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Spatial variation of the K1, O1, and M2 constituents of the southern Ross Sea tide

E. S. ROBINSON, R. T. WILLIAMS, *and* H. A. C. NEUBURG

Department of Geological Sciences
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

We completed our survey of the southern Ross Sea tide during the 1977-78 antarctic field season by measuring tidal variations of gravity for 39 days at site O-19 (79.6°S. 196.7°W.) and for 30 days at site C-16 (81.2°S. 189.5°W.). Results from C-16 are in close agreement with those we obtained there 1 year earlier. Measurements were repeated at C-16 to help us evaluate the reliability of our recording gravimeters. Field operations at O-19 and C-16 were similar to those described by Robinson *et al.* (1977) for the other six sites we have occupied since beginning our survey in 1973. Measurements at these sites (figure 1) and earlier results from Little America (Thiel *et al.*, 1960) and McMurdo Sound (Heath, 1971) provide information about the ocean tide at 10 locations (table) over the southern Ross Sea.

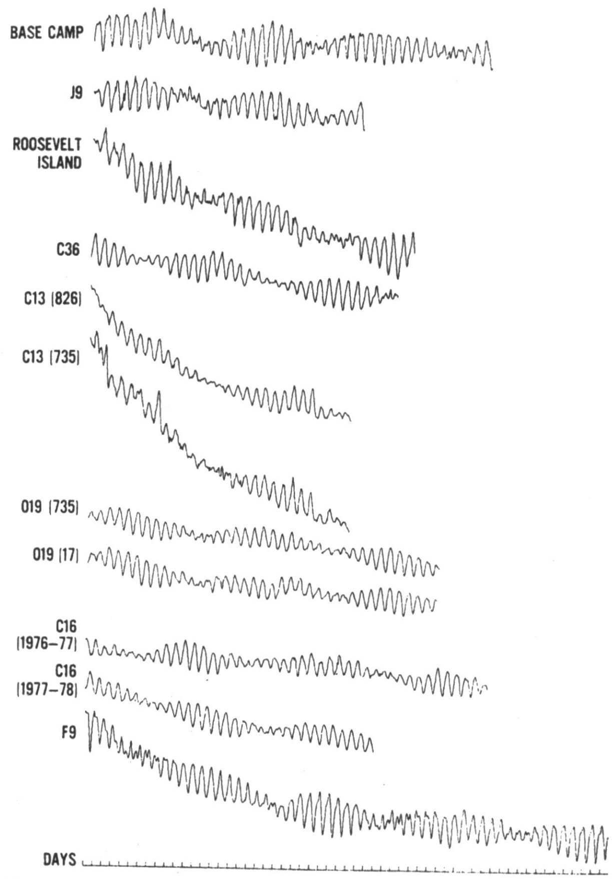

Figure 1. Tidal gravity records from eight locations on the Ross Ice Shelf.

Tidal harmonic constituents in the southern Ross Sea.

Site	Record length[a]	K1		P1		O1		M2		S2		N2	
		A[b]	P[c]	A	P	A	P	A	P	A	P	A	P
Base(82.5°S.-166.0°W.)	44	43	186	14	186	35	174	8	213	10	112	9	87
J9(82.4°S.-168.6°W.)	30	37	191	12	191	37	172	7	205	8	106	7	60
RI(80.2°S.-161.6°W.)	36	44	160	15	160	38	140	5	130	10	26	9	12
C36(79.8°S.-169.1°W.)	34	37	160	12	160	32	153	3	75	6	25	4	22
C13(79.3°S.-180.7°W.)	29	30	200	10	200	34	190	3	300	4	130	5	153
O19(79.6°S.-196.7°W.)	39	31	208	10	208	29	196	4	340	2	190	3	180
C16(81.2°S.-189.5°W.)	76	31	200	10	200	27	190	3	310	2	160	4	140
F9(84.3°S.-171.3°W.)	58	41	206	14	206	40	190	8	258	11	142	8	143
LAS(78.2°S.-162.3°W.)	30	34	154	11	154	25	141	3	35	5	342	5	344
McM(77.9°S.-193.4°W.)	—	23	212	8	213	21	195	4	242	2	327	2	263

[a]Record length in days.
[b]Amplitude in centimeters.
[c]Phase angle in degrees relative to the Greenwich Meridian.

