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ARCTIC TIDAL PROBLEMS

WITH SPECIAL REGARD  
TO NORTHEAST-GREENLAND

BY

ASGER LUNDBAK

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WITH 6 FIGURES AND 10 TABLES  
IN THE TEXT

С РУССКИМ РЕЗЮМЕ

KØBENHAVN

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### Abstract.

The following treatment deals with the astronomical tide in the Arctic Ocean taking into account the static and dynamic conditions. The observational material comprises various published material and also some new material, especially from Northeast-Greenland. Although a main conclusion is, that the tide in the Arctic Ocean is narrowly connected with and influenced by the rather well developed tide in the Greenland Sea east of Greenland, it appears, that an internally developed tide in the Arctic Ocean must also be reckoned with. Accepting this it may be puzzling, that the partial tides with almost diurnal periods—the so-called diurnal tides—are less developed in nearly all parts of the Arctic Ocean than the semi-diurnal tides, as an opposite conclusion might be drawn, when the theoretical equilibrium tide in the Arctic Ocean is considered. An explanation may be, that a grand-scale oscillation takes place in the main and deeper part of the Arctic Ocean. Amphidromic systems are not prevalent here because of the great depths and the corresponding relatively weak tidal streams.

As to the amplitudes of the partial tidal waves in and near the Arctic Ocean it can be mentioned, that the  $M_2$ -amplitude is about 100 cm at the northern Norwegian coast and in the sound along NW-Greenland.  $M_2$ -amplitudes up to 50 cm occur at the westcoast of the Norwegian group of islands Svalbard and at the coast of E-Greenland. In most inner parts of the arctic sea area the  $M_2$ -amplitude is of the order of magnitude 10 cm or still less. The  $S_2$ - amplitude is in most cases between one third and one half of the  $M_2$ -amplitude. Regarding the amplitudes of the diurnal tidal waves the  $K_1$ -amplitude amounts to 30—40 cm in the above-mentioned sound along NW-Greenland, but to less than 10 cm in most other arctic areas. The  $O_1$ -amplitude is still less than the  $K_1$ -amplitude in most cases; in several cases it is only about one half or one third of the  $K_1$ -amplitude.

## I. EARLIER MATERIAL AND TREATMENTS

The astronomical tide in the Arctic Ocean has been dealt with and discussed by various authors. Among the outstanding contributions can be mentioned one by ROLLIN A. HARRIS (1911) and one by J. E. FJELDSTAD (1936). It may be of special interest to emphasize that on the basis of tidal results from the coasts along the Arctic Ocean HARRIS concluded that a rather extended island or a shallow bank might exist in the area between the Canadian Archipelago, Alaska and the North-pole. It may also be emphasized that on the basis of tidal material, which was at his disposal, i. a. from the Maud-expedition 1918-25, FJELDSTAD predicted that a rather shallow ridge might extend from the Siberian continental shelf and possibly divide the Arctic Ocean into two deep basins. It is now known that the predictions made by Harris and especially those made by FJELDSTAD have some reality in the so-called Lomonosov Ridge connecting the area around "Novosibirskiye Ostrova" with the shelf north of Greenland and Ellesmere Land. Nevertheless, the present author is of the opinion that the tides in the Arctic Ocean are rather little influenced by the ridge mentioned. The designation "Arctic Ocean" is here and in the following used for the whole deep-sea area north of Europe, Asia and America.

From certain points of view the tides in the Arctic Ocean must attract special interest. Firstly, the Arctic Ocean is unique in the respect that it covers a polar area and is real circumpolar, contrary to the other deep oceans of the Earth. Another circumstance, which is particular for the Arctic Ocean, is the ice-covering of the sea; the stress of the wind on the sea is counteracted hereby, as waves cannot be set up to any noticeable height because of the ice. Moreover, the tides themselves may effect the ice conditions in various ways. For instance, cracks in the ice can be produced by the tides, and exchange of cold and warm water masses is advanced by varying tidal streams. Finally, the so-called equilibrium tide may—as it appears from the following chapter—play a role in arctic seas.

Table I presents the available tidal material including 65 series of harmonic analysis originating from 65 localities along or near the coasts of the Arctic Ocean. The sequence is so, that values from the

Table I

Area	Nr.	Name	lat. (N)		long.		M <sub>2</sub>			S <sub>2</sub>		
			°	'	°	'	H	em	κ	g <sub>G</sub> <sup>o</sup>	H	em
Norway	1.	Rörvik.....	64	52	11	15E	77.6	336	314	26.5	10	348
	2.	Bodø.....	67	17	14	23	86.7	358	329	28.8	36	7
	3.	Kabelvåg.....	68	13	14	30	90.8	4	335	32.9	44	15
	4.	Andenes.....	69	20	16	08	64.2	10	338	22.1	50	18
	5.	Hammerfest.....	70	40	23	41	88.3	67	20	27.7	106	59
	6.	Vardø.....	70	20	31	06	100.7	164	102	28.6	205	143
Kola peninsula	7.	Ekaterininskaya.....	69	12	33	28	116.0	192	125	33.9	236	169
Novaya Zemlya	8.	Kamenka bay.....	70	36	57	25	21.4	94	339	9.5	173	58
	9.	Matotchkin Shar.....	73	15	56	23	15.0	54	301	7.5	116	3
	10.	Russkaya Gavan.....	76	16	63	03	15.2	289	163	6.9	336	210
	11.	Mys Zhelaniya.....	76	56	68	58	15.0	311	173	7.2	359	221
Arctic Siberia	12.	Mys Zverboi.....	73	48	85	34	14.0	63	252	7.8	120	309
	13.	Rade de Zarya.....	76	08	95	08	17.7	26	196	8.2	99	269
	14.	Domaschnii isl.....	79	30	91	08	10.4	31	209	3.9	89	267
	15.	Hansen isl.....	77	34	102	24	6.6	34	189	2.5	63	218
	16.	Mys Tcheliuskine.....	77	43	104	19	12.8	333	124	5.2	24	175
	17.	Maud Harbour.....	77	32	105	35	12.6	324	113	5.0	3	152
	18.	Samuel isl.....	77	26	106	40	15.4	318	105	6.5	359	146
	19.	Dashka isl.....	72	02	128	40	3.0	55	156	2.1	102	203
	20.	Lena entrance.....	72	01	129	06	3.7	311	53	3.7	24	126
	21.	Bykov.....	71	59	129	09	7.1	316	58	4.2	14	116
	22.	Tixi bay.....	71	35	128	55	13.8	35	137	5.0	103	205
	23.	Tixi bay.....	71	44	129	26	11.8	15	116	8.9	65	166
	24.	Kotelni isl.....	75	22	137	10	7.3	25	111	4.6	91	177
	25.	Four Pillar isl.....	70	44	162	30	1.0	60	95	0.5	110	145
	26.	Ajon isl.....	69	53	167	52	1.7	347	11	0.9	35	59
	27.	Pitlekaj.....	67	03	173	30W	2.5	184	171	0.9	240	227
	28.	Mys Serdze Kamen.....	66	53	171	38	3.9	221	204	1.5	307	290
29.	Uellen.....	66	10	169	50	6.0	238	218	1.8	342	322	
Alaska	30.	Port Clarence.....	65	13	166	24	14.4	213	186	0.9	346	319
	31.	Barrow.....	71	18	156	40	5.0	336	289	2.0	16	329
	32.	Flaxman isl.....	70	11	145	50	6.6	354	286	2.9	37	329
Ellesmere Land	33.	Cape Columbia.....	83	07	69	40	11.5	230	9	5.0	284	63
	34.	Cape Sheridan.....	82	27	61	30	24.5	303	66	11.5	351	114
	35.	Fort Conger.....	81	44	64	44	59.8	335	104	27.1	19	148
Greenland	36.	Thule (air base).....	76	32	68	54	79.9	317	95	31.4	354	132
	37.	Port Foulke.....	78	18	73	00	110.9	322	108	46.4	5	151
	38.	Rensselaer Bugt.....	78	37	70	53	102.8	333	115	45.5	12	154
	39.	Thank God Harbour.....	81	36	61	40	54.7	352	115	25.2	33	156
	40.	Kap Bryant.....	82	21	54	30	12.8	4	113	7.1	47	156
	41.	Kap Morris Jesup.....	83	40	33	35	4.2	307	14	2.4	14	81
	42.	Jörgen Brönlund Fjord...	82	11	30	30	10.6	295	356	4.0	346	47
	43.	Kap Holbæk.....	80	40	23	30	11.0	305	352	5.0	343	30
	44.	Danmarkshavn.....	76	46	18	46	50.8	306	344	18.8	351	29
	45.	Godthaabs Golf.....	73	59	21	08	44.9	315	357	19.5	0	42
46.	Danmark Ø.....	70	27	26	12	33.5	338	30	15.2	29	81	
Jan Mayen	47.	Kvalrossbukta.....	70	58	8	41	41.1	327	344	14.9	10	27
	48.	Mary Mussbukta.....	71	00	8	28	40.2	328	345	13.1	18	35
Svalbard	49.	Austervåg.....	74	29	19	12E	34.2	50	12	13.0	83	45
	50.	Husdalen.....	76	30	25	04	25.3	265	215	11.7	336	286
	51.	Kvalvågen.....	77	30	18	12	26.0	355	319	20.4	25	349
	52.	Sveagruba.....	77	53	16	43	48.4	46	13	21.6	101	68
	53.	Kapp Linné.....	78	03	13	38	50.2	26	359	15.5	70	43
	54.	Grönfjorden.....	78	04	14	15	50.7	21	352	18.3	63	34
	55.	Adventfjorden.....	78	15	15	42	48.1	34	3	18.1	72	41
	56.	Ny-Ålesund.....	78	56	11	57	42.5	32	8	16.8	78	54
	57.	London.....	78	58	12	03	44.4	26	2	15.0	68	44
	58.	Virgohamn.....	79	43	10	44	41.4	38	17	14.3	70	49
	59.	Mosselbukta.....	79	53	16	04	35.0	87	55	13.1	121	89
	60.	Sorgfjorden.....	80	00	16	52	28.0	99	65	10.7	150	116
	61.	Sveanor.....	79	56	18	18	25.1	92	55	11.1	138	101
	62.	Brennevinsfjorden.....	80	53	19	29	28.0	83	44	10.0	135	96
Franz Josef Land	63.	Mys Flora.....	79	57	49	59	13.3	279	179	4.4	333	233
	64.	Tikhoi bay.....	80	20	52	48	9.3	252	146	2.9	306	200
	65.	Teplitz bay.....	81	47	57	59	15.5	178	62	6.3	229	113

Harmonic constants.

