Qualls Surface Flux Site #9
Young Field Site

Introduction
This document contains information about the Qualls Surface Flux site operated during the CASES97 field experiment, near Wichita, Kansas.

PI:
Russell J. Qualls
Assistant Professor
Department of Civil, Environmental, and Architectural Engineering
University of Colorado
Boulder, CO 90309-0428

Tel: 303-492-5968
Fax: 303-492-7317
Email: Qualls@colorado.edu

Requested Form of Acknowledgment.

The Surface Flux, Meteorological, and Soil Observations (Qualls Site) were collected and analyzed by Dr. Russell J. Qualls at the University of Colorado, Boulder, Colorado. The contribution of these data is appreciated.

Location:
Latitude: 37.738 N, Longitude: 97.184 W
NW 1/4 of Section 2, Township 27S, Range 2E

Site Description:
Relatively flat, grassland site (see description of vegetation heights below). Predominant wind directions were from the N-NW, and from the SW-S-SE. The field was approximately rectangular, with 400 m clear fetches to the N and to the S. The fetches to the E and W were 200 m. At the limits of these fetches, were wind-rows of deciduous trees whose heights were approximately 6 to 8 m. There was a ridge that ran N-S the entire length of the field. The ridge was approximately one-third of a meter high, with the fields to the west level with the bottom of the ridge and the fields to the east level with the top. The flux station was located about 2 m east of the ridge on the high side. Preliminary calculations with data from April 28, 29 and 30, 1997, show that the zero-plane displacement height, do, and momentum roughness length, zom, were different for fetches to the N-NW than for fetches to the SW-S-SE, presumably due to the ridge.

Duration:
April 6 - May 24, 1997
Missing Data: All data between May 1, 22:00 GMT and May 3, 14:20 GMT are missing.

See also comments about eddy correlation data, below.

Data Sampling:
Eddy Correlation (Sensible Heat Flux, H): 10 Hz., 10 minute averages stored. Note that the instrument used to collect eddy correlation measurements could not be left mounted during rain, so it was only deployed periodically during the experiment. Data are available for days 118-121 (April 28-May 1), 128-137 (May 8-17), and 140-142 (May 20-22).

Slow response sensors (all others): 0.1 Hz., 10 minute averages stored

Times recorded as CDST, but converted to GMT for archive.The time format used for this data set is YYYYDDDHHMMSS.S where YYYY is the year, DDD is the numerical day of year, HH is the hour in military time, MM is the number of minutes past the hour, and SS.S is the seconds and tenths of seconds into the current minute.

OVERVIEW OF DATA COLLECTED:

Energy Fluxes:
H, Sensible Heat Flux, W/m^2, 2.56 m above ground level (agl)
Rn, Net Radiation, W/m^2, 2 m agl
G_5, Ground Heat Flux, W/m^2, 5 cm below ground level (bgl)

Sign Convention:
Rn taken as positive toward the plane of the surface; H, G, and Latent heat flux, LE, taken as positive away from the plane of the surface.

Soil State Variables:
G_5 (see above)
T_s, soil temp, Degrees C, average across 1-4 cm bgl
SM_m, soil moisture, (kg H2O/kg dry soil)*100%, average across 2-3 cm bgl

Atmospheric State Variables:
U1, Wind Speed, m/s, 1.00 m agl, 245 degrees CW from magnetic N
U2, Wind Speed, m/s, 2.00 m agl, 245 degrees CW from magnetic N
U3, Wind Speed, m/s, 2.95 m agl, 186 degrees CW from magnetic N
Udir, wind direction, degrees CW from Magnetic N, 2.95 m agl
Ta1, Air Temperature, degrees C, 1.00 m agl, east side of tripod, pointing south
Ta2, Air Temperature, degrees C, 2.00 m agl, east side of tripod, pointing south

RH1, Relative Humidity, %, 1.00 m agl, east side of tripod, pointing south
RH2, Relative Humidity, %, 2.00 m agl, east side of tripod, pointing south
Tb, Radiometric Brightness Temperature, degrees C, 1.66 m agl, oriented S at 20 degrees from horizontal.
Tb was determined assuming a surface emissivity of 0.97, but reflected longwave radiation was not subtracted out.

Vegetation Heights
Vegetation heights were measured occasionally during the experiment and are given in Table 1 below.

Table 1: Vegetation heights recorded at Qualls site.

