Satellite Landsat TM Extr. Data (FIFE)

Summary:

The Thematic Mapper sensor system was used to collect the original data between February 1987 and October 1989 from which this data set was produced. Landsat TM extract data contains the average instrument corrected spectral radiances for each of the seven spectral bands. In addition, the associated view and solar angles are available for each of 39 FIFE ground measurement sites. The Site Reflectances Extracted from Landsat TM Imagery Data Set also contains reflectance values and exoatmospheric reflectance values for these seven spectral bands. These reflectances were derived using the sensor calibrated radiances which were corrected for exoatmospheric effects using atmospheric aerosol optical thickness and gaseous absorption profile measurements, when available. The atmospheric correction algorithm of Fraser et al. (1989) was used to calculate reflectance in the visible and infrared channels. The thermal data were corrected using parameters derived from the Lowtran-7 atmospheric path radiance model (Kneizys et al. 1988).

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1. Data Set Overview:

Data Set Identification:

Satellite Landsat TM Extr. Data (FIFE)
(Site Reflectances Extracted from Landsat TM Imagery)

Data Set Introduction:

The Site Reflectances Extracted from Landsat TM Imagery Data Set contains the average instrument corrected spectral radiances for each of the seven spectral bands. In addition, the associated view and solar angles are available for each of 39 FIFE ground measurement sites. This data set also contains reflectance values and exoatmospheric reflectance values for these seven spectral bands.

Objective/Purpose:

The FIFE Staff Science effort covered those activities which were FIFE community level activities, or required uniform data collection procedures across sites and time. These activities included acquiring and processing data from the Thematic Mapper (TM) instruments on the Landsat satellites.

As part of the FIFE staff science data collection effort, the FIFE Information System (FIS) processed the level-1 Landsat TM products to extract products.

Summary of Parameters:

Site specific radiance, exoatmospheric reflectance, surface reflectance, and surface temperature.

Discussion:

Landsat TM extract data contains the average instrument corrected spectral radiances (in [Watts][meter^-2][steradian^-1][micrometer^-1]) for each of the seven spectral bands. In addition, the associated view and solar angles are available for each of 39 FIFE ground measurement sites. This data set also contains reflectance values and exoatmospheric reflectance values for these seven spectral bands. These reflectances were derived using the sensor calibrated radiances which were corrected for exoatmospheric effects using atmospheric aerosol optical thickness and gaseous absorption profile measurements, when available. The atmospheric correction algorithm of Fraser et al. (1989) was used to calculate reflectance in the visible and infrared channels. The thermal data were corrected using parameters derived from the Lowtran-7 atmospheric path radiance model (Kneizys et al. 1988). These extracts were produced using TM images collected between February 1987 and October 1989. However, only one image was available for 1989. In 1987 and 1988 extracts are available roughly every 30 days.

Related Data Sets:

- Landsat Thematic Mapper (TM) Averages. (Imagery data)
- Level-3 Landsat Thematic Mapper (TM) Normalized Differences Vegetation Index Images. (Imagery data)
- Site Average Reflectances Extracted from AVHRR-LAC Imagery.

- Site Reflectances Extracted from SPOT HRV Imagery.
- Satellite Image Value Conversion Coefficients.
- Daily and Site Radiation Flux Averages Derived from GOES.

FIS Data Base Table Name:

SATELLITE_EXTRACT_LTM_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Staff Science.

Title of Investigation:

Staff Science Satellite Data Acquisition Program.

Contact Information:

Contact 1:
Jeffrey A. Newcomer
NASA/Goddard Sp. Fl. Ctr.
Greenbelt, MD.
(301) 286-7858
newcomer@ltp.gsfc.nasa.gov

Requested Form of Acknowledgment.

The Landsat TM extract data were produced by the FIFE Information System staff. The dedicated work of Scott Goetz and Jeff Newcomer is especially appreciated.

3. Theory of Measurements:

Radiance and reflectance from Landsat TM bands are useful in discrimination of vegetation type and vigor, plant and soil moisture measurement, differentiation of clouds and snow, and identification of hydrothermal alteration in certain rock types. Six of the seven bands have a spatial resolution of 30 x 30 m, while the thermal infrared band has a spatial resolution of 120 x 120 m.

