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Research Article

Variations Of Parameters Of Mandovi And Zuari Estuarine Waters

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ABSTRACT

These coastal and estuarine waters are complex, and the optically active substances that interact with underwater light may not co-vary with the phytoplankton or chlorophyll. So the research topic was in the field of marine optics and ocean color applications. The focuses of the studies were to understand the light properties of the optically complex waters of Goa, which included the two estuaries Mandovi and Zuari and the coastal waters off Goa (Latitude 15.35 to 15.55° N, Longitude 73.65 to 74.047° E). In this paper, the variations of the optical parameters and associated physical and biological parameter variations are presented of the two estuaries, Mandovi and Zuari, and the coastal waters off Goa. These variations are described in three parts; the first part describes the variations of parameters at gross and seasonal scales; the second part describes the spatial variations of parameters in the estuaries, and the third part characterizes the optical parameters associated with *Trichodesmium spp.*

Keywords: Gross Variation, Coastal Water, Optics etc.

1. INTRODUCTION

These coastal and estuarine waters are complex, and the optically active substances that interact with underwater light may not co-vary with the phytoplankton or chlorophyll. These waters were categorized as Case 2 waters from an earlier scheme of classifications of water types for optical studies. The studies of underwater light and ocean color applications of such waters are important. The coastal waters selected here were also different from other coastal waters as these coastal waters were off the mouth of estuaries and would have the influence of estuaries. Monsoon and tides play an important role in these monsoonal estuaries, which modulate the physical, biological, chemical, and other environmental parameters.

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Marine optics, ocean optics, optical oceanography, and ocean color studies are synonymous as all are focused on the interaction of light and the optically active constituents in water. Earlier, there used to be a lack of good commercial optical instruments, and hence studies in marine optics tended to focus on theoretical studies to understand the underwater light field, optical properties, and interactions of light with constituents of water. With the advent of advanced in-situ measuring optical instruments and the launch of ocean color satellites, marine optics has been taken over by studies of ocean color. One of the earliest reference to 'ocean color' remote sensing began with measurements from aircraft of backscattered light to map chlorophyll.

When light enters the water, there are two processes - absorption and scattering of light. The constituents inside the water will absorb the photons or scatter them. These absorption and scattering components vary spectrally depending on the constituents. Dissolved material such as CDOM (Colored Dissolved Organic Matter) may not scatter but will absorb, while phytoplankton will scatter, and the pigments in phytoplankton will absorb light spectrally. Hence the spectral light which enters the water will be modified by the optically active constituents, and when they exit from the surface of the water, they will be spectrally altered. Hence the "color" of the water will be determined by the interactions of incident light with optically active substances present in the water. This forms the basis for changes in the color of the water as well as the satellite ocean color remote sensing. Hence, analyzing the spectral properties that exit the surface of the water will yield information about the constituents.

2. EXPERIEMNTAL RESULTS

2.1 Gross variations of parameters

The gross variations of the bio-optical parameters of the three regions, two estuaries of Mandovi and Zuari and the coastal waters, are given in Table 1 - 6. There were distinct variations in the parameters among these three sites. It may be noted that these variations are listed in tabular form in the interests of summarizing the data without loss of numerical detail.

The physical parameters temperature, salinity, and density agree with those reported earlier for these waters. Solar radiation, as indicated by $E_S(490)$ and PAR, was found to be lower over the estuaries and higher over the coastal waters.

Two parameters that have been used to indicate the penetration of light in water were Z_{90}(m) and Z_{sd} (m). The values of Z_{90} light show that light penetrates the deepest in coastal waters, and among estuaries, the light penetrations in Mondovi were deeper than Zuari. Similar was the case observed of the transparencies of water, Z_{sd}. Since $Z_{90}(\lambda)$ was spectral, the value of Z_{90} given here was the maximum values of $Z_{90}(\lambda)$. The euphotic depths, Z_{eu} also follow a similar pattern of variations. The wavelength at maximum $Z_{90}(\lambda)$ was about 577 nm in the estuaries and was higher compared to the coastal waters, which was at about 545 nm. The values of $E_d(\lambda)$ at $Z_{90}(\lambda)$ also followed the same patterns of variations for these waters. The % PAR at Z_{eu} and Z_{sd} were comparable for similar water types (Table 1- 3).

