A Preliminary Test of Super-parameterization in an Idealized Framework

Joon-Hee Jung and Akio Arakawa
University of California, Los Angeles
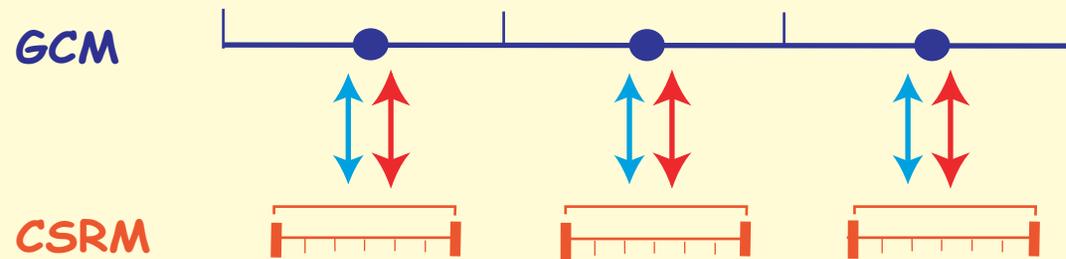
The purpose of the present study

To test and revise the method of coupling a cloud-system-resolving model (CSRM) and a **GCM** in the "Super-parameterization".

- Lateral boundary conditions of the CSRM
- Communications between the GCM and the CSRM

The Original Method of Coupling, 2D

○ **CSRM is confined to each column of a GCM with a cyclic lateral boundary condition. (no communication between CSRMs)**

○ **Communications between the GCM and the CSRM at the ●points.**

  – **Large-scale advective tendencies of thermodynamic variables are given to CSRM.**

  – **The thermodynamic variables of GCM are updated by horizontal averaging of the CSRM fields.**

  – **The E-W flows of CSRM and GCM are coupled by relaxing one to each other on a finite time-scale.**

A Revised Method of Coupling, 2D
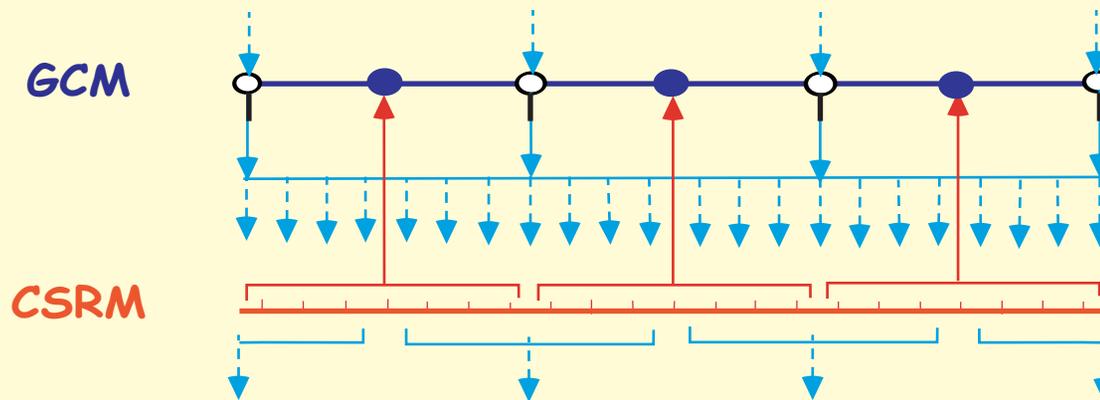
○ **CSRM shares the whole domain of GCM.**

○ **Communications between the GCM and the CSRM at the • and ○ points.**

- The thermodynamic variables of GCM are updated by horizontal averaging of the CSRM fields.

- The E-W flows of CSRM and GCM are coupled at the ○ points by relaxing one to each other on a finite time-scale.

"GCM and CSRM share approximately the same fluxes of mass and other quantities at the borders of GCM grid boxes."

Experiments

○ **We set up a two-dimensional model that combines a CSRM** [*]**, with detailed formulations of microphysics, radiation and turbulence, and a "GCM" which is a lower-resolution version of the same model but without physics.**

  [*] **The UCLA/University of Utah/CSU Cloud-System-Resolving Model (CSRM)**

○ **Under idealized tropical conditions, we perform**

  – **CSRM runs (CONTROLs),**
  – **runs with the "Super-parameterization" using the original and revised methods of coupling for the selected realizations of CONTROL.**

  Domain size of "GCM": 19km (height) × 512km (width)

  Horizontal resolution: 2km for CSRM, 16 and 64km for "GCM"

  Vertical resolution: 34 layers with a stretched vertical grid

  Initial conditions and prescribed large-scale forcing: GATE Phase-III mean sounding.

CONTROL (over land, strong forcing, geostrophic wind shear)

