Cloud Properties Retrieved from Airborne Measurements of Transmitted and Reflected Shortwave Spectral Radiation

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SEAC4RS science team meeting
2015-04-29

Instrument and measurements

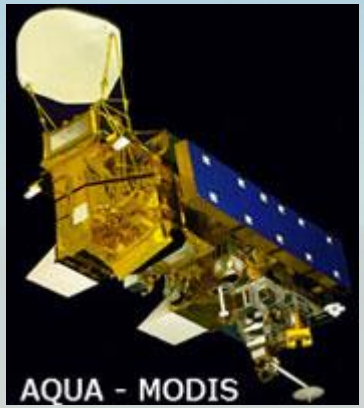
Instrument and Measurements

4STAR – **S**pectrometer for **S**ky-**S**canning, **S**un-**T**racking **A**tmospheric **R**esearch

- Measures direct sun irradiance and sky radiances (including zenith)
- Spectral range: between ~350 nm and ~1700 nm
- Many operating modes

Focus on Zenith mode

Remote sensors based on reflected and transmitted light



MODIS

eMAS
(enhanced MODIS airborne simulator)

RSP
(Research Scanning Polarimeter)

SSFR
(Solar Spectral Flux Radiometer)

CPL
(Cloud Physic Lidar)

4STAR

SSFR

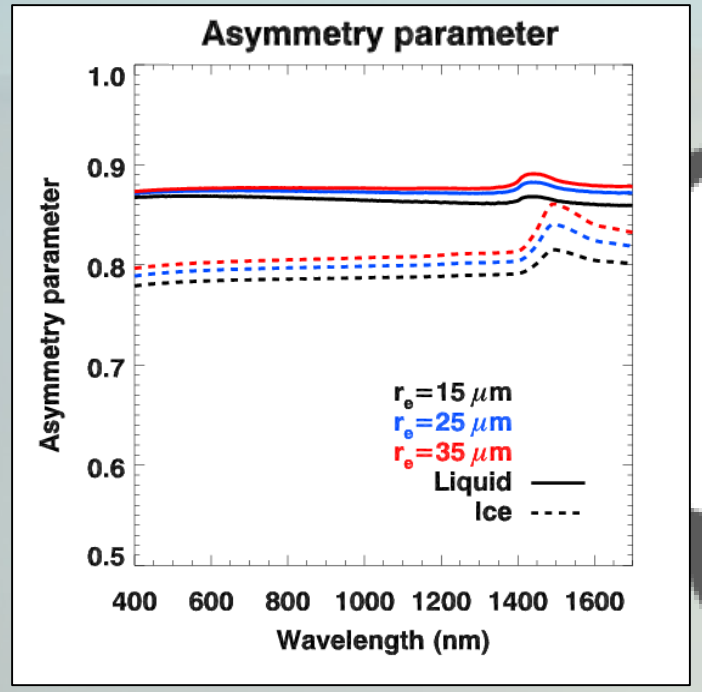
Cloud probes

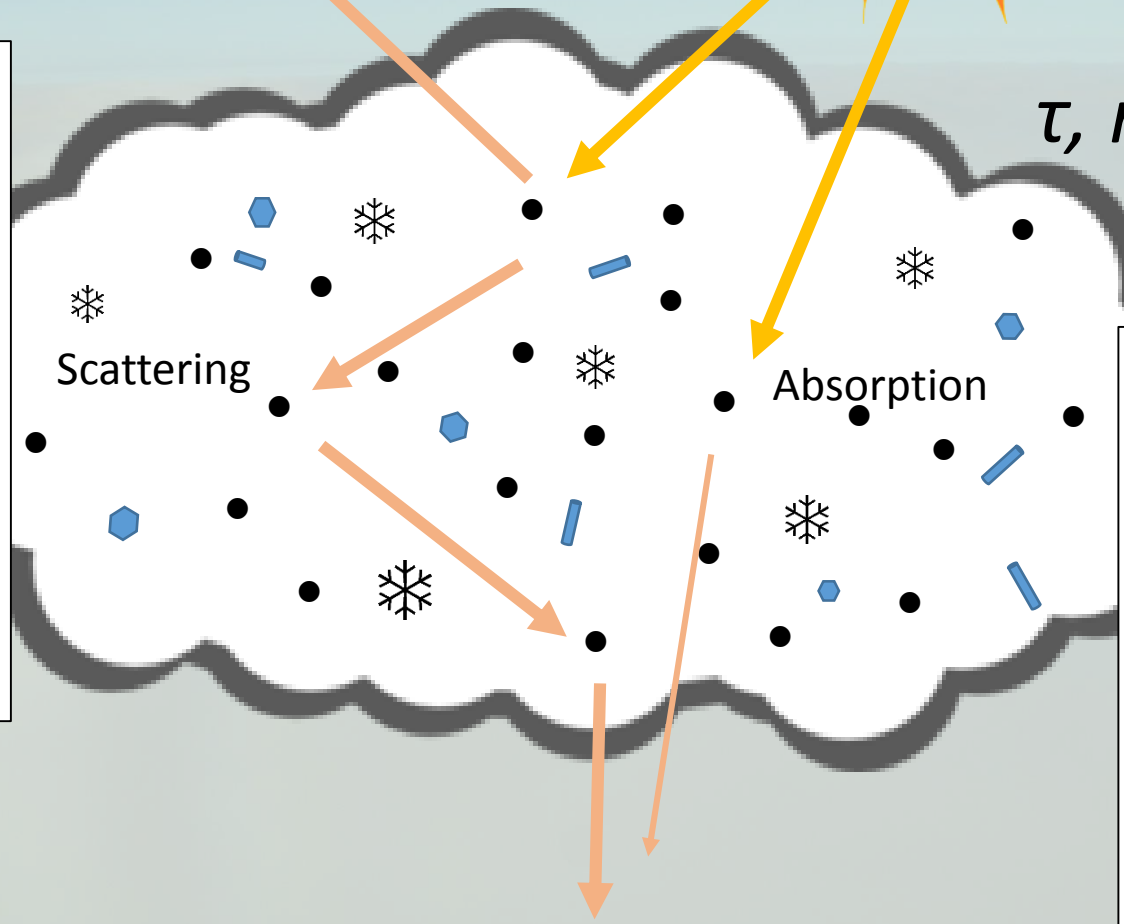
APR-2

Theory and summary of new retrieval

Radiative transfer theory

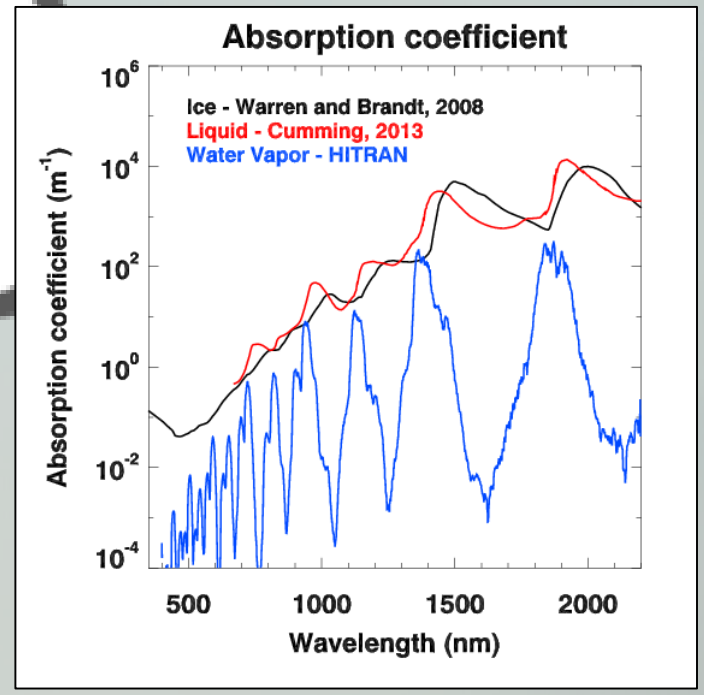
Reflection (eMAS, RSP, SSFR)





τ, r_{eff}, *and* φ

(thermodynamic phase)

