Resolution dependence of the diurnal cycle of precipitation over land in the tropics simulated by a global cloud permitting model

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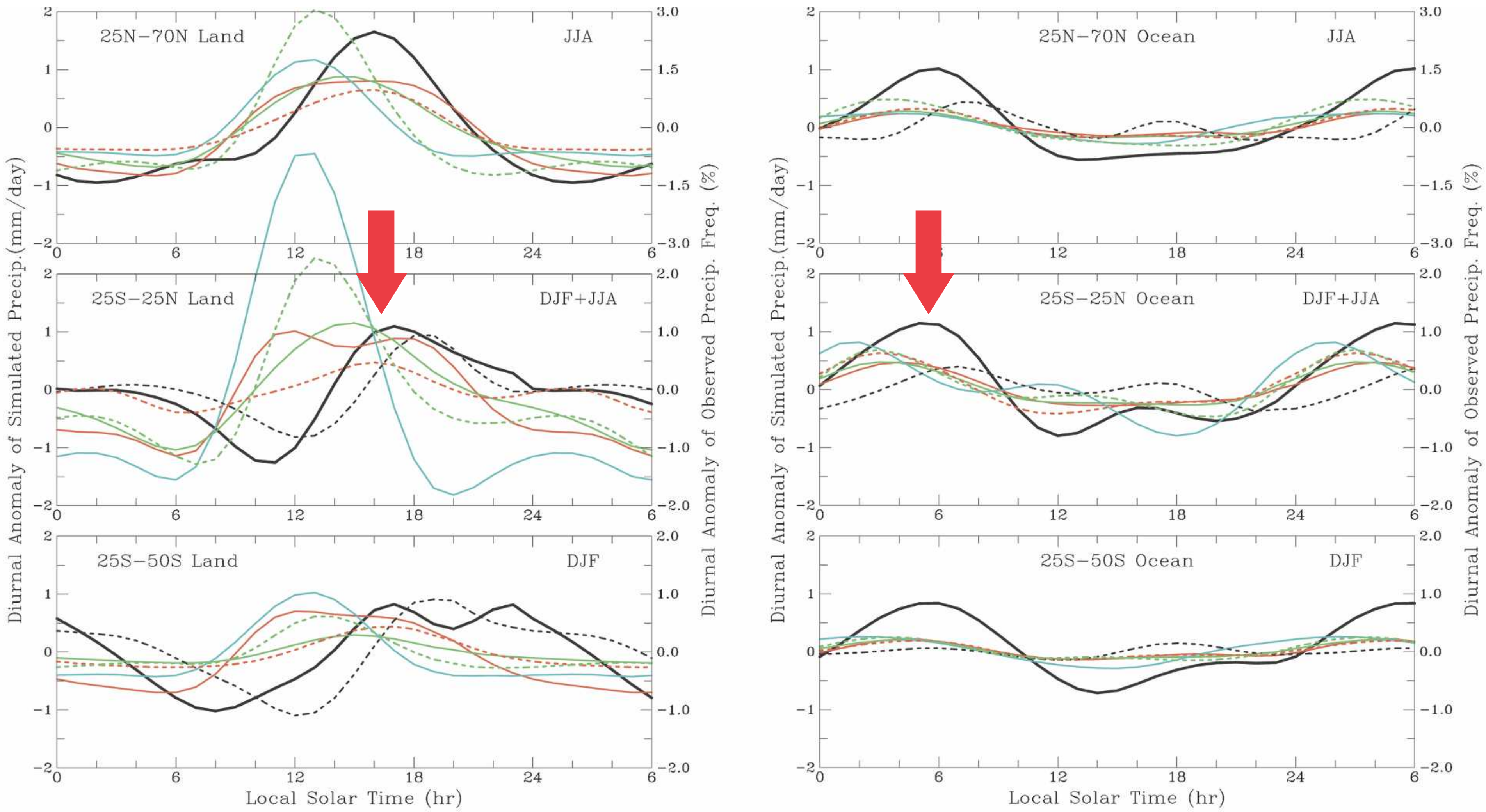
The first global sub-km weather simulation on the K computer

- **Miyamoto, Y.**, Y. Kajikawa, R. Yoshida, T. Yamaura, H. Yashiro, and H. Tomita **(2013)**: Deep moist atmospheric convection in a subkilometer global simulation, Geophys. Res. Lett., doi:10.1002/grl.50944.
- **Miyamoto, Y.**, R. Yoshida, T. Yamaura, H. Yashiro, H. Tomita, and Y. Kajikawa **(2015)**: Does convection vary in different cloud disturbances? Atmos. Sci. Lett., doi:10.1002/asl2.558.
- **Leinonen, J.**, Lebsock, M. D., Tanelli, S., Suzuki, K., Yashiro, H., and Miyamoto, Y. **(2015)**: Performance assessment of a triple-frequency spaceborne cloud–precipitation radar concept using a global cloud-resolving model, Atmos. Meas. Tech., 8, 3493-3517, doi:10.5194/amt-8-3493-2015
- **Kajikawa, Y.**, Y. Miyamoto, R. Yoshida, T. Yamaura, H. Yashiro, H. Tomita **(2016)**: Resolution dependence of deep convections in a global simulation from over 10-kilometer to sub-kilometer grid spacing, Progress in Earth and Planetary Science, 3:16, doi: 10.1186/s40645-016-0094-5.
- **Yashiro, H.**, Y. Kajikawa, Y. Miyamoto, T. Yamaura, R. Yoshida, and H. Tomita **(2016)**: Resolution Dependence of the Diurnal Cycle of Precipitation Simulated by a Global Cloud-System Resolving Model, Scientific Online Letters on the Atmosphere, Vol. 12, P. 272-276 , doi: 10.2151/sola.2016-053
- **Miyamoto, Y.**, T. Yamaura, R. Yoshida, H. Yashiro, H. Tomita, and Y. Kajikawa **(2016)**: Precursors of deep moist convection in a subkilometer global simulation, Journal of Geophysical Research Atmospheres, doi: 10.1002/2016JD024965

Diurnal cycles of precipitation in the Tropics

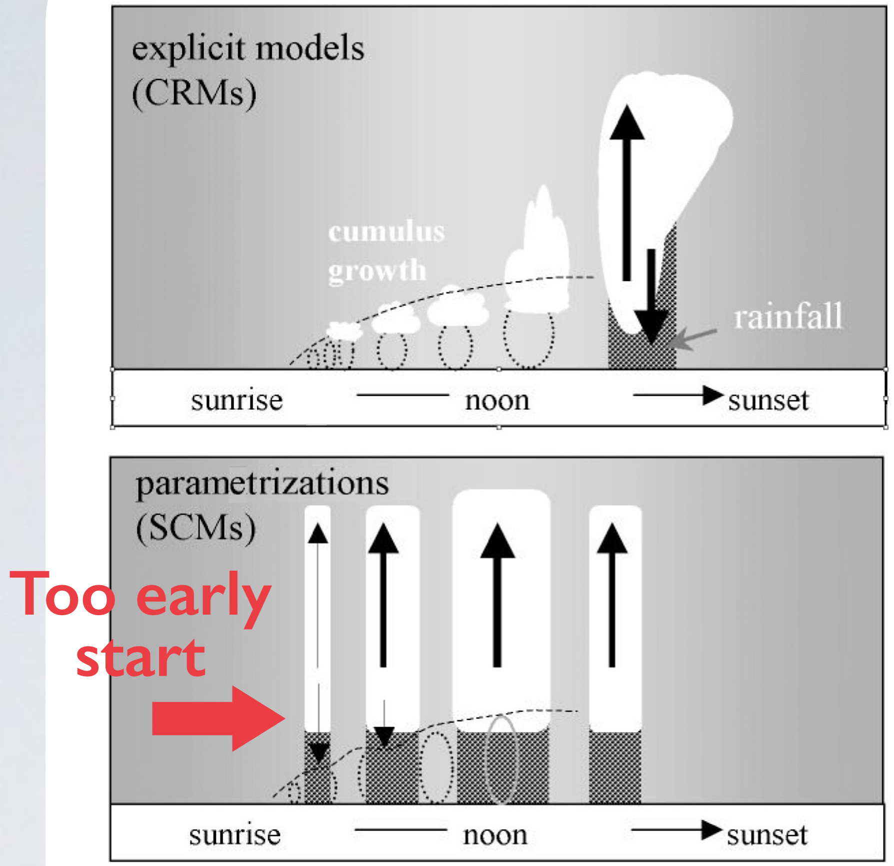
Land **Observation** **Ocean**



Dai, 2006

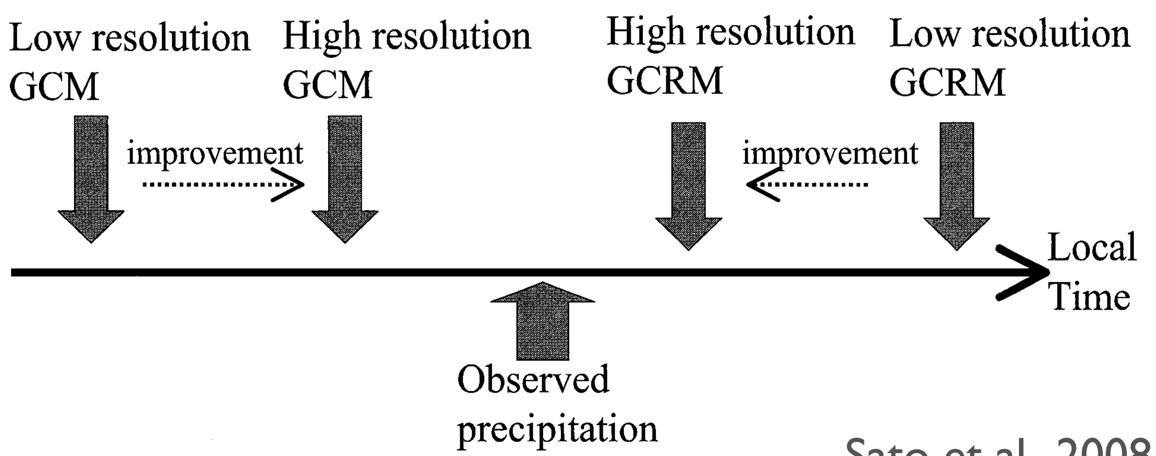
- Early morning peak over the ocean
- Late afternoon peak over the land

Reproducibility in the global model



Guichard et al., 2004

Diurnal cycle of precipitation over the land is poorly reproduced in conventional GCMs



