# The balance and interaction of convective parametrization and microphysics scheme.

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## Introduction

- Representations of resolved and subgrid scale convections in NWP models are critical to their performance, in particular when the model can partially resolve convective clouds ("grey zone" resolution).
- To understand the behavior of the Japan Meteorological Agency (JMA)'s regional model under the grey zone resolution, a case study of shallow convection over the tropical ocean, which is one of the set of preliminary experiments for the second phase of the Grey Zone Project, an international collaboration, has been conducted using the Japan Meteorological Agency's operational regional model (JMA,2019) .
- The experiments were examined with horizontal grid-spacings of 5km and 500m, and in experiments the representations of precipitation and cloud were mainly focused on.
- This presentation shows the following three topics from the results of the experiments:
  1. The representation of shallow convection in our model under grey zone resolution,
  2. The behavior of the convection scheme under the grey zone resolution,
  3. The behavior of simulated convection affected by cloud microphysics and its interaction with the convective parameterization.

## JMA's regional model and its convection scheme and cloud microphysics

- Model : new-generation nonhydrostatic model ASUCA (Ishida et al. 2009, 2010)
- Convection scheme : A bulk mass flux type scheme based on Kain-Fritsch ( Kain and Fritsch 1990; Kain 2004 ).
  - An effective convective plume with entrainment/detrainment is considered as the cloud model.
  - As trigger process, each parcel is diagnosed whether it has positive buoyancy at the LCL by comparing the fluctuation-added temperature of lifted parcel with that of environment. The fluctuation is mainly determined turbulent buoyant flux.
- Cloud microphysics: a three-ice bulk microphysics scheme (Ikawa and Saito 1991) based on Lin et al. (1983).
- More details are in JMA(2019).

## Results of experiment O(5km) vs O(500m)

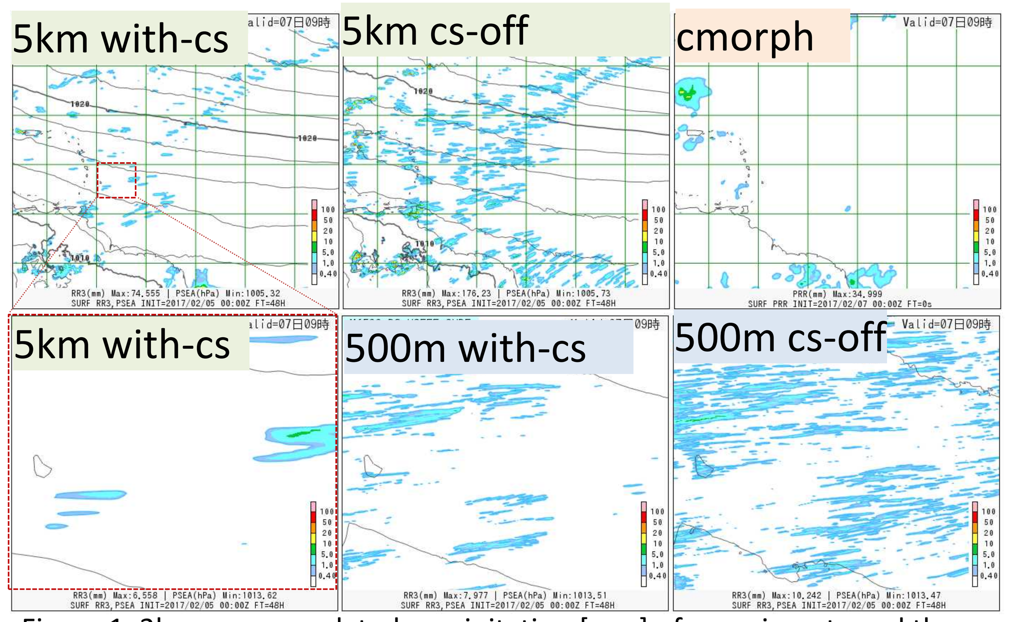


Figure 1. 3hours accumulated precipitation [mm] of experiments and the satellite-based precipitation product (cmorph). "with cs" means experiments with the convection scheme and "cs off" means experiments without the convection scheme. Forecast range is 48hours, and areas are 0.51N-30.51N, 68.12W- 35.13W(top) and 11.34N-15.09N, 59.94W-55.81W.