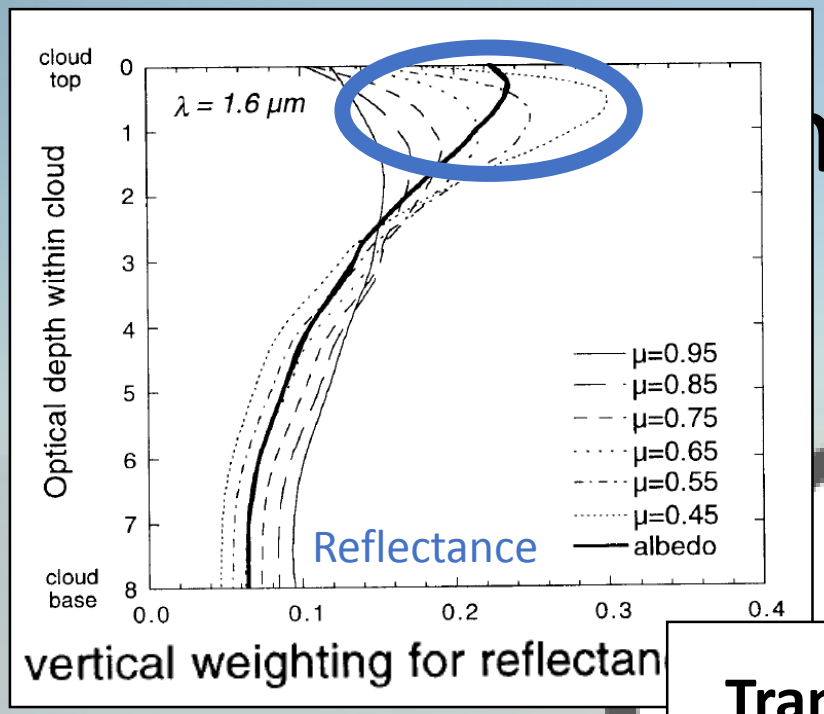


Transmission (4STAR, SSFR)

LeBlanc et al. [2015]

nsfer theory

Reflection (eMAS, RSP, SSFR)

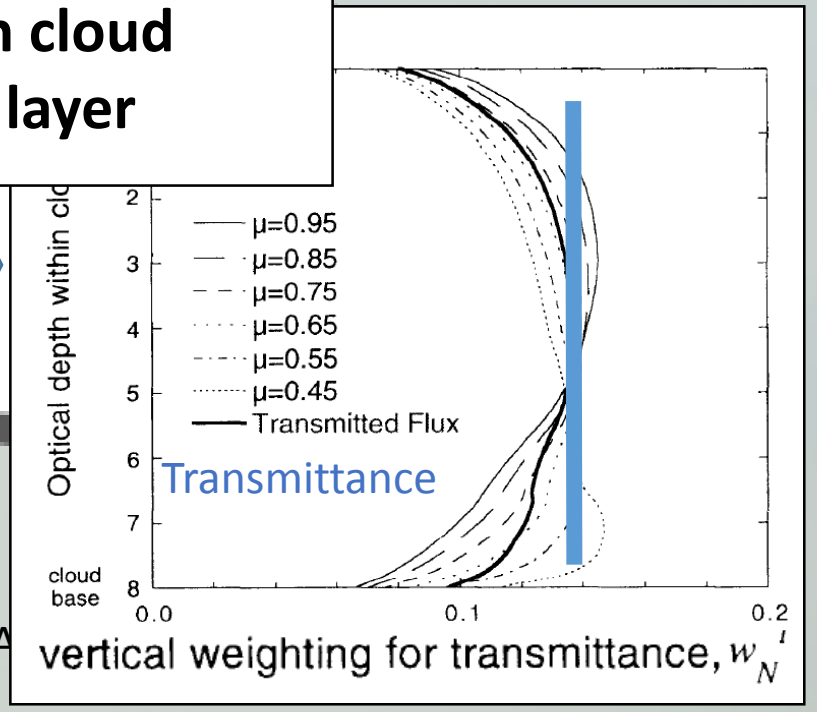


τ, r_{eff}, and φ

(thermodynamic phase)

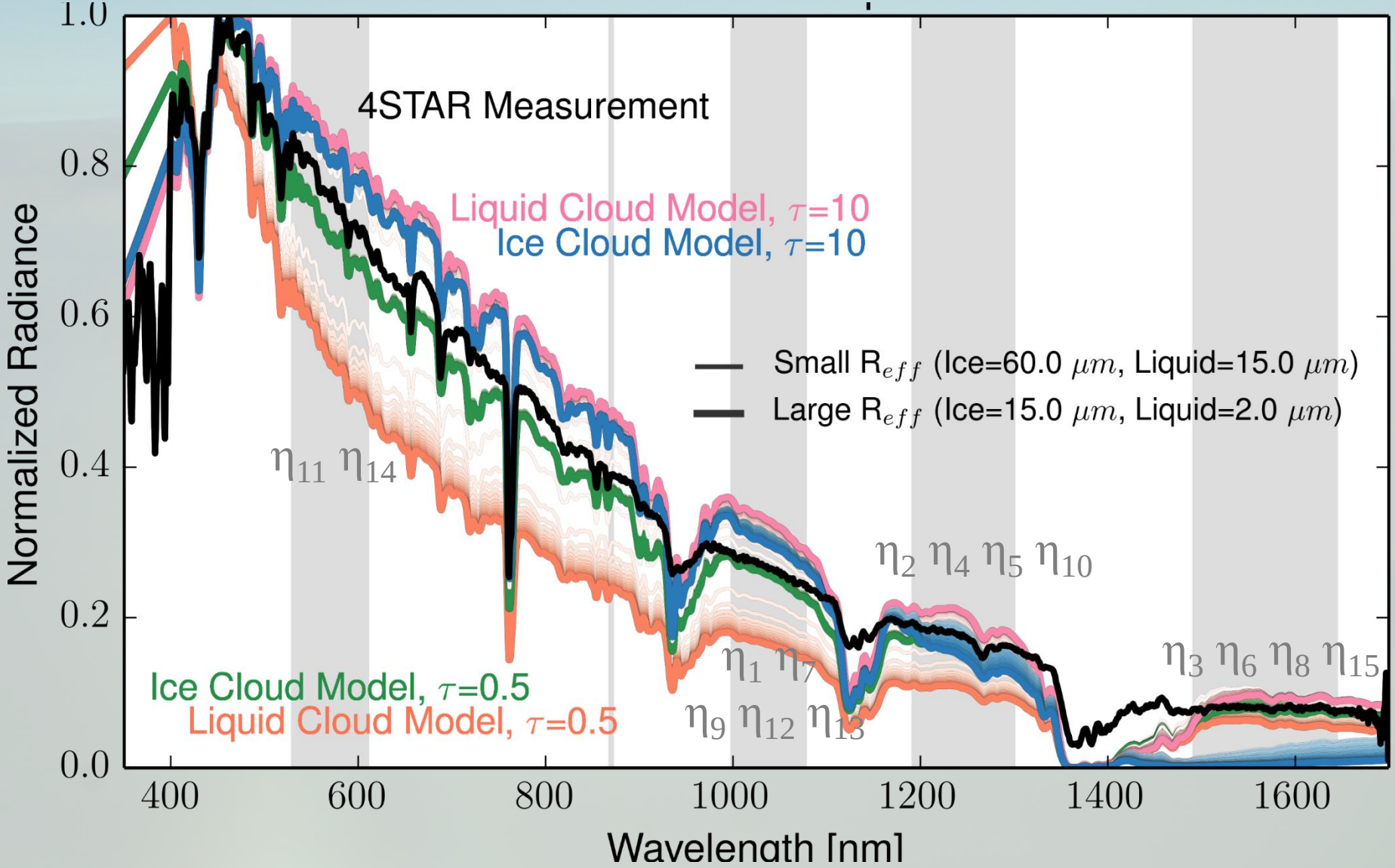
Transmitted light interacts with cloud particles throughout the cloud layer

