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Effects of teleconnection patterns on the atmospheric routes, precipitation and deposition amounts in the north-eastern Iberian Peninsula

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HIGHLIGHTS

- WeMO index better describes winter precipitation in the NE Iberian Peninsula than NAO.
- Element deposition was correlated with NAO and WeMO depending on air provenance.
- Few studies have analyzed the relationship between rain chemistry vs. NAO and WeMO.

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ABSTRACT

The North Atlantic Oscillation (NAO) has been identified as one of the atmospheric patterns which mostly influence the temporal evolution of precipitation and temperature in the Mediterranean area. Recently, the Western Mediterranean Oscillation (WeMO) has also been proposed to describe the precipitation variability in the eastern Iberian Peninsula. This paper examines whether the chemical signature and/or the chemical deposition amounts recorded over NE Iberian Peninsula are influenced by these climatic variability patterns. Results show a more relevant role of the WeMO compared to NAO in the deposition of either marine (Cl^-, Na^+, Mg^{2+}) or anthropogenic pollutants (H^+, NH_4^+, NO_3^- and SO_4^{2-}). A cluster classification of provenances indicated that in winter (December to March) fast Atlantic air flows correspond to positive WeMO indices, while negative WeMOi are associated to Northeastern and Southwestern circulations. The negative phase of WeMO causes the entry of air masses from the Mediterranean into the Iberian Peninsula, that are enriched with marine ions and ions of anthropogenic origin (NH_4^+, NO_3^- and SO_4^{2-}). For these later, this suggests the advection over the Mediterranean of polluted air masses from southern Europe and the scavenging and deposition of this pollution by precipitation during the WeMO negative phases. This will carry transboundary pollutants to the NE Iberian Peninsula. However, local pollutants may also contribute, as precipitation events from the Mediterranean and the Atlantic (associated to both WeMO phases) may incorporate emissions that accumulate locally during the winter anticyclonic episodes typical of the region.

1. Introduction

The chemical composition of precipitation is strongly influenced by the predominant atmospheric transport patterns, which affect the scavenging of pollutants depending on the pollution climate encountered. Also, the precipitation amount is important as it influences the dilution and amount of pollutants. The Iberian Peninsula (IP) is located in the south-western corner of the European continent, with the Atlantic Ocean to the west and the Mediterranean to the east, the industrialised Europe to the north and the arid Africa to the south, thus it is in a crossroads influenced by pollutant sources differing strongly in strength and character, which will affect the precipitation chemistry. The levels of atmospheric particulate matter (PM) in this area and its chemical composition has been shown to depend on the origin of air masses (Pérez et al., 2008; Querol et al., 2009; Pey et al., 2009, 2010; Cusack et al., 2012) and the chemical composition of precipitation as well (Àvila and Alarcón, 1999, 2003; Izquierdo et al., 2012). African

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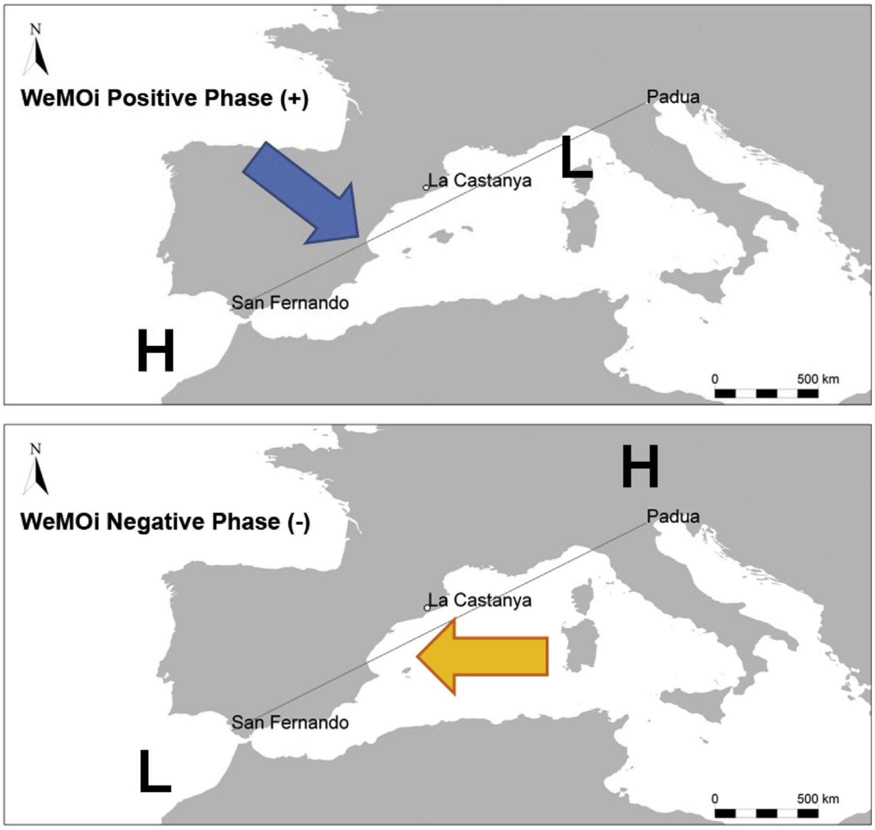

