Progress with convective parameterization for Improved simulation of the MJO

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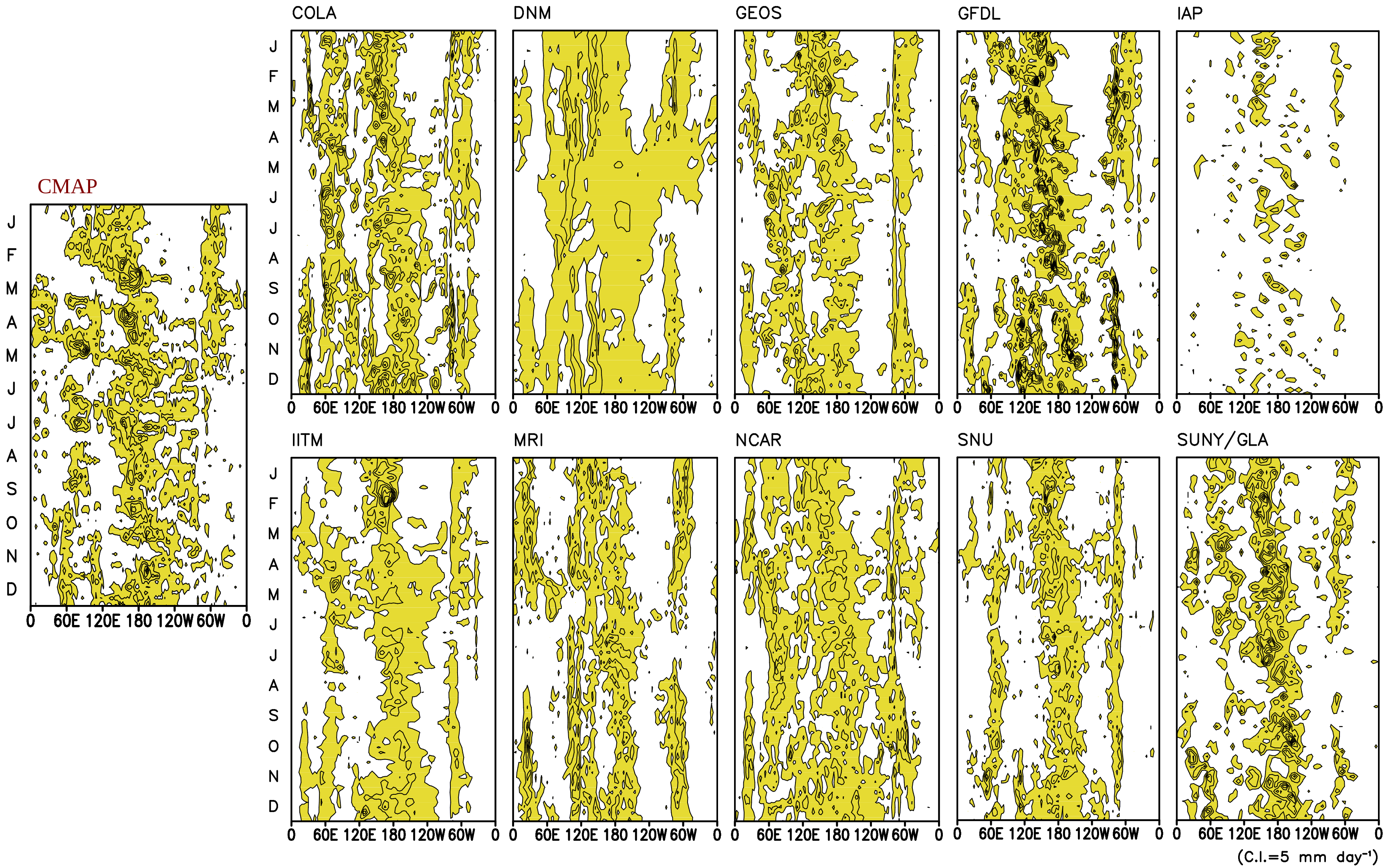
Content

1. Motivation
2. Various convective parameterizations
3. Modifications of A/S scheme
4. Cloud Radiation Interaction
5. High Resolution Model
6. A New Mass Flux Scheme

CLIVAR Monsoon Intercomparison - MJO

10^oS-10^oN Time-longitude Cross Section of Precipitation during 1997



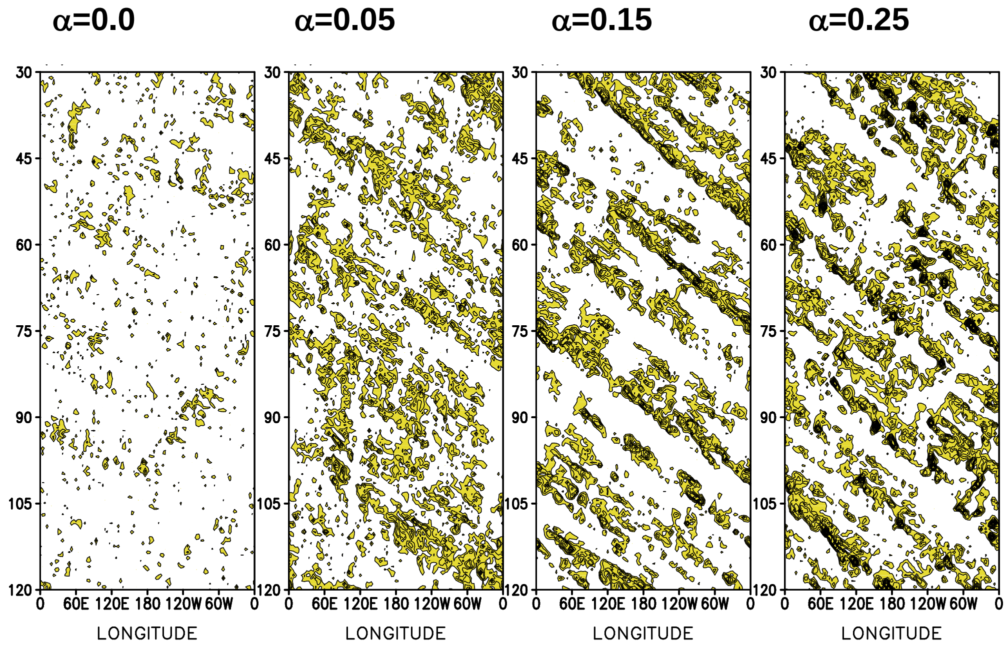
Modification1: Cumulus Entrainment Constraint

