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Light scattering phase functions of turbid coastal waters measured in LEO-15 experiment in 2000

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Abstract — In this paper we propose additional 60 new experimental phase functions of light scattering by natural seawater measured in very turbid waters of Atlantic during LEO-15 experiment off the New Jersey coast. Previously published experimental phase functions include 15 phase functions by Petzold measured in California Bay and 41 phase functions by Mankovsky measured in waters of Atlantic, Indian and Southern oceans, Mediterranean and Black seas, and lake Baikal. All previously published phase functions correspond to waters with beam scattering coefficients in the range of 0.08 to 1.8 1/m. The newly measured phase functions expand the range of scattering coefficients more than five times up to 9.3 1/m.

1. INTRODUCTION

Light scattering phase functions by seawater that are experimentally measured over thirty years by Petzold became very popular among scientists involving in radiative transfer modeling in the ocean. The original work of Petzold is published as a report [1] and gives numerical values of fifteen phase functions at 515 nm for 21 scattering angles between 0.338°-170° with the values of absorption, scattering and backscattering coefficients. Thirty years later since the release of Petzold report two publications [2, 3] have been released with the tables of 41 experimental seawater light scattering phase functions at 520 nm measured at 33 scattering angles between 2°-162.5° in waters of Atlantic, Indian and Southern oceans, Mediterranean and Black seas, and lake Baikal. In this paper we propose additional 60 new experimental phase functions measured during 2000 LEO-15 experiment off the New Jersey Atlantic coast in ocean waters with light scattering coefficient varying between 0.38 and 9.3 1/m.

For the remote optical sensing of oceans and inland water basins and estimation of visibility properties of seawater, and light propagation it is very important to know relationships between some inherent optical properties, like scattering and backscattering coefficients, average cosines and probability of backscattering or ratio of backscattering to scattering coefficients, etc. A number of practically useful relationships between these properties based on 60 new phase functions are proposed.

2. MEASURING DEVICE

The maximum intensity of light source in the polar nephelometer was centered at 550 nm with ten nm spectral sensitivity half width. Measurements of light scattering phase functions have been made with the precision of 5% at 590 scattering angles between 0.6 and 177.3 degrees. A complete set of technical parameters of the polar nephelometer can be found in Refs. [4] and [5].

3. SCATTERING PHASE FUNCTIONS

Due to the space restrictions in this publication we give here the tables of measured phase functions (PhFs) only at 36 scattering angles, while all integral properties of these phase functions are computed using the full set of measurements at 590 scattering angles. The set of angles given in Tables 1-12 is carefully chosen to represent all measured phase functions in a maximum detail of accuracy, especially in the forward direction of scattering. The most important integral properties of these phase functions useful for purposes of light propagation and image transfer are computed and given in these tables. Below we give exact definitions of all these parameters.

Phase functions of light scattering $p(\theta)$ are normalized according to the following formula:

$$0.5\int_0^{\pi} p(\theta)\sin\theta \, d\theta = 1. \qquad (1)$$

Ratio of backscattering b_B to scattering b coefficients, b_B/b, or probability of backscattering B is defined as follows:

Table 1. Natural logarithms of PhFs $p(\theta)$ No. 01-05

angle	phf01	phf02	phf03	phf04	phf05
0.6	6.2377	6.3112	6.0822	6.1957	6.4288
0.9	5.5308	5.5974	5.3500	5.4726	5.7519
1.2	5.1278	5.2083	5.0552	4.9661	5.4065
1.8	4.6235	4.6764	4.4105	4.3214	4.6351
3.0	3.7486	3.8659	3.4757	3.3635	3.7716
4.2	3.1614	3.2534	2.8770	2.7257	3.1131
5.7	2.5904	2.6870	2.2300	2.1592	2.5052
7.5	2.0562	2.0906	1.6290	1.5582	1.9296
9.9	1.3723	1.4574	0.9843	0.9112	1.2480
12.3	0.8772	0.9853	0.4639	0.3816	0.6562
15.0	0.4651	0.6008	0.0356	0.0316	0.2234
18.0	0.0875	0.2025	-0.3535	-0.4128	-0.1773
21.3	-0.2303	-0.1061	-0.6805	-0.7259	-0.5227
24.9	-0.5619	-0.4353	-1.0328	-1.0529	-0.8888
28.8	-0.8981	-0.7784	-1.4012	-1.3960	-1.2388
33.0	-1.2757	-1.1376	-1.7305	-1.7828	-1.6095
37.5	-1.6003	-1.4738	-2.0482	-2.0798	-1.9595
42.3	-1.9181	-1.7778	-2.3867	-2.3999	-2.2588
47.4	-2.2220	-2.1001	-2.6861	-2.7061	-2.5697
52.8	-2.5513	-2.4133	-2.9923	-3.0262	-2.9404
58.2	-2.8460	-2.7103	-3.2801	-3.3002	-3.2305
64.2	-3.1131	-3.0027	-3.5795	-3.5834	-3.5345
70.5	-3.3964	-3.2929	-3.8788	-3.8689	-3.8177
76.8	-3.6105	-3.5116	-4.0952	-4.1038	-4.0687
83.7	-3.8200	-3.7350	-4.3370	-4.3249	-4.2598
90.0	-3.9674	-3.8915	-4.4913	-4.5045	-4.4394
98.1	-4.1424	-4.0596	-4.6640	-4.6633	-4.6374
105.6	-4.2690	-4.1840	-4.7676	-4.7877	-4.7387
113.7	-4.3312	-4.2553	-4.8344	-4.8475	-4.8585
121.8	-4.3957	-4.2991	-4.8965	-4.9028	-4.9137
130.5	-4.4417	-4.3313	-4.9449	-4.9419	-4.9298
139.2	-4.4325	-4.3267	-4.9495	-4.9466	-4.9275
148.2	-4.4256	-4.3175	-4.9219	-4.9235	-4.9160
157.8	-4.3773	-4.2761	-4.8942	-4.8844	-4.8631
167.4	-4.2345	-4.1540	-4.7192	-4.7623	-4.6328
177.3	-4.0365	-3.9146	-4.5212	-4.4791	-4.1677
b,1/m	2.5580	2.3391	3.5328	3.7970	2.4405
bB,1/m	0.0348	0.0343	0.0289	0.0309	0.0203
bB/b	0.0260	0.0256	0.0216	0.0224	0.0171
<muF>	0.9389	0.9372	0.9471	0.9461	0.9545
<muB>	0.4774	0.4719	0.4775	0.4794	0.4783
<cos>	0.9021	0.9011	0.9163	0.9141	0.9300
<cos2>	0.8869	0.8841	0.9019	0.9003	0.9159
<thet>	0.2704	0.2747	0.2391	0.2406	0.2120
<thet2>	0.2500	0.2506	0.2127	0.2188	0.1764

