

# Multiangle cloud remote sensing from POLDER3/PARASOL

## Cloud phase, optical thickness and albedo

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## Instrumental Background



- CNES/LOA instrument, Parosol launched Dec. 2004

- ~ 705 km polar orbits, ascending (13:30 a.m.)

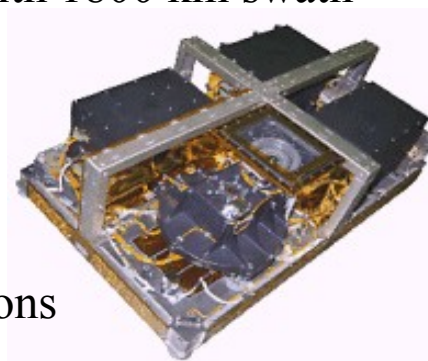
**Data available from March 2005 to Jan 2010 within A-TRAIN and more**

- Sensor Characteristics

- 10 spectral bands ranging from 0.443 to 1.020  $\mu\text{m}$
- 3 polarised channels

- Wide FOV CCD Camera with 1800 km swath width

- +/- 43 degrees cross track
- +/- 51degrees along track

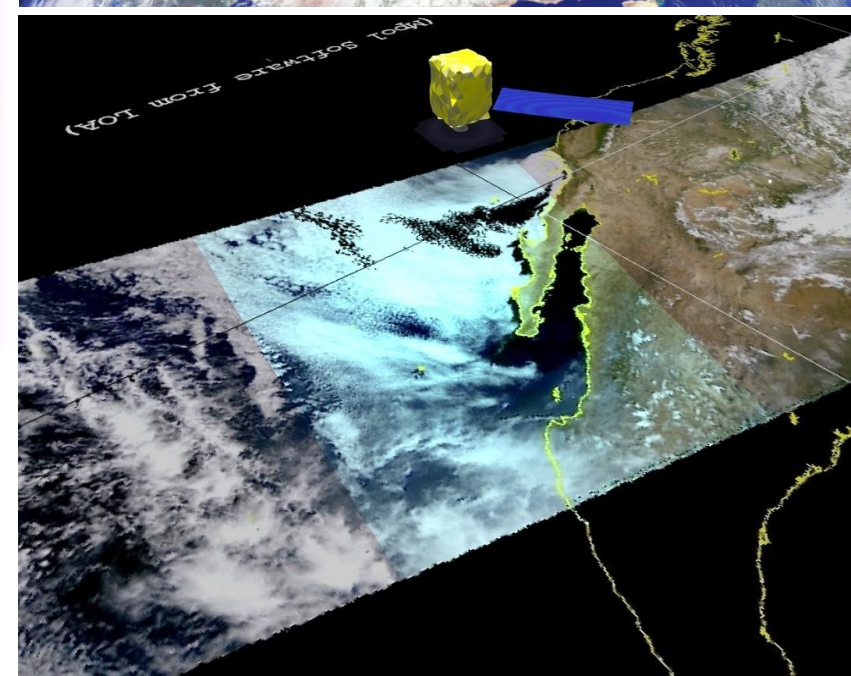
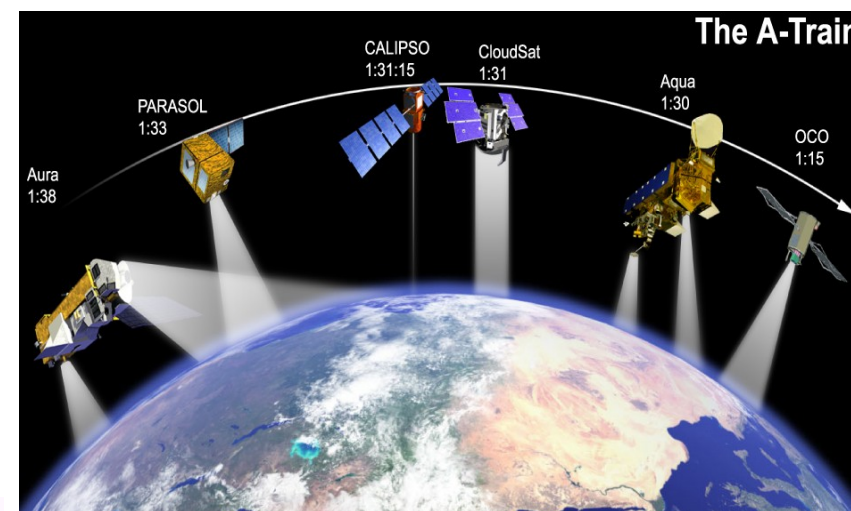


- Multidirectionnal observations (up to 16 directions)

- Spatial resolution : 6x7 km

- No onboard calibration system - Inflight vicarious calibration :

- 2-3% absolute calibration accuracy
- 1% interband – 0.1% interpixel over clouds



# ERB, WV and Clouds Level 2 processing scheme

Level 1 georeferenced data – Int. Sinusoidal grid 6km x 6km

Gaseous absorption correction

Apparent pressure determination

Cloud detection

*Clear sky  
only* ↓

Water vapor content

Cloud phase

*Ice only*

Cloud Optical Thickness  
and spectral albedo

Microphysical index  
from polarisation

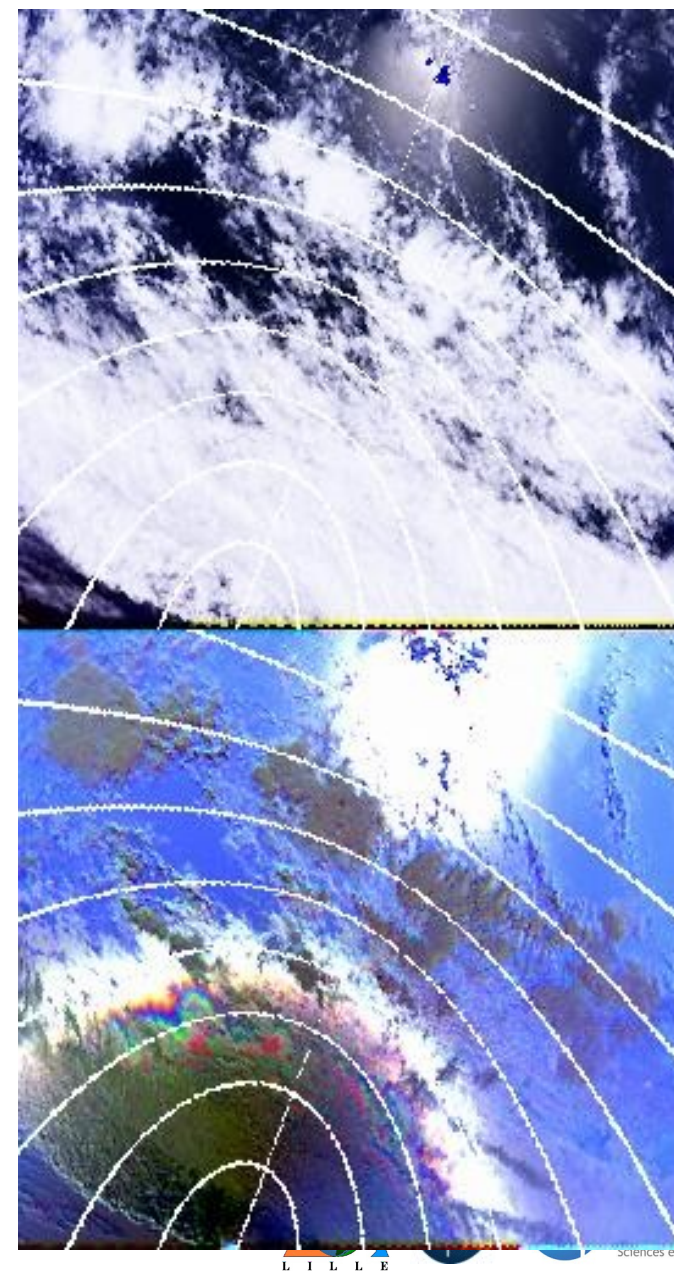
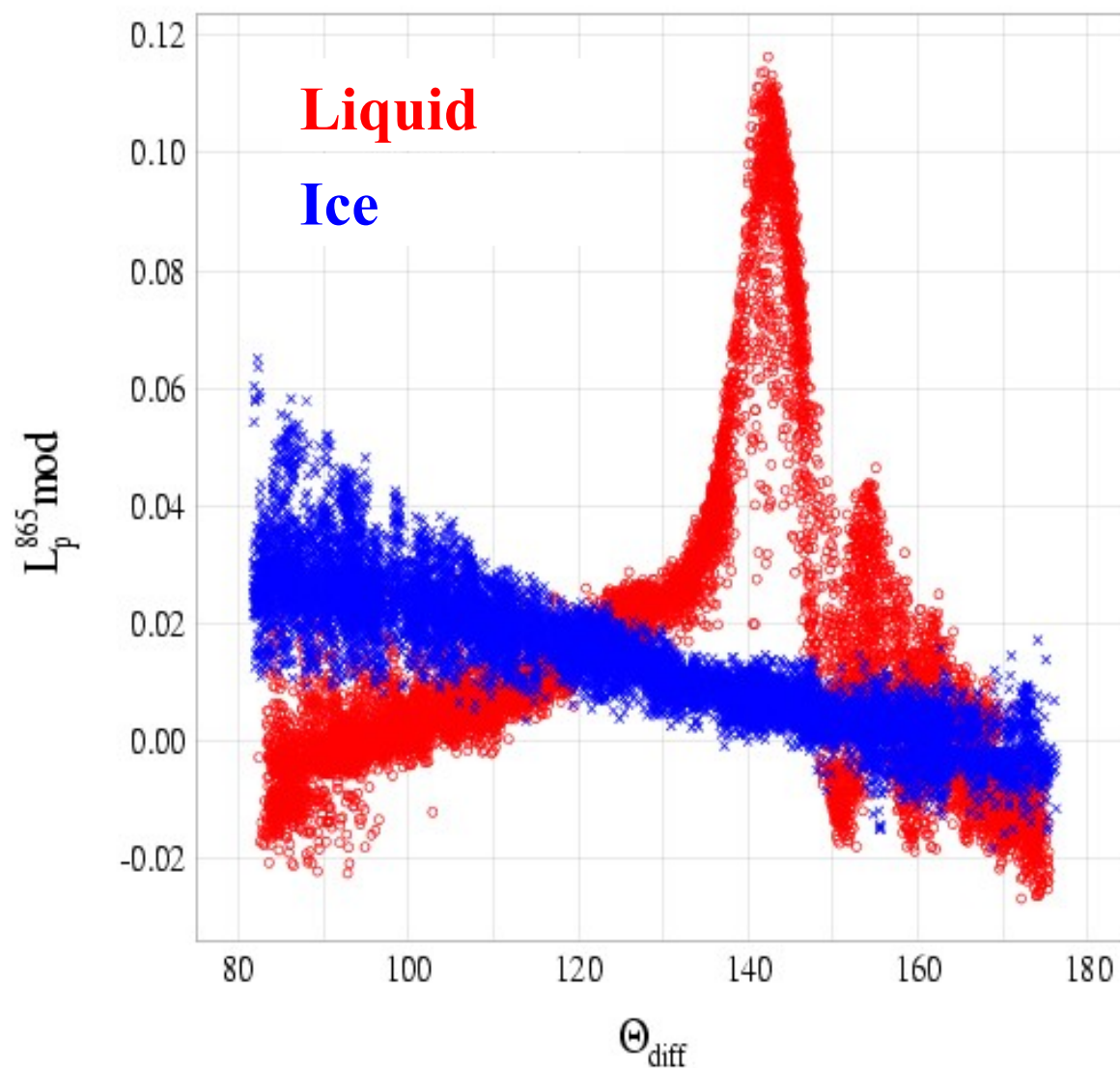
SW albedo integration

