Local and large-scale controls of the exceptional Venice floods of November 2019

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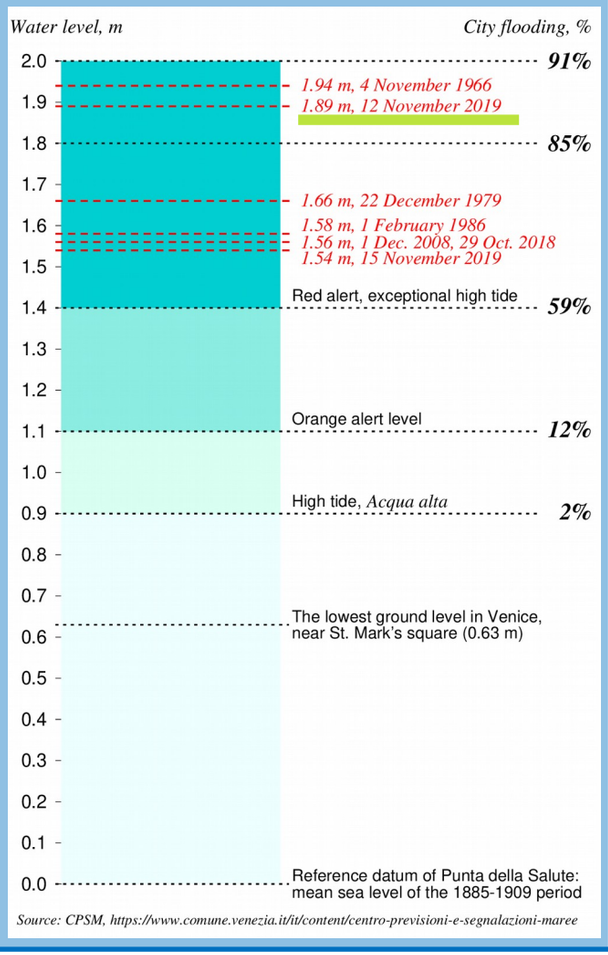
On the 12th November 2019, an **exceptional flood** event occurred in **Venice** (Northern Italy), second only to the one that occurred on November 4th, 1966. Moreover, with four extremely high tides since November 11th, this was the **worst week for flooding** in Venice since 1872 when official statistics were first produced.

Venice experienced something similar to what regular tides will be in the next decades with the forecasted **sea level rise**.

In this study, the large set of **available observations and high-resolution numerical simulations** were used to quantify the contribution of the different drivers on the peak flood event and to investigate the peculiar weather and sea conditions during the Venice's floods of November 2019.

Photo credit: Vera Mantengoli



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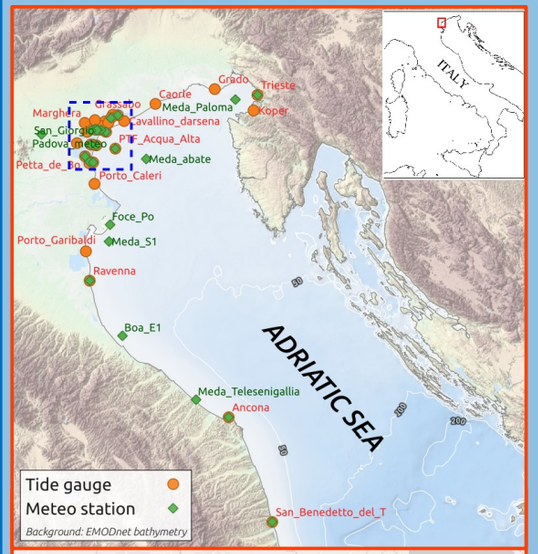
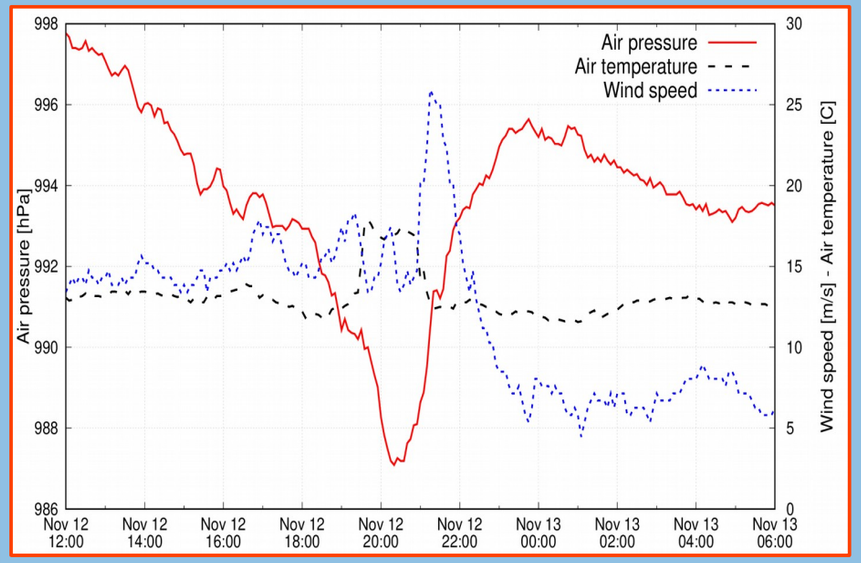
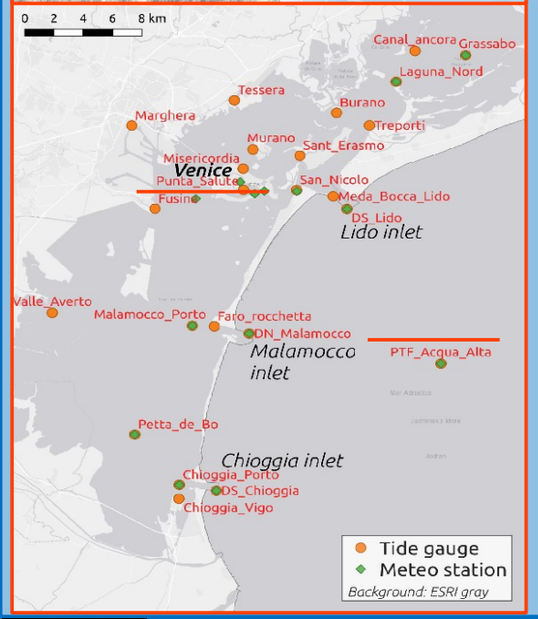
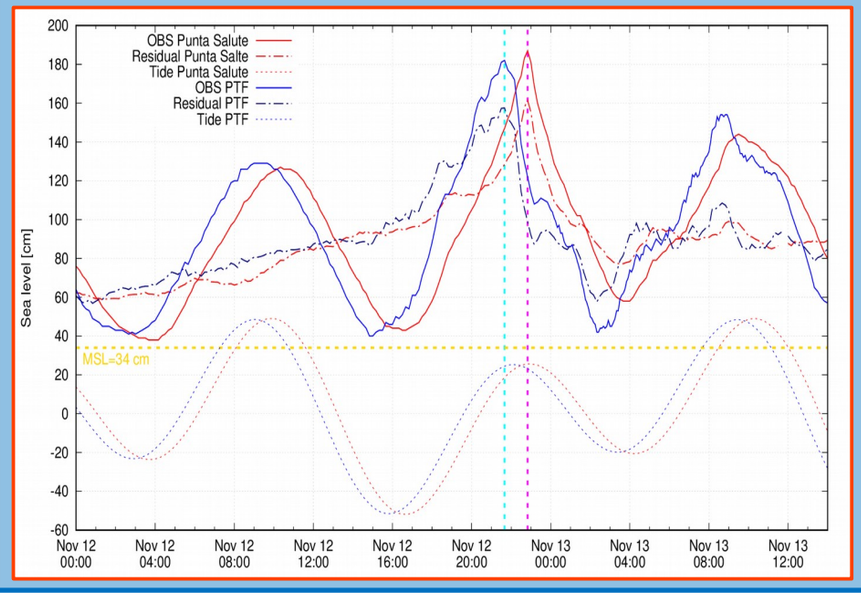
Evidences from observations