Table 2. Natural logarithms of PhFs $p(\theta)$ No. 06-10

angle	phf06	phf07	phf08	phf09	phf10
0.6	6.6066	6.3934	6.6798	6.2300	6.4831
0.9	5.9158	5.6819	5.7657	5.5692	5.8752
1.2	5.3678	5.2904	5.1670	5.1271	5.3549
1.8	4.8106	4.7125	4.5062	4.5768	4.7861
3.0	3.9126	3.8859	3.6151	3.8261	4.0263
4.2	3.2679	3.1444	3.0463	3.3035	3.3723
5.7	2.6047	2.5481	2.4108	2.6841	2.7944
7.5	2.0176	1.9632	1.8398	2.0670	2.1428
9.9	1.3337	1.2885	1.1329	1.3624	1.4220
12.3	0.7235	0.7014	0.6263	0.7338	0.8142
15.0	0.3436	0.3422	0.2118	0.2272	0.3513
18.0	-0.0870	-0.0746	-0.1497	-0.2034	-0.1230
21.3	-0.4163	-0.4039	-0.4651	-0.6063	-0.5329
24.9	-0.7939	-0.7677	-0.8036	-0.9840	-0.9312
28.8	-1.1876	-1.1752	-1.1697	-1.3961	-1.3411
33.0	-1.5492	-1.4907	-1.4875	-1.7807	-1.7256
37.5	-1.8761	-1.8292	-1.8052	-2.1468	-2.1216
42.3	-2.2307	-2.1285	-2.1138	-2.5175	-2.5108
47.4	-2.5899	-2.4693	-2.4062	-2.8790	-2.8746
52.8	-2.8593	-2.7824	-2.6825	-3.2589	-3.2453
58.2	-3.1955	-3.0749	-2.9819	-3.5813	-3.5631
64.2	-3.5110	-3.3396	-3.3088	-3.9151	-3.8831
70.5	-3.7919	-3.6298	-3.5483	-4.1822	-4.1525
76.8	-4.0152	-3.8715	-3.7348	-4.4517	-4.4104
83.7	-4.2363	-4.0558	-3.9328	-4.6750	-4.6407
90.0	-4.4021	-4.2077	-4.0664	-4.8546	-4.8157
98.1	-4.5840	-4.3965	-4.2483	-5.0365	-5.0068
105.6	-4.7267	-4.5186	-4.3542	-5.1516	-5.1288
113.7	-4.7590	-4.6038	-4.4325	-5.2576	-5.1680
121.8	-4.8257	-4.6567	-4.4947	-5.3105	-5.2462
130.5	-4.8557	-4.6705	-4.5108	-5.3381	-5.2900
139.2	-4.8856	-4.6775	-4.5223	-5.3381	-5.2831
148.2	-4.8695	-4.6613	-4.4854	-5.3266	-5.2785
157.8	-4.8096	-4.6383	-4.4670	-5.2460	-5.1933
167.4	-4.5724	-4.4633	-4.3127	-4.9398	-4.8502
177.3	-4.0175	-3.9752	-3.7855	-4.2030	-3.9292
b,1/m	2.1881	2.3882	2.4580	2.8347	2.3648
bB,1/m	0.0190	0.0246	0.0288	0.0157	0.0140
bB/b	0.0160	0.0205	0.0240	0.0119	0.0111
<muF>	0.9571	0.9492	0.9455	0.9626	0.9660
<muB>	0.4718	0.4670	0.4555	0.4773	0.4882
<cos>	0.9342	0.9201	0.9119	0.9455	0.9499
<cos2>	0.9203	0.9057	0.8983	0.9306	0.9366
<thet>	0.2032	0.2313	0.2412	0.1890	0.1768
<thet2>	0.1650	0.2016	0.2232	0.1345	0.1245

$$b_B / b \equiv B = 0.5\int_{\pi/2}^{\pi} p(\theta)\sin\theta\, d\theta . \qquad (2)$$

The shape of the seawater phase function is well described by the following seven integral parameters: probability of backscattering B given by the Eq. (2), average cosine in the forward direction, <muF>:

$$<\cos>_F = \int_0^{\pi/2} p(\theta)\cos\theta\sin\theta\, d\theta \Big/ \int_0^{\pi/2} p(\theta)\sin\theta\, d\theta , \quad (3)$$

average cosine in the backward direction, <muB>:

$$<\cos>_B = -\int_{\pi/2}^{\pi} p(\theta)\cos\theta\sin\theta\, d\theta \Big/ \int_{\pi/2}^{\pi} p(\theta)\sin\theta\, d\theta , \quad (4)$$

total average cosine, <cos>:

$$<\cos\theta> = 0.5\int_0^{\pi} p(\theta)\cos\theta\sin\theta\, d\theta , \qquad (5)$$

total square of average cosine, <cos2>:

$$<\cos^2\theta> = 0.5\int_0^{\pi} p(\theta)\cos^2\theta\sin\theta\, d\theta , \qquad (6)$$

average scattering angle, <thet>:

$$<\theta> = 0.5\int_0^{\pi} p(\theta)\,\theta\sin\theta\, d\theta , \qquad (7)$$

and average square of scattering angle, <thet2>:

$$<\theta^2> = 0.5\int_0^{\pi} p(\theta)\,\theta^2\sin\theta\, d\theta . \qquad (8)$$

