Hydrodynamic models for coastal flooding and surface runoff assessments along the coast of Ofanto River (Apulia, Italy)

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Introduction

The **Ofanto River** is one of the most important watercourses in Southern Italy. It originates at an altitude of approximately **715 meters above sea level** and flows for about **170 km** before emptying into the **Adriatic Sea**.

Its **hydrological regime** is distinctly torrential, with an **average discharge at the mouth of about 15 m³/s**, and it is characterized by prolonged periods of low flow with almost **negligible discharge**.

Nevertheless, **significant flood events** are not uncommon and have been **well documented since ancient times**.

OBJECTIVE
To study the **combined effect of coastal flooding and surface runoff**, which represents a crucial research topic aimed at supporting intervention strategies. The goal is to assess the **feasibility of specific actions** that could help maintain the **morphological balance at the river mouth**.

Methods

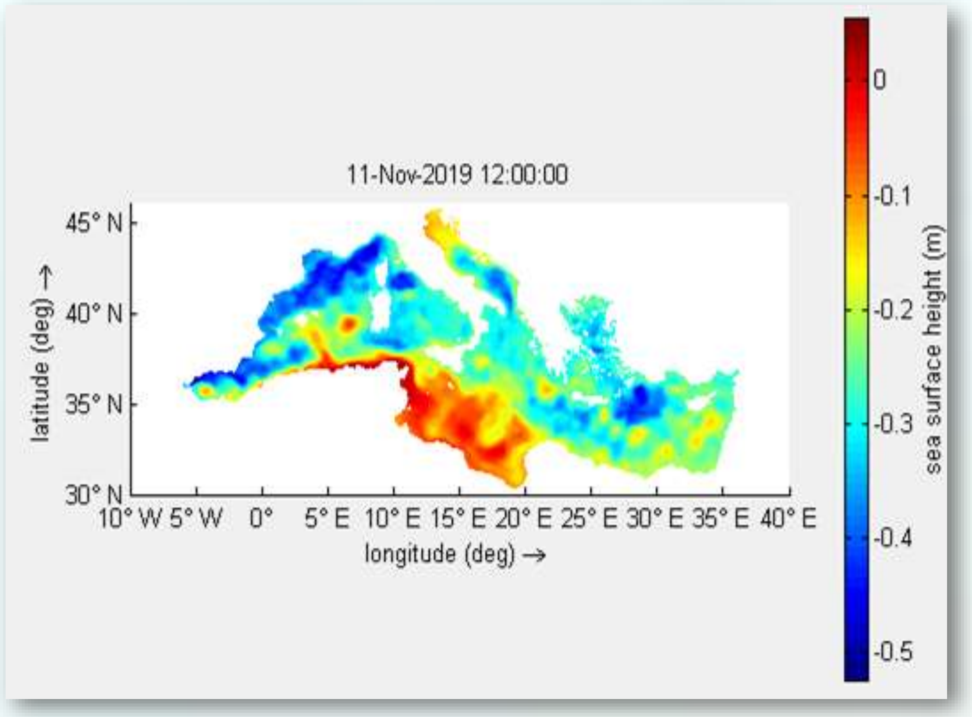
The available data are the result of a **reanalysis** that combines **observational data**, including **satellite data**, to reproduce a **unique scenario for each time interval**.

DATASET
SEA SURFACE
- **SSH** - Sea surface height (m)

WIND
- 10 metre **U** wind component (m/s)
- 10 metre **V** wind component (m/s)
- **WIND** - speed wind component (m/s)
- **WW** - direction wind component (deg)

WAVE
- **SWH** -Significant height of combined wind waves and swell (m)
- **VMDR** - Mean wave direction (degree)
- **MWT** - Mean wave period (s)
- Peak wave period (s)