Clouds, precipitation and wind

An example of the development of cloud systems for 1 hour period

local time: 12 h

local time: 13 h

CONTROL (over land, strong forcing, geostrophic wind shear)
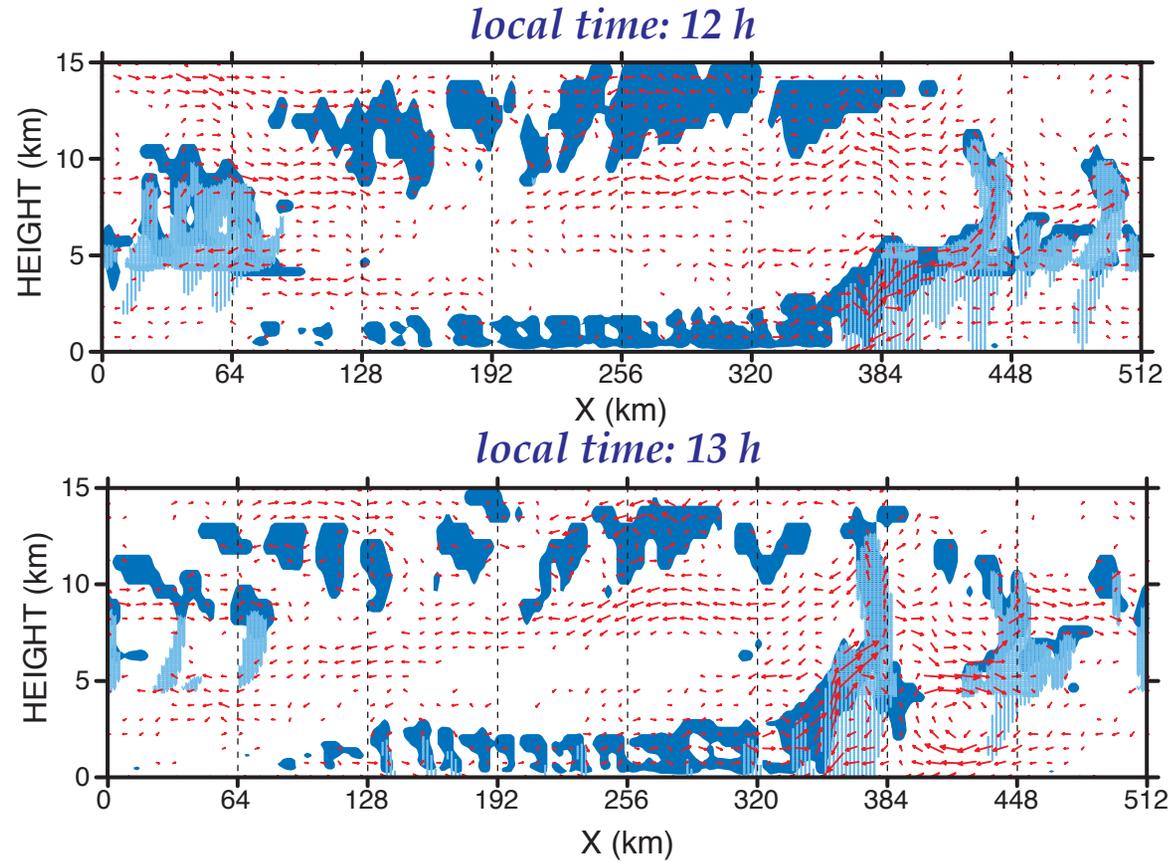
Moist Static Energy (K)
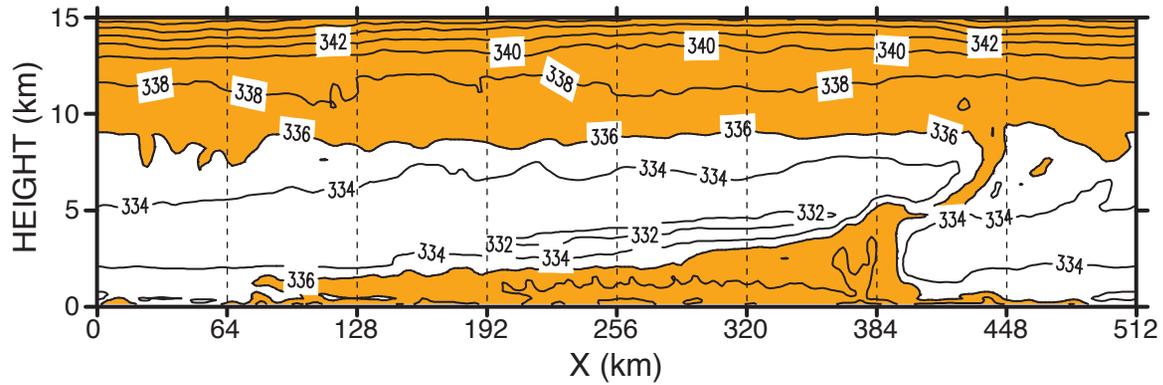
local time: 12 h

local time: 13 h

Moist Static Energy (K)
local time: 13 h
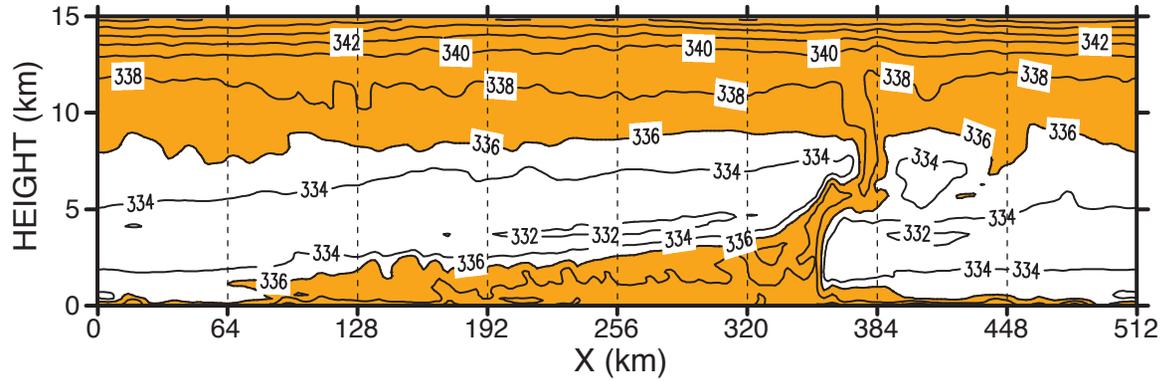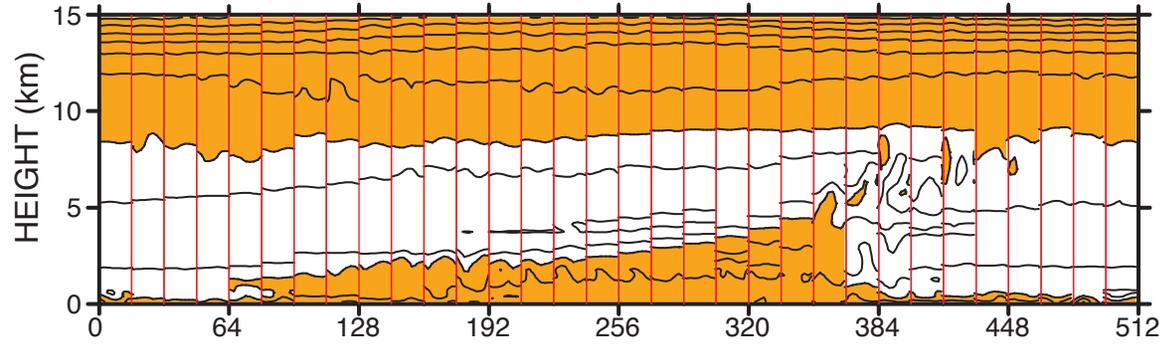
CONTROL

HEIGHT (km)

The original method of coupling

CRCP_16km

HEIGHT (km)

CRCP_64km

HEIGHT (km)

X (km)

Moist Static Energy (K)
local time: 13 h

CONTROL

HEIGHT (km)

The revised method of coupling

CRCP_16km
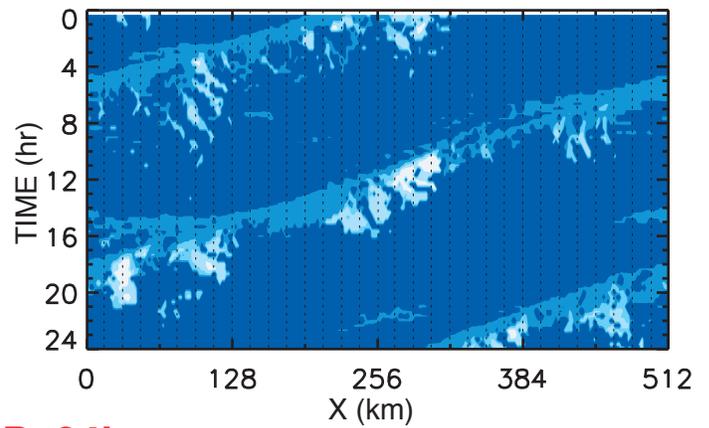
HEIGHT (km)

