MMR Helicopter Data (FIFE)

Summary:

The Surface Reflectance Measured with a Helicopter-borne MMR Data Set contains surface reflectance measurements in Landsat-TM bands at low to intermediate altitudes. The helicopter operated during all Intensive Field Campaigns (IFCs) and was available to support all satellite overpasses. The average flight time was 2 hours, during which an average of 11 FIFE sites plus one special target were covered.

The helicopter missions were designed to provide a rapid means of intensively spectrally characterizing each FIFE site while providing FIFE study area coverage, and to provide an intermediate scale of sampling between that of the surface measurements and the higher altitude aircraft and spacecraft multispectral imaging devices. The Modular Multiband Radiometer (MMR) instrumentation was chosen to provide compatibility with surface-based radiometers and TM spacecraft sensors. Off-nadir measurements were made as a means of providing more accurate estimates of hemispherical reflectance and for use with bi-directional reflectance models.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

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

Data Set Introduction:

The Surface Reflectance Measured with a Helicopter-borne MMR Data Set contains helicopter-borne MMR radiances and reflectances in the 8 MMR bands.

Objective/Purpose:

The FIFE Staff Science effort covered those activities which were community level activities, or which required uniform data collection procedures across sites and time. Hence, these activities were more appropriate for a team under the direction of a single scientist who would respond to the needs of the Science Steering Group of the experiment. This included the acquisition of the multispectral radiometer data from FIFE sites using a helicopter platform.

Summary of Parameters:

Helicopter-borne MMR radiances and reflectances in the 8 MMR bands.

Discussion:

The helicopter-borne MMR provides surface reflectance measurements in Landsat-TM bands at low to intermediate altitudes. The helicopter operated during all Intensive Field Campaigns (IFCs) and was available to support all satellite overpasses. During IFC-1 through IFC-4; 11, 10, 16, and 10 'clear day' missions were flown, respectively. The average flight time was 2 hours, during which an average of 11 FIFE sites plus one special target were covered. During IFC-5 10 missions were flown on 6 days in late July and early August 1989.

The helicopter missions were designed to provide 1) a rapid means of intensively spectrally characterizing each FIFE site while providing FIFE study area coverage, and 2) to provide an intermediate scale of sampling between that of the surface measurements and the higher altitude aircraft and spacecraft multispectral imaging devices. The MMR instrumentation was chosen to provide compatibility with surface-based radiometers and TM spacecraft sensors. Off-nadir measurements were made as a means of providing more accurate estimates of hemispherical reflectance and for use with bi-directional reflectance models.

Related Data Sets:

- Surface Reflectance Measured with Mast-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 (1989).

- SE-590 Leaf Level Spectral Observations from GSFC.
- Surface Temperatures from UNL.
- Surface Temperature Measured with a Helicopter-borne Infrared Thermometer (1989 only).
- Vegetation Species and Cover Abundance.
- Vegetation Species Reference.
- Biophysical Properties of Vegetation.

Color 35 mm aerial photographs and video records were made during 1987 MMR data collection. The video record includes helicopter crew cabin intercom conversations and an audible tone that was initiated each time the MMR was triggered.

Surface-based MMR measurements collected by the University of Nebraska were frequently obtained coincident with helicopter MMR data collection from the same site.

During 1989 only a video record was made during the helicopter missions (i.e., no photographs were taken).

FIS Data Base Table Name:

MMR_HELO_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Staff Science.

Title of Investigation:

Staff Science Helicopter Data Acquisition Program.

Contact Information:

Contact 1:
Charles L. Walthall
University of Maryland
College Park, MD
(301) 405-4058
cw7@umail.umd.edu

Contact 2:
Mr. K. Fred Huemmrich
NASA/Goddard Space Flight Center
Greenbelt, MD

(301) 286-4862
fred@ltpsun.gsfc.nasa.gov

Requested Form of Acknowledgment.

The helicopter MMR data was processed by K. Fred Huemmrich of the FIFE Information System. Thanks for collecting the data must also be given to the NASA Helicopter crew: Charles Walthall, mission scientist; William Dykes, pilot; Charles Smith, mechanic and observer; Ed Bohles, mechanic and observer; Richard Huey, photographer; Wayne Dulaney, calibration panel and instrument operator; David Pierce, engineer; Douglas Young, engineer; and to the US Army 82nd Medical Helicopter Unit, Ft. Riley, Kansas, for on-site hanger space and helicopter technical support.

3. Theory of Measurements:

Not available at this revision.

4. Equipment:

Sensor/Instrument Description:

The Barnes Modular Multiband Radiometer (MMR) was designed to acquire multispectral radiance data over the visible, near infrared, middle infrared and thermal regions of the electromagnetic spectrum. It produces analog voltage responses to scene radiance in 8 spectral bands. Voltages from thermistors attached to the instrument chopper and detectors are recorded to provide a means of compensating for thermal effects on sensor response and for calculation of target surface temperatures. The 8 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, 2.08-2.35, and 10.4-12.5 um. Bands 1-4 have silicon detectors and bands 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 the device weighs 6.4 kg.

