

# エアロゾルの雲特性への影響に 関するモデリング研究

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2006/3/29-30 第2回沼口敦さん記念シンポジウム

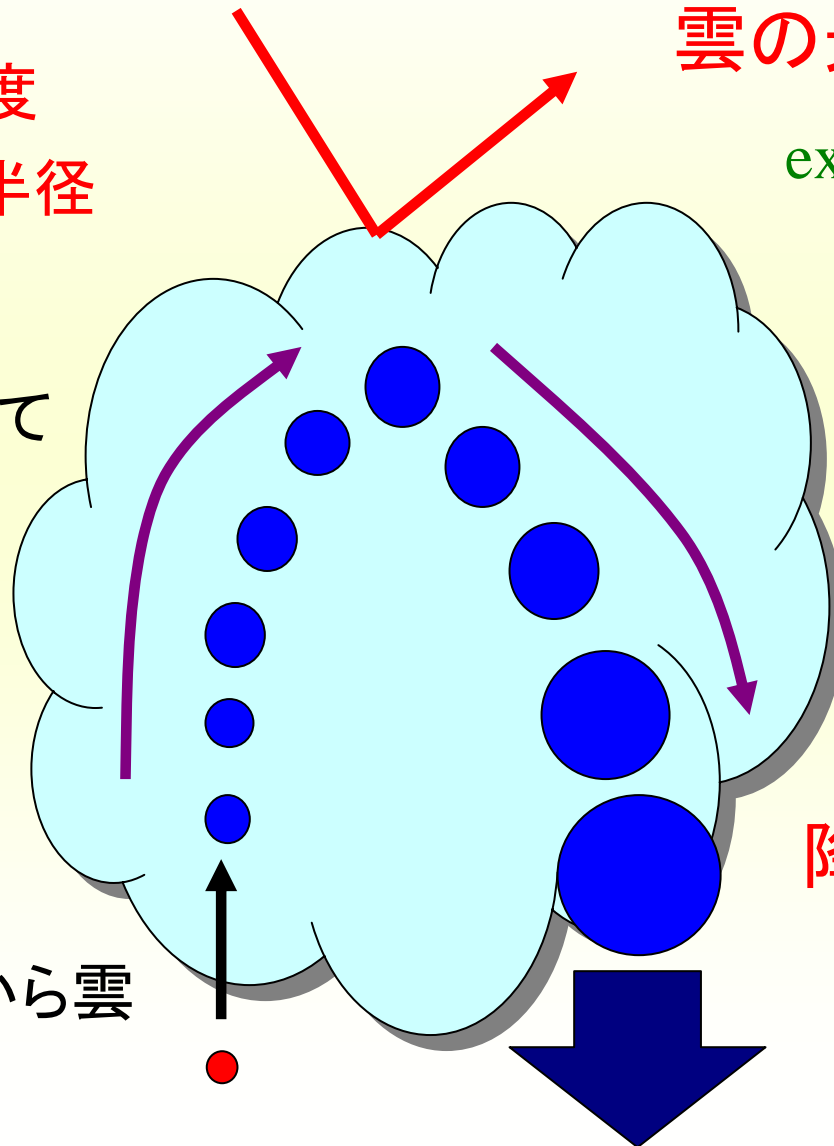
# エアロゾルと雲微物理過程

$N_c$ : 雲粒数密度

$r_e$ : 雲粒有効半径

水蒸気を吸って  
凝結成長

エアロゾルから雲  
粒生成



雲の光学特性

ex. 光学的厚さ:

$$\tau_c \propto N_c r_e^2$$

粒子が衝突・併合  
により成長

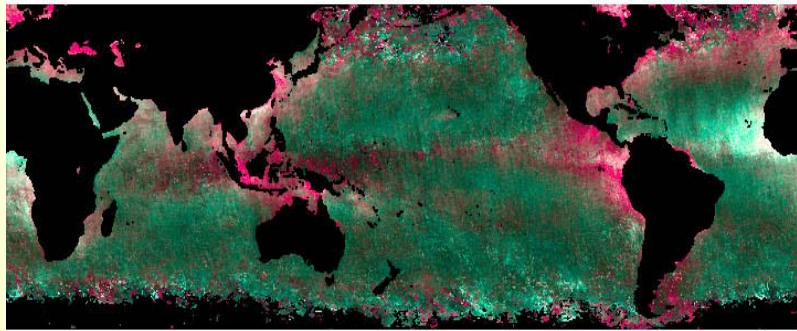
降水生成効率

ex. 降水時定数:

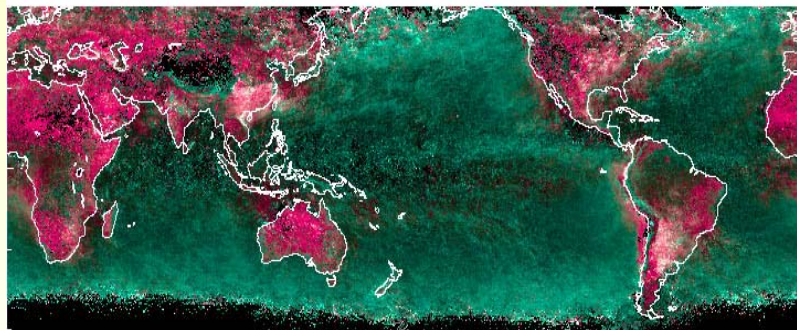
$$\tau_p = f(N_c, r_e)$$

# 雲・エアロゾルの衛星観測

Aerosol (Higurashi and Nakajima, 1999)

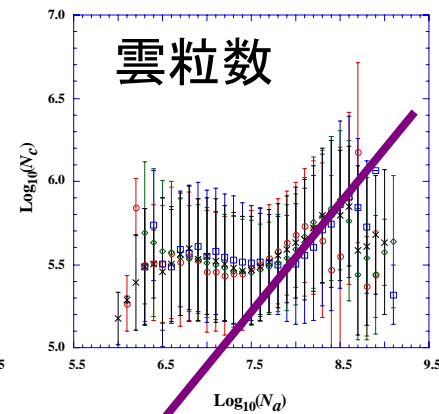
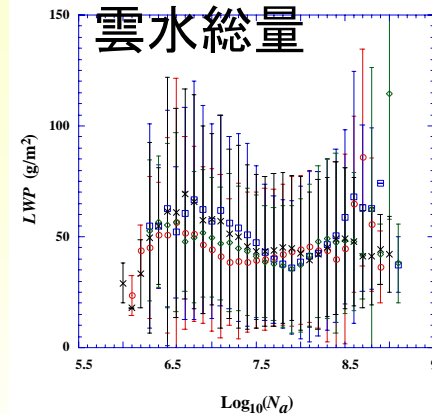
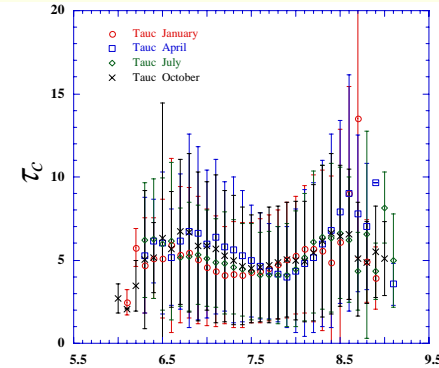
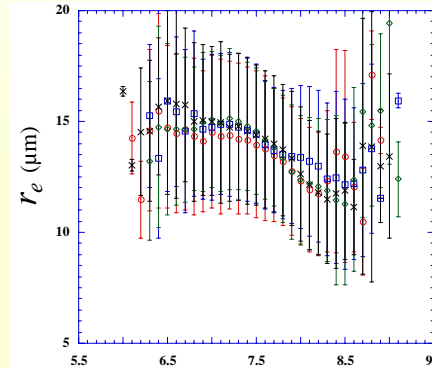
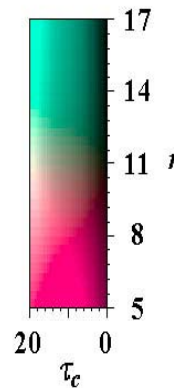
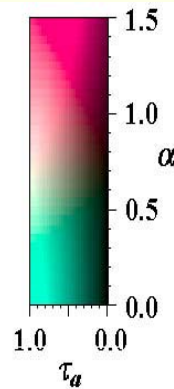


Low cloud (Kawamoto et al., 2001)



雲粒有効半径

光学的厚さ



Nakajima et al. (GRL 2001)

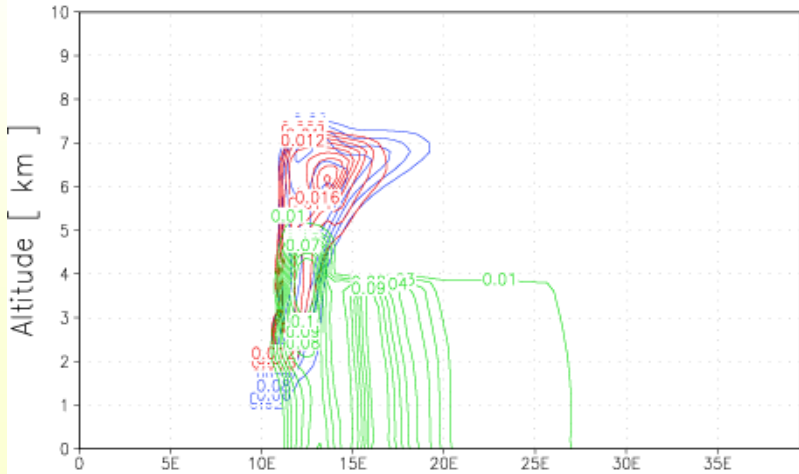
どうしてこういう分布なのか？

→  $\text{Log}_{10}(N_a)$

$$N_c \propto N_a^{0.50}$$

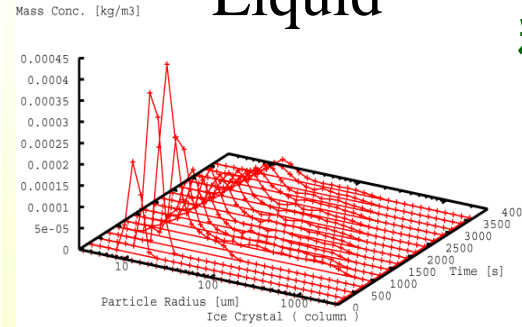
# 非静力学ビン法雲モデルの開発

Blue=Cloud, Red=Drizzle, Green=Rain



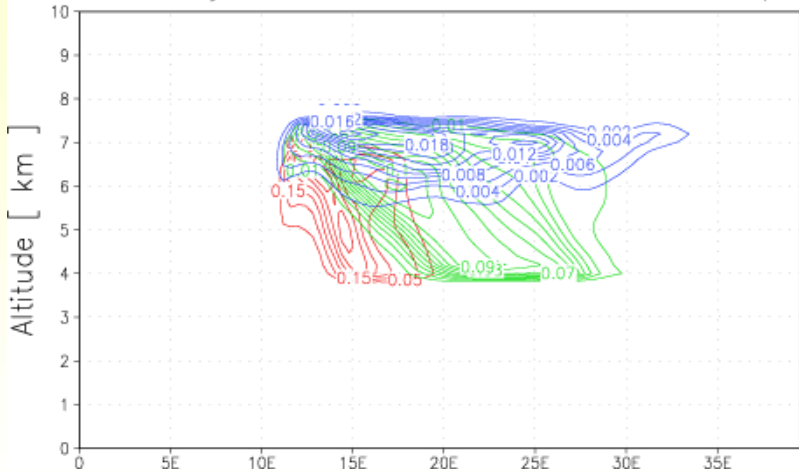
Liquid

## Liquid

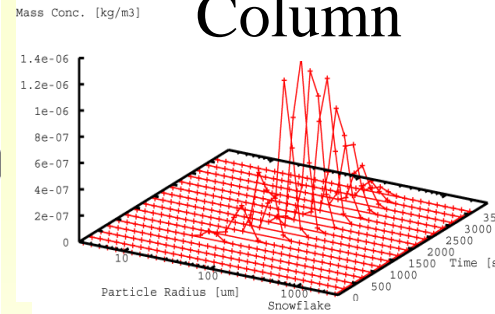


粒径分布を陽に予報

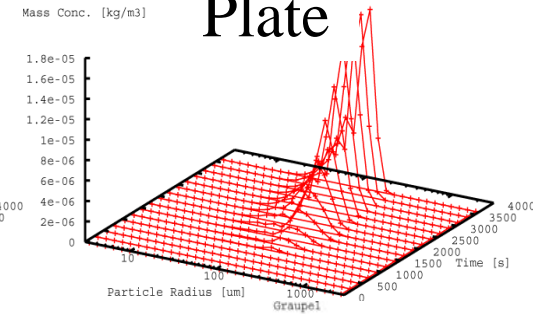
Blue=Crystals, Green=Snow, Red=Graupel



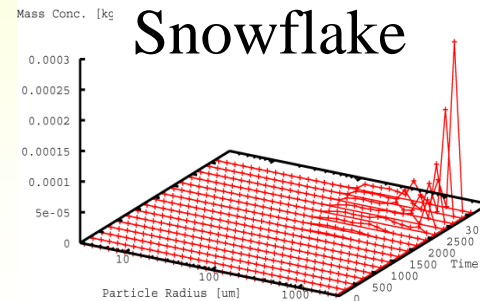
## Column



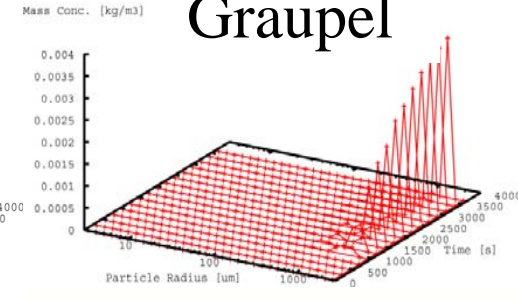
## Plate



## Snowflake



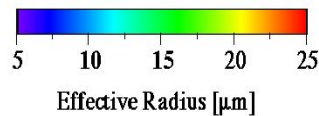
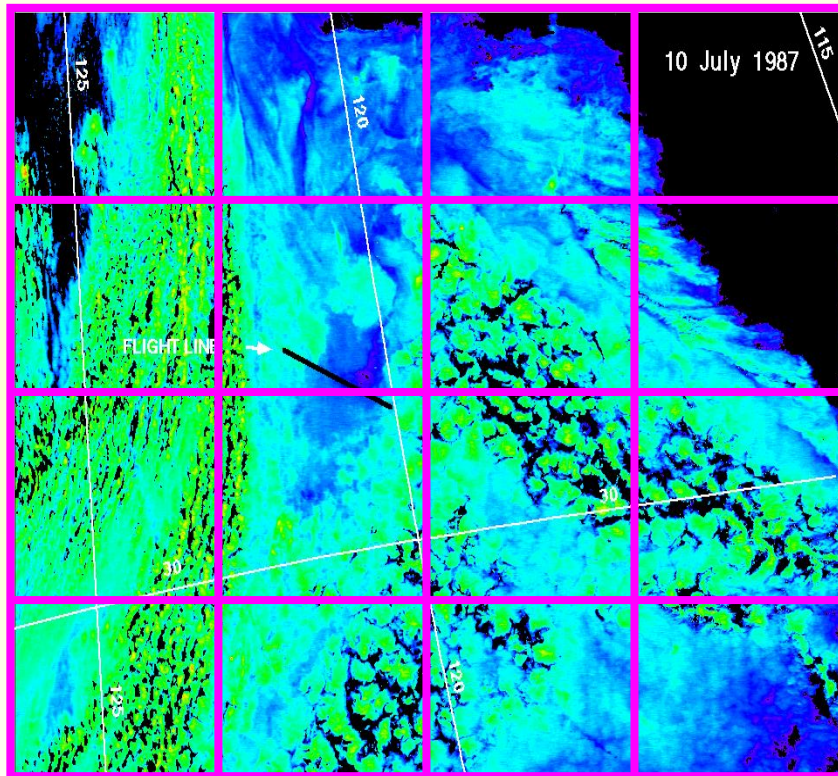
## Graupel



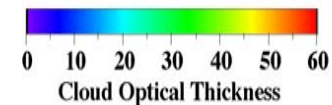
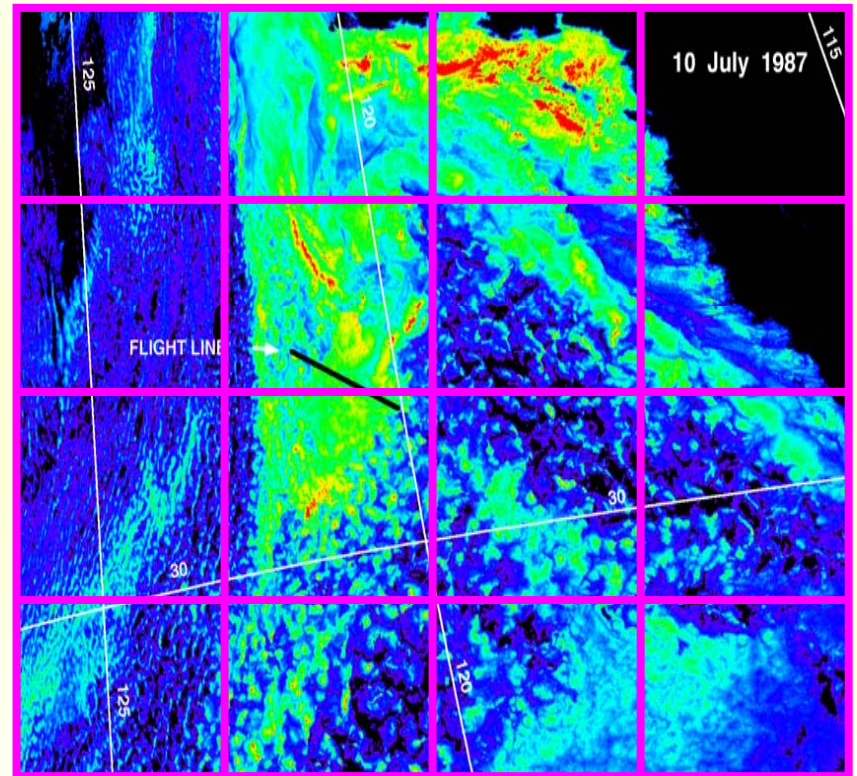
40km

# 雲の光学特性の衛星観測

有効粒子半径  $r_e$



光学的厚さ  $\tau_c$

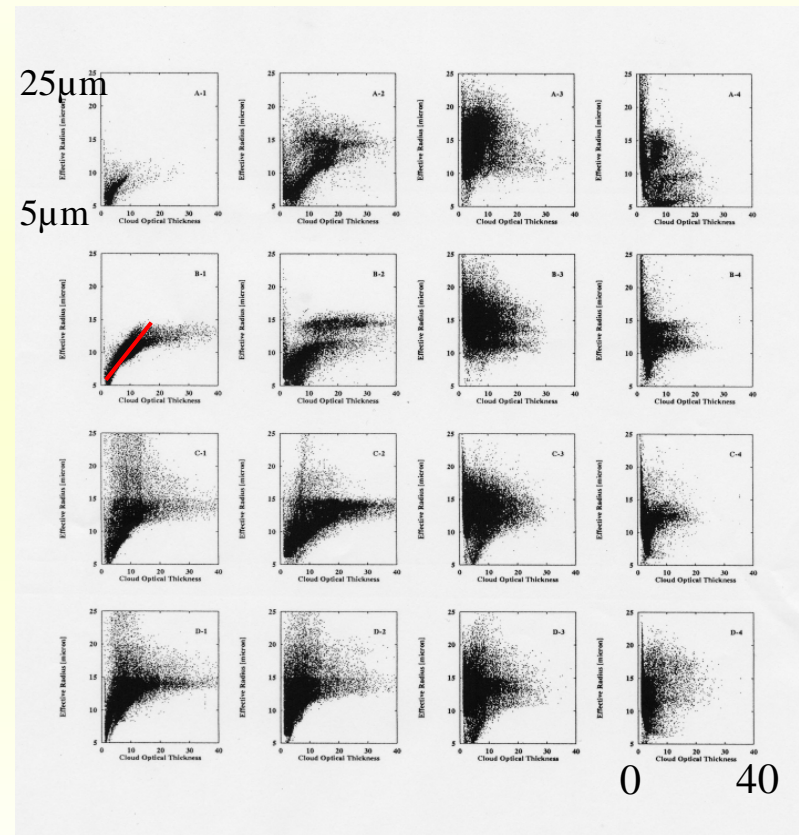
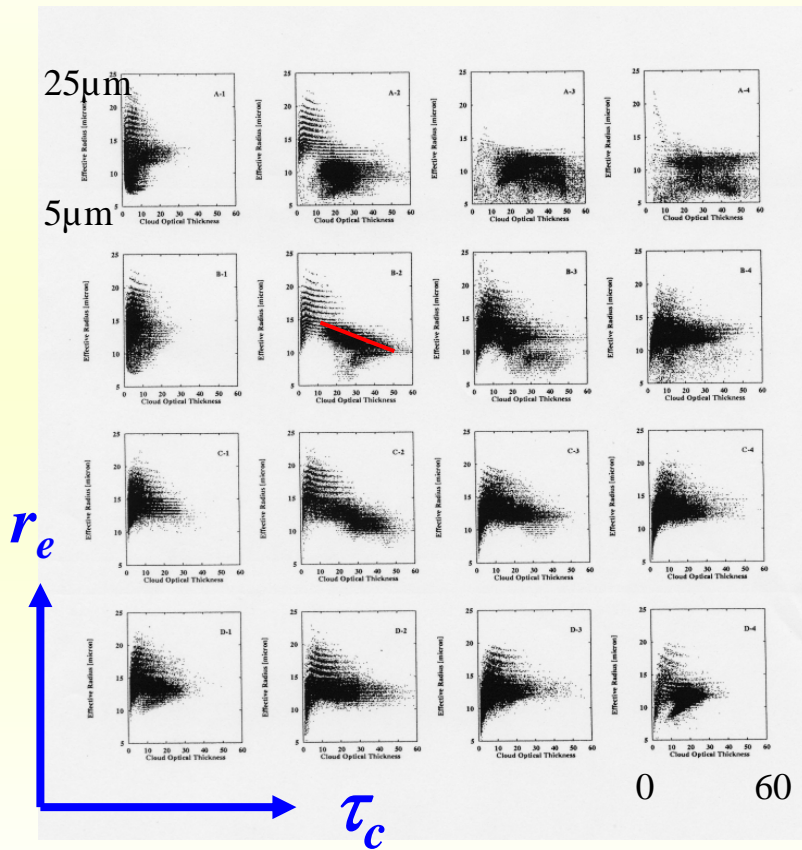


Nakajima and Nakajima (JAS 1995)

# 有効半径 $r_e$ と光学的厚さ $\tau_c$ の相関

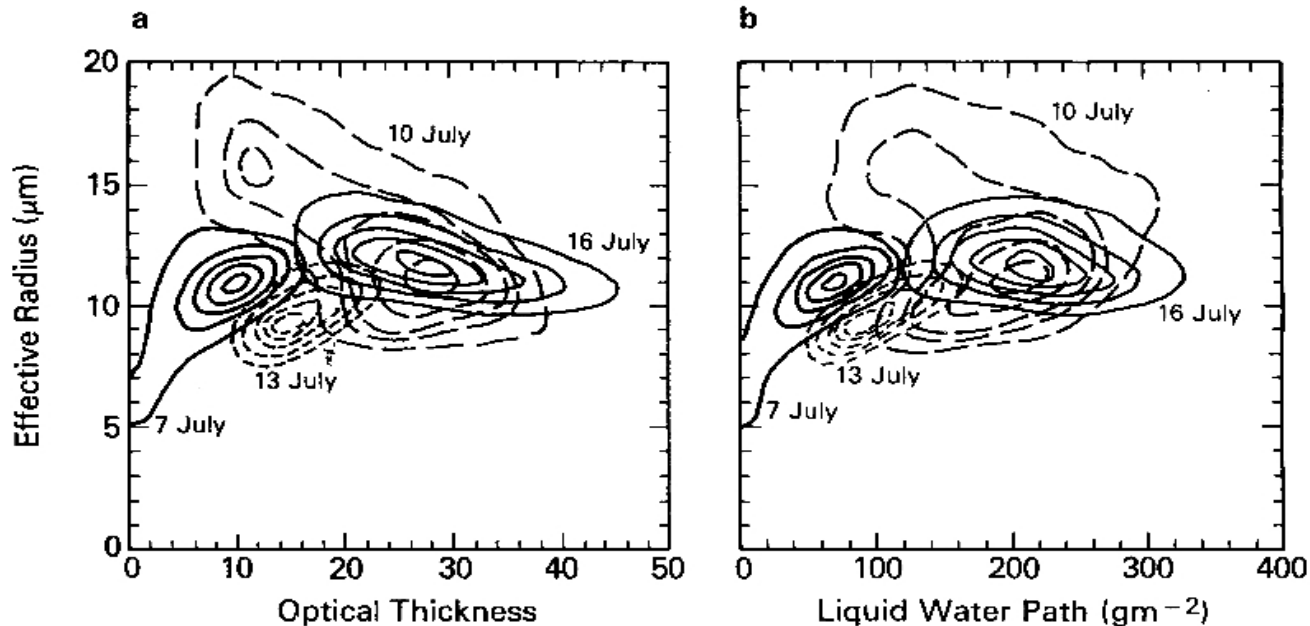
FIRE region (California)

ASTEX region (North Atlantic)



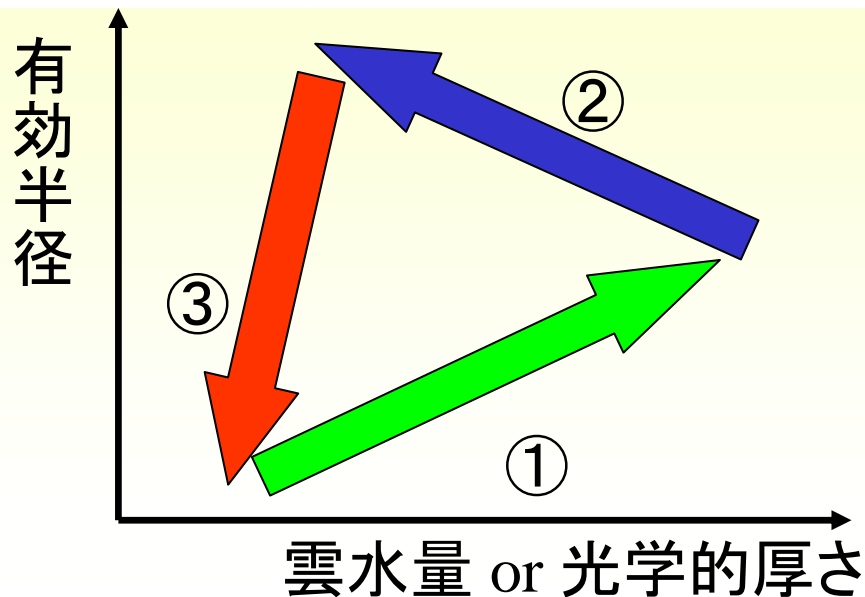
Nakajima and Nakajima (JAS 1995)

# 観測的に知られる $r_e - \tau_c$ 相関パターン



正相関と負相関

Nakajima et al.  
(JAS 1991)



① 降雨前の雲

② 降雨中の雲

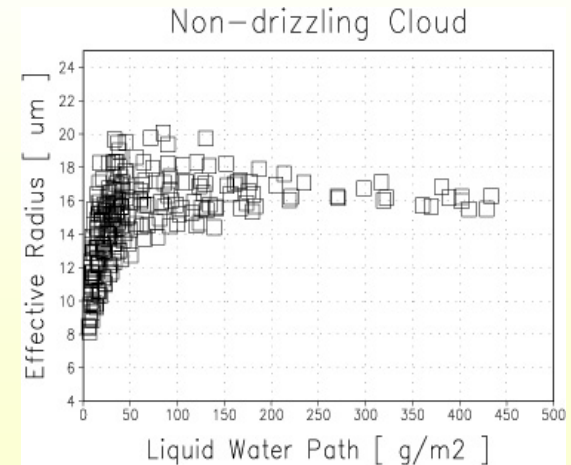
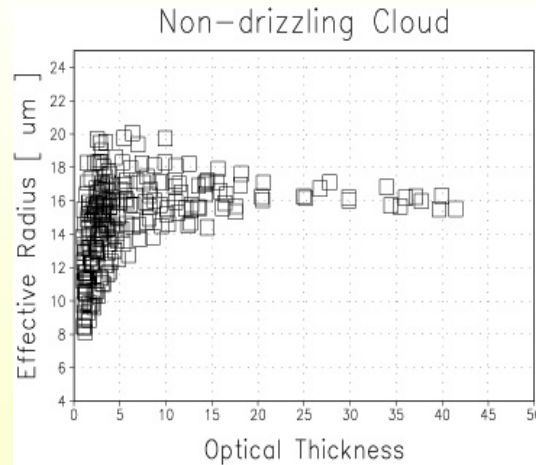
③ 降雨後の雲

雲の微物理過程の情報が含まれている

# ビン法雲モデルで再現された相関

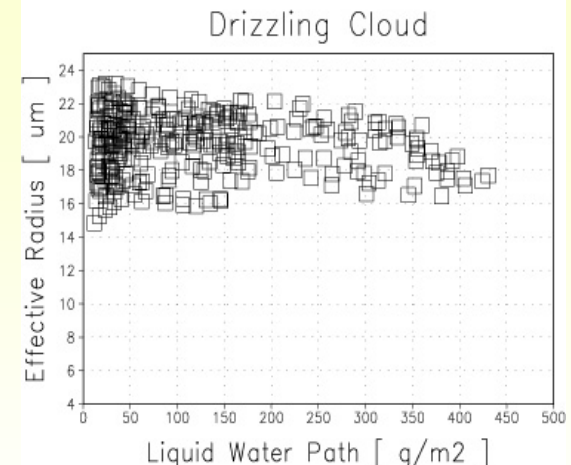
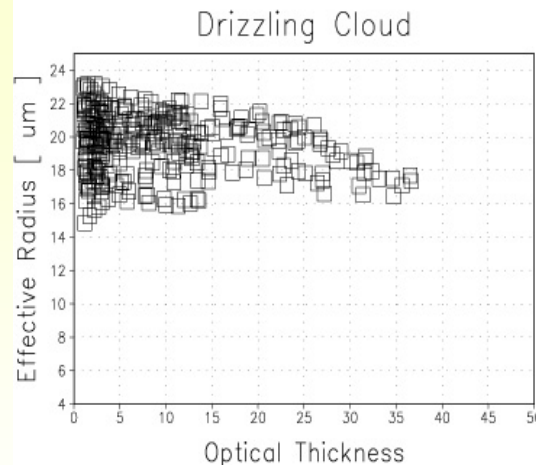
## 降雨の無い雲

正相関: 粒子成長とともに雲は厚くなる



## 降雨を伴う雲

負相関: 粒子成長とともに雲は薄くなる(雲水 → 雨水の変換)



$$r_e = \frac{\int n(r)r^3 dr}{\int n(r)r^2 dr} \quad \tau_c = \iint 2\pi n(r)r^2 dr dz$$

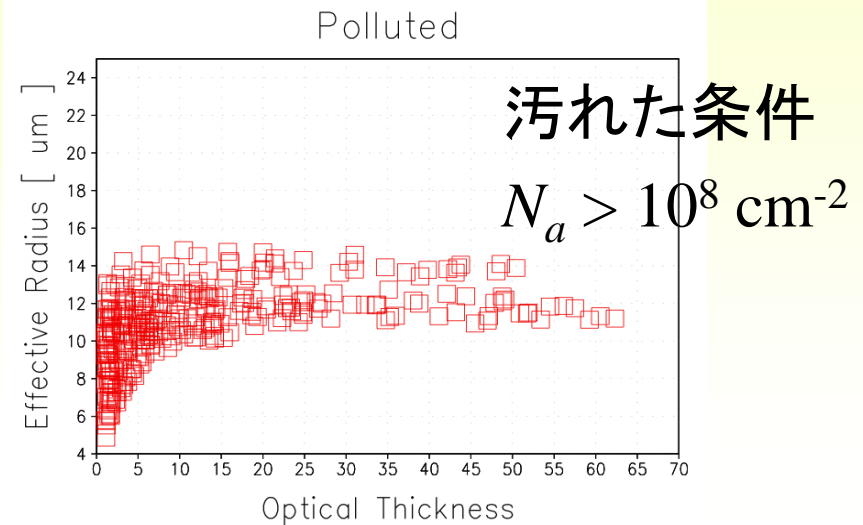
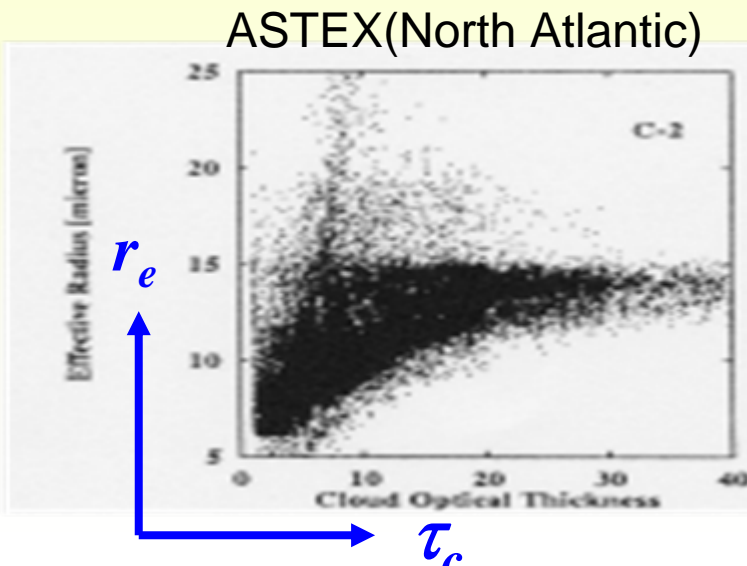
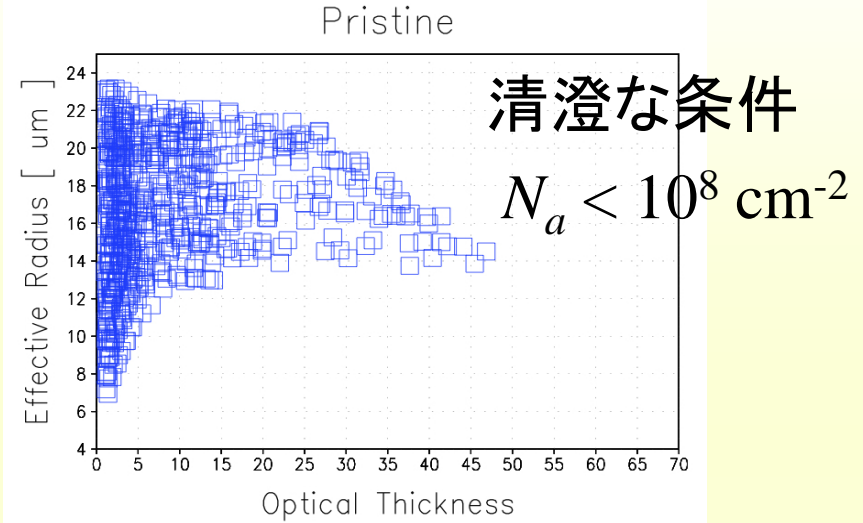
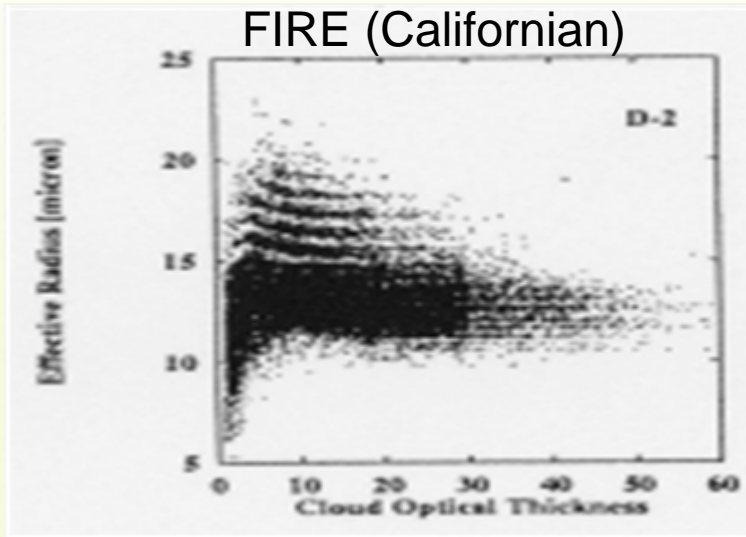
Suzuki et al. (GRL submitted)



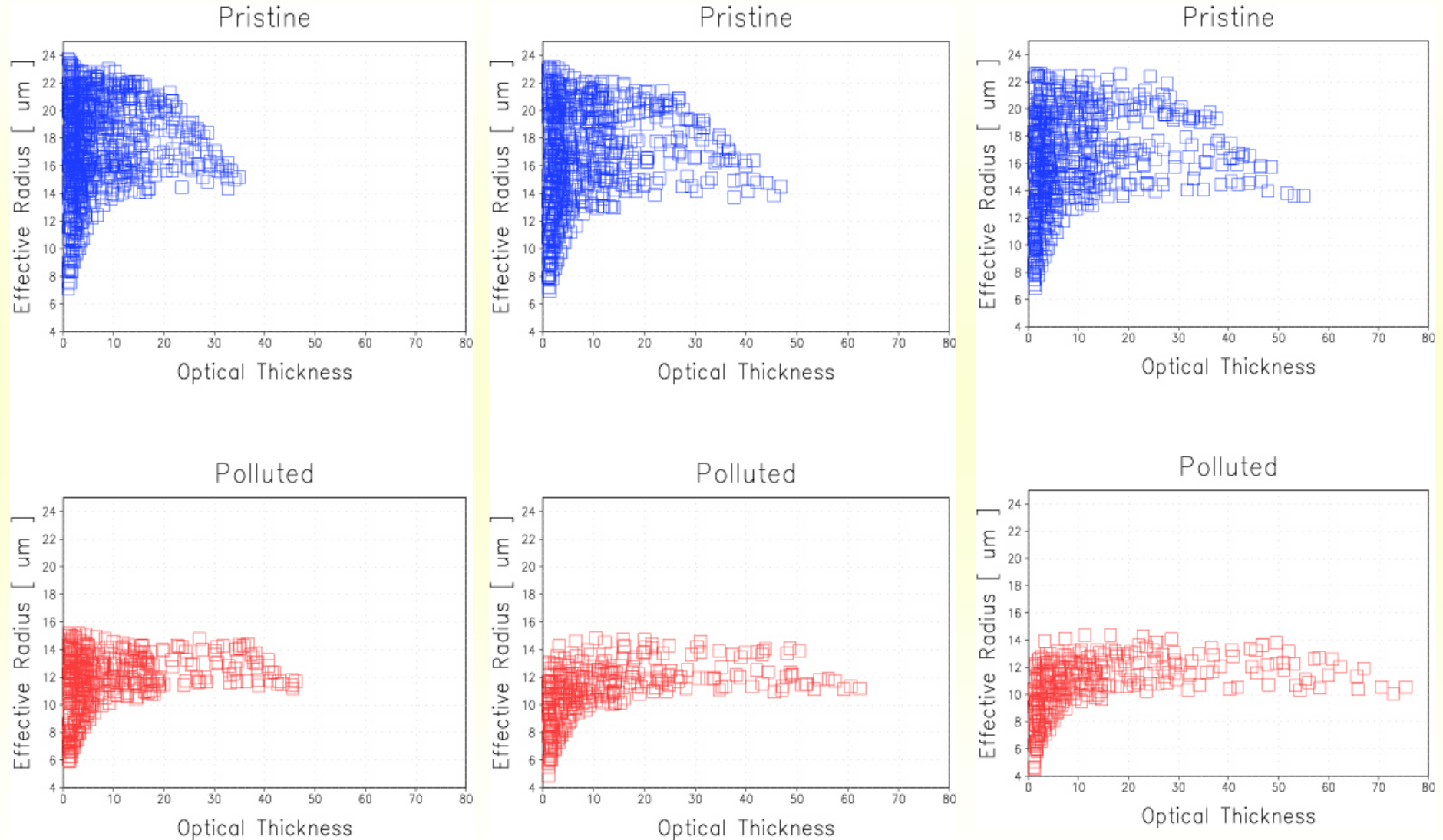
# エアロゾル量の $r_e - \tau_c$ 相関への影響

衛星観測 (N&N JAS95)

ビン法雲モデル (Suzuki et al., GRL submitted)



# 力学安定度の影響



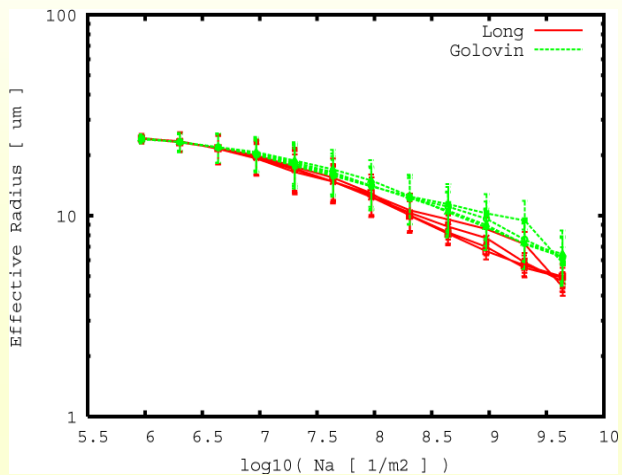
stable



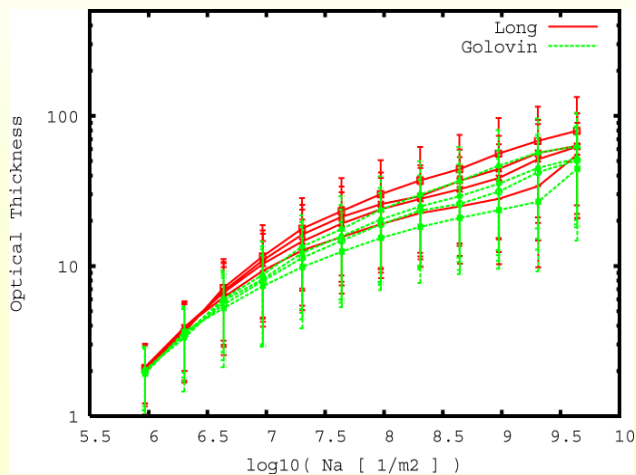
unstable

# 雲物理量のエアロゾル数依存性

## 有効半径

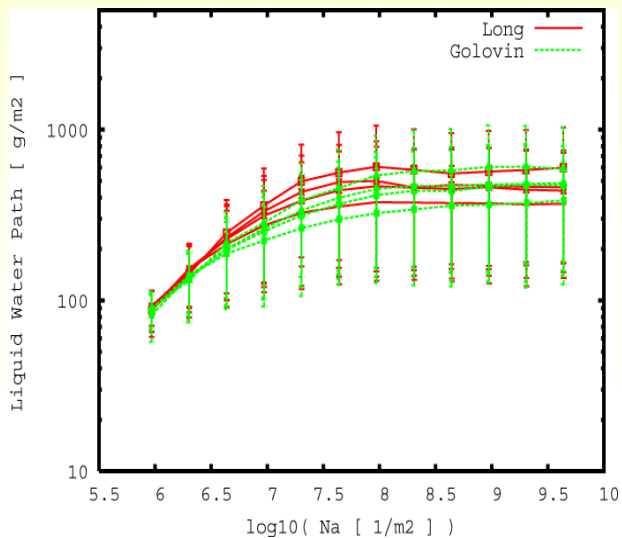


## 光学的厚さ

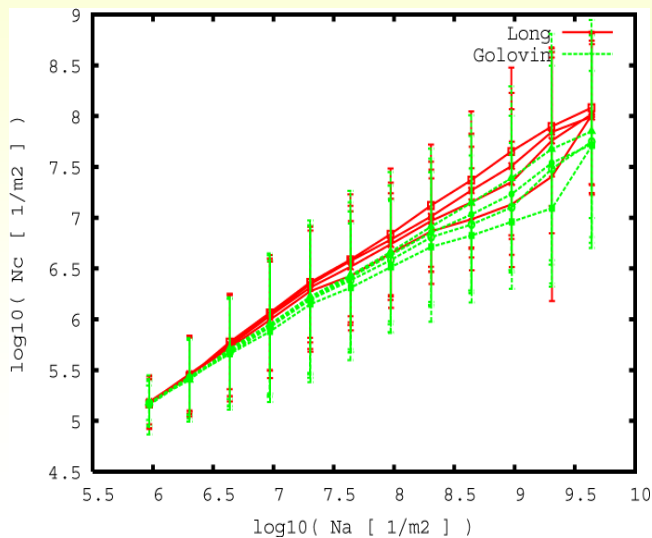


定性的な傾向は  
衛星観測と一致

## 雲水総量



## 雲粒子数



$$N_c \propto N_a^{0.70}$$

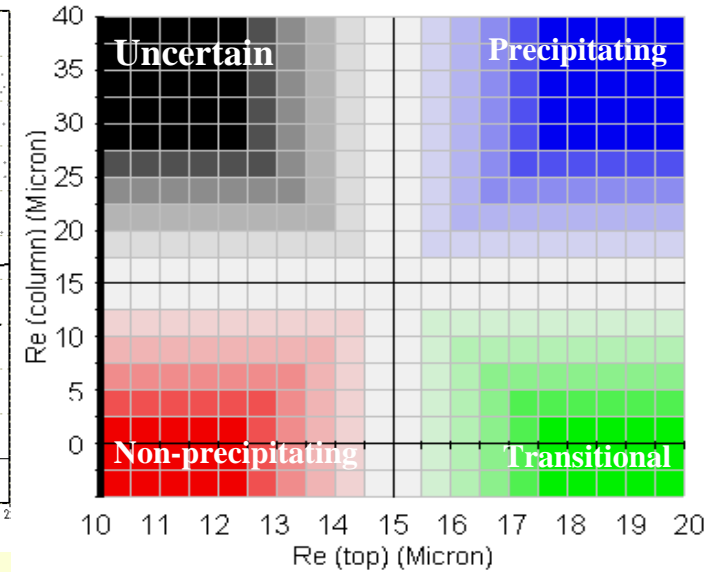
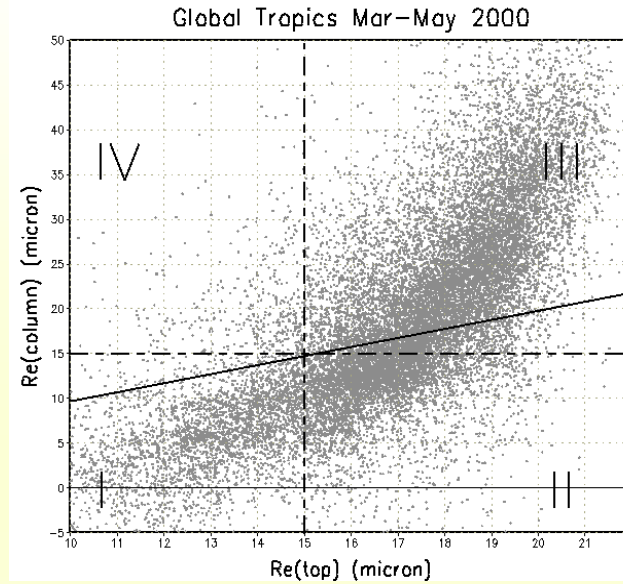
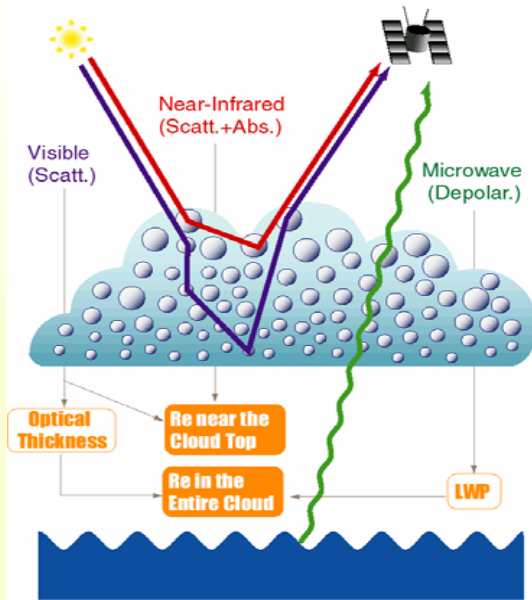
cf. satellite obs.:

$$N_c \propto N_a^{0.50}$$

# TRMM多波長センサーによる雲観測

Masunaga et al. (JGR 2002), Matsui et al. (GRL 2004)

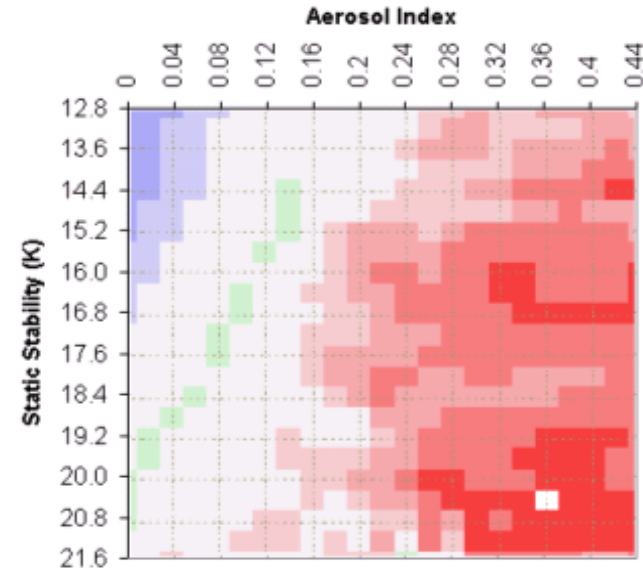
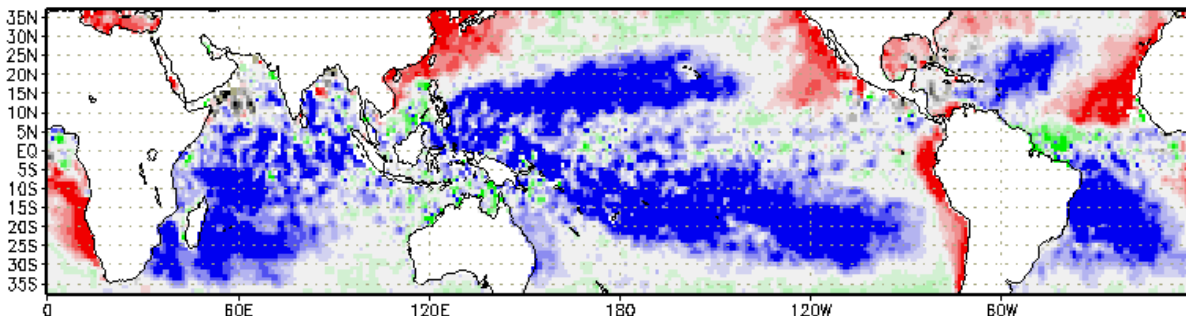
Multi-sensor Cloud Observation



$r_e(top)$  : 雲頂付近の粒径 (主に近赤外)

$$r_e(column) = \frac{2}{3} \frac{1}{\rho_w} \frac{LWP}{\tau_c} : \text{雲層平均の粒子半径}$$

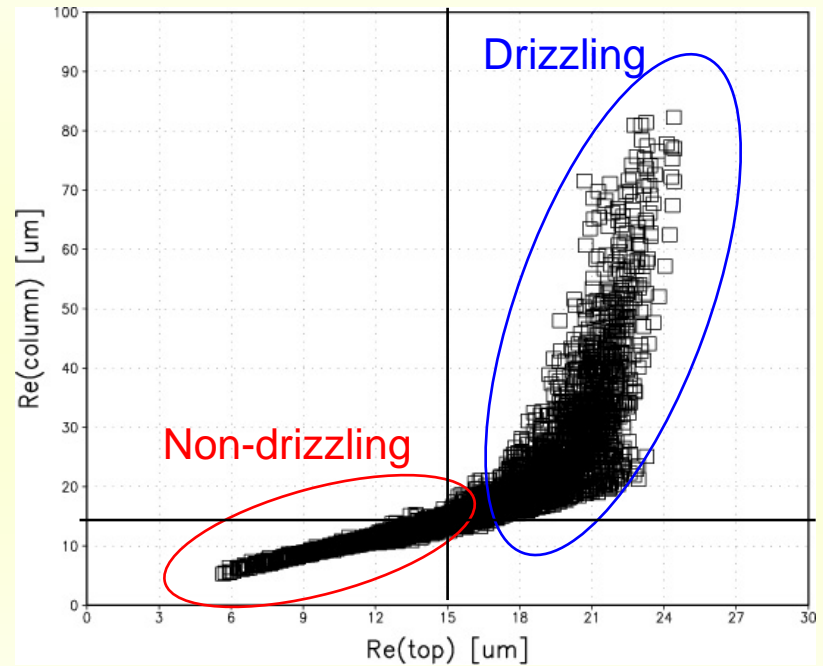
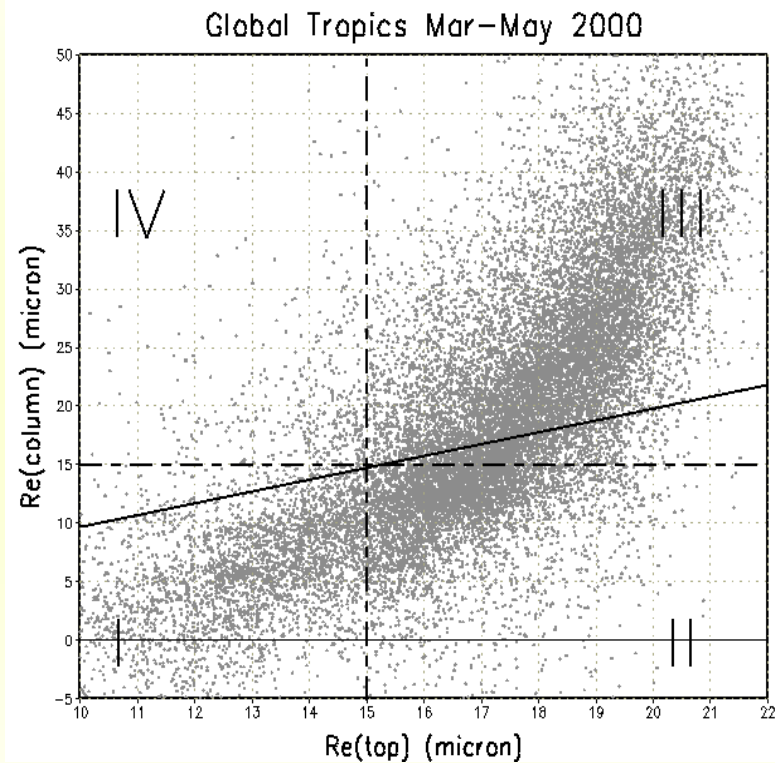
← マイクロ波(Drizzle検出可)  
 ← 主に可視



# ビン法雲モデルによる再現

TRMM観測 (Matsui et al., GRL 2004)

ビン法雲モデル (Present Study)

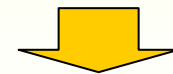


$r_e(top)$  : 雲頂付近の粒径 (主に近赤外)

$$r_e(column) = \frac{2}{3} \frac{1}{\rho_w} \frac{LWP}{\tau_c} : \text{雲層平均の粒子半径}$$

← マイクロ波(Drizzle検出可)  
← 主に可視

エアロゾル・力学安定度の影響は？



これらの条件を系統的に変えた感度実験

# 今後の展望

- 多波長センサー搭載の衛星観測は今後飛躍的に増える
  - CloudSat, GOSAT, EarthCare etc.
- エアロゾルの雲核効果と対流性力学を同時に組み込んだ雲解像モデルが必要
  - 全球非静力学モデルNICAMとエアロゾル輸送モデルSPRINTARSの結合(+将来的にはビン法雲物理)
- モデルを用いた衛星観測の解釈
  - 雲・降水場に対するエアロゾルの効果と力学的効果を分離した理解