Ocean Effects on Gravity Tides in the Iberian Peninsula

R. VIEIRA, C. TORO and P.K. SUKHWANI, Madrid

with 1 figure and 4 tables

Vieira, T., Toro, C., & Sukhwani, P.K., 1983: Ocean effects on Gravity Tides in the Iberian Peninsula. Proceedings of the Ninth International Symposium on Earth Tides, pp. 431-436.

Abstract: As a continuation of our research presented at the 8th International Symposium on Earth Tides in Bonn, we have completed a total of 14 stations of the vertical component in Spain.

The strong ocean influence in these data makes them a good test for the different maps of oceanic tides. Starting from the maps of Schwiderski, Hendershott, Parke and Zahel, the effects of the ocean tides have been computed for our gravimetric stations.

We have prepared maps for the neighborhood of the Iberian peninsula, including the Alboran and Balearic seas, using results from hydrography and pelagic observations. The new maps, digitized with a grid of $0^{\circ}.5 \times 0^{\circ}.5$, have been computed for the Spanish stations, and they have been completed simultaneously for the mentioned maps.

Keywords: gravity tides, ocean maps, Spain.

1. Gravity tide observations

Observations have been made in 14 stations of earth tides in Spain (see Figure 1). With the exception of Madrid and Valle de los Caídos, the time series are four to six months long. The characteristics of these stations are shown in Table 1, and Table 2 shows the results for the main components, diurnal and semidiurnal.

2. Ocean effects

Because of the strong semidiurnal character of the ocean data in the latitude, where the stations are located, we have studied the ocean effect mainly of the wave M_2.

Table 3 shows the values of the observed and calculated loading and attraction effects for Schwiderski, Hendershott, Parke, Zahel and the Iberian maps. We can observe that the best fit is undoubtedly given by Schwiderski's map. Except for the stations very near the sea, the differences between observed values and those computed for Schwiderski's map are smaller than 1μg.

The strong influence of the Gulf of Biscay causes, as we foresaw, a decreasing phase difference in the profile towards the center of the peninsula. The same effect is observed in the amplitudes and phases of the residuals. Because of this strong influence, we have prepared a map for the Iberian M_2 wave which includes the zone between the parallels 32°N and 47°N and meridians 8°E and 15°W, digitized with a grid of $0^{\circ}.5 \times 0^{\circ}.5$. We plan to improve it with a better study of the results and errors of the hydrographic observations.

Table 1. Stations of the Iberian Tidal Gravity Profiles

Nº	NAME	λ (W)		φ		h	d	N	INST.
0401	VALLE	4	05	40	23	1280	350	1200	*
0402	MADRID	4	16	40	16	630	310	500	**
0403	GRANADA	3	22	37	07	774	50	140	L301
0404	SANTANDER	3	49	43	27	25	0	132	L434
0405	BURGOS	3	43	42	21	850	120	166	A212
0406	S.FERNANDO	6	15	36	28	25	0	90	L434
0407	SEPULVEDA	3	44	41	18	1040	240	160	A212
0408	ARCAS	2	08	40	00	990	170	180	L434
0409	CUBILLOS	5	44	41	34	667	220	120	L301
0410	TOLEDO	4	02	39	52	512	320	130	L301
0411	SANTIAGO	8	33	42	52	250	40	170	L301
0412	CARBONERO	4	16	41	07	920	315	90	L434
0413	C.REAL	3	56	38	59	600	250	160	L301
0414	S.ILDEFONSO	4	00	40	54	1191	280	80	L301
0480	PORTO ***	8	40	41	05	50	0	---	L258

* A212,L434,L301,ET15

** A212,L434

*** GROTEN 1978

d : aproximate distance to the nearest see.

N : nº of days of recording.

Table 2 DIURNAL AND SEMIURNAL WAVES

	N	$\delta(O_1)$	$\delta(P_1S_1K_1)$	$\alpha(O_1)$	$\alpha(P_1S_1K_1)$	INSTR.
S.FERNANDO	1676	1.1510	1.1518	-0.11	0.43	L.434
GRANADA	2880	1.1630	1.1584	-0.41	0.18	L.301
C.REAL	3600	1.1446	1.1509	-0.45	0.64	L.301
TOLEDO	2592	1.1635	1.1650	-0.35	0.97	L.301
ARCAS	2976	1.1503	1.1272	-0.48	4.81	L.434
MADRID	7200	1.1540	1.1520	-0.40	0.30	*
VALLE	12000	1.1520	1.1420	-0.20	0.44	**
CARBONERO	2016	1.1526	1.1383	-0.45	0.47	L.434
SEPULVEDA	2976	1.1563	1.1124	-0.61	0.30	A.212
CUBILLOS	2640	1.1452	1.1438	-0.38	0.49	L.301
BURGOS	3696	1.1543	1.1676	-0.70	1.12	A.212
SANTIAGO	3456	1.1733	1.1656	-1.01	0.61	L.301
SANTANDER	2784	1.1610	1.1661	-0.45	1.14	L.434

* A212,L434.

