Satellite AVHRR Extracted Data (FIFE)

Summary:

The Advanced Very High Resolution Radiometer (AVHRR) is a four- or five-channel scanning radiometer capable of providing global daytime and nighttime sea-surface temperature and information about ice, snow, and clouds. The sensor measures emitted and reflected radiation in five channels (bands) of the electromagnetic spectrum. The Site Average Reflectances Extracted from AVHRR-LAC Imagery Data Set consists of averages of pixel extracts from AVHRR-LAC (1 km resolution) scenes that overlay the FIFE site. Average radiances for dates are available for the five sensor wavebands and average reflectance and exoatmospheric reflectances are available for wavebands 1 and 2. Site averages are clustered in 1987 and during the summer of 1989. Some data are also available for early 1988.

The AVHRR is capable of operating in both real-time or recorded modes. Direct readout data were transmitted to ground stations of the automatic picture transmission (APT) class at low-resolution (4x4 km) and to ground stations of the high-resolution picture transmission (HRPT) class at high resolution (1x1 km). Data recorded on board were available for processing in the NOAA Central Computer Facility. They included local area coverage (LAC) data which were from selected portions of each orbit with a 1x1 km resolution. 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.

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1. Data Set Overview:

Data Set Identification:

Satellite AVHRR Extracted Data (FIFE)
(Site Average Reflectances Extracted from AVHRR-LAC Imagery)

Data Set Introduction:

The Site Average Reflectances Extracted from AVHRR-LAC Imagery Data Set consists of averages of pixel extracts from AVHRR-LAC (1 km resolution) scenes that overlay the FIFE site. Average radiances for dates are available for the five sensor wavebands and average reflectance and exoatmospheric reflectances are available for wavebands 1 and 2.

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 Advanced Very High Resolution Radiometer (AVHRR) instruments on the NOAA-9, NOAA-10, and NOAA-11 satellites.

As part of the FIFE staff science data collection effort, the FIFE Information System (FIS) processed the level-1 NOAA AVHRR Local Area Coverage (LAC) products to extract products.

Summary of Parameters:

Site specific radiance, exoatmospheric reflectance and surface reflectance.

Discussion:

This data set consists of averages of pixel extracts from AVHRR-LAC (1 km resolution) scenes that overlay the FIFE site. The entire FIFE area is designated as STATION_ID 99 (sitegrid=FIFE-LAC) in the data set. Average radiances for dates are available for five sensor wavebands and average reflectance and exoatmospheric reflectances are available for wavebands 1 and 2. Site averages are clustered in 1987 and during the summer of 1989. Some data are also available for early 1988.

Related Data Sets:

- Level-1 Advanced Very High Resolution Radiometer (AVHRR) Images. (Imagery data)
- Site Reflectances Extracted from Landsat at TM 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_AVHRR_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Staff Science.

Title of Investigation:

Staff Science Satellite Data Acquisition Program.

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Requested Form of Acknowledgment.

The Site Average Reflectance Extracted from AVHRR-LAC Imagery were produced by the FIFE Information System staff. The dedicated work of Scott Goetz and Jeff Newcomer is especially appreciated.

3. Theory of Measurements:

The Advanced Very High Resolution Radiometer (AVHRR) is a four- or five-channel scanning radiometer capable of providing global daytime and nighttime sea-surface temperature and information about ice, snow, and clouds. They have also been used to make measurements related to vegetation and other land surface parameters (Tucker 1984).

The sensor measures emitted and reflected radiation in five channels (bands) of the electromagnetic spectrum: 1) A blue (0.58 to 0.68 um) band that used for daytime cloud and surface mapping; a reflective infrared (0.725 to 1.1 um) band used for surface water delineation, and vegetation cover mapping; a mid-infrared (3.55 to 3.93 um) band used for sea surface temperature, and nighttime cloud mapping; a thermal infrared (10.5 to 11.5 um) band used for surface temperature, and day/night cloud mapping; and another thermal infrared (11.5 to 12.5 um) band used for surface temperature mapping (Kidwell, 1991).