Meteo/marine monitoring networks

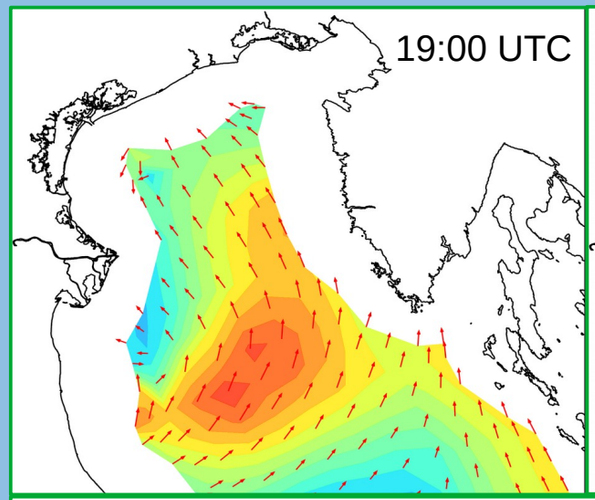


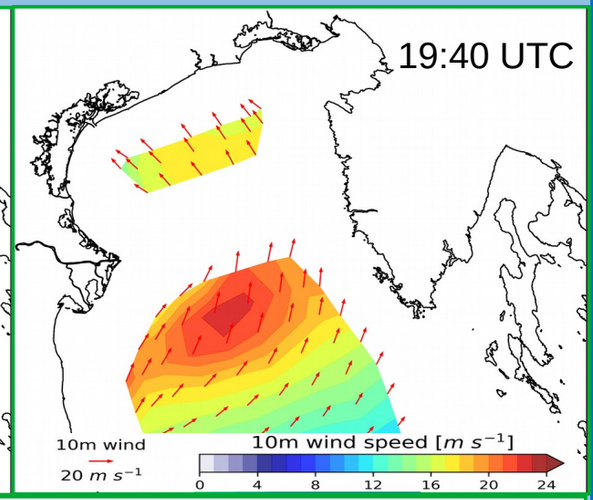


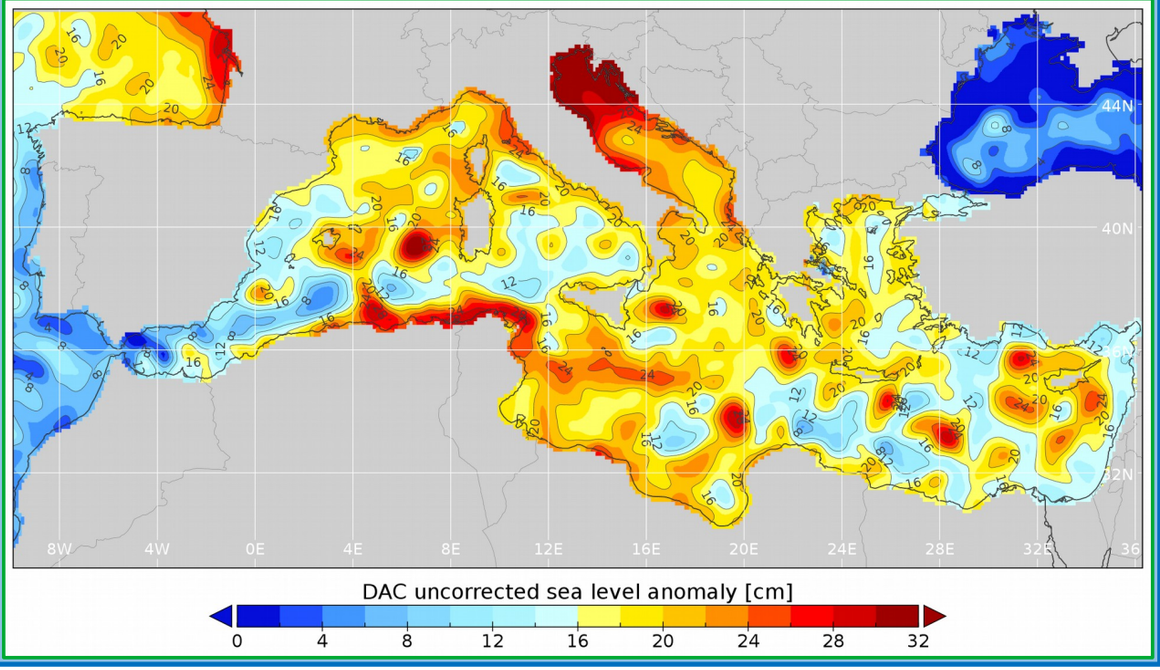




EO scatterometer and altimeter







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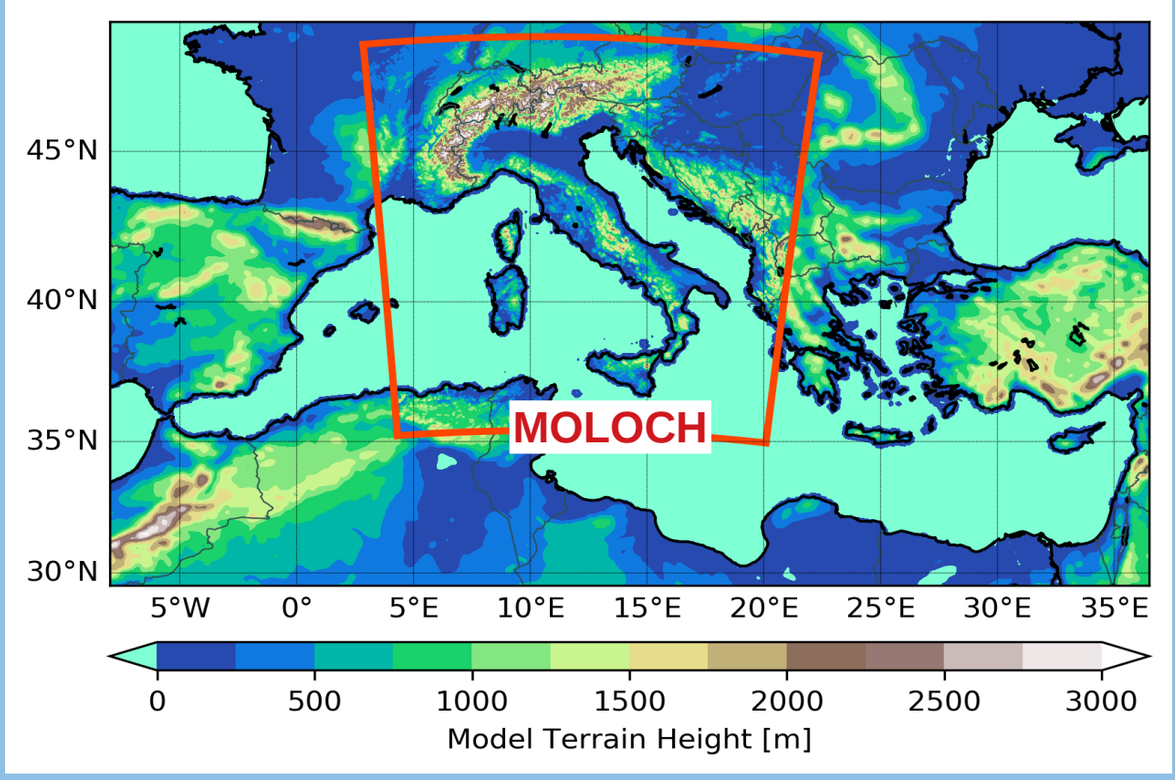
Modelling approach

Meteorological models

ERA5 reanalysis and dynamic **downscaling** using the **MOLOCH** non-hydrostatic high-resolution model (1.25 km). The model domain covers **Italy and nearby seas**.

