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Diurnal and Semi-Diurnal Tides on the Great Barrier Reef

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DIURNAL AND SEMI-DIURNAL TIDES ON THE GREAT BARRIER REEF

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Abstract

Tidal amplitude and phase constants for constituents Q_1, O_1, P_1, K_1, N_2, M_2, L_2, S_2 and K_2, for the Great Barrier Reef area are presented and discussed. Graphs of the constants at the coast are given as functions of latitude. The relations between P_1 and K_1, K_2 and S_2 from series longer than 182 days are tabulated, together with their means.

Introduction

This report presents a collation of available tidal amplitude and phase constants for the Great Barrier Reef Area, for the main constituents in the diurnal and semi-diurnal tidal bands. The aim is to make existing data more readily available to research workers. No attempt has been made to interpret the data.

The Data

Amplitude and phase constants for the following nine constituents were extracted:

Q_1, O_1, P_1, K_1, N_2, M_2, L_2, S_2, K_2,

These constituents were chosen because they are most likely to be available from analyses of short lengths of data, and because they account for most of the tidal variance in the diurnal and semidiurnal bands (for example, 99.3% and 99.2%, respectively, at Townsville). The same set has been chosen for a recent world tidal model study by Schwiderski (1980).

The following guidelines were adopted in choosing data for inclusion in the file:

- The constants should be based on the analysis of at least 28 days of data.
- Stations in Torres Strait were not included, as it was felt this area needed special study. Specifically, stations west of 143°30'E and north of 10°50'S were excluded.
- Two stations in Papua New Guinea (Port Moresby and Kaligola I.) were included for reference, but stations further east, in the Louisade Archipelago, have not been included.
- Four stations south of the main part of the Reef (Bundaberg, Fraser I., Brisbane, Danger Point) were included for reference.
- When more than one set of constants was available for a given station, all were included.

Inferred Constituents

A record length of at least 183 days is usually required for direct estimation of P_1 or K_2 in tidal analyses, since their frequencies differ from those of K_1 and S_2 respectively by only 2 cycle/year. When shorter records are analysed, it is usual to infer the constants for P_1 and K_2 by specifying ratios of the amplitude constants (P_1/K_1, K_2/S_2) and differences in the corresponding phases. The specified ratios and phase differences can be taken from the results at a nearby station where a longer record has been analysed, or from equilibrium theory. If no inference is included in the analysis of records shorter than 183 days, the reported 'constants' for K_1 and S_2 may have errors as high as 20% in amplitude and 20° in phase.

Judging by the absence of constants for P_1 or K_2, many of the data sets received had resulted from analyses in which no inference was included. For these, the necessary inference calculations were made, using the formulae in section 2.3.4. of Foreman (1977) (see also Godin (1972), pp. 179-183). The calculations require the central time and date of the observation set, and its length in hours. Often only the central day and length in days were available, but the resulting errors are small. Equilibrium ratios and phase differences were used, the values being as follows:

	Ratio	Phase lag difference
P_1, K_1	0.331	0.0°
K_2, S_2	0.272	0.0°

Data sets in which this 'post-analysis' inference was used are identified in Table 1 by a 1 in the column headed INF. For other short (i.e. less than 183 days) data sets, it is assumed that inference of P_1 and K_2 was included in the original analysis. In some cases equilibrium ratios and phase differences appear to have been used, and in others the ratios and phase differences for a nearby port were used.

Lennon (private communication) has pointed out that the constituent T_2, whose frequency differs from that of S_2 by 1 cycle/year, should also be inferred in analyses of short data sets, but this is rarely done. Its equilibrium amplitude is 5.9% of the S_2 amplitude, so its exclusion may lead to S_2 amplitude errors of this order, and S_2 phase errors of order 3°.

Checking

The data were checked in two ways.

The first check was a careful inspection of plots of height and phase lag as functions of latitude. The second was an inspection of a listing, in order of latitude, of ratios of amplitude constants to that of K_1 (for Q_1, O_1, P_1) and to that of M_2 (for N_2, L_2, S_2, K_2), and of corresponding phase lag differences. As a result, data for several stations were deleted from the overall data set.

The above checking was probably fairly effective for the main constituents, but less effective for Q_1, and even less for the small and very variable L_2. The checking revealed only those data sets that differed grossly from sets at neighbouring stations, due either to errors in the data or analyses, or to severe local influences. A more careful inspection of the data in Table 1 showed a number of less obvious discrepancies, which are discussed below.

Results

Table 1 shows the data, with stations arranged in order of latitude. The date is the central date, and LENG is the length of data analysed, in days. The entry under CODE identifies the source of each set of constants, as detailed in Table 4. (Note that this may not identify the origin of the original tidal data, nor does it imply that the source was responsible for the analysis.)

The amplitude constants are in millimetres, and the phases are Greenwich Phase Lags for time zone - 10 (g(-10)). (The term 'Greenwich Phase Lag' will be abbreviated to 'phase' in this report.)

Figure 1 shows the position of each station.

Several methods of graphing the data were considered. It was initially planned to prepare co-range and co-tidal maps for each constituent, but there were not enough offshore data to permit making such maps with confidence for the long narrow reef area. It was decided to limit the graphs to plots of amplitude and phase at the coast (but including a few islands within about 20km of the coast), as functions of latitude. Figures 2-8 show these graphs for Q_1, O_1, K_1, N_2, M_2, L_2 and S_2. Mean curves have been fitted by eye, except for L_2. P_1 and K_2 have not been plotted, since constants for these two constituents have been obtained by inference in the majority of cases, so they do not include new information. Variation in the offshore direction is discussed below.

Where more than one set of data for a particular station appears in Table 1, only the set based on the longest record, or on the most recent record, is chosen for plotting. The chosen sets are identified by numbers preceding the station names in Table 1.

Accuracy

It is not usual for tidal analysts to publish, or even compute, estimates of the probable errors in tidal constants, although methods for doing this (based on the residual variance) are available (e.g. Godin (1972), p211). One can get a subjective idea of accuracy by comparing results where more than one analysis has been made at a particular station, and such multiple sets of data have been included in Table I for this purpose. Objective estimates could probably be obtained by pooling the differences in all the multiple sets, with due regard for lengths of data, but this has not been attempted. Since some idea of accuracy is almost essential in trying to interpret Figures 2-8, I have added error bars based on observed variability of the relevant constants from 29 separate 369-day analyses of data for Fort Denison (Sydney Harbour) (Lennon, Hamon and Greig in preparation). The error bars shown are $\pm 2k\sigma$, where σ is the standard deviation from the Fort Denison data set, and k (= $(369/29)^{\frac{1}{2}}$) converts the estimate to the shorter data span of 29 days, which is the length of record in most of the Reef data. These error bars are intended only as a very rough guide for use in interpreting Figures 2-8. They may underestimate the errors from 29-day analyses, since they do not take into account the perturbations due to constituents that have not been inferred, such as T_2.

Main features of tidal constants at coastal stations

Discussion will be confined to stations south of 11°S, i.e. the four stations in Papua New Guinea will not be considered.

(a) Semi-diurnal (N_2, M_2, L_2, S_2)

L_2 (Figure 7) is very variable particularly in phase, so not much more can be said about it. Lennon (private communication) has been investigating reasons for this, and has a paper in preparation. Since the variability is so marked, the L_2 constants should not be used for prediction.

N_2, M_2 and S_2 (Figures 5, 6, 8) show many common features. With increasing latitude, amplitudes and phases first decrease (11°-13°S), then remain relatively constant (13°-20°S) before increasing sharply towards Broad Sound (22.5°S). There is then a discontinuity in the graph, corresponding to the more-or-less east-west orientation of the coast across the entrances to Broad Sound and Shoalwater Bay. South of 22.5°S, the phases and amplitudes decrease again, fairly rapidly.

Minor peaks in the amplitude graphs appear at 14°S for N_2, M_2 and S_2, and at 19°S for N_2 and S_2.

All six graphs (and the amplitude graph for L_2) have their maxima at the one station, McEwin I., just inside the entrance to Broad Sound.

The phase of S_2 is about 24° less than that of M_2 in latitudes 11-13°S, but 14° greater in latitudes 23-25°S. The corresponding S_2/M_2 amplitude ratios are 0.65 (11-13°S) and 0.35 (23-25°S).

(b) Diurnal (Q_1, O_1, K_1)

Q_1 (Figure 2) has the smallest amplitude, and the most variable phase. There is a weaker amplitude maximum about 22°S, and amplitude appears to increase with latitude, 11°-13°S.

O_1 and K_1 (Figures 3,4) have amplitude and phase graphs generally similar to one another, as might be expected. They have amplitude maxima at 22°S, and probably a discontinuity there in amplitude and phase, as found in the semi-diurnal tides. The amplitude ratio O_1/K_1, varies from 0.46 at 11°-13°S to 0.52 at 23°-25°S. The phase of O_1 is less than that of K_1 by about 41° over the latitude range 12°-25°S.

Offshore Islands

(a) 11°-19°S.

In this northern part of the Reef, away from the Broad Sound area, it seemed worth while to compare amplitudes and phases at offshore islands with the corresponding quantities at the coast, at the same latitude as each island. The amplitude ratios (island/coast) and phase differences Δg (coastal g minus island g), are given in Table 2, together with approximate distances offshore. The coastal values were read from the smooth curves fitted to Figures 2-8.

Although there are a number of anomalies, the following appear to be the main features of the data in Table 2: (i) Amplitude ratios are slightly less than 1.00, and are smaller for the semidiurnal tides than for the diurnal tides. (ii) Phase differences tend to be positive and small (less than 10°). Only for Raine I. are the semi-diurnal phase differences appreciably different from those of the two principal diurnal constituents, O_1 and K_1.

