U.S. DEPARTMENT OF ENERGY | Office of Science

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Continuous Light Absorption Photometer (CLAP) Final Campaign Report

A Jefferson

May 2014

ARM CLIMATE RESEARCH FACILITY

DISCLAIMER

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Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
CLAP	Continuous Light Absorption Photometer
GMD	Global Monitoring Division
LED	light-emitting diodes
MAO	AMF Deployment, Manacapuru, Brazil
NOAA	National Oceanic and Atmospheric Administration
NSA	North Slope of Alaska
PAAS	photoacoustic absorption spectrometer
PGH	AMF Deployment, Ganges Valley, India
PSAP	particle soot absorption photometer
RH	relative humidity
SGP	Southern Great Plains
UTC	Coordinated Universal Time

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1.0 Introduction

The Continuous Light Absorption Photometer (CLAP) measures the aerosol absorption of radiation at three visible wavelengths; 461, 522 and 653 nanometers (nm). Data from this measurement is used in radiative forcing calculations, atmospheric heating rates, and as a prediction of the amount of equivalent black carbon in atmospheric aerosol and in models of aerosol semi-direct forcing. Aerosol absorption measurements are essential to modeling the energy balance of the atmosphere.

Current direct measurements of wavelength-dependent aerosol absorption include filter-based techniques such as CLAP, the aethelometer and particle soot absorption photometer (PSAP), and the in-situ, absorption of aerosols with the photoacoustic absorption spectrometer (PAAS). The laser instability, high noise as well as high cost of the PAAS make it difficult to deploy for long-term measurements. Filter-based absorption techniques are inexpensive, robust, and easy to operate, yet have known problems with secondary scattering and liquid aerosols spreading into the filter matrix.

The current PSAP and aethelometer measurements have problems with water condensation on the filter and ambiguous internal signal processing, which make them difficult to evaluate.

2.0 Background

The National Oceanic and Atmospheric Administration (NOAA) Global Monitoring Division (GMD) Aerosol Group designed CLAP to minimize known problems with filter-based absorption and optimize the data acquisition. Instead of one filter spot that needs daily or even hourly changing in high aerosol environments, the unit has a single large filter with 10 filter spots. Two of these spots are reference spots and the other eight spots are sample spots where aerosol deposits. Two reference spots are needed to account for slight changes in the pressure across the filter and filter matrix flexing when the instrument changes spots. Spot change is automated and changes when the light transmission through the filter is below 0.7. Filter changes involve a simple pressing of a red button on the outside of the instrument. The site tech changes the filter and presses the button again to signal the end of the filter change. The instrument automatically checks the light stability through the filter and normalizes the sample to the reference signal at the start of a new spot. Should the filter be placed upside down, or multiple filters are present in the holder, then the instrument issues a warning and flag. The entire CLAP optical block is heated to minimize noise and signal degradation associated with water and liquid aerosol condensing on the filter.

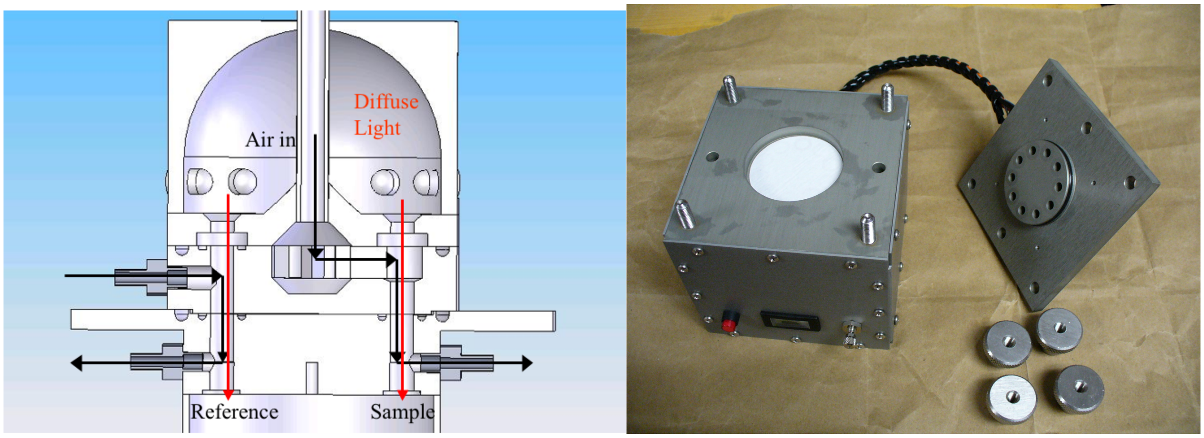


Figure 1. Above is a schematic of the instrument and photo.

