

# Role of Time Series Sediment Traps in understanding the Indian Summer Monsoon

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The word "Monsoon", meaning "season" is from the Arabic word "mausim", defining the seasonally changing wind pattern. The Indian summer monsoon system is driven by the differential atmospheric pressure between land and ocean. Boreal cooling of the land mass during winter and heating during summer results in pressure gradient over the Asia. The strongest and most well known monsoons are those which affect India and Southeast Asia. The summer monsoon, which blows southwesterly across the Indian Ocean (June – September), is extremely wet. While the winter monsoon (November – February), in contrast, blows northeasterly and is generally dry (Fig- 1).

The evolution of monsoons is intimately related to the development of the monsoonal wind phenomenon over India during Miocene Period to the uplift of the Himalayas and the Tibetan Plateau, when India collided into the Asian continent. These mountains played a very prominent role in developing monsoons by acting as barrier to prevent cold northerly winds which otherwise would have made the continents preventing heating up during summer. Ancient Greeks and Roman were very familiar with the monsoon wind system in their navigation.

Monsoons have a direct impact on the socio-economic fabric of the vast population living in the tropical region. The SW monsoon or the summer monsoon winds over the Arabian Sea cause strong coastal upwelling of cold nutrient rich waters along the Arabian Peninsula leading to high biological productivity. This in turn helps fishermen to reap their bounty, a reward of monsoons. Despite the fact that the monsoons are punctual every year their intensity is inconsistent and highly variable resulting in drought due to less rain or floods caused by heavy rains.

## Time-series sediment traps

Time series sediment traps are the most versatile and innovative sampling gears that are deployed in the oceans to collect the rain of settling particles in the water column sinking toward the sea floor. These traps collect tiny particles or sediment or larger accumulations called *marine snow* – which are comprised of organic matter, dead organisms, tiny shells, dust particles, minerals etc. These sediment traps are capable of collecting settling particles hourly to yearly time scale. Therefore, sediment traps are immensely important in obtaining the vital

information on the vertical transport of particle flux through the water column and also to understand the temporal variation in relation to monsoons. The term "flux" denotes the rate of transfer of material with time from water column to the trap which can be defined as the quantity of the component settling through a given horizontal area in a given time. Flux is calculated following the following formula:

$$\text{Flux} = \text{mg dry weight/m}^2 \text{ /day}$$

Flux estimates are essential pre requisites in modeling of biogeochemical processes, which enable to study the seasonal variations of particle fluxes. By and large the biogeochemical processes that are taking place in the ocean layers contribute to the particle flux of the ocean, which also act as 'carriers' that scavenge fine particles from the water column and effectively transport them to the sea floor. The sedimentation and the acceleration of sinking particles were demonstrated by Honjo (1982) and Deuser et al. (1983). Analysis of the samples helps in understanding how fast various particulate matter, nutrients etc move from the ocean surface to the deep ocean. Because, these materials are largely used by the deep-sea life as food for their survival as the plants cannot grow in the dark due to lack of sunlight. Furthermore, the study on trace elements provide vital information on *ocean circulation* during the past and also how upwelling currents create such productive fishing areas.

The basic sediment trap consists of a multi-celled baffle with a long funnel of 152 cm with an opening of 90 cm diameter (Fig-2a, b, c). The traps are clamped at a specific depth intervals to a fixed cable attached to a buoy. Depending on our requirement, normally traps are deployed at three depths in an anchored mooring where they can catch sediment at surface, middle and deep oceans. New, automated traps carry up to 21 collection vials or cups on a motorized tray. The pre-programmed unit swaps out the vials at set intervals. Each of these sealed vials or cups store most important information on the changing hydrography with time. At the time of retrieval of traps, remote-controlled device called an acoustic release is activated. The release severs the line between the trap and its anchor, and the trap floats to the surface with its samples which are brought on board the ship.

The first ever sediment trap was deployed in 1978 off Bermuda at a depth of 3,200 meters of water. But in India, sediment traps were deployed for the first time in the Arabian Sea in 1986 under a collaborative program between India and Germany which later extended to the Bay of Bengal also in 1987. This mega program continuously deployed traps for over a period of 17 years to monitor the annual and inter annual variation in particulate flux which ultimately reflects on the variation in the intensity of monsoon. It was believed that the nutrients and the tiny bodies of plankton would sink very slowly, taking centuries or millennia to finally reach the sea floor. But, the recent studies inferred that much of the material would re-dissolve or be consumed by sea life and never reach bottom.

Sediment traps showed much larger particles (to 12 mm [0.5 inch] long) than expected. This marine snow sinks as fast as 200 meters (656 feet) per day and can reach bottom in just a few weeks. At that speed, transient surface conditions, like a summer bloom of phytoplankton, can be felt on the sea floor in the form of a blizzard of marine snow. Trap data collected till date indicated that about 740 million metric tons (815 million tons) of carbon reaches the global sea floor every year which is about 1 percent of the ocean's total production of carbon in a year. Sediment traps are the only means for to get actual information on fluxes quantitatively and qualitatively

It should be ensured that the traps are always to remain vertical in the water column to achieve optimum results. Traps deployed in strong currents must continuously record their tilt angle to ascertain unbiased

collection of samples. In deep water, it takes a long time to collect enough sediment for a sample.

