University of Genoa
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Tsunami inundation maps and damage sceneries through the GIS GRASS

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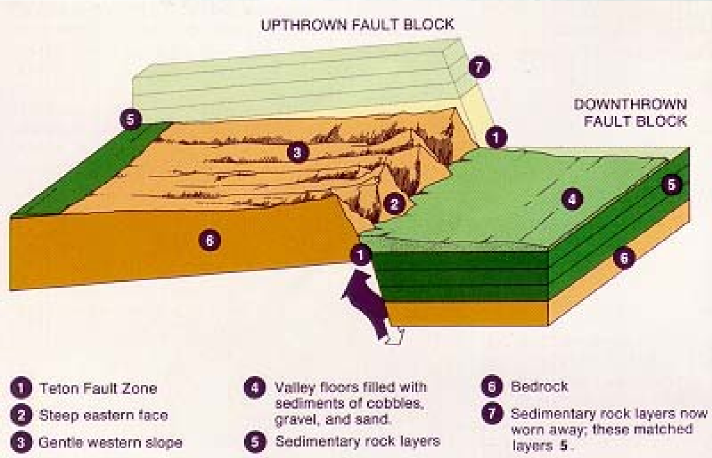
Topics:

- **Introduction**
  - Tsunami
  - Test area
- **Hydraulic model**
- **Application**
  - preliminary phases
  - Run-up maps
  - Inundation maps
  - Hazard maps
- **Conclusion**

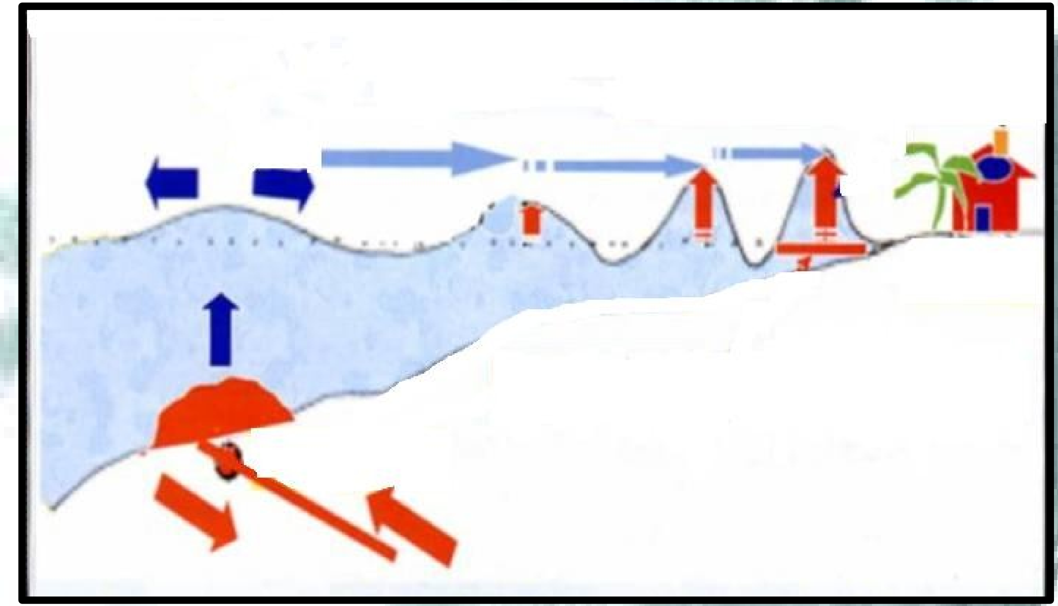
WHAT IS A TSUNAMI?

wave train generally due to:

- **Earthquakes**
- **Landslides close to the coastline**
- **Volcanic eruptions**



Characteristics of the tsunami waves



offshore

Wave lenght L 70 ÷ 160 km
Height offshore H_0 60 cm ÷ 3 m

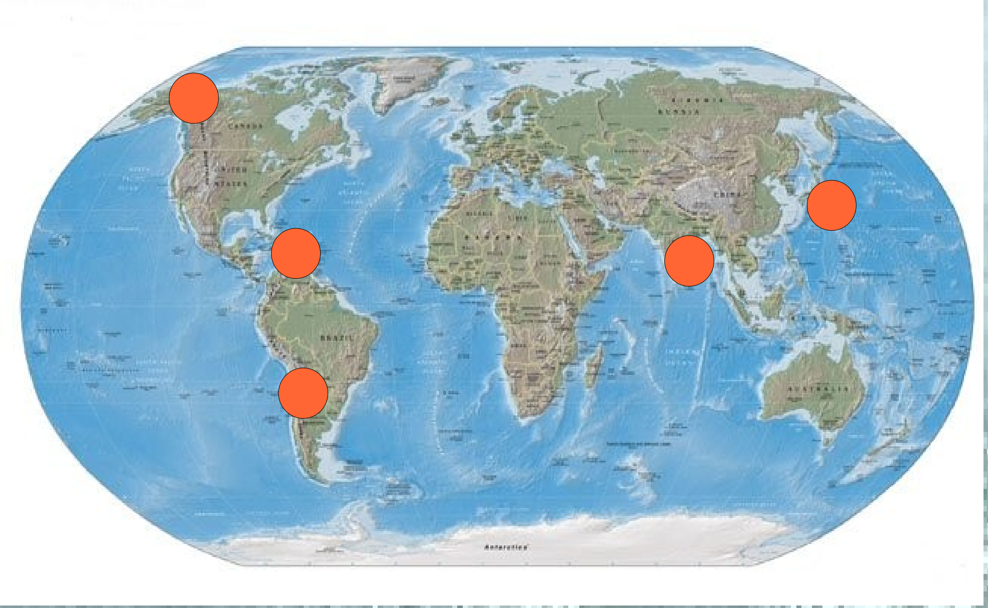
- *Toward shore, it increase its height and decrease its lenght*
- *The waves are very wide (200 m ÷ 1 Km)*

