Revue Paralia, Volume 3 (2010) pp 3.13-3.24
Keywords: Coastal engineering, Tide, Currents, Maritime hydraulics, Harmonic components, General circulation, Gulf of Gabes, Tunisia

Hydrodynamics of the gulf of Gabes deducted from the observations of currents and water levels

Mohamed Jamel HATTOUR [1], Chérif SAMMARI [2], Sassi BEN NASSRALLAH [3]

1. Ecole Nationale d'Ingénieurs de Monastir, rue Ibn Eljazar, 5019 Monastir, Tunisie. *hattour@yahoo.fr*
2. Institut National des Sciences et Technologies de la Mer, 28 rue du 2 mars 1934, 2025 Salammbô, Tunisie.
3. Laboratoire d'Etudes des Systèmes Thermiques et Energétiques, rue Ibn Eljazar, 5019 Monastir, Tunisie.

Abstract:
The objective of this study is to verify and to explain the dynamics along the coast of the gulf of Gabes (East Coast of Tunisia) by *in situ* observations. We made various measurements of height of water and current in some significant points of this region which, with the Adriatic (in a lesser measure), benefit from the biggest amplitude of tide in the Mediterranean Sea.
This study presents the first results of the analysis of the temporal series. The instruments used are ADCP (Acoustic Doppler Current Profiler) for the current and submersible tide loggers immersed for the height of water. The average lengths of our temporal series are 40 days and are distributed from 2007 till 2008.
The preliminary results are decisive: although the harmonic components were in accordance with those already established by various authors, the absolute values of the heights of water as well as the phases presenting significant gas at least in two zones. Besides, the heights showed the existence of a loop of the current of the Mediterranean Sea which penetrates into the gulf of Gabes.

Received 4 January 2010, accepted 25 March 2010, available online 6 September 2010.
Translated version not certified, published under the responsibility of the article authors.

How to cite the original paper:
HATTOUR M.J., SAMMARI C., BEN NASSRALLAH S. (2010). *Hydrodynamique du golfe de Gabès déduite à partir des observations de courants et de niveaux*. Revue Paralia, Vol. 3, pp 3.1–3.12.
DOI:10.5150/revue-paralia.2010.003 (disponible en ligne – http://www.paralia.fr – available online)

1. Introduction

The dynamics of the gulf of Gabes is directly related to the general circulation of the Mediterranean Sea and to the distributions of the tide waves inside this gulf. Certainly, the studies of MOLINES (1991), ABDENNADHER & BOUKTHIR (2006) and SAMMARI *et al*. (2006), focused well on the dynamics of the gulf of Gabes, contrary to others, who centered their studies on the Oriental Mediterranean Sea (such as TSIMPLIS *et al*., 1995). It is more and more plausible to confirm or to counter their results by *in situ* measurements, in particular in the coastal zone.
We present in the first part, the Tunisian coast and particularly the gulf of Gabes, in the second part we shall expose the data of the harmonic analysis. The last one will be concerned with the results of this analysis and their comparisons with the previous studies.

2. The gulf of Gabes

2.1 General characteristics

The Tunisian coast presents a remarkable contrast between the North part (the Algerian border to Ras Kapudia) and the South part (until the Libyan border). In the North, the sea is generally deep near the coast, lands are more or less high and visible from rather large distances, "in brief, the relief of the ground and that of the bottom are stressed (MANEN & HERAUD, 1890)". In Ras Kapudia, the configuration changes totally: the coast falls, there is no more than flat slopes, and the small reliefs are farther from the sea. But it is especially the immense continental shelf which makes the main characteristic of this region. The shallow water surrounds the Kerkennah (or Cercina) island, covers a considerable part of the gulf of Gabes, surrounds the island of Jerba, ends near the Libyan coast, for about fifteen miles east of the frontier point Ras Ashdir. This continental shelf is the widest of the Mediterranean Sea. Its outline, measured only on the isobaths of 20 meters, is 110 nautical miles. The depths of 50 meters reach more than 70 nautical miles off the islands of Kerkennah (MANEN & HERAUD, 1890).
This peculiarity makes the Gulf of Gabes a remarkable zone for at least three aspects:
a) The wealth of the biological resources.
b) The nautical properties, where we find quiet zones in almost any weather.
c) An unprecedented amplitude of the tide in the Mediterranean Sea.

2.2 Tide

The strongest tide in the Mediterranean Sea is in the gulf of Gabes. Indeed: in the Adriatic, the observed tides hardly overtake, even by adding to it the effect of disturbance of winds, 1 meter of amplitude; in the Ionian Sea, the maximal amplitudes hardly reach 0.75 meters; in Tripoli and in the gulf of Syrte, the influence of winds can create 0.60 meter oscillations. While in Gabes, the amplitude reaches, and overtakes, 2 meters.

This unusual tidal range in the Mediterranean Sea, not completely explained, is due to a phenomenon of tidal resonance in the gulf of Gabes between Ras Kapudia and Zarzis (SAMMARI *et al.*, 2006).