Collection Environment:

Airborne.

Source/Platform:

The MMR (serial number 117) was mounted on a hinged plate on the nose of a NASA Bell UH-1B "Huey" helicopter. This system was developed for prior experiments over forested areas (Williams et al., 1984).

Source/Platform Mission Objectives:

There were two type of helicopter optical system missions: H-1a and H-1b. The objective of the H-1a missions was to acquire spectral data at specific FIFE sites coincident with surface, atmospheric and satellite measurements. The objective for the H-1b missions was to acquire multispectral data of as many FIFE sites as possible during the available flight time. All regular FIFE sites were measured from a hover. Some special sites were flown in a slow-flight transect mode.

The area for observations was a doughnut-like ring around the automated weather stations or over areas where surface radiance and biology measurements were being conducted. The ring around the weather stations was 2-3 times the width of the weather station areas (the instruments were normally bounded by fences). During 1989 transects designed to follow the wind-aligned-blob or WABs were flown.

Key Variables:

Reflected radiation, emitted radiation, surface temperature.

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.

Sensor/Instrument Measurement Geometry:

When mounted on the helicopter the optical head is equipped with lenses having a 1 degree FOV. Given a nominal data acquisition altitude of 300 m, spectral irradiance from the ground surface area of approximately 5 m in diameter is recorded. Prior to the FIFE mission the instrument pallet was modified to accommodate both nadir and a range (15, 30, 45, 60 degrees) of off-nadir view angles.

During 1989 missions a pointable pallet mounted on the side of the helicopter cabin was used. An altitude of 330 m above ground level was used during data collection.

Manufacturer of Sensor/Instrument:

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

Note that this instrument was designed and produced to meet NASA specifications for a field radiometer in the late 1970s. Since that time the MMR has been considered the industry standard for broad band field measurements. It is currently out of production.

Calibration:

With the exception of IFC-1, detector and chopper temperature voltages were recorded on the Omnidata Polycorder. Without these data during IFC-1 it is not possible to calculate reflectance in the lead sulfide channels during the period. Calibration of the MMR for absolute radiance and compensation for thermal effects (lead sulfide channels) was carried out by Staff/GSFC. Estimates of irradiance were derived from the use of a separate MMR (serial number 102) located on the surface mounted over a horizontal $BaSO_4$ reflectance panel using a 15 degree field of view lens. During IFC-1 the $BaSO_4$ panel was located near the FIFE headquarters building on the Konza (northwest corner of the study area). Due to concerns raised by FIFE investigators over the influence of diffuse radiation from this location, the panel was moved to site 16 (4439-HLM) (centrally located) for the remainder of the FIFE 1987. To minimize any background effects, the MMR was suspended over the panel using an extendible boom mounted on the back of a pick-up truck. The panel itself was placed on a raised platform above the cab of the truck. In addition to use in calculating downwelling irradiance for reflectance calculations, the MMR data from the calibration panel can be used to examine each day for cloudiness. These measurements were corrected for the spectral and non-lambertian characteristics of the panel according to the procedures of Jackson et al., 1983. Reflectance factors were calculated for all but the thermal band by dividing the helicopter-borne MMR target radiances by the corrected reflectance panel radiances. Data consists of means and standard deviations of radiance for each band and means and standard deviations of reflectance and surface temperature by band. Five minute running averages of the reflectance panel data were used to calculate reflectance factors.

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:

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. $BaSO_4$ measurements were made at one minute intervals beginning 30 minutes prior to the first helicopter mission and ending 30 minutes after the last helicopter mission of the day.

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 will change the gains and offsets but will not change the temperature sensitivity coefficients.

5. Data Acquisition Methods:

The NASA Bell UH-1B helicopter optical remote sensing system for 1987 supported a data acquisition system consisting of a foresighted MMR; a color video camera; and two 35 mm flight research cameras loaded with color film (one with a 1 inch focal length and the other with a 6 inch focal length). Controller units for all the optical devices were rack- mounted inside the helicopter and were wired such that a single switch closure triggered all devices. The switch closure also activates an audible tone which was recorded on one of the two audio tracks of a Beta- format video recording system. The other audio track of the VCR was used to record cabin intercom conversations among the helicopter crew. If one desires to examine site conditions in greater detail, the higher resolution 35 mm still photography can be reviewed. [Video tapes and 35 mm files are in the permanent FIFE archive]

During the 1987 FIFE campaigns, the radiometric instruments were placed on a moveable mount located on the nose of the helicopter so that the instruments could be pointed nadir or at preselected angles of up to 55 degrees off-nadir. Coincident surface-based measurements of the calibrated reference panel were supplemented with occasional data collection from the helicopter instrumentation while hovering over a calibrated 6 m by 6 m canvas panel on the surface.

