Atmospheric Pollution Research 7 (2016) 1–8

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Atmospheric Pollution Research

journal homepage: http://www.journals.elsevier.com/locate/apr

Original article

Impact of sea-land breezes on ^{210}Pb in southern Iberian Peninsula – Feasibility study on using submicron-sized aerosol particles to analyze ^{210}Pb hourly patterns

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ARTICLE INFO

Article history:
Received 17 February 2015
Received in revised form
22 June 2015
Accepted 23 June 2015
Available online 23 October 2015

Keywords:
^{210}Pb
Accumulation mode particles
Sea-land breezes
Southern Iberian Peninsula

ABSTRACT

This work addresses the impact of mesoscale circulations on ^{210}Pb concentrations in southwestern Iberian Peninsula by analysing the ^{210}Pb database at El Arenosillo station during 2004–2011 (128 periods with a time scale of 48 h).

The analysis of surface winds during each one of these periods has revealed the positive impact of the two sea-land breeze patterns (pure and non-pure), previously identified in this region, on ^{210}Pb activity concentrations. An average value of 0.80 ± 0.09 mBq m^{-3} was obtained for the pure pattern (34 periods), 0.54 ± 0.09 mBq m^{-3} for the non-pure pattern (23 periods) and 0.46 ± 0.04 mBq m^{-3} for the rest (71 periods).

The analysis of one representative period of each sea-land breeze patterns is also presented. To perform this analysis we have used: hourly surface wind observations, surface wind fields simulated by the WRF mesoscale model and the hourly database of sub-micron-particle size range in the accumulation mode (N_{ACC}). The use of this type of particles to investigate the hourly temporal variability of ^{210}Pb is based on the high correlation, obtained in the present work, between ^{210}Pb activity and particles in the accumulation mode ($R = 0.90$).

The analysis reveals that the highest concentrations of N_{ACC}, and hence, ^{210}Pb, are obtained when the sampling area is under the influence of the pure breeze, due to it favours the accumulation of particles previously transported by Mediterranean flows along the Guadalquivir valley. In the case of the non-pure pattern, the increase in the concentration of particles is related to the arrival of background synoptic winds from the continental areas of western Iberian Peninsula. In the latest, the increment of N_{ACC} is faster and around 400 particles cm^{-3}, while in the case of the pure pattern, it is progressive up to 1400 particles cm^{-3}.

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1. Introduction

The natural radionuclide ^{210}Pb (half-life of 22.1 years) is supplied into the troposphere (near the surface level) by the radioactive decay of its precursor ^{222}Rn ($T_{1/2} = 3.8$ days), a noble gas produced from the decay of ^{226}Ra, which in turn belongs to the ^{238}U chain. ^{222}Rn decays through several short-lived daughters to ^{210}Pb and thus, more than 99.9% of the total ^{210}Pb in the atmosphere originates from radon exhaled from continental areas (Rehfeld and Heimann, 1995).

^{210}Pb is routinely measured in many parts of the world and it has been proven to play a key role in the knowledge of the transport, residence time and deposition velocities of aerosols (Baskaran,

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Peer review under responsibility of Turkish National Committee for Air Pollution Research and Control.

http://dx.doi.org/10.1016/j.apr.2015.06.011
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2011). It is also used in several applications, such as, to investigate the atmospheric transport (McNeary and Baskaran, 2003; Salvador et al., 2010) or to test atmospheric models (Liu et al., 2001; Heinrich and Jamelot, 2011).

Due to the usual long-term representativeness of ^{210}Pb values (Lozano et al., 2012), it has been traditionally used in studies of synoptic-scale (Dueñas et al., 2011). This fact prevents obtaining a direct relationship between the occurrence of mesoscale processes and ^{210}Pb activity concentrations. In this sense, the sea–land breeze is a phenomenon widely studied in many regions around the world due to its high influence on local episodes of high pollutant concentrations (Augustin et al., 2006). In the specific case of ^{210}Pb, the limitation of air mass renewal processes associated with this mesoscale pattern can increase its deposition and concentration at ground levels. In this sense, ^{210}Pb and ^{210}Po are the natural radionuclides with the highest contributions to the annual effective dose received by the population for ingestion and inhalation of uranium and thorium radionuclide series, excluding Radon and its short-lived products (UNSCEAR, 2000).

Despite this potential impact, the link between mesoscale circulations and the temporal variability of ^{210}Pb concentrations has not been usually investigated. Hence, the main objective of this work is to infer the influence of sea-land breeze patterns on ^{210}Pb activity concentrations in surface layers. To reach this objective, due to the low time scale of ^{210}Pb samplings (48 h), we have analyzed the hourly impact of sea-land breeze circulations on ^{210}Pb activity concentrations by means the hourly pattern of submicron-sized aerosol particles.