The AVHRR is capable of operating in both real-time or recorded modes. Direct readout data were transmitted to ground stations of the automatic picture transmission (APT) class at low-resolution (4x4 km) and to ground stations of the high-resolution picture transmission (HRPT) class at high resolution (1x1 km). Data recorded on board were available for processing in the NOAA Central Computer Facility. They included local area coverage (LAC) data which were from selected portions of each orbit with a 1x1 km resolution.

4. Equipment:

Sensor/Instrument Description:

The AVHRR sensor system used to collect the original data from which this data set was produced is described in detail in the documentation for Level-1 Advanced Very High Resolution Radiometer (AVHRR) Images data set. See that document for more details.

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 Site Average Reflectances Extracted from AVHRR-LAC Imagery were produced from the FIFE level-1 AVHRR data by FIFE staff at Goddard Space Flight Center. The original imagery from the Advanced Very High Resolution Radiometer instruments on the NOAA-9, NOAA-10, and NOAA-11 satellites were acquired from the Naval Research Laboratory (NRL) and the EROS Data Center.

6. Observations:

Data Notes:

Not available.

Field Notes:

None.

7. Data Description:

Spatial Characteristics:

The FIFE site, 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 extracted data cover the area of the FIFE site, i.e., the area between 38 degrees 52 minutes 30 seconds and 39 degrees 07 minutes 30 seconds North latitude, and between 96 degrees 22 minutes 30 seconds and 96 degrees 37 minutes 00 seconds West longitude.

Spatial Coverage Map:

Not available.

Spatial Resolution:

The resolution of these data is approximately 15 km since the site average was produced using 200-300 pixels scattered throughout the site.

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Temporal Coverage:

NOAA AVHRR-LAC acquisition used for extract products covers the period from February 3, 1987 through October 13, 1989.

Satellite extracts were computed for 331 days over the range of data collection. The distribution of extracts by month over these 33 months is as follows:

Month/Year	Date Averages per Month	Month/Year	Date Averages per Month
Feb. 1987	17	July 1988	4
March 1987	15	Aug. 1988	3
April 1987	24	Sept. 1988	9
May 1987	15	Oct. 1988	2
June 1987	21	Nov. 1988	0
July 1987	26	Dec. 1988	0
Aug. 1987	23	Jan. 1989	0
Sept. 1987	24	Feb. 1989	0
Oct. 1987	25	Mar. 1989	0
Nov. 1987	17	Apr. 1989	0
Dec. 1987	17	May 1989	0
Jan. 1988	16	June 1989	4
Feb. 1988	4	July 1989	16
Mar. 1988	6	Aug. 1989	10
Apr. 1988	4	Sept. 1989	11
May 1988	5	Oct. 1989	5

Temporal Coverage Map:

Not available.

Temporal Resolution:

The average interval between images used to produce the extract data was roughly 12 hours. There are generally two overpasses per day per satellite at approximate times of 0200, 0900, 1400, and 2100 GMT. However, not all of these data were processed due to cloud cover and other limitations of the data.

Data Characteristics:

The SQL definition for this table is found in the SAT_AVHR.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 (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). [Degrees, Minutes, Seconds]

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). [Degrees, Minutes, Seconds]

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). [Degrees, Minutes, Seconds]

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 [Degrees, Minutes, Seconds]

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	[Watts]

radiance values over the site for band 3 of the designated sensor.	[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 site for band 5 of the designated sensor.	[Watts] [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]
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]
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]
FIFE_DATA_CRTFCN_CODE	

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

Footnote:

Valid levels

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

The certification code modifiers are: PRE-NFP Preliminary - Not for publication, at the request of investigator. CPI-MRG PAMS data that are "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
FIFE-LAC	99	03-FEB-87	1401	LAC1001975N-1	NOAA-10
FIFE-LAC	99	07-FEB-87	1414	LAC1002032N-1	NOAA-10
FIFE-LAC	99	08-FEB-87	135	LAC1002039N-1	NOAA-10
FIFE-LAC	99	10-FEB-87	1449	LAC1002075N-1	NOAA-10

