Constraining aerosol properties with ground-based lidar and other remote sensing techniques

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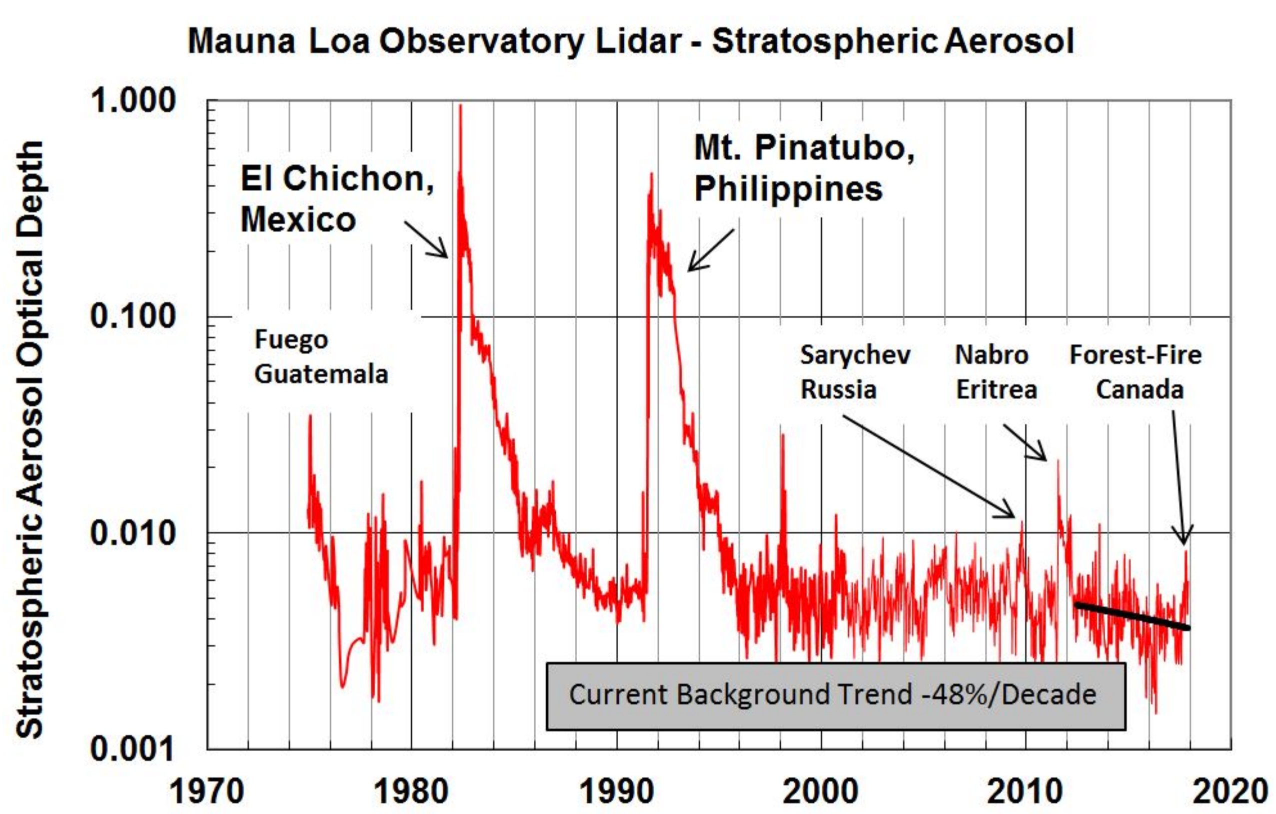
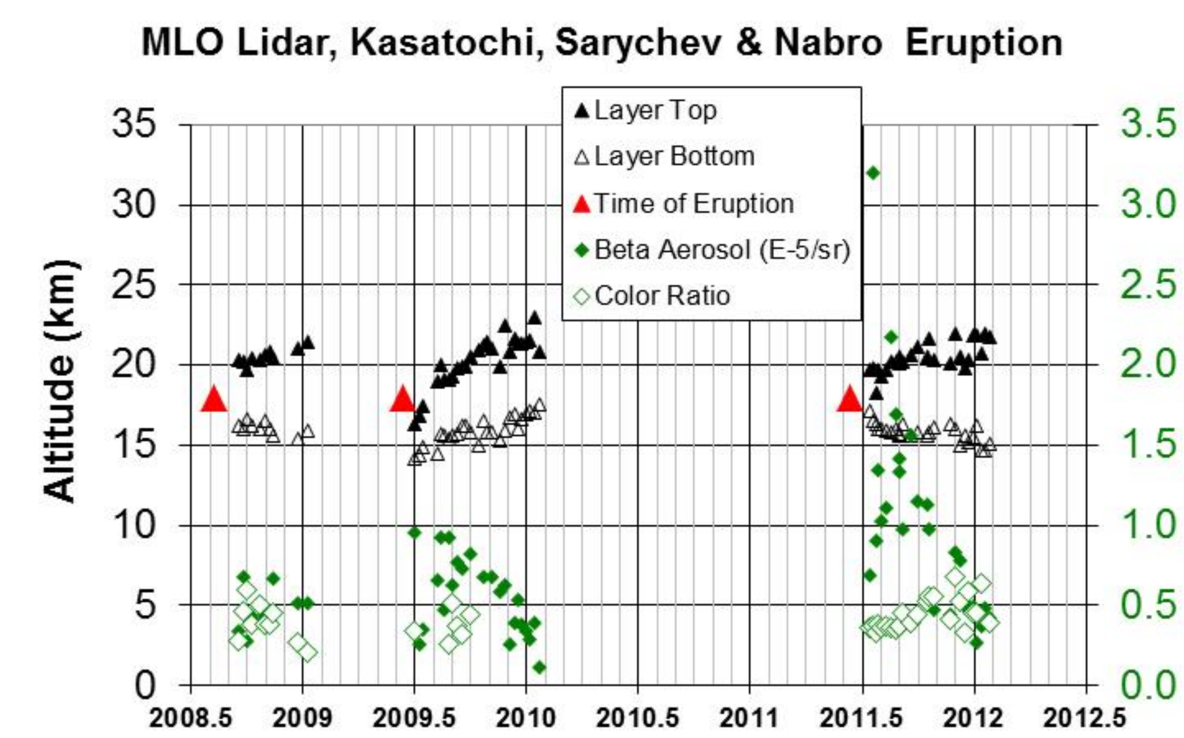


