Indian Journal of Geo Marine Sciences
Vol. 48 (06), June 2019, pp. 936-942

Total organic carbon profile in water and sediment in coral reef ecosystem of Agatti Island, Lakshadweep Sea

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Received 3 August 2017; revised 27 November 2017

Total organic carbon profile in sea water (depth-wise) and sediment has been investigated on seasonal basis in the coral reef ecosystem of Agatti island, Lakshadweep sea. The TOC values of sea water and sediment were converted into percentage to understand its level of distribution. The level of TOC in the surface sea water ranged from 0.40 to 1.02 ppm and the level of TOC at the ~5 m depth ranged from 0.18 to 1.86 ppm. The pH did not show any variation depth-wise (7.65 to 8.49). Sedimentary organic carbon (SOC) was found in the range of 0.21 to 2.35 mg C/g. Significant seasonal variation was not found for water TOC and SOC levels. The pH for sediment was recorded from 7.79 to 8.62. Water pH showed significant positive correlation with sediment pH (R^2=0.959). The sand fraction was found more in the texture followed by silt and clay. Clay was found to have positive correlation with SOC (P >0.01). The TOC profile in the Lakshadweep sea was found in the order: Surface water TOC < water TOC at ~5 m depth < SOC. The percentage composition of SOC showed more than 1000 times as compared to water TOC. However, the levels recorded in this study are found within the limit prescribed by EPA and its influence on coral reef ecosystem is discussed.

[Keywords: TOC and SOC profile; pH; Coral reef ecosystem; Lakshadweep sea; Agatti island]

Introduction

Lakshadweep is an archipelago (Group of islands) having 39 islands located about 200-400 km off the south-western coast of India. The Lakshadweep sea has 12 atolls, three reefs, and five submerged banks. The submerged banks are sunken atolls. Therefore, Lakshadweep is known as coral islands of India in the Arabian Sea. The Lakshadweep sea is an ideal location for the oceanographers because of the presence of coral reefs, submarine ridges, particularly the Laccadive-Chagos ridge, which has a great influence over water circulation and contributes to the enrichment of surface water[1,2].

Importance of the organic carbon and storage of organic matter in oceanic waters is reported at the global scale[3,4]. The preservation efficiency of organic matter in deep-sea sediments was reported with a global sequestration rate of 0.16 x 10 15 ($g•C•y^{-1}$)[5]. It varies in different sediment types and is controlled by the rate of organic matter production[6], the export rate and its origin were also indicated elsewhere[7,8]. There are reports on depth wise level of organic carbon in continental slope and the abyssal plain of Gulf of Mexico[9]. Some studies have been made on hydrobiology in the Lakshadweep sea in earlier days much earlier[10,11,12,13,14 &15].

There are reports available on textural composition, organic matter, nutrients and major ions in the coral reef ecosystem of Gulf of Mannar[16,17]. But there was no such study on water and sedimentary organic carbon profile and their significance in the coral reef ecosystem in Agatti island, Lakshadweep sea. In view of this, an attempt is made to investigate the organic carbon profile and its flux pattern between water and sediments from Agatti Island, Lakshadweep sea. Agatti Island is 5.6 km long, situated with coral atoll. It is located about 459 km off Kochi. The nearest island is Kavaratti which is the administrative head for all the islands in Lakshadweep Sea. Since Lakshadweep sea is rich in biological diversity and coral reef ecosystem, it has been declared as highly protected area[18]. Though the Lakshadweep sea is restricted from anthropogenic disturbances but bleaching and depletion of corals could be noticed and this event might be due to high SST (Sea surface temperature). The interest of this particular study is to understand the organic load distribution and its significance on coral reefs.

Materials and Methods

Study area

For the present study, Agatti Island (Lat.10° 51'39.51" N; Long.72°11'25.41" E) at the Lakshadweep Sea was selected (Fig. 1). Regular sampling was made in the eastern side of the island.

Sample collection

Surface water and water at ~ 5 m depth were collected from the selected island covering all the seasons using Niskin water sampler for a period of 10 months (January to October) in the year 2015. Sediment sample was collected using Peterson grab at 8-10 m depth. The samples were collected in the region of coral reef ecosystem without disturbing the corals. The collected samples were preserved immediately in ice and brought to the laboratory for the analysis.

