TRMM Third NASA/JAXA International Conference
February 6, 2008

Accurate retrieval of cirrus cloud properties from satellite measurements

Kazuhiko Masuda
and
Takahisa Kobayashi

Meteorological Research Institute
1-1, Nagamine, Tsukuba, Ibaraki 305-0052 Japan

Summary

We retrieved <u>optical thickness</u> (τ) and <u>effective radius</u> (R_{eff}) of ice clouds using 0.63 and 1.61μm channels of VIRS.

From the estimated τ and R_{eff} together with the <u>brightness temperature of 10.8μm channel</u> [BT(10.8)], characteristics of ice clouds are examined in precipitation and non-precipitation areas which are determined from surface rain rate measured by PR.

It is observed that

[1] Median value of τ increase with decreasing of BT(10.8),

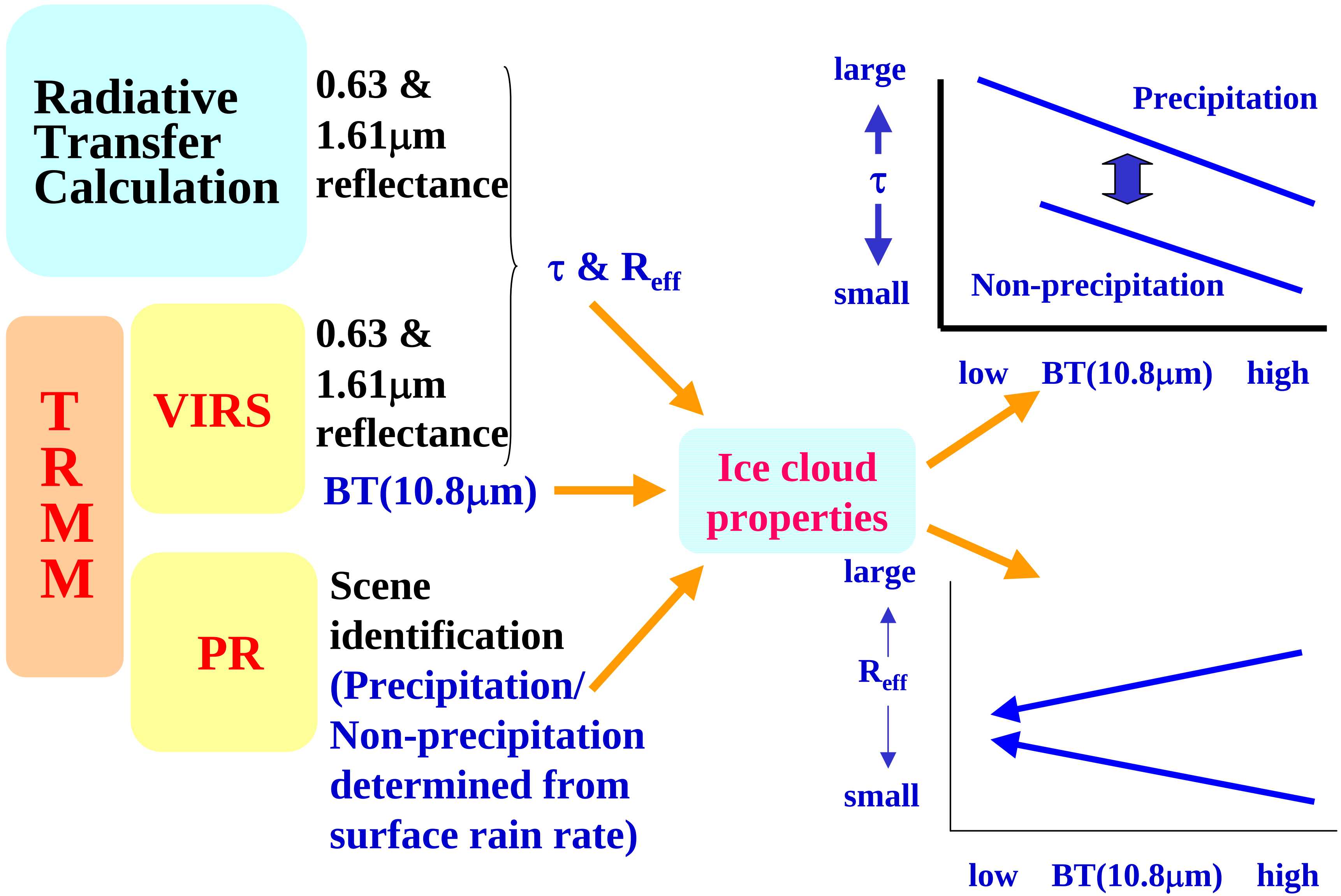
[2] Frequency of precipitation is large for areas with τ >10 and BT(10.8)<220K ,

[3] R_{eff} near the top of cloud converges to ≈ 30μm with decreasing of BT(10.8).