Transmission (4STA



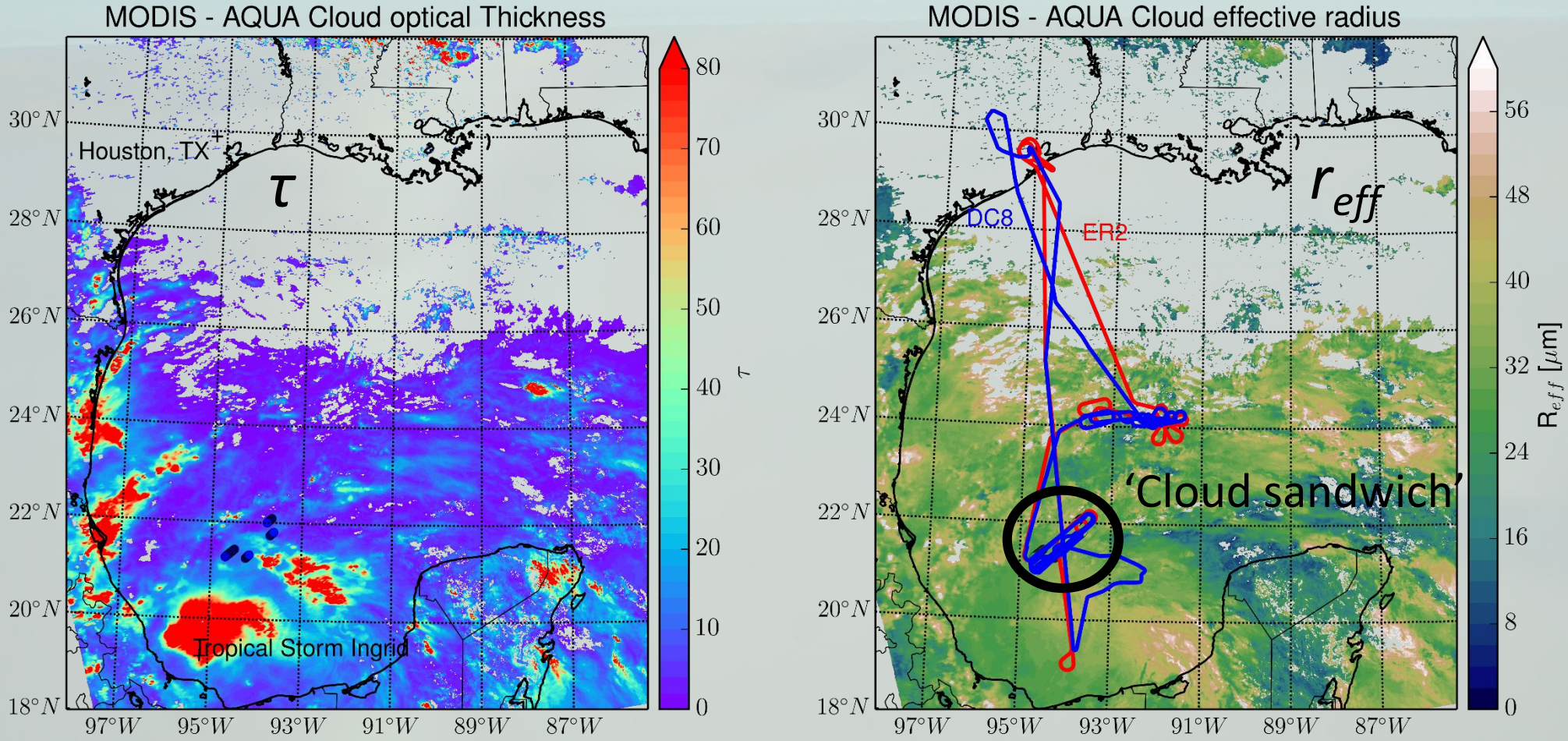
Platnick [2000]

Zenith radiances under clouds show different spectral shapes depending on cloud properties



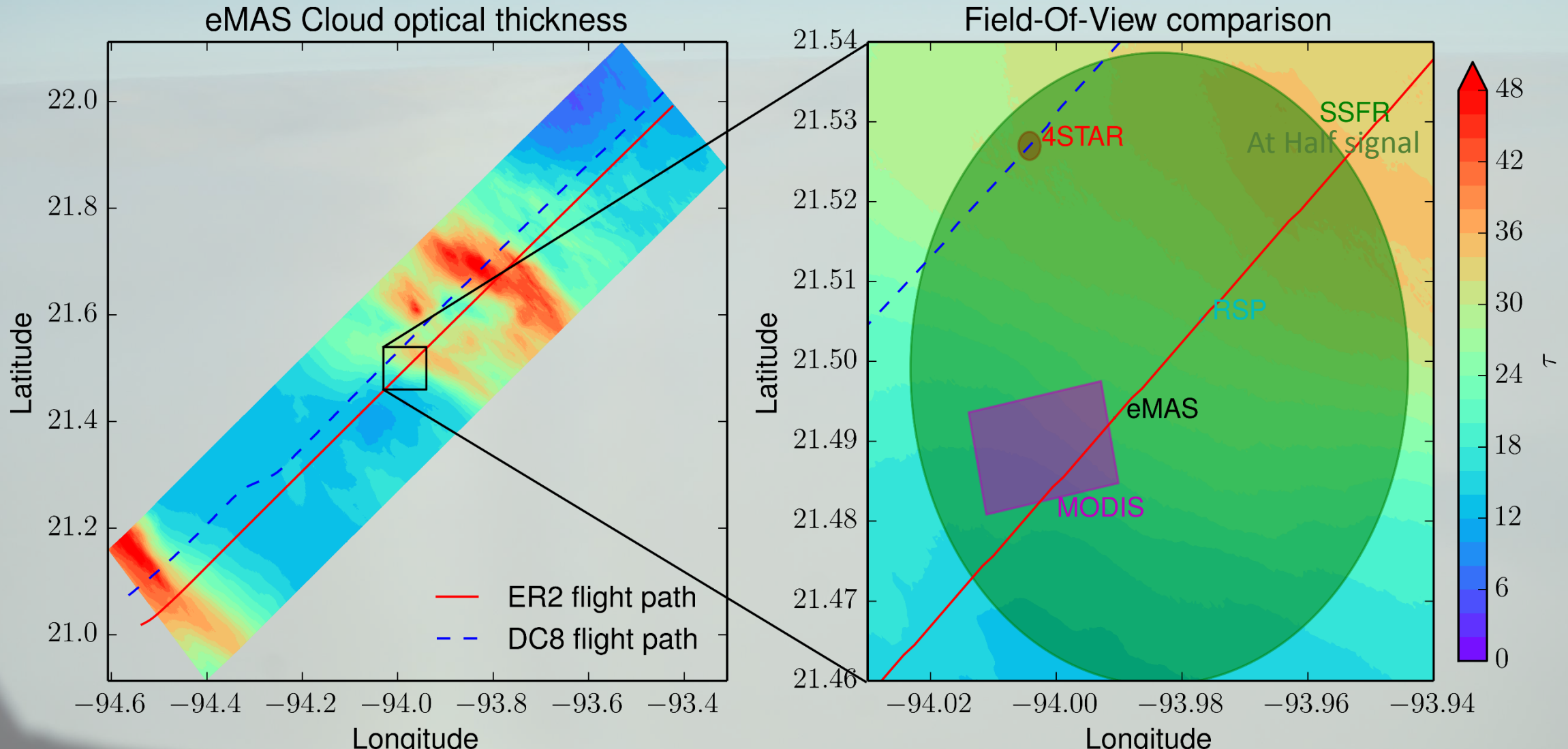
Case study of Flight on September 13th , 2013 “Hurricane Ingrid”

