A study of microphysical mechanism for correlation patterns between droplet radius and optical thickness of warm clouds simulated idealized and downscaling simulation by a three-dimensional spectral bin microphysical model.

Yousuke Sato[1,3], Kentaroh Suzuki[2], Teruyuki Nakajima[1]

1:Atmosphere and Ocean research institute, Univ. Tokyo

2:Colorado States University

3:Research fellow of JSPS

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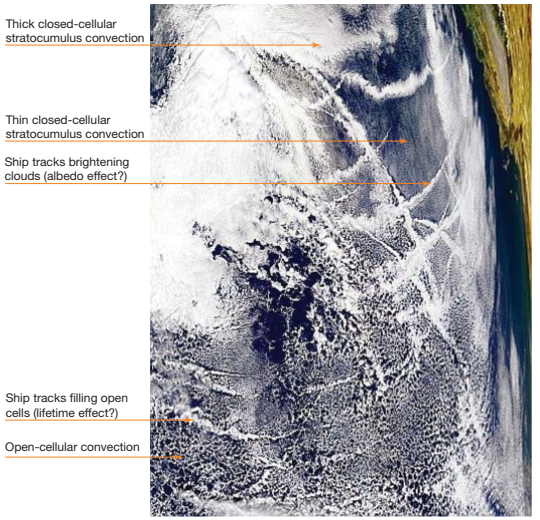
OUTLINE

1. **Introduction**
2. Idealized experiment
3. Downscaling simulation
4. conclusion

MARINE STRATOCUMULUS



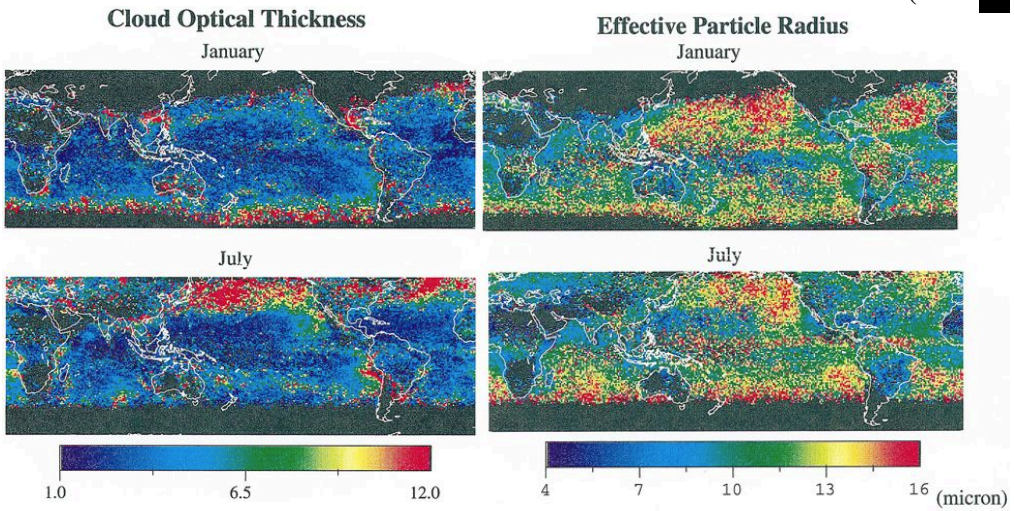
Stevens and Feingold (2009)

Warm clouds (which include marine stratocumulus (Sc)) make significant influence on radiation budget of earth's climate.

Radiative properties of cloud are characterized cloud optical parameter like Cloud effective radius (r_{eff}) and optical thickness (COT).

COT and r_{eff} are observed by satellite and aircraft (e.g. Han et al. 1994, Kawamoto et al. 2001, Brenguier et al. 2001).

Kawamoto et al. (2001



Nakajima et al. (1991) : Air-craft observation in FIRE region

- Positive correlation ⇒ non-drizzling clouds
- Negative correlation ⇒ drizzling clouds

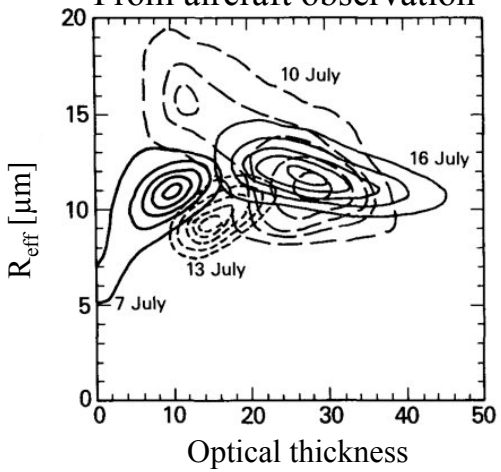
Nakajima and Nakajima (1995): Satellite observation (in FIRE region)

Correlation pattern reflects growth stage of cloud

The difference of the pattern have important implications for radiative characteristics of cloud.

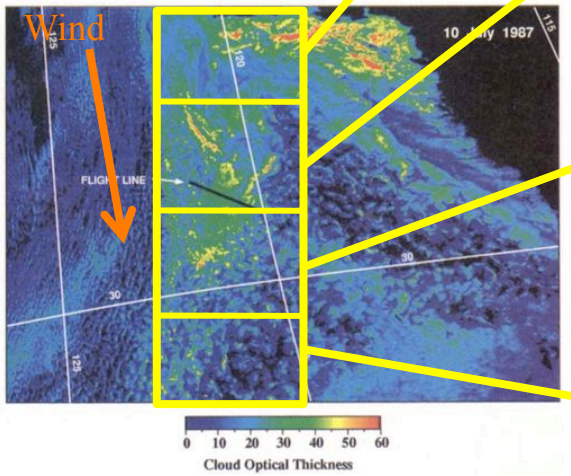
⇒It is important to understand this pattern.

From aircraft observation

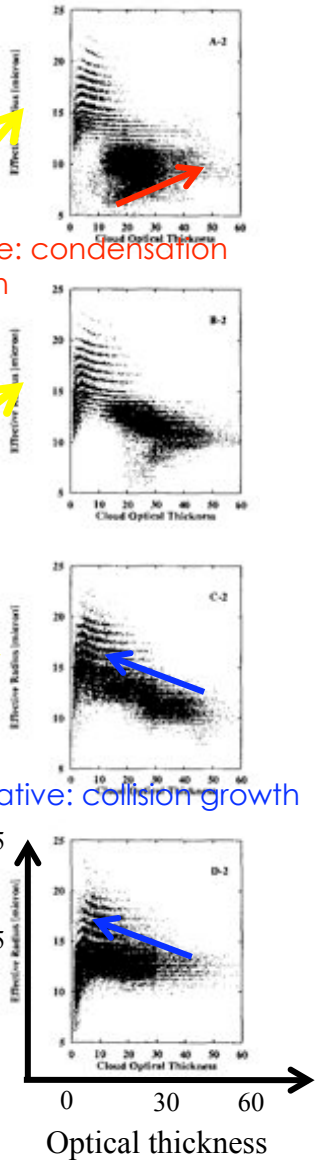


Nakajima et al. [1991]

COT from Satellite



Nakajima and Nakajima [1995]

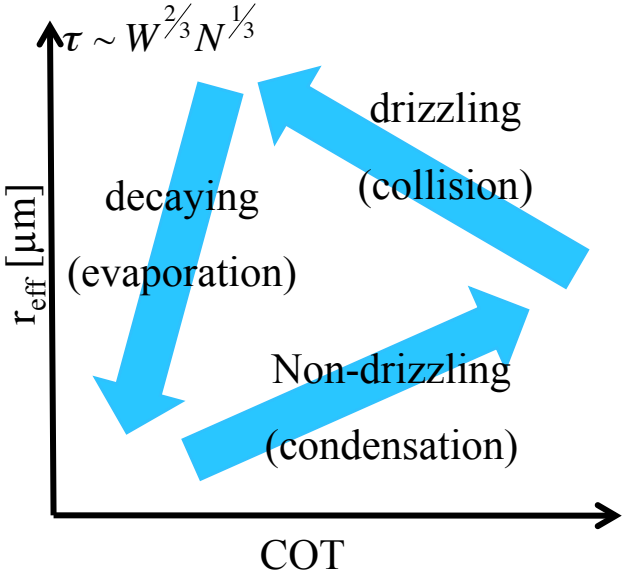


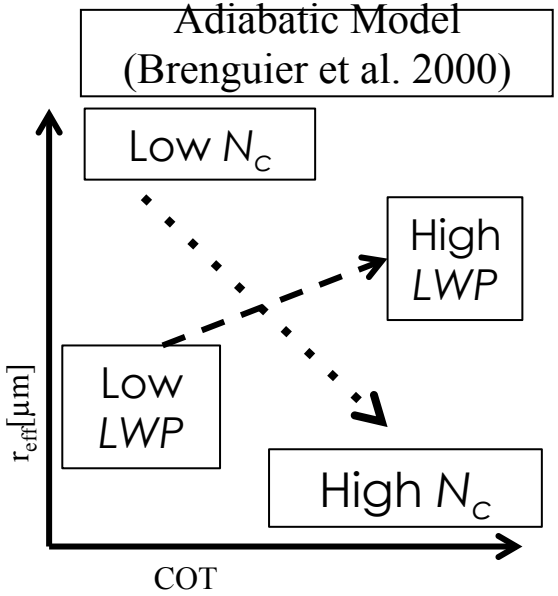
Spectral Bin model is very strong tool to investigate COT and r_{eff}