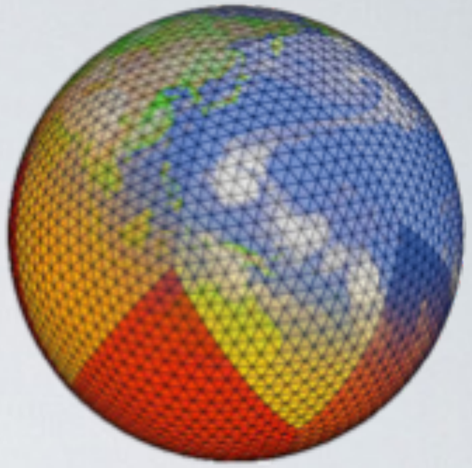
Sato et al., 2008

Low-resolution Global Cloud-Resolving Simulation shows late peak of precipitation

Motivation of this study

- Super-high resolution global simulation can reproduce the diurnal cycle of the precipitation well?
- How fine resolution is required to reproduce?

Experimental Setting



NICAM (Satoh et al., 2014, PEPS)

- Horizontal resolution : 14km, 7km, 3.5km, 1.7km, 0.87km
- Vertical : 94layers up to 40km
- Same slope of topography and land-ocean distribution are used in all experiments
- Physics
  - No convection parameterization schemes
  - Cloud microphysics: one-moment bulk (Tomita et al., 2008)
  - Radiation : mstrnX (Sekiguchi and Nakajima, 2008)
  - Surface flux : Louis-type scheme (Uno et al.,1995)
  - Turbulence : MYNN lv.2 (Nakanishi and Niino, 2006; Noda et al., 2010)
- Land: bucket, Ocean: slab ocean

Simulations on the K computer

- 3-days spin-up with lower resolution from 20120822UTC
- 2-days simulation
- 163840 cores are used for 0.87km run with 230 TFLOPS

"Big-data" analysis

Every 30min Snapshot for 0.87km run: ~3TB
x 48 steps (for last 1day output) = 160TB

Grid remapping
from icosahedral
to latitude-longitude

2 months on the post-process cluster

File I/O issue!

