Characteristics of water cloud optical properties as simulated by non-hydrostatic spectral microphysics cloud model

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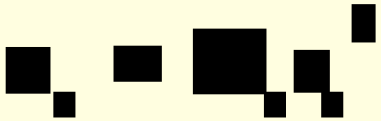
Climatic significance of cloud microphysics

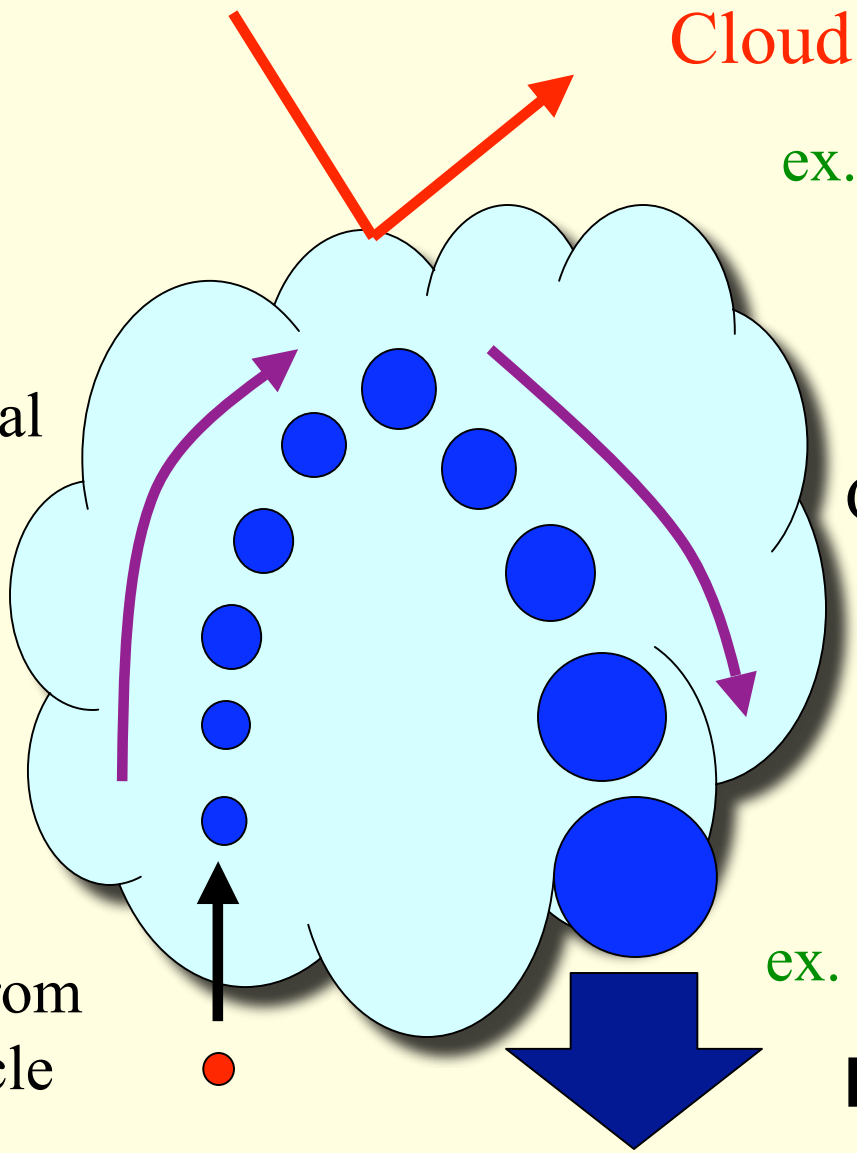
N_c : Number Conc.
r_c : Particle Radius

Cloud Optical Property

ex. optical thickness :



Condensational growth



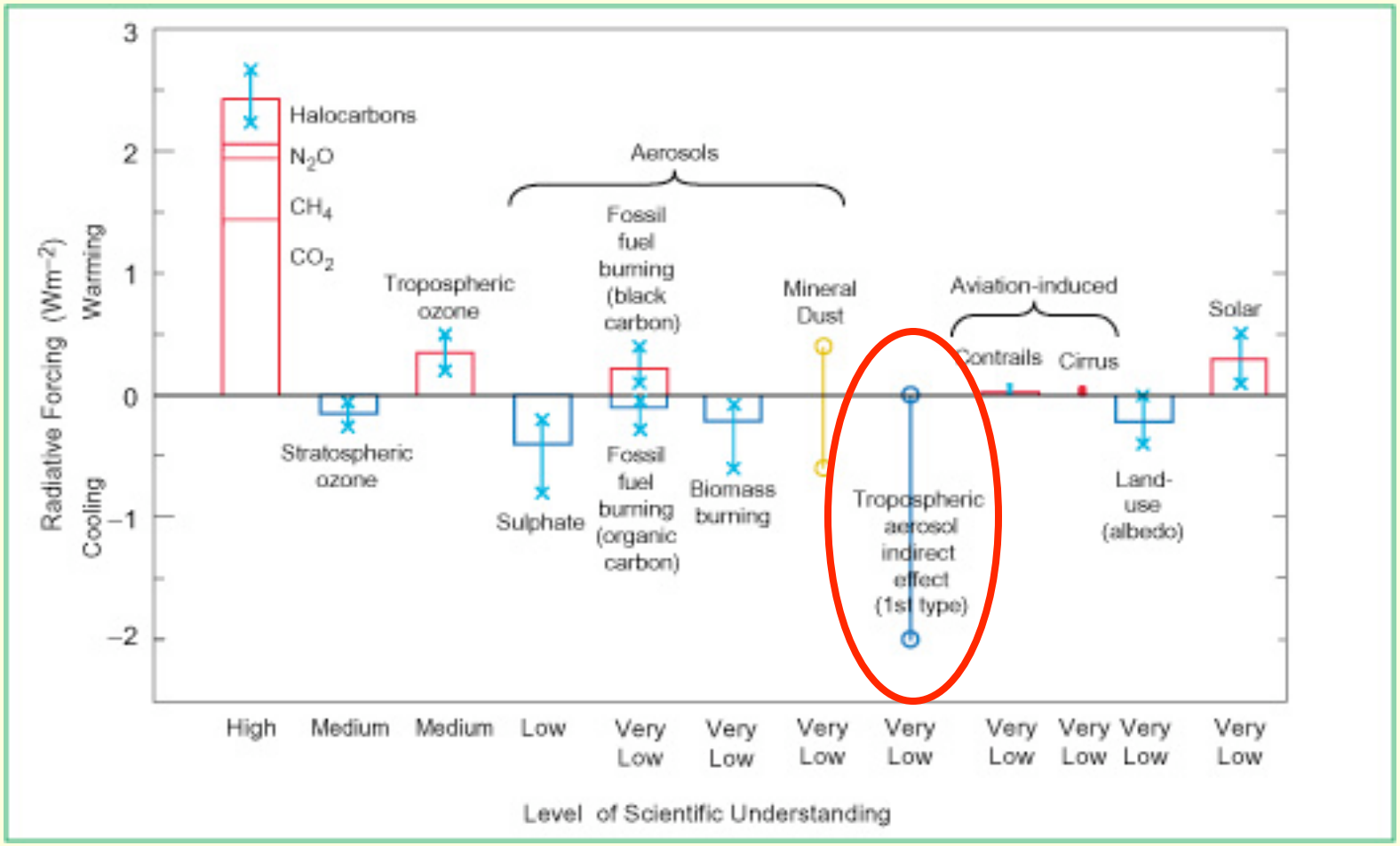
Collision-Coagulation

Precipitation Efficiency

ex. rainfall time scale :

