MMR Ground Data (FIFE)

Summary:

Surface reflectance factors, radiances, and temperatures were measured with a Mast-borne Modular Multiband Radiometer (MMR), predominantly in the solar principal plane, with nadir and off-nadir, view-zenith angles. The MMR was mounted on a portable mast in order to achieve a spatial sampling at a variety of sites as well as within each site. The portable mast alignment varied from the solar principal plane, to the azimuthal plane aligned perpendicular to the principal plane and aligned with the satellite azimuthal plane. Measurements were periodically collected with the MMR over a barium sulfate reference panel. Measurements were typically coordinated with aircraft and/or satellite overpasses. Solar radiation data at or near the specific site should be used to screen possible times of variable cloud cover.

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1. Data Set Overview:

Data Set Identification:

MMR Ground Data (FIFE).
(Surface Reflectance Measured with a Mast-borne MMR).

Data Set Introduction:

The Surface Reflectance Measured with a Mast-borne MMR Data Set contains mast-borne MMR ground radiances and reflectances measurements in the 8 MMR bands.

Objective/Purpose:

The Surface Reflectance measurements made using an MMR during FIFE by Prof. Blaine Blad's team had five scientific objectives:

1. Characterize bi-directional reflectance factor distributions in the solar principal plane for a tall grass prairie.
2. Estimate surface albedo from bi-directional reflectance factor and radiance data.
3. Determine the variability of reflected and emitted fluxes in selected spectral wavebands as a function of topography, vegetative community and management practice.
4. Determine the influence of plant water status on surface reflectance factors.
5. Determine sun angle effects on radiation fluxes.

Summary of Parameters:

Mast-borne MMR ground radiances and reflectances measurements in the 8 MMR bands.

Discussion:

Surface reflectance factors, radiances, and temperatures were measured with a Barnes Model 12-1000 Modular Multiband Radiometer (MMR), predominantly in the solar principal plane, with nadir and off-nadir, view-zenith angles.

- 1987 - The MMR was mounted on a portable mast in order to achieve a spatial sampling at a variety of sites as well as within each site. A number of plots were identified at the sites varying from 8-27 depending on the site. Sites 8 (SITEGRID_ID = 3129-MMR) and 18 (SITEGRID_ID = 4439-MMR) each had a bare soil plot (PLOT_NUM 999). See the 1989 discussion for details on bare soil plots. The portable mast was predominantly aligned in the solar principal plane and occasionally in an azimuthal plane aligned perpendicular to the principal plane or aligned with the satellite azimuthal plane. Measurements were periodically collected with the MMR over a barium sulfate reference panel. Measurements were typically coordinated with aircraft and/or satellite overpasses. Solar radiation data at or near the specific site should be used to screen possible times of variable cloud cover.
- 1988 - The MMR was mounted on a portable mast in order to achieve a spatial and temporal sampling at site 811 (SITEGRID_ID = 4439-MMR). Four (4) plots were identified at the site. The portable mast was usually aligned in the solar principal plane. Measurements were periodically collected with the MMR over a halon reference panel. Measurements were occasionally coordinated with satellite overpasses. Solar radiation data at site 811 (SITEGRID_ID = 4439-MMR) should be used to screen possible times of variable cloud cover.

- 1989 - The MMR was mounted on a portable mast in order to achieve a spatial and temporal sampling at sites 906 (SITEGRID_ID = 2133-MMR), 916 (SITEGRID_ID = 4439-MMR), and 966 (SITEGRID_ID = 2437-MMR). At sites 906 (SITEGRID_ID = 2133-MMR) and 916 (SITEGRID_ID = 4439-MMR), six (6) plots were identified. One of the 6 plots, at each site, was a bare soil plot (PLOT_NUM 999) prepared with a weed trimmer that removed the surface vegetation but left the root systems intact. On days when measurements were not made the bare soil was covered with a plastic mulch that allowed moisture to penetrate the surface but hindered the regrowth of the vegetation. The portable mast was always aligned in the solar principal plane at the above sites. Measurements were periodically collected with the MMR on the portable mast over a halon panel. There was also another MMR mounted over the same panel collecting data at one minute intervals primarily to measure the incoming radiation for the helicopter's instrumentation. These data were used for the incoming radiation measurements on August 11, 1989 rather than the periodically collected measurements. Measurements were typically coordinated with aircraft and/or satellite overpasses. At site 966 (SITEGRID_ID = 2437-MMR), sixteen (16) plots were identified. One of these plots was a bare soil plot (PLOT_NUM 999) that was treated in the aforementioned manner. At this site the portable mast was aligned parallel to the aspect of each plot (i.e., north-south or east-west). Measurements were periodically collected with the MMR over the halon panel. On August 9, 1989 measurements of the panel were collected at one minute intervals by another MMR. Solar radiation data at or near the specific site should be used to screen possible times of variable cloud cover.

Related Data Sets:

- Surface Reflectance Measured with a Helicopter-borne MMR.
- Leaf Optical Properties from UNL.
- SE-590 Spectroradiometer Reflectance Factors from GSFC.
- SE-590 Reflectance Factors and Radiances from UNL.
- SE-590 Reflectance Factors and Radiances Measured from a Helicopter.
- SE-590 Leaf Level Spectral Observations from GSFC.
- Surface Temperature from UNL.
- Surface Temperature Measured at Multiple Angles.
- Surface Temperatures, Reflected and Emitted Radiation, and PAR from UNL.
- Incoming Longwave Radiation Data from UNL.
- Leaf Area Index and PAR Determined from UNL Light Bar Measurements.
- Indirect Leaf Area Index Obtained from the UNL Light Wand.
- Total Leaf Tissue Water Potential.
- Biophysical Properties of Vegetation.
- Vegetation Species and Cover Abundance.
- UNL Topography of Plots information in the GRABBAG (i.e., UNL_Plot.T87, UNL_Plot.T88, and UNL_Plot.T89). (Imagery)

FIS Data Base Table Name:

MMR_GROUND_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Blaine L. Blad, Professor and Head
Elizabeth A. Walter-Shea, Asst. Professor
University of Nebraska

Title of Investigation:

Measuring and Modeling Near-Surface Reflected and Emitted Radiation Fluxes at the FIFE Site.

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Requested Form of Acknowledgment.

The Surface Reflectance Measured with a Mast-borne MMR data were collected by B.L. Blad, E.A. Walter-Shea, C.J. Hays, and M.A. Mesarch of the University of Nebraska. Their contribution of these data is particularly appreciated.

3. Theory of Measurements:

Light radiation striking a vegetative canopy interacts with individual phytoelements (leaves, stems, branches) and the underlying substrate. The interaction depends on light quality, radiative form (direct or diffuse), illumination incidence angle, vegetative component optical properties and canopy architecture. Radiation is reflected, transmitted or absorbed. Researchers have shown that phytoelements and substrates are not perfect Lambertian reflectors, i.e., they do not reflect equally in all directions (Breece and Holmes 1971; Walter-Shea et al., 1989; Brakke et al., 1989;

Irons et al., 1989). The amount of leaf area and leaf angle distribution will determine the amount of vegetation and substrate that is sunlit and shaded. The amount of vegetative and substrate and respective amounts of sunlit and shaded components in a scene will vary depending upon the angle at which it is viewed, i.e., the canopy is itself a non-Lambertian surface. Thus, canopy, illumination and viewing geometry's are critical in determining the amount of reflected radiation received at the sensor. The measurements reported in the mast-borne MMR data set were predominantly made in the solar principal plane since the greatest variation in observed reflected radiation is expected to occur in that plane due to extremes in sunlit and shaded portions of the canopy (Norman and Walthall 1985).

Reflected radiation measurements were converted to radiances and reflectance factor. The reflectance factor is the ratio of the target reflected radiant flux to an ideal radiant flux reflected by an ideal Lambertian standard surface irradiated in exactly the same way as the target. Reflected radiation from a field reference panel corrected for non-perfect reflectance and sun angle was used as an estimate of the ideal Lambertian standard surface (Walter-Shea and Biehl 1990).

