SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000

Abstract

Considerable attention has been given to temperate and tropical forest ecosystems because of their potential contribution to the carbon balance. Much less attention, however, has been paid to the carbon balance of savanna ecosystems, despite the fact that this ecosystem covers an area of 17 x 106 km^2 of the Earth's surface; a greater area than is occupied by either temperate or boreal/temperate forests. The Harry Oppenhiemer Okavango Research Center (HOORC), of the University of Botswana, is located in Maun and is the focus of research activities in the region. The Maun micrometerological tower site is one of the core SAFARI 2000 sites and is one of the sites visited by many researchers along the Kalahari Transect field campaign.

An eddy covariance system was used to measure the seasonal variation in carbon dioxide, water vapor, and energy flux in this broadleaf semi-arid savanna in Southern Africa. The tower is located approximately 20 km east of Maun in northeastern Botswana. The open woodland studied consists of an overstory dominated by *Colophospermum mopane* with a sparse understory of grasses and herbs. Measurements presented in this data set cover the wet and dry season periods that coincided with field activities of the SAFARI 2000 project in February-April and August-September, 2000, respectively.

Background Information

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Project: SAFARI 2000

Data Set Title: SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000

Site: Maun, Botswana
  Westernmost Longitude: 23°.33' E
  Easternmost Longitude: 23°.33' E
  Northernmost Latitude: 19° 54' S
  Southernmost Latitude: 19° 54' S

Data Set Citation:

Lloyd, J., O. Kolle, E. Veenendaal, A. Arneth, and P. Wolski. 2004. SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Data File Information

The data files contain numeric values that represent 30-minute averages from instrumentation mounted on the Maun tower for February-April and August-September, 2000. The data files are stored as ASCII table files, one file per month, in comma-separated-value (.csv) format, with column headers. The files are:

maun_met_flux_2000-02.csv
maun_met_flux_2000-03.csv
maun_met_flux_2000-04.csv
maun_met_flux_2000-08.csv
maun_met_flux_2000-09.csv

Missing data values are represented by a value of -9999. The content of the data files are described below.

Column Name	Column Description	Units
Date	Date of measurement	dd-mon-yyyy
Time	Time at end of 30-min measurement period	hh:mm UTC

p	Air pressure	mbar
T	Air temperature (tower top)	degrees Celsius
Tpot	Potential temperature	K
Tdew	Dew point temperature	degrees Celsius
rh	Relative humidity	%
VPmax	Vapor pressure maximum	mbar
VPact	Vapor pressure actual	mbar
VPdef	Vapor pressure deficit	mbar
sh	Specific humidity	$g\ kg^{-1}$
H_2O C	Water vapor concentration	$mmol\ mol^{-1}$
rho	Density	$g\ m^{-3}$
vhor_cup	Horizontal windspeed, measured by cup anemometer	$m\ s^{-1}$
vhor_sonic	Horizontal windspeed, measured by sonic	$m\ s^{-1}$
H	Sensible heat	$W\ m^{-2}$
LE	Latent heat	$W\ m^{-2}$
E	Water vapor flux	mmol
C	CO2 Flux	$\mu mol\ m^{-2}\ s^{-1}$
U*	Friction velocity	$m\ s^{-1}$
corr. LE	corrected Latent exchange	$W\ m^{-2}$
corr. E	corrected Latent exchange	mmol
corr. C	corrected Latent exchange	$\mu mol\ m^{-2}\ s^{-1}$
rain	Precipitation	mm
Srain	Sum precipitation	mm
Tpyr	Temperature, pyranometer	degrees Celsius
TDR	Total downward radiation	$W\ m^{-2}$
TUR	Total downward radiation	$W\ m^{-2}$

SWDR	Shortwave downward radiation	W m^{-2}
SWUR	Shortwave upward radiation	W m^{-2}
Albedo	Albedo	%
LWDR	Longwave downward radiation	W m^{-2}
LWUR	Longwave upward radiation	W m^{-2}
TRAD	Temperature radiometer	degrees Celsius
PAR	Photosynthetically active radiation	µmol m^{-2} s^{-1}
Rn	Net radiation	W m^{-2}
SHF1	Sensible heat flux, probe 1	W m^{-2}
SHF2	Sensible heat flux, probe2	W m^{-2}
SHF3	Sensible heat flux, probe 3	W m^{-2}
SHF4	Sensible heat flux, probe 4	W m^{-2}
SHF5	Sensible heat flux, probe 5	W m^{-2}
SHFM	Sensible heat flux mean	W m^{-2}
ST002a	Soil temperature, 0.02 m depth, probe a	degrees Celsius
ST005a	Soil temperature, 0.05 m depth, probe a	degrees Celsius
ST010a	Soil temperature, 0.1 m depth, probe a	degrees Celsius
ST050a	Soil temperature, 0.5 m depth, probe a	degrees Celsius
ST100a	Soil temperature, 1 m depth, probe a	degrees Celsius
ST002b	Soil temperature, 0.02 m depth, probe b	degrees Celsius
ST005b	Soil temperature, 0.05 m depth, probe b	degrees Celsius
ST010b	Soil temperature, 0.1 m depth, probe b	degrees Celsius
ST050b	Soil temperature, 0.5 m depth, probe b	degrees Celsius
ST100b	Soil temperature, 1 m depth, probe b	degrees Celsius
ST002M	Soil temperature, 0.02 m depth, probe M	degrees Celsius
ST005M	Soil temperature, 0.05 m depth, probe M	degrees Celsius
ST010M	Soil temperature, 0.1 m depth, probe M	degrees Celsius

