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Investigation of a recent extreme-high temperature event in the Tokyo metropolitan are using numerical simulations: the potential role of a 'hybrid' foehn wind

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A record-breaking high surface air temperature in Japan of 39.8 ºC occurred at 1420 Japan Standard Time (JST) 24 June 2011 in Kumagaya located 60-km northwest of central Tokyo. This extreme temperature, the third-highest ever recorded in Kumagaya, forced 70 people in the local prefecture to be rushed to hospitals due to heat stroke. The day had westerly winds in the inland area of Tokyo and localized rainfall in the windward direction over the Chubu Mountains. Thus, the extreme high temperature (EHT) may have been influenced by a traditional foehn wind. But, as in Takane and Kusaka (2011), other EHT event occurred in 2007 may have been caused by a complex mechanism involving a combination of several types of foehn winds. Determining the mechanism requires the use of extensive observations and numerical simulations.

The purpose of this study is to clarify quantitatively the mechanism of the EHT event on 24 June 2011, with a particular focus on the possible contributions of several combinations of foehn wind types. The contributions to temperature increase are analysed using a heat budget analysis of the control volume, a backward trajectory analysis, a Lagrangian energy budget analysis, an Eulerian forward tracer analysis, and an analysis of diabatic heating from the surface.

In 2011 EHT event, surface air temperatures exceeding 37.0 ºC were recorded in and around Kumagaya, an area just north of the convergence line between westerly winds from the Chubu Mountains (complex terrains) and southwesterly sea breeze from the Pacific Ocean. To determine the mechanism of this EHT event, we applied various analyses using the Weather Research and Forecasting (WRF) model Version 3.1.1.

The WRF model successfully reproduces the physical features of the wind and temperature distributions and diurnal variations. To quantitatively evaluate the mechanism underlying the temperature change in the mixed layer on high-temperature area, we analyze the heat budget of a control volume. According to this analysis, during the morning most of the sensible heat supply to the mixed layer come from the net heat input, due to surface sensible heat transported by subgrid-scale turbulent diffusion. However, most of the net heat input came from advective heat transport after noon, when the westerly wind penetrated the EHT area.

This westerly wind, according to backward trajectory, Lagrangian energy budget and Eulerian forward tracer analyses, arose from a combination of two kinds of foehn flow ('hybrid'-type foehn wind). Specifically, the westerly wind became a foehn wind that was caused by dry-adiabatic heating and wet-diabatic heating with water vapour condensation. Additional analysis showed that development of the mixed layer in the leeward urban area was a requirement for onset of above 'hybird' foehn wind. This 'hybrid' foehn wind was an important factor in causing the present EHT event and may not have previously been considered as a trigger mechanism for an EHT event.