Geophysical Research Abstracts
Vol. 13, EGU2011-8764, 2011
EGU General Assembly 2011

Atmospheric Boundary Layer in a Narrow-Coastal Valley: Modelling Implications

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The atmospheric boundary-layer (ABL) measurements in a narrow, semi-urbanised, coastal valley located in eastern central Italy are discussed in this paper. The interest is conditions of low synoptic forcing, whence thermal circulation dominates and clear transition periods are present. The data were collected during two field campaigns, one in the spring and the other in the summer of 2009 under the aegis of an international study called the 'Biferno Valley Project' coordinated by Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA). A suite of instruments were deployed, including three towers with sonic anemometers, temperature and humidity sensors along the main axis of the valley and an aerosol lidar for boundary-layer height measurements. Wind velocity and turbulence data taken during low synoptic periods display special features that are different from those of typical inland valleys. This is a result of the non-linear interaction between pressure gradients that drive katabatic and anabatic circulation with those associated with sea breeze circulation.

It is observed that morning transition (break-up of the nocturnal stable layer and the start of anabatic flow) is associated with clockwise rotation of winds, followed by initiation of sea breeze that aids the anabatic flow. Pressure gradients associated with urban heat island development intervene with anabatic flow during the afternoon, which complicates the evening transition mechanism and lead to longer transition periods. Continuous measurements of ABL using lidar and sonic anemometers show that its diurnal evolution does not follow the typical trends of successive stable, transition and convective periods. Instead, the ABL undergoes a sharp growth before the noon, followed by a decrease to an essentially constant value that persists till late afternoon. Some previous works have noted that in coastal areas the effect of flow advection from the sea in form of sea breeze inhibits the boundary-layer growth so as to maintain a shallow ABL even in summer days of strong surface heating. Nevertheless, a sharp increase of the ABL height and a decrease thereafter even before peaking of the sensible heat flux has seldom been observed and explained. Some authors (Beare, 2008) have recently showed using Large Eddy Simulations that in early stages of morning transition there is a coupling of stable and convective layers, and that wind-shear plays a key role in the boundary layer growth. Simple analytical models (Martano, 2002) have also shown that the morning increase of ABL can be explained in terms of a fetch change associated with the wind rotation. The increase of turbulence production so introduced supports the hypothesis that wind-shear can be a dominant mixed layer growth mechanism in the early morning. Thus, our observations implicate that when the transition is associated with wind rotation, there can be an additional turbulent kinetic energy generation mechanism that may cause rapid rise of the ABL depth in the morning, which should be taken into account in parameterizations. We note that the boundary-layer parameterisation schemes often switch between a local stable scheme and a non-local convective scheme when the surface heat flux is greater than zero, thus predicting a typical bell-shape distribution of the ABL during the day. Models that do not consider the effects of shear production in convective boundary-layer growth therefore are expected to give erroneous results for the morning ABL growth. This is an important result in air pollution meteorology, given that the air pollutant concentrations are directly related to the ABL height.

Beare, R.J., 2008: The role of shear in the morning boundary layer transition. Boundary-Layer Meteorology, 129, 395-410.

Martano, P., 2002: An algorithm for the time-dependent mixing height in coastal sites. Journal of Applied Meteorology, 41, 351-354.