POLLUTANTS DIFFUSION NUMERICAL MODELLING IN AUGUSTA HARBOUR SEAWATER SYSTEM (SIRACUSE, ITALY)

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AARHUS UNIVERSITY
DCE - DANISH CENTRE FOR ENVIRONMENT AND ENERGY

SCIENCE FOR THE ENVIRONMENT
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GENERAL AIMS OF THE RESEARCH

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With regard to the Augusta Harbour seawater system, the research aims to:

- Verify the influence of hydrodynamic conditions on the pollutants diffusion by means of a 3D conservative pollutants propagation model
- Analyse the influence of wind and tide on the contaminant diffusion

STUDY AREA

Augusta Harbour (Siracuse, Italy)

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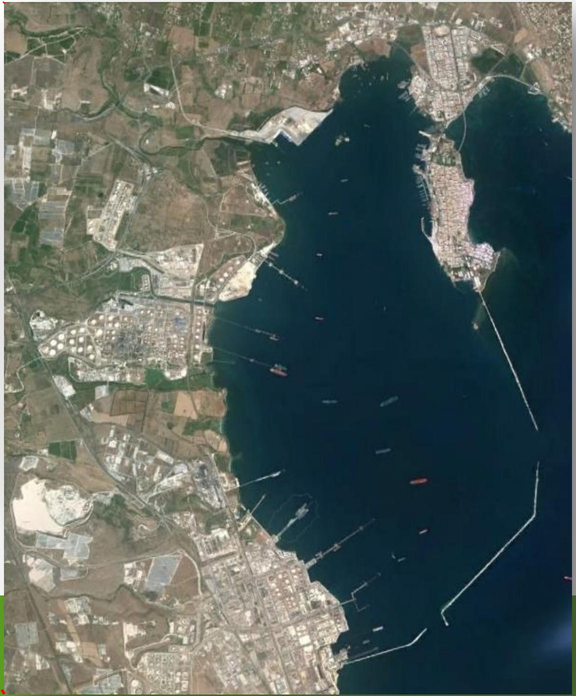

- N-S length: 8 km
- E-W length: 4 km
- Mean depth: 15 m
- Area: 23.5 km2
- 2 mouths connect the Harbour with open sea
- Several piers are located along the coastline

STUDY AREA

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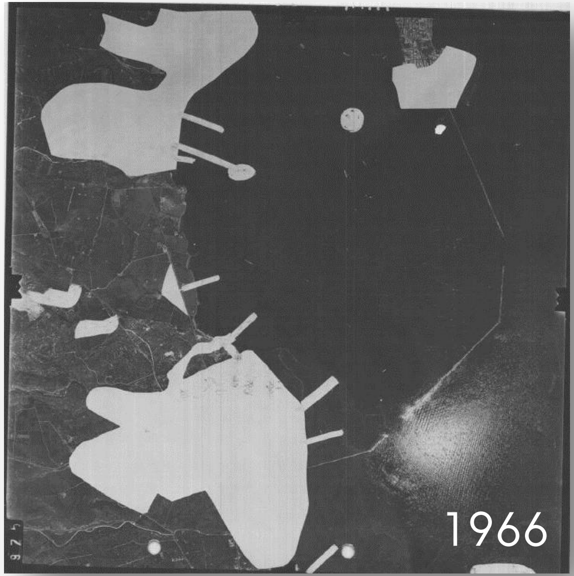
Augusta Harbour (Siracuse, Italy)

- 1950 Construction of the breakwater
- 1955 First petrochemicals plants
- 1958 Montedison chlorine-soda plant
- 1998 Contaminated Site of National Interest



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STUDY AREA

Augusta Harbour (Siracuse, Italy)