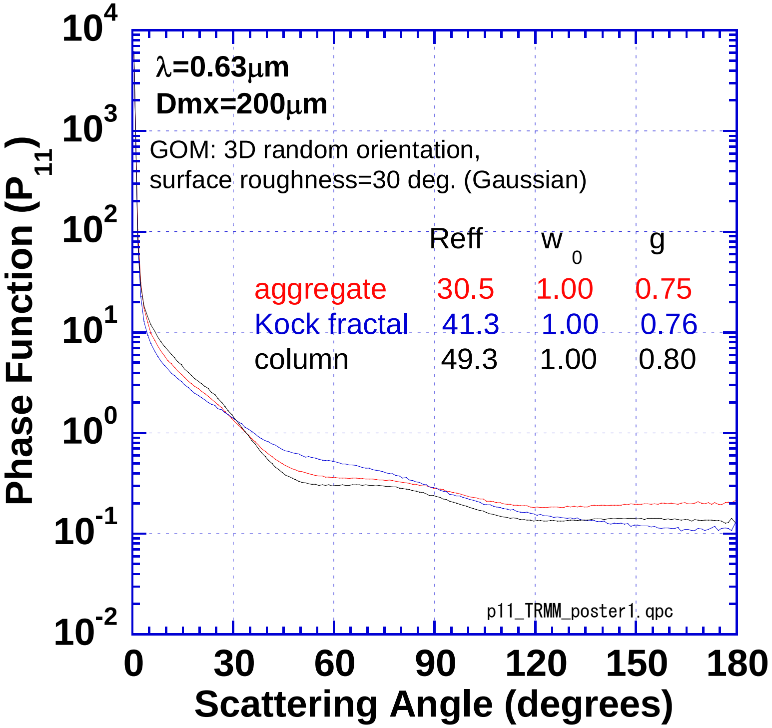
TRMM data is very useful to better understanding of ice cloud properties in precipitation area.

Method

Results



Single scattering properties of ice crystal model



Calculation

Geometrical Optical Approximation [Ref.2]
(Ray tracing + Fraunhofer diffraction)

Crystal habit

Type 1 Aggregates [Ref.3] 
Type 2 Koch Fractals (generation=2) [Ref.4] 
Type 3 Hexagonal columns 

Size (Maximum dimension (Dmx [μm]))

25, 50, 100, 200, 400, 800

Roughness of crystal surface

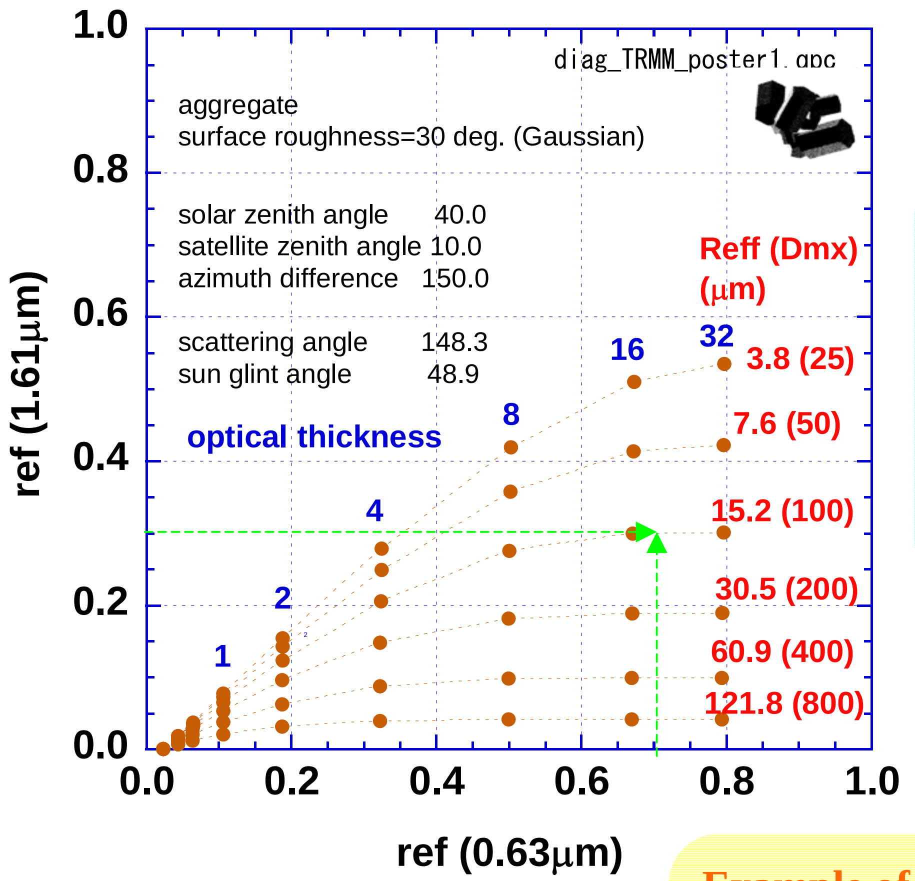
Gaussian with σ=30°

Dmx: maximum dimension,
R_{eff}: effective radius defined as
$R_{eff}= (3/4)\times V/P$ [Ref.1],
where V and P are volume and averaged projected area, respectively,
w_0: single scattering albedo,
g: asymmetry factor.