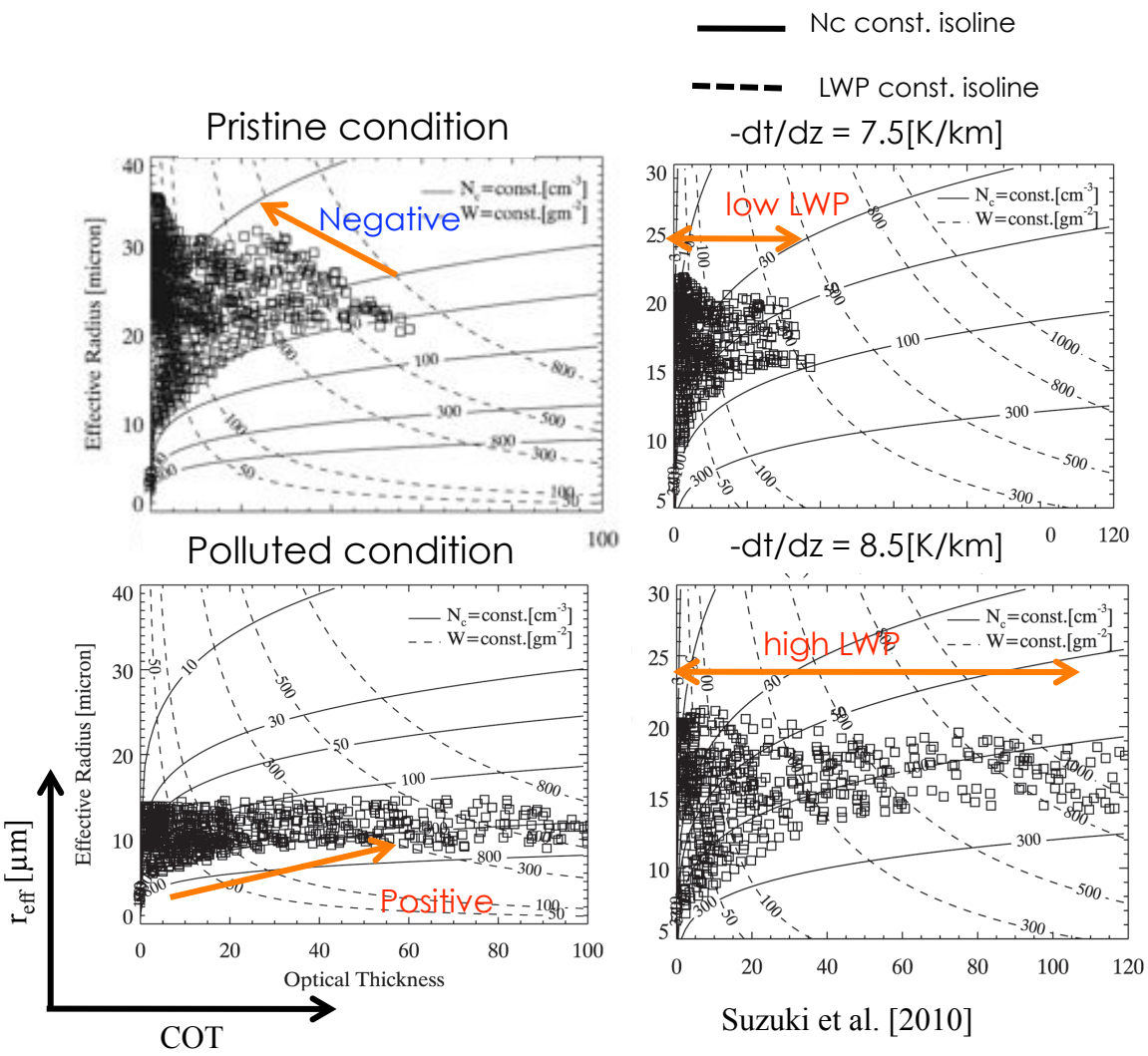
PREVIOUS MODELING STUDY (SUZUKI ET AL. 2006, 2010)

$r_{eff} \sim W^{1/3} N^{-1/3}$

$\tau \sim W^{2/3} N^{1/3}$







These results are obtained from coarse grid (500m) two-dimensional, isolated cloud modeling

PURPOSE

- Investigate effects of aerosol and stability on the pattern by three dimensional real type simulation for wide calculation domain.

problem

1. High resolution is needed to represent Sc
2. Computational cost of spectral bin model is too large to do wide area simulation with high resolution.

Strategy

1. Investigate effects of resolution on the pattern by idealized simulation for relatively narrow calculation domain.
2. Investigate effects of aerosol amount and stability on the pattern by real type, three dimensional spectral bin model for wide area.

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MODEL DESCRIPTION

Model [JMANHM+HUCM (Iguchi et al., 2008)]

Dynamics : JMANHM (Saito et al., 2001, 2006)

Turbulence : Deadroff (1980)

Cloud Microphysics :

- HUCM (spectral bin) (Khain et al., 2000)+Aero 5 version (Choi, 2010)
  - nucleation, condensation/evaporation, collision (only warm cloud)

Radiation : Simple scheme (Stevens et al. 2005)

Regeneration of aerosol (Feingold, 1996)

EXPERIMENTAL SET (BASED ON DYCOMS-II RF02)

Experimental set

Calculation domain : 30 km × 30km × 1.5 km

Grid resolution : 50m (horizontal), 20m (vertical)

Aerosol chemical component and amount: Sulfate (500cc^{-1})

Calculation time : 8 hour (dt=0.5 s for dynamics)

Surface flux : 16 Wm^{-2} (latent), 93 Wm^{-2} (sensible)

Large scale subsidence : 3.75×10^{-6} s^{-1}

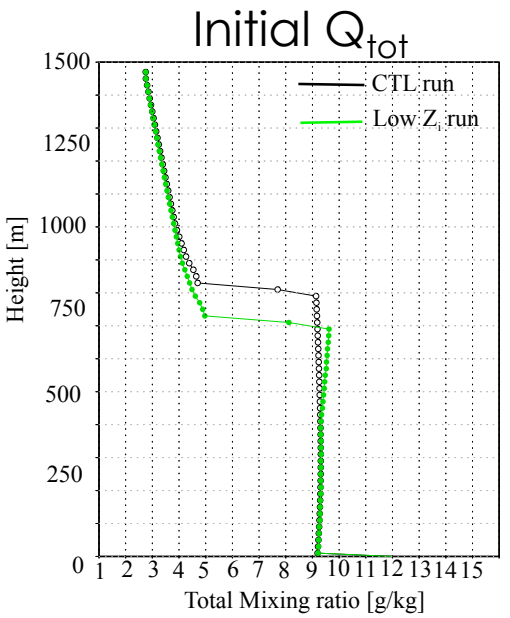
Initial dynamical condition :

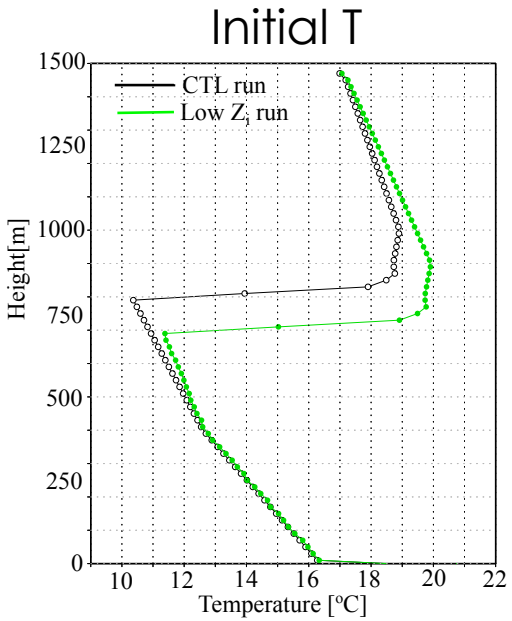
Based on DYCOMS-II RF02 model study (Ackermann et al., 2009)

