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

Thomas A. Kovacs and M. Patrick McCormick
Hampton University

July 2005

Table of Contents

1. Introduction
- 1.1 Revision History
- 1.2 Purpose and Scope

2. Strategy
- 2.1 Approach
- 2.2 Data products
- 2.3 Aerosols
- 2.4 Clouds
- 2.5 IIR derived data products

3. Existing Instrument Networks and Individual Sites
- 3.1 Aeronet
- 3.2 Asian Dust NETwork (AD-NET)
- 3.3 Atmospheric Radiation Measurement (ARM)
- 3.4 Baseline Surface Radiation Network (BSRN)
- 3.5 Climate Monitoring and Diagnostics Laboratory (CMDL)
- 3.6 Commonwealth of Independent States Lidar Network (CIS-LiNet)
- 3.7 EARLINET
- 3.8 Institut Pierre Simon Laplace (IPSL) Lidar Network
- 3.9 Micro-Pulse Lidar Network (MPLNET)
- 3.10 Network for the Detection of Stratospheric Change (NDSC)
- 3.11 Regional East Atmospheric Lidar Mesonet (REALM)
- 3.12 USDA MFRSR network
- 3.13 Individual Sites

4. Coverage of Various Aerosol and Cloud Regions
- 4.1 Aerosols
- 4.2 Clouds

5. Implementation
- 5.1 The QPQ validation milestones
- 5.2 Communication with sites
- 5.3 Data Exchange, Storage, and Handling

6. References

7. Appendices
- 7.1 Latitude, Longitude, and Altitude of all QPQ validation sites. Sites are listed under each network. Some sites are listed under multiple networks
- 7.2 Map of the 16-day CALIPSO repeating orbit ground-track and the location of all the QPQ validation sites with 80 and 160 km range rings
- 7.3 Data exchange protocol

1. Introduction

1.1 Revision History

QPQ Validation Plan 0.6 - May 2002
QPQ Validation Plan 1.0 - July 2003
QPQ Validation Plan 1.1 - January 2004
QPQ Validation Plan 1.2 - February 2004
QPQ Validation Plan 1.3 - January 2005
QPQ Validation Plan 1.31 - May 2005
QPQ Validation Plan 1.32 - July 2005

1.2 Purpose and Scope

The *quid pro quo* (QPQ) measurements in collaboration with existing sites and other activities (e.g. field programs) are an important part of the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) validation program. These sites and field programs will provide data relevant to CALIPSO validation at times when the ground-track of the CALIPSO satellite is within a specified coincident distance. Exchange of data between CALIPSO and these sites will occur with no risk and cost to the project and follow appropriate protocols of exchange. Coordination of the validation measurements will be made through the CALIPSO homepage (http://www-calipso.larc.nasa.gov), the QPQ validation website (http://calipsovalidation.hamptonu.edu), email notices, fax, phone, and conventional mail announcements. This document will describe only permanent sites and not field campaigns sponsored and funded by other groups, although these will be pursued.

Sites are invited to collaborate in the QPQ validation program if data produced at these sites validate CALIPSO Level II data products. The number of coincident measurements, measurement and calibration history of the instruments, publications, and location of data files will be gathered or calculated and stored in a database allowing a user to determine the quality of the measurements and easily find what data are available. A web interface will allow the user to search this database to find data based on their own search criteria.

2. Strategy

2.1 Approach

To a considerable degree, data products from the CALIPSO satellite mission will be validated through comparisons with correlative in-situ and remote sensing measurements. For the CALIPSO mission, validation is defined as an assessment of the accuracy and precision of the derived science products by independent means. 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. The difference between two measurements that are not collocated in space or time or have different resolutions will include some measure of geophysical variability, which is unrelated to measurement uncertainty. 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.

2.2 Data products

Table 1 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.

Table 1: 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
Effective 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			

2.3 Aerosols

Clouds and aerosols vary on different spatial and temporal scales and, thus, require different validation strategies. Aerosols typically have longer spatial correlation distances than clouds providing a greater opportunity for coincident comparisons between instruments. An exception to this rule is polar stratospheric clouds (PSCs), which, in most cases, have coincident distances much larger than tropospheric clouds and aerosols.

Aerosol height and thickness will be calculated from the attenuated aerosol backscatter coefficient. Comparisons are needed with similar or superior detection and ranging capabilities such as ground-based lidars or backscattersondes. Because aerosol height and thickness tends to remain fairly consistent over long distances, except near local sources (e. g. smoke stacks, fires, etc.), the coincident distances (50-100 km) between the CALIPSO ground track and validation site can be much larger than for clouds.

For CALIPSO, Level 2 aerosol optical depth and extinction products are retrieved from backscatter measurements. These parameters require validation of the data products and the assumptions used to calculate them; namely, the value of the extinction-to-backscatter ratio, S_a. A layer averaged S_a can be estimated by CALIPSO measurements and a density profile for elevated aerosol layers, but S_a is estimated using a variety of ancillary data for non-elevated layers. A large number of observations in the literature indicate that optical depth and extinction are much more variable than the aerosol layer properties of height and thickness and, therefore, require more stringent coincidence criteria (<50 km).

A high spectral resolution lidar, elevation-scanned backscatter lidar, or 532 nm Raman lidar would be extremely valuable for validating the extinction profile and selection of S_a in the retrieval algorithm. Unfortunately, few of these systems exist worldwide and fewer yet can resolve the boundary layer. A 355 nm Raman lidar would be helpful to validate the extinction profile at 532 and 1064 nm, but the extinction profile would need to be transferred from 355 nm. A backscatter lidar colocated with a sunphotometer would also be suitable to validate the extinction profile and S_a, though assumptions still need to be made to calculate these parameters and the layers would need to have a near-constant lidar ratio. A sunphotometer or multi-filter rotating spectroradiometer (MFRSR) would be useful to validate aerosol optical depth.

2.4 Clouds

Optical properties of clouds are usually more variable horizontally than layers of aerosols. Hogan and Illingworth (2000) find that for cirrus clouds, (the best case) matching errors by stations separated by 5 km were approximately 100% and for 1-2 km the matching error is 25-50%. Therefore, validation of cloud properties will largely rely on statistical techniques. Because correlation scales are small for cloud properties, particularly optical depth, sites with frequent long-term measurements that have many coincident measurements within a short distance will be given high priority.

Cloud height and thickness is calculated in the same manner as for aerosol height and thickness and, therefore, requires such instruments as lidars or backscattersondes. Millimeter cloud radars will also be useful; but, because of the large difference in the detection sensitivities between lidars and radars, data from these instruments will be used in a more limited role for validation. The effect of multiple scattering on the determination of cirrus cloud height and thickness is expected to be small for the limited field of view of CALIPSO so that only attenuated backscatter is necessary to measure cloud height and thickness. These two parameters have the longest horizontal correlation scales for clouds (20-50 km) so that some direct comparisons may be made, particularly for non-convective clouds. Low clouds will be much more difficult to validate from the ground because for most low clouds the returned lidar signal for CALIPSO will be fully attenuated, so that it only cloud top is measured, while a ground lidar will be fully attenuated before reaching cloud top and measure only cloud base. A millimeter wavelength cloud radar may be more useful for these clouds. For nonattenuating low clouds, the effects of multiple scattering will be larger for the CALIPSO lidar and must be considered for all cloud data products.

Cloud optical depth, extinction profiles, and S_c are calculated similar to the analogous aerosol properties, but the correlation scales for clouds are quite small (< 5 km). Surface lidar sites can only be used where the clouds are overcast and uniform on scales similar to the distance between the surface site and the CALIPSO ground track. Only Raman and HSRL lidars can be used to validate cloud optical depth and extinction profiles, while for S_c a 532 or 1064 nm lidar must be present (a 355 nm Raman lidar alone will not suffice). Therefore, surface sites will play a small role in validating these cloud parameters.

Cloud ice/water phase is determined from the 532 nm depolarization ratio. Surface depolarization lidar at 532 nm is best, but a 355 nm depolarization lidar can be helpful, particularly for large particles (> 1 μm), where depolarization changes little with wavelength (Mishchenko et al., 1996). Correlation distances for cloud ice/water phase are larger than other cloud properties and the coincident distance (~ 50 km) may be large enough for direct comparisons.

2.5 IIR derived data products

Comparisons between the CALIPSO IIR and ground-based instruments are needed to support IIR calibration analysis and validation of its derived data products. Correlative measurements are needed along the satellite track that provide knowledge on the degree of cloudiness and altitude of cloud layers, profile information on temperature and humidity, and characterization of surface conditions such as temperature and emissivity. These measurements are needed for day and night satellite overpasses as well as over land and ocean with varying surface conditions.

To illustrate these requirements one can examine the IIR data product for effective emissivity, ε_c, of a cloud. This parameter is calculated from the relationship, $\varepsilon_c = (L_i - L_o)/(L_b - L_o)$, where L_i is the upward radiance measured by the IIR, L_o is the radiance measured in a cloud free atmosphere, and L_b is the radiance from an opaque cloud at the same temperature. This latter term is obtained from temperature and humidity profiles for the cloud height determined from lidar observation. Comparisons with facilities that can independently reproduce this calculation and verify it with surface radiometers will be extremely valuable for evaluating the IIR emissivity product quality.

Cloud particle size is another data product that will be produced from the IIR. It is a challenging product to validate because it may vary considerably over short horizontal distances (< 1 km) and within thin vertical layers (< 300 m). Some sites, notably ARM sites, use a radar-IR or radar-lidar technique to produce particle size measurements. This technique would need to be validated by in-situ measurements of particle sizes before it may be used to directly validate CALIPSO particle size measurements. Effective emissivity and particle size will only be retrieved for thin cirrus and therefore validation will only focus on thin cirrus.

3. Existing Instrument Networks and Individual Sites

The following instrument networks and individual sites have been identified by the CALIPSO validation implementation team as being suitable for participating in validation activities and have been contacted for, or expressed interest in, participating in the QPQ validation program. Each network has a long history of measurements and a measurement and calibration protocol. For each network, a brief description of the network is given followed by a list of pertinent measurements and CALIPSO level II parameters that they validate.

