The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2051-4

Workshop on High Resolution Climate Modelling

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Moist Physics Parameterization for High Resolution Climate Models

KANG In Sik

Seoul National University
School of Earth and Environmental Sciences
Department of Atmospheric Sciences
San 56-1 Shillim-dong, Kwanak-ku, Seoul 151-747
REPUBLIC OF KOREA

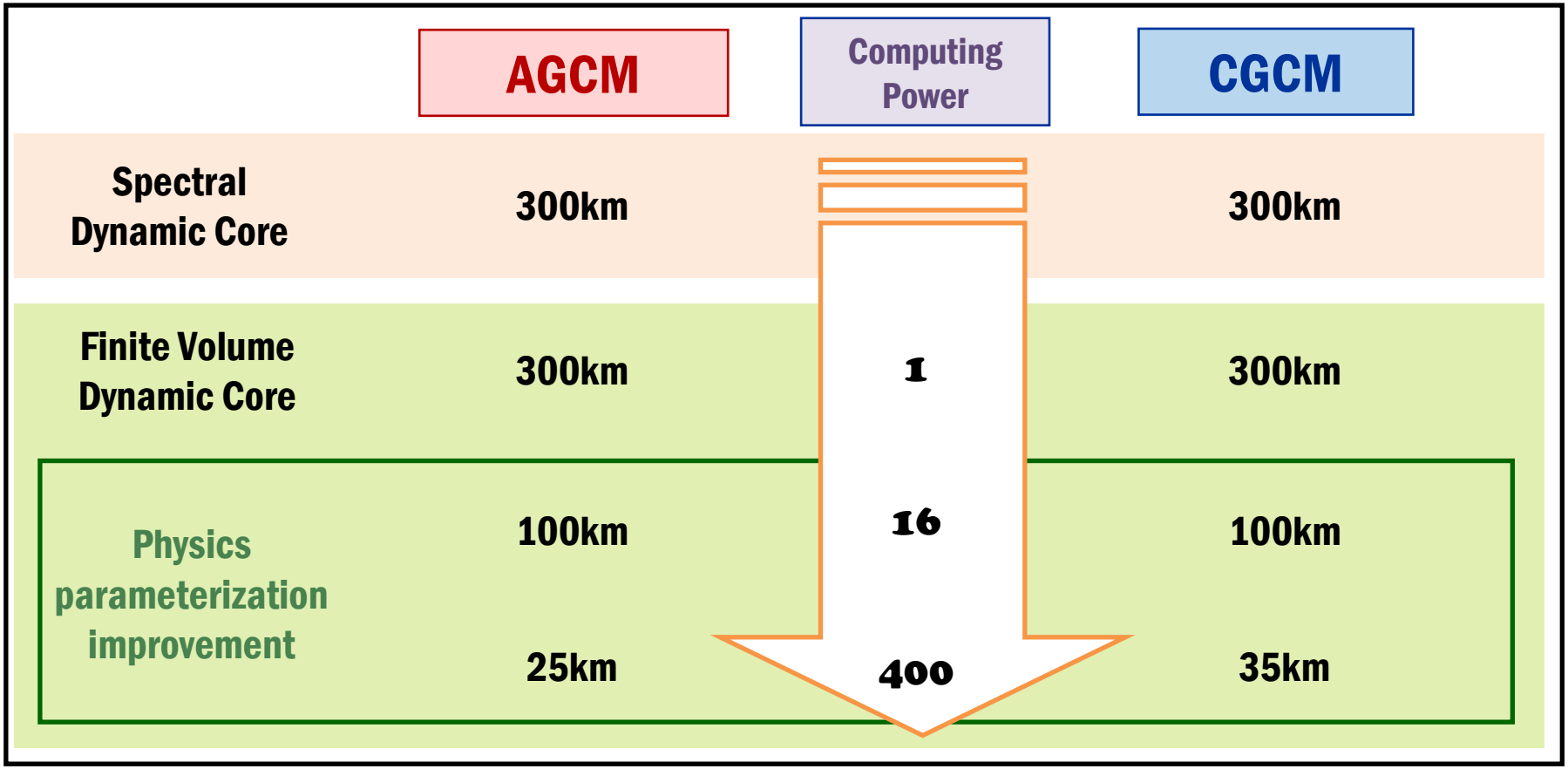
Moist Physics Parameterization for High Resolution Climate Models

In-Sik Kang

Seoul National University

Daehyun Kim, Sung-Bin Park, Ildae Choi, Young-Min Yang

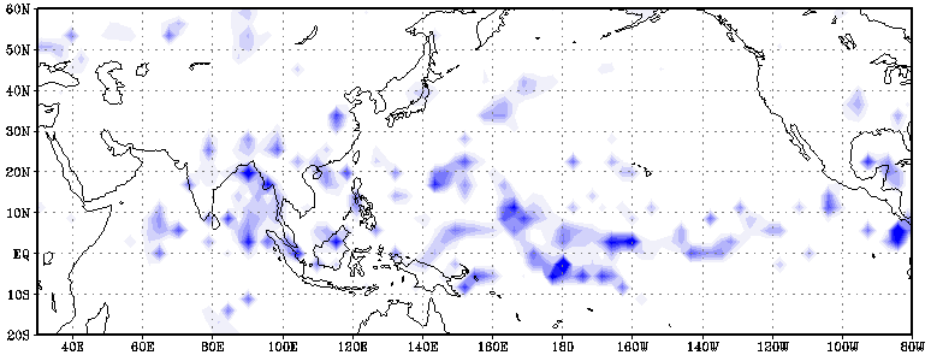
High resolution modeling



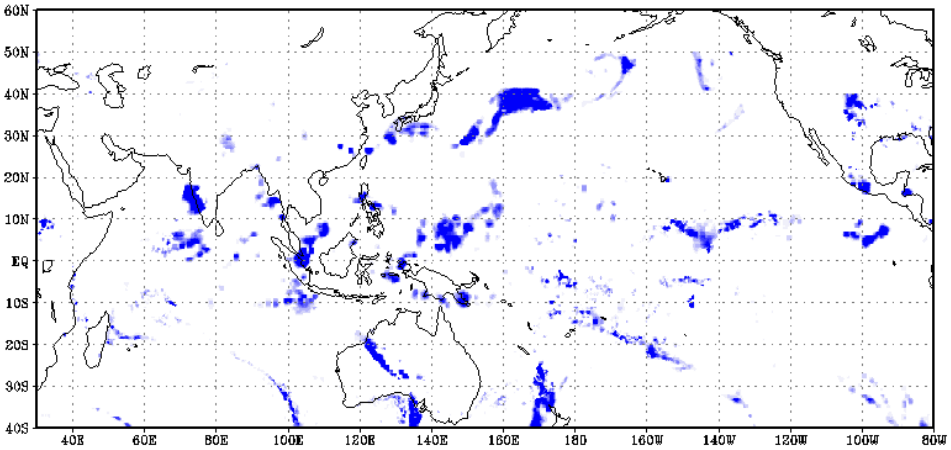
Resolution impact with same physics

prcp 1096hour T42

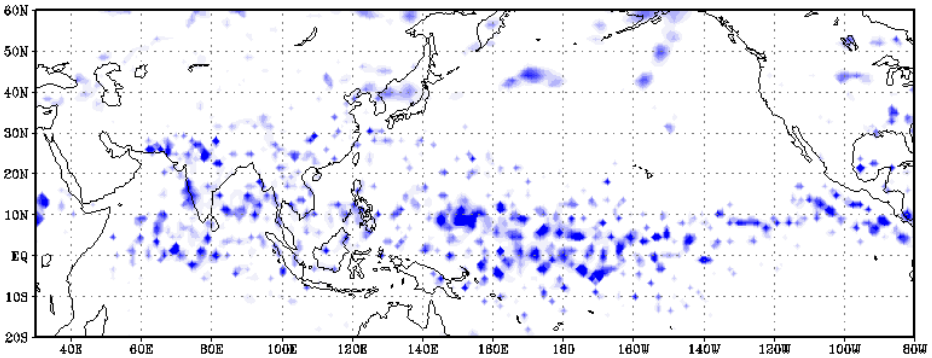
300km resolution



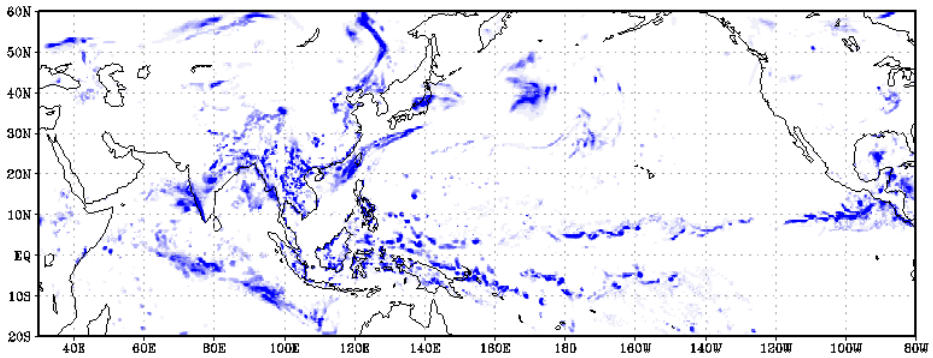
TRMM: Satellite data (Precipitation)



