

NOTES

CONCERNING THE "TIDE TABLES FOR THE MAJOR PORTS OF THE WORLD"(*)

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Early in January, 1983, on the occasion of the Paris Boat Show, the Hydrographic and Oceanographic Service of the French Navy (SHOM) presented to the public a new publication, the "Tide Tables for the Major Ports of the World", Pub. N° 540, which enables one, within a few minutes, with the aid of a programmable pocket calculator, and without any other document, to predict the tides in 855 ports all over the world for the period 15 October 1582 (date of the start of the Gregorian calendar) to 28 February 2100; the accuracy obtained is sufficient for the needs of navigation.

The publication was immediately welcomed by the public, and generated a great deal of interest, judging by the voluminous correspondence received as a result. Interesting discussions followed between SHOM and some particularly interested persons.

But let there be no misunderstanding; in our opinion, the success achieved is linked to a great extent to :

- (1) the public's current interest in individual micro-computer systems, and its desire to try any new application of these;
- (2) the fact that this publication enabled the public, if not to understand thoroughly the phenomenon of the tide, always an esoteric subject, at least to realize that tide prediction was not really mysterious and could be mastered relatively easily.

Thanks to the publicity recently given to this publication by the International Hydrographic Bureau, to whom we extend warm thanks for their initiative, the "Tide Tables for the Major Ports of the World" has begun to reach international circles and will now be studied by the hydrographic community. We will be particularly happy to receive their subsequent reviews.

Since publication N° 540, of an entirely new conception, was drawn up in accordance with the strict rules of conciseness and exactness applicable to nautical

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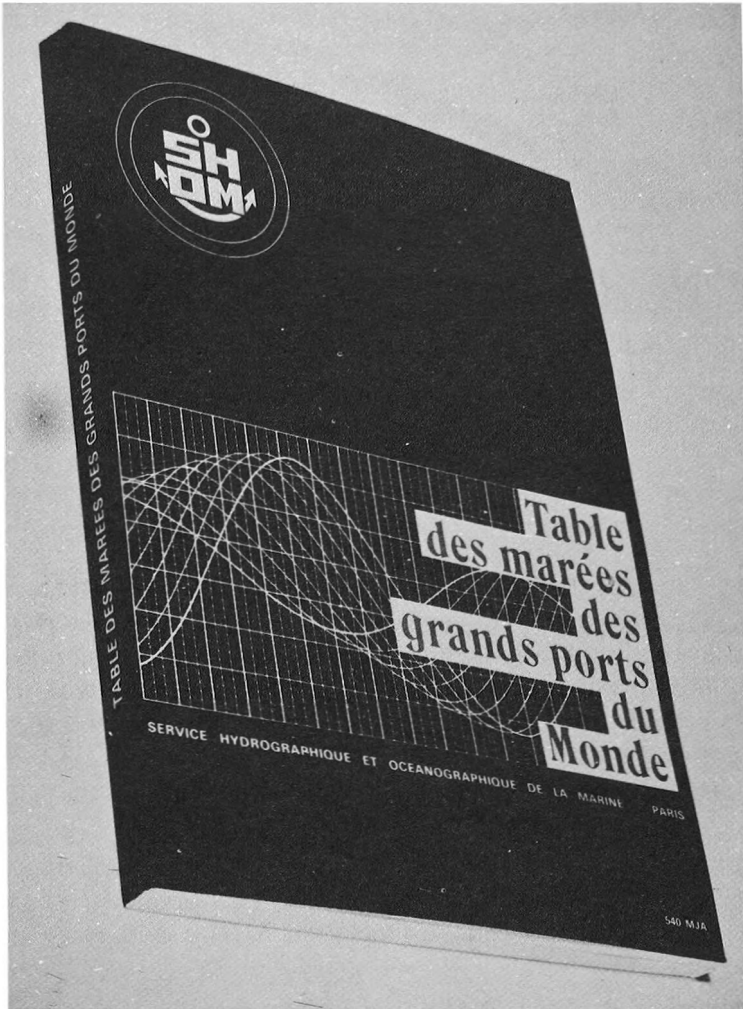


FIG. 1

documents, it seemed worthwhile to make some comments and to specify certain points with regard to :

- the choices that were made in the light of the constraints imposed;
- the methods used in producing the book itself, but especially those used for checking and validating the method of calculation; and
- finally, some results and the views of the first users of the Tables, together with the prospects for further development.

To understand this article, it is presumed that the reader has had time to familiarise himself with the publication and, more specifically, with its introduction and with the method of calculation, which it would take too long to reproduce here.

