Cloud Properties for Partly Cloudy Pixels

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Goal: Quantify biases in fractional cloud cover, effective radius, cloud liquid water, cloud altitude, TOA and surface radiative fluxes, etc. that arise through neglect of partial cloud cover when retrieving cloud properties.

Retrieval Method

Retrieval scheme follows Arking and Childs (1985)

- **For single-layered cloud systems, identify overcast pixels and determine emission altitude (temperature) of cloud layer.**

- **For each pixel, radiances are given by**

$$I = (1 - A_C)I_S + A_C I_C$$

A_C **= Fractional cloud cover within a pixel**

I_S **= Average cloud-free radiance within a pixel**
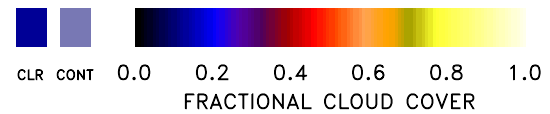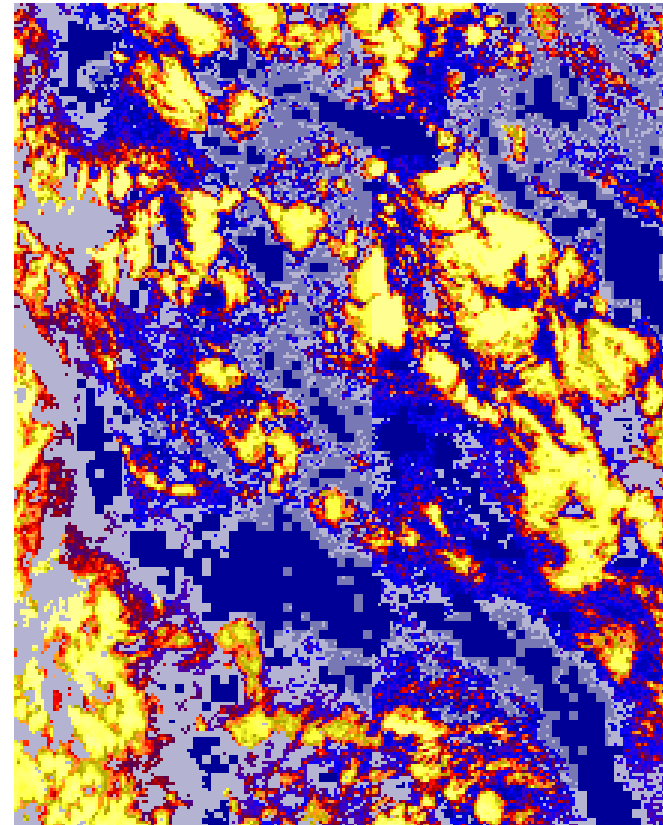
I_C **= Average overcast radiance within a pixel**

- **For each pixel, retrieve** $A_C, \tau, r_e,$ **etc.**

Fractional Cloud Cover

0.64-μm

Partly cloudy retrieval

CLR CONT 0.0   0.2   0.4   0.6   0.8   1.0
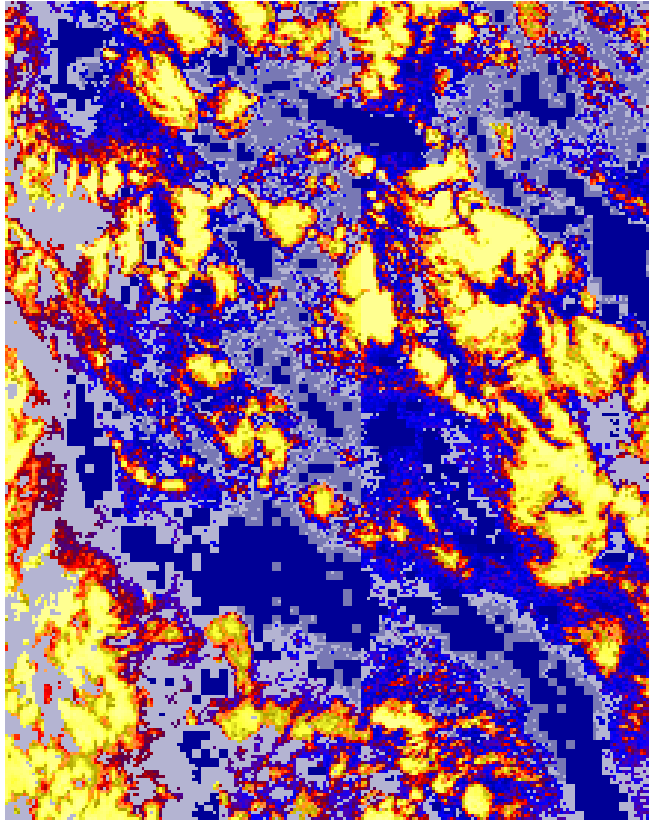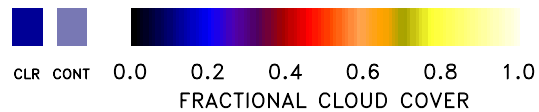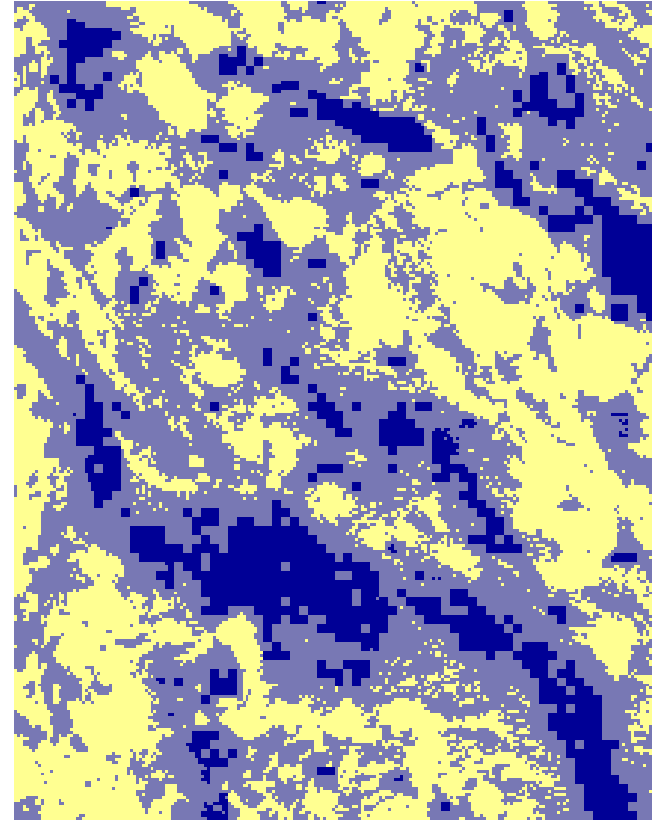FRACTIONAL CLOUD COVER

