PERIODIC CHANGES IN SPECTRAL SCATTERING AND SPECTRAL TRANSMISSION OF DAYLIGHT IN TIDAL WATER

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Seasonal changes in the transmission of certain spectral bands of solar radiation in the inshore waters of the Pacific Northwest were reported by Williams and Utterback (*1*) for the year 1934 and by Utterback and Miller (*2*) for the years 1935 and 1936. During each of these periods approximately one month elapsed between sets of observations, hence the results were computed from data taken at fairly long intervals of time. Also, in these same waters, some measurements on the scattering of certain spectral bands were made by Utterback and Jorgensen. (*3*) In view of the results of these observations it seemed desirable to make a series of weekly measurements of the simultaneous values of absorption and scattering in the same locality. The results of these measurements are here presented.

A location was selected west of Crane Island which is one of the islands in the San Juan group. The depth of the water at this station is approximately 35 meters. Throughout the series of observations very favorable conditions prevailed. The sky was unusually clear and the water was relatively smooth, even though tidal flow existed.

A submarine photometer, designed to simultaneously measure the relative intensities of the upward and the downward traveling light, was constructed of an eight-inch pipe closed at each end with 3/8 inch boiler plate caps. The upper cap was constructed so that it held two water-tight windows behind which were mounted two Photronic cells. These cells were connected and operated independently in order that any shadow effect of the cables and the cable supports might be detected. A large Electrocell, facing downward, was mounted behind a window in the lower cap. Identical filters, for defining the band of light admitted to the cells, were placed between each cell and its window.

The conducting cables were brought out through a water-tight gland and terminated on board the small boat from which the measurements were made. A deck photometer, also provided with identical filters, was used to observe the intensity of the light incident upon the surface.

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TABLE I

Spectral Extinction Coefficients Per Meter

Depth Range, Meters	*June 27*	*July 1*		*July 8*		*July 15*	*July 22*		*July 29*	*Aug. 5*	*Aug. 12*		*Aug. 19*	
						4600 Angstroms								
0–5				.241		.370	.316	.325	.522	.372	.517	.495	.363	
5–10				.232		.350	.310	.317	.494	.351	.491	.464	.325	
10–15				.223		.331	.307	.303	.508	.324	.480	.442	.315	
15–20				.222		.314	.297	.283	—	.314	—	.428	.317	
20–25				.218		—	—	.251	—	—	—	—	—	
						4800 Angstroms								
0–5		.360	.386	.266		.322	.278		.446	.345	.474	.448	.324	
5–10		.368	.338	.238		.322	.266		.442	.315	.432	.438	.314	
10–15		.364	.346	.212		.344	.250		.446	.300	.412	.434	.318	
15–20		.358	.358	.230		.370	.262		.444	.300	.422	.432	.308	
20–25		—	—	.236		.358	.260		—	.282	—	—	.300	
25–30		—	—	—		—	.248		—	—	—	—	—	
						5150 Angstroms								
0–5				.187		.279	.224		.225	.407	.274		.388	.246
5–10				.192		.280	.241		.239	.402	.274		.376	.252
10–15				.191		.280	.237		.246	.394	.271		.377	.249
15–20				.197		.283	.238		.257	.383	.275		.379	.250
20–25				.201		.283	.237		.257	.376	.277		.376	.245
25–30				.203		.269	.289		—	—	—		—	.239
						5300 Angstroms								
0–5	.224	.272	.265	.198	.198	.241	.221		.326	.284	.349		.221	.253
5–10	.226	.278	.263	.193	.193	.249	.216		.335	.281	.330		.234	.264
10–15	.228	.280	.267	.167	.179	.316	.214		.331	.289	.335		.252	.273
15–20	.223*	.284	.266	.167	.165	.308	.212		.330	.267	.312		.248	.239
20–25	—	.290	.256	.181	.176	.310	.211		.328	.263	.299		.238	.233
25–30	—	—	—	.192	.188	.305	.221		.328	—	.298		—	—
30–33	—	—	—	—	.195*	.300*	.230*		—	—	—		—	—

TABLE I—Continued

Depth Range, Meters	*June 27*	*July 1*		*July 8*	*July 15*	*July 22*	*July 29*	*Aug. 5*	*Aug. 12*		*Aug. 19*	
						6000 Angstroms						
0–5		.428	.428	.374	.448	.407	.480	.466	.503		.400	.464
5–10		.428	.428	.375	.455	.414	.473	.461	.497		.404	.453
10–15		.420	.422	.380	.448	.411	.465	.453	.475		.397	.439
15–20		.414	.414	.377	.445	.409	.466	.449	.470		.389	.424
20–25		.400	.412	—	.436	—	.464	—	—		.376	—
						6600 Angstroms						
0–5						.675	.534	.826	.770	.706	.736	
5–10						.570	.698	.612	.472	.580	.600	
10–15						.428	.496	—	—	.512	.562	

* 3-Meter Interval.

