Resolution dependence of deep convections in a global simulation from over 10-kilometer to sub-kilometer grid spacing

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Introduction

The success of sub-kilometer global atmospheric simulation opens the door for resolving deep convections, which are essential elements of cloudy disturbances that drive global circulation. **Miyamoto et al. (2013)** found that the increasing rate-of-convection number and grid number within convection cores are **drastically changed between 3.5 km and 1.7 km** grid spacing.

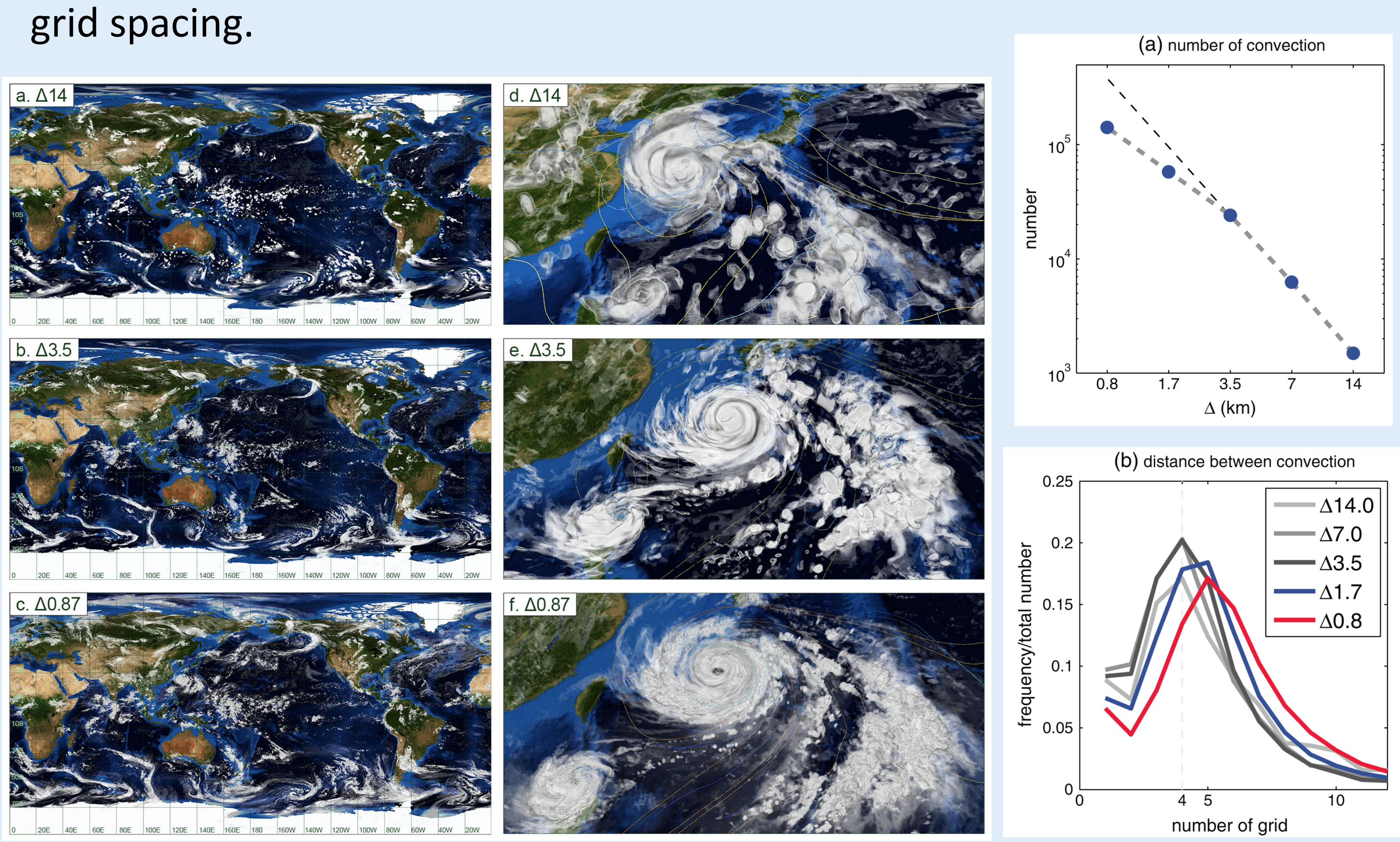
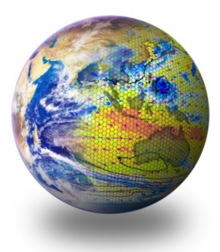


Figure 1 (Left): Global & regional view of simulated cloud distribution. **(Right)**: Resolution dependence of convective features (a) number of convection core and (b) grid distance to the nearest convection core.

However, several issues to be address remains:

1. **in what area** does convection make the largest contribution to the global mean?
2. **What environmental condition** is effective in producing the diversity of convection properties; i.e., what is the resolution relationship between the number of deep convections, areas of deep convection and OLR?

Model: NICAM (Satoh et al., 2014)

