370 Evaluation Study for Predictability of a Heave Localized Rainfall using WRF and Climate Change Database

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1. INTRODUCTION

A heavy localized rainfall with maximum daily rainfall of 545.5mm was historically recorded on July 5th, 2017, at Asakura city, Kyushu, Japan. It triggered landslide disasters that left 36 human fatalities and damaging more than 600 residential buildings. It required better understanding of the meteorological processes as well as the predictability of the rainfall event.

In this study, sensitivity of the rainfall over this area was evaluated to investigate the physical schemes in the meteorological numerical model with a downscaled -grid resolutions in the nesting method. The Weather Research and Forecasting Model (WRF) model with NCEP-FNL and NCEP-GDAS/FNL datasets were used for the sensitivity analysis.

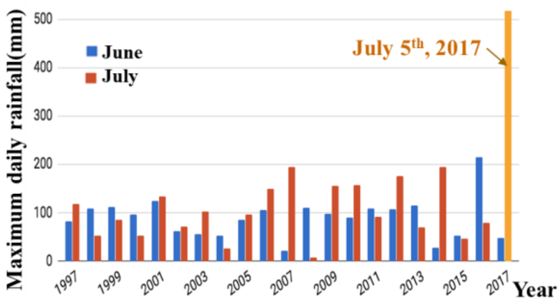


Fig.1. Rainfall on July 5th,2017 in comparison with its behavior over the past 20 years at the Asakura city

2. NUMERICAL METHOD

In this study a computational model was constructed as shown in Fig.1. Table-1 describes the model configuration, simulation condition and numerical schemes. The parent domain has 300×300 grids with the horizontal spatial resolution of 16.2km. The 5 stages of nesting were done to achieve the nested domains with the horizontal spatial resolution of 5400m, 1800m, 600m and 200m. Moreover, the topography for the domain regions was obtained from the United States Geological Survey (USGS) and the Geospatial Information Authority of Japan topography data. These domains were also centered at the rainfall outbreak location, and had 60 unequally spaced sigma (no-dimensional pressure) levels in the vertical profiles.

Initial and boundary conditions were derived from the 6h Final Operational Global Analysis datasets on 1 degree grids ((NCEP-FNL) and 0.25 degree grids (NCEP-GDAS/FNL) from the July 5^{th} 09:00 to July 6^{th} 09:00 JST. Analysis fields, including temperature, moisture, geopotential height and wind were interpolated to the WRF domain grids. Simulation was conducted in two-way coupling for the domain. The New Thompson et al. microphysics scheme, the surface layer physics Monin-Obukhov scheme, the Unified Noah LSM land surface physics scheme, and the Kain-Fritsch (new Eta) cumulus parameterization scheme were implemented for the simulation. Two planetary boundary-layer (PBL) schemes: Yonsei University scheme (**YSU**) and Mellor-Yamada Nakanishi and Niino Level 2.5 (**MYNN2.5**) were investigated in here.

Table 2 summaries the four study-cases which were conducted to investigate the impact of the PBL schemes and the initial/ boundary condition dataset.

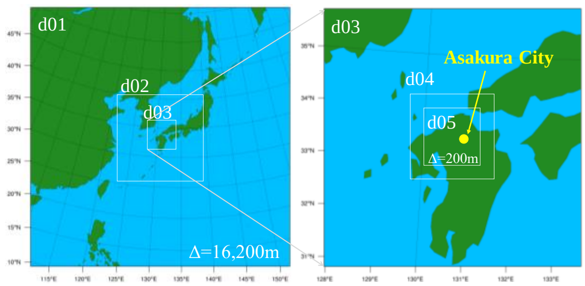


Fig.2. Computational model

Table 1. Model Configuration

Schemes/Domain	[Nested] Description
Grid numbers$^{1/2}$	300, [300, 300, 300, 600]
Grid resolution(m)	16,200, [5400, 1800, 600, 200]
Topography data	USGS 10min, 2min, 30s GSI 50m, 50m
Time step(sec)	60, [20, 6.67, 2.22, 0.74]
Vertical levels	60
Parent-nest inter.	Two-way
Microphysics	New Thompson et al. scheme
Surf. Layer Physics	Monin-Obukhov
Land Surf. Physics	Unified Noah LSM
Planetary Boundary Layer (PBL)	**YSU**: Yonsei University scheme **MYNN2.5**: Mellor-Yamada Nakanishi and Niino Level 2.5
Cumulus Param.	Kain-Fritsch (new Eta) scheme
Initial & Boundary Condition	**NCEP-FNL** (1 deg.), **NCEP-GDAS/FNL** (0.25 deg.) July 5^{th} 09:00:00 - 6^{th} 09:00:00 JST

