ISMAR Istituto di Scienze Marine

JONSMOD Latest modeling techniques for shallow seas

Florence - October 17-19, 2018

CONSORZIO LaMMA

The role of numerical modeling in coastal zone management

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What is a model?

- A Model is a partial, simplified and mostly inadequate representation of the real world
- A Model can never describe the whole complexity of the system modeled
- A Model has to make basic, very often unjustified assumptions of the system it wants to describe
- A Model has to neglect most of the complicated, little understood relationships of the system

- So why do we use models?

Models and measurements

- Measurements are the primary source of information on the coastal ocean, its ecosystem and its variability. There is no point of attempting to model a coastal zone without having data !
- However, data are difficult to obtain because of
  - The technology of sensing instruments and platforms;
  - The costs of observations over long durations and large domains.
- In this context, models become important as a complement to observations.

Models: a complement to observations

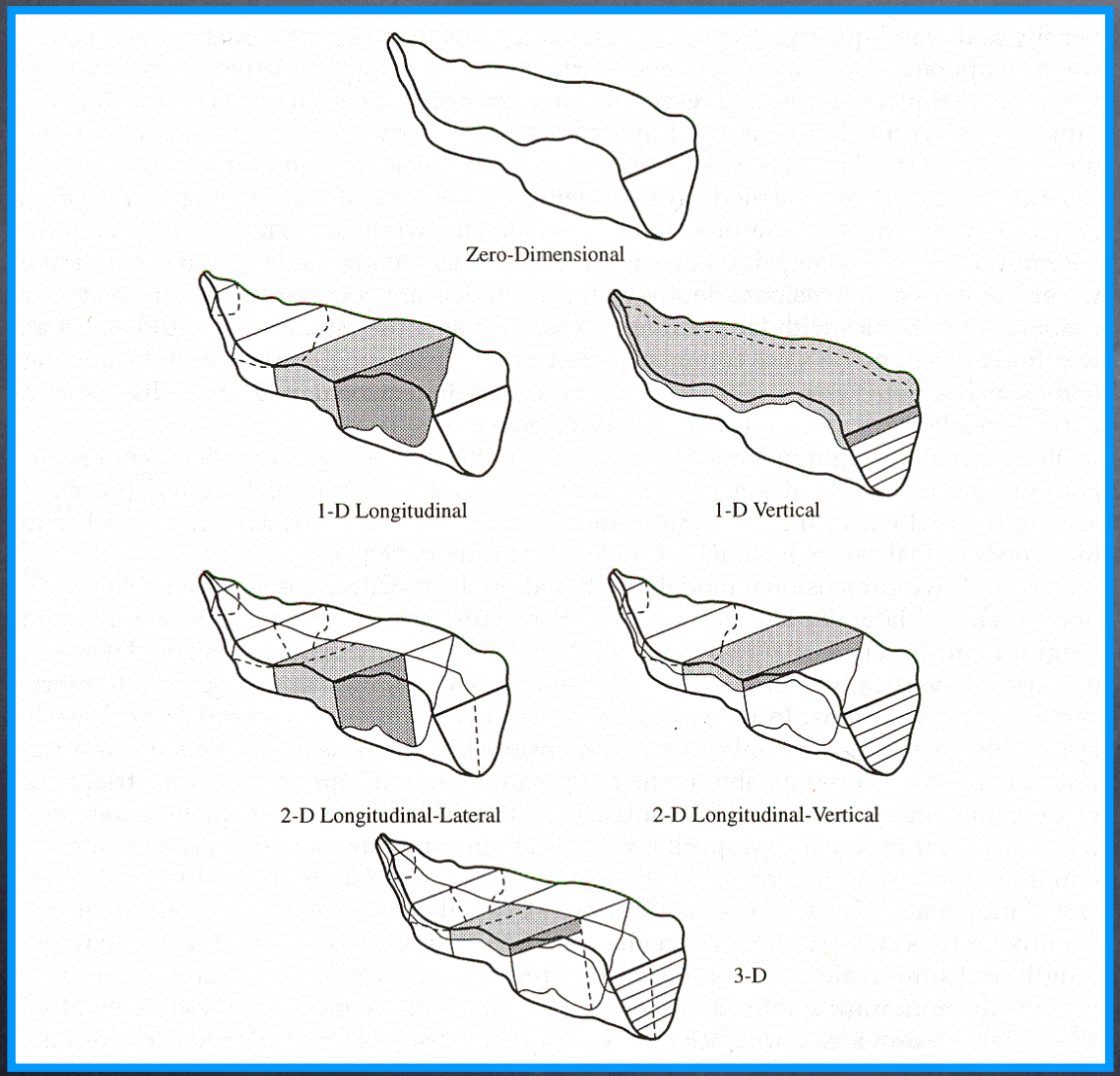
- Models complement observations in coastal management by:

1. Interpolating in 4 dimensions (space-time) the observations;
2. Predicting the future evolution of the system;
3. Simulating the impacts of non-observed forcing scenarios (what-if scenarios).

The hydrodynamic engine

- The hydrodynamic model is the « engine » that transports and mixes all ecosystem constituents, including the water itself.
- The hydrodynamic equations of conservation of mass and momentum are solved numerically, in every cell of a computational grid, taking into account the information present in adjacent cells.