The sensor measures radiation in seven bands of the electromagnetic spectrum:

1. A blue (0.45 to 0.52 um) band that provides increased penetration of water bodies, as well as supporting analyses of land use, soil, and vegetation characteristics. The shorter-wavelength cutoff is just below the peak transmittance of clear water, while the upper-

wavelength cutoff is the limit of blue chlorophyll adsorption for healthy green vegetation. Wavelengths below 0.45 um are substantially influenced by atmospheric scattering and absorption;

2. A green (0.52 to 0.60 um) band that spans the region between the blue and red chlorophyll absorption bands and therefore, corresponds to the green reflectance of healthy vegetation;
3. A red (0.63 to 0.69 um) chlorophyll absorption band of healthy green vegetation that represents one of the most important bands for vegetation discrimination. It is also useful for soil-boundary and geological delineations. This band may exhibit more contrast than bands 1 and 2 because of the reduced effect of atmospheric attenuation. The 0.69-um cutoff is significant because it represents the beginning of a spectral region from 0.68 to 0.75 um, where vegetation reflectance crossovers take place that can reduce the accuracy of vegetation investigations;
4. A reflective-infrared (0.76 to 0.90 um) band that is especially responsive to the amount of vegetation biomass present in a scene. This band is useful for crop identification and emphasizes soil-crop and land-water contrasts. For reasons discussed above, the lower cutoff for this band was placed above 0.75 um;
5. A mid-infrared (1.55 to 1.75 um) band that is sensitive to the turgidity or amount of water in plants. Such information is useful in crop drought studies and in plant vigor investigations. In addition, this is one of the few bands that can be used to discriminate between clouds, snow, and ice, which is so important in hydrologic research;
6. A mid-infrared (2.08 to 2.35 um) band that is important for the discrimination of geologic rock formations. It has been shown to be particularly effective in identifying zones of hydrothermal alteration in rocks;
7. A thermal infrared (10.4 to 12.5 um) band that measures the amount of infrared radiant flux emitted from surfaces. The apparent temperature is a function of the emissivities and true or kinetic temperature of the surface. It is useful for locating geothermal activity, thermal inertia mapping for geologic investigations, vegetation classification, vegetation stress analysis, and soil moisture studies.

4. Equipment:

Sensor/Instrument Description:

The Thematic Mapper sensor system used to collect the original data from which this data set was produced has been described in detail in the document Landsat Thematic Mapper (TM) Averaged Data found on FIFE CD-ROM Volume 1. See that document for details on the collection of the original TM images.

Collection Environment:

See the *Sensor/Instrument Description Section*.

Source/Platform:

See the *Sensor/Instrument Description Section*.

Source/Platform Mission Objectives:

See the *Sensor/Instrument Description Section*.

Key Variables:

See the *Sensor/Instrument Description Section*.

Principles of Operation:

See the *Sensor/Instrument Description Section*.

Sensor/Instrument Measurement Geometry:

See the *Sensor/Instrument Description Section*.

Manufacturer of Sensor/Instrument:

See the *Sensor/Instrument Description Section*.

Calibration:

Specifications:

See the *Sensor/Instrument Description Section*.

Tolerance:

See the *Sensor/Instrument Description Section*.

Frequency of Calibration:

See the *Sensor/Instrument Description Section*.

Other Calibration Information:

See the *Sensor/Instrument Description Section*.

5. Data Acquisition Methods:

The TM site reflectances were extracted from the FIFE level-1 TM data by FIFE staff at Goddard Space Flight Center. Members of the staff selected pixels from the TM Level-1 images that overlaid specific stations within the FIFE study area. The original imagery from the Thematic Mapper instruments on the Landsat satellites were acquired from the Earth Observation Satellite Company (EOSAT), Lanham, Maryland.

6. Observations:

Data Notes:

Not available.

Field Notes:

None.

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:

The data were extracted at 40 different locations scattered throughout the FIFE study area. The exact locations of the extracted pixels are given below.

