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Prevailing surface winds in Northern Serbia in the recent and past time periods; modern- and past dust deposition

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A B S T R A C T

This study utilizes four different methodological approaches to examine the prevailing surface winds and their associated aeolian processes in Northern Serbia, focusing on the southeastern part of the Carpathian Basin. We utilized wind and atmospheric pressure data from 1939–2014 and 1960–2010 for the climatological analyses. Geomorphological data and numerical simulations were used to estimate prevailing paleowind systems. Northern Serbia is currently dominated by surface winds coming from the fourth (270°–360°) and second (90°–180°) quadrants, with frequencies of ca. 116 and 105 days/year, respectively. Comparable frequencies within Banatska Peščara are 115 and 129 days/year, respectively. Crestal orientations of the vast majority of the ≈1300 parabolic dunes here suggest that they have formed from winds derived from the second quadrant, indicating formation during the early Holocene. The remaining dunes, of the transverse type, have orientations aligned to the third quadrant. Grain size analysis of loess deposits near Banatska Peščara points to deposition driven by southeasterly winds, probably during the period between the Last Glacial Maximum (LGM) and the early Holocene. Modern wind measurements and geomorphological data showed that the prevailing winds in the recent and past periods were from the same quadrant, in and around Banatska Peščara. These results were confirmed with an explicit numerical simulation that modelled prevailing winds from the second quadrant during the LGM. Thus, the various geomorphologic and climatic data analyzed in this study show that the general air circulation patterns in the recent period are not dissimilar to those operative during the LGM.

1. Introduction

Atmospheric circulations are often divided into planetary, synoptic, meso-, and small horizontal scales, ranging from 10^4 km to 10 km, respectively, and into temporal scales that range from hours to years (Charney, 1948; Haltiner and Williams, 1980). In this paper, atmospheric circulations will be analyzed for the prevailing surface winds in Northern Serbia, for both the recent and past periods.

1.1. Prevailing winds and planetary circulations

The term "prevailing wind" is usually applied to descriptions of permanent winds. We employ the definition from the American Meteorological Society (2000) for prevailing wind: the wind most frequently observed during a given time period, over spans of days, months, seasons, and years. White (1831) defined the term "prevailing wind" by describing the regularity in the distribution of the wind at eight compass points, over periods of time measured in days and months. The methods for determination of prevailing winds vary from a simple count of periodic observations to the computation of a wind rose.

The best known and most frequently studied prevailing wind is the Prevailing Westerlies or Westerlies (e.g., Palmén and Newton, 1969). In this case, the term "prevailing" is used to mark westerly surface winds

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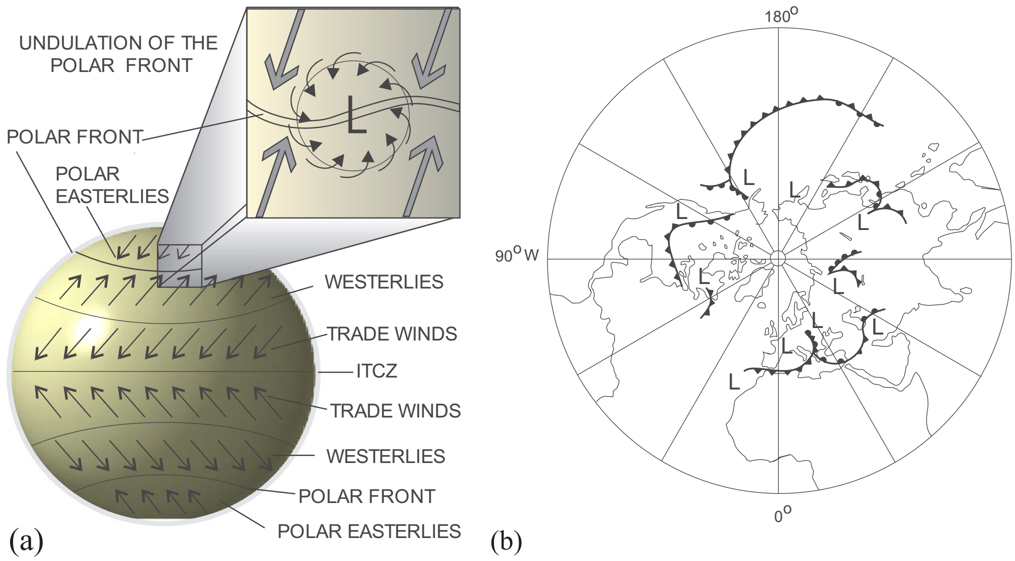

Fig. 1. (a) Generalized representation of the global circulation of the atmosphere, the position of the Polar Front, the prevailing surface winds (arrows), and (b) a typical position of the Polar Front in the Northern Hemisphere, showing centers of low pressure (L), cold, warm, and occluded fronts.

