

# Monsoon wind and maritime trade: a case study of historical evidence from Orissa, India

Sila Tripathi and L. N. Raut

*Monsoon plays a predominant role in the daily life of the people of South Asia. Use of the monsoon wind in the Indian Ocean for maritime trade was a boon to sailing ships to reach overseas countries. The first known evidence about knowledge of monsoon wind is from Hippalus (AD 45–47). Mariners from Orissa, India used to set out on their journey to Southeast Asian countries during the northeast monsoon (trade wind) and return during the southwest monsoon. The flow of wind and current was favourable for both the onward and return journey. Similarly, during the historical period, Arabs sailed in the Indian Ocean with the help of monsoon wind and Europeans, particularly the Portuguese, sailed their vessels in such a manner that they could reach the shores of India before the southwest monsoon and return only after the beginning of the northeast monsoon.*

*This note details the historical evidence, which indicates that the mariners of Orissa were aware of the monsoon wind and currents and its use for maritime trade since the last two thousand years, if not earlier. Additionally, the study shows that maritime trade to far-off countries was a seasonal phenomenon and there is no change of seasons of southwest and northeast monsoons since then.*

The varied physical phenomena of the ocean have attracted mariners, sailors and travellers since early times. Among other features, the monsoon, current(s), tide(s), etc. are the most interesting aspects related to the ocean and hence all are keen to acquire the knowledge on them. The monsoon plays a predominant role in survival of life on the earth. It is significant to note that the economy of India as well as some other countries depends on the monsoon. Weaker monsoon rainfall causes severe drought and famine. Similarly, excessive rain leads to floods, making thousands homeless and leads to distress. Several Indian legends and folklores mention the worship of the rain God *Indra* to avert drought and famine. Prayers are also offered for pacifying the river goddesses to avoid floods. Monsoon is required for agriculture and food. Archaeological and historical evidences indicate that several civilizations of the world, including the Indian subcontinent have disappeared or people have migrated due to fluctuations in the monsoon<sup>1,2</sup>.

'Monsoon' has been derived from the Arabic word *mausam* or *mausim*, meaning season. The first known evidence about knowledge of monsoon is from Hippalus<sup>3</sup> (AD 45–47). Generally, it is understood that the wind over the northern Indian Ocean which reverses semi-annually is known as monsoon. These winds blow from the southwest direction during June to November and during the other six months (December–May) from the north-

east direction. It appears that areas of the earth which experience large-scale movement of air from colder to warmer hemisphere are the principal monsoon lands of the world. Monsoon winds are pronounced in the summer season during June–August in the northern hemisphere and during January and February in the southern hemisphere. The wind which blows from the southern hemisphere during June penetrates into the northern hemisphere towards India and in wider stretches to Southeast Asian countries and to a lesser extent towards Africa. In January, the northeast trade winds sweep across the southern coast of the Bay of Bengal and generate precipitation over southern India. This is known as the winter monsoon or northeast monsoon. It is difficult to determine when the southwest monsoon or summer monsoon ends and when northeast monsoon begins over south of the Indian peninsula<sup>4</sup>.

### Historical evidence of monsoon

Historical evidence on the description of monsoon is available in the *Periplus Maris Erythrei* (*Periplus of the Erythraean Sea*) (AD 60–100) and the *Natural History* of Pliny (AD 23–79). The author of the former, a Greek navigator, has mentioned about ports and harbours along the Arabian Sea and Bay of Bengal, anchorages, names of coasts, approaches to ports, prevailing winds, rulers and people of the

regions, sailing conditions, and exports and imports. Further, he has provided ample evidence on maritime activities of the Arabian Sea and Bay of Bengal, but has not made direct reference to the monsoon; the reasons for ignoring the monsoon winds and currents are not clear<sup>5</sup>. Pliny has also mentioned about the southwest monsoon in his book<sup>6</sup>. Fa-Hien, the Chinese traveller had visited India during AD 399–414 to gather information on Buddhism. After his return to China in AD 414, he wrote the book *Record of Buddhist Kingdoms*, where he made an indirect reference to the northeast (winter) monsoon in connection with his voyage along the east coast of India. Fa-Hien has not mentioned about currents; omission of currents is not significant because his knowledge of the sea was limited<sup>7</sup>. The arrival of the monsoon in India has been described by Kalidas<sup>8</sup> (AD 450) in the Sanskrit poem *Meghaduta*. Similarly, Cosmas Indicopleustes, the Graeco-Egyptian merchant (AD 535) refers to currents near the mouth of the Gulf of Aden in the *Christian Topography* (AD 535–547). It is not clear whether he had known about currents. However, he has not mentioned monsoon; probably being an experienced sailor he might have ignored to refer to it in the text. Cosmas describes the pepper trade at the Malabar coast; ports on the west coast of India and Ceylon were the centres of commerce between China, the Gulf of Persia and the Red Sea region<sup>9</sup>.

Harappans were the first mariners from India who had maritime trade relations with countries outside India. They sailed up to the coast of Bahrain, Meluhha, Oman Peninsula and Mesopotamia using monsoon winds and currents, but no evidence is available in this regard. Greek and Roman mariners were able to reach the Indian coast to carry out extensive maritime trade with the help of monsoon winds. It is clear that the seafarers were not able to see the flow of winds and currents, but felt that there are forces that assist in driving the ship faster than the normal movement. The use of monsoon winds and currents for maritime trade by mariners is less known to all of us. Probably the knowledge of use of monsoon wind and current for maritime trade was only confined to sailors and mariners.

