Radiant Temp. Helicopter Data (FIFE)

Summary:

The Surface Radiant Temperature Measured with a Helicopter-borne Infrared Thermometer Data Set were collected for six days during July and August of 1989 to provide the radiant temperature of the FIFE sites and as a check of the thermal band on the MMR. The average and standard deviation of radiant temperature were measured with an Everest infrared thermometer. The Everest Series 4000 Infrared Thermometer (IRT) was mounted on the NASA Bell UH-1B helicopter in conjunction with the Barnes Multiband Modular Radiometer (MMR) and the Spectron Engineering SE590 Spectroradiometer for the 1989 field campaign. The IRT collected radiant temperature data as the helicopter hovered over individual sites within the FIFE study area.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

Radiant Temp. Helicopter Data (FIFE).
(Surface Radiant Temperature Measured with a Helicopter-borne Infrared Thermometer).

Data Set Introduction:

The Surface Radiant Temperature Measured with a Helicopter-borne Infrared Thermometer Data Set contains average and standard deviation of radiant temperature measured with an Everest infrared thermometer. These data were collected over the FIFE study area for six days during July and August of 1989.

Objective/Purpose:

These data were collected by FIFE staff in 1989 to provide the radiant temperature of the sites and as a check of the thermal band on the MMR.

Summary of Parameters:

Average and standard deviation of radiant temperature measured with an Everest infrared thermometer.

Discussion:

An Everest Series 4000 Infrared Thermometer (IRT) was mounted on the NASA Bell UH-1B helicopter in conjunction with the Barnes Multiband Modular Radiometer (MMR) and the Spectron Engineering SE590 Spectroradiometer for the 1989 field campaign. The IRT collected radiant temperature data as the helicopter hovered over individual sites within the FIFE study area. There are data available over the study area for six days during July and August of 1989.

Related Data Sets:

There are several data sets which contain ground based measurements that also have thermal data. These data sets are listed below:

1. Surface Temperature from UNL.
2. Surface Temperature Measured at Multiple Angles.
3. Surface Temperatures Reflected and Emitted Radiation and PAR from UNL.
4. Surface Reflectance Measured with Mast-borne MMR.

In addition, there are two other helicopter data sets which are coincident with the one described here. They are as follows:

1. Surface Reflectances measured with a Helicopter-borne MMR. and
2. High Spectral Resolution Measurements from the Russian Gemma Instrument.

FIS Data Base Table Name:

RADIANT_TEMP_HELO_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Staff Science.

Title of Investigation:

Staff Science Helicopter Data Acquisition Program.

Contact Information:

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Requested Form of Acknowledgment.

The Surface Radiant Temperature Measured with a Helicopter-borne Infrared Thermometer data were collected by a dedicated team of pilots, mechanics, photographers and scientists. The efforts of the following individuals are notable: Helicopter crew: Charles Walthall, mission scientist; William Dykes, pilot; Charles Smith, mechanic and observer;

Ed Bohles, mechanic and observer; Richard Huey, photographer; David Pierce, engineer; Douglas Young, engineer; US Army 82nd Medical Helicopter Unit, Ft. Riley, Kansas for on-site hanger space and helicopter technical support.

3. Theory of Measurements:

An infrared thermometer measures the emitted radiation from a surface. The emitted thermal radiation is related to the temperature by the Stephan-Boltzmann equation:

$$Rb = e * a * T^4$$

Where:

Rb is the emitted flux density [W][m^-2],
e is the emissivity of the surface,
a is the Stephan-Boltzmann constant (5.67*10^-8 [W][m^-2] [K^-4]), and
T is the surface temperature [K].

Long wave emissivities for most natural surfaces are between .90 and .99.

4. Equipment:

Sensor/Instrument Description:

Measurements were made with an Everest Series 4000 Infrared Thermometer (IRT) with a 4 degree field of view. The Everest was mounted with the MMR on the helicopter. Measurements were made at nadir and off-nadir within 10 degrees of the principal plane at views of 20, 35, and 50 degrees in forward and backscatter positions. Responses were recorded with an Omnidata Polycorder.

Collection Environment:

Airborne.

Source/Platform:

The IRT was mounted on a pointable mount on the side of the helicopter adjacent to the MMR and SE590.

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 reflectance and emittance data of 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 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 within a site differed for the three primary sites (906, 916 and 928) from the other FIFE sites. The "WAB" area was outlined by crews on the surface with flags: the two edges and a center line directly into the wind were marked. Using these lines as guides, slow flight transects with an average of 8 observations per line were flown. Sampling of the other FIFE sites followed the 1987-type pattern of sampling. The sample area for these sites 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).

Key Variables:

Radiant temperature.

Principles of Operation:

The IRT is an optical device operating in the thermal (8-14 mm) wavelength regions. Two analog voltage signals are recorded: one related to the detector temperature and one target signal. These voltages are converted to digital signals and stored in the data logger.

