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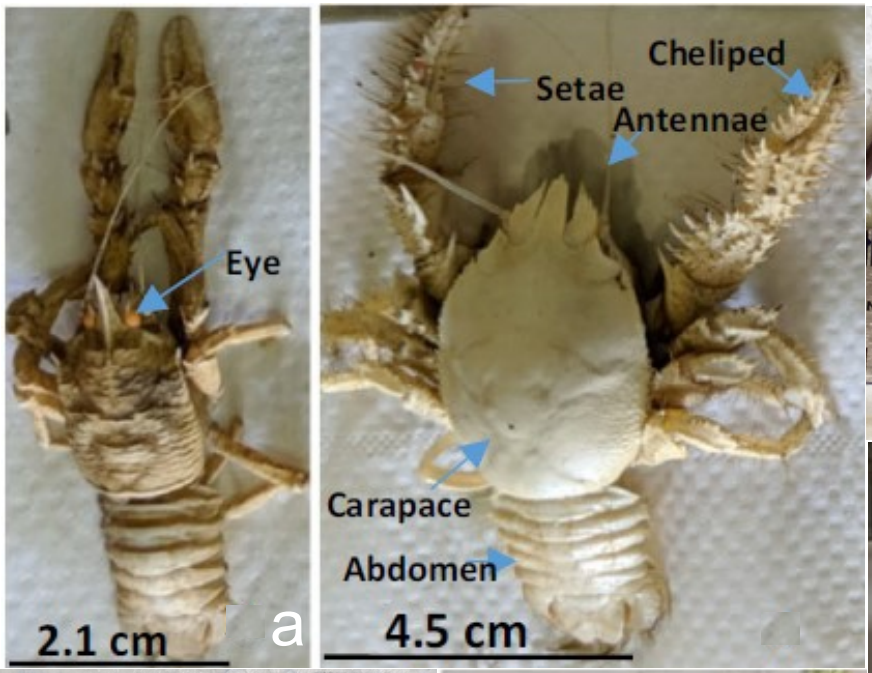

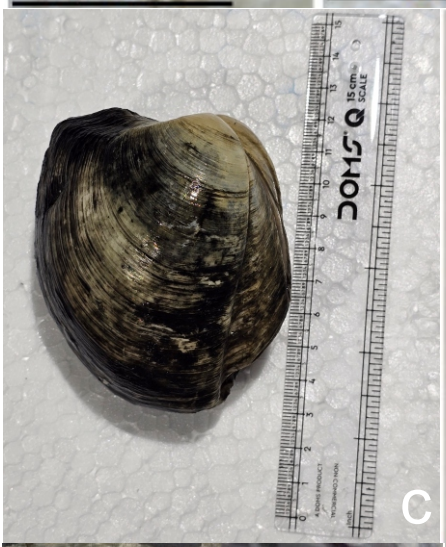

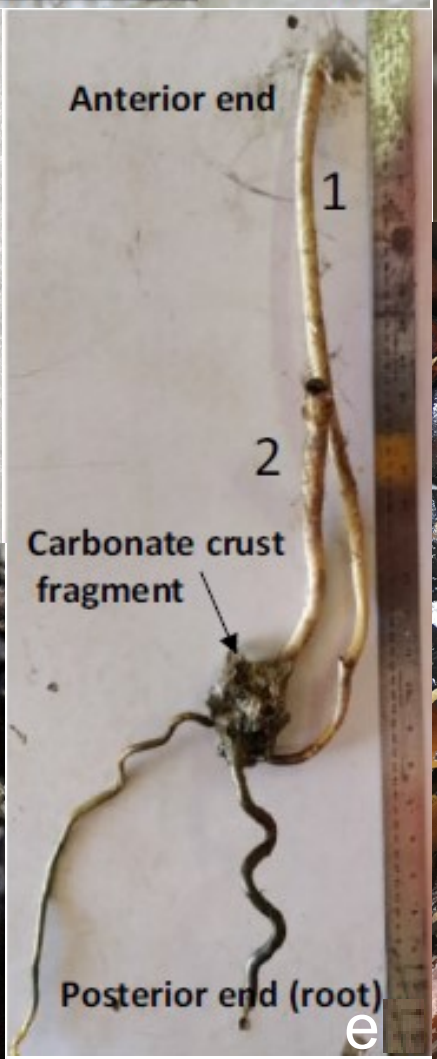

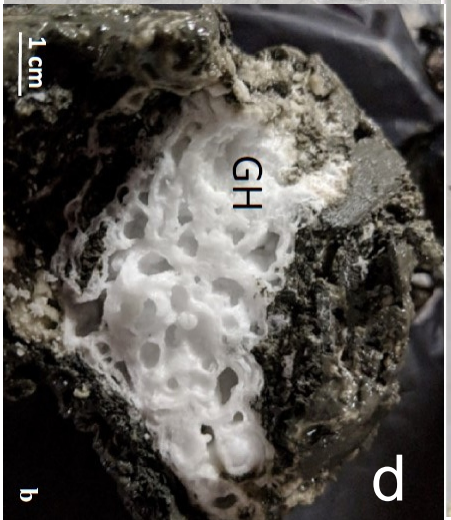

Quantitative analysis of *Nonionella* sp. (a benthic foraminifera) from polar and tropical zones using Four Dimensional X-Ray Microscopy

Rohan Subba and Anupam Ghosh

Department of Geological Sciences, Jadavpur University, Kolkata, 700032, West Bengal.
Corresponding Author: anupam.ghosh@jadavpuruniversity.in

Abstract

The morphological characteristics of a calcareous test in benthic foraminifera reflect the condition of the marine habitat during the calcification process. Based on biometry, the ontogenetic variation in the relative thickness of the internal chamber of benthic foraminifera, *Nonionella* sp. from arctic and tropical zones has been addressed. Four Dimensional X-ray Microscopy (FDXM) has been used, providing tomographic imaging and quantifying the internal structure. We report that the thickness of the internal chamber during the ontogenetic phases in the species *Nonionella* sp. is not geographically constant.