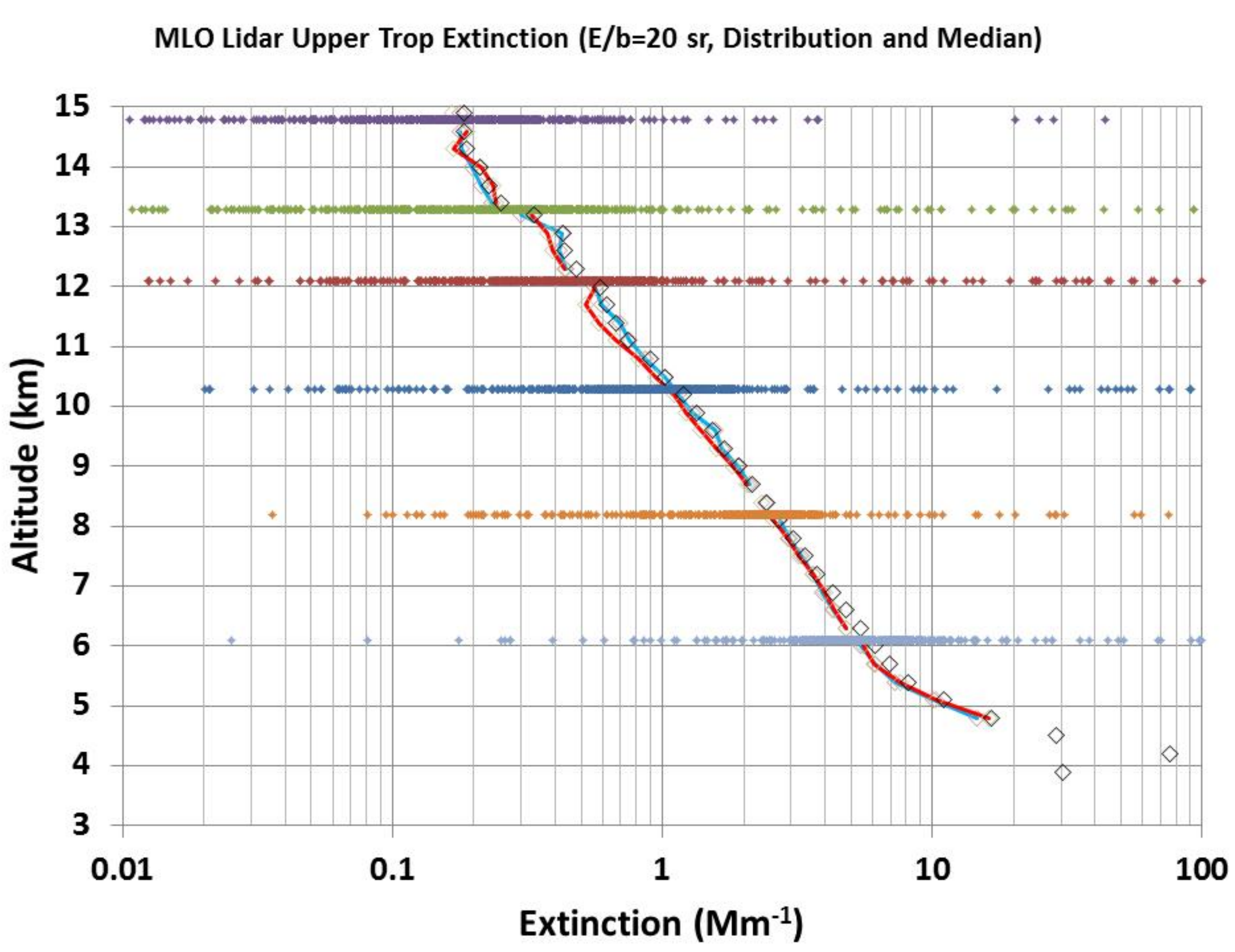
An Extinction to backscatter ratio of 50 sr has been used to calculate Stratospheric Aerosol Optical Depth (SAOD) at 532 nm. The stratospheric range used is 15.8 to 33 km.