Single scattering properties

Dmx	Reff	w0(0.63)	w0(1.61)	g(0.63)	g(1.61)
Aggregates 					
25	3.8	1.00	0.99	0.74	0.76
50	7.6	1.00	0.98	0.75	0.77
100	15.2	1.00	0.96	0.75	0.78
200	30.5	1.00	0.92	0.75	0.79
400	60.9	1.00	0.86	0.75	0.82
800	121.8	1.00	0.78	0.75	0.86
Koch fractals 					
25	5.2	1.00	0.98	0.76	0.77
50	10.3	1.00	0.97	0.76	0.78
100	20.6	1.00	0.95	0.76	0.79
200	41.3	1.00	0.90	0.76	0.81
400	82.5	1.00	0.83	0.76	0.84
800	165.0	1.00	0.73	0.76	0.89
columns 					
25	7.2	1.00	0.98	0.78	0.80
50	14.3	1.00	0.96	0.78	0.81
100	28.6	1.00	0.93	0.79	0.83
200	49.3	1.00	0.88	0.80	0.85
400	76.3	1.00	0.84	0.82	0.88
800	114.2	1.00	0.79	0.83	0.91

Retrieval of τ and R_{eff} using 0.63 & 1.61μm reflectance



Calculation of radiative transfer

- Doubling-adding method [Ref.5],
- 4-layers in the atmosphere,
- ice cloud: located in 9 – 11 km layer,
- aerosols: not included,
- molecule absorption: Tropical model used in LOWTRAN,
- surface: ocean model