SITEGRID	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEV	SLOPE	ASPECT
0847-LTM	4332344	714439	39 06 57	-96 31 11	418	1	TOP
1246-LTM	4331625	714200	39 06 34	-96 31 22	410	12	S
1445-LTM	4331160	714090	39 06 19	-96 31 27	400		
1478-LTM	4331223	720664	39 06 15	-96 26 53	375	2	N
1563-LTM	4331100	717610	39 06 14	-96 29 01	366	18	W
1916-LTM	4330282	708259	39 05 55	-96 35 30	351	2	N
1935-LTM	4330195	711927	39 05 49	-96 32 58	425	20	N
1942-LTM	4330133	713414	39 05 46	-96 31 56	422	1	TOP
2043-LTM	4329952	713679	39 05 40	-96 31 45	415		
2123-LTM	4329866	709506	39 05 41	-96 34 39	405	1	TOP
2133-LTM	4329706	711577	39 05 34	-96 33 13	443	1	TOP
2139-LTM	4329843	712789	39 05 37	-96 32 23	385		
2330-LTM	4329314	711066	39 05 22	-96 33 35	424	5	E
2428-LTM	4329265	710635	39 05 20	-96 33 53	415		
2516-LTM	4328956	708102	39 05 12	-96 35 38	405		
2655-LTM	4328787	716070	39 05 00	-96 30 07	367	4	E
2731-LTM	4328678	711110	39 05 01	-96 33 34	446		
2915-LTM	4328167	708028	39 04 47	-96 35 42	415		
3021-LTM	4328000	709250	39 04 40	-96 34 52	410	11	NW
3129-LTM	4327822	710820	39 04 33	-96 33 47	431	14	E
3221-LTM	4327682	709112	39 04 30	-96 34 58	410		
3317-LTM	4327395	708485	39 04 22	-96 35 24	427	15	W
3409-LTM	4327244	706850	39 04 18	-96 36 32	420	12	E
3414-LTM	4327286	707854	39 04 19	-96 35 51	410		
3479-LTM	4327134	720890	39 04 02	-96 26 49	420		
3921-LTM	4326116	709185	39 03 39	-96 34 57	415		
4139-LTM	4325850	712780	39 03 28	-96 32 27	385	3	W

4268-LTM	4325630	718500	39 03 16	-96 28 30	420	1	TOP
4439-LTM	4325193	712773	39 03 06	-96 32 28	443	2	N
4509-LTM	4324960	706850	39 03 04	-96 36 35	390	3	SE
4609-LTM	4324890	706705	39 03 02	-96 36 41	390		
5926-LTM	4322227	710270	39 01 32	-96 34 16	370		
6221-LTM	4321583	709247	39 01 12	-96 34 59	410		
6340-LTM	4321500	713000	39 01 07	-96 32 23	410	4	SW
6469-LTM	4321189	718752	39 00 51	-96 28 25	440	3	NE
6735-LTM	4320652	712073	39 00 40	-96 33 03	385	1	BOTTOM
6833-LTM	4320346	711660	39 00 30	-96 33 20	410		
6912-LTM	4320111	707336	39 00 26	-96 36 20	397	2	N
6943-LTM	4320147	713500	39 00 22	-96 32 04	415		
8739-LTM	4316699	712845	38 58 31	-96 32 35	442	1	TOP

Spatial Coverage Map:

Not available.

Spatial Resolution:

The IFOV is 30 m for bands 1 through 5 and band 7, but 120 m for band 6.

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Temporal Coverage:

The TM images from which the pixels were extracted spanned the growing seasons of 1987 and 1988 (April - October), and August of 1989.

Temporal Coverage Map:

Not available.

Temporal Resolution:

The average interval between images used to produce the extract data was roughly 30 days in 1987 and 1988, but only one image was available from 1989.

Data Characteristics:

The SQL definition for this table is found in the SAT_LTM.TDF file located on the 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 (expressed as DD-MMM-YY), on which the image data was recorded.

OBS_TIME
The time (GMT) when the data at the center of the level-1 image were collected.

IMAGE_ID
The FIS image identification code for the level-1 satellite image from which the site statistics were derived.

PLATFORM
The satellite platform on which the data collecting instrument is mounted.