N <sub>2</sub>			K <sub>2</sub>			K <sub>1</sub>			O <sub>1</sub>			P <sub>1</sub>			ref.	period	nr.
H em	$\kappa$	$g_{Gr}^{\circ}$	H em	$\kappa$	$g_{Gr}^{\circ}$	H em	$\kappa$	$g_{Gr}^{\circ}$	H em	$\kappa$	$g_{Gr}^{\circ}$	H em	$\kappa$	$g_{Gr}^{\circ}$			
15.8 312 290			7.7 7 345			7.4 182 171			5.4 53 42			2.3 170 159			G	2 years 1 year	1
18.1 334 305			8.4 27 358			10.9 207 193			3.7 48 34			2.9 202 188			G		2
18.6 340 311			8.9 37 8			10.5 212 198			3.9 54 40			2.8 202 188			A		3
14.1 344 312			6.2 46 14			5.9 191 175			4.3 60 44			0.7 261 245			E		4
18.7 39 352			9.1 99 52			8.1 237 213			3.3 70 46			2.4 224 200			G		5
20.9 133 71			8.8 204 142			11.9 283 252			2.6 100 69			3.5 282 251			G		6
25.4 162 95			9.9 236 169			13.2 295 262			2.5 104 71			3.1 288 255			J	370 days	7
4.3 94 339			2.6 173 58			2.8 351 294			6.6 27 330			0.9 351 294			Q	15 days	8
3.0 54 301			2.0 116 3			3.3 243 187			5.0 27 331			1.1 243 187			P	15 days	9
2.8 259 133			1.8 336 21			3.3 148 85			3.2 266 203			1.1 148 85			P	15 days	10
3.2 311 173			1.9 359 221			1.7 217 148			2.3 302 233			0.6 217 148			Q	45 days	11
2.8 63 252			2.1 120 352			2.7 134 48			1.7 70 344			0.9 134 48			P	28 days	12
3.7 6 176			2.4 99 269			3.7 3 268			2.4 8 273			1.2 3 268			N	120 days	13
1.7 343 61			1.1 89 267			5.6 47 316			1.6 37 306			1.9 47 316			Q	30 days	14
1.3 34 189			0.7 63 218			3.0 22 280			3.0 4 262			1.0 22 280			Q	15 days	15
2.6 333 124			1.4 24 175			5.1 38 294			2.6 16 272			1.7 38 294			Q	30 days	16
2.7 312 101						4.8 24 278			2.0 4 258						C	93 days	17
3.1 318 105			1.8 359 146			7.6 12 265			0.8 32 285			2.5 12 265			Q	15 days	18
0.7 9 110						2.4 147 18			2.1 130 1						M		19
2.4 331 73			0.9 24 126			0.6 326 197			2.4 160 31			0.3 326 197			L	30 days	20
1.5 280 22						4.1 64 295			4.6 77 308						M		21
2.8 35 137			1.4 103 205			3.2 105 336			1.0 84 315			1.1 105 336			Q	15 days	22
						6.4 101 332			4.8 45 276						M		23
1.5 3 89						0.6 293 156			0.3 350 213						K	120 days	24
0.2 33 68						0.5 12 210			0.4 76 274						C	172 days	25
0.3 9 33						0.4 355 187			0.4 12 204						C	210 days	26
0.5 154 141						1.2 53 226			1.3 63 236						C	163 days	27
1.2 186 169						1.5 77 249			1.3 64 236						C	90 days	28
1.2 238 218			0.5 342 322			0.8 61 231			1.1 92 262			0.3 61 231			Q	30 days	29
4.4 133 106			0.2 346 319			7.6 115 281			3.7 287 93			2.5 115 281			S	29 days	30
0.9 312 265			0.5 16 329			1.6 347 144			1.6 20 177			0.5 347 144			S	105 days	31
0.9 331 263			0.3 62 354			2.3 7 153			2.7 45 191			0.8 7 153			S	58 days	32
1.9 194 333			1.3 284 63			5.2 311 21			3.3 281 351			1.7 311 21			S	29 days	33
4.3 276 39			3.2 348 111			4.8 298 360			2.7 279 340			1.6 296 358			S	220 days	34
11.5 309 78			9.1 17 146			8.5 222 287			2.8 199 264			2.3 233 298			S	369 days	35
16.4 296 74			8.5 354 132			39.6 187 256			12.3 141 210			13.1 187 256			V	29 days	36
20.4 293 79			12.6 5 151			31.9 187 260			12.4 145 218			10.5 187 260			S	58 days	37
21.4 303 85			12.4 12 154			25.9 193 264			12.8 150 221			8.6 193 264			S	116 days	38
10.8 326 89			6.9 33 156			12.3 246 308			4.6 209 271			4.1 246 308			S	174 days	39
2.4 350 99			1.9 47 156			9.8 286 340			4.1 262 316			3.3 286 340			S	29 days	40
						7.6 340 14			5.7 312 346						C	10 days	41
2.0 269 330			1.1 346 47			6.4 351 21			2.6 326 356			2.1 351 21			W	15 days	42
2.0 295 342			2.0 10 57			7.0 6 29			4.0 337 0			2.0 357 20			W	8 days	43
10.5 272 310			5.1 352 30			8.4 43 62			6.3 8 27			2.8 43 62			U	58 days	44
11.9 289 331						11.8 75 96			7.6 25 46						B	30 days	45
6.1 313 5			3.1 29 81			9.1 66 92			9.1 37 63			3.1 66 92			T	86 days	46
7.6 293 310						6.0 107 116			6.4 60 69						F	29 days	47
8.6 300 317			3.6 18 35			3.2 97 105			6.0 49 57			1.1 97 105			S	105 days	48
6.7 35 357						5.4 230 211			4.4 66 47						B	30 days	49
4.4 228 178						11.8 11 346			3.2 51 26						F	29 days	50
7.3 307 271						6.8 352 334			1.4 47 29						F	29 days	51
13.0 30 357						7.3 233 216			1.2 144 127						F	15 days	52
8.4 359 332						6.8 208 194			3.4 128 114						R	14 days	53
9.8 356 328						6.7 232 218			3.3 96 82						F	360 days	54
9.6 34 3			4.9 72 41			7.3 161 145			3.5 132 116			2.4 161 145			O	15 days	55
8.7 2 338						6.7 295 283			2.1 128 116						F	29 days	56
7.5 5 341						5.4 251 239			2.1 92 80						I	58 days	57
7.6 13 351			8.1 91 69			2.7 215 204			1.2 12 1			0.9 215 204			S	29 days	58
6.7 61 29						7.0 245 229			2.7 72 56						H	104 days	59
7.1 71 37			2.9 150 116			7.3 270 253			2.2 70 53			2.4 270 253			S	105 days	60
4.9 57 20						8.7 271 253			1.8 78 60						C		61
8.0 44 5						4.0 273 254									D	14 days	62
2.5 245 145						6.8 30 340			2.2 47 357						S	105 days	63
1.9 198 92			0.8 306 200			6.9 36 343			1.9 42 349			2.3 36 343			P	30 days	64
3.0 155 39						3.1 26 328			1.3 49 351						S	58 days	65

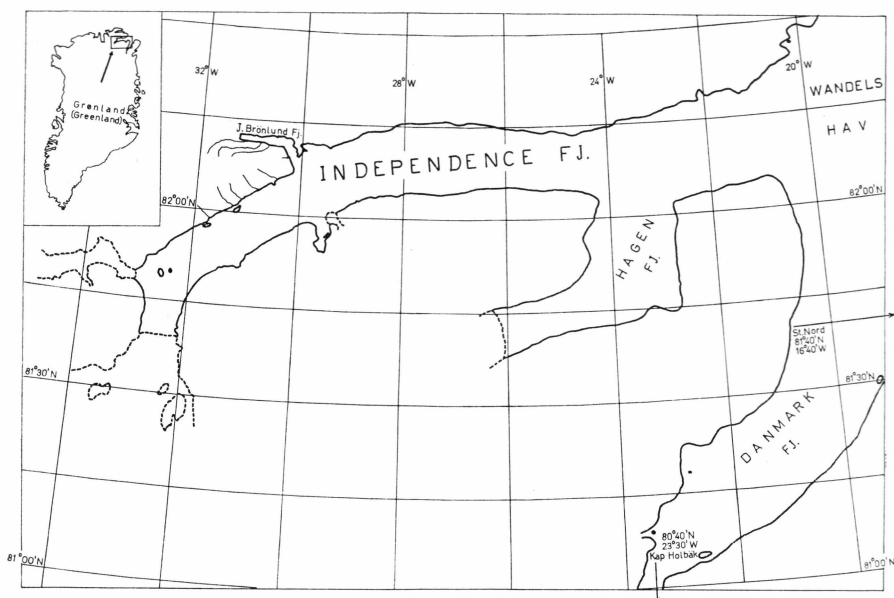


Fig.1. Contour-map of Independence Fjord, Hagen Fjord and Danmark Fjord, worked out on the basis of available material, i. a. maps by Lauge Koch from surveys in 1921. The geographical coordinates are brought in accordance with recent measurements performed by the Pearyland Expedition 1947-50. The contours just east and south of the area presented here are uncertain; but the positions of Station Nord to the east and that of Kap Holbæk to the south are indicated by arrows and by their geographical coordinates.

Norwegian coast are presented in the uppermost part of the table; thereupon a counter-clockwise direction is followed around the Arctic Ocean concluding with values from the Norwegian group of islands Svalbard and the Russian group of islands Zemlya Frantsa-Iosifa. The table is aimed to include results from all localities, which face the Arctic Ocean more or less directly, whereas a number of localities in the inner parts of the neighbouring bays have been excluded.

The table indicates—from left towards right—1) geographical area, 2) number and name of locality, 3) geographical coordinates, 4) partial tides, starting with the semi-diurnal tides  $M_2$ ,  $S_2$ ,  $N_2$  and  $K_2$ , and concluding with the diurnal tides  $K_1$ ,  $O_1$  and  $P_1$ . For each partial tide is stated a) amplitude  $H$  in cm, b) phase delay  $\alpha$  in degrees of arc relative to the local equilibrium tide, and c) phase delay  $g_{Gr}$  in degrees of arc relative to the equilibrium tide at the Greenwich meridian, i. e. not relative to any local standard meridian, which is common use. This last-mentioned quantity  $g_{Gr}$  makes it possible to decide rather easily, if tidal waves at different localities are more or less contemporary, and also to determine the absolute difference in time between such tidal

waves; as to  $M_2$ , f. inst., a  $g_{Gr}$ -difference of  $28^{\circ}984$ —the so-called speed number for  $M_2$ — corresponds to one solar hour. Finally, by capital letters in the third last column are indicated references, which can be found on the concluding pages 36—37. The second last column indicates length of period of observations, whereas the last column repeats the numbers of the stations.

In some cases the length of period of observations is not indicated. For the Norwegian values numbered 1, 2, 5 and 6 the cause is, that the values are taken from yearly published Tide Tables, which are corrected from time to time; these values are rather precise. In other cases, when the length of period is not given in table I, the cause is, that no information thereabout is available; in some of these cases the period may be rather short. In cases, when some of the partial tides are missing in table I, the cause is, that they have not been calculated, mainly because of insufficient material. In other cases more partial tides have been calculated than the stated ones; but they have little significance for our purpose.

Almost all of the harmonic constants etc. in table I originate—as it is seen—from various published papers. Only the stated values with references V and W, i. e. Thule (No. 36), Jörgen Brönlund Fjord (No. 42) and Kap Holbäk, have not been published at earlier occasions. At Thule tidal observations took place during approximately two months, i. e. August and September 1932; but only 29 days of this interval have been used for the harmonic analysis. In Jörgen Brönlund Fjord the observations took place in August 1947 and September 1949, whereas the observations at Kap Holbäk took place in July and August 1955 (further information in the Appendix).

## II. STATIC THEORY

Suppose  $U_1(P)$  to be the tidal potential originating from the Moon and  $U_2(P)$  to be the tidal potential originating from the Sun in an arbitrary point P of the Earth, which can in this connection with sufficient accuracy be regarded as spherical. When the combined potential  $U_1(P) + U_2(P)$  is divided by the gravity acceleration  $G$  the height  $H_1 + H_2$  of the equilibrium tide in the point P is obtained. The two heights  $H_1$  and  $H_2$ , representing the equilibrium tides of the Moon and the Sun respectively, can be dealt with in analogous ways.

According to common procedure (cf. DOODSON & WARBURG, 1941) it holds good that

$$H_1 = \frac{U_1}{G} = \frac{M}{E} \cdot \frac{e^4}{r^3} \left[ \left( \frac{3}{2} \cos^2 u - \frac{1}{2} \right) + \frac{e}{r} \left( \frac{5}{2} \cos^3 u - \frac{3}{2} \cos u \right) + \frac{e^2}{r^2} \left( \frac{35}{8} \cos^4 u - \frac{30}{8} \cos^2 u + \frac{3}{8} \right) \dots \right].$$

$u$  means the momentary zenith distance of the Moon,  $e$  the radius of the Earth, which can be fixed at 637 000 000 cm. The ratio  $\frac{e}{c}$  between the radius of the Earth and the mean distance to the Moon's centre from the Earth's centre is almost exactly  $1/60.35$  or  $0.0166$ , and the ratio  $\frac{M}{E}$  between the masses of the Moon and the Earth is  $1/81.31$ . The resulting mean value of  $\frac{M}{E} \frac{e^4}{r^3}$  appears to be 35.6 cm. The corresponding value in the case of the Sun is 16.4 cm and the exact ratio between these two values  $1:0.46051$  (DIETRICH & KALLE, 1957, p. 349).