Thermal radiant energy (**Rb**) is composed of an emitted component (**e * a * Ts**4**) and a reflected component [**(1 - e) ILW**]:

Rb = a * Tirt4 = e * a * Ts**4 + (1 - e) ILW**

where:

e = surface emissivity [unitless]
Ts = surface temperature [K]
ILW = incoming longwave radiation [W][m^-2]
a = Stefan-Boltzmann constant [W][m^-2][K^-4]
Tirt = temperature measurement from instrument [K]

4. Equipment:

Sensor/Instrument Description:

The Barnes Modular Multiband Radiometer (MMR) produces analog voltage responses to scene radiance in 8 spectral bands, and to the instrument chopper and detector temperatures. The 8 wavebands are approximately 0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90, 1.15-1.30, 1.55-1.75, 2.08-2.35, and 10.4-12.5 um. Wavebands 1 - 4 have silicon detectors, wavebands 5 - 7 have lead sulfide detectors and waveband 8 has a Lithium Tantalum trioxide detector. The MMR's dimensions are 26.4 cm by 20.5 cm by 22.2 cm and weighs 6.4 kg.

In 1987 3 MMRs were used. The serial numbers and dates when they were used are:

- SN 128 for May 30 - July 15.
- SN 103 for August 7 - August 20.
- SN 111 for October 7.

- SN 103 for October 9 - October 13.

In 1988 SN 108 was used.
In 1989 SN 114 was used.

Collection Environment:

Ground-based.

Source/Platform:

A portable, pointable mast.

Source/Platform Mission Objectives:

Not applicable.

Key Variables:

Surface radiances and reflectance factors in 8 wavebands (0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90, 1.15-1.30, 1.55-1.75, 2.08-2.35 um), surface temperature in one waveband (10.4-12.5 um).

Principles of Operation:

The MMR is a multi-sensor optical device operating in the visible, near infrared, middle infrared and thermal wavelengths. A mechanical chopper is used and the temperatures of the sensors and the chopper are monitored and stored with each 8-channel observation. Analog voltages from each sensor, detector thermistor, and chopper thermistor are converted to digital numbers and stored in the data logger. The MMR was mounted 3.4 m above the soil surface on a portable, pointable mast which allowed the MMR to view approximately the same surface area, regardless of the view zenith angle.

Sensor/Instrument Measurement Geometry:

The MMR was mounted on a portable, pointable mast. The mast allowed the MMR to view approximately the same surface area, regardless of the view zenith angle. The MMR was located at 3.4 m above the soil surface with a 15 degree field-of-view and a spot size of approximately 0.75 m diameter at nadir. The filter characteristics of the MMR are described in the literature (Markham 1987).

Manufacturer of Sensor/Instrument:

Barnes Engineering Company
30 Commerce Road
Stamford, Connecticut 07904
(203) 348-5381

Calibration:

- 1987: Pre-season and post-season calibrations were supplemented by daily stability checks using a 30 cm integrating sphere (for the first 7 wavebands) and an Everest Model 1000 calibration source (for the thermal waveband). The optical and thermal detectors are known to be temperature sensitive. The calibration procedures and specifics can be found in Jackson et al., 1983; Markham 1987; and Markham et al., 1988.
- 1988: A post-season calibration was performed on the optical detectors using the same procedure as in 1987. The thermal detector did not function. No daily stability checks were performed.
- 1989: Daily stability checks were only performed during the IFC-5 period. The same basic procedures were performed as in 1987 with the following exceptions:
    1. The 30 cm integrating sphere, operated at two lamp intensities, and Everest Model 1000 calibration source were located in an environmental chamber (at the Kansas State Evapotranspiration Laboratory) that was kept at a near constant ambient temperature during the daily stability checks,
    2. Temperature sensitivity correction data for the optical detectors were only obtained when the chamber was not being used for stability checks (i.e., no pre-season and post-season calibrations were performed). The other calibration procedures were performed pre-season and post-season.

Specifications:

Not available at this revision.

Tolerance:

The absolute error in calibration is estimated to be approximately 5% in wavebands 1-4 and approximately 10% in wavebands 5 - 7 (Sellers et al., 1990). The error in the thermal waveband is + or - 0.5 degrees Centigrade (Markham 1987).

Frequency of Calibration:

Described above in the *Calibration Section*.

Other Calibration Information:

The MMR instruments used during FIFE showed good stability over the study period, changing a maximum of 5% between calibrations (Markham et al., 1988).

Changing the field-of-view changed the gains and offsets but did not change the temperature sensitivity coefficients.

1987 Calibration coefficients used for data reduction (Markham 1987):

	SN 103			
Waveband	Gain	Offset	Temperature	Temperature

			Sensitivity coefficient in degrees Centigrade (IFC1-IFC3)	Sensitivity coefficient in degrees Centrigrade (IFC-4)
1	0.00696	-0.0028	597.0	590.0
2	0.00726	-0.0043	-1067.0	-1780.0
3	0.00738	-0.0066	-695.0	-732.0
4	0.01014	-0.0066	325.0	334.0
5	0.02207	0.0038	-64.7	-65.5
6	0.06377	0.0155	-62.1	-62.7
7	0.14616	-0.0105	-63.8	-63.8

Gains in [Volts][Watts^-1][m^-2][sr^-1][um^-1]
Offsets in Volts
Reference Temperature 25.8 degrees Centigrade.

There are no coefficients for the Thermal waveband because of malfunction.

SN 111

Waveband	Gain	Offset	Temperature Sensitivity coefficient in degrees Centigrade (IFC1-IFC3)	Temperature Sensitivity coefficient in degrees Centigrade (IFC-4)
1	0.00676	-0.0022	11170.0	11530.0
2	0.00711	-0.0048	1108.0	1040.0
3	0.00778	-0.0083	-778.0	-810.0
4	0.01045	-0.0083	421.0	430.0
5	0.02612	0.0089	-73.8	-76.2
6	0.04901	0.0002	-71.0	-71.7
7	0.14986	-0.0074	-71.0	-72.4

Gains in [Volts][Watts^-1][m^-1][sr^-1][um^-1]
Offsets in Volts
Reference Temperature 25.5 degrees Centigrade.

Thermal waveband 8 coefficients

AC = 0.16091
BC = 14.508
AA = -0.83334E-03
AB = -0.50983E-06
KA = 0.41768E-03
KB = 0.24520E-06

Where AC and BC are calibration coefficients for the equation used to calculate the calibration corrected temperature (Tc), and AA, AB, KA and KB are the calibration coefficients for the equation used to calculate the surface radiance (Ls). All of these coefficients are unitless.

SN 128

Waveband	Gain	Offset	Temperature Sensitivity coefficient in degrees Centigrade (IFC1-IFC3)	Temperature Sensitivity coefficient in degrees Centigrade (IFC-4)
1	0.00692	0.0012	6768.0	2758.0
2	0.00715	-0.0013	779.0	639.0
3	0.00748	-0.0037	-837.0	-1144.0
4	0.01004	-0.0057	465.0	415.0
5	0.02314	0.0055	-70.3	-71.5
6	0.05439	0.0105	-70.4	-71.9
7	0.14673	-0.0019	-67.1	-67.7

Gains in [Volts][Watts^-1][m^-2][sr^-1][um^-1]
Offsets in Volts
Reference Temperature 25.5 degrees Centigrade.

Thermal waveband 8 coefficients

AC = 0.15173
BC = 13.727
AA = -0.93338E-03
AB = -0.38504E-05
KA = 0.43947E-03
KB = 0.19048E-05

Where AC and BC are calibration coefficients for the equation used to calculate the calibration corrected temperature (Tc), and AA, AB, KA and KB are the calibration coefficients for the equation used to calculate the surface radiance (Ls). All of these coefficients are unitless.

See the *Formulae Section* for details on calibration equations.

1988 Calibration coefficients use for data reduction (Markham 1988):

SN 108

Waveband	Gain	Offset	Temperature Sensitivity coefficient in degrees Centigrade
1	0.00503	-0.0022	860.0
2	0.00607	-0.0026	3460.0
3	0.00694	-0.0056	-961.0

4	0.00978	-0.0067	269.0
5	0.01967	0.0037	-68.5
6	0.04201	0.0298	-72.0
7	0.07451	0.0027	-70.7

Gains in [Volts][Watts^-1][m^-2][sr^-1][um^-1]
Offsets in Volts
Reference Temperature 27.0 degrees Centigrade.

There are no coefficients for the Thermal waveband because of malfunction.

See the *Formulae Section* for details on calibration equations.