3.1 Aeronet

http://aeronet.gsfc.nasa.gov/

Aeronet is a federation of ground-based remote sensing aerosol networks, largely sunphotometers, around the world. Aerosol optical thickness at 1020, 870, 670, 500, 440, 380, and 240 nm are derived at most places. Sky radiance measurements along the solar alumcantar (i.e. at constant elevation angle with varied azimuth angles) and the solar principal plane (i.e. at constant azimuth angle with varied scattering angles) are made at 440, 670, 870, and 1020 nm to retrieve size distribution and phase function. Aerosol optical thickness is derived every 15 minutes or 0.25 air masses; whichever is more frequent, from an air mass of 7 in the morning to an air mass of 7 in the evening. Each measurement consists of a triplet of measurements at each wavelength that are analyzed for cloud screening and averaged. Sky radiance measurements are taken 6 times a day along the solar alumcantar and 9 times a day along the solar principal plane. Sun photometers are calibrated by the Langley method every 2-3 months, which is then transferred to field sunphotometers pre- and post-deployment to an accuracy of 1-2% for aerosol optical thickness, and every 9-12 months to get an accuracy of 5% for sky radiance.

The following measurements from the Aeronet sites listed in Section 7.1 would be suitable for CALIPSO validation (validated parameters in parentheses):

Sunphotometer (τ_a (532 nm), τ_a(1064 nm))

3.2 Asian Dust NETwork (AD-Net)

http://info.nies.go.jp:8094/kosapub/index.html

The AD-Net is an international virtual community, which was formed in February 2001. It was setup to provide rapid communication via the Internet on Asian dust events. The network observation of Asian dust was originally started in 1997 mainly with lidar groups in Japan. Since 1998, exchange of Asian dust information with lidar and other surface observations expanded to the East Asia countries of China and Korea. The AD-Net primary observation campaign take place every year in northern springtime from March 1 to May 31. Many of the lidars in the network belong to research programs on the atmospheric radiation and/or regional air-pollution, and the lidars are operated continuously throughout year.

Table 2 presents a list of instruments, the resolution in time and space of available lidar, and the CALIPSO Level II parameters validated for each site in the network.

Table 2: List of instruments, vertical range and resolution, time resolution, and parameters validated for each station within the AD-Net.

Station	Instrument	Lidar range (resolution)	Lidar time resolution	Validated parameter
Beijing	532 nm w/polarization, 1064 nm lidar.	0.1-15 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Cheju	See MPLNET			
Chung-Li	532 nm, 1064 m w/polarization lidar	1- 30 km (24 m)		aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Fukue	532 nm w/polarization, 1064 nm lidar.	0.1-15 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Fukuyama	532 nm w/polarization lidar.	0-15 km	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Gwangju	355 nm, 532nm w/polarization, 1064 nm, 387 nm Raman lidar	0.5-30 km (7.5 m)	10 mins.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_a (1064), $S_c(532)$, $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Hedo	532 nm w/polarization, 1064 nm lidar.	0.1-18 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Hefei	532 nm w/polarization, 1064 nm lidar.	0-18 km (30 m)	Day and night operation, 15 minute resolution	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Hohhot	532 nm w/polarization lidar	0.1-15 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$

Miyako-jima	532 w/polarization, 1064 nm lidars	0.1-18 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Nagasaki	532 nm w/polarization, 1064 nm lidar	0.1-18 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Nagoya	355, 532 w/polarization, 1064 nm, and Raman lidar	troposphere and stratosphere (30 m)	5 mins.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_a (1064), $S_c(532)$, $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Okayama	532 nm w/polarization lidar	0.1-15 km	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Sapporo	532 nm w/polarization, 1064 nm lidar	0.1-18 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Sri Samrong	532 nm w/polarization, 1064 nm lidar	0.1-18 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Suwon	532 nm w/polarization, 1064 nm lidar	0.1-18 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Tokyo	355nm, 532 nm w/polarization, 1064 nm, 387, 408, 607 nm Raman lidar, sun photometer	0.1-15 km (7.5 m)	5-10 min.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_a (1064), $S_c(532)$, $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Toyama	532 nm w/polarization, 1064 nm lidar	0.1-18 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)$
Tsukuba	532 nm w/polarization, 1064 nm lidar, 523 nm HSRL	0.1-15 km (6 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_a (1064), $S_c(532)$, $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$

3.3 Atmospheric Radiation Measurement (ARM)

http://www.arm.gov/

The Atmospheric Radiation Measurement (ARM) Program is a multi-laboratory, interagency program that was created in 1989 with funding from the U.S. Department of Energy (DOE). The ARM Program is part of DOE's effort to resolve scientific uncertainties about global climate change with a specific focus on improving the performance of general circulation models

(GCMs) used for climate research and prediction. These improved models will help scientists better understand the influences of human activities on the earth's climate. In pursuit of its goal, the ARM Program establishes and operates field research sites, called Cloud and Radiation Testbeds (CARTs), in several climatically significant locations. Scientists collect and analyze data obtained over extended periods of time from large arrays of instruments to study the effects and interactions of sunlight, radiant energy, and clouds on temperatures, weather, and climate. Sites include instruments to measure atmospheric profiles of aerosols and cloud optical properties, surface eddy flux, and surface meteorology. The instruments available for CALIPSO validation are discussed below and in Table 3.

The following measurements from the ARM sites would be suitable for CALIPSO validation and are summarized in Table 3 (validated parameters in parentheses):

Southern Great Plains (SGP) Central Facility (aerosol height/thickness, cloud height/thickness, τ_a(532nm), τ_a(1064nm), σ_a(532), S_a(532), τ_c(532 nm), σ_c(532), S_c(532), $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$, ice particle size, ice cloud effective emissivity)
Sunphotometer measurements at 1020 and 499 nm
Multi-filter rotating shadowband radiometer at 500 nm
Raman Lidar (runs day/night with 39 m range resolution) with 355 nm depolarization channel and a 387 nm Raman channel
Ceilometer measurements at 905 nm
Micro-pulse lidar at 523 nm
mm-Wavelength cloud radar

The following instruments are also present but do not directly validate any CALIPSO parameters: condensation nuclei counter, optical particle counter (31 channels between 0.1-10 μm and one greater than 10 μm), ozone monitor, microwave radiometer (31.4 GHz), atmospheric emitted radiance interferometer (3-20 μm or 500-3300 cm^{-1}, resolution 1 cm^{-1}), radiosondes, 50 and 915 MHz Radar wind profiler/RASS, camera centered on zenith, whole sky imager (450 and 650 nm), narrow field of view sensor (869 nm, centered on zenith), absolute solar transmittance interferometer (1-5 μm or 2000-10000 cm^{-1}, resolution 2 cm^{-1}, pyranometer, pyrgeometer, pyrheliometer, uv-b radiometer, solar radiance transmission interferometer (620-1350, 1500-2050, 2020-2550, 2420-3080, 3010-3830, 4020-4300 cm^{-1}, 3 times a day), shortwave spectrometer, uv spectroradiometer, surface meteorological observing system (1 minute wind speed and direction, temperature, relative humidity, pressure, rain amount), temperature and humidity at 25 and 60 m, and a chilled mirror.

Southern Great Plains (SGP) Extended Facilities (sites listed in Section 7.1) (τ_a(532nm))
Multi-filter rotating shadowband radiometer for 500 nm

Also, a surface meteorological observing system (1 minute wind speed and direction, temperature, relative humidity, pressure, rain amount) is present.

Tropical Western Pacific (TWP) - Manus Island, Nauru Island, and Darwin (aerosol height/thickness, cloud height/thickness, τ_a(532nm), τ_a(1064nm), σ_a(532), S_a(532), ice particle size, ice cloud effective emissivity)

Ceilometer at 905 nm
Micropulse lidar at 523 nm
mm-Wavelength cloud radar
Sunphotometer at 1020 and 499 nm
Multi-filter rotating shadowband radiometer at 500 nm

The following instruments are also present but do not directly validate any CALIPSO parameters: microwave radiometer (31.4 GHz), atmospheric emitted radiance interferometer (3-20 μm or 500-3300 cm^{-1}, resolution 1 cm^{-1}), radiosondes, 915 MHz Radar wind profiler/RASS, whole sky imager (450 and 650 nm), absolute solar transmittance interferometer (1-5 μm or 2000-10000 cm^{-1}, resolution 2 cm^{-1}), pyranometer, pyrgeometer, pyrheliometer, uv-b radiometer, solar radiance transmission interferometer (620-1350, 1500-2050, 2020-2550, 2420-3080, 3010-3830, 4020-4300 cm^{-1}, 3 times a day), surface meteorological observing system (1 minute wind speed and direction, temperature, relative humidity, pressure, rain rate).

North Slope of Alaska - Barrow (aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064), $\beta'(R, 532nm)_{\|}/\beta'(R, 532nm)_{\perp}$, ice particle size, ice cloud effective emissivity)
High spectral resolution lidar (HSRL) (100 m to 37.5 km with day/night operation) 532 nm w/depolarization and 1064 nm
Ceilometer at 905 nm
Micropulse lidar at 523 nm
mm-Wavelength cloud radar
Sunphotometer for 1020 and 499 nm
Multi-filter rotating shadowband radiometer for 500 nm

The following instruments are also present but do not directly validate any CALIPSO parameters: microwave radiometer (31.4 GHz), atmospheric emitted radiance interferometer (3-20 μm or 500-3300 cm^{-1}, resolution 1 cm^{-1}), radiosondes, 915 MHz Radar wind profiler/RASS, whole sky imager (450 and 650 nm), absolute solar transmittance interferometer (1-5 μm or 2000-10000 cm^{-1}, resolution 2 cm^{-1}), pyranometer, pyrgeometer, pyrheliometer, uv-b radiometer, solar radiance transmission interferometer (620-1350, 1500-2050, 2020-2550, 2420-3080, 3010-3830, 4020-4300 cm^{-1}, 3 times a day), wind speed and direction, temperature, relative humidity at 2, 10, 20, and 40 m and pressure, visibility, and precipitation at the ground.

North Slope of Alaska - Atqasuk (τ_a(532nm))
Multi-filter rotating shadowband radiometer for 500 nm

Table 3: Summary of instruments describe above at the various ARM sites.

	Southern Great Plains Central Facility	**Southern Great Plains Extended Facilities**	**Tropical Western Pacific**	**North Slope of Alaska (Barrow)**	**North Slope of Alaska (Atqasuk)**
Sun Photometer	1020 and 499 nm		1020 and 499 nm	1020 and 499 nm	

MFRSR	500 nm	500 nm	500 nm	500 nm	500 nm
Raman Lidar	355 nm with polarization and 387 nm, both with 39 m vertical resolution				
Ceilometer	905 nm		905 nm	905 nm	
Micro-pulse Lidar	523 nm		523 nm	523 nm	
HSRL				532 nm with polarization, 1064 nm, both with 100 m vertical resolution and range to 37.5 km	
Mm wavelength cloud radar	Yes	No	Yes	Yes	No
Other instruments not directly related to validation	Yes (see text)	Yes (see text)	Yes (see text)	Yes (see text)	No

3.4 Baseline Surface Radiation Network (BSRN)

http://bsrn.ethz.ch/

BSRN is a project of the World Climate Research Programme (WCRP) aimed at detecting important changes in the earth's radiation field, which may cause climate changes. The objective of the BSRN is to provide, using a high sampling rate, observations of the best possible quality, for short and longwave surface radiation fluxes. These readings are taken from a small number of selected stations, in contrasting climatic zones, together with collocated surface and upper air meteorological data and other supporting observations.

The following measurements from the BSRN sites listed in Section 7.1 would be suitable for CALIPSO validation (validated parameters in parentheses):

Sunphotometer (τ_a (532 nm), τ_a(1064 nm))

Also all stations measure global, direct, and diffuse broadband solar radiation while most stations measure downward longwave, temperature, relative humidity, and pressure. Payerne, Von Neumayer, and Boulder measure upward shortwave and longwave irradiance and have radiosondes. Toravere and Tateno measure upward shortwave and longwave irradiance.

3.5 Climate Monitoring and Diagnostics Laboratory (CMDL)

http://www.cmdl.noaa.gov/aerosol/

The CMDL of the National Oceanic and Atmospheric Administration (NOAA) conducts research related to the atmospheric constituents that are capable of forcing change in the climate of the earth or may deplete the ozone layer. Aerosol measurements began at the CMDL baseline observatories in the mid-1970s as part of the Geophysical Monitoring for Climate Change. The goal of this regional-scale monitoring program is to characterize means, variability, and trends of climate-forcing properties of different types of aerosols, and to understand the factors that control these properties.

The following measurements would be suitable for CALIPSO validation (validated parameters in parentheses):

Lidars at Mauna Loa Observatory and Boulder, Colorado are capable of measuring stratospheric and tropospheric aerosols and the height and thickness of cirrus clouds. A third lidar station at American Samoa will be operating. The lidars are restricted to nighttime measurements at 532 nm. The Mauna Loa Observatory lidar also measures 1064 nm aerosol scattering and water vapor in the troposphere using the Raman method. The lidars are permanently deployed and operated routinely. (Aerosol Height/Thickness, Cloud Height/Thickness)

3.6 Commonwealth of Independent States Lidar Network (CIS-LiNet)

http://www.cis-linet.basnet.by/

CIS-LiNet (Commonwealth of Independent States Lidar Net) includes stationary and mobile lidar stations all over former USSR countries. CIS-LiNet was established in 2004 in the frame of the International Science and Technology Center (ISTC) Project. The net's aims are regular measurements of aerosol and ozone vertical profiles to study their large-scale spatial and temporal transformations.

Table 4 presents a list of instruments, the resolution in time and space of any available lidar, and the CALIPSO Level II parameters validated for each site in the network.

Table 4: List of instruments, vertical range and resolution, time resolution, and parameters validated for each station within the CIS-LiNet.

Station	Instrument	Lidar range (resolution)	Lidar time resolution	Validated parameter
Minsk	Backscatter Lidar 1064, 532, 355 nm w/polarization, CIMEL sunphotometer	2-30 km(64 m)	10 min	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Moscow	Backscatter Lidar 532 nm			aerosol height/thickness, cloud height/thickness
Sergut	Backscatter Lidar 532 nm	0.5-30 km (15-300 m)	10-30 min	aerosol height/thickness, cloud height/thickness
Teplokluchenka, Kyrgyzstan	Raman Lidar 532, 608 nm	2-20 km(37 m)		aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_c(532)$, $\sigma_c(532)$, S_a (532), $S_c(532)$
Tomsk, stationary	Raman Lidar 308, 532 nm, humidity, temperature, Aerosol Station, Standard Meteorological measurements,	8-50 km(60 m)	15 mins.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, S_a (532)

	CIMEL sunphotometer			
Tomsk, mobile	Raman Lidar 532 w/polarization, 608 nm	0,2-12 km (5-15 m)	1-12 min.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_c(532)$, $\sigma_c(532)$, S_a (532), $S_c(532)$, $\beta'(R, 532nm)_{\|\|}/\beta'(R, 532nm)_{\perp}$
Vladivostok, stationary	Backscatter Lidar 532 nm	2-20 km (60 m)	10-30 mins.	aerosol height/thickness, cloud height/thickness
Vladivostok, mobile shipboard	Backscatter Lidar 532 nm	1.5-15 km(60 m)	10-30 min	aerosol height/thickness, cloud height/thickness
Yakutsk	Backscatter Lidar 532 nm	3-50 km (30 m)	15-60 min	aerosol height/thickness, cloud height/thickness

3.7 EARLINET
http://www.earlinet.org/

EARLINET's objective is to establish a quantitative comprehensive statistical database of the horizontal, vertical, and temporal distribution of aerosols on a continental scale. The goal is to provide aerosol data with unbiased sampling, for important selected processes, and air-mass history, together with comprehensive analyses of these data. The objectives will be reached by implementing a network of 21 stations distributed over most of Europe, using advanced quantitative laser remote sensing to directly measure the vertical distribution of aerosols, supported by a suite of more conventional observations. Special care will be taken to assure data quality, including intercomparisons at instrument and evaluation levels.

Table 5 presents a list of instruments, the resolution in time and space of any available lidar, and the CALIPSO Level II parameters validated for each site in the network.

Table 5: List of instruments, vertical range and resolution, time resolution, and parameters validated for each station within the EARLINET.

Station	Instrument	Lidar range (resolution)	Lidar time resolution	Data products available for validation
Athens_EARLINET	355, 532, 387 nm lidar, meteorological data (P,T,U)	0.5-12 km (15 m)	6 mins. extinction only at night-time	aerosol height/thickness, cloud height/thickness $\tau_a(532)$, $\sigma_a(532)$, S_a (532), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), ice cloud effective emissivity
Barcelona_EARLINET	532,607, 1064 nm lidar, aerosol spectrometer, pyranometer, sunphotometer	0.25-10 km (7.5 m)	1 min	aerosol height/thickness, cloud height/thickness $\tau_a(532)$, $\sigma_a(532)$,

				$\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064)
Bilthoven_EARLINET	355 nm and 532 nm Raman lidar and 1064 nm backscatter lidar	1-15 km (7.5 m)	30 min.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064)
Cabaw_EARLINET	355, 532 w/depolarization, 1064 nm Raman lidar, AERONET sunphotometer, Ceilometer, Radiosonde,10, 35, 95 GHz radar, and other instrumentation available (similar to ARM SGP site)	1-5 km	5 min.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064), $\beta'(R, 355nm)_{\parallel}/\beta'(R, 355nm)_{\perp}$, ice particle size, ice cloud effective emissivity
Garmisch_EARLINET	355 nm, 532 nm, 1064 nm lidar (HSRL), visibility meter, pyranometer, spectrally resolved UV 532 nm backscatter lidar	0.2-10 km (3.75 m) 1.5-40 km (15 m/3.75 m)	10 s-3 min extinction 532 at daytime 1-7 min	aerosol height/thickness, cloud height/thickness $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064)
Hamburg_EARLINET	355, 387, 407, 532, 607, 1064 nm Raman lidar, 355, 532nm pure rotational Raman lidar, 1064 s+p-pol, and AERONET sunphotometer, ceilometer	0.3-10 km (15 m)	10 s	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064), $\beta'(R, 355nm)_{\parallel}/\beta'(R,$

				355nm)$_{\perp}$
Jungfraujoch_EARLINET	355, 387, 532, 607, 1064 nm w/polarization (355 nm); Raman lidars- Pure rotational Raman at 532 nm for temperature aerosol extinction/ backscatter measurement, sunphotometer (Meteoswiss),	4-11 km (7.5-300m m)	100 s	aerosol height/thickness, cloud height/thickness, τ_a(532), σ_a(532), τ_a(1064), σ_a(1064), S_a (532), S_a (1064), τ_c(532), σ_c(532), S_c (532), τ_c(1064), σ_c(1064), S_c (1064), β'(R, 355nm)$_{\|}$/β'(R, 355nm)$_{\perp}$
L'Aquila_EARLINET	351nm, 382 nm, 393nm, 403nm Raman lidar, PTU and PTO_3 radiosonde	.3-8 km a.g.l. (30 m)	10 mins.	aerosol height/thickness, cloud height/thickness, ice cloud effective emissivity
Lecce_EARLINET	351, 383 w/ depolarization, 404 nm Raman lidar, AERONET sunphotometer, meteo station (P, T, RH, wind), Vaisala radio sonde for (P,T,RH)	0.4 - 7 km (1.5 m)	3 mins. extinction, depolarization, water vapor, and temperature profiles at night-time only	aerosol height/thickness, cloud height/thickness, τ_a(532), τ_a(1064), β'(R, 351nm)$_{\|}$/β'(R, 351nm)$_{\perp}$
Leipzig_EARLINET	355, 532 (polarization), 1064, 387, 408, 529, 530.2, 533.7, 535, and 607 nm Raman lidar, sun photometer (380, 440, 500, 670, 870, 1020, and 1640 nm), Vaisala radio sonde (P, T, RH)	0.5 km - trop. for extinction and 0.1 - trop. for backscatter (60 m)	30 mins. (raw 30 s)	aerosol height/thickness, cloud height/thickness, τ_a(532), σ_a(532), τ_a(1064), σ_a(1064), S_a (532), S_a (1064), τ_c(532), σ_c(532), S_c (532), τ_c(1064), σ_c(1064), S_c (1064), β'(R, 355nm)$_{\|}$/β'(R, 355nm)$_{\perp}$, ice cloud effective emissivity
Minsk_EARLINET	355, 532, 1064 nm and 532 w/polarization lidars; AERONET sunphotometer	Lidar #1 (lidar #2) 0.3(1)-10(30) km (15 m (128m))	5 (30) mins.	aerosol height/thickness, cloud height/thickness, τ_a(532), σ_a(532), τ_a(1064), σ_a(1064), S_a (532), S_a (1064), β'(R, 532nm)$_{\|}$/β'(R,

