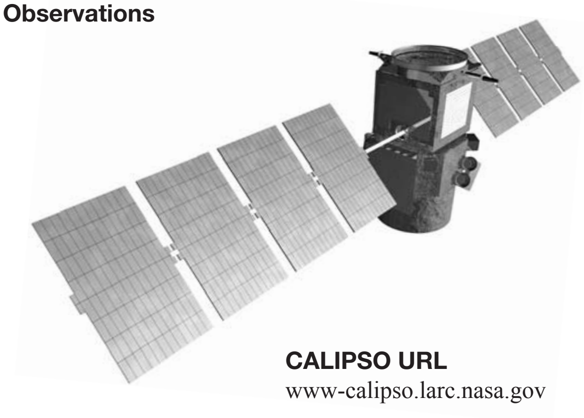
CALIPSO

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations



CALIPSO URL
www-calipso.larc.nasa.gov

Summary

CALIPSO is a joint U.S. (NASA)/French (Centre National d'Etudes Spatiales/CNES) mission. Observations from spaceborne lidar, combined with passive imagery, will lead to improved understanding of the role aerosols and clouds play in regulating the Earth's climate, in particular, how aerosols and clouds interact with one another.

Key CALIPSO Facts

Joint with France

Spacecraft: PROTEUS

Orbit:
- Type: Sun-synchronous
- Altitude: 705 km
- Inclination: 98.2°
- Period: 99 minutes
- Repeat Cycle: 16 days

Dimensions: 1.49 m × 1.84 m × 2.31 m

Mass: 600 kg

Power: 562 W

Design Life: 3 years

Average Data Rate: 34 Gb/day

Downlink: S-band@600 kbps, Kiruna; X-band@20 Mbps, North Pole, Alaska

Platform Pointing Requirements (3σ):
- Control: 0.05°
- Knowledge: 0.04°

Design Life: 3 years.

Contributors: CNES, Alcatel

Instruments

- Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)
- Imaging Infrared Radiometer (IIR)
- Wide-Field Camera (WFC)

Points of Contact

- *Principal Investigator:* Dave Winker, NASA Langley Research Center
- *French Co-Principal Investigator:* Jacques Pelon, l'Institut Pierre Simon Laplace
- *U.S. Co-Principal Investigator:* Pat McCormick, Hampton University

Other Key Personnel

- *Program Scientist:* Donald Anderson, NASA Headquarters
- *Program Executive:* Steve Volz, NASA Headquarters
- *Mission Manager:* Bryant Cramer, NASA Goddard Space Flight Center
- *Project Manager:* Dale Schulz, NASA Goddard Space Flight Center

Mission Type

Earth Observing System (EOS) Exploratory Mission (Earth System Science Pathfinder)

Launch

- *Date and Location:* April 28, 2006 (shared launch with CloudSat), from Vandenberg Air Force Base, California
- *Vehicle:* Delta II rocket

Relevant Science Focus Areas

(see NASA's Earth Science Program section)

- Atmospheric Composition
- Climate Variability and Change
- Water and the Energy Cycles
- Weather

Related Applications

(see Applied Sciences Program section)

- Air Quality
- Aviation
- Homeland Security
- Public Health

CALIPSO Mission Background

Aerosols affect the Earth's radiation budget through the scattering and absorption of incoming sunlight, which acts as a significant radiative forcing. Aerosols are also intimately linked to the formation of clouds and to precipitation processes and thus to the hydrologic cycle. It now appears likely that aerosols resulting from human activities such as the use of fossil fuels and agricultural burning are affecting global climate. Aerosols also affect public health in heavily polluted regions. Unlike greenhouse gases, tropospheric aerosols are highly variable in space and time due to variable sources and short atmospheric residence times. Because of this variability and the difficulty of monitoring aerosols using satellite instruments, basic questions remain on the global distribution and properties of aerosols. Model estimates of the radiative forcing from aerosols are still uncertain, and improved capabilities to observe aerosols from space are required to constrain key assumptions in these models.