VIRS 2-km pixels, 500-km region, marine stratus, South Atlantic

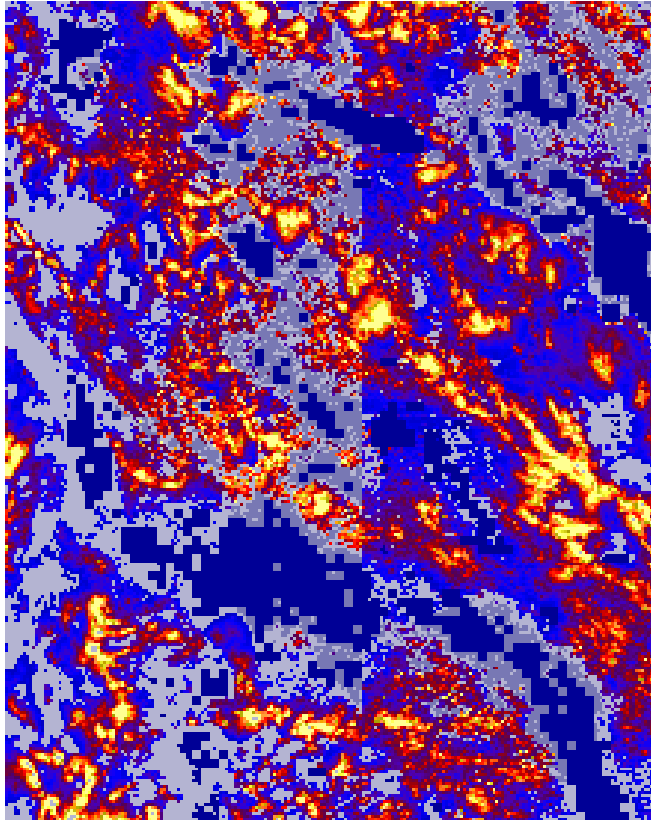# Partly Cloudy and Threshold Retrievals

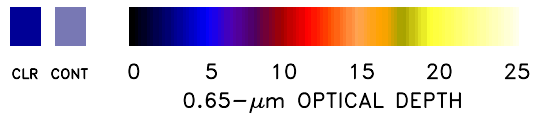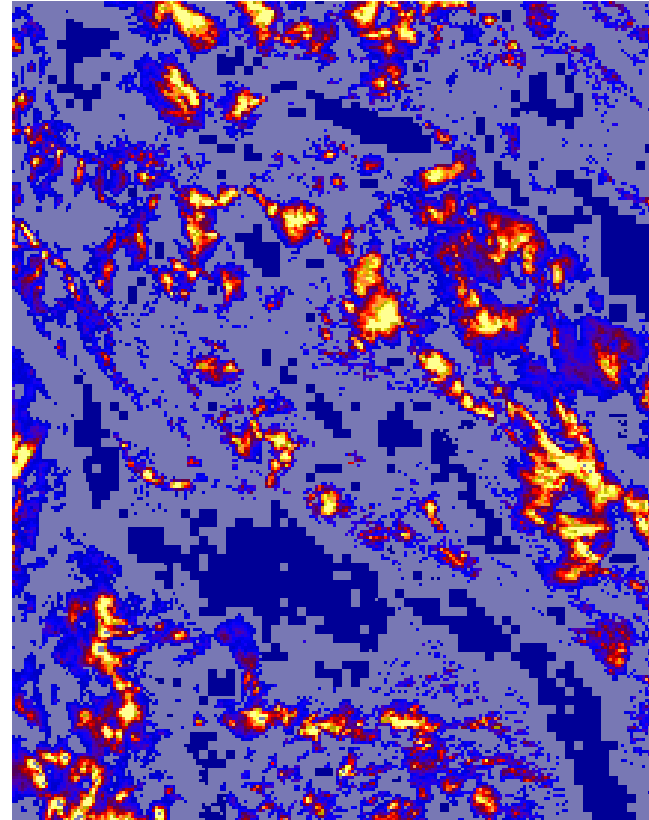Partly cloudy $A_C = 0.28$

Threshold $A_C = 0.39$

CLR CONT 0.0   0.2   0.4   0.6   0.8   1.0
FRACTIONAL CLOUD COVER

Threshold set at $A_C = 0.2$

0.64-μm Optical Depth

Partly cloudy τ = 7.8

Threshold τ = 6.2

CLR CONT 0   5   10   15   20   25

0.65-μm OPTICAL DEPTH
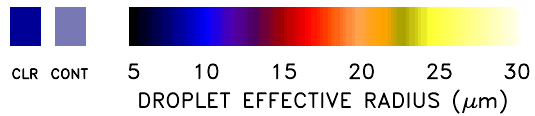
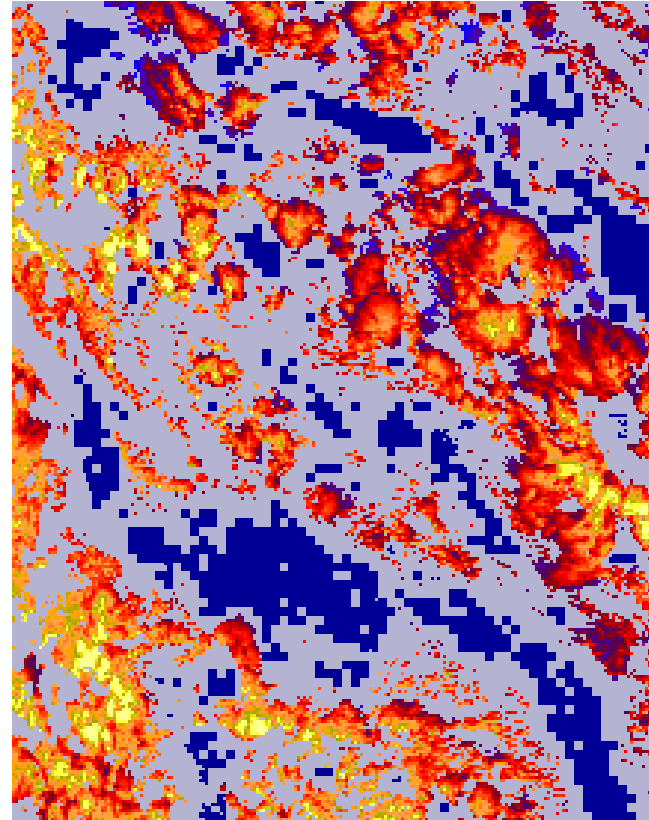# Droplet Effective Radius

