Earth and Planetary Science Letters 396 (2014) 134–142

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Millennial-scale Atlantic/East Pacific sea surface temperature linkages during the last 100,000 years

Nathalie Dubois [a,*,1], Markus Kienast [b], Stephanie S. Kienast [b], Axel Timmermann [c]

[a] Woods Hole Oceanographic Institution, 266 Woods Hole Road, MA 02543, USA
[b] Dalhousie University, 1355 Oxford Street, Halifax, NS, B3H 4R2, Canada
[c] International Pacific Research Center, University of Hawaii, 2525 Correa Road, HI 96822, USA

ARTICLE INFO

Article history:
Received 4 October 2013
Received in revised form 28 March 2014
Accepted 6 April 2014
Available online 23 April 2014
Editor: J. Lynch-Stieglitz

Keywords:
Eastern Pacific
Heinrich events
winds
sea surface temperature
alkenone
EOF

ABSTRACT

Amplifying both internally generated variability and remote climate signals from the Atlantic Ocean via coupled air–sea instabilities, the eastern tropical Pacific (ETP) is well situated to detect past climate changes and variations in Central American wind systems that dynamically link the Atlantic and the Pacific.

Here we compare new and previously published alkenone-based sea surface temperature (SST) reconstructions from diverse environments within the ETP, i.e. the Eastern Pacific Warm Pool (EPWP), the equatorial and the northern Peruvian Upwelling regions over the past 100,000 yr. Over this time period, a fairly constant meridional temperature gradient across the region is observed, indicating similar hydrographic conditions during glacial and interglacial periods. The data further reveal that millennial-scale cold events associated with massive iceberg surges in the North Atlantic (Heinrich events) generate cooling in the ETP from ~8°N to ~2°S. Data from Heinrich event 1, however, indicate that the response changes sign south of 2°S. These millennial-scale alterations of the SST pattern across diverse environments of the ETP support previous climate modeling experiments that suggested an Atlantic–Pacific connection caused by the intensification of the Central American gap winds, enhanced upwelling and mixing north of the equator and supported by positive air–sea feedbacks in the eastern tropical Pacific.

1. Introduction

The ETP is home to the El Niño–Southern Oscillation (ENSO) phenomenon, which affects weather and climate patterns worldwide. Recent studies on remote triggers of ETP climate variability have suggested possible extratropical atmospheric influences (Alexander et al., 2010; Caballero and Anderson, 2009; Vimont et al., 2003), along with potential effects from tropical Atlantic SSTs (Okumura et al., 2009; Timmermann et al., 2007; Zhang and Delworth, 2005). Given the limited degrees of freedom in the short instrumental record, the Atlantic/tropical Pacific linkage is difficult to establish with statistical confidence. Paleoclimate data could provide additional insight into the mechanisms that communicate Atlantic climate anomalies into the tropical Pacific. Moreover, understanding this pan-oceanic atmospheric bridge and the associated changes in moisture transport across Central America (Leduc et al., 2007; Richter and Xie, 2010) will shed further light on the long-term behavior and stability of the Atlantic Meridional Overturning Circulation vis-à-vis Deep Water Formation in the North Pacific (Okazaki et al., 2010).

Here we compare three ETP alkenone-based SST reconstructions of the past 100,000 yr that document a recurring link between Atlantic and Pacific climate on millennial timescales, thus extending previous studies that identified a connection between Atlantic climate change, Pacific hydroclimate variability (Benway et al., 2006; Leduc et al., 2007; Pahnke et al., 2007) and Pacific SSTs (Kienast et al., 2006; Pahnke et al., 2007; Koutavas and Sachs, 2008) during the last glacial termination. We perform empirical orthogonal function (EOF) analyses of these three 100,000 yr long SST records and of a compilation of eleven previously published alkenone-based SST records from the ETP covering the last 25,000 yr.