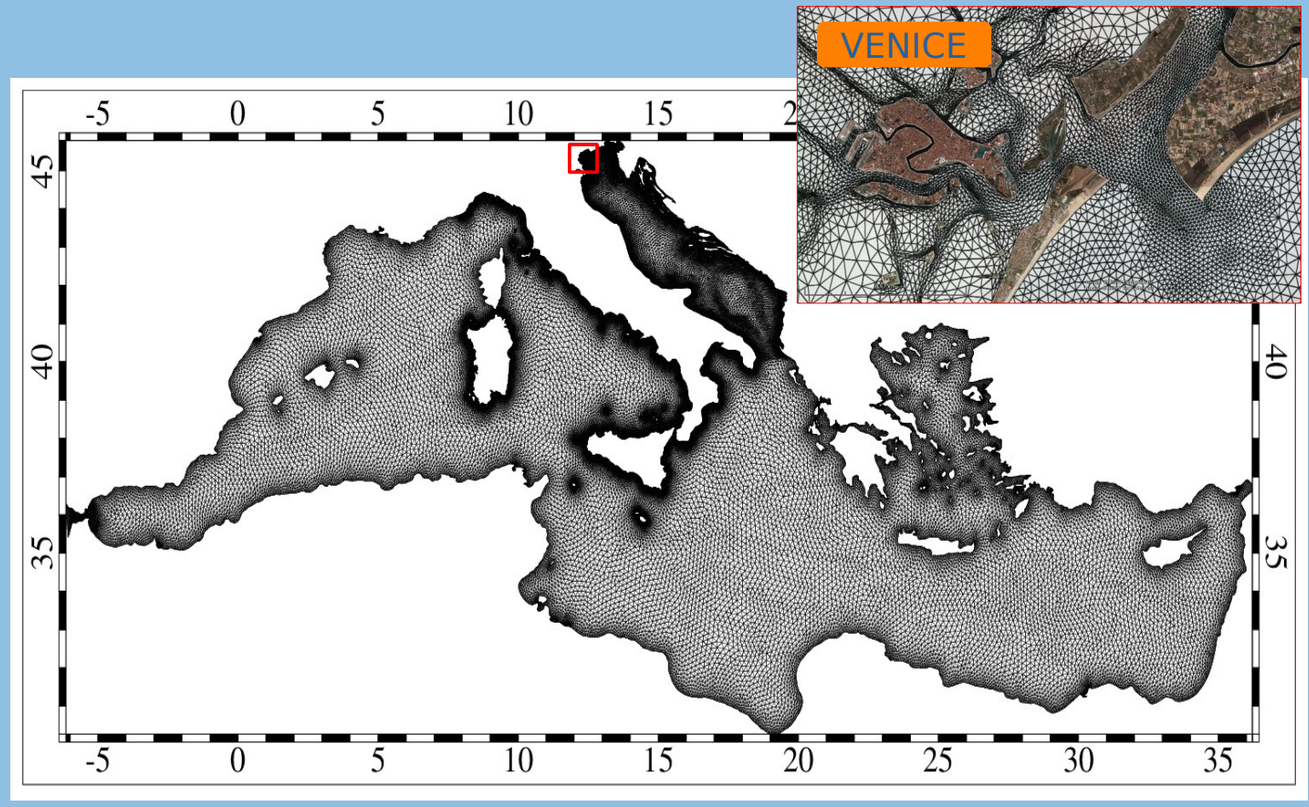
http://www.isac.cnr.it/dinamica/projects/forecasts



Hydrodynamic model

Storm surge simulation performed with **SHYFEM,** a 3D finite element hydrodynamic model. The model domain covers the **Mediterranean Sea** with very **high resolution** in the **Adriatic** and **Venice** Lagoon.

