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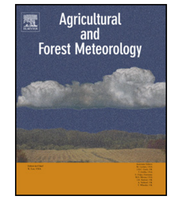

A mechanism for long distance transport of *Ambrosia* pollen from the Pannonian Plain

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ABSTRACT

The pollen grains of ragweed are important aeroallergens that have the potential to be transported long distances through the air. The arrival of ragweed pollen in Nordic countries from the Pannonian Plain can occur when certain conditions are met, which this study aims to describe for the first time. Atmospheric ragweed pollen concentrations were collected at 16 pollen-monitoring sites. Other factors included in the analysis were the overall synoptic weather situation, surface wind speeds, wind direction and temperatures as well as examining regional scale orography and satellite observations. Hot and dry weather in source areas on the Pannonian Plain aid the release of ragweed pollen during the flowering season and result in the deep Planetary Boundary Layers needed to lift the pollen over the Carpathian Mountains to the north. Suitable synoptic conditions are also required for the pollen bearing air masses to move northward. These same conditions produce the jet-effect Kosava and orographic foehn winds that aid the release and dispersal of ragweed pollen and contribute towards its movement into Poland and beyond.

1. Introduction

IgE-associated allergic diseases are a global health problem that is increasing in prevalence and severity (Bousquet et al., 2011). Exposure to aeroallergens is associated with two principal allergic diseases that are closely related: allergic rhinitis (hay fever) and asthma (Demoly and Bousquet, 2006; Tan and Corren, 2011). Allergic rhinitis and asthma significantly reduce quality of life and have a significant economic impact on society (Bousquet et al., 2001). The pollen grains of ragweed (*Ambrosia* spp.) are important aeroallergens (Ziska et al., 2011). The prevalence of sensitisation to ragweed is increasing in Europe and reflects the spread of ragweed plants (Burbach et al., 2009). Ragweed pollen grains can be transported large distances when conditions are favourable (Cecchi et al., 2006, 2007; Stach et al., 2007; Smith et al., 2008; Šikoparija et al., 2009), although the clinical impact of the long distance transport (LDT) of allergenic ragweed pollen remains unclear (Cecchi et al., 2010). When examining the atmospheric transport of pollen, the size of the source is an important consideration; larger sources produce more pollen and thereby increase the likelihood that it will travel long distances (Rieger et al., 2002; Stokstad, 2002). The Pannonian Plain (PP) is the largest documented source of ragweed pollen in Europe (Skjøth et al., 2010, 2013), covering approximately 3.156×10^5 km^2. However, it is suggested that Ukraine and European Russia could also be a notable, if not the largest, source of ragweed pollen in Europe (Reznik, 2009) and play an important role in the LDT of ragweed pollen to several European regions (Kasprzyk et al., 2011; Zemmer et al., 2012). It is likely that this can have an impact as far away as Scandinavia. A number of studies using back-trajectory analysis for investigating regional scale or LDT of

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Table 1
Airborne pollen sampling stations, the maximum daily average ragweed pollen concentration recorded during the episode and contribution of the pollen recorded during the episode (27–28 August) to the annual ragweed pollen catch in 2011. The six letter code for each station is taken from the European Aeroallergen Network database (https://ean.polleninfo.eu/Ean/en/start).

Country	Station	EAN code	Lat (N)	Long (E)	Maximum daily average concentration ($P\,m^{-3}$)	Contribution to the annual pollen catch (%)
Serbia	Nis	RSNIS1	43.31	21.92	643	7
	Smederevo	RSSMED	44.66	20.93	872	25
	Zrenjanin	RSZREN	45.37	20.39	469	12
	Novi Sad	RSNOVI	45.25	19.85	510	12
	Sombor	RSSOMB	45.77	19.11	747	21
Poland	Poznan	PLPOZ1	52.42	16.88	122	52
Sweden	Malmö	SEMALM	55.59	13.00	7	70
	Nässjö	SENAES	57.66	14.70	17	100
	Göteborg	SEGOET	57.72	12.05	5	56
	Västervik	SEVAES	57.75	16.63	50	98
	Jönköping	SEJOEN	57.77	14.18	14	93
	Norrköping	SENORR	58.57	16.18	41	90
	Stockholm	SESTOC	59.37	18.05	29	87
	Eskilstuna	SEESKI	59.37	16.53	36	100
	Borlänge	SEBORL	60.48	15.40	20	94
Denmark[a]	Copenhagen	DKCOPE	55.72	12.57	–	–