*Configurations*

- Model : JMA's operational regional model,
- Location : tropical Atlantic,
- Grid Spacing (and grid number, step of time integration): 5km (1101x901, 100/3s) 500m (1801x1001, 12s)
- Initial : 5th,Feb,2017
- Forecast Range : 120hrs
- Initial and boundary conditions: JMA's operational global model,
- Main target : shallow convection,
- Experiments with the convection scheme(with-cs) and without it (cs-off).

*Result*

*precipitation*

- In this case, the satellite observation showed that shallow cumulus was widely spreading and precipitation area was narrowed.
- However, the precipitation in the model was wider than the satellite-based precipitation product (cmorph), and the spread of weak precipitation with the grid spacing of 500m was distinctly larger than that with the grid spacing of 5km.(Fig (1))
- The weak precipitation was almost caused by strong grid scale updraft and grid scale condensation in microphysics in the model. The grid scale updraft occurred more frequently in higher resolution.
- Also, cs-off experiments was examined. Then it was found that the precipitation area from cs-off experiments was more widely spread than that from with-cs experiments and went further away from the satellite observation.

→ These results imply that some convection scheme is still needed in that scale.

*Cloud water content*

- Cloud water content was much less predicted in the experiments than that in ECMWF reanalysis.
- Much rain was predicted in the experiments compared to that in ECMWF reanalysis.

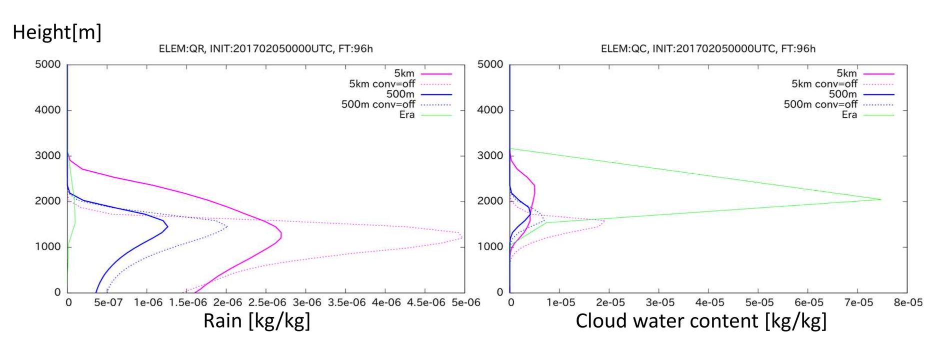


Figure 2. The profiles of area average of rain(left) and cloud water(right) of models with grid-spacings 5km and 500m and ECMWF reanalysis. Solid lines are the results of experiments with the convection scheme, and dashed lines are the results of experiments without the scheme.

## Scale awareness of the convection scheme

- The case study experiments implied some convective parameterization under the grey zone resolution at least for shallow convection is a necessity.
- A "scale aware" convection scheme is expected that the parameterized mass flux decreases as the resolved mass flux increase in accordance with grid scale.
- This section reveals that whether "scale awareness" is achieved in our model.

