MODEL OF GIBRALTAR'S SHORT PERIOD OSCILLATIONS

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Abstract
Tide gauge records from different harbours in the Strait of Gibraltar area show events of short period oscillations (SPOs), with periods ranging from some minutes to tens of minutes, that persist from several hours to one-two days. The numerical model developed to investigate these oscillations shows that they correspond with harbour resonances, which are excited by the normal modes of the Strait of Gibraltar (regional domain): coupled model of normal modes.
Keywords : Air-sea Interactions, Coastal Models, Strait Of Gibraltar, Sea Level, Waves.

The exchange of Mediterranean and Atlantic waters through the Strait of Gibraltar is a complex phenomenon which responds to physical forcing of different temporal and spatial scales [1]. The shortest time-scale actually found in the Strait of Gibraltar corresponds to the SPOs (Short Period Oscillations), of few minutes of period, and that are known to affect the sea level within the harbours in the Strait area (see tide gauge record at Figure 1). They are an interesting and striking phenomenon by themselves, despite the fact that observations do not support any dynamical relation of the short period oscillations with the water exchange in the Strait.
The amplitude of these SPOs ranges from 1 cm to 10 cm, that is, they are one or two order of magnitude below the predominant tidal signal (around 0.5 m). It is also noticeable that the SPOs are more frequently observed in summer, pointing to a certain seasonal variability. Spectral analysis show relevant peaks between 7 and 30 minutes, and highlight a clear relation between the geographical location and the typical excited frequencies in a set of 4 bands, named here as A (∼7-8 min, typical of Tarifa harbour), B (∼11-14 min, Algeciras and Ceuta), C (∼17-21 min, Algeciras), and D (∼23-27 min, less clear than the rest) bands.

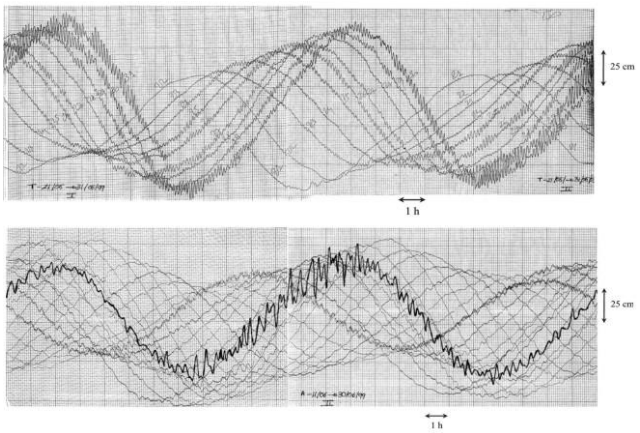

Fig. 1. Upper plot: tide gauge record in Tarifa from 21 to 31 of May, 1999. SPOs of large amplitude are present the 30 and 31 of May although they are observed from 25 of May. Lower panel shows the tide gauge record in Algeciras from 11 to 30 of June, 1999. The thick line remarks the observations on June 28, when SPOs of considerable amplitude were registered.

The selective frequency response at the different harbours, suggest that observed SPOs are a very local phenomenon, basically an excitation of the normal modes of the different harbours. The resonant modes have been calculated using a model that solves the two-dimensional periodic linear barotropic equations of continuity and moment (depth averaged-shallow water equations), without friction nor rotation [2, 3]. Boundary conditions are: 1) no flow in the solid boundary, 2) no oscillation in the harbour's mouth (open boundary) [4]. The proposed harbour resonance explanation for the SPOs is quite satisfactory for the A frequency band at Tarifa and the B band at Ceuta and Algeciras. However, C and D band at Algeciras, are not properly modelled.

Despite the fact of a different frequency response at Tarifa than at the other two ports, we have found that the SPOs appear often simultaneously at the three ports. A straightforward calculation shows that half-wave stationary oscillations between North and South coasts (L∼15km) would produce SPOs of O(10min) for a bottom depth of H∼400m, in the same range that the observed and modeled SPOs. The most probable mechanism would be some type of atmospheric disturbances that would excite sea level oscillations (at least) all over the Strait (at regional scale), which themselves would produce sea level co-oscillations within the harbours whenever the fundamental periods of both systems match (resonant mechanism).

The possible normal modes of oscillation in the regional domain have been constructed applying the former barotropic port's model to the geometry of the Strait with opened contours located at different distances [5]. The model found a set of normal modes: the higher periods ones (T>18min) fit with observed modes of the bay of Algeciras (generating SPOs in the bands C and D) whereas the lower periods (<14min) fit with normal oscillations modes of the Strait. These, in turn, are subdivided in normal oscillations of the broadest Eastern part (T>10min) and normal oscillations of the section of minimal width (T<10min), just in the frequency range capable to excite harbours SPOs at B and A bands, respectively.

The similar frequency ranges of the regional and local normal modes is the key factor in the process. A coupled model of regional SPOs-port resonances produces a profit that depends on model's friction. For reasonable values, the amplification factor ranges between 5 and 10. This is sufficient to justify the observations if the regional SPOs are O(1cm), which only happens if these in turn are generated by periodic pressure disturbances or synthetic atmospheric disturbances with energetic content in the high frequency.

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