### Maritime trade and monsoon

The concept of trade during the ancient period is quite different from modern times. Literary references, epigraphic sources and representation of art on the walls of stupas and temples indicate that in ancient times, traders, mariners, sailors, Buddhist monks and saints as well as Hindu religious leaders used to sail together and this trend continued till the advent of the modern shipping.

Along the coastline of India, several ports flourished in different periods of history. Among them, ports and trade centres along the coast of Orissa were Sisupalgarh, Jaugada, Tamralipti, Palur, Manikapatna and Kalingapatnam (Figure 1). Explorations and excavations at these sites have yielded northern black polished ware (NBP), rouletted ware, knobbed ware, Red and Black ware, Roman and punch mark coins and semi-precious stone beads. All these archaeological findings are datable to 2500 to 2000 BP, if not earlier.

During the early historical period, Buddhism played a significant role in maritime trade; it could spread throughout Southeast Asia with the help of maritime trade. Hence similar type of pottery has been reported from explorations and excavations of ancient ports, trade centres and Buddhist settlements all along the coast of Andhra Pradesh, Orissa, Tamil Nadu, West Bengal, Bali, Sumatra, Vietnam, Java, Sri Lanka and Thailand. Mariners used to exchange their cargo at various ports and sail to their destination along with local sailors with the help of

monsoon winds and currents. This system continued over a long period, which was possible because of existence of maritime trade. Similar type of pottery found all along the ports and trade centres of Orissa and the east coast of India clearly indicates that traders visited every port on their way to Southeast Asia, and monsoon wind and currents assisted them during their voyages.

### Navigation and overseas routes

The seafarers of India had knowledge about the sea pertaining to weather, winds, currents, waves and tides. Their observations were often correct and they succeeded in presenting a general picture of the physical conditions of the Arabian Sea, Bay of Bengal and Indian Ocean. Information on these early concepts is found in Pali, Sanskrit and Tamil literature and also archaeological excavations, numismatics and paintings<sup>10</sup>.

Climatic conditions of the Bay of Bengal are crucial in determining sailing from the ports of the east coast of India. Sailing was carried out north and south along the coast and eastwards across the Bay. Communities of mariners, pilots and merchants acquired vast knowledge through generations of sailing.

In ancient times coastal voyages were made only when the sea conditions were favourable and vessels could cast anchor at night under dangerous circumstances. The crew were dependent upon the captain's sense of orientation and knowledge of the coastline, which enabled him to determine the position of the vessel in relation to a number of fixed points such as topographic features and identifiable landmarks. These features were often noted on old coastline maps of India. Buildings having conspicuous features served also as orientation point, e.g. the Konark and Puri temples on Orissa coast<sup>11</sup>, the Narashima temple at Bhimunipatnam (Bimlipatnam) on the Andhra coast and the pagodas at Mahabalipuram, Nakur (Nagore) near Nakappattinam (Nagapatnam) in Tamil Nadu. Similarly, hillocks and other coastal structures located on the east coast of India also served as landmarks for the sailors.

Sailing within territorial waters was possible through direct observation, without any instruments. Open sea navigation was not possible without the supporting orientation of landmarks, use of specific

procedures and instruments. Sailors possessed precise astronomical knowledge and navigated with an approximation in relation to azimuth of the sun and stars according to time and season. The position of a ship was estimated with its average speed on the basis of experience of the crew and velocity of the wind or the prevailing conditions of the sea. Ships carried tamed birds (*Disa Kaka*) on-board to indicate the direction on land<sup>12</sup>. Ancient Indian texts emphasized the skill of the pilots, their nautical experiences to know the conditions of the sea and changes in the behaviour of wind and colour of water.

Ships voyaging from ports on the east coast of India, namely, Tamralipti, Chilika, Palur, Kalingapatnam, Dharanikota, Masulipatnam, Arikamedu, Kaveripatnam, Nagapatnam and Sopatma to overseas countries used the Nicobar Islands as the halting station. The Chinese traveller I-Tsing (AD 635–713) has mentioned that from Tamralipti to Nicobar Islands it was thirty days sail and similarly from Sri Vijaya to China it was twenty days sail. Further, he states that it took about three months to sail from Sri Lanka to Java under tempestuous weather, breaking journey at an island for repair of leakage of ship and two months from Sri Vijaya to Nagapatnam<sup>13</sup>. Ships of Orissa which were bound directly for Southeast Asian countries passed via the Andaman and Nicobar Islands (Figure 2). People from all over India came by land or river to the nearest sea port and then made a coastal voyage either to Tamralipti, Palur or Masulipatnam, from where ships made a direct voyage to the Far East countries across the Bay of Bengal.

While making their voyages to Southeast Asian countries, the sailors and merchants of Orissa and others might have sailed around the Malay Peninsula through the Strait of Malacca, then to the East Indies and Indo-China and beyond. The other route to Southeast Asian countries from Orissa has been between the Andaman and Nicobar Islands or between Nicobar Islands and Achin, the northern tip of Sumatra, disembarking on the peninsula around Takuapa or at Kedah. On return they would come directly to Sri Lanka and then to other ports on the east coast of India (Figure 3). Further, these ships took a course to the northeast from Java to reach Canton. This route was followed by merchants who traded with the West and the East<sup>14</sup>. Sailors and merchants of Orissa had landed at various places, in-

