Bowen Ratio Surface Flux: USGS (FIFE)

Summary:

The Bowen Ratio Surface Flux Observations (USGS) Data Set contains surface flux and micrometeorological collected from one location within the Northwest quadrant of the FIFE study area. Data were collected daily at this location only during the IFC's during the period from late May through mid-October, 1987. Each Bowen ratio station was capable of measuring the fluxes of net radiation, sensible heat, and latent heat. The Bowen ratio stations measured the soil heat flux as well.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

Bowen Ratio Surface Flux: USGS (FIFE).
(Bowen Ratio Surface Flux Observations (USGS)).

Data Set Introduction:

The Bowen Ratio Surface Flux Observations (USGS) Data Set contains surface flux and micrometeorological collected from one location within the Northwest quadrant of the FIFE study area.

Objective/Purpose:

The combined aim of the surface flux group was to use a network of ground based observing systems to measure fluxes of heat, water vapor and radiation at a number of points within the FIFE study area.

Summary of Parameters:

Latent heat flux, net radiation, sensible heat flux, soil heat flux, heat storage, soil temperature, Bowen ratio, air temperature, wet bulb temperature, vapor pressure.

Discussion:

The major data collection effort was conducted in 1987 when 16 stationary sites were equipped with Bowen ratio equipment. In 1988 and 1989, Bowen ratio surface flux stations were installed at 12 and 19 sites, respectively. Each Bowen ratio station was capable of measuring the fluxes of net radiation, sensible heat, and latent heat. The Bowen ratio stations measured the soil heat flux as well.

The surface flux and micrometeorological measurements available in this data set were collected from one location (Sitegrid_ID = 6912) within the Northwest quadrant of the FIFE study area. Data were collected daily at this location only during the IFC's during the period from late May through mid-October, 1987.

Related Data Sets:

- Eddy Correlation Surface Flux Observation (USGS).
- Eddy Correlation Surface Flux Observation (UNL).
- Eddy Correlation Surface Flux Observation (GSFC).
- Eddy Correlation Surface Flux Observation (UK).
- Eddy Correlation Surface Flux Observation (Argonne).
- Bowen Ratio Surface Flux Observation (GSFC).
- Bowen Ratio Surface Flux Observation (KSU).
- Bowen Ratio Surface Flux Observation (Fritschen).
- Bowen Ratio Surface Flux Observation (UNL).
- Bowen Ratio Surface Flux Observation (Smith).

FIS Data Base Table Name:

SURFACE_FLUX_30MIN_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Dr. Harold L. Weaver

Title of Investigation:

Surface flux measurement and analysis at the FIFE site.

Contact Information:

Contact 1:
Dr. Harold L. Weaver
Baker City, OR
Telephone: (503) 893-6467

Contact 2:
David I. Stannard
U.S. Geological Survey
Denver, CO
Telephone: (303) 236-4983

Requested Form of Acknowledgment.

The Bowen Ratio Surface Flux Observations (USGS) at site 6912-BRW were collected by L. Weaver and D.I. Stannard, both at the USGS Water Resources Division in Denver, Colorado. The contribution of these data is particularly appreciated.

3. Theory of Measurements:

At site 24 (6912-BRW) the components of the energy balance were determined with the Bowen Ratio Energy Balance (BREB) method. The BREB is a combination of the transport and the energy balance equations. The Bowen ratio, **B** {a ratio of the transport or gradient equations of sensible heat, **H**, and latent heat, **E**} is given by:

$$B = H / L \quad (1).$$

where:

$$H = -\rho c_p K_h \frac{dT}{dz}$$

$$L = -\frac{\rho \varepsilon}{P} l_v K_v \frac{de}{dz}$$

where symbols are defined as:

e = Air vapor pressure (kaP)
epsilon = Ratio of the molecular weights of wet and dry air

c(p) = Specific heat of air (J/kg.K)
K(h) = Eddy diffusivity for heat
K(v) = Eddy diffusivity for water vapor
P = Atmospheric pressure (kaP)
rho = Air density (kg/m^3)
T = Air temperature (C)
z = Height or depth
l(v) = Latent heat of vaporization (J/kg)

Substituting (1) in the energy balance equation (2) yields the BREB (3). **Q** is net radiation and **G** is soil heat flux density.

Q + G + H + E = 0 (2).

In this system surface-air interface is considered as a closed system. Any energy flux coming in is considered positive and going out as negative (Personal communication, Dr. Harold Weaver).

E = -(Q + G) / (1 + B) (3).

The Bowen ratio equation can also be written as (personal communication, Dr. Harold Weaver):

B = H / L = rho.c(p).R.T'.dT'/lv.de

T' = T + 273.13

Where:

H = Sensible heat flux (w/m^2)

L = Latent heat flux (w/m^2)

rho = 1.2929 (273.13 / (T + 273.13) (P - 0.3783.e) / 101.323

c(p) = 1004 + 1820.4.M / (1 + M)

R = 0.4619

l(v) = 2501300 (1 - 0.000946.Tw) #

e = Es - 0.063115 (1 - 0.000946.Tw)(T - Tw) #

P = 101.323E - Z / 8229.6

M = 0.622e / P - e

Es = {6.1078 + Tw (0.443652 + Tw (0.01428946 + Tw (2.65065 * 10^-4 + Tw (3.03124 * 10^-6 + Tw (2.03408 * 10^-8 + 6.13682 * 10^-11Tw)))))} / 10, [kPa]; $

where new symbols are defined as:

R = gas constant (kaP.m^3/kg.K)
M = Mixing Ratio
Es = Saturation vapor pressure (kaP)
Tw = Wet bulb temperature (C)

Fritschen, L.J. and L.W. Gray. 1979.

$ Lowe, P.R. 1977.

4. Equipment:

Sensor/Instrument Description:

- Net radiation sensor: Swissteco
- Method of calculating Rn: Average 2 second samples from single net radiometer.
- Soil heat flux sensor: CSI modified Peltier cooler
- Upper layer heat storage sensor: Four-probe thermocouples in parallel.
- Method of calculating G1: Average 2 second samples from three plates.
- Method of calculating G2: Average 10 minute samples from three dT/dt measurements.
- Heat capacity equation: C(s) = rho(s) (0.785 + 4.18 RWC)
- Bowen ratio sensor: Dual T -T(w) fan-aspirated thermistor psychrometers (used with mechanical exchanger).
- Lower arm height IFC 1, 2, 3: 0.7 m, IFC 4: 1.0 m (measured above canopy).
- Lower-upper arm separation: 1.0 m
- Pressure: parameter in specified psychrometric constant
- Temperature and vapor sampling: 2 second frequency
- Exchange frequency: 5 minutes
- Duty cycle for 30 minutes: 90% averaging period

For more information on the instrumentation used to collect these data see Stannard 1985, and Weaver and Campbell 1985.

Collection Environment:

Ground-based.

Source/Platform:

Ground: instruments supported by combinations of tripods and vertical and horizontal pipe supports. Heights above the ground varied from .7 m to 2.0 meters depending upon the campaign and the arm making the measurement. See the *Field Notes Section* for details.

Source/Platform Mission Objectives:

Not available.

Key Variables:

Latent heat flux, net radiation, sensible heat flux, soil heat flux, heat storage, soil temperature, Bowen ratio, air temperature, wet bulb temperature, vapor pressure.

Principles of Operation:

Gradients of vapor pressure and air temperature were measured by two wet-bulb psychrometers, one above the other. To reduce the effects of instrument bias they were mounted on a 1-m arm that interchanged their positions every 5 minutes. Comparison with KSU's roving Bowen-ratio system indicated that the temperatures measured by the Delta-T psychrometers were somewhat elevated, probably due to a design susceptible to radiation loading. This had an insignificant effect on the calculated BETA; thus the uncorrected temperatures were used to calculate BETA, and are reported here.

Sensor/Instrument Measurement Geometry:

Instrument and Vegetation heights by IFC:

- IFC-1 and IFC-2: Measurement Height (m)

  Q* = 1.47
  T1 = 1.05
  T2 = 2.05
  Vegetation = 0.3

- IFC-3:

  Q* = 1.47
  T1 = 1.12
  T2 = 2.12
  Vegetation = 0.3

- IFC-4:

  Q* = 1.69
  T1 = 1.35
  T2 = 2.35
  Vegetation = 0.3

  where:

  Q* = Radiometer
  T1 = Lower arm height
  T2 = Upper arm height

Manufacturer of Sensor/Instrument:

Soil heat transducer:

Made by investigator (Weaver and Campbell 1985).