enormous volume of water

Where may we find a tsunami?

In the oceans

- Japan
- Alaska
- Hawaii
- Southern America
- Asian south-east



In the mediterranian basin

- *It presents many conditions for tsunami occurrence (high seismicity, volcanic eruptions)*
- *tsunami was in the past a "common" phenomenon in the Mediterranean Sea.*

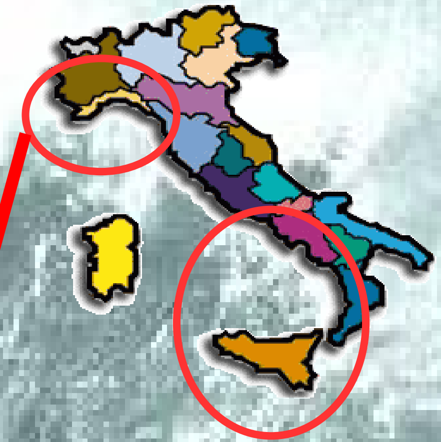
obviously different intensities, because of their different dimensions

1. Very light
2. Light
3. Rather strong
4. Strong
5. Very strong
6. Disastrous

TEST AREA

In the last 1000 year, 71 tsunamis in Italy of which:

- **23 in the south part**
- **14 in the western part of the Ligurian coast**



reach of the Ligurian coast between Bergeggi and Spotorno (Savona)

Analysis of two main coastal type:

gentle slope beaches

rock cliffs

In the Mediterranean Sea, the time between the generation of an earthquake or a landslide and the coming of the tsunami wave on the coast could be very limited.

Importance of:

- *a support to plan the post-event*
- *improving the sensibility of the population on this particular hazard*

GRASS 6.0

↓

procedure to realize Tsunami Inundation Maps and Tsunami Hazard Maps, as a starting point in the realization of a tsunami warning system

Approximations:

- Rectangular wave identified through the first crest
- The first wave is the most destructive
- The wave front is locally parallel to the coast
- Absence of bays or straits that increase the wave height

The data introduced in our model refer to the tsunami caused by the catastrophic Ligurian earthquake of February 23, 1887 (estimated of magnitude *6.2 – 6.5*)

offshore water depth: h_0 = 2000 m (near the fault)

onshore water depth: h = 3 m

offshore wave height: H_0 = 0.10 – 0.50 m (same order of the fault displacement)