The last four parameters are used to compute a modu-

Table 3. Natural logarithms of PhFs $p(\theta)$ No. 11-15

angle	phf11	phf12	phf13	phf14	phf15
0.6	6.5818	6.6330	6.4881	6.4280	6.6860
0.9	5.9394	5.9376	5.8641	5.7326	5.9538
1.2	5.4397	5.3320	5.4565	5.2099	5.5255
1.8	4.8641	4.8393	4.8164	4.6412	5.0212
3.0	4.0881	3.9988	4.0704	3.8583	4.2383
4.2	3.4641	3.5107	3.4187	3.2665	3.7179
5.7	2.8286	2.7923	2.8891	2.6540	3.1124
7.5	2.2276	2.1453	2.3089	2.0001	2.4953
9.9	1.5161	1.4292	1.5882	1.2218	1.8644
12.3	0.9313	0.9779	1.0263	0.6185	1.1621
15.0	0.5444	0.5288	0.5750	0.1005	0.8098
18.0	-0.0266	-0.1113	0.1099	-0.3624	0.3700
21.3	-0.4779	-0.5534	-0.2999	-0.7515	-0.0007
24.9	-0.9039	-0.9494	-0.6891	-1.1544	-0.3714
28.8	-1.3713	-1.4076	-1.1312	-1.5850	-0.8251
33.0	-1.7651	-1.8290	-1.5180	-1.9511	-1.2119
37.5	-2.1772	-2.2665	-1.9164	-2.3541	-1.5826
42.3	-2.5871	-2.6050	-2.3124	-2.7478	-1.9787
47.4	-2.9555	-2.9895	-2.6877	-3.1278	-2.3586
52.8	-3.3446	-3.3533	-3.0492	-3.4939	-2.7224
58.2	-3.6992	-3.7148	-3.3808	-3.8370	-3.0793
64.2	-4.0032	-4.0280	-3.7147	-4.1524	-3.4155
70.5	-4.2933	-4.3204	-3.9795	-4.4149	-3.6503
76.8	-4.5282	-4.5553	-4.2489	-4.6659	-3.8576
83.7	-4.7354	-4.7832	-4.4515	-4.8823	-4.0993
90.0	-4.9288	-4.9674	-4.6587	-5.0780	-4.2951
98.1	-5.0601	-5.1263	-4.8337	-5.2438	-4.5161
105.6	-5.0923	-5.0802	-4.9328	-5.3682	-4.6243
113.7	-5.1752	-5.2138	-5.0341	-5.4488	-4.7049
121.8	-5.1867	-5.2460	-5.0640	-5.5063	-4.7510
130.5	-5.3018	-5.3957	-5.1193	-5.5294	-4.7786
139.2	-5.3893	-5.4279	-5.1377	-5.5478	-4.7740
148.2	-5.3985	-5.4487	-5.1124	-5.5271	-4.7717
157.8	-5.3111	-5.3727	-5.0133	-5.4373	-4.7118
167.4	-4.8782	-4.9720	-4.6081	-5.0320	-4.3457
177.3	-3.8052	-3.8783	-3.5328	-4.1271	-3.2520
b,1/m	2.1734	2.2631	2.2297	2.7781	1.7422
bB,1/m	0.0119	0.0116	0.0154	0.0127	0.0177
bB/b	0.0095	0.0092	0.0117	0.0099	0.0137
<muF>	0.9697	0.9698	0.9626	0.9688	0.9594
<muB>	0.4594	0.4402	0.4791	0.4833	0.4981
<cos>	0.9561	0.9568	0.9458	0.9544	0.9395
<cos2>	0.9427	0.9430	0.9305	0.9417	0.9246
<thet>	0.1652	0.1630	0.1898	0.1659	0.2032
<thet2>	0.1068	0.1042	0.1334	0.1127	0.1516

Table 4. Natural logarithms of PhFs $p(\theta)$ No. 16-20

angle	phf16	phf17	phf18	phf190	phf20
0.6	6.6548	6.4987	6.2549	6.2367	6.3454
0.9	5.9617	5.8309	5.6815	5.6587	5.7306
1.2	5.4897	5.4441	5.4098	5.3571	5.4151
1.8	4.9555	5.0043	5.1220	4.9426	4.9523
3.0	4.2716	4.3089	4.3921	4.3716	4.1810
4.2	3.6660	3.7356	3.7842	3.7361	3.4879
5.7	3.0489	3.0885	3.1648	3.0637	2.7902
7.5	2.5907	2.4853	2.5408	2.4305	2.1892
9.9	1.8240	1.6909	1.7464	1.7973	1.3511
12.3	1.2391	1.0876	1.2352	1.0927	0.7363
15.0	0.8131	0.6685	0.7770	0.6529	0.3287
18.0	0.3020	0.1942	0.3418	0.1694	-0.1663
21.3	-0.1286	-0.1466	-0.0680	-0.2336	-0.5808
24.9	-0.4717	-0.5380	-0.4802	-0.6412	-0.9837
28.8	-0.9069	-1.0147	-0.9407	-1.0994	-1.4189
33.0	-1.3306	-1.4314	-1.2976	-1.4632	-1.8035
37.5	-1.7589	-1.8298	-1.7029	-1.8523	-2.1742
42.3	-2.1112	-2.1913	-2.0344	-2.2875	-2.5403
47.4	-2.5118	-2.5597	-2.5203	-2.6398	-2.9571
52.8	-2.9332	-2.9926	-2.8703	-2.9299	-3.2886
58.2	-3.2624	-3.3011	-3.1604	-3.3029	-3.6409
64.2	-3.5503	-3.6074	-3.4459	-3.6414	-3.9195
70.5	-3.8726	-3.9136	-3.7591	-3.9845	-4.2350
76.8	-4.0637	-4.1347	-4.0630	-4.2401	-4.4768
83.7	-4.3308	-4.3488	-4.2749	-4.4588	-4.7231
90.0	-4.5128	-4.5584	-4.4959	-4.6085	-4.9373
98.1	-4.6762	-4.6850	-4.6295	-4.8411	-5.1353
105.6	-4.7891	-4.8185	-4.7630	-4.9447	-5.2827
113.7	-4.8328	-4.8462	-4.8160	-5.0230	-5.3633
121.8	-4.9272	-4.8554	-4.8989	-5.0414	-5.3702
130.5	-4.9410	-4.9475	-4.9334	-5.0736	-5.4323
139.2	-4.9687	-4.9889	-4.9495	-5.0759	-5.4531
148.2	-4.9641	-4.9982	-4.9081	-5.0713	-5.3863
157.8	-4.8581	-4.8508	-4.7975	-4.9608	-5.2873
167.4	-4.4690	-4.4294	-4.4360	-4.5809	-4.8935
177.3	-3.2509	-3.2827	-3.2341	-3.6529	-4.0070
b,1/m	1.8224	1.9048	1.8562	2.0120	2.2978
bB,1/m	0.0143	0.0147	0.0162	0.0147	0.0108
bB/b	0.0111	0.0113	0.0123	0.0111	0.0085
<muF>	0.9630	0.9642	0.9615	0.9642	0.9690
<muB>	0.4679	0.4591	0.4984	0.4941	0.4463
<cos>	0.9471	0.9481	0.9436	0.9480	0.9570
<cos2>	0.9310	0.9328	0.9284	0.9334	0.9425
<thet>	0.1890	0.1859	0.1979	0.1879	0.1623
<thet2>	0.1291	0.1267	0.1403	0.1286	0.1033

lation transfer function used in underwater visibility calculations. The dependence of backscattering on scattering coefficient is shown in Fig. 1. Below we give a number of regressions that connect all integral parameters with each other and scattering coefficient:

$$B \equiv b_B / b = 0.00458 + 0.00334\, b, \quad r^2 = 0.589, \tag{9}$$

$$< \cos\theta > = 0.986 - 3.29 b_B / b, \quad r^2 = 0.991, \tag{10}$$

$$< \cos^2\theta > = 0.974 - 3.43 b_B / b, \quad r^2 = 0.976, \tag{11}$$

$$< \cos^2\theta > = 0.985 < \cos\theta >, \quad r^2 = 0.996, \tag{12}$$

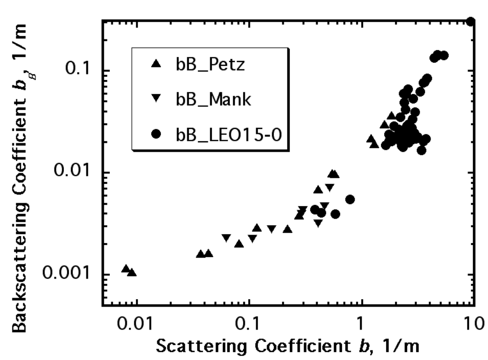

Fig. 1. Dependence of backscattering coefficient on scattering coefficient for three sets of data.