It is hard to accept the difference in Δg between M_2 (35°) and S_2 (1°) for Bougainville Reef, so that the analysis for this station should be regarded as very doubtful. Boland (personal communication) has advised that the data for Bougainville were obtained from a bottom-mounted pressure recorder situated in a shallow position inside the lagoon; this poor location might be responsible. The amplitude ratios appear normal.

The amplitude ratios for Beaver Reef are inconsistent with all others. No explanation has been found for such large values.

The tendency to negative phase differences (phase lags greater at the islands than at the coast) for the more southerly island stations may be due to nearness to Broad Sound.

(b) 19°-25°S.

The constants for Hook, Carlisle, Scawfell and Penrith Islands generally agree with those at the coast at the same latitudes, but the rapid variations of coastal amplitude and phase with latitude in this part of the coast made it impossible to get meaningful ratios and differences of the kind shown in Table 2. The large differences between semi-diurnal constants for the two sets of data in Table 1 for Penrith I. may be noted.

Further south, the amplitudes at offshore islands are nowhere as large as those at McEwin I. (with one exception - Q_1 for North West I.), confirming the relatively local nature of the amplification near Broad Sound.

The maximum separation within the group of four islands in the Capricorn Group (Tryon, North West, Heron and One Tree) is only 40 km, so they would be expected to have similar tidal constants. The spread in phase is 10° and 15° for M_2 and S_2 respectively. Amplitudes range from 796 to 1090mm for M_2, and from 307 to 415mm for S_2. These ranges appear large, and the relation to latitude is not a simple one, so the results for this group should be treated with caution.

At Fraser I., amplitudes in the semi-diurnal band are very small compared to Urangan or Bundaberg - only about one-half for M_2, for example. The agreement is much better for diurnal amplitudes. The Fraser I. results should be regarded as doubtful, as such large changes in M_2 amplitude are unlikely.

Constants for P_1 and K_2

The only independent (non-inference) estimates of amplitudes and phase lags for P_1 and K_2 are summarized in Table 3, in the form of amplitude ratios (P_1/K_1, and K_2/S_2) and phase lag differences ($g(K_1)-g(P_1)$ and $g(S_2)-g(K_2)$). The ratios and phase lag differences are close to the equilibrium values, but the differences are significant, especially for the pair P_1, K_1. There does not appear to be any clear dependence of amplitude ratio or phase lag difference on latitude in either case.

In future analyses of short records for the Reef area, it must be decided if the mean values in Table 3 should be used for inference, or the values from the nearest station. The standard deviations in Table 3 are of the order that one would expect from the standard deviations of the individual amplitudes and phases at Fort Denison. Together with the lack of dependence on latitude, this suggests that the variability in Table 3 is due to chance, and not to real effects near each station, and that the mean values should be used for inference, at least until more data are available.

The inferred constants in Table 1 for P_1 and K_2 could have been corrected approximately for the difference between equilibrium values and the relevant means in Table 3, but this has not been done.

(Note that, in spite of the long records, inference appears to have been used in the original analyses for Magnetic I. and Fraser I. The data sheets note that the results are 'vector means of four sets', or 'five sets', respectively. The length of each set was not stated. Inference has probably also been used for Rocky I., since the phase lag differences are 0.0 for both pairs P_1, K_1 and S_2, K_2, though the reason is not clear in this case.)

Discussion

At first glance, Figure 1 might be interpreted as representing an adequate coverage of the reef area, since it shows 74 stations for which constants based on at least 28 days of data are available. However, on more detailed inspection the coverage is far from adequate.

Figures 5-8 stress the narrow range of latitudes (approx 20-24°S) affected by the well-known amplification in the semi-diurnal band near Broad Sound. In this range, tidal constants change rapidly, both coastwise and in the off-shore direction. Particularly in this area, there are not enough data from the outer edge of the Reef.

Apart from possible analysis errors, some of the data reported are almost certainly influenced by local effects, such as position of the gauge within a bay or river mouth. The larger M_2 lags for McIvor River, Normanby River and Brisbane, relative to the mean curve, are probably due to such effects. (The constants for Danger Point (28°10'S) were included because it was felt they more nearly represent conditions well south of the Reef than do the Brisbane constants. Tidal effects within Moreton Bay are discussed by Milford and Church (1977).)

Some of the more recent analyses are based on data from bottom-mounted pressure recorders. If these are sited where there are strong currents, errors may be introduced due to dynamic effects of the flow in the immediate vicinity of the pressure sensor (Muir 1978).

Re-analysis of some of the earlier data sets would almost certainly be worth while, using the latest analysis and error-checking techniques.

All lists of constants received have been sent to Flinders Institute of Atmospheric and Marine Science, Flinders University, South Australia, for inclusion in their national tidal data bank. This appeared to be the best way to make available the constants for constituents other than the nine chosen for this report, and to ensure updating.

Acknowledgements

In addition to those who contributed constants (Table 4), I would like to thank Dr E. Wolanski, who collected and made available some of the data analysed by CSIRO. Computer time for setting up the data file and for plotting was made available by CSIRO Division of Oceanography. Comments from G. Lennon, A. Easton and J. Church are gratefully acknowledged.

References

Foreman, M.G.G. (1977). Manual for tidal heights analysis and prediction. Inst. Ocean Sci., Patricia Bay, Canada, Rept. 77-10, 97 pp (unpublished ms).

Godin, G. (1972). The Analysis of Tides. Liverpool University Press. 264pp.

Milford, N. and J. Church (1977). Simplified circulation and mixing models for Moreton Bay, Queensland. *Australian Journal of Marine and Freshwater Research* **28**, 23-34.

Muir, L.R. (1978). Bernoulli effects on pressure - activated water level gauges. *International Hydrographic Review* **55**, 111-119.

Schwiderski, E.W. (1980). On charting global ocean tides. *Review of Geophysics and Space Physics* **18**, 243-268.

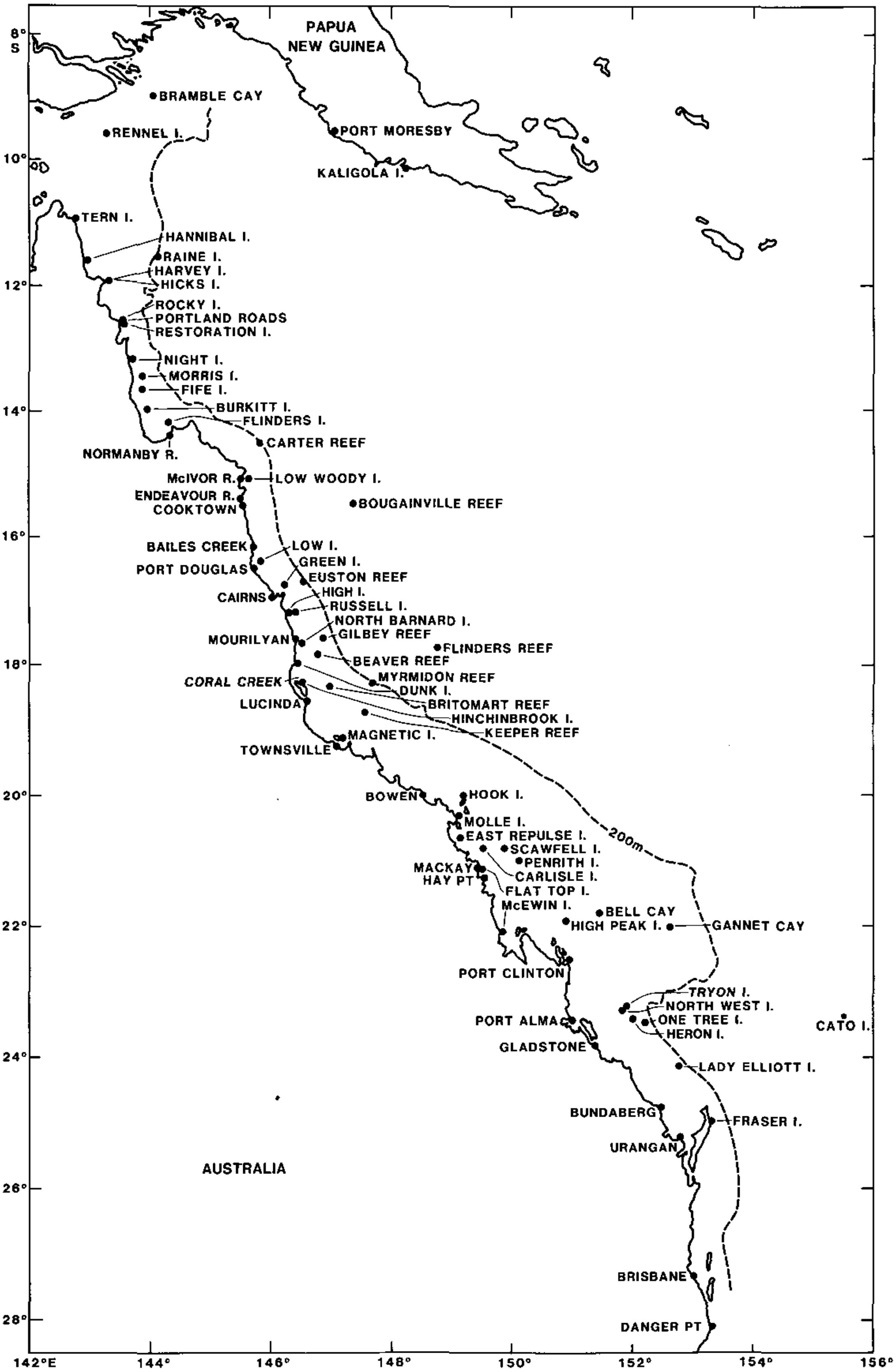

Figure 1 Positions of Tidal Stations.

