Effect of Cloud Microphysics Scheme and Ice Nuclei on Forecasts for the September 2015 Heavy Rainfall Event in Kanto and Tohoku Regions

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1. Introduction

Extreme rainfall occurred in the Kanto and Tohoku regions of Japan in September 2015, and flooding and landslides associated with the rainfall killed 8 people. The rainfall amount reached 600 mm in the nourthern Kanto (Fig. 1). The heavy rainfall in Kanto was produced by linear convective systems from 9 to 10 September under the atmospheric condition with a moist southerly airflow associated with an extratropical cyclone over the Japan Sea and southeasterly airflow from Typhoon Kilo (Fig. 2a). A moist easterly airflow also formed linear convective systems and caused the heavy rainfall in Tohoku from 10 to 11 September (Fig. 2b). The operational mesoscale model (MSM) of Japan Meteorological Agency (JMA) successfully forecasted the occurrence of the heavy rainfall events, but a quantitative forecast of rainfall amount remains challenges. Although the aerosols indirect effect has been known to be important in not only the global warming but also mesoscale convective systems, it is not known how the aerosols indirect effect especially by ice nuclei affects precipitation amounts and the atmospheric conditions. For heavy snowfall events in Kanto, it is indicated that aerosols indirect effect by ice nuclei and cloud microphysics schemes considerably affected snowfall amounts and distribution (Araki and Murakami, 2015; Araki, 2016). In this study, we investigated the effects of cloud microphysics schemes and aerosols indirect effect by ice nuclei on the forecast for the rainfall and the atmospheric condition in the September 2015 heavy rainfall event in Kanto and Tohoku regions.

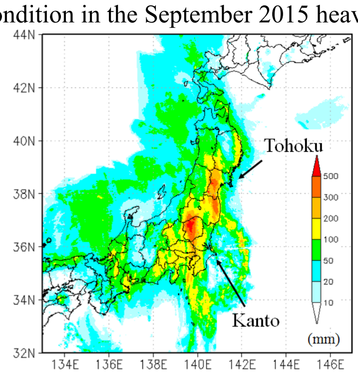

Figure 1. Precipitation amount derived from JMA radar analysis accumulated from 18 UTC on 8 to 00 UTC on 11 September 2015.

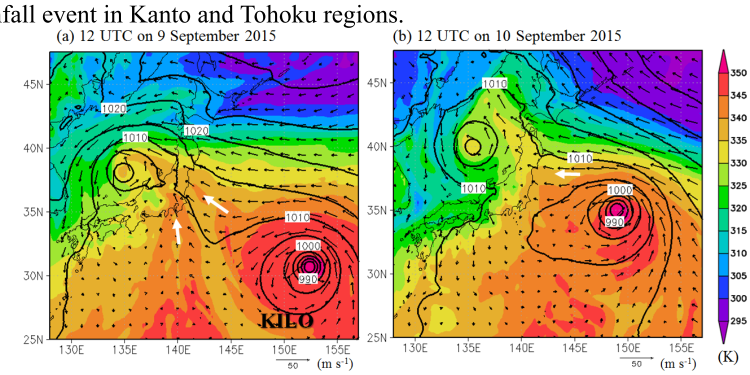

Figure 2. Synoptic conditions derived from the JMA global analysis at (a) 12 UTC on 9 and (b) 12 UTC on 10 September 2015. Shade and contour line indicate equivalent potential temperature (K) at 950 hPa and sea level pressure (hPa), respectively. Vectors show horizontal wind at 950 hPa.

2. Model settings of sensitivity experiments

Numerical simulations were performed by the JMA Non-Hydrostatic Model (NHM) with a domain of 7,000x7,000 km covering Japan and a horizontal grid spacing of 5 km. The initial and boundary conditions were provided from the JRA-55 reanalysis data and the models were run from 18 UTC on 8 to 06 UTC on 11 September 2015. A bulk cloud microphysics scheme with 2-moment cloud ice, snow, and graupel was used in a control run (CNTL). As sensitivity experiments on cloud microphysics schemes, we performed two numerical experiments with a bulk cloud microphysics scheme with 2-moment cloud ice and 1-moment snow and graupel (Ice-2m), and with 1-moment cloud ice, snow, graupel (Ice-1m). Another experiment with the Kain-Fritsch convection parameterization and the cloud microphysics scheme same as CNTL (KF) was also performed. Focusing on the aerosol indirect effect by ice nuclei, two experiments with changing coefficients in the formulas of deposition/condensation-freezing-mode ice nucleation (Meyers, 1992) and immersion-freezing-mode ice nucleation (Bigg, 1955) by factors of 0.1 (IN01) and 10 (IN10) were performed. The other setups in each experiment were the same as those used in the MSM.

