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GLOBAL OCEAN TIDES. PART IX. THE DIURNAL ELLIPTICAL LUNAR TIDE --ETC(U)
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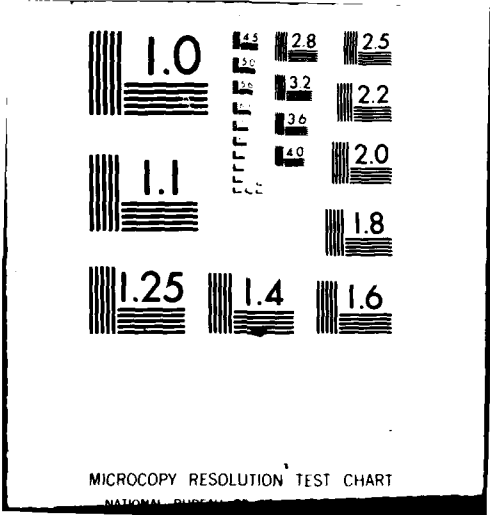
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grid system in an atlas of 42^o x 71^o ^{نقشه} overlapping charts covering the whole oceanic globe. A corresponding atlas of global corange and cotidal maps is included to provide the reader with a quick general overview of the major tidal phenomena. The specifying hydrodynamical parameters of the model are listed along with quoted sources of empirical tide data, and significant tidal features are explained and discussed. The diurnal Q_1 tide resembles all other computed diurnal tides K_1 , O_1 , and P_1 (see Parts IV, V, and VII). Qualitative similarities exist also between the diurnal and semidiurnal species M_2 , S_2 , N_2 , and K_2 (see Parts II, III, VI, and VIII).

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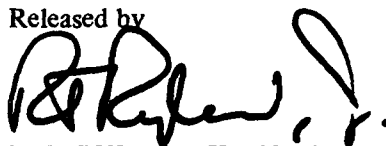
FOREWORD

In Part I of this report (Schwiderski, 1978a), a combined hydrodynamical-empirical method was introduced to compute numerically harmonic partial tides in the world oceans with an accuracy of better than 5 cm, which is needed in various military and civil applications of today. In this report, the computed diurnal elliptical lunar tide (Q_1) is displayed in an atlas of tabulated tidal charts and plotted corange and cotidal maps.

This project was supported by the Naval Surface Weapons Center's Independent Research Fund and by a grant from the National Geodetic Survey of the Department of Commerce/NOS/NOAA.* It is the author's most pleasant obligation to acknowledge the sustained and generous sponsorship of Mr. R. T. Ryland, Jr., Head of the Strategic Systems Department, his Associate, Mr. R. J. Anderle, and Mr. D. R. Brown, Jr., Head of the Space and Surface Systems Division. Many critical and stimulating suggestions were gratefully received from the author's colleagues, Drs. C. J. Cohen, C. Oesterwinter, and B. Zondek. The involved computer programs were all prepared by Mr. L. T. Szeto in a competent and effective manner.

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ABSTRACT

In Part I (Schwiderski, 1978a) of this report, a unique hydrodynamical interpolation technique was introduced, extensively tested, and evaluated in order to compute partial global ocean tides in great detail and with a high degree of accuracy. This novel method has been applied to construct the diurnal elliptical lunar (Q_1) ocean tide with a relative accuracy of better than 5 cm anywhere in the open oceans. The resulting tidal amplitudes and phases are tabulated on a $1^\circ \times 1^\circ$ grid system in an atlas of $42^\circ \times 71^\circ$ overlapping charts covering the whole oceanic globe. A corresponding atlas of global corange and cotidal maps is included to provide the reader with a quick general overview of the major tidal phenomena. The specifying hydrodynamical parameters of the model are listed along with quoted sources of empirical tide data, and significant tidal features are explained and discussed. The diurnal Q_1 tide resembles all other computed diurnal tides K_1 , O_1 , and P_1 (see Parts IV, V, and VII). Qualitative similarities exist also between the diurnal and semidiurnal species M_2 , S_2 , N_2 , and K_2 (see Parts II, III, VI, and VIII).

I. INTRODUCTION

Part I of this report (Schwiderski, 1978a) introduced a unique combination of hydrodynamical and empirical methods to model detailed ocean tides with a relative component accuracy of better than 5 cm anywhere in the open oceans. This enormous accuracy is well above minimum requirements set by, for instance, the National Aeronautics and Space Administration (NASA) and the Department of Defense (DoD) to map the geoid at sea by satellite altimetry to within 10 cm. The following features of this unique hydrodynamical interpolation model made the achievement of this accuracy possible.

a. A spherically graded $1^\circ \times 1^\circ$ grid system is set up in connection with a corresponding $1^\circ \times 1^\circ$ bathymetry to assure a sufficient resolution of all important tidal phenomena.

b. The bathymetry of the gridwise, simply connected ocean basin is hydrodynamically defined (Schwiderski, 1978c) by appropriate modifications of earlier realistic depth data collections. The hydrodynamical redefinition was needed in order to model the well-known strong distortion and retardation effects of shallow continental shelves, narrow ocean ridges or island chains, and other significant bottom irregularities.

c. The Boussinesq substitution of the turbulent Reynolds stresses is applied in the form of eddy dissipation with a novel physically meaningful eddy viscosity that depends linearly on the lateral grid-cell area and, hence, directly on the ocean depth.

d. The linear law of bottom friction is introduced with a bottom-friction coefficient depending linearly on the bottom grid-cell area which is independent of the ocean depth. In boundary cells, the otherwise constant friction coefficient is subjected to an indirect cellwise adjustment in order to permit a consistent hydrodynamical interpolation (see h., below) of empirical tide data known from tide gauge stations at continental shores, islands, or other shallow-ocean bottom irregularities.

e. The effects of the terrestrial tide and the oceanic tidal load are included as simple second-order approximations in the sense of Love and Accad and Pekeris (1978).

f. The Hansen-Zahel (Zahel, 1970 and 1977; Estes, 1977) finite differencing technique is modified by a new differencing scheme in time which improved decay, dispersion, and stability characteristics of the numerical procedure and facilitates the simple indirect adjustment of the bottom-friction coefficient in the hydrodynamical interpolation technique (see d. and h.).

g. At land-ocean cell walls, the conditions of no-flow across and free-slip along the boundaries are enforced. The no-flow condition is subsequently relaxed by allowing controlled periodic inflows and outflows over the mathematically assumed boundaries. This allowance redefines indirectly more realistic shorelines in order to further improve the consistency of the hydrodynamical interpolation of empirical data (see d. and h.).

h. A unique hydrodynamical interpolation technique is introduced which incorporates into the theoretical model empirical tidal constants collected from over 2 000 tide-gauge stations around the world in a hydrodynamically consistent fashion (see d., f., and g., above).

i. A new higher order approximation of Arctic Ocean tides is used, that is described in Schwiderski (1981g).

With these features, the new model was successfully applied to chart the semidiurnal principal lunar (M_2) ocean tide with the desired accuracy. The technique and accuracy of the model were extensively described and discussed in Part I of this report as well as in subsequent publications and symposia presentations by the author (Schwiderski 1978a, b; 1979a, b, c, d, e; and 1980).

The same hydrodynamical interpolation technique has been applied to chart the diurnal elliptical lunar Q_1 ocean tide with the same relative accuracy as M_2 . Again, it must be emphasized that the enormous accuracy achieved over all open ocean regions diminishes somewhat near coastal areas where known empirical data are marginal in quantity and/or quality.

A complete listing of all sources of empirical ocean tide data, which were interpolated into the Q_1 tidal charts, is presented in Appendix A. In the meantime, Section 2 of this report lists the significant hydrodynamical input parameters that specified the constructed Q_1 ocean tide. The major features of the global Q_1 tide are discussed in Section 3. A complete numerical display is presented in Appendix A where all tidal amplitudes and phases are gridwise tabulated in map-like charts. Corange (equi-amplitude) and cotidal (equi-phase) maps of the Q_1 ocean tide are plotted in Appendix B.

