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Spectral Relative Clarity of Black and Aegean Seas

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Abstract – The data on relative clarity or visibility of blue, green, red, and white (Secchi) disks measured in 1984 at the Black and Aegean seas during the 9th trip of the research vessel "Professor Kolesnikov" are presented. The analysis of results of measurements show strong correlation between visibilities of colored and Secchi disk. The regressional relationship between visibilities of blue, green and red disks and the visibility of the Secchi (white) disk are given and discussed.

INTRODUCTION

The idea to use colored Secchi disks to estimate relative spectral clarity of seawater was proposed in 1968 by N. Jerlov [1]. Yet in spite of the abundance of works devoted to the visibility of white Secchi disk there are almost no publications about visibility of colored disks except the black one [2]. World oceanographic archives contain millions of Secchi disk measurements made during the period of more than one hundred years [3-5]. These measurements give very little information about spectral characteristics of studied waters. The regressional relationships between visibility of colored disks and Secchi disk proposed in this paper will give us means to convert historical non-spectral Secchi disk data into spectral information.

IN SITU MEASUREMENTS

The results of simultaneous measurements of the spectral relative clarity, or visibilities of blue, green, red and white (Secchi) disks, made in 1984 at the Black and Aegean seas are presented. The measurements are made at 45 stations during the 9th trip of the research vessel "Professor Kolesnikov". At about seventy percent of the oceanographic stations the simultaneous measurements of yellow and black disks also have been made. The spectral albedos of Secchi and colored disks have been measured with a spectral photometer and presented in Fig. 1.

WHITE AND COLORED DISKS VISIBILITY

The results of statistical analysis show strong correlation between visibilities of blue, green, red (Z_b, Z_g, Z_r) and Secchi (Z_w) disks (See. Fig. 2). They are represented by the following regressions:

$$Z_b = 0.675923821 \cdot Z_w^{1.066472}, \quad r^2 = 0.9234386, \qquad (1)$$

$$Z_g = 0.890360716 \cdot Z_w^{0.948397}, \quad r^2 = 0.8837671, \qquad (2)$$

$$Z_r = 0.646411940 \cdot Z_w^{0.849426}, \quad r^2 = 0.7662292. \qquad (3)$$

The theories of the Secchi disk visibility [6, 7] are based on the non-spectral approach. It is possible to modify these theories to incorporate the spectral dependencies of the inherent optical properties of the sea [8-10]. In this case it is possible to formulate a theory of the color disk visibility that incorporates spectral contrasts and averaging procedure over CIE chromatic coordinates [11]. The inherent optical properties of seawater may be expressed through four concentrations of substances suspended and dissolved in seawater: concentration of chlorophyll, concentration of large biogenic particles, concentration of small terrigenic particles, and concentration of yellow substance. Consequently, the four theoretic equations for visibility of Secchi and three colored disks include eight unknown parameters: four disk visibility depths and four concentrations of dissolved and suspending matter. In order to solve them we need an additional four equations. Equations (1)-(3) of this note may serve this purpose. As an additional fourth equation we may choose a regression that connects the Secchi disk visibility depth with the concentration of chlorophyll [5, 10] or with the beam attenuation coefficient [12, 13].

CONCLUSION

It was shown that the visibility of colored disks is closely connected with the visibility of white or Secchi disk. The derived empirical relationships between relative clarities of colored and white disks may be used for the restoration of the spectral dependencies of inherent optical properties from the Secchi disk measurements.