www.ismar.cnr.it/shyfem



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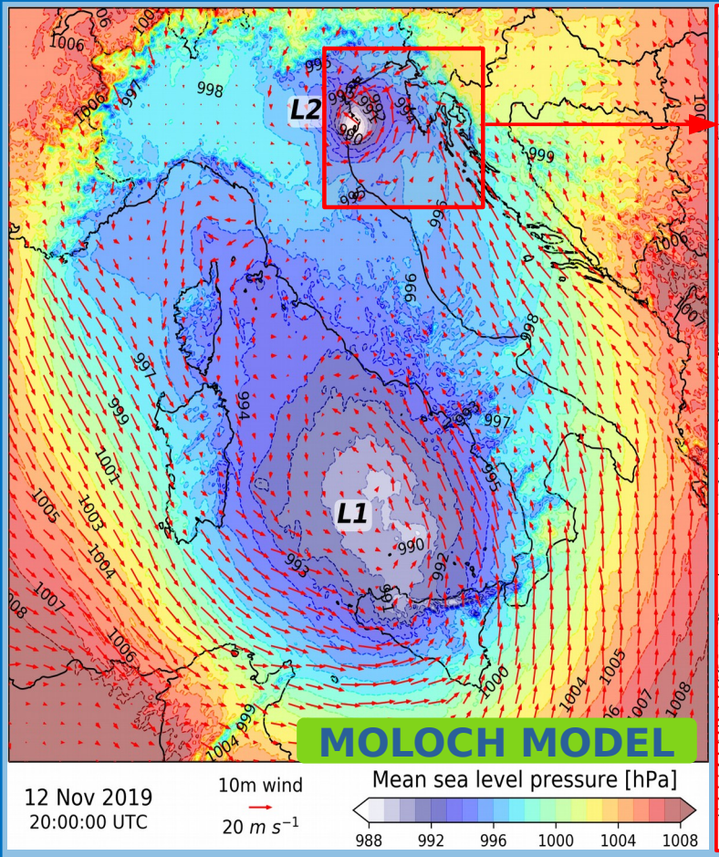
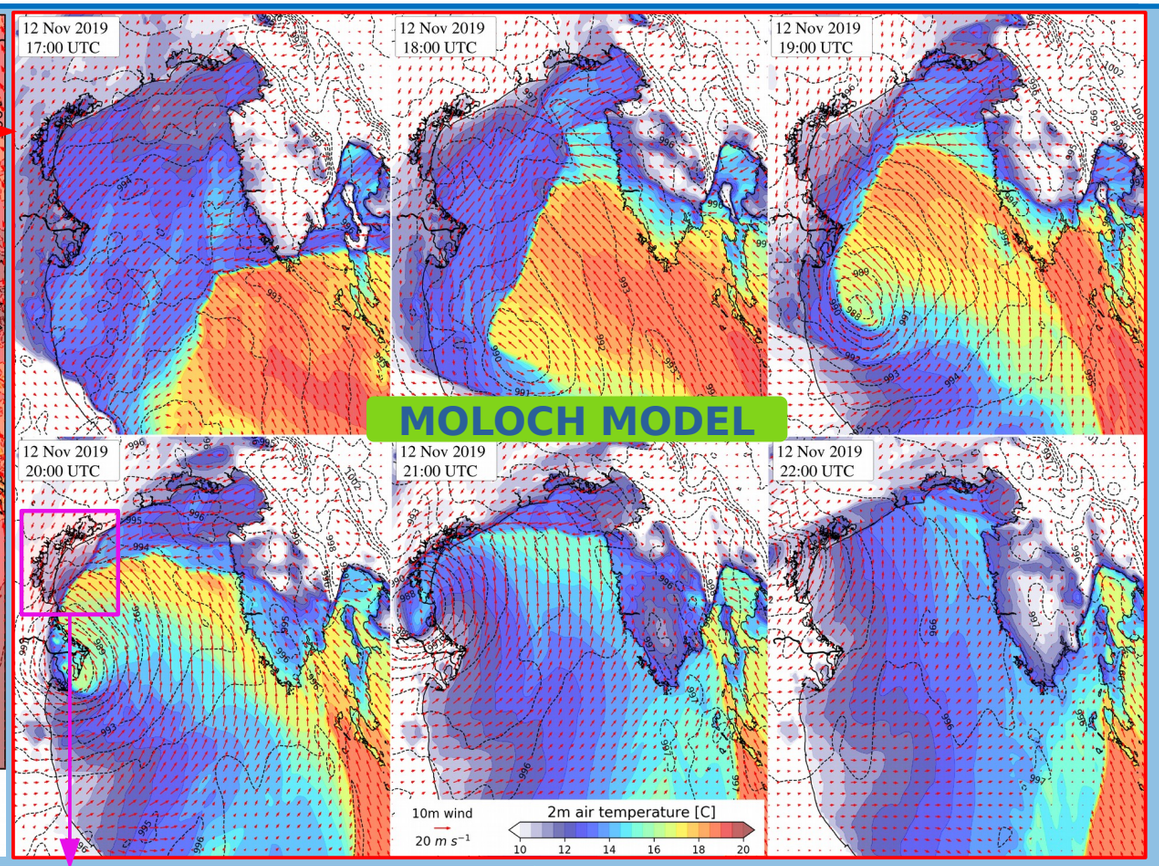
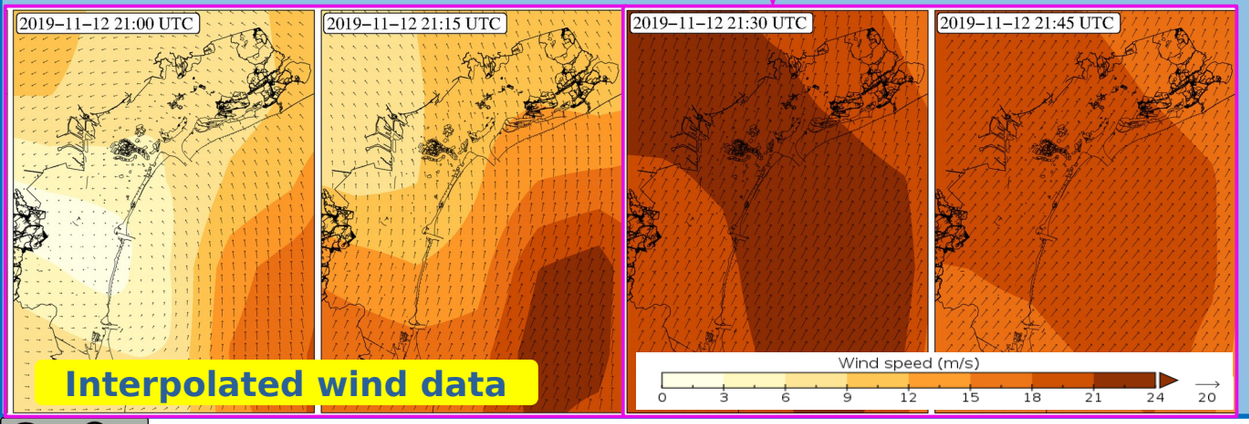
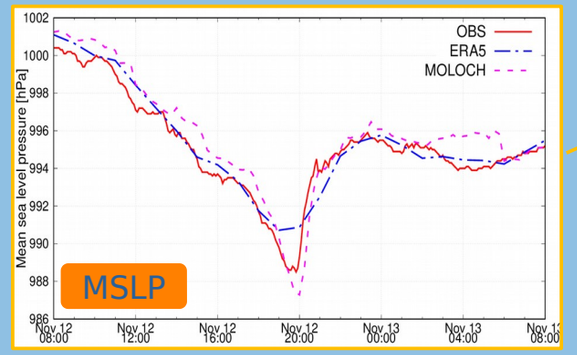
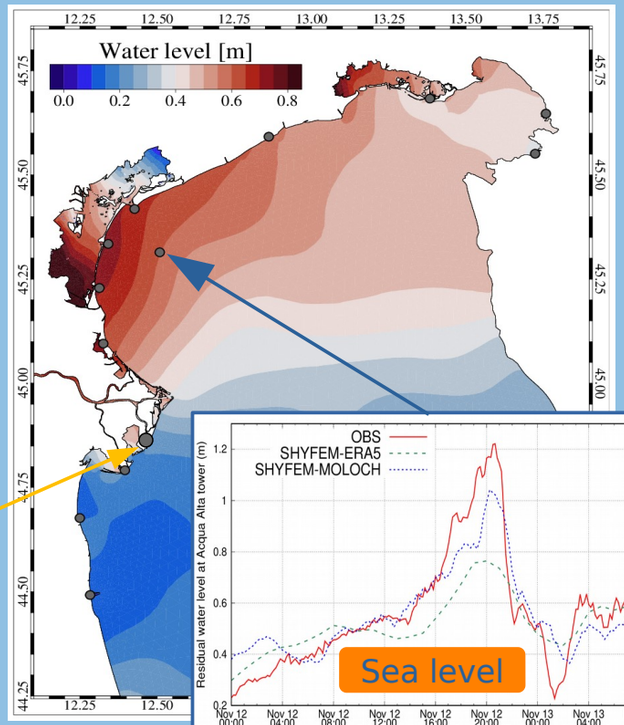
The storm evolution











A **deep low pressure system** over the central-southern Tyrrhenian Sea (**L1**), generated strong **Scirocco** (warm, south-easterly) winds in the Adriatic Sea, while **Bora** (cold, north-easterly) winds blew over NAD (northern Adriatic). In addition, NAD was affected by a **secondary vortex** (**L2**) fast moving along the east coast and generating strong sea level gradients.