Soil thermocouples:

Made by investigators.

Net radiometer:

Swissteco Pty., Ltd.
Melbourne Vic. Australia 31.

Psychrometer:

Delta-T Instruments.

Bowen-ratio machine:

Made by David Stannard, USGS-Denver.

Data logging system:

Campbell Scientific, Inc.
P.O. Box 551
Logan, Utah 84321.

Calibration:

A net radiometer calibration was accomplished using a transfer pyheliometer standard on loan from the Solar Energy Research Institute.

Soil heat transducers last calibrated in 1986 by USDA Water Conservation Laboratory, Phoenix, Arizona.

Specifications:

Several of the radiometers were calibrated by the shading technique and compared over the succeeding 24 hour period using data collected every 5 minutes.

Tolerance:

Not available at this revision.

Frequency of Calibration:

Varies according to sensor. About every two years for net radiometers (shortwave), and soil heat transducers. Less often for other classes of sensor.

Other Calibration Information:

Soil heat flux plates were calibrated in several laboratories under different conditions.

Soil heat transducers were last calibrated in 1986 by P.J. Pinter, USDA Water Conservation Laboratory, Phoenix, Arizona.

Net radiometer (shortwave) calibration checked against pyranometer by shading method.

Net radiometer calibration was supplied by the manufacturer.

Soil heat transducer calibration was performed by the investigator (Weaver and Campbell 1985).

5. Data Acquisition Methods:

The data were acquired with Campbell 21x data loggers and transferred to cassette tapes. A single computer program used 21x data as input to output the data files on this disc. All quality controls and algorithms are formal and explicit in the processing programs, written in Pascal.

6. Observations:

Data Notes:

Not available.

Field Notes:

Site 24 (6912-BRW) had a Bowen-ratio system set up on a level pasture within PAM 19's enclosure. The PAM was to the N and NE of the site and quite close: 3 to 15 m away. When the PAM was upwind it may have affected measurements appreciably. The pasture also sloped away to the N about 60 m N of the site. A hill to the SSW caused a grade break about 150 m in that direction. An E-W gravel road ran about 60 m S of the site. The vegetation here was quite different from most of the other surface-flux sites. There was less grass and more forbs. Among the latter, ragweed and Psoralea were common. After rainy weather shallow pools of water remained on the surface for many days to the S between the site and the road.

Some reported soil-temperatures during and immediately following rain events may have been affected by preferential flow of rainwater along the temperature-sensor leads.

Instrument and Vegetation heights by IFC:

- IFC-1 and IFC-2: Measurement Height (m)

  Q*= 1.47
  T1 = 1.05
  T2 = 2.05
  Vegetation = 0.3

- IFC-3:

  Q* = 1.47
  T1 = 1.12
  T2 = 2.12
  Vegetation = 0.3

- IFC-4:

  Q* = 1.69
  T1 = 1.35
  T2 = 2.35
  Vegetation = 0.3

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:

These data were collected at the following locations:

GRID_ID	STATION_ID	LATITUDE	LONGITUDE	NORTHING	EASTING	ELEV
6912-BRW	24	39 00 26	-96 36 20	4320111	707336	397

Spatial Coverage Map:

Not available.

Spatial Resolution:

These are point data except that the Bowen ratio flux instruments effectively sample fluxes from an area about 100 meters upwind of the sensors.

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Temporal Coverage:

Surface flux data were collected on 63 days from May 26, 1987 through October 17, 1987.

Temporal Coverage Map:

Not available.

Temporal Resolution:

These data are 30 minute averages of the measured values. The data were collected at 10 minute reporting intervals.

Measurements are daily during each of the 4 IFC's: May 27 - June 7, June 24 - July 12, August 5 - August 21, and October 4 - October 17, 1987. There are no measurements between these periods.

Data Characteristics:

The SQL table definition for this data table is found in the SF_30MIN. TDF file located on FIFE CD-ROM Volume 1. The following chart lists only those variables that are contained in the data set described here.