Table 5. Natural logarithms of PhFs $p(\theta)$ No. 21-25

angle	phf21	phf22	phf23	phf24	phf25
0.6	6.4808	6.3733	6.6997	6.6128	6.6323
0.9	5.7923	5.8000	6.0457	5.9220	5.9070
1.2	5.4653	5.3878	5.5254	5.5237	5.5086
1.8	4.8666	4.8675	5.0464	4.8928	4.9813
3.0	4.0055	3.9833	4.2981	4.0362	4.1087
4.2	3.2502	3.3063	3.7063	3.3385	3.3580
5.7	2.5548	2.5257	3.1076	2.7375	2.6949
7.5	1.8457	1.7889	2.6471	2.0514	2.0594
9.9	1.1088	1.0958	1.7606	1.3261	1.2926
12.3	0.4227	0.4235	1.2333	0.7942	0.7446
15.0	-0.0632	-0.0854	0.7912	0.3889	0.3601
18.0	-0.5191	-0.4930	0.3584	-0.1061	-0.1442
21.3	-0.8737	-0.9212	-0.0492	-0.5275	-0.5518
24.9	-1.2836	-1.3196	-0.3831	-0.9074	-0.9455
28.8	-1.7164	-1.7295	-0.8597	-1.3495	-1.4198
33.0	-2.1401	-2.0817	-1.2558	-1.7387	-1.7975
37.5	-2.4809	-2.4939	-1.6541	-2.1554	-2.1797
42.3	-2.8033	-2.8923	-2.0064	-2.5400	-2.6011
47.4	-3.1763	-3.2192	-2.4370	-2.9199	-2.9695
52.8	-3.5608	-3.5485	-2.7985	-3.2883	-3.3103
58.2	-3.8763	-3.9031	-3.1738	-3.6015	-3.6418
64.2	-4.2746	-4.1978	-3.4962	-3.9538	-3.9918
70.5	-4.4980	-4.4880	-3.7472	-4.2577	-4.2290
76.8	-4.7858	-4.8472	-3.9429	-4.4903	-4.5076
83.7	-4.9976	-5.0360	-4.1962	-4.7343	-4.7770
90.0	-5.2095	-5.2455	-4.3896	-4.9162	-4.9958
98.1	-5.3730	-5.4228	-4.5415	-5.0866	-5.1477
105.6	-5.5295	-5.5333	-4.6935	-5.1995	-5.2237
113.7	-5.6193	-5.5863	-4.5830	-5.3399	-5.2905
121.8	-5.6769	-5.6646	-4.7603	-5.3146	-5.3158
130.5	-5.6493	-5.7290	-4.7465	-5.3652	-5.4171
139.2	-5.6976	-5.7221	-4.7948	-5.3975	-5.4425
148.2	-5.6723	-5.6830	-4.7948	-5.3583	-5.4379
157.8	-5.5917	-5.6093	-4.7119	-5.2777	-5.3158
167.4	-5.2187	-5.2939	-4.3136	-4.8241	-4.8898
177.3	-4.5717	-4.6422	-2.9413	-3.7143	-3.7777
b,1/m	2.6099	2.6465	1.7336	2.2687	2.2867
bB,1/m	0.0093	0.0098	0.0151	0.0118	0.0112
bB/b	0.0076	0.0080	0.0117	0.0096	0.0090
<muF>	0.9726	0.9724	0.9615	0.9679	0.9690
<muB>	0.4309	0.4685	0.4409	0.4712	0.4563
<cos>	0.9620	0.9608	0.9451	0.9541	0.9561
<cos2>	0.9491	0.9488	0.9279	0.9402	0.9422
<thet>	0.1455	0.1477	0.1935	0.1671	0.1619
<thet2>	0.0908	0.0955	0.1325	0.1121	0.1061

Table 6. Natural logarithms of PhFs $p(\theta)$ No. 26-30

angle	phf26	phf27	phf28	phf29	phf30
0.6	6.4330	6.3828	6.3512	6.4573	6.4655
0.9	5.7929	5.6805	5.6858	5.7366	5.7885
1.2	5.3738	5.3259	5.2529	5.3083	5.3534
1.8	4.9064	4.7641	4.7325	4.7741	4.7708
3.0	4.0475	3.7947	3.8713	3.8093	3.8198
4.2	3.3407	3.1407	3.1000	3.0356	3.0531
5.7	2.6982	2.4016	2.3355	2.2596	2.2426
7.5	2.0834	1.7177	1.7415	1.5366	1.5679
9.9	1.2914	0.9510	0.8780	0.7376	0.7620
12.3	0.6996	0.3293	0.1803	0.1021	0.1058
15.0	0.2667	-0.0760	-0.2019	-0.3169	-0.3156
18.0	-0.2145	-0.5941	-0.6970	-0.8051	-0.7485
21.3	-0.5853	-1.0062	-1.0769	-1.2034	-1.1468
24.9	-0.9882	-1.4000	-1.4891	-1.6156	-1.5429
28.8	-1.4395	-1.8259	-1.9266	-2.0278	-1.9712
33.0	-1.8402	-2.2450	-2.3364	-2.4077	-2.3442
37.5	-2.2454	-2.6365	-2.7164	-2.8037	-2.7241
42.3	-2.6276	-2.9565	-3.0571	-3.1537	-3.0833
47.4	-3.0191	-3.3733	-3.4440	-3.5014	-3.4540
52.8	-3.3368	-3.7348	-3.8078	-3.8537	-3.8063
58.2	-3.7007	-4.0549	-4.1255	-4.1991	-4.1402
64.2	-4.0437	-4.4048	-4.4801	-4.5537	-4.4603
70.5	-4.3753	-4.7272	-4.7657	-4.8369	-4.7619
76.8	-4.5964	-5.0219	-5.0397	-5.0511	-5.0198
83.7	-4.8566	-5.2430	-5.3137	-5.3297	-5.2731
90.0	-5.0454	-5.4709	-5.5278	-5.5162	-5.4688
98.1	-5.2135	-5.6782	-5.7327	-5.7142	-5.6507
105.6	-5.3332	-5.8071	-5.8225	-5.8339	-5.7773
113.7	-5.4207	-5.8808	-5.9123	-5.9583	-5.9270
121.8	-5.4667	-5.9061	-6.0229	-5.9905	-5.9362
130.5	-5.4852	-5.9476	-5.9768	-6.0158	-5.9546
139.2	-5.5013	-5.9176	-6.0252	-6.0274	-5.9777
148.2	-5.4690	-5.9061	-5.9929	-5.9974	-5.9385
157.8	-5.3792	-5.8071	-5.9077	-5.8915	-5.8787
167.4	-4.9855	-5.4249	-5.5324	-5.5807	-5.5471
177.3	-4.0460	-4.6121	-4.9084	-4.9889	-4.9783
b,1/m	2.4601	3.0087	3.1137	3.0848	3.0168
bB,1/m	0.0115	0.0089	0.0088	0.0086	0.0087
bB/b	0.0091	0.0072	0.0072	0.0073	0.0073
<muF>	0.9690	0.9734	0.9740	0.9755	0.9748
<muB>	0.4792	0.4748	0.4796	0.4703	0.4635
<cos>	0.9559	0.9629	0.9635	0.9650	0.9644
<cos2>	0.9423	0.9507	0.9519	0.9545	0.9533
<thet>	0.1640	0.1442	0.1411	0.1337	0.1356
<thet2>	0.1078	0.0897	0.0889	0.0855	0.0866