Analysis on
latitude-longitude grid

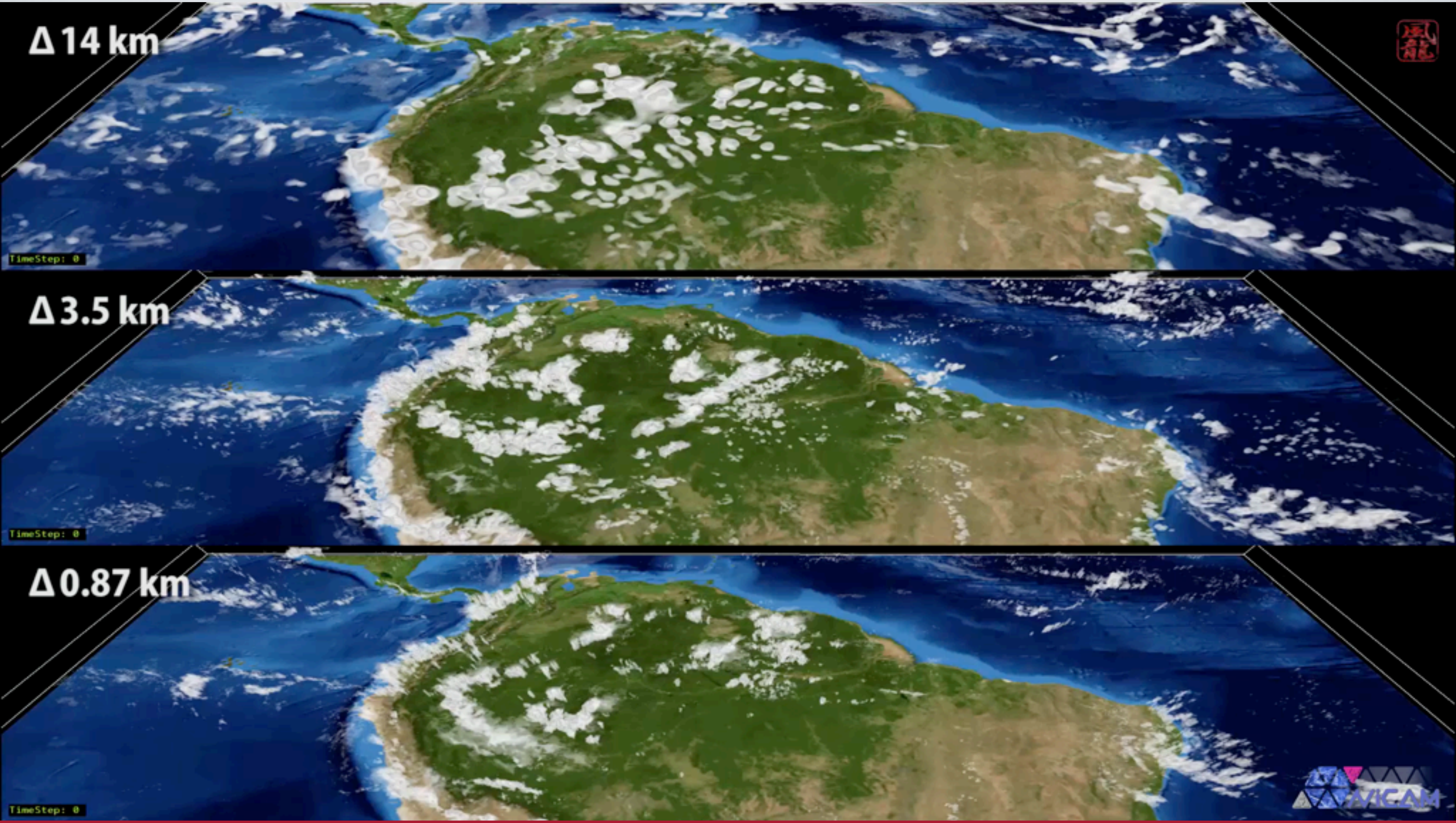
2 months on the post-process cluster

Analysis on
icosahedral grid

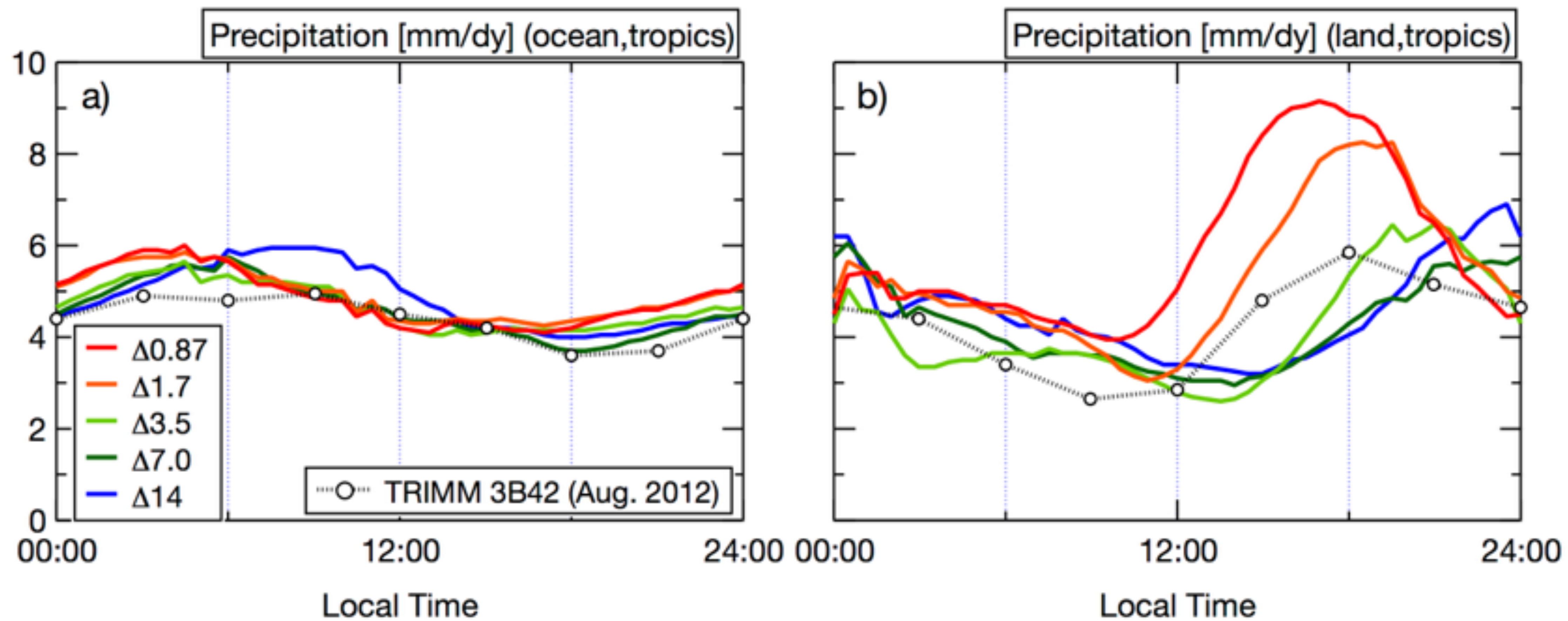
1 hour on the K computer

Animation of total hydrometeors (00-24UTC)

by Ryuji Yoshida(AICS,Kobe U.)



