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A general discussion about the normalization of gravimeters
in the Iberian gravity tide profile

R. VIEIRA; J.M. TORROJA and C. TORO

with 1 figures and 7 tables

Vieira, R.; Torroja, J.M. & Toro, C.; 1985: A general discussion about the normalization of gravimeters in the Iberian gravity tide profile. Proceedings of the Tenth International Symposium on Earth's Tides, pp. 165-176.

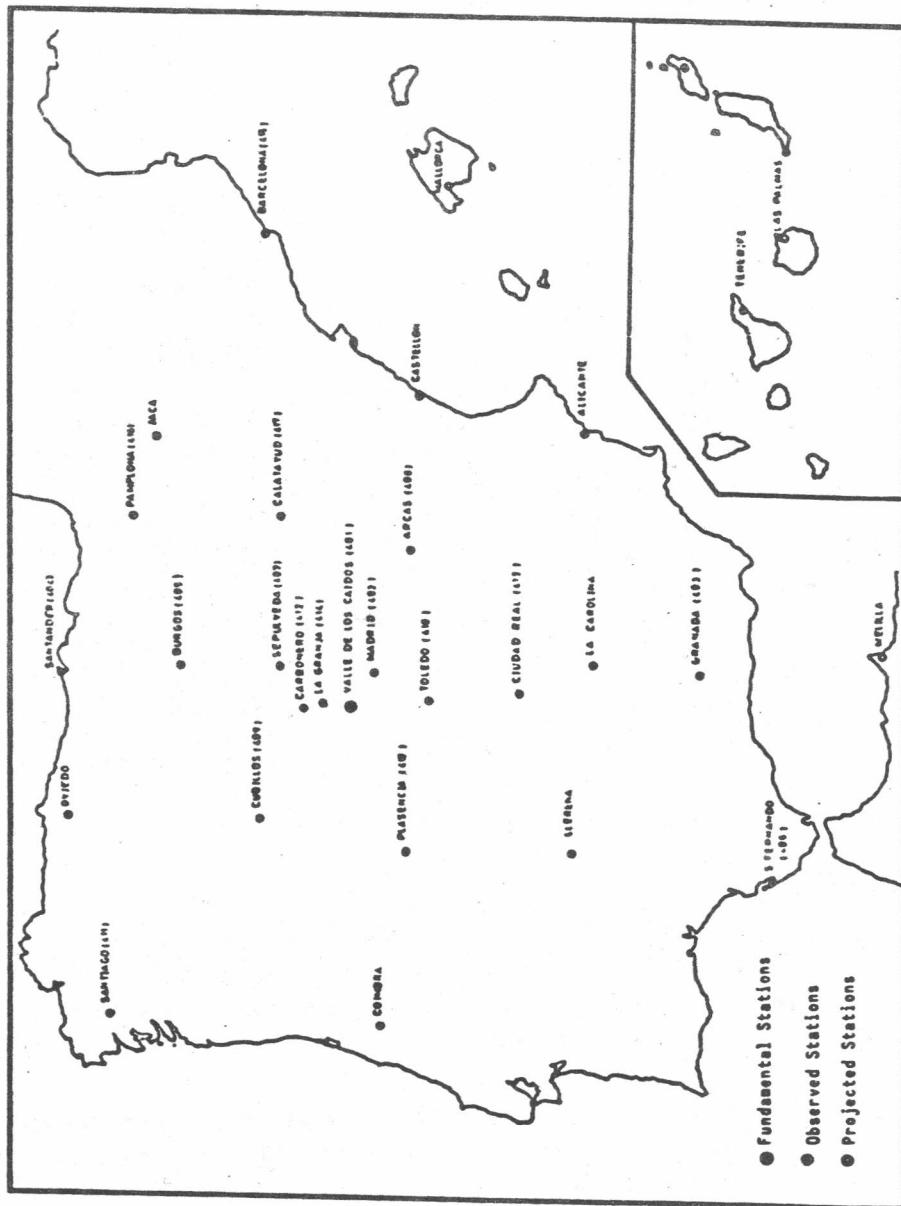
Abstract: The interpretation of gravity tide observations is conditioned by reasons with different origins; the instrumental problems, the theoretic hypotheses assumed, the peculiar characteristics of the geographic zones where the observations have been made, the own station conditions, the influence of phenomena related with the observable, as the ocean tide or the atmosphera effects, ect., are circumstances to be studied closely if we want to get the geodetic and geophysical information that these observations have. In the Symposia at Bonn and New York as in several articles published, we have dealed with some of these problems; in this paper, we expose some considerations about precision and calibration of the gravimeters used in the so called Iberian Network of Gravity Tides Stations, and about the model determination of the fundamental station at Valle de los Caídos as well.

Keywords: gravimeters, calibration, fundamental station.

INTRODUCTION

In 1973 we started a wide research project on gravity tides in Spain; the scientific aims (Vieira et al., 1977) covered a great part of the problems established, as much from the observational point of view as from the geodynamic, geodetic, oceanographic, etc., interpretation one too. The project is based in the gravity tides observation in a station network spread throughout the Iberian Peninsula, Balearic Islands and Canary Isles, with a density of one station per 250 km approximately in the peninsular land. The present state of this observations can be seen in Figure 1.

The observation precision is logically depending on the type of gravimeters used, the characteristics of



Iberian Network of Gravity Tide Stations

Figure 1

each station, as much from the point of view of peculiar characteristics the observation place as its care and maintenance quality, and physical parameters precision of the system know in each moment, that's to say, the determination of the supposed constants of equipment normalization. The determination precision of the gravimetric factors and the different harmonic phases which can be separated by analytic methods will depend on this last condition. The instruments we have used in the observations are specified in Table 1. All of them are relative gravimeters used in this kind of gravity tide profile researches. Some of them have been modified along these years looking for the best development of their possibilities.

Gravimeter Askania GS-15 nº 212

Gravimeter LaCoste Romberg mod. G. nos. 301, 434 and 665

Gravimeter Askania GS-15 nº 212, zero method **

Gravimeter LaCoste Romberg mod. G nº 434 with automatic control*

Gravimeter LaCoste Romberg mod. ET nº 15 ***

Gravimeter LaCoste Romberg mod. G nos. 434 and 665 zero method****

Gravimeter LaCoste Romberg mod. G nos. 402 and 487 zero method*****

* (Lambás, F.; Vieira , R & Giménez, E.; 1983)

** (Orejana, M. & Vieira, R.; 1983)

*** Colaboration with the I.O.S. of U.K.

**** Modified by Dr. Van Ruymbeke of O.R.B.

***** Colaboration with O.R.B. in the Kevo-Brussels-Madrid profile

Table 1

In the Table 2 the instruments distribution is given.

STATIONS OF THE IBERIAN TIDAL GRAVITY PROFILE										
#	name	λ	05	40	23	h	d	M	inst.	
0401	Valle	4	05	40	23	1280	350	2200	*	
0402	Madrid	4	16	40	16	630	310	1000	**	
0403	Granada	3	22	37	07	774	50	150	L301&A212	
0404	Santander	4	49	13	27	25	0	132	L434	
0405	Burgos	3	43	42	21	850	120	166	A212	
0406	S. Fernando	6	15	36	25	25	0	90	L434	
0407	Sepúlveda	3	61	41	18	1040	240	160	A212&L301	
0408	Arcas	2	08	40	00	990	170	180	L434	
0409	Cubillos	5	41	41	34	667	220	190	L301	
0410	Toledo	4	02	39	52	512	320	130	L301	
0411	Santiago	8	33	42	52	250	40	180	L301	
0412	Carbonero	4	16	41	07	920	315	90	L434	
0413	C. Real	3	56	38	59	600	250	180	L301	
0414	S. Ildefonso	4	00	40	54	1191	280	120	L301	
0415	Barcelona	-2	05	41	30	200	20	240	L301	
0416	Pamplona	1	40	42	48	450	50	230	L434	
0417	Calatayud	1	37	41	22	500	225	230	L301	
0418	Plasencia	6	05	40	02	657	236	250	L434	

(λ , ϕ , h) coordinates

d: approximate distance to the nearest sea

M: nos. of days of recording

* A212; L301; L434; L665; LET15

** A212; L434; L665; L487-0; L402-0, L434-0; L665-0

Table 2

FUNDAMENTAL STATION OF THE NETWORK

All the observations made are referred to what we have defined as fundamental station in Valle de los Caídos (Vieira, 1978). The station at Valle is working from the beginning of these researches in 1974 and the

gravimeters used for the observations in the network have been periodically installed there, looking for the maximum homogeneity in the results. The Madrid station, 40 km southwards from Valle, has been used as an auxiliary fundamental station since Madrid was an observation point of the North-South of Europe profile between Kevo-Brussels-Madrid due to perativity circumstances (Ducarme et al., 1985 a). The fundamental constant which permit to define a model for Valle station have been determined comparing with the fundamental station at Brussels (Ducarme, 1975); for that, gravimeters from the Institute of Astronomy and Geodesy have been removed to Royal Observatory of Belgium three times in order to determine their constants and then to define the model corresponding to this station by means of an observation stage in Valle. The experiences were carried out according to the scheme in Table 3. The values

NORMALIZATION OF GRAVIMETERS IN BRUSSELS

ASK GS-15 n°212
Classical System

74/07/01 - 74/12/21

NORMALIZATION FACTOR: 1.06097
PHASE LAG θ_1 1.00 θ_2 2.10

ASK GS-15 n°212
New System

78/03/14 - 78/09/28

NORMALIZATION FACTOR: 0.99956
PHASE LAG θ_1 0.00 θ_2 0.00

L.C.R. mod. 6 n° 434

78/03/14 - 78/09/28

NORMALIZATION FACTOR: 0.98156
PHASE LAG θ_1 1.03 θ_2 1.00

L.C.R. mod. 6 n° 665-0

84/10/19 - 85/02/27

NORMALIZATION FACTOR: 1.00000
PHASE LAG θ_1 0.00 θ_2 0.00

Table 3

from these observations that were assigned to Valle station and that have served to determine the constants of all the gravimeters used in the Iberian Network are:

$$\kappa(O_1) = -0.30; \quad \delta(M_2) = 1.1500; \quad \kappa(M_2) = 5.15 \quad (1)$$

SOME COMMENTS TO THE VALLE DE LOS CAIDOS MODEL

The values assigned to the base of Valle de los Caídos have been obtained comparing with Brussels as we have commented however, we believe suitable to stand out, some points:

1. Apart from the experiments with Brussels, collaborating with the Institute of Oceanographic Sciences of U.K. the LaCoste Romberg gravimeter mod. ET nº 15 was removed to Valle station registering during 7 months. The analysis results of these observations made in Bidston and Madrid have been on discussion for some time due to the existing indetermination in the normalization factor of this gravimeter. The value of 1.0075 initially given was later modified by 1.0145 and more recently Dr. Baker confirmed us 1.0075 as optimum value after the experiments previous to the transformation to electrostatic feedback system made in U.S.A. in 1982 (Baker, 1982). Having in mind this normalization factor, there is a difference of excess amplitude about 0.8% between the value determined from Brussels and the one obtained from the Institute of Oceanographic Sciences gravimeter. The phases, however, are practically the same as much in the diurnal frequencies as in the semi-diurnal ones.
2. The results obtained from the astatic LaCoste Romberg gravimeters mod. C have not fiability bigger than 1% in amplitude and 0.5° in phase, and so having the biggest care on doing the observations in optimum conditions. The reason for this imprecision is

basically the impossibility to preserve in time the equilibrium inner conditions of the system variations in the mass relative positions respect to the structure, that's to say, pendulum's slope angle variations, produce significative changes in the normalization factor in amplitude and phase, even within the interval of less sensibility to slope.

3. The modification made in 1979 to the Askania gravimeter turning it to a zero instrument, has substantially improved the characteristics of this instrument that along five registering years, in Valle station has maintained a significative constancy in its sensibility and, as a consequence, it presents an appreciable homogeneity in the results of the total and partial analyses made during this long time period.
4. We must point out that the LaCoste Romberg gravimeters mod. G have been notably improved transformed into a zero instrument by Dr. Van Ruymbeke (Van Ruymbeke, M., 1985) according basicly to Harrison and Sato procedure (Harrison and Sato, 1983) as we could see after the analysis of the observations made in Madrid with the LaCoste Romberg gravimeters mod. G. nº 402 and 487 from R.O.B. and nº 434 and 665 from I.A.G., these last two still being in a taking data period. These observations have been taken within the collaboration project of Kevo-Brussels-Madrid profile. Values of amplitude and phase for O_1 and M_2 obtained with these four instruments are shown in Table 4, considering a normalization factor of 1 and corrections of null phases in the gravimeters nº 402, 487 and 665, and a normalization factor of 0.99212 for the LaCoste Romberg gravimeter mod. G nº 434. The mean values for amplitudes and phases of O_1 and M_2 of four gravimeters at Madrid, as the typical deviations and variants are given in Table 5. These values are very near in amplitude

L.R. mod.G-9	$\delta\alpha_1$	$\kappa\alpha_1$	δM_2	κM_2	$\frac{\delta\alpha_1}{\kappa\alpha_1}$	$\frac{\delta M_2}{\delta\alpha_1}$
402	1.1495 0.0014	-0.48 0.07	1.1483 0.0007	4.38 0.04	1.0112	0.9989
487	1.1503 0.0023	-0.60 0.11	1.1451 0.0012	4.31 0.06	1.0129	0.9955
665	1.1481 0.0010	-0.54 0.05	1.1458 0.0005	4.25 0.03	1.0089	0.9976
434	1.1488 0.0024	-0.60 0.12	1.1458 0.0009	4.19 0.04	1.0188	0.9973

Table 4

$\bar{\delta}(\alpha_1) = 1.1492$	$\sigma = 9.0 \times 10^{-4}$	$\sigma^2 = 6.6 \times 10^{-7}$
$\bar{\kappa}(\alpha_1) = -0.55$	$\sigma = 5.0 \times 10^{-2}$	$\sigma^2 = 2.4 \times 10^{-3}$
$\bar{\delta}(M_2) = 1.1462$	$\sigma = 1.4 \times 10^{-3}$	$\sigma^2 = 1.5 \times 10^{-6}$
$\bar{\kappa}(M_2) = 4.28$	$\sigma = 8.0 \times 10^{-2}$	$\sigma^2 = 4.9 \times 10^{-3}$
$\bar{\delta}(\alpha_1)$ --- = 1.0128	$\sigma = 4.3 \times 10^{-3}$	$\sigma^2 = 1.4 \times 10^{-5}$
$\bar{\delta}(\kappa_1)$ ---		
$\bar{\delta}(M_2)$ --- = 0.9974	$\sigma = 1.0 \times 10^{-3}$	$\sigma^2 = 1.4 \times 10^{-6}$
$\bar{\delta}(\alpha_1)$		

Table 5

to the ones accepted for Madrid and Valle de los Caidos, although they are inferior in phase about 0.50° in the semi-diurnal component M_2 and about 0.25 in α_1 . These results seem to be confirmed if we bear in mind the ones obtained for Brussels from observations in R.O.B. with LaCoste Romberg gravimeter mod. G. 665 modified as zero instrument, from october 1984 to the end of february 1985, before its installation in Madrid. These results, given in Table 6, are very close to the ones obtained

GRAVIMETER LACOSTE ROMBERG N° 665 -ZERO METHOD.

STATION: BRUSSELS

PERIOD: 20/10/1984 to 26/02/1985

$$\delta(O_1) = 1.1548 \\ 0.0018$$

$$\delta(M_2) = 1.1842 \\ 0.0009$$

$$\kappa(O_1) = -0.02 \\ 0.09$$

$$\kappa(M_2) = 2.44 \\ 0.04$$

Standard deviation

$$D = 1.89$$

$$S.D. = 0.80$$

Table 6

in Brussels with the superconducting gravimeter (Ducarme et al., 1985 b) with a difference in amplitude of 0.5% as for O_1 as M_2 coinciding practically in phases although these should be corrected about 0.4° for M_2 considering the classic model of Brussels.

5. If we extrapolate the values obtained for Madrid corrected in phase, to Valle de los Caídos, bearing in mind the coordinates difference and the different oceanic effect calculated from Schwiderski maps, and in the case of M_2 from the Iberian M_2 map, we would obtain the following values of this station:

$$\delta(O_1) = 1.1490 \quad \kappa(O_1) = -0.20$$

$$\delta(M_2) = 1.1444 \quad \kappa(M_2) = 5.11^\circ$$

That are about 0.5% smaller than the normalized ones with the classic model of Brussels. This difference is like the one pointed out before for the LR. 665 gravimeter in Brussels, that indicates the good determination of Valle constants by comparing it with the classic model of Brussels and a guarantee of working of the LaCoste Romberg gravimeter mod. G 665 transformed into zero gravimeter.

		A(μg)	L	λ	A _{corr} (μg)	δ	κ
VALLE	MOLODENSKY	50.1724	4.502	101.7	49.46	1.1435	5.11
	WAHR	49.8091			49.09	1.1351	5.15
	EXP. MELCHIOR	50.6062			49.89	1.1535	5.07
MADRID	MOLODENSKY	50.4393	4.224	101.0	49.89	1.1454	4.78
	WAHR	50.0771			49.45	1.1371	4.81
	EXP. MELCHIOR	50.6062			50.25	1.1556	4.73

Table 7

6. If we consider Molodensky and Wahr models and the experimental one by Melchior, and we correct the values corresponding to the oceanic effect according to Schwiderski, complemented with Iberia M_2 for M_2 , we find the results of Table 7 for this harmonic and Valle and Madrid stations. The values obtained for δM_2 and $\kappa(M_2)$ in Madrid with observations, and in Valle with extrapolation, fit very well with the ones for Molodensky I model, being about 0.8% bigger than Whar model and in the same rate but inferior to the results of the experimental model by Melchior.

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An European Tidal Gravity Profile over a 30° Latitude difference (Kevo - Bruxelles - Madrid).

B. DUCARME , R. VIEIRA , J. KÄÄRIÄINEN

with 1 figure and 7 tables

Ducarme, B., Vieira, R., Kääriäinen, J., 1985 :
Proceedings of the Tenth International Symposium on Earth Tides.
pp. 199 - 212.

Abstract : Tidal gravity measurements have been performed in 1984-85 at Kevo (North Finland), Bruxelles and Madrid with two LaCoste-Romberg model G gravimeters transformed into zero method instruments. All gravimeters were normalized at Brussels.

According to the Wahr model, a thirty degrees latitude difference should produce more than one per cent decrease of the δ factor between Madrid and Kevo.

Due to the uncertainties in the oceanic loading computations we cannot derive firm conclusions for the semidiurnal waves.

The latitude effect is clearly seen on the diurnal waves between Bruxelles and Kevo but not between Madrid and Bruxelles. It may be concluded that local anomalies may conceal the latitude effect.

Keywords : Latitude effect, Indirect oceanic effect.

1. Introduction

Since Love (1911), it is well known that the tidal gravimetric δ factors are latitude dependent. Wahr (1981) calculated the coefficients of this dependence for different Earth models.

A first experimental confirmation was brought by Melchior (1983) who studied the worldwide distribution of the δ factors of the main tidal waves in function of the latitude. This analysis showed a good agreement in the slope of the regression line but a systematic disagreement of the order of one per cent for the constant term. Further studies confirmed that fact (Melchior, De Becker, 1983). However the scattering of the tidal results is very large compared to the investigated phenomenon (Fig. 1) and only stations at very high or very low latitude may significantly contribute to the determination of this latitude effect.(Vieira, R., 1981)

It is a reason why we decided to observe a tidal gravity profile extending over a range of 30° of latitude in Europe from Madrid (Spain) to Kevo (Finland). The forecasted latitude effect is larger than one per cent and reaches already 0.75 per cent between Brussels and Kevo (Table 1). Unfortunately, in the semidiurnal tidal band, the amplitudes become very low at high latitude (M_2 reaches only 10 μgal at Kevo, but 30 μgal at Brussels and 40 μgal at Madrid).

It is thus necessary to reach a precision better than 0.1 μgal on the correction of the oceanic indirect effects at Kevo, a precision which corresponds to 10 per cent of the computed effect. Such a precision is probably not insured due to the imperfect knowledge of the oceanic tides in the Arctic Ocean.

We must therefore mainly rely upon the diurnal earth tides which are twice larger than the semidiurnal ones at this latitude and which are disturbed by much smaller indirect effects : 10 per cent error in the loading computation will produce only an error of 0.1 per cent on the corrected δ factor of O_1 .

In the southern segment of the profile the tidal amplitudes are larger but the indirect effects are also bigger in the semidiurnal band so that a 10 per cent error in the loading computation will also affect the corrected δ factor by one per cent for M_2 and only 0.1 per cent for O_1 .

2. Choice of the instruments and site selection

The objective of the measurements being to reach a precision of a few thousandths on the measured tidal amplitudes and one tenth of a degree on the phases it was necessary to select the best available gravimeters.

In 1983, Van Ruymbeke succeeded in transforming LaCoste-Romberg model D and G gravimeters into zero method instruments, using Sato-Harrison principle (Van Ruymbeke, 1985; Harrison, J., Sato, T., 1983.). As a result the perturbations due to the tilt of the instrument are drastically reduced (Zhou Kungen and Van Ruymbeke, 1985). The sensitivity remains stable within one per cent in normal observing conditions while with non zero instruments a ten per cent variation was usual. As there is practically no more displacement of the beam, the elastic after effects of the spring are suppressed and it is no more necessary to correct the instrumental phase lags by adjusting a rheological model (Ducarme, 1975). We identify these zero methods instruments by the letters LCZ.

It was decided to perform parallel registrations with two instruments in Finland and to intercompare them at the Brussels Fundamental Station at the Royal Observatory of Belgium.

Kevo is the Northernmost available site in Finland. It is the location of a Subarctic Research Station depending from the Turku University. Technicians are working there all the year round and electrical generators provide emergency power in case of electrical failure. This site had been already occupied by the late Professor Honkasalo in 1972 with a Geodynamics gravimeter (Ducarme and Kääriäinen, 1980).

In Madrid there are two tidal gravity stations : one is located in the Campus of the Universidad Complutense and the other in the National Monument of Valle de los Caídos, some fifty kilometers from the city center. The two stations have been intercompared by using many gravimeters. For the facility of the maintenance it was decided to install the gravimeters at the University.

3. Calendar of the Observations

The profile started in march 1984 with the installation of two gravimeters in Kevo :

LCZ 402 belonging to the Royal Observatory of Belgium (ROB)

LCZ 665 belonging to the Instituto de Astronomia y Geodesia del Consejo Superior de Investigaciones Cientificas (CSIC).

The LCZ 402 was already normalized in the Brussels system.

In september 1984, LCZ 665 was moved to Brussels for intercomparison and LCZ 402 to Madrid. In the same time the LCZ 487, a second belgian gravimeter, was installed in Madrid.

Finally in march 1985 all gravimeters returned to their home countries. A summary of the registration periods is given in Table 2.

4. Improved Brussels System

The so-called Brussels Tidal Gravity System (Ducarme, 1975) is based upon an accepted value for $\delta(O_1)$:

$$\delta(O_1) = 1.161$$

and phase differences :

$$\alpha(O_1) = -0^\circ 2, \quad \alpha(M_2) = 2^\circ 8$$

These values were determined from observations performed between 1958 and 1970 using exclusively Askania gravimeters either of type GS11 or BN

modified. With this normalization, which includes the inertial correction, the results of observations performed during the Trans European Tidal Gravity Profile (1970-1973) and the Trans World Tidal Gravity Profile (after 1973) fit well the Molodensky model I corrected for indirect oceanic effects computed from the Schwiderski maps (Melchior & alii, 1981).

The phase differences were confirmed independently by the Superconducting gravimeter (Ducarme, 1983) and by the LCZ gravimeters (Van Ruymbeke, 1985).

However, as already stated in the Introduction, a contradiction exists between the Brussels Tidal System and the most recent model for the body tides (Wahr, 1981). The debate is obscured by the fact that the inertial correction (Pariisky, 1961) is included in the Wahr model and should no more be applied on the observations.

It is why we show, in Table 3, the results of the Superconducting Gravimeter normalized to the Brussels Tidal System with the inertial correction removed (A) together with the Molodensky I (B) and Wahr (C) models corrected for the indirect oceanic effects by using the Schwiderski maps, the Farrell algorithm and a mass conservation proportional to the amplitude (Moens & alii, 1980).

Considering the high internal precision of the Superconducting gravimeter we may consider the variations of the B/A ratio as reflecting the uncertainties on the tidal loading corrections in the semidiurnal band. On M_2 a 5 per cent error may be suspected. From Table 4 which summarizes the results for Belgium and Luxemburg one sees that the discrepancies expressed by the final residue \bar{X} (X , χ) are lower than 0.2 μgal , a value which could corresponds to a 10 per cent error on the load vector. However no systematic pattern is observed in the Belgium-Luxemburg area. We therefore are of the opinion that a 10 per cent uncertainty on the tidal loading computations is overestimated and that 5 per cent is more probable.

It is clear that the amplitudes should be reduced by 0.6 per cent to fit the Molodensky model and by 1.6 per cent to fit Wahr's theory.

As the goal of this profile is only to check a latitude dependence of the tidal factors we may adopt any normalization. We decided to use an improved tidal model fitting very closely the Molodensky I model at Brussels :

$$\delta (O_1) = 1.155 \quad \delta (M_2) = 1.186$$

$$\alpha (O_1) = 0^\circ 0 \quad \alpha (M_2) = 2^\circ 7$$

Of course, as the LCZ gravimeters do not have instrumental phase lags, it is only necessary to normalize the amplitudes by fitting the $\delta(O_1)$ tidal factor.

5. Discussion of the results obtained at Kevo

The agreement between the two LCZ instruments at Kevo is very satisfactory (Table 5). The strongest discrepancy is found for K_1 , because with only six months of observations it cannot be separated from the meteorological wave S_1 . The observations made with GEO 761 in 1972 are in good agreement with the new ones for O_1 and M_2 .

As already stated in the Introduction we should not rely on the semi-diurnal waves to study the latitude dependence of the tidal factors. We do probably not know the indirect effects in this area with a precision better than 10 per cent. This represents 0.1 μgal (or one per cent) on the $\delta(M_2)$ tidal factor, an uncertainty larger than the expected latitude effect.

However from the observed values of $\delta(O_1)$, with the three instruments, we may say that half a per cent decrease between Brussels and Kevo seems to be a realistic order of magnitude (Table 7) while the uncertainty of the load correction is only of the order of 0.1 per cent in the diurnal band.

6. Discussion of the results obtained at Madrid

Although our observations have been performed in Madrid, it is interesting to include the results of the nearby station Valle de los Caidos in the Table 6 which provides two more intercomparisons with the Askania 212 gravimeter which has been calibrated in Brussels in 1978 and with the Tidal La-Coste (ET 15) belonging to the Tidal Institute of Bidston (Liverpool). Direct comparison between Valle and Madrid is insured by LCR 434. In any case, the error on the differential tidal loading between the two stations is at least one order of magnitude below the observational errors. (Visira, R., et. al., 1985)

Here again we give the corrected tidal factors for the main waves. The general agreement is excellent especially for the LCZ gravimeters and ET 15. Considering now the difference with Brussels, we observe a decrease of one per cent on $\delta(O_1)$ instead of an increase of half a per cent.

A slight decrease also appears for M_2 but for the semidiurnal band the uncertainty on the loading is at least 5 per cent (see § 4) which corresponds to half a per cent on the δ factors.

7. Conclusions

From the results summarized in Table 8 it may be concluded that strong regional anomalies may conceal the latitude dependence. These anomalies more or less compensate each other at a global scale. It is why the effect was discovered by Melchior (1983) in the results of the Trans World Tidal Gravity Profiles.

Which anomalies can we suspect ? In Yanshin & alii (1985) the authors show a correlation between the final residue component $X \cos x$ and the heat flow. Cold regions are associated to negative values of $X \cos x$ which correspond to a smaller amplitude of the body tides. Hot regions associated to positive values of $X \cos x$ seem to correspond to larger tidal amplitudes.

Imperfect mass compensation in the oceanic tides may also produce large scale errors in the loading computations but only for semidiurnal tides.

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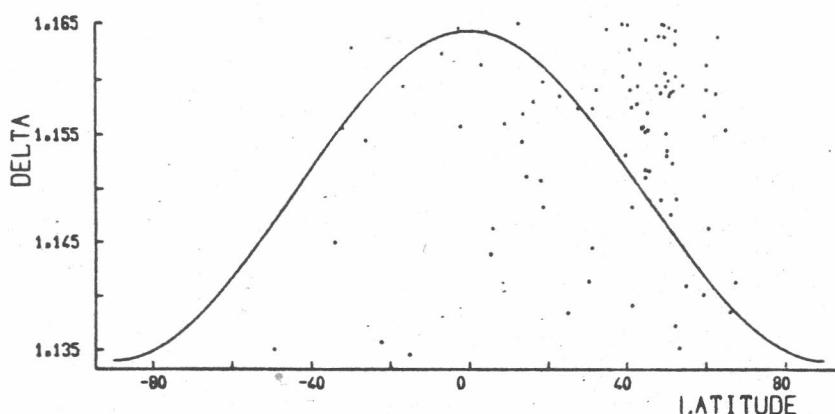


Figure 1 : Répartition of the observations of the Trans World Tidal Gravity profiles compared with the Wahr model (full line).

TABLE 1
Latitude Dependence of the Gravimetric Tidal Factors

$$\text{diurnal waves} : \delta = \delta_0 + \delta_1 (\sqrt{6}/4) (7 \sin^2 \phi - 3)$$

$$\text{semi diurnal waves} : \delta = \delta_0 + \delta_1 (\sqrt{3}/2) (7 \sin^2 \phi - 1)$$

Theoretical model
(Wahr, 1980; Dehant, 1985)

Experimental model
(Melchior and De Becker, 1983)

Wave	δ_0	δ_1	δ_0	δ_1
O_1	1.1520	-0.0065	1.1618 ± 0.0016	-0.0028 ± 0.0015
K_1	1.1320	-0.0063	1.1458 ± 0.0012	-0.0059 ± 0.0013
M_2	1.1599	-0.0045	1.1751 ± 0.0021	-0.0046 ± 0.0010

		ϕ	$\delta(O_1)$	$\delta(K_1)$	Semidiurnal
WAHR	MAORID	40°64'	1.1521	1.1321	1.1514
	BRUSSELS	50°80'	1.1475	1.1275	1.1460
	KEVO	69°76'	1.1404	1.1204	1.1376
MOLODENSKY I			1.1595	1.1376	1.1600

TABLE 2

Registration Periods

	KEVO		BRUSSELS		MADRID	
LCZ 402	84 04 01	84 09 12	84 01 02	84 03 19	84 10 04	85 03 01
LCZ 487			84 03 30	84 08 24	84 10 10	85 03 01
LCZ 665	84 04 03	84 09 15	84 09 30	85 02 16	85 03 16	85 07 25
GEO 761	72 08 02	72 12 19	73 06 05	73 09 15		

TABLE 3

Comparison of the models at Brussels

A			B			C		
Brussels Tidal Gravity System without inertial correction			Molodensky Model + Schwiderski Maps			Wahr Model + Schwiderski Maps		
Q ₁	1.1629	-0.31	1.1561	-0.23	1.0059	1.1439	-0.24	1.0167
D ₁	1.1622	0.04	1.1551	0.03	1.0061	1.1431	0.07	1.0167
P ₁	1.1624	0.22	1.1545	0.24	1.0068	1.1432	0.24	1.0168
K ₁	1.1493	0.27	1.1398	0.24	1.0083	1.1296	0.24	1.0175
N ₂	1.1764	3.05	1.1783	3.09	0.9984	1.1655	3.12	1.0093
M ₂	1.1933	2.71	1.1898	2.69	1.0029	1.1771	2.72	1.0138
S ₂	1.2074	1.15	1.1968	1.22	1.0089	1.1843	1.24	1.0195
K ₂	1.2068	1.34	1.1929	1.12	1.0117	1.1806	1.13	1.0222
M ₃ *	1.0753	1.18	1.0700	0.00	0.9988	1.0600	0.00	1.0083

Adjustment of the Amplitudes

	A/B	A/C
Diurnal	1.0068	1.017
Semidiurnal	1.0055	1.016
Proposed	1.0060	1.0165

*No cotidal map available.

TABLE 4

Results for the wave M_2
in Belgium and Luxembourg

Stations	D(km)	B	β	L	λ	X	χ	Q
Veurne	6	1.82	112°	2.00	96°	0.57	-148°	6.3
Gistel	5	1.77	90°	1.97	86°	0.24	-127°	6.8
Damme	10	2.01	69°	1.90	74°	0.19	18°	2.6
Brussel- Bruxelles	110	1.76	61°	1.88	63°	0.13	-92°	54.2
Louvain- la-Neuve	130	2.07	58°	1.88	62°	0.24	26°	7.1
Walferdange	220	1.74	57°	1.84	61°	0.16	-70°	34.0

\bar{B} (B, β) residual vector (observed minus Molodensky I model)

\bar{L} (L, λ) tidal loading computations (Schwiderski maps)

\bar{X} (X, χ) final residue ($\bar{B} - \bar{L}$)

Q quality factor

D distance to the sea

TABLE 5

Results at Kevo

CORRECTED TIDAL FACTORS

Wave	Theoretical amplitude (microgal)	Tidal loading B (microgal)	β	LCZ 402 δ α	LCZ 665 δ α	GEO 761 δ α
O_1	20.2	0.24	118°	1.1554 -0.03	1.1549 -0.36	1.1571 -0.43
K_1	28.4	0.30	-78°	1.1436 -0.36	1.1338 0.07	(1.1577)(-0.36)
N_2	1.7	0.25	89°	1.1356 -0.76	1.1289 -1.13	(1.1769)(-0.44)
M_2	9.0	1.37	52°	1.1308 0.31	1.1195 0.08	1.1246 0.03
S_2	4.2	0.43	27°	1.1463 -0.65	1.1400 -0.07	(1.0992)(-0.36)

TABLE 6
Results in Spain a) Valle de Los Caídos

Wave	Theoretical amplitude (microgal)	Tidal loading		CORRECTED TIDAL FACTORS			
		B	β	ET 15	ASK 212*	LCR 434	
		δ	α	δ	α	δ	α
O ₁	30.72	0.28	-139°	1.1507	0.16	1.1539	-0.01
K ₁	43.20	0.34	101°	1.1356	-0.05	1.1236	0.57
N ₂	8.28	0.92	120°	1.1581	1.05	1.1648	0.55
M ₂	43.25	4.31	101°	1.1599	0.25	1.1613	0.21
S ₂	20.12	1.51	75°	1.1593	0.12	(1.1293	-0.41)
						1.1683	0.10

* Normalized in the Brussel's Improved Tidal System

| | Normalized on ET 15.

b) Madrid

Wave	Theoretical amplitude (microgal)	Tidal loading		CORRECTED TIDAL FACTORS			
		LCR 434	LCZ 402	LCZ 487	LCZ 665		
		δ	α	δ	α	δ	α
O ₁	30.68	0.26	-139°	1.1465	-0.47	1.1483	-0.20
K ₁	43.15	0.32	101°	1.1399	-0.68	1.1310	-0.16
N ₂	8.33	0.86	119°	(1.1929	1.13)	1.1491	0.27
M ₂	43.49	4.05	100°	1.1577	0.06	1.1573	-0.22
S ₂	20.23	1.42	74°	1.1623	0.10	1.1584	-0.18
						1.1580	-0.03
						1.1617	0.09

TABLE 7

Differential latitude effects along the profile
(in per cent of Amplitude factors)

	Madrid	Brussels*	Kevø
Wahr model	+0.46	—	-0.71
Observations $\delta (O_1)$	-1.0	adjusted	-0.4
$\delta (K_1)$	-0.3	+0.2	-0.1

* based on the results of the Superconducting gravimeter (Ducarme et alii, 1985).

Ocean Tides in the nearby of the Iberian Peninsula. Part. I: M_2
Iberia Map

R. VIEIRA; C. TORO; E. MEGIAS

with 11 figures and 1 table

Vieira, R.; Toro, C.; Megias, E.; 1985: Ocean Tides in
the nearby of the Iberian Peninsula. Part. I: M_2 Iberia
Map. Proceedings of the Tenth International Symposium
on Earth's Tides, pp. 679-696.

Abstract: The correction of the ocean effects is certainly one of the serious problems which limit the interpretation of Earth Tides. Following the recommendations of the IX International Symposium on Earth Tides, we have started the drawing up of ocean tides maps of the main lunisolar potential harmonics for a zone close to Iberian Peninsula. The M_2 Iberian Map is the first of a serie built up with two fundamental criteria, in one hand, it is an empiric map obtained from the harmonic constants observed in the zone and its neighbourings and on the other hand it has been maintained the criterion that in the externe limits the isolines of amplitudes and phases must link with the corresponding to the Schwiderski maps, (Schwiderski, 1979), which are the ones nearest to the observed reality in the gravimetric tide observations made in the Iberian Peninsula.

Keywords: Ocean Tide; Iberian Peninsula; M_2

INTRODUCTION

Among the several circumstances which condition the precision and interpretation of the gravimetric tides observations, there are two which we can consider very important; one is the questions related with instrumentation, and another, the correction of the oceanic effects. The instrumental problems are being the aim of a lot of studies and their results are shown in the publications about these themes, pointing out two questions of great interest

as the stability in the response time of the sensors and the precise determination of the instrumental constants.

The solution to the oceanic problem is conditioned by the obtention of the corrections to be applied to the phenomenon observed in order to eliminate the ocean tide influence, that's to say, to delimit the system to the case of a non oceanic land. The importance of the oceanic correction is shown by the magnitude of the phenomenon itself, that in certain zones of the planet becomes more than 15% of the observed signal, being very difficult to evaluate it with the precision had by, the more modern gravimeters nowadays and that is better than the microgal. The oceanic effect is very strong in the South-Western zone of Europe, and particularly in the Gulf of Vizcaya region; for that the Iberian Peninsula is a suitable place for these studies (Vieira, 1979). It is necessary to correct the oceanic effects to have tide maps which correspond with the real movement of the oceans as a consequence of the action of forces derived from the astronomic potential and this is needed for the different harmonics of this potential or at least for those which have a significative amplitude. On comparing the observation of gravimetric tides made in the Iberian Peninsula with oceanic effect calculated from several maps, we have arrived to the conclusion that only the Schwiderski maps are near the reality. The trials made with the Zahel, Parke, Henderschott, Bogdanov, etc..... maps do not give satisfactory results for the main semidiurnal component from the astronomic potential M_2 , at least for the Iberian Peninsula. This same conclusion was obtained by other researches in several regions of the planet (Melchior et al. 1983). It is convenient, for that, to use the Schwiderski maps as a base to evaluate the oceanic correction, as it was recommended in the IX International Symposium on Earth Tides. However, there are possibilities to improve those maps overall in zones near the island and continents with singular conditions which can affect the results. Therefore, the Schwiderski maps do not take into account the interior seas nor the Mediterranean Sea, in this case there is a significative cause of imprecision in the station

observations placed in the South of Spain. We must not forget that we pass rapidly from the important Atlantic tides, with a special semidiurnal character, to a quasi-static system in the Mediterranean Sea, through a zone -The Alboran Sea- where the tides have even more significative values (Vieira, R. et al. 1981).