Rayleigh and Oxygen  
cloud pressure

Level 2 gridded product  
Int. Sinusoidal 20km x 20km



# Multiangle polarisation measurements and Cloud Phase



# Multiangle polarisation measurements and Cloud Phase

Cloud Phase

20050924\_v1.0.048

September 24, 2005

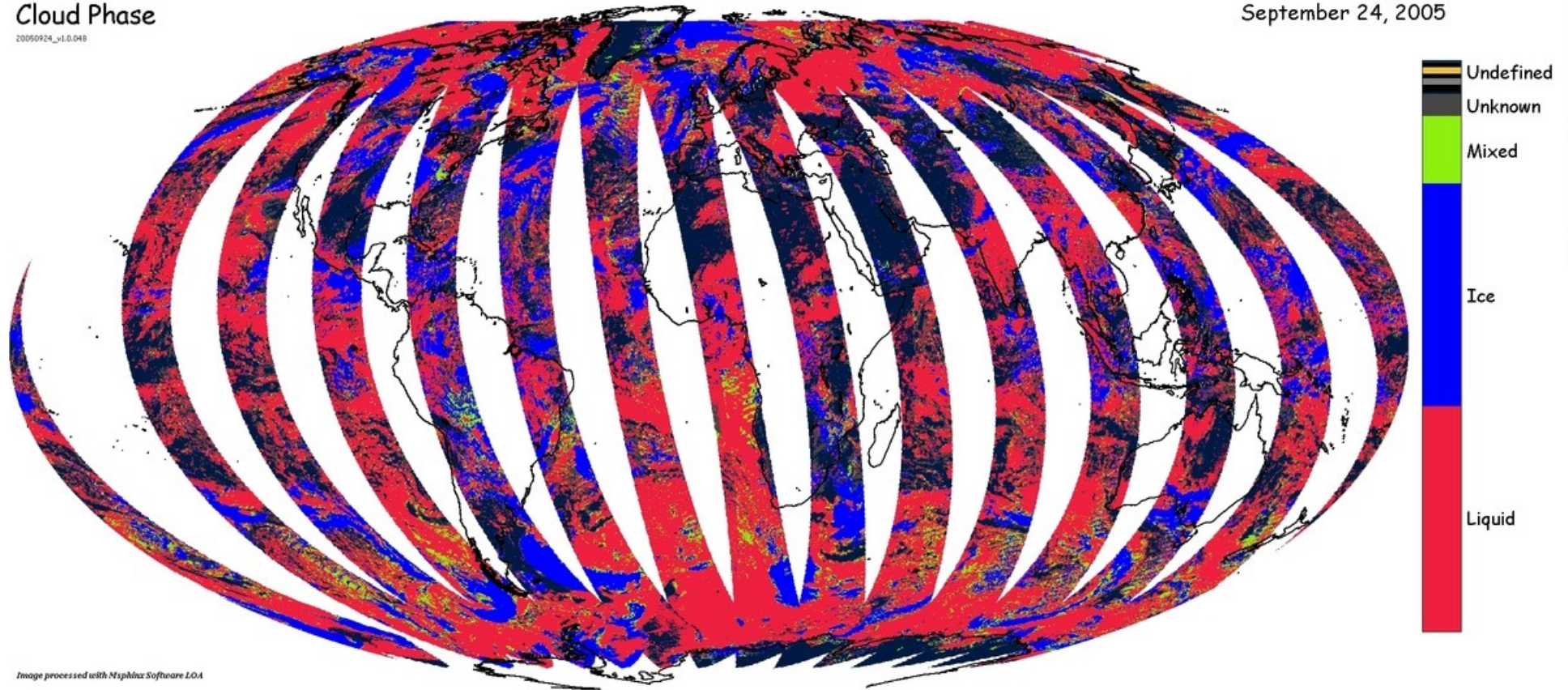


Image processed with Nephlix Software LOA

Cloud phase at 20x20 km resolution

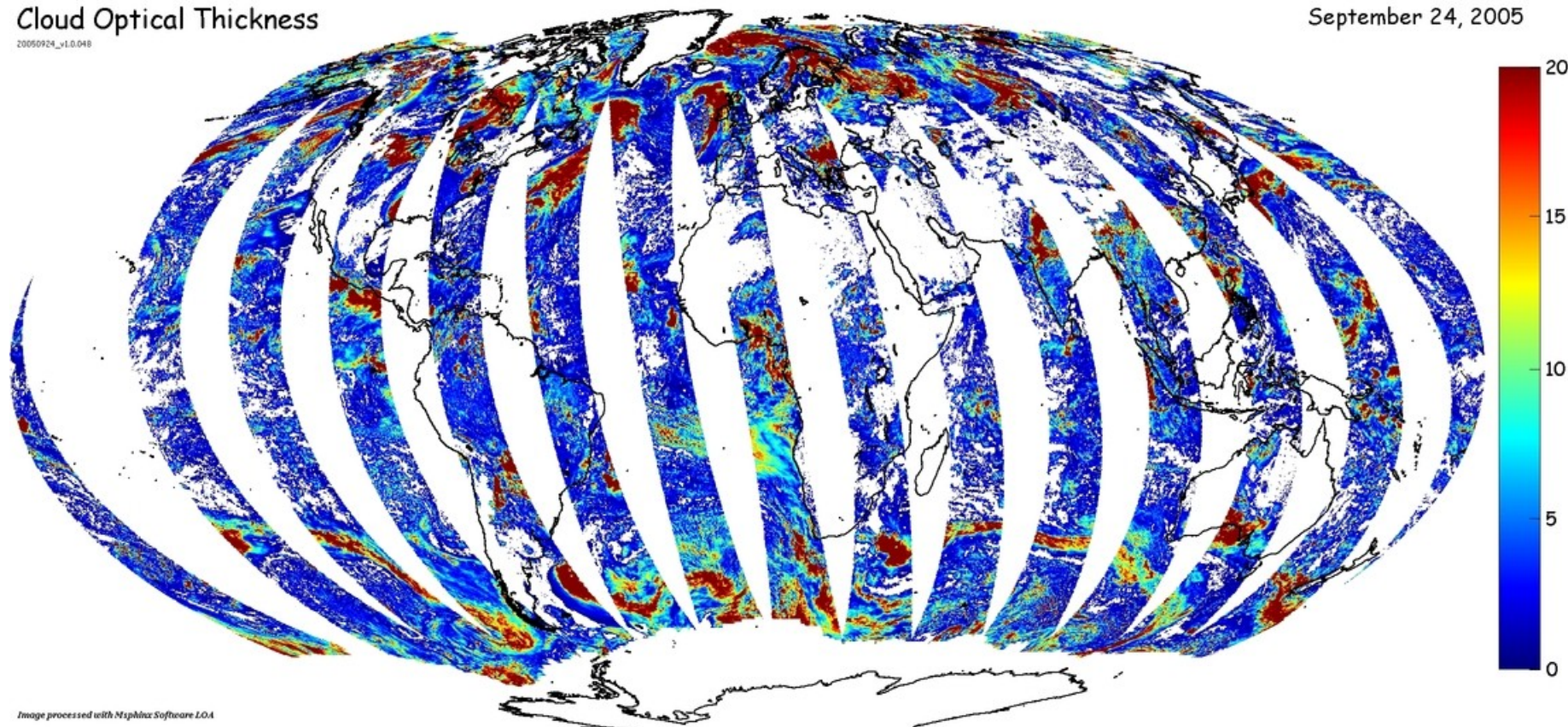
Liquid, Ice, Mixed, Unknown with individual quality index within each.

# Multiangle multispectral measurements

Cloud Optical Thickness

20050924\_v1.0.048

September 24, 2005



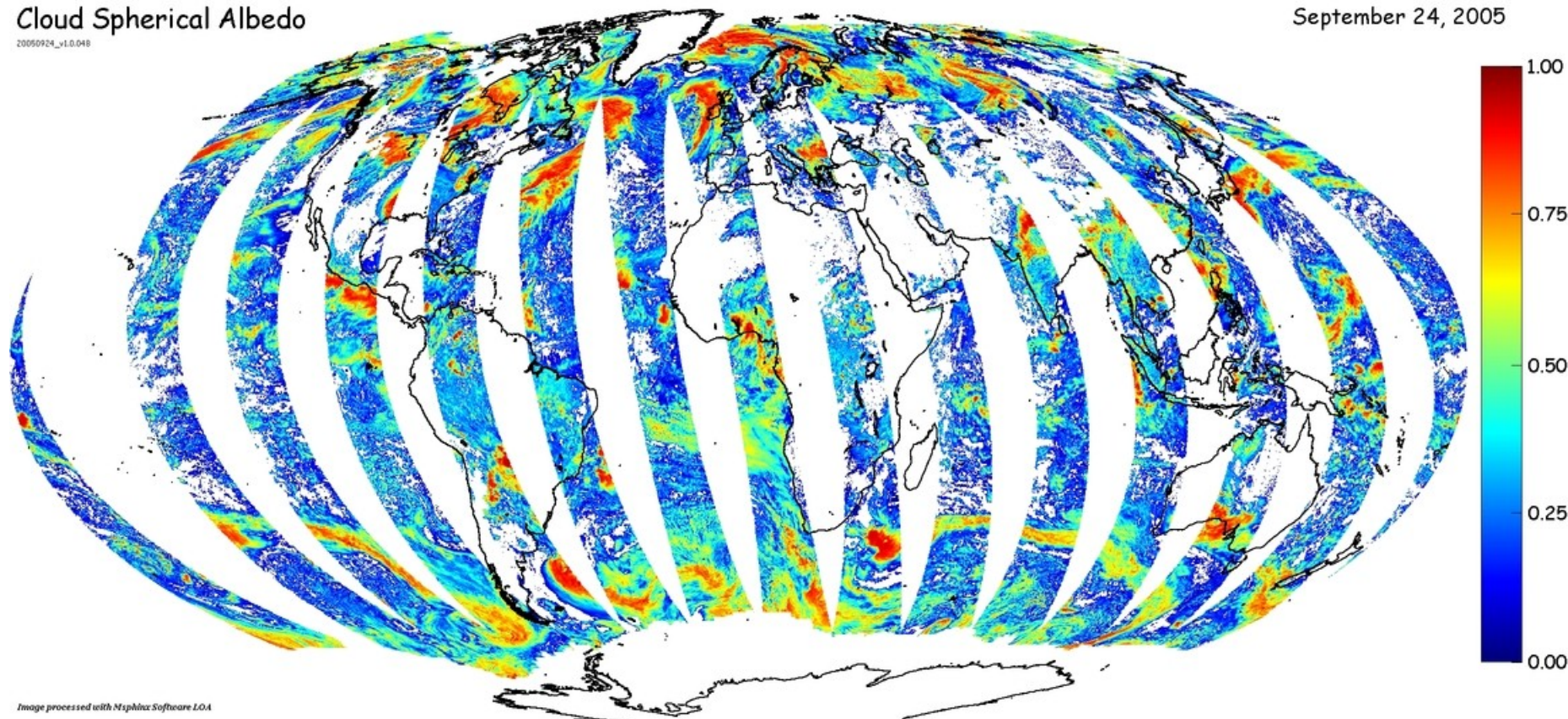
Cloud optical thickness is retrieved under up to 16 directions  
Directional product provided at  $\lambda = 670\text{nm}$  (land) and  $865\text{ nm}$  (ocean)

# Multangle multispectral measurements

Cloud Spherical Albedo

20050924\_v1.0.048

September 24, 2005



Cloud spherical albedo is retrieved under up to 16 directions  
Directional product provided at  $\lambda = 670\text{nm}$  (land) and  $865\text{ nm}$  (ocean)

# Multiangle multispectral measurements

ShortWave Albedo

20050924\_v1.0.048

September 24, 2005

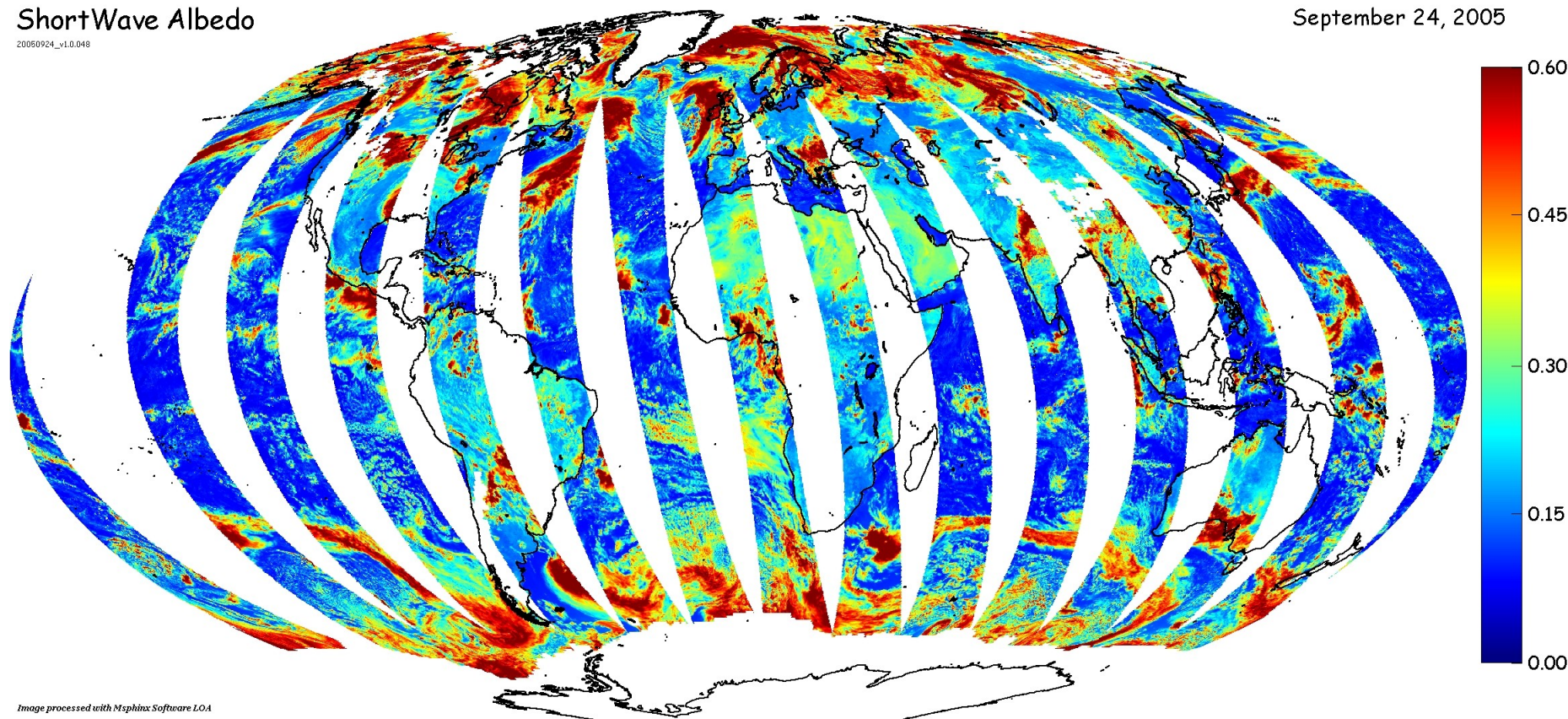
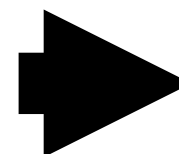


