MMR Leaf Optical Properties Data (FIFE)

Summary:

The Leaf Optical Properties from UNL Data Set contains leaf-level spectral observations acquired in situ with the Nebraska Multiband Leaf Radiometer (NMLR) coupled with a LiCor LI-1800-12 integrating sphere. The NMLR measured leaf reflectance and transmittance in the seven MMR bands. Data were collected in 1987, 1988, and 1989.

During 1987, measurements were always made on the most recently expanded leaf of the selected plant. Measurements were made on a variety of forbs and grasses. During 1988, measurements were made on the most recently expanded leaf of the selected plant unless specified. Measurements were also made of older green, yellow and brown leaves on a plant. Measurements were usually made on grasses (i.e., Indian grass, Switch grass and Big bluestem). A few forbs were measured. The same leaf was sometimes measured throughout the day. During 1989, measurements were usually made on the most recently expanded leaf of the selected plant unless specified. Typically, leaves of the dominant grass species at a site were measured. At least two samples of each species were measured. Typically, during all collections (i.e., 1987 - 1989) an external light source with a restricted beam spot (slitted illuminator) was used to restrict the illumination spot on narrow grass leaves so that only leaf material was illuminated.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

MMR Leaf Optical Properties Data (FIFE).
(Leaf Optical Properties from UNL).

Data Set Introduction:

The Leaf Optical Properties from UNL Data Set contains leaf reflectance and transmittance data for MMR bands 1 through 7. These data were collected in 1987, 1988, and 1989.

Objective/Purpose:

The purpose in collecting leaf reflectance and transmittance data was to characterize the optical properties of the canopy components to gain a better understanding of how these optical properties contribute to canopy reflectance and absorption of radiation.

Summary of Parameters:

Leaf reflectance and transmittance for MMR bands 1 through 7.

Discussion:

Leaf-level spectral observations were acquired in situ with the Nebraska Multiband Leaf Radiometer (NMLR) coupled with a LiCor LI-1800-12 integrating sphere. This system was held in place by a tripod. The NMLR measured leaf reflectance and transmittance in the seven MMR bands. Data were collected in 1987, 1988, and 1989.

- 1987: Measurements were made at four stations 18 (SITEGRID_ID = 4439-BBN), 26 (SITEGRID_ID = 8739-BBN), 28 (SITEGRID_ID = 6943-BBN), and 40 (SITEGRID_ID = 1246-BBN). Measurements were always made on the most recently expanded leaf of the selected plant. Measurements were made on a variety of forbs and grasses. An external light source with a restricted beam spot (slitted illuminator) was used, to restrict the illumination spot on the leaf, so that only the leaf was illuminated.
- 1988: Measurements were made at three sites 10 (SITEGRID_ID = 3414-BBN), 11 (SITEGRID_ID = 4439-BBN), and 31 (SITEGRID_ID = 2139-BBN). All three sites were 1987 experiment sites which were revisited in 1988. Measurements were made on the most recently expanded leaf of the selected plant unless specified. Measurements were also made of older green, yellow and brown leaves on a plant. Measurements were usually made on grasses (Indian grass, Switch grass and Big bluestem). A few forbs were measured. The same leaf was sometimes measured throughout the day. Measurements were usually coordinated with leaf water potential measurements. An external light source with a restricted beam spot (slitted illuminator) was used, to restrict the illumination spot on the leaf, so that only the leaf was illuminated.