Simulated Diurnal Cycles of the Precipitation

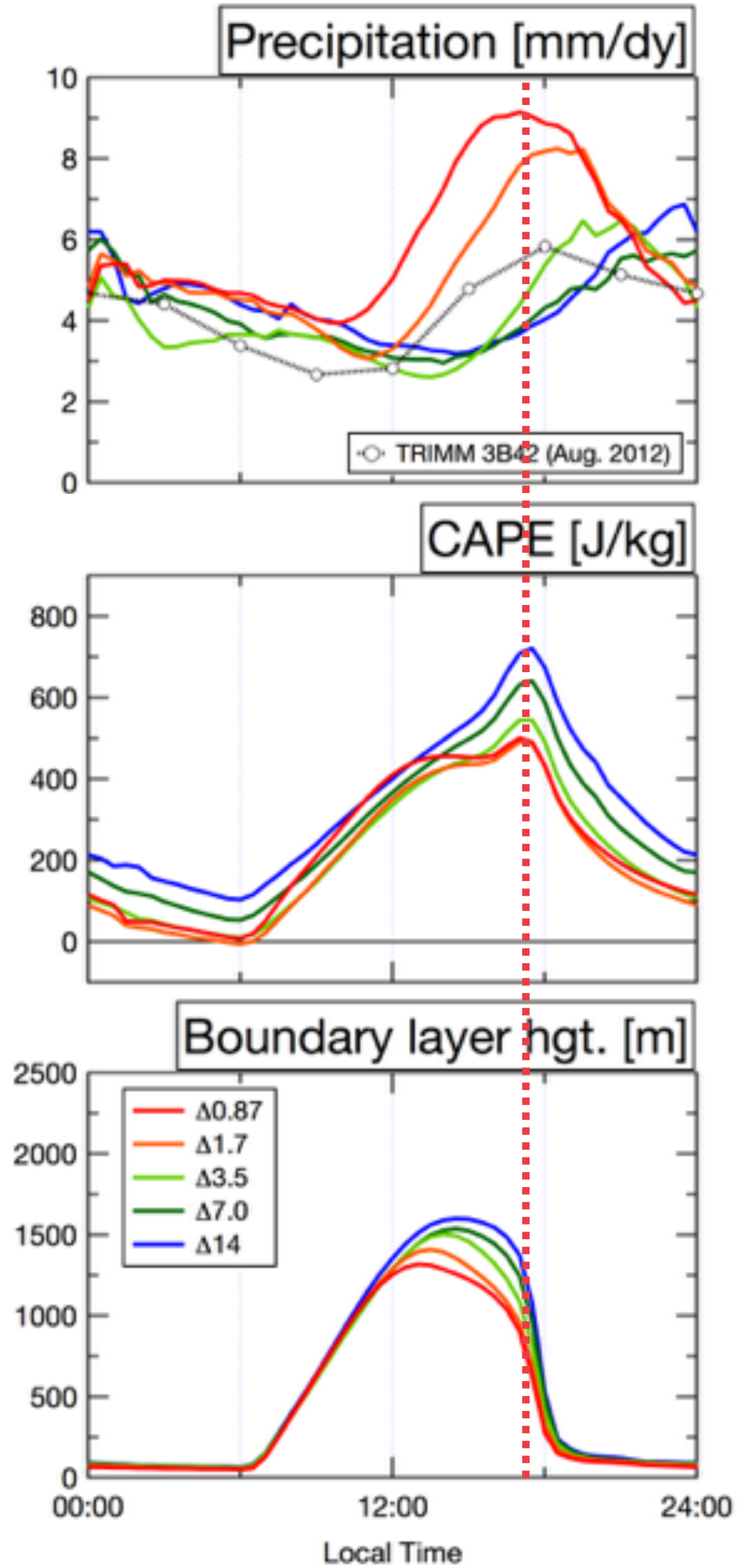


TRMM data was compiled by A.T.Noda(JAMSTEC)

In the tropics (15°N-15°S)

- Early morning peak over the ocean is well reproduced
- Diurnal cycles over the land show resolution dependency

  : the peak maximum appears earlier and larger with increasing the horizontal resolution



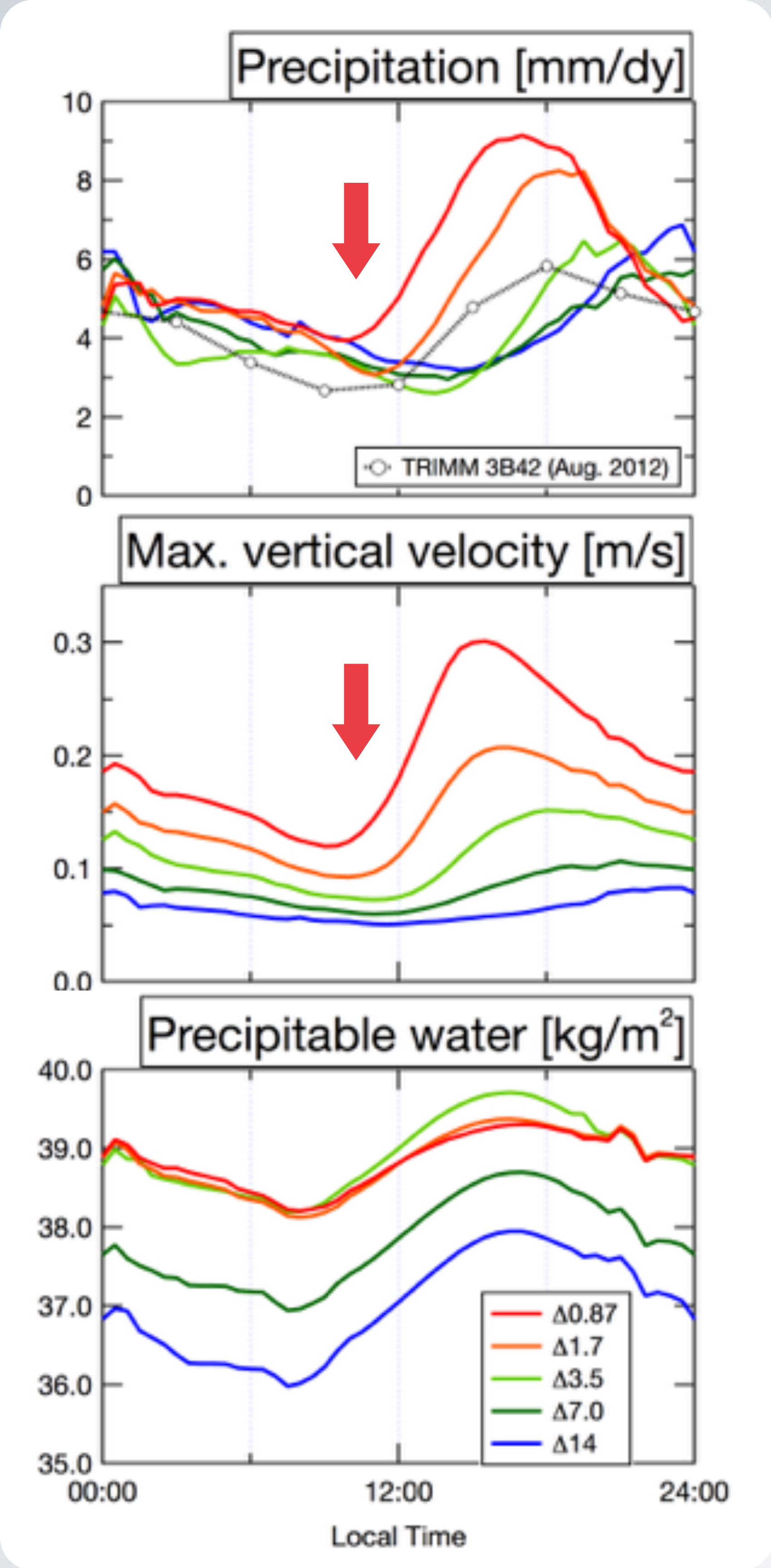
Diurnal Cycles over the land in the tropics

