ANTARCTIC TIDES

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Up to the present, widely-differing opinions have been expressed concerning the behaviour of the tide in the Antarctic; and this is no doubt due to lack of continuous reliable observations so necessary for research work of this nature.

During the 1948-49 season carried out in the Antarctic by the Argentine tug-boat "Sanavirôn" under the auspices of the "Dirección General de Navegación e Hidrografía" of Buenos Aires, and thanks to the sense of duty, the efforts and praiseworthy spirit of sacrifice of its members, it was possible to collate amongst other valuable contributions to science, one month's consecutive tidal observations at Puerto Neko which permit the greater part of tidal characteristics in these distant latitudes to be recorded.

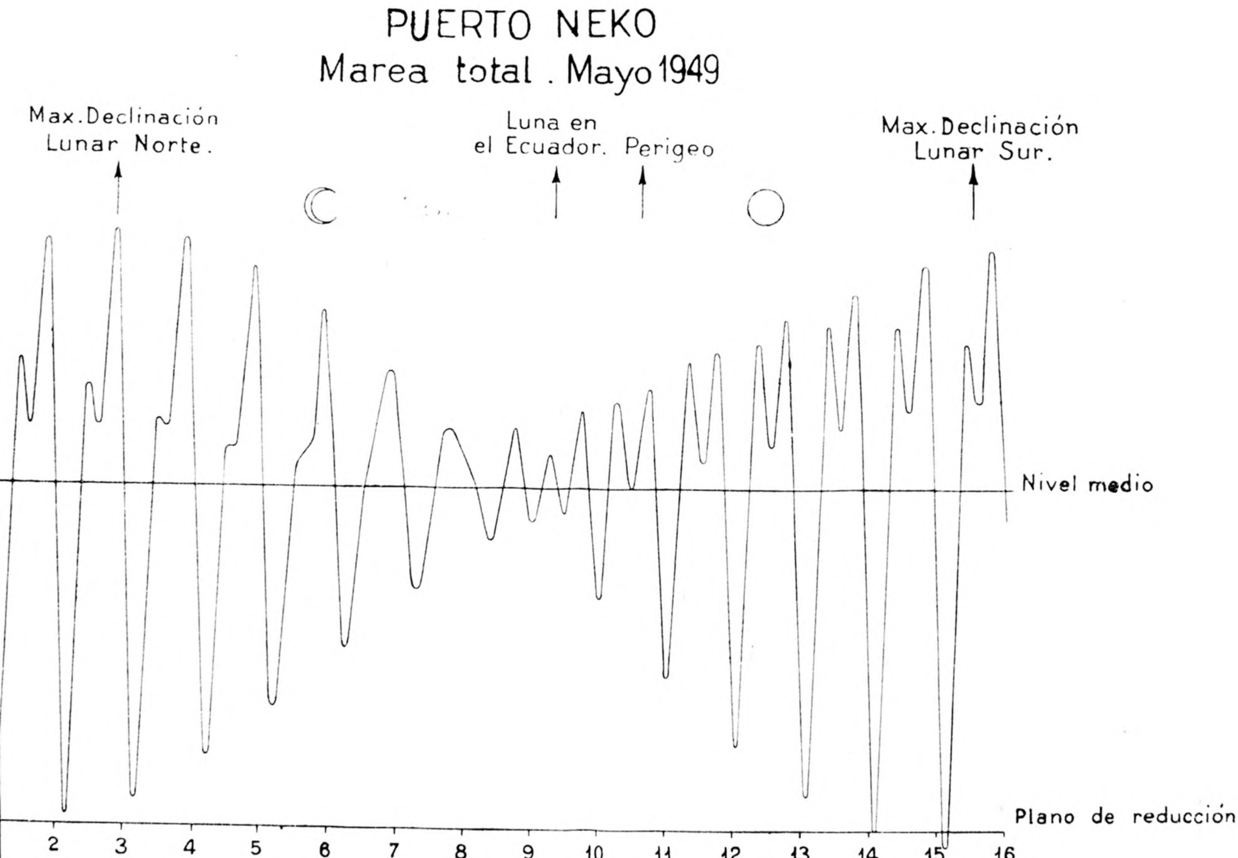

FIG. 1

It was no easy work; however, the sacrifices of the personnel have not been unfruitul in results for, after due study and analysis of these observations, the " Dirección General de Navegación e Hidrografía " are already not only in possession of a knowledge of this tidal system and its components but can also compute predictions and thus add, with the southernmost of Argentine ports, to the list of constants entered in our Tide Tables.

