Impacts on local heavy rainfalls of surface winds measurement by seabirds

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1. Introduction

Observations in the surface boundary layer over the ocean are valuable because of rarity. In addition, the vertical profile of winds near the sea surface is not well known so that the Monin-Obukhov similarity theory is used in the atmosphere model. A recent study of Yonehara et al. (2016) reported a new method for the estimation of surface winds by observations of seabirds soaring over the sea. We used a bird-based wind dataset to study the impact of surface winds measurement on the September 2015 Heavy Rainfall Event in Tohoku Regions using the local ensemble transform Kalman filter (LETKF) implemented with the nonhydrostatic model (NHM) developed by the Japan Meteorological Agency (JMA)(Kunii, 2014).

2. Data and method

Data assimilation experiments were conducted by using NHM-LETKF. The specification is shown in Table 1. Yonehara et al. (2016) reported a method to estimate wind velocity from Global Positioning System (GPS) track data (one second interval) of soaring seabirds by taking into account the effect of wind drift to the ground velocity of the birds. This method was applied to the track of three streaked shearwaters released in September 2015 to obtain wind's guess data per five minutes when the bird was flying. The period was from 2000UTC 9 to 2100 UTC 10 in September. 10-m wind data was estimated based on the similarity theory and were used for assimilation in the test experiment (TEST), while the control experiment (CTL) was conducted by the NHM-LETKF without wind data by seabirds soaring (Table 2). Mesoscale Analysis (MA) dataset and Comprehensive Database for Assimilation (CDA) archived in JMA were used in both experiments.

Observation data within ± 5 minutes at the reference time of each cycle were averaged over the model grid spacing because of the horizontal resolution of 15 km and the assimilation interval of 1 hour. The data used in the TEST experiment were regarded as super observations. The observation error was preliminarily set to 1.0 ms^{-1}, which is the same as the error of the other typical in situ observations.

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	$u, v, w, t, p, q_v, q_c, q_r, q_{ci}, q_s, q_g$
Extended forecast	817 x 661 x 50 (Δx = 5 km), up to 48 hours

Table 2 Experiments

Experiment	Observations
CTL	MA CDA4
TEST	MA CDA4 + winds by seabirds soaring

Forecast experiments were performed by a 3-km mesh atmosphere-wave-ocean coupled model based on the NHM (Wada et al., 2010). The initial time was 1200 UTC 10 September in 2015 and the integration time was 36 hours. The grid size was 1141 x 961 x 55. The time step of the NHM was 4 seconds, that of the ocean model was 24 seconds and that of the ocean wave model was 10 minutes. Atmospheric initial and boundary conditions were created from the analysis in the CTL and TEST experiments, respectively. Oceanic initial conditions were obtained from the objective analysis of JMA with the horizontal resolution of 0.5° in the latitude-longitude coordinate system.

3. Results

3.1 Impacts for analysis on surface winds

Figure 1a shows the horizontal distribution of the trajectory of three seabirds during the observation period. In situ surface winds were obtained along the east coast of Tohoku Region. Figures 1b-e show the horizontal distributions of the difference in surface winds between CTL and TEST experiments at 0600 UTC (Figures 1b-c) and 1800 UTC (Figures 1d-e) on 10 September. At 0600 UTC, the difference appears east of Tohoku Region with the amplitude less than 3 m s^{-1}. The area of the difference with the amplitude higher than 1 m s^{-1} shifted eastward where the extratropical cyclone transited from Typhoon Etau existed as if the difference was propagated by environmental flow enhanced by Typhoon Kilo. However, the amplitude of the difference decreased with time. In addition, the seabird winds measurement could not affect the analysis of Typhoon Kilo on the upstream side: Easterly winds were frequently observed by seabird soaring along the east coast of Tohoku Region.

