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A 500,000 year record of Indian summer monsoon dynamics recorded by eastern equatorial Indian Ocean upper water-column structure

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ABSTRACT

The Indian Summer Monsoon (ISM) is an inter-hemispheric and highly variable ocean–atmosphere–land interaction that directly affects the densely populated Indian subcontinent. Here, we present new records of palaeoceanographic variability that span the last 500,000 years from the eastern equatorial Indian Ocean, a relatively under-sampled area of ISM influence. We have generated carbon and oxygen stable isotope records from three foraminiferal species from Ocean Drilling Program Site 758 (5°N, 90°E) to investigate the oceanographic history of this region. We interpret our resultant $\Delta\delta^{18}O$ (surface-thermocline) record of upper water-column stratification in the context of past ISM variability, and compare orbital phase relationships in our Site 758 data to other climate and monsoon proxies in the region. Results suggest that upper water-column stratification at Site 758, which is dominated by variance at precession and half-precession frequencies (23, 19 and 11 ka), is forced by both local (5°N) insolation and ISM winds. In the precession (23 ka) band, stratification minima at Site 758 lag northern hemisphere summer insolation maxima (precession minima) by 9 ka, which is consistent with Arabian Sea ISM phase estimates and suggests a common wind forcing in both regions. This phase implicates a strong sensitivity to both ice volume and southern hemisphere insolation forcing via latent heat export from the southern subtropical Indian Ocean. Additionally, we find evidence of possible overprinting of millennial-scale events during glacial terminations in our stratification record, which suggests an influence of remote abrupt climate events on ISM dynamics.

1. Introduction

The south Asian, or Indian, summer monsoon, a subsystem of the Asian summer monsoon, is a large-scale, highly dynamic ocean–atmosphere–land interaction centred on the Indian subcontinent, which affects crop production and the livelihoods of over a billion people (e.g. Webster et al., 1998; Ding and Chan, 2005; Wang et al., 2005). The Indian summer monsoon (ISM) is driven by asymmetric heating between the cooler Indian Ocean and the warmer Indo-Asian landmasses such that, during boreal summer (May–September), intense heating results in a strong pressure gradient between Asia (low pressure) and the southern subtropical Indian Ocean (SSIO, high pressure) that leads to large-scale shifts in the position of the Intertropical Convergence Zone (ITCZ). Low pressure over Asia is driven by both sensible (direct) heating of the Asian landmass and latent (condensational) heating in the overlying troposphere. Latent heat that originates from evaporation of surface waters over the SSIO is transported northward as moisture-rich winds toward the high-altitude Himalayas, where it is released as precipitation, which further enhances low pressure over Asia during the summer monsoon (Krishnamurti, 1985; Webster, 1987; Clemens et al., 1991; Webster et al., 1998; Schott and McCreary, 2001; Shankar et al., 2002; Gadgil, 2003; Wang et al., 2003a; Gadgil et al., 2007).

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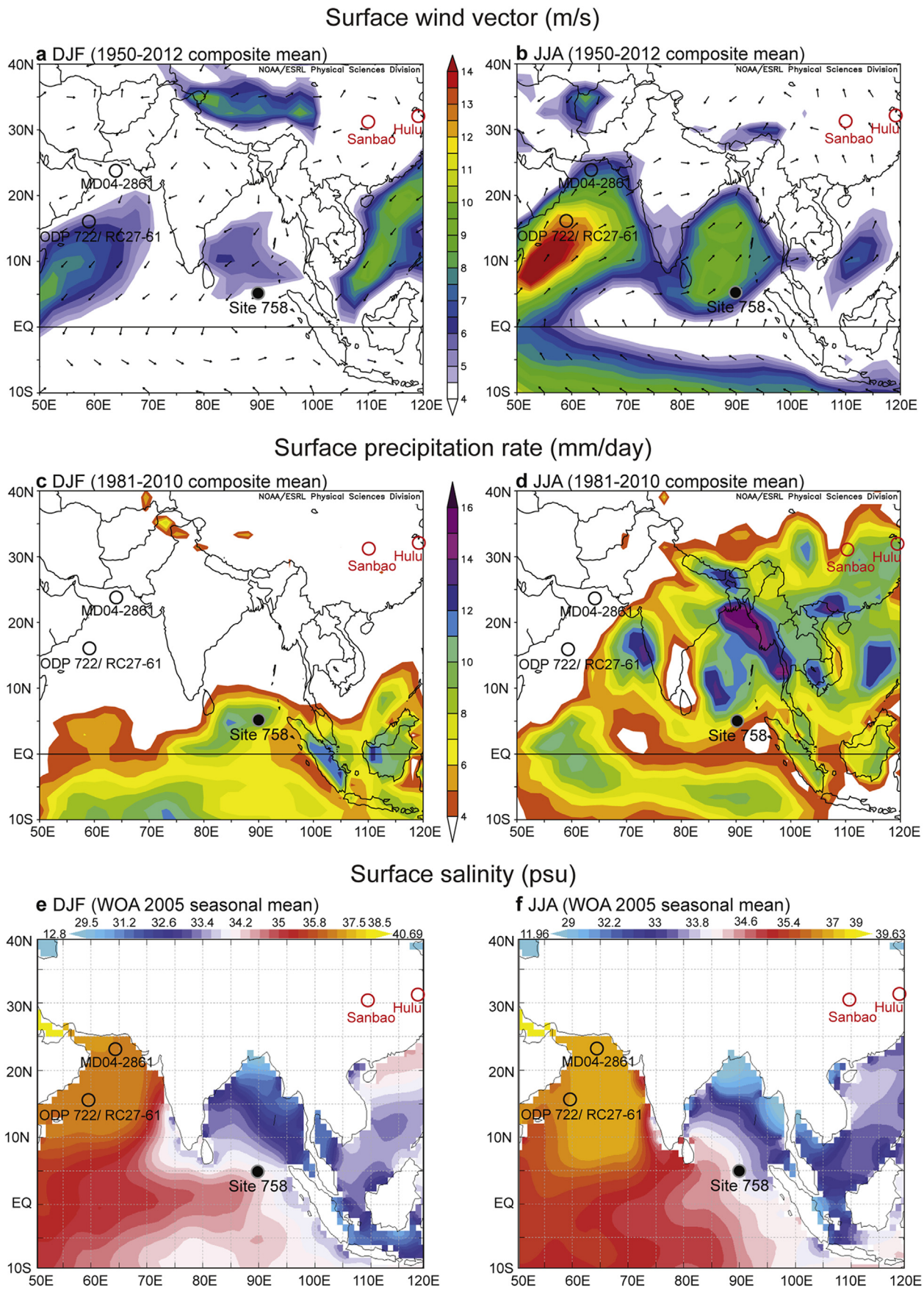
Surface wind vector (m/s)
a DJF (1950-2012 composite mean)
b JJA (1950-2012 composite mean)
NOAA/ESRL Physical Sciences Division
Sanbao
Hulu
MD04-2861
ODP 722/ RC27-61
Site 758
40N
30N
20N
10N
EQ
10S
50E
60E
70E
80E
90E
100E
110E
120E
14
13
12
11
10
9
8
7
6
5
4
Surface precipitation rate (mm/day)
c DJF (1981-2010 composite mean)
d JJA (1981-2010 composite mean)
16
14
12
10
8
6
4
Surface salinity (psu)
e DJF (WOA 2005 seasonal mean)
12.8
29.5
31.2
32.6
33.4
34.2
35
35.8
37.5
38.5
40.69
f JJA (WOA 2005 seasonal mean)
11.96
29
32.2
33
33.8
34.6
35.4
37
39
39.63