

# Cloud Liquid Water Path from Spaceborne Measurements



EUMETSAT

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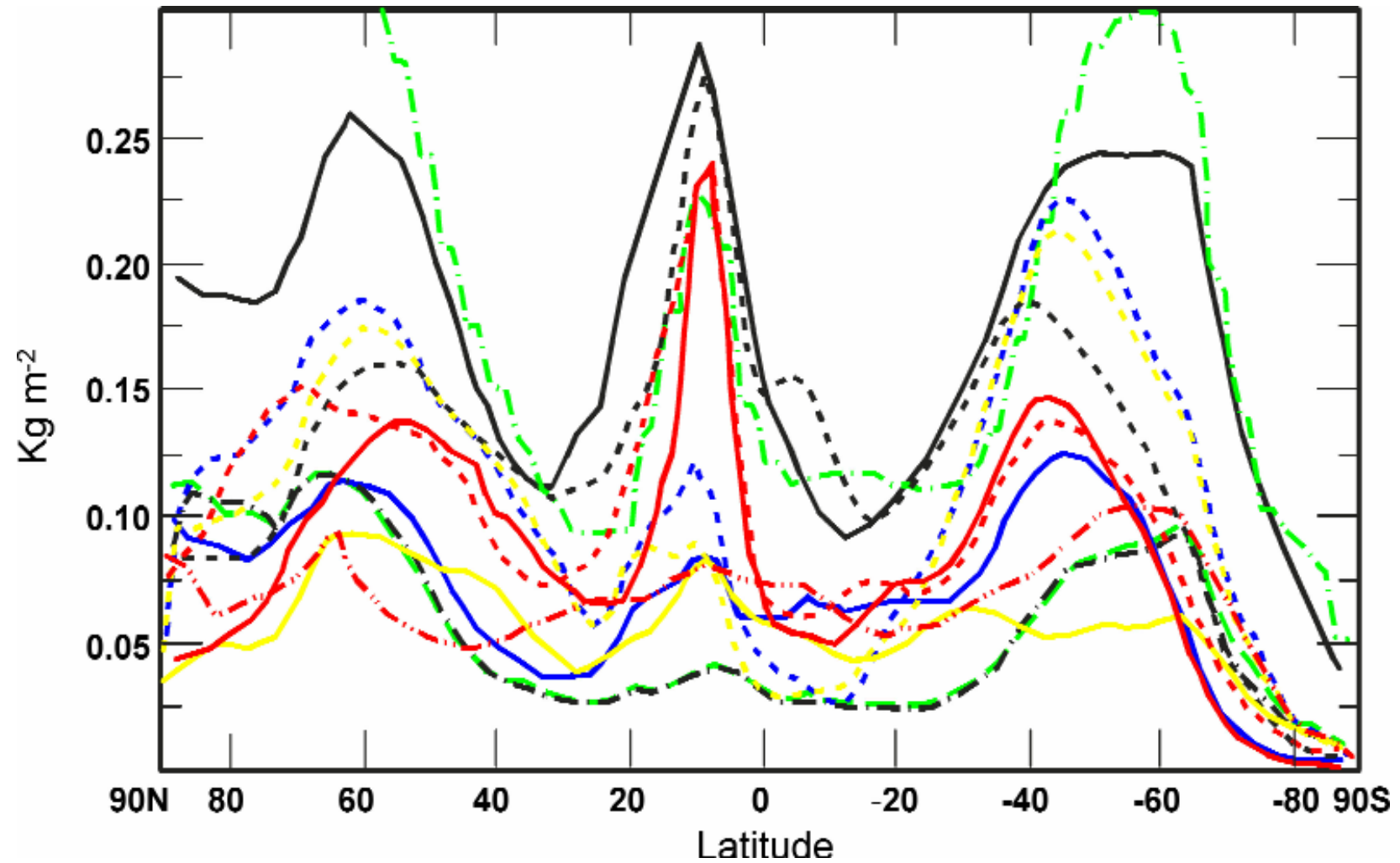
# Motivation

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- The earth's radiation budget is largely influenced by cloud properties, such as cloud amount, liquid water path, and droplet effective radius
- To quantify the contribution of clouds on climate change, we require highly accurate satellite measurements of cloud properties, to model them in to the global climate models
- Unfortunately, passive satellite remote sensing of clouds still suffers from poorly characterized retrieval errors
- Our aim is to make a step forward in characterizing these retrieval errors



# Zonal Mean LWP: AMIP Models



## **Current Status:**

Large discrepancies in both satellite observations and climate model simulations of cloud liquid water path

## **Question:**

How can we construct a better set of LWP data from different satellite measurement techniques?

## **Objective:**

Better constraining cloud liquid water path by systematically investigating inconsistencies between microwave and optical cloud liquid water path estimates

## Microwave (AMSR-E/TMI) Retrieval Technique

- Measure emitted MW radiation (brightness temperature)
- LWP is calculated based on Liquid water absorption
- Only over Ocean, both day and night



## VIS-NIR (MODIS/SEVIRI) Retrieval Technique

- Measure reflected sun light
- VIS channel gives optical thickness ( $\tau$ )
- NIR channel gives effective radius ( $r_e$ )
- LWP derived from ( $\tau$ ) and ( $r_e$ )



$$LWP \approx \frac{2}{3} \rho_w \tau_{e,top}$$

- Both Land and Ocean, only daytime
- retrieval algorithm is based on 1D, homogeneous clouds

**Global Comparison of Cloud Liquid Water Path  
from  
AMSR-E and MODIS**

# Data & Methodology

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## ■ AMSR-E

- Advanced Microwave Scanning Radiometer for Earth Observing System
- Cloud liquid water path, rain rate, water vapor, SST, and wind speed over ocean at 6 frequencies: 6.925, 10.65, 18.7, 23.8, 36.5, 89.0 GHz

## ■ MODIS

- Moderate Resolution Imaging Spectroradiometer
- Visible / near Infrared sensor (0.4 – 14.4  $\mu\text{m}$ ) with 36 channels

## Analysis

- 1-year (2007) of data gridded at 25 km resolution
- non-raining, warm (liquid) oceanic clouds only