So, having in mind that we are carrying out a wide investigation project on Earth Tides in Spain (Vieira, R. et al. 1977) it is convenient to try the improvement of the existing oceanic maps. In this way, we have started the drawing up of maps, called Iberia by us, for the same harmonics used by Schwiderski (Schwiderski, E.W., 1980) and from empiric data obtained as much in the Peninsula shore and its close islands, as from observations done with ocean bottom tide gauges. In this paper we present the results of the Iberia M_2 map.

CHARACTERISTICS OF THE IBERIA M_2 MAP

The Iberia M_2 map has been built up from 120 series or harmonic constants data corresponding to observations done in the peninsular coast, north of Africa, the close islands and the French, Atlantic and Mediterranean coasts and the experiences made with ocean bottom tide gauges (C. Toro, 1984). The information sources have been:

- a.- Publications about harmonic constants by the Instituto Español de Oceanografía.
- b.- List of harmonic analyses made by the Instituto Hidrográfico de la Marina since 1927.
- c.- I.A.P.S.O. Public. Scient. nº 30 (Cartwright, D. E. et al. 1979).
- d.- Data bank of harmonic components of oceanic tides of the International Hydrographic Organization.

From 120 series, approximately the 20% has been eliminated, as they do not pass any coherent test with the rest of the observations. The causes of these eliminations are due to one of these three factors:

- 1) Historic series of doubtful quality.
- 2) Observations done in peculiar places and whose results could be due, at first, to the peculiarities of the corresponding tide gauge settlement. In this case, we have tide gauge in the harbors - bays, big rives mouths, etc.
- 3) Those observations with results highly discrepant from the ones obtained in next places. Usually, - they are short time series.

As a consequence of this study to unify and improve the Spanish network of tide gauge is needed, depending nowadays on three different public organisms, as well as to reference it to the First Order National Leveling Network.

For the drawing up of the Iberia M_2 , a zone has been delimited in latitude by the following values:

$$\begin{aligned}48^{\circ} \text{N} \geq \phi &\geq 31^{\circ} \text{N} \\8.250^{\circ} \text{E} \geq \lambda &\geq -16^{\circ} \text{W}\end{aligned}$$

In the figure 1, the limits of the Iberia map are shown.

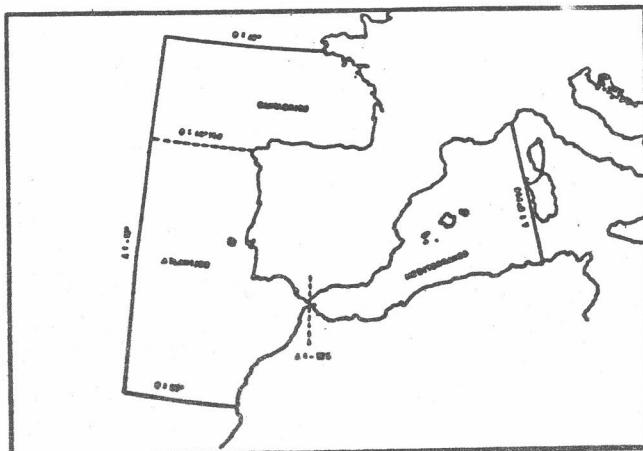


Fig. 1

As an additional condition, the cotidal lines must link with the corresponding of Schwiderski M_2 map, to get the homogeneity of the results and at the same time it permits a comparative study between the obtained values for the Schwiderski map and the Iberia one.

DIGITALIZATION OF THE IBERIA M_2 MAP

As it is well known, the Schwiderski maps were digitalized from a grid of $1^\circ \times 1^\circ$. This division of the oceanic surface does not permit an exact adaptation to the shore shape in spite of the quite regular outline of the Atlantic and Cantabric coasts in the Peninsula. (Fig. 2)

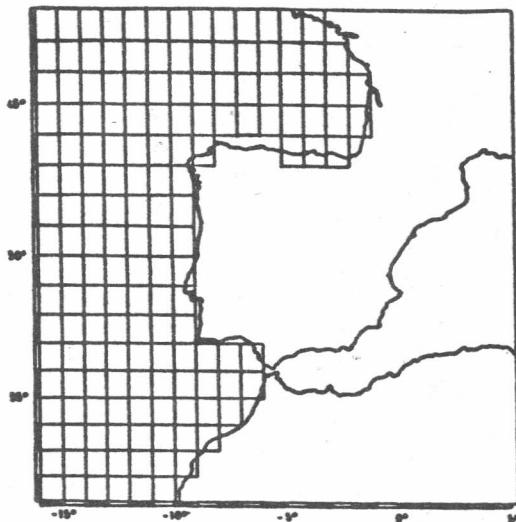


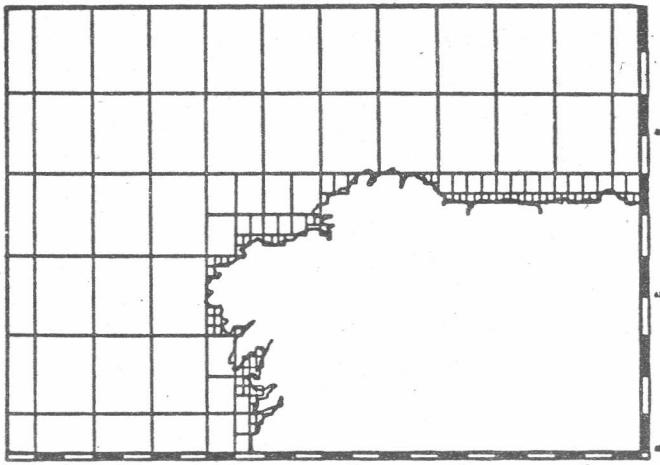
Fig. 2

As grid, the basic digitalization for the Iberia map taken is the one of $0^\circ 5 \times 0^\circ 5$ but in the coastal zones this grid has been reduced depending one the shape; to smaller sizes coming to round squares of $0^\circ 0625 \times 0^\circ 0625$. The total of the zone included within the limits of the map has been divided in a whole of 1.580 polygons with the following distribution:

774 poligons of $0^{\circ}5 \times 0^{\circ}5$
297 poligons of $0^{\circ}250 \times 0^{\circ}250$
316 poligons of $0^{\circ}125 \times 0^{\circ}125$
193 poligons of $0^{\circ}0625 \times 0^{\circ}0625$

Among the 1.580 poligons, 436 belong to the Mediterranean Sea and 1.114 to the Atlantic Ocean and the Cantabric Sea.

Fig. 3



In the figure 3 it can be seen how the grid in its several sizes adapts to the coast in the zone of Galicia, the one with a more irregular shape. This grid will be the base of the following maps to be done. In its externe part, the grid links with the Schwiderski one of $1^{\circ} \times 1^{\circ}$ without gaps nor superpositions.

OCEANIC EFFECTS CALCULUS

For the oceanic effect calculi, the program I.C.E.T. was used, (Melchior et al. 1980), that applies the convolution process developped by Farrell (1972). This programs is based in the following principles:

a) The newtonian attraction is calculated directly taking into account the distance of each poligon of the oceanic map and the latitude of the point whose effect we want to find.

b) The load effect is obtained by a polynomial interpolation of Lagrange from the Green's function tables obtained by Farrell.

c) The effect of mass redistribution has been considered as proportional to the attraction effect.

RESULTS AND CONCLUSIONS

In the figures 4 and 5 the digitalized map Iberia M_2 of amplitude and phase is shown. The values corresponding to the polygons with little surface near the coast have been substituted by symbols.

The results for the Iberian Peninsula are given in the figures 6 and 7, which have been obtained from the values L_{IBM_2} (L, λ) over a grid of $0^{\circ}5 \times 0^{\circ}5$ that covers the whole Peninsula the south of France and the zone of Morocco in the north of Africa, till the $34^{\circ}N$ parallel. The isolines of amplitudes and phase for Iberia M_2 are given in the figures 8 and 9. In the figures 10 and 11 are given the values for the Iberian Peninsula obtained from Schwiderski map for the zone included in the Iberia map.

The values of the oceanic effect calculated from Schwiderski and Iberia M_2 maps are given in Table 1, as well as other partial results. The V column of this table is of special interest, as we can check the existing differences between Iberian M_2 and the same zone in the Schwiderski map. In general these differences are less than one microgal, although in the coastal stations it present values even of 1.0 microgal, as in the case of Santander; in the stations placed in the centre of the peninsula, the differences are about 0.2 microgals.

It would be important to point out the small but perceptible, influence of the close Mediterranean Sea on the Granada station, placed in the South of the peninsula at about 70 km straightley from the shore; this effect is bigger in places next to the coast between Gibraltar and Málaga.