Example of retrieval of τ & R_{eff}

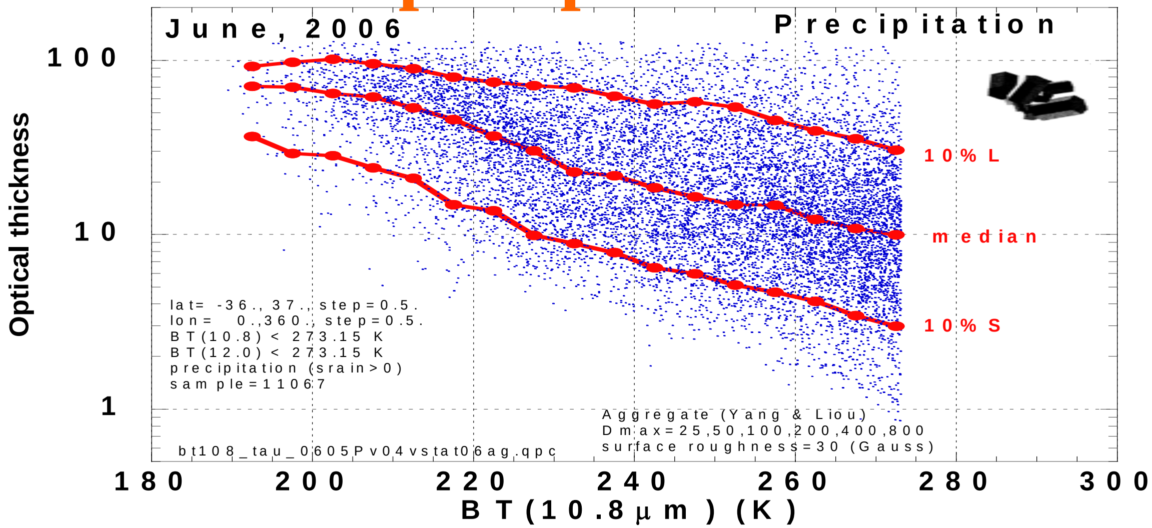
(bi-directional) reflectance

ref(0.63)=0.7 & ref(1.61)=0.3

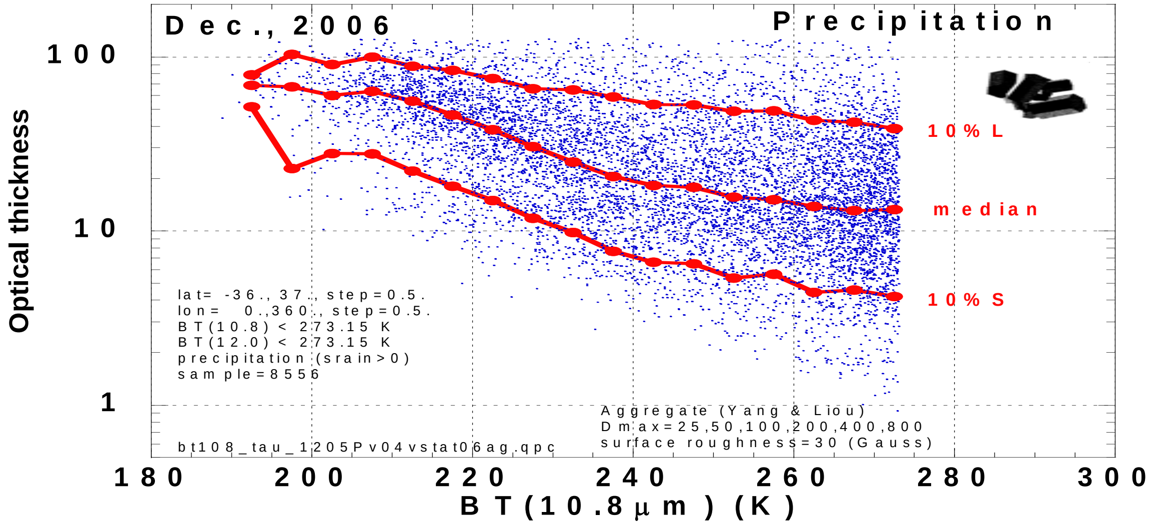
===>

τ=20 & R_{eff}=15

τ retrieved in precipitation area

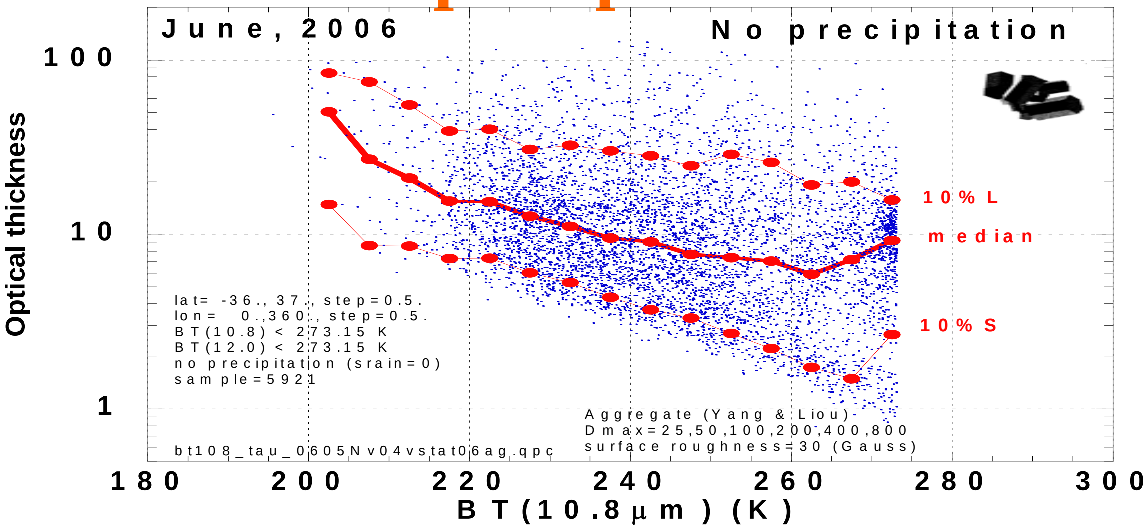


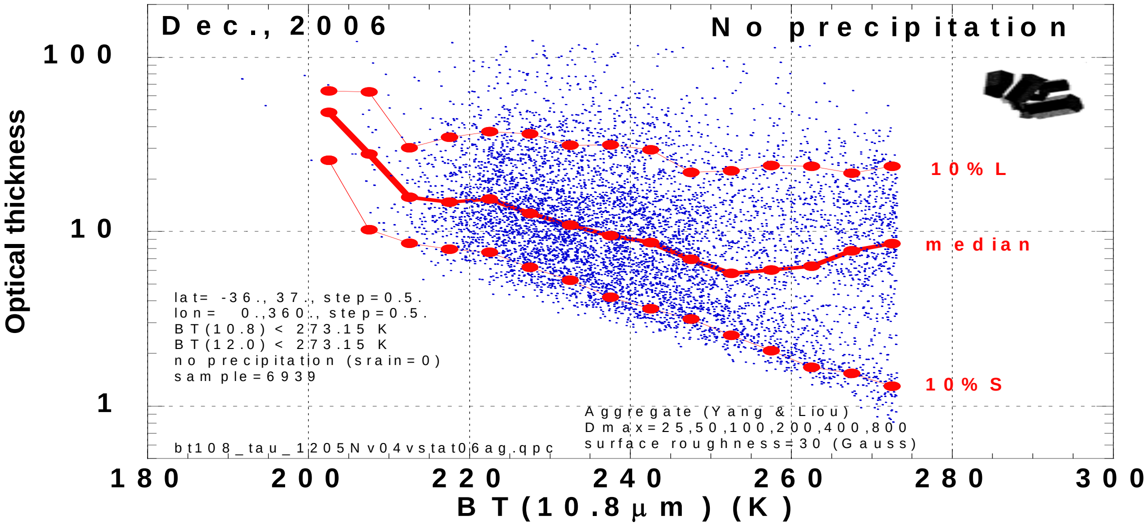
- ● statistics every 5K interval
- 10%L: largest 10% value.
- median: median value.
- 10%S: smallest 10% value.