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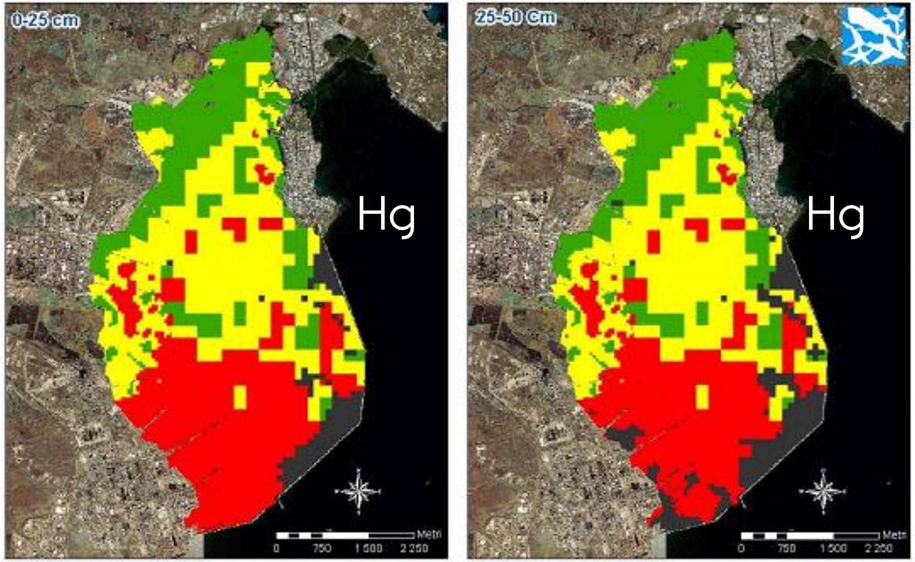
STUDY AREA

chlorine-soda plant



Uncontrolled drain of Hg dregs from 1958 to 1985

GOVERNING EQUATIONS

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Reynolds Averaged Navier-Stokes equations for free-surface, constant density flows:

$$\frac{\partial \overline{u}_i}{\partial t} + \frac{\partial \overline{u}_i \overline{u}_j}{\partial x_j} - \nu \frac{\partial^2 \overline{u}_i}{\partial x_j \partial x_j} + \frac{1}{\rho}\frac{\partial \overline{q}}{\partial x_i} - \epsilon_{ij3} f \overline{u_j} + g\frac{\partial \eta}{\partial x_i} + \frac{\partial \overline{u'_i u'_j}}{\partial x_j} = 0$$

where *q* is the "dynamic" pressure, *f* the Coriolis parameter and   the water surface level updated according to the Kinematic boundary condition for the water surface, given by:

$$\frac{\partial \eta}{\partial t} + u_1 \frac{\partial (Z_B + \eta)}{\partial x_1} + u_2 \frac{\partial (Z_B + \eta)}{\partial x_2} - u_3 = 0$$

Where Z_B is the bottom level and u_1, u_2 and u_3 are the velocities at the free surface

POLLUTANT DISPERSION

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Pollutant dispersion in the coastal regions the numerical model resolves, jointly with the system of conservation equations for momentum, the conservation equations for any pollutant present in the water body, which are convected and diffused by the currents and by turbulence effects according to:

$$\frac{\partial C}{\partial t} + \frac{\partial\, Cu_i}{\partial x_i} - \alpha \frac{\partial^2 C}{\partial x_i \partial x_i} + \frac{\partial\, \Lambda_j}{\partial x_j} - F_c = Q$$

C is the tracer concentration

α the molecular diffusivity

Λ_j the turbulent diffusive flux modelled as

$$\Lambda_j = -\Gamma \frac{\partial C}{\partial x_j}$$

Γ the turbulent diffusivity

NUMERICAL MODEL

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The equations are solved using an in-house 3D finite-volume numerical model solver developed in cooperation between the University of Palermo and Enna. (**PANORMUS**, *Parallel Numerical Open-souRce Model for Unsteady Flows*)

A second-order accurate semi-implicit method is used for the time advancement of the solution (*Crank-Nicolson* implicit method for the vertical diffusive and turbulent terms, *Adams-Bashfort* explicit scheme for the remaining terms)

The pressure-velocity decoupling problem typical of incompressible fluids is overcome using a fractional-step method: at each time step RANS equations are solved assuming a hydrostatic pressure distribution without imposing mass conservation (predictor-step); a Poisson-like equation then is solved to obtain a conservative velocity field, to be added to the predictor-step field to obtain the divergence-free velocity field (corrector-step).

Parallelization is achieved using the Message Passing Interface (MPI) libraries.