Difference from Ackermann et al.(2009) : Wide calculation domain, no general wind

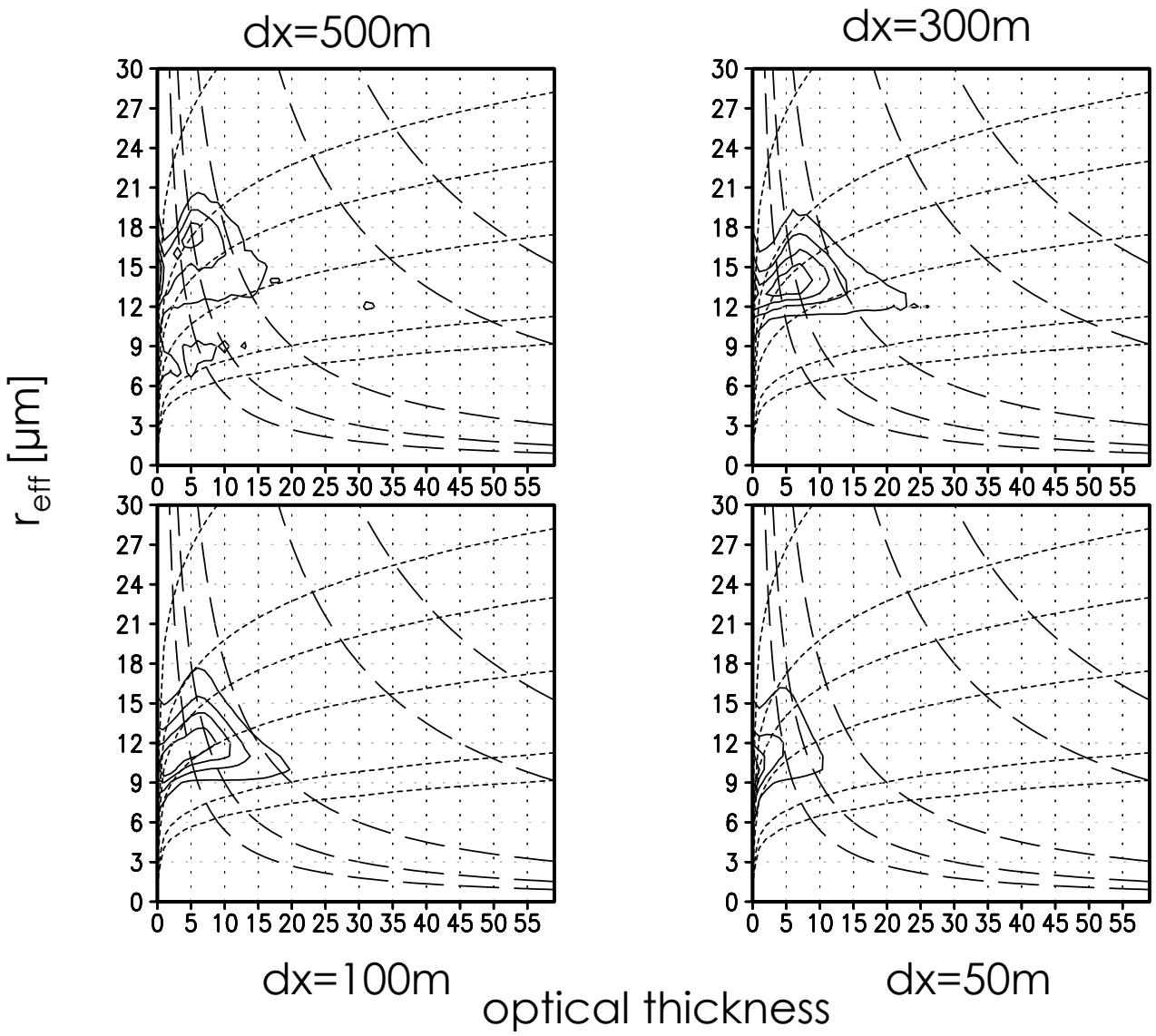
Sensitivity experiment :

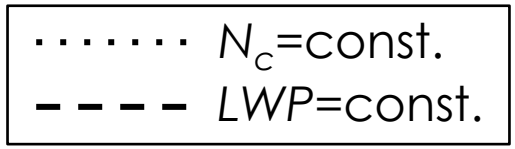
1. Grid resolution(50m, 100m, 300m, 500m)
2. Inversion height (800m, 600m)
3. Aerosol amount (60 cc^{-1} (Pristine), 500 cc^{-1} (Polluted))

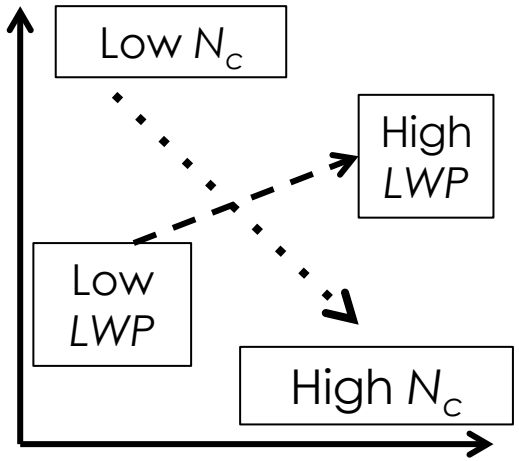




EFFECT OF HORIZONTAL RESOLUTION ON THE PATTERN







SENSITIVITY FOR AEROSOL AMOUNT AND INVERSION HEIGHT

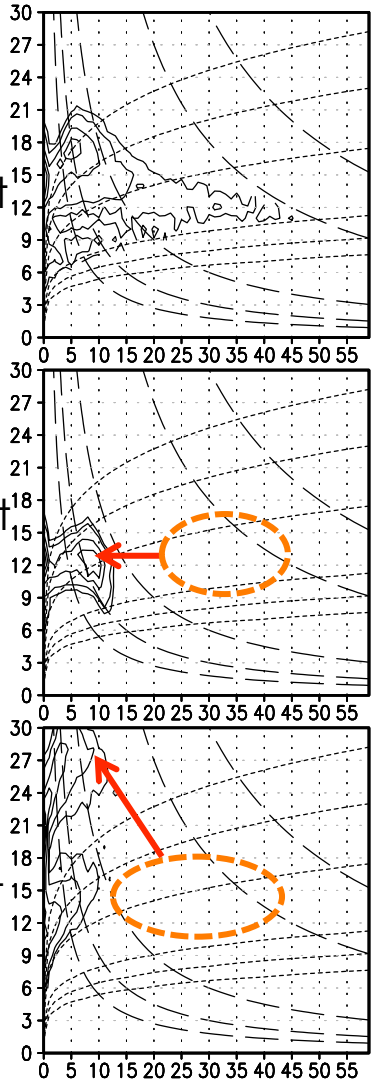
dx=500m

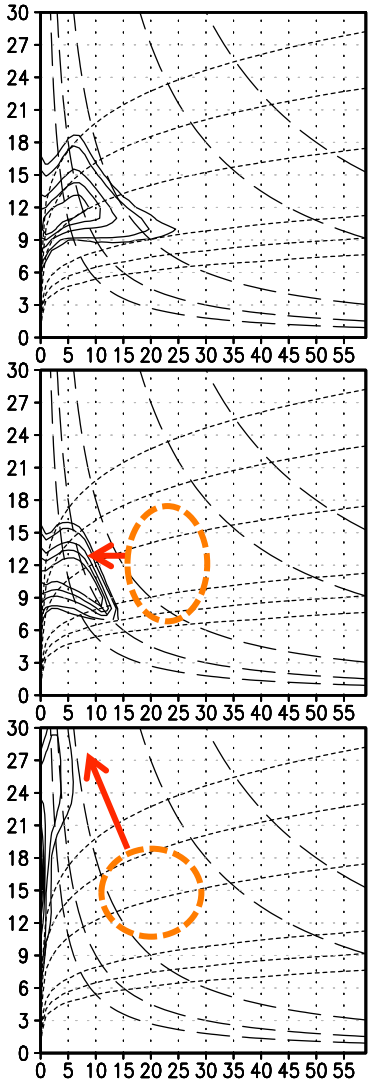
dx=100m

Polluted(500cc^{-1})
CTL inversion height

Polluted(500 cc^{-1})
Low inversion height

Pristine(60cc^{-1})
CTL inversion height



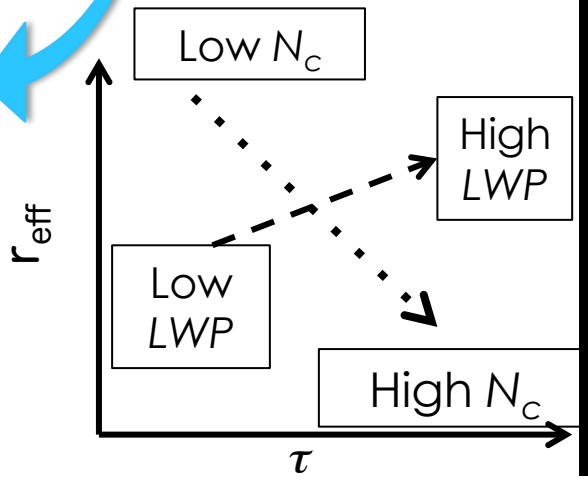


GrADS: COLA/IGES

N_c=const.
LWP=const.