2. Q₁ OCEAN-TIDE PARAMETERS

The astronomical diurnal elliptical lunar (Q₁) equilibrium tide η (or tide-generating potential $G\eta$; see Schwiderski, 1978a) at the geographical point (λ, ϕ) and instant (Y, D, t) is determined by

$$\eta = K \sin 2\phi \cos(\sigma t + \chi + \lambda) \quad (1)$$

where

G = 9.81 m/sec² earth gravity acceleration

λ = longitude (east in rad)

ϕ = latitude (north in rad)

Y (≥ 1975) = year number

D = day number of year Y ($D = 1$ for January 1)

t = universal standard time of day D (in sec)

K = 0.019256 m = Q₁ equilibrium tide amplitude

σ = $0.649\ 59 \cdot 10^{-4}$ sec⁻¹ = Q₁ tide frequency

χ = $\pi(h_0 - 3s_0 + p_0 - 90)/180$ = Q₁ astronomical argument (in rad)

h_0 $\left\{ \begin{array}{l} = 279.696\ 68 + 36\ 000.768\ 930\ 485T + 3.03 \cdot 10^{-4} T^2 \\ = \text{mean longitude of the sun relative to Greenwich midnight of day } D \text{ (in deg)} \end{array} \right.$

s_0 $\left\{ \begin{array}{l} = 270.434\ 358 + 481\ 267.883\ 141\ 37T - 0.001\ 133T^2 + 1.9 \cdot 10^{-6} T^3 \\ = \text{mean longitude of the moon relative to Greenwich midnight of day } D \text{ (in deg)} \end{array} \right.$

p_0 $\left\{ \begin{array}{l} = 334.329\ 653 + 4.069\ 034\ 032\ 957\ 5T - 0.010325T^2 - 1.2 \cdot 10^{-5} T^3 \\ = \text{mean longitude of lunar perigee at Greenwich midnight of day } D \text{ (in deg)} \end{array} \right.$

T = $[27\ 392.500\ 528 + 1.000\ 000\ 035\ 6\bar{D}]/36\ 525$

\bar{D} = $D + 365(Y - 1975) + \text{Int}[(Y - 1973)/4]$

$\text{Int}[x]$ = integral part of x

The corresponding instantaneous ocean partial tide (Schwiderski, 1978a) is determined by

$$\zeta = \xi \cos(\sigma t + \chi - \delta), \quad (2)$$

where the local harmonic constants

$\xi = \xi(\lambda, \phi) = Q_1$ ocean tide amplitude (in m)

and

$\delta = \delta(\lambda, \phi) = Q_1$ ocean tide Greenwich phase (in rad)

must be determined, say, by linear interpolation in the tidal charts of Appendix A.

A simple second-order approximation in the sense of Love and Accad and Pekeris (see Part I, Schwiderski, 1978a, 1979c, and 1980; and Accad and Pekeris, 1978) yields

$$\zeta^e \approx 0.612\eta \text{ and } \zeta^{e0} \approx -0.0667\zeta, \quad (3)$$

i.e., the corresponding terrestrial tide ζ^e and the earth dip ζ^{e0} (yielding) under the oceanic tidal load ζ , respectively. A more elaborate and probably slightly more accurate earth dip ζ^{e0} may be computed by using Farrell's Green function (see Farrell, 1972 and 1973; and Schwiderski, 1980). In linear superposition, one finds the corresponding instantaneous geocentric partial Q_1 tide:

$$\zeta^g = \zeta + \zeta^e + \zeta^{e0}. \quad (4)$$

A detailed description of the hydrodynamical-empirical model to compute the ocean tidal amplitudes ξ and phases δ (listed in Appendix A) was given in Schwiderski (1978a, 1979c, d, and 1980). In particular, all model input parameters such as the dimensionless eddy coefficient ϵ (Eq's. 103 and 123), the bottom-friction parameter b (Eq's. 4a and b), and the differencing parameters κ and $\bar{\kappa}$ (Eq's. 64 and 72) were all specified in Schwiderski (1978a) (referenced equations). These parameters were determined for M_2 by extensive trial-and-error computations and remained unchanged for the construction of Q_1 .

In the computation of the Q_1 tide model, the following mode-dependent parameters were used (see referenced equations in Schwiderski, 1978a):

- a. The time step Δt (Eq's. 64, 123)

$$\Delta t = 201.5113 \text{ sec} \quad (5)$$

- b. The hydrodynamical interpolation control limits, k_1 , k_2 , and k_3 (Eq's. 88, 89, 94, 97, and 99)

$$k_1 = 0.025, k_2 = 0.040, k_3 = 0.5. \quad (6)$$

It may be noted that the input parameters k_1 and k_2 of Equation 6 are the same as for all diurnal K_1 , O_1 , and P_1 components, but differ from those values used for the semidiurnal M_2 , S_2 , N_2 and K_2 species (see Parts II through VIII).

3. Q_1 OCEAN-TIDE FEATURES

The entire constructed Q_1 ocean tide is gridwise displayed in map-like amplitude and phase tables in Appendix A. The $42^\circ \times 71^\circ$ charts cover the whole globe north of colatitude 169° (Antarctica) in three zones: a northern zone N from 0° to 71° colatitude, a middle zone M from 48° to 118° colatitude, and a southern zone S from 98° to 168° colatitude. The overlapping geographical areas of the tidal charts have been chosen to provide a worldwide coverage for special applications and to allow the reader to scan the large amplitude and phase charts together in order to evaluate their quality and visualize the important tidal features. In addition, a generally superficial overview of some tidal features can be recognized by inspecting the more schematically plotted corange and cotidal maps provided in Appendix B.

For an easy evaluation of the tidal charts in Appendix A, all hydrodynamically interpolated empirical tidal amplitudes and phases have been visibly marked by subbars for all shore data and subbrackets for all near-shore deep-sea input constants. Furthermore, the charts display the approximate locations of distant off-shore deep-sea stations by subtildes under the computed amplitude and phase data. The corresponding empirical data, which were excluded from hydrodynamical interpolation (see Sect. 1 and Schwiderski, 1978a, 1979d, and 1980), are listed and compared with the modeled data in Tables 1, 2, and 3. Finally, the approximate geographical locations of the important amphidromic points of zero amplitudes are marked by a circled \otimes .

The tidal charts and maps permit the viewer to follow the tidal waves, that is the high water fronts (crests), in forward (or backward) direction, for instance, on their rotation around the amphidromic points. In the tidal phase charts of Appendix A, it is best to start from the prominently visible $0^\circ = 360^\circ$ or 100° cotidal lines. Since the Greenwich phases specify the time lags (in degrees: $15^\circ \approx 1$ hour) of the tidal crests relative to the cresting time of the corresponding equilibrium tide along Greenwich meridian, one gathers a vivid impression of the significant global and local tidal phenomena.

By following the tidal waves on their periodic rotations, one finds these waves passing through the specially marked stations in empirically correct time and with the correct height. In fact, all over the globe over 2 000 tidal phases and 2 000 amplitudes are coherently integrated. This is particularly impressive for the charts of the Pacific Ocean, where the empirical data from so many clustered and scattered island stations fit smoothly into the surrounding computed tides. From the smoothness features of erratically interpolated tidal data (see Parts I and II), one concludes that this result is not an artifact of the interpolation applied but constitutes a vivid manifestation of the excellent compatibility of both the empirical and hydrodynamical procedures combined.

On the basis of this observation, it can again (see Schwiderski, 1978a, b; 1979a, b, d, e; 1980, and 1981a - f) be estimated that the Q_1 tidal charts permit a tide prediction with a uniform accuracy relative to M_2 of better than 5 cm anywhere in the open oceans. Naturally, near rough ocean basin reliefs (e.g., Arctic and Antarctic shores), where empirical tide (and depth) data are marginal in quality and quantity, a somewhat lesser accuracy must be expected. The estimated

accuracy of the computed Q_1 tide is, of course, fully validated by all 32 empirical tide data from distant off-shore deep-sea tide gauge stations, which are listed along with the computed data in Tables 1, 2, and 3. The differences (not necessarily errors) range from 0 to 1 cm in amplitudes and 0° to 23° (100 minutes) in phases and thus verify the estimated prediction accuracy. In this connection one may recall the accuracy discussion of the deep-sea empirical data presented in Part IV of this report.

Table 1. North Atlantic Ocean Deep-Sea Empirical and Modeled Q_1 Tides

LONG W	LAT N	EMP ξ	MOD ξ	$\Delta\xi$	EMP δ	MOD δ	$\Delta\delta$	IAPSO NR	SOURCES
13°51'	58°16'	3	2	-1	329	323	-6	1.1.37	C
24°43'	62°50'	1	1	0	21	358	-23	1.1.29	C
28°46'	60°12'	1	1	0	3	359	-4	1.1.30	C
29°58'	57°01'	1	1	0	2	351	-11	1.1.31	C
30°10'	53°39'	0	1	+1	347	341	-6	1.1.32	C
25°06'	53°31'	1	1	0	330	325	-5	1.1.33	C
20°00'	53°39'	1	1	0	315	312	-3	1.1.34	C
28°11'	48°45'	1	1	0	328	326	-2	1.1.38	C
28°09'	45°21'	1	1	0	312	306	-6	1.1.39	C
27°57'	41°25'	1	1	0	272	284	+12	1.1.40	C
20°05'	37°09'	2	1	-1	246	267	+21	1.1.41	C
14°15'	36°41'	2	1	-1	262	264	+2	1.1.42	C
75°38'	32°42'	2	1	-1	185	187	+2	1.2. 3	C, M
76°25'	30°26'	1	1	0	184	191	+7	1.2.11	C, P
76°48'	28°27'	1	1	0	193	196	+3	1.2.15	C
76°47'	28°01'	2	1	-1	200	196	-4	1.2.14	C
67°32'	28°14'	1	1	0	192	197	+5	1.2. 5	C, Z
69°45'	28°08'	1	1	0	193	196	+3	1.2. 4	C, Z
69°40'	27°59'	2	1	-1	196	199	+3	1.2. 8	C, Z
69°40'	27°58'	1	1	0	191	199	+6	1.2. 7	C, Z
69°20'	26°28'	1	1	0	195	201	+6	1.2.10	C, Z
69°19'	26°27'	1	1	0	194	201	+7	1.2. 9	C, Z

