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Airborne pollen assemblages and weather regime in the central-eastern Loess Plateau, China

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HIGHLIGHTS

- The influxes of *Artemisia* and Chenopodiaceae will increase in dust weather obviously.
- The pollen influx coming from dust weather contributes more to the total influx.
- Pollen assemblages are more sensitive to climate change than vegetation composition.

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ABSTRACT

This paper presents the results of pollen trapping studies designed to quantify the pollen assemblages carried in the winds of the Loess Plateau in Luochuan and Hunyuan. The one-year-collection samples analysis results show that pollen assemblages can be more sensitive to the change of climate than the vegetation composition, because of the change of pollen production. The analysis results of pollen traps in different weather regimes indicate that the pollen influx coming from dust weather contribute more to the total pollen influx than that coming from non-dust weather. The wind speed is the most important influenced factor to pollen assemblages, then the mean temperature and the mean relative humidity, the wind direction also contributes some. Strong wind coming from dust direction can make the percent and influx of *Artemisia* and Chenopodiaceae increase obviously with averagely higher than over 2.7 times in dust weather than in non-dust samples. The influences of wind speed and wind direction are not serious to some arboreal pollen such as Rosaceae, *Quercus*, *Betula*, *Pinus* and *Ostryopsis*, which are mainly influenced by temperature or the relative humidity such as *Salix*, *Hippophae*, *Carpinus*, Brassicaceae, Cupressaceae, Fabaceae.

1. Introduction

Alternating loess and paleosol sequences in the extensive Loess Plateau of China provide one of the best terrestrial records of past climates (Liu, 1985; Rutter et al., 1991; Guo et al., 1993; Ding et al., 1995). However, limited by the characters of loess and paleosol, there is no consensus about variation of the paleovegetation (Zhao, 1984; Wang et al., 1991; Sun et al., 1995; Li et al., 2003; Lv et al., 2003; Jiang and Ding, 2005; Li and Sun, 2005), as the pollen assemblages are typically dominated by herbaceous taxa both in loess and paleosol sedimentary periods. Increasing evidences show that pollen can transport over much greater distances similar to conventional atmospheric aerosols (Rogers and Levetin, 1998; Belmonte et al., 2000; Sofiev et al., 2006; Siljamo et al., 2008; Dai and Weng, 2011; Izquierdo et al., 2011). So pollen transport process and the long-distance pollen should be considered in the explanation of pollen assemblages. But up to now, the pollen assemblages are usually assumed to reflect the local vegetation at the time of soil formation.

Airborne pollen can be used to identify both source areas of pollen transported and the dominant wind direction, thus it can

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help to understand fossil pollen spectra correctly and reconstruct paleovegetation accurately (Hjelmroos and Franzén, 1994; Gassmann and Pérez, 2006; Rousseau et al., 2006; Lu et al., 2010; Dai and Weng, 2011). Today the region's weather is characterized by periods of dry, windy weather – 'dust weather', when strong winds carry sand from actively eroding areas with discontinuous vegetation (e.g. desert, semi-desert and desert-steppe) into the surrounding more humid areas which support closed semi-natural vegetation (e.g. shrublands) and farmland – interspersed by non-dust-bearing winds. In this paper, we explore the hypothesis that these 'dust winds' also carry herbaceous pollen types from the arid areas into the more humid regions in sufficient quantities to alter the composition of soil pollen assemblages and therefore lead to misleading interpretations of past local vegetation from palaeosol assemblages. As a first step to developing a better model for reconstructing past vegetation from the pollen assemblages preserved in palaeosols of the Loess Plateau, this paper presents the results of pollen trapping studies designed to quantify the pollen assemblages carried in the winds of the Loess Plateau in different vegetation assemblages in dust and non-dust weather conditions.

2. Region and vegetation settings

The climate of the Loess Plateau region shows a marked gradient from warm sub-humid climates in the southeast into semi-arid and arid climates in the northwest, and this is reflected in a sequence of vegetation types from forest and forest steppe into steppe and then desert steppe. Two aerial pollen trapping locations were employed for this study, one (trap A) in the central region with sub-humid climate and potential vegetation of broad-leaved forest, and one (trap B) in the semi-arid, forest-steppe region.