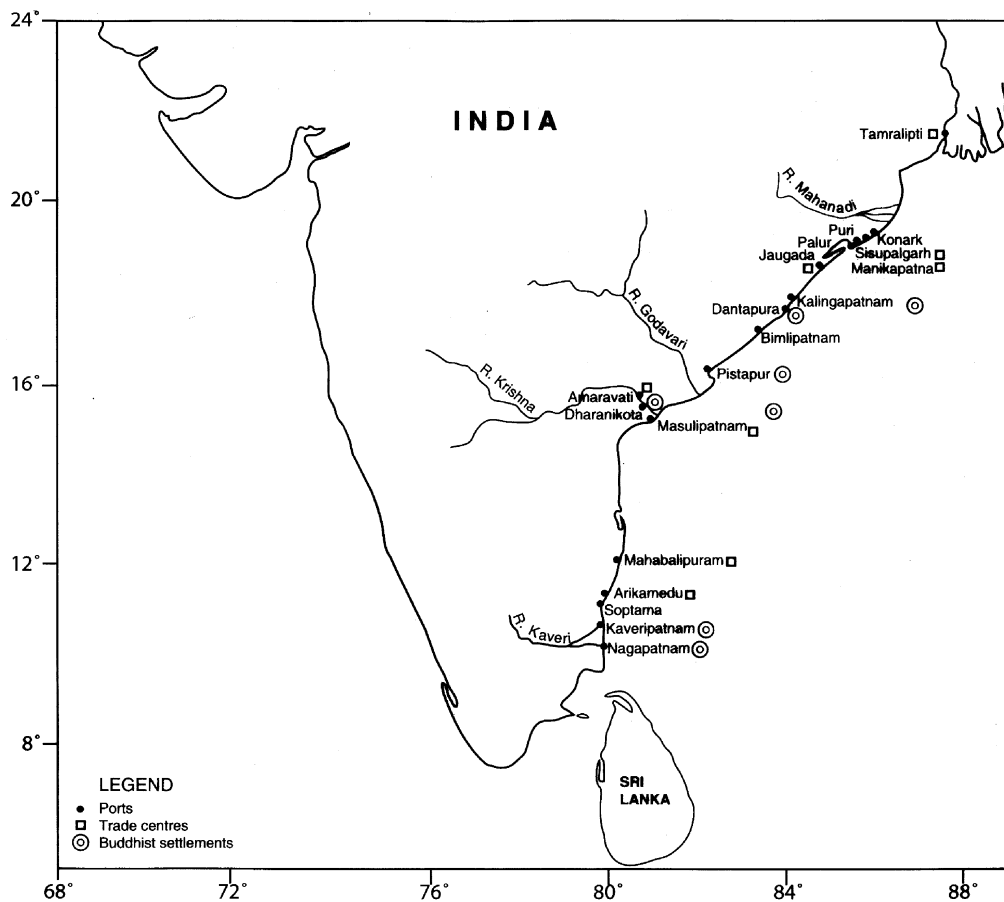


Figure 1. Ports, trade centres and Buddhist settlements along the east coast of India.

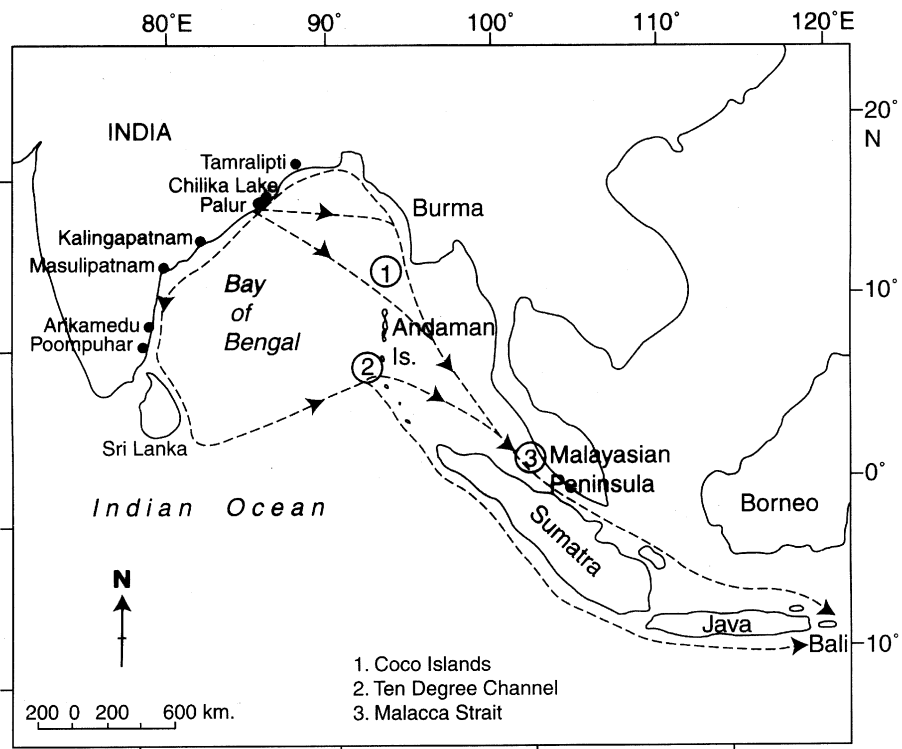


Figure 2. Sea routes from Orissa to Andaman and Nicobar Islands and Southeast Asian countries.

