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Impact of medium-distance pollution sources in a Galician suburban site (NW Iberian peninsula)

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HIGHLIGHTS

- Airborne quality has not been investigated broadly in this Atlantic region.
- Varimax-rotated scores and ANOVA gave daily, monthly and seasonal differences.
- Pollutants associated to very weak winds were from a nearby residential area.
- Moderate wind speeds showed a combination of urban and industrial sources.
- Maxima and minima of O_3 and nitrogen oxides appeared later than in Mediterranean cities.

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ABSTRACT

This work studies airborne quality in a geographical area that has not been investigated broadly: a suburban site nearby A Coruña (Galicia, NW Iberian Peninsula). In contrast to major Spanish cities, the site has Atlantic characteristics: rainy, scarce calm weather and infrequent prolonged sunny periods. The relationships between several gaseous pollutants (NO, NO_2, NO_x, CO, O_3, PM_{10}, $PM_{2.5}$ and PM_1) and their temporal trends (daily, monthly and seasonal) were evaluated. The aim was to unravel whether medium- and long-distance sources were impacting upon the site. Univariate studies focused on factorizing the pollutants according to a codifying factor (wind direction, hour of the day, season and month). Multivariate studies (Varimax-rotated factorial analysis) were done separately on both weekdays and weekends. The intensity of the daily maxima for NO, NO_2, NO_x and CO was lower during the weekends, with O_3 behaving opposite. PM average values agreed with previous historical reports for a rural background station relatively close to the site and they decreased daily between 11:00 and 19:00 h, likely because of the marine breeze. With moderate wind speeds the pollutants were associated to medium-distance pollution sources, mainly the city of A Coruña and a combination of industrial pollution sources (a power plant, a solid waste incinerator and a regional airport).

1. Introduction

The main driver for air quality improvement in urban and suburban areas is the protection of human health (Bigi and Harrison, 2010) as air pollution may seriously affect it (Ostro et al., 2007; Chen et al., 2010). Adverse effects on respiratory (Damato et al., 2010) and cardiovascular systems (Mills et al., 2009) coming up as acute reduction in lung function, aggravation of asthma, increased risk of pneumonia in the elderly, and low birth weight and high death rates in newborns had been related to airborne pollution (Wilson et al., 2004). In recent years air pollution abatement policy has been informed by the availability of exposure–response functions derived from epidemiological studies of whole urban populations (Bigi and Harrison, 2010).

Public concern on the quality of breathable air rose exponentially in the last years and so did the scientific studies undergone to ascertain (monitor) the presence of pollutants in both the gaseous and particulate phases. As a matter of example (a complete review is out of the scope of this paper) some researches can be outlined. In Spain most previous studies focused on the central and Eastern Spanish regions and much less works were done on the North-Western one. Baldasano et al. (2014) analyzed the atmospheric dynamics of the Santa Cruz de Tenerife region during 2011, in particular of SO_2, NO_2, O_3 PM_{10} and $PM_{2.5}$. Moreno et al. (2009) combined large datasets from monitoring stations at Torrelavega with back-trajectories and other meteorological information to reveal the patterns of, and controls on, short-lived peaks in urban

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background air pollutant concentrations. The evolution of NO, NO_2, SO_2, O_3 and PM_{10} concentrations from 2000 to 2012 at urban, suburban and regional observatories in the Balearic Islands was studied (Cerro et al., 2015). The influence of traffic on PM_{10} and $PM_{2.5}$ in Madrid was studied from 1999 to 2008 (Artiñano et al., 2004), as well as their spatial and temporal variations in the metropolitan area (Salvador et al., 2011). Temporal and geographical patterns of surface O_3 concentrations in Catalonia, along with its correlations with other pollutants (SO_2, H_2S, NO, NO_2, CO and particulate matter) were studied (Felipe-Sotelo et al., 2006). The nitric oxide patterns registered in Catalonia from 2001 to 2006 were analyzed using multivariate data analyses (Alier et al., 2009). The suitability of a number of monitoring techniques was assessed by examining their relation to the different emission sources and/or atmospheric processes affecting the urban Mediterranean area of Barcelona (Pey et al., 2010).

The work from Hellebust et al. (2010) is also of relevance here because it considers a coastal Atlantic site (Cork, Ireland), as well as those from Pires et al. (2008) in Porto and Russo et al. (2014) in Lisbon (Portugal). Long-term trends, annual, weekly and diurnal cycles of air pollutants in central London and their correlation with meteorological variables were assessed (Bigi and Harrison, 2010).

The present work summarizes the results obtained in a first monitoring campaign in the NW region of Spain (A Coruña, Galicia), which has not been investigated broadly. Contrary to major Spanish cities (e.g., Barcelona and Madrid), the site has no Mediterranean or continental climate-type characteristics but Atlantic ones; rainy, without calm weather and scarce prolonged sunny periods. The relationships among several gaseous pollutants (NO, NO_2, NO_x, CO, O_3, PM_{10}, $PM_{2.5}$ and PM_1) and some physical parameters (wind direction, wind speed, air temperature, and rain) were evaluated during 2009 and 2010. Annual, weekly and daily cycles of air pollutants were assessed employing univariate and multivariate statistical approaches.