Image processed with Msphnix Software LOA

3 Spectral  
Cloud Albedo

$\lambda = 443 \text{ nm} \rightarrow 200 - 550 \text{ nm}$   
 $\lambda = 670 \text{ nm} \rightarrow 550 - 700 \text{ nm}$   
 $\lambda = 865 \text{ nm} \rightarrow 700 - 4000 \text{ nm}$



**SW CLOUD ALBEDO**

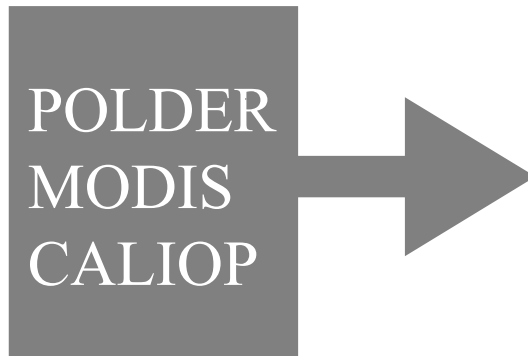


# **Analysis of cloud phase against MODIS and CALIOP**



# Cloud phase as seen by POLDER, MODIS & CALIOP

Level 2 official data



**PM dataset:**

(Level 2 of MODIS & POLDER data)

- resolution : 20 x 20km<sup>2</sup>
- sinusoidal grid
- MODIS averaged over POLDER pixel

**CALTRACK dataset:**

(Level 2 of MODIS, POLDER & CALIOP data)

- resolution : 5km
- available through ICARE Data & Services Center  
<http://www.icare.univ-lille1.fr>

$$f_{re_{ice/liquid}} = \frac{number_{ice/liquid}}{number_{total}}$$

$$f_{re_{agree/disagree}} = \frac{number_{agree/disagree}}{number_{total}}$$

**Period:** From 12/2007 to 11/2008

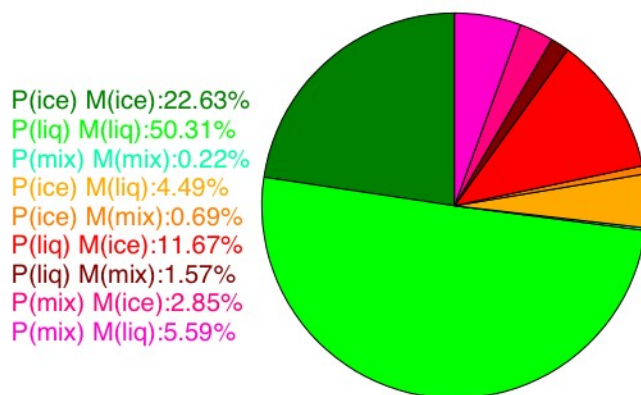


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# MODIS / POLDER global match & mismatch

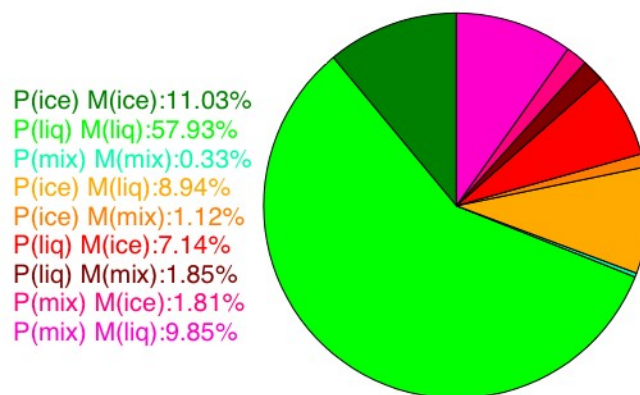
Data: PM dataset, 12/2007-11/2008, [90°S-90°N]