The values of IOPs, namely absorption $a(\lambda)$, beam attenuation $c(\lambda)$, scattering $b(\lambda)$, backscattering $b_b(700)$, coefficients and the AOP, $K_d(\lambda)$, were much higher in the estuarine waters compared to the coastal waters. The bulk refractive index, n_p in the estuaries were relatively higher than coastal waters. The exponent of the particle size distribution (PSD), ξ was relatively higher in the estuarine waters as compared to coastal waters. The shape of $R_{rs}(\lambda)$ in the estuaries, resembled typical spectral variations observed in turbid waters.

The chlorophyll was higher in the estuaries, and it was higher in the Zuari compared to Mandovi. TSM values were comparable in the estuaries and lower in the coastal waters. Though CDOM was marginally higher in the Zuari, detritus contribution was higher in the Mandovi. In the estuaries, the contributions from detritus were the highest, while in the coastal waters absorptions due to phytoplankton were highest. In coastal waters, CDOM was more than detritus, and in the estuaries, detritus was more than CDOM.

Light availability at Z_{90} was the same in the estuaries, marginally higher in coastal waters. %PAR was nearly similar. The wavelength of maximum light decreased in coastal waters.

Table 1 Mean parameter values of Mandovi

Parameter	**Mean**	**σ**	**Minimum**	**Maximum**
		Physical		
Temperature (°C)	29.1	1.66	25.06	33.17
Salinity	25.03	10.07	0.05	36.28
Density σ (Kg/m^3)	15.67	6.11	0.05	22.82
Solar radiation at surface				
E_S(350) (W/m^2/nm)	0.3142	0.1251	0.0285	1.05
E_S(490) (W/m^2/nm)	0.9862	0.3657	0.0721	1.7289
PAR E_S (W/m^2)	275.3638	102.6299	19.0796	478.6248
Light penetration				
Z_{Max} (m)	6.3	2.27	1.2	12.33
□ (of maximum Z_{90}) (nm)	571	11	481	599
Z_{90} (m)	1.31	0.77	0.41	5.01
Z_{SD} (m)	1.64	0.99	0.41	7
Z_{eu} (m)	6.03	3.53	1.89	23.07
PAR at Z_{90}(μmole/m^2/s)	305.12	140.72	0.01	784.73
%PAR at Z_{90}	24.3	5.13	3.92	45.31
PAR at Z_{SD}(μmole/m^2/s)	183.69	181.97	6.17	1017.4
%PAR at Z_{SD}	18.72	10.22	0.46	74.56
□ (of Maximum E_d) (nm)	575	10	479	611
E_d at Z_{90}(W/m^2/nm)	0.4617	0.1923	0.0001	1.0098
□ (at Maximum E_{SD}) (nm)	575	10	479	584
E_d at Z_{SD}(W/m^2/nm)	0.318	0.2386	0.0164	1.3137
IOP				
b_b(700) (m^{-1})	0.08287	0.07126	0.01096	0.49437
a(412) (m^{-1})	1.424	0.6832	0.0006	4.5887
a(440) (m^{-1})	1.0809	0.4965	0.3722	3.4193
a(488) (m^{-1})	0.6451	0.3444	0.1772	2.2677
a(490) (m^{-1})	0.6315	0.3445	0.1857	2.4162
a(510) (m^{-1})	0.4947	0.2815	0.0837	2.2382
a(532) (m^{-1})	0.3855	0.324	0.1461	3.3364
a(555) (m^{-1})	0.2677	0.3389	0.091	3.8052
a(650) (m^{-1})	0.1048	0.1588	0.0187	1.5148
a(676) (m^{-1})	0.137	0.1082	0.0166	1.0002
a(715) (m^{-1})	0	0	0	0
c(412) (m^{-1})	5.6143	5.5007	0.0006	61.3425

