Nature-based Solutions for hydro-meteorological risks

NbS Modelling– Part two

Beatrice Pulvirenti – University of Bologna

EU funded project
GA no. 776848

Modelling chains in OPERANDUM project

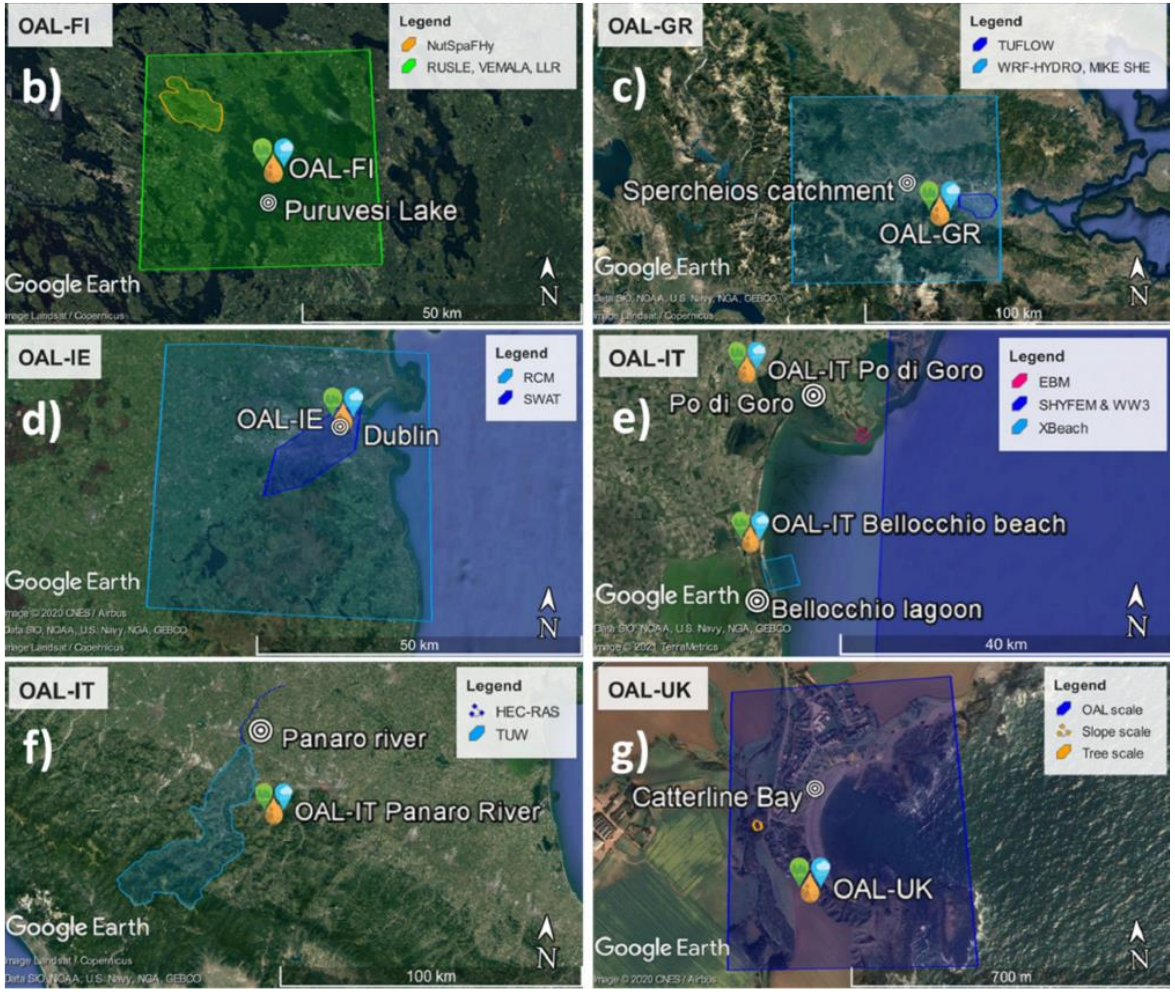
resources

MDPI

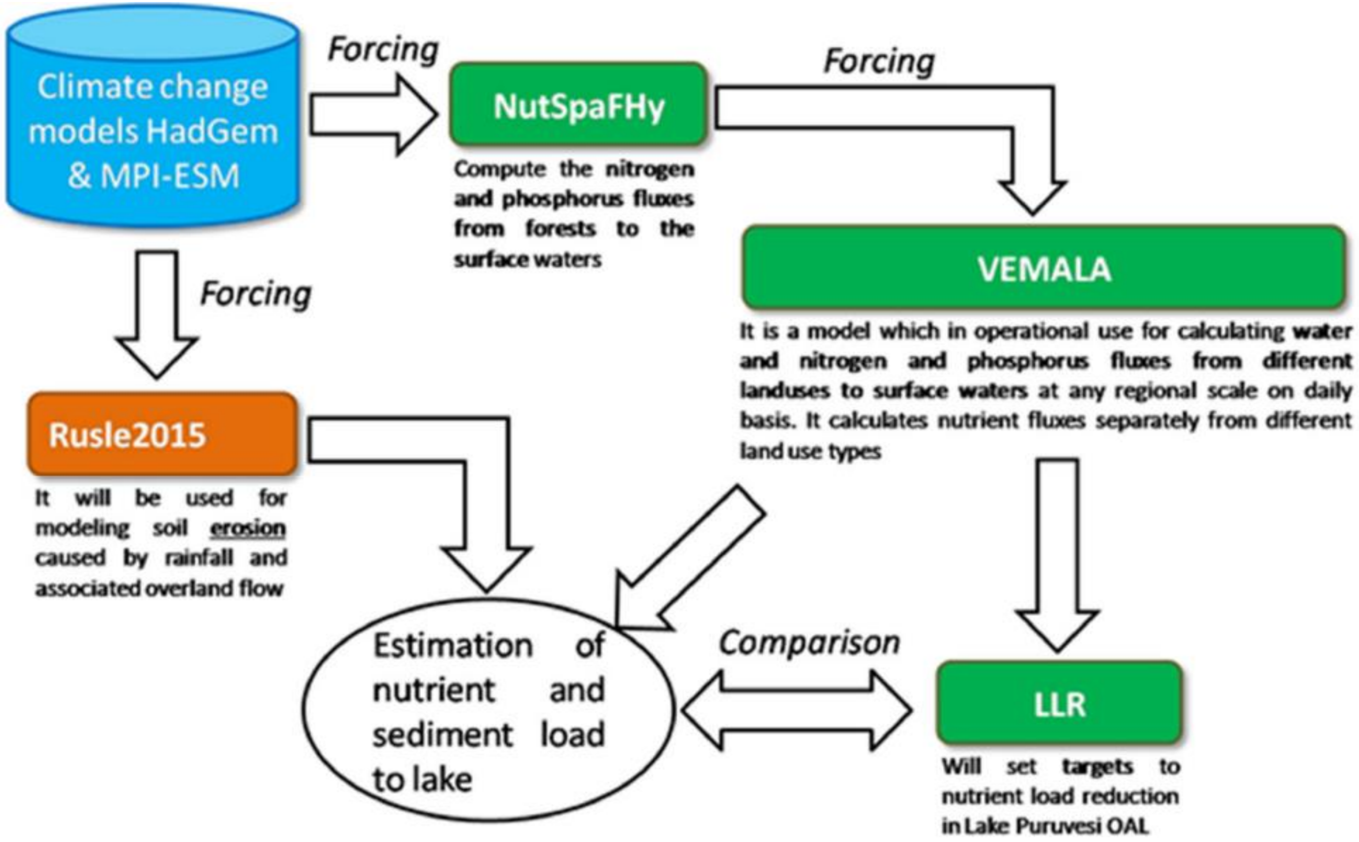
Article

On the Management of Nature-Based Solutions in Open-Air Laboratories: New Insights and Future Perspectives

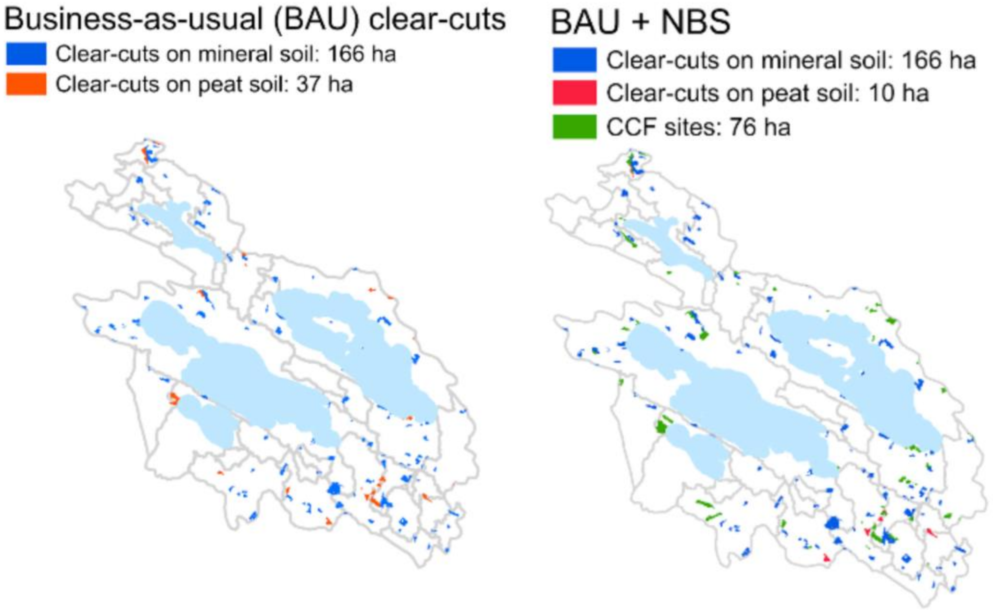
Glauco Gallotti [1,*], Marco Antonio Santo [1], Ilektra Apostolidou [2], Jacopo Alessandri [1], Alberto Armigliato [1], Bidroha Basu [3,4], Sisay Debele [4], Alessio Domeneghetti [5], Alejandro Gonzalez-Ollauri [6], Prashant Kumar [4,5], Angeliki Mentzafou [2,7], Francesco Pilla [3], Beatrice Pulvirenti [1], Paolo Ruggieri [1], Jeetendra Sahani [4], Aura Salmivaara [8], Arunima Sarkar Basu [3], Christos Spyrou [2,9], Nadia Pinardi [1], Elena Toth [5], Silvia Unguendoli [10], Umesh Pranavam Ayyappan Pillai [1], Andrea Valentini [10], George Varlas [7], Giorgia Verri [11], Filippo Zaniboni [1] and Silvana Di Sabatino [1]



OAL Finland



The business-as-usual (BAU) harvesting scenario represents nutrient export caused by the clear-cuts, based on historical harvesting data from the area.



The input data are derived from the general circulation models MPI-ESM (representing medium equilibrium climate sensitivity) and HadGEM2 (representing high equilibrium climate sensitivity).

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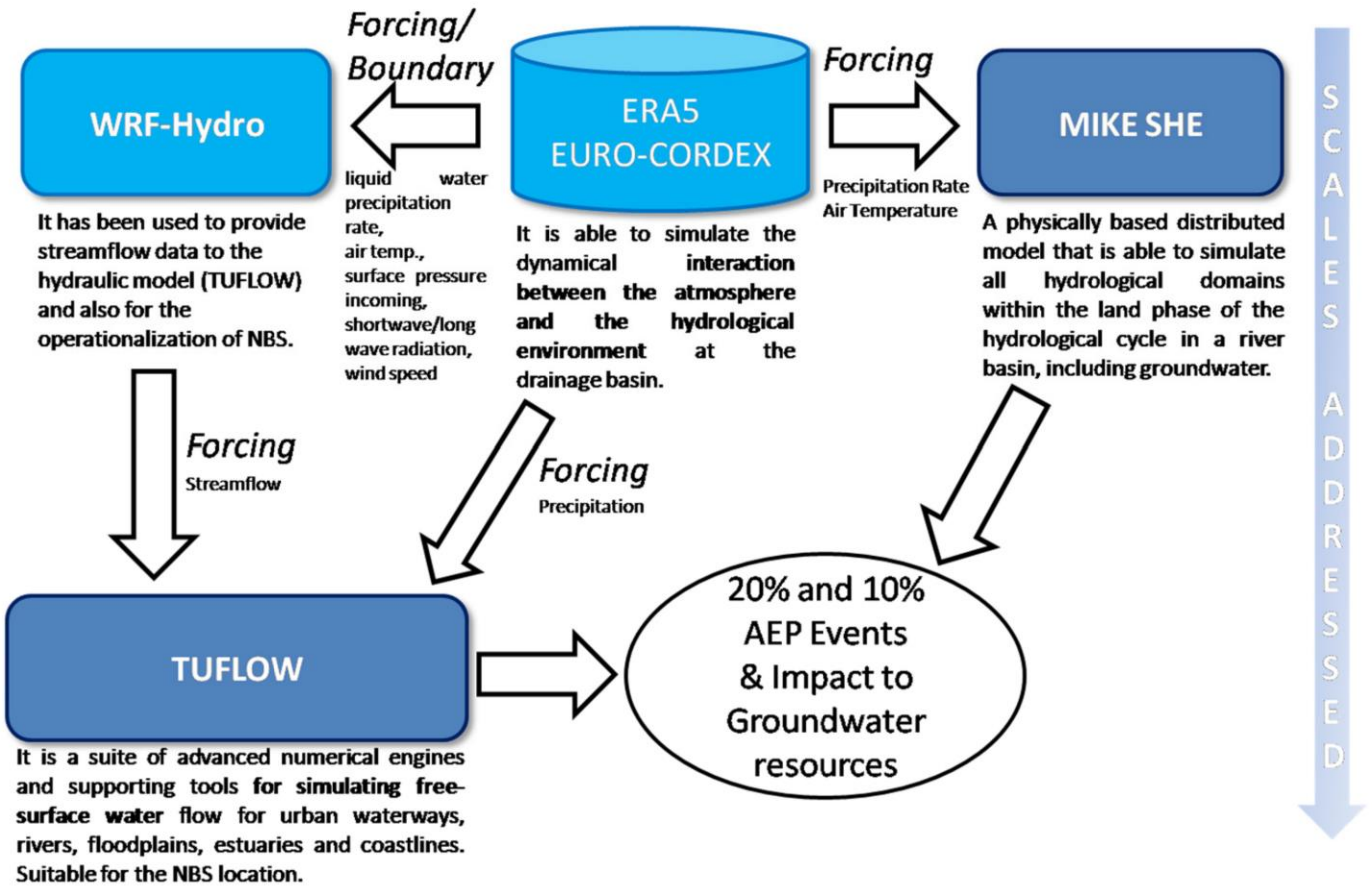
OAL Greece