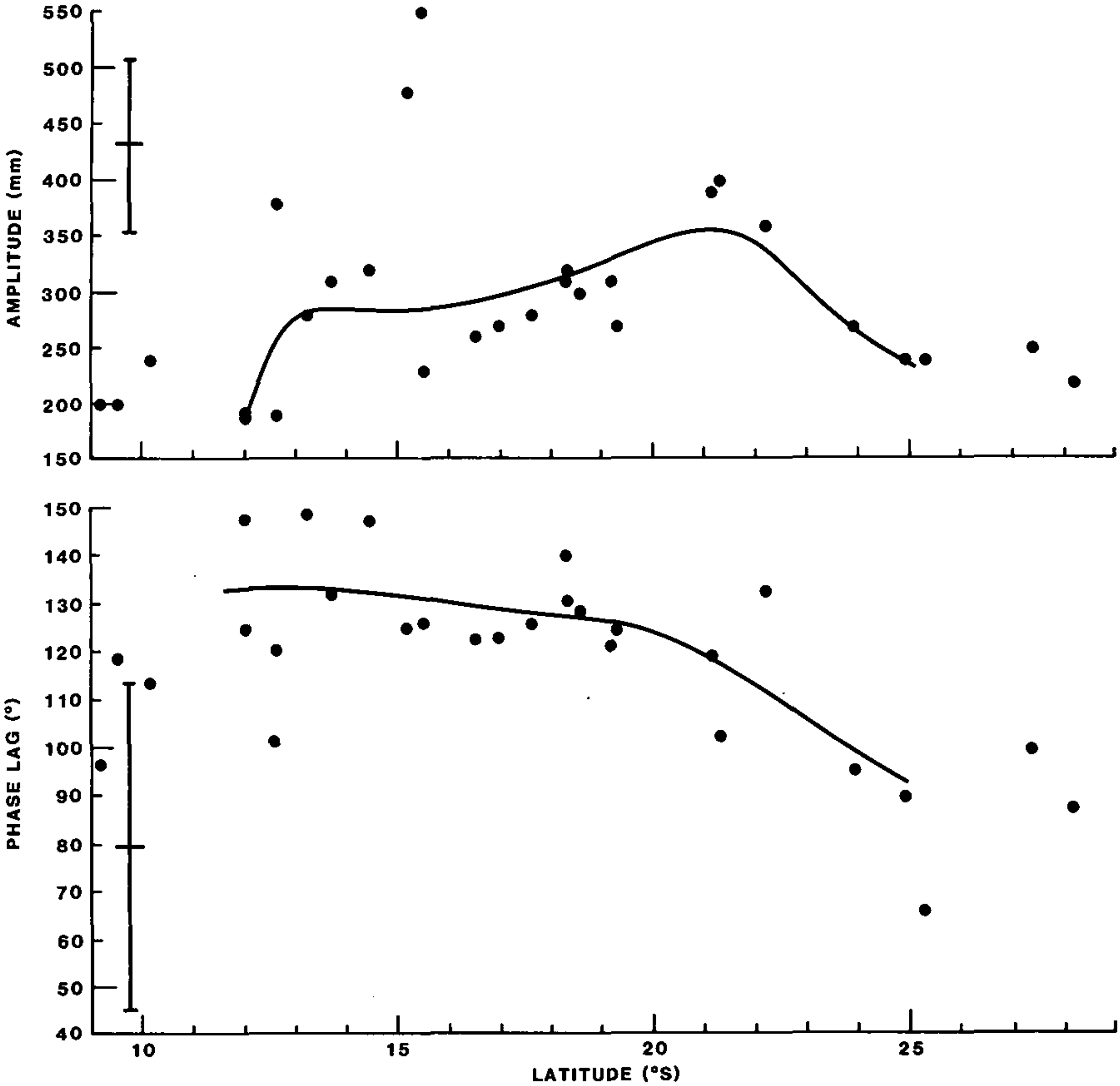

Figure 2 Amplitude and phase as functions of latitude for the constituent Q_1, for coastal and near-shore islands. The mean curves have been fitted by eye for the latitude range 11-25°S. Vertical bars are ± 2 x (standard deviation) for 29 day analyses, estimated from Fort Denison results (see text).