$$<\cos\theta>_F = 0.986 - 1.896 b_B/b, \quad r^2 = 0.974. \quad (13)$$

The average cosine over backward hemisphere has no significant dependence on B and can be estimated as:

$$<\cos\theta>_B = 0.476 \pm 0.016. \quad (14)$$

Average scattering angles correlate nicely with b_B/b and with each other as well as average cosine:

$$<\theta> = 0.107 + 6.332 b_B/b, \quad r^2 = 0.976, \quad (15)$$

$$<\theta^2> = 0.029 + 8.640 b_B/b, \quad r^2 = 0.997, \quad (16)$$

$$<\theta^2> = 2.614 - 2.622 <\cos\theta>, \quad r^2 = 0.9998, \quad (17)$$

$$<\cos\theta> = 0.997 - 0.381 <\theta^2>, \quad r^2 = 0.9998. \quad (18)$$

The regressional relationships (9)-(18), proposed above, represent coastal waters with the scattering coefficient varying between 0.38 and 9.3 1/m, with the maximum value of scattering coefficient b more than five times larger than the maximum value of b measured by Petzold [1]. These relationships may be used for modeling of light propagation and visibility in murky coastal waters.

The average of all 60 phase functions given in Tables 1-12 with its standard deviation is shown in Figure 2.

Table 7. Natural logarithms of PhFs $p(\theta)$ No. 31-35

angle	phf31	phf32	phf33	phf34	phf35
0.6	6.3338	6.4777	6.5594	6.8406	5.9818
0.9	5.6661	5.7155	5.7465	6.0416	5.3785
1.2	5.2700	5.2320	5.2837	5.6041	5.0584
1.8	4.7312	4.6379	4.6689	4.9755	4.6163
3.0	3.8632	3.8182	3.8446	3.9232	3.7713
4.2	3.1793	3.2218	3.2528	3.2370	3.0966
5.7	2.4425	2.6485	2.6450	2.5140	2.4266
7.5	1.7885	2.0590	2.0923	1.9015	1.7381
9.9	1.0425	1.3706	1.4384	1.1993	0.8977
12.3	0.4737	0.8364	0.8996	0.6374	0.1908
15.0	0.0754	0.4173	0.5358	0.2391	-0.3204
18.0	-0.4358	-0.0432	0.0292	-0.2122	-0.7901
21.3	-0.8548	-0.4278	-0.3622	-0.6152	-1.2530
24.9	-1.2601	-0.8192	-0.7813	-0.9905	-1.7135
28.8	-1.7183	-1.2636	-1.2257	-1.3773	-2.1625
33.0	-2.1121	-1.6504	-1.6033	-1.7250	-2.5516
37.5	-2.5150	-2.0281	-1.9855	-2.0934	-2.9523
42.3	-2.9041	-2.4172	-2.3655	-2.4342	-3.3460
47.4	-3.2726	-2.7764	-2.7270	-2.7566	-3.7098
52.8	-3.6318	-3.1402	-3.0931	-3.1020	-4.0990
58.2	-3.9679	-3.4603	-3.4362	-3.4312	-4.4397
64.2	-4.2880	-3.7918	-3.7194	-3.7467	-4.7966
70.5	-4.6058	-4.1004	-4.0394	-4.0161	-5.1006
76.8	-4.8683	-4.3583	-4.2881	-4.2395	-5.3838
83.7	-5.1031	-4.6185	-4.5391	-4.4697	-5.6279
90.0	-5.2873	-4.8004	-4.7371	-4.6263	-5.8328
98.1	-5.4876	-5.0076	-4.9213	-4.8220	-6.0377
105.6	-5.6005	-5.1435	-5.0848	-4.9371	-6.1851
113.7	-5.6880	-5.2194	-5.1424	-5.0200	-6.2680
121.8	-5.7294	-5.2747	-5.2253	-5.0799	-6.3348
130.5	-5.7478	-5.3046	-5.2529	-5.0914	-6.3463
139.2	-5.7594	-5.3069	-5.2253	-5.1006	-6.3486
148.2	-5.7271	-5.2747	-5.2138	-5.0408	-6.2956
157.8	-5.6419	-5.1826	-5.1240	-4.9993	-6.1828
167.4	-5.2436	-4.8695	-4.8384	-4.7161	-5.7062
177.3	-4.5090	-4.3353	-4.2444	-4.2441	-5.4644
b,1/m	2.9318	2.6125	2.4951	2.1016	3.5378
bB,1/m	0.0105	0.0150	0.0150	0.0144	0.0071
bB/b	0.0084	0.0115	0.0115	0.0126	0.0057
<muF>	0.9711	0.9611	0.9607	0.9649	0.9770
<muB>	0.4761	0.4795	0.4675	0.4684	0.4728
<cos>	0.9589	0.9445	0.9443	0.9468	0.9687
<cos2>	0.9461	0.9281	0.9274	0.9346	0.9572
<thet>	0.1552	0.1921	0.1930	0.1723	0.1354
<thet2>	0.1002	0.1361	0.1359	0.1325	0.0751