Nucleation from aerosol particle

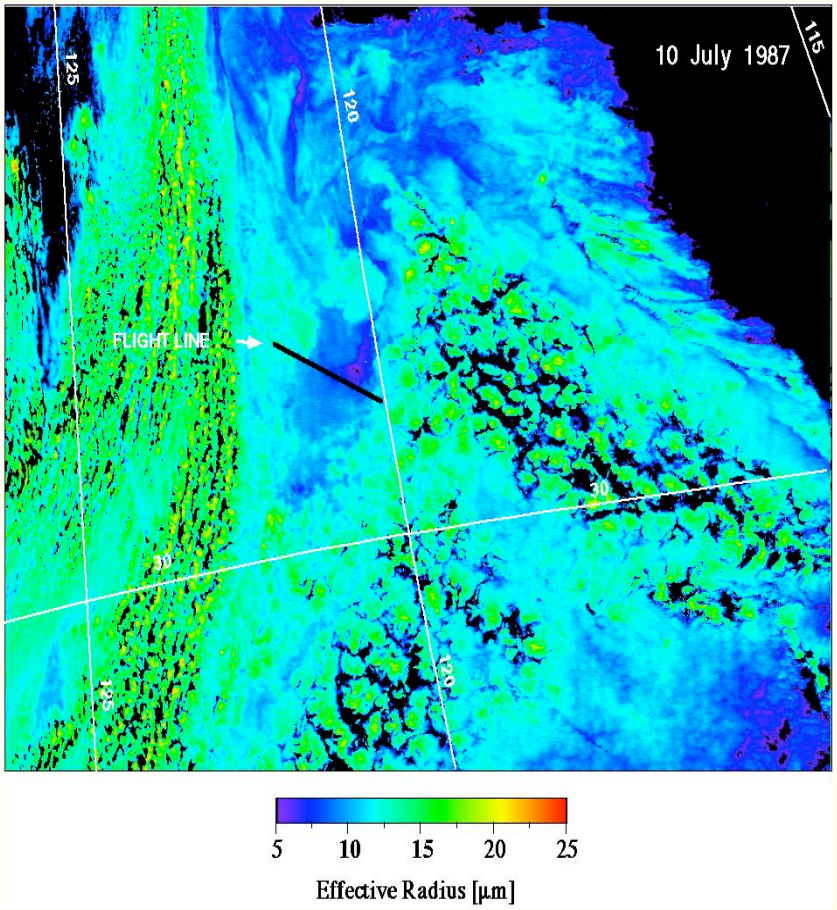
Our motivation : aerosol indirect effect



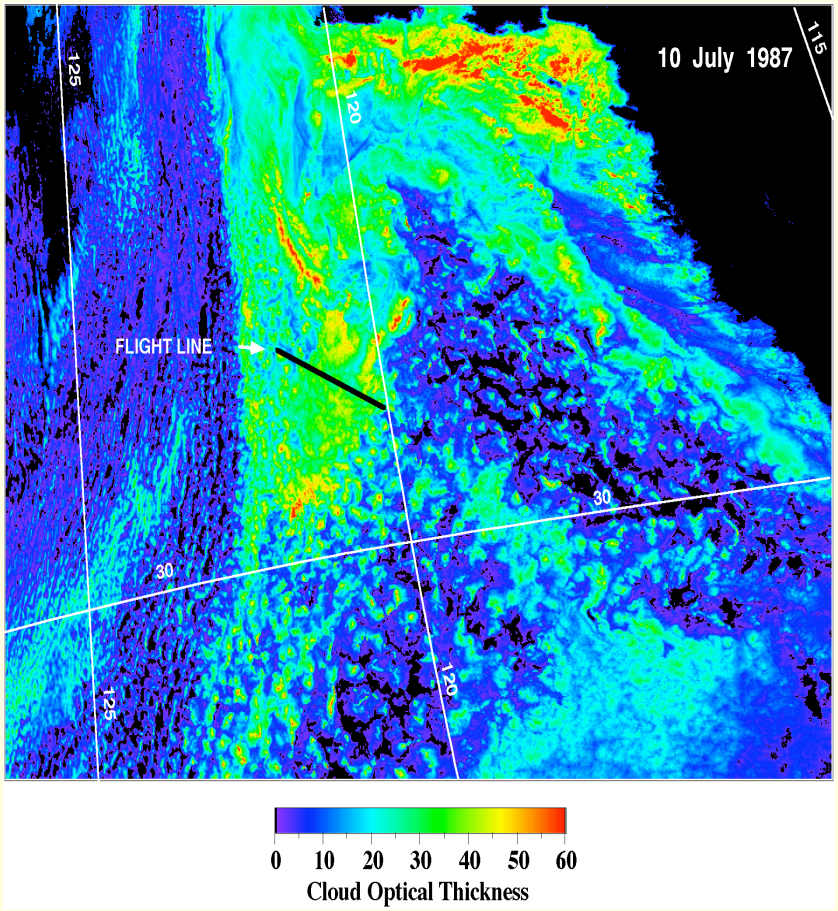
IPCC－TAR (2001)

Satellite-retrieved water cloud optical property

Effective Radius



Optical Thickness



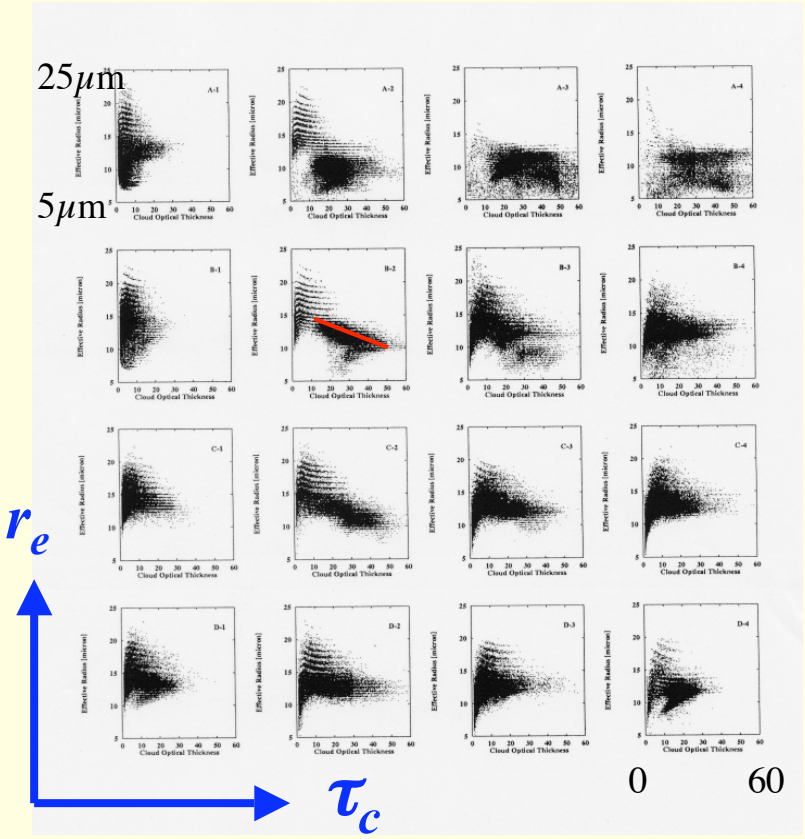
AVHRR

Nakajima and Nakajima (JAS 1995)

