# Measuring Aerosol Optical Depth (AOD) and Aerosol Profiles Simultaneously with a Camera Lidar


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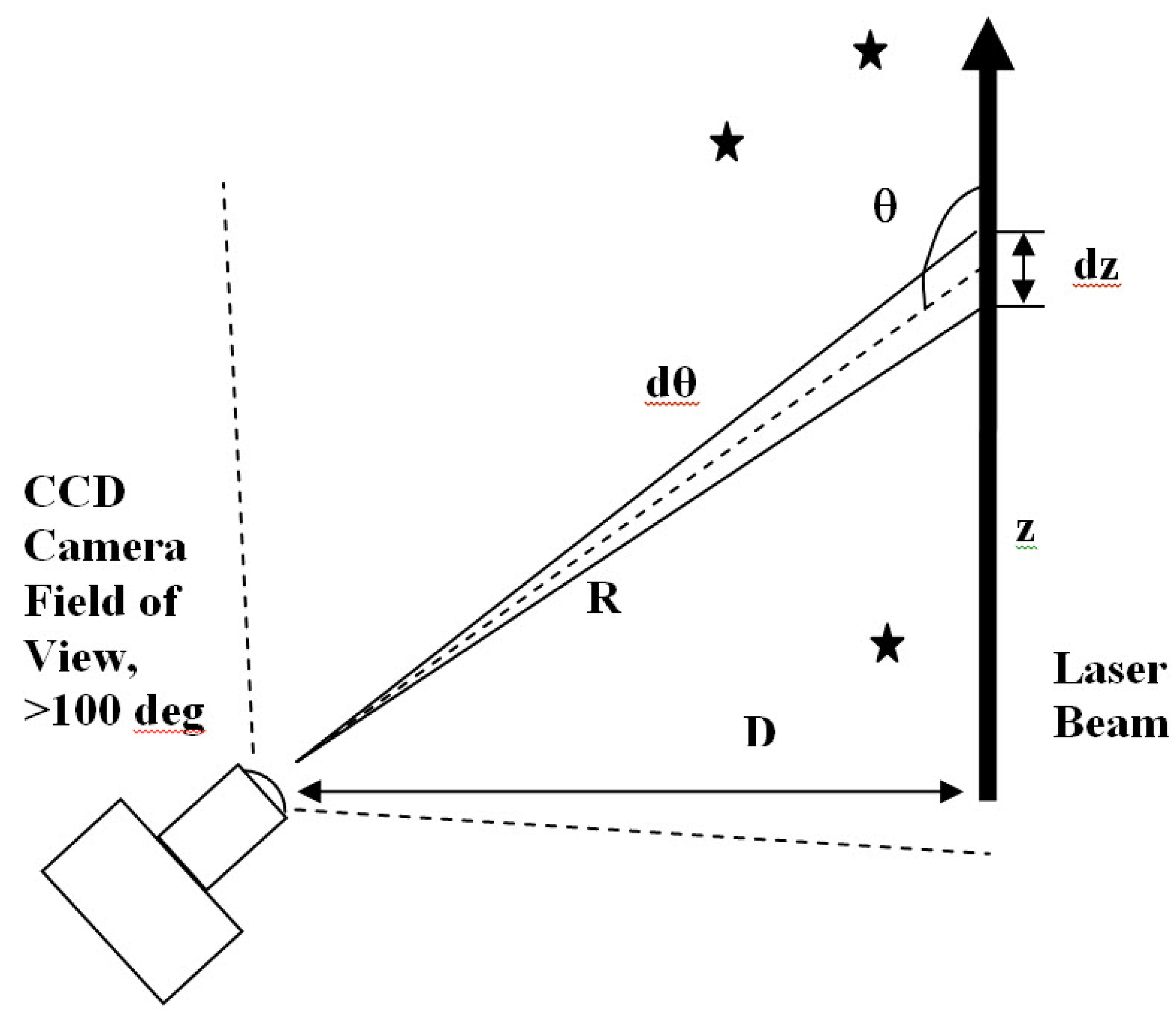
## ABSTRACT

CLidar or camera lidar is a simple, inexpensive technique to measure nighttime tropospheric aerosol profiles. Stars in the raw data images used in the CLidar analysis can also be used to calculate aerosol optical depth simultaneously. A single star can be used with the Langley method or multiple star pairs can be used to reduce the error and eliminate the need for a Langley calibration. The estimated error from data taken under clear sky conditions at Mauna Loa Observatory is approximately +/- 0.01..