ST050M	Soil temperature, 0.5 m depth, probe M	degrees Celsius
ST100M	Soil temperature, 1 m depth, probe M	degrees Celsius
Tlog	Temperature, datalogger	degrees Celsius
Vref1	Reference voltage1	mV
Vref2	Reference voltage2	mV
SM010a	Soil moisture, 0.10 m, probe a	%
SM050a	Soil moisture, 0.50 m, probe a	%
SM100a	Soil moisture, 1 m, probe a	%
SM150a	Soil moisture, 1.5 m, probe a	%
SM010b	Soil moisture, 0.10 m, probe b	%
SM050b	Soil moisture, 0.50 m, probe b	%
SM100b	Soil moisture, 1 m, probe b	%
SM150b	Soil moisture, 1.5 m, probe b	%
SM010c	Soil moisture, 0.10 m, probe c	%
SM050c	Soil moisture, 0.50 m, probe c	%
SM100c	Soil moisture, 1 m, probe c	%
SM150c	Soil moisture, 1.5 m, probe c	%


View of Maun Site from the Eddy Covariance Tower. Photo provided by Caroline Nichol.

Measurement Site

The study site is located in a broad-leaved *Colophospermum mopane* (Kirk ex Benth.) savanna woodland, located about 20 km east of Maun, Botswana. The long-term climate of this site is semi-arid, with a mean annual rainfall of 464 mm. There is a distinct dry season during the winter months from May to September. Appreciable rainfalls are normally limited to the period between December and March.

A 12.6 m micrometerological tower is erected in the middle of a homogeneous stand of tall mopane trees with a maximum canopy height of about 8 m. Patches of shrub mopane (maximum canopy height 2 m) are located about 300 m to the northeast and west of the tower. This type of vegetation pattern stretches in all directions for at least 2.5 km. The *C. mopane* trees were often associated with the hemi-parasitic shrub *Ximenia americana*. Canopy cover of the mopane trees in the stand is estimated at 30-40% (Bird et al., 2004). The marginal understorey consists of grasses with a canopy cover of 15% or less, and some herb coverage as well.

The soil slope in the area was < 0.5%.

The study area is under communal land use, and for many decades was primarily used for cattle grazing and firewood collection. During the period of this study, only a few cattle were present, due to disease control measures 2.5 years prior to the study.

C. mopane is a drought-deciduous tree with an almost total absence of leaves during the dry season. Maximum leaf area index for the stand varies at the peak of the growing season between 0.9 and 1.3 (Mantlana, 2002).

Long term climatic data of the Maun area (monthly rainfall, maximum recorded monthly rainfall, mean maximum daily temperature, mean minimum daily temperature, and potential evapotranspiration) are provided below:

Maun Climatic Variables					
Time Period	**Rainfall (mm)**	**Max Rainf. (mm)**	**Max Temp (°C)**	**Min Temp (°C)**	**P.E.T. (mm)***
July	0.1	5.4	25.3	7.1	111
August	0.3	9.6	28.5	9.9	147
September	3	31.9	32.5	14.7	185
October	17	101.1	33.6	18.6	211
November	50	169.6	33.3	19.5	197
December	79	262.2	32.7	19.2	196
January	110	395.9	32.1	19.6	180
February	100	365.7	30.8	19.2	155
March	73	273.8	31.2	18.2	165
April	25	120.4	30.1	15.1	139
May	6	62.3	27.8	7.1	123
June	1	17.1	25.1	7.1	101
Annual	**464**	**1183.9**	**30.3**	**14.9**	**1910**

*Potential Evapotranspiration according to Penman. Source: Bhalotra (1987).

Meteorological and Flux Instrumentation

Wind speed, air temperature, water vapor pressure, and CO_2 concentration were measured with a closed eddy covariance system consisting of a sonic anemometer (with an omni-directional head) installed at 12.6 m height on the north-east corner of the walk-up tower in the prevailing wind direction, and a Licor 6262 closed path infrared gas analyzer. Air was drawn through 1/8" BEV-A-LINE tubing and pushed through the analyzer at approximately 7 L min^{-1}. A pressure transducer was used to correct for pressure fluctuations. The analyzer was used in absolute mode. Pure N_2 was used to continuously flush the reference cell. The gas analyzer was checked weekly and recalibrated every two to three weeks, or more often, when deemed necessary. Calibration was performed with a calibration gas of known CO_2 concentration (between 340 and 380 ppm) and with air of known H_2O concentration from a dewpoint generator. Drift in the measurements between calibrations was mostly below 1% and never above 3% of the range. Sensible heat (H) and latent heat (LE) were calculated on-line after coordinate rotation (Aubinet et al., 2000). Signals from the sonic anemometer and the gas analyzer were digitally synchronized. Loss of high frequency signals in the closed path system were accounted for by aligning the LE and CO_2 cospectra with that of H while accounting for differences in time lag between the anemometer and gas concentration measurements (Eugster and Senn, 1995; Moncrieff et al., 1997; Grace et al., 1998).