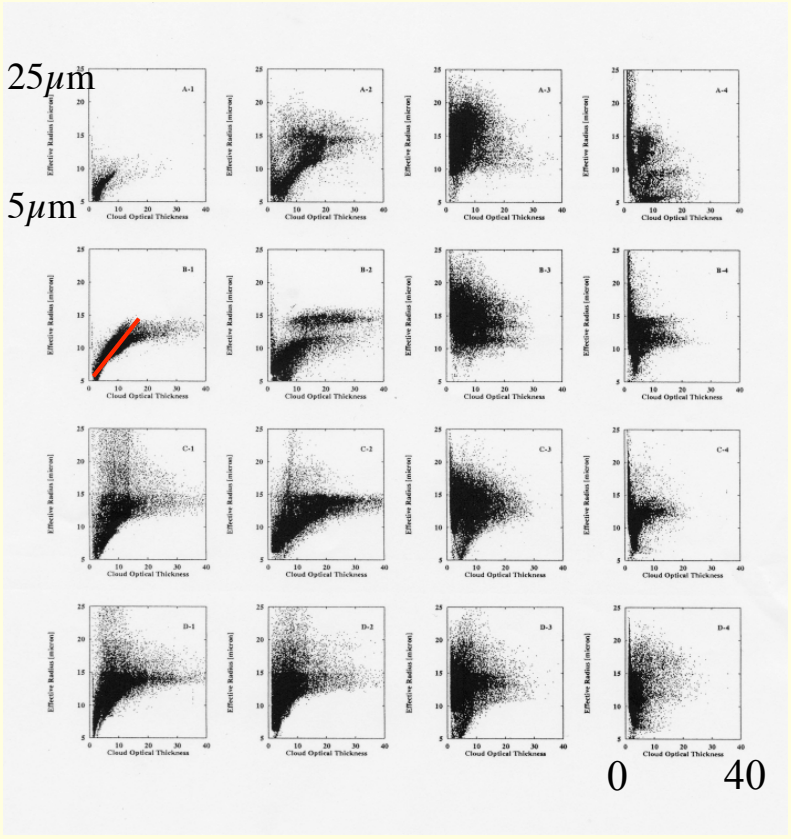
with the algorithm of Nakajima and King (JAS 1990)

Correlation between r_e and τ_c

FIRE region (California)



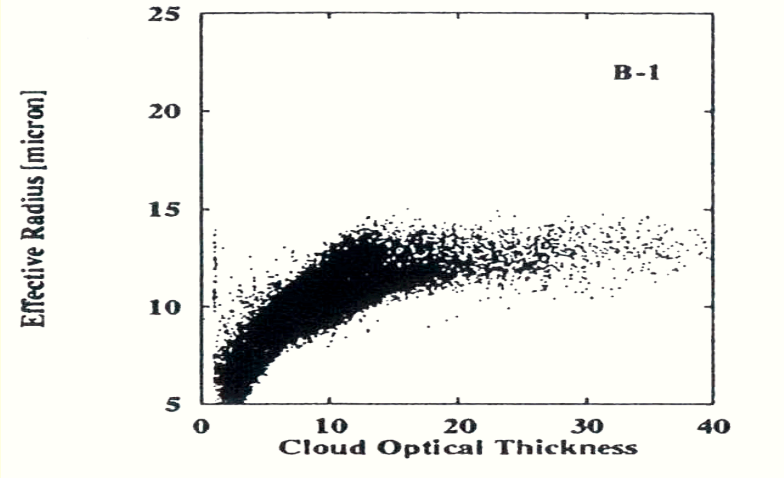
ASTEX region (North Atlantic)



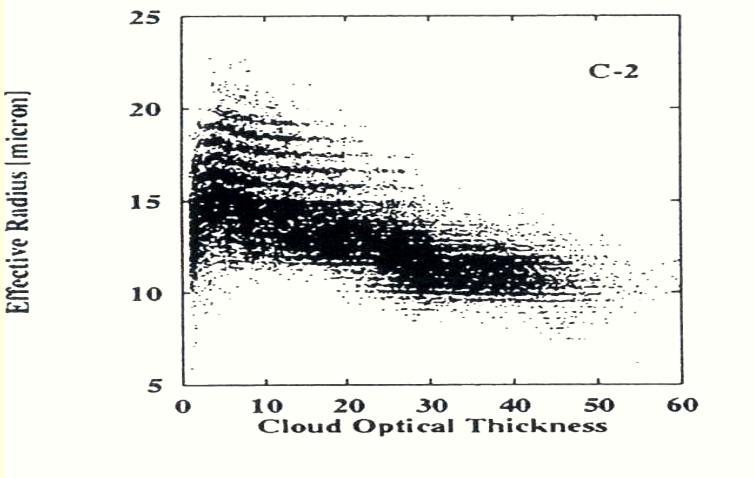
Nakajima and Nakajima (JAS 1995)

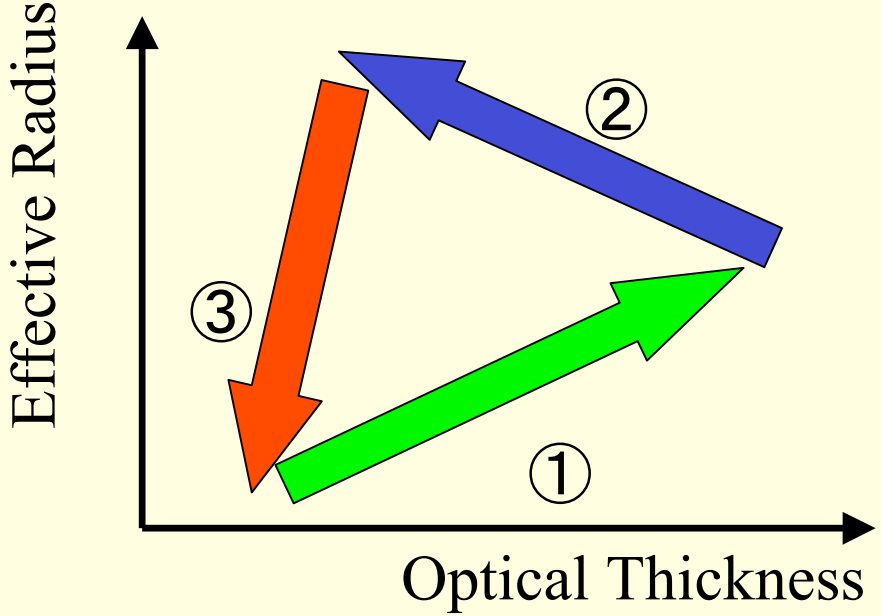
Optical property depends on cloud regime