A consideration of the successive terms in the edged parenthesis reveals that the second term contains the factor  $\frac{e}{c} = 0.0166$ , the third term the factor  $\frac{e^2}{c^2} = 0.000,276$ , whereas the first term contains no such factor. This means that the second term contributes less than 2 per cent compared with the first term, and that the third and the following terms are quite insignificant. Regarding the corresponding terms in the case of the Sun it is easily seen that only the first term in the formula for the Sun's tide is of greater significance.

When the latitude  $\varphi$  and the longitude  $\lambda$ —reckoned positive towards west—of the place P and also the declination  $\delta$  and the Greenwich hour angle  $t$  of the Moon are introduced, the first term in the  $H_1$ -formula can be written:

$$\left(\frac{3}{2} \sin^2 \varphi - \frac{1}{2}\right) \left(1 - \frac{3}{2} \cos^2 \delta\right) + \frac{3}{4} \sin 2\varphi \sin 2\delta \cos(t - \lambda) + \frac{3}{4} \cos^2 \varphi \cos^2 \delta \cos 2(t - \lambda).$$

When we multiply this quantity with the mean value 35.6 of the common factor  $\frac{M}{E} \frac{e^4}{r^3}$  and make some small alterations, we get for  $H_1$ , except  $\pm 1-2$  per cent as explained above:

$$H_1 = 26.7 \left[ \left(\frac{1}{2} - \frac{3}{2} \sin^2 \varphi\right) \left(\frac{2}{3} - 2 \sin^2 \delta\right) + \sin 2\varphi \sin 2\delta \cos(t - \lambda) + \cos^2 \varphi \cos^2 \delta \cos 2(t - \lambda) \right].$$

The three quantities in the edged parenthesis depend on 1) the latitude  $\varphi$  of the place P in question, 2) the declination  $\delta$  of the Moon, and as to the second and third quantity 3) the hour angle  $(t - \lambda)$  of the Moon.

Point 3) is in accordance with the fact that the second quantity represents the diurnal species of the tide and that the third quantity represents the semi-diurnal species of the tide. The first quantity represents the longperiodic species, which are independent of the longitude of the place.

As to the factor  $\left(\frac{2}{3} - 2 \sin^2 \delta\right)$  in the longperiodic quantity—represented in the so-called Mf-term—in the formula we arrive at the value 0.6667 when  $\delta = 0^\circ$  and the value 0.3487 when  $\delta = \pm 23.5^\circ$ , i. e. maximal (as a first approximation). Consequently this factor must have an amplitude, which is the half of the difference between these two values. On the basis of exact computations, where also the second term in formula (1) is counted, an amplitude of 0.15642 is obtained; it represents the so-called relative coefficient of Mf (cf. table II).

Table II. Factors involved in various partial waves of equilibrium tide.

(1) Celestial body	(2) Name of tide	(3) Period	(4) Speed per solar hour	(5) Common coeff. (cm)	(6) Relat. coeff.	(7) Final coeff. (cm)	(8) Latitude coeff.
Moon	N <sub>2</sub>	12.6584 hours	28°.4397295	26.7	0.17387	4.64	cos <sup>2</sup> φ
—	M <sub>2</sub>	12.4206 —	28°.9841042	—	0.90812	24.25	—
—	K <sub>2</sub>	11.9672 —	30.0821373	—	0.07858	2.10	—
Sun	K <sub>2</sub>	11.9672 —	30.0821373	—	0.08648	0.97	—
—	S <sub>2</sub>	12.0000 —	30.0000000	—	0.42286	11.29	—
Moon	Q <sub>1</sub>	26.8684 —	13.3986609	—	0.07216	1.93	sin 2 φ
—	O <sub>1</sub>	25.8194 —	13.9430356	—	0.37689	10.06	—
—	K <sub>1</sub>	23.9345 —	15.0410686	—	0.36233	9.67	—
Sun	K <sub>1</sub>	23.9345 —	15.0410686	—	0.16817	4.49	—
—	P <sub>1</sub>	24.0659 —	14.9589314	—	0.17554	4.69	—
Moon	Mf	13.6608 days	1.0980331	—	0.15642	4.18	$\frac{1}{2} - \frac{3}{2} \sin^2 \varphi$
—	Mm	27.5546 —	0.5443747	—	0.08254	2.20	—
Sun	Ssa	182.6211 —	0.0821373	—	0.07287	1.95	—

Regarding the second and diurnal quantity in the formula the factor  $\sin 2 \delta$  adopts the value 0.7314 when  $\delta = +23.5^\circ$  and the value  $-0.7314$  when  $\delta = -23.5^\circ$ . So, the corresponding amplitude of this factor has just this numerical value; but the said quantity also contains the factor  $\cos(t - \lambda)$ , which is more rapidly varying than the factor  $\sin 2 \delta$ , and therefore the amplitude in question must be divided into two parts, one belonging to the O<sub>1</sub>-tide and one belonging to the K<sub>1</sub>-tide. Their exact relative coefficients are stated in table II.

The value of the factor  $\cos^2 \delta$  in the last and semi-diurnal quantity is 1.0000 when  $\delta = 0^\circ$ , and 0.8410 when  $\delta = \pm 23.5^\circ$ . The average of these two values corresponds to the amplitude of the M<sub>2</sub>-tide, the varying part to the amplitude of the K<sub>2</sub>-tide. The exact relative coefficients can be seen in table II.

A similar set of relative coefficients belongs to the tides generated by the Sun; as to the solar relative coefficients in table II it is implied

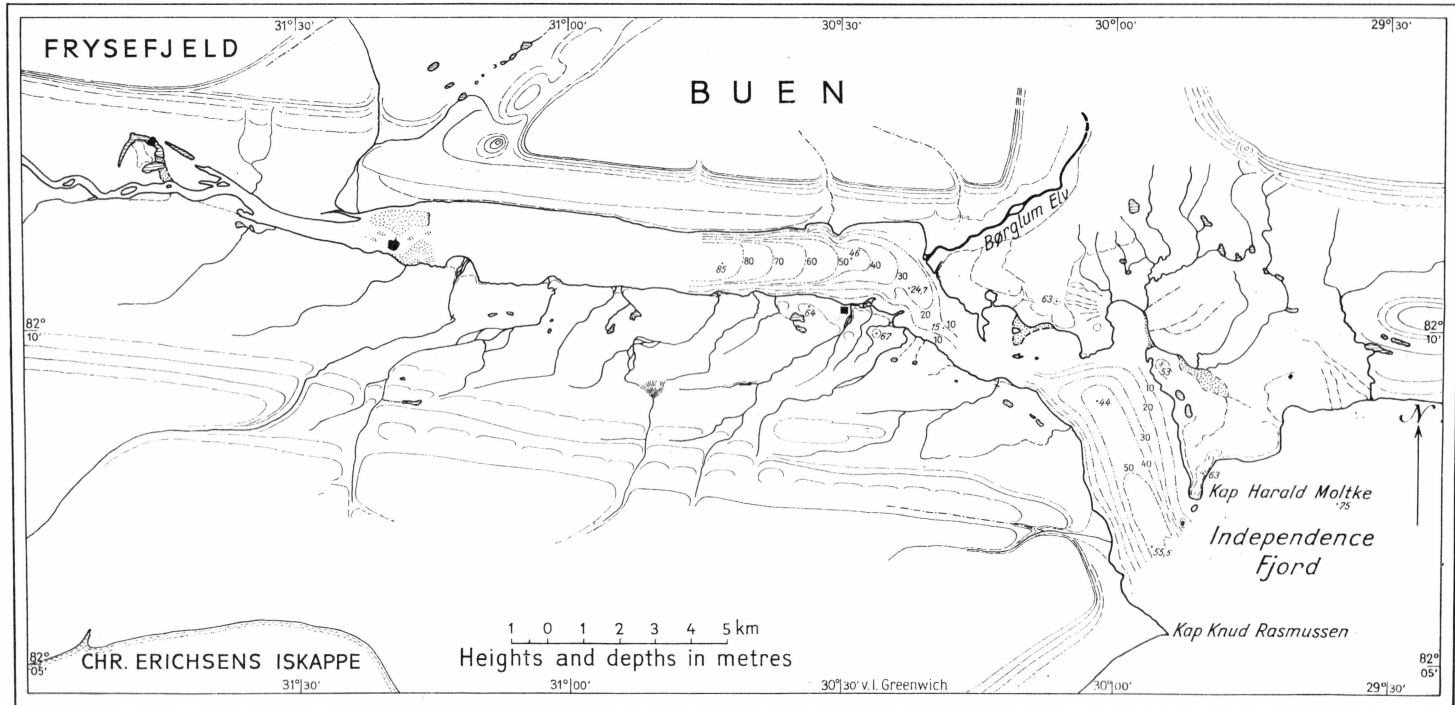


Fig. 2. Map of Jørgen Brönlund Fjord and surroundings worked out by Thorkild Höy. The domicile of the Pearyland Expedition is indicated by a black quadrangle at the southern coast of Jørgen Brönlund Fjord.

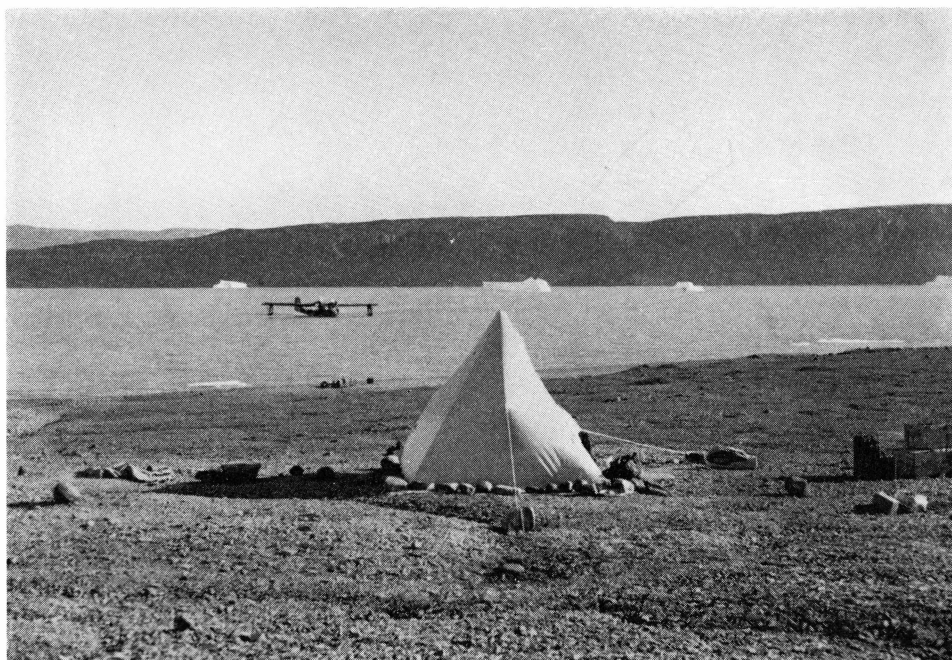


Fig. 3. The temporary station at Kap Holbæk in Danmark Fjord. Tidal readings were undertaken on a staff placed in the water to the left of the tent.

that the common factor is still 26.7 cm. The names of the Sun-tides, which correspond to the Moon-tides dealt with, are  $S_{sa}$ ,  $K_1$ ,  $P_1$ ,  $S_2$  and  $K_2$  (cf. table II). The relative coefficient of the  $K_1$ -tide of the Sun can—as revealed by more thorough analysis—be added to the relative coefficient of the  $K_1$ -tide of the Moon, and the two  $K_2$ -coefficients can also be added.