❖ **Minimum cumulus entrainment rate in RAS (Tokioka et al. 1988)**

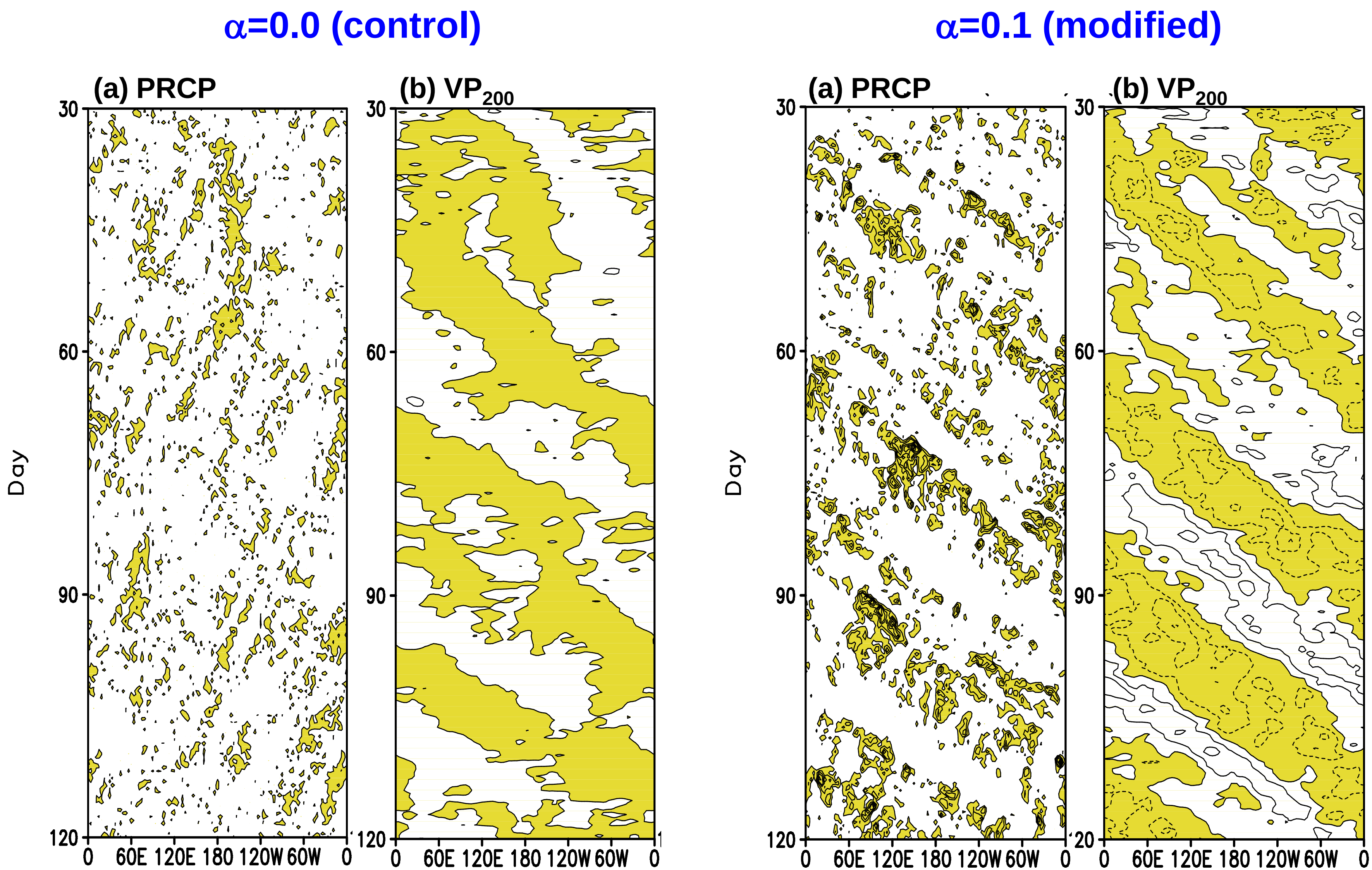
$$\mu_{\min} = \frac{\alpha}{D}$$

D: PBL depth
α: non-negative constant

Convection can be triggered in case of $\mu \geq \mu_{min}$



SNU Aqua-planet AGCM with a fixed radiation



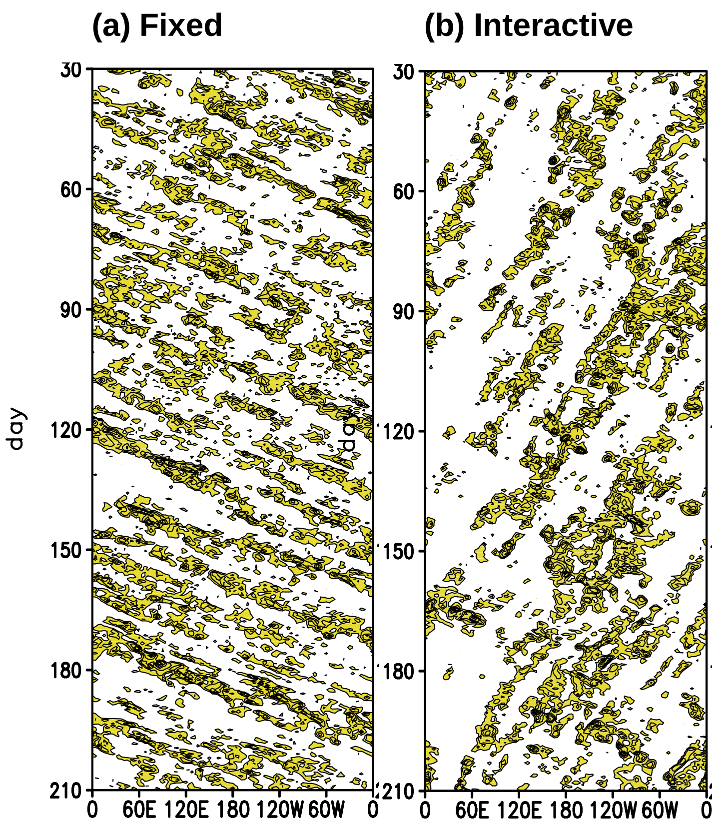
ISO with turning on Cloud-Radiation Interaction

❖ **Two Experiments in Aqua-Planet**

Experiment	Description
Fixed	Prescribed zonally uniform radiative heating rate
Interactive	Fully interactive radiation

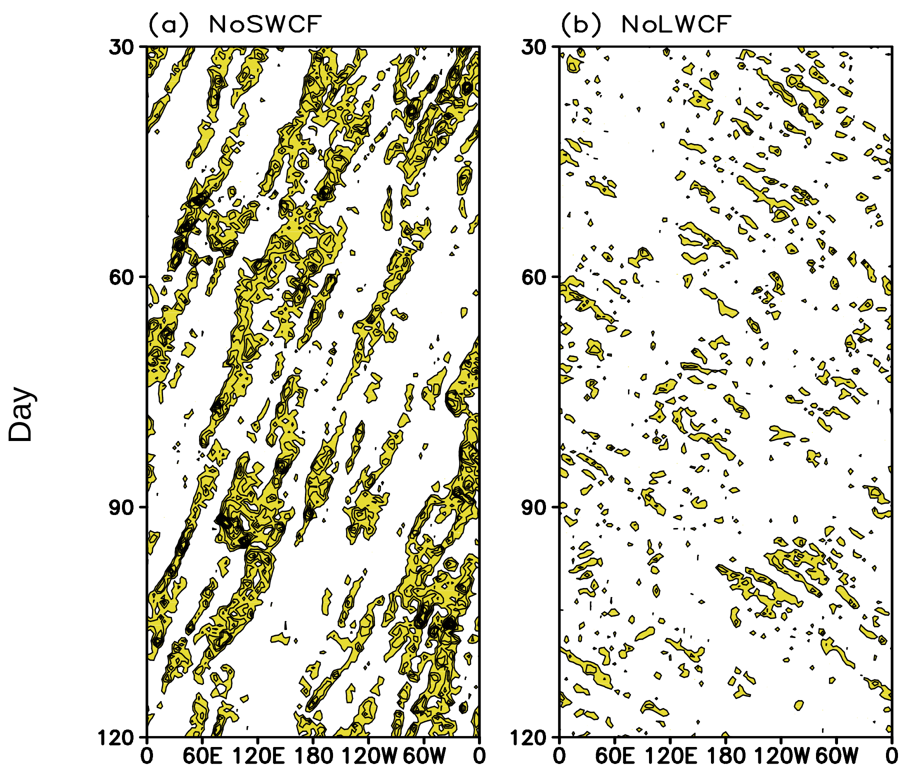
◆ **Cloud-radiation interaction simulated in the model (in particular, RAS scheme) prevents the eastward propagation of large-scale waves and make westward moving transients more prominent.**

Time-longitude Diagram of Rainfall



ISO with turning on Cloud-Radiation Interaction

2^{o}S-2^{o}N Time-longitude Cross Section of Precipitation



without shortwave cloud radiative forcing

without longwave cloud radiative forcing

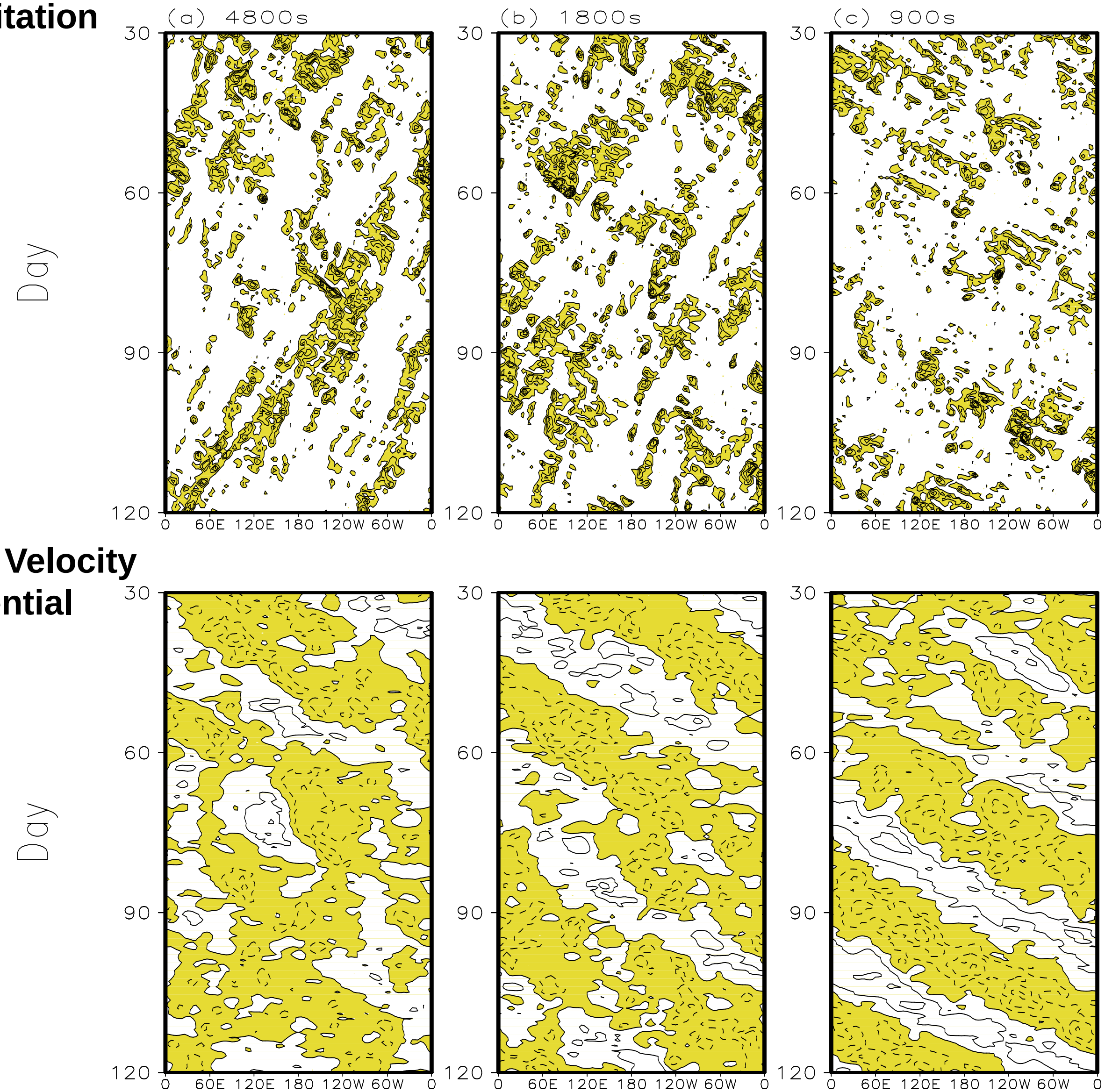
- The longwave ACRF feedback is more crucial for this feature in RAS scheme.

