SAFARI 2000 BRDF Measurements at Sua Pan and Skukuza, Dry Season 2000

Abstract

The Multi-angle Imaging SpectroRadiometer (MISR) Validation team was deployed to southern Africa from August 18 to October 2, 2000 to participate in the SAFARI 2000 Dry Season Aircraft Campaign. During the first part of the campaign, the team was located at the Sua Pan in the Magkadigkadi region of Botswana. At the end of the campaign, the team moved to Skukuza tower site in the Kruger National Park, South Africa. The experiment was designed to collect the suite of data necessary for multi-angle top-of-atmosphere radiance predictions in order to provide a vicarious calibration for the MISR instrument aboard the Terra satellite platform.

The Jet Propulsion Laboratory's (JPL) Portable Apparatus for Rapid Acquisition of Bidirectional Observation of the Land and Atmosphere (PARABOLA), version III, instrument collected data at the Sua Pan and adjacent grassland sites on 6 separate days, and at the Skukuza tower site on 5 separate days. The PARABOLA instrument is a sphere-scanning radiometer that views the entire radiant environment in all directions.

Coincident aircraft overflights occurred on September 16, 23, and 25 and collected aerial photographs, in-situ aerosol and BRDF data on selected dates. See Myers (2004), Hobbs (2004), and Piketh et al., (2004a and 2004b) for more information.

Background Information

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Project: SAFARI 2000

Data Set Title: SAFARI 2000 BRDF Measurements at Sua Pan and Skukuza, Dry Season 2000

Site: Sua Pan, Botswana
Westernmost Longitude: 26.04889° E
Easternmost Longitude: 26.08033° E
Northernmost Latitude: -20.523° S
Southernmost Latitude: -20.57717° S

Site: Sua Pan Grassland, Botswana
Westernmost Longitude: 26.0298° E
Easternmost Longitude: 26.0394° E
Northernmost Latitude: -20.5168° S
Southernmost Latitude: -20.5259° S

Site: Skukuza, South Africa
Westernmost Longitude: 31.4968 E
Easternmost Longitude: 31.4968 E
Northernmost Latitude: -25.0198 S
Southernmost Latitude: -25.0198 S

Data Set Citation:

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Web Site: http://www-misr.jpl.nasa.gov/mission/valwork/val_reports/000813_safari/safari.html

Data File Information

PARABOLA Data Files

The file names include scan number, date, and time of data collection. For example, PARABOLA scan number 1 table on August 25, 2000 at 04:21 local time is named:

parabola001_20000825_0421.csv

Each file contains 37 rows by 72 columns of ASCII integer values of radiance counts, separated by commas, for 8 bands for each 3 minute data collection. All of the data for the first band are reported, followed by a blank record, then the next band, and so on. Note that there is a 180° azimuthal offset between two groups of four bands each, depending on the head number. See spectral resolution section below.

PARABOLA Data File Format:

Variable	Description	Units	Range
Radiance Counts	Proportional to physical radiance via quadratic fit coefficients with dark current offset.	Digital Numbers (DN or counts)	0-1048576

Zenith Angle (implied by DN position in file)	Vertical position in array, reported in 5° increments. Row 1 = 0°, Row 37 = 180°.	degrees	0-180 (row position 1-37)
Azimuth Angle (implied by DN position in file)	Horizontal position in array, reported in 5° increments. Column 1 = 0°, Column 72 = 355° Absolute alignment to geographic north determined by apparent sun position and ephemeris.	degrees	0-355 (column position 1-72)

PARABOLA Average Dark Current Readings

Also included are files containing a set of average dark current readings, in ASCII .csv format, empirically determined by covering the detectors. For example, **parabola001_DarkCurr_0926.csv**. Note that zenith and azimuth are not actual reported values in the data files, rather, the 5 degree field-of-view increments are implied by the DN position within the data array.

PARABOLA Site-Specific Auxiliary Information

The parameters listed below are stored in the ASCII text (.csv) file, **parabola_aux_info.csv**. One record for each date of PARABOLA data collection. The temperatures and pressures were collected around the time of the MISR overpass (10:00-11:00 am local time).