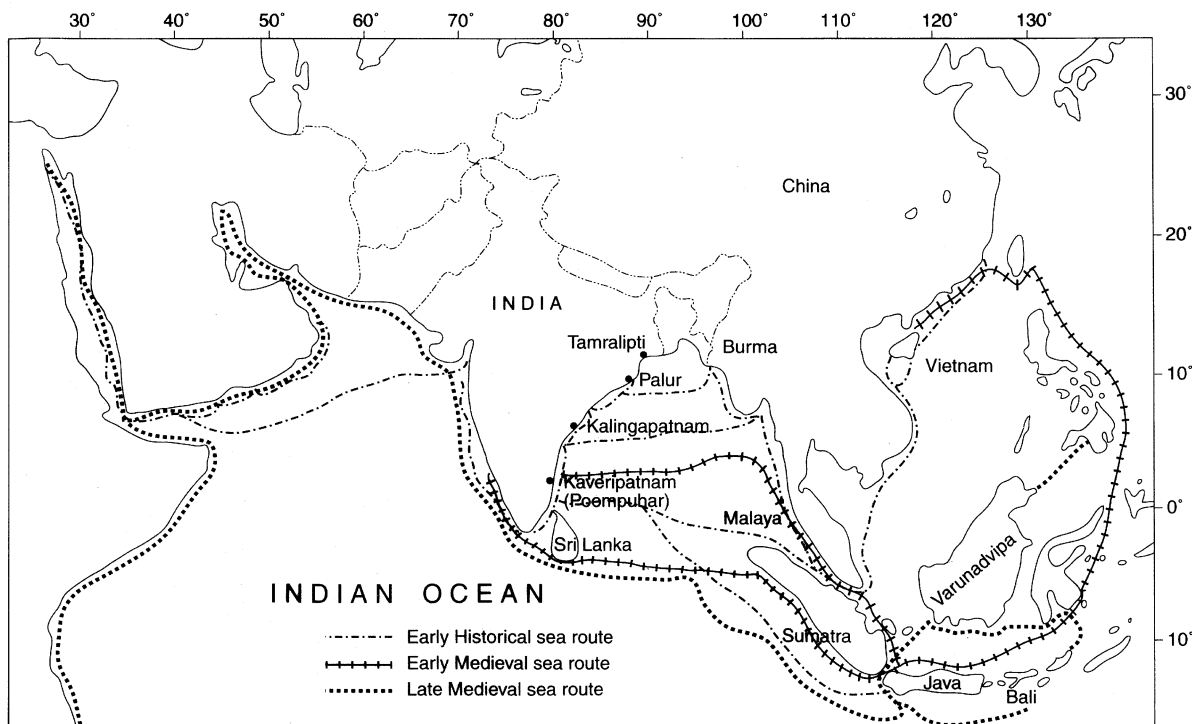


Figure 3. Map showing sea routes between ports of east coast of India and Orissa to Southeast Asian countries.

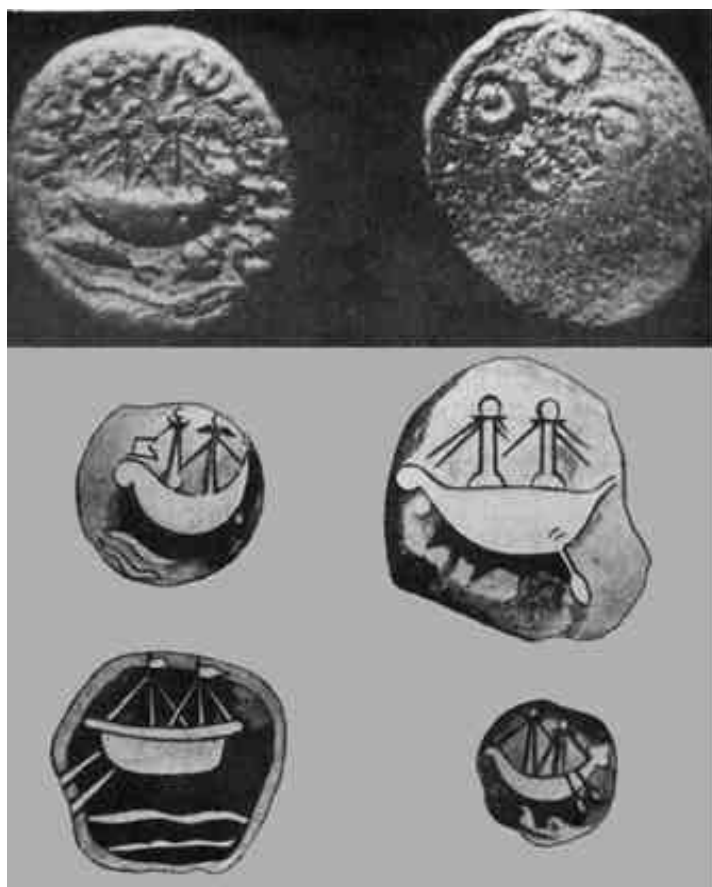


Figure 4. Satavahana coins showing masts on ships.

cluding Srikshetra in Burma, Takkola, Kokkonagara, Kataha Kadharam in the Malaya Peninsula, Sri Vijaya in Sumatra, Purva Kalinga in Java, Tonking in Cambodia and Kwang-fu in China for maritime trade<sup>15</sup>. There was a regular coastal voyage from the mouth of the river Ganges along the east coast of India to Sri Lanka. Subsequently, with the help of the equatorial current, the merchants/sailors proceeded towards Java and other countries of Southeast Asia. The Chinese traveller Hiuen Tsang (AD 600–654), followed this route for his return journey to China from India. Mariners from the east coast of India first went to Sri Lanka and then to other countries and returned through the same route because of two factors, viz. direction of the wind and movement of the water (currents) for their journey.