MOLOCH better reproduces **L2** perturbation than ERA5, even if it slightly underestimates the intensity of the storm.

SHYFEM sea levels forced by **MOLOCH** are closer to OBS than the ones forced by ERA5.

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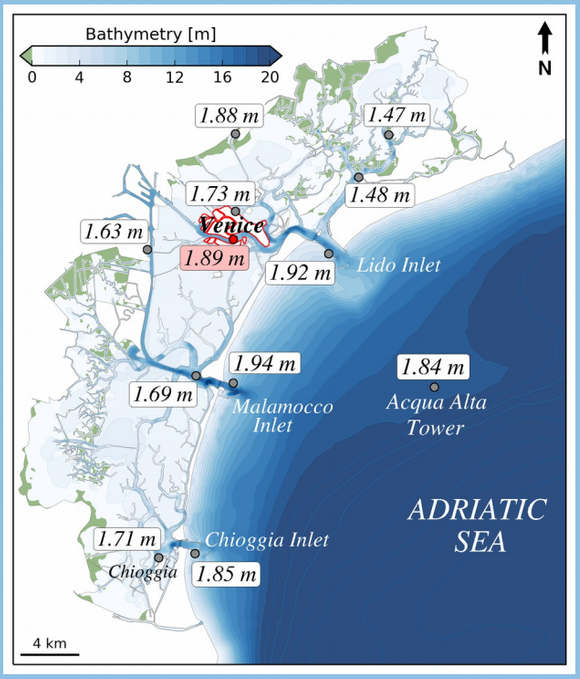
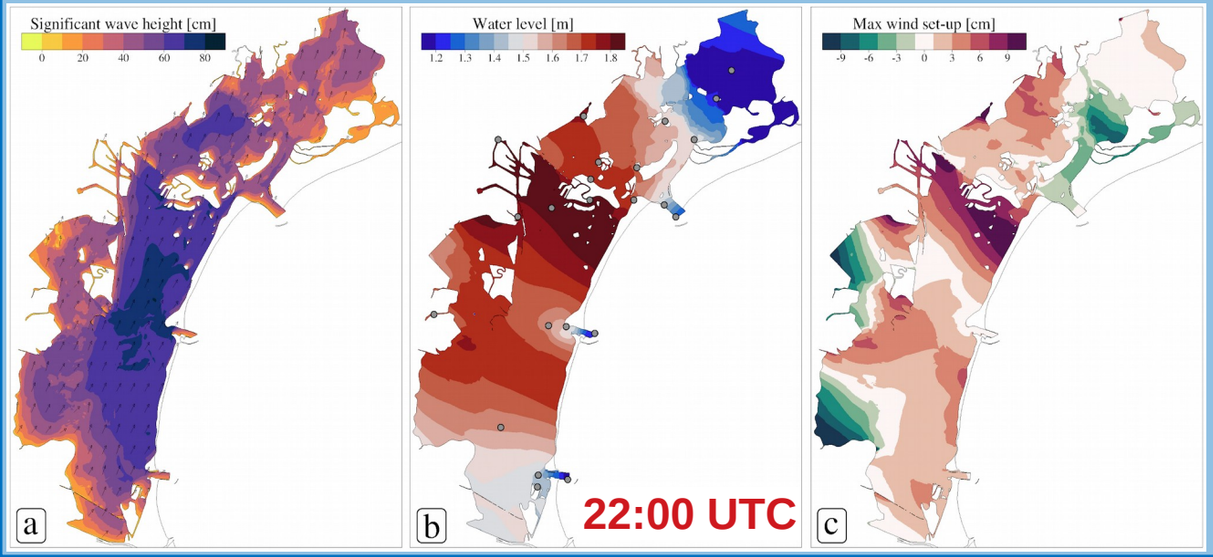
Local and large-scale controls



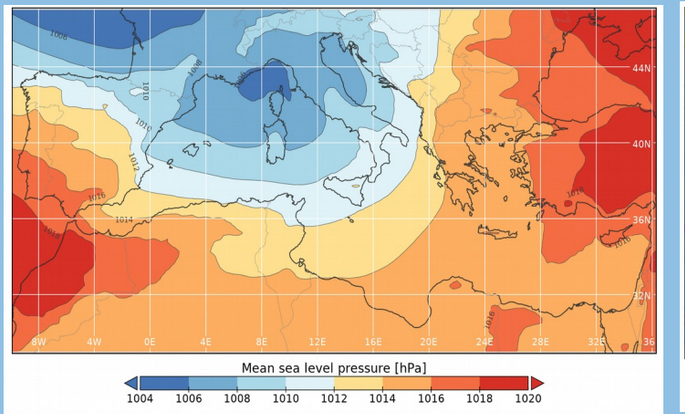
The peculiar **local** meteorological situation associated with the local minimum that occurred on November 12th resulted in a **high variability** of the **maximum water levels** in the lagoon.