Table 8. Natural logarithms of PhFs $p(\theta)$ No. 36-40

angle	phf36	phf37	phf38	phf39	phf40
0.6	6.1323	5.9719	6.4741	6.7934	6.0449
0.9	5.4852	5.3618	5.7856	5.9829	5.3703
1.2	5.0662	5.0026	5.3597	5.4602	4.9305
1.8	4.6195	4.5743	4.7702	4.8800	4.3479
3.0	3.8044	3.7707	3.9413	4.0902	3.4637
4.2	3.1343	3.0338	3.2620	3.4040	2.8236
5.7	2.4619	2.3385	2.5252	2.7363	2.2134
7.5	1.7965	1.6408	1.8920	2.1307	1.5963
9.9	0.9123	0.8464	1.1874	1.4445	0.9562
12.3	0.1778	0.1671	0.5864	0.8827	0.4819
15.0	-0.2896	-0.3187	0.2249	0.4544	0.1089
18.0	-0.7525	-0.8299	-0.3300	0.0399	-0.2872
21.3	-1.2406	-1.2973	-0.7514	-0.3446	-0.6073
24.9	-1.7103	-1.7371	-1.1451	-0.6969	-0.9388
28.8	-2.1478	-2.1884	-1.5734	-1.0860	-1.3211
33.0	-2.5784	-2.6006	-1.9372	-1.4452	-1.6572
37.5	-3.0090	-3.0127	-2.3102	-1.7975	-1.9980
42.3	-3.4096	-3.4157	-2.6671	-2.1360	-2.3020
47.4	-3.8149	-3.8071	-3.0402	-2.4653	-2.6174
52.8	-4.2063	-4.1825	-3.3763	-2.8130	-2.9260
58.2	-4.5748	-4.5347	-3.7171	-3.1238	-3.2230
64.2	-4.9501	-4.8824	-4.0418	-3.4162	-3.5292
70.5	-5.2494	-5.1703	-4.3135	-3.7156	-3.7963
76.8	-5.5188	-5.4351	-4.5530	-3.9435	-4.0519
83.7	-5.7721	-5.6676	-4.7786	-4.1715	-4.2937
90.0	-5.9747	-5.8749	-4.9651	-4.3580	-4.4802
98.1	-6.1727	-6.0729	-5.1447	-4.5468	-4.6483
105.6	-6.3132	-6.2064	-5.2529	-4.6688	-4.7749
113.7	-6.4283	-6.3216	-5.3658	-4.7609	-4.8532
121.8	-6.4813	-6.3722	-5.4210	-4.7955	-4.9085
130.5	-6.4744	-6.3814	-5.4602	-4.8346	-4.9108
139.2	-6.4652	-6.3929	-5.4533	-4.8208	-4.8993
148.2	-6.4352	-6.3354	-5.4072	-4.8116	-4.8785
157.8	-6.2994	-6.2248	-5.3335	-4.7356	-4.8187
167.4	-5.7560	-5.7459	-4.9997	-4.4662	-4.6667
177.3	-5.3853	-5.2923	-4.5345	-4.0011	-4.1026
b,1/m	3.3968	3.7196	2.4638	1.9339	3.7723
bB,1/m	0.0060	0.0072	0.0127	0.0175	0.0311
bB/b	0.0049	0.0058	0.0109	0.0148	0.0220
<muF>	0.9789	0.9771	0.9678	0.9583	0.9432
<muB>	0.4788	0.4734	0.4968	0.4741	0.4792
<cos>	0.9718	0.9687	0.9517	0.9371	0.9119
<cos2>	0.9606	0.9573	0.9400	0.9228	0.8956
<thet>	0.1290	0.1352	0.1679	0.1980	0.2505
<thet2>	0.0672	0.0753	0.1209	0.1571	0.2227

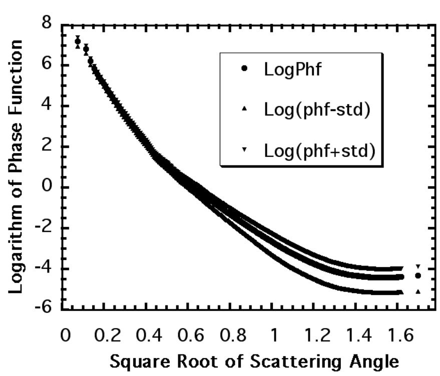

Fig. 2. Average phase function of scattering plus-minus standard deviation at LEO-15 (2000).

4. CONCLUSIONS

Presented here sixty new experimental light scattering phase functions represent an addition to the Petzold [1, 6] and Mankovsky [2. 3, 6] phase functions for the case of turbid coastal ocean waters of Atlantic. They expand the range of variability of measured phase functions from 1.8 1/m (Petzold plus Mankovsky) to 9.3 1/m (LEO-15 in 2000).

These phase functions with the associated optical properties may be used for modeling of light propagation and image transfer in turbid coastal waters as well as for developing algorithms of processing remote optical information.