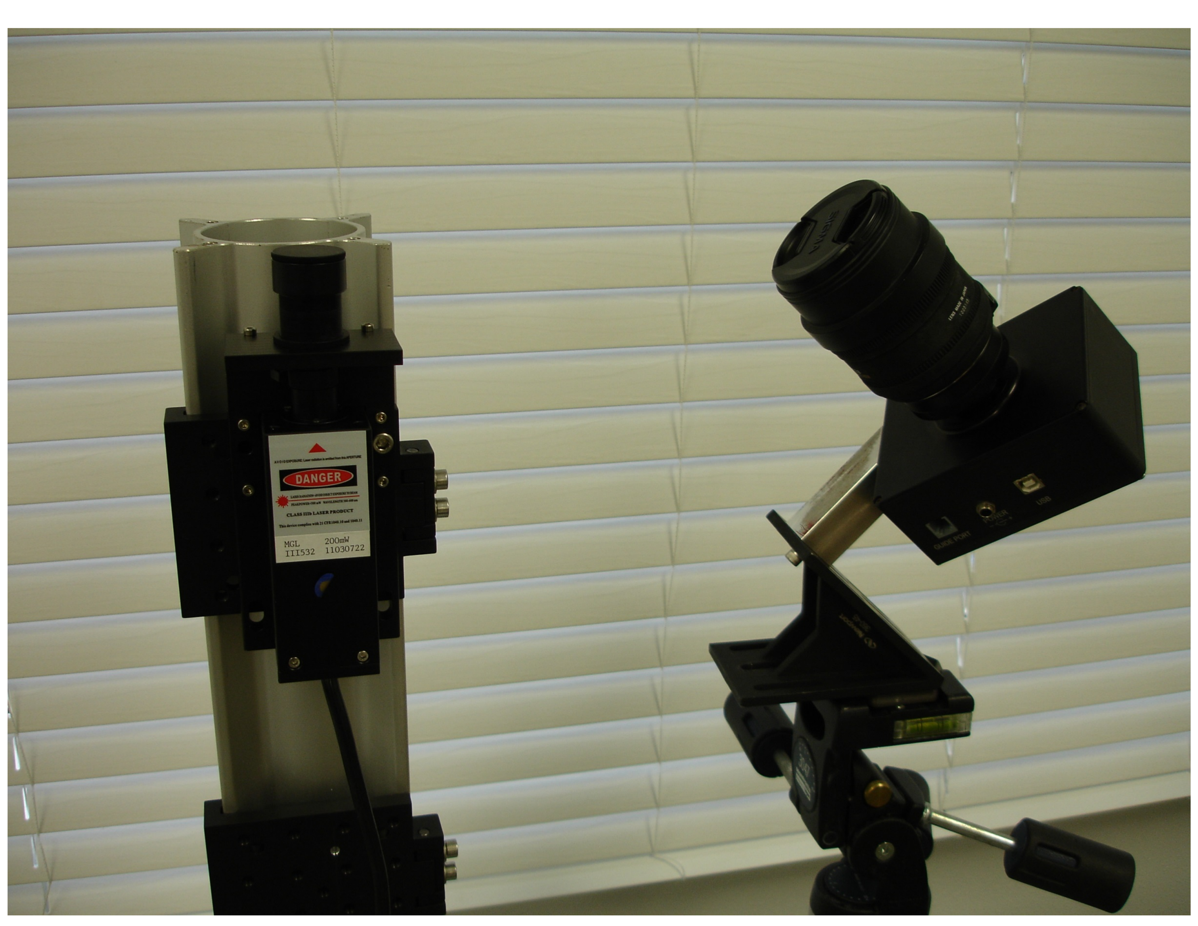




## AOD Constraint on Lidar/CLidar Retrievals

Lidars and CLidars both measure profiles of light scattered at a single angle. For the lidar that is 180 degree backscattered light. It is often desired to convert these measurements into Extinction or Total Scatter ($m^{-1}$) but the conversion parameter is often unknown.

If the AOD is known the Lidar/CLidar profile can be integrated and an average conversion parameter can be calculated.

AOD is measured at same wavelength, same time, and same location as the aerosol profile with the same equipment.