**Ancient knowledge of the winds**

The *Buddhist Jatakas* and the Jain canonical literature<sup>16</sup> refer to ships moving by the force of wind *Pavanabalasamahaya*. The masts of ships (Figure 4) depicted on the Satavahana coins (2nd century BC to 3rd century AD) testify to the use of winds in oceanic navigation during the early centuries of the Christian era<sup>17</sup>. As

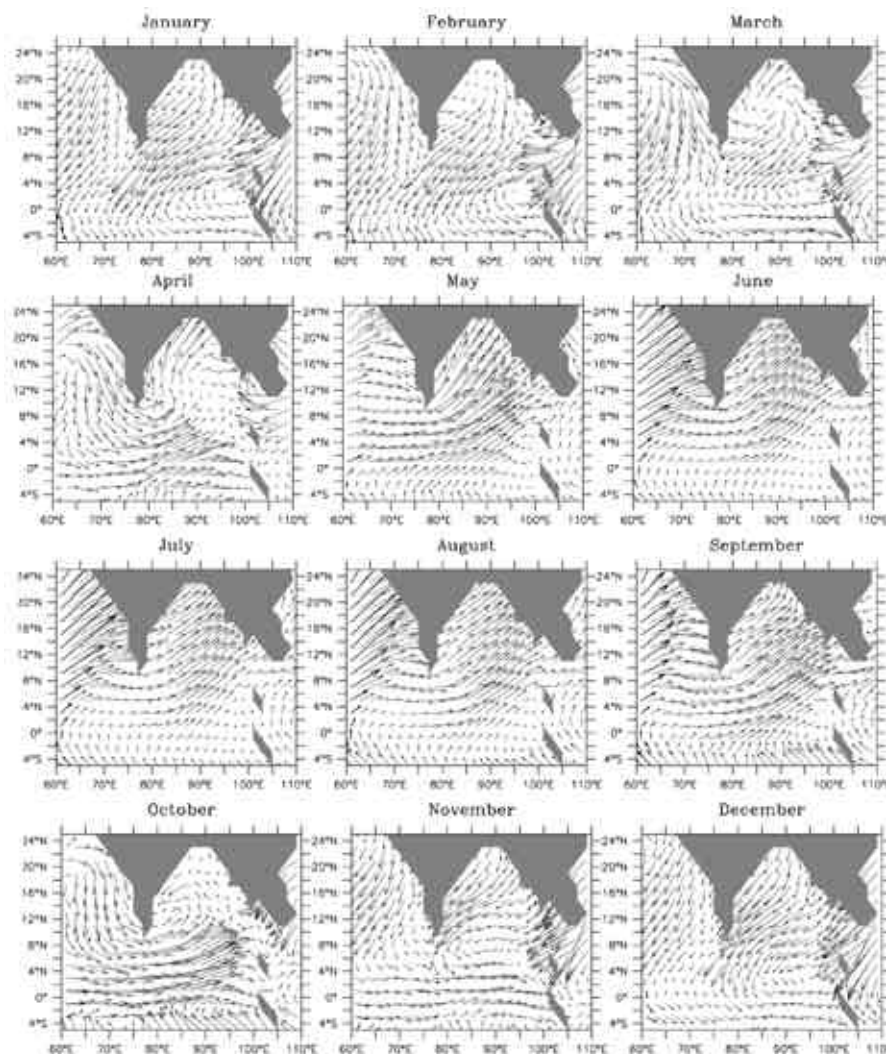


Figure 5. Present climatological wind pattern over the Indian Ocean region (after Hellerman and Rosenstein<sup>20</sup>).

ships could set sail only with a favourable wind and currents, ancient voyages had necessarily to be timed according to season. The force of wind in the Bay of Bengal is a predominant factor. The seasonally reversing winds are almost consistent during the monsoon period. However, a number of weather disturbances occur during the pre-monsoon, monsoon and post-monsoon periods. During such disturbances, sailors avoid venturing into the sea. The problem of studies related to circulation is whether the large-scale mean wind field remains a factor controlling circulation or local dynamics and affects the whole system during such weather disturbances<sup>18</sup>.