INSTR_ID
The instrument which collected

the image data.		
NUM_OBS The number of observations (pixels) found within the site coordinate boundaries and used in the statistics calculations.		
MIN_LAT The minimum latitude of all the pixels extracted from the level-1 image and used to derive the site statistics (expressed as DD MM SS.SS).		
MAX_LAT The maximum latitude of all the pixels extracted from the level-1 image and used to derive the site statistics (expressed as DD MM SS.SS).		
MIN_LON The minimum longitude of all the pixels extracted from the level-1 image and used to derive the site statistics (expressed as DDD MM SS.SS).		
MAX_LON The maximum longitude of all the pixels extracted from the level-1 image and used to derive the site statistics (expressed as DDD MM SS.SS).		
VIEW_ZEN_ANG The view zenith at the center of the site.	[degrees]	
VIEW_AZIM_ANG The view azimuth at the center of the site (North = 0, East = 90, South = 180, West = 270).	[degrees from North]	
SOLAR_ZEN_ANG The solar zenith at the center of the site.	[degrees]	

SOLAR_AZIM_ANG The solar azimuth at the center of the site (North = 0, East = 90, South = 180, West = 270).		[degrees from North]
BAND1_AVG_RADNC The average radiance over the site for band 1 of the designated sensor.		[Watts] [meter^-2]
BAND1_SDEV_RADNC The standard deviation of the radiance values over the site for band 1 of the designated sensor.	*	[Watts] [meter^-2]
BAND2_AVG_RADNC The average radiance over the site for band 2 of the designated sensor.		[Watts] [meter^-2]
BAND2_SDEV_RADNC The standard deviation of the radiance values over the site for band 2 of the designated sensor.	*	[Watts] [meter^-2]
BAND3_AVG_RADNC The average radiance over the site for band 3 of the designated sensor.		[Watts] [meter^-2]
BAND3_SDEV_RADNC The standard deviation of the radiance values over the site for band 3 of the designated sensor.	*	[Watts] [meter^-2]
BAND4_AVG_RADNC The average radiance over the site for band 4 of the designated sensor.		[Watts] [meter^-2]
BAND4_SDEV_RADNC The standard deviation of the radiance values over the site for band 4 of the designated sensor.	*	[Watts] [meter^-2]
BAND5_AVG_RADNC The average radiance over the		[Watts]

site for band 5 of the designated sensor.		[meter^-2]
BAND5_SDEV_RADNC The standard deviation of the radiance values over the site for band 5 of the designated sensor.	*	[Watts] [meter^-2]
BAND6_AVG_RADNC The average radiance over the site for band 6 of the designated sensor.		[Watts] [meter^-2]
BAND6_SDEV_RADNC The standard deviation of the radiance values over the site for band 6 of the designated sensor.	*	[Watts] [meter^-2]
BAND7_AVG_RADNC The average radiance over the site for band 7 of the designated sensor.		[Watts] [meter^-2]
BAND7_SDEV_RADNC The standard deviation of the radiance values over the site for band 7 of the designated sensor.	*	[Watts] [meter^-2]
BAND1_AVG_REFL The average reflectance over the site for band 1 of the designated sensor.		[percent]
BAND2_AVG_REFL The average reflectance over the site for band 2 of the designated sensor.		[percent]
BAND3_AVG_REFL The average reflectance over the site for band 3 of the designated sensor.		[percent]
BAND3_SDEV_REFL The standard deviation of the reflectance values over the site for band 3 of the designated sensor.		[percent]

BAND4_AVG_REFL The average reflectance over the site for band 4 of the designated sensor.	[percent]
BAND5_AVG_REFL The average reflectance over the site for band 5 of the designated sensor.	[percent]
BAND7_AVG_REFL The average reflectance over the site for band 7 of the designated sensor.	[percent]
BAND1_EXOATMOSIC_REFL The at-satellite reflectance for band 1 of the sensor, calculated as observed reflected radiance divided by the solar irradiance at the top of the atmosphere.	[percent]
BAND2_EXOATMOSIC_REFL The at-satellite reflectance for band 2 of the sensor, calculated as observed reflected radiance divided by the solar irradiance at the top of the atmosphere.	[percent]
BAND3_EXOATMOSIC_REFL The at-satellite reflectance for band 3 of the sensor, calculated as observed reflected radiance divided by the solar irradiance at the top of the atmosphere.	[percent]
BAND4_EXOATMOSIC_REFL The at-satellite reflectance for band 4 of the sensor, calculated as observed reflected radiance divided by the solar irradiance at the top of the atmosphere.	[percent]
BAND5_EXOATMOSIC_REFL The at-satellite reflectance for band 5 of the sensor, calculated as observed reflected radiance divided by the solar irradiance at	[percent]

```
the top of the atmosphere.
```

```
BAND7_EXOATMOSIC_REFL
The at-satellite reflectance for                          [percent]
band 7 of the sensor, calculated
as observed reflected radiance
divided by the solar irradiance at
the top of the atmosphere.
```

```
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).
```

Footnotes:

Missing values are indicated by a -99.

