Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Quid Pro Quo Validation

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Introduction

The Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission, a collaboration between the National Aeronautics and Space Administration (NASA) Langley Research Center, the French Centre National d'Etudes Spatiales, Hampton University, the Institut Pierre Simon Laplace, and the Ball Aerospace and Technologies Corporation, is scheduled to launch in the spring of 2004. The goal of CALIPSO is to increase our understanding of the radiative effects of aerosols and clouds, which are presently the largest uncertainties in our ability to predict future climate change. Figure 1 shows a schematic of the CALIPSO satellite and Table 1 shows CALIPSO instrument characteristics. CALIPSO includes a two-channel (532 and 1064 nm) polarization-sensitive lidar, an Imaging Infrared Radiometer measuring radiances at 8.7, 10.6, and 12.0 μm, and a wide-field camera. Important to the CALIPSO validation program are the quid pro quo activities in cooperation with existing measurement sites. These sites will provide data relevant to CALIPSO validation at times when the ground-track of the CALIPSO satellite is within a specified coincident distance, or the air masses are shown to be similar. Exchange of data between CALIPSO and these sites will occur freely and follow appropriate protocols of exchange.

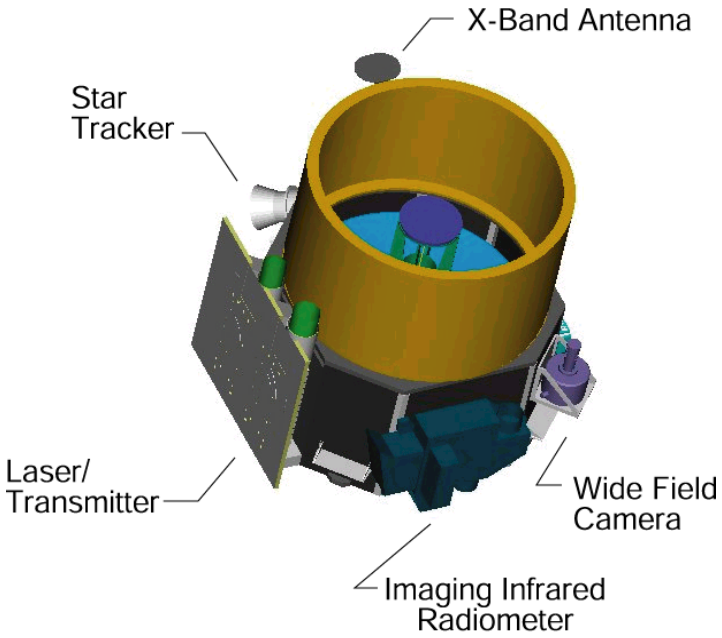

Figure 1. Schematic drawing of the CALIPSO satellite instrumentation.

Table 1. Characteristics of the CALIPSO lidar, infrared imager, and wide-field camera.

Lidar	
Laser	2 ND: YAG @ 110 mJ
Wavelength	532 nm, 1064 nm
Repetition Rate	20.16 Hz
Receiver telescope	1.0 m diameter
Polarization	532 $\parallel$ and $\perp$
Wide Field Camera	
Wavelength	645 nm
Spectral Width	50 nm
IFOV	125 m
Swath	60 km
Imaging Infrared Radiometer	
Wavelength	8.7, 10.6, 12.0 μm
Spectral Resolution	0.8 μm
IFOV	1 km
Swath	64 km

Strategy

Validation of CALIPSO data assesses the agreement between a CALIPSO satellite measurement and a quid pro quo validation site measurement. Agreement shall occur when the error bars between measurements overlap. This agreement can occur either through direct comparison of two measurements or through a comparison of probability distribution functions (PDFs). Direct comparison requires that the correlative measurements by a site occur in similar atmospheric conditions as observed by the CALIPSO satellite. Therefore, for each CALISPO data product or assumption, a maximum separation in time and space between a site's measurement and the CALIPSO measurement will be defined. Any measurement made within this maximum separation in time and space is considered a coincident measurement. An alternative criterion is for an investigator to show, by trajectory analysis, that the validation site and the CALIPSO satellite are sampling the same aerosol or cloud mass. During any direct comparison, the different sampling volumes between the lidar and the ground sites must be addressed by comparing spatial averages from the lidar with temporal averages from the ground sites. Statistical comparisons can be made with either regional or zonal CALIPSO statistics, but should consist of large ensembles of data.

Table 2 lists all the variables measured or assumed in the calculation of each CALIPSO data product. Cloud and aerosol data products have different spatial and temporal statistics that require different validation strategies. In general, aerosol data products have a larger horizontal spatial correlation than cloud data products and, therefore, can be validated by a more direct comparison between individual CALIPSO and ground site measurements. An exception to this rule occurs for polar stratospheric clouds (PSCs), which have coincident distances much larger than tropospheric clouds. The number of coincidences is larger with the increase in spatial correlation.

Figure 2 shows a map of North America and the ground-track for the 16-day repeating orbit of CALIPSO. Also plotted are high and middle latitude stations along with circles indicating 80 and 160 km distances. The number of coincident observations during 16 days of orbits for each validation site generally increases with latitude. However, for validation to be effective, validation of aerosol and cloud parameters should be globally distributed to allow validation of these parameters for a variety of aerosol and cloud types.

