# OBSERVATION OF INTERNAL WAVES IN THE STRAIT OF GIBRALTAR

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## Abstract

Data analysis of temperature and current velocities from two mooring lines installed in the Strait of Gibraltar during May 2003 has been carried out. The Empirical Modes Decomposition analysis confirms the regular existence of energetic internal waves in the Strait of Gibraltar during spring tides, which are grouped in wave trains that are observed with semidiurnal periodicity. During neap tides, this phenomenon is weaker or even inexistent. The phase velocity of oscillations is 1.6 m/s in average. Nevertheless, this value has a noticeable dependence on the diurnal inequality existing in the flow, thus demonstrating that the advection is not negligible compared to the intrinsic phase velocity.

*Keywords : Strait Of Gibraltar, Waves, Bathymetry, Stratification.*

One of the main oceanographic features of the Strait of Gibraltar is the regular presence of internal waves [1, 2]. These waves have their origin in the internal bore formed downstream of Camarinal Sill (the main sill of the Strait of Gibraltar, CC in figure 1) during the flood tide. When the tidal current slackens, the internal bore is released producing internal waves trains.

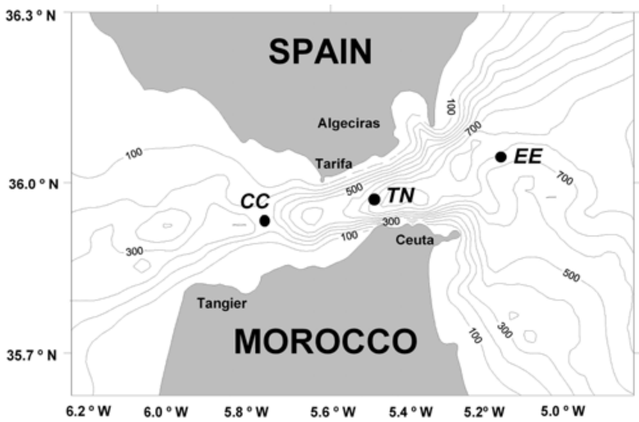


Fig. 1. Bathymetry of the Strait of Gibraltar with isobaths plotted each 100 m. The map shows the location of the mean sill of the Strait (CC), and the positions of the two sites where the data used in the study were collected (TN, EE).

The data of this work were collected in Tarifa Narrows, the section of minimum width in the Strait of Gibraltar (35.960°N, 5.567°W, TN in figure 1), and in the eastern part of the Strait (36.056°N, 5.168°W, EE in figure). The instruments used, a set of Recording Current Meters at different depths, recorded temperature and velocity every two minutes from 29$^{th}$April-22$^{nd}$May, and 1$^{st}$ May-3$^{rd}$ June 2003 respectively.

Empirical Modes Decomposition analysis (EMD, [3]) has been carried out. EMD analysis is a recent algorithm able to deal with non-stationary and nonlinear signals, achieving a satisfactory response in time-frequency. This technique separates the signal in intrinsic mode functions (IMF), each of this IMF contains a narrow band of frequencies of the original signal, from the higher to the lower as the mode increases. The temporal reliance of instantaneous amplitude and frequency of each IMF is evaluated by the Hilbert transform. The waves have been identified by portions of the signals with high energy at high frequencies (oscillations in the first and second IMF with periods around 25 minutes). The analysis reveals that the phenomenon is especially intense during spring tides, with amplitudes around 50 meters and internal wave trains arriving with semidiurnal periodicity. On the other hand, during neap tides oscillations are weaker or they could not be detected. During the period of observations, the mean phase velocity between CC and TN was 1.59 m/s, and between TN and EE it was 1.78 m/s. Nevertheless, these average values are not very representative because of the variability induced by the diurnal inequality existing in the flow through the Strait of Gibraltar. Such inequality is also observed in the phase velocities, due to the different importance of the advection. For instance, between TN and EE the velocity of internal wave trains observed during the same day differs in 0.45 m/s in average.

The period and amplitude of internal waves are variable within a wave train, changing from high periods and amplitudes at the head, to low values at the rear. Characteristic values are 30-10 min for periods, and 50-10 m for amplitudes. Those properties, together with the increase of oscillations in a wave packet, its spreading, and the recovery of isopycnals at the rear of the wave trains, have been well detected in the data and compared with a model based on an analytical solution of the Korteweg de-Vries equation [4].

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