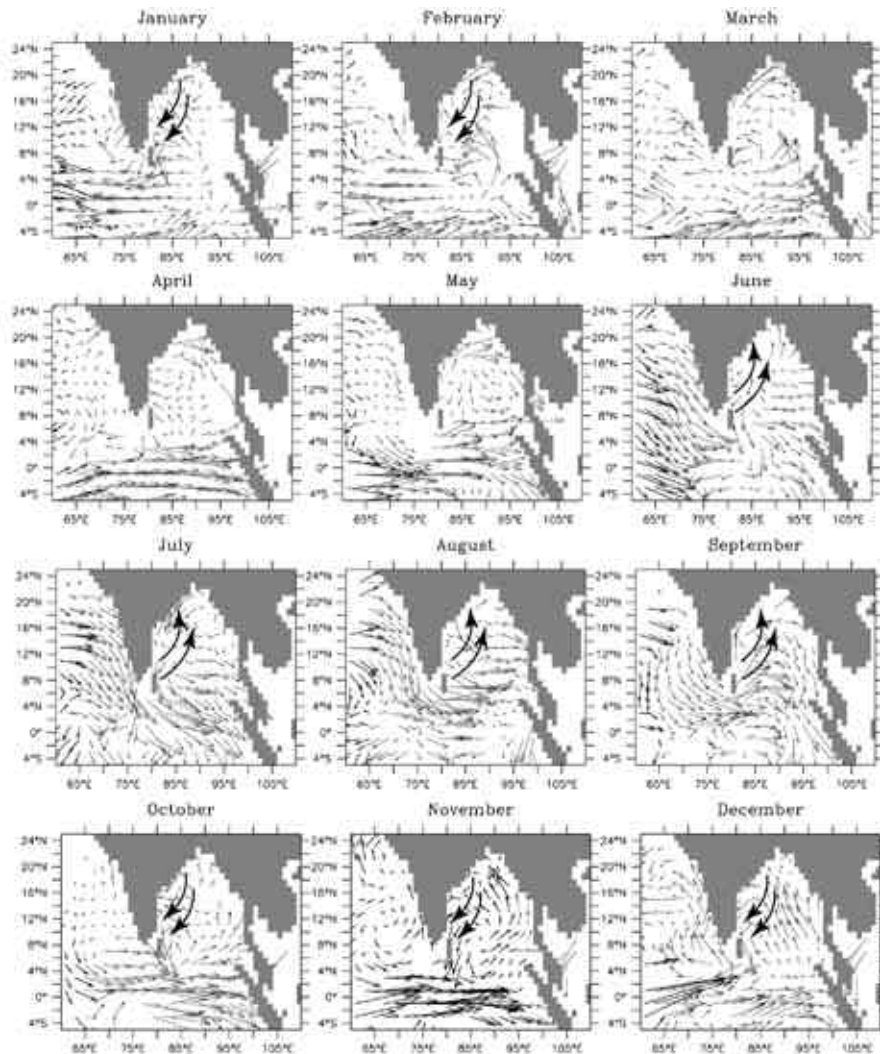
**Present climatological wind pattern**

Annual cycle of winds<sup>19,20</sup> over the Bay of Bengal on a climatological basis is

shown in Figure 5. During January the wind field shows the presence of northeast monsoon winds (blowing from the northeast direction) prevailing all over the Bay, more so in the central and southern Bay. These northeast winds are also known as northeast trade winds. During this period, winds turn clockwise over the northern part of the Bay. In the northeastern part, the northerlies are present. Generally, the magnitudes of the wind speed are weak all over the Bay. During March, the development of the anticyclone wind field over the Bay of Bengal, particularly in the central region with weak winds is quite conspicuous. During April, the winds are relatively strong in the northwestern Bay. Elsewhere in the Bay, the winds are weak. In the month of May, the wind system is almost southwesterly, indicating the onset of the southwest monsoon. In the northernmost

regions, the southerly wind system prevails with weak intensity. In the southern Bay, the southwest monsoon winds become fully established.

During June southwesterly winds prevail all over the Bay of Bengal. Higher wind speeds prevail in the central Bay and the direction of the wind field is consistent throughout July and August, with maximum wind speeds (9 m/s) occurring during July. During the monsoon period, the central Bay is subjected to maximum wind force and magnitudes reduce towards the land-bound regions. September also shows southwesterly winds almost all over the Bay. However, withdrawal of the southwest monsoon takes place from the north Bay, with its magnitudes decreasing considerably<sup>21</sup>. The wind field is quite irregular and becomes weak in magnitude by October. This forms the transition period between the southwest



**Figure 6.** Present climatological current pattern over the Indian Ocean region (after Shenoi *et al.*<sup>23</sup>).

and northeast monsoons. The northeast trade winds set in by November through the eastern half of the Bay. The southern Bay is under the presence of a cyclonic wind field, whereas the northern and western parts experience northeasterly winds. These winds with high magnitudes establish all over the Bay during December.

#### Ancient knowledge about currents

The *Satapatha Brahmana* (9th–8th century BC) of the later Vedic period text, provides some information on the circulation of oceanic water. The text mentions ‘the ocean flows round this world on all sides: Eggeling’s commentary for turning to the right, i.e. from the east to the south following the course of the sun’. An examination of the above passage reveals

that it refers to the southwest monsoon, which lasts from May to September<sup>22</sup>. During this period the general flow of the current is from east to south. In the *Jatakamala* (4th century AD), Aryasura has differentiated waves from currents and terms the latter as *salila*. It is interesting to note that seafarers were aware of three physical phenomena of the ocean, namely tides, currents and waves. By observing fishes, colour of water, birds, rocks and islands, sailors knew in which area of the sea they were sailing. They threw a handful of sand or shell and feathers into the calm sea. Drifting of feathers on the surface and sinking of sand or shell in the sea provided an estimate of the rate of current. Based on this information, they chose their anchorage off the coast. Some of these early practices still survive along the east coast of India.

#### Present circulation pattern

Information on climatology of surface currents in the Indian Ocean is well documented recently<sup>23–25</sup> and the monthly mean current vectors are shown in Figure 6. In January, an equatorward current is present along the east coast of India and the equatorial current is directed westward from the Sumatra coast. The coastal current along the east coast reverses swiftly northward, while the equatorial current still continues towards west. This circulation pattern prevails up to March/April. However, the westward equatorial flow weakens and is absent in April. The circulation is clockwise in the Bay of Bengal during March–April. A weak eastward flowing current is developed near the equator east of 80°E. The northward-flowing coastal current along the

east coast of India still persists till May, while the eastward current in the eastern equatorial Indian Ocean is strengthening.