100km resolution

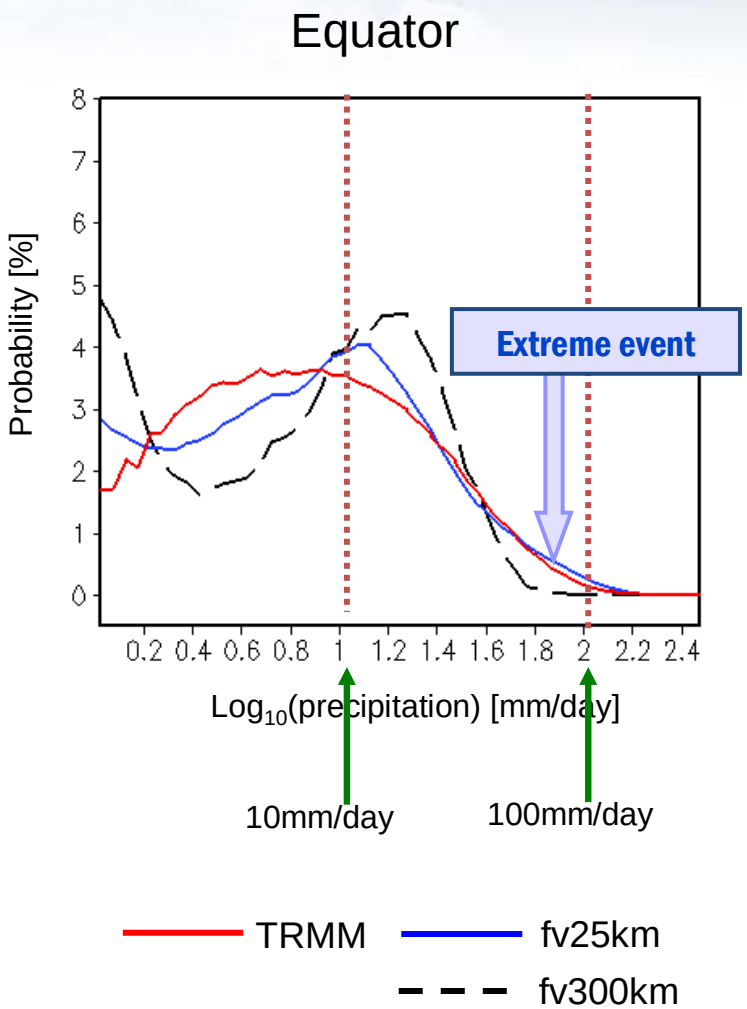


25km resolution



Advantage of high resolution

Probabilistic distribution of different resolution



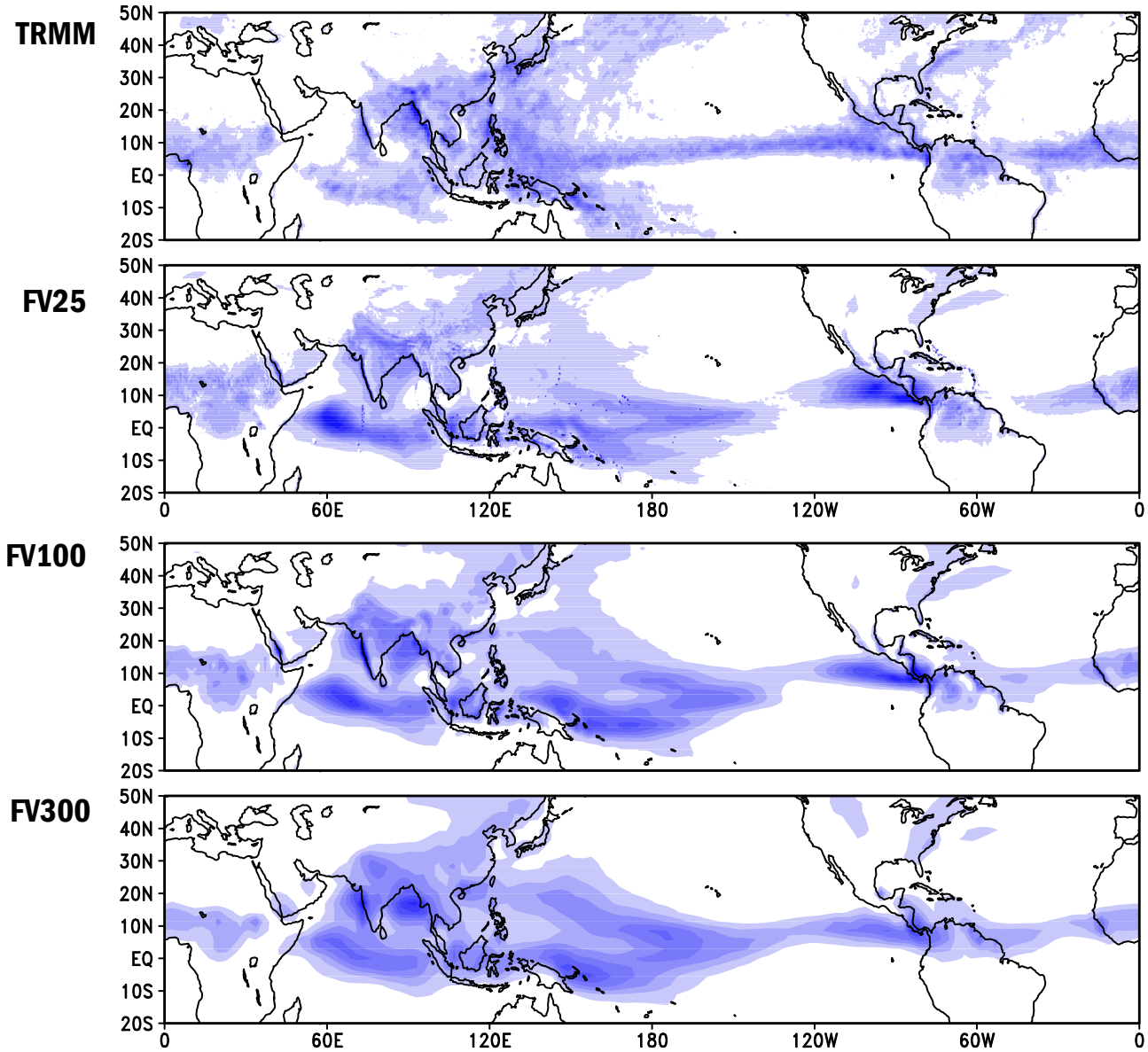
AGCM Mean state

Precipitation

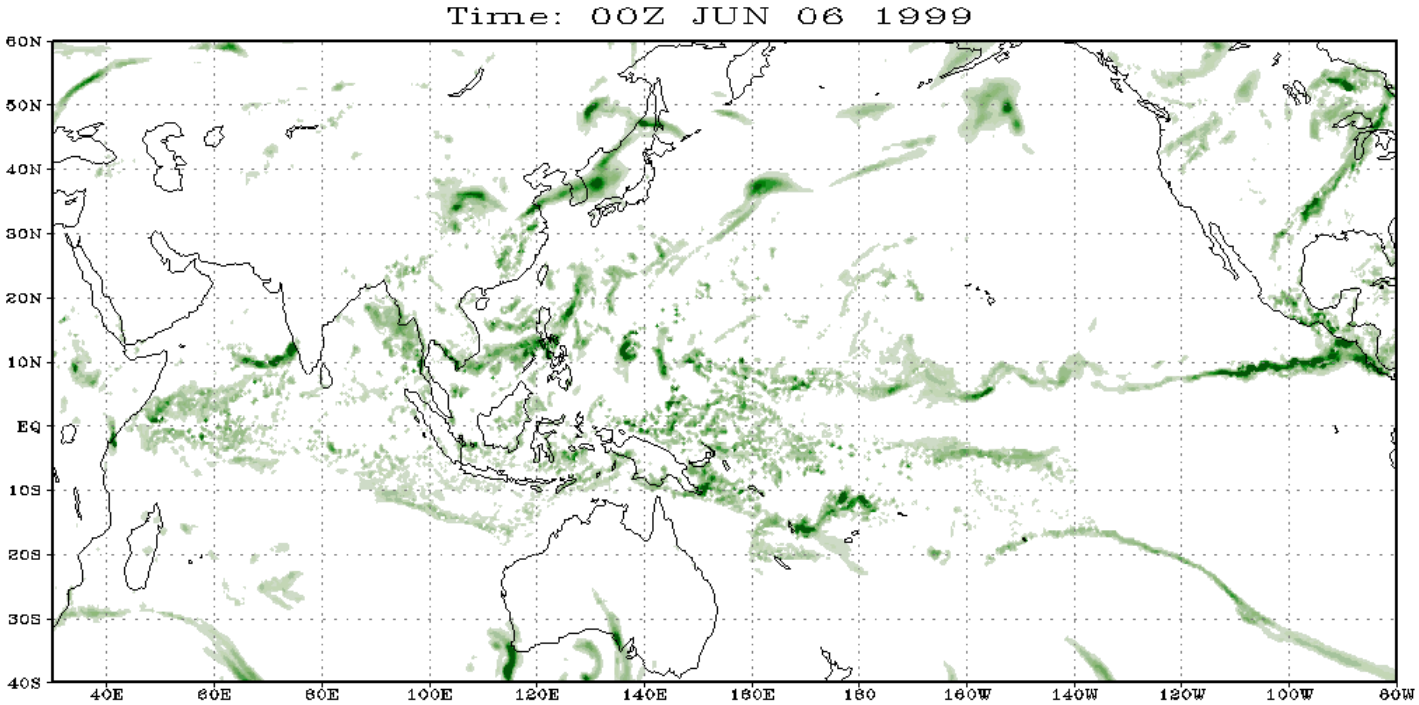
Seasonal Mean

1997/1999
JJA mean

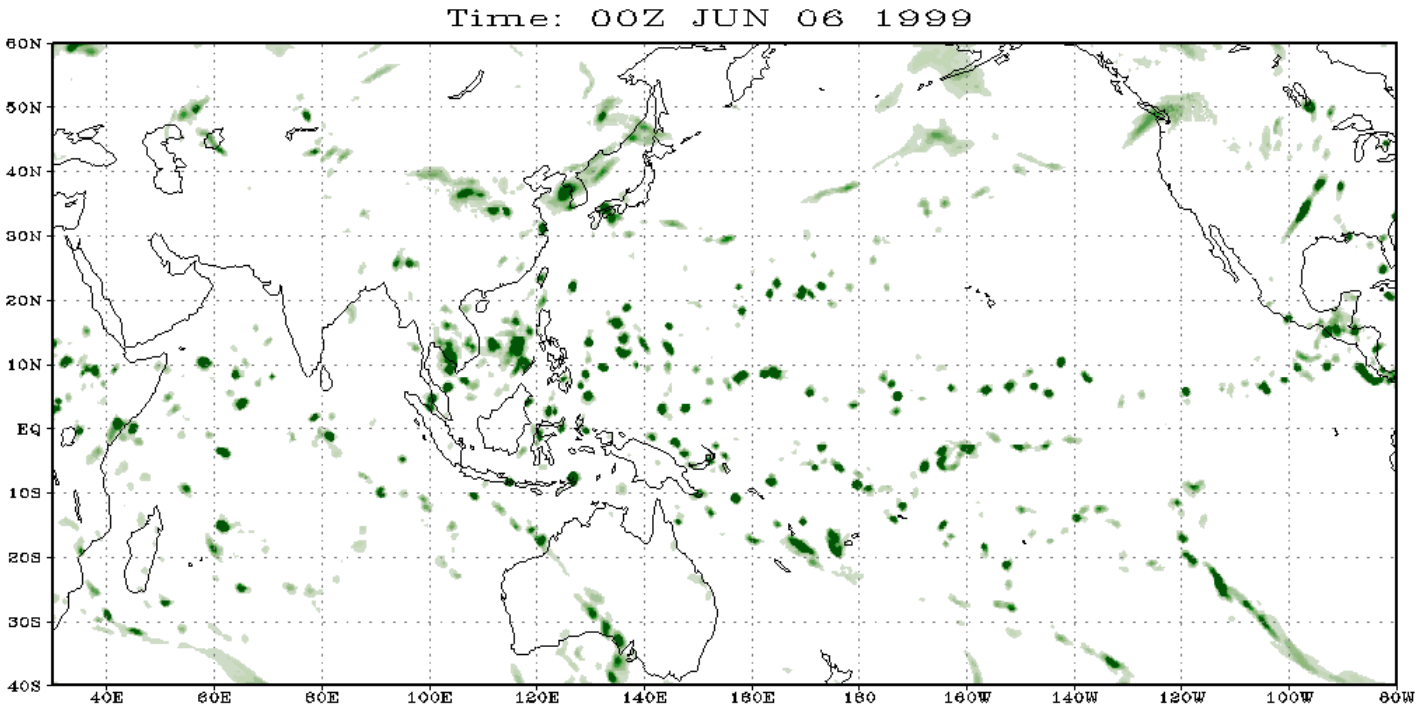
precipitation



RAS



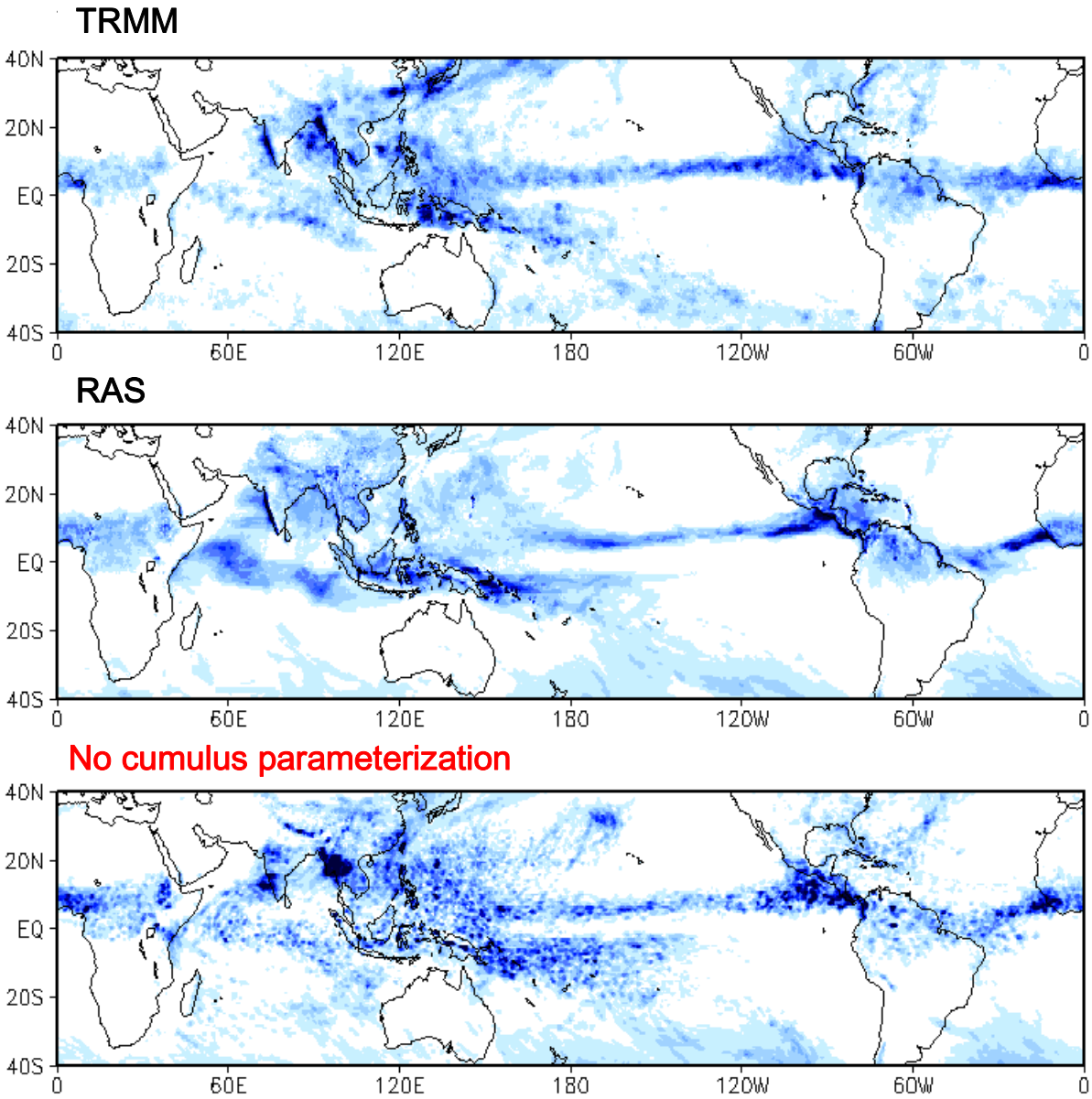
No cumulus parameterization



Monthly Mean

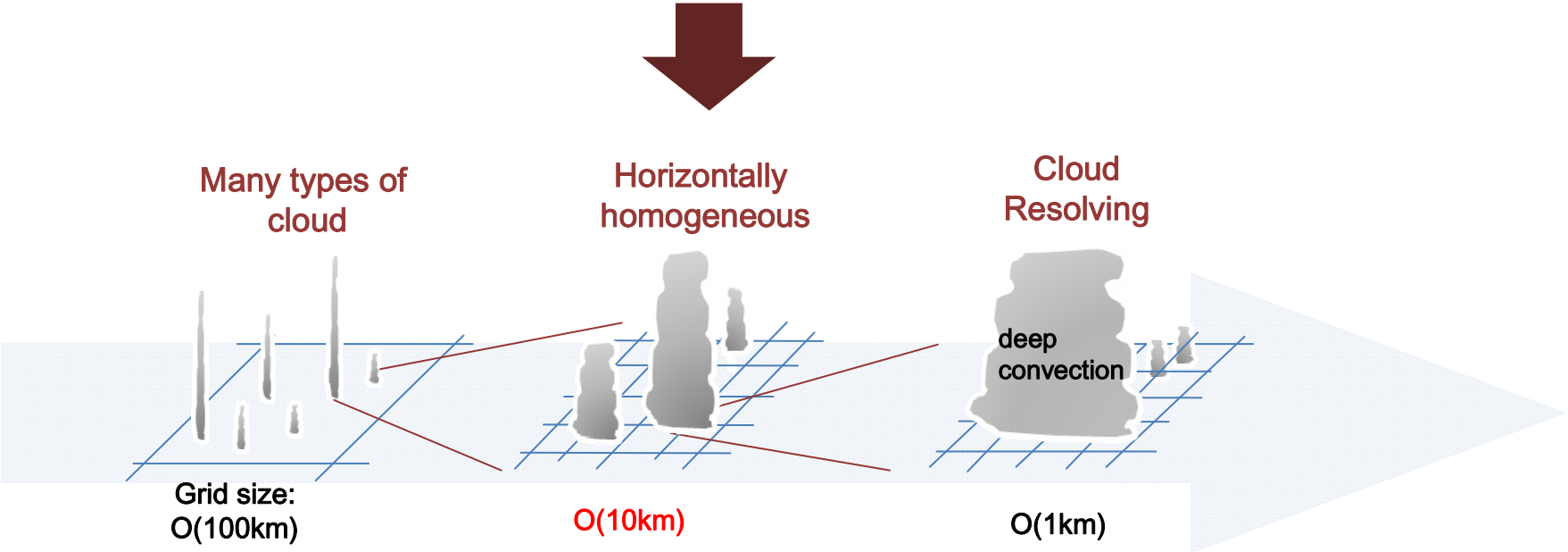
1999
June mean

precipitation



Parameterization is still needed for O(10km) models
But not as it is in O(100km) models

Targeted resolution



➢ Equilibrium assumption →