Top: June, 2006; bottom: December, 2006
Retrievals were performed using "aggregate" ice crystal model, at grid points with both BT(10.8) and BT(12.0) < 273.15K.
τ increases with decreasing BT(10.8).

τ retrieved in non-precipitation area



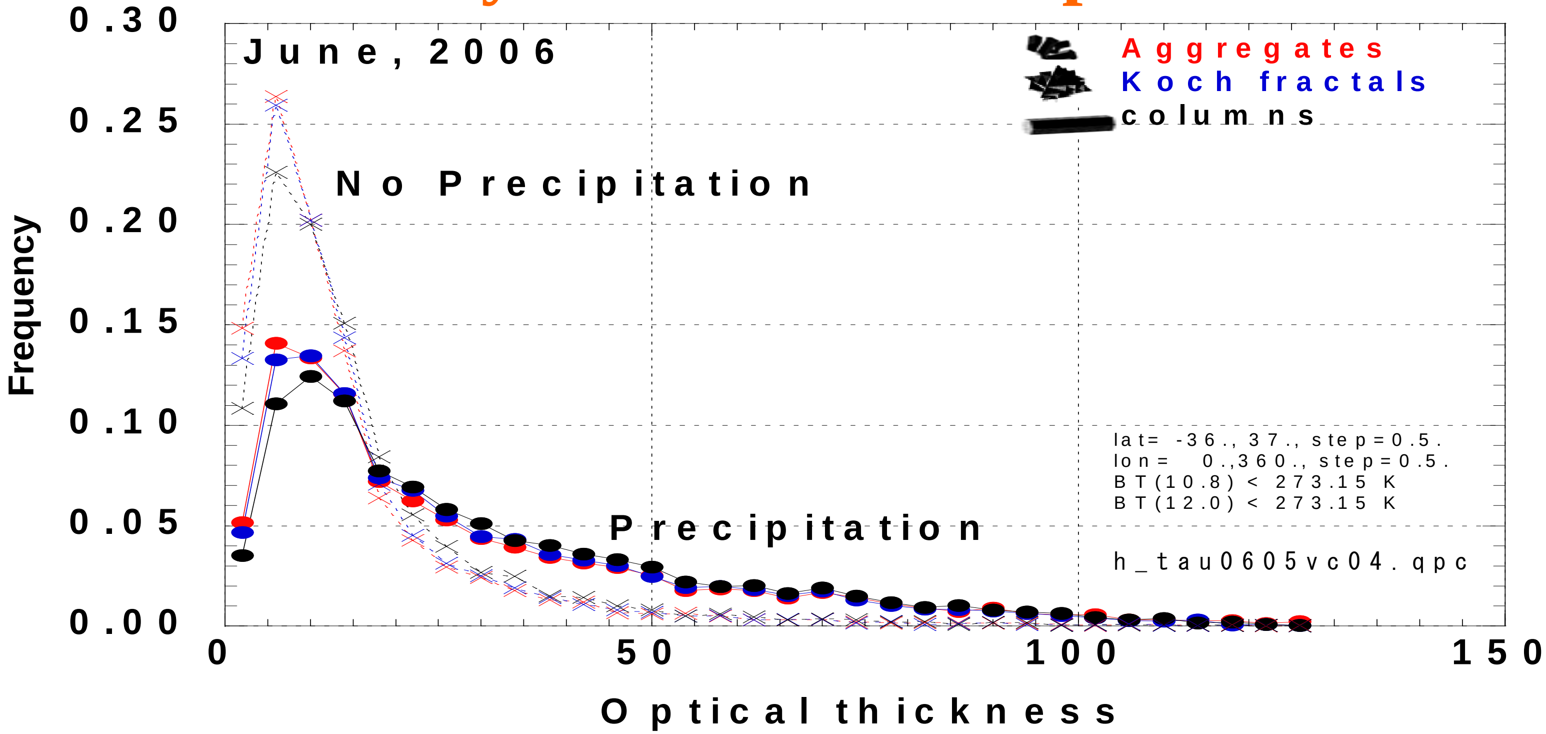


Top: June, 2006, bottom: December, 2006.

