A global LES simulation: Preliminary results about deep convection and turbulence scheme.

Shuhei Matsugishi

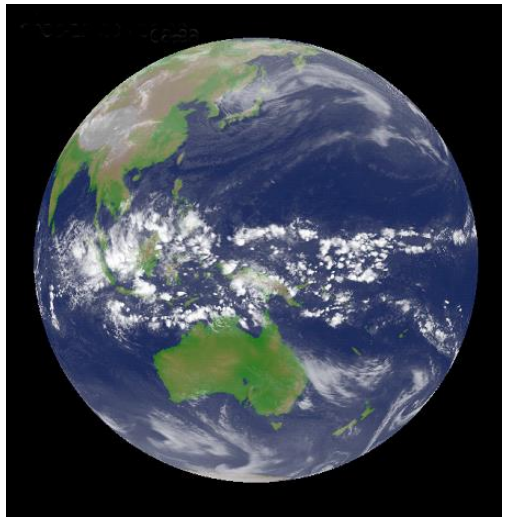
Atmosphere Ocean Research Institute

The University of Tokyo

NICAM & Resolution

NICAM (Tomita and Satoh 2004; Satoh et al. 2008)

2007 3.5km (GL11)

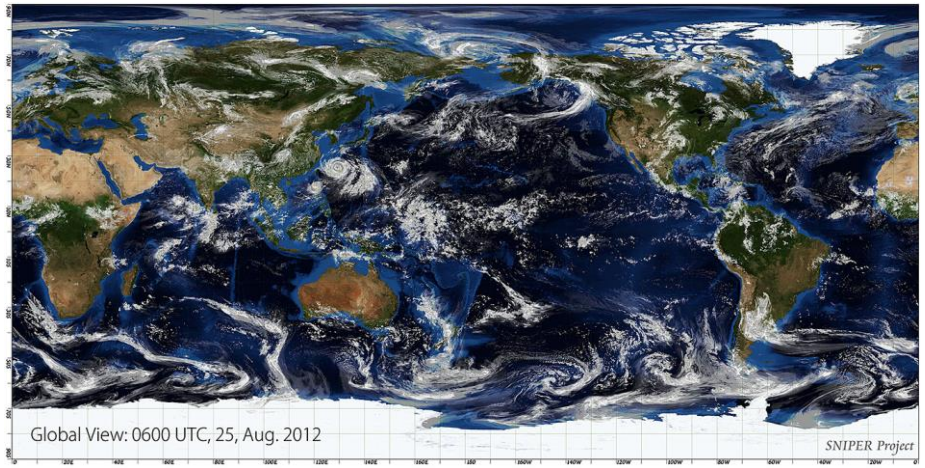


Miura et al. 2007

Earth Simulator 40TF

First global cloud resolving

2013 0.87 km(GL13)

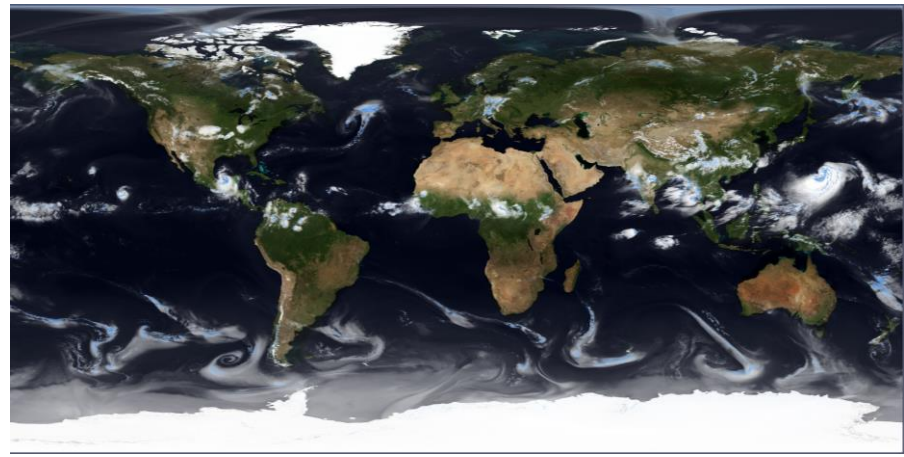


Miyamoto et al. 2013

K computer 10PF

First Sub-km global simulation

2023 0.22 km(GL15)



This study

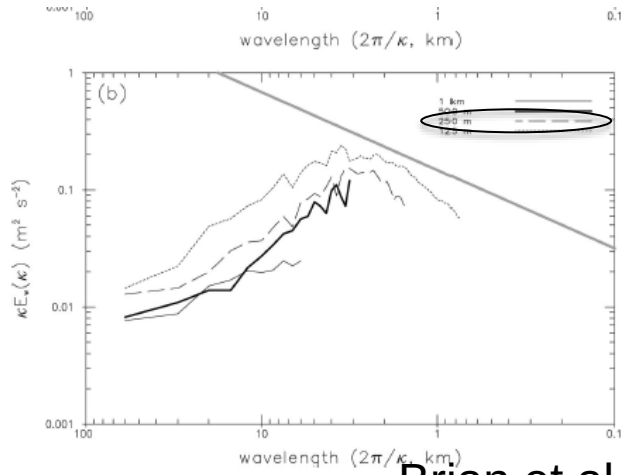
Fugaku 488PF

First global LES?

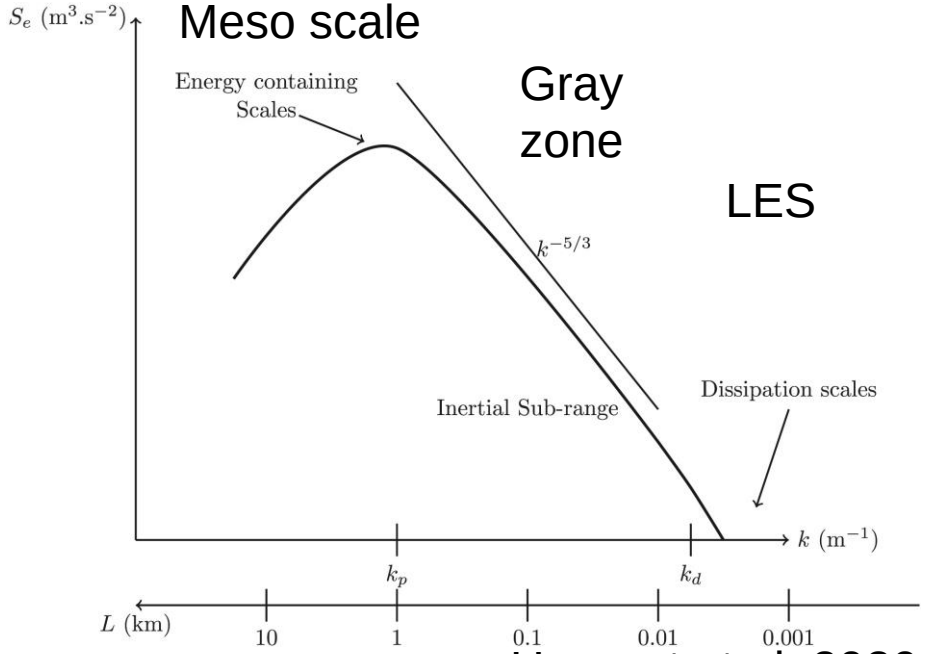
Is 220m simulation a Global “LES”?

- Deep convection need dx < 250 m
- Sub-km scale is “Grayzone” for <u>boundary layer</u> turbulence
- “Eddy” scale depends on stability
  Smoller eddy under high stable condition

dx=220m is still hard to be called full global LES
but
possibly called global LES for deep convection



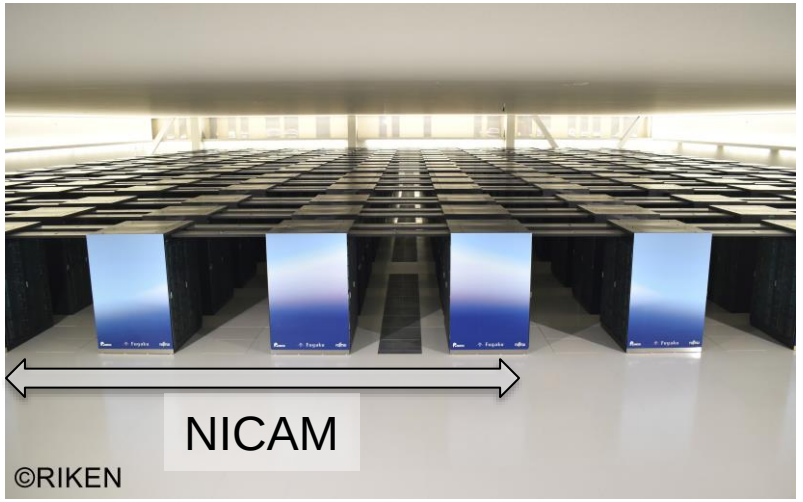
Brian et al. 2003

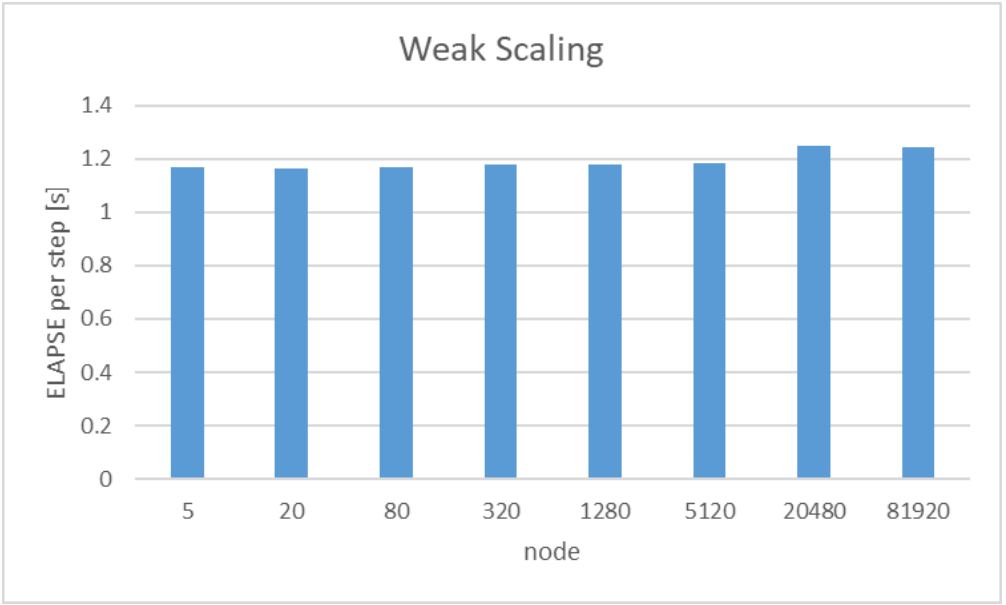


Honnert et al. 2020

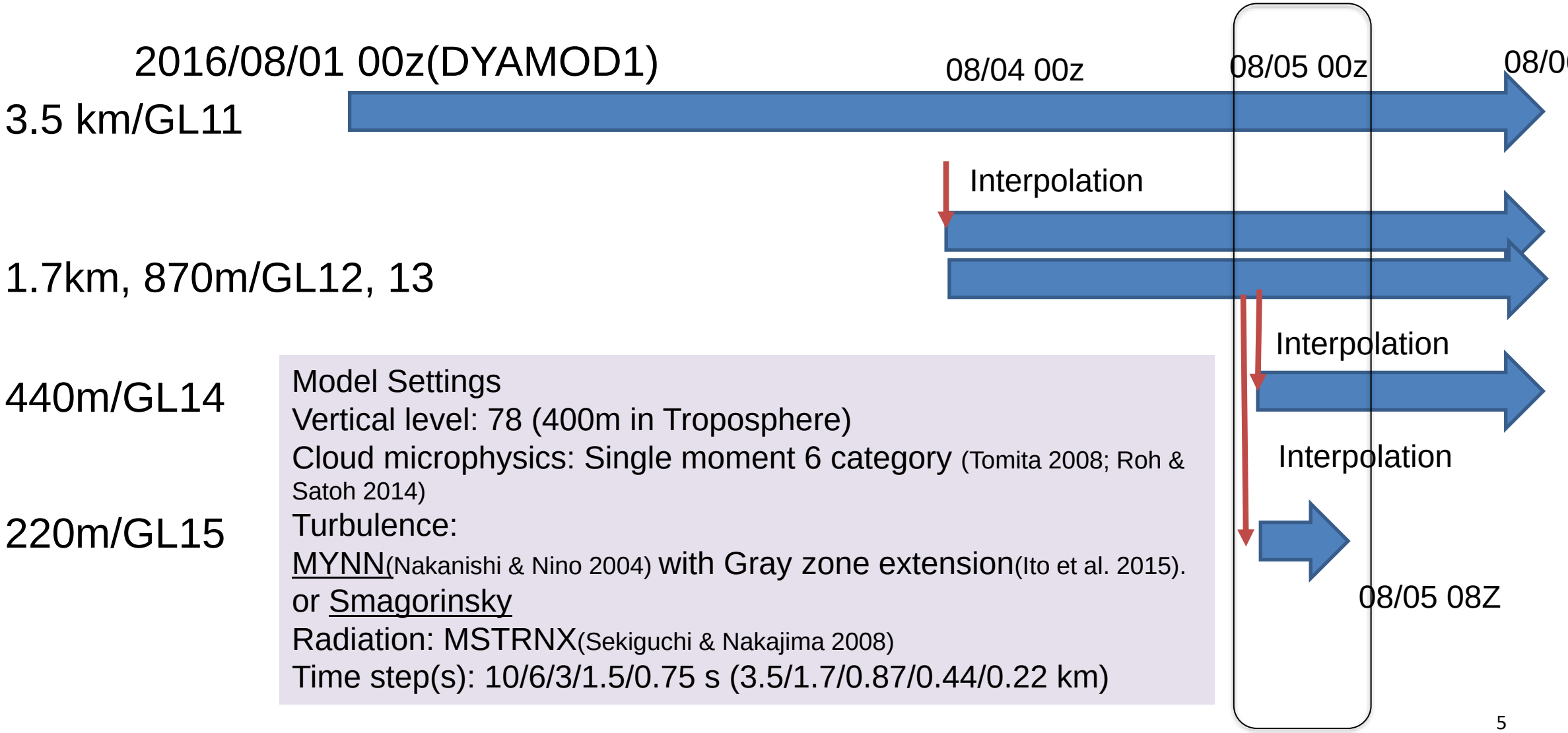
Computational Cost

- 81,920 node in Fugaku (more than half of total nodes)
  3,932,160 core: 2.3 PB Memory
- NICAM with Mixed precision version (Nakano et al. 2017)
  327,680 MPI + 12 OMP
- Input: 3 file per MPI, Output: 2 file per MPI
  Total : 1.6 million file I/O
- Output size: 3D:3TB, 2D:40GB without compression
- NICAM is good week scaling
- 2 h simulation with 5 h wall clock time





Simulation Design



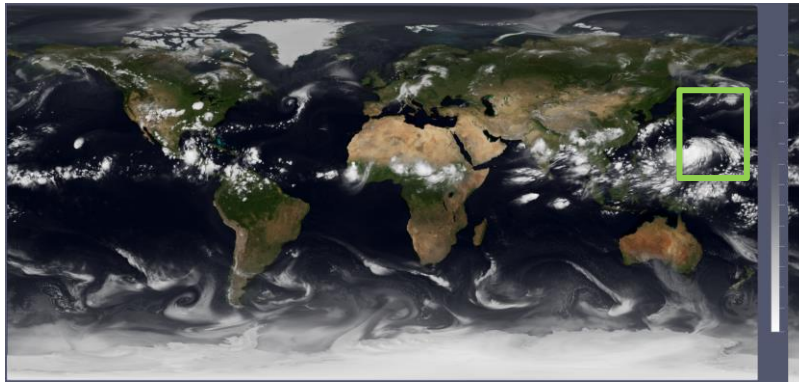
Model Settings
Vertical level: 78 (400m in Troposphere)
Cloud microphysics: Single moment 6 category (Tomita 2008; Roh & Satoh 2014)
Turbulence:
MYNN(Nakanishi & Nino 2004) with Gray zone extension(Ito et al. 2015).
or Smagorinsky
Radiation: MSTRNX(Sekiguchi & Nakajima 2008)
Time step(s): 10/6/3/1.5/0.75 s (3.5/1.7/0.87/0.44/0.22 km)