- 1989: Measurements were made at three sites 916 (SITEGRID_ID = 4439-BBN), 906 (SITEGRID_ID = 2133-BBN) and 966 (SITEGRID_ID = 2437-BBN). Measurements were usually made on the most recently expanded leaf of the selected plant unless specified. Typically, leaves of the dominant grass species at a site were measured (i.e., Indian grass, Switch grass and Big bluestem at site 916 (SITEGRID_ID = 4439-BBN)). At least two samples of each species were measured. Measurements were usually coordinated with leaf water potential measurements (see the Total Leaf Tissue Water Potential document for a description). Typically, an external light source with a restricted beam spot (slitted illuminator) was used to restrict the illumination spot on narrow grass leaves so that only leaf material was illuminated. An external light source with an unrestricted beam occasionally was used when measurements were coordinated with leaf optical measurements made by E.M. Middleton; during these comparisons, measurements were made using the procedure of Middleton (i.e., two leaves were taped together to create a sample large enough to fill the sample port). See the SE-590 Leaf Level Spectral Observations from GSFCdocument for a description of this technique.

Related Data Sets:

- Surface Reflectance Measured with a Mast-borne MMR.
- Surface Reflectance Measured with a Helicopter-borne MMR.
- 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_LEAF_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Blaine L. Blad, Professor and Head
Elizabeth A. Walter-Shea, Asst. Professor
Department of Agricultural Meteorology

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 MMR leaf optical properties measurements were made 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:

To measure reflectance and transmittance of leaf surfaces an integrating sphere is used. The integrating sphere collects all of the radiation reflected from or transmitted through a surface. In the LiCor 1800-12 integrating sphere the sample is held to the outside of the sphere, with a small section of the sample acting as part of the sphere wall. The interior of the sphere is coated with barium sulfate to make a uniform diffuse reflector. In this type of sphere the sensor does not directly observe the sample. The field of view of the sensor is on a section of the sphere wall.

To calculate reflectance a comparison of the wall illumination caused by a beam of radiation reflected by the sample material to that reflected from the reference material. The LiCor 1800-12 uses the same illumination source for both cases. The source is moved between ports to

illuminate the sample and reference material. Under ideal conditions the sample reflectance **Rs** is given by:

Rs = Is / Ir

Where **Is** is the output when the sample is illuminated and **Ir** is the reference output. In reality other factors must be considered. First, the reference material is not a perfect reflector, and second, not all of the incoming radiation beam hits the sample or reference, some radiation is scattered off of the sphere walls without hitting the target. Taking these factors into account the reflectance is given by:

Rs = ((Is - Id) * Rr) / (Ir - Id)

Where **Rr** is the reflectance of the reference material and **Id** is the radiation scattered without hitting the target. **Id** can be determined by illuminating the sample port with no sample in it such that no external radiation can enter. Thus the only radiation illuminating the sample wall will be internally scattered.

Transmittance is calculated by comparing the wall illumination from radiation passed through the sample to the illumination caused by radiation that did not pass through the sample. For diffusive samples, the transmittance **Ts** is:

Ts = (Is * Rr) / Ir

where **Rr** is the reflectance of the reference material, **Is** is the output when the sample is illuminated and **Ir** is the output when the reference material is illuminated.

Leaf optical properties can be directly or indirectly related to leaf water content. Mild water stress decreases relative water content (RWC) (10-20%) and turgor slightly, which is accompanied by cell wall relaxation, resulting in decreases in cell dimension, cell surface, cell volume and intercellular space (Levitt and Ben Zaken 1975). Severe water stress can greatly decrease RWC (below 70-80%) and turgor, and result in cell collapse (Levitt and Ben Zaken 1975). Changes in intercellular arrangement may affect the radiative scattering within the leaf resulting in an alteration in overall leaf reflectance and transmittance.

4. Equipment:

Sensor/Instrument Description:

The seven waveband radiometer (Nebraska Multiband Leaf Radiometer (NMLR)) produces an analog voltage response in 7 spectral bands. The nominal bandwidths of the 7 spectral bands 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 and 2.08-2.35 microns. The detector is a single silicon-lead sulfide detector. Wavebands 1 through 4 are monitored by the silicon side and wavebands 5 through 7 are monitored by the lead sulfide side of the detector. The filters for the NMLR are the same filters used for the seven visible and near infrared bands of the Modular Multiband Radiometer (MMR) (Markham 1987).