Lower resolution experiments

- Larger CAPE in daily mean
  : The large grid spacing needs more energy to activate the convection
- Precipitation starts after decreasing CAPE and the boundary layer height
  : Mechanical forcing such as orographic lift is more important

Higher resolution experiments

- Rapid increase of CAPE in the morning
  - One possible cause : resolved small local convergence of moisture?



Diurnal Cycles over the land in the tropics

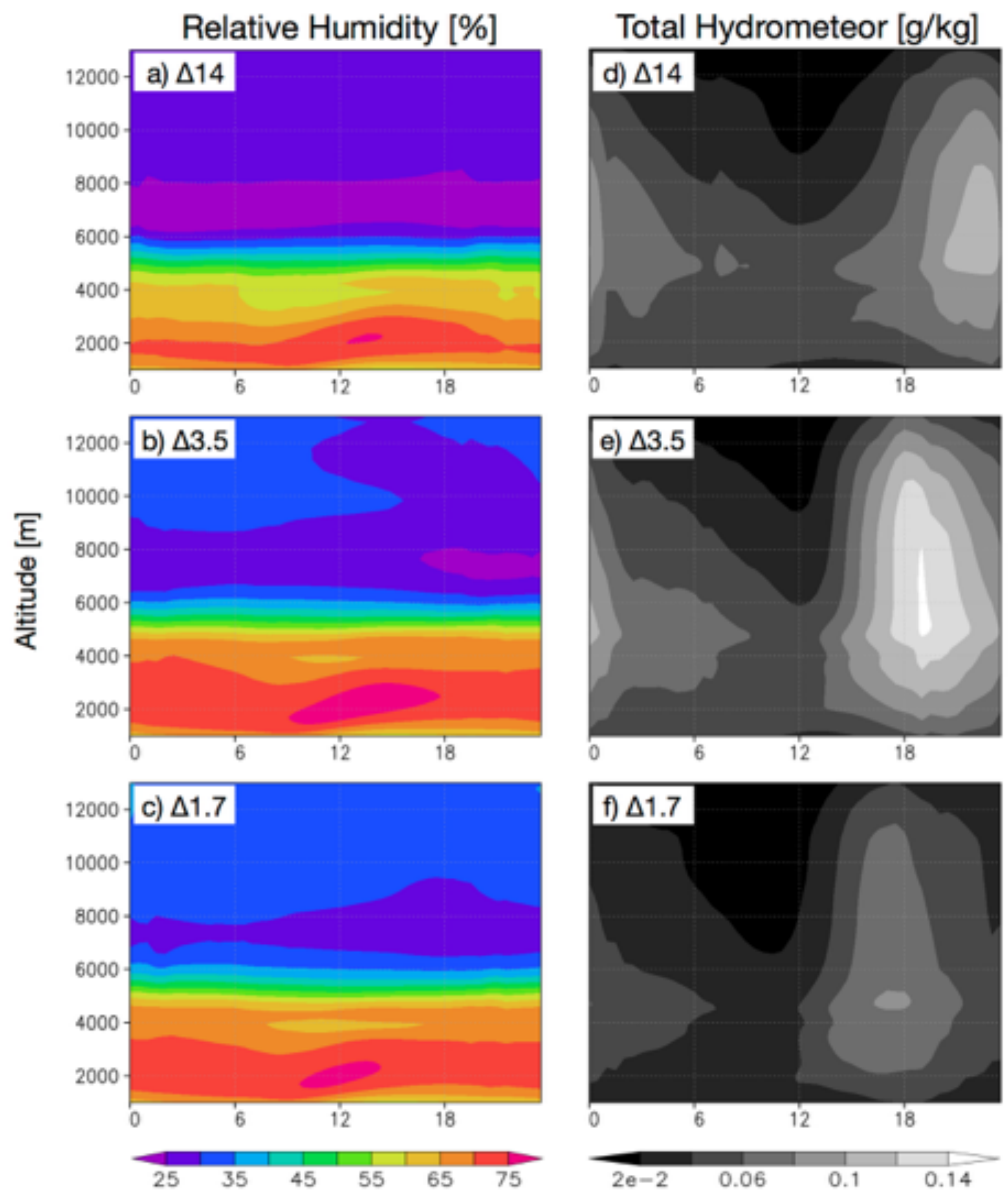
Resolution dependency of the precipitable water

- Daily mean PW increases with increasing the horizontal resolution from Δ14 to Δ3.5
- The difference between Δ3.5 and Δ1.7 is not so large

Resolution dependency of the start time of peak

- The precipitation starts earlier in Δ1.7 and Δ0.87. The convection activities also shows early start

Diurnal Cycles over the land in the tropics



What is the cause of change between Δ3.5 and Δ1.7?