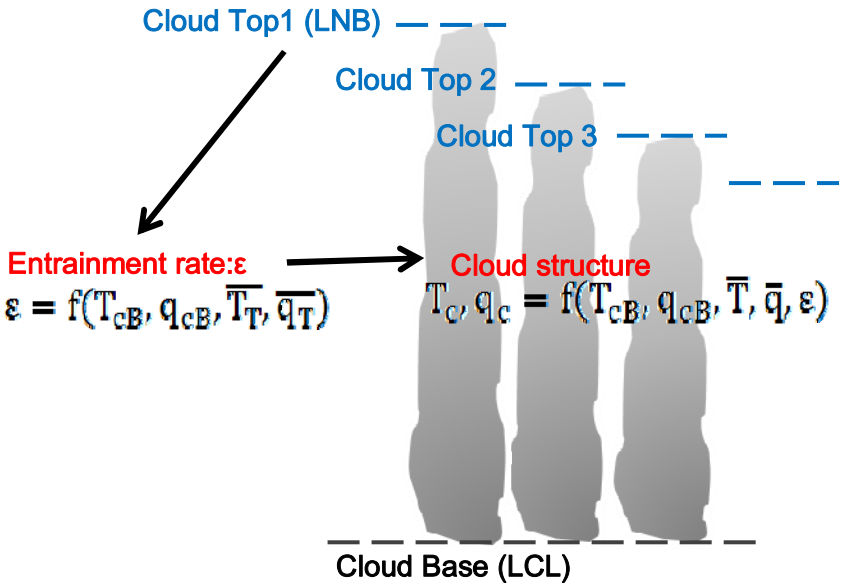
❖ **All types of clouds coexists**
➔ **Cumulus ensemble**

❖ Cloud is homogeneous in horizontal space
➔ Bulk model

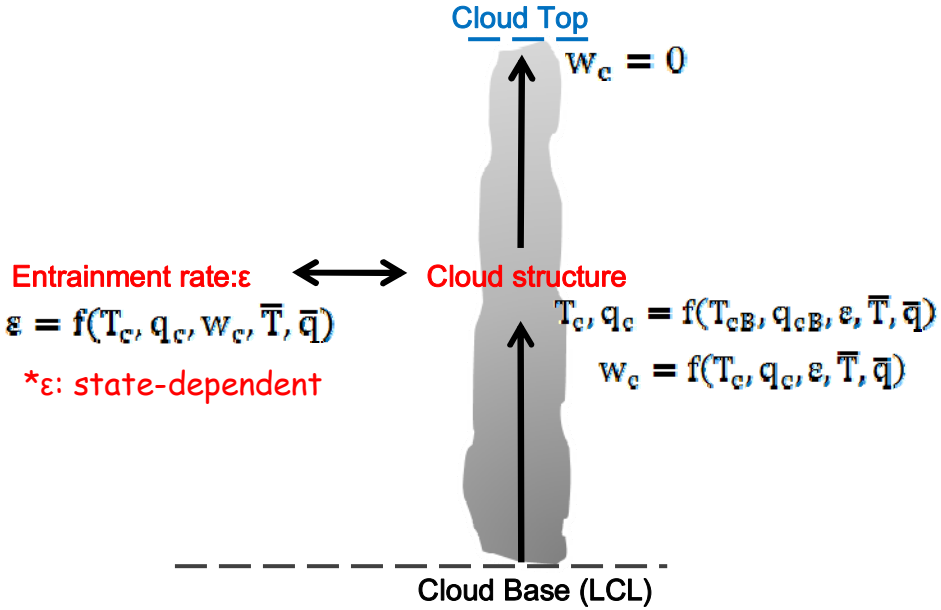
❖ But, still vertically inhomogeneous
➔ Turbulence ensemble

Physics of cumulus parameterization

Cumulus ensemble (A-S) type



Bulk type



***similar approach: ECMWF, MPI, UKMO**

- **All types of clouds coexists**
  - ➔ **Cumulus ensemble**
- **Cloud top/entrainment rate**
  - ➔ **Deterministic, insensitive to environment**

- Cloud is homogeneous in horizontal space
  - ➔ Bulk model
- Entrainment rate is state-dependent
  - ➔ Environment affects cloud-top