The LI-COR LI-1800-12 Integrating Sphere is an instrument for collecting radiation that has been reflected from or transmitted through a sample material. An external light source with a restricted beam was usually used to restrict the illumination spot on the leaf. The lamp used in

the external light source is a 6 Volt 10 Watt glass-halogen For a further description see the LI-COR Integrating Sphere Instruction Manual.

Collection Environment:

Ground-based.

Source/Platform:

The Nebraska Multiband Leaf Radiometer and LI-COR LI-1800-12 Integrating Sphere were mounted on a tripod.

Source/Platform Mission Objectives:

To measure leaf reflectance and transmittance in situ.

Key Variables:

Hemispherical reflectance and transmittance factors of individual leaves illuminated at near-normal incidence measured using a LI-COR LI-1800-12 Integrating Sphere and external light source attached to a seven-waveband leaf radiometer.

Principles of Operation:

The Nebraska Multiband Leaf Radiometer is described in Mesarch et al., (1991).

The Li-COR LI-1800-12 Integrating Sphere is an external integrating sphere, which means that the sample is external to the sphere; when it is in place, a small part of the sample actually makes up part of the sphere wall. For further information see the LI-COR 1800-12 Integrating Sphere instruction manual.

Sensor/Instrument Measurement Geometry:

The Nebraska Multiband Leaf Radiometer (NMLR) is mounted on a tripod and the LI-COR LI-1800-12 Integrating Sphere is mounted on top of the NMLR. The assembly can be inverted and held under the tripod to reach samples low to the ground. A modified external light source with a slitted beam (3.5 mm x 11 mm) was used to illuminate narrow leaf samples (such as grasses) and reference. In 1989, an external light source with an unrestricted beam was also used so that measurement procedures were comparable to the procedures of E.M. Middleton. See the SE-590 Leaf Level Spectral Observations from GSFC document.

Manufacturer of Sensor/Instrument:

Nebraska Multiband Leaf Radiometer (NMLR)
Barrett Robinson
Department of Electrical Engineering

Purdue University
West Lafayette, IN 47907

LI-COR LI-1800-12 Integrating Sphere
LI-COR, Inc.
Box 4425
Lincoln, Nebraska 68504
(402) 467-3576

Calibration:

1987, 1988 & 1989: Periodically the Nebraska Multiband Leaf Radiometer (NMLR) response was checked using a screen or neutral density filter of a known transmittance (Mesarch et al., 1991). No corrections were made to the NMLR response. The collimation of the LI-COR LI-1800-12 Integrating Sphere illuminator was checked periodically by making a stray light measurement (LI-COR 1983).

Specifications:

Reflectances and transmittances may not be as accurate for wavebands 5 - 7 as they are for wave bands 1 - 4 (the MBEs (see the *Tolerance Section*)) for the lead-sulfide wavebands are larger than those for silicon wavebands). This is especially true for waveband 7 when using the slitted illuminator due to combined effect of low light produced by the slitted illuminator and the lead-sulfide detector response to low light. Ambient temperature can alter the voltage response with the lead sulfide detector (as temperature decreases, the voltage decreases).

Tolerance:

Calibrations performed in the Fall of 1989 (Mesarch et al., 1991) indicate that the calculated reflectance and transmittance values may be in error. MBEs for the unrestricted light source are: -0.17%, 0.05%, 0.03%, 0.23%, 0.88%, 0.72% and 3.25% for wavebands 1 through 7. MBEs for the restricted light source are: -0.31%, 0.05%, -0.06%, -0.05%, 1.87%, 1.02% and 4.59% for wavebands 1 through 7.

Frequency of Calibration:

Not available at this revision.

Other Calibration Information:

A calibration procedure was developed in the Fall of 1989. The procedure is described by Mesarch et al., (1991). The FIFE data were not corrected and may be in error (as indicated by the mean square error) as follows: 0.09% (waveband 1), 0.02% (waveband 2), 0.05%(waveband 3), 0.2% (waveband 4), 1.3% (waveband 5), 0.5% (waveband 6), and 9.8% (waveband 7).