Keywords: *Nonionella* sp., tomography, FDXM, thickness, t-test statistics.

Benthic foraminifera are marine protists with rich diversity and extensive geographical coverage (Lei et al., 2015). Foraminifera has the ability of phenotypic plasticity towards the changing marine conditions such as pH, salinity, and temperature so the morphological characteristics of a calcitic test correlate with the ecological habitat (Corliss, 1985; Murray, 2006). The distribution of *Nonionella* sp. as a cosmopolitan species extends from the tropical marine environment to arctic zones.

The study is aimed to understand, whether any significant variation exists in the thickness of the internal chamber, during the ontogenetic changes in *Nonionella* sp. from two different latitudinal zones.

Recently, the application of X-ray micro-computed tomography (micro-CT) has advanced in different fields of science for analyzing various types of specimens. It is a versatile tool that provides the benefit of non-destructive analysis and 3D reconstruction of specimens at a micrometer (µm) to submicrometer scale (du Pleiss et al., 2017). In micropaleontological aspects such as foraminifera, micro-CT allows biometric quantification of the internal structure and evaluation of the morphological variation. Moreover, the preservation condition of microfossils (Johnstone et al., 2010) and their shell thickness can also be assessed (Ujiié et al., 2019 and Fox et al., 2020). Four Dimensional X-ray Microscopy (FDXM) provides similar features as that of micro-CT with the capability of 3D X-ray imaging.

Samples were collected from the tropics (19°42'03"N long. to 85°25'03"E lat.) and arctic (79°02'32.4"N long. to 11°36'55.3"E lat.) zones, focussed on modern and living specimens. Initially, the samples were processed by wet sieving at <63 µm size fraction followed by oven drying at about 50°C until completely dry. Picking and sorting of foraminifera were conducted under a stereo zoom microscope (Nikon-SMZ1000). Rose Bengal stained, pink coloured, living foraminifera were differentiated from the unstained fossil specimens. After the species were properly identified, only the complete and pristine shells of the adult specimens bearing no physical or chemical alteration were considered for further analysis. Tomographic analysis was conducted with Zeiss, Xradia Versa 520, 3D X-ray microscope at Four Dimensional X-ray Microscopy (FDXM-IRCC) Central Facility of IIT Bombay.

A total of two specimens of *Nonionella* sp., one each from the tropics and arctic have been analyzed through a 3D X-ray microscope. With 9 chambers each for two specimens, a total of 18 chambers were measured for the thickness of the internal chamber. The measured values have been shown in Table 1 and illustrated in Figure 1.

Table 1: Thickness measurement of the internal chamber in *Nonionella* sp. from the arctic and tropical zones.

Chamber Number	Arctic (µm)	Tropical (µm)
1	4.436	3.946
2	4.811	3.772
3	3.848	3.715
4	3.468	3.138
5	4.953	2.479
6	3.968	2.736
7	9.477	2.611
8	7.832	4.438
9	8.989	4.103

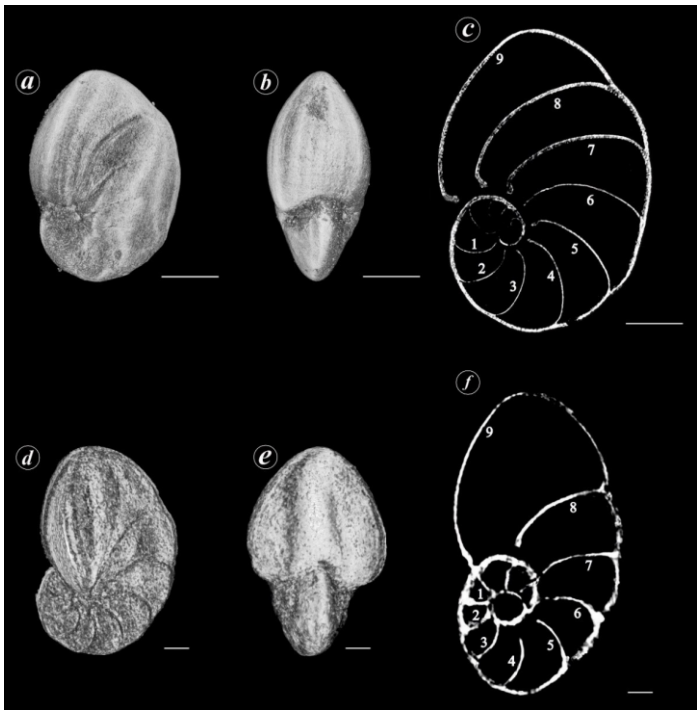

Figure 1. a, *Nonionella* sp. (planispiral), b, Apertural view, c, Tomographic photomicrograph; a–c, Arctic specimen (bars represent 100 µm); d, *Nonionella* sp. (planispiral), e, Apertural view, f, Tomographic photomicrograph; d–f, Tropical specimen (bars represent 10 µm); (1–9) chamber number

The results show a relative variation in the thickness of the chamber in *Nonionella* sp. from two different zones. It has been shown in (Figure 2). The species associated with the tropical zone has a relatively lower thickness than its counterpart in the arctic zone. .

Paired t-test statistics (Student's t-test) were calculated for the data set between the two specimens using PAST (Paleontological Statistics; Hammer et al., 2001) software. It provides information on the difference in means between two dependent samples (same species). It was calculated for all the chambers as measured for tomographic analysis. The calculated value of the t-statistic (t) is -2.985 with a probability (p) value of 0.003. Thus, it can be stated that there is a significant difference in the thickness of the internal chamber, between the two specimens from two different latitudinal zones.

