Palaeogeography, Palaeoclimatology, Palaeoecology 462 (2016) 112–124

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Changes in Timor Strait hydrology and thermocline structure during the past 130 ka

Elena Lo Giudice Cappelli [a,b,*], Ann Holbourn [a], Wolfgang Kuhnt [a], Marcus Regenberg [a]

[a] Institute of Geosciences, Christian-Albrechts-Universität zu Kiel, Ludewig-Meyn-Str. 14, 24118 Kiel, Germany
[b] School of Geography and Geology, University of St Andrews, St Andrews, Fife, Scotland KY16 9AL, UK

ARTICLE INFO

Article history:
Received 24 February 2016
Received in revised form 12 September 2016
Accepted 13 September 2016
Available online 14 September 2016

Keywords:
Indonesian Throughflow
Timor Sea
Lower thermocline
Hoeglundina elegans Mg/Ca
X-ray fluorescence core scanning

ABSTRACT

Paleostudies of the Indonesian Throughflow (ITF) are largely based on temperature and salinity reconstructions of its near surface component, whereas the variability of its lower thermocline flow has rarely been investigated. We present a multi-proxy record of planktonic and benthic foraminiferal $\delta^{18}O$, Mg/Ca-derived surface and lower thermocline temperatures, X-ray fluorescence (XRF)-derived runoff and sediment winnowing for the past 130 ka in marine sediment core SO18471. Core SO18471, retrieved from a water depth of 485 m at the southern edge of the Timor Strait close to the Sahul Shelf, sits in a strategic position to reconstruct variations in both the ITF surface and lower thermocline flow as well as to investigate hydrological changes related to monsoon variability and shelf dynamics over time. Sediment winnowing demonstrates that the ITF thermocline flow intensified during MIS 5d-a and MIS 1. In contrast during MIS 5e, winnowing was reduced and terrigenous input increased suggesting intensification of the local wet monsoon and a weaker ITF. Lower thermocline warming during globally cold periods (MIS 4 – MIS 2) appears to be related to a weaker and contracted thermocline ITF and advection of warm and salty Indian Ocean waters.

1. Introduction

The Indonesian Throughflow (ITF) is a complex ocean current system that transports cool and fresh waters from the Pacific Ocean to the Indian Ocean and, thus, plays an important role in modulating local and global climate (Cresswell et al., 1993; Gordon and Fine, 1996; Gordon, 2005; Oppo and Rosenthal, 2010). The Timor Strait provides the main exit path for the ITF, as about half of the total transport (~7.5 Sv) takes place through this passage (Sprintall et al., 2009). To date, our understanding of the past evolution of the ITF remains largely based on temperature and salinity reconstructions of its near surface component, down to ~200 m, whereas the variability of the lower thermocline component along the ITF pathway has rarely been investigated. The scarcity of investigations addressing past variability of intermediate and deep waters reflects to a large extent the difficulties in developing sensitive proxy recorders of temperature for the deeper ocean, where variations are generally more muted than at or close to the surface. Based on a new Mg/Ca paleothermometry calibration study (Lo Giudice Cappelli et al., 2015), we present the first Timor Strait record of lower thermocline temperatures spanning the last ~130 ka. We combine this benthic foraminiferal Mg/Ca data set from Core SO18471 with a multi-proxy record of planktonic and benthic foraminiferal $\delta^{18}O$, Mg/Ca-derived surface temperature and X-ray fluorescence (XRF)-derived runoff and sediment winnowing from the same core. The location of core SO18471 is strategic to reconstruct the variability of the ITF vertical structure over time, as it sits in a relatively shallow location, in a water depth of 485 m corresponding to the ITF lower thermocline flow, which allows to reconstruct the hydrological evolution of both surface and deeper water masses (Fig. 1). In addition, the proximity of core SO18471 to the Sahul Shelf allows monitoring of changes in sediment discharge and winnowing related to variations in the Indonesian-Australian Monsoon system and shelf dynamics over time. We compare our results with published isotope ($\delta^{18}O$) and Mg/Ca data from the Timor Sea to explore the regional variability in temperature and water mass properties and to assess the impact of glacial – deglacial sea level changes on regional hydrography.

2. Regional oceanography and climate dynamics

The Timor Sea encompasses the Timor Strait to the north and the Sahul Shelf to the south (Cresswell et al., 1993). The Timor Strait is dominated by the year-round southwestward flow of the ITF, while circulation on the Sahul Shelf strongly depends on the monsoon cycle (Cresswell et al., 1993; Sprintall et al., 2009; Schiller, 2011). The ITF is driven across the Indonesian Archipelago by the pressure gradient between the tropical western Pacific and the Indian Ocean (Cresswell et

* Corresponding author at: School of Geography and Geology, University of St Andrews, St Andrews, Fife, Scotland, KY16 9AL, UK
E-mail address: elgc@st-andrews.ac.uk (E. Lo Giudice Cappelli).

