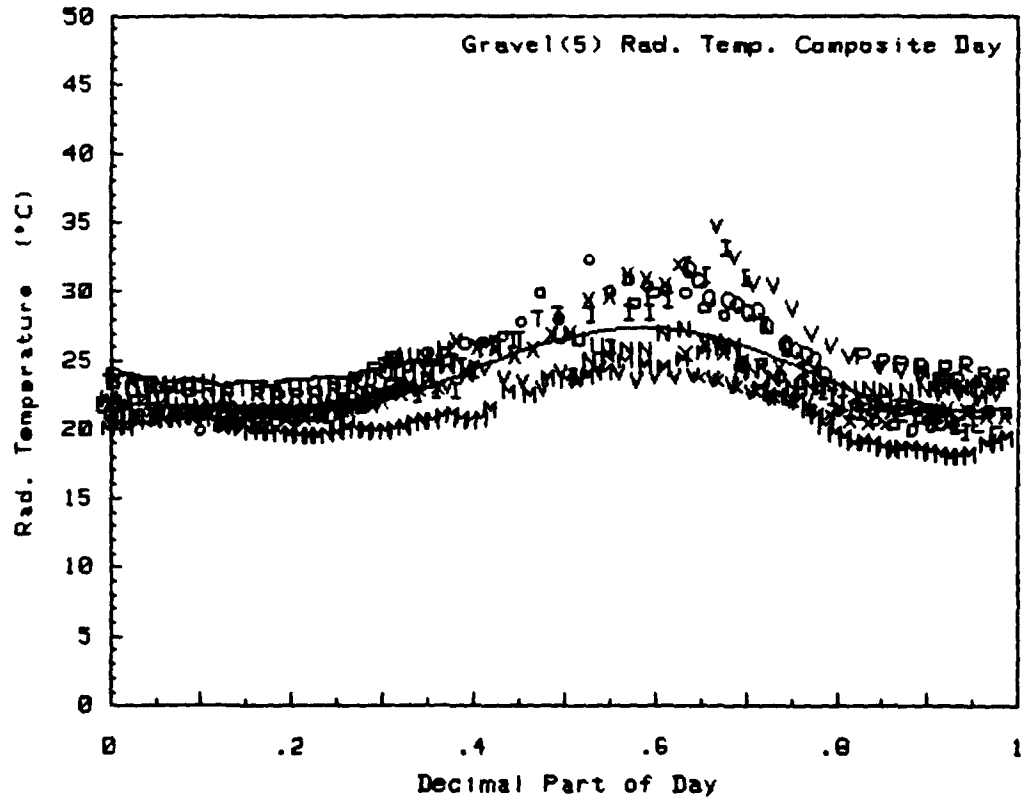

Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87



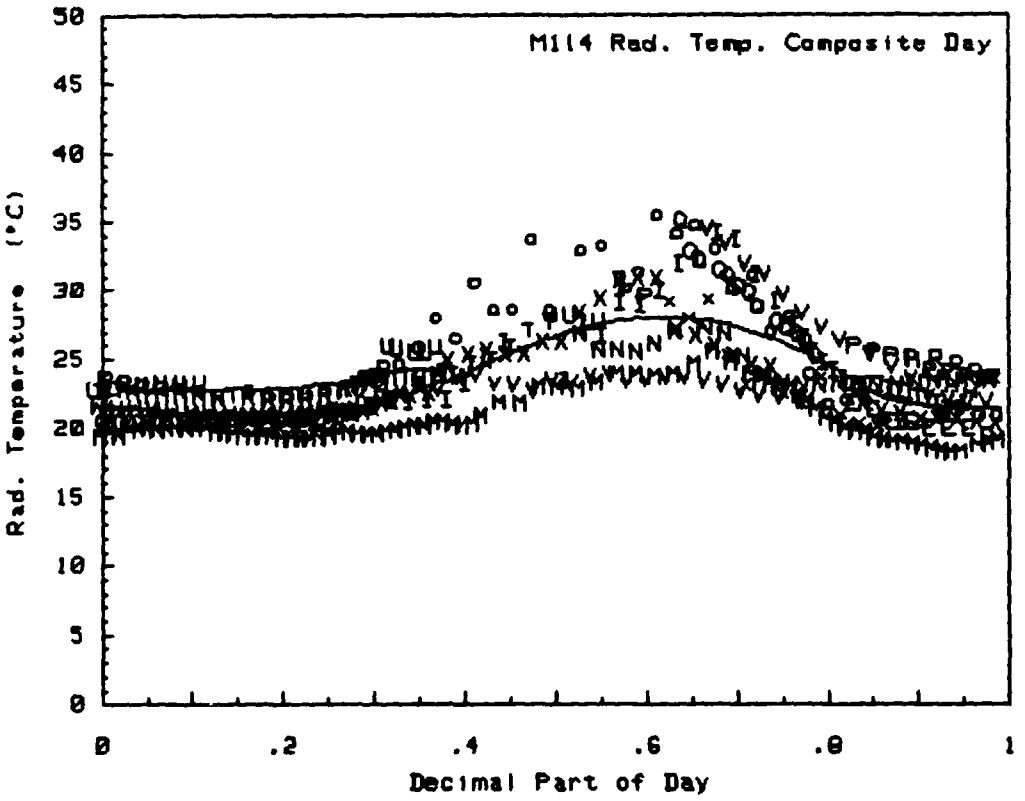

Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87