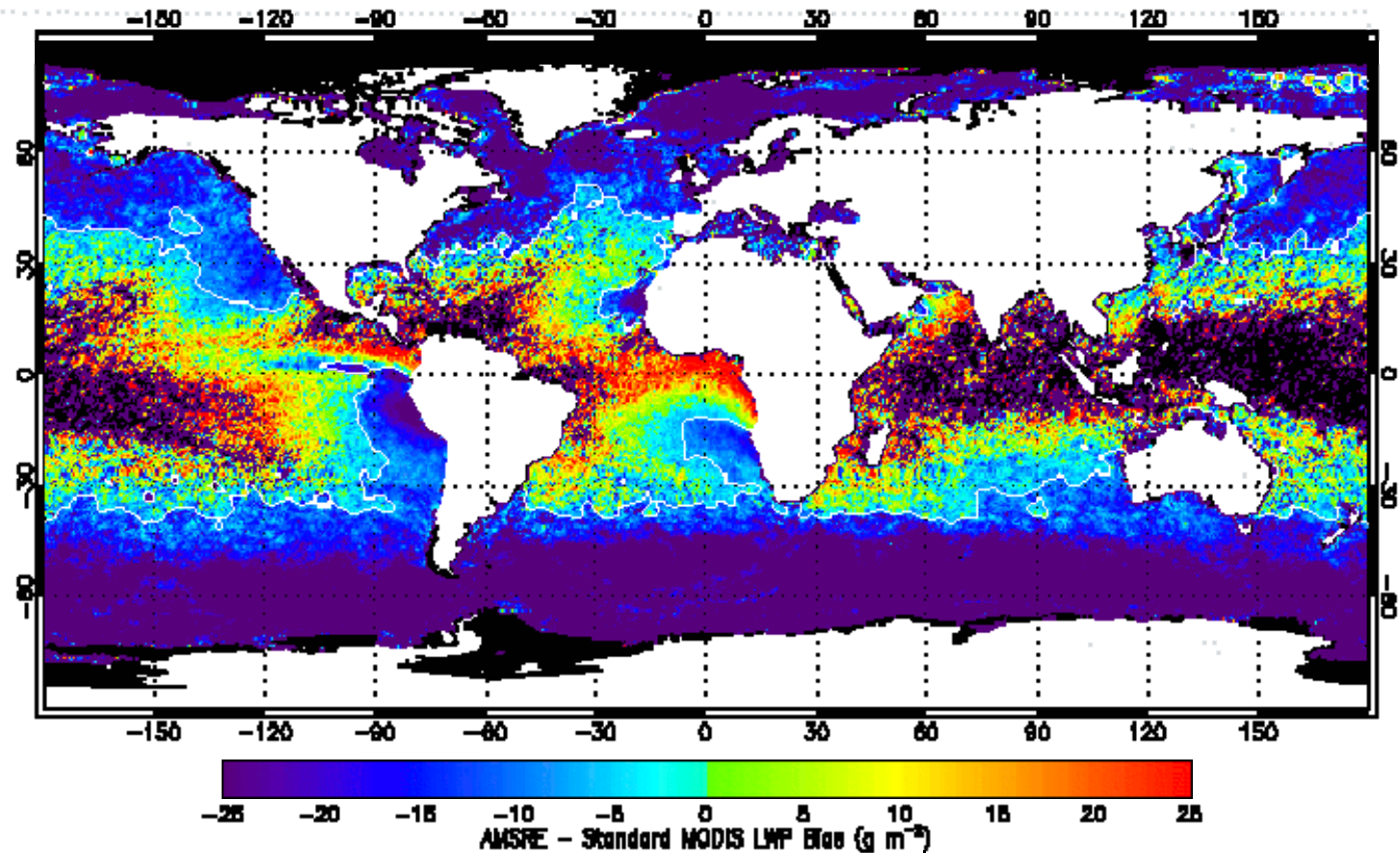
# Global Annual Mean Statistics

	All Domains	Overcast Domains (Cloud Fraction > 95%)	
	Standard (g/m <sup>2</sup> )	Standard (g/m <sup>2</sup> )	Adiabatic (g/m <sup>2</sup> )
AMSRE LWP	58	91	91
MODIS LWP	40	108	90
Absolute bias	18	-17	1
RMS	42	38	31
Correlation	0.71	0.83	0.83

AMSR-E overestimation in broken cloud fields

# Annual Mean (AMSR-E - MODIS) LWP Bias / LCF: 95-100%

Standard  
MODIS



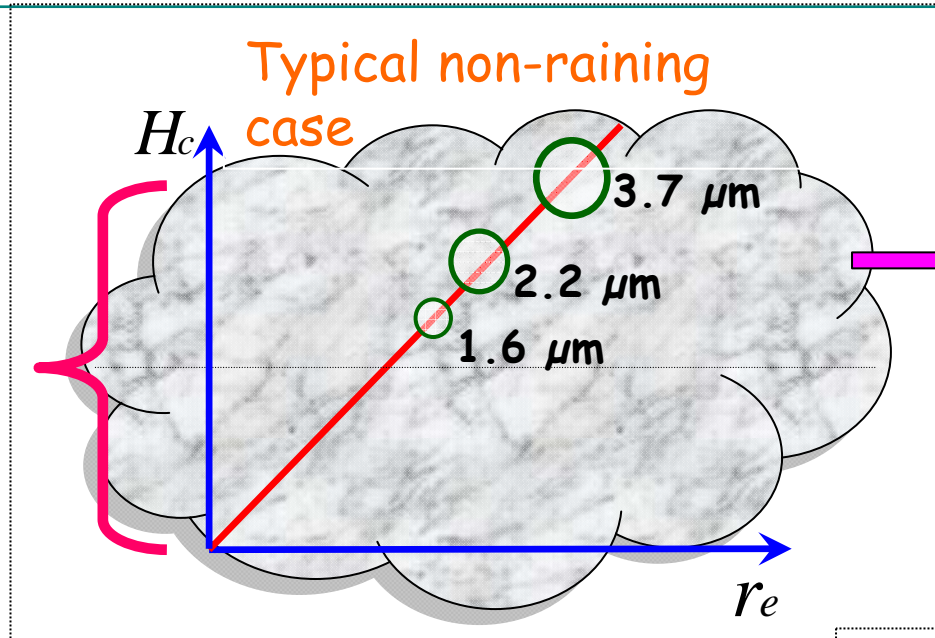
1. Over extensive marine stcu regions the datasets agreed relatively well
2. In broken scenes AMSR-E overestimated MODIS
3. At higher latitudes MODIS severely overestimated AMSR-E



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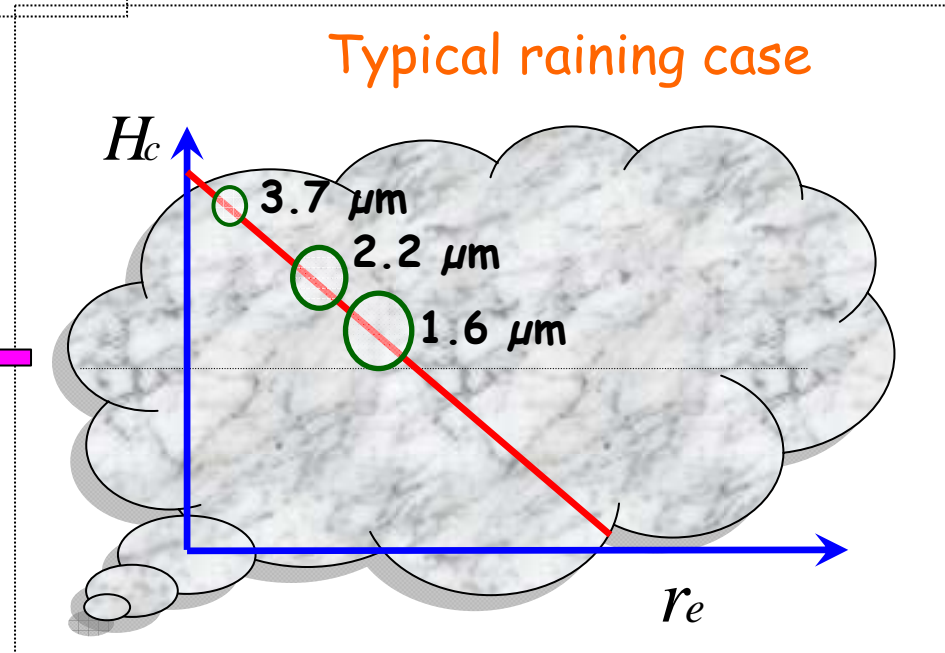
**What causes this bias structure ?**