Fig. 1. Location of La Castanya study site (LC) and WeMO phases.

events have been found to be related with the specific position of cyclonic lows in the western or southern flank of the IP or the permanence of high pressures over North Africa in summer (Escudero et al., 2005, 2011). A higher contribution of African precipitation events for particular years significantly affects the acidity/alkalinity balance of precipitation and the contribution of crustal components (Àvila et al., 1997, 2007; Àvila and Rodà, 2002; Pulido-Villena et al., 2006; Morales-Baquero et al., 2013). Furthermore, the region is subject to a large load of anthropogenic emissions from the intense activity of large cities such as Marseille, Barcelona and Tarragona and their industrial surroundings and of the heavy traffic along the eastern coast of IP. The pollutant climate in this area is further modulated by a marked seasonality. In winter, the frequent entry of Atlantic relatively clean air fluxes induces the replacement of air masses, thus reducing the levels of atmospheric pollutants that may have accumulated during periods of anticyclonic stability (Rodríguez et al., 2003; Escudero et al., 2007). In contrast, the synoptic scenario in summer is characterised by very weak pressure gradients in the western Mediterranean which produce local circulations enhancing the regional accumulation of pollutants (Millán et al., 1991, 1997; Rodríguez et al., 2003).

In the Mediterranean area, a year to year variability in the amount of precipitation (Xoplaki et al., 2004; Lionello et al., 2006; Mariotti and Dell'Aquila, 2012) and dust transport (Moulin et al., 1997; Gionux et al., 2004; Pey et al., 2013) has been related to the atmosphere–ocean interaction defined as the North Atlantic Oscillation (NAO). The NAO strongly influences the atmospheric circulation and the hydrological cycle in the Northern hemisphere (Hurrell, 1995; Wallace, 2000; Hurrell et al., 2004; Hurrell and Deser, 2010). An intensification of NAO (producing more westerly winds across the North Atlantic and into Eurasia) has been observed over the past few decades (Hurrell, 1995). This intensification would bring an increase in precipitation in mid-latitude zones in Europe. Although many models suggest that such a change might be the result of anthropogenic greenhouse warming (Carnell and Senior, 2002; Zhang et al., 2007; Min et al., 2011), most models seem to underestimate the magnitude of this circulation change in central Europe (Gillett et al., 2005). In the Mediterranean, Barkhordarian et al. (2013) indicate that changes in atmospheric greenhouse gas and sulphate concentrations are not the dominant forcing process affecting precipitation changes in this area. Additional anthropogenic forcing agents potentially have a larger effect on regional scale precipitation. The emission of aerosols related to traffic and industry and/or forcing from land-use changes such as deforestation are missing in current climate models and need to be incorporated.

Recently, the Western Mediterranean Oscillation (WeMO) climatic variability has been proposed to describe the synoptic framework of the western Mediterranean basin (Martín-Vide and Lopez-Bustins, 2006). The WeMO index is calculated as the difference between the standardised surface pressure values recorded at Padua (45.40°N, 11.48°E) in northern Italy, an area with a relatively high barometric variability due to the influence of the central European anticyclone, and San Fernando (Cádiz) (36.28°N, 6.12°W) in south-western Spain, an area often influenced by the Azores anticyclone (Fig. 1). This regional pattern strongly determines the variability of rainfall in the eastern façade of the IP (Martín-Vide and Lopez-Bustins, 2006; Gonzalez-Hidalgo et al., 2009). As in most of the variability patterns of the Northern Hemisphere, WeMO shows its most relevant dynamics during the winter (Martín-Vide and Lopez-Bustins, 2006). The WeMO positive phase has been shown to trigger air masses from the Atlantic to move into the IP, while its negative phase is associated to flows from the Mediterranean (Martín-Vide and Lopez-Bustins, 2006; Lopez-