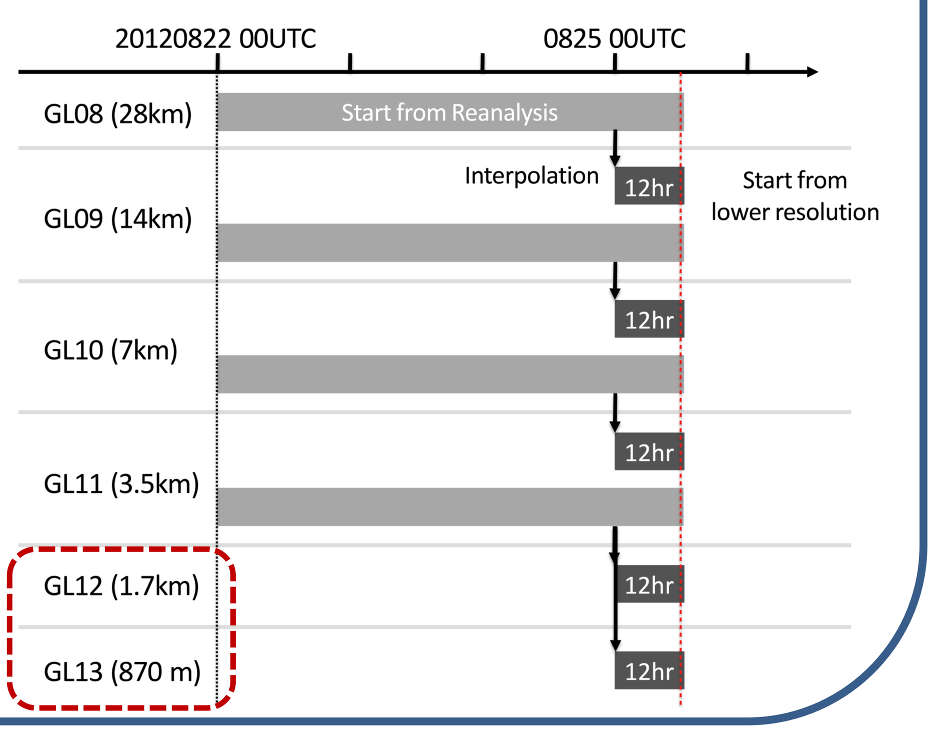


SST: JMA GPV + nudging (Reynolds SST),
Land: Model adjusted produced by 5 year run,
Surface flux: Louis (1979), **Cloud physics:** NSW6 (Tomita 2008),
Turbulence: MYNN (Nakanishi and Niino 2004, Noda et al. 2008),
Radiation: MSTRNX (Sekiguchi and Nakajima 2008)

K computer

How to **detect a Convection core**?

1. Define convective grids based on ISSCP cloud categorization. Optical thickness (>35), cloud top pressure (<400hPa)
2. Detect the convection core as the grid which the W averaged in the troposphere is greater than that in all neighboring grids.



Resolution Dependence in the Global Field

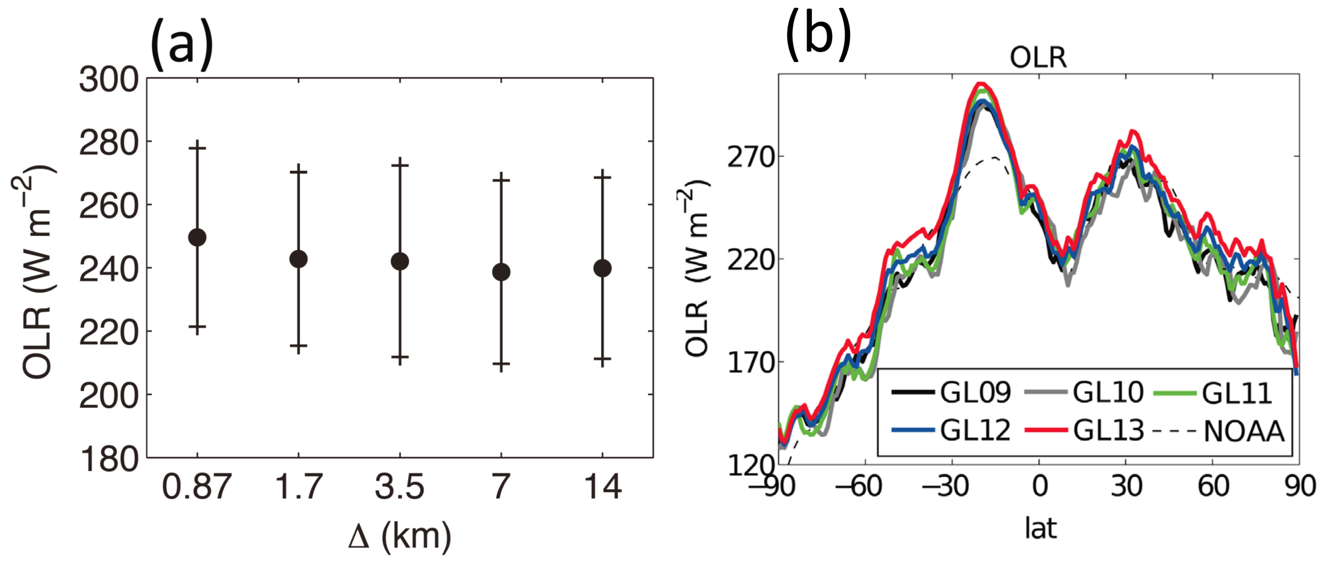


Figure 2: Resolution dependencies of (a) global mean OLR and (b) zonal mean OLR.