Contents of this presentation

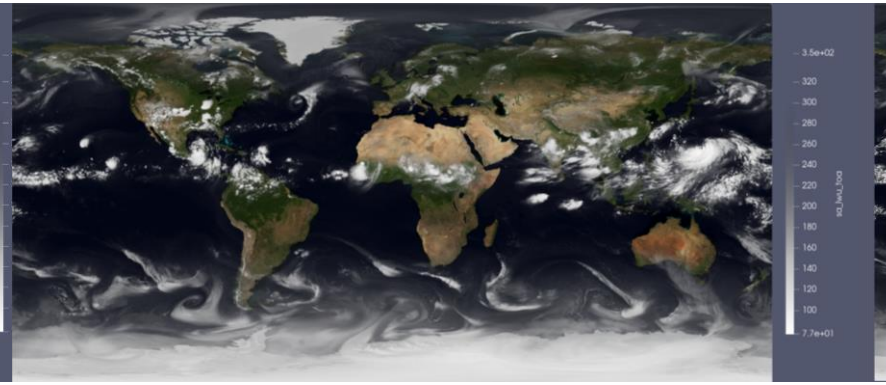
- Overview of simulation
- Precipitation and convection
- Cloud and radiation
- Difference between turbulence schemes: MYNN(RANS) and Smagorinsky (LES)
- Global kinetic energy spectra

08/05 02Z Global OLR

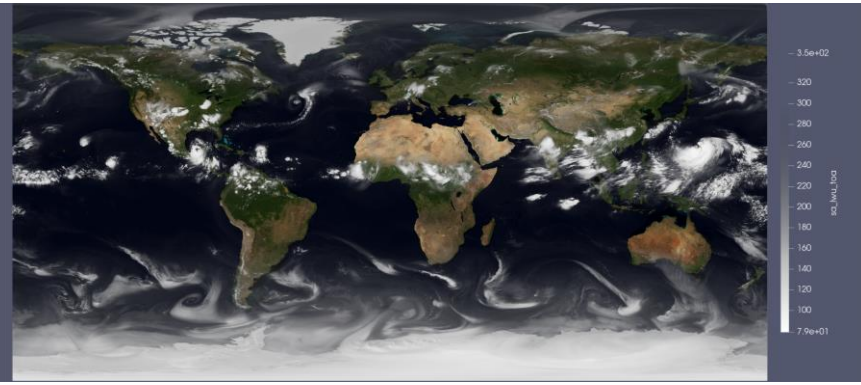
3.5km (GL11)

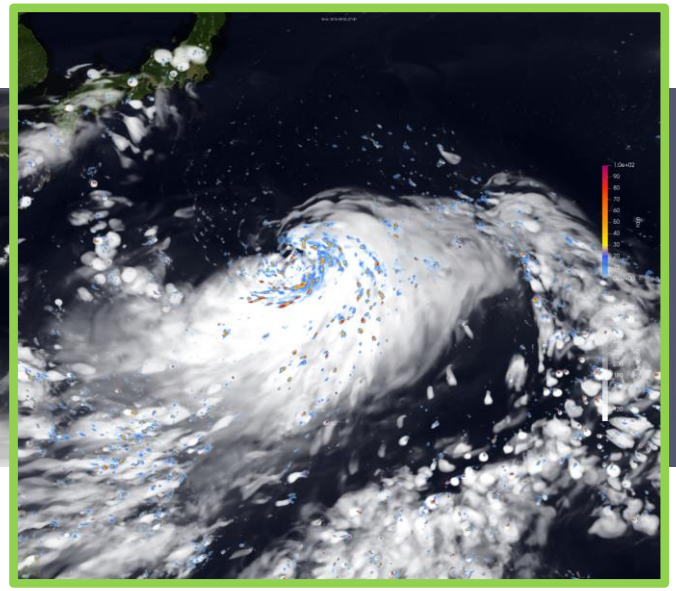


1.7km (GL12)

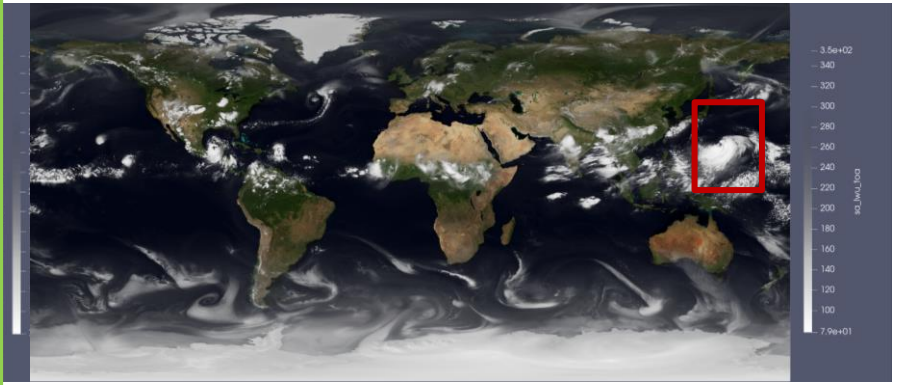


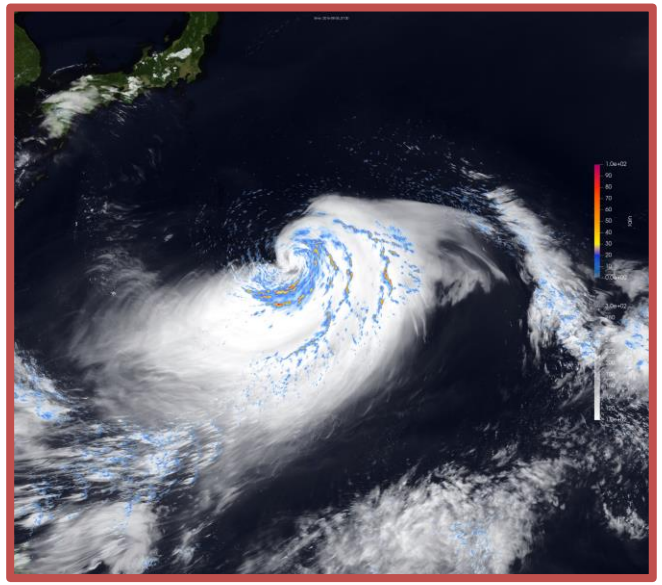
0.87km GL13





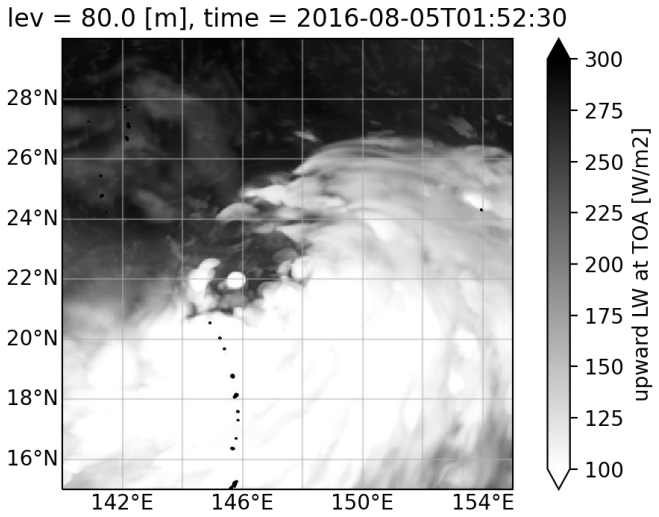
0.22 km (GL15)



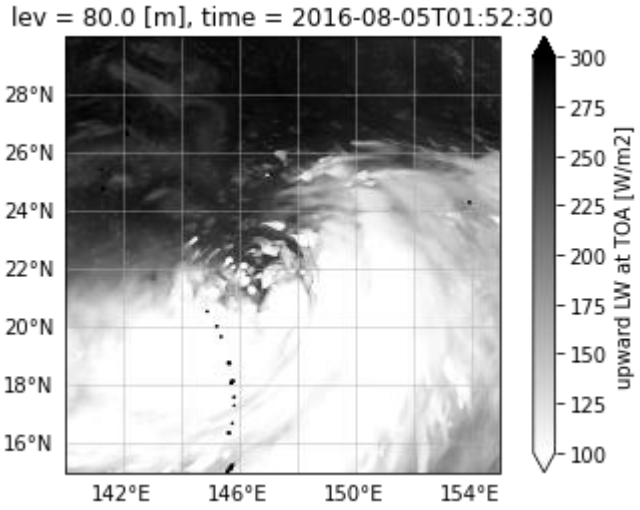


Tropical cyclone Western Pacific(OLR)

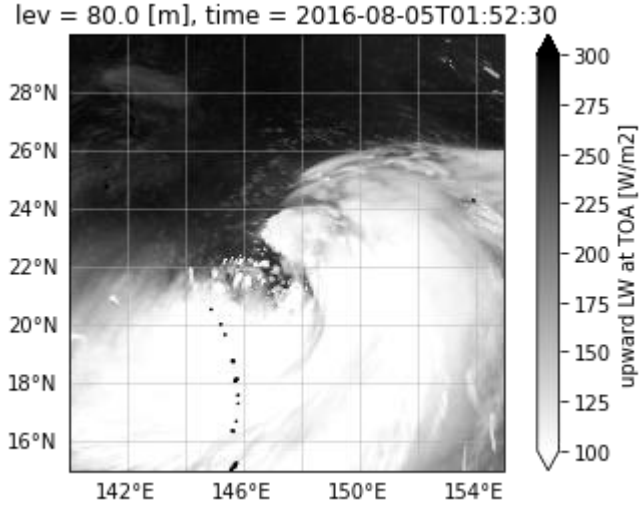
3.5km (GL11)



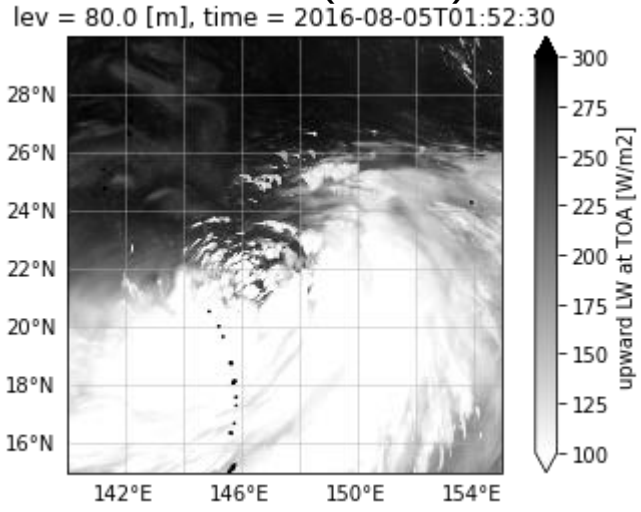
1.7km (GL12)



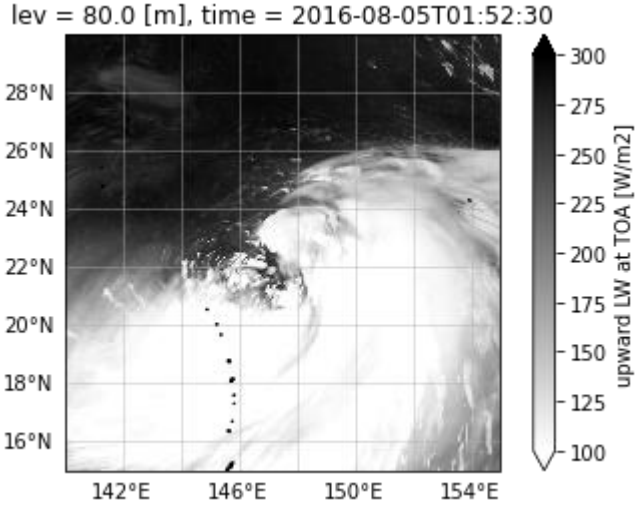
0.87km GL13



0.44 km(GL14)

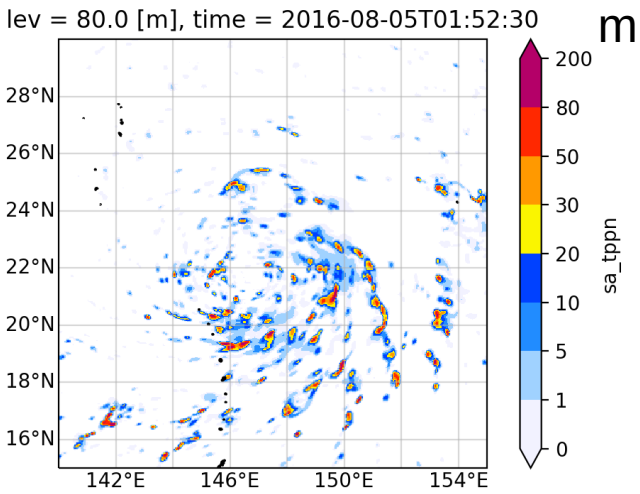


0.22 km (GL15)



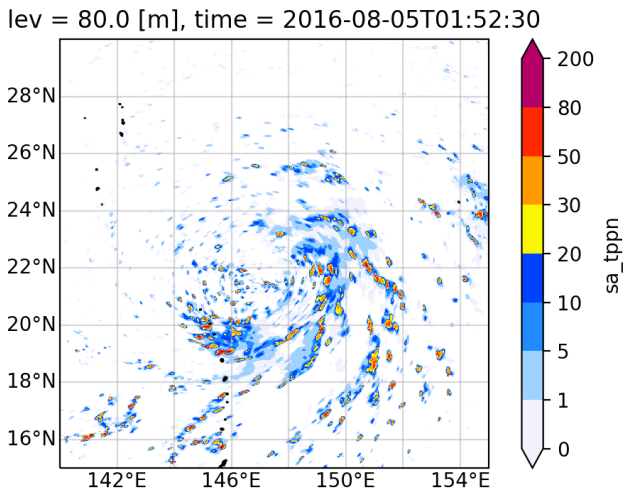
Tropical cyclone Western Pacific (Precipitation)

3.5km (GL11)

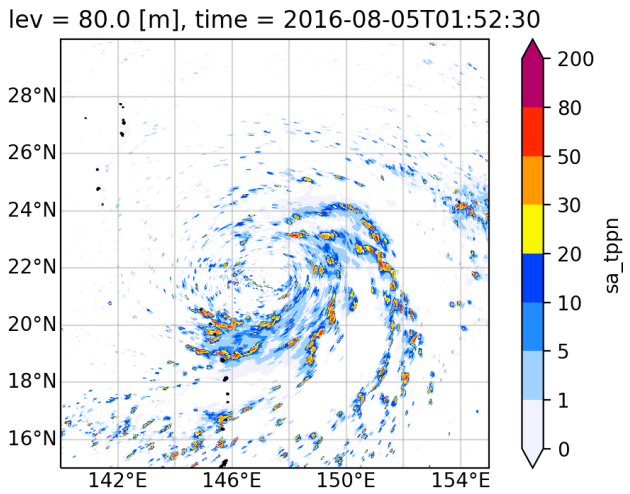


mm/hr

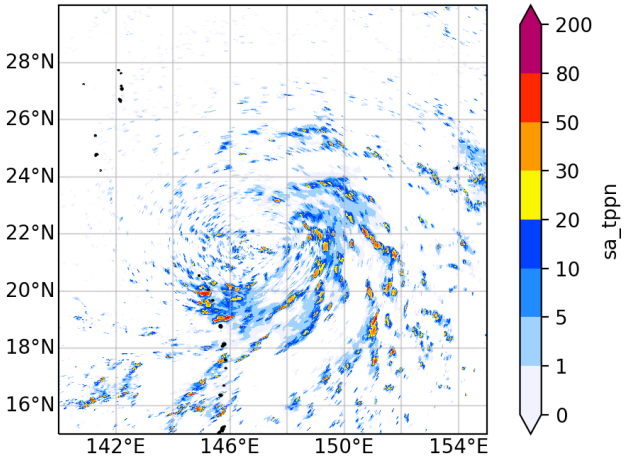
1.7km (GL12)



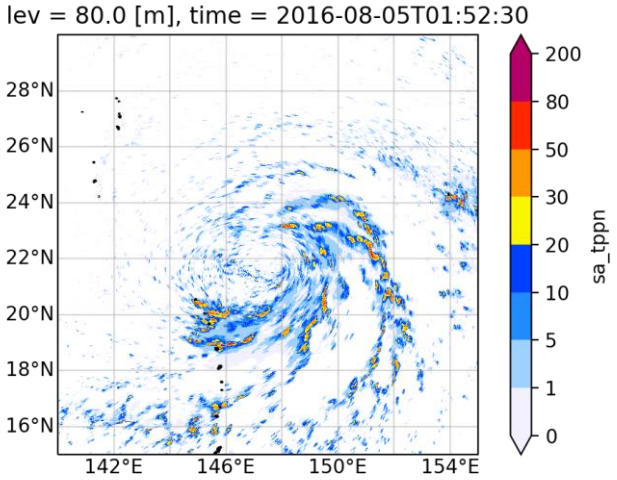
0.87km GL13



0.44 km(GL14)