Shoaling process →

$$H = H_0 \left(\frac{h_0}{h} \right)^{\frac{1}{4}}$$

H = 0.5 m

H = 1.5 m

H = 2.5 m

Calculation of the run-up

Kinetic volume: $V_c = HL$

Potential volume: $V_p = H\left(\frac{z_{max} \tan\alpha}{2}\right)$

Kinetic energy: $H_c = \frac{U^2}{2g}$

Potential energy: $H_p = z_{max}$

mechanical energy conservation

↓

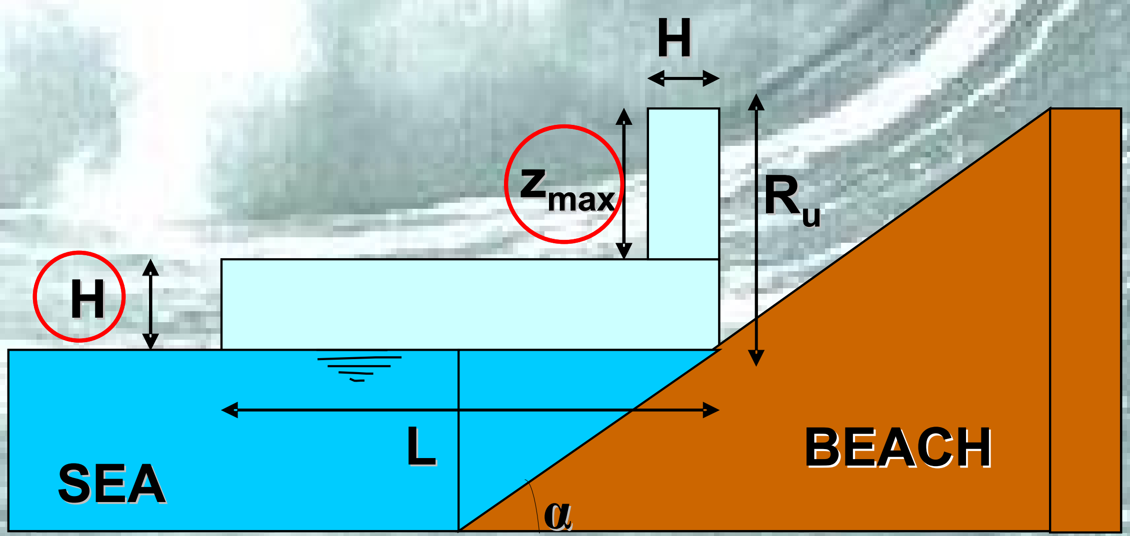
$\rho g V_c H_c = \rho g V_p H_p$

↓

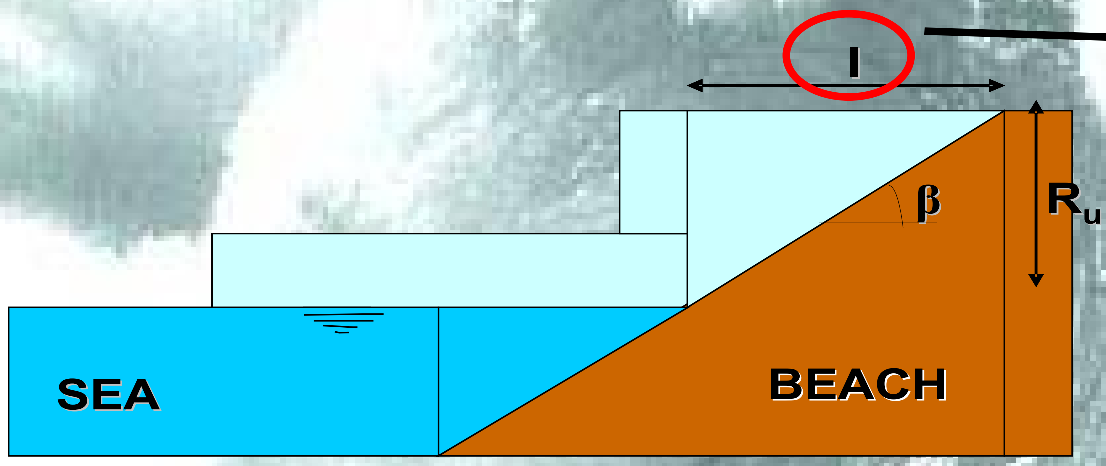
$z_{max} = \sqrt{\frac{L \tan\alpha}{g}}\, U$

↓

Run-Up = H + Z_{max}



Flooded area:



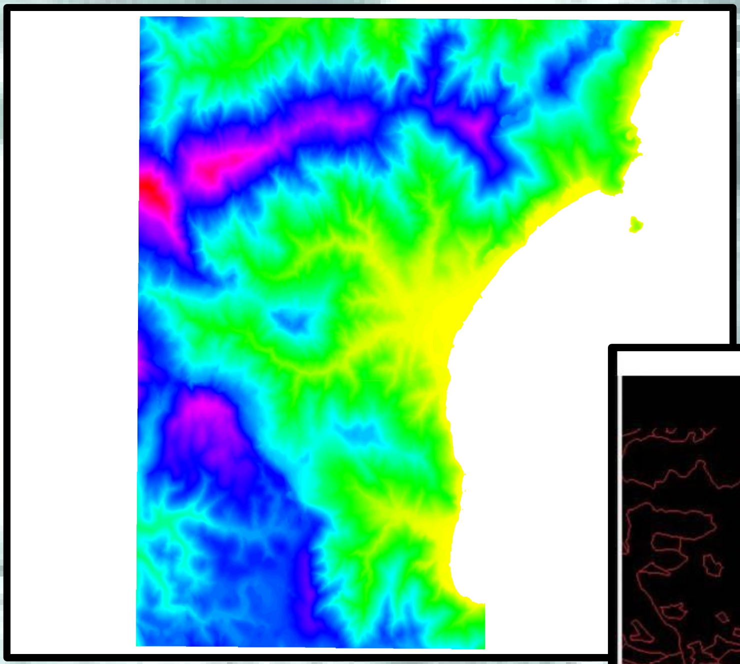
$$I = \varepsilon \frac{R_U}{\tan \beta}$$