Decrease inversion height

Decrease aerosol amount



FROM IDEALIZED STUDY

- **Grid resolution can affect the correlation pattern.**
- **In spite of this effect, response of the correlation pattern to aerosol amount and inversion height is not dependent upon resolution.**

OUTLINE

1. Introduction
2. Idealized experiment
3. **Downscaling simulation**
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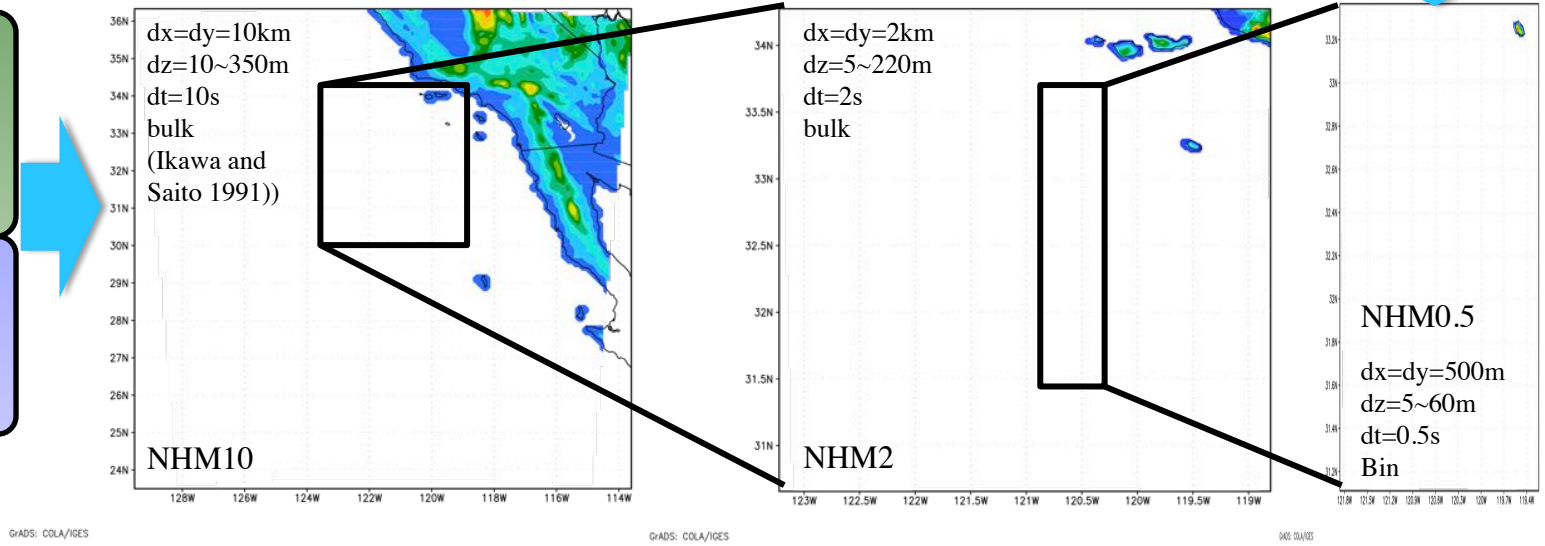
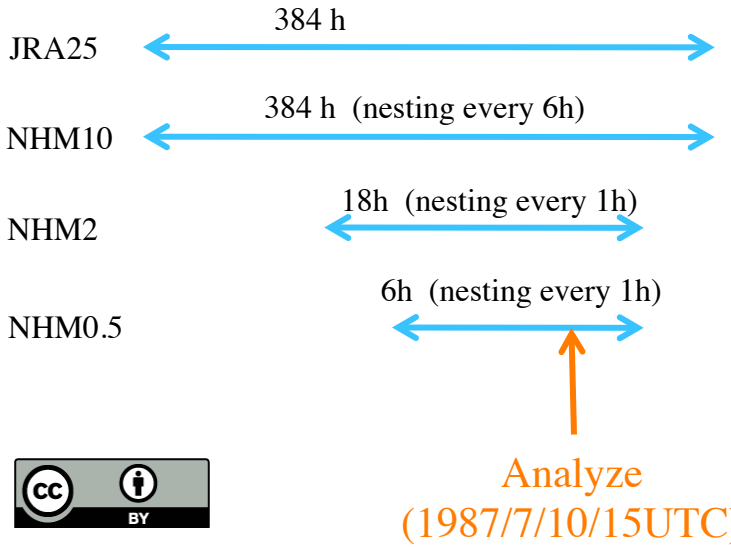
EXPERIMENTAL SET

