Comparison of parameterized/resolved cloud top height and satellite observation

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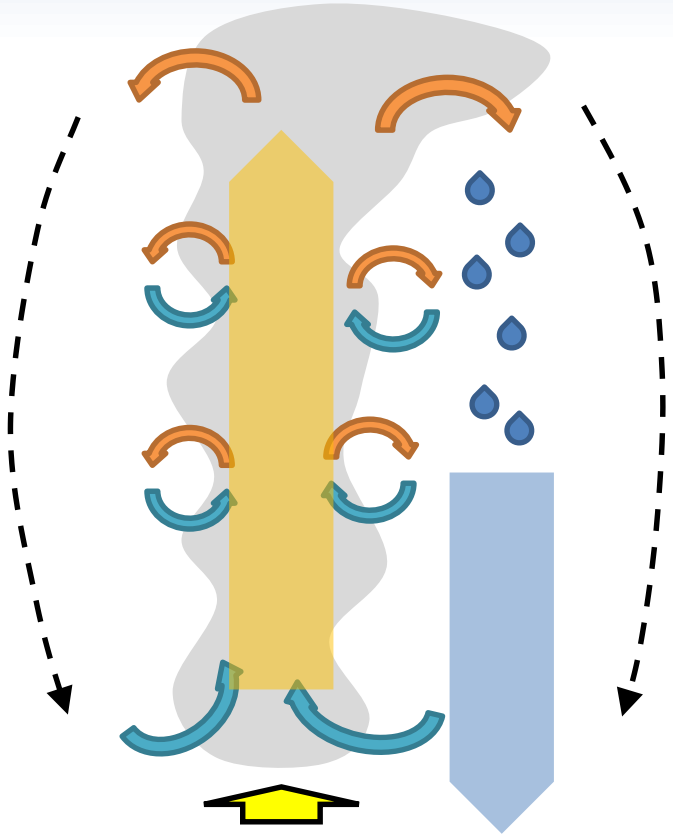
Introduction