ξ = Amplitudes (cm)

δ = Greenwich Phases (deg)

IAPSO = Int. Assoc. for the Phys. Sci. of the Oceans

C = Cartwright et al. (1979)

M = Mofjeld (1975)

P = Pearson (1975)

Z = Zetler et al. (1975)

Table 2. Northeastern Pacific Ocean Deep-Sea Empirical and Modeled Q₁ Tides

LONG W	LAT N	EMP ξ	MOD ξ	$\Delta\xi$	EMP δ	MOD δ	$\Delta\delta$	IAPSO NR	SOURCES
144°22'	56°08'	5	5	0	242	246	+4	2.1.17	C
135°38'	53°19'	5	5	0	240	236	-4	2.1.16	C
132°47'	49°35'	5	5	0	230	230	0	2.1.15	C
145°00'	34°00'	-	3	-	-	284	-	-	-
145°00'	34°00'	-	3	-	-	284	-	-	-
124°26'	27°45'	3	3	0	181	190	+9	2.1.13	C, M
129°01'	24°47'	2	3	-1	190	195	+5	2.1.10	C, M

ξ = Amplitudes (cm)

δ = Greenwich Phases (deg)

IAPSO = Int. Assoc. for the Phys. Sci. of the Oceans

C = Cartwright et al. (1979)

M = Munk et al. (1970)

Table 3. Southeast Indian Ocean Deep-Sea Empirical and Modeled Q₁ Tides

LONG E	LAT S	EMP ξ	MOD ξ	$\Delta\xi$	EMP δ	MOD δ	$\Delta\delta$	IAPSO NR	SOURCES
132°01'	37°01'	3	3	0	226	211	-15	4.1. 1	C, IS
132°09'	50°02'	3	2	-1	220	217	-3	4.1. 2	C, IS
132°07'	60°01'	4	4	0	187	200	+13	4.1. 3	C, IS

ξ = Amplitudes (cm)

δ = Greenwich Phases (deg)

IAPSO = Int. Assoc. for the Phys. Sci. of the Oceans

C = Cartwright et al. (1979)

IS = Irish and Snodgrass (1972)

From the tidal charts and maps in Appendixes A and B, one concludes that the rotating tidal waves of the diurnal tides Q₁, K₁, O₁, and P₁ display general similarities (see Parts IV, V, and VII). Similarities between the diurnal tides and the semidiurnal components (M₂, S₂, N₂, and K₂) exist but to a considerably lesser degree (compare Parts II, III, VI, and VIII).

4. CONCLUSIONS

The hydrodynamical interpolation technique has been applied to construct the diurnal elliptical lunar tide (Q_1) with a relative accuracy of better than 5 cm anywhere in the open oceans. The constructed tide is displayed by tabulated charts in Appendix A and by corange and cotidal maps in Appendix B. The major features of the Q_1 tide are discussed in Section 3. A comparison with the earlier computed diurnal and semidiurnal ocean tides reveals general and qualitative similarities, respectively.

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APPENDIX A

**ATLAS OF $1^{\circ} \times 1^{\circ} Q_1$ OCEAN-TIDE AMPLITUDE
AND PHASE CHARTS FOR $42^{\circ} \times 71^{\circ}$ AREAS**

APPENDIX A

ATLAS OF 1° x 1° Q₁ OCEAN-TIDE AMPLITUDE AND PHASE CHARTS FOR 42° x 71° AREAS

1. GUIDE TO TIDAL CHARTS

- M = m: Longitude Number
N = n: Colatitude Number
 λ_m = (m - 0.5)°: Geographical Longitude East
 θ_n = (n - 0.5)°: Geographical Colatitude
 $\xi_{m,n}$ = $\xi(\lambda_m, \theta_n)$: Amplitude (in mm)
 $\delta_{m,n}$ = $\delta(\lambda_m, \theta_n)$: Greenwich Phases (in deg.; 15° ≈ 1 h)
⊗ = Amphidromic Points
- = Subbars Mark Empirical Input Data at Shore Stations
┌ = Subbrackets Mark Empirical Input Data at Near-Shore Deep-Sea Stations
~ = Subtildes Mark Approximately Distant Offshore Deep-Sea Stations with Excluded Empirical Tide Data Listed in Tables 1, 2, and 3

2. SOURCES OF EMPIRICAL TIDE DATA

Publications:

National Ocean Survey (1942), British Admiralty (1977), International Hydrographic Bureau (1978), Defant (1961), Miyazaki et al. (1967), Nowroozi et al. (1969), Munk et al. (1970), Zahel (1970), Irish et al. (1971), Irish and Snodgrass (1972), Nowroozi (1972), Luther and Wunsch (1975), Mofjeld (1975), Pearson (1975), Zetler et al. (1975), Cartwright et al. (1979), and Pugh (1979).

Private Communications:

D. C. Simpson (1977), National Ocean Survey, Rockville, Maryland; S. K. Gill and D. L. Porter (1978), National Ocean Survey, Rockville, Maryland; K. Wyrski (1978), University of Hawaii, Honolulu, Hawaii, and D. E. Cartwright and D. Pugh (1978), Institute of Oceanographic Sciences, Bidston Observatory, U.K.

TABLE 3N. $1^\circ \times 1^\circ \text{O}_1$ OCEAN TIDE GREENWICH PHASES δ (DEG)

1	203	262	262	261	261	260	260	259	259	259	259	259	258	258	257	257	257	256	256	256	255	255	255	254	254	253	253	253	252	252	252	251	251	251	250	250	250				
2	265	265	264	263	262	261	260	259	258	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228			
3	270	263	267	265	264	262	261	260	258	257	256	254	253	251	250	249	248	247	245	244	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225			
4	258	265	264	262	261	259	257	255	254	252	251	249	248	246	245	243	242	241	240	239	238	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219		
5	252	260	258	256	254	252	250	249	248	246	245	243	242	241	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215		
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9	255	254	253	252	251	250	249	248	247	246	245	243	242	241	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215		
10	258	258	258	257	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222		
11	265	264	264	263	262	261	260	259	258	257	256	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	
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13	263	262	261	260	259	258	257	256	255	254	253	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	
14	264	261	258	256	254	252	251	250	249	248	247	245	244	243	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215
15	257	261	259	257	255	253	252	251	250	249	248	246	245	244	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216
16	251	244	239	233	229	226	224	223	221	219	217	215	214	213	211	210	209	208	207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187	186	
17	181	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	
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TABLE 6N. 1° X 1° O₁ OCEAN TIDE AMPLITUDES ξ (MM)

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TABLE 7N: 1° X 1° O₁ OCEAN TIDE GREENWICH PHASES δ (DEG)