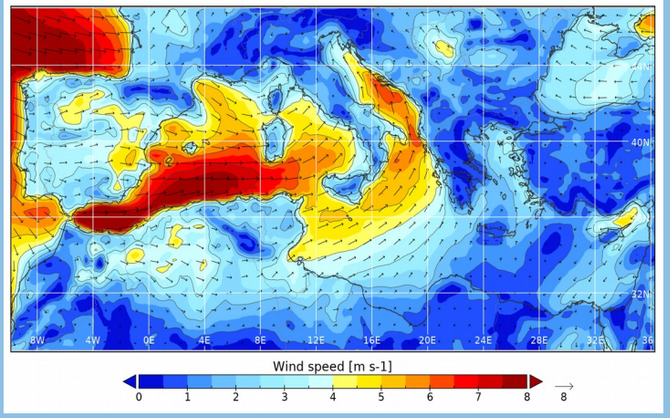
SHYFEM simulations coupled with a wave model and forced by the interpolated observed wind data allowed to estimate the **wind/wave setup** within the **Venice Lagoon**.

Water was effectively pushed against the southern side of Venice resulting in a peak value of **1.89 m** and **flooding of 85% of the town**.



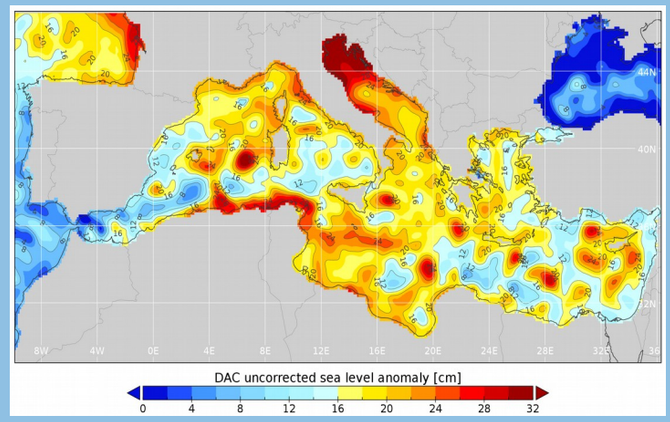
November 2019 monthly mean of **air pressure** (**ERA5**) show a trough of **planetary atmospheric wave** persisting over the whole month on the West Mediterranean and Adriatic seas.

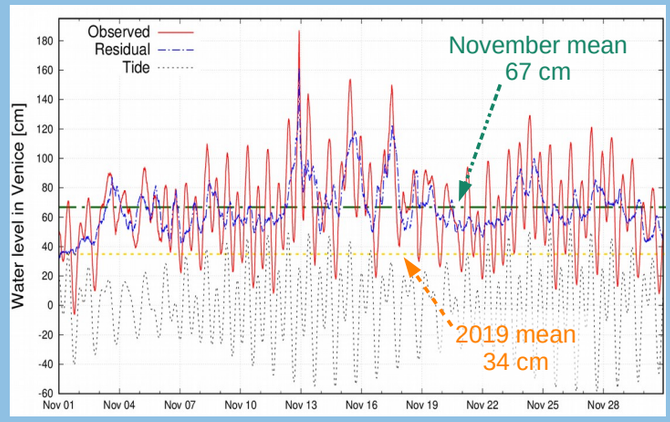




Related **winds** are also persisting over the West Mediterranean (up to 8 m/s), Ionian and Adriatic (south-easterly, **Scirocco**) seas for whole month.

Sea levels (from **altimetry**) are **high** in the Adriatic Sea throughout the month and considerably surpassing the inverted barometer effect (**coherent action** of atm. **pressure** and **wind**).





It has **never** been registered so **high monthly mean sea level** (as absolute value and anomaly) in **Venice** (Punta della Salute).

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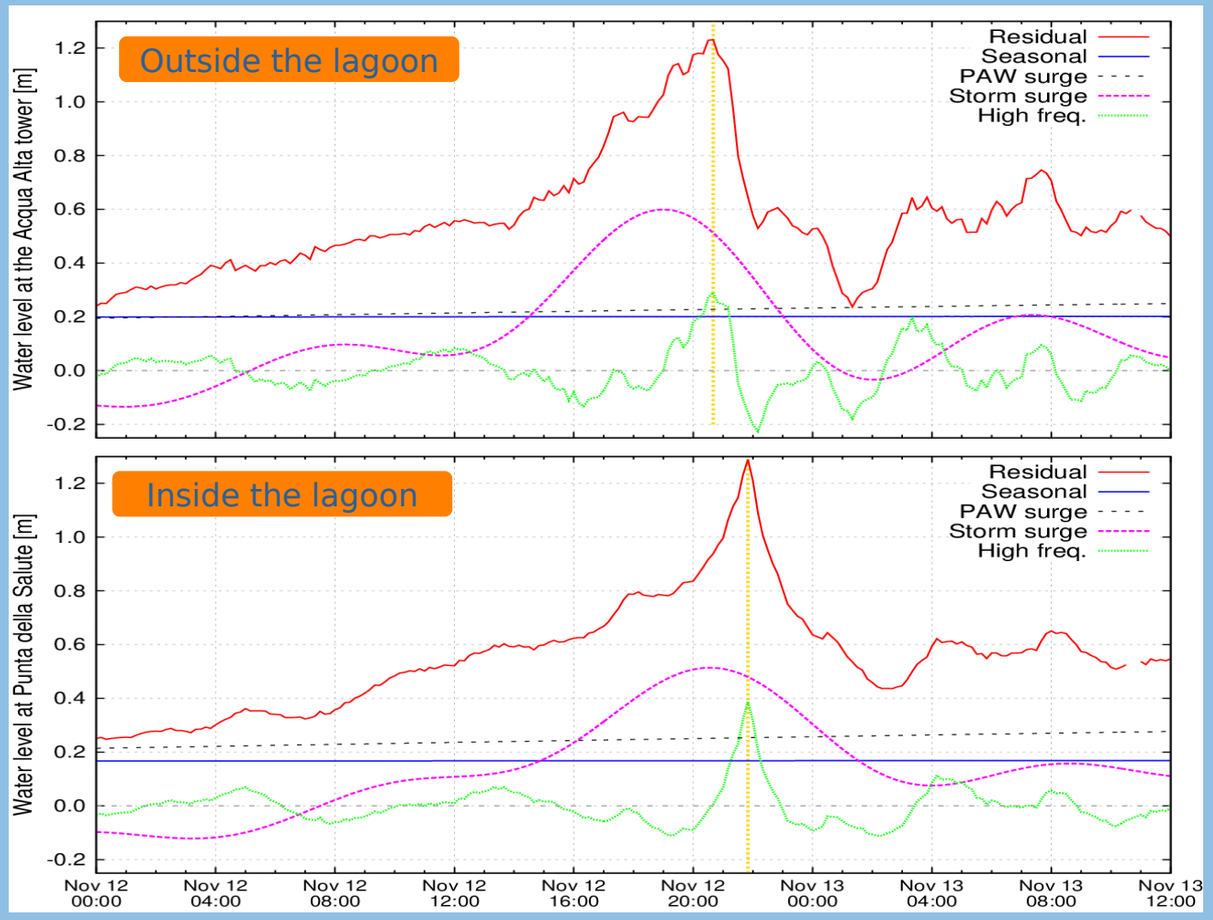
An exceptional sum of factors