5. Data Acquisition Methods:

1987:

Leaves remained attached to plants during measurements. The most recently expanded leaf was always measured. A screen filter was measured periodically to check instrument response and to determine the appropriate data reduction method using electronic background (dark) measurements (Mesarch et al., 1991). Measurements were always made with an external light source with a restricted beam spot (slitted illuminator), to restrict the illumination spot on the leaf, so that only leaf material was illuminated.

The tripod was adjusted so that the leaf could be placed in the LI-COR LI-1800-12 Integrating Sphere sample port without disturbing the plant and to maintain the light source in the horizontal plane to reduce illuminator variation (LI-COR manual). The leaf was placed in the sample port with the adaxial side facing the inside of the sphere without disturbing the plant. Reference adaxial, reflected adaxial, and transmitted abaxial measurement were made. The leaf was removed and reinserted in the sample port so that the abaxial surface was placed toward the inside of the sphere. Transmitted adaxial, reflected abaxial and reference abaxial measurements were made to complete a set of leaf measurements. For more details on the LI-COR LI-1800-12 Integrating Sphere configuration for each measurement see Mesarch et al., (1991). After each measurement, a measurement of the electronic background signal (dark measurement) was made. The next leaf was selected and the above measurements were repeated.

1988:

Usually the most recently expanded leaf was measured, exceptions are: dead leaves, yellow leaves, and the second and fourth to the most recently expanded leaves. Leaves remained attached to the plant with the exception of the dead leaf samples. On June 29th at site 811 (SITEGRID_ID = 4438-BBN) the same leaves were measured throughout the day. On August 9th at site 811 (SITEGRID_ID = 4438-BBN) 3 leaves were measured on the same plant (most recently expanded leaf, second expanded leaf, and fourth expanded leaf). Unless otherwise noted the same procedure as in 1987 was followed.

1989:

Usually the most recently expanded leaf was measured from grasses of the site's dominant species. The leaves remained attached to the plant during the measurement. Generally, two samples of each species were measured during each measurement period. Occasionally, an external light source with an unrestricted beam spot was used with two leaves taped together to fill the sample port to replicate the measurement procedure of E.M. Middleton for comparison of measurement results. Unless otherwise noted the same procedure as in 1987 was followed.

6. Observations:

Data Notes:

Not available.

Field Notes:

- 1987: Filters from MMR serial number 128 were used.
- 1988: Filters from MMR serial number 108 were used.
- 1989:
    - July 11 - Filters from MMR serial number 114 were installed.
    - July 13 - Filters from MMR serial number 114 were installed.
    - July 24 - Filters from MMR serial number 108 were installed.
    - July 28 - leaf optical measurements in conjunction with E.M. Middleton's photosynthesis measurements.
    - Aug. 2 - Measurements in conjunction with E.M. Middleton's SE590 leaf optical measurements
    - Aug. 5 - Measurements made of same leaves as E.M. Middleton had made on Aug. 4 with the SE590.
    - Aug. 7 - Leaf optical properties on the same leaves taped together that were measured earlier by E.M. Middleton. An unrestricted external light source was used to duplicate E.M. Middleton's procedure with the SE590. One of each pair of taped leaves was also measured with the restricted external light source.
    - Aug. 10 - Measured leaf optical properties on one of each pair of leaves used by E.M. Middleton's SE590 leaf measurements.

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.

Species were selected to be representative of the site.

Spatial Coverage:

Measurements were taken at representative areas scattered throughout the FIFE study area.