2. Regional setting

The ETP is characterized by prominent climatic asymmetries and large seasonal variations in wind patterns, surface currents, temperature and salinity. North of the equator, the EPWP is

* Corresponding author.
E-mail address: nathalie.dubois@eawag.ch (N. Dubois).
[1] Present address: Eawag, Überlandstasse 133, 8600 Dübendorf, Switzerland.

http://dx.doi.org/10.1016/j.epsl.2014.04.008

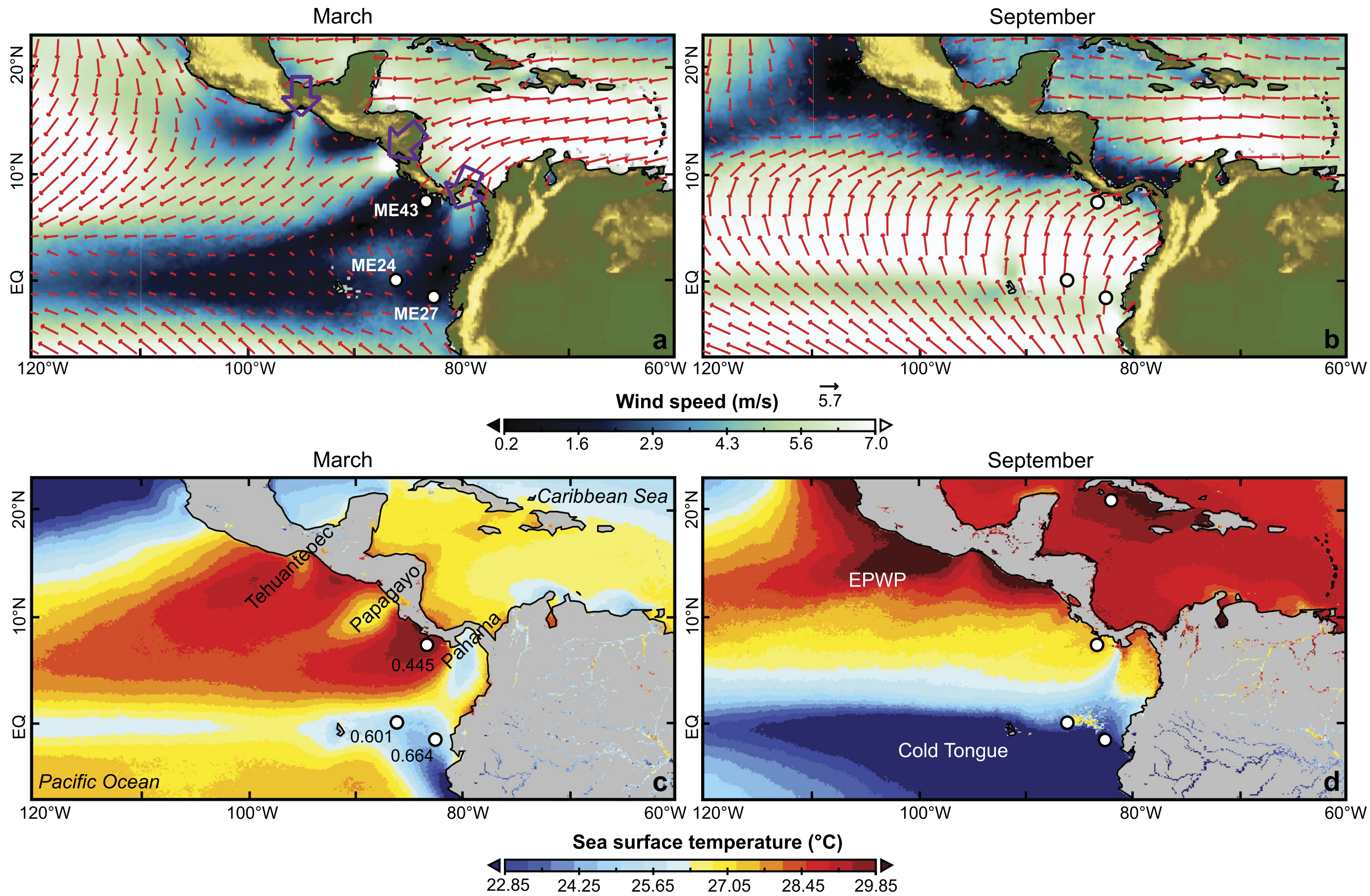

Fig. 1. (a) Relief of the Central American Isthmus with core locations (white dots) and approximate location of low-level wind-jets (gaps winds, arrows (purple in the web version)). Climatological QuikScat wind vectors (2000/01–2008/12 inclusive) show wind direction and speed for March (a) and September (b). QuikScat data are produced by Remote Sensing Systems and sponsored by the NASA Ocean Vector Winds Science Team. Data are available at www.remss.com. The lower panels show mean monthly SST for March (c) and September (d) based on satellite estimates (AVHRR Pathfinder Version 5.0 data; Casey et al., 2010). Numbers next to core sites in (c) show the leading long-term EOF1 pattern.

characterized by annual mean temperatures exceeding 27.5 °C and exceptionally low salinities (∼32 practical salinity units, psu), resulting from intense rainfall associated with the Intertropical Convergence Zone (ITCZ) and atmospheric water vapor export from the Caribbean across the Panama Isthmus (Joussaume et al., 1986; Mitchell and Wallace, 1992; Li and Philander, 1996; Xie et al., 2005) via the northeasterly trade winds (Fig. 1).

Straddling the equator on the other side are the southeasterly trade winds that converge into the northern hemisphere ITCZ. These winds cause Ekman divergence along the equator and give rise to the equatorial Cold Tongue (mean SST of 24 °C, Fig. 1d). The southeasterly trades also cause upwelling off the coast of Peru. The Peru Current advects cold coastal waters into the far eastern tropical Pacific, thus contributing to the low temperatures in the Cold Tongue region.