Harmonic analysis has yielded the following results :-

PUERTO NEKO.... $\varphi = 64°48'$ S. W = 62°23' W.
= 4 h. 10 m.

COMPONENTS	SEMIAMPLITUDE H	PHASE-LAG K
M_2	28 cm. = 0.928 pies	189°8
S_2	20 cm. = 0.699 —	274°2
K_1	33 cm. = 1.093 —	33°9
O_1	31 cm. = 1.040 —	15°9
P_1	11 cm. = 0.361 —	33°9
K_2	5 cm. = 0.180 —	274°2
N_2	2 cm. = 0.082 —	132°6
M_4	1 cm. = 0.023 —	210°8
$(MS)_4$	1 cm. = 0.030 —	81°1

Chart datum : 123 cm. below mean level.

During the favourable 1949-1950 season, the " Dirección General de Navegación e Hidrografía " added to available tidal data in the Antarctic through the installation of an automatic recording tidal station at the Naval

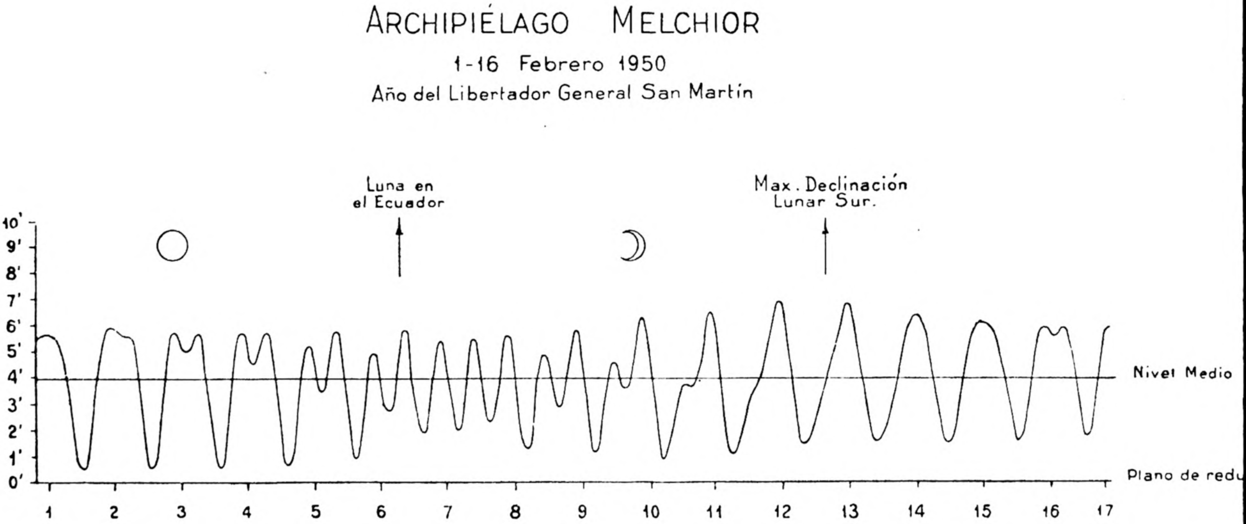

Fig. 2

post in Melchior Archipelago. This station began to operate regularly in January, 1950, and will continue to operate until the appearance of ice prevents its doing so.

The record obtained at this new tidal station confirms the character of the antarctic tide already revealed by the mareometric station installed at Puerto Neko the preceding season.

Diagram No. 2 shows the tidal records of the Melchior station for the month of February, 1950.

The study of tides in this area of the Antarctic is of special interest.

Although the tidal system may be included among those classed under the title : " Diurnal Inequalities ", the particularity of its " Double High Waters " is quite apparent.

This fact, now clearly demonstrated by analysis, leads the uninformed observer into the most varied hypotheses.

