Improving Clouds and Precipitation for NWP Assimilation Using Satellite Measurements

Nai-Yu Wang[1], Fu-Lung Chang[2]
1. University of Maryland, ESSIC
College Park, Maryland
2. National Institute of Aerospace
Hampton, Virginia

Outline

- Motivation
- Satellite observations of clouds and precipitation
- AMSR-E microwave radiances simulations- clear, cloudy conditions
- CloudSat cloud vertical profiles
- MODIS multi-layer, multi-phase cloud properties
- On going and future work

Motivation

- To improve microwave radiance assimilation in cloudy and rainy conditions, major sources of errors in assimilating microwave radiances into NWP model cloud and precipitation profiles include
  - Sub-grid scale cloud variability (cloud fraction, geometry, vertical distribution, overlap)
  - precipitating hydrometeors scattering modeling error characteristics

Approach

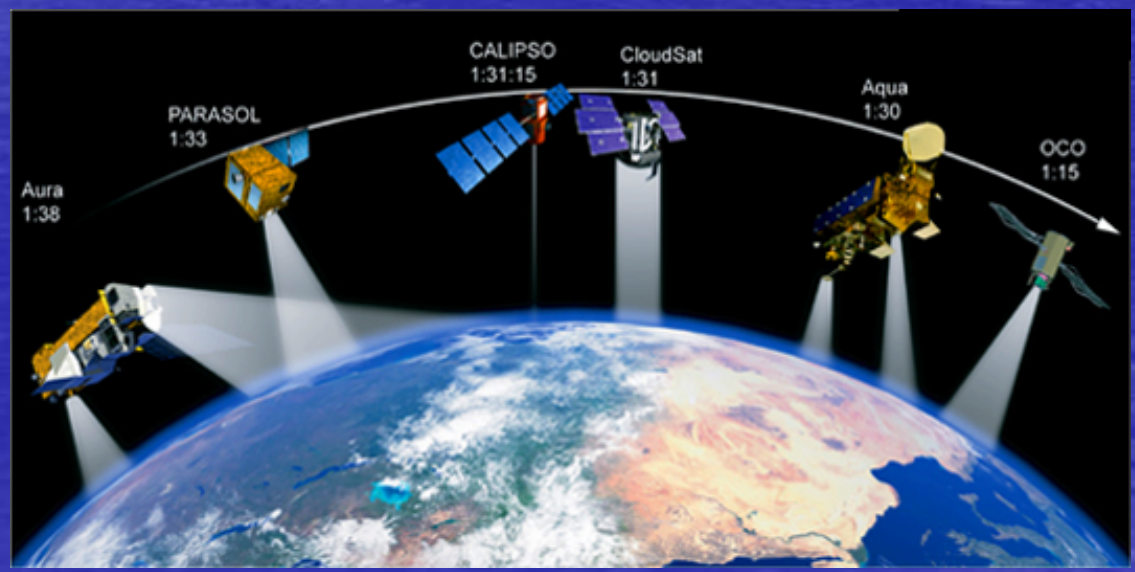
- Utilize collocated VIS/IR/microwave observations to detect and evaluate the effects of sub-grid variability on the microwave radiances measurements and radiative transfer modeling
  - Simulate microwave radiative transfer for clear, clear and cloudy fraction based on higher resolution radar and VIS/IR cloud information

Satellite Observations of Clouds

- Passive radiometry: primarily provide path-integrated information
  - Microwave: path integrated cloud/ice water
  - Multi-frequency VIS/IR: cloud top, cloud type detection, cloud optical properties, water cloud effective droplet radius profile
- Active radar and lidar: profile information about optical properties, microphysics

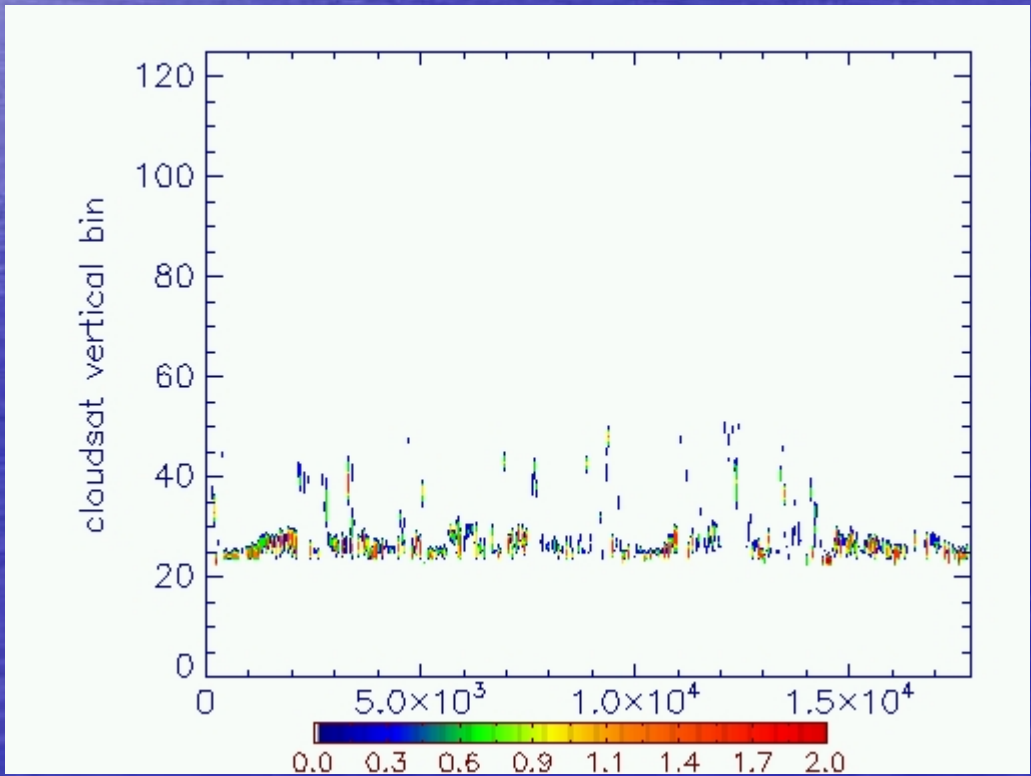
Satellite Observation of clouds and precipitation

- A-train constellation
  - wide range of sensors, MODIS, AMSR-E, CloudSat and Calipso
  - View the same clouds within minutes



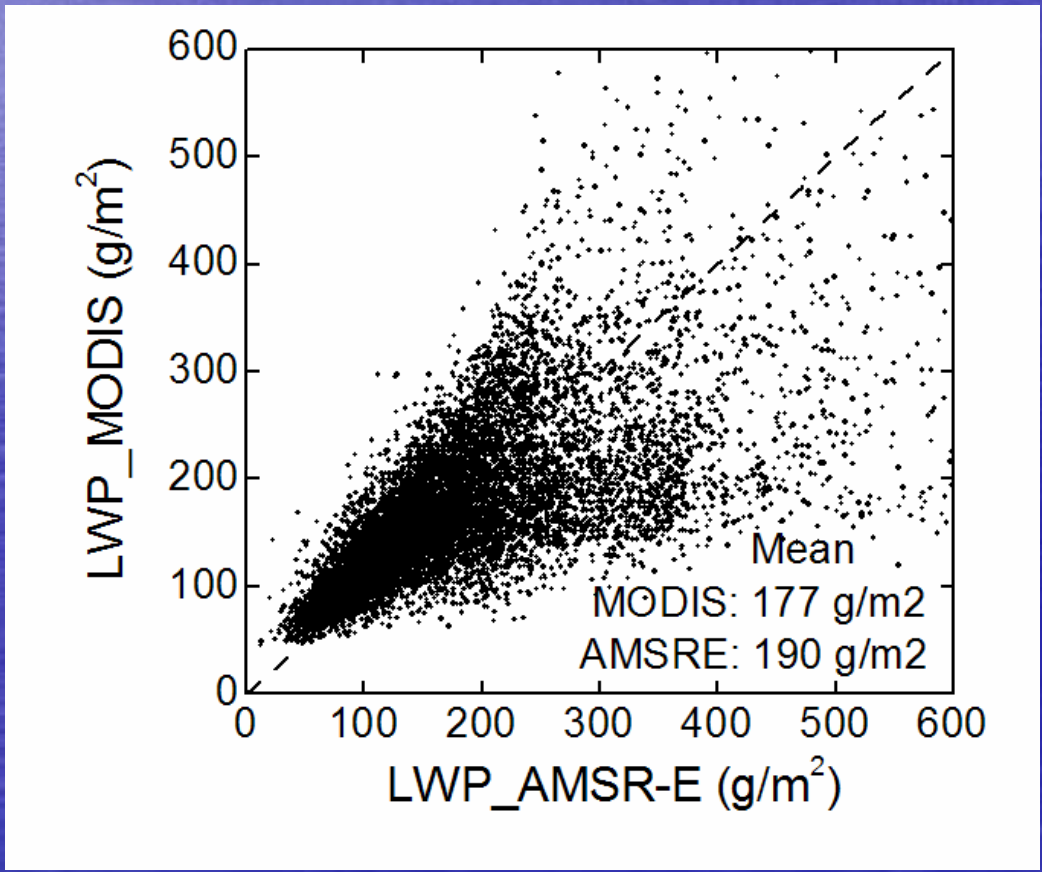
CloudSat
Vertical cloud water distribution

- 3 days (Oct 15-17 2006), global ocean, 20% occurrence of clouds



Comparison of AMSR-E and MODIS cloud water path

Overcast cloud LWP over oceans (1 day)
each point represents an area of 9kmX14km AMSR-E footprint



AMSR-E simulations
Ocean

Microwave radiative transfer:

- plane parallel, slant path
- two-scale ocean surface emissivity model
- Rosenkranz/Liebe gas (oxygen, water vapor) and cloud liquid water absorption models

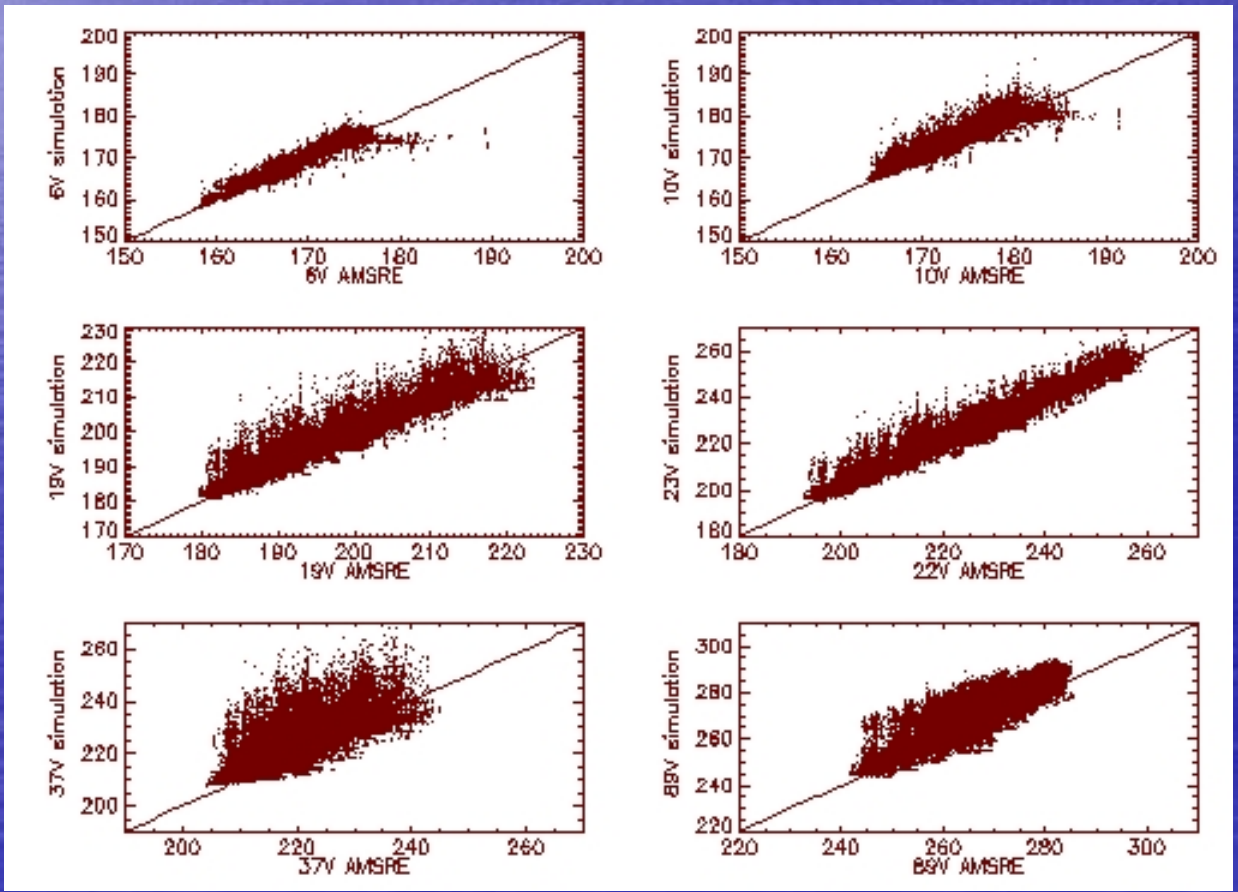
Inputs:

– CloudSat-only cloud liquid water contents

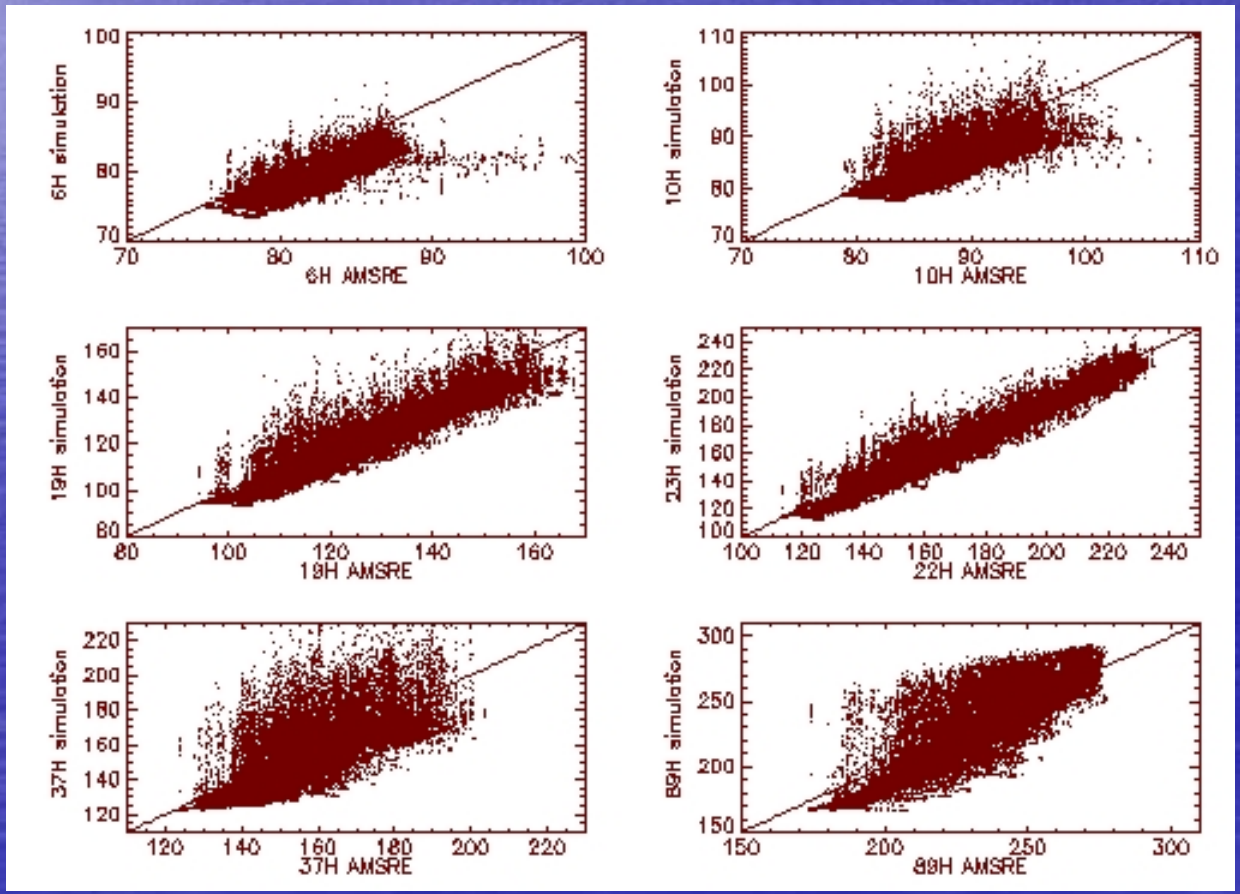
– ECMWF surface temperature,
pressure, temperature, specific humidity profiles

AMSR-E simulations v.s. observations
Clear sky, low wind
V-pol

Clear sky according to CloudSat LWP (= 0) , AMSR-E footprint 50km, cloudsat profile every 1.1 km

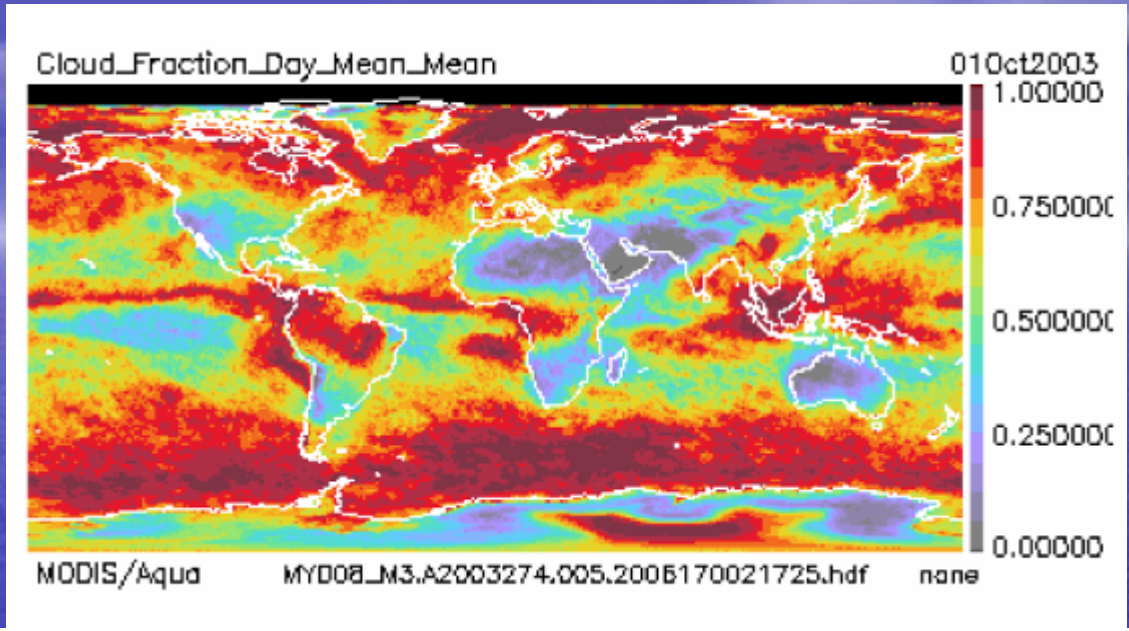


AMSR-E simulations v.s. observations
Clear sky, low wind
H-pol

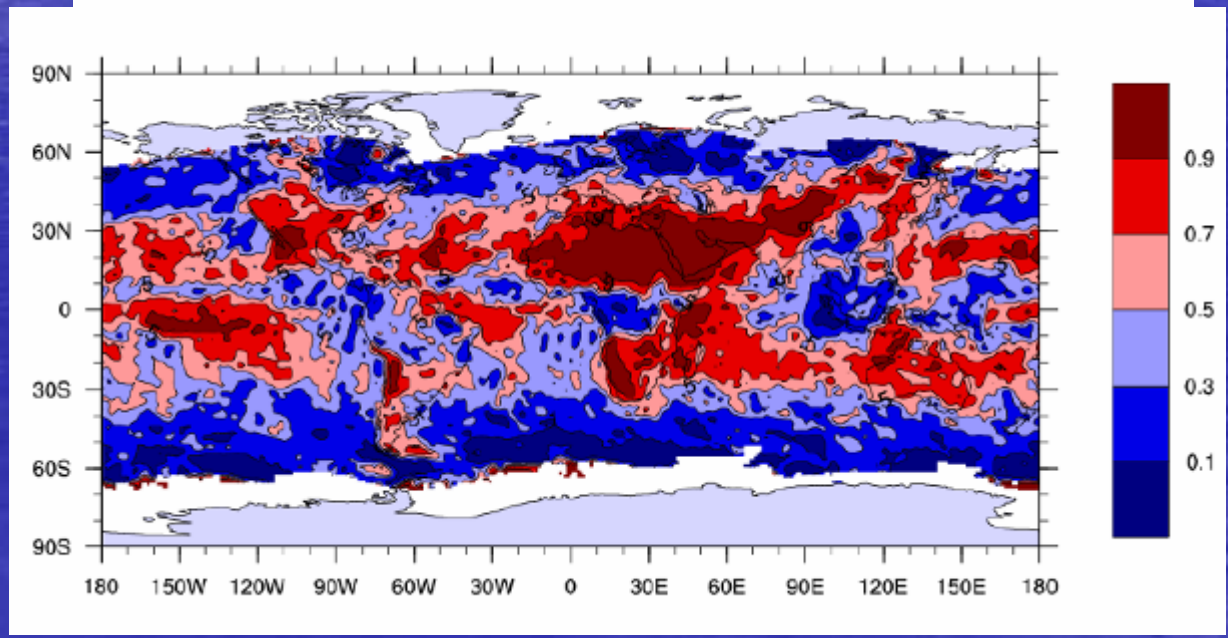


Comparison of MODIS Cloud/Clear Fraction

- MODIS Level-3 Cloud_Fraction_Day_Mean (October)

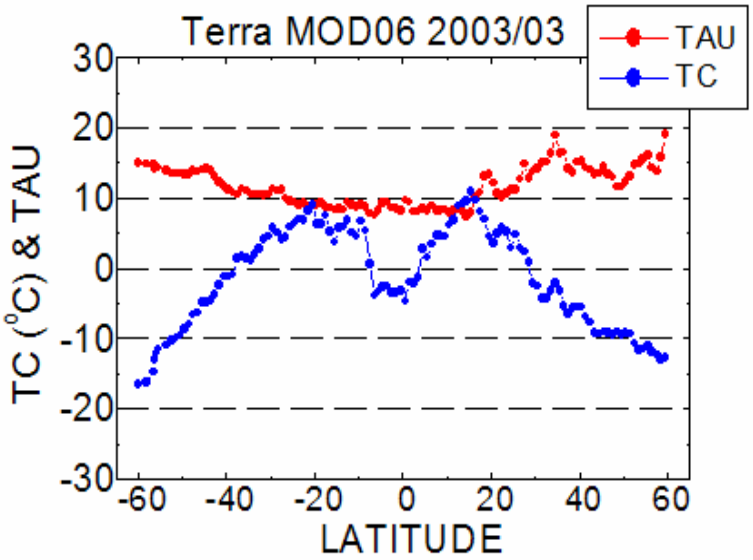


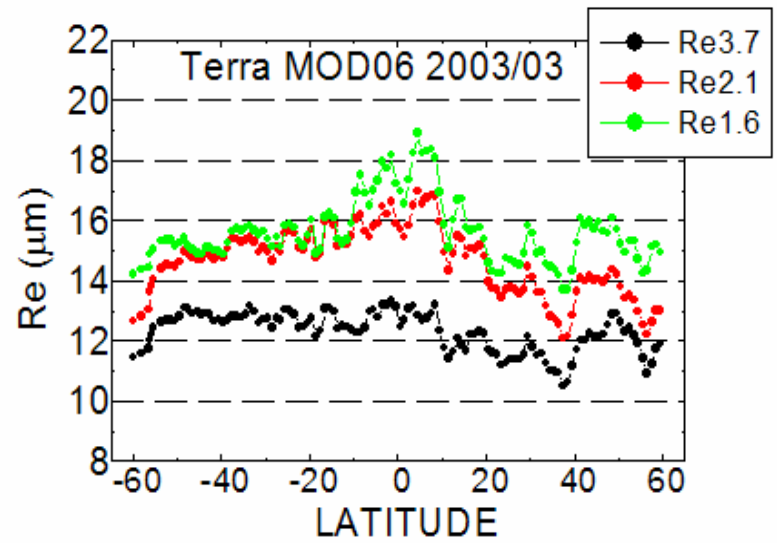
- MODIS Level-2 cloud-free fraction + cloud fraction with non-measurable cloud optical depth (<0.2)



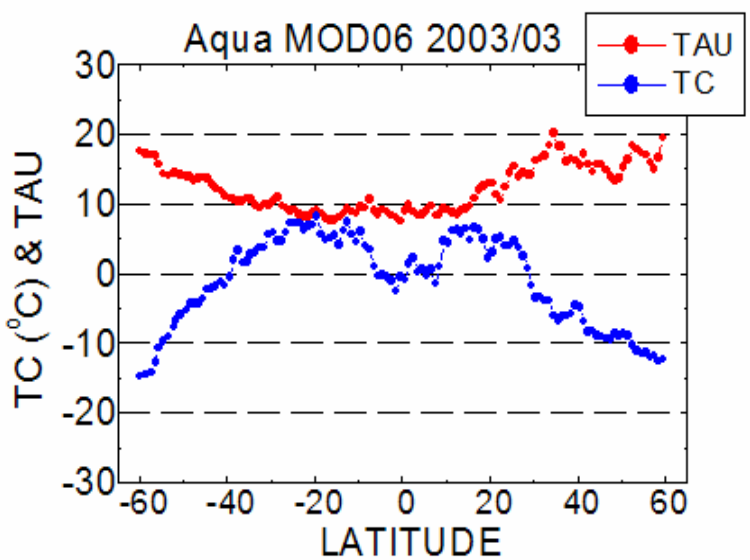
Comparison of March 2003 Water-Cloud Properties

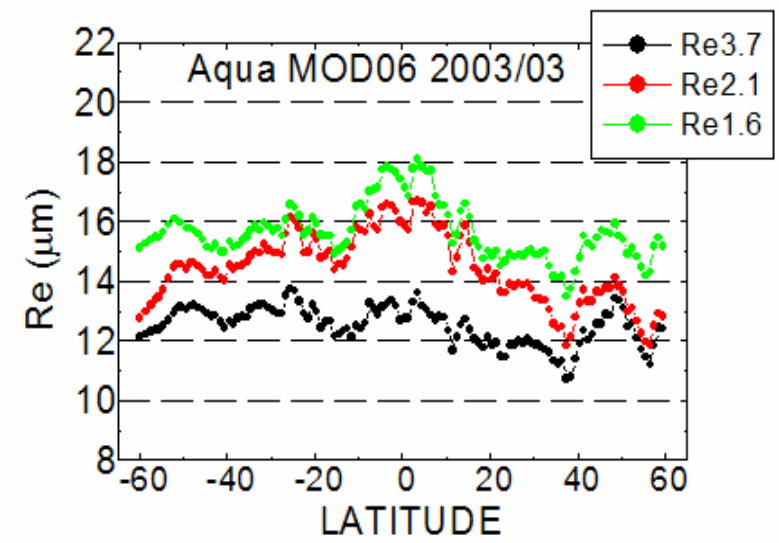
- Terra MOD06 over ocean





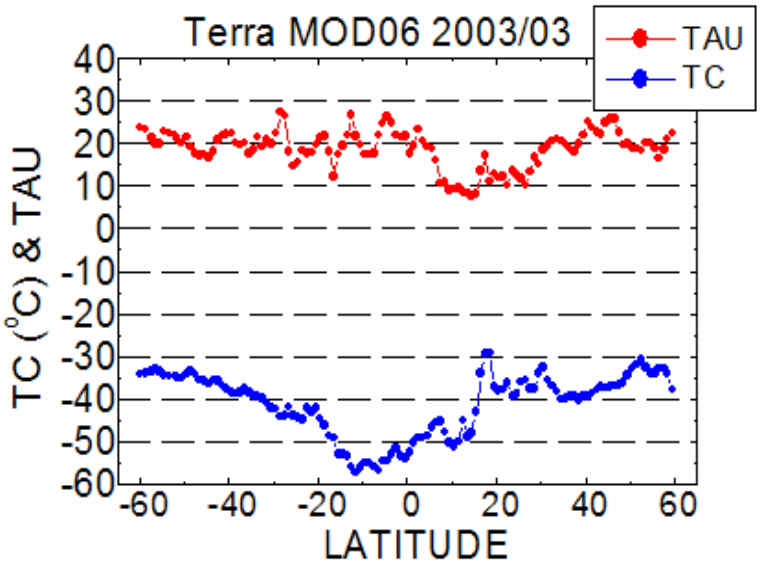
- Aqua MOD06 over ocean

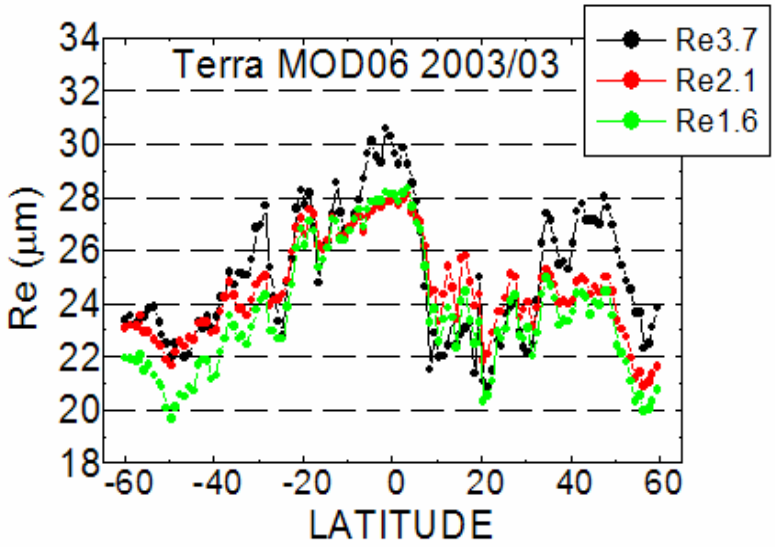




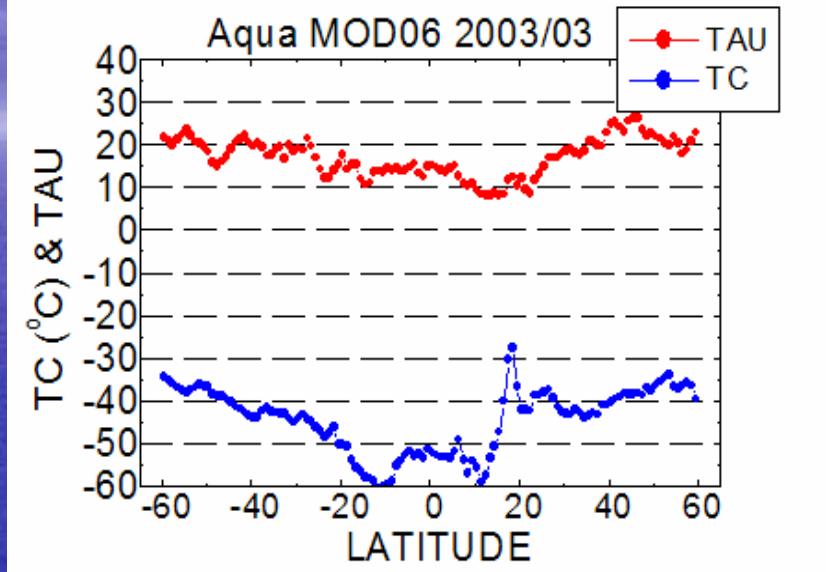
Comparison of March 2003 Ice-Cloud Properties

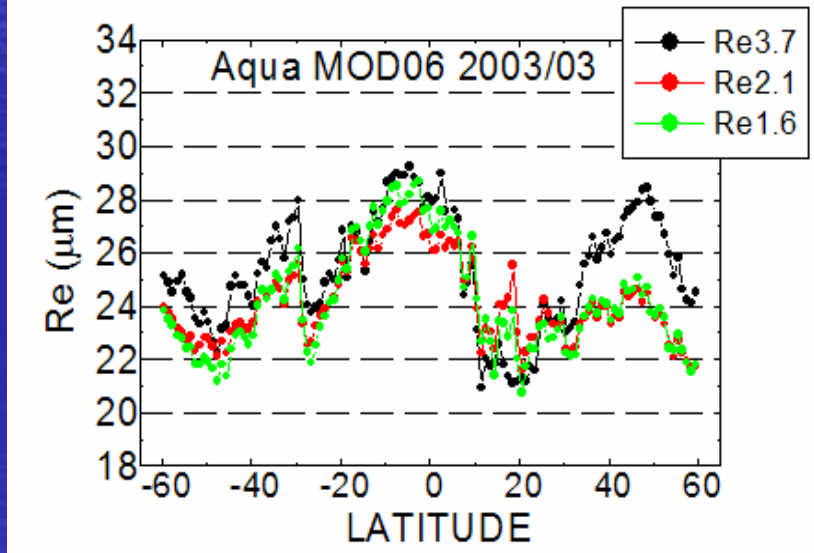
- Terra MOD06 over ocean





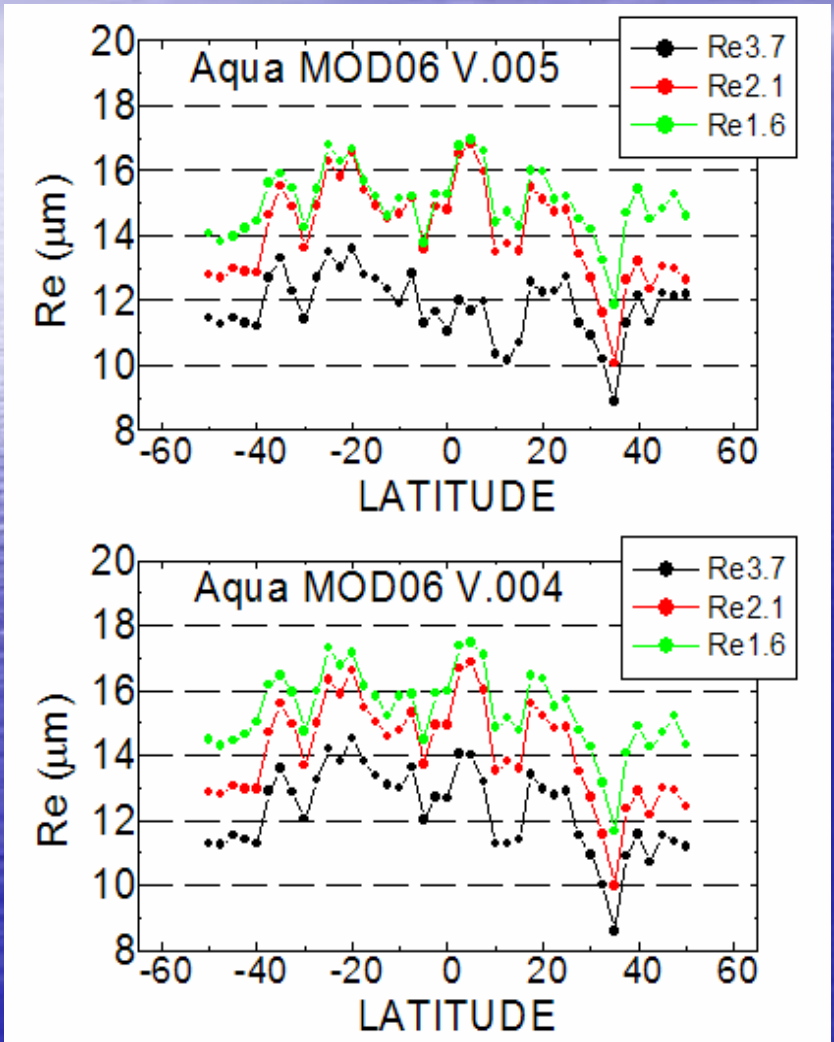
- Aqua MOD06 over ocean



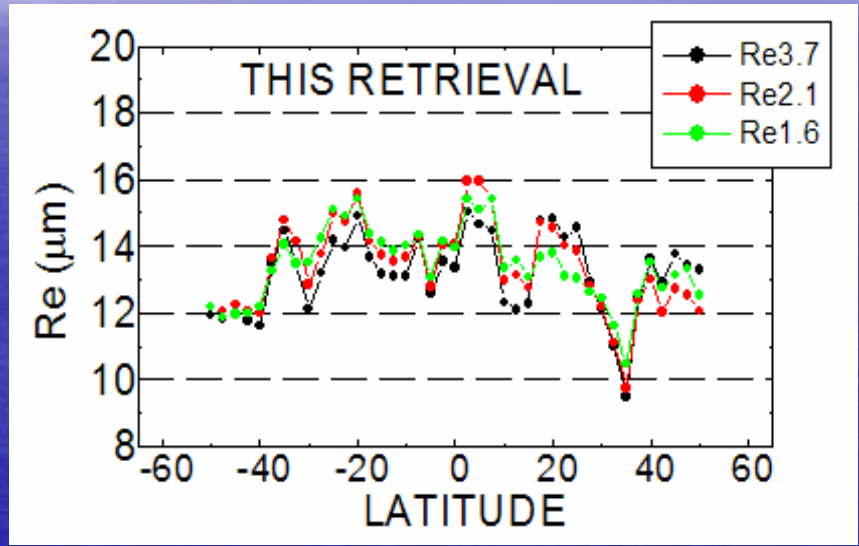


Comparing Water-Cloud Droplet Effective Radius Retrievals

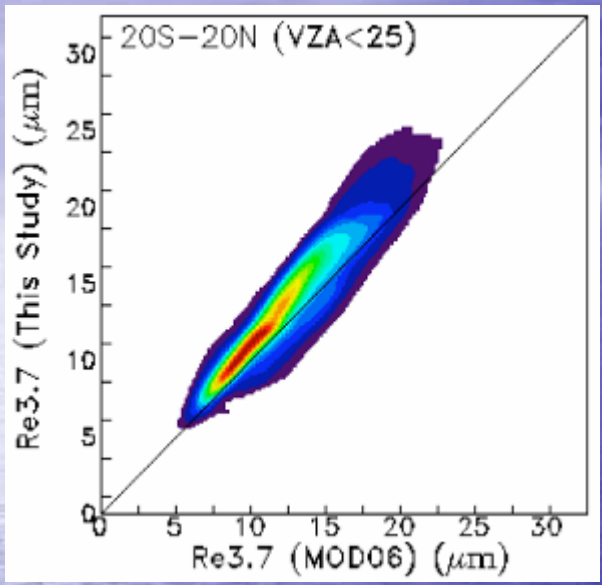
- One-day zonal means over ocean (2003.03.01): Most Confident QC from both Collections 005 and 004

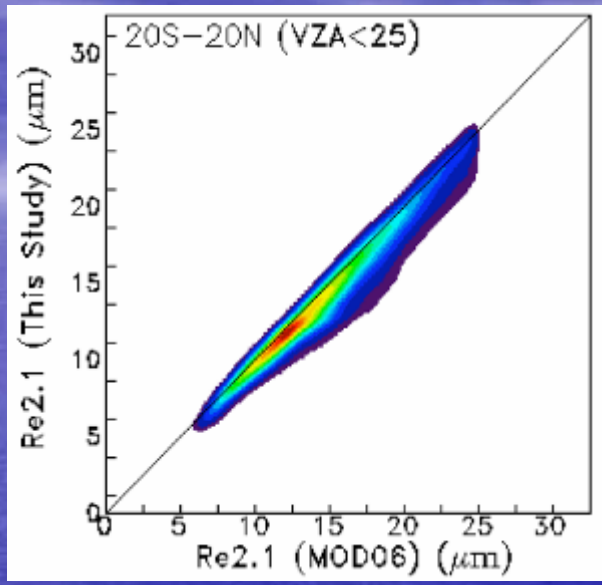


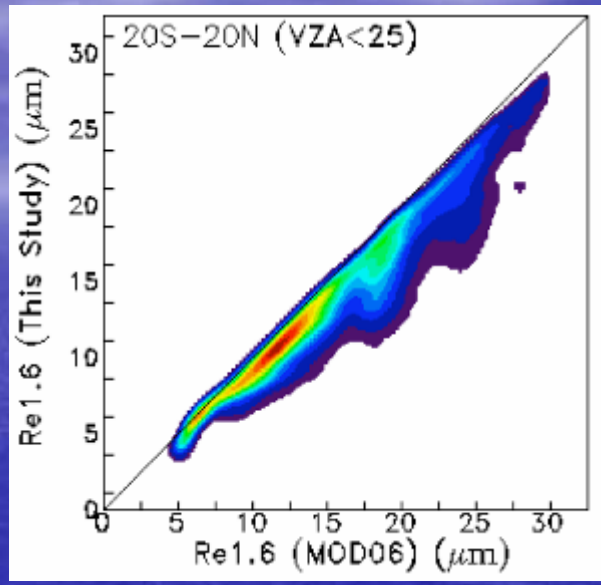
- Results from application of an independent retrieval technique to the coincident MOD02_1KM data

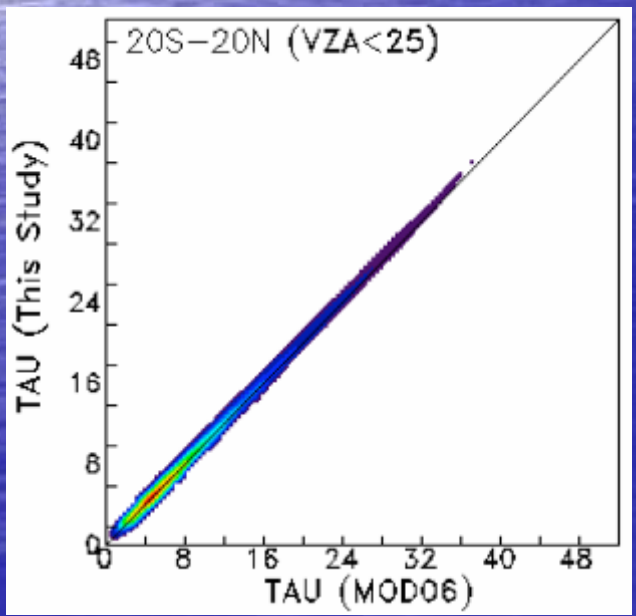


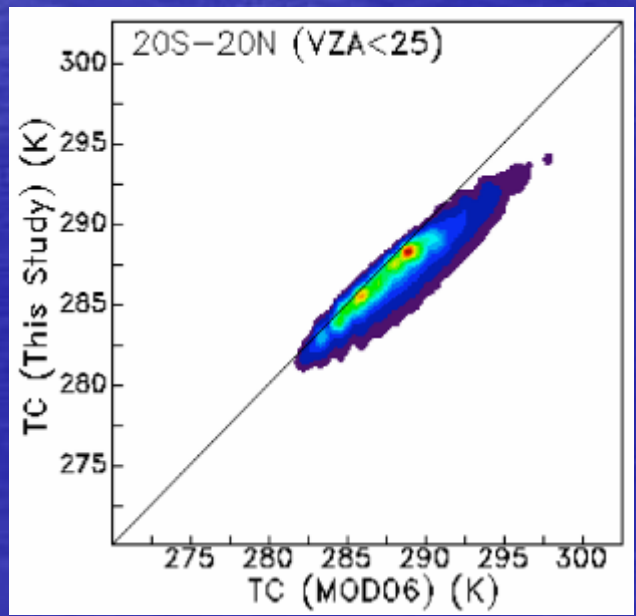
Comparison of 1-km Pixel-scale Water-Cloud Property Retrievals









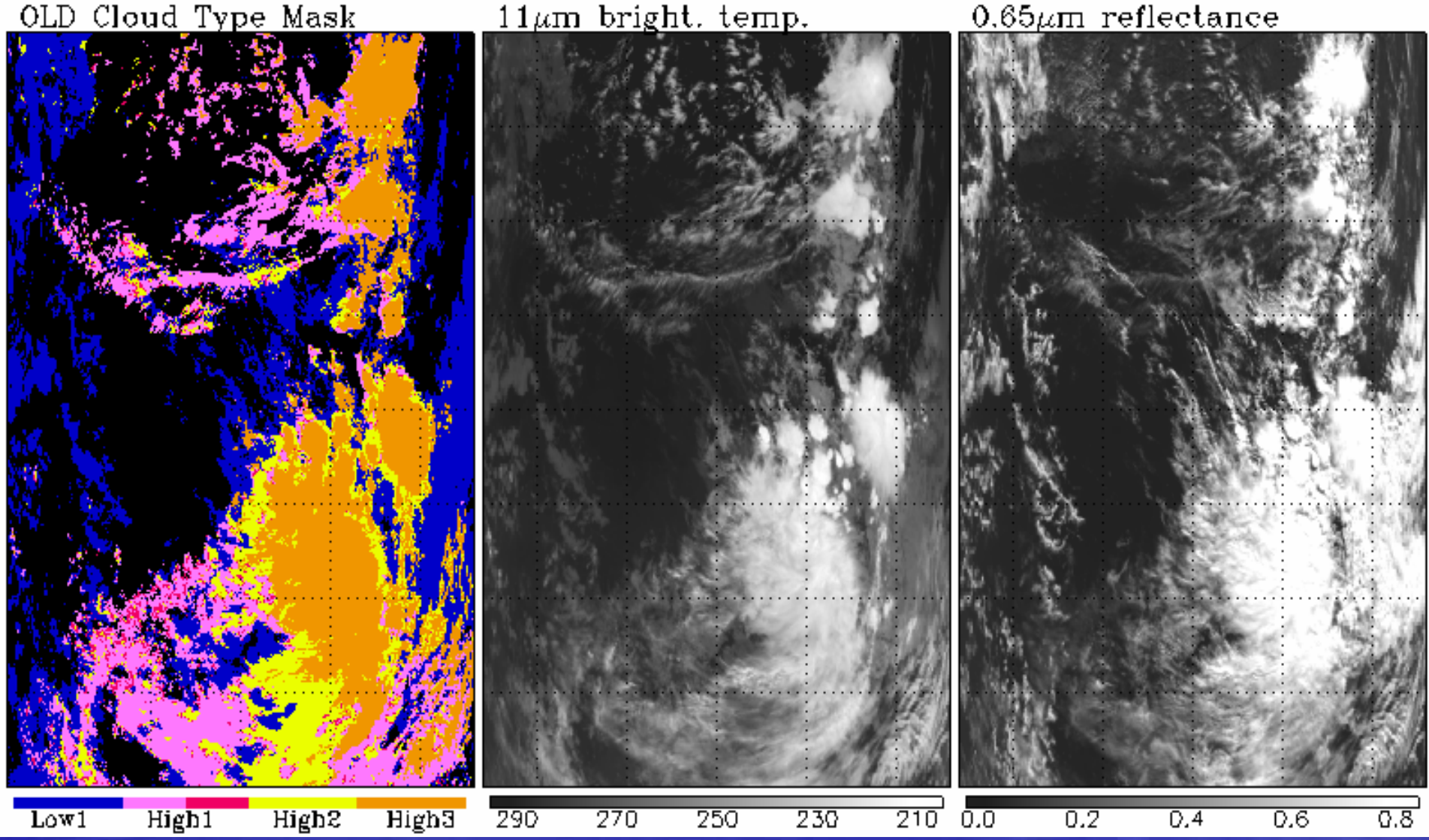


- Warmer colors indicate larger frequencies of occurrence

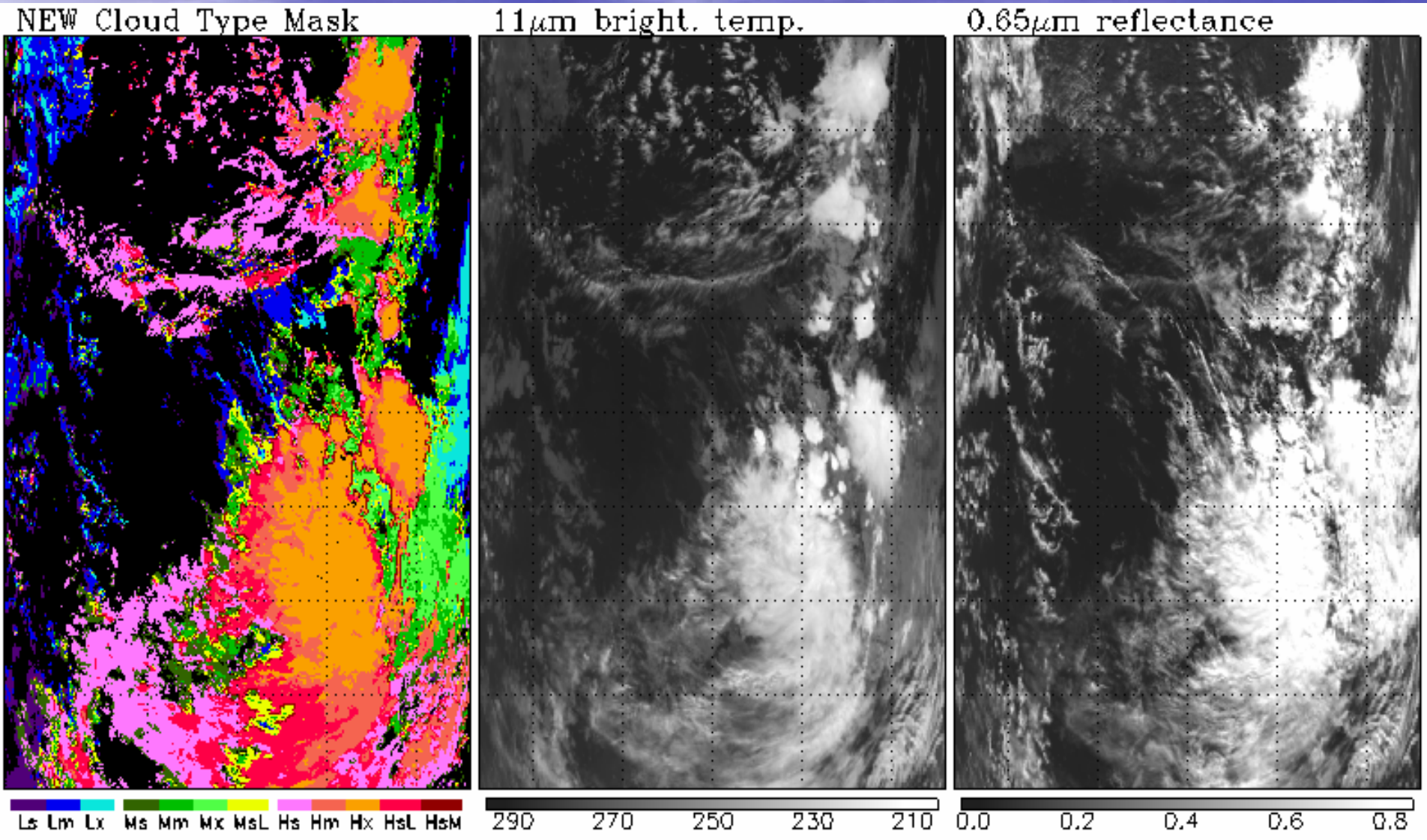
The Method of Chang and Li (2005)

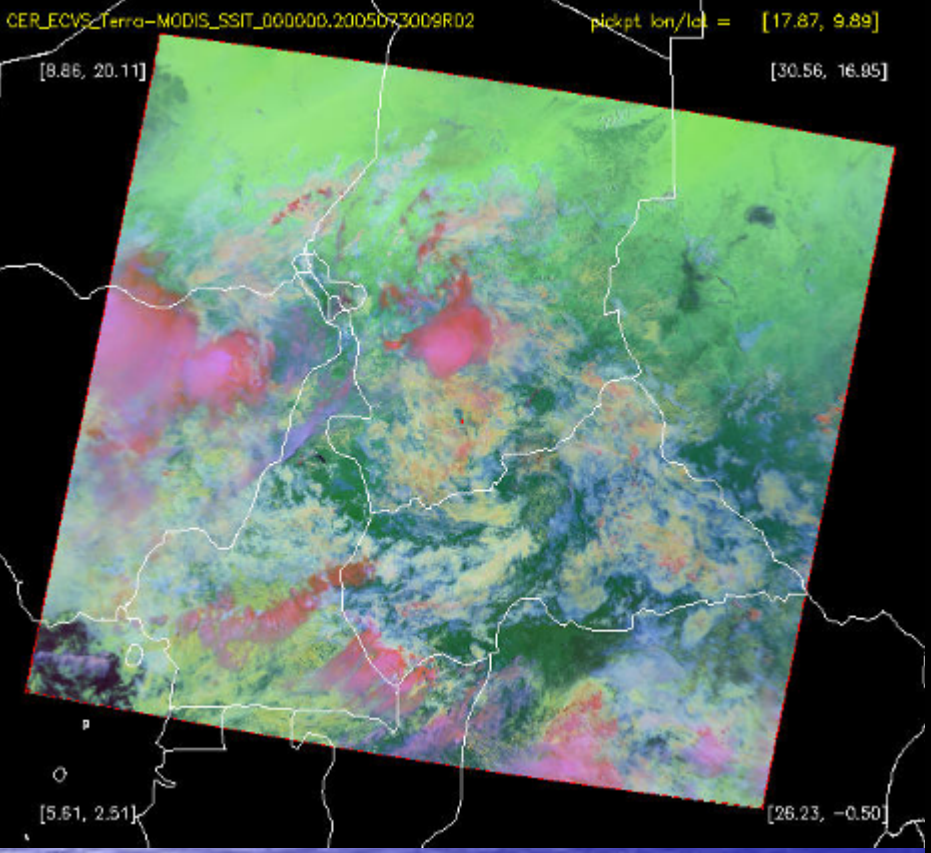
Low1: Single-layer low

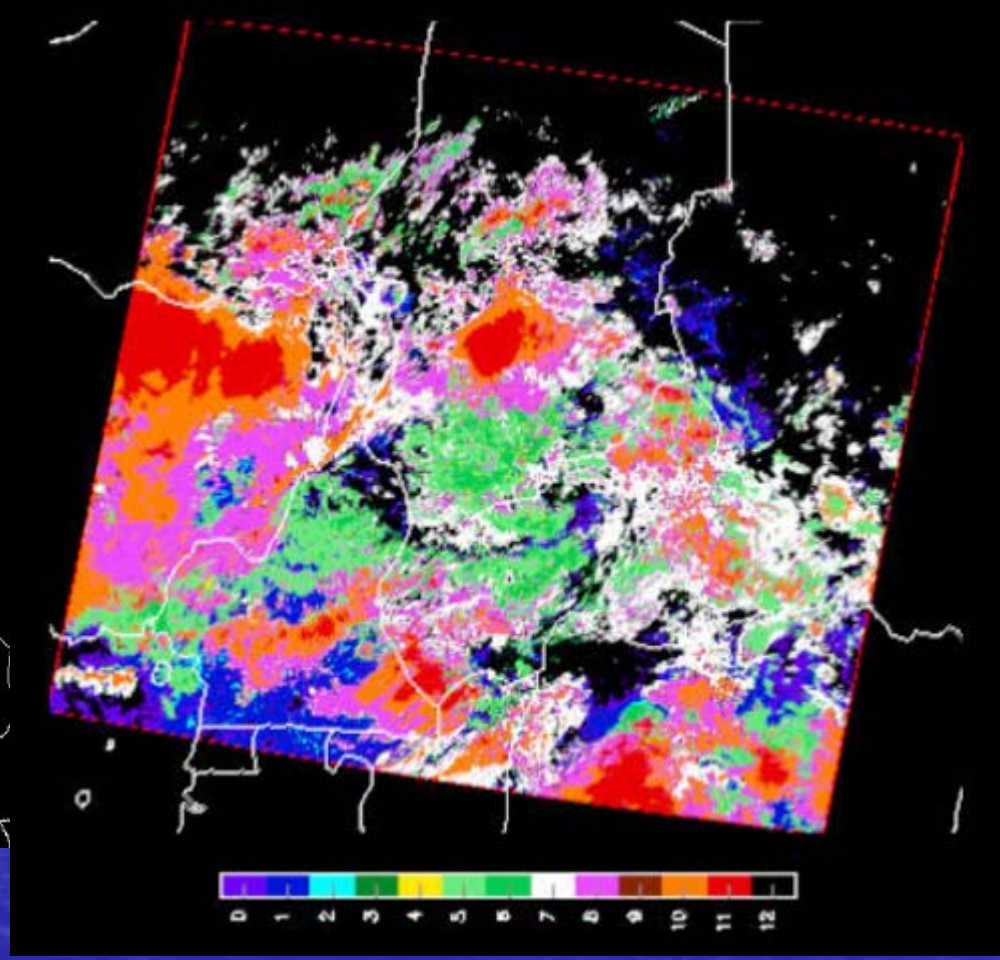
High1: Single-layer high High2: Two-layer cloud High3: Thick high cloud



The Multi-layer Cloud Classification (Chang et al. 2006)







Low Cloud (> 680 mb)		Mid Cloud (440-680 mb)		High Cloud (< 440 mb)	
0	$\tau < 3.6$	3	Single; $\tau < 3.6$	7	Cirrus; $\tau < 3.6$
1	$\tau = 3.6\text{-}23$	4	Overlap	8	Overlap
2	$\tau > 23$	5	Thick but $\tau < 23$	10	Thick but $\tau < 23$
		6	Thick and $\tau > 23$	11	Thick and $\tau > 23$

Summary

- In the last 6 months (first year), work has begun to
  - Gather and analyze AMSR-E, CloudSat and MODIS clear/cloudy sky data
  - AMSR-E simulations for Clear/cloudy sky ocean using a radiative transfer model
  - Cloud information assessment from CloudSat and MODIS, for microwave radiative transfer model simulations

Ongoing and future work

- Generating MODIS/AMSR-E/CloudSat matchups
- Will add MODIS cloud mask/type/integrated path information for microwave clear/cloudy sky simulations
- Will Incorporate CRTM hydrometeor scattering modules for simulate microwave cloudy and precipitating conditions