SPRINTARS
(Takemura etal 2005)
aerosol

GTOPO-30
Topography
Data

JRA-25
reanalysis

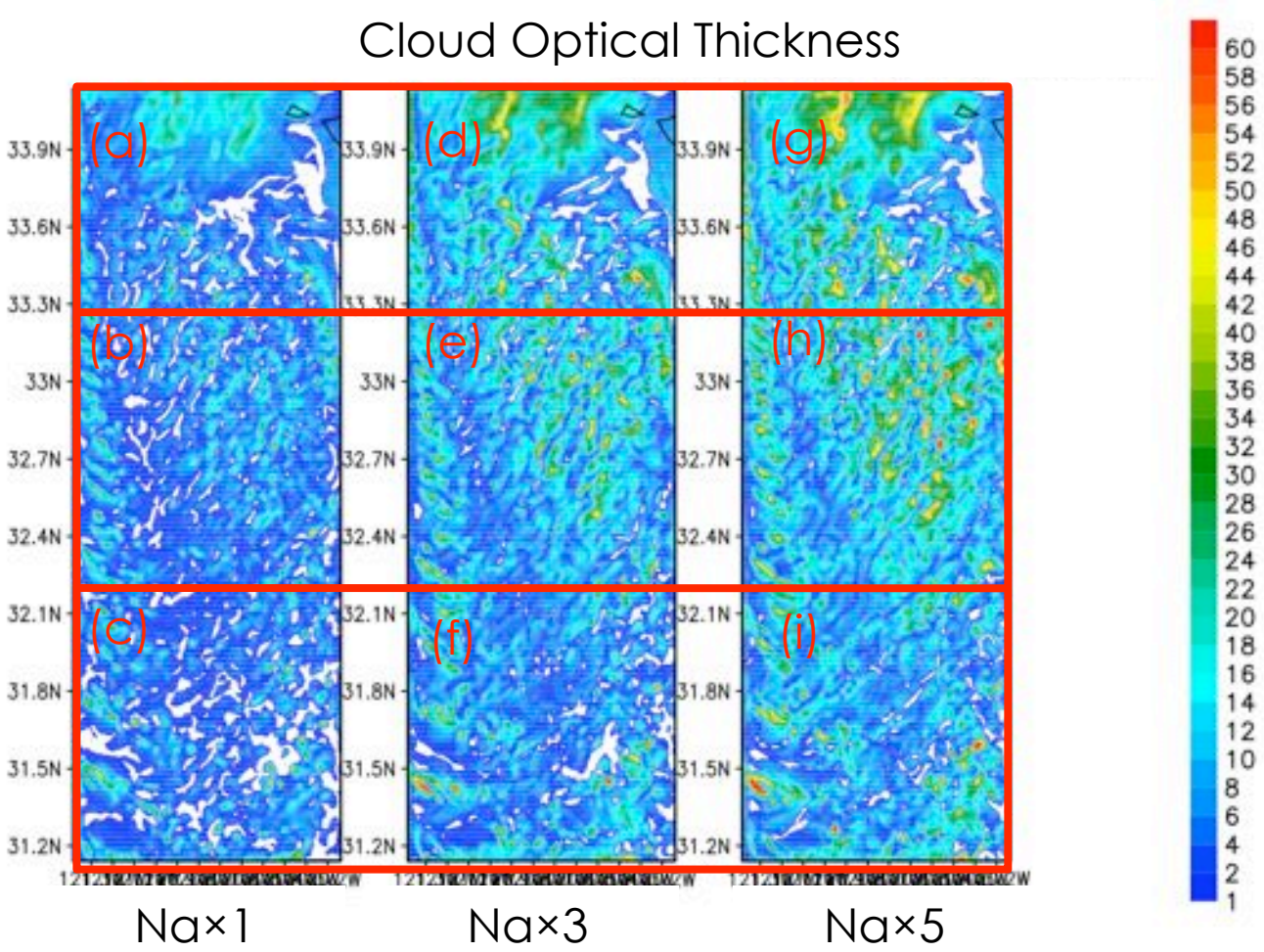




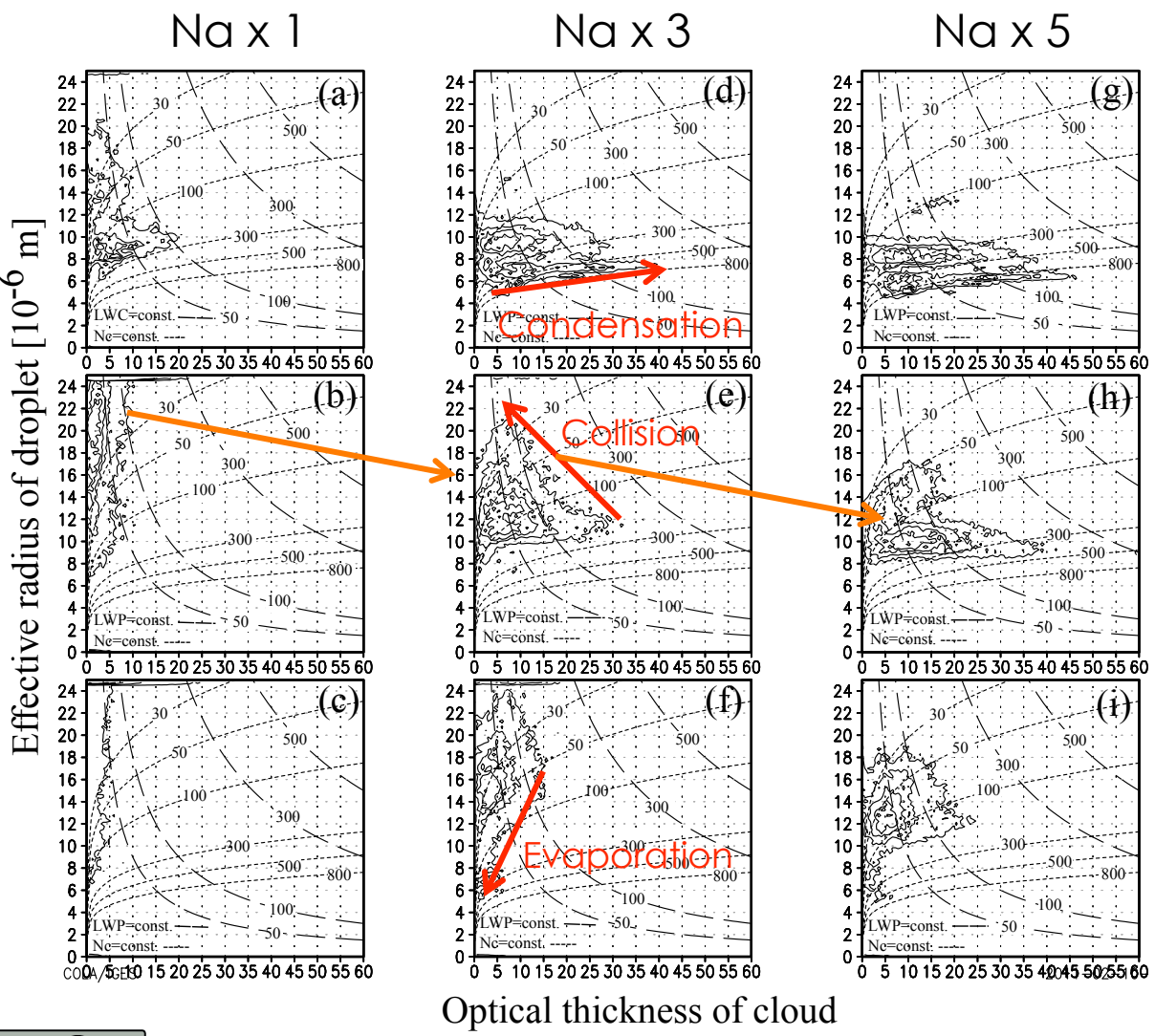
Parameters changed in sensitivity experiments

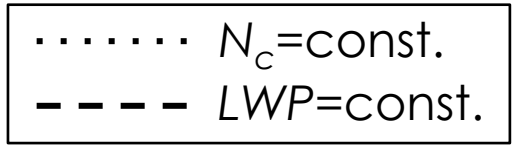
- Aerosol number concentration (×1~5)
- Height of inversion (+300, +500m)