However, before going into the details of this paper, it is important to elucidate exactly what use the publication “Tide Tables for the Major Ports of the World” is intended for. It is essentially (one might say exclusively) intended for the *average mariner* who carries out tidal calculations only as and when he needs them in preparing for a voyage. It will certainly rival the traditional “Annuaire des

Marées" (yearly Tide Tables), but the latter will survive, since sedentary users, i.e. : pilots, lock-keepers, small fishermen, etc.) need to know the tide at the place where they usually are at all times, and to possess more or less long term predictions in order to plan their activities. They also often need to have more accurate predictions than those that the new Tables can provide.

1. METHOD OF CALCULATION

This has been worked out for the purpose of fulfilling the following requirements :

- sufficient accuracy for navigation;
- solution of the three tidal problems confronting the mariner;
- speed of calculation;
- possibility of programming on the most current programmable calculators with as small a memory as possible, such as the TI 59 (Texas Instruments) or the HP 67 (Hewlett Packard).

It was this last requirement which was the most constraining and which, finally, influenced the choice and the form of the programmes. Formulation of the calculation method, the choice of constituents and the accuracy of predictions would obviously have been very different if we had confined ourselves to more powerful small calculators.

Thus the method of calculation, an adaptation of the harmonic formula, is the result of a compromise between these often conflicting requirements.

1.1. The small memory available in the HP 67 did not enable us to consider harmonic constants other than those of the following constituents :

$$S_a, Q_1, O_1, K_1, N_2, M_2, S_2, MN_4, M_4, MS_4 .$$

However, these constituents are insufficient to guarantee good prediction in many ports.

That is why other constituents are taken into consideration, but their harmonic constants are calculated on the basis of the preceding ones, adopting certain, generally well-proven, hypothetical theories. There are thus seven deduced constituents :

$$P_1, 2 N_2, \mu_2, \nu_2, L_2, T_2, K_2 .$$

Besides, resort to nodal factors has been avoided, as this would otherwise have led to the introduction of annual values and would have caused the Tables to lose their permanent nature in assimilating (according to DOODSON) the nodal corrections of the principal constituents, M_2, K_2, O_1, K_1 , with the supplementary constituents deduced from the preceding ones.

- On the other hand, it was not possible to consider sixth diurnal constituents which are sometimes very important. It is noted that it is possible

to introduce them into the calculation on calculators more powerful than the HP 67, e.g. the SHARP PC 1500.

1.2. Calculation of predictions calls upon two programmes, the division line between them being imposed by the types of calculators addressed; however, good speed of execution is maintained when it is desired to make several calculations of times and heights of tide for a single day.

The first programme, in fact, proceeds with initializations for a given date, and the second programme, which calculates the actual tide itself, is rapid because it uses a simplified expression, valid for 24 hours, of water level as a function of time.

The diurnal, semidiurnal and quarter-diurnal species are each represented by a vector, the module and variation of which vary linearly in the course of the day. This formula is particularly well adapted to the calculation of high and low water using an iterative method.

In fact, if t_0 is the approximate time of an extremum, a better approximation, t_1 , of this extremum is obtained by means of the formula :

$$t_1 = t_0 - \frac{h'(t_0)}{h''(t_0)}$$

where $h'(t_0)$ and $h''(t_0)$ are the first and second derivations, respectively, at the time t_0 of the height of water $h(t)$.

These derivations are easily obtained from the vectors representative of the species, due to the facilities offered by pocket calculators for converting polar coordinates into rectangular coordinates.

The same formula may also be used to calculate the time at which the tide attains a given height h_0 . It suffices to substitute $h(t_0) - h_0$ for $h'(t_0)$ and $h'(t_0)$ for $h''(t_0)$ in the preceding formula.

Then one may use the same programme instructions for both calculations.

1.3. It is worthwhile to give here, for notational purposes, the times of calculation observed on an HP 41 C :

- Initializing programme for the date : 1 minute 16 seconds.
- Calculation of high and low water : 38 seconds for the first; 23 seconds for subsequent ones.
- Calculation of a height of tide : 14 seconds.

1.4. Our publication would have been incomplete and would certainly have been received by the mariner cautiously or with reticence had we not been able to guarantee reliability of use in all circumstances.

First of all, it was necessary to protect the mariner against his own possible mistakes during the making of programme cards and, above all, when making a data card.

In the event of an error in the programme card, it is very doubtful that the calculation can be made at all; on the other hand, an error in transcribing the mean level or a constant onto a card could produce wildly erratic results.

Therefore, a check value has been provided for each port.

Furthermore, at sea, and notably in small craft, a pocket calculator remains a very vulnerable piece of equipment. It was therefore necessary to find a means of making a prediction using the Tables even if a calculator is not available.