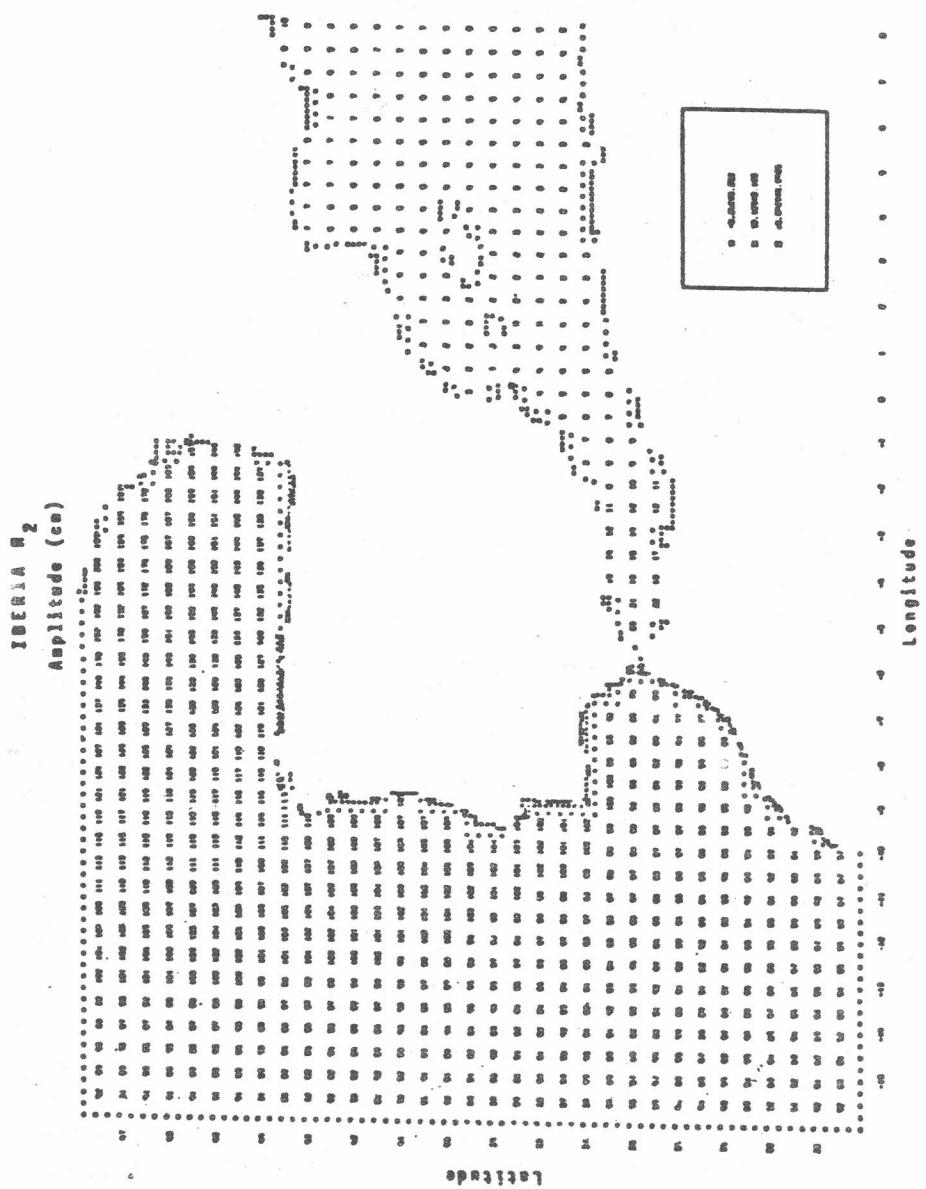


FIG. 4

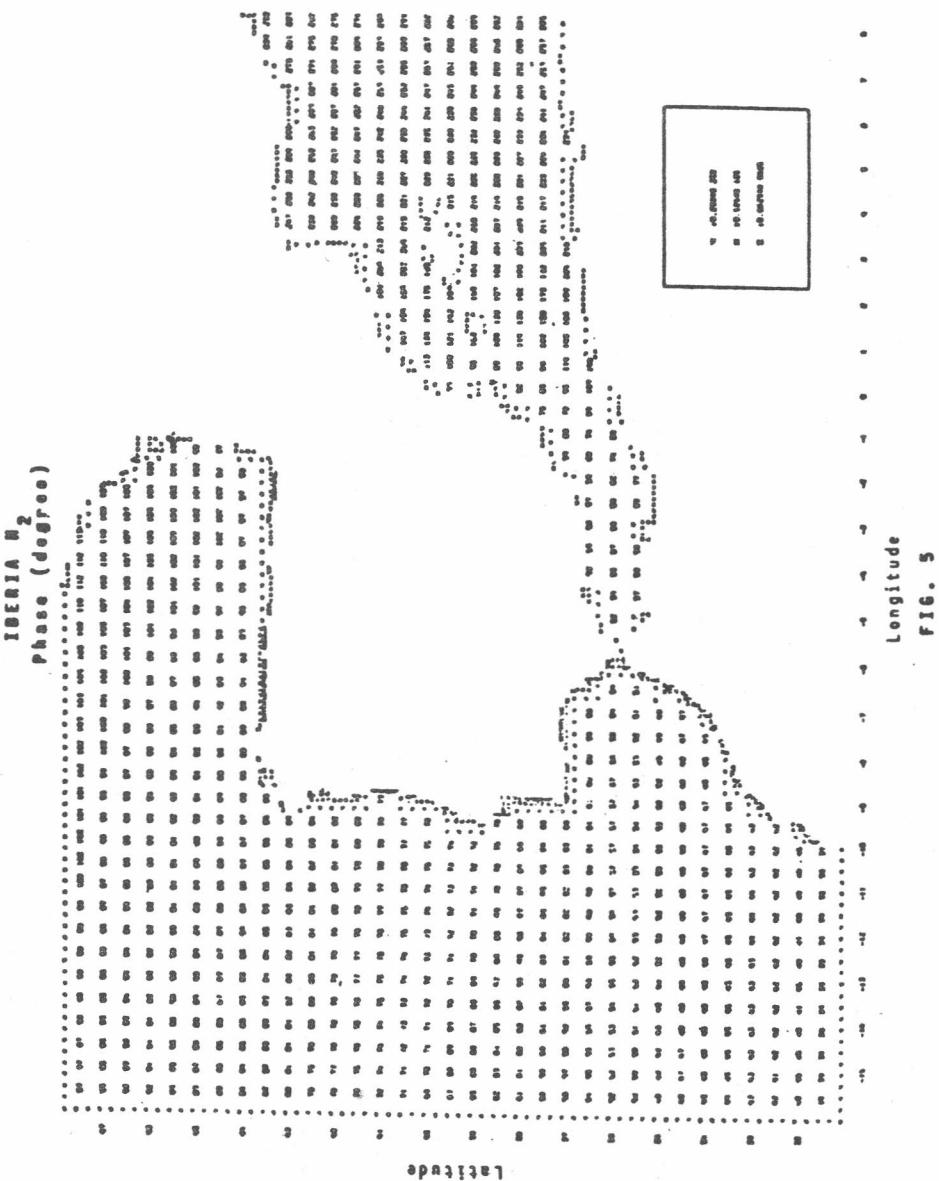


FIG. 5

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Longitude Fig. 6

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Longitude. 7

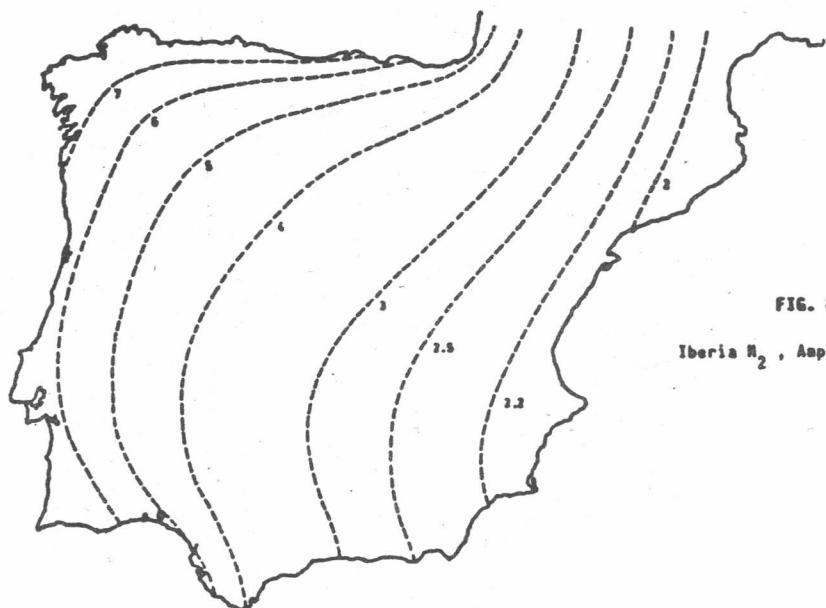


FIG. 8

Iberia N_2 , Amplitude (μg)



FIG. 9

Iberia N_2 , Phase (Degree)

SCENARIOS (2)

