LIDAR

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What is LIDAR?

Stands for **LI**ght **D**etection **A**nd **R**anging

Micropulse LASERs

Measurements of (usually) backscatter from clouds and aerosols in the transmission path

Uses frequencies in the near UV, visible, and near IR

One of the most common wavelengths is 532 nm

LIDAR systems

- ground-based (this lecture): MPLNET (colocated with AERONET sites), other unaffiliated LIDARs
- space-based: CALIPSO (next half of the lecture)

Kinds of LIDAR

- backscatter LIDAR
- differential absorption LIDAR (DIAL)
- Doppler LIDAR
- fluorescence LIDAR
- Raman LIDAR

Backscatter LIDAR

- By far the most common
- functions almost exactly like RADAR but at a different wavelength

Differential Absorption LIDAR (DIAL)

- Calculation of molecular species in the atmosphere
- Transmit pulses at two different frequencies determined by the absorption line of the species you want to measure

Doppler LIDAR

- Works on calculation of phase shift
- Very similar to wind profilers

Fluorescence LIDAR

- Try to induce fluorescence in the species you’re measuring

Raman LIDAR

- Works on the principle of Raman scatter

LIDAR Equation

$$E_r(t) = \frac{CE_0}{z^2}\Big(\beta_r(180,z) + \beta_a(180,z)\Big)\exp\left[-2\int_0^z \Big(c_r(z') + c_a(z')\Big)\,dz'\right]$$

E_r = received power (what the LIDAR actually measures)
E_0 = transmitted power (what the LIDAR transmits)
C = LIDAR constant (unique to each LIDAR)
$\beta_r(180,z)$ = Rayleigh (molecular) backscatter
$\beta_a(180,z)$ = aerosol backscatter
c_r = Rayleigh (molecular) extinction
c_a = aerosol extinction (what we want)

$z = tc/2$

LIDAR Equation

If there is a layer of clear air above the aerosol layer, Rayleigh scattering dominates, and we can ignore aerosol backscatter:

$$E_r(t) = \frac{CE_0}{z^2}\beta_r(180, z)\text{exp}\left[-2 \cdot \text{AOD} - 2\int_0^z c_r(z')\, dz'\right]$$

Then we can solve for Aerosol Optical Depth (AOD) if we assume power decays at a certain rate with height according to Rayleigh scatter theory

Determining C

$$E_r(t) = \frac{CE_0}{z^2}\beta_r(180, z)\exp\left[-2 \cdot \mathrm{AOD} - 2\int_0^z c_r(z')\, dz'\right]$$

Perform the same aerosol optical depth measurement using a sun photometer (next lecture) and backsolve

Sometimes finding a layer of clear air above the aerosol layer is tricky or impossible. We need a method that will work in all circumstances.

Extinction-to-Backscatter Ratio

$$E_r(t) = \frac{CE_0}{z^2}\Big(\beta_r(180, z) + \beta_a(180, z)\Big)\exp\left[-2\int_0^z \Big(c_r(z') + c_a(z')\Big)\,dz'\right]$$

Assume a relationship (ratio) between
β (km^{-1} sr^{-1}) and c (km^{-1})

c/β (sr)

Sources of Error

- Overlap function - loss in signal strength at close range (less than 4 km) due to poor focusing by the detector (optics)
- Afterpulse function - cross-talk between the laser pulse and the detector, includes internal noise
- Multiple scattering
- Incorrect estimate of extinction-to-backscatter ratio
- Deliquescence
- Wavelength dependence

Extinction-to-Backscatter Ratio

Example values

~70 sr for tropospheric aerosols/pollution
18 sr for water clouds
near (but not equal to) 0 for clear air
~40 sr (?) for stratospheric aerosols

Aerosol values can range between 15 and over 120 sr

Deliquescence

Certain aerosols are very good at picking up water molecules. This changes their optical characteristics.

Wavelength Dependence

Aerosol backscatter can be highly dependent upon the wavelength used. This needs to be taken into account.