The theory of the "manual" method proposed in the Tables for this purpose, and the details of the calculations which resulted in the compiling of the enclosed card and the diagrams (manual calculation graphs), are not described in the publication. They formed the subject of an article published in the "Annales Hydrographiques" (N° 759 (1983) , p. 17).

We will merely note in passing that the two diagrams to be used to calculate high and low water are directly derived from those of Mr Rollet de Lisle published in 1896 in the "Annales Hydrographiques" (2nd series — Vol. 18, p. 212-248). There is therefore nothing new in the matter; it was only necessary to recall that our predecessors who worked out everything manually had had to solve the problem.

2. LIST OF PORTS AND COMPILING OF THE PUBLICATION

2.1. List of ports

There are several ways of approaching this tricky problem. The most logical way — obviously — was to study the international list of the world's ports (World Ports Index) and then make a selection based on the number of ships calling at such ports, and more especially — since this is a French publication — their use by French ships.

What a tedious and arid job it would be to collect all relevant information and then draw up a list of ports, after which the harmonic constants for the selected ports would have to be found.

We preferred a different approach. Knowing that, in any case, our list of ports would be neither exhaustive nor perfect, we first selected those ports for which the tide is well known and the harmonic constants correct.

This applies, particularly, to the principal ports^(*) shown in the various foreign Tide Tables published.

This easily-drawn-up list was transferred to the computer for automation of the subsequent work.

It was automatically compared with the list of ports classified as "major" and "minor" in the World Ports Index and any omissions noted were duly filled in.

The automatic plotting of the position of ports in the list, obtained from a world map, enabled their placement to be determined and some regions with very few ports were detected, where additional ports could be inserted.

(*) A "principal port" is a port for which predictions are made of the times and heights of high and low water.

2.2. Compiling the publication

From the moment the list of ports (consisting of names (toponyms), positions and time kept in each case) was transferred on magnetic tape, all subsequent work was entirely automated, apart from the task of checking.

Port by port, the harmonic constants were extracted automatically from a copy on magnetic tape which had been kindly provided to us by the Canadian Hydrographic Service from the international harmonic constants data bank.

A few problems were encountered during this part of the work because the Canadian tape shows the name of each tidal station concerned and this is not necessarily identical with the name of the port to which it refers.

The 'check' values were calculated automatically; thus we were able to produce directly a photo-typesetting ribbon making possible automated output of the book's tables of harmonic constants.

The updating (by re-edition) of the Tables will be greatly facilitated because it is automated.

3. VERIFICATION

3.1. Validity of the method of calculation

This operation, obviously, was carried out before compiling the book by comparing the results of the prediction by mini-calculator with the predictions given by the French Tide Tables (2 volumes) for a certain number of typical ports :

Ports with semidiurnal tides	Roscoff, Conakry
Ports with semidiurnal tides having significant quarter-diurnal constituents	La Rochelle
Ports with diurnal tides	Do.Son
Ports with mixed tides	Port Martin, Kompong Son
Ports with diurnal inequality	Djibouti, Singapore.

The differences in times noted were rarely more than 15 minutes and the differences in height, 20 cm.

To illustrate this, figures 2 to 5 give comparisons between observed tidal curves and those predicted by Tables 540 and the Annual Tide Tables. When the Annual Tide Tables give only high and low water, the tidal curves are reconstituted by means of standard curves.

The new Tables give very good results when the tide is semidiurnal.

Conversely, at Le Havre, where the sixth diurnal constituents are significant, the Tide Tables give a better prediction than that in the new Tables.

As for Portland, the tide curve obtained by using the new Tables is not very accurate; the real discrepancies between predicted and observed tides remain, however, within acceptable limits, considering the complex nature of the tide in this port.

3.2. Checking of the publication

This operation was tiresome and difficult. As the preceding paragraph suggests, it was not comprehensive as regards harmonic constants, and we made do with only a sampling of these.

Exhaustive checking was carried out for the typography of programmes and the values of mean levels.

For mean levels we compared values supplied by the data bank of harmonic constants with those given in yearly Tide Tables and in the Admiralty Tide Tables (U.K.). In cases of differences between the various sources of information, we referred to the charts and the accepted rule was to adopt as a mean value the figure shown on the largest scale chart of the port produced by the country in which it was to be found.

For some minor ports, when there was a doubt which could not be clarified, for reasons of efficiency and time-saving these were simply left out of the Tables.

It will be understood that, under these circumstances, we are eager to receive critical reviews of the Tables from various Hydrographic Offices concerning their area of responsibility.

4. COMMENTS BY THE FIRST USERS

The first users who have answered the questionnaire included in Publication 540 are all French. Most of them are either laymen or former merchant navy captains, now retired. We have, in fact, received very few comments from active practising mariners. It must be said that thorough examination of the publication and study of the programmes requires sufficient time at one's disposal.

