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EXTREME EVENTS IN VENICE AND IN THE NORTH ADRIATIC SEA: 28-29 OCTOBER 2018

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Introduction

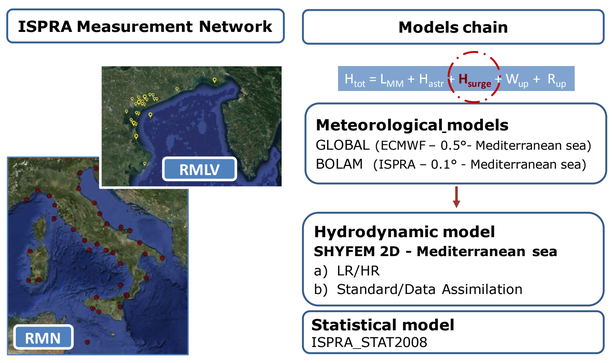
In the last century the city of Venice has seen an increase in the frequency and intensity of the flooding events that periodically submerge parts of the old city centre; during the 28-29 October 2018 Venice and the North Adriatic in particular, have been exposed to a marine extreme event due to severe weather conditions and dangerous consequences had to be faced as concerning the coastal risk as well as the hydrogeological one.

To be able to face these floodings and to manage their occurrence, it has been invested in the safeguarding of Venice through the planning and building of flood barriers, many other structural measures as well as through forecasting operational systems, measurement networks and extreme events research activities.

Data and Method

In this work it will be described the weather situation that led to the considered storm surge event and the sea level operational forecasting system developed by ISPRA.

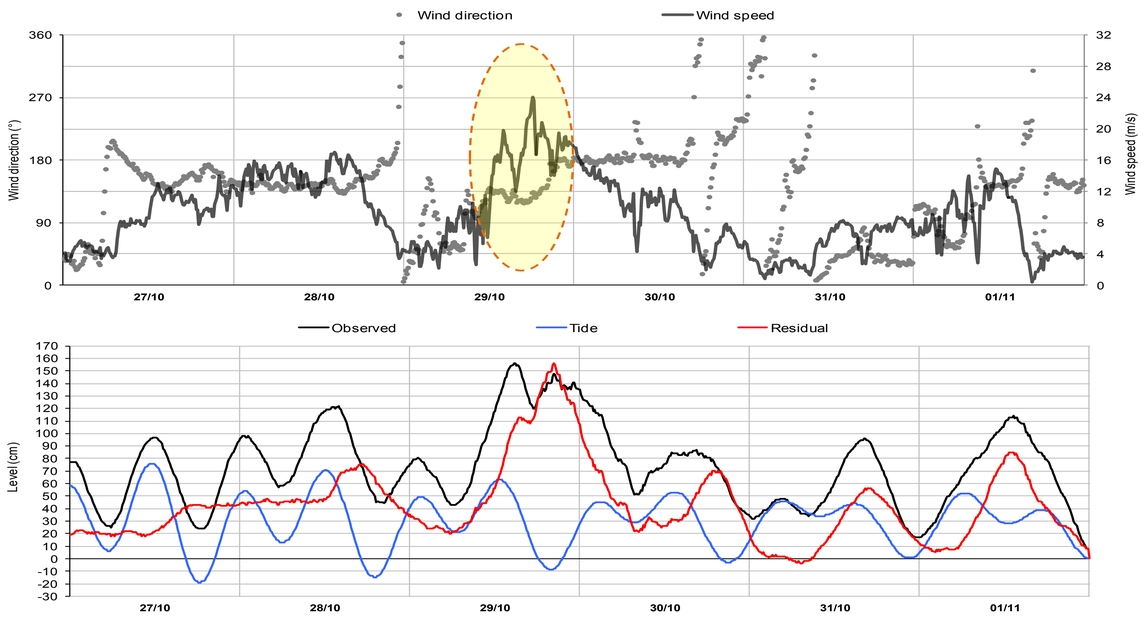
Moreover, in order to deal with extreme events and to characterize their rareness, a deep investigation of the longest time series recorded in Venice have been applied, pointing out information referred to return periods and return levels.



Observed data

Measured data have been used as for feeding the integrated operational system as well as for the analysis of sea level extreme events phenomena; data provided by tide gauges belonging to the ISPRA Sea Level Measurement Networks (RMN and RMLV) have been considered.