Date	Grass (cm) Range/Average/Comments			Taller Stalks/Bushes (cm) Range/Average/Comments		
4/20	0-7	4	none	--	--	none
4/27	--	5	none	--	30	none
5/1	10-18	--	none	--	--	none
5/6	15-18	--	SE-NE fetch	--	--	none
5/6	--	23	Patches to NW	--	--	none
5/8	15-18	--	none	25-30	--	none
5/8	20-23	--	NW fetch	--	--	none
5/11	--	20	none	--	30	none
5/14	--	20	none	--	38	~15% coverage
5/17	18-25	--	SW fetch	33-53	43	15-20% coverage, SW fetch
5/19	--	25	75-70% cover	25-58	48	25-30% coverage
5/19	33-46	--	on ridge to N	--	--	none
5/23	--	25	none	--	48	none

Notes: "--" or "none" means that no value or comment was recorded for this item. Sometimes multiple entries appear for the same date when information about different fetches is given.

INSTRUMENTS USED:

CSI=Campbell Scientific, Inc., Logan UT
REBS=Radiation and Energy Balance Systems, Inc. Seattle, WA

Energy Fluxes:
H, Sensible Heat Flux: CSI 1-D Sonic Anemom. with fine-wire thermocouple
Rn, Net Radiation: REBS Q*7.1 net radiometer
G_5, Ground Heat Flux: REBS HFT 3.1

Soil State Variables:
G_5 (see above)
T_s, soil temp: REBS STP-1, average across 1-4 cm

SM_m, soil moisture: REBS SMP-2, average across 2-3 cm

Atmospheric State Variables:
U1, U2, U3, Wind Speeds: RM Young Cup Anemometers
Udir, wind direction: RM Young wind sentry
Ta1, Ta2, Air Temp.: REBS THP (shielded and aspirated)
RH1, RH2, Relative humidity: REBS THP (shielded and aspirated)
Tb, Radiometric Brightness Temperature: Everest Intersci., 4000.4GL, 15 deg FOV

DATA ACCESS:
The data set is available online through:

http://www.eol.ucar.edu/projects/cases97

The file is a tab delimited ascii file (Qualls02.dat) arranged in columns, with each column representing a different variable, and each row representing values of ten minute averages of the variable listed in each column. There is a 4 row header in which row 1 contains a letter for each column (A-U), row 2 has the variable names (as defined above, but not in that order), row 3 has the variable units, and row 4 has the height at which the variable was measured. The remaining rows (5-6632) contain the 10 minute averages of the variables.

PROBLEMS:
1-D sonic intermittently mounted (instrument cannot withstand rain without damage)

Quality Control:
Bad or missing values flagged with -999

VALUE ADDED PRODUCTS:

SM_v, Volumetric Moisture Content, Volume H2O/Unit Bulk Volume, 2-3 cm bgl
G_0 soil heat flux at surface-calculated by accounting for heat storage in layer 0-5 cm
Rnc, Wind-corrected Net Radiation, W/m^2, 2 m agl
LE, Latent Heat Flux, W/m^2, by energy budget (LE=Rnc-H-G_0)(also can get both LE and H from M-O similarity with Ta, q)
U*, friction velocity-Not yet calculated, but all data available for user to do so.
Zom, momentum roughness length-Not yet calculated, but all data available for user.
do, zero-plane displacement height-Not yet calculated, but data available for user;
note: Zom and do different for wind from N than from S.

Calculation of value-added products:

Volumetric Moisture Content

The volumetric moisture content, SM_v, is required to calculate the changes of heat storage within the 0-5 cm
layer of soil in order to calculate the ground heat flux at the surface by means of the soil heat flux at 5
cm below the surface. The volumetric moisture content may be calculated as,

(1) SM_v = SM_m*SG*(1-n) or SM_m*SG/(1+e)

Where SM_m=soil moisture (mass H2O/Mass dry soil)
SG=specific gravity of soil solids=2.81*
n=porosity of the soil=0.436*
e=void ratio of the soil=0.773*

* see explanation following

SM_m was measured by the REBS SMP. This sensor measures a resistance ratio from which the natural logarithm of the matric potential (Ln(P)) may be calculated. The soil moisture content (mass H2O/Mass dry soil) is calculated from the Ln(P)No undisturbed soil samples were collected. A disturbed soil sample was retrieved from the field which has not yet been analyzed. However, the soil was a fairly heavy clay, and SG, n and e were determined as follows: Properties from a stiff and soft clay are given in Table 2 below (Das, 1985). The maximum observed SM_m value at the Qualls field site during CASES-97 was 26.27. This value occurred after several heavy rain events, with intervening dry-down events, and was assumed to represent the natural moisture content of the soil in a saturated state.