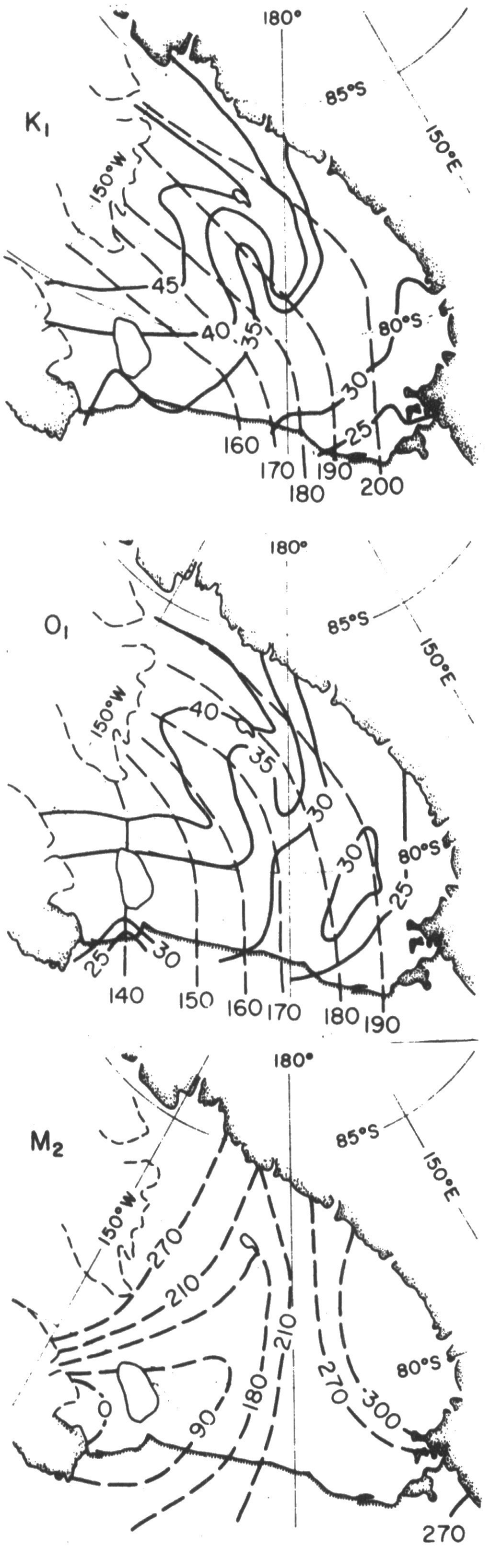

Figure 2. Cotidal-coamplitude charts of the K1 and O1 ocean tidal constituents, and a cotidal chart of the M2 constituent in the southern Ross Sea. (Cotidal lines indicate times, expressed in degrees rather than hours, of simultaneous high tide relative to the Greenwich Meridian. Coamplitude contours are loci of points of equal tidal amplitude expressed in centimeters.)

We calculated amplitudes and phase angles of the ocean tidal constituents K1, P1, O1, M2, S2, and N2 from tidal variations of gravity (Robinson *et al.*, 1977). The results (see table) show the dominance of the diurnal constituents. These results indicate patterns of spatial variation that are displayed on cotidal-coamplitude charts for the K1 and O1 constituents and on a cotidal chart for the M2 constituent (figure 2). The coamplitude contours on the diurnal charts show more irregularity than at first may seem justified by measurements from only 10 locations. However, comparison of tidal amplitudes and water-layer thicknesses at these locations (figure 3) indicates an apparent relationship that we used to estimate positions of the coamplitude contours. Analysis of the propagation of long waves in a canal of varying cross-section (Lamb, 1932) indicates amplitude (A) dependence on the inverse 4th root of water thickness (h), and a constant (b) related to canal width. Therefore, assuming that b is related in some way to the distance between trajectories taken in the direction of propagation of the diurnal tidal constituents, we fitted curves of the form $A = bh^{-.25}$ to our data (figure 3). We propose to study the amplitude-depth relationship more thoroughly. In the meantime we have used these curves