Partly Cloudy r_e = 14.6 μm

Threshold r_e = 17.2 μm

CLR CONT 5 10 15 20 25 30
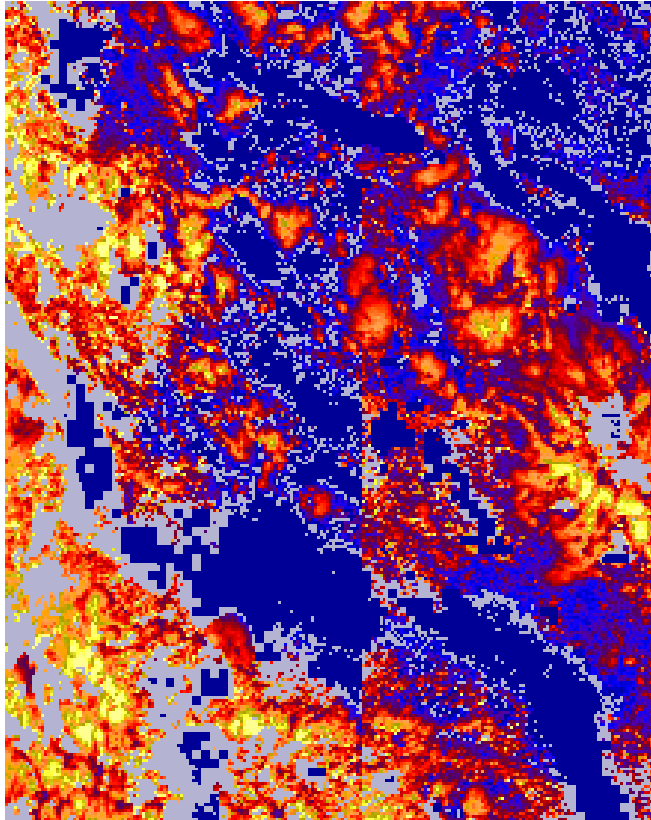
DROPLET EFFECTIVE RADIUS (μm)
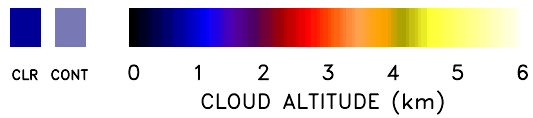
Cloud Altitude