Maun Walk-up Tower. Photo provided by Todd Scanlon.

The tower was also equipped with a data logger with additional micrometeorological sensors for short and longwave radiation, air temperature and humidity, and photon flux density. These sensors were attached to 2 m long aluminium masts on the opposite side of the tower from the sonic. Rainfall, soil temperature, and soil heat flux were measured to the east of the tower at a distance of about 20 m. Soil temperature was measured at depths of 0.02 m, 0.05 m, 0.10 m, 0.50 m and 1.00 m with platinum resistance thermometers (3 at each depth). Soil heat flux plates were inserted at 5 locations at a depth of 0.05 m, and soil moisture by volume was measured at depths of 0.10 m, 0.5 0 m, 1 m, and 1.5 m, with 3 probes for each depth. The relation between volumetric soil water content and soil matric potential was determined by sampling the drying curve water release characteristic, using the filter paper method (Deka et al., 1995).


Aerial view of Maun site from helicopter. Photo provided by Caroline Nichol.

Data Analysis

Eddy covariance measurements were taken with a frequency of 20 Hertz and integrated as half hour means with the EDISOL software (Aubinet et al., 2000; Knohl et al., 2002; Kolle and Rebmann, 2002). Derived variables, such as aerodynamic and surface conductance and canopy-to-air vapor pressure deficit, were calculated using the formula in Miranda et al. (1997) and Grace et al. (1998). Fetch distances were calculated according to Schuepp et al. (1990) and Kolle and Rebman (2002). Missing data due to equipment failure in the data set amounted to approximately 15% during the period from March 1999 to the end of the dry season of the following year, September 2000. These data were either replaced through interpolation (gaps of less than 2-3 hours). For gaps greater than 3 hours, a Michaelis Menten formula was used for daytime fluxes, and Lloyd and Taylor's equation (Lloyd and Taylor, 1994) was used for night time fluxes.

Instrumentation on the Maun Eddy Covariance Tower

Measurement	Instrument	Model	Manufacturer	Output Units
Turbulence (u, v,w)	3-D Sonic anemometer	Solent R3	Gill Instruments, Lymington, UK	m s^{-1}
CO_2 and H_2O mixing ratio	Closed path infrared gas analyzer	LiCor 6262	LI-COR, Lincoln, Nebraska, USA	mmol mol^{-1}
Air pressure	Pressure transducer	PTP101B	Vaisala, Helsinki, Finland	mb
Air temperature	Humidity and Temperature Probe	HMP 45a	Vaisala, Uppsala Sweden	°C
Relative humidity	Humidity and Temperature Probe	HMP 45a	Vaisala, Uppsala Sweden	%
Dewpoint temperature	Dewpoint generator	LI-610	LI-COR Lincoln, Nebraska, USA	°C
Incoming shortwave radiation	Pyranometer	CM3	Kipp & Zonen, Delft, The Netherlands	W m^{-2}
Precipitation	Tipping Bucket Rain Gauge	52202	R.M. Young Company, Traverse City, MI, USA	mm
Photon flux density	Quantum Sensor	LI 190 SA	LI-COR, Lincoln, Nebraska, USA	µmol m^{-2} s^{-1}
Soil Temperature	Platinum resistance thermometers		Geratherm Geschwenden, Germany	°C

Soil Heat Flux	Soil heat flux plates	Rimco HP3	McVan Instruments Victoria, Australia	W m^{-2}
Soil Moisture	Soil moisture sensor	Theta Mx2	Delta T Devices, Burwell, UK	%
Date and Time	Data logger	CR23X	Campbell Scientific, Cambridge, MA, USA	

Note: Data collected at the Maun site was a result of the considerable efforts by members of the SABISA (Savanna Biogeochemistry in Southern Africa) Project, an initiative started by the HOORC and the Max Planck Institute for Biogeochemistry in Jena. Research support was provided by Max Planck Institute for Biogeochemistry.

Additional Sources of Information

Related Data Sets

The Maun site is part of the Kalahari Transect which was the focus of several complementary studies by colleagues from Southern Africa and elsewhere during SAFARI 2000. Many of these studies are archived by ORNL DAAC. A list of these data sets is available at: http://www.daac.ornl.gov/S2K/safari.html.

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Revision Date: Thursday, September 30, 2004