DATA MARINE COPERNICUS



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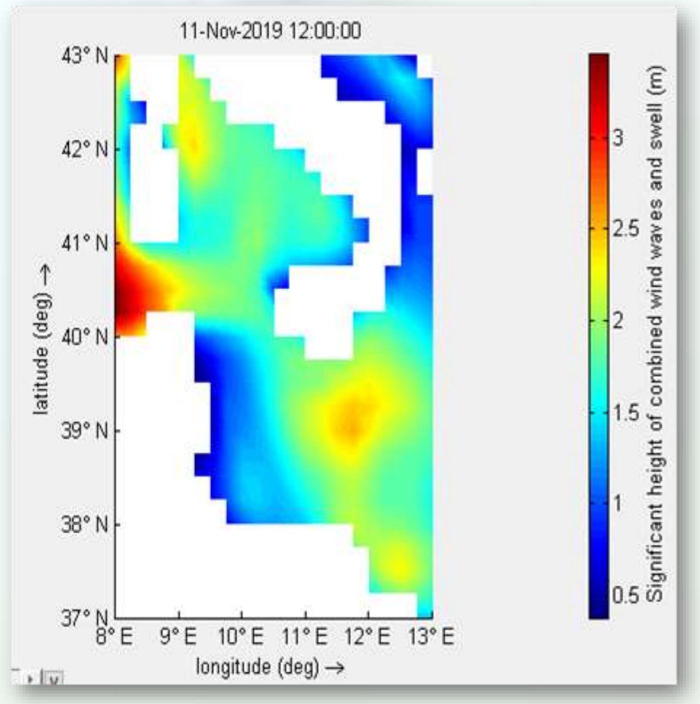
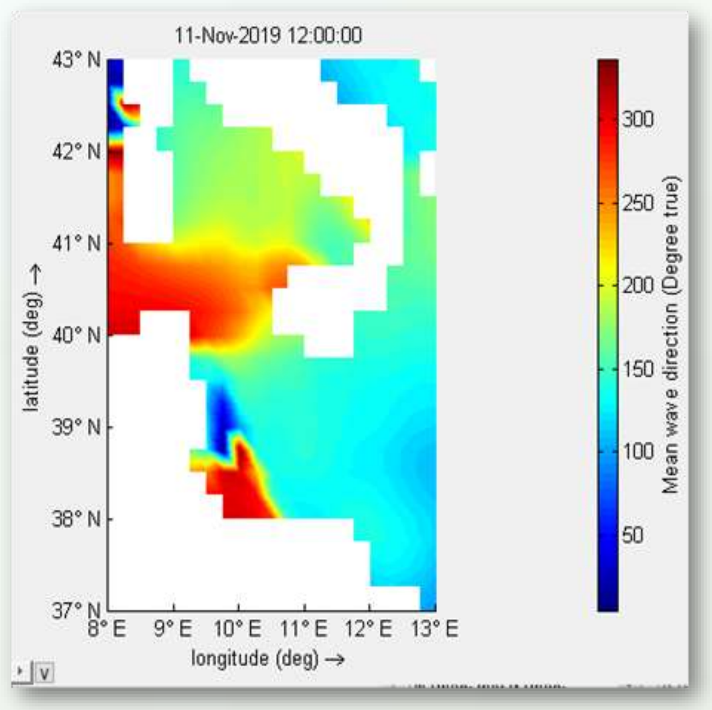