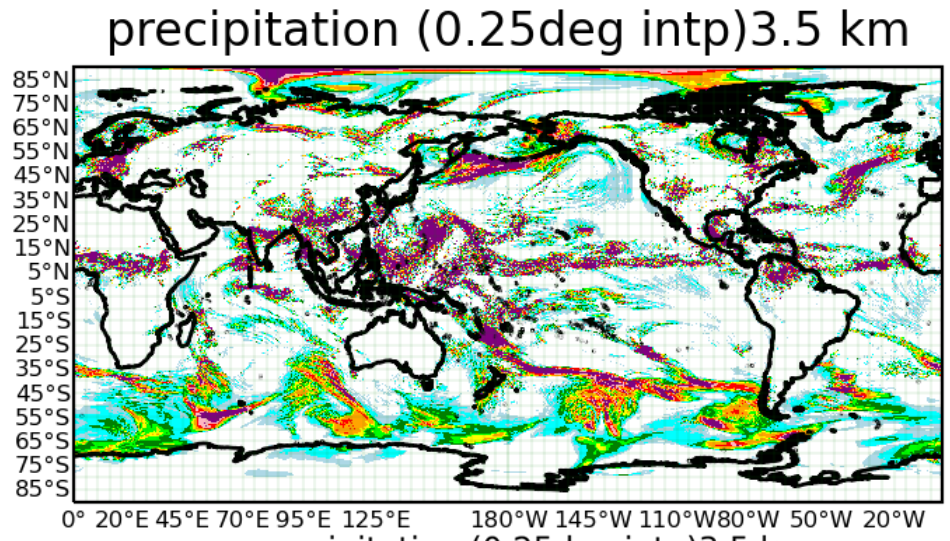
0.22 km (GL15)

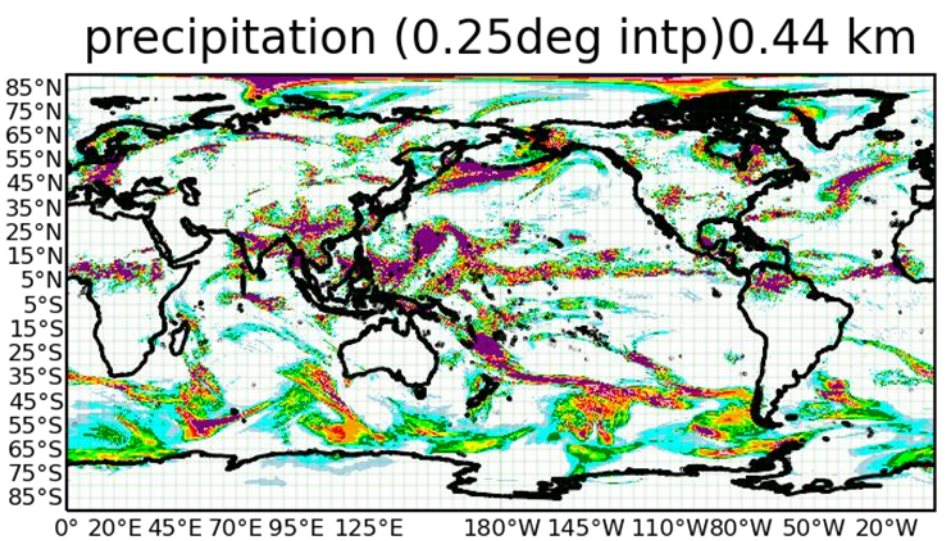


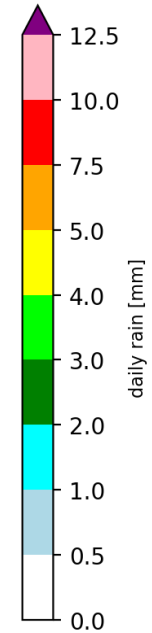
15 minutes average precipitation

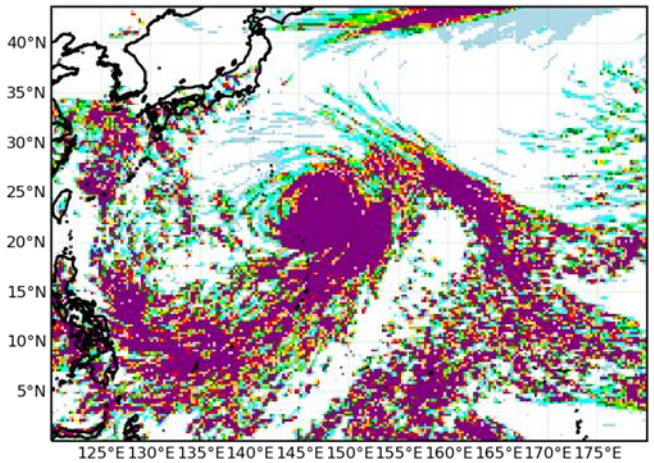
Daily mean precipitation

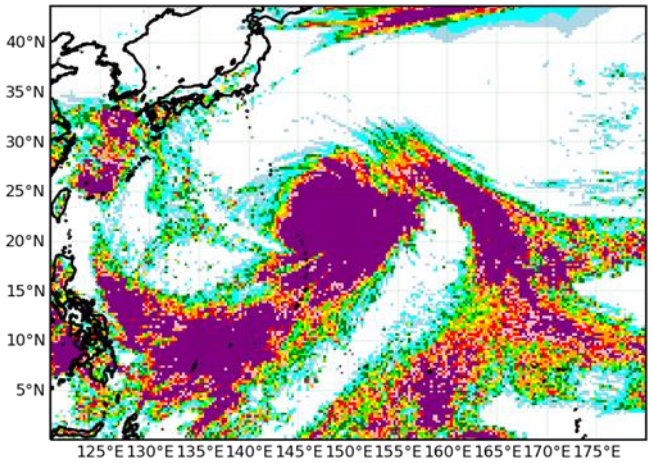
Align to the same resolution (0.25 deg)







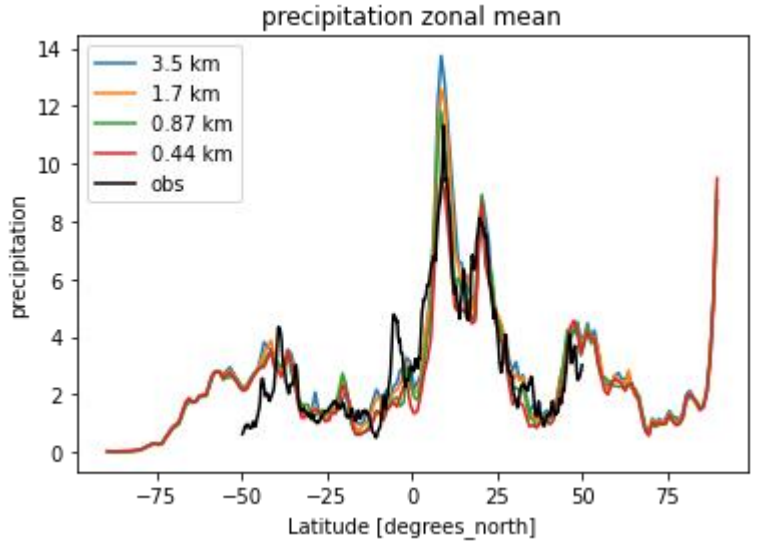




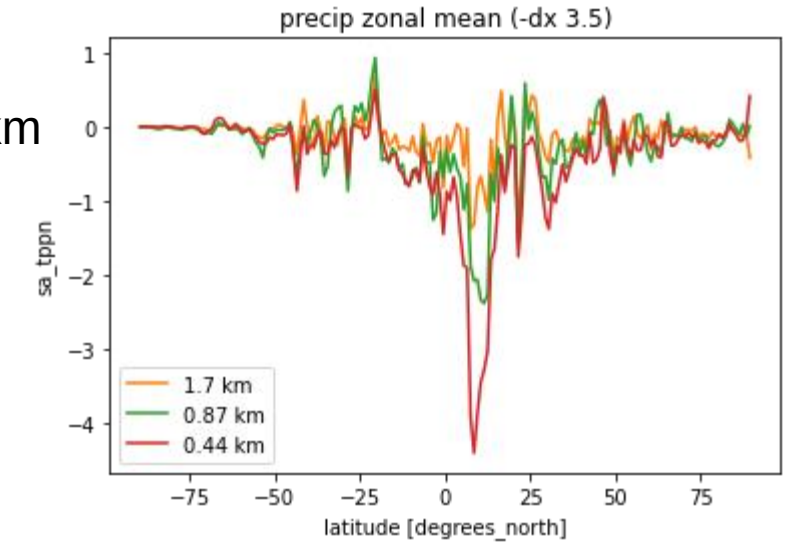
Precipitation zonal mean/histogram

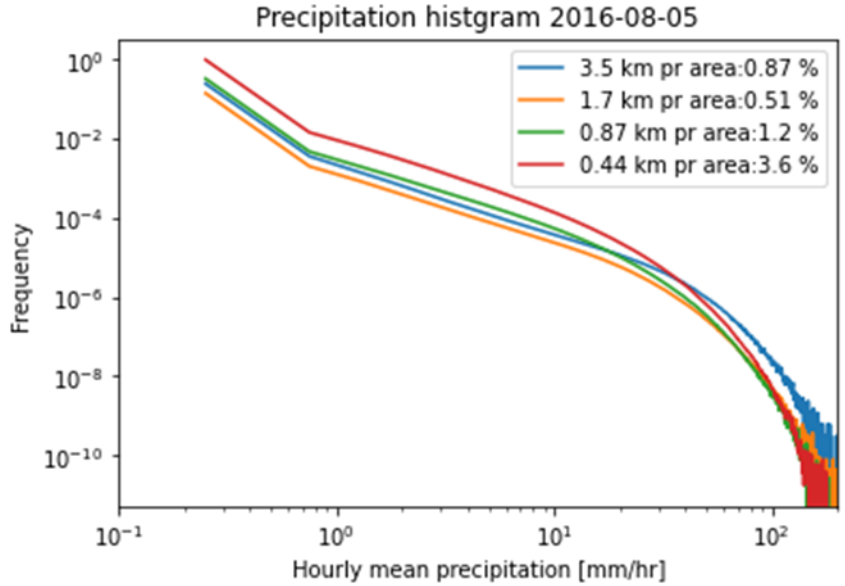
Daily mean Precipitation

mm/day



Diff. from 3.5km





Hourly rain [mm]

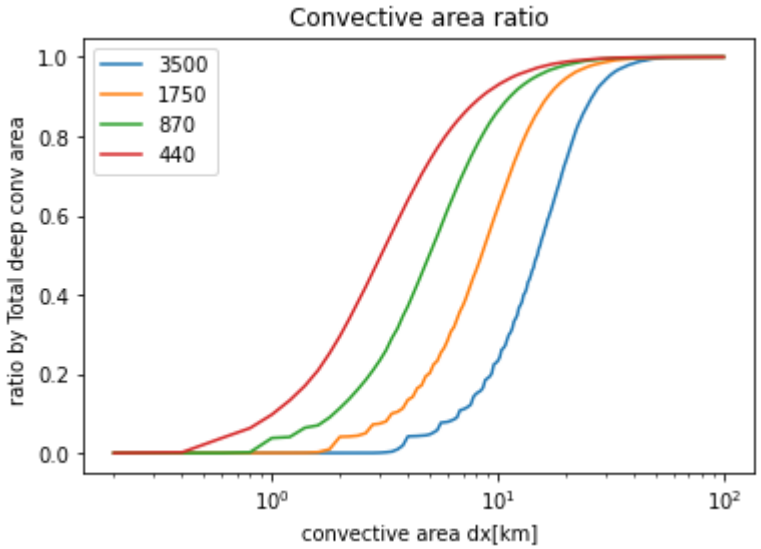
- Decrease heavy rain
- Increase weak rain

Deep convection area

ISCCP deep thick & mean vertical wind > 0.5 m/s
4-connectiveity labeling (Sueki et al. 2019)

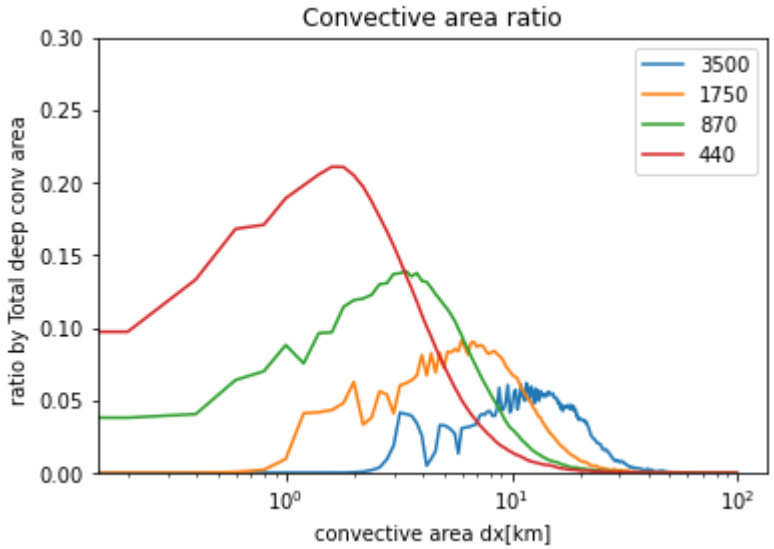
- Deep convection area has peak at about 8 Δx
- Low resolution has grid scale peak

Cumulative probability distribution



sqrt(Convective area) [km]

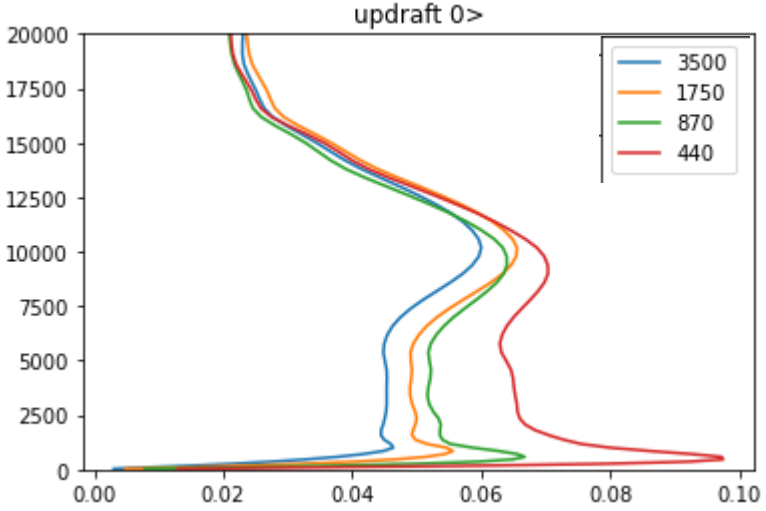
Differential of cumulative probability distribution



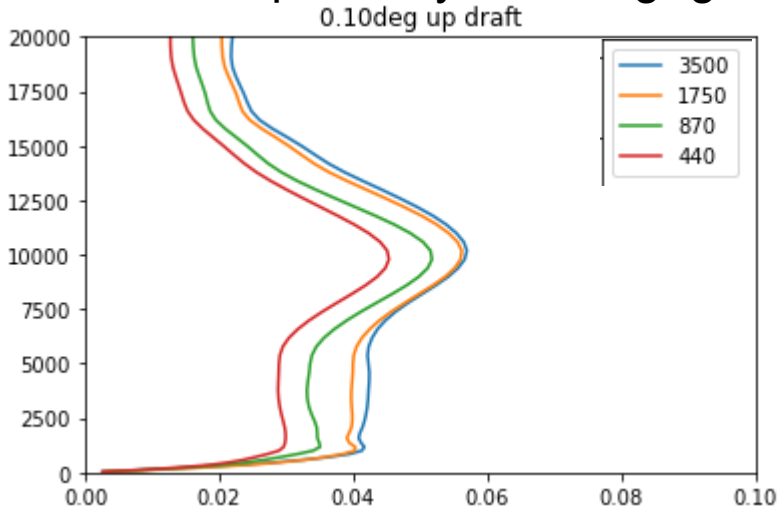
sqrt(Convective area) [km]