Sites are selected based on a number of criteria including the number of data products validated, the number of coincident measurements, measurement and calibration history of the instruments, the prospects for making measurements during the CALIPSO mission duration, and location. Further consideration will be given to sites if they satisfy a measurement need or are located in a unique place or climate.

Several instrument networks have been identified by the *quid pro quo* validation team as potentially suitable for the validation of CALIPSO data products. These networks include: the AErosol RObotic NETwork (AERONET), Asian Dust NETwork (AD-NET), Atmospheric Radiation Measurement (ARM) program, Baseline Surface Radiation Network (BSRN), Climate Monitoring and Diagnostics Laboratory (CMDL), European Aerosol Research LIdar NETwork (EARLINET), Network for the Detection of Stratospheric Change (NDSC), Surface Radiation (SurfRad) budget network, Atmospheric Science and Research Center (ASRC) at the State University of New York at Albany, U.S. Department

Table 2. Aerosol, cloud, and radiation measurements made by CALIPSO.

Data Products	Measurements and Assumptions
Aerosols	
Height and thickness	Attenuated backscatter at 532 nm
Optical depth	Attenuated backscatter at 532 nm and 1064 nm Extinction-to-backscatter ratio at 532 and 1064 nm
Extinction profile	Attenuated backscatter at 532 nm and 1064 nm Extinction-to-backscatter ratio at 532 and 1064 nm
Clouds	
Height and thickness	Attenuated backscatter at 532 nm
Optical depth	Attenuated backscatter at 532 nm and 1064 nm Extinction-to-backscatter ratio at 532 and 1064 nm
Extinction profile	Attenuated backscatter at 532 nm and 1064 nm Extinction-to-backscatter ratio at 532 and 1064 nm
Ice/water phase	Depolarization ratio
Radiation	
Emissivity	Upward radiance at 8.7, 10.6 and 12 μm
Ice particle size	Upward radiance at 8.7, 10.6 and 12 μm

of Agriculture (USDA) multi-filter rotating shadowband radiometer (MFRSR) network, and World Ozone and Ultraviolet Data Center (WOUDC). These networks are considered because of their measurements from instruments suitable for CALIPSO validation including: lidars, cloud radars, sunphotometers, MFRSRs, infrared radiometers, backscattersondes, nephelometers, and absorption photometers. Other networks and individual stations will be considered when they are identified. All of these networks will be further assessed to determine the best available sites for validation.

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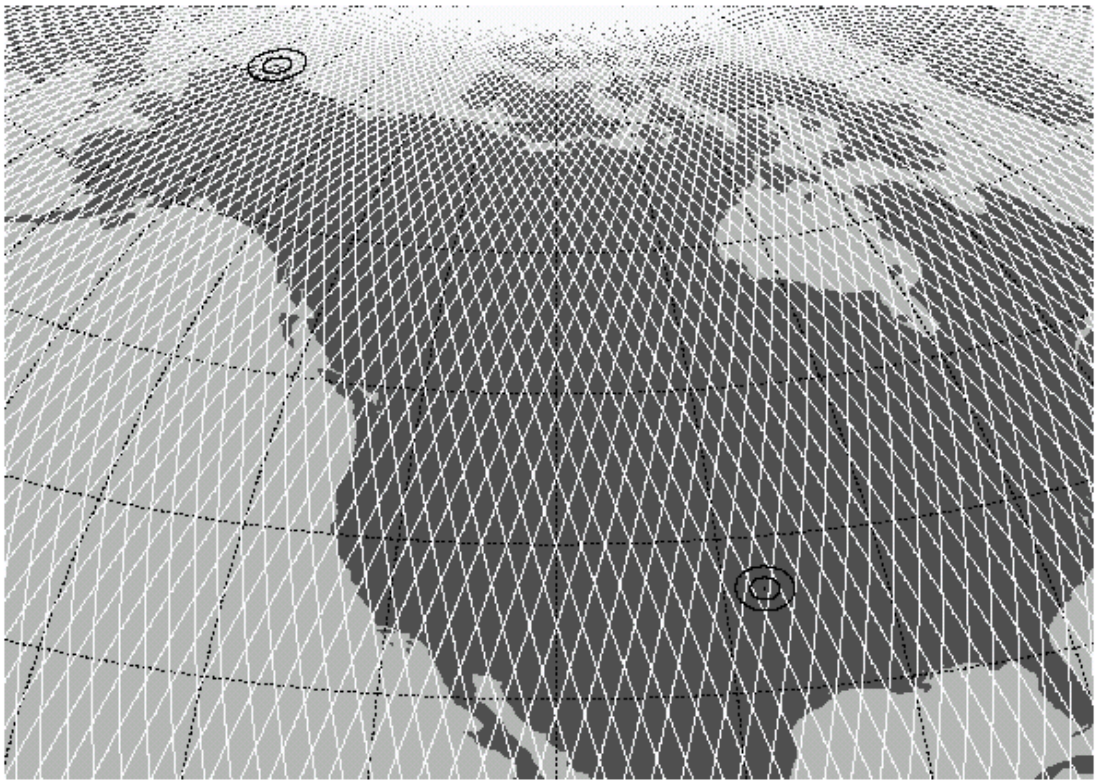

Figure 2. CALIPSO 16-day repeating orbit ground tracks with circles around sites indicating 80 and 160 km distances.