OPERANDUM



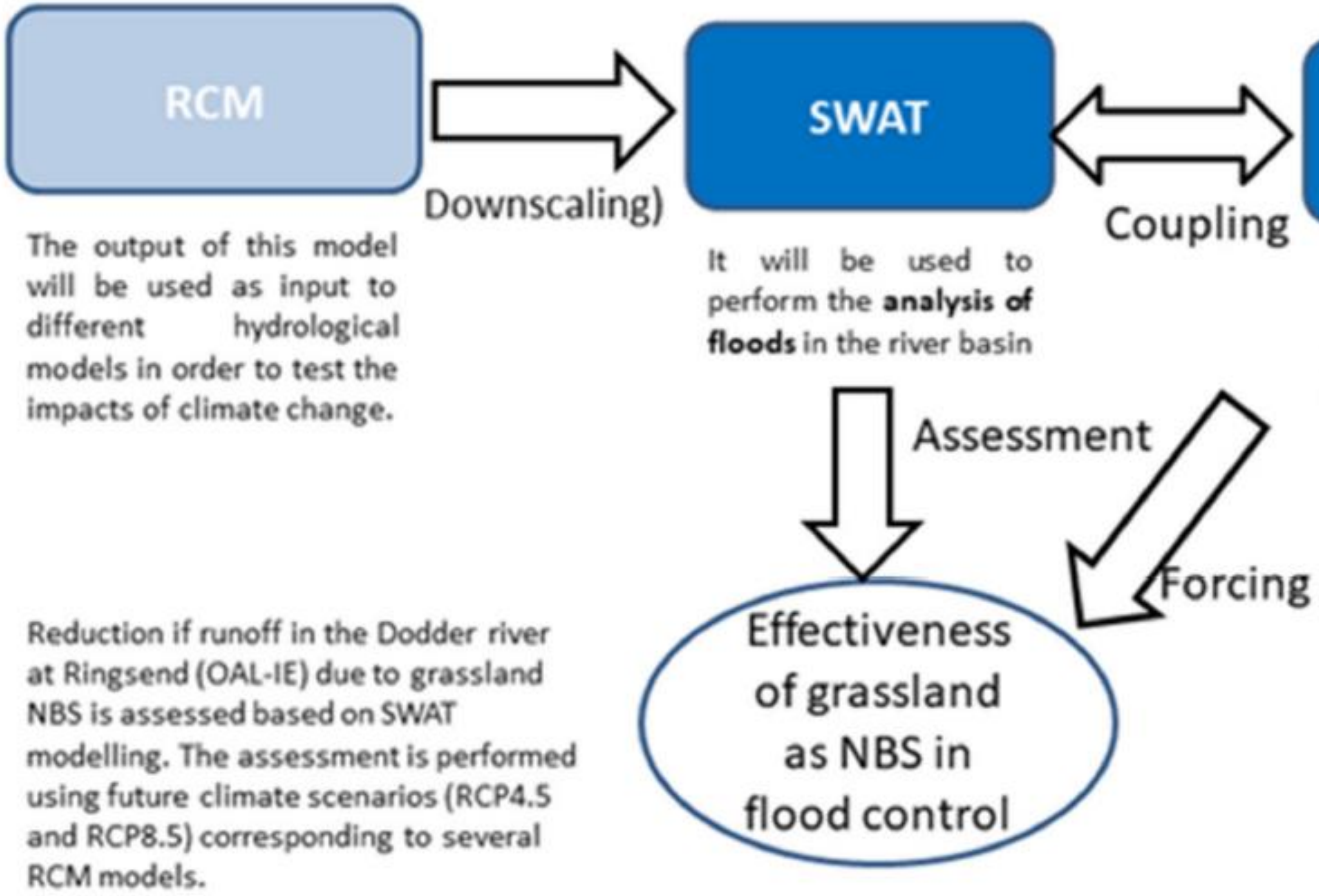
Modeling strategy for OAL-GR. AEP indicates the Annual Exceedance Probability

WRF-Hydro to facilitate an improved representation of terrestrial hydrologic processes related to the spatial redistribution of surface, subsurface, and channel waters across the land surface

TUFLOW for the flood levels and the flood mapping outputs. It consists of a suite of advanced numerical engines and supporting tools for simulating free-surface water flow for urban waterways, rivers, floodplains, estuaries, and coastlines.

The final aim is to provide information on the impact that the NBS has on the flood levels and the flood mapping outputs.

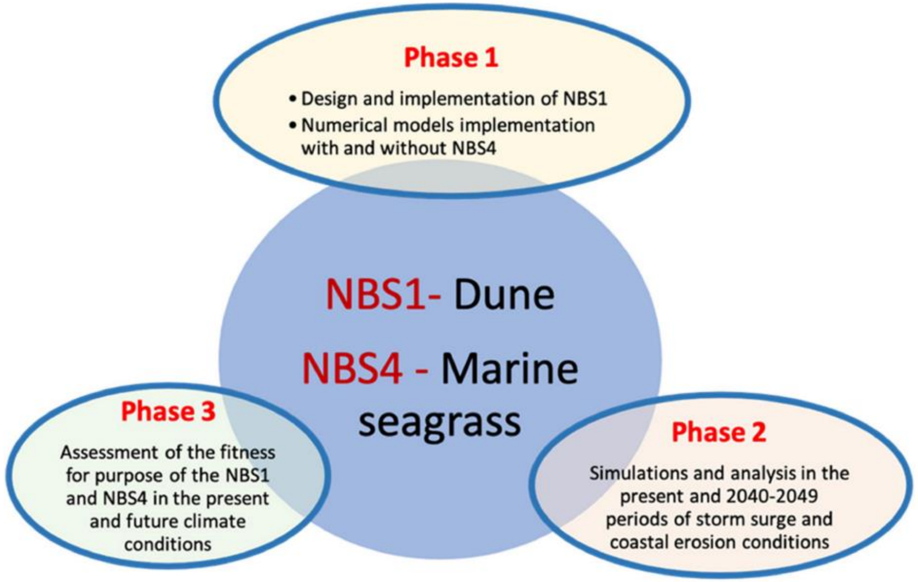
OAL Ireland



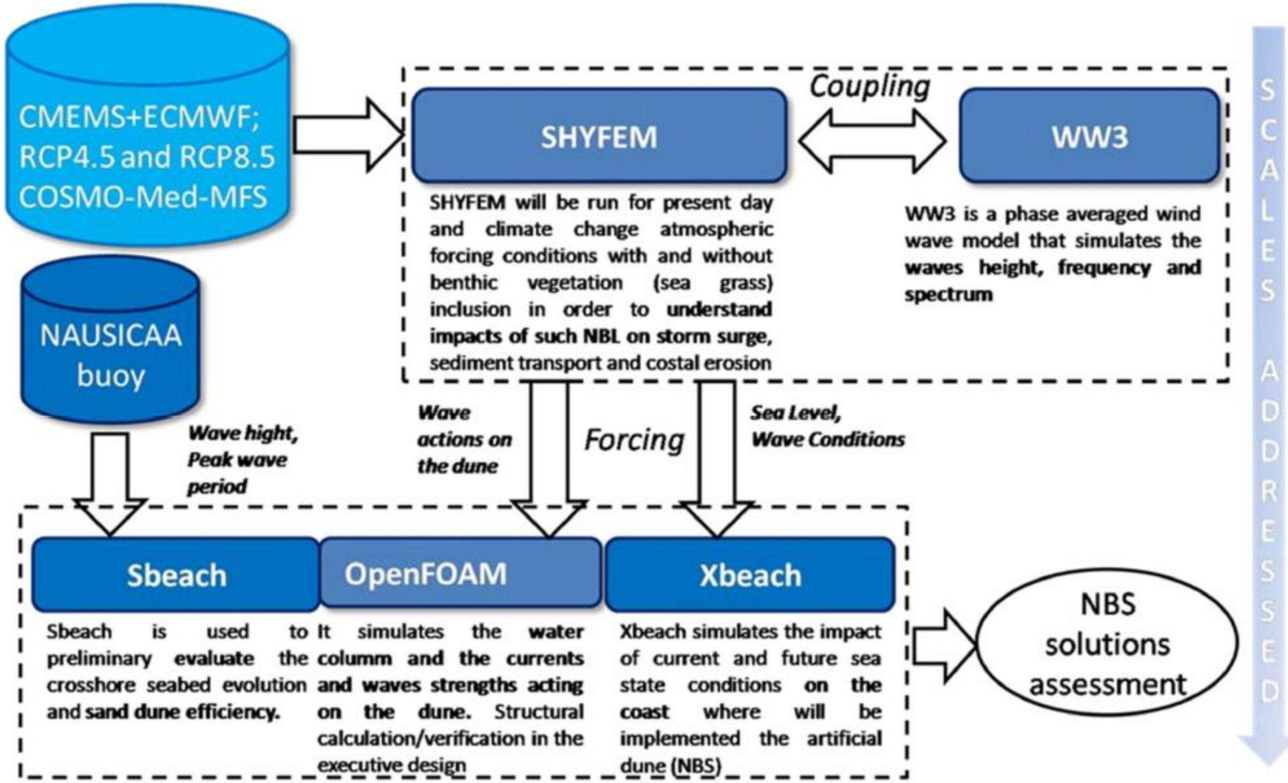
Modeling strategy for OAL-IE, including regional climate models (RCM) and the Soil-Water Assessment Tool model (SWAT)

The Soil Water Assessment Tool (SWAT) model has been used to simulate streamflow at River Dodder for understanding fluvial flooding and pluvial flooding in terms of rainfall.
The advantage of the SWAT model is that it accounts for the fluvial as well as the pluvial flooding in the area. It is a physically based, semi-distributed rainfall-runoff model.

OAL Italy – coastal erosion

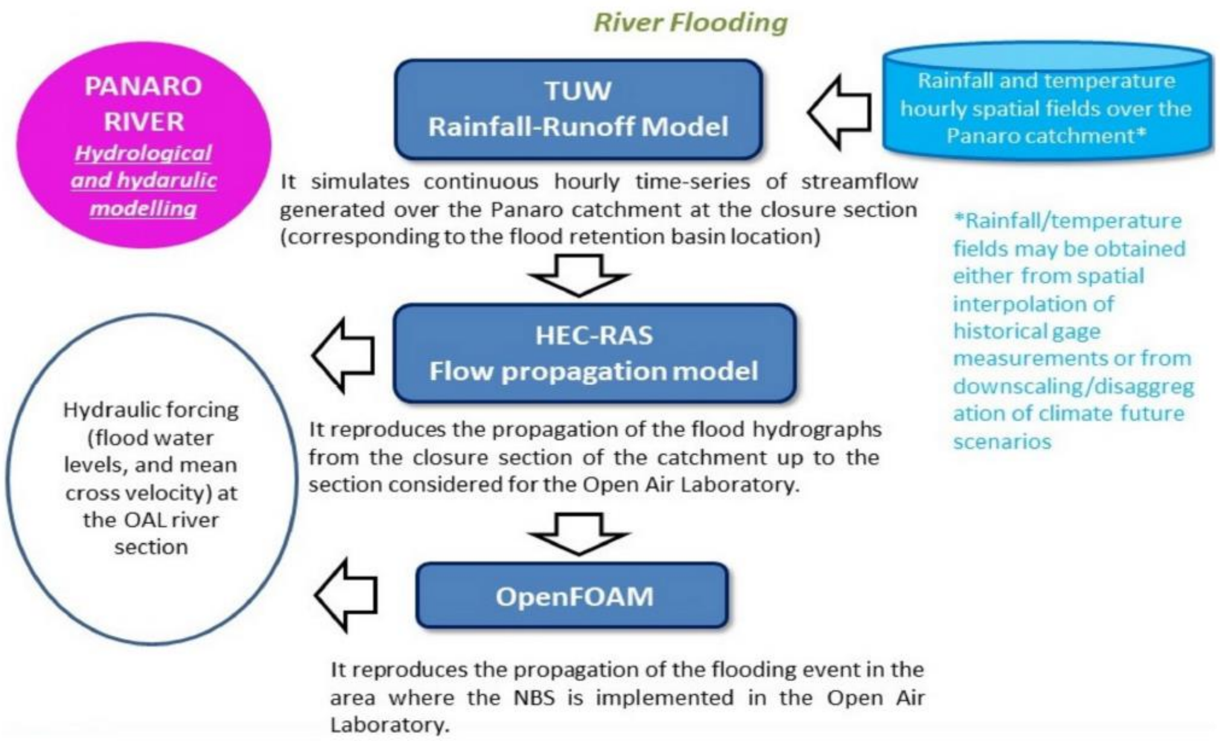


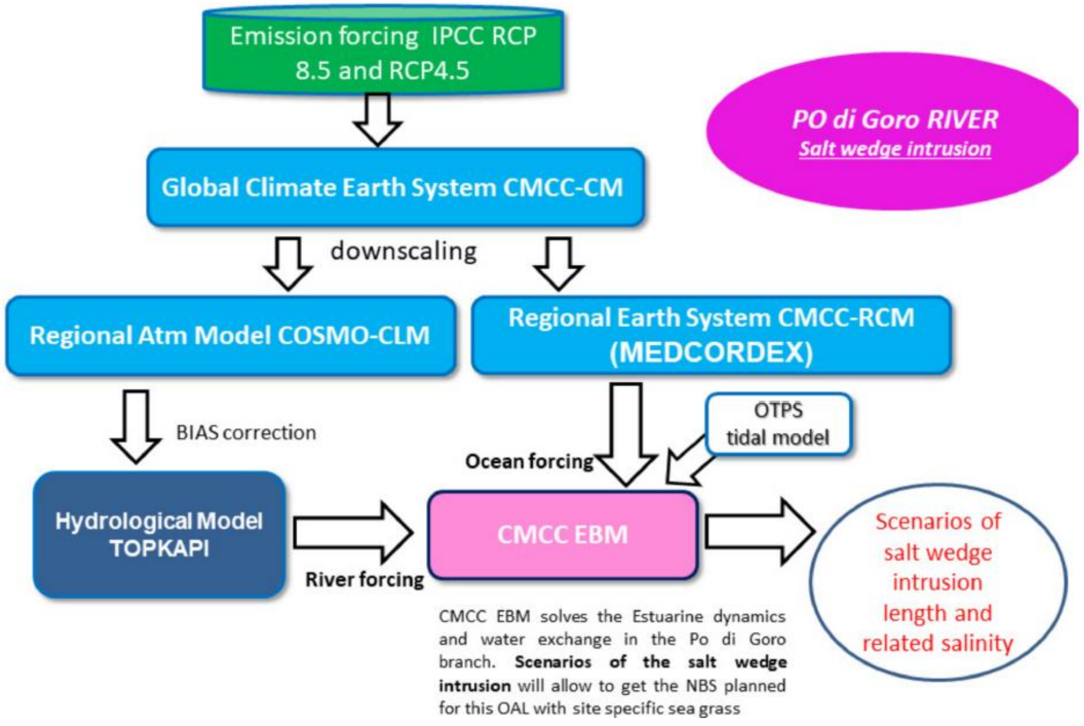
The three step process to assess the two NBSs (NBS1 = dune, NBS4 = seagrass) in the OAL-Italy coastal area



The sea-level model is based on the hydrostatic primitive equations for the ocean and accounts for thermodynamic and hydrodynamic processes. The horizontal and vertical scales are in the order of hundreds of meters and tens of meters, respectively. In particular, the SHYFEM unstructured grid hydrodynamical model is used here to evaluate the fitness for purpose of submerged aquatic vegetation on the sea level extremes, under present and future climate conditions.