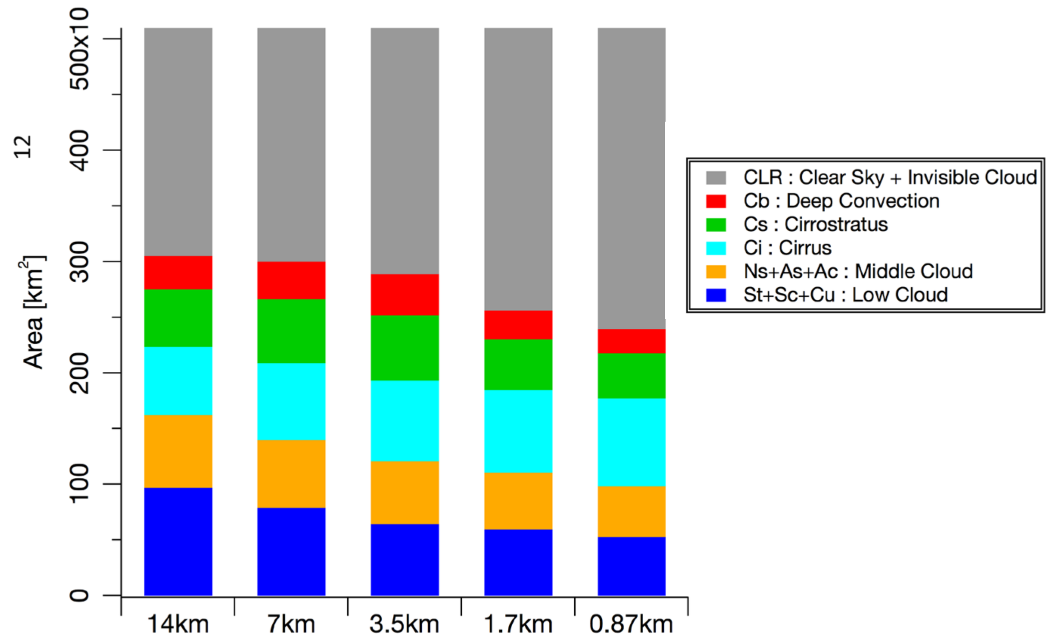
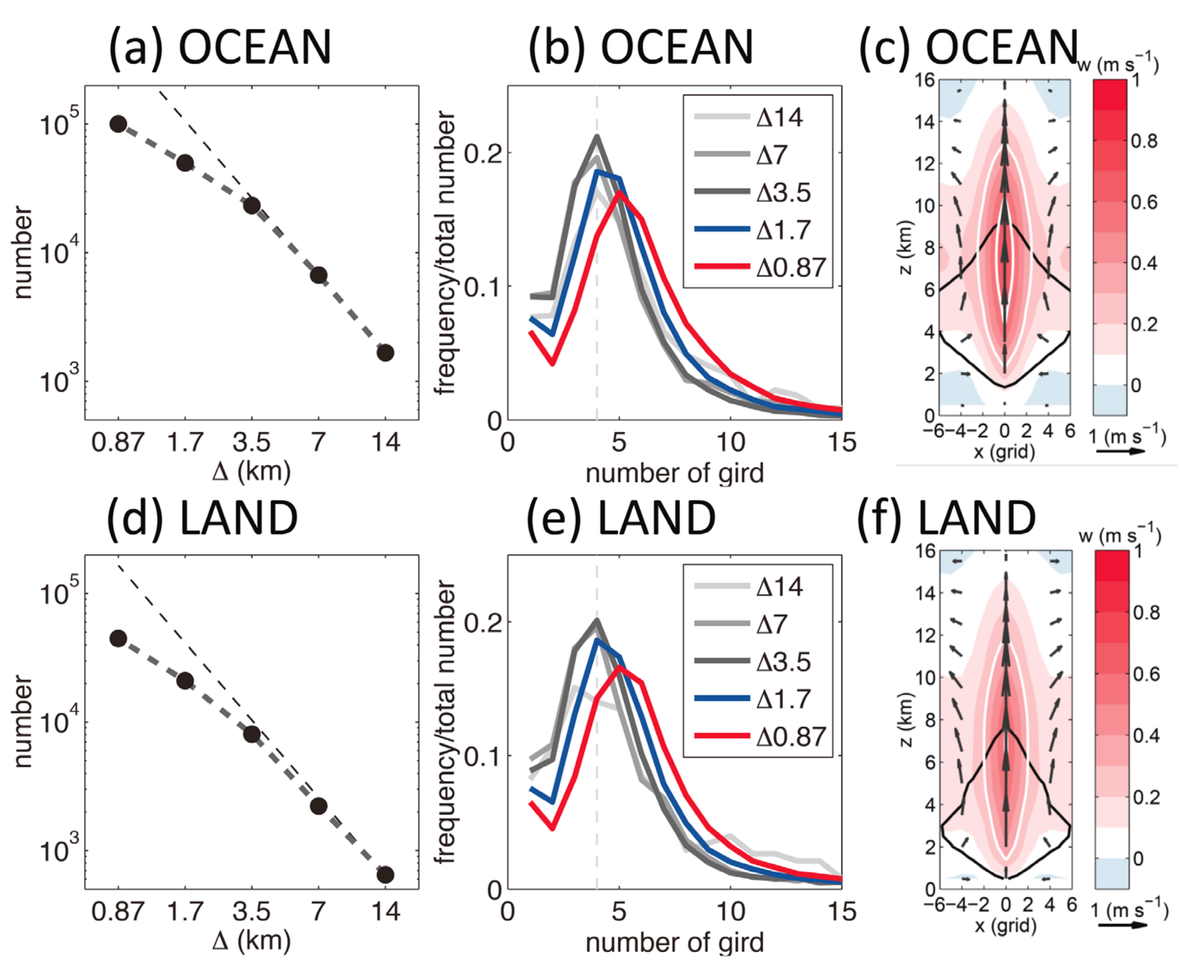


Figure 3: Resolution dependence of total area of clear sky and selected type of clouds averaged over the globe.

Land and Ocean difference



Resolution Dependence on Convection Properties

Figure 4: Resolution dependence of (a & d) number of convections and (b & e) grid distance to the nearest convection core detected. (c & f) Radius-height cross section for composites of vertical velocity and velocity vector of radial and vertical velocity for simulated convection core

Latitudal Difference

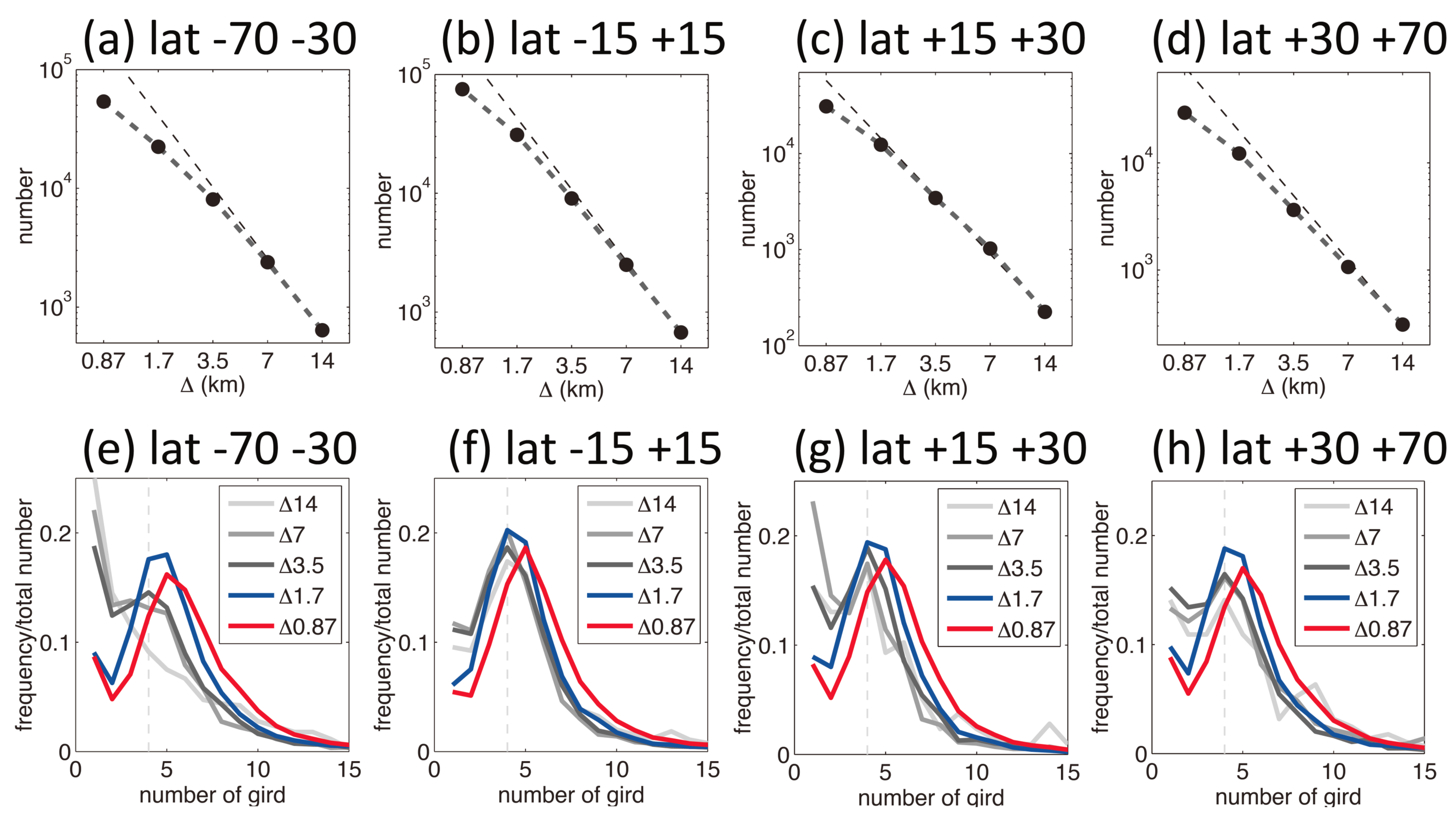


Figure 5: Resolution dependence of (a) number of convections and (b) grid distance to the nearest convection core detected over the latitudal area between (a) 70S and 30S, (b) 15S and 15N, (c) 15N and 30N and (d) 30N and 70N.

References

Yoshiyuki Kajikawa, ykaji@riken.jp

Kajikawa, Y., et al., 2015: Resolution dependence of deep convections in a global simulation from over 10-kilometer to sub-kilometer grid spacing, **submitted to Prog. Earth Planet. Sci**.

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Miyamoto et al., 2015: Does convection vary in different cloud disturbances?, *ASL*, **16**, 305-309.

Different Cloudy Disturbance

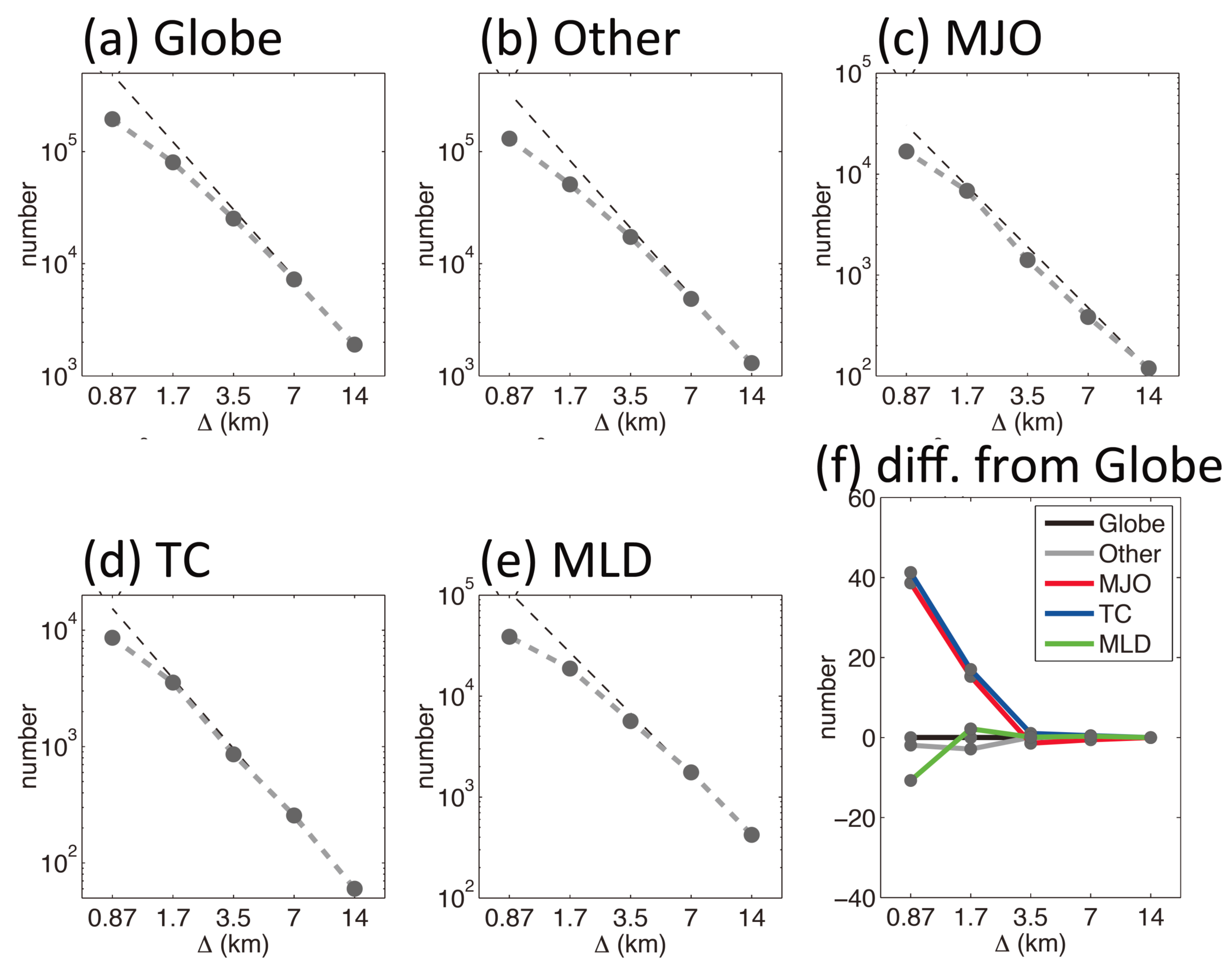

Figure 6: Resolution dependence of number of detected convections in (a) the globe, (b) other, (c) MJO, (d) TC, (e) MLD, and (f) difference from globe after notarizing based on the convection number of Δ14 in each disturbance.

Summary

We found that the essential change in convection properties was different in location and environment for each cloudy disturbance. The convections over the tropics show larger resolution dependence than convections over mid-latitudes, whereas no significant difference was found in convection over land or ocean. Furthermore, convections over cloudy disturbances show essential change of convection properties at about 1-km grid spacing, suggesting resolution dependence. As a result, convections not categorized as cloudy disturbances make a large contribution to the global-mean convection properties. This affects the latitude difference of the resolution dependence of convection properties, and hence the zonal mean OLR.

Despite the diversity of convection properties, most convection become to be resolved at less than 1-km grid spacing. In the future, longer time integration with 0.87-km grid spacing, will stimulate significant discussion about the interaction between the convections and cloudy disturbances.

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Factor analysis in downscaled regional climate change

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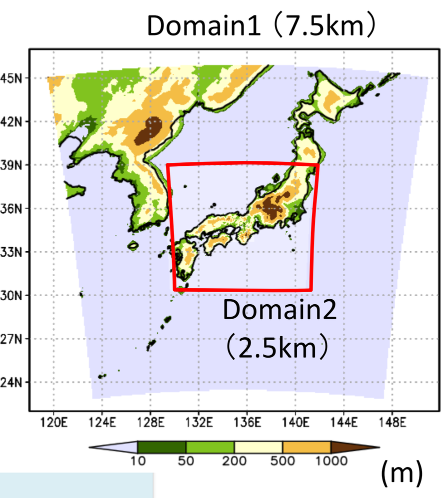
Introduction

It is worthwhile and rather necessary to estimate the future climate change in regional scale for urban design and disaster prevention and mitigation. Especially, future precipitation change of amount, intensity, and frequency is highly concerned. The dynamical downscaling by using regional climate model (RCM) is one of the effective methods to estimate and evaluate the future climate change, and it has been used in many previous studies.

However, the comprehensive understanding the cause of future precipitation change remains as an issue. Specifically, it is important to estimate the effect of synoptic disturbance(e.g. Tropical cyclone (TC), mid-latitude Low and Baiu Front) and the other precipitation change unaffected by the synoptic disturbance for the future precipitation change. It is necessary to examine how much difference in precipitation change with disturbances between GCM results and downscaled results constrained by GCM. We defined the precipitation affected by TC, mid-latitude Low and Baiu and applied them to GCM and RCM results in the area over the western Japan as a demonstration.

Domain	Domain1	Domain2
Horizontal resolution	7.5km	2.5km
Number of vertical levels	36	60
Grid number	336 x 336	432 x 384
Δt_dyn	10 sec	2.5 sec



Physical schemes
- Turbulence: MYNN level 2.5
- Microphysics: 1-moment bulk (Tomita et al., 2008)
- Cumulus parameterization: not used
- Radiation: MSTRN-X (Sekiguchi and Nakajima, 2008)
- Land: Slab model
- Ocean: Constant at initial value
- Urban: Single-layer UCM (Kusaka et al., 2001)

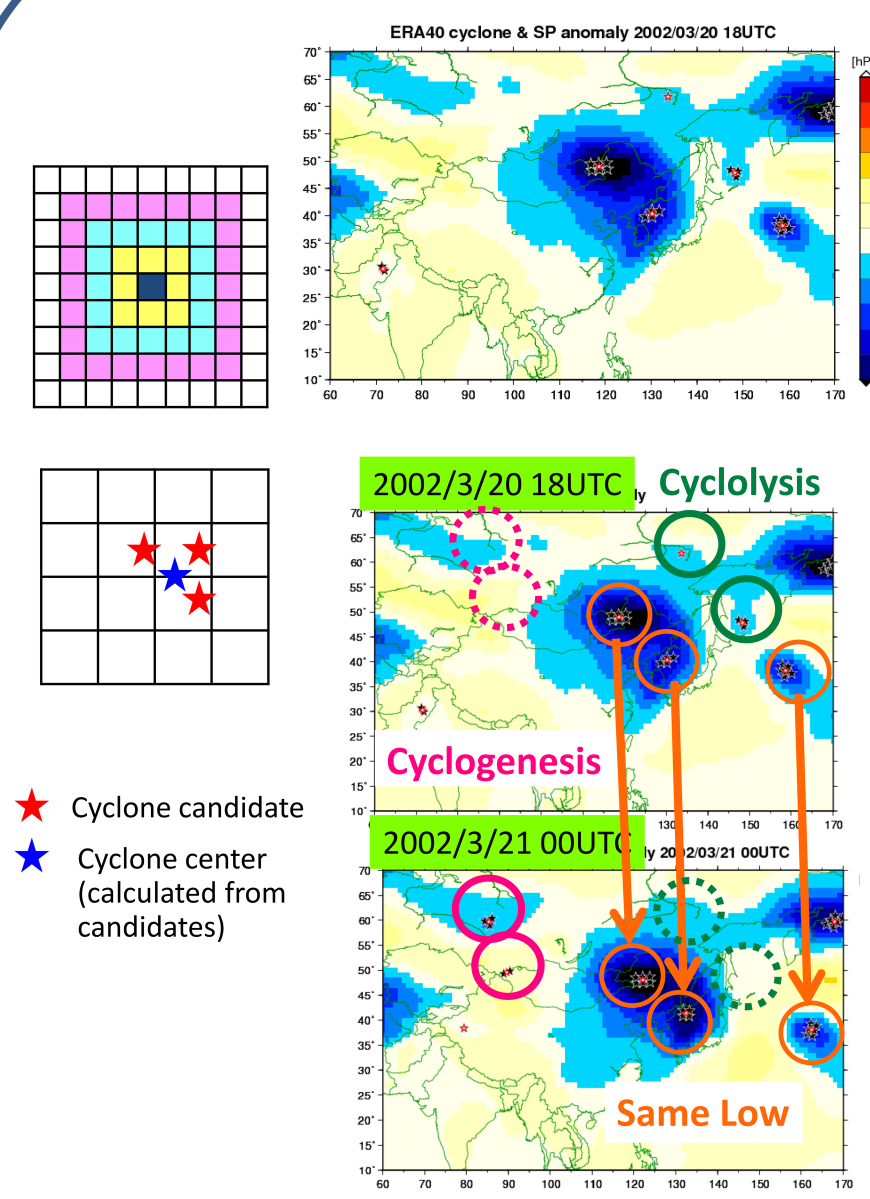
Used Model (SCALE-RM)