c(440) (m^{-1})	5.3922	5.5546	0.718	63.0754
c(488) (m^{-1})	4.9457	6.2143	1.0008	73.9259
c(490) (m^{-1})	4.9295	6.2668	0.9939	74.6913
c(510) (m^{-1})	4.6929	6.805	0.476	82.3452
c(532) (m^{-1})	4.6842	5.6729	0.9044	66.7399
c(555) (m^{-1})	4.4384	2.8049	0.5943	17.7681
c(650) (m^{-1})	3.8171	4.7881	0.0703	56.1165
c(676) (m^{-1})	3.6727	2.4714	0.0166	17.0104
c(715) (m^{-1})	3.4282	5.9881	0.3052	56.8263
γ	1.08	0.35	0.11	3.56
ξ	4.06	0.4	2.19	6.56
n_p	1.1078	0.0422	1	1.2174
AOP				
K_d(350) (m^{-1})	1.2866	1.4997	0.0003	8.6982
K_d(412) (m^{-1})	1.7779	1.0682	0.0014	7.96
K_d(443) (m^{-1})	1.5409	0.8811	0.0027	6.4523
K_d(490) (m^{-1})	1.1724	0.6762	0.0014	5.5066
K_d(510) (m^{-1})	1.0591	0.5863	0.0154	4.7507
K_d(532) (m^{-1})	0.9531	0.4962	0.015	4.0595
K_d(555) (m^{-1})	0.8661	0.4383	0.0117	3.2474
K_d(566) (m^{-1})	0.8286	0.448	0.0004	5.7426
K_d(620) (m^{-1})	0.9957	0.371	0.0068	2.6201
K_d(650) (m^{-1})	0.9957	0.3565	0.0061	2.2766
K_d(670) (m^{-1})	1.0923	0.3717	0.0057	2.4624
K_d(676) (m^{-1})	1.1004	0.3735	0.0056	2.2115
K_d(681) (m^{-1})	1.0988	0.3749	0.0053	2.183
K_d(700) (m^{-1})	1.164	0.403	0.0126	2.8292
R_{rs}(350) (sr^{-1})	0.000592	0.0022	1E-006	0.026466
R_{rs}(412) (sr^{-1})	0.001294	0.051691	6E-006	0.928595
R_{rs}(443) (sr^{-1})	0.002095	0.040963	3.8E-005	0.997833
R_{rs}(490) (sr^{-1})	0.004027	0.005703	1E-006	0.082804
R_{rs}(510) (sr^{-1})	0.005036	0.00534	5.7E-005	0.075802
R_{rs}(532) (sr^{-1})	0.006513	0.005354	0.000203	0.071124
R_{rs}(555) (sr^{-1})	0.008285	0.005536	0.000455	0.070594
R_{rs}(566) (sr^{-1})	0.009132	0.006241	0.000604	0.073313
R_{rs}(620) (sr^{-1})	0.005884	0.005292	0.00035	0.05958
R_{rs}(650) (sr^{-1})	0.005367	0.005129	0.000303	0.056105
R_{rs}(670) (sr^{-1})	0.00441	0.004947	5.1E-005	0.053719
R_{rs}(676) (sr^{-1})	0.004377	0.004896	0.000146	0.053014
R_{rs}(681) (sr^{-1})	0.004409	0.00483	0.000134	0.051862
R_{rs}(700) (sr^{-1})	0.003347	0.006367	2.8E-005	0.119225
Biological				
Chlorophyll (mg/m^3)	2.18	3.05	0.13	16.14
Chlorophyll(mg/m^3)-Sensor	1.72	1.45	0.13	7.4
TSM (g/m^3)	8.01	16.5	0.02	160