Model dimensions



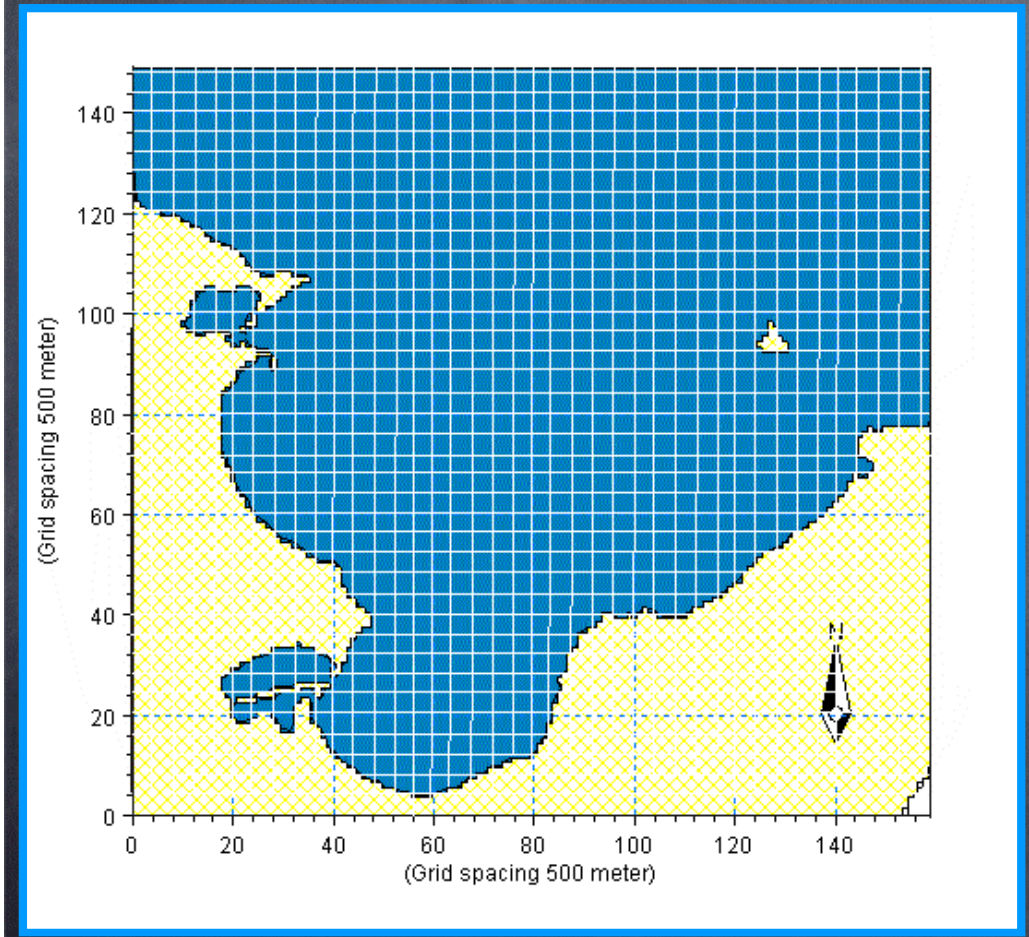
0D

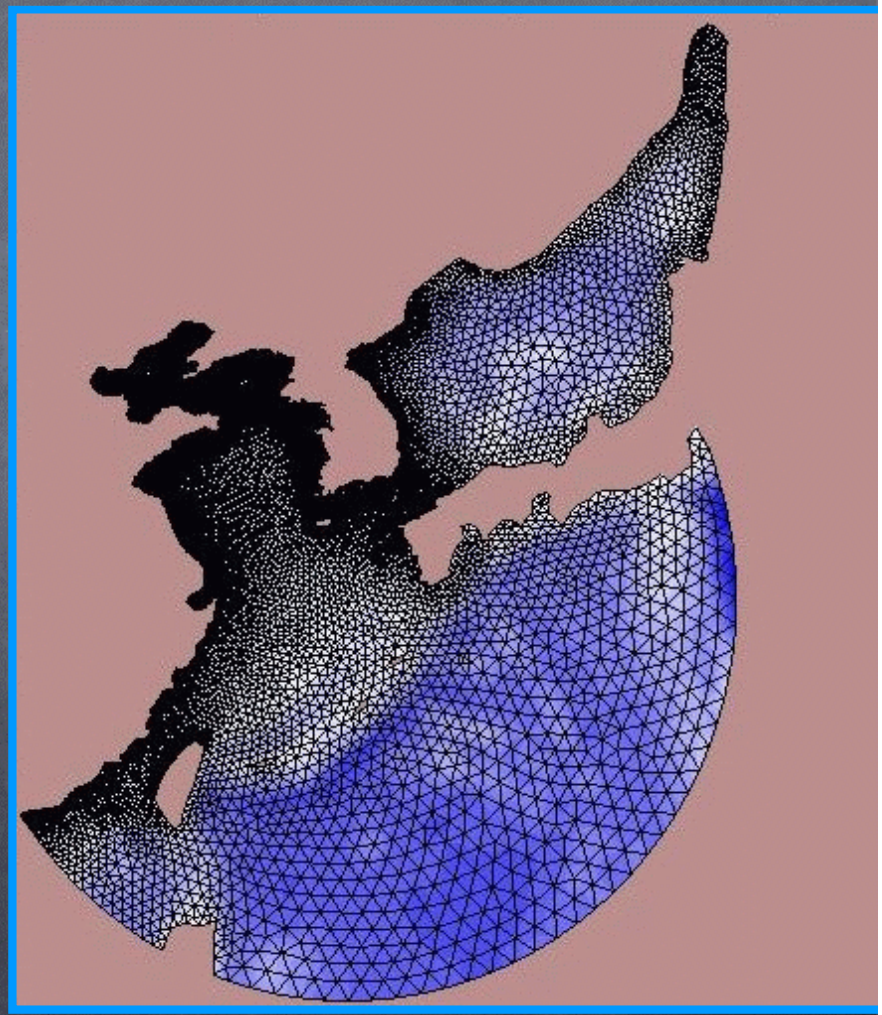
1D

2D

3D

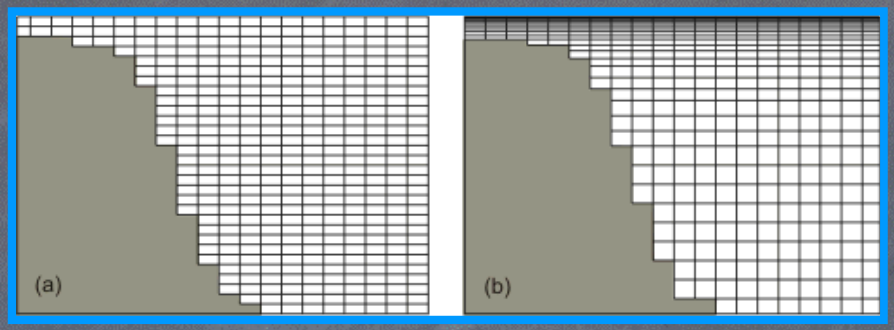
Structured and unstructured grids



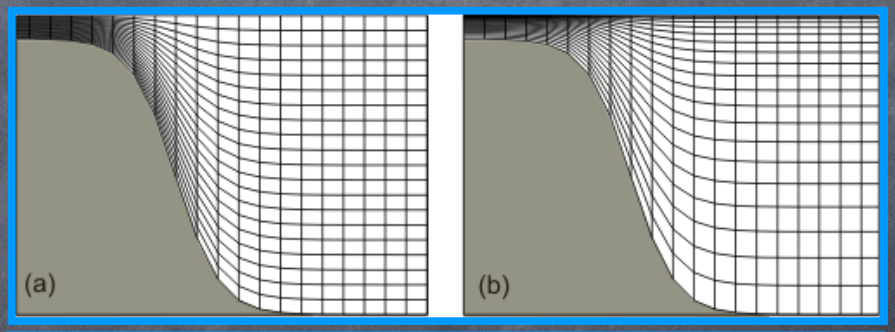


Vertical discretization

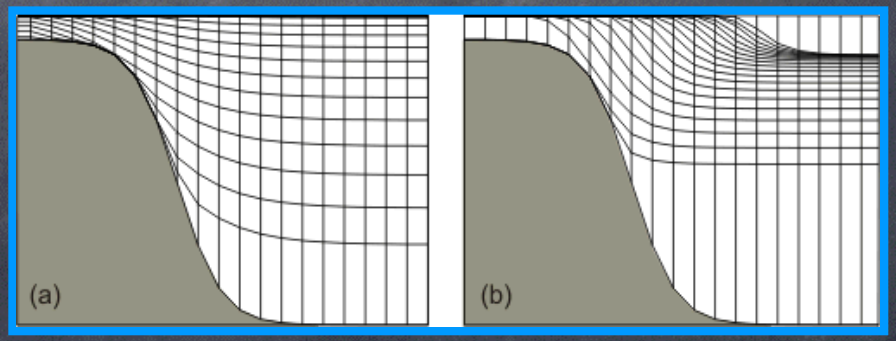
Z - levels



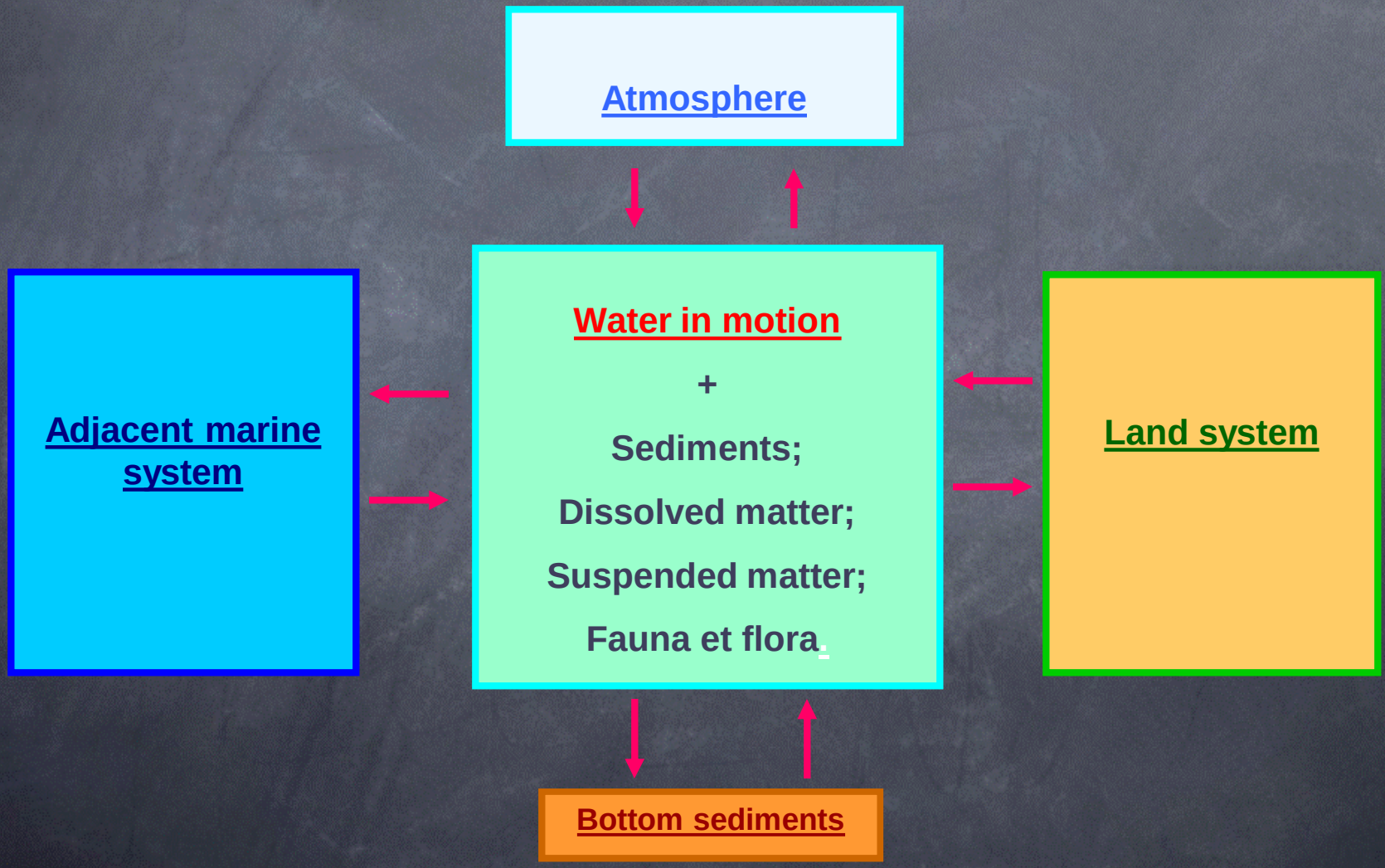
Sigma - levels



Isopycnal - levels



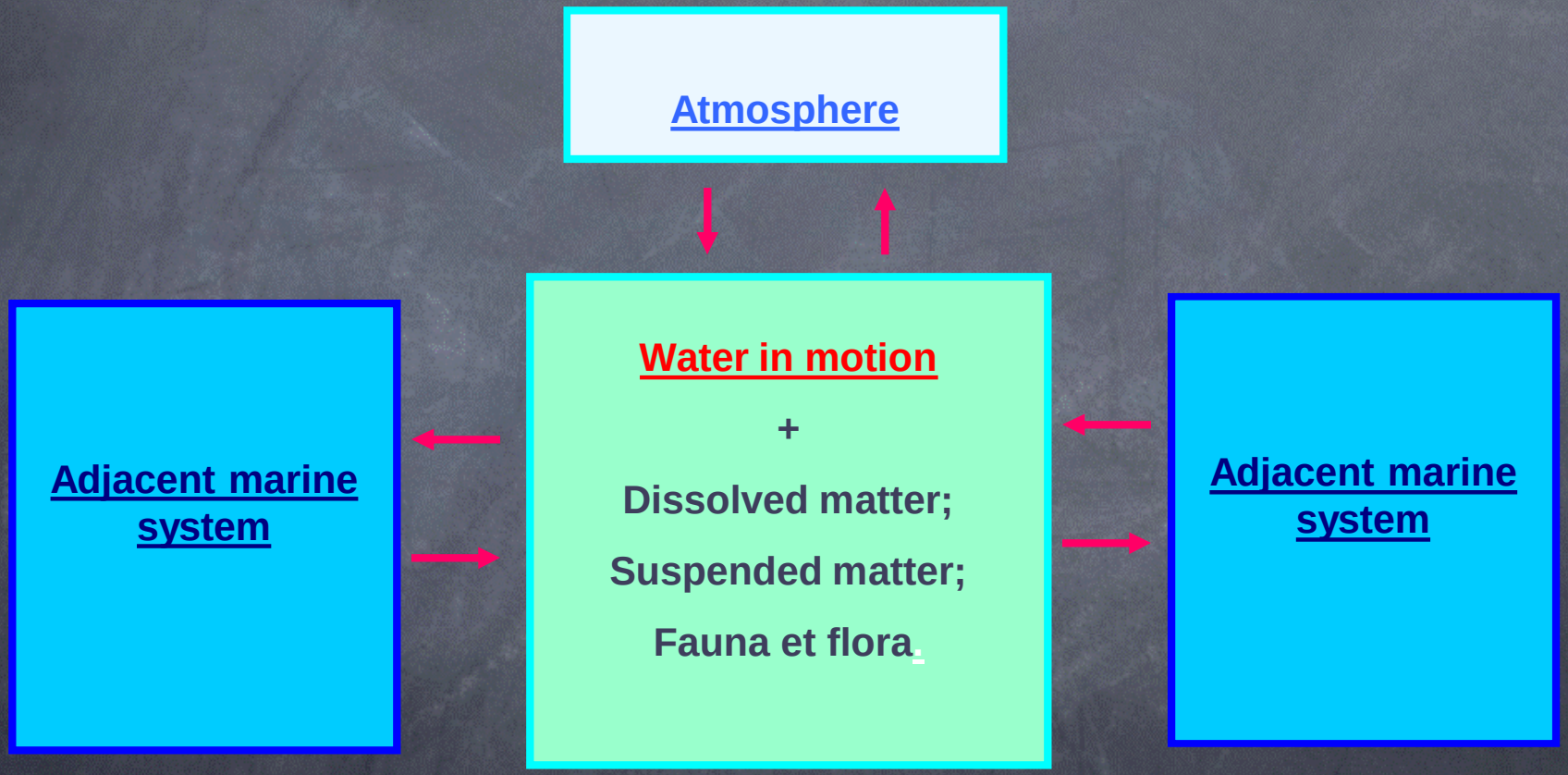
Conceptual modeling approach



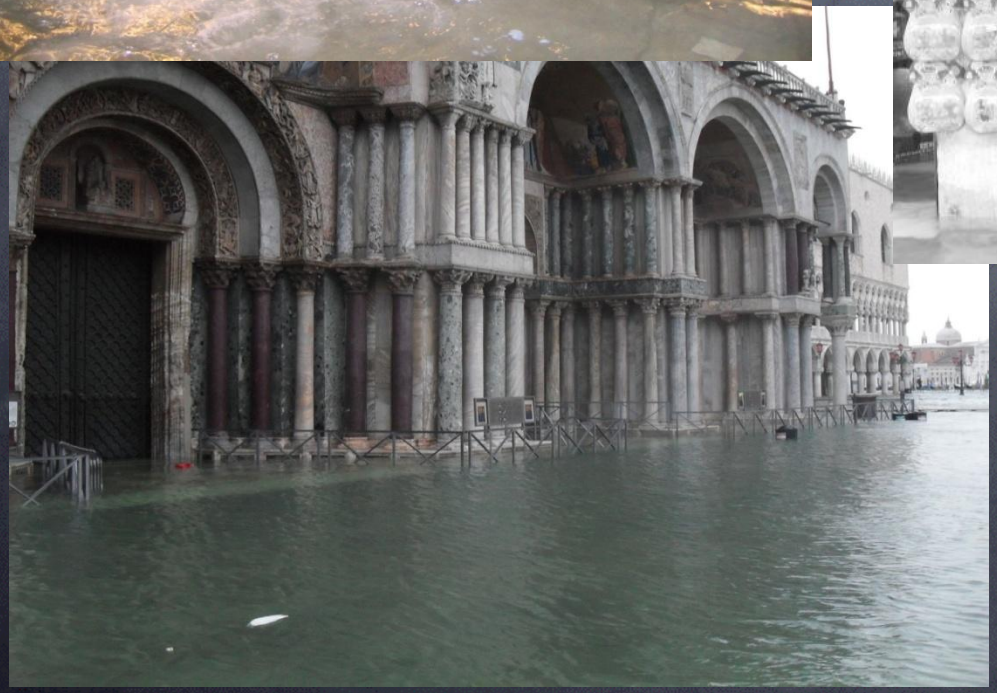
Why is the coastal zone so special?