INSTR_ID	NUM_OBS	MIN_LAT	MAX_LAT	MIN_LON
AVHRR-LAC	475	38 52 30.58	39 07 28.58	-96 37 28.31
AVHRR-LAC	615	38 52 30.94	39 07 29.66	-96 37 29.66
AVHRR-LAC	687	38 52 31.81	39 07 28.09	-96 37 29.88
AVHRR-LAC	499	38 52 31.22	39 07 29.42	-96 37 24.47

MAX_LON	VIEW_ZEN_ANG	VIEW_AZIM_ANG	SOLAR_ZEN_ANG	SOLAR_AZIM_ANG
-96 22 30.72	35.8	97.5	85.4	115.7
-96 22 30.44	21.0	99.2	82.3	117.0
-96 22 34.59	7.7	259.5	110.1	266.3
-96 22 30.53	33.3	284.8	75.8	122.4

BAND1_AVG_RADNC	BAND1_SDEV_RADNC	BAND2_AVG_RADNC	BAND2_SDEV_RADNC
6.706	.4231	4.097	.4460
9.293	.7923	6.578	.6955
-1.407	.1872	-1.171	.0232
17.703	1.8272	12.248	1.3916

BAND3_AVG_RADNC	BAND3_SDEV_RADNC	BAND4_AVG_RADNC	BAND4_SDEV_RADNC
.111	.0043	5.563	.0528
.129	.0047	6.117	.0518
.146	.0099	6.496	.1248
.164	.0056	6.252	.0989