SM_msat was used to estimate values of e and Gamma_d from Table 2 by interpolation between a stiff and soft clay. This resulted in e=0.773, and Gamma_d=98.8 lb/ft^3. From these, the porosity, n, and specific
gravity SG of the soil were determined by

(2) n = e/(1+e) = 0.436
(3) SG = Gamma_d*(1+e)/Gamma_w = 2.81

where Gamma_w is the specific weight of water equal to 62.4 lb/ft^3. Note that the specific gravity for clays should lie between 2.67 and 2.9 (Das, 1986). Then the volumetric water content may be evaluated based on measurements of SM_m throughout the field experiment. The value of SM_v corresponding to the natural moisture content in saturated state is 0.416 (41.6%) based on SM_m=26.27 %. The minimum value of SM_v calculated by (1) is 0.293 (29.3%)

Table 2: Void ratio, e, natural moisture content in saturated state, SM_msat, and bulk dry unit weight,
Gamma_d for two types of clay.

Soil Type	e	SM_msat (%)	Gamma_d (lb/ft^3)
Stiff Clay	0.6	21	108
Soft Clay	0.9-1.4	30-50	73-93

Soil Heat flux at surface, G_0

The soil heat flux at the surface, G_0, is determined by soil calorimetry (Brutsaert, 1982, p. 149):

(4) G_0=G_5+Cs*DT_s/Dt*DZ

where G_5 is the heat flux into the soil at 5 cm below the surface, Cs is the volumetric heat capacity of the soil, DT_s/Dt is the rate of change of soil temperature with time, and DZ = 5 cm is the thickness of the layer. DT_s/Dt is determined by finite differencing between the previous time step (j-1) and the upcoming time step (j+1), as

(5) Dt_s/Dt = (T_s(j+1)-T_s(j-1)) / (2*Dt)

where Dt is a single time increment of 10 minutes (600 seconds).

Cs is determined from the volume fractions of mineral soil (V_m), organic matter (V_c), water (SM_v) and air (V_a) in the soil, and the corresponding densities (d) and specific heats (c) of the individual constituents, by

(6) Cs = d_m*V_m*c_m + d_c*V_c*c_c + d_w* SM_v *c_w+ d_a*V_a*c_a

Air is neglected since its specific heat is small, and the organic component is also neglected since it comprises a small portion of the soil. Instead, V_m is taken to be equal to 1-n. The specific heats and densities used in (6) are given in Table 3 below (Brutsaert, 1982, p. 146):

Table 3: Properties of soil components at 293 K

Component	Specific heat c (J/kg/K)	Density d (kg/m^3)
Soil Minerals	733	2650
Soil Organic Matter	1926	1300
Water	4182	1000
Air	1005	1.20

Net Radiation Wind Correction

Radiation measurements are influenced by wind. The measured Rn values were corrected for this wind effect by means of the manufacturer-supplied empirical equations:

(7) Rnc=Rn/(1-0.059[1-2.8^(-U2)]-0.0096*U2/[0.216+U2^3]) for Rn >= 0

(8) Rnc=Rn/(1-0.021[1-1.45^(-U2)]-2*U2^(-7*U2)/100) for Rn < 0

where Rnc is the wind-corrected net radiation, and U2 is the wind speed at 2 meters.

ACKNOWLEDGEMENTS:
Professor Qualls would like to thank Steve Oncley of NCAR for transporting his equipment from Boulder, Colorado to the CASES field experiment, David Yates of NCAR for his assistance in setting up the equipment, and Julie Lundquistof the University of Colorado, for monitoring the equipment during the experiment. Partial funding for this experiment was provided by the Council on Research and Creative Work, of the Graduate School of the University of Colorado, Boulder, CO.

REFERENCES

Brutsaert, W., *Evaporation into the Atmosphere*, D. Reidel Publ. Co., Boston, 1982.
Das, B.M., Principles of Geotechnical Engineering, PWS Engineering, Boston, 1985.
Das, B.M., Soil Mechanics Laboratory Manual, Engineering Press, Inc., San Jose, CA, 1986.

file: readme.txt