Foehn-like wind with a traditional foehn effect plus dry-diabatic heating from the ground surface contributing to high temperatures at the end of the leeward area

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Introduction

Extreme high-temperature (EHT) events, including heat waves relating to climate change, have recently occurred frequently in many parts in the world. The EHT events are triggered not only by global and synoptic factors, but also by meso- and micro-scale factors. In geographically complex regions, including near complex terrain, basins, seas, and urban areas, EHTs are influenced by many factors, such as Urban Heat Island, foehn winds, basin effects (including thermally induced local circulations), and sea breezes.

A foehn wind is an important factor in the occurrence of many extreme high-temperature events in geographically complex regions. In this study, we verified the hypothesis that a foehn-like wind contributes to high temperatures at the end of the leeward (eastward) area using three different approaches: field experiments, numerical experiments, and statistical analyses. According to the hypothesis, a foehn-like wind has the features of the sum of a traditional foehn effect with adiabatic heating and dry-diabatic heating from the ground surface along the fetch of the wind.

Field experiment (Observation)

We conducted field experiments at seven points around the Nobi Plain, Japan from 1 to 3 August 2015 to observe surface meteorological elements in the locations at which the mesoscale westerly wind blew over the Nobi Plain. The Mailbara (Ma), Ogaki (Ok), Ichinomiya (Ic), and Tajimi (Tj) stations were located along the track of the mesoscale westerly wind (Route W). In addition, the Motosu (Mo), Kakamigahara (Kg), and Tajimi (Tj) stations were located along the track of the mesoscale northwesterly wind (Route NW).

Diabatic heating derived using a mixed-layer model

To confirm the diabatic heating from the urban surface, the simplified estimate of the effect of this on the potential temperature increase on the leeward area was obtained using a simple mixed-layer model, and the results were compared to the observed potential temperatures.

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Numerical experiment

We used the WRF model to determine (recheck) dry-diabatic heating from the windward ground surface.

Model setting

Field experiment (Observation)

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Statistical analysis

The effect of diabatic heating from the ground surface on air temperature in the leeward area was also assessed by a statistical analysis using observational data, and SWI (soil moisture) data

Graphs showing the effect of diabatic heating from the ground surface on air temperature in the leeward area.

Summary

- Field experiments conducted at seven observational points on Nobi Plain, Japan, where a mesoscale westerly wind blew, revealed that the westerly wind clearly had the features of a traditional foehn effect in the western part of the Nobi Plain.
- In addition to field experiments, a simplified estimate using a simple mixed-layer model demonstrated that the wind was further heated by dry-diabatic heating (sensible heat supply) from the ground surface along the fetch (especially in urbanized areas in the eastern region of the Nobi Plain) of the wind.
- This diabatic heating effect along the fetch of the wind on the high temperature at the end of the leeward area was also supported by both additional numerical experiments and a statistical analysis.

These results proved that the hypothesis is correct and indicated that ground conditions and the land use and land cover (LULC) in the windward area were strongly related to air temperature at the end of the leeward area, where an extremely high temperature was observed.

Map of Japan with the outline of the Nobi Plain and route of the wind.