What Lidars Can Tell Us About Optical Properties of Thick Clouds

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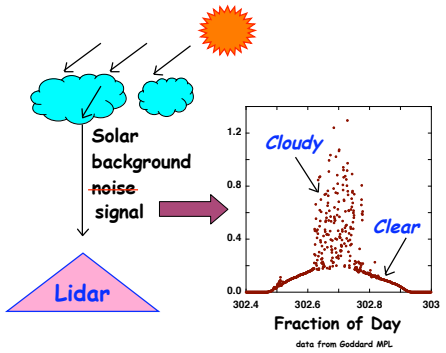
Key Points:

- One man's noise is another man's signal. When lidars points straight up, the solar background noise is the solar zenith radiance, which can be used to retrieve cloud optical depth.
- We calibrate solar background light against zenith radiance measurements from principal plane observations using a co-located AERONET (Aerosol Robotic Network) sunphotometer.



Summary

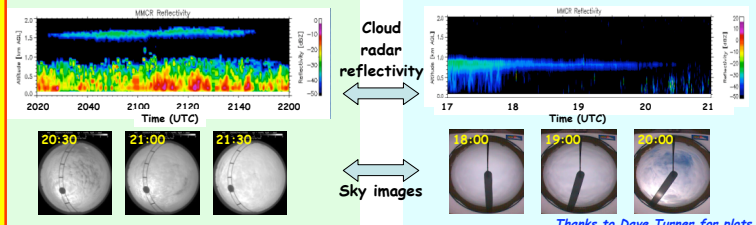
- Lidars can retrieve optical depth of thick clouds using solar background light as a signal, rather than (as now) merely a noise to be subtracted.
- In general, it may be possible to retrieve "simultaneously" both aerosol and cloud properties using a single lidar. Thus, lidar observations have great untapped potential to study interactions between clouds and aerosols.
- Validations against other instruments and methods show that retrieved cloud optical depth agree within 10–15% for overcast stratus and broken clouds.

First MPL and Raman lidar (thick) cloud optical depth retrievals using solar background signal (overcast cases)

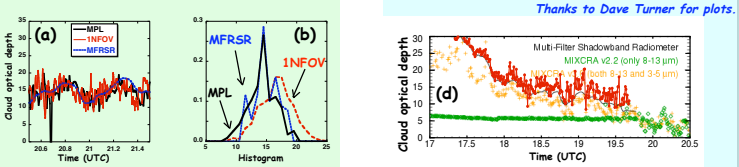
Micropulse Lidar (MPL)

Case 1: Stratus on March 14, 2000

Case 2: Stratus on Nov. 6, 2003

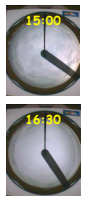


Thanks to Dave Turner for plots.

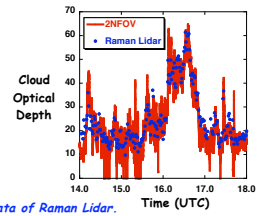


- Case 1: Figs.(a)-(c) present the time series, histograms, and scatter plots of cloud optical depths retrieved from MPL, MFRSR and 1-channel narrow field-of-view (1NFOV) radiometer.
- Case 2: Fig.(d) shows retrievals from MPL (red), MFRSR, and MIXCRA.

Raman Lidar

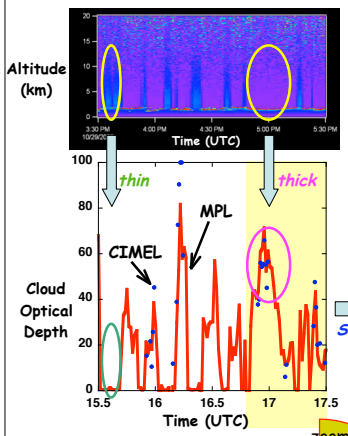


Another case is on 2004/11/11 at SGP – sky images are shown left. We calibrated solar background signal of Raman lidar at 408 nm wavelength and retrieved cloud optical depths (see right). These retrievals are then compared with those from the 2-channel narrow field-of-view (2NFOV) radiometer that provides unambiguous retrievals.

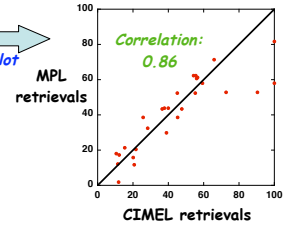


Thanks Diana Petty & Dave Turner for providing solar background light data of Raman Lidar.

Broken cloud case -- MPL versus CIMEL



A time series of MPL backscatter vertical profile is shown left. We use solar background light to retrieve cloud optical depths and compare them with CIMEL retrievals (the left-middle Fig.). Due to the ambiguity of retrievals from *only one channel*, we adapted a criterion to separate 'thin' clouds from 'thick' clouds: For the same value of the solar background signal, when the returned lidar signal is not completely attenuated, clouds are called 'thin' (green circle); when the returned signal is completely attenuated, clouds are called 'thick' (magenta circle).



Problem free? Not really...

The problem arises when both of these optical depth solutions result in *completely attenuated lidar pulses* (as shown by magenta circles). In these cases, both optical depths (green solid/dashed lines) correspond to the same value of solar background light and we *cannot* determine which one (solid or dashed line) is the correct solution. As a result, cloud optical depths ranging approximately from 3 to 15 (depending on solar zenith angle) are unresolved for retrievals.