Still three partial tides with the designations  $N_2$ ,  $Q_1$  and  $M_m$  are set up in table II. Their origin is, that the common coefficient  $\frac{M}{E} \frac{e^4}{r^3}$  in the Moon's potential is not constant, as has hitherto been assumed; but  $r$  is varying because of the elliptic form of the Moon's orbit. The Sun's orbit is less varying, and therefore the Sun-tides, caused hereby, are rather insignificant. Nevertheless, the longperiodic elliptic tide  $S_a$  is often met with, although its relative coefficient amounts to 0.01176 only. A rather high amplitude of  $S_a$  is really observed at several localities; its main cause is a yearly periodicity of the winds and the air pressure. The theoretical speed per mean solar hour of  $S_a$  is  $0^{\circ}0410667$ , the corresponding period 365.2596, i e. just an anomalistic year.

Sometimes one or both of two other longperiodic tides can be observed. They are named  $M_{Sm}$  and  $M_{Sf}$ , and they are mainly caused

by an uneven increase of the Moon's longitude. The relative coefficient, the speed per mean solar hour and the period of the MSm-tide are 0.01578,  $0^{\circ}47'15.211$  and 31.8119 days, of MSf 0.01370,  $1^{\circ}01'58.958$  and 14.7653 days, respectively.

In table II the essentials about all partial tides with relative coefficients equal to or greater than the relative coefficient of the solar  $K_2$ -tide are presented. The resulting coefficients in column (7) are products of the common coefficient in column (5) and the relative coefficient in column (6). When we multiply this resulting coefficient and the latitude coefficient in column (8), we obtain for the corresponding latitude the amplitude of the partial equilibrium tide in question.

In table III such amplitudes of the partial equilibrium tides are presented for various latitudes. The negative signs of the amplitudes of the longperiodic constituents remind of the fact that their phases are opposite in equatorial and polar regions.

It is clearly to be seen that the diurnal and the longperiodic constituents are dominating the equilibrium tide in polar regions. This is further illustrated in fig. 4, where their amplitudes are drawn as functions of latitude. Also the amplitude of the strongest semi-diurnal constituent  $M_2$  is drawn as function of latitude. Further, two vertical lines are inserted in fig. 4, corresponding to the latitude  $71^{\circ}18'N$  of Point Barrow and to the latitude  $83^{\circ}40'N$  of Kap Morris Jesup. The exact latitude, where the amplitude of the  $K_1$  equilibrium tide surpasses the amplitude of the  $M_2$  equilibrium tide, is  $40^{\circ}6'$ , and the amplitude of the  $K_1$  equilibrium tide is surpassed itself at a latitude of  $81^{\circ}7'$ , namely by the amplitude of the Mf equilibrium tide.

Because of their long periods the actually occurring longperiodic tides in the Arctic Ocean must be expected to be similar to the corre-

Table III. Amplitude in cm of equilibrium partial tide as function of latitude.

$\varphi =$	$90^{\circ}$	$85^{\circ}$	$80^{\circ}$	$75^{\circ}$	$70^{\circ}$	$65^{\circ}$	$60^{\circ}$
$N_2$ . . . . .	0.00	0.04	0.14	0.31	0.54	0.83	1.16
$M_2$ . . . . .	0.00	0.18	0.73	1.62	2.84	4.33	6.06
$K_2$ . . . . .	0.00	0.02	0.09	0.21	0.36	0.55	0.77
$S_2$ . . . . .	0.00	0.09	0.34	0.76	1.32	2.02	2.82
$Q_1$ . . . . .	0.00	0.34	0.66	0.96	1.24	1.48	1.67
$O_1$ . . . . .	0.00	1.75	3.44	5.03	6.47	7.71	8.71
$K_1$ . . . . .	0.00	2.46	4.84	7.08	9.10	10.85	12.26
$P_1$ . . . . .	0.00	0.81	1.60	2.34	3.01	3.59	4.06
Mf . . . . .	-4.18	-4.13	-4.01	-3.76	-3.45	-3.06	-2.61
Mm . . . . .	-2.20	-2.17	-2.10	-1.98	-1.81	-1.61	-1.38
Ssa . . . . .	-1.95	-1.93	-1.86	-1.75	-1.61	-1.43	-1.22

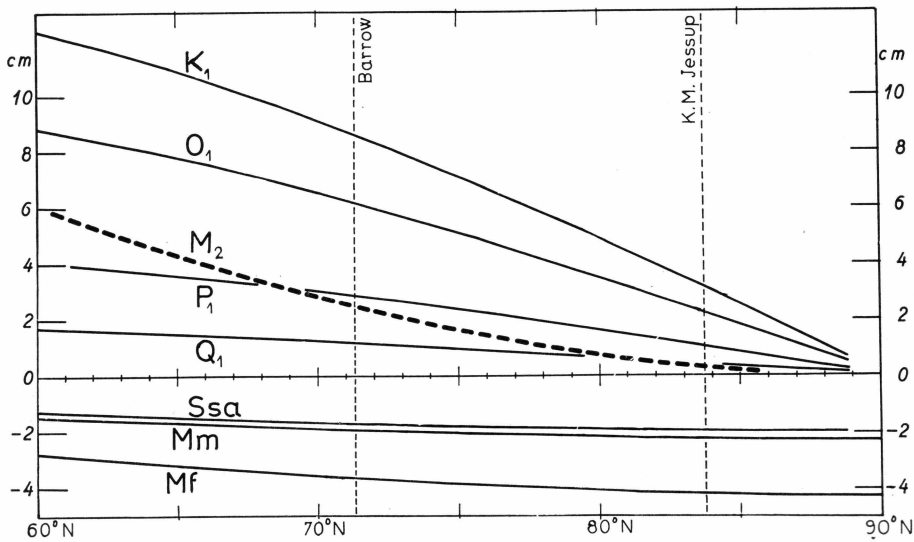


Fig. 4. Amplitudes of various partial waves in the equilibrium tide as function of latitude between  $60^\circ$  and  $90^\circ$ . Whereas the amplitudes of the diurnal and semi-diurnal waves are zero at the pole (at the right end of the figure), the amplitudes of the more longperiodic Mf-, Mm- and Ssa-waves are from 2 to a little more than 4 cm at the pole (they are chosen to be negative here, because they may be said to be in counterphase). The amplitudes of these three waves diminish slowly with growing distance from the pole. Contrarily the amplitudes of the diurnal waves rise rather steeply with growing distance from the pole, and the amplitudes of the semi-diurnal waves—here represented by the  $M_2$ -wave—rise more slowly at the beginning, but faster at medium latitudes.

sponding equilibrium tides. This means that the actual Mf tide must be expected to have a mean amplitude about 4 cm, and the actual Mm tide must be expected to have a mean amplitude about 2 cm in the Arctic Ocean.

Sometimes it can be difficult to separate the real astronomical tides and the tides, which have no astronomical origin. This is often the case with the Ssa tide and especially—as already mentioned—with the yearly Sa tide. The harmonic constants, which can be derived for them, are normally influenced by periodic weather conditions.

The equilibrium values of the diurnal and the semi-diurnal tides are seldom met with in the various oceans. One cause is that the free oscillations, which are determined by the dimensions of the sea areas in question, have periods of the same order of magnitude as the diurnal and semi-diurnal tides themselves. It is also known that in V-shaped bays the height of the tidal wave is often considerably augmented. In certain regions the actual  $M_2$ -amplitude is 10 or still more times greater than the equilibrium value, which is 24.25 cm at the equator.

### III. SOME DYNAMICAL CONSIDERATIONS

A long wave, especially a tidal wave, which is submitted to no other force than the gravity, proceeds as a so-called channel wave. The simple formula for the velocity  $v$  of such a wave is

$$v = \sqrt{gd},$$

where  $g$  is the gravity acceleration and  $d$  the depth.

It is known that a tidal wave, which is presumed to move along the equator from east towards west, cannot be in resonance with the Moon. In such a case the tidal wave would have to accompany the Moon in its daily motion around the Earth in 24 hours and 50 minutes; but according to the above formula this would require a depth of the sea all along the equator of almost 25 km. On the other hand, if we presume that a channel exists along the equator with an essentially smaller depth, it can be shown that the tidal wave will be inverted, i. e. be in counter-phase with the Moon, and it will be lower than the equilibrium wave.

If we think of various hypothetic channels encircling the Earth and following the various circles of latitude, it is possible to appoint a tidal resonance depth lesser than 25 km to each circle of latitude.

If we require a resonance period of 24 hours (for the sake of simplicity not 24 hours and 50 minutes as above), the latitudes, which correspond to various depths, can be computed. They are inserted in the scheme below. Moreover, the corresponding wave velocity in m/sec and in km/hour is indicated.

sea depth	velocity of wave		latitude
	m/sec	km/hour	
m			
10	9.9	35.7	88°.8
40	19.8	71.4	87°.6
90	29.7	107	86°.3
250	49.6	178	83°.9
1000	99.1	357	77°.7
4000	198.2	713	64°.7

It is seen that north of the northern polar circle and south of the southern polar circle (66,5° N or S) a depth of 4 km is sufficient to ensure a free moving wave to fulfil a revolution within 24 hours, provided that such a circumpolar channel exists all along the circle of latitude in question. This condition about the depth is really not far from being

fulfilled along the southern polar circle; but, naturally various disturbing effects also act, i. a. because no ideal and narrow east-west-running channel occurs in the sense presumed.

A circumpolar and also sea-covered circle of latitude in the northern region must be searched as far north as  $83\frac{1}{2}^{\circ}\text{N}$  and still more northerly. On the other hand, a depth of about 300 m is sufficient here to secure occurrence of equilibrium waves and possibly resonance waves, f. inst. of  $M_2$ ,  $K_1$ ,  $S_2$  and other constituents. Of course, disturbing effects are in action in the Arctic Ocean as in the Southpolar Ocean, f. inst. when tidal waves, which are generated at different latitudes, interfere with each other.

A second and very important factor in the dynamics of the tides—as in the dynamics of wind systems and of windproduced sea-currents—is Coriolis acceleration. This acceleration  $g$  can be computed by the formula

$$g = 2\omega u \sin \varphi$$

where  $\omega$  is the Earth's angular velocity, namely the constant value  $7.29 \times 10^{-5} \text{ sec}^{-1}$ ,  $u$  velocity (i. e. horizontal velocity of water movement, not wave velocity as above) and  $\varphi$  latitude.

It is seen that the last factor,  $\sin \varphi$ , attains its greatest value at the pole, and that the variation of this factor per degree of latitude is comparatively smaller at high latitudes than at low latitudes. It is also seen that Coriolis acceleration is directly proportional with the velocity; this means i. a. that relatively slight Coriolis-acceleration is connected with tides in deep oceans, as small velocities are here sufficient to build up the vertical tidal variations of sea level.

If a particle on the Earth's surface is allowed to move in the horizontal plane at a velocity  $u$ , it will—owing to Coriolis acceleration—describe a curve with a radius  $r$  of curvature determined by the formula

$$r = \frac{u}{2\omega \sin \varphi}.$$

On the basis of this formula it can be computed that a free moving particle in a horizontal plane near the pole describes a circle with a radius of about 7 km, if its velocity is 1 m/sec.

It is known that tidal phenomena often develop in so-called amphidromic systems, especially owing to the effect of Coriolis acceleration. This is dealt with in various textbooks (cf. DOODSON and WARBURG, 1941). It may be unnecessary to elucidate the theoretical background of amphidromic systems at this place; but it should be stressed, as DOODSON and WARBURG (1941, p. 182–187) have done, that although amphidromic systems in the northern hemisphere are as a rule rotating in an anti-clockwise direction, a rotation in the opposite direction, i. e.

in a clockwise direction, can also occur in the northern hemisphere namely in such cases, where the sea area is rather deep or of rather small extension.

#### IV. THE TOPOGRAPHICAL CONDITIONS

Two possibilities exist concerning the actually occurring tide of astronomical origin in the Arctic Ocean. One possibility is that it is a direct result of the equilibrium tide in the Arctic Ocean itself. Another possibility is that it is of more indirect character and arrives at the Arctic Ocean from more southerly oceans. Provided that this is the case, entirely or partly, the tide must pass through one or more straits or other sea connections between the Arctic Ocean and the more southerly sea areas.

