BARBADOS WORKSHOP

TIDAL ANALYSIS AND PREDICTION

SILVIA COSTA

It has been observed that the tide can be synthesized through the superposition of a series of simple waves. These waves have periods that can be grouped into five basic types:

- The **periods of the Moon's orbit** around the Earth and the Earth's orbit around the **Sun** (waves M2 and S2).
- The periods of waves that allow us to emulate the **effects of elliptical orbits** (L2, N2, R2, and T2) and the declinations of the Moon and Sun (K1, O1, and P1).
- The periods of **long period waves** (Mfm, Mf, Msf, Mm, MSm, Ssa, and Sa, among others).
- The **periods of waves that simulate the effects of deformation** due to wave velocity and friction, corresponding to double and triple frequencies of the basic ones.
- The periods of waves that simulate the **non-linear interactions** of the previous waves (MNS2, 2MS2, 2SM2, MK3, 2MK3, SK3, SO3, MS4, MN4, MK4, 2MS6, 2MN6, 2SM6, MSN6, 3MS8, 2MSN8, etc.)

$$\eta(\tau) = a_0 + \sum_{n=1}^{k} a_0 * \cos(\omega_n t + \alpha_n)$$

Tide height at an instant t

Mean level amplitude

Amplitude of the constant

Angular frequency of the constant. KNOWN VALUE

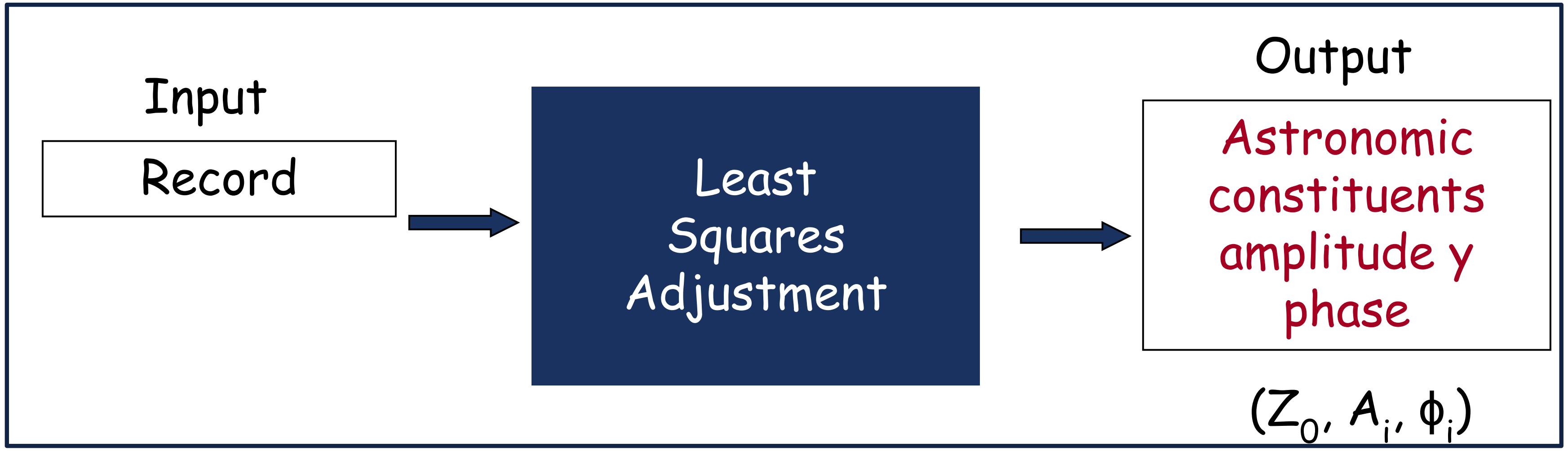
Constant phase

HARMONIC ANALYSIS

The harmonic analysis of observed tidal data enables:

- Establishing the basis for **predicting** the tide at a future instant.
- Explaining the **behavior** of the tide in a specific area through a **few variables that contain the fundamental essence of the phenomenon**.
- Interpreting the analysis results in terms of the **hydrodynamics** of the studied area (and its response to the tidal generating force).

The foundation of harmonic analysis is the assumption that the **tidal variations** at a given point can be represented as the **sum of a finite number of harmonic terms**, due to the fact that the **angular velocity of these harmonics is known a priori**.

