HIGH-FREQUENCY SEA LEVEL OSCILLATIONS OBSERVED AND MODELLED IN THE SPLIT HARBOUR (ADRIATIC SEA)

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Abstract

The paper deals with the high-frequency analysis based on the data of pressure gauge located in the Split harbour, collecting the data of sea and air pressure. The analysis included the spectral analysis and filtering, revealing harbour seiches having periods of 6.5, 3.0, 2.2, 1.6 and 1.15 min. The seiches were modelled and verified numerically. Furthermore, a strong peak was found on period of 11.9 min of air pressure data, highly correlated to the sea pressure with phase lag of about 90o and gain of about 14 cm/hPa.

Keywords: Adriatic Sea, sea level, atmospheric input

Introduction

The seiches in harbours and small basins can be of high importance when the ships are entering there, as they can produce a rather strong currents and large sea level displacements [1]. In the Adriatic, the investigations of seiches in small basing started early in the century [2], and periods of oscillation were estimated for a great part of the basin where tide-gauges were mounted [3]. Moreover, an extreme strong events were observed in some parts of the Mediterranean [4,5] and Adriatic [6], as a consequence of resonant air pressure forcing on sea levels near seiche period, so-called Proudman resonance [6], having sea-level amplitudes up to 3 m and producing and extreme damages on the infrastructure affected by the event.

Data and methods

Dataset analyzed in this paper is collected in the period August-October 2000, comprising air and sea pressure measured at the tide gauge placed near the entrance of the harbour within MedGLOSS project. Air pressure is measured every 2 minutes, whereas bottom pressure data resolution is 0.5 minutes. In addition, sea-level data measured at the old float-type tide gauge will be examined, as it is positioned far from the harbour entrance.

The methods of analysis applied here include spectral analysis [7] (40 degrees of freedom) in order to visualize energy peaks related to the seiche and other oscillatory movements in the harbour, high and band pass filtering on the resonance frequency (11.9 min), and finally analytical and numerical 2D barotropic modelling of the harbour seiches. The modelling is done by applying backward-forward numerical procedure and by assuming zero sea level displacement at the entrance of the harbour and zero horizontal velocity on the side walls.

Results

Power spectra, both of the bottom and air pressure, are given in Fig 1 (periods higher than 4 min). A number of energy peaks can be seen in the frequency range between 0.04 and 0.12 min^{-1} (8.3 and 25 min), but its origin cannot be precisely defined: they can belong to resonant oscillation forced by air pressure or to the seiches of some wider area. The first mode occurs at a period of 6.6 min, but with no strong energy as the tide gauge is positioned near the entrance of the harbour (nodal line). Higher modes can be detected on periods of 3.0, 2.2, 1.6 and 1.15 min, revealing higher seiche modes of the whole harbour or oscillation of some parts of the harbour. Applying 2D barotropic model on the harbour, the theoretical period of the uninodal seiche is calculated to be 7.3 min during the low tide, but it falls to 6.9 min when adding 0.7 m (tide + storm surge) on sea level in the harbour. Higher theoretical modes can be traced on periods of 5.1, 3.1, 2.2, 1.64 and 1.24 min, thus they reproduce the empirical period well.

An interesting peak can be traced both on the air and sea pressure spectra on frequency of 0.084 1/min (11.9 min). Thus, an intense oscillatory movement occurred in the atmosphere forcing sea level to oscillate, during the storm passage on 31 August / 1 September 2000. Gain between air and sea is –14 cm/hPa. Fortunately, the resonant oscillation was not placed in the frequency area with high energies, thus, no strong oscillation occurred in the harbour. Maximum amplitude of air and sea pressure can be estimated to be 0.3 hPa and 0.45 dbar (4.5 cm) by applying very narrow band-pass filter. Nevertheless, if the resonant movement occurs on the seiche or near-seiche periods, resulting sea level amplitude can rise enormously, as happened in a number of places [4,5] such as Vela Luka Bay [6], where the resonance appeared with maximum sea level amplitude of about 3 m.

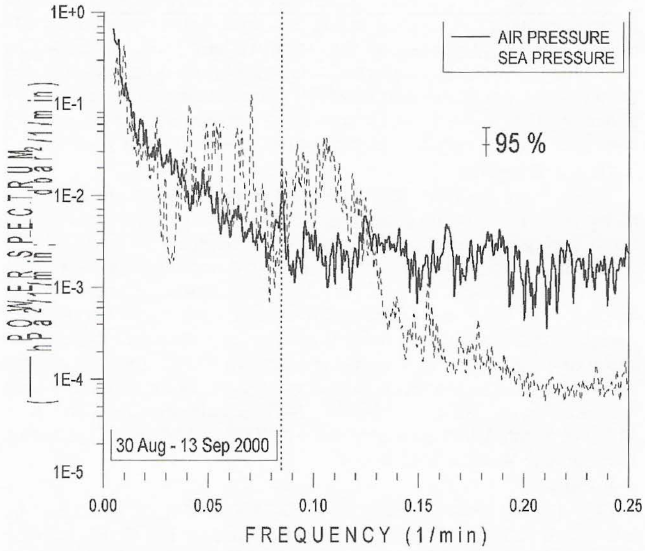

Figure 1: Power spectra of the air and sea pressure measured on the MedGLOSS tide gauge.

References

1 - Wu J., Tsanis I.K. and Chiocchio F., 1996. Observed currents and water levels in Hamilton harbour. *Journal of Great Lakes Research*, 22, 2: 224-240.

2 - Sterneck R.v., 1914. Ueber "Seiches" an den Kuesten der Adria. *Sitzungberichte der Kaiserliche Akademie der Wissenschaften*, Wien, Iia/123: 2199-2232.

3 - Vilibic I. And Orlic M., 1999. Surface seiche and internal Kelvin waves observed off Zadar (East Adriatic). *Estuarine, Coastal and Shelf Science*, 48: 125-136.

4 - Candela Perez J., Mazzola S., Sammari C., Limeburner R., Lozano C.J., Patti B. and Bonano A., 1999. The "Mad Sea" phenomenon in the Strait of Sicily. *Journal of Physical Oceanography*, 29: 2210-2231.

5 - Gomis D., Monserrat S. and Tintore J., 1993. Pressure-forced seiches of large amplitude in inlets of the Balearic Islands. *Journal of Geophysical Research*, C98, 14437-14445.

6 - Orlic M., 1980. About a possible occurrence of the Proudman resonance in the Adriatic. *Thalassia Jugoslavica*, 16, 1: 79-88.

7 - Jenkins G.M. and Watts, D.G., 1968. *Spectral Analysis and Its Applications*, Holden Day, New York, 532 pp.