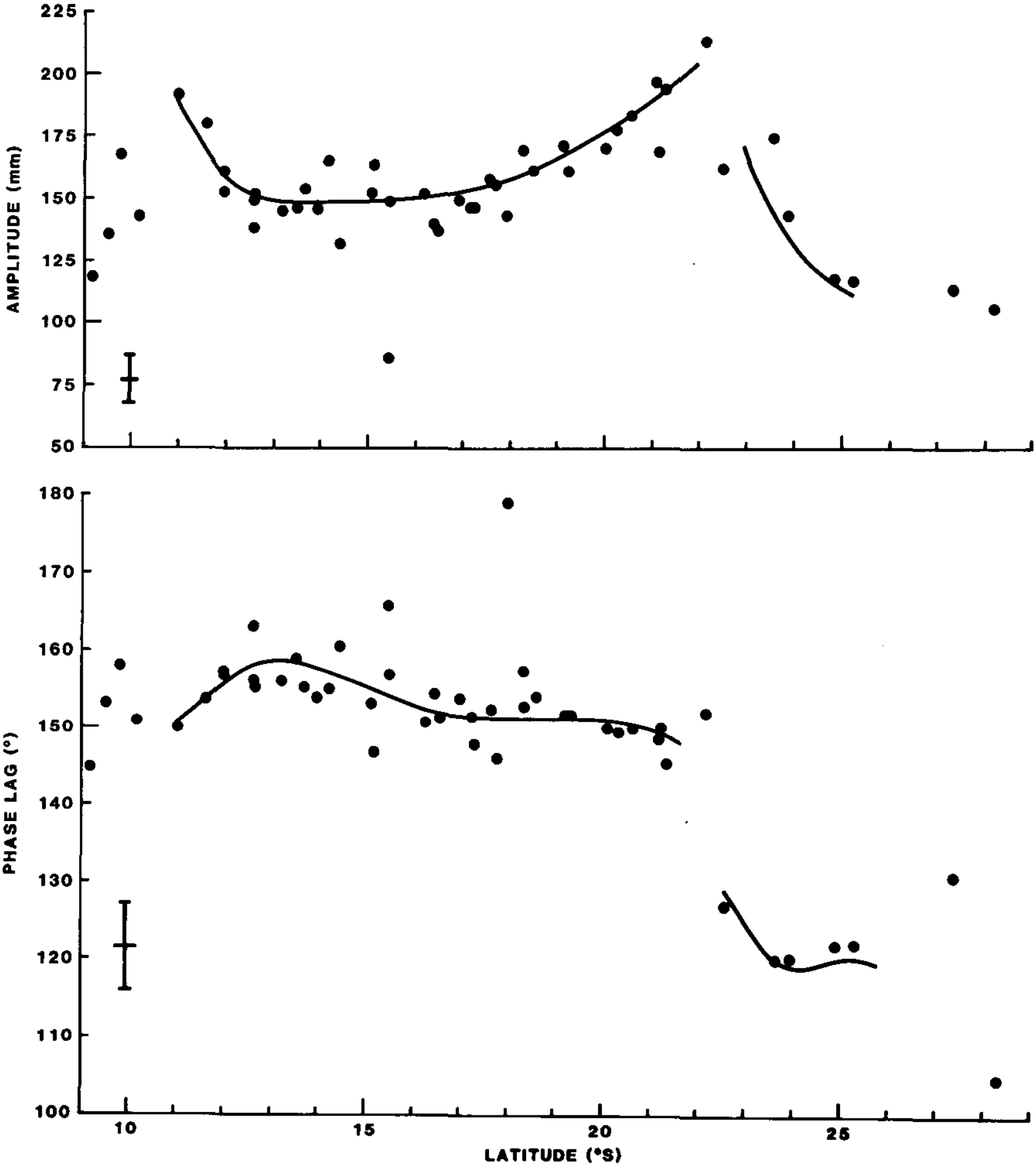

Figure 3 As for Figure 2, but for O_1

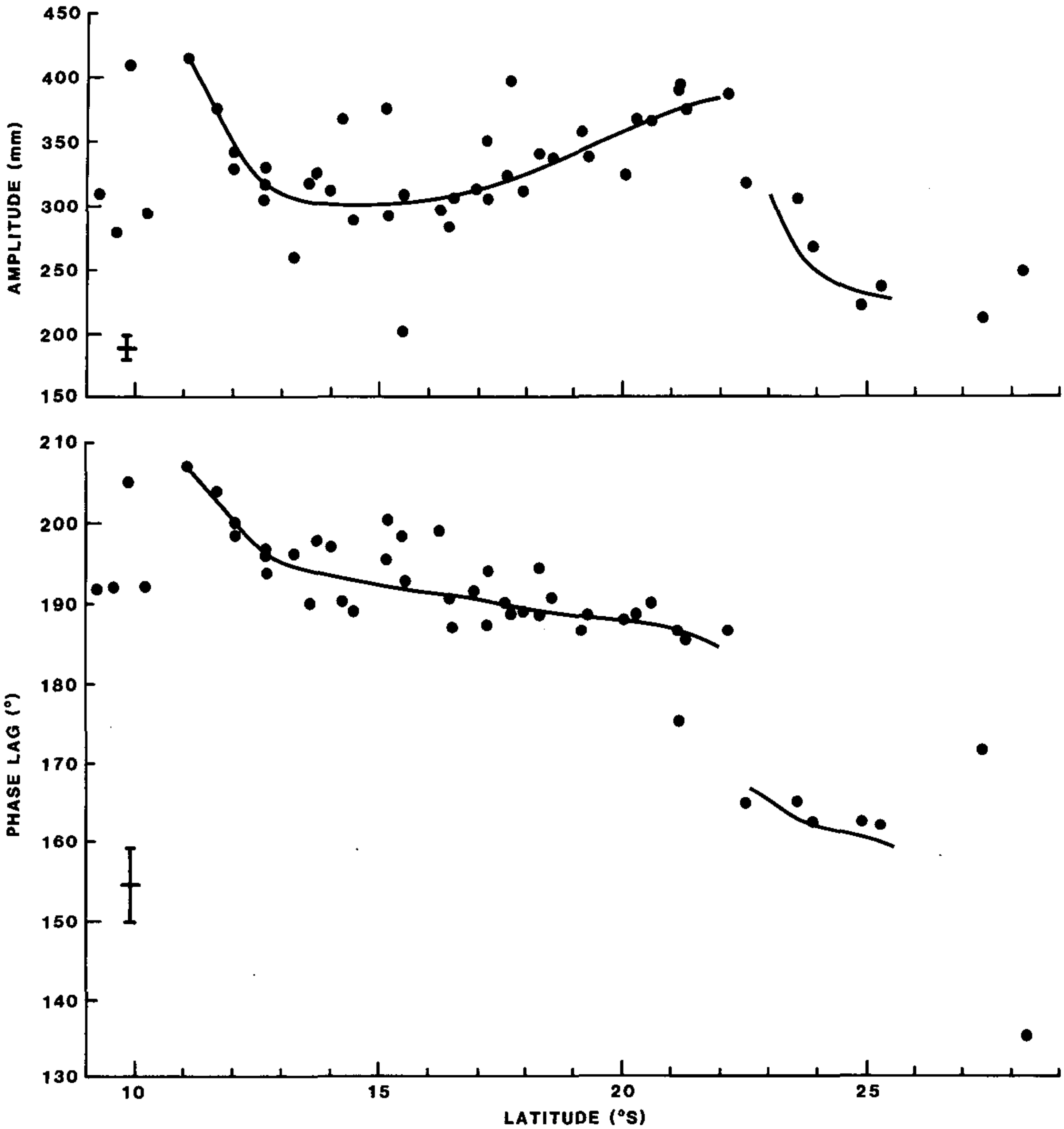

Figure 4 As for Figure 2, but for K_1

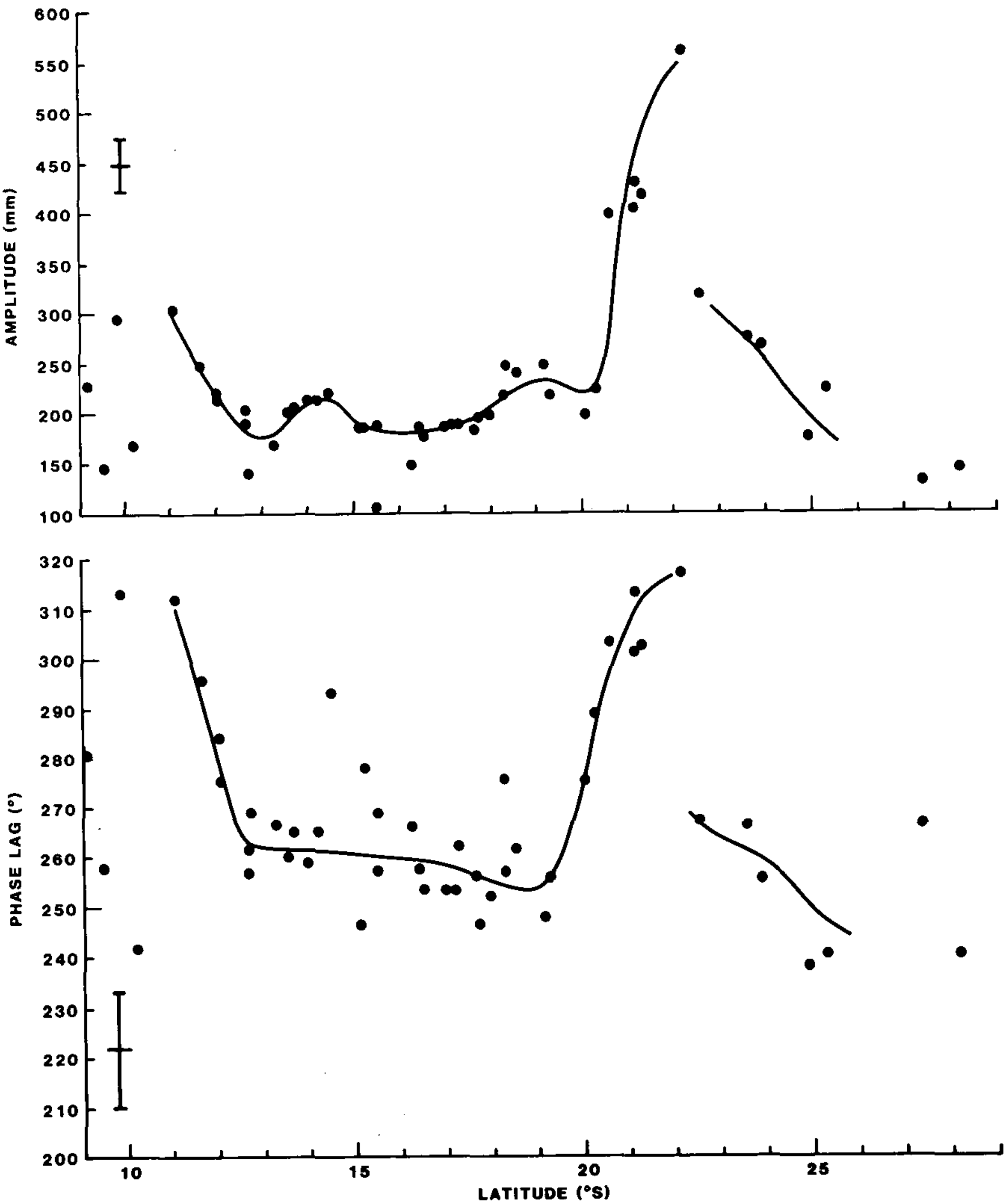

Figure 5 As for Figure 2, but for N_2

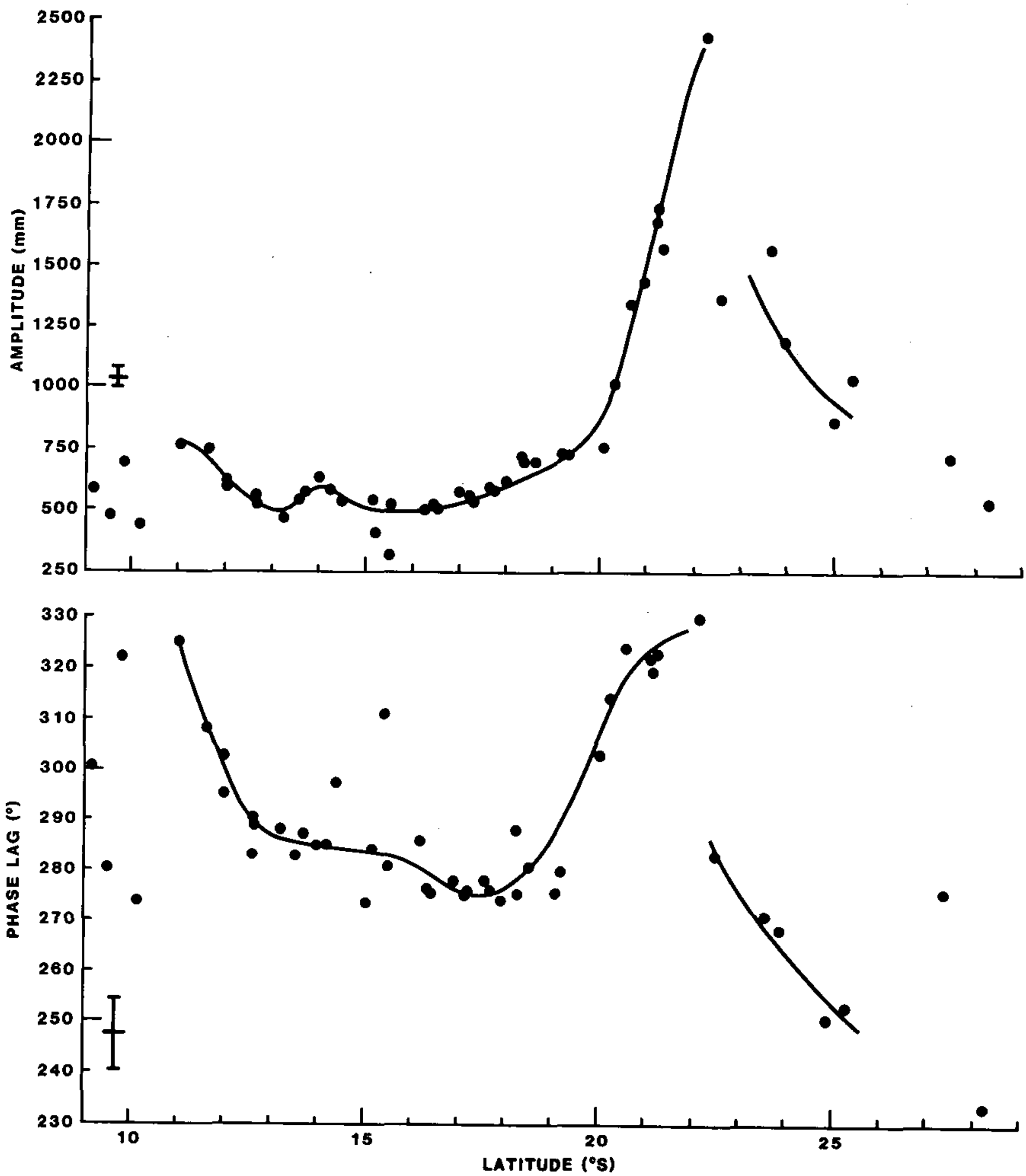

Figure 6 As for Figure 2, but for M_2

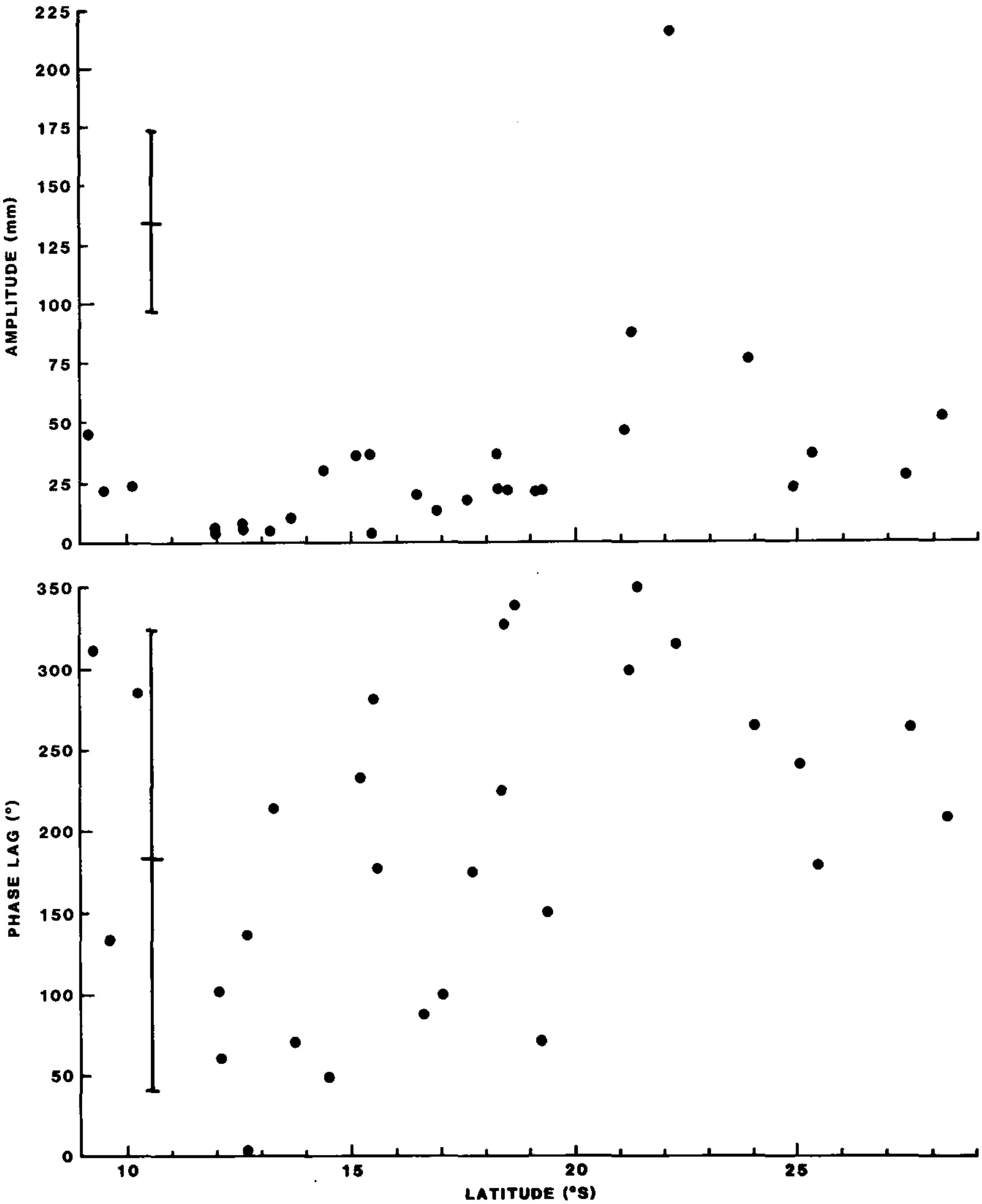

Figure 7 As for Figure 2, but for L_2

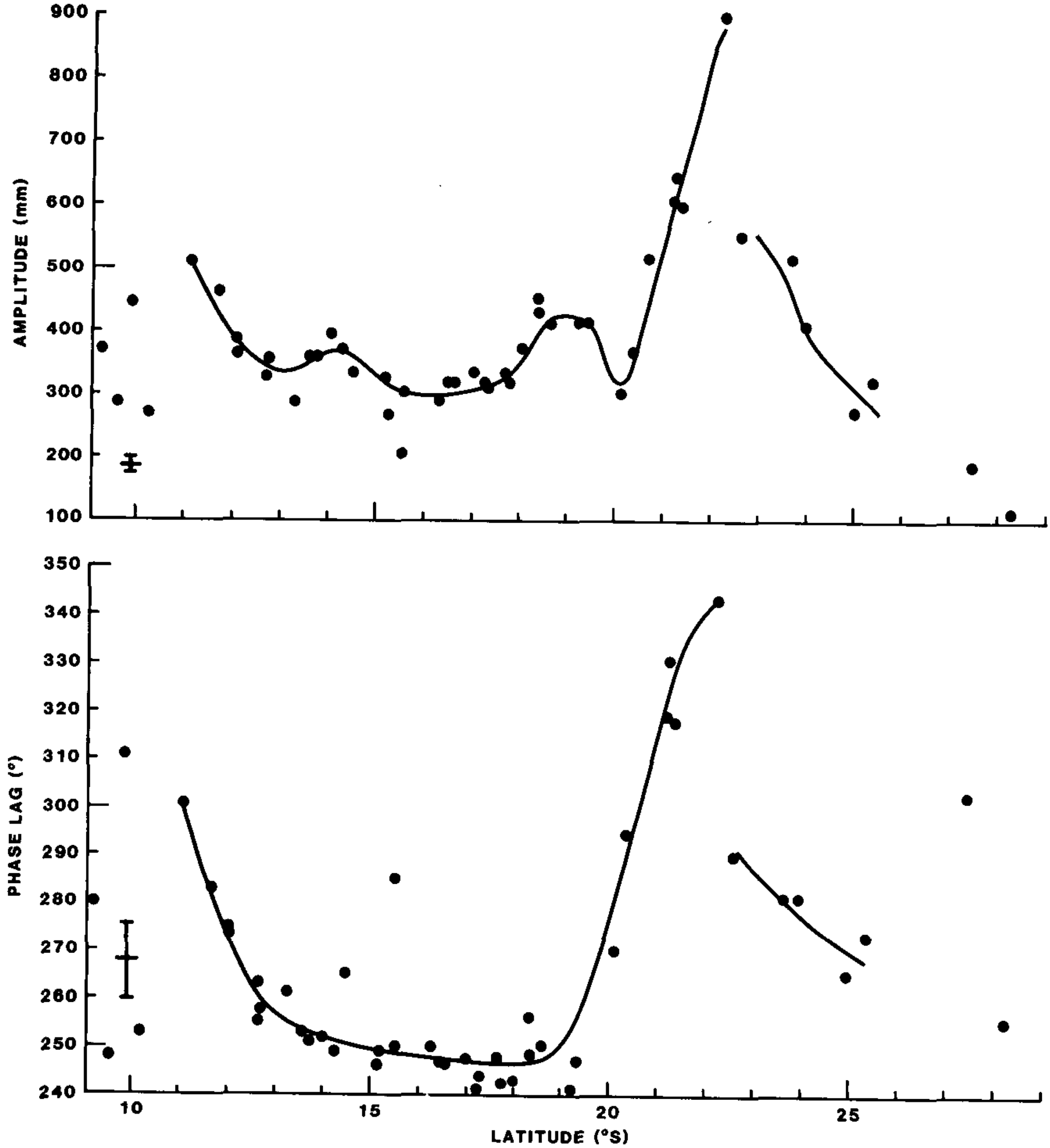

Figure 8 As for Figure 2, but for S_2

TABLE 1 SEMIDIURNAL

NO	STATION	LAT	LONG	DY	MO	YEAR	LENG	CODE	INF	N2	M2	L2	S2	K2
1	BRAMBLE CAY	909	14353	22	2	1971	29	FI	1	227 280.8	587 300.7	46 311.6	372 280.1	101 280.1
2	PORT MORESBY	929	14706	1	1	1940	365	IHB		146 257.9	478 280.4	22 132.8	288 248.1	81 243.8
3	RENNEL IS.	946	14316	0	0	1944	44	IHB		293 313.0	692 322.0	0 0.0	445 311.0	122 312.0
	RENNEL IS.	946	14316	8	6	1944	28	FI		273 306.2	718 322.8	8 138.3	475 311.1	129 311.1
4	KALIGOLA IS.	1008	14815	23	1	1963	30	IHB		168 242.0	442 274.0	24 285.0	271 253.0	73 253.0
5	TERN IS.	1100	14245	1	10	1891	29	IHB		302 312.0	765 325.0	0 0.0	512 301.0	137 301.0
6	RAINE IS.	1135	14402	15	5	1979	29	FI		190 246.6	464 271.7	61 19.5	323 251.3	88 251.3
7	HANNIBAL IS.	1136	14256	15	10	1892	29	IHB		247 295.9	747 308.4	0 0.0	463 282.8	125 282.9
8	HARVEY IS.	1158	14316	22	10	1969	29	FI		221 284.1	622 302.8	6 60.4	388 274.8	109 274.9
9	HICKS IS.	1159	14316	10	2	1978	163	FI		212 275.3	594 295.4	4 102.5	365 273.4	99 273.4
10	ROCKY IS.	1235	14325	1	7	1977	369	FI		190 256.8	526 283.2	8 136.5	327 255.2	89 255.2
11	PORTLAND ROADS	1236	14325	10	5	1969	29	FI		204 261.5	563 290.5	6 3.0	331 263.4	93 263.5
12	RESTORATION IS.	1238	14327	15	7	1894	29	IHB		140 268.9	521 288.8	0 0.0	357 257.7	98 257.7
	NIGHT IS.	1311	14335	21	11	1968	29	FI	1	214 265.1	526 287.3	22 66.8	318 250.1	86 250.1
13	*NIGHT IS.*	*1311*	*14335*	*16*	6	*1975*	33	FI		168 266.4	468 288.2	5 213.9	289 261.3	81 261.4
14	MORRIS IS.	1330	14343	23	7	1898	29	IHB		201 260.0	543 283.0	0 0.0	360 253.0	98 253.0
15	FIFE IS.	1339	14343	21	10	1968	27	FI		206 265.1	578 287.3	10 70.5	362 251.0	102 251.1
16	BURKITT IS.	1356	14345	0	0	1898	29	IHB		213 259.0	631 285.0	0 0.0	396 252.0	107 253.0
17	FLINDERS IS.	1410	14415	15	8	1899	29	IHB		213 265.3	582 285.1	0 0.0	372 248.9	101 248.9
18	NORMANBY R.	1424	14409	3	9	1980	64	NM	1	219 293.2	537 297.5	31 48.5	336 265.2	91 265.2
	NORMANBY R.	1424	14409	2	2	1979	39	NM	1	230 260.3	642 284.9	24 279.9	433 255.9	118 255.9
19	CARTER REEF	1432	14535	27	7	1980	114	CS		166 258.3	488 276.1	10 26.9	306 249.4	63 252.3
20	LOW WOODED IS.	1505	14523	15	9	1889	29	IHB		*186 246.5*	*543 273.6*	*0 0.0*	*329 246.3*	88 246.4
21	MCIVOR R.	1509	14515	20	10	1980	28	NM	1	187 278.0	411 284.4	37 233.1	270 249.2	73 249.2
22	ENDEAVOUR R. NTH.	1526	14500	28	1	1979	36	NM	1	107 268.9	316 311.1	37 281.5	208 285.1	56 285.1
23	COOKTOWN	1528	14515	3	8	1968	369	EA		187 257.1	525 280.7	4 176.8	306 250.0	86 250.1
24	BOUGAINVILLE REEF	1530	14708	22	6	1980	123	CS	1	135 217.0	411 247.9	14 351.3	235 248.7	64 248.7