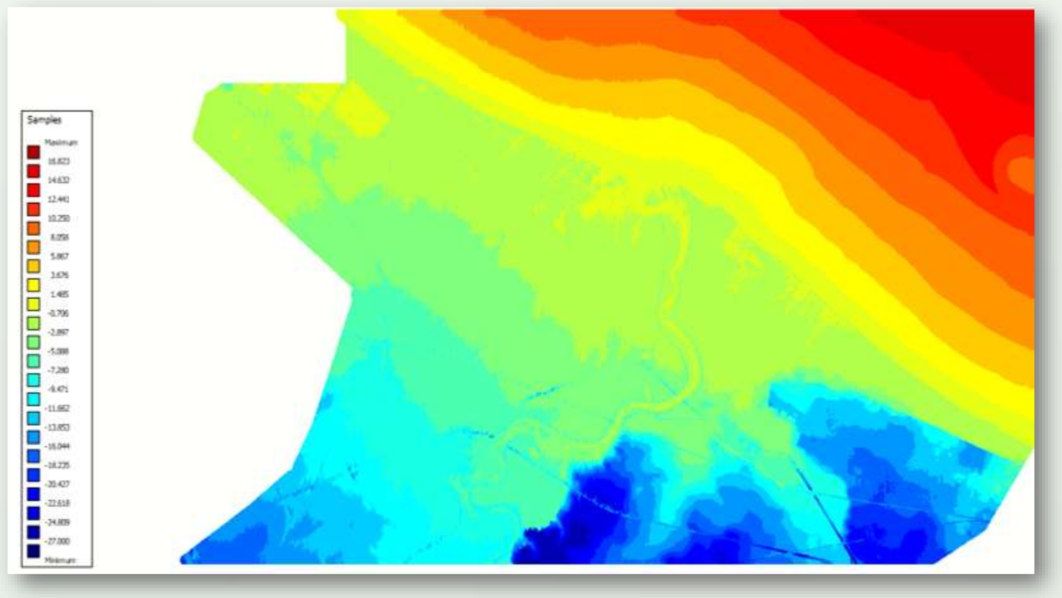


LiDAR with bathymetric data

The **topographic data** used in this study were derived from **LiDAR surveys conducted in 2016**, with a **2x2 meter cell resolution**.

This applies both to **coastal areas** and to **bathymetric data**, which were obtained through **multibeam surveys** and used to generate **digital elevation models**.

As an interpolation method, the 'grid cell averaging' moving average has been used.



What are the processes?

Currently, the **mouth of the Ofanto River** has recently entered a phase of **rapid retreat** due to major river engineering and regulation works.

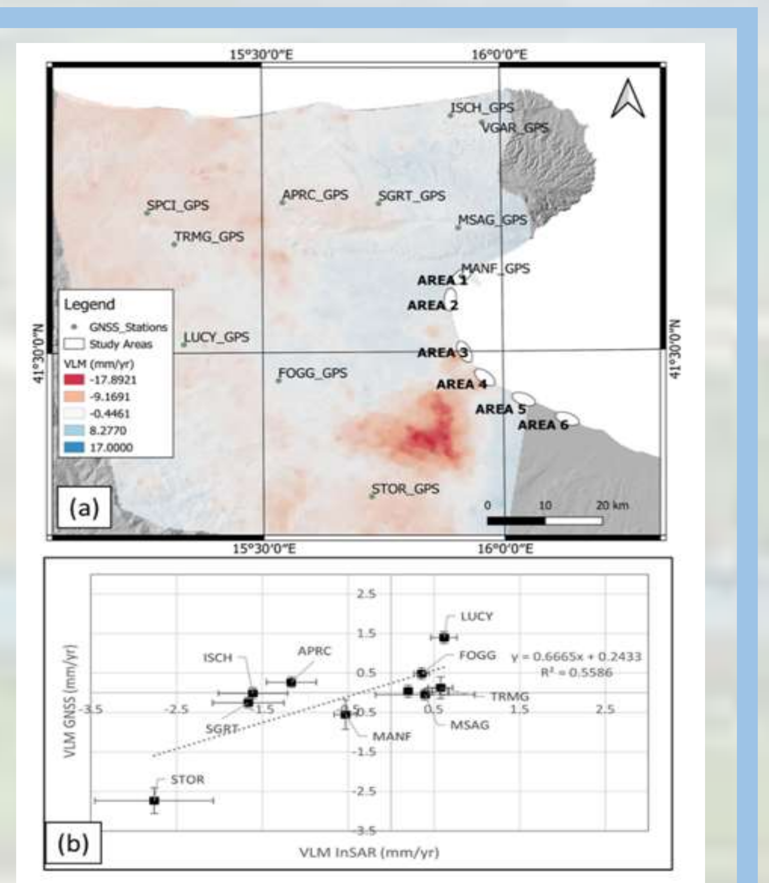
An **average retreat rate of approximately 2 meters per year** has been estimated.

A **complete disappearance of the river mouth cusp** has been observed, along with the **overall retreat of the coastal arc** facing the river mouth. Low-lying coastal areas are highly vulnerable to sea level rise, which is exacerbated by **land subsidence**.