Sensor/Instrument Measurement Geometry:

When mounted on the helicopter the optical head is equipped with lenses having a 4 degree FOV. Given a nominal data acquisition altitude of 330 m for 1989, irradiance from the ground surface area of approximately 23 m in diameter is recorded. Multiple observations were collected and averaged together.

Manufacturer of Sensor/Instrument:

Everest Interscience
P.O. Box 3640
Fullerton, Ca 92634-3640
(714) 992-4461

Calibration:

The factory supplied calibration of the IRT was used. The instrument calibration was checked in the laboratory using a precision black body source and found to agree within 1 K of the blackbody over a range of ambient and blackbody temperatures.

Specifications:

The instrument accuracy specifications is +/- 0.5 K.

Tolerance:

Per the *Calibration Section* the observed accuracy was better than 1K, typically better than 0.7K.

Frequency of Calibration:

Not available.

Other Calibration Information:

Not available.

5. Data Acquisition Methods:

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 IRT instrumentation was chosen to provide compatibility with surface-based radiometers and TM spacecraft sensors.

The NASA Bell UH-1B helicopter optical remote sensing system for 1989 supported a data acquisition system consisting of a bore-sighted SE590; a Barnes MMR; an Everest IRT; and a color video camera. Controller units for all the optical devices are rack-mounted inside the helicopter and are wired such that a single switch closure triggers all devices. The switch closure also activates an audible tone which is 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. Note that the 35 mm camera was secured in a nadir-looking configuration. The video camera was mounted on the pointable platform with the radiometric instruments.

6. Observations:

Data Notes:

Not available.

Field Notes:

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 helicopter was able to collect data over many of the FIFE sites in a single flight lasting approximately two hours, however the main flux sites were given priority.

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

Spatial Coverage:

In 1989 measurement plots were located northeast of the Wind Aligned Blob (WAB) site (Sellers et al., 1989). A topography file containing the northing and easting of the plots at each site, except for site 18 (4439-BRV) and 170 (0939-BBM) in 1987 and site 966 (2437-BBS) in 1989, is in the grab bag (UNL_PLOT_87, UNL_PLOT_89). The file UNL_PLOT_87 also includes the slope, aspect, soil depth and vegetative height of the plots.

The number and spatial distribution of the sites covered on each mission varied according to the specific mission objectives as established by the Science Steering Group.

Spatial Coverage Map:

Not available.

Spatial Resolution:

The ground resolution of the Helicopter IRT is 420 square meters at nadir and changed with view zenith angle. Multiple observations were collected at each site and averaged together.

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Flights lasted approximately 2 hours. Every site was not observed in each flight.

Temporal Coverage:

The IRT helicopter data was collected on 6 days between July 28, 1989 and August 11, 1989. Missions were dependent on the availability of clear sky conditions.

Temporal Coverage Map:

Not available.

Temporal Resolution:

Observation time over each site was 2 to 5 minutes during which an average of 25 measurements were made (maximum of 56).

Data Characteristics:

The SQL definition for this table is found in the IRT_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).			
NUM_OBS The number of observations averaged together.			
VIEW_ZEN_ANG The view zenith angle of the observations.		[degrees]	
ALTITUDE The altitude of the helicopter at the site.		[meters]	
OBS_TYPE The area of the site observed, WAB are observations of the WAB, FULL are of the entire site, SRB are of the same area as the ground observations.			
MISSION_ID The mission identification for the helicopter flight.			

TARGET_TEMP
The surface temperature. [degrees Celsius]

TARGET_TEMP_SDEV
The standard deviation of the surface temperature. [degrees Celsius]

DETECTOR_TEMP
The temperature of the detector. [degrees Celsius]

DETECTOR_TEMP_SDEV
The standard deviation of the detector temperature. [degrees Celsius]

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	NUM_OBS	VIEW_ZEN_ANG	ALTITUDE
2133-HIR	906	28-JUL-89	1659	25	.0	305
4439-HIR	916	28-JUL-89	1706	20	.0	305
4439-HIR	916	28-JUL-89	1710	25	.0	305
8739-HIR	926	28-JUL-89	1718	24	.0	305

OBS_TYPE	MISSION_ID	TARGET_TEMP	TARGET_TEMP_SDEV	DETECTOR_TEMP

WAB	890605B	40.51	2.096	29.47
WAB	890605B	36.80	1.059	28.60
SRB	890605B	39.39	1.050	28.26
WAB	890605B	46.76	.766	28.00

DETECTOR_TEMP_SDEV	FIFE_DATA_CRTFCN_CODE	LAST_REVISION_DATE
.217	CPI	09-AUG-90
.127	CPI	09-AUG-90
.036	CPI	09-AUG-90
.018	CPI	09-AUG-90

8. Data Organization:

Data Granularity:

The data was collected on 6 days between July 28, 1989 and August 11, 1989. The ground resolution of the data is 420 square meters at nadir and changed with view zenith angle. Multiple observations were collected at each site and averaged together.