No drizzle cloud



Drizzling cloud





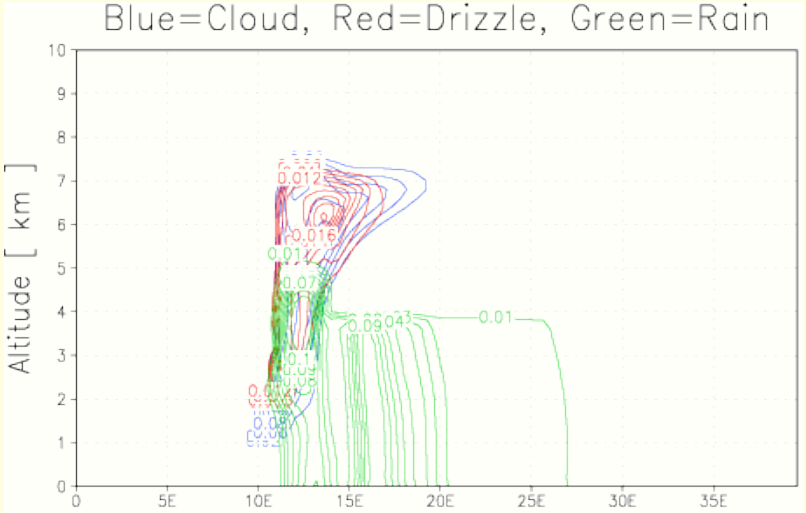
①No drizzle

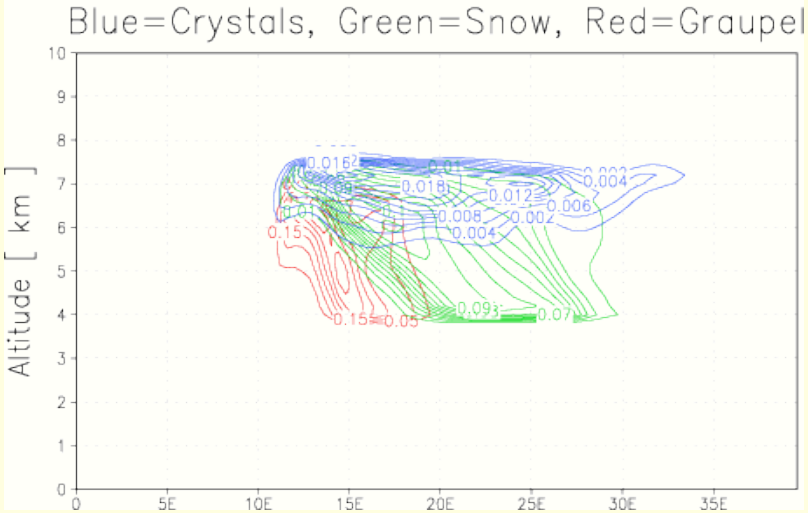
②Drizzling

③Decaying?