TABLE II

UPWARD LIGHT INTENSITY IN PER CENT OF THE DOWNWARD LIGHT INTENSITY

Depth in Meters	*June 27*	*July 1*		*July 8*	*July 15*	*July 22*	*July 29*	*Aug. 5*	*Aug. 12*		*Aug. 19*
						4600 Angstroms					
0						.42	.92	1.68	1.76	2.64	3.13
5						.76	.95	1.92	1.85	2.46	3.39
10						.99	.98	2.10	2.44	2.38	2.52
15						1.14	1.00	2.25	4.06	2.61	2.70
						4800 Angstroms					
0		.95	1.14	1.70	1.68	1.27	1.00	1.64	1.36	2.30	2.24
5		.69	.93	2.69	1.94	1.49	1.07	2.00	1.66	2.10	2.60
10		.70	.82	2.84	1.76	1.52	.86	1.80	1.84	1.96	2.24
15		.92	.84	2.84	1.75	1.48	1.02	1.75	1.82	1.89	2.13
20		2.20	1.17	3.14	2.12	1.57		1.88	1.88		2.17
25			4.6	3.02	2.37	1.97		2.59			

TABLE II—Continued

Depth in Meters	*June 27*	*July 1*		*July 8*	*July 15*	*July 22*	*July 29*	*Aug. 5*	*Aug. 12*	*Aug. 19*	
					5150 Angstroms						
0						1.75	1.42	3.24	2.72	3.18	
5						1.98	1.44	2.43	2.80	3.05	
10						1.91	1.44	2.30	2.52	2.73	
15						1.96	1.58	2.34	2.51	2.20	
20						2.01	1.64	2.59	2.66	1.82	
25						1.90		3.29		1.74	
					5300 Angstroms						
0	1.24	.91	1.16	1.99	1.67	1.13	.80	2.02	1.48	1.87	2.10
5	1.41	1.00	1.18	2.32	2.31	1.46	1.17	2.13	1.85	1.98	2.76
10	1.88	.65	.66	2.34	2.33	1.73	1.33	1.85	1.68	1.94	2.79
15	2.02	.77	.74	2.25	2.18	1.80	1.25	1.69	1.73	1.72	2.90
20		1.13	.96	2.07	2.18	1.63	1.09	1.93	2.09	1.66	
25			2.01	2.30	2.94	1.62	1.64	4.36	2.99	1.85	
30				3.64	4.57	2.65	3.58		4.70	3.92	
					6000 Angstroms						
0		.30	.47	1.94	.49	.38	.47	.93	.78	.85	
5		.26	.56	2.01	.97	.45	.67	.96	.97	.86	
10		.31	.63	2.52	1.09	.62	.75	1.18	1.12	.84	
15		.62	.91	5.41	1.58	1.00	.92	1.28	1.39	.97	
20		1.65	3.09		2.55	2.26	1.40	1.40	2.38	1.34	
					6600 Angstroms						
0						.08	.19	.43	.44	.26	.44
5						.64	.82	1.47	1.19	1.09	1.42
10						2.78	2.24	2.38	1.54	5.30	5.80

The method of making the measurements, the electrical instruments, the light filters, and the precautions taken have been previously described by the authors. (*3, 4*) However, in the observations here reported, the photometer was lowered to six inches beneath the surface of the water and then by subsequent intervals of five meters until the limit of the indicating apparatus was reached. The measurements were repeated, at the same depths, on returning the apparatus to the surface. The extinction coefficients, for each color were computed as previously described and the results given in Table I.

When two independent sets of data were taken on the same day for any particular spectral band they are recorded as independent sets in Table I. The extinction coefficients for six color bands were computed. However, as but three of these bands were employed during all of the measurements, only the variations in the coefficients corresponding to these bands are shown in Figure 9.

Just beneath the curves for each color filter is a curve representing the mean height of tide at the time observations were made. These curves have significance only at the points in question, the lines being drawn for visual aid. Small arrows are drawn near the plotted points to indicate flooding, ebbing or slack tides.