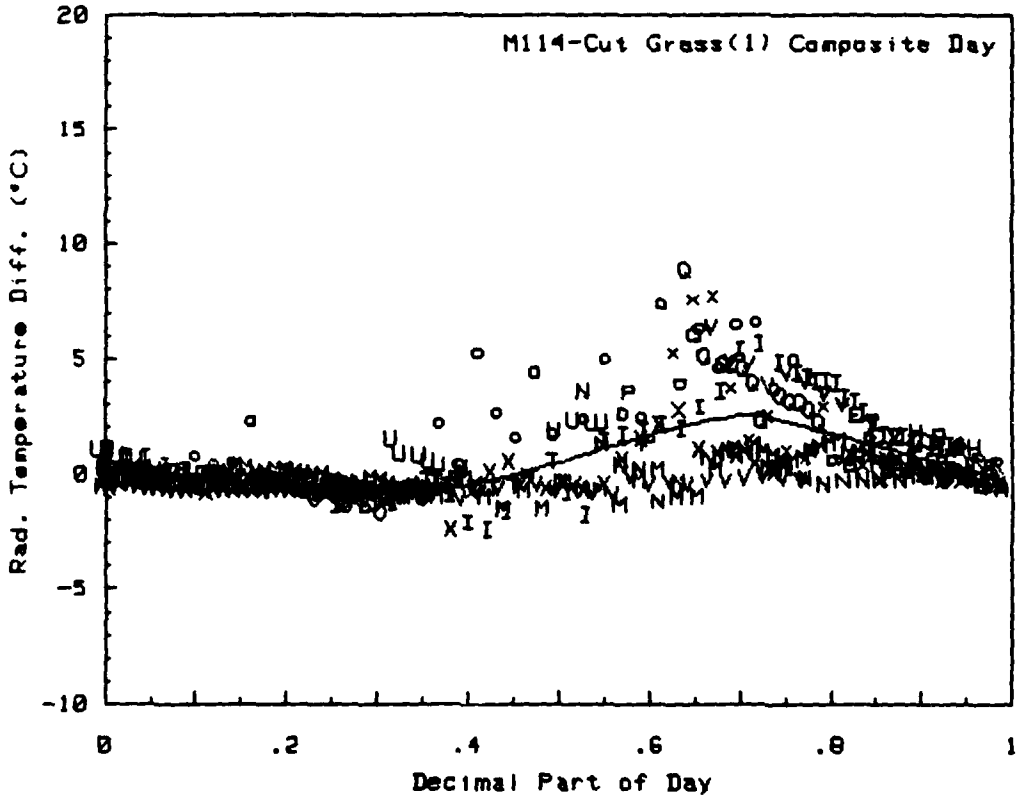

Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87



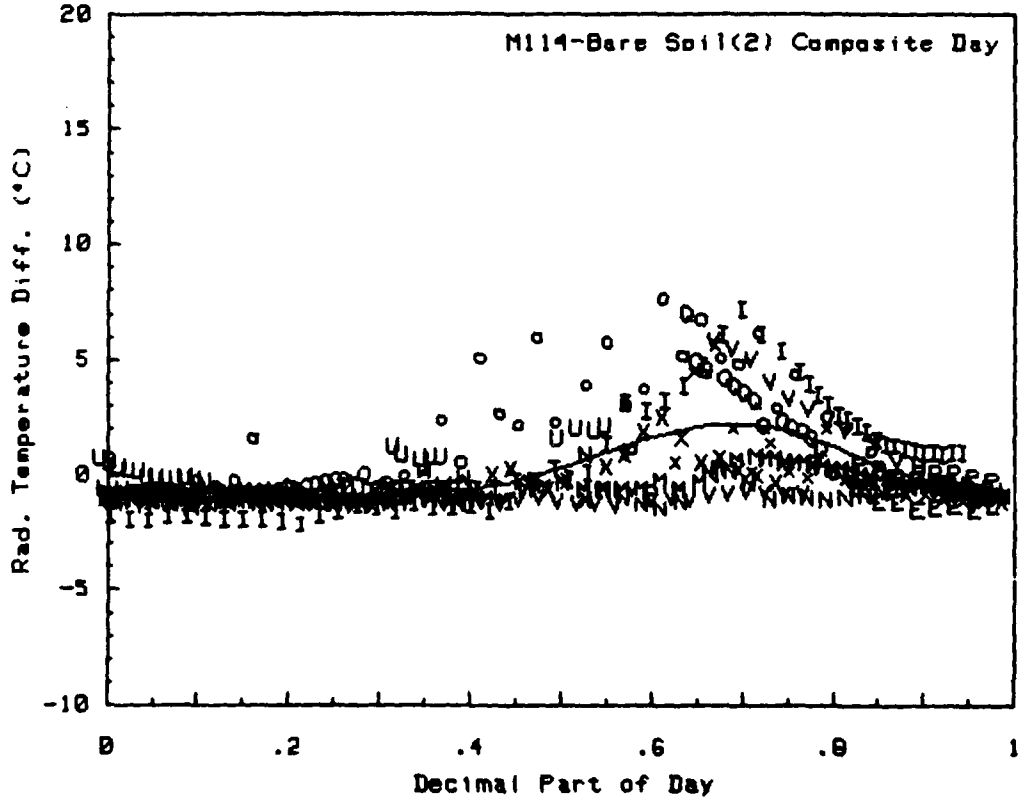

Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87



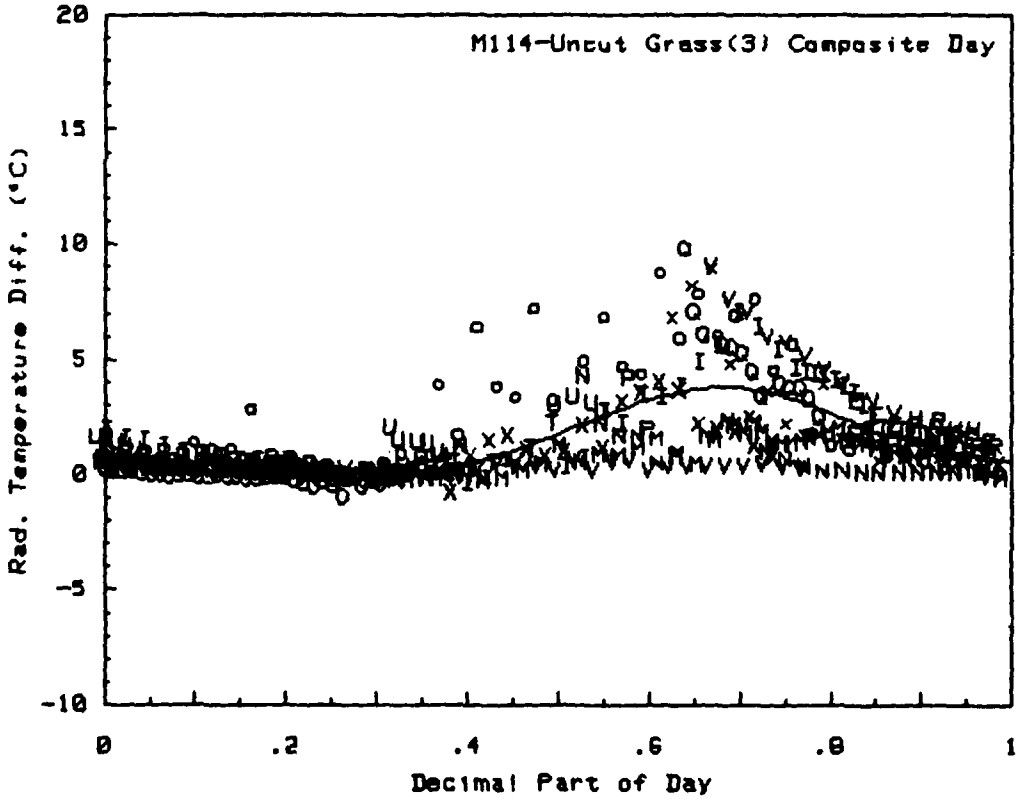

Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87



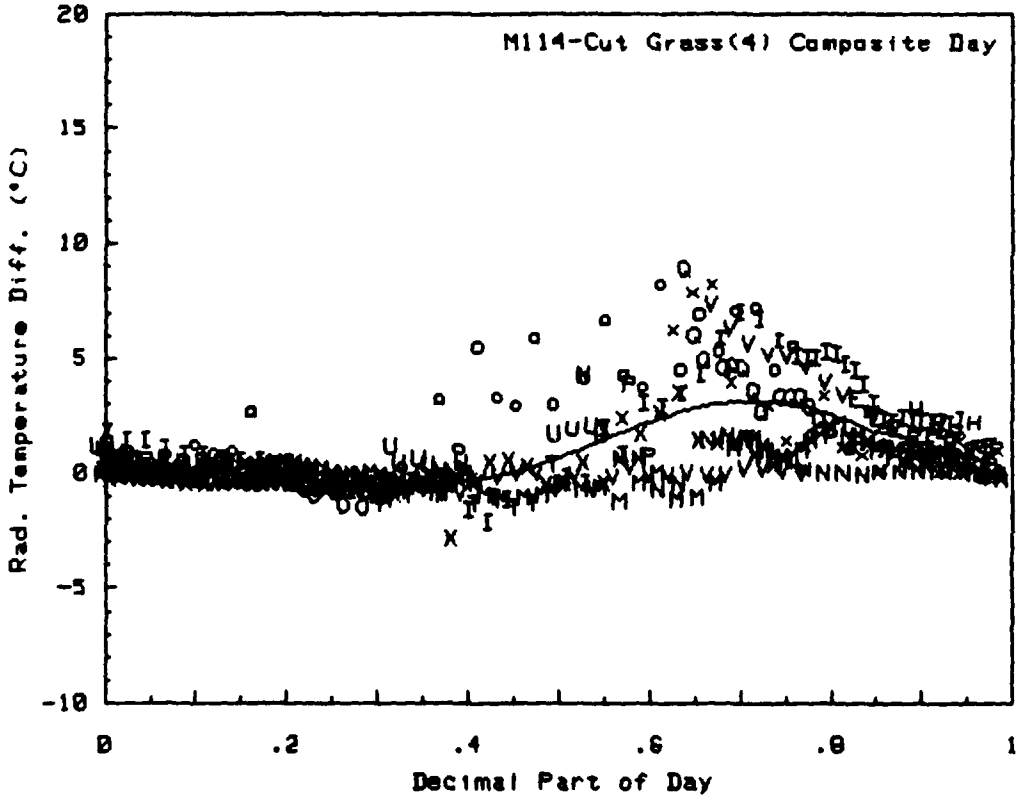

Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87



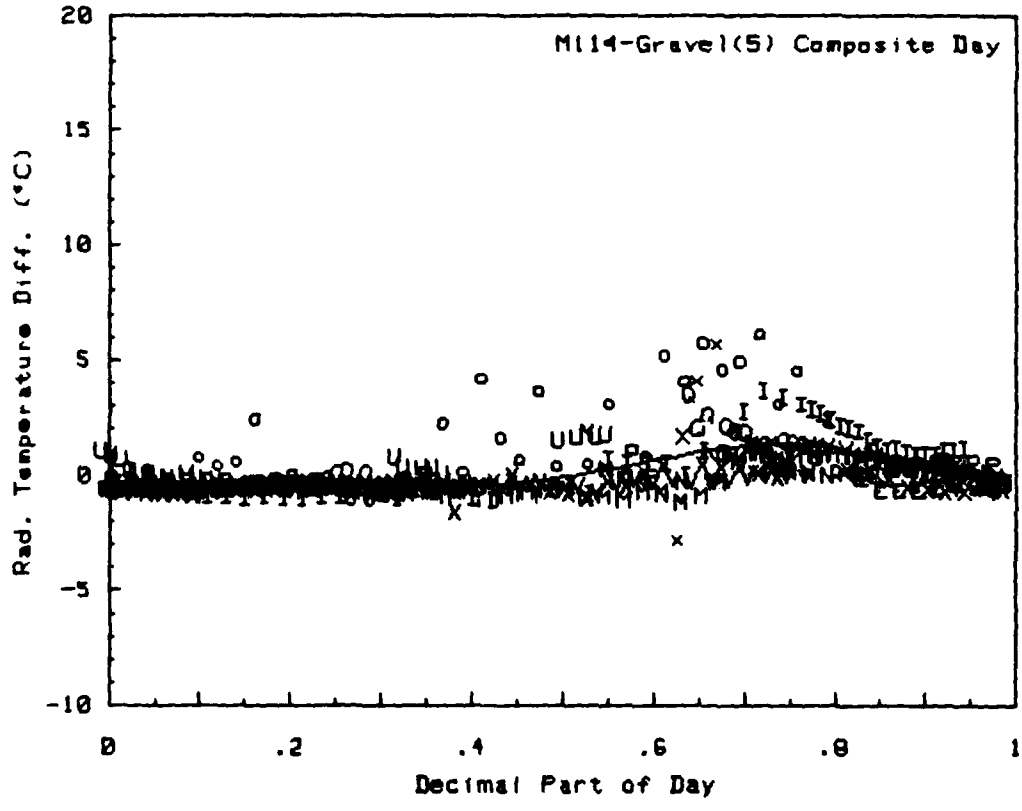

Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87




Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87




Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87




Summer Rain
Overcast
1984-5 Composite
Records 1-469
1/14/87