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PREDICTING MARINE CURRENTS IN THE STRAIT OF MESSINA

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(communicated by Paolo V. Giaquinta)

ABSTRACT. We present a new computational tool for predicting the behaviour of marine currents through the Strait of Messina. Presently, their evaluation is based on the "tavole di corrente" (currents tables) edited by the Hydrographic Institute of the Italian Navy. These tables are published every year and contain, for each day and at a fixed location, the maximum, minimum and zero values of the marine currents at the time in which they are expected. In the present work we describe a new software that corrects the inconsistencies present in the Navy publication and predicts the status of the currents at any time, regardless of a particular date.

1. Introduction

The Strait of Messina (Italy) is a marine channel which joins the Ionian and Tyrrhenian Seas and separates Sicily from Italy. The Strait is like a funnel, about 10.8 nm (20 Km) long. By convention, its north end is placed on the Tyrrhenian Sea between Capo Peloro (Sicily) and Torre Cavallo (Calabria) and is about 1.73 nm (3.2 Km) wide. The south end, placed in the Ionian Sea between Capo d'Alì (Sicily) and Punta di Pellaro (Calabria), is about 8.4 nm (16 Km) wide. The strait has its minimum depth (72 m) between Ganzirri and Punta Pezzo; the depth increases up to 1000 m towards the Eolian Islands and up to 2000 m on the opposite side, abeam of Acireale. From an oceanographic point of view, the Strait of Messina exhibits a rare feature, represented by the marine currents which can reach (and even exceed) the value 5 m/s (9.7 Kn)(Mosetti 1988; Ribaud 1884; Tomasino 1995; Vercelli 1925; Vercelli and Picotti 1926). The velocity of the currents is due to a phase delay of about 180° between the Ionian and the Tyrrhenian Sea tides. This is expecially true for the so called "main semi-diurnal tide" component. The waters flow behaviour shows, as described elsewhere (Vercelli and Picotti 1926), an inversion of the direction every 6h 8m 24s, a period which amounts to 22104 s. The knowledge of these data is extremely useful for navigation over these waters.

2. Experimental

In order to develop a software for predicting, at fixed time and location, the velocity and direction of the tidal current in the Strait of Messina, we decided to make use of the data reported in the "tide tables" edited by the Istituto Idrografico della Marina Militare Italiana (2007). The Navy's tables provide the modulus and direction of the current which

TABLE 1. Amplitude and phase of the harmonic components at two locations on the Strait of Messina

Location		M_2	S_2	N_2	K_2	K_1	O_1	P_1	M_4	V_0
Punta Pezzo	$H^{(a)}$	3.2	0.9	0.5	0.3	0.8	0.4	0.3	0.3	−0.70
	$g^{(b)}$	129	147	122	147	73	56	73	82	
Ganzirri	$H^{(a)}$	2.6	0.7	0.4	0.2	0.7	0.3	0.2	0.2	−0.17
	$g^{(b)}$	129	147	122	147	73	56	73	82	

$^{(a)}$ knots $^{(b)}$ degrees

are obtained upon adding the permanent density current (denoted V_0) and eight more contributions, each referring to a single tidal current component, which are represented as harmonic functions:

$$f_i(t) = H_i \sin(\omega t + g_i) \tag{1}$$

where H_i is the amplitude and g_i is the phase (with $1 \leqslant i \leqslant 8$), $\omega = 1/T$ where $T = 22104$ s, and t is the time. The eight components are labelled as follows:

M_2, main lunar semidiurnal;
S_2, main solar semidiurnal;
N_2, major elliptical lunar semidiurnal;
K_2, lunar solar semidiurnal declination;
K_1, lunar solar diurnal declination;
O_1, main lunar diurnal;
P_1, main solar diurnal;
M_4, tidal component in shallow waters.

The values of V_0 and of the amplitude and phase of each harmonic function are reported in Table 1 for two specific locations, Punta Pezzo and Ganzirri.

Now, let us suppose that, at a particular instant of time, the sum of the sine functions yields a current peak in the south-north direction (a "going up current" which, by convention, is denoted with a positive sign). According to the tides normal alternation, after 6h 8m 24s (22104 s) we would expect a peak in the opposite current (the "going down current" which, by convention, has a negative sign). Unfortunately, we note that in the algorithm described above (Istituto Idrografico della Marina Militare Italiana 2007), all the amplitudes (H) related to a single tidal component are positive (see Table 1). As a result, each sine function yields a positive value, since the associated phases (g) are all in the range $0-180°$. In fact, a change of the sign may result from the product

$$\omega t = (1/22104)t\,.$$

which, after 22104 s, becomes:

$$\begin{aligned} \omega t_2 &= (1/22104)(t+22104) \\ &= (t/22104)+1 \\ &= \omega t + 1 \end{aligned}$$