# 1. Constant Droplet Effective Radius Assumption in MODIS

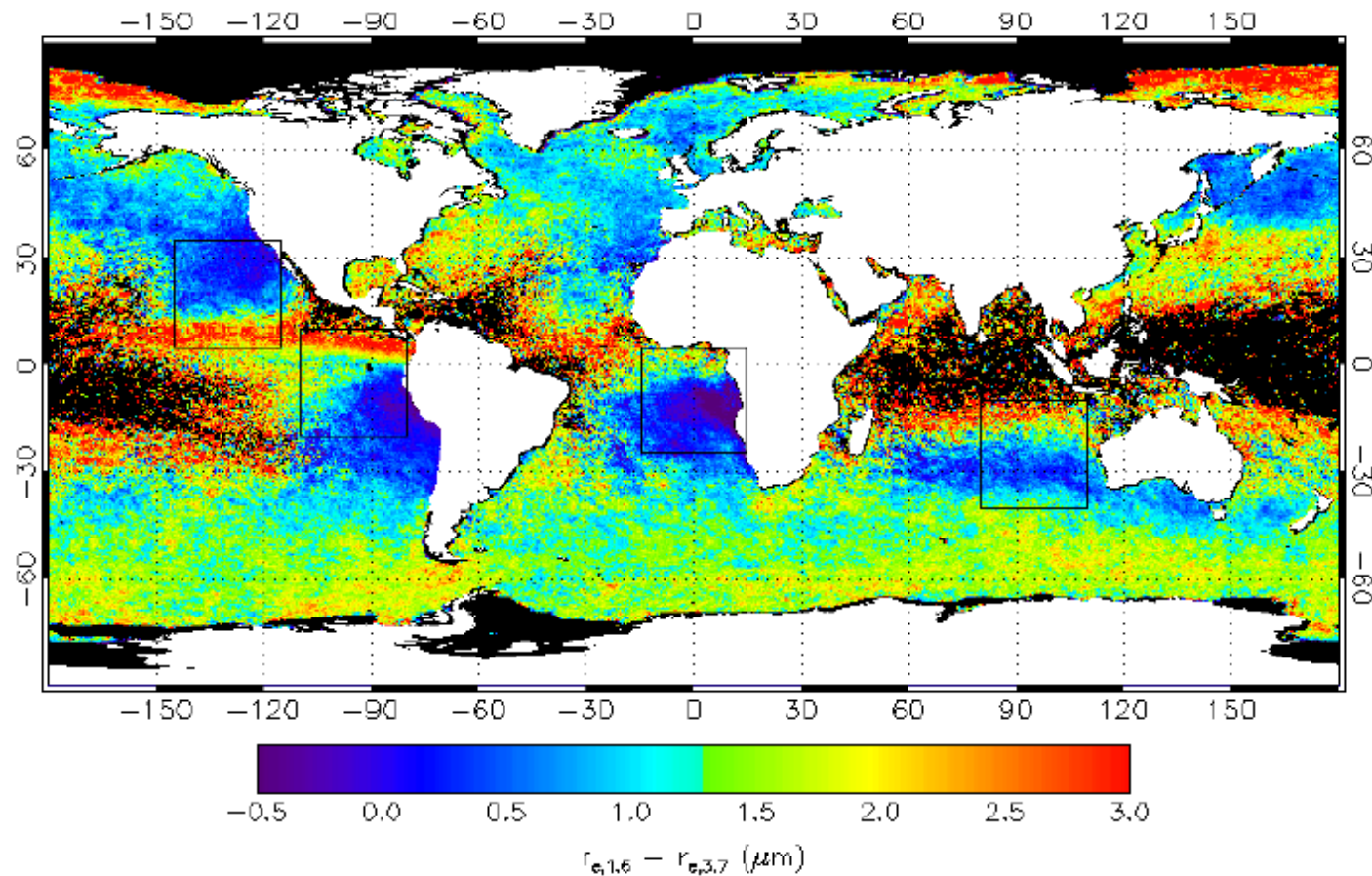


Overestimates  $r_e$  and LWP in non-raining clouds

Underestimates  $r_e$  and LWP in raining clouds



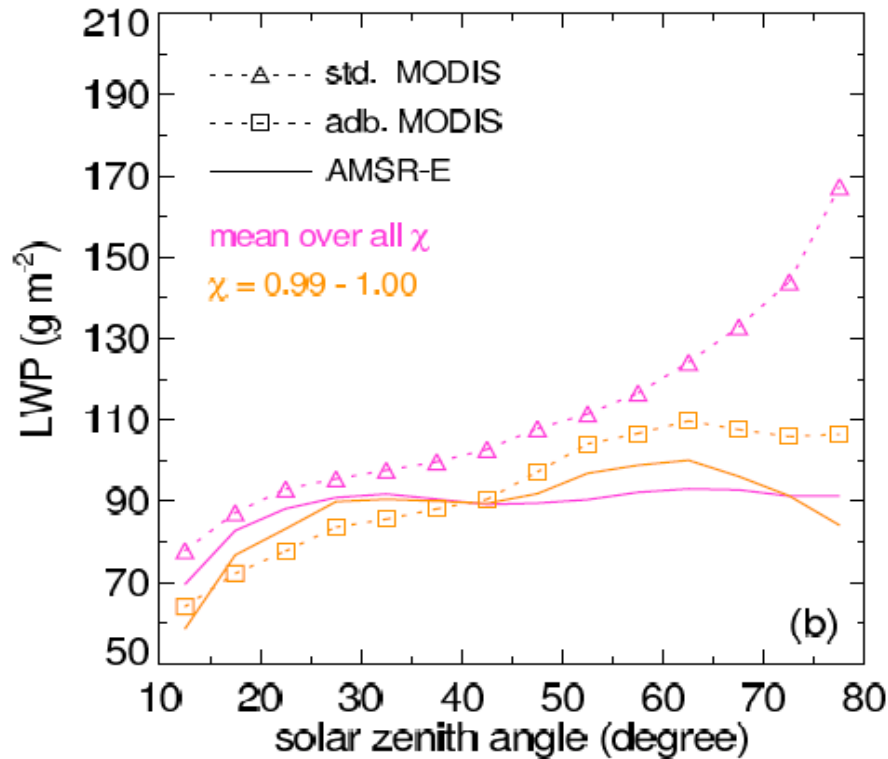
# Annual Mean Effective Radius Difference in MODIS



$$\Delta r_e = r_{e,1.6} - r_{e,3.7}$$

- In the tropics,  $r_e$  difference map is similar to the LWP bias pattern

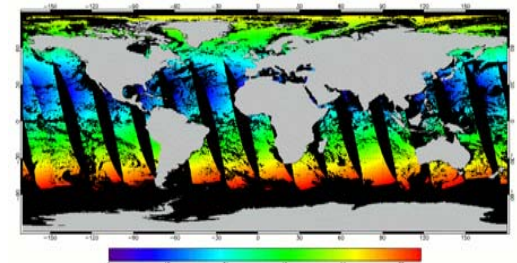
## 2. Cloud Heterogeneity Effect in MODIS