The intensity of the upward traveling light expressed in per cent of the downward traveling light is recorded in Table II.

Figure 10 represents the fluctuations of the scattered light of the three bands which were used during the entire series of observations.

Net hauls were made at the time and depth of each observation by Professor R. C. Miller who is making an analysis of the microscopic organism content in conjunction with the periodic changes shown in Figures 9 and 10.

The variations in the extinction coefficients, as shown in Figure 9, appear to be cyclic with high extinction on flooding tides and low extinction on ebbing tides. In view of this it is supposed that on flood tides the water runs from the east to west through Harney Channel carrying more or less stagnant water from West Sound and from East Sound past Crane Island to give high extinction of light. On the ebb tides the clear water from the Gulf of Georgia, to the north, flows south past Crane Island to give low light extinction. The observed flow of the tide is in agreement with this hypothesis.

During the observations any list of the boat and any errors in reading the position of the photometer resulted in an uncertainty in the depth which, for a single observation, might be as much as five per cent. Any changes in the transparency of the water during the measurements affect the values of the extinction coefficients. For each set of observations the data were taken with the photometer descending and again when it was ascending, and generally required but a few minutes. Since variations in the observed

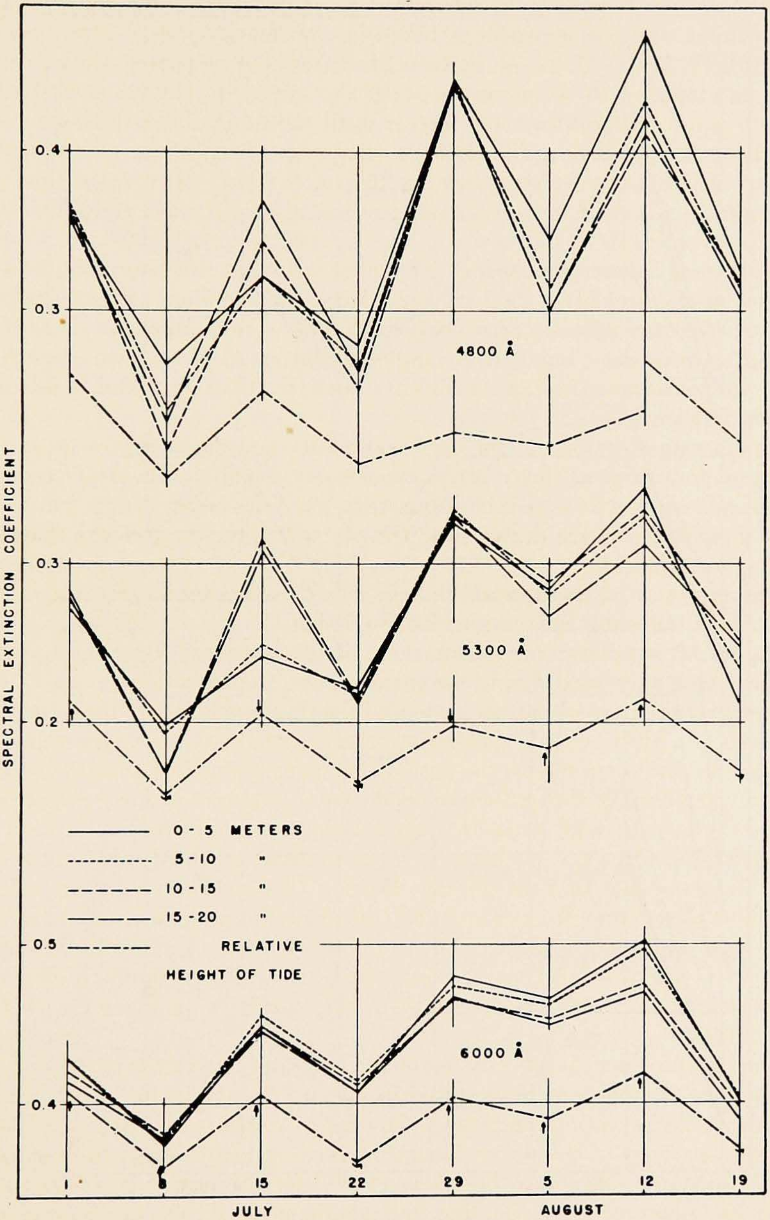

Figure 9. Variation of the extinction coefficients.