The sensitivity of the climate response to radiative forcings from aerosols, greenhouse gases, and other sources is largely controlled by the interactions between clouds and radiation. Advances in modeling capabilities to predict climate change require improved representations of cloud processes in models and decreased uncertainties in parameterizations of cloud-radiation interactions. In particular, the largest sources of uncertainty in estimating longwave radiative fluxes at the Earth's surface and within the atmosphere are connected with current difficulties in determining the vertical distribution and overlap of multi-layer clouds and the ice-water path of these clouds. The CALIPSO mission will provide unique profile measurements to improve our understanding of the role of aerosols and clouds in the Earth's climate system. CALIPSO will enhance current capabilities by providing: global, vertically-resolved measurements of aerosol and cloud distributions; height-resolved discrimination of aerosols into several types; and observations of aerosols over bright and heterogeneous surfaces both day and night. CALIPSO will also provide vertically-resolved identification of cloud ice/water phase and, together with the cloud profiling radar on CloudSat, will provide comprehensive observations of cloud vertical structure on a global scale. CALIPSO will fly as part of the A-Train of satellites including four other NASA missions—Aqua, Aura, CloudSat, and Orbiting Carbon Observatory (OCO)—as well as a CNES mission called Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL). This combination of observations offers an unprecedented resource for exploring aerosol-chemistry-cloud interactions.

The CALIPSO payload consists of three nadir-viewing instruments: the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP–pronounced 'caliope') and two passive instruments, the Imaging Infrared Radiometer (IIR) and the Wide-Field Camera (WFC).

Key CALIOP Facts

Heritage: Lidar In-space Technology Experiment (LITE), military laser rangefinders

Instrument Type: Nadir-pointing dual-wavelength polarization lidar

Wavelengths: 532 nm (polarization-sensitive) and 1064 nm

Science Operations Mode:
Pulse Rate: 20 Hz
Vertical sampling: 30 m, 0–40 km
Footprint spacing: 333 m along-track
Duty Cycle: 100%

Repeat Cycle: 16 days

Dimensions: 1 m × 1.49 m × 1.31 m
Sensor Unit: 1 m (dia) × 1.31 m
Control Unit: 30 cm × 30 cm × 25 cm

Technical Resource Allocations:
Mass: 156 kg
Power: 207 W
Data Rate: 332 kbps

Performance:
Pulse Power: 110 mJ
Pulse Length: 20 ns
Footprint Diameter: 70 m
Calibration: 5% (532 nm)
Linear Dynamic Range: 4×10^6 : 1

Thermal Control: Provided by heaters and passive radiators

Contributor: Ball Aerospace & Technologies Corp.

Key IIR Facts

Heritage: IASI Infrared Sensor Module

Instrument Type: Imaging spectroradiometer

Scan Type: Earth imaging, nadir pointing

Calibration: Onboard black body source, deep space view

Field of View (FOV): 64 km

Instrument IFOV: 1 km

Transmission Rate: N/A

Swath: 64 km

Spatial Resolution: 1 km, 64 × 64 pixels

Spectral Range: 3 channels centered at 8.65, 10.6, and 12.05 µm

Dimensions: 490 mm × 550 mm × 320 mm

CALIOP

Cloud-Aerosol Lidar with Orthogonal Polarization

Two-wavelength, polarization lidar capable of providing aerosol and cloud profiles and properties.

CALIOP provides information on the vertical distribution of aerosols and clouds and their optical and physical properties. CALIOP will improve not only our understanding of aerosols and clouds, but also our understanding of aerosol-cloud interactions. CALIOP is built around a diode-pumped Nd:YAG laser producing linearly-polarized pulses of light at 1064 nm and 532 nm. The atmospheric return is collected by a 1-m telescope, which feeds a three-channel receiver measuring the backscattered intensity at 1064 nm and the two orthogonal polarization components at 532 nm (parallel and perpendicular to the polarization plane of the transmitted beam). Two-wavelength polarization measurements provide information on aerosol size and hydration. Lidar polarization measurements also allow discrimination of cloud ice/water phase. Data from CALIOP will be combined with data from the other CALIPSO instruments (IIR and WFC), to retrieve cirrus emissivity and particle size. Information on radiative fluxes will be provided by combining CALIOP profile measurements with TOA fluxes from CERES and multi-spectral observations from Aqua's MODIS. CALIOP and the Cloud Profiling Radar on CloudSat have complementary cloud sensing capabilities that allow the production of a comprehensive combined cloud profile product.

IIR

Imaging Infrared Radiometer

Three-channel infrared imager that complements CALIOP and provides additional cloud properties.

The IIR provides calibrated radiances at 8.65, 10.6, and 12.05 µm over a 64 km swath centered on the lidar footprint. These wavelengths are chosen to optimize combined lidar/IIR/WFC retrievals of cirrus emissivity and particle size. The IIR is built around an Infrared Sensor Module developed for the IASI instrument. Use of a microbolometer-detector array in a non-scanning, staring configuration allows a simple and compact design to perform measurements at a 1-km resolution with a NEΔT better than 0.3 K (at 210 K) in all spectral bands. The IIR instrument is provided by CNES with algorithm development performed by the Institute Pierre Simon Laplace (Paris).

