The influence of climate change on the Adriatic Sea meteotsunamis

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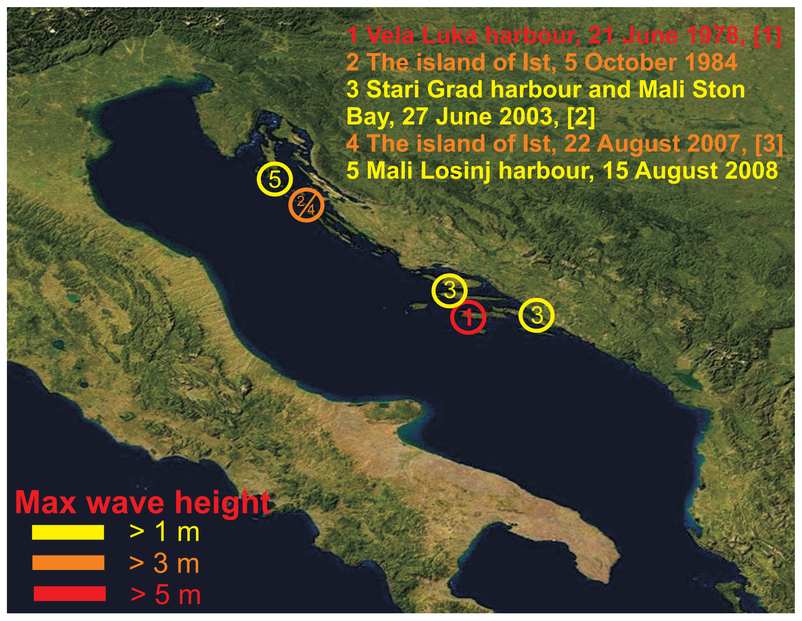
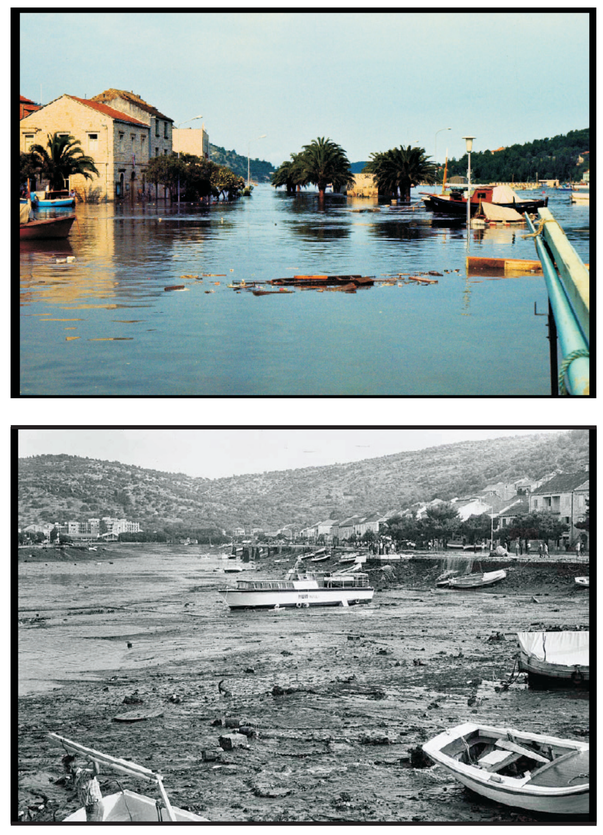
ABSTRACT

Throughout last three decades several eastern Adriatic harbours have been struck by extreme sea-level oscillations having crest-to-trough heights up to 6 m and periods of between few and tens of minutes. Those devastating events are provoked by propagating air pressure disturbances, and are also known as meteotsunamis. In order for meteotsunami to occur, air pressure disturbances must have applicable speed, direction of propagation and high temporal gradient. They should also be non-dispersive and long-lived. These conditions are very restrictive, and nowadays Adriatic meteotsunamis are quite rare. However, anticipated climate change might dramatically increase frequency of meteotsunamis occurrence. A boost of meteotsunamis is expected to follow from the sea-level rise, as the amplitude of sea oscillations able to cause significant damage will then become lower. Furthermore, it's hypothesised that projected increase of extreme events will also be reflected in enhanced convective activity above the Adriatic Sea and consequently in amplification of destructive sea-level oscillations. Namely, air pressure disturbances that generate meteotsunamis usually occur in the summer time and are mostly related to convective cloudiness and heating processes. As a result of climate change, more of these pressure disturbances could be generated in the atmosphere, and subsequently more of the meteotsunamis could happen.