6. Observations:

Data Notes:

Not available.

Field Notes:

Special targets include tree stands northeast of the HQ building and east of Highway I-77. Transects for Dr. David Schimel include ones west of site 40, southwest of site 8, east of site 4, and west of site 4. Correction/calibration targets for Dr. Carol Bruegge include the oil spill at site 30/32, bare soil near the HQ building, ponds near site 6, 2 ponds near the road and a tarp in the road west of site 16, and the blacktop at the entrance to site 16.

Off-nadir data is limited to backscatter measurements, and is limited in quantity. Data quality checks have not been made.

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 scattered throughout the FIFE study area.

They were made in the following 32 sitegrids.

SITEGRID	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEV	SLOPE
0847-HLM	4332344	714439	39 06 57	-96 31 11	418	1 TOP
1246-HLM	4331625	714200	39 06 34	-96 31 22	410	12 S
1445-HLM	4331160	714090	39 06 19	-96 31 27	400	
1478-HLM	4331223	720664	39 06 15	-96 26 53	375	2 N
1511-HLM	4331080	707287	39 06 22	-96 36 10		
1544-HLM	4330975	713795	39 06 13	-96 31 39		
1916-HLM	4330282	708259	39 05 55	-96 35 30	351	2 N
1942-HLM	4330121	713402	39 05 46	-96 31 57	420	1 TOP
2043-HLM	4330003	713536	39 05 42	-96 31 51	415	
2123-HLM	4329866	709506	39 05 41	-96 34 39	405	1 TOP
2132-HLM	4329774	711336	39 05 36	-96 33 23	405	
2133-HLM	4329706	711577	39 05 34	-96 33 13	443	1 TOP
2330-HLM	4329314	711066	39 05 22	-96 33 35	424	5 E
2516-HLM	4328956	708102	39 05 12	-96 35 38	405	
2619-HLM	4328874	708868	39 05 09	-96 35 07		
2655-HLM	4328787	716070	39 05 00	-96 30 07	367	4 E
2731-HLM	4328678	711110	39 05 01	-96 33 34	446	
2915-HLM	4328167	708028	39 04 47	-96 35 42	415	
2929-HLM	4328244	710726	39 04 47	-96 33 50	440	
3129-HLM	4327822	710820	39 04 33	-96 33 47	431	14 E
3317-HLM	4327395	708485	39 04 22	-96 35 24	427	15 W
3414-HLM	4327286	707854	39 04 19	-96 35 51	410	
3479-HLM	4327134	720890	39 04 02	-96 26 49	420	
4268-HLM	4325633	718582	39 03 16	-96 28 26	420	1 TOP
4439-HLM	4325219	712795	39 03 07	-96 32 27	445	2 N
4609-HLM	4324766	706700	39 02 58	-96 36 41	398	
4631-HLM	4324830	711253	39 02 56	-96 33 32	405	
6340-HLM	4321500	713000	39 01 07	-96 32 23	410	4 SW
6735-HLM	4320652	712073	39 00 40	-96 33 03	385	1 BOTTOM
6912-HLM	4320178	707307	39 00 29	-96 36 21	385	2 N
6943-HLM	4320147	713500	39 00 22	-96 32 04	415	
8739-HLM	4316699	712845	38 58 31	-96 32 35	442	1 TOP

Spatial Coverage Map:

Not available.

Spatial Resolution:

The ground resolution of the Helicopter MMR is 12.7 square meters at nadir and changed with view-zenith angle. The values in this data set are averaged values over a larger area of 10 to 100 square meters.

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Missions were dependent on the availability of clear sky conditions.

Every site was not observed on every flight.

Temporal Coverage:

Helicopter-borne MMR observations were obtained in 1987 and 1989 during the FIFE IFCs.

IFC#	Dates
IFC-1	05/26/87 - 06/06/87
IFC-2	06/25/87 - 07/11/87
IFC-3	08/06/87 - 08/21/87
IFC-4	10/05/87 - 10/16/87
IFC-5	07/24/89 - 08/12/89

Temporal Coverage Map:

Not available.

Temporal Resolution:

Observation time over each site was 2 to 5 minutes during which an average of 20 measurements were made (maximum of 150). Only averages of each site visit are reported in the FIFE data set. In general, sites were visited every couple of days.

Data Characteristics:

The SQL definition for this table is found in the MMR_HELO.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).			
DURATION The length of time over which the observations were made.		[seconds]	
MISSION_ID The FIFE mission id number for this helicopter flight.			
OBS_TYPE This is the area of the site observed. FULL is the entire site, WAB is only the WAB area, UNL is the area where the ground reflectance measurements were made, and PARA is at the Parabola site.			