The studies of MOLINES (1991) and ABDENNADHER & BOUKTHIR (2006) are, to our knowledge, the only thorough studies which emphasized the tide along the Tunisian coast during the last decades. The authors drew cotidal lines of the main harmonic components in the gulf of Gabes. These studies indicate that the maximum lunar amplitude M_2 is 48 cm is in the gulf of Gabes, which was published by the IHO (1979). This amplitude decreases going north of the channel of Sicily (12 cm), and towards the oriental deep regions (6 cm). The maximum amplitudes of the S_2 component is also localized in the gulf of Gabes, which varies from 38 to 4 cm in the East direction. The amphidromic point of S_2 is situated between Cap Bon (Tunisia) and Mazzara (Sicily), line whose the phase is in counterclockwise rotation. Compared to the M_2 component it is slightly moved northward (0.3°). The big features of the other semi diurnal components are similar to those of the M_2 component but with reduced amplitudes, particularly for the N_2 component (Lunar elliptic, semi-diurnal). The amplitude of the component N_2 in the gulf of Gabes is very weak compared to the other semi diurnal components, approximately 6 cm, and elsewhere the amplitude is very weak and does not exceed 3 cm.

2.3 Currents

The knowledge of sea currents in this zone is not well defined, although than it is better compared to the parameters of the wave. The general currents of surface in the Mediterranean Sea are generated by the Atlantic waters, which are characterized by their weaker salinity, which penetrate by the Strait of Gibraltar.

According to MANEN & HERAUD (1890), in the South of Ras Kapudia, the currents are perceptible, they are regular and show alternative directions of propagation corresponding to the tide which engenders them. The stream comes from the N.E. or East, and follows directions included between the N.W. and the S.W.. It meet the big plateau of Kerkennah and by-passes it by the North and by the South to penetrate into the channel and into the pits which exist in the middle of the banks. In Ras Kapudia, it divides, a branch going back with a low speed towards Mahdia, whereas the other one goes to the South to fill the channel. At the tip of Mahres, by a similar fork, a branch goes to the North to the natural harbour of Sfax and the channel, the other one goes to the South towards the entrance of the bay of Kenis.

In the South, the stream runs in front of Humt Suk on the West and, from Bordj Djilidj, extends into the gulf of Gabes; its extreme branches go respectively towards the bay of Kenis and the channel of Adjim.

Finally, beyond Djerba, the stream runs parallel to the coast, westward in front of Biban, in the N.W. in front of Zarzis. The ebb tide follows directions appreciably inverse.

In the wide, the slack and the turnings of the currents occur near the moments of the high and the low waters, and the highest speeds at the middle-tide; but, in channels, the slacks delay more and more farther away from the entrance, and for example, in Sidi Mansur or in front of Ajim, we notice that the currents change about the middle-stream and at the middle-ebb tide and that the highest speeds correspond to the moments of the high and the law waters.

While MANZELLA *et al*. (1988), remarked that in the North of the Italian island of Lampedusa the current of Atlantic origin splits into two branches: the first one goes to the Southeast by leaving the island on the West while the second turns southward and is going to feed the circulation off the Gulf of Gabes. The flow of the MAW (Modified Atlantic Water), through the Sicilo-Tunisian strait, presenting a well marked seasonal variability, the intensity of this branch is subject, accordingly, to fluctuations which in turn are directly going to affect the circulation off the gulf of Gabes (fig 1).

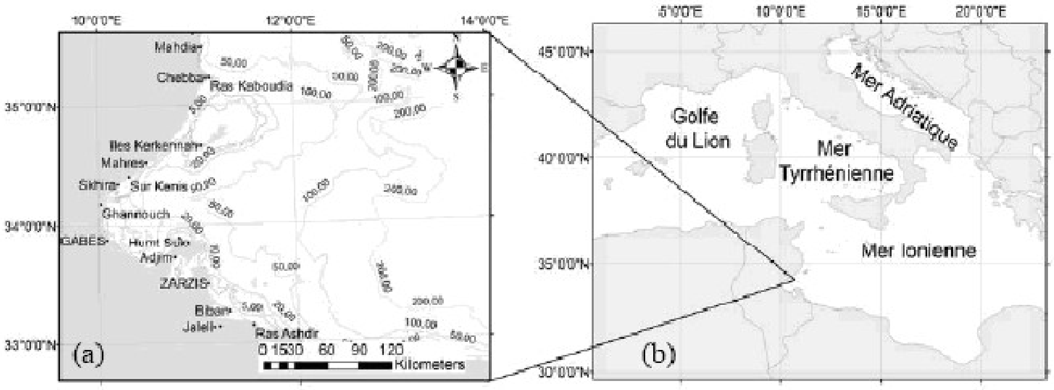

Figure 1. Bathymetric map of the gulf of Gabes (to the left) and the map of the Mediterranean Sea (to the right).