Trap A is located at Heimugou Village, Luochuan County, Shaanxi Province, with 1072 m asl, in a region with a warm semi-humid mainland monsoon climate (annual mean annual temperature 9.2 °C, mean annual precipitation 622 mm). The village is near the China Quaternary loess standard geological profile (Wang et al., 2006). The region's potential vegetation is warm-temperature broadleaved deciduous forest and scrub-grassland. The dominant species of the scrub-grassland include the grasses *Bothriochloa ischaemum*, *Arundinella hirta* and *Themeda triandra* and the shrubs *Radix Glycyrrhizae*, *Sophora flavescens* and *Bupleurum chinense*. Much of the landscape today is occupied by farmland (including *Triticum aestivum*, *Zea mays*, *Sorghum bicolor*, *Setaria italica*, *Solanum tuberosum* and various beans) and cultivated woods (including *Malus domestica*, *Ziziphus*, *Juglans regia*, *Populus*, *Salix*, *Ulmus*, *Sophora*, *Paulownia* and *Ailanthus altissima*). Some secondary forest (including *Quercus, Platycladus orientalis*, *Pinus tabuliformis* and *Pobulus davidian*) is found in hilly areas (Liu, 2008).

Trap B is located at Wucheng Village in Hunyuan County, Shanxi Province. Hunyuan is a region with an arid and semiarid temperate continental monsoon climate (annual mean annual temperature 6.2°C and mean annual precipitation of 380 mm). The regional potential's vegetation is warm-temperate forest steppe, and the landscape is deeply dissected with natural gullies and human-created ditches (Zhang and Li, 2010; Wang et al., 1999). In the area around the sampling point, the actual land cover is mainly farmland with some steppe. *Z. mays*, *S. italica*, *Avena nuda*, *S. bicolor*, *S. tuberosum*, *Brassica campestris* and several kinds of beans are the major crops, with scattered trees (e.g. *Populus, Salix, Ulmus*) near the villages. Hilly areas are dominated by scrub (including *Hippophae rhamnoides*, *Ostryopsis davidiana*, *Rosa davurica* and *Prunus armeniaca*) with small stands of *Populus* and *P. tabuliformis* forest. *Artemisia* and Chenopodiaceae are abundant in wild place.

3. Research methods

3.1. Field work

Atmospheric dust fall samples were collected every two weeks at both locations between 2007 and 2009, and air-borne pollen was sampled using weather-vane type traps. On the front part of the weather vane, 20 cm × 20 cm strainers were installed perpendicular to each other to trap the pollen. Since the vane rotates with the wind, the strainers will always be pointing windward. The strainers were made of six layers of cotton mesh, soaked with silicone oil (Xu et al., 1999). One strainer was left in place for a calendar year, whilst the other was changed fortnightly. During each fortnightly sampling period, one or two strainers were exchanged, one put up on dust weather days, if there was (those when the weather was described by the local weather report as dust, flying dust or sandstorm), and the other deployed on non-dust days. The shortest collection time for a dust weather sample was 1 day. The exact duration of exposure of each strainer in these fortnightly pairs was recorded to allow pollen flux calculations to take account of the different lengths of weather phases. In order to reduce the influence of local vegetation, the pollen traps were put on building roofs about 3.5 m above the ground. This paper presents preliminary results from a selection of dust weather and non dust-weather samples and the collections of calendar year, from the same locations (see Table 1). This research only involves the analysis results of 4 samples from whole calendar year and 6 dust samples in the dust period and 6 corresponding non-dust samples. The sampling time and the climate during sampling period are shown in Fig. 1.

3.2. Laboratory

The filter screens were soaked in concentrated H_2SO_4 to decompose the fabric, and a known quantity of *Lycopodium* spores added to allow quantification of pollen abundance (Stockmarr, 1971). Once the screen material was completely broken down, the slurry was neutralized by washing with distilled H_2O then treated with HF to remove silicates, HCl to remove any carbonates and NaOH to remove non-pollen organic material before heavy fluid separation and acetolysis before storing the residues in glycerol (Xu et al., 2000).

Pollen counting was carried out at ×400 magnification under an Olympus BX-53 microscope and wherever possible a sum of at least 400 pollen grains and spores was counted, along with *Lycopodium* spores. Pollen counts were then used to calculate pollen flux estimates in units of grains cm^{-2} day^{-1} for special weather regime samples and in units of grains cm^{-2} $year^{-1}$ for one-year-collection samples.

3.3. Data analysis

In order to explore the influence of environmental parameters to pollen assemblages in the different weather regime, Detrended Correspondence Analysis (DCA) was first carried out to decide the length of environmental gradient. If the length of gradient is more than 4, CCA (Canonical Correspondence Analysis) should be used to calculate the relationship between pollen assemblages and environmental parameters. Otherwise, RDA (Redundancy analysis) should be used. 6 environmental parameters in the period of sample collection were collected: mean wind speed (s/m) (m-WS), day's wind speed maximum (s/m) (Max), dominant wind direction (WD), mean values of daily wind speed maximum in the sampling period (m-MAX) mean temperature (M-T), and mean relative humidity (M-H) in the sampling period. Precipitation only appears in part of sampling period, so it was not used at the data analysis.