As may be seen from the recorded tidal diagram for Puerto Neko (Fig. 1), the epochs at which two consecutive High Waters occur are very

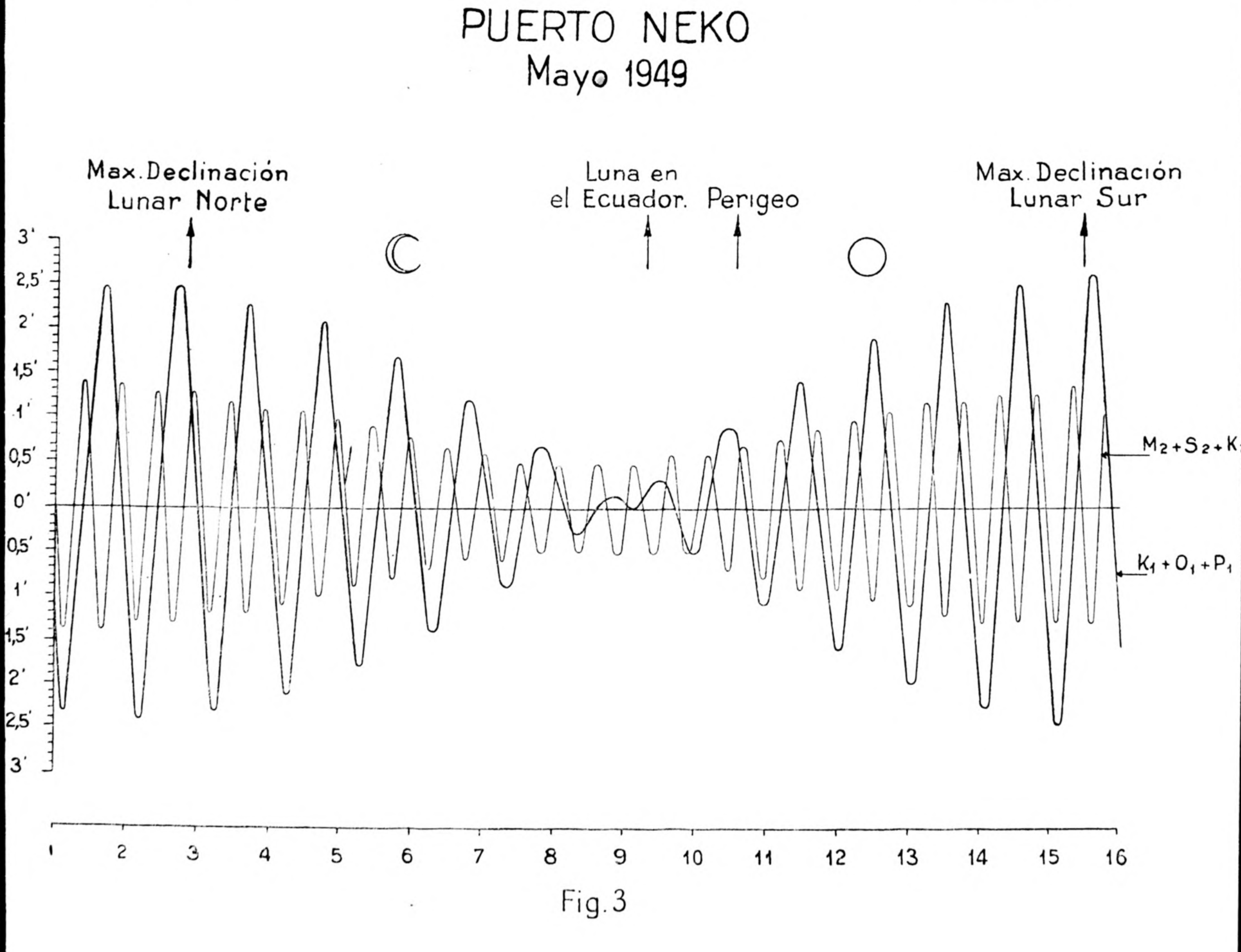

Fig. 3

frequent but in the interval between these High Waters the fall of sea-level does not reach its usual limits. The time interval between the moment when the tide begins to rise and the moment when it decisively begins to fall, is therefore greater than 15 hours.

If this phenomenon begins to appear in the early hours of the considered day, the observer notes a constant rise of water level even a certain time after night has set in.

The following day the phenomenon occurs, its phase varying concurrently with the relative position of the component waves.

If in these circumstances observations were interrupted during the night hours, which was the case, difficulties with regard to deduction of the exact regime would result. If the observations are extended to the 24 hours of each day and during a continuous period of one month, the salient characteristics of the system are established with great exactitude.

Given the geographical position of Puerto Neko in the vicinity of the limit between the Atlantic and Pacific Oceans, its tide is influenced by the predominant tidal waves in each of these seas respectively. Generally speaking, it may be said that in those latitudes the diurnal wave predominates in the Pacific, the semi-diurnal in the Atlantic. At Puerto Neko the range of the diurnal tide reaches 1.50 metres while the semi-diurnal reaches only 1.06 metres (Fig. 3).