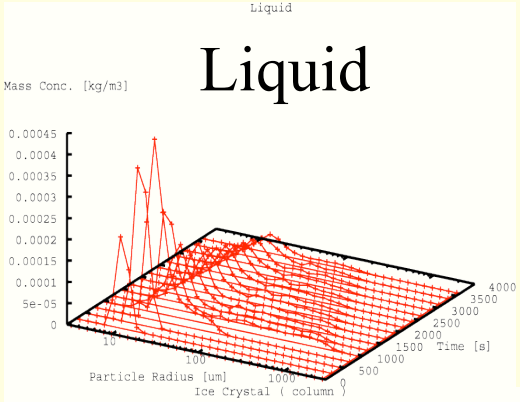
→ Interpretation with model

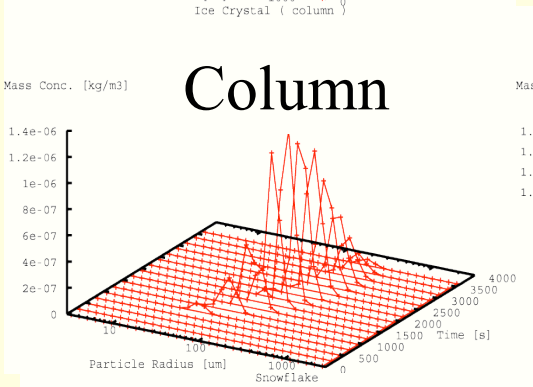
Bin Cloud Model Developed

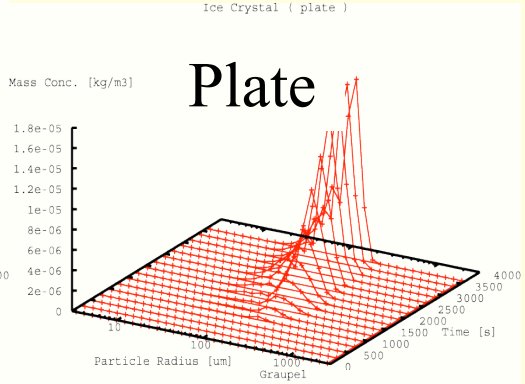


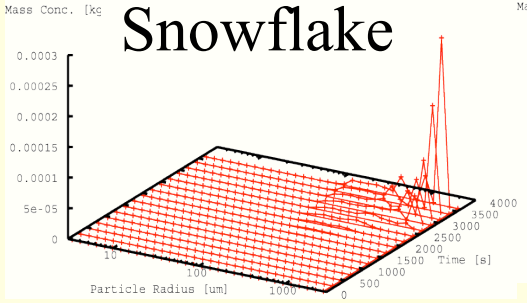


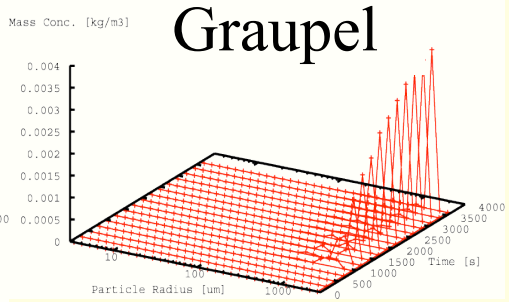
40km











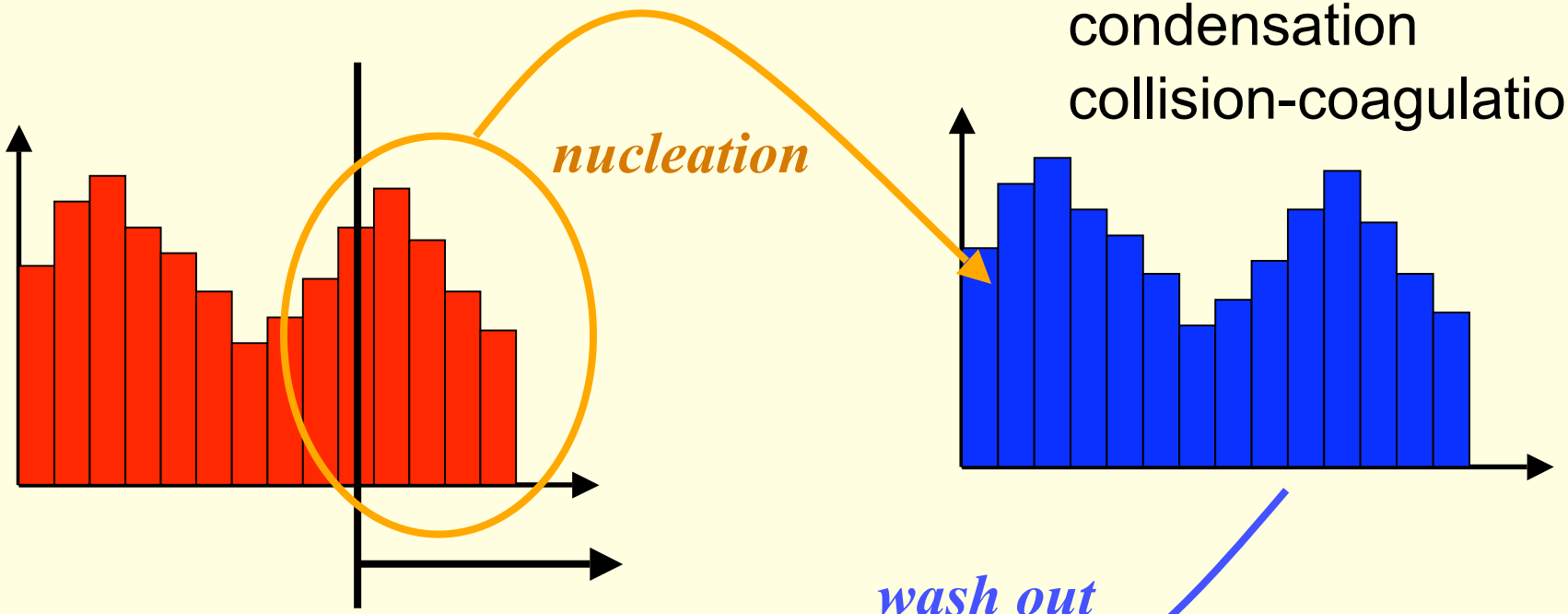
Aerosol-Cloud Coupling

Aerosol Particle

Liquid Cloud

condensation

collision-coagulation



Critical Radius $r_{N,crit}(S)$

$$r_{N,crit}(S) = \frac{A}{3}\left(\frac{4}{B}\right)^{1/3} S^{-2/3}$$

$$A = \frac{2\sigma}{R_v \rho_w T} \qquad B = i\frac{\rho_s}{\rho_w}\frac{m_w}{m_s}$$

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

Correlation obtained from cloud model

$$r_e = \frac{\int n(r) r^3 dr}{\int n(r) r^2 dr}$$

$$\tau_c = 2\pi \int dz \int n(r) r^2 dr$$

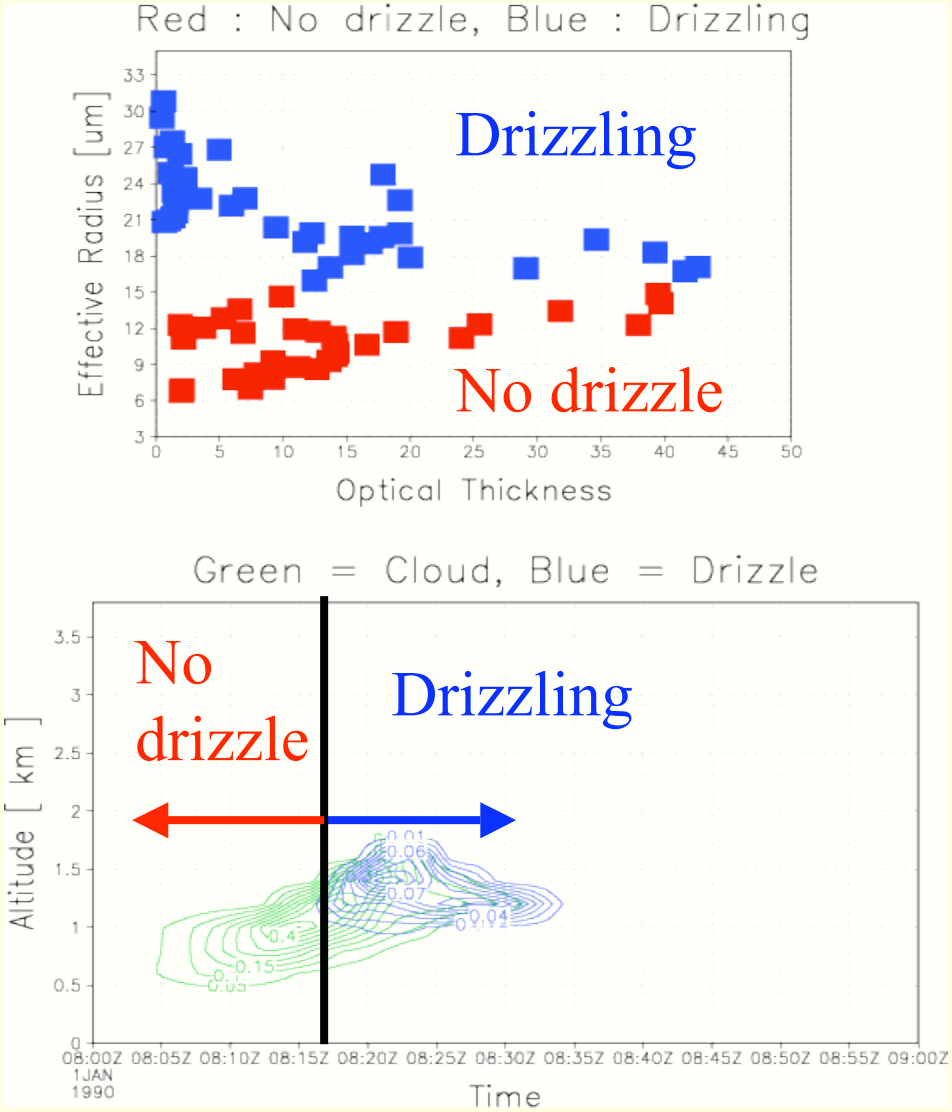
Domain: 20km(H) ×4km(V)

Resolution: 500m(H) ×200m(V)

