Progress with convective parameterization for
Improved simulation of the MJO

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Sung-Bin Park
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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

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

<table>
<thead>
<tr>
<th>Model</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
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(C.I.= 5 mm day⁻¹)
Modification 1: Cumulus Entrainment Constraint

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

\[ \mu_{\text{min}} = \frac{\alpha}{D} \]

D: PBL depth
\( \alpha \): non-negative constant

Convection can be triggered in case of \( \mu \geq \mu_{\text{min}} \)
SNU Aqua-planet AGCM with a fixed radiation

\( \alpha = 0.0 \) (control) \hspace{2cm} \alpha = 0.1 \) (modified)

(a) PRCP \hspace{2cm} (b) \( \text{VP}_{200} \)
Two Experiments in Aqua-Planet

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Description</th>
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<tbody>
<tr>
<td>Fixed</td>
<td>Prescribed zonally uniform radiative heating rate</td>
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<tr>
<td>Interactive</td>
<td>Fully interactive radiation</td>
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</tbody>
</table>

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.
ISO with turning on Cloud-Radiation Interaction

The longwave ACRF feedback is more crucial for this feature in RAS scheme.
Modification 2: Layer-cloud Precipitation time Scale

Sensitivity to Precipitation Timescale: Time-longitude Diagram

Precipitation

![Time-longitude diagram for Precipitation at 4800s, 1800s, and 900s](image)

200 hPa Velocity Potential

![Time-longitude diagram for 200 hPa Velocity Potential at 4800s, 1800s, and 900s](image)
Modification 2: Layer-cloud Precipitation time Scale

**Strategy**

- For the reduction of longwave ACRF
- Modulation of model cloudiness
- Reduction of precipitation timescale for reducing longwave heating induced by ACRF

**Characteristic precipitation timescale, \( \tau_p \)**

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

(Sundqvist, 1978)

- \( l_c \): critical cloud liquid water content
- \( t_o \): characteristic timescale for conversion of cloud droplets into raindrops

**Precipitation rate**

\[
P = \frac{l}{\tau_p}
\]

- \( P \): precipitation rate
- \( l \): cloud liquid water content
- \( \tau_p \): characteristic precipitation timescale

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

- The reduction of \( \tau_p \) means fast autoconversion from cloud liquid water to precipitable raindrops
- **Reducing Cloud Lifetime**
- Longwave ACRF (atmosphere cloud radiative forcing) heating reduced

Constant \( \tau_p = 9600 \) sec (original)  
smaller value up to 900 sec
Zonal Mean OLR during Sep96 ~ Aug98

Experimental Design

<table>
<thead>
<tr>
<th></th>
<th>Tokioka effect</th>
<th>Layer-cloud precipitation timescale</th>
<th>Coupling with mixed layer</th>
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<tr>
<td></td>
<td>RAS cumulus</td>
<td>Reduced region</td>
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<td></td>
<td>entrainment</td>
<td>LSC time scale $\tau_0$</td>
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<tr>
<td></td>
<td>minimum</td>
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<td>No</td>
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<tr>
<td>Exp1</td>
<td>$\alpha=0.1$</td>
<td>20°S~20°N</td>
<td>9600 sec</td>
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<td></td>
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<td>9600/900 sine curve</td>
<td>Slab ocean mixed-layer</td>
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<td>model (Waliser et al. 1999)</td>
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<tr>
<td>Exp2</td>
<td>$\alpha=0.1$</td>
<td>20°S~20°N</td>
<td>9600/900 sine curve</td>
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<tr>
<td>Exp3</td>
<td>$\alpha=0.1$</td>
<td>Whole globe</td>
<td>1800 sec</td>
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</table>
Simulated precipitation

- RAS
- Saturation deficit
- Bulk
Modification3: Relative Humidity Criteria

- **10°S-10°N Time-longitude Cross Section of Precipitation**

(a) Control

(b) Modified

**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 30-70 days)  

IPCC AR4 models

- **different colors** - different climate models
- **different colors** - different convection schemes

Convection scheme:
- Represent model diversity in MJO variability
Resolution impact with same physics

TRMM: Satellite data (Precipitation)
MJO simulation

200hPa VP (20-70 day filter) : 1999yr

OBS

MAY1999
JUN1999
JUL1999
AUG1999
SEP1999
OCT1999

ENS1

ENS2

ENS3
A new convective parameterization in SNU AGCM

Based on
A Mass Flux Scheme

Representation of cumulus cloud

Spectral method

Top-oriented / spectrum
e.g. Arakawa and Schubert (1974)

Cloud Base (LCL)

Cloud Top 1 (LNB)

Cloud Top 2

Cloud Top 3

Entrainment rate: ε

Cloud structure

Surface

Cloud top determination

Deterministic

Bulk method

Bottom-oriented / Bulk
e.g. Tiedtke (1989)

Cloud Top

Entrainment rate: ε

Cloud structure

Surface

Cloud top determination

Depends on environment
Practical representation of cumulus ensemble

**Bulk method**

*(Kim and Kang 2010, Clim Dyn.)*

- **Bottom-oriented / Bulk**

- **In-cloud vertical velocity**

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

- **Entrainment rate**

\[
\varepsilon = C_\varepsilon \frac{aB}{w_u^2}
\]

*Gregory (2001)*

\[
\varepsilon = \left(\frac{1}{\text{RH}} - 1\right) \frac{aB}{w_u^2}
\]

*Environmental RH effect*  
*Bechtold et al. (2009)*

- **Detrainment rate**

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

*Above max. buoyancy*  
*(linear decrease to zero)*

- **Cloud top determination**

- **depends on environment**
Equatorial (5S-5N averaged) precipitation

a) TRMM
b) Bulk
c) RAS

*year: 2000
Lag-correlation diagram (U850, 20-100day filtered)

- Reference point: 155-160°E, 5°N-5°S averaged
Lag-correlation diagram
(U850, 20-100day filtered)

Reference point
155-160°E, 5°N-5°S averaged
Northward propagation

CMT

No CMT

Sperber and Annamalai (2008)

CMIP3 & 2+ Models

<table>
<thead>
<tr>
<th>Northward propagation</th>
<th>CMT</th>
<th>No CMT</th>
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<tbody>
<tr>
<td>O (9)</td>
<td>8</td>
<td>1</td>
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<td>X (8)</td>
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Northward propagation of Monsoon Convection

- Extended EOF (40-110E, 15S-30N)
  - CMT: more strong northward propagation (northern region of 5N)
Physical interpretation

South Asian Monsoon Region

Convection ➔ momentum mixing
Reducing shear
Secondary circulation
Northward propagation