** A212,L301,L434,ET15.

	$\delta(N_2)$	$\delta(M_2)$	$\delta(S_2K_2)$	$\alpha(N_2)$	$\alpha(M_2)$	$\alpha(S_2K_2)$	INSTR.
S.FERNANDO	1.0612	1.1058	1.1692	3.67	6.26	5.48	L.434
GRANADA	1.1015	1.1588	1.2044	3.13	3.58	2.64	L.301
C.REAL	1.1146	1.1499	1.1880	2.95	3.19	2.42	L.301
TOLEDO	1.1281	1.1593	1.2106	1.77	3.75	2.02	L.301
ARCAS	1.1184	1.1563	1.1944	4.06	3.91	4.52	L.434
MADRID	1.1160	1.1530	1.1820	5.55	4.50	2.85	*
VALLE	1.1190	1.1509	1.1870	5.40	5.10	3.50	**
CARBONERO	1.0906	1.1554	1.1922	6.28	5.07	2.46	L.434
SEPULVEDA	1.1270	1.1725	1.2117	2.23	4.10	1.50	A.212
CUBILLOS	1.1084	1.1461	1.2018	7.20	6.50	4.72	L.301
BURGOS	1.1379	1.1840	1.3035	6.55	6.38	3.52	A.212
SANTIAGO	1.0701	1.1435	1.2414	11.93	11.31	7.64	L.301
SANTANDER	1.1102	1.2048	1.2841	15.25	12.17	6.13	L.434

* A212,L434

** A212,L301,L434,ET15

Table 3. Observed and calculated loading and attraction effects residues with respect to Molodensky I.

TIDAL WAVE M_2	Observed load		SCHWIDERSKY		HENDERSCHOTT		PARKE		ZAHEL(4X4)		IBERIAM M_2	
	B	β	L	λ	L	λ	L	λ	L	λ	L	λ
S.FERNANDO	6.5	117	6.4	121	8.2	117	11.2	119	4.9	138	4.5	129
GRANADA	3.4	93	3.4	108	6.2	106	8.8	109	3.7	120	2.8	117
C.REAL	3.0	101	3.7	105	8.4	106	11.3	108	3.9	119	2.7	108
TOLEDO	3.4	93	3.9	103	7.9	102	10.8	105	4.1	118	2.8	110
ARCAS	3.5	95	3.4	97	5.1	109	7.4	98	3.6	110	2.4	105
MADRID	4.0	99	4.0	100	7.1	98	9.7	102	4.1	116	2.8	107
VALLE	4.5	97	4.3	101	7.8	99	10.6	102	4.2	118	3.0	108
CARBONERO	4.3	95	4.6	100	8.1	97	10.9	101	4.3	117	3.2	106
SEPULVEDA	3.6	84	4.3	98	7.5	94	10.2	99	4.3	115	3.2	104
CUBILLOS	5.5	99	5.4	103	11.0	99	14.3	102	5.0	123	3.8	108
BURGOS	5.4	83	5.5	95	8.8	91	11.6	95	4.5	113	4.0	100
SANTIAGO	9.2	100	9.1	108	11.3	101	14.5	104	7.7	133	6.6	113
SANTANDER	10.1	86	8.7	94	9.8	89	12.7	93	4.9	112	6.9	95

Table 4. Trans Iberian tidal gravity profile observed and calculated loading and attraction effects residues with respect to Molodenski model I.