Partly Cloudy Altitude = 3.7 km   Threshold Altitude = 2.6 km
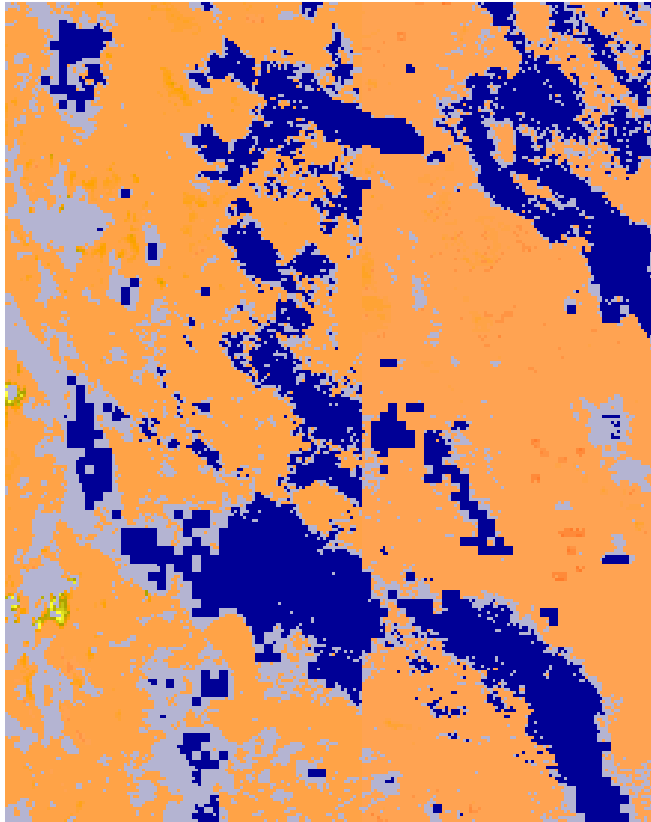
CLR CONT   0   1   2   3   4   5   6
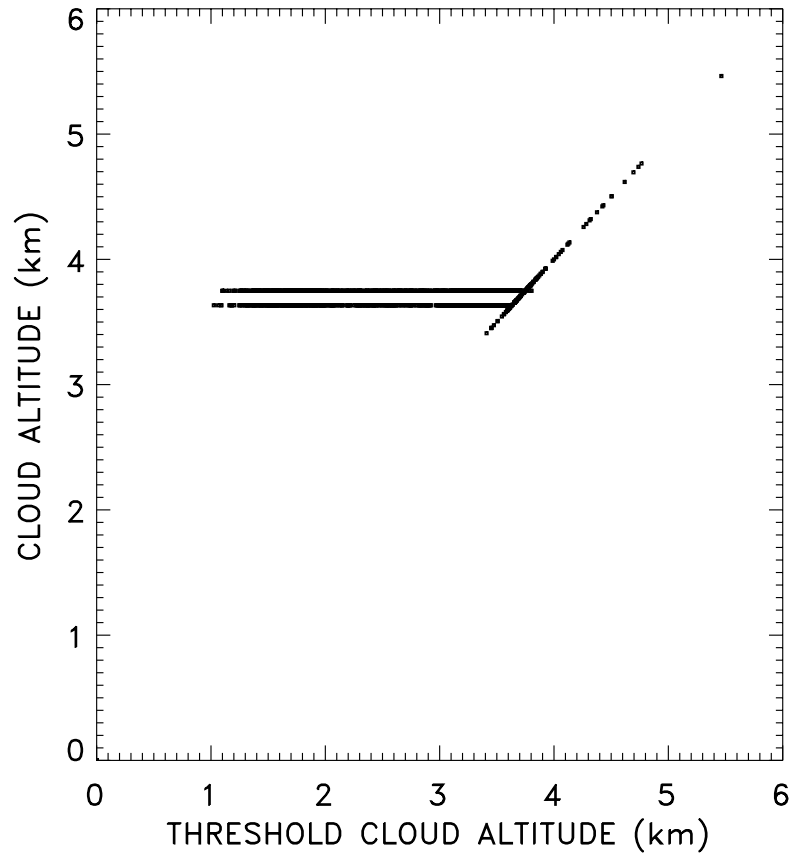CLOUD ALTITUDE (km)
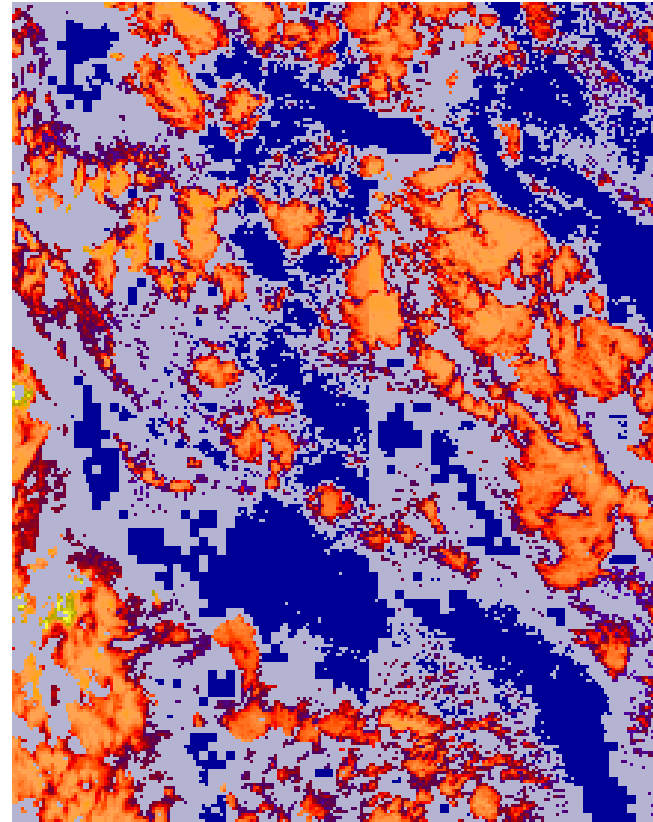
Partly Cloudy and Threshold Retrievals
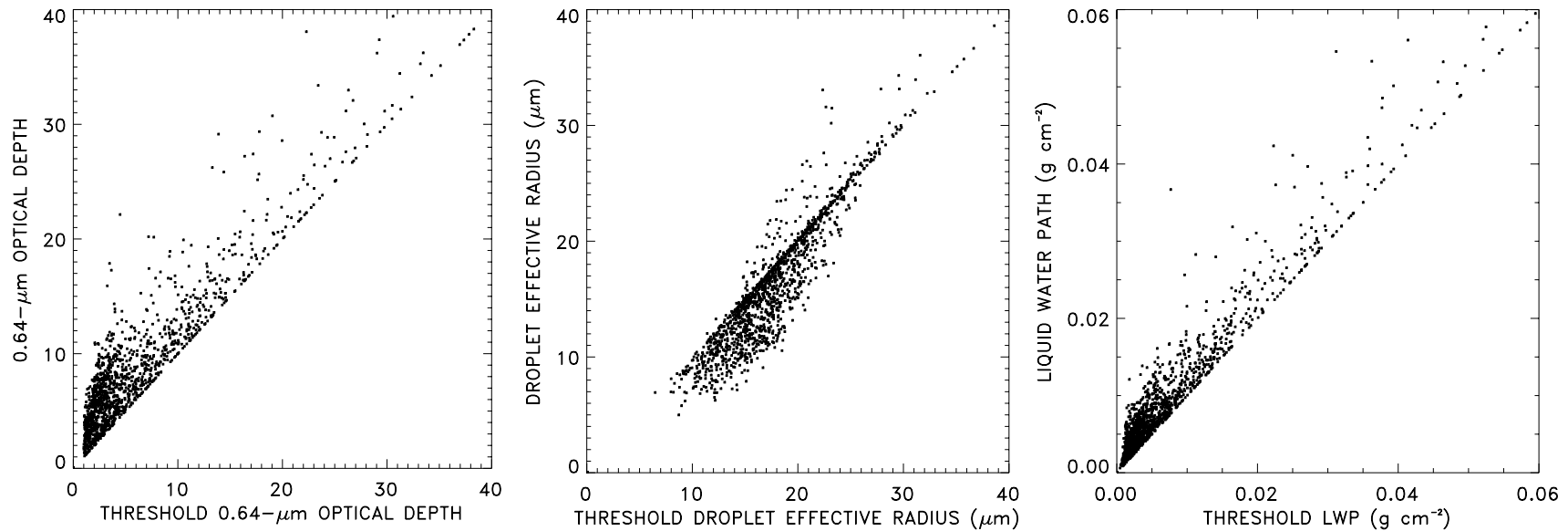
2-km pixel-scale threshold optical depths are smaller and threshold droplet effective radii are larger than those obtained with partly cloudy retrievals.