CLAP signal collection is transparent with raw photon counts as well as processed signal in the output files.

Table 1. CLAP has five output data streams listed below.

Variable	**Description**
a	High frequency. Absorption, filter information, transmittance and sample length.
m	Low frequency. Additional filter information, intensities, flows and temperatures.
n	Triggered by spot change. Spot normalization factors.
w	Triggered by white filter. White filter parameters.
i	Instrument real time (1 second). Instantaneous intensity values.

A full list of CLAP variables and descriptions can be found at:
http://www.esrl.noaa.gov/gmd/aero/software/aerosols/cpd2variables.html#clap-3w.

The user has the ability to select the integration time of each individual wavelength, which is of use in aircraft deployments to optimize instrument signal/noise. The user could select to only measure the green wavelength or to measure green for twice as long as blue or red. CLAP output data stream was optimized for future signal processing using a radiative transfer model, which requires the one-second, instantaneous photon counts as input.

Each CLAP instrument has spot-size calibration using a high-pixel image. Each spot is measured digitally with a software imaging program. The wavelengths of the instrument light-emitting diodes (LEDs) are measured with a grating spectrometer and the instrument flow is calibrated by using a polynomial fit of the flow with a flow calibration device. The instrument is periodically leak-checked for leaks across each individual spot.

The filter substrate used in CLAP (PallFlex Membrane Filter E70-2075W) is the same filter type as used in the PSAP, except larger. Because of a similar filter substrate in both instruments, we assume that the Bond et al. (1999) corrections for aerosol scattering and transmission through the filter for the PSAP works as well for CLAP.

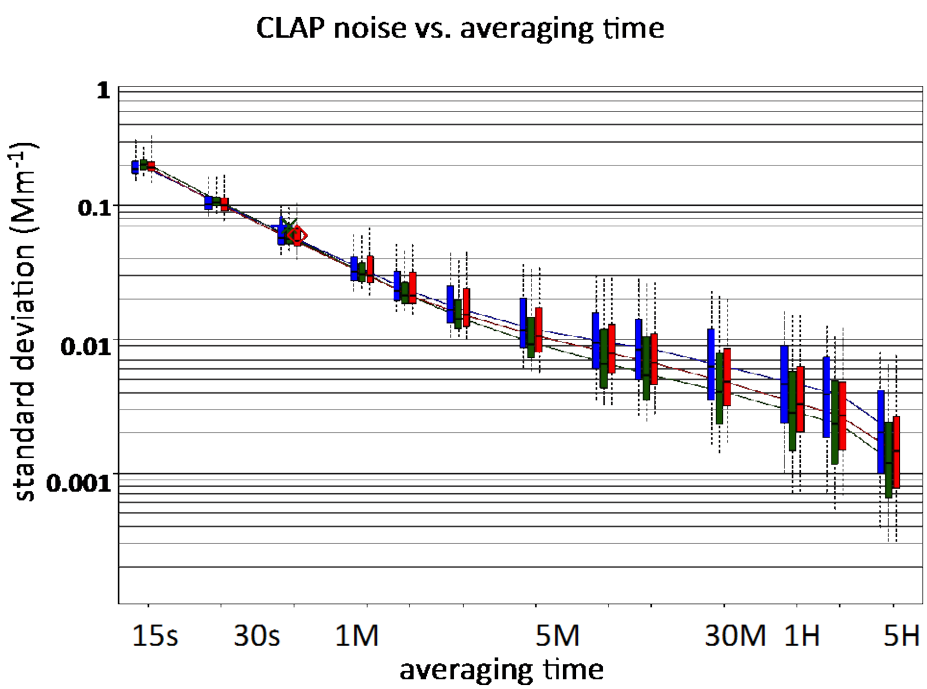


Figure 2. This figure shows an Allen plot showing the sensitivity of 194 CLAP detectors with signal integration time. The signal noise is about 0.1 Mm^{-1} after 30 seconds of averaging.

3.0 Preliminary Results

Data were collected from five sites: Southern Great Plains (SGP); North Slope of Alaska (NSA); Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF) Deployment, Ganges Valley, India (PGH); AMF Deployment, Cape Code National Seashore, North Truro, Massachussetts (PVC); and AMF Deployment Manacapuru, Brazil (MAO) for both the PSAP and CLAP instruments. For this review, both instruments were processed using the Bond et al. (1999) corrections for filter transmission and aerosol scattering from the filter surface. The largest difference between the two instruments is the percent data retrieval. When the PSAP filter falls below 0.7, the data is unusable until a filter change. For CLAP, the data is unusable when the transmission of the eighth spot falls below 0.7 until a filter change. Techs receive instructions to change CLAP filter if it is at spot #6 or higher on Fridays to prolong the data collection over the weekend. Below is a plot of CLAP and PSAP data from week 12 of 2014 at SGP. Times are Coordinating Universal Time (UTC). Data is missing from Sunday and Monday because the PSAP transmission fell below 0.7.

