COORDINATION OF QUID PRO QUO GROUND-BASED MEASUREMENTS OF CLOUD AND AEROSOL OPTICAL PROPERTIES FOR VALIDATION OF THE CALIPSO MISSION

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1. INTRODUCTION

The Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission is a collaboration between 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. CALIPSO is scheduled to launch in the spring of 2005. 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. Fig. 1 shows a schematic of the CALIPSO satellite payload and Table 1 shows the instrument characteristics. CALIPSO includes a two wavelength (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.

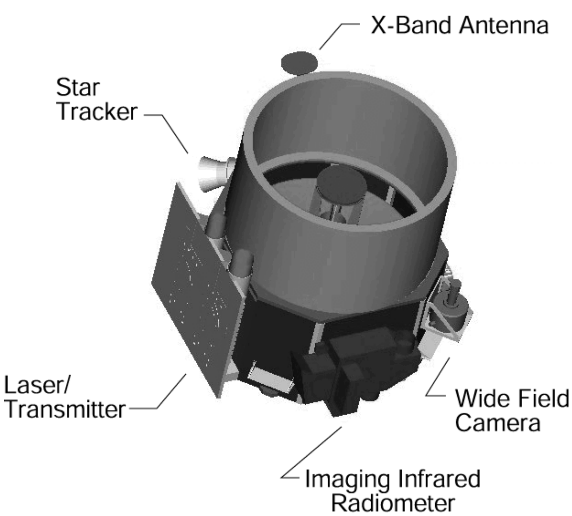

Fig. 1. Schematic drawing of the CALIPSO satellite instrumentation

Important to the CALIPSO validation program are the Q*uid Pro Quo* (*QPQ*) 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. The *QPQ* or free exchange of data between CALIPSO and these sites will follow appropriate protocols of exchange.

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 ∥ and ⊥
Ground foot print	70 m

Wide Field Camera

Wavelength	645 nm
Spectral Width	50 nm
IFOV	125 m
Swath	60 km

Imaging Infrared Radiometer

Wavelength (spectral resolution)	8.65 (0.9) μm , 10.60 (0.6) μm, 12.05 (1.0) μm
IFOV	1 km
Swath	64 km

2. STRATEGY

To a considerable degree, data products from the CALIPSO satellite mission will be validated through comparisons with correlative in situ and remote sensing measurements. Assessment of the relative agreement between data sets can occur either through a direct comparison of two or more measurements or, through a comparison of probability distribution functions (PDFs). Direct comparison implies that the correlative measurements view the same atmospheric features (e.g., same cloud or aerosol layers) as observed by all instruments. In the best of circumstances, the instruments would share the same field of view and occur simultaneously. For ground-based systems, matching measurements with satellite observations can be exceedingly difficult because of the brief window of opportunity during a satellite overpass, and especially for spaceborne lidars or radars, with a very narrow field of view. Fortunately, aerosol air masses can have correlation scales of 50-100 km and several hours or more. For clouds, the length scales can be significantly smaller (a few kilometers to tens of kilometers) and lifetimes as short as a few minutes. These length and time scales, thus, provide guidelines on matching requirements needed between sensor systems for aerosol and cloud features. Trajectory analysis may also be employed to improve matching conditions for observations that have large spatial and temporal separations.

An alternative approach to direct comparisons is to consider an ensemble of observations collected over a long period or a variety of conditions. This approach is especially appealing for geophysical phenomena that have very restrictive matching requirements such as for cumulus clouds.

Table 2 lists the primary Level 2 data products that will be produced by the CALIPSO satellite mission. Details on these products are provided in the Lidar and Infrared Imaging Radiometer Algorithm Theoretical Basis Documents (ATBDs). The table also provides information on the expected uncertainty and the horizontal and vertical resolution of the products. Correlative measurements of comparable or superior accuracy and resolution should be acquired to validate these CALIPSO data products.

Fig. 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.

Table 2. CALIPSO Level 2 Aerosol and Cloud Measurements

Data Product	Measurement Capabilities and Uncertainties	Data Product Resolution	
		Horizontal	Vertical
Aerosols			
Height, thickness	For layers with $\beta > 2.5 \times 10^{-4}$ km^{-1} sr^{-1}	5km	60 m
Optical depth, τ	40% *	5 km	N/A
Backscatter, $\beta_a(z)$	20 - 30%	40 km 40 km	Z < 20 km 120 m Z ≥ 20 km: 360 m
Extinction, $\sigma_a(z)$	40 % *	40 km 40 km	z < 20 km 120 m z ≥ 20 km: 360 m
Clouds			
Height	For layers with $\beta > 1 \times 10^{-3}$ km^{-1} sr^{-1}	1/3, 1, 5 km	30, 60 m
Thickness	For layers with $\tau < 5$	1/3, 1, 5 km	30, 60 m
Optical depth, τ	within a factor of 2 for $\tau < 5$	5 km	N/A
Backscatter, $\beta_c(z)$	20 - 30%	5 km	60 m
Extinction, $\sigma_c(z)$	within a factor of 2 for $\tau < 5$	5 km	60 m
Ice/water phase	Layer by layer	5 km	60 m
Ice cloud emissivity, ε	±0.03	1 km	N/A
Ice particle size	±50% for $\varepsilon > 0.2$	1 km	N/A
Note: * assumes 30% uncertainty in the aerosol extinction-to-backscatter lidar ratio, S_a			