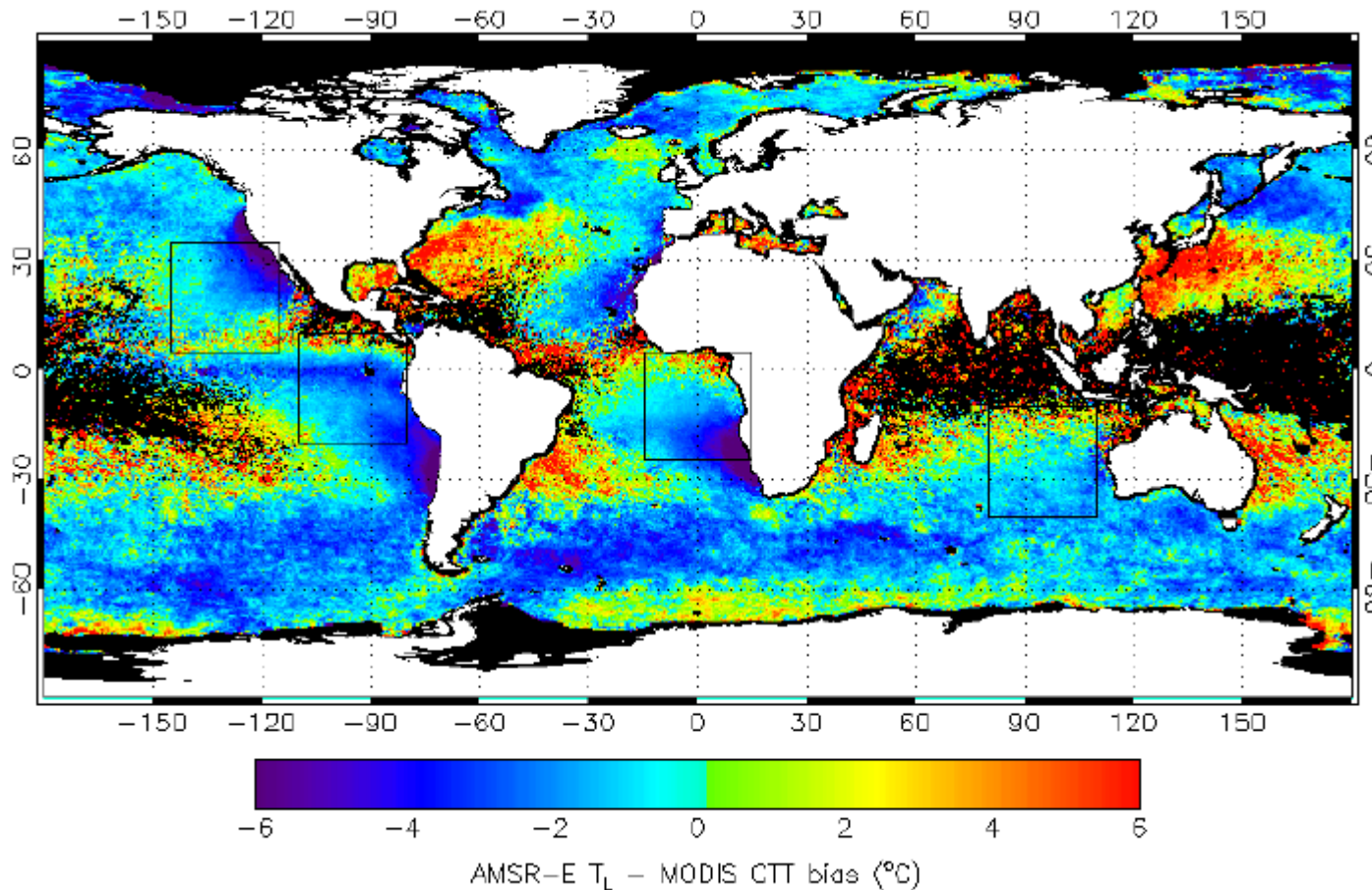
Inhomogeneity parameter:

$$\chi = \frac{e^{\overline{\ln \tau}}}{\overline{\tau}}$$

- 3D optical effect dominates at low SUN
- Overestimates LWP Retrieval



### 3. Annual Mean Cloud Temperature Bias in AMSR-E



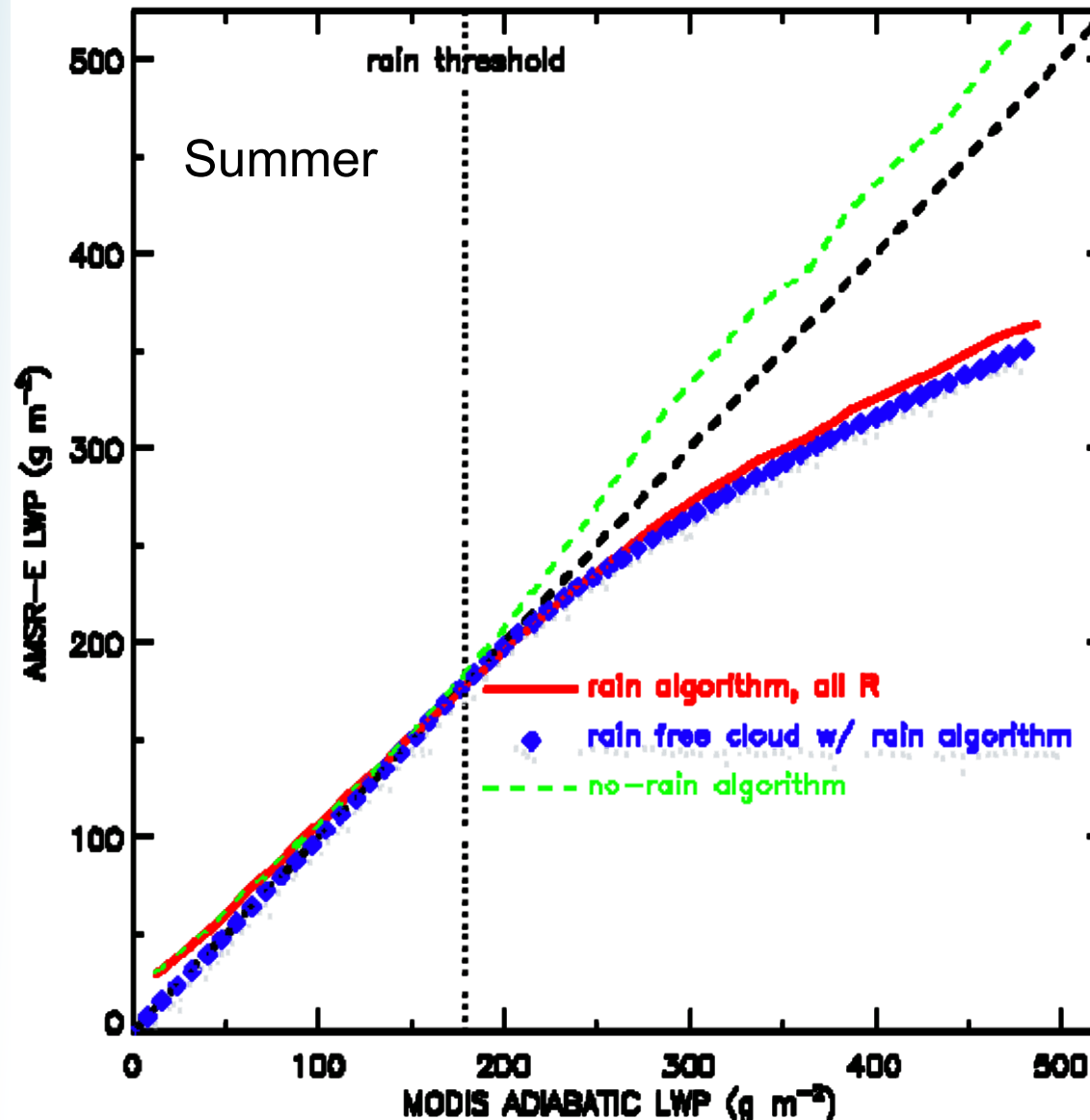
- AMSR-E LWPs are sensitive to the assumed liquid temperature
- LWP bias variation might be related to similar variations in cloud temperature error

