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Mid-late Holocene climate variability in the Indian monsoon: Evidence from continental shelf sediments adjacent to Rushikulya river, eastern India

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A B S T R A C T

We present elemental and grain-size distributions obtained from the sediment core of the continental shelf adjacent to the Rushikulya river mouth, eastern India to quantify the paleoclimatic changes. The retrieved 1.60 m long well dated core spans the past ca. 6800 cal BP. The modern spatial distribution of grain size and geochemistry of the inner-mid shelf sediments has been carried out to understand the seafloor morphology and sedimentary processes. Based on the modern investigations, the proportion of particle size (clay vs sand) and variation in elemental values (TiO_2 vs Al_2O_3) has been used to interpret the changes in terrigenous supply. The grain-size and elemental distribution data from the core sediments indicates a period of enhanced surface water runoff from 6800 to 3100 cal BP followed by a drier condition (3100 cal BP to present) suggesting weakening of monsoon. The weakening of the monsoonal strength is coeval with other records from the Indian sub-continent and suggests response of Indian monsoon to changing solar insolation during late Holocene.

1. Introduction

The understanding of the past and present climatic variability in the Indian monsoon realm is critical to produce better future climate forecast models. However, the available long term continental palaeomonsoon record has limited geographical coverage with majority of research carried out in NW India (e.g., Prasad et al., 1997; Enzel et al., 1999; Prasad and Enzel, 2006; Prasad et al., 2014a; Raj et al., 2015; Amekawa et al., 2016) and Himalayan region (Phadtare, 2000; Demske et al., 2009; Wünnemann et al., 2010; Anoop et al., 2013a; Leipe et al., 2014; Rawat et al., 2015; Mishra et al., 2015; Kotlia et al., 2015). To understand the variability of monsoon rainfall and the physical mechanisms inherit in it, a large dataset covering longer time scales is required from various climate sensitive regimes across the Indian subcontinent. Barring a few exceptions (e.g., Khandelwal and Gupta, 1999; Khandelwal et al., 2008) limited to palynological investigations on lacustrine sediments, the Holocene climate changes are yet to be evaluated from eastern India.

The sedimentary bodies on continental shelves have been widely used to infer the sea level fluctuations (Milliman and Emery, 1968; Gingele et al., 2004; Zhao et al., 2008; Yoo et al., 2014) and variations in terrigenous sediment input (Mendes et al., 2010; Nizou et al., 2010; Zheng et al., 2010; Rosa et al., 2011; Wang et al., 2014; Perez et al., 2016; Tu et al., 2016) interpreted in terms of past environmental changes. The terrigenous coarse- and fine-grained sediments supply to the continental shelf is mostly controlled by fluvial discharge (Prins et al., 2000; Briceño-Zuluaga et al., 2016). The paleoclimate records from continental shelves provide critical information connecting continental with deep marine records (González-Álvarez et al., 2005). However, paleoclimate records from continental shelf areas of the Indian subcontinent are very scarce. In this study, we present a continuous record of the mid-late Holocene climate obtained from a 1.60 m long sediment core (VC-04) retrieved from the continental shelf sediments adjacent to the Rushikulya river mouth (Fig. 1). The understanding of modern sedimentation patterns in the continental shelf has been used to refine palaeoenvironmental interpretations and gain a long term perspective on environmental variability. The