A case study of clouds near tropical storm Ingrid in the Gulf of Mexico

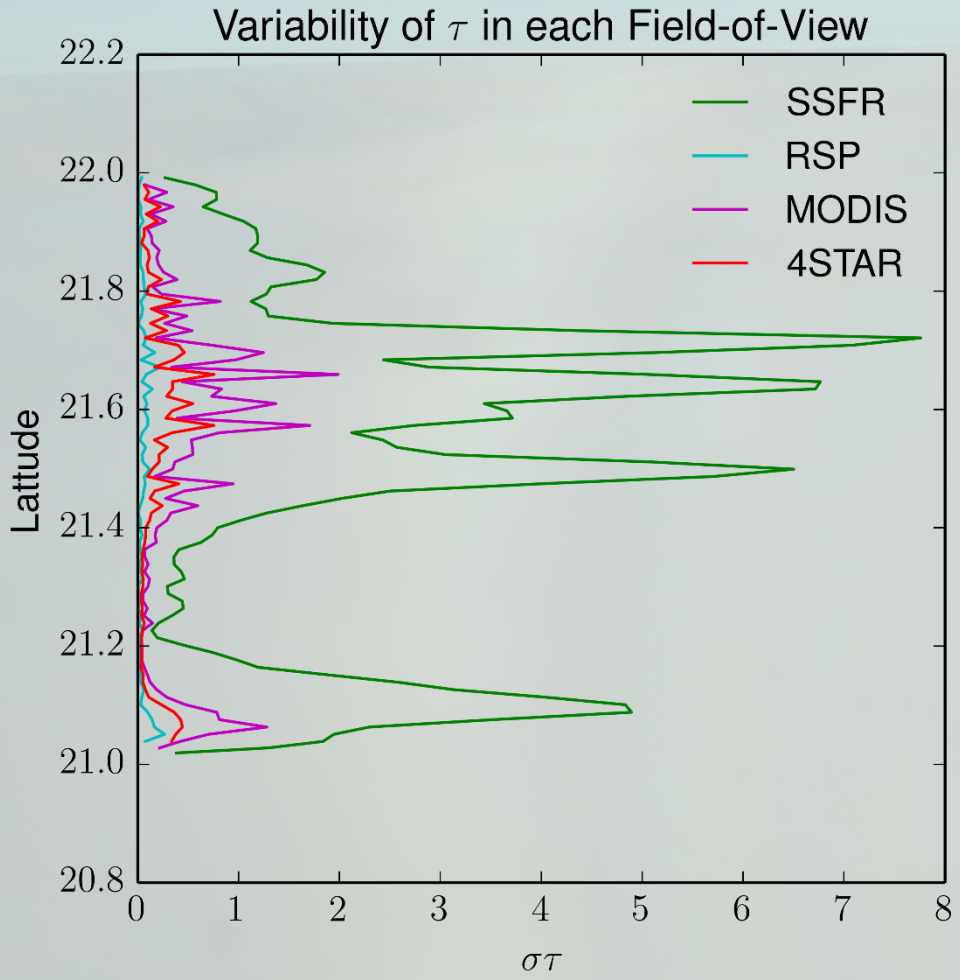


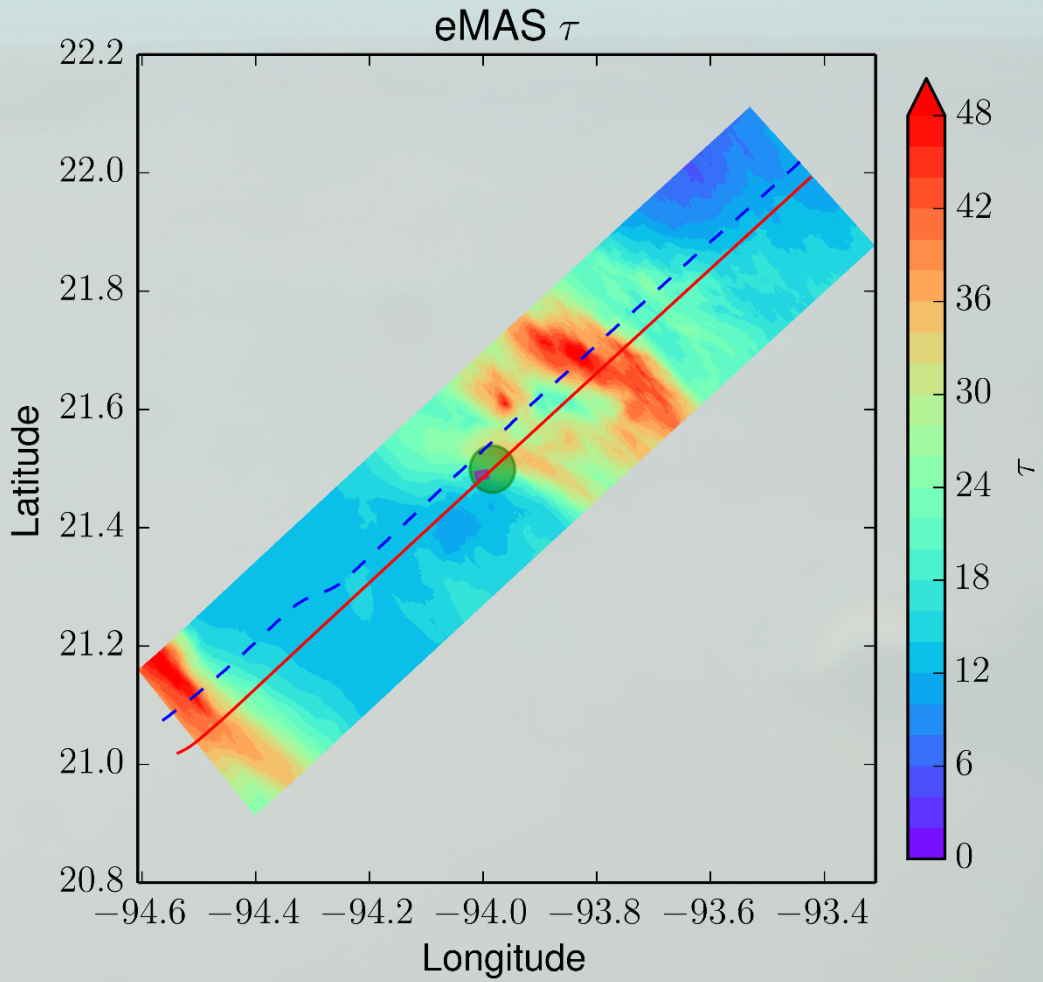
2013 – 09 – 13

Comparing sampling area of the different remote sensors

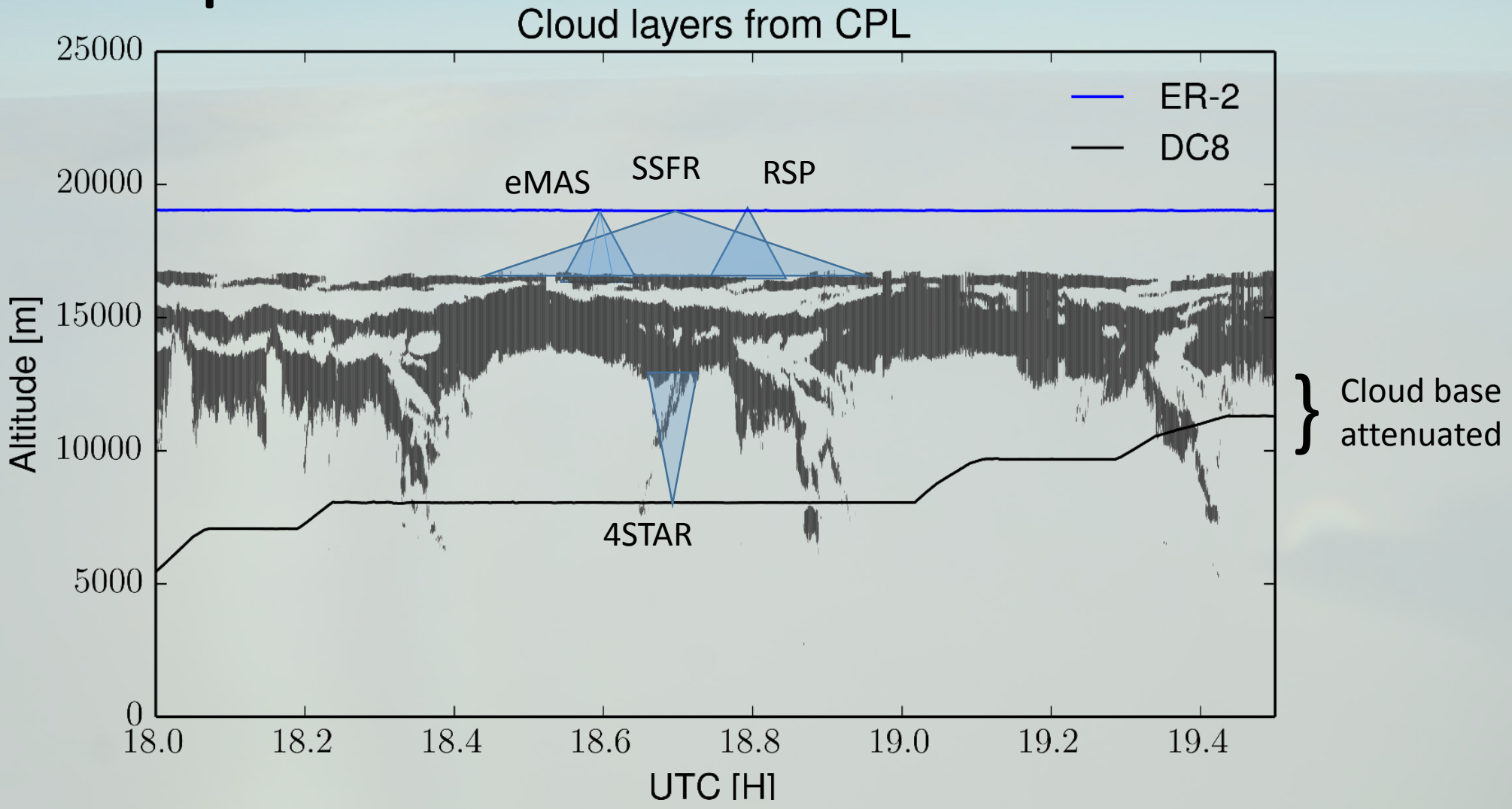