Besides general satisfaction, we note, firstly, that people handle mini-computers very capably, because most of the replies to the questionnaire discuss certain instructions or programme steps.

It is also noted that, although the absence of a flow-diagram is often regretted, the method of calculation as formulated in the Introduction is sufficiently explicit for someone who is not an expert on tides to work out a programme adapted to his own particular calculator.

This was realized, in fact, when the publication was developed, since the HP 67 programme itself was written for us by a volunteering enthusiast.

The Basic programme adapted for the SHARP PC 1500, which we have often been asked for, as a matter of fact, has just been supplied to us, already prepared, by a former Merchant Navy captain. It will soon be added to the publication in the form of a separate card.

The questionnaire included in the publication was for the purposes, inter alia, of determining the need felt by users for pre-programmed modules to obviate the need of (tedious) writing of programmes on magnetic cards and to increase the

reliability of calculations, and, subsequently, in order to decide whether to produce a series of modules and estimate the potential for their sale, to recover the cost of their production, at a reasonable unit price.

Unfortunately, the replies received so far do not help in taking any decision on this point for the moment.

Finally, many responses ask us to add ports to the existing list. This is, of course, hardly surprising in view of the method employed in compiling the list in the first place. These requests will be duly considered, and it may be possible to satisfy them in the next edition of the publication.

This next edition, the date of which has not yet been fixed, will thus comprise :

- a *more comprehensive list of ports*,
- a detailed flow-diagram of the programmes, which will be offered in two alternative versions :
 - a simplified version corresponding to the present programmes;
 - a version enabling sixth diurnal constituents to be introduced, usable on calculators with higher performance characteristics than the HP 41 C.

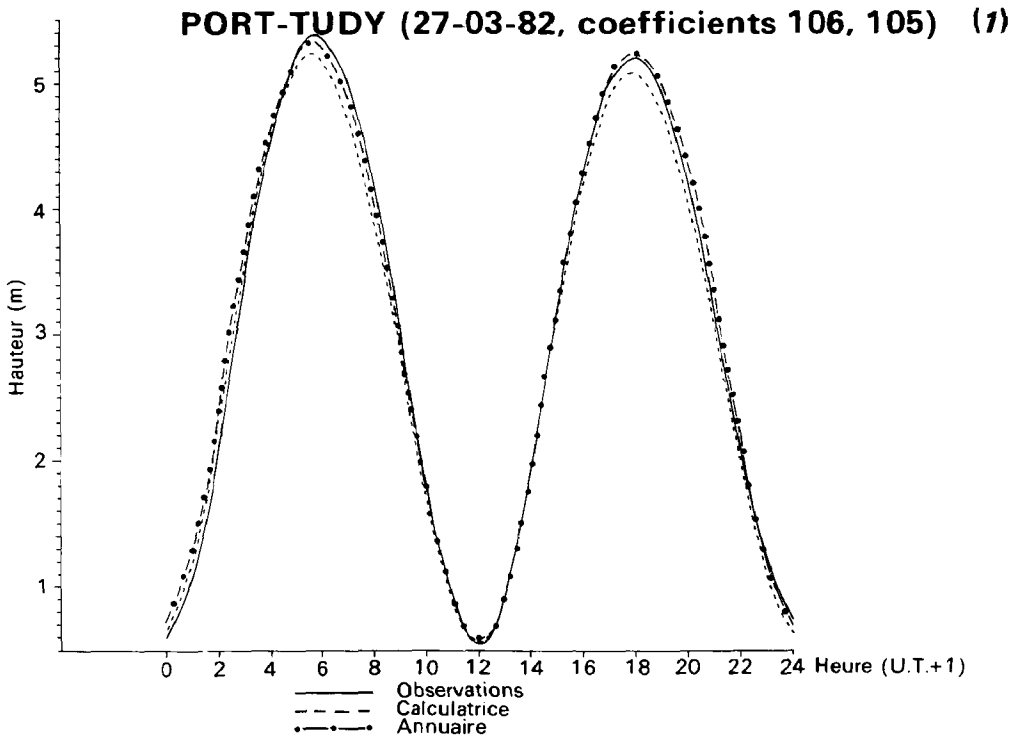
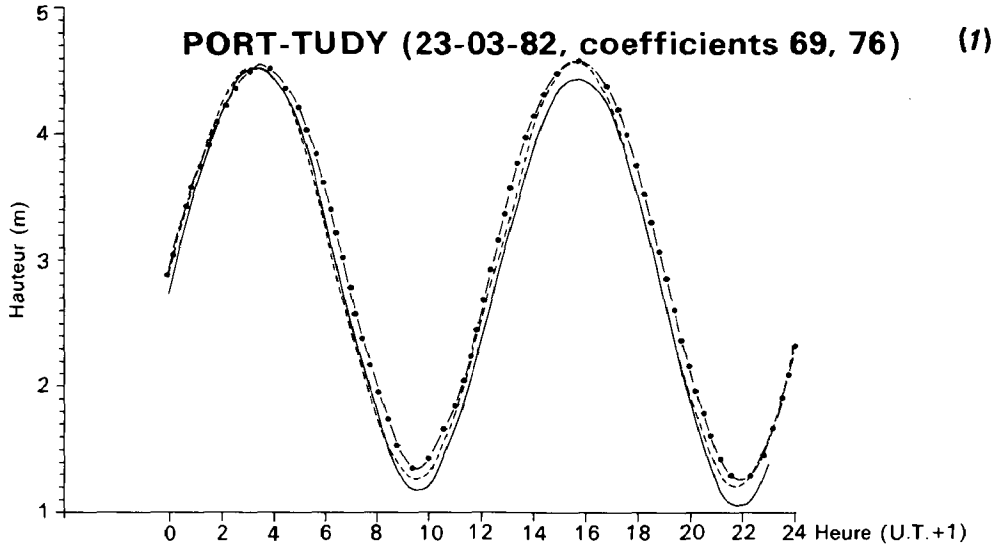
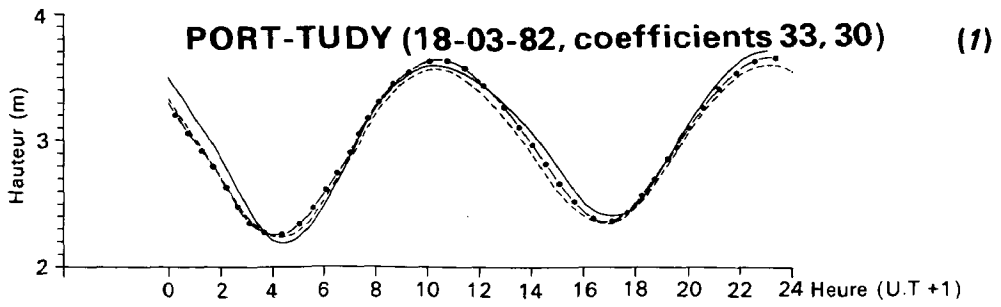
In this new edition, the explicit programmes will no longer be integrated in the publication, but will be available on request in the form of separate leaflets. This should avoid the publication becoming outdated as rapid developments are made in the field of micro-computers.

5. GENERAL CONCLUSION

The more widespread day-to-day use of micro-calculators, and particularly their use on the ship's bridge, will certainly contribute to the success of the "Tide Tables for the Major Ports of the World" published by SHOM, provided these contain all the ports useful to mariners.

It is still premature to contend that it will become a universal publication : that can only be achieved within the framework of international cooperation and with the support of all Hydrographic Offices and mariners the world over.

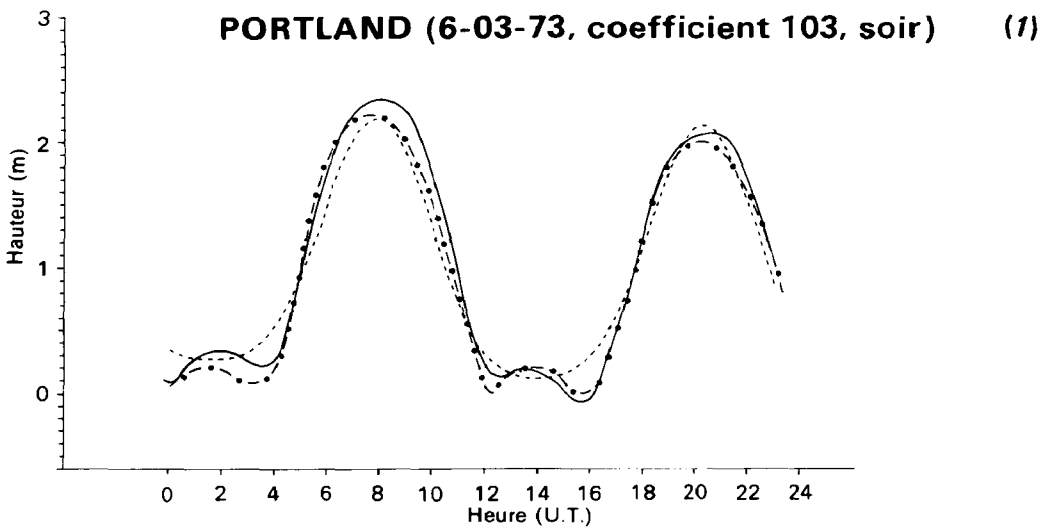
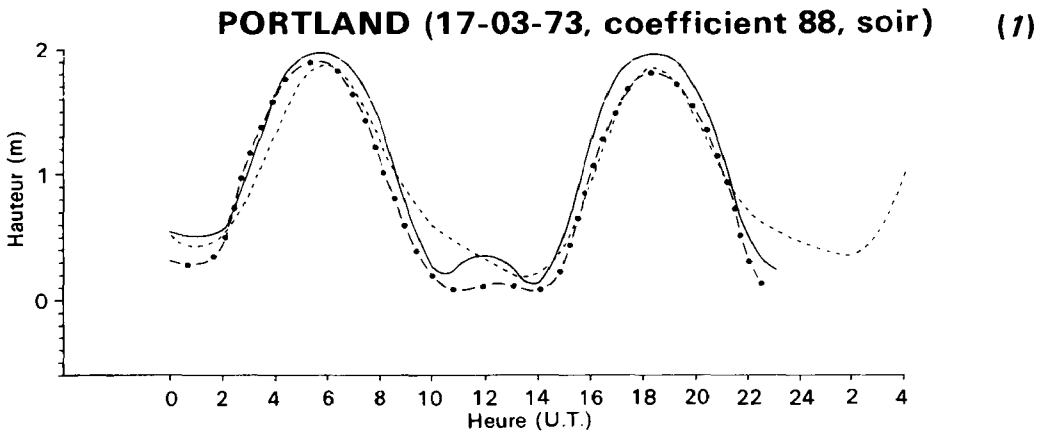
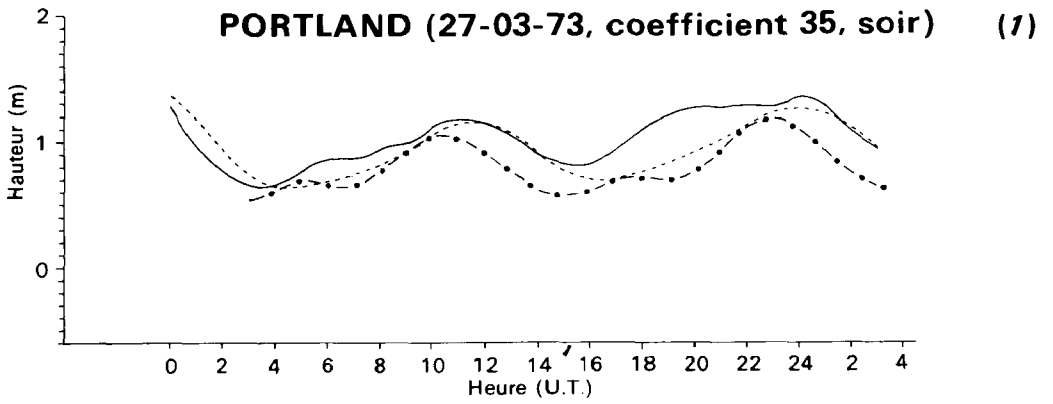
Then the idea might emerge again of an "international" publication of tidal predictions, for which the "Tide Tables for the Major Ports of the World" will have sown the seed.



(1) Voir NOTA.

FIG. 2

Read at bottom of page : Observations; Calculator; Tide Tables. (1) See NOTA.



