Characteristics of Optically-Thin Coastal Florida Cumuli derived from surface-Based Micropulse Lidar measurements

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Introduction
- Clouds play an important role in Earth’s climate and energy budget.
- Clouds of low optical depth are underrepresented in climate models, with their response to a warmer climate poorly understood, including changes in their vertical distribution.
- Over South Florida, the small cumuli that are iconic of trade wind regions are common year-round. This makes our study site, located 3 km east of mainland Miami, Florida, a good location for studying such clouds.
- We characterize the optical depth and sizes of shallow cumuli with a micropulse lidar during a 10 week period.

Finding the Lidar Constant (Inversion with AOD)
- The raw lidar signal is converted to normalized relative backscatter (NRB) after applying the overlap, afterpulse, deadline, and range corrections:
  \[ S_{NRB}(z) = C(\beta_a(z) + \beta_m(z))e^{-2(\tau_a(z)+\tau_m(z))} \]
- The molecular portions (m) of \( S_{NRB} \) are characterized using a US Standard Atmosphere Model, which agrees well with local sounding measurements.
- The lidar constant (C) is found using a molecular fitting algorithm developed at the University of Miami to find the statistically best top of the aerosol layer and is constrained to on-site Aeronet AOD measurement.

Finding Extinction (Inversion with C)
- A molecular fitting algorithm is applied similar to that which finds the lidar constant method, but begins with the previously-derived lookup table of C values.
- The new profile’s molecular fitting constant is combined with the look-up C value to solve for the total optical depth.
- The aerosol/cloud backscatter coefficient (\( \beta_a \)), extinction (\( \sigma_a \)), integrated optical length (\( \tau_a \)) are obtained using the Fernald algorithm.
- Aerosol and cloud are discriminated and separately characterized.

Identifying the Cloud Threshold
- Clouds are identified using an empirically-derived particle backscatter coefficient threshold based on visual identification of clouds from sky camera imagery.

Cloud Size and Optical Depth
- Lidar-derived frequency (solid) and cumulative frequency (dashed) distributions for cloud base height, cloud thickness, and cloud horizontal extent:

Examples of lidar extinctions and optical depths
- Indicate a) aerosol hygroscopic swelling barely becoming a cloud before dissipating again (latter not shown) and b) multi-layer clouds, at edges of ceilometer-detected clouds, indicative of Miami’s two boundary layer (marine and land).

Conclusion
- Clouds with optical depths less than one constitute 12% of the sampled dataset, indicating they are ubiquitous in this synoptically-suppressed environment.
- Such clouds, at this location, occur most frequently at the top of the surface-based mixed layer, are less than 50 m thick and extend horizontally for less than 200 m, most frequently for 110 m and occasionally up to 2 km
- These clouds are too small to be detected by space-based lidar

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