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FIG. 10

	I	II	III	IV	V	VI
BALLE	L 4.305	3.149	1.195	3.349	0.202	4.502
	A 101.12	105.86	88.56	100.34	112.85	101.89
BAGEDO	L 4.082	2.945	1.138	3.130	0.187	4.224
	A 100.39	105.25	97.87	105.70	114.12	100.99
BAGANAS	L 3.400	2.473	0.943	2.779	0.347	3.084
	A 100.21	111.89	98.00	115.25	145.18	111.17
SANTANDER	L 9.741	8.005	0.834	7.111	1.845	7.886
	A 92.85	97.54	88.50	94.89	104.12	91.36
BORGES	L 9.523	6.248	1.338	6.360	0.143	5.86
	A 95.49	100.38	98.00	98.10	98.01	96.95
S. FERRAZO	L 0.299	5.770	0.571	5.156	0.782	5.696
	A 120.86	122.08	97.81	120.23	-03.00	125.30
SEPULVEDA	L 4.306	3.323	1.225	3.516	0.187	4.086
	A 98.21	103.32	94.50	103.05	100.03	98.25
ARCAS	L 3.401	2.429	1.069	2.503	0.155	3.552
	A 98.92	102.38	93.73	102.02	110.03	97.49
COCILLOS	L 9.461	6.020	1.420	6.342	0.314	5.713
	A 102.17	107.04	90.46	107.71	108.61	103.67
TOLEDO	L 3.060	3.071	1.129	3.060	0.197	4.153
	A 102.95	107.39	91.59	100.48	124.55	103.05
SANTIAZO	L 0.026	0.958	1.033	7.602	0.666	9.285
	A 107.86	111.48	96.63	111.05	119.27	100.39
CABRONEGO	L 4.567	-2.365	1.246	3.574	0.208	4.774
	A 100.13	104.05	97.02	103.94	106.49	100.61
C. REAL	L 2.764	2.711	1.059	2.902	0.209	3.028
	A 104.95	100.13	96.19	110.89	134.38	106.45
LA GRANJA	L 4.307	3.202	1.207	3.309	0.197	4.562
	A 99.88	104.86	98.00	105.07	108.00	100.36
BARCELONA	L 2.613	1.800	0.872	1.820	0.096	2.666
	A 93.08	91.42	85.86	88.45	11.86	81.11
PAPLOSA	L 4.370	3.027	1.217	3.095	0.207	5.168
	A 99.39	94.87	71.01	93.09	96.10	90.10
GALATICO	L 2.702	2.710	1.045	2.058	0.143	3.866
	A 92.04	98.41	75.27	97.80	96.13	91.02
PLASENCIA	L 4.877	3.848	1.268	3.903	0.278	5.133
	A 100.76	112.57	97.73	113.82	131.91	100.67

TABLE I
(Explanation)

- I. General results of the Schuidderski M_2 map.
- II. Results of the Schuidderski M_2 map for the zone included in the Iberia M_2 map.
- III. Effects calculated from the Schuidderski M_2 map eliminating the zone included in the Iberia M_2 map.
- IV. Effects calculated from Iberia M_2 .
- V. Difference between the results of the Iberia M_2 and Schuidderski M_2 maps in the same zone (difference between the columns IV and II).
- VI. Results on substituting the Iberia M_2 map in the Schuidderski M_2 map (sum of the columns III and IV).

From all above, we can conclude that the Schwiderski map M_2 represents the oceanic effect in the Peninsula quite well, although if precisions of the gravimetric tide observation become about tenths of microgal, it would be convenient to apply this local maps.

We think these results have not to be extrapolated to other zones, since, as we have commented above, the regular shape of the Peninsula permits to cover this peninsular outline with a great approximation in its Northern and Western coasts with a grid of $1^\circ \times 1^\circ$, the one used by Schwiderski.

The Iberia M_2 map will be followed by the rest of the components drawn up by Schwiderski. Those maps will be improved depending on the new data of the harmonic constants obtained in zones included in the interior of the limits and its neighbourings; we want to extend it Southwards till including the zone of the Canarian Island, having to reach to 23° parallel.

These researches are developed in the Instituto de Astronomía y Geodesia (C.S.I.C.-U.C.M.) with grants given by the Comisión Asesora de Investigación Científica y Técnica.

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Ocean Tides in the nearby of the Iberian Peninsula. Part II: S_2 Iberia map.

R. VIEIRA, C. TORO and J. FERNANDEZ

with 6 figures and 1 table

Vieira, R., Toro, C. and Fernández, J.; 1985:
Ocean Tides in the nearby of the Iberian Peninsula.
Part II: S_2 Iberia map. Proceedings of the Tenth International Symposium on Earth Tides, pp.697-706.

Abstract: The Iberia S_2 map is the second one of the serie that we are drawing up in the oceanic zone close to the Iberian Peninsula, for the main harmonics of the lunisolar potential. As we have commented in Vieira et al. (1985), we pretend to improve the present maps with these ones, specially the Schwiderski's (Schwiderski, 1979), that have shown to be the closest ones to the observed reality of all those for we have made the calculus of the so called oceanic effect. It's an empiric map, imposing the condition that the correspondent isolines of amplitude and phase must be joined completely to Schwiderski's, in order to avoid death zones or gaps on using the Iberia maps as a complement to Schwiderski's.

Keywords: Ocean Tides, S_2 , Iberian Peninsula.

INTRODUCTION

In Vieira et al. (1985) we made a serie of considerations about the Iberia maps, that are suitable as much for M_2 as for all constituting the serie Iberia.

The mainly semi-diurnal character of the tide in the nearby of the Iberian Peninsula is the reason why we have started this serie of the main semi-diurnal harmonics of the lunisolar potential. Among them, S_2 represents the main semi-diurnal solar wave of argument $2t$ and angular velocity $30^\circ/h$ exactly. In the Southern Europe zone, S_2 has a considerable amplitude contributing highly to the oceanic effect in the stations of gravimetric and clinometric tides, observed up to now in the Iberian Peninsula. Due to its proximity in frequency to K_2 , the sum of declinational solar and lunar

waves K_2^S and K_2^M , it is absolutely necessary to have long and good observation series to get the values of amplitude and phase corresponding to S_2 .

IBERIA S_2 MAP

The maps of amplitude and phase of S_2 , have been obtained from the series which we have referred to in Vieira et al. (1985), although we have had to suppress the biggest amount of observations, approximately a 30% of the analyses we had. The reasons have been mainly the lack of quality in some series of availables and the aberrant values in other, within the context of the rest of observations.

The map limits, how in the rest of the serie, are comprised between the parallels of latitude $31^{\circ}N$ and $48^{\circ}N$, and the meridians $8.250^{\circ}E$ and $16^{\circ}W$, including what we could call close Mediterranean Sea, that is, the part from Corsica and Sardinia westwards.

The digitalization grid comprises a whole of 1580 polygons with sizes from $0^{\circ}5 \times 0^{\circ}5$ for 774 polygons in more distant zones, till the 193 ones with $0^{\circ}0625 \times 0^{\circ}0625$, that permits us to have in mind the different geographic accidents that shape the coasts, in a way very similar to reality.

The Iberia M_2 digitalized maps of amplitude and phase are shown in Figures 1 and 2. In these maps, the values corresponding to polygons with lesser sizes have been substituted by symbols, since we cannot represent them by their numerical values. The oceanic effect over the Iberian Peninsula and its nearby, obtained from Iberia S_2 and calculus programmes of ICET (Melchior et al., 1980), is represented in Figures 3 and 4, having in mind a grid of $0^{\circ}5$ each side. The representations in isoline way of the above values for the Iberian Peninsula are given in Figures 5 and 6.

Table 1, made taking the stations of gravimetric tides observed in Spain in the last years (Vieira et al., 1984) as a base, permits us appreciate the existing differences between the values obtained directly using Schwiderski's maps (column I) or using these maps for the near zones,

FIGURE 32

Amplitude (cm)

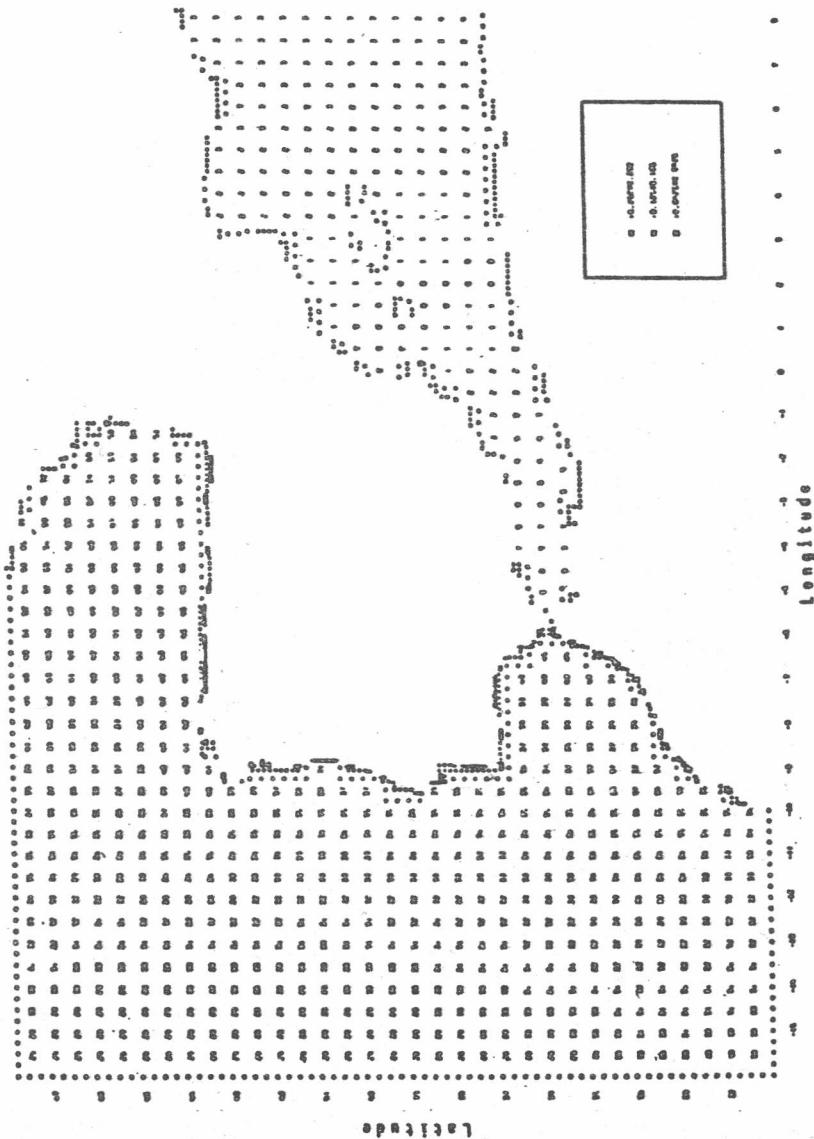


FIG. 1

I O F E R I A S₂
Phase (degrees)