Variable	Description	Units	Instrument	Range
Date	Day, Month, Year of measurement	DDMMYYYY	Magellan GPS	Aug & Sep 2000
Time	Time of measurement (Terra overpass)	hhmm (UTC)	Magellan GPS	0820-0845
Latitude	Instrument location, latitude	decimal degrees	Magellan GPS	Southern Africa
Longitude	Instrument location, longitude	decimal degrees	Magellan GPS	Southern Africa
Pressure	barometric pressure	millibars	Davis Met Package	916-990 mb
Temperature	air temperature measured by electronic thermometer	°C	Davis Met Package	21-32° C

Az_Offset	azimuthal offset estimated by comparison of apparent solar position to ephemeral prediction.	degrees	Calculated. User must verify this quantity on a case-by-case basis.	0-180°

Site Description

Sua Pan was chosen as an in-region vicarious calibration target because of the appearance of large areas of uniformly bright reflectance from space. Also, its proximity to areas of interest for atmospheric transport meant that radiometric measurements could be used to estimate atmospheric aerosols and thus help to validate circulation models. With additional data from overflights of sampling aircraft, optical techniques for measuring atmospheric aerosols could be compared to the results obtained via in-situ collection methods. The Skukuza tower site was selected because it is one of the main SAFARI 2000 data collection sites, and is also an Earth Observation System (EOS) core validation site.

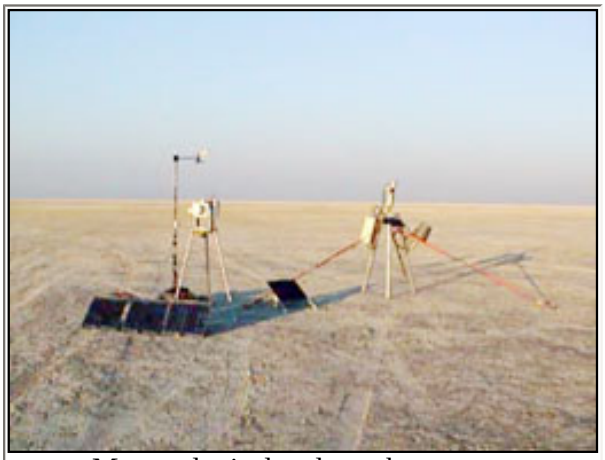
The Sua Pan site is a large salt playa in the desert. The pan surface itself, while homogeneous at the 100 m scale, is somewhat heterogeneous at the 1 m scale. It is essentially a semi-hard clay mud with varying degrees of water saturation in its upper layers and a thin salt crust (mostly halides) on top. The entire pan surface floods seasonally. A multi-angle surface bi-directional reflectance analysis of MISR satellite data was performed to determine where the driest zones on the pan might be to set up the experiment. Fortunately, a large relatively dry area was found near the researchers' encampment on the peninsula.

Sua Pan is nearly bisected by a long peninsula (see imagery below under Site Overview), some 2-3 meters above the pan surface, which supports vegetation. The peninsula is actually an ancient riverbed, and its sediments have enough permeability to resist saltation and allow plant growth. The dominant vegetation here are grasses, mainly *Odyssea paucinervis* and *Sporobolus spicatus.* The grasslands provided large homogeneous areas for comparison of scale between ground measurements and remote sensing results.

The Skukuza tower site is within Kruger National Park in northeastern South Africa. The tower site is named for the Skukuza camp that is located nearby. The main tower at Skukuza was located between two distinct savanna types, a broad-leaved *Combretum* savanna and fine-leafed *Acacia* savanna.

Sua Grassland.

Sua Grassland closeup.



Meteorological and sunphotometer instrumentation at the Sua Pan.

The PARABOLA III instrument being carried on its pole across the Sua Pan.

The view southeast from the Skukuza tower after fire passed through the previous night. Photo taken September 26, 2000.

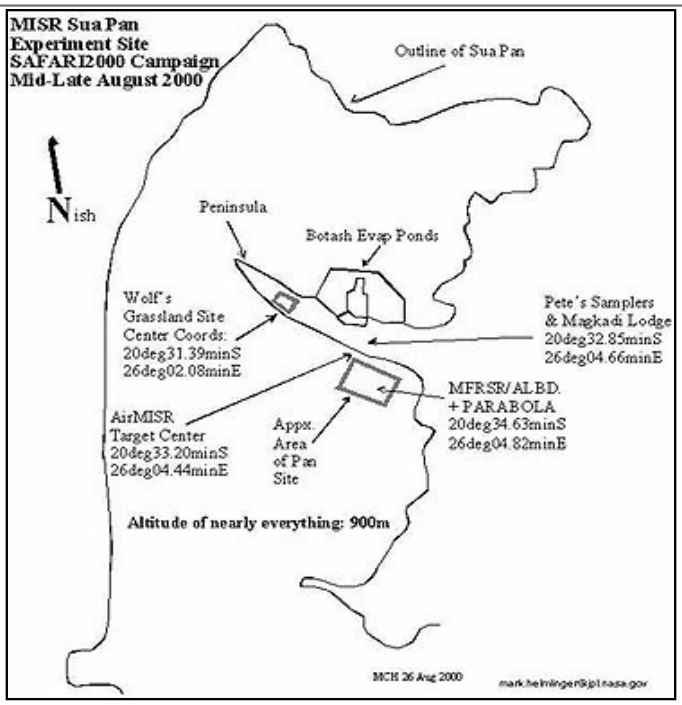
Skukuza tower (pre-fire), August 2000, with the PARABOLA III instrument mounted at the top of the tower.