3. Data

We have obtained, between September, 2007 and December, 2008, ten temporal series in stations indicated in figure 3 (height of water obtained by submersible tidegage and current obtained by ADCP, see figure 1). We also exploited the series obtained by SAMMARI *et al*. (2006) summarized in figure 2. These last ones will enrich our analysis and especially will make the validation of our measures easier.

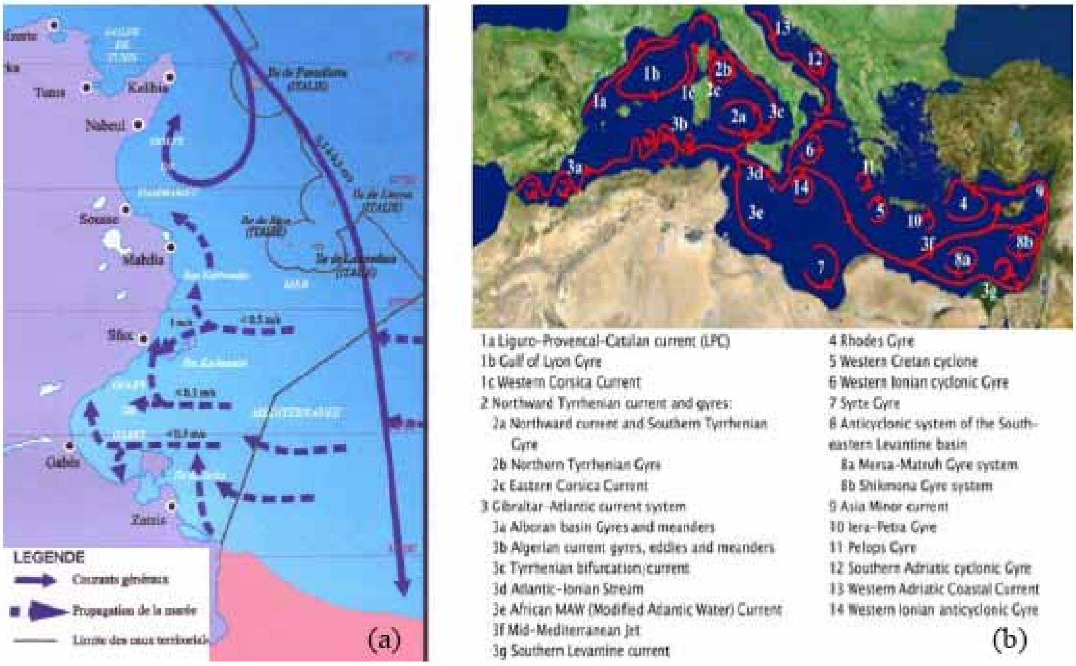

Figure 2. Left: The simplification of the surface currents from the observations and the simulations by PINARDI and ZAVATARELLI (2005).
Right: The map by the Laboratoire Central d'Hydraulique de France LCHF (1978) within the framework of a report on the fishing ports (hydraulic studies) along the Tunisian coast (ribs).

Table 1. Stations of made measures.

Id	*Instrument*	*Nom*	*Lon.*	*Lat.*	*Δt (sec)*	*Début*	*Durée (jrs)*	*Prof. (m)*
1	RBR 2050	Gabes_1	33°53’	10°07’	360	11/09/2007	65.6	3.6
2	RBR 2050	Taguermess	33°49’	11°03’	360	12/09/2007	64.5	3.2
3	RBR 2050	Gabes_2	33°53’	10°07’	360	6/03/2008	70.1	7.1
4	RBR 2050	Cercina	34°44’	11°05’	360	10/09/2007	45.3	3.9
5	RBR 2050	Mahres	34°07’	10°25’	360	19/03/2009	73.0	16
6	RBR 2050	Elkantara	33°39’	10°55’	360	28/05/2008	40.9	3.2
7	Argonaut	Elkantara	33°39’	10°55’	1200	28/05/2008	40.9	3.2
8	ADCP	Taguermess	33°49’	11°03’	1200	12/09/2007	46.8	3.2
9	ADCP	Chebba	35°06’	11°32’	3600	25/12/2008	82.8	15
10	ADCP	Mahres	34°07’	10°25’	3600	24/12/2008	52.7	16