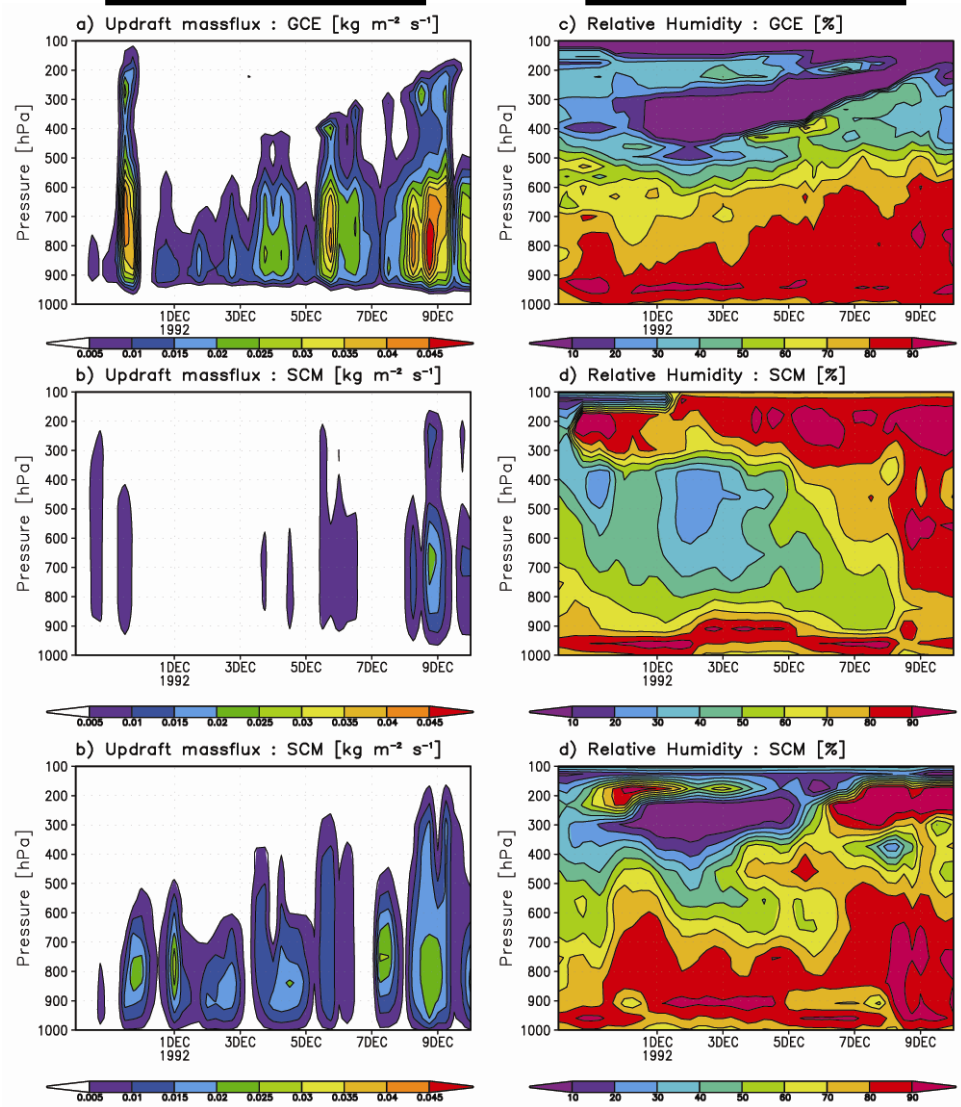
Massflux

RH

CRM

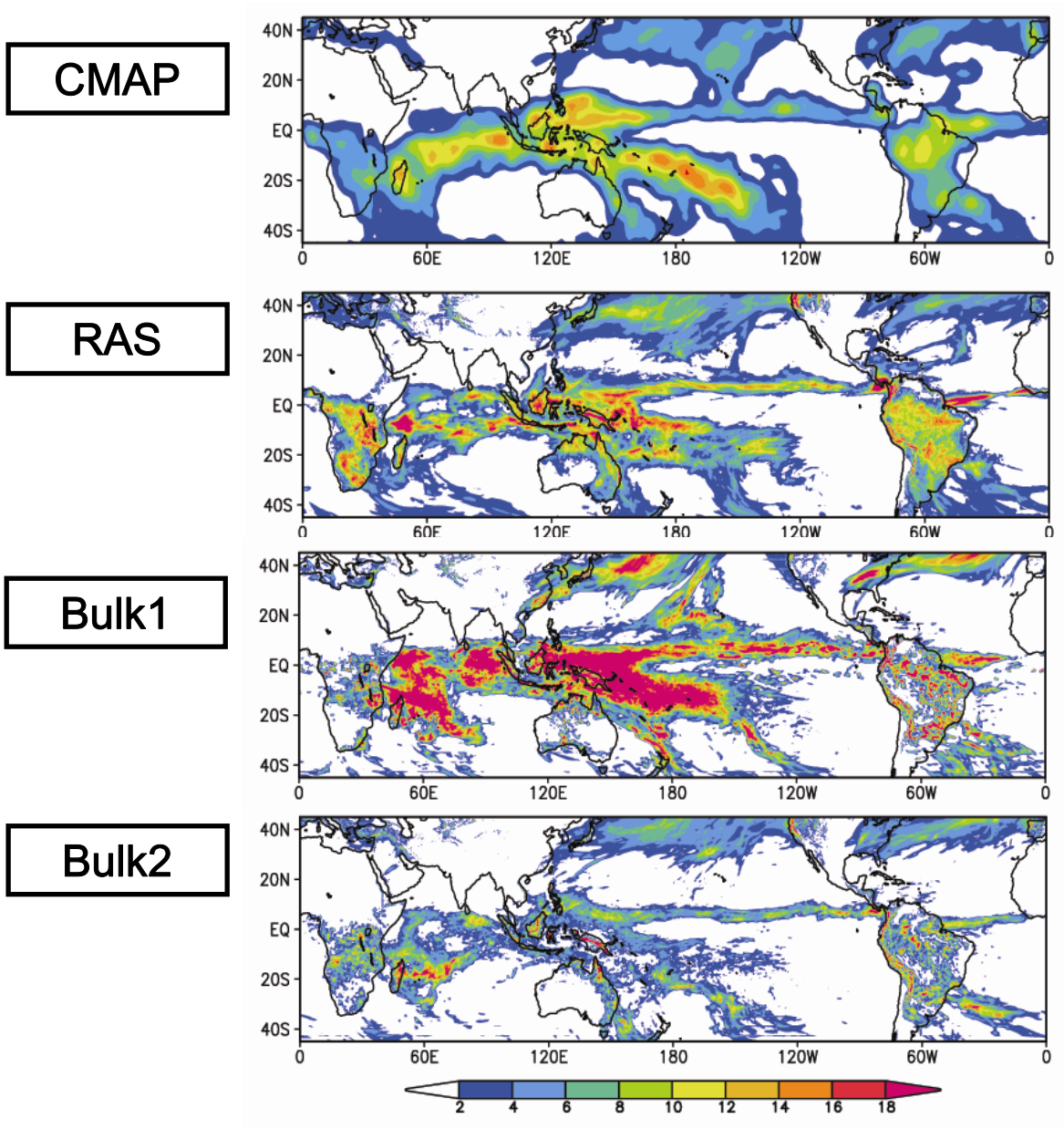
RAS

Bulk



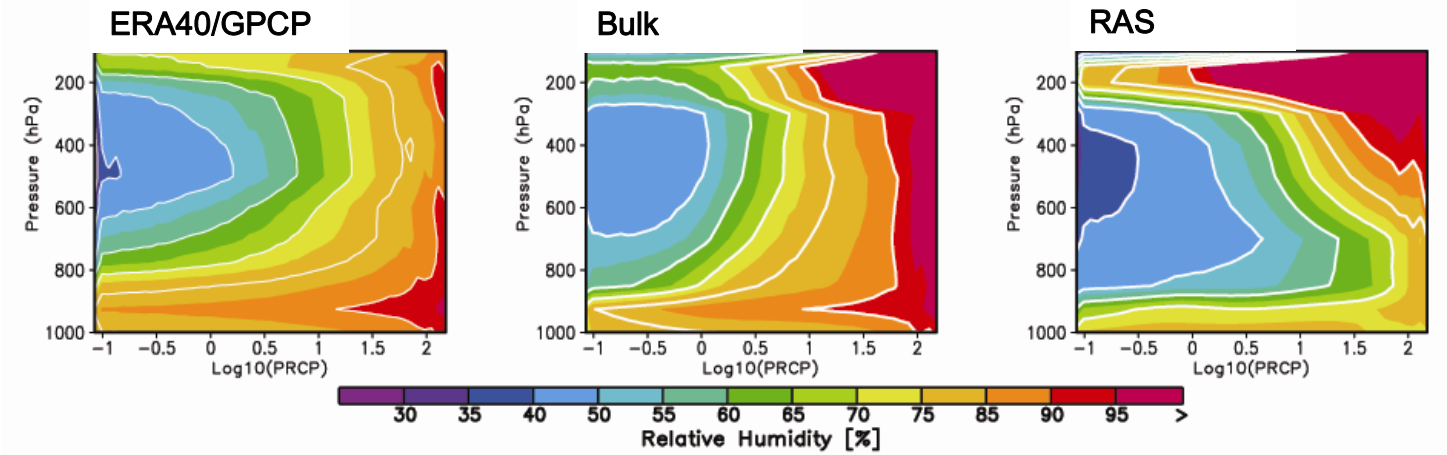
SCM experiment
*TOGA-COARE forcing
*28NOV1992-10DEC1993

35 km resolution simulation - Jan1996

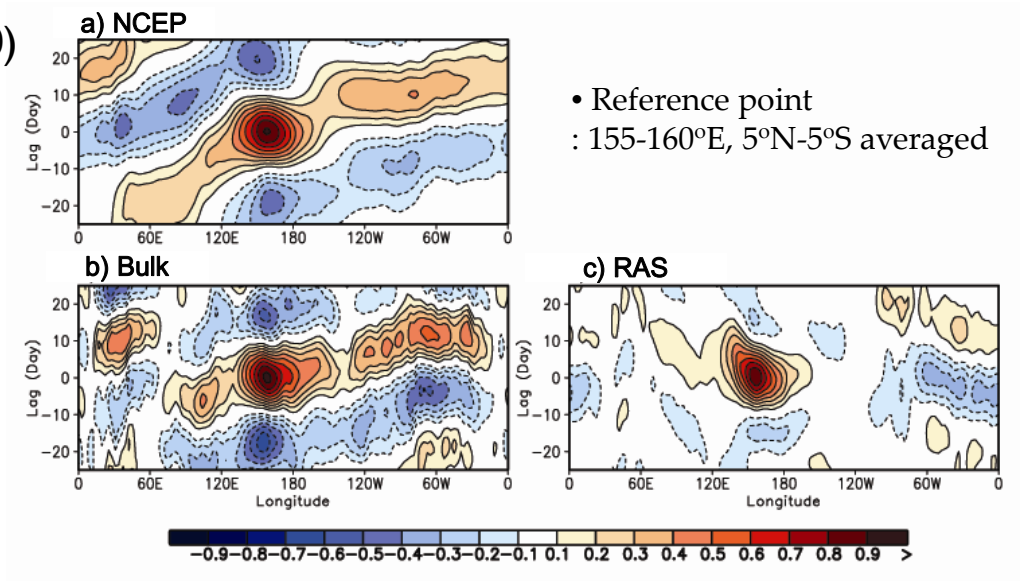


RH composite and lag correlation diagram

- Relative humidity composite based on precipitation



- Lag correlation (U850)