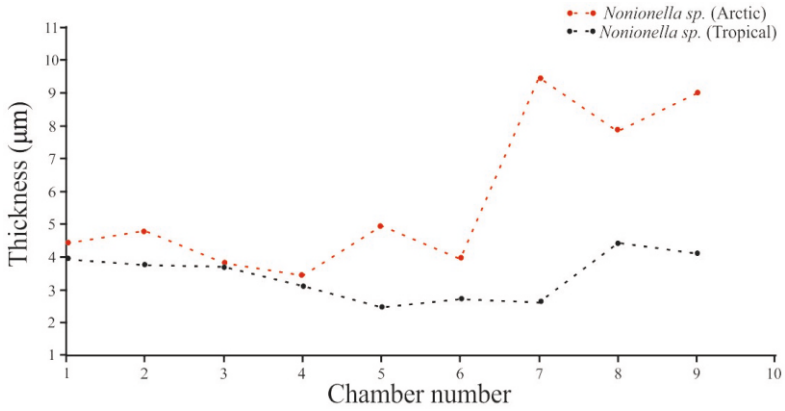

Figure 2: Graph showing the internal chamber thickness of *Nonionella* sp. from arctic and tropical zones

In *Nonionella* sp. the thickness of the internal chambers from the tropics is lower, indicative of a lower state of calcite saturation. Whereas, the arctic specimen shows a higher rate of calcification hence, a thicker chamber. The process of calcification is controlled by several environmental parameters (de Villiers et al., 2004) which are yet to be deciphered.

The biodiversity of a geographic region is regulated by various ecological and climatic factors (Wollenburg et al., 2007). The hypothesis of 'physical tolerance' states that the diversity of species is governed by the facets of the biophysical environment (Schluter and Ricklefs, 1993). Another hypothesis, 'energy richness' asserts that the species richness is higher in warmer regions (Hutchinson, 1959). Consequently, the biodiversity in the tropics is more enriched than in the arctic areas.

The internal chamber of the test consists of the ontogenetic or primary calcite so, it is very susceptible to dissolution compared to the external test (Steinhardt et al., 2015). So, the study may pave the way to understanding the latitudinal gradients to correlate the saturation state of calcite with the process of calcification (Barker and Elderfield, 2002; Spero et al., 1997) using foraminifera as a proxy. A closer perspective on the associated physical attributes would be beneficial to understand the climatic variation between the latitudes. Benthic species such as *Nonionella* sp. have the potential to be used as a proxy indicator due to their wide latitudinal extent.

Acknowledgements

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References

Barker, S. Elderfield, H. (2002) Foraminiferal calcification response to glacial-interglacial changes in atmospheric CO_2. Science 297: 833–836.

Corliss, B. H. (1985) Microhabitats of benthic foraminifera within deep-sea sediments. Nature 314: 435–438.

de Villiers, S. (2004) Optimum growth conditions as opposed to calcite saturation as a control on the calcification rate and shell-weight of marine foraminifera. Marine Biology 144: 45–49.

du Plessis, A., Broeckhoven, C., Guelpa, A., le Roux, S. G. (2017) Laboratory x-ray micro-computed tomography: A user guideline for biological samples. GigaScience 6: 1–11.

Fox, L., Stukins, S., Hill, T., Miller, C. G. (2020) Quantifying the Effect of Anthropogenic Climate Change on Calcifying Plankton. Scientific Reports 10: 1–9.

Hammer, Ø., Harper, D. A. T, Ryan, P. D. (2001) Past: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4:1-9.

Hutchinson, G. E. (1959) Homage to Santa Rosalia, or why are there so many kinds of animals? The American Naturalist 93:145-159.

Johnstone, H. J. H., Schulz, M., Barker, S., Elderfield, H. (2010) Inside story: An X-ray computed tomography method for assessing dissolution in the tests of planktonic foraminifera. Marine Micropaleontology 77: 58–70.

Lei, Y. L., Li, G.T., Bi, H., et al. (2015) Responses of benthic foraminifera to the 2011 oil spill in the Bohai Sea, PR China. Marine Pollution Bulletin 96: 245–260.

Murray, J. W. (2006) Ecology and applications of benthic foraminifera. Cambridge University Press pp. 249.

Schluter, D., Ricklefs, R. E. (1993) Convergence and the regional component of species diversity. In Species Diversity in Ecological Communities. Historical and Geographical Perspectives. University of Chicago Press, 230–242.

Speijer, R. P., Denis, V.L., Masschaele, B., et al. (2008) Quantifying foraminiferal growth with high-resolution X-ray computed tomography: New opportunities in foraminiferal ontogeny, phylogeny, and paleoceanographic applications. Geosphere 4: 760–763.

Spero, H. J., Bijma, J., Lea, D. W., et al. (1997) Effect of seawater carbonate concentration on foraminiferal carbon and oxygen isotopes. Nature 390:497–500.

Steinhardt, J., de Nooijer, L. L. J., Brummer, G. J., Reichart, G. J. (2015) Profiling planktonic foraminiferal crust formation. Geochemistry, Geophysics, Geosystems 16: 2409–2430.

Ujiié, Y., Kimoto, K., Ishimura, T. (2019) Advanced approach to analyzing calcareous protists for present and past pelagic ecology: Comprehensive analysis of 3D-morphology, stable isotopes, and genes of planktic foraminifers. PLoS One 14:1–19.

Wollenburg, J. E., Mackensen, A., Kuhnt, W. (2007) Benthic foraminiferal biodiversity response to a changing Arctic palaeoclimate in the last 24.000 years. Palaeogeography, Palaeoclimatology and Palaeoecology 255:195-222.