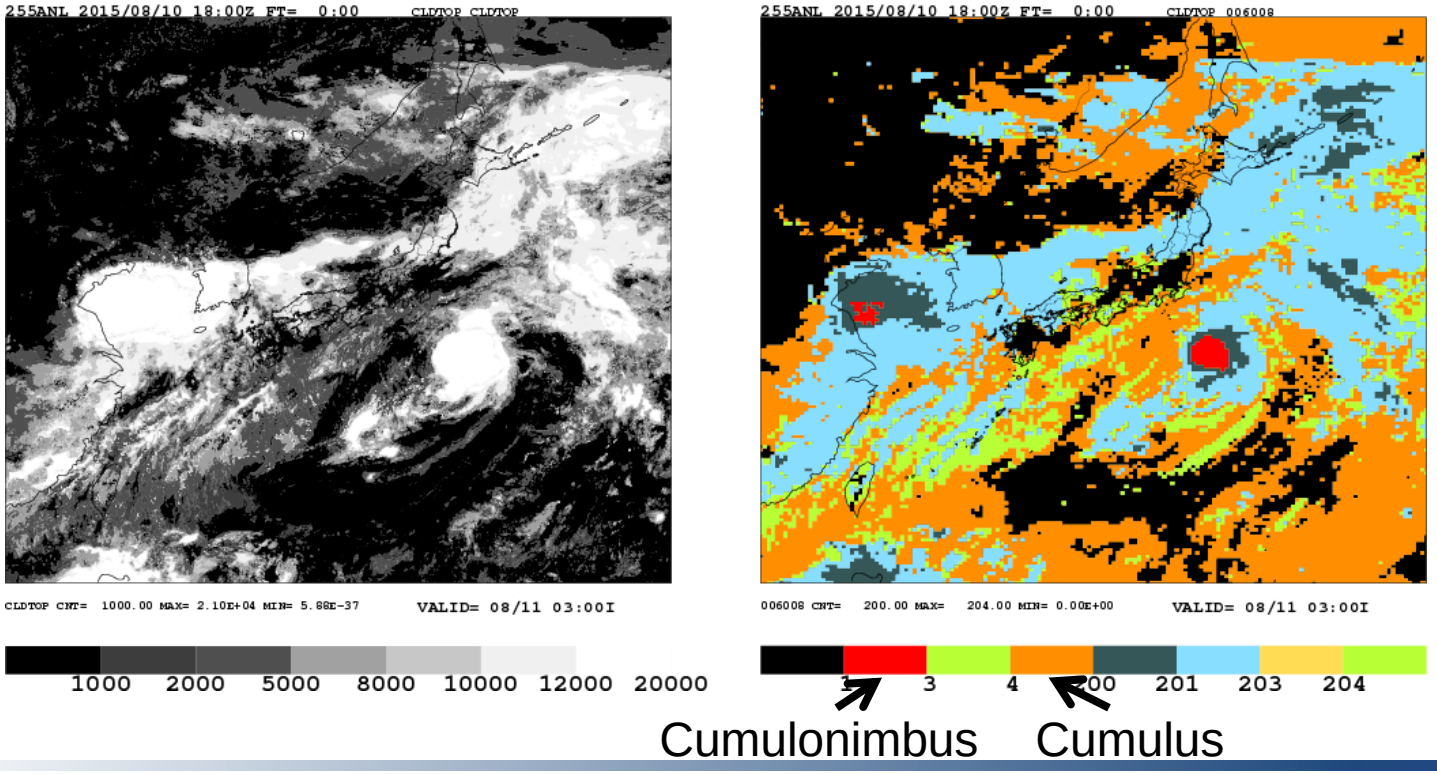


Convection

- Vertical transport of heat, moisture and momentum
- condensation/freezing
- Entrainment and detrainment (E&D)
  - driven by small scale turbulence
  - incorporating relatively dry and cold air into updraft
  - various uncertainties in their formulation
  - hard to validate them by observations
  - large impact on the performance of cumulus parameterization

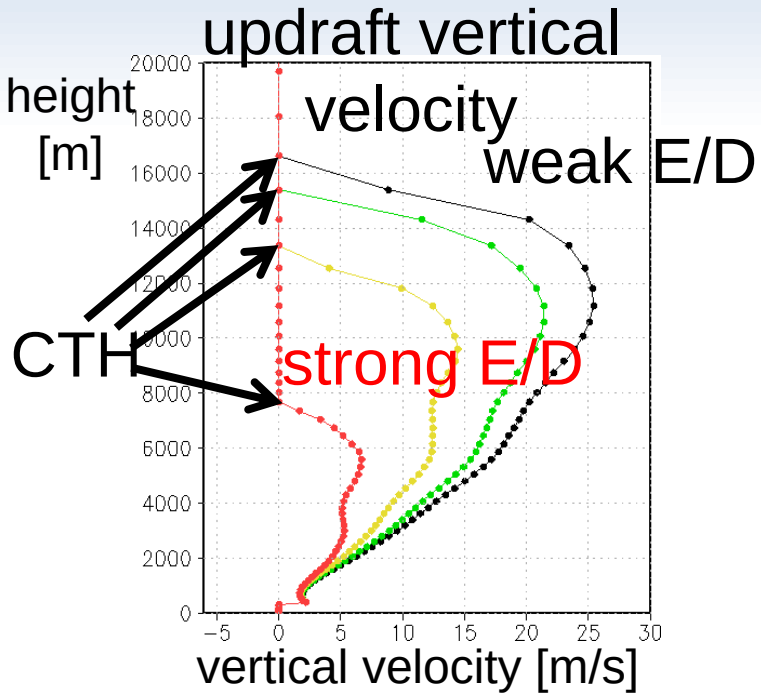
Himawari-8 Cloud Top Height Product

- Developed by Meteorological Satellite Center in JMA.
  - estimate cloud top height(CTH) by using Advanced Himawari Imager, radiative transfer model and cloud type product(CT).