OAL Italy - rivers



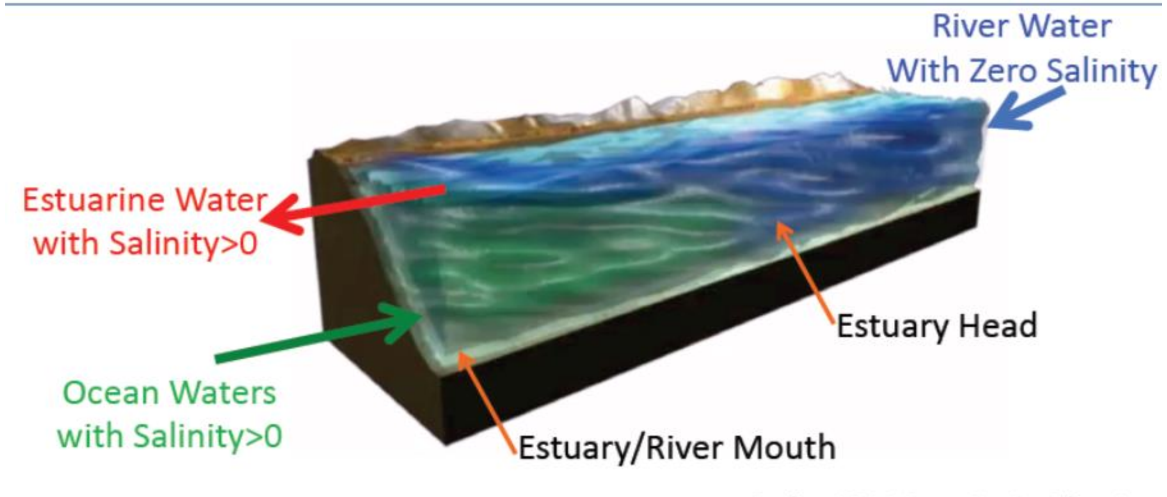


Deep rooting perennial herbaceous species, whose aerial parts are expected to reduce the mechanical impact of raindrops, while belowground parts (deep thin roots) are demanded to mechanically reinforce the embankment-forming materials, facilitate drainage in the topmost layers of the earth embankment, and promote the plant water uptake.

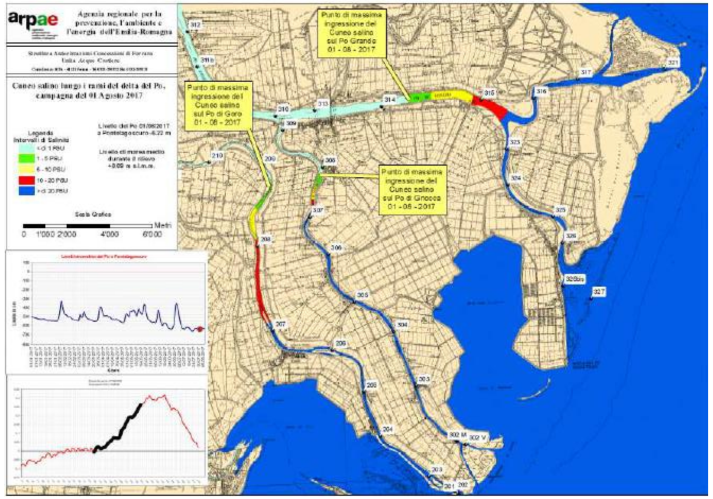
The core of the system is a 2-layer 1D Estuary Box Model, the so-called CMCC EBM. It aims to represent the net river release at the estuary mouth in terms of volume flux and salt flux and estimate the length of the salt-wedge intrusion.

OAL Italy – salt intrusion

Set up a novel Estuary Box Model to provide scenarios of estuarine water exchange and salt wedge intrusion

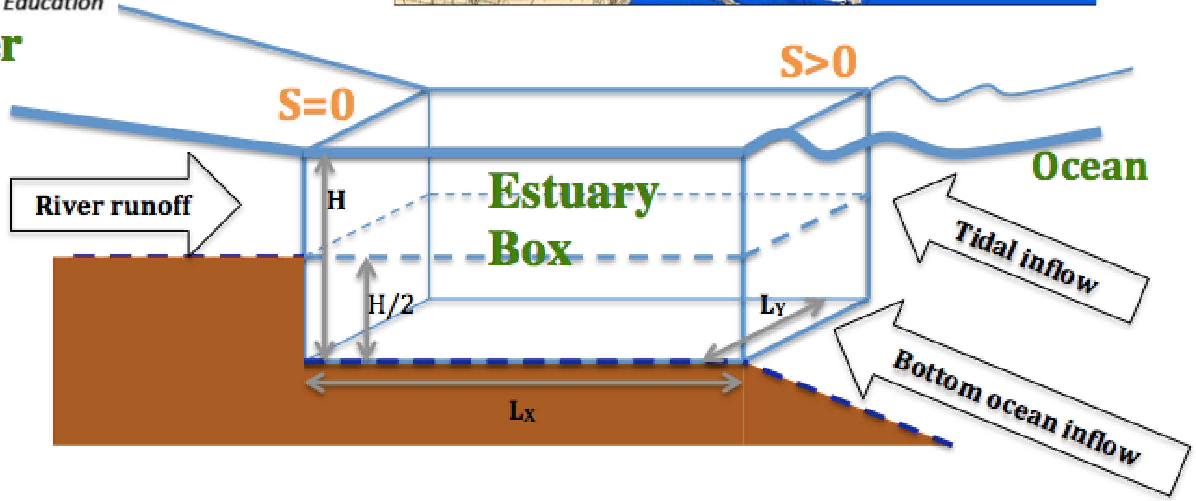


Credits: NOAA Ocean Service Education

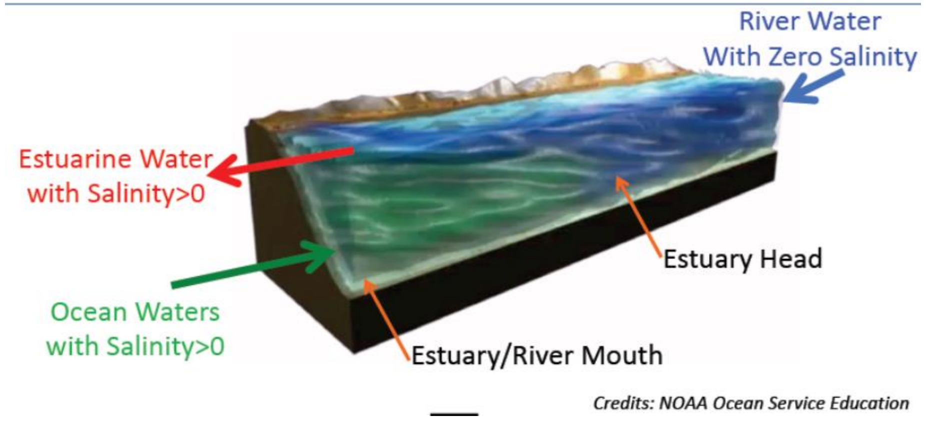


Method:

- ✓ 1D Box modeling of the estuarine water exchange with 2-layer flow at the estuary mouth
- ✓ Extension of the Box is based on the length of the salt wedge intrusion L_X
- ✓ Coupling with an hydrological model/obs at the estuary head and an ocean model/obs at the estuary mouth

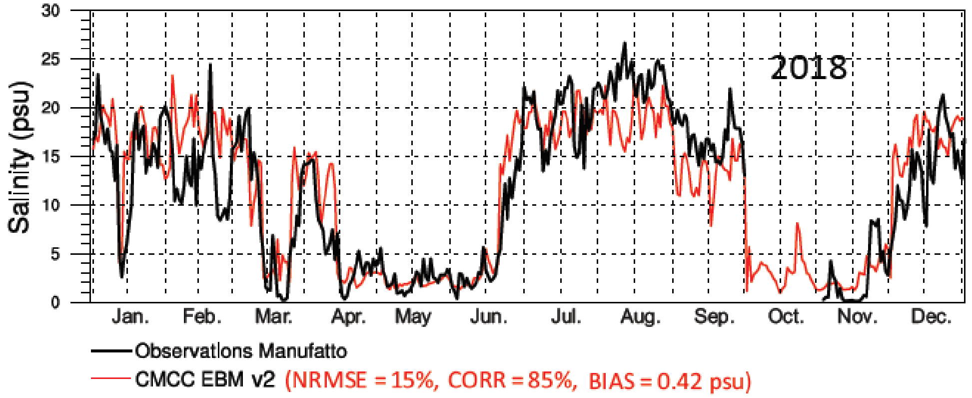


OAL Italy – salt intrusion

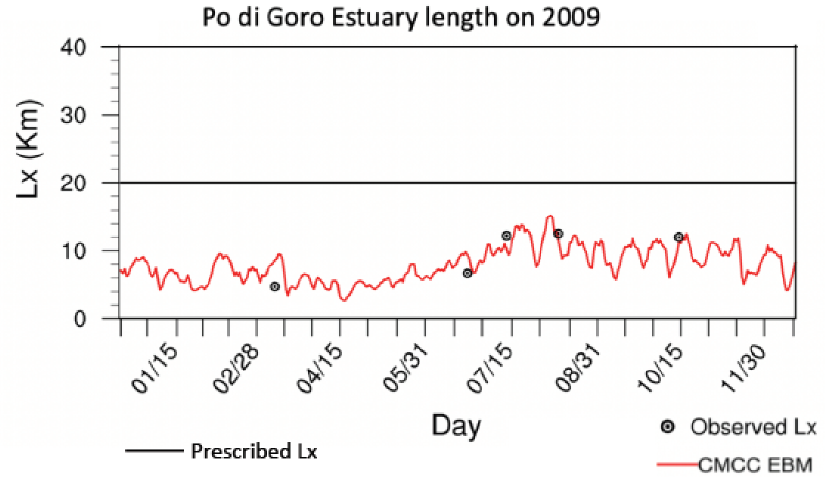


Credits: NOAA Ocean Service Education

1. Reliable representation of salinity at river mouths



2. Reliable representation of length of salt wedge intrusion



Modelling by CMCC

OAL Italy – seagrass

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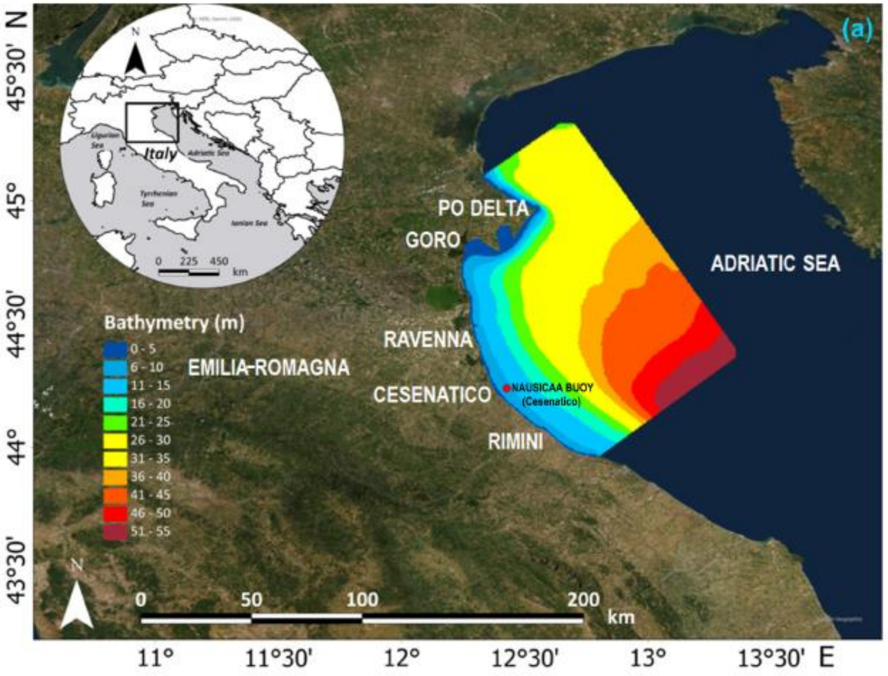

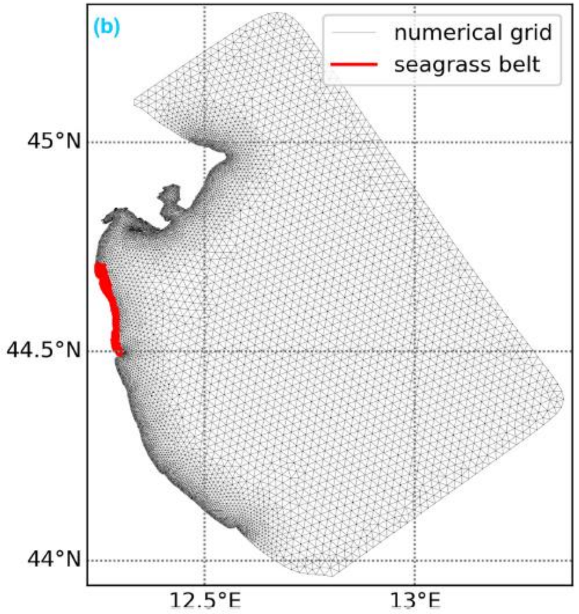

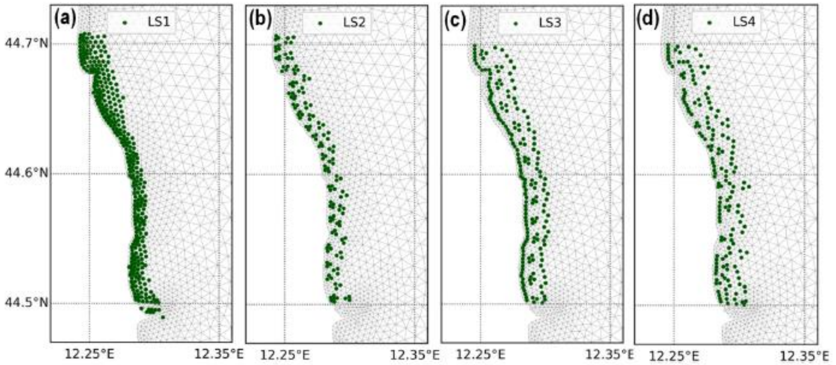

Seagrass landscape designs (a) LS1: continuous mask, (b) LS2: lower density cluster, (c) LS3: continuous stripes with clusters, and (d) LS4: broken strips with clusters.