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Multiscale Surface Circulation Features in the Western Andaman Sea: Observations from HF Radars

Samiran Mandal[1], Sourav Sil[2], Avijit Gangopadhyay[3,2], Ramakrishnan Balaji[4,5], Glen Gawarkiewicz[6], Basanta Kumar Jena[4], Ramasamy Venkatesan[7]

[1]Centre for Atmospheric Sciences, Indian Institute of Technology Delhi.
[2]School of Earth, Ocean, and Climate Sciences, Indian Institute of Technology Bhubaneswar, India.
[3]School for Marine Science and Technology, University of Massachusetts Dartmouth, Massachusetts, USA.
[4]National Institute of Ocean Technology, India.
[5]Department of Civil Engineering, Indian Institute of Technology Bombay, India.
[6]Physical Oceanography Department, Woods Hole Oceanographic Institution, Massachusetts, USA.
[7]Institute for Ocean Management, Department of Civil Engineering, Anna University, Chennai University, Tamil Nadu, India

The Bay of Bengal (BoB) is a tropical ocean basin in the northern Indian Ocean (NIO). The eastern part of the NIO is occupied by a regional sea (91–95 °E, 6–14 °N) known as the Andaman Sea (AnS). It is enclosed by Myanmar, Malaysia, Andaman, and Nicobar Islands and is linked to the South China Sea and the Pacific Ocean through the Malacca Strait. Compared to the rest of the BoB, the circulation pattern of AnS has not been explored as it is one of the poorly observed regional seas. However, due to the limitations in the availability of observations, earlier studies have investigated the dynamics in the AnS utilizing models. In recent years, the Indian Coastal Ocean Radar Network (ICORN) has installed a pair of high-frequency radars (HF Radar) along the eastern coast of the Andaman Islands, with the primary objective of capturing the higher resolution surface currents to overcome the unavailability of in situ current observations in the AnS. The current datasets from the two direction-finding HF Radars (SeaSonde) are extensively utilized in this study, which have been installed at Hut Bay and Port Blair along the WAnS to observe the surface currents with a typical range of ~200 km (source: INCOIS and NIOT, India). In a global scenario, the HF Radars are reliable enough to understand the sub-mesoscale and mesoscale oceanic processes, dynamics of the frontal eddies, and geostrophic filaments associated with the East Australian Current, Florida Jet, and the Western Boundary Current - East India Coastal Current system in BoB. Also, the hourly surface currents are used to investigate the tidal dynamics, such as the extraction of tidal currents, characterization of tidal asymmetry, and tide-current-bathymetry interactions. Thus, these shore-based HF Radars are one of the essential components of the coastal ocean observing systems. Highlights from these studies are presented here focusing on three spatio-temporal multiscale aspects: (i) tidal scale, (ii) seasonal scale and (iii) submesoscale.

1. Tidal Scale

The comparison of tidal currents from BD12 and HF Radar currents indicates a reasonable match in terms of the order of amplitudes of the tidal currents (CC= 0.95) during November 2016 (Fig. 1a). Also, the match is noteworthy with higher correlations (CC= 0.89) for the tidal currents from the zonal component than the meridional component, which is due to the mean westward circulation pattern during November 2016. The harmonic analysis of HF Radar-derived currents indicates the dominance of M2 tidal currents (8.83 cm/s, followed by other semidiurnal constituents (S2, 4.30 cm/s and N2, 2.63 cm/s, and diurnal tidal constituents (K1, 2.24 cm/s and Q1, 1.58 cm/s in the WAnS (Fig. 1b and 1c). Moreover, the shallow water tidal constituents, M4 (1.25 cm/s and MS4 (0.87 cm/s, are also observed with significant amplitudes in the shallow water regions (Fig. 1d). The domain has a semidiurnal tidal regime ($F < 0.25$), with total tidal variance ranging between 10% and 50%. The circulation pattern in a day indicates the reversal of M2-driven tidal currents with westward (eastward) propagation of the currents during the low (high) tides (Fig. 1b). The intensification of M2 tidal currents at the center of the domain and around Little Andaman Island is observed. The M2 tidal currents with higher amplitudes (12 cm/s skirt around Little Andaman Island, with stronger currents through the 11° channel, which persists throughout the year. This intensification of the M2 tidal currents in the 11° channel can be attributed to the convergence of tidal waves on their interaction with the islands on either side of the channel and nonlinear interactions with bathymetry.

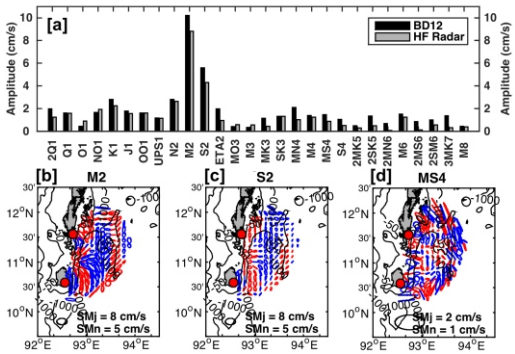

Figure 1: (a) Comparison of semi-major axes amplitudes of the tidal constituents extracted from the BD12 and HFR currents during November 2016. The spatial distribution of (b) M2, (c) S2, and (d) MS4 tidal ellipses during November 2016–October 2017. The blue (red) ellipses show clockwise (anticlockwise) rotations, and the black ellipse is the reference ellipse

2. Seasonal Scale

The northward and southward flows are observed from the HF Radars during the northeast (November–February) and southwest (June–October) monsoons with current speeds of ~0.41 and ~0.22 m/s, respectively (Fig. 2a and 2b). Also, the vertical structures of temperature and salinity indicate slight changes in the upper ocean throughout the year. The evidence of large temperature gradients in the AnS between the surface and bottom (from 28 °C to 5 °C) indicates the strong internal waves in this region. The seasonal reversal of currents leads to the exchange of waters through the 11° channel, i.e., the water masses flow into the AnS (BoB) during June–October (November–February) but are restricted to the local region. The local winds predominantly influence the seasonality of the circulation pattern compared to the coastal Kelvin Waves and reflected Rossby Waves (Fig. 2c).