Horizontal variations of cloud properties due to differences in Field-of-View



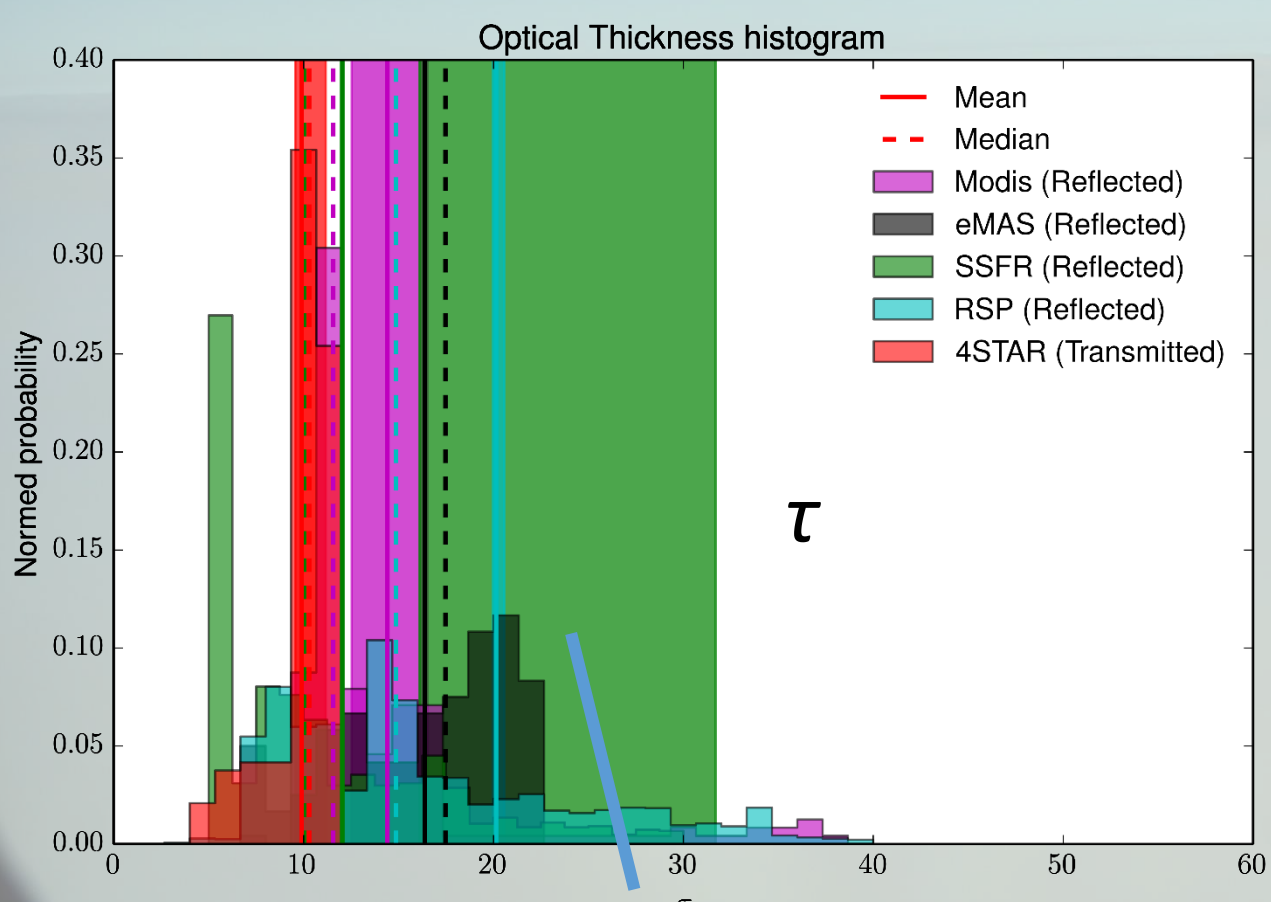


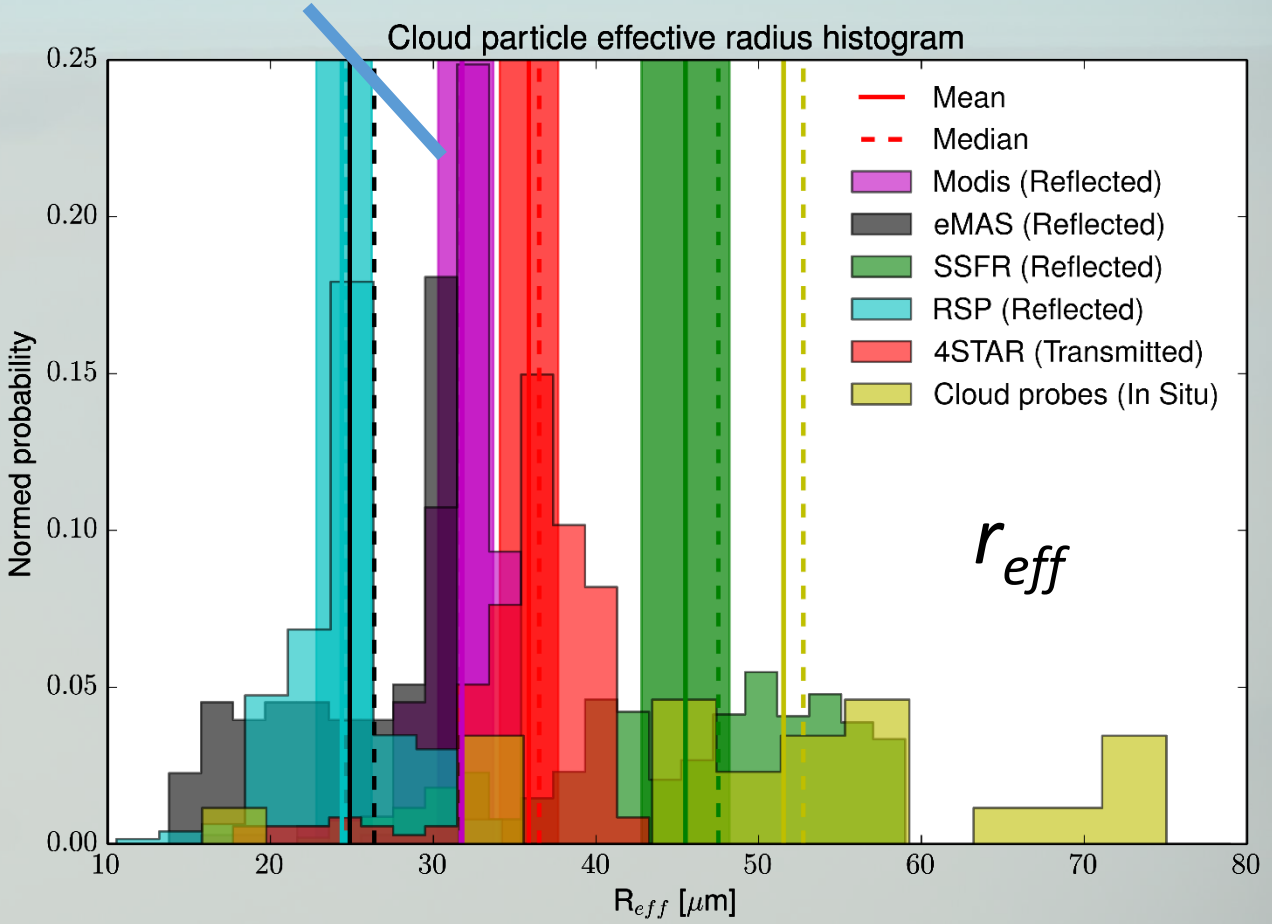
Reflectance-based remote sensors see a different part of the cloud than 4STAR