Firstly, a rather broad—about 400 km—sea connection of the kind mentioned exists east of Greenland at 80° northern latitude, where the Nansen Ridge is situated between the north-eastern corner of Greenland and Svalbard. The threshold-depth of the ridge is not known very accurately, but it probably exceeds 1000 m<sup>1</sup>). Tidal waves may also arrive at the Arctic Ocean by crossing a line between Svalbard and Zemlya Frantsa-Iosifa as well as crossing a line between Zemlya Frantsa-Iosifa and the still more easterly group of islands Severnaya Zemlya. Now, the Barents Sea south of the first-mentioned line is rather shallow compared with the sea area south of the Nansen Ridge, i. e. the Greenland Sea and the Norwegian Sea, as the depths of the Barents Sea are of the order of magnitude 200 m, and as banks are situated in the northerly and the northwesterly part of the Barents Sea. The Westsiberian Sea south of the last-mentioned line is also shallow, possibly more shallow than the greater part of the Barents Sea. Altogether, no noticeable tidal energy can arrive at the Arctic Ocean through the Barents Sea or the Westsiberian Sea. Contrarily, tidal waves from the Arctic Sea may to some extent be responsible for tidal phenomena in the Barents Sea and the Westsiberian Sea, as the Arctic Ocean is considerably deeper than these seas. More westerly the situation must be so that tidal waves are not damped essentially, either if they pass from the Greenland Sea to the Arctic Ocean, or if they pass in the opposite direction.

Three more sea connections between the Arctic Ocean and the more southerly oceans can be mentioned. The Bering Strait is one of these; it is about 80 km broad, and its threshold-depth is possibly a

<sup>1</sup>) Recent Russian depth soundings reveal that the level of the assumed ridge is as low as 3000 m below sea-level on both sides of the 0°-longitude (cf. Petermanns Geographischen Mitteilungen, 1961, 1, p. 73).

little more than 50 m. Furthermore, the seas south and north of the Bering Strait are rather shallow, and therefore the role of the Bering Strait as to the tide in the Arctic Ocean may be rather insignificant.

The two remaining connections are firstly the strait between the northwestern Greenland and Ellesmere Land and secondly an east-west running strait in the Canadic Archipelago. Following the first-mentioned strait from south to north, it is bearing the successive names: Smith Sund, Kane Bassin, Kennedy Kanal, Hall Bassin and Robeson Kanal. Following the last-mentioned strait from east to west, it is bearing the successive names: Lancaster Sound, Barrow Strait, Melville Sound and Mac Clure Strait. The depths of the two connections are not known with any great accuracy, but their threshold-depths are presumably greater than the threshold-depth of the Bering Strait. Both of them are connecting the Arctic Sea with the Baffin Bay. The average depth of the Baffin Bay may be about 1000 m, and it is provided with rather strong tides, which are arriving at the Baffin Bay from the North Atlantic Ocean through the Labrador Sea and the Davis Strait, successively.

From available material about depths and the like the accompanying map (fig. 5) has been drawn. The dotted lines in the Arctic Ocean itself are enclosing areas with estimated depths greater than 4000 m. The curves with single dots represent depths of 1000 m, and the dashed lines represent depths of 200 m; these lines may represent the outer borders of the continental shelves.

It is seen, that the Arctic Ocean is dominated by a great basin with its greatest extension along the longitudes of  $40^{\circ}$  E and  $140^{\circ}$  W. The Lomonosov Ridge is nearly perpendicular to this direction and divide the deeper parts of the Arctic Ocean into two separate basins, which we—according to their positions—will name the European Basin and the Alaskan Basin, respectively.

A satisfactory theory about the tide in the Arctic Ocean and in the marginal seas must first of all explain, why the semi-diurnal constituents are so well developed here in comparison with the diurnal constituents. Can the full explanation be, that the tide in the Arctic Ocean is of external origin (i. e. arrives to the Arctic Ocean from neighbouring sea areas, especially from the Greenland Sea), or may some factor in the Arctic Ocean itself in some way or other reinforce the semi-diurnal constituents and at the same time let the diurnal constituents remain un-affected or even weaken the diurnal constituents?

The answer must be, that resonance conditions, which depend on the dimensions of the sea area in question, are favourable for some constituents, the semi-diurnal ones, and unfavourable for the other constituents, the diurnal ones.

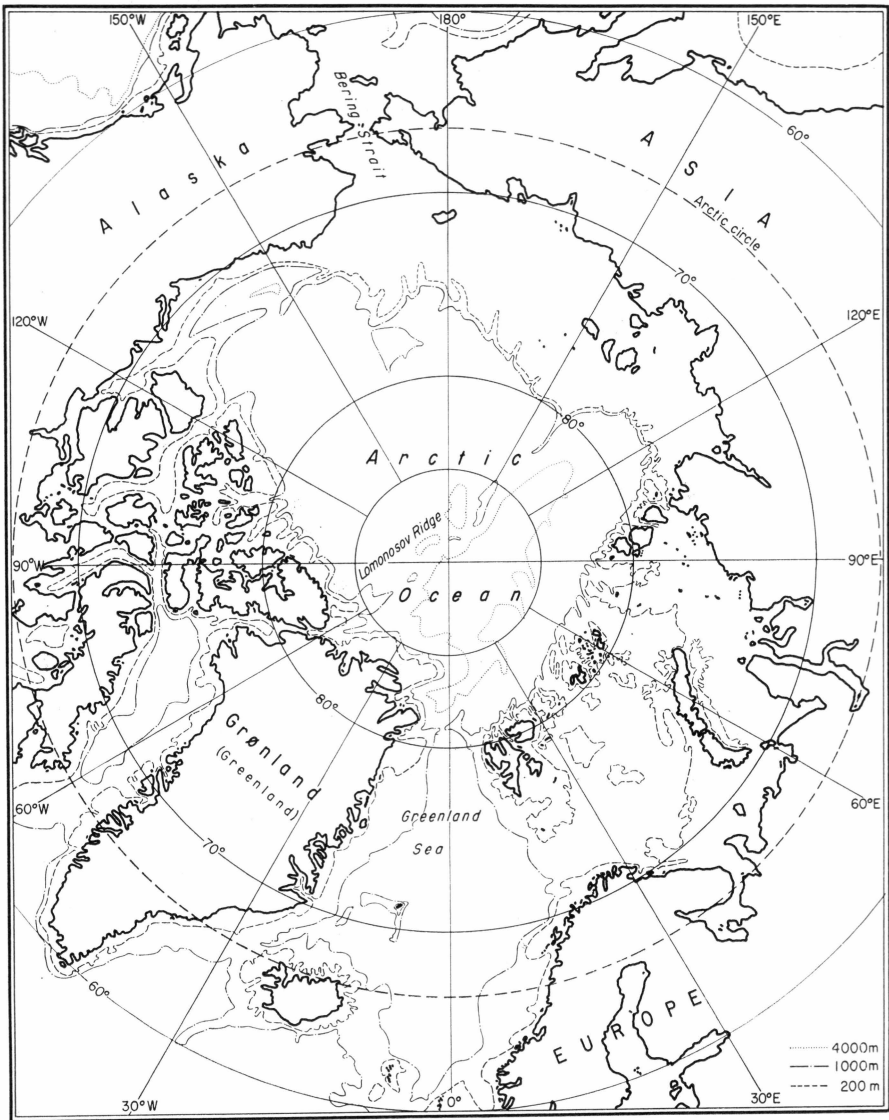


Fig. 5. The Arctic Ocean with surroundings. The dotted curves near the pole represent depths of 4000 m, the curves near the coast depths of 200 m, and the intermediate curves depths of 1000 m. These curves are founded on available material, but may in some of the northerly regions be rather inaccurate.

A standing  $M_2$ -oscillation can be produced in the Arctic Ocean, if the travelling time between opposing borders (really borders of shelves) is near the half of the  $M_2$ -period. This half is 6.2 hours, and the distance from the innermost Alaska-shelf to the shelf outside Svalbard is very near 3000 km. A free progressive wave travels with the

speed  $\sqrt{gh}$ , where  $g$  is the gravitational acceleration and  $h$  the depth. In the case considered  $h$  (in m) can be determined by

$$\frac{3000 \times 1000}{6.2 \times 3600} = \sqrt{9.83 h}$$

$$h = 1800 \text{ (m)}.$$

As the mean depth between Alaska and Svalbard is near to 2000 m or possibly a little greater, it is concluded, that the conditions for  $M_2$ -oscillations and other semi-diurnal oscillations are better than the conditions for the diurnal oscillations. More evidence concerning a standing  $M_2$ -oscillation in the Arctic Ocean will be presented in the next chapter.

## V. RESULTS FROM NE-GREENLAND AND CONCLUSIONS

Up to 1947 no tidal observations were reported from the north-eastern part of Greenland, the part north of  $77^\circ$  N; but such observations were realized by the "Danish Pearyland Expedition", which took place in the years 1947, 1948 and 1949. The place for observations has the geographic coordinates  $82^\circ 11'$  N and  $30^\circ 30'$  W and may be seen on the accompanying maps. The observed heights of water are reported in the appendix, and harmonic analysis—according to The Admiralty Tide Tables, Part III: Instructions etc. (cf. "Hydrographic Department" in references)—has revealed the following constants.

	$M_2$	$S_2$	$N_2$	$K_2$	$K_1$	$O_1$	$P_1$
H (cm)	10.6	4.0	2.0	1.1	6.4	2.6	2.1
$\varkappa$	$295^\circ$	$346^\circ$	$269^\circ$	$346^\circ$	$351^\circ$	$326^\circ$	$351^\circ$
$g_{Gr}$	$356^\circ$	$47^\circ$	$330^\circ$	$47^\circ$	$21^\circ$	$356^\circ$	$21^\circ$

The figures in the three lines represent, as hitherto, amplitude  $h$ , lag  $\varkappa$  of the phase of the tidal constituent behind the phase of the corresponding equilibrium constituent at the place and the lag  $g_{Gr}$  of the phase of the tidal constituent behind the phase of the corresponding equilibrium constituent at Greenwich (presupposed that Greenwich-time is used everywhere).

The observations in Jørgen Brönlund Fjord were undertaken at a point, which was about 40 km from the outlet of Jørgen Brönlund Fjord to the great Independence Fjord (cf. the maps). In this outer half of Jørgen Brönlund Fjord the depths are 50 m or less, and a threshold with depths of 10–15 m exists halfway between the outlet

and the point in question. It follows from the preceding, that a mean velocity of the tidal wave of about 15–18 m/sec in Jörgen Brönlund Fjord is reasonable. It means, that the wave needs about 10 minutes to travel to the point of observation from the outlet, or in other words that the arrivals of the various partial tides in this part of Independence Fjord are 10 minutes earlier than the arrivals at the point of observation. Therefore, the lags of the semi-diurnal waves must be about  $5^\circ$  less in Independence Fjord just outside Jörgen Brönlund Fjord than at the observation point in Brönlund Fjord, whereas the corresponding difference for the diurnal waves must be  $2^\circ$ – $3^\circ$ . From such considerations the  $g_{Gr}$ -value for  $M_2$  in this part of Independence Fjord may be fixed at  $356^\circ - 5^\circ = 351^\circ$ .

At a later instant—the summer of 1955, cf. the appendix—a few shorter series of tidal observations were undertaken at a point (Kap Holbæk) in Danmark Fjord with the approximate coordinates  $80^\circ 40' N$  and  $23^\circ 30' W$ . The material in question is insufficient for a detailed harmonic analysis; but by use of a tidal machine and a few reasonable assumptions it has been possible to fix rather well-founded harmonic constants. They are as follows.