Water total organic carbon (WTOC) and pH

The collected water samples were filled in pre-cleaned and dried tubes and kept in deep freezer at -20°C until analysis. TOC was determined by the high temperature combustion method using a TOC analyzer (Model: Sievers Innovox lab 0462)[19]. Standards were prepared with potassium hydrogen phthalate (Merck). Sodium persulfate as an oxidiser and ortho-phosphoric acid for digestion and the blank (Milli-Q water) was run before and after sample analysis. The analytical precision was ≤3%. The pH of the water sample was measured by a calibrated pH pen (pH Ep-3 Model)[20].

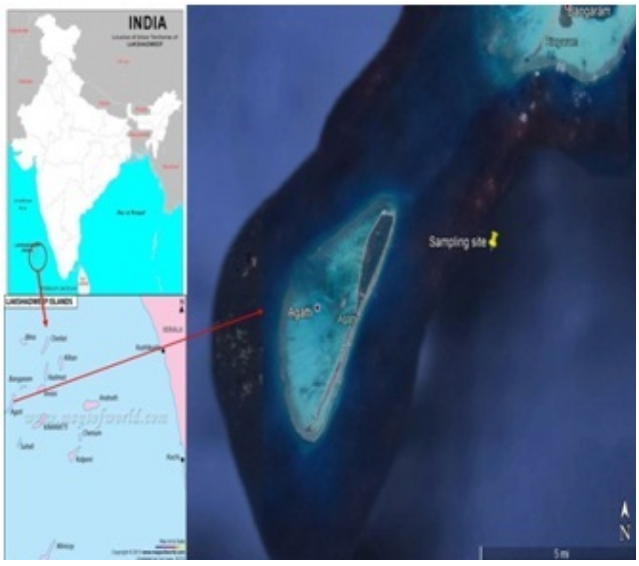

Fig. 1 — Map showing the study area

Sediment textural composition and pH

Sediment samples were also collected at same period of time. Sediment textural composition, air-dried sediment samples were used as such. Dried sediment sample (100 g) was sieved with help of mechanical shaker[21] to study sediment textural composition. The sand fraction was determined as the amount of sediment retained by sieve of 125 mm size is sand. The portion which passes through the sieve of 125 mm but retained by sieve of 0.063 mm is silt and the fraction which passes through the sieve of 0.063 mm is clay. The pH of sediment was measured *in situ* by calibrated soil pH meter (Hanna: HI1292D)

Sedimentary carbon (SOC)

The surface sediment (upper 2 cm) in the grab was taken for analysis of organic carbon. Sedimentary organic carbon content (SOC) was estimated using chromic acid oxidation followed by titration with ammonium ferrous sulphate (EL Wakeel and Riley method) as modified by Gaudette et al., (1974)[22].

Results and Discussion

The study area is in the region of coral reef ecosystem of Agatti island, Lakshadweep sea. The water from this region is oligotrophic in nature where localised water currents play a major role for upwelling. The season-wise and depth-wise (~5 m) levels of total organic carbon in water (WTOC), bottom sedimentary organic carbon (SOC), water pH and sediment pH are presented in Table 1.

The total organic carbon of the surface water was found to be in the range of 0.40 to 1.02 ppm with an average value of 0.72 ppm. When compared to surface water, slightly higher level of total organic carbon was noticed at ~5 m depth with more fluctuation and the value was found to be in the range of 0.18 to 1.86 ppm with an average value of 1.08 ppm. There was no wide variation found between seasons, but slightly higher average level (0.84 ppm) of total organic carbon in water was noticed during winter season in surface water. Like surface water, the total organic carbon at ~5 m depth shown no variation between seasons however, slightly higher average level (1.24 ppm) was noticed during summer season. The pH of surface water and water from ~5 m depth was not shown any variation so, the values for water was presented as common. The value of pH for water samples (both) was found to be in range of 7.65 to 8.49 with an average value of 8.07. In summer season, higher level of pH (8.49) was recorded.

The sedimentary organic carbon (SOC) was found to be at the range of 0.21 to 2.35 mg C/gm with an average value of 1.74 mgC/g. Season-wise variation was not found in the SOC level. However, slight higher average level could be noticed during summer and winter monsoon seasons (2.35 mgC/g). The value of pH in sediment was found to be at the range of 7.79 to 8.62 with an average value of 8.24. In summer season, higher level of sediment pH (8.62) could be recorded.