(a) POLDER/MODIS Swath  
All Case



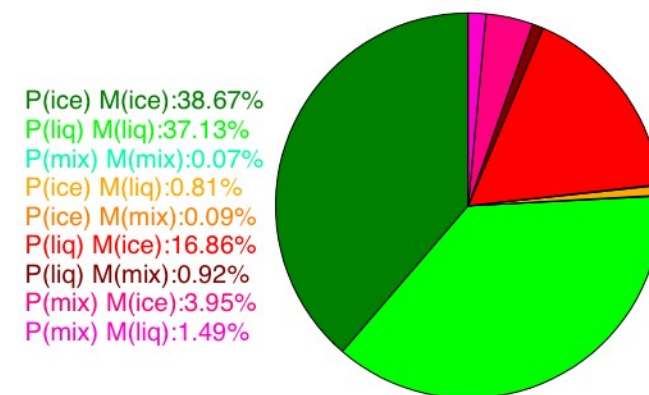
Total Num.:2.09E+08

(b) POLDER/MODIS Swath  
Broken Scene



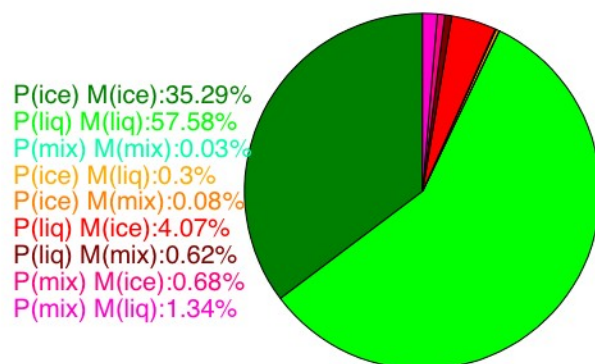
Total Num.:7.72E+07

(c) POLDER/MODIS Swath  
Overcast Scene



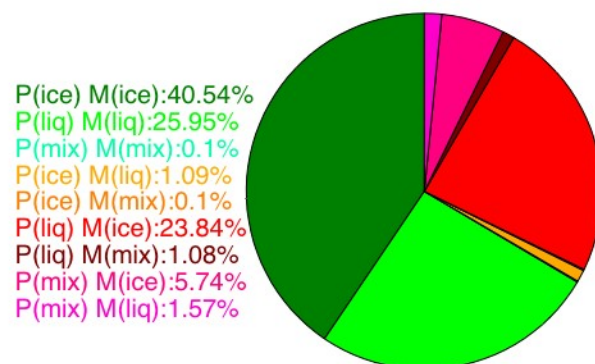
Total Num.:8.2E+07

(d) POLDER/MODIS Swath  
Overcast & Single Layer



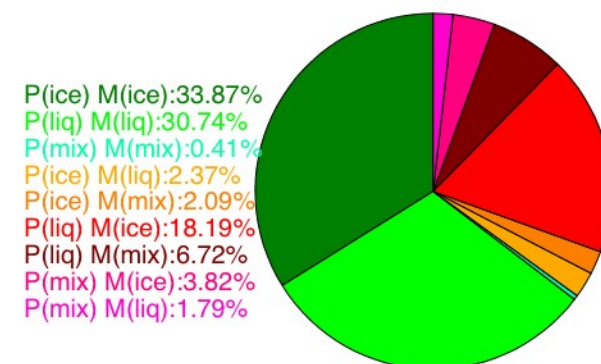
Total Num.:2.89E+07

(e) POLDER/MODIS Swath  
Overcast & Multiple Layer



Total Num.:5.28E+07

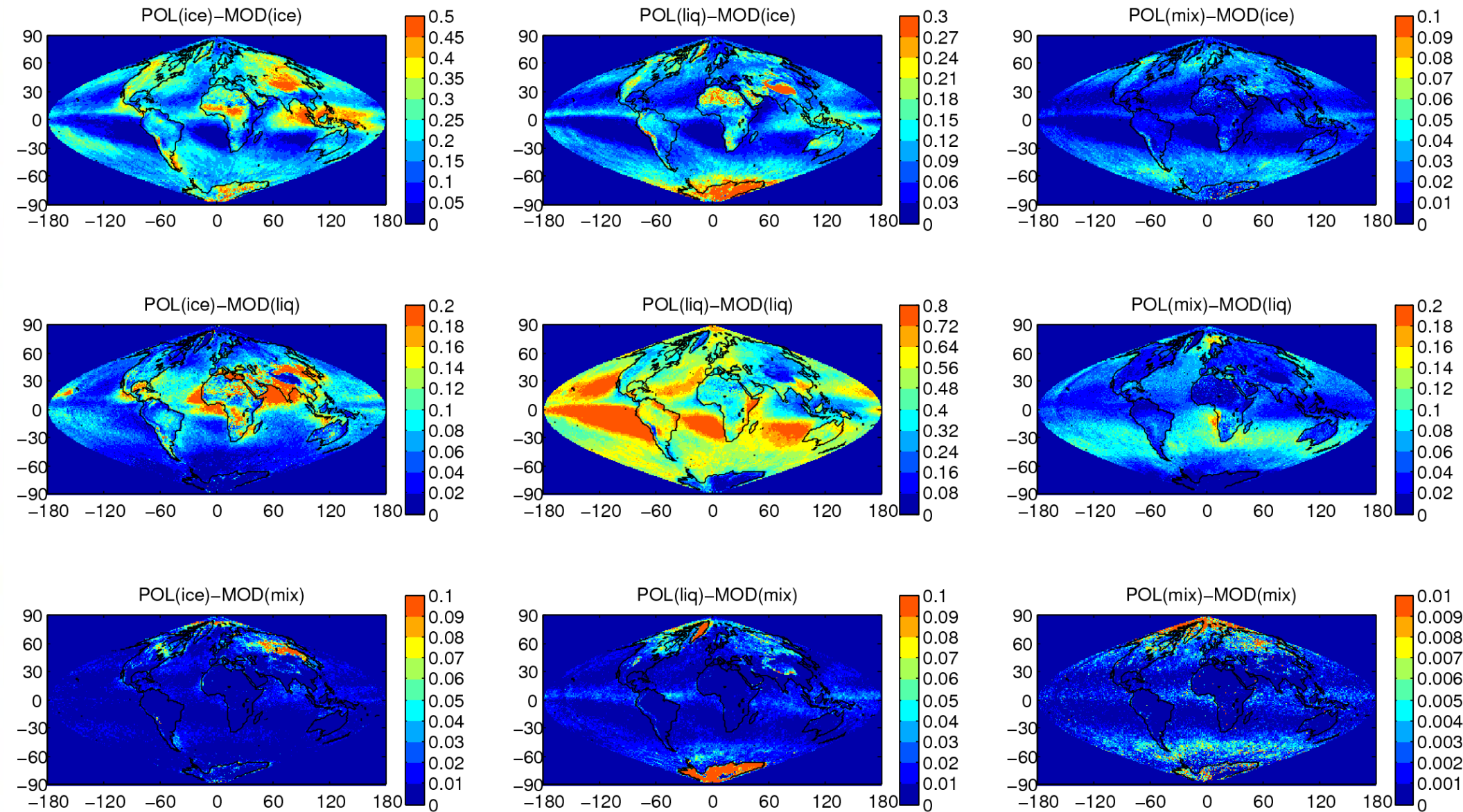
(f) POLDER/MODIS Swath  
Over Snow



Total Num.:1.37E+07

# Geographical Distributions of Phase Frequency

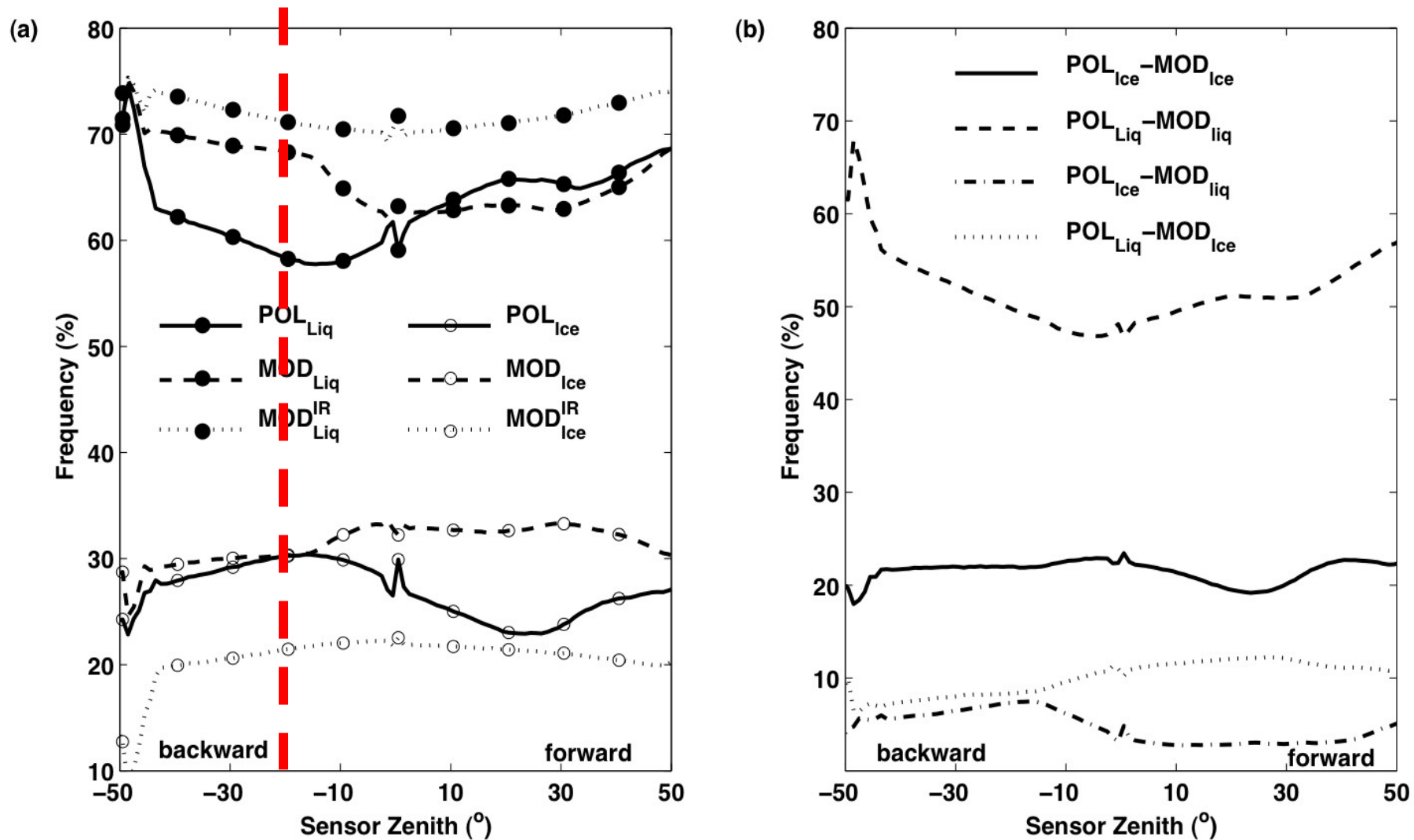
Data: PM dataset, 12/2007-11/2008, [90°S-90°N]



# View zenith angle analysis of Phase detection

Data: PM dataset, 12/2007-11/2008, [90°S-90°N]

## CALIOP SAMPLING LOCATION

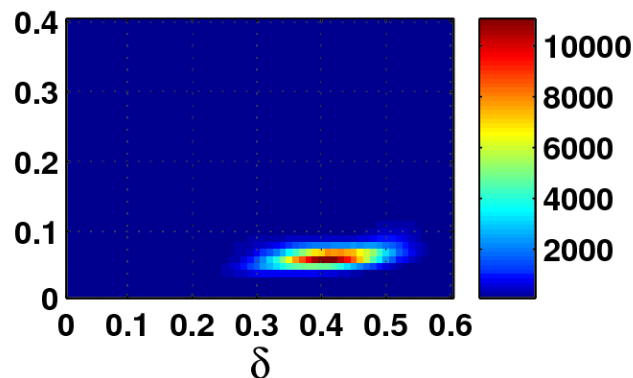


# POLDER/MODIS phase in CALIOP space

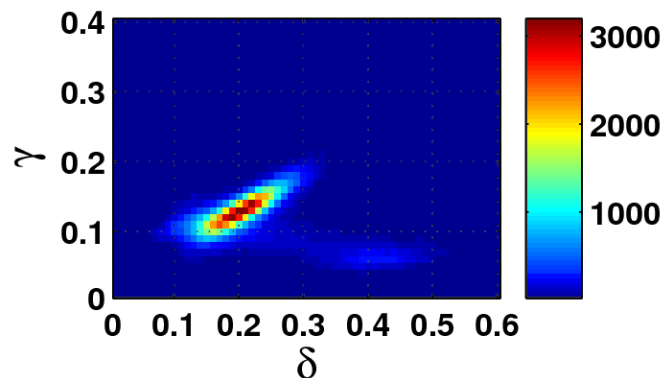
Data: CALTRACK dataset, 12/2007-11/2008, [90°S-90°N]

## Opaque Clouds

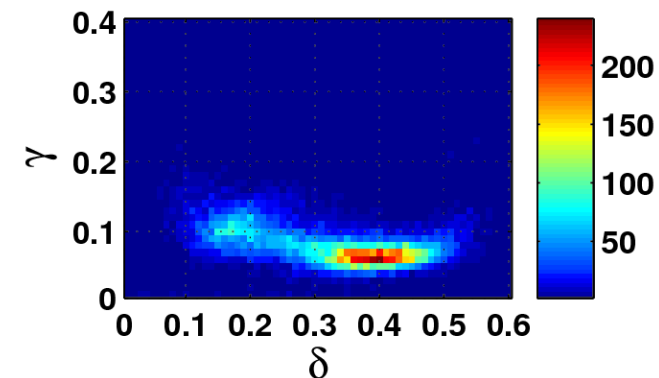
POL(ice)-MOD(ice) total N. :4.2E+05



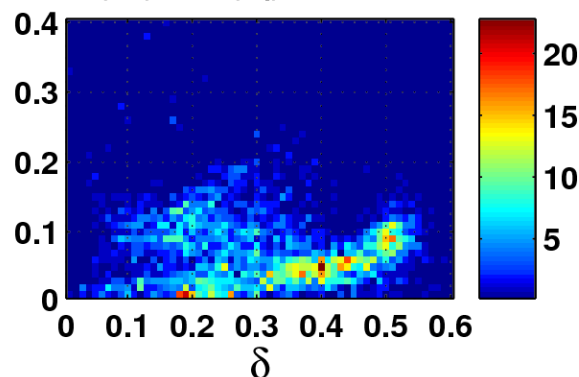
POL(liq)-MOD(ice) total N. :1.5E+05



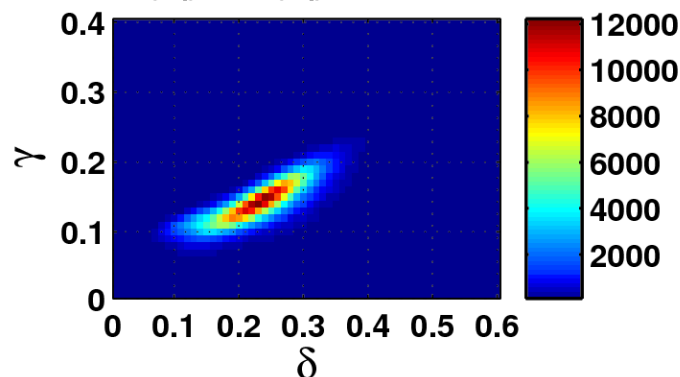
POL(mix)-MOD(ice) total N. :1.9E+04



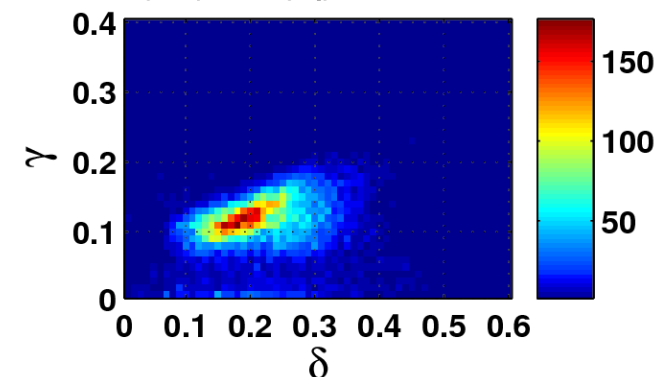
POL(ice)-MOD(liq) total N. :3E+03



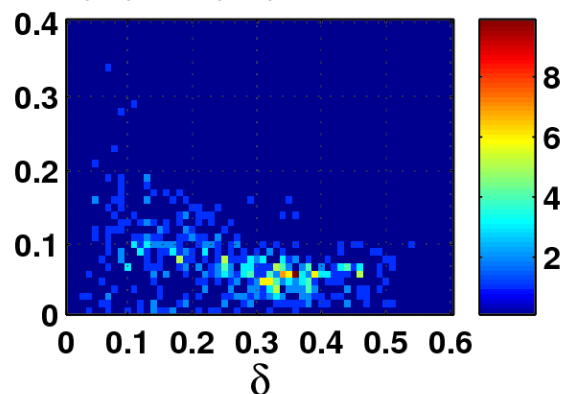
POL(liq)-MOD(liq) total N. :7E+05



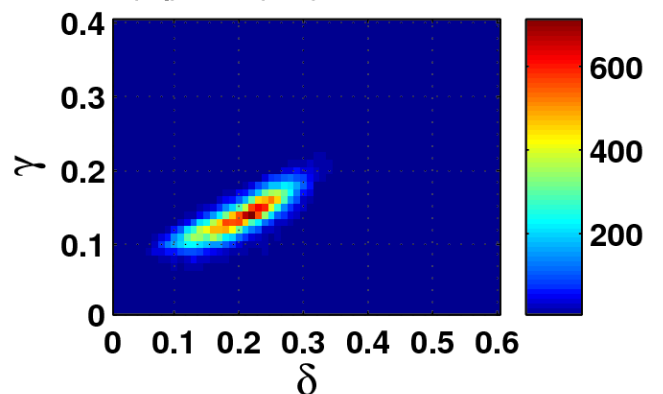
POL(mix)-MOD(liq) total N. :1.6E+04



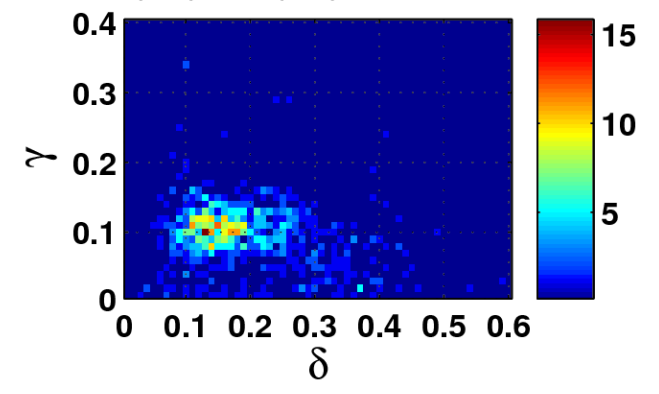
POL(ice)-MOD(mix) total N. :4.9E+02



POL(liq)-MOD(mix) total N. :3.3E+04



POL(mix)-MOD(mix) total N. :8.3E+02

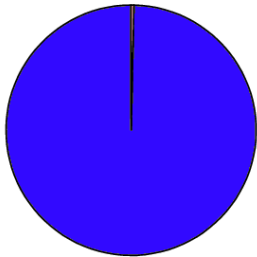


# POLDER/MODIS vs CALIOP phase product

Data: CALTRACK dataset, 12/2007-11/2008, [90°S-90°N]