3. Sub-Mesoscale Features

A sub-mesoscale coastal anticyclonic eddy is also observed on the lee side of LA Island from the HFR surface circulation maps from August 4–10, 2017 (Fig. 2d-2f).

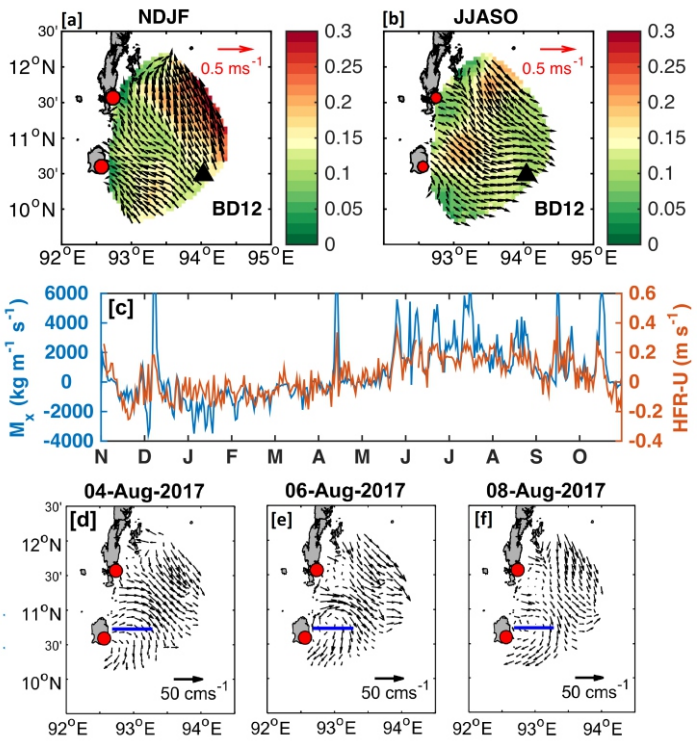

Figure 2: Surface circulation pattern during (a) November-February (NDJF) and (b) June-October (JJASO) from the HF Radars along the western Andaman Sea. (c) Time-series comparison of zonal component of Ekman mass transport (Mx) and the HF Radar surface currents. (d-f) HF Radar surface current maps during the different stages of the sub mesoscale anticyclonic lee eddy.

The eddy has a mean radius of ~11 km and lasts for six days (Mandal et al., 2022). Negative values of normalized vorticity, divergence, OW parameter, and lower values of strain characterize the anticyclonic eddy. A term-by-term vorticity budget analysis indicates higher variability of the vortex stretching term compared to the advection term, indicating the dynamic role of the vortex stretching term in the evolution of the lee eddy. In addition, higher negative values of wind stress curl during the concurrent time period of the genesis of Lee Eddy indicate the dominant role of the local winds (Mandal et al., 2022).

To conclude, this study highlights the capability and need for higher resolution datasets from multiple data sources (HF Radar and satellite maps) to resolve the dynamical features related to the sub-mesoscale coastal eddies.

This article is based on the following papers,

Mandal S, Sil S, Gangopadhyay A, Jena BK, Venkatesan R, Gawarkiewicz G (2020). Seasonal and tidal variability of surface currents in the Western Andaman Sea using HF radars and buoy observations during 2016–2017. IEEE Transactions on Geoscience and Remote Sensing, 59 (9), 7235-7244.

Mandal S, Gangopadhyay A, Ramakrishnan B, Sil S (2022). Evolution of a sub-mesoscale eddy leeward of Andaman Islands from HF radars. IEEE Geoscience and Remote Sensing Letters, 19, 1-4.

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Research Highlights

Unlocking the Holocene climate and global teleconnection from southern Saurashtra, Western India

Upasana S. Banerji
National Centre for Earth Science Studies (NCESS),
Thiruvananthapuram-695011, Kerala
Email: upasana.s.banerji@gmail.com

This article is based on the following paper

Banerji, U. S., Bhushan, R., Joshi, K. B., Dabhi, A., Sudheer, A., Dubey, C. P., Panda, R. K., Haridas, N. V., & Gaddam, M. (2024). Geochemical records of mudflat sediments from southern Saurashtra, Western India: Implications for Holocene climate and global teleconnection. The Holocene, 34(11), 1700-1720.

The Earth's climate system is a complex interplay of oceanic and atmospheric heat transport, driven by latitudinal imbalances in solar radiation. Understanding the dynamics of this system is crucial for predicting future climate scenarios, particularly in the context of anthropogenic climate change. The Indian Summer Monsoon (ISM) is a critical component of the Asian Monsoon System playing a prime role in the global hydrological cycle and delivering over 80 % of the annual rainfall to the Indian subcontinent and nearby regions, primarily during June-September, as a result of the northward migration of the Intertropical Convergence Zone (ITCZ). Variations in the ISM strength have profoundly impacted human societies and led to the rise and fall of civilisation during the Holocene epoch. Thus, the Holocene epoch is a valuable window to decode the natural climate variables and their associated changes in the Earth's climate system (Banerji et al., 2020; Banerji and Padmalal, 2022; Berkelhammer et al., 2015).