PANORMUS

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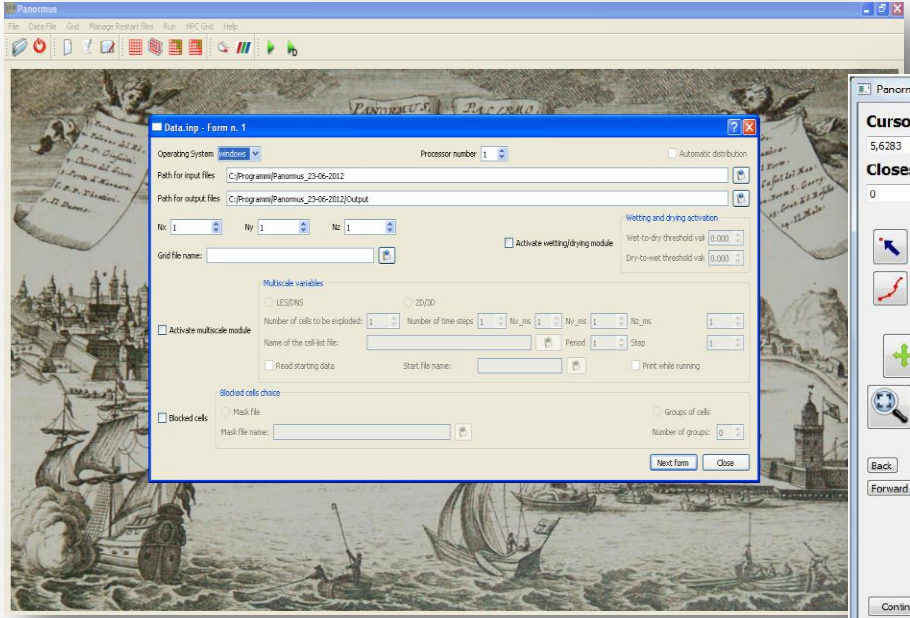