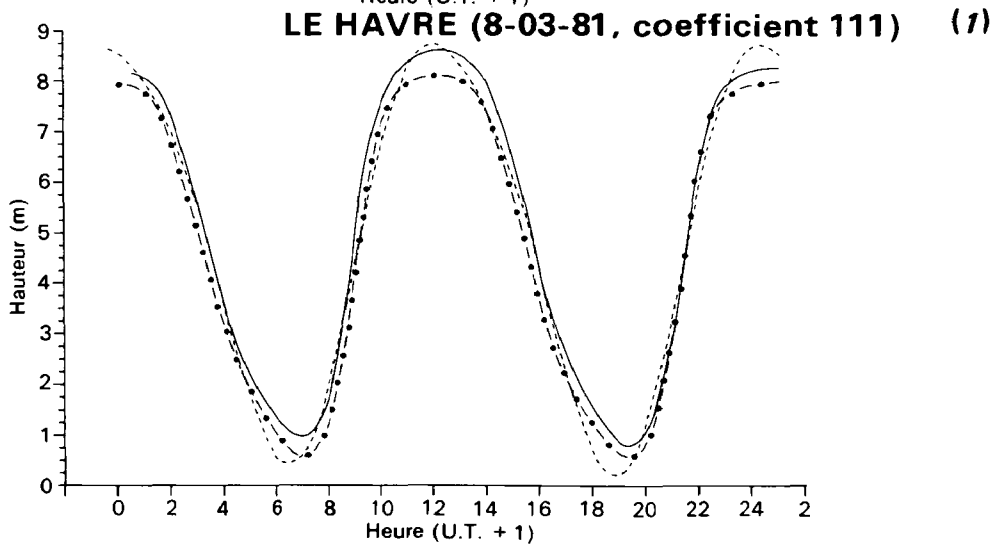
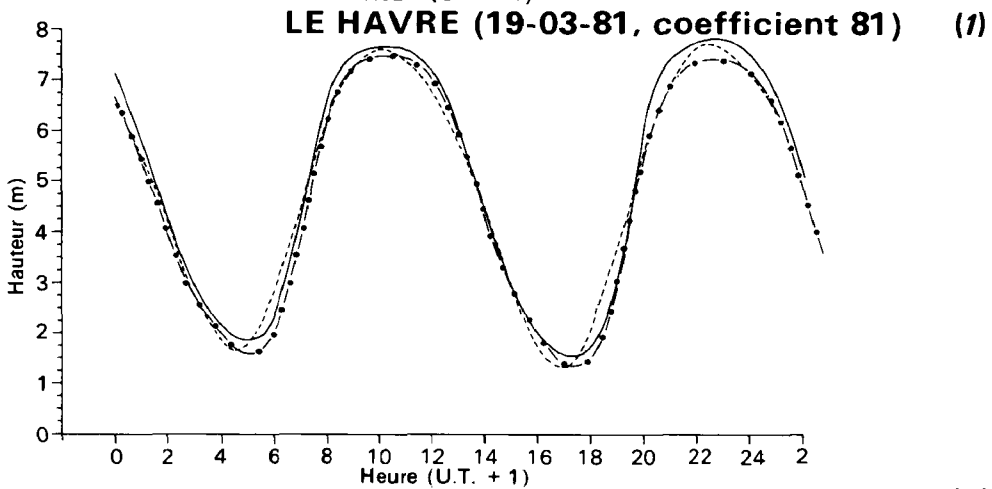
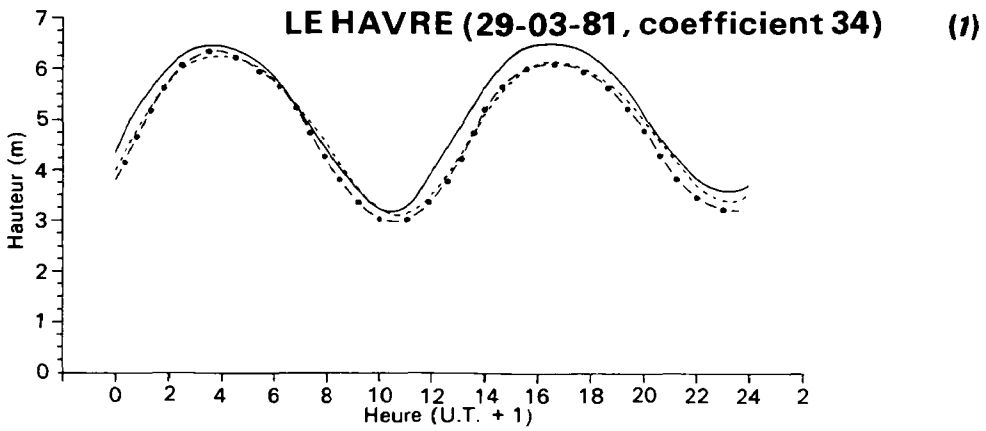
LEGENDE

- Observations (avec Nm journalier)
- - - Calculatrice
- - · - · A.T.T.

(1) Voir NOTA

FIG. 3

Read at bottom of page : Observations (including daily mean sea level); Calculator; Admiralty Tide Tables. (1) See NOTA.