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ELSEVIER

A Digital Twin modelling framework for the assessment of seagrass Nature Based Solutions against storm surges

Umesh Pranavam Ayyappan Pillai [a,*], Nadia Pinardi [a], Jacopo Alessandri [a,b], Ivan Federico [c], Salvatore Causio [c], Silvia Unguendoli [b], Andrea Valentini [b], Joanna Staneva [d]

Modelling of the wave, sea level and current attenuation due to seagrass NBSs. (i) are indigenous seagrass meadows able to reduce the energy of storm surges, and if so how? (ii) what are the best seagrass types and their landscaping for optimal wave and current attenuation?

OAL Italy – seagrass

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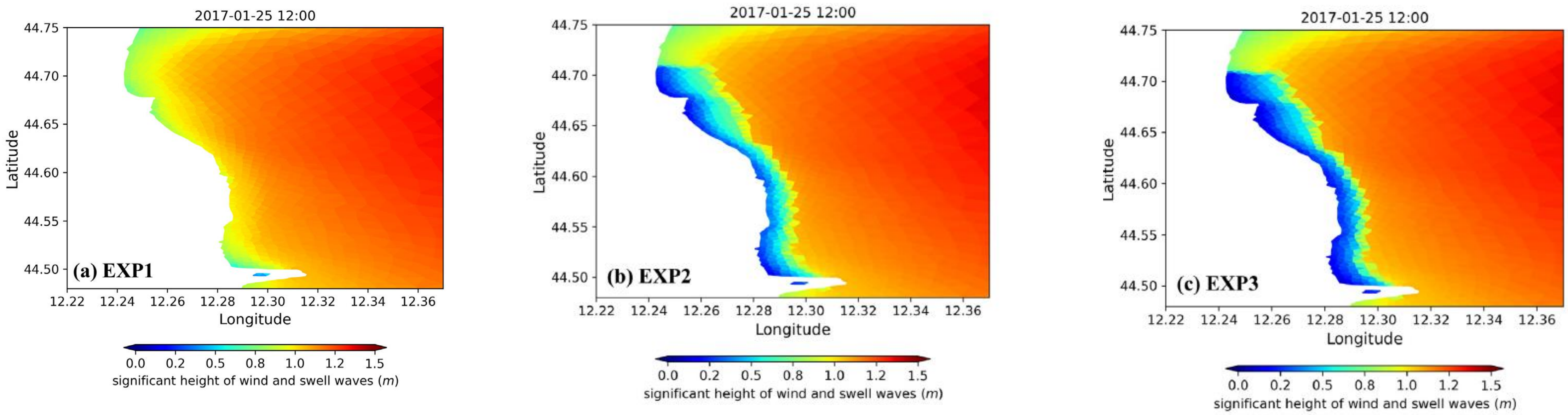

The amount of significant reduction in wave height depends on the seagrass landscaping.

A combination of broken strips and clusters of vegetation has been shown to be effective in reducing wave energy on the coast compared to other landscape designs.

Seagrass is shown for our model configuration not to have a direct impact on sea level, but significantly reduce current amplitudes.

OAL Italy – river flooding

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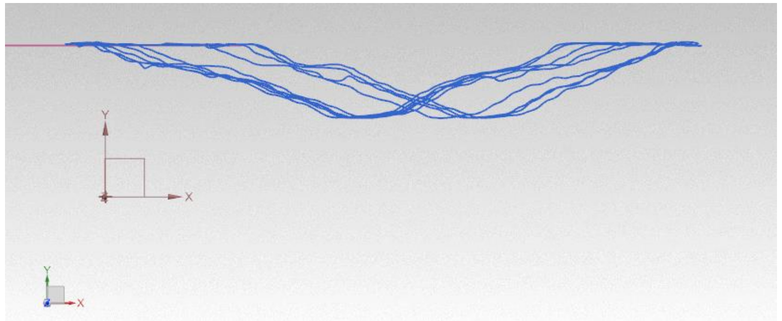
From a Lidar relief of the Emilia-Romagna a 3D model of the river is obtained using QGis

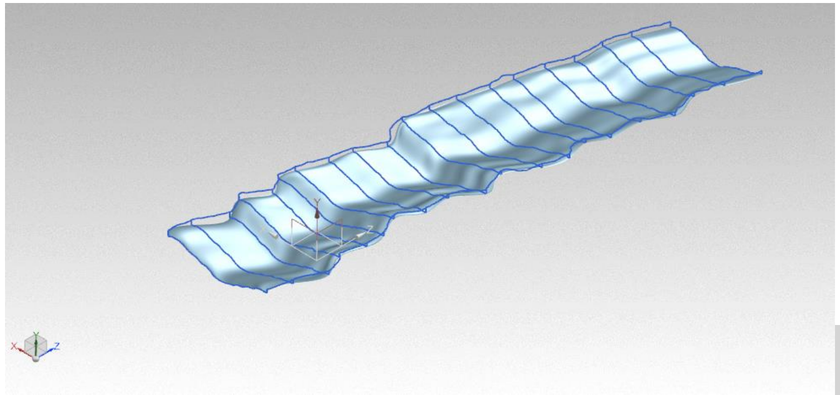
The relief is refered to the stretch of river from Bomporto to Camposanto. (Map physical-political 1:250.000-services WMS Geoportal region Emilia-Romagna.)

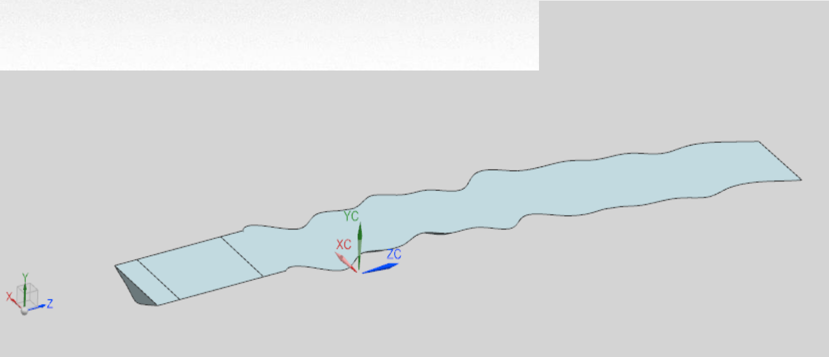
Coordinate of the NBS: 44.74605587894496, 11.053309770431378

OAL Italy – river flooding

For the realization of the geometry several profiles of the river's bed







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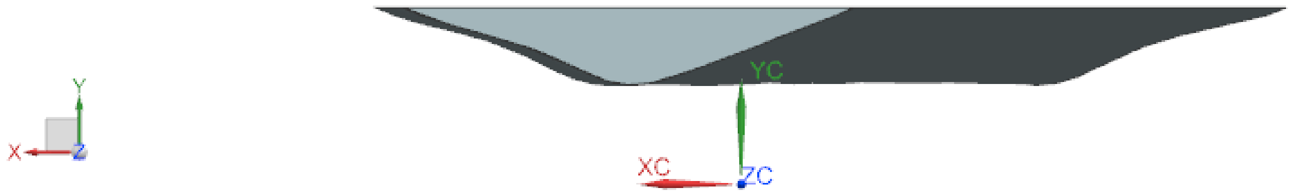

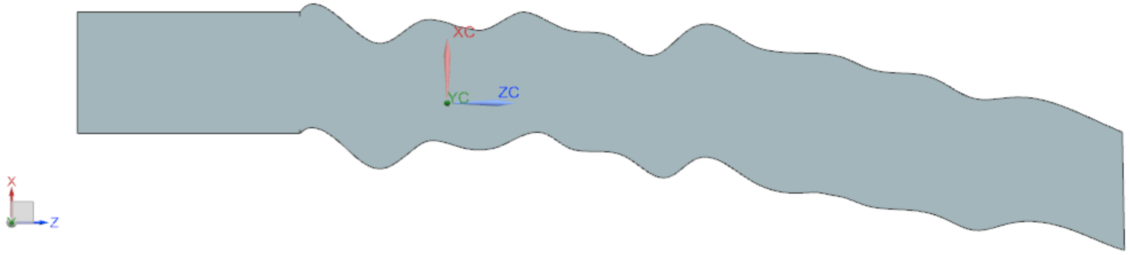

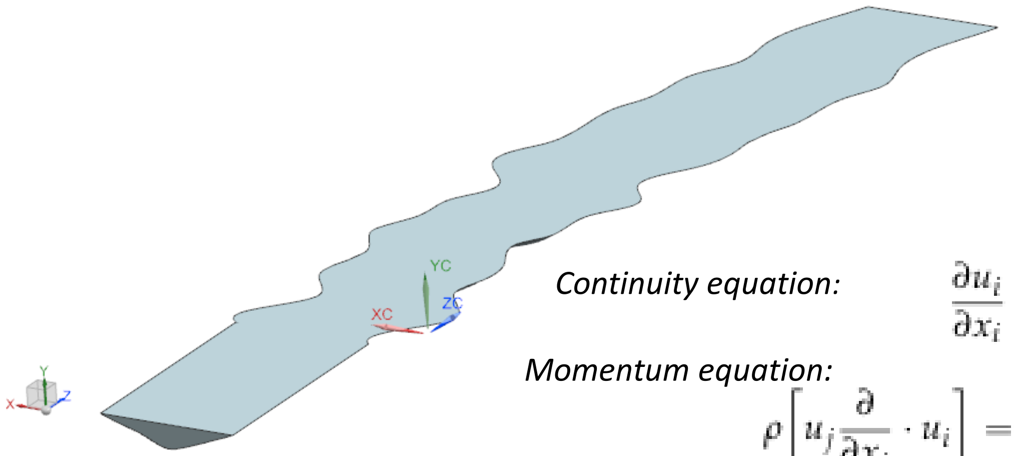

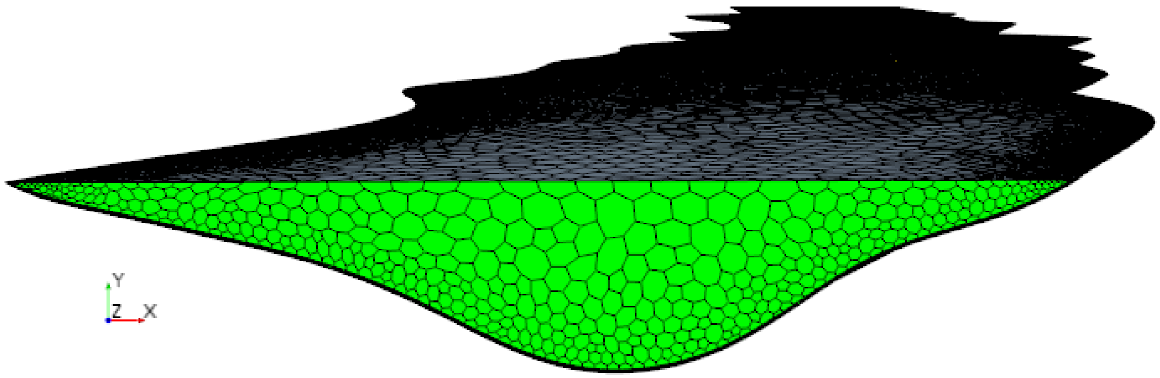

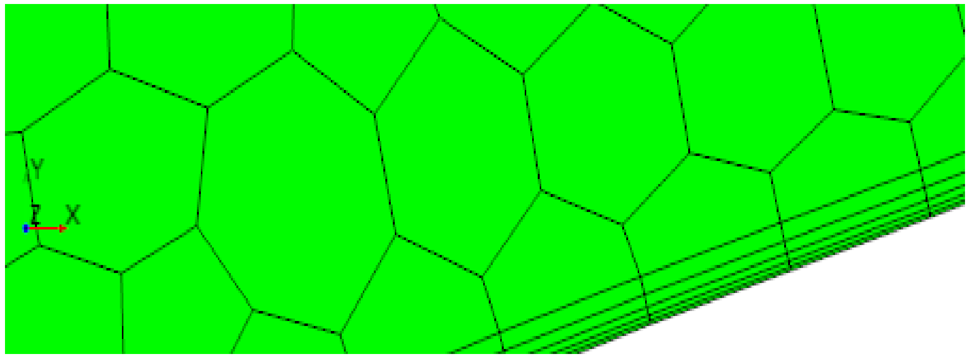

Continuity equation:

$$\frac{\partial u_i}{\partial x_i} = 0$$

Momentum equation:

$$\rho\left[u_j \frac{\partial}{\partial x_j} \cdot u_i\right] = -\frac{\partial p}{\partial xi} + \mu \nabla^2 u_i$$