Gujarat, the westernmost state of India, reveals varied climatic patterns ranging from humid to arid, reflecting the variability in ISM rainfall patterns. The Saurashtra peninsula of western Gujarat is geologically characterized by Deccan basalt, Tertiary and Quaternary limestone, and alluvium fringing the coastal region (Merh, 1995). The Saurashtra region experiences a mean annual rainfall of approximately 600 mm, with the majority of precipitation occurring during the ISM. The mean maximum and minimum temperatures witnessed by the region are 34°C and 19°C, respectively (Gundalia and Dholakia, 2013) while the forest type classification for the study area falls under the 5A/C-1a (very dry teak forest) category (Champion and Seth, 1968). The southern Saurashtra coast, characterized by 40–50 m vertical cliffs of miliolite limestone and extensive tidal mudflats, is an ideal location for paleoclimate studies. The active mudflats receive terrestrial input during the monsoon rainfall, when seasonal rivers are activated, and while during high tides, the region receive marine sediments. The modern tidal flat sediments are dominated by clay, the beach sediments are dominated by biogenic carbonate. The present study aims to reconstruct paleomonsoon variability and decipher global teleconnections during the Holocene Epoch using sediment cores from the Jaffrabad mudflats of the Southern

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Saurashtra coast, Western Gujarat. The specific objectives of the study are: (i) to understand paleoweathering and paleo-sediment sources in the mudflats of the southern Saurashtra coast; (ii) to reconstruct past ISM rainfall variability from the southern Saurashtra region; and (iii) to deconvolute the possible teleconnections of the ISM with regional and global climate scenarios.

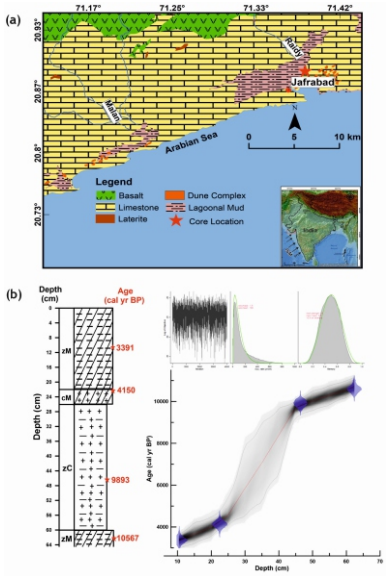

Figure 1: (a) Geology of the study area. (b) Litholog and age-depth model for the sediment core.

A sediment core of ~65 cm long was retrieved from the exposed mudflat of Jaffrabad (MIT; Latitude: 20.889°N; Longitude: 71.382°E) using a hand-operated PVC corer (Figure 1). The sediment core was subsampled at 1 cm intervals and was subjected to various geochemical analyses using ICP-MS, ICP-AES, Elemental Analyser and Coulometer at the Physical Research Laboratory (PRL), Ahmedabad. The core was chronologically supported by AMS radiocarbon dates obtained from AURIS, PRL. Further, the Wavelet analysis of the geochemical data was employed to explore the periodicities embedded in the geochemical signals and to identify the dominant forcing mechanisms driving monsoon variability.

The geochemical analysis of the Jaffrabad mudflat sediment core supported by AMS radiocarbon ages revealed significant variations in sediment composition, weathering intensity, and monsoon rainfall patterns during the Holocene epoch. The majority of the sediments were primarily derived from the hinterland's Deccan basalts, with the addition of intermediate sources (Figure 2). The weathering proxies revealed mature sediment deposited during 10,650-5,500 cal yr BP followed by a dramatic decline in the sediment maturity after 5,500 cal yr BP thereby reflecting changes in temperature and precipitation during the Holocene epoch. High concentrations of terrestrial proxies were associated with strong monsoon periods (10,650-5,500 cal yr BP), while low concentrations (5,500-2,700 cal yr BP) indicated weaker monsoon conditions (Figure 2). The strong monsoon rainfall during 10,650-5,500 cal yr BP was attributed to enhanced solar insolation and orbital forcing, which led to the northward migration of the ITCZ and increased moisture transport to the Indian subcontinent. The weak monsoon conditions during 5,500-2,700 cal yr BP were linked to the southward migration of the ITCZ and increased El Niño-like conditions in the Pacific Ocean.

The southward migration of the ITCZ would have reduced rainfall over the Indian subcontinent, while increased El Niño-like conditions would have suppressed the Walker circulation and weakened the monsoon. The wavelet analysis revealed that solar variability, orbital forcing, and North Atlantic forcing exerted a combined influence on monsoon variability throughout the Holocene.

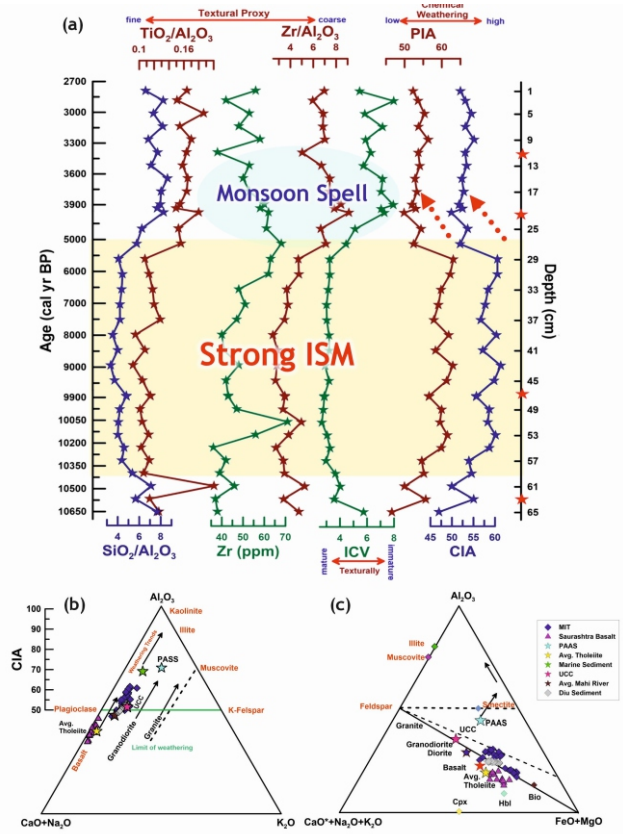

Figure 2: (a) Downcore variation of geochemical proxies. (b) Ternary plot of Al_2O_3 - CaO + Na_2O - K_2O; (c) Ternary plot of Al_2O_3 - CaO + Na_2O + K_2O - FeO + MgO.