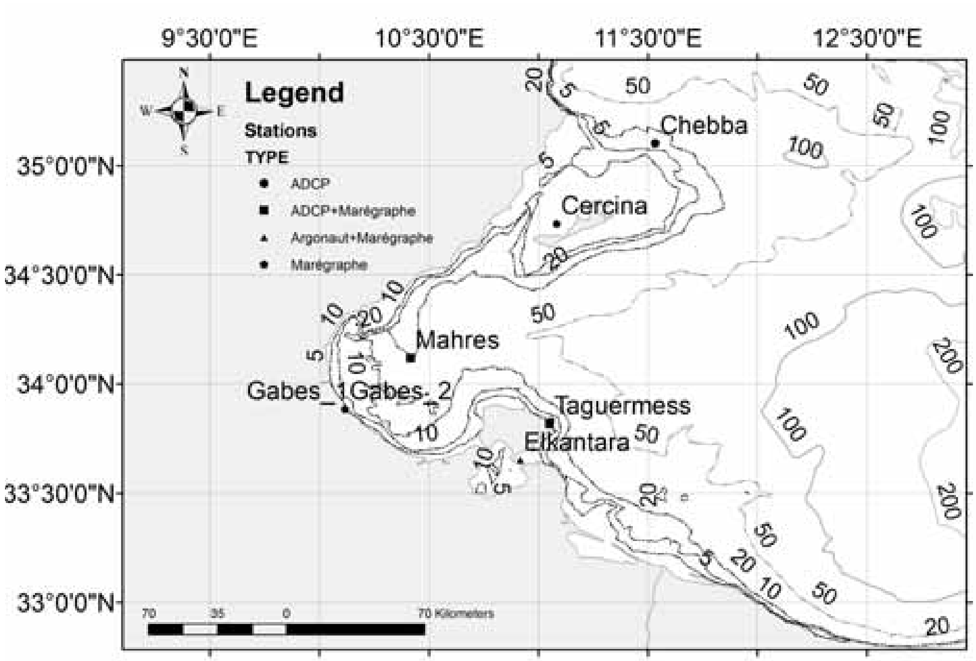

Figure 3. The relative positions of the various stations.

Table 2. Stations of measures SAMMARI et al. (2006).

Id	*Instrument*	*Nom*	*Lon.*	*Lat.*	*Δt (sec)*	*Début*	*Durée (jrs)*
11	*MicroTide*	*Kerkennah*	*34°39'*	*10°58'*	*360*	*04/04/2003*	*86.8*
12	*MicroTide*	*Ganouch*	*33°55'*	*10°07'*	*360*	*03/04/2003*	*87.8*
13	*MicroTide*	*El Jorf*	*33°42'*	*10°44'*	*360*	*02/04/2003*	*88.5*
14	*MicroTide*	*Aghir*	*33°44'*	*11°00'*	*360*	*02/04/2003*	*88.5*

4. Methodology: the harmonic analysis (exploitation of the measures)

The harmonic analysis of the tide allows to represent it in the form of a sum of harmonic components of period and phase well determined, corresponding to the end of the luni-solar astronomical generative strength and to complementary terms of hydrodynamic origin.

This tool is the fruit of the works of GODIN (1972) & GODIN (1976), their programming on computer was introduced by FOREMAN (1977) on Fortran then taken up by PAWLOWICZ *et al*. (2002) with Matlab.

It is usual, for the observations of the measures of vertical movement (also called "rise") of the water level and the horizontal movement of the water (also called "current") at a definite depth, that a proportion of their oscillations are attributed to the astronomical origins, noted respectively: rise of tide and tide current.

This method indicates on one side, the percentage of the signal's variance explained by the tide, and on the other hand, the harmonic components responsible for these movements.

5. Results and discussions

5.1 Amplitudes and phases

Based on the analysis's results of the height of water of the various stations (see table 4) we confirm those of MOLINES (1991), TSIMPLIS *et al*. (1995), GASPARINI *et al*. (2004), and ABDENNADHER & BOUKTHIR (2006), for the zone of Ghanouch and the Skhira. Indeed, the amplitude of M_2 decreases going East by 50 cm near Ganouch to 40 cm in the South of Kerkennah. Other main harmonic components according to the decreasing order: S_2, K_2, N_2, K_1 et O_1, present the same qualitative characteristics, with a reduced amplitude.

Significant deviations of amplitude (see table 3) were however observed around the island of Jerba.

We consider that these deviations are due to under estimation of the effects of the small depths, lower than 10 m (which are far from being unimportant).

Table 3. Comparison of the amplitudes calculated with those obtained by ABDENNADHER & BOUKTHIR (2006).

Station	***Composant***	***Calculated value (cm)***	***Calculated value in 2006 (cm)***
Taguermess	M_2	*28*	*32*
	S_2	*17*	*26*
El Jorf	M_2	*27*	*48*
	S_2	*16*	*38*
Aghir	M_2	*25*	*34*
	S_2	*14*	*24*
Kerkennah or	M_2	*41*	*34*
Cercina	S_2	*25*	*26*

A phase deviation of the tide waves was located in two zones of this gulf; it concerns sub-basin at the level of the Kerkennah channel and lake Bou Ghrara, in these zones of phase delays which can reach 50°. These "containers" seem to fill and empty in phase, by their access. This is moreover in compliance with the observations reported by all the sailors who frequented these places. Indeed, the tide wave approximately comes from the East: the gulf thus fills (and empties) by the East while the channel of Kerkennah, between the Sfax coast and the Kerkenie archipelago, fills (at the same time) by the South and by the North, and also for the lake of Bou Ghrara, except that the filling (and the emptying) is in the East and West directions. The delays of high tide between the various sites are not only owed to the differences of longitude, but also to the viscous friction on the small depths. This friction, strong in shallow depths, is very important at the level of the gulf of Gabes, TSIMPLIS *et al*. (1995) showed that for this gulf's area, which represents only approximately 5% of the total surface of the Mediterranean basin, the waste, due to the friction, is estimated at $8{,}8\times10^{8}$ W.

