Extreme coastal flooding on the eastern Adriatic coast on 28/29 October 2018 documented at I-STORMS project

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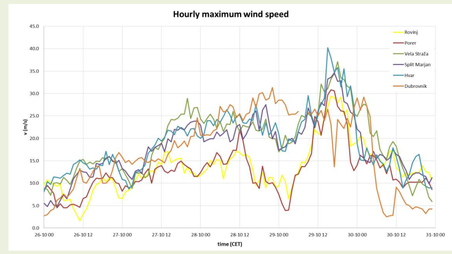
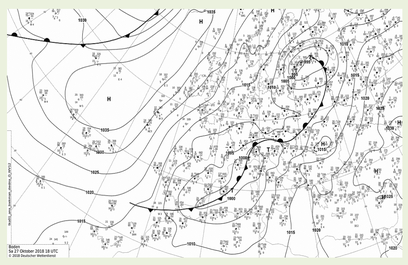
Introduction

Flooding induced by storm tides, high waves and meteotsunamis is the major coastal hazard. Within the framework of the I-STORMS (**Integrated Sea sTORm Management Strategies**) project we are aiming to identify the most vulnerable hotspots in the Adriatic-Ionian area and to design the catalogue of the sea flooding events. Reanalysis of the low frequency but high impact severe weather events is crucial for developing a risk reduction strategies and hazard maps. In this study we present the recent flooding event from the end of October 2018 when very high sea levels and waves were recorded along the Adriatic basin. The series of Mediterranean cyclones and the presence of the anticyclone eastern of the Adriatic sea determined a very strong zonal pressure gradient and favoured intense prevailing southeasterly winds. The funnelling of the wind between the mountain chains surrounding the Adriatic basin further increased the wind speed. Retrospective analysis by means of measurements on the stations along the Croatian eastern part of the Adriatic Sea is shown for this case of persistent strong and gale force southerly wind. During the 28th and 29th October, the precipitation was extreme only in some locations, the pressure minimum was not particularly deep, the peak gusts were between 25 and 40 m/s and the waves were exceptionally high. The wind, wave and sea level analysis for the city of Rovinj and Dubrovnik area is presented to highlight the differences between the deeper southern and very shallow northern part of Croatian coast, which is particularly vulnerable to high magnitude storm surges. The main reason for damaging high sea levels and waves was the first stage of the event on the 26th when jugo (southeasterly) wind started and generated the waves with significant height over 1 meter prior to the cyclone and associated cold front passage on the 29th October.

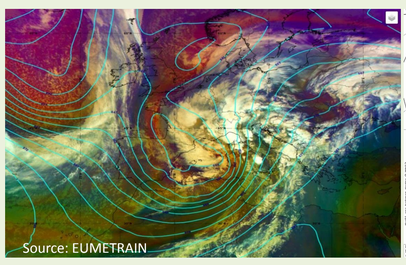


Synoptic overview and data analysis

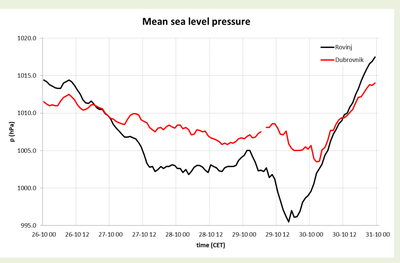


27th October, 18 UTC

- First shallow surface low was moving on 26-27th October northern of Italy, it was reabsorbed by a large system passing above central Europe; strong zonal gradient with anticyclone on the east (≈ 15hPa)
- simultaneously on the 27th October the new cyclogenesis started over the western Mediterranean and the new surface low was rapidly deepening while moving to the east; deep trough with cold air intrusion
- cyclone's maximum intensity was reached on 29th October with surface pressure around 980 hPa near Sardinia and then it followed a more northern unusual path; severe storms formed on the cold front



