SAFARI 2000 Surface Albedo and Radiation Fluxes at Mongu and Skukuza, 2000-2002

Abstract

Top-of-the-canopy broadband albedo and radiation fluxes are calculated from measurements at the Mongu and Skukuza flux tower sites in southern Africa from March 2000 through December 2002. Data were collected by instrumentation deployed at the top of the 30 m tower in the Kataba Local Forest near Mongu, Zambia, and atop the 20 m tower at the Skukuza tower site in Kruger National Park, South Africa.

At the Mongu site, Kipp and Zonen albedometers housing both upward- and downward-looking pyranometers were outfitted with clear and red domes to collect broadband albedo and radiation fluxes in the shortwave (SW) and near-infrared (NIR) wavebands, respectively. The data are mean values provided at 15-minute intervals for 2000-2002. At the Skukuza tower, Kipp and Zonen albedometers (also outfitted with clear and red domes) collected broadband albedo and radiation fluxes in the SW and NIR wavebands. In addition, a pyrgeometer was used to collect longwave radiation flux in thermal infrared (TIR) wavebands. The data at Skukuza are mean values provided at 30-minute intervals for 2000-2002, except for the TIR data, which are provided for 2001 and 2002 only. For both sites, photosynthetically active radiation can be calculated from measurements.

These data were primarily obtained for Earth Observation System (EOS) product validation and energy and mass flux modeling. They are calibrated and available for immediate use.

Background Information

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Project: SAFARI 2000
Southern Africa Validation of EOS (SAVE)

Data Set Title: SAFARI 2000 Surface Albedo and Radiation Fluxes at Mongu and Skukuza, 2000-2002

Site: Skukuza, South Africa
Westernmost Longitude: 31° 29' 04"
Easternmost Longitude: 31° 29' 04"
Northernmost Latitude: -25° 01' 12"
Southernmost Latitude: -25° 01' 12"

Site: Mongu, Zambia
Westernmost Longitude: 23° 15.162'
Easternmost Longitude: 23° 15.162'
Northernmost Latitude: -15° 26.298'
Southernmost Latitude: -15° 26.298'

Data Set Citation:

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Data File Information

The data are provided in comma-delimited ASCII files, with column headers. The SW and NIR data for both sites are provided in one file per year per site for 2000-2002. The Skukuza longwave data are provided separately, and for years 2001 and 2002 only. The data files are described below.

Mongu Data

An error in the data are indicated with the value -99.99 for flux columns and -9.99 for albedo columns.

Column	Description	Units	Instrument	Range
Year	Year	YYYY	data logger	2000 to 2002
Day	Day of year (Julian)	days	data logger	1 to 366
Time	Time at the end of the averaging period	HHMM GMT	data logger	500 to 1600
SW_in_mean	Mean shortwave irradiance	W m^{-2}	Kipp and Zonen CM14 with clear dome	0 to 600
SW_in_max	Maximum shortwave irradiance	W m^{-2}	Kipp and Zonen CM14 with clear dome	0 to 600
SW_out_mean	Mean shortwave exitance	W m^{-2}	Kipp and Zonen CM14 with clear dome	0 to 600
NIR_in_mean	Mean near infrared irradiance	W m^{-2}	Kipp and Zonen CM14 with red dome	0 to 1300
NIR_out_mean	Mean near infrared exitance	W m^{-2}	Kipp and Zonen CM14 with red dome	0 to 1300
SW_albedo	Mean shortwave Albedo	unitless	Ratio of SW_out_mean to SW_in_mean	0 to 1.0
NIR_albedo	Mean near infrared Albedo	unitless	Ratio of NIR_out_mean to NIR_in_mean	0 to 1.0
Solar_Zenith_Angle	Solar Zenith Angle	degrees	calculated	0 to 90
Solar_Azimuth_Angle	Solar Azimuth Angle	degrees	calculated	0 to 360
QA_Flag	Quality Assessment Flag	unitless	N/A	0 to 12

Skukuza Data

Skukuza SW and NIR Data Files

Bad data fill values are indicated in the Range column below.

