SAFARI 2000 Cloud Absorption Radiometer BRDF, Dry Season 2000

Abstract

The Cloud Absorption Radiometer (CAR) is an airborne multi-wavelength scanning radiometer that can perform several functions including:

- determining the single scattering albedo of clouds at selected wavelengths in the visible and near-infrared
- measuring the angular distribution of scattered radiation
- measuring bidirectional reflectance of various surface types
- acquiring imagery of cloud and Earth surface features

The CAR was designed to operate from a position mounted on various aircraft. For SAFARI 2000, it was flown in the improved nose cone on a Convair CV-580 from the University of Washington. In addition to its traditional starboard viewing mode, the CAR instrument can be operated in zenith viewing, nadir viewing, and bidirectional reflectance distribution function (BRDF) mode. The instrument can be switched between each of these four modes during flight.

Background Information

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Project: SAFARI 2000

Data Set Title: SAFARI 2000 Cloud Absorption Radiometer BRDF, Dry Season 2000

Site: Southern Africa

Data Set Citation:

King, M.D., C. Gatebe, and S. Platnick. SAFARI 2000 Cloud Absorption Radiometer BRDF, 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, USA.

Web Site: http://car.gsfc.nasa.gov/index.html [Internet Link]

Data File Information

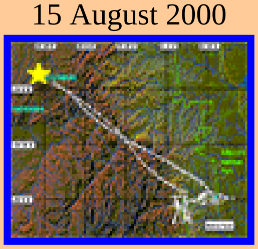
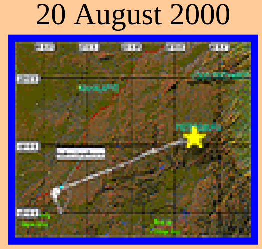
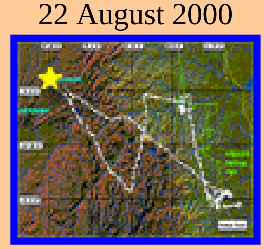
CAR BRDF data of various surfaces and of clouds were collected in southern Africa during the SAFARI-2000 Dry Season Aircraft Campaign (14 August - 16 September 2000). Data were collected over 5 different sites and include a set of cloud measurements over Namibia as well. The data have been zip compressed for each site. Within the zip archive you will find the Level 2a and Level 2c files. The Level 2a product represents top of the atmosphere reflectances on a 1 x 1 degree radial-azimuthal surface. The Level 2c data are derived from Level 2a by correcting for atmospheric absorption and scattering. The Level 2a product is derived from CAR Level 1b data, which is time-referenced instrument data at full resolution that have been corrected with radiometric coefficients and corrected for aircraft pitch and roll, and located by position on the Earth surface.

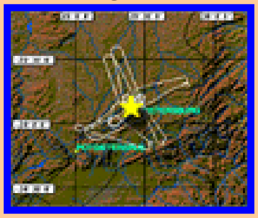
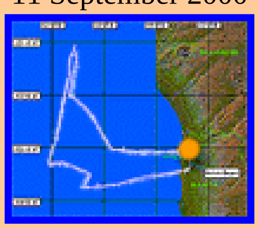
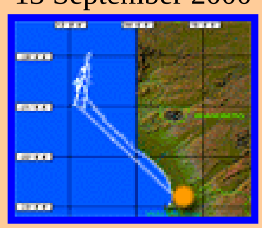
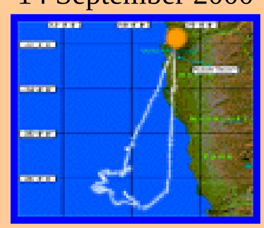
- Level 2a data files are named for the target location and date of measurements. For example, the Skukuza the file is named: skukuza_20000829_l2a.asc. In each file a header that precedes the data describes the format and includes latitude/longitude and time, followed by data for channels 1 to 8 (at 0.34, 0.38 .47, .68, .87, 1.03, 1.22, and 1.27 microns).
- Level 2c data are named and formatted differently. Each channel is a separate ASCII gridded file. The file names begin with the prefix CAR, followed by date and time of measurements, brdf, and channel number. For example, car_20000829_1350_brdf01.asc, is CAR BRDF data for channel 1 measurements taken on 29 August 2000 starting at 1350 UTC over Skukuza. Each Level 2c file contains 181 x 181 data points on an x-y grid. Because the data are in spherical coordinates (181 points along the diameter), points outside the diameter but within the x-y grid are assigned a fill value of -8421. Consequently, the central values represent nadir; and the principal plane is from mid-point left (forward scattering plane) through nadir (center) to mid-point right (backward scattering plane).