## 4. Cloud-rain partitioning issues in AMSR-E

- Simple relation for rain-cloud separation is

$$L = \alpha(1 + \sqrt{HR})$$


; Where  $\alpha = 180 \text{ g/m}^2$   
H is rain column height  
 $\alpha$  is rain-cloud threshold



# Conclusions

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- ✓ The AMSR-E – MODIS LWP bias strongly varies with cloud type and latitude, resulting in significant global structure
- ✓ The global bias distribution emerges due to:
  1. Geographic variations in droplet effective radius profile
  2. 3D optical effects at large solar zenith angles, affecting optical retrievals
  3. Uncertainties in cloud temperature parameterization
  4. Cloud-rain partitioning issues, affecting microwave retrievals



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**Diurnal Cycle of Cloud Liquid Water Path**  
**from**  
**SEVIRI and TMI**

# Data & Methodology

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## ■ TMI

- TRMM Microwave Imager
- Cloud liquid water path, rain rate, water vapor, SST, and wind speed over ocean at 6 frequencies: 6.925, 10.65, 18.7, 23.8, 36.5, 89.0 GHz

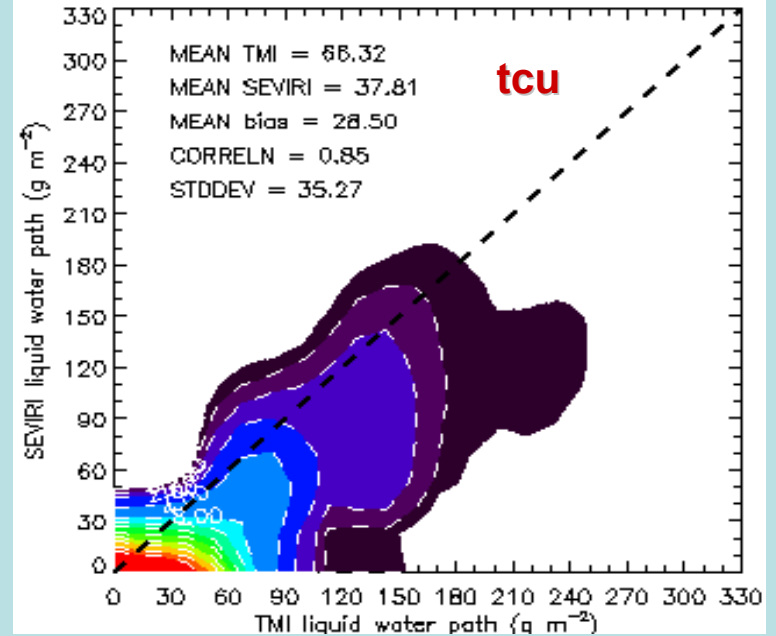
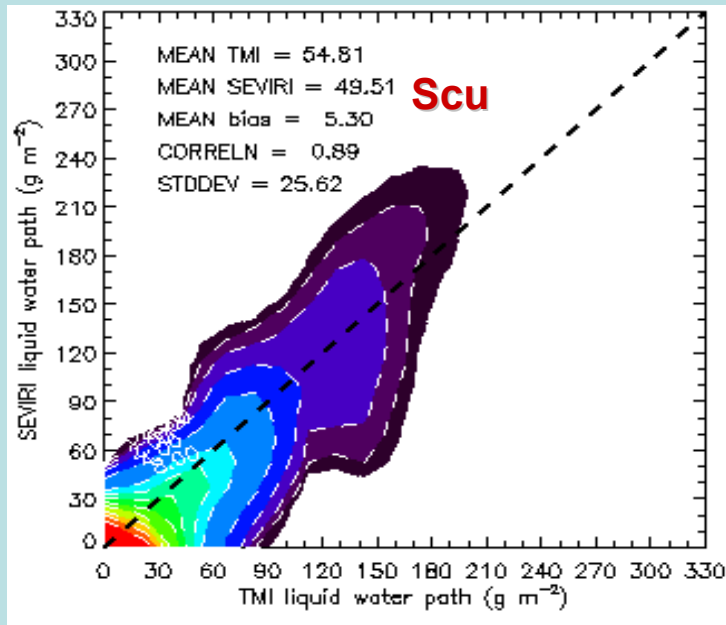
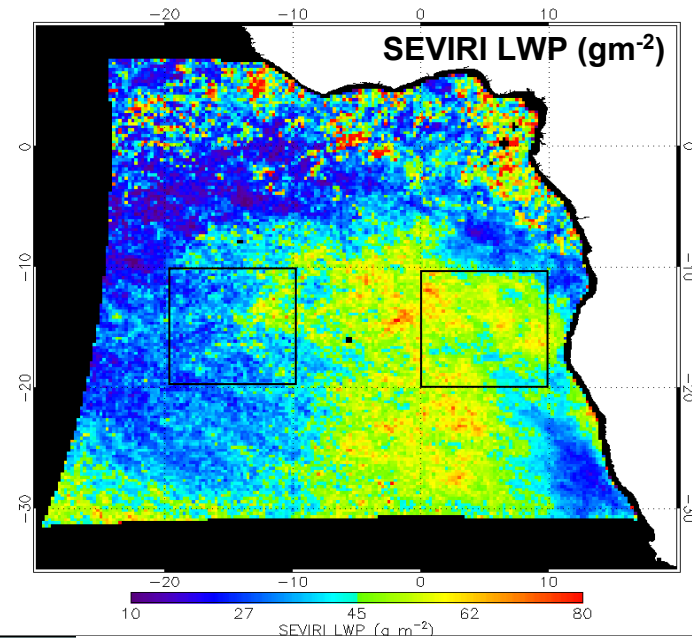
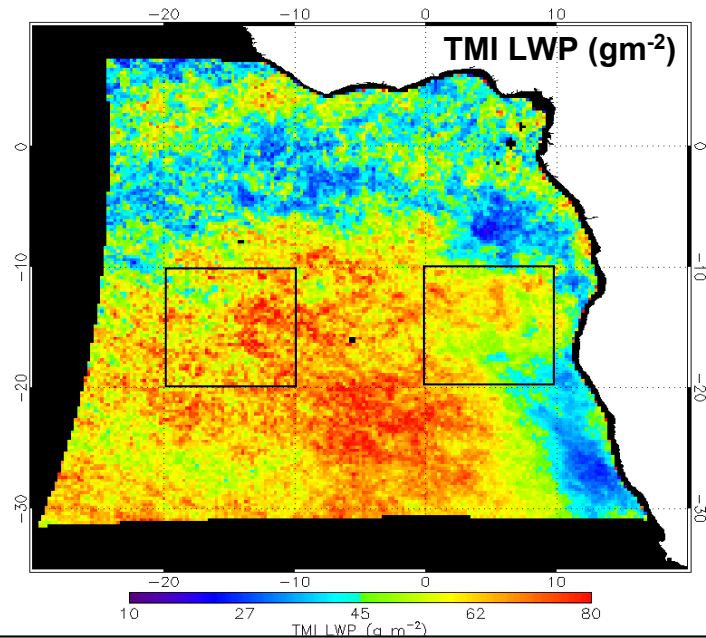
## ■ SEVIRI