** 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 which 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       IMAGE_ID        PLATFORM
-----------   ----------   ---------   --------   ----------------  ----------
0847-LTM         52        06-JUN-88     1634       4215216345-1     LANDSAT-4
1246-LTM         40        06-JUN-88     1634       4215216345-1     LANDSAT-4
1445-LTM         42        06-JUN-88     1634       4215216345-1     LANDSAT-4
1563-LTM         27        06-JUN-88     1634       4215216345-1     LANDSAT-4
     INSTR_ID    NUM_OBS      MIN_LAT        MAX_LAT        MIN_LON
---------   -------   ------------  -----------   --------------
TM           1      39 06 56.52   39 06 56.52   -96 31 11.78
TM           2      39 06 32.36   39 06 33.27   -96 31 20.09
TM           2      39 06 17.30   39 06 18.20   -96 31 26.19
TM           1      39 06 11.80   39 06 11.80   -96 28 57.88
       MAX_LON        VIEW_ZEN_ANG   VIEW_AZIM_ANG   SOLAR_ZEN_ANG   SOLAR_AZIM_ANG
--------------  ------------   -------------   -------------   --------------
-96 31 11.78         4.4            281.0           28.5           117.0
```

-96 31 19.88	4.4	281.0	28.5	117.0	
-96 31 26.00	4.4	281.0	28.5	117.0	
-96 28 57.88	4.7	281.0	28.5	117.0	

BAND1_AVG_RADNC	BAND1_SDEV_RADNC	BAND2_AVG_RADNC	BAND2_SDEV_RADNC
52.719	.0000	41.843	.0000
59.647	2.1298	46.542	1.6614
50.611	.4256	40.080	.8306
56.936	.0000	44.192	.0000

BAND3_AVG_RADNC	BAND3_SDEV_RADNC	BAND4_AVG_RADNC	BAND4_SDEV_RADNC
29.428	.0000	84.022	.0000
37.489	1.1399	79.135	1.1516
25.801	.5699	85.651	1.1512
31.846	.0000	74.248	.0000

BAND5_AVG_RADNC	BAND5_SDEV_RADNC	BAND6_AVG_RADNC	BAND6_SDEV_RADNC
11.302	.0000	10.291	.0000
12.329	.5349	10.433	.1205
9.357	.1528	10.234	.0803
10.329	.0000	9.779	.0000

BAND7_AVG_RADNC	BAND7_SDEV_RADNC	BAND1_AVG_REFL	BAND2_AVG_REFL
2.245	.0000	4.0	5.8
3.014	.4431	5.6	7.0
1.875	.1209	3.5	5.4
2.302	.0000	5.0	6.4

BAND3_AVG_REFL	BAND4_AVG_REFL	BAND5_AVG_REFL	BAND7_AVG_REFL
5.4	33.3	25.5	14.0
7.6	31.3	27.9	18.9
4.4	34.0	21.1	11.6
6.1	29.4	23.3	14.3

BAND1_EXOATMOSIC_REFL	BAND2_EXOATMOSIC_REFL	BAND3_EXOATMOSIC_REFL
9.9	8.4	7.0
11.2	9.4	8.9
9.5	8.1	6.1
10.7	8.9	7.5

BAND4_EXOATMOSIC_REFL	BAND5_EXOATMOSIC_REFL	BAND7_EXOATMOSIC_REFL
29.5	19.0	11.1
27.8	20.7	14.9
30.1	15.7	9.3
26.1	17.3	11.4

FIFE_DATA_CERTFN_CODE	LAST_REVISION_DATE
CPI	16-JAN-91
CPI	16-JAN-91
CPI	16-JAN-91
CPI	16-JAN-91

8. Data Organization:

Data Granularity:

The IFOV is 30 m for bands 1 through 5 and band 7, but 120 m for band 6.

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:

Derivation Techniques and Algorithms:

The procedure used to calculate TM atmospherically corrected reflectance was developed at GSFC as part of the FIFE staff science effort. The images were calculated from FIFE level-1 data and the reflectance and atmospheric correction calculations were performed using data and information available in the FIFE data collection.

Sensor calibrated radiances for the FIFE Landsat-TM images were converted to surface reflectance and temperature using the following procedures and information available in the FIFE satellite extracts coefficients data set. The thermal data were corrected using parameters derived from the Lowtran7 atmospheric path radiance model (Kneizys et al., 1988)

1. Derive at-satellite radiance:

   Radiance = DN(I) * GAIN(I) + OFFSET(I)

   where:

Radiance = spectral radiance for channel I [Watt][cm^-2] [sr^-1][um^-1]
DN(I) = Digital number for channel I [counts]
GAIN(I) = sensor gain for channel I [Watt][cm^-2][sr^-1][um^-1][count^-1]
OFFSET(I) = sensor offset for channel I [Watt][cm^-2][sr^-1][um^-1]

2. Convert to exoatmospheric reflectance (L'm) for each band:

L'm = (pi * Lm) / (F'o * cos(szen))

where (an apostrophe indicates a subscript):

pi = 3.14159265
Lm = apparent at-satellite calibrated spectral radiance [Watt][m^-2][sr^-1][um^-1]
F'o = Fo / (R^2)
R = d / d'
d = Earth-Sun distance (astronomical units)
d' = average Earth-Sun distance = 1 astronomical unit
szen = solar zenith angle in degrees
Fo = extraterrestrial solar irradiance in the TM bandpass as listed below:

	Landsat4	**Landsat5**	
TM1	1958.0	1957.0	[Watt][m^-2][um^-1]
TM2	1828.0	1829.0	
TM3	1559.0	1557.0	
TM4	1045.0	1047.0	