	SITEGRID	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEV
1246-BBN	4331625	714200	39 06 34	-96 31 22	410	
2133-BBN	4329706	711577	39 05 34	-96 33 13	443	
2139-BBN	4329843	712789	39 05 37	-96 32 23	385	
2437-BBN	4329150	712375	39 05 15	-96 32 41		
3414-BBN	4327286	707854	39 04 19	-96 35 51	410	
4439-BBN	4325219	712795	39 03 07	-96 32 27	445	
6943-BBN	4320147	713500	39 00 22	-96 32 04	415	
8739-BBN	4316699	712845	38 58 31	-96 32 35	442	

	SITEGRID	SLOPE	ASPECT

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1246-BBN     12          S
2133-BBN      1          TOP
2139-BBN
2437-BBN
3414-BBN
4439-BBN      2          N
6943-BBN
8739-BBN      1          TOP
```

Spatial Coverage Map:

Not available.

Spatial Resolution:

The external light source with a restricted beam spot illumination size is 3.5 mm x 11 mm whereas the unrestricted external light source has an illumination spot with a diameter of 11.4 mm.

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Measurements were made throughout a day. Measurements of one leaf required a minimum of 10 minutes.

Temporal Coverage:

On an individual day measurements were taken from 1200 to 2358 GMT. The overall time period of the measurements was June of 1987, and July and August of 1988 and 1989. Measurements were not made continuously.

Temporal Coverage Map:

Not available.

Temporal Resolution:

Measurements were made at varying intervals during the measurement periods. On a given day, the optimum time interval between leaf measurements was a few minutes.

Data Characteristics:

The SQL definition for this table is found in the MMR_LEAF.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 the east (EE) cell number in a 100 x 100 array of 200 m square cells. The last 3 characters (III) are an instrument identifier.			
STATION_ID The station ID designating the location of the observations.			
OBS_DATE The date of the observations, in the format (DD-MMM-YY).			
OBS_TIME The time that the observation was taken in GMT. The format is (HHMM).		[GMT]	
PLOT_NUM The plot number at the site where the data were collected.			
SPECIES_NAME The common name of the plant being measured.			
LTER_SPECIES_CODE The LTER species code (see VEG_SPECIES_REF) for the species			

of the leaf measured.

OBS_TYPE
Type of measurement: RT,
reflectance from leaf top; TT,
transmittance through leaf top,;
RB, reflectance from leaf bottom;
TB, transmittance through leaf
bottom.

BAND1_REFL
The percent reflectance or [percent]
transmittance of the leaf in MMR
band 1, 0.45-0.52 um.

BAND2_REFL
The percent reflectance or [percent]
transmittance of the leaf in MMR
band 2, 0.52-0.60 um.

BAND3_REFL
The percent reflectance or [percent]
transmittance of the leaf in MMR
band 3, 0.63-0.69 um.

BAND4_REFL
The percent reflectance or [percent]
transmittance of the leaf in MMR
band 4, 0.76-0.90 um.

BAND5_REFL
The percent reflectance or [percent]
transmittance of the leaf in MMR
band 5, 1.15-1.30 um.

BAND6_REFL
The percent reflectance or [percent]
transmittance of the leaf in MMR
band 6, 1.55-1.75 um.

BAND7_REFL
The percent reflectance or [percent]
transmittance of the leaf in MMR
band 7, 2.08-2.35 um.

COMMENTS
Any comments about the data.

```
FIFE_DATA_CRTFCN_CODE                                *
The FIFE Certification Code for
the data, in the following format:
CPI (Certified by PI), CPI-???
(CPI - questionable data).
```

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LAST_REVISION_DATE
data, in the format (DD-MMM-YY).
```

Footnote:

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	SPECIES_NAME
4439-BBN	916	04-AUG-89	1444	BIG	BLUESTEM
4439-BBN	916	04-AUG-89	1444	BIG	BLUESTEM
4439-BBN	916	04-AUG-89	1444	BIG	BLUESTEM
4439-BBN	916	04-AUG-89	1444	BIG	BLUESTEM

LTER_SPECIES_CODE	OBS_TYPE	BAND1_REFL	BAND2_REFL	BAND3_REFL	BAND4_REFL
2	RT	10.02	17.50	8.78	42.96
2	TT	6.31	18.24	6.78	51.75
2	RB	9.91	17.44	8.48	42.98
2	TB	6.07	17.82	6.26	51.45