Modification2: Layer-cloud Precipitation time Scale

Sensitivity to Precipitation Timescale: Time-longitude Diagram

Precipitation

200 hPa Velocity Potential



Modification2: Layer-cloud Precipitation time Scale

Strategy

For the reduction of longwave ACRF

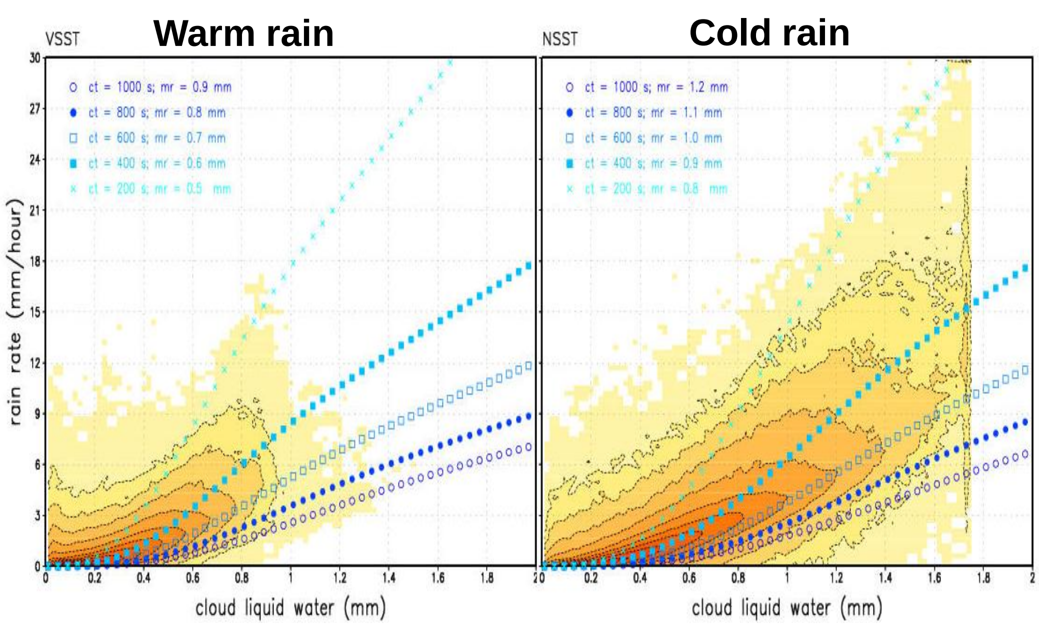
↓

Modulation of model cloudiness

↓

Reduction of precipitation time scale for reducing longwave heating induced by ACRF

Observational evidence: Autoconversion precipitation timescale over the tropics is 200–800 sec (Lau et al. 2003)



❖ Characteristic precipitation timescale, τ_p

$$\tau_p = \tau_0 \left\{ 1 - \exp\left[-\left(\frac{l}{l_0} \right)^2 \right] \right\}^{-1}$$

(Sundqvist, 1978)

l_c : critical cloud liquid water content

t_o : characteristic timescale for conversion of cloud droplets into rain drops

❖ Precipitation rate

$$P = \frac{l}{\tau_p}$$

P: precipitation rate

l : cloud liquid water content

τ_p: characteristic precipitation timescale

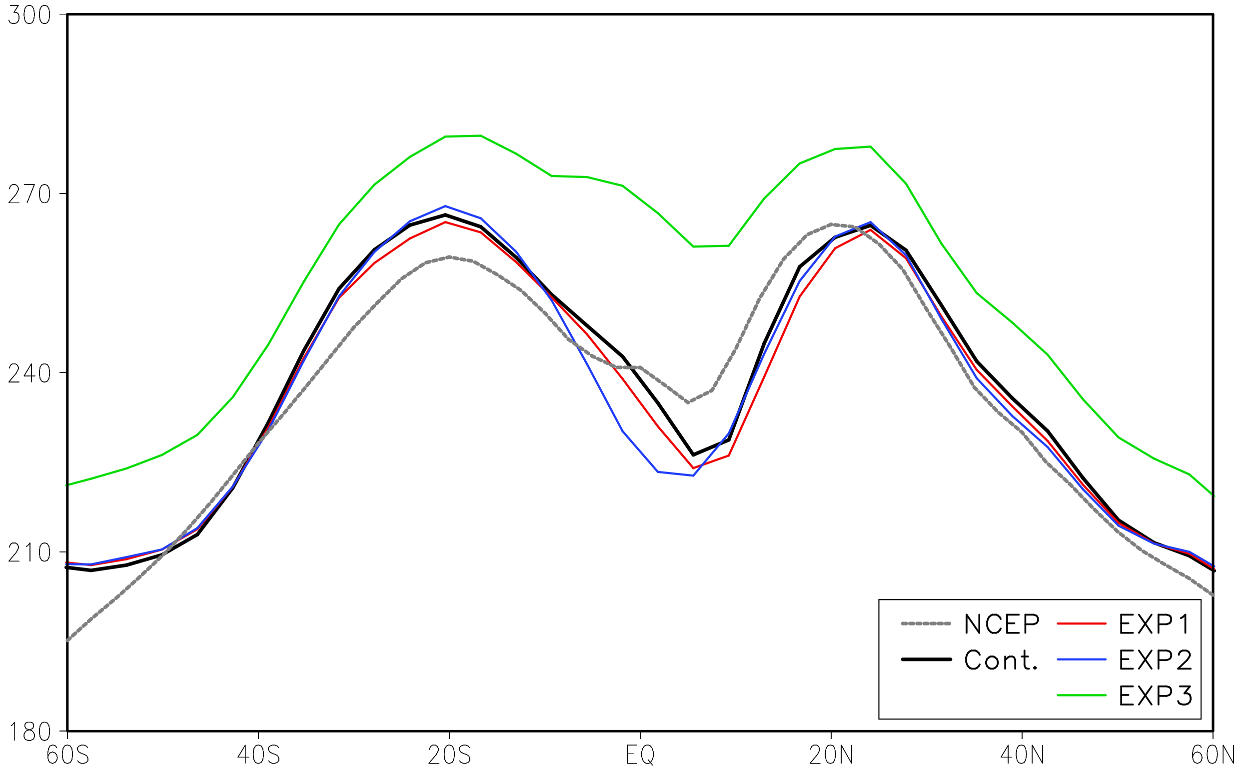
→ The reduction of τ_p means fast autoconversion from cloud liquid water to precipitable raindrops