CRCP_64km

HEIGHT (km)

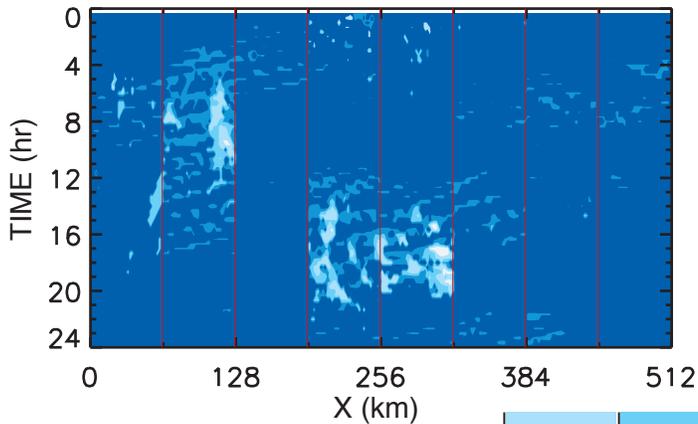X (km)
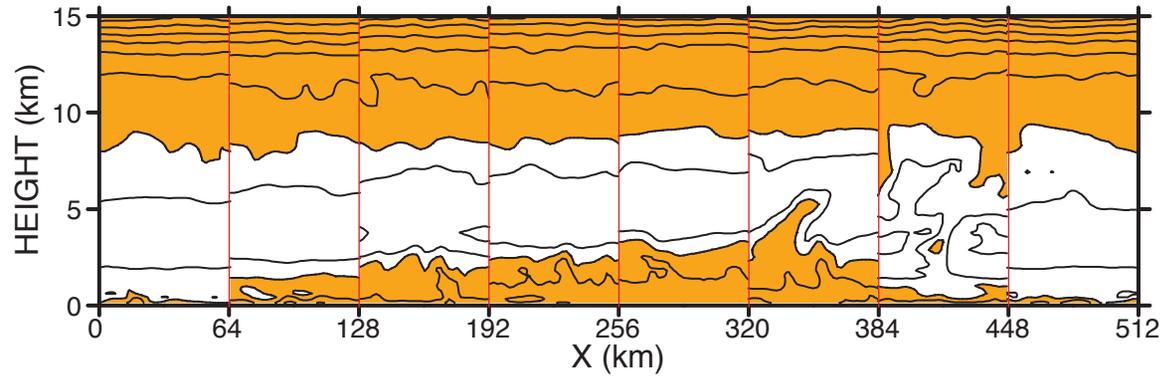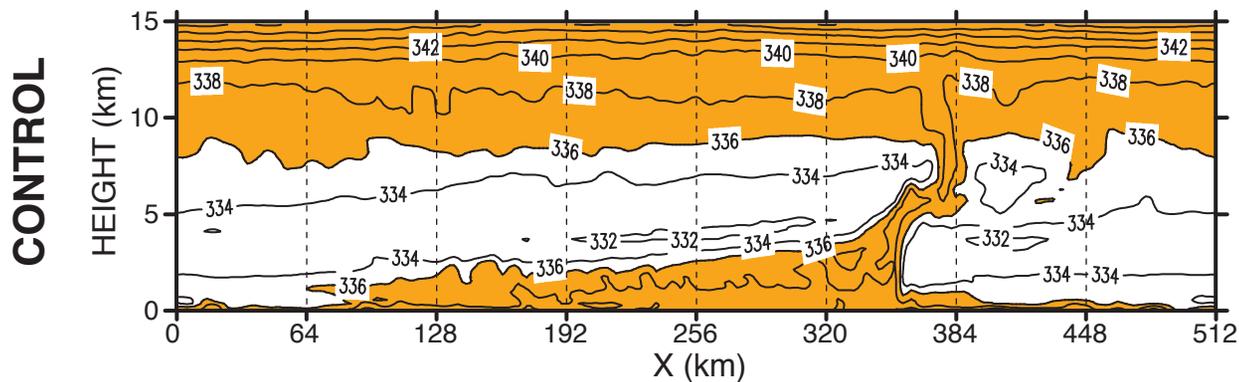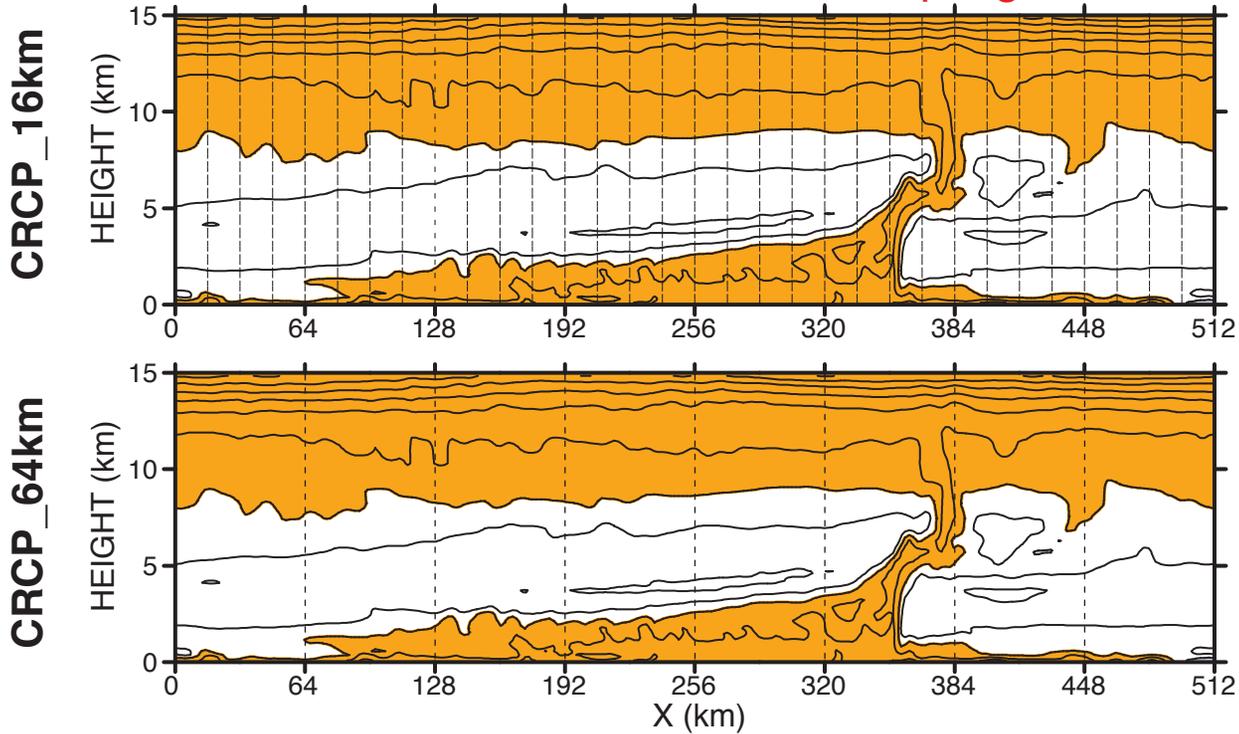
Upward Mass Flux
(after 20 min. integration)