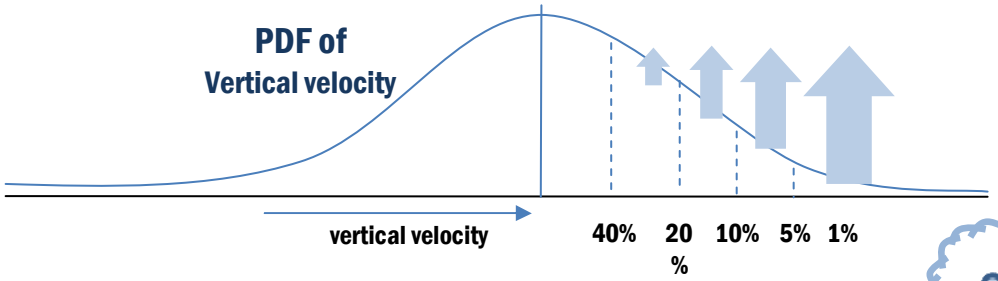


• Reference point
: 155-160°E, 5°N-5°S averaged

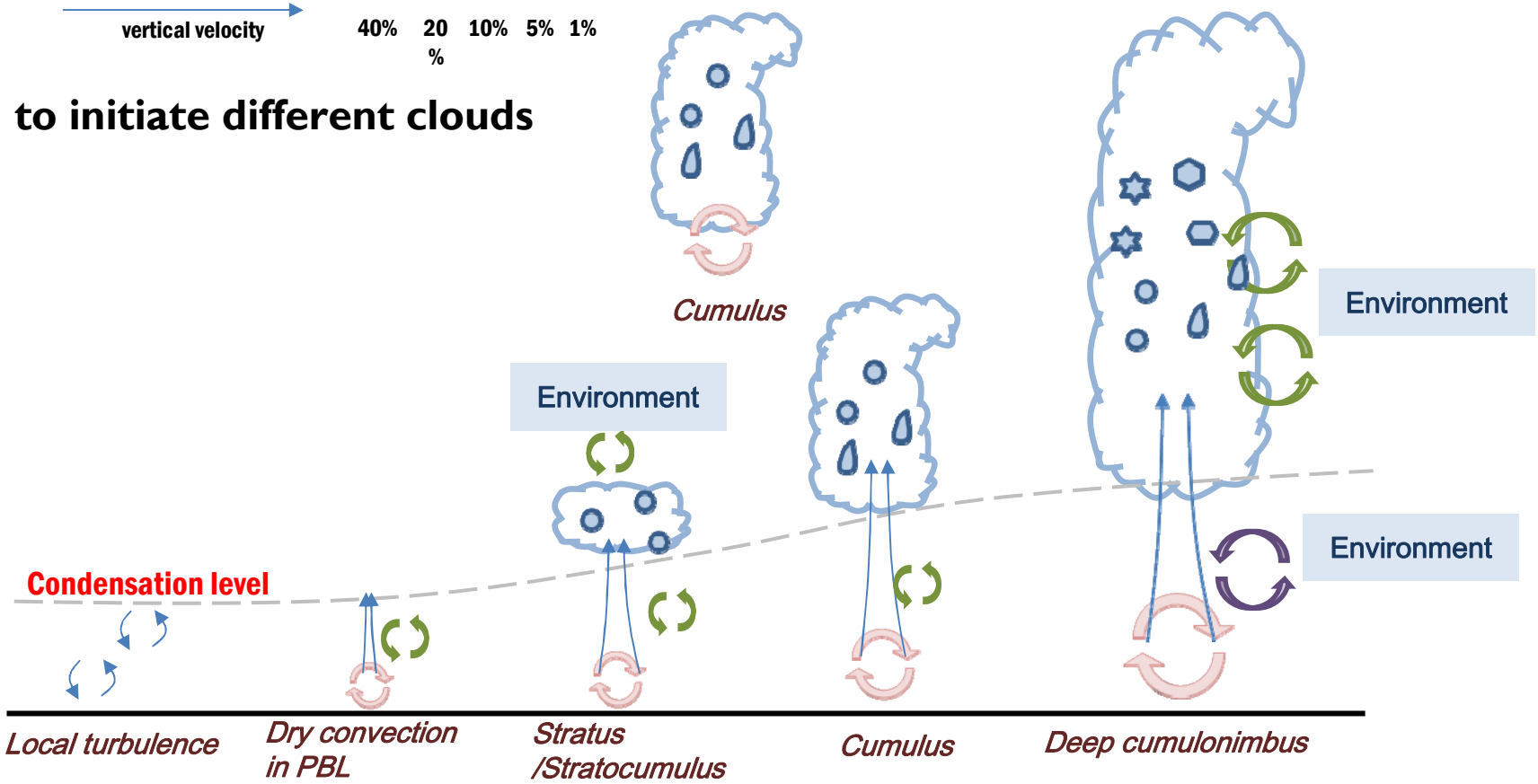
*Kim and Kang (2009)

PDF based Turbulence Ensemble

- Horizontally homogeneous, vertically inhomogeneous

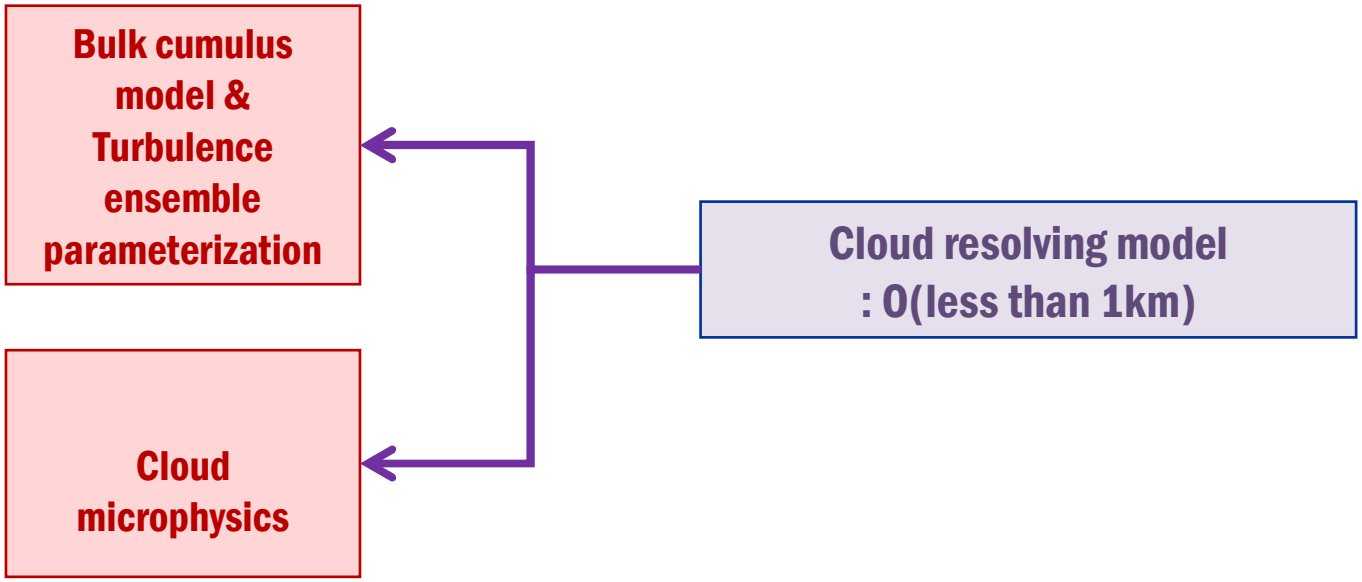


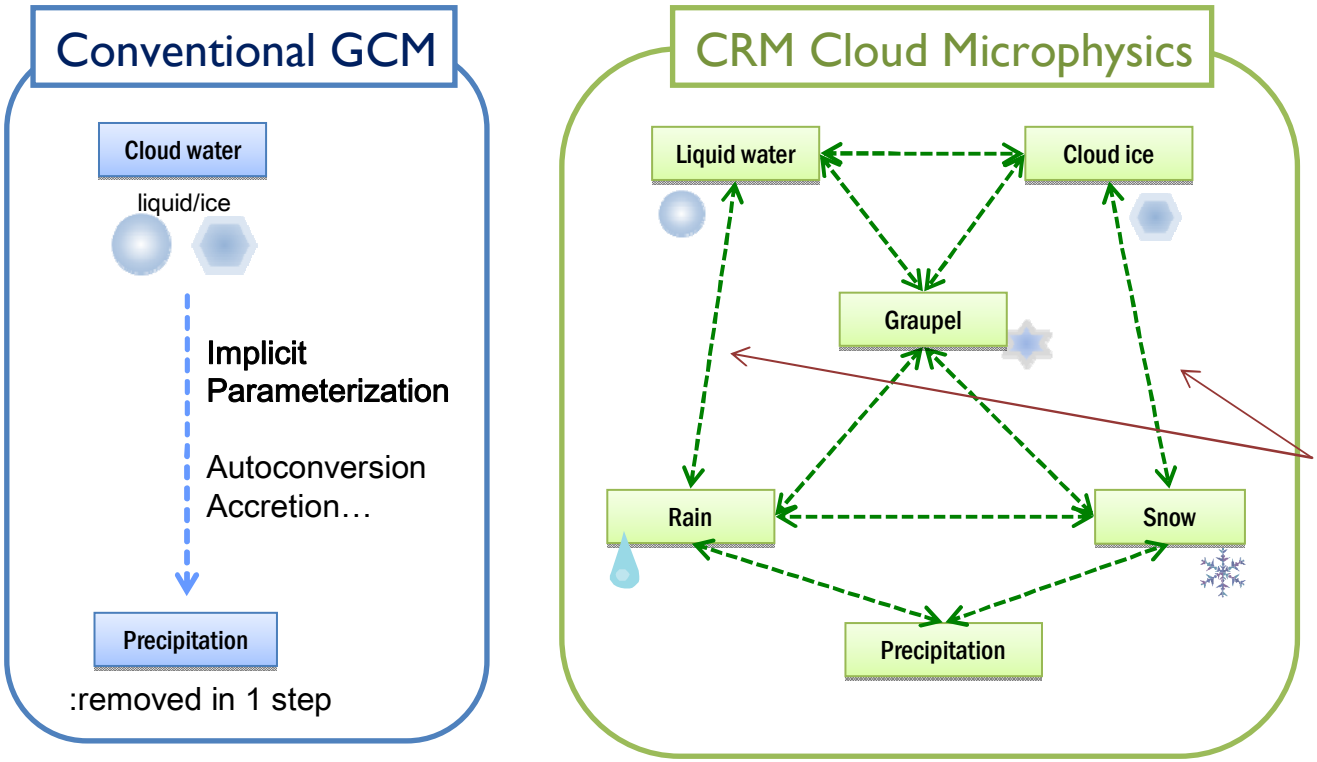
➔ **Used to initiate different clouds**



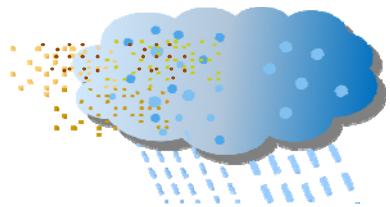
Low resolution ~O(100km)

High resolution ~O(10km)





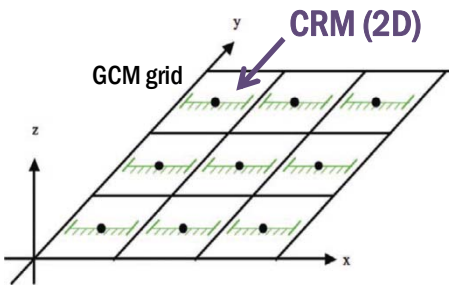
Explicit
Parameterization



Aerosol Indirect Effect
- Global radiation budget change
→Climate change simulation
- Regional climate impact
→ Change monsoon circulation

❖ Current approaches

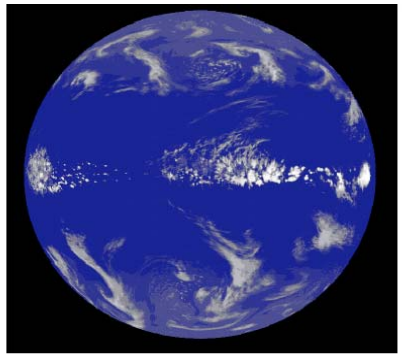
Multi-scale Modeling Framework (Superparameterization)



NASA/GSFC, CSU

*Horizontal Resolution of CRM: 4km

Global Cloud Resolving Model



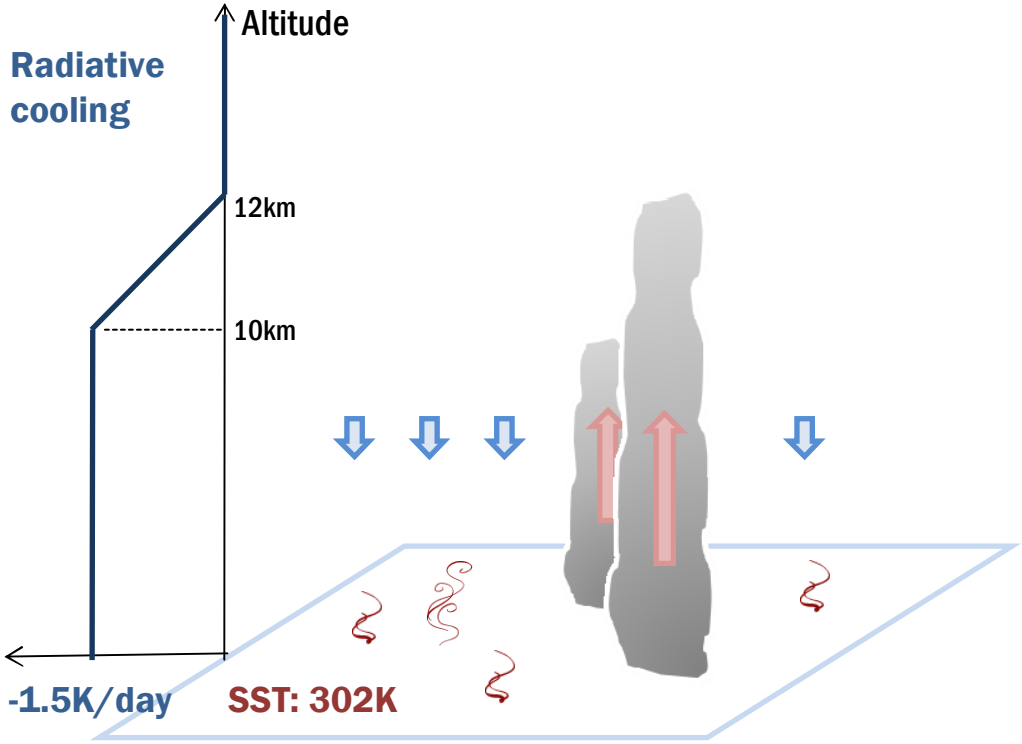
NICAM (Japan)