pH	7.72	0.32	6.97	8.16
□ (FLH R_{rs})	693	3	685	698
R_{rs}(□) FLH (sr^{-1})	0.00143	0.00075	0.00016	0.00446
□ (FLH L_w) nm	687	8	678	698
L_w(□) FLH ($\mu Wcm^{-2}sr^{-1}$)	0.03933	0.03754	0.00591	0.24399
a_{ph}(412) (m^{-1})	0.0677	0.0935	0.0096	0.5426
a_{ph}(440) (m^{-1})	0.0657	0.0727	0.0068	0.4422
a_{ph}(488) (m^{-1})	0.0628	0.0529	0.0041	0.3151
a_{ph}(490) (m^{-1})	0.0471	0.0369	0.0002	0.2081
a_{ph}(510) (m^{-1})	0.0316	0.0304	0.0002	0.1708
a_{ph}(532) (m^{-1})	0.0189	0.0195	0.001	0.1051
a_{ph}(555) (m^{-1})	0.0114	0.014	0.0002	0.0628
a_{ph}(650) (m^{-1})	0.0327	0.027	0.001	0.1206
a_{ph}(676) (m^{-1})	0.0305	0.0267	0.0014	0.1194
a_{ph}(715) (m^{-1})	0.0141	0.0103	0.0007	0.0476
a_g(412) (m^{-1})	0.3654	0.1656	0.0483	0.7771
a_g(440) (m^{-1})	0.2368	0.1172	0.0064	0.5673
a_g(488) (m^{-1})	0.1186	0.0738	0.0259	0.3642
a_g(490) (m^{-1})	0.0756	0.0586	0.0126	0.2894
a_g(510) (m^{-1})	0.0699	0.0541	0.008	0.2644
a_g(532) (m^{-1})	0.0512	0.0443	0.0041	0.2112
a_g(555) (m^{-1})	0.0379	0.0321	0.0025	0.1462
a_g(650) (m^{-1})	0.0187	0.0256	0.0029	0.1028
a_g(676) (m^{-1})	0.0009	0.0014	0.0001	0.0061
a_g(715) (m^{-1})	0.0002	0.0004	0.0002	0.0009
a_d(412) (m^{-1})	0.5351	0.3359	0.0916	2.1825
a_d(440) (m^{-1})	0.4394	0.282	0.0745	1.9047
a_d(488) (m^{-1})	0.3551	0.2305	0.0571	1.6273
a_d(490) (m^{-1})	0.303	0.2046	0.0474	1.4726
a_d(510) (m^{-1})	0.2752	0.1874	0.0424	1.3573
a_d(532) (m^{-1})	0.2263	0.159	0.0321	1.1665
a_d(555) (m^{-1})	0.1535	0.1096	0.0161	0.8092
a_d(650) (m^{-1})	0.0848	0.0622	0.0024	0.4566
a_d(676) (m^{-1})	0.0257	0.0214	0.0026	0.1521
a_d(715) (m^{-1})	0.0092	0.0076	0.0011	0.0546

Table 2 Mean parameter values of Zuari

Parameter	**Mean**	**σ**	**Minimum**	**Maximum**
Physical				
Temperature (°C)	29.71	1.84	26.47	33.08
Salinity	24.63	9.68	0.15	35.15
Density (Kg/m^3)	15.27	5.94	0.31	22.57
Solar radiation at surface				
E_S(350) ($W/m^2/nm$)	0.311	0.1178	0.0061	0.5413
E_S(490) ($W/m^2/nm$)	0.9636	0.3651	0.0196	1.6048