Coastal subsidence in the coastal area of the Gulf of Manfredonia:
a) **Vertical ground movements** assessed using InSAR data;
b) **Calibration of InSAR data** with GNSS measurements.
Vertical Land Movement **(VLM)** rates and coastal erosion rates for the Gulf of Manfredonia.

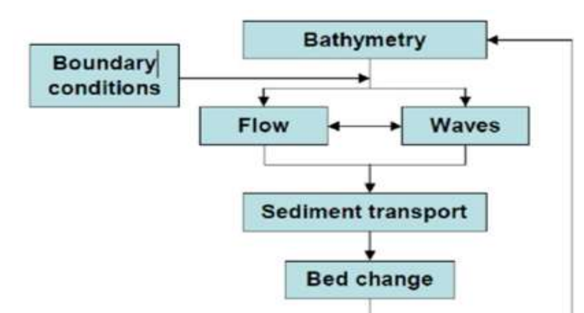
Study Areas	Sites	VLM Rates	Effective Shoreline Change Rate
Area 1	Manfredonia	−0.45 ± 0.25 mm/yr	−0.196 ± 0.06 m/yr
Area 2	Siponto sandy coast	−1.08 ± 0.2 mm/yr	−1.079 ± 0.32 m/yr
Area 3	Ippocampo	−7.5 ± 1.7 mm/yr	−2.983 ± 0.89 m/yr
Area 4	Zapponeta	−4.1 ± 1.5 mm/yr	−2.733 ± 0.82 m/yr
Area 5	Torre Pietra	−2 ± 1.5 mm/yr	−2.762 ± 0.83 m/yr
Area 6	Margherita di Savoia	−0.13 ± 0.08 mm/yr	−5.825 ± 1.75 m/yr

Scardino et al., 2022, Remote Sensing).

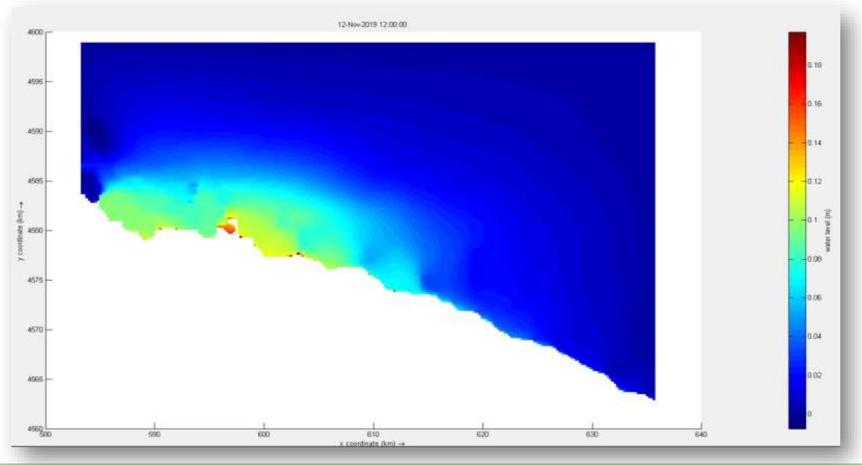


Results : Hydrodynamic Models to evaluate coastal flooding using Delft3D ,XBeach, and HecRas

DELFT 3D WAVE-FLOW COUPLING



To identify the **most critical condition** from a precautionary perspective, approximately 20 simulations (one per week) were carried out over the period **from September 2019 to December 2019**, using the spectral wave resolution method in SWAN. Among these, the most critical situation was identified, which occurred in November 2019.

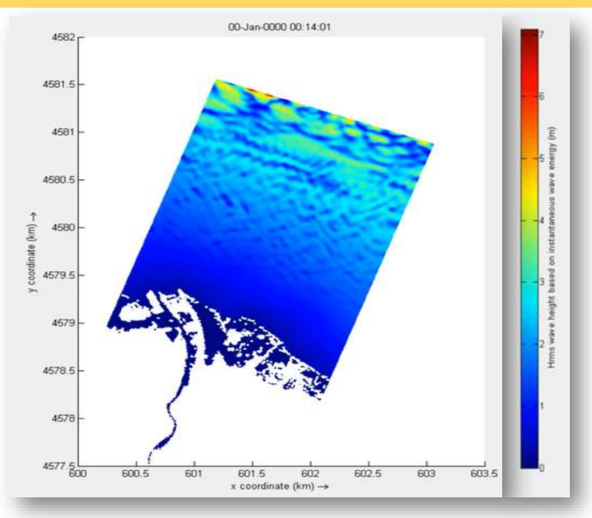


X-Beach

The reference period, based on the results obtained from the coupled wave-flow model, falls within the **week of November 7 to November 13**.