“Typical” retrieval

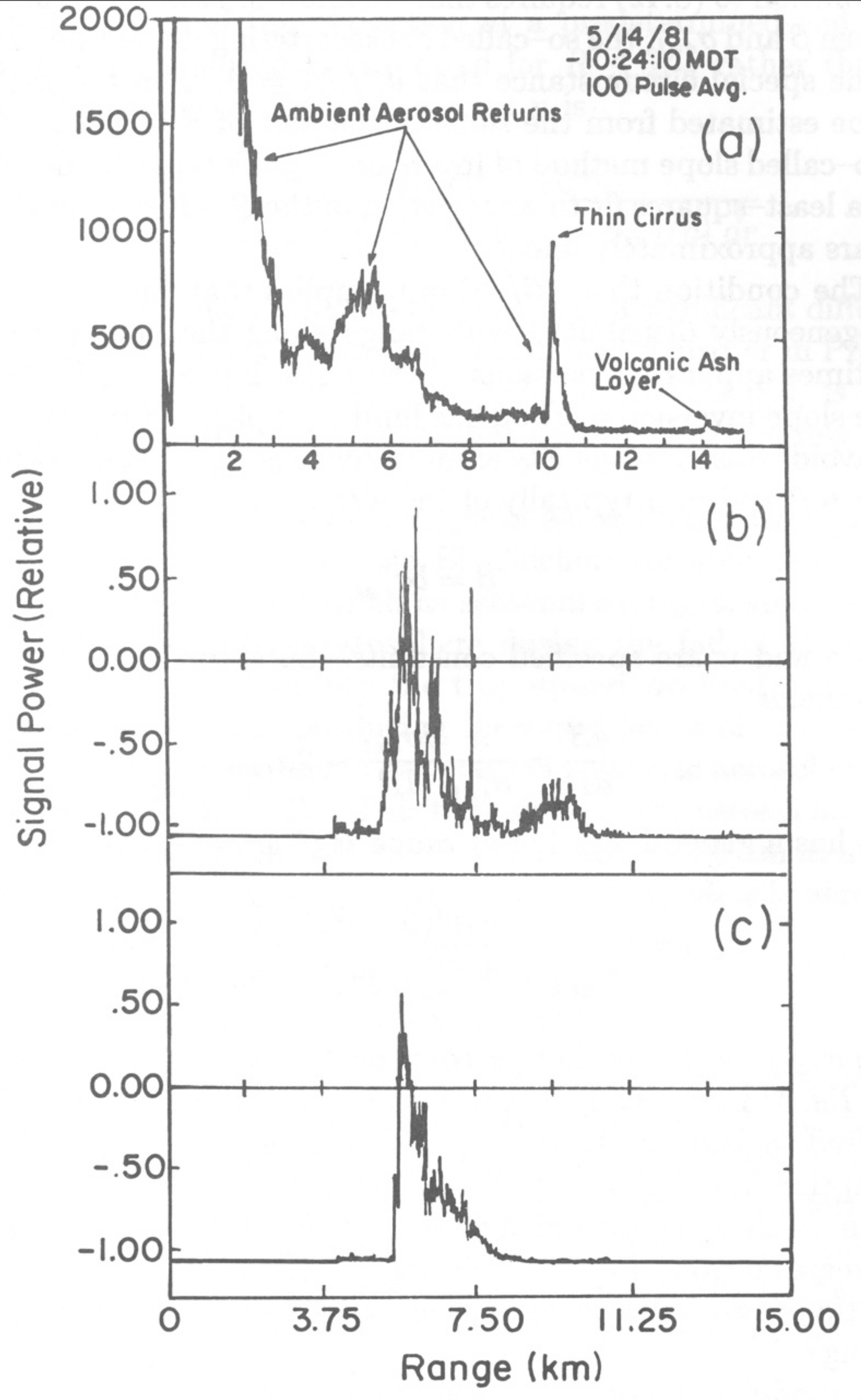

Figure 8.15 (a) A “typical” vertical backscatter profile averaged over 100 pulses. (b) Profiles of received backscatter power as a function of altitude through a deep cirrostratus cloud showing slight attenuation of the pulse. (c) Same as (b) but for strong attenuation (lower two panels from Platt, 1981).

Ground-based LIDAR network

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