TR 9

CONTROL

Original Coupling

Revised Coupling

CRCP_16km

CRCP_64km

0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45

$(kg\ m^{-2}\ s^{-1})$
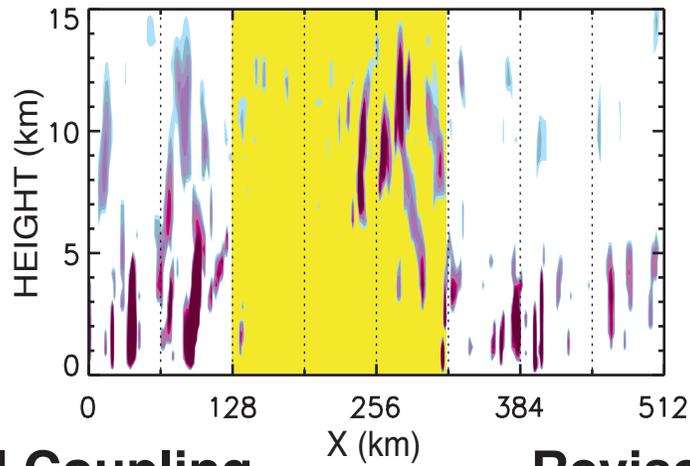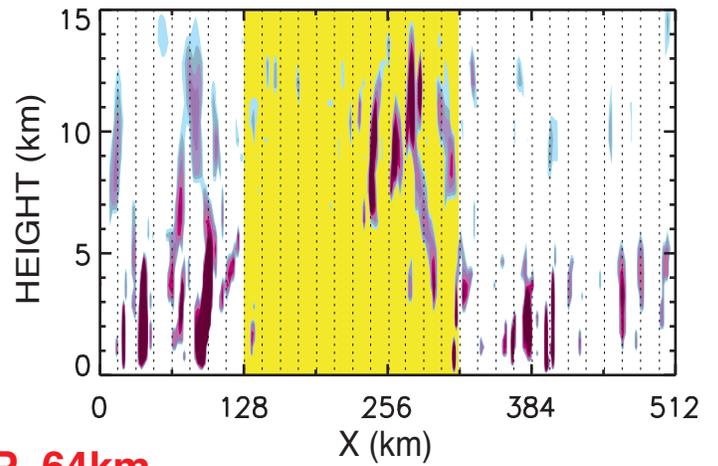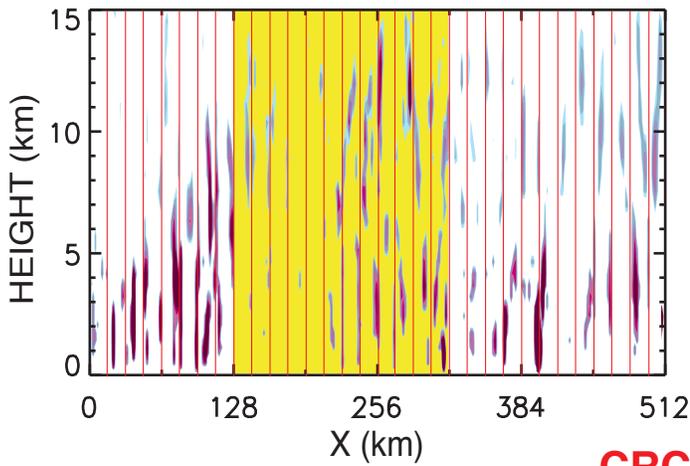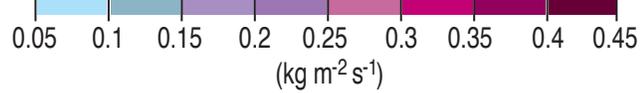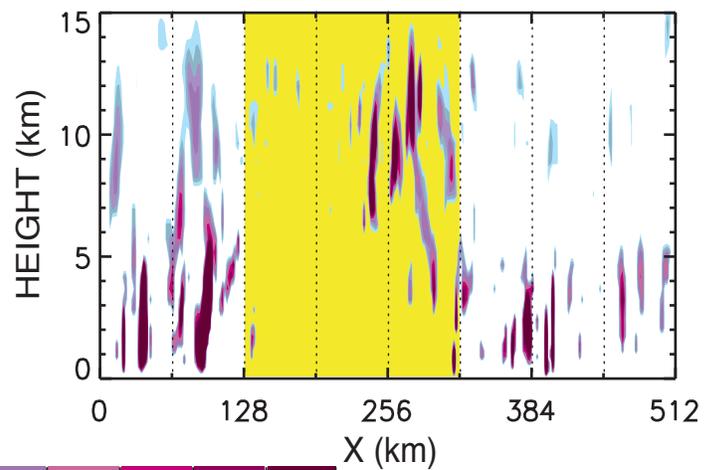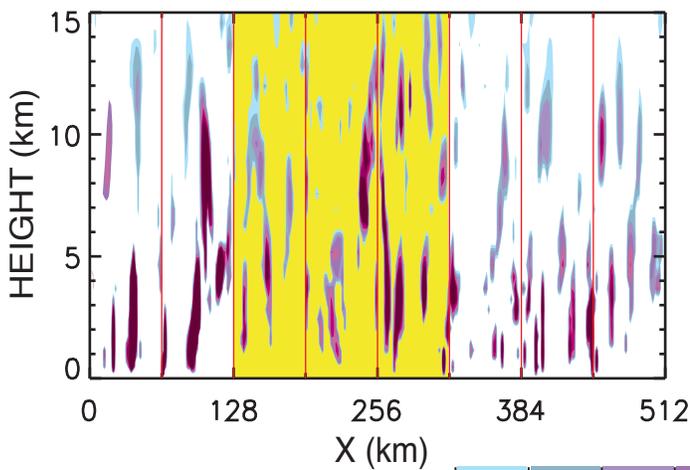
Cloud Top Temperature