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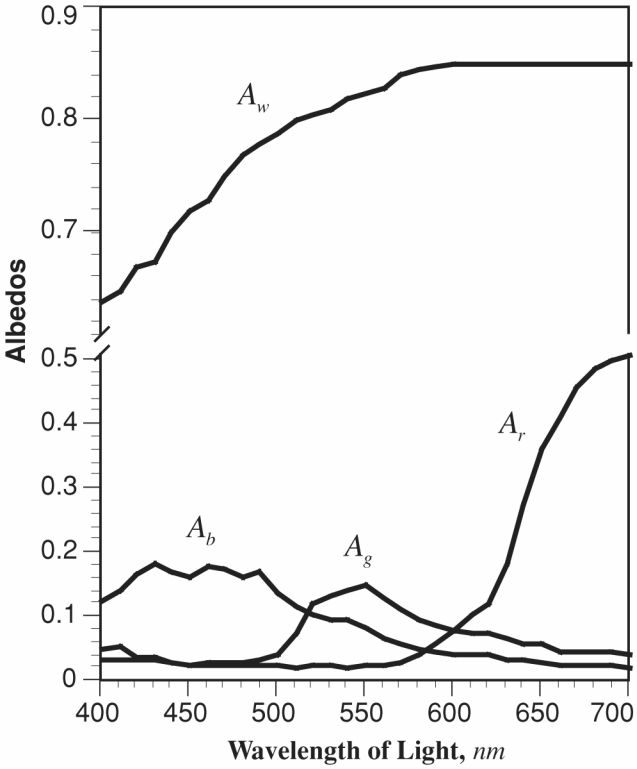

Figure 1. Spectral albedos of white (or Secchi), blue, green and red disks.

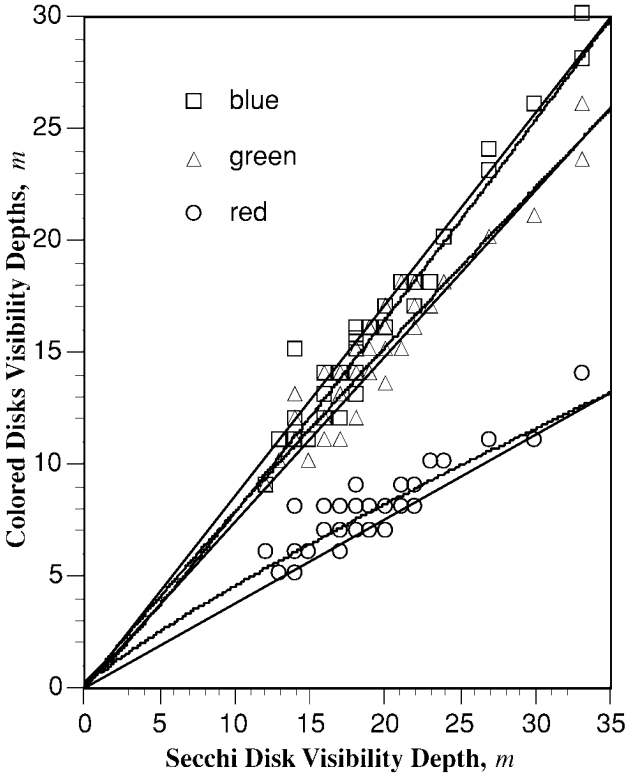

Figure 2. Visibility of blue, green and red disks in the Black and the Aegean seas as a function of white (or Secchi) disk visibility.

APPENDIX 1: RELATIVE CLARITIES OF WHITE (SECCHI), BLUE, GREEN, AND RED DISKS

Table A1. Spectral relative clarity of the Black (B) and the Aegean (A) seas during the 9th voyage of the R/V "Professor Kolesnikov" in 1984.