	Domain 1	Domain 2
Model	SCALE ver. 4.2.4	
Initial and boundary condition	MRI-AGCM3.2S (Mizuta et al. 2012) U, V, T, Z, QV, MSLP, Ts, soil moisture: 6-hourly, SST: 5-days average	
Integration	May 31 00UTC – Sep 30 00UTC 5-day time slice experiment (inc. 1-day spin-up)	
resolution	7.5km	2.5km
grids	336 x 336	432 x 384
Vertical layer	36	60

Summary

We defined the precipitation affected by TC, mid-latitude Low and Baiu (all remains are categorized others) and applied them to GCM and RCM results in the area over the western Japan as a demonstration. For the future precipitation change, we found the large contribution of precipitation associated with the synoptic disturbance (especially TC) in the GCM result, while it is not negligible to consider the precipitation change unaffected by the synoptic disturbance (Other) in the downscaled results. This implies we should consider the local precipitation more for the future change. Precipitation change affected by TC has still large contribution in large intensity precipitation events.

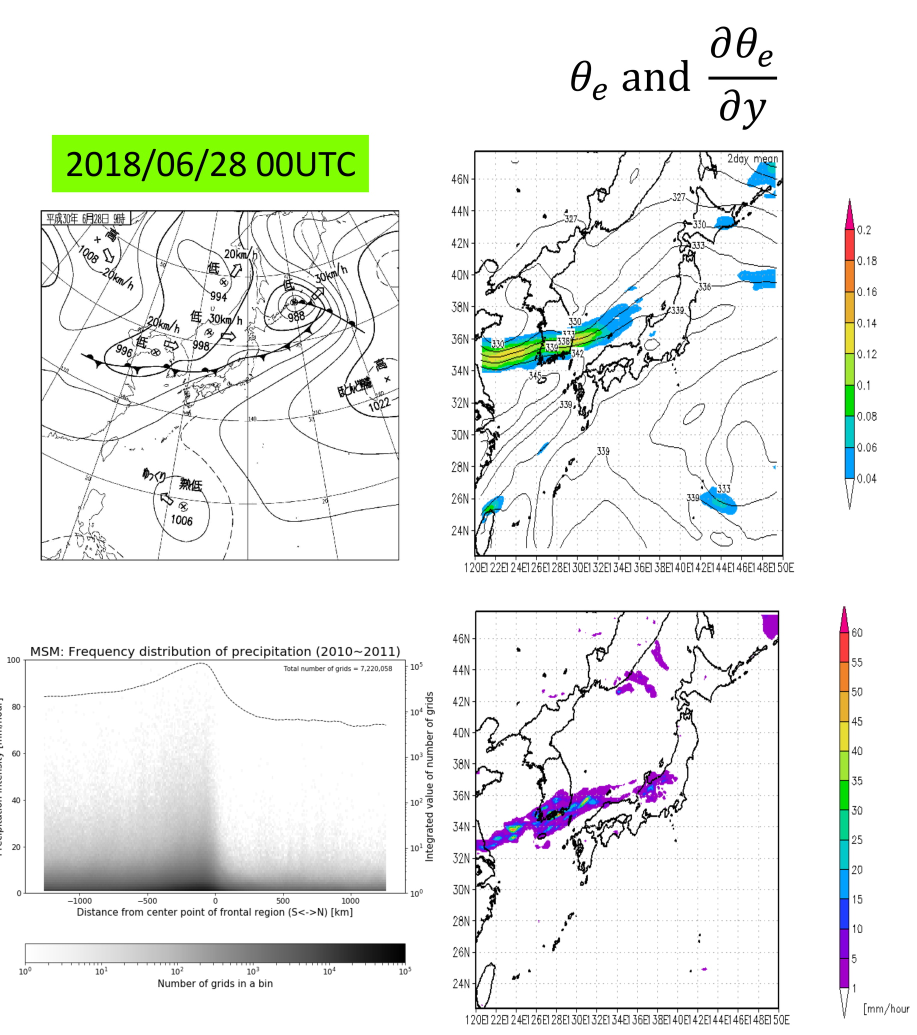
TC and mid Latitude Low Detection



Adachi and Kimura (2007)

1. Use 6 hourly surface pressure and make anomaly with removing the climatology (31 day running mean)
2. Pick up the negative anomaly grids (< -0.8hPa) than surrounding grids.
3. Detect a center grid and define it as the center of cyclone.
4. Compare the cyclone center with that in next time (6hr) and define nearest cyclone center within certain distance as the same cyclone.➔ Cycloysis and Cyclogenesis
5. Define a cyclone life time > 24hr.
6. TC is defined as a cyclone that comes from south of 25N. (Others: mid-latitude Low).

