# SAFARI 2000 Cloud Physics Lidar (CPL) Quicklook Images and Maps

## Abstract

The Cloud Physics Lidar is an airborne lidar system designed specifically for studying clouds and aerosols using the NASA ER-2 High Altitude Aircraft and provides a complete battery of cloud physics information. Provided with this data set are quicklook images (.gif) of the CPL data and maps of the ER-2 flightline for each data collection flight during August-September 2000. Interested users may obtain additional images and may order the CPL binary output files through the SAFARI Cloud Physics Lidar Page (http://cpl.gsfc.nasa.gov/safari2000_pass.htm/).

SAFARI was the first field deployment for the CPL. During the SAFARI campaign, the CPL provided data on cloud height and structure as well as aerosol and smoke plume structure. Quantitative optical characteristics of both clouds and smoke layers were determined. The CPL data will be used in conjunction with other airborne and ground-based instrumentation, as well as satellite data, to quantify and validate the regional emissions.

The Cloud Physics Lidar (successor to the Cloud Lidar System) is an airborne lidar system designed specifically for studying clouds and aerosols using the NASA ER-2 High Altitude Aircraft. Because the ER-2 typically flies at an altitude of 65,000 feet (20 km), its instruments are above 94% of the Earth's atmosphere, thereby allowing ER-2 instruments to function as spaceborne instrument simulators. The Cloud Physics Lidar provides a unique tool for atmospheric profiling and is sufficiently small and low cost to include in multiple instrument missions.

The Cloud Physics Lidar provides a complete battery of cloud physics information. Data products include:

- Cloud profiling with 30 m vertical and 200 m horizontal resolution at 1064 nm, 532 nm, and 355 nm;
- Aerosol, boundary layer, and smoke plume profiling;
- Optical depth estimates (column and by layer); and
- Extinction profiles.

The CPL provides information to permit a comprehensive analysis of radiative and optical properties of optically thin clouds. To determine the effects of particulate layers on the radiative budget of the earth-atmosphere system certain information about the details of the layer and its constituents is required. The effect of clouds is often referred to as cloud radiative forcing. Cloud radiative forcing, in general, is the alteration that the presence of clouds has on the energy budget. The information required to compute the radiative forcing includes the vertical distribution of short wave cross section, a parameter that the CPL provides up to the limits of optical signal attenuation.

Using optical depth measurements determined from attenuation of Rayleigh and aerosol scattering, and using the integrated backscatter, the extinction-to-backscatter parameter can be derived. This permits rapid analysis of cloud optical depth since only lidar data is required; there is no need to use other instrumentation. Using the derived extinction-to-backscatter ratio, the internal cloud extinction profile can then be obtained.

The CPL uses photon-counting detectors with a high repetition rate laser to maintain a large signal dynamic range. This dramatically reduces the time required to produce reliable and complete data sets.

ORNL DAAC has archived CPL quicklook data samples from the SAFARI 2000 Field Campaign. The samples were provided by the CPL group at the NASA Goddard Space Flight Center (GSFC). The actual CPL data are stored at the CPL Web Site at NASA GSFC and can be accessed at [http://virl.gsfc.nasa.gov/cpl/safari2000_pass.htm]. Data users are asked to read and abide by the CPL Data Usage Policy. For systems specifications and other information regarding Cloud Physics Lidar, please visit the Cloud Physics Lidar Web Site.

## Background Information

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**Site:** Southern Africa

**Data Set Citation:**

McGill, M. J., D. L. Hlavka, and W. D. Hart. 2004. SAFARI 2000 Cloud Physics Lidar (CPL) Quicklook Images and Maps. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

**Web Site:** http://cpl.gsfc.nasa.gov/

## Data File Information

The data files archived at ORNL DAAC are simple "quicklook" files (in GIF format), one sample CPL output image of the atmosphere and one flightline map per flight.