Vertical velocity

Mean Updraft by “native” grid



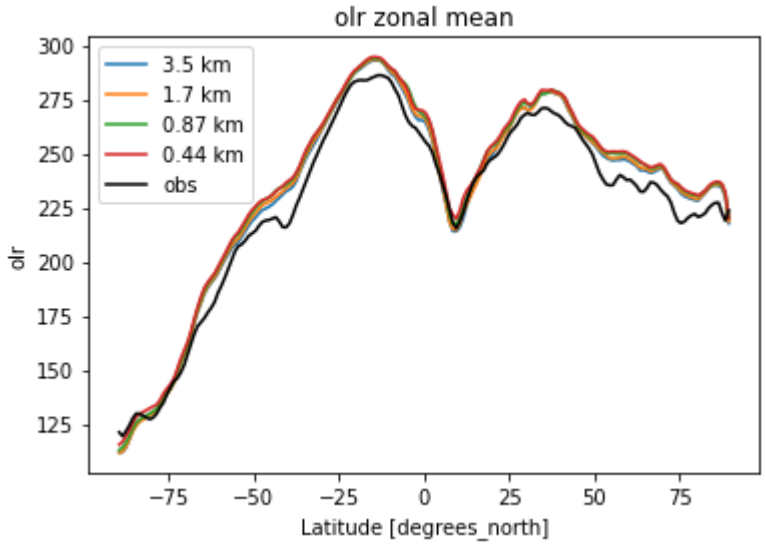
Mean Updraft by “0.10deg” grid



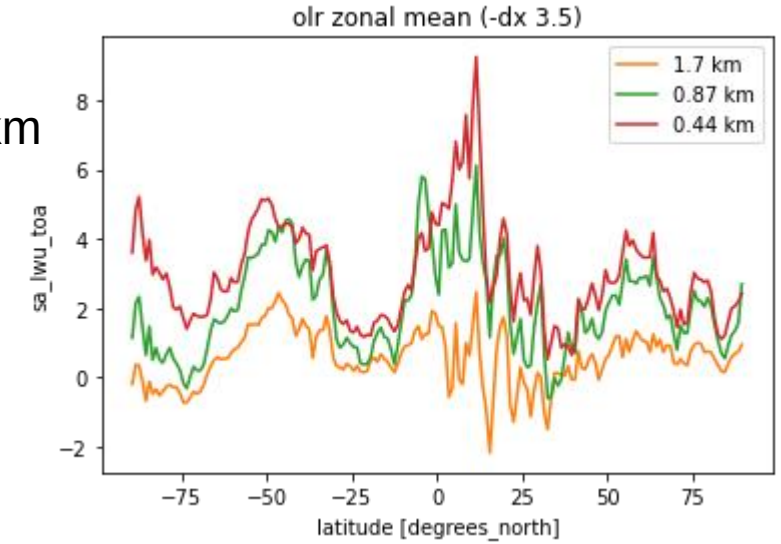
- Grid scale updraft become strong but mean updraft become weak

Zonal mean Radiation

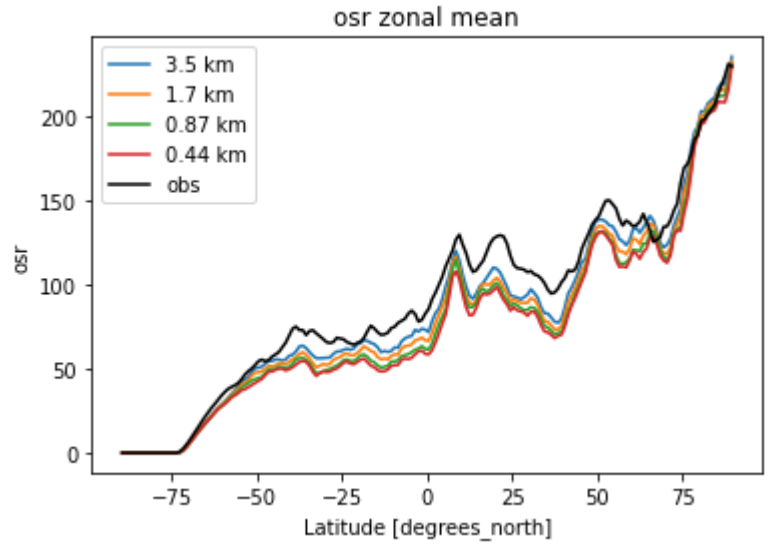
OLR

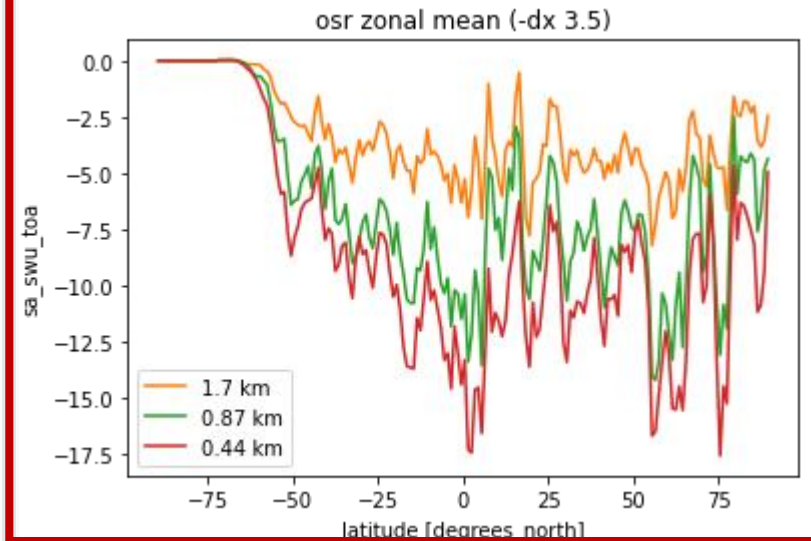


Diff. from 3.5km



OSR

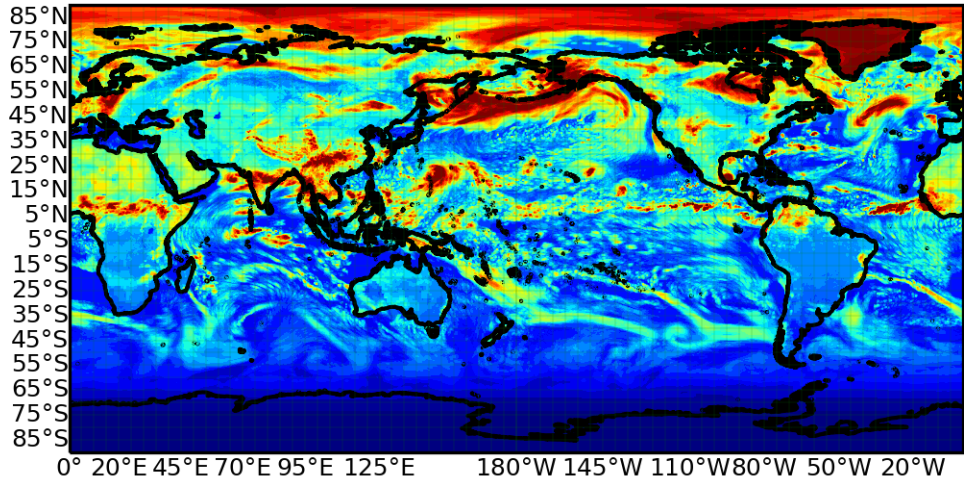




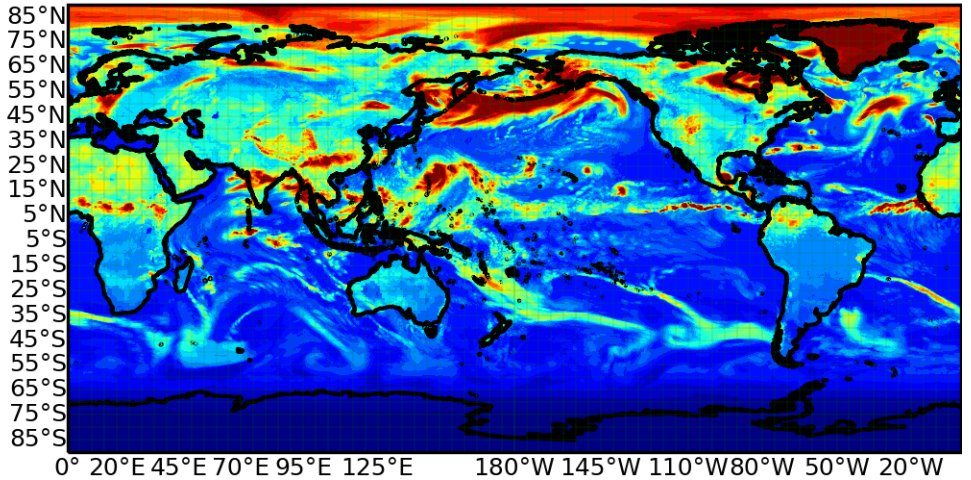
OSR horizontal map

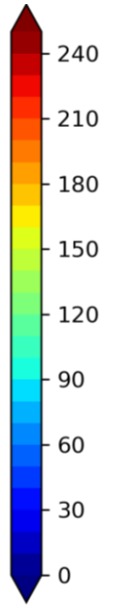
Align to the same resolution (0.25 deg)

OSR 3.5 km

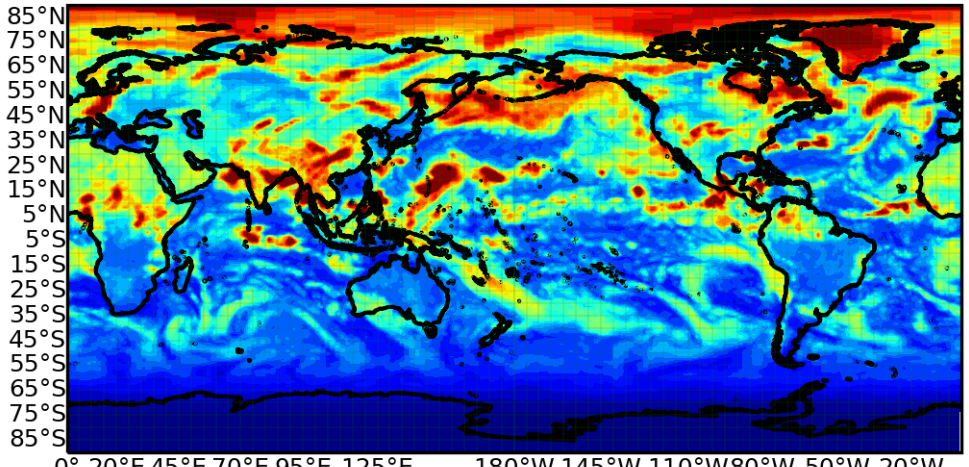


OSR 0.44 km





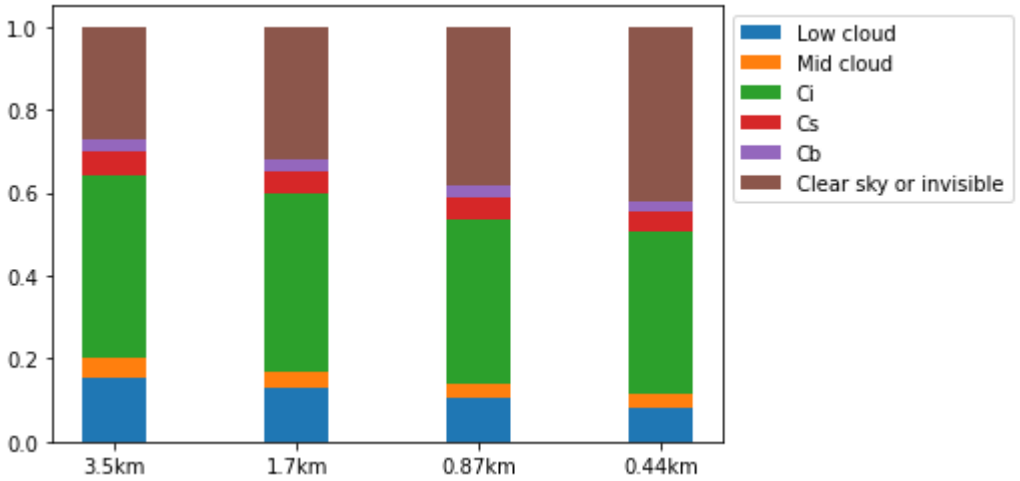
OBS(CERES) 1deg



Decrease in lower clouds over the ocean

Cloud fraction (Tropical)

By ISCCP simulator

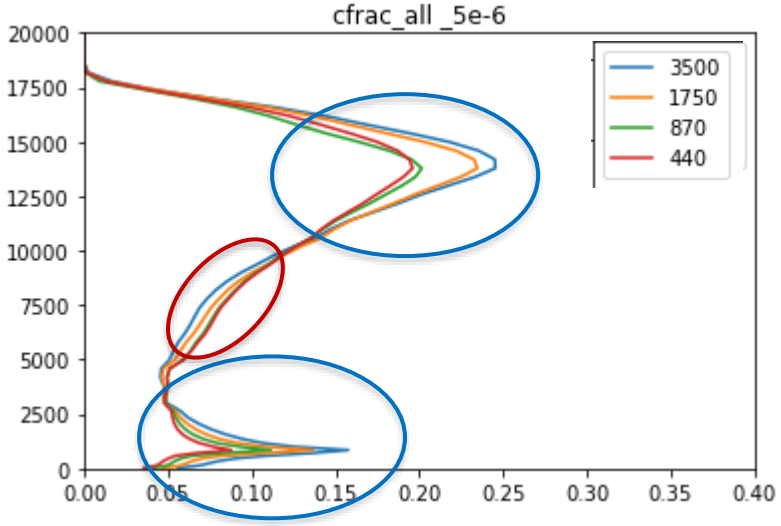


3.5 km

0.44 km

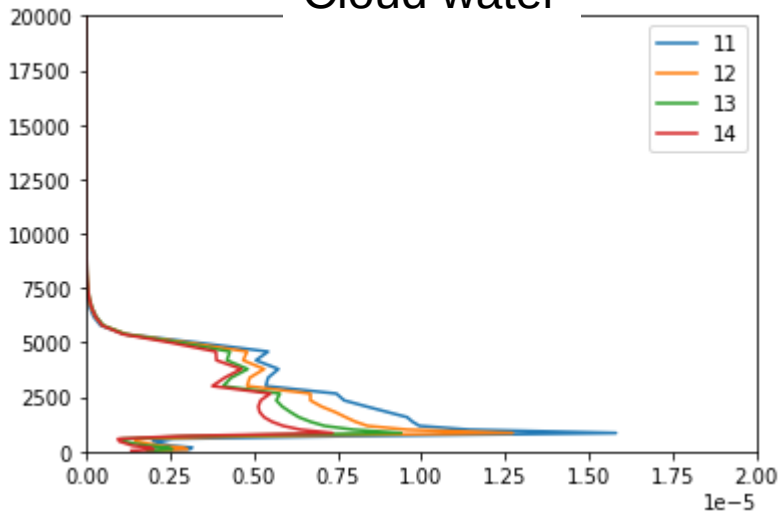
Decrease cloud fraction except Cs

CRM criteria (Hydrometeor > 5.e-5)