Cloud liquid water paths are larger for the partly cloudy retrievals.
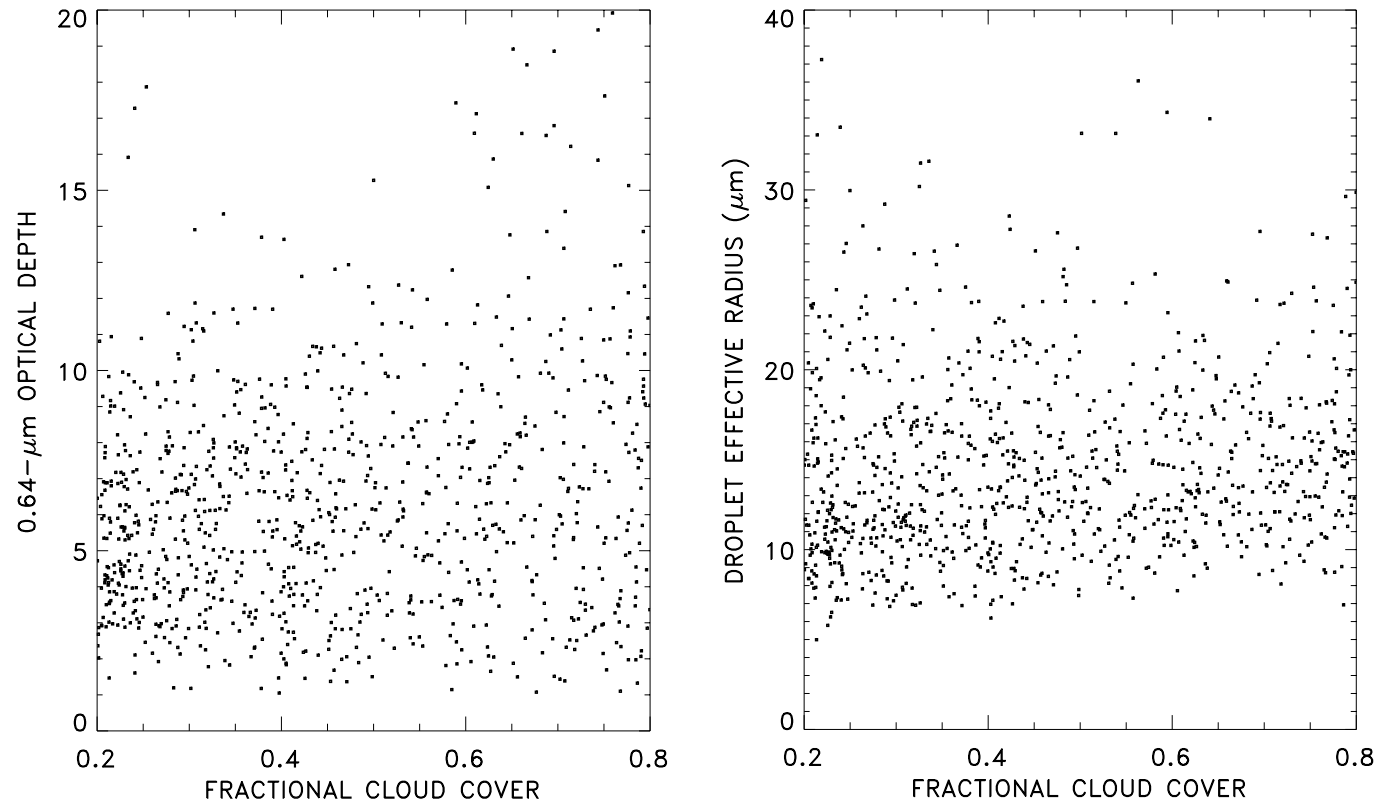
Cloud Altitude

The altitude of clouds in partly cloudy pixels is set equal to the average altitude of the clouds in the nearby overcast pixels.

Threshold altitudes for the partly cloudy pixels fall below the altitude associated with the layer.

Optical Depths, Droplet Effective Radii, and Fractional Cloud Cover

Neither optical depth nor droplet effective radius exhibits significant dependence on pixel-scale fractional cloud cover.

Linear dependence of radiances on fractional cloud cover appears to be correct.

Optical Depth and Droplet Effective Radius

Partly Cloudy
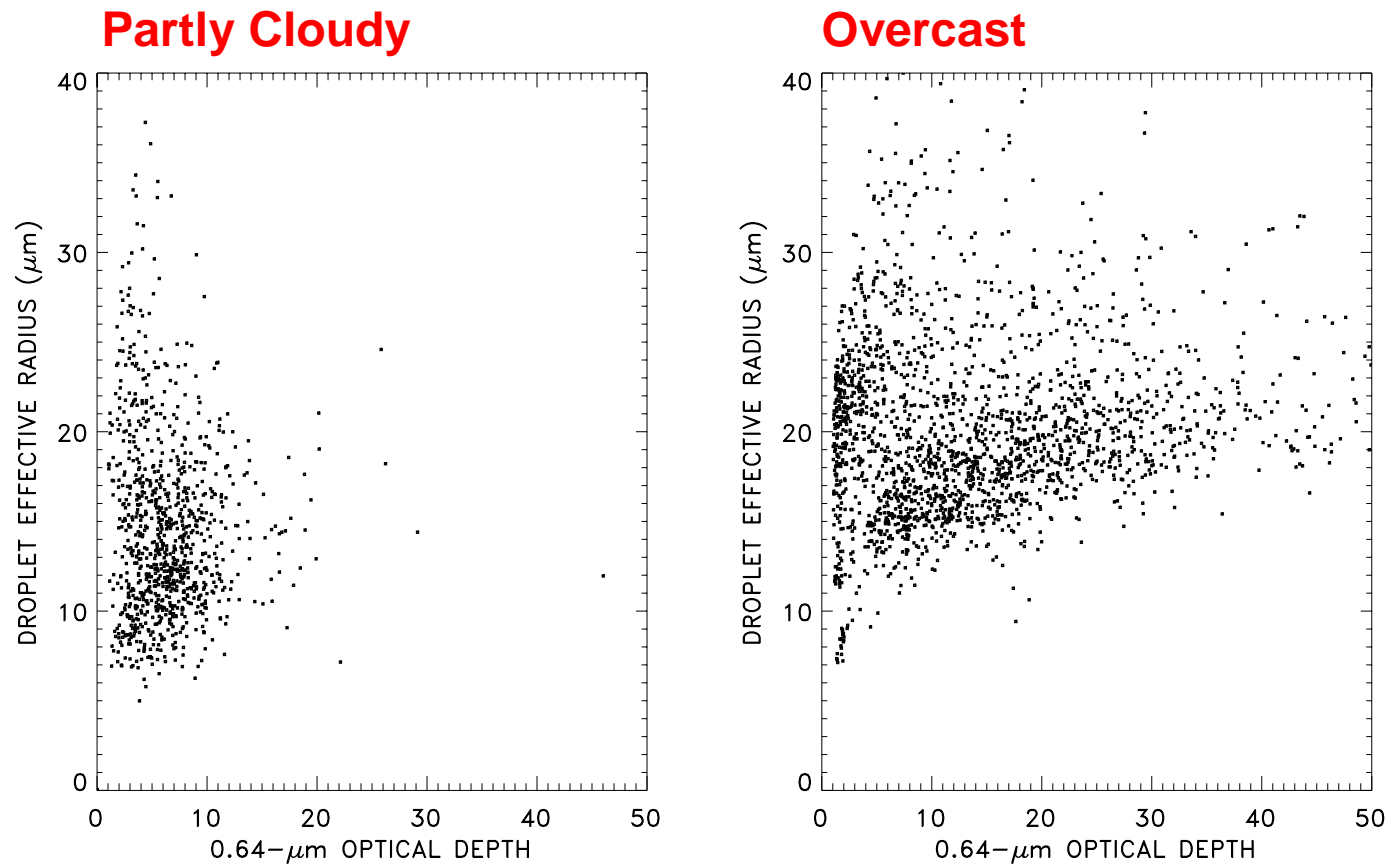
Overcast

Optical depths and droplet effective radii are generally larger for overcast pixels.