Baiu Front Detection



Front and Precipitation

1. Use θ_e between 925 and 700hPa.
2. 24hors running average.
3. Define front index

$$max\left[\sqrt{\left(\frac{\partial(\theta_e)}{\partial y}\right)^2}\right] > 0.07$$

$$\frac{\partial \theta_e}{\partial y} < 0$$

4. Horizontal scale > 500km
5. $\theta_e$meets
   $320 < [\theta_e] < 350$
6. Precipitation south of Baiu front (0 - 400km) is defined as Baiu Precipitation.

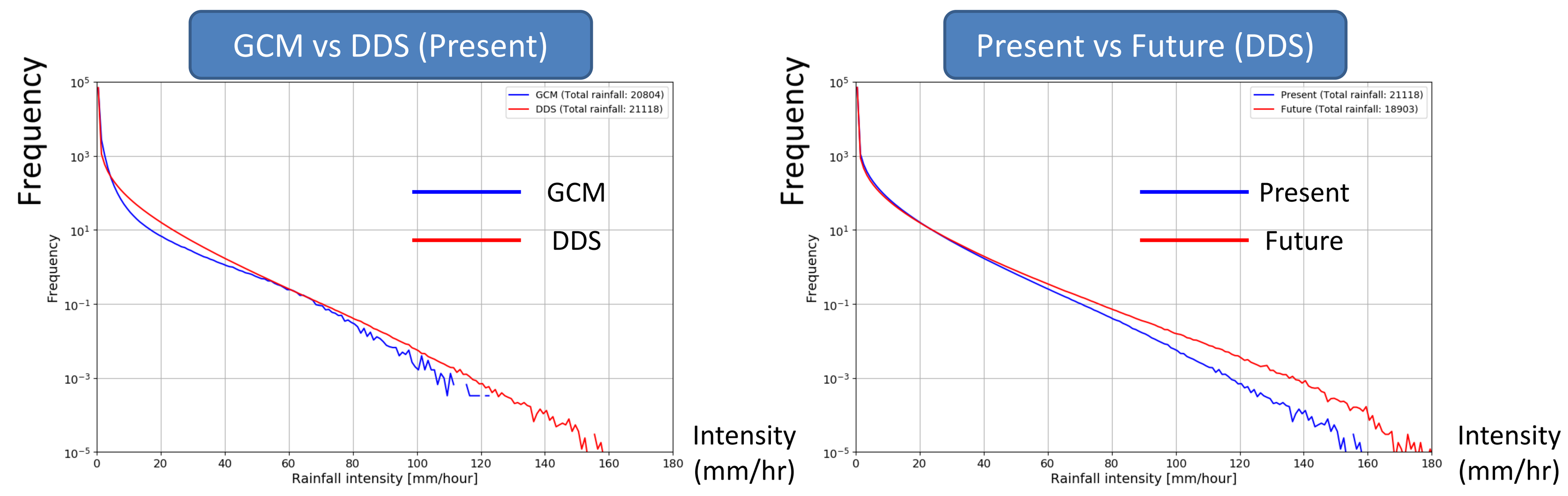


Figure 1: Frequency-intensity relationship of Domain average rainfall (Left: GCM vs DDS under present climate, Right: Present vs Future in DDS).

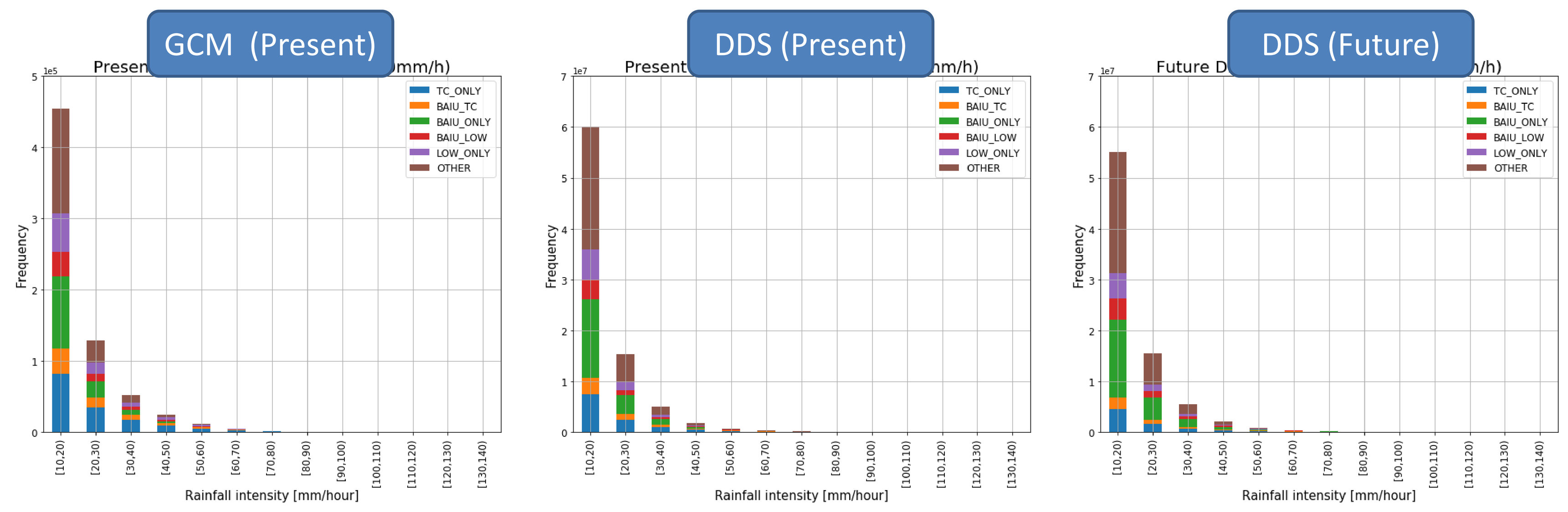


Figure 2: Frequency-intensity relationship of Domain average rainfall in GCM and DDS (present and future) classified by Factor disturbance.