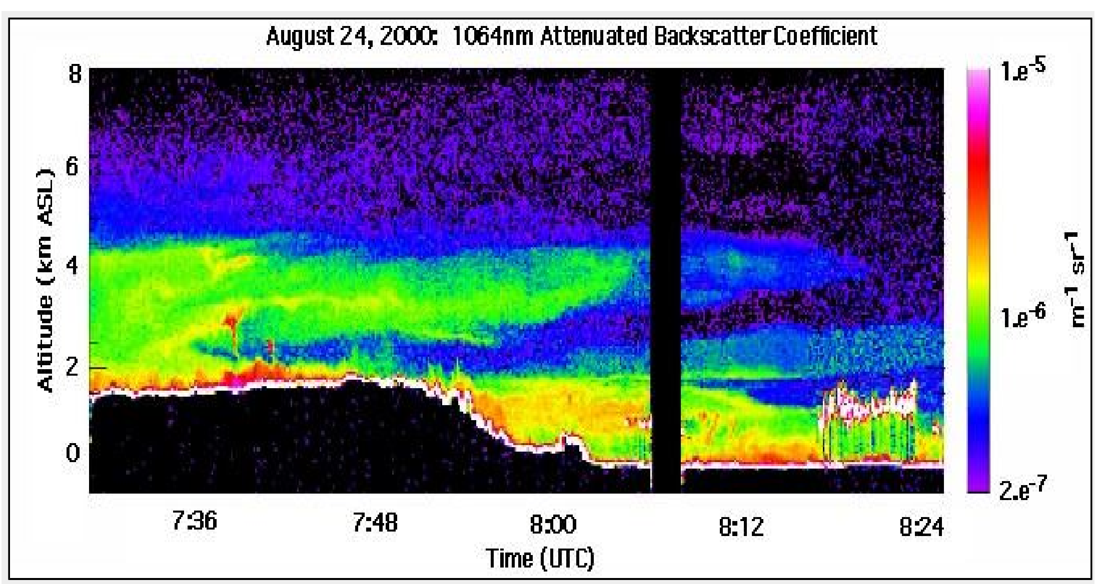
The actual Cloud Physics Lidar data are stored on the CPL Web Site at NASA GSFC. To access this CPL data, please visit the Cloud Physics Lidar Web Site and click on the "SAFARI 2000" link on the left. This will give you access to the CPL data.

The CPL data at the CPL Web Site is organized by flight day. Data products are available for each flight day on separate pages, accessed by clicking on the appropriate calendar date. On each data page users can find the following data that is available for downloading and use:

- flightline map (map);
- summary atmosphere image of the entire flight (imgsum);
- atmosphere images broken into higher-resolution 30-minute segments (imgseg);
- images showing cirrus cloud optical depth (CIOD), boundary layer optical depth (PBLOD), total cloud optical depth (COD), total aerosol optical depth (AOD), and total column optical depth (TOD);
- images showing extinction profiles, in 30-minute segments (EXTSEG);
- text file containing cloud and layer boundaries at 1-second intervals (layers);
- text file containing optical depth and extinction-to-backscatter ratio for cirrus and boundary layer regions (CIPBL).

In addition, on each data page on the CPL Web Site at NASA GSFC there is a request form for the large binary output files. These files do not reside on the CPL web server due to size (typically ~500 MB) but are available to users. To obtain these files, click on the "request data product" button at the very bottom of each page and an email will be sent to the CPL team. You will then be contacted to arrange for ftp transfer of the files.

An example of the fundamental CPL data product is shown in Figure 1 below. This image is typical of CPL data, showing high resolution structure of the cloud and aerosol features. Such images are useful in identifying atmospheric features, identifying presence or absence of clouds, and examining internal structure of features. From this basic data product higher level data products can be derived, including cloud/aerosol boundaries, optical depth, and extinction profiles.



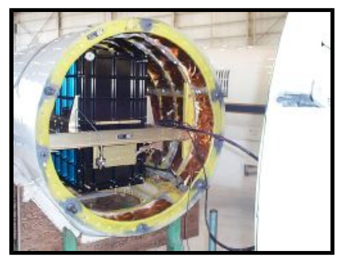
Note: Figure 1 image of CPL attenuated backscatter coefficient from a 1-hour segment on August 24, 2000 shows boundary layer smoke/aerosol moving off the Highveld region (left side of image) out over Inhaca Island and the Indian Ocean (right side of image). Temperature inversion at 2 km inhibits mixing of the airmasses, producing the characteristic "clean slot" often observed in the Southern Africa area. The white signatures are at the far right side of the image are low-level clouds over the Indian Ocean.

## Cloud Physics Lidar (CPL) Instrument Overview

The Cloud Physics Lidar (successor to the Cloud Lidar System] is an airborne lidar system designed specifically for studying clouds and aerosols using the NASA ER-2 High Altitude Aircraft. Because the ER-2 typically flies at 65,000 feet (20 km), its instruments are above 94% of the earth's atmosphere, thereby allowing ER-2 instruments to function as spaceborne instrument simulators. The CPL flies on the ER-2 along with other instruments and is typically located in the forward section of the left wing superpod. A window in the bottom of the superpod allows the instrument to look directly at nadir (this is a non-scanning system).