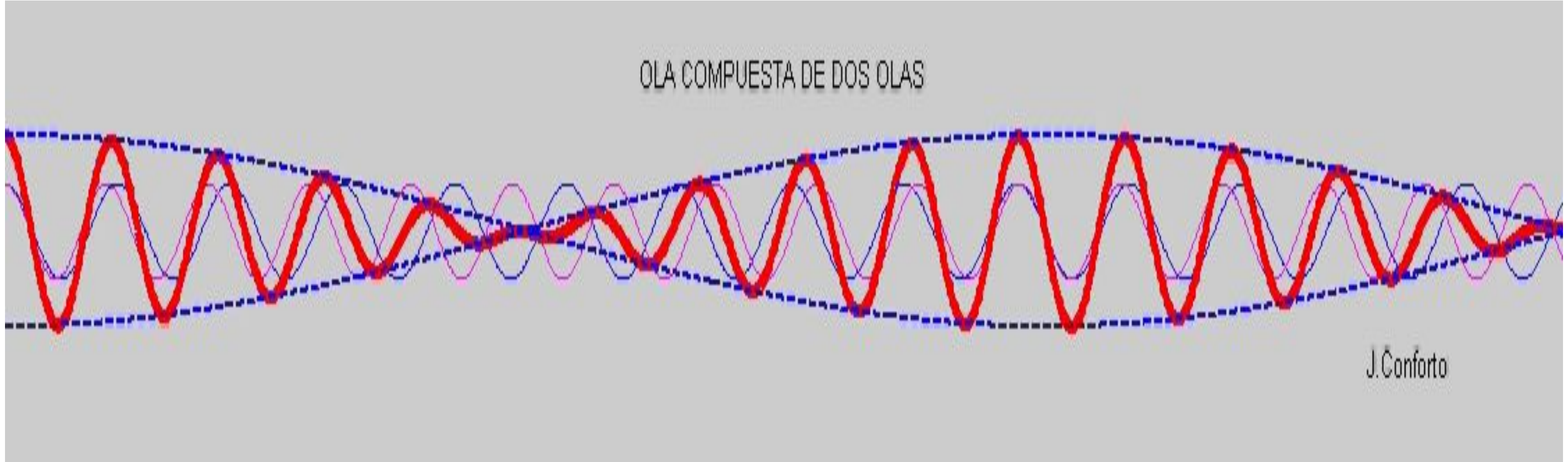


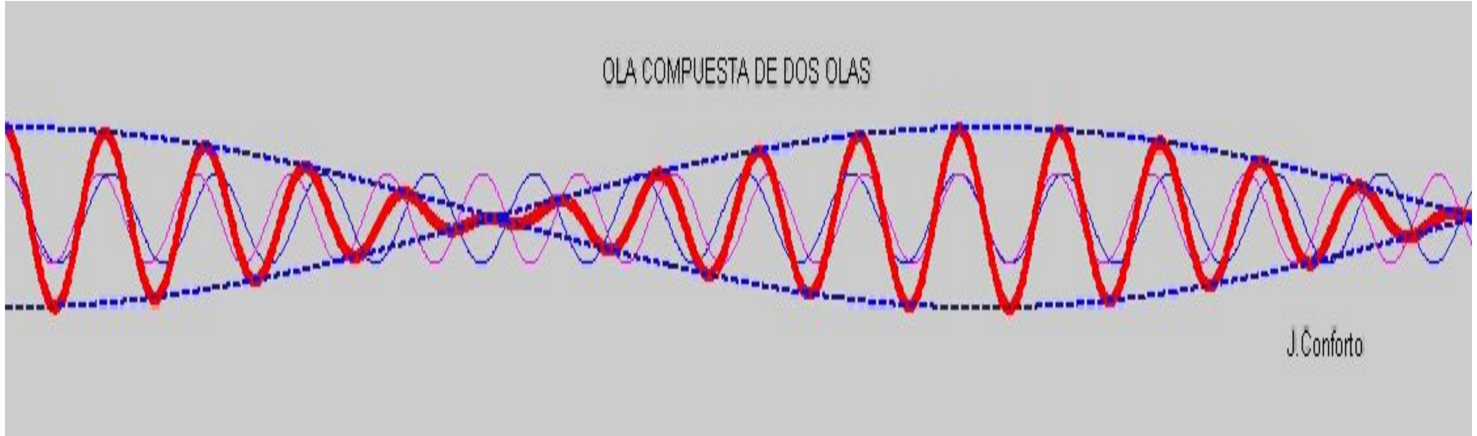
The length of the data record will determine the extent to which we can extract more or fewer waves from it. Typically, the so-called **Rayleigh Criterion** is used in the analysis of tide records. This criterion allows us to **a priori determine which waves we will be able to extract from a data record of a given duration**.

To study the problem, we can consider a pair of components with frequencies close to $\omega 1$ and $\omega 2$, and similar amplitudes.

The resulting combination of two waves with nearby periods and similar amplitudes forms a group oscillating with a period intermediate between the two, and an amplitude modulated by an envelope with a longer period.

The **amplitude** of this system exhibits **maxima** when the two constituent waves are **in phase**, and nodes when they are in phase opposition.