BAND5_AVG_RADNC	BAND5_SDEV_RADNC	BAND1_AVG_REFL	BAND2_AVG_REFL

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---------------   ----------------   --------------   --------------
5.563             .0515
6.113             .0438
6.495             .1251
6.245             .0971              3.1              22.7
     BAND1_EXOATMOSIC_REFL    BAND2_EXOATMOSIC_REFL   FIFE_DATA_CERTFN_CODE
---------------------   ---------------------   --------------------
CPI
CPI
CPI
13.3                  14.7                       CPI
     LAST_REVISION_DATE
------------------
31-JUL-90
31-JUL-90
31-JUL-90
25-APR-91
```

8. Data Organization:

Data Granularity:

The resolution of these data is approximately 15 km since the site average was produced using 200-300 pixels scattered throughout the site. The average interval between images used to produce the data was roughly 12 hours.

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 AVHRR atmospherically corrected reflectance was developed at GSFC as part of the FIFE staff science effort. The data 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.

The radiance values for bands 1 and 2 (RAD1, RAD2) were calculated using the pre-launch gains and offsets given below. The radiance values for bands 3, 4, and 5 were derived based upon the information contained in the NOAA Polar Orbiter User's Guide (Kidwell 1990) and Data Extraction and Calibration of TIROS-N/NOAA Radiometers documents. The conversion from digital counts to radiance is as follows:

I) Derive at-satellite radiance:

The radiance values for the respective bands were calculated as follows:

Radiance = (DN(I) - OFFSET(I)) / GAIN(I)

where:

Radiance = spectral radiance for channel I
[Watt][m^-2][sr^-1][um^-1] for I = 1,2;
[mWatt][cm][m^-2][sr^-1] for I = 3,4,5;
DN(I) = digital number for channel I [counts]
OFFSET(I) = sensor offset for channel I [counts]
GAIN(I) = sensor gain for channel I [counts][radiance unit^-1]

Note: FIFE terminology for GAIN and OFFSET is reversed from NOAA's :

NOAAGAIN(I) = 1.0/GAIN(I)
NOAAOFFSET(I) = -(OFFSET(I)/GAIN(I))

A) GAIN, OFFSET Determination.

1) Reflective Channels (1,2)

Use pre-launch gains (GSFC calculated)

NOAA-9 : GAIN(1) = 1.908; GAIN(2) = 3.040
NOAA-10 : GAIN(1) = 1.957; GAIN(2) = 2.899
NOAA-11 : GAIN(1) = 1.912; GAIN(2) = 3.178

Radiances calculated using these pre-launch gains can be updated using a multiplication factor for observed degradation.

Use SPACE VIEWS as offsets

> **OFFSET(I)** = average space view of the channel from FIFE Level-1 ASCII image header file

2) Thermal Channels (3,4,5)

Calculate gains from FIFE Level-1 ASCII image header file information (negative radiance of space not used)

Let,

> **K1** = 1.1910659E-05 [mWatt][cm][m^-2][sr^-1]
> **K2** = 1.438833 [cm][deg K]

WAVE CENTER (VC) TABLE (cm-1)

NOAA-9			NOAA-10		
Temp. Deg (K)	BAND 3	BAND 4	BAND 5	BAND 3	BAND 4	BAND 5
180-225	2670.93	928.50	844.41	2658.53	908.73	909.73
225-270	2674.81	929.02	844.80	2657.60	909.18	909.18
270-310	2677.67	929.39	845.12	2660.35	909.52	909.52
310-320	2678.11	929.46	845.19	2660.76	909.58	909.58

	NOAA-11		
Temp. Deg (K)	BAND 3	BAND 4	BAND 5
180-225	2663.50	926.81	841.40
225-270	2668.15	927.36	841.81
270-310	2670.96	927.75	842.14
310-320	2671.40	927.83	842.20

Based on the platform, set **VC** to the values for the 270 - 310 temp range, then,

> **ENUM = (K1 * VC(I+2)) * VC(I+2) * VC(I+2)**
> **DENOM = EXP[K2 * VC(I+2) / BB_TEMP] - 1**
> **BB_RAD = ENUM / DENOM**
> **GAIN(I+2) = (BB_VIEW(I+2) - OFFSET(I+2)) / BB_RAD**

where:

> **BB_TEMP** is the average black body temp (K) given in the FIFE level-1 ASCII image header file.
> **BB_VIEW(I+2)** is the respective average black body view (DN) of the channel obtained from the FIFE level-1 ASCII image header file.
> **OFFSET(I+2)** is the average space view (DN) of the channel obtained from the FIFE level-1 ASCII image header file.
> **I** = 1, 2, 3 (**I+2** designates the respective channels)

B) Non-linearity correction for bands 4 and 5:

The basic equation provides the final radiances (except for unit conversions) for channels 1, 2, 3. Channels 4 and 5 require a non-linearity correction which depends on the instrument temperature.

1) Calculate average scene temperatures for bands 4 and 5 using the assumed wave centers.

ENUM = K2 * VC(I+3)
DENOM = (K1 * VC(I+3)) * VC(I+3) * VC(I+3)