	$M_2$	$S_2$	$N_2$	$K_2$	$K_1$	$O_1$	$P_1$
H (cm)	11	5	2	2	7	4	2
$\alpha$	$305^\circ$	$343^\circ$	$295^\circ$	$10^\circ$	$6^\circ$	$337^\circ$	$357^\circ$
$g_{Gr}$	$352^\circ$	$30^\circ$	$342^\circ$	$57^\circ$	$29^\circ$	$0^\circ$	$20^\circ$

It is an interesting coincidence, that the  $g_{Gr}$ -values here—especially the  $g_{Gr}$ -value for  $M_2$ —are almost the same as the  $g_{Gr}$ -values in the above-mentioned part of Independence Fjord. As the distances of the two observation points in question from the common outlet of Independence Fjord and Danmark Fjord at the northeastern corner of Greenland are of the same orders of magnitude, one conclusion may be, that the depths in the two fjords are nearly alike and probably rather great, several hundred meters (only very slight depth-sounding material is realized in these fjords).

As a consequence, tidal material from the common outlet mentioned may be a clue to the tidal progress in the two fjords. In the course of the International Geophysical Year material of this kind was obtained by E. HJORTENBERG KNUDSEN, who was in charge of the seismic station at Station Nord (primarily a weather station). He was able to make telescope sightings to a fixed point on the ice at some—sufficient—distance from the coast. HJORTENBERG KNUDSEN had no opportunity for longer series; but the isolated values for height of water are inserted as small circles in the drawing in figure 6. The stippled

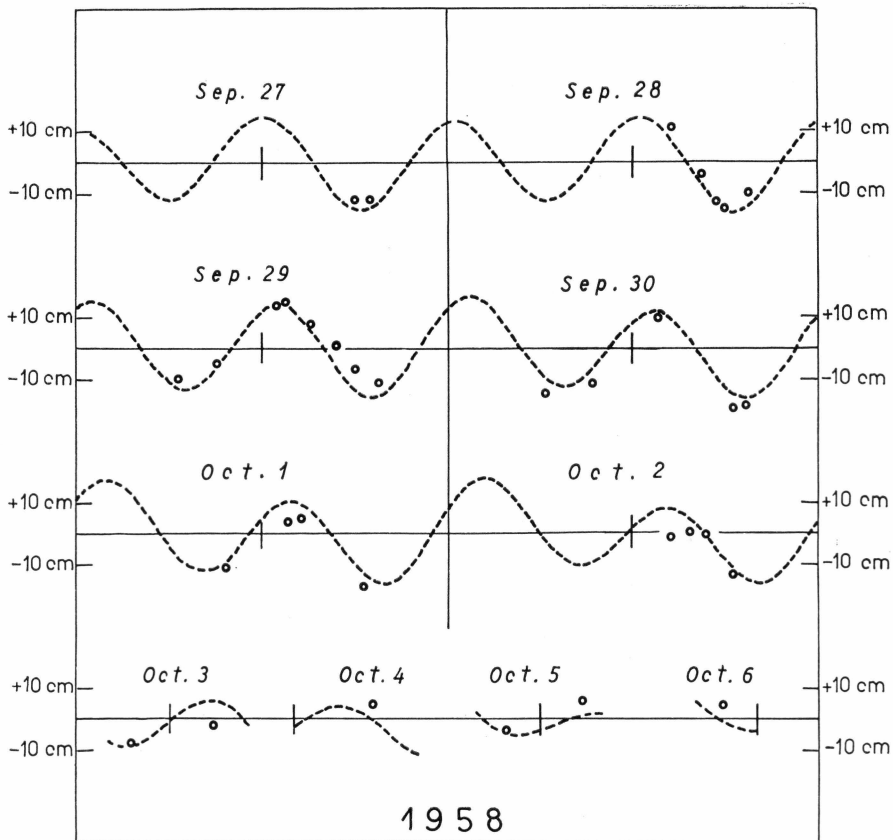


Fig. 6. The stippled curve represents the—common—tidal variations in the fjord-complex Independence Fjord-Danmark Fjord in the period Sept. 27—Oct. 6, 1958 (with some interruptions) constructed on the basis of harmonic analysis undertaken. The small circles represent momentary tidal values at Station Nord.

tidal curve is constructed on the basis of means of the harmonic constants for Jörgen Brönlund Fjord and Kap Holbäk (all of the stated constants have been used, and corrections for the 18.6-yearly periodicity have been applied). The geographic coordinates of the observation point at Station Nord are fixed at  $81^{\circ}40' N$  and  $16^{\circ}40' W$ , and it can be added, that the values represented by the inserted small circles are corrected for variations in air pressure; actually they refer to 1010 mbar after correction, and the original values are diminished by 195 cm.

Each of the observed water heights, stated in the table and represented in the drawing, are means of 5–9 single values obtained by the telescope sightings mentioned; their standard deviations are about 2 cm. Therefore, a strict accordance in the figure between the small circles and the curve cannot be expected. Further, a slow and gradual

## Water heights at Station Nord.

date	time	height + corr.	date	time	height + corr.	date	time	height + corr.
1958	UT	cm	1958	UT	cm	1958	UT	cm
Sept. 27	18.00	185-2	Sept. 29	15.10	196+7	Oct. 1	14.30	205-5
	19.10	185-2		16.50	188+8		18.30	183-5
Sept. 28	14.35	206-0		18.05	180+8	Oct. 2	14.30	190+4
	16.30	191-0		19.40	176+8		15.40	192+4
	17.20	182-0	Sept. 30	06.20	175+6		16.45	190+5
	18.00	180-0		09.25	179+5		18.30	177+5
	19.40	185-0		13.40	202+3	Oct. 3	09.30	191-3
Sept. 29	06.35	182+3		18.35	179-3		14.50	201-8
	09.05	186+4		19.20	180-3	Oct. 4	17.10	204-4
	12.55	203+6	Oct. 1	09.40	189-5	Oct. 5	09.45	198-6
	13.30	203+7		13.40	204-5		14.40	205-4
						Oct. 6	09.50	197+3

shifting of the observed values against the curve may be accounted for by a corresponding vertical shifting of the fixed point, which is observed in the telescope, against the ice.

An interesting fact appears from the graph, namely that the arrival times for the predominant tidal waves at Station Nord deviate very little from the arrival times in the two above-mentioned fjords. The conclusion is, that flow and ebb are contemporary in all of the deeper parts of Independence Fjord and Danmark Fjord as well at their common entrance. The phase-angles  $g_{Gr}$  against Greenwich must also be identical, in any case regarding  $M_2$ . The phenomenon can hardly be explained otherwise than stated earlier, namely by a standing oscillation, so that one side of a standing oscillation is dominating the fjord-system. Consequently, the phase angles must be identical, whereas the amplitudes may differ somewhat.

If the whole halfpart of such a standing oscillation just occupied the fjordsystem, a nodal line might exist near the outlet of the system. Regarding the observations at Station Nord this last conclusion appears to be unlikely, as the amplitude at Station Nord is really about the same as the amplitudes in the inner parts of the fjords. We must assume therefore, that the considered halfpart of the oscillation occupies an essentially greater area than the fjordsystem. Various considerations lead to the assumption in chapter IV, that the deeper part of the Arctic Ocean, the part lying on the European side of the Lomonosov Ridge, actually oscillates as a whole representing one half of a standing  $M_2$ -oscillation. The other half must occupy the deeper part of the Arctic Ocean, which lies on the Alaskan side of the Lomonosov Ridge.

It may be sufficient here to notify a few essentials regarding the standing oscillation in question. Because of the equilibrium conditions the  $M_2$ -forces or accelerations may be able to produce greater tidal amplitudes south of  $80^\circ$  latitude than north of this latitude. It is a fact, that the only extended deep area of the Arctic Ocean, which lies south of  $80^\circ$  latitude, is situated at the Alaskan side. This part is almost symmetrical around longitude  $150^\circ$  W.

We now assume, that a standing oscillation has arisen for some reason or other, and we realize—according to the wellknown mechanism for standing oscillations—that the acceleration from the Moon must be maximal and directed southwards along the longitude mentioned, when it is ebb here (so that flow can be produced here half a period later). Contemporarily it is flow at the opposite side, i. e. in the so-called European basin, and this flow must correspond to a delay of the  $M_2$ -phase against Greenwich amounting to  $2 \times 150^\circ = 300^\circ$ . We conclude, that the  $g_{Gr}$ -value for the European basin is about  $300^\circ$ , and consequently that the  $g_{Gr}$ -value for the other basin—the Alaskan basin—is about  $120^\circ$ , provided that no other effects play an important role.

Undoubtedly, some other effects are really of some importance. The oscillation in question can be initiated and maintained by more than one agent. Besides the agent mentioned above, i. e. the direct acceleration from the Moon—resp. the Sun—a possible agent is the tidal wave, which arrives from the Greenland Sea, and which at the beginning is a progressive wave. These two agents have been treated independently in the preceding; but they may be mutually undistinguishable in the observational material. Altogether, the phase of the standing oscillation, which can be observed, may be a compromise between the phase calculated above and a phase from the Greenland Sea tidal wave. The  $g_{Gr}$ -value of this last one is  $17^\circ$  at the northwestern corner of Svalbard (cf. Virgohamn in the great scheme, plate I). The phase calculated above of the directly produced oscillation is  $-60^\circ$  ( $= 300^\circ$ ) in the same area, and we may therefore expect a resulting  $g_{Gr}$ -value for the European basin between  $+17^\circ$  and  $-60^\circ$ . It appears, that such a compromise is actually realized in Independence Fjord and Danmark Fjord, where a  $g_{Gr}$ -value of the order of magnitude  $351^\circ$ – $352^\circ$  has turned out.

Our assumption of a  $g_{Gr}$ -value in the European basin, which may be fixed at  $352^\circ$ , is further confirmed by consideration of tidal values from various localities near this deep-sea basin. The following localities, enumerated as in the great scheme, are confirmative, especially when their distances from the basin are considered also.

	M <sub>2</sub> -ampli- tude (H)	M <sub>2</sub> -phase (g <sub>Gr</sub> )	g <sub>Gr</sub> -352°	hours (solar)
33. Cape Columbia . . . . .	11.5 cm	9°	17°	0.6
41. Kap Morris Jesup . . . . .	4.2	14	22	0.8
59. Mosselbukta . . . . .	35.0	55	63	2.2
62. Brennevinsfjorden . . . . .	28.0	44	52	1.8
65. Teplitz bay . . . . .	15.5	62	70	2.4
16. Mys Tcheliuskine . . . . .	12.8	124	132	4.6
17. Maud Harbour . . . . .	12.6	113	121	4.2
18. Samuel Island . . . . .	15.4	105	113	3.9

The second last column indicates the M<sub>2</sub>-phase g<sub>Gr</sub> diminished by 352° (or augmented by 8°). The corresponding delays in solar hours, which are stated in the last column, are obtained by dividing with 28.984.

It is seen in the last column, that the M<sub>2</sub>-wave uses 0.6 and 0.8 hours, respectively, to arrive at Cape Columbia and Kap Morris Jesup from the deep basin. The M<sub>2</sub>-wave passes—which can be seen by the g<sub>Gr</sub>-values in the great scheme—Cape Sheridan (No. 34) about two hours later and Kape Bryant (No. 40) about 3½ hours later than Cape Columbia. Altogether, reasonable accordance appears to exist between the breadths of the shelves and the delays stated.

Only two coastal points with known tidal constants face the Alaskan Basin directly. They are Barrow (No. 31) and Flaxman island (No. 32). We treat them in the same way as above, remembering that the g<sub>Gr</sub>-value in the deep-sea basin here is 352° - 180° = 172° according to the hypothesis brought forward.

	M <sub>2</sub> -ampli- tude (H)	M <sub>2</sub> -phase (g <sub>Gr</sub> )	g <sub>Gr</sub> -172°	hours (solar)
31. Barrow . . . . .	5.0 cm	172°	117°	4.0
32. Flaxman Island . . . . .	6.6	286	114	3.9

It is seen, that there is a common delay of abt. 4 hours.

## VI. APPENDIX

The following tables contain tidal material, which has been obtained by readings on a tidal staff at two localities in the north-eastern part of Greenland. One of the localities has the geographical coordinates 82°11' N and 30°30' W. It is situated in Jörgen Brönlund Fjord, a small westerly branch of the big Independence Fjord, which debouches in Wandels Hav at the north-eastern corner of Greenland (cf. the map, fig. 5). The other locality, which has the geographical coordinates 80°40' N and 23°30' W, is named Kap Holbäk. It is situated in the

southern part of Danmark Fjord, the estuary of which is common with the estuary of Indenpendence Fjord (cf. the map, Fig. 1).