OLA COMPUESTA DE DOS OLAS
J.Conforto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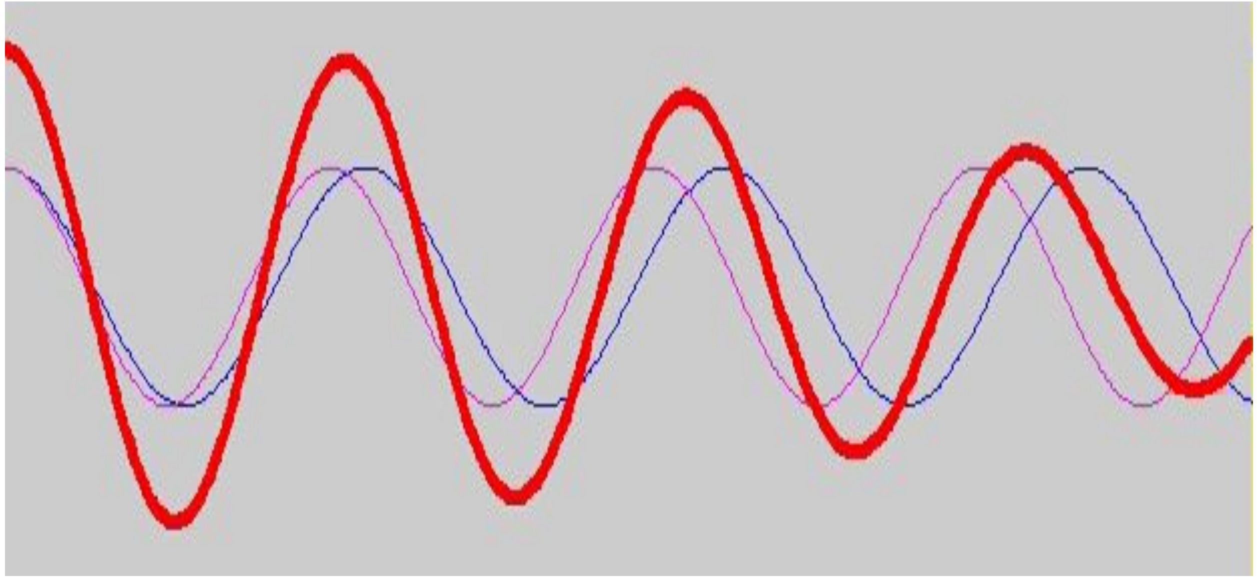
J.Conforto

The envelope period is also known as the **Synodic Period**:

TS = 2p/(w1 - w2)

If we want to analyze the data record and be able to distinguish that both waves *w1* and *w2* are present, it will be necessary to have **observed the complete cycle of the envelope** they produce.



Therefore, to separate these two components, it is necessary to have at least one record covering the duration of a synodic period.

For example, to separate the **M2** and **S2** components, the minimum required recording period is:

$$T = \frac{2\pi}{\Omega_{S2} - \Omega_{M2}} = \frac{360º}{30.00º/hr - 28.982º/hr} = 14.7\ days$$

Therefore, in this case, a recording period of approximately 15 days is necessary.

	P1	K1	O1	Q1
P1	-	182.6	14.8	9.6
K1		-	13.7	9.1
O1			-	27.6

	S2	K2	M2	N2	L2	2MS
S2	-	182.6	14.8	9.6	31.7	7.4
K2		-	13.7	9.1	27.1	7.1
M2			-	27.6	27.6	14.8
N2				-	13.8	9.6
L2					-	9.6

There are many component combinations with synodic periods TS of approximately 29×n days (n=1,2,3, ...).

Therefore, 29 days is generally considered the minimum necessary period to perform an adequate tide analysis.

Likewise, 369 days is also approximately a multiple of most synodic periods; thus, for more detailed prediction, a recording period of 369 days (1 year + 4 days) is usually considered.

In Spain, the tide is represented by **69 harmonic constants.**

When the tidal wave exhibits refractions, resonances, and other propagation issues, it will be necessary to increase the number of harmonic constants.

The best approximation of the prediction series to the measured record from the tide gauge is calculated using the **LEAST SQUARES FITTING METHOD**. This method consists of minimizing the squares of the differences between the calculated value (formula) and the measured value (tide gauge record) at each instant.
We define:

$\eta(\tau)$ as the calculated value at a given instant t.

η_τ as the measured value (tide gauge record) corresponding to that same instant.

The difference $[\eta(\tau) - \eta_\tau]$ between these two values represents the error made when trying to reproduce the tide measured by the tide gauge with our numerical prediction. This difference can be positive or negative. To simplify the subsequent calculations, this difference is squared so that the result is always positive. What we aim to **minimize is the total accumulated error**, that is, the sum of the squares of these differences, ideally reaching zero.