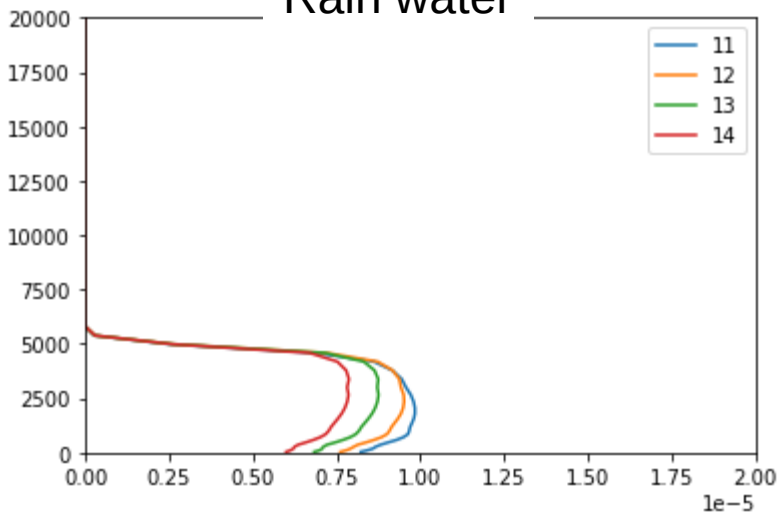


Hydrometeor and RH profile

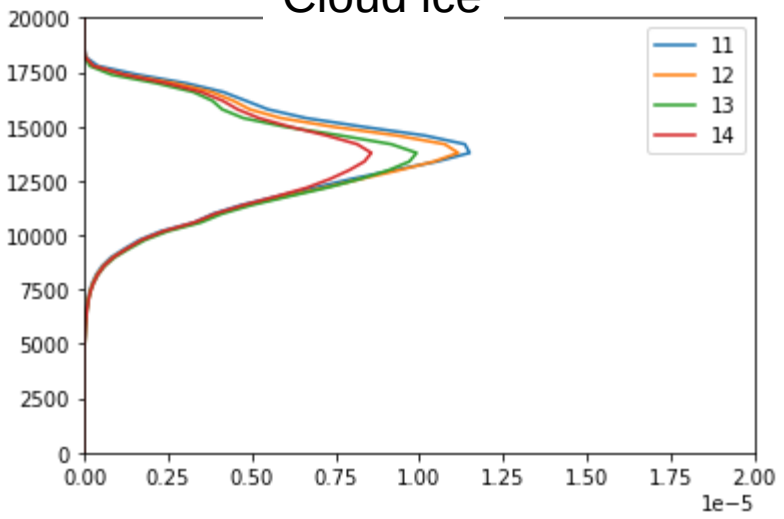
Cloud water



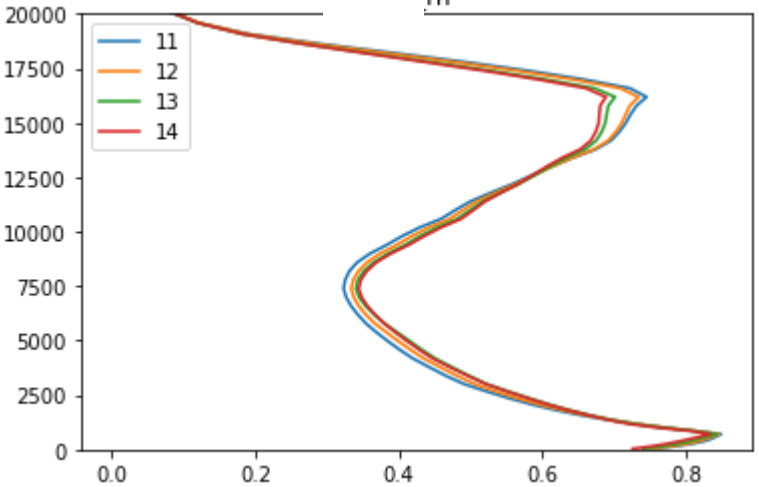
Rain water



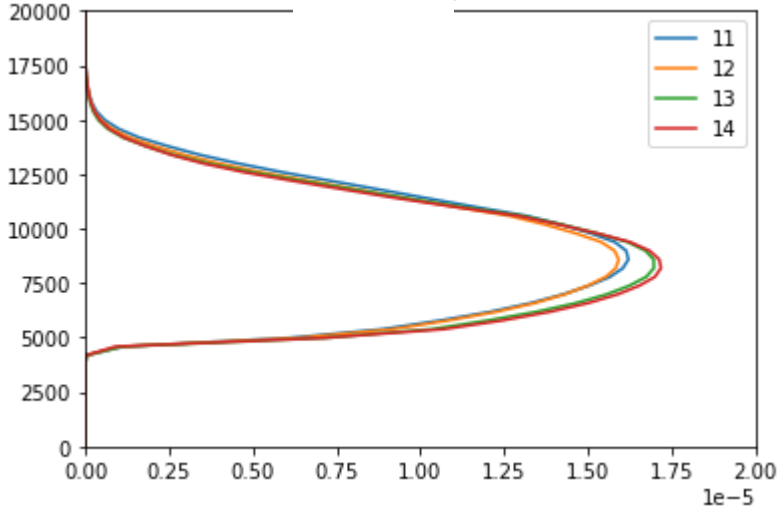
Cloud ice



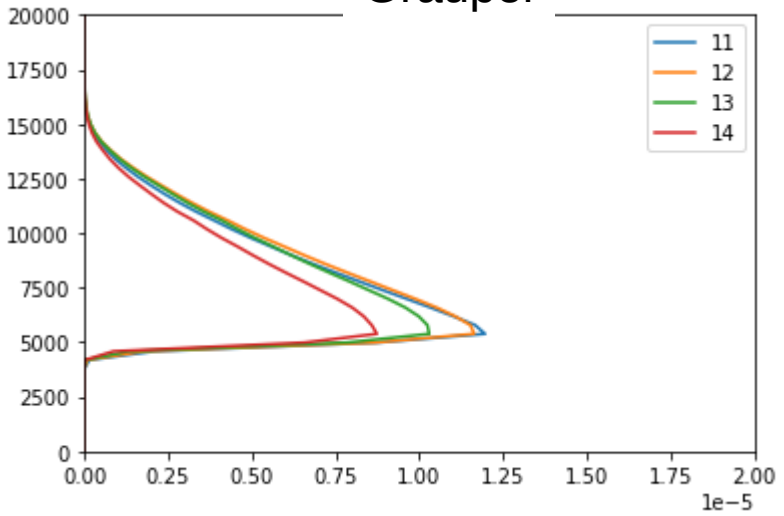
Rh rh



Snow



Graupel

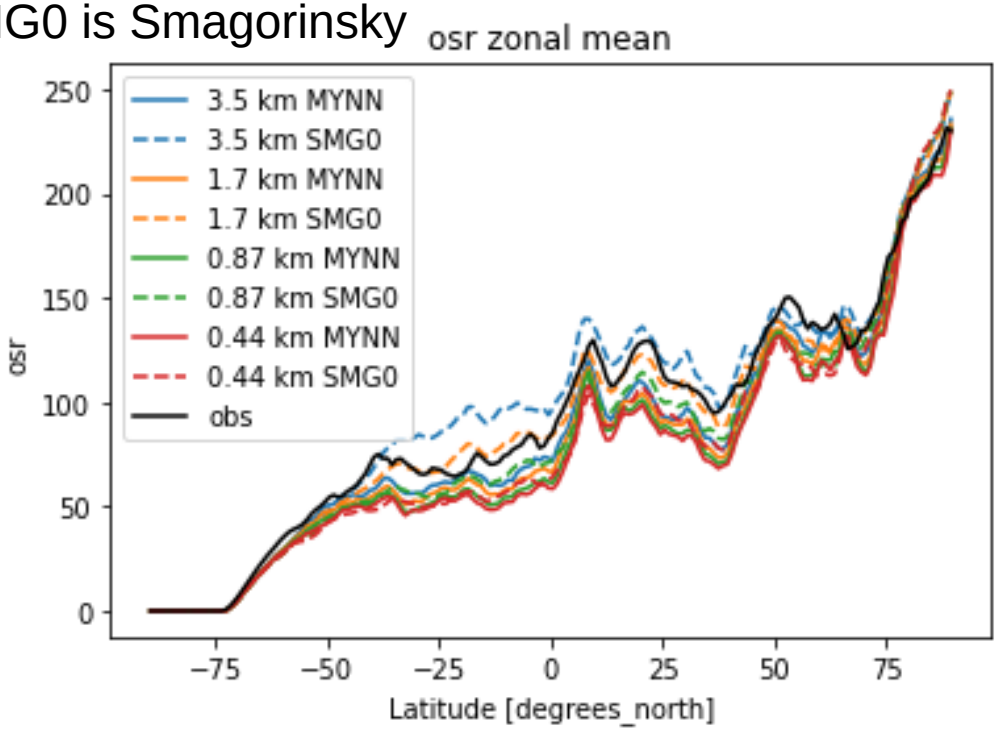


Turbulence scheme dependence

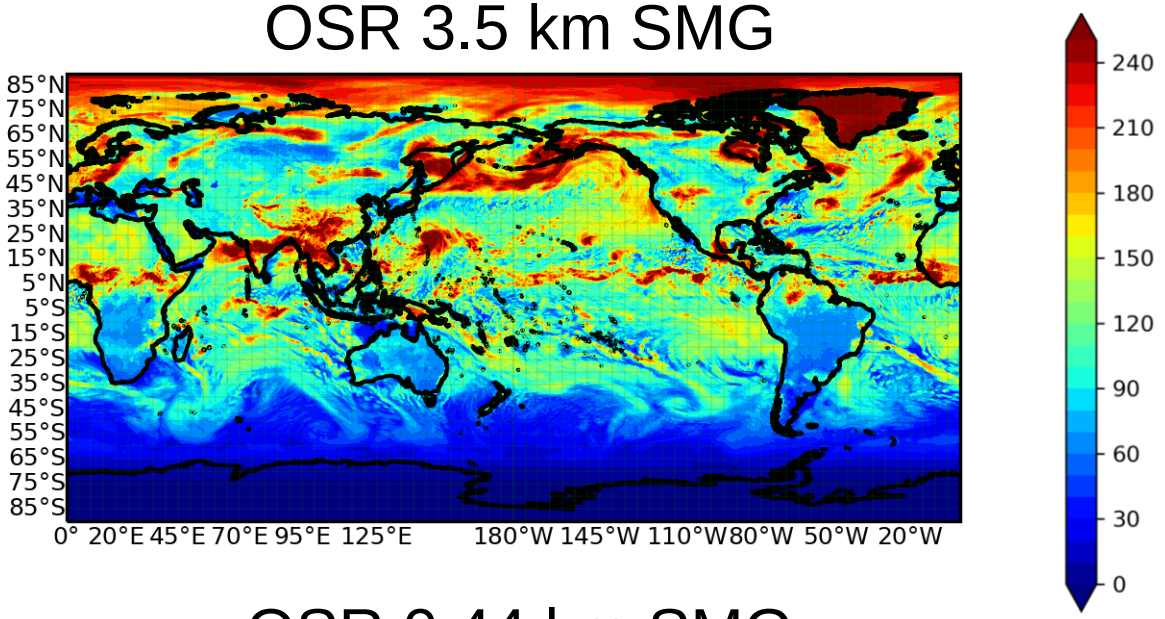
- Resolution dependency is similar to MYNN
- OSR/Low cloud is different between MYNN and SMG

