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Long-term hydrological changes in the northeastern Gulf of Mexico (ODP-625B) during the Holocene and late Pleistocene inferred from organic-walled dinoflagellate cysts

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ABSTRACT

Palynological analyses are used in conjunction with oxygen isotopes and Mg/Ca ratios in foraminifers in order to document the response of dinoflagellate cysts (dinocysts) assemblages to changing climate conditions in the northeastern Gulf of Mexico over the Holocene and late Pleistocene. During MIS 6, but also during the cooler phases of MIS 5, *Impagidinium* species and *Operculodinium centrocarpum* were dominating the assemblages. By contrast, during the last interglacial (LIG) and the Holocene, assemblages were mainly composed of *Spiniferites* taxa and characterized by high relative abundance of *Spiniferites mirabilis-hyperacanthus*, *Operculodinium israelianum* and/or *Polysphaeridium zoharyi*. These two periods exhibit ~1-2 °C difference in temperature as inferred from Mg/Ca ratios and show significantly distinct assemblages, with higher percentages of *S. mirabilis* during the LIG and higher percentages of *P. zoharyi* during the Holocene. This likely denotes important differences in the hydrogeographical conditions (e.g. surface circulation, bathymetric configuration) between the present and last interglacial. The importance of environmental parameters other than temperature and salinity for dinocyst assemblage dynamics is furthermore illustrated.

1. Introduction

In the Gulf of Mexico, the interplay between the Mississippi River discharge, open ocean water masses and atmospheric circulation creates a complex dynamic system responsible for hydrological fluctuations on both annual and long-term timescales. To better understand the impact of these parameters on the regional climate, a number of marine sediment studies has focused on the hydrologic evolution of the basin during the Holocene (Poore et al., 2003; Lo Dico et al., 2006; Richey et al., 2007; Meckler et al., 2008; Montero-Serrano et al., 2010) and the last interglacial (LIG) interval (Joyce et al., 1990, 1993; Tripsanas et al., 2007; Nürnberg et al., 2008; Ziegler et al., 2008; Kujau et al., 2010; Montero-Serrano et al., 2011; Simms et al., 2013). The LIG, referred to as Marine Isotope Stage (MIS) 5e in marine sediments and spanning the interval between ~130 and 115 kyrs (Liesecki and Raymo, 2005), has experienced conditions warmer than those of the current interglacial in response to higher levels of insolation during boreal summer (e.g., CAPE, 2006; Otto-Bliesner et al., 2006; Hearty et al., 2007). Regional data from the Gulf of Mexico indicate that overall sea-surface temperatures were generally warmer by 1-2 °C (Nürnberg et al., 2008; Ziegler et al., 2008; Montero-Serrano et al., 2011) and relative sea-level was approximately 4-6, possibly 9 meters above the present limit (Simms et al., 2013, and references therein). Numerous paleoceanographic investigations therefore stem on the recognition that this interval may represents a possible analogue for future climate and could help infer potential changes in hydrographic conditions in the context of global warming.

Dinoflagellate cysts (dinocysts), which are the organic-walled remains of unicellular algae routinely recovered in palynological preparations, have proven to be a good proxy for paleoenvironmental changes in the upper water column (e.g. Rochon et al., 1999; de Vernal and Marret, 2007). Their assemblages are not only controlled by temperature, but also depend on other environmental parameters (e.g., productivity, salinity, sea-ice cover, seasonality, sea-level etc) as shown by multivariate analyses of distribution patterns in middle to high latitudes of the Northern Hemisphere (e.g., de Vernal et al., 1997; Devillers and de Vernal, 2000; Pospelova et al., 2008; Radi and de Vernal, 2008; Price and Pospelova, 2011; Bonnet et al., 2012) and in the Gulf of Mexico (Limoges et al., 2013). Therefore, the analysis of dinocyst assemblages has the potential to assess past hydrographic conditions in a fairly nuanced way. While dinocysts have been widely used in paleoceanographic reconstructions for the high latitudes (Mudie et al., 2001 and references therein; de Vernal et al., 2005),

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they remain a less-exploited tool for such reconstructions in the tropical areas, which is in part due to the lower availability of modern reference datapoints for these regions. For the Gulf of Mexico, the relationship between dinocyst assemblages and modern sea-surface parameters was documented by Limoges et al. (2013) allowing for a more comprehensive interpretation of their regional distribution.

Here, we combine the analyses of stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) and trace elements (Mg/Ca) in planktic foraminiferal carbonate with palynological analyses from sediments collected at the Ocean Drilling Program (ODP) site 625B in the Gulf of Mexico (Fig. 1A), in order to document long-term changes in hydrological conditions over the MIS 1 (0 - 11 kyr), MIS 5 (b-e) (90 - 130 kyr) as well as the glacial-interglacial transition MIS 6/5 (130 - 160 kyr). Located in the northeastern part of the Gulf of Mexico, at the outer reaches of the seasonal influence of the Loop Current and near to the Mississippi River Mouth, site ODP-625B is ideally positioned to record changes in paleoproductivity and sea-surface conditions related to long-term hydroclimatic changes. Our study also evaluates the potential of dinocysts as paleoceanographic proxy in tropical areas.