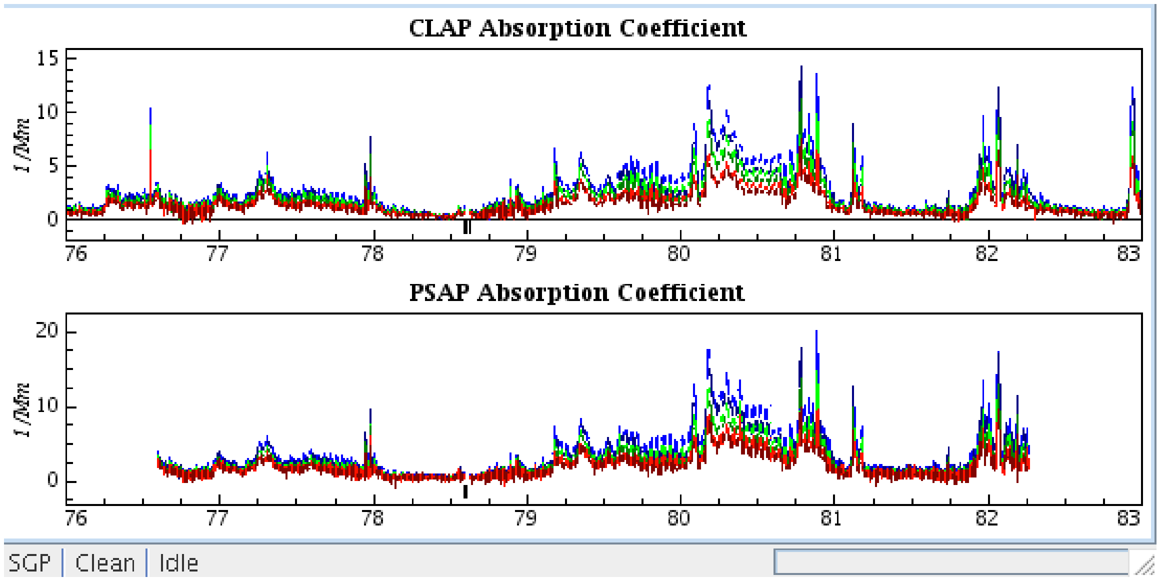


Figure 3.

The discrepancy between the two instruments' data retrieval is even more pronounced at a polluted site. Below are plots of CLAP and PSAP signal from week 11 of 2012 at PGH (Nainital, India).

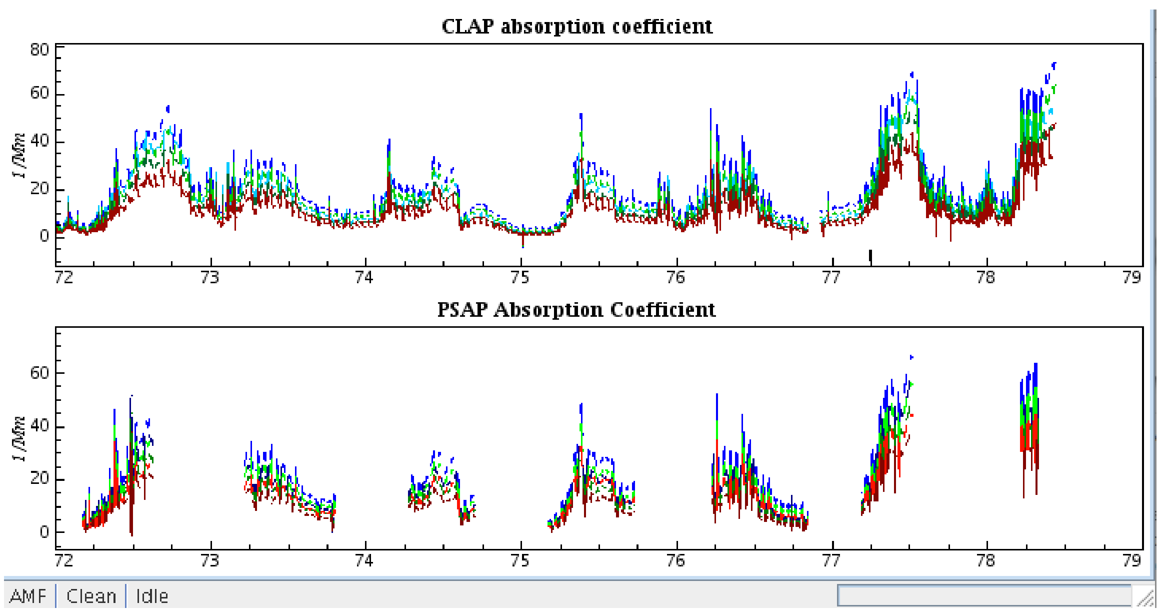


Figure 4.