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1	246	247	247	248	248	249	249	249	249	250	251	251	252	252	253	253	254	254	255	255	256	256	257	257	258	258	259	259	260	260	261	261	262	262	263	263	264	264	264	264																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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3	192	192	192	192	193	193	194	194	195	196	196	197	197	198	198	201	203	204	205	207	208	211	215	218	222	226	229	233	237	241	246	251	257	262	267	272	276	282	284	287	289	291	293	295	298	300	302	304	306	308	310	312	315	318	321	324	327	330	333	336	339	342	345	348	351	354	357	360	363	366	369	372	375	378	381	384	387	390	393	396	399	402	405	408	411	414	417	420	423	426	429	432	435	438	441	444	447	450	453	456	459	462	465	468	471	474	477	480	483	486	489	492	495	498	501	504	507	510	513	516	519	522	525	528	531	534	537	540	543	546	549	552	555	558	561	564	567	570	573	576	579	582	585	588	591	594	597	600	603	606	609	612	615	618	621	624	627	630	633	636	639	642	645	648	651	654	657	660	663	666	669	672	675	678	681	684	687	690	693	696	699	702	705	708	711	714	717	720	723	726	729	732	735	738	741	744	747	750	753	756	759	762	765	768	771	774	777	780	783	786	789	792	795	798	801	804	807	810	813	816	819	822	825	828	831	834	837	840	843	846	849	852	855	858	861	864	867	870	873	876	879	882	885	888	891	894	897	900	903	906	909	912	915	918	921	924	927	930	933	936	939	942	945	948	951	954	957	960	963	966	969	972	975	978	981	984	987	990	993	996	999	1002	1005	1008	1011	1014	1017	1020	1023	1026	1029	1032	1035	1038	1041	1044	1047	1050	1053	1056	1059	1062	1065	1068	1071	1074	1077	1080	1083	1086	1089	1092	1095	1098	1101	1104	1107	1110	1113	1116	1119	1122	1125	1128	1131	1134	1137	1140	1143	1146	1149	1152	1155	1158	1161	1164	1167	1170	1173	1176	1179	1182	1185	1188	1191	1194	1197	1200	1203	1206	1209	1212	1215	1218	1221	1224	1227	1230	1233	1236	1239	1242	1245	1248	1251	1254	1257	1260	1263	1266	1269	1272	1275	1278	1281	1284	1287	1290	1293	1296	1299	1302	1305	1308	1311	1314	1317	1320	1323	1326	1329	1332	1335	1338	1341	1344	1347	1350	1353	1356	1359	1362	1365	1368	1371	1374	1377	1380	1383	1386	1389	1392	1395	1398	1401	1404	1407	1410	1413	1416	1419	1422	1425	1428	1431	1434	1437	1440	1443	1446	1449	1452	1455	1458	1461	1464	1467	1470	1473	1476	1479	1482	1485	1488	1491	1494	1497	1500	1503	1506	1509	1512	1515	1518	1521	1524	1527	1530	1533	1536	1539	1542	1545	1548	1551	1554	1557	1560	1563	1566	1569	1572	1575	1578	1581	1584	1587	1590	1593	1596	1599	1602	1605	1608	1611	1614	1617	1620	1623	1626	1629	1632	1635	1638	1641	1644	1647	1650	1653	1656	1659	1662	1665	1668	1671	1674	1677	1680	1683	1686	1689	1692	1695	1698	1701	1704	1707	1710	1713	1716	1719	1722	1725	1728	1731	1734	1737	1740	1743	1746	1749	1752	1755	1758	1761	1764	1767	1770	1773	1776	1779	1782	1785	1788	1791	1794	1797	1800	1803	1806	1809	1812	1815	1818	1821	1824	1827	1830	1833	1836	1839	1842	1845	1848	1851	1854	1857	1860	1863	1866	1869	1872	1875	1878	1881	1884	1887	1890	1893	1896	1899	1902	1905	1908	1911	1914	1917	1920	1923	1926	1929	1932	1935	1938	1941	1944	1947	1950	1953	1956	1959	1962	1965	1968	1971	1974	1977	1980	1983	1986	1989	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022	2025	2028	2031	2034	2037	2040	2043	2046	2049	2052	2055	2058	2061	2064	2067	2070	2073	2076	2079	2082	2085	2088	2091	2094	2097	2100	2103	2106	2109	2112	2115	2118	2121	2124	2127	2130	2133	2136	2139	2142	2145	2148	2151	2154	2157	2160	2163	2166	2169	2172	2175	2178	2181	2184	2187	2190	2193	2196	2199	2202	2205	2208	2211	2214	2217	2220	2223	2226	2229	2232	2235	2238	2241	2244	2247	2250	2253	2256	2259	2262	2265	2268	2271	2274	2277	2280	2283	2286	2289	2292	2295	2298	2301	2304	2307	2310	2313	2316	2319	2322	2325	2328	2331	2334	2337	2340	2343	2346	2349	2352	2355	2358	2361	2364	2367	2370	2373	2376	2379	2382	2385	2388	2391	2394	2397	2400	2403	2406	2409	2412	2415	2418	2421	2424	2427	2430	2433	2436	2439	2442	2445	2448	2451	2454	2457	2460	2463	2466	2469	2472	2475	2478	2481	2484	2487	2490	2493	2496	2499	2502	2505	2508	2511	2514	2517	2520	2523	2526	2529	2532	2535	2538	2541	2544	2547	2550	2553	2556	2559	2562	2565	2568	2571	2574	2577	2580	2583	2586	2589	2592	2595	2598	2601	2604	2607	2610	2613	2616	2619	2622	2625	2628	2631	2634	2637	2640	2643	2646	2649	2652	2655	2658	2661	2664	2667	2670	2673	2676	2679	2682	2685	2688	2691	2694	2697	2700	2703	2706	2709	2712	2715	2718	2721	2724	2727	2730	2733	2736	2739	2742	2745	2748	2751	2754	2757	2760	2763	2766	2769	2772	2775	2778	2781	2784	2787	2790	2793	2796	2799	2802	2805	2808	2811	2814	2817	2820	2823	2826	2829	2832	2835	2838	2841	2844	2847	2850	2853	2856	2859	2862	2865	2868	2871	2874	2877	2880	2883	2886	2889	2892	2895	2898	2901	2904	2907	2910	2913	2916	2919	2922	2925	2928	2931	2934	2937	2940	2943	2946	2949	2952	2955	2958	2961	2964	2967	2970	2973	2976	2979	2982	2985	2988	2991	2994	2997	3000	3003	3006	3009	3012	3015	3018	3021	3024	3027	3030	3033	3036	3039	3042	3045	3048	3051	3054	3057	3060	3063	3066	3069	3072	3075	3078	3081	3084	3087	3090	3093	3096	3099	3102	3105	3108	3111	3114	3117	3120	3123	3126	3129	3132	3135	3138	3141	3144	3147	3150	3153	3156	3159	3162	3165	3168	3171	3174	3177	3180	3183	3186	3189	3192	3195	3198	3201	3204	3207	3210	3213	3216	3219	3222	3225	3228	3231	3234	3237	3240	3243	3246	3249	3252	3255	3258	3261	3264	3267	3270	3273	3276	3279	3282	3285	3288	3291	3294	3297	3300	3303	3306	3309	3312	3315	3318	3321	3324	3327	3330	3333	3336	3339	3342	3345	3348	3351	3354	3357	3360	3363	3366	3369	3372	3375	3378	3381	3384	3387	3390	3393	3396	3399	3402	3405	3408	3411	3414	3417	3420	3423	3426	3429	3432	3435	3438	3441	3444	3447	3450	3453	3456	3459	3462	3465	3468	3471	3474	3477	3480	3483	3486	3489	3492	3495	3498	3501	3504	3507	3510	3513	3516	3519	3522	3525	3528	3531	3534	3537	3540	3543	3546	3549	3552	3555	3558	3561	3564	3567	3570	3573	3576	3579	3582	3585	3588	3591	3594	3597	3600	3603	3606	3609	3612	3615	3618	3621	3624	3627	3630	3633	3636	3639	3642	3645	3648	3651	3654	3657	3660	3663	3666	3669	3672	3675	3678	3681	3684	3687	3690	3693	3696	3699	3702	3705	3708	3711	3714	3717	3720	3723	3726	3729	3732	3735	3738	3741	3744	3747	3750	3753	3756	3759	3762	3765	3768	3771	3774	3777	3780	3783	3786	3789	3792	3795	3798	3801	3804	3807	3810	3813	3816	3819	3822	3825	3828	3831	3834	3837	3840	3843	3846	3849	3852	3855	3858	3861	3864	3867	3870	3873	3876	3879	3882	3885	3888	3891	3894	3897	3900	3903	3906	3909	3912	3915	3918	3921	3924	3927	3930	3933	3936	3939	3942	3945	3948	3951	3954	3957	3960	3963	3966	3969	3972	3975	3978	3981	3984	3987	3990	3

TABLE 3M. 1° x 1° OCEAN TIDE GREENWICH PHASES δ (DEG)

Lat	100°E	90°E	80°E	70°E	60°E	50°E	40°E	30°E	20°E	10°E	0°	10°W	20°W	30°W	40°W	50°W	60°W	70°W	80°W	90°W	100°W															
80	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
70	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
60	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
50	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
40	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
30	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
20	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
10	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
0	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
10	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
20	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
30	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
40	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
50	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
60	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
70	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
80	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121
90	122	105	104	109	107	97	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121

SOUTHEASTERN CHINA

SOUTHEAST ASIA

INDONESIA

SUMATRA

BANGLADESH

EASTERN INDIA

NORTHWESTERN AUSTRALIA

80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121

TABLE 6M: 1° x 1° O₁ OCEAN TIDE AMPLITUDES ξ (MM)

NW	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201																																																																																																																																																																																																					
48	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201

TABLE 5M. 1° x 1° O₁ OCEAN TIDE GREENWICH PHASES δ (DEG)

180	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201																																																																																																																							
40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201

TABLE 7M: 1° x 1° O₁ OCEAN TIDE AMPLITUDES ξ (MM)

141 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280

Lat	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280																																																																																																																																			
40	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280

SOUTHERN USA

CALIFORNIA

MEXICO

MIDDLE AMERICA

FLORIDA

AMERICA

TABLE 18: 1° X 1° O₁ OCEAN TIDE GREENWICH PHASES δ (DEG)

181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
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SOUTHERN AFRICA