NASA's ER-2 in descent. Note the wing superpods.

The CPL instrument housed in the left wing superpod.



Closeup inside the superpod, looking at the CPL instrument.

In recent years, there have been significant advances in the approach to lidar design. A now-proven approach to lidar design is to use a high PRF laser, multiple kHz rather than 10's of Hz, at low pulse energies. Ground-based systems of this type, the Micro Pulse Lidar, have been in use since the early 1990's. The advantages of the high PRF design are the potential of eye safety from low pulse energies, a much more compact size, greater reliability, and turnkey ease of use. A basic requirement of the high PRF approach is a very narrow FOV (along with narrowband filtering) to minimize solar background noise. The FOV is small enough to essentially eliminate multiple scattered signals. The data acquisition is simple photon counting using PC-104 architecture and the high PRF and pulse averaging results in wide dynamic range.

The overall instrument design is driven by the desire to use photon-counting detection. The system transmits three wavelengths (1064, 532, and 355 nm) simultaneously and collinear. Return signal collected by the telescope is separated by use of dichroics. The 1064 nm return is further separated into polarization components.

The 1064 nm detectors are EG&G single photon counting modules (SPCMs). These detectors have approximately 3% quantum efficiency and low thermal noise. The 532 nm channel also utilizes EG&G SPCMs, and the quantum efficiency is approximately 60%. The 355 nm channel uses a photomultiplier tube to allow for high quantum efficiency and larger dynamic range for the enhanced Rayleigh signal. Outputs from the detectors are counted by special multi-channel range-gating cards made by ASRC Aerospace Corporation.

The optical breadboard is housed in a sealed box to maintain a clean, stable, and dry environment. For vibration isolation, the breadboard mounts to the box via a three-point kinematic mounting system. The mechanical and structural design for the CPL was performed by Sigma Research and Engineering.

## System Parameters

| Parameter | Value |
|---|---|
| Wavelengths | 1064, 532, and 355 nm |
| Laser type | solid-state Nd:YVO4 |
| Laser repetition rate | 5 kHz |
| Laser output energy | 50 uJ at 1064 nm<br>25 uJ at 532 nm<br>50 uJ at 355 nm |
| Telescope diameter | 8 inches |
| Telescope type | off-axis parabola |
| Telescope field of view | 100 microradians |
| Filter bandwidth | 400 pm at 1064 nm<br>120 pm at 532 nm<br>150 pm at 355 nm |
| Detector efficiency | 3% at 1064 nm<br>60% at 532 nm<br>10 % at 355 nm |
| Raw data resolution | 1/10 second<br>(30 m vertical by 20 m horizontal) |
| Processed data resolution | 1 second<br>(30 m vertical by 200 m horizontal) |

## Additional Sources of Information

### CPL Specific Publications

McGill, M. J., D. L. Hlavka, W. D. Hart, E. J. Welton, and J. R. Campbell. 2003. Airborne lidar measurements of aerosol optical properties during SAFARI-2000. Journal of Geophysical Research, 108, doi:10.1029/2002JD002370. (download PDF file)

McGill, M. J., D. L. Hlavka, W. D. Hart, J. D. Spinhirne, V. S. Scott, and B. Schmid. 2002. The Cloud Physics Lidar: Instrument description and initial measurement results. Applied Optics, 41:3725-3734, June 2002. (download PDF file)

**CPL-Related Publications**

Schmid, B., J. Redemann, P. B. Russell, P. V. Hobbs, D. L. Hlavka, M. J. McGill, W. D. Hart, B. N. Holben, E. J. Welton, J. Campbell, O. Torres, R. Kahn, D. Diner, M. Helmlinger, D. A. Chu, C. Robles-Gonzalez,, and G. de Leeuw. 2003. Coordinated airborne, spaceborne, and ground-based measurements of massive, thick aerosol layers during the dry season in Southern Africa. Journal of Geophysical Research, 108 (D13), 8496, doi:10.1029/2002JD002297.

**Selected Abstracts**

Hlavka, D. L., M. J. McGill, W. D. Hart, and J. D. Spinhirne. 2002. Cloud Physics Lidar optical measurements during the SAFARI-2000 field campaign. IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (Toronto, Canada), June 24-28, 2002.

McGill, M. J., D. L. Hlavka, W. D. Hart, J. D. Spinhirne, and V. S. Scott. 2001. Cloud Physics Lidar measurements during the SAFARI-2000 field campaign. American Geophysics Union (AGU) Fall Meeting (San Francisco, CA), December 2001.

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