TR 10

CONTROL
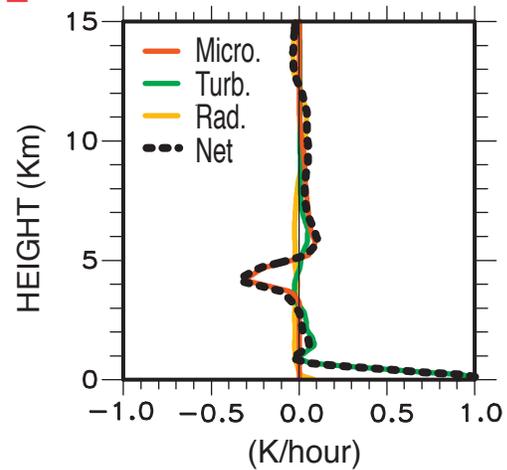

Original Coupling

Revised Coupling

CRCP_16km
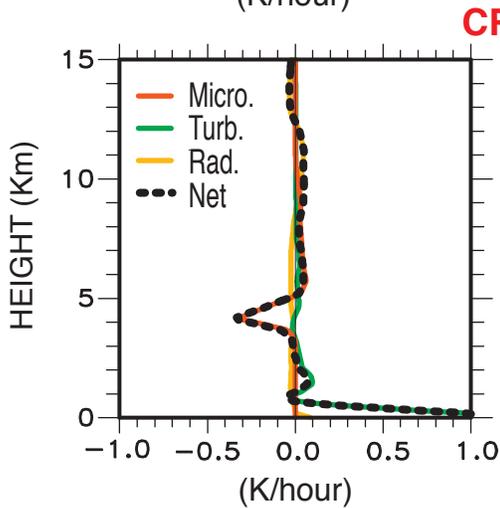

CRCP_64km

220 240 260 280

(K)
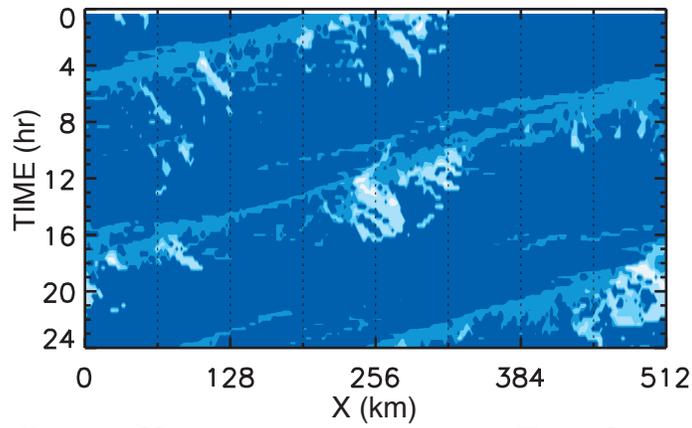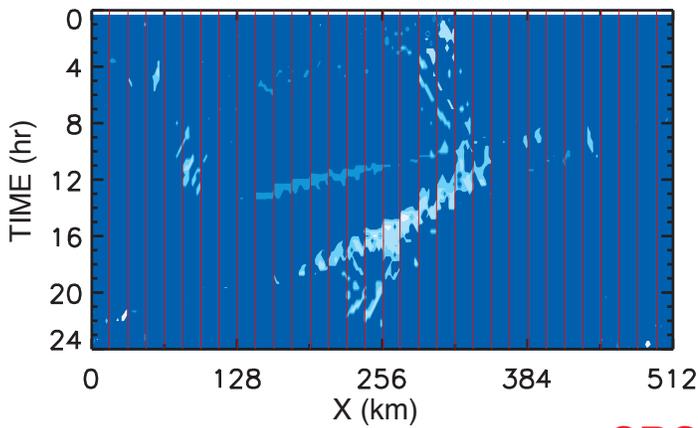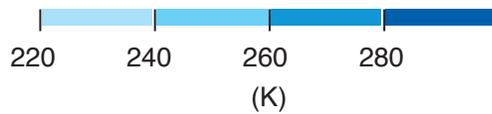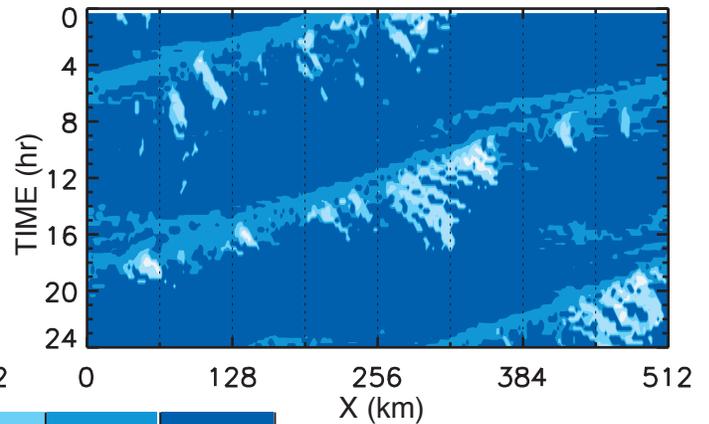
Ensemble/Domain Averaged Profiles of Real Sources
Moist Static Energy