Pixel and Regional Scale Fractional Cloud Cover
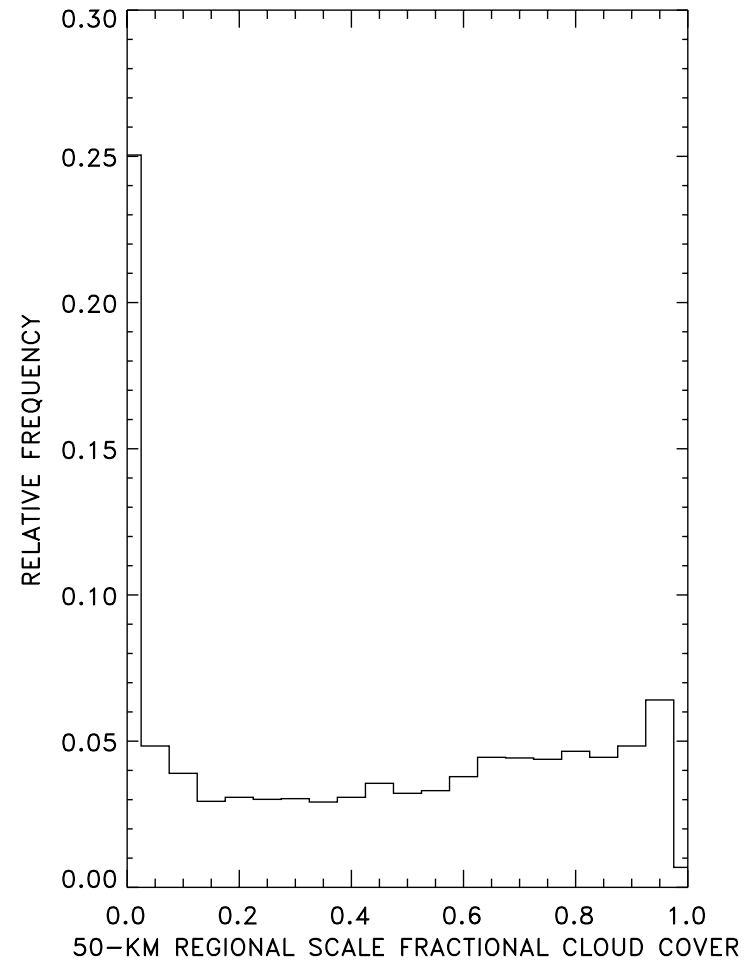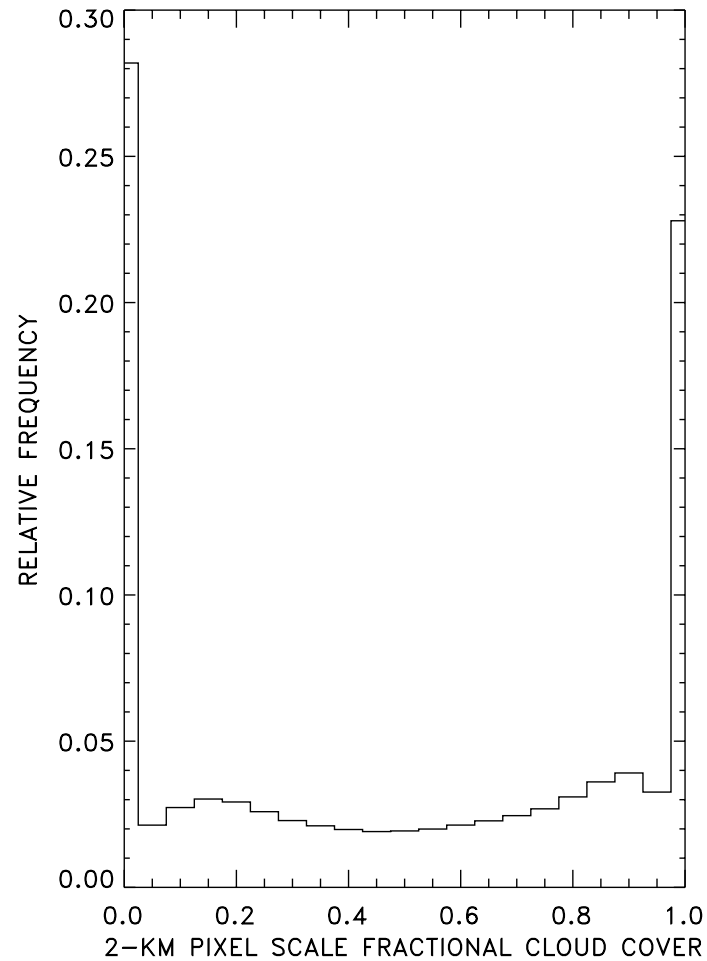
Analysis restricted to ocean scenes containing single-layered cloud systems with nearby cloud-free pixels.

Statistics drawn from over 10,000 50-km scale regions.