Table 2. Study cases

Case	Dataset	Scheme
1	NCEP-FNL	YSU
2	NCEP-FNL	MYNN2.5
3	NCEP-GDAS/FNL	YSU
4	NCEP-GDAS/FNL	MYNN2.5

3. VERIFICATION AND RESULTS

3.1. Vertical Profiles

Fig.2 and Fig.3 show the comparison between the profiles of wind velocity, wind direction, air temperature and relative humidity of aerological observation data at Fukuoka station (Obs.) near Asakura city, and WRF results at 09:00JST and 21:00JST, respectively. The WRF results are the initial values that are interpolated from the NCEP-NFL and NCEP-GDAS/FNL data. The simulated profiles are agreed reasonably well with the observation results.

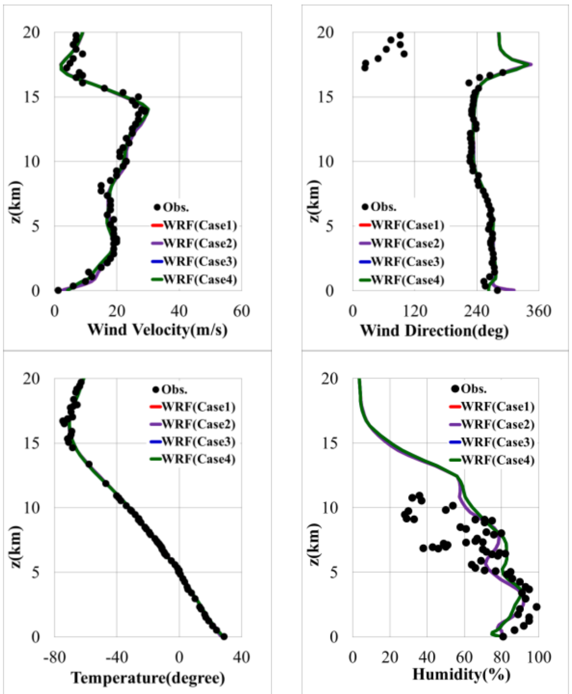


Fig.3. Comparison of the profiles of WRF and Aerological Observation at 09:00 JST

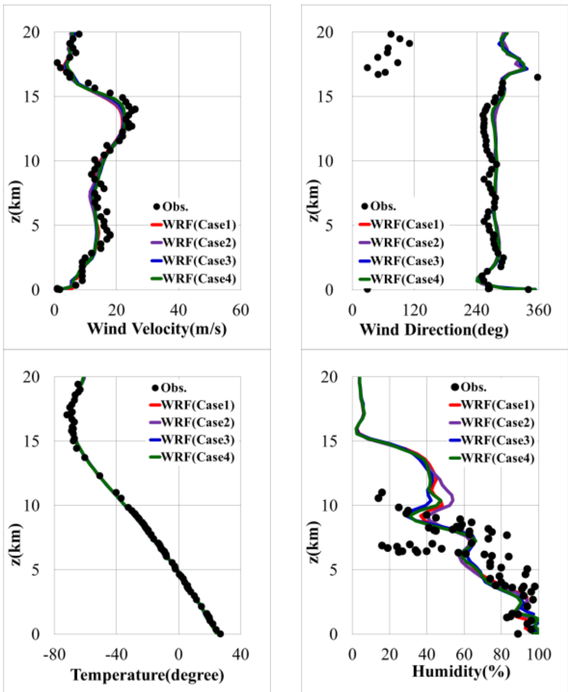


Fig.4. Comparison of the profiles of WRF and Aerological Observation at 21:00 JST

3.2. Time Series

Fig.5 shows the time series of rainfall of WRF and the observation from the Automated Meteorological Data Acquisition System (AmeDAS) at the Asakura station. Fig.6 shows their cumulative rainfall. It also should be noted that, the 24-hours cumulative rainfall obtained from the Radar is about 1,000mm. Although, the results from the NCEP-GDAS/FNL data (Case 3, 4) shows larger results than the other ones (Case 1, 2), WRF shows quite good agreement with the AMeDAS and RADAR observed results, for the hourly and 24-hours accumulated rainfall.