Although the front of the PSAP is insulated and there is a nafion dryer on the instrument, inlet noise and signal degradation are apparent during periods with high ambient relativity humidity (RH). Sites like SGP that have a high ambient RH in the summer and large difference between the ambient air and inside trailer temperature are susceptible to water condensation on the filter substrate. CLAP is also affected by water condensation, but a heated optical block minimizes the noise. Below are plots of the raw CLAP and PSAP signals from SGP in July 2012. The periodic behavior of CLAP is from hourly zeros of the instrument with filtered air.

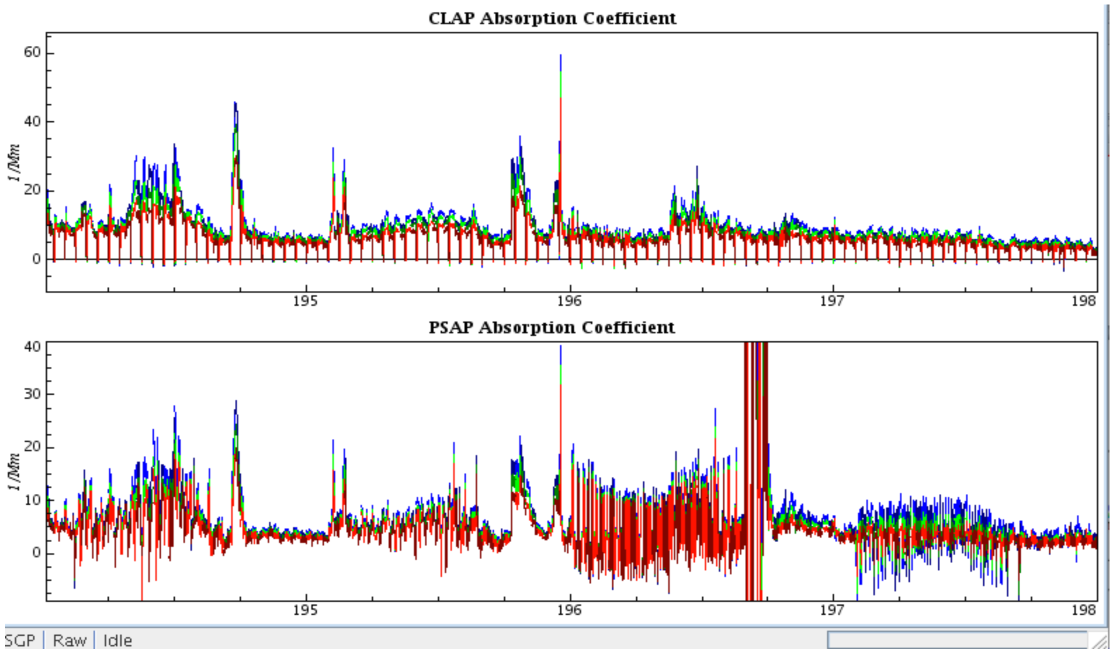


Figure 5.

Problems associated with water can and are mitigated by mixing dry, filtered air into the sample stream as is done at MAO (Manacapuru, Brazil). At SGP, this type of dilution can and likely will be done with the system reconfiguration. The dilution impacts all the instruments downstream of the sample inlet, which has the effect of reducing signal and increasing the S/N ratio.

Below are plots of CLAP vs. PSAP with several non-linear least square type of fits. The green line has the fit, with outliers subtracted, that uses a principle component analysis of the data. This is the most reliable fit routine to compare the two instruments. Data from the three AMF sites are presented below; PGH, PVC and MAO. Note that the MAO sample air stream is dried with dilution air.