that flow in an approximately constant direction within the Ferrel circulation cells (Fig. 1a). Prevailing easterly surface winds blow out of the Hadley circulation cells on both sides of the Inter Tropical Convergence Zone (ITCZ; Fig. 1a), (e.g., Holton, 1972); these winds are widely known as the Trade winds. Other easterly winds (Polar Easterlies; Fig. 1a) diverge out of the Polar circulation cells, poleward of the Polar Front (Bjerknes and Solberg, 1922). Unlike the surface winds in the Ferrel cells, Trade winds and Polar Easterlies do not have the term "prevailing" in their names, but they do have some "prevailing" characteristics. In all three cases, these winds blow from approximately constant directions, as a result of the general and semi-permanent circulation of the atmosphere (e.g., Lorenz, 1967).

Other, less permanent, circulations, such as monsoons (e.g., Saha, 2010), also lead to important prevailing wind patterns that undergo seasonal reversals. The surface winds of the summer monsoon blow from the ocean onto the continent, whereas the winter monsoonal flow is in the opposite direction.

The Polar Front is a planetary circulation (Charney, 1973), along which extra-tropical depressions and/or cyclones develop (e.g., Djuric, 1994). The Polar Front and its accompanying circulations are the dominant influences on the weather and winds in the middle latitudes, and especially in Central Europe, Southeastern Europe, the Mediterranean, and Northern Serbia (e.g., Gburčik, 1960; Fig. 1).

1.2. Studies of prevailing winds

The study of prevailing winds rose to a higher level of interest very early, before many other world problems. This is understandable, because prevailing winds were drivers for seafaring ventures and other endeavors. In recent decades, research on prevailing winds has become of great practical use around the world for the estimation of wind power (e.g., Troen and Lundtang Petersen, 1989), for spatial planning (e.g., Seemi and Bharat, 2012), in health research (e.g., Cho, 2007) and for wind erosion research (e.g., Chepil et al., 1964). Geomorphology and aeolian science use information about prevailing winds in research on aeolian landforms and sediments.

According to Janc (2002), the Serbian scientist Andrija Stojković in his 1802 book "Physics II" described a northeasterly wind which he called "Szegedinac" (i.e., coming from the town of Szeged in Hungary) near the town of Ruma (Srem subregion) in Northern Serbia. This statement is considered one of the first written descriptions of a wind in Serbia. One of the first articles about observed prevailing winds in Serbia was published by Jakšić (1863), showing the frequency of winds at four compass points (or quadrants) per months and seasons, as of 1862.

During the first half of the 20th century, research continued on the winds of Serbia and/or Yugoslavia. Conrad (1921) investigated the strong winds (in terms of the Beaufort scale) in southwestern Serbia, and in the mountainous and coastal areas of Montenegro, during World War I. Vujević (1930) explored the winds on the Adriatic island of Hvar (Croatia) for the period of 1871–1880. Küttner (1940) was one of the first to author a paper on the local southeasterly prevailing wind Košava (a.k.a., Koshava, Kossava, Kosava) over Northern Serbia, which is known as the "Banat wind" (i.e., blowing in Banat subregion) (Barbu et al., 2009). Several publications about the Košava wind followed. Climatological characteristics of the Košava were studied by Milosavljević (1950). The spatial structure of the Košava was presented by Vukmirović (1985). Unkašević et al. (1998, 1999) discussed a statistical analysis of wind data in the main influence area of the Košava wind. A spectral analysis of the Košava wind was presented by Unkašević et al. (2007), whereas a comprehensive analysis, including basic characteristics, vertical structure and modelling, of the Košava wind was given by Unkašević and Tošić (2006). More general works regarding winds over Serbia and/or Yugoslavia can be found in Vujević (1953), Sokolović et al. (1984), and Gburčik et al. (2006). Upper air flow over Yugoslavia, as well as characteristic surface winds in this area, was examined by Dobrilović (1960).

In this study, we focus on the prevailing winds over Northern Serbia, using meteorological, geomorphological, and sedimentological data, as well as data generated in numerical simulations. The main objective of this study is to link climatological, synoptic, geomorphological, and numerical (simulated) data, so as to better understand the atmospheric dynamics of Northern Serbia.

2. Study area

Northern Serbia is located in the southeastern part of the Carpathian (Pannonian) Basin (Fig. 2). The region is mostly flat, but contains four mountain zones: Vršačke Planine (641 m above mean sea level (AMSL)) and Ramsko Pobrdje (282 m AMSL) in the southeast, Fruška Gora (539 m AMSL) in the southwest, and Avala (511 m AMSL) in the south. Other significant geomorphological features include two sandy terrains,