25	BAILAY CK.	1612	14527	0	0	1905	29	IHB		149 266.0	503 286.0	0 0.0	293 250.0	79 251.0
26	LOW IS.	1623	14534	1	5	1929	168	IHB		186 257.4	518 276.5	0 0.0	320 246.9	85 246.9
	LOW IS.	1623	14534	9	10	1976	39	FI		176 251.7	529 278.7	16 59.1	328 243.7	91 241.6
	LOW IS.	1623	14534	16	11	1978	31	FI		178 252.4	555 274.3	18 44.7	327 243.9	91 241.8
27	PORT DOUGLAS	1629	14528	3	11	1978	58	FI		176 253.3	502 275.3	20 87.3	321 246.4	89 244.3
28	EUSTON REEF	1641	14615	29	9	1980	230	AIM		178 255.0	496 273.3	13 353.5	314 244.9	89 245.1
	EUSTON REEF	1641	14615	7	8	1980	40	CS	1	168 258.6	495 268.7	21 343.9	300 239.8	82 239.8
	EUSTON REEF	1641	14615	28	6	1980	40	CS	1	150 245.8	502 266.0	10 347.0	295 243.0	80 243.0
	EUSTON REEF	1641	14615	1	8	1981	204	AIM		168 254.2	478 272.1	11 295.4	296 244.2	76 237.6
	GREEN IS.	1645	14559	16	10	1907	29	IHB		180 234.8	543 268.9	0 0.0	317 237.1	85 237.1
29	*GREEN IS.*	1646	14558	26	10	1978	72	FI		187 249.3	514 270.3	9 71.4	330 239.9	90 234.3
30	CAIRNS	1655	14546	30	6	1968	0	FI		186 253.2	572 277.9	13 99.8	337 247.5	89 243.3
31	HIGH IS.	1710	14601	15	8	1908	29	IHB		189 253.2	556 275.4	0 0.0	320 241.4	85 241.4
32	RUSSELL IS.	1713	14606	0	0	1910	29	IHB		189 262.0	536 276.0	0 0.0	311 244.0	85 245.0
33	FLINDERS REEF	1733	14833	21	9	1980	305	CS		173 250.6	499 269.7	15 332.9	287 241.3	79 233.6
34	GILBEY REEF	1735	14636	7	8	1980	123	CS		182 251.1	544 268.4	30 349.0	304 241.1	63 244.0
	GILBEY REEF	1735	14636	5	8	1980	40	CS	1	171 271.6	539 283.8	18 349.4	306 255.3	83 255.3
	GILBEY REEF	1735	14636	26	6	1980	40	CS	1	165 252.8	556 281.0	31 29.4	284 256.3	77 256.3
35	MOURILYAN *HBR.*	*1735*	*14605*	*25*	*1*	*1975*	*370*	*HYD*		*180 256.1*	589 278.0	18 174.6	337 248.0	89 247.6

TABLE 1 SEMIDIURNAL

NO	STATION	LAT	LONG	DY	MO	YEAR	LENG	CODE	INF	N2	M2	L2	S2	K2
36	NORTH BARNARD IS.	1741	14611	15	8	1924	29	IHB		195 246.4	576 276.0	0 0.0	320 242.4	85 242.4
37	BEAVER REEF	1750	14630	2	6	1980	29	NM	1	239 249.6	734 277.7	27 355.7	418 253.3	114 253.3
38	DUNK IS.	1756	14609	3	12	1922	29	IHB		198 252.0	619 274.0	0 0.0	375 243.0	98 243.0
39	HINCHINBROOK IS	1815	14615	15	12	1974	77	NM	1	217 275.6	719 288.0	37 224.6	454 256.3	124 256.3
40	BRITOMART REEF	1815	14639	30	10	1980	289	CS		210 258.0	597 277.2	18 339.2	363 248.6	98 245.1
	BRITOMART RF.	1815	14639	21	6	1979	45	NM	1	208 257.3	617 271.6	17 339.1	327 242.4	89 242.4
41	MYRMIDON REEF	1816	14723	4	5	1981	382	AIM		177 250.4	517 268.1	15 307.8	304 241.2	96 239.5
42	CORAL CREEK	1817	14613	17	12	1980	424	AIM		246 256.8	695 275.5	22 327.3	431 248.5	107 248.7
43	LUCINDA	1831	14620	1	3	1963	365	HYD		239 261.5	695 280.8	21 338.9	415 250.4	121 251.4
44	KEEPER REEF	1845	14716	2	11	1980	250	CS		217 263.6	624 283.1	24 332.9	375 251.7	108 249.0
45	MAGNETIC IS.	1908	14652	0	0	1977	459	NM		248 247.8	731 275.6	21 70.8	415 241.3	113 241.3
46	TOWNSVILLE	1915	14650	2	2	1967	369	FI		217 255.6	725 279.8	21 149.9	417 247.1	111 244.7
	TOWNSVILLE	1916	14650	1	10	1951	365	IHB		255 248.6	716 277.8	14 23.7	423 244.4	109 241.6