Additional photographs of both areas are available from the S2K Photo Gallery pages.

Sua Pan Site Overview

This image of Sua Pan was taken by the MISR sensor aboard Terra satellite on the 18th of August, 2000.

Sua Pan Site Map



Overview of the Sua Pan and Grassland experiment site.

Data Collection

The conditions at the time of measurement were dry at all sites, as it was the end of the dry season. The grasses at the grassland site were completely senescent; at Skukuza, the understory was dry and only evergreen tree species had leaves. Data collection dates at each site are listed in the table below. Measurements were made on cloud-free days of Terra satellite overpasses. It was assumed that the reflectance of the pan surface and senescent grasses would be invariant over the few weeks of the experiment.

Site	Subsite	Latitude	Longitude	Acquisition Dates	MISR Overpass Dates
Sua Pan	PA	-20.5755	26.0818	August 25, 27	August 27-September 3
	PB	-20.5773	26.0777	September 3	
	PC	-20.5781	26.081	September 4	
Sua Grassland	GA	-20.5232	26.0347	August 30	
	GB	-20.5205	26.035	September 1	
Skukuza	tower	-25.0198	31.4968	September 23, 26, 28, 30 October 2	September 23, 25 October 2

PARABOLA III measures the downwelling sky radiance and the Hemispherically Distributed Reflectance Function (HDRF) of the surface. The HDRF consists of the component Bi-directional Reflectance Distribution Function (BRDF) with a lesser contribution from the indirect illumination field of the entire downwelling hemisphere.

As mounted at Sua Pan, the effective surface coverage could be described as a circle with a 50 meter radius. The PARABOLA instrument was installed here at 3 random locations on the Pan and at 2 locations within the grassland site. The instrument was mounted at each location on a 3 meter telescoping pole. At Skukuza, PARABOLA was installed on the same telescoping pole 3 meters above the top of the 16 m Skukuza tower. Here the effective radius was on the order of 200 meters.

A reflectance standard was placed beneath the instrument within its field of view to obtain reflectance ratios from the measured DNs. The reflectance standard measurements are included as part of regular scans. Such dimensionless angular reflectances are considered to be more accurate than derived radiances.

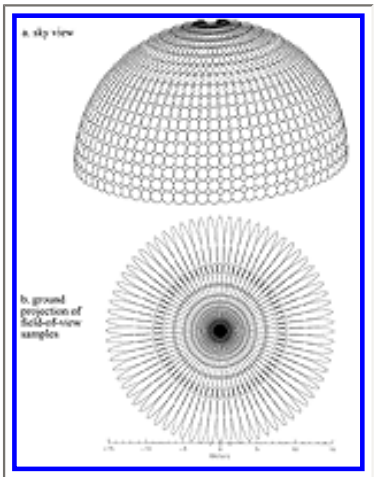
Other measurements were also concurrently made at the same target, such as surface spectral reflectance and optical depth determinations. It is in this radiometric context that PARABOLA data are best analyzed.

PARABOLA III Instrument

PARABOLA III was designed and built by Sensit Technologies, Inc. (Portland, ND). PARABOLA III consists of two separate sensor heads mounted at opposite ends of a central horizontal scanning beam that rotates continuously through 360 degrees in azimuth. Each of these two sensor heads has four independent radiometers which, in turn, scan synchronously from zenith to nadir. The instrument is well suited for field conditions, as the azimuth and the zenith drives are the only parts that move. The motions about the vertical and horizontal axes generate a stepwise pattern of 5 degree elevation angle increments and a similar pattern of 5 degree azimuth angle increments. An entire scan of both sky and ground hemispheres generates 2664 (37 x 72) 8-band data samples in about 3.3 minutes (Brugge et al., 2000).

The PARABOLA III scanning radiometer. Shown are the four sensor heads (each with four spectrally-filtered radiometers), a reflectance standard, power supply, Zip drive housing, and guy-wired stand.

PARABOLA field operation is best done in a flat region of relative homogeneous cover over 30 m spatial scales. The instrument is mounted on a pole, and stabilized with three guy wires. Bottom-mounted connectors allow all cables to be run down the center axis.



The PARABOLA field-of-view projection onto the sky hemisphere, and ground projections.

The spherical scan pattern results in a series of overlapping measurements, depending on zenith angle, best visualized as a dome of linked circles (see figure on the left), with 72 circles crowded together at the very top and bottom (0° and 180° zenith) and with various amounts of overlap (oversampling) to the horizon (90°) where the 72 circles are just touching. The azimuthal scan direction is clockwise, as seen from above the instrument. The zenith scan is from zenith to nadir, incrementing 5° every other azimuthal rotation of the instrument head.

For the case of the upwelling radiant field, the sampling grid is a projection of the dome described above onto a flat surface (the ground), resulting in a pattern of variously overlapping circles directly below the instrument to progressively elongated ellipses out to the horizon.

The geometric fields of view of each channel are determined by a field stop located in front of the detector plane, and a front entrance aperture located behind the filter. Although the filter is located external to this aperture, it does not restrict or define the field-of-view. This arrangement produces a

full-field-of-view (apex at detector center) of 5°, and an annular surrounding zone of partial illumination extending out to full angle of 8°. Three baffles arranged along the telescope tube help to reduce stray light.

Spectral Resolution

PARABOLA III has eight spectral channels are at wavelengths of 444, 551, 581, 650, 860, 944, 1028, and 1650 nm. Four of these channels (444, 551, 650, and 860 nm) are similar to those of the MISR sensor.

Additional PARABOLA spectral parameters can be found in the Brugge et al. (2000) paper. PARABOLA's eight radiometers are mounted in groups of four on two zenithally rotating heads, each mounted on either end of a single azimuthally rotating bar. This means that there is an azimuthal offset of 180° between two sets (see head number in the table below) of four bands. The band characteristics and organization are as indicated below.

Band (reported order)	Center wavelength (nm)	Bandwidth (nm)	Head #
1	444.4	42.4	1
2	551.2	37.7	1
3	650.3	41.9	1
4	1028.4	121.9	1
5	580.7 (PAR)	307.2	2
6	869.7	55.2	2
7	944	32.2	2
8	1649.6	140.8	2

Temporal Resolution

PARABOLA completes each spherical scan of 2664 readings in about three minutes. As typically operated over a day of acquisition, PARABOLA repeats these scans continually from dawn until the operator shuts it down at sunset. This results in hundreds of scans of the target area as the solar illumination angle changes in zenith and azimuth. The clock in PARABOLA is set to Universal Time, and latitude and longitude are recorded in auxiliary files (although the PARABOLA was stationary at all sites in this deployment). The measured solar position, time, and instrument location can be compared to ephemeral models to determine the true instrument orientation for each day.

