Dense Cloud Probing with Wide-Angle Imaging Lidar (WAIL)

Summary & Outlook
WAIL has broken new ground in active probing of dense cloud from ground, at least at night. The same multiple scattering concept has been implemented for airborne (incl. in-situ) and space-based sensors. Defeat solar background with sophisticated magneto-optical (Faraday) filter? Or synergy with O, A-band? Transfer engineering aspects to industry under SBIR/STTR program?

Cloud Remote Sensing Problem
After determining base height by standard laser ceilometer, find parameters • H (cloud thickness) and • σ (volume-average cloud extinction) or τ = τH (mean cloud optical depth) from observed I(ce),ρb, averaged azimuthally; see Davis et al. [1997,1999].

Asymptotic diffusion theory (i.e., scaling arguments based on random walk statistics): The “asymmetry factor” of the scattering phase function is a known quantity: g = E(θσ/σθ) ≃ 0.85.

-prob of reflection: R = 1 - T ≈ 1 - O(1/(1-g)τ)
-mean path length: ⟨ct⟩ ≈ H, independently of τ
-RMS path length: ⟨ct⟩2 ≈ H × (1-g)τ
-RMS spot size: ⟨p⟩2 ≈ H/[(1-g)τ]

Cloud Boundaries

-“TREMOL” lidar path extinction in data
-Cloud Profiles

Cloud Remote Sensing Problem (Mono-Layer, α = 2 case)
Use Davis and Marshak’s [2002] detailed diffusion model to estimate • H (cloud thickness) and • σ (volume-average cloud extinction) or τ = τH (mean cloud optical depth) from retrieved ⟨⟨ct⟩⟩_{TREMOL}g = 1.2. And what about ⟨⟨ct⟩⟩_{Radin}g = 1.2,3, ... ?

Asymptotic trends, a.k.a. “anomalous diffusion” model (Estep) = ∞ for q ≥ α: T ~ τ_w^{−αq} and ⟨ct⟩ ~ H^−α, 1 < α ≤ 2, as τ_q = (1-g)τ ∝ ∞ [Davis & Marshak];

R = 1 − τ and ⟨⟨ct⟩⟩_{TREMOL}^{1/2} ~ B^τ_{W}^{1/(1+2α)q−1} as τ_q = (1-g)τ ∝ ∞ [Davis’85, in progress].

Multi-Broken-Layer Cloud Field Problem (1 < α < 2)
1. What kind of cloud-radiation diagnostic can we do with new ground-based observables ⟨⟨ct⟩⟩_{TREMOL}g = 1.2,3, ... derived from hi-res O_2 line spectroscopy in the A-band (760-770 nm)? [Answer: Signature of spatial variability at q=1.]
2. Anticipating the A-band capability in NASA’s Orbiting Carbon Observatory (OCO), to be launched in 2008, what more can we do with global retrievals of ⟨⟨ct⟩⟩_{Radin}g = 1.2,3, ... ?
[Answer: Get H, τ, and variability parameter α.]

Cloud-oxide Process Model

-Theory curves combine Davis & Marshak (1997)

Numerical (Monte Carlo) solution of new 1D RTE (from Davis [2005] where “ct” is denoted by “L”)
Pathlength stats from A-band (from Scholl et al. [2006])
Millimeter-wavelength cloud radar
3-breakup phases are color-coded

REFERENCES: