

# Search for “Adiabatic” Marine Stratus Using MODIS Cloud Products

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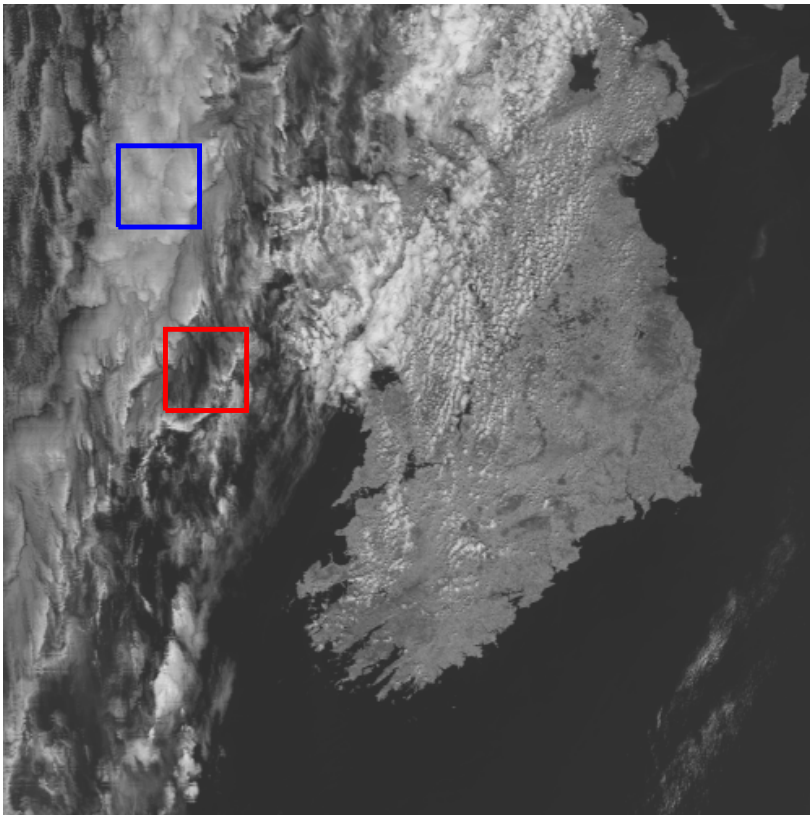
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- **Goal:** *Use MODIS imagery to determine the degree to which marine stratus behave like “adiabatic” clouds.*

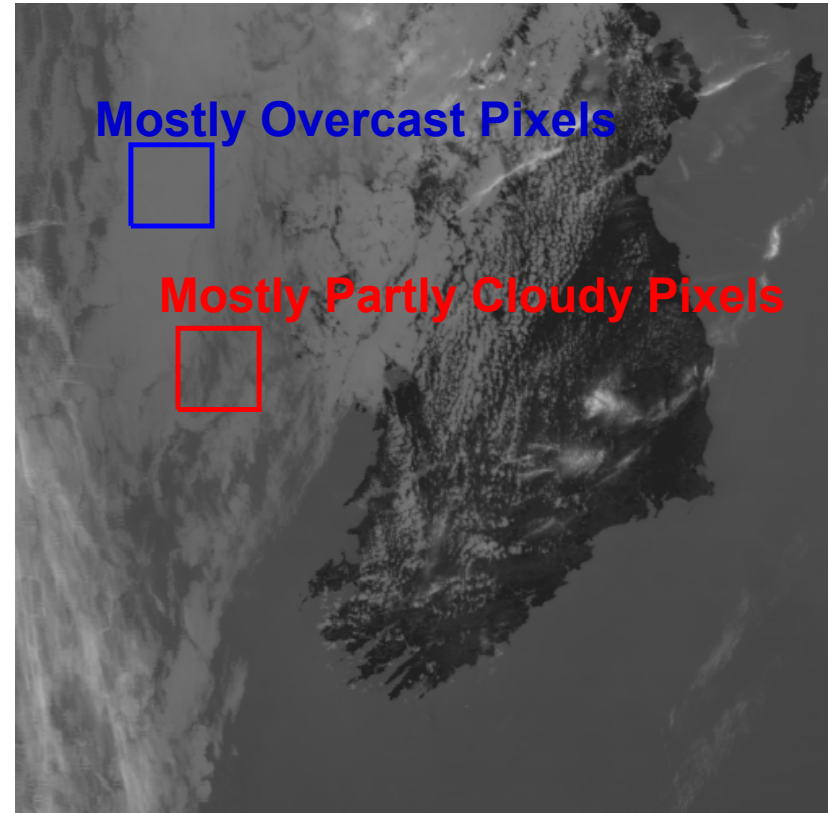
# 1-km MODIS Imagery

Terra 1 May 2001 1140 Z North Atlantic

0.84  $\mu\text{m}$

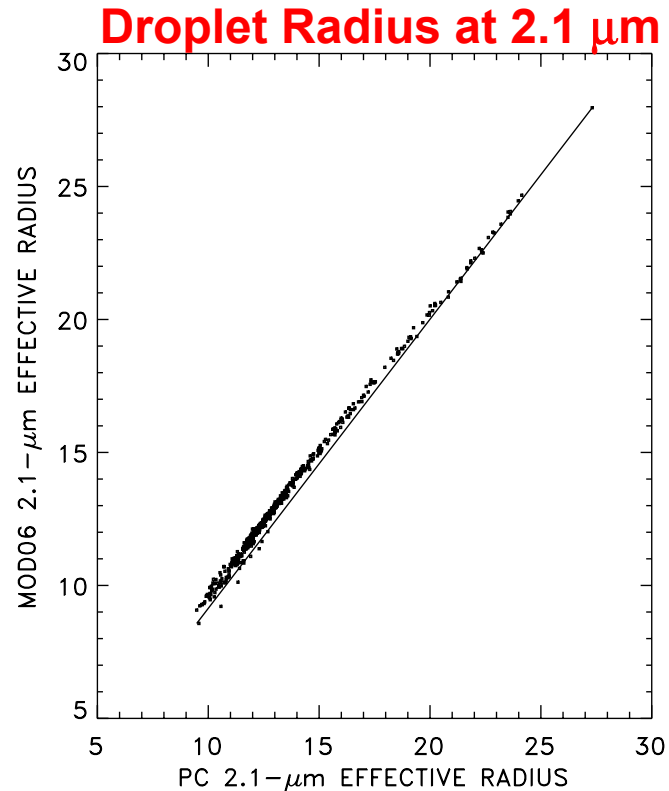
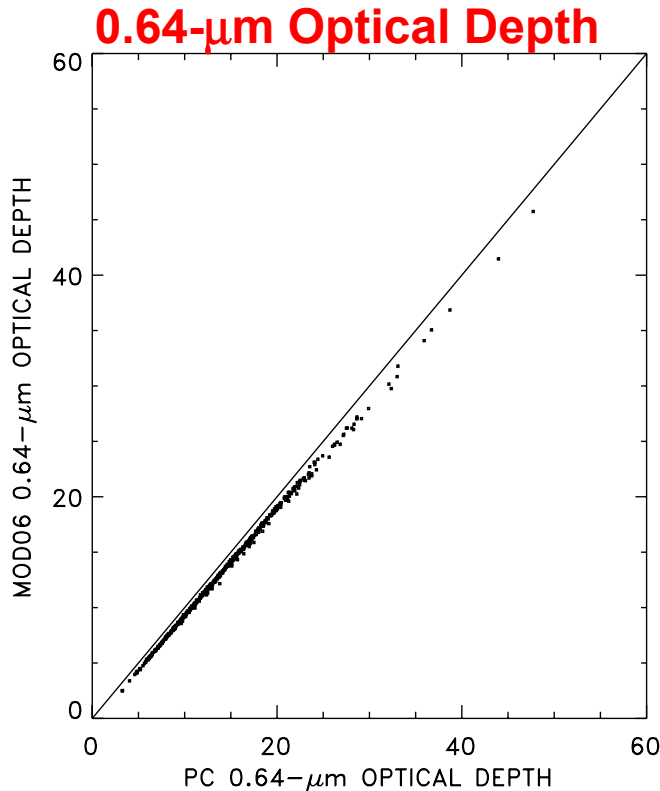


11  $\mu\text{m}$



*50-km scale regions selected that contain only single-layered, low-level marine stratocumulus.*

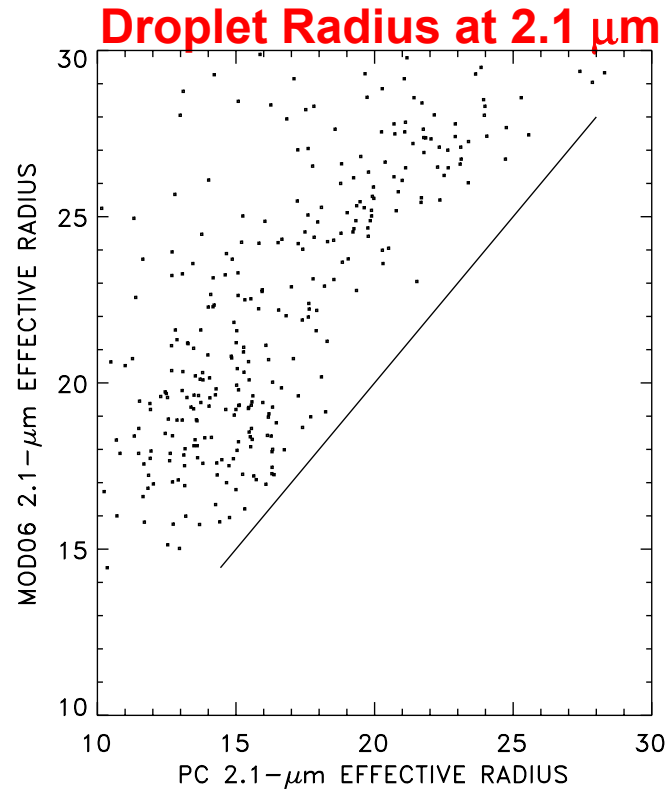
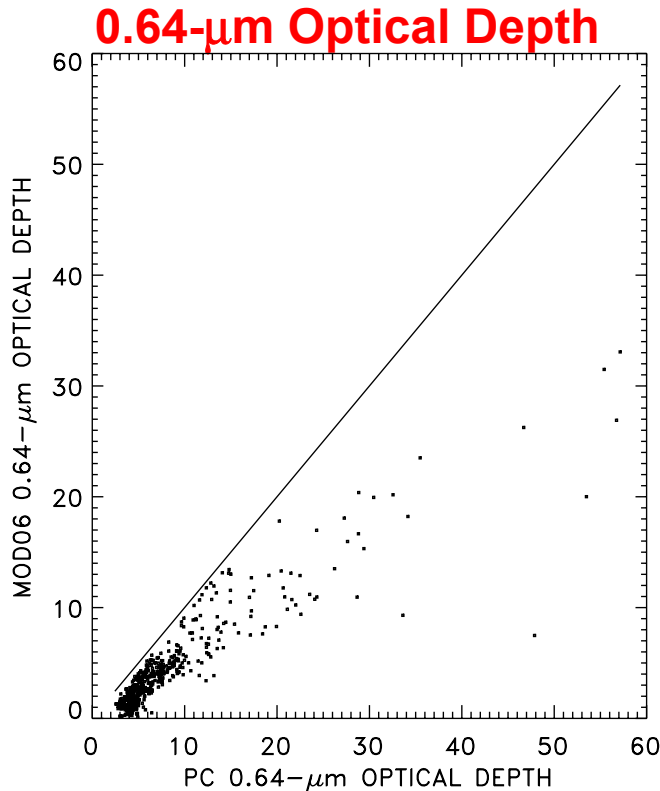
# Optical Depth and Droplet Effective Radius for *Overcast Pixels*



*1-km overcast pixels drawn from 50-km scale region containing mostly overcast pixels.*

*MOD06 cloud products and partly cloudy pixel retrievals agree when 1-km pixels are overcast.*

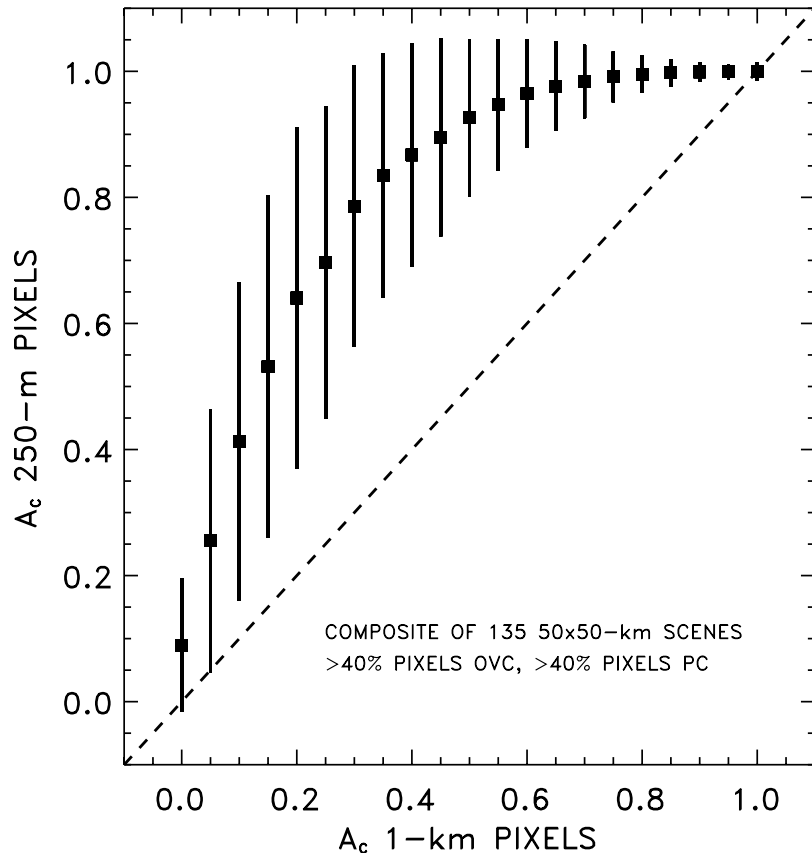
# Optical Depth and Droplet Effective Radius for *Partly Cloudy Pixels*



*1-km partly cloudy pixels drawn from 50-km scale region containing mostly partly cloudy pixels.*

*MOD06 optical depths too small and droplet radii too large when 1-km pixels are partly cloud covered.*

# Cloud Cover



Cloud cover derived for partly cloudy pixel retrievals at 1 km and MOD06 cloud flag at 250 m and then aggregated to 1 km.

Results are for 50-km scale regions that contained only single-layered, marine stratocumulus in the north Atlantic.

Based on the partly cloudy pixel retrievals, the 50-km regions selected had more than 40% of the 1-km pixels overcast and more than 40% of the pixels partly cloudy.

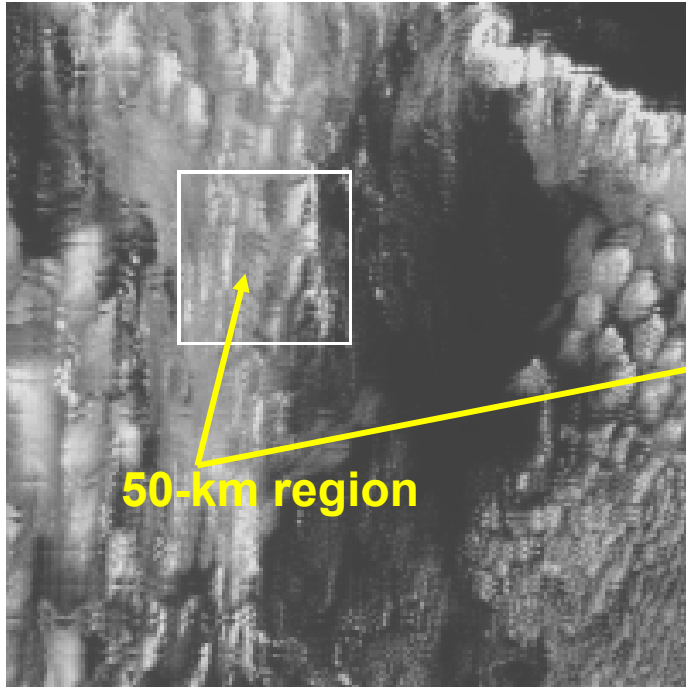
Cloud cover fractions binned according to pixel-scale fractional cloud cover.

***MODIS 250-km cloud mask severely overestimates the fractional cover.***

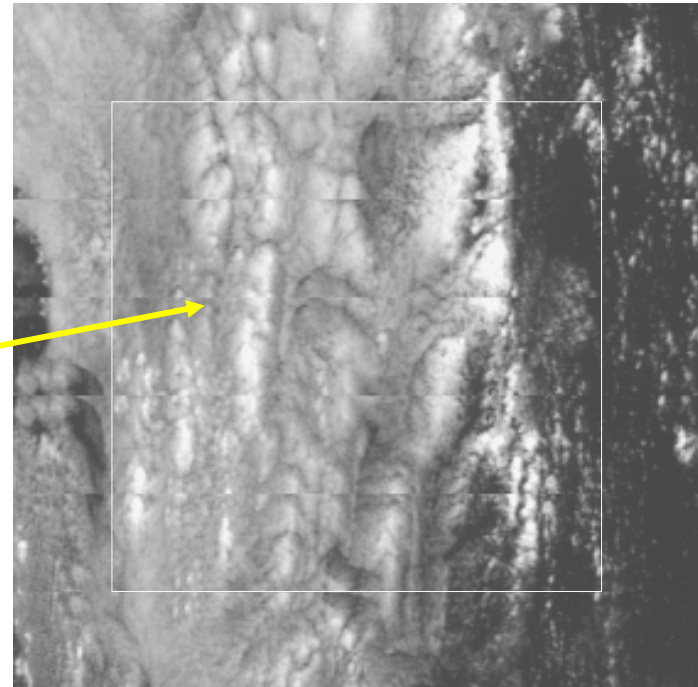
# Partly Cloudy Marine Stratocumulus

0.64- $\mu\text{m}$  Reflectances Terra 13 May 2004 1110 UTC

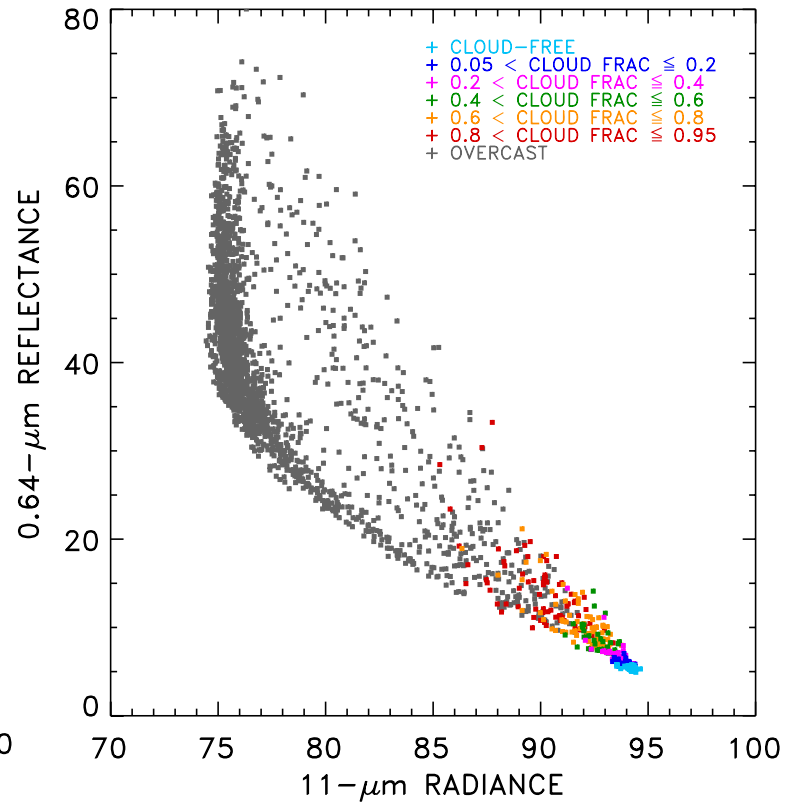
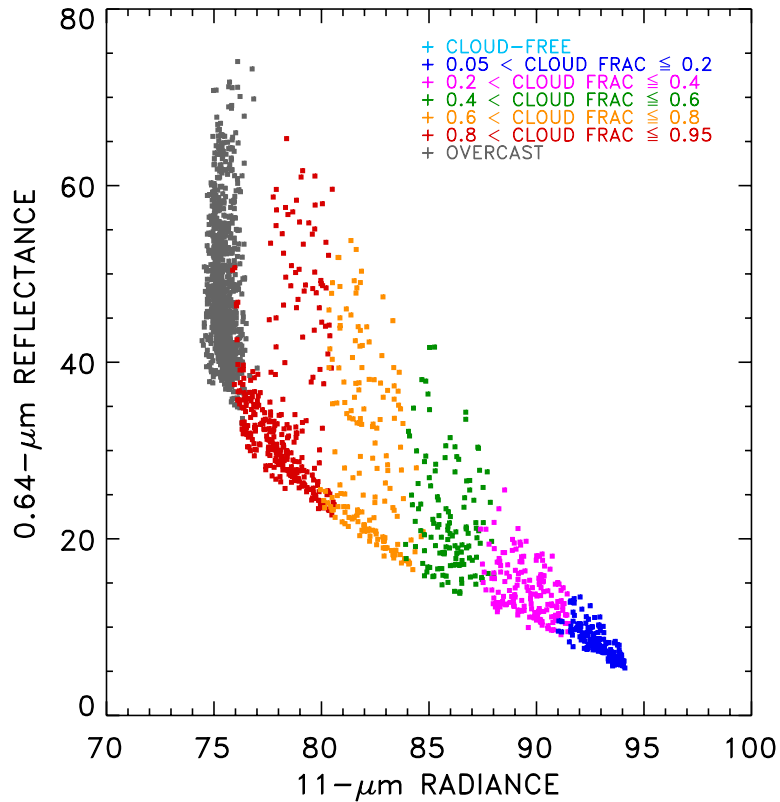
1-km



250-m



# Visible-IR Interpretation



# *Adiabatic Clouds:*

## **Expected Relationships Among Cloud Properties**

$$w \propto (Z - Z_{\text{LCL}}) \propto H \quad R_e \propto (Z - Z_{\text{LCL}})^{1/3} \propto H^{1/3}$$

$Z_{\text{LCL}}$

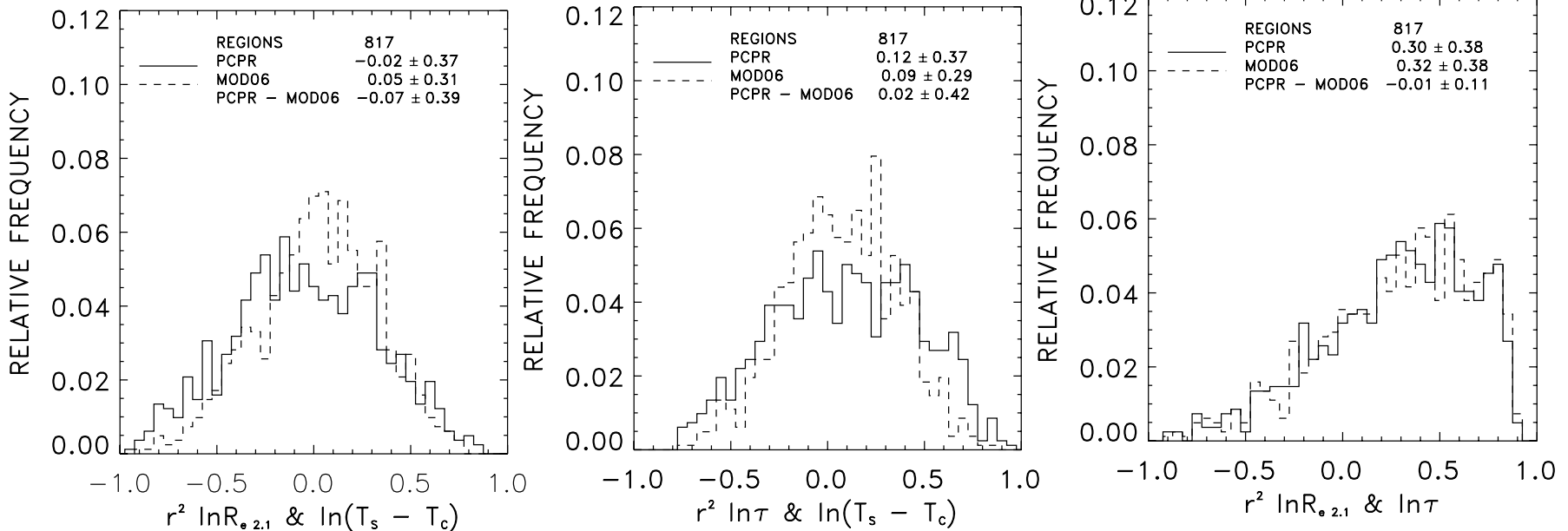


$$\tau \approx \int_{Z_{\text{LCL}}}^{Z_{\text{LCL}}+H} dz' 2\pi R_e^2(z') n \propto H^{5/3}$$
$$d \ln R_e / d \ln \tau = 1/5$$