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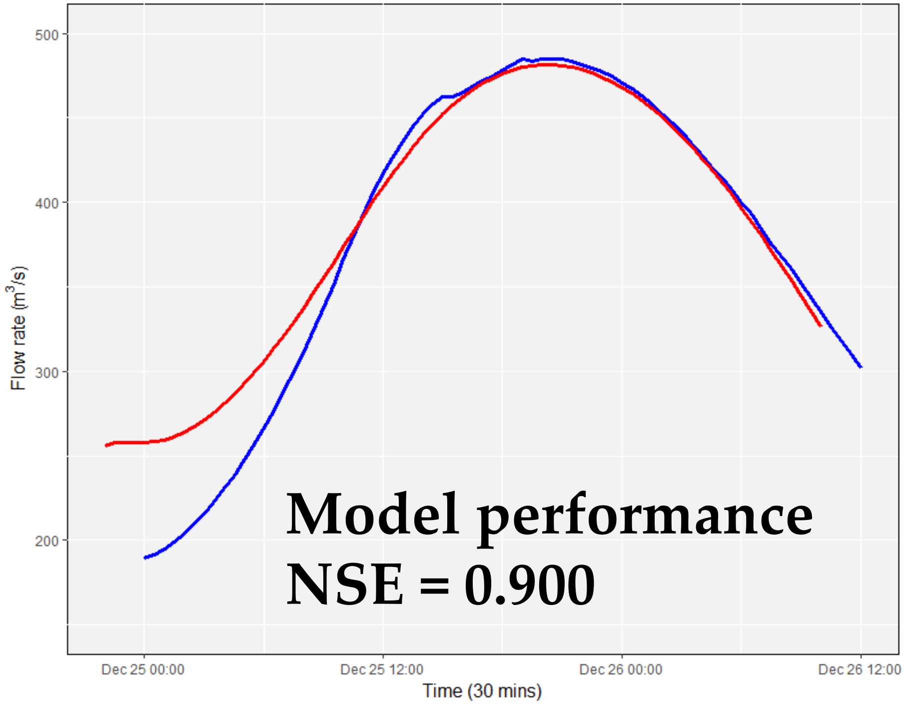
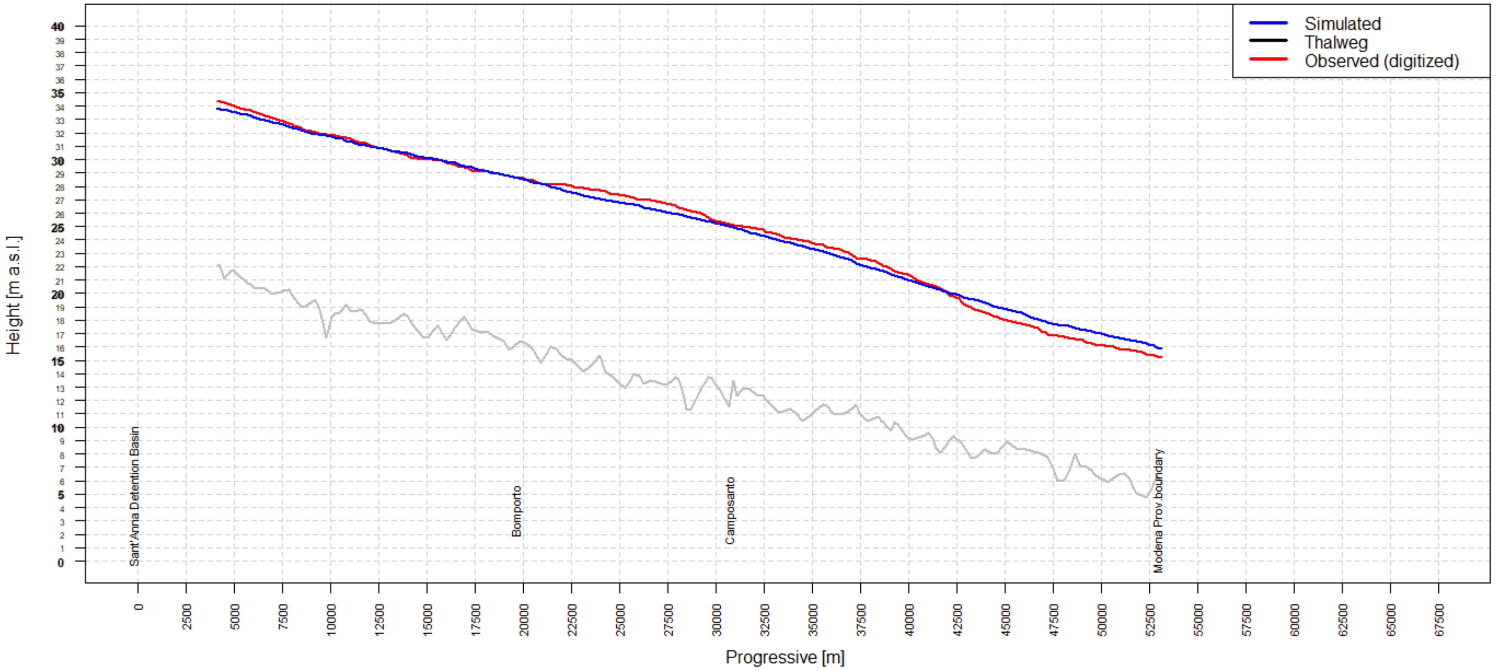
Boundary conditions

FLOW HYDROGRAPH
AT BOMPORTO



Model performance
NSE = 0.900

LONGITUDINAL WATER PROFILE – NSE = 0.993



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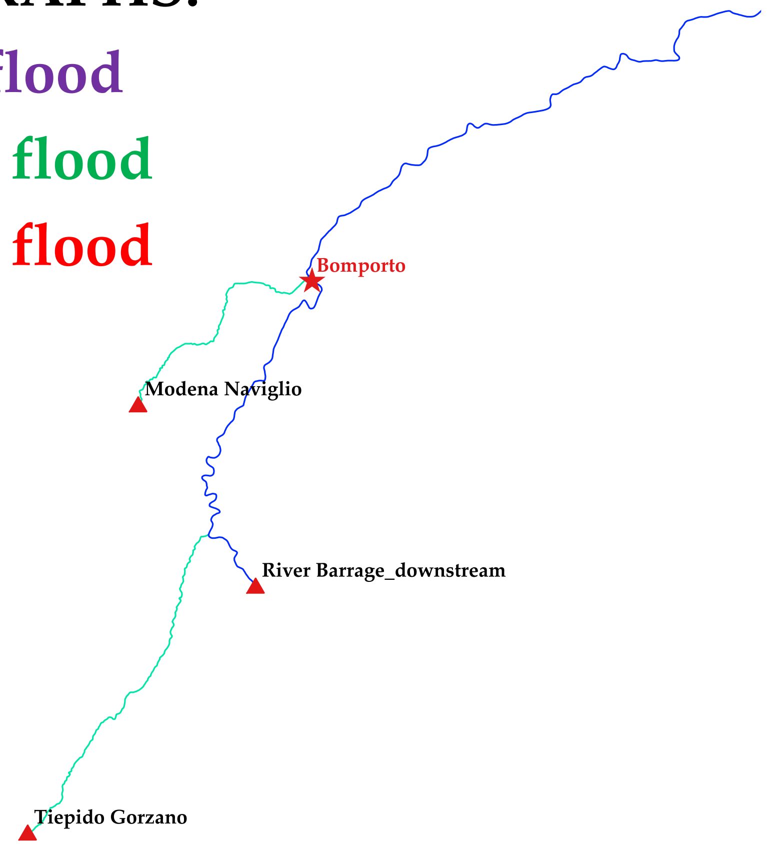
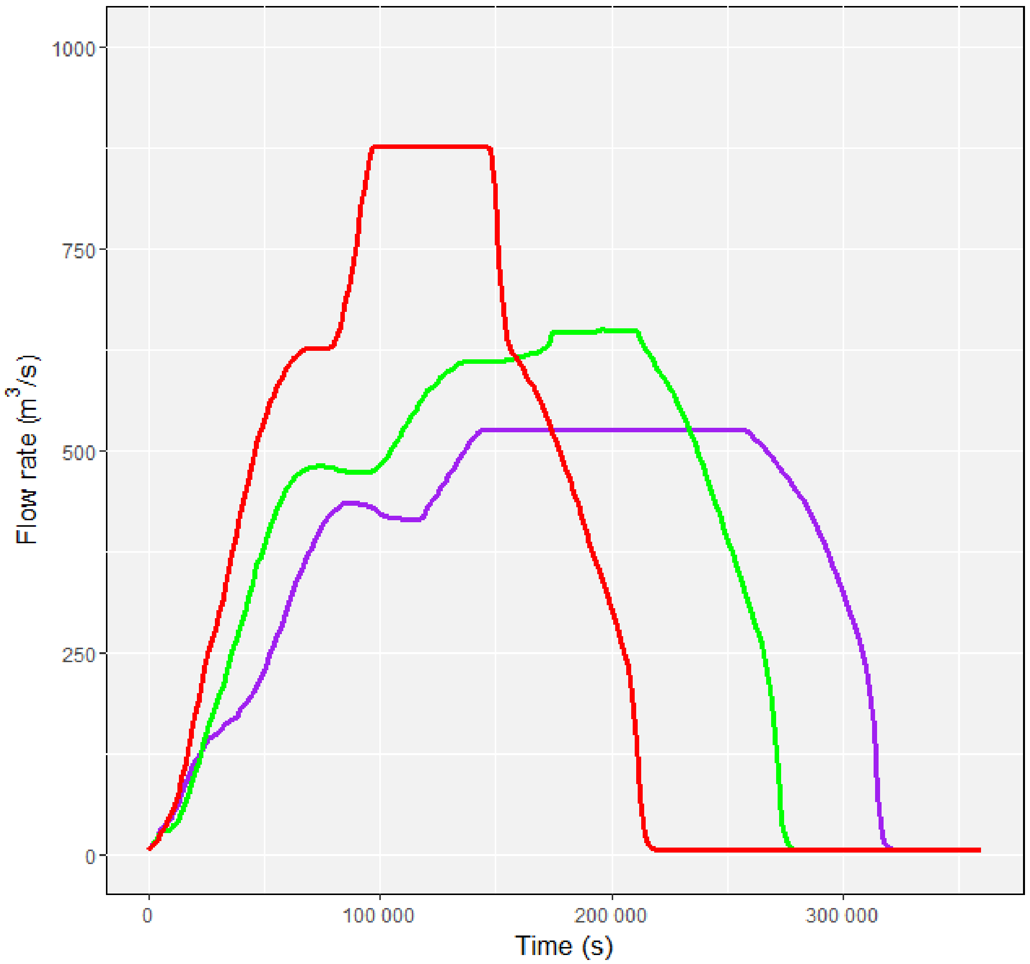
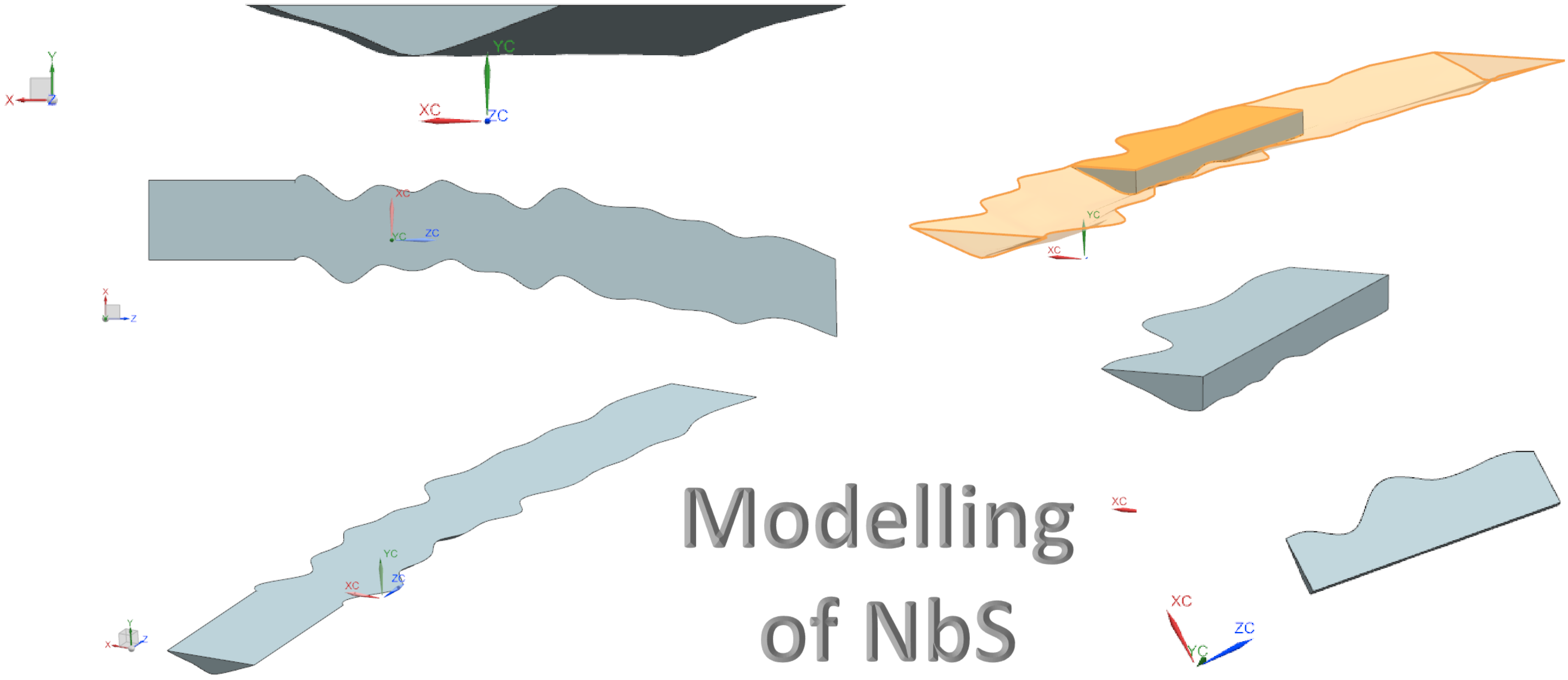
FLOW WAVE HYDROGRAPHS:

- 50-year flood
- 100-year flood
- 200-year flood





OAL Italy – river flooding



Modelling of NbS

OAL Italy – river flooding

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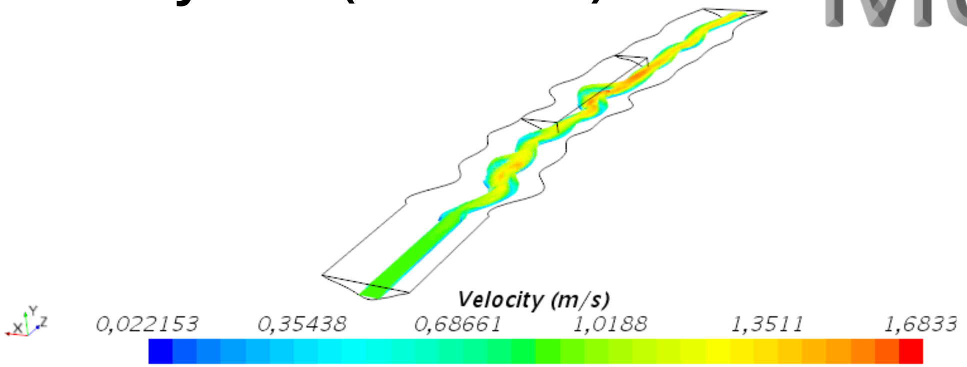
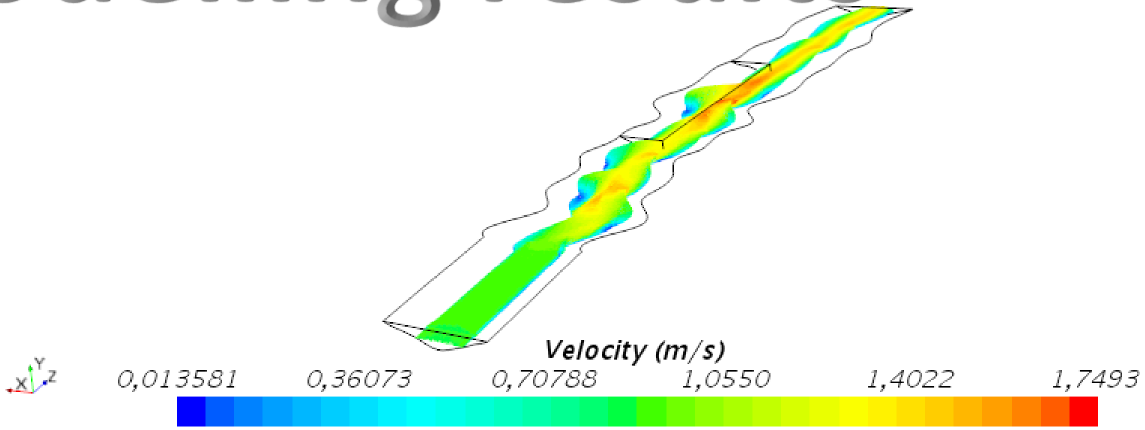
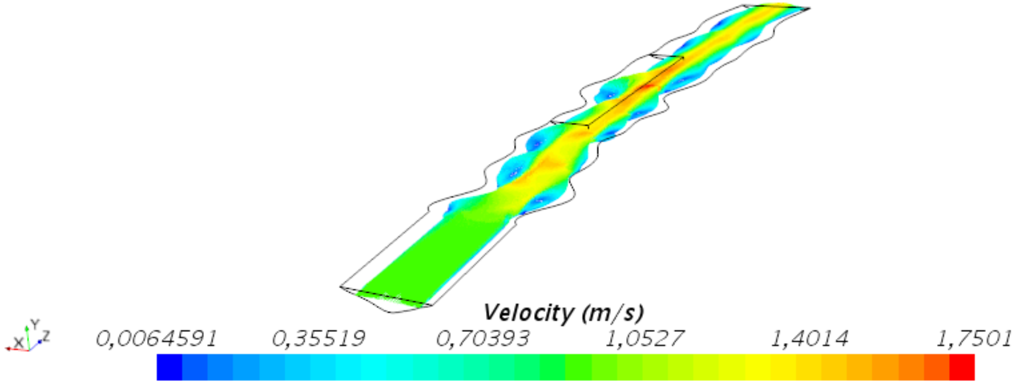
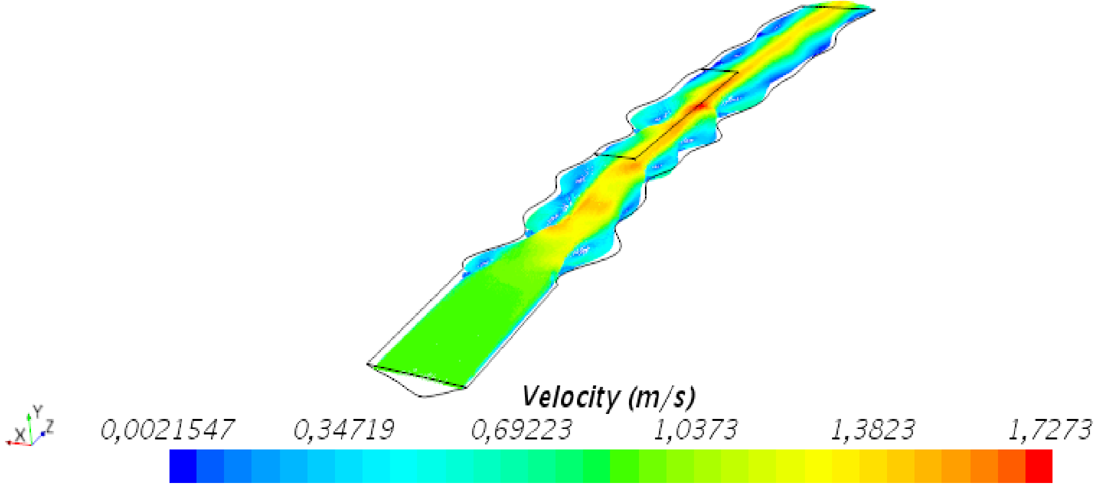
Modelling results

Velocity field **(without NBS):**









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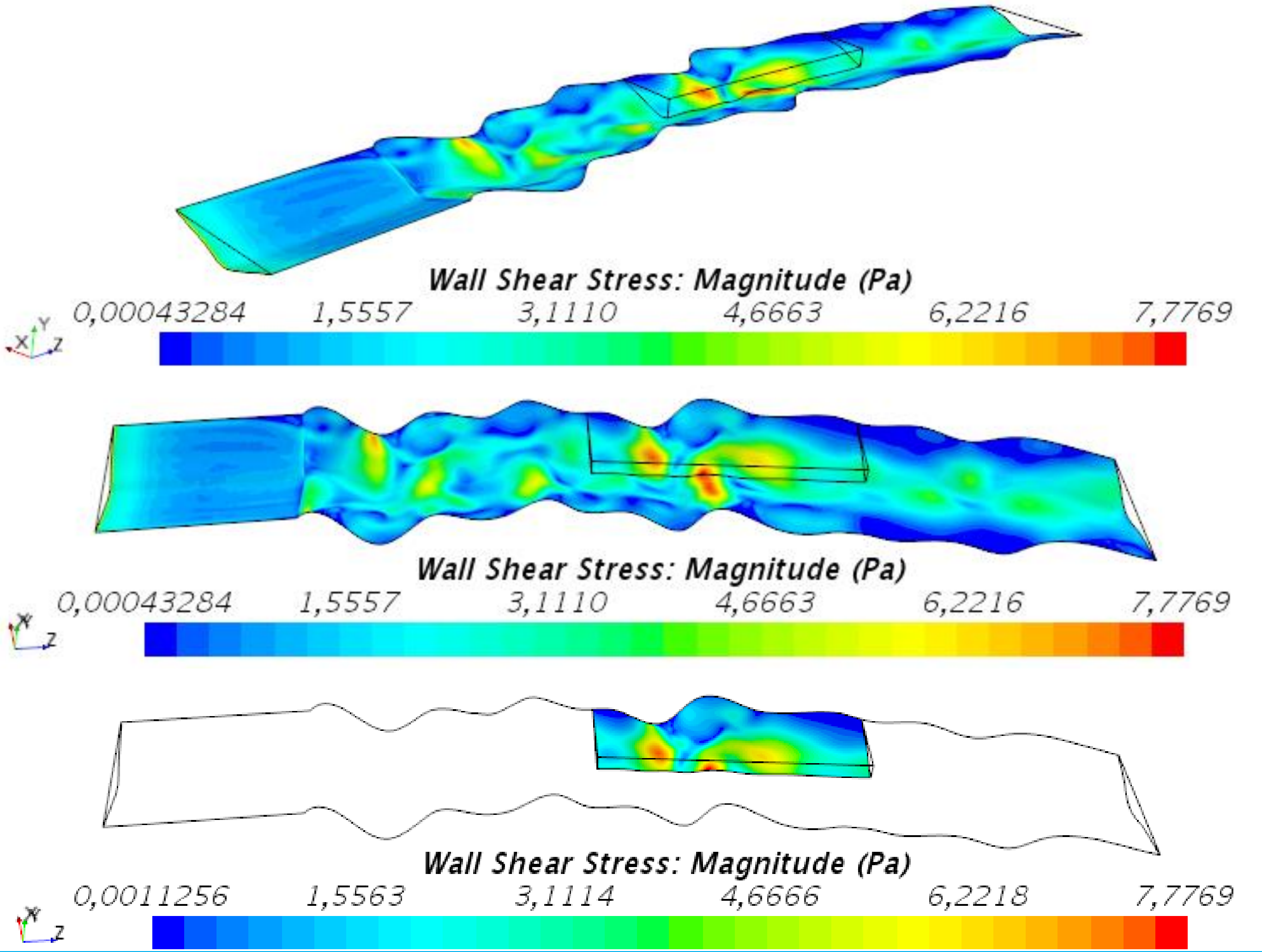
OAL Italy – river flooding

Wall shear stress (without NBS):



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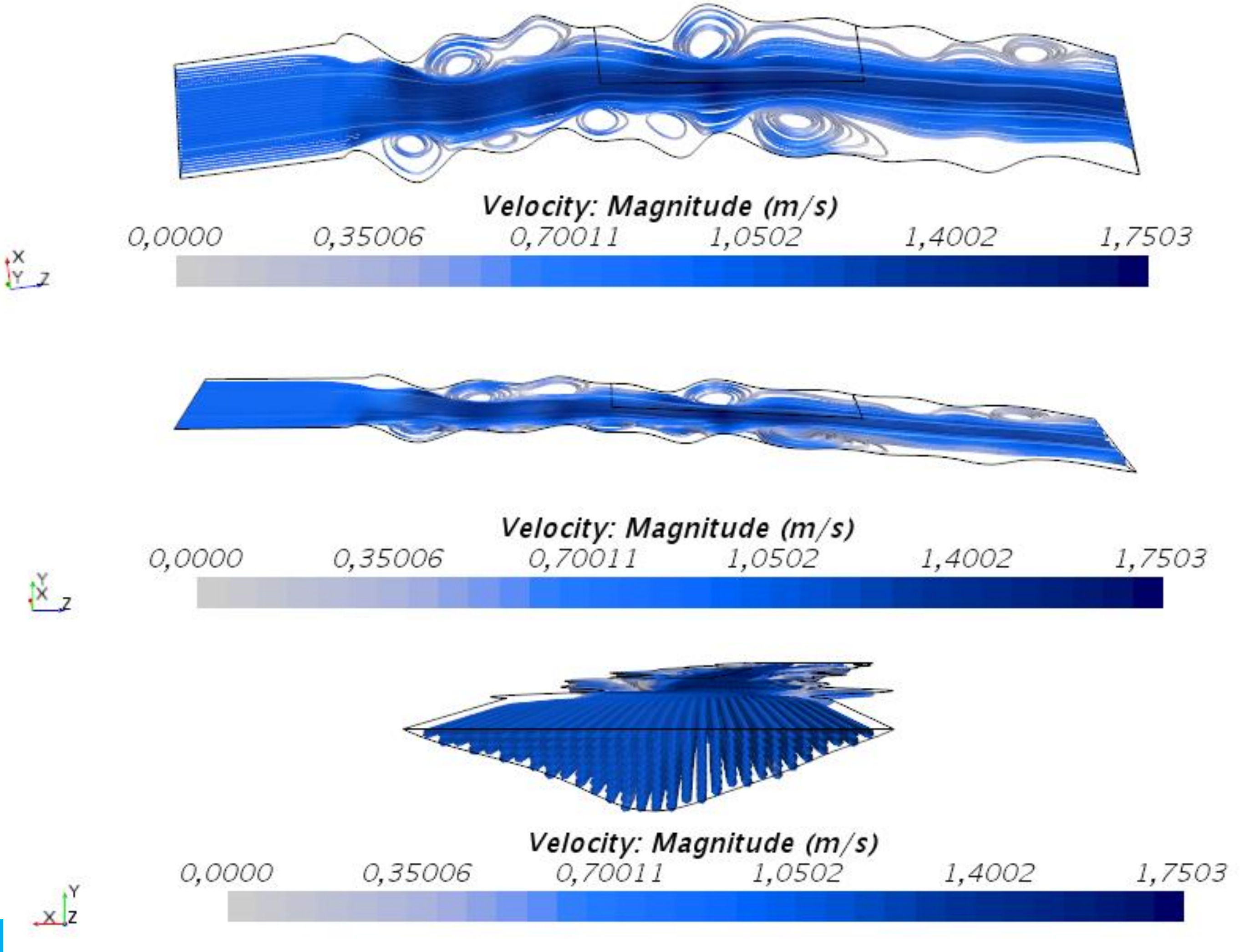
OAL Italy

Velocity streamlines (without NbS):



