Science of the Total Environment 532 (2015) 771–779

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Is long range transport of pollen in the NW Mediterranean basin influenced by Northern Hemisphere teleconnection patterns?

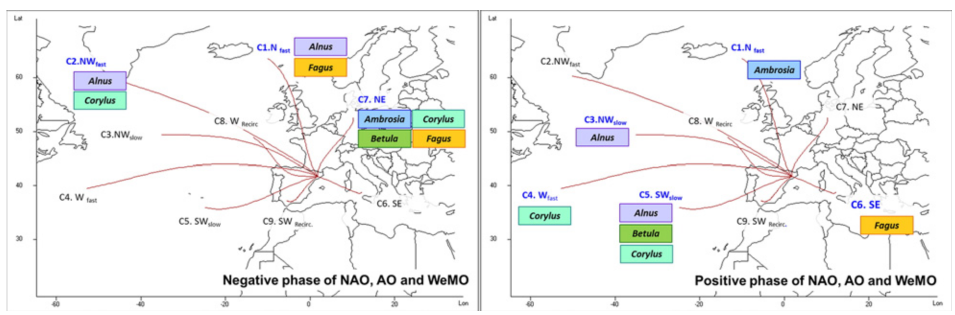
Rebeca Izquierdo [a,*], Marta Alarcon [a], Cristina Periago [a], Jordina Belmonte [b,c]

[a] Departament de Física i Enginyeria Nuclear, Universitat Politècnica de Catalunya, C/Urgell 187, 08036 Barcelona, Spain
[b] Institut de Ciencia i Tecnología Ambientals (ICTA), Universitat Autònoma de Barcelona (UAB). Edifici C, 08193 Bellaterra, Spain
[c] Departament de Biologia Animal, Biologia Vegetal i Ecologia, Universitat Autònoma de Barcelona (UAB). Edifici C, 08193 Bellaterra, Spain

HIGHLIGHTS

- Teleconnection patterns influence atmospheric circulation in Mediterranean basin.
- Effects of climatic variability on airborne pollen transport were examined.
- Pollen transport from Europe was related with negative NAOi, AOi and WeMOi.
- Pollen transport from S and W Europe was linked with positive AOi and WeMOi.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 8 April 2015
Received in revised form 3 June 2015
Accepted 13 June 2015
Available online 27 June 2015

Editor: D. Barcelo

ABSTRACT

Climatic oscillations triggered by the atmospheric modes of the Northern Hemisphere teleconnection patterns have an important influence on the atmospheric circulation at synoptic scale in Western Mediterranean Basin. Simultaneously, this climate variability could affect a variety of ecological processes. This work provides a first assessment of the effect of North Atlantic Oscillation (NAO), Arctic Oscillation (AO) and Western Mediterranean Oscillation (WeMO) on the atmospheric long-range pollen transport episodes in the North-Eastern Iberian Peninsula for the period 1994–2011. *Alnus*, *Ambrosia*, *Betula*, *Corylus* and *Fagus* have been selected as allergenic pollen taxa with potential long-range transport associated to the Northern Hemisphere teleconnection patterns in the Western Mediterranean Basin. The results showed an increase of long range pollen transport episodes of: (1) *Alnus*, *Corylus* and *Fagus* from Western and Central Europe during the negative phase of annual NAO and AO; (2) *Ambrosia*, *Betula* and *Fagus* from Europe during the negative phase of winter WeMO; (3) *Corylus* and *Fagus* from Mediterranean area during the positive phase of the annual AO; and (4) *Ambrosia* from France and Northern Europe during the positive phase of winter WeMO. Conversely, the positive phase of annual NAO and AO are linked with the regional transport of *Alnus*, *Betula* and *Corylus* from Western Iberian Peninsula. The positive phase of annual WeMO was also positively correlated with regional transport of Corylus from this area.