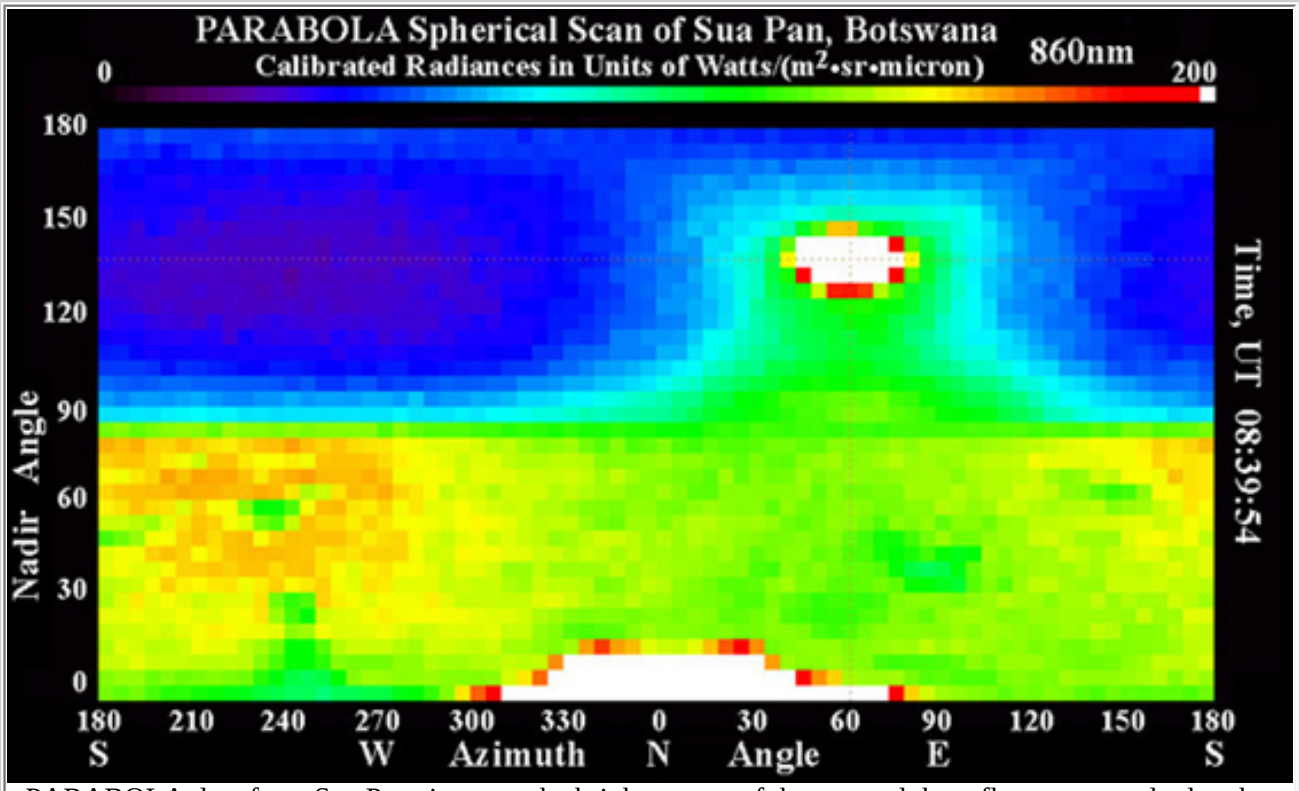
Radiance Conversion

The data can be processed to radiance using a series of second order polynomial fit coefficients and a dark current offset. The following quadratic formula can be used to convert PARABOLA DN to radiance, at about 10% accuracy:

Radiance (W m^{-2} str^{-1} μm^{-1}) = (SQRT(**B**^{2} - 4**A**·(**C**-DN)) - **B**) / 2**A**

Where **A**, **B**, and **C**, are second order polynomial fit coefficients found in the table below.

Band	A	B	C	Empirical dark current DNs
1	-0.000142	3.72	54.1	16
2	-0.0000268	4.11	4.93	0
3	-0.00041	5.05	126.68	45
4	0.00134	7.87	-3.71	0
5	-0.00002	3.37	45.13	17
6	0.000287	6.32	40.12	45
7	-0.000879	20.61	-186.52	350
8	0.0374	9.98	78.25	45



PARABOLA data from Sua Pan site, note the bright targets of the sun and the reflectance standard at the base of the sensor.

Quality Assessment

Data quality can be assessed by presenting PARABOLA data as a series of images and examining the overall appearance for counter-intuitive anomalies. The sun should rise and set along a known path as predicted by a solar ephemeris. Shadows should appear 180° in azimuth from the sun. In the blue band, the sky is often brighter than the ground. In other bands, the sky is often very dark. The standard reflectance target should appear at the bottom of the image, and the horizon line in the middle, etc.

Acknowledgments

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Additional Sources of Information

More information can be found at: http://www-misr.jpl.nasa.gov/mission/vinstrum.html

For additional details about the PARABOLA III instrument, please refer to Brugge et al. (2000).

Detailed photographs that complement the experimental descriptions for this data set are available on the S2K Photo Gallery pages.

Related Data Sets

Buermann, W. and M. Helmlinger. 2004. SAFARI 2000 LAI and FPAR Measurements at Sua Pan, Botswana, Dry Season 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.

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

Auxiliary information exists regarding instrument placement, setup, and analysis. Extensive digital photographic and digital video documentation exists of both sites and MISR Ground Truth activities. A one-hour video documentary of SAFARI 2000 has been produced for public outreach. DVD and tape formats are available upon request. Inquiries should be directed to: mark.helmlinger@jpl.nasa.gov

References

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Piketh, S. J., T. Elias, and D. C. Stein. 2004b. SAFARI 2000 JRB Aerocommander Trace Gas and Aerosol Data, Dry Season 2000. 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.

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