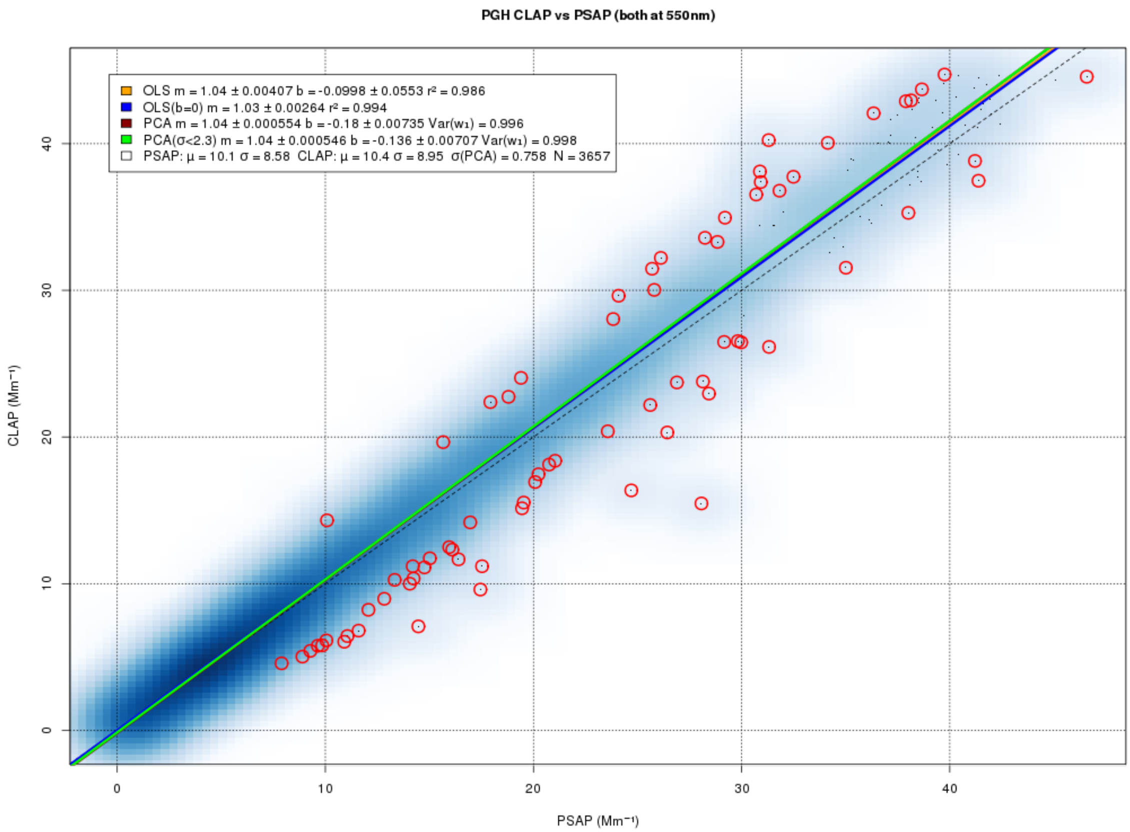


Figure 6.

PGH: Nainital, India June 10,2011 to March 25, 2012.