3. Effect on rainfall and atmospheric condition

The results of forecasted precipitation in CNTL and the differences from CNTL for each experiment are shown in Fig. 3. Although the CNTL somewhat overestimated the precipitation amount especially in the northern Japan including Tohoku compared with the observation, the heavy rainfalls in Kanto and Tohoku regions were successfully reproduced. In each sensitivity experiment, there were the difference of heavy rainfall areas with precipitation amount over 100 mm from CNTL because the differences of the representation for the location, duration time, and precipitation intensity of linear convective systems. In Tohoku, precipitation amount increased in the coastal areas and decreased inland areas in both KF and IN01 compared with the CNTL, and opposite features were found in Ice-2m, Ice-1m, and IN01. To examine the atmospheric conditions causing the differences in precipitation between these experiments, equivalent potential temperature (EPT) fields at 950 hPa were investigated (Fig. 4). It is found that there were positive (negative) differences of EPT on the windward side of the Tohoku in KF and IN01 (Ice-2m, Ice-1m, and IN01) from CNTL because of the changes of the convective activity associated with the Kilo. It is indicated that the cloud microphysics scheme in models can affect atmospheric thermodynamic fields causing mesoscale convective systems and the forecast on rainfall amount is quite sensitive to the cloud microphysiscs scheme in this case. It is desired that the uncertainty in the cloud microphysics scheme including the parameterization of ice nuclei should be reduced in the future.