$$\eta(\tau) = a_0 + \sum_{n=1}^{k} a_n \cos(\omega_n t + \alpha_n)$$

$$\mu^2 = \sum_{\tau=-p}^{\tau=p} \left[\eta(\tau) - \eta_\tau\right]^2 = 0$$

LET'S GO TO DO THE PREDICTIONS

https://www.po.gso.uri.edu/~codiga/utide/utide.htm

Based on Foreman´s equation

uTide

Unified Tidal Analysis and Prediction
Using the "UTide" Matlab Functions

September 2011

- Designed specifically to handle record times that are irregularly distributed and/or gappy.
- Suitable for multi-year analyses: accurate nodal/satellite corrections are not limited to record lengths shorter than 1-2 years.
- Can provide easy-to-use and comprehensive diagnostics to aid the constituent selection process.
- Handles sea level (amplitude and phase), or currents (current ellipse parameters), with similar syntax.
- Generates confidence intervals based on spectra (FFT for regular times, Lomb-Scargle for irregular times) of the residuals between the raw input and the harmonic fit.
- Incorporates the robust L1/L2 solution method to minimize influence of outliers.
- Enables analysis of groups of time sequences (such as records from an array of instruments, or from a group of model gridpoints) with one m-function call.
- Builds on, and integrates in to a common framework, the t_tide (Pawlowicz et al 2002), r_t_tide (Leffler and Jay 2009), and "versatile" (Foreman et al 2009) approaches.
- Flexible interface with mix-and-match choices of analysis configurations accessible by arguments to m-functions.


MAREAS
IMPORTAR DATOS
PROCESAR DATOS
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PREDICCIONES
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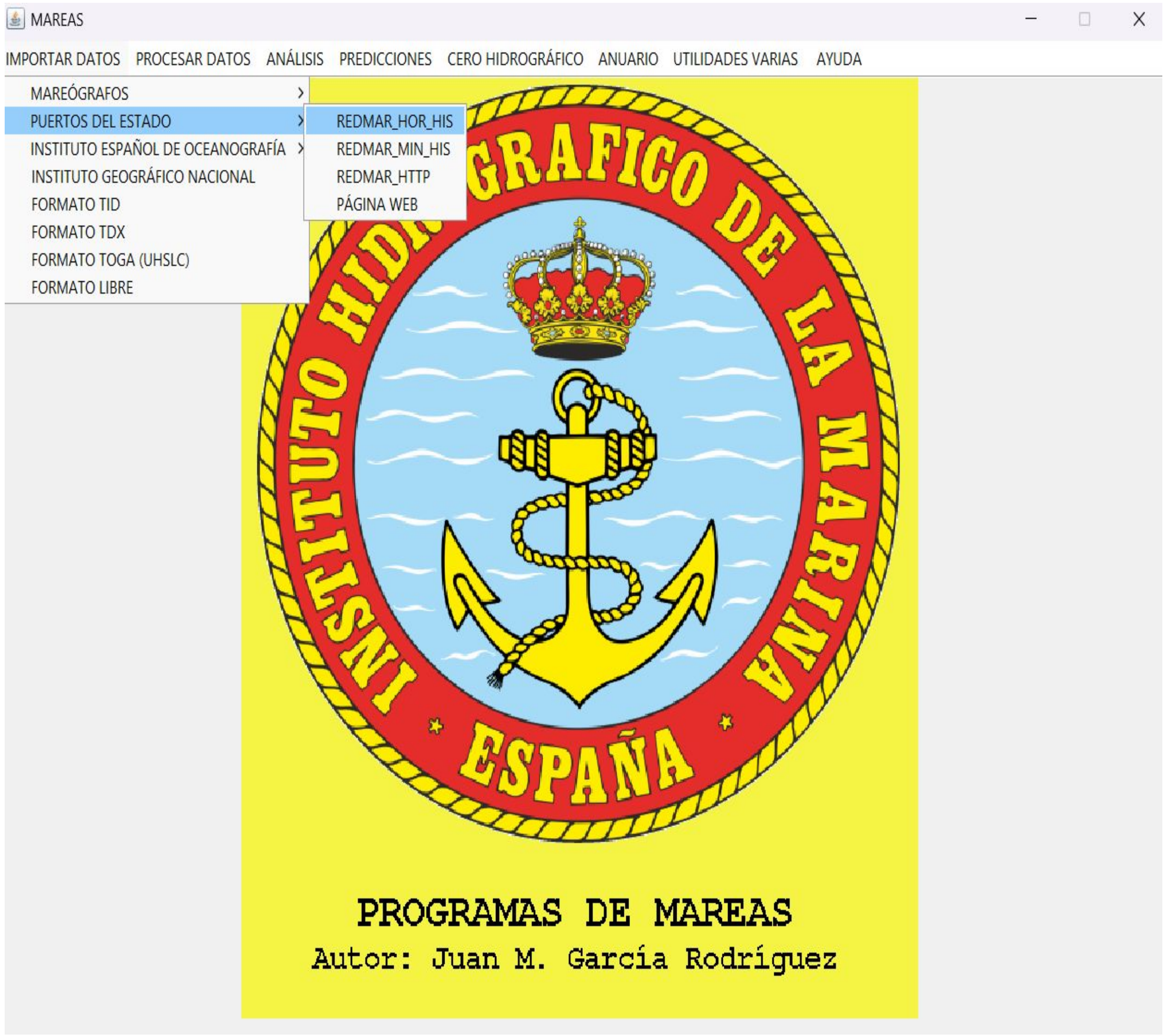
ANUARIO
UTILIDADES VARIAS
AYUDA
INSTITUTO HIDROGRAFICO DE LA MARINA
ESPAÑA
PROGRAMAS DE MAREAS
Autor: Juan M. García Rodríguez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PUERTOS DEL ESTADO
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UNIR y RELLENAR ARCHIVOS con FORMATO IHM
REFERENCIA VERTICAL DE LOS DATOS
ELIMINAR VALORES ANÓMALOS
INTERPOLAR HUECOS MENORES DE 2 HORAS
LOCALIZAR RESIDUOS ANÓMALOS
INTERPOLAR DATOS a MINUTOS EXACTOS
FILTRADO de DATOS del NIVEL del MAR
SEGREGAR los DATOS por AÑOS
ANÁLISIS ESPECTRAL (PERIODOGRAMA)
CALCULAR MAREAS MÁXIMA, MÍNIMA Y RANGO DE MAREA
FILTRAR (ELIMINAR) la SEÑAL de MAREA
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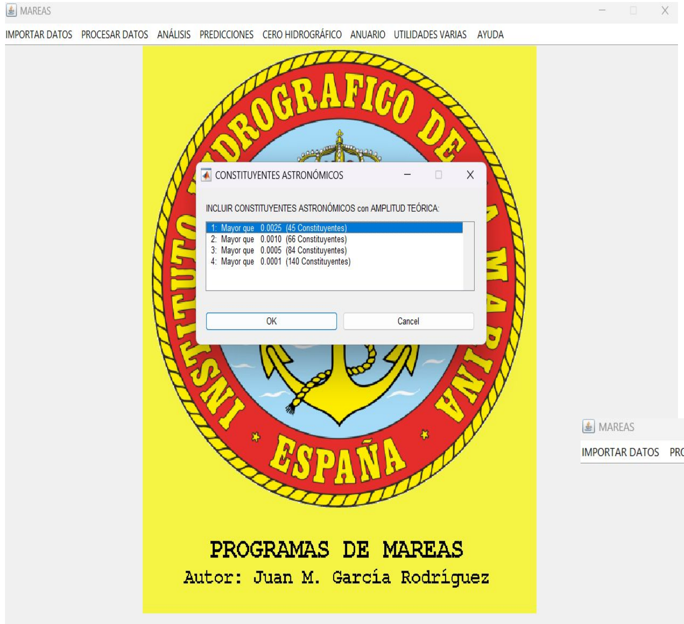
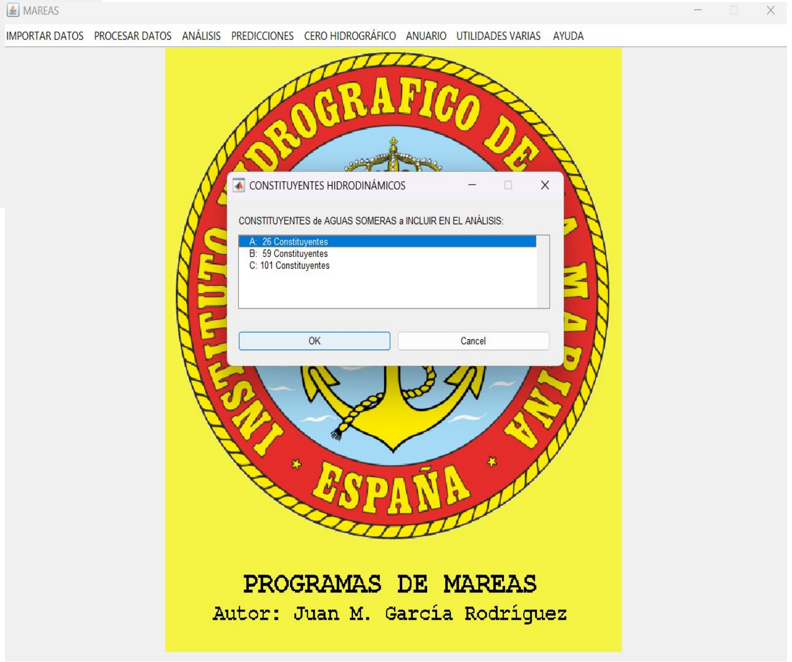
Option 1:
This option includes all the main Harmonic Constituents of astronomical origin, both diurnal and semidiurnal, whose theoretical amplitudes are greater than 0.0025 (Total: 45 HCs).