→ Reducing Cloud Lifetime

→ Longwave ACRF (atmosphere cloud radiative forcing) heating reduced

Constant τ_p = 9600 sec (original)
→ smaller value up to 900 sec

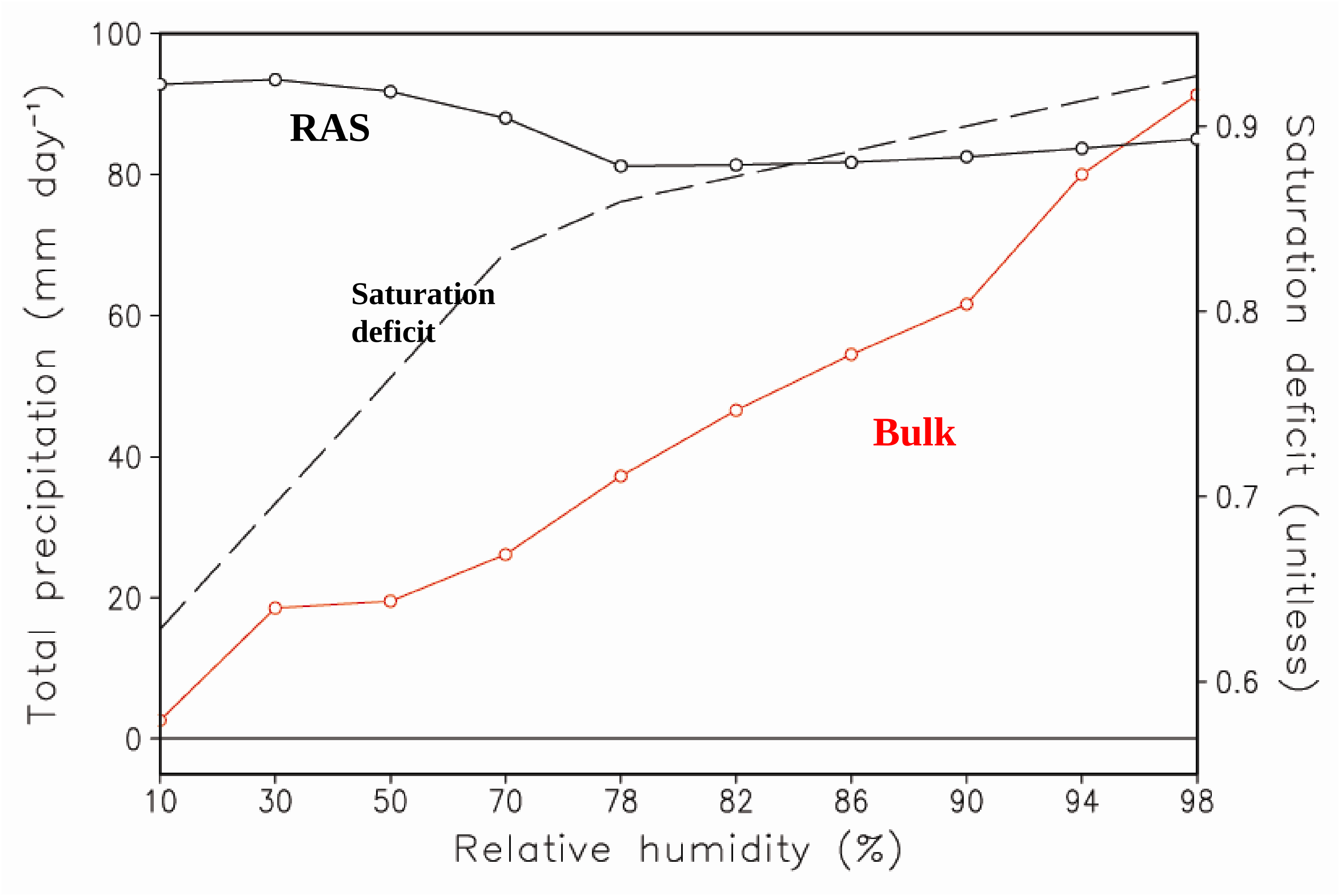
Zonal Mean OLR during Sep96 ~ Aug98



❖ Experimental Design

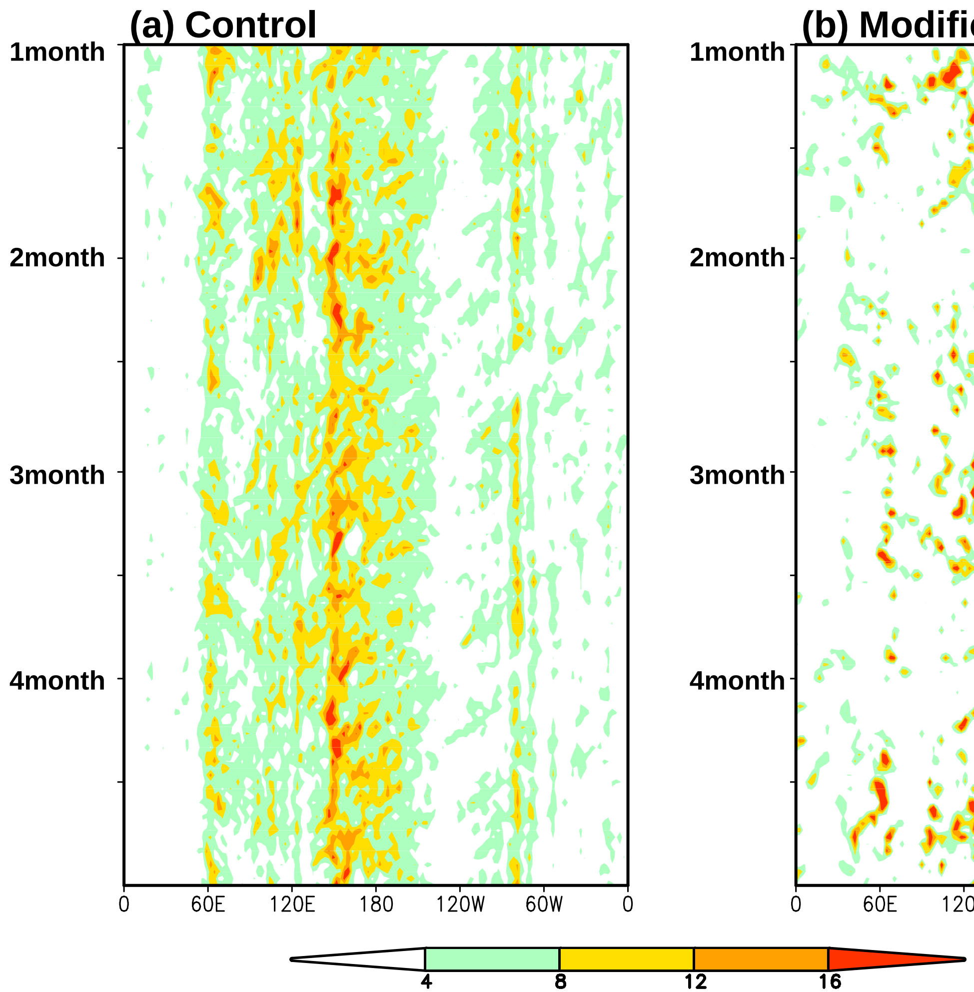
	Tokioka effect	Layer-cloud precipitation timescale		Coupling with mixed layer
	RAS cumulus entrainment minimum	Reduced region	LSC time scale τ_0	
Control	Off	No	9600 sec	
Exp1	α=0.1	20ºS~20ºN	9600/900 sine curve	
Exp2	α=0.1	20ºS~20ºN	9600/900 sine curve	Slab ocean mixed-layer model (Waliser et al. 1999)
Exp3	α=0.1	Whole globe	1800 sec	

Simulated precipitation



Modification3: Relative Humidity Criteria

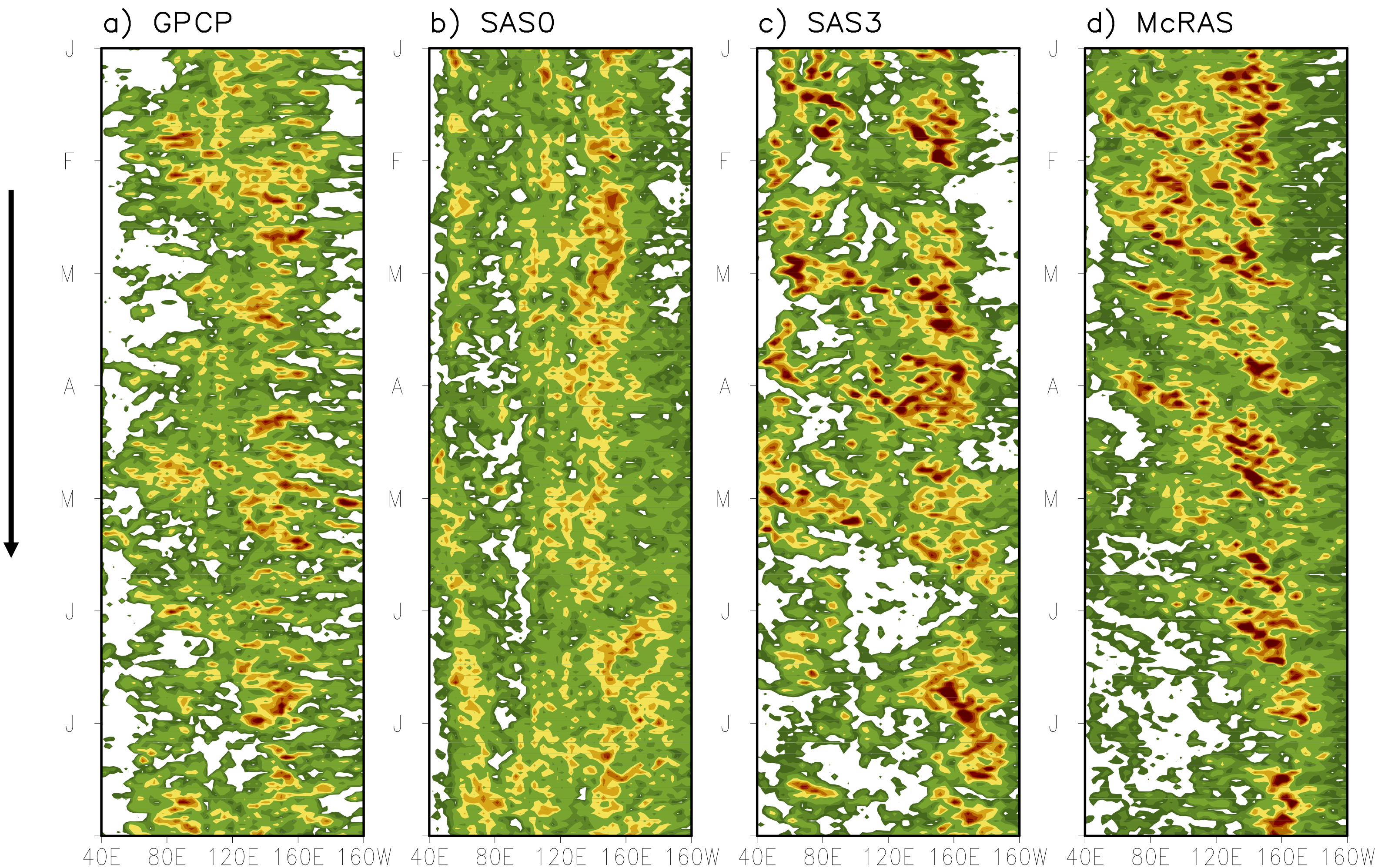
❖ 10^oS-10^oN Time-longitude Cross Section of Precipitation



Perpetual Experiment
- Resolution: T31 (3.75x3.75) L20
- 4 months simulation with June condition
- For modified case, RH_c is 80%

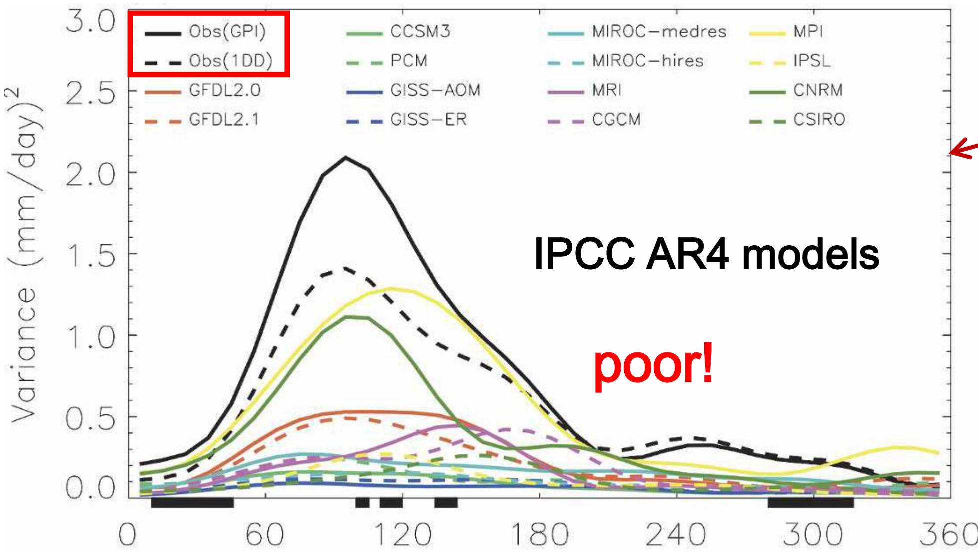
Low Resolution (300km)