The textural composition of sediment is represented in Figure 2. The texture was found with mostly loamy sand fractions followed by silt and clay. The percentage of sand fraction was recorded at the range of 52.48 to 97.18% with an average percentage of 66.93%. The percentage of silt and clay were

Table 1 — Water total organic carbon, sedimentary organic carbon, water pH and sediment pH from Agatti island, Lakshadweep for the year 2015

	Winter				Summer				Summer monsoon				Winter Monsoon*			
	Jan to Feb				March to May				Jun to Sep				Oct -Dec			
	Mini	Max	Aver	SD	Mini	Max	Aver	SD	Mini	Max	Aver	SD	Mini	Max	Aver	SD
S WTOC (ppm)	0.64	1.02	0.84	±0.19	0.4	0.89	0.73	±0.19	0.46	0.9	0.63	±0.14	0.55	0.8	0.68	±0.18
WTOC (ppm) (~5M)	0.18	1.06	0.64	±0.37	0.48	1.86	1.24	±0.50	0.72	1.82	1.22	±0.46	0.68	1.76	1.22	±0.76
SOC (mgC/g)	1.66	2.21	2.02	±0.25	1.04	1.93	1.56	±0.38	0.21	2.35	1.41	±0.82	1.59	2.35	1.97	±0.54
SpH	8.02	8.31	8.13	±0.13	8.22	8.62	8.44	±0.16	7.79	8.44	8.14	±0.23	8.12	8.4	8.26	±0.20
WpH	7.78	8.25	7.94	±0.21	8.05	8.49	8.28	±0.17	7.65	8.24	7.95	±0.23	7.93	8.28	8.11	±0.25

SWTOC- Surface water TOC; WTOC at ~5m depth; SOC- Sedimentary organic carbon; WpH-water pH; S pH- Sediment pH
*Sampling was made in October month only for winter monsoon season

