# Comparison of convective behaviors in meso scale models depending on the horizontal resolutions


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# Point of View

Compare convective behaviors depending on horizontal resolutions using TRMM-LBA database and our model, JMA-NHM

- to explain the concentrated convection problem on the JMA's regional NWP model through the comparison
- to discuss the problems about our convective parameterization, Kain-Fritsch scheme adopted to 5km grid spacing operational model, and
- to find a suitable convective parameterization for the horizontal grid spacing of a few km (# Future Work)

# JMA-NHM = Japan Meteorological Agency – Nonhydrostatic Model

# Outline

## 1. Introduction

JMA's Regional NWP systems i.e. MSM and LFM

Concentrated convection problem aka Grid Point Storm

## 2. Convective behaviors with the JMA-NHM

Idealized experiment : TRMM-LBA case

Comparison in the scope of horizontal resolutions

## 3. Summary

# 1. Introduction

## Regional NWP systems operated @ JMA

**To prevent natural disasters**

- **MSM**
  = **Meso Scale Model**
- To predict heavy precipitation
- Grid spacing: **5** km
- Vertical layers: **50**
- Top : ~ 22 km
- First layer : 20 m
- Domain : whole Japan
- Convective parameterization
  → **Kain-Fritsch scheme**

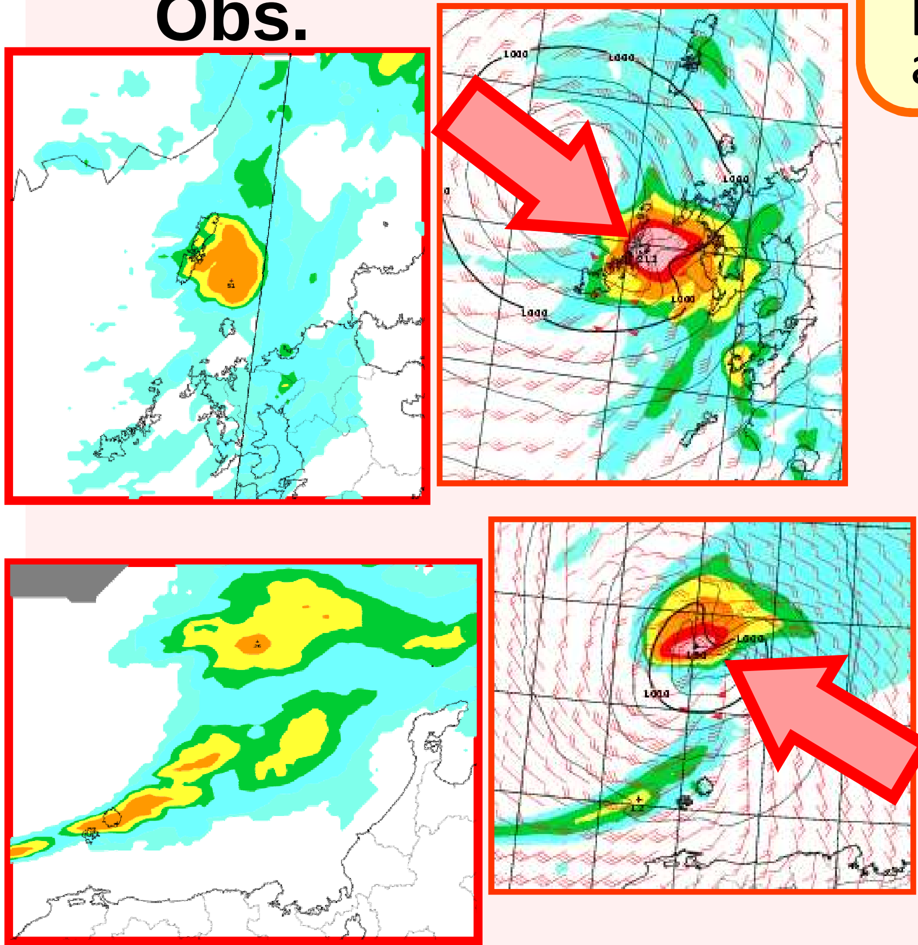
- **LFM**
  = **Local Forecast Model**
- To predict more local phenomena (heavy precipitation)
- Grid spacing: **2** km
- Vertical layers: **60**
- Top : ~ 21 km
- First layer : 20 m
- Domain : part of Japan
- **No** convective parameterization
- **Under trial operation**
  ( regular operation planned in 2012 on the next Super-Computer )

**Both models based on JMA-NHM**

# 1. Introduction
## Problem about Grid Point Storm on MSM and LFM

- **MSM** Grid spacing : **5** km

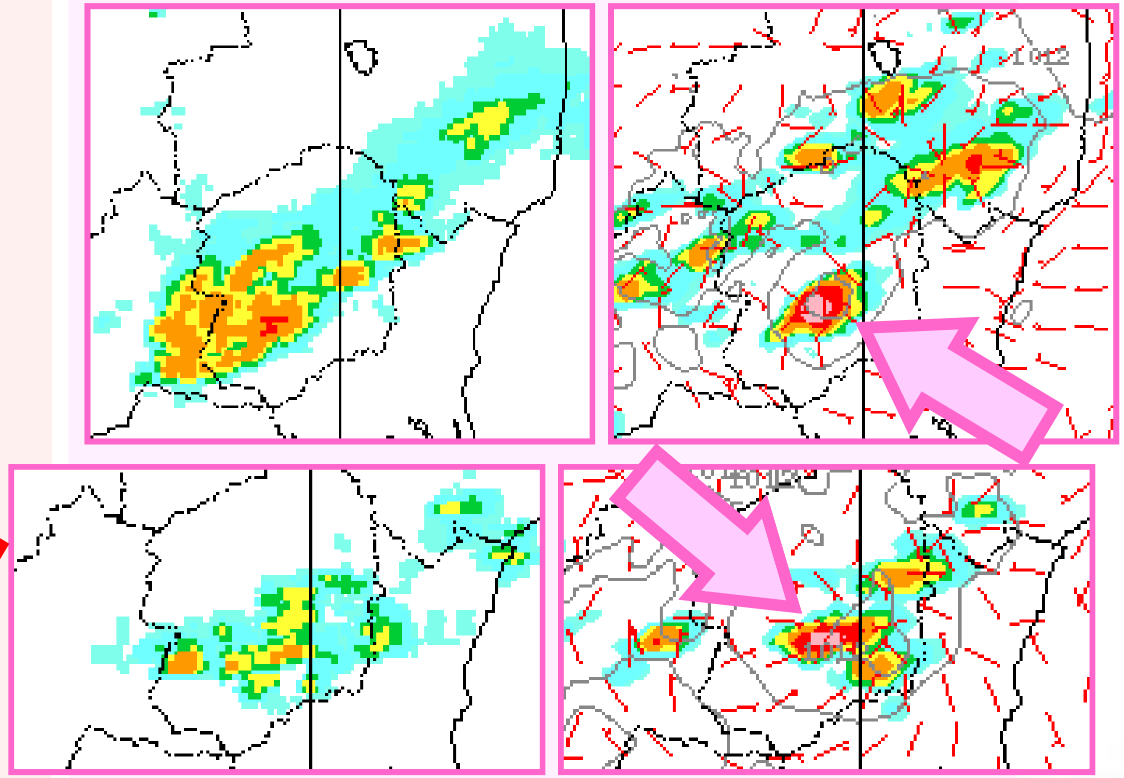
**Obs.** **MSM forecasts**



- **LFM** Grid spacing : **2** km

In some cases,
precipitation of **more than 100 mm/h** predicted against observations