The format for these data should be considered preliminary, alternative data formats are available from Tom Arnold (arnold@climate.gsfc.nasa.gov) or Charles Gatabe (gatebe@climate.gsfc.nasa.gov), or visit the CAR web site http://car.gsfc.nasa.gov/index.html [Internet Link].

CAR Mission (Flight) Pages

Pietersburg, S.A. Kasane, Bot. Walvis Bay, Nam.

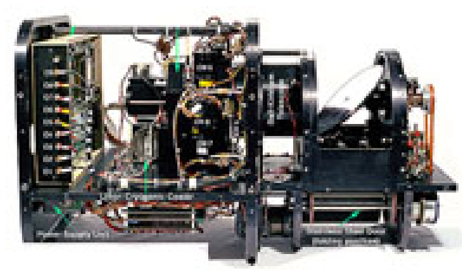
SAFARI 2000 Missions			
15 August 2000  **Flight #1814** Skukusa Tower (Bndry Layr Profile)	18 August 2000  **Flight #1816** Madikwe Reserve (Fire and Smoke)	20 August 2000  **Flight #1819** Madikwe Reserve (Fire and Smoke)	22 August 2000  **Flight #1820** Skukusa Tower (Full Profile)

22 August 2000  **Flight #1821** Pietersburg, S.A. (Aerocmndr. Comp.)	24 August 2000  **Flight #1822** Inhaca Island (Full Profile)	29 August 2000  **Flight #1824** Skukusa Tower (BRDF)	31 August 2000  **Flight #1825** Mozambq. Coast (Layer Meas.)
01 September 2000  **Flight #1826** Kasane & Kaoma (Miambo Burn)	01 September 2000  **Flight #1828** Kasane, Bot. (Transit)	02 September 2000  **Flight #1829** Maun Tower (Closure Study)	03 September 2000  **Flight #1830** Sua Pan (Pan BRDF)
05 September 2000  **Flight #1831** Kaoma, Zambia (Grass Fire)	06 September 2000  **Flight #1832** Kasane & Mongu (Vertical Profile)	06 September 2000  **Flight #1833** Kasane (Transit)	07 September 2000  **Flight #1834** Timbavati Park (Largest Fire)
10 September 2000  **Flight #1835** Walvis Bay (Transit)	11 September 2000  **Flight #1836** Namibia Coast (Marine Stratus)	13 September 2000  **Flight #1837** Namibia Coast (Marine Stratus)	14 September 2000  **Flight #1838** Namibia Coast (Cumulus)
16 September 2000  **Flight #1839** Etosha Park (BRDF)			

Pietersburg, S.A. Kasane, Bot. Walvis Bay, Nam.

Flight Track Maps by U.WASH

CAR Instrument Overview



The Cloud Absorption Radiometer measures scattered light in 14 spectral bands

The Cloud Absorption Radiometer (CAR), considered the most frequently used airborne instrument built in-house at NASA Goddard Space Flight Center, is capable of measuring scattered light by clouds in fourteen spectral bands.

The scan mirror, rotating at 100 rpm, directs the light into a Dall-Kirkham telescope where the beam is split into nine paths. Eight light beams pass through beam splitters, dichroics, and lenses to individual detectors (0.34 - 1.27 µm), and finally are registered by eight data channels. They are sampled simultaneously and continuously. The ninth beam passes through a spinning filter wheel to a Stirling cycle cooler. Signals registered by the ninth data channel are selected from among six spectral bands (1.55 - 2.30 µm). The filter wheel can either cycle through all six spectral bands at a prescribed interval (usually changing filters every fifth scan line), or lock onto any one of the six spectral bands and sample it continuously.

The CAR instrument is housed in the nose cone of the CV-580 aircraft. In this photo, CAR's stainless steel sliding door is in the closed position, protecting the scan mirror and optics assembly from dust and other foreign objects during takeoff and landing.

The electronic functions of the cloud absorption radiometer are mainly divided into three physical sections: scanner, control, and data acquisition. The analog signal is digitized internally to 16 bits at a rate of 1.2 kHz and then transmitted serially at a baud rate of 460.8 kbits per second to an external flight computer for display and storage. Also built into the data acquisition system are two reference voltages. The front-end 7.5 V reference voltage that provides temperature stable reference to translate the input voltage to be compatible with analog digital converter and a 2.5 V reference voltage for providing an external reference to the analog digital converter. The conversion from voltage to radiance is accomplished through a laboratory pre-and-post-flight calibration procedure.