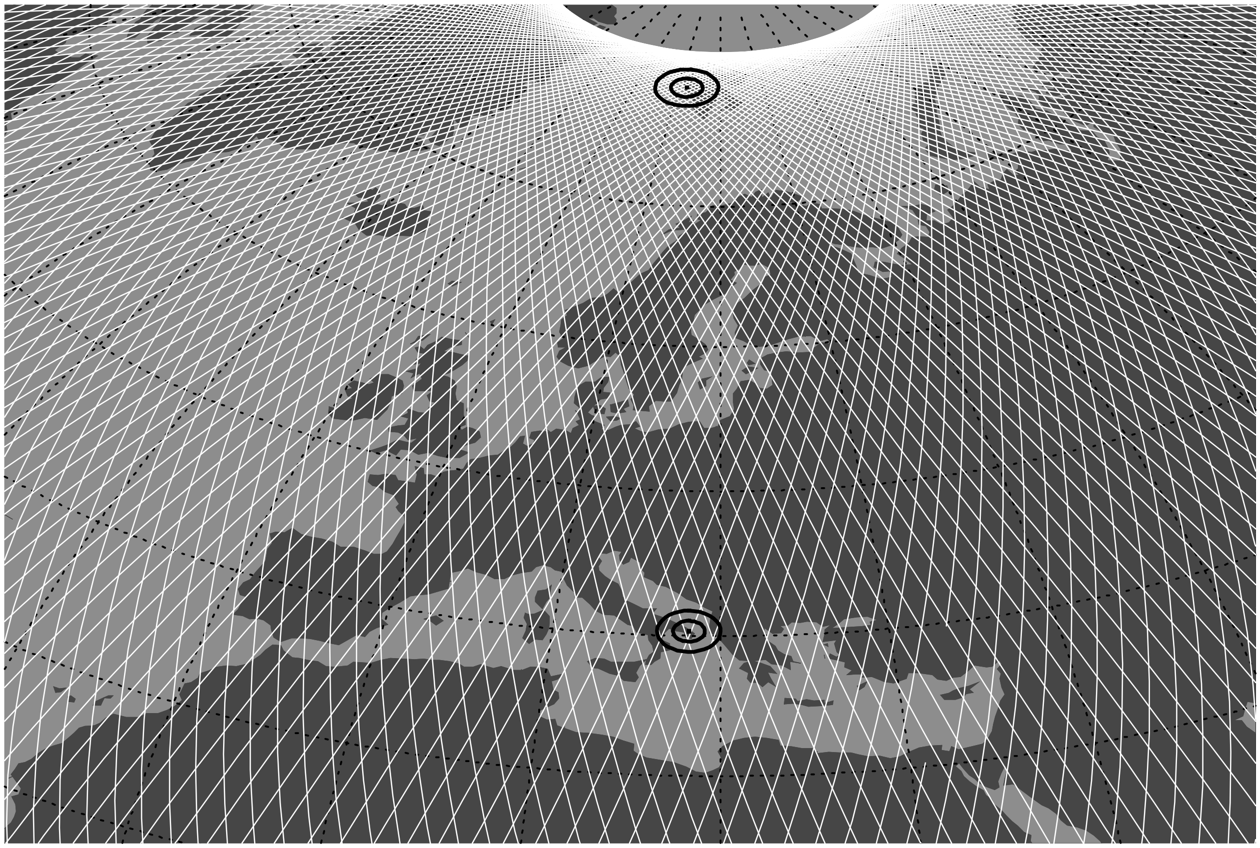

Fig. 2. CALIPSO 16-day repeating orbit ground tracks with circles around sites indicating 80 and 160 km distances.

Sites are selected for invitation to collaborate in the *QPQ* validation program if data produced at these sites validate CALIPSO Level II data products. The measurement and calibration history of the instruments, publications, and location of coincident data files will be gathered and stored in a database allowing a validation data user to determine the quality of the measurements and easily find what coincident data are available. A web interface (http://calipsovalidation.hamptonu.edu) will allow the data user to search this database to find coincident data based on their own search criteria.

Hampton University (HU) will provide an interface through this website for validation sites to upload data to the HU data archive. Sites that utilize a network data archive will not need to upload their data to the HU data archive, but will be expected to update the validation implementation team on the availability of coincident data. These network data archives must provide adequate data access for the CALIPSO science and validation implementation teams. A listing of the specific sources and resources needed to utilize the data will be prepared as part of a data catalog and will include URLs, point of contact, email addresses, access instructions, data format, file naming conventions, etc. The data catalog will update coincident data available at these sites and from the HU server so that any validation data user knows what coincident validation data are available. The data providers will supply this information each time they upload CALIPSO validation data to a data archive.

Several instrument networks and individual sites have been identified by the *QPQ* validation implementation team as potentially suitable for the validation of CALIPSO data products. The networks include: the AErosol RObotic NETwork (AERONET), Asian Dust NETwork (AD-NET), Atmospheric Radiation Measurement (ARM) program, Climate Monitoring and Diagnostics Laboratory (CMDL), European Aerosol Research LIdar NETwork (EARLINET), Micro Pulse Lidar Network (MPLNET), Network for the Detection of Stratospheric Change (NDSC), Regional East Atmospheric Lidar Mesonet (REALM), Surface Radiation (SurfRad) budget network, US Department of Agriculture (USDA) and the Multi-Filter Rotating Shadowband Radiometer (MFRSR) network. 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 sites will be considered when they are identified.