47	BOWEN	2001	14815	15	11	1851	29	FI		198 275.0	752 303.0	0 0.0	304 270.0	85 270.0
48	HOOK IS.	2004	14855	14	7	1959	30	IHB		226 281.0	860 310.0	0 0.0	317 291.0	85 291.0
49	MOLLE IS.	2015	14850	15	8	1932	29	IHB		223 288.7	1012 314.2	0 0.0	369 294.3	101 294.2
50	EAST REPULSE IS.	2035	14853	7	6	1928	29	IHB		398 303.0	1341 324.0	0 0.0	517 312.0	140 312.0
51	CARLISLE IS.	2047	14918	21	11	1926	29	IHB		380 295.0	1399 318.0	0 0.0	517 311.0	140 311.0
52	SCAWFELL IS.	2052	14937	7	11	1928	29	IHB		405 309.0	1432 318.0	0 0.0	536 312.0	143 312.0
	PENRITH IS.	2100	14954	16	6	1955	29	HYD	1	405 300.0	1533 313.0	0 0.0	817 317.3	222 317.3
53	PENRITH IS.	2101	14954	7	7	1980	165	JM		337 326.8	1358 319.6	155 61.9	450 311.9	91 306.5
	MACKAY	2107	14914	2	11	1966	369	FI		399 305.0	1676 322.2	129 293.0	614 319.1	179 317.3
	MACKAY	2107	14914	20	6	1949	365	IHB		403 304.3	1675 322.3	121 273.9	596 319.0	172 316.8
	MACKAY	2107	14914	5	7	1967	369	FI		391 304.8	1684 322.5	98 254.2	607 319.4	181 315.7
54	MACKAY	2107	14914	30	6	1968	369	FI		404 301.1	1680 322.0	47 299.6	608 319.1	178 316.6
55	FLAT TOP IS.	2109	14916	11	6	1929	29	IHB		430 312.9	1731 319.3	0 0.0	649 330.5	177 330.3
56	HAY POINT	2117	14918	26	8	1969	29	FI		418 302.5	1569 322.8	88 349.7	600 317.8	189 317.8
57	BELL CAY	2148	15115	12	3	1973	34	FI	1	208 282.2	1126 291.8	15 282.3	472 296.7	128 296.7
58	HIGH PEAK IS.	2158	15041	11	5	1973	137	FI		358 283.9	1487 297.9	79 282.7	562 303.2	177 303.2
59	GANNET CAY	2159	15228	12	3	1973	32	FI	1	117 274.0	622 269.6	13 171.6	241 275.3	65 275.3
60	MCEWIN IS	2209	14936	17	7	1969	29	FI		560 316.8	2427 329.9	216 315.1	901 343.2	284 343.2
61	PORT CLINTON	2232	15045	14	6	1954	29	IHB		317 267.0	1369 283.0	0 0.0	555 290.0	149 290.0
62	TRYON IS.	2315	15147	11	10	1929	29	IHB		192 254.0	863 258.0	0 0.0	326 267.0	88 267.0
63	CATO IS.	2315	15532	15	6	1971	28	FI		121 210.8	510 230.0	24 239.4	167 239.3	33 225.4
64	NORTH WEST IS.	2318	15142	21	9	1979	34	NM	1	301 234.5	1090 256.7	62 263.8	415 260.8	113 260.8
65	HERON IS.	2326	15154	25	4	1973	97	FI		177 242.9	796 255.0	47 262.5	307 260.8	60 246.9
66	ONE TREE IS.	2330	15205	12	11	1979	29	NM	1	189 220.4	924 248.2	16 258.4	333 252.4	91 252.4
67	PORT ALMA	2334	15052	20	9	1976	29	IHB		274 266.0	1565 271.0	0 0.0	517 281.0	140 281.0
68	GLADSTONE	2353	15112	0	0	1979	366	HM		267 255.3	1191 268.2	77 264.6	411 280.9	121 280.0
69	LADY ELLIOT IS.	2407	15245	12	5	1926	29	IHB		140 219.7	649 235.8	0 0.0	213 256.6	58 256.6
70	BUNDABERG	2446	15223	30	6	1967	369	EA		176 237.9	863 250.8	23 240.2	274 265.1	85 258.6
	BUNDABERG	2446	15223	1	1	1962	365	HYD		174 238.5	832 243.7	45 258.7	266 269.3	76 268.0
71	FRASER IS.	2458	15321	0	0	1977	365	NM		104 240.8	467 245.1	11 281.6	152 242.6	43 242.6
72	URANGAN JETTY	2517	15255	0	0	1958	60	IHB		223 240.0	1036 253.0	37 178.0	323 273.0	88 273.0
73	BRISBANE	2721	15311	30	6	1968	369	FI		132 266.1	710 275.4	28 263.3	190 302.5	53 294.1
74	DANGER POINT	2810	15333	26	8	1966	30	EA	1	145 240.1	531 233.5	53 207.2	117 255.3	32 255.3