2. Material and methods

2.1. Regional setting

The Gulf of Mexico is an oceanic basin located on the northwestern edge of the Atlantic Ocean. Its dominant surface current is the Loop Current: warm and salty waters originating from the Caribbean Sea enter into the Gulf via the Yucatán channel, loop northwest and exit through the Florida Strait as the Florida Current, eventually feeding the Gulf Stream (Fig. 1B) (Elliot, 1982; Blumberg and Mellor, 1985; Hofmann and Worley, 1986; Oey et al., 2005; Jochens and DiMarco, 2008; Auladell et al., 2010). The latitudinal extension of the Caribbean water inflow into the basin is seasonally modulated by the position of the Intertropical Convergence Zone (ITCZ) (Fig. 1B). A northward migration of the ITCZ during boreal summer causes the Loop Current to propagate farther north, influencing the hydrological properties of the entire basin (temperature, salinity). Consequently, in the modern climate system, the Atlantic Warm Pool reaches into the Gulf of Mexico during late summer, with temperatures above 28.5 °C in the entire basin during this

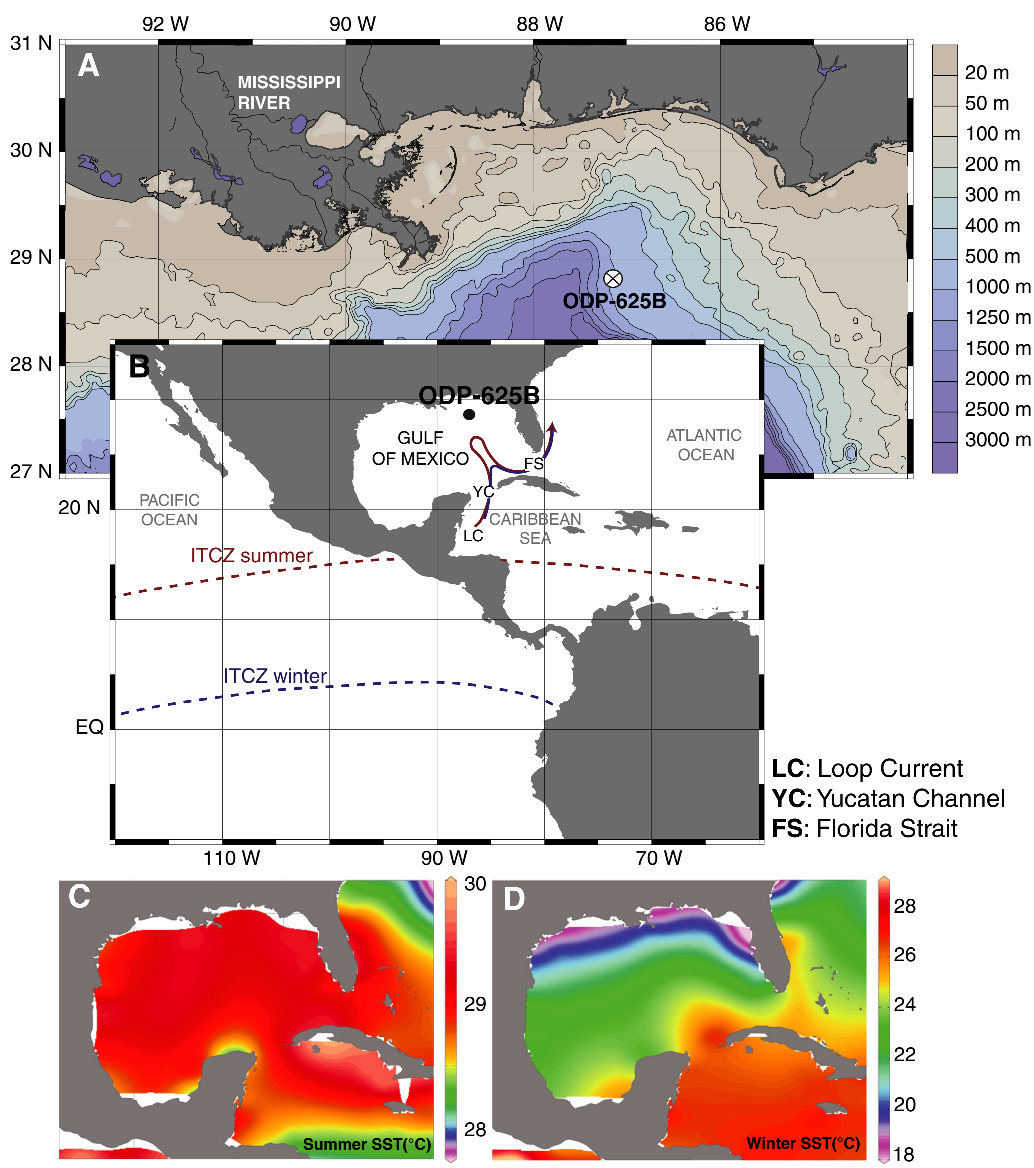

Fig. 1. A) Position of site ODP-625B (28.83°N, 87.16°W), B) Simplified map of the Loop Current (dashed line in the inset) and seasonal (summer and winter) position of the ITCZ. Abbreviations: LC: Loop Current, YC: Yucatan Channel, FS: Florida Strait, C) Distribution of summer (July-September) temperatures (°C), D) Distribution of winter (January-March) temperatures (°C) (Ocean Data View (Antonov et al., 2010; Garcia et al., 2010a, 2010b; Locarnini et al., 2010; Schlitzer, 2012)).