- In the open sea the only thing that can be done do is to observe processes
- In the coastal zone processes are strongly influenced by men
- This strong human impact gives us also the chance to actively influence and manage the coastal zone

Conceptual modeling approach in the open ocean



The Acqua Alta Phenomenon



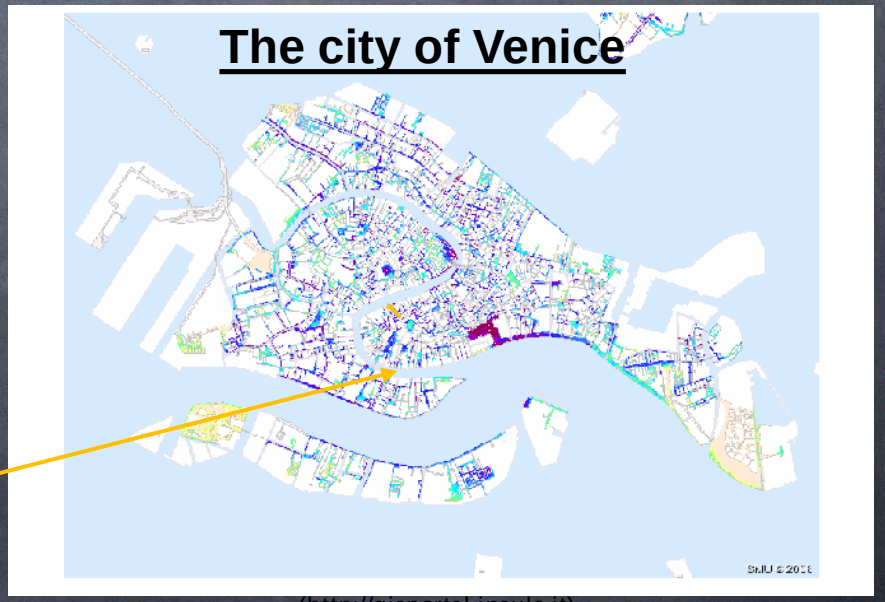
Acqua Alta

Sea level	Flooded surface
190 cm	100%
140 cm	90%
130 cm	69%
120 cm	35%
110 cm	12%
100 cm	4%

The pavement level in the city is low with respect to the sea level.