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:

The emitted thermal radiation is related to the temperature by the Stephan-Boltzmann equation (see the *Theory of Measurements Section*). In the processing of the IRT data the emissivity is set to 0.98. The radiance intercepted by the detector is converted to voltages.

The detector temperature (**Td**) is a linear function of the detector temperature voltage (**Ed**):

Td = -62.16856 * (0.8258 + Ed)

where:

Td is in degrees Celsius and
Ed is negative voltage.

The IRT determines a relative temperature between the target and the detector. The relative temperature (**Trel**) in degrees Celsius is determined from the radiation signal voltage (**Erel**) using a fifth order polynomial equation:

Trel = 0.8313 + 67.508 * Erel - 20.069 * Erel^2 + 21.415 * Erel^3 - 20.932 * Erel^4 + 7.2806 * Erel^5

The target temperature (**Tt**) is the sum of the detector and relative temperatures:

Tt = Td + Trel

Derivation Techniques and Algorithms:

See: Everest Interscience IRT operating manual.

Data Processing Sequence:

Processing Steps:

See: Everest Interscience IRT operating manual.

Processing Changes:

Not applicable.

Calculations:

Special Corrections/Adjustments:

No adjustment was made for emissivity. The emissivity factor was set at 0.98.

Calculated Variables:

- Detector temperature,
- Relative temperature between the target and the detector, and
- Target temperature.

Graphs and Plots:

None.

10. Errors:

Sources of Error:

Errors associated with the measurements can occur due to orientation of the IRT. 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.

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:

Comparison's have been made with the thermal channel on the helicopter MMR. Results are generally consistent to better than 1 deg. K.

Confidence Level/Accuracy Judgment:

Our estimate is better than 1K accuracy at the helicopter. No atmospheric corrections have been done to the data. The estimated error of ignoring atmospheric is also less than 1K.

Measurement Error for Parameters:

Not available at this revision.

Additional Quality Assessments:

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

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

Usage Guidance:

These data are an alternate source of thermal IR data over the sites in 1989. Note that the (1) field-of-view of this instrument is larger than the comparable thermal band on the MMR, (2) the IRT is less noisy than the MMR and (3) the bandpass of this instrument is nominally 8-14 um as opposed to 10-12 on the MMR.

Any Other Relevant Information about the Study:

Not available.

12. Application of the Data Set:

This data set is an alternate source of thermal IR data over the FIFE sites in 1989. This data set is also a check of the thermal band on the MMR.

13. Future Modifications and Plans:

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

investigators are continuing to analyze and model the data from the field campaigns to produce new data products.

14. Software:

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

15. Data Access:

Contact Information:

ORNL DAAC User Services
Oak Ridge National Laboratory

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

Email: ornldaac@ornl.gov

Data Center Identification:

ORNL Distributed Active Archive Center
Oak Ridge National Laboratory
USA

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

Email: ornldaac@ornl.gov

Procedures for Obtaining Data:

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

Data Center Status/Plans:

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

16. Output Products and Availability:

The Surface Radiant Temperature Measured with a Helicopter-borne Infrared Thermometer data are available on the FIFE CD-ROM Volume 1. The CD-ROM filename is as follows:

DATA\SUR_REFL\IRT_HELO\ydddMULT.RTH

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: *ydddMULT.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 of the year). The filename extension (*.sfx*), identifies the data set content for the file (see the *Data Characteristics Section*) and is equal to .RTH for this data set.

17. References:

Satellite/Instrument/Data Processing Documentation.

Everest Interscience Inc., IRT users guide circa 1988

Journal Articles and Study Reports.

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).

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 BPI Byte per inch CCT Computer Compatible Tape DAAC Distributed Active Archive Center EOSDIS Earth Observing System Data and Information System FIFE First ISLSCP Field Experiment FIS FIFE Information System IFC Intensive Field Campaign IFOV Instantaneous Field of View IRT Infrared Thermometer ISLSCP International Satellite Land Surface Climatology Project Mbps Megabyte per second MMR Modular Multiband Radiometer ORNL Oak Ridge National Laboratory URL Uniform Resource Locator WAB Wind Aligned Blob

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

20. Document Information:

April 22, 1994 (citation revised on October 16, 2002).

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.

Document Review Date:

July 11, 1996.

Document ID:

ORNL-FIFE_IRT_HELO.

Citation:

Cite this data set as follows:

Markham, B. L., and C. Walthall. 1994. Radiant Temp[erature]. Helicopter Data (FIFE). Data set. Available on-line [http://www.daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. :10.3334/ORNLDAAC/70. Also published in D. E. Strebel, D. R. Landis, K. F. Huemmrich, and B. W. Meeson (eds.), Collected Data of the First ISLSCP Field Experiment, Vol. 1: Surface Observations and Non-Image Data Sets. CD-ROM. National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, U.S.A. (available from http://www.daac.ornl.gov).

Document Curator:

DAAC Staff

Document URL:

http://daac.ornl.gov