TM5	219.1	219.3	
TM7	74.6	74.5	

3. Calculate surface reflectance (rho) for each band:

rho = f / (1 + s * f)

where:

s = backscattering ratio (column BACKSCAT_RATIO in the satellite extract coefficients data set on FIFE CD-ROM Volume 1)
f = (L'm - L'o) / (F'd * T)
L'm = from (2) above
F'd = normalized surface flux (column IRRAD_NC in the satellite extract coefficients data set on FIFE CD-ROM Volume 1)
L'o = normalized path radiance (column NORMLZD_PATH_RADNC in the satellite extract coefficients data set on FIFE CD-ROM Volume 1)
T = path transmission (column TRNSMTNC in the satellite extract coefficients data set on FIFE CD-ROM Volume 1)

4. Correct satellite radiance to surface radiance for atmospheric conditions:

L'm = (Lm - (PRAD / RADCNV)) / TRNS

where:

L'm = apparent surface radiance.
Lm = apparent at-satellite calibrated spectral radiance [Watt][m^-2][sr^-1][um^1]
PRAD = filtered path radiance from Lowtran7
RADCNV = peak normalized bandpass [Landsat4 = 1.2614, Landsat5 = 1.8481] (converts in-band to spectral radiance)
TRNS = filtered path transmission from Lowtran7 (Lowtran units are multiplied by 10000
to convert from [Watt][cm^-2][sr^-1][um^-1] to [Watt][m^-2][sr^-1][um^-1]

5. Calculate surface temperature from corrected radiance:

T = K2 / ln ((K1 / L'm) + 1)

where:

K1 = calibration constant [Watt][m^-2][sr^-1][um^-1] [Landsat4 = 671.62, Landsat5 = 607.76]
K2 = calibration constant [degrees K] [Landsat4 = 1284.3, Landsat5 = 1260.56]
L'm = apparent surface radiance from (4) above.

The final site radiances, reflectances, surface temperatures, and exoatmospheric reflectances are averaged over the site and the mean and standard deviation for each channel is reported.

Data Processing Sequence:

Processing Steps:

FIFE staff creates the average instrument corrected spectral radiance data by :

1. Enumerating the pixel and line coordinates of the pixels that fall within each of the 39 sites.
2. Extracting the spectral, geographic, viewing, and solar information for the enumerated pixels.
3. Converting and correcting the digital spectral counts to radiance.

FIFE staff creates the reflectance data by :

1. Extracting the date, time, station_id, level-1a sensor calibrated radiances, solar zenith angles, view zenith angles, and observation height information from the FIS, for all dates, sites, and TM visible and IR channels.

2. Correcting the apparent at-sensor radiances for Earth-Sun distance and solar zenith angle by converting them to exoatmospheric (top of the atmosphere) reflectances, calculated as described in Fraser, et al. (1989), and in Markham and Barker (1986).
3. Extracting optical thickness measurements from the FIS for the variety of instruments that collected such data, and calculating the aerosol optical thickness for the TM-channel wavelengths. Optical thickness measurements are interpolated to the TM channels using a linear fit of the log of wavelength regressed against the log of optical thickness. TM-channel model wavelengths are calculated as described in Fraser et al. (1989). For the acquisitions in which no optical thickness measurements were available, a default value calculated from the median of all such measurements taken in 1988 and 1989 is used. The default values used are 0.18, 0.14, 0.12, 0.09, 0.04, 0.03 for TM channels 1-7 respectively, excluding channel 6 (thermal).
4. Calculating default extinction coefficients (optical thicknesses) due to water vapor and other gas (carbon dioxide and ozone) absorption from the Lowtran7 mid-latitude summer model. The default values calculated are listed below (the quantities are dimensionless):

Landsat-TM	Water	Other
Band1	0.00000	0.00671
Band2	0.00020	0.03194
Band3	0.00673	0.01829
Band4	0.05011	0.00339
Band5	0.12750	0.00849
Band7	0.09722	0.00792

5. Calculating ground-level downward irradiance, upward radiance, and surface reflectance in the TM channels for each of the sites in each acquisition using the algorithm of Fraser et al. (1989) and all the atmospheric, geometric, and radiometric data from above. The algorithm also outputs coefficients that allow conversion of any other portion of the scene to be corrected to surface reflectance. These coefficients are included in the satellite coefficients data set.