Table 4. Results of the harmonic analysis of the water level.

Comp,	***T (hr)***	***Gabes_1***		***Taguermess***		***Gabes_2***		***Cercina***		***Mahres***		***Elkantara***	
		A	***P***	***A***	***P***	***A***	***P***	***A***	***P***	***A***	***P***	***A***	***P***
MM	*661.29*	-	-	-	-	-	-	*0.014*	*95*	*0.037*	*247*	-	-
MSF	*354.37*	-	-	*0.016*	*156*	-	-	*0.044*	*353*	*0.051*	*218*	*0.045*	*65*
Q_1	*26.87*	-	-	-	-	-	-	-	-	-	-	*0.003*	*146*
O_1	*25.82*	-	-	*0.011*	*87*	*0.008*	*99*	*0.008*	*100*	*0.016*	*105*	*0.012*	*138*
P_1	*24.07*	*0.011*	*36*	-	-	-	-	-	-	-	-	*0.004*	*63*
K_1	*23.93*	*0.033*	*29*	*0.010*	*347*	*0.015*	*13*	*0.009*	*321*	*0.035*	*32*	*0.011*	*56*
N_2	*12.66*	*0.082*	*77*			*0.092*	*75*	*0.055*	*110*	*0.062*	*71*	*0.015*	*142*
M_2	*12.42*	*0.525*	*73*	*0.278*	*73*	*0.520*	*76*	*0.329*	*118*	*0.471*	*71*	*0.104*	*135*
L_2	*12.19*	-	-	-	-	-	-	-	-	-	-	*0.007*	*124*
S_2	*12.00*	*0.325*	*95*	*0.169*	*86*	*0.344*	*90*	*0.216*	*133*	*0.289*	*93*	*0.044*	*200*
K_2	*11.97*	*0.088*	*117*	*0.046*	*108*	*0.094*	*112*	*0.059*	*155*	*0.079*	*116*	*0.012*	*223*

** A: The amplitude of the considered harmonic component of the tide (m)*

** P: The phase of the considered harmonic component of the tide at Universal Time (TU)*

5.2 Types of tide and shape factor

The semi-diurnal tide is general on the Tunisian coast ABDENNADHER & BOUKTHIR (2006). Indeed, the calculation of the shape factor F (AMIN, 1986) (see equation 1) shows that it does not exceed 0.1 for all the stations, which indicates a net ascendancy of the semi-diurnal tides (F included between 0 and 0.25).

$$F = \frac{O_1 + K_1}{M_2 + S_2} \tag{1}$$

where:

S_2 = Amplitude of the semi-diurnal principal solar tide

M_2 = Amplitude of the semi-diurnal principal lunar tide

K_1 = Amplitude of Lunar-solar declinational tide

O_1 = Amplitude of principal lunar declinational tide

Indeed, there is in this region a cyclonic local permanent water circulation LACOMBE & TCHERNIA, 1972; OVCHINNIKOV, 1966) which is going to give up a part, more or less important, of its waters to the sub-branch of the Atlantic current. Furthermore, BEL HASSEN *et al*. 2009, because of observations of phytoplankton in the zone, suspect the presence of Atlantic waters.

Table 5. Results of the harmonic analysis of the current.