Atmospheric pressure and wind intensity have been analyzed; a very high *Scirocco* wind speed event (20-24 m/s) on the 29th October 2018 (yellow circle in the first figure), combined with a very high pressure gradient along the Adriatic Sea caused the sea level growth.



Measured wind (top), measured water level, astronomical tide and residual at Punta della Salute (bottom)

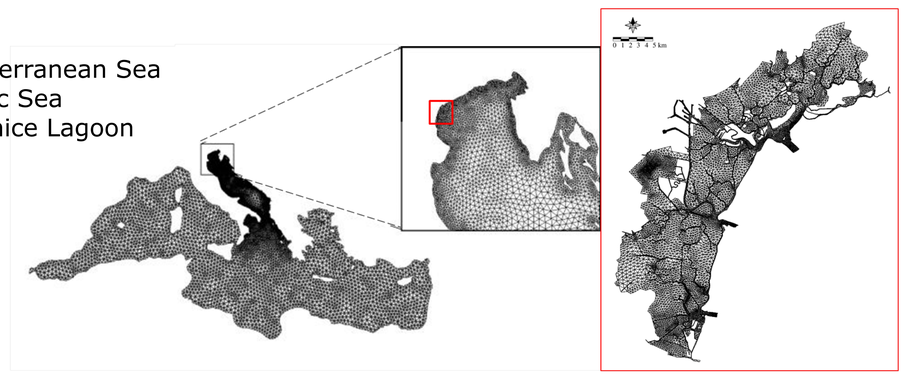
The highest values were reached on the 29th October during the maximum wind intensity; the peak recorded at Venice city centre at 2.40 p.m. was 156 cm as referred to the Zero Tide Level at Punta della Salute; this value is **the fifth highest case** of the time series starting from 1872 and about the 70% of the historical city centre was flooded for more than two hours. The highest meteorological contribution was exactly 156 cm in the evening.

Storm Surge Forecasting System

ISPRA developed an integrated operational forecasting system based on two different models in order to predict dangerous events and to manage their occurrence: a numerical model, SHYFEM, and a statistical one.

SHYFEM, developed at ISMAR-CNR, is an hydrodynamic model based on finite element method and used to compute the storm surge contribution under the action of atmospheric forcing fields in the Mediterranean Sea.

Grid resolutions
40 Km in the Mediterranean Sea
2 Km in the Adriatic Sea
~ 100 m in the Venice Lagoon



A data assimilation module based on the 4-D Physical Space Assimilation System was developed for integrating the residual sea level measurements from the tide-gauges of the ISPRA observation network located alongside the Adriatic coastline. The operational system produces therefore eight runs per day for all the locations of interest in the Venice Lagoon and in the northern Adriatic Sea.

Extreme events analysis

Peak Over Threshold Method and Generalized Pareto Distribution (POT-GPD)

The Generalized Pareto Distribution (GPD) model is a distribution characterized by parameters such as the scale parameter, the shape parameters and the location one. It could be fitted for independent observed extreme data over a high threshold; the threshold needs to be neither too high (to get enough observations) nor too low (not to take into account non-extreme values) and just maxima separated by 78 hours below the threshold have been chosen, in order to ensure extreme independence.

Generalized Extreme Values (GEV)

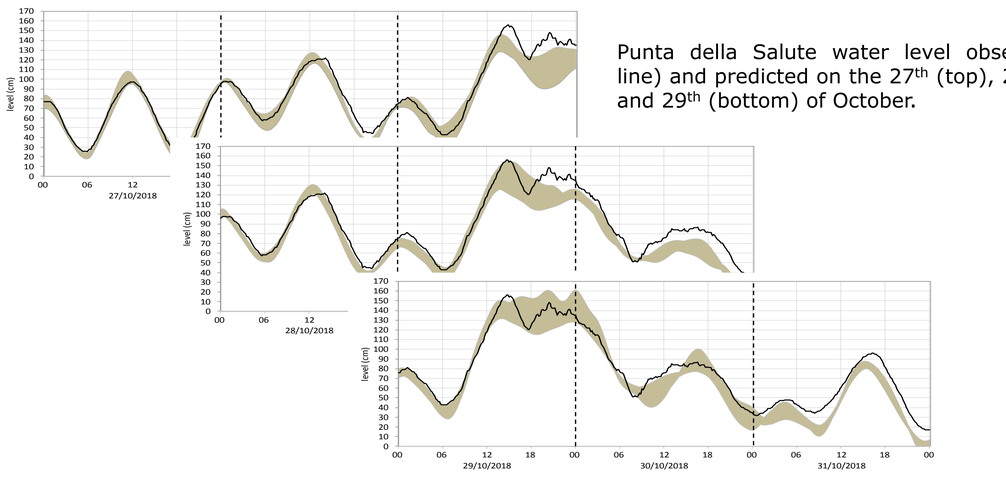
Similarly to the GPD, the Generalized Extreme Values model could be fitted for the annual maxima and it is specified by two parameters: the scale parameters and the shape one (Gumbel, Frechet, Weibull). Both models lead to the evaluation of return period and the related return level ranging from 1 to 100 years.