# Optical Depth, Droplet Radius, and Cloud Altitude

## Overcast 1-km Pixels

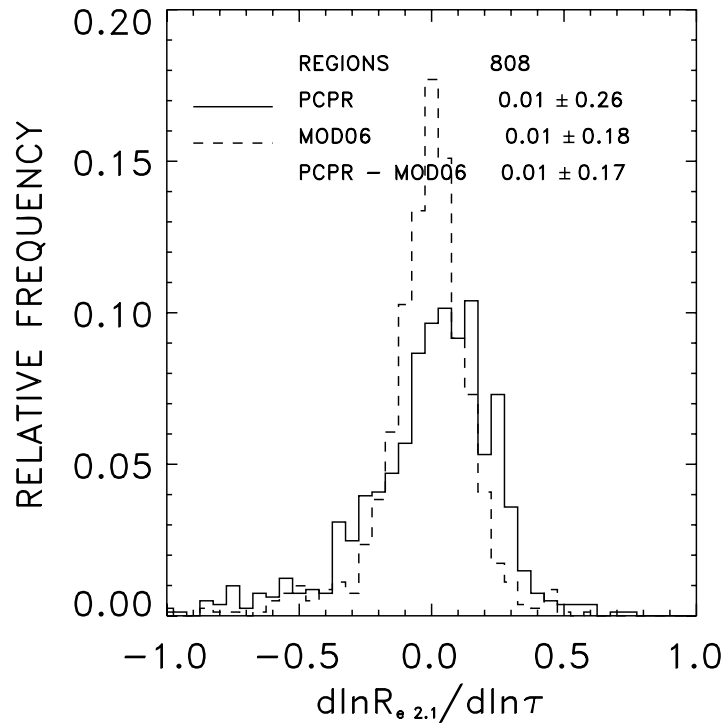


**Variability of properties within 50-km scale regions containing no clouds other than a single-layer of marine stratocumulus.**

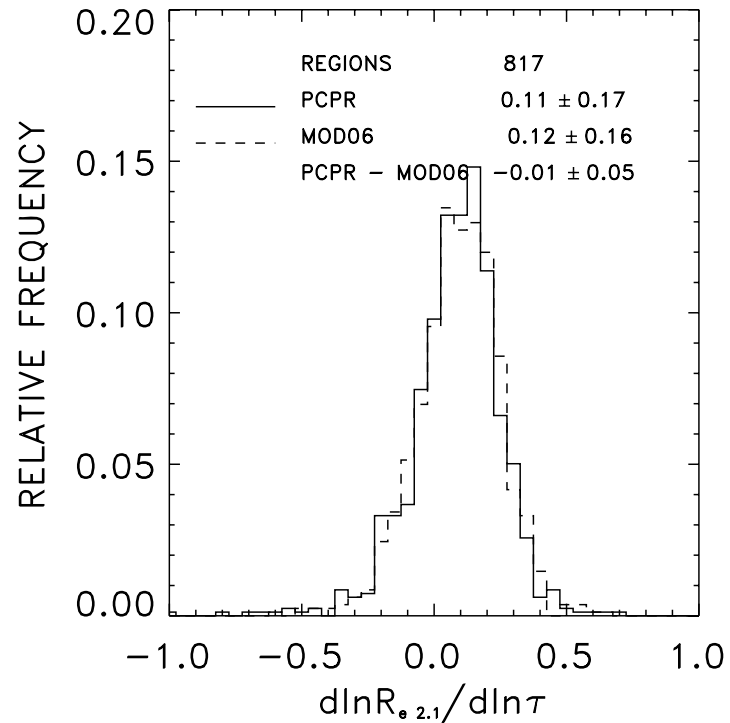
*Droplet radius and optical depth show no correlations with cloud-top altitudes, but droplet radius and optical depth are correlated for **OVERCAST 1-km pixels.***