Therefore even moderate surge can produce flooding in the city

pavement lower than 90 cm



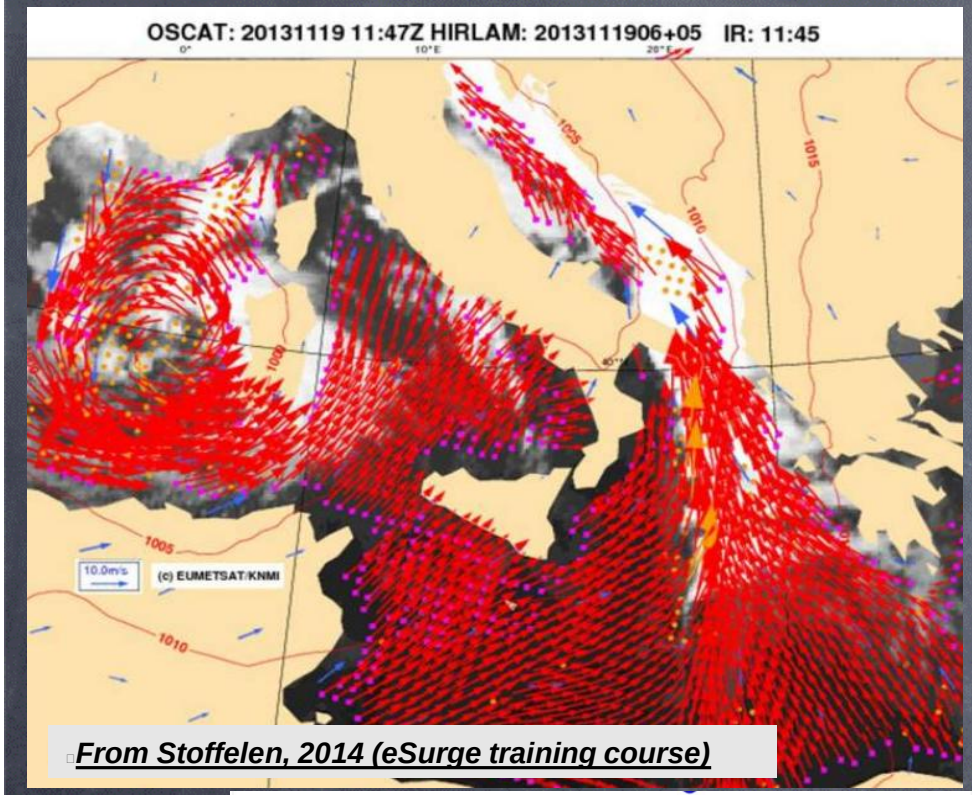
(http://gisportal.insula.it)

The mobile barriers MOSE

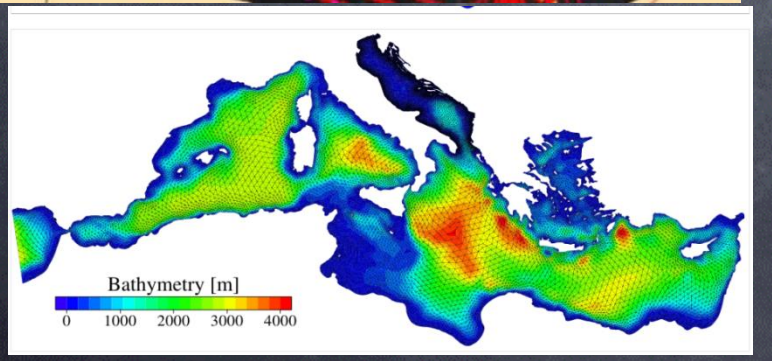
First closure of the MOSE barriers on 29.11.2014.

In few years in Venice the new mobile barriers will be operational. In order to operate them safely a good forecast will be needed. Otherwise the barriers will be either not closed or will be closed without any need.

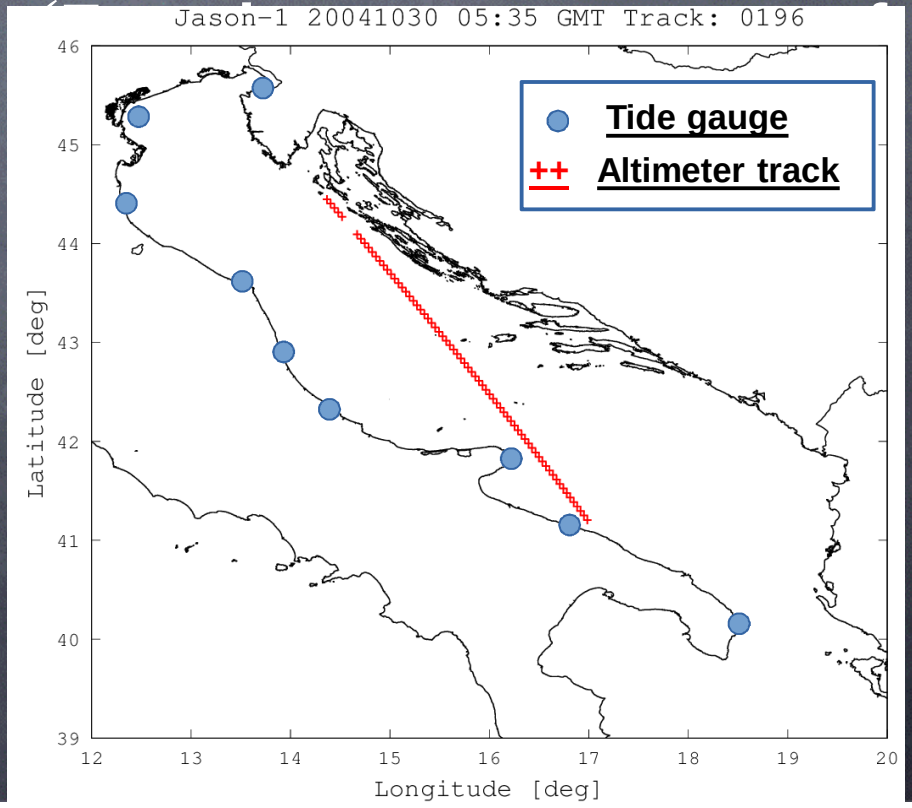
Storm Surge Forecast in Venice



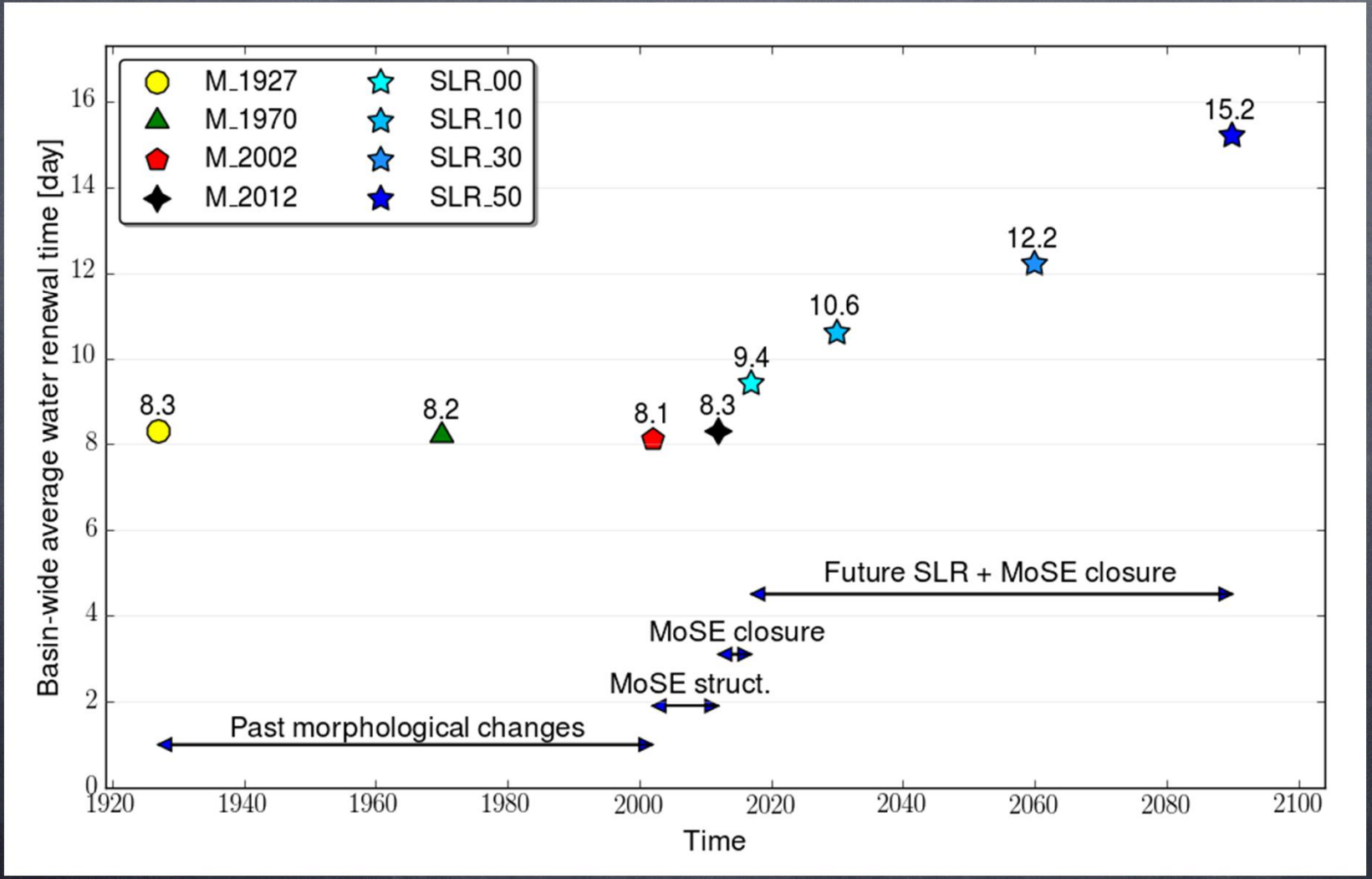
From Stoffelen, 2014 (eSurge training course)