**PHASE CASE: POLDER (ice) MODIS(ice)**

CALIOP liquid: < 1%

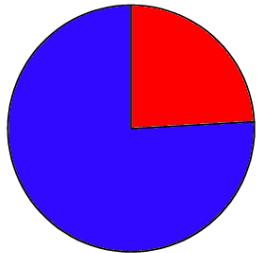


CALIOP ice: 100%

Total Number: 4.2E+05

**PHASE CASE: POLDER (ice) MODIS(liquid)**

CALIOP liquid: 24%

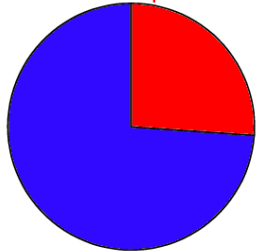


CALIOP ice: 76%

Total Number: 3E+03

**PHASE CASE: POLDER (ice) MODIS(mixed)**

CALIOP liquid: 26%

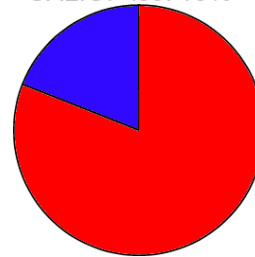


CALIOP ice: 74%

Total Number: 4.9E+02

**PHASE CASE: POLDER (liquid) MODIS(ice)**

CALIOP ice: 19%

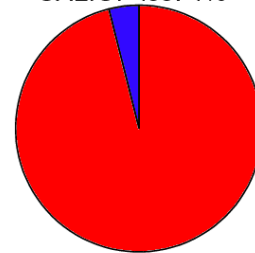


CALIOP liquid: 81%

Total Number: 1.5E+05

**PHASE CASE: POLDER (liquid) MODIS(liquid)**

CALIOP ice: 4%

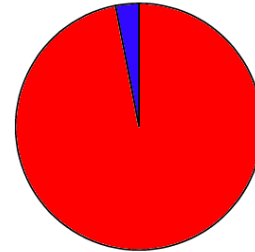


CALIOP liquid: 96%

Total Number: 7E+05

**PHASE CASE: POLDER (liquid) MODIS(mixed)**

CALIOP ice: 3%

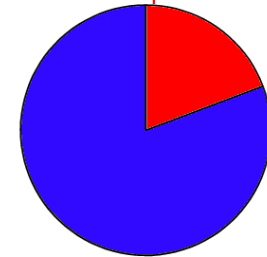


CALIOP liquid: 97%

Total Number: 3.3E+04

**PHASE CASE: POLDER (mixed) MODIS(ice)**

CALIOP liquid: 19%

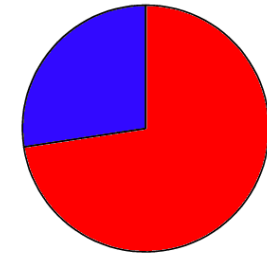


CALIOP ice: 81%

Total Number: 1.9E+04

**PHASE CASE: POLDER (mixed) MODIS(liquid)**

CALIOP ice: 27%

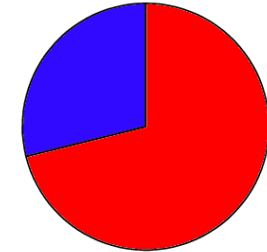


CALIOP liquid: 73%

Total Number: 1.6E+04

**PHASE CASE: POLDER (mixed) MODIS(mixed)**

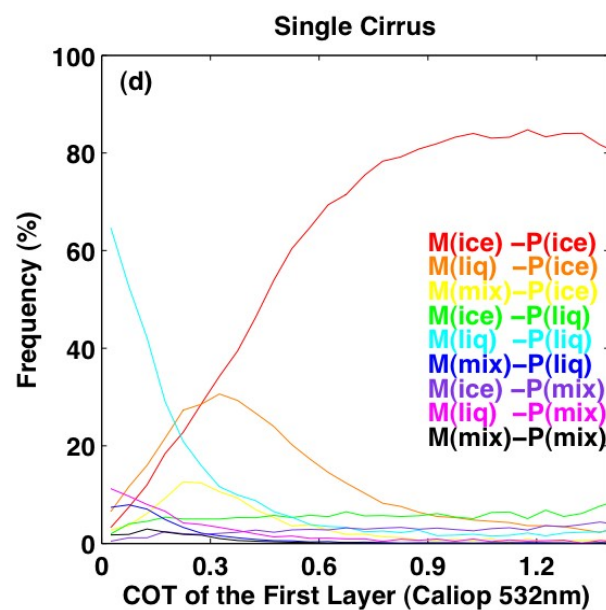
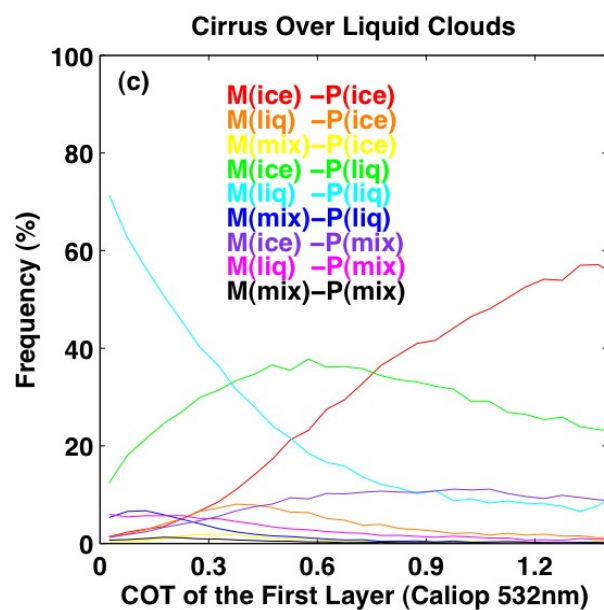
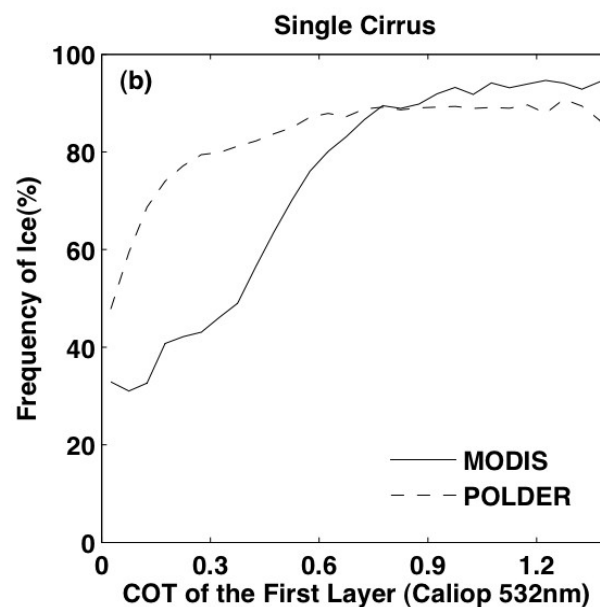
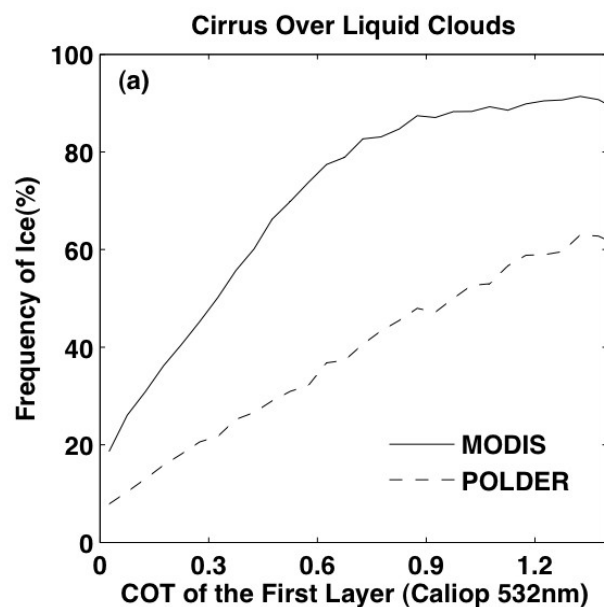
CALIOP ice: 29%



CALIOP liquid: 71%

Total Number: 8.3E+02

# Sensitivity to thin cirrus

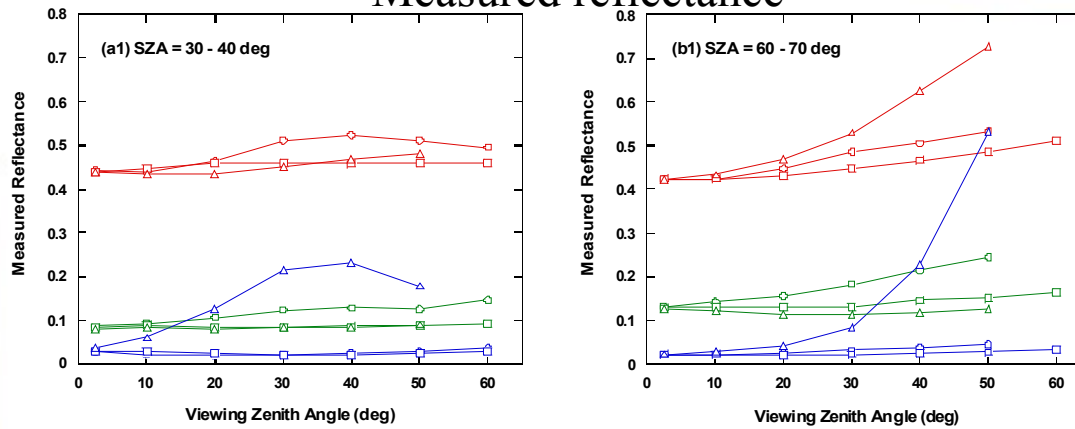


# **Analysis of cloud optical thickness/albedo**

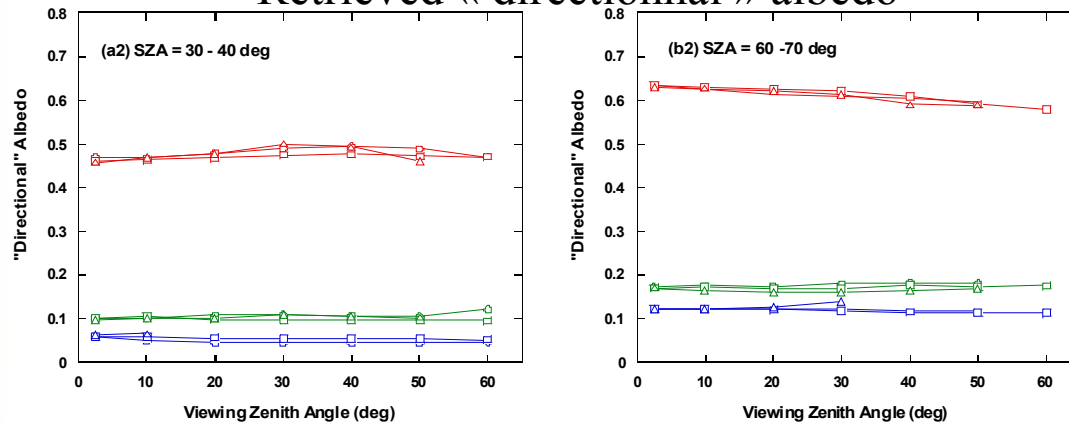
## **POLDER / MODIS**



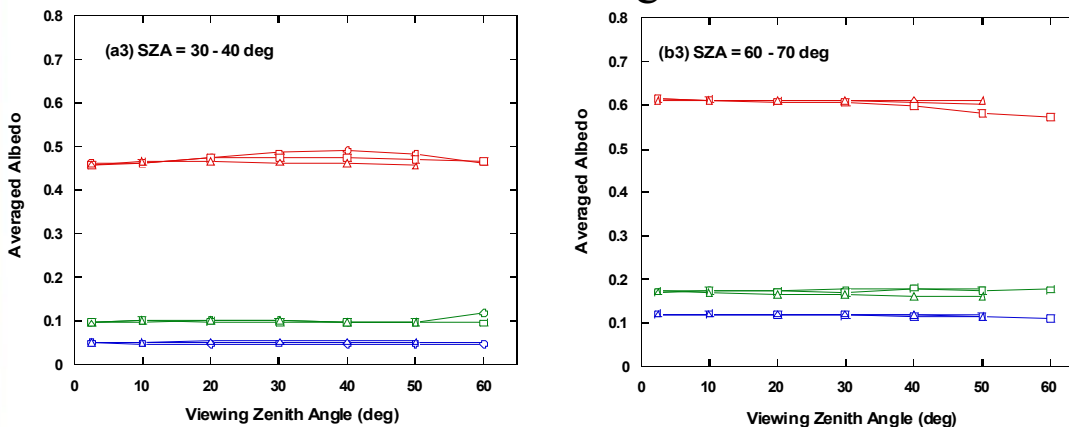
## Measured reflectance



## Retrieved «directional» albedo



## Retrieved «average» albedo



Retrieved albedo should be independent of viewing geometry.

Plots here for 2 sun elevations, as a function of view zenith angle.