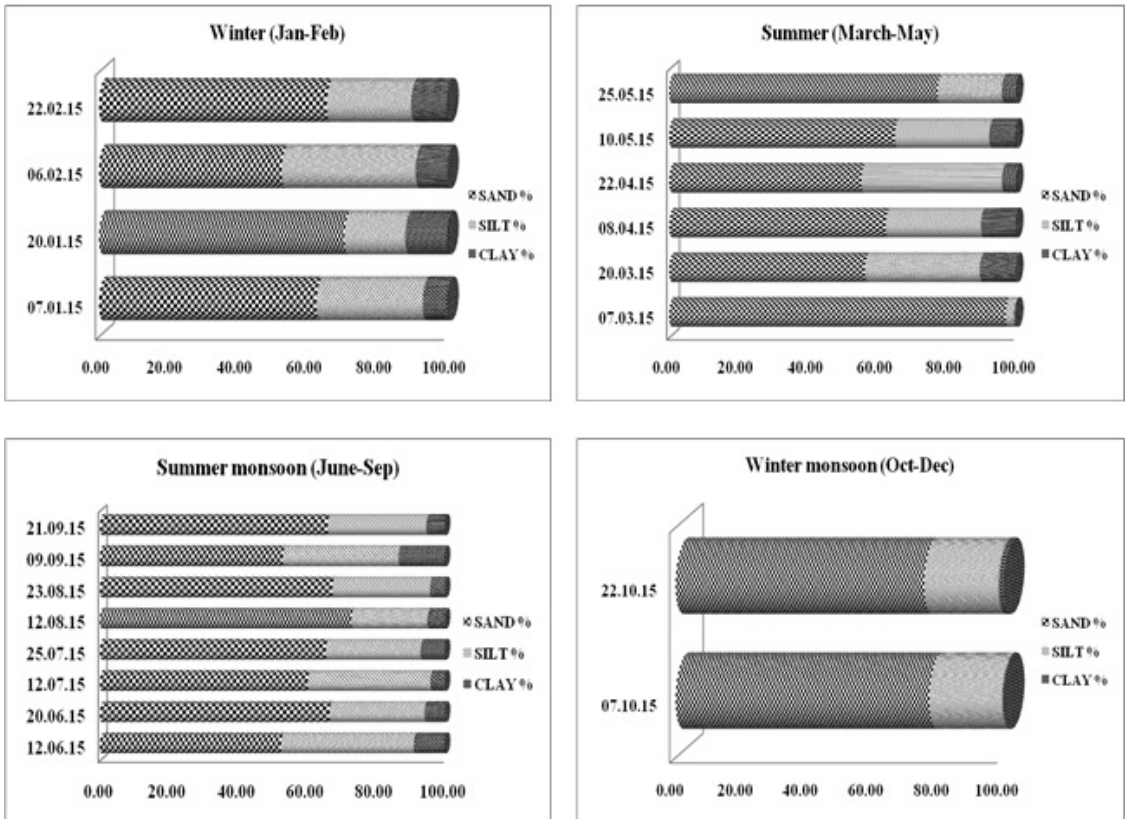

Fig. 2 — Seasonal sediment textural composition at Agatti island, Lakshadweep for the year, 2015

recorded in the range of 2.25 to 40.48% and 0.32 to 13.38% with average values of 26.75% and 6.60%, respectively. No wider variation within the percentage composition of sand, silt and clay was observed between seasons. However, slightly elevated level of silt could be noticed during summer monsoon (Fig. 3).

The pH of water and sediment showed highly significant positive correlation (R^2=0.959) indicating that the sediment pH is highly influenced by the water pH (Fig. 4). The pH of sediments was observed higher than the water pH. This is because of the deposition of calcium carbonate into the bottom sediment originated from the debris and remains of corals[17]. The deposition of inorganic carbon as calcium carbonate was reported to have shifted the pH of water by 0.15 within shark bay of Western Australia[23].

The TOC values were converted to percentage for easy comparison of their levels between surface WTOC, WTOC at ~5 m depth and SOC in bottom sediments (Fig 3). A significant variation was noticed between surface WTOC and WTOC at ~5m depth as shown in Figure 3. This variation was also confirmed through statistical analysis (ANOVA; *P*-7.09E-06) (Table 2). This indicates that the sinking of death and decay of micro/macroplankton into the next level of water column and also re-suspension of organic carbon from bottom sediment to sub-surface level due to upwelling. The percentage of SOC showed a marked difference with that of the WTOC as it was found exhibited more or less thousand times higher. The higher percentage of OC in sediment may be due to the detritus formation and release during death and