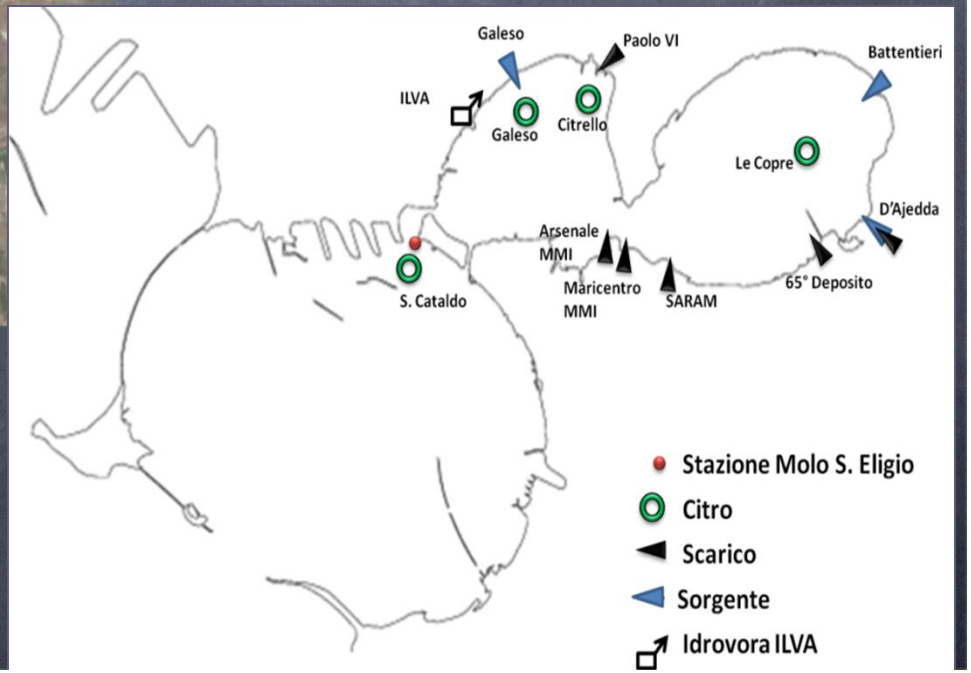
Operational model with tide gauge data assimilation with dual 4D-Var (ISPRA-VE forecasting system)



Changes in water renewal time



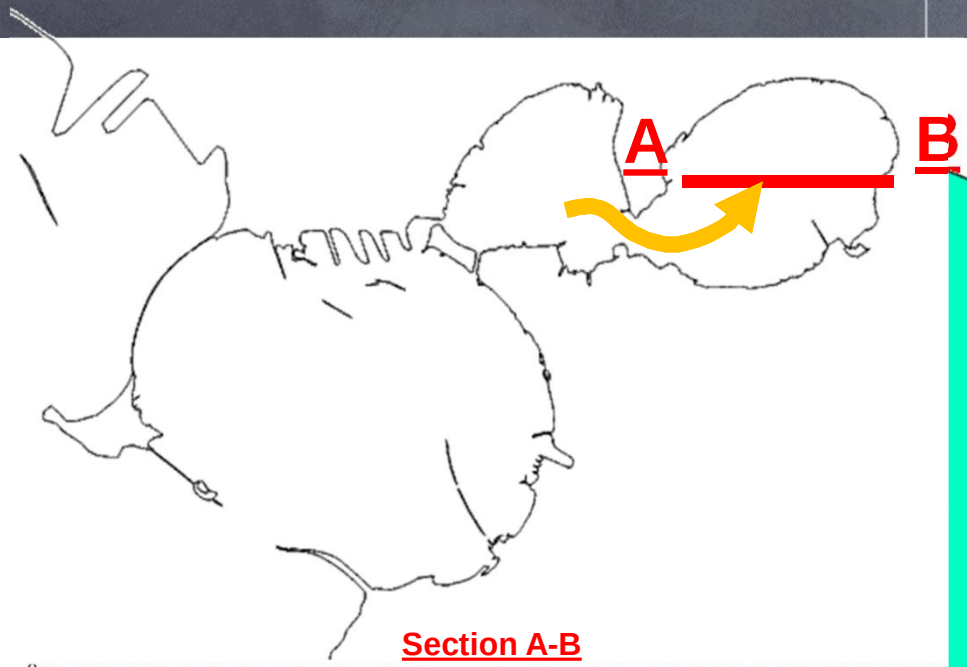
The Taranto Sea



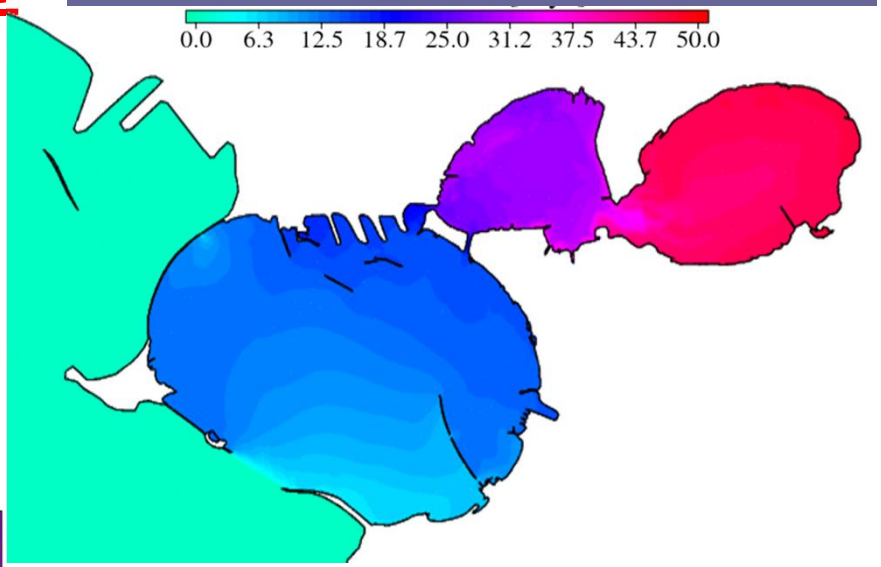
Surface [km^2]	Mean/max depths [m]	Volume [10^6 m^2]	Runoff [m^3 s^{-1}]	Tidal range [m]
56.8	12 / 42	672.7	5.4	0.19

ILVA dewatering pump – 40 m^3 s^{-1}

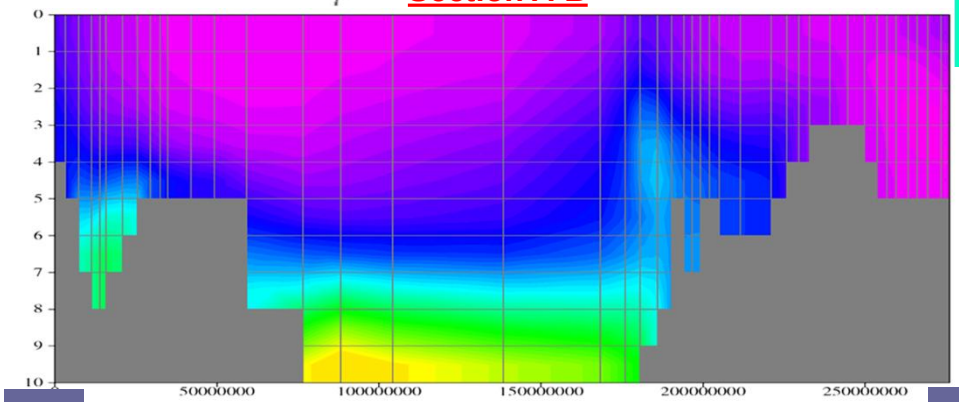
Water renewal time



Barotropic Water Renewal time [days]