Pixel and Regional Scale Cloud Fraction
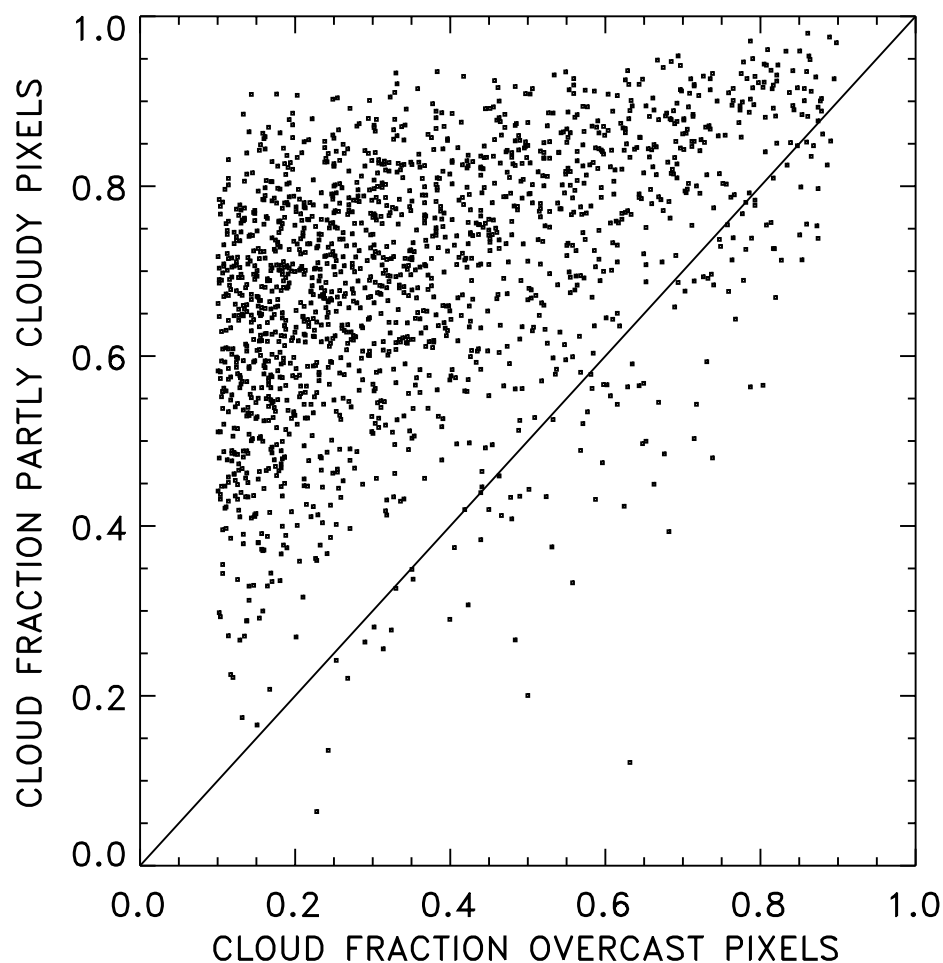
Analysis restricted to regions with single-layered clouds in which at least 10% of the pixels were overcast and 10% were partly cloud covered.

Within 50-km scale regions, fractional cloud cover for 2-km pixels is correlated with regional scale cloud cover.

Partly Cloudy and Overcast Optical Depth, Effective Radius, and Liquid Water Path
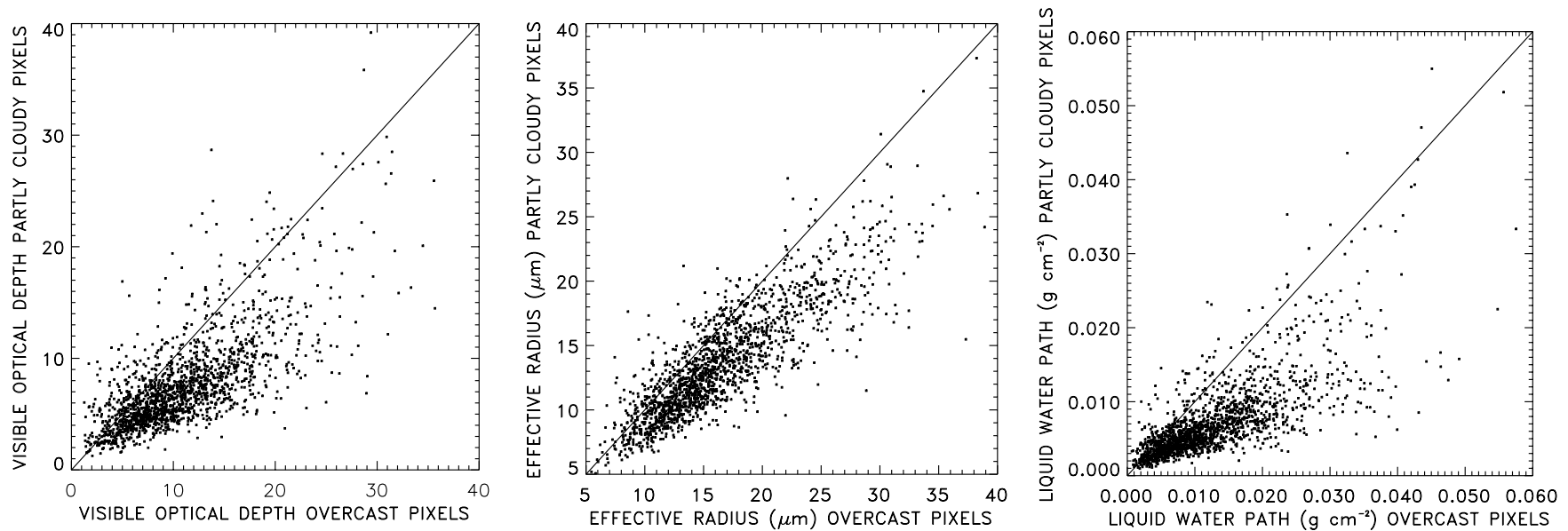
Clouds that only partially cover 2-km pixels have smaller optical depths and droplet effective radii than found in nearby clouds that completely cover the pixels.