Red : clouds

Green : clear sky land

Blue : clear sky ocean

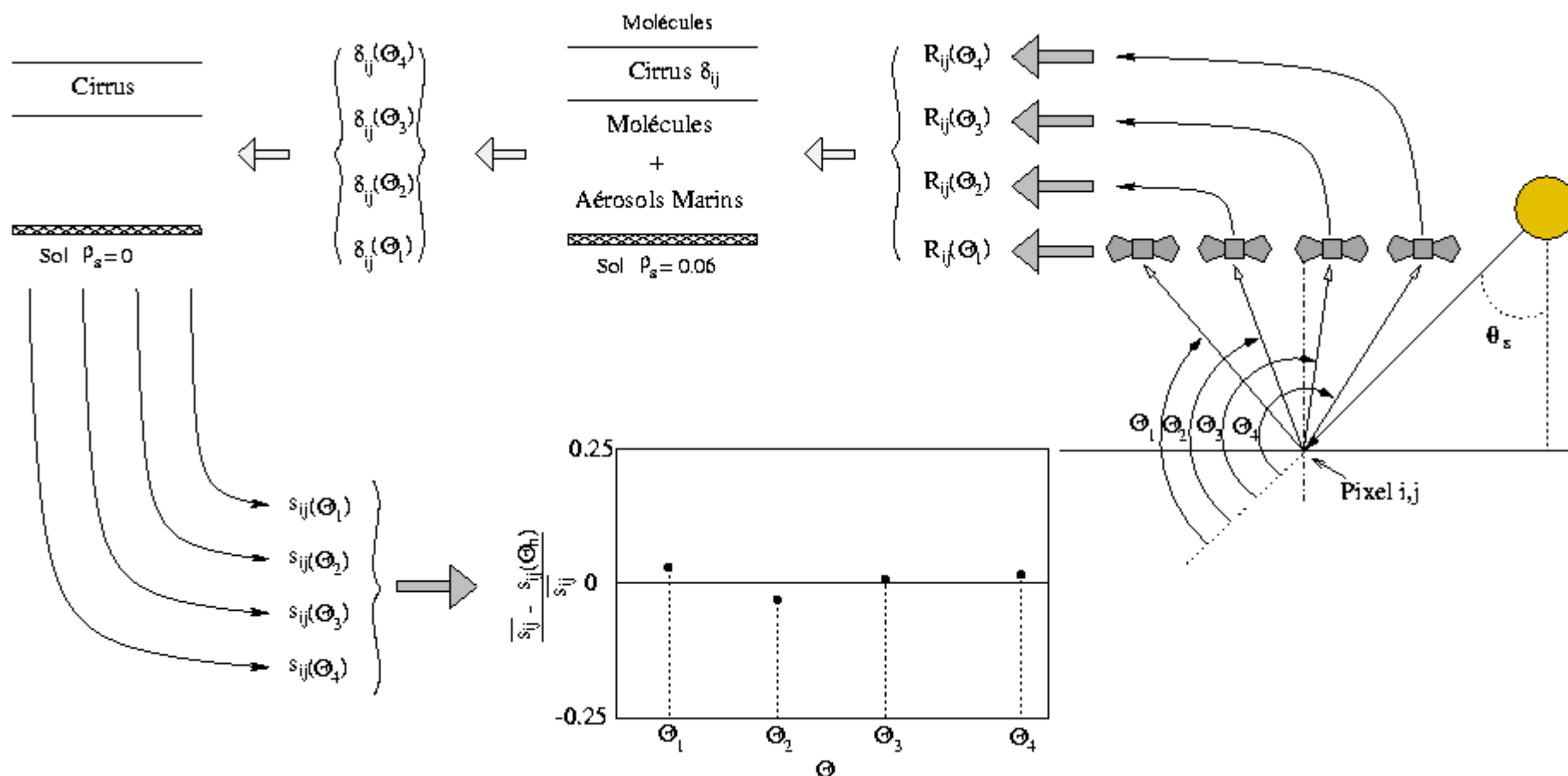
Albedo RMS of :

0.006 in clear sky

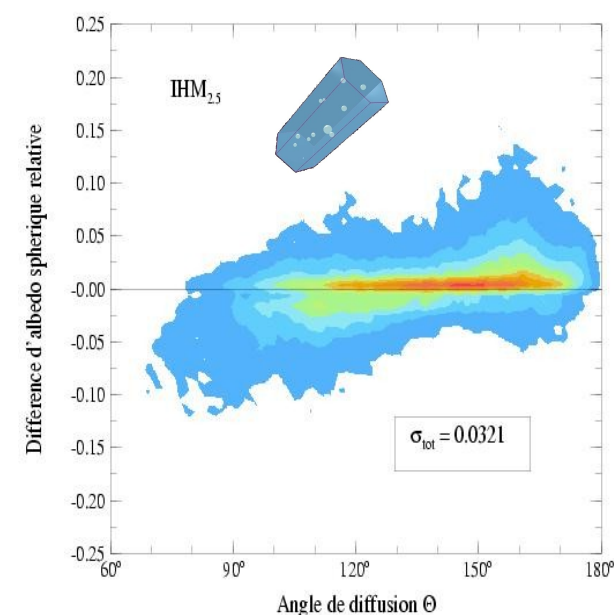
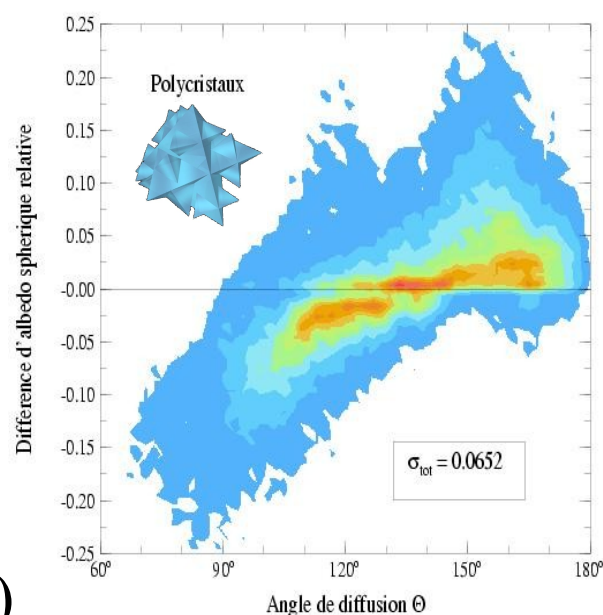
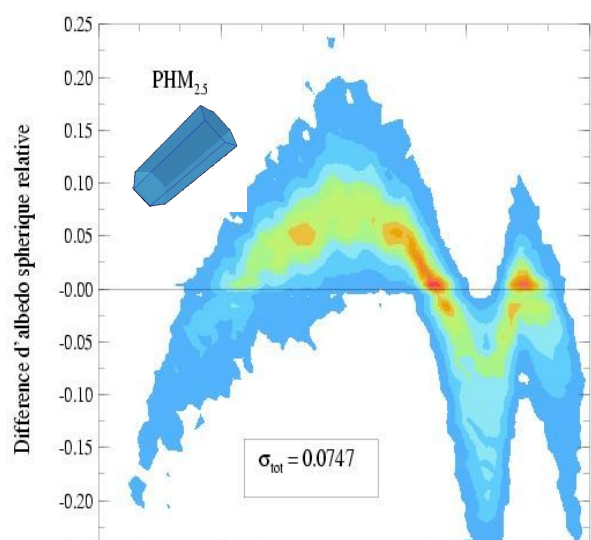
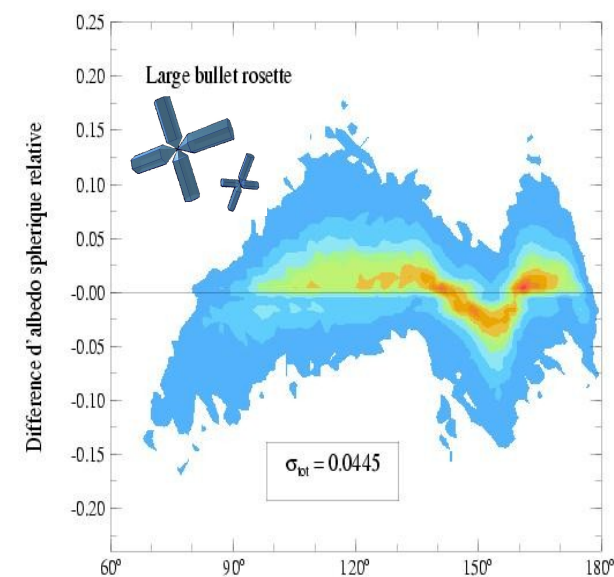
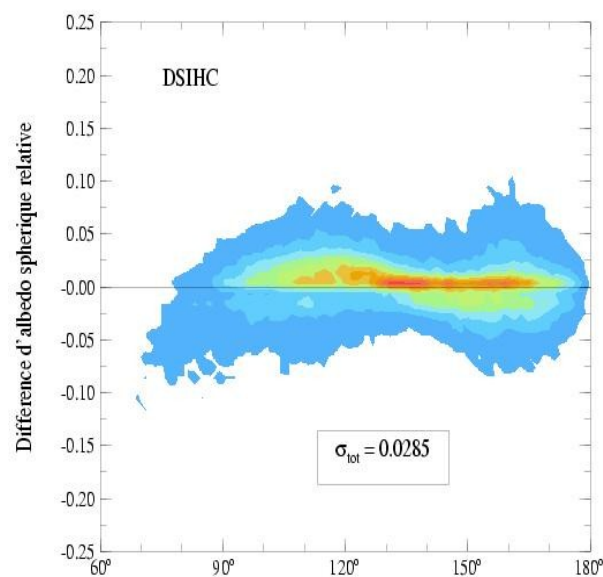
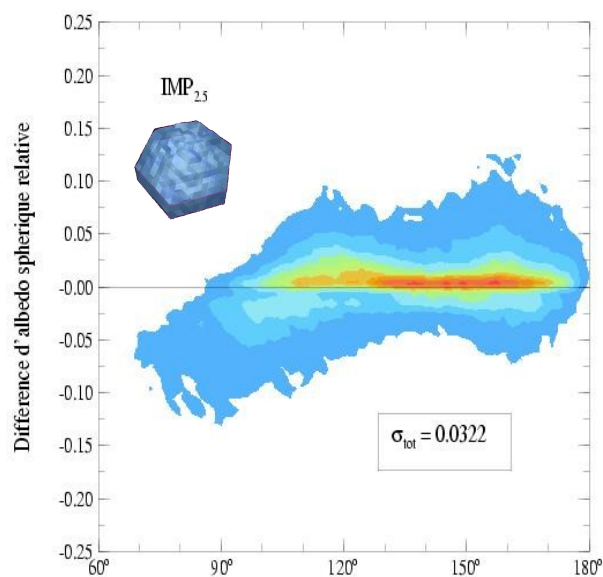
0.012 – 0.016 for clouds



# Testing cloud models from multiangle observation



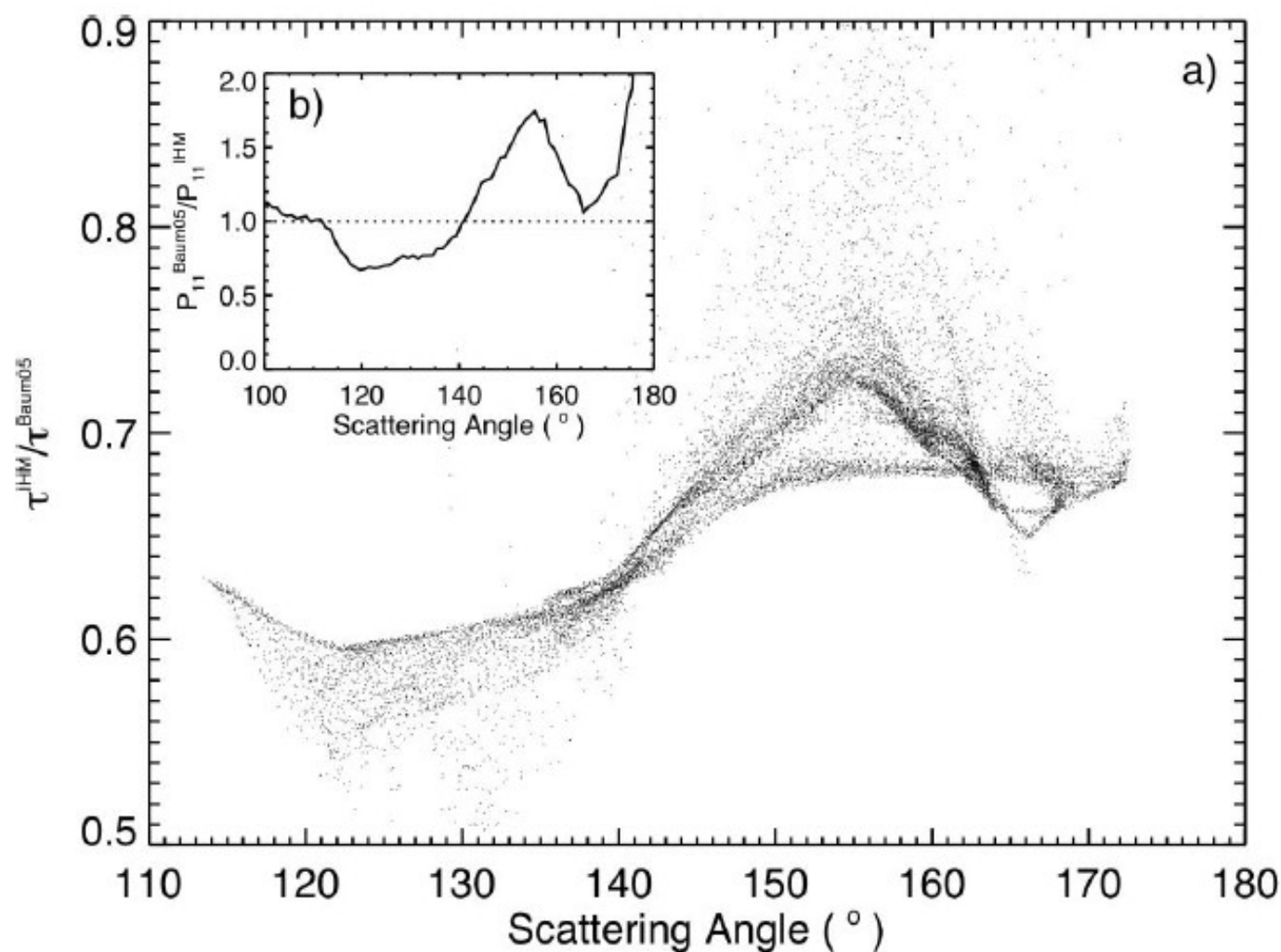
# Testing cloud models from multiangle observation