Cloud : 30bin for 3-3000μm

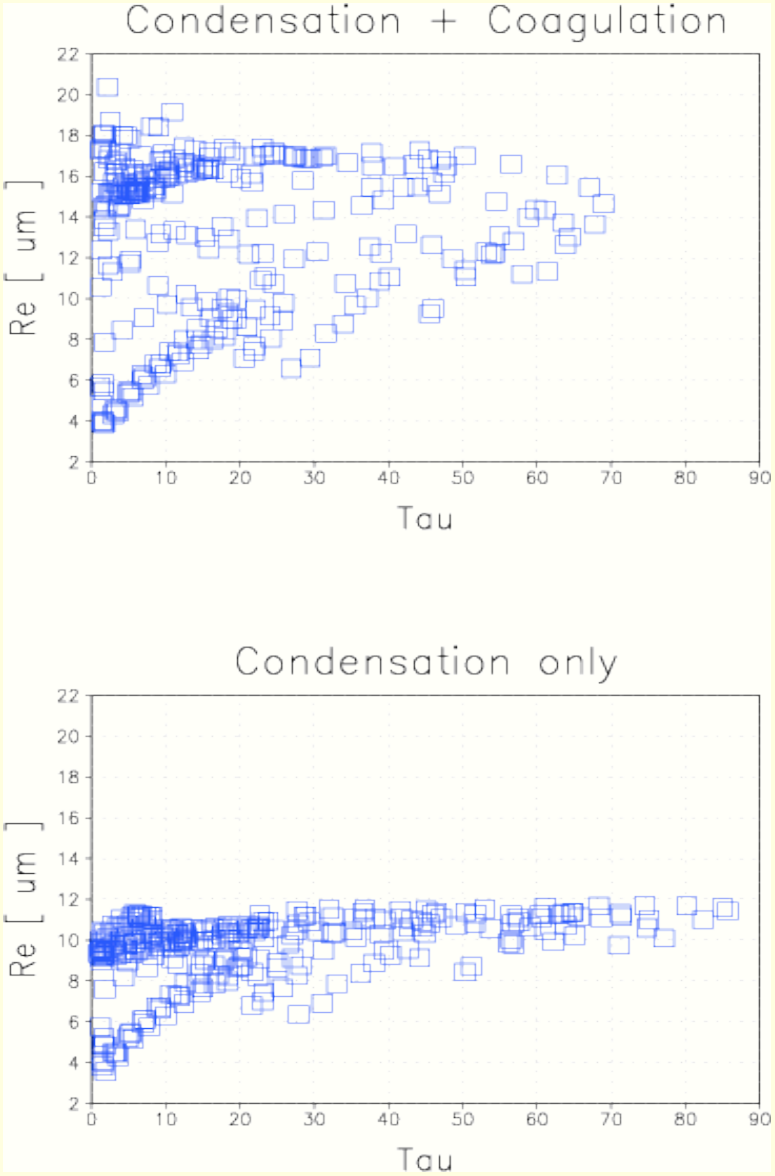
Aerosol: 10bin for 0.01-1μm

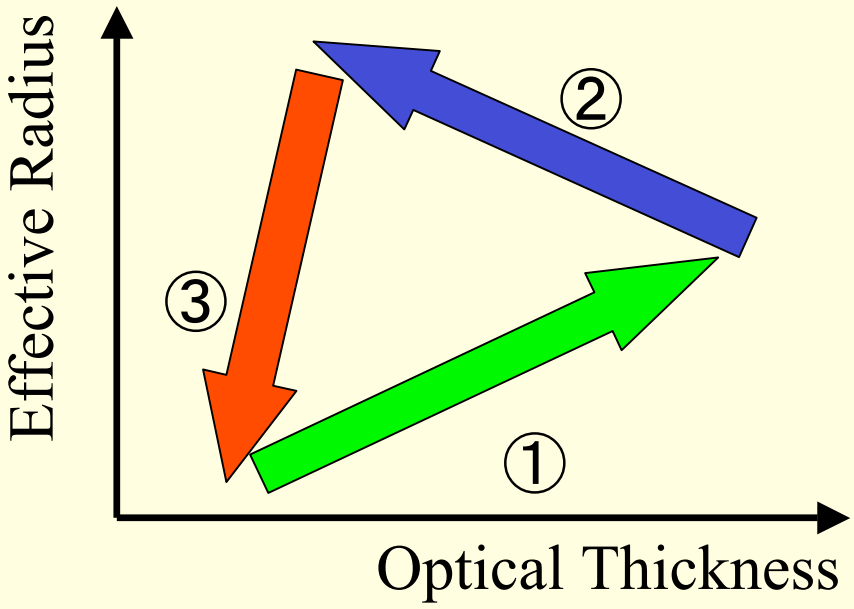
Low-level water cloud was formed in the experiment



0 1H

What process is responsible for correlation ?



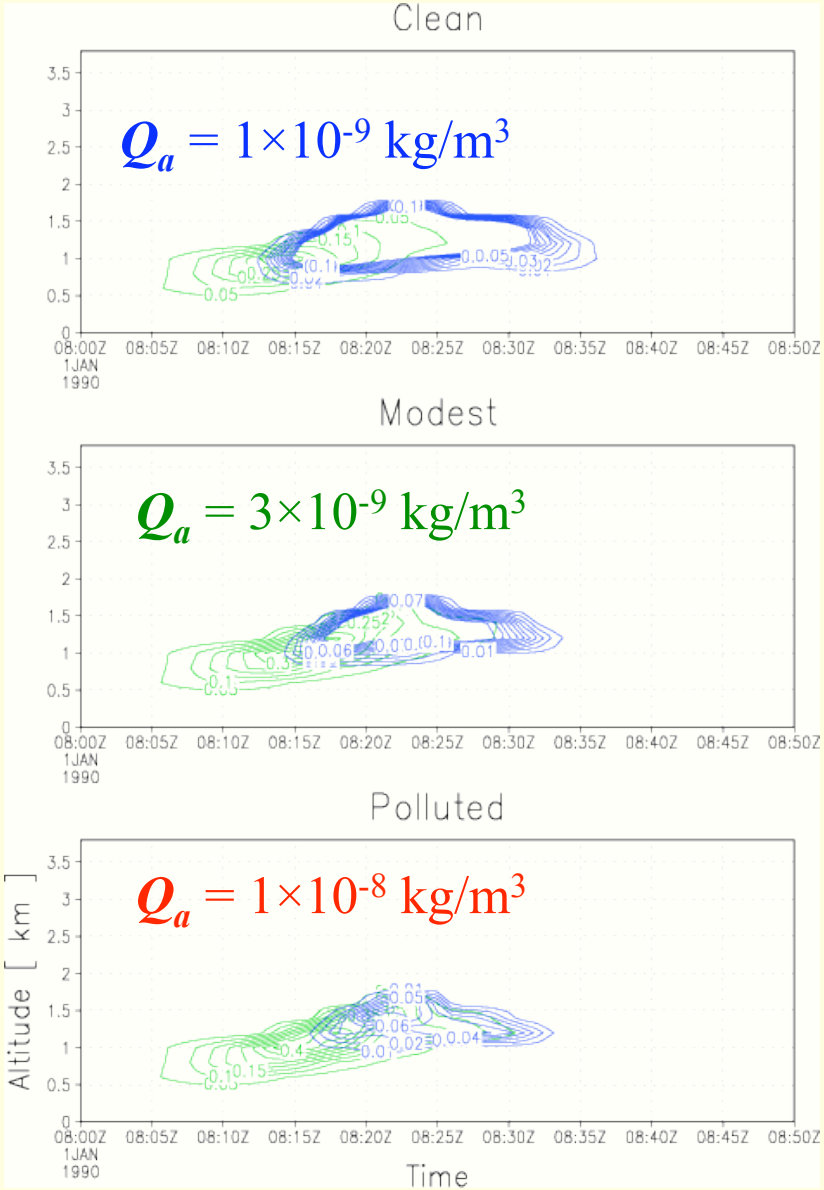


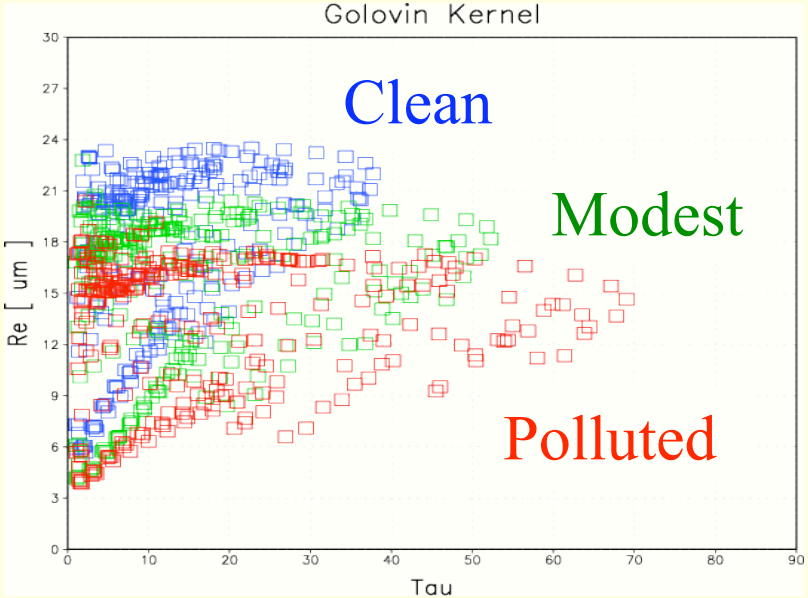
① Condensation : no drizzle phase

② Coagulation : drizzling phase

③ Evaporation ?