Column	Description	Units	Instrument	Range (bad data fill value)
Year	Year	YYYY	data logger	2000 to 2002
Day	Day of year (Julian)	days	data logger	1 to 366
Time	Time at the end of the averaging period	HHMM GMT	data logger	500 to 1600
SW_in1	Mean shortwave irradiance	W m^{-2}	Kipp and Zonen CM14 with clear dome	0 to 600 (-9999)
SW_out1	Mean shortwave exitance	W m^{-2}	Kipp and Zonen CM14 with clear dome	0 to 600 (-9999)
SW_in2	Mean shortwave irradiance, 2nd instrument	W m^{-2}	Kipp and Zonen CM14 with clear dome	0 to 600 (-9999)
SW_out2	Mean shortwave exitance , 2nd instrument	W m^{-2}	Kipp and Zonen CM14 with clear dome	0 to 600 (-9999)
NIR_in	Mean near infrared irradiance	W m^{-2}	Kipp and Zonen CM14 with red dome	0 to 1300 (-9999)
NIR_out	Mean near infrared exitance	W m^{-2}	Kipp and Zonen CM14 with red dome	0 to 1300 (-9999)
PAR_in	Mean PAR irradiance	W m^{-2}	Computed as (SW_in1 - NIR_in)	0 to 500 (-9999)
PAR_out	Mean PAR exitance	W m^{-2}	Computed as (SW_out1 - NIR_out)	0 to 35 (-9999)
SW_albedo1	Mean shortwave Albedo	unitless	Ratio of SW_out1 to SW_in1	0 to 1.0 (-9.99)
SW_albedo2	Mean shortwave Albedo, 2nd instrument	unitless	Ratio of SW_out2 to SW_in2	0 to 1.0 (-9.99)
NIR_albedo	Mean near infrared Albedo	unitless	Ratio of NIR_out to NIR_in	0 to 1.0 (-9.99)
PAR_albedo	Mean PAR Albedo	unitless	Ratio of PAR_out to PAR_in	0 to 0.08 (-9.99)
Solar_Zenith_Angle	Solar Zenith Angle	degrees	calculated	0 to 90 (99.99)
Solar_Azimuth_Angle	Solar Azimuth Angle	degrees	calculated	0 to 360 (999.99)
QA_Flag	Quality Assessment Flag	unitless	N/A	0 to 12

Skukuza Longwave Data Files

Note that if the solar angle was not recorded, it was replaced by '#N/A'. If the solar zenith angle was reported but was greater than 90 degrees, then the values 99.99 and 999.99 were replaced in the solar zenith and azimuth angle columns, respectively. These data are available for 2001 and 2002 only.

Column	Description	Units	Instrument	Range
Year	Year	YYYY	data logger	2000 to 2002
Day	Day of year (Julian)	days	data logger	1 to 366
Time	Time at the end of the averaging period	HHMM GMT	data logger	500 to 1600
LW_in	Mean longwave irradiance	W m^{-2}	Kipp & Zonen CG21 Pyrgeometer	0 to 600
LW_out	Mean longwave exitance	W m^{-2}	Kipp & Zonen CG21 Pyrgeometer	0 to 600
LW_ratio	Mean longwave Ratio	unitless	Ratio of LW_out to LW_in	0 to 1.0
Solar_Zenith_Angle	Solar Zenith Angle	degrees	calculated	0 to 90
Solar_Azimuth_Angle	Solar Azimuth Angle	degrees	calculated	0 to 360
QA_Flag	Quality Assessment Flag	unitless	N/A	0 to 12

Data File QA Flag Column Description

QA Flags are set when any check suggests a measurement is faulty. The values used and their definitions are shown below:

0=No errors detected. Best data.
1=spare - not currently used.
2=SW up mean data saturated
3=SW albedo is nonsense
4=SW up is nonsense
5=SW up max is nonsense
6=SW down is nonsense
7=NIR up is nonsense
8=NIR down is nonsense
9=NIR albedo is nonsense
10=PAR_albedo is nonsense
11=PAR_in is nonsense
12=PAR_out is nonsense

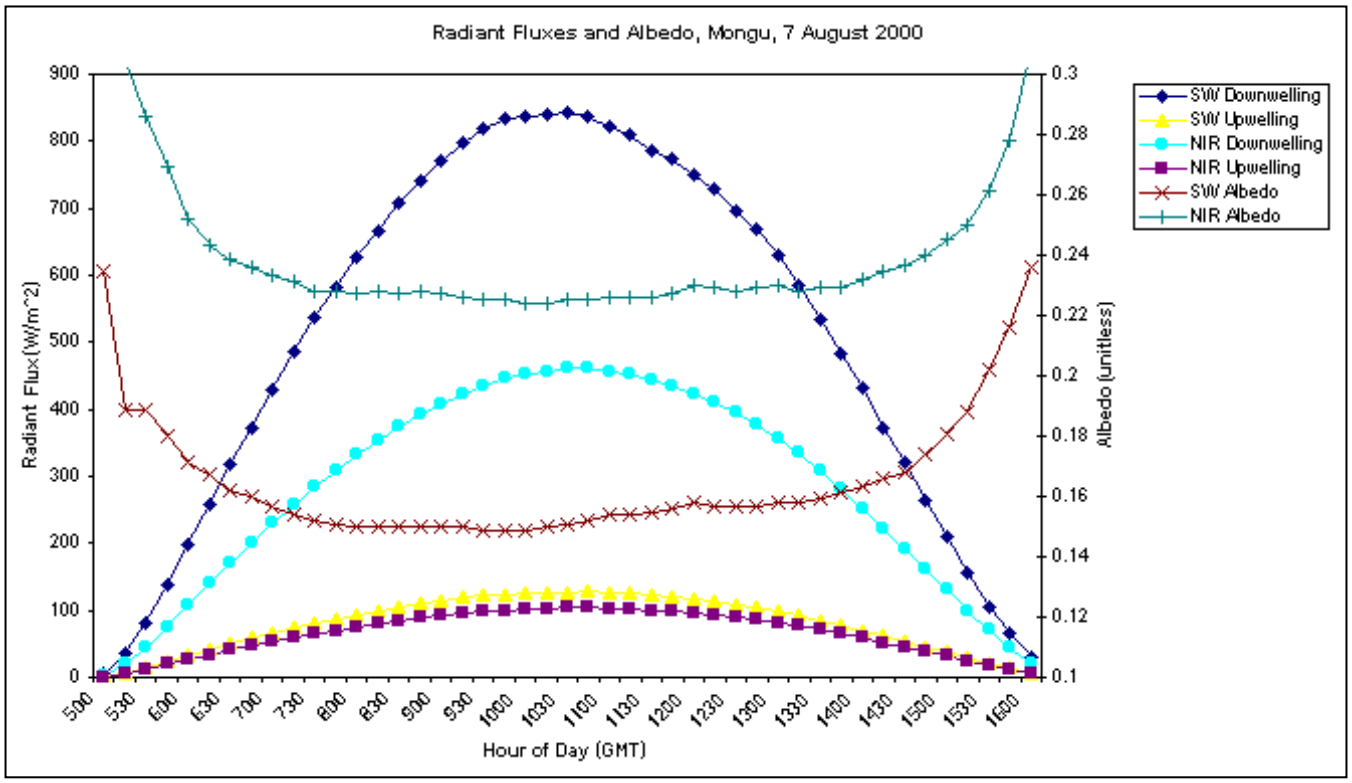
Data Set Summary

This data set contains the top-of-canopy broadband albedo and radiation fluxes in the SW (0.3-2.8 micron), PAR (0.3-0.7 micron), NIR (0.7-2.8 micron), and TIR (5-25 microns) wavebands. At the Mongu site, SW and NIR data are provided at 15 minute intervals. At Skukuza, SW, PAR, NIR and TIR data are provided at 30 minute intervals. Additional parameters such as solar geometry with time are included. All data are provided between the hours 0500-1600 GMT (7 a.m. - 6 p.m. local time).