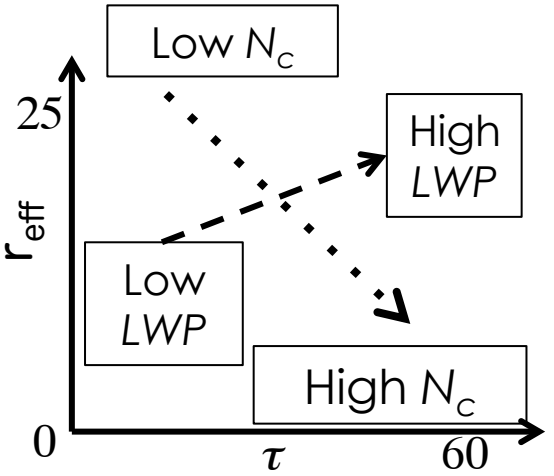
SENSITIVITY OF AEROSOL CONCENTRATION



CORRELATION PATTERN BETWEEN OPTICAL THICKNESS AND EFFECTIVE RADIUS

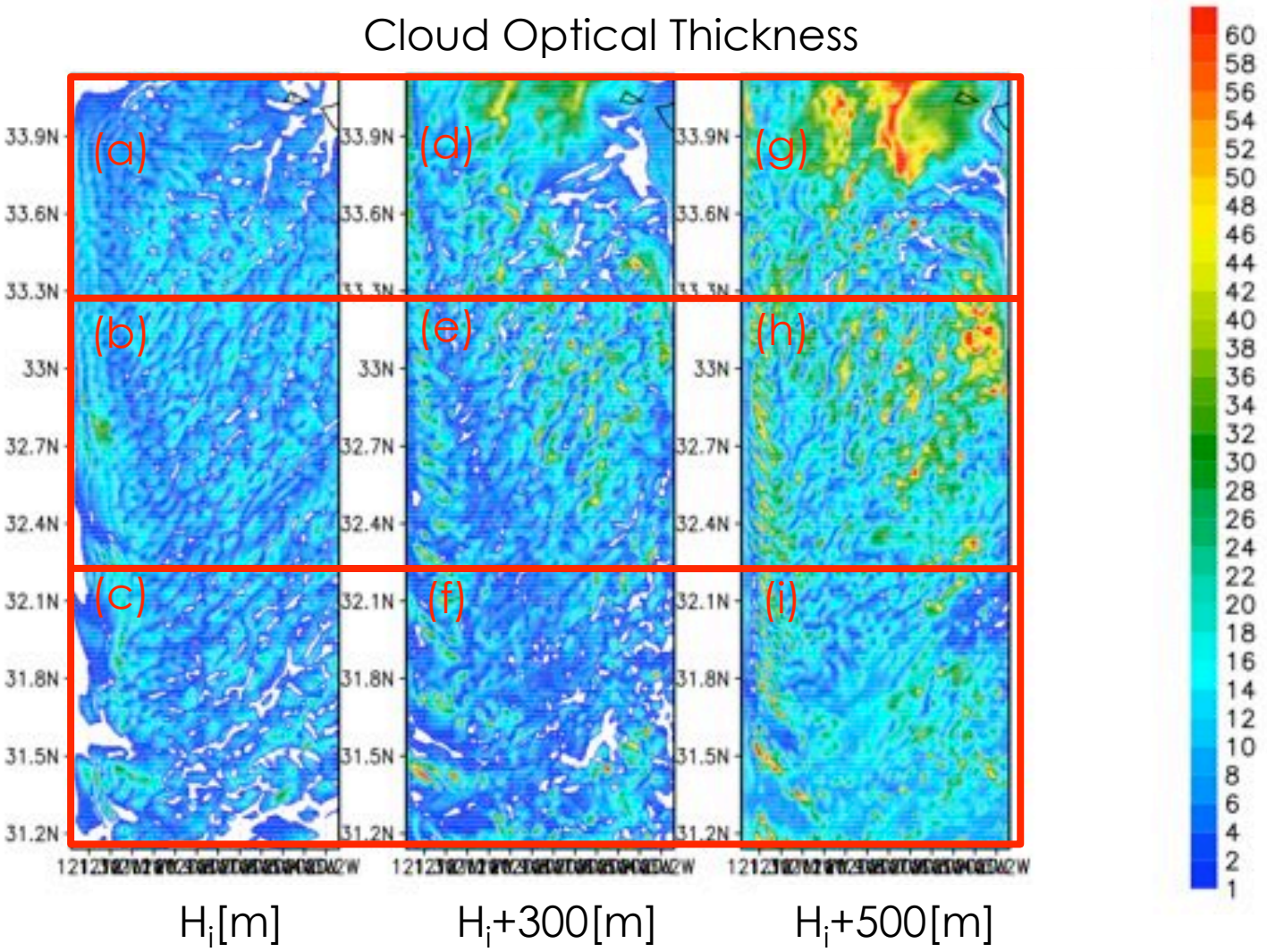






Large Aerosol amount
↓
High N_c
(LWP is almost const.)