Wave propagation was modeled by applying **JONSWAP spectra** *(Hasselmann et al., 1973).*

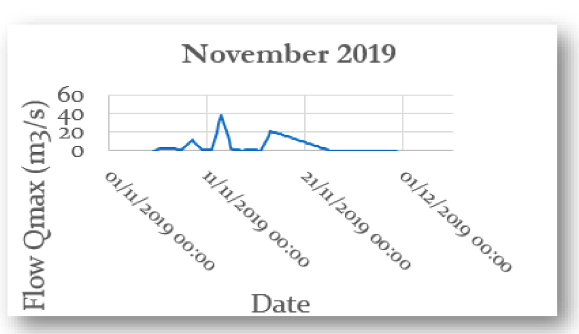
To achieve more reliable results at the mouth of the Ofanto River, the **750x550 grid** (70x70 resolution) was refined by applying the **output from the high-resolution 200x400 grid** (20x20 resolution) simulated in **Delft3D** for the most critical day.

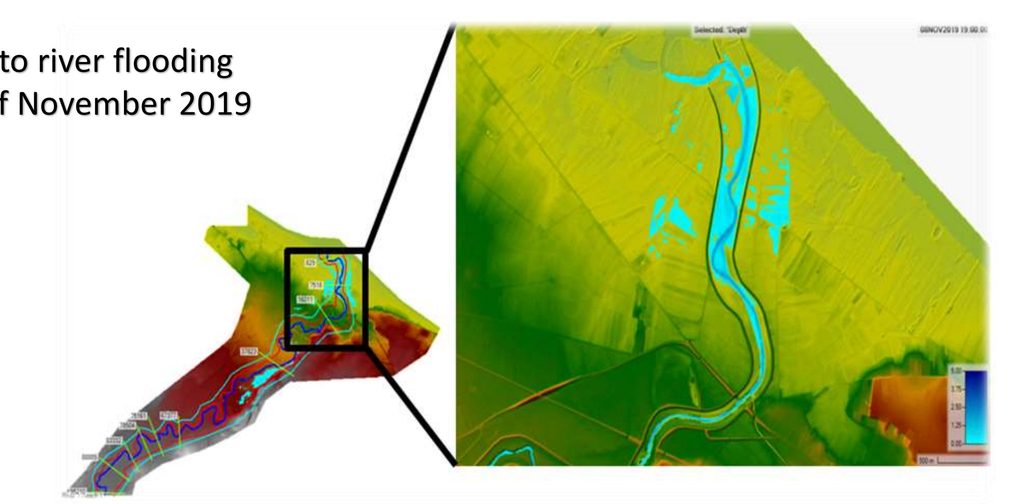


HEC-RAS

The river hydrodynamic simulation was carried out using the HEC-RAS analysis system through a two-dimensional modeling approach under unsteady flow conditions.
The graph shows a peak discharge of approximately 40 m³/s.

Assessment of the Ofanto river flooding during the storm event of November 2019





Discussion & Conclusion

How can the feasibility of strategic interventions be determined?

The approach commonly adopted in hydraulic risk mitigation interventions is typically based on riverine hydraulic modeling. However, there are numerous examples of interventions that proved unsuitable for the hydrodynamic conditions of the coastline—such as the straight groynes built along the shores of this area, which are characterized by very low elevations above mean sea level. As a result, even relatively moderate storm surges frequently lead to flooding.

The extreme weather event of November 2019, at the mouth of the Ofanto River, clearly highlighted the exposure of low-lying coastal areas to intense storm events, emphasizing their vulnerability. It is therefore necessary to adopt an integrated forecasting approach, simulating the combined influence of both fluvial and marine-coastal contributions, in order to improve the understanding of morphodynamic processes.

Abstract