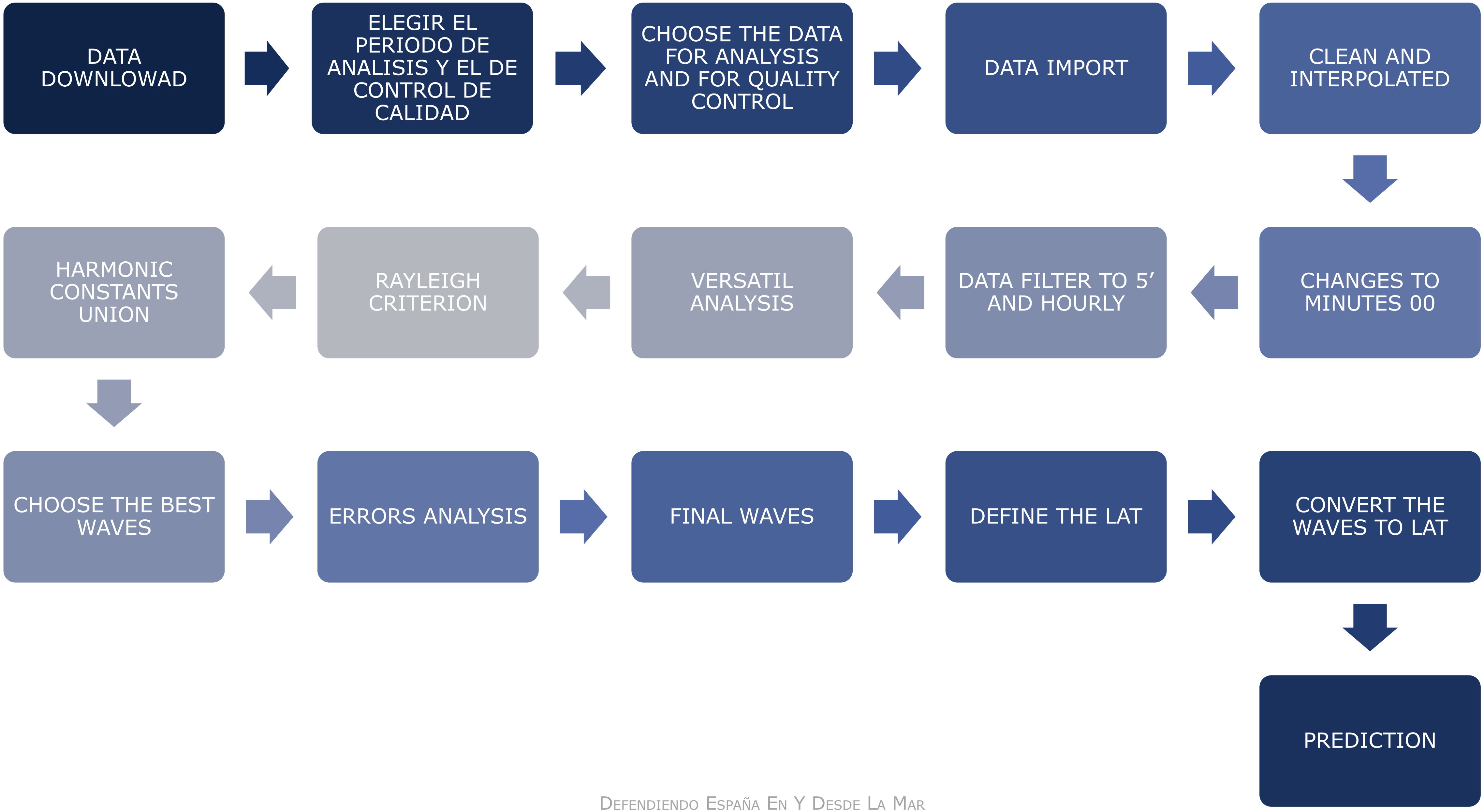
Option A:
Includes the 24 hydrodynamic origin constituents (from shallow waters), initially the most important, total: 26 CA.