				532nm)$_{\perp}$
Munich_EARLINET	355, 387, 532, 607, 1064 nm lidar	0.2-5 km (3.75 m)	0.1 s	aerosol height/thickness, cloud height/thickness $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064)
Napoli_EARLINET	355, 387, 407, 532, 607 nm, Raman lidar, meteo. station (P,T,RH)	0.25-12 km (15 m), 0.1-8 Km (60m) for WV mixing ratio	1 min.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064),
Neuchatel_EARLINET	532 nm w/polarization, meteo station	1-10 km (30 m)	200-600 s	aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
SIRTA_EARLINET	See IPSL Network			
OHP_EARLINET	See IPSL Network			
Potenza_EARLINET	355, 387, 407, 532, 607, 1064 nm Raman lidar, meteo station (P,T,RH,winds), AERONETsunphotometer, ceilometer, radiosonde, MW radiometer	0.5 km-a.l.s. – troposphere for extinction and 0.2 km a.l.s.- troposphere for backscatter (15 m)	1 min.	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\tau_c(532)$, $\sigma_c(532)$, S_c (532), $\tau_c(1064)$, $\sigma_c(1064)$, S_c (1064), ice cloud effective emissivity
Thessaloniki_EARLINET	355, 532, 387, 607 nm lidar, meteorological data (P,T,U) AERONET sunphotometer Brewer spectroradiometer 266, 289, 316 nm lidar, spectral UV-B, meteo. Station.	0.8-12 km (30 m) 0.7-8 km (7.5 m)	5 mins. extinction only at night-time 4 mins.	aerosol height/thickness, cloud height/thickness $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, S_a (532), $\tau_c(532)$, $\sigma_c(532)$, S_c (532)

Belsk_EARLINET	694, 532, 1064 nm	Trophosphere up to 8 km Stratosphere (night time) up to 30 km (15 m)	2 min 30 min	aerosol height/thickness, cloud height/thickness
Sofia_EARLINET	510.6 nm, 578 nm; 1 lasers with CuBr-vapor (We use only the wavelength 510.6 nm)	Up to 7-8 km at daytime; ~15 - 20 km at night-time Resolution: 15m or 30 m	1 min	Aerosol height/thickness Cloud height/thickness
Madrid_EARLINET	532 nm lidar. aerosol spectrometer (GRIMM 1108)	0.15-15 km (6 m)	5 mins.	aerosol height/thickness, cloud height/thickness
Granada_EARLINET	355, 387, 532, 607, 1064 nm Raman lidar, meteo station (P,T,RH,winds), AERONETsunphotometer, Bentham DMc150 spectroradiometer, all sky camera, Multifilter Rotating Shadowband Radiometer, broadband radiometers (Solar, UVB, UVA, Thermal IR), TSI 3563 Integrating Nephelometer, Multi Angle Absorption Photometer, MAAP.	0.25-12 km (7.5 m)	1 min.	aerosol height/thickness, cloud height/thickness, τ_a(532), σ_a(532), τ_a(1064), σ_a(1064), S_a (532), S_a (1064), τ_c(532), σ_c(532), S_c (532), τ_c(1064), σ_c(1064), S_c (1064)

3.8 Institut Pierre Simon Laplace (IPSL) Lidar Network

IPSL operates five ground-based sites of interest to CALIPSO for validation purposes. Palaiseau (SIRTA), Haute Provence, and La Reunion Island are collaborating to define common algorithms. The macrophysics algorithm developed at SIRTA will be implemented at the other sites to retrieve cloud and aerosol layer detection, boundary layer height detection, cloud optical depth, and cloud ice/water discrimination. Further collaborations are in place to improve retrievals of aerosol optical properties using Raman channels.

Table 6 presents a list of instruments, the resolution in time and space of any available lidar, and the CALIPSO Level II parameters validated for each site in the network.

Table 6: List of instruments, vertical range and resolution, time resolution, and parameters validated for each station within the IPSL Lidar Network.

Station	Instrument	Lidar range	Lidar time resolution	Validated parameter

		(resolution)		
Andoya	355 nm, 532 nm w/polarization, 1064 nm lidar, 387 nm, 607 nm Raman lidar			aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_c (532), S_a (1064), $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Dumont d'Urville	532 nm w/polarization, 1064 nm lidar, 607 Raman lidar	Stratosphere		aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_c (532), S_a (1064), $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Haute Provence	532 nm lidar, 607 nm Raman lidar	Troposphere and stratosphere		aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_c(532)$, $\sigma_c(532)$, S_a (532), $S_c(532)$
La Reunion Island	532 nm with polarization, 1064 nm lidar, 607 Raman lidar	Troposphere and stratosphere		aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_c (532), S_a (1064), $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Palaiseau	532 nm w/polarization, 1064 nm lidar, CIMEL sunphotometer, 94 GHz radar	0.5-15 km (15 m)	10 s	aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$, ice particle size

3.9 Micro-Pulse Lidar Network (MPLNET)

http://mplnet.gsfc.nasa.gov/

MPLNET is a worldwide network of micro-pulse lidar (MPL) systems. MPLNET is run by the members of the Cloud and Aerosol Lidar Group in Code 912 at GSFC and is funded by NASA's EOS program. The MPL is a single channel (523 nm), autonomous, eye-safe lidar system originally developed at GSFC and now commercially available. The MPL is used to determine the vertical structure of clouds and aerosols with a 30 - 300 m vertical resolution up to 20 km. The MPL data are analyzed to produce optical properties such as extinction and optical depth profiles of clouds and aerosols. The primary goal of MPLNET is to provide long-term data sets of cloud and aerosol vertical distributions at key sites around the world. The long-term data sets will be used to validate and help improve global and regional climate models, and also serve as ground-truth sites for NASA/EOS satellite programs.

The following measurements from the MPLNET sites listed in Section 7.1 would be suitable for CALIPSO validation (validated parameter in parentheses):

Micro-pulse lidar at 523 nm (aerosol height/thickness and cloud height/thickness)

3.10 Network for the Detection of Stratospheric Change (NDSC)

http://www.ndsc.ncep.noaa.gov/

The NDSC is a set of remote sounding research stations for observing and understanding the physical and chemical state of the stratosphere. NDSC began network operations in January 1991. Several international sites are actively taking measurements of the following: aerosol, ozone, and temperature via lidars; ozone, temperature, and relative humidity sondes; and FTIR for measuring HCl, HF, CH_4, C_2H_6, C_2H_2, N_2O, O_3, CO, CHF_2Cl, HCN, HNO_3, $CLONO_2$, NO, and NO_2.

Table 7 presents a list of instruments, the resolution in time and space of any available lidar, and the CALIPSO Level II parameters validated for each site in the network.

Table 7: List of instruments, vertical range and resolution, time resolution, and parameters validated for each station within the NDSC.

Station	Instrument	Lidar range (resolution)	Lidar time resolution	Validated parameter
Andoya	See IPSL Lidar Network			
Dumont d'Urville	See IPSL Lidar Network			
Garmisch	lidar			aerosol height/thickness, cloud height/thickness
GSFC	See REALM			
Haute Provence	See IPSL Lidar Network			
Lauder	Lidar, backscattersonde	6-36 km		aerosol height/thickness, cloud height/thickness
Mauna Loa	See CMDL			
McMurdo	Lidar, backscattersonde		Nighttime only	aerosol height/thickness, cloud height/thickness
Ny Alesund	355, 532, 1064 nm Lidar, nepholometer, sunphotometer, in-situ aerosol measurements, backscattersonde, radiosondes	10-40 km (7.5 m)		aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, S_a (532), S_a (1064), ice cloud effective emissivity
Okinawa	Lidar			aerosol height/thickness, cloud height/thickness
Poker Flats	532 nm w/polarization lidar			aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
La Reunion Island	See IPSL Lidar Network			
Suwon	See AD-Net			
Table Mountain	lidar			aerosol height/thickness, cloud height/thickness
Thule	lidar		Day and night	aerosol height/thickness, cloud height/thickness

Toronto	lidar		Day and night	aerosol height/thickness, cloud height/thickness

Several other sites have backscattersondes only and are listed in Section 7.1.

3.11 Regional East Atmospheric Lidar Mesonet (REALM)

REALM is a proposed loose confederation of lidar sites building on the research capabilities already established at a number of Eastern North America lidar facilities. Lidar systems in REALM are expected to deliver (at minimum) lidar backscatter ratio at the fundamental or one of the harmonics of the Nd:YAG laser.

Table 8 presents a list of instruments, the resolution in time and space of any available lidar, and the CALIPSO Level II parameters validated for each site in the network.

Table 8: List of instruments, vertical range and resolution, time resolution, and parameters validated for each station within the REALM.

Station	Instrument	Lidar range (resolution)	Lidar time resolution	Validated parameter
CCNY	355 nm, 532 nm, and 1064 nm lidar			aerosol height/thickness, cloud height/thickness,
Dalhousie University	532 nm w/polarization			aerosol height/thickness, cloud height/thickness, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Ground-winds	532 nm lidar			aerosol height/thickness, cloud height/thickness
GSFC	355 nm, 532 nm w/polarization, and 1064 w/ polarization lidar, 387 nm and 607 Raman lidar			aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_c (532), S_a (1064), $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$
Hampton University	532 and 1064 nm lidar			aerosol height/thickness, cloud height/thickness
Howard University	532 nm lidar			aerosol height/thickness, cloud height/thickness
MSC	532 nm and 1064 nm lidar	(3.75 m)	1 minute	aerosol height/thickness, cloud height/thickness
Penn State University	355 nm and 532 nm lidar	0-10 km		aerosol height/thickness, cloud height/thickness
UAH	532 nm and 1064 nm lidar			aerosol height/thickness, cloud height/thickness
UMBC	355 nm, 532 nm w/polarization, and1064 w/polarization lidar, 387 nm and 607 Raman lidar			aerosol height/thickness, cloud height/thickness, $\tau_a(532)$, $\sigma_a(532)$, $\tau_c(532)$, $\sigma_c(532)$, $\tau_a(1064)$, $\sigma_a(1064)$, $\tau_c(1064)$, $\sigma_c(1064)$, S_a (532), S_c (532), S_a (1064), $S_c(1064)$, $\beta'(R, 532nm)_{\parallel}/\beta'(R, 532nm)_{\perp}$

3.12 USDA MFRSR network

http://uvb.nrel.colostate.edu/UVB/home_page.html
http://hog.asrc.cestm.albany.edu/

The USDA UVB Radiation Monitoring Program is a program of the US Department of Agriculture's Cooperative State Research, Education and Extension Service (CSREES). The program was initiated in 1992, through a grant to Colorado State University, to provide information on the geographical distribution and temporal trends of UVB (ultraviolet -B) radiation in the United States. This information is critical to the assessment of the potential impacts of increasing ultraviolet radiation levels on agricultural crops and forests.

