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Integrated assessment of air pollution using observations and modelling in Santa Cruz de Tenerife (Canary Islands)

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HIGHLIGHTS

- Integrated assessment of air pollution using observations and modelling
- Santa Cruz de Tenerife is affected by specific pollution episodes.
- Significant emission, meteorological and orographic conditions play a key role.
- The refinery plume plays an important role in the SO_2 levels.
- Particulate matter episodes are caused by intrusions of Saharan dust.

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ABSTRACT

The present study aims to analyse the atmospheric dynamics of the Santa Cruz de Tenerife region (Tenerife, Canary Islands). This area is defined by the presence of anthropogenic emissions (from a refinery, a port and road traffic) and by very specific meteorological and orographic conditions—it is a coastal area with a complex topography in which there is an interaction of regional atmospheric dynamics and a low thermal inversion layer. These factors lead to specific atmospheric pollution episodes, particularly in relation to SO_2 and PM_{10}. We applied a methodology to study these dynamics based on two complementary approaches: 1) the analysis of the observations from the air quality network stations and 2) simulation of atmospheric dynamics using the WRF-ARW/HERMESv2/CMAQ/BSC-DREAM8b and WRF-ARW/HYSPLIT modelling systems with a high spatial resolution (1×1 km^2). The results of our study show that the refinery plume plays an important role in the maximum SO_2 observed levels. The area of maximum impact of the refinery is confined to a radius of 3 km around this installation. A cluster analysis performed for the period: 1998–2011 identified six synoptic situations as predominant in the area. The episodes of air pollution by SO_2 occur mainly in those with more limited dispersive conditions, such as the northeastern recirculation, the northwestern recirculation and the western advection, which represent 33.70%, 11.23% and 18.63% of the meteorological situations affecting the study area in the year 2011, respectively. In the case of particulate matter, Saharan dust intrusions result in episodes with high levels of PM_{10} that may exceed the daily limit value in all measurement station; these episodes occur when the synoptic situation is from the east (3.29% of the situations during the year 2011).

1. Introduction

The impact of air quality on human health has been widely studied (WHO, 2006, 2013). In Europe, atmospheric pollution is regarded as one of the environmental factors that has the greatest impact on human health (EEA, 2005). This conclusion has led to a significant increase and standardisation of network monitoring and modelling techniques for atmospheric pollution. The European Commission has shown great interest in the dynamics and transportation of pollutants to ensure compliance with legislation and to inform the population about pollutant levels (EC, 2008).

The legislation is particularly demanding when air pollution concentrations exceed certain thresholds and limit values, in which case a detailed diagnosis of territorial areas exceeding the pollution levels and a forecast of the evolution of the air quality levels are demanded. The articles 6, 7, 10 and 14 of the 2008/50/CE Directive (EC, 2008) recommend that analyses of air quality levels are supplemented with measurements that are based on the use of modelling techniques or objective estimations to assess the air quality.

The maximum levels and corresponding allowable exceedances that have been established by legislation (EC, 2008) continue to be exceeded in Europe, particularly in Spain (de Leeuw and Vixseboxse, 2010). With

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respect to SO_2, the urban population that is exposed to levels that are higher than the legal limits has declined significantly in recent decades (EEA, 2010). Nonetheless, in the Canary Islands (Fig. 1a), and more precisely in the city of Santa Cruz de Tenerife, SO_2 levels remain high, surpassing legislative limits in 2011. This is the only area in Spain in which the hourly (350 μg m^{-3}) and daily limits (125 μg m^{-3}) are exceeded (MAGRAMA, 2012).

The interaction between the synoptic and local dynamics in areas of complex topography has a significant effect on air quality levels (Baldasano et al., 1994; Perez et al., 2004; Rodriguez et al., 2008; Flocas et al., 2009). The Canary Islands benefit from the dispersion and transport that involve trade winds (Morales and Perez, 2000). However, in the case of Santa Cruz de Tenerife, the combination of anthropogenic emission sources: refinery, port and road traffic, and the Islands' singular meteorological and orographic characteristics lead to specific pollution episodes. Those singular characteristics include the following:

1) The interaction between topography and prevailing winds. At a synoptic level, the prevailing winds in the area are the so-called trade winds, i.e., moderate to strong winds from the northeast. These winds interact with the complex topography of the island of Tenerife (Fig. 1b) (including the Mount Teide (3718 m amsl) in the centre of the island and the mountains of Anaga (992 m amsl) upwind of Santa Cruz de Tenerife (Fig. 1)), which results in the development of geographic effects in the lower layers of the atmosphere (Jorba et al., 2008).
2) The local winds present daily cycles marked by breezes due to the coastal location. This means that, during the day, the sea breeze favours the transport of pollutants from the coast (where the port and refinery are) to the town of Santa Cruz de Tenerife (Rodriguez et al., 2008).
3) The ocean current that bathes the Canary Islands is a cold current (the Canary Current). Therefore, surface air masses are cold and wet, which leads to the presence of thermal inversion approximately between 900 and 1200 m (Cuevas et al., 2012), that hinders convective motions.