WFC

Wide-Field Camera

Single-channel, nadir-viewing, push-broom, visible imager that, when combined with IIR data, provides meteorological context around the lidar footprint.

The WFC is a modified star tracker camera, with a single channel covering the 620–670-nm spectral region, providing images of a 61-km swath with a spatial resolution of 125 m. The WFC provides meteorological context for the lidar measurements and allows highly accurate

Key IIR Facts *(cont.)*

Mass: 21 kg

Power: 26.6 W

Duty Cycle: 8.184 s

Data Rate: 48.2 kbps

Contributors: CNES, SODERN (Paris)

Key WFC Facts

Heritage: Star tracker cameras

Radiometric Response Stability: < 1% over 24 hours

Duty Cycle: 39% (Daylight portions of orbit with solar zenith angle (SZA) < 70°)

Data Rate: 16.1 kbps

FOV: 61-km cross-track × 125-m along-track

Incidence Angle: Nadir

Instrument IFOV: 125 m × 125 m

Dimensions: 14 cm diameter × 24 cm sensor unit

Mass: 2.6 kg

Power: 7.9 W

Thermal Control: TEC and passive radiator

Thermal Operating Range: CCD operates at 0° C

Sampling Interval: 18.5 ms

Spatial Resolution:

- Central high-resolution swath (within 2.5 km of lidar footprint): 125 m × 125 m
- Low-resolution swath (28 km either side of high res. swath): 1 km × 1 km

Wavelength: 645 nm

Spectral Resolution: 50 nm

Contributor: BATC

spatial registration, when required, between CALIPSO and instruments on other satellites of the A-Train afternoon constellation. WFC data are also used in daytime retrievals of cloud properties.

CALIPSO References

Winker, D. M., J. Pelon, and M. P. McCormick, 2002: The CALIPSO Mission: Spaceborne lidar for observation of aerosols and clouds. *Proc. SPIE*, **4893**, 1–11.

Winker, D. M., W. H. Hunt, and C. A. Hostetler, 2004: Status and performance of the CALIOP Lidar. *Proc. SPIE*, **5575**, 8–15.

CALIPSO Data Products

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
CALIOP			
Attenuated Backscatter Profiles	1B	Global, for altitudes of -0.5–40 km	-0.5–8.2 km altitudes: 0.33 km horizontal resolution (hres), 30 m vertical resolution (vres); 8.2–20.2 km altitudes: 1.00 km hres, 60 m vres; 20.2–30.1 km altitudes: 1.67 km hres, 180 m vres; 30.1–40 km altitudes: 5 km hres, 300 m vres/ every 16 days
Aerosol Layer Heights	2	Global	0–30.1 km altitudes: 5 km hres; 30–180 m vres/ every 16 days
Aerosol Backscatter Profiles	2	Global, 0–30.1 km	0–20.2 km altitudes: 40 km hres, 120 m vres; 20.2–30.1 km altitudes: 40 km hres, 360 m vres/ every 16 days
Aerosol Extinction Profiles	2	Global, 0–30.1 km	0–20.2 km altitudes: 40 km hres, 120 m vres; 20.2–30.1 km altitudes: 40 km hres, 360 m vres/ every 16 days
Cloud Top and Base Heights	2	Global, 0–20.2 km	0.33 km hres, 1 km hres, and 5 km hres; 30–60 m vres/every 16 days
Cloud Extinction Profiles	2	Global, 0–20.2 km	5 km hres, 60 m vres/ every 16 days
Cloud Ice / Water Phase	2	Global, 0–20.2 km	1 km hres, 30-60 m vres/ every 16 days
IIR			
Infrared Radiances	1B	Global	1 km hres/every 16 days
WFC			
Visible Reflectances	1B	Global	0.125 km hres and 1 km hres/ every 16 days
CALIOP/IIR/WFC			
Cloud Emissivity	2	Global	1 km hres/every 16 days
Cloud Particle Size	2	Global	1 km hres/every 16 days
Surface Radiative Fluxes (with CERES from Aqua)	4	Global	30 km hres/every 16 days
Atmospheric Radiative Flux Profiles (with CERES from Aqua)	4	Global, TOA to surface	30 km hres; 18 vertical levels/every 16 days

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