At Skukuza, a second redundant albedometer was used on the tower. These two sets of SW data can be treated as independent, but with identical temporal and spatial characteristics. The PAR flux is determined by subtracting the NIR flux from the SW flux. PAR flux is not provided in the Mongu data, but can easily be computed in the same way.

At Mongu, the data cover the period from March 2, 2000 to December 31, 2002. At Skukuza, the data cover the period from April 9, 2000 to December 31, 2002. The data loggers sampled the sensors every minute, and recorded the mean for each 15 or 30 minute interval.

These data can be used to determine vegetation photosynthetic efficiency, surface energy balance, and the relationship of irradiance to atmospheric conditions.



Study Sites

The Mongu site is located in the Kataba Local Forest, approximately 20 km south of Mongu in Western Province, Zambia. The Local Forest is a Zambezian woodland (miombo-like) on Kalahari Sands, about 11 m in height, that undergoes subsistence harvesting. Mongu is situated at an elevation of 1187 m near the Zambezi River with a seasonality defined by wet and dry cycles. The rainy season extends from about November to April; and the dry season from about May to October. Temperature averages 30º C in the dry season and 26º C in the wet season. Annual rainfall averages 949 mm, occurring primarily in the wet season.

The Skukuza site is in an open savanna consisting primarily of *Acacia* and *Combretum* trees. Tree height is about 7-8 m on average. A dense grass layer covers the soil. The Skukuza study site is located in the southern region of Kruger National Park (KNP) in northeastern South Africa on a gently undulating landscape. The climate is semi-arid subtropical, with hot, rainy summers, warm dry winters, and an annual average rainfall of 550-650 mm. The natural disturbance regime of the site includes frequent fire (typically 3-8 yrs), as well as grazing and browsing by numerous species of wild ungulate. The instrument tower is located between two distinct savanna types, a broad-leafed *Combretum* savanna and a fine-leafed *Acacia* savanna.

Theory of Measurements

The principal incident and reflected SW radiation measurements are made with Kipp and Zonen CM14 albedometers. It is a single body instrument that houses both an upward- and downward-looking pyranometer. The instruments were mounted on steel brackets that extended horizontally from the tower tops, such that the sensors were mounted approximately 1.5 m from the tower. At Skukuza, the duplicate sensors providing SW_in1 and SW_out1 were mounted approximately 2.5 m from the tower, while the other sensors at both sites were mounted at 1.5 m. No correction was applied for potential shadowing from the tower. At Mongu, the sensors were mounted on the East side of tower. At Skukuza, the sensors on the North side of the tower. A white screen prevents the body of the albedometer from heating up. A conical lower screen shades the lower glass dome at sunrise and sunset. All albedometers are supplied with a calibration certificate.

The instrument complies with the specifications for 'secondary standards' as published in the Guide to Meteorological Instruments and Methods of Observation, Fifth Edition of the World Meteorological Organization. The CM14 has a response time of <15 seconds, a spectral range of 305-2800 nm (50% points), or 335-2200 nm (95% points). It has a Schott K5 optical glass (2 mm) dome.

The CG1 Pyrgeometer is designed for thermal IR radiation measurement, for both atmospheric and material testing research applications. The pyrgeometer CG 1 is a sensor that measures the far infrared irradiance on a plane surface. The CG1 is intended for mounting and operation in an upward (skyward) facing horizontal plane, for accurate measurement of incoming IR sky irradiance from 5 - 50 mm. The CG1 can also be mounted and operated in an inverted downward facing horizontal plane, to measure surface emitted IR radiation. The field of view is 150 degrees.