Number of samples, BT(10.8)<220K, in non-precipitation area is much smaller than precipitation area.

On average, τ in non-precipitation area is smaller than that in precipitation area.

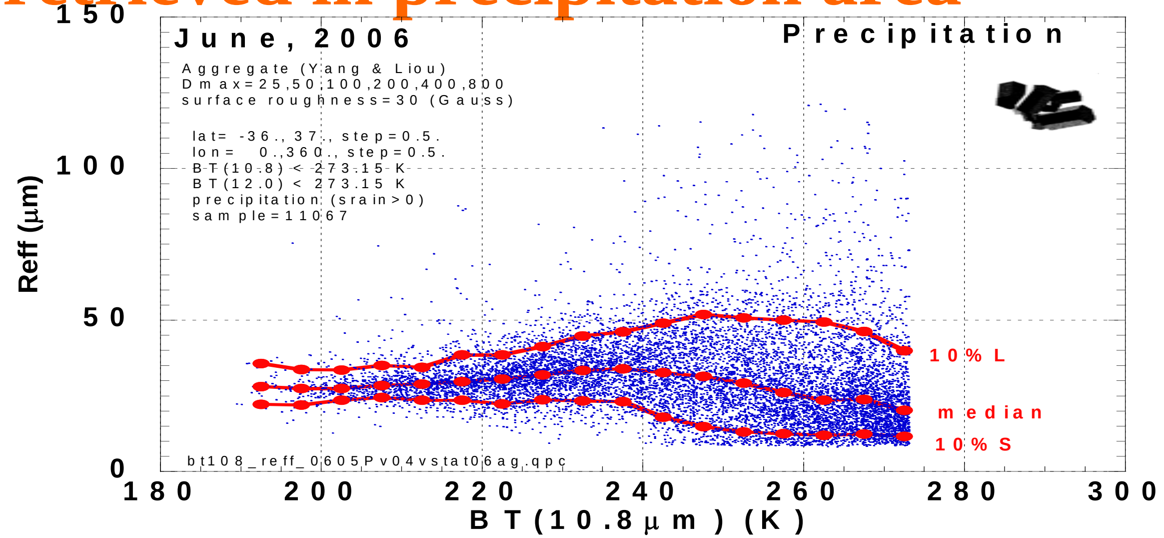
Sensitivity of τ estimation to ice crystal model assumptions

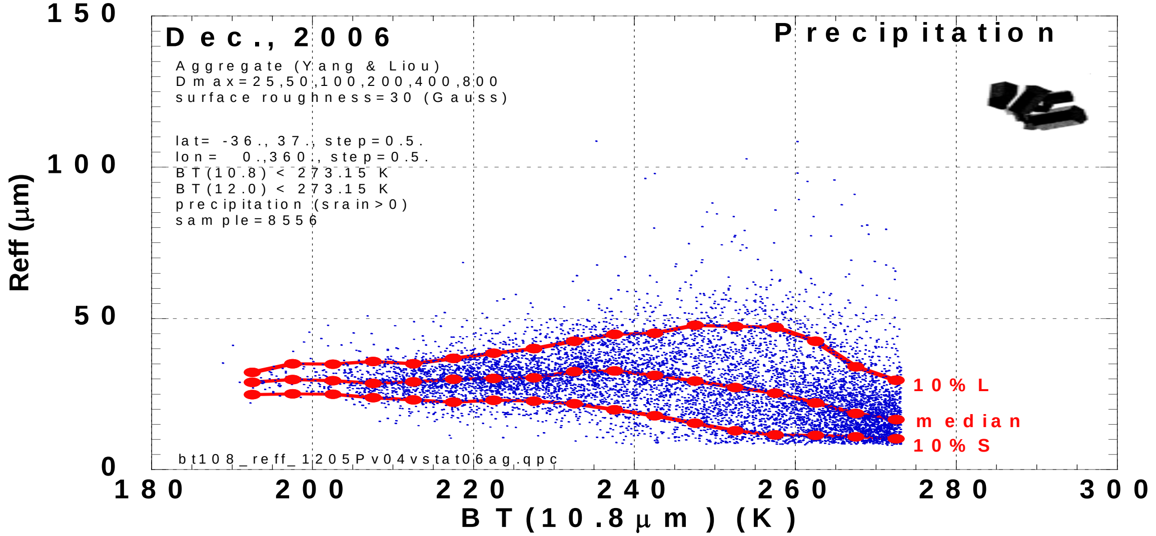


June, 2006

τ estimated using "column" model are slightly larger than those using "aggregate" and "Koch fractal" models.