NUM_OBS The number of observations made at the site.	
SOLAR_ZEN_ANG The solar zenith angle.	[degrees]
SOLAR_AZIM_ANG The solar azimuth angle, where 0=north, 90=east, 180=south and 270=west.	[degrees from North]
VIEW_ZEN_ANG The view zenith angle.	[degrees]
VIEW_AZIM_ANG The view azimuth angle. from North]	[degrees
HEIGHT_ABV_GRND_LVL The height of the radiometer above ground level.	[meters]
BAND1_RADNC The average reflected radiance at this site from the Barnes MMR channel 1 (.45 - .52 microns). [mic^-1]	[Watts] [meter^-2] [ster^-1]
BAND2_RADNC The average reflected radiance at this site from the Barnes MMR channel 2 (.51 - .60 microns). [mic^-1]	[Watts] [meter^-2] [ster^-1]
BAND3_RADNC The average reflected radiance at this site from the Barnes MMR channel 3 (.63 - .68 microns). [mic^-1]	[Watts] [meter^-2] [ster^-1]
BAND4_RADNC The average reflected radiance at this site from the Barnes MMR channel 4 (.75 - .88 microns). [mic^-1]	[Watts] [meter^-2] [ster^-1]

BAND5_RADNC

The average reflected radiance at this site from the Barnes MMR channel 5 (1.17 - 1.33 microns).	[Watts] [meter^-2] [ster^-1] [mic^-1]

BAND6_RADNC

The average reflected radiance at this site from the Barnes MMR channel 6 (1.57 - 1.80 microns).	[Watts] [meter^-2] [ster^-1] [mic^-1]

BAND7_RADNC

The average reflected radiance at this site from the Barnes MMR channel 7 (2.08 - 2.37 microns).	[Watts] [meter^-2] [ster^-1] [mic^-1]

BAND8_RADNC

The average reflected radiance at this site from the Barnes MMR channel 8 (10.4 -12.3 microns).	[Watts] [meter^-2] [ster^-1] [mic^-1]

TARGET_TEMP

The average radiant temperature of the site.	[degrees Celsius]

CHOPPER_TEMP

The average radiometer chopper temperature.	[degrees Celsius]

DETECTOR_TEMP

The average temperature of the detector.	[degrees Celsius]

BAND1_REFL

The average reflectance factor at this site for the Barnes MMR channel 1 (.45 - .52 microns).	[percent]

BAND2_REFL

The average reflectance factor at this site for the Barnes MMR channel 2 (.51 - .60 microns).	[percent]

BAND3_REFL

The average reflectance factor at	[percent]

this site for the Barnes MMR
channel 3 (.63 - .68 microns).

BAND4_REFL
The average reflectance factor at this site for the Barnes MMR channel 4 (.75 - .88 microns). [percent]

BAND5_REFL
The average reflectance factor at this site for the Barnes MMR channel 5 (1.17 - 1.33 microns). [percent]

BAND6_REFL
The average reflectance factor at this site for the Barnes MMR channel 6 (1.57 - 1.80 microns). [percent]

BAND7_REFL
The average reflectance factor at this site for the Barnes MMR channel 7 (2.08 - 2.37 microns). [percent]

BAND1_RADNC_SDEV
The standard deviation of the reflected radiances (expressed as percent of the mean) for MMR channel 1 (.45 - .52 microns). [percent]

BAND2_RADNC_SDEV
The standard deviation of the reflected radiances (expressed as percent of the mean) for MMR channel 2 (.51 - .60 microns). [percent]

BAND3_RADNC_SDEV
The standard deviation of the reflected radiances (expressed as percent of the mean) for MMR channel 3 (.63 - .68 microns). [percent]

BAND4_RADNC_SDEV
The standard deviation of the reflected radiances (expressed as percent of the mean) for MMR channel 4 (.75 - .88 microns). [percent]

BAND5_RADNC_SDEV

The standard deviation of the reflected radiances (expressed as percent of the mean) for MMR channel 5 (1.17 - 1.33 microns).	[percent]
BAND6_RADNC_SDEV The standard deviation of the reflected radiances (expressed as percent of the mean) for MMR channel 6 (1.57 - 1.80 microns).	[percent]
BAND7_RADNC_SDEV The standard deviation of the reflected radiances (expressed as percent of the mean) for MMR channel 7 (2.08 - 2.37 microns).	[percent]
BAND8_RADNC_SDEV The standard deviation of the reflected radiances (expressed as percent of the mean) for MMR channel 8 (10.4 -12.3 microns).	[percent]
TARGET_TEMP_SDEV The standard deviation of the radiant temperatures (expressed as percent of the mean) of the site.	[percent]
CHOPPER_TEMP_SDEV The standard deviation of the radiometer chopper temperatures (expressed as percent of the mean).	[percent]
DETECTOR_TEMP_SDEV The standard deviation of the detector temperatures (expressed as percent of the mean).	[percent]
BAND1_REFL_ATM_COR The atmospherically corrected reflectance at this site for the Barnes MMR channel 1 (.45 - .52 microns).	[percent]
BAND2_REFL_ATM_COR The atmospherically corrected reflectance at this site for the Barnes MMR channel 2 (.51 - .60 microns).	[percent]