Lidar Only Measurements

Lidars measure profiles of 180 degree back-scattered light. It is often desired to convert these measurements into Extinction or Total Scatter (m^{-1}) but the conversion parameter must often be assumed. Raman scattered wavelengths can measure extinction directly but require higher aerosol loading for accuracy. Multiple wavelengths can also be used to constrain aerosol parameters.



Well defined aerosol layers can be tracked over time after a volcanic eruption. The color ratio uses both the 532 and 1064 nm backscatter but can be noisy due to the weak 1064 nm signal.



About 750 weekly lidar measurements at MLO have been used to generate this plot. Averaging heavily weights the profiles toward clouds, but simply using the Median instead shows a profile remarkably well fit by an exponential over two or three scale heights. An Extinction to backscatter ratio of 20 sr is used which can be typical of the troposphere.

The grand Median is shown by the diamonds, summer (JJA) by the red, and winter (DJF) by the blue. The entire distribution (colored points) is shown for selected altitudes. Aerosols increase more rapidly near the observatory altitude (3.4 km).

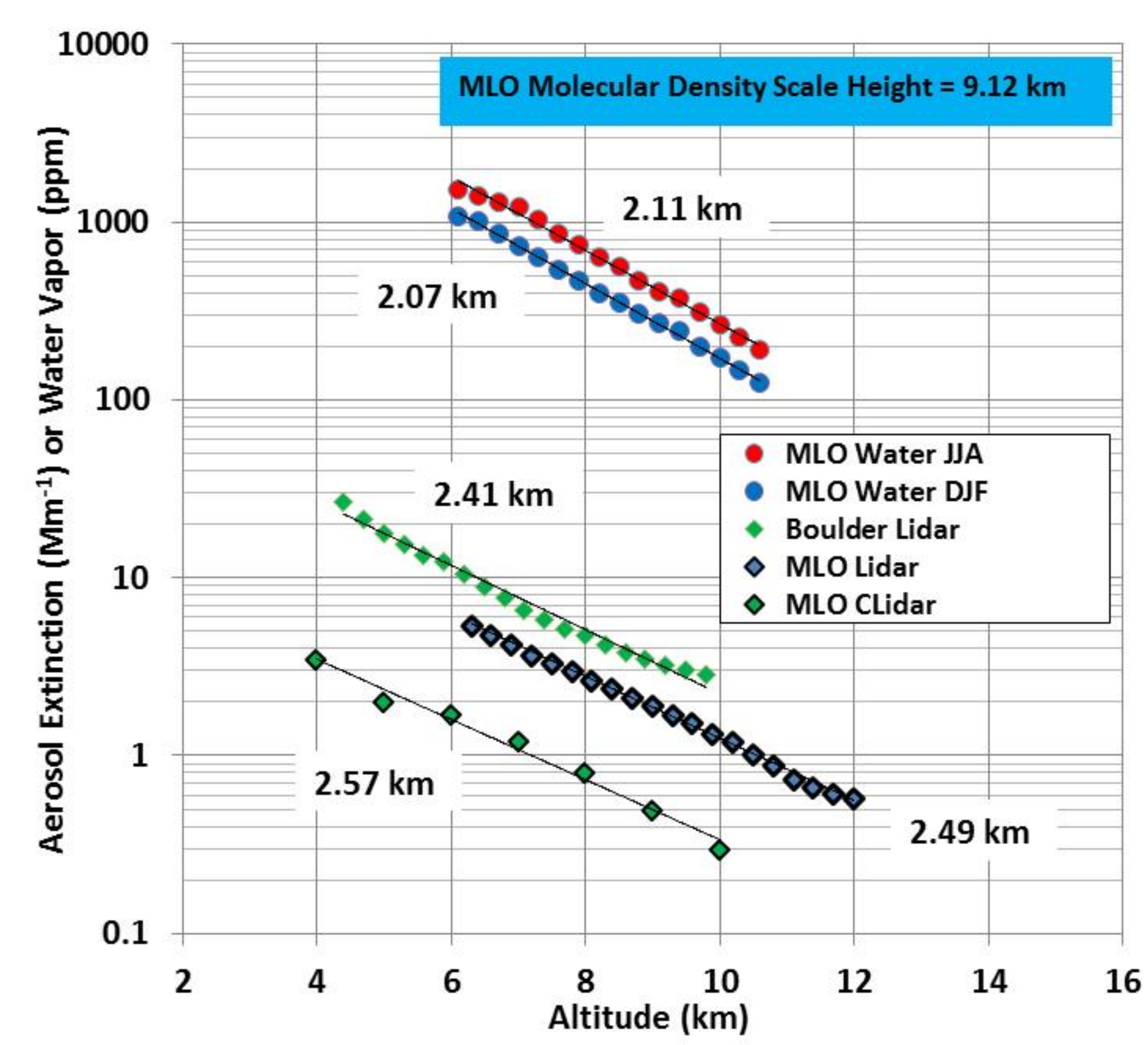
Aerosol Scale Height

The scale height, H, is defined by the exponential function:

$$A(z) = C * \exp(-z/H)$$

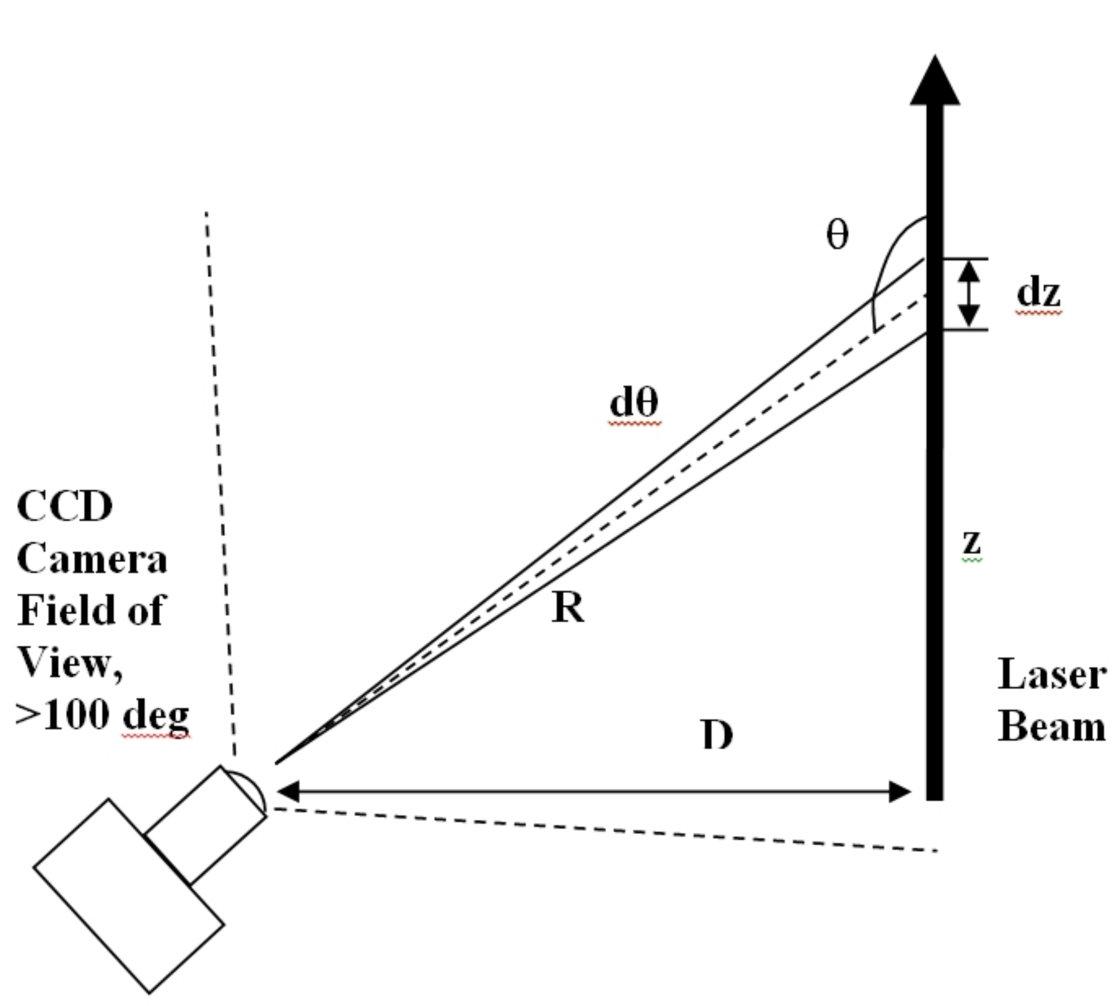
The aerosol scale height of the Median of many aerosol profiles fits an exponential function remarkable well over a range two or three scale heights.

This relationship may constrain the sources and sinks used to model tropospheric aerosol.



Scale heights for aerosols, water vapor, and molecular density are shown for MLO. The aerosol scale height for Boulder, CO is also shown. At MLO aerosol profiles were measured independently by the Lidar and Clidar.

CLidar (camera lidar)



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 figure to the left. 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 are no data acquisition electronics other than the computer to operate the camera. An important property of the fisheye lens used is that each pixel maps to a constant angle.

Another difference with CLidar is that light is scattered at 90 degrees at the ground and approaches 180 degree scatter as altitude increases. By using multiple lasers with different polarizations, aerosol parameters can potentially be constrained much better than with a lidar.

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

M.I. Mishchenko et al. / Journal of Quantitative Spectroscopy & Radiative Transfer 184 (2016) 180–192 181