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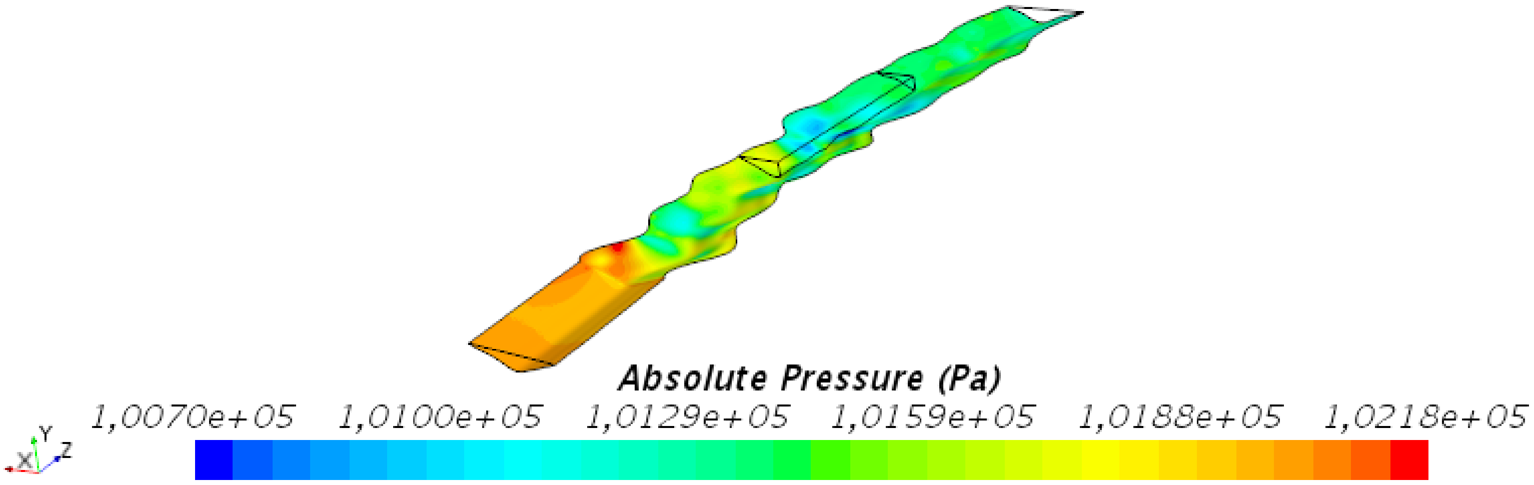
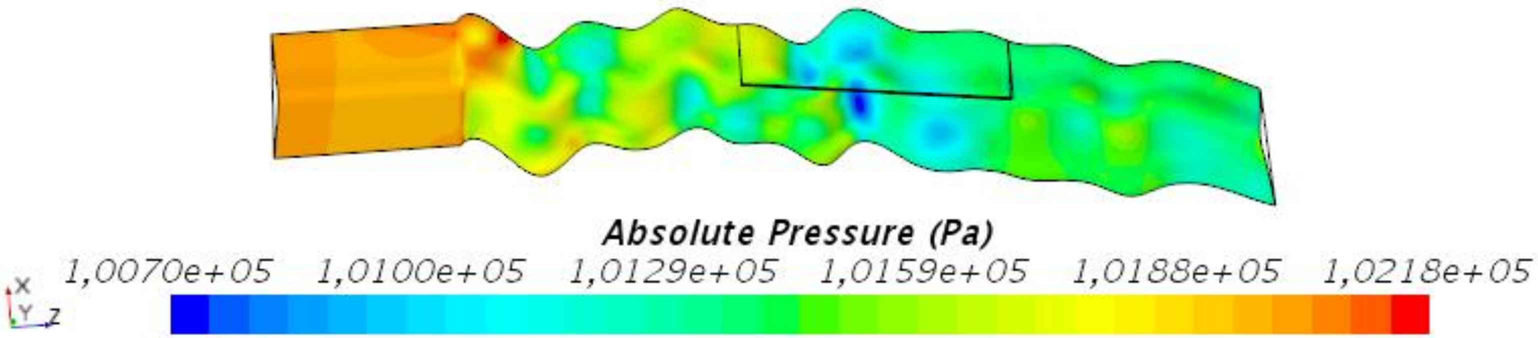
Pressure field **(without NbS):**





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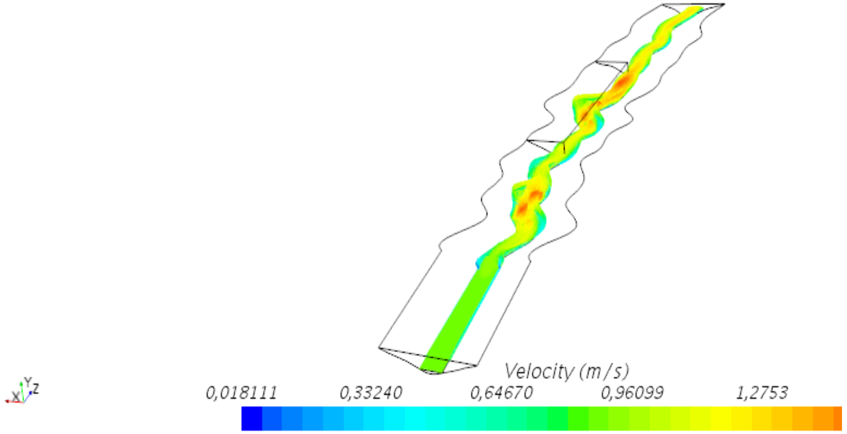
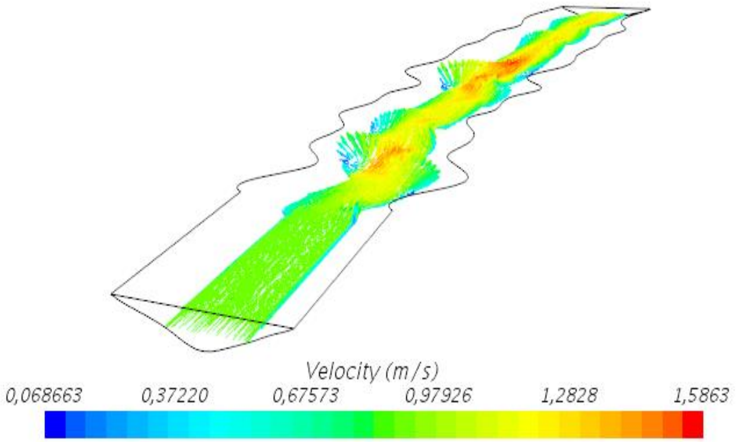
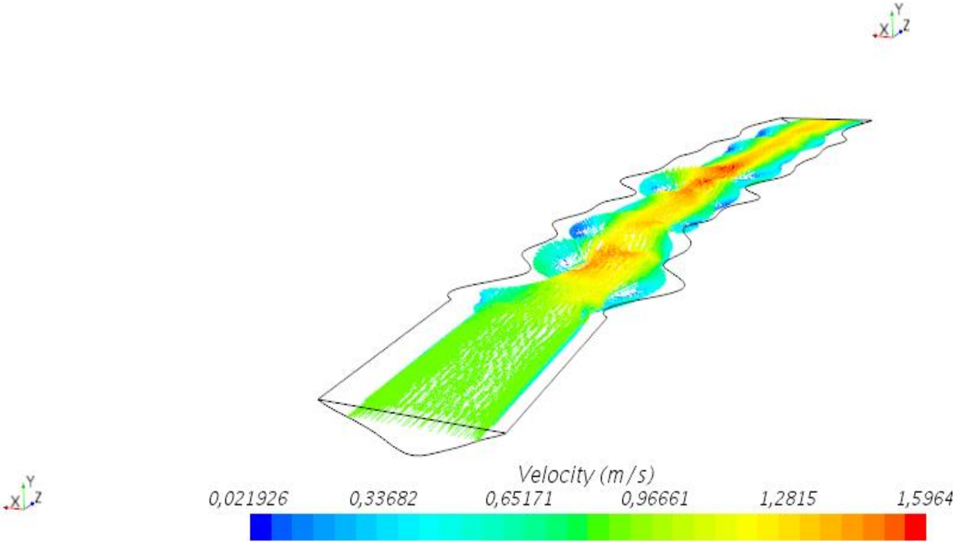
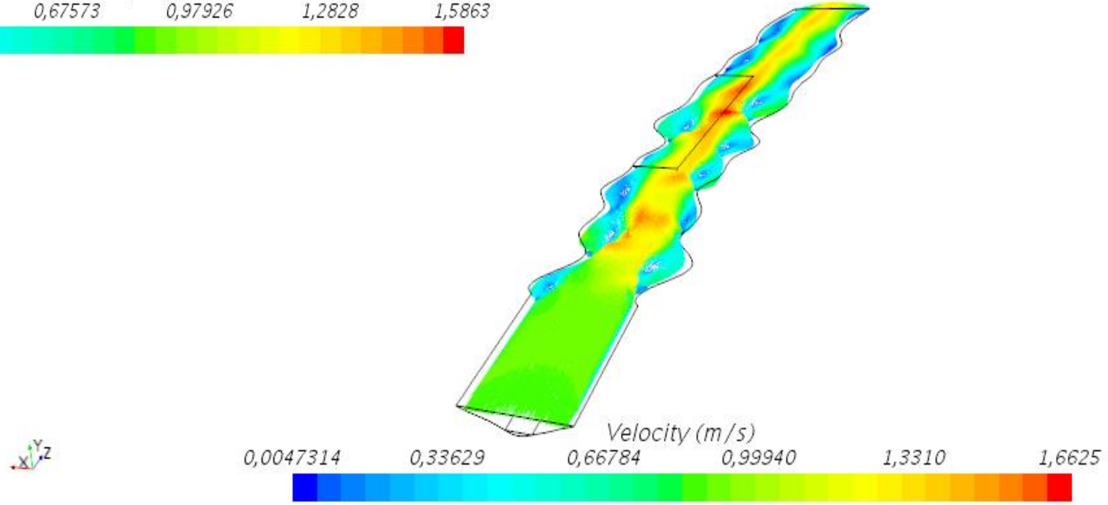
Velocity field **(with NBS):**









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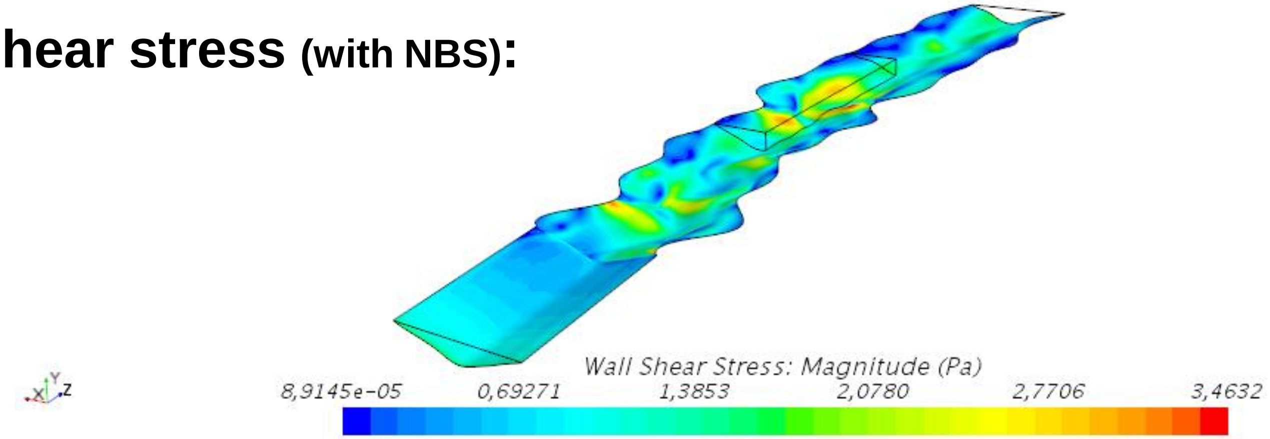
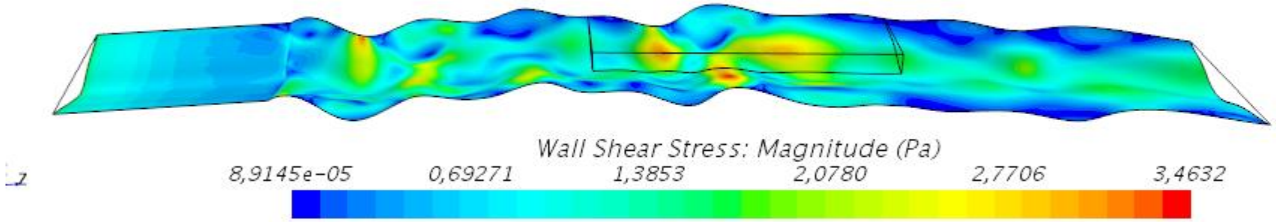
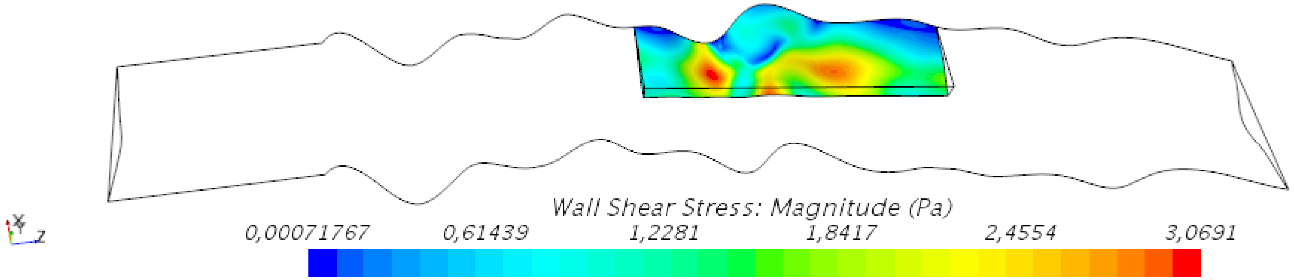
Wall shear stress **(with NBS):**







