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Impact of the Rhône and Durance valleys on sea-breeze circulation in the Marseille area

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Abstract

Sea-breeze dynamics in the Marseille area, in the south of France, is investigated in the framework of the ESCOMPTE experiment conducted during summer 2001 in order to evaluate the role of thermal circulations on pollutant transport and ventilation. Under particular attention in this paper is the sea-breeze channelling by the broad Rhône valley and the narrow Durance valley, both oriented nearly-north–south, i.e., perpendicular to the coastline, and its possible impact on the sea-breeze penetration, intensity and depth, which are key information for air pollution issues. One situation of slight synoptic pressure gradient leading to a northerly flow in the Rhône valley (25 June 2001) and one situation of a weak onshore prevailing synoptic wind (26 June 2001) are compared. The impact of the Rhône and Durance valleys on the sea-breeze dynamics on these two typical days is generalized to the whole ESCOMPTE observing period.

The present study shows by combining simple scaling analysis with wind data from meteorological surface stations and Doppler lidars that (i) the Durance valley always affects the sea breeze by accelerating the flow. A consequence is that the Durance valley contributes to weaken the temperature gradient along the valley and thus the sea-breeze circulation. In some cases, the acceleration of the channelled flow in the Durance valley suppresses the sea-breeze flow by temperature gradient inhibition; (ii) the Rhône valley does not generally affect the sea breeze

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significantly. However, if the sea breeze is combined with an onshore flow, it leads to further penetration inland and intensification of the low-level southerly flow. In this situation, lateral constriction may accelerate the sea breeze. Simple scaling analysis suggests that Saint Paul (44.35°N, about 100 km from the coastline) is the lower limit where sea breeze can be affected by the Rhône valley. These conclusions have implications in air quality topics as channelled sea breeze may advect far inland pollutants which may be incorporated into long-range transport, particularly in the Durance valley.

Keywords: Sea breeze; Valley flows; Doppler lidar

1. Introduction

Breeze dynamics has been studied for a long time theoretically, experimentally, and numerically (e.g., Atkinson, 1981 and Simpson, 1994 for reviews). Land/sea-breeze flow is a thermally induced wind due to the differential heating between land and sea. This difference produces a pressure gradient at low-level in the atmosphere and causes the low-level land/sea-breeze circulation. Flows in the breeze cell have a pronounced diurnal cycle: the flow near the surface blows landward during daytime (sea-breeze circulation) and, at night, it sometimes reverses causing an offshore wind, the land breeze, weaker than the sea-breeze flow. The depth of the breeze flow may be less than 50 m at night and it can reach a thousand meters during the day. Typical velocity within this layer is about 5 m s^{-1}. This circulation affects the populations not only living along the coasts but further inland as it can penetrate up to hundred kilometers inland. Theory predicts that, in condition of flat terrain, the sea-breeze direction veers during the day, due to the diurnal oscillation and the earth's rotation. It is then expected to veer clockwise in the Northern hemisphere, but absence of rotation or sometimes anticlockwise rotation can occur in mountainous regions when the breeze flow combines with slope winds (Kusuda and Alpert, 1983; Simpson, 1994).

The topography effects are not limited to the modification of the sea-breeze direction. Banta et al. (1993) who used a Doppler lidar to observe the Monterey bay sea breeze, numbered some differences in sea-breeze characteristics from studies in other areas. They attributed some of these differences to two major topographic effects, slope and valley circulations over the complex terrain. In particular, additional mesoscale simulations by Darby et al. (2002) show that major coastal mountain ridge can affect both low- and upper-level winds and can enhance the depth of the sea-breeze flow but not necessarily its speed.

The understanding of land/sea-breeze flow-related processes is of high importance since breeze circulations are known to contribute significantly to matter and energy transport, and to affect pollution ventilation, species concentration, and inland pollutants transport (e.g., Lyons and Olsson, 1973). For instance, Kolev et al. (1998, 2000), Murayama et al. (1999), and Vijayakumar et al. (1998) assessed the influence of the sea breeze on the properties of aerosols in coastal regions. Clappier et al. (2000) used a differential absorption lidar to monitor ozone concentration vertical profiles in Athens, Greece, during a sea-breeze event. Also in Athens, Klemm et al. (1998) studied summer