PAR E_S (W/m^2)	268.5979	101.9028	4.5553	444.6871
Light penetration				
Z_{Max} (m)	7.68	2.2	2.5	11.12
□ (of maximum Z_{90}) (nm)	569	15	481	597
Z_{90} (m)	1.19	0.92	0.32	5.1
Z_{SD} (m)	1.32	0.85	0.42	4.65
Z_{eu} (m)	5.48	4.26	1.47	23.49
PAR at Z_{90}(µmole/m^2/s)	306.52	136.03	1.19	630.82
%PAR at Z_{90}	24.27	5.45	3.62	41.06
PAR at Z_{SD}(µmole/m^2/s)	226.09	198.78	0.07	1028.97
%PAR at Z_{SD}	21.27	11.06	0.01	64.16
□ (of Maximum E_d) (nm)	572	28	350	641
E_d at Z_{90}(W/m^2/nm)	0.468	0.2109	0.006	1.6468
□ (at Maximum E_{SD}) (nm)	576	17	480	641
E_d at Z_{SD}(W/m^2/nm)	0.4088	0.2855	0.006	1.7418
IOP				
b_b(700) (m^{-1})	0.07902	0.15288	0.00898	0.94901
a(412)	1.5636	1.5665	0.3136	8.1592
a(440)	1.156	1.071	0.2376	6.1354
a(488)	0.6702	0.6805	0.1752	4.0704
a(490)	0.6553	0.6679	0.1739	3.9978
a(510)	0.4976	0.5509	0.147	3.2724
a(532)	0.3583	0.4282	0.115	2.5679
a(555)	0.2471	0.3052	0.0886	1.9258
a(650)	0.1091	0.0748	0.0088	0.5926
a(676)	0.1557	0.0873	0.0479	0.535
a(715)	0	0	0	0
c(412)	7.263	13.0164	1.1912	90.3878
c(440)	6.6177	13.2313	0.9914	93.9163
c(488)	5.713	13.9795	0.601	88.0719
c(490)	5.6907	13.7622	0.5942	86.3662
c(510)	5.4676	11.9739	0.5264	87.0369
c(532)	5.3182	12.1892	0.5615	87.7747
c(555)	5.074	11.4187	0.5969	92.952
c(650)	4.5594	11.7138	1.1321	87.6738
c(676)	4.3874	11.3484	1.1081	86.6148
c(715)	4.1077	11.0491	0.8617	85.8137
γ	1.09	0.38	0.11	2.26
ξ	4.05	0.46	2.49	5.26
n_p	1.0931	0.0477	1	1.1996
AOP				
K_d(350)	1.1551	1.6501	0.0204	7.9599

K_d(412)	1.9033	1.3645	0.0011	7.4171
K_d(443)	1.6536	1.1723	0.0011	8.9725
K_d(490)	1.1683	0.9193	0.0029	6.5051
K_d(510)	1.0231	0.8913	0.0389	6.6501
K_d(532)	0.9209	0.7912	0.0039	5.68
K_d(555)	0.8301	0.7759	0.0176	6.5023
K_d(566)	0.7859	0.6859	0.0314	5.2542
K_d(620)	0.983	0.6503	0.0345	7.2615
K_d(650)	1.0159	0.6306	0.086	6.4544
K_d(670)	1.1179	0.6471	0.051	6.2507
K_d(676)	1.1356	0.5604	0.0526	4.1552
K_d(681)	1.1256	0.6896	0.0163	7.8948
K_d(700)	1.2134	0.6608	0.0573	7.6665
R_{rs}(350)	0.000613	0.001895	8E-006	0.015133
R_{rs}(412)	0.001624	0.005378	1.6E-005	0.08132
R_{rs}(443)	0.002586	0.004215	8.4E-005	0.06275
R_{rs}(490)	0.004697	0.002933	5.3E-005	0.027518
R_{rs}(510)	0.006176	0.021855	0.000306	0.389835
R_{rs}(532)	0.007953	0.016769	0.000749	0.298861
R_{rs}(555)	0.009905	0.012975	0.000176	0.228967
R_{rs}(566)	0.010702	0.011481	4.3E-005	0.200007
R_{rs}(620)	0.006856	0.008813	0.000458	0.143418
R_{rs}(650)	0.006286	0.008062	0.000384	0.12767
R_{rs}(670)	0.004873	0.007732	0.000141	0.122574
R_{rs}(676)	0.004857	0.007421	0.000145	0.11604
R_{rs}(681)	0.004931	0.007545	0.000182	0.118978
R_{rs}(700)	0.003522	0.007004	0.000158	0.111533
Biological				
Chlorophyll (mg/m^3)	4.28	2.88	0.02	11.62
Chlorophyll(mg/m^3)-Sensor	2.28	1.44	0.71	8.49
TSM (g/m^3)	8.05	12.16	2	130
pH	7.6	0.24	7.09	8.13
□1 FLH R_{rs}	693	4	671	698
R_{rs}(□1) FLH	0.0014	0.00079	0.00045	0.00384
□1 FLH L_w	689	9	671	698
L_w(□1) FLH	0.03834	0.05313	0.00291	0.33339
a_{ph}(412)	0.0757	0.1449	0.0016	0.8483
a_{ph}(440)	0.069	0.1199	0.0015	0.672
a_{ph}(488)	0.0568	0.0903	0.0013	0.4959
a_{ph}(490)	0.0424	0.0659	0.0012	0.4084
a_{ph}(510)	0.0338	0.055	0.0003	0.3615
a_{ph}(532)	0.0246	0.0398	0.0007	0.278
a_{ph}(555)	0.0158	0.0261	0.0004	0.1802
a_{ph}(650)	0.0352	0.0351	0.0002	0.1831