The CAR scan mirror scans 360° in a plane perpendicular to the direction of flight and the data are collected through a 190° field of view. In the normal mode of operation onboard the CV-580 aircraft, the CAR views 190° of earth-atmosphere scene around the starboard horizon. This configuration permits observations of both local zenith and nadir with as much as a 5° aircraft roll. In addition to the starboard viewing mode, the CAR instrument can now be rotated in-flight into three other viewing positions: downward-looking imaging mode, upward-looking imaging mode and a dedicated BRDF viewing mode.

The instrument incorporates several novel features. Since it is sometime flown through clouds, there is the possibility that moisture may be deposited on optical surfaces, especially the scan mirror, producing large errors. The instrument is mounted outside the airplane and cannot be observed in flight. In order to check for water on the mirror, a unique detection system was devised. A thin beam of light is shone on the edge of the mirror, and the reflected beam is monitored by a photodiode. If any condensation appears on the mirror the reflected light scatters, reducing the photodiode's output and flagging data likely to be in error. Another novel feature maintains low offset (ensuring that zero volts at the output always correspond to a zero-radiance input) by using the scan mirror as a type of radiation chopper. It works by forcing the electrical output to zero during each backscan while the detectors are all completely darkened by means of a scanner-synchronized moveable shutter. Long time constant coupling in the amplifier then ensures that data measured during the active part of the scan remains accurately related to this zero reference level.

Table 1: Summaries of the characteristics of the CAR sensor, platform and scanning system.

SPECIFICATIONS	
CAR Platform	
Platform (Aircraft)	Convair CV-580 (April 1998 - Present) C-131A (May 1985 - July 1996)
Host Organization	University of Washington
Airspeed	80 m/s (nominal)
Altitude (Min, BRDF, Transit, Max)	50m, 600m, 3000m, 4200m asl
CAR Instrument	
Total Field of View	190°
Instantaneous Field of View	1°
Imaging Modes	4 (zenith, BRDF, starboard, & nadir)
Scan Rate	100 scans/minute (1.67 Hz)
Pixels Per Scan Line	382 (nominal)
Spectral Bands	14
Spectral Range	0.34 - 2.30 µm
CAR Data System	
Data Channels	9
Bits Per Channel	16 bits
Sampling Rate	137 kbps
Data Platform (OS)	Pentium III (Windows NT)

At the beginning of each mirror scan cycle, the CAR data acquisition system first records a ten byte header. It contains information such as flight number, current date, roll angle and scan line counter, etc. Following the header is the data stream from eight data channels. The figure below on the left shows a sample digital output of one complete scan from one of the CAR channels. Two sync pulses denote the start and end of an active scan segment. These pulses are distinguished by their differing time durations. Assuming zero aircraft roll and pitch angle, the CAR scan mirror should be looking at 5° before zenith direction at the first pulse and 5° past nadir at the second pulse. Also multiplexed into each channel on each scan cycle are the set of reference voltage as well as measurements from the four internal thermistors. The reference voltages range from 0.00 to 8.00 V in steps of 1.00 V and give the appearance of a staircase. This voltage staircase permits the conversion of digital counts to voltage, while the conversion from voltage to radiance is accomplished through a laboratory pre-and-post-flight calibration procedure. See http://car.gsfc.nasa.gov/instrument_detail.html [Internet Link] for more instrument information.

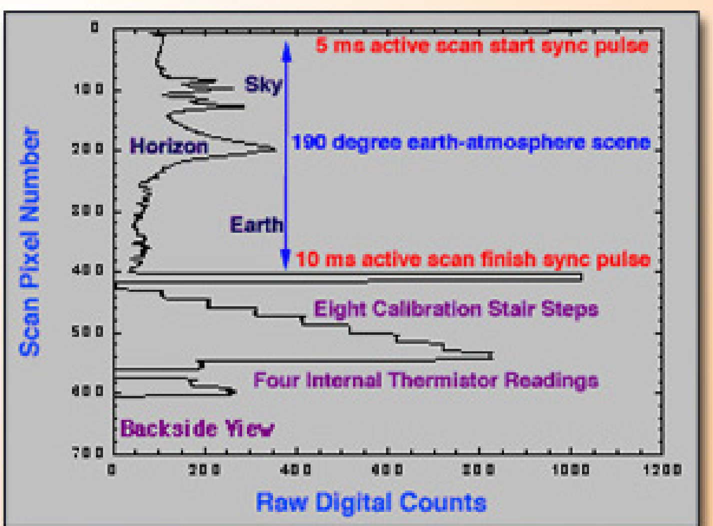
Bidirectional Reflectance Distribution Functions (BRDF)

To measure the BRDF, the aircraft assumes a closed circular flight pattern over a uniform surface of interest, collecting data in a series of circles over the area. The BRDF data for these circles is determined and then "averaged" over the number of circles.