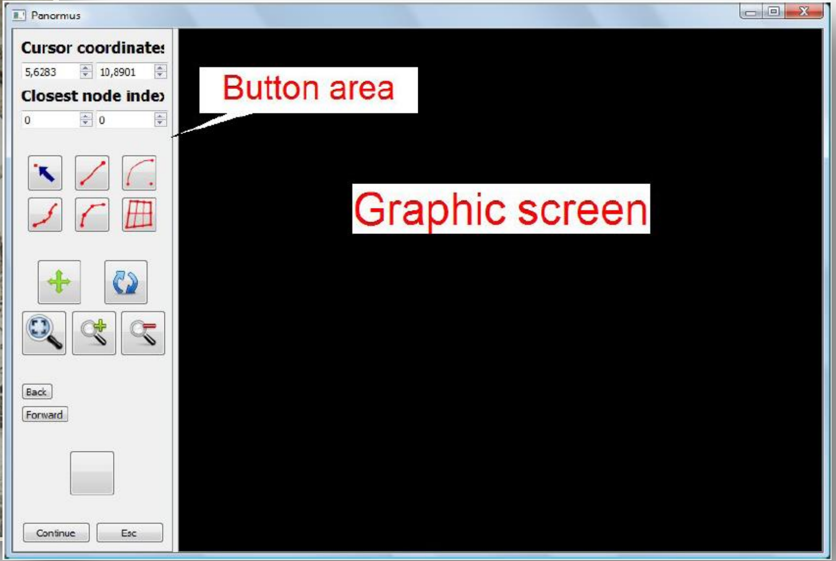

open source software available at the site: www.panormus3d.org

PHYSICAL DOMAIN AND COMPUTATIONAL GRID

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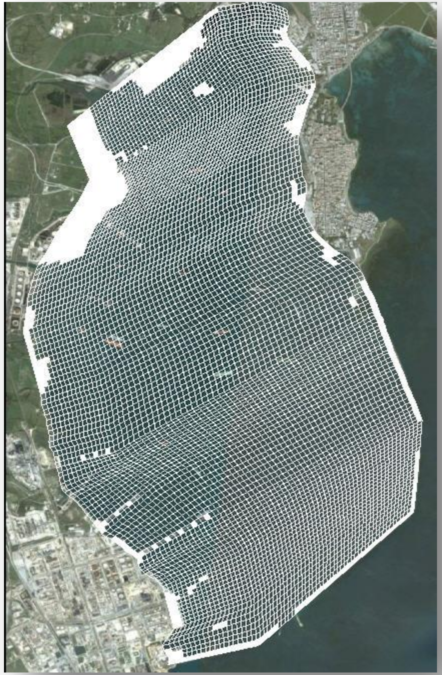
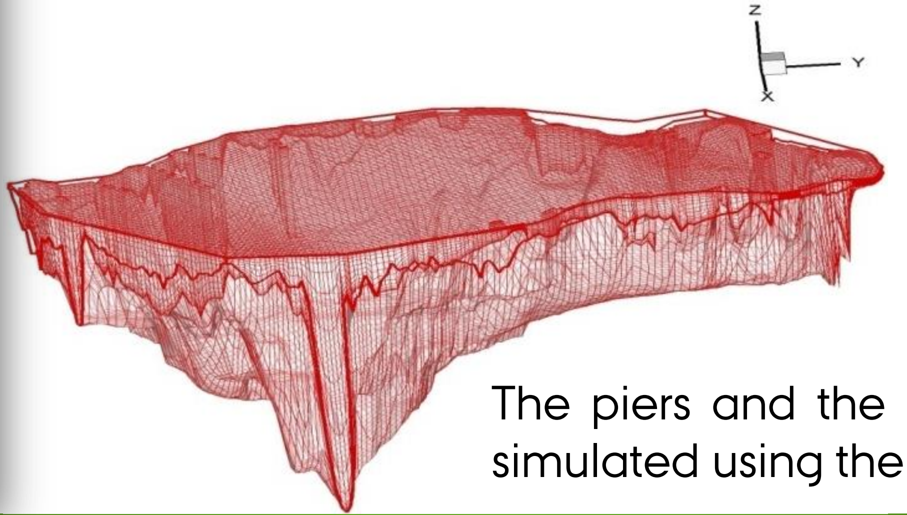


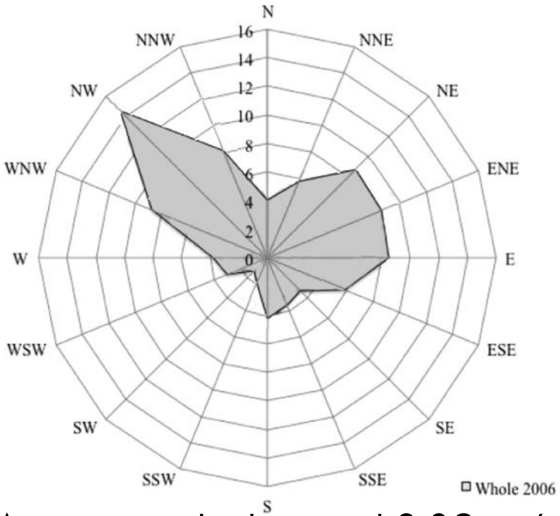
The domain was discretized into 64 x 128 cells in the east-west and north-south directions, while the vertical columns were divided into 16 cells, clustered near the surface and the bottom.



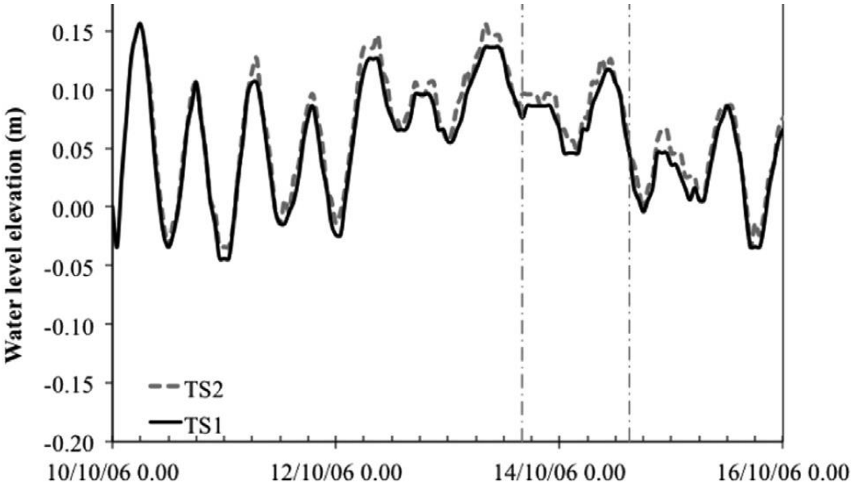
The piers and the artificial barriers where simulated using the blocked cells

FORCES ACTING

Wind and Water Level Variation:



Average wind speed 2.80 m/s



Mean tides excursion 0.10 m

NUMERICAL SIMULATIONS

In order to analyse the main forces driving the pollutants propagation in the Augusta Harbour, two different simulations were carried out:

Wind Only

Wind & Tide

RESULTS

Wind Only

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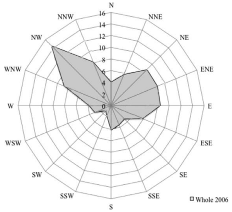
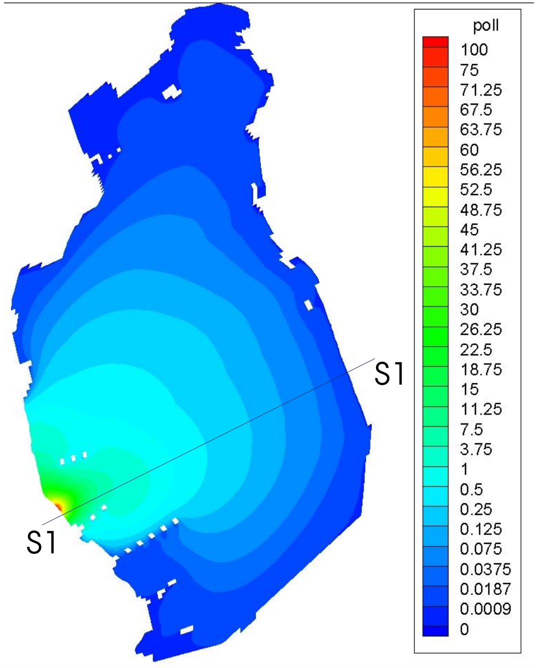
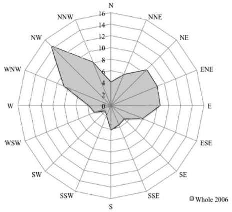


wind direction
NW

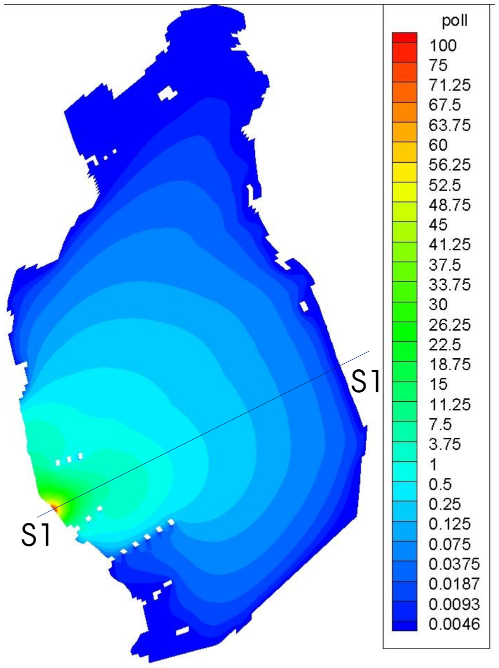
S1-S1 cross section





wind direction
NE

S1-S1 cross section



RESULTS

Wind & Tide

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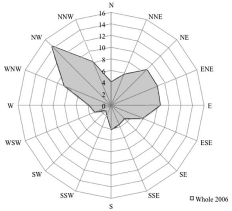
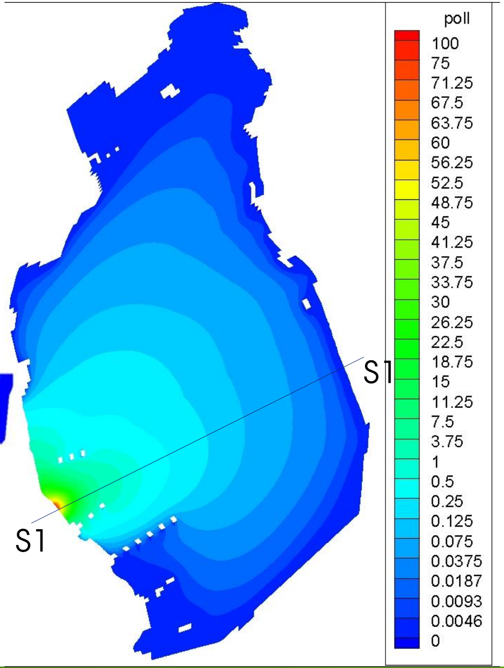
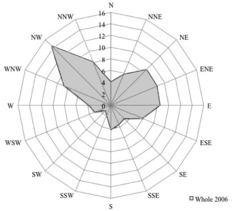