SMG0 is Smagorinsky

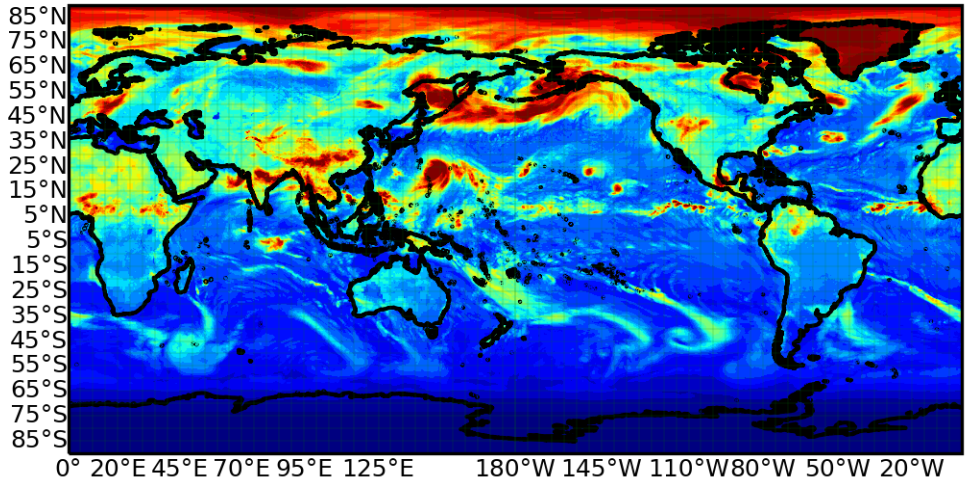
OSR



OSR 3.5 km SMG

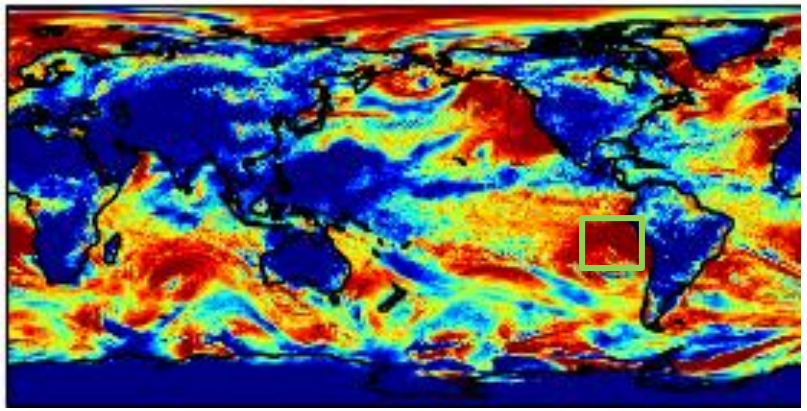


OSR 0.44 km SMG

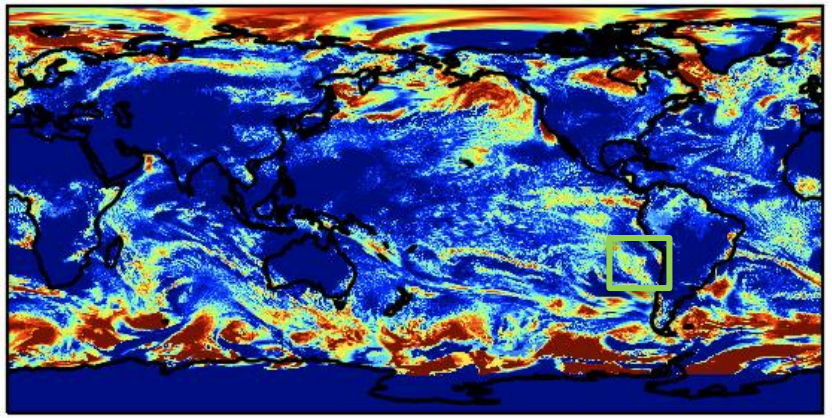


Low cloud by ISCCP simulator

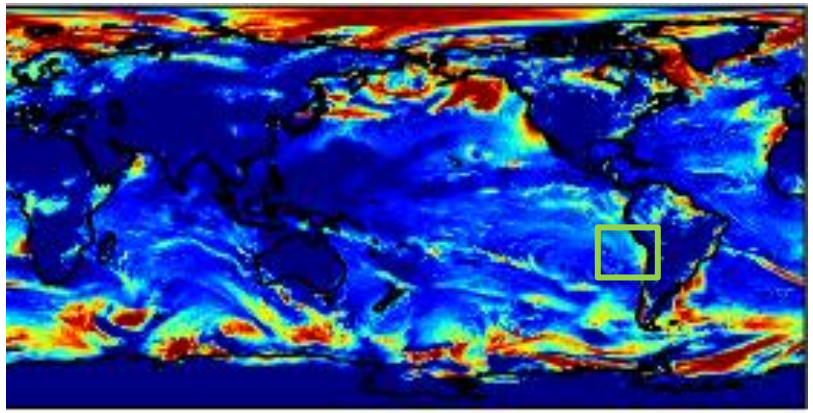
3.5 km Smagorinsky



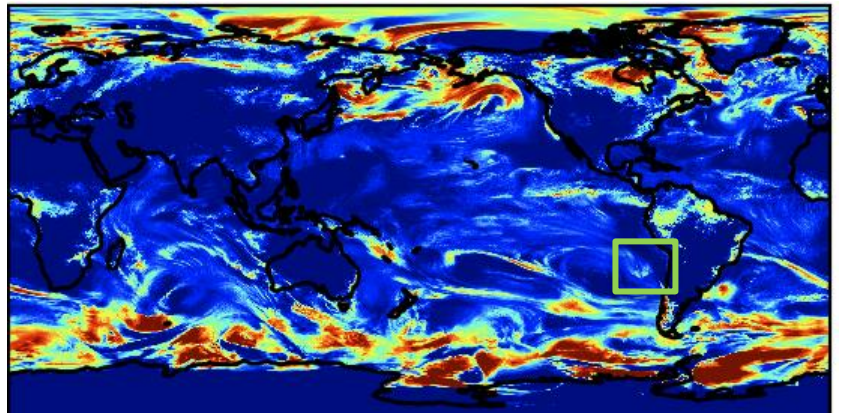
3.5 km MYNN

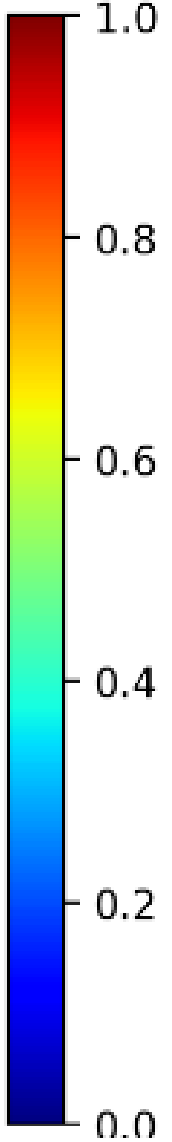


0.44 km Smagorinsky



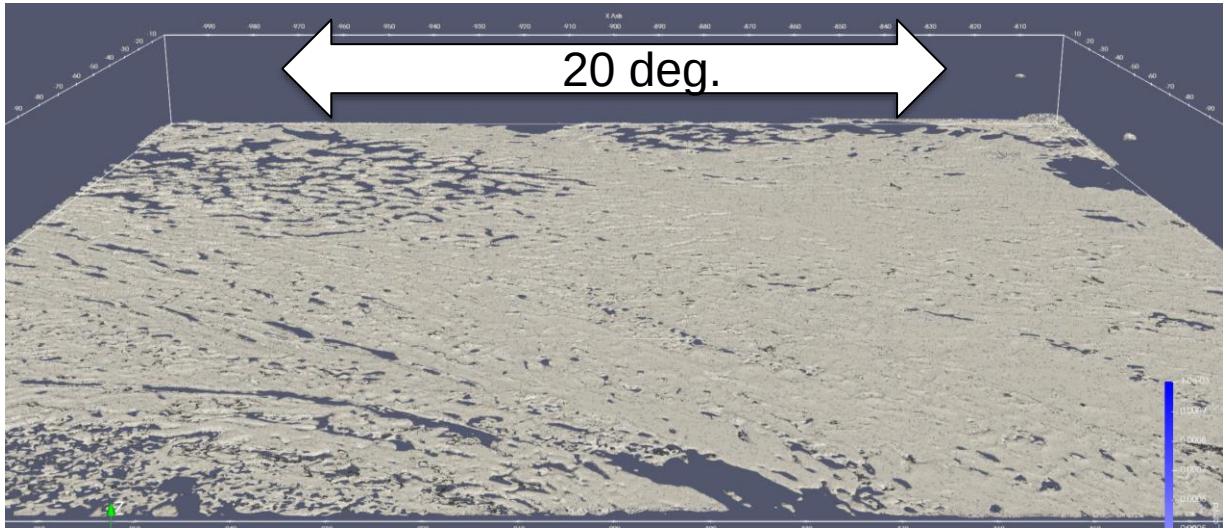
0.44 km MYNN



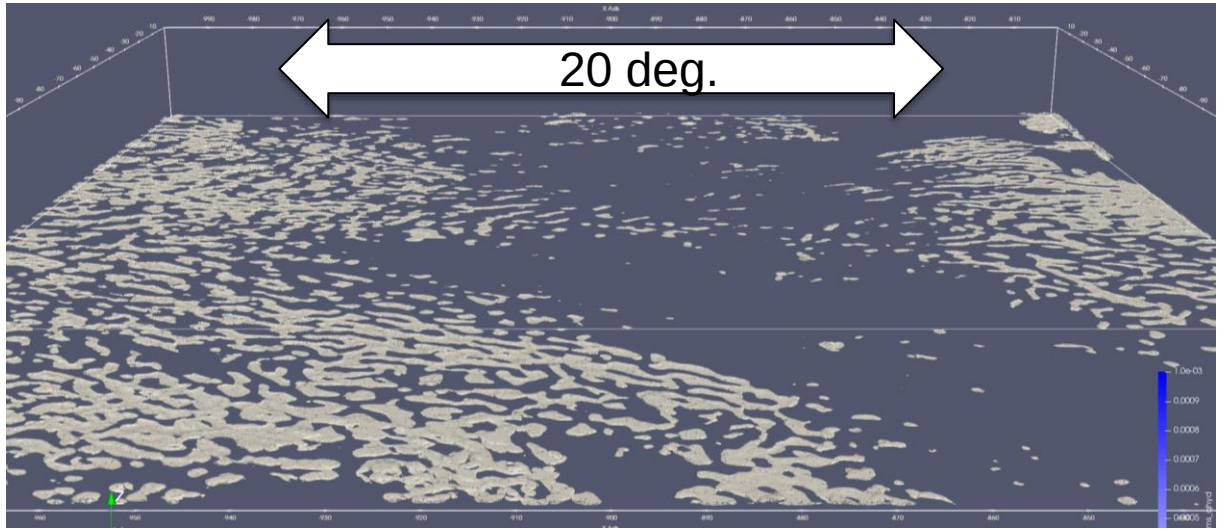


Low cloud off the coast of Peru

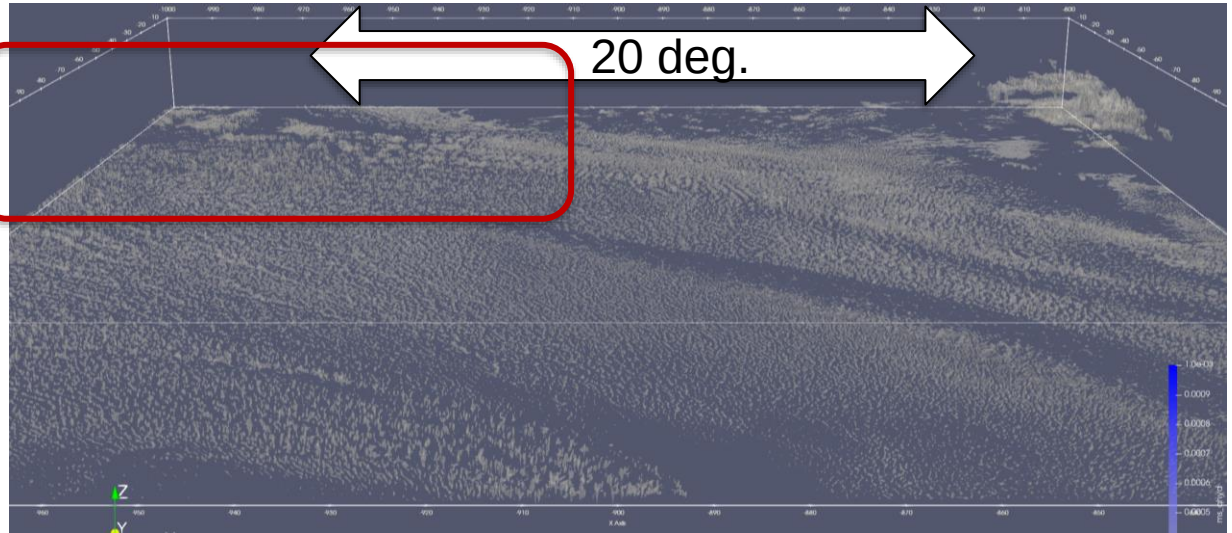
3.5 km Smagorinsky



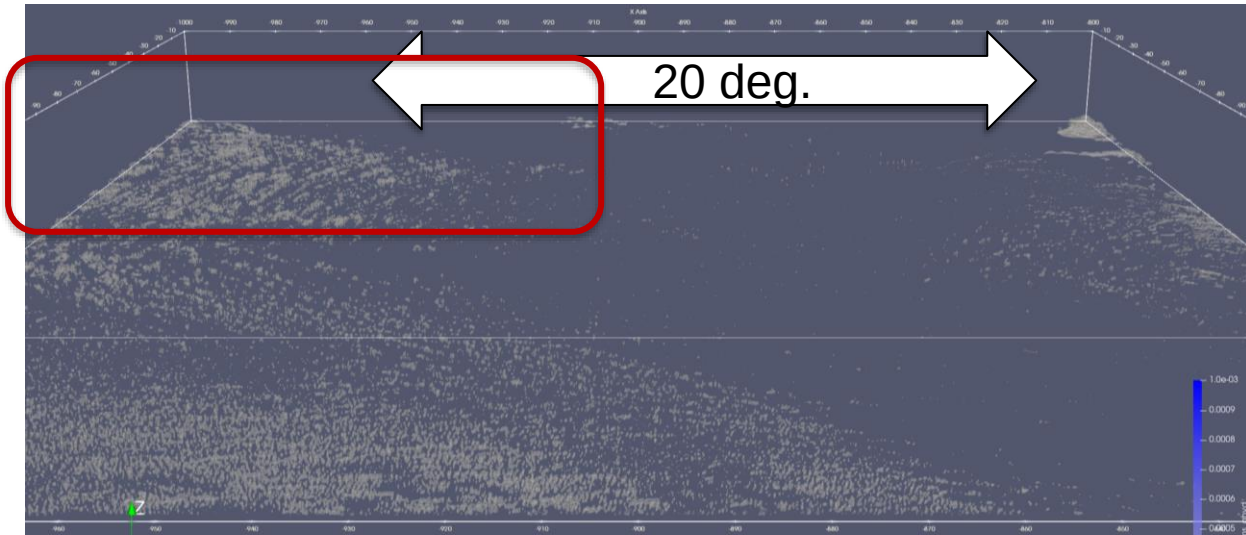
3.5 km MYNN



0.44 km Smagorinsky

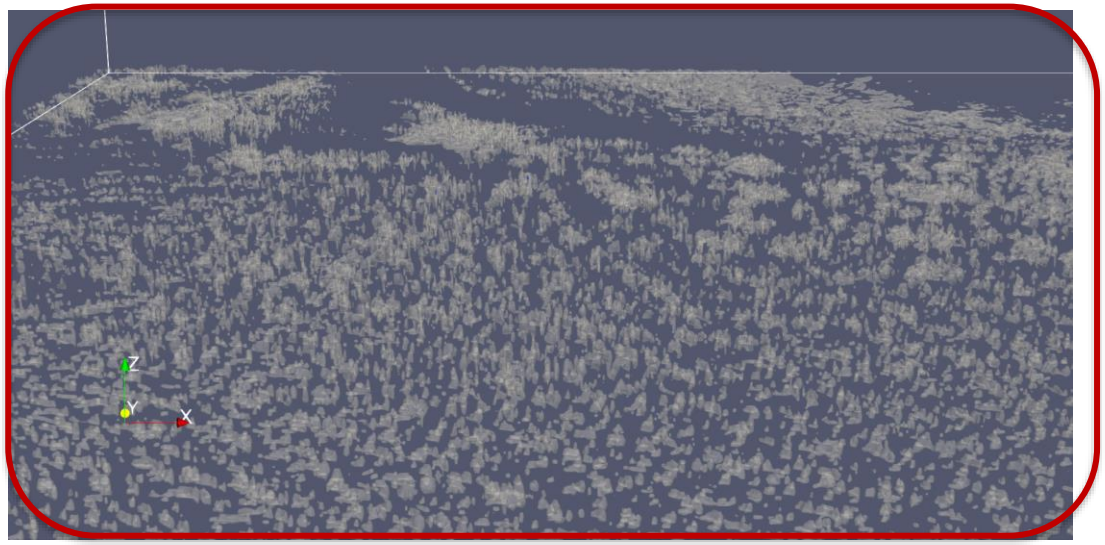


0.44 km MYNN

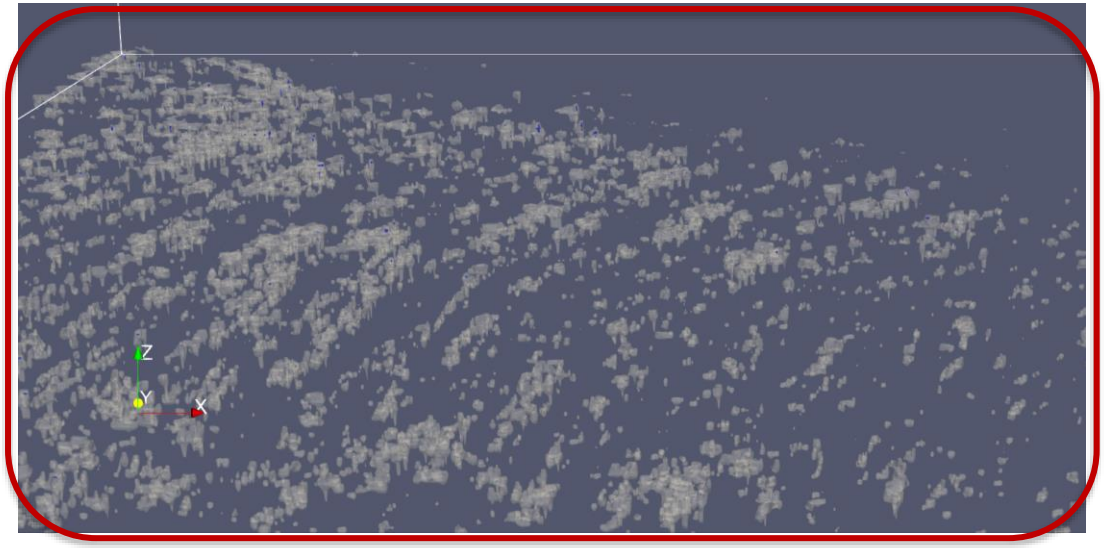


Low Cloud shape

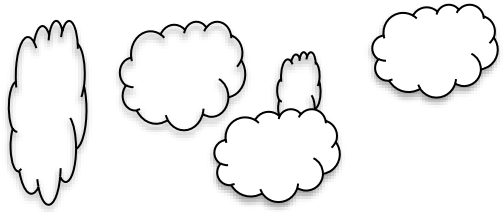
0.44 km Smagorinsky



0.44 km MYNN