	B	β	L_s	λ_s	X_s	χ_s	L_I	λ_I	X_I	χ_I	L_s-L_I	$\lambda_s-\lambda_I$
S.FERNANDO	6.56	117	6.40	121	0.48	48	4.49	129	2.38	92	2.06	80
GRANADA	3.45	93	3.40	108	0.90	13	2.77	117	1.48	42	0.80	75
C.REAL	2.95	101	3.73	105	0.81	-60	2.66	108	0.45	54	1.08	97
TOLEDO	3.35	93	3.96	103	0.88	-35	2.76	110	1.07	44	1.27	87
ARCAS	3.49	95	3.45	97	0.13	24	2.44	105	1.17	73	1.09	71
MADRID	4.00	99	4.05	100	0.09	-25	2.82	107	1.28	80	1.30	85
VALLE	4.44	97	4.31	101	0.33	32	2.99	108	1.60	76	1.39	86
S.ILDEFONSO	4.08	98	4.35	100	0.25	-39	3.10	106	1.10	75	1.31	86
CARBONERO	4.35	95	4.57	100	0.45	-31	3.19	106	1.36	68	1.44	87
SEPULVEDA	3.58	84	4.52	98	1.36	-42	3.17	104	1.25	23	1.41	84
CUBILLOS	5.53	99	5.39	103	0.41	31	3.80	108	2.04	69	1.64	91
BURGOS	5.44	83	5.51	96	1.24	-3	4.02	100	1.98	47	1.52	85
SANTIAGO	9.18	100	9.10	108	1.28	17	6.61	113	3.09	72	2.58	95
SANTANDER	10.07	86	8.70	94	1.89	46	6.92	95	3.45	66	1.78	90
PORTO*	5.10	110	7.57	114	2.51	-57	5.00	118	0.71	32	2.60	106