1. Introduction

The atmospheric dynamics in the Western Mediterranean Basin is conditioned by complex interactions of climatic and topographic factors (Millán et al., 1997; Rodríguez et al., 2003; Ulbrich et al., 2012). Indeed,

* Corresponding author.
E-mail address: rebeca.izquierdo@upc.edu (R. Izquierdo).

http://dx.doi.org/10.1016/j.scitotenv.2015.06.047
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the Mediterranean region is among the "Hot Spots" likely to experience major climatic changes in the twenty-first century as a result of the global increase in greenhouse gas concentrations (Giorgi, 2006; IPCC, 2007). Changes in naturally-occurring patterns or "modes" of atmospheric and oceanic variability such as the North Atlantic Oscillation (NAO), the Arctic Oscillation (AO), and the Western Mediterranean Oscillation (WeMO) have an important influence on the temporal variability of atmospheric circulation at synoptic scale and rainfall in Western Mediterranean Basin (Goodess and Jones, 2002; Dünkeloh and Jacobeit, 2003; Martín-Vide and Lopez-Bustins, 2006). Concretely, the Iberian Peninsula, and particularly its Mediterranean fringe, is an area of confluence of several atmospheric patterns acting synchronically with different intensity and effects on precipitation (Gonzalez-Hidalgo et al., 2009; Izquierdo et al., 2014).

At the same time, there is a growing appreciation that changes in the frequency and amplitude of modes of climate variability profoundly influence a variety of ecological processes determining both species density and distribution in a wide range of terrestrial ecosystems (Ottersen et al., 2001; Stenseth et al., 2002; Mysterud et al., 2003; Straile and Stenseth, 2007). Many studies point out the role of phenology as one of the most important bio-indicators to study the direct impact of global change on different species, both at temporal and spatial levels (Menzel et al., 2006; Jochner and Menzel, 2015). In this context, the pollen content in the air offers a quantitative variable to measure the flora phenology and abundance of anemophilous plants.

A lengthening of the active growing season in Europe has been related to increases in winter and spring temperatures, which may in turn be associated with strongly positive indices of NAO (Marshall et al., 2001; Ottersen et al., 2001). The NAO influence on the timing and severity of pollen season has also been detected on different pollen taxa in Northern and Central Europe (D'Odorico et al., 2002), including allergenic pollen as *Betula* and Poaceae (D'Odorico et al., 2002; Stach et al., 2008a,b). However, a NW–SE gradient of spatial differences in the amount of influence exerted by NAO on the timing and magnitude of Poaceae pollen season has been identified in Europe (Smith et al., 2009). Then, the weakest relationship between start dates of Poaceae pollen season and winter averages of the NAO were seen at southern Iberian Peninsula (Smith et al., 2009). Despite the feeblest influence of NAO in the Mediterranean area, the start and the end of pollen season, as well as the peak day of Cupressaceae pollen concentration, were related with phases of NAO in central Italy (Dalla Marta et al., 2011). In addition, a recent study carried on NE Iberian Peninsula showed that years of positive phases of NAO, AO and WeMO indices involved a decrease of annual pollen index, and, at the same time, an advance and enlargement of pollination season for most of 22 pollen taxa considered of high interest due to the abundance, landscape importance and/or allergenic significance in the Western Mediterranean Basin (Izquierdo et al., under review).

Taking into account that airborne pollen concentrations depend both on local flora and atmospheric transport from distant regions, the study of airborne pollen transport may help to comprehend pollen count variations and more accurately predict its atmospheric concentrations (Damialis et al., 2005; Prank et al., 2013). The computation of backward trajectories through the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler et al., 2009) is broadly used to explain atmospheric transport of pollen (Smith et al., 2008; Skjøth et al., 2009; Izquierdo et al., 2011; Zemmer et al., 2012). Cluster analysis has been widely used to categorize back trajectories (Dorling and Davies, 1995; Jorba et al., 2004; Markou and Kassomenos, 2010) and to identify synoptic weather regimes and long-range transport patterns that affect air quality (Cape et al., 2000; Salvador et al., 2007; Valenzuela et al., 2012). Recently, this procedure has been also used for interpreting airborne pollen levels (Makra et al., 2010; Hernández-Ceballos et al., 2011, 2014).