Section A-B

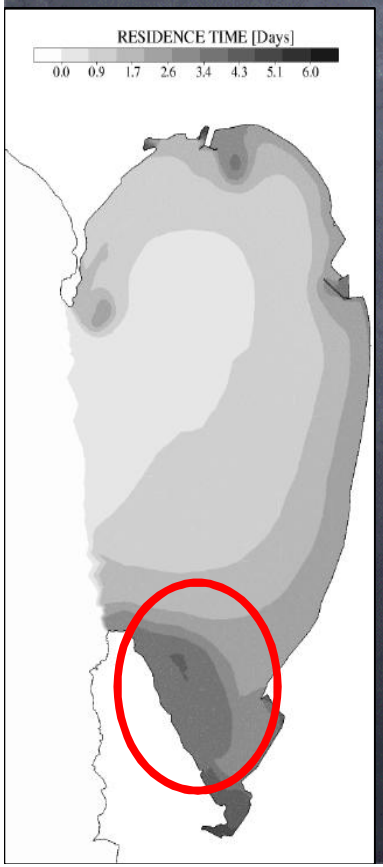


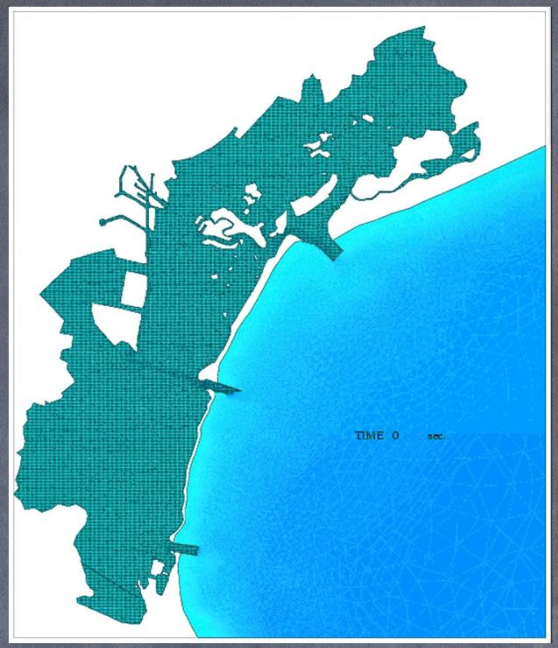
A B

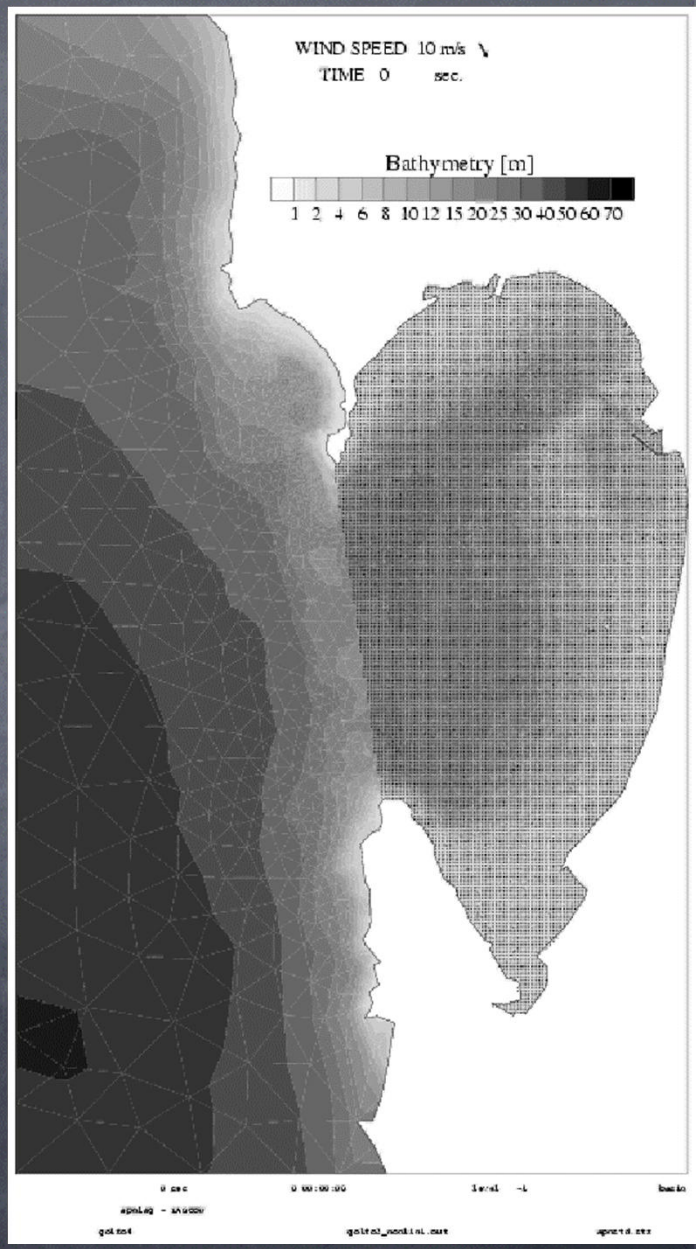
Water Renewal time [days]

The difference between bottom and surface layer is around 7 days

Residence times and turn over time

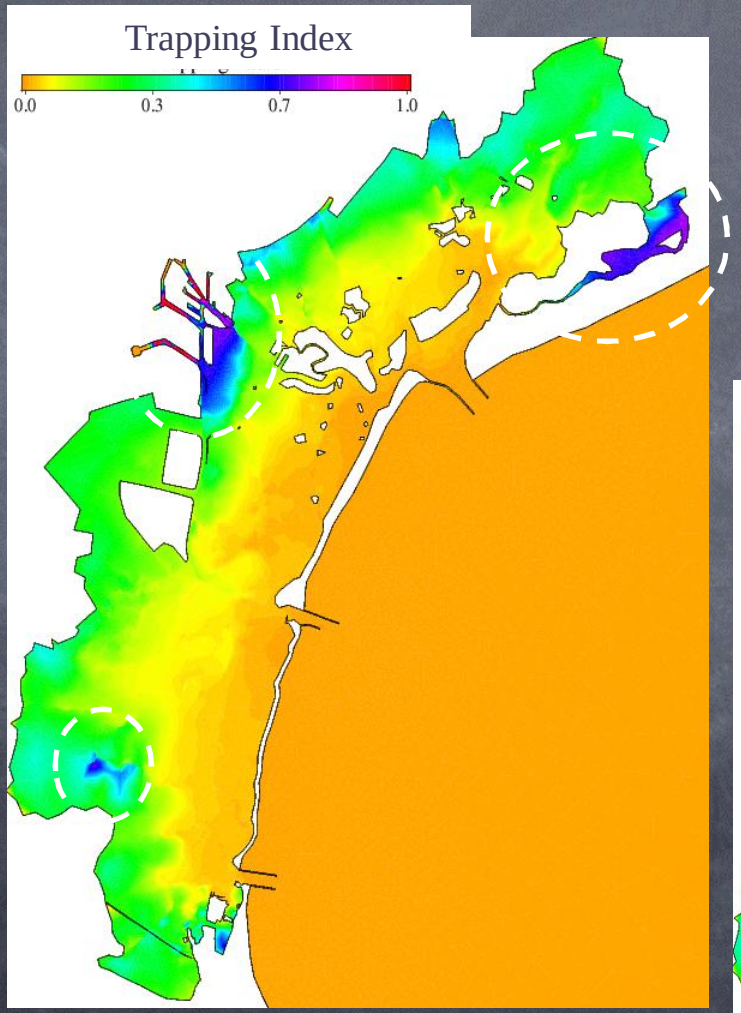


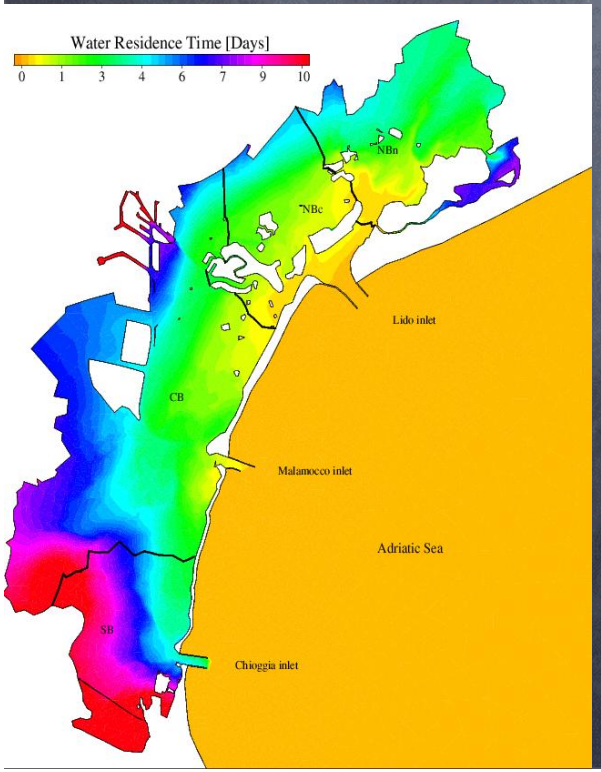


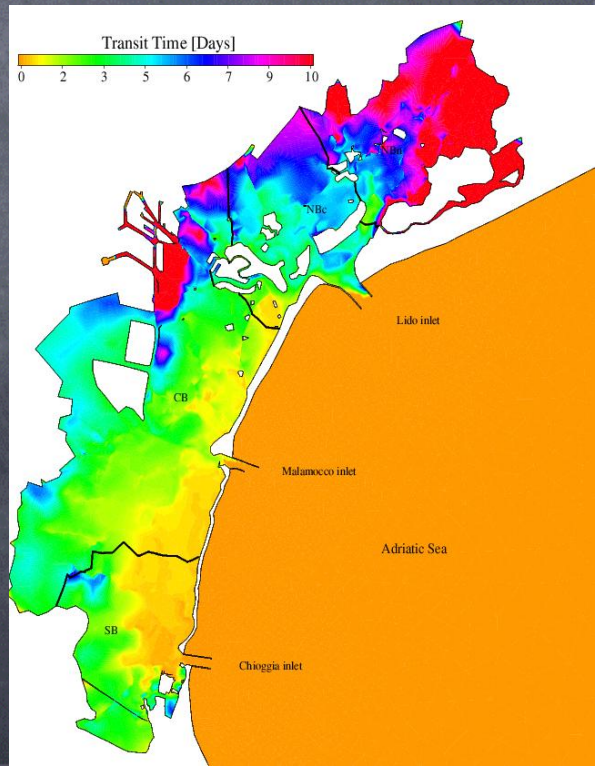


- **Simulate transport processes and dispersion of tracers and pollutants**
- **Estimate the renewal time of the basin**
- **Characterize water masses with the help of time dependent parameters**
- **Correlate physical, biological and chemical characteristics between each other**