Table 9. Natural logarithms of PhFs $p(\theta)$ No. 41-45

angle	phf41	phf42	phf43	phf44	phf45
0.6	5.7006	6.1473	6.3077	6.1279	5.9608
0.9	5.0398	5.4588	5.5617	5.4625	5.3414
1.2	4.6299	4.9868	5.1564	5.0572	4.7243
1.8	4.0727	4.4687	4.4956	4.4102	4.1417
3.0	3.2415	3.4878	3.5815	3.3579	3.0987
4.2	2.6382	2.8039	2.8815	2.6510	2.4240
5.7	2.0211	2.1454	2.3058	2.0823	1.7539
7.5	1.4293	1.5582	1.7164	1.4790	1.1898
9.9	0.8007	0.9526	1.1108	0.8573	0.5981
12.3	0.3448	0.4645	0.6180	0.3968	0.1652
15.0	-0.0098	0.2020	0.3417	0.0008	-0.2032
18.0	-0.4081	-0.2769	-0.1418	-0.3907	-0.5786
21.3	-0.7075	-0.6154	-0.4803	-0.6946	-0.8595
24.9	-1.0367	-0.9562	-0.8303	-1.0285	-1.1726
28.8	-1.3936	-1.3730	-1.2424	-1.3900	-1.5295
33.0	-1.7275	-1.7161	-1.5855	-1.7331	-1.8266
37.5	-2.0407	-2.0499	-1.9263	-2.0785	-2.1167
42.3	-2.3561	-2.3700	-2.2671	-2.3962	-2.3884
47.4	-2.6554	-2.6993	-2.5987	-2.6817	-2.6739
52.8	-2.9433	-3.0170	-2.9095	-3.0018	-2.9410
58.2	-3.2219	-3.3025	-3.2066	-3.2643	-3.1621
64.2	-3.5120	-3.6249	-3.5335	-3.5890	-3.4384
70.5	-3.7975	-3.8966	-3.8190	-3.8837	-3.6917
76.8	-4.0531	-4.1614	-4.0654	-4.1531	-3.9426
83.7	-4.2880	-4.4147	-4.3233	-4.4409	-4.1591
90.0	-4.4699	-4.6035	-4.5006	-4.5906	-4.3364
98.1	-4.6495	-4.7739	-4.6825	-4.7748	-4.5206
105.6	-4.7807	-4.9120	-4.7976	-4.9083	-4.6611
113.7	-4.8636	-4.9834	-4.8759	-4.9981	-4.7532
121.8	-4.9120	-5.0318	-4.9427	-5.0442	-4.8038
130.5	-4.9281	-5.0456	-4.9611	-5.0718	-4.8245
139.2	-4.9166	-5.0249	-4.9496	-5.0580	-4.8337
148.2	-4.8959	-4.9949	-4.9105	-5.0281	-4.7969
157.8	-4.8659	-4.9420	-4.8483	-5.0005	-4.7716
167.4	-4.7715	-4.7324	-4.6365	-4.8324	-4.6864
177.3	-4.2811	-4.1269	-4.0332	-4.2107	-4.2097
b,1/m	5.3669	3.2965	2.8587	3.6220	4.6682
bB,1/m	0.0441	0.0237	0.0230	0.0274	0.0427
bB/b	0.0265	0.0190	0.0186	0.0213	0.0307
<muF>	0.9340	0.9477	0.9487	0.9449	0.9311
<muB>	0.4803	0.4759	0.4818	0.5073	0.4730
<cos>	0.8966	0.9207	0.9220	0.9140	0.8879
<cos2>	0.8794	0.9040	0.9056	0.8994	0.8740
<thet>	0.2820	0.2334	0.2315	0.2435	0.2864
<thet2>	0.2630	0.1987	0.1960	0.2204	0.2881

In addition to the tables of 60 phase functions the practically useful relationships (9)-(18) between these properties based on these new phase functions are proposed.

5. ACKNOWLEDGMENT

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Table 10. Natural logarithms of PhFs $p(\theta)$ No. 46-50

angle	phf46	phf47	phf48	phf49	phf50
0.6	5.9666	6.0180	5.2191	6.2927	6.3269
0.9	5.3196	5.3042	4.6204	5.6250	5.6545
1.2	4.7416	4.8022	4.2820	5.2266	5.2240
1.8	4.1176	4.2036	3.7316	4.7477	4.7312
3.0	3.1367	3.1720	2.9419	4.1398	4.1256
4.2	2.3055	2.4858	2.3317	3.5250	3.6190
5.7	1.7598	1.8595	1.7652	2.9379	2.9582
7.5	1.2394	1.2770	1.2103	2.3231	2.3572
9.9	0.5970	0.6852	0.6278	1.5655	1.5790
12.3	0.1364	0.2270	0.1949	0.9047	0.9342
15.0	-0.2343	-0.1184	-0.1137	0.5570	0.5382
18.0	-0.6004	-0.4983	-0.4683	-0.0417	-0.0144
21.3	-0.8767	-0.7908	-0.7492	-0.5391	-0.4911
24.9	-1.2152	-1.1062	-1.0831	-0.9719	-0.9332
28.8	-1.5283	-1.4562	-1.4261	-1.4302	-1.3845
33.0	-1.8599	-1.7717	-1.7485	-1.8285	-1.7782
37.5	-2.1523	-2.0572	-2.0571	-2.2268	-2.1673
42.3	-2.4079	-2.3450	-2.3518	-2.6091	-2.5496
47.4	-2.6911	-2.6121	-2.6511	-2.9913	-2.9341
52.8	-2.9721	-2.8861	-2.9389	-3.3920	-3.3025
58.2	-3.2115	-3.1256	-3.1968	-3.7258	-3.6341
64.2	-3.4671	-3.4065	-3.5031	-4.0965	-3.9864
70.5	-3.7319	-3.6529	-3.7610	-4.3844	-4.2811
76.8	-3.9714	-3.8831	-4.0235	-4.6837	-4.5275
83.7	-4.1970	-4.1249	-4.2606	-4.9163	-4.7992
90.0	-4.3674	-4.2999	-4.4563	-5.1534	-5.0110
98.1	-4.5493	-4.4818	-4.6290	-5.3192	-5.2137
105.6	-4.6944	-4.6176	-4.7603	-5.4712	-5.3403
113.7	-4.7865	-4.6936	-4.8478	-5.5541	-5.4117
121.8	-4.8164	-4.7489	-4.9077	-5.5955	-5.4808
130.5	-4.8579	-4.7811	-4.9261	-5.5978	-5.4900
139.2	-4.8648	-4.7834	-4.9284	-5.6024	-5.4623
148.2	-4.8348	-4.7604	-4.9030	-5.5587	-5.4232
157.8	-4.8233	-4.7328	-4.8892	-5.4251	-5.3104
167.4	-4.7312	-4.6338	-4.9560	-4.8909	-4.7416
177.3	-4.1464	-4.1318	-4.8593	-3.9492	-3.7331
b,1/m	4.6497	4.3863	9.2629	2.3216	2.2576
bB,1/m	0.0410	0.0417	0.0767	0.0099	0.0104
bB/b	0.0301	0.0303	0.0328	0.0077	0.0082
<muF>	0.9320	0.9311	0.9188	0.9699	0.9686
<muB>	0.4682	0.4694	0.4764	0.4926	0.4681
<cos>	0.8898	0.8886	0.8731	0.9586	0.9568
<cos2>	0.8755	0.8740	0.8529	0.9442	0.9418
<thet>	0.2829	0.2865	0.3320	0.1663	0.1697
<thet2>	0.2823	0.2852	0.3230	0.1003	0.1038