The present study has several important implications for understanding Holocene climate variability and its possible drivers. This study underscores the significance of paleoclimate studies for understanding the Earth's climate system and addressing the challenges of future climate trends. It also reinforces the idea that understanding past climate dynamics is crucial for predicting and mitigating the effects of future climate scenarios, especially in regions profoundly dependent on monsoon rainfall like the Indian landmass.

References

Banerji US, Arulbalaji P and Padmalal D (2020) Holocene climate variability and Indian Summer Monsoon: An overview. Holocene 30(5): 744–773: doi:10.1177/0959683619895577.

Banerji US and Padmalal D (2022) Bond events and monsoon variability during Holocene-Evidence from marine and continental archives. In: Kumaran KPN and Padmalal D (eds) Holocene Climate Change and Environment. Elsevier, 293338.

Berkelhammer M, Sinha A, Stott L, Cheng H, Pausata FSR and Yoshimura K (2015) An Abrupt Shift in the Indian Monsoon 4000 Years Ago. Climates, Landscapes, and Civilizations, 75–87.

Champion HG and Seth SK (1968) A Revised Survey of the Forest Types of India. Delhi, India: Manager of Publications.

Gundalia MJ and Dholakia MB (2013) Modelling pan evaporation using mean air temperature and mean pan evaporation relationship in middle south Saurashtra Region . International Journal of Water Resources and Environmental Engineering 5(11): 622–629.

Merh SS (1995) Geology of Gujarat. Bangalore : Geological Society of India.

Water Quality, Pubic Health, and Citizen Science

Jasmin C[1,2] and Nandini Menon N[1,2]

[1]Nansen Environmental Research Centre India (NERCI), Kochi 682 506, India
[2]Trevor Platt Science Foundation (TPSF), Kochi 682 018, India

Whether our house is on the coast, away from shore, or on the riverbank, we are often plagued by questions on water quality: Is the tap water safe to drink? Will I get sick if I swim in this lake? Why are so many fish dying in the estuary? Why does this water look unusually murky, discoloured, or even remarkably clear?

Water is a fundamental resource for all life on Earth. It is essential for the survival and sustenance of life on Earth. However, with the constant increase in urbanisation, tourism, industrialisation, agriculture, and climate change effects, water quality degradation has become a pressing global concern. Environmental concerns such as eutrophication, harmful algal blooms and proliferation of pathogens also loom large as the health of water bodies deteriorates, jeopardising drinking water supplies, human health and the economy. In 2021, 66 countries reported that a considerable proportion of their population relies on untreated surface water (rivers, lakes and ponds) for drinking (World Health Organisation and United Nations Children's Fund, 2021). This reliance on unimproved drinking water sources puts users at risk of contamination and diseases. The perception of risk from water quality issues varies according to age, education, and interaction with the environment. The rise in leptospirosis cases in Kerala during monsoon season is an example of environmental influence, wherein the people are forced to interact with contaminated water.

In this context, instead of the questions we usually ask, perhaps one of the most important questions is: How do we know our water is healthy? To put it simply, healthy water is the one that can support and sustain life. In scientific terms, we define water quality based on physical, chemical and biological standards, and there are umpteen tests to evaluate each criterion, ranging from the colour and odour of water to bacterial content and biodiversity. Continuous observations can help avoid significant health problems or readily identify them when they do occur. So, water quality monitoring programs that deliver long-term and spatially diverse trend information are required. Many national authorities or even academia, especially those in low-income countries, cannot collect water quality data at the requisite spatial and temporal scales to provide science-based information for water resource management decisions.

The reality that significant water quality data gaps exist globally (UNEP, 2021) and that national authorities struggle to collect sufficient data presents an opportunity for citizen scientist-generated data to fill this void. Local citizens live close to the water body and can collect samples in response to target hydrological conditions, such as peak flow conditions, or in response to an observed pollution incident. This can significantly increase the amount of water quality data available to government agencies for bodies of water that may otherwise go unassessed. Citizen science involves the participation of non-professional volunteers in scientific research, data collection, and analysis. Various citizen science programs, where non-scientists participate in the design, collection, or interpretation of data, have been successfully implemented in several fields of study, such as ecology, ornithology, and astronomy. Citizen scientists with simple monitoring tools and mobile applications contribute valuable data from diverse geographical locations, including remote and under-served areas. In the field of water quality monitoring, the easiest and most direct way to assess water quality is by observing its colour and clarity. However, it could also be complex, as in microbial pollution studies, where bacterial content is assessed using specific microbial kits.