Parameter/Variable Name

Parameter/Variable Description **Range** **Units** **Source**

SITEGRID_ID
This is a FIS grid location code.
Site grid codes (SSEE-III) give
the south (SS) and the east (EE)
cell number in a 100 x 100 array

of 200 m square cells. The last 3 characters (III) are an instrument identifier.		
STATION_ID The station ID designating the location of the observations.		
OBS_DATE The date of the observations, in the format (DD-mmm-YY).		
OBS_TIME The time that the observation was taken, in GMT. The format is HHMM.	[GMT]	
LATENT_HEAT_FLUX The latent heat flux, the flux of the energy due to the evaporation of water.	[Watts] [meter^-2]	
NET_RADTN The net radiation, including both downward and upward energy.	[Watts] [meter^-2]	
SENSIBLE_HEAT_FLUX The sensible heat flux, the flux of the energy due to temperature differences.	[Watts] [meter^-2]	
SOIL_HEAT_FLUX The surface soil heat flux, the flux of energy into the soil.	[Watts] [meter^-2]	
SOLAR_RADTN_DOWN The downward (incoming) solar radiation.	[Watts] [meter^-2]	
SOLAR_RADTN_UP The upward (outgoing) solar radiation.	[Watts] [meter^-2]	
SOIL_HEAT_FLUX_0_TO_5CM The soil heat flux recorded somewhere between 0 and 5 cm in depth. This is an average	[Watts] [meter^-2]	

from 0 to 5 cm.	
HEAT_STORAGE The heat storage in the top soil layer.	[Watts] [meter^-2]
SOIL_TEMP_0_TO_25MM The soil temperature recorded somewhere between 0 and 25 mm in depth. Recorded at 25 mm.	[degrees Celsius]
SOIL_TEMP_5_TO_10CM The soil temperature recorded somewhere between 5 and 10 cm in depth. Recorded at 10 cm.	[degrees Celsius]
SOIL_TEMP_20_TO_50CM The soil temperature recorded somewhere between 20 and 50 cm in depth. Recorded at 50 cm.	[degrees Celsius]
BOWEN_RATIO The Bowen Ratio, the ratio of the SENSIBLE_HEAT_FLUX to the LATENT_HEAT_FLUX.	
WIND_SPEED The average wind speed in this 30 minutes.	[meters] [sec^-1]
WIND_DIR The average wind direction in this 30 minutes.	[degrees from North]
WIND_SPEED_VERT_SDEV The standard deviation for the vertical wind speed.	[meters] [sec^-1]
AIR_TEMP_MEAN The mean air temperature in this 30 minutes.	[degrees Celsius]
AIR_TEMP_MEAN_SDEV The standard deviation for the mean air temperature.	[degrees Celsius]

VAPOR_PRESS_MEAN The mean vapor pressure in this 30 minutes.	[kiloPascals]
VAPOR_PRESS_SDEV The standard deviation for the vapor pressure.	[kiloPascals]
FRICTION_VELOC The friction velocity.	[meters] [sec^-1]
W_T_MEAN The mean of AIR_TEMP_MEAN x WIND_VELOC_VERT_MEAN in this 30 minutes.	[Watts] [meter^-2]
W_E_MEAN The mean of VAPOR_PRESS_MEAN x WIND_VELOC_VERT_MEAN in this 30 minutes.	[Watts] [meter^-2]
FIFE_DATA_CRTFCN_CODE The FIFE Certification Code for * the data, in the format: CGR (Certified by Group), CPI (Certified by PI), CPI-??? (CPI - questionable data).	
LAST_REVISION_DATE in the format (DD-MMM-YY).	

Footnotes:

* 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.

** There are several missing value indicators in each column. The values can be positive or negative 9.9, 9.99, 99.99, 999, 999.99, 9999, or 99999.99.

Sample Data Record:

The following sample record contains all the fields in the surface flux record but only those fields that are described here (i.e., reported by H.L. Weaver) contain data.