Longitude-time diagram of total precipitation (5S-5N)



unit : [mm/day]

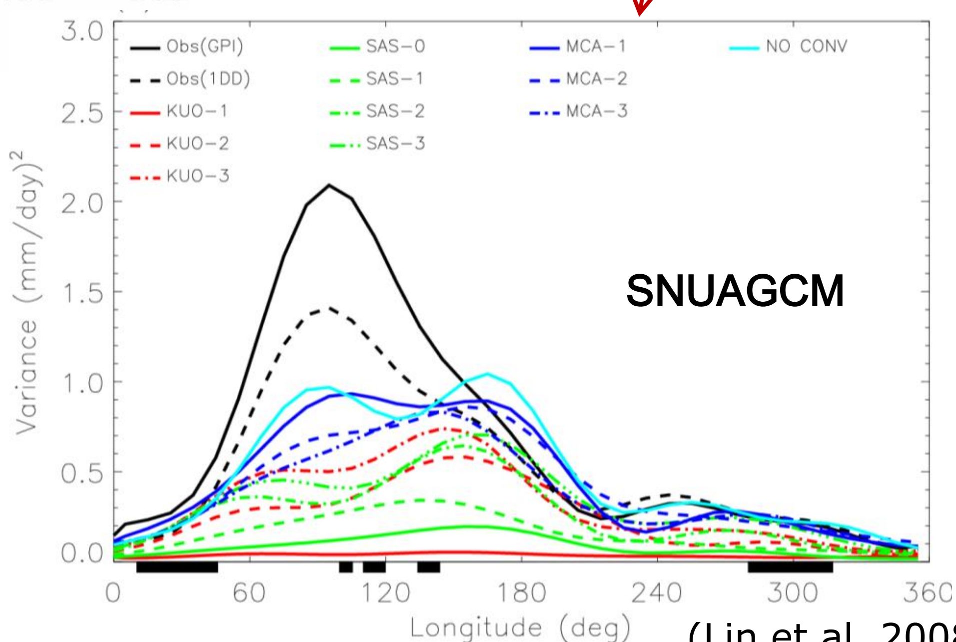
MJO Variance (eastward wavenumber 1-6, periods 30-70days)



(Lin et al. 2006)

different colors
- different climate models

different colors
- different convection schemes



(Lin et al. 2008)

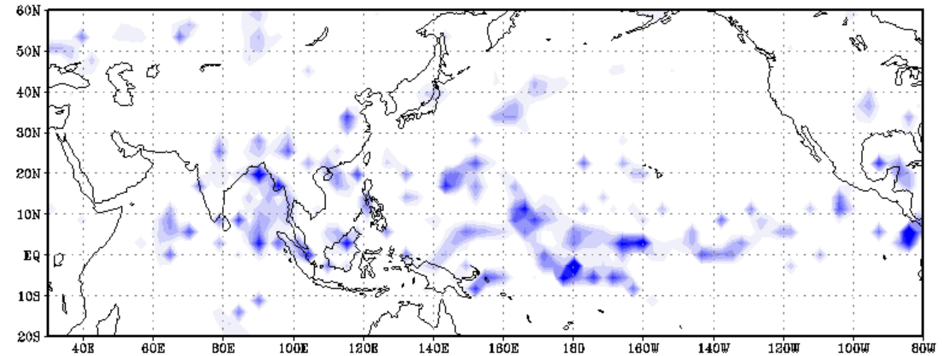
Convection scheme

: represent model diversity in MJO variability

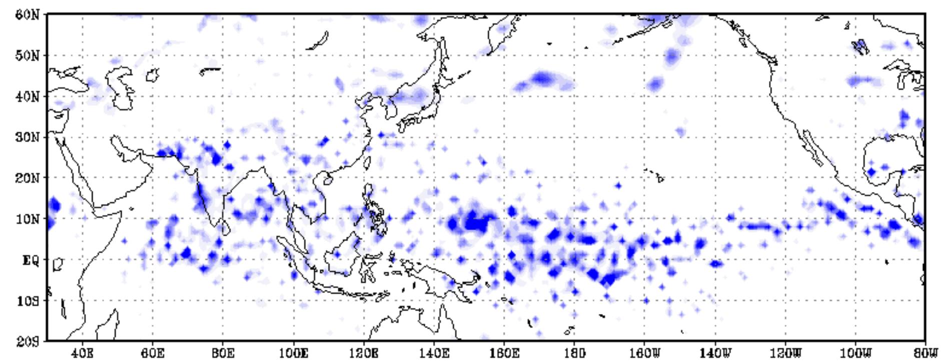
Resolution impact with same physics

prcp 1096hour T42

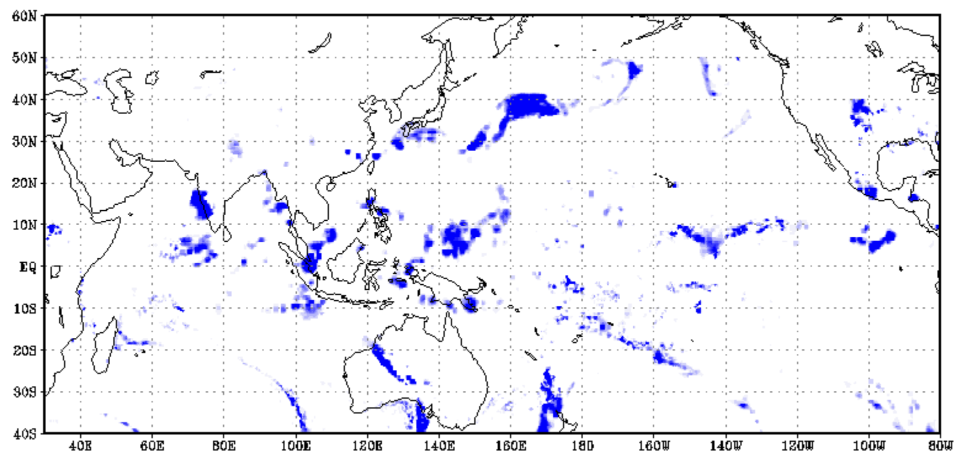
300km resolution



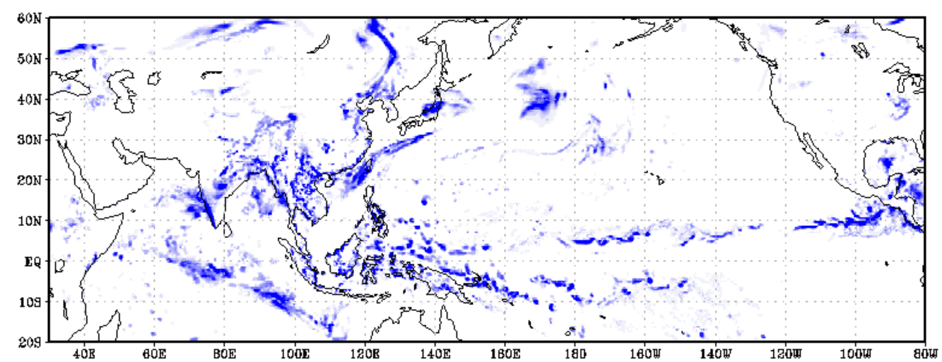
100km resolution



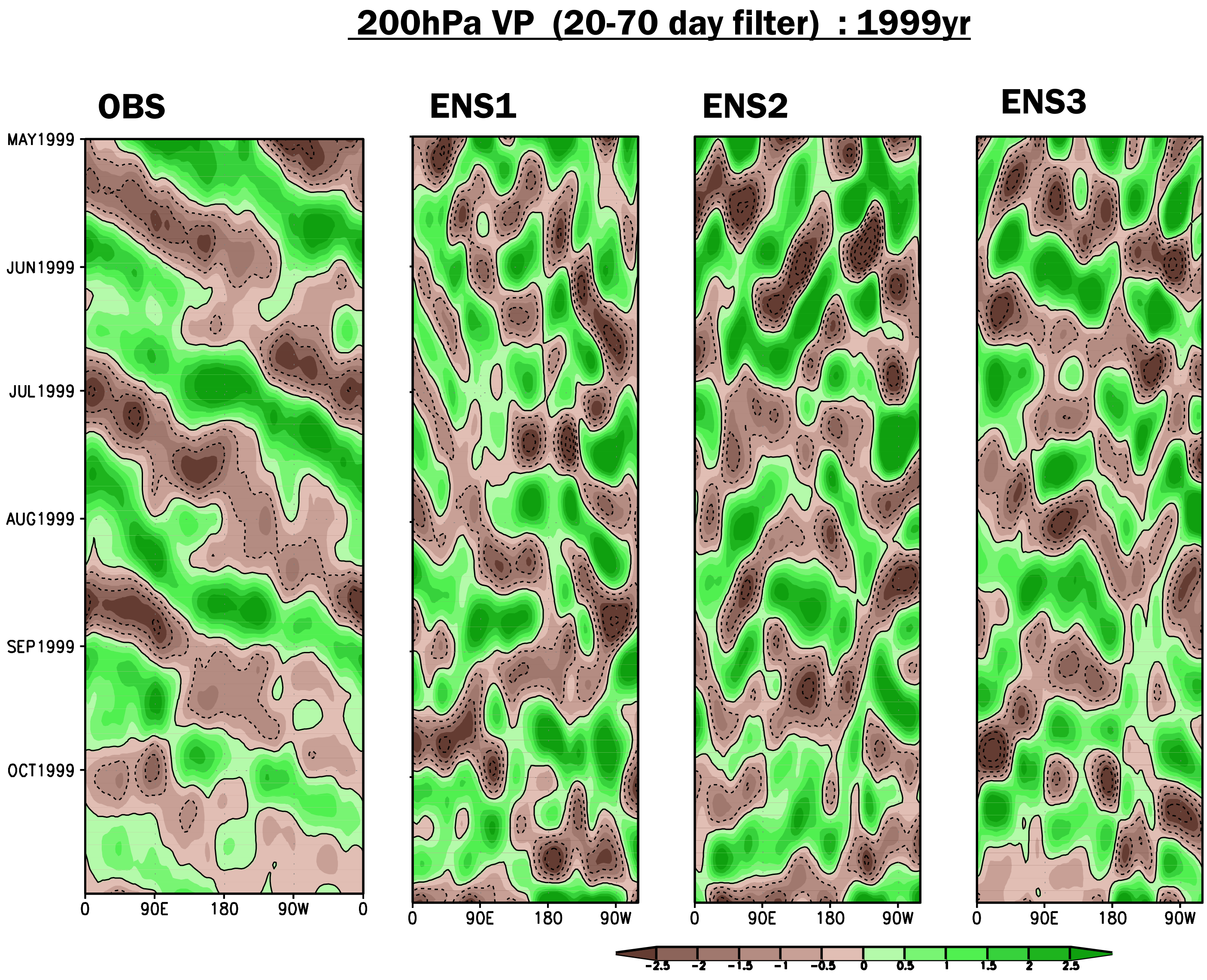
TRMM: Satellite data (Precipitation)