1A	02/11/2025 20:28	Dos
1C	02/11/2025 20:38	Dos
4A	02/11/2025 20:44	Dos
CAS	02/11/2025 20:43	Dos
contador	02/11/2025 20:44	Doc
Mohamed	20/10/2025 10:10	Fich
Mohamed.05m	02/11/2025 19:52	Fich
Mohamed.60m	02/11/2025 19:52	Fich
Mohamed-EVA.05m	02/11/2025 18:32	Fich
Mohamed-raw.05m	02/11/2025 17:44	Fich
MohamedResumenAnalisis	02/11/2025 20:46	Feu
NMO-Mohamed-EVA.fig	02/11/2025 18:33	Fich
NMO-Mohamed-raw.fig	02/11/2025 17:45	Fich

DATOS	1A	1C	4A	CAS
Fecha inicio	01:00 H, 01/01/2017	01:00 H, 01/01/2017	01:00 H, 01/01/2017	01:00 H, 01/01/2017
Fecha fin	23:00 H, 09/05/2018	23:00 H, 09/05/2018	23:00 H, 09/05/2018	23:00 H, 09/05/2018
NDP	11855	11855	11855	11855
NDV	11813	11813	11813	11813
PDV	99,65	99,65	99,65	99,65
VMD	0,3327	0,3327	0,3327	0,3327
DTD	0,1042	0,1042	0,1042	0,1042
ANÁLISIS	1A	1C	4A	41CAS
Ray	1	1	1	
NCA	71	142	161	41
NCS	17	17	42	41
NCOND	1,7427	2,1201	2,6923	1,3797
VR	0,0072	0,0073	0,0059	0,0058
CDC	0,334569	0,326778	0,454671	0,462735
AIC	-4,917489933	-4,894049617	-5,101604329	-5,136463268
SBIC	-4,829439	-4,717322	-4,901147	-5,085881
RESIDUOS (cm)				
Máximo	41,74	41,54	35,7	35,17
Mínimo	-23,14	-23,16	-23,73	-23,95
Medio	-5,07915E-06	-7,61873E-06	-1,7777E-05	-3,2168E-05
DT	8,45	8,45	7,59	7,62
|RESIDUOS| (cm)				
Medio	6,45	6,45	5,67	5,7
DT	5,46	5,46	5,05	5,05
CH y Z0				
Z0 (ref. CM)	0,341	0,341	0,342	0,342
CH (ref. CM)	0,157	0,159	0,057	0,071