SITEGRID_ID	STATION_ID	OBS_DATE	OBS_TIME	LATENT_HEAT_FLUX
6912-BRW	24	28-MAY-87	1215	-26
6912-BRW	24	28-MAY-87	1245	-68
6912-BRW	24	28-MAY-87	1315	-119
6912-BRW	24	28-MAY-87	1345	-151

NET_RADTN	SENSIBLE_HEAT_FLUX	SOIL_HEAT_FLUX	DIFFUSE_SOLAR_RADTN_DOWN
14	7	4	
78	1	-11	
189	-33	-38	
232	-40	-42	

SOLAR_RADTN_DOWN	SOLAR_RADTN_UP	SOLAR_RADTN_NET	SOLAR_RADTN_DOWN_SDEV

SOLAR_RADTN_UP_SDEV	PAR_DOWN	PAR_UP	SURF_ALBEDO

LONGWAVE_RADTN_DOWN	LONGWAVE_RADTN_UP	LONGWAVE_RADTN_NET

BB_TEMP_LONGWAVE_DOWN	BB_TEMP_LONGWAVE_UP	TOTAL_RADTN_DOWN

TOTAL_RADTN_UP	SOIL_HEAT_FLUX_0_TO_5CM	SOIL_HEAT_FLUX_5_TO_10CM
15		
11		
3		
-9		

SOIL_HEAT_FLUX_10_TO_20CM	HEAT_STORAGE	SOIL_WATER_POTNTL_0_TO_5CM
-11		
-22		
-41		
-33		

SOIL_WATER_POTNTL_5_TO_20CM	SURF_RADIANT_TEMP	SURF_RADIANT_TEMP_SDEV

SOIL_TEMP_0_TO_25MM	SOIL_TEMP_25MM_TO_5CM	SOIL_TEMP_5_TO_10CM
17.6		17.67
17.84		17.65
18.28		17.63
18.78		17.66

SOIL_TEMP_10_TO_20CM	SOIL_TEMP_20_TO_50CM	RAINFALL	BOWEN_RATIO

```
18.47                          -.27
18.46                          -.01
18.4                            .27
18.35                           .26
```

WIND_SPEED	WIND_DIR	WIND_SPEED_MIN	WIND_SPEED_MAX	WIND_SPEED_SDEV

WIND_DIR_SDEV	TIME_WIND_SPEED_MIN	TIME_WIND_SPEED_MAX

TIME_WIND_DIR_MIN	TIME_WIND_DIR_MAX	WIND_SPEED_HOR_MEAN

WIND_SPEED_LAT_MEAN	WIND_SPEED_VERT_MEAN	WIND_SPEED_HOR_SDEV

WIND_SPEED_LAT_SDEV	WIND_SPEED_VERT_SDEV	AIR_TEMP_LOW	AIR_TEMP_HIGH

```
16.63          16.68
17.43          17.44
18.96          18.85
19.96          19.84
```

AIR_TEMP_OTHER	AIR_TEMP_MEAN	AIR_TEMP_MEAN_SDEV	AIR_TEMP_OTHER_SDEV

DELTA_TEMP	WET_BULB_TEMP_LOW	WET_BULB_TEMP_HIGH	VAPOR_PRESS_LOW

```
.05            15.13              15.08            1.622
0               15.55              15.47             1.646
-.1             16.35              16.19             1.692
-.12            16.7               16.5              1.691
```

VAPOR_PRESS_HIGH	VAPOR_PRESS_MEAN	VAPOR_PRESS_SDEV	REL_HUMID_LOW

```
1.61
1.631
1.668
1.662
```

REL_HUMID_HIGH	REL_HUMID_SDEV	SURF_AIR_PRESS	FRICTION_VELOC

W_T_MEAN	W_E_MEAN	CO2_CONTENT	OZONE_CONTENT	CO2_CONTENT_SDEV

OZONE_CONTENT_SDEV	CO2_FLUX	OZONE_FLUX	FIFE_DATA_CRTFCN_CODE

```
CPI
CPI
CPI
CPI
```

LAST_REVISION_DATE

```
13-OCT-88
13-OCT-88
13-OCT-88
13-OCT-88
```

8. Data Organization:

Data Granularity:

These are point data except that the Bowen ratio flux instruments effectively sample fluxes from an area about 100 meters upwind of the sensors. These data are 30 minute averages of the measured values. The data were collected at 10 minute reporting intervals.

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 begin 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, and principal investigator name.

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.)

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:

See the *Theory of Measurements Section*.