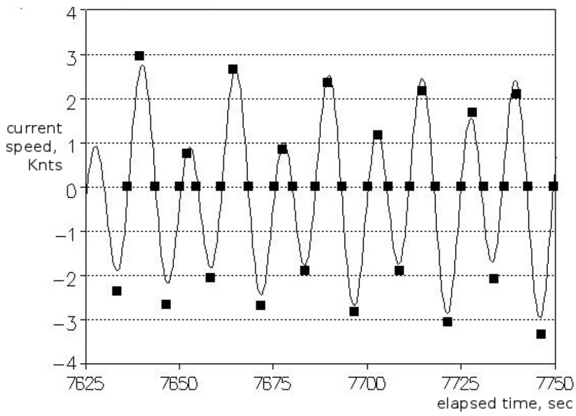

FIGURE 1. The continous line represents a best fit of the data

TABLE 2. Fit parameters

Harmonic function	Amplitude (knots)	Period (hours)	Phase
# 1	2.6	12.4206	0.744556
# 2	0.7	12.0	0.174842
# 3	0.4	12.6583	4.39×10^{-5}
# 4	0.2	11.9672	6.22×10^{-9}
# 5	0.7	23.9345	0.427921
# 6	0.3	25.8193	1.87228
# 7	0.2	24.0659	0.290699
# 8	0.2	6.2103	2.71778

Hence, after every period T the value of ωt increases by 1. This makes a sign change of the function possible only after a few months. Accordingly, the algorithm does not reproduce the behaviour of the currents in a realistic way and should be modified.

3. Experimental set up and results

We used a set of 39 data (Istituto Idrografico della Marina Militare Italiana 2007), which refer to maximum, minimum and zero values from November 15 to 19, 2007, and processed them in order to obtain a best fit with the function

$$F(t) = \sum_{i=1}^{8} a_i \sin\left[\left(\frac{2\pi t}{b_i}\right) + c_i\right] \tag{2}$$

where a_i is the amplitude, b_i is the period, c_i is the phase, and t is the time (hours). The fit of the data was performed with the Jandel Scientific Peakfit package (ver. 3.0); the optimal values of the parameters, producing a fit with regression coefficient $r^2 = 0.980$, are listed for each function in Table 2, where the periods are coherent with the astronomical components.The resulting fitting function is displayed in Fig.1.

```
 CALCOLO DELLA CORRENTE DI MAREA NEI VARI PUNTI DELLO STRETTO DI MESSINA


 Inserire anno (dal 2007 in poi):
2012
 Anni bisestili:  2
 Anni secolari non bisestili:  0
 Anni secolari bisestili:  0
 Inserire mese (numero da 1 a 12):
2
 Inserire giorno:
23
 Inserire ora (numero da 0 a 23):
13
 Inserire minuto (numero da 0 a 59):
15
 Inserire secondo (numero da 0 a 59):
10
 ora=  45109.2539
```

FIGURE 2. Client input data box

```
Punta Pezzo:  -2.95111537 nodi
Zona Centrale tra Scilla e Capo Peloro (30 minuti dopo l'ora inserita):
-0.742667317 nodi
Zona Centrale tra Torre Cavallo e Capo Peloro  (15 minuti dopo l'ora inserita):

-1.47533464 nodi
Centro della Trasversale Ganzirri-Punta Pezzo:  -2.02600384 nodi
Adiacenze di S.Agata (15  minuti prima dell'ora inserita):  -1.45822489 nodi
Adiacenze di Pace (1 ora e 30 minuti prima dell'ora inserita):  -0.725557685
 nodi
Adiacenze SW di Torre Cavallo (15 minuti dopo l'ora inserita):  -1.47533464
 nodi
Adiacenze NW di Torre Cavallo (15 minuti dopo l'ora inserita):  -1.72555768
 nodi
Bacino a NW di Scilla (45 minuti dopo l'ora inserita):  -0.342667311 nodi
Spiaggia tra Ganzirri e Torre Faro (10 minuti dopo l'ora inserita):
-1.17578077 nodi
Dintorni NE di Capo Peloro (30 minuti dopo l'ora inserita):  -2.12555766 nodi


TENDENZA PER LE PROSSIME 7 ORE NEL CENTRO DELLA TRASVERSALE GANZIRRI-PUNTA PEZZO


Dopo  1h :   0.0871417224 nodi
Dopo  2h :   1.49587548 nodi
Dopo  3h :   2.38364959 nodi
Dopo  4h :   2.53517318 nodi
Dopo  5h :   1.92224252 nodi
Dopo  6h :   0.708240092 nodi
Dopo  7h :  -0.795371771 nodi


Ricominciare?(digita la scelta, poi premi INVIO)
3=  Sì
4=  No
```

FIGURE 3. Output data box

The good matching between experimental and predicted data affects all the forecast values; hence, we conclude that the developed harmonics model is fairly reliable as for the tidal currents temporal alternation. In addition, the function in Eq. 2 with the fitting parameters was used as an input in a FORTRAN code which provides, forever and at any time, the currents status in the Strait. As an example, we present two screenshots produced with this code: the first one (Fig. 2) is related to the data input submission while the second one (Fig. 3) shows the currents data output calculated at various positions and at the requested time along the Strait of Messina.

4. Conclusions

This work removes the inconsistencies found in the only available paper source providing marine currents data in the Strait of Messina. Our calculation allowed us to obtain currents data at any time, not only when the maximum or zero velocities occur. A qualitative check in the 2007 – 2012 years range highlights the existence of a very good overlap between the predicted data and the real situation: the currents direction is always verified at the right time. We think that it would be necessary to develop a set of currents velocity measurements in order to update the data of Mosetti (1988).

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