1989 Calibration coefficients used for data reduction (Markham 1989):

SN 114

Waveband	Gain	Offset	Temperature Sensitivity coefficient in degrees Centigrade
1	0.00601	-0.0039	625.00
2	0.00689	-0.0039	1112.00
3	0.00712	-0.0042	-1486.00
4	0.01024	-0.0094	286.00
5	0.02048	0.0096	-74.40
6	0.04108	0.0322	-73.12
7	0.12229	0.0076	-70.24

Gains in [Volts][Watts^-1][m^-2][sr^-1][um^-1]
Offsets in Volts
Reference Temperature 28.5 degrees Centigrade.

Thermal waveband 8 coefficients AC = 0.1296
BC = 14.42
AA = -0.75249E-03
AB = -0.43519E-05
KA = 0.39019E-03
KB = 0.19078E-05

Where AC and BC are calibration coefficients for the equation used to calculate the calibration corrected temperature (Tc), and AA, AB, KA and KB are the calibration coefficients for the equation used to calculate the surface radiance (Ls). All of these coefficients are unitless.

See the *Formulae Section* for details on calibration equations.

5. Data Acquisition Methods:

In 1987 the MMR was mounted on a pointable, portable mast at a height of 3.4 m above the soil surface. The mast allowed the sensor to view the same surface area regardless of the viewing direction. A reference panel was positioned at a height of approximately 1 m above the soil surface. This panel was located within easy access to our plots and was measured to estimate the incoming radiation needed for data reduction. A measurement of the reference panel was made at the beginning of the measurement period. The mast was then positioned within the plot and aligned in the solar principal plane or the desired plane. Measurements were usually made at nadir and at 20, 35 and 50 degree view-zenith angles at each view-azimuth angle (occasionally 30 degrees was substituted for the 35 degree view-zenith angle). The angles were measured by an inclinometer mounted on the mast. The mast was then moved from plot to plot. After 20 to 25 minutes another measurement of the reference panel was made and the above procedure was repeated ending with a measurement of the reference panel. During IFC-1 in 1987 only one replication at each view zenith angle was recorded. Afterwards three replications were made (Blad et al., 1990).

In 1988 measurements were usually made in the solar principal plane and the view zenith angles were at nadir and 20, 35 and 50 degrees at each view azimuth angle. Three replications at each view zenith angle were recorded. Unless otherwise noted, the same procedure as in 1987 was followed.

In 1989 at sites 906 (SITEGRID_ID = 2133-MMR) and 916 (SITEGRID_ID = 4439-MMR) measurements were always made in the solar principal plane and the view-zenith angles were nadir and 20, 35 and 50 degrees at each view azimuth angle. Three replications at each view zenith angle were recorded. At site 966 (SITEGRID_ID = 2437-MMR) the measurements were made parallel to the aspect of the plot (i.e. north-south or east-west). In addition to the view-zenith angles measured at sites 906 (SITEGRID_ID = 2133-MMR) and 916 (SITEGRID_ID = 4439-MMR) a view zenith angle perpendicular to the slope of the plot was added at the appropriate view azimuth angle. The reference panel was measured periodically with the MMR mounted on the pointable mast, and at one minute intervals with a different MMR. The 1-minute data were primarily for the use of helicopter's radiometers but was also used as estimates of the incoming radiation for our data reduction on August 9 and 11. Unless otherwise noted, the same procedure as in 1987 and 1988 was followed.

All view-zenith angles were measured with respect to gravity not in relation to the slope of the plot.

6. Observations:

Data Notes:

Not available.

Field Notes:

1987:

- June 3 Site 40 (1246-MMR) clear skies, measurement period: 2007-2059 GMT.
- June 4 Site 8 (3129-MMR) clear skies, measurement periods: 1344-1417, 1443-1515, 1544-1610, 1810-1859, 1951-2047, 2055-2147 GMT.
- June 5 Site 18 (4439-MMR) clear skies, measurement periods: 1534-1731, 1746- 1835 GMT. Site 32 (4268-MMR) clear skies, measurement period: 2035-2118 GMT.
- June 6 Site 26(8739-MMR) clear skies, measurement period: 1719-1757 GMT. Site 5 (2123-MMR) slight haze, measurement period: 2111-2135 GMT.
- June 16 Site 42 (1445-MMR) no notes.
- June 26 Site 18 (4439-MMR) clear skies, measurement periods: 1506-1611, 1724-1751, 1810-1838, 1848-1911 GMT. Site 26 (8739-MMR) clear skies then clouds moved in, measurement period 2023-2038 GMT.
- June 27 Site 26 (8739-MMR) clouds moved in measurements aborted, measurement period: 1750-1753 GMT.
- June 28 Site 32 (4268-MMR) clear skies, measurement period: 2000-2104 GMT.
- July 1 Site 26 (8739-MMR) cumulus, measurement periods: 1525-1559, 1723- 1801 GMT.
- July 6 Site 5 (2123-MMR) increasing haze measurements aborted, measurement periods: 1439-1513, 1612-1703, 1752-1809 GMT.
- July 10 Site 28 (6943-MMR) variable haze, measurement periods: 1401-1436, 1441-1515 GMT.
- July 11 Site 18 (4439-MMR) slight haze, measurement periods: 1418-1518, 1546-1609 GMT. Site 42 (1445-MMR) clear skies, measurement period: 1719-1805 GMT. Site 40 (1246-MMR) some haze and cirrus, measurement period: 2006- 2047 GMT.
- July 14 Site 42 (1445-MMR) some cirrus, measurement period: 1546-1705 GMT. Site 5 clear skies, measurement period: 2023-2104 GMT.
- July 15 Site 170 (0939-MMR) clear skies, measurement period: 1715-2113 GMT.
- Aug. 7 Site 18 (4439-MMR) slight haze, measurement period: 1726-1844 GMT. Site 28 (6943-MMR) slight haze, measurement period: 2018-2058 GMT.
- Aug. 10 Site 32 (4268-MMR) measurements aborted due to cirrus, measurement period: 1414-1432 GMT. Site 26 (8739-MMR) slight haze, measurement period: 1738-1810 GMT. Site 32 (4268-MMR) cumulus, very dry conditions, measurement period: 2051-2203 GMT.
- Aug. 11 Site 40 (1246-MMR) clear skies, measurement period: 1355-1430 GMT. Site 42 (1445-MMR) slight haze, measurement period: 1727-1809 GMT.
- Aug. 15 Site 18 (4439-MMR) clear skies, measurement periods: 1444-1526, 1621-1715 GMT. Site 28 (6943-MMR) clear skies, measurement periods: 1846-1917, 2006-2046 GMT.
- Aug. 16 Site 26 (8739-MMR) slight haze, measurement period: 1617-1653 GMT. Site 29(0847-MMR) clear skies, measurement period: 2014-1046 GMT.
- Aug. 17 Site 18 (4439-MMR) clear skies, measurement period: 1719-1843 GMT. Site 32 (4268-MMR) clear skies, measurement period: 2019-2058 GMT.
- Aug. 19 Site 170 (0939-MMR) measurements aborted due to clouds, measurement periods: 1628-1701, 1947-2025 GMT.
- Aug. 20 Site 29 (0847-MMR) clear skies, measurement period: 1354-1430 GMT. Site 42 (1445-MMR) clear skies, measurement periods: 1551-1632, 1720-1759 GMT. Site 40

(1246-MMR) measurements aborted due to clouds, measurement period: 2114-2140 GMT.

- Oct. 7 Site 18 (4439-MMR) cirrus and haze, measurement periods: 1726- 1754, 2048-2152 GMT.
- Oct. 9 Site 40 (1246-MMR) cumulus and cirrus, measurement period: 2016-2116 GMT.
- Oct. 11 Site 29 (0847-MMR) clouds on horizon, measurement period: 1520-1552 GMT. Site 42 (1445-MMR) clear skies, measurement period: 2004-2042 GMT.
- Oct. 12 Site 28 (6943-MMR) clear skies, contrails, measurement period: 1446- 1523 GMT. Site 40 (1246-MMR) cirrus and contrails, measurement period: 1803- 1836 GMT. Site 18 (4439-MMR) cirrus, measurement period: 2118-2148 GMT.
- Oct. 13 Site 32 (4268-MMR) cirrus, measurement period: 1426-1519 GMT. Site 18 (4439-MMR) cirrus, measurement period: 1738-1755 GMT.