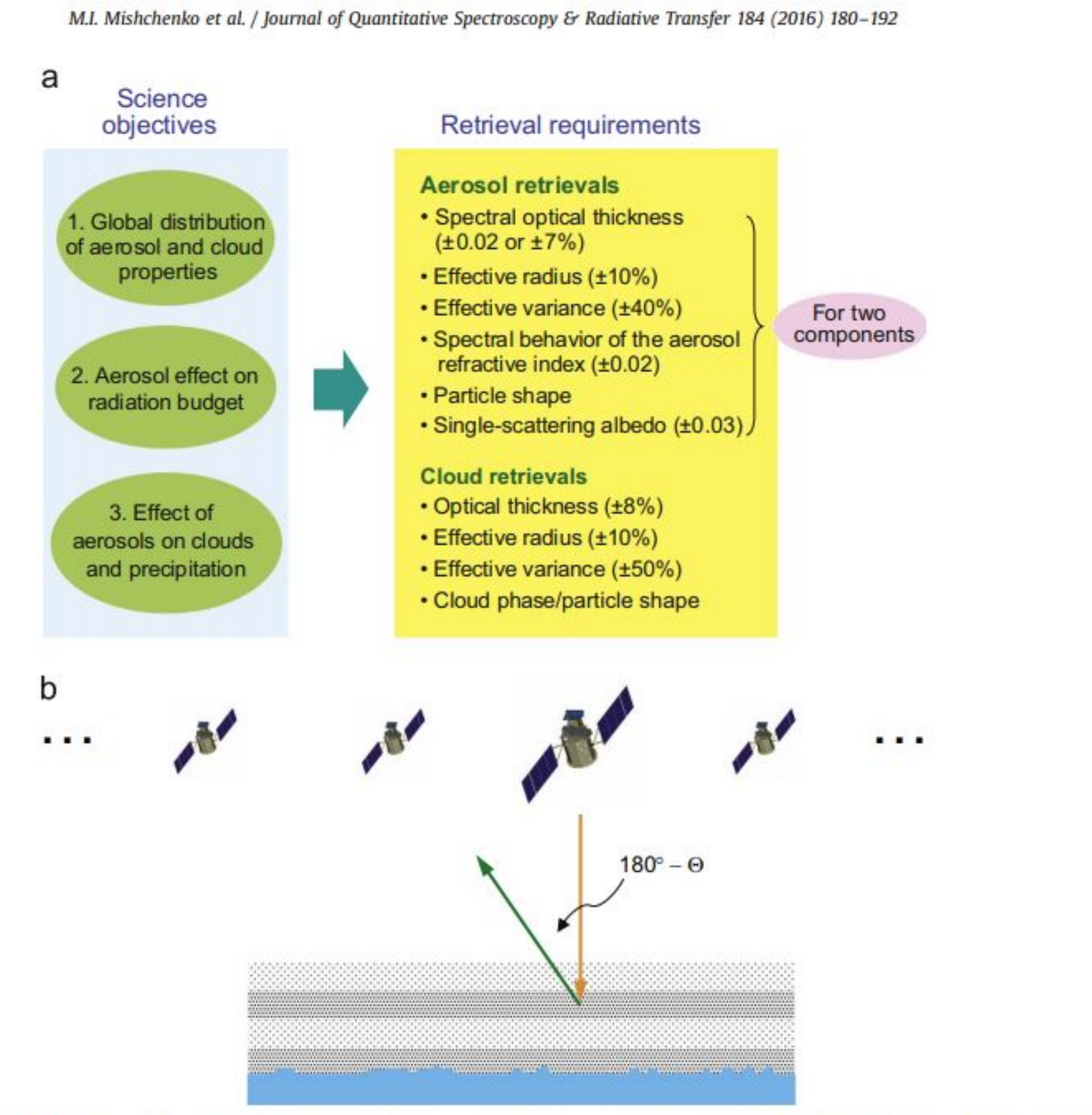


Fig. 1. (a) Aerosol and cloud retrieval requirements follow from the overarching science objectives. (b) Orbital multistatic lidar system. The primary satellite is equipped with a nadir-pointing backscattering lidar, while one or more secondary platforms carry additional receivers of scattered laser light. The scattering angle $\theta \neq 180°$ characterizes the bistatic configuration formed by the transmitted laser beam and the receiver on a secondary platform.

This figure is taken from Mishchenko et al., 2016. The paper compares the retrieval of aerosol parameters from space with a high spectral resolution lidar (HSRL), to the retrieval with an added second receiver at 165 degrees. The second receiver reduces the modeled errors substantially, often by a factor of 5 or more. The MLO lidar differs from the HSRL and the error reduction possible for MLO lidar/CLidar is currently under study.

Mishchenko et al., Multistatic aerosol-cloud lidar in space: A theoretical perspective, J. of Quant. Spec. and Radiative Transfer, 2016.
Alexandrov and Mishchenko, Information content of bistatic lidar observations from space, Optics Express, 2017.