The following measurements from the USDA MFRSR sites listed in Section 7.1 would be suitable for CALIPSO validation (validated parameter in parentheses):

Multi-filter rotating shadowband radiometer (τ_a(532nm))

The following instruments are also present at USDA sites, but do not directly validate any CALIPSO parameters: downward looking photometer, broadband uv-b pyranometer (280-330 nm), UV MFRSR (300, 305.5, 311.4, 317.6, 325.4, 332.4, and 368 nm), and instruments to measure temperature and humidity.

3.13 Individual Sites

Several investigators interested in participating in the QPQ validation program have provided the details, summarized in Table 9 of their proposed measurements that would be suitable for CALIPSO validation.

Table 9: Instruments and locations of several sites not affiliated with any instrumented networks.

Site	Investigators	Lat(°)	Lon(°)	Alt(m)	Instruments
Buenos Aires_Quel	Eduardo Quel	-34.55	-58.50	15	355, 532, 1064 nm backscatter lidar (300 m-10 km), a Raman lidar observing backscatter at 308, a Raman N2 channel at 332 nm, and a sunphotometer.
Buenos Aires_Lavorato	Mario Lavorato	-34.6	-58.5	15	532 nm with polarization, 1064 nm backscatter lidar (70 m-22 km, 20 s time resolution), radiosonde, and an Aeronet sunphotometer.
City U. of Hong Kong	Andrew Cheng	22.34	114.17	44	532 nm lidar, 0.1-8 km range (7.5m resolution), 1 min. time resolution. Also similar mobile lidar with 5-15 min. time resolution. Sunphotometer is also available at the stationary location.
Davis Station	Andrew Klekociuk	-68.58	77.97		532 nm HSRL with polarization minimum altitude at 5-20 km
Dome-C	Vito Vitale	-75.10	123.29	3200	532 nm w/polarization, 1064 nm lidar, sunphotometer

Hohenheim, Germany	Andreas Behrendt	48.7	9.2		532 nm and 1064 nm Backscatter Lidar (3m and 0.03 s resolution, day/night) and 355 nm Raman Lidar (0.03 s resolution)
Jabiru	Ross Mitchell	-12.66	132.8	30	sunphotometer
Kototabang, Indonesia	Chikao Nagasawa	-0.2	100.3		532 nm Raman Lidar with depolarization (100m resolution)
Lake Argyle	Ross Mitchell	-16.11	128.75	150	sunphotometer
Ny Alesund	Cristoph Ritter	78.92	11.93	7	355, 387, 407, 532 w/depolarization, 607, 1064 nm Raman Lidar, and sunphotometer
Potenza, Italy	Paolo Di Girolamo	40.64	15.85	770	Raman Lidar 355 nm with polarization, 387, 532 nm (0-30 km)
Pune, India	Panuganti Devara	18.53	73.85	559	514.5 nm lidar with depolarization, sunphotometer
Qingdao, China	Xiaoquan Song	36.07	120.33		Micro Pulse Lidar at 532 nm 1 hour time resolution
Quebec, Canada	Luc Bissonnette	46.88	-71.47		532 and 1064 nm backscatter lidar with polarization (0.2-3 km range) measuring mainly lower cloud properties.
Quito	Alan Robock	0.00			lidar
Rio Gallegos	Eduardo Quel	-51.92	-69.23	0	355, 532, 1064 nm backscatter lidar and sunphotometer. Also water vapor and ozone lidar.
Rome, Italy	Gian Paolo Gobbi	41.84	-12.65	130	532 nm backscatter lidar with polarization (0.2-14 km day range, 0.2-20 km night range, 6 min. resolution) and CIMEL sunphotometer.
Sao Paulo	Eduardo Landulfo	-23.56	-46.74		532 nm lidar (0-30 km night range, 0-12 km day range), CIMEL sunphotometer
Shigaraki, Japan	Takuji Nakamura	34.9	136.1		532 nm Raman lidar (9 m 10 s resolution night only, backscatter data products day/night)
Tinga Tingana	Ross Mitchell	-28.98	139.99	50	sunphotometer
Trivandrum, India	M Satyanarayana	8.55	76.96	6	355, 532 w/depolarization, 1064 nm lidar. Can also run Raman channels.
Zanjan, Iran	Hamid Khalesifard	36.67	48.48		532 nm backscatter lidar
NOAA/ETL	Janet Intrieri	Mobile			523 nm lidar with polarization
Natal, Brazil	James Rosen				backscattersondes
Cruises in the northern part of the Atlantic Ocean, and campaigns on Svalbard (Spitsbergen)	Michael Kahnert and Jakob Stamnes				Cloud Particle Imager on a tethered balloon

4. Coverage of Various Aerosol and Cloud Regions

When the distance between the CALIPSO ground-track and a ground site is within a threshold distance that event is called a coincident observation. Section 7.2 in the appendix shows a table of the expected number of coincident observations during 16 days of orbits for validation sites at every 10 degrees of latitude for several separation distances between the CALIPSO ground-track and a validation site. For the validation network to be effective, however, it must cover various different aerosol and cloud regions. Validation of aerosol and cloud parameters should be distributed to allow validation of these parameters for a variety of aerosol and cloud types.

4.1 Aerosols

Aerosol types and the sites that observe those types are included in Table 10. Height, thickness, and optical depth have complete coverage of all aerosol types. Extinction profiles and the information needed to calculate the extinction-to-backscatter ratio do not have nearly as many sites. However, the coverage is similar to the height/thickness parameter with the exception of the lack of any sites in China for the extinction coefficient and S_a.

Table 10: Aerosol types and regions and the sites that sample those aerosols

Aerosol Type	Height/Thickness	τ_a	σ_a	S_a
Urban/polluted				
Eastern U.S.	Several REALM sites, COVE	Several Aeronet sites Several MFRSR sites	GSFC, UMBC	GSFC, UMBC
Central Europe	Several Earlinet, IPSL, and NDSC sites, Rome, Potenza	Several Aeronet sites Several BSRN sites Several Earlinet sites, Haute Provence, Palaiseau	Several Earlinet sites, Haute Provence, Palaiseau	Several Earlinet sites, Haute Provence Palaiseau
China	Several AD-NET sites, Hong Kong, Qingdao	Several Aeronet sites, Hong Kong	Hong Kong	Hong Kong
India/Indian Ocean	Pune, Reunion Island, Maldives	Male, Kanpur, Pune, Reunion Island	Pune, Reunion Island	Pune, Reunion Island
Biomass burning				
South America	Buenos Aires, Sao Paulo	Several Aeronet Sites	Buenos Aires	Buenos Aires
Southern Africa	Reunion Island	Several Aeronet Sites	Reunion Island	Reunion Island
Indonesia	Darwin, Kototabang	Darwin, Kototabang	Darwin, Kototabang	Darwin, Kototabang
Desert dust				
Saharan	Several Earlinet sites, Dakar	Dakar, Several Earlinet Sites	Several Earlinet sites	Several Earlinet Sites
Asian	Several AD-Net sites, Hong Kong, Qingdao	Several Aeronet sites	Gwangju, Tokyo, Tsukuba	Gwangju, Tokyo, Tsukuba
Polluted marine (sea salt, sulfate, soot)	Aberystwyth, COVE, Lisbon, Napoli, Okinawa, Palaiseau, Rome, Monterey	COVE, Okinawa, Palaiseau	Aberystwyth, Palaiseau	Palaiseau
Dusty marine (sea salt, sulfate, dust)	Napoli, Suwon, Nagasaki, Dakar	Azores, Capo Verde, Bermuda	Suwon	Suwon
Clean Continental	SGP, Haute Provence	Several Aeronet Sites Several ARM sites, Haute Provence	SGP, Haute Provence	SGP, Haute Provence
Clean Marine (sea salt)	American Samoa, Manus, Nauru, Mauna Loa, Barbados, Maldives	Manus, Nauru, Hilo, Mauna Loa, Tahiti, Kwajalein, Roosevelt Roads	Manus, Nauru, Mauna Loa	Manus, Nauru, Mauna Loa

Arctic haze	Andoya, Barrow, Ny Alesund	Andoya, Barrow, Atqasuk, Ny Alesund	Andoya, Barrow, Ny Alesund	Andoya, Barrow, Ny Alesund

4.2 Clouds

Cloud types and the sites that observe those types are included in Table 11. The height/thickness parameter has sites for all cloud types and the phase parameter is missing only tropical cloudy and Mediterranean sites. The coverage for S_c, τ_c, and σ_c are not as good as the coverage for aerosols because the sites with sunphotometers can no longer be used to measure or constrain the calculation of these parameters for clouds. Only twelve sites can validate τ_c and $\sigma_{c,}$ and only nine sites can validate S_c.

Table 11: Cloud types and the sites that sample those clouds

Cloud Type	Height/Thickness	τ_c and σ_c	S_c	Phase
Tropical cloudy	American Samoa, Barbados, Dakar, Darwin, Kototabang, Maldives, Manus, Nauru	Kototabang	Kototabang	Kototabang
Desert marine	Dakar, Suwon, Nagasaki			Suwon, Nagasaki
Subtropical • land • ocean	 Gwangju, Hefei, Sri Samrong, Mauna Loa, Reunion Island	 Gwangju Reunion Island	 Gwangju Reunion Island	 Gwangju, Hefei, Sri Samrong Reunion Island
Mediterranean	Several EARLINET sites, Haute Provence, Rome	Potenza	Potenza	Potenza
Mid to high latitude • land • ocean	 Several AD-Net sites, SGP, Several CIS-LiNET sites, Several EARLINET sites, Several NDSC sites, Several REALM sites Aberystwyth, Cove, Suwon, Lisbon	 Cabauw, Kuhlungsborn, Leipzig, Teplokluchenka, Tomsk Aberystwyth	 Cabauw, Kuhlungsborn, Leipzig, Teplokluchenka, Tomsk Aberystwyth	 Several AD-NET sites, Several EARLINET sites, Minsk, Tomsk Suwon
Polar troposphere • Antarctic • Arctic	 Dome Concordia, Dumont d' Urville, McMurdo, Syowa Andoya, Barrow, Ny Alesund	 Dumont d' Urville Andoya, Barrow	 Dumont d' Urville Andoya, Barrow	 Dome Concordia, Dumont d' Urville Andoya, Barrow
PSCs • Antarctic	 Davis Station, Dome Concordia, Dumont d'	 Davis Station, Dumont d' Urville	 Davis Station, Dumont	 Davis Station, Dome

	Urville, McMurdo, Syowa		d'Urville	Concordia, Dumont d'Urville
• Arctic	Barrow, Several NDSC sites	Andoya, Barrow	Andoya, Barrow	Andoya, Poker Flats

5. Implementation

Dr. Thomas A. Kovacs will lead the CALIPSO QPQ validation effort with support from Dr. M. Patrick McCormick (CALIPSO Co-Principal Investigator). The CALIPSO QPQ validation implementation team will work closely with the CALIPSO mission validation team led by Dr. Charles R. Trepte of NASA LaRC to make sure that the QPQ activities are consistent and collaborative with the overall mission validation. Dr. Kovacs will serve as the point of contact for coordination of the QPQ validation sites. He will also obtain, transfer, and catalog all data from these sites for validation studies, and provide data storage for validation sites without accessible storage and for data requested by the CALIPSO PI.