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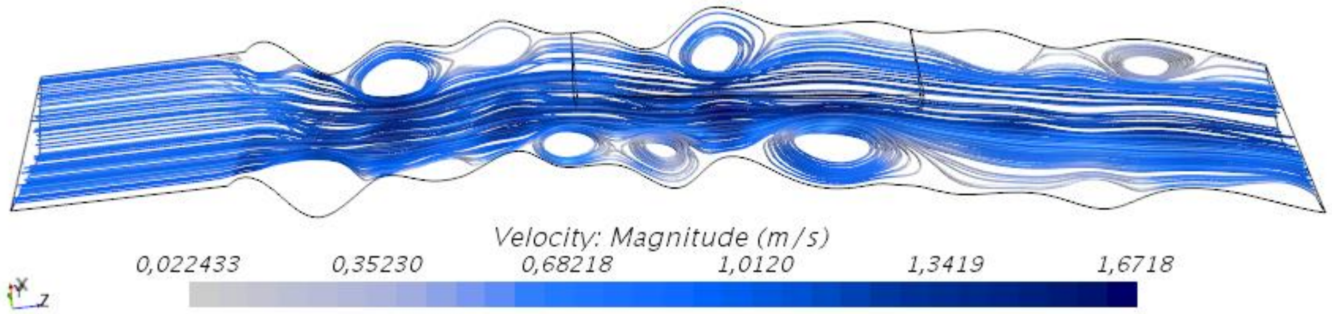
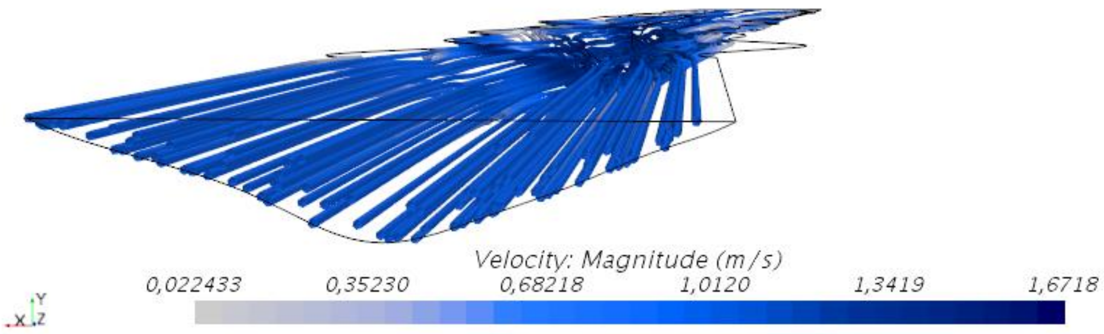
OAL Italy – river flooding

Velocity streamlines (with NbS):





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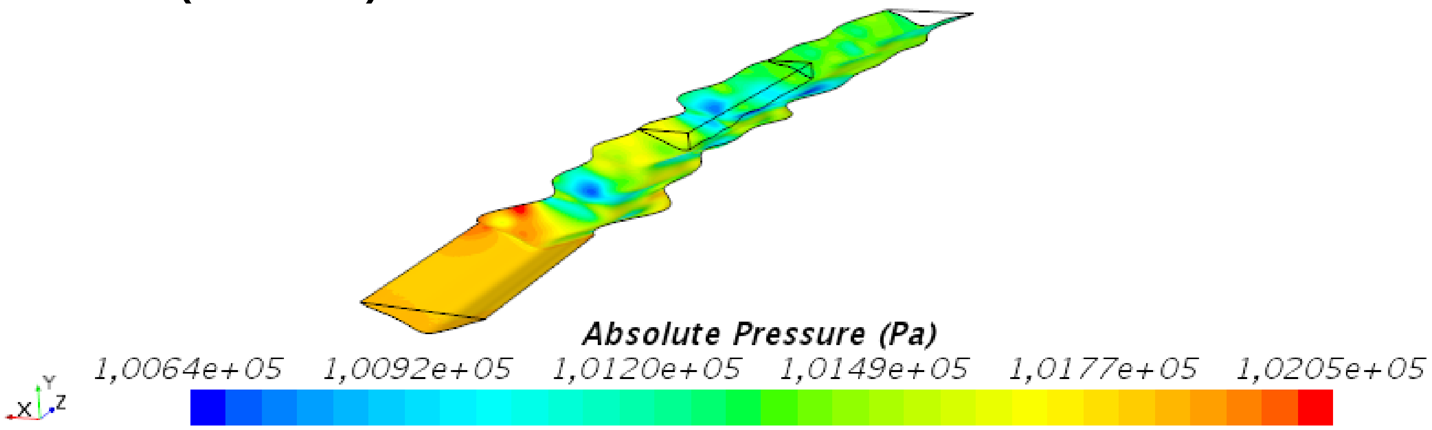
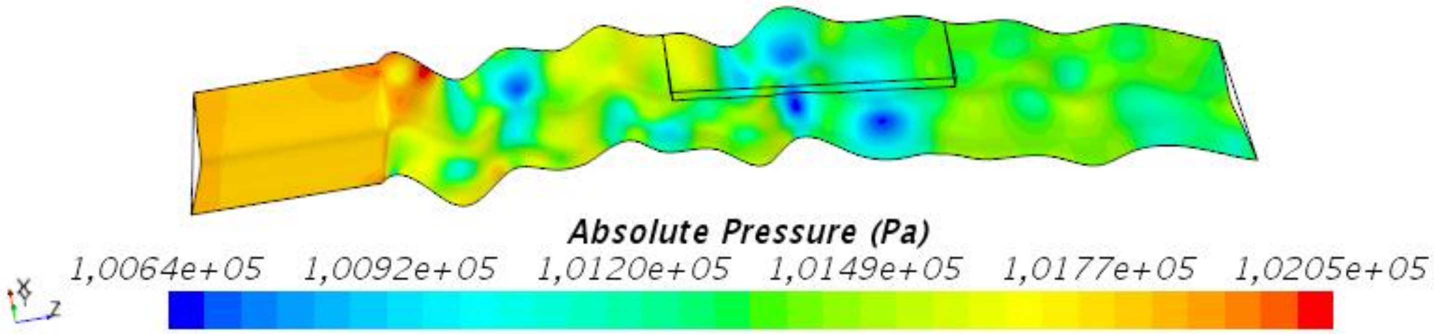
Pressure field **(with NBS):**





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OAL Italy – river flooding

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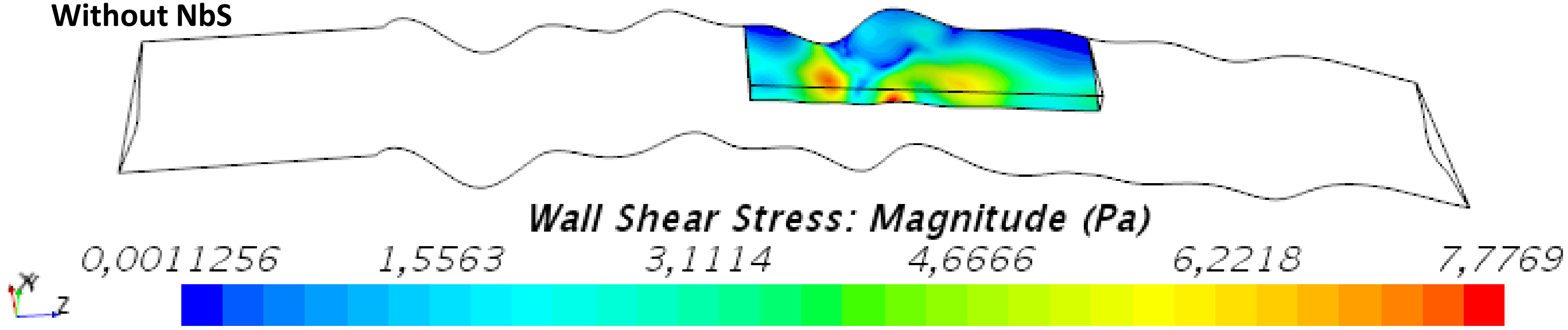
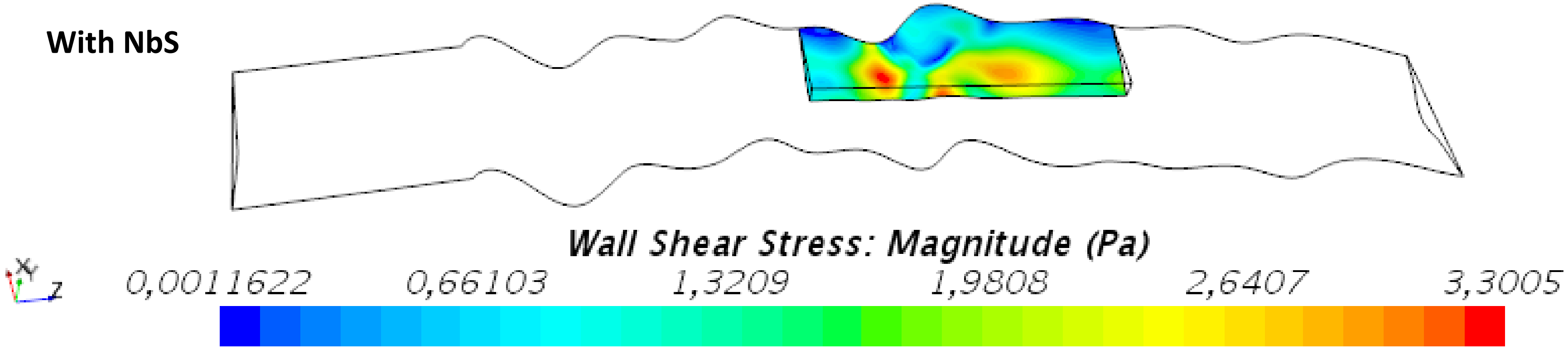
Comparison of shear stress:

Without NbS



With NbS



OAL Italy – river flooding

	Pressure drop inlet-outlet [Pa]	Pressure drop NBS [Pa]	Average pressure river [Pa]	Average pressure NBS [Pa]	Average w.s.s. river [Pa]	Average w.s.s. NBS [Pa]
smooth	2.665953X10^{2}	1.485383X10^{2}	1.014626X10^{5}	1.012370X10^{5}	0.8773391	1.305984
Bed roughness= 15 cm NBS roughness=15 cm	3.884601X10^{2}	2.471745X10^{2}	1.015562X10^{5}	1.013068X10^{5}	1.629926	2.460496
bed roughness=15cm NBS roughness=0.025cm	3.677017X10^{2}	1.700991X10^{2}	1.015381X10^{5}	1.012920X10^{5}	1.629046	1.465995
bed roughness=15cm, NBS roughness=0.0cm	3.643368X10^{2}	1.630215X10^{2}	1.015357X10^{5}	1.012918X10^{5}	1.628962	1.338739
bed roughness=15cm NBS roughness=2cm	3.885934X10^{2}	2.470729X10^{2}	1.015563X10^{5}	1.013068X10^{5}	1.629857	2.460398
bed roughness=2cm NBS roughness=2cm	3.885766X10^{2}	2.471944X10^{2}	1.015563X10^{5}	1.013069X10^{5}	1.629743	2.460497

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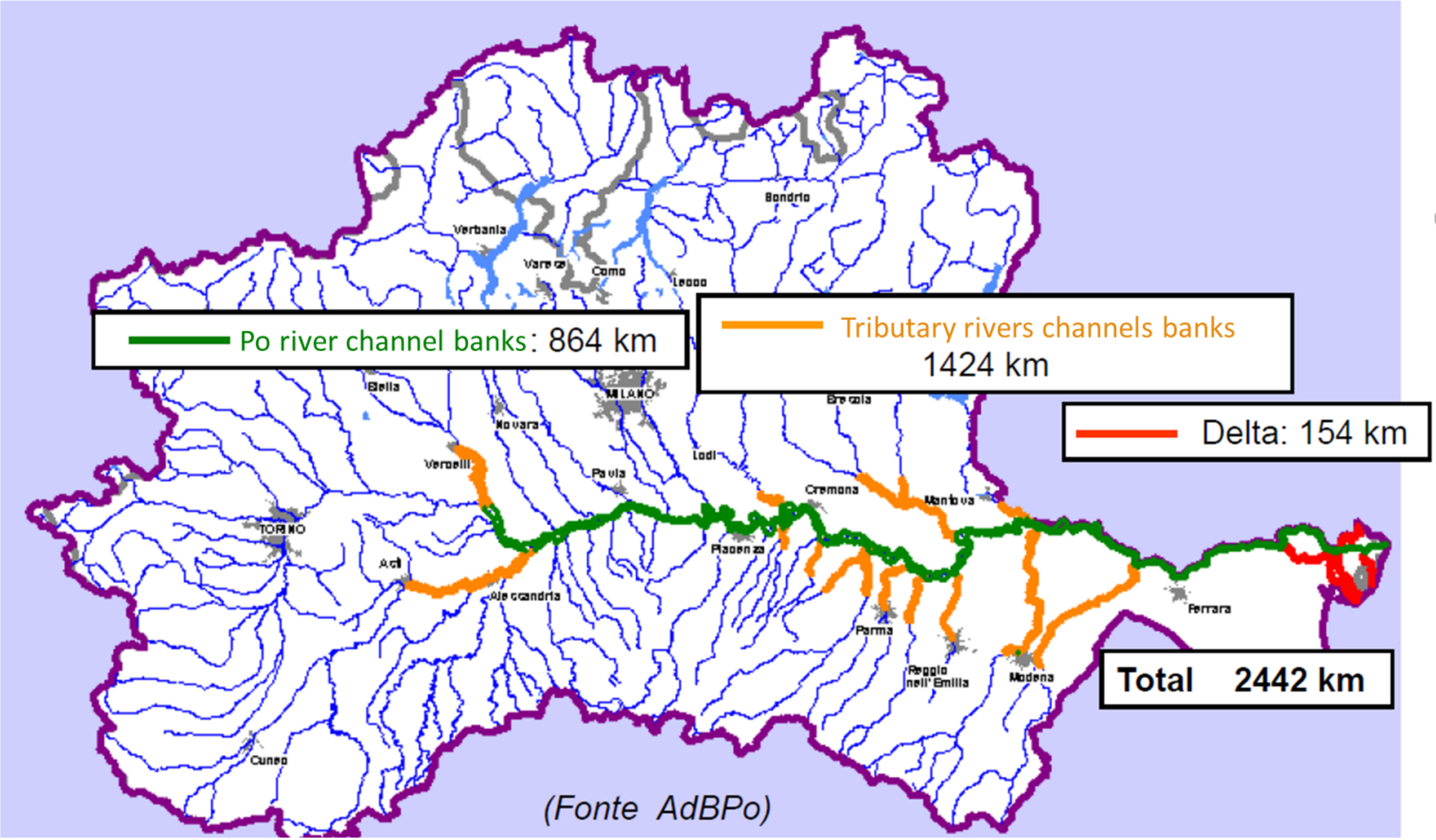
OAL Italy – a picture for the future



A digital twin of the Po valley

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OPERANDUM

Thank you!

NBS Modelling

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