(B, β) OBSERVED

(L_s, λ_s) CALCULATED SCHWIDERSKI MAP M_2

(L_i, λ_i) CALCULATED IBERIAN MAP

$(X_s, \chi_s) = (B, \beta) - (L_s, \lambda_s)$

$(X_i, \chi_i) = (B, \beta) - (L_i\ \lambda_i)$

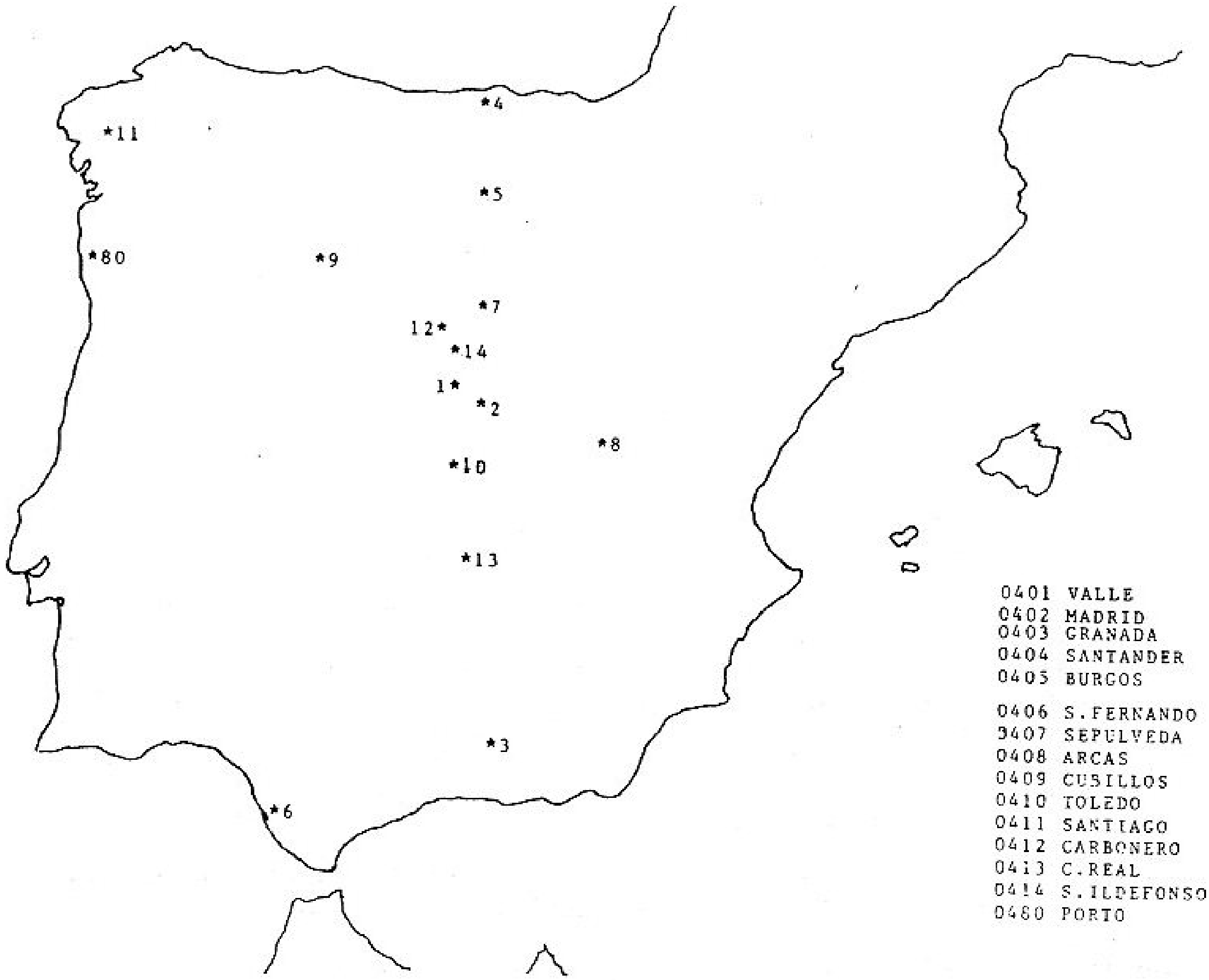

Figure 1. Stations

ACKNOWLEDGEMENTS

We want to express our gratitude to the International Centre for Earth Tides for its collaboration. Calculation programs given by the ICET have been used.

This research is being conducted at the Department of Mechanics and Astronomy of the C.S.I.C. and the Department of Astronomy and Geodesy of Complutense University, with support of both Centers and with subvention given for this purpose by the Assesory Commission of Scientific and Technical Investigation of the Presidency of the Government.

REFERENCES

Baker, T.F., 1980. Tidal gravity in Britain: tidal loading and the spatial distribution of the marine tide. Geophys. J., R.

Astron. Soc., 62: 249-267.
Chiaruttini, C., 1976. Tidal load on the Italian peninsula, Geophys. J., R. Astron. Soc., 46: 773-793.
Ducarme, B., 1975. Fundamental station for trans-world tidal gravity profiles. Phys. Earth Planet. Inter. 11: 119-127.
Ducarme, B. & Kääriäinen , J., 1980. The Finnish tidal gravity registrations in Fennoscandia, Publ. Finn. Geod. Inst. 90: 1-43.
Ducarme, B. & Melchior, P., 1978. A trans-world tidal gravity profile. Phys. Earth Planet. Inter., 16: 257-276.
Gerstenecker, C. & Groten, E., 1976. Messung der vertikalen Erdgezeiten-Komponente in Mitteleuropa. Beiträge zur Gravimetrischen Geodäsie and Gezeitenforschung. Deutsch. Geod. Kom. B. 117.
Hendershott, M.C., 1973. Ocean Tides EOS Trans. Am. Geophys. Union, 54: 76-96.
Melchior, P., 1978. The tides of the Planet Earth, pp. 609. Pergamon Press, Oxford.
Melchior, P. & Ducarme, B., 1980. Tidal Gravity Profiles 1973-1980. Bull. Obs. R. Belg., 4: fasc. 5.
Melchior, P., Kuo, J.T. & Ducarme, B., 1976. Earth tide gravity maps for Western Europe. Phys. Earth Planet. Inter., 13: 184-196.
Melchior, P., Moens, M., Ducarme, B. & VanRuymbeke, M., 1981. Tidal loading along a profile Europe East Africa-South Asia-Australia and the Pacific Ocean. Phys. Earth Plane. Inter., 25: 71-106.
Parke, M.E. & Hendershott, M.C., 1979. M_2, S_2, K_1 models of the global ocean tide on an elastic Earth, Mar. Geod., 3: 379-408.
Schwiderski, E.W., 1979. Global ocean tides, Part II: The semidiurnal principal lunar tide (M_2), atlas of tidal charts and maps. Naval Surface Weapons Center, Dahlgren Laboratory TR 79, 414, Dahlgren. V.A.
Schwiderski, E.W., 1980. Ocean tides, Part I: Global ocean tidal equations. Part II: A hydrodynamical interpolation model, Mar. Geod., 3: 161-255.
Souriau, M., 1979. Spatial analysis of tilt and gravity observations of Earth tides in western Europe, Geophys. J., R. Astron. Soc., 57: 585-608.
Vieira, R., 1979. Influencia de la marea oceánica sobre la marea de la tierra sólida. R. Acad. Ciencias. Madrid, Vol. LXXIII. Cuad. 1: 102-105.
Wahr, J.H.N., 1981. Body tides on an elliptical, rotating, elastic and oceanless Earth, Geophys. J., R. Astron. Soc., 64: 677-703.
Zahel, W., 1977. A global hydrodynamic numerical model of the ocean tide, the oscillation system of the M_2 tide and its distribution of energy dissipation, Ann. Geophys., 33: 24-31.

Vieira, R.
Departamento De Mechanica y Astronomia
Ciudad Universitaria
Madrid 3, Spain

Toro, C., Sukhwani, P. K.
Departamento De Mecanica y Astronomia C.S.I.C.
Catedra De Astronomia y Geodesia
Facultad De Ciencas Matematicas
Universidad Complutense
Madrid, Spain