CONTROL
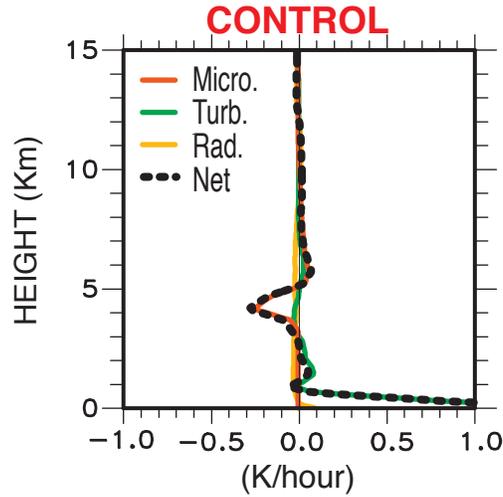
Original Coupling

Revised Coupling

CRCP_16km

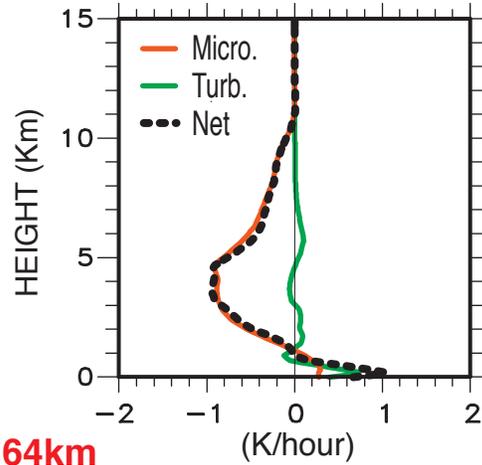### CRCP_64km

Ensemble/Domain Averaged Profiles of Real Sources Total Water
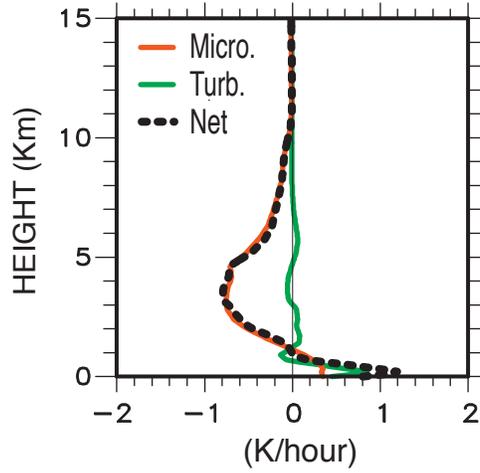
Ensemble/Domain Averaged Profiles of
Required and Simulated Sources
(late afternoon, 1 hour interval for physics)

Moist Static Energy

Original Coupling   **Revised Coupling**

CRCP_16km

CRCP_64km

Ensemble/Domain Averaged Profiles of
Required and Simulated Sources
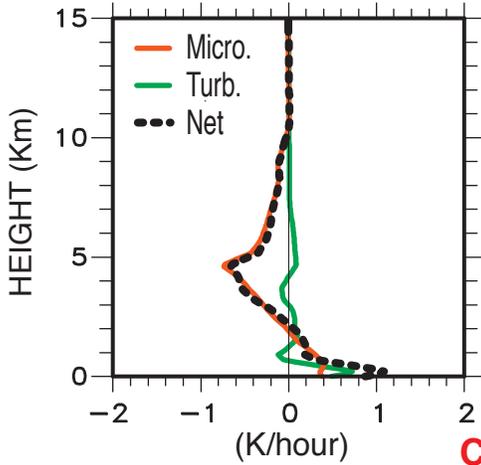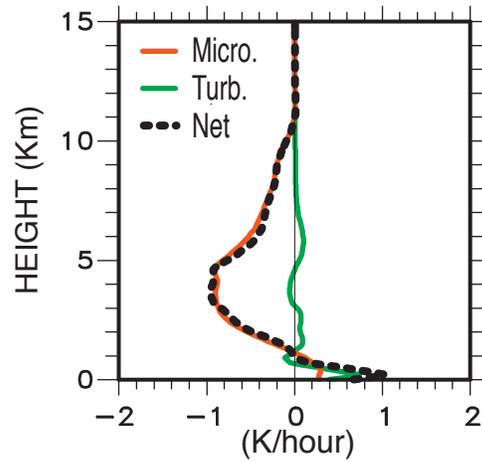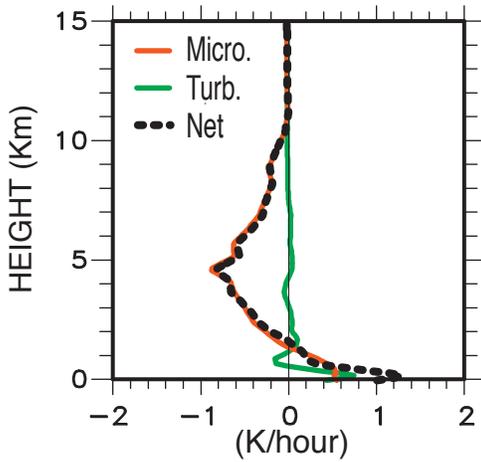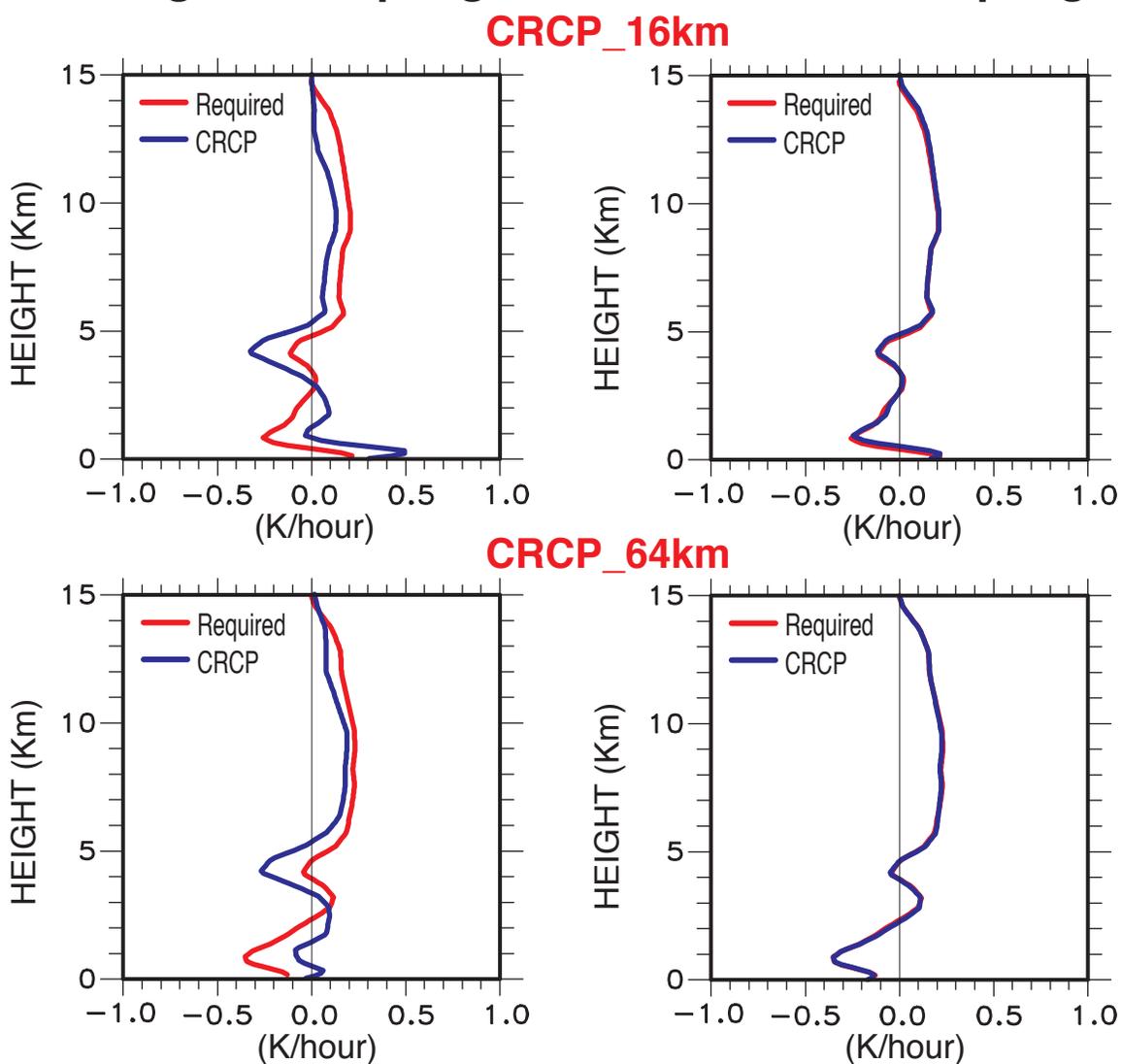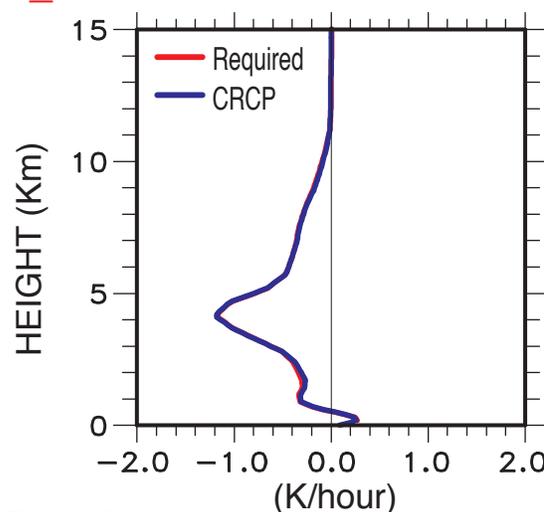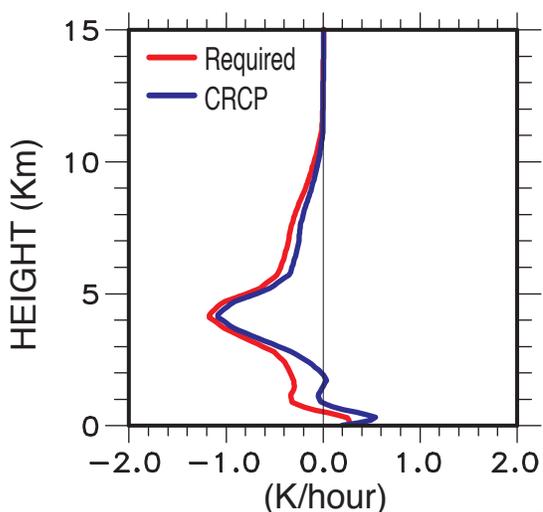### (late afternoon, 1 hour interval for physics)
Total Water