25km resolution



MJO simulation



A new convective parameterization in SNU AGCM

Based on
A Mass Flux Scheme

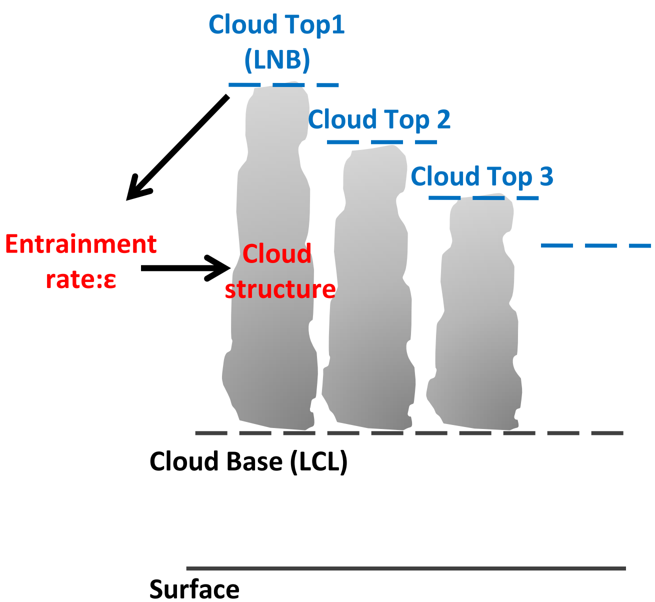
Kim and Kang (2010)

Representation of cumulus cloud

Spectral method

Top-oriented / spectrum

e.g. Arakawa and Schubert (1974)

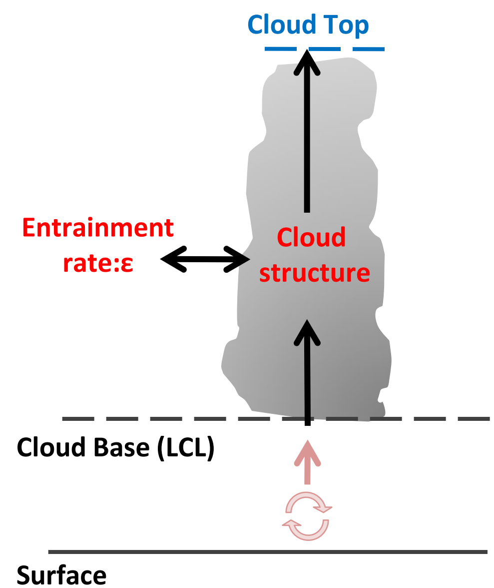


❖ **Cloud top determination**
➔ **deterministic**

Bulk method

Bottom-oriented / Bulk

e.g. Tiedtke (1989)

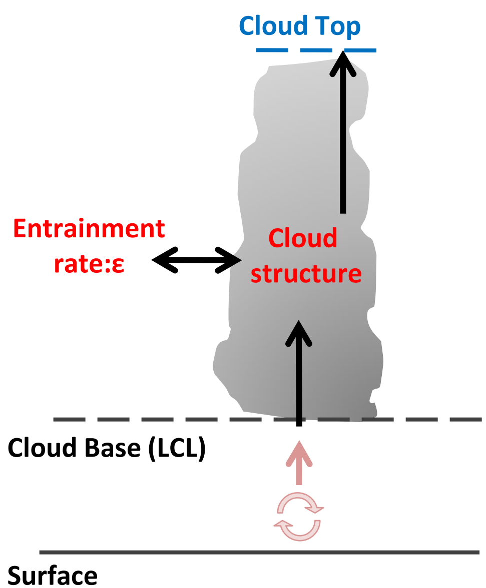


❖ **Cloud top determination**
➔ **depends on environment**

Practical representation of cumulus ensemble

Bulk method
(Kim and Kang 2010, Clim Dyn.)

Bottom-oriented / Bulk



❖ **Cloud top determination**
➔ depends on environment

❖ In-cloud vertical velocity

$$\frac{1}{2}\frac{\partial w_u^2}{\partial z} = aB - b\varepsilon w_u^2$$

Buoyancy   Entrainment rate

*a=1/6, b=2

❖ Entrainment rate

$$\varepsilon = C_\varepsilon \frac{aB}{w_u^2}$$

Gregory (2001)

$$\varepsilon = \left(\frac{1}{\overline{\overline{RH}}} - 1\right)\frac{aB}{w_u^2}$$

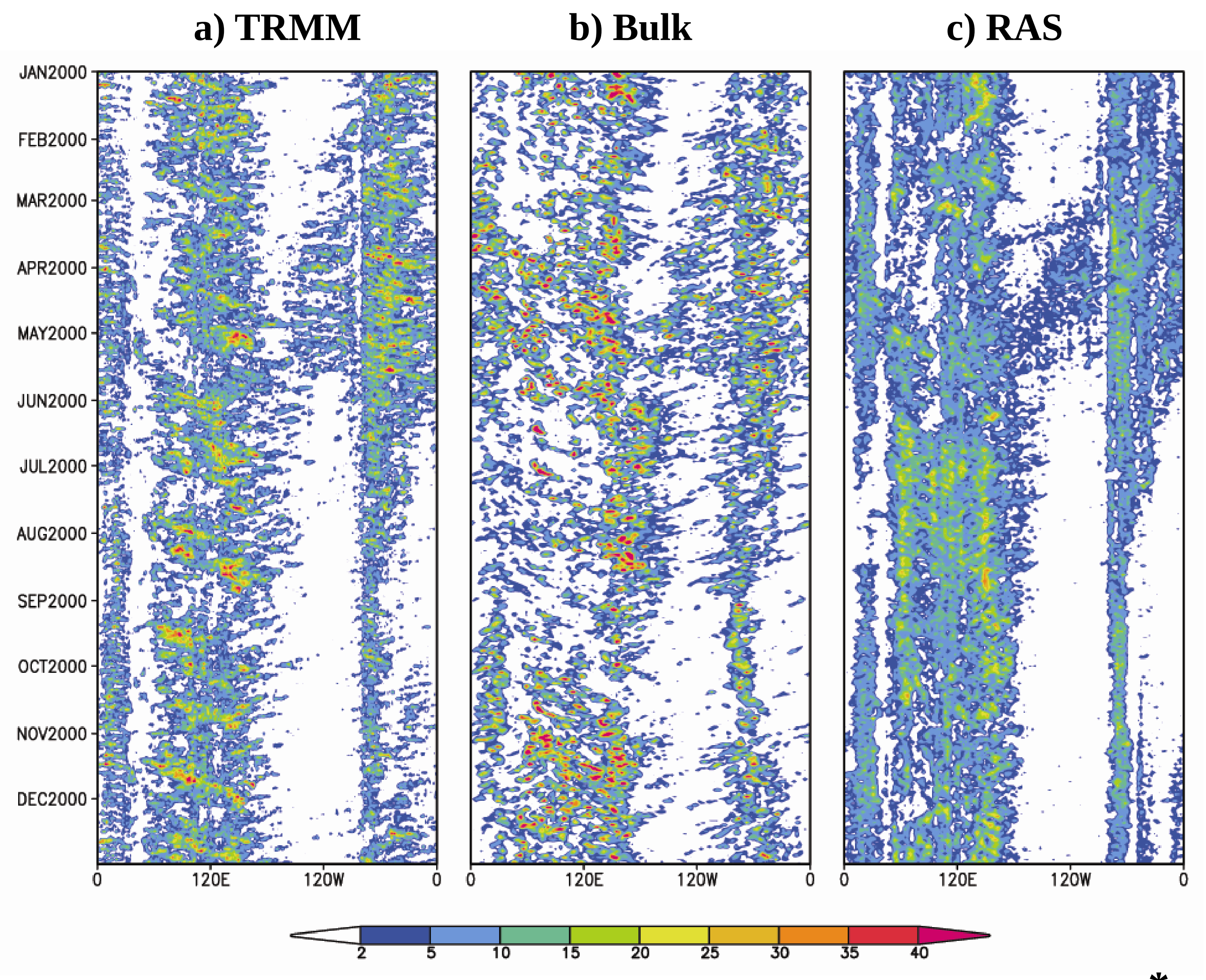
Environmental RH effect
Bechtold et al. (2009)

