THE NATURE OF EXTRAORDINARY TSUNAMI-LIKE OSCILLATIONS OBSERVED ON ISLAND OF IST (ADRIATIC SEA)

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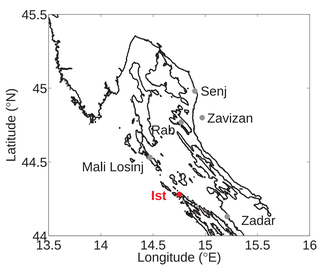
ABSTRACT

Destructive sea waves, with crest-to-trough heights surpassing 4 m, stroke funnel-shaped Široka Bay on island of Ist in the afternoon hours of 22 August 2007, causing significant material damage and injuring one tourist. Synoptic and mesoscale meteorological situation leading to these extreme sea-level oscillations is thoroughly examined. Air-pressure records from the surrounding meteorological stations reveal the presence of an abrupt pressure drop (4 hPa/12 min) propagating over the coastal northern Adriatic toward east with a speed of 20 - 24 m/s at the time of occurrence of destructive ocean waves. The air-pressure spectra indicate a substantial increase in energy at all frequencies during the passage of the disturbance. It is hypothesized that the air pressure disturbance generated barotropic ocean waves at the 50 - 70 m deep and about 200 km wide shelf through the Proudman resonance, and that these waves were additionally amplified upon hitting coastal areas and intensified to a destructive level by the harbour resonance.

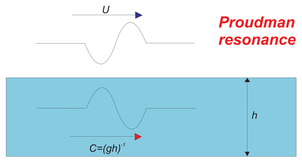
1. THE EVENT



Geographical location of the investigated area. Grey circles mark meteorological stations, and red circle marks Široka Bay on island of Ist.

Ship run aground as a consequence of tsunami-like sea oscillations.

2. GENERATION MECHANISM (E.g. Orlić, 1980; Vilibić et al., 2003)

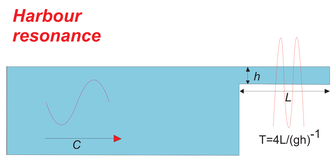


a) Proudman resonance

Resonant transfer of energy between air pressure disturbance propagating with speed U and open sea wave propagating with speed $C = (gh)^{-1} = U$.

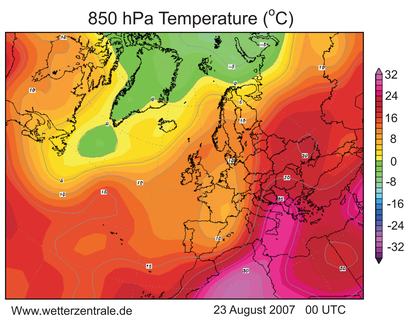
b) Harbour resonance

Resonant transfer of energy between open sea wave and internal harbour oscillations. Dominant frequency of open sea wave should be equal to internal harbour oscillations frequency.

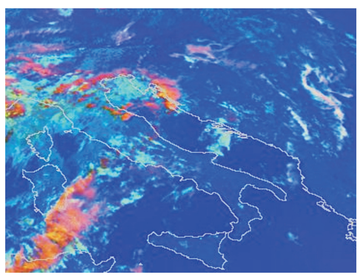


3. METEOROLOGICAL SITUATION

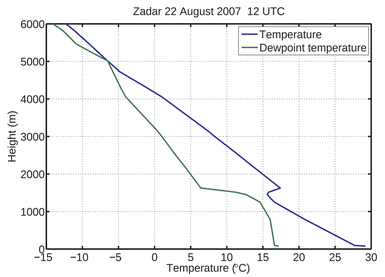
Favourable conditions for generation and propagation of air pressure disturbances (as described by e.g. Belušić et al. (2007), Vilibić et al. (2008)) existed in the atmosphere on 22 August 2007.



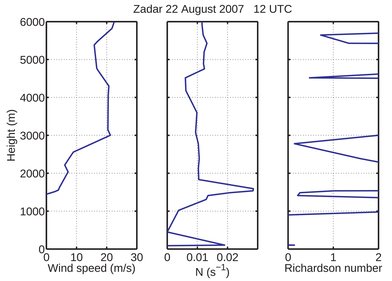
Temperature distribution on 850 hPa surface on 23 August 2007 at 00 UTC. While very warm African air mass spread into east Europe, maritime air mass advected into western Mediterranean over France, resulting in development of broad frontal zone over investigated area.



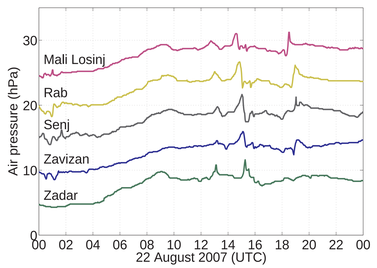
Convective cloud activity satellite imagery (source: EUMETSAT) taken at 14:42 UTC on 22 August 2007. Imagery shows presence of convective clouds and frontal zone clouds over the area of interest shortly before the occurrence of destructive sea-level oscillations. Frontal zone instabilities and convective clouds are known to be a source of air-pressure disturbances.



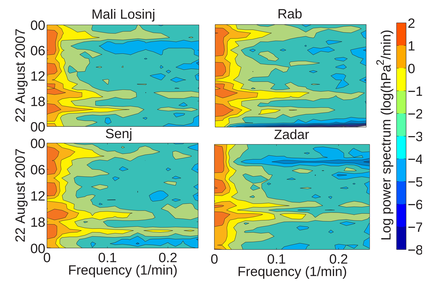
Upper air soundings at Zadar station containing temperature and dewpoint temperature. Strong inversion around 850 hPa depicting inflow of warm African air is clearly visible.



Upper air soundings at Zadar station containing western component of wind speed, Brunt-Väisälä frequency and Richardson number. Level around 3000 m with wind speed of around 20 m/s, small Brunt-Väisälä frequency and Richardson number smaller than 0.25 is favourable for trapping of atmospheric pressure disturbances.



Air pressure time series measured at Mali Lošinj, Rab, Senj, Zavižan and Zadar meteorological stations with analogue barographs and digitized with a 2 min interval. Series show propagation of two distinct air pressure disturbances of which the first one passed over Adriatic Sea shortly before extreme sea-level oscillations on island of Ist were observed. Speed and direction of the first atmospheric disturbance were calculated to be, respectively, c = 20 - 24 m/s and γ =260 - 274°. Speed of propagation is favourable for occurrence of Proudman resonance between atmospheric disturbance and open ocean waves at a nearby 50 - 70 m deep shelf.



Power spectra of the high-frequency component of the air pressure oscillations (with the cut-off period of 12 h) measured at Mali Lošinj, Rab, Senj and Zadar meteorological stations for the two hours intervals shifted in time using FFT with two hann windows of 1.5 hour widths. During the passage of the first air pressure disturbance, energies of oscillations are increased up to frequencies of 0.15 min^{-1} (periods of ~ 6.5 min), closely corresponding to the Široka Bay eigenperiod (between 5 - 7 min) and therefore allowing for the development of the harbour resonance and extreme sea-level oscillations.

References

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