Comparing cloud retrievals from transmitted and reflected light

Variability in r_{eff} is directly linked to vertical sampling of the cloud

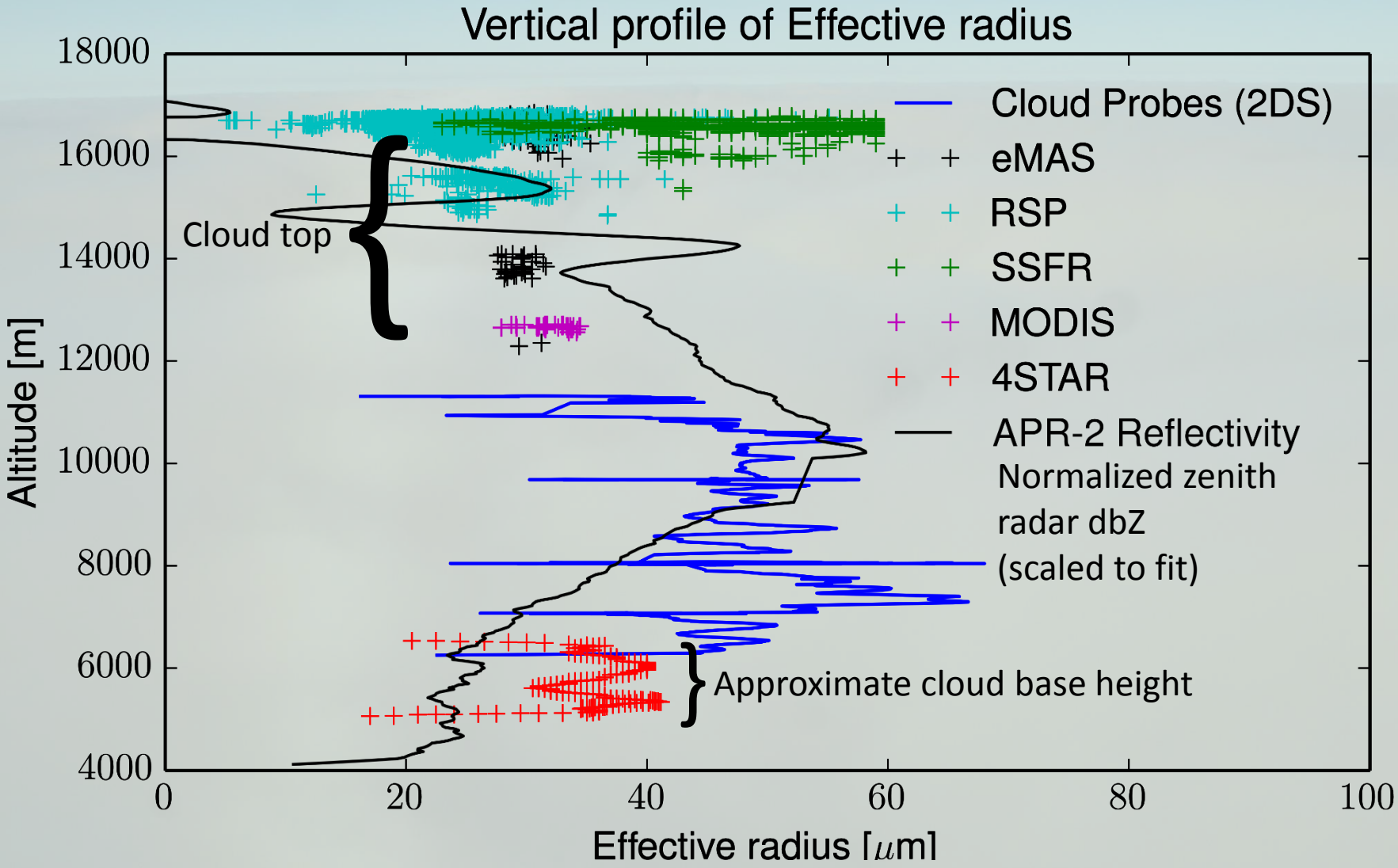




Variability in τ partially explained by differences in horizontal field-of-view

SSFR variability may be due to 3D effects

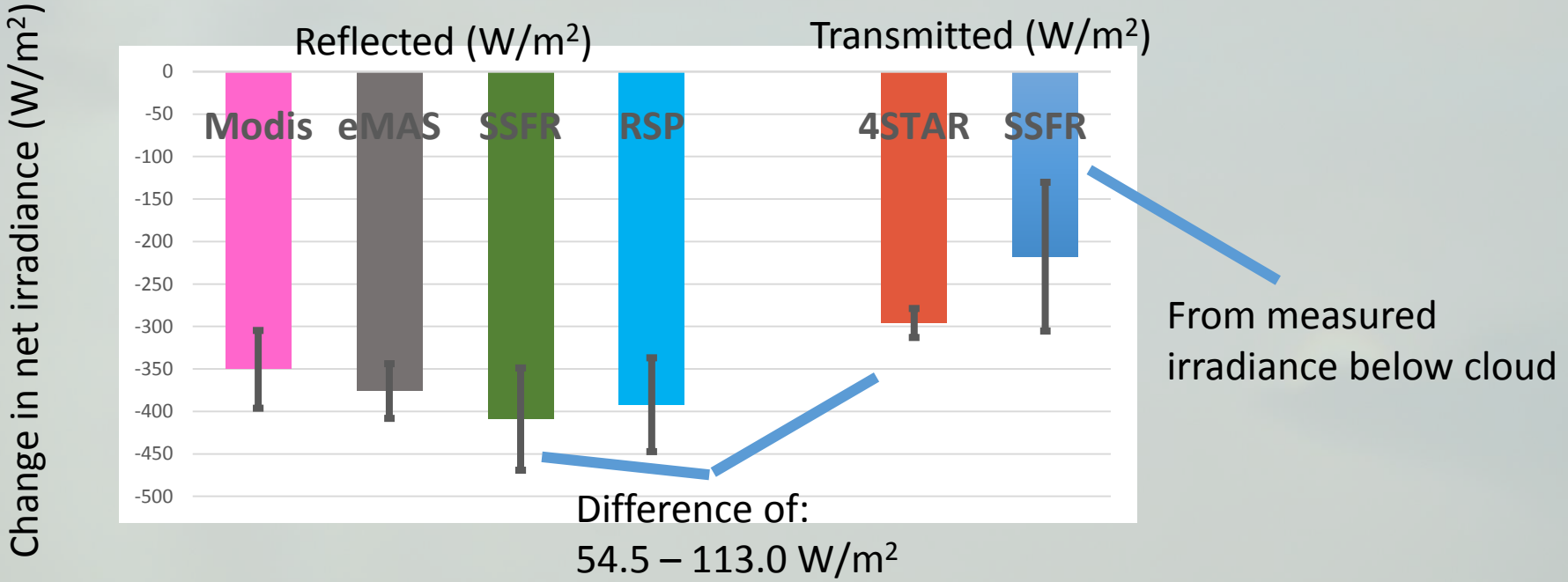
Approximate vertical sampling of different measurements



Using retrieved cloud properties to model below-cloud shortwave radiative effect

$$Radiative\ effect = Net\ irradiance_{Cloudy} - Net\ irradiance_{clear}$$

Modeled irradiances based on average retrieved properties for wavelengths 350 nm – 1700 nm



Summary

- Clouds modulate transmitted light in a spectrally dependent manner
- 4STAR uses measurements of spectral shapes of transmitted light to retrieve cloud optical depth, cloud particle effective radius, and thermodynamic phase.
- Using transmitted light gives a different sampling volume, which may be more representative of the entire cloud layer and more relevant to surface energy budget considerations
- By estimating cloud radiative effect below cloud, transmitted light based retrievals result in 54.5 – 113.0 W/m^2 less radiative effect for one case study. Within variability of measurement based estimates.


Thank you
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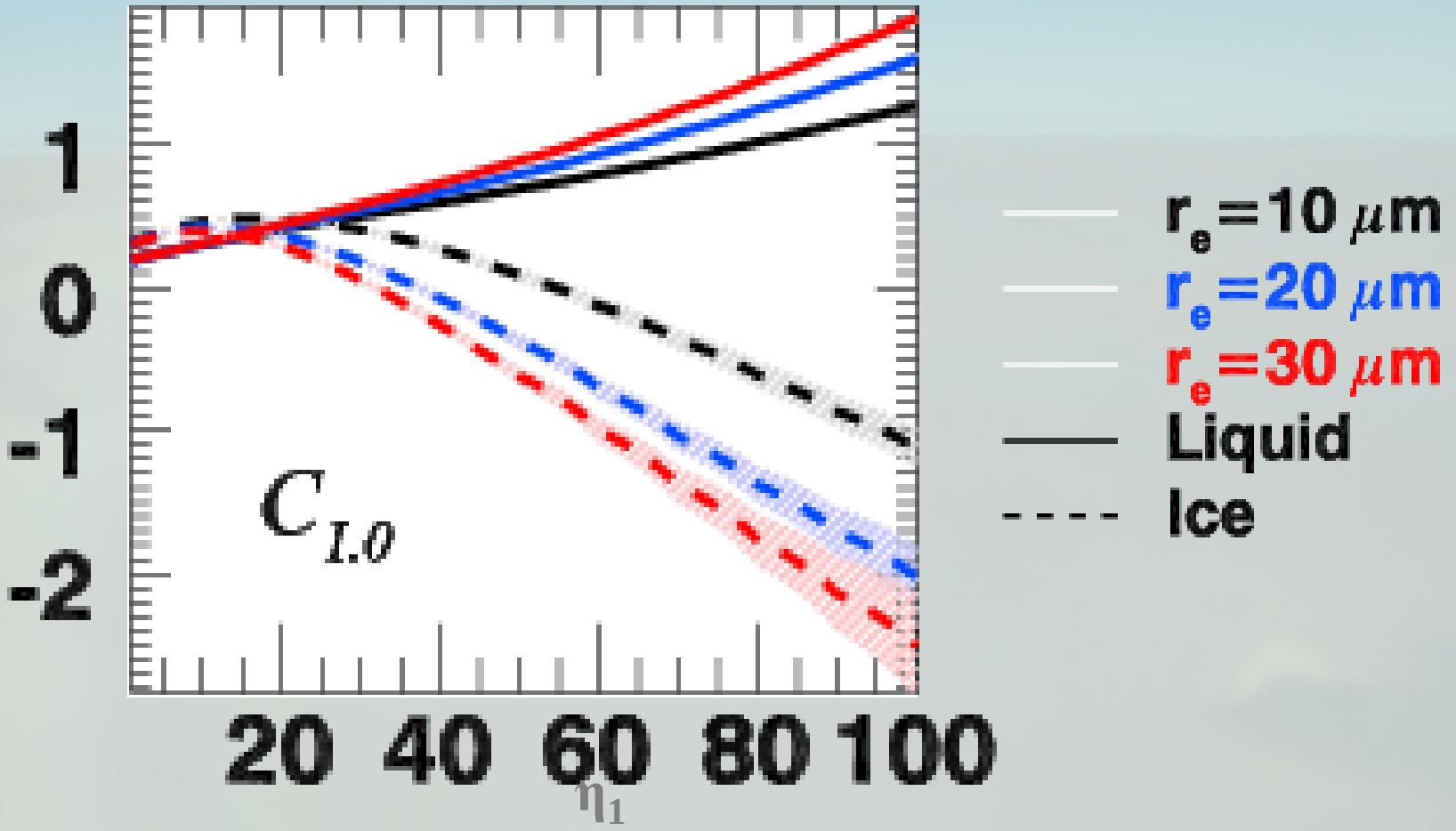
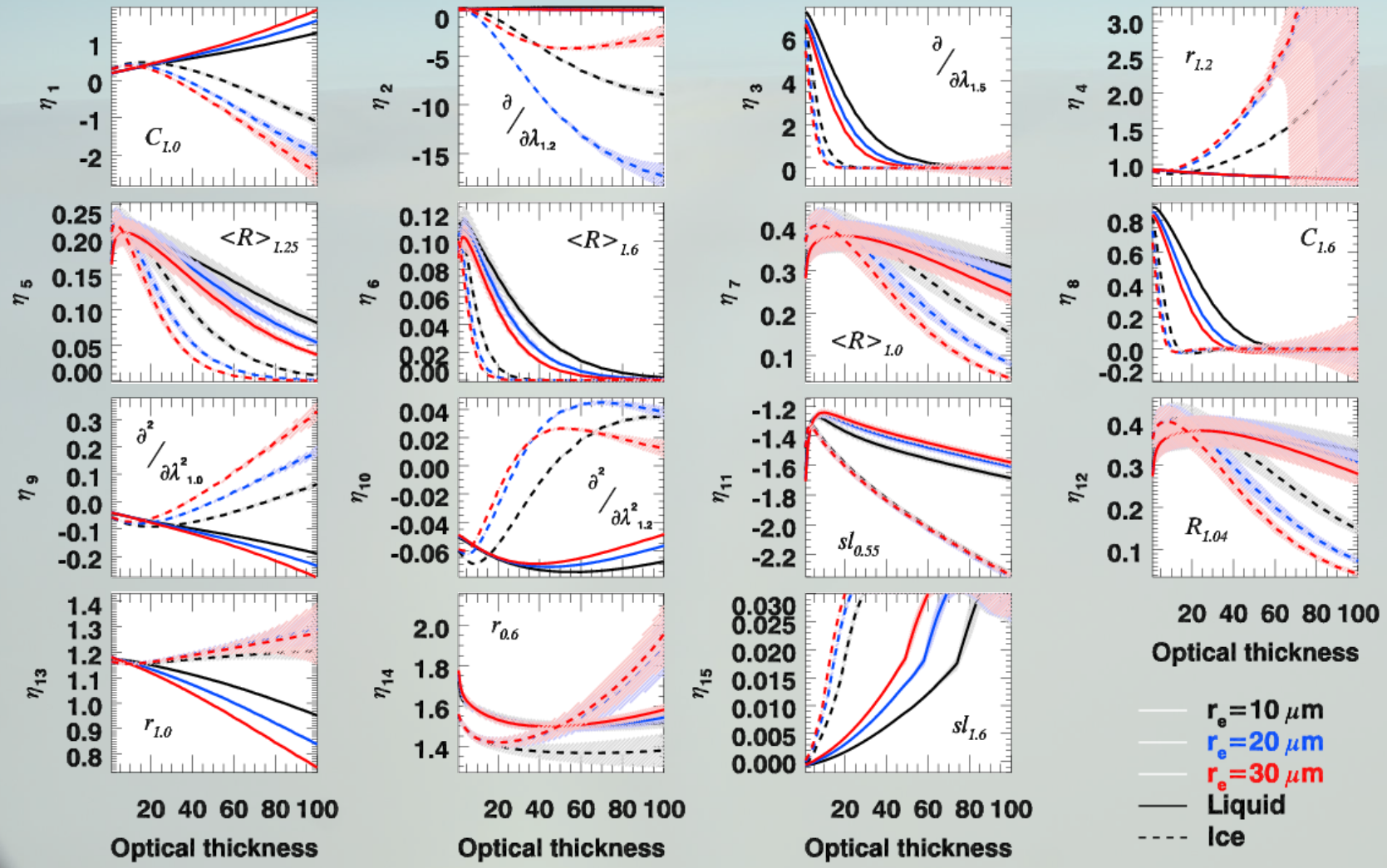
Extra slides