Results

The comparison between observed and forecasted sea level data at Punta della Salute shows that all models underestimate the real values 72h in advance, a good forecast for the peak of 156 cm 48h in advance, and a good prediction also for the second peak 24h in advance (panels from top to bottom in the figure). The colored area represents the min-max range calculated with all daily model runs: the wider the range is, the more different the predicted levels are.

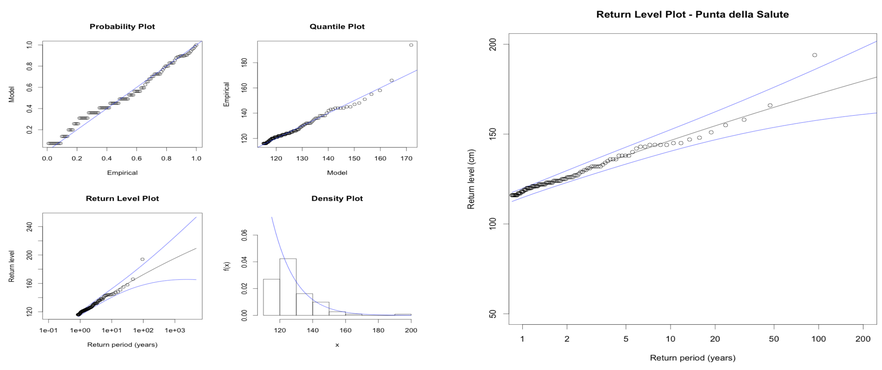
To evaluate the model performance, the mean error and the RMSE for each forecast lag (72, 48, 24 hours) were calculated. The models forced by the BOLAM meteo fields show:

- a better performance
- underestimation of the real water level 48h and 72h in advance
- overestimation in the last forecast, 24h in advance
- performance better than ever and better than ECMWF



Punta della Salute water level observed (black line) and predicted on the 27th (top), 28th (middle) and 29th (bottom) of October.

The very high sea level event occurred on the 29th October 2018, reached 156 cm at Punta della Salute. Extreme event analysis (GPD-POT and GEV) does not state a fully certainty of reality, but it's very useful to characterize exceptionality and rareness of an event on the basis of measured data. Many different locations have been considered and return periods and return levels evaluated. Some results:



Punta della Salute GPD-POT analysis (left panel), Punta della Salute return level and return period (right panel)

- the event corresponds moreover to a 20 years return period
- it has about 5% of chance of being exceeded in any one year (figure 4)
- the highest value ever measured (194 cm in 1966) is absolutely exceptional and out of the range of predictability, having a theoretical return period of almost 1000 years.

Conclusions

ISPRA developed and manages the described integrated forecasting system and applies in research activities, in order to monitor, analyse and forecast the physical state of the marine environment at short and medium range and to prevent and mitigate flooding, storm surge, tsunami and extreme wave events impacts and effects (Flood Directive 2007/60/EC).

These infrastructures, the monitoring systems and the operational one, open to all stakeholders, aims to share its potential with the scientific community as well as with the institutions responsible for environmental monitoring and defence, and that have to deal with the undesired effects associated with *acqua alta* (flooding of Venice) and that need to promptly react and take decisions. They represent a very useful tool to support the management of the marine environment and its resource, in particular regarding the coastal zone planning, protection and management, the assistance to many operational activities, the safety at the sea, the support to the navigation and to the mitigation and rescue actions.

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