1. The Adriatic Sea meteotsunamis



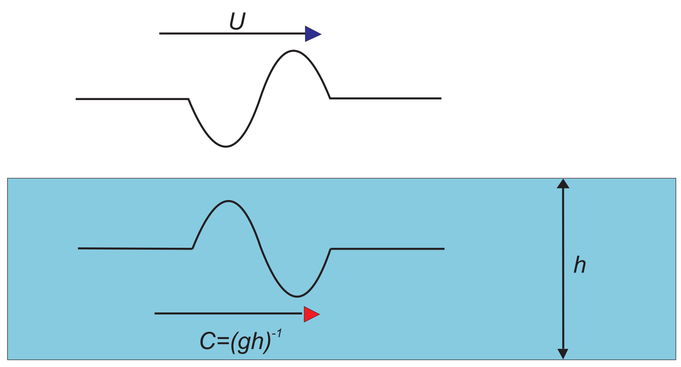
The Adriatic Sea meteotsunamis observed during the last 30 years. Meteotsunamis have been observed both in the northern and middle Adriatic. Three significant events in the last decade might indicate increase in the meteotsunami appearance frequency.



Photographs taken in Vela Luka harbour on the island of Korčula during the meteotsunami of 1978. Upper photography shows the harbour during water ascend, and lower during descent. The period of the waves was around 20 min and maximum crest-to-through height was around 6 m.

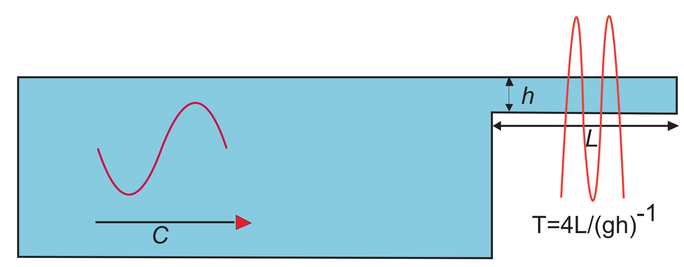
1. Meteotsunami generating mechanism

Proudman resonance

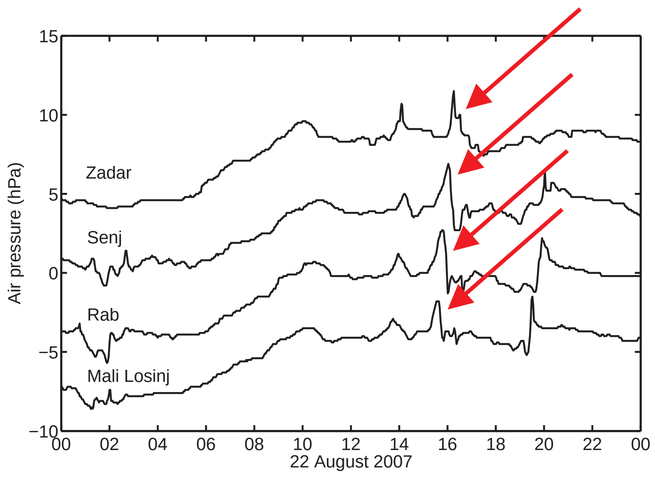


Resonant transfer of energy between air pressure disturbance propagating with the speed U and open sea wave propagating with the speed $C = (gh)^{-1} = U$. The air pressure disturbance should have high temporal gradient and be long-lived to sufficiently transfer the energy to the open sea waves.

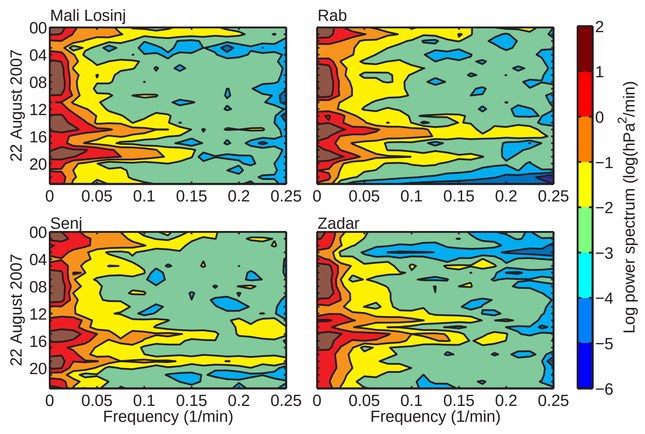
Harbour resonance



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

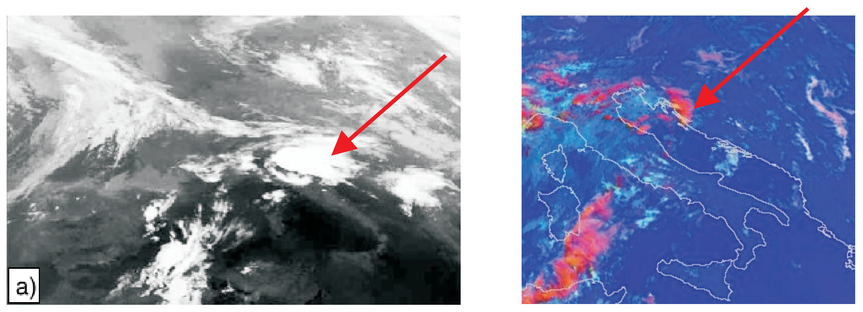


Air pressure time series measured on 22 August 2007 at the stations surrounding the Island of Ist [3]. Red arrows point to a pronounced and long-lived disturbance that provoked the meteotsunami.

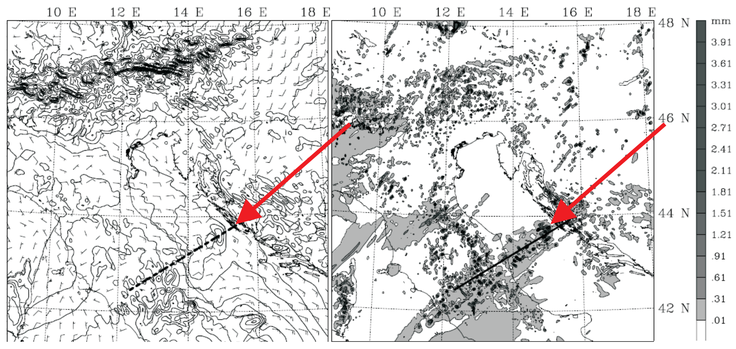


Time-running power spectra of high frequency component of air pressure oscillations (with cut-off period of 4h) on 22 August 2007, measured at the meteorological stations surrounding the Island of Ist [3]. As a result of a passage of the pronounced pressure disturbance around 15 CET energy increased on periods including those of the flooded bay on the Island of Ist.

2. Sources of the Adriatic meteotsunamis



Convective clouds associated with the Adriatic Sea meteotsunamis. On the left is IR satellite image taken at 00 UTC on 27 June 2003 [4]. Pressure disturbance maintained through the Wave-CISK mechanism in the cloud at which the red arrow points provoked the meteotsunami of the Stari Grad harbour and Mali Ston Bay. On the right is a satellite image taken at 1457 UTC on 22 August 2007 (source: EUMETSAT). Air pressure disturbance that caused the meteotsunami on the island of Ist was closely related to the cloud pointed to with the red arrow. Flood of Mali Lošinj on 15 August 2008 was, as well, preceded by a passage of a thunderstorm cloud above the Adriatic Sea.



Modelled sea level pressure (on the left) and modelled column integrated cloud water (on the right) at 1512 UTC on 22 August 2007 [3]. Arrows point to the pressure/cloud disturbance that provoked meteotsunami on the island of Ist. Modelling was done with the Weather Research and Forecast model.

CONCLUSIONS

- The Adriatic Sea meteotsunamis can be highly destructive.
- Air pressure disturbances that cause the Adriatic Sea meteotsunamis have been mainly related to the convective clouds generated at the Alps or the Apennines.
- **Increased number of extreme events and convective events due to climate change might lead to increased number of destructive meteotsunamis.**
- Due to projected sea-level rise, meteotsunamis with smaller amplitudes might cause more damage.

References:

[1] Orllić, M. (1980), About a possible occurrence of the Proudman resonance in the Adriatic, *Thalassia Jugoslavica, 16*(1), 79-88.
[2] Vilibić, I., N. Domijan, M. Orlić, N. Leder, and M. Pasarić (2004), Resonant coupling of a traveling air pressure disturbance with the east Adriatic coastal waters, *J. Geophys. Res., 109*, C10001, doi: 10.1029/2004JC002279.
[3] Šepić, J., I. Vilibić, and D. Belušić, The source of the 2007 Ist meteotsunami (Adriatic Sea), *submitted.*
[4] Belušić, D., B. Grisogono, and Z. B. Klaić (2007), Atmospheric origin of the devastating coupled air-sea event in the east Adriatic, *J. Geophys. Res., 112*, D17111, doi: 10.1029/2006JD008204.

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