1
0
-1
-2
$C_{1.0}$
20 40 60 80 100
η_1
Optical thickness
r_e=10 μm
r_e=20 μm
r_e=30 μm
Liquid
Ice

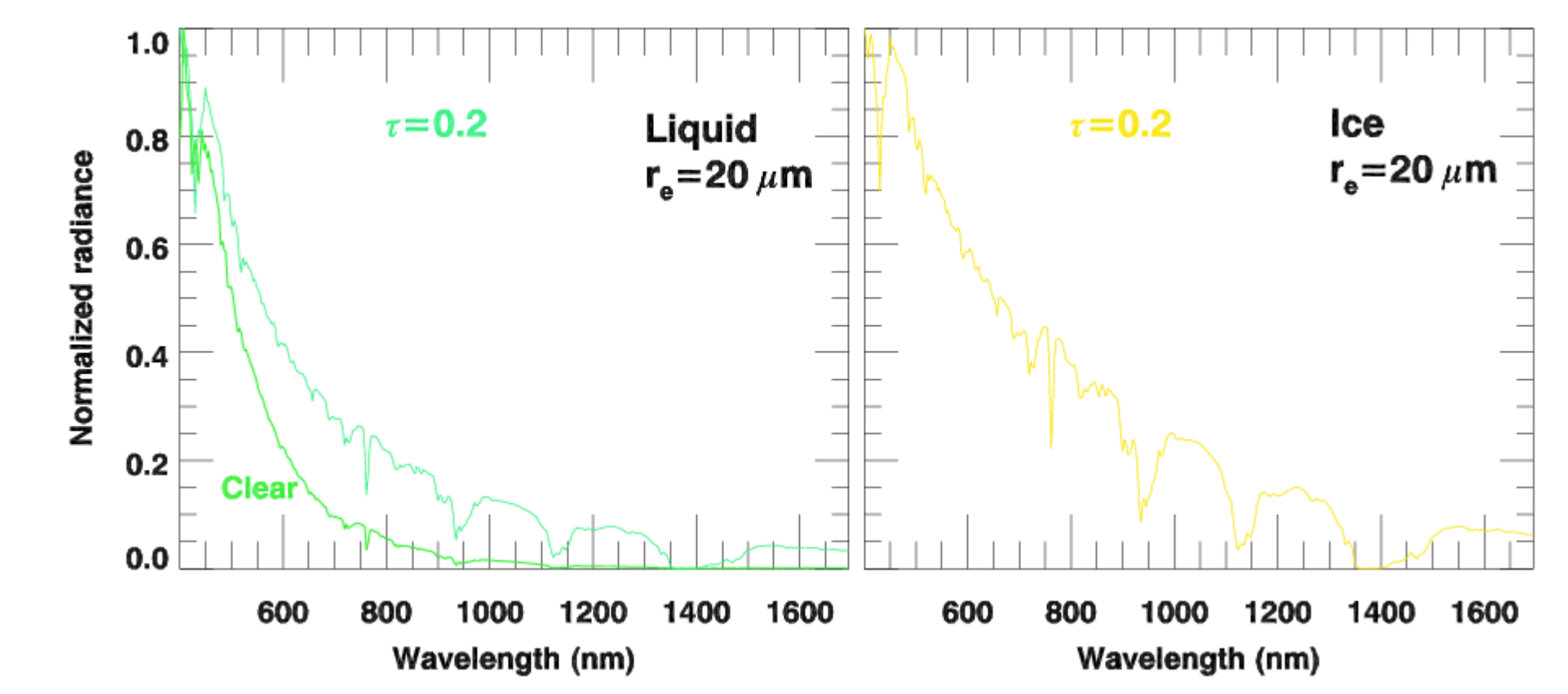
Parameters are defined to quantify the spectral shapes – basis of new retrieval method



R	:	Normalized radiance
$<R>$	:	Mean normalized radiances
r	:	Ratio of normalized radiances
sl	:	Slope of normalized radiances
$\frac{\partial}{\partial\lambda}$	:	Spectral derivative of normalized radiances
$\frac{\partial^2}{\partial\lambda^2}$	:	Slope of derivative
C	:	Curvature of normalized radiances