The seasonal cycle of ETP SST and ocean currents is linked to the seasonal meridional migration of the ITCZ (Fig. 1a–d). During present-day boreal summer and autumn (May to late November), when the ITCZ is in its northernmost position (10–12°N, Fig. 1b), the southerly winds are strongest over the equator and the Equatorial and Peruvian Upwelling intensify (Fig. 1d; Wyrtki, 1981). A strong meridional SST gradient develops across the equator, between the EPWP and the Cold Tongue with a well-pronounced Equatorial Front near 2–5°N (Wyrtki, 1996; Pak and Zaneveld, 1974). At the equator, SSTs are at their minimum in September (Fig. 1d).

This stage is contrasted by conditions in boreal winter and spring (December to April), when the ITCZ is at its most equatorial position, strong northeasterly trades cross the Central American Isthmus (Fig. 1a) and southeast trade winds and the equatorial Cold Tongue are relatively weak (Fig. 1c; Li and Philander, 1996). SSTs reach their maximum in March. As the strong northeasterly trades accelerate through topographic gaps in the Central American Cordillera, they form smaller-scale features known as the Tehuantepec, Papagayo and Panama wind jets (Fig. 1a; Xie et al., 2005; Chelton et al., 2000). The wind stress curl associated with these jets causes localized upwelling, thermocline changes and SSTs minima extending off the coast off Central America (Figs. 1a and 1c; Kessler, 2002; Xie et al., 2005; Willett et al., 2006). Of particular importance is the Panama Jet (January to April) which generates a cold SST patch in its wake (Fig. 1c) that can inhibit convection and breaks the winter ITCZ into two parts (Alory et al., 2012). The Papagayo Jet and its related wind stress curl pattern create the so-called Costa Rica Dome, an oceanic upwelling center where the thermocline ascends to very near the sea surface (Fiedler, 2002; Kessler, 2006). A local SST minimum at 9°N, 89°W marks the Costa Rica Dome (Fig. 1c), which ranges in diameter from 100 to 900 km. These gap winds (i.e., winds that are accelerated by an along-gap pressure gradient) have been associated with variations in the Caribbean trade winds (Frankenfield, 1917) and high pressure systems of midlatitude origin that move southeastward across the Gulf of Mexico (a.k.a. "Northers" or "Central American Cold Surges"; Schultz et al. 1997, 1998).