BAND5_REFL	BAND6_REFL	BAND7_REFL	COMMENTS
40.59	30.16	21.03	HEALTHY PLANT MATERIAL
54.17	46.10	34.63	HEALTHY PLANT MATERIAL
41.41	31.72	22.36	HEALTHY PLANT MATERIAL
54.20	46.67	35.31	HEALTHY PLANT MATERIAL

FIFE_DATA_CRTFCN_CODE	LAST_REVISION_DATE
CPI	13-FEB-90
CPI	13-FEB-90
CPI	13-FEB-90
CPI	13-FEB-90

8. Data Organization:

Data Granularity:

Measurements were taken at representative areas scattered throughout the FIFE study area. Measurements were made at varying intervals during the measurement periods.

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:

LEAF REFLECTANCE CALCULATION:

Equation 1:

REFL(i) = ((R(i) - D(i)) - (STR(i) - D(i))) / ((REF(i) - D(i)) - (STR(i) - D(i))) * 100

where:

REFL = Hemispherical reflectance of adaxial or abaxial leaf surface (percent)
i = Waveband
R = adaxial or abaxial reflected measurement in volts
STR = stray light measurement in volts
REF = adaxial or abaxial reference measurement in volts
D = electronic background (dark) measurement in volts

LEAF TRANSMITTANCE CALCULATION:

Equation 2:

TRAN(i) = (T(i) - D(i)) / ((REF(i) - D(i)) - (STR(i) - D(i))) * 100

where:

TRAN = Hemispherical transmittance adaxial or abaxial leaf surface (percent)
i = Waveband
T = adaxial or abaxial transmitted measurement in volts
STR = stray light measurement in volts
REF = adaxial or abaxial reference measurement in volts
D = electronic background (dark) measurement in volts

Derivation Techniques and Algorithms:

A screen filter was measured periodically to determine the appropriate data reduction calculation using the electronic background (dark) measurements. The dark measurements are always subtracted for wavebands 1 - 4 (silicon detector); for wavebands 5 - 7 (lead-sulfide detector), the dark measurements are either ignored, added or subtracted. The dark measurements are usually subtracted. For details see Mesarch et al., (1991).

The stray light measurements were made only during calibrations (see the *Calibration Section*).

Data Processing Sequence:

Processing Steps:

Equation 1 is used to calculate the hemispherical reflectance for the adaxial and abaxial leaf surfaces. Equation 2 is used to calculate the hemispherical transmittance of the adaxial and abaxial leaf surfaces.

Processing Changes:

Not applicable.

Calculations:

Special Corrections/Adjustments:

Not applicable.

Calculated Variables:

- Leaf Reflectance, and
- Leaf Transmittance.

Graphs and Plots:

None.

10. Errors:

Sources of Error:

Errors can result if the leaf sample has a thickness which does not permit proper sealing around the sample holder (this can be a problem especially in the mid-vein area.) Light entering from the loose seal can enter the sphere causing erroneous values. If the light source is not maintained in a horizontal position, the light output can vary, leading to errors.

Quality Assessment:

Data Validation by Source:

Comparisons have been made between our measurements and those by E.M. Middleton. See the SE-590 Leaf Level Spectral Observations from GSFC document.

Confidence Level/Accuracy Judgment:

Calibrations performed in the Fall of 1989 (Mesarch et al., 1991) indicate that the calculated reflectance and transmittance values may be in error. Mean Bias Errors (MBEs) for the unrestricted light source are: -0.17%, 0.05%, 0.03%, 0.23%, 0.88%, 0.72% and 3.25% for wavebands 1 through 7. MBEs for the restricted light source are: -0.31%, -0.05%, -0.06%, -0.05%, 1.87%, 1.02%, 4.59% for wavebands 1 through 7.

Measurement Error for Parameters:

Not available.