14, 7, 3.5km

Radiative-Convective equilibrium experiment

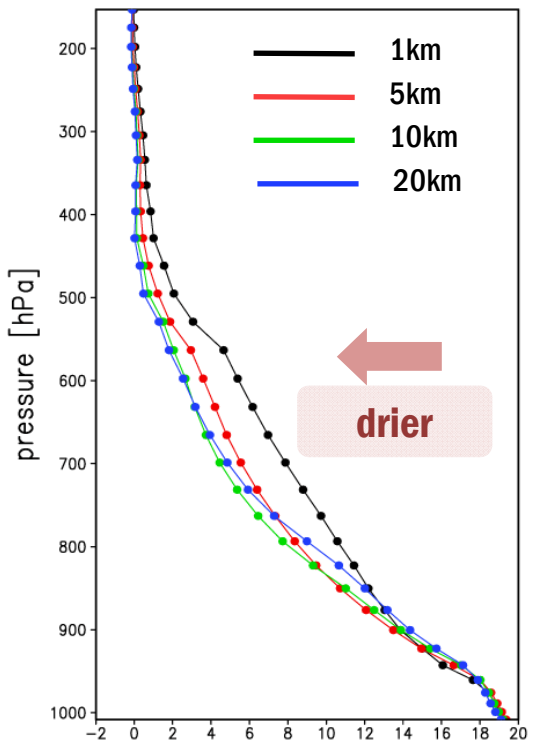
Experimental design

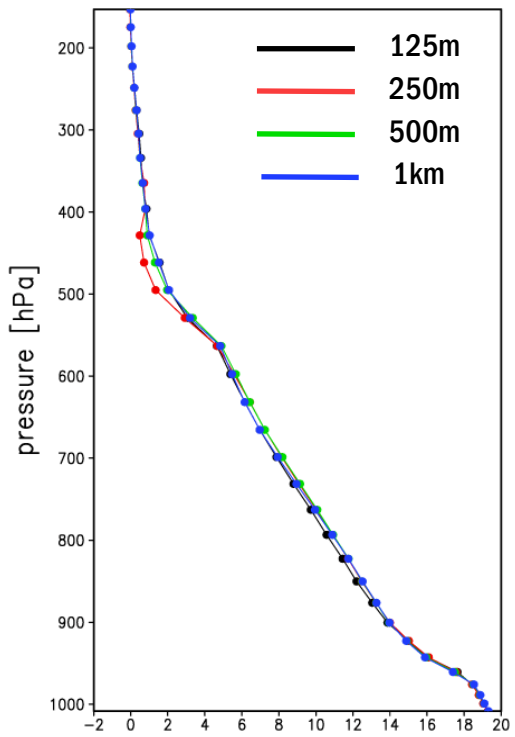
Self adjusted by energy balance



1, 5, 10, 20km resolution (2000 grids)

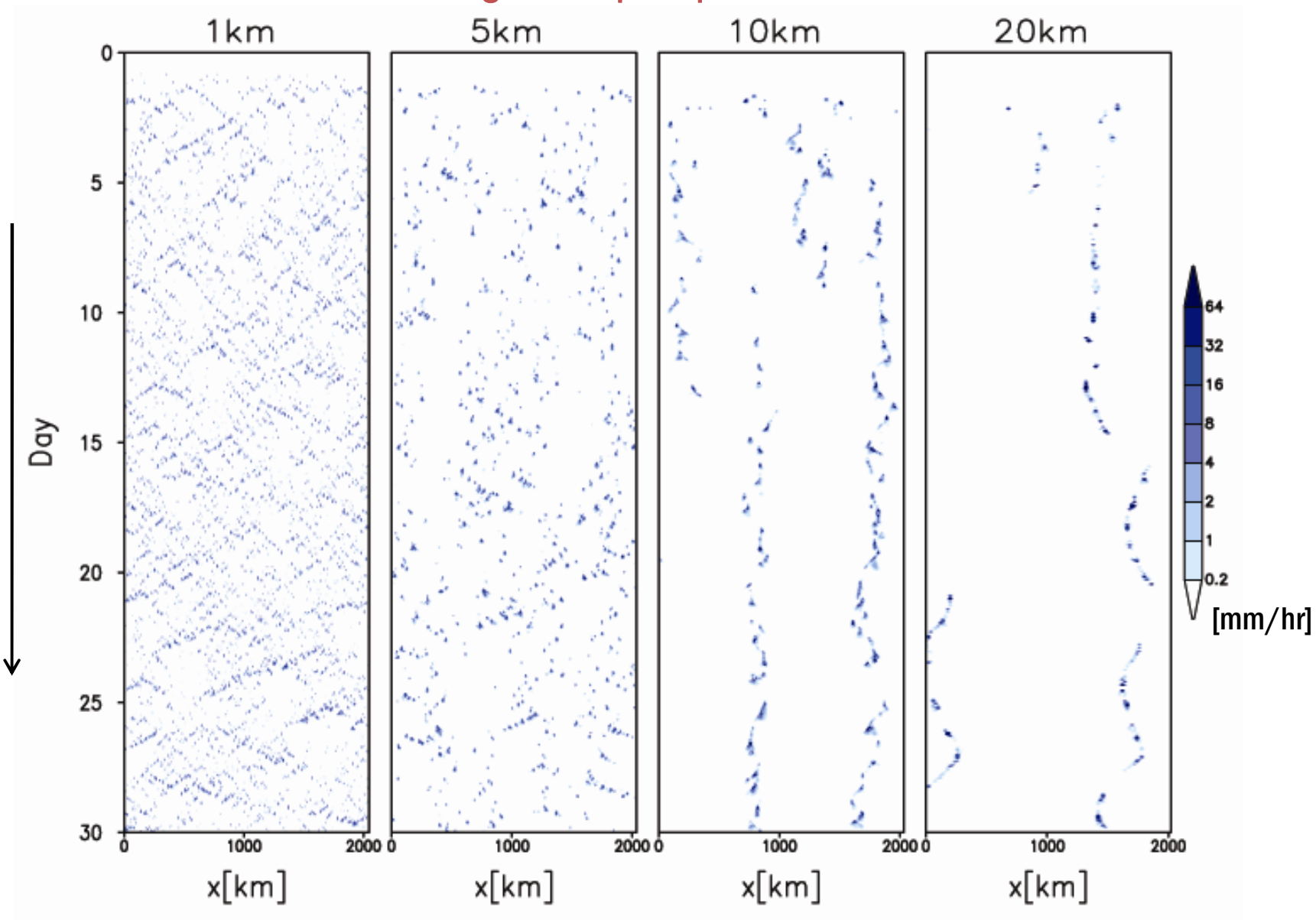
Radiative-Convective equilibrium experiment of Goddard Cumulus Ensemble model





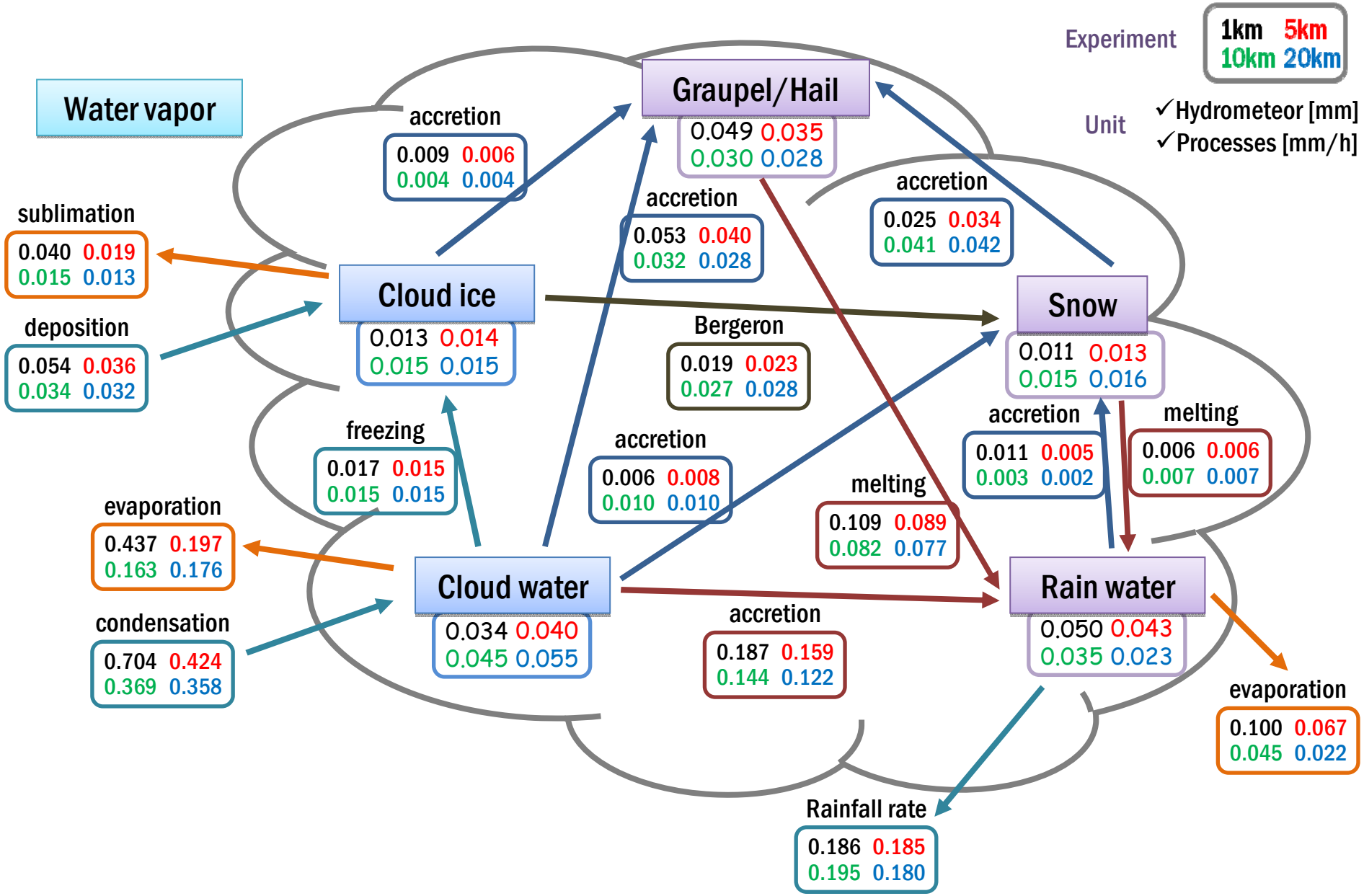
Specific Humidity [g/kg]

Hovmuller diagram of precipitation Mean wind : 0m/s



1km	5km	10km	20km
3.9mm/day	3.8mm/day	3.8mm/day	4.3mm/day

Microphysics budget of GCE



Modification on condensation process

❖ Condensation process in GCE model

$$\text{condensation} = \left(\frac{T_{air} - T_{00}}{T_0 - T_{00}}\right) \times \frac{q_v - q_{sat}}{1 + r_2 A_3}$$