Slope: 1.04 Offset: -0.14

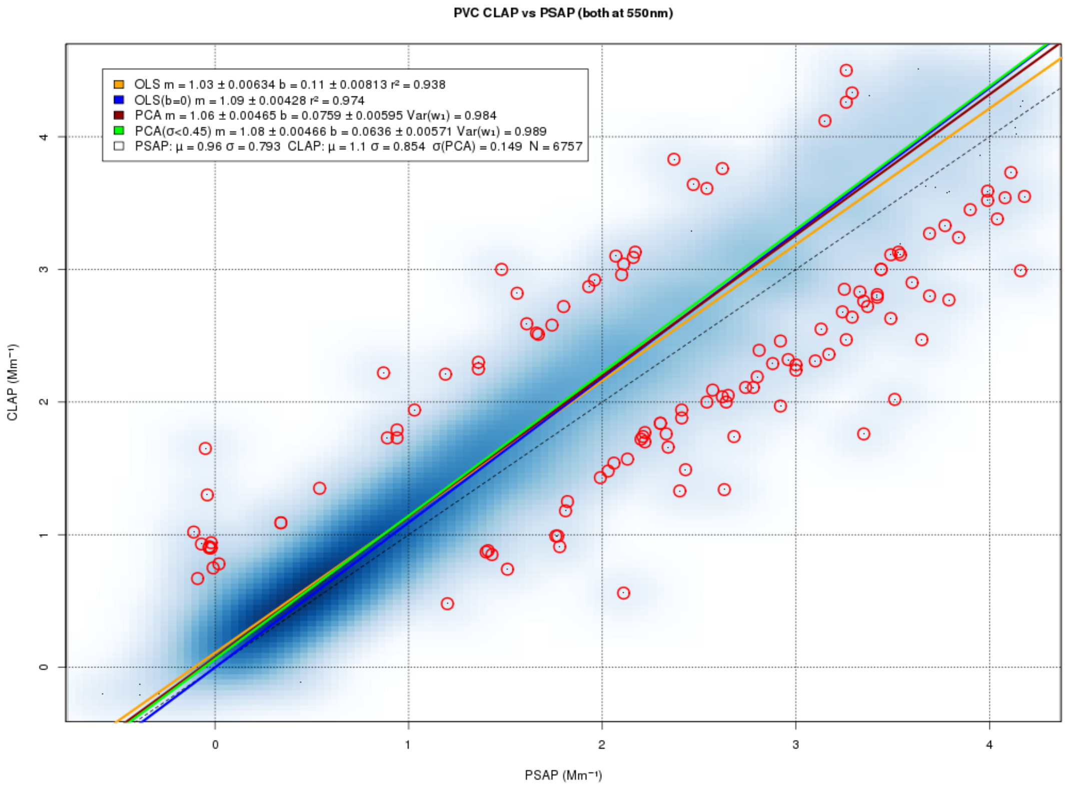


Figure 7.

PVC: Cape Cod, MA, USA July 17, 2012 to June 20, 2013

Slope: 1.08 Offset: 0.06

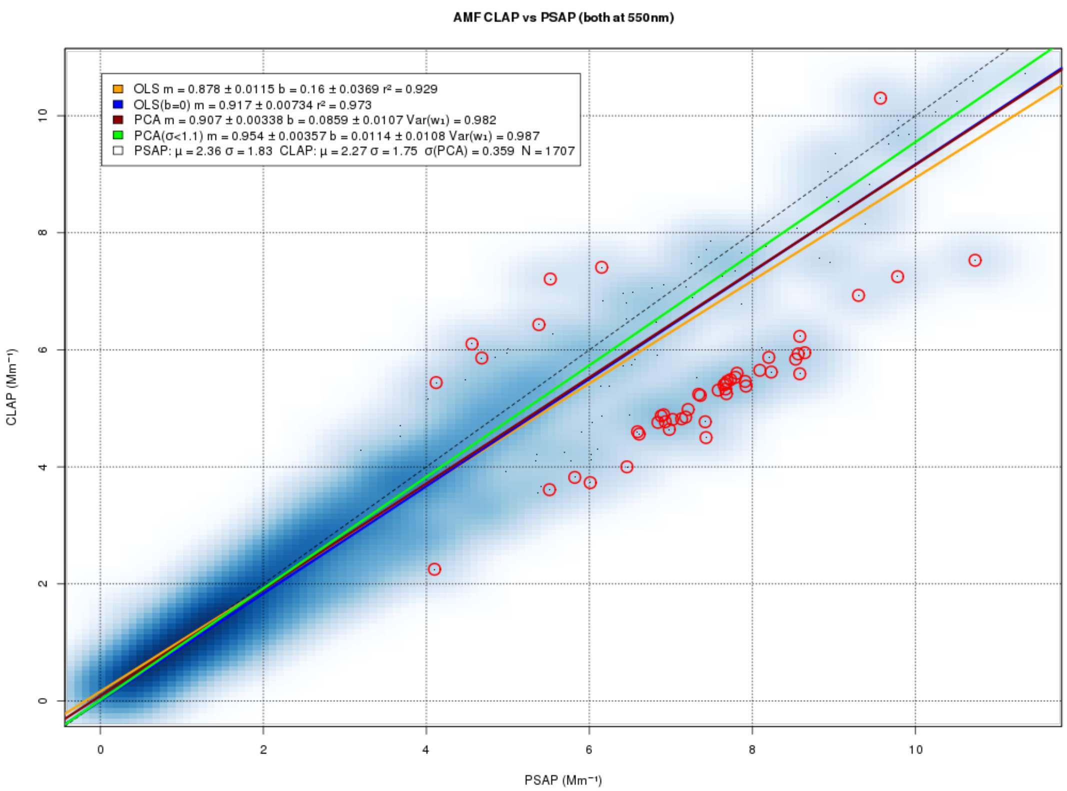


Figure 8.

MAO: Manacapuru, Brazil Jan.10, 2014 to Mar.31,2014

Slope: 0.95 Offset: 0.01

Below is the comparison from NSA. Note the high scatter in the data is related to the very low signal, which is near or below the instrument detection limit most of the time.