ANTARCTICA

295 302 305 309 313 316 319 322 325 328 331 334 337 340 343 346 349 352 355 358 361 364 367 370 373 376 379 382 385 388 391 394 397 400 403 406 409 412 415 418 421 424 427 430 433 436 439 442 445 448 451 454 457 460 463 466 469 472 475 478 481 484 487 490 493 496 499 502 505 508 511 514 517 520 523 526 529 532 535 538 541 544 547 550 553 556 559 562 565 568 571 574 577 580 583 586 589 592 595 598 601 604 607 610 613 616 619 622 625 628 631 634 637 640 643 646 649 652 655 658 661 664 667 670 673 676 679 682 685 688 691 694 697 700 703 706 709 712 715 718 721 724 727 730 733 736 739 742 745 748 751 754 757 760 763 766 769 772 775 778 781 784 787 790 793 796 799 802 805 808 811 814 817 820 823 826 829 832 835 838 841 844 847 850 853 856 859 862 865 868 871 874 877 880 883 886 889 892 895 898 901 904 907 910 913 916 919 922 925 928 931 934 937 940 943 946 949 952 955 958 961 964 967 970 973 976 979 982 985 988 991 994 997 1000

TABLE 58. 1° X 1° O₁ OCEAN TIDE AMPLITUDES ξ (MM)

160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201																																																																																																																																																
98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169																																																																																																																		
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201

ANTARCTICA

TABLES: $1^\circ \times 1^\circ \text{O}_1$ OCEAN TIDE GREENWICH PHASES δ (DEG)

Lat	Lon	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
98	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000

ANTARCTICA

TABLES: $1^\circ \times 1^\circ \text{O}_1$ OCEAN TIDE GREENWICH PHASES δ (DEG)

180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243																																																																																		
98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243

ANTARCTICA

TABLE 78: 1° X 1° Q₁ OCEAN TIDE GREENWICH PHASES δ (DEG)

184	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
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ANTARCTICA

TABLE 8S: 1° X 1° O₁ OCEAN TIDE AMPLITUDES ξ (MM)

184 284 295 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325

98	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168																																															
284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100																										

SOUTHERN SOUTH AMERICA

ANTARCTICA

TABLE 88. 1° X 1° O₁ OCEAN TIDE GREENWICH PHASES δ (DEG)

180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	360	359	358	357	356	355	354	353	352	351	350	349	348	347	346	345	344	343	342	341	340	339	338	337	336	335	334	333	332	331	330	329	328	327	326	325	324	323	322	321	320	319	318	317	316	315	314	313	312	311	310	309	308	307	306	305	304	303	302	301	300	299	298	297	296	295	294	293	292	291	290	289	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166	165	164	163	162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	360	359	358	357	356	355	354	353	352	351	350	349	348	347	346	345	344	343	342	341	340	339	338	337	336	335	334	333	332	331	330	329	328	327	326	325	324	323	322	321	320	319	318	317	316	315	314	313	312	311	310	309	308	307	306	305	304	303	302	301	300	299	298	297	296	295	294	293	292	291	290	289	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166	165	164	163	162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	360	359	358	357	356	355	354	353	352	351	350	349	348	347	346	345	344	343	342	341	340	339	338	337	336	335	334	333	332	331	330	329	328	327	326	325	324	323	322	321	320	319	318	317	316	315	314	313	312	311	310	309	308	307	306	305	304	303	302	301	300	299	298	297	296	295	294	293	292	291	290	289	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166	165	164	163	162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	360	359	358	357	356	355	354	353	352	351	350	349	348	347	346	345	344	343	342	341	340	339	338	337	336	335	334	333	332	331	330	329	328

APPENDIX B

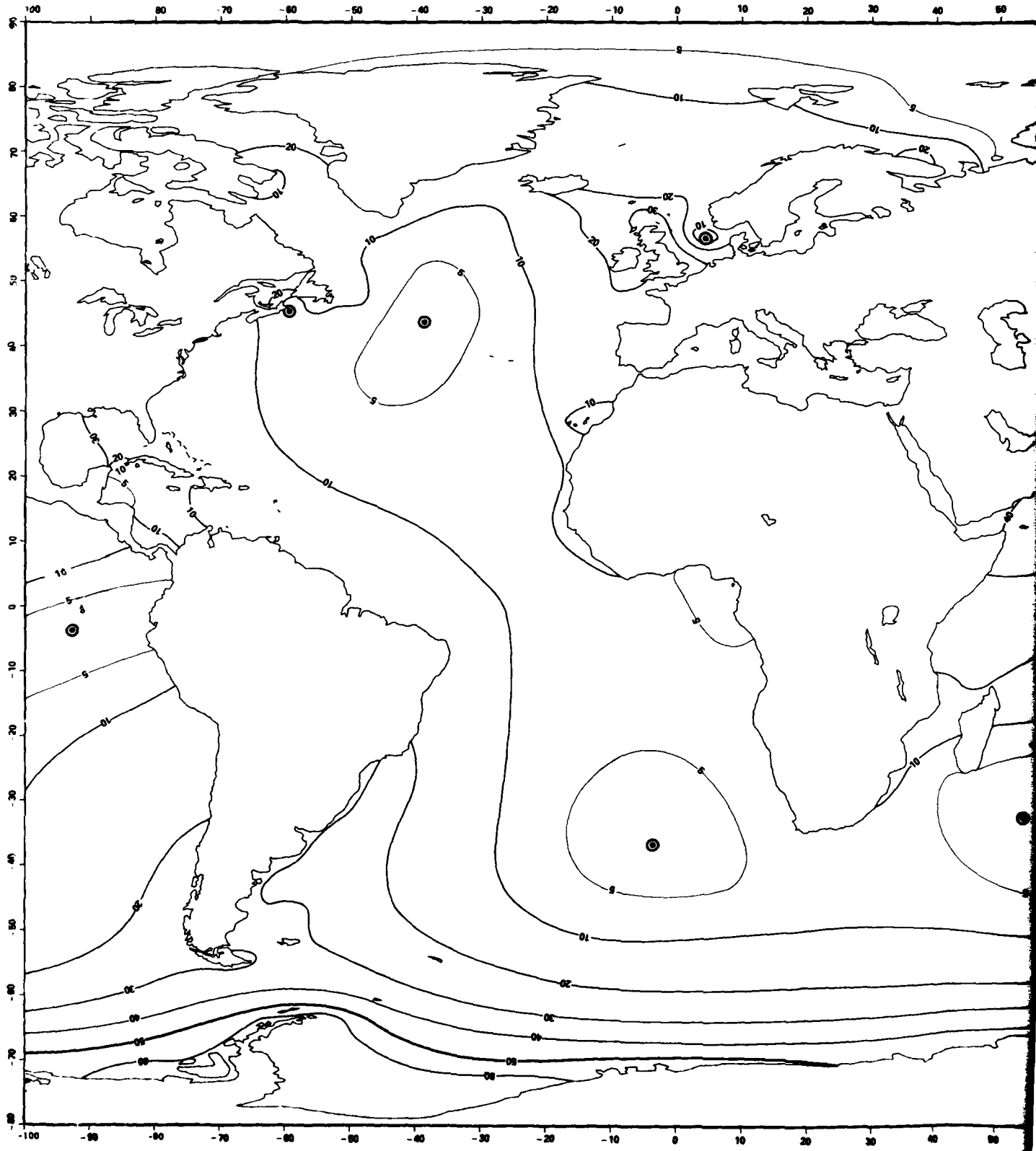
**ATLAS OF GLOBAL Q_1 OCEAN-TIDE
CORANGE AND COTIDAL MAPS**