Relation between E&D and CTH

- weak E&D -> high CTH
- strong E&D -> low CTH

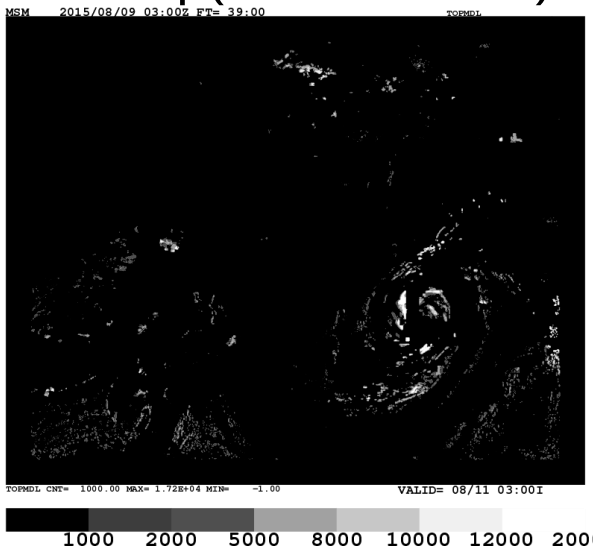


- CTH comparison with JMA regional NWP models as a proxy of direct verification of E&D
  1. 5km grid length model w/ cumulus parameterization
  2. 2km grid length model w/o cumulus parameterization

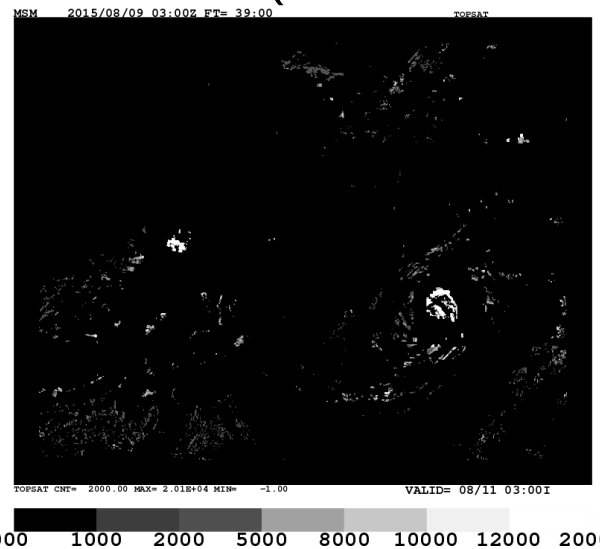
Comparison between parameterized CTH and Himawari-8 CTH product

- Sub-grid convection CTHs(CTHp) in the 5km model are excessively higher than Himawari-8 CTH product(CTHsat).

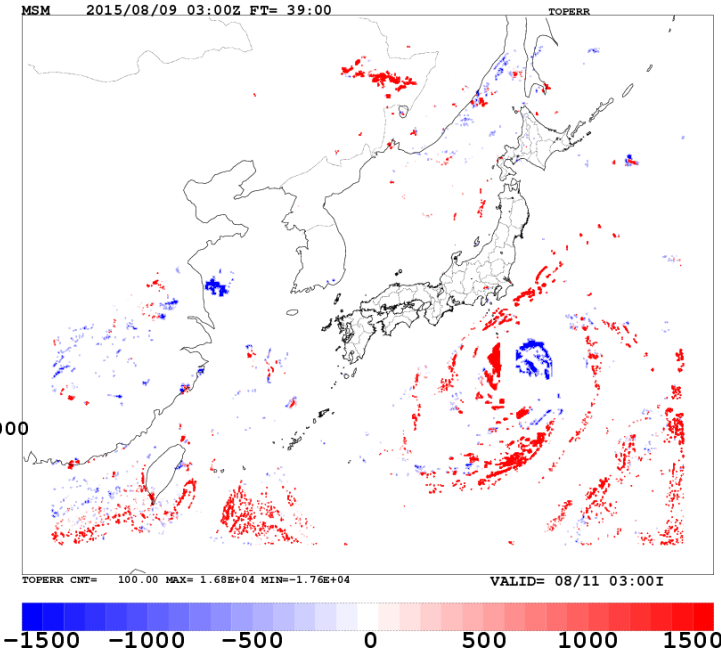
CTHp(39hr forecast)