Baran & Labonnote (2001)

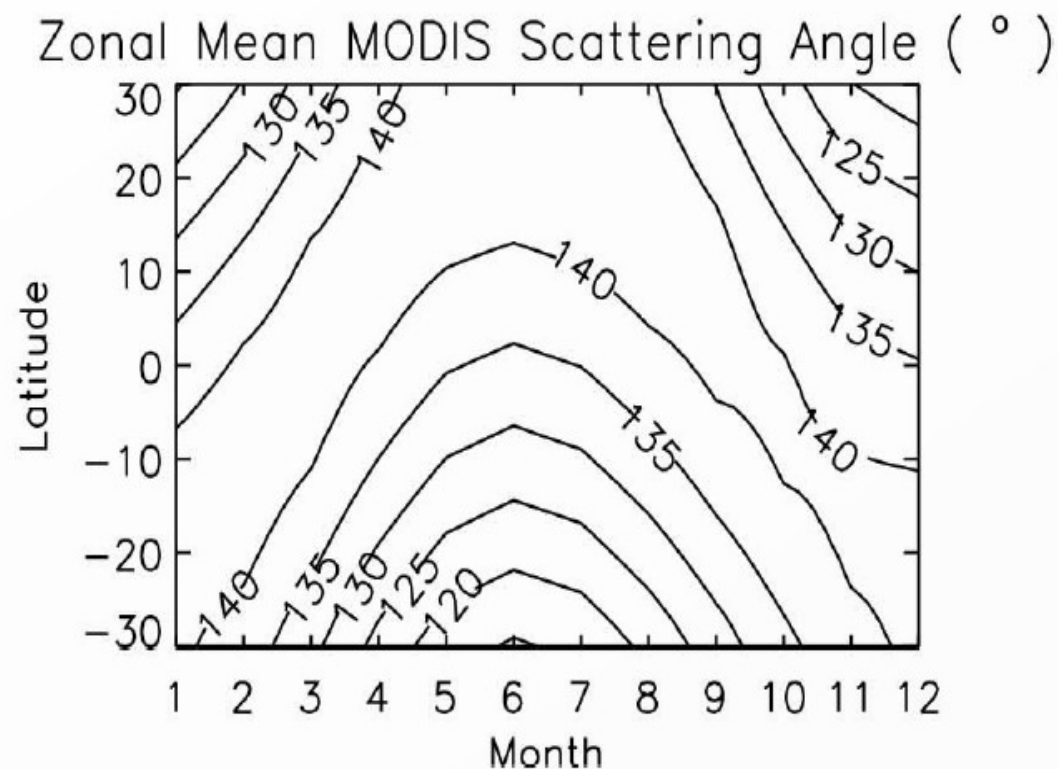
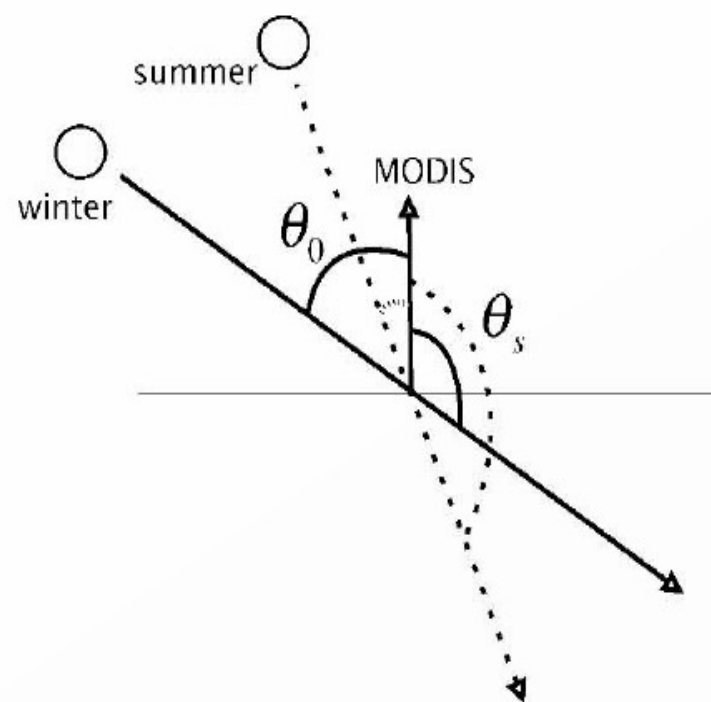
sité

ologies



**Fig. 7.** The ratio of (a)  $\tau_c^{\text{IHM}} / \tau_c^{\text{Baum05}}$  and (b)  $P_{11}^{\text{Baum05}} / P_{11}^{\text{IHM}}$  as a function of scattering angle.

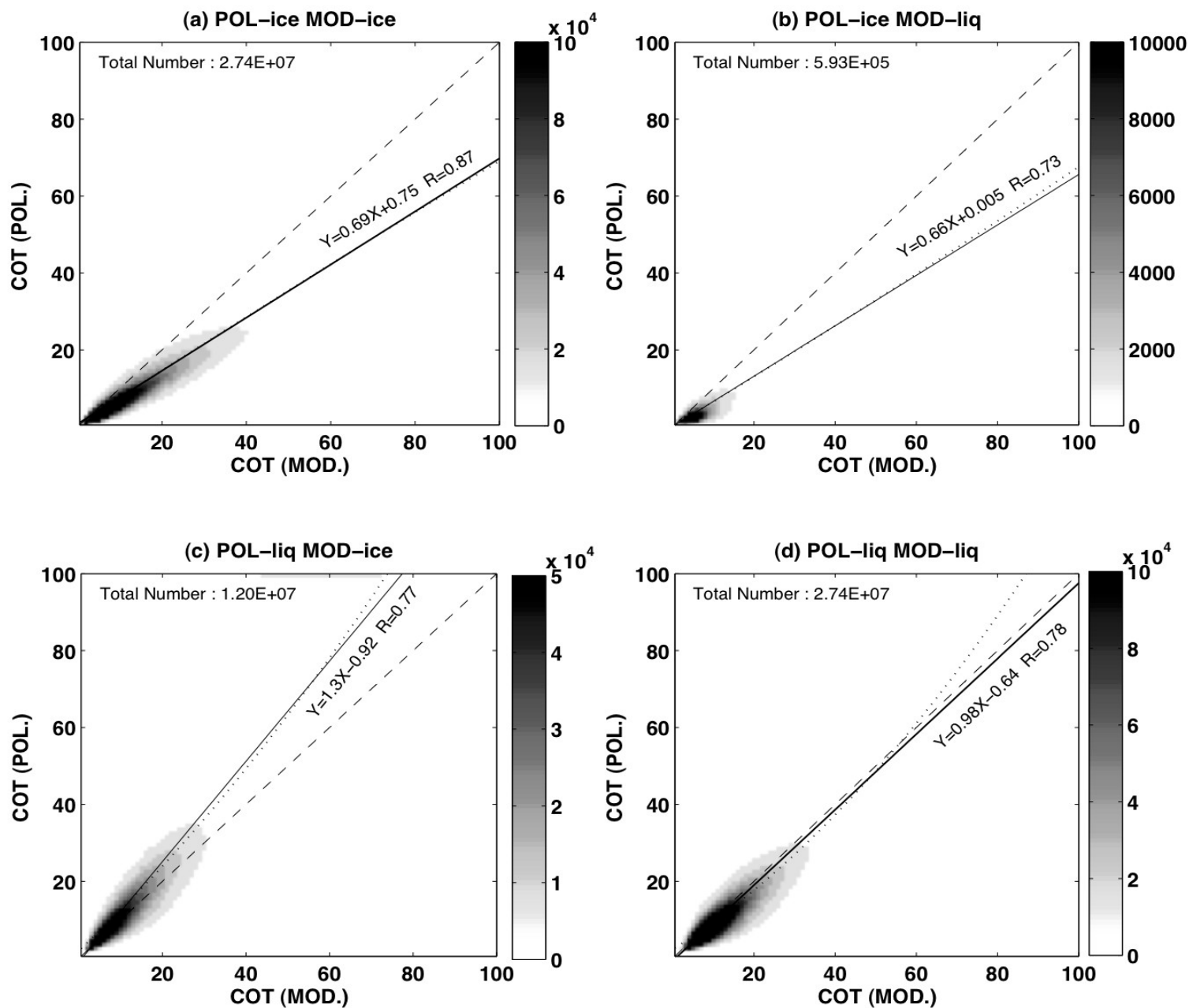
*From Zhang et al, 2009 (ACP)*



**Fig. 9.** (a) Schematic illustration of the seasonal dependence of solar zenith angle  $\theta_0$  and MODIS scattering angle  $\theta_s$ . (b) Zonal mean  $\theta_s$  as functions of latitude and month.

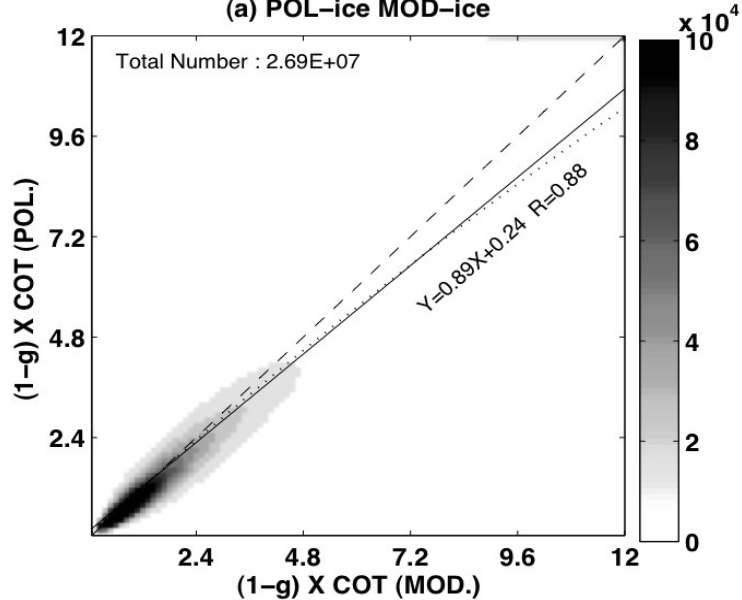
From Zhang et al, 2009 (ACP)