Fig.7 shows the snapshots of the hourly rainfall of WRF and the radar observation (JMA, 2017) at 13:00, 15:00 and 17:00. The WRF results are agreed reasonably well with the observation ones.

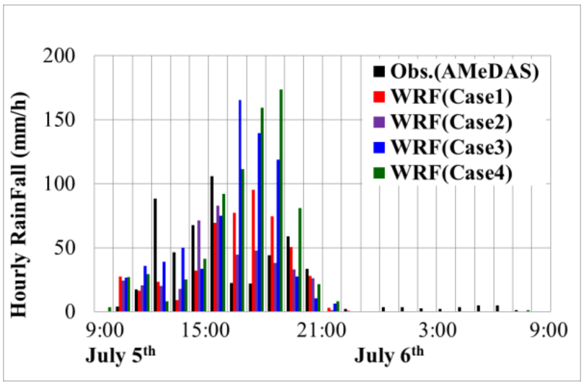


Fig.5. Comparison of the rainfall of WRF and observation

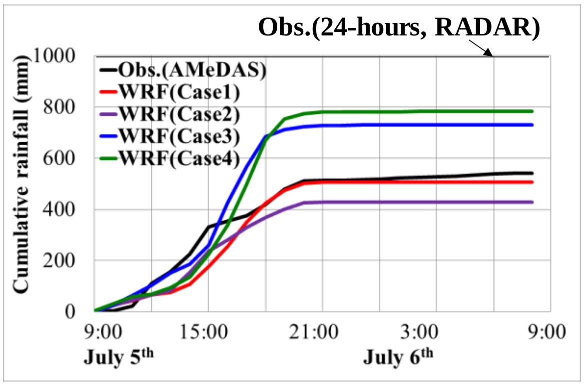
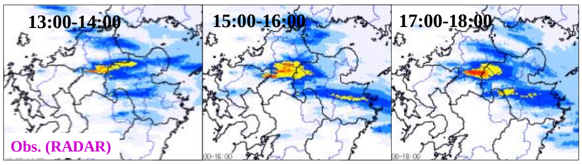
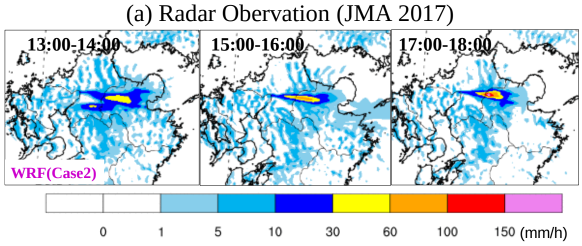


Fig.6. Comparison of the rainfall of WRF and observation



(a) Radar Obervation (JMA 2017)



(b) WRF

Fig.7. Comparison of the hourly rainfall of WRF and Radar Observation

3.3. Phenomena

Fig. 8 and Fig.9 show the water vapor distribution of the lower layer (height of 500m) and the temperature distribution of the upper layer (height of 5,500m) at 15:00 JST, respectively. It is found that the warm moist air from the southwest and the cold air from the northwest flowed into the location of localized rainfall. In here, the cumulonimbus clouds are repeatedly generated and developing furiously from the west to east, in a phenomenon known as back-building storm.

Moreover, Fig.10 shows the reflection intensity of Radar obtained from the X-band MP Radar (NIED, 2017), and WRF (Case 2). High intensity is found near the Asakura city, where the heavy localized rainfall occurred, and it is also agreed reasonably well with the observation results.