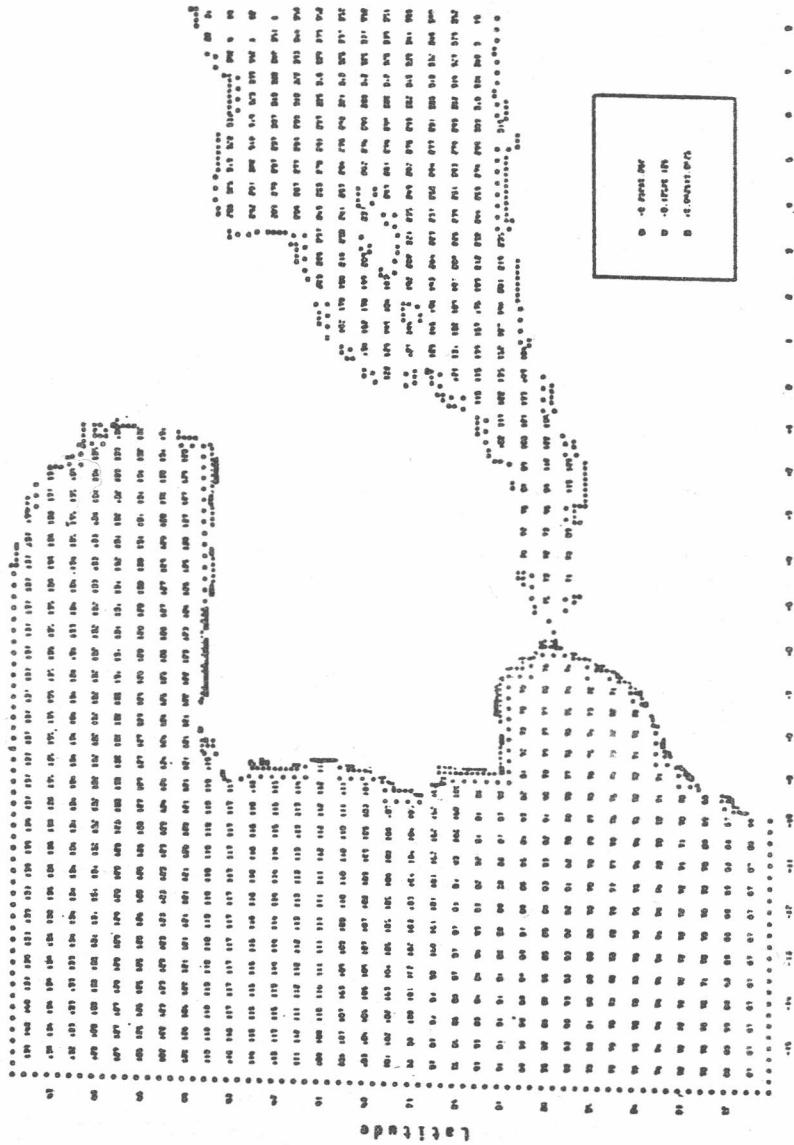


FIG. 2
Longitude

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Ampistudo (dB) 0.5 0.9 1.1 1.0 1.0 0 -1.9 -1.7 -1.0 -0.6 -0.5

Longitude

- 702 -

Longitude

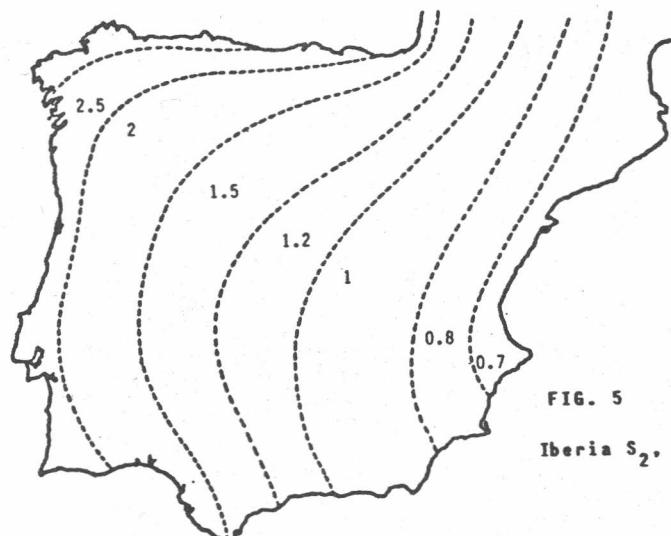


FIG. 5
Iberia S_2 , Amplitude(μg)

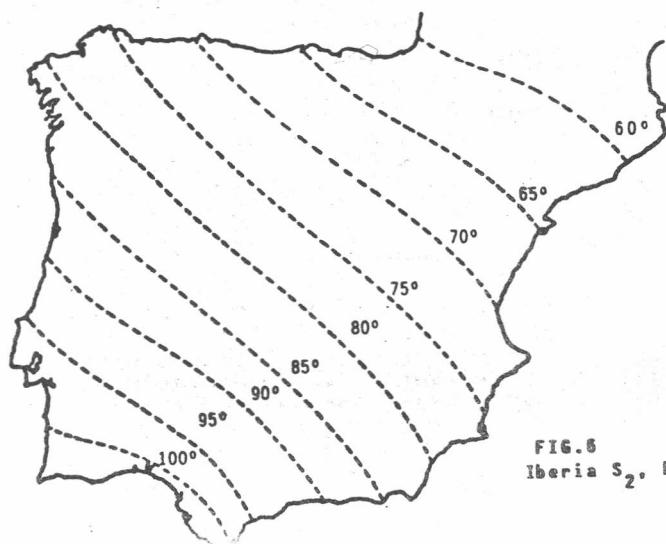


FIG. 6
Iberia S_2 , Phase(Degree)

	I	II	III	IV	V	VI
VALLE	L 1.508	1.134	0.376	1.123	0.012	1.606
	A 76.63	76.57	68.77	76.36	66.00	76.45
MADRID	L 1.470	1.060	0.362	1.056	0.010	1.410
	A 76.64	76.02	68.24	75.99	70.26	74.00
GRANADA	L 1.221	0.889	0.3315	0.977	2.101	1.308
	A 64.51	64.81	63.78	67.94	-63.36	66.87
SANTANDER	L 3.170	3.069	0.130	2.302	0.688	2.485
	A 63.03	65.30	21.26	64.37	68.00	62.18
BURGOS	L 1.040	1.559	0.307	1.453	0.107	1.044
	A 66.73	60.15	57.18	66.52	77.70	66.00
S. FERNANDEZ	L 2.300	2.113	0.197	1.962	0.217	2.146
	A 68.09	69.41	63.30	103.54	59.14	102.61
SEPULVEDA	L 1.576	1.203	0.367	1.172	0.031	1.534
	A 70.00	73.10	63.23	72.01	67.52	70.53
ARCAS	L 1.101	0.872	0.321	0.868	0.006	1.106
	A 70.87	73.16	64.64	73.44	31.76	71.07
CORUÑA	L 1.093	1.457	0.440	1.440	0.295	1.005
	A 76.00	70.02	69.20	70.01	150.10	75.16
TOLEDO	L 1.395	1.031	0.365	1.032	0.005	1.396
	A 77.25	70.75	73.01	70.01	-23.18	77.44
SANTIAZO	L 3.109	2.532	0.505	2.673	0.128	3.054
	A 66.31	62.20	72.00	79.50	163.01	78.18
CARBONERO	L 1.600	1.216	0.367	1.195	0.023	1.576
	A 73.11	75.23	66.44	74.70	68.50	72.75
C. REAL	L 1.323	0.973	0.351	0.900	0.022	1.330
	A 60.02	61.17	70.83	62.00	-54.63	60.00
LA CORUÑA	L 1.529	1.155	0.376	1.130	0.010	1.511
	A 73.17	75.26	66.74	74.97	63.00	72.03
BARCELONA	L 0.901	0.645	0.265	0.604	0.064	0.861
	A 66.05	61.21	43.30	50.72	61.00	54.76
PAMPLONA	L 1.744	1.400	0.356	1.330	0.003	1.686
	A 60.07	63.16	47.76	62.47	77.00	59.41
CALATAYUD	L 1.289	0.981	0.315	0.954	0.020	1.262
	A 64.00	68.05	53.70	67.06	74.01	66.30
PLASENCIA	L 1.710	1.308	0.411	1.317	0.014	1.727
	A 63.27	66.67	79.45	63.00	-146.43	62.00

Table 1

- I. General results of the SchneiderSKI S_2 map.
- II. Results of the SchneiderSKI S_2 map for the zone included in the Iberia S_2 map.
- III. Effects calculated from the SchneiderSKI S_2 map eliminating the zone included in the Iberia S_2 map.
- IV. Effects calculated from Iberia S_2 .
- V. Difference between the results of the Iberia S_2 and SchneiderSKI S_2 maps in the same zone (difference between the columns IV and III).
- VI. Results on substituting the Iberia S_2 map in the SchneiderSKI S_2 map (sum of the columns III and IV).

complemented with the Iberia S_2 maps (column V). Certainly the differences for S_2 (column IV) are only about tenths of microgal, what shows the quality of Schwiderski's work, although in the present state of the gravimetric precision in tide investigation, these values begin to be significant. In this table, other partial values from Schwiderski S_2 and Iberia S_2 maps are given.

The Iberia S_2 map will be followed by the rest of the components drawn up by Schwiderski. Those maps will be improved depending on the new data of the harmonic constants.

These researches are developed in the I.A.C. (C.S.I.C.-U.C.M.) whit grants given by the Comisión Asesora de Investigación Científica y técnica.

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