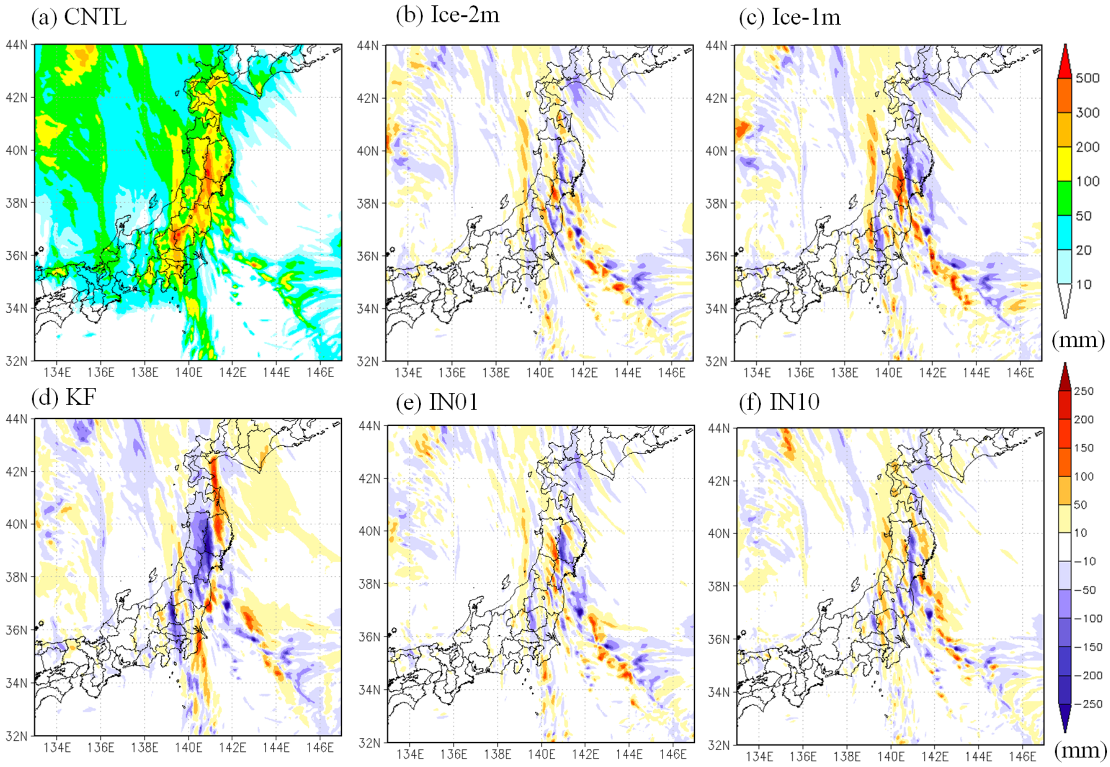

Figure 3. (a) Horizontal distribution of precipitation amounts from 18 UTC on 8 to 00 UTC on 11 September 2015 in CNTL, and the differences from CNTL for each experiment.

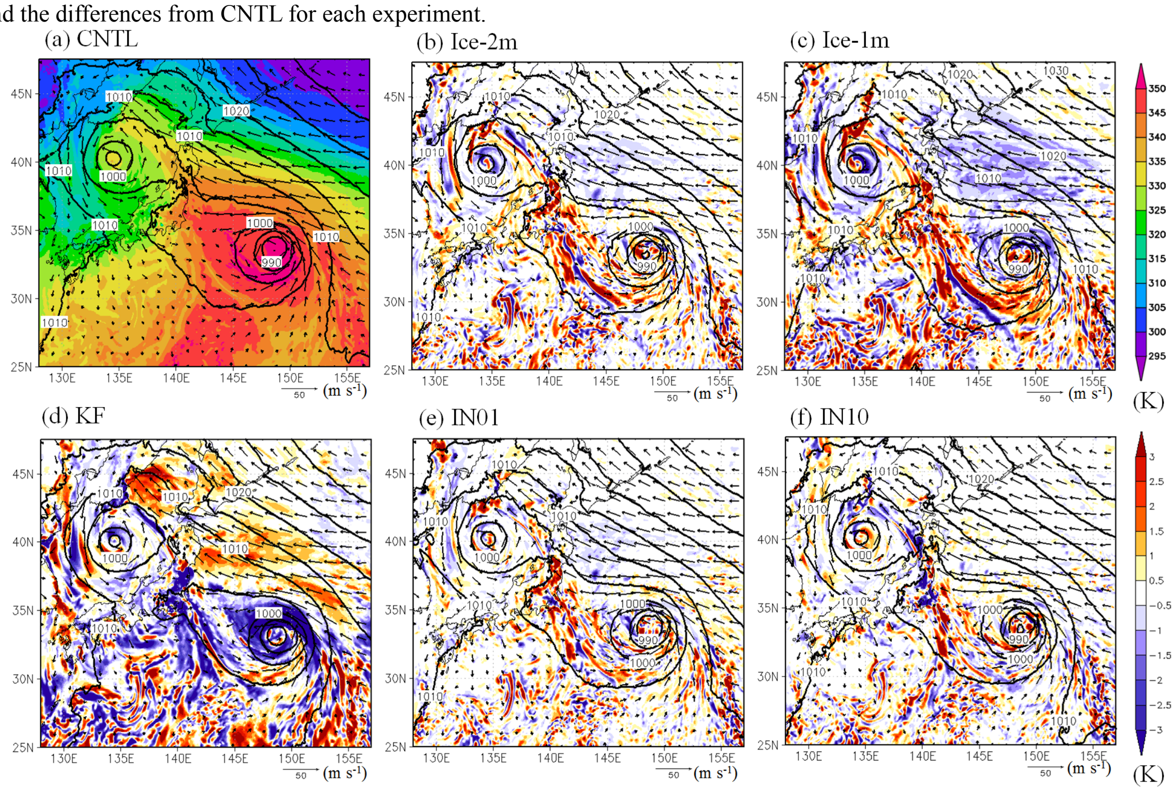

Figure 4. (a) Equivalent potential temperature at 950 hPa at 12 UTC on 10 September in CNTL, and the differences from CNTL for each experiment. Contour lines and vectors respectively indicate sea level pressure (hPa) and horizontal wind at 950 hPa in each experiment.

References:

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