$a_{ph}(676)$	0.0328	0.0338	0	0.1823
$a_{ph}(715)$	0.0158	0.0126	0.0057	0.0743
$a_g(412)$	0.4068	0.2245	0.0001	1.3856
$a_g(440)$	0.2742	0.1599	0.0001	1.04
$a_g(488)$	0.1512	0.1018	0.0001	0.702
$a_g(490)$	0.1107	0.0812	0.0001	0.5644
$a_g(510)$	0.0995	0.0736	0.0041	0.5147
$a_g(532)$	0.0787	0.06	0.0004	0.4181
$a_g(555)$	0.053	0.0407	0.0008	0.285
$a_g(650)$	0.0346	0.0268	0.0008	0.1785
$a_g(676)$	0.0011	0.0059	0.0003	0.0337
$a_g(715)$	0	0	0	0
$a_d(412)$	0.4707	0.577	0.0817	2.742
$a_d(440)$	0.3848	0.4767	0.0626	2.2336
$a_d(488)$	0.2976	0.3811	0.0436	1.7349
$a_d(490)$	0.2568	0.335	0.0343	1.4969
$a_d(510)$	0.2316	0.3043	0.0285	1.3488
$a_d(532)$	0.1869	0.2528	0.0207	1.0965
$a_d(555)$	0.1246	0.1712	0.0112	0.739
$a_d(650)$	0.0703	0.0958	0.0034	0.4291
$a_d(676)$	0.0199	0.0327	0.0029	0.1693
$a_d(715)$	0.0077	0.0119	0.0011	0.0604

Table 3 Mean parameters values of coastal waters

Parameter	**Mean**	**ρ**	**Minimum**	**Maximum**
Physical				
Temperature (°C)	29.04	1.37	26.47	32.13
Salinity	34.77	0.72	32.21	36.44
Density σ (Kg/m^3)	21.88	0.63	19.8	23.32
Solar radiation at surface				
$E_S(350)$ (W/m^2/nm)	0.3677	0.0937	0.0873	0.6169
$E_S(490)$ (W/m^2/nm)	1.1574	0.2743	0.245	1.5977
PAR E_S (W/m^2)	322.7538	76.3252	67.5449	440.6275
Light penetration				
Z_{Max} (m)	17.12	5.88	4.3	30
□ (of maximum Z_{90}) (nm)	545	26	482	573
Z_{90} (m)	4.28	3.02	1.58	16.29
Z_{SD} (m)	4.04	2.24	1.29	13.5
Z_{eu} (m)	19.73	13.92	7.28	75.02
PAR at Z_{90}(µmole/m^2/s)	313.85	81.33	93.13	529.07
%PAR at Z_{90}	21.43	3.58	8.52	37.99
PAR at Z_{SD}(µmole/m^2/s)	365.35	159.87	113.18	948.27
%PAR at Z_{SD}	24.77	7.93	9.5	52.15
□ (of Maximum E_d) (nm)	545	24	479	576
E_d at Z_{90}(W/m^2/nm)	0.4891	0.1144	0.1369	0.8191