A schedule of the milestones for implementing the QPQ validation plan is given below. A protocol for the free exchange of data will be included in a follow-up letter to responders to the QPQ validation announcement letters and is included in the appendix in Section 7.3.

5.1 The QPQ validation milestones

2001
Submitted QPQ validation plan draft - Oct.

2002
Submitted final draft of the QPQ validation plan - June
Sent QPQ validation announcement letter – June
Set up initial QPQ validation website at http://calipsovalidation.hamptonu.edu – October

2003
Complete coincident statistics for main sites - July
Data exchange protocols developed for approval - November

2004
Order server and QPQ validation storage media - March
Send follow up letters to announcement responders - April

2005
Set up ftp server web site, data storage, and catalog in coordination with LaRC ≥ L - 4 months
Send out password access to the data catalog ≥ L - 4 months
Store selected data, update data catalog, and continue validation studies - Post launch
Continue communication of coincidence and orbital path with QPQ validation
sites and campaigns - Post launch
Validation data should begin to be gathered - L + 40 days
Obtain level IIa validation data for preliminary data validation ≤ L + 135 days

Complete preliminary validation studies on level IIa data within the first 135 days of launch ≤ L + 135 days
Workshop on Level 1 and Level 2a data products approximately L + 4 months

2006
Workshop on comprehensive data comparison approximately L + 15 months

5.2 Communications with Sites

In 2003, coincident statistics were completed for all interested sites and networks. NASA LaRC will propagate the latest CALIPSO orbital predicts for 16 days using STK and supply HU with the coincident statistics for the QPQ validation sites that HU will provide. These statistics will be uploaded to the QPQ validation website weekly after launch and is available on the QPQ validation website. The data exchange protocol (Section 7.3) is complete and uploaded to the same website. A follow-up letter was sent to provide the interested sites with important information related to the QPQ validation plan and to verify and gather further information including: type of instruments, calibration protocol, archival protocol, observational protocol (times, altitudes, etc.), and aerosol types typically observed at each site that the point of contact manages. In order to keep the communication to a manageable level only top-level network administrators will be contacted for networked sites.

5.3 Data Exchange, Storage, and Handling

The data storage system will be procured and set up at Hampton University. This storage system will involve and require a server/workstation, archival tapes, and a data manager specialist. The workstation/server will be set up as an ftp server to obtain and disseminate data and will need software for validation data analysis. The ftp server will be accessible to the CALIPSO science team, the QPQ validation implementation team, and the PIs of the validation sites for as long as the PI requests. Sites that utilize a network data archive will be expected to update the validation implementation team on the availability of data of interest to the CALIPSO science and validation implementation teams. These network websites must provide adequate data access for the CALIPSO science and validation implementation teams. A listing of these 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, etc. The data catalog will update data available at these sites and from the HU server so that any interested investigator knows what data are available for validation. The data providers will supply this information each time they upload CALIPSO validation data to a data archive. Any network that does not have an existing archive must upload their data to HU's data storage to insure that all interested parties have access to validation data when needed.

The data manager specialist is responsible for making sure that data provided by a validation site is readable and conforms to any prearranged data format. This person will then put the data onto an ftp site where the science and validation implementation teams and the individual data PIs will have read-only access via a password. If data do not conform to the prearranged data format, decided by the validation implementation team, it will be stored in a separate folder. It is up to the data providers to periodically check that their data are being placed in the correct folder. For security purposes anybody who wants to upload or download data must supply an IP address for the machine that they will use to transfer the data. The data manager will move data to an archive tape when the ftp site becomes full and replace data on the ftp site for a short period of time when requests for archived data are received. This person will also backup the data and insure the data are secure from outside manipulation.

In 2005, the ftp server web site, data storage, and catalog in coordination with LaRC will be set-up and fully tested before launch. All data exchange protocols will be agreed upon and signed electronically when a validation team member logs into the data catalog. Orbital predicts and coincident statistics will be updated on the website on a regular basis, a month or so before launch, then routinely after launch at reasonable intervals. These statistics will provide sites with times of satellite overpasses. The orbital predicts will provide mobile sites with locations and times of the CALIPSO overpasses so that they may plan to position their instruments appropriately. Also, we will attempt to involve new sites as they become available/discovered, tempered with needs and our judgment of quality.

Storing of validation data will begin at the request of the CALIPSO PI. During the first 135 days after launch, studies will be performed to preliminarily validate level 2a data before the data are released to the public. QPQ validation is critical at this time as it may be the only source of validation data. Sites identified by the science and validation implementation teams will be contacted to arrange for a timely data exchange within a short time after observations are made.

If at any time during the validation period, an event deemed significant by the CALIPSO science team, such as a volcanic eruption, should take place, the QPQ validation program will be critical in validating the calibration and algorithms for the CALIPSO mission. For example, during a major volcanic eruption, sites that monitor the stratosphere will become especially important and validation studies with these sites will take priority. For an eruption that causes the atmosphere to become optically thick, special care will be given to increased errors in the tropospheric aerosol measurements due to transmission losses. Calibration, which is done by normalization with a clear region of the stratosphere could be affected if aerosols reach altitudes used for normalization by CALIPSO. Ground based measurements will be used to monitor the aerosol loading in these assumed clear regions.

After launch the HU validation implementation team will begin conducting validation studies consistent with the approach described in Section 2.1 and the data exchange protocol. In the first 135 days after launch, HU will assist in conducting preliminary validation studies. Because of HU's involvement and expertise in stratospheric aerosol and cloud studies, validation studies in this area will be a focus and will involve a graduate student. HU will also be involved in validation studies during significant events as describe above because of their involvement in coordinating validation sites during these events. Other studies will be initiated as the QPQ validation program matures.

6. References

Hogan, R. J., and A. J. Illingworth, "Deriving cloud overlap statistics from radar, *Quart. J. Roy. Meteorol. Soc.*, **126**(569A)**,** 2903-2909 (2000).

Mishchenko, M., L. Travis, and A. Macke, “Scattering of light by polydisperse, randomly oriented, finite circular cylinders”, *Applied Optics*, **35,** 4927-4940 (1996).

7. Appendix

7.1 Latitude, Longitude, and Altitude of all QPQ validation sites. Sites are listed under each network. Some sites are listed under multiple networks.

AD-Net

Station Name	Lat.	Long.	Alt.
Beijing	39.90	116.30	100
CheJu	33.00	126.00	*
Chung-Li	25.00	121.00	*
Fukue	32.63	128.83	*
Fukuyama	34.47	133.23	*
Gwangju	35.10	126.53	*
Hedo	26.90	128.30	*
Hefei	31.90	117.16	*
Hohhot	40.94	111.37	*
Miyakojima	24.70	125.30	*
Nagasaki	32.78	129.86	*
Nagoya	35.10	137.00	*
Okayama	34.41	133.57	*
Sapporo	43.10	141.30	*
Sri_Samrong	17.15	99.95	*
Suwon	37.14	127.04	*
Tokyo	35.66	139.80	*
Toyama	36.70	137.10	*
Tsukuba	36.05	140.12	*

Aeronet

Station Name	Lat.	Long.	Alt.
Abracos	-10.75	-62.35	200
Aguascalientes	21.70	-102.32	2000
Aguas_Emendadas	-15.58	-47.66	1100
Aire_Adour	43.70	0.25	80
Albuquerque	35.05	-106.54	1645
Al_Dhafra	24.25	54.53	40
Alta_Floresta	-9.92	-56.02	175
Andros_Island	24.70	-77.80	0
Angiola	35.93	-119.53	210
Anmyon	36.52	126.32	47
Arica	-18.46	-70.30	25
Ariquiums	-9.92	-63.03	80
Ascension_Island	-7.97	-14.40	30
Avignon	43.91	4.86	32
Azores	38.53	-28.62	50
Babina	-1.91	-59.48	80
Bahrain	26.31	50.50	0
Banizoumbou	13.53	2.65	250
Barbados	13.17	-59.50	0

ARM

Station Name	Lat.	Long.	Alt.
Ashton_KS	37.13	-97.27	*
Atqasuk_AK	70.47	-157.41	*
Barrow_AK	71.27	-156.83	*
Byron_OK	36.88	-98.29	*
Christmas_Island	1.87	-157.33	*
Coldwater_KS	37.33	-99.31	*
Cordell_OK	35.35	-98.98	*
Cyril_OK	34.88	-98.21	*
Darwin	-12.46	130.93	*
El_Reno_OK	35.56	-98.02	*
Elk_Falls_KS	37.38	-96.18	*
Halstead_KS	38.11	-97.51	*
Hillsboro_KS	38.31	-97.30	*
Lamont_OK_ARM	36.61	-97.49	*
Larned_KS	38.20	-99.32	*
LeRoy_KS	38.20	-95.60	*
Manus	-2.06	147.43	*
Meeker_OK	35.56	-96.99	*
Morris_OK	35.69	-95.86	*
Nauru_ARM	-0.52	166.90	*
Okmulgee_OK	35.62	-96.07	*
Pawhuska_OK	36.84	-96.43	*
Plevna_OK	37.95	-98.33	*
Ringwood_OK	36.43	-98.28	*
Seminole_OK	35.25	-96.74	*
Southern_Great_Plains	36.60	-97.50	*
Towanda_KS	37.84	-97.02	*
Tyro_KS	37.07	-95.79	*
Vici_OK	36.06	-99.13	*