1988 (all data collected at Site 811(4439-PAM)):

- May 24 Hazy skies, measurement period: 1830-1920 GMT.
- May 25 Haze near end of measurements, measurement period: 1808-1855 GMT.
- May 27 Clear skies during the first two measurement periods, hazy skies for the last three measurement periods, measurement periods: 1506-1549, 1624-1704, 1803-1843, 1911-2011, and 2049-2122 GMT.
- June 28 Clear skies, measurement period: 1535-1634 GMT.
- July 12 Cumulus developing near sun at end of measurement period: 1502-1548 GMT.
- July 13 Clear skies, measurement periods: 1546-1635, 1748-1835, 1921- 2006, 2112-2155 GMT.
- Aug. 11 Clear skies for first two measurement periods, cumulus developing during last 3 measurement periods, cumulus interfering with the sun during the last measurement period, measurement periods: 1418-1506, 1545-1629, 1825-1926, 2018- 2058, 2133-2212 GMT.

1989:

- June 15 Site 966 (2437-MMR), few cumulus clouds near sun for first measurement period: then clear skies, measurement periods: 1500- 1600, 1730- 1930, and 2100-2230 GMT.
- July 14 Site 966 (2437-MMR), clear skies for first measurement period, cumulus aborted second measurement period, measurement periods: 1430-1530 and 1600-1620 GMT.
- July 26 Site 916 (4439-MMR), few clouds on horizon, measurement periods: 1400-1425 and 1425-1455 GMT.
- July 27 Site 916(4439-MMR), cumulus clouds, measurement period: 1430-1530 GMT.
- July 28 Site 916 (4439-MMR) clear skies except for cumulus during last measurement period, measurement periods: 1400-1430, 1500-1530, 1630-1715, 1800-1900 GMT.
- Aug. 4 Site 916 (4439-MMR), clear skies, measurement periods: 1400-1500, 1700-1800, 1930-2000 GMT.
- Aug. 6 Site 906 (2133-MMR), clear skies, measurement periods: 1430-1500, 1600-1630, 1800-1840, 1930-2000, 2045-2100 GMT.

- Aug. 7 Site 906 (2133-MMR), cumulus during first measurement period, then clear skies, measurement periods: 1730-1300 and 1930-2000 GMT.
- Aug. 8 Site 916 (4439-MMR), clear skies, measurement periods: 1415-1510, 1620-1745, 2010-2030, 2110-2135 GMT.
- Aug. 9 Site 966 (2437-MMR), clear skies for first measurement period, then cumulus, measurement periods: 1530-1630 and 1730-1840 GMT.
- Aug. 11 Site 916 (4439-MMR), lots of cumulus clouds, measurement period: 2150-2230 GMT.

7. Data Description:

Spatial Characteristics:

The FIFE study area, with areal extent of 15 km by 15 km, is located south of the Tuttle Reservoir and Kansas River, and about 10 km from Manhattan, Kansas, USA. The northwest corner of the area has UTM coordinates of 4,334,000 Northing and 705,000 Easting in UTM Zone 14.

Spatial Coverage:

Measurements were made at the following twelve locations scattered throughout the FIFE study area. However, most sites were located in the northwest quadrant of the study area.

SITEGRID	STN	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEV
0847-MMR	29	4332344	714439	39 06 57	-96 31 11	418
0939-MMR	170	4332200	712750	39 06 54	-96 32 22	
1246-MMR	40	4331666	714212	39 06 35	-96 31 21	365
1445-MMR	42	4331160	714090	39 06 19	-96 31 27	400
2123-MMR	5	4329866	709506	39 05 41	-96 34 39	405
2133-MMR	906	4329726	711604	39 05 34	-96 33 12	443
2437-MMR	966	4329150	712375	39 05 15	-96 32 41	
3129-MMR	8	4327702	710711	39 04 30	-96 33 51	430
4268-MMR	32	4325626	718579	39 03 15	-96 28 27	445
4439-MMR	18	4325218	712792	39 03 07	-96 32 28	445
4439-MMR	916	4325193	712773	39 03 06	-96 32 28	443
4439-MMR	811	4325219	712795	39 03 07	-96 32 27	445
6943-MMR	28	4320147	713500	39 00 22	-96 32 04	415
8739-MMR	26	4316699	712845	38 58 31	-96 32 35	442

SITEGRID	SLOPE	ASPECT
0847-MMR	1	TOP
0939-MMR		
1246-MMR		
1445-MMR		
2123-MMR	1	TOP
2133-MMR	1	TOP
2437-MMR		
3129-MMR		
4268-MMR		
4439-MMR		
4439-MMR	2	N
4439-MMR	2	N
6943-MMR		

In 1987 and 1988 measurement plots generally encircled the AMS station located at that site. In 1989 measurements plots were located northeast of the Wind Aligned Blob (WAB) site (Sellers et al., 1989). Topography files containing the northing and easting of the plots at each site, except for site 18 (SITEGRID_ID=4439-MMR) and 170 (SITEGRID_ID = 0939-MMR) in 1987 and site 966 (SITEGRID_ID = 2437-MMR) in 1989, are available in the GRABBAG section of FIFE CD-ROM Volume 1 in the UNL directory, in files UNL_PLOT.T87, UNL_PLOT.T88, UNL_PLOT.T89. These files also include the slope, aspect, soil depth, species and vegetative height of the plots.

Spatial Coverage Map:

Not available.

Spatial Resolution:

The footprint (surface area viewed by the MMR) had a diameter of 0.75 m at nadir and changed with view-zenith angle. The plot size was approximately 3 m x 3 m.

6.3 Temporal Characteristics.

The overall coverage for these data is from June 3, 1987 through August 11, 1989. During this period there are 46 days of data. In 1987 there are 27 days of data during the growing season (June 3-October 13). Measurements in 1988 were made on seven days from May 24-August 11. Finally in 1989, measurements were made on twelve days from June 15-August 11.

- 1987 and 1988: The reference panel was measured every 20 to 25 minutes. Measurements of all the plots at a site required one hour.
- 1987: Measurements at a site were usually coordinated with aircraft and satellite overpasses.
- 1988: Measurements at a site were occasionally coordinated with satellite overpasses.
- 1989: The reference panel was measured at one minute intervals with a MMR primarily for use by the helicopter's radiometers except when it was moved to allow the MMR on the pointable mast to measure the panel at 20 to 25 minute intervals. The 1-minute data were used to estimate incoming radiation for data reduction on August 9 and 11, otherwise data from the MMR mounted on the pointable mast were used. Measurements on all the plots at sites 906 (SITEGRID_ID = 2133-MMR) and 916 (SITEGRID_ID = 4439-MMR) required 30 minutes or less and were coordinated with aircraft and satellite overpasses. Measurements of all the plots at site 966 (SITEGRID_ID = 2437-MMR) required 2 to 3 hours.

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Temporal Coverage:

The measurement time ranged from 1351 to 2200 GMT. Measurements were not continuously made over this range but were in discrete measurement periods depending on the number of plots in a site and coordination with aircraft and satellite overpasses.

In 1987 data were generally obtained at several sites during a day, hence a lot of time was spent moving and resetting equipment.

In 1988 data were obtained at site 811 (4439-MMR) only. A maximum of five (5) discrete measurement periods throughout the day was obtained.

In 1989 data were obtained at only one site per day. A maximum of five (5) discrete measurement periods throughout the day was obtained.

Temporal Coverage Map:

Not available.

Temporal Resolution:

The optimum time interval between plot measurements was approximately 5 minutes. The typical time interval between plots was approximately 10 minutes. The time interval depended on the distance between the plots, the terrain, and sky conditions.

Data Characteristics:

The SQL definition for this table is found in the MMR_GRND.TDF file located on FIFE CD-ROM Volume 1.