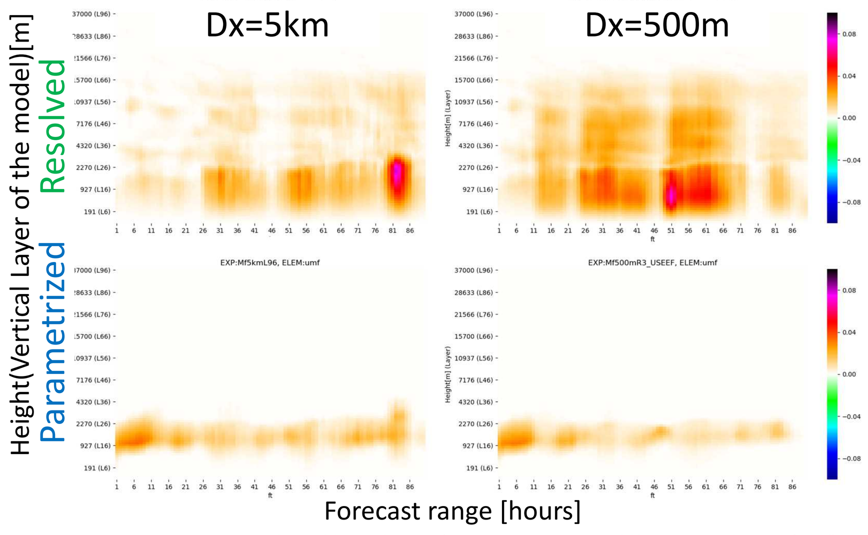


Figure 3. Resolved(top) and parametrized(bottom) updraft [kg/m^2/s] in the model with grid spacing 5km(left) and 500m(right) and area averaged.

*Result*

- The resolved mass flux and vertical velocity in the 500m model were larger than those in the 5km. However, the parametrized values in the 500m model were not less than those in the 5km model (Fig 3, 4).
- The frequency of the activation of the convection scheme was not changed by grid size (No figure).
- Mass flux and frequency of the activation of the convection scheme did not depend on the grid size.
- The resolved updraft mass flux and parametrized mass flux with the convection scheme appeared in the same grids at the same time (Fig 5) with grid-spacings both 5km and 500m.
- In these grids, double counting of the mass flux which was parametrized and resolved occurred.

→ These results suggest the lack of scale awareness with trigger and/or closure process in the convection scheme.

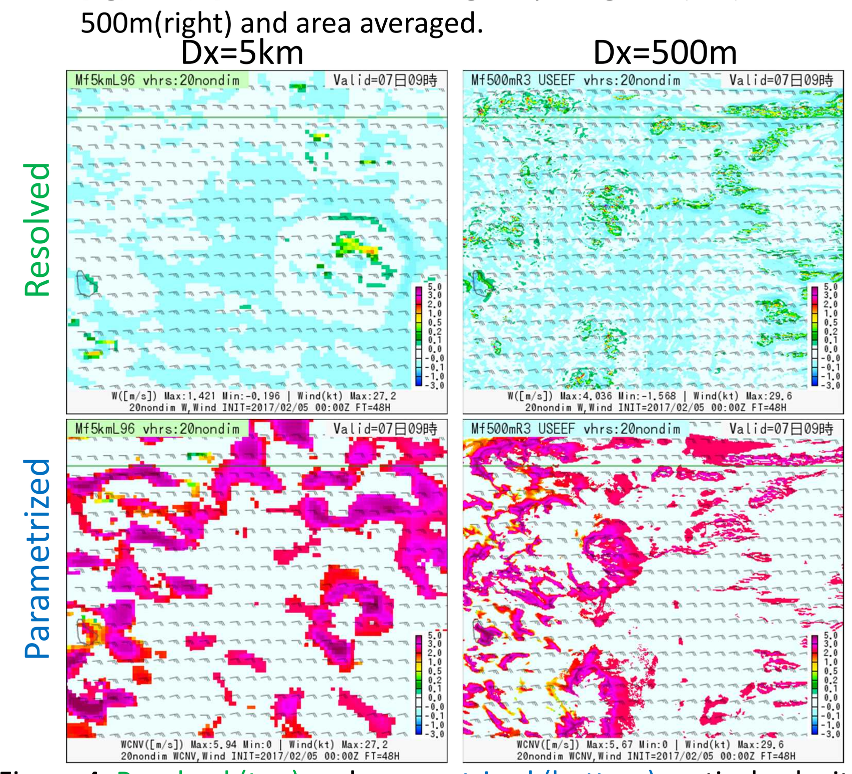


Figure 4. Resolved (top) and parametrized (bottom) vertical velocity [m/s] in the model with grid spacing 5km (left) and 500m (right) and area averaged. Drawing area is 11.81N-15.56N 60.04W-55.91W, forecast range is 48hour and the height is approximately 1400m.