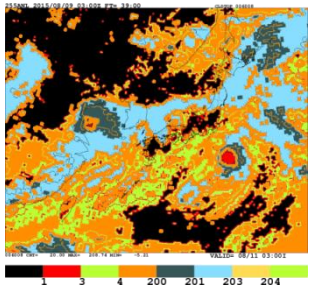


CTHsat(2015/08/10



CTHp - CTHsat



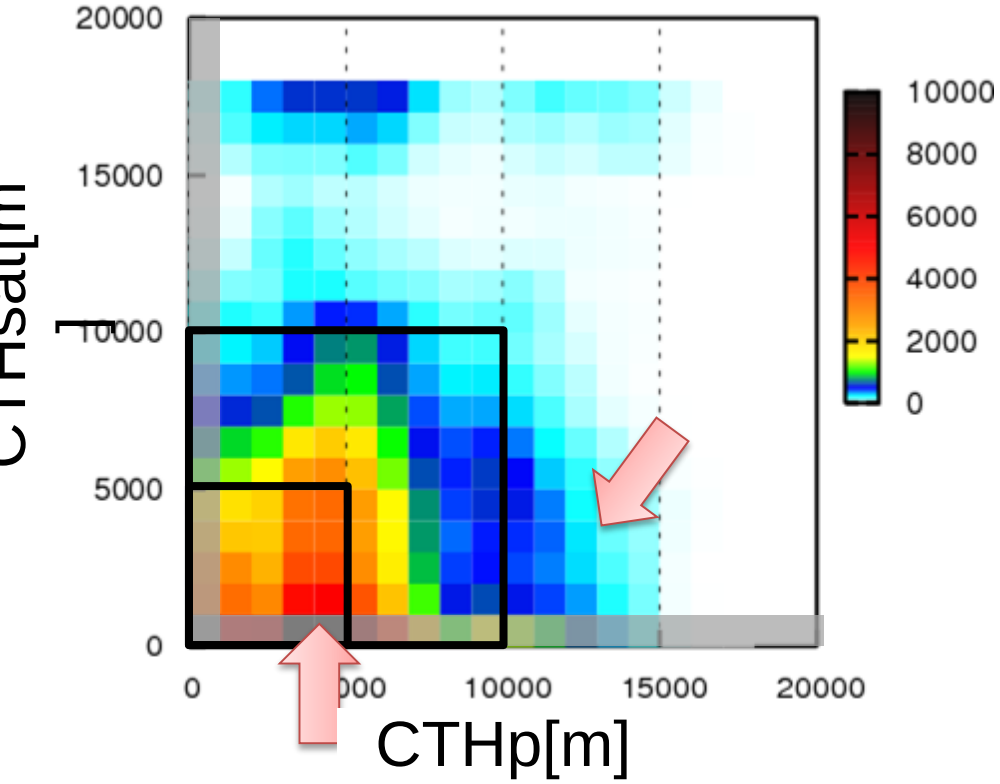


cloud type

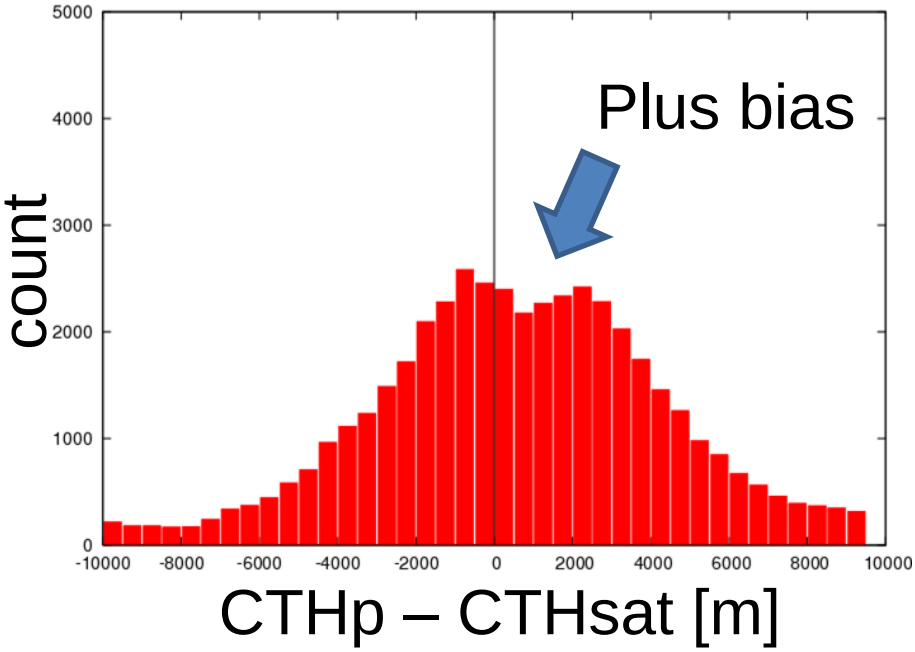
Only cumulonimbus and cumulus are used for comparison.