# Slope of Droplet Radius and Optical Depth Relationship at 2.1 $\mu\text{m}$

*Partly Cloudy 1-km Pixels*



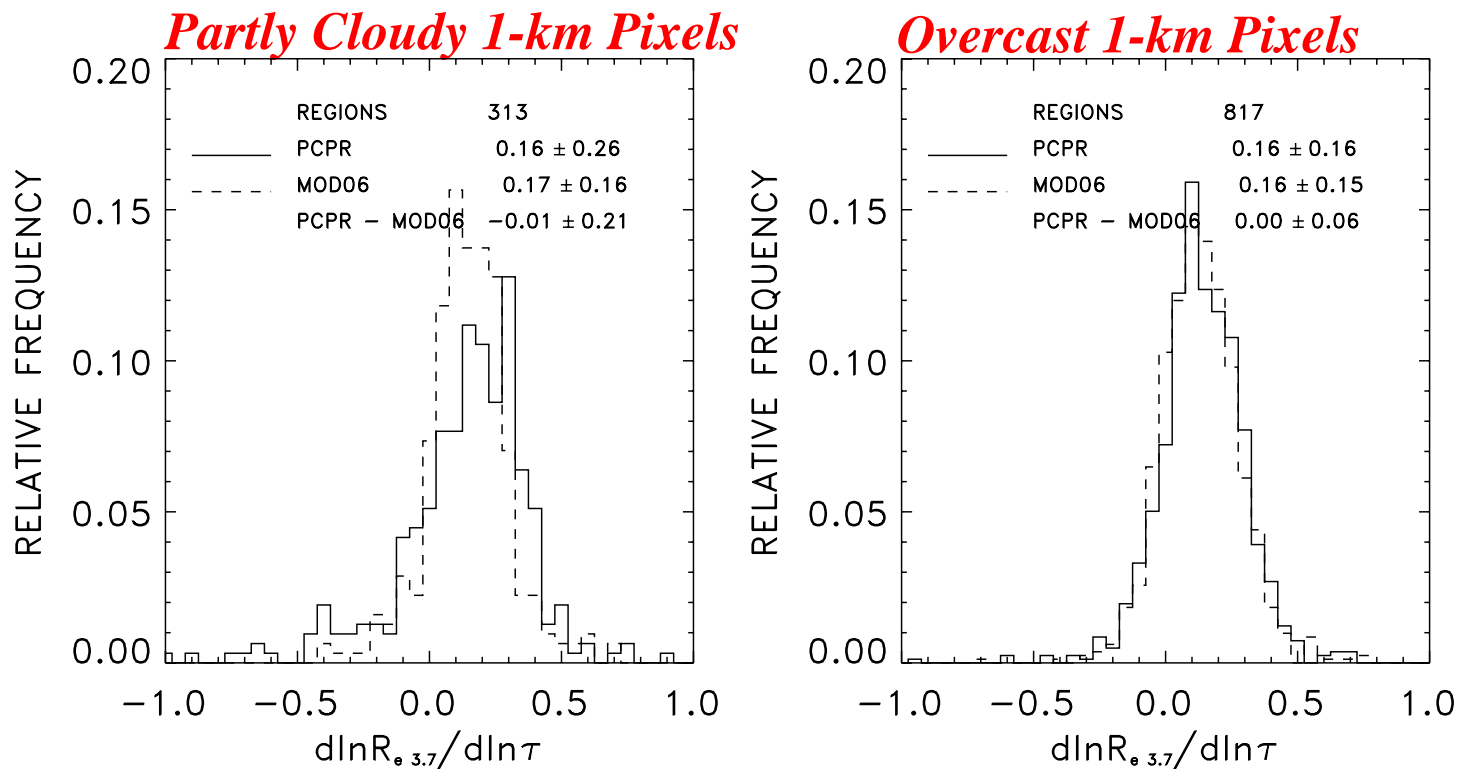
*Overcast 1-km Pixels*



**Overcast pixels show half the value of  $d \ln R_e / d \ln \tau$  expected for “adiabatic clouds.”**

*Partly cloudy pixels show no correlation for either the MOD06 product or the partly cloudy pixel retrievals.*

# Slope of Droplet Radius and Optical Depth Relationship at 3.7 $\mu\text{m}$



*Retrievals of droplet radius at 3.7- $\mu\text{m}$  give  $d \ln R_e / d \ln \tau$  closer to the expected value of 0.2 whether for partly cloudy or overcast pixels.*

# Remaining Mystery

## Properties of marine stratocumulus within 50-km scale regions

	MOD06		Partly Cloudy Pixel Retrieval	
	Overcast Pixels	Partly Cloudy Pixels	Overcast Pixels	Partly Cloudy Pixels
Optical Depth	16.8 ± 10.0	7.3 ± 6.0	17.6 ± 10.0	10.4 ± 8.0
1.6- $\mu\text{m}$ Radius	12.0 ± 3.9	13.2 ± 5.6	12.1 ± 3.8	11.2 ± 4.4
2.1- $\mu\text{m}$ Radius	12.2 ± 3.8	13.3 ± 5.6	12.4 ± 3.8	11.6 ± 4.6
3.7- $\mu\text{m}$ Radius	12.0 ± 3.4	11.7 ± 4.1	12.3 ± 4.0	11.2 ± 4.3

Based on diffusion lengths for photons at 1.6, 2.1, and 3.7  $\mu\text{m}$  and the growth of droplet radius with altitude within “adiabatic” clouds, droplet radii retrieved using 3.7- $\mu\text{m}$  reflectances should be larger than those retrieved using 2.1 and 1.6- $\mu\text{m}$  reflectances.

*While  $d \ln R_e / d \ln \tau$  greater with droplet radii retrieved using 3.7- $\mu\text{m}$  reflectances for overcast pixels, those at 2.1 and 1.6  $\mu\text{m}$  are equal.*