**Obs.** **LFM forecasts**



0.4 1 5 10 20 50 100 mm/h

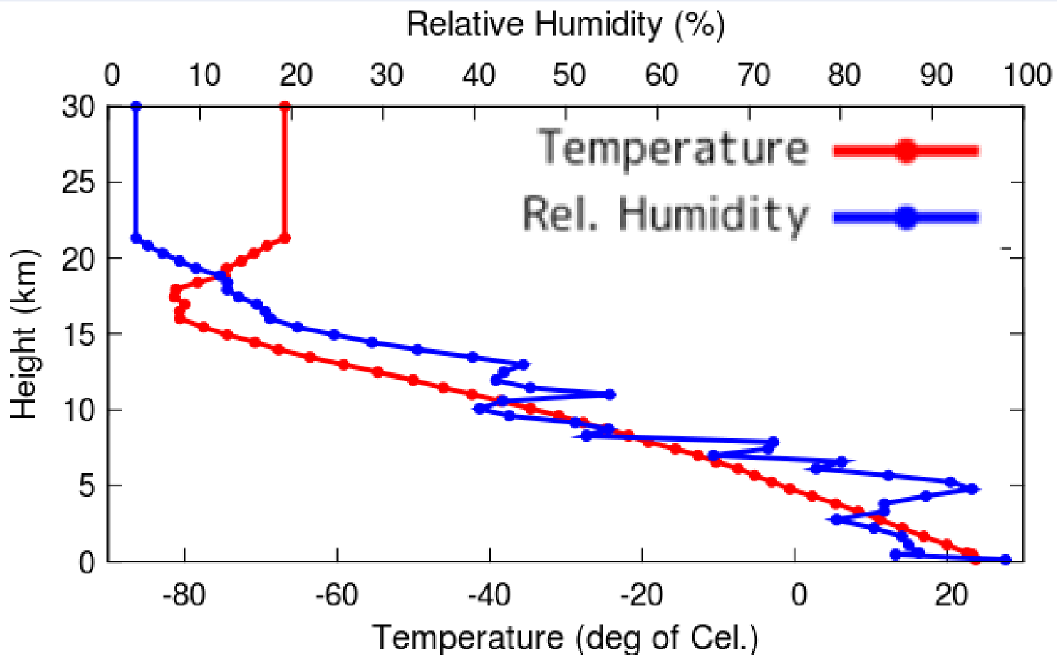
# 2. Convective behaviors with the JMA-NHM

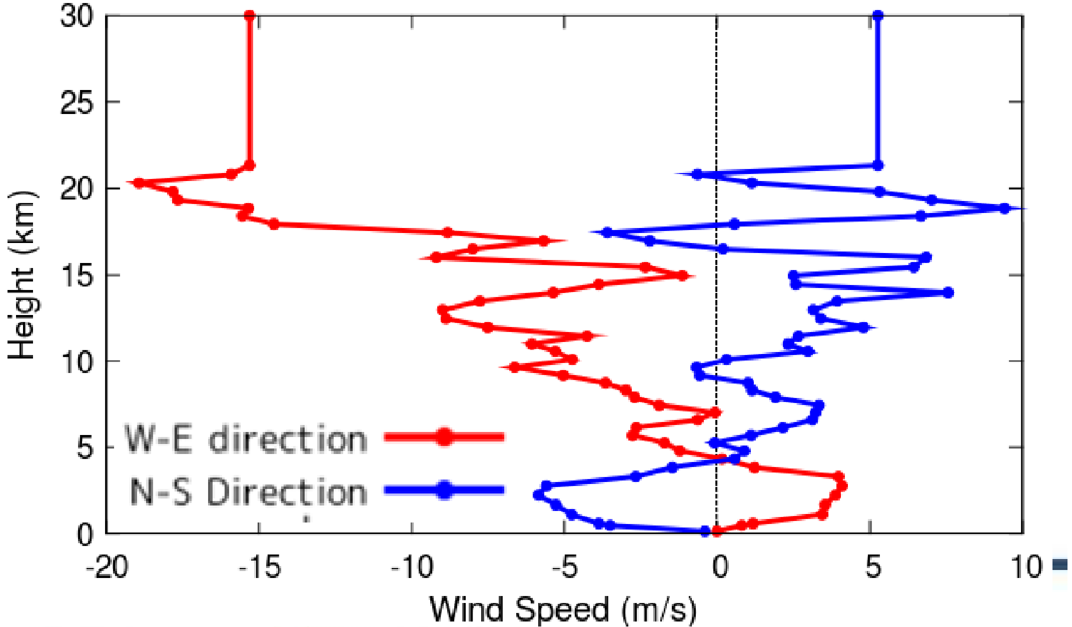
- For more reasonable forecasts and better numerical stability, we are investigating the convective behaviors with our model, JMA-NHM, under the ideal situation.
- Platform of an ideal model run comes from model intercomparison projects on “GEWEX Cloud System Study – Working Group 4”.
- That idealized experiment focuses daytime convective development over land based on the TRMM-LBA observation campaign.

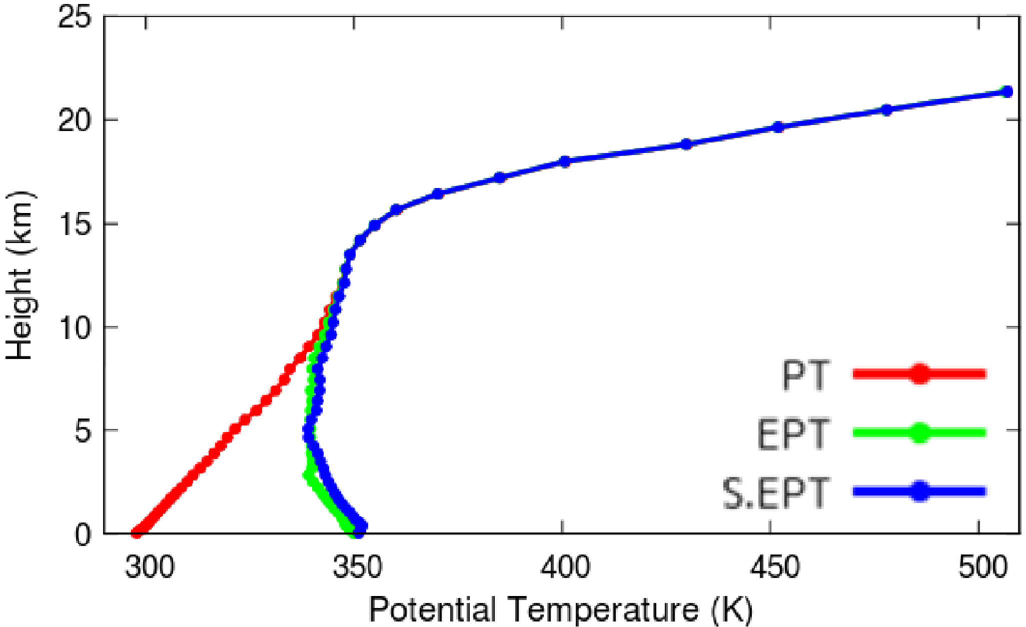
# 2. Convective behaviors with the JMA-NHM
## Condition of exp. under TRMM-LBA case

- **Initial State**

Sounding (profile in the tropics)
at Rondonia, Brazil
at 7:30 AM on 23th, Feb 1999
during the TRMM-LBA field campaign



# 2. Convective behaviors with the JMA-NHM
## Condition of exp. under TRMM-LBA case

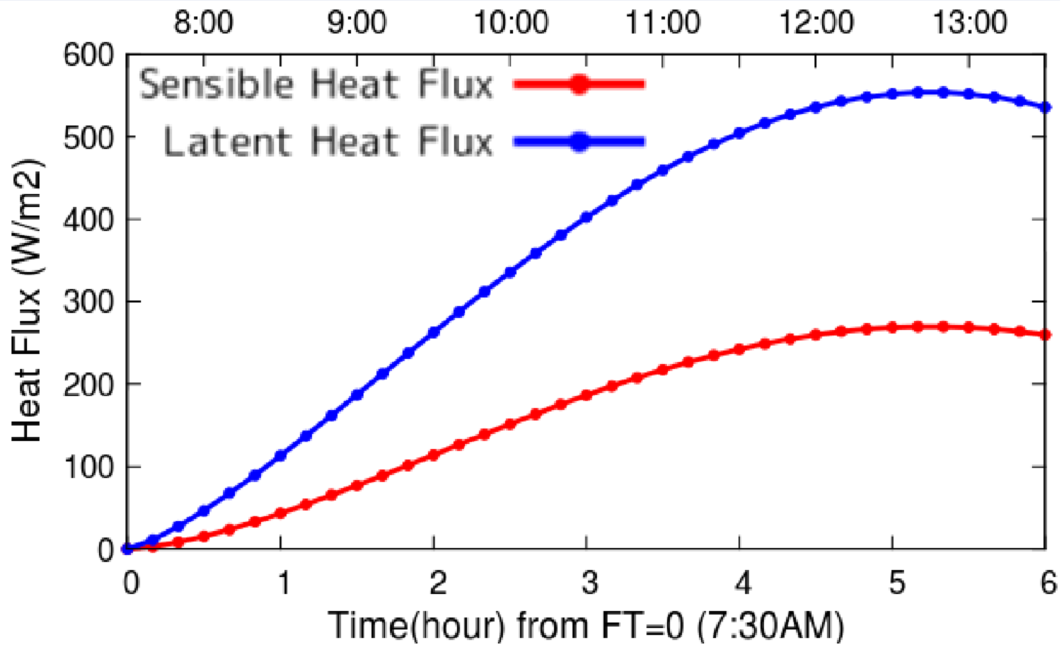
- **Forcing**

  until 6 hours later

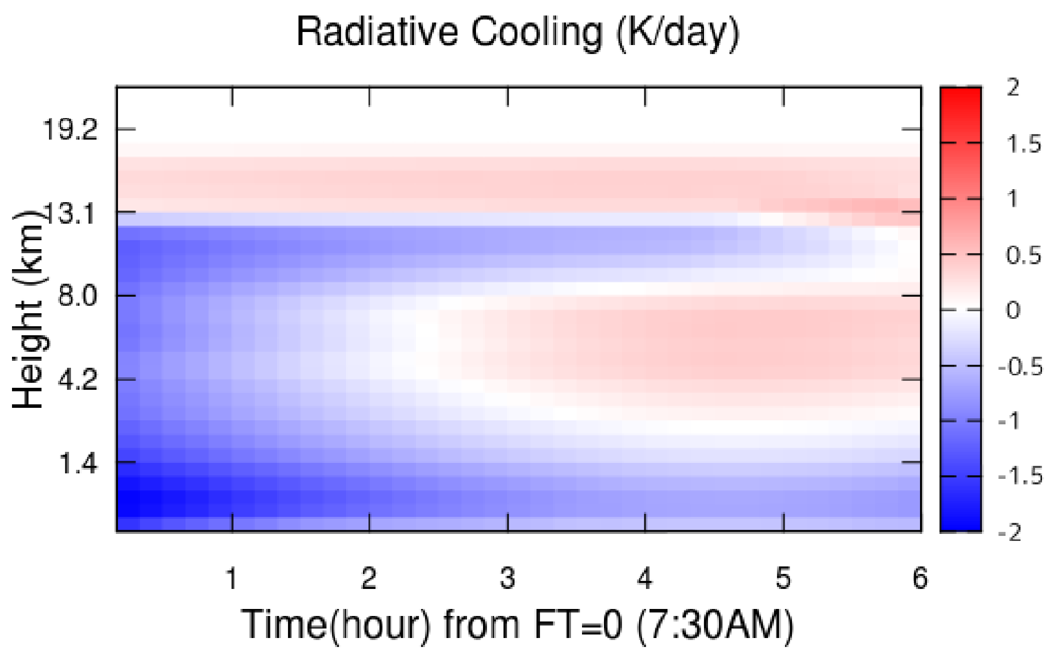
  (i.e. maximum forecast time = 6 hrs)

Sensible and latent heat fluxes from the surface

+ random perturbation (±10%)




Radiative cooling



# 2. Convective behaviors with the JMA-NHM

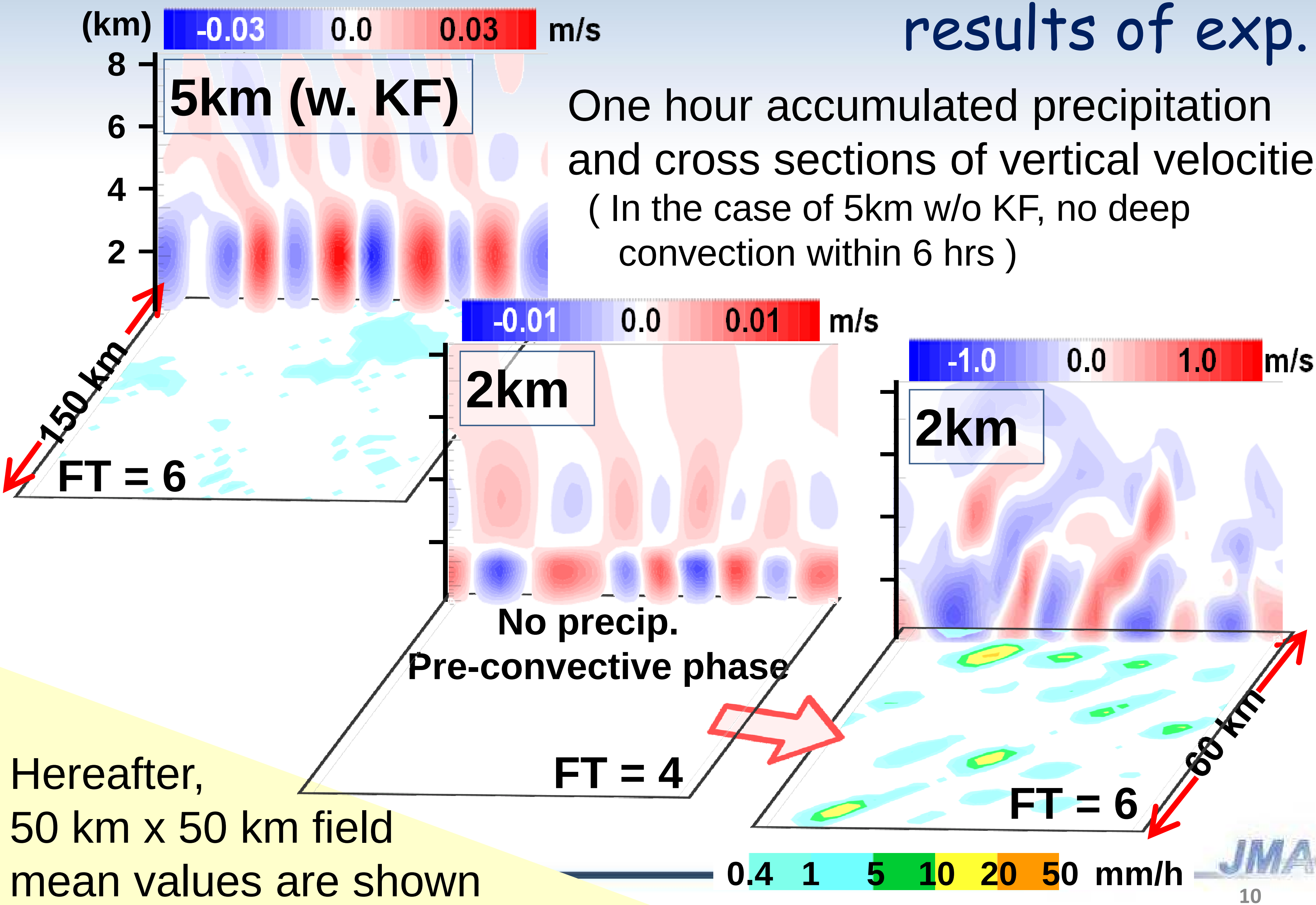
## Configuration of exp.

- Horizontal grid spacing : 5 km and 2 km
  - Spec of "**5 km** - model" based on operational MSM
    - 50 layers, **with K-F convective parameterization**
  - Spec of "**2 km** – model" based on operational LFM
    - 60 layers, **with no convective parameterization**
- Grids : 30 x 30 x 50 (5km-model) or 60 (2km-model)
- Initial condition : horizontally uniform
- Cyclic lateral boundary condition
- Additional runs :
  - 5 km - model without convective parameterization (i.e. treating deep convections explicitly) indicated as "**5km w/o KF**" hereafter
  - **1 km** - model as more realistic reference ( 50 x 50 x 60 )

# 2. Convective behaviors with the JMA-NHM results of exp.

One hour accumulated precipitation and cross sections of vertical velocities

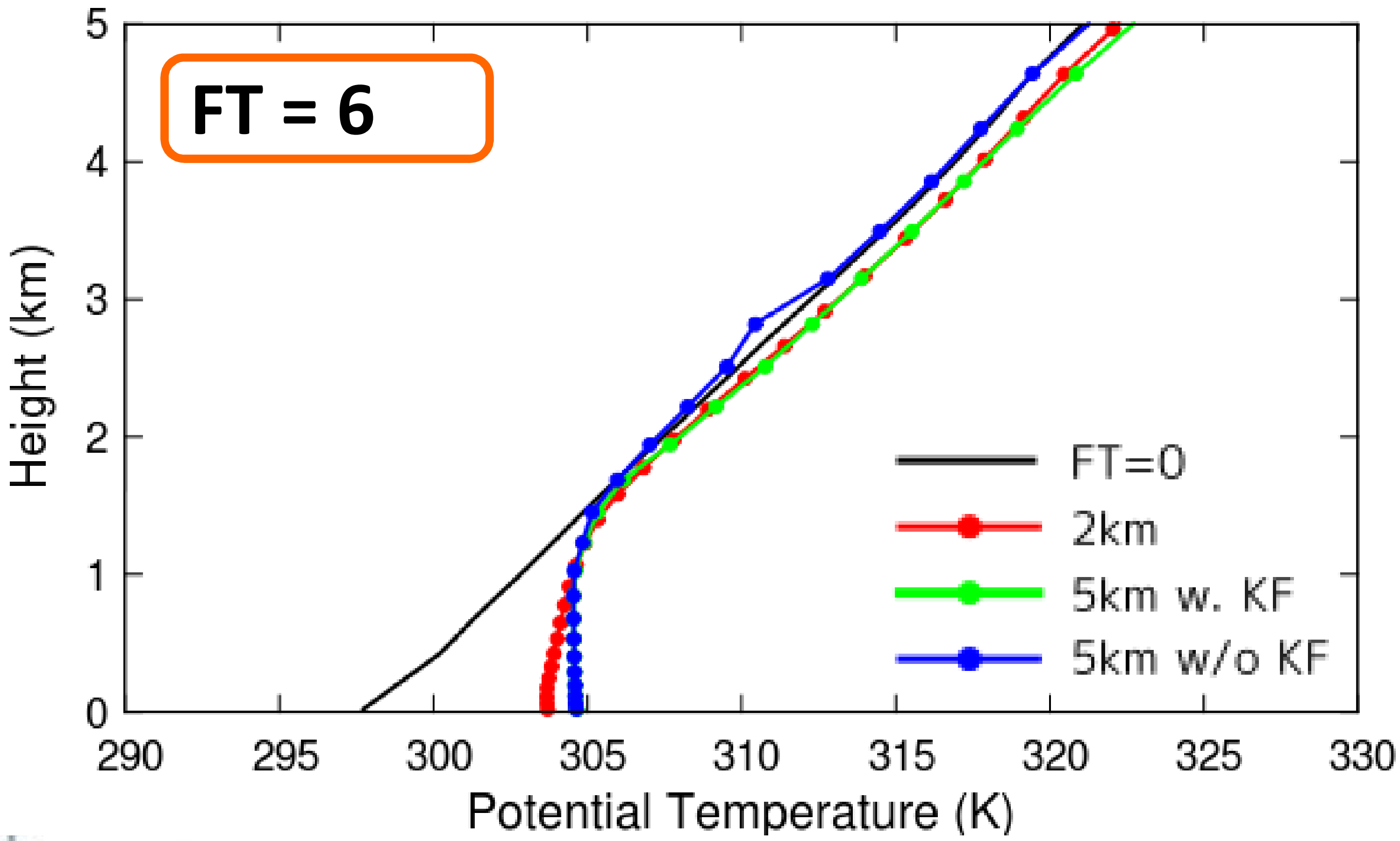
( In the case of 5km w/o KF, no deep convection within 6 hrs )




Hereafter,
50 km x 50 km field
mean values are shown

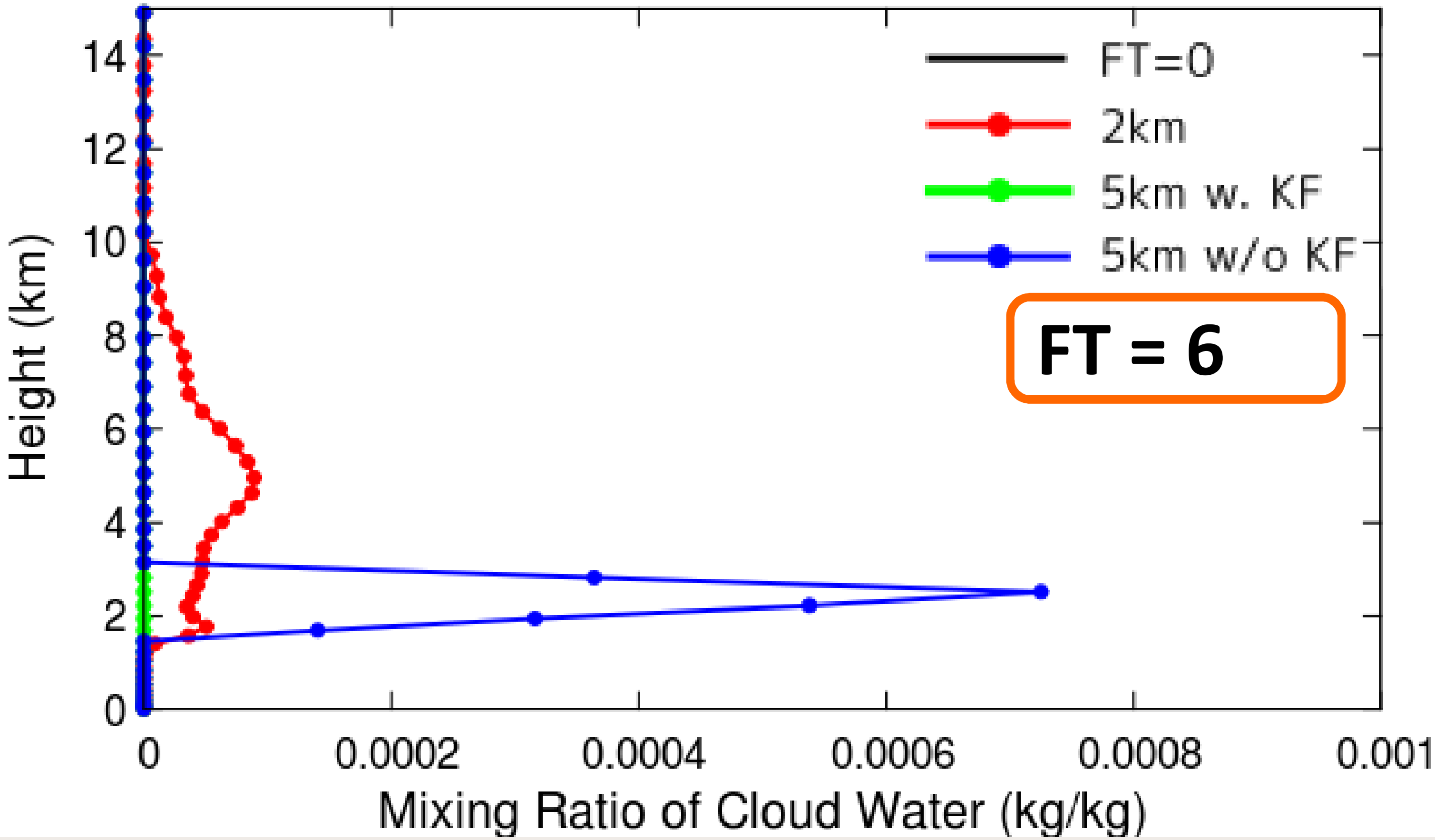
# 2. Convective behaviors with the JMA-NHM
## mean vertical profile : potential temperature

- **2km** : turns into the deep convection around FT = 5.5
- **5km** : convection occurs earlier by KF scheme
  keeps the developed mixed layer in spite of KF worked
- **5km w/o KF** : no transition into the deep convection phase for 6 hrs



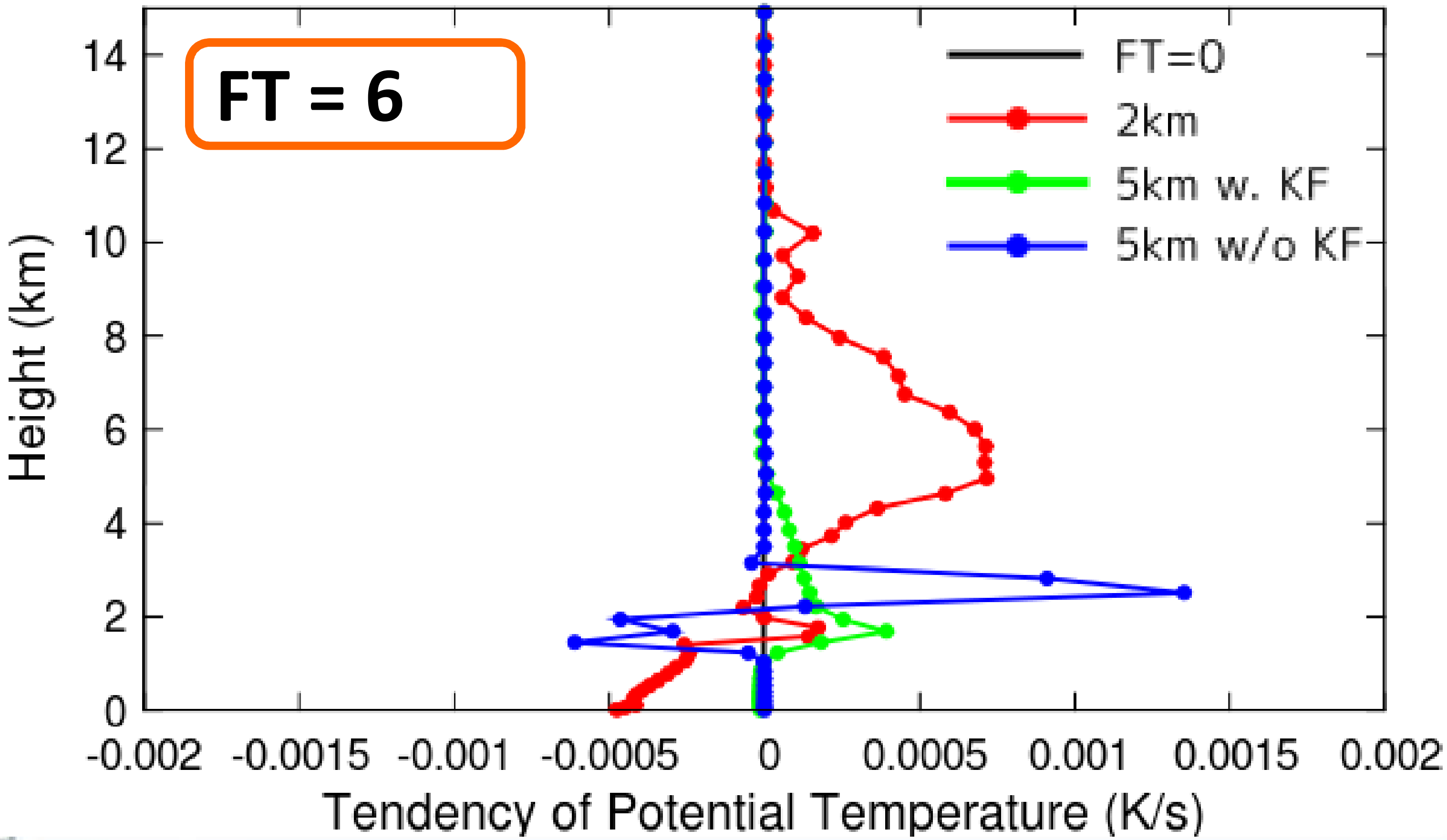
# 2. Convective behaviors with the JMA-NHM
## mean vertical profile : cloud water

- **2km** : expected development of convection (from shallow to deep)
- **5km** : shallow convective cloud spoiled by KF scheme
  insufficient cloud water created in KF scheme
- **5km w/o KF** : expected development of shallow convection but deep



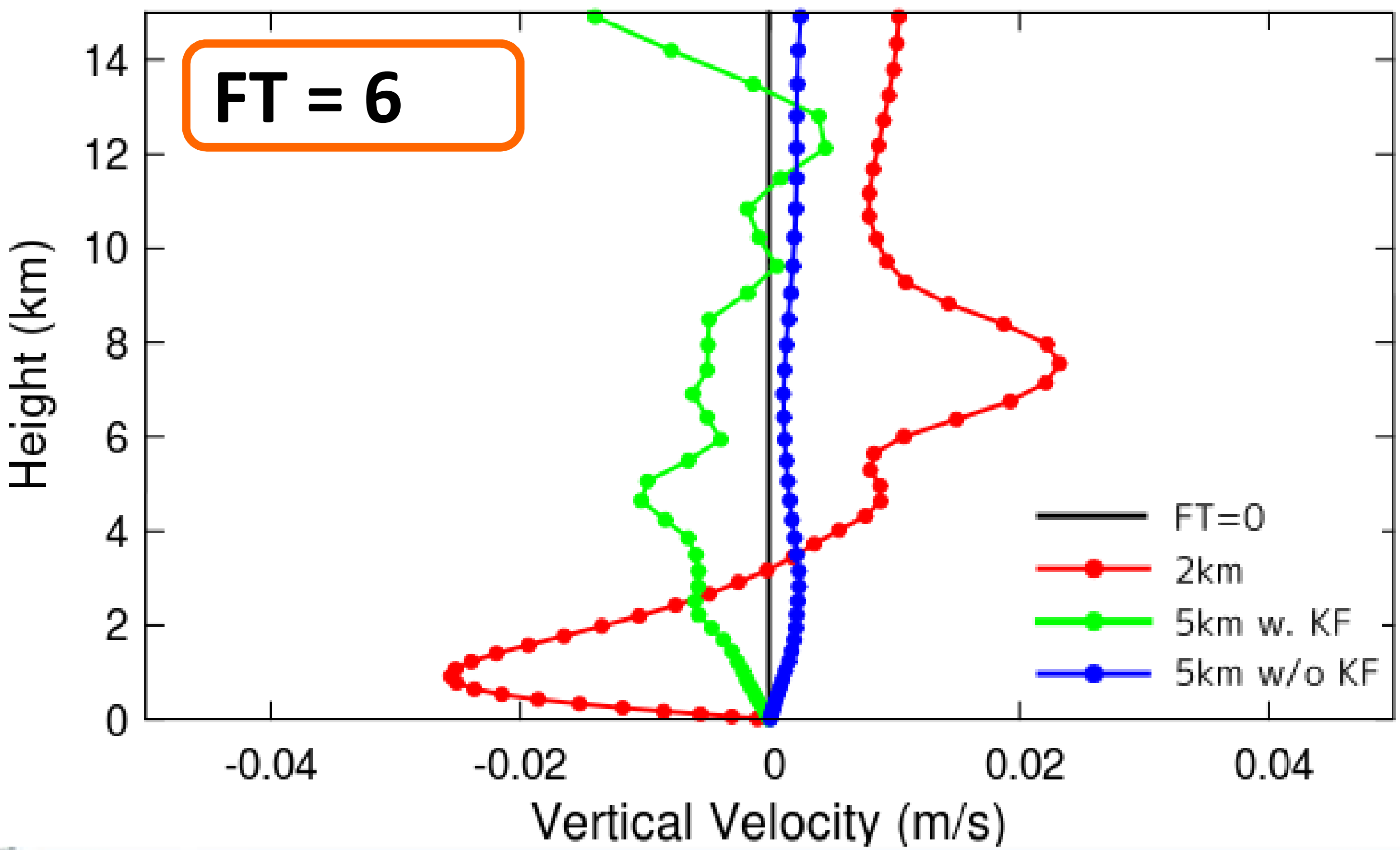
# 2. Convective behaviors with the JMA-NHM
## mean vertical profile : heating rate

- **2km** : expected development of convection (from shallow to deep)
- **5km** : deep convection by KF scheme
  heats from lower to upper simultaneously .
- **5km w/o KF** : expected development of shallow convection but deep

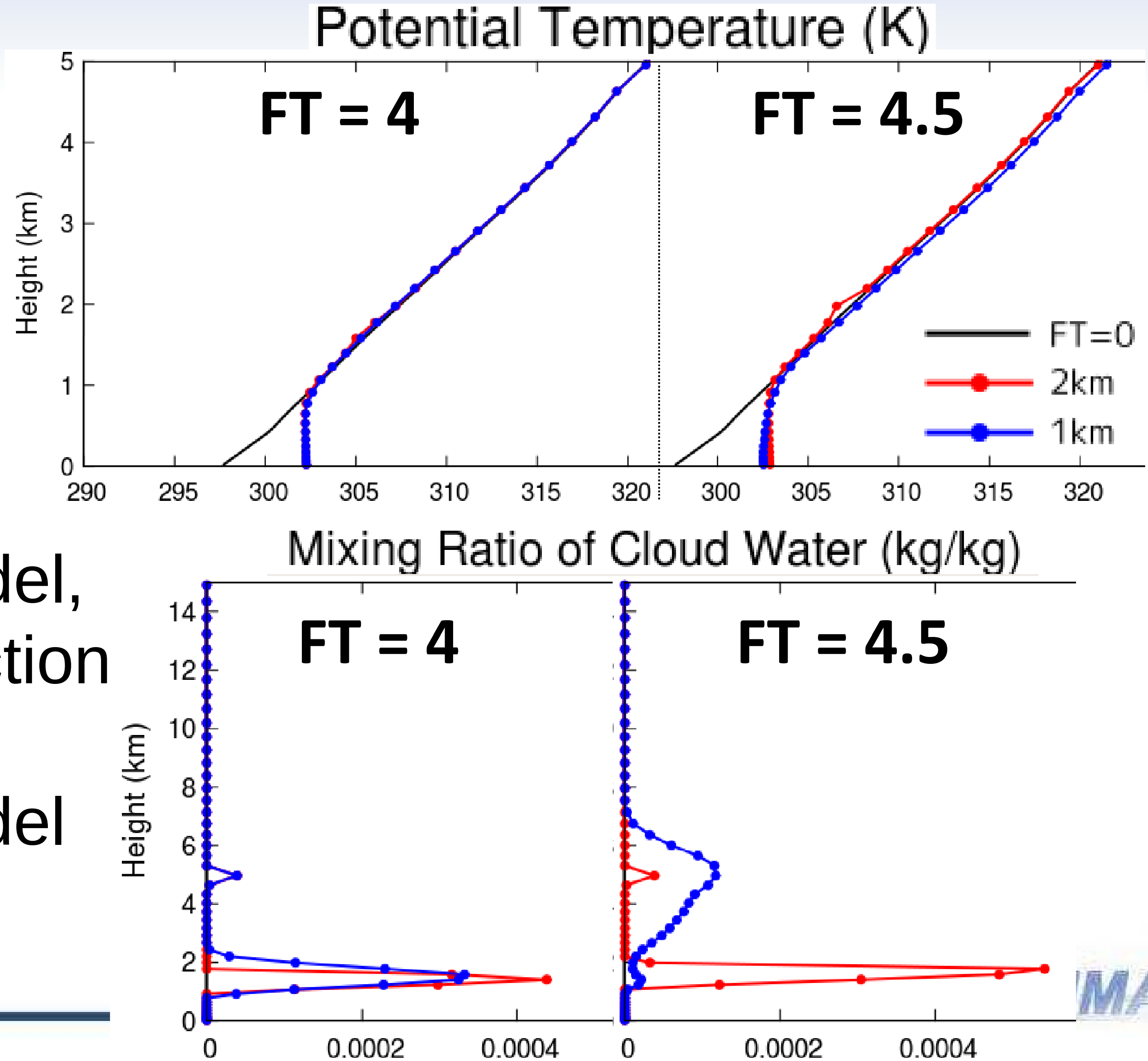


# 2. Convective behaviors with the JMA-NHM
## mean vertical profile : vertical velocity

- **2km** : turns into the deep convection around FT = 5.5
- **5km** : vertical motion induced earlier by KF scheme
- **5km w/o KF** : no transition into the deep convection phase for 6 hrs



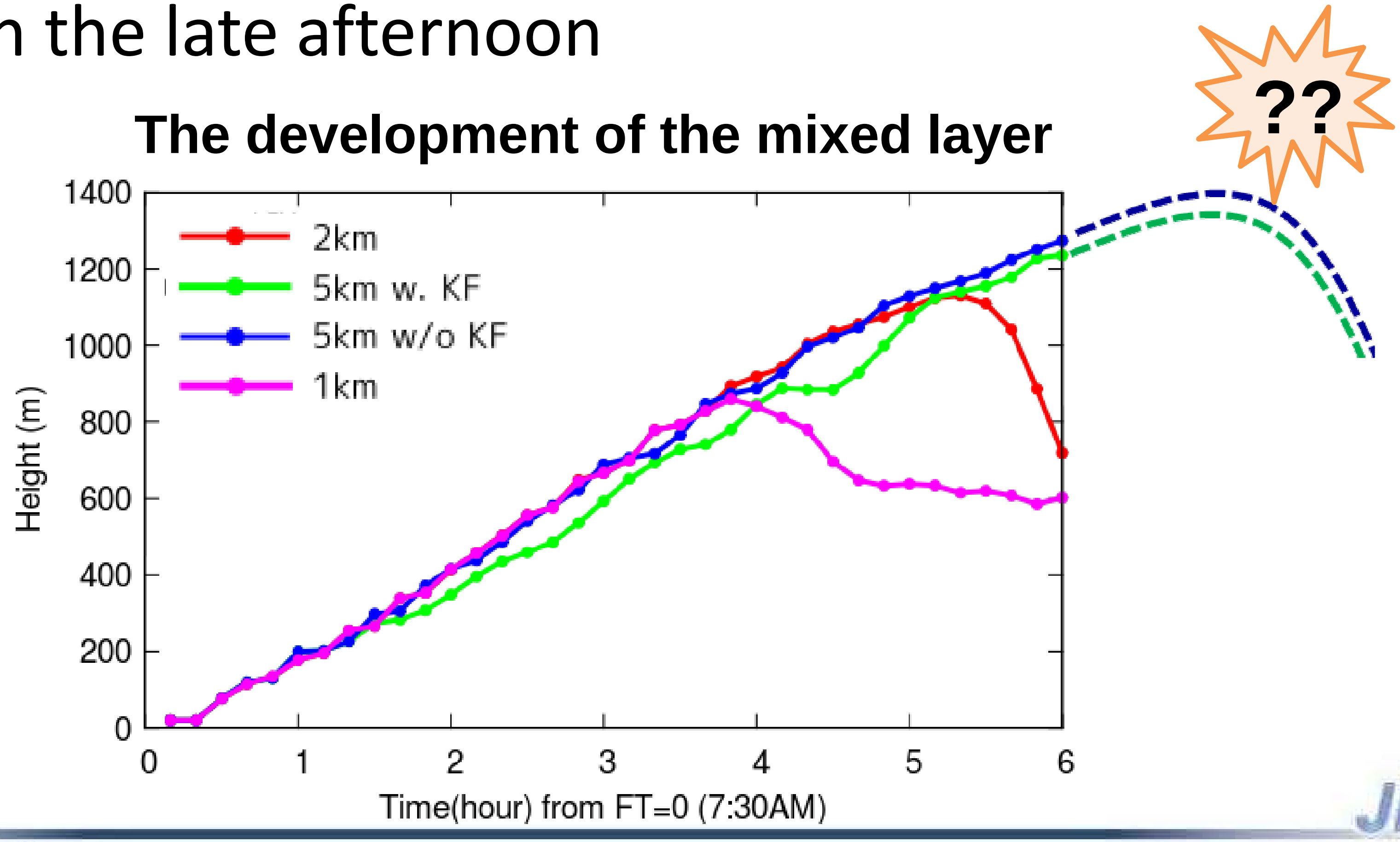
# 2. Convective behaviors with the JMA-NHM
comparison with 1 km grid spacing model




In the 1 km - model,
the deep convection
starts earlier
than 2 km - model

# 2. Convective behaviors with the JMA-NHM
# sudden transition into the deep convection

- In the cases of 5km w/o KF and even 5km (with KF), the mixed layer is still growing.
  → high probability of violent deep convections in the late afternoon



# 3. Summary

Through idealized experiments based on TRMM-LBA observations

- We found that coarser horizontal resolution delays transition into deep convection phase.
- That delay stores much more thermal energy within the mixed layer.
  - so that deep convections occur violently on the coarser grid model.

# 3. Summary

- Kain-Fritsch convective scheme imitates deep convective phenomena somewhat, but …
  - Spoil the shallow convection phase
  - Once KF works, thermal energy is redistributed vertically up to upper layers. That is not as the life of convection.
  - Although KF as deep convection works, the mixed layer still keep on growing. ( keeping a risk of bursts ! )

# 3. Summary

- With some idealized tests, we need to make sure of adoption of the convective parameterization into the LFM, and to improve that adopted into the MSM.
- We expect that our study will tends to improve the operational mesoscale models.

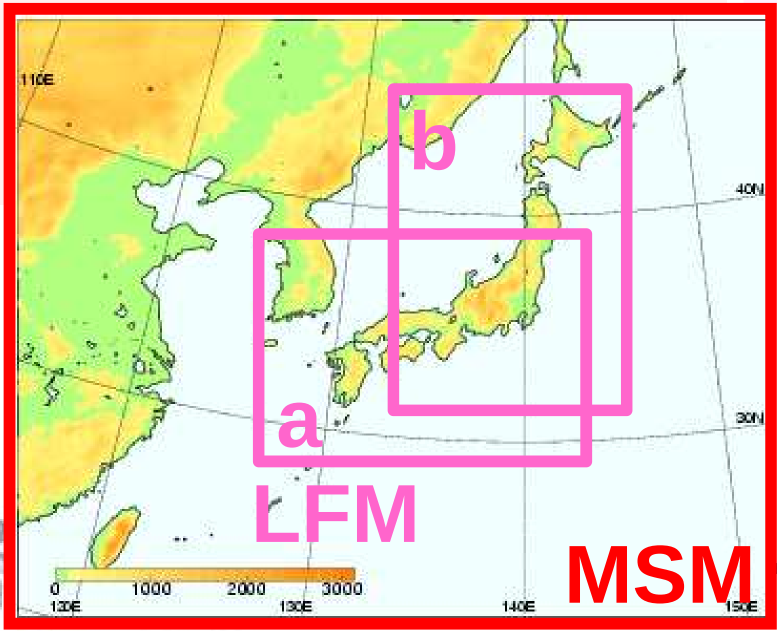
# Vielen Dank !