- Spinning Enhanced Visible and InfraRed Imager
- Visible / near Infrared sensor (0.4 – 13.4  $\mu\text{m}$ ) with 12 spectral channels

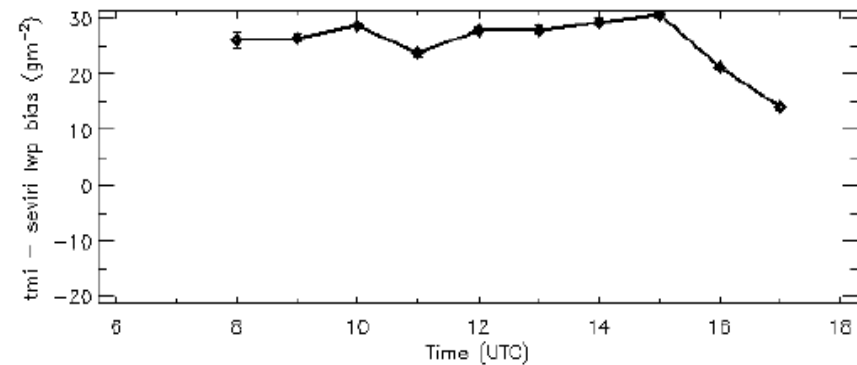
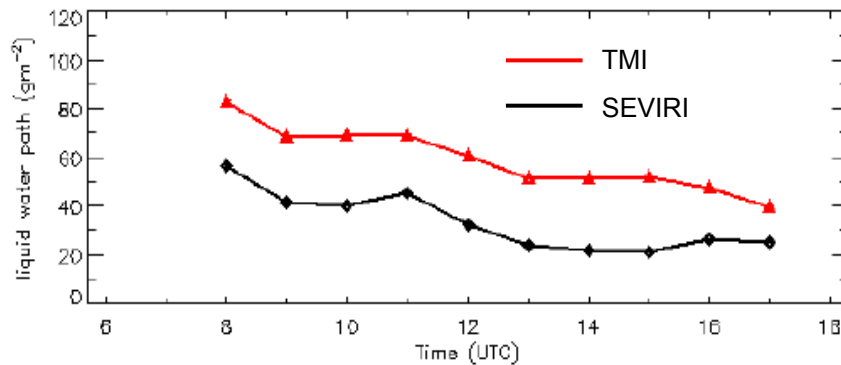
## Analysis

- 4 months (Aug 08, Nov 08, Feb 09, May 09) of data gridded at 25 km resolution
- non-raining, warm (liquid) South Atlantic oceanic clouds only

# Mean (Four Months ) Cloud Properties



## Diurnal cycle (Four Month Mean) of CPP over trade cumulus



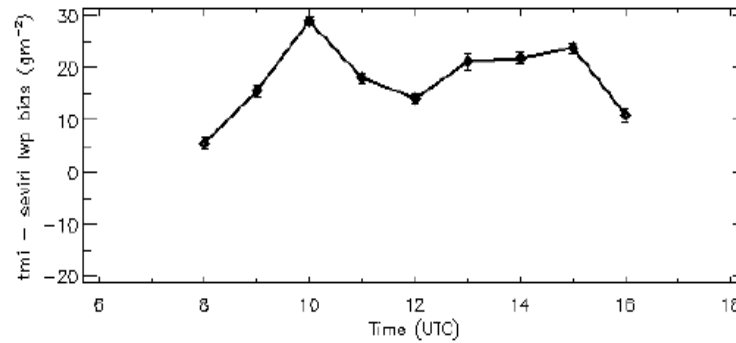
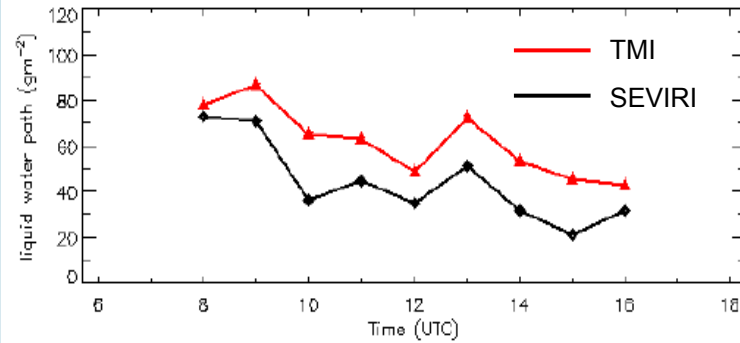
### TMI:

- TMI Clear Sky LWP bias
- Microwave reduced sensitivity to low LWP at 37 GHz
- Cloud-rain partitioning error

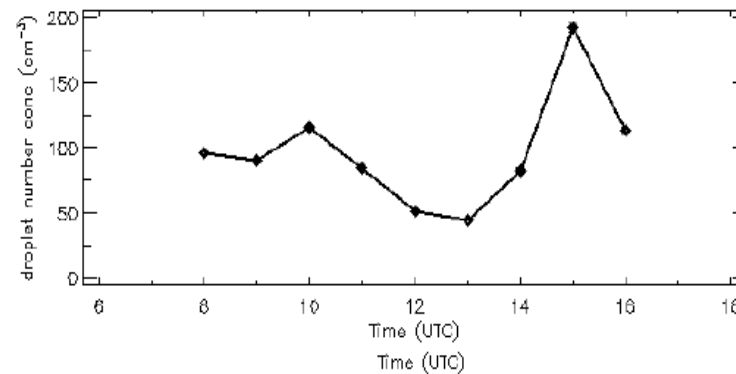
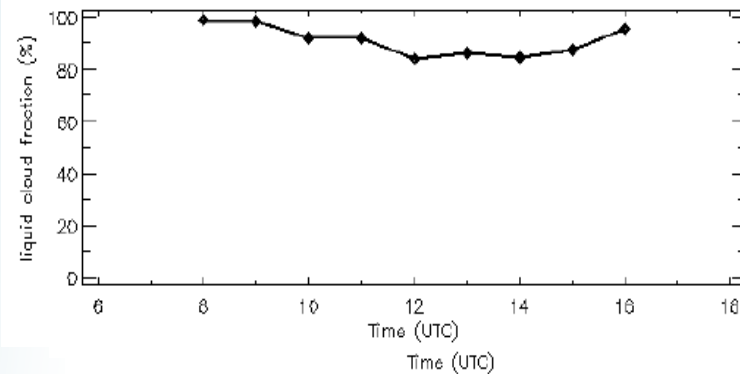
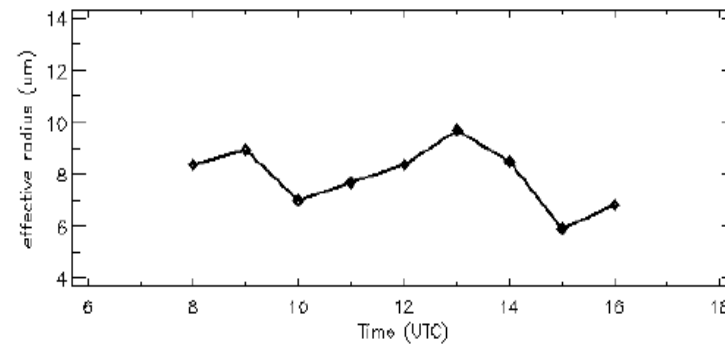
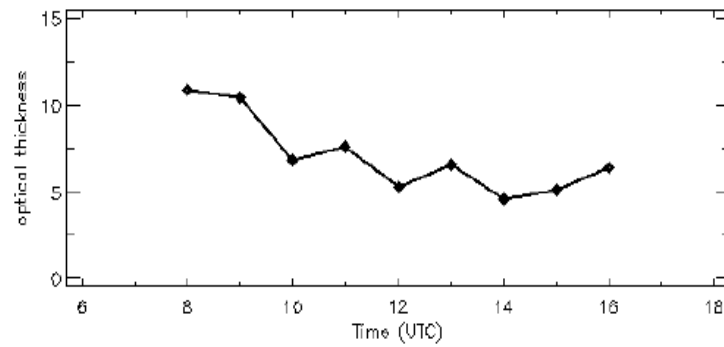
### SEVIRI:

- 3D cloud effects larger in broken clouds (cloud darkening/brightening)
- SEVIRI cloud mask uncertainties, less sensitivity to thin clouds
- Plane-parallel bias due to non-linear relations between optical thickness and reflectance

# Diurnal cycle of CPP over stratocumulus



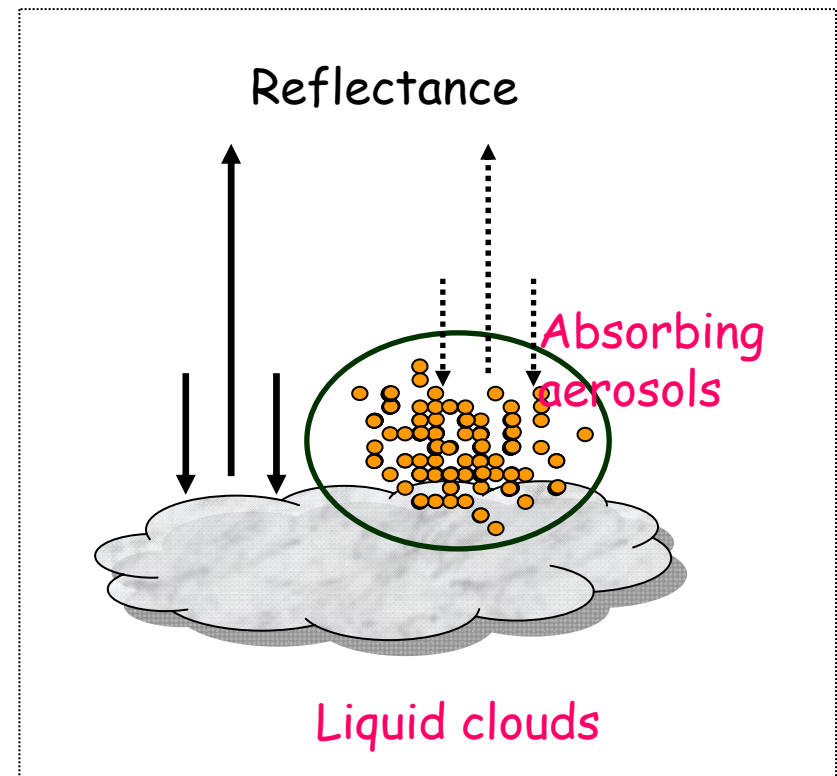
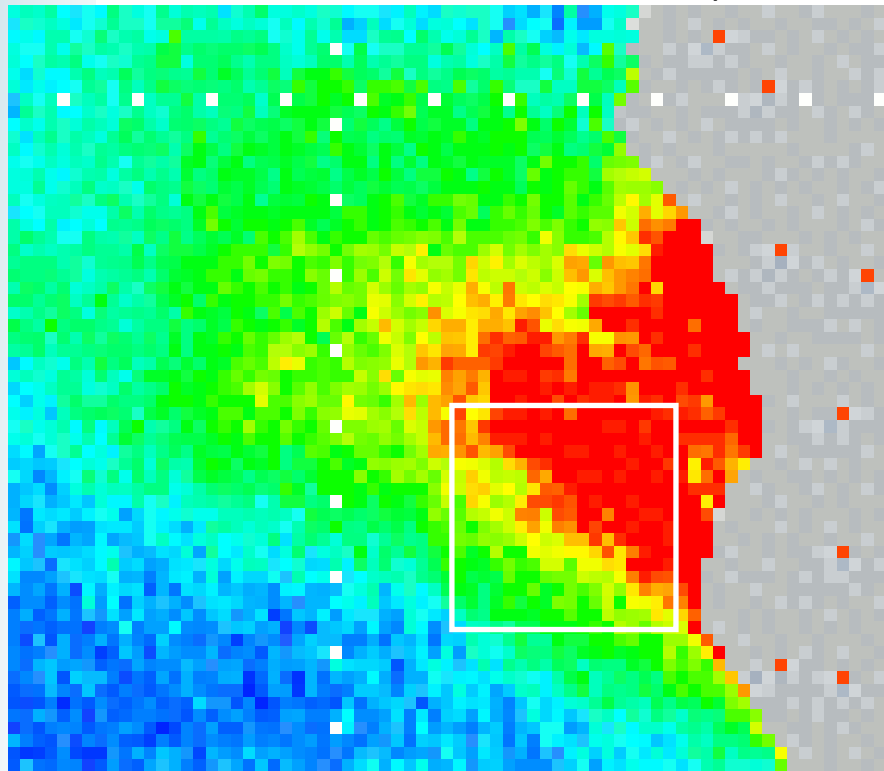
Nov 08  
= May 09  
Aug 08



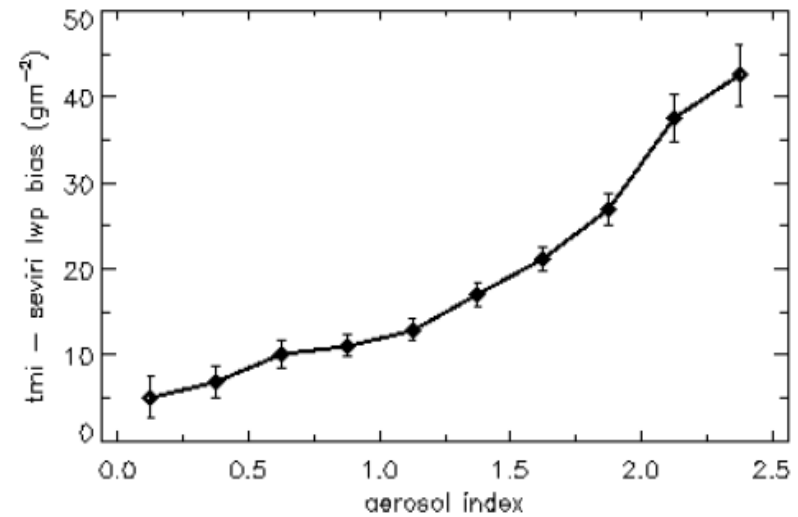
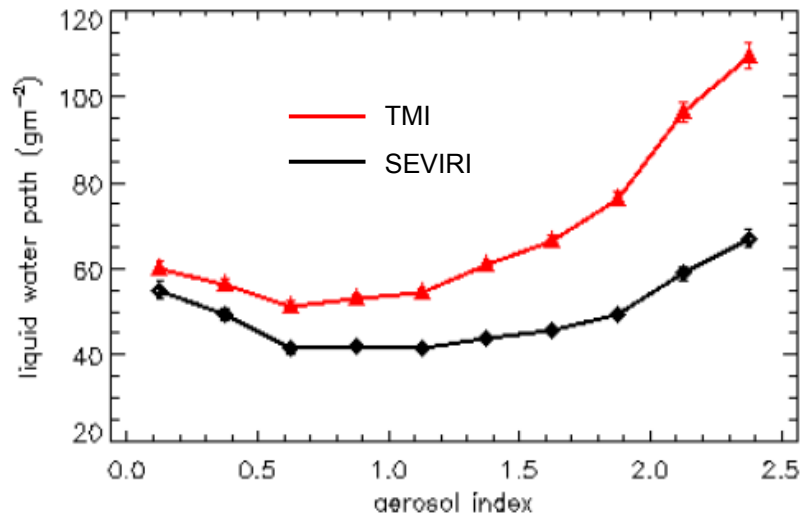
# Absorbing Aerosol Effects on SEVIRI LWP