New method described in LeBlanc et al. [2015], AMT

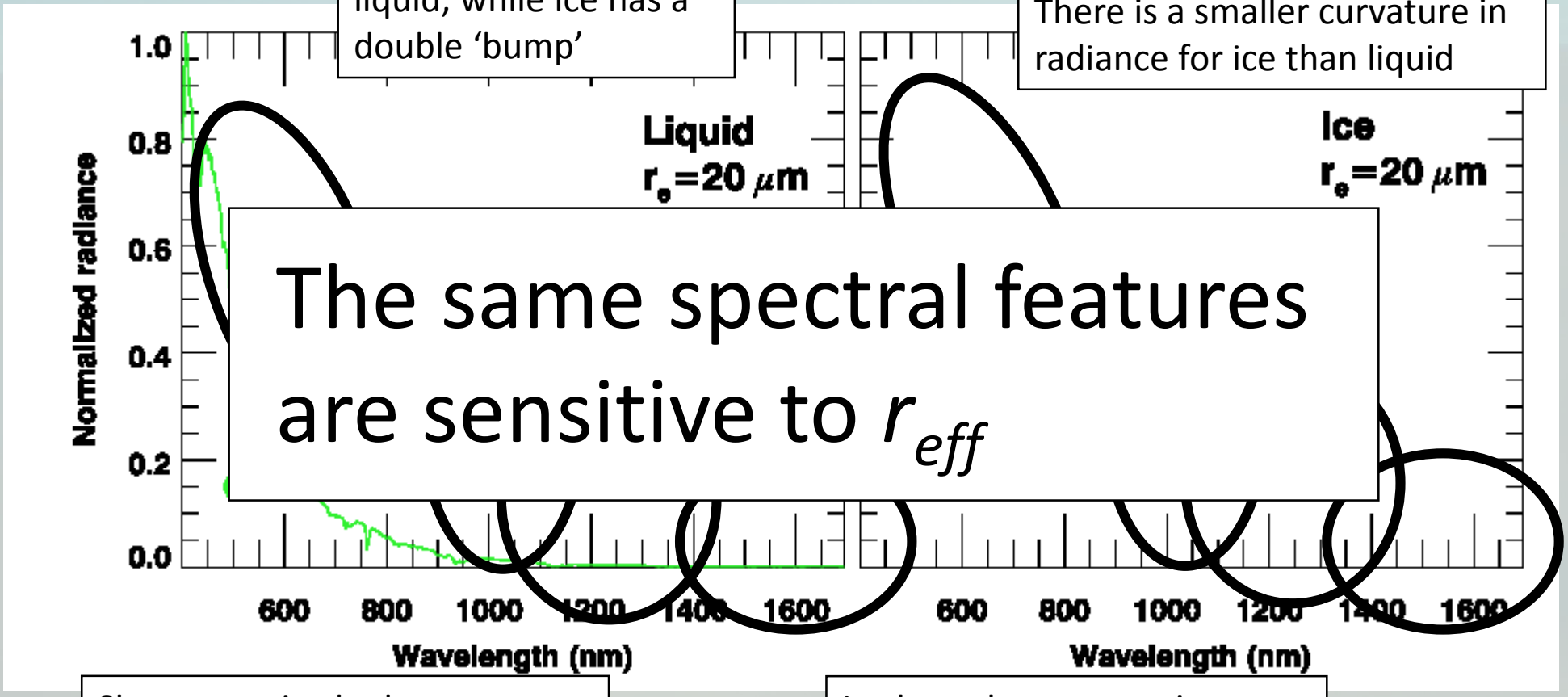
Spectral shapes are sensitive to Cloud optical depth, effective radius, and thermodynamic phase



Spectral shapes are sensitive to Cloud optical depth, effective radius, and thermodynamic phase

Radiance peaks for liquid, while ice has a double 'bump'

There is a smaller curvature in radiance for ice than liquid



The same spectral features are sensitive to r_{eff}

Slope magnitude decreases with increasing optical thickness due to scattering

Ice has a larger negative slope than liquid at 1200 nm

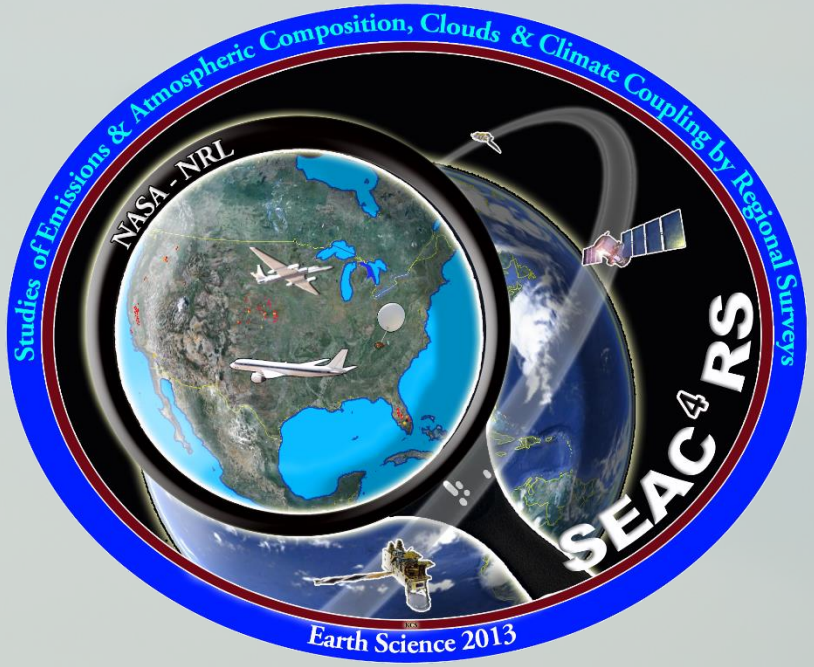
LeBlanc, et al. [2015]

Instrument and Measurements

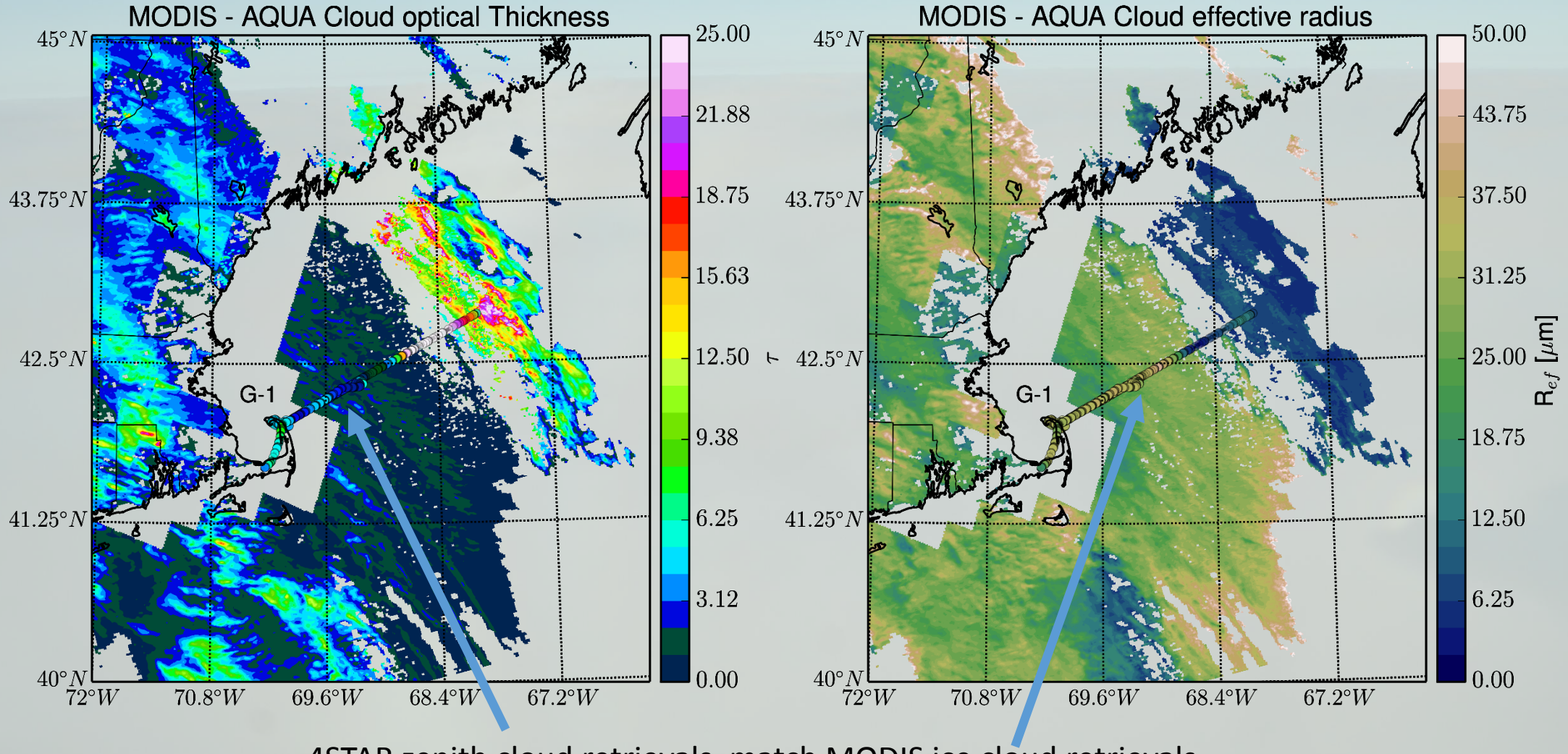
SEAC4RS – **S**tudies of **E**missions and **A**tmospheric **C**omposition, **C**louds and **C**limate **C**oupling by **R**egional **S**urveys:

August – October 2013

Based out of Houston, TX



4STAR cloud retrievals during TCAP



4STAR zenith cloud retrievals, match MODIS ice cloud retrievals

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