St.#	Date	Time	Z_w	Z_b	Z_g	Z_r	N	Sea
1166	25.08	15:30	20	16	16	7	5	B
1167	25.08	18:40	17	14	13	8	5	B
1172	26.08	-	16	13	11	7	5	B
1173	26.08	-	18	15.5	15	9	5	B
1179	27.08	-	19	16	14	7	4.5	B
1180	27.08	-	16	12	12	7	4.5	B
1181	27.08	17:35	14	15	13	8	5	B
1187	29.08	19:45	17	14	13	7	5	B
1187	30.08	10:30	20	16	13.5	8	5	B
1188	31.08	09:40	18	15	14	7	6	B
1189	03.09	11:00	16	12	11	8	3	A
1189	03.09	14:35	17	14	14	8	3.5	A
1190	07.09	-	33	30	23.5	14	3	A
1191	07.09	-	22	18	17	9	3	A
1192	07.09	-	27	24	20	11	3	A
1193	07.09	-	27	23	20	11	3	A
1201	08.09	-	33	28	26	14	3	A
1202	08.09	-	30	26	21	11	3	A
1204	10.09	09:15	20	16	16	8	5	B
1205	10.09	13:00	23	18	17	10	4.5	B
1206	10.09	16:12	24	20	18	10	4	B
1211	11.09	10:10	21	18	18	8	5	B
1212	11.09	14:25	22	18	18	9	4.5	B
1213	11.09	17:15	20	16	15	7	5.5	B
1218	12.09	11:55	19	16	14	8	6	B
1219	12.09	14:50	18	13	12	7	5	B
1224	13.09	10:37	22	18	16	9	4.5	B
1225	13.09	14:13	19	16	16	8	4.5	B
1226	13.09	16:10	17	12	11	6	5	B
1230	14.09	10:10	20	16	16	8	5	B
1231	14.09	14:10	21	18	15	9	5	B
1232	14.09	18:39	22	17	17	8	5	B
1236	15.09	09:45	14	12	12	5	6	B
1237	15.09	13:15	18	16	15	7	5	B
1238	15.09	17:20	18	14	14	8	5	B
1242	16.09	09:40	16	14	14	7	7	B
1243	16.09	13:26	15	11	10	6	6	B
1244	16.09	17:45	13	11	10	5	6	B
1250	17.09	14:10	16	14	12	8	6	B
1251	17.09	18:10	14	11	11	6	6.5	B
1256	18.09	11:05	17	14	13	8	6	B
1261	19.09	10:42	16	12	12	7	5	B
1262	19.09	13:05	20	17	17	7	5	B
1263	19.09	17:05	19	16	15	7	5	B
1267	21.09	14:15	12	9	9	6	6	B

Note: N in Table A1 stands for the water color according to the Forel-Uhle scale.

APPENDIX 2: SPECTRAL ALBEDOS OF WHITE (SECCHI), BLUE, GREEN, AND RED DISKS

Table A2. Spectral albedos of white and colored disks.

λ, nm	A_w	A_b	A_g	A_r
400	0.640	0.123	0.032	0.05
410	0.650	0.143	0.032	0.054
420	0.670	0.165	0.032	0.039
430	0.675	0.182	0.032	0.038
440	0.700	0.170	0.030	0.029
450	0.720	0.163	0.026	0.027
460	0.730	0.181	0.028	0.024
470	0.750	0.177	0.030	0.025
480	0.770	0.164	0.031	0.025
490	0.780	0.172	0.035	0.026
500	0.790	0.139	0.043	0.023
510	0.800	0.118	0.076	0.022
520	0.805	0.104	0.120	0.024
530	0.810	0.097	0.135	0.023
540	0.820	0.094	0.142	0.022
550	0.825	0.085	0.149	0.023
560	0.830	0.068	0.128	0.025
570	0.840	0.057	0.112	0.029
580	0.845	0.051	0.097	0.042
590	0.848	0.046	0.088	0.060
600	0.850	0.042	0.080	0.080
610	0.850	0.040	0.076	0.105
620	0.850	0.040	0.074	0.121
630	0.850	0.035	0.065	0.184
640	0.850	0.032	0.060	0.275
650	0.850	0.030	0.057	0.362
660	0.850	0.027	0.047	0.411
670	0.850	0.025	0.047	0.46
680	0.850	0.025	0.046	0.488
690	0.850	0.024	0.046	0.500
700	0.850	0.022	0.041	0.510

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