## OMI-Aerosol Index

(African biomass smoke region;  
-20°S - 0°N: -15°W - 10°E)



## Effect of Absorbing Aerosol on LWP, for Aug 08 over Sc

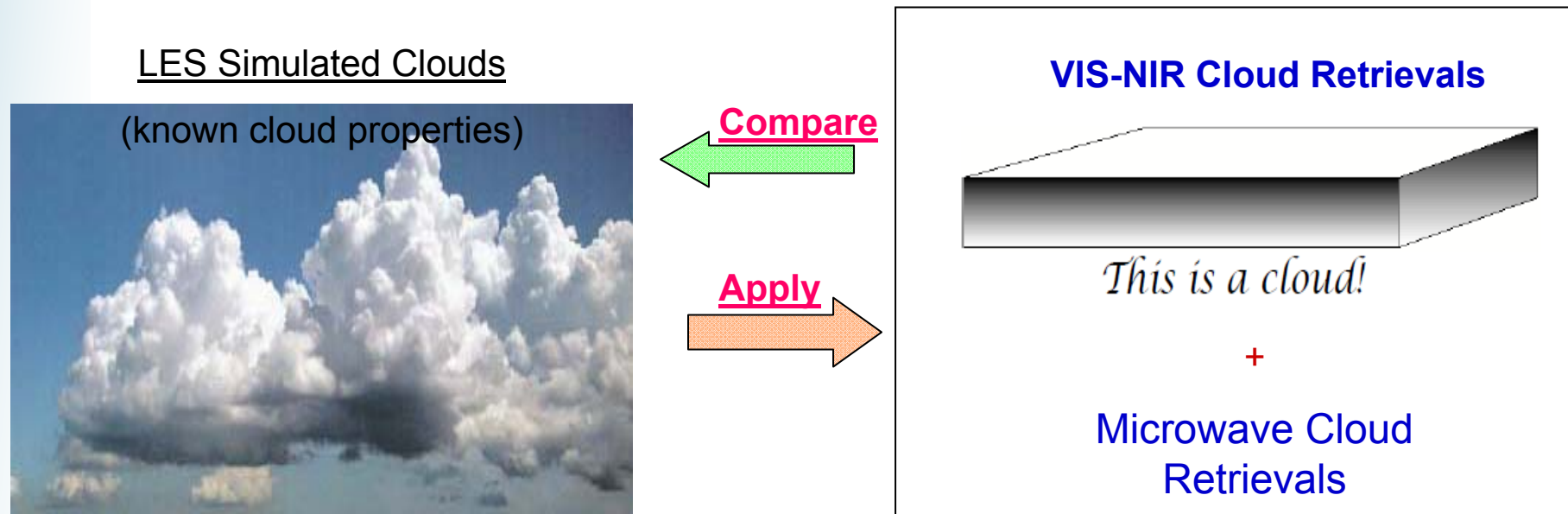


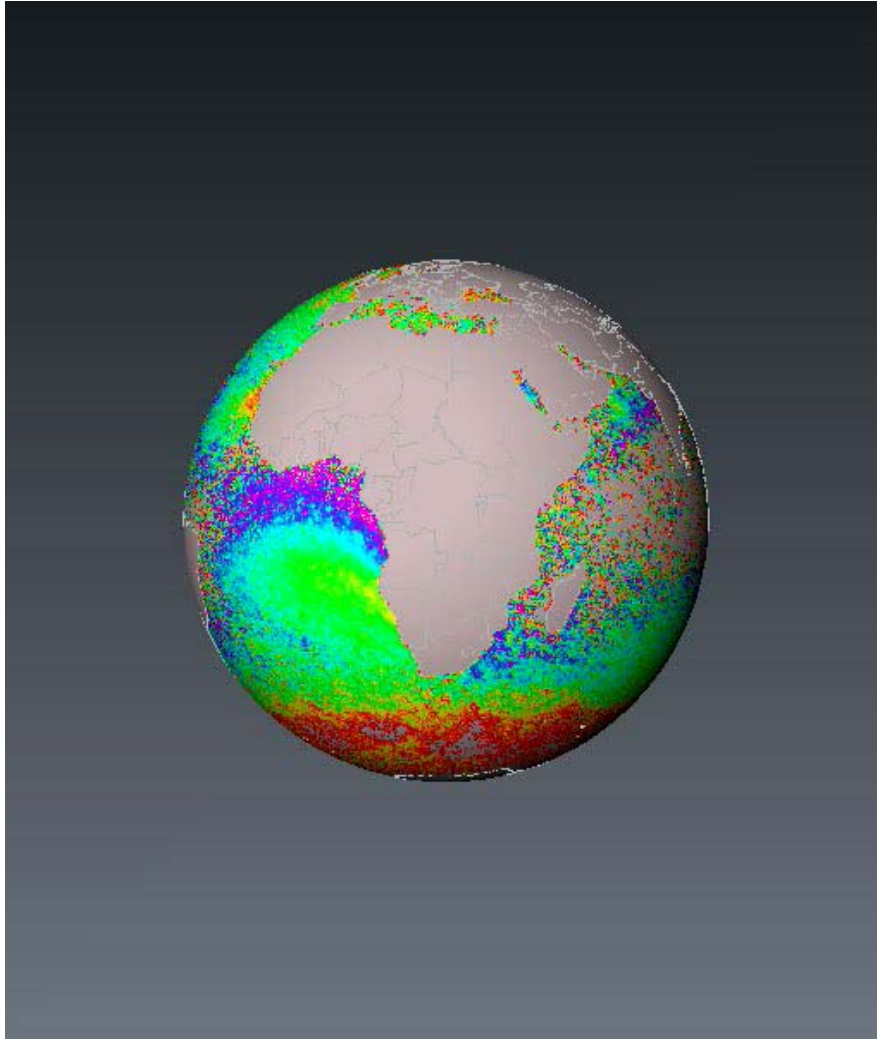
- SEVIRI highly underestimated TMI LWP, with absorbing aerosol

## Overall Conclusions and Outlook

- ✓ Over the marine Sc regions, both the microwave and VIS-NIR technique showed very good agreement in retrieved LWP (both global mean and the diurnal cycle)
- ✓ Over the trade cu region, large bias is observed due to retrieval difficulties in both technique

### What to do next ?





### Acknowledgement:

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**Thank You !**