The tidal material from these two localities is placed at the authors disposal by EIGIL KNUTH, who planned and directed the two expeditions in question. In Jørgen Brönlund Fjord the readings of the tidal heights were taken by EIGIL KNUTH himself, BÖRGE FRISTRUP and THORKILD HÖY. In Danmark Fjord the readings were taken by EIGIL KNUTH and KRISTEN SÖRENSEN.

In Jørgen Brönlund Fjord tidal heights were first read in the interval of time from Aug. 5, 16.00 U. T.—Aug. 11, 24.00 U. T., year 1947. Later and more numerous tidal heights were read in the time interval Sept. 1, 12.00 U. T.—Sept. 17, 24.00 U. T., 1949. From the tables it is seen, that the tidal staff was turned over some times, hereby causing a change of datum. The interval Sept. 3—Sept. 17, 1949, in which the datum appears to have been rather fixed, has been used by the author for harmonic analysis according to a method, which is published by the Hydrographic Department of the Admiralty in London (1944). Beforehand the applied values were corrected for variations in air pressure by letting one millibar correspond to one cm in water level. Lateron, the such computed amplitudes and phase lags have been checked by comparisons with the readings in the other and unapplied intervals. The finally determined amplitudes "H" in cm, the phase-lags  $\alpha$ , which are related to the local meridian, and the phase-lags  $g$ , which in this case refer to the time meridian 30° west of Greenwich are the following:

	M <sub>2</sub>	S <sub>2</sub>	N <sub>2</sub>	K <sub>1</sub>	O <sub>1</sub>	K <sub>2</sub>	P <sub>1</sub>
H (cm)	10.6	4.0	2.0	6.4	2.6	(1.1)	(2.1)
$\alpha$ (°)	295	346	269	351	326	(346)	(351)
$g$ (°)	296	347	270	351	326	(347)	(351)

The amplitudes of K<sub>2</sub> and P<sub>1</sub> are placed in parenthesis, as they have been computed from S<sub>2</sub> and K<sub>1</sub> by applying the factors 0.27 and 0.33, respectively. The phase-lags of K<sub>2</sub> and P<sub>1</sub>, which are placed in parenthesis also, have been directly transferred from S<sub>2</sub> and K<sub>1</sub>, respectively.

Also at Kap Holbæk in Danmark Fjord the tidal readings were realized by means of a temporary tidal staff. The time intervals were July 1, 09.00 U. T.—July 5, 10.30 U. T. and Aug. 3, 17.00 U. T.—Aug. 6, 22.00 U. T., both in 1955. As the number of days are rather insufficient for a thorough harmonic analysis, a kind of trial- and error-method has been used, applying a small tide predicting machine. The accuracy of the obtained harmonic values appears to be tolerable. The harmonic values are presented in table I (No. 43).

Table IV. Jørgen Brönlund Fjord.

82° 11' N, 30° 30' W.

Readings in cm on tidal staff. Year 1947.

Date	U.T.	Height	Date	U.T.	Height	Date	U.T.	Height
Aug. 5	16 <sup>h</sup> 00 <sup>m</sup>	0 cm	Aug. 8	11 <sup>h</sup> 00 <sup>m</sup>	13.5 <sup>2</sup> cm	Aug. 10	00 <sup>h</sup> 00 <sup>m</sup>	5.5 cm
	16 30	- 5		12 00	16.5		01 00	11.5
	17 00	-10		14 00	17.5		02 00	16.5
	17 30	-12		15 00	31.5		03 00	21.0
	18 00	-15		16 00	32.5		04 00	27.0
	18 30	-20		17 00	30.5		05 00	33.2
	19 00	-25		18 10	25.0		06 00	31.5
	19 30	-30		19 00	20.0		07 00	29.5
	20 00	-30		21 00	10.0		08 00	27.5
	20 30	-35		22 10	5.0		09 00	21.0
	21 00	-35		23 00	5.0		10 00	17.5
	21 30	-35					11 00	14.5
	22 00	-35	Aug. 9	00 00	9.5		12 00	13.5
	23 00	-30		01 00	18.0		13 00	14.3
				02 00	22.5		14 00	19.0
Aug. 6	00 00	-25		03 00	28.0		15 00	22.3
	01 00	-20		04 00	32.0		16 00	22.5
	02 00	-15		05 00	32.0		17 00	24.5
	03 00	-10		06 00	34.0		18 00	25.0
	04 00	-20		07 00	32.5		19 00	21.5
	05 00	-25		08 00	22.0		20 00	17.0
				09 00	19.5		21 00	12.0
	11 00	-20		10 00	14.0		22 00	10.5
	13 00	-10		11 00	13.5		23 00	8.0
	14 00	- 5		12 00	14.5			
	15 00	0		13 00	18.5	Aug. 11	00 00	7.5
	16 00	- 5		14 10	26.0		01 00	11.5
	17 00	-10 <sup>1</sup>		15 00	28.0		02 00	15.0
	19 00	-30		16 00	28.5		17 00	18.0
	20 00	-20		17 00	28.5		18 00	34.5
	23 00	-20		18 00	25.5		20 00	29.0
	24 00	-10		19 00	22.0		21 00	26.0
				20 00	15.0			
				21 00	8.5			
				22 00	5.0			
				23 00	3.0			

<sup>1</sup> The staff has been moved to another place, and a corresponding correction has been added to the following readings on Aug. 6.

<sup>2</sup> A new datum, 39 cm lower than the preceding, has been applied in the days Aug. 8–Aug. 11.

NB. As better material has been obtained at a later instant (cf. the following table), the purpose of the above readings, which was somewhat hampered by the weather- and ice-conditions, may most fittingly be to yield a raw control of the harmonic tidal values, which can be computed on the basis of the better tidal material. By a control of this kind it has been proved, that the above values are consistent with the following tables.

Table V. Jørgen Brönlund Fjord.

82°11' N, 30°30' W.

Readings in cm on tidal staff. Year 1949.

Date	U.T.	Height	Atm.pr. (mb)	Wind (m/sec)	Date	U.T.	Height	Atm.pr. (mb)	Wind (m/sec)	
Sept. 1	12 <sup>h</sup> 00 <sup>m</sup>	44 cm	1026.2	W 6	Sept. 4	00 <sup>h</sup> 00 <sup>m</sup>	31 cm	1021.2	E 2	
	13 00	41	1026.3	W 5		03 00	25	1021.7	E 2	
	14 00	41-42	1026.1	W5-6		06 00	30	1021.0	E 3	
	15 00	45	1026.1	W5-6		09 00	48	1021.2	E 3-4	
	16 00	47	1025.9	W 6		12 00	55	1020.8	E 1	
	17 00	?	?	?		15 00	34	1019.9	E 3	
	18 00	47	1026.0	W6-7		18 00	26	1018.9	E 1	
	19 00	46-47	1026.3	W 4		21 00	35	1017.9	E 3-4	
	20 00	45	1026.4	W 4		Sept. 5	00 00	36	1017.6	E 3-4
	21 00	40	1026.7	W3-4			03 00	28	1017.6	0
	22 00	37	1027.1	W3-4			06 00	28	1017.1	0
23 00	34	1026.9	W2-3	09 00	48		1015.7	0		
Sept. 2	00 00	34	1026.9	W3-4	15 00		46	1013.9	W 5	
	03 00	30	1027.1	W 7	18 00		33	1012.8	W1-2	
	06 00	47	1027.4	W 2	21 00		38	1012.1	E 5-6	
	09 00	63	1027.8	E 3	Sept. 6	00 00	45	1011.2	E 6	
	12 00	51	1027.5	0		03 00	40	1009.7	E 5	
	15 00	49	1025.7	0		06 00	30	1008.6	E 6	
	18 00	46	1024.3	W 4		07 00	40	1008.2	E 6	
21 00	48	1023.3	W 4	08 00		45	1008.1	E 4		
Sept. 3	00 00	44	1022.5	W3-4		09 00	53	1007.5	E 4-5	
	03 00	48	1021.6	W1-2		10 00	59	1007.2	E 5	
	10 00	55	1020.5	W 6	11 00	64	1006.7	E 5		
	12 00	45	1020.4	W8-9	12 00	72	1006.2	E 5-6		
	15 00	24	1020.0	W 8	13 00	65	1005.4	E 4		
	18 00	33	1019.7	W 6	14 00	60	1005.2	E 4-5		
	21 00	38	1020.7	E 2	15 00	55	1004.9	E 3-4		
					16 15	45	1003.8	E 3-4		
				17 00	40	1003.5	E 4			
				18 00	34	1003.2	E 4-5			
				19 00	37	1003.0	E 4			
				20 00	40	1002.4	E 4			
				21 00	45	1002.4	E 4			
				22 00	50	1002.0	E 3			
				23 00	55	1001.7	E 2			

Table VI. Jørgen Brönlund Fjord.

82° 11' N, 30°30' W.

Readings in cm on tida lstaff. Year 1949.

Date	U.T.	Height	Atm.pr. (mb)	Wind (m/sec)	Date	U.T.	Height	Atm.pr. (mb)	Wind (m/sec)
Sept. 7	00 <sup>h</sup> 00 <sup>m</sup>	58cm	1001.3	E 2	Sept. 9	00 <sup>h</sup> 00 <sup>m</sup>	49cm	996.4	0
	03 00	49	1000.0	SW 1		01 00	53	996.6	W 6
	06 00	37	999.3	0		03 00	47	997.2	SW6
	07 00	40	999.2	SW1		06 00	31	997.5	E 12
	08 00	48	998.7	0		09 00	30	997.2	E 10
	09 00	51	998.4	0		10 00	44	996.7	SSE6
	10 00	61	998.1	WSW3		11 00	49	996.4	SSE5
	14 30	60	997.8	0		12 00	55	996.4	SSE5
	15 00	52	996.2	W1-2		13 15	60	996.4	E 1-2
	16 00	43	995.6	0		14 00	60	996.2	0
	17 00	37	995.5	0		15 00	55	996.4	0
	18 00	32	995.5	0		16 00	45	996.6	0
	19 00	28	994.8	0		17 00	37	997.1	WSW6
	20 00	33	994.7	0		18 00	30	997.4	WSW4
	21 00	34	994.5	0		19 00	25	998.1	WSW6
	22 00	41	994.2	0		20 00	23	998.1	WSW4
	23 00	46	994.2	0		21 00	28	998.8	W3-4
Sept. 8	00 00	50	993.8	0	22 00	30	999.2	WSW2	
	03 00	44	993.0	0	23 00	37	999.8	E 4	
	06 00	34	992.8	S 6	Sept. 10	00 00	45	1000.3	0
	09 00	34	992.6	0		01 00	47	1000.4	0
	10 00	43	992.5	0		02 00	48	1000.4	0
	11 00	58	992.5	0		06 00	36	1001.7	0
	12 00	61	992.5	E 6		07 00	34	1001.9	0
	13 00	62	992.6	0		08 00	33	1002.0	0
	14 00	62	992.6	0		09 00	31	1002.2	0
	15 00	58	993.2	0		10 00	30	1002.4	SW1
	16 00	49	993.6	0		11 00	30	1002.2	0
	17 00	40	993.9	0		12 00	32	1002.0	0
	18 00	32	993.9	0		13 00	35	1002.1	0
	19 00	28	994.8	E 2-3		15 00	40	1001.4	WSW2
	20 00	28	995.2	E 2-3		18 00	28	1001.0	WSW0-1
21 00	34	995.5	0	21 00		20	1001.0	WSW4	
22 00	39	995.7	0						
23 00	46	996.3	0						

Table VII. Jörgen Brönlund Fjord.  
82°11' N, 30°30' W.

Readings in cm on tidal staff. Year 1949.