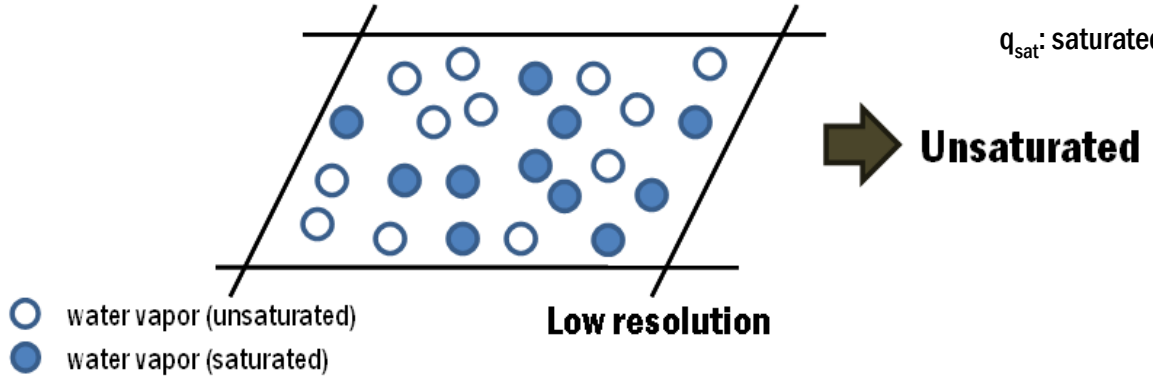
T_0: melting temperature (0°C)

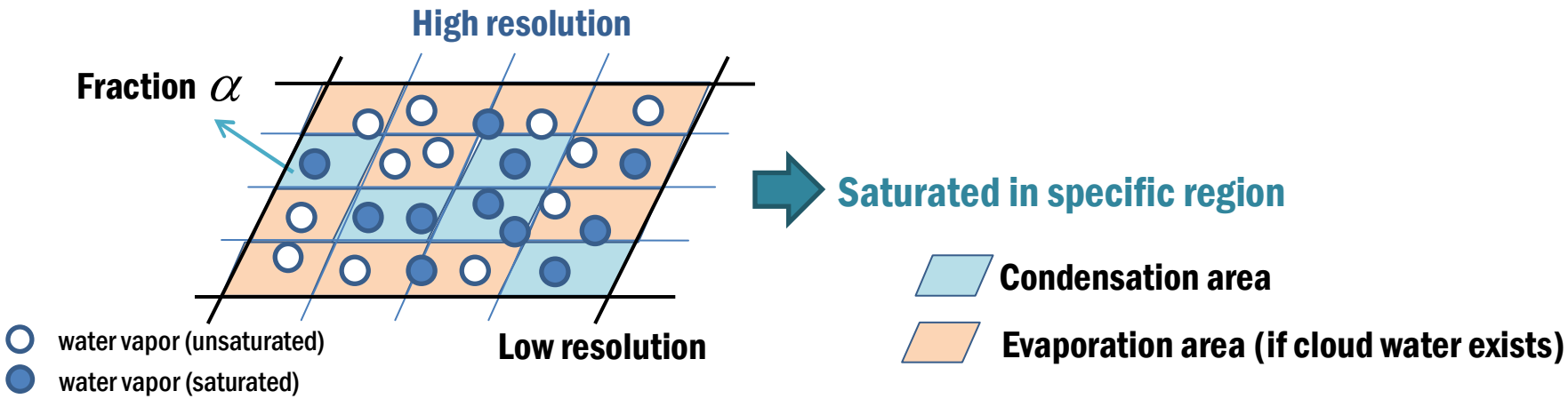
T_{00}: reference temperature (-35°C)

q_v: mixing ratio of water vapor [g/g]

q_{sat}: saturated mixing ratio of water vapor

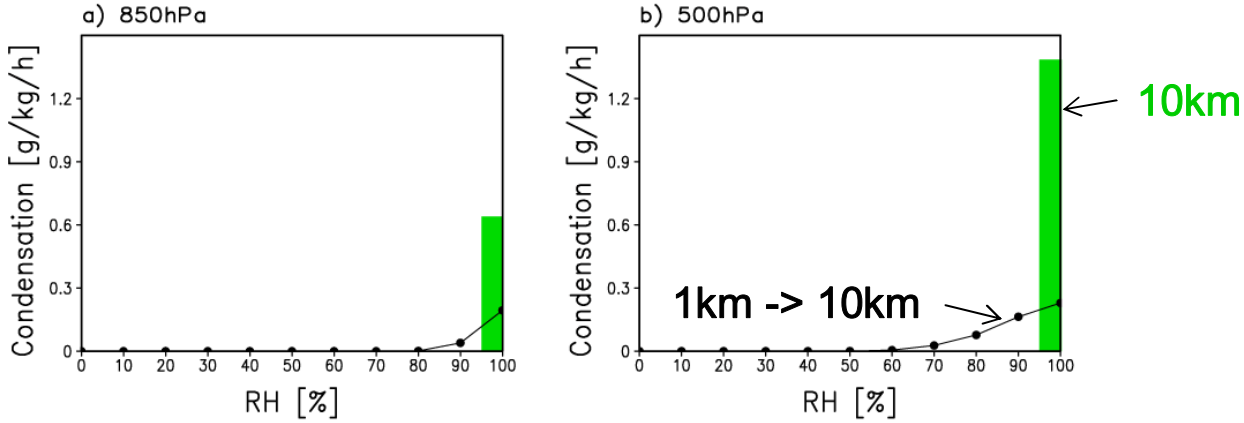
✓ Condensation criteria $q_v > q_{sat}$



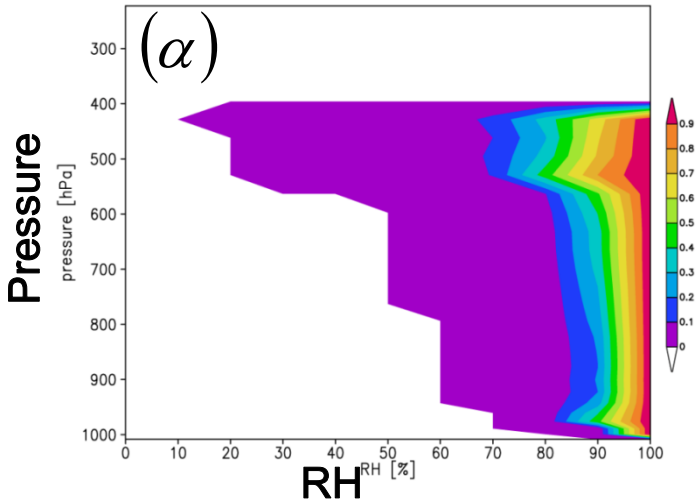


Modification on condensation process

RH vs. amount of condensation



Fraction of condensation area



Total condensation rate in low resolution grid

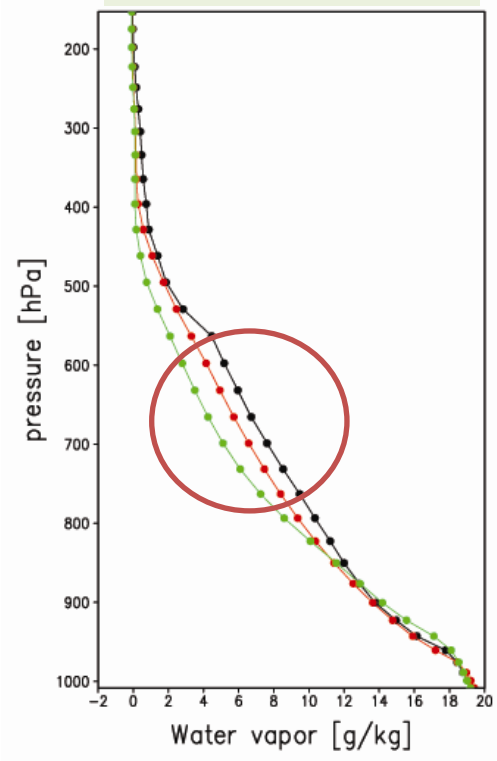
= condensation $\times \alpha$ + evaporation $\times (1-\alpha)$

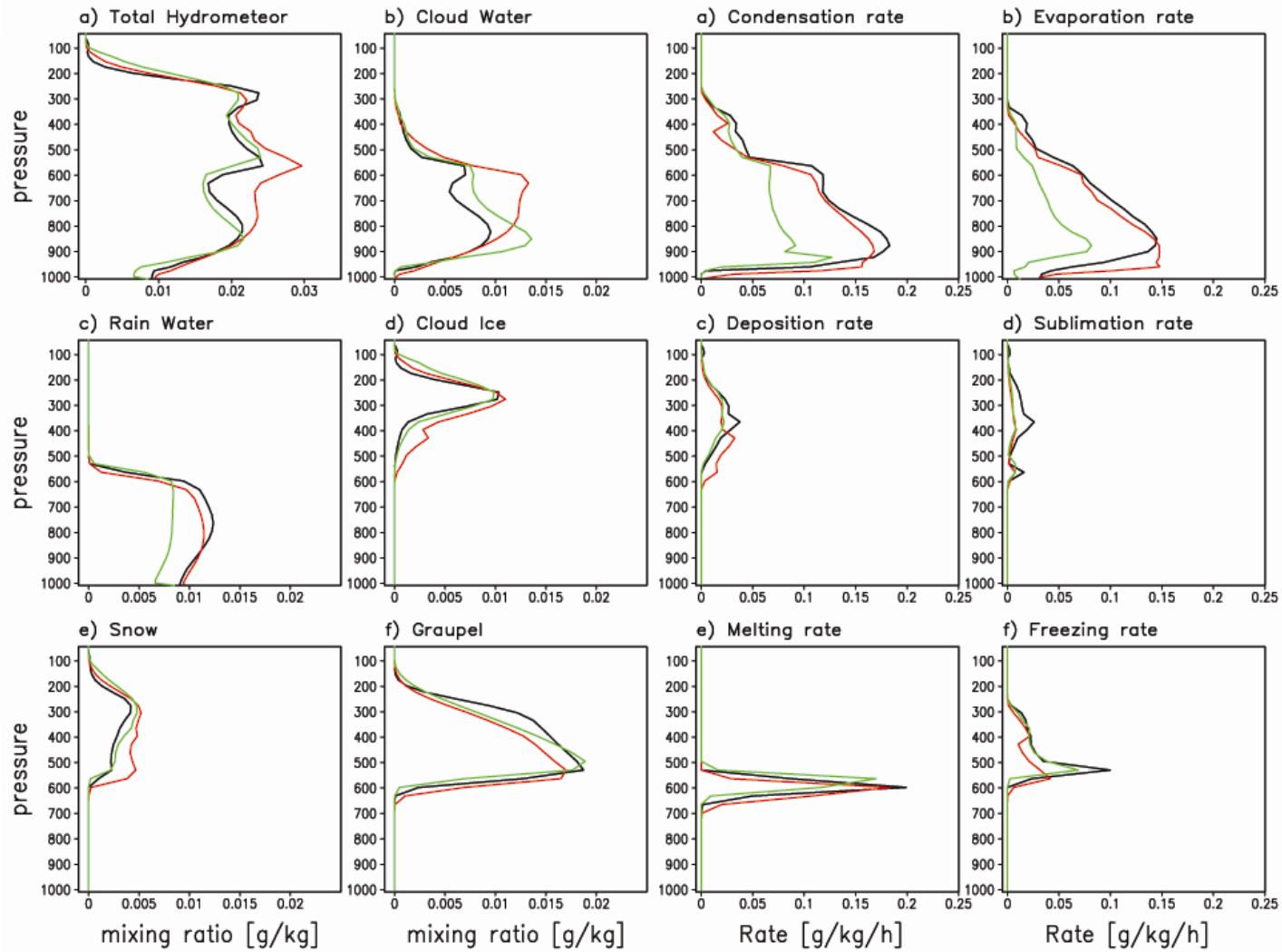
GCE results

6th day ~ 15th day
(10 days mean)