## POLDER vs MODIS Optical thickness for different phase categories

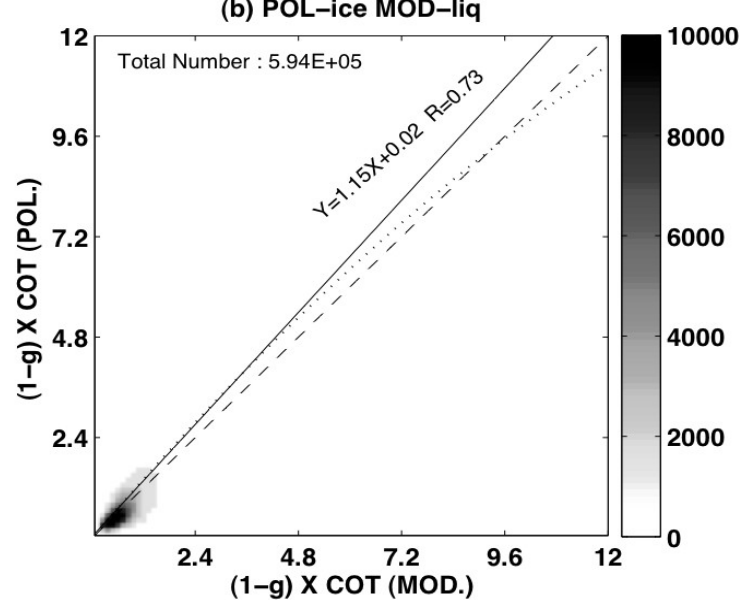


## POLDER vs MODIS Scaled Optical thickness for different phase categories

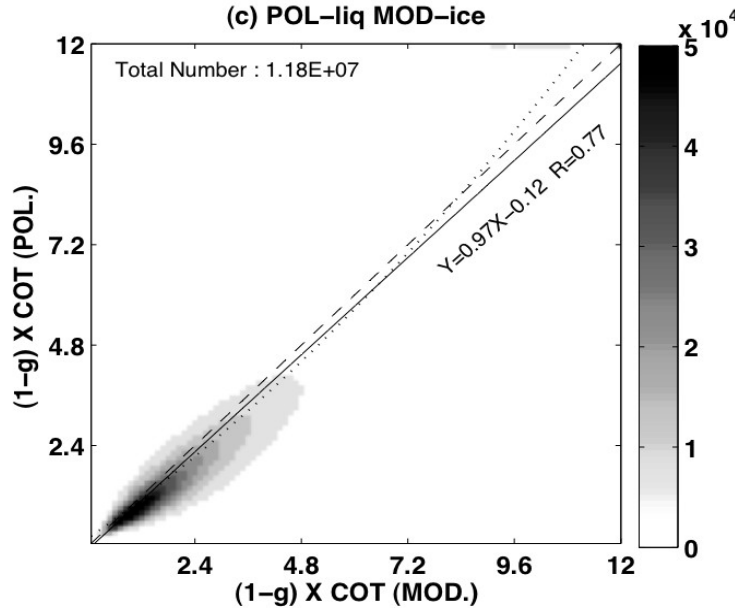
(a) POL-ice MOD-ice



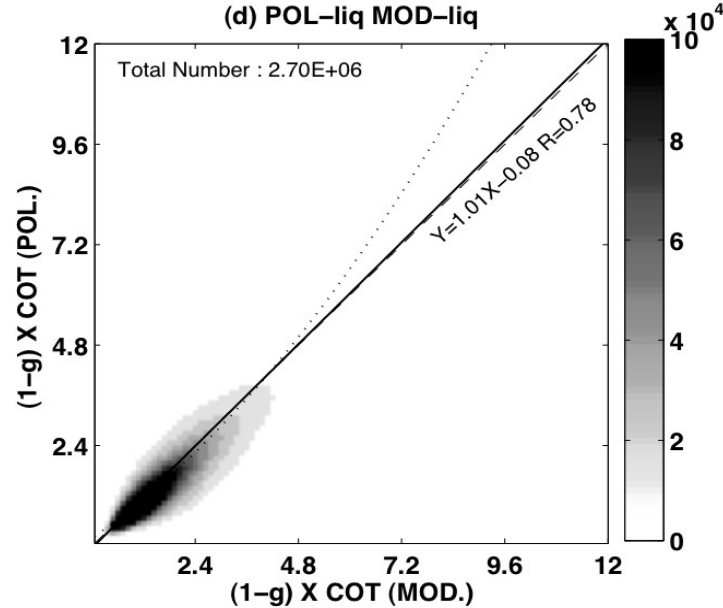
(b) POL-ice MOD-liq



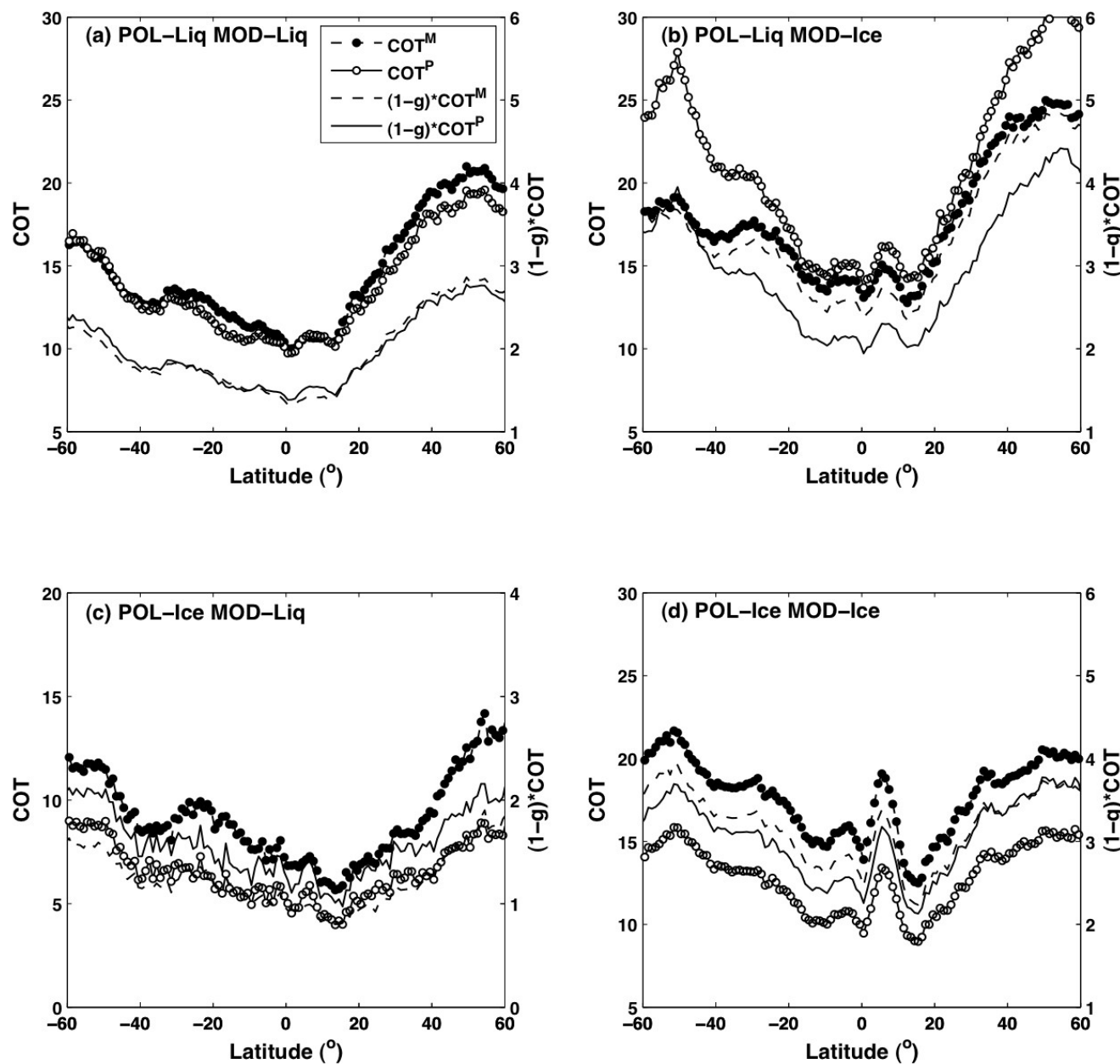
(c) POL-liq MOD-ice



(d) POL-liq MOD-liq

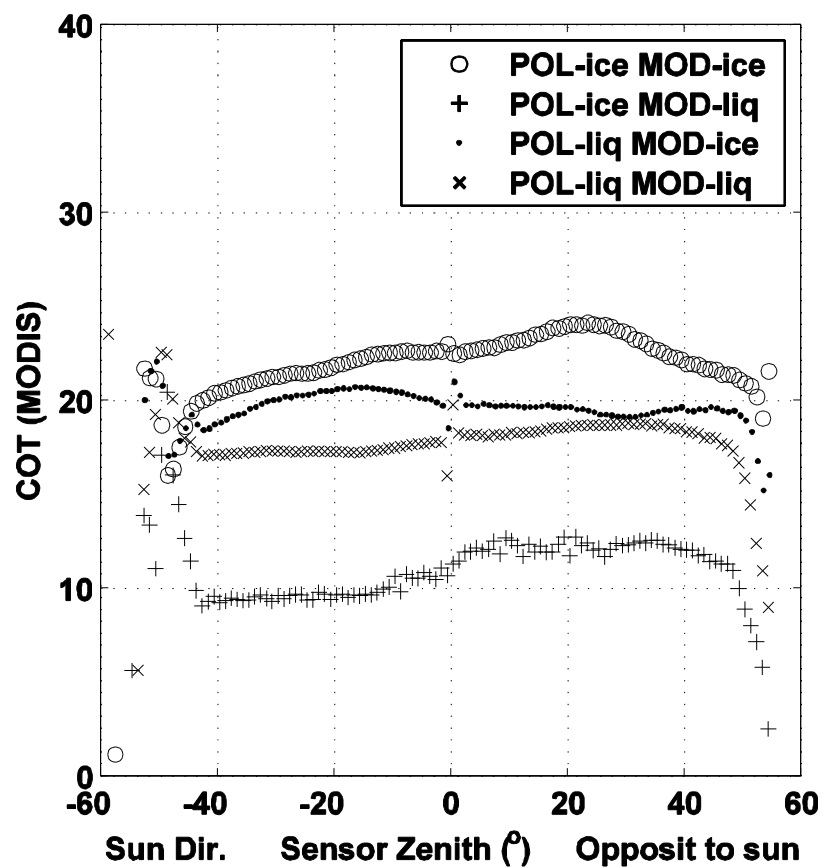


## Optical thickness and scaled optical thickness zonal variation

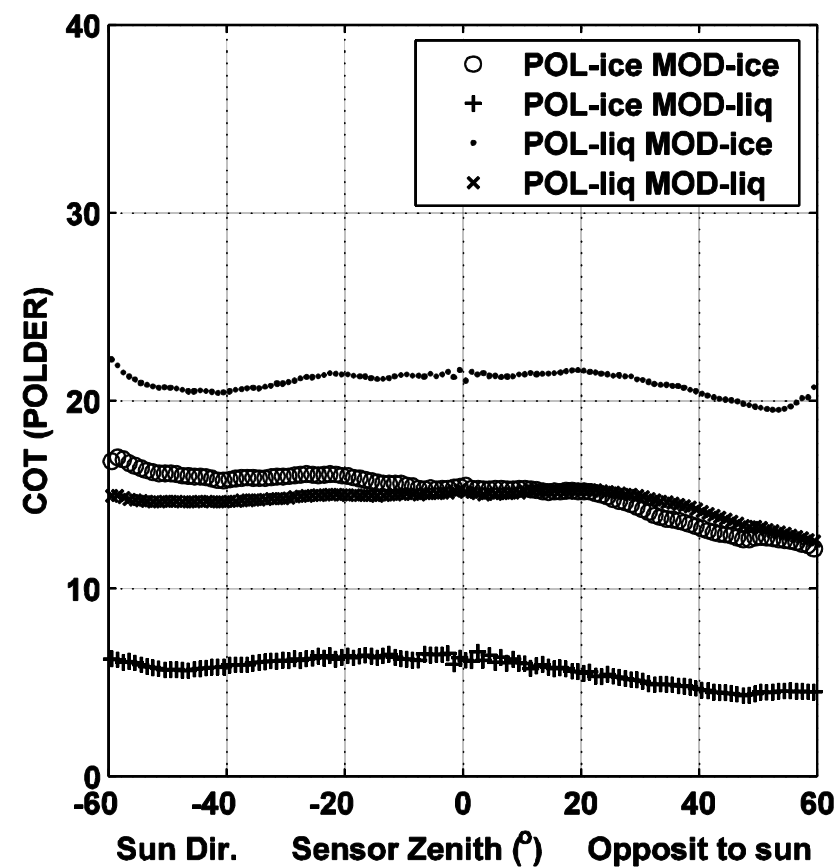


## View zenith angle analysis

MODIS



POLDER



# Summary

- POLDER phase product provides a reliable information on thermodynamic phase independent of cloud temperature and particle size
- In conjunction, POLDER and MODIS can be used to create a reference cloud phase dataset for benchmark studies of models or other sensors
- POLDER multiangle observations provide a unique way to constrain cloud models (micro and macro physics) and get « less biased » optical thickness/albedo
- Comparing scaled optical thickness (or albedo) can make our life easier in a first stage for this GEWEX exercise