Date	U.T.	Height	Atm. pr. (mb)	Wind (m/sec)	Date	U.T.	Height	Atm. pr. (mb)	Wind (m/sec)
Sept. 11	00 <sup>h</sup> 00 <sup>m</sup>	42cm	1001.6	WSW5	Sept. 15	00 <sup>h</sup> 00 <sup>m</sup>	17cm	1017.7	0
	03 00	41	1002.6	WSW3		03 00	38	1018.3	0
	06 00	30	1002.0	0		06 00	41	1018.9	0
	09 00	24	1001.6	E 5		09 00	27	1019.9	0
	12 00	44	1000.2	E 6		12 00	22	1020.6	0
	15 00	50	997.1	E 7		15 00	28	1020.1	0
	19 00	30	995.1	E 1-2		19 00	21	1019.7	0
	21 00	27	994.3	0		21 00	17	1019.5	0
Sept. 12	00 00	47	993.8	WSW5	Sept. 16	00 00	18	1019.5	0
	03 00	49	994.5	W 8		03 00	35	1019.8	W 3
	06 00	41	995.5	W 10		06 00	41	1019.3	0
	09 00	29	997.4	W 11		09 00	42	1018.9	SE 4
	12 00	40	998.9	W 13		12 00	27	1019.1	SE 2
	15 00	37	1000.0	W 14		15 00	28	1017.8	0
	18 00	35	1000.7	W 16		18 00	28	1017.5	0
	21 00	24	1002.9	W 14		21 00	21	1017.9	0
Sept. 13	01 00	38	1005.1	W 10	Sept. 17	00 00	20	1018.1	0
	03 00	39	1008.2	W 14		03 00	37	1018.6	0
	07 00	23	1011.3	W 12		06 00	41	1018.6	0
	09 00	15	1012.9	W 13		09 00	40	1018.7	E 2-3
	13 00	20	1015.4	W 10		12 00	31	1018.1	ESE4-5
	15 00	29	1015.8	W 11		15 00	27	1016.8	0
	19 00	10	1016.5	W 6		19 30	26	1015.8	S 1
	21 00	6	1017.0	W 5		21 00	24	1015.6	0
Sept. 14	00 00	17	1017.6	0	24 00	19	1015.0	S 1-2	
	03 00	35	1017.6	WSW2					
	06 00	36	1017.5	SSE2					
	09 00	19	1017.7	SE 3					
	12 00	18	1017.8	0					
	16 00	26	1017.0	SE 3					
	19 00	21	1017.0	SE 3					
	21 00	12	1017.0	SE3-4					

Table VIII. Kap Holbæk.

abt. 80°40' N, 23°30' W.

Readings in cm on tidal staff. Year 1955.

Date	U.T.	Height	Atm. pr. (mb)	Wind (knot)	Date	U.T.	Height	Atm. pr. (mb)	Wind (knot)
July 1	09 <sup>h</sup> 00 <sup>m</sup>	50.0 cm	1014.9	SSW 6	July 4	01 <sup>h</sup> 00 <sup>m</sup>	35.0 cm		N E 22
	10 00	48.0				02 00	32.0		
	11 00	45.0				08 30	ca. 40.0		
	12 00	43.0	1015.6	S 4		11 00	ca. 61.0		
	13 00	40.0				12 00	59.0	1006.0	NE 25
	14 00	33.0				13 00	57.5		
	15 00	28.0	1016.6			14 00	53.5		
	16 00	25.0				15 00	47.5		
	17 00	24.0				16 00	41.0		
	18 00	25.0	1014.6	NE 5		17 00	32.0		
	19 00	28.0				18 00	27.0	1005.3	NE 20
	20 00	27.0				19 00	25.0		
	21 00	30.0				20 00	29.0		
	22 00	28.5				21 00	32.0		
23 00	28.5			22 00	32.5				
24 00		1014.2	NE 3	23 00	35.0				
July 2	09 00	49.0	1012.5		July 5	01 00	36.5		
	11 00	50.0				02 00	34.5		
	12 00	52.0	1012.0	NE 5		03 00	29.0		
	13 00	45.0				04 00	25.0		
	14 00	42.0				05 00	24.0		
	15 00	38.0				06 00	27.5		
	17 15	26.0				07 00	32.0		
	18 00	24.0	1009.3	NE 2		08 00	37.0		
	21 00	30.0				09 00	44.0		
	22 00	30.5				10 00	54.0		
	23 00	30.5				10 30	59.0		
24 00	34.0	1008.0	0	12 00		1003.3	NE 12		
July 3	10 30	58.0							
	11 00	60.0							
	12 00	58.0	1004.6	NE 10					
	14 00	50.0							
	16 00	38.0							
	17 00	31.0							
	18 00	28.0	1004.2	NE 15					
	19 00	30.0							
	20 00	30.0							
	21 00	35.0							
	22 00	34.0							
23 00	36.0								
24 00	35.0	1004.8	NE 22						

Table IX. Kap Holbäk.

abt. 80°40' N, 23°30' W.

Readings in cm on tidal staff. Year 1955.

Date	U.T.	Height	Atm. pr. (mb)	Wind (knot)	Date	U.T.	Height	Atm. pr. (mb)	Wind (knot)
Aug. 3	17 <sup>h</sup> 00 <sup>m</sup>	12.5 cm		0	Aug. 4	09 <sup>h</sup> 00 <sup>m</sup>	12.0 cm	1016.8	0
	17 30	8.5		0		09 30	17.5		0
	18 00	6.0	1014.2	0		10 00	22.0		0
	18 30	5.0				10 30	25.5		
	19 00	4.5		NE 2		11 00	30.0		
	19 30	3.5		NE 2		11 30	32.5		
	20 00	5.5		NE 3		12 00	35.0	1015.6	S 3
	20 30	7.5		NE 3		12 30	36.0		
	21 00	9.0	1014.8	NE 4		13 00	36.5		
	21 30	11.0				13 30	35.5		
	22 00	12.5				14 00	35.0		
	22 30	13.5				14 30	32.0		
	23 00	16.0				15 00	28.2	1014.9	0
	23 30	17.0		0		15 30	24.0		changing
	24 00	17.5	1015.3	0		16 00	20.0		0
						16 30	14.0		0
Aug. 4	00 30	18.5		0		17 00	10.5		0
	01 00	17.5		0		17 30	7.5		0
	01 30	15.0		0		18 00	4.0	1014.1	0
	02 00	14.0		0		18 30	0.5		0
	02 30	13.0		0		19 00	0.0		0
	03 00	8.0		0		19 30	0.0		0
	03 30	5.0		0		20 00	1.0		0
	04 00	3.5		0		20 30	2.5		NE 2
	04 30	0.5		0		21 00	3.0	1013.9	NE 2
	05 00	0.0		0		21 30	5.0		NE 2
	05 30	-2.0		0		22 00	7.0		NE 2
	06 00	-2.5		0		22 30	11.5		E 2
	06 30	-3.0		NW 1		23 00	14.0		E 2
	07 00	-1.5		0		23 30	16.5		
	07 30	0.0		0		24 00	17.5	1015.4	S 2
	08 00	4.5		0					
	08 30	8.0		SW 1					

Table X. Kap Holbæk.

abt. 80°40' N, 23°30' W.

Readings in cm on tidal staff. Year 1955.

Date	U.T.	Height	Atm. pr. (mb)	Wind (knot)	Date	U.T.	Height	Atm. pr. (mb)	Wind (knot)
Aug. 5	00 <sup>h</sup> 30 <sup>m</sup>	18.5 cm		0	Aug. 5	20 <sup>h</sup> 00 <sup>m</sup>	-1.5cm		
	01 00	19.0				20 30	0.5		
	01 30	20.5		NE 2		21 00	1.0	1011.3	0
	02 00	18.5		NE 4		21 30	5.5		
	02 30	15.5		NE 3		22 00	8.5		
	03 00	13.5	1015.7	NE 6		23 40	17.5		
	03 30	12.5		NE 8		24 00	17.8	1012.6	0
	04 00	8.0		NE 8					
	04 30	7.0		NE 8	Aug. 6	00 30	21.0		
	05 00	4.0		NE 8		01 00	22.0		
	05 30	3.0		NE 8		01 30	23.0-24.0		
	06 00	0.5	1016.0	NE 8		02 00	22.0-23.0		
	06 30	0.0		NE 8		04 30	11.0-12.0		
	07 00	-2.0		NE 8		10 00	14.5		
	07 30	-3.0		NE 5		10 30	19.5		
	08 00	1.5		NE 2		11 00	23.0		
	08 30	5.5				11 30	25.5		
	09 00	7.5	1016.0	0		12 00	29.0	1008.9	SW 5
	09 30	12.0		0		12 30	33.0		SW 6
	10 00	15.5		0		13 00	37.0		SW 5
	10 30	21.0		0		13 30	39.0		SW 5
	11 00	25.0		0		14 00	40.0		SW 5
	11 30	28.0		0		14 30	39.0		SW 5
	12 00	30.0	1014.8	0		15 00	36.0	1008.2	SW 5
	12 30	35.0		0		15 30	33.0		SW 5
	13 00	35.5				16 00	29.0		SW 5
	13 30	37.0				16 30	26.0		SW 6
	14 00	34.0				17 00	21.0		SW 6
	14 30	32.0				17 30	17.0		SW 6
	15 00	30.5	1013.7	0		18 00	14.0	1006.6	SW 8
	15 30	27.0				18 30	11.0		SW 8
	16 00	23.5				19 00	7.0		SW 8
	16 30	19.5		0		19 30	5.0		SW 8
	17 00	16.0		0		20 00	3.0		SW 8
	17 30	11.0		0		20 30	2.0		SW 8
	18 00	8.5	1012.8	0		21 00	2.0	1006.4	SW 8
	18 30	4.5				21 30	3.0		SW 8
	19 00	1.5				22 00	7.0		SW 8
	19 30	÷1.0				24 00		1007.3	

## VII. РЕЗЮМЕ

В настоящем труде обсуждается вопрос об астрономических приливе и отливе в Арктическом океане с учётом статических и динамических условий. Наблюдательный материал охватывает различный уже опубликованный материал, но, кроме того, и новый материал, в частности, из Северо-Восточной Гренландии. Несмотря на то, что в общем выводе можно считать, что прилив и отлив в Арктическом океане вызываются и тесно связаны с весьма сильно развитыми приливом и отливом в Гренландском море к востоку от Гренландии, то из этого, все же, следует, что необходимо также учитывать существование внутренне развитых прилива и отлива в Арктическом океане. Признав это, мы считаем, однако, странным, что частичные приливы и отливы почти с суточными периодами, - так называемые суточные приливы и отливы, - почти во всех частях Арктического океана менее развиты, чем полусуточные приливы и отливы, поскольку можно будет сделать и противоположный вывод, если принять в соображение теоретические равновесные прилив и отлив в Арктическом океане. "Об ясном может послужить то, что в более глубокой и главной части Арктического океана происходит мамонтовая осцилляция. Амфидромные системы не являются там частыми, вследствие больших глубин и соответствующих слабых течений приливов и отливов.

Что касается амплитуды волн частичных прилива и отлива в Арктическом океане и вблизи него, то можно отметить, что амплитуда  $M_2$  равняется приблизительно 100 см у северного норвежского побережья и в проливе вдоль Северо-западной Гренландии. Амплитуды  $M_2$ , доходящие до 50 см, встречаются у западного побережья норвежской группы островов Шпицберген и у побережья Восточной Гренландии. Во внутренних частях Арктического океана амплитуда  $M_2$  имеет порядок величины 10 см или менее. Амплитуда  $S_2$  в большинстве случаев составляет между одной третью и половиной амплитуды  $M_2$ . Что касается амплитуды волн суточных прилива и отлива, то амплитуда  $K_1$  равняется 30-40 см в вышеуказанном проливе вдоль Северо-западной Гренландии, но менее 10 см в большинстве других арктических районов. Амплитуда  $O_1$  еще менее, чем в большинстве случаев амплитуда  $K_1$ ; в некоторых случаях она равняется приблизительно лишь половине или одной трети амплитуды  $K_1$ .

## VIII. LITERATURE

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