# 1. Introduction
## Regional NWP systems operated @ JMA

- **MSM** Grid spacing : **5** km
- **LFM** Grid spacing : **2** km

**Topographical Features**

**Finer structure resolved**




**Forecast Domain**

LFM : Area **a** is to be replaced by area **b** right today !

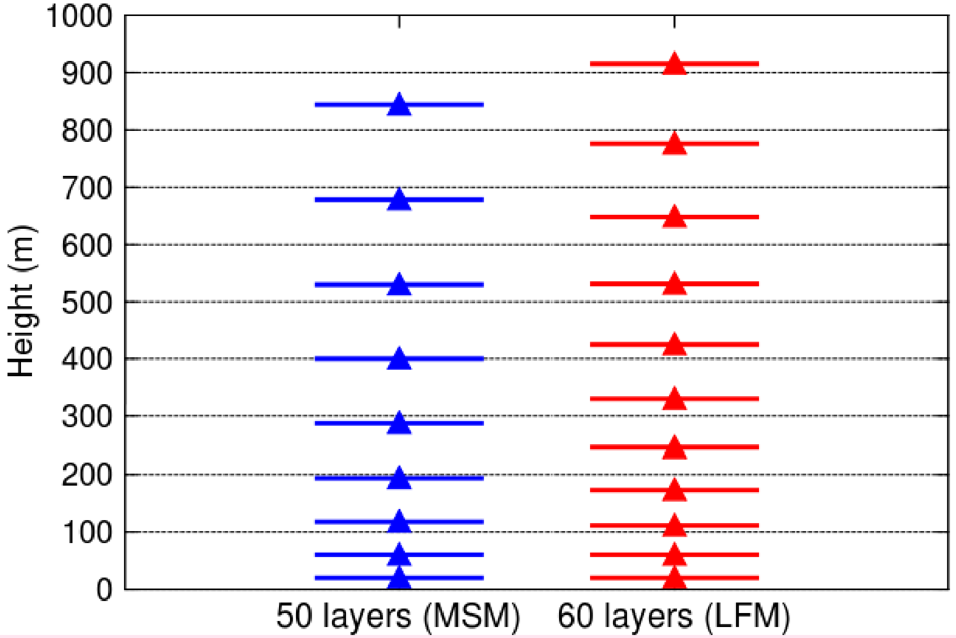
# 1. Introduction

## Regional NWP systems operated @ JMA

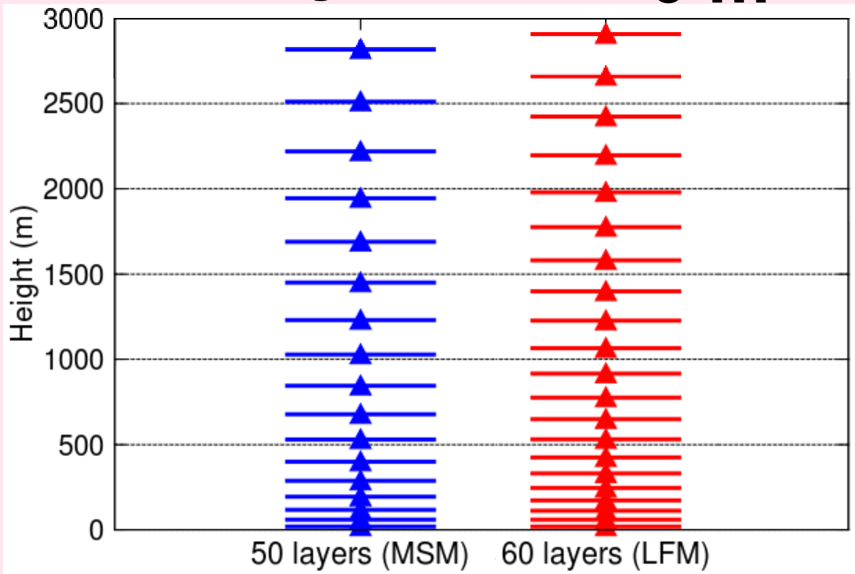
- **MSM** Grid spacing : **5** km
- **LFM** Grid spacing : **2** km