		Elkantara				***Taguermess***				***Chebba***				***Mahres***			
Comp,	***T(hr)***	***G. A***	***P. A***	***I.***	***P.***	***G. A***	***P. A***	***I.***	***P.***	***G. A***	***P. A***	***I.***	***P.***	***G. A***	***P. A***	***I.***	***P.***
MM	*661,29*	*6,86*	*-0,05*	*32*	*256*	-	-	-	-	-	-	-	-	-	-	-	-
MSF	*354,37*	*8,50*	*0,17*	*34*	*8*	*10,57*	*1,48*	*168*	*176*	-	-	-	-	*1,53*	*0,14*	*94*	*55*
Q1	*26,87*	-	-	-	-	*1,42*	*0,12*	*131*	*343*	-	-	-	-	-	-	-	-
O1	*25,82*	*3,48*	*-0,02*	*29*	*298*	*1,38*	*-0,95*	*154*	*24*	-	-	-	-	-	-	-	-
P1	*24,07*	*2,72*	*0,07*	*31*	*245*	*2,18*	*-0,24*	*147*	*210*	-	-	-	-	-	-	-	-
K1	*23,93*	*8,23*	*0,20*	*31*	*237*	*6,59*	*-0,71*	*147*	*203*	*2,49*	*-0,07*	*157*	*17*	*1,02*	*-0,77*	*154*	*97*
J1	*23,10*	*2,36*	*-0,07*	*33*	*158*	*1,29*	*0,13*	*88*	*339*	-	-	-	-	*1,59*	*-0,27*	*48*	*174*
OO1	*22,31*	-	-	-	-	*0,70*	*-0,28*	*95*	*183*	-	-	-	-	-	-	-	-
EPS2	*13,13*	*1,42*	*0,14*	*26*	*74*	-	-	-	-	-	-	-	-	-	-	-	-
MU2	*12,87*	*3,01*	*-0,09*	*23*	*49*	-	-	-	-	*0,48*	*-0,43*	*171*	*78*	-	-	-	-
N2	*12,66*	*11,17*	*0,16*	*29*	*283*	*4,45*	*-0,68*	*142*	*293*	*0,78*	*-0,22*	*145*	*74*	*2,34*	*0,37*	*59*	*176*
M2	*12,42*	*54,73*	*0,47*	*29*	*294*	*18,34*	*-1,15*	*151*	*287*	*6,81*	*-2,76*	*142*	*79*	*14,53*	*1,22*	*48*	*156*
L2	*12,19*	*3,59*	*0,09*	*29*	*326*	-	-	-	-	*0,37*	*0,02*	*146*	*165*	-	-	-	-
S2	*12,00*	*27,83*	*0,16*	*29*	*338*	*13,93*	*-1,10*	*149*	*305*	*4,87*	*-2,48*	*148*	*95*	*11,29*	*1,63*	*41*	*193*
K2	*11,97*	*7,57*	*0,04*	*29*	*1*	*3,79*	*-0,30*	*149*	*328*	*1,33*	*-0,67*	*148*	*117*	*3,07*	*0,44*	*41*	*216*
ETA2	*11,75*	*1,71*	*0,11*	*26*	*351*	-	-	-	-	*0,27*	*-0,17*	*48*	*355*	*1,45*	*-0,12*	*64*	*194*
MO3	*8,39*	*1,76*	*0,11*	*27*	*179*	-	-	-	-	-	-	-	-	-	-	-	-
M3	*8,28*	-	-	-	-	*1,68*	*-0,13*	*157*	*146*	*0,37*	*-0,03*	*135*	*197*	-	-	-	-
MK3	*8,18*	*0,94*	*-0,01*	*31*	*82*	*1,87*	*-0,26*	*165*	*87*	*0,37*	*-0,07*	*165*	*143*	-	-	-	-
SK3	*7,99*	*0,69*	*0,07*	*32*	*135*	-	-	-	-	-	-	-	-	-	-	-	-
MN4	*6,27*	*3,98*	*0,33*	*31*	*115*	*0,83*	*-0,22*	*93*	*267*	-	-	-	-	*0,60*	*-0,17*	*82*	*161*
M4	*6,21*	*6,06*	*0,98*	*31*	*124*	*2,19*	*0,39*	*143*	*32*	-	-	-	-	*1,24*	*-0,41*	*19*	*236*
SN4	*6,16*	*1,01*	*0,19*	*34*	*287*	*1,12*	*0,27*	*177*	*78*	*0,43*	*0,06*	*18*	*305*	-	-	-	-
MS4	*6,10*	*5,22*	*0,59*	*28*	*141*	*4,97*	*1,08*	*161*	*77*	-	-	-	-	*0,83*	*-0,37*	*48*	*253*
S4	*6,00*	*1,06*	*0,04*	*22*	*183*	-	-	-	-	-	-	-	-	*0,76*	*-0,18*	*29*	*222*
2MK5	*4,93*	*1,41*	*0,07*	*26*	*286*	*0,62*	*-0,25*	*174*	*325*	-	-	-	-	-	-	-	-
2MN6	*4,17*	*3,02*	*0,11*	*31*	*330*	-	-	-	-	-	-	-	-	-	-	-	-
M6	*4,14*	*3,73*	*-0,03*	*28*	*346*	-	-	-	-	*0,32*	*-0,20*	*162*	*176*	*0,47*	*0,24*	*39*	*358*
2MS6	*4,09*	*4,08*	*-0,03*	*31*	*9*	-	-	-	-	*0,39*	*-0,04*	*66*	*29*	*0,47*	*-0,14*	*6*	*26*
2SM6	*4,05*	*1,16*	*-0,09*	*31*	*90*	*0,78*	*-0,48*	*112*	*95*	*0,36*	*-0,05*	*23*	*72*	*0,57*	*0,24*	*12*	*90*
3MK7	*3,53*	-	-	-	-	-	-	-	-	-	-	-	-	*0,42*	*-0,29*	*32*	*171*
M8	*3,11*	*0,48*	*0,25*	*25*	*169*	*0,58*	*0,06*	*149*	*130*	*0,29*	*0,02*	*165*	*255*	-	-	-	-
M10	*2,48*	*0,42*	*-0,03*	*37*	*69*	-	-	-	-	-	-	-	-	*0,74*	*0,23*	*52*	*296*

G.A: half a main line (cm), P.A: half a small axis (cm), I: the slope (°) and P: the phase of the considered harmonic component at (UT) Universal Time

We analyzed the data of currents (see figure 5), which showed that in station 9 (see figure 1) 47% of the variance is explained by the tide, and by going inward of the gulf (station 10), 76% is explained in the same way. While in Taguermess (station 8), the variance explained by the tide does not exceed 33%. The residual of the current in these stations remains unidirectional and coincides with the coast line. We conclude that the general current of the Mediterranean Sea contains one or several branches rushing into the gulf of Gabes.