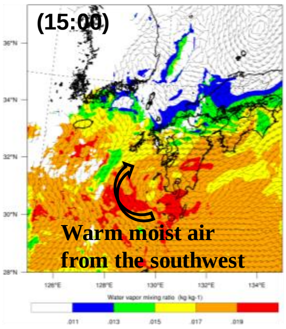


Fig.8. Water vapor distribution of the lower layer (Height:500m)

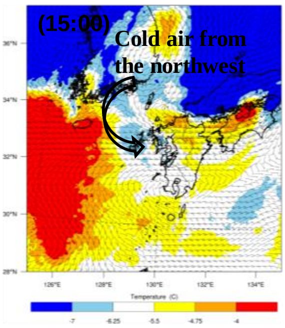
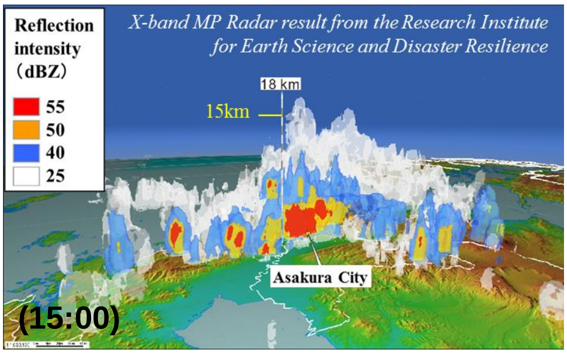
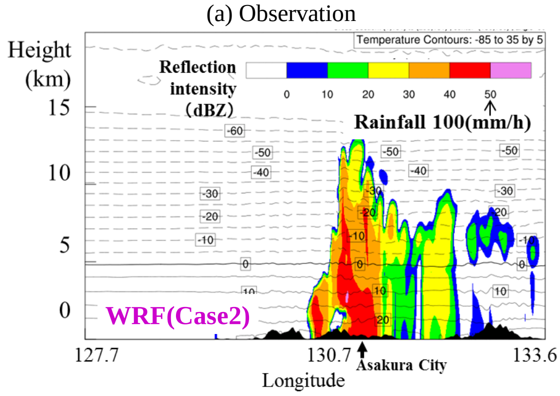


Fig.9. Temperature distribution of the upper layer (Height: 5,500m)



(a) Observation



(b) WRF

Fig.10. Reflection intensity of Radar and WRF

4. CLIMATE CHANGE EFFECT

Climate Change database called "**Database for Policy Decision Making for Future Climate Change**" (**d4PDF**, +4C) was also used to investigate the changing of precipitation in the area under global warming effects. Although the future daily rainfall of the area is found to be increased under global warming, but its value is smaller than the precipitation which was recorded from this heave localized rainfall event. It could be resulted from the insufficient resolution of grid spacing of 20km which is used in the d4PDF.

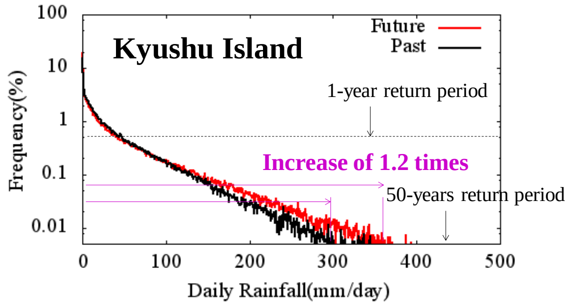


Fig.11. Frequency of daily rainfall over Kyushu Island obtained from d4PDF for the past and future

5. SUMMARY

Meteorological simulation using the WRF model has been carried out to investigate the sensitivity of the rainfall over the Asakura city with a downscaled grid resolution in the nesting method. YSU and MYNN2.5 showed good agreement with observation results. Climate change database d4PDF was used to investigate the daily precipitation to find the increase under global warming.

6. ACKNOWLEDGEMENT

Part of the results was obtained by using the **TSUBAME** supercomputer of Tokyo Institute of Technology. The **d4PDF** has been provided by the **Program for Risk Information on Climate Change (SOUSEI)** and the **Data Integration and Analysis System (DIAS)**, Japan.

7. REFERENCES

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6. d4PDF: http://www.miroc-gcm.jp/~pub/d4PDF/