APPENDIX B

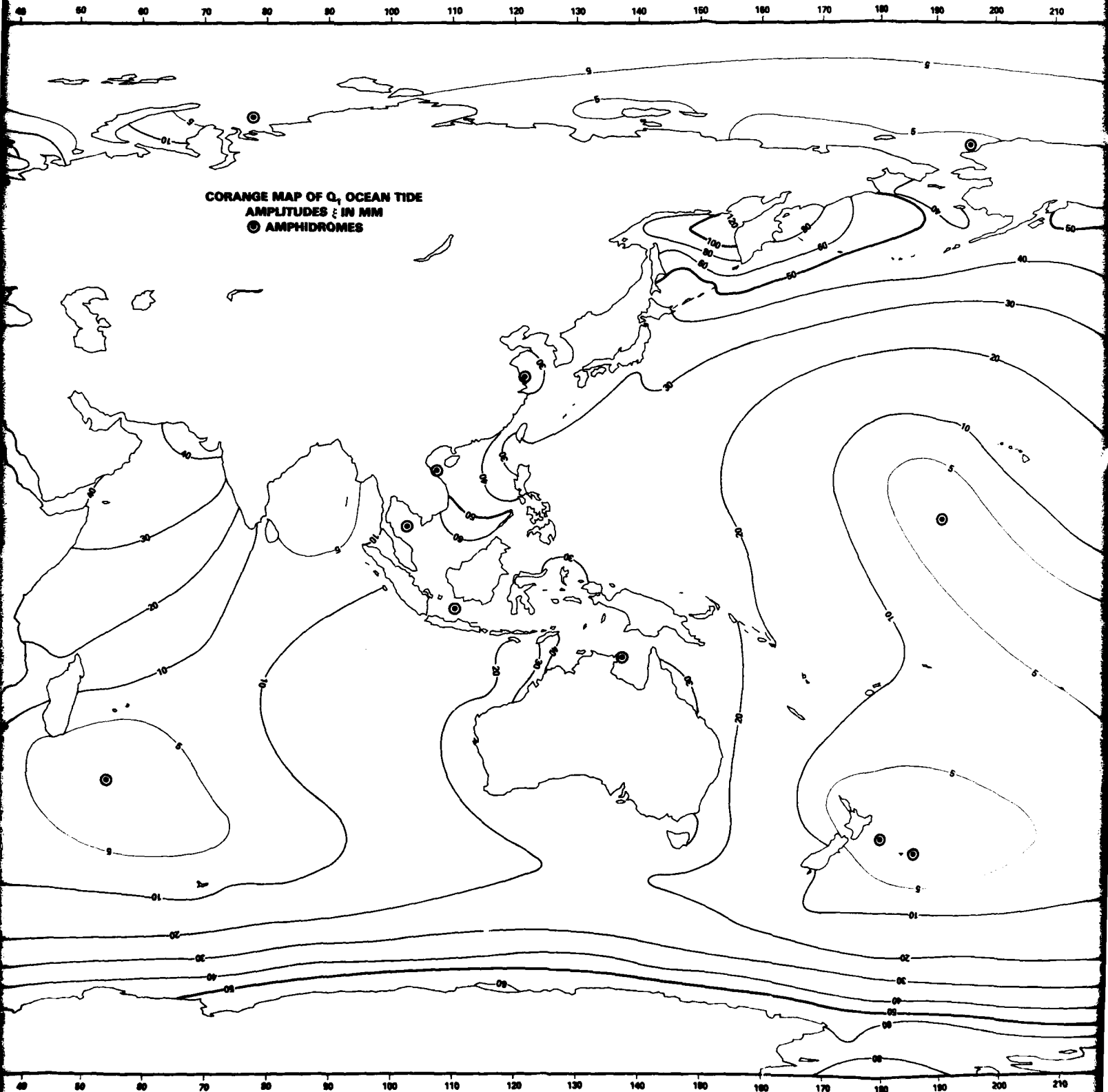
**ATLAS OF CORANGE AND COTIDAL MAPS
OF THE Q₁ OCEAN TIDE**

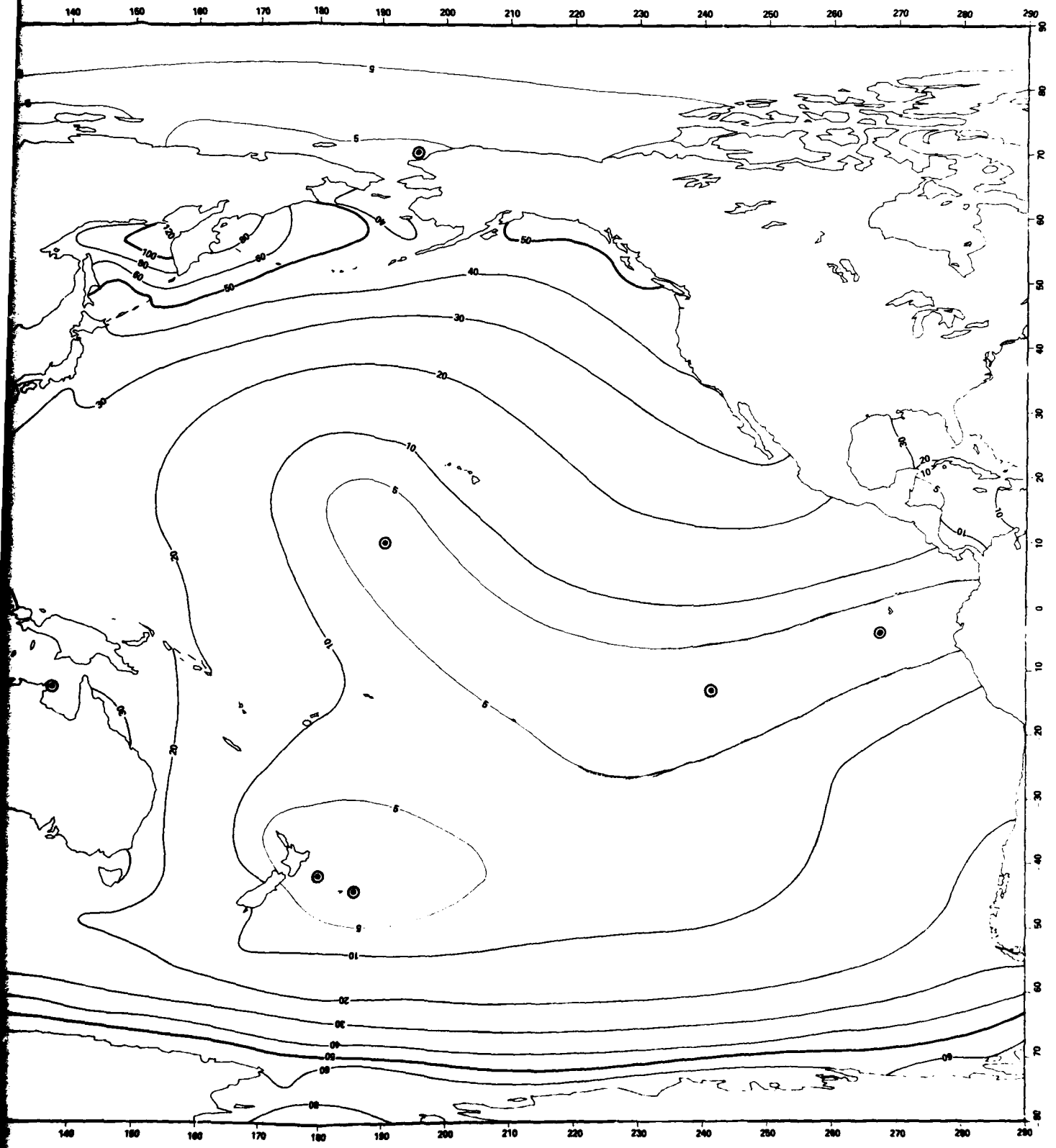
Amplitudes ξ of corange lines in mm.

Greenwich phases δ of cotidal lines in 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180, 195, 210, 225, 240, 255, 270, 285, 300, 315, 330, 345, 360 = 0° where 15° \approx 1 hour.