□ (at Maximum E_{SD}) (nm)	544	25	479	580
E_d at Z_{SD}($W/m^2/nm$)	0.5546	0.2102	0.2028	1.3513
IOP				
b_b(700) (m^{-1})	0.00993	0.01586	0.002	0.07025
a(412) (m^{-1})	0.3992	0.2731	0.0006	2.4675
a(440) (m^{-1})	0.2957	0.1885	0.0012	0.9396
a(488) (m^{-1})	0.2061	0.1887	0.0012	2.3954
a(490) (m^{-1})	0.2023	0.1773	0.0011	2.2152
a(510) (m^{-1})	0.1718	0.0869	0	0.4379
a(532) (m^{-1})	0.146	0.0699	0.0012	0.4877
a(555) (m^{-1})	0.1112	0.0493	0.0012	0.3177
a(650) (m^{-1})	0.069	0.027	0.0003	0.1442
a(676) (m^{-1})	0.0904	0.0682	0.001	0.7385
a(715) (m^{-1})	0	0	0	0
c(412) (m^{-1})	1.631	2.2848	0.0006	17.3559
c(440) (m^{-1})	1.5436	2.2093	0.0012	17.3937
c(488) (m^{-1})	1.3045	1.3526	0.0012	6.2211
c(490) (m^{-1})	1.2993	1.3474	0.0011	6.1916
c(510) (m^{-1})	1.2603	1.2999	0	5.8967
c(532) (m^{-1})	1.2268	1.2766	0.0012	5.7375
c(555) (m^{-1})	1.1716	1.2627	0.0012	5.621
c(650) (m^{-1})	1.0634	1.7664	0.0003	17.0363
c(676) (m^{-1})	1.0215	2.13	0.0023	18.1733
c(715) (m^{-1})	0.9291	7.6567	0.0054	90.9966
γ	0.99	0.33	0.16	1.91
ξ	3.91	0.53	0.52	4.91
np	1.0778	0.0494	1	1.2221
AOP				
K_d(350) (m^{-1})	0.5161	0.4481	0.0146	3.9393
K_d(412) (m^{-1})	0.3979	0.3321	0.0243	1.8967
K_d(443) (m^{-1})	0.3447	0.281	0.0033	1.65
K_d(490) (m^{-1})	0.2584	0.2184	0	1.2515
K_d(510) (m^{-1})	0.2525	0.197	0	1.1424
K_d(532) (m^{-1})	0.2522	0.1776	0	1.0497
K_d(555) (m^{-1})	0.2513	0.1606	0	0.9757
K_d(566) (m^{-1})	0.2505	0.1538	0.0081	0.9438
K_d(620) (m^{-1})	0.4953	0.1564	0.0227	1.1455
K_d(650) (m^{-1})	0.5325	0.1679	0.0116	1.3517
K_d(670) (m^{-1})	0.6173	0.2077	0.0161	1.8103
K_d(676) (m^{-1})	0.6244	0.2156	0.0036	2.2225
K_d(681) (m^{-1})	0.618	0.205	0.0061	1.3717
K_d(700) (m^{-1})	0.6877	0.2616	0.0197	2.4331
R_{rs}(350) (sr^{-1})	0.002019	0.115458	1E-006	2.459452
R_{rs}(412) (sr^{-1})	0.003095	0.001614	0.000215	0.012657
R_{rs}(443) (sr^{-1})	0.003779	0.001932	0.000238	0.015313