The following research issues are addressed:

- To analyze the impact of sea-land breeze circulations on ^{210}Pb activity concentrations,
- To analyze the potential use of the hourly variation of submicron-particle size range as a tool to study the hourly ^{210}Pb variability,
- To determine the variability of hourly concentration of ^{210}Pb, by means of N_{ACC}, caused by the daily evolution of sea-land breeze circulations.

To achieve these objectives, the database of ^{210}Pb activity concentration collected from July 2004 to July 2011 (128 sampling periods of 48 h) at El Arenosillo station (coastal area in southwesten Iberian Peninsula) has been used. In the first part of the study we focus on the analysis of surface wind patterns during these periods by considering hourly wind series at El Arenosillo (Section 3.1) to statistically quantify the impact of sea-land breezes on 48 h ^{210}Pb values. The second part is dedicated to analyze the correlation between concentrations of ^{210}Pb and particles during the 48 h sampling periods (Section 3.2). To perform this analysis, mean 48 h values of particles were analyzed and correlated with the corresponding 48 h ^{210}Pb values. In the last part, we examine in detail, combining the use of modelled (Weather Research and Forecasting – WRF model, Skamarock et al., 2012) and observed (hourly surface winds and particles) information, the influence of sea-land breezes on the hourly temporal behaviour of N_{ACC} and, hence, on ^{210}Pb activity concentrations (Section 3.3).

2. Materials and methods

2.1. Study area

The study have been carried out at the Atmospheric Sounding Station – El Arenosillo (37.1 N; 6.7 W, 40 m above sea level), belonging to the National Institute for Aerospace Technology and located in the southwest coast of the Iberian Peninsula (Fig. 1a). The observatory is in the coastline (less than 1 km to the Atlantic Ocean), and close to the Mediterranean Sea and the North African continent. It is situated in a protected natural area, known as Doñana National Park. The closest large population centre is the city of Huelva, 26 km to the northwest (Fig. 1a).

According to Hernández-Ceballos et al. (2013a) this area is typically affected by five different air masses: the Arctic, the Tropical, the Polar, the Continental and the Saharan. The most frequent surface wind direction is northeast during the cold season, while in the warm season the arrival of southwest and northwest winds dominates (Hernández-Ceballos, 2011). These directions are associated with the location of El Arenosillo station at the mouth of the Guadalquivir valley, which acts as a natural channel for the transport of air masses along its axis (southwest–northeast). Due to its location and the favourable conditions, sea-land breeze circulations often occur during the whole year, reaching frequencies of up to 35% from June to September (Adame et al., 2010).

2.2. Observational datasets

2.2.1. ^{210}Pb

The whole experimental procedure to measure ^{210}Pb concentrations can be found elsewhere (Lozano et al., 2011, 2012). From

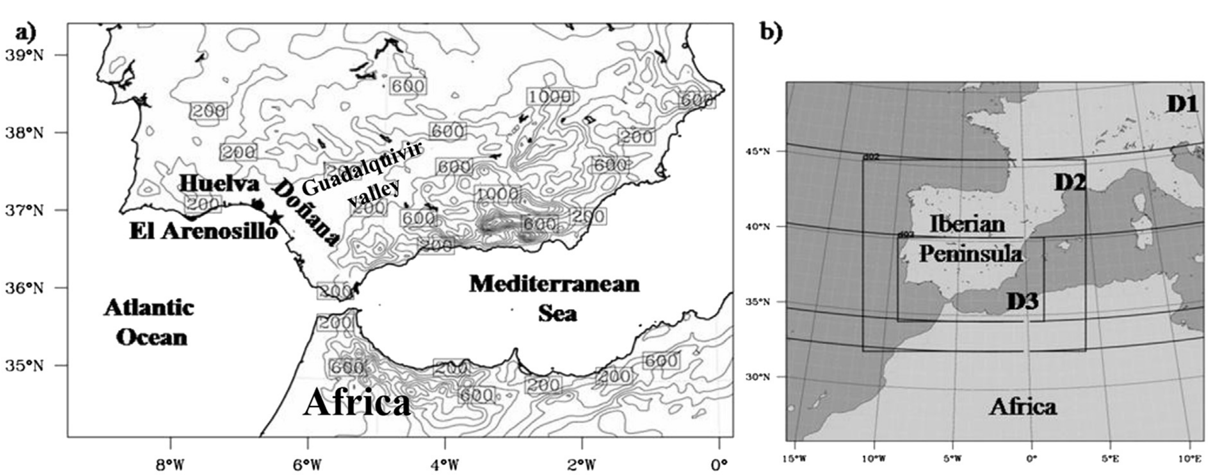

Fig. 1. a) Location of El Arenosillo station in the southwestern Iberian Peninsula with the topography of the inner domain and b) the nest configuration of the three research domains (Lambert Conformal projection) used in the WRF model.

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