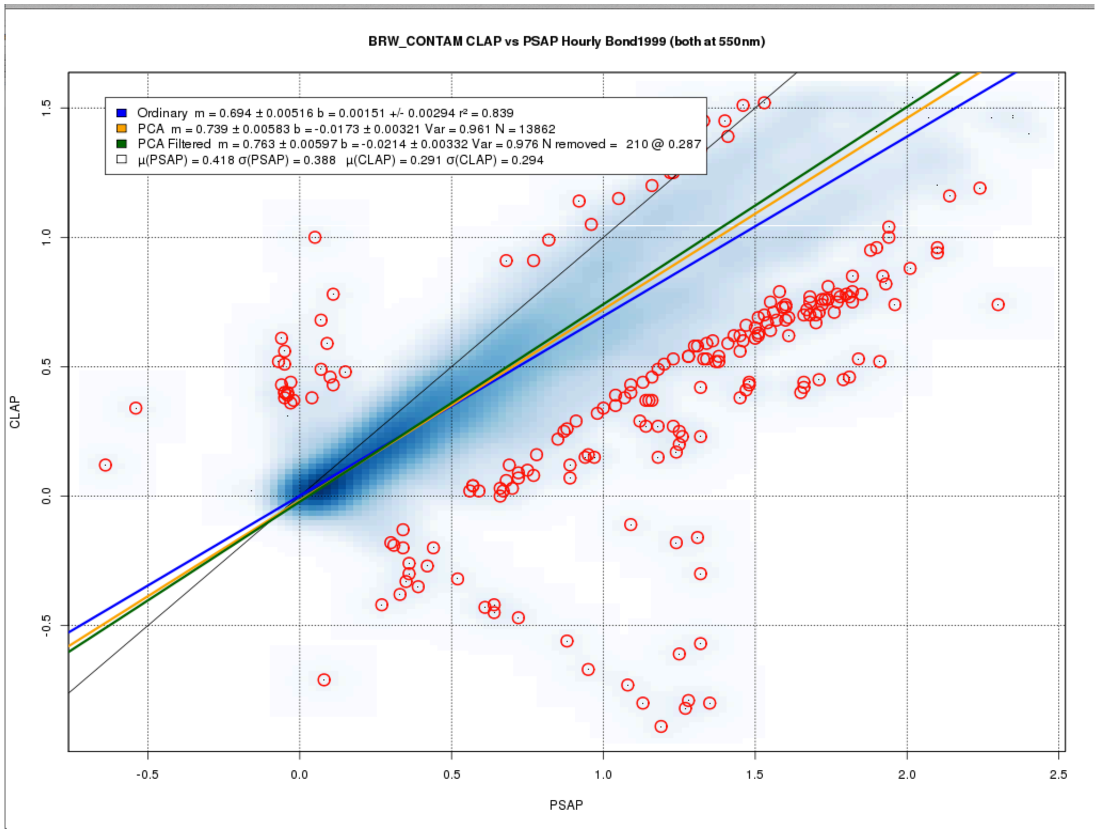


Figure 9.

NSA: slope: 0.76 offset: -0.02

Below is the comparison for all of 2012 from SGP.

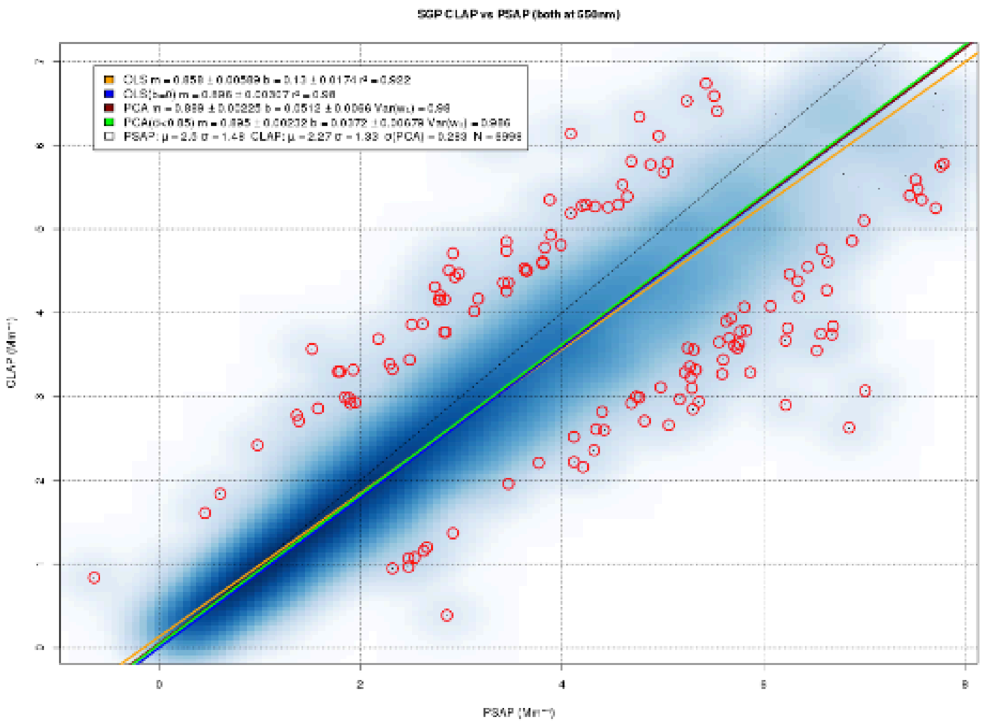
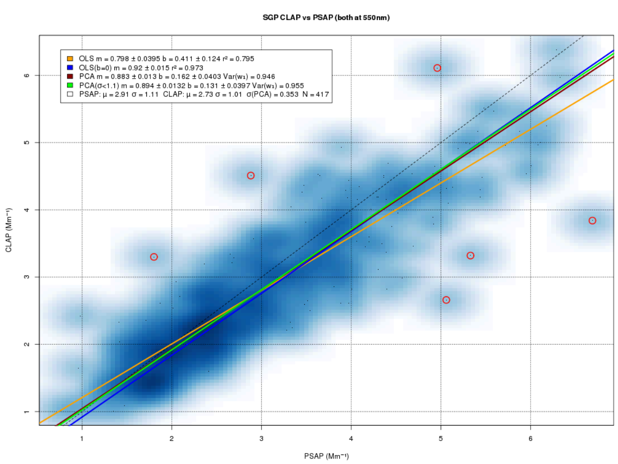