According to the spatial variations observed, further research is necessary to well-understand the influence of NAO and other atmospheric teleconnection patterns on production, release, dispersal and transport of pollen at regional scale, specially the effects on allergenic pollen. The hypothesis of this study is that long range transport (LRT thereafter) of pollen can be partly explained as an effect of the Northern Hemisphere teleconnection patterns. Therefore, the aim here is to study the influence of the main circulation patterns as represented by North Atlantic Oscillation (NAO), Artic Oscillation (AO) and Western Mediterranean Oscillation (WeMO) on 5 pollen taxa with potential LRT collected at 6 localities in Catalonia (NE Iberian Peninsula) during the 18-years period 1994–2011, in order to determine a possible increase of LRT episodes of pollen associated to climate variability which could affect allergenic diseases and the public health.

2. Data & methodology

2.1. Pollen records

Airborne pollen data were recorded by the Aerobiological Network of Catalonia at six stations located in: Barcelona (BCN), Bellaterra (BTU), for the 18-year period 1994–2011, and Girona (GIC), Lleida (LLE), Manresa (MAN), and Tarragona (TAU) for the 16-year period 1996–2011 (Fig. 1). Samples were obtained daily from Hirst samplers (Hirst, 1952), the standardized method in European aerobiological networks, and analyzed following the standardized Spanish method (Galán Soldevilla et al., 2007). The daily pollen concentrations for 5 pollen taxa considered of potential LRT in the Western Mediterranean Basin (Belmonte et al., 2000, 2008a,b; Fernández-Llamazares et al., 2012) have been used: *Alnus*, *Ambrosia*, *Betula*, *Corylus* and *Fagus*. These pollen taxa are regarded of high interest due to their allergenic significance, excepting *Fagus* (Skjøth et al., 2012).

The airborne pollen season has been calculated as the period between the date when the sum of daily mean pollen concentrations reaches 2.5% of the total annual sum and the date when the sum reaches 97.5%; i.e., the time with 95% of the whole pollen amount (Andersen, 1991; Torben, 1991). The seasonal pollen index (SPI) was the sum of the daily pollen concentrations recorded during this period.

2.2. Trajectory computation and cluster analysis

A daily analysis was undertaken based on 96-h isosigma back-trajectories at 12:00 h UTC and 1500 m.a.s.l. at Manresa station, considered by its situation as representative of the synoptic scale circulation features of the Catalan area, by using the HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) 4.0 dispersion model from the Air Resources Laboratory (ARL, available at http://www.arl.noaa.gov/ready/hysplit4.html, Draxler and Rolph, 2003). This height can be taken as representative of the mean atmospheric transport at a synoptic scale within the upper boundary layer (Izquierdo et al., 2014). The meteorological input was obtained from the NCEP (National Center for Environmental Prediction) using the ARL reanalysis database for the 1994–1996 period, the FNL archive for the 1997–2005 period, and the GDAS (Global Data Assimilation System) database for the 2006–2011 period.

Cluster analysis statistically aggregates observations into groups so that each of them is as homogeneous as possible with respect to the clustering variables (Sharma, 1996). To compose each cluster, HYSPLIT has a grouping module based on variations in the total spatial variance between different clusters which is compared to the spatial variance within each cluster component. The final number of clusters is determined by a change in total spatial variance as clusters are iteratively paired (Draxler et al., 2009). This statistical methodology was applied to daily back-trajectories for the period from 1994 to 2011 with the aim to analyze the main atmospheric circulation patterns. The 24 h-time interval was used (thus 4 coordinates each back trajectory of 96-h) to conduct the cluster analysis in a single run.