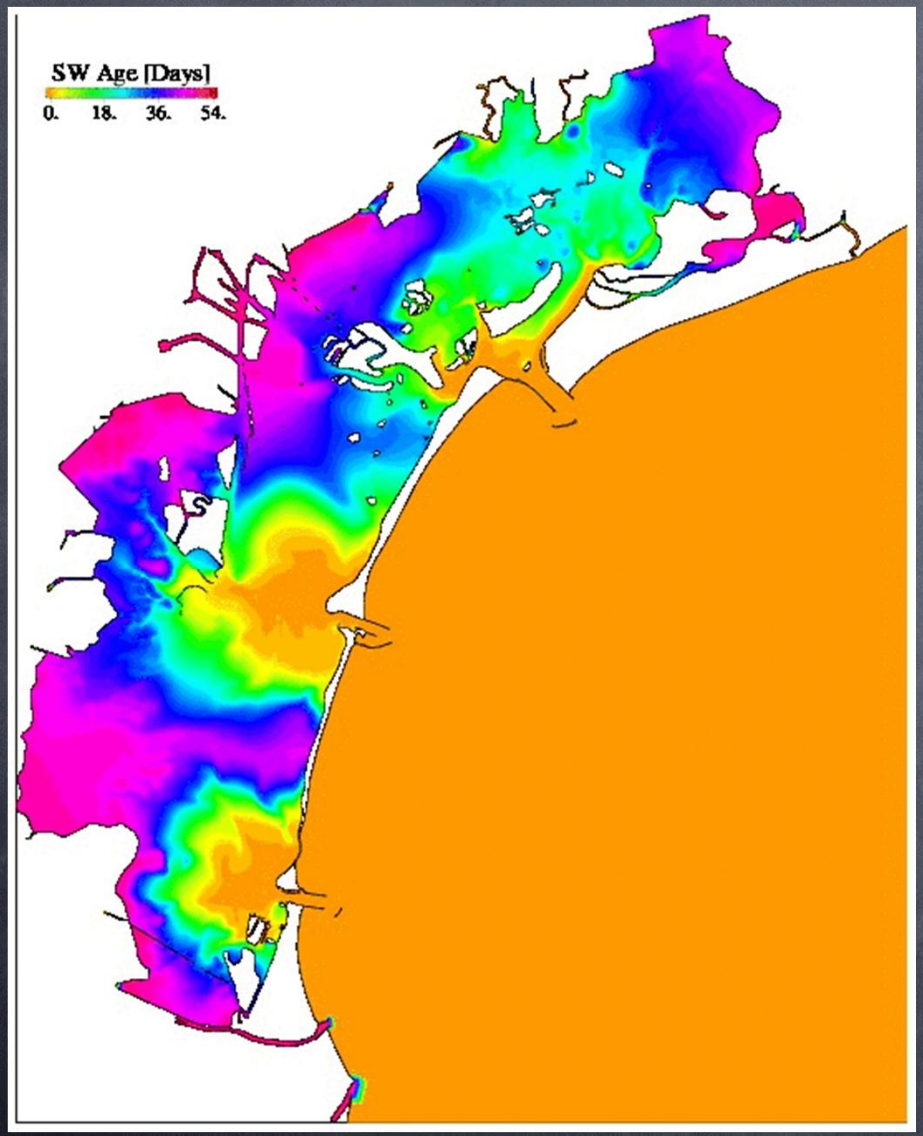
The Trapping Index







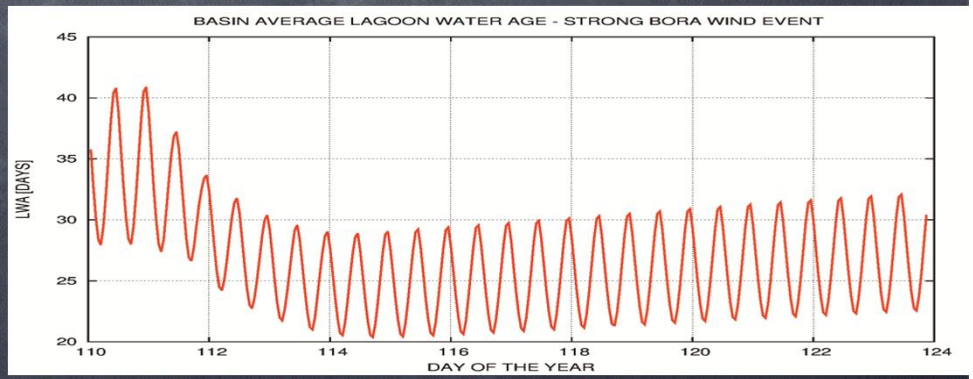
Modeling Age



Synthetic semidiurnal tides

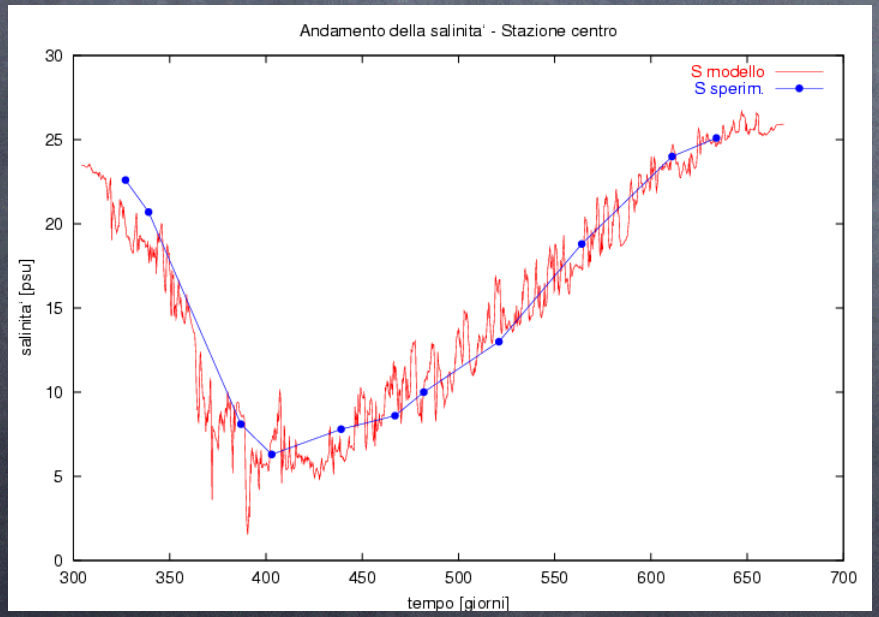
2 days of NE wind event (Bora)