❖ Detrainment rate

$$\delta = \varepsilon + \frac{1}{z_t - z}$$

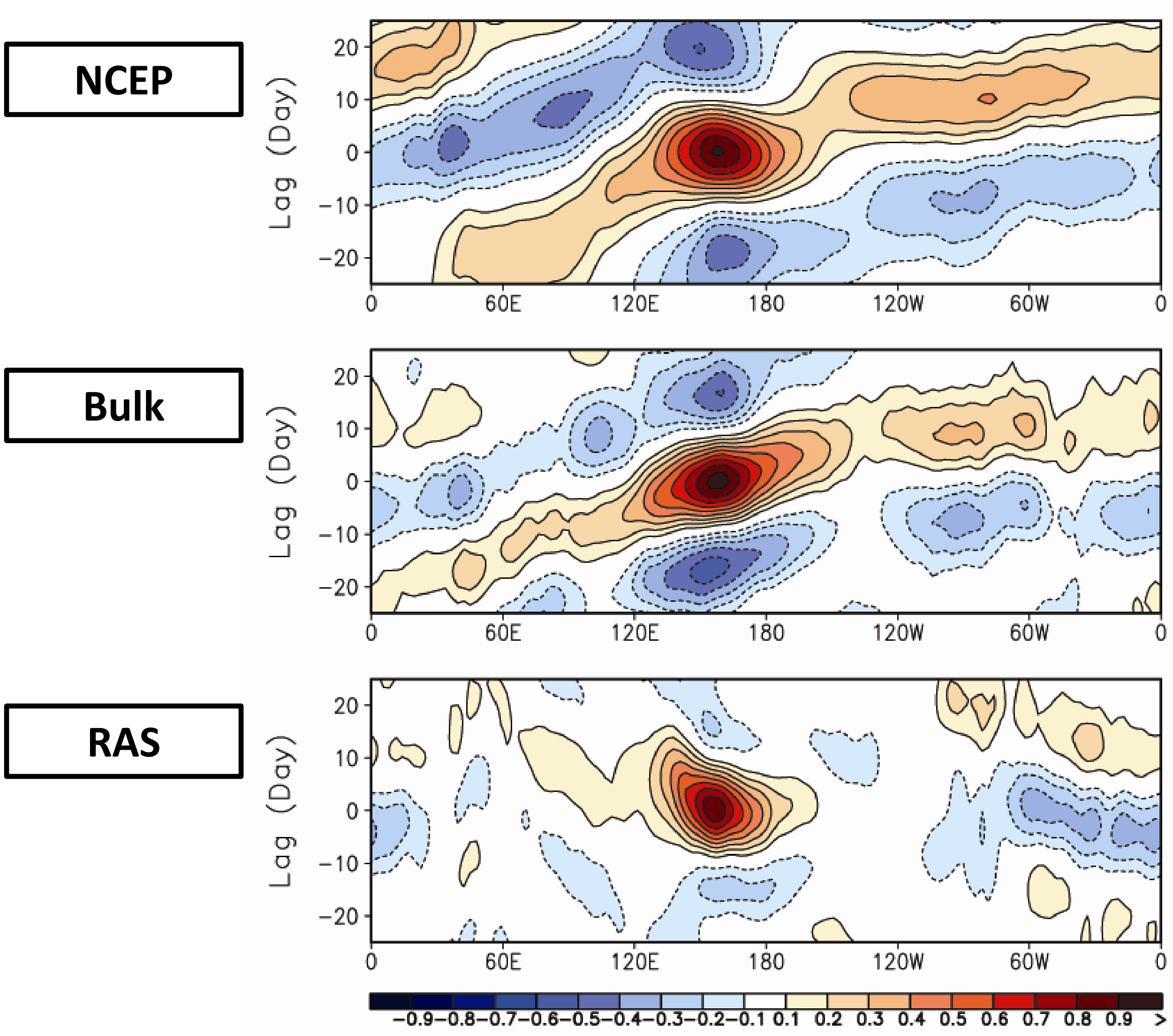
*Above max. buoyancy
(linear decrease to zero)

Equatorial (5S-5N averaged) precipitation



*year: 2000

Lag-correlation diagram (U850, 20-100day filtered)



- Reference point
: 155-160^{o}E, 5^{o}N-5^{o}S averaged

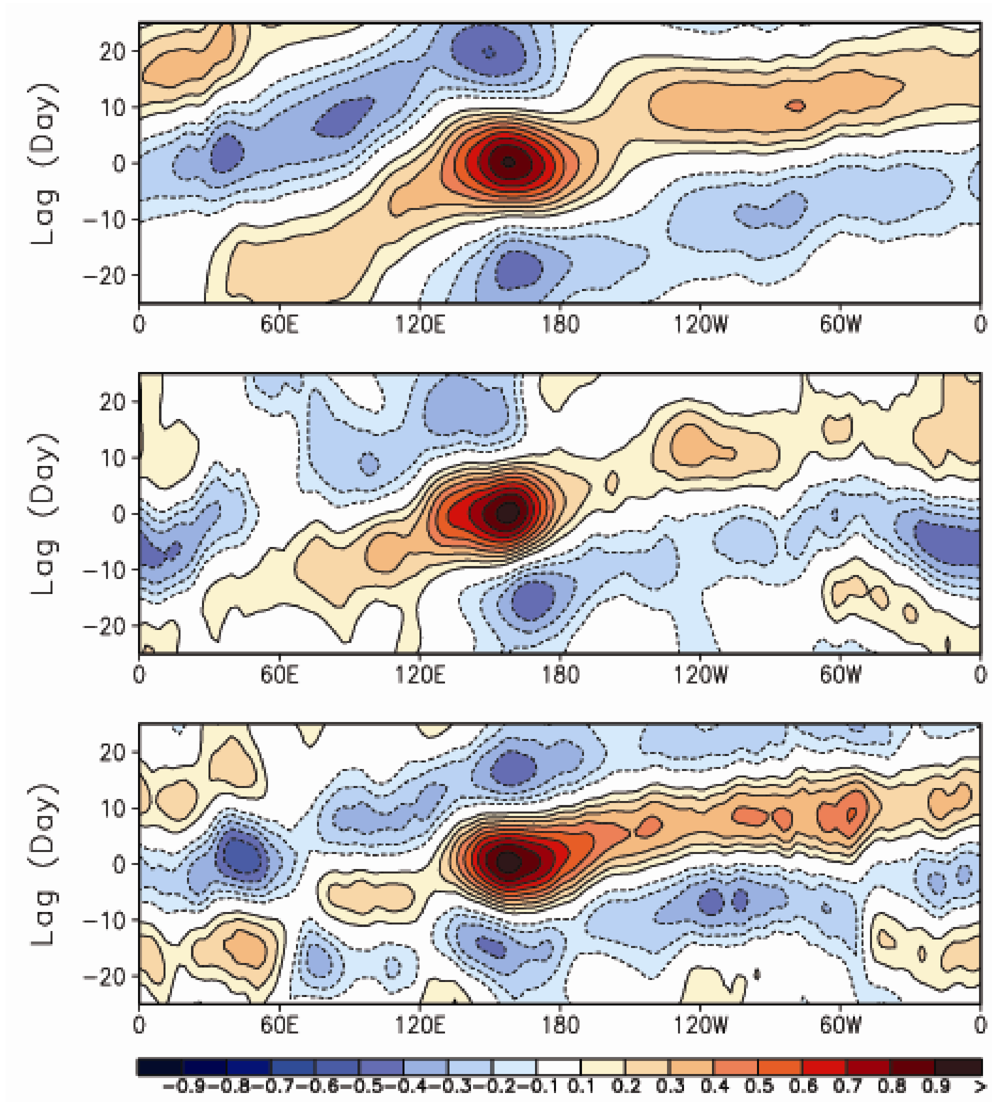
Lag-correlation diagram

(U850, 20-100day filtered)