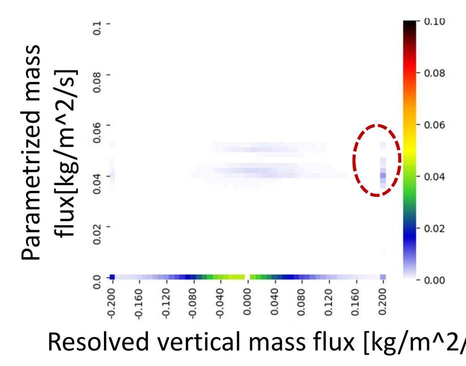


Figure 5. The fractions of the number of the grids in each bins of resolved mass flux (horizontal axis) and parametrized mass flux (vertical axis) with grid spacing 500m.

## Interaction with cloud physics

- The lack of cloud water in the case study experiments might be caused by not only the convection scheme but also the cloud microphysics. Because the cloud water is mainly generated in the cloud microphysics and the convection scheme (Fig 6(a)).
- As a sensitivity experiment, raising the threshold for conversion from cloud water into rain in the microphysics process was examined to increase underestimated cloud water content.

*Result*

- Raising the threshold increases the cloud water content as expected, however, also causes decrease of generation rate of cloud water content from the convection scheme (Fig 6(d)).
- Raising the threshold decreases the conversion from cloud water to rain(Fig 6(b)), therefore it causes decrease of rain and reduction of rain evaporation (Fig 6(c)). This means the decline of the source of water vapor from the perspective of the convection scheme, and induces less generation of cloud water in the convection scheme(Fig 6(b)). In these processes, water vapor, cloud water and rain are balanced.

→ It implies we should focus not only on developing a scale aware convection scheme but also on the interaction with the microphysics.

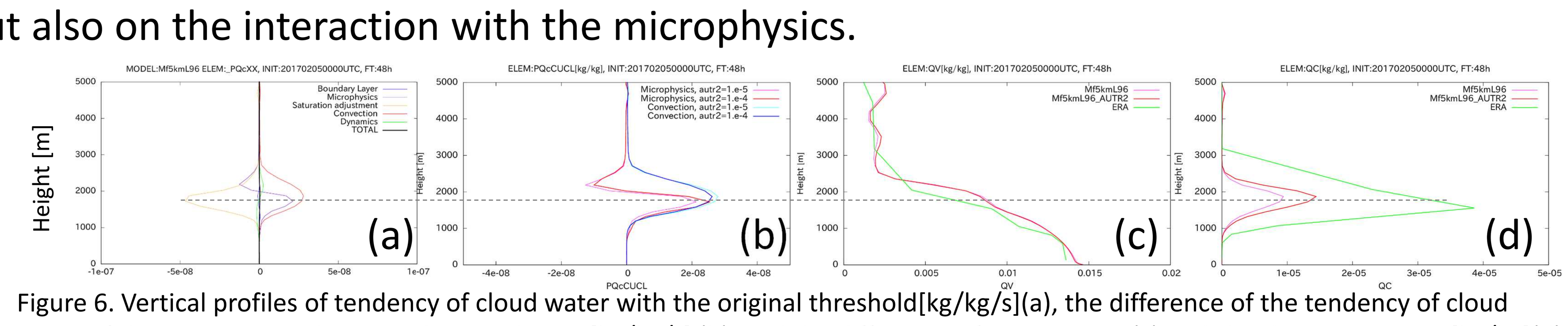


Figure 6. Vertical profiles of tendency of cloud water with the original threshold[kg/kg/s](a), the difference of the tendency of cloud water of the convection scheme and microphysics [kg/kg/s] (b), and the difference of water vapor (c) and cloud water content [kg/kg](d)

## Summary

- The experiments of the case study of shallow convection for the second phase of the Grey Zone Project showed following suggestions about issues of our model:
  1. Overestimation of spread of light precipitation without convection parametrization experiments implies that some convection scheme is needed even with a gird spacing of 500m to eliminate the instability of atmosphere.
  2. The mass flux and the frequency of activation of the convective parametrization does not depend on grid size under the grey zone resolution. This suggests our current convection scheme has lack of scale awareness issues particularly in trigger and/or closure processes.
  3. Sensitivity to configuration of cloud microphysics suggests the necessity of more consideration of the interaction between microphysics and a convection scheme.

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