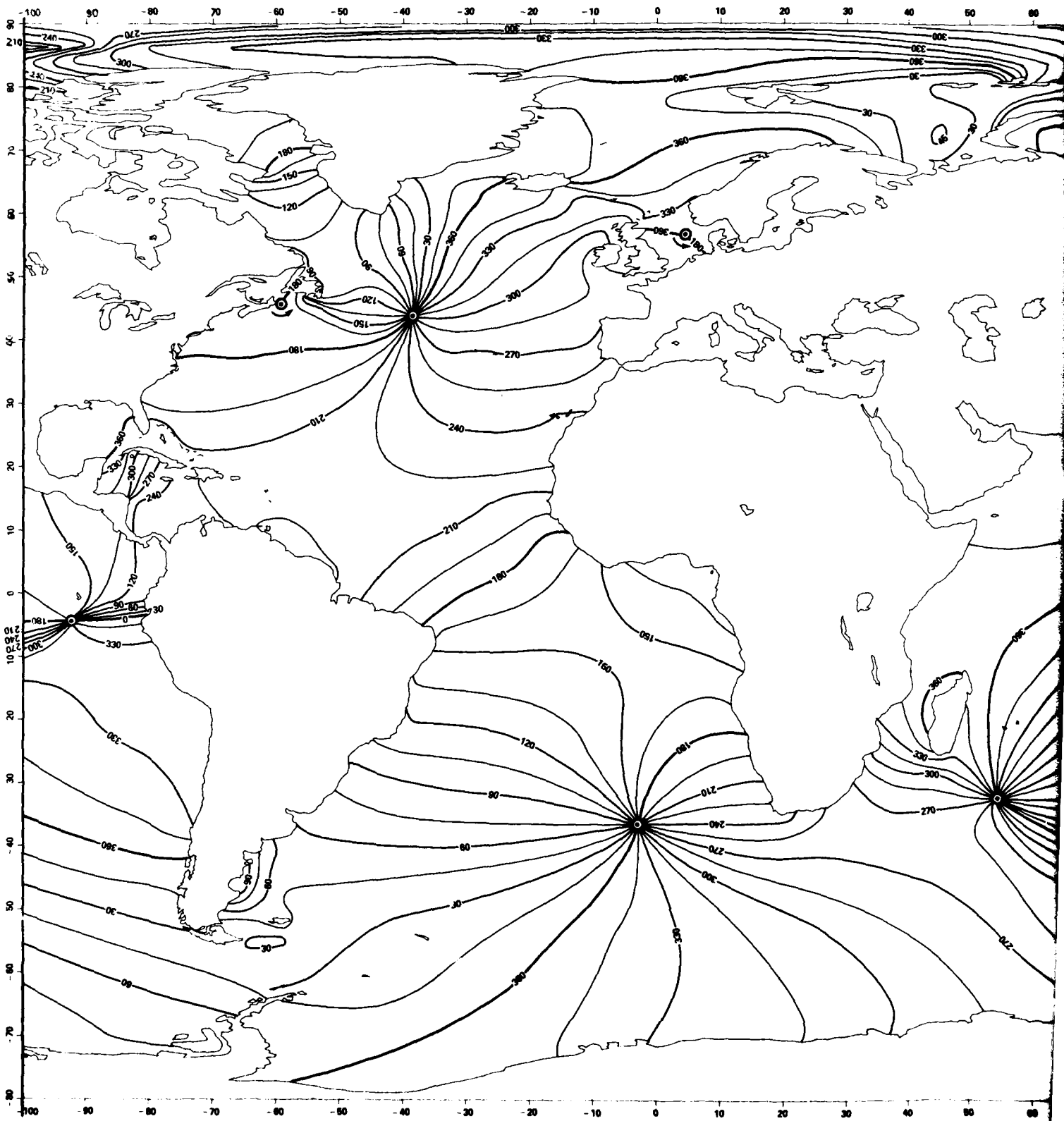


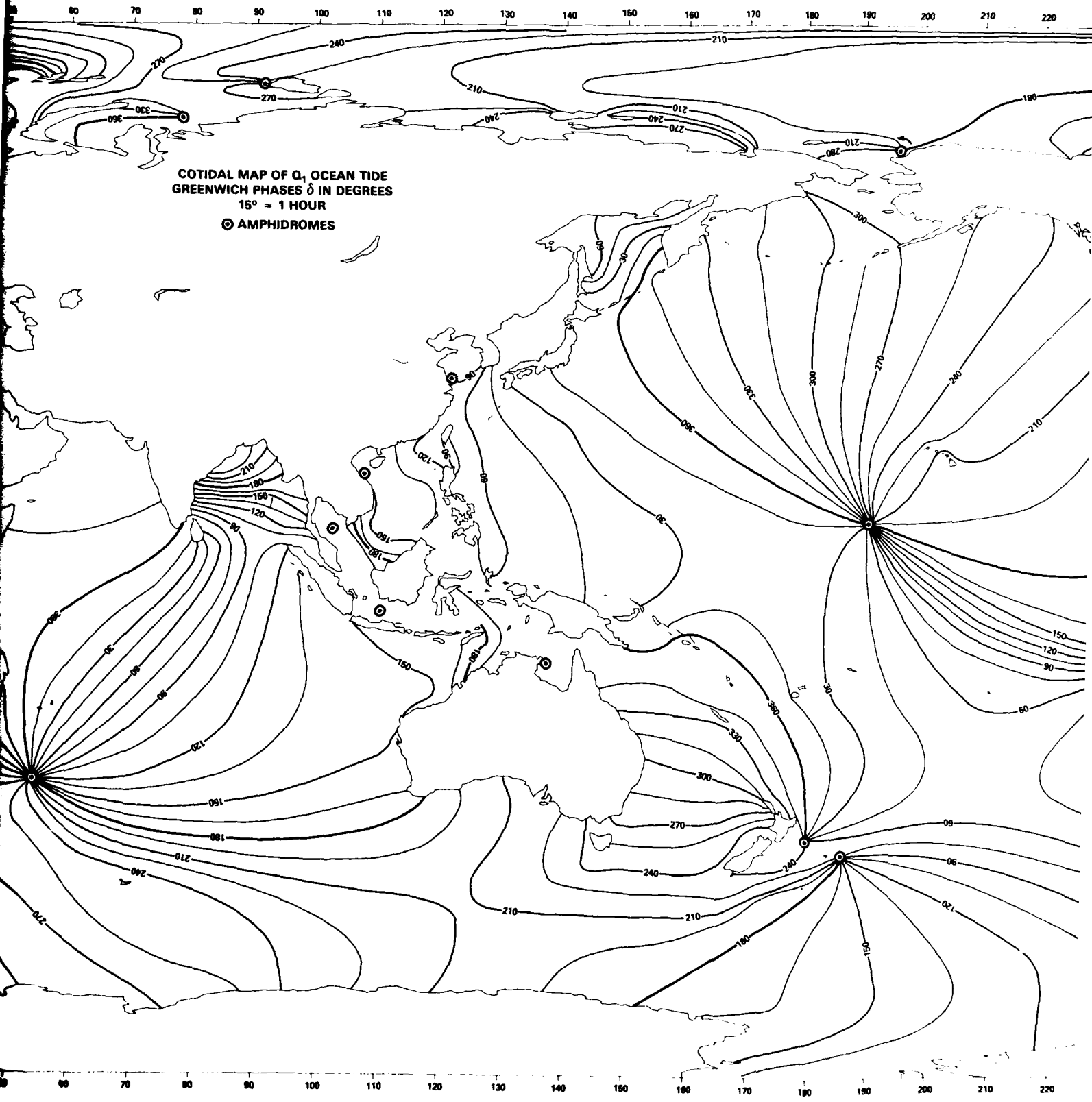
CORANGE MAP OF Q, OCEAN TIDE
AMPLITUDES ξ IN MM
⊙ AMPHIDROMES