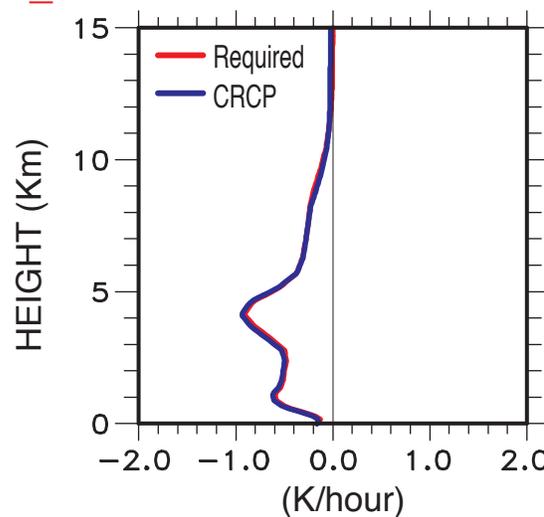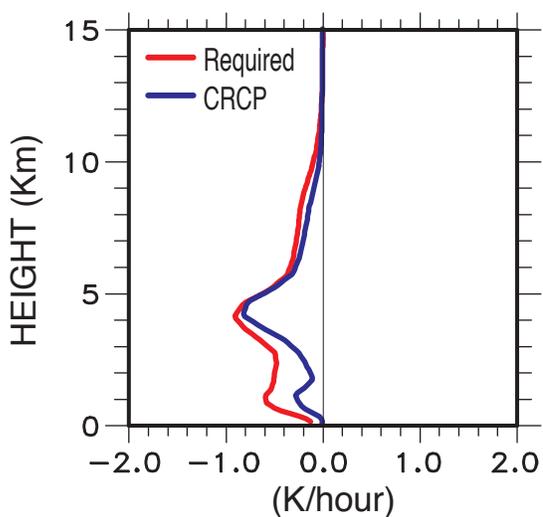## Original Coupling   Revised Coupling