Keeping equipment and sampling procedures simple for citizen science projects is recommended to allow more people to participate and keep participants motivated. Simple methods may also reduce errors. One example is the Mini Secchi disc (MSD) with Forel-Ule colour scale stickers designed to monitor the transparency and colour of inland waters; paired with a mobile application “TurbAqua” to transmit the data to the server in near-real time. The citizen science network established with the support of students from 16 colleges affiliated with three universities of Kerala (India) and research institutions, and stakeholders such as houseboat owners, non-government organisations (NGOs), regular commuters, inland fishermen, and others residing in the vicinity of Vembanad Lake, as part of the Indo-UK water quality project 'Rehabilitation of Vibrio infested waters of Vembanad Lake: pollution and solution (REVIVAL Helped to observe the water quality of the lake continuously and generate maps of water colour and clarity. In recent years, the fusion of remote sensing technologies and citizen science has revolutionised water quality monitoring efforts. In the DST-WOSB project 'Validation of 3D- printed Mini Secchi Disc (3DMSD) for environmental pollution monitoring using in situ measurements and remote sensing' the MSD data were correlated with satellite chlorophyll-a concentration and abundance of Vibrio cholerae in the Vembanad Lake as well as the nearby coastal waters. This helped in establishing remote sensing algorithms which could be applied to study water quality using satellite remote sensing data.

Citizen science-based mobile applications offer user-friendly interfaces, real-time data visualisation, and educational resources, enabling users to easily collect, upload, and share water quality data on an unimaginable scale. The same REVIVAL team has built a mobile application, 'CLEANSE', to collect information on the sanitation status of the coastal community, which impacts the health of the water body and the shore community. Often, the involvement of local leaders or a local water quality issue serves as the “catalyst” to initiate and sustain activities. The mobile app 'CLEANSE' gained popularity due to Kerala's recent hike in waterborne diseases. Going beyond the initiation of activities, expanding citizen science from small catchment areas to large catchments and ultimately to national, regional, or global scales could promote the concept of “connecting to something bigger.” Showcasing the success stories of citizen science initiatives, through social media platforms is found to be adequate to reinforce people's awareness and other stakeholders' support.

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Ensuring that the collected data leads to meaningful information is critical. In-person training, tutorials, guides, or video demonstrations are essential to ensure citizen scientist initiatives generate meaningful and useful data. As part of the DST-WOSB project, training was given to college students on using the Mini Secchi disc and the associated mobile app TurbAqua. Data quality control is another key component of citizen science programs. Continuous capacity building, active involvement of expert scientists, and validation using satellite or in-situ data collected by scientists are needed to ensure the quality of the data. Technical advancements such as testing the user's colour resolving power are incorporated in the TurbAqua mobile app to minimise errors in estimating water colour by citizen scientists. Communication and feedback practices are also considered essential within citizen science projects. Efforts are needed to improve users' capabilities to navigate and interpret the data, and the information generated must be returned to inform local actions. In the case of the 'CLEANSE' app, the responses fed by the citizen scientists are subjected to a statistical evaluation of the vulnerability of the environment, which is provided to the user through the app itself upon completion of the questionnaire survey. This will help disprove the belief that locally generated knowledge often has nowhere to go. Another attraction is the cost-effectiveness of the citizen science programs. Data collection in an aquatic environment is often tiresome and expensive, and the limited observations are often insufficient to meet the scientific requirements. Citizen science data carves out a separate niche for such observational lacunae in in-situ data at a low cost. Collaboration through partnerships, such as a partnership between academia, local authorities, and citizens, can help scale up and pool resources and yield long-term positive outcomes.

To summarise, citizen science is a resource with huge potential, mainly because it can fill knowledge gaps in the territory, increase environmental awareness to inspire behavioural change, and cost-effectively facilitate traditional monitoring. Potentially, we are all citizen scientists and actors of change who can bring about revolutionary changes in water resource management through concerted efforts.

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List of OSI PG Dissertation Award 2023 Winners

Sr No	Name of Candidate	Name of the Supervisor	Dissertation Title	Affiliation	Theme
1.	Moulik Mandal	Dr. Naresh Krishna Vissa, Department of Earth and Atmospheric Sciences NIT Rourkela	Influence of summer monsoon intra-seasonal oscillations on the occurrence of Marine Heatwave over the North Bay of Bengal	NIT Rourkela	Ocean and Atmospheric Sciences
2.	Pranali P Marbade	Dr. Deepak Agarwal, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam	A study on salinity adaptability and its effect on growth through gene expression profiling in pearl spot (Etroplus s.)	Institute of Fisheries Post Graduate Studies (IFPGS), Chennai	Marine Microbiology/ Biotechnology
3.	Kalpana B Prusty	Dr.Jigneshkumar Trivedi Department of Life Sciences Hemchandracharya North Gujarat University, Gujarat	Bioaccumulation of microplastics in Bombau duck Harpadon nehereus (Hamilton, 1822) along northwest coast of India	H. N. Gujarat University, Gujarat	Biological Oceanography
4.	Anusri Saha	Dr. Raj Kumar Singh, School of Earth, Ocean, and Climate Sciences IIT Bhubaneswar	A comparative study of various sea surface temperature reconstruction methods - a case study from East China Sea	IIT Bhubaneswar	Geological Oceanography
5.	Aharna Sarkar	Dr. Supriyo Chakroborty, Indian Institute of Tropical Meteorology, Pune Dr. Pramit Kumar Deb Burman, Centre for Climate Change Research IITM Pune	Evaluating Tree-Ring proxies for ecosystem productivity in India through observations and model products.	IISER Pune	Ocean Engg. & Technology

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Cover Photo: *Photographs of marine life at cold seep environments from Krishna-Godavari and Mannar basins. a)squat lobsters, b) cold seep polychaete, c) thyasiridae bivalve, d) methane hydrate with air pockets, e)lamellibrachia polycheatae tube, f) acharax bivalve, g) assemblage of bathymodiolus and squatlobsters. Image courtesy: Dr. Aninda Mazumdar, Chief Scientist and Dr Aditya Peketi, Principal Scientist, CSIR-National Institute of Oceanography, Goa.*