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A 12,000-yr pollen record off Cape Hatteras — Pollen sources and mechanisms of pollen dispersion

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ABSTRACT

Integrating both marine and terrestrial signals from the same sediment core is one of the primary challenges for understanding the role of ocean–atmosphere coupling throughout past climate changes. It is therefore vital to understand how the pollen signal of a given marine record reflects the vegetation changes of the neighboring continent. The comparison between the pollen record of marine core JPC32 (KNR178JPC32) and available terrestrial pollen sequences from eastern North America over the last 12,170 years indicates that the pollen signature off Cape Hatteras gives an integrated image of the regional vegetation encompassing the Pee Dee river, Chesapeake and Delaware hydrographic basins and is reliable in reconstructing the past climate of the adjacent continent. Extremely high quantities of pollen grains included in the marine sediments off Cape Hatteras were transferred from the continent to the sea, at intervals 10,100–8800 cal yr BP, 8300–7500 cal yr BP, 5800–4300 cal yr BP and 2100–730 cal yr BP, during storm events favored by episodes of rapid sea-level rise in the eastern coast of US. In contrast, pollen grains export was reduced during 12,170–10,150 cal yr BP and 4200–2200 cal yr BP, during episodes of intense continental dryness and slow sea level rise episodes or lowstands in the eastern coast of US.

The near absence of reworked pollen grains in core JPC32 contrasts with the high quantity of reworked material in nearby but deeper located marine sites, suggesting that the JPC32 record was not affected by the Deep Western Boundary Current (DWBC) since the end of the Younger Dryas and should be considered a key site for studying past climate changes in the western North Atlantic.

1. Introduction

Directly linking continental and marine records is one of the best approaches for understanding atmosphere–ocean–land connections and their impact/role in global climate variability (e.g. Heusser and Shackleton, 1979; Naughton et al., 2009; Sanchez-Goni et al., 2012). In recent decades several efforts have been undertaken to understand vegetation response to past climate variability detected in the eastern (e.g. Hooghiemstra et al., 1992; Sanchez Goñi et al., 2000, 2012, 2013; Roucoux et al., 2001, 2005; Tzedakis et al., 2004; Desprat et al., 2007, 2009; Naughton et al., 2007a, 2007b, 2009; Margari et al., 2010; Bouimetarhan et al., 2012) and western North Atlantic regions (e.g. Balsam and Heusser, 1976; de Vernal et al., 1993; McCarthy and Gostlin, 2000; Mudie and McCarthy, 2006) by directly linking both terrestrial (pollen) and marine (e.g. planktonic foraminifera, dinoflagellates, coccolithophores) proxies from the same sediment. However, before assessing land–sea linkages during past climate changes of a given region and time period, it is important to understand the present and past pollen signals of each area (e.g. Heusser, 1983; McCarthy and Mudie, 1998; Naughton et al., 2007a). This ensures that both present and past pollen signals in a given marine record generally reflect similar trends in the vegetational patterns and/or changes of the neighboring landmasses (e.g. Heusser, 1983; Naughton et al., 2007a). Thus the main source area of pollen grains included in marine sediments is recognized and the processes/mechanisms behind the transfer of pollen grains from the continent to the sea are distinguished

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(e.g. Heusser, 1983; McCarthy and Mudie, 1998; Mudie and McCarthy, 2006; Naughton et al., 2007a). Evaluating present marine pollen signatures from the mid-latitudes of the western North Atlantic was previously achieved by Heusser (1983). Based on 94 randomly distributed core top sediment samples, Heusser (1983) visibly demonstrated that modern pollen grains included in western North Atlantic mid-latitudes sediments are at present mainly transferred from the continent to the sea by rivers, in particular those draining the Chesapeake and Delaware hydrographic basins, and that the marine pollen signature of this area clearly reflects the vegetation patterns of the adjacent landmasses. Balsam and Heusser (1976) performed the first direct-sea land comparison in two records (V24-1 and V26-176) from the upper and lower continental rise between Cape Hatteras and Chesapeake Bay spanning the last 20,000 yr. They suggest that the three main vegetational phases detected since the last deglaciation were generally similar to those detected in continental pollen sequences of the adjacent continental United States, in particular of the Chesapeake Bay watershed. However, the poor resolution and limited age control in their sediment cores as well as the few available terrestrial sites at that time did not allow high resolution documentation of most major vegetation changes during the Holocene and did not identify continental sites that might reflect similar trends of vegetational changes from marine pollen sequences off Cape Hatteras. Here we present the first high temporal resolution pollen data, from a deep-sea core (KNR178JPC32; hereafter JPC32) retrieved off the Cape Hatteras region. We also investigate the reliability of the marine pollen signal in this region by comparing the well-resolved marine data with that revealed by available terrestrial pollen sequences from eastern North America.

2. Area of study and environmental setting

Core KNR178JPC32 (JPC32 hereafter) was retrieved off Cape Hatteras at 35°58.58′N; 74°42.77′W, 1006 m water depth; and ~83 km offshore, on the continental slope (Rona and Clay, 1967) (Fig. 1; Table 1).