SBIG ST-8300 camera with Sigma Fisheye Lens
~2W Continuous Laser
Approx. Cost: $5000 US

## CLidar (camera lidar), Shared Technology

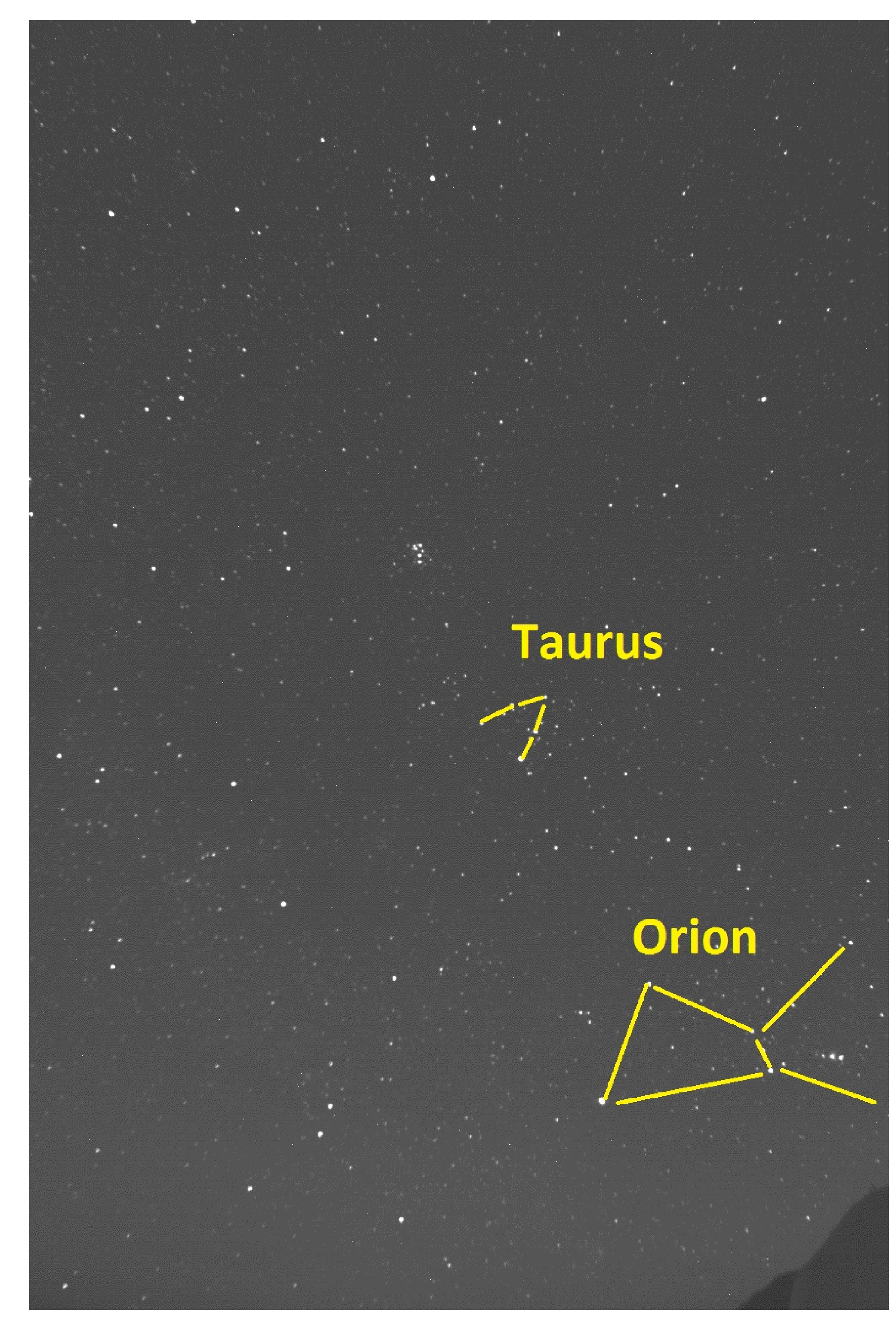
The CLidar technique uses a wide-angle lens on a CCD camera to image a laser beam, usually pointed vertically, from the ground to the zenith . The geometry is shown in the above figure. The technique is currently limited to nighttime conditions. A continuous laser can be used since the altitude information is determined by the distance from the camera to the laser beam (usually a few 100 m), and the angle of observation. The CLidar has no overlap function as in lidar, and there is no data acquisition electronics other than the computer to operate the camera. Another difference with lidar is that light is scattered at 90 degrees at the ground and approaches 180 degree scatter as altitude increases. An important property of the fisheye lens used is that each pixel maps to a constant angle..


Barnes, J. E., S. Bronner, R. Beck, and N. C. Parikh, 2003: Boundary layer scattering measurements with a CCD camera lidar, Applied Optics, 42, 2647-2652.

