Geophysical Research Abstracts
Vol. 17, EGU2015-10272, 2015
EGU General Assembly 2015

A theoretical study of urban breeze-mountain wind interactions

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The interactions of urban breeze circulation with mountain slope winds are theoretically examined in a linear system that includes mountain mechanical forcing and non-zero basic-state wind. Flows induced by urban thermal forcing, mountain thermal forcing, and mountain mechanical forcing are linearly superposed. Thermally induced asymmetric circulations in the presence of non-zero basic-state wind result in distinct flow patterns depending on the location of the urban area relative to the mountain area. In the cases of the urban area being located on the downstream of the mountain area, strong positive near-surface horizontal wind induced by urban heating interacts with diverging (converging) flow from the mountain area in the nighttime (daytime). In the cases with the urban area being located on the upstream of the mountain area, strong positive near-surface horizontal wind is restricted in the urban area. Mountain mechanical forcing enhances downslope winds on the both sides of the mountain and updraft (downdraft) upstream (downstream) of the mountain. Sensitivities of the interactions to mountain height and basic-state wind speed are also examined. The vertical flux of horizontal momentum is analyzed by dividing the total momentum flux into five components. While terms that are related to flow induced by urban heating are dominant in the daytime, interaction terms that are related to flows induced by two thermal sources and by thermal and mechanical sources play important roles over the rest of times. Moreover, the total momentum flux is dependent on the location of the urban area relative to the mountain area and basic-state wind speed.