2.1. Recent sedimentation

The Cape Hatteras region is part of a complex geomorphological system that characterizes the northwestern Atlantic Ocean (e.g. Riggs et al., 2008). In particular, the region off Cape Hatteras is marked by a narrow shelf (30 km), a steady continental slope and upper and lower continental rise which plunges to the Hatteras Abyssal Plain (Rona and Clay, 1967) (Fig. 1). The narrowing of the shelf in the Cape Hatteras region facilitates cross-isobath flows and exchanges between the shelf and the open ocean (Bigelow, 1933; Churchill and Cornillon, 1991). Shelf break and slope eddies are considered to be important agents in the exchange of water and suspended fine sediments between the shelf and slope domains (Churchill and Gawarkiewicz, 2009). The transfer of fine suspended sediments from the continent to the shelf is mainly facilitated by rivers during flood episodes and/or extreme climate events (e.g. Nichols, 1993; Townsend et al., 2004) since most estuaries trap the suspended sediments delivered by rivers (e.g. Meade, 1972; Woodruff et al., 2001). Ten main drainage areas from eastern North America supply relative high amounts (128×10^8 kg/yr) of suspended fine sediments to the North Atlantic (Curtis et al., 1973). The Delaware, Potomac, Susquehanna and Pee Dee Rivers are the main fine sediment suppliers off Cape Hatteras (Curtis et al., 1973). The Delaware is the longest undammed river east of the Mississippi, extending 330 miles from the east and west branches at Hancock, New York to the mouth of Delaware Bay, discharging 749 thousands of tons of suspended matter to the shelf (Curtis et al., 1973). Both the Susquehanna and the Potomac rivers are included in the Chesapeake watershed and receive water from six states: New York, Pennsylvania, Delaware, Maryland, Virginia and West Virginia. Chesapeake Bay discharges around 2740 thousand tons of suspended fine particles into the North Atlantic (Curtis et al., 1973). After being released from estuaries to the shelf, fine sediments or plumes are swept away by the net equatorward coast-parallel flow (Townsend et al., 2004; Muscarella et al., 2011), especially during the rainy season (Churchill and Gawarkiewicz, 2012).

2.2. Oceanography

The JPC32 core is located at the meeting point between the Gulf Stream (GS) and the underlying Deep Western Boundary Current (DWBC) (e.g. Barrett, 1965; Pickart and Smethie, 1993; Pickart, 1994). In particular, the GS is responsible for the fast flow of warm and salty water transported along the path of GS and North Atlantic Current, while the DWBC caries several cold and less salty water masses from high to low latitudes (Watts, 1991; Pickart, 1992). Larger (lower) southward transports in the DWBC are dependent on southward (northward) shifts of the GS path (Peña-Molino and Joyce, 2008), which in turn are associated with changes in the North Atlantic Oscillation (NAO) (Taylor and Stephens, 1998; Joyce et al., 2000; Rossby and Benway, 2000; Hurrell and Deser, 2009). Indeed, the NAO is the predominant natural mode of climate variability over eastern, northeastern and northern North America on monthly and decadal time scales (e.g. Hurrell and Deser, 2009). When the NAO, dominant during winter (e.g. Hurrell and Deser, 2009), is in a positive mode (i.e. increased atmospheric pressure gradient between the Azores and Iceland), mid-latitude westerly winds over the North Atlantic shift northward as well as the GS path and position of the subtropical waters (Taylor and Stephens, 1998). In contrast, the negative NAO mode, marked by a reduced pressure gradient between the Azores high and Iceland low, results in weaker westerly winds, weakening of the subpolar gyre, and expansion of the subtropical gyre, favoring the southward displacement of the GS position (Taylor and Stephens, 1998).

2.3. Present seaward pollen transfer

The transfer of pollen grains from the continent, and in particular the region between Cape Hatteras and Delaware Bay to the western North Atlantic, is mainly driven by river runoff, as revealed by maximal pollen concentrations deposited adjacent to the rivers mouth (Balsam and Heusser, 1976; Heusser, 1983). The present-day wind-transported pollen grains contribution to the area is very reduced (Heusser, 1983).

Pollen grains once in water act like any fine sedimentary particle of terrigenous origin, obeying the physical laws that govern transport of suspended minerals (e.g. Stanley, 1966; Heusser, 1983). After being released from the continent by rivers and streams jointly with the suspended sediments, favored by tidal exchanges and storm surges (Mudie and McCarthy, 1994), some pollen grains settle on the shelf whereas others can be transported by coastal and then ocean currents to the outer shelf (e.g. Stanley, 1966; Heusser, 1983; Naughton et al., 2007a). Several other processes can compromise the transfer of pollen grains from the continent to the shelf such as: pollen production, dispersal by oceanic and/or atmospheric circulation, the distance from the continent and sediment type (Koreneva, 1966).

2.4. Vegetation and continental climate

The upper Delaware basin's forest is composed of beech-birch in the northernmost area followed by maple-hemlock to the south (41–42° N). Forest cover of both the Delaware (south of 41° N) and Chesapeake basins is mainly composed of beech-birch in the northernmost area and maple-hemlock oak-hickory in the east. Oak-pine leads to the west on the Appalachian plateau, oak-chestnut in the Appalachian dry ridges, sugar-maple and basswood in the Appalachian wetter valleys, oak-hickory in the east and finally oak to the west within