Bowen Ratio, BETA was calculated as:

BETA = 6.436 * 10^-7 (P - 0.378e) / (1 - 0.000946T) (1004 + 1820.4M) / (1 + M) dT/de

where:

e = Es - 0.63115(1 - 0.000946Tw) (T - Tw), [kPa] (Lowe, 1977)

Es = {6.1078 + Tw (0.443652 + Tw (0.01428946 + Tw (2.65065 * 10^-4 + Tw (3.03124 * 10^-6 + Tw (2.03408 * 10^-8 + 6.13682 * 10^-11 Tw))))} / 10, [kPa];

M = 0.922e / (P - e)

T = dry bulb temperature [C]

Tw = wet bulb temperature [C]

P = 101.323E - Z / 8229.6 [kPa]

Z = elevation [m]

Es = saturated vapor pressure

All data are derived from a combination of raw field data, "constants" approved by the FIFE surface flux group, and instrument calibrations. Each ten minute data set was tested for three conditions:

1. If abs(de)<0.0001 then de = -0.0001.
   {to avoid meaninglessly large Bowen ratios}
2. If LE * de < 0 then BETA = -2.5.
   { to avoid counter-gradient water vapor flux }
3. If abs(BETA + 1) < 0.3 then BETA = -2.5.
   {avoids singularity in Bowen-ratio energy-balance method}

The thirty minute averages of H, LE and Beta reported are calculated from averages of the ten minute gradients of air temperature and vapor pressure.

Symbol definitions:

BETA = Bowen ratio

de = Vapor pressure difference [kPa]

LE = Latent heat flux [W/sq m]

Data Processing Sequence:

Processing Steps:

1. Remove data sets from processing stream if instruments malfunction.
2. Remove wet and dry-bulb temperature bias as determined by interchange of instrument position (a design feature of the Bowen ratio instrument used here).
3. Calculate key variables for 10 minute intervals.
4. Report 30 minute averages of key variables.

Processing Changes:

None.

Calculations:

Special Corrections/Adjustments:

Net radiometer Swissteco #7377 radiation values increased 2.5% per FIFE Surface Flux Group radiometer comparisons/calibrations.

Calculated Variables:

- Bowen Ratio,
- Saturated vapor pressure

Graphs and Plots:

None.

10. Errors:

Sources of Error:

The delta-T psychrometer design is a known source of error. See the *Known Problems with the Data Section* for a detailed description.

Quality Assessment:

It was recognized early in the study that standardization's of "constant" (e.g., physical constants of the air, psychrometric constant, etc.), methods of computation, integration and reporting time, etc. were necessary. These were agreed upon in planning sessions. Preliminary data sets were compared among stations and instruments from different manufacturers for estimating net radiation, soil heat flux, water vapor density, temperature, solar radiation, and wind speed, it was necessary to have confidence that differences in observations were due to site differences and not due to instrumentation.

Data Validation by Source:

Spot checks of the raw data were performed daily. The data were scanned into the data-logger memory and hand recorded in the field notes several times each day. Data values were qualitatively assessed for accuracy against previous data from the site and from other USGS surface flux sites.

The Hydrological Sciences Branch at NASA Goddard Space Flight Center was given the responsibility to compare flux data from all flux stations. This served two purposes: 1) as a data quality check, and 2) as a preliminary analysis of site differences.

Confidence Level/Accuracy Judgment:

The following are the best estimates of accuracy for a single flux estimate:

- Net radiation +/- 4 to 7%
- Soil heat flux +/- 30%
- Latent heat flux +/- 15 to 20 % or +/-30 W m^-2, whichever is larger
- Sensible heat flux +/- 15 to 20 % or +/-30 W m^-2, whichever is larger

None of these estimates address the variability of flux estimates from site-to-site.

Measurement Error for Parameters:

Not available at this revision.

Additional Quality Assessments:

Several of the key surface flux parameters have undergone extensive intercomparison and examination for spikes in the data. The data have also been checked for an imbalance in the energy equation. Details of these analyses are described in the Surface Flux Baseline 1992 document on FIFE CD-ROM Volume.

FIS staff applied a general QA procedure to some of the fields, in this data set 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 a numerical field. Inconsistencies and problems found in the QA check are described is the *Known Problems with the Data Section*.

Data Verification by Data Center:

The data verification performed by the ORNL DAAC deals with the quality of the data format, media, and readability. The ORNL DAAC does not make an assessment of the quality of the data itself except during the course of performing other QA procedures as described below.