wind direction
NW

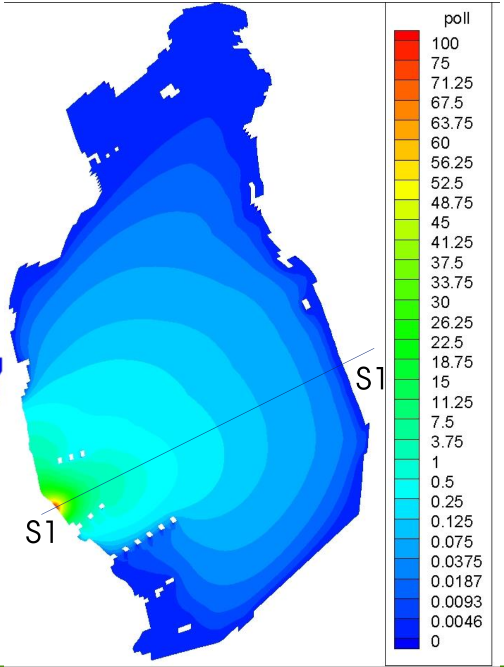
S1-S1 cross section





wind direction
NE

S1-S1 cross section



RESULTS

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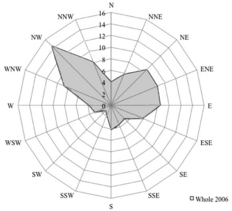
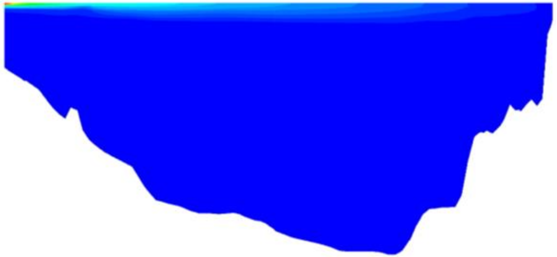
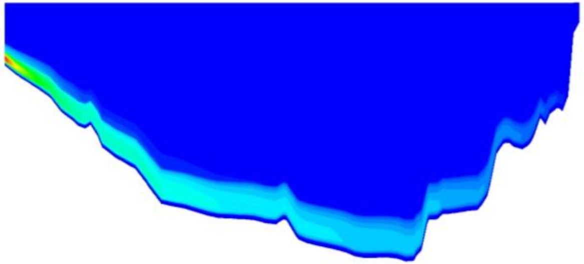
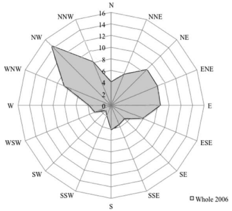


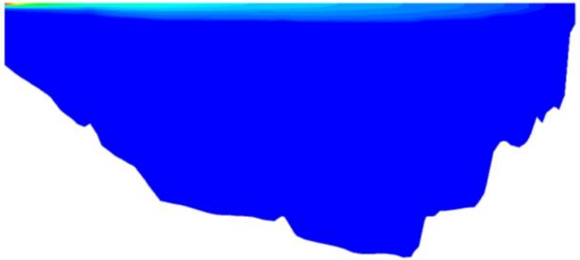
wind direction
NW

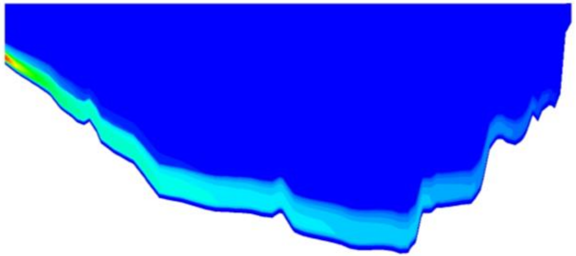






wind direction
NE





CONCLUSION

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- Wind and tidal are not responsible of the pollutants propagation inside the Augusta Harbour
- Augusta Harbour hydrodynamic's is the only force that drives the pollutants inside the port
- Use of 3D numerical models could be combined with a Decision Support System to design an economic seawater-monitoring plan or evaluate the potential risks of new industrial plants

CONTACTS

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