To determine the incoming longwave irradiance (E), the detector microvolt channel (V), the detector temperature (T), and the calibration factor (C) have to be taken into account.

$$E = V/C + 5.67e\text{-}08 * T^4$$

Spatial Resolution:

The albedometer is composed of two pyranometers, one facing up to measure incident radiation, and one facing down to measure reflected radiation. Each pyranometer has a near-hemispherical field-of-view. The cosine error (in terms of directional response) is +/- 10%, meaning the unit is of ISO9060 Secondary Standard quality. The pyranometers effectively integrate radiances over the hemisphere. At Mongu, the mounting configuration provided a ~200 m diameter circular footprint for 0 to 80 degree incident angles. At Skukuza, the footprint diameter was more than 170 m (i.e., this value assumes a consistent 7 m high overstory). In both cases, the landscape components are well mixed over the footprint area.

Processing Steps:

1. Only complete days (0-24 h) are ingested into processing.
2. Linear interpolation is applied for small (<1 hour) data gaps.
3. The data are calibrated using factory calibration information. This only affects the flux values since the same calibration coefficients are used for both sensors.
4. Based on the time, date and location, the sun angle is determined from a model-generated look-up table.
5. Cloudless periods are determined (available independently from the PI).
6. QA checks are run.

Error Sources:

The primary sources of error are due to infrequent cleaning of the glass domes on the sensors. Physical and financial

constraints limited the number of times the sensors were cleaned. In Mongu, the sensors were cleaned approximately 3 times a year. Since rainfall occurs frequently in the wet season, it is likely the sensors were reasonably clean from November to April. In the dry season, dry aerosol deposition (dust and particulates) is significant, though this was the season that most cleanings occurred.

Other notable error sources include tower effects (structure within the field of view and shadow of the structure), the limited spatial sampling area (ideally, the sensors would be higher or moved during sampling, e.g., on an aircraft), and cosine errors of the sensors themselves. The total uncertainty in the measurements due to these factors has not been estimated. Future comparisons against albedo and BRDF data from the CV-580 aircraft should help indicate accuracy. Finally, the sensors were not perfectly level, however, since we found that the measured peak values were obtained when the sun was highest in the sky, it appears that leveling problems were small.

Limitations of the Data:

The sensors were not cleaned periodically. In the wet season (November-April), this probably has little effect. In the dry season, dust builds up on the sensors. In Mongu, the sensors were cleaned upon deployment in February 2000. In addition, they were also cleaned in September 2000, June 2001, September 2001, June 2002, and August 2002, and approximately bimonthly thereafter. At Skukuza, the sensors were cleaned upon deployment in April 2000, and after that were cleaned only during the field campaigns in March and August 2000, and in August 2001.

Known Problems with the Data:

The NIR albedometer at Skukuza, and the shortwave albedometer (uplooking sensor) at Mongu degraded in 2000. At Mongu, there was an Eppley pyranometer also mounted on the tower (beginning in August 2000) that interested users could use as a substitute to generate shortwave albedo (see Privette and Mukelabai, 2005). The degraded NIR sensor at Skukuza was replaced with new one on Aug 27, 2000. At Mongu, the faulty SW sensor was replaced on September 2, 2001.

Note in some cases, the irradiance was sufficiently high that the data logger exceeded the allowed range (due to the relatively high gain value used). In these cases, the mean fluxes were usually error numbers while the maximum allowable flux value was stored properly. In these cases, we used the maximum value instead of the mean value for the albedo computation. These cases were noted with QA flags.

Instrument Description

These sensors were leveled as well as possible on a platform connected to the tower top. Each had an unobscured view of the full sky dome, and a relatively clear view of the ground. The one obvious obstruction on the down-looking sensor's field of view was the support tower itself.

The CM14 Albedometer, a single body instrument with both an upward- and downward-looking pyranometer, on the Mongu tower.