ARG = ALOG(DENOM / PIX_RAD(I+3) + 1.0)
TEMP(I+3) = ENUM / ARG

where:

I = 1, 2 (**I + 3** designates the respective channels)
PIX_RAD(I+3) is the band radiance for a given pixel
TEMP(I+3) is the temperature for the given pixel

2) Reset the wave centers (**VC**) for bands 4, 5 based on the respective average scene temperatures.

Note: The temperature to radiance conversion is a fitted equation with the parameter **VC** fit for different temperature ranges.

3) Convert Band 4 and 5 radiances to temperatures [deg K] with the updated wave centers.

ENUM = K2 * VC(I+3)
DENOM = (K1 * VC(I+3)) * VC(I+3) * VC(I+3)
ARG = ALOG(DENOM/PIX_RAD(I+3) + 1.0)
TEMP(I+3) = ENUM/ARG

where:

I = 1, 2 (**I + 3** designates the respective channels)
PIX_RAD(I+3) = the band radiance for a given pixel
TEMP(I+3) = the temperature for the given pixel

4) Perform linear interpolation between tabulated temperature correction sets to derive needed correction set for black body temperature obtained from FIFE level-1 ASCII image header file. The result is a column of non-linearity corrections for the observed BB_TEMP.

NOAA-9				NOAA-10					
BAND 4			BAND 5			BANDS 4 & 5			
BB_TEMP (K)			BB_TEMP (K)			BB_TEMP (K)			
PIXEL TEMP	283	288	293	283	288	293	283	288	293
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320	2.3	2.3	2.3	0.8	1.0	1.2	2.1	1.6	1.5
315	1.8	1.9	1.8	0.6	0.9	0.9	1.8	1.3	1.2
310	1.6	1.4	1.3	0.8	0.7	0.7	1.5	1.0	0.9
305	1.3	1.0	0.9	0.7*	0.4	0.5	1.1	0.7	0.6
295	0.7	0.4	0.2	0.4	0.2	0.1	0.5	0.2	0.1
285	0.0	-0.2	-0.5	0.0	-0.1	-0.2	-0.1	-0.3	-0.3
275	-0.5	-0.7	-0.9	-0.3	-0.3	-0.5	-0.2	-0.5	-0.6
265	-0.8	-1.1	-1.2	-0.5	-0.6	-0.7	-0.5	-0.9	-0.9
255	-1.0	-1.3	-1.6	-0.7	-0.8	-1.0	-0.9	-1.1	-1.2
245	-1.1	-1.3	-1.7	-0.8	-0.8	-1.2	-1.3	-1.4	-1.4
235	-1.2	-1.4	-1.6	-1.1	-1.2	-1.2	-1.5	-1.5	-1.6
225	-1.3	-1.3	-1.5	-1.2	-1.0	-1.1	-1.7	-1.7	-1.8
215	-1.2	-1.5	-1.4	-1.2	-1.4	-1.4	-2.0	-1.9	-1.8
205	-1.6	-1.5	-0.7	-1.7	-1.6	-1.1	-2.3	-2.1	-1.8

Footnote:

On October 27, 1990 a typographical error was reported in the values of the above table. For NOAA-9 band 5 at a target temperature of 305 K and a blackbody temperature of 283 K, the value should be 0.7, not 1.1 as previously reported. The old value of 1.1 was replaced with the new value of 0.7 in the table above. However, the extracted FIFE AVHRR site data were processed using the old value of 1.1. The error resulting from this change has not been assessed.

NOAA-11

BAND 4			**BAND 5**		
BB_TEMP (K)			**BB_TEMP (K)**		
PIXEL TEMP	**283**	**288**	**293**	**283**	**288**	**293**
320	4.29	3.71	3.25	1.43	1.26	1.12
315	3.50	2.98	2.55	1.23	1.03	0.89
310	2.85	2.33	1.91	1.05	0.84	0.70
305	2.23	1.73	1.32	0.85	0.64	0.47
295	1.05	0.68	0.22	0.43	0.28	0.09
285	0.24	-0.21	-0.67	0.07	-0.07	-0.23
275	-0.45	-0.79	-1.15	-0.19	-0.34	-0.47
265	-1.06	-1.37	-1.66	-0.37	-0.51	-0.60
255	-1.41	-1.72	-2.03	-0.60	-0.77	-0.78
245	-1.70	-1.96	-2.22	-0.72	-0.90	-0.92
235	-1.87	-2.10	-2.28	-0.84	-1.02	-1.00
225	-1.90	-2.14	-2.36	-0.94	-1.06	-1.16
215	-1.82	-2.02	-2.20	-1.12	-1.24	-1.16
205	-1.54	-1.76	-1.98	-1.15	-1.27	-1.23

5) Perform linear interpolation between derived temperature correction set values (from above) to get pixel specific correction value based on calculated pixel temperature and apply (add) the temperature corrections to bands 4 and 5 of each pixel.

6) Convert the corrected temperatures back to radiance.

ENUM = (K1 * VC(I+3)) * VC(I+3) * VC(I+3)
DENOM = EXP[K2 * VC(I+3) / PIXEL_TEMP(I+3)] - 1
PIXEL_RAD(I+3) = ENUM / DENOM

where:

I = 1, 2 (**I + 3** designates the respective channels)
PIX_RAD(I+3) = the band radiance for a given pixel
TEMP(I+3) = the temperature for the given pixel

C) Unit conversion:

Convert the radiances from [mWatt][cm][m^-2][sr^-1] to [Watt][m^-2][sr^-1][um^-1] for bands 3,4,5. Let,

FACTOR = 1.383, 11.600, 14.032 FOR NOAA-9
= 1.401, 12.111, 12.111 FOR NOAA-10
= 1.392, 11.647, 14.131 FOR NOAA-11

Then,

PIX_RAD(I) = PIX_RAD(I) / FACTOR(I-2)

where:

I = 3, 4, 5 for the respective bands

The final radiances are averaged over the FIFE site and the mean and standard deviation for each channel are reported in the data base.

II) Atmospheric correction and reflectance calculations:

The radiance data (calculated as described above) were converted first to exoatmospheric reflectance, corrected for atmospheric attenuation, and then converted to surface reflectance. The conversion to exoatmospheric reflectance normalizes the data for solar zenith angle and Earth-Sun distance variation, and generates reflectance values expected outside of the atmosphere (exoatmospheric reflectance). The method of Markham and Barker (1986) was used.

A) Convert to exoatmospheric reflectance (**L'm**) for each band:

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

where (an apostrophe indicates a subscript):

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 (degrees)
Fo = extraterrestrial solar irradiance in the AVHRR-LAC bandpass as listed below:

Exoatmospheric Reflectance
([Watt][m^-2][um^-1])

Band	NOAA-9	NOAA-10	NOAA-11
1	1631.0	1660.5	1633.5
2	1046.0	1037.0	1046.0

B) Optical thickness were assumed constant across the few degrees of the scan view angle that covered the area selected as the FIFE site (see the FIFE AVHRR level-1 documentation for view angle determination). Sunphotometer measurements of the atmospheric properties over the FIFE site were not available for most dates on which acquisitions were acquired. Instead of generating a data set of reflectances based on inconsistent atmospheric property measurements (i.e., some measured and some climatological), a set of default optical thickness values were generated and used to correct all scenes. Aerosol optical thicknesses were determined from an average of mid-afternoon sunphotometer measurements collected throughout the year in 1988 over the FIFE site. Optical thicknesses due to water vapor and other absorbing gases were calculated from the standard mid-latitude summer atmospheric model of the Lowtran-7 radiative transfer algorithm (Kneizys, et al., 1988). The following optical properties resulted and were used to correct all scenes:

Default Atmospheric Optical Thicknesses
(all quantities are dimensionless)

Water Channel	Other Aerosols	Vapor	Gases
Channel-1	0.15	0.0208	0.0247
Channel-2	0.10	0.1156	0.0152

C) The FIFE atmospheric correction algorithm (Fraser et. al., 1989) was then run using the solar angles, viewing angles, and aerosol optical property values described above. Coefficients generated from the correction process were tabulated and formatted as a look-up table. The coefficients were also entered into the satellite coefficients data. The coefficients are used to calculate surface reflectances using the method described below. A program was developed to search the look-up table and match the input image by date, extract the coefficients, and calculate surface reflectance (**rho**) on a pixel-by-pixel basis for each image. Surface reflectance was calculated as:

rho = f / (1 + s * f)

where:
s = backscattering ratio (column BSCAT in FIS)

f = (L'm - L'o) / (F'd * T)
L'm = from (1) above
F'd = normalized surface flux (column IRRAD in FIS)
L'o = normalized path radiance (column PATH_RAD in FIS)
T = path transmission (column TRANS in FIS)

III) Surface temperature calculations:

Spectral radiances (in [mW][cm][m^-2][sr^-1]) from thermal channels 4 and 5 of the NOAA-9 AVHRR were used to calculate apparent surface temperature with the split-window technique of Price (1983). Apparent at-sensor temperatures (T4, T5) are first calculated for channels 4 and 5 using the non-linearity corrections described in the previous section.

Surface temperature (**Ts**) is then derived as:

Ts = T4 + 3.33 * (T4 - T5)

Temperatures are scaled by 10 to retain 1/10 degree precision. Divide the values on tape by 10 to get degrees K, and subtract 273 to get degrees Celsius.

To date, no atmospheric correction of the NOAA-10 or NOAA-11 data acquired as part of the FIFE initiative has been undertaken. This is due, in part, to the lack of cloud-free data collected from these platforms and to decisions by the Science Steering Group regarding the utility of these data to the FIFE science objectives.

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 the latitudes of 38.875 and 39.125 degrees N and within the longitudes of 96.375 and 96.625 degrees W.
2. Extracting the spectral, geographic, viewing, and solar information for the enumerated pixels.
3. Converting and correcting the digital spectral counts to radiance.
4. Storing appropriate information in the data base.

FIFE staff creates the atmospherically corrected spectral reflectance and temperature data by :

1. Converting and correcting the digital spectral counts to at-sensor radiance.