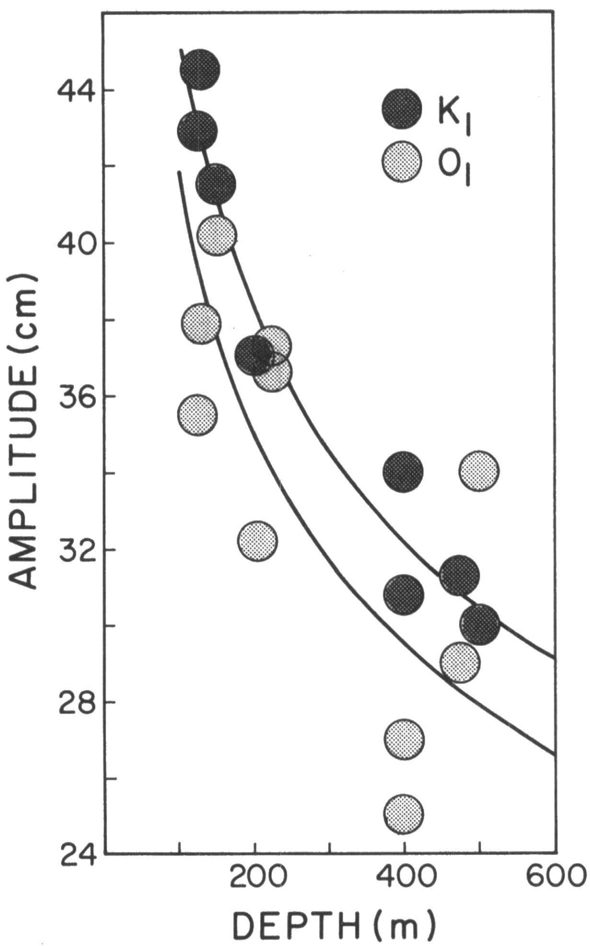

Figure 3. Comparison of K1 and O1 tidal amplitudes (A), in centimeters, and water-layer thickness (h), in meters, at nine sites on the Ross Ice Shelf. (Curves have the form $A = bh^{-.25}$, where b = 144 for the K1 constituent, and b = 132 for the O1 constituent.)

together with the recent map of water thickness (Greischar and Bentley, 1978) to guide the location of K1 and O1 coamplitude contours.

The southern Ross Sea tide is dominated by the diurnal constituents, so it is different from most parts of the ocean where the semi-diurnal constituents are largest. Amplitudes of the K1, P1, and O1 constituents are much too large to be explained simply in terms of equilibrium tide theory. Resonance related to the shape of the embayment and water-layer thickness variations amplify these constituents and control their direction of propagation. Wavelengths of the diurnal constituents are seen (figure 2) to be approximately 4 times the length of the Ross Sea measured in the direction of progressing tide from the edge of the continental shelf. This is a condition for diurnal resonance.

Spatial variation of the M2 constituent is considerably more complicated. There is no simple relationship between amplitude and water-layer thickness. Different empirical cotidal charts that could be compiled from our data (see table) must also be consistent with the M2 tide in the south Pacific that borders the Ross Sea. One pattern (figure 2) displays no actual amphidromes within the Ross Sea and merges with the global M2 cotidal chart of Zahel (1970). Other patterns requiring at least two amphidromes in the Ross Sea are also consistent with the results of Zahel.

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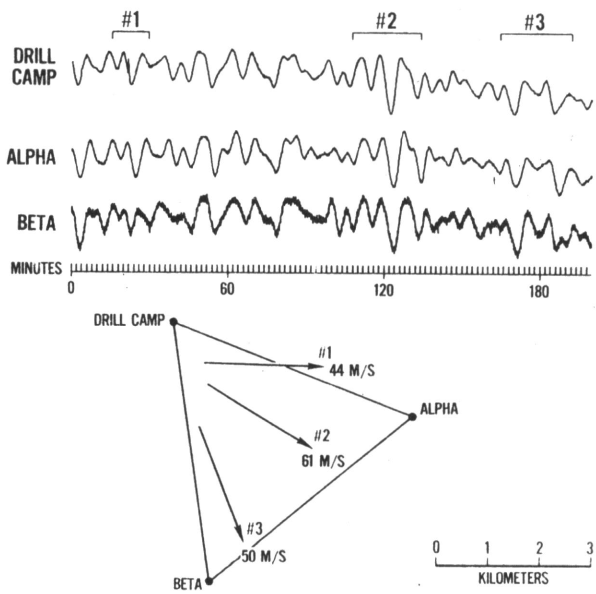
Ocean wave measurements at the RISP J-9 camp

R. T. WILLIAMS, E. S. ROBINSON *and* H. A. C. NEUBURG

Department of Geological Sciences
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Waves having periods of between 1 minute and 15 minutes propagate in the ocean beneath the Ross Ice Shelf. These waves produce gravity fluctuations on the ice shelf surface that are related to changing elevation and water mass. During November 1977 we operated three gravimeters near the J-9 Camp (82.4°S.168.6°W.) in a 5-kilometer triangular array (see figure) to determine the velocity and direction of these ocean waves. Gravimeter output was recorded at 4-second intervals on magnetic tape cassettes using microprocessor-based digital recording systems of our own design. The three instruments operated simultaneously for a total of 58 hours.

We have completed a preliminary analysis of the three wave groups indicated on the simultaneous record segments in the figure. Vectors representing the velocity and propagation direction of these wave groups were determined from time shifts of corresponding peaks and troughs along the different sides of the triangular recording array. The velocities of these three wave groups are reasonably close to the value of 48 meters per second expected for a long gravity wave in the water layer, which is 238 meters thick at J-9. Their directions of propagation are consistent with the supposition that they have traveled from the northern Ross Sea into the ocean beneath the ice shelf.



Simultaneous gravimeter records from three sites in a triangular array near J-9 display fluctuations produced by ocean waves. (Vectors represent the velocity and direction of the three separate wave groups that are marked on the gravimeter records. M/S=meters per second.)