Parameter/Variable Name

Parameter/Variable Description **Range** **Units**
Source

SITEGRID_ID

This is a FIS grid location code. Site grid codes (SSEE-III) give the south (SS) and east (EE) cell number in a 100 x 100 array of 200 m square cells. The last 3 characters (III) are an instrument identifier.			FIS
STATION_ID The FIS site identifier used to designate this site.	min = 5, max = 966		FIS
OBS_DATE The date on which the data were collected.	min = 03-JUN-87, max = 11-AUG-89		
OBS_TIME The time that the observation was taken.	min = 1351, max = 2220	[GMT]	
PLOT_NUM The plot number at the site where the data was collected.	min = 1, max = 999		FIS
SOLAR_ZEN_ANG The solar zenith angle, the vertical angle of the sun from zenith. Zero degrees is straight up; 90 degrees is on the horizon.	min = 15.6, max = 73.4	[degrees]	
SOLAR_AZIM_ANG The solar azimuth angle, the horizontal angle of the sun from north.	min = 84.2, max = 269.3	[degrees from North]	
VIEW_ZEN_ANG The view zenith angle, the angle from the surface normal (straight up) to the observing instrument.	min = 0, max = 50	[degrees]	
VIEW_AZIM_ANG The view azimuth angle, the horizontal angle of the measurement from north.	min = 0, max = 360	[degrees from North]	
BAND1_RADNC The reflected radiance for band 1 (.45 - .52 microns) of the MMR.	min = .69, max = 347.51	+ [Watts] [meter^-2]	

[ster^-1]
[mic^-1]

BAND2_RADNC		+
The reflected radiance for band 2 (.51 - .60 microns) of the MMR.	min = 7.41, max = 334	[Watts] [meter^-2] [ster^-1] [mic^-1]
BAND3_RADNC		+
The reflected radiance for band 3 (.63 - .68 microns) of the MMR.	min = 6.49, max = 300.11	[Watts] [meter^-2] [ster^-1] [mic^-1]
BAND4_RADNC		+
The reflected radiance for band 4 (.75 - .88 microns) of the MMR.	min = 11.6, max = 202.6	[Watts] [meter^-2] [ster^-1] [mic^-1]
BAND5_RADNC		+
The reflected radiance for band 5 (1.17 - 1.33 microns) of the MMR.	min = 6.74, max = 64.75	[Watts] [meter^-2] [ster^-1] [mic^-1]
BAND6_RADNC		+
The reflected radiance for band 6 (1.57 - 1.80 microns) of the MMR.	min = 2.19, max = 24.54	[Watts] [meter^-2] [ster^-1] [mic^-1]
BAND7_RADNC		+
The reflected radiance for band 7 (2.08 - 2.37 microns) of the MMR.	min = .082, max = 17.971	[Watts] [meter^-2] [ster^-1] [mic^-1]
BAND8_RADNC		+
The reflected radiance for band 8 (10.4 - 12.3 microns) of the MMR.		[Watts] [meter^-2] [ster^-1] [mic^-1]
RADIANT_TEMP		
The radiant temperature of the site.	min = 11.35, max = 99.9	[degrees Celsius]

CHOPPER_TEMP The radiometer chopper temperature.	min = 14.43, max = 99.9	[degrees Celsius]
DETECTOR_VOLTAGE The voltage reading of the detector.	min = 10.62, max = 37.91	[Volts]
BAND1_REFL The reflectance for band 1 (.45 - .52 microns) of the MMR.	min = .26, max = 95.85	[percent]
BAND2_REFL The reflectance for band 2 (.51 - .60 microns) of the MMR.	min = 2.8, max = 96.66	[percent]
BAND3_REFL The reflectance for band 3 (.63 - .68 microns) of the MMR.	min = 2.4, max = 95.87	[percent]
BAND4_REFL The reflectance for band 4 (.75 - .88 microns) of the MMR.	min = 6.85, max = 91.25	[percent]
BAND5_REFL The reflectance for band 5 (1.17 - 1.33 microns) of the MMR.	min = 12.49, max = 80.33	[percent]
BAND6_REFL The reflectance for band 6 (1.57 - 1.80 microns) of the MMR.	min = 7.43, max = 64.44	[percent]
BAND7_REFL The reflectance for band 7 (2.08 - 2.37 microns) of the MMR.	min = .44, max = 96.87	[percent]
DATASET_ID An identification code for this group of data to link it to other information in the inventory table.	min = UNL154, max = UNL89223	
FIFE_DATA_CRTFCN_CODE The FIFE Certification Code for the data, in the following format: CPI (Certified by PI), CPI-???	* CPI = checked by principal investigator	

(CPI - questionable data).

LAST_REVISION_DATE
data, in the format (DD-MMM-YY).   max = 05-AUG-91

Footnotes:

+ mic = micrometers

* Valid levels

The primary certification codes are: EXM Example or Test data (not for release) PRE Preliminary (unchecked, use at your own risk) CPI Checked by Principal Investigator (reviewed for quality) CGR Checked by a group and reconciled (data comparisons and cross checks)

The certification code modifiers are: PRE-NFP Preliminary - Not for publication, at the request of investigator. CPI-MRG PAMS data that is "merged" from two separate receiving stations to eliminate transmission errors. CPI-??? Investigator thinks data item may be questionable.

Sample Data Record:

SITEGRID_ID	STATION_ID	OBS_DATE	OBS_TIME	PLOT_NUM	SOLAR_ZEN_ANG
4439-MMR	18	07-AUG-87	1754	5	23.9000
4439-MMR	18	07-AUG-87	1754	5	23.9000
4439-MMR	18	07-AUG-87	1754	5	23.9000
4439-MMR	18	07-AUG-87	1754	5	23.9000

SOLAR_AZIM_ANG	VIEW_ZEN_ANG	VIEW_AZIM_ANG	BAND1_RADNC	BAND2_RADNC
160.6000	50.0000	160.0000	31.440	55.290
160.6000	50.0000	160.0000	31.290	55.290
160.6000	35.0000	160.0000	30.830	53.100
160.6000	35.0000	160.0000	30.670	53.100

BAND3_RADNC	BAND4_RADNC	BAND5_RADNC	BAND6_RADNC	BAND7_RADNC
45.360	118.940	49.400	15.750	3.073
45.500	119.130	49.510	15.830	3.098
45.360	112.330	47.680	15.700	3.235
45.230	111.940	47.250	15.400	3.125

BAND8_RADNC	RADIANT_TEMP	CHOPPER_TEMP	DETECTOR_VOLTAGE	BAND1_REFL
99.9000	99.9000	32.0100	8.010	
99.9000	99.9000	32.0100	7.980	
99.9000	99.9000	32.0200	7.860	
99.9000	99.9000	32.0200	7.820	

BAND2_REFL	BAND3_REFL	BAND4_REFL	BAND5_REFL	BAND6_REFL	BAND7_REFL
13.200	12.240	46.630	50.210	33.510	16.110
13.200	12.270	46.700	50.320	33.670	16.240
12.680	12.240	44.030	48.460	33.400	16.960
12.680	12.200	43.880	48.020	32.760	16.380

DATASET_ID	FIFE_DATA_CRTFCN_CODE	LAST_REVISION_DATE

UNL219	CPI	30-JAN-89
UNL219	CPI	30-JAN-89
UNL219	CPI	30-JAN-89
UNL219	CPI	30-JAN-89

8. Data Organization:

Data Granularity:

The overall coverage for these data is from June 3, 1987 through August 11, 1989. During this period there are 46 days of data. The plot size was approximately 3 m x 3 m.

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

Data Format:

The CD-ROM file format consists of numerical and character fields of varying length separated by commas. The character fields are enclosed with a single apostrophe. There are no spaces between the fields. Each file begins with five header records. Header records contain the following information: Record 1 Name of this file, its table name, number of records in this file, path and name of the document that describes the data in this file, and name of principal investigator for these data. Record 2 Path and filename of the previous data set, and path and filename of the next data set. (Path and filenames for files that contain another set of data taken at the same site on the same day.) Record 3 Path and filename of the previous site, and path and filename of the next site. (Path and filenames for files of the same data set taken on the same day for the previous and next sites (sequentially numbered by SITEGRID_ID)). Record 4 Path and filename of the previous date, and path and filename of the next date. (Path and filenames for files of the same data set taken at the same site for the previous and next date.) Record 5 Column names for the data within the file, delimited by commas. Record 6 Data records begin.

Each field represents one of the attributes listed in the chart in the *Data Characteristics Section* and described in detail in the TDF file. These fields are in the same order as in the chart.