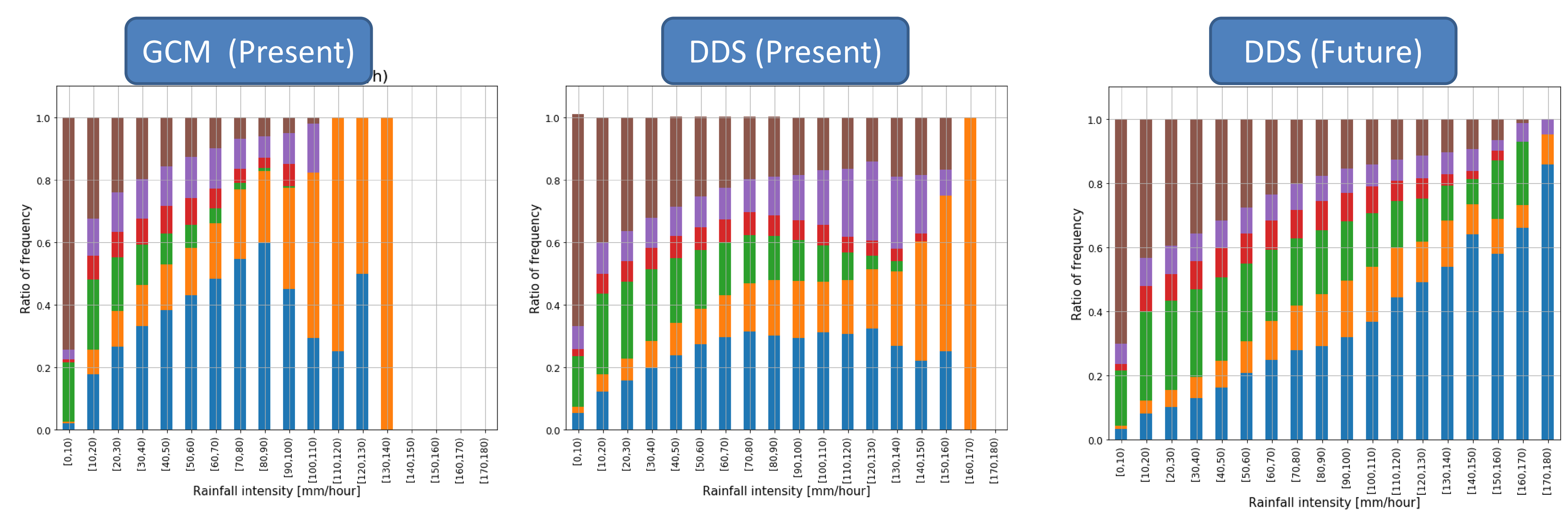


Figure 3: same as Figure 2 but for the ratio of frequency.

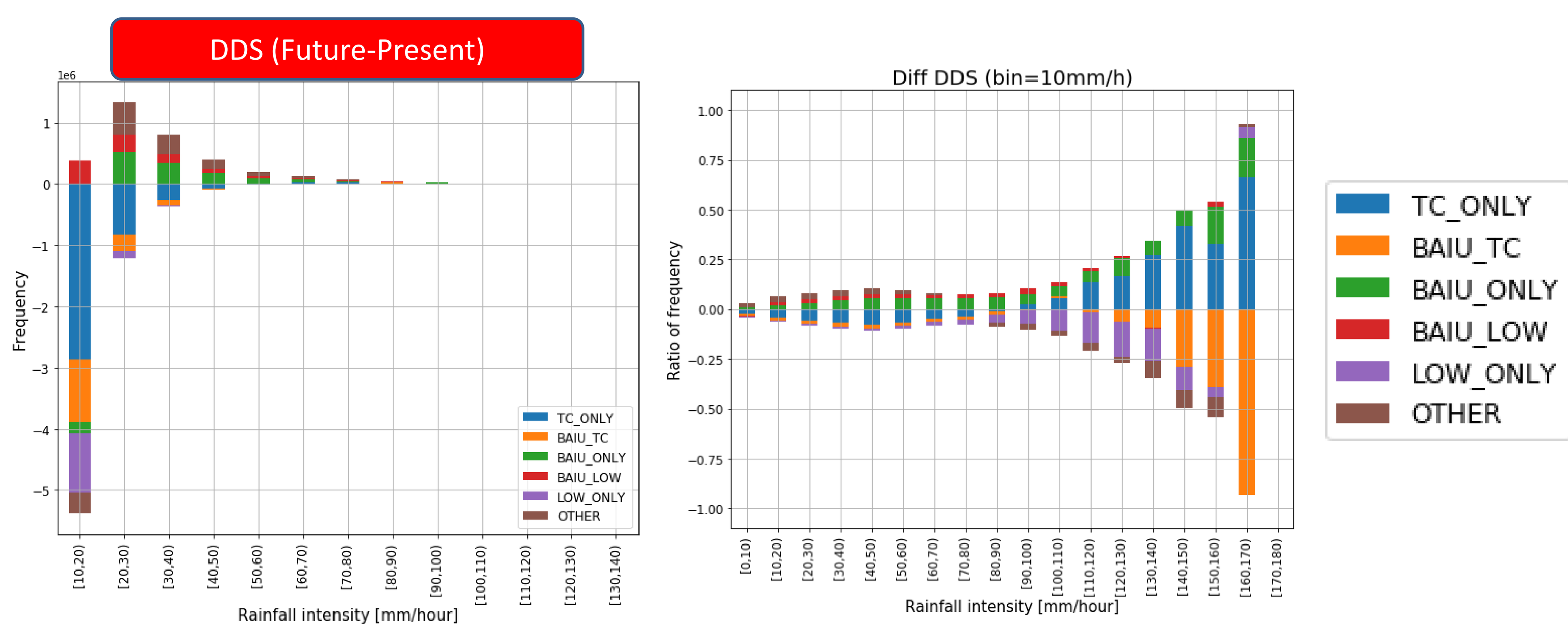


Figure 4: Difference of rainfall frequency and intensity relationship between Future and present climate in DDS (Left: Frequency, Right: Ratio of Frequency).

Acknowledgment

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