BSRN

Station Name	Lat.	Long.	Alt.
Alice_Springs_Australia	-23.70	133.87	547
Bermuda_BSRN	32.37	-64.33	8
Billings_ARM_CART	36.60	-97.49	317
Carpetras_France	44.05	5.05	100
Florianapolis_Brazil	-27.58	-48.48	11
Ibrin_Nigeria	8.53	4.57	350
Kwajalein_Marshall_Islan	8.72	167.73	10
Lindenberg_Germany	52.22	14.12	125
Ny_Alesund_BSRN	78.93	11.93	11

Barrow	71.31	-156.67	0
Barnaul	53.00	83.00	0
Beijing	39.78	116.58	100
Belterra	-2.63	-54.95	70
Ben_McDhui	-30.71	27.62	2450
Bermuda_Aeronet	32.37	-64.68	10
Bethlehem	-28.25	28.33	1709
Biarritz	43.48	-1.55	0
Big_Meadows	38.52	-78.44	1082
Billerica	42.52	-71.25	0
Bonanza_Creek	64.73	-148.30	150
Bondoukoui	11.85	-3.75	0
Bondville	40.05	-88.37	212
Bordeaux	44.78	-0.57	40
Bragansa	-0.83	-46.63	55
Brasilia	-15.92	-47.90	1100
Bratts_Lake	50.26	-104.70	586
BSRN_BAO_Boulder	40.03	-105.00	1604
Bucarest	44.45	26.52	44
Buena_Vista	35.22	-119.26	0
Burtonsville	39.10	-76.94	50
Campo_Grande	-20.45	-54.62	500
Capoverde	16.72	-22.93	60
Carlsbad	32.37	-104.23	942
Cartel	45.37	-71.92	300
Cart_Site	36.60	-97.40	315
CCNY	0.05	-73.95	100
CEILAP_BA	-34.57	-58.50	10
Che_Ju	33.00	126.00	0
Chequamegon	45.92	-90.25	0
China_Lake	35.67	-117.75	800
Chinhae	35.16	128.65	69
Churchill	58.73	-93.82	10
Clermont_Ferrand	45.76	2.96	1464
Cocunut_Island	21.41	-157.78	0
Coleambally	-34.81	146.06	127
Columbia_SC	34.02	-81.04	95
Concepcion	-16.13	-62.02	500
Cordoba_CETT	-31.52	-64.45	730
COVE	36.88	-75.70	0
Creteil	48.78	2.43	57
CUIABA_MIRANDA	-15.72	-56.02	210
Dahkla	23.72	-15.95	12
Dakar_Aeronet	14.38	-16.95	0
Dalanzadgad	43.57	104.42	1470
Davos	46.80	9.83	1596
Dead_Horse	69.43	-148.70	332
Dharwar	15.43	74.99	700
Dongsha_Island	20.70	116.07	5
Dry_Tortugas	24.60	-82.78	0

Payerne_Switz	46.82	6.93	491
Regina_CA	50.20	-104.28	578
Syowa_Base_Antarctica	-69.00	39.58	18
Taterno_Japan	36.05	140.13	25
Toravere_Obs_Estonia	58.33	26.47	70
VonNeumayer_Antarctica	-70.65	-8.25	42

CIS-LiNet

Minsk	53.90	27.38	*
Moscow	55.00	37.00	*
Sergut	61.2	73.5	*
Teplokluchenka	42.50	78.40	*
Tomsk	56.50	85.00	*
Vladivostok	43.00	131.90	*
Yakutsk	61.40	129.30	*

CMDL

American_Samoa	-14.23	170.56	*
Boulder_Colorado	40.03	-105.00	1604
Mauna_Loa_Observatory	19.54	-155.58	3397

EARLINET

Athens	37.90	23.60	111
Barcelona	41.39	2.12	*
Belsk	51.80	20.80	190
Bilthoven	52.12	5.20	5
Cabauw	51.97	4.93	1
Garmisch	47.60	11.06	730
Granada	37.16	-3.60	680
Hamburg	53.57	9.97	*
Haute Provence	43.93	5..70	590
Jungfraujoch	46.55	7.98	3580
LAquila_Italy	42.35	13.38	683
Leece_Italy	40.33	18.10	*
Leipzig	51.35	12.43	*
Madrid	40.27	-3.43	*
Minsk_Belarus	53.92	27.60	*
Munich	48.15	11.57	*
Napoli	40.83	14.30	118
Neuchatel_Switzerland	47.00	6.96	487
Palaiseau_France	48.60	2.20	*
Potenza_Italy	40.60	15.73	760
Sofia	42.65	23.38	550
Thessaloniki	40.60	22.97	60

IPSL Lidar Network

Dunhuang	40.03	94.68	1300
Egbert	44.21	-79.75	264
El_Arenosillo	37.10	-6.70	0
El_Refugio	-14.77	-62.03	225
Eopace	36.18	-75.75	0
ETOSHA_PAN	-19.17	15.90	1131
Flin_Flon	54.67	-101.69	305
Gaithersburg	39.13	-77.28	50
Goa_India	15.45	73.81	20
Gerlitzen	46.66	13.90	1900
GISS	40.78	-73.95	50
Gotland	57.92	18.93	10
GSFC	39.02	-76.87	50
Guadeloup	16.32	-61.50	0
Harvard_Forest	42.53	-72.19	322
Hamburg	53.57	9.97	105
Helgoland	54.17	7.88	33
Hermosillo	29.08	-110.96	237
HJ_Andrews	44.23	-122.22	830
Homburi	15.32	1.53	0
Howland	45.20	-68.72	100
IFT_Leipzig	51.35	12.43	125
Ilorin	8.32	4.33	350
IMC_Oristano	39.90	8.50	10
IMS_METU_ERDEM	36.55	34.25	0
Inhaca	-26.04	32.91	73
Inner_Mongolia	42.66	115.95	1343
Ispra	45.80	8.62	235
Izana	28.30	-16.50	2367
Jabiru	-12.66	132.89	30
Jamari	-8.63	-62.75	100
Joberg	-26.19	28.03	1736
JonesERC	31.23	-84.47	50
Jornada	32.35	-106.52	1288
Jug_Bay	38.77	-76.78	10
Kaashidhoo	4.97	73.47	0
Kanpur	26.43	80.33	142
Kaomi	-14.78	24.78	1179
Kasama	-10.17	31.18	1300
Katibougou	12.92	-7.53	0
Kejimkujik	44.38	-65.28	154
Kolfield	39.80	-74.48	50
KONZA_EDC	39.10	-96.60	457
Krasnogarsk	56.00	93.00	0
La_Jolla	32.50	-117.15	0
Lake_Argyle	-16.11	128.75	150
La_Paguera	17.96	-67.03	0
Latoya	-15.68	23.30	1064
Lampedusa	35.52	12.62	45
Lanai	20.82	-156.98	80

Andoya	69.30	16.00	360
Dumont d'Urville	-66.67	140.01	20
Haute Provence	43.94	5.71	590
La Reunion Island	-21.80	55.50	*
Palaiseau	48.42	2.16	*

MPLNET

Barbados	13.17	-59.50	0
COVE	36.90	-75.71	0
Dakar	14.39	-16.96	0
GSFC	39.02	-76.87	50
Maldives	4.97	73.47	0
Moneterey	36.80	-121.79	0
Ny_alesund	78.93	11.93	11
Syowa	-69.00	39.58	18

NDSC

Alert	82.50	-62.30	*
Andoya	69.30	16.00	360
Arkhar	64.60	40.50	*
Dumont_d_Urville	-66.67	140.01	20
Garmisch	47.48	11.06	734
GSFC	38.90	-76.70	50
Haute_Provence	43.94	5.71	*
Heiss	80.60	58.10	*
Kiruna	67.84	20.41	419
Laramie	41.30	-105.60	*
Lauder	-45.05	169.68	370
Mauna_Loa	19.54	-155.58	3397
McMurdo	-77.85	166.63	10
Ny_Alesund	78.92	11.93	15
Okinawa	26.00	128.00	*
Poker_Flats	65.00	-147.00	*
Resolute	74.20	-95.00	*
Reunion_Island	-21.80	55.50	*
Salekhard	67.50	67.50	419
Scoresbysund	70.48	-21.97	10
Sodankyla	67.37	26.65	100
Sondrestromfjord	67.02	-50.72	180
Suwon	37.20	127.60	150
Table_Mountain	34.40	-117.70	2300
Thule	76.53	-68.74	30
Toronto	43.80	-79.50	*
Yakutsk	62.00	130.90	*

REALM

CCNY	40.82	-73.95	*

Lan_Yu_Island	22.03	121.55	348
Lille	50.60	3.13	60
Lochiel	49.03	-122.60	0
Los_Fieros	-14.56	-60.93	170
Lunar_Lake	38.38	-115.98	1908
Lydenburg	-24.57	30.77	1186
Madison	43.07	-89.41	326
MALE	4.18	73.52	2
Mammoth_Lake	37.62	-119.03	2930
Maricopa	33.07	-111.97	0
Marina	36.81	-121.81	15
Marseille	43.27	5.37	100
Mauna_Loa	19.53	-155.57	3397
Maun_Tower	-19.90	23.55	940
McMurdo	-77.63	162.88	75
MD_Science_Center	39.27	-76.62	15
Mexico_City	19.33	-99.17	2268
Miami	25.75	-80.20	0
Midway_Island	28.20	-177.37	0
MISR_JPL	34.25	-118.25	450
Missoula	46.91	-114.06	1028
Modena	44.63	10.95	56
Moldova	47.02	28.75	0
Monclova	25.95	-101.47	600
Mongu	-15.25	23.15	1107
Monterey	36.80	-121.79	0
Mont_Joli	48.63	-68.15	30
Moscow_MSU_MO	55.70	37.51	50
MPI_Mainz	49.99	8.24	147
Munich_University	48.57	11.57	533
Mwinilunga	-11.74	24.43	1430
Nauru_Aeronet	-0.52	166.90	7
NCU_Taiwan	24.88	121.08	0
Ndola	-13.00	28.66	1270
Nes_Ziona	31.92	34.78	40
New_York	40.77	-74.00	0
Niabrara	42.77	-100.02	730
North_Slope	69.63	-148.67	100
Noto	37.33	137.13	200
NSA_YJP_Boreas	55.90	-98.29	290
OceolaNF	30.21	-82.44	0
OkefenokeeNWR	30.74	-82.13	0
Okinawa	26.35	127.77	46
Oostende	51.22	2.92	30
Orizaba	19.10	-97.32	3246
Osaka	34.65	135.59	50
Ouagadougou	12.18	-1.38	29
Owens_Lake	36.49	-117.87	1167
Oyster	37.28	-75.92	8
Paddockwood	53.50	-105.50	503

