Section 9

Development of and studies with coupled and Earth system models and data assimilation systems.

Numerical simulations of a local heavy rainfall event south of Kanto region by using a coupled atmosphere-wave-ocean model with a regional air-sea coupled data assimilation system based on NHM-LETKF

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1. Introduction

On July 18 in 2017, local heavy rainfalls were observed south of the Kanto region (Fig. 1). A notable event was hail observed in Ikebukuro, Tokyo. This study focused on the heavy rainfall event and roles of the ocean including Tokyo Bay. Numerical experiments were conducted by using a regional atmosphere-wave-ocean coupled model based on a nonhydrostatic model (NHM) developed by Japan Meteorological Agency in collaboration with the Meteorological Research Institute and the regional air-sea coupled data assimilation system based on the NHM and the local ensemble transform Kalman filter (NHM-LETKF). Himawari-8 (Bessho et al. 2016) hourly sea surface temperature (SST) data were used for data assimilation.

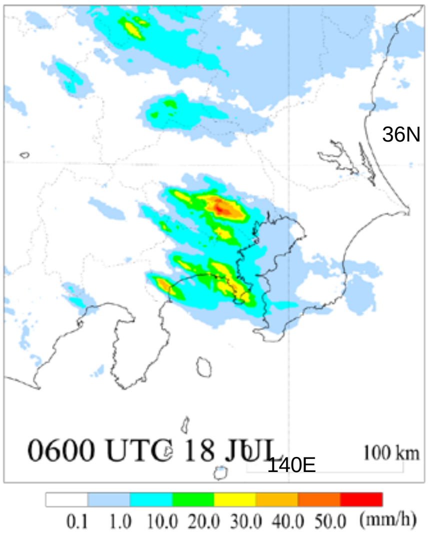

Figure 1. Horizontal distribution of the Radar-Raingauge analyzed hourly precipitation amount at 06 UTC on 18 July in 2017.

2. Experimental design

The experimental design consists of two procedures. One is the analysis using the air-sea coupled NHM-LETKF. The other is the forecast experiments carried out using the NHM and the atmosphere-wave- ocean coupled model with the analysis by the air-sea coupled NHM- LETKF.

2.1 Analysis by the air-sea coupled NHM-LETKF

Data assimilation experiments were conducted by using the air-sea coupled NHM-LETKF (Wada and Kunii, 2017). The specification is shown in Table 1. The analysis period was from 0000 UTC 1 July to 1800 UTC 7 August. Mesoscale Analysis (MA) dataset and Comprehensive Database for Assimilation (CDA) archived in JMA were used for data assimilation together with Himawari-8 hourly SST data. The analysis cycle was 6 hours. Figure 2 shows the horizontal distribution of the hourly precipitation forecast at 07 UTC on 18 July in 2017, 1-hour forecast initiated from 06 UTC. South of the Kanto region, relatively large hourly precipitation was forecasted. Note that such heavy rainfall was not analyzed at other analysis time.

Table1 NHM-LETKF specifications

Ensemble size	50
Grid size	273 x 221 x 50 (Δx = 15 km)
Covariance inflation	relaxation-to-prior spread (Whitaker and Hamill 2012)
Covariance localization	Horizontal 200 km, Vertical 0.2 ln p
Analyzed variables	u, v, w, t, p, q_v, q_c, q_r, q_{ci}, q_s, q_g
Observations	MA CDA4

2.2 Forecast experiment

Forecast experiments were performed by a 1-km mesh NHM and atmosphere-wave-ocean coupled model based on the NHM (Wada et al., 2010). The initial time was 0600 UTC 18 July in 2017. The integration time was 12 hours. The grid size was 601 x 601 x 55. The time step of the NHM was 3 seconds, that of the ocean model was 18 seconds and that of the ocean wave model was 5 minutes.

Atmospheric initial and boundary conditions were created from the analysis by the air-sea coupled NHM-LETKF. Oceanic initial conditions were obtained from the objective analysis of JMA with the horizontal resolution of 0.5˚ in the latitude and longitude coordinate system based on topography obtained from the 50-m dataset developed by the Geospatial Information Authority of Japan, Geographical Survey Institute. However, SST at the initial time was provided from the analysis by the air-sea coupled NHM-LETKF because Himawari8 SST was assimilated in the analysis.

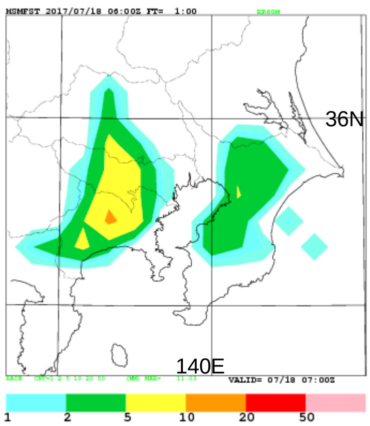

Figure 2. Horizontal distribution of the hourly precipitation forecast at 07 UTC on 18 July in 2017.

3. Results

3.1 Precipitation pattern

Figures 3a-d show the horizontal distribution of the Radar-Raingauge analyzed hourly precipitation. South of the Kanto region, local precipitation was observed for two hours from 0600 UTC (Fig. 1) to 0800 UTC. The forecast conducted by the NHM could capture the precipitation pattern south of the Kanto region to some extent (Figs. 3e-h). However, the amount of hourly precipitation tended to overestimate, and the area of forecasted precipitation could not extend westward compared with the Radar-Raingauge analysis.