2. Correcting the at-sensor radiances for atmospheric attenuation and converting to surface reflectance.
3. Storing the atmospherically corrected mean values by date and time in the data base.

Processing Changes:

None.

Calculations:

Special Corrections/Adjustments:

None.

Calculated Variables:

- Radiance values for bands 1 through 5,
- Sensor Gains,
- Average scene temperatures,
- Average site radiances,
- Surface reflectance, and
- Surface temperature.

Graphs and Plots:

None.

10. Errors:

Sources of Error:

Errors could arise in the acquired imagery due to location accuracy, distortion of lengths, anisomorphism, instrument's local coherence, multispectral registerability, 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.

On October 27, 1990 a typographical error was reported for NOAA-9 band 5 at a target temperature of 305 K and a blackbody temperature of 283 K, the value should be 0.7, not 1.1 as previously reported. However, the extracted FIFE AVHRR site data were processed using the old value of 1.1.

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:

No quantitative assessment was made, see the *Confidence Level/Accuracy Judgment Section*.

Other errors mentioned in the *Sources of Error Section* were not assessed.

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, that 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:

- Although bands 4 and 5 of NOAA-10 images are supposedly duplicates, average band counts have shown differences of 2 to 3 counts in some images. The source of the difference is currently unknown.
- For NOAA-10, if the mean space view values in the level-1 ASCII header file differ by more than 1.0 counts from 37.0, all these data should be treated as questionable.
- For NOAA-11 data processed prior to June 8, 1990, the EDC used incorrect central wave numbers and did not account for the nonlinear response of channels 4 and 5 in their gain calculations for the gains contained on the level-0 (NOAA 1b) tapes. The values used by FIS to derive the level-1a products were correct in that the basic calibration information was used along with proper wave numbers and nonlinear terms to perform the calculations.
- Channel 3 data was not atmospherically corrected due to inherent noise problems, the inability to accurately characterize the atmospheric properties in that channel, and the inherent complexity in interpreting daytime data in this channel.
- For the data collected from NOAA-9 the following problems were found in the data for the parameters listed:

Parameter/Variable	Comments
BAND1_AVG_REFL	2 values > 20
BAND1_AVG_RADNC	4 values > 70 (MAX 103)
BAND2_AVG_RADNC	6 values > 70 (MAX 89)
BAND1_EXOATMOSIC_REFL	2 values > 21 (25.2, 28.9)

- For the data collected from NOAA-10 the following problems were found in the data for the parameters listed:

Parameter/Variable	Comments
BAND1_AVG_REFL	3 values > 25, 10 values < 0
BAND2_AVG_REFL	3 values > 60 (MAX 103)
BAND1_EXOATMOSIC_REFL	4 values > 20 (MAX 50.1)
BAND2_EXOATMOSIC_REFL	1 value > 40 (48.5)

Usage Guidance:

AVHRR data are used in the preparation of a number of products required for meteorological, climate, and land research, for the NOAA operational weather forecasting system, and for the international weather forecast community. Other applications include geographical and ecological research. In addition, AVHRR data are used to determine vegetation cover for large regions. These products include temperature and water vapor soundings, oceanographic and hydrological products, radiation budget products, and a variety of mapped and gridded imagery.

Any Other Relevant Information about the Study:

None.

12. Application of the Data Set:

AVHRR data are used in the preparation of a number of products required for meteorological, climate, and land research, for the NOAA operational weather forecasting system, and for the international weather forecast community. Other applications include geographical and ecological research. In addition, AVHRR data are used to determine vegetation cover for large regions.

13. Future Modifications and Plans:

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

14. Software:

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

15. Data Access:

Contact Information:

ORNL DAAC User Services
Oak Ridge National Laboratory