IHM | ARMADA


DATA DOWNLOWAD
ELEGIR EL PERIODO DE ANALISIS Y EL DE CONTROL DE CALIDAD
CHOOSE THE DATA FOR ANALYSIS AND FOR QUALITY CONTROL
DATA IMPORT
CLEAN AND INTERPOLATED
CHANGES TO MINUTES 00
DATA FILTER TO 5’ AND HOURLY
VERSATIL ANALYSIS
RAYLEIGH CRITERION
HARMONIC CONSTANTS UNION
CHOOSE THE BEST WAVES
ERRORS ANALYSIS
FINAL WAVES
DEFINE THE LAT
CONVERT THE WAVES TO LAT
PREDICTION

NOMBRE DE LA COMPONENTE	SÍMBOLO	VELOCIDAD	PERIODO	COEFTE.
Lunar Semidiurno Principal	M2	28.9841	12.42	1
Solar Semidiurno Principal	S2	30.00	12.00	0.466
Lunar Semidiurno Elíptico Mayor	N2	28.4397	12.66	0.192
Lunar-Solar Semidiurno	K2	30.0843	11.97	0.127
Solar Semidiurno Elíptico Mayor	T2	29.9589	12.01	0.027
Lunar Semidiurno Elíptico Menor	L2	29.5285	12.19	0.028
Solar Semidiurna Elíptico Menor	R2	30.0411	11.98	
Lunar-Solar Diurno Declinatoria	K1	15.0411	23.93	0.584
Lunar Diurno Principal	O1	13.9430	25.82	0.415
Solar Diurno Declinatoria Principal	P1	14.9589	24.07	0.194
Lunar Diurno Elíptico Mayor	Q1	13.3986	26.87	0.079
Lunar Diurno Elíptico Menor	M1	14.4967	24.84	0.033
Lunar Quincenal	Mf	1.098	327.9	0.172
Lunar Varacional Quincenal	Msf	1.0159	354.57	0.009
Lunar Mensual	Mm	0.544	661.3	0.091
Solar Semianual	Ssa	0.082	4383	0.080
Solar Anual	Sa	0.041	8780.5	0.013
…	…	…	…	…

