Geophysical Research Abstracts
Vol. 19, EGU2017-13036, 2017
EGU General Assembly 2017
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The impact of Surface Wind Velocity Data Assimilation on the Predictability of Plume Advection in the Lower Troposphere

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The authors investigated the impact of surface wind velocity data assimilation on the predictability of plume advection in the lower troposphere exploiting the radioactive cesium emitted by the Fukushima nuclear accident in March 2011 as an atmospheric tracer. It was because the radioactive cesium plume was dispersed from the sole point source exactly placed at the Fukushima Daiichi Nuclear Power Plant and its surface concentration was measured at many locations with a high frequency and high accuracy.
We used a non-hydrostatic regional weather prediction model with a horizontal resolution of 3 km, which was coupled with an ensemble Kalman filter data assimilation system in this study, to simulate the wind velocity and plume advection. The main module of this weather prediction model has been developed and used operationally by the Japan Meteorological Agency (JMA) since before March 2011. The weather observation data assimilated into the model simulation were provided from two data resources; [#1] the JMA observation archives collected for numerical weather predictions (NWPs) and [#2] the land-surface wind velocity data archived by the JMA surface weather observation network. The former dataset [#1] does not contain land-surface wind velocity observations because their spatial representativeness is relatively small and therefore the land-surface wind velocity data assimilation normally deteriorates the more than one day NWP performance. The latter dataset [#2] is usually used for real-time weather monitoring and never used for the data assimilation of more than one day NWPs.
We conducted two experiments (STD and TEST) to reproduce the radioactive cesium plume behavior for 48 hours from 12UTC 14 March to 12UTC 16 March 2011 over the land area of western Japan. The STD experiment was performed to replicate the operational NWP using only the #1 dataset, not assimilating land-surface wind observations. In contrast, the TEST experiment was performed assimilating both the #1 dataset and the #2 dataset including land-surface wind observations measured at more than 200 stations in the model domain. The meteorological boundary conditions for both the experiments were imported from the JMA operational global NWP model results. The modeled radioactive cesium concentrations were examined for plume arrival timing at each observatory comparing with the hourly-measured “suspended particulate matter” filter tape’s cesium concentrations retrieved by Tsuruta et al. at more than 40 observatories.
The averaged difference of the plume arrival times at 40 observatories between the observational reality and the STD experiment was 82.0 minutes; at this time, the forecast period was 13 hours on average. Meanwhile, The averaged difference of the TEST experiment was 72.8 minutes, which was smaller than that of the STD experiment with a statistical significance of 99.2 %. In summary, the land-surface wind velocity data assimilation improves the predictability of plume advection in the lower troposphere at least in the case of wintertime air pollution over complex terrain. We need more investigation into the data assimilation impact of land-surface weather observations on the predictability of pollutant dispersion especially in the planetary boundary layer.