http://dx.doi.org/10.1016/j.palaeo.2016.09.010
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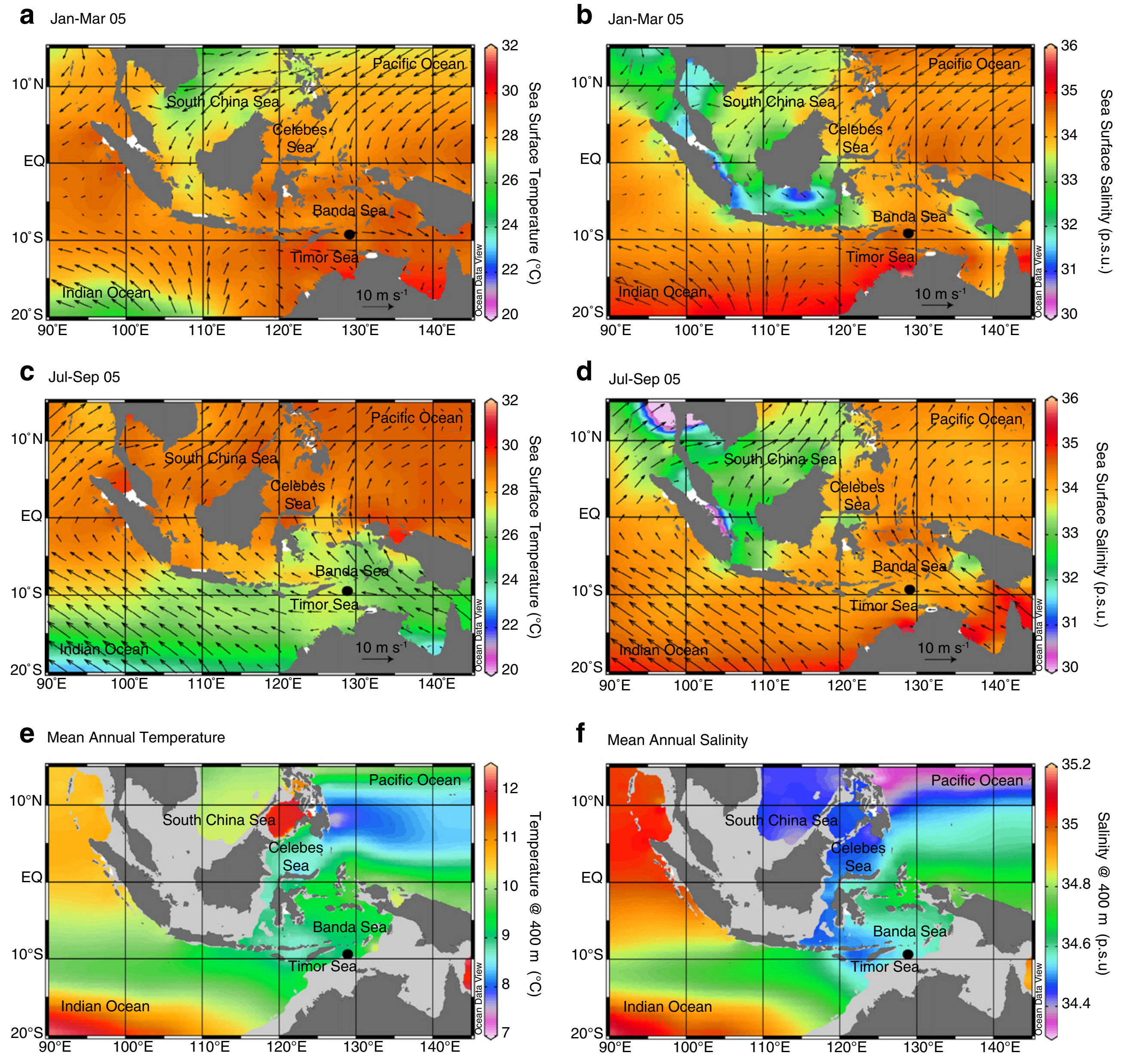

Fig. 1. Monsoon-induced seasonal variations in temperature, salinity and wind trajectory in the tropical Indo-Pacific Ocean plotted with Ocean Data View (Schlitzer, 2013). a) and b) Austral summer (January–March) seasonal SST and salinity variations. c) and d) Austral winter (July–September) seasonal SST and salinity variations. e) and f) Mean annual temperature and salinity at 400 m. Temperature and salinity data are from the World Ocean Atlas 2005 (Locarnini et al., 2006). Superimposed are winds trajectories (arrows) in February (a and b) and August (c and d). Wind data are monthly averages for February and August 2005 from NCEP Reanalysis Dataset (http://www.esrl.noaa.gov/psd/). Black circle indicates location of core SO18471.

al., 1993) and consists of surface to upper thermocline waters stemming from the North Pacific, and lower thermocline and intermediate waters of South Pacific origin (Gordon and Fine, 1996; Talley and Sprintall, 2005; Sprintall et al., 2009). On their way to the Timor Strait, these water masses are intensely modified by tidal mixing (Egbert and Ray, 2001; Ray et al., 2005; Koch-Larrouy et al., 2010), monsoon-driven upwelling (Moore et al., 2003), and air-sea exchanges (Wijffels et al., 2008) in the Banda Sea (Fig. 1) before entering the Indian Ocean (Ffield and Gordon, 1992; Gordon and Susanto, 2001; Sprintall et al., 2009).

Seasonal wind reversals linked to the Indonesian-Australian Monsoon system influence the circulation in the Timor Sea. During the austral summer monsoon (NW monsoon), the ITF and northeast currents on the Sahul Shelf are weaker because the pressure gradient between the Pacific and Indian Oceans is at its lowest (Cresswell et al., 1993; Sprintall et al., 2009; Schiller, 2011). As the Intertropical Convergence Zone (ITCZ) is in its southernmost position, Indonesia and NW Australia experience a warm and wet season (Fig. 1a and b). Freshwater and terrigenous material reach the Sahul Shelf from the Victoria, Daly and Adelaide Rivers (NW Australia), and variations in riverine discharge depend on the strength of the austral summer monsoon (NW monsoon) (Fig. 2) (Alongi et al., 2013). However, most terrigenous material is not of Australian but of Indonesian origin, as about 30 rivers in the western part of New Guinea represent a significant source of sediments for the Arafura and Timor Sea due to the steep topography of New Guinea, promoting intense discharge (Fig. 2) (Alongi et al., 2013). In contrast, during the austral winter monsoon (SE monsoon), both the ITF and the Sahul Shelf currents flow to the southwest and are intensified, as the