Figures 3i-l show the horizontal distribution of hourly precipitation forecasted by the atmosphere-wave-ocean coupled model. The maximum value of hourly precipitation forecasted by the coupled model differed from that forecasted by the NHM. Nevertheless, the horizontal pattern of hourly precipitation did not change significantly. This indicates that the effect of ocean coupling on the forecast of hourly precipitation was not essential. This result is consistent with the result of the case study of Typhoon Sinlaku (2008) reported in Wada and Kunii (2017).

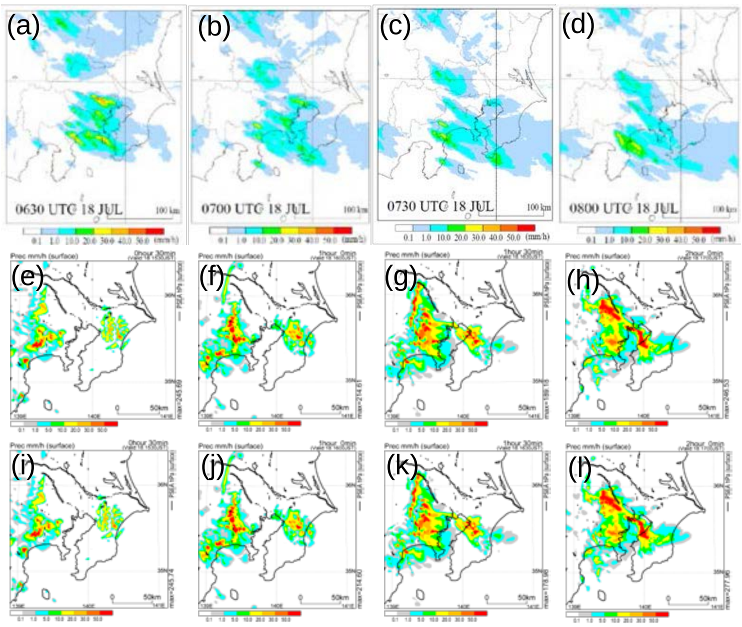

Figure 3. Horizontal distributions of (a-d) the Radar-Raingauge analyzed hourly precipitation amount at (a) 0630 UTC, (b) 0700 UTC, (c) 0730UTC and (d) 0800 UTC on 18 July in 2017, those of hourly precipitation amount forecasted with the NHM at (e) 0630 UTC, (f) 0700 UTC, (g) 0730UTC and (h) 0800 UTC on 18 July in 2017, and those of hourly precipitation amount forecasted with the coupled model at (i) 0630 UTC, (j) 0700 UTC, (k) 0730UTC and (l) 0800 UTC on 18 July in 2017.

3.2 Verification of SST

Figure 4 shows the time series of observed SST at the Hiratsuka offshore experiment tower and the Kuroshio Extension Observatory buoy site equipped over the open ocean. The SST analyzed by the coupled NHM-LETKF from 15 to 20 July 2017 was validated with the two observations.

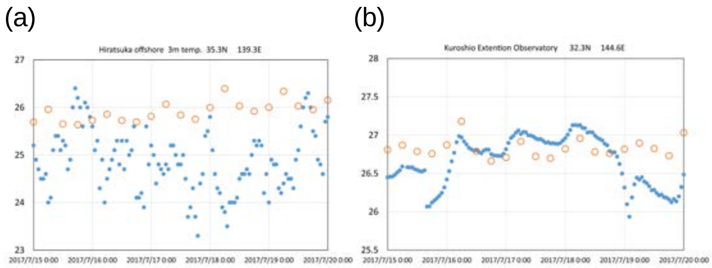

Figure 4. Time series of SST observed at (a) the Hiratsuka offshore experiment tower at 35.3˚N, 139.3˚E and (b) the Kuroshio Extension Observatory buoy site at 32.3˚N, 144.6˚E (Blue closed circles) together with the analyzed SST (orange open circles) from 15 to 20 July 2017.

The amplitude of diurnal cycle of SST particularly observed at the Hiratsuka offshore experiment tower could not be well analyzed. In addition, the analyzed SST tended to be high. However, the SST observed at the Kuroshio Extension Observatory buoy site was reasonably analyzed by the coupled NHM-LETKF with Himawari8 SST from 16 to 18 July. The poor reproduction of SST analysis around the coastal area is because of insufficient coverage of SST data by Himawari8 and the poor skill of the ocean model, particularly in description of the processes related to the SST diurnal cycle.

4. Future plans

This is a preliminary study on the role of the ocean in local heavy precipitation by using the air-sea coupled data assimilation system and high-resolution atmosphere-wave-ocean coupled model with satellite SST observations. Our future plans are the coupled data assimilation with 5-km mesh horizontal resolution, the comparison between NHM-LETKF and the coupled NHM-LETKF. In addition, the atmosphere-wave-ocean coupled model will be developed in order to reproduce realistic diurnal cycle of skin SST. The regional coupled system will apply the other extreme atmospheric events such as heavy snowfall south of the Kanto region and tropical cyclones.

References

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