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Boundary layer dynamics in the Grenoble valley during strongly stable and polluted episodes

Yann Largeron, Jean-Pierre Chollet, and Chantal Staquet
LEGI, CNRS & University of Grenoble, Grenoble, France (chantal.staquet@legi.grenoble-inp.fr)

Air pollution in the Alpine environment is a subject of active debate at political and public levels. In a valley environment, the dispersion of pollutants is strongly determined by topographically-driven flows and turbulent mixing induced at the scale of the valley. Also, the interactions between local-scale and synoptic-scale flows can produce complex circulation patterns. Serious air pollution episodes however develop mostly under circumstances whereby the boundary-layer flow is not subjected to any strong synoptic forcing. Such a decoupling often occurs when the boundary layer is capped by an inversion layer and the atmosphere is stably stratified. In this case, the pollutants are confined into the shallow layer up to the inversion level, increasing dramatically near-surface pollutant concentrations. Such a situation occurs mainly in winter and is the focus of the present study, for the Grenoble valley. More specifically, we investigate the boundary layer dynamics in the Grenoble valley for both strongly stable and strongly polluted episodes in winter. Although the Grenoble area is one of the most populated areas in the Alps (with about half a million inhabitants), there has been no detailed study of such situations.

We first analysed ground temperature data at various altitudes from Meteo-France during 5 months (November-March) of winter 2006-2007 to detect strongly stable events. These were defined by the episode-averaged vertical gradient of the absolute temperature being positive, the episode lasting at least 5 days. Five episodes were selected from this criterion, ranging from the beginning of November to the beginning of February.We also analyzed air quality data from the local air quality agency (Atmo Rhône-Alpes) to detect strongly polluted events for PM10 and found that the five episodes were also strongly polluted episodes. We focus our study upon those five strongly stable and strongly polluted episodes. To perform a more detailed analysis, we reproduced their dynamics with the numerical code Meso-NH developed by Meteo-France and the Aerology Laboratory in Toulouse. Four nested domains were used for this purpose, the resolution in the innermost domain (containing the Grenoble valley) being as low as 4 meters above ground level because of the strongly stable stratification (the horizontal resolution is 333 m).

The boundary layer dynamics was found to be decoupled from the (anticyclonic, weak) synoptic flow, as expected. Hence, the wind circulation is local, being due to thermal (katabatic or drainage) winds flowing from the higher altitude valleys which surround Grenoble. Remarkably, the same flow pattern was found in the valley, both horizontally and vertically, during the five episodes implying that this pattern solely depends upon the geometry of the topography once a strong enough thermal inversion has occurred. A detailed analysis of one such episode was therefore conducted, since it is representative of the four others. We thus found that the wind displays a strong vertical veering shear as a result of the superposition of the katabatic winds flowing from the different valleys, which may result in vertical ventilation if shear turbulence occurs in maximum shear regions. Horizontal ventilation occurs in the valley despite of the strong stratification but we also identified many stagnation regions which are critical for air quality.

References

Largeron Y. 2010. Dynamics of the stable atmospheric boundary layer over complex terrain. Application to PM10 pollution episodes in Alpine valleys. PhD thesis (in french), University of Grenoble.