9. Data Manipulations:

Formulae:

WAVEBAND'S 1-7 FORMULAE

Vc(j) = ((R(j) + Td,0) / (R(j) + Td)) * V(j) [1]

where:

j = MMR waveband 1-7
R(j) = specific waveband linear temperature sensitivity coefficient degrees Centigrade

Td,0 = reference temperature degrees Centigrade
Td = (ln(V10 - 1.9316)) / (-0.04446) from Barnes Engineering

where:

V10 = response in volts of detector thermistor
V(j) = waveband response in volts
Vc(j) = waveband response volts corrected to **Td,0**

Ls(j) or Lp(j) = [Vc(j) - O(j)] / G(j) [2]

where:

G(j) = waveband gain [volts][W^-1][m^-2][sr^-1][um^-1]
O(j) = waveband offset (volts)
Ls(j) or **Lp(j)** = waveband spectral radiance for surface or reference panel [W][m^-2][sr^-1][um^-1]

Lp(t,j) = Lp(t1,j) + {((t - t1)/(t2 - t1)) * (Lp(t2,j) - Lp(t1,j))} [3]

where:

Lp(t1,j) and **Lp(t2,j)** = waveband reference panel radiance bracketing the surface radiances at times **t1** and **t2** [W][m^-2][sr^-1][um^-1]
Lp(t,j) = waveband radiance of the reference panel at the surface radiance time **t** [W][m^-2][sr^-1][um^-1]

Lp(t,j) = Lp(t1,j) * (sin(sea(t1)) / sin(sea(t))) [4]

where:

sea(t1) = solar elevation angle at time **t1**
sea(t) = solar elevation angle at time **t**

RF(j) = Ls(j) / (Lp(t,j) / RFp(j)) [5]

where:

Ls(j) = waveband surface radiance [W][m^-2][sr^-1][um^-1]
RF(j) = waveband surface reflectance factor (%)
RFp(j) = waveband reflectance factor for the reference panel(%)

WAVEBAND 8 (THERMAL) FORMULAE

Tc = (V9 - AC) * BC [6]

where:

Tc = chopper temperature (C)
V9 = response (volts) of the chopper thermistor
AC, BC = calibration coefficients

$$Lc = 0.11927 / \{\exp(1278.88 / (Tc + 273.00)) - 1.0\} \quad [7]$$

where:

Lc = chopper radiance [W][m^-2]

$$Ld = 0.11927 / \{\exp(1278.88 / (Td + 273.00)) - 1.0\} \quad [8]$$

where:

Ld = detector radiance [W][m^-2]

$$Ls = Lc + (KA + KB * Tc) * V8 + (AA + AB * Tc) \quad [9]$$

where:

V8 = waveband 8 response voltage
Ls = surface radiance [W][m^-2]
KA, KB, AA, AB = calibration coefficients

$$Ls = Ld + (KA + KB * Td) * V8 + (AA + AB * Td) \quad [10]$$

where:

V8 = waveband 8 response voltage
Ls = surface radiance [W][m^-2]
KA, KB, AA, AB = calibration coefficients

$$Tc = 1278.88 / \ln((0.11927 / Ls) + 1.0) - 273.0 \quad [11]$$

where:

Tc = calibration corrected temperature measurement degrees Centigrade

SURFACE TEMPERATURE FORMULA

$$Ts = \{[a * (Tc + 273.16)^{4} + (1 - e) * ILW] / (e * a)\}^{.25} - 273.16 \quad [12]$$

where:

e = surface emissivity (unitless)
a = Stefan-Boltzmann constant [W][m^-2][K^-4]

ILW = incoming longwave radiation [W][m^-2]
Ts = surface temperature, degrees Centigrade

Derivation Techniques and Algorithms:

REFERENCE PANEL CORRECTIONS

In 1987 two pressed barium sulfate reference panels were used (NEB1 and NEB2). NEB1 was used for the first IFC and NEB2 was used for the last three IFC's. The panels were calibrated in July, 1987 by Dr. Ray D. Jackson at the U.S. Water Conservation Laboratory in Phoenix, Arizona. The method of Jackson et al., (1987) was used.

In 1988 and 1989 a Lapsphere molded halon reference panel was used. This panel was calibrated in September 1989 by the University of Nebraska following the procedure of Jackson et al., (1987).

The calibration yields the coefficients to a third order polynomial of the form:

RFp(j) = C0 + C1 * ZEN + C2 * ZEN2 + C3 * ZEN**3**

where:

C0, C1, C2, and **C3** = the calibration coefficients
ZEN = solar zenith angle at the time of the surface measurement (degrees)

The result of this equation **RFp(j)** is used in equation [5].

Panel coefficients

1987:

NEB1

Waveband	C0	C1	C2	C3
1	97.45057	5.584734E-02	-3.959692E-03	9.882025E-06
2	97.54819	5.666440E-02	-3.940689E-03	9.039184E-06
3	97.83009	2.959063E-02	-3.426001E-03	6.630198E-06
4	97.99712	1.562715E-02	-2.707314E-03	1.116180E-06
5	96.42652	-2.559037E-02	-9.758750E-04	-9.890963E-06
6	93.98231	2.807484E-02	-1.788550E-03	-2.213021E-06
7	88.83311	7.468207E-02	-2.506758E-03	3.913525E-06

1987:

NEB2

Waveband	C0	C1	C2	C3
1	102.40660	-7.996049E-02	5.068796E-04	-3.423062E-05
2	102.23610	-8.242803E-02	1.107736E-03	-4.046916E-05
3	102.87460	-1.375718E-01	2.305963E-03	-4.769363E-05
4	102.78210	-1.352304E-01	2.514470E-03	-4.980858E-05
5	101.74110	-2.097449E-01	4.728492E-03	-6.302641E-05
6	98.79391	-1.605808E-01	3.859259E-03	-5.455406E-05
7	92.51772	-1.235733E-01	3.302859E-03	-4.998493E-05

1988 and 1989:

Halon

Waveband	C0	C1	C2	C3
1	105.79300	0.9812652E-01	-0.5175089E-02	0.1390845E-04
2	106.73860	0.8086680E-02	-0.2866652E-02	-0.3902893E-05
3	106.30450	0.4490710E-01	-0.3717498E-02	0.1859340E-05
4	105.94070	0.7618627E-01	-0.4686755E-02	0.9638660E-05
5	104.80800	0.8175281E-01	-0.3934094E-02	0.2798061E-05
6	103.11720	0.6749086E-01	-0.2412556E-02	-0.8442320E-05
7	101.17420	0.1416389E-00	-0.4732779E-02	0.6610390E-05

SURFACE TEMPERATURE CALCULATIONS

The surface temperature was calculated using the calibration corrected temperature measurement, incoming longwave radiation (**ILW**) and surface emissivity values (Eq. 12).

Values for incoming longwave radiation were calculated for each MMR data record.

ILW = (((air6) * 5.31E-14) * 10.) - ((0.035) * (elev / 1000.) * (a * air**4)))**

where:

a = Stefan-Boltzmann constant [W][m^-2][K^-4]
air = MMR chopper or detector temperature [K]
ILW = incoming longwave [W][m^-2]
elev = elevation of each site [m]

The equation is valid for clear daytime conditions (Deacon 1970). These values were averaged over the measurement period at a specific site. The values are in the data set described in the Longwave Radiation UNL data document found on FIFE CD-ROM Volume 1.

Surface emissivity measurements were made under completely overcast sky conditions or at night and not in conjunction with the MMR measurements. An Everest model 112C IRT measured the temperature of the surface (**Tu**) and the temperature of the surface covered by an aluminum tent (**Ta**). The incoming longwave radiation under these conditions was determined using an IRT temperature measurement of an aluminum plate (**T**) of known emissivity (**ep**) and a thermocouple temperature of the plate (**Tp**).

The incoming longwave at the time of the surface emissivity measurement was calculated as:

ILW = (a * (T + 273.16)4 - ep * a * (Tp + 273.16)**4) / (1.0 - ep)**

where:

a = Stefan-Boltzmann constant [W][m^-2][K^-4]
Tu, or Ta, or T = a + b * Te
where:

Te = temperature measurement from the Everest (degrees C) of the appropriate surface.
a,b = Calibration coefficients (same procedure as for the Everest Model 4000 transducers described in Blad et al., 1990)

- 1987 and 1988 calibration coefficients:

SN 680 a=1.175373885 (C) b=0.980765782 (unitless)

- 1989 calibration coefficients:

  SN 680 was calibrated and adjusted pre-season so no calibration coefficients were applied.

  Emissivity measurements were made over a sampling of plots at a specific site during each IFC period in 1987. The emissivity is calculated as:

  e = (a * (Tu + 273.16)4 - ILW) / (a * (Ta + 273.16)**4 - ILW)**

  where:

  e = surface emissivity (unitless)(used in Eq. 12)
  a = Stefan-Boltzmann constant [W][m^-2][K^-4]

Emissivity values were averaged per site per IFC for calculation of true surface temperatures. The following is a listing of the emissivity values used in 1987.