- modification on condensation process
- modification on cloud water autoconversion process
- modification on diffusion (add shallow convection scheme)

Specific humidity



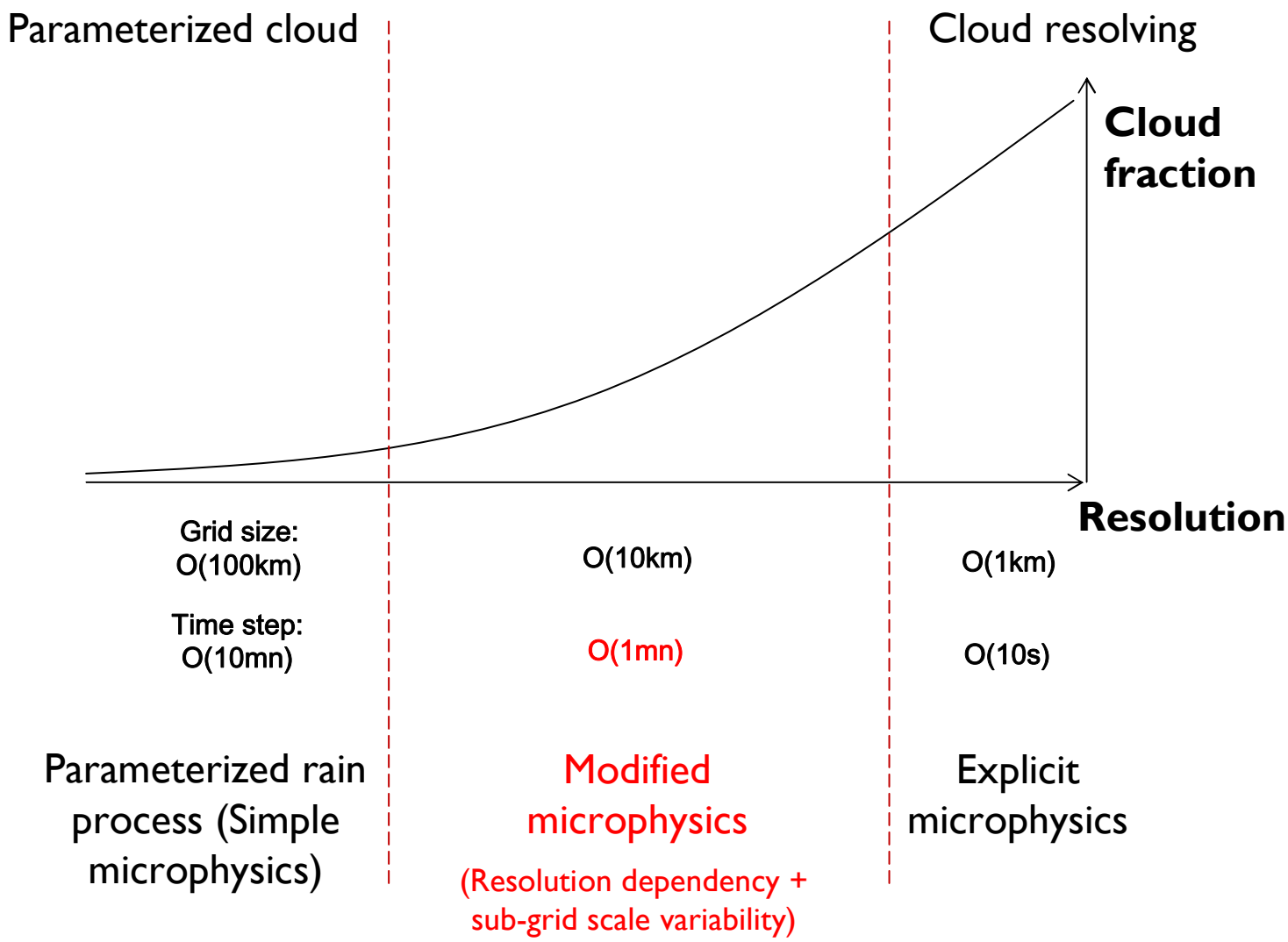


1km CTL

10km CTL

10km MOD

Resolution dependency in microphysics



Conclusion

➢ **Moist physics for high resolution model ~ O(10km)**

❖ Cumulus convection	❖ Cloud microphysics
Bulk cumulus & PDF-based turbulence ensemble cloud	**Semi-explicit microphysics**

Statistics from cloud resolving model

~O(less than 1km)

Thank you!

Semi-explicit microphysics

- modification of condensation process (sub-grid concept)

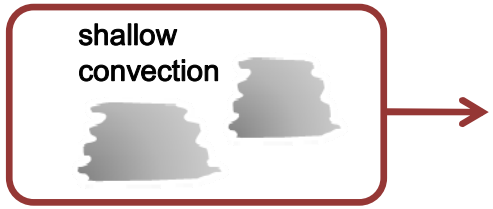
Auto-conversion process

$$P_{RAUT} = \alpha\rho(q_c - q_{c0})$$

If $q_c < q_{c0}$ (no process to make rain water)

the criteria (q_{c0}) should be reduced in coarse resolution

Un-resolved eddies - shallow convection

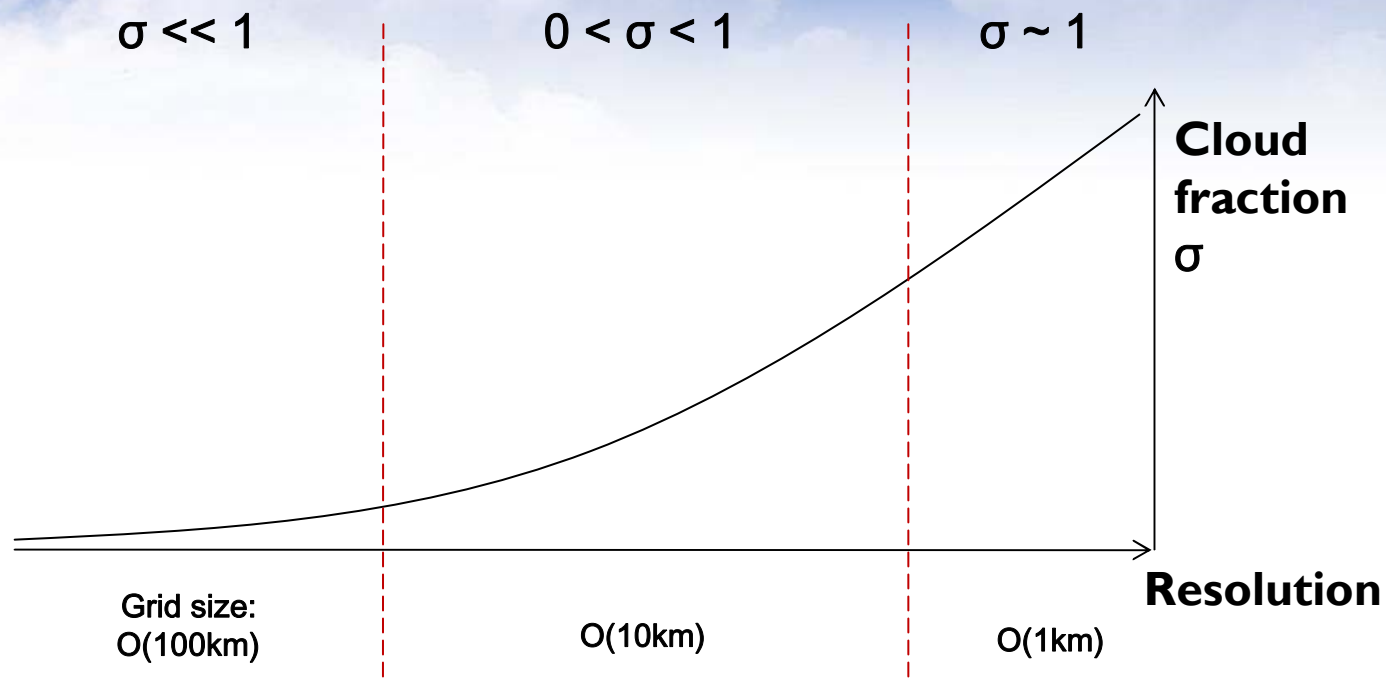


No precipitation, Diffusion type (Tiedtke 1984)

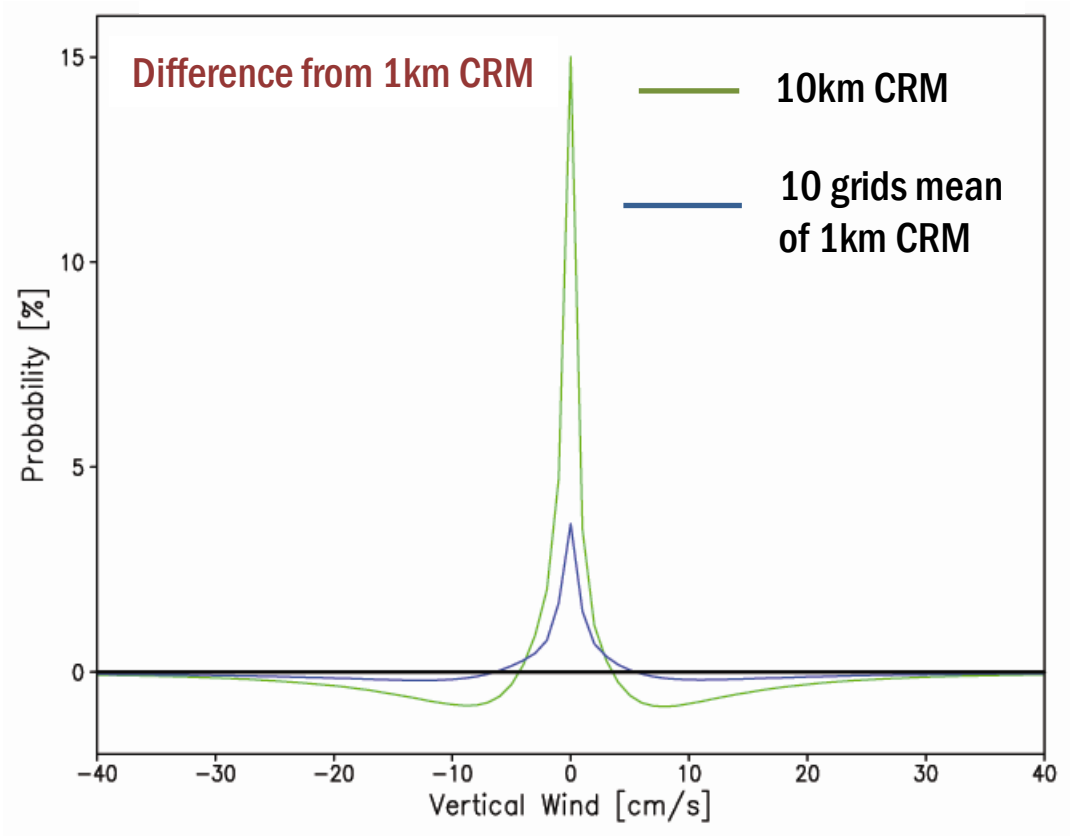
Effects: Temperature, Water vapor mixing

Enhanced vertical mixing is expected to reduce the dry bias in the middle of troposphere.

Resolution dependent assumption



Cloud statistics	Cumulus ensemble	Bulk Turbulence ensemble	Cloud resolved
Rain Processes	Simple parameterization	Modified Microphysics	Microphysics

Turbulence characteristics

PDF of vertical wind