SENSITIVITY TEST OF INVERSION HEIGHT

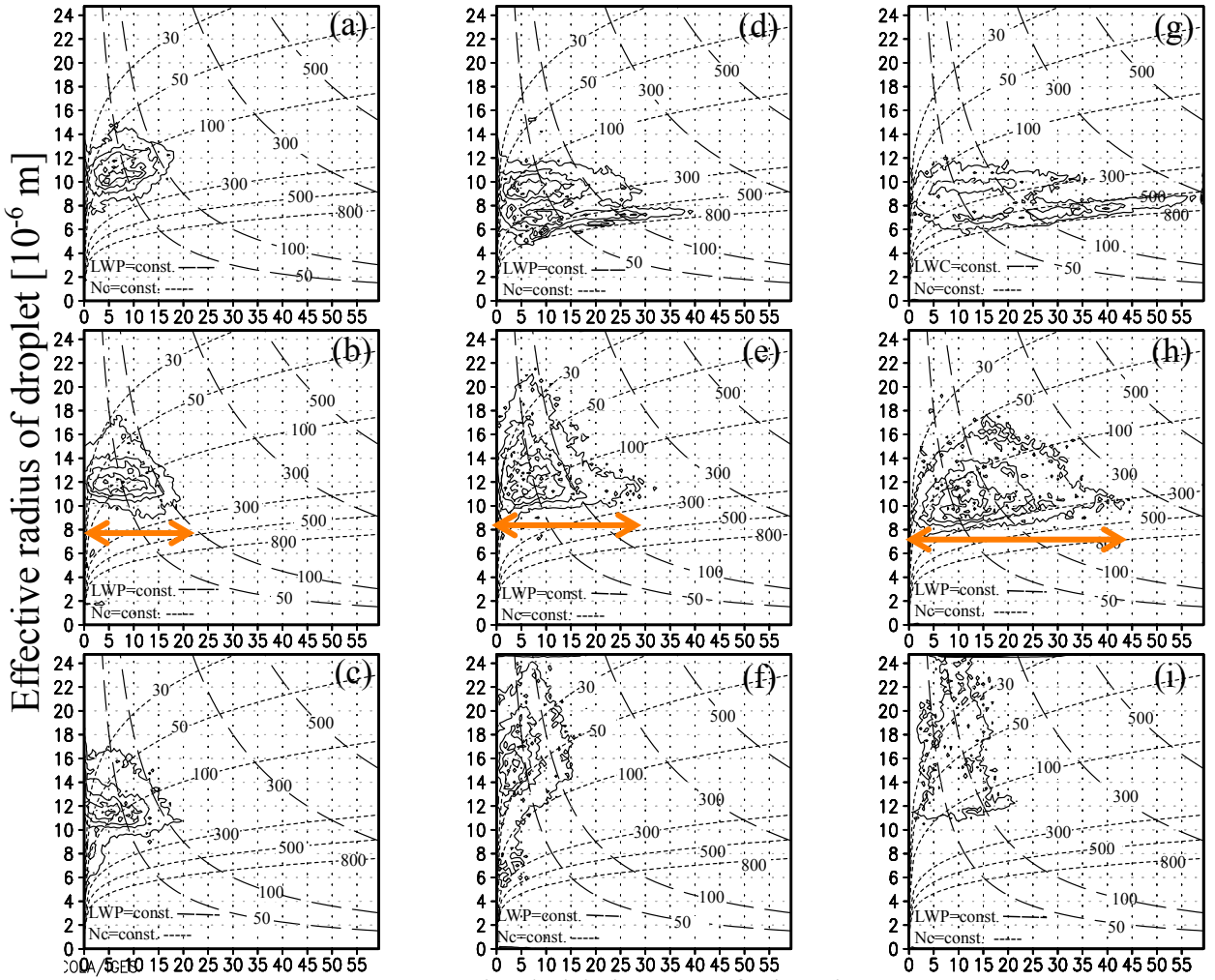


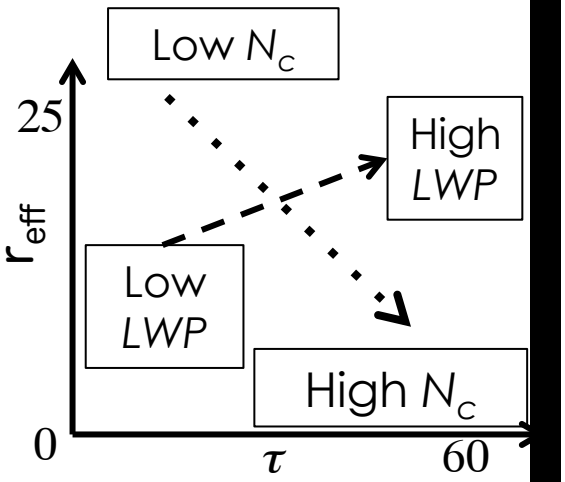
GrADS: COLA/IGES

CORRELATION PATTERN BETWEEN OPTICAL THICKNESS AND EFFECTIVE RADIUS

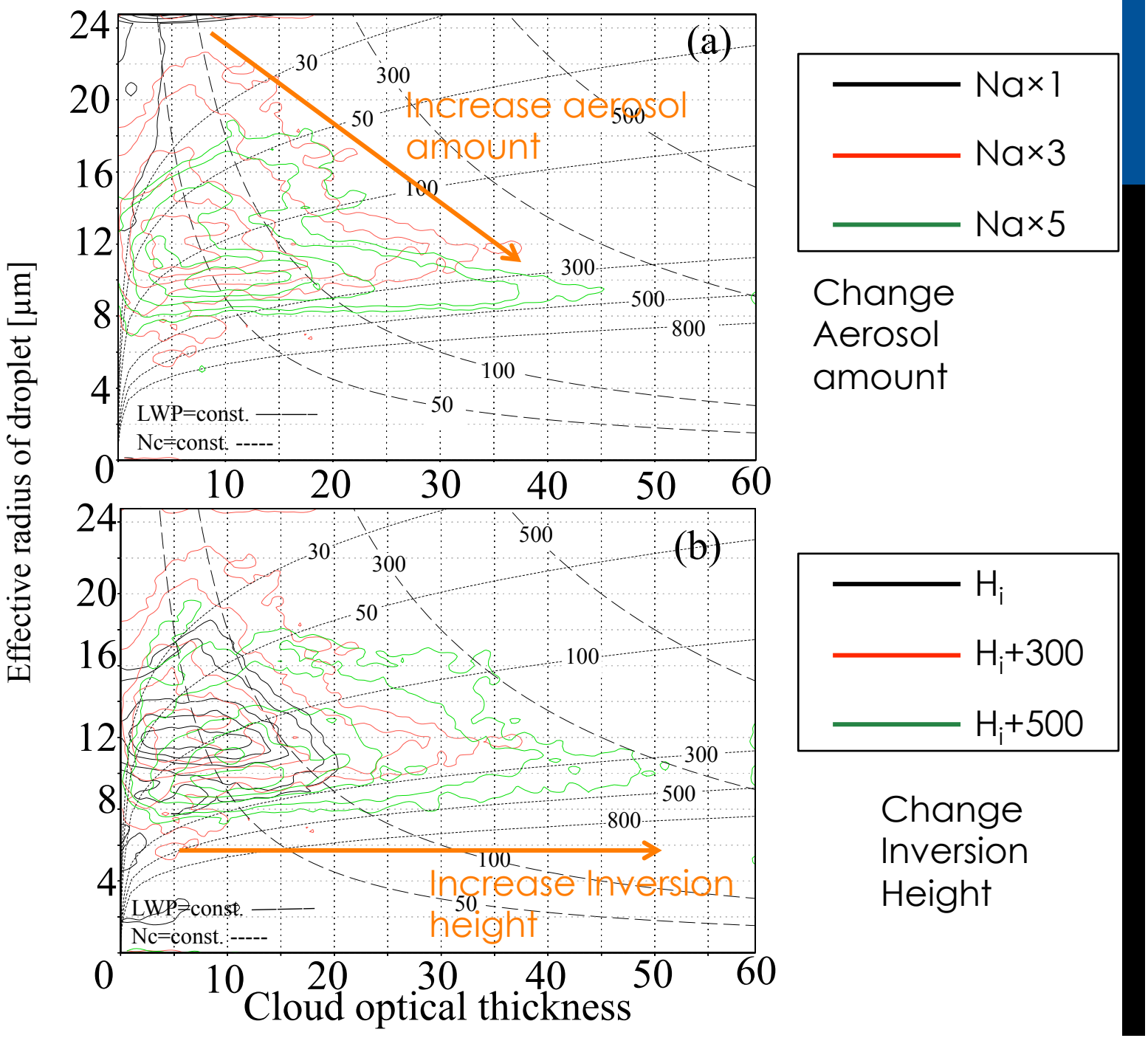
N_c=const.
LWP=const.

H_i[m] H_i +300[m] H_i+500[m]

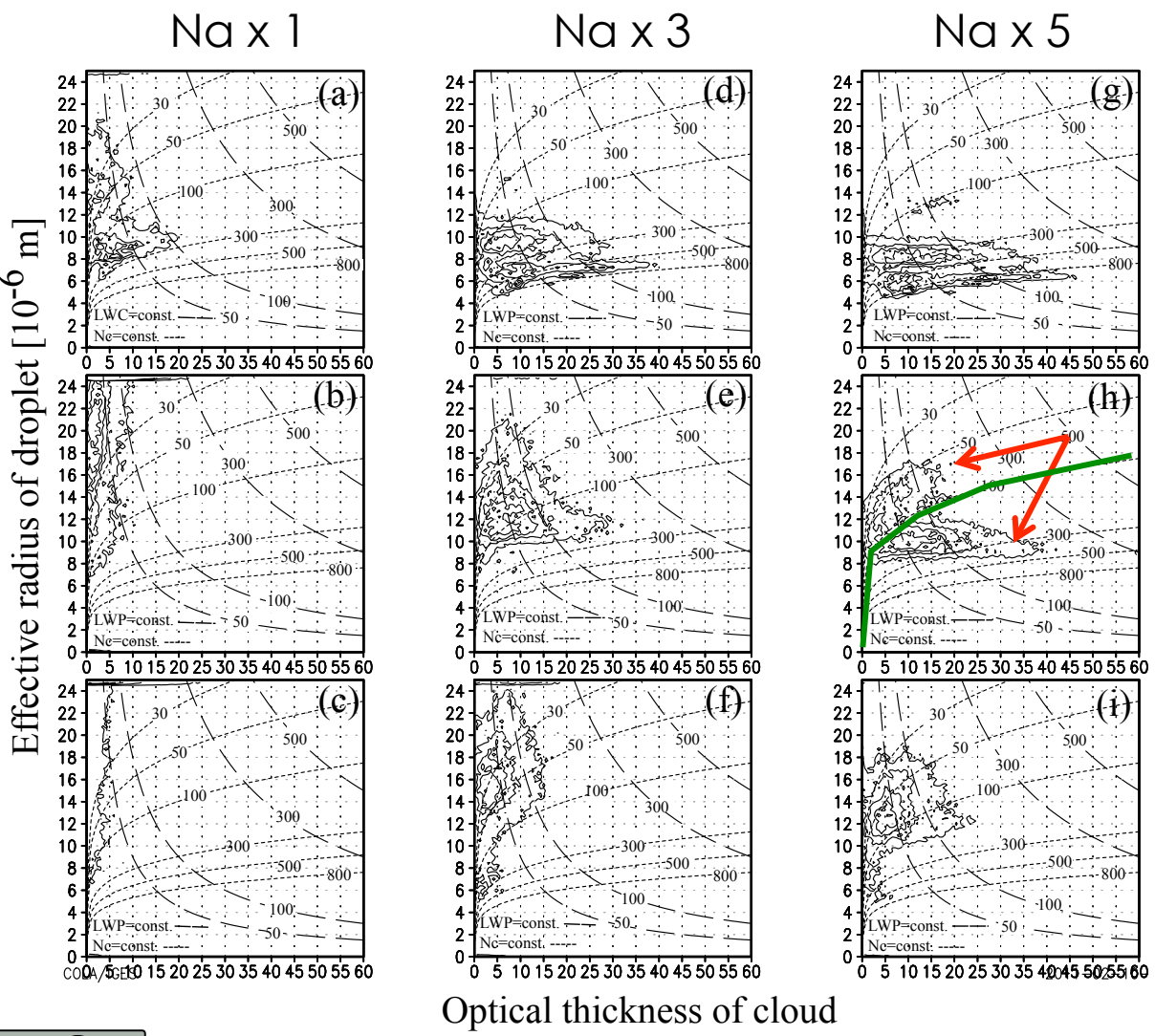




High Inversion height
(High cloud top)
↓
High LWP
(N_c is almost const.)


(a)
(b)
Increase aerosol amount
Increase Inversion height
LWP=const.
Nc=const.
Effective radius of droplet [μm]
Cloud optical thickness
Na×1
Na×3
Na×5
Change Aerosol amount
H_i
H_i+300
H_i+500
Change Inversion Height

CORRELATION PATTERN BETWEEN OPTICAL THICKNESS AND EFFECTIVE RADIUS

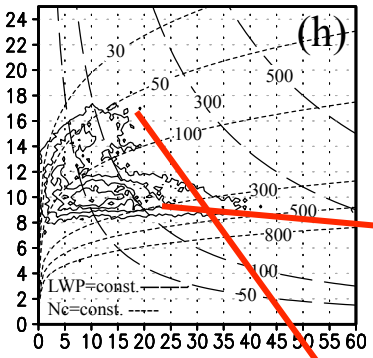


N_c=const.

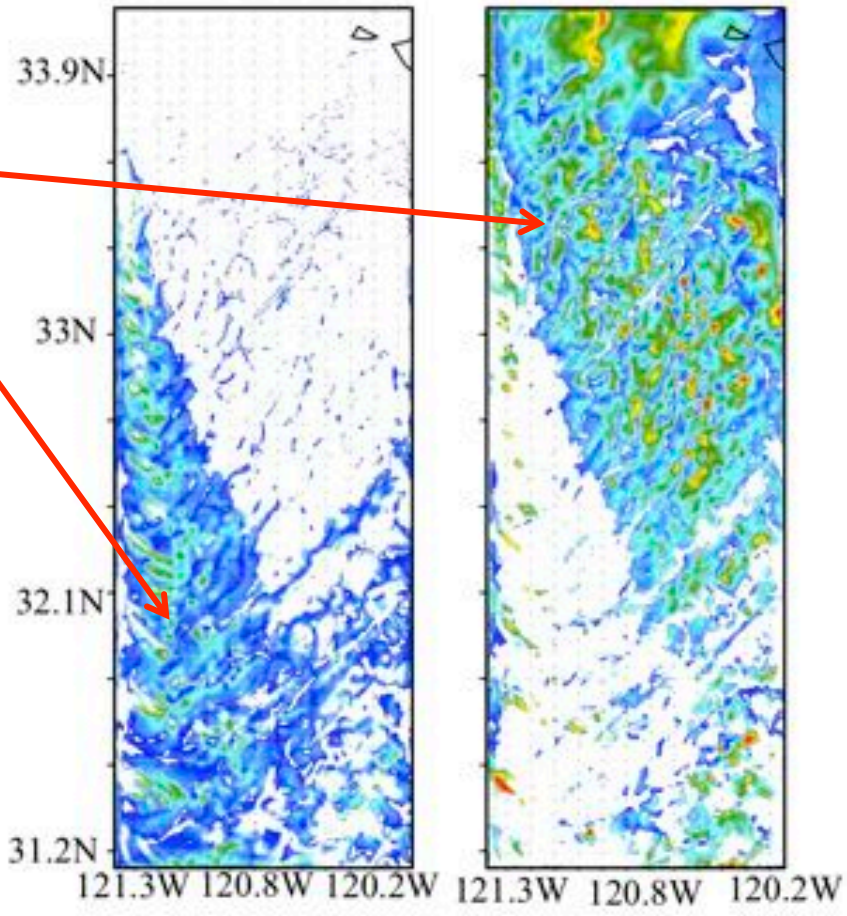
LWP=const.