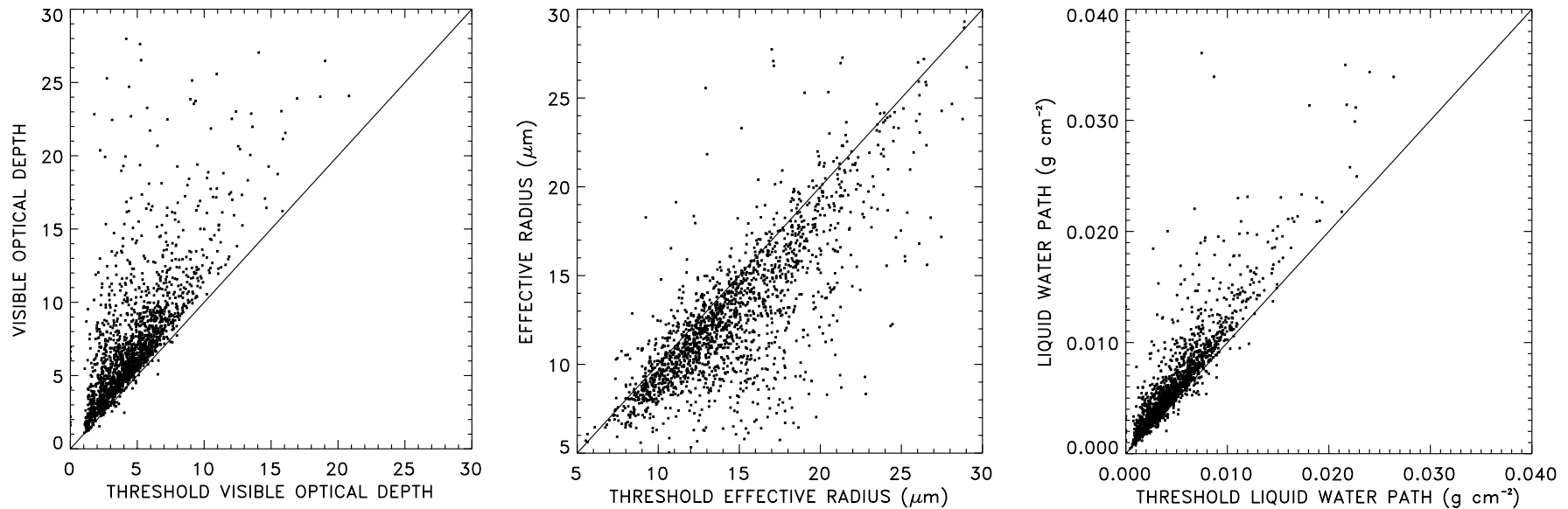# Threshold and Partly Cloudy Retrievals Regional Scale Optical Depth, Droplet Effective Radius, and Liquid Water Path

Threshold retrieval underestimates regional scale cloud optical depths by 2-4.

Threshold retrieval overestimates droplet effective radii by 2-3 μm.

Threshold retrieval underestimates cloud liquid water path by 20-30%.

Threshold and Partly Cloudy Retrievals
Regional Scale Cloud Cover and Cloud Altitude
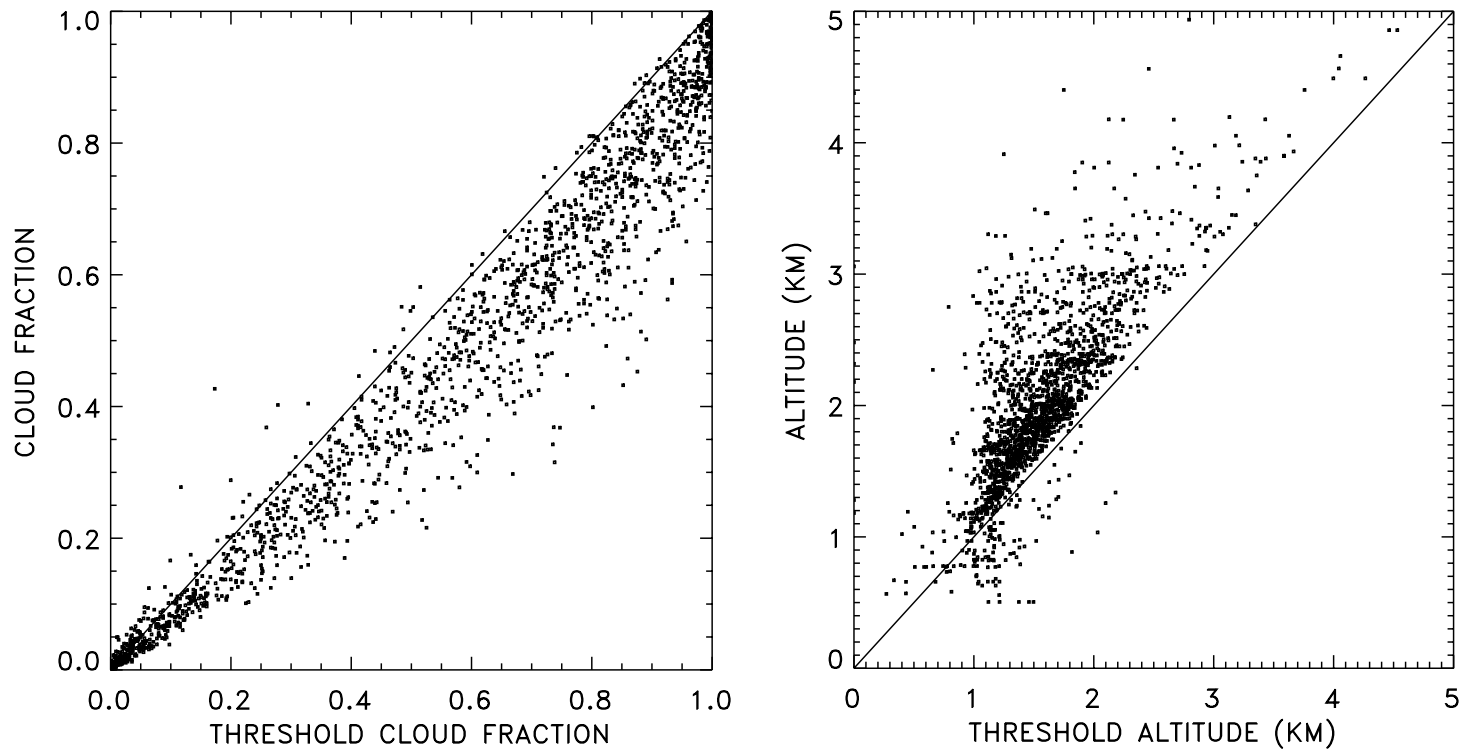
Threshold retrieval overestimates regional fractional cloud cover by 0.1.

Threshold retrieval underestimates cloud altitude by 200-400 m.

Summary

- For ocean regions, approximately 50% of all 2-km pixels are either overcast or cloud-free. The remaining 50% contain clouds that only partially fill the field of view.

- Compared with nearby clouds that completely cover imager pixels, clouds that only partially cover imager pixels have smaller optical depths, droplet effective radii, and cloud liquid water.

- Threshold retrievals generally overestimate regional scale fractional cloud cover and droplet effective radius and underestimates cloud altitude, visible optical depth, and cloud liquid water path.

Work to be Done

- Are the results sensitive to the size of the pixel?

- How sensitive are the cloud properties retrieved for partly cloudy pixels to uncertainties in the cloud-free radiances and the altitude of the cloud layer?

- What are the implications for TOA and surface radiative fluxes?