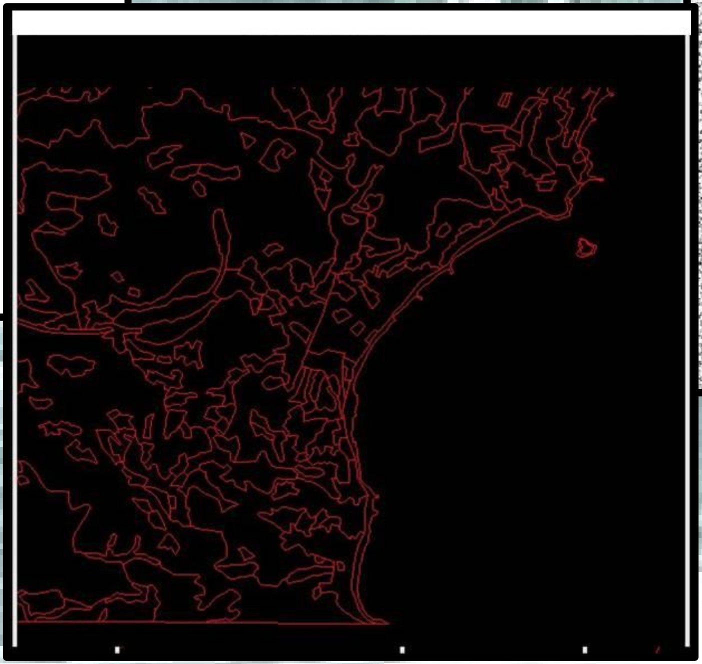
β terrain local slope

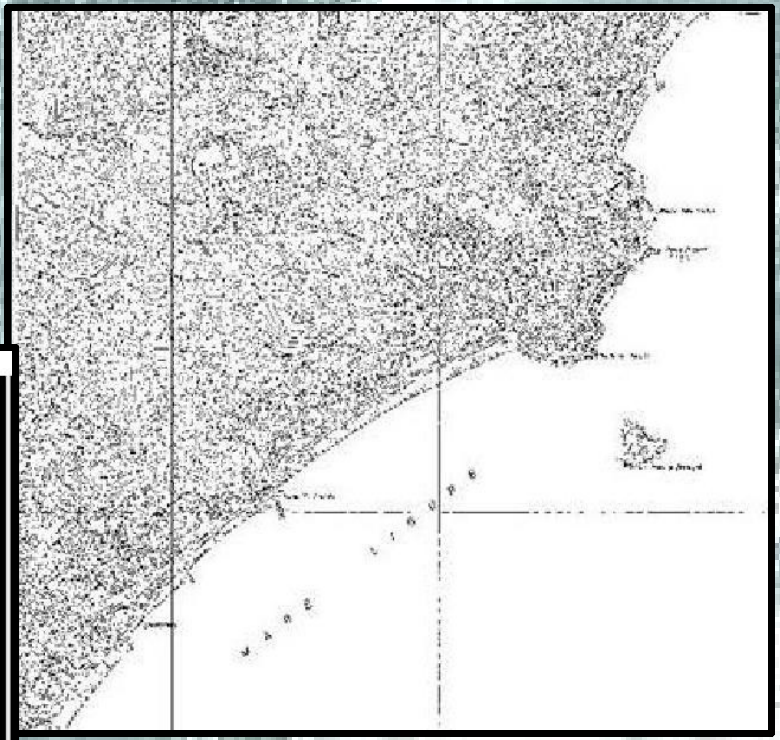
ε terrain roughness (function of the obstacles that the wave meets during its inland propagation)

Input data:

- Digital Terrain Model
- Land use cartography
- Regional technical cartography

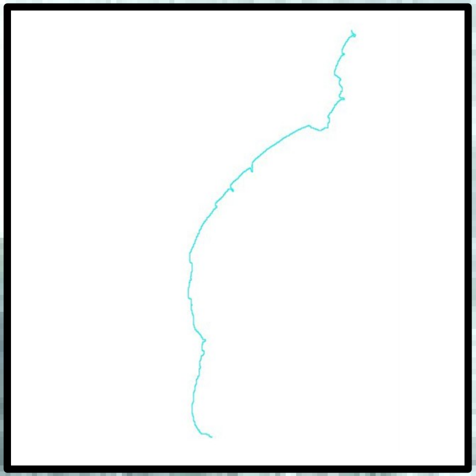


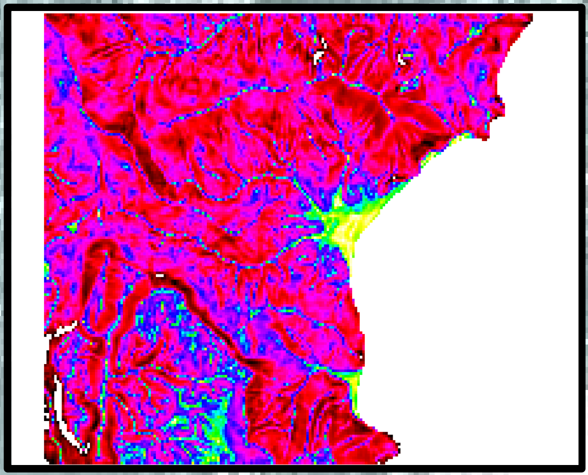


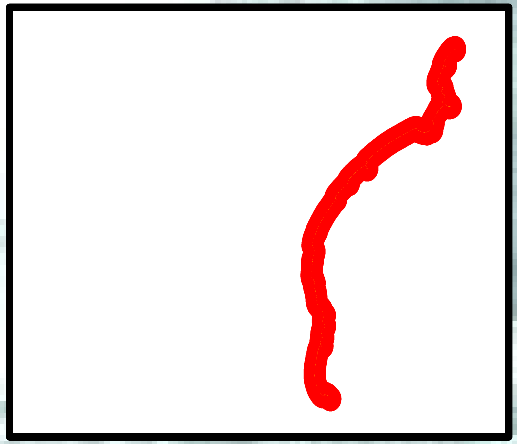


Application

- Definition of the coastline
- Calculation of the slope map
- Buffer around the coastline
- Overlap of buffer and slope
- Run-up maps



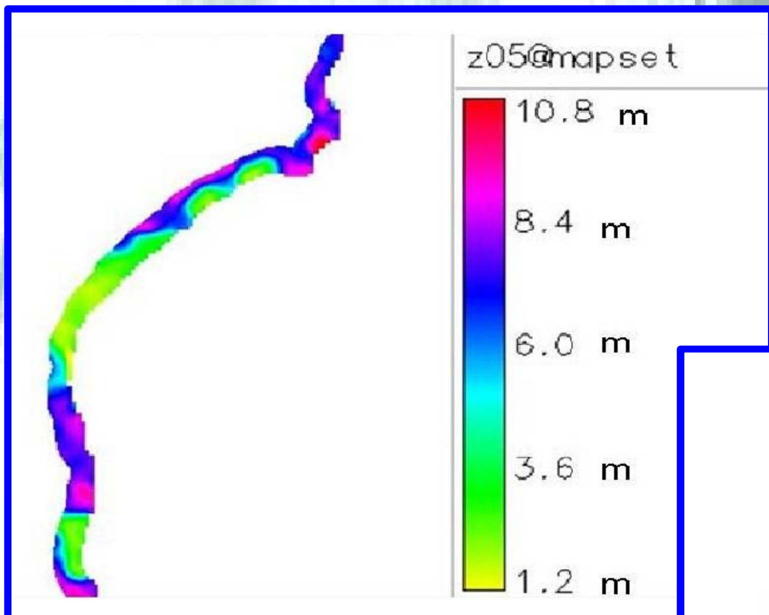




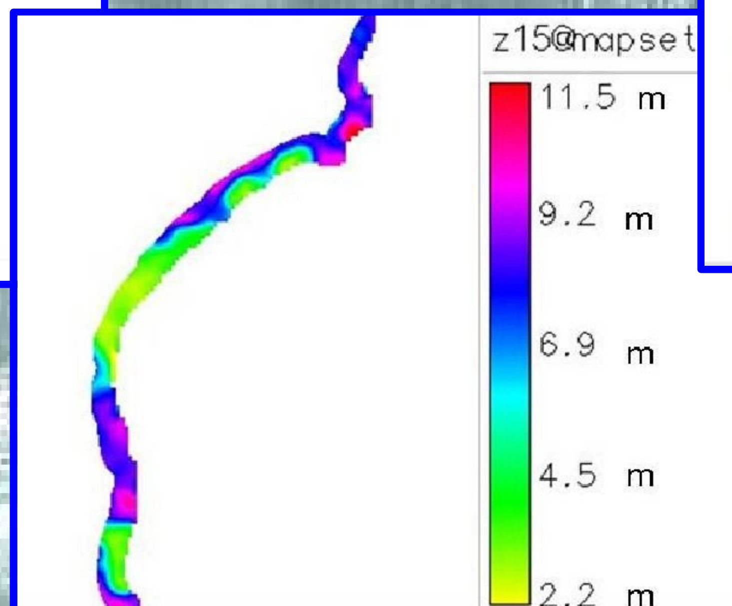
The analysis was performed in a 200 m wide and 6 km long strip from the coastline