2. Experimental

2.1. Samples

The sampling station is located in a suburban emplacement (43° 20′ 14″ N, 8° 21′ 7″ O, Lians, Oleiros) close to a medium-size city (A Coruña, Galicia, NW Iberian peninsula; ca. 250,000 inhabitants within the city, plus 250,000 ones in the surrounding metropolitan area). The station is in an open parcel surrounded by small forests, 5 km off the city of A Coruña and also close to the sea (ca. 500 m). The site is influenced by (Fig. 1): a nearby road (500 m, NNW), with medium-high traffic density (ca. 25,000 vehicles per day) during rush hours and, most notably, during summer as it drives to some popular beaches; a power station (Meirama, 25 km SSW); a solid waste incinerator (25 km SSW); an airport (6 km SSW); a power station (As Pontes, 60 km NNE); a petrochemical refinery (10 km W); a harbor (4 km NNW); the city of A Coruña and two small industrial zones (Sabón and A Grela-Pocomaco) (ca. 10 km, WNW and W).

The area of A Coruña has an Atlantic climate, with rain events spread throughout the whole year which yielded a total annual precipitation (for 2009 and 2010) around 1000 mm (Aemet, 2014), spread throughout the whole year though less frequent in summer (July–September, 148.8 mm in 2009 and 74.2 mm in 2010). The region is often overcast, with moderate-strong winds from the Atlantic depression. In autumn and winter the winds blow predominantly from the South whereas in spring/summer they blow from the North. In general, winds are weaker during the night than during the day, with maximum values around noon.

The station measured gaseous pollutants (NO_x, SO_2, CO and O_3), particulate matter (PM_{10}, $PM_{2.5}$ and PM_1) and recorded meteorological parameters (temperature, relative humidity, solar radiation, pressure, rainfall, wind speed and wind direction) real-time. The analysis methods are the reference ones according to the Spanish legislation (RD 102/2011, 2011), although PM_1 has no specific legislation. Continuous measurements of PM_1 were performed using a GRIMM 1107 laser spectrometer and corrected when necessary with simultaneous 24 h gravimetric measurements. SO_2 was not considered here because it had too many missing values due to several instrumental faults.

2.2. Chemometric methods

The dataset was composed of hourly averages (from January, 2009 to December, 2010) of the measured parameters and only complete records were considered for statistical data analysis. Note that every reference to the hours through this paper corresponds to UTC (Coordinated Universal Time). Suspicious samples were assessed by a preliminary PCA (Principal Components Analysis). Up to 38 samples had an outlying behavior; 18 corresponded to the nigh of St John the Baptist (23rd of June; a worldwide festivity that welcomes the summer solstice in the Northern hemisphere; and whose celebration in Galicia involves lightening thousands of fires). Finally, 3260 samples (from 2009 (2322 weekdays and 938 weekends)) and 4975 ones from 2010 (3595 weekdays and 1380 weekends) were considered.

2.2.1. Univariate analysis

Traditional statistics (average, standard deviation and median) were calculated for the overall data set as an exploratory approach. A one-way analysis of variance (ANOVA) was performed on each variable considering hour, week and month to ascertain whether they caused statistical differences between samples (95% confidence).

2.2.2. Factorial analysis

Principal Components Analysis (PCA) is the most important and widely used multivariate statistical technique in atmospheric sciences (Rousi et al., 2015). In brief, PCA summarizes the variability of a given dataset through a few orthogonal variable-related patterns, called loadings, and a set of corresponding sample-related values, called scores.

The environmental interpretation of the principal components, PCs, may be difficult because all the analytical variables participate in the mathematical definition of each PC. Hence, to simplify their interpretation it is desirable to have only a few high loadings (close to unity) and many loadings equal (or close) to zero. This was addressed by Kaiser in 1958 (Reyment and Jöreskog, 1993) by developing Varimax (variance maximization) rotation. The final PCs (or factors) are still orthogonal so that they can be interpreted independently. Accordingly, the samples become described mostly by a few original variables. Other advanced techniques consider positive matrix factorization (Paatero, 1997) or constrained PCA (Felipe-Sotelo et al., 2006) but they were not considered here.

2.3. Software

Statgraphics Centurion XV (Statpoint Technology, Inc.) was employed. Openair (Carslaw and Ropkins, 2012) was used to visualize pollutants as a function of wind speed/direction.

3. Results and discussion

3.1. Univariate studies

The overall mean concentrations obtained for NO (2.5 $\mu g\ m^{-3}$), NO_2 (9.3 $\mu g\ m^{-3}$), NO_x (12.8 $\mu g\ m^{-3}$) and CO (0.1 $\mu g\ m^{-3}$) were low when compared to Barcelona (Spain) (Pey et al., 2010) and an Atlantic suburban background station at Porto's metropolitan area (Portugal) (Pires et al., 2008). The low average values measured in our sampling site can be explained by the absence of a major industrial area in the close vicinity of the site, its suburban characteristic and the indirect impact of road traffic, the most relevant source for NO_x (Dongarrà et al., 2010; Im et al., 2013).