Figure 10.

SGP slope:0.89 offset: 0.04

The comparison between CLAP and PSAP at SGP is much lower than desired. Some of the low slope can be explained by seasonal differences in water deposition on the filter. Below are side-by-side graphs of CLAP vs. PSAP in July (left, slope:0.89 offset:0.13) and November (right, slope: 0.91 offset: 0.03). Water condensation on the PSAP during the summer months will cause high noise and a higher signal on this instrument.

CLAP vs PSAP July 2012



CLAP vs PSAP November 2012

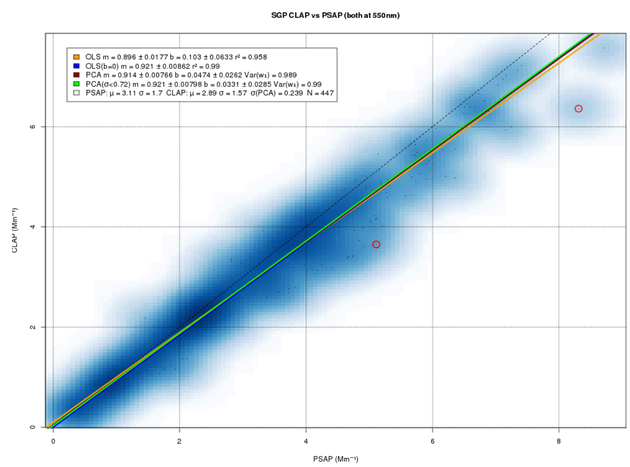


Figure 11.

At SGP, CLAP is a first-generation instrument. CLAPs at NSA and AMF were manufactured in later batches using a different machinist and different LED sources. In 2013, the instrument was repaired after a leak was detected. During this time the instrument solenoids were replaced, the optical block was painted with a different reflective paint, and the LEDs were replaced. Even after these changes, CLAP was still 10 to 15 percent lower than the PSAP. The instrument is now at NOAA for extensive testing against a PSAP and another CLAP. There may be some batch-to-batch variability in CLAP filters that cause the low correlation. One set of 100 CLAP filters lasts for approximately 600 days, which would account for almost 2 years of low correlation. Filter quality is just one variable that will be tested.

4.0 CLAP Campaign Publications

Ogren, J, J Wendell, P Sheridan, D Hageman, and A Jefferson. Continuous Light Absorption Photometer (CLAP) Performance, Poster, ASR Meeting, Potomac, MD, March 2013.

McComisky, A, A Jefferson, M Dubey, A Aiken, J Fast, C Flynn, E Kassianov, and G Feingold. Assessment of Aerosol Absorption Measurements, Poster, ASR Meeting, Potomac, MD, March 2014.

5.0 Reference

Bond, TC, TL Anderson, and D Campbell. 1999. "Calibration and Intercomparison of Filter-Based Measurements of Visible Light Absorption by Aerosols." *Aerosol Science and Technology* 30(6): 582-600.

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