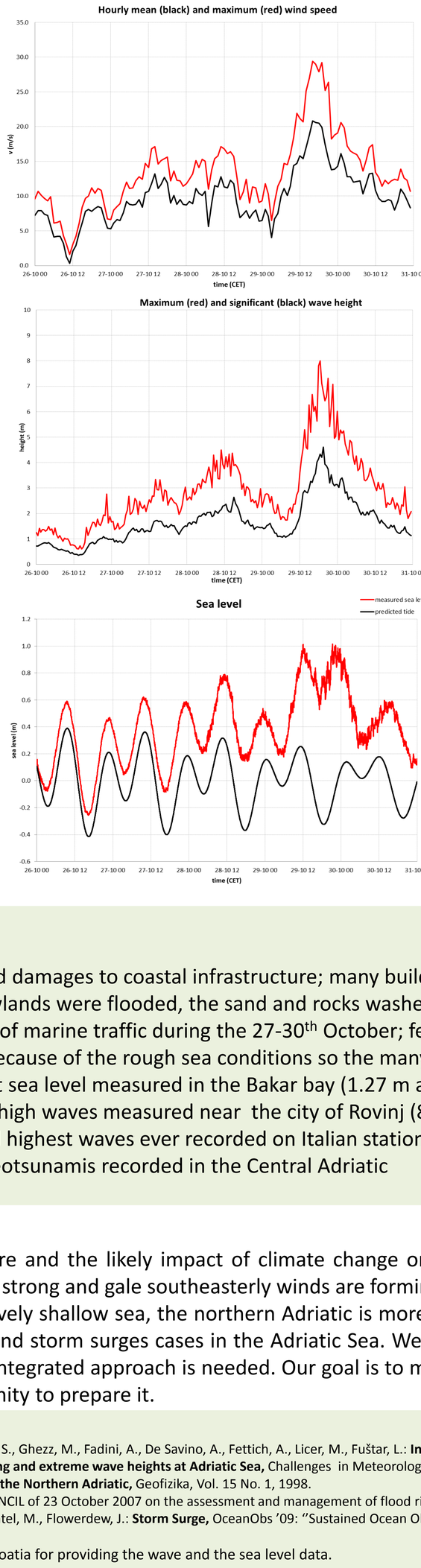
29th October, 12 UTC



26-30th October

Rovinj

- during the 26-28th October sustained SE winds of about 10 m/s build up waves with SWH>1 m
- short decrease in wind speed and change of direction to E while the new surface low was deepening
- sudden sharp increase in wind speed and wave heights with cyclone and the associated cold front rapidly approaching
- first maximum of the sea level (**1.01 m** above average) reached around the same time as the Acqua Alta happened in Venice
- during the frontal passage peak wind speed gusting up to **29.4 m/s** and highest wave height of **8.0 m** (SWH=**4.34 m**) was recorded which luckily coincided with the low tide, but still the sea level reached **1.73 m** over the predicted
- very rough sea (SWH>4 m) lasted **2.5 h**
- secondary maximum sea level (**1.02 m**) after the frontal passage when the wind and waves were decreasing, but the tide was rising (at 21:20 CET on 29th October reaching **1.17 m** over the predicted)



Dubrovnik

- during the 26-28th October steady increase of SE winds reaching peak values of average speed **22.6 m/s** with gusts up to **31.3 m/s** around 23 CET on the 28th that build up the highest wave of **9.03 m** (SWH=**4.11 m**) and the sea level of **0.20 m** above average which was **0.30 m** over predicted
- very rough sea (SWH>4 m) lasted **9.5 h**
- short decrease in wind speed and change of direction to ESE while the new surface low was deepening
- secondary maximum of wind speed ahead and during the frontal passage reaching around **29 m/s** between 00 and 03 CET on the 30th October coinciding with the half way up the rising tide, and the maximum sea level of **0.49 m** was recorded at 3:38 CET which exceeded by **0.49 m** the negative values that was predicted
- rough sea conditions (SWH>2.5 m) lasted **57 h**
- due to the deeper water, amplitudes and residuals sea levels are much lower as compared to those in the shallower northern Adriatic Sea

Impact

Opatija
(Credit: Nel Pavletić / Pixsell)

- widespread damages to coastal infrastructure; many buildings wrecked by pounding waves and seawalls heavily destroyed
- coastal lowlands were flooded, the sand and rocks washed onto shore roads and many boats sunken
- disruption of marine traffic during the 27-30th October; ferry service cancelled almost all of the scheduled sailings on 29th October because of the rough sea conditions so the many islands were cut off from the mainland for more than a day
- the highest sea level measured in the Bakar bay (1.27 m above average) and the fourth highest Acqua Alta in Venice (1.56 m)*
- extremely high waves measured near the city of Rovinj (8.0 m) and Dubrovnik (9.03 m)*
- the second highest waves ever recorded on Italian stations in the Adriatic sea*
- weak meteotsunamis recorded in the Central Adriatic

Promenade between Ičići and Ika
(Credit: Eduard Kišić / HR Radio Rijeka)

Conclusion*

The growing coastal population and infrastructure and the likely impact of climate change on the occurrence of extreme weather events and expected sea level rise, makes the coastal flooding a significant and increasing hazard. The long lasting strong and gale southeasterly winds are forming high waves in the Adriatic Sea and push the water in the same direction along the basin. Since the most pronounced storm surges generally arise in relatively shallow sea, the northern Adriatic is more prone to coastal flooding. The study of this recent event from October 2018 reveals that it had a similar synoptic pattern of the historical extreme wave and storm surges cases in the Adriatic Sea. We would like stress out that the reanalysis of the severe weather phenomena is crucial for risk assessment along the diverse Adriatic coastline and that the integrated approach is needed. Our goal is to make a series of region specific hindcast studies and the I-STORMS projects new Transnational Multi Model Ensemble System (TMES) will give us the opportunity to prepare it.

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Acknowledgments to the Hydrographic Institute of the Republic of Croatia for providing the wave and the sea level data.
*as of May 2019