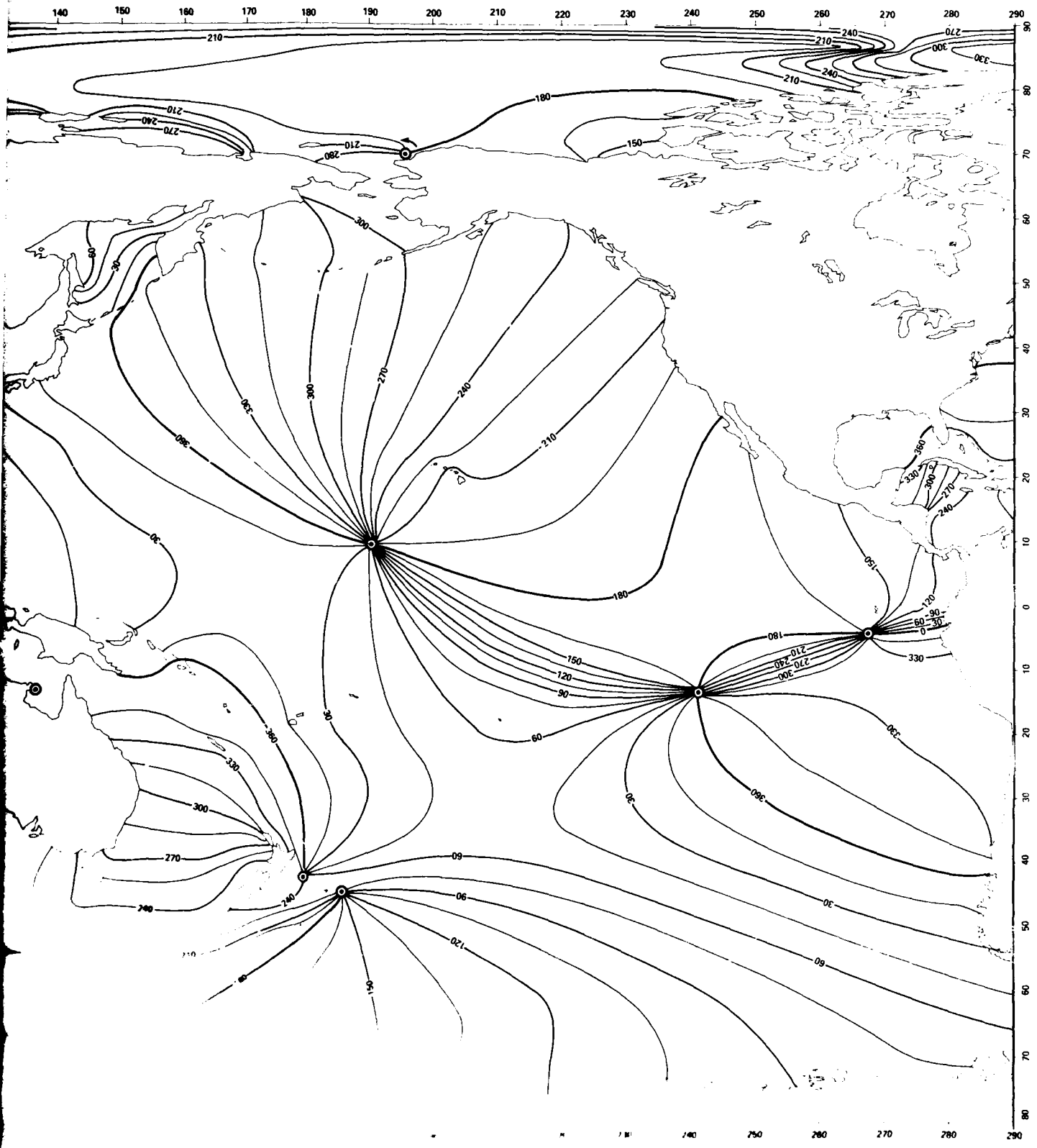


3

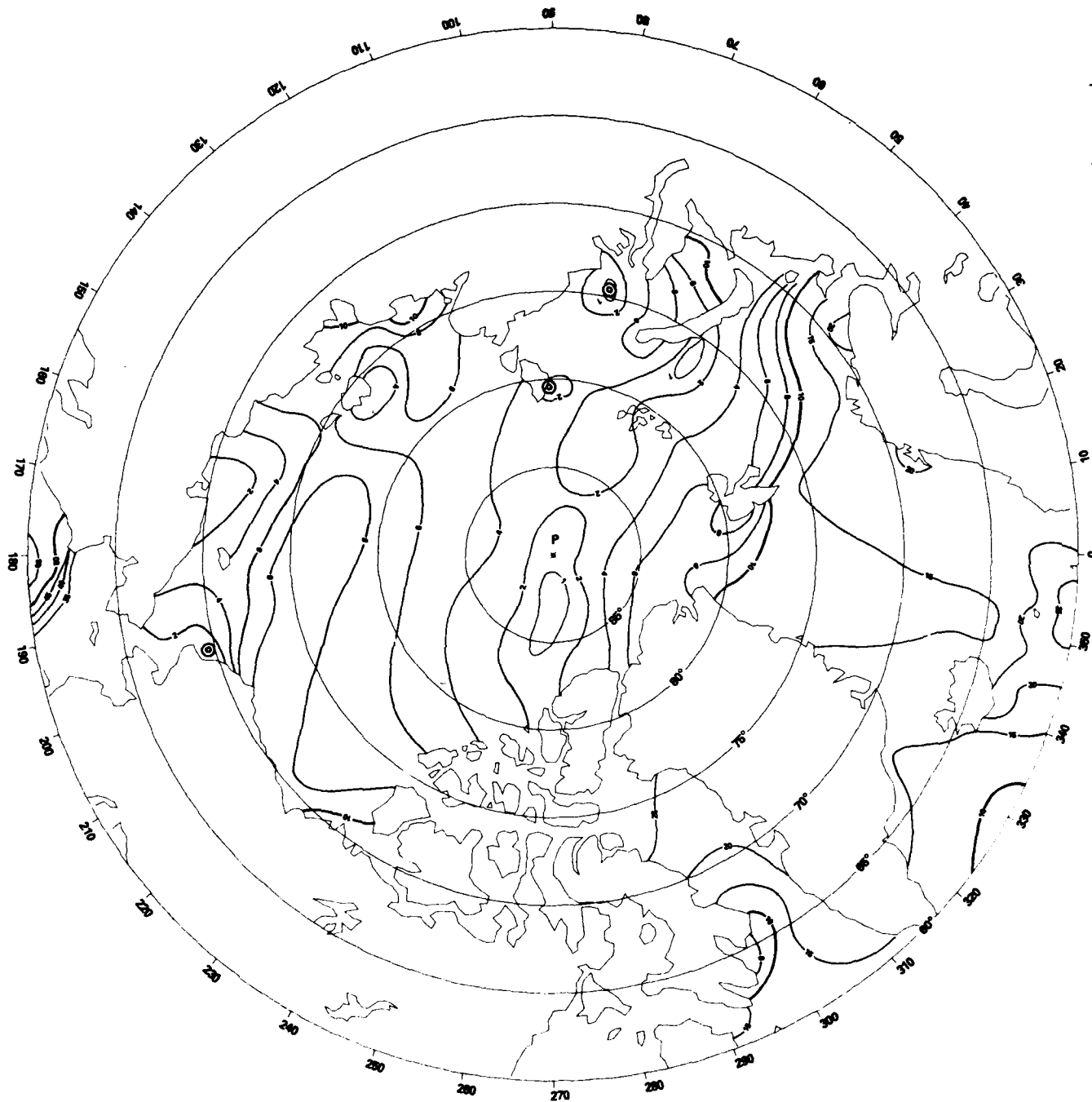




2



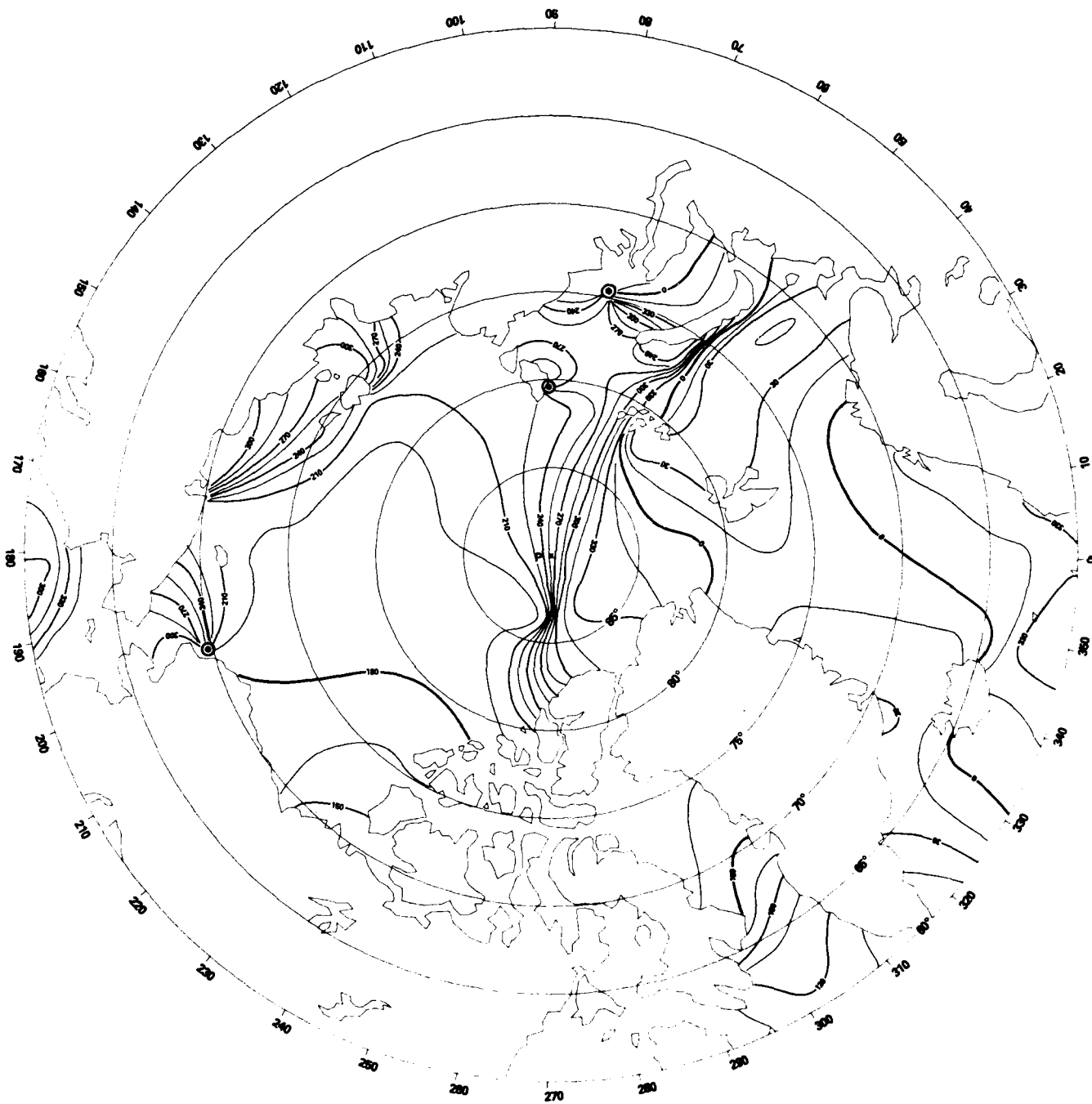
121



ARCTIC CORANGE MAP OF Q₁ OCEAN TIDE
AMPLITUDES ξ IN MM

⊙ AMPHIDROMES

* P NORTH POLE



ARCTIC COTIDAL MAP OF Q₁ OCEAN TIDE
 GREENWICH PHASES δ IN DEGREES
 15° ≈ 1 HOUR

⊙ AMPHIDROMES ★ P NORTH POLE

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