The CM14 Albedometer, the 'red dome' (NIR) and 'clear dome' sensors (left), and the second 'clear dome' sensor (right), on the Skukuza tower.

Manufacturer of Sensor:

Kipp & Zonen B. V.
P.O. Box 507 2600 AM
Delft, The Netherlands
T +31 (0)15 2698 000
F +31 (0)15 2620 351
E-mail: info.holland@kippzonen.com
http://www.kippzonen.com/

CG1 Specifications:

Sensitivity (nominal) 14 µV/Wm-2
Spectral range 5 to 50 µm
Window heating offset 15 W/m_ (nominal), under direct solar irradiance
Operating temperature -30°C to +40°C
Response time (1/e) < 5 sec
Thermopile output range -250 to +250 W/m-2
Temperature dependence < ±2 % (-20ºC to +30ºC)
Thermal gradient offset < 1 W/m2 (5º C/hr)
Field of view 150°

Additional Sources of Information

The radiation fluxes were collected by J. Privette, M. Mukelabai, and N. Hanan. Additional processing support was provided by Z. Hao.

Albedo data were also collected at the Skukuza airport over grass during the August 1999 campaign. These data are available on request from the PI.

A derived, cloud-cleared data set of surface albedo and radiation fluxes at Mongu and Skukuza is available separately from the PI.

Related Data Sets:

Hanan N., R. Scholes, and M. Coughenour. 2004. SAFARI 2000 Meteorological Tower Measurements, Kruger National Park, 2000-2002. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Pinheiro, A. C. and J. L. Privette. 2004. SAFARI 2000 Soil Properties, Moisture, and Temp, Skukuza and Mongu, 1999 to 2001. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Privette J. L. and M. Mukelabai. 2005. SAFARI 2000 Surface Irradiance Measurements, Mongu Tower Site, Zambia, 2000-2002. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Privette, J. L., M. M. Mukelabai, and K. F. Huemmrich. 2005. SAFARI 2000 FPAR TRAC Data for Mongu, Zambia, 1999-2002. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Privette, J. L., M. M. Mukelabai, and K. F. Huemmrich. 2005. SAFARI 2000 Leaf Area Measurements at the Mongu Tower Site, Zambia, 2000-2002. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Additional related data sets collected at the Mongu and Skukuza sites during SAFARI 2000 are archived by ORNL DAAC. A list of these data sets is available at: http://www.daac.ornl.gov/S2K/safari.html.

References:

Frohlich, C. and J. London (eds.). 1986. Revised instruction manual on radiation instruments and measurement. Prepared by the Radiation Commission of the International Association of Meteorology and Atmospheric Physics (IAMAP), WMO/TD-No. 149.

Huemmrich, K. F., J. L. Privette, M. Mukelabai, R. B. Myneni, and Y. Knyazikhin. 2005. Time-series validation of MODIS land biophysical products in a Kalahari woodland. Int. J. Remote Sens. In press.

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Privette, J. L., R. B. Myneni, Y. Knyazikhin, M. Mukufute, G. Roberts, Y. Tian, Y. Wang, and S. G. Leblanc. 2002. Early spatial and temporal validation of MODIS LAI product in Africa. Remote Sensing of Environment, 83(1-2): 232-243.

Privette J. L., M. Mukelabai, Z. Hao, and C. B. Schaaf. 2004. Validation of the MODIS albedo product in African savannas and woodlands. IEEE Geosciences and Remote Sensing, submitted.

For a description of the Skukuza site, see:

Scholes, R. J., N. Gureja, M. Giannecchinni, D. Dovie, B. Wilson, N. Davidson, K. Piggott, C. McLoughlin, K. van der Velde, A. Freeman, S. Bradley, R. Smart, and S. Ndala. 2001. The environment and vegetation of the flux measurement site near Skukuza, Kruger National Park. Koedoe 44(1): 73-83.

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