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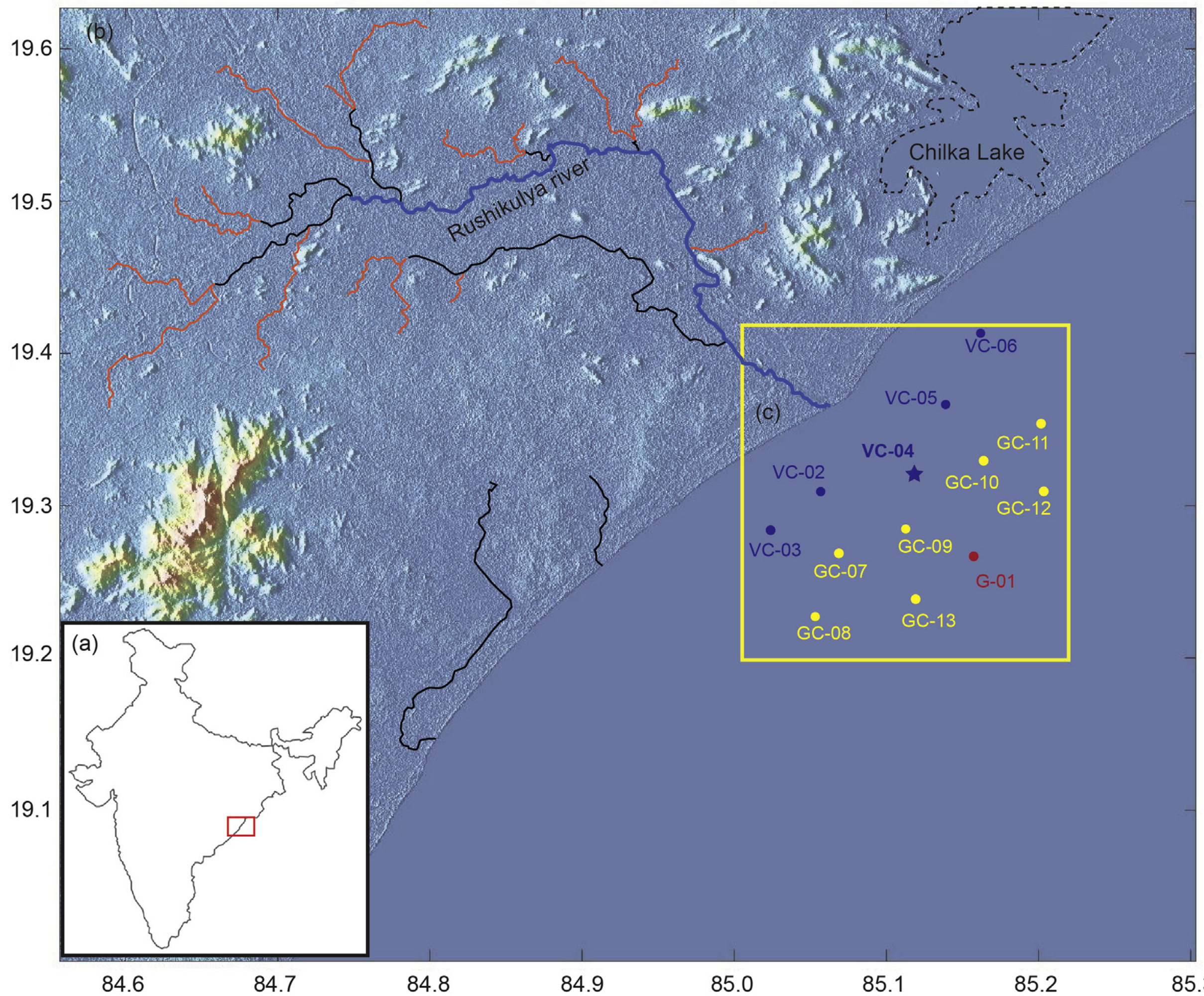

Fig. 1. Map showing study area and location of the retrieved core (VC-04) for paleoclimate reconstruction. The blue, yellow and red circles denote the location of vibro, gravity and grab samples used to understand the modern continental shelf dynamics. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

elemental and grain-size distributions supplemented with sedimentation rate calculations obtained from the sediment core are used to quantify the paleoclimatic changes.

The objectives of this present study are: i) to identify suitable proxies for paleoenvironment reconstruction by establishing the linkages between contemporary processes and sediment distribution in the modern Rushikulya river mouth and adjacent continental shelf sediments; ii) use of climate sensitive proxies to reconstruct paleoenvironmental conditions during mid-late Holocene; and iii) regional comparison of the climate data to understand the physical mechanisms that control the spatial temporal variability of monsoon precipitation in the region.

2. Study area

2.1. Regional setting

The investigated region includes inner to mid continental shelf of Rushikulya river mouth extends between 19°11.9′-19°23.4′N and 85°00.6′-85°13.9′E covering an area of 245 km^2. The Rushikulya river emerges from the slopes of Araha bity and Kutrabor hills of Eastern ghats with a drainage area of 82,100 km^2 running for approximately 165 km before meeting the Bay of Bengal at Puruna Bandha of Chhatarpur region (Jain et al., 2007). The average annual water discharge of the Rushikulya river is ~1800 million m^3 with discharge highly seasonal due to the monsoonal conditions (Panigrahy et al., 1999).

2.2. Regional climate and geomorphology

The climate over the east coast of India is mainly tropical in nature administered by the SW monsoon between June and September, and NE monsoon during October to December. The study area receives an average annual rainfall of ~1200 mm with SW monsoon accounts for ~80% of the total precipitation (Jain et al., 2007). The maximum and minimum temperatures recorded in the region are 45°C and 12°C respectively (Jain et al., 2007). The wind force over the region is fairly high during the period of south-western monsoon and the whole of Odisha coast is vulnerable to frequent cyclonic storms during October–November (Mascarenhas, 2004).

The high energy waves from the south and the southeast during the monsoon season generate the long shore current that heads towards north and is reversed during winter months due to prevailing northeasterly waves generating littoral current that runs towards south (Mishra et al., 2001). The coastal region of the study area is characterised by major geomorphic features like beach ridges, sand spits, and barrier spits (Markose et al., 2016). The