[a] No airborne ragweed pollen grains were recorded.

ragweed pollen during specific episodes have implicated the PP as the possible source area (Cecchi et al., 2006, 2007; Stach et al., 2007; Smith et al., 2008; Šikoparija et al., 2009). The LDT of ragweed pollen to Sweden is not a frequent occurrence (Dahl et al., 1999), and it can therefore be speculated that the arrival of noteworthy ragweed pollen concentrations in Sweden (>10 ragweed pollen grains/m^3 daily average) is only possible if certain conditions are met. This is the first study to describe the conditions required for the LDT of ragweed pollen from the PP to Nordic countries, using an episode of ragweed pollen recorded in Sweden on the 27–28 August 2011 as an example.

2. Materials and methods

2.1. Pollen data

Atmospheric ragweed pollen concentrations were collected at 16 sites (Table 1, Fig. 1) by volumetric spore traps of the Hirst design (Hirst, 1952) and analysed using methods that are internationally recognised and shown to produce comparable results (Cariñanos et al., 2000). Daily average (00:00–24:00 h) ragweed pollen counts and diurnal variations (2-h counts) are expressed as particles per cubic metre of air ($P\,m^{-3}$) (Comtois, 1998).

2.2. Meteorological data

The overall synoptic weather situation was investigated using analysed weather maps from the UK Met Office and exchanged under the World Meteorological Organisation (WMO) World Weather Watch Programme and represents the synoptic situation at 00 UTC each day. Wind speed, wind direction and surface temperatures were obtained from the European Weather Observational network and delivered by http://www.wetterzentrale.de. Satellite pictures from the MSG satellite taken at 12UTC and delivered by Karlsruhe University were analysed for possible cloud forming structures over the mountains surrounding the PP. The depth of the Planetary Boundary Layer (PBL) during the main emission period for ragweed pollen has been estimated using meteorological calculations from the GDAS dataset (see Section 2.4). Bi-hourly values of the PBL for each site are found in Table S2 in the supplementary information. Observations of wind speeds with 6 h resolution (Table S3) were available from four sites in Serbia – an area that is exposed to the Kosava. These values are accompanied with an animation that shows the direction and strength of observed wind speeds in Europe during the period 24–29 August (Animation S1).

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.agrformet.2013.05.014.

2.3. Orography data

The regional scale orography are analysed in 3D using the software ArcScene from ESRI using two high resolution Digital Elevation Models (DEM): (1) a DEM that is based on observations from the Aster Satellite – the ASTER Global DEM V001 is a product of METI and NASA, (2) a DEM from the CGIAR-CSI SRTM Database (http://srtm.csi.cgiar.org.) with spatial resolutions of 30 m and 90 m, respectively. The regional topography in 3D, surface winds and surface temperatures are analysed in combination with the satellite observations over the PP area to identify possible orographic induced forcing of air flow that affects release and dispersal of ragweed pollen in the atmosphere.

2.4. Air mass trajectory calculations – forward and backward

In the trajectory analysis, backward trajectories (Fig. 2B and D) are used to show the path taken by air masses as they approached source areas, and thereby describe potential mechanistic properties of air masses, such as dry air due to foehn effects and increased wind speeds due to channel effects. Forward trajectories (Fig. 2A and C) are used to show where ragweed pollen travelled to after being released from known ragweed source areas. Air mass trajectory calculations were based on meteorological calculations from the GDAS reanalysed meteorological dataset with 3 h temporal resolution and 1° spatial resolution in combination with the HYSPLIT trajectory model (Draxler and Hess, 1998). There is a definite diurnal periodicity in *Ambrosia artemisiifolia* flowering (Bianchi et al., 1959), with peak atmospheric concentrations of *Ambrosia* pollen at the source being recorded from ~06:30 to around midday (Ogden et al., 1969). For this reason, trajectories were calculated 72 h backwards and 96 h forwards for the heights 500 m, 1000 m and 1500 for each 2 h interval during the flowering time for ragweed. Dispersal and uncertainty in the trajectory calculations are examined