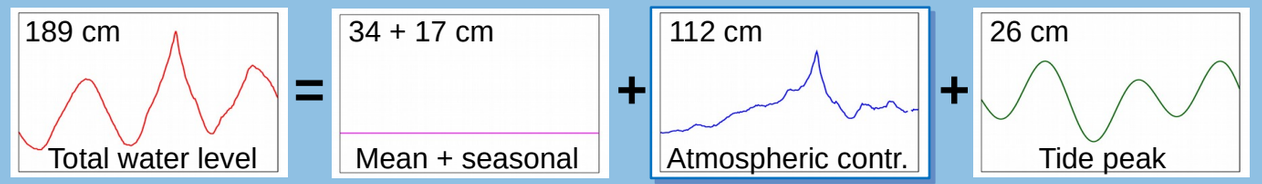
Spectral analysis of the water levels revealed the coexistence of different factors: **seasonal, PAW surge, storm surge**, **meteotsunami**.

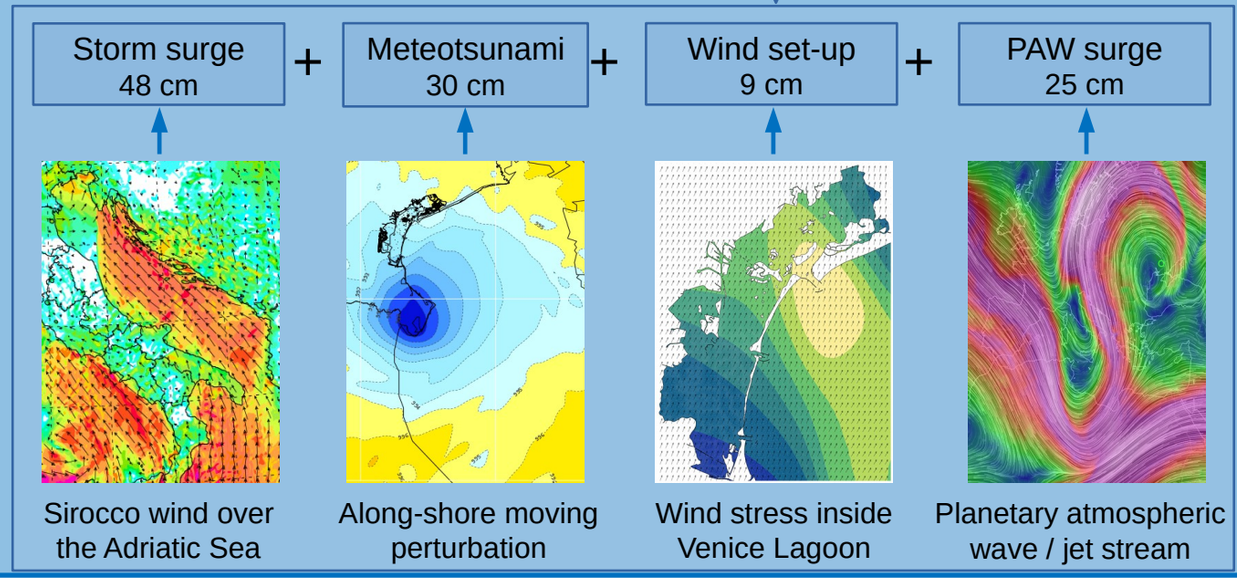
Contribution to sea level	*Cut-off period*
Seasonal anomaly	> 120 days
PAW surge	120 days – 10 days
Storm surge in the sea	10 days – 10 hours
Meteotsunami in the sea	< 10 hours
Wind setup in the lagoon	< 10 hours



CONCLUDING, several factors made this event so exceptional:

- the in-phase timing between the peak of the storm and the tide;
- a deep low-pressure system that generated strong Sirocco winds along the main axis of the Adriatic Sea pushing the Adriatic waters to the north;
- a fast-moving local depression - and the associated wind perturbation - travelling along the Italian coast and generating a meteotsunami;
- very strong winds over the Venice Lagoon which led to a rise in water levels and damages to the historic city;
- an anomalously high monthly mean sea level in the Adriatic Sea induced by a standing low-pressure and wind systems over the Mediterranean Sea





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