Multi-sensor Retrievals of Cloud Properties

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Objectives & Approach

Our goal is to document the radiative and water budgets of tropical cirrus, relate one to the other and each to governing environmental factors.

Our approach is to assimilate multiple sources of CRYSTAL data, obtained from multiple platforms, included in this approach are:

- Inversion of lidar data to obtain profiles of visible extinction
- Inversion of MAS data to obtain bulk cloud optical properties
- Inversion of mm radar data, combined with optical depth to obtain ice aerosols and microphysical properties.
- Evaluate these using in-situ microphysical data
- Use these data to simulate the radiative budgets of cirrus and compare to relevant measured fluxes.
- Use these data to evaluate cloud model simulations of selected cases and explore relationships between convection and cirrus

Preliminary Example: 2002 Jul 23

MAS Retrievals

MAS data will be used in conjunction with active measurements from either radar or lidar to determine cloud particle effective radius and optical depth. The optimal estimation retrieval developed by Cooper et al. (2003) for infrared radiance is currently being expanded to include visible and IR wavelengths both to maximize information content and to ensure retrieved cloud properties are consistent with all available MAS measurements.

Radar Microphysics Retrievals

- The radar retrieval is formulated in an optimal estimation approach where the measurements, y, are expressed in terms of a forward model that is a function of the quantity to be retrieved, x, and associated errors, σ_y and σ_x.
- Inversion proceeds through minimization of a cost function, where the forward model is constrained by a column visible optical depth estimate from the Cloud Physics Lidar (CPL).

The Forward Model

- Assume ice crystal size spectra follow the gamma distribution. Further assume that number concentration, n, and spectrum width, =, are constant with height.
- Knowns: Reflectivity Z (height), z
- Unknowns: Diameter D (height), D

\[ n_z = \frac{Z(z)D^2}{8\pi^2 \rho A_s} \]

Error

Temperature

Retrieved Ice Water Content and Particle Radii

Lidar Retrieval of Cirrus of Extinction Coefficient

The lidar equation is inverted by an optimal estimation technique to obtain a vertical profile of extinction:

\[ \frac{dL}{dz} = \frac{1}{\pi} \left( \frac{1 - \rho_0}{\rho_0} \right) \frac{dL}{dz} \]

The retrieval is constrained by visible optical depth and retrieves a vertically averaged value of the backscatter to extinction ratio, =.

Radiative Heating Rates

Longwave and shortwave cloud heating rates can be derived from cloud ice distributions retrieved through the combined radar-lidar method shown at left.

Uncertainties

Mean effective radius

Ice water path

Optical depth

 Coastal State University
 Knowledge to Go Places


Optical Properties


Radar Microwave Algorithm


Lidar algorithm