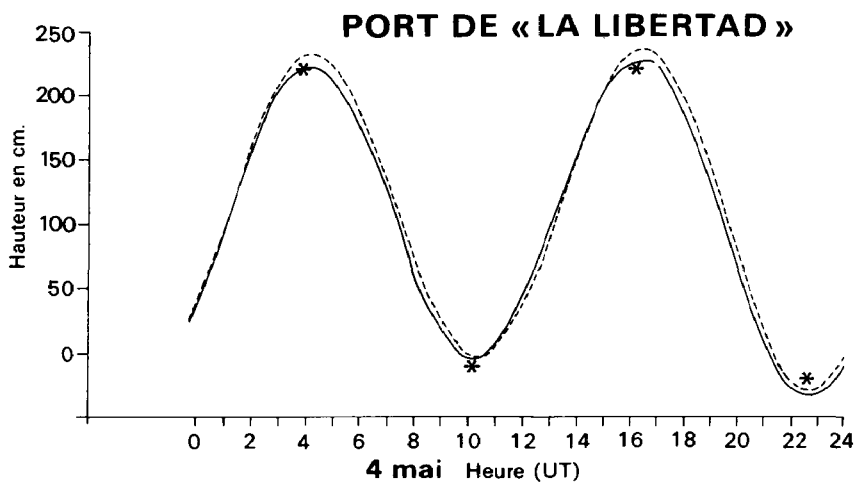
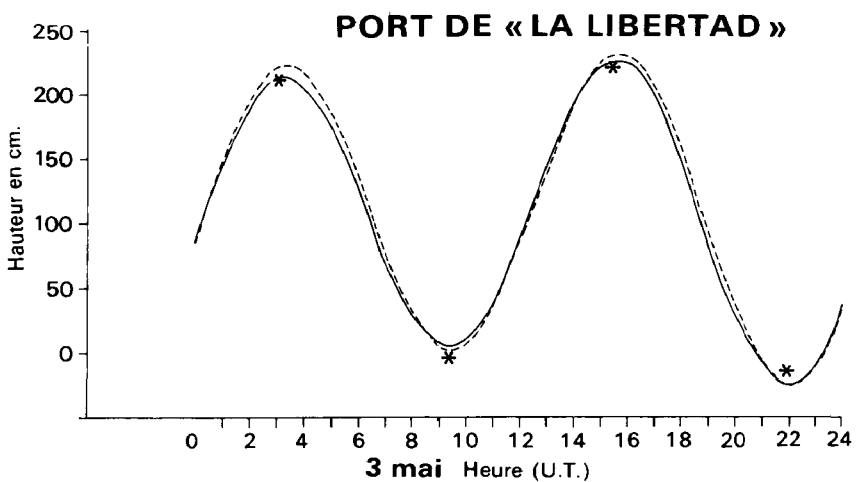
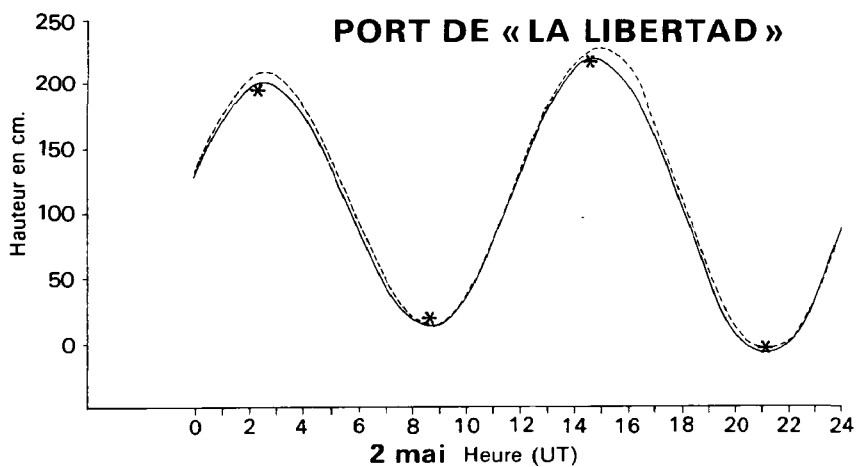
LEGENDE

- Observations
- - - Calculatrice
- · · Annuaire

(1) Voir NOTA.

FIG. 4

Read at bottom of page : Observations; Calculator; Tide Tables. (1) See NOTA.



LEGENDE

- Hauteurs observées rapportées au niveau moyen $Z_0 = 107$ cm.
- - - Hauteurs calculées (programme H.P. 41).
- * Pleines mers et basses mers calculées avec les A.T.T. (1977).

FIG. 5

Read at bottom of page : Observed heights referred to mean sea level $Z_0 = 107$ cm; Calculated heights (H.P. 41 programme); High waters and low waters calculated with the Admiralty Tide Tables (1977).

NOTA

The tidal coefficient is the quotient of the half-range of the semidiurnal tide at Brest and the unit of height (3.21 m).

It is expressed in hundredths and its value is given in the French "Annuaire des Marées" (Annual Tide Tables) for the coasts of France for all high tides at Brest.

The characteristic values are as follows :

	Coefficient	Range at Brest
— Maximum spring tide (equinox, lunar perigee and on the equator).....	120	7.70 m
— Equinoctial maximum spring tide (bodies on the equator at their mean distances)	100	6.42 m
— Mean spring tide	95	6.10 m
— Minimum spring tide (maximum declinations, solstices, lunar apogee)	69	4.62 m
— Maximum neap tide	63	4.02 m
— Mean neap tide	45	2.88 m
— Minimum neap tide	20	1.28 m
— Mean tide level (above chart datum at Brest)		4.45 m