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

Email: ornldaac@ornl.gov

Data Center Identification:

ORNL Distributed Active Archive Center
Oak Ridge National Laboratory
USA

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

Email: ornldaac@ornl.gov

Procedures for Obtaining Data:

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

Data Center Status/Plans:

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

16. Output Products and Availability:

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

\DATA\SAT_OBS\SAT_AVHR\Yyyyy\ydddFIFE.AVH

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 .AVH for this data set.

17. References:

Satellite/Instrument/Data Processing Documentation.

Newcomer, J.A., S.J. Goetz, D.E. Strebel, and F.G. Hall. 1989. Image processing software for providing radiometric inputs to land surface climatology models. IGARSS '89. 12th Can. Symp. on Remote Sensing. pp. 1779-1782.

Fraser, R.S., R.A. Ferrare, Y.J. Kaufman, and S. Mattoo. 1989. Algorithm for atmospheric corrections of aircraft and satellite imagery. NASA Technical Memorandum 100751. 106 pp.

Kidwell, K. 1991. NOAA Polar Orbiter Data User's Guide. NCDC/SDSD. National Climatic Data Center, Washington.

Kneizys, F.X., E.P. Shettle, W.O. Gallery, J.H. Chetwynd, L.W. Abreu, J.E.A. Selby, S.A. Clough, and R.W. Fenn. 1988. Atmospheric transmittance/radiance: computer code LOWTRAN-7, AFGL-TR-88-0177. Air Force Geophysics Lab. Hanscomb AFB, Massachusetts.

Markham, B.L., and J.L. Baker. 1986. Landsat MSS and TM post-calibration dynamic ranges, exoatmospheric reflectances and at-satellite temperatures. EOSAT Landsat Tech. Notes 1:3-7. Lanham, Maryland.

Price, J.C. 1983. Estimating surface temperatures from satellite thermal infrared data - a simple formulation for the atmospheric effect. Remote Sensing Environment. 13:353-361.

Journal Articles and Study Reports.

Duggin, M.J., D. Piwinshi, V. Whitehead and G. Tyland. 1982. Evaluation of NOAA-AVHRR Data for Crop Assessment. Appl. Opt. 21:1873-1875.

Justice, C.O., B.N. Holben, and M.D. Gwynne. 1986. Monitoring East African Vegetation Using AVHRR Data. Int. J. Remote Sens. 7:1453-1474.

Ormsby, J.P. 1982. Classification of Simulated and Actual NOAA-6 AVHRR Data for Hydrological Land-Surface Feature Definition. IEEE Transactions on Geoscience and Remote Sensing. GE-20:262-268.

Strebel, D.E., J.A. Newcomer, J.P. Ormsby, F.G. Hall, and P.J. Sellers. 1990. The FIFE information system. IEEE Transactions on Geoscience and Remote Sensing. 28(4):703-710.

Taconet, O., R. Bernard and D. Vidal-Madja. 1986. Evapotranspiration Over an Agricultural Region Using a Surface Flux/Temperature Model Based on NOAA-AVHRR Data. J. Climate Appl. Meteor. 25:284-307.

Tucker, C.J., J.A. Gatlin, and S.P. Sneider. 1984. Monitoring Vegetation in the Nile Delta with NOAA-6 Imagery. Photogram. Engr. Remote Sens.50:53-62.

Yates, H.W. and J.D. Tarpley. 1982. The Role of Meteorological Satellites in Agricultural Remote Sensing." Proc. of the 8th International Symposium on Machine Processing of Remotely Sensed Data. Purdue University, Indiana. pp. 23-32.

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:

AVHRR Advanced Very High Resolution Radiometer CD-ROM Compact Disk-Read Only Memory DAAC Distributed Active Archive Center EOSDIS Earth Observing System Data and Information System EROS Earth Resources Observation System FIFE First ISLSCP Field Experiment FIS FIFE Information System HRPT High Resolution Picture Transmission IFC Intensive Field Campaign ISLSCP International Satellite Land Surface Climatology Project LAC Local Area Coverage NOAA National Oceanic and Atmospheric Administration NRL Naval Research Laboratory ORNL Oak Ridge National Laboratory URL Uniform Resource Locator UTM Universal Transverse Mercator

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

20. Document Information:

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Warning: This document has not been checked for technical or editorial accuracy by the FIFE Information Scientist. There may be inconsistencies with other documents, technical or editorial errors that were inadvertently introduced when the document was compiled or references to preliminary data that were not included on the final CD-ROM.

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.

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