Alicante1-1018-52CAS.twv: Bloc de notas

Archivo Edición Formato Ver Ayuda

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2 RESULTADOS DEL ANALISIS: AMPLITUDES, FASES, DT estimadas de AMP y FASE y valor t-test
2   0051  Alicante1-1018        GMT  38  20 -000 -29
 001 Z0        0.000000000  -1.15734      0.000     0.00029      0.000      0.000
 002 SA        0.000114074   0.07093    255.008     0.00041      0.339    172.760
 003 SSA       0.000228159   0.03051     64.018     0.00041      0.770     73.571
 004 X2        0.000342233   0.01534     31.332     0.00041      1.559     37.038
 005 X3        0.000456307   0.01563    343.705     0.00041      1.537     37.827
 006 X4        0.001195707   0.00212     40.614     0.00041     11.081      5.127
 007 MSM       0.001309781   0.00460     54.569     0.00041      5.107     11.102
 008 X5        0.001398078   0.00233     44.033     0.00041     10.082      5.616
 009 MM        0.001512152   0.00425     68.459     0.00041      5.527     10.241
 010 X6        0.001626226   0.00290    299.201     0.00042      8.148      6.998
 011 X7        0.001740311   0.00148    176.593     0.00041     15.872      3.575
 012 X9        0.002619562   0.00801     36.589     0.00041      2.933     19.348
 013 X10       0.002707859   0.00278    198.488     0.00041      8.450      6.718
```

Armónico	Frecuencia	Amplitud	Fase
Z0	0.000000	211.26	0.00
ALP1	0.034396	0.29	194.22
2Q1	0.035706	0.39	199.91
SIG1	0.035908	0.29	240.07
Q1	0.037218	1.81	256.34
RHO1	0.037420	0.34	260.45
O1	0.038730	6.36	320.62
NO1	0.040268	0.75	6.89
PI1	0.041438	0.37	50.88
P1	0.041552	2.17	54.56
S1	0.041666	0.90	249.66
K1	0.041780	7.20	62.91
PSI1	0.041894	0.21	77.86
PHI1	0.042008	0.09	72.27
OQ2	0.075974	0.35	355.74
EPS2	0.076177	0.92	1.51
2N2	0.077487	3.36	31.71
MU2	0.077689	3.89	33.33
N2	0.078999	23.41	59.31
NU2	0.079201	4.47	62.96
H1	0.080397	0.41	67.24
M2	0.080511	110.67	78.11
LDA2	0.081821	0.70	74.79
L2	0.082023	2.41	83.72
T2	0.083219	2.21	104.30
S2	0.083333	38.56	107.32
R2	0.083447	0.20	62.71
K2	0.083561	10.79	104.74
ETA2	0.085073	0.52	134.68
M3	0.120767	0.64	302.03
SK3	0.125114	0.21	26.19
MN4	0.159510	0.38	182.83
M4	0.161022	0.79	233.07
MS4	0.163844	0.45	296.25
2MK5	0.202803	0.05	15.40
2MN6	0.240022	0.20	76.88
M6	0.241534	0.31	117.95
2MK6	0.244584	0.06	169.54

TIDE YEARBOOK The locations of tide stations are organized in a hierarchy:

a. PERMANENT TIDE CONTROL STATIONS are generally those that have been operating and producing data for 19 years or more, expected to operate continuously in the future, and are used to obtain a continuous record of water levels at a site. Tide Control Stations are positioned to maintain datum control for national applications and are located wherever necessary to control the datum.

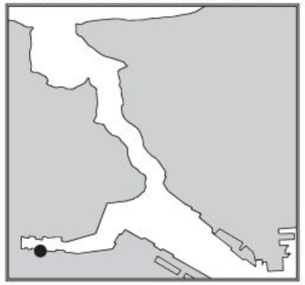
b. PRIMARY TIDE STATIONS are those that have been operating for less than 19 years but more than one year and have a limited service life. They provide more accurate tide data for parcels, bays, and estuaries where local tidal effects differ from the nearest control station.

c. SECONDARY TIDE STATIONS are those that have been operating for more than one month but less than one year. Short-term water level measurement stations can have their data reduced or adjusted to 19-year tide datums if simultaneous mathematical comparisons are made with a nearby control station.

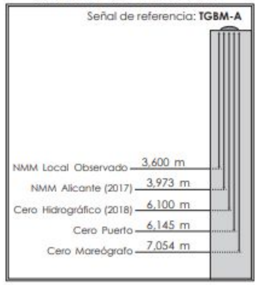
PASAIA - PASAJES

Puerto Principal

UBICACIÓN ESTACIÓN DE MAREAS



REFERENCIAS VERTICALES



MAREÓGRAFO

Tipo de instalación: Permanente

Propietario: Fundación AZTI-Tecnalia

Ubicación: Latitud 43° 19,2' N
Longitud 001° 55,5' W

CERO HIDROGRÁFICO

Año de cálculo: 2018

Periodo de datos empleados: Desde mayo de 2007 hasta mayo de 2018

Referencia terrestre (BM):
El cero hidrográfico se encuentra 6,100 metros por debajo del clavo de referencia "TGBM-A" del Puerto de Pasajes, situado en el muelle de Herrera, junto al edificio de la fundación AZTI-Tecnalia.

Observaciones:
El nivel medio del mar (NMM) local observado es el nivel medio horario calculado para el período de datos empleados en el cálculo del cero hidrográfico.

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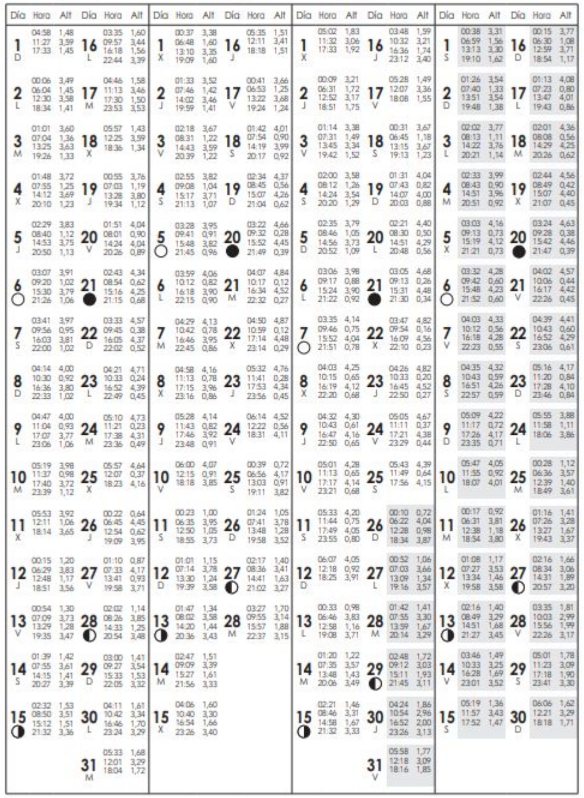
ANUARIO DE MAREAS 2023

MINISTERIO DE DEFENSA

2023 **PASAIA - PASAJES**



Las alturas expresadas se sumarán a las sondas de las cartas españolas para obtener la sonda en las horas de pleamar o bajamar. Horas en UTC: Horario de invierno, para hora oficial súmese una hora. Horario de verano, para hora oficial súmense dos horas.

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