Frequency distribution (5km model)

2-D histogram
model vs. satellite obs.



histogram of errors
between CTHp and CTHsat



Too frequent high CTHp !

E&D in our convection scheme

- Excessively high CTH suggests possibility of too weak E&D.
  - E&D reduce updraft.
- In our scheme, E&D are parameterized as

$$E, D \propto \frac{1}{R}$$

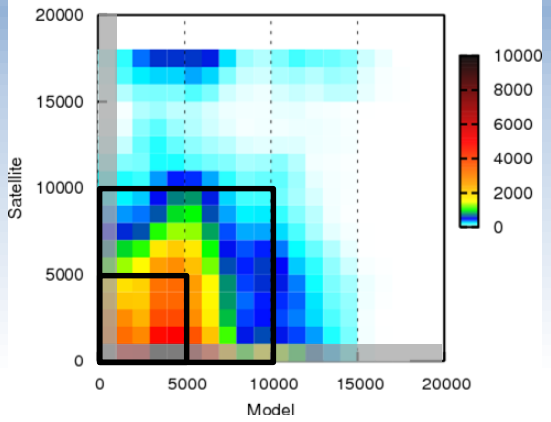
R : updraft radius

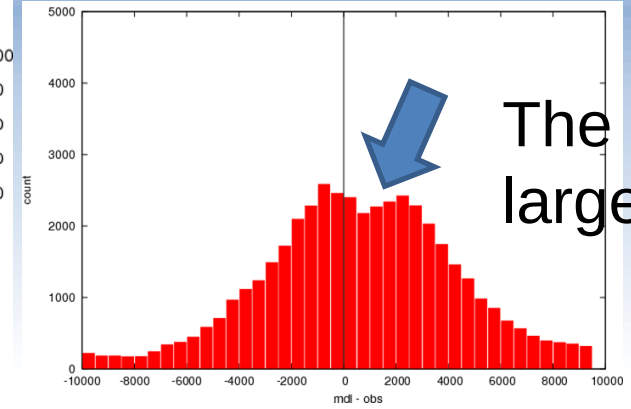
based on Kain and Fritsch(1990), Simpson(1983).

R is a key parameter to control E&D.
There is no direct observation of neither E, D nor *R.*

Instead of direct evaluation of *R,* E&D by observation,
we tried to determine *R* by evaluating CTHp by CTHsat.

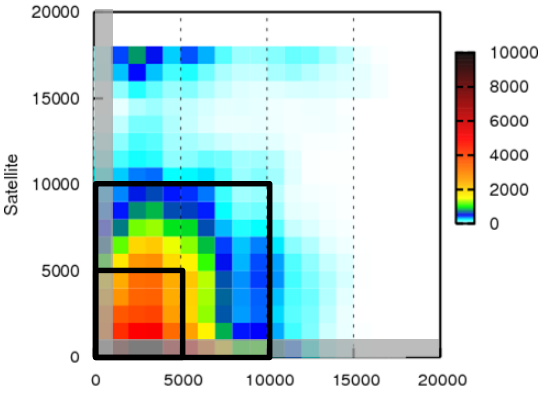
Original
R
= 1000m

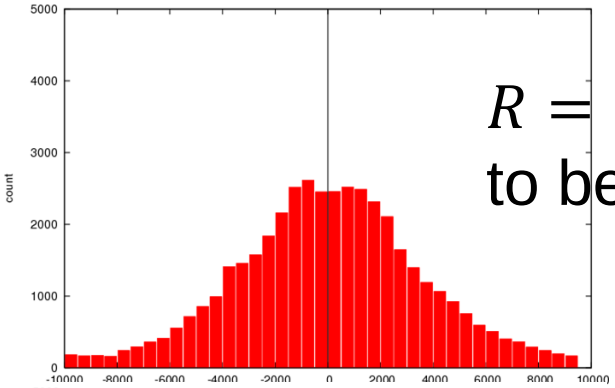




The mean error is larger than zero.