SEMI-DIURNAL TIDE.—The semi-diurnal tide at Puerto Neko is sufficiently well represented by the components M_2, S_2 and K_2, for the other principal components have no appreciable influence.

Throughout the synodic month the range of the semi-diurnal tide varies according to diagram No. 3 which represents a part of its development where the syzygies and lunar quadratures tides exist.

DIURNAL TIDE.—It becomes evident from the study of diagram No. 3 that the diurnal wave represented by its principal components K_1, O_1 and P_1 is preponderant at Puerto Neko.

During the tropical month its range varies according to whether the phase are in coincidence (syzygies) or differ by 180° (quadratures).

TIDAL SEQUENCE.—The combination of these two waves (semi-diurnal and diurnal), perfectly defined at Puerto Neko, engenders various forms of the tide which may be examined on the consequent tides diagram (Fig. 1).

The diurnal form of the tide remains more or less the same at known epochs such as, for instance, those corresponding to the lunar tropics (Maximum rise). (Grande croissance.)

Given the predominance of the diurnal wave, the latter imposes, in conjunction with the component M_2 (semi-diurnal), the salient characteristic of the tide.

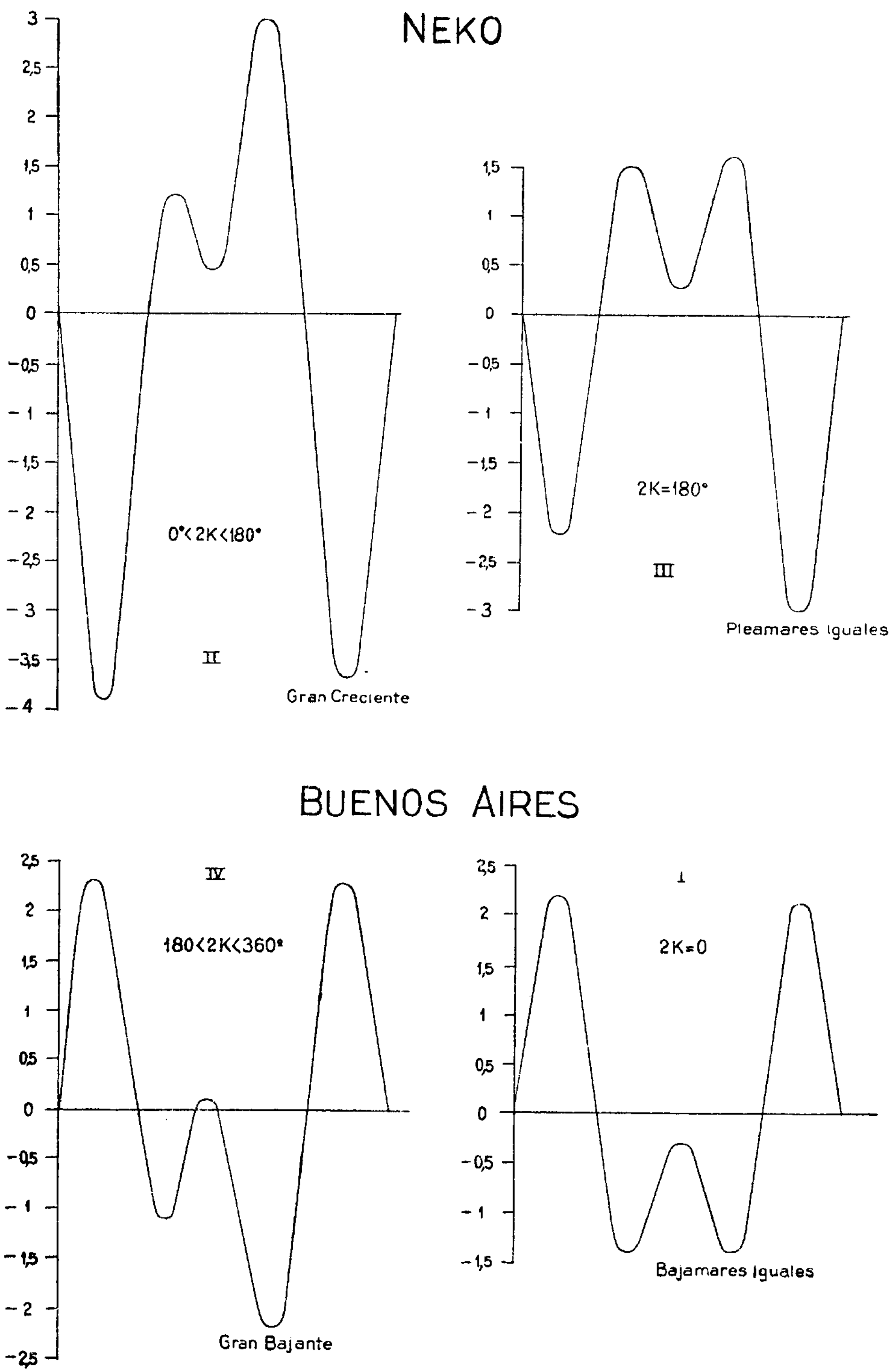
NEKO
3
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
-3
-3,5
-4
0°< 2K<180°
II
Gran Creciente
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
-3
2K=180°
III
Pleamares iguales
BUENOS AIRES
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
IV
180<2K<360°
Gran Bajante
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
I
2K=0
Bajamares iguales