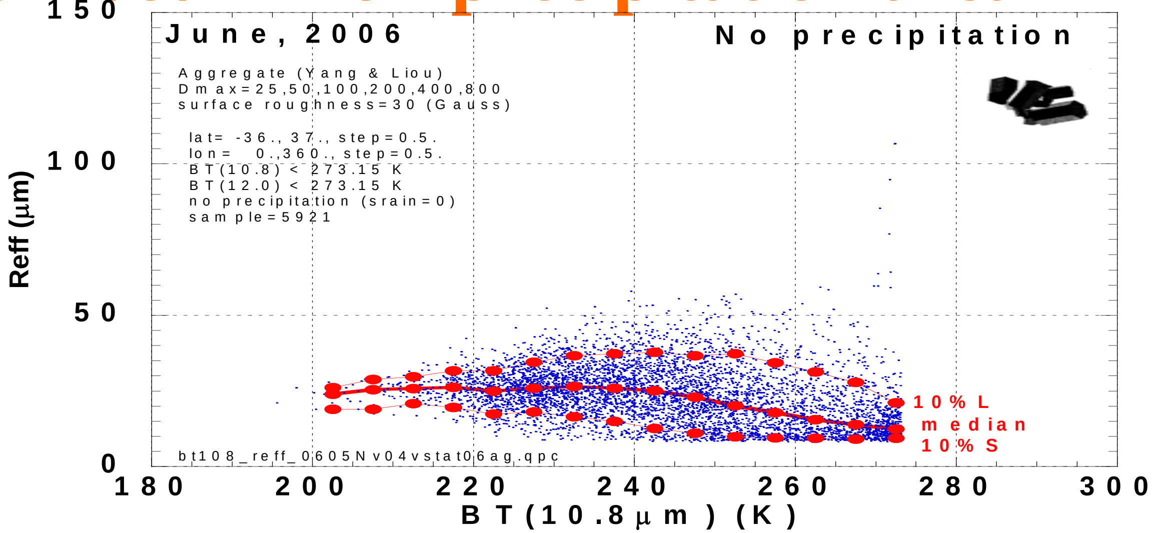
R_{eff} retrieved in precipitation area

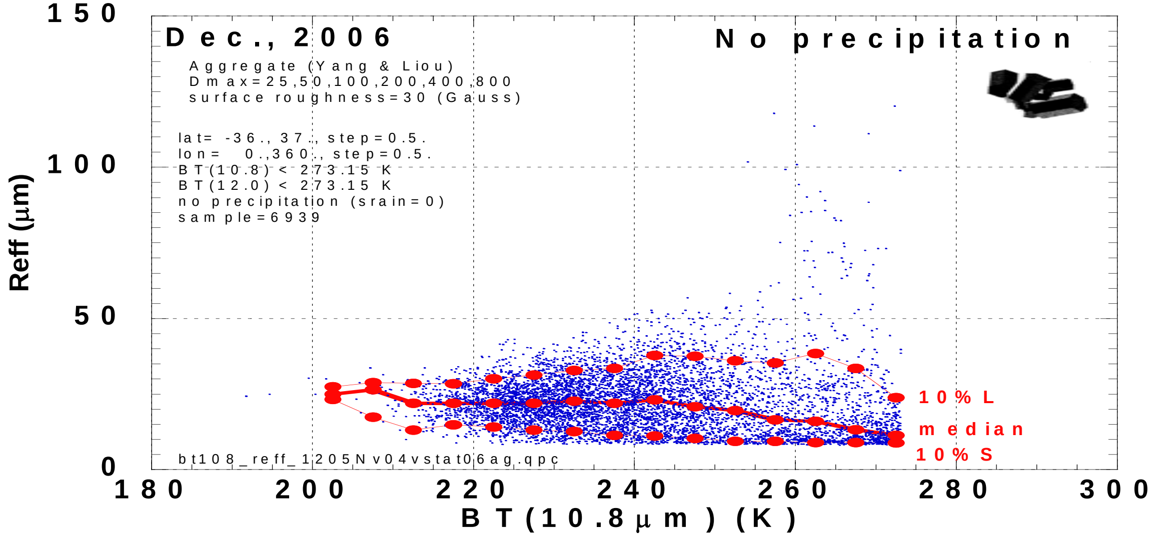




Top: June, 2006, bottom: December, 2006.
Retrievals were performed using "aggregate" ice crystal model, at grid points with both BT(10.8) and BT(12.0) < 273.15K.
R_{eff} converges to 25~35μm with decreasing BT(10.8).