At the beginning of the southwest monsoon, the northward coastal current along the east coast of India is weakened, while the eastward flowing monsoon current is widened and intensified (Figure 6 May–June). As the southwest monsoon intensifies, the coastal currents are once again directed northward along the east coast of India and a strong eastward-flowing monsoon current is intensified in the southern Bay of Bengal (Figure 6 July–October). As the southwest monsoon withdraws from the Bay of Bengal, coastal currents along the east coast of India swiftly reverse equatorward from October and persist up to December (Figure 6 October–December). Along the east coast of India, equatorward coastal currents prevail from September to December. The poleward coastal currents prevail from February to August. In the southern Bay the currents are westward from November to March and eastward from April to October. Studies carried out by Shetye *et al.*<sup>26</sup> concluded that the east India coastal currents along the east coast of India during the northeast monsoon are towards south. Further studies by Suryanarayana *et al.*<sup>27</sup> show that during the southwest monsoon along the east coast of India the circulation is in gyres and general flow of the coastal currents is towards north and during northeast monsoon, the currents are towards south.

### Discussion

Maritime trade is of recent origin compared to the monsoon. Sailors might have sailed to overseas countries during different seasons and monsoon winds might have favoured them in their voyages. However, they might have not been aware of the monsoon winds and currents. Once sailors acquired knowledge about the seasonal monsoon wind, sailing has been carried out with the help of such winds and maritime trade became seasonal. During the monsoon season, the velocity of winds and currents is more. This helped the sailing ships to reach their destinations in less time. The discovery of archaeological artefacts such as pottery, coins, beads, etc. all along the east coast of India, corroborates that there was prolific maritime trade which was supported

by monsoon winds since the last 2000 years or more.

The Indian Ocean is different from other oceans in several aspects. Among others, the most striking difference is the seasonal monsoon (winter monsoon or northeast monsoon and summer monsoon or southwest monsoon). In the Indian Ocean, maritime trade started considerably much earlier than other seas around the world. Seafarers of India had a fair amount of knowledge about monsoons. Harappans, the earliest mariners of India, must have used the monsoon winds for their overseas trade, but no direct evidence has been found regarding this. The Arab and Greek mariners set sail with the help of summer monsoon winds and were able to return during the winter monsoon, whereas mariners of Orissa set sail during the winter monsoon and returned during the summer monsoon.

During the period from October to February, monsoon winds and currents flow from the northeast helped ships to sail from Orissa and the east coast of India to Sri Lanka and other Southeast Asian countries. The onward journey during the northeast monsoon can be corroborated with regional festivals like *Kartika Purnima* (full moon day of Kartika in the month of November), symbolizing that traders have a safe journey. This festival has been celebrated by the people of Orissa since a long time and was the day of the commencement of sea voyages. The day is celebrated as *Bali Yatra* (voyage to Bali) throughout Orissa. In the recent past, the Government of Orissa and the Indian Navy had organized a voyage to Bali Island in a sailing boat as a remembrance day. This voyage was organized in the same manner as it was followed in ancient times.

From June to September, the southwest monsoon wind blowing from southwest naturally helped the ships to return from Southeast Asian countries, Sri Lanka to Tamil Nadu, Andhra, Orissa and Bengal coast. Similarly, *Khudurukuni Osha* is celebrated in the month of September by unmarried girls of Orissa who used to wait for their brothers to return with wealth and gifts. This festival anticipates the return journey. The social and religious festivals as well as wind and current data corroborate that the mariners of Orissa probably commenced their journey between November and February and returned between June and September. None of the foreign authors or tra-

vellers has mentioned the association of social festivities of India and elsewhere in relation to monsoon and maritime trade.

The southwest monsoon of the Northern Hemisphere helped ships of the Arab and Greek countries to enter into the Arabian Sea and the Bay of Bengal. During the period of the northeast monsoon of the Northern Hemisphere, using the favourable winds they made their homeward journey. It was the reversing currents associated with the monsoon winds of the northern Indian Ocean that favoured most of this traffic. Just like Arabs who had a thorough knowledge of the winds and currents of the Arabian Sea, sailors of Orissa and southern India had expert knowledge about those of the Bay of Bengal. To sum up, the knowledge of sailing, wind, current, seasonal monsoons, etc. helped the mariners of east coast of India nurture a rich maritime heritage for centuries together.

Studies of Indian–Asian monsoon show that there is a change in the strength of the SW and NE monsoons over past millennia because of changes in the orbital parameters of the earth and the influence of seasonal and latitudinal distribution of solar radiation. These seasonal wind systems have been in place for many millennia. If there were any changes in the monsoon, probably it was bit stronger in the past than today, with maximum increases occurring about 6–9000 years ago. It appears that the current seasonal winds would have been similar to those over the past 2500–2000 years. There could be differences in the strengths of monsoon in individual years or decades, but the overall conditions have probably been in place for about 10,000 years<sup>28</sup>.

### Conclusion

Nowadays, rarely sailing vessels are sighted that are engaged in overseas trade. Technology changed from wood to steel, mast and sail to engine and the size and carrying capacity also increased dramatically over the period of time. However, the tradition still prevails as it was in the ancient times. People celebrate festivals by remembering the past maritime activities in Orissa. Furthermore, there are no changes in the flow of the wind, currents and the seasons of monsoon, but changes in the behaviour and pattern of monsoon have been observed over the centuries.

Scientific studies indicate that the evolution of monsoon started around 9 million years before<sup>29</sup>. Since then, Arab, Greek, Rome and Portuguese sailors have used monsoon winds and currents for their maritime contacts with India. Sailors of east coast of India were the first to obtain knowledge on the use monsoon winds and currents for maritime trade. Monsoon winds were the main sources driving sailing boats to reach safely to far off countries, without much problem.