Dalhousie_University	44.64	-63.59	*
Ground_Winds	44.10	-71.16	*
GSFC	38.99	-76.84	*
Hampton_University	37.02	-76.34	*
Howard_University	39.00	-77.00	*
MSC	44.23	-79.78	*
Penn_State	41.00	-78.00	*
UAH	34.72	-86.64	*
UMBC	39.25	-76.71	*

USDA

Alaska_Fairbanks	65.10	-147.40	510
Arizona_Flagstaff	36.10	-112.20	2037
California_Davis	38.50	-121.80	18
California_Holtville	32.80	-115.40	-18
Colorado_Nunn	40.80	-104.80	1641
Col_Steamboat_Spring	40.50	-106.70	3220
Florida_Homestead	25.40	-80.70	0
Georgia_Griffin	33.20	-84.40	270
Hawaii_Hilo	19.50	-155.60	3397
Illinois_Bondville	40.00	-88.40	213
Indiana_West_Lafayette	40.50	-87.00	216
Louisiana_Baton_Rouge	30.40	-91.20	7
Maryland_Beltsville	39.00	-77.00	34
Maryland_Queenstown	38.90	-76.10	7
Maine_Presque_Isle	46.70	-68.00	144
Michigan_Pellston	45.60	-84.70	238
Minnesota_Grand_Rapids	47.20	-93.50	394
Mississippi_Starkville	33.50	-88.80	85
Montana_Poplar	48.30	-105.10	634
Nebraska_Mead	41.10	-96.50	353
New_Mexico_Las_Cruces	32.60	-106.70	1317
New_York_Geneva	42.90	-77.00	218
Oklahoma_Billings	36.60	-97.50	317
Ontario_Toronto	43.80	-79.50	80
Saskatchewan_Regina	50.20	-104.70	580
Texas_Panther_Junction	29.10	-103.50	670
Utah_Logan	41.70	-111.90	1368
Vermont_Burlington	44.50	-72.90	408
Washington_Pullman	46.80	-117.20	804
Wisconsin_Dancy	44.70	-89.80	381

Individuals

Buenos_Aires	-34.55	-58.50	15
Davis_Station	-68.58	77.97	*
Dome_Concordia	-75.10	123.29	3200
Hong Kong	22.34	114.17	44
Jabiru	-12.66	132.89	30

Palaiseau	48.70	2.21	156
Paris	48.87	2.33	50
Penn_State_Univ	40.74	-78.08	401
Philadelphia	40.03	-75.00	20
Pic_du_midi	42.94	0.14	2898
Pietersburg	-23.88	29.45	1200
Porco_Nacional	-11.00	-48.00	210
Prince_Albert	53.20	-105.70	425
Puerto_Madryn	-42.78	-65.00	0
Railroad_Valley	38.50	-115.95	1435
Realtor	43.52	5.43	208
Rimrock	46.48	-116.98	824
Rio_Branco	-9.95	-67.86	0
Rochester	44.23	-77.59	0
Rogers_Dry_Lake	34.91	117.88	680
Rome_Tor_Vergata	41.83	12.63	130
Roosvelt_Roads	18.20	-65.60	10
Rottnest_Island	-32.00	115.28	40
Saclay	48.73	2.17	160
Sandy_Hook	40.45	-73.99	0
San_Nicolas	33.25	-119.48	133
Santa_Cruz	-17.25	-63.23	225
Santiago	-33.49	-70.72	510
Sao_Paulo	-23.55	-46.73	865
Saturn_Island	48.77	-123.12	200
SEDE_BOKER	30.52	34.47	480
Senanga	-16.11	23.29	1025
Seoul_SNU	37.45	126.95	116
SERC	38.87	-76.50	10
Sesheke	-17.48	24.30	951
Sevilleta	34.35	-106.88	1477
Shelton	50.75	-98.76	563
Shirahama	33.68	135.35	10
Sioux_Falls	43.73	-96.62	500
Skukuza	-24.98	31.58	150
SMHI	58.57	16.13	0
Solar_Village	24.90	46.40	650
Solwezi	-12.17	26.36	1333
Sopot	54.45	18.55	0
SSA_YJP_Borea	53.68	-104.65	490
Steamboat_Spring	40.40	-106.80	2120
Stennis	30.37	-89.62	20
St_John_Island	18.32	-64.73	0
Sua_Pan	-20.53	26.07	1100
Surinam	5.78	-55.20	0
Swakopmund	-22.66	14.56	250
Tabes_Etal	43.22	0.05	332
Table_Mountain	34.38	-117.68	2200
Tahiti	-17.56	-149.60	98
Tahoe_City	39.17	-120.14	1899

Kototabang	-0.20	100.30	*
Lake_Argyle	-16.11	128.75	150
NOAA_ETL	*	*	*
Ny Alesund	78.92	11.93	7
Potenza, Italy	40.65	15.81	770
Pune_India	18.53	73.85	559
Qingdao_ORSI	36.07	120.33	*
Quebec_Canada	46.88	-71.47	*
Quito	0.00	-78.60	*
Rio Gallegos	-51.92	-69.23	0
Rome_Tor_Vergata	41.84	12.65	130
Sao_Paulo	-23.56	-46.74	*
Tinga_Tingana	-28.98	139.99	50
Trivandrum_India	8.55	76.95	6
Zanjan	36.67	48.48	*

Tall_Tijmbers	30.66	-84.24	0
Tarbes	43.25	0.08	350
Tenerife	28.03	-16.63	10
THALA	35.53	8.67	1091
The_Hague	52.11	4.33	18
Thompson	55.78	-97.83	218
Tinga_Tingana	-28.98	139.99	38
Tombstone	31.74	-110.05	1408
Toulouse	43.56	1.36	150
Toronto	43.97	-79.47	300
Tucson	32.21	-110.95	779
Uberlandia	-19.90	-48.28	850
UCSB	34.42	-119.85	33
USDA	39.03	-76.88	50
Venise	45.30	12.50	10
Vinon	43.72	5.80	304
Walker_Branch	35.95	-84.28	365
Wallops	37.93	-75.47	10
Walvis_Bay	-22.66	14.56	250
Waskesiu	53.92	-106.07	550
Xiang_He	39.75	116.95	36
Yulin	38.27	109.72	1080
Zambezi	-13.53	23.11	1040

7.2 Expected number of coincident measurement opportunities during the 16 day repeating orbit of CALIPSO at each 10 degrees of latitude. Opportunities are given for separation distances of 10, 20, 40, 80, and 160 km between the CALIPSO ground-track and a validation site.

Latitude	10 km	20 km	40 km	80 km	160 km
0	0-2	0-2	0-2	0-2	3-4
10	0-2	0-2	0-2	2-3	4-5
20	0-2	0-2	0-2	2-3	4-5
30	0-2	0-2	0-2	2-4	4-5
40	0-2	0-2	0-2	2-4	4-6
50	0-2	0-2	1-2	2-4	6-8
60	0-2	0-2	2-3	4-6	8-10
70	0-2	0-2	2-4	5-7	10-14
80	2-3	3-6	6-12	13-24	24-58

7.3 Exchange Protocol for preliminary CALIPSO data

Protocol For Making CALIPSO Coincident Measurements

- Correlative measurements should be acquired as close as possible in time and location to the CALIPSO ground track.
- Correlative measurements should be located as close as possible in space and time to the CALIPSO overpass. Intercomparisons should include an assessment of spatial and temporal matching errors.
- Correlative measurements should be of comparable or superior accuracy and resolution to the CALIPSO measurements.
- The primary CALIPSO validation period begins approximately 45 days after launch and ends about 18 months after launch. All CALIPSO data is considered preliminary until it is released to the public.

Protocol For The Exchange Of Information And Data

- The CALIPSO QPQ validation team will consist of correlative measurement investigators that actively participate in the acquisition and interpretation of observations for validation studies.
- The CALIPSO QPQ validation implementation team will consist of those responsible for developing and implementing the QPQ validation program.
- Members of the CALIPSO science and QPQ validation implementation teams will have access to the QPQ correlative measurement database. These data will not be made available to persons outside of these teams during the validation period without the expressed approval of the QPQ Principal Investigator (PI) for the correlative data set. Likewise, CALIPSO data shall not be provided to persons other than those scientists that have supplied coincident data without the expressed approval of the CALIPSO PI.
- QPQ validation network PIs will have access to data products from the CALIPSO mission that are coincident with the validation data that have been made available for

comparison. The CALIPSO data will be distributed in segments of a half-orbit or less that overlap with the QPQ site.
- Predictions of overpass times for all QPQ validation network sites will be updated on the QPQ validation website (http://calipsovalidation.hamptonu.edu) once per week. The status of the CALIPSO satellite will also be available at this site.
- Members of the QPQ validation team should submit a "Request For CALIPSO Data" to the Atmospheric Sciences Data Center at http://eosweb.larc.nasa.gov and the appropriate coincident CALIPSO data products will be forwarded to the requestor.
- Members of the QPQ validation team without a data archive that is readily accessible to the CALIPSO science and validation implementation teams, should upload their data to Hampton University's QPQ data archive. These data should conform to the common data format specified by the QPQ validation coordinator. Data products submitted to this server can be updated by the QPQ validation team member as often as needed. The data will be considered as “Preliminary” until the CALIPSO team is notified that they are ready for public distribution.
- QPQ correlative measurement data set will be archived at a public facility following the validation phase of the mission. Data submitted to this public archive is voluntary.

Protocol For Publishing CALIPSO Data Comparisons

- The criteria for publication shall be the ability to make a definitive statement on the quality of the CALIPSO data products based upon comparisons between the QPQ validation network and CALIPSO data.
- Manuscripts that include observations from the QPQ validation network and CALIPSO for publication in peer-reviewed journals and conference proceedings shall include, as authors, scientists involved in the preparation of the measurements and their interpretation. The manuscript must be circulated to all co-authors for review and approval. PIs/Co-Is responsible for generating a measurement or a data product from a QPQ validation site shall be offered the right of co-authorship.
- Presentations of these data and findings in public meetings may be made subject to the approval of the coauthors.
- Publication of preliminary CALIPSO data products requires co-authorship with a CALIPSO Science Team member and approval of the CALIPSO PI and Co-PIs.