Fig. 4

As is known, the sequence of the tidal curve can take, according to the relative value of the fundamental components ($K_1 + O_1$) of the diurnal tide and M_2 (semi-diurnal), four principal forms[1] depending on the value of the formula :-

$$2\,K = K_{M_2} - (K_{K_1} + K_{O_1}) + n\,720^\circ ;$$

therefore (Fig. 4) for Puerto Neko :

$$2\,K = 189.8 - (33.9 + 15.9) = 140^\circ$$

it remains between case No. 2 and case No. 3. Case No. 2 occurs at lunar tropical epochs and case No. 3 at intermediary epochs between the latter and lunar equator transit.

As the value of the coefficient $2K = 140^\circ$ is in the neighbourhood of 180° (which is ideal condition) the predominant characteristic of Puerto Neko is that of equal (double) H. W.

From examination of Fig. 3 it will be seen that at the epochs of double H. W. the L. W. of the semi-diurnal wave undergoes progressive lag of phase towards the vicinity of diurnal tide H. W., and from this the production of the phenomenon originates.

It follows that if at this moment the diurnal tide is represented by $R_1 \cos nt$ the semi-diurnal tide will be represented by $R_2 \cos (2\,nt + 180^\circ)$.

It is not absolutely necessary, however, that the phase of the semi-diurnal tide be exactly twice of the diurnal tide plus 180°, but simply approximate.

The ratio between the amplitudes of these two tides should also be considered. If we generalize the concept of double High Waters[2] : the demi-amplitudes of the waves at the considered moment will be : $R_1 \cos nt$ for the diurnal wave; $R_2 \cos 2\,nt$ for the semi-diurnal wave.

Taking into account the serial development of the cosine of a small angle, we have :-

$$R_1 \left(1 - \frac{n^2\,t^2}{2}\right) \text{ and } - R_2 \left(1 - \frac{4n^2\,t^2}{2}\right).$$

For the manifestation of " double H. W. " it is necessary that within a lapse of time *t*, the fall of the diurnal tide level $\frac{(R_1\,n^2\,t^2)}{2}$ be smaller than the rise engendered by the semi-diurnal tide ($2R_2\,n^2\,t^2$), i. e.

$$R_1 < 4R_2$$

At Puerto Neko the ranges of the diurnal and semi-diurnal tides are in the ratio 10:7, provided that the above-established condition is amply fulfilled.

According to the relative position of these tides, the total tide will occur

(1) A. COURTIER, *International Hydrographic Review*, Vol. XVI, N° 1. May, 1939.
(2) A. T. DOODSON, *Admiralty Manual of Tides*, 1941.

in conformity with distinct systems passing gradually from the diurnal to the semi-diurnal system and conversely.

In general, the diurnal regime will be predominent in winter and summer ($K_1 + O_1 + P_1$) and the semi-diurnal regime in Spring and autumn ($M_2 + S_2 + K_2$) (Fig. 3).

These appearances will consequently be more remarkable at certain epochs as, for instance, those which coincide with the maxima of lunar declination and the lunar transit through the Equator for the diurnal tide and with the lunar syzygies and quadratures for the semi-diurnal tide.

Finally it may be noted that the Antarctic tidal regime in the region dealt with had not so far been recorded; however, it is to some extent similar to that of the Mar del Plata and of Buenos Aires with the difference that in the latter places the phenomenon is inverted, i. e. equality occurs for L. W. and the sequence is of the " Grande décroissance " (Maximum fall) type.