FIFE staff creates the surface temperature data by:

1. Extracting the date, time, station_id, level-1a sensor calibrated radiances, solar zenith angles, view zenith angles, and observation height information from the FIS, for all dates and sites in the TM thermal channel (10.45 - 12.46 um).
2. Reducing radiosonde data, sampling more frequently in the boundary layer, to 30 altitude levels for input to Lowtran7. Note that The FIFE Radiosonde Data are only available for correction of the August 15, 1987 and August 4, 1989 TM data.
3. Calculating atmospherically emitted path radiance and path transmittance using the Lowtran7 mid-latitude summer model for the observing conditions from (item 4 in the *Derivation Techniques and Algorithms Section*) above, and radiosonde data from (item 5 in the *Derivation Techniques and Algorithms Section*) above (when available).
4. Filtering the Lowtran7 output by the sensor response function of the appropriate Landsat sensor using the Lowtran7 Filter Function program. Figure 1 shows the relative sensor response, averaged for the four detectors in the TM thermal channel (channel 6) for the Landsat 4 and 5 instruments.

5. Calculating apparent at-satellite temperatures as described in Markham and Barker (1986), see the *Derivation Techniques and Algorithms Section*.
6. Calculating surface temperature (see the *Derivation Techniques and Algorithms Section*) for each of the sites in every acquisition.

Processing Changes:

None.

Calculations:

Special Corrections/Adjustments:

None.

Calculated Variables:

- Atmospherically emitted path radiance and path transmittance,
- Ground-level downward irradiance,
- Upward radiance,
- Default extinction coefficients (optical thicknesses),
- Surface reflectance (rho) for each band,
- Surface temperature,
- Final site radiances, reflectances, surface temperatures, and exoatmospheric reflectances are averaged over the site, and
- Mean and standard deviation for each channel is reported.

Graphs and Plots:

None.

10. Errors:

Sources of Error:

Errors could arise in the acquired imagery due to location accuracy, distortion of lengths, anisomorphism, the instrument's local coherence, the ability to register multispectral data, and relief plotting accuracy. Other errors could arise from inherent radiometric imperfections of the sensors. Spectral errors arise due to image wide signal-to-noise ratio, saturation, cross-talk, spikes, response normalization due to change in gain.

Whatever the processing level, the geometric quality of the image depends on, a) the accuracy of the viewing geometry, and b) the ground control points as required to adjust the viewing model. Errors arise from the processing of the data to level-1A due to calibration inaccuracies (gains and

offsets/drift of sensor characteristics/optical degradation), and resampling/positioning in geometric corrections.

Quality Assessment:

Data Validation by Source:

The FIFE staff was responsible for screening imagery for quality, applying radiometric corrections, computing geometric corrections corresponding to the required map projection, applying geometric corrections, and screening for cloud cover on imagery during processing.

Confidence Level/Accuracy Judgment:

The precision of satellite remote sensing estimates of surface reflectance (Hall et al., 1992), calibrated and corrected for atmospheric effects, was no worse than about 1 percent absolute. The errors may actually be smaller, but an upper bound of 1 percent results from sampling variance caused by differences among the satellite and ground sensors in spatial resolution, atmospheric effects, and calibration.

Measurement Error for Parameters:

There are also known, but as yet uncorrected, effects associated with temperature-dependence of the TM internal calibrator that may be contributing to apparent discontinuous changes at launch and to the continuous changes of gain while in orbit. Additional uncertainties for exoatmospheric reflectances are probably less than 2% in the visible/near-infrared and less than 5% in the short-wave infrared portion of the spectrum as judged by the current differences in estimates of the solar irradiance.