Barnes, John E., N. C. Parikh Sharma and Trevor B. Kaplan, 2007: Atmospheric aerosol profiling with a bistatic imaging lidar system, Applied Optics, 46, 2922-2929.

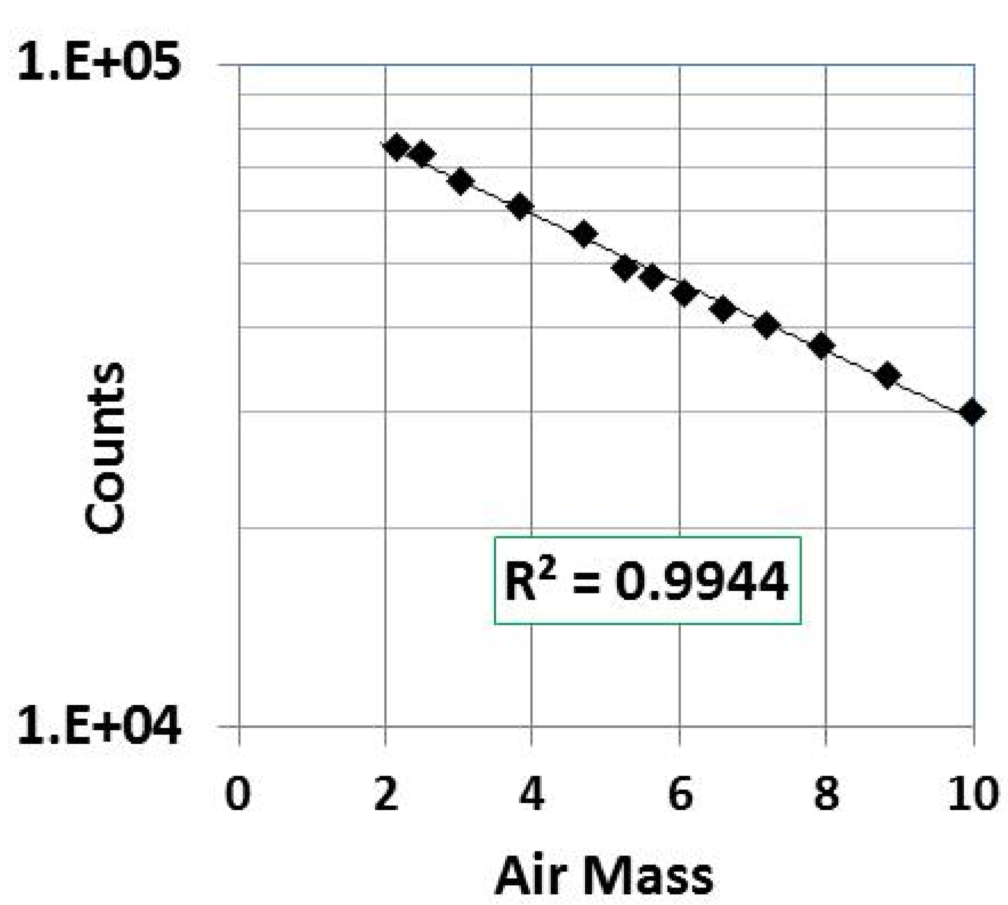
Parikh Sharma, N. C., John E. Barnes, Trevor B. Kaplan, and Antony D. Clarke, Coastal aerosol profiling with a camera lidar and nephelometer, J. of Atmos. Oceanic Technology, 28, 2011.

Barnes. John E.  and Nimmi C. P. Sharma, An inexpensive active optical remote sensing instrument for assessing aerosol distributions, JAWMA, 2012


## Single Star (Langley) Method for AOD

The standard calibration method for sun-photometers, the Langley calibration, is to measure the sun as it rises or sets during which the air mass changes. An air mass change of 2 to 8 or more is often desired. The change of the log of the star brightness with air mass is linear, and the slope and zero air mass intercept are the calibration constants.




Langley plot using the star Rigel in Orion under very low aerosol conditions. The $R^2$ of 0.9944 is equivalent to an AOD error of about **0.02**.