Run-Up maps

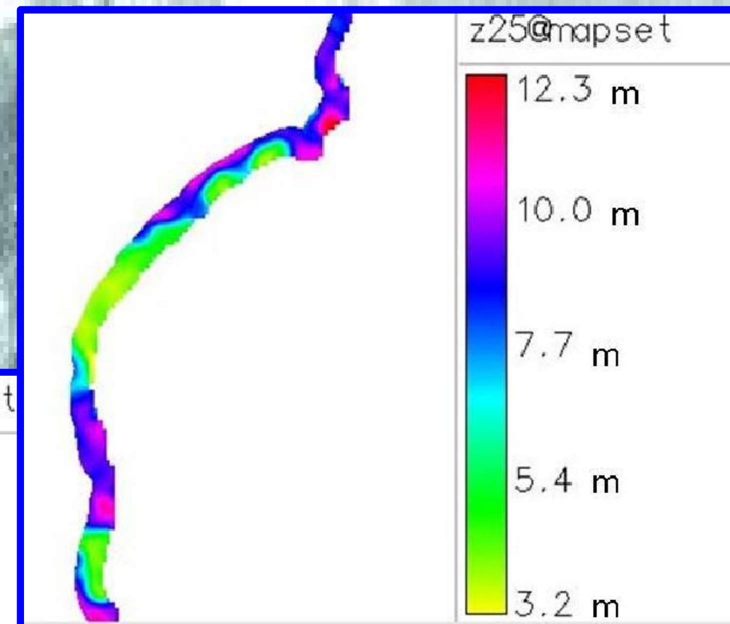
H = 0.5 m



H = 1.5 m

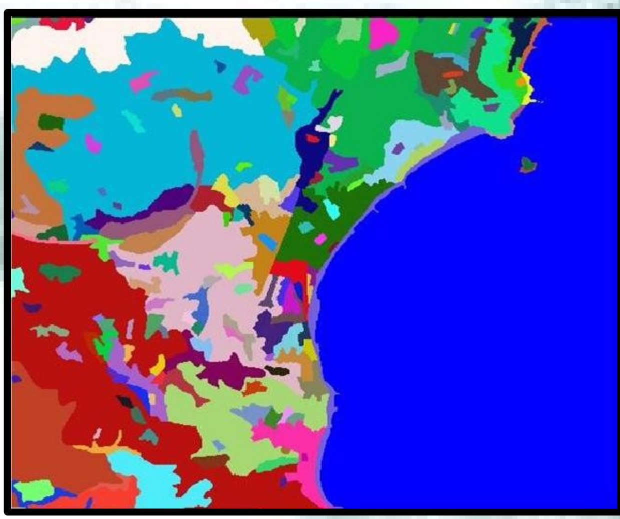


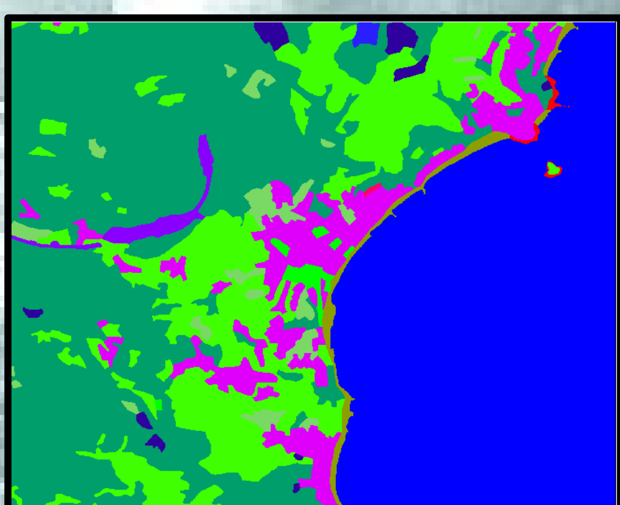
H = 2.5 m



Roughness maps

Roughness Map obtained by reclassification of Land Use Cartography





	ε
High vegetation	0,2
Middle vegetation	0,5
Short vegetation	1
Build up areas	0,8
Green urban areas	0,9
Industrial or commercial areas	0,8
Beaches	1
Rock cliffs	1
Rocks	1
Dumps	1
Highway and railway	1
Sea	1