R_{rs}(490) (sr^{-1})	0.005557	0.00243	0.000513	0.017729
R_{rs}(510) (sr^{-1})	0.005847	0.002653	0.000631	0.018092
R_{rs}(532) (sr^{-1})	0.006173	0.002999	0.00076	0.01916
R_{rs}(555) (sr^{-1})	0.005903	0.003317	0.000832	0.01943
R_{rs}(566) (sr^{-1})	0.005667	0.003465	0.00087	0.019555
R_{rs}(620) (sr^{-1})	0.001501	0.002062	7.1E-005	0.013871
R_{rs}(650) (sr^{-1})	0.001233	0.001866	4.2E-005	0.013121
R_{rs}(670) (sr^{-1})	0.000974	0.001473	5.1E-005	0.010945
R_{rs}(676) (sr^{-1})	0.001017	0.001462	5.2E-005	0.011274
R_{rs}(681) (sr^{-1})	0.001031	0.001453	4E-006	0.010957
R_{rs}(700) (sr^{-1})	0.000649	0.006554	3E-006	0.128804
Biological				
Chlorophyll (mg/m^3)	1.16	25.42	0.15	247.2
Chlorophyll(mg/m^3)-Sensor	0.98	1.02	0.17	6.81
TSM (g/m^3)	6.2	15.38	2	134.5
pH	7.99	0.17	7.27	8.16
□ (FLH R_{rs})	688	4	681	698
R_{rs}(□) FLH (sr^{-1})	0.00046	0.00035	2E-005	0.00184
□ (FLH L_w) nm	683	5	678	708
L_w(□) FLH (µWcm^{-2}sr^{-1})	0.02653	0.02564	0.00216	0.16376
a_{ph}(412) (m^{-1})	0.0492	9.4502	0.0089	55.0764
a_{ph}(440) (m^{-1})	0.0487	8.4761	0.0099	48.8126
a_{ph}(488) (m^{-1})	0.044	7.05	0.0093	40.2027
a_{ph}(490) (m^{-1})	0.0331	5.5805	0.0046	31.9769
a_{ph}(510) (m^{-1})	0.0262	4.5638	0.0022	26.0304
a_{ph}(532) (m^{-1})	0.0163	2.9377	0.0033	16.7079
a_{ph}(555) (m^{-1})	0.0102	1.9484	0.0013	10.8445
a_{ph}(650) (m^{-1})	0.0169	4.2281	0.0011	23.4327
a_{ph}(676) (m^{-1})	0.0151	4.0694	0.0006	22.4182
a_{ph}(715) (m^{-1})	0.0071	2.0196	0.0011	11.3249
a_g(412) (m^{-1})	0.1385	4.7074	0.0271	24.6247
a_g(440) (m^{-1})	0.0878	4.3584	0.0127	25.2086
a_g(488) (m^{-1})	0.0408	5.0287	0	31.8148
a_g(490) (m^{-1})	0.0248	6.4517	0.001	41.8861
a_g(510) (m^{-1})	0.0208	6.0002	0	39.543
a_g(532) (m^{-1})	0.0172	6.8161	0	41.85
a_g(555) (m^{-1})	0.0137	5.3625	0.0004	31.9666
a_g(650) (m^{-1})	0.0114	2.5632	0.0003	15.4531
a_g(676) (m^{-1})	0.0022	0.1746	0.0002	0.9171
a_g(715) (m^{-1})	0.0003	0.0001	0.0001	0.0004
a_d(412) (m^{-1})	0.0738	2.2551	0.0093	13.2128
a_d(440) (m^{-1})	0.0572	2.0804	0.0059	12.5151
a_d(488) (m^{-1})	0.0419	2.0788	0.0027	13.0169
a_d(490) (m^{-1})	0.0347	2.224	0.0001	14.2135
a_d(510) (m^{-1})	0.0334	2.127	0.0007	13.5052

$a_d(532)$ (m^{-1})	0.0288	2.0927	0.0004	13.2891
$a_d(555)$ (m^{-1})	0.0207	1.5606	0.0002	9.8819
$a_d(650)$ (m^{-1})	0.0119	0.8713	0.0001	5.4403
$a_d(676)$ (m^{-1})	0.0044	0.2473	0.0003	1.3946
$a_d(715)$ (m^{-1})	0.0017	0.1075	0	0.6287

3. CONCLUSION

There were distinct spatial and temporal variations of optical, biological, physical, and ancillary parameters of both coastal and estuarine waters. The solar radiation was maximum during summer and lowest during monsoon. However, during clear sunny days of monsoon, the solar lights were also much higher. The solar light decreased moving from coastal waters to upstream of the estuary, which indicated the increase of atmospheric turbidity or aerosols in the interiors of Goa. There was sufficient light available in these waters till the bottom during all seasons, and average %PAR at Secchi depth, Zsd was about 22%. The bulk refractive index was higher in the estuaries, indicating more mineral particles. The particle sizes were relatively smaller in the estuaries. Monsoons play an important role in modulating the physical, biological, and optical parameters of these estuaries. Monsoons were observed to promote CDOM, detritus, and sediment and restrict the light availability in water. During monsoon, low chlorophyll, despite the availability of nutrients and sufficient light, was attributed to high discharge and flow rates. The low transparencies during monsoon were due to high optical properties. The penetration depth, Z90, and Zsd values were the highest during the winter and lowest during the monsoon. Contributions of CDOM and detritus were significant in the estuaries, with the highest during monsoon. Since Z90 and Zsd were comparable, and Zsd which could be measured with ease and could be used to provide a rough estimate of Z90 and Zeu. The chlorophyll and CDOM were higher in the Zuari and the highest detritus were observed in the Mandovi.

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