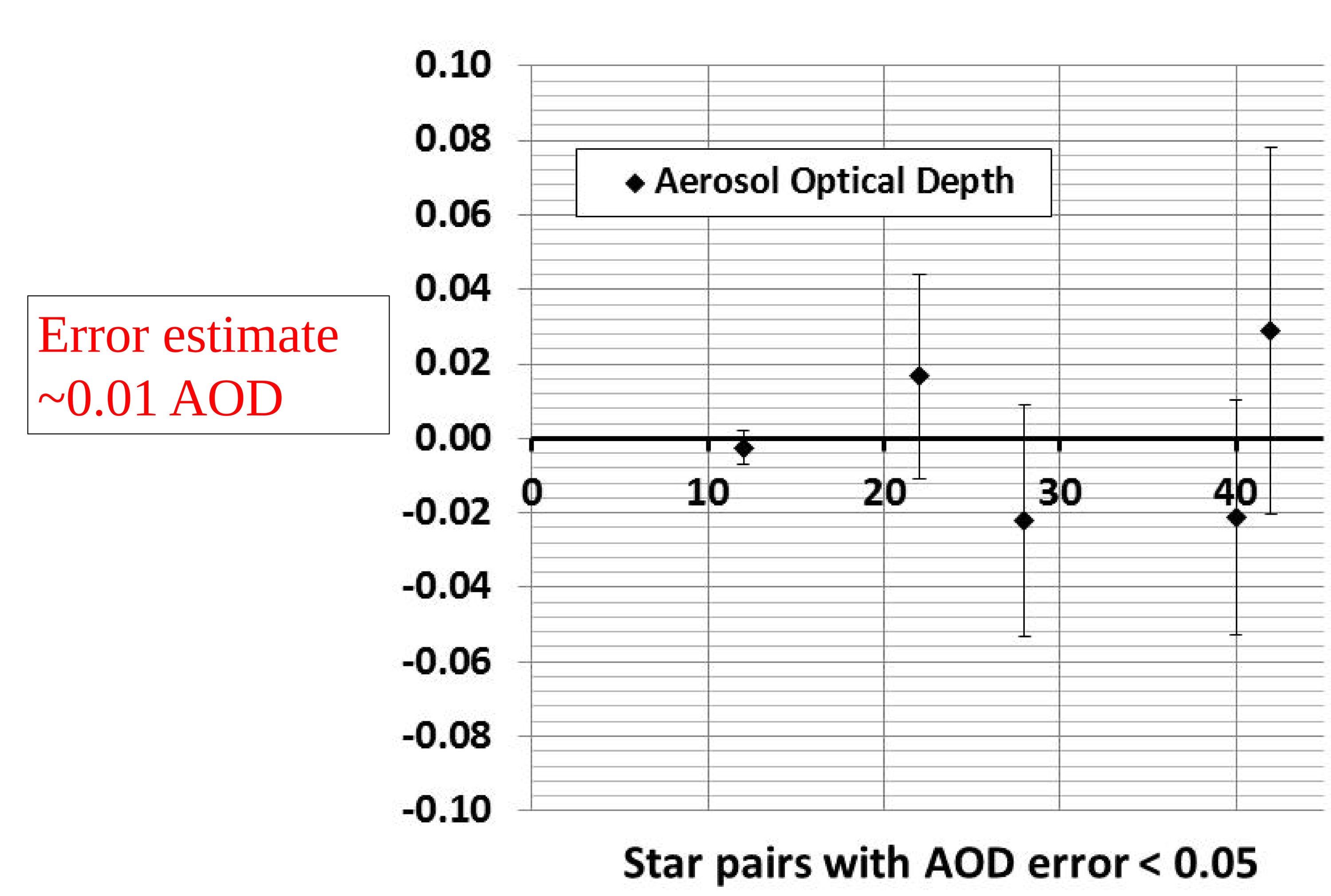

Leiterer, U., et al., 1995: A new star photometer developed for spectral aerosol optical thickness measurements in Lindenberg, *Beitr. Phys. Atmosph.*, 68, 133-141.

Perez-Ramirez, D. et al., Development and calibration of a star photometer to measure the aerosol optical depth: smoke observations at a high mountain site, *Atmos. Environ.*, 42, 2733-2738.

Lanciano, O. and G. Fiocco, 2007: Nighttime measurements of atmospheric optical thickness by star photometery with a digital camera, *Applied Optics*, 46, 5176-5182.


## Multiple Star Method for AOD

The multi star method takes advantage of star brightness measured by astronomers. By using a pair of stars and the stellar magnitudes for each, the AOD can be measured without the calibration constants.




In this example 10 of the brighter stars in the image were chosen which created 45 possible pairs. Many of these pairs used stars with similar air masses and generated large errors. The exposure time was 15 seconds.