Evaluation of inundation

$$W = \varepsilon * R_u - Z$$

ε *roughness index (from roughness map)*

Z *height of the ground (from DTM)*

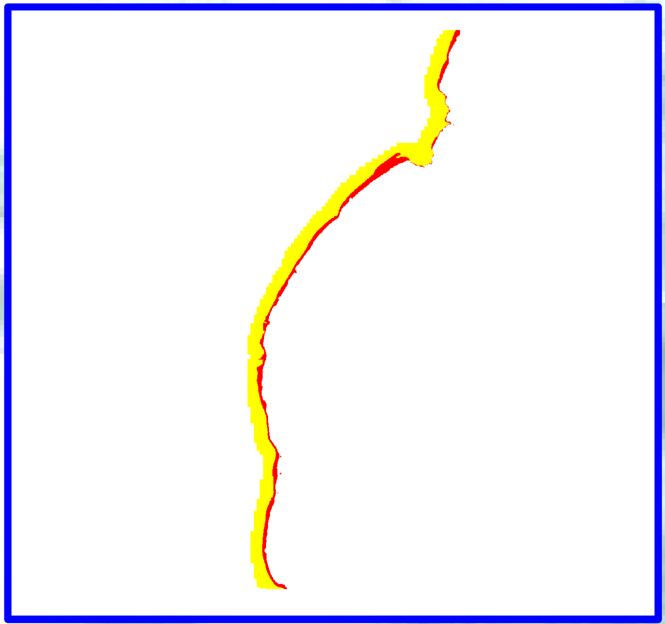
R_u *Run-up*

If $W>0$ inundation pixel value=1 wet

If $W<0$ no inundation pixel value=0 dry

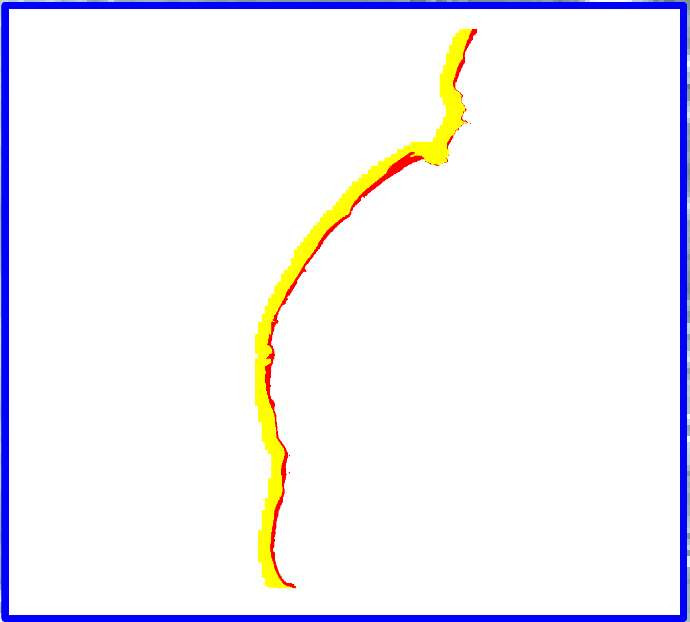
Inundation maps

H = 0.5 m



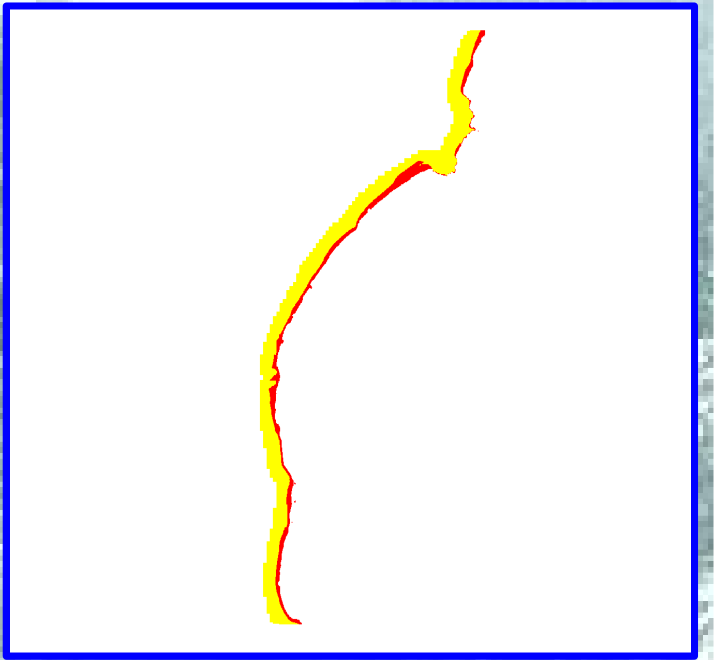
Flooded area: 272,280 m²

H = 1.5 m



Flooded area: 274,276 m²

H = 2.5 m



Flooded area: 286,424 m²

The red zones indicate the areas that might experience inundation

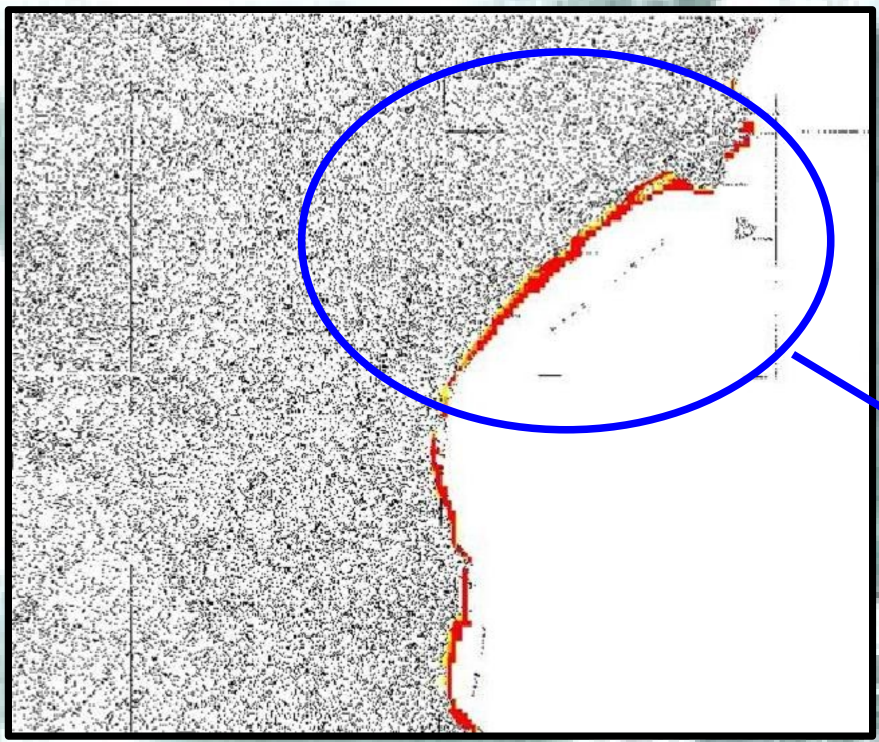
Hazard maps

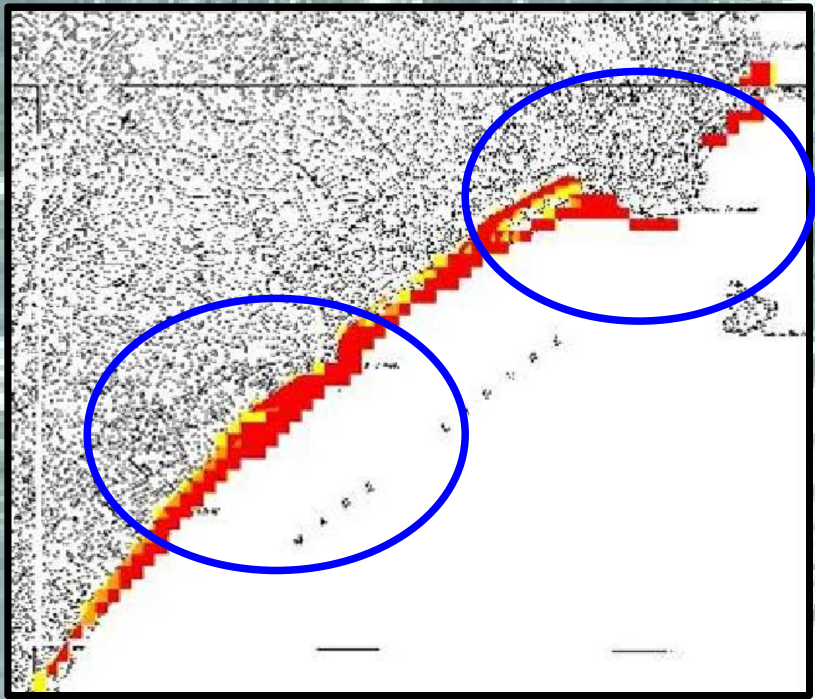
Overlap of the inundation maps for three different H

H = 0.5 m

H = 1.5 m

H = 2.5 m

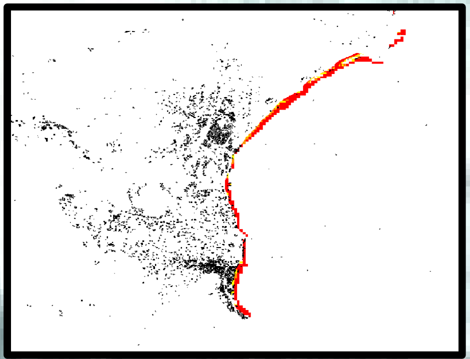




Reach of the Ligurian coast between Bergeggi and Spotorno and zoom on rock cliffs and gentle slope beaches. As expected, the topography influences the extension of the flood, even for highest offshore waves.

Hazard maps

Report of buildings:



H = 0,5	1850 m^2
H = 1,5	1900 m^2
H = 2,5	2200 m^2

The tsunami wave can be very dangerous, especially in summer, due to the increasing number of tourist

Report of :	Beaches	bathing hut	equipment	people
H = 0,5	48677 m^2	1604	1764	7218
H = 1,5	49079 m^2	1617	1779	7277
H = 2,5	51239 m^2	1688	1857	7600

To quantify		bathing hut	equipment
H = 0,5	€	1.600.000	560.000
H = 1,5	€	1.620.000	570.000
H = 2,5	€	1.700.000	600.000

CONCLUSION 1

- *the maximum inundation ranges from 50 to 100 m inland*
- *rock cliffs are less liable to damage also for the highest waves than gentle slope beaches without protection*

These are realistic results that match most of the data derived from actual cases in other parts of the world.

The model can be applied to any reach (Mediterranean Sea, Atlantic or Pacific Ocean and so on) provided that proper information are available for those coasts.

CONCLUSION 2

These maps might have some informative and preventive functions:

- *to improve the sensibility of the population on this particular hazard*
- *to indicate to public administrations that particular structures (like harbour, depuration systems, hospital, school, road, railways, etc.) should be protected to manage better the emergence.*
- *to provide an esteem of the extension of flooded area and a qualitatively evaluation of likely damages*
- *to design safer facilities*
- *identification of safe areas where to convey and to shelter people during a tsunami event*

Thanks