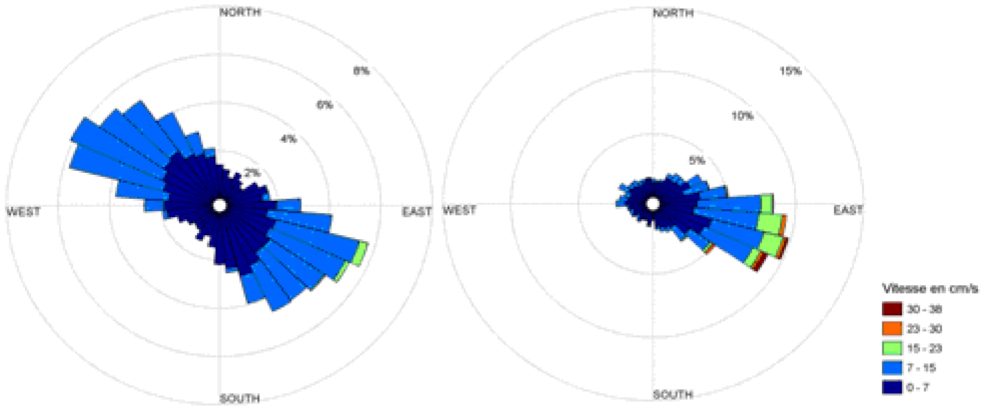

Figure 4. Rose of current predicted to the left and the residual current to the right (station 10).

For station 9 the current is of West-Northwest direction which can reach the maximal speed of 15 cm s^{-1} and the ebb tide is in the opposite direction set with a maximun slightly superior (23 cm s^{-1}). These currents combine with a general East-Southeast current of maximal speed equal to 38 cm s^{-1} (stronger than that of the currents of tide). In station 10 (in front of Kneis islands), the tide currents (flood current: S-W, 24 cm s^{-1} and ebb current: 30 cm s^{-1}) have to combine with a N-E general current which can reach a maximun speed of 30 cm s^{-1} with a 15 cm s^{-1} mean value (see figure 3). In station 8 the tide currents (flood current W-NW: 39 cm s^{-1} and ebb current: E-SE, 65 cm s^{-1}) have to combine with a general W-NW current, which can reach a maximun speed of 65 cm s^{-1} with a mean value 30 cm s^{-1}. We conclude that there is a countercurrent against the general current of the Mediterrannean Sea and which is connected with it. And moreover, it is of the same type of that of the gulf of Hammamet detected by LCHF (1978).
This current could penetrate in the gulf along the north coast of the island of Jerba and come out from it off the south point of Kerkennah (or Cercina) islands (figure 5).

6. Conclusion

The taken measures allowed us to calculate the tide’s components of the gulf of Gabes, and so verify that they are in coherence with the values established by the previous studies. They also allowed to specify the path of distribution of this tide wave, in particular, near the islands of Kerkennah (also named Cercina) and Jerba. Additionally, we noticed pertinent deviation with the values calculated by ABDENNADHER and

BOUKTHIR (2006) and located a branch of the general current of the Mediterranean Sea, which shows a countercurrent penetrating into the gulf of Gabes then joining the general current, which follows the south coast of the Mediterranean basin.