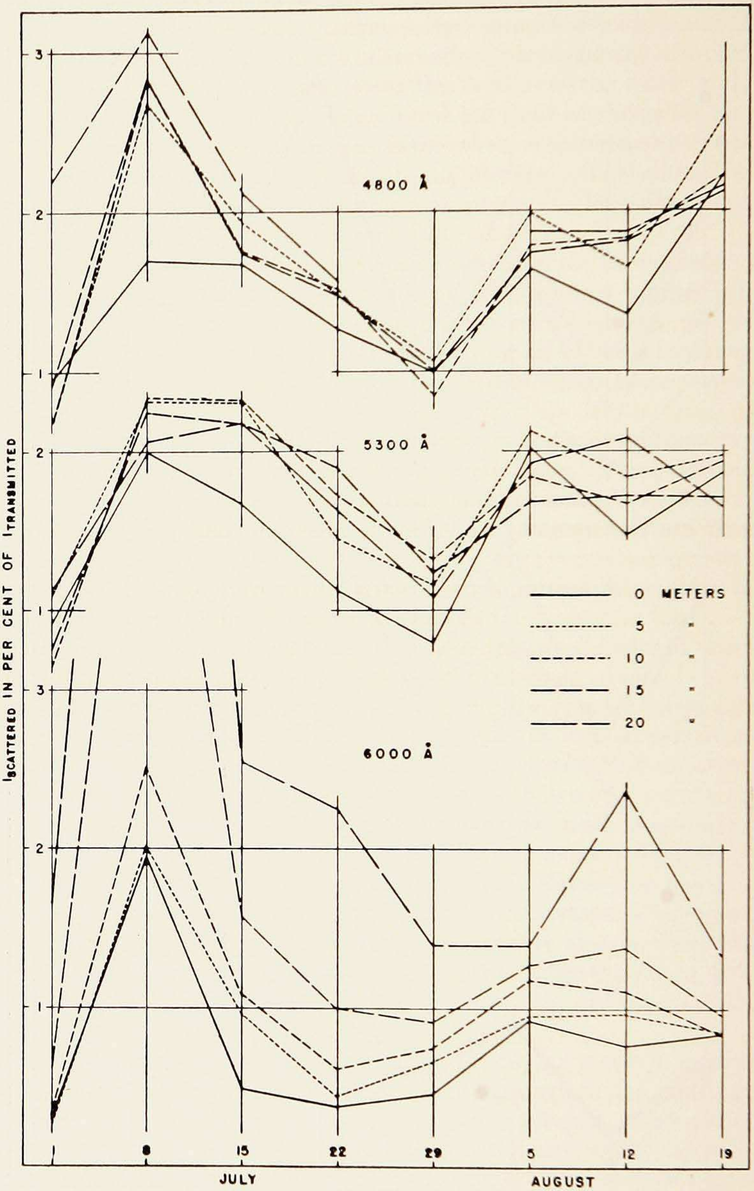

Figure 10. Variations in scattered light.

intensity were those primarily due to the change in water and variations in depth, the values obtained experimentally were found to be distributed about a mean geometrically instead of algebraically. The mean of duplicate sets of data was thus obtained by taking logarithms of the relative intensities and then determining the mean value algebraically.

The light scattered, in per cent of the light transmitted, was calculated for each individual observation. These ratios were found to be equally distributed on each side of the mean and so were averaged algebraically. Usually duplicate sets of individual data checked within three per cent.

The numerical values of the extinction coefficients ranged from 0.23 to 0.52 per meter for the 4600 Å band and from 0.48 to 0.83 per meter for the 6600 Å band, while for the 5300 Å band the variation was from 0.17 to 0.34 per meter. From the data in Table I it is found that variations in the extinction coefficients amounted to about 75 per cent of the mean for the 4600 Å band and only about 30 per cent of the mean for the 6000 Å band, which shows that the extinction characteristics of the short wave lengths are more dependent upon the turbidity of the water than are those of the long wave lengths. This variation is consistent with the observed shift in the region of maximum transparency from blue to green on coming to inshore waters from the open ocean. (*4*)

The relative intensities of the scattered light were found to range from 1 per cent to 3 per cent for the short wave lengths and from 0.5 per cent to 2 per cent for the long wave lengths. The relative intensities of the scattered light were found to increase in the immediate vicinity of the bottom in those instances where it was possible to make measurements very near the bottom of the water body.

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