BAND3_REFL_ATM_COR The atmospherically corrected reflectance at this site for the Barnes MMR channel 3 (.63 - .68 microns).		[percent]
BAND4_REFL_ATM_COR The atmospherically corrected reflectance at this site for the Barnes MMR channel 4 (.75 - .88 microns).		[percent]
BAND5_REFL_ATM_COR The atmospherically corrected reflectance at this site for the Barnes MMR channel 5 (1.17 - 1.33 microns).		[percent]
BAND6_REFL_ATM_COR The atmospherically corrected reflectance at this site for the Barnes MMR channel 6 (1.57 - 1.80 microns).		[percent]
BAND7_REFL_ATM_COR The atmospherically corrected reflectance at this site for the Barnes MMR channel 7 (2.08 - 2.37 microns).		[percent]
DATASET_ID This field contains an identification code for this group of data to link it to other information in the inventory table.		
FIFE_DATA_CRTFCN_CODE The FIFE Certification Code for the data, in the following format: CPI (Certified by PI), CPI-??? (CPI - questionable data).	*	
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	DURATION	MISSION_ID	OBS_TYPE
0847-HLM	29	06-JUN-87	1641	161	870412A	FULL
1445-HLM	42	06-JUN-87	1645	105	870412A	FULL
2043-HLM	44	06-JUN-87	1654	108	870412A	FULL
2655-HLM	36	06-JUN-87	1650	121	870412A	FULL

NUM_OBS	SOLAR_ZEN_ANG	SOLAR_AZIM_ANG	VIEW_ZEN_ANG	VIEW_AZIM_ANG
40	27.400	119.210	.000	.000
41	26.660	120.740	.000	.000
40	25.280	123.860	.000	.000
40	25.940	122.330	.000	.000

HEIGHT_ABV_GRND_LVL	BAND1_RADNC	BAND2_RADNC	BAND3_RADNC	BAND4_RADNC
229	22.81	32.82	26.47	90.33
229	18.24	28.23	18.15	100.52
229	21.37	31.55	23.18	94.60
229	22.87	33.27	26.44	89.29

BAND5_RADNC	BAND6_RADNC	BAND7_RADNC	BAND8_RADNC	TARGET_TEMP	CHOPPER_TEMP
39.46	14.29	2.618	10.009	31.724	22.998
37.77	11.21	1.680	9.719	29.635	23.046
38.73	12.95	2.261	10.027	31.842	22.983
40.48	14.85	2.779	10.235	33.331	22.975

DETECTOR_TEMP	BAND1_REFL	BAND2_REFL	BAND3_REFL	BAND4_REFL	BAND5_REFL
24.960	5.65	7.35	6.79	32.28	-9.99
24.436	4.49	6.28	4.63	35.73	-9.99
24.273	5.18	6.91	5.82	33.15	-9.99
24.263	5.58	7.33	6.68	31.47	-9.99

BAND6_REFL	BAND7_REFL	BAND1_RADNC_SDEV	BAND2_RADNC_SDEV	BAND3_RADNC_SDEV
-9.99	-9.99	11.40	9.38	17.26
-9.99	-9.99	6.77	5.46	10.40
-9.99	-9.99	4.50	3.70	6.60
-9.99	-9.99	2.78	2.19	3.15

BAND4_RADNC_SDEV	BAND5_RADNC_SDEV	BAND6_RADNC_SDEV	BAND7_RADNC_SDEV
2.72	3.60	6.48	8.51
5.64	3.12	3.68	6.66
8.88	3.31	3.34	7.83
2.91	1.36	1.96	3.78

BAND8_RADNC_SDEV	TARGET_TEMP_SDEV	CHOPPER_TEMP_SDEV	DETECTOR_TEMP_SDEV

1.03	2.32	.13	.83
.92	2.20	1.75	.19
2.19	4.93	.06	.04
1.04	2.25	1.65	.12

BAND1_REFL_ATM_COR	BAND2_REFL_ATM_COR	BAND3_REFL_ATM_COR
4.51	7.08	6.63
3.53	6.02	4.47
4.11	6.66	5.68
4.45	7.07	6.54

BAND4_REFL_ATM_COR	BAND5_REFL_ATM_COR	BAND6_REFL_ATM_COR
34.35		28.58
37.91		22.25
35.24		25.36
33.48		29.27

BAND7_REFL_ATM_COR	DATASET_ID	FIFE_DATA_CRTFCN_CODE
15.62	HEL157A	CPI
9.94	HEL157A	CPI
13.20	HEL157A	CPI
16.34	HEL157A	CPI

LAST_REVISION_DATE
20-SEP-88
20-SEP-88
20-SEP-88
20-SEP-88

8. Data Organization:

Data Granularity:

Measurements were scattered throughout the FIFE study area. The values in this data set are averaged values over a larger area of 10 to 100 square meters.