Sensitivity to aerosol amount





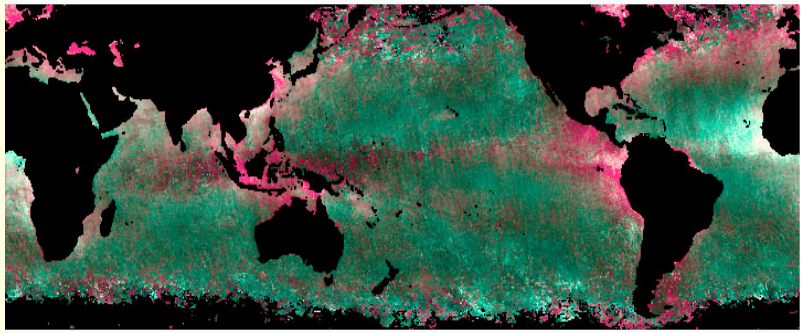
Aerosol significantly modifies the cloud optical property

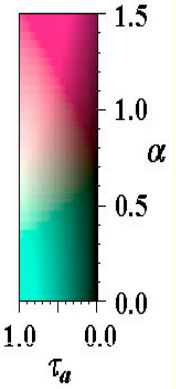
Blue = drizzle water content

Green = cloud water content

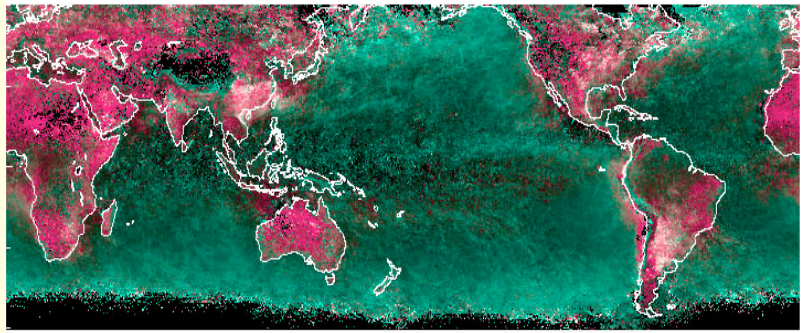
Satellite-detected aerosol effect on cloud

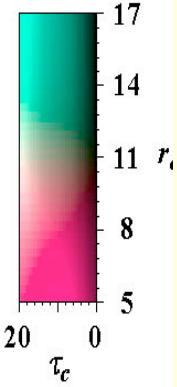
Aerosol (Higurashi and Nakajima, 1999)



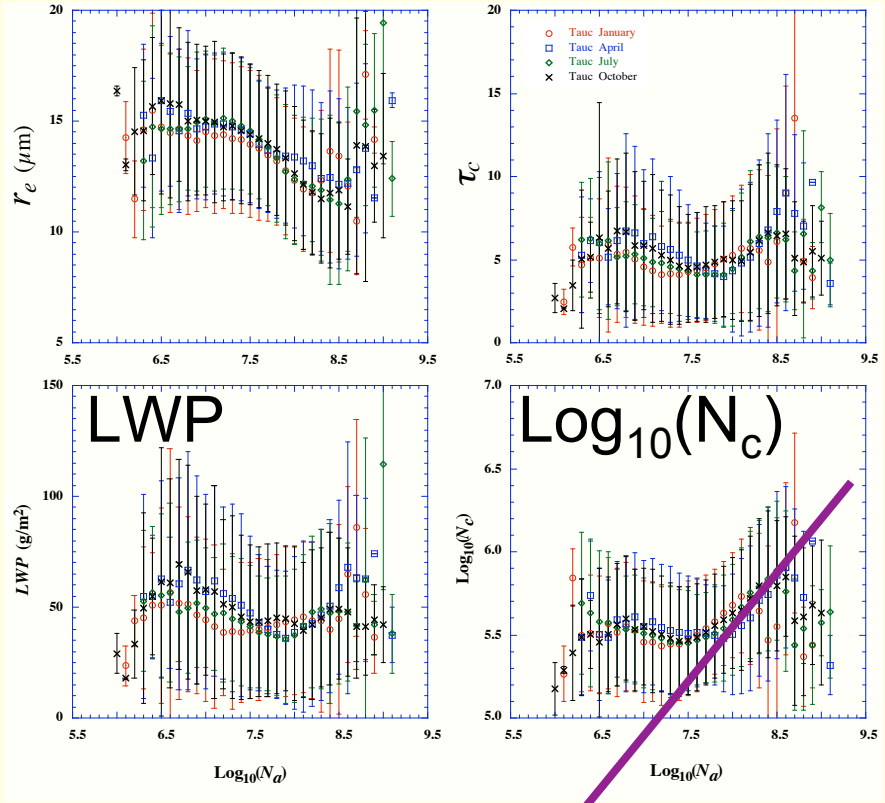


Low cloud (Kawamoto et al., 2001)





r_e τ_c

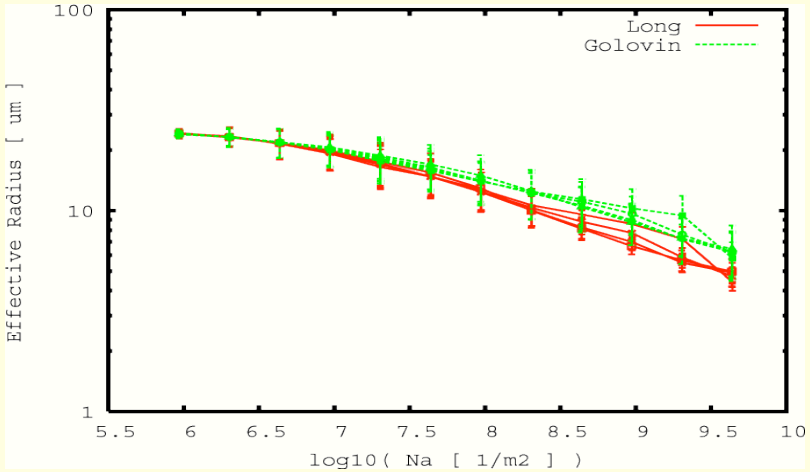


→ $Log_{10}(N_a)$

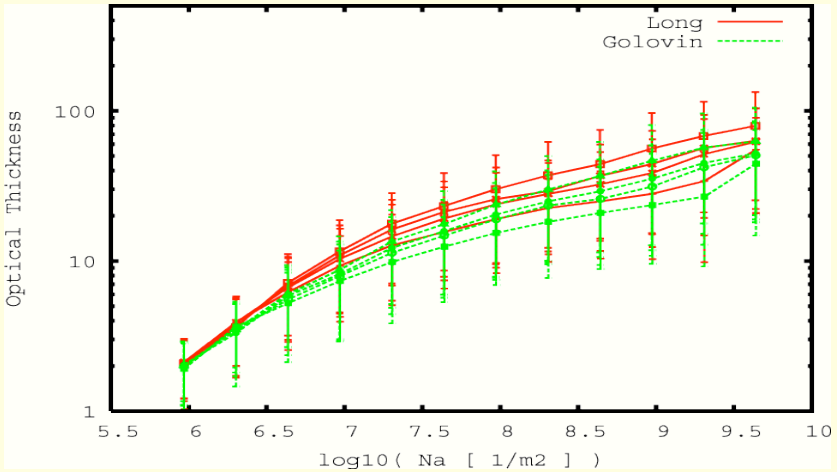
Nakajima et al. (GRL 2001)