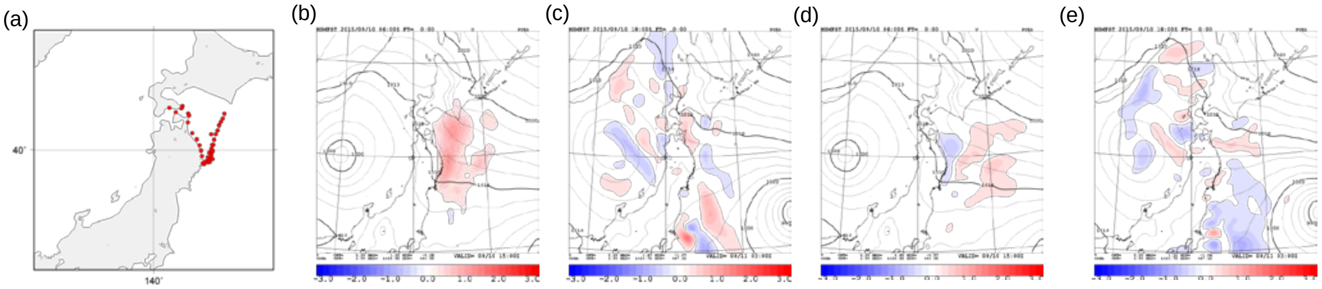

Figure 1 (a) Horizontal distribution of the locations of surface winds measurement during the observation period. (b) Horizontal distribution of the difference in surface zonal winds (color shades) between CTL and TEST (TEST-CTL) at 0600 UTC 10 September, (c) same as (b) except at 1800 UTC, (d) same as (b) except in the surface meridional winds and (e) same as (d) except at 1800 UTC with simulated sea-level pressures. The contour interval is 2 hPa.

3.2 Impacts for forecasts on local heavy rainfalls

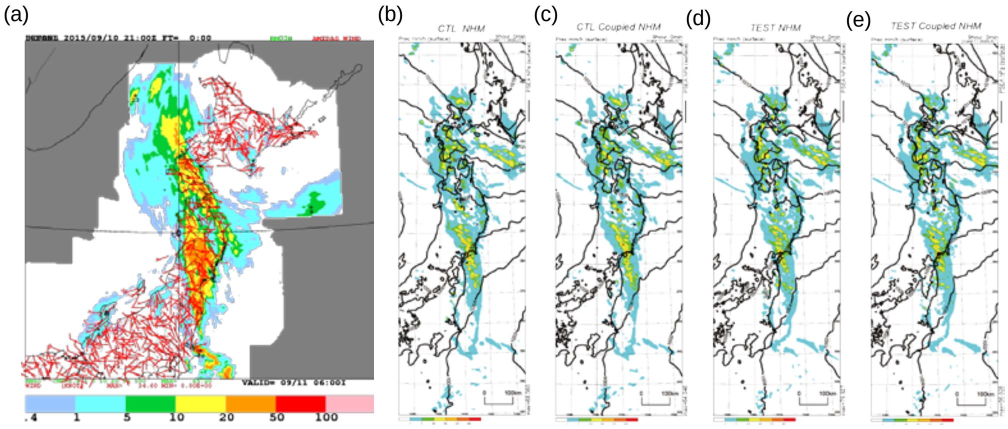

Figure 2 (a) Horizontal distribution of analyzed hourly rainfalls (shades) with 10-m winds (red vectors) at 1800UTC 10 September. (b-e) Horizontal distributions of hourly rainfall forecasts (b) by the NHM and (c) by the coupled NHM in the CTL experiment and (d) by the NHM and (e) by the coupled NHM in the TEST experiment. Contours indicate sea-level pressures with the interval of 2 hPa.

Figure 2a shows the horizontal distribution of analyzed hourly rainfall and 10-m winds at 1800 UTC 10 September. A linear rainband with two locally salient linearly rainfall areas was analyzed in the northern Japan Region, including Tohoku Region. Figures 2b-e show the results of numerical simulation for a 9-h forecast starting at 1200 UTC, valid 3 hours later than the analysis shown in Figure 2a. A linear rainband shown in Figure 2a was reasonably simulated at that time. There was no significant difference among the four experiments: simulations by the NHM and the coupled NHM in the CTL experiment and those in the TEST experiment. The results suggest that there was less impact on the linear rainfall of surface winds measurement by seabirds soaring over the ocean although the heavy precipitation occurred on the downstream side of the observations and the difference propagated toward the location of the linear rainband.

4. Concluding remarks

We set the horizontal resolution of 15 km and the assimilation interval of 1 hour in the TEST experiment, which seems to be too coarse to utilize in situ observations more efficiently because the area of the observations was spatially and temporally limited. Further computational resources are needed to conduct the assimilation experiments by high-resolution NHM-LETKF and to investigate the impact more precisely.

Acknowledgements

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