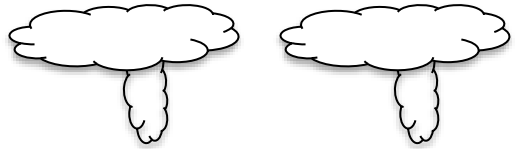


Height



Various cloud

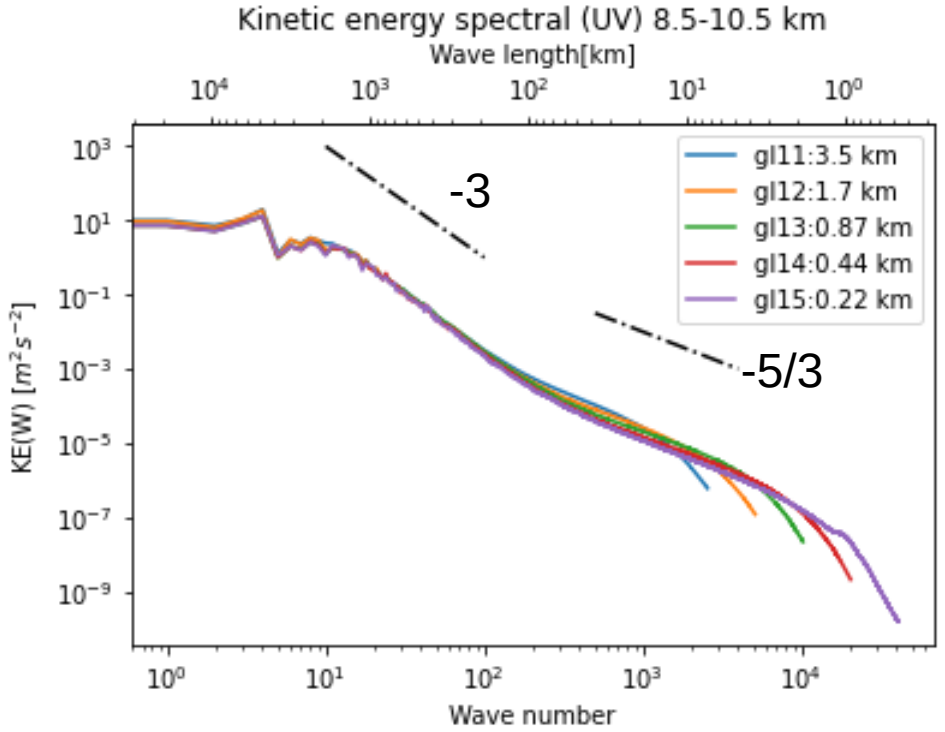
Height



Strongly controlled by boundary layer height

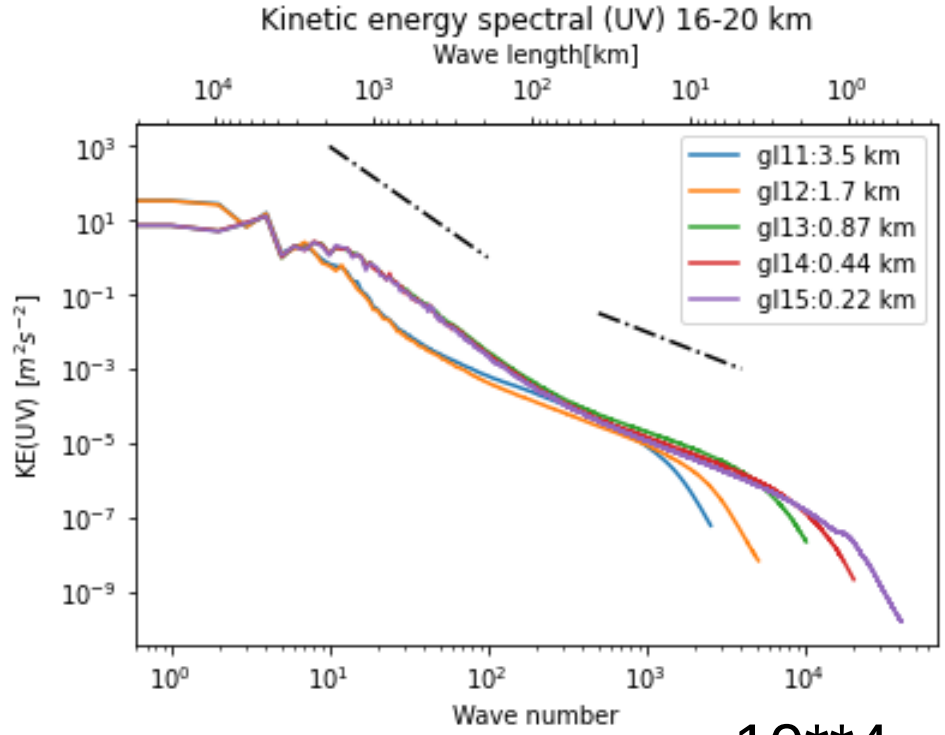
Kinetic energy spectral

Troposphere 8.5-10.5km



10**4

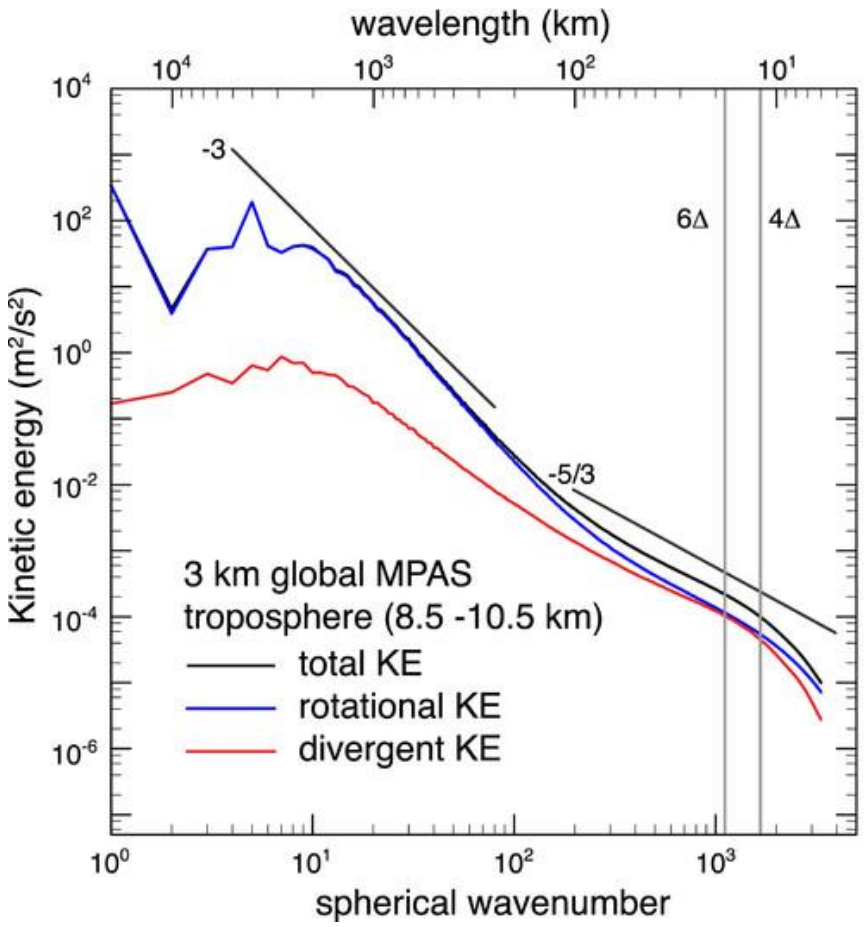
Stratosphere (16-20km)



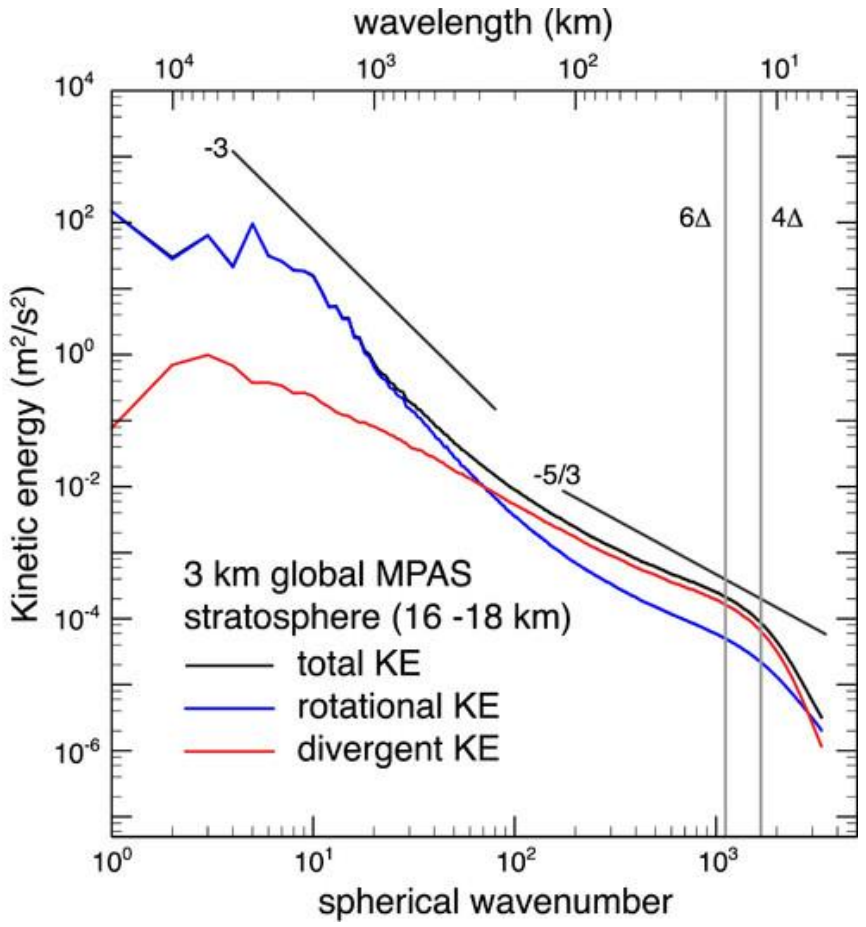
10**4

Gravity wave penetrate to stratosphere?
Or aspect ratio?

MPAS (Skamarock et al. 2014)



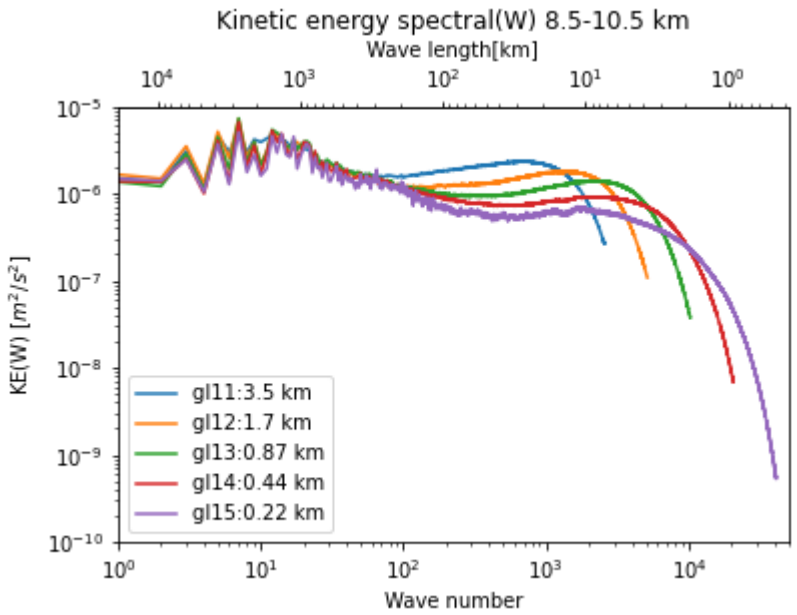
10**3



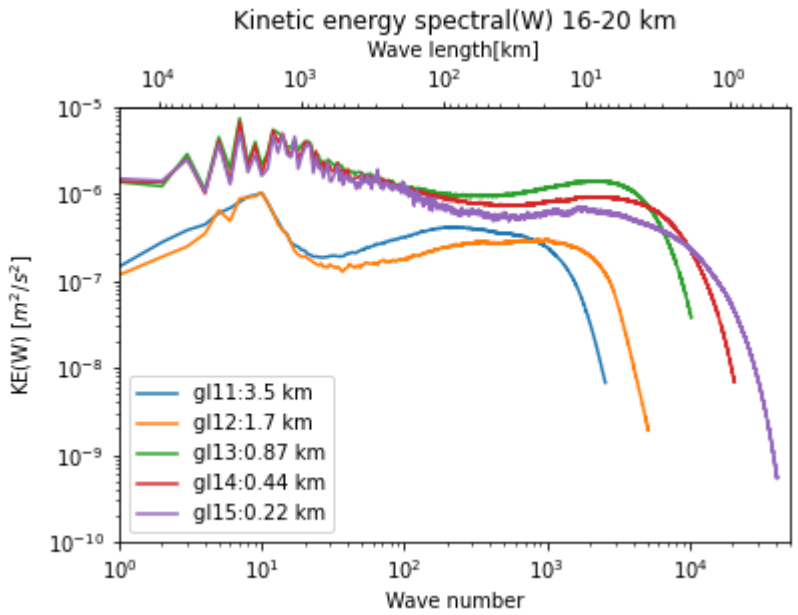
10**3

Vertical wind Spectra (MYNN)

Troposphere 8.5-10.5km

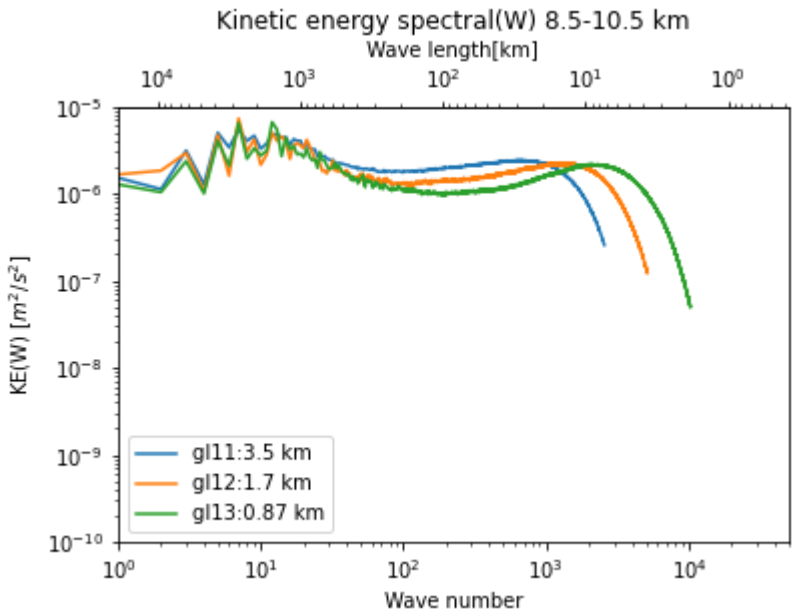


Stratosphere (16-20km)

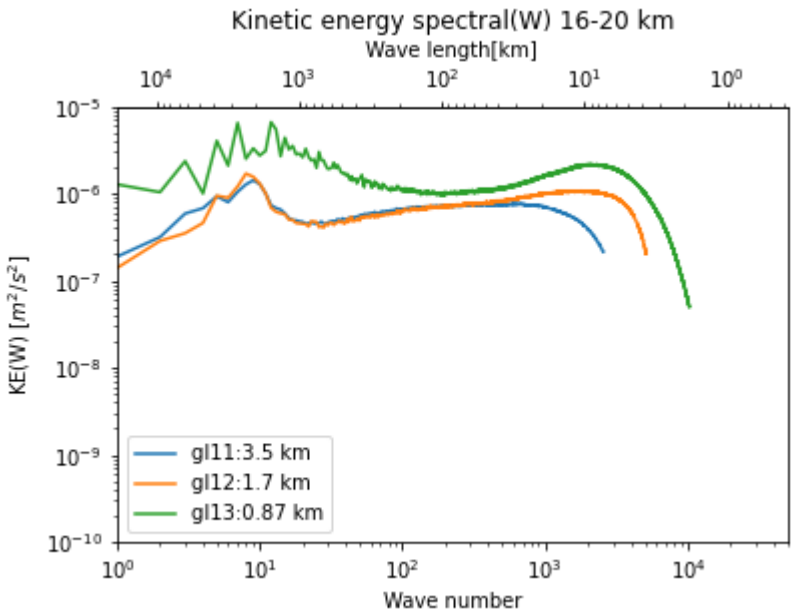


Vertical wind Spectra (MYNN)

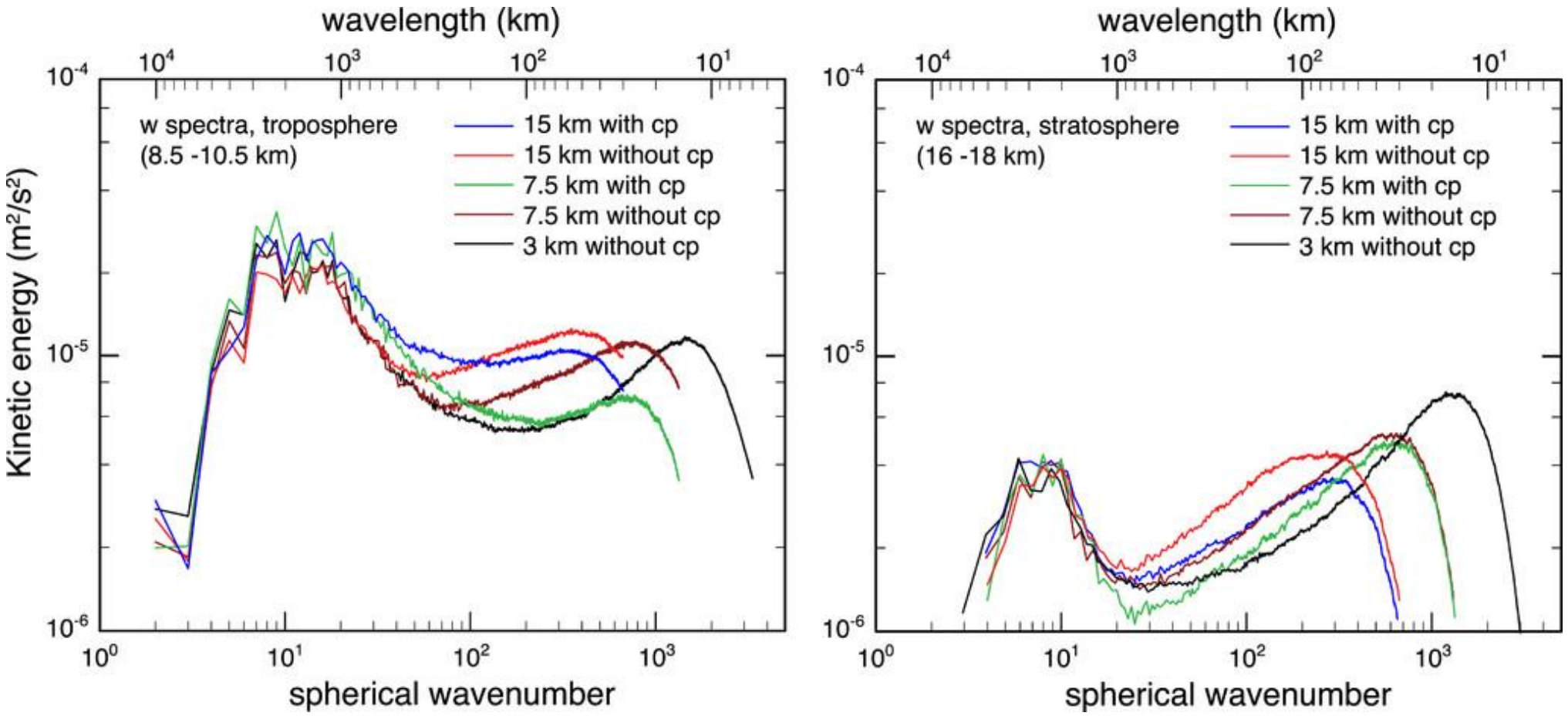
Troposphere 8.5-10.5km



Stratosphere (16-20km)



MPAS (Skamarock et al. 2014)