- Site 5 (2123-MMR): An average emissivity of 0.98 for IFC-2 was used for all dates in which data were taken (IFC-1 and IFC-2).
- Site 8 (3129-MMR): No emissivity values were measured, an assigned value of 0.98 was used.
- Site 18 (4439-MMR): An average emissivity of 0.97 from data taken during IFC-2 was used for IFC-1 and IFC-2 data; average emissivities of 0.98 and 0.97 were used for IFC-3 and IFC-4 data, respectively. Bare soil emissivity was 0.96.
- Site 26 (8739-MMR): An average emissivity of 0.96 from data taken during IFC-2 was used for IFC-1 and IFC-2 data; average emissivities 0.99 and 0.97 were used for IFC-3 and IFC-4 respectively.
- Site 28 (6943-MMR): An average emissivity of 0.98 from data taken during IFC-3 was used for IFC-1, IFC-2, and IFC-3; average emissivity of 0.98 was used for IFC-4 data.
- Site 29 (0847-MMR): An average emissivity of 0.98 was used for IFC-3 and IFC-4.
- Site 32 (4268-MMR): An average emissivity of 0.97 from data taken during IFC-2 was used for IFC-1 and IFC-2; average emissivity of 0.98 was used for IFC-3 and IFC-4 data.
- Site 40 (1246-MMR): An average emissivity of 0.98 from data taken during IFC-3 was used for IFC-1, IFC-2, and IFC-3; average emissivity of 0.96 was used for IFC-4 data.
- Site 42 (1445-MMR): An average emissivity of 0.99 from data taken during IFC-4 was used for IFC-2, IFC-3, IFC-4.
- Site 170 (0939-MMR): Emissivity data was taken between IFC-2 and IFC-3 and averaged according to the mowing treatment. Average emissivities of 0.97, 0.98, 0.98, and 0.98 were used for the mowing plots of 5 cm height, 20 cm height or no mowing.

Emissivity measurements were made over a sampling of plots at site 811(4439-MMR) close to days of MMR measurements in 1988. The measurements were averaged per site for the specific days listed. The following is a listing of the emissivity values used in 1988.

- May 24, 25, 27, June 28, July 12 and 13 average emissivity of 0.991
- August 11 average emissivity of 0.983.

Emissivity measurements were made over a sampling of plots at Sites 906(2133-MMR), 916(4439-MMR), and 966(2437-MMR) close to days of MMR measurements in 1989. The values were averaged per site for specific days for the canopy and bare soil. The following are the emissivity values used in 1989:

- Site 916(4439-MMR), all days, average canopy emissivity of 0.964
- Site 916(4439-MMR), all days, average bare soil emissivity of 0.960
- Site 906(2133-MMR), all days, average canopy emissivity of 0.980
- Site 906(2133-MMR), all days, average bare soil emissivity of 0.98
- Site 966(2437-MMR), all days, average bare soil emissivity of 0.96
- Site 966(2437-MMR), June 15 and July 14, average canopy emissivity of 0.990
- Site 966(2437-MMR), August 9, average canopy emissivity of 0.980

Data Processing Sequence:

Processing Steps:

Wavebands 1 - 7 Processing Steps

Equation 1 is used to correct the MMR wavebands for the detectors' thermal sensitivity. This equation adjusts the MMR voltage to that which would occur at a reference temperature (Td,0). The temperature sensitivity coefficient and reference temperature for each MMR is listed in the *Other Calibration Information Section*. Equation 2 is then used to change the corrected voltages to radiances. The gains and offsets for each MMR are listed in the *Other Calibration Information Section*(Markham 1987). Usage of Equations 3 and 4 is dependent on the measurement interval of the reference panel. These equations interpolate the reference panel radiance output for the time of surface reflectance measurements. If measurements of the reference panel are made less then every 30 minutes but not every minute, Equation 3 is then applied (Bauer et al., 1981). If the measurements of the reference panel are greater then 30 minutes apart then Equation 4 is used. If the reference panel was measured every minute Equations 3 and 4 can be omitted. The reference panel Reflectance Factor for each surface measurement time is determined as explained in the *Derivation Techniques and Algorithms Section*. This provides a correction for the reference panel's non-Lambertian properties and the dependence on the solar zenith angle. Equation 5 is then used to calculate the surface reflectance factor using surface and reference panel radiances and the reference panel reflectance factor.

Waveband 8 (thermal) processing Steps

If the chopper thermistor is functioning Equations 6 and 7 are used to calculate the chopper temperature and radiance. Then Equation 9 is used to calculate a surface radiance. If the chopper thermistor is malfunctioning then Equation 8 is used to calculate the detector radiance and Equation 10 is used to calculate a surface radiance. Equation 11 is then used to convert the surface radiance to a calibration corrected temperature measurement (Markham 1987).

The calibration corrected temperature measurement, incoming longwave radiation and surface emissivity values are used to calculate surface temperature using Equation 12 (Blad et al., 1976).

Processing Changes:

Not applicable.

Calculations:

Special Corrections/Adjustments:

Not applicable.

Calculated Variables:

- Waveband response volts corrected to Td,0,
- Waveband spectral radiance for surface or reference panel,
- Waveband radiance of the reference panel at the surface radiance time t,
- Waveband surface reflectance factor (%),
- Chopper temperature,
- Chopper radiance,
- Detector radiance,
- Surface radiance,
- Calibration corrected temperature measurement,
- Surface temperature,
- Incoming longwave radiation , and
- Surface emissivity values.

Graphs and Plots:

None.

10. Errors:

Sources of Error:

Errors associated with the measurements can occur due to orientation of the MMR. The view-zenith angle could only be measured to +/- 2 degrees Centigrade and the view-azimuth angle could only be measured to +/- 10 degrees Centigrade.

The shadowing caused by the MMR and the mast in measuring the "hot spot" area is another source of error.

Variable cloud cover could be an error source with reflectance factors since the incoming radiation measurements were not made simultaneously with the surface measurements.

Quality Assessment:

Data Validation by Source:

Comparisons have been made with Surface Reflectance Measured by the PARABOLA, helicopter mounted radiometers (MMR, SE590, Surface Radiant Temperatures) and SE590 measurements (Ground and Leaf).

Confidence Level/Accuracy Judgment:

On days with variable cloud conditions the data should be used with caution. The AMS incoming solar radiation data at the site or nearby site should be consulted.

On clear days the measurements fall within the precision of the instrument and errors that were discussed in previous sections.

Measurement Error for Parameters:

Not available at this revision.

Additional Quality Assessments:

FIS staff applied a general QA procedure to the data to identify inconsistencies and problems for potential users. As a general procedure, the FIS QA consisted of examining the maximum, minimum, average, and standard deviation for each numerical field in the data table. Inconsistencies and problems found in the QA check are described is the *Known Problems with the Data Section*.

Data Verification by Data Center:

The data verification performed by the ORNL DAAC deals with the quality of the data format, media, and readability. The ORNL DAAC does not make an assessment of the quality of the data itself except during the course of performing other QA procedures as described below.

The FIFE data were transferred to the ORNL DAAC via CD-ROM. These CD-ROMs are distributed by the ORNL DAAC unmodified as a set or in individual volumes, as requested. In addition, the DAAC has incorporated each of the 98 FIFE tabular datasets from the CD-ROMs into its online data holdings. Incorporation of these data involved the following steps:

- Copying the entire FIFE Volume 1, maintaining the directory structure on the CD-ROM;
- Using data files, documentation, and SQL code provided on the CD-ROM to create a database in Statistical Analysis System (SAS); and
- Creating transfer files to transfer the SAS metadata database to Sybase tables.

Each distinct type of data (i.e. "data set" on the CD-ROM), is accompanied by a documentation file (i.e., .doc file) and a data format/structure definition file (i.e., .tdf file). The data format files on the CD-ROM are Oracle SQL commands (e.g., "create table") that can be used to set up a relational database table structure. This file provides column/variable names, character/numeric type, length, and format, and labels/comments. These SQL commands were converted to SAS code and were used to create SAS data sets and subsequently to input data files directly from the CD-ROM into a SAS dataset. During this process, file names and directory paths were captured and metadata was extracted to the extent possible electronically. No files were found to be corrupted or unreadable during the conversion process.