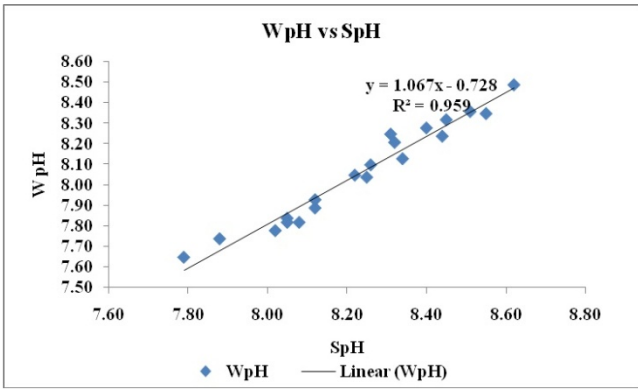

Fig. 4 — Liner regression between water pH vs sediment pH

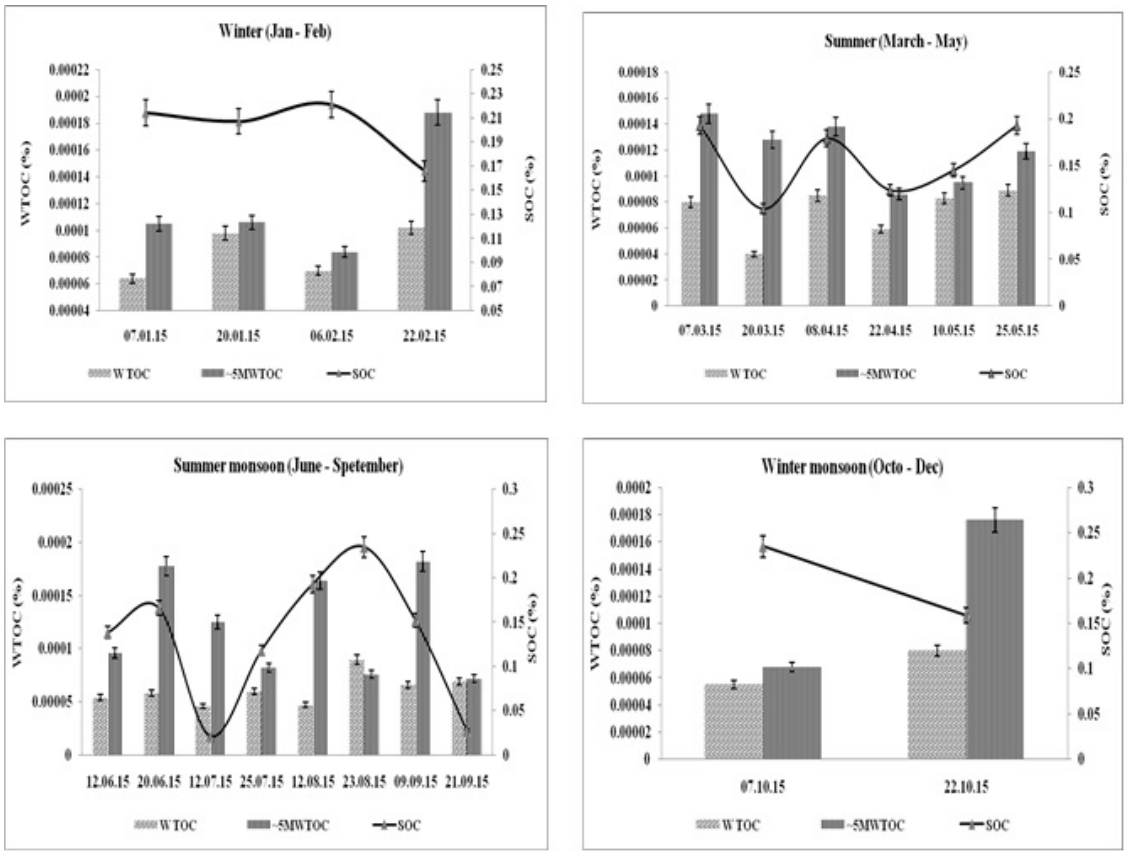

Fig. 3 — Percentage composition of Surface water TOC, water TOC (~5 m depth) and Sedimentary organic carbon (SOC) at Agatti island, Lakshadweep for the year 2015

Table 2 — ANOVA between surface water TOC and water TOC at ~5 m depth

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.606103	1	2.606103	27.04537	7.09E-06	4.09817166
Within Groups	3.661695	38	0.09636			
Total	6.267798	39				

Table 3 — Correlation between SOC and sediment texture

	SAND %	SILT %	CLAY %	SOC	SpH
SAND %	1				
SILT %	-0.949**	1			
CLAY %	-0.658*	0.385	1		
SOC	-0.158	0.358	0.648*	1	
Sed. pH	0.358	-0.291	-0.249	0.186	1

*Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed)

decay from benthic diversity which have been viewed as major sources of organic carbon in the coral reef sediment[24]. The excretory wastage of crustaceans, molluscan groups, aggregate fish waste (mainly from ornamental fishes) could also be another source of SOC in the reef areas[25,26,27]. Since the clay and silt concentrations are responsible for retaining the organic carbon in sediments, the less level of SOC recorded in Agatti island might be due to very less amount of clay and silt. The TOC profile in the Lakshadweep sea was found in the order: Surface WTOC < WTOC at ~5m depth < SOC.

In Agatti island, as the loamy sand was found incorporated more in the sediments, there was no significant relationship found between SOC and sand fraction (Table 3). The smaller percentage of silt and clay was found to be the key factors in retaining certain amount of TOC in sediment especially clay was found playing a major role in retaining TOC as it was revealed a significant correlation with SOC ($P > 0.01$). The layer-wise linear regression was assessed between surface WTOC Vs WTOC at ~5 m depth (weak negative correlation $R^2 = 0.009$) and between WTOC at ~5m depth Vs SOC (weak negative correlation $R^2 = 0.050$) (Figs 5 & 6). This correlation indicates that, there is organic carbon flux from surface to sub surface and also from sub-surface to bottom, but not at significant level. The WTOC was re-suspended into water due to the transport of bottom organic load by upwelling[28].