- Δ3.5 showed the same RH level as Δ1.7 in the middle troposphere in the morning, but precipitation was not significant until the afternoon
- The grid spacing affects not only moisture transport from the boundary layer to the middle troposphere, but also the rapid formation of rain

Summary

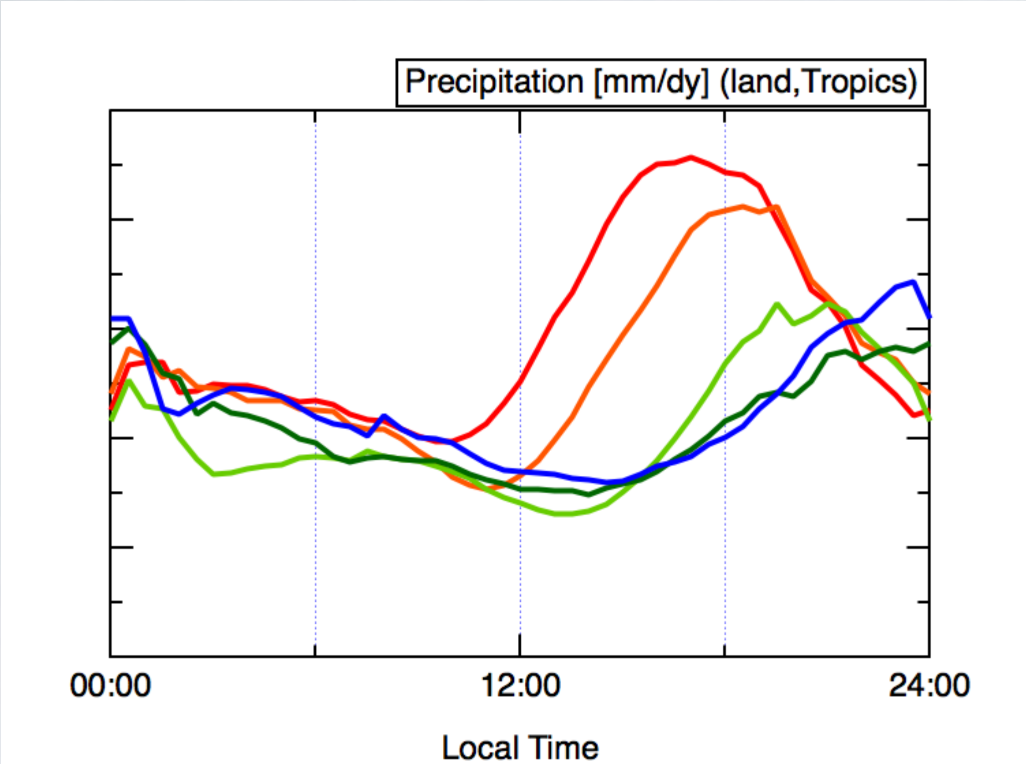
The diurnal cycles of precipitation over the land in the tropics (15°N~15°S) show clear resolution dependency

- In the lower resolution experiments (Δ14~Δ7), precipitation peak appears around midnight and peak amplitude is weak
  → Suggesting that the orographic lift of water vapor plays an important role
- With increasing the horizontal resolution, the timing of precipitation peak appears earlier and the peak amplitude becomes larger
- The higher resolution experiments (Δ1.7~Δ0.87) have the ability to reproduce weak convection with precipitation in the late morning
  → Contributing to the good representation of diurnal precipitation cycle
- The characteristics of the diurnal precipitation cycle changed at a grid spacing of around 2–3 km.
  → The change of expression of convection shown by Minamoto et al. (2013) can be affected to the change of diurnal cycle in this study