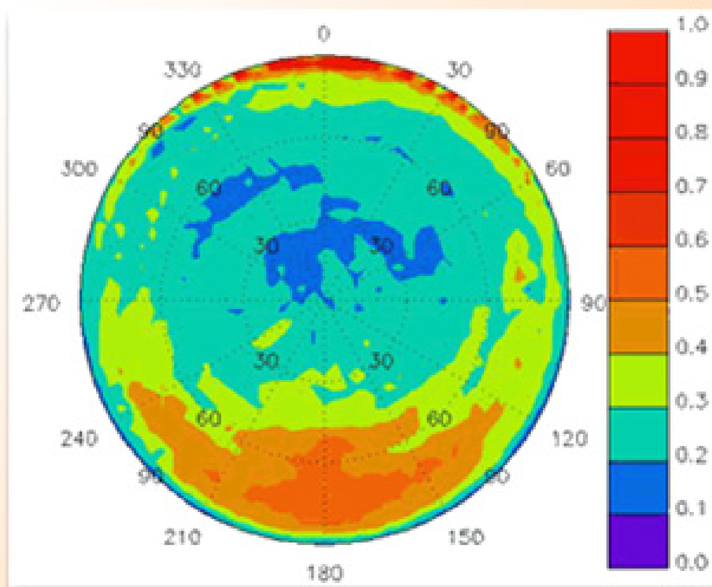
While flying these circular patterns, the pilot attempts to maintain a constant altitude near 2,000 feet, with a constant aircraft speed, and a roll angle of 20°. Unlike any ground based BRDF measuring instrument, which characterizes BRDF over an area no larger than tens of meters in diameter, CAR can survey the BRDF characteristics of a region on the order of kilometers in diameter.

The image below on the right shows BRDF pattern of a cerrado (Brazilian savanna) surface that is highly symmetrical around the principal plane and has a clear reflection in the anti-solar direction. When these measurements were made, the sun was illuminating the scene at an average solar zenith of 59°. The observed strong backscatter peak around 60° view zenith angle in the principal plane is known as the hot spot.

In this case (0.87 µm), the BRDF has a value as high as 56%. The surface anisotropy retains a similar pattern but becomes less pronounced in the visible region due to chlorophyll absorption (Tsay 1998). The plot was constructed using a data set collected on September 6, 1995, near Porto Velho, Brazil. It reveals even better symmetry around the principal plane. However the hot spot diminished due to a weak direct backscattering peak and an enhancement in multiple scattering. See http://car.gsfc.nasa.gov/application_brdf.html [Internet Link] for more information.



Sample digital output of a complete scan cycle from one of the CAR spectral channels.



Measurements of BRDF at 0.87 microns over cerrado surface (18 August 1995) Brasilia, Brazil

Additional Sources of Information

Gatebe, C. K., M. D. King, S. Platnick, G. T. Arnold, E. F. Vermote, and B. Schmid, 2003: Airborne spectral measurements of surface-atmosphere anisotropy for several surfaces and ecosystems over southern Africa.. J. Geophys. Res., 108(D13), 8489, doi: 10.1029/2002JD002397.

King, M.D., M.G. Strange, P. Leone and L.R. Blaine, 1986: Multiwavelength scanning radiometer for airborne measurements of scattered radiation within clouds. Journal of Atmospheric Oceanic Technology, 3, 513-522. [Internet Link]

Tsay, S. C., M. D. King, G. T. Arnold, and J. Y. Li, 1998: Airborne spectral measurements of surface anisotropy during SCAR-B. Journal of Geophysical Research, 103, 31943-31953.

CAR Home Page: http://car.gsfc.nasa.gov/index.html [Internet Link]

For more information about the 21 CAR missions in support of SAFARI see: http://car.gsfc.nasa.gov/data_safari2000.html [Internet Link]