TABLE 1 DIURNAL

NO	STATION	LAT	LONG	DY	MO	YEAR	LENG	CODE	INF	Q1		O1		P1		K1	
1	BRAMBLE CAY	909	14353	22	2	1971	29	FI	1	20	97.1	119	144.8	102	191.7	309	191.7
2	PORT MORESBY	929	14706	1	1	1940	365	IHB		20	118.9	136	153.2	79	188.0	278	191.9
3	RENNEL IS.	946	14316	0	0	1944	44	IHB		0	0.0	168	158.0	134	204.0	408	205.0
	RENNEL IS.	946	14316	8	6	1944	28	FI		24	162.3	153	154.9	122	203.6	369	203.6
4	KALIGOLA IS.	1008	14815	23	1	1963	30	IHB		24	114.0	143	151.0	98	192.0	293	192.0
5	TERN IS.	1100	14245	1	10	1891	29	IHB		0	0.0	192	150.0	137	207.0	415	207.0
6	RAINE IS.	1135	14402	15	5	1979	29	FI		43	70.0	91	154.9	86	198.1	260	198.1
7	HANNIBAL IS.	1136	14256	15	10	1892	29	IHB		0	0.0	180	153.7	125	203.9	375	203.9
8	HARVEY IS.	1158	14316	22	10	1969	29	FI		19	147.8	161	157.3	108	194.0	341	200.0
9	HICKS IS.	1159	14316	10	2	1978	163	FI		19	124.9	153	157.0	109	198.4	328	198.4
10	ROCKY IS.	1235	14325	1	7	1977	369	FI		19	101.9	138	156.1	101	196.5	304	196.5
11	PORTLAND ROADS	1236	14325	10	5	1969	29	FI		38	120.9	150	163.1	100	190.1	316	196.1
12	RESTORATION IS.	1238	14327	15	7	1894	29	IHB		0	0.0	152	155.1	110	193.6	329	193.7
	NIGHT IS.	1311	14335	21	11	1968	29	FI	1	31	143.0	138	152.0	95	198.2	289	198.2
13	NIGHT IS.	1311	14335	16	6	1975	33	FI		28	148.9	145	156.1	82	190.1	259	196.1
14	MORRIS IS.	1330	14343	23	7	1898	29	IHB		0	0.0	146	159.0	104	190.0	317	190.0
15	FIFE IS.	1339	14343	21	10	1968	27	FI		31	132.3	154	155.2	103	191.6	325	197.6
16	BURKITT IS.	1356	14345	0	0	1898	29	IHB		0	0.0	146	154.0	104	196.0	311	197.0
17	FLINDERS IS.	1410	14415	15	8	1899	29	IHB		0	0.0	165	155.0	122	190.0	366	190.1
18	NORMANBY R.	1424	14409	3	9	1980	64	NM	1	32	147.5	132	160.5	95	187.0	288	189.0
	NORMANBY R.	1424	14409	2	2	1979	39	NM	1	27	119.3	128	148.9	101	193.6	304	193.6
19	CARTER REEF	1432	14535	27	7	1980	114	CS		29	138.6	151	149.9	98	195.7	314	189.8
20	LOW WOODED IS.	1505	14523	15	9	1889	29	IHB		0	0.0	152	153.2	125	195.4	375	195.4
21	MCIVOR R.	1509	14515	20	10	1980	28	NM	1	48	125.4	164	146.8	97	200.3	292	200.3
22	ENDEAVOUR R. NTH.	1526	14500	28	1	1979	36	NM	1	55	56.0	86	165.8	66	198.3	201	198.3
23	COOKTOWN	1528	14515	3	8	1968	369	EA		23	126.3	149	156.9	97	186.8	308	192.8
24	BOUGAINVILLE REEF	1530	14708	22	6	1980	123	CS	1	26	65.3	131	115.5	87	187.2	262	187.2
25	BAILAY CK.	1612	14527	0	0	1905	29	IHB		0	0.0	152	151.0	98	198.0	296	199.0
26	LOW IS.	1623	14534	1	5	1929	168	IHB		0	0.0	140	154.5	94	190.6	283	190.6
	LOW IS.	1623	14534	9	10	1976	39	FI		30	138.7	146	154.0	97	185.1	328	189.7
	LOW IS.	1623	14534	16	11	1978	31	FI		34	112.8	158	153.7	96	182.9	323	187.5
27	PORT DOUGLAS	1629	14528	3	11	1978	58	FI		26	122.8	137	151.4	90	182.4	306	187.0
28	EUSTON REEF	1641	14615	29	9	1980	230	AIM		30	129.3	153	151.4	94	185.5	307	189.0
	EUSTON REEF	1641	14615	7	8	1980	40	CS	1	28	137.0	148	149.7	101	185.1	306	185.1
	EUSTON REEF	1641	14615	28	6	1980	40	CS	1	26	118.5	162	150.9	96	186.1	291	186.1
	EUSTON REEF	1641	14615	1	8	1981	204	AIM		27	127.5	148	150.9	93	186.2	294	188.3
	GREEN IS.	1645	14559	16	10	1907	29	IHB		0	0.0	140	148.4	94	189.3	286	189.3
29	GREEN IS.	1646	14558	26	10	1978	72	FI		26	120.6	155	149.3	99	181.6	319	185.7
30	CAIRNS	1655	14546	30	6	1968	0	FI		27	123.2	149	153.8	92	188.3	312	191.5
31	HIGH IS.	1710	14601	15	8	1908	29	IHB		0	0.0	146	151.6	116	187.2	350	187.2
32	RUSSELL IS.	1713	14606	0	0	1910	29	IHB		0	0.0	146	148.0	101	193.0	305	194.0
33	FLINDERS REEF	1733	14833	21	9	1980	305	CS		29	124.2	150	147.7	93	178.9	304	185.9
34	GILBEY REEF	1735	14636	7	8	1980	123	CS		30	168.7	155	149.6	101	190.6	322	184.7
	GILBEY REEF	1735	14636	5	8	1980	40	CS	1	31	144.6	151	155.9	105	190.5	317	190.5
	GILBEY REEF	1735	14636	26	6	1980	40	CS	1	28	134.0	162	159.2	100	191.4	301	191.4
35	MOURILYAN HBR.	1735	14605	25	1	1975	370	HYD		28	126.2	158	152.5	96	186.0	323	189.9