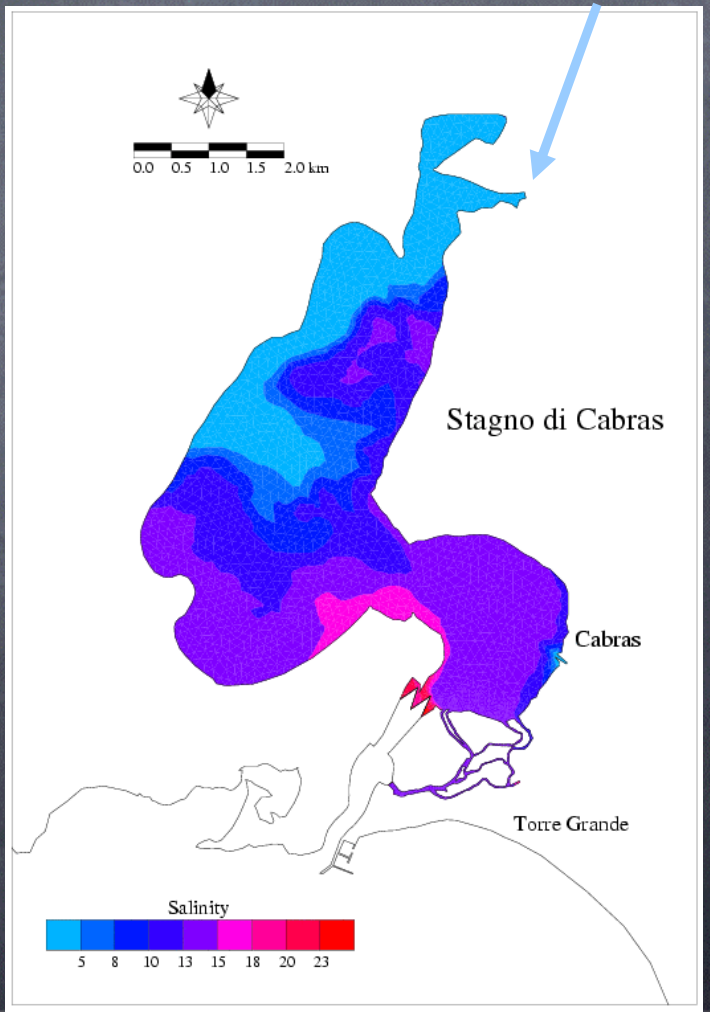
12 m/s constant wind speed



Managing fresh water in lagoons

The Cabras lagoon in Sardinia: salinity trend





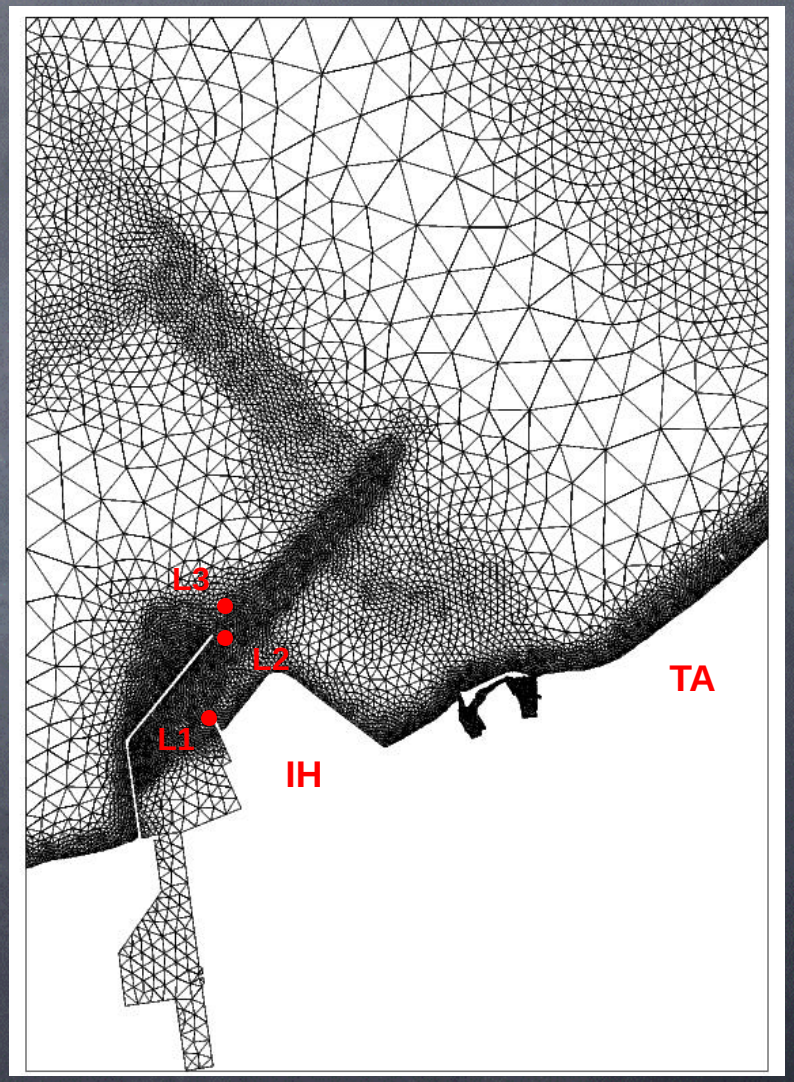
Impact of waste water discharge

Plan sewage outfall in the sea

Assess impact of the sewage outfall to the surrounding areas

Test area:

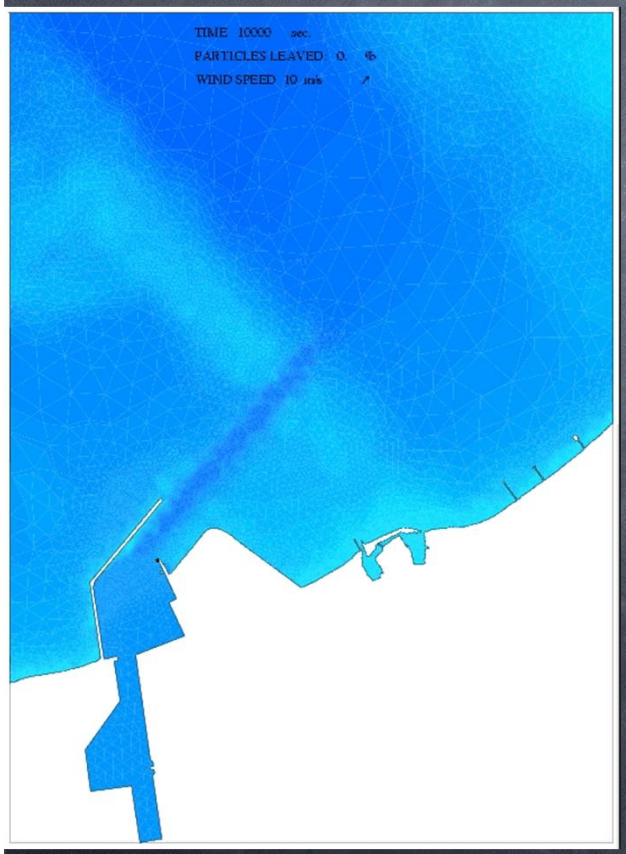
- **Industrial port [IH]**
- **Possible sewage outlet position [L1, L2, L3]**
- **Touristic area [TA]**



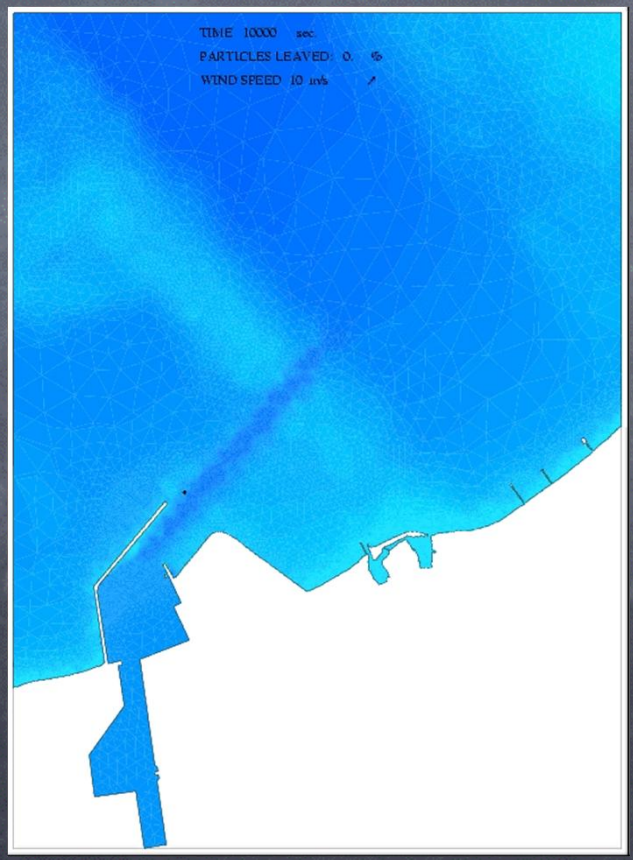
Evaluate impact of pollutants

- **constant SW wind with speed of 8 m/s**

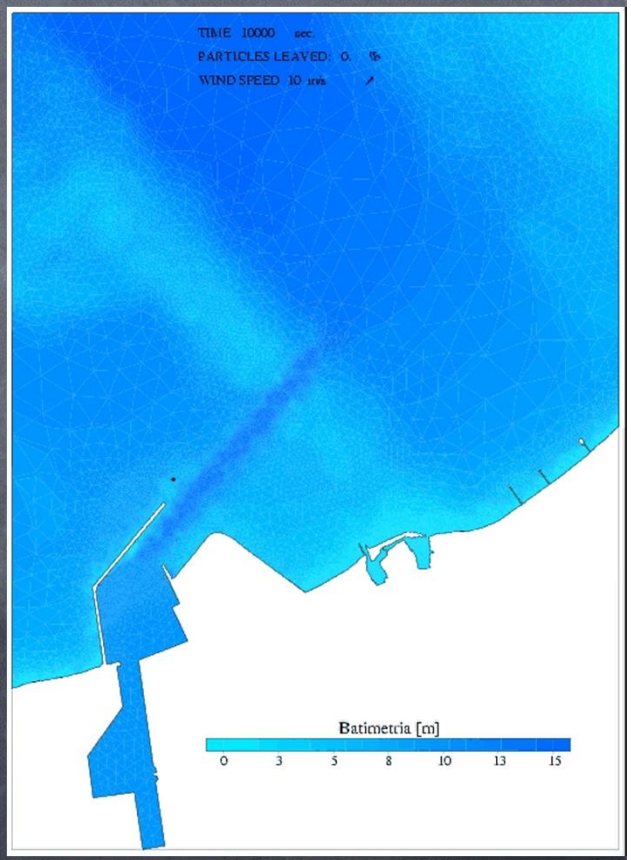
L1



L2