R_{eff} retrieved in non-precipitation area

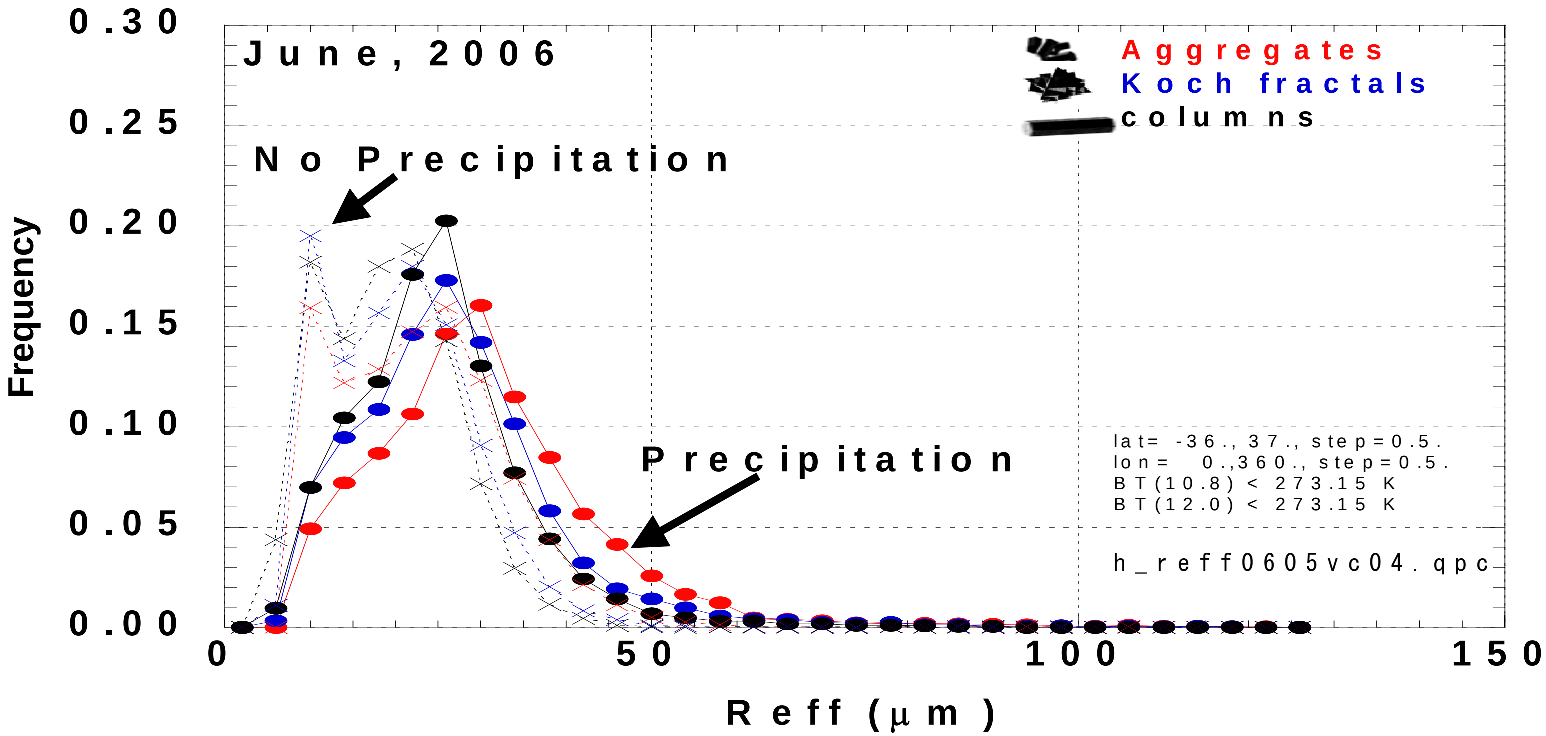




Top: June, 2006, bottom: December, 2006.

R_{eff} converges to 25~35μm with decreasing BT(10.8).

Sensitivity of R_{eff} estimation to ice crystal model assumptions



June, 2006

R_{eff} estimated using "aggregate" model are larger than those using "column" and "Koch fractal" models.

References

[1] Foot, J. S., 1988, Some observation of the optical properties of clouds. Part II: Cirrus. *Quart. J. Roy. Meteorol. Soc. Res.*, **105**, 4699-4718.

[2] Masuda, K., and T. Takashima, 1997, Scattering matrix of nonspherical ice particles determined by the geometrical optics approximation method. *Proceedings SPIE's International Symposium on Optical Science, Engineering and Instrumentation*, 27 July –1 August, 1997, San Diego, CA.

[3] Yang, P., and K.N. Liou 1998, Single-scattering properties of complex ice crystals in terrestrial atmosphere. *Contr. Atmos. Phys.*, **71**, 223-248.

[4] Macke, A., 1996, Single scattering properties of atmospheric ice crystals. *J. Atmos. Sci.*, **53**, 2813-2825.

[5] Masuda, K., and T. Takashima, 1990, Deriving cirrus information using the visible and near-IR channels of the future NOAA-AVHRR radiometer. *Remote Sens. Environ.*, **31**, 65-81.