

Impact of Foehn on generating abnormally high surface air temperatures in the Tokyo metropolitan area -Demonstration experiments-

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The generation of abnormally hot weather is a serious problem in the Tokyo metropolitan area. Fujibe (1998) showed that extremely hot days, which were defined as days when the maximum surface air temperature exceeded 36.0 degreeC, increased after the 1970s in the northern part of the Tokyo metropolitan area, e.g., at Maebashi and Kumagaya. His study and recent reports released by the Japan Meteorological Agency (JMA) indicated that one of the main causes of the increase in the occurrence of extremely hot days is an increase in the occurrence frequency of the pressure distribution that tends to produce a foehn phenomenon in the metropolitan area.

The record-breaking high surface air temperature in Japan, 40.9 degreeC, was observed at Kumagaya city on an extremely hot day, August 16, 2007. This study investigated the impact of the foehn on the generation of abnormally high surface air temperatures on that day. For the investigation, we performed observing systems simulation experiments (OSSEs). OSSEs are defined as a type of sensitivity study. We can examine the impact of the foehn on the generation of the abnormally high surface air temperatures without using real observation data.

First, the abnormally hot weather event on August 16, 2007 was simulated by using WRF (Weather Research and Forecasting) model. Grid point values of the model computed by the simulation were used as 'simulated observations' data. This simulation was carried out with a horizontal grid interval of 3 km and with an initial time at 0900 JST on August 15, 2007. The meso-scale objective analysis data of JMA (JMA-MANAL) were used for the initial and boundary conditions. Subsequently, a control run was carried out by using the WRF model with a horizontal grid interval of 6 km and with an initial time at 0900 JST on August 16, 2007. The global-scale objective analysis data of the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP/NCAR reanalysis data) were used for the initial and boundary conditions. The forecast accuracy of the control run was purposely decreased by using the coarser spatial resolution objective analysis data, the coarser spatial resolution horizontal grids, and the shorter period numerical integration. Also, virtual observation sites were installed at Tokyo, Yokohama, Chiba, Saitama, Mito, Utsunomiya, and Maebashi cities. Wind profilers and temperature profilers such as RASS are useful for observing foehn phenomena that usually expand in vertical direction. It is assumed that remote-sensing observations by using those instruments were conducted at those sites on August 16, 2007. The simulated observation data were used as results of the remote-sensing observations. Vertical profiles of the simulated observations at altitudes below 3.5 km above ground level at 0900 JST on August 16, 2007 were assimilated into an initial field of the control run, and then conducted forecasts. This study classified the experiments into the cases of the assimilation of the vertical profiles of 1) wind data, 2) air temperature data, 3) both wind and temperature data, derived from the simulated observations at a) one of those sites or b) several sites. We examined which of the results of the forecasts at 1400 JST on August 16, 2007 was closest to the simulated observations.

Results of OSSEs demonstrated that northwesterly winds blowing across a mountainous region and high-temperature air associated with the foehn strongly affect the generation of a large area of abnormally high surface air temperatures in the metropolitan area. Also, the results indicated that southerly sea breezes that well develops under cloudless summer sunny days prevent the area of abnormally high surface air temperatures from spreading to the southern part of the metropolitan area. These results indicate that both the foehn and the sea breezes determine where the abnormally high surface air temperatures generate in the metropolitan area.