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Table 11. Natural logarithms of PhFs $p(\theta)$ No. 51-55

angle	phf51	phf52	phf53	phf54	phf55
0.6	6.5352	6.2628	6.3216	6.0977	6.1801
0.9	5.8721	5.5812	5.6424	5.4139	5.5422
1.2	5.4553	5.1138	5.2279	4.9925	5.0978
1.8	4.9833	4.6487	4.7443	4.5182	4.6696
3.0	4.4030	3.8981	4.0490	3.7998	3.9074
4.2	3.9011	3.3477	3.5700	3.2517	3.4031
5.7	3.3508	2.7445	2.9161	2.5955	2.8344
7.5	2.7705	2.1826	2.3566	1.9991	2.1643
9.9	1.9922	1.5126	1.5990	1.3268	1.4828
12.3	1.3890	0.8563	0.9128	0.7350	0.8081
15.0	0.9998	0.4511	0.5053	0.3597	0.4029
18.0	0.5025	-0.0969	-0.0519	-0.1722	-0.1567
21.3	0.0673	-0.5183	-0.4848	-0.5751	-0.5895
24.9	-0.3242	-0.9466	-0.9499	-0.9758	-1.0063
28.8	-0.7501	-1.3933	-1.4059	-1.4133	-1.4047
33.0	-1.1692	-1.7525	-1.8019	-1.7771	-1.8514
37.5	-1.5676	-2.1416	-2.1611	-2.1202	-2.2198
42.3	-1.9521	-2.4847	-2.5387	-2.4679	-2.5836
47.4	-2.3274	-2.8324	-2.9210	-2.8017	-2.9474
52.8	-2.7073	-3.1916	-3.2917	-3.1471	-3.3066
58.2	-3.0504	-3.5117	-3.6163	-3.4488	-3.5990
64.2	-3.3590	-3.8248	-3.9226	-3.7619	-3.9490
70.5	-3.6445	-4.1311	-4.2058	-4.0544	-4.2230
76.8	-3.8863	-4.3820	-4.5282	-4.3099	-4.5062
83.7	-4.1073	-4.6307	-4.7630	-4.5586	-4.7572
90.0	-4.3030	-4.8587	-4.9979	-4.7728	-4.9575
98.1	-4.5172	-5.0544	-5.1591	-4.9478	-5.1671
105.6	-4.6668	-5.1787	-5.3249	-5.0928	-5.3283
113.7	-4.7635	-5.2893	-5.3341	-5.1642	-5.4066
121.8	-4.8142	-5.3169	-5.4607	-5.2264	-5.4457
130.5	-4.8441	-5.3422	-5.4515	-5.2471	-5.4733
139.2	-4.7981	-5.3284	-5.4423	-5.2563	-5.4802
148.2	-4.7843	-5.3123	-5.4054	-5.2287	-5.4135
157.8	-4.6576	-5.1972	-5.2903	-5.1412	-5.3144
167.4	-4.3145	-4.7389	-4.7561	-4.7705	-4.8309
177.3	-3.6353	-3.7696	-3.7568	-3.9300	-3.8661
b,1/m	1.6314	2.5851	2.2565	2.9872	2.6492
bB,1/m	0.0152	0.0143	0.0112	0.0176	0.0130
bB/b	0.0115	0.0111	0.0090	0.0132	0.0101
<muF>	0.9608	0.9630	0.9680	0.9581	0.9654
<muB>	0.4809	0.4805	0.4925	0.4663	0.4861
<cos>	0.9442	0.9470	0.9549	0.9392	0.9507
<cos2>	0.9274	0.9316	0.9407	0.9227	0.9360
<thet>	0.1999	0.1881	0.1726	0.2034	0.1808
<thet2>	0.1367	0.1303	0.1103	0.1494	0.1208

Table 12. Natural logarithms of PhFs $p(\theta)$ No. 56-60

angle	phf56	phf57	phf58	phf59	phf60
0.6	6.1245	7.6418	8.3703	8.4558	7.8869
0.9	5.4475	6.8474	7.5413	7.5416	7.0856
1.2	5.0492	6.3800	7.0808	7.0051	6.6458
1.8	4.6808	5.7537	6.3946	6.3627	6.0840
3.0	4.0015	4.9294	5.5657	5.4325	5.2873
4.2	3.4673	4.3998	4.9970	4.7670	4.6610
5.7	2.8594	3.8034	4.3891	4.1315	4.0646
7.5	2.1963	3.0988	3.6914	3.4246	3.3554
9.9	1.4249	2.2423	2.9200	2.6509	2.5357
12.3	0.7779	1.6183	2.3467	2.0477	1.8771
15.0	0.2437	1.1531	1.8562	1.5457	1.4811
18.0	-0.2675	0.6535	1.3635	1.0806	0.9791
21.3	-0.7326	0.2022	0.9974	0.7122	0.5670
24.9	-1.1309	-0.2169	0.6658	0.3484	0.1318
28.8	-1.5915	-0.6659	0.2467	-0.0684	-0.3310
33.0	-1.9783	-1.0573	-0.1816	-0.4645	-0.7685
37.5	-2.3651	-1.4672	-0.5661	-0.8329	-1.1623
42.3	-2.7451	-1.8932	-0.9598	-1.2519	-1.5929
47.4	-3.1526	-2.2869	-1.3605	-1.6664	-2.0234
52.8	-3.5256	-2.7267	-1.6990	-1.9703	-2.4080
58.2	-3.8687	-3.0537	-1.9845	-2.2927	-2.7626
64.2	-4.1842	-3.3047	-2.3253	-2.6128	-3.1425
70.5	-4.5273	-3.6984	-2.6177	-2.9259	-3.4464
76.8	-4.7713	-3.9701	-2.8479	-3.1769	-3.7573
83.7	-5.0476	-4.1796	-3.0874	-3.4394	-4.0060
90.0	-5.2618	-4.3731	-3.2693	-3.5775	-4.1487
98.1	-5.4368	-4.5250	-3.3914	-3.7226	-4.3767
105.6	-5.5934	-4.6309	-3.4996	-3.7986	-4.4550
113.7	-5.6670	-4.6425	-3.5157	-3.8815	-4.5425
121.8	-5.7269	-4.7369	-3.5848	-3.8861	-4.5839
130.5	-5.7476	-4.7230	-3.5502	-3.8654	-4.5517
139.2	-5.7476	-4.7622	-3.5640	-3.8470	-4.5079
148.2	-5.6716	-4.7207	-3.5088	-3.7986	-4.4366
157.8	-5.5381	-4.6263	-3.4167	-3.6835	-4.2892
167.4	-4.9648	-4.0875	-2.9285	-3.2874	-3.6330
177.3	-3.9102	-2.9593	-1.4203	-1.9266	-2.2445
b,1/m	2.7387	0.7823	0.3796	0.4341	0.5807
bB,1/m	0.0100	0.0075	0.0118	0.0096	0.0072
bB/b	0.0076	0.0070	0.0115	0.0093	0.0068
<muF>	0.9703	0.9750	0.9687	0.9731	0.9751
<muB>	0.4742	0.4791	0.5002	0.4898	0.5235
<cos>	0.9594	0.9648	0.9518	0.9594	0.9650
<cos2>	0.9450	0.9530	0.9409	0.9493	0.9535
<thet>	0.1638	0.1434	0.1668	0.1455	0.1440
<thet2>	0.0978	0.0854	0.1212	0.1010	0.0860

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