NCEP

CGCM v.2

CGCM v.2 + Bulk

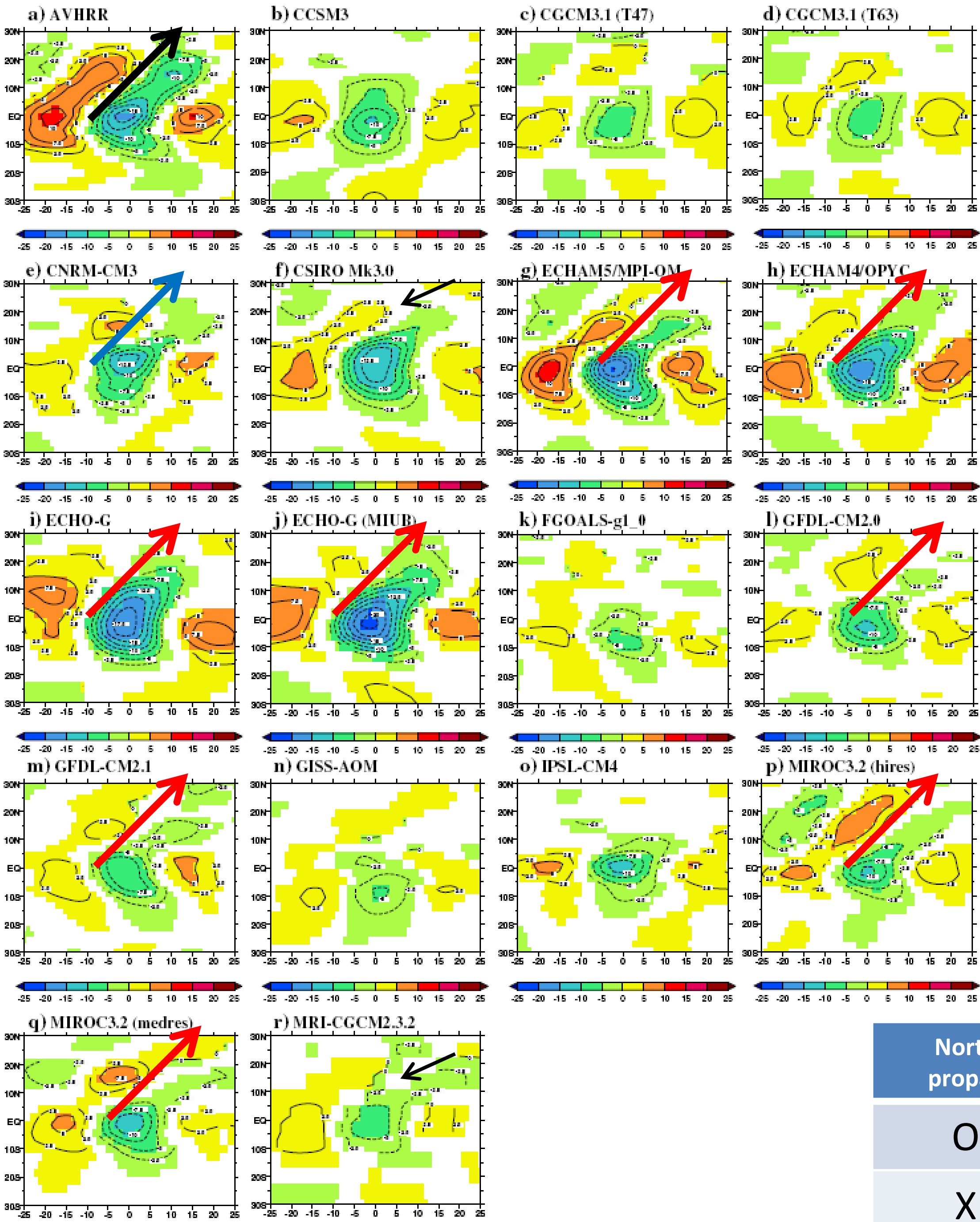


➢ Reference point

: 155-160^{o}E, 5^{o}N-5^{o}S averaged

Sperber and Annamalai (2008)

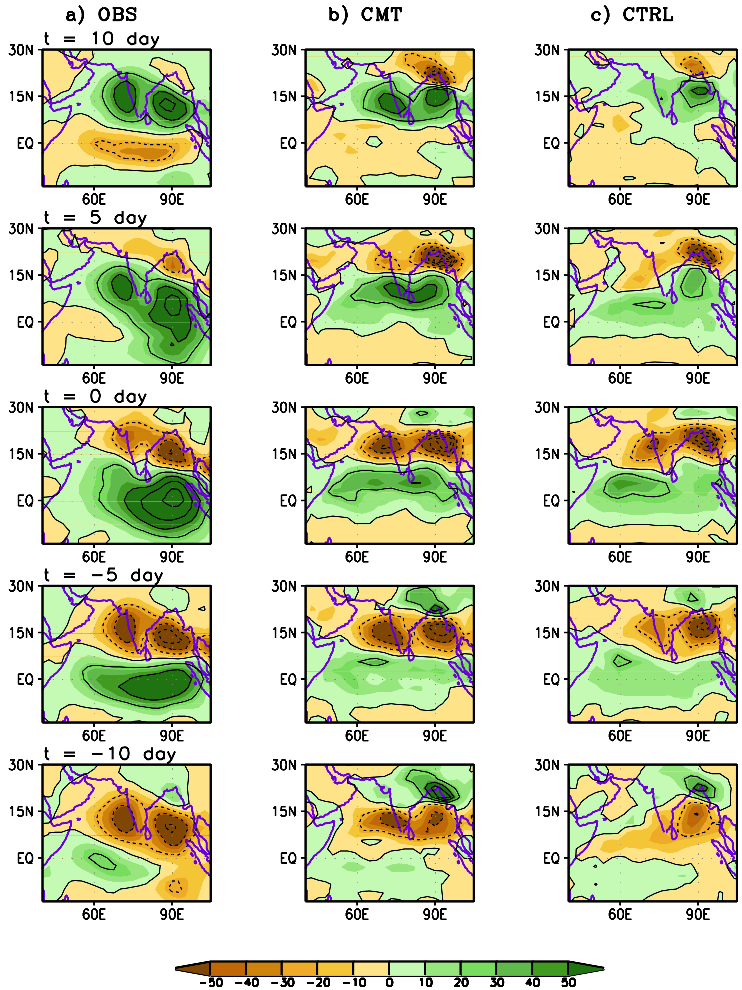
CMIP3 & 2+ Models



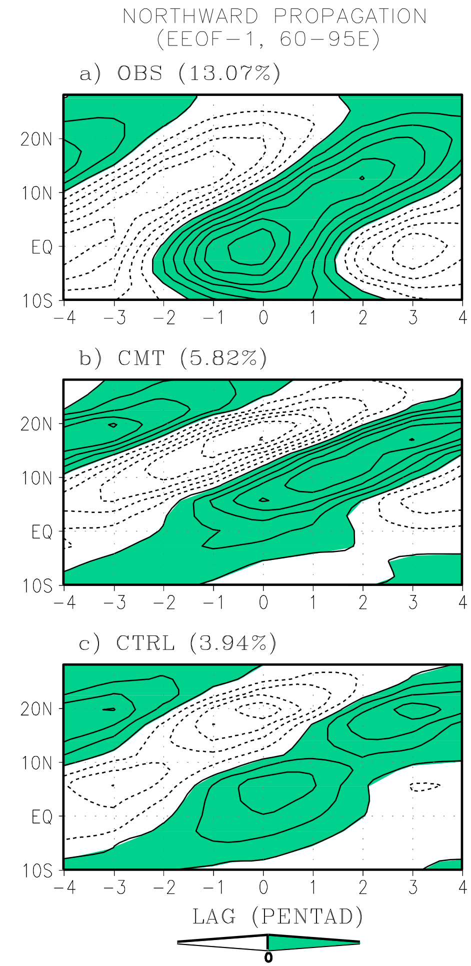
Northward propagation	CMT	No CMT
O (9)	8	1
X (8)	0	0

Northward propagation of Monsoon Convection

- Extended EOF (40-110E, 15S-30N)

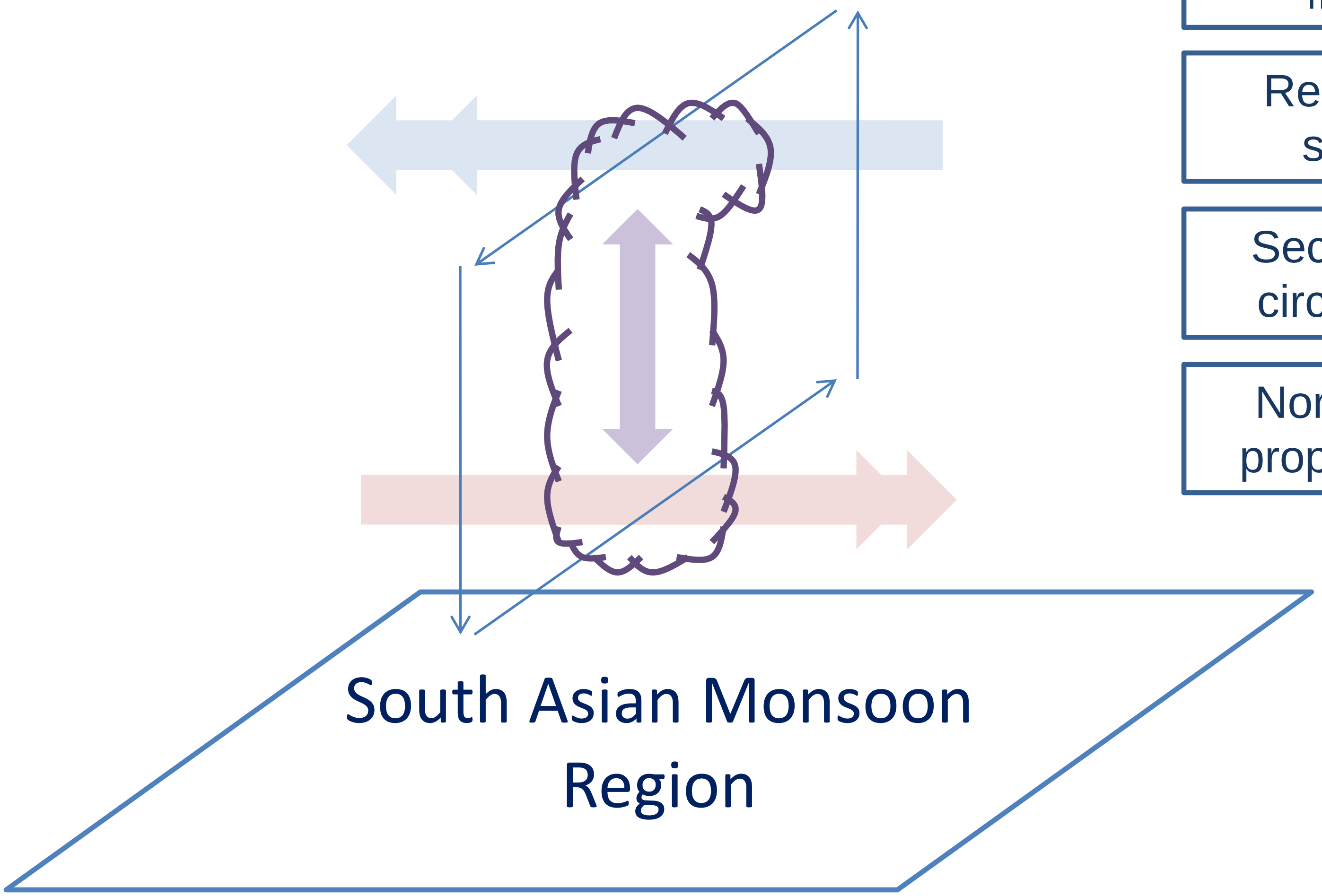


EEOF1 60-95E



- CMT: more strong northward propagation (northern region of 5N)

Physical interpretation



Convection
➔ momentum mixing

Reducing shear

Secondary circulation

Northward propagation