The FIFE data were transferred to the ORNL DAAC via CD-ROM. These CD-ROMs are distributed by the ORNL DAAC unmodified as a set or in individual volumes, as requested. In

addition, the DAAC has incorporated each of the 98 FIFE tabular datasets from the CD-ROMs into its online data holdings. Incorporation of these data involved the following steps:

- Copying the entire FIFE Volume 1, maintaining the directory structure on the CD-ROM.
- Using data files, documentation, and SQL code provided on the CD-ROM to create a database in Statistical Analysis System (SAS).
- 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:

Delta-T psychrometers were inadequately shielded, resulting in elevated temperature measurements on sunny days. Dry-bulb temperatures usually were in greater error than wet-bulb temperatures. Effects of these errors on gradient estimates, hence on Bowen ratio and flux estimates, were small. See Dave Stannard for suggested corrections to the air temperature and humidity values.

Different missing values are used within each column. They can be positive or negative 9.9, 9.99, 99.99, 999.99, 9999, or 99999.99.

The missing value indicator in the following fields may have been inadvertently converted to 1000. Use these data with caution.

Name	Name
DIFFUSE_SOLAR_RADTN_DOWN	TOTAL_RADTN_DOWN
SOLAR_RADTN_DOWN	TOTAL_RADTN_UP
SOLAR_RADTN_UP	HEAT_STORAGE
SOLAR_RADTN_NET	RAINFALL
SOLAR_RADTN_DOWN_SDEV	WIND_DIR_MIN
SOLAR_RADTN_UP_SDEV	WIND_DIR_MAX
LONGWAVE_RADTN_DOWN	CO2_CONTENT
LONGWAVE_RADTN_UP	O3_CONTENT
LONGWAVE_RADTN_NET	CO2_STDEV
BB_TEMP_LONGWAVE_DOWN	O3_STDEV
BB_TEMP_LONGWAVE_UP	

Usage Guidance:

None.

Any Other Relevant Information about the Study:

None.

12. Application of the Data Set:

Not available.

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:

Bowen Ratio Surface Flux Observations (USGS) data are available on FIFE CD-ROM Volume 1. The CD-ROM filename is as follows:

\DATA\SUR_FLUX\30_MIN\GRIDxxxx\YyyMmm\ydddgrid.BRW or
\DATA\SUR_FLUX\30_MIN\GRIDxxxx\Yyyyy\ydddgrid.BRW

Where *xxxx* is the four digit code for the location within the FIFE site grid, *yy* is the last two digits of the year (e.g., Y87 = 1987), *yyyy* is the four digits of the century and year (e.g., Y1987 = 1987), *mm* is the month of the year (e.g., M12 = December), and *ddd* is the day of the year, (e.g., 061 = sixty-first day in the year). Note: capital letters indicate fixed values that appear on the CD-ROM exactly as shown here, lower case indicates characters (values) that change for each path and file.

The format used for the filenames is: *ydddgrid.sfx*, where *grid* is the four-number code for the location within the FIFE site grid, *y* is the last digit of the year (e.g., 7 = 1987, and 9 = 1989), and *ddd* is the 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 .BRW for this data set.

17. References:

Satellite/Instrument/Data Processing Documentation.

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Tanner, C.B.. 1960. Energy balance approach to evapotranspiration from crops. Soil Sci. Soc. Amer. Proc. 24:1-9.

Verma, S.B.. 1990. Micrometeorological methods for measuring surface fluxes of mass and energy. Remote Sensing Reviews, 5:99-115.

Wesely, M.L., D.H. Lenschow, and O.T. Denmead. 1989. Flux measurement techniques In: Global Tropospheric Chemistry-Chemical Fluxes in the Global Atmosphere. pp. 31-46. National Center for Atmospheric Research, Boulder, CO. 107 pp.

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:

BPI Byte per inch BREB Bowen Ratio Energy Balance CCT Computer Compatible Tape DAAC Distributive Active Archive Center EOSDIS Earth Observation System Data and Information System FIS FIFE Information System IFOV Instantaneous Field of View LAI Leaf area index Mbps Megabyte per second ORNL Oak Ridge National Laboratory PAMS Portable Automatic Mesonet REBS Radiation and Energy Balance Systems URL Uniform Resource Locator

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

20. Document Information:

April 28, 1994 (citation revised on October 15, 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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