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:

See references in the *Processing Steps Section*.

Derivation Techniques and Algorithms:

See the *Processing Steps Section*.

Data Processing Sequence:

Processing Steps:

An MMR was mounted to continually view a Barium Sulfate panel (the Kansas State University #3 panel in 1987 and the University of Nebraska at Lincoln #2 panel in 1989). A measurement was automatically collected every minute during the helicopter flights. In the data processing the MMR voltage values from both the helicopter and calibration panel site were corrected to radiances. If detector voltages were recorded then the detector temperature (**Td**) was determined from the channel 10 voltage (**V10**):

Td = (LOG(V10) - 1.9316) / (-.04446). (1)

For each channel (**k**) the voltage (**Vk**) is adjusted for temperature effects:

V'k = ((Ck + Tc) / (Ck + Td)) * Vk (2)

where:

V'k is the adjusted voltage for channel **k**,
Ck is the temperature adjustment coefficient for channel **k**, and
Tc is the calibration temperature.

The radiance for channel **k** (**Rk**) in [Watts] [m^-2][sr^-1][micron^-1] is calculated using the calibration gains (**Gk**) and offsets (**Ok**):

Rk = ((V'k - Ok) / Gk) * 100. (3)

If the detector temperature was not available the voltage (**Vk**) was used in Equation 3 instead of the temperature adjusted voltage (**V'k**).

Calibration coefficients for channels 1 through 7 were determined using the Goddard Space Flight Center calibration hemisphere and thermal calibration from the United States Department of Agriculture at Phoenix.

MMR SN #102 with a 15 degree field-of-view lens (this MMR was used for the calibration panel observations):

Optical calibration done July 1987, thermal calibration done May 1987.

	k	Gk	Ok	Ck
1	.6730	-.0027	558	
2	.7030	-.0069	2280	
3	.7560	-.0124	-805	
4	1.033	-.0217	388	
5	2.122	-.0083	-68.7	
6	4.524	-.0081	-67.7	
7	13.416	-.0239	-61.3	

Calibration temperature (**Tc**) = 25.8 degrees Centigrade

Temperature calibration parameters:

Ac	Bc	Ka	Kb	Aa	Ab
.2332	14.98	3.9767e-04	1.14575e-06	-7.91868e-04	-3.08147e-06

MMR SN #102 with a 15 degree field-of-view lens

Optical calibration done December 1987, thermal calibration done November 1987.

	k	Gk	Ok	Ck
1	.6590	-.0024	558	
2	.6920	-.0070	2280	
3	.7430	-.0134	-805	
4	1.009	-.0185	388	
5	2.133	-.0110	-68.7	
6	4.718	-.0072	-67.7	
7	14.121	-.0269	-61.3	

Calibration temperature (**Tc**) = 25.8 degrees Centigrade

Temperature calibration parameters:

Ac	Bc	Ka	Kb	Aa	Ab
.1780	14.39	3.9741e-04	1.2111e-06	-8.1345e-04	-2.3683e-06

MMR SN #117 with a 1 degree field-of-view lens (this MMR was used on the helicopter):

Optical calibration done December 1987, thermal calibration done November 1987.

	k	Gk	Ok	Ck
1	.617	-.0054	4370	
2	.6560	-.0081	872	
3	.7100	-.0122	-1073	
4	.9450	-.0177	382	

5	2.615	.0263	-72.7	
6	5.437	.0300	-84.0	
7	15.407	-.0069	-70.4	

Calibration temperature (**Tc**) = 25.8 degrees Centigrade

Temperature calibration parameters:

Ac	Bc	Ka	Kb	Aa	Ab
.1433	14.25	3.87660E-04	1.52420E-06	-7.515800E-04	-2.5883E-06

MMR SN #117 with a 1 degree field-of-view lens

Optical calibration done May 1989, thermal calibration done June 1989.

k	Gk	Ok	Ck	
1	.563	-.0032	1175	
2	.644	-.0037	1196	
3	.685	-.0046	-1217	
4	.927	-.0065	356	
5	2.418	.0484	-71.9	
6	4.858	.0523	-85.0	
7	14.167	.0250	-69.6	

Calibration temperature (**Tc**) = 28.5 degrees Centigrade

Temperature calibration parameters:

Ac	Bc	Ka	Kb	Aa	Ab
.1975	14.76	3.96060e-04	1.25000e-06	-7.35310e-04	-3.5036e-06

The calibration panel radiances were then corrected for the anisotropy of the calibration panel:

R'k = Rk / (A1k + A2k * SZA + A3k * SZA^2 + A4k * SZA^3) (4)

where:

R'k is the radiance for channel **k** corrected for the anisotropy of the calibration panel;
A1k, A2k, A3k, and **A4k** are the coefficients for channel **k** for a specific panel, and
SZA is the solar zenith angle.