CRCP_16km

CRCP_64km

Errors of the Ensemble Time/Domain Averaged Profiles Predicted with CRCP

Original Coupling **Revised Coupling**

Moist Static Energy

Total Water

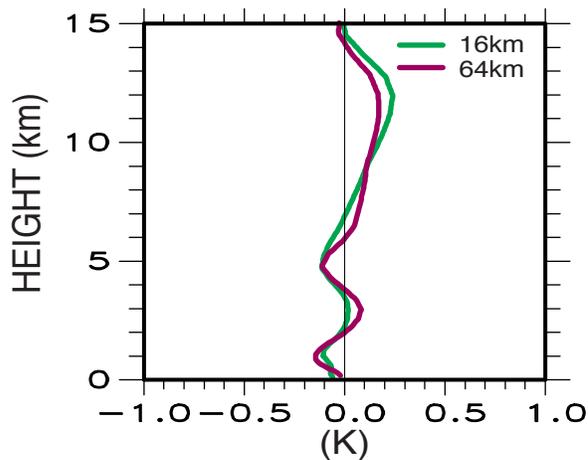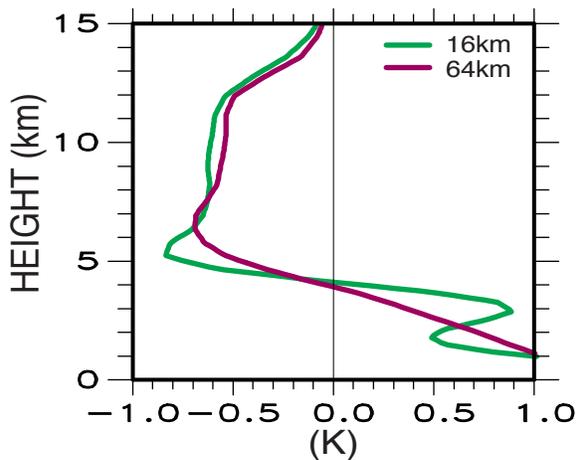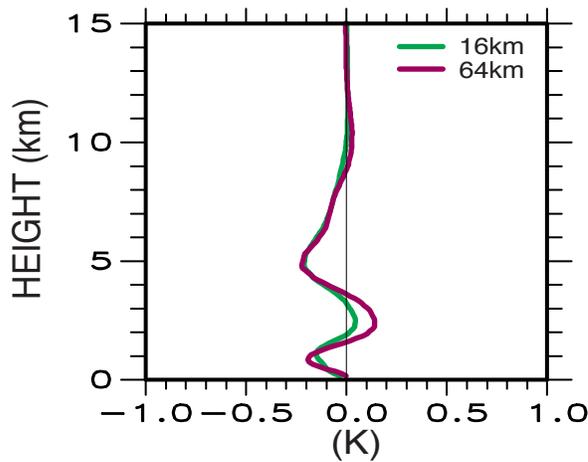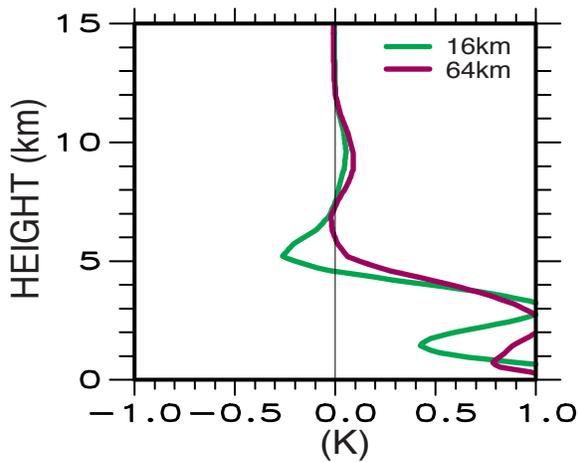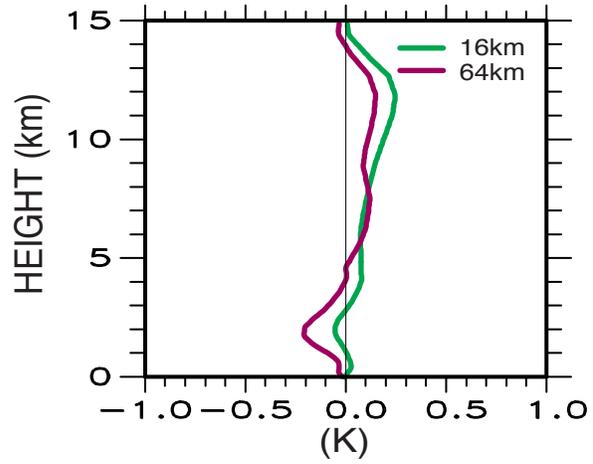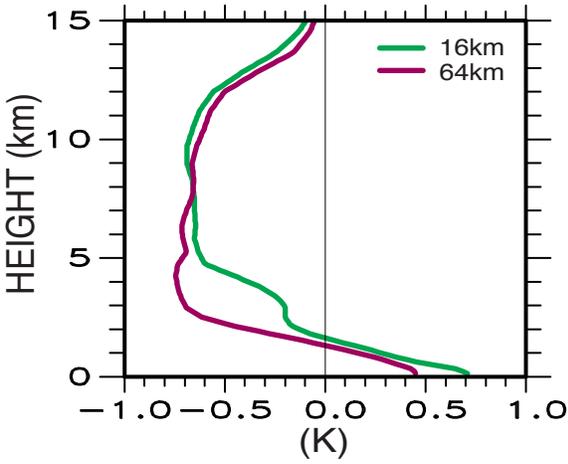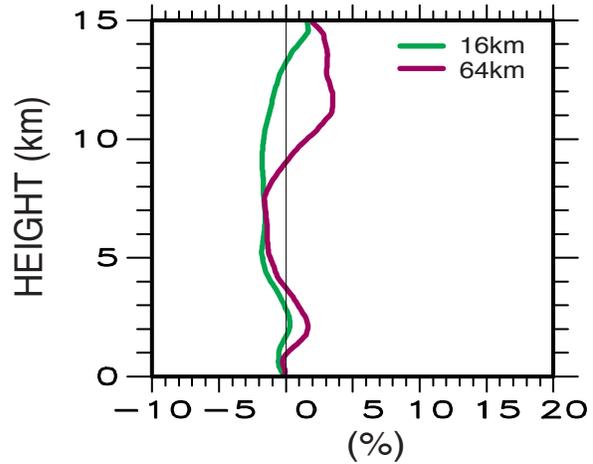# Errors of the Ensemble Time/Domain Averaged Profiles Predicted with CRCP

Original Coupling **Revised Coupling**

Temperature

Relative Humidity

SUMMARY AND CONCLUSIONS
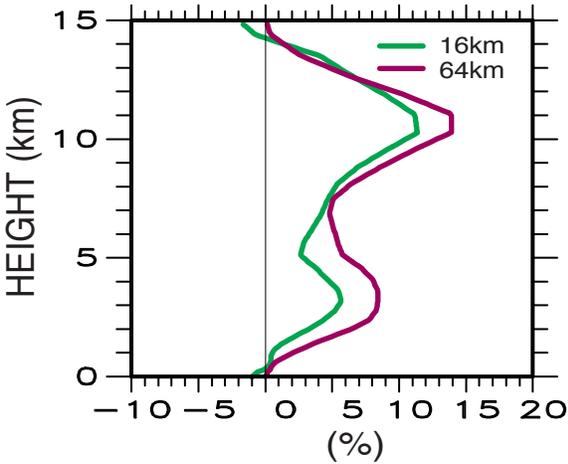
○ **The original and revised methods of coupling a CSRM and a GCM are tested in the two-dimensional framework.**

  With the original method of coupling,
  - **cloud systems can propagate only when the grid size of GCM is very fine,**
  - **spurious vertical fluxes are generated due to the cyclic lateral boundary condition,**
  - **simulated sources are generally weaker than the required sources, so that errors appear on large-scale thermodynamic fields.**

  With the revised method of coupling,
  - **cloud systems propagate properly,**
  - **no spurious vertical fluxes due to the cyclic lateral boundary condition exist,**
  - **errors appearing on large-scale thermodynamic fields are relatively small.**

SUMMARY AND CONCLUSIONS

○ **The sensitivity to the choice of relaxation times for thermodynamic fields and momentum are also tested.**

The revised method of coupling
is not sensitive to the choice of relaxation times for momentum up to 6 hours, and is sensitive to that for thermodynamic fields.

Errors of the Ensemble Time/Domain Averaged Profiles Predicted with CRCP_64km
(revised coupling with different relaxation times for thermodynamic variables)