Archaeological and historical evidences indicate that sailors of Orissa were aware of the use of monsoon winds and currents for more than 2000 years, if not earlier, for their maritime trade with other parts of India and Southeast Asian countries. The social customs which are practised today have a long traditional history. As traditional knowledge passes on from one generation to the next, similarly knowledge of the use of monsoon wind might have passed down, though no written documents are found to support this.

This study shows that the sailors from Orissa set sail during the northeast monsoon and returned during the southwest monsoon. The winds and currents were favourable during their voyages. Archaeological findings corroborate to the early centuries of the Christian era. There is no change in the seasons of monsoon over the past 2000 years or so and the prevailing social festivals celebrated during northeast and southwest monsoons indicate the past glory of maritime trade.

1. Gupta, A. K. and Anderson, D. M., *J. Geol. Soc. India*, 2005, **65**, 54–60.
2. Yasuda, Y. and Shinde, V. (eds), *Monsoon and Civilization*, Roli Books, New Delhi, 2004.
3. Hariharan, K. V., *J. Univ. Bombay*, 1957, **25**, 9–16.

4. Das, P. K., *The Monsoon*, National Book Trust, New Delhi, 1968, pp. 5–10.
5. Schoff, W. H., *The Periplus of Erythraean Sea*, Oriental Books Reprint Co-operation, New Delhi, 1974.
6. Warmington, E. H., *The Commerce between the Roman Empire and India*, Vikas Publishing House, New Delhi, 1974, pp. 35–83.
7. Giles, H. A. (Tr.), *The Travels of Fa-Hien, Record of the Buddhist Kingdoms*, Cambridge, 1923.
8. Majumdar, R. C. (ed.), *The Classical Age*, Bharatiya Vidya Bhavan, Bombay, 1970, pp. 305–312.
9. McCrindle, J. W. (Tr.), *The Christian Topography of Cosmas*, London, 1897, p. 161.
10. Panikkar, N. K. and Srinivasan, T. M., *Indian J. Hist. Sci.*, 1975, **10**, 235–241.
11. Horsburgh, J., *India Directory*, London, 1836, vol. 1, p. 513.
12. Mookerji, R., *A History of Indian Shipping*, Longmans, Green and Co, Bombay, 1912, p. 73.
13. Mukerjee, R. K., *A History of Indian Civilization*, Hind Kitabs Limited, Bombay, p. 376.
14. Prasad, P. C., *Foreign Trade and Commerce in Ancient India*, Abhinav Publications, New Delhi, 1977, p. 154.
15. Sila Tripati, *Maritime Archaeology: Historical Descriptions of the Seafarings of the Kalings*, Kaveri Books, New Delhi, 2000, p. 72.
16. Jain, J. C., *Life in Ancient India as Depicted in the Jain Canons*, Munshiram Manoharlal, New Delhi, 1984, p. 118.
17. Sarma, I. K., *Coinage of the Satavahana Empire*, Agam Kala Prakashan, New Delhi, 1980, pp. 257–258.
18. Leetmaa, A. and Bunker, A. F., *J. Mar. Res.*, 1978, **36**, 311–322.
19. Hastenrath, S. and Lamb, P. J., *Climatic Atlas of the Indian Ocean: Part-I. Surface Climate and Atmospheric Circulation*, The University of Wisconsin Press, Wisconsin, 1979, p. 109.
20. Helleman, S. and Rosenstein, M., *J. Phys. Oceanogr.*, 1983, **13**, 1093–1104.

21. Horsburgh, J., *India Directory*, London, 1836, vol. 1, pp. 606–609.
22. Eggeling, J. (Tr.), *Satapatha Brahmana, Sacred Books of the East*, Oxford, 1882–1900, vols 12–26, p. 301.
23. Sheno, S. S. C., Saji, P. K. and Almeida, A. M., *J. Mar. Res.*, 1999, **57**, 885–907.
24. Shankar, D., Vinayachandran, P. N. and Unnikrishnan, A. S., *Prog. Oceanogr.*, 2002, **52**, 63–120.
25. Cutler, A. N. and Swallow, J. C., Surface Currents of the Indian Ocean (to 25°S, 100°E): Compiled from historical data archived by the Metrological Office, Bracknell, UK, Report 187, Institute of Oceanographic Sciences, Wormley, England, 1984, p. 8.
26. Shetye, S. R. et al., *J. Geophys. Res. (Oceans)*, 1996, **101**, 14011–14025.
27. Suryanarayana, A., Murty, C. S. and Rao, D. P., *Aust. J. Mar. Freshwater Res.*, 1992, **43**, 1517–1533.
28. Kutzbach, J. E., Gallimore, R., Harrison, S. P., Behling, P., Selin, R. and Laarif, F., *Quat. Sci. Rev.*, 1998, **17**, 473–506.
29. Prell, W. L., Murray, D. W., Clemens, S. C. and Anderson, D. M., *Geophys. Monogr.*, 1992, **70**, 447–469.

ACKNOWLEDGEMENTS. We thank the Director, National Institute of Oceanography, Goa and K. H. Vora for encouragement. Thanks are also due to G. S. Michael for providing wind and current figures, Satish Chitarti, Arun Mahale and R. Uchil for computer tracing of figures. This is NIO Contribution No. 4095.

Sila Tripati\* is in the Marine Archaeology Centre, National Institute of Oceanography, Dona Paula, Goa 403 004, India; L. N. Raut is in the PG Department of History, Berhampur University, Berhampur 760 007, India.

\*e-mail: sila@nio.org