Kansas State University #3 panel coefficients (this panel was used in 1987):

k	A1	A2	A3	A4
1	.9290196	2.306627e-04	-4.65592e-05	2.59352e-07
2	.9195879	5.812958e-04	-5.164272e-05	2.977609e-07
3	.911211	5.37265e-04	-4.971094e-05	2.935253e-07
4	.9055673	3.424218e-04	-3.873801e-05	1.908786e-07
5	.8883391	2.91882e-04	-2.947789e-05	1.204603e-07

6	.8733857	6.246419e-04	-3.213795e-05	1.273971e-07
7	.8247155	1.075296e-03	-3.702393e-05	1.485077e-07

University of Nebraska at Lincoln #2 panel coefficients (this panel was used in 1989):

k	A1	A2	A3	A4
1	1.024066	-7.996049e-04	5.068796e-06	-3.423062e-07
2	1.022361	-8.242803e-04	1.107736e-05	-4.046916e-07
3	1.028746	-1.375718e-03	2.305963e-05	-4.769363e-07
4	1.027821	-1.352304e-03	2.514470e-05	-4.980858e-07
5	1.017411	-2.097449e-03	4.728492e-05	-6.302641e-07
6	.9879391	-1.605808e-03	3.859259e-05	-5.455406e-07
7	.9251772	-1.235733e-03	3.302859e-05	-4.998493e-07

The corrected radiance values are described in the MMR Calibration document on FIFE CD-ROM Volume 1.

Radiance values from the helicopter MMR were calculated from voltages the same way as the calibration panel MMR radiances were determined, by using equations 1 through 3 and the coefficients for instrument #117. To calculate reflectance factors for bands 1 through 7 the helicopter and calibration panel radiances must be combined. First, the calibration panel radiances were smoothed using a five minute running average and the data were visually examined to detect the presence of clouds. Intermittent clouds caused noticeable fluctuations in the calibration panel radiance data and these data were removed. The smoothed calibration panel radiances were matched by times and the reflectance factor for channel **k** (**Rflk**) were calculated as follows:

Rflk = (Rhk / Rpk) * 100. (5)

where:

Rhk is the radiance from the helicopter for channel **k**,
Rpk is the radiance from the calibration panel for channel **k**, and the factor of 100 is to express the reflectance factor as a percent.

The radiant temperature of the site was calculated from the helicopter MMR channel 8 radiance and the instrument temperature. The instrument temperature (**Ti**) was determined using the channel 9 voltage (**V9**) and the temperature calibration parameters **Ac** and **Bc** and the instrument temperature was used to calculate the instrument radiance (**Ri**):

Ti = (V9 - Ac) * Bc. (6)

Ri = .11927 / (EXP(1278.88 / (Ti + 273)) - 1) (7)

The radiance from the ground (**Rg**) was calculated from the instrument temperature and radiance, the channel 8 voltage (**V8**) and the temperature calibration parameters **Ka, Kb, Aa,** and **Ab** as follows:

Rg = Ri + (Ka + Kb * Ti) * V8 + (Aa + Ab * Ti) (8)

The ground radiance was expressed as a radiant temperature (**Tg**) using the Stephan-Boltzmann equation:

$$Tg = 1278.88 / LOG(.11927 / Rg + 1) - 273. \quad (9)$$

Finally, the individual radiance, reflectance, and temperature values were grouped for each site overpass and an average and standard deviation were calculated. The standard deviation was expressed as a percent of the mean. Also in that grouping the duration of the site overpass and the midpoint time were determined.

Processing Changes:

Not applicable.

Calculations:

Special Corrections/Adjustments:

Not applicable.

Calculated Variables:

- Detector temperature,
- Adjusted voltage for channel **k**,
- Radiance for channel **k**,
- Radiance for channel **k** corrected for the anisotropy of the calibration panel,
- Reflectance factor for channel **k**,
- Radiant temperature of the site,
- Radiance from the ground,
- Reflectance average and standard deviation,
- Temperature average and standard deviation, and
- Radiance average and standard deviation.

Graphs and Plots:

None.

10. Errors:

Sources of Error:

Errors associated with the measurements can occur due to orientation of the MMR. The angle of attack of the helicopter varies during flight. The motion of the helicopter cabin beneath the main rotor blades is analogous to a pendulum swinging. "Swings" resulting in off-nadir views up to 8 degrees off-nadir are possible. There has been no quantitative inquiry into this effect as only very small (estimated at 1 to 2 degrees) off-nadir-induced errors have been estimated in extreme cases. The instrument operator can normally wait for this motion to stop or can anticipate the position of the helicopter before triggering the instruments. The helicopter roll, pitch and yaw are dependent on atmospheric conditions, engine performance and aircrew fatigue. Off-nadir observations are especially questionable under less-than-optimal atmospheric conditions.