Our studies from the northern Indian Ocean have enabled us to observe that the sinking particles showed seasonality which is related to the monsoons with higher fluxes occurring during both the summer and winter monsoons.

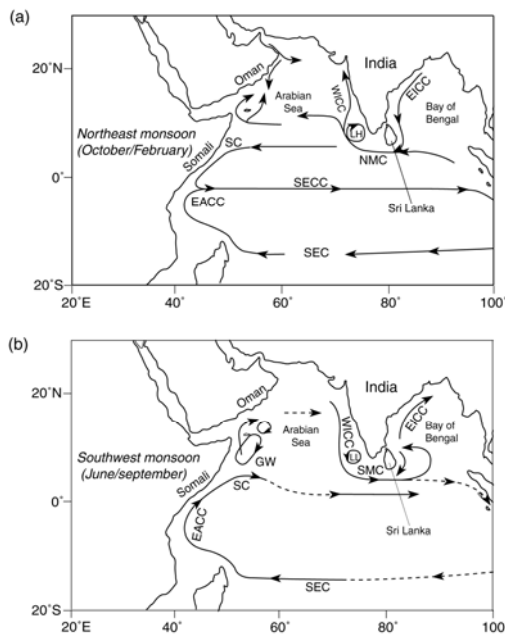
### Some significant results

1. Most of the total annual fluxes are contributed during monsoons. In general particulate fluxes are higher during the SW monsoon than during NE and inter monsoons.

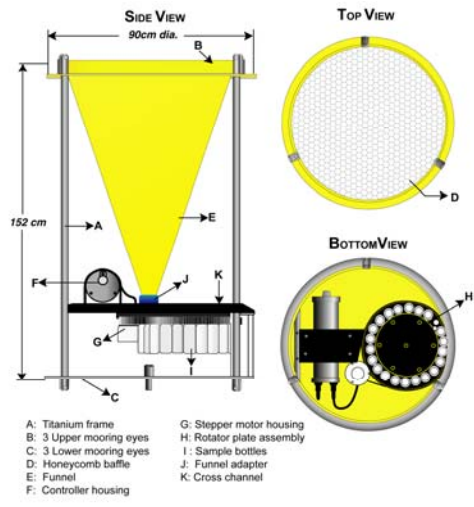
2. The average SW and NE monsoon fluxes at 3000 m depth revealed variations over the years 1988-1990. It was also observed that the NE and inter monsoon fluxes varied by about 45% of the mean, whereas the SW monsoon displayed a variation by about 30%. Thus, it indicated that the 1988 was a year of very strong monsoon and 1987 a very weak one.

3. Foraminiferal studies revealed that the highest fluxes were recorded during SW monsoon followed by NE monsoon with lowest fluxes during inter monsoons. Thus showing a very strong seasonality with monsoons

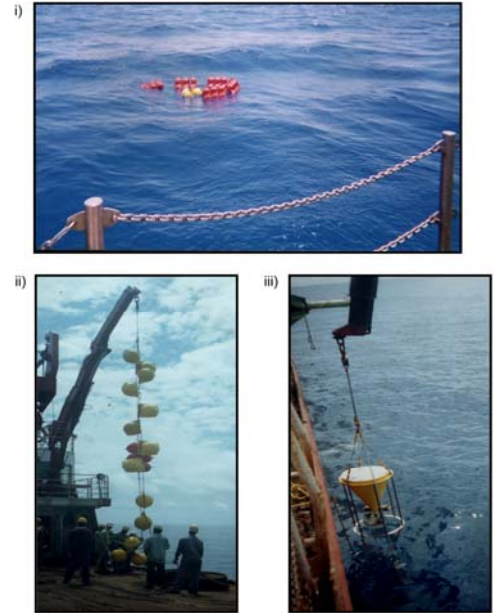
4. Similarly, strong seasonality in coccolithophores was also observed. Increased fluxes were recorded at the beginning of the SW monsoon, while highest fluxes found during NE monsoons.



**Fig. 1.** A schematic representation of Current patterns of the Indian Ocean during (a) Northeast monsoon and (b) Southwest monsoon. Abbreviations for the different currents indicated are: Southwest monsoon Current (SEC), South Equatorial Countercurrent (SECC), Southwest and Northeast Monsoon Current (SMC and NMC), Somali Current (SC), East African Coast Current (EACC), Great Whirl (GW), West Indian Coastal Current (WICC), East Indian Coastal Current (EICC), Lacadive High and Low (LH and LL) (after Schott and McCreary, 2001)



**Fig. 2a.** Schematic diagram of a sediment trap in three different views (from Oceanus) **Fig. 2b.** Mooring diagram of the sediment trap for retrieval after the anchor weights are released (from Oceanus)



**Fig. 2c.** i) Photograph showing three sphere radio float with glass flotation spheres at the surface before retrieval. ii) Photograph showing the retrieval of sediment trap array iii) Photograph showing the retrieval of sediment trap.