Similar values of TOC in sediment in terms of percentage was reported (TOC=0.8±0.2%, n=22) from continental slope region of Gulf of Mexico[9]. It also indicates that significant differences at different depth intervals as shown in the present study. Similar

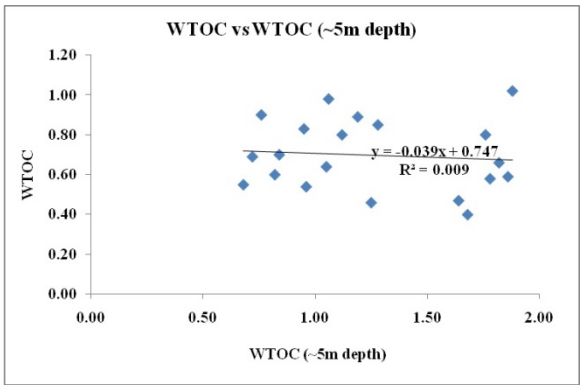

Fig. 5 — Liner regression between surface water TOC vs water TOC at ~5 m depth

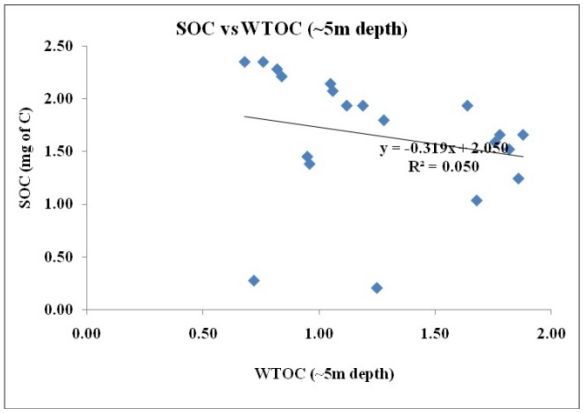

Fig. 6 — Liner regression between ~5 m water TOC vs sedimentary organic carbon

or higher level of TOC (0.34-1.59%) were reported from northern Gulf of Mexico[29, 30,31] and in the Arabian Sea (0.04-1.5%) by Grandel *et al*. (2000)[32]. Comparable to the present study, at 5 m depth, slight higher level of organic carbon was reported in the

unfiltered samples from Aegean Sea[33]**.** Similar to the present investigation, Agah et al. (2013)[34] reported the TOC levels ranging from 0.5 to 3.5 % in sediments of the Strait of Hormoz**,** the Persian Gulf. The TOC in the sediment and the benthic communities are important for ecological quality, especially in coral reef ecosystem. Ansari et al., (2014)[35] observed that the density and biomass peaked at moderate level of TOC (3%). Albayrak et al. (2006)[36] reported that low risks at TOC of 2.2%. TOC in the sediment above 3.5% acts as reducing factor for benthic abundance, biomass and species diversity[37,33], but comparatively, the SOC levels recorded in this study was very low. EPA, (2002)[38] noticed that the thresholds are still under evaluation for TOC in sediments, but recommended the following assessment categories for impaction: low at 1-3% carbon and high at >3% carbon.

Conclusion

In brief, the present study revealed a variation in the TOC profile in water and sediments of Agatti island, Lakshadweep sea. It was observed that the water sample from ~5 m depth was suspended with more TOC than surface water, which could be due to the supply of organic carbon from both surface layer of the sea (down welling) and bottom of the sea (up welling). Distinct variation was observed depth-wise and between sediment and overlying water. The trapping ability of TOC by coral reef sediments was found poor since the percentage of clay and silt were not high enough to retain the SOC. The profile of organic carbon in this ecosystem would not be a major threat to the coral reefs as the sediments were found in the medium and low organic level. At the same time, the investigation on WTOC and SOC to be extended in relation to local water current system to speculate the main source of organic carbon to various islands of Lakshadweep sea. So, when compared to the limit prescribed by EPA, (2002)[36], presently, there is no serious impact due to organic load to the coral reef ecosystem of Agatti island, Lakshadweep.

Acknowledgement

The authors are thankful to the Director, IITM-MoES, Government of India, Pune, for providing financial support through the Fluxnet/Metflux India project (CCCR/fluxnet/SK/2012-2018) and the authorities of Annamalai University for providing necessary facilities. The authors also sincerely thank, Dr. K. J. Ramesh, Scientist 'G', Director General of Meteorology, IMD-MoES, Govt. of India, for his scientific advices and encouragements.

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