The shadowing caused by the MMR and the helicopter 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. Differences in irradiance between the reference panel location and the site being measured are an additional source of error (spatial distribution of atmospheric properties affecting irradiance).

There is also some debate on the amount of atmosphere in the pathlength between the helicopter and the surface. This has not been resolved and is under investigation at the time of this writing.

Quality Assessment:

Data Validation by Source:

Comparisons have been made with Surface Reflectances Measured by the PARABOLA, Surface Reflectances Measured with Mast-borne MMR and SE590 measurements (e.g., SE590 Spectroradiometer Reflectance Factors from GSFC, SE590 Reflectance Factor and Radiances Measured from a Helicopter, etc.). Plots of all helicopter MMR observations used in calculations of site averages have been made and examined for selected cases. The video tapes for these flights were reviewed as well. No obvious errors were detected.

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 provided by the Principal Investigator.

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 in 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:

Actual locations of the observations used to calculate a site average may not coincide exactly with locations of surface-based radiance measurements.

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.

Any Other Relevant Information about the Study:

Not available at this revision.

12. Application of the Data Set:

This data set spectrally characterizes each FIFE site, and provides an intermediate scale of sampling between that of the surface measurements and the higher altitude aircraft and spacecraft multispectral imaging devices.

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:

Tape Products.

Video tapes of the flights are available from the ORNL DAAC.

Film Products.

35 mm film products from some of the flights in 1987 are available from the ORNL DAAC.

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

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

Jackson, R.D., D.A. Dusek, and E.E. Ezra. 1983. Calibration of the thermal channel on four Barnes model 12-1000 multi-modular radiometers. U.S. Water Conservation Laboratory Report 12. Phoenix, Arizona.

Jackson, R.D., S.M. Moran, P.N. Slater, and S.F. Biggar. 1987. Field calibration of reference reflectance panels. Remote Sensing of Environment. 17:103-108.

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.

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Journal Articles and Study Reports.

Bauer, M.E., B.F. Robinson, C. Daughtry, and L.L. Biehl. 1981. Field Measurement Workshop. Oct. 14-16, Laboratory for application of Remote Sensing. Purdue University. Lafayette, Indiana.

Blad, B.L., E.A. Walter Shea, C.J. Hays, and M.A. Mesarch. 1990. Calibration of field reference panel and radiometers used in FIFE 1989. AgMet Progress Report 90-3. Department of Agricultural Meteorology. Univ. of Nebraska-Lincoln. Lincoln, Nebraska. 68583- 0728.

Markham, B.L., F.M. Wood, and S.P. Ahmad. 1988. Radiometric calibration of the reflective bands of NS001 Thematic Mapper Simulator (TMS) and Modular Multispectral Radiometers

(MMR). Society of Photo-Optical Instrumentation Engineers Recent Advances in Sensors, Radiometers, and Data Processing for Remote Sensing. 924:96-108.

Sellers, P.J. and F.G. Hall. 1989. FIFE-89 Experiment Plan. GSFC/NASA, Greenbelt, MD 20771.

Sellers, P.J., F.G. Hall, D.E. Strebel, R.D. Kelly, S.B. Verma, B.L. Markham, B.L. Blad, D.S. Schimel, J.R. Wang, and E. Kanemasu. 1990. FIFE Interim Report. GSFC/NASA, Greenbelt, MD 20771.

Walthall, C.L., 1989. The FIFE Helicopter Mission: Summary. Laboratory for Global Remote Sensing Studies. Univ. of Maryland. College Park, MD.

Walthall, C.L. and E.M. Middleton. 1992. Assessing spatial and spectral variations in grasslands with the use of a helicopter platform. J. Geophys. Res. FIFE issue. (in press).

Williams, D.L., C.L. Walthall and S.N. Goward. 1984. Collection of in-situ forest canopy spectra using a helicopter: A discussion of methodology and preliminary results. Proced. of 1984 Symp. on Machine Processing of Remotely Sensed Data. Purdue Univ. West Lafayette Indiana. p. 94-106.

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 CD-ROM Compact Disk - Read Only Memory DAAC Distributed Active Archive Center EOSDIS Earth Observing System Data and Information System FIFE First ISLSCP Field Experiment FIS FIFE Information System IFC Intensive Field Campaign IFOV Instantaneous Field-of-View ISLSCP International Satellite Land Surface Climatology Project Mbps Megabyte per second MMR Modular Multiband Radiometer ORNL Oak Ridge National Laboratory URL Uniform Resource Locator UTM Universal Transverse Mercator WAB Wind Aligned Blob

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:

ORNL- FIFE_MMR_HELO.

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DAAC Staff

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