N_c=100 cc^{-1}

OPTICAL THICKNESS DIVIDED 100 CC^{-1}

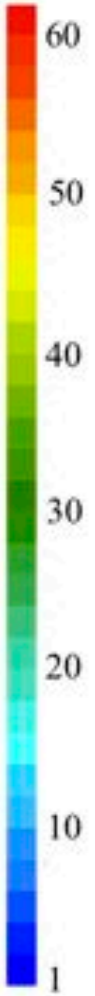


N_c<100 cc^{-1} N_c>100 cc^{-1}

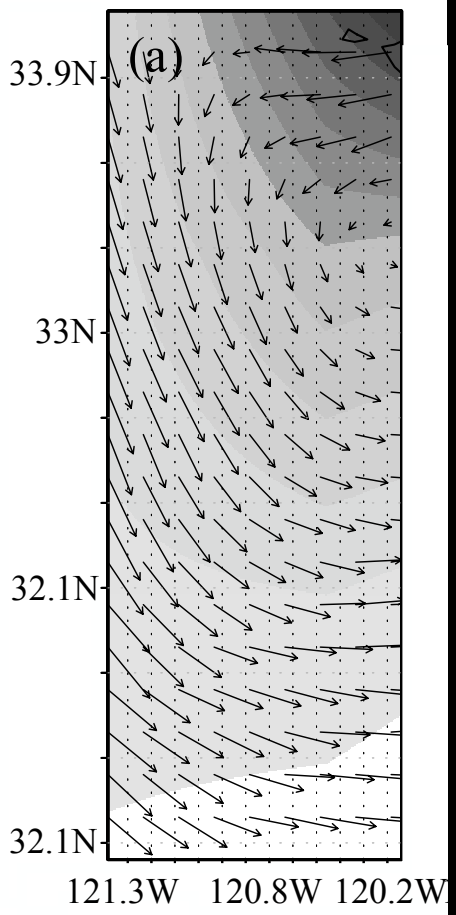


Clean airmass *Polluted airmass*

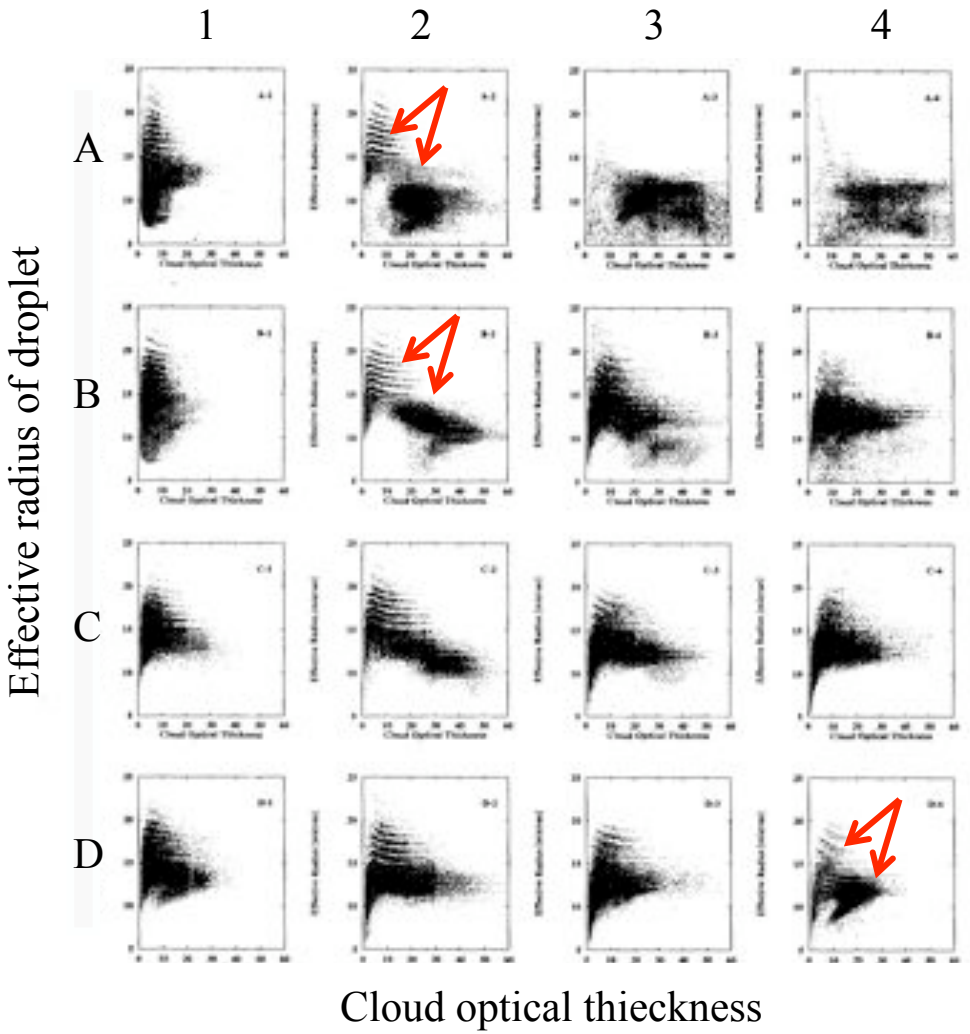
Correlation pattern are mixture of several type of cloud

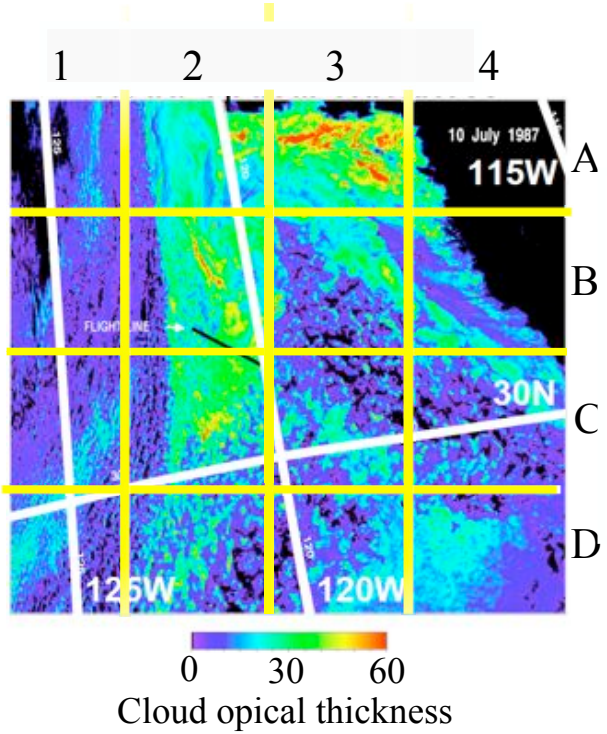


Aerosol and wind direction



SATELLITE OBSERVATION (NAKAJIMA AND NAKAJIMA 1995)





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CONCLUSION

- Three-dimensional simulation conducted to represent the correlation pattern between r_{eff} and τ.
- Resolution of grid affect the correlation pattern, but response of the pattern to aerosol amount and inversion height is not dependent upon resolution
- Responses of the pattern to aerosol amount and inversion height are same as that in previous study (Suzuki et al. 2010)
- The pattern consist of several type of clouds whose characteristics is different from each other.
- It is seemed that the pattern observed from satellite also consists several type of clouds.