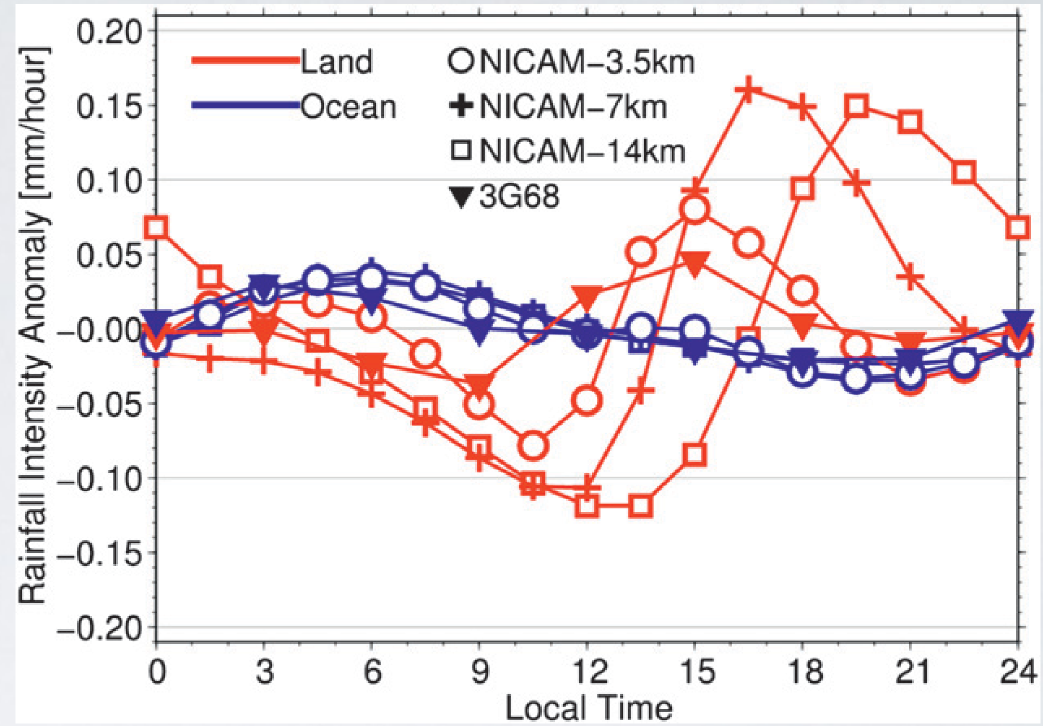
Possible cause of overestimation of the precipitation maximum

Δ1.7~Δ0.87 experiments overestimate precipitation maximum?

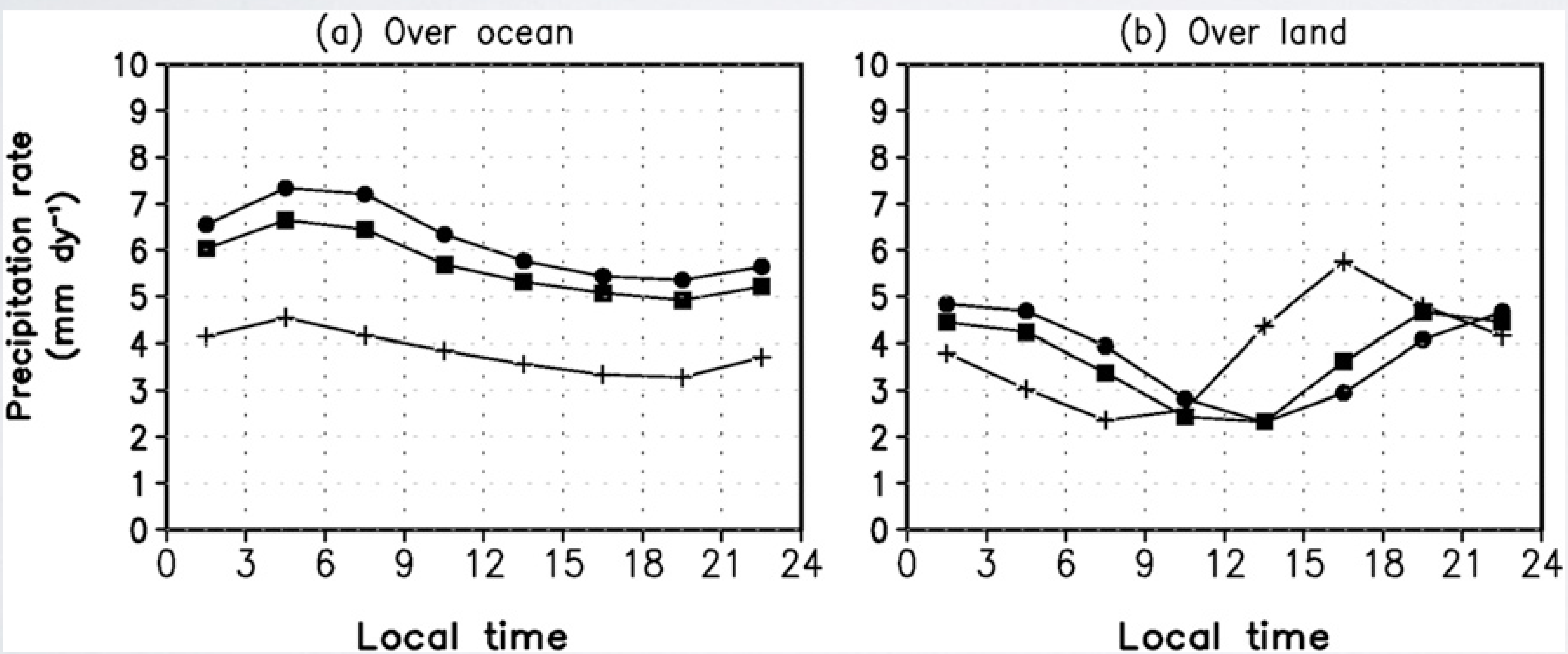
- In this study, no schemes to explain the sub-grid scale entrainment were adopted
    - The artificial fourth-order hyper-diffusion term can act as an entrainment/detrainment term
- The simulation resolved the deep convection with multiple grids in the Δ1.7 and Δ0.87
    - Scale-selective hyper-viscosity can lose the role of the entrainment term at these resolutions?
    - We have to incorporate eddy-viscosity term to explain the effect of lateral mixing



This study



Sato et al., 2008, JC



Noda et al., 2012, JC