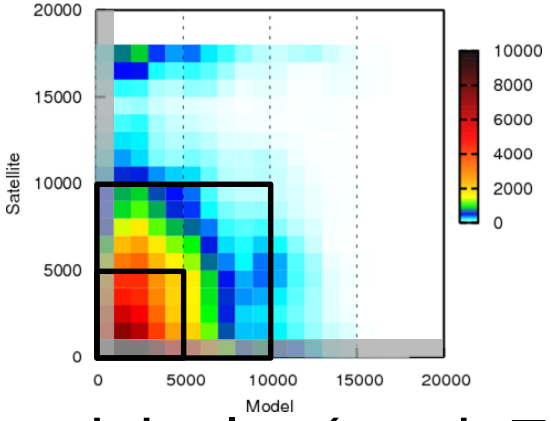
R = 750m

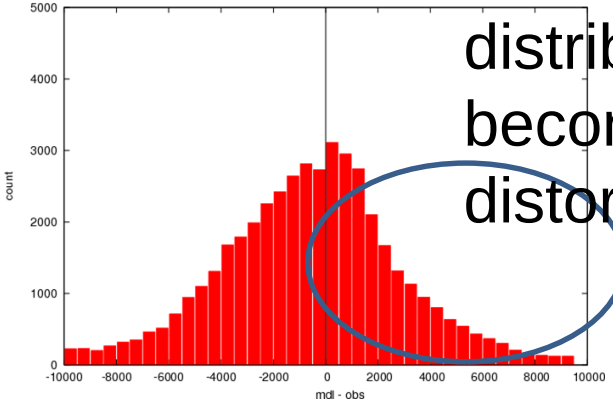




R = 750m seems to be the best.

R = 500m



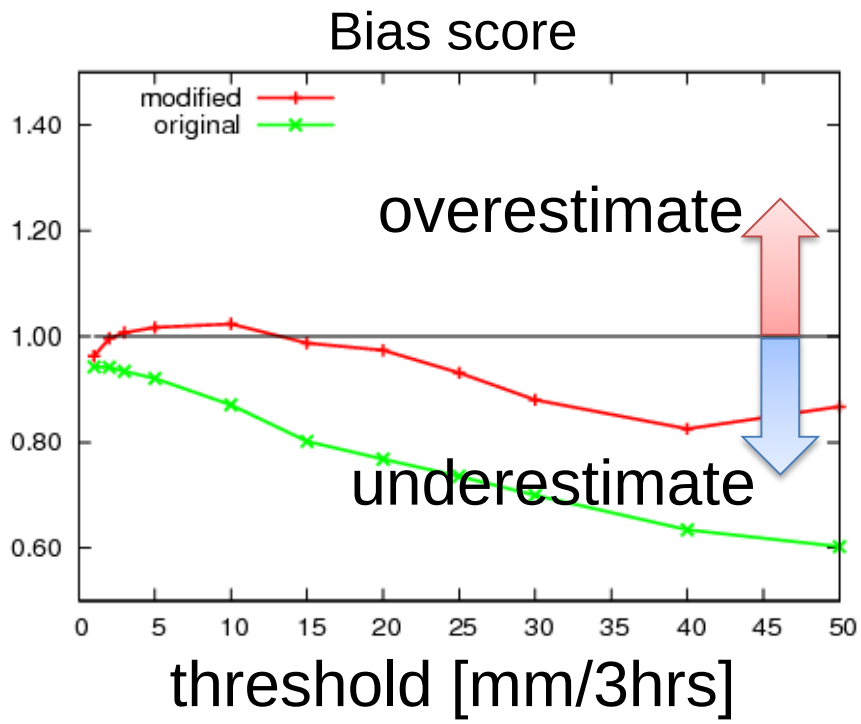


distribution becomes distorted.

Though the original R (weak E&D) caused too strong convection, the modified R weaken the strength of convection.

Improvement in quantitative precipitation forecasts

- New R modified underestimation of precipitation frequency through improvements of static stability.



New *R* improves not only CTH but also precipitation frequency.

Convection permitting models?

- Vertical convective transport is explicitly calculated, but…
- Are small scale processes such as entrainment/detrainment resolved in grey zone?