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:

As of the revision data of this document, the following discrepancies or errors in the data have been reported:

- Erroneous data is coded -99.
- July 13, 1989 observation times are erroneous.
- MMR bands 2 and 6 had values of 0 (considered very low) at site 31 (SITEGRID_ID = 2139-BBN) on July 6, 1988.
- MMR bands 5 and 6 had values of 95.55 and 71.88 (considered very high), respectively, at site 11 (SITEGRID_ID = 4439-BBN) on June 29, 1988.
- MMR band 5 had a value of 78.86 (considered very high) at site 916 (SITEGRID_ID = 4439-BBN) on July 28, 1989.
- MMR band 5 had a value of 73.74 (considered very high) at site 916 (SITEGRID_ID = 4439-BBN) on August 4, 1989.

Usage Guidance:

Reflectances and transmittances may not be as accurate for wavebands 5-7 as they are for wave bands 1-4 (the MBEs (see the *Tolerance Section*) for the lead-sulfide wavebands are larger than those for silicon wavebands). This is especially true for waveband 7 when using the slitted illuminator due to combined effect of low light produced by the slitted illuminator and the lead-sulfide detector response to low light. Ambient temperature can alter the voltage response with the lead sulfide detector (as temperature decreases, the voltage decreases).

Any Other Relevant Information about the Study:

Pregnant women and people with bad backs can have a difficult time working with short plants.

12. Application of the Data Set:

This data set can be used to gain a better understanding of how optical properties contribute to canopy reflectance and absorption of radiation.

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:

Leaf Optical Properties from UNL data are available on FIFE CD-ROM Volume 1. The CD-ROM file name is as follows:

DATA\SUR_REFL\MMR_LEAF\GRIDxxxx\Yyyyy\ydddgrid.MRL

Where *xxxx* is the four digit code for the location within the FIFE study area, *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 sitegrid, *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 .MRL for this data set.

17. References:

Satellite/Instrument/Data Processing Documentation.

Barnes Engineering. 1982. Calibration and data book: Multispectral 8- channel radiometer. Barnes Engineering Company. Stamford, CT.

LI-COR LI-1800-12 Integrating Sphere instruction manual. Pub. No. 8305-0034. LI-COR, inc. Lincoln, NE. (1983).

Markham, B.L. 1987. Memo on review of Phoenix calibration of MMR Channel 8. GSFC/NASA, Greenbelt, MD 20771.

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Robinson, B.F., M.E. Bauer, D.P. DeWitt, L.F. Silva and V.C. Vanderbilt. 1979. Multiband radiometer for field research. Measurements of Optical Radiation. Proceedings of the Society of Photo-Optical Instrumentation Engineers. 196:8-15.

Robinson, B.F., and L.L. Biehl. 1979. Calibration procedures for measurement of reflectance factor in remote sensing field research. Measurements of Optical Radiation. Proceedings of the Society of Photo-Optical Instrumentation Engineers. 196:16-26.

Journal Articles and Study Reports.

Mesarch, M. A., E.A. Walter-Shea, B.F. Robinson, J.M. Norman and C.J. Hays. 1991. Performance evaluation and operation of a field-portable radiometer for individual leaf optical measurements. AgMet Progress Report 91-2. Department of Agricultural Meteorology. University of Nebraska-Lincoln. Lincoln, Nebraska. 68583-0728.

Levitt, J. and R. Ben Zaken. 1975. Effects of small water stresses on cell turgor and intercellular space. Physiol. Plant. 34, 273-279.

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:

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 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 MBE Mean bias error MMR Barnes Modular Multiband Radiometer NMLR Nebraska Multiband Leaf Radiometer ORNL Oak Ridge National Laboratory RWC Relative water content UNL University of Nebraska - Lincoln URL Uniform Resource Locator

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

20. Document Information:

April 26, 1994 (citation revised on October 16, 2002).

This document has been reviewed by the FIFE Information Scientist to eliminate technical and editorial inaccuracies. Previous versions 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 13, 1996.

Document ID:

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