Additional Quality Assurance procedures were performed as follows:

- Statistical operations were performed to calculate minimum and maximum values for all numeric fields and to create a listing of all values of the character fields. During this process, it was determined that various conventions were used to represent missing values. (Note: no modifications were made to any data by the DAAC). In most cases, missing value identification conventions were discussed in the accompanying .doc file. Based on a visual check of the minimum and maximum values, no glaring errors or holes were identified that might indicate errors introduced during CD-ROM mastering by the FIFE project or data ingest by the DAAC.
- Some minor inconsistencies and typographical errors were identified in some of the character fields and column labels, however, no modifications were made to the data by the DAAC.
- Some conversions of ASCII data were necessary to move the data from a DOS platform to a UNIX platform. Standard operating system conversion utilities were used (e.g., dos2unix).
- Much of the metadata required for archival is imbedded in the narrative documentation accompanying the data sets and extracted manually by DAAC staff who have read the .doc files provided on the CD-ROM and have hand entered this information into the metadata database maintained by the DAAC. QA procedures have been performed on these metadata to identify and eliminate typographical errors and inconsistencies in naming conventions, to ensure that all required metadata is present, and to ensure the accuracy of file names and paths for retrieval.
- Data requested for distribution to users are checked to verify that files copied from disk to other media remain uncorrupted.

As errors are discovered in the online tabular data by investigators, users, or DAAC staff, corrections are made in cooperation with the principal investigators. These corrections are then distributed to users. CD-ROM data are corrected when re-mastering occurs for replenishment of CD-ROM stock.

11. Notes:

Limitations of the Data:

Not available.

Known Problems with the Data:

For 1987 the following data are erroneous for Waveband 7:

- Aug. 20 Site 42 (1445-MMR) Plot 7, view-zenith angles of 50, 35 and 20 with observation times equal to 1751, 1752, and 1753 GMT.
- Oct. 9 Site 40 (1246-MMR) Plot 6 view-zenith angle of 35 with observation times equal to 2106 and 2107 GMT.
- Oct. 9 Site 40 (1246-MMR) Plot 7 view-zenith angles of 35 and 20 with observation times equal to 2110 and 2111 GMT.
- Oct. 13 Site 18 (4439-MMR) Plot 13 view-zenith angles of 30 and 50 with observation time equal to 1745 GMT.
- Oct. 13 Site 18 (4439-MMR) Plot 14 view-zenith angles of 20, 30 and 50 with observation times equal to 1749 and 1750 GMT.

Channel 7 occasionally malfunctioned. Other problems were with the surface and chopper temperatures. A value of 99.9 was assigned to erroneous data. During IFC's 3 and 4 the detector for waveband 8 (thermal) on SN 103 was malfunctioning so there are no surface temperatures. During IFC's 1 and 2 the chopper detector on SN 128 was malfunctioning.

In 1988 all of the surface temperature values are assigned a value of 99.9 because the detector for waveband 8 in SN 108 was malfunctioning.

In 1989 there are no known problems.

Usage Guidance:

Before using reflectance factors the incoming radiation from the AMS station at the site or nearby site should be checked for possible cloud-induced error in reflectance factors.

Always check plot numbers before constructing a site average. Plot 999 is an artificially created and maintained bare soil plot.

Any Other Relevant Information about the Study:

One day when Ghassem Asrar was handling FIFE Operations, he called on the radio and told Blaine Blad and Don Deering that he was sending the helicopter up and for them to start taking measurements. Both Blaine and Don answered that it was too cloudy and that he shouldn't send the helicopter. Ghassem replied that it was clear since Erwin had forecast clear skies. The moral of this story is that one should always look out the window before commenting on sky conditions.

12. Application of the Data Set:

This data set can be utilized to characterize bi-directional reflectance factor distributions in the solar principal plane for a tall grass prairie; estimate surface albedo from bi-directional reflectance factor and radiance data; determine the variability of reflected and emitted fluxes in selected spectral wavebands as a function of topography, vegetative community and management practice; determine the influence of plant water status on surface reflectance factors; and determine sun angle effects on radiation fluxes.

13. Future Modifications and Plans:

The FIFE field campaigns were held in 1987 and 1989 and there are no plans for new data collection. Field work continues near the FIFE site at the Long-Term Ecological Research (LTER) Network Konza research site (i.e., LTER continues to monitor the site). The FIFE investigators are continuing to analyze and model the data from the field campaigns to produce new data products.

14. Software:

Software to access the data set is available on the all volumes of the FIFE CD-ROM set. For a detailed description of the available software see the *Software Description Document*.

15. Data Access:

Contact Information:

ORNL DAAC User Services
Oak Ridge National Laboratory

Telephone: (865) 241-3952
FAX: (865) 574-4665

Email: ornldaac@ornl.gov

Data Center Identification:

ORNL Distributed Active Archive Center
Oak Ridge National Laboratory
USA

Telephone: (865) 241-3952
FAX: (865) 574-4665

Email: ornldaac@ornl.gov

Procedures for Obtaining Data:

Users may place requests by telephone, electronic mail, or FAX. Data is also available via the World Wide Web at http://daac.ornl.gov.

Data Center Status/Plans:

FIFE data are available from the ORNL DAAC. Please contact the ORNL DAAC User Services Office for the most current information about these data.

16. Output Products and Availability:

The Surface Reflectance Measured with a Mast-borne MMR data are available on FIFE CD-ROM Volume 1. The CD- ROM filename is as follows:

DATA\SUR_REFL\MMR_GRND\GRIDxxxx\Yyyyy\ydddgrid.MRG.

Where *xxxx* is the four digit code for the location within the FIFE site grid, *yyyy* are the four digits of the century and year (e.g., Y1987 = 1987). Note: capital letters indicate fixed values that appear on the CD-ROM exactly as shown here, lower case indicates characters (values) that change for each path and file.

The format used for the filenames is: *ydddgrid.sfx*, where *grid* is the four-number code for the location within the FIFE site grid, *y* is the last digit of the year (e.g. 7 = 1987, and 9 = 1989), and *ddd* is the day of the year (e.g. 061 = sixty-first day in the year). The filename extension (.*sfx*), identifies the data set content for the file (see the *Data Characteristics Section*) and is equal to .MRG for this data set.

17. References:

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Archive/DBMS Usage Documentation.

Contact the EOS Distributed Active Archive Center (DAAC) at Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee (see the *Data Center Identification Section*). Documentation about using the archive and/or online access to the data at the ORNL DAAC is not available at this revision.

18. Glossary of Terms:

A general glossary for the DAAC is located at Glossary.

19. List of Acronyms:

AMS Automatic Meteorological Station APAR Absorbed Photosynthetically Active Radiation BPI Byte per inch CCT Computer Compatible Tape DAAC Distributed Active Archive Center EOSDIS Earth Observing System Data and Information System FIFE First ISLSCP Field Experiment FIS FIFE Information System GMT Greenwich Mean Time IFC Intensice Field Campaign IFOV Instantaneous Field of View IPAR Intercepted Photosynthetically Active Radiation IRT Infrared Thermometer ISLSCP International Satellite Land Surface Climatology Project LAI Leaf Area Index Mbps Megabyte per second MMR Modualr Multiband Radiometer ORNL Oak Ridge National Laboratory PAMS Portable Automatic Mesonet SAMS Super AMS URL Uniform Resource Locator WAB Wind Aligned Blob

A general list of acronyms for the DAAC is available at Acronyms.

20. Document Information:

April 27, 1994 (citation revised on October 16, 2002).

This document has been reviewed by the FIFE Information Scientist to eliminate technical and editorial inaccuracies. Previous version of this document have been reviewed by the Principal Investigator, the person who transmitted the data to FIS, a FIS staff member, or a FIFE scientist generally familiar with the data. It is believed that the document accurately describes the data as collected and as archived on the FIFE CD-ROM series.

Document Review Date:

August 8, 1996.

Document ID:

ORNL- FIFE_MMR_GRND.

Citation:

Cite this data set as follows:

Blad, B. L., and E. A. Walter-Shea. 1994. MMR Ground Data (FIFE). Data set. Available on-line [http://www.daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/52. Also published in D. E. Strebel, D. R. Landis, K. F. Huemmrich, and B. W. Meeson (eds.), Collected Data of the First ISLSCP Field Experiment, Vol. 1: Surface Observations and Non-Image Data Sets. CD-ROM. National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, U.S.A. (available from http://www.daac. ornl.gov).

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