TABLE 1 DIURNAL

NO	STATION	LAT	LONG	DY	MO	YEAR	LENG	CODE	INF	Q1		O1		P1		K1	
36	NORTH BARNARD IS.	1741	14611	15	8	1924	29	IHB		0	0.0	155	146.1	131	188.7	396	188.7
37	BEAVER REEF	1750	14630	2	6	1980	29	NM	1	39	121.8	200	154.1	129	189.6	391	189.6
38	DUNK IS.	1756	14609	3	12	1922	29	IHB		0	0.0	143	179.0	104	189.0	311	189.0
39	HINCHINBROOK IS	1815	14615	15	12	1974	77	NM	1	31	140.2	169	157.5	112	194.2	340	194.2
40	BRITOMART REEF	1815	14639	30	10	1980	289	CS		31	133.0	161	152.9	97	183.4	327	188.6
	BRITOMART RF.	1815	14639	21	6	1979	45	NM	1	33	143.8	159	152.6	105	184.6	316	184.6
41	MYRMIDON REEF	1816	14723	4	5	1981	382	AIM		30	125.9	156	148.3	99	179.3	319	184.7
42	CORAL CREEK	1817	14613	17	12	1980	424	AIM		32	130.8	161	152.7	99	183.0	339	188.5
43	LUCINDA	1831	14620	1	3	1963	365	HYD		30	128.8	161	154.2	103	185.3	336	190.6
44	KEEPER REEF	1845	14716	2	11	1980	250	CS		31	137.3	163	155.1	104	184.8	337	190.7
45	MAGNETIC IS.	1908	14652	0	0	1977	459	NM		31	121.6	171	151.7	119	186.5	357	186.5
46	TOWNSVILLE	1915	14650	2	2	1967	369	FI		27	124.9	161	151.8	100	184.2	337	188.5
	TOWNSVILLE	1916	14650	1	10	1951	365	IHB		34	127.9	165	151.8	97	180.0	335	187.2
47	BOWEN	2001	14815	15	11	1851	29	FI		0	0.0	170	150.0	106	188.0	323	188.0
48	HOOK IS.	2004	14855	14	7	1959	30	IHB		30	112.0	177	150.0	119	190.0	354	190.0
49	MOLLE IS.	2015	14850	15	8	1932	29	IHB		0	0.0	177	149.6	122	188.8	366	188.6
50	EAST REPULSE IS.	2035	14853	7	6	1928	29	IHB		0	0.0	183	150.0	122	190.0	365	190.0
51	CARLISLE IS.	2047	14918	21	11	1926	29	IHB		0	0.0	177	150.0	122	189.0	365	189.0
52	SCAWFELL IS.	2052	14937	7	11	1928	29	IHB		0	0.0	213	151.0	122	189.0	365	189.0
	PENRITH IS.	2100	14954	16	6	1955	29	HYD	1	0	0.0	192	147.0	89	183.1	271	183.1
53	PENRITH IS.	2101	14954	7	7	1980	165	JM		28	137.1	178	141.6	76	180.3	301	178.7
	MACKAY	2107	14914	2	11	1966	369	FI		35	119.3	199	146.9	115	184.0	388	186.4
	MACKAY	2107	14914	20	6	1949	365	IHB		38	115.6	200	145.9	116	181.7	384	186.6
	MACKAY	2107	14914	5	7	1967	369	FI		36	117.0	195	147.4	120	183.7	388	187.0
54	MACKAY	2107	14914	30	6	1968	369	FI		39	119.4	196	148.6	115	184.2	389	186.5
55	FLAT TOP IS.	2109	14916	11	6	1929	29	IHB		0	0.0	168	150.2	131	172.3	393	175.1
56	HAY POINT	2117	14918	26	8	1969	29	FI		40	102.7	193	145.5	112	181.7	374	185.4
57	BELL CAY	2148	15115	12	3	1973	34	FI	1	34	121.6	163	131.5	106	167.2	319	167.2
58	HIGH PEAK IS.	2158	15041	11	5	1973	137	FI		32	115.8	173	134.1	104	170.1	348	173.8
59	GANNET CAY	2159	15228	12	3	1973	32	FI	1	27	120.8	155	132.9	89	170.8	269	170.8
60	MCEWIN IS	2209	14936	17	7	1969	29	FI		36	132.8	213	152.1	115	182.8	386	186.6
61	PORT CLINTON	2232	15045	14	6	1954	29	IHB		0	0.0	162	127.0	104	165.0	317	165.0
62	TRYON IS.	2315	15147	11	10	1929	29	IHB		0	0.0	158	118.0	79	170.0	238	170.0
63	CATO IS.	2315	15532	15	6	1971	28	FI		20	87.1	102	118.4	61	154.3	206	157.6
64	NORTH WEST IS.	2318	15142	21	9	1979	34	NM	1	45	99.2	175	115.6	109	163.1	328	163.1
65	HERON IS.	2326	15154	25	4	1973	97	FI		25	115.4	116	120.7	70	151.1	236	154.4
66	ONE TREE IS.	2330	15205	12	11	1979	29	NM	1	30	88.1	153	115.6	90	153.5	271	153.5
67	PORT ALMA	2334	15052	20	9	1976	29	IHB		0	0.0	174	120.0	101	165.0	304	165.0
68	GLADSTONE	2353	15112	0	0	1979	366	HM		27	95.5	143	120.3	78	157.4	267	162.5
69	LADY ELLIOT IS.	2407	15245	12	5	1926	29	IHB		0	0.0	110	107.3	61	156.8	189	156.8
70	BUNDABERG	2446	15223	30	6	1967	369	EA		24	90.2	117	121.8	62	154.7	222	162.4
	BUNDABERG	2446	15223	1	1	1962	365	HYD		30	96.4	121	124.1	68	156.2	216	164.8
71	FRASER IS.	2458	15321	0	0	1977	365	NM		19	94.0	111	120.3	75	142.9	226	142.9
72	URANGAN JETTY	2517	15255	0	0	1958	60	IHB		24	66.0	116	122.0	79	162.0	235	162.0
73	BRISBANE	2721	15311	30	6	1968	369	FI		25	99.8	113	130.9	55	168.6	211	171.5
74	DANGER POINT	2810	15333	26	8	1966	30	EA	1	22	87.7	105	99.9	81	136.6	248	136.6

Table 2

Variation of Constants in Offshore Direction, 11°-19°S.

Station	Distance offshore (Km)	Amplitude ratio (see text)						Phase difference Δg(°) (see text)					
		N_2	M_2	S_2	Q_1	O_1	K_1	N_2	M_2	S_2	Q_1	O_1	K_1
Raine I.	100	.78	.78	.79	2.25	.53	.70	48	33	39	66	0	6
Carter Rf	50	.77	.90	.87	1.00	1.01	1.04	3	8	1	-6	6	3
Bougainville Rf	190	.74	.81	.76	.91	.88	.87	43	35	1	65	38	5
Euston Rf	50	.98	.96	1.00	1.00	1.00	1.00	3	4	2	0	1	2
Green I.	25	1.02	1.00	1.05	.87	1.01	1.02	9	7	7	8	2	5
Flinders Rf	240	.89	.84	.89	.94	.96	.95	5	5	6	4	3	3
Gilbey Rf	50	.94	.95	.95	1.00	1.00	1.02	4	6	6	-40	2	5
Beaver Rf	40	1.19	1.18	1.23	1.28	1.28	1.23	5	0	-7	8	3	0
Britomart Rf	45	.97	.94	.91	1.00	1.00	.99	-3	1	-2	-5	-2	1
Myrmidon Rf	115	.82	.80	.76	.97	.96	.97	3	10	6	2	3	5
Keeper Rf	65	.94	.92	.89	.96	.98	1.00	-11	0	-2	-9	-3	-2

Table 3

Amplitude Ratios and Phase Lag Differences for K_2, S_2 and P_1, K_1

Station	Latitude	Amplitude Ratio K_2/S_2	Amplitude Ratio P_1/K_1	Phase Lag Difference (°) $g(S_2)-g(K_2)$	Phase Lag Difference (°) $g(K_1)-g(P_1)$
Port Moresby	09°29'	.281	.284	4.3	3.9
Cooktown	15°28'	.281	.317	-0.1	6.0
Euston Reef (1980)	16°41'	.282	.307	-0.2	3.5
Euston Reef (1981)		.255	.317	+6.6	2.1
Mourilyan	17°35'	.264	.297	0.4	3.9
Myrmidon Reef	18°16'	.316	.309	1.7	5.3
Coral Creek	18°17'	.248	.291	-0.2	5.5
Lucinda	18°31'	.293	.309	-1.0	4.3
Townsville (1951)	19°16'	.258	.290	2.8	7.2
Townsville (1967)		.266	.297	2.4	4.3
Mackay (1949)	21°07'	.289	.302	2.2	4.9
Mackay (1966)		.292	.298	1.8	2.4
Mackay (1967)		.299	.310	3.7	3.3
Mackay (1968)		.293	.296	2.5	2.3
Gladstone	23°53'	.294	.292	0.9	5.1
Bundaberg (1962)	24°46'	.288	.316	1.3	7.6
Bundaberg (1967)		.311	.279	6.5	5.7
Brisbane	27°21'	.278	.261	8.4	2.9
Mean*		.283	.302	2.0	4.6
Standard Deviation*		.019	.011	2.1	1.6
Equilibrium Values		.272	.331	0.0	0.0

(*Excluding Brisbane and Port Moresby)

Table 4. Sources of Data

Code (Table 1)	Source
HM	Department of Harbours and Marine, Brisbane.
FI	Flinders Institute for Atmospheric and Marine Science, Flinders University, South Australia.
NM	Division of National Mapping, Department of National Development and Energy, Canberra.
HYD	Hydrographer, Royal Australian Navy, Sydney.
CS	CSIRO Division of Oceanography.
IHB	International Hydrographic Bureau. (Tape of world tidal constant data, held by CSIRO Division of Oceanography).
EA	Easton, A.K. (1970) The Tides of the Continent of Australia. Horace Lamb Centre, Flinders University of South Australia, Research Paper No 37, 326pp.
JM	Dr J. Middleton, Univ. of N.S.W.
AIM	Australian Institute of Marine Science, Townsville.

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