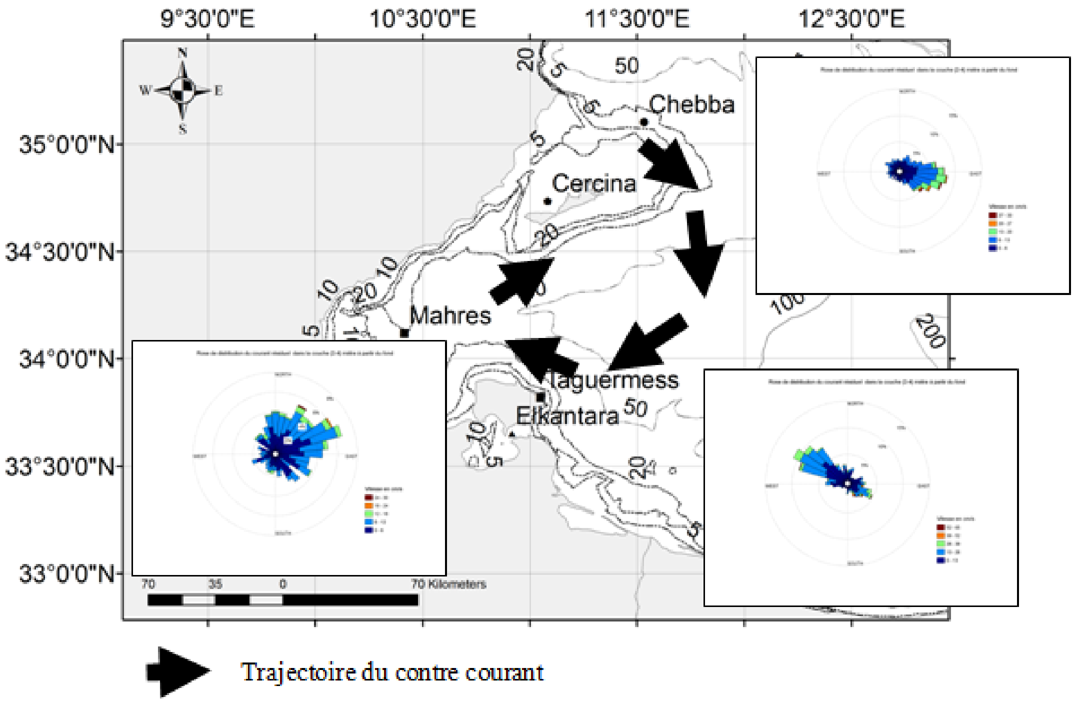

Figure 5. Trajectory of the branch of the general current of the Mediterranean Sea.

7. References

ABDENNADHER J., BOUKTHIR M. (2006). *Numerical simulation of the barotropic tides in the Tunisian Shelf and the Strait of Sicily*. Journal of Marine Systems, 63, pp 162–182. doi:10.1016/j.jmarsys.2006.07.001

AMIN M. (1986). *On the classification of tides*. International Hydrographie Review, n° 63(1), pp 161-174.

BEL HASSEN M., DRIRA Z., HAMZA A., AYADI H., AKROUT F., MESSAOUDI S., ISSAOUI H., ALEYA L., BOUAIN A. (2009). *Phytoplankton dynamics related to water mass properties in the Gulf of Gabes: Ecological implications*. Journal of Marine Systems, vol. 75, issue 1-2, pp 216-226. doi:10.1016/j.jmarsys.2008.09.004

FOREMAN M.G.G. (1977). *Manual for Tidal Heights Analysis and Prediction*. Institute of Ocean Sciences, Patricia Bay, Victoria, B.C Pacific Marine Science Report n° 77-10, 97 p.

GASPARINI G.P., SMEED D.A., ALDERSON S., SPARNOCCHIA S., VETRANO A., MAZZOLA S. (2004). *Tidal and subtidal currents in the Strait of Sicily*. Journal of Geophysical Research (Oceans). n° 109, C02011. doi:10.1029/2003JC002011

GODIN G.G. (1976). *The reduction of current observations with the help of the admittance function.* Marine Environmental Data Service Environment Canada. Ottawa, Technical Note n° 14, 13 p.

GODIN G.G. (1972). *The Analysis of Tides.* University of Toronto Press, 264 p.

IHO -International Hydrographique Organisation- (1979). *IHO tidal component bank.* Ottawa.

LACOMBE H., TCHERNIA P. (1972). *Caractères hydrologiques et circulation des eaux en Méditerranée*. The Mediterranean Sea, A Natural Sedimentation Laboratory, pp 25–36.

LCHF (1978). *Etude des ports de pêche côtière, études hydrauliques*. Rapport n03A.

MANEN L., HÉRAUD G. (1890). *Reconnaissance hydrographique des Côtes de Tunisie 1882 - 1886*. Paris, Imprimerie Nationale.

MANZELLA G., GASPARINI G., ASTRALDI M. (1988). *Water exchange between the eastern and western Mediterranean through the strait of Sicily*. Deep Sea Research Part I: Oceanographic Research n° 35, pp 1021–1035.

MOLINES J.M. (1991). *Modeling the barotropic tides in the strait of Sicily and Tunisian coasts*. Oceanologica Acta, n° 14 (3), pp 241–251.

OVCHINNIKOV I. (1966). *Circulation in the surface and intermediate layers of the Mediterranean*. Okeanologiya 6 n° 1, pp 48–59.

PAWLOWICZ R., BEARDSLEY B. LENTZ S. (2002). *Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE.* Computer Geoscience, Pergamon Press, Inc. n° 28, pp 929–937.

PINARDI N., ZAVATARELLI M. (2005). *The physical, sedimentary and ecological structure and variability of shelf areas in the Mediterranean Sea* The Sea, Vol. 14, pp 1245-1331.

SAMMARI C., KOUTITONSKY V.G., MOUSSA M. (2006). *Sea level variability and tidal resonance in the Gulf of Gabes, Tunisia.* Continental Shelf Research n° 26 pp 338-350. doi:10.1016/j.csr.2005.11.006

TSIMPLIS M., PROCTOR R., FLATHER R. (1995). *A two dimensional tidal model for the Mediterranean Sea.* Journal of Geophysical Research n° 100, pp 16223–16239. doi:10.1029/95JC01671