The magnitude of other errors as described in the *Sources of Error Section* is unknown.

Additional Quality Assessments:

FIS staff applied a general Quality Assessment (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. An attempt was made to find an explanation for unexpected high or low values, values outside of the normal physical range for a variable, or standard deviations that appeared inconsistent with the mean. In some cases, histograms were examined to determine whether outliers were consistent with the shape of the data distribution.

The discrepancies which were identified are reported as problems 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:

discrepancies or errors in the data have been reported:

- The original scene received from EOSAT for August 15, 1987 had a one line drop-out that cuts across the Konza. On the level-1 image it will be a straight line cutting across the Konza. On a registered image it will run diagonally across the image. The bad line occurred in bands 1, 2, 3, 5, and 7 at line 2057. There were no problems in bands 4 and 6. EOSAT was notified and they subsequently sent a replacement tape.
- The replacement imagery received from EOSAT also had bad lines in the 1024 x 1024 FIFE subset. These lines were in band-1 at line 887 (samples: 484-615), band-2 at line 813 (samples: 581-645), band-5 at line 391 (samples: 610-703), band-7 at line 391 (samples: 611-699).
- This problem was finally corrected by merging the good portions of the original image and those of the replacement image to obtain a bad-line free image, which was processed to FIS level-1 image and used to create the extract products.
- The thermal band (band 6) has no data for the exoatmospheric reflectances or for the band averages.
- Several other data points look suspicious and should be used with caution. Listed by satellite, they are
    - Landsat 4
        - Band 7 average reflectances have 3 values greater than 25.
        - Band 7 average radiances have 1 value greater than 4 (5.34).
        - Band 3 average radiances have 1 value greater than 45 (52.267).
        - Band 5 average radiances have 1 value greater than 15 (16.994).
    - Landsat 5
        - Band 4 averages reflectances have 8 values less than 10.
        - Band 2 exoatmospheric reflectances have 3 values greater than 13 (max of 14.2).

Usage Guidance:

Landsat TM data are used for analysis and inventory of surface resources of the Earth, namely, vegetation, soils, geology, flood and fire hazards, etc. Other applications include geographical and ecological research.

Any Other Relevant Information about the Study:

None.

12. Application of the Data Set:

Radiance and reflectance from Landsat TM bands are useful in discrimination of vegetation type and vigor, plant and soil moisture measurement, differentiation of clouds and snow, and identification of hydrothermal alteration in certain rock types. Other applications include geographical and ecological research.

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:

Site Reflectances Extracted from Landsat TM Imagery are available on FIFE CD-ROM Volume 1. The CD-ROM file name is as follows:

\DATA\SAT_OBS\SAT_LTM\Yyyyy\ydddFIFE.LTM

Where *yyyy* are the four digits of the century and year (e.g. 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: *ydddFIFE.sfx*, where *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 .LTM 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:

CD-ROM Compact Disk-Read Only Memory DAAC Distributed Active Archive Center EOSAT Earth Observation Satellite Company EOSDIS Earth Observing System Data and Information System FIFE First ISLSCP Field Experiment FIS FIFE Information System IFOV Instantaneous Field-of-View ISLSCP International Satellite Land Surface Climatology Project ORNL Oak Ridge National Laboratory TIPS Thematic Mapper Image Processing System TM Thematic Mapper URL Uniform Resource Locator UTM Universal Transverse Mercator

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

20. Document Information:

April 27, 1994 (citation revised on October 14, 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.

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Document Curator:

DAAC Staff

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