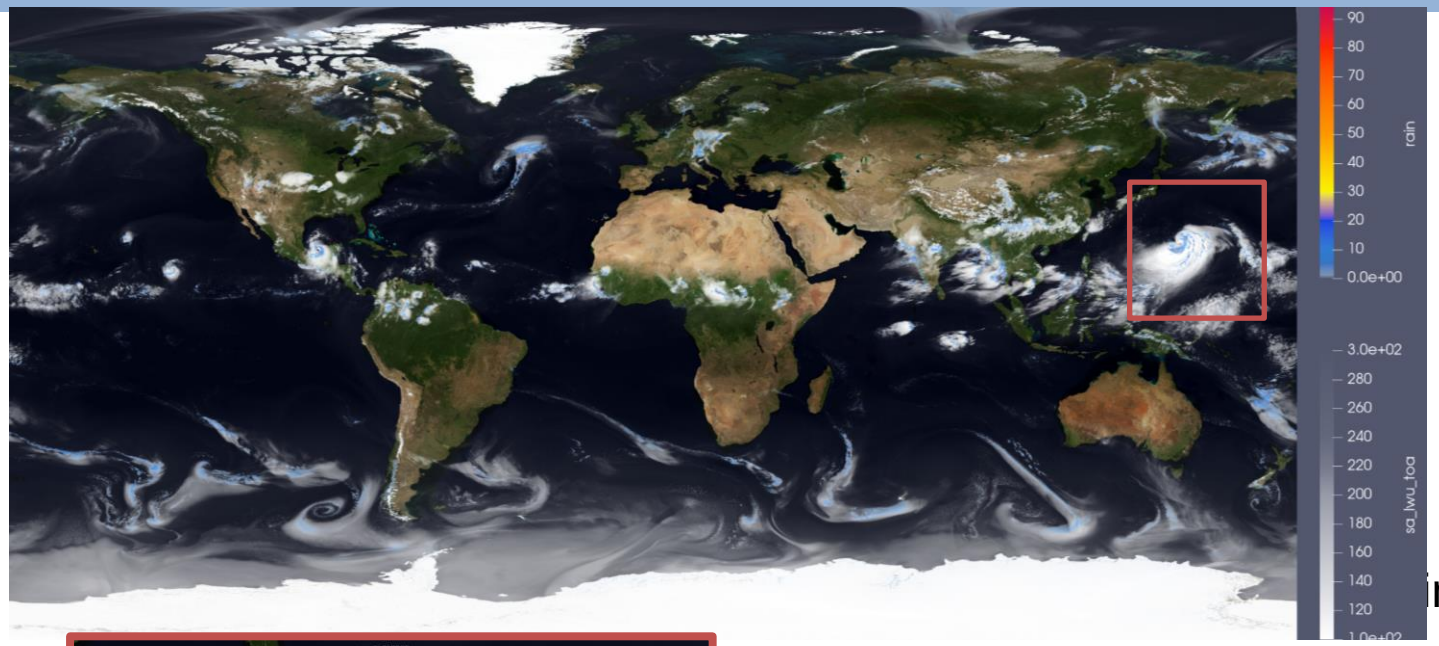
Summary

- Global LES for deep convection was conducted
- Get to higher resolution simulation
  - Increase or strong
    weak precipitation
    midlevel moisture
    grid scale updraft
  - Decrease or weak
    cloud cover: especially low cloud
    mean updraft
- Turbulence scheme controls low cloud fraction and shape.

Appendex

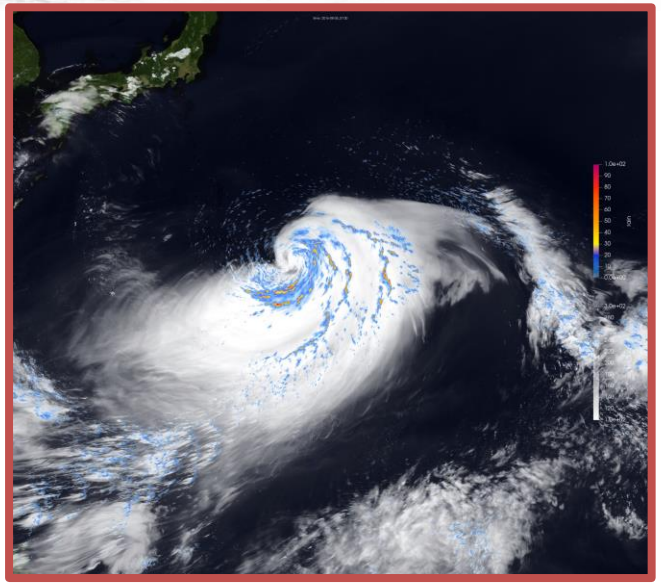
Global 220m simulation

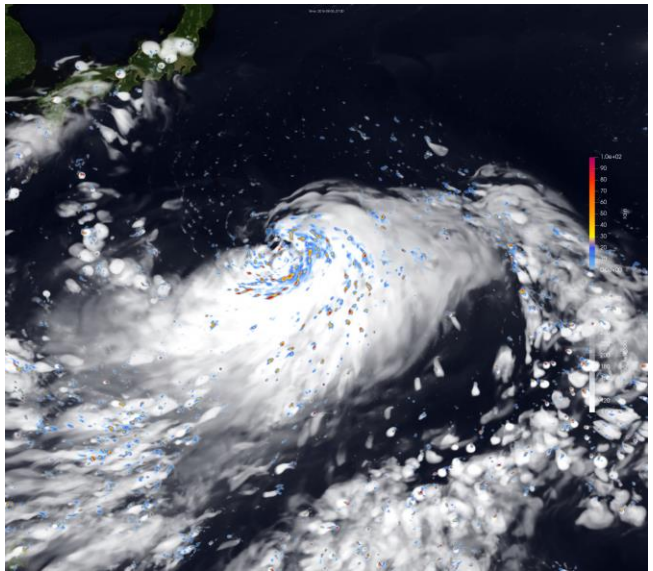
Global 220m run OLR/Rain



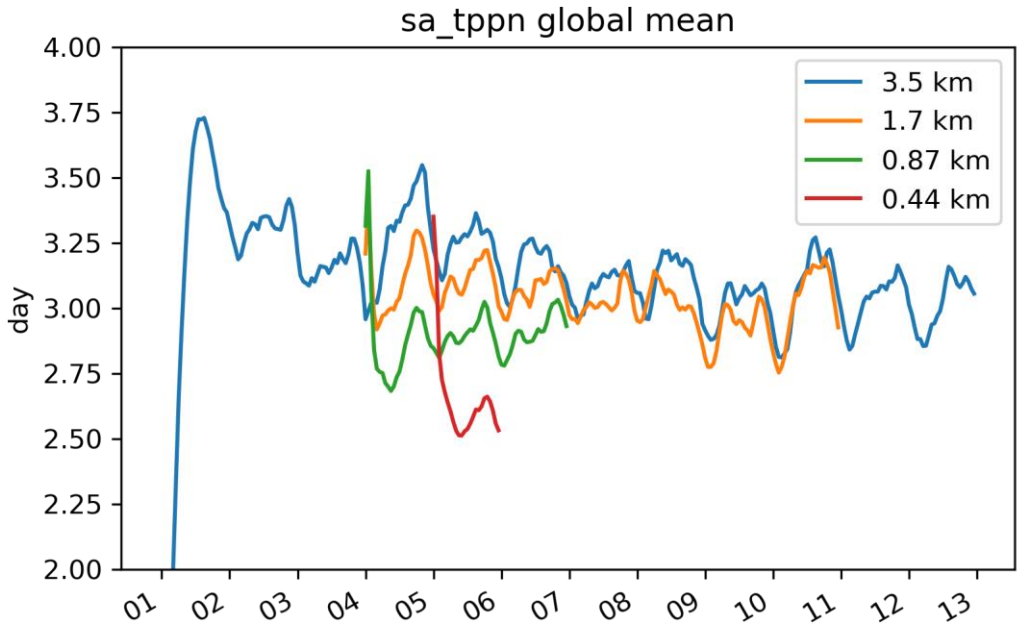
n Global 3.5 km run

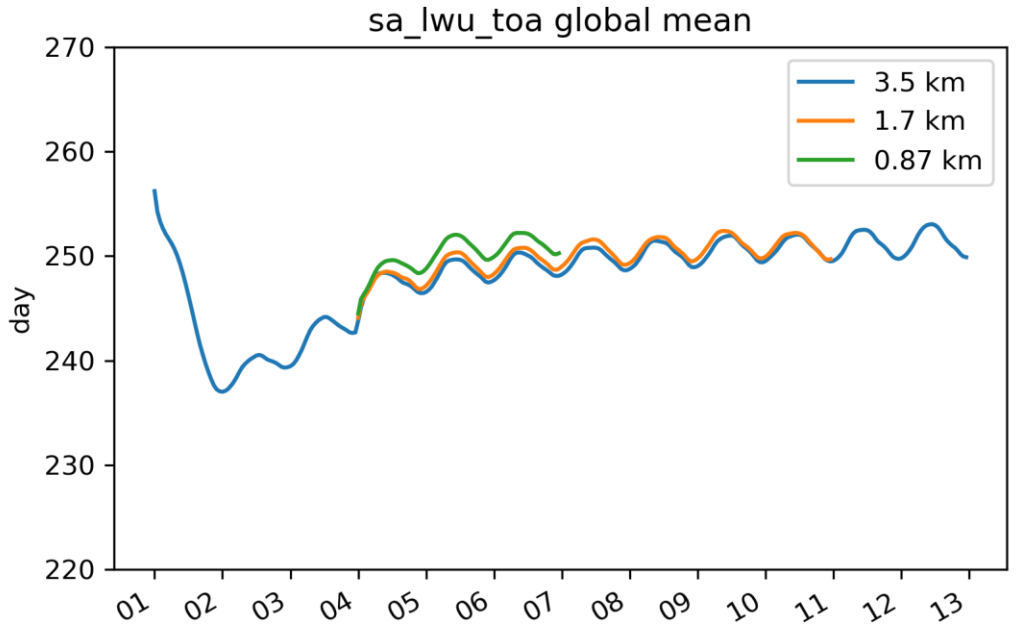
l cyclone in Global 220m run





全球平均の時系列



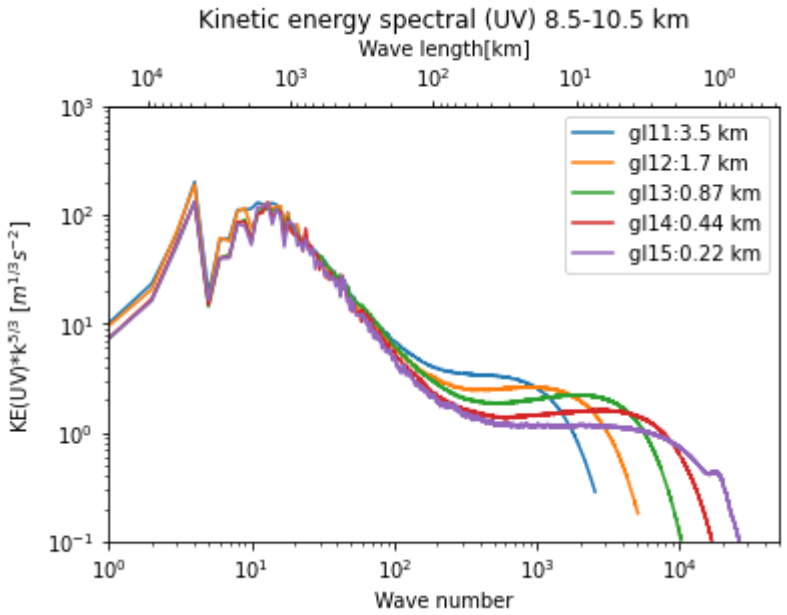


雨は落ち着くまで少しかかる(全球)が
傾向はあまり変わらない(gl11 v.s. gl12 6日目の比較)

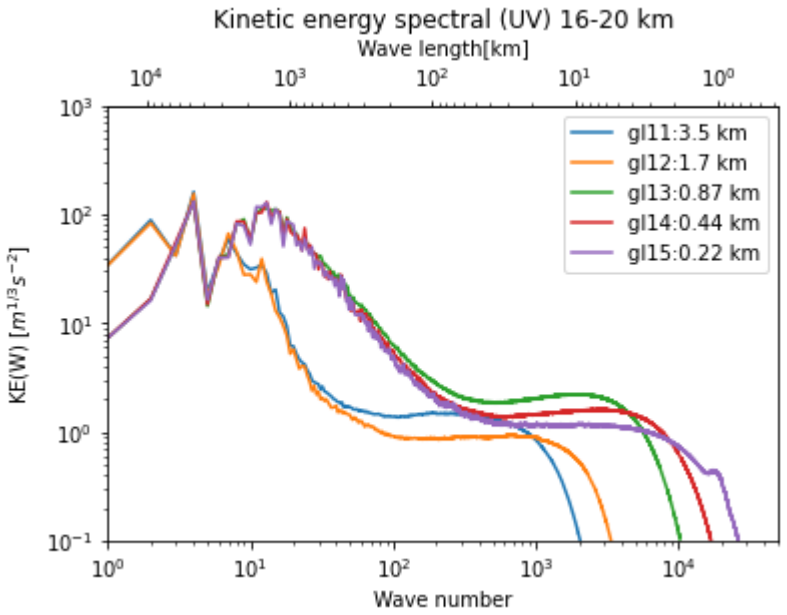
運動エネルギーのスペクトル

K^(5/3)をかけたもの

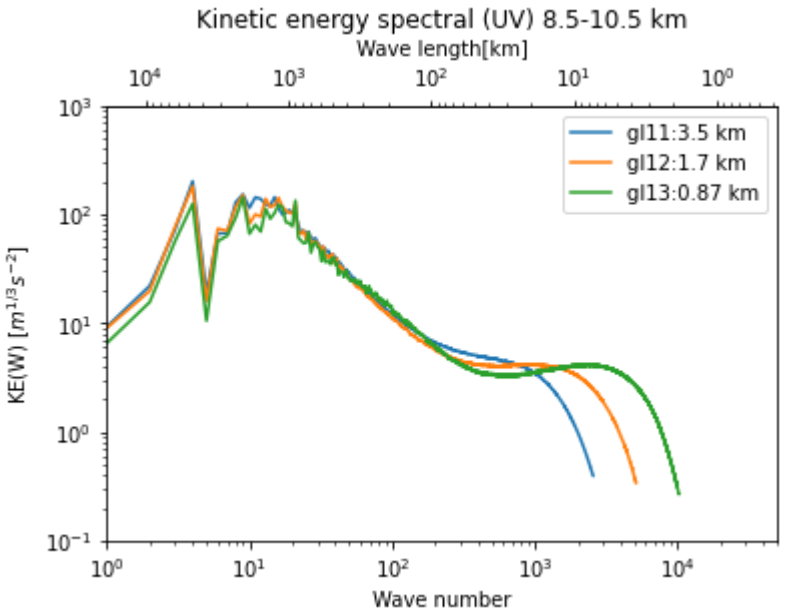
対流圏

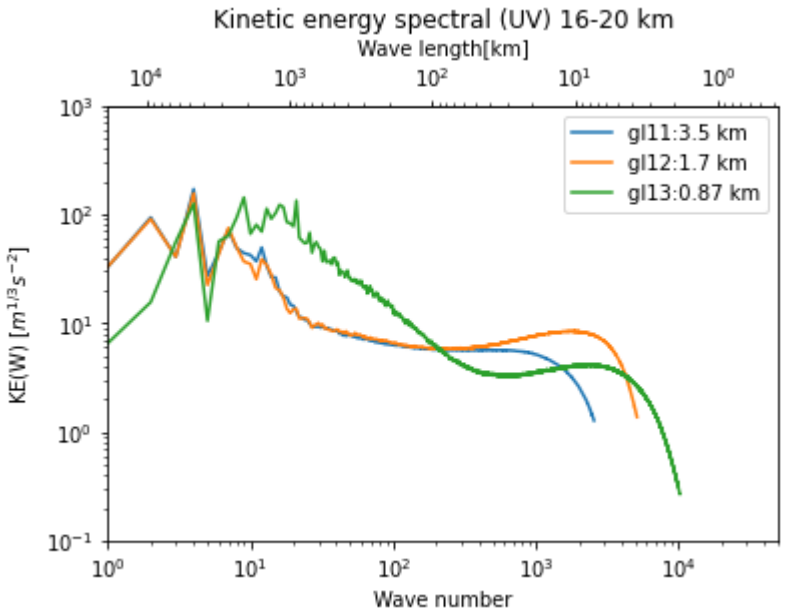


成層圏



SMG0


Kinetic energy spectral (UV) 8.5-10.5 km
Wave length[km]
10^4 10^3 10^2 10^1 10^0
10^3 10^2 10^1 10^0 10^{-1}
KE(W) $[m^{1/3}s^{-2}]$
gl11:3.5 km
gl12:1.7 km
gl13:0.87 km
10^0 10^1 10^2 10^3 10^4
Wave number


Kinetic energy spectral (UV) 16-20 km
Wave length[km]
10^4 10^3 10^2 10^1 10^0
10^3 10^2 10^1 10^0 10^{-1}
KE(W) $[m^{1/3}s^{-2}]$
gl11:3.5 km
gl12:1.7 km
gl13:0.87 km
10^0 10^1 10^2 10^3 10^4
Wave number

MPAS (Skamarock et al. 2014)