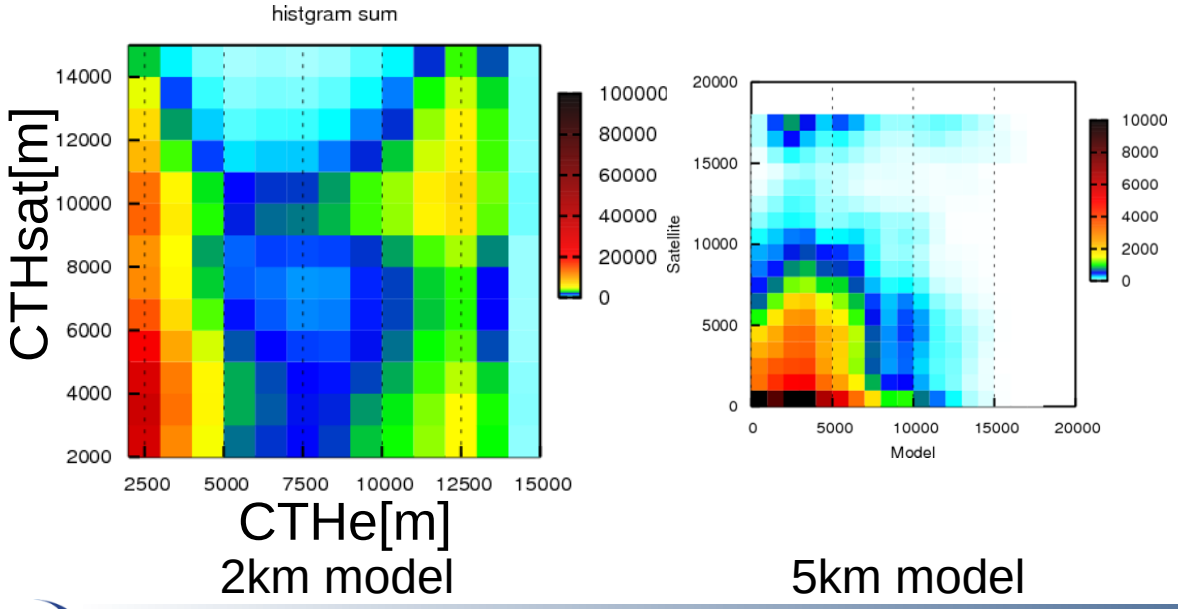
We investigated our operational convection permitting model with a grid length of 2km using same method.

CTHe is defined as the top where the vertical velocity is larger than 1 m/s in each column.

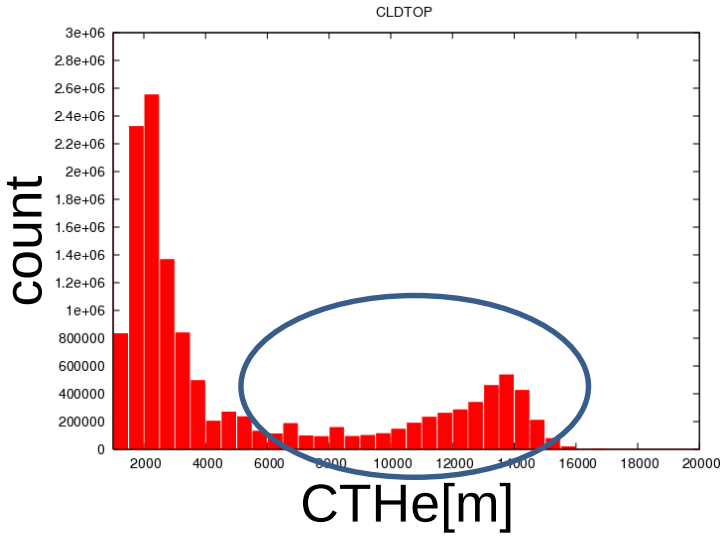
Convection in JMA 2km model

- CTHe tends to be too high.
  - Few frequency around 4000m to 10000m
  - High frequency below 4000m corresponds not convection but orographic uplift

2-D histogram
model vs. satellite obs.
(statistics for 3weeks)



CTHe frequency distribution
for cloud base < 2000m



Convection in 2km model

- Too high CTH are often predicted.
  - By analogy with parameterized convection, E&D might be too weak.
- E&D are driven by very small scale turbulence.
  - Although the vertical transport is explicitly represented in the 2km model, the E&D are not necessary resolved.

- E&D should be still parameterized even if vertical transport is well resolved.

Summary

- Comparison of CTH using satellite products gives us implications of convection scheme problems.
  - We modified E&D based on the comparison.
  - This modification improved quantitative precipitation forecast as well.
- Parameterizations related to small scale phenomena of convection (e.g. E&D) is necessary even if convective transport is fully/partially resolved in convective permitting models.