**Structure of Vertical Layers**

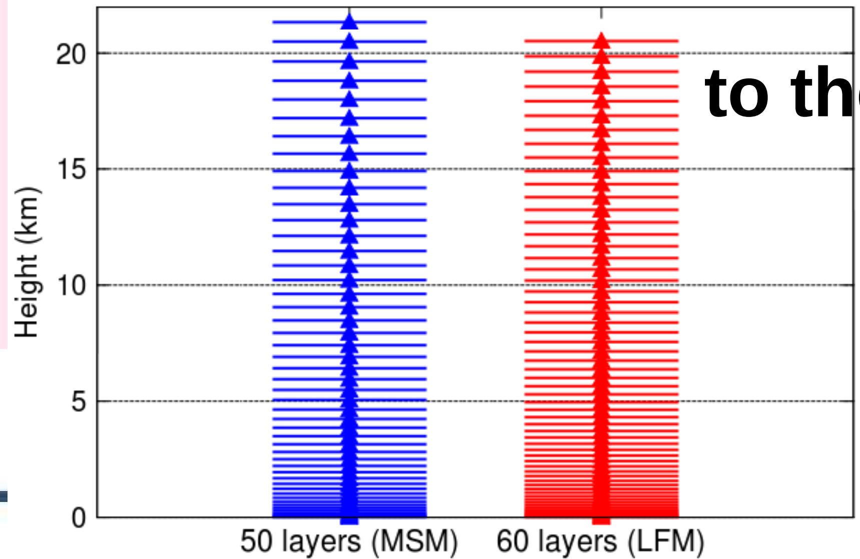
**0 m ～ 1000 m**




**0 m ～ 3 km**




**to the Top**



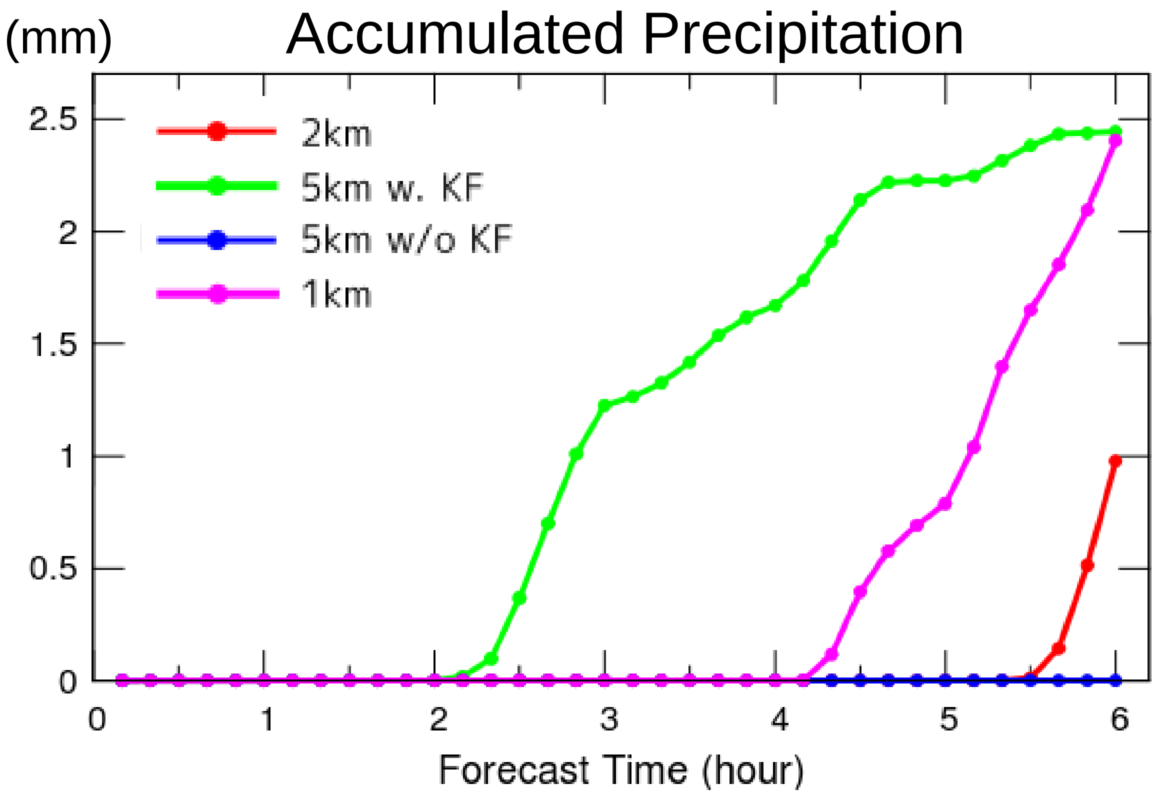

**LFM : finer vertical grids**

気象庁 Japan Meteorological Agency

JMA

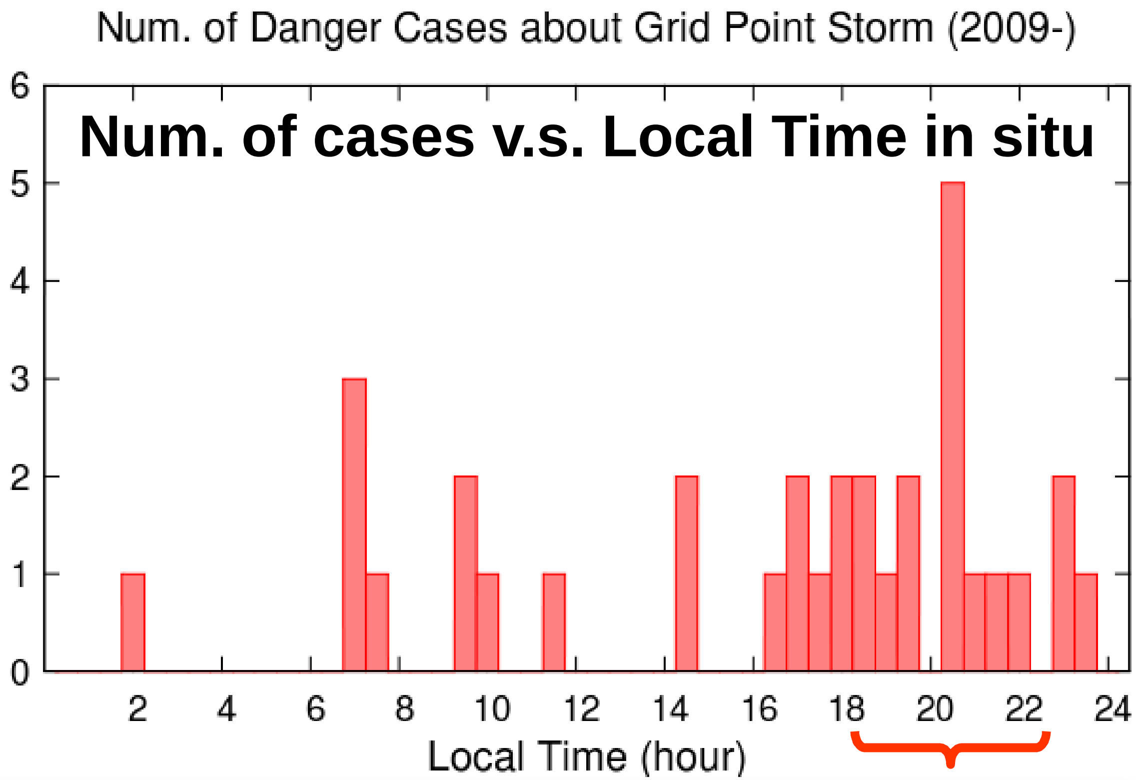
# 2. Convective behaviors with the JMA-NHM amount of precipitation

- Time series of accumulated precipitation shows the difference for the beginning of convection clearly.



# 2. Convective behaviors with the JMA-NHM risk of numerical instability

- High risk cases of the numerical instability by too much upward velocity for operational MSM from 2009
- Remarkable amount of cases happened in the evening or after sunset



# moist physics processes in the MSM

- Cloud Microphysics

  A bulk parameterization scheme

  (Lin et al.1983, Ikawa and Saito 1991)

  mixing ratio : water vapor, cloud water, rain,

  cloud ice, snow, graupel

  number concentration : cloud ice

# moist physics processes in the MSM

- Convective Parameterization

  the Kain-Fritsch scheme

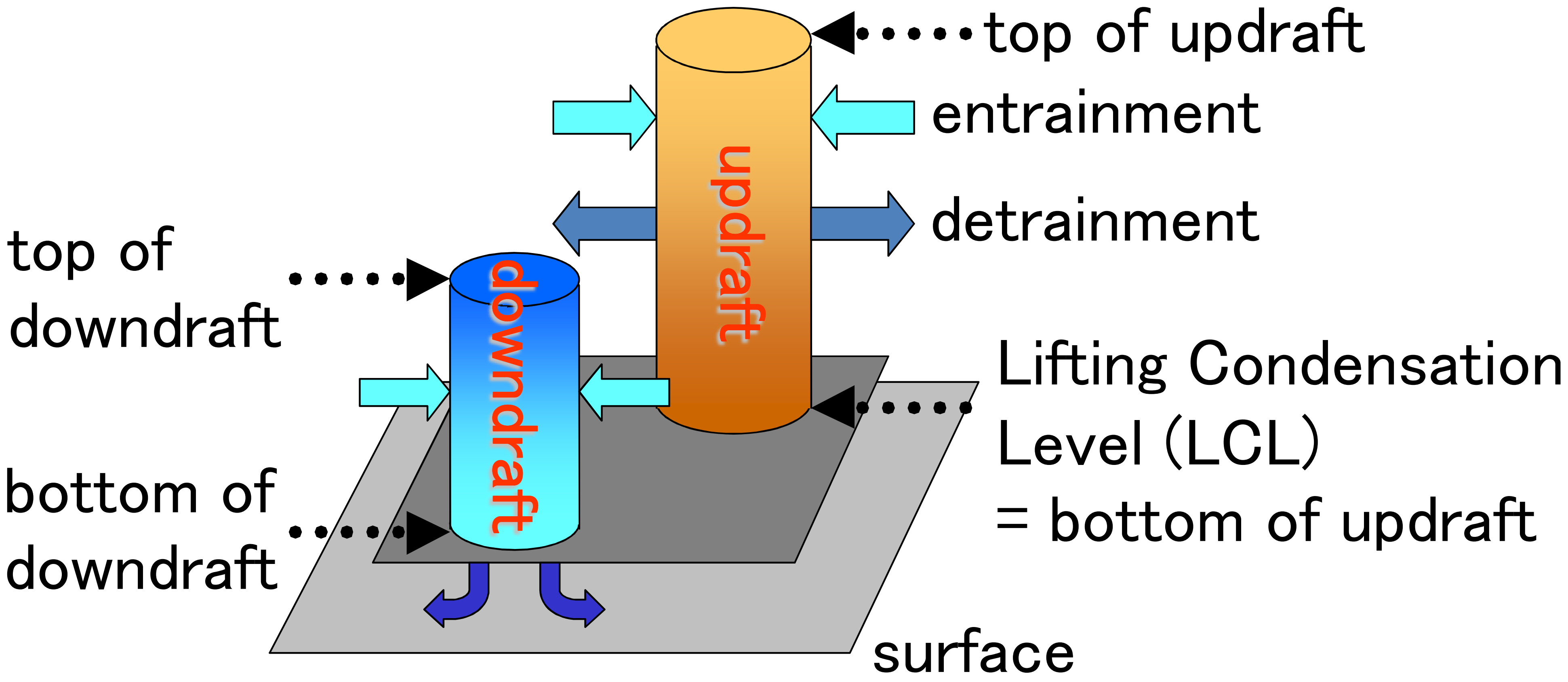
  (Kain and Fritsch 1990, Kain 2004)

  – Originally developed for the Weather Research and Forecast (WRF) modeling system
  – Implemented to MSM in April 2002 with Dr. Kain's consent
  – Applied some modifications and adjustments to the original KF scheme

# brief aspect of the KF scheme

- A mass flux parameterization
- One-dimensional entraining/detraining plume model
- A pair of up-and-down drafts represents a subgrid-scale convective cloud
- CAPE closure

# schematic of vertical transports in the KF scheme




Entrainment and detrainment modify the mass flux of the updraft and downdraft