Saharan dust intrusions have a strong impact on air quality because of the proximity of the Canary Islands to the African continent (approximately 300 km) and the Azores anticyclone (Córdoba-Jabonero et al., 2011; Alonso-Pérez et al., 2011a, 2011b). The result

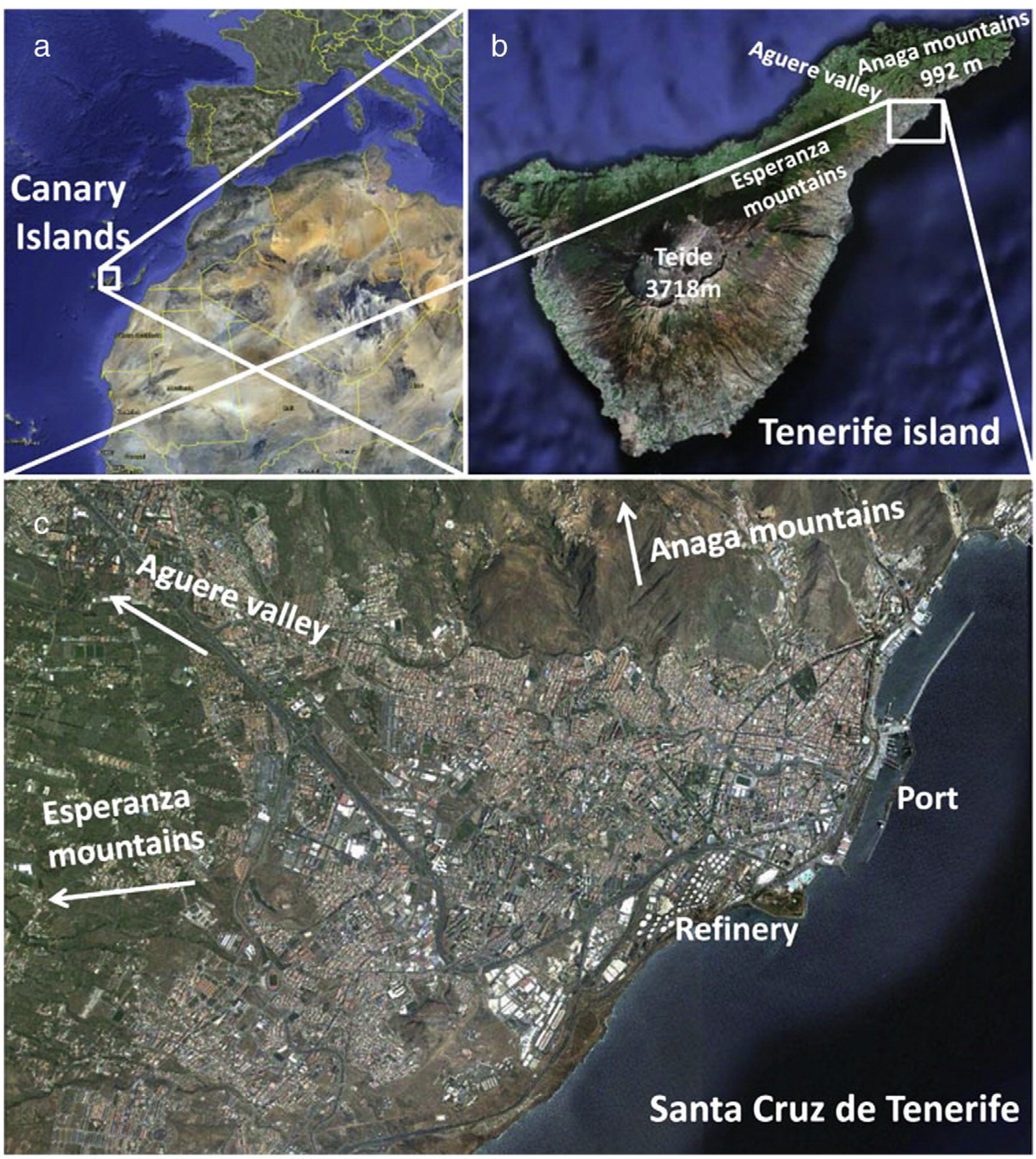

Fig. 1. Location of the Canary Islands (top left) and the major topographical features of Tenerife Island (top right). Details of the study area (5 km radius).