Correlation from bin cloud model

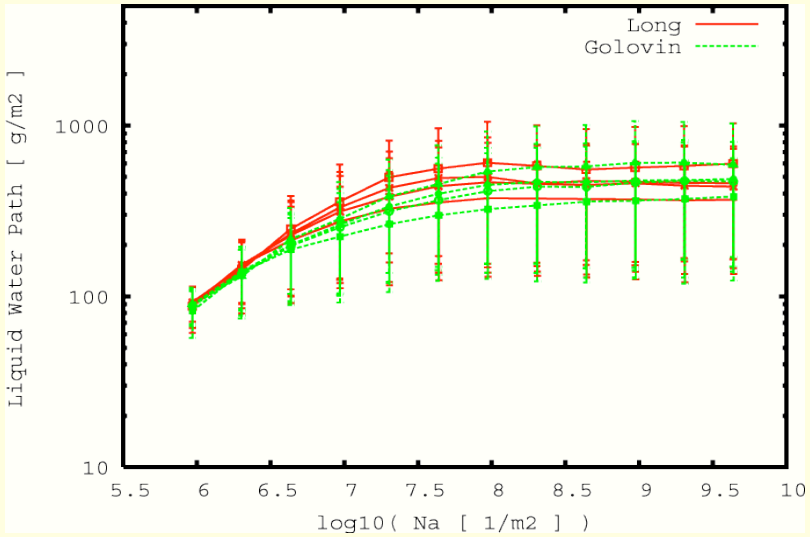
Effective Radius



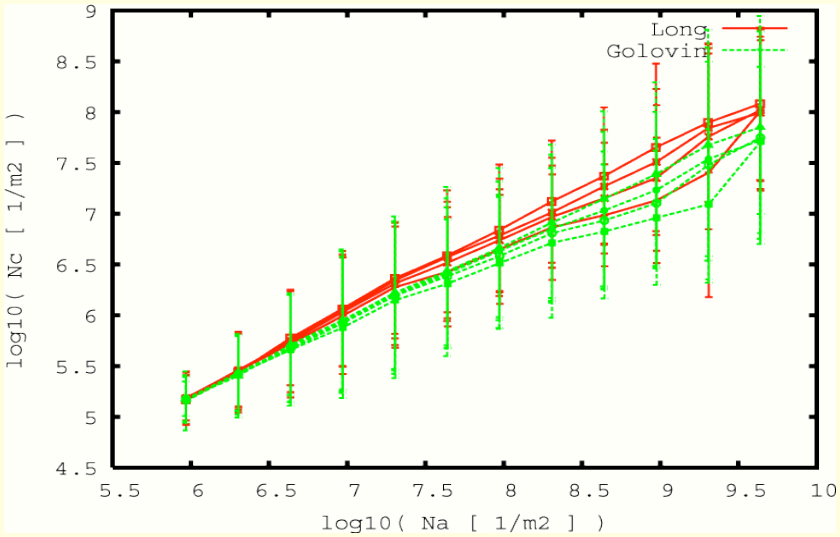
Optical Thickness



Liquid Water Path



Cloud Droplet Number



Cloud-Aerosol Correlation Statistics

Sensitivity of Cloud Droplet Number N_c to Aerosol Number N_a

$$\Delta \log_{10} N_c = b_N \Delta \log_{10} N_a \quad \Leftrightarrow \quad N_c \propto N_a^{\,b_N}$$

Reference	b_N
In-situ statistics (Kaufman et al., 1991)	0.7-0.8
Jones et al. (1994)	0.26
AVHRR (Nakajima et al., 2001)	0.50
Binned model (this study)	0.72

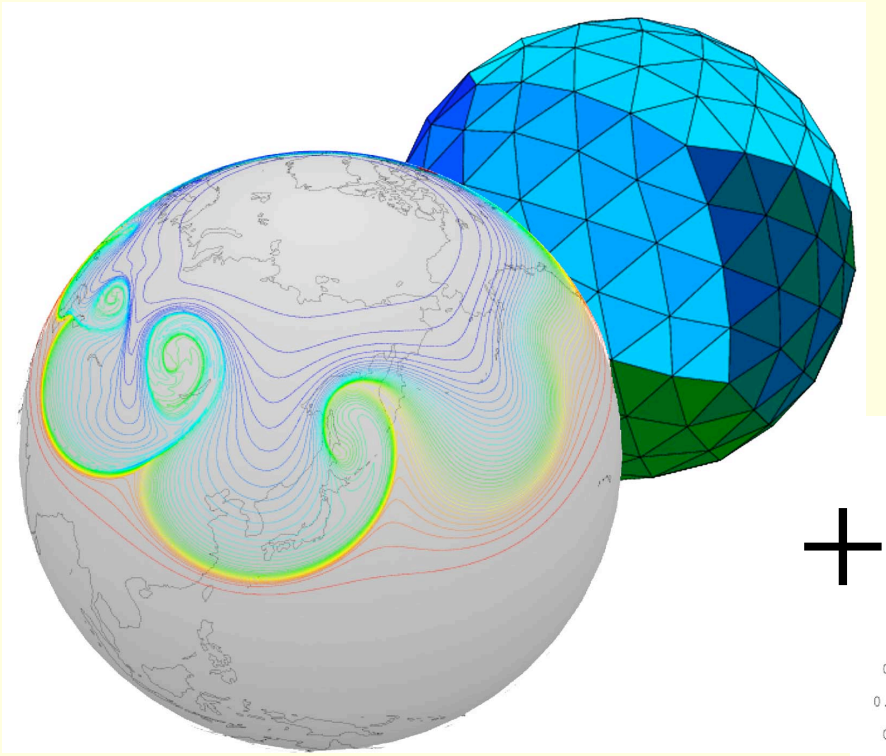
Global statistics from satellite may dilute the sensitivity due to the mixture of various types of clouds

Summary

- Satellite-detected characteristics of water cloud optical property (τ_c and r_e) was simulated by bin microphysics cloud model
  - Positive correlation : no drizzle regime
  - Negative correlation : drizzling regime
- Responsible processes were identified
  - Positive correlation : condensation
  - Negative correlation : coagulation
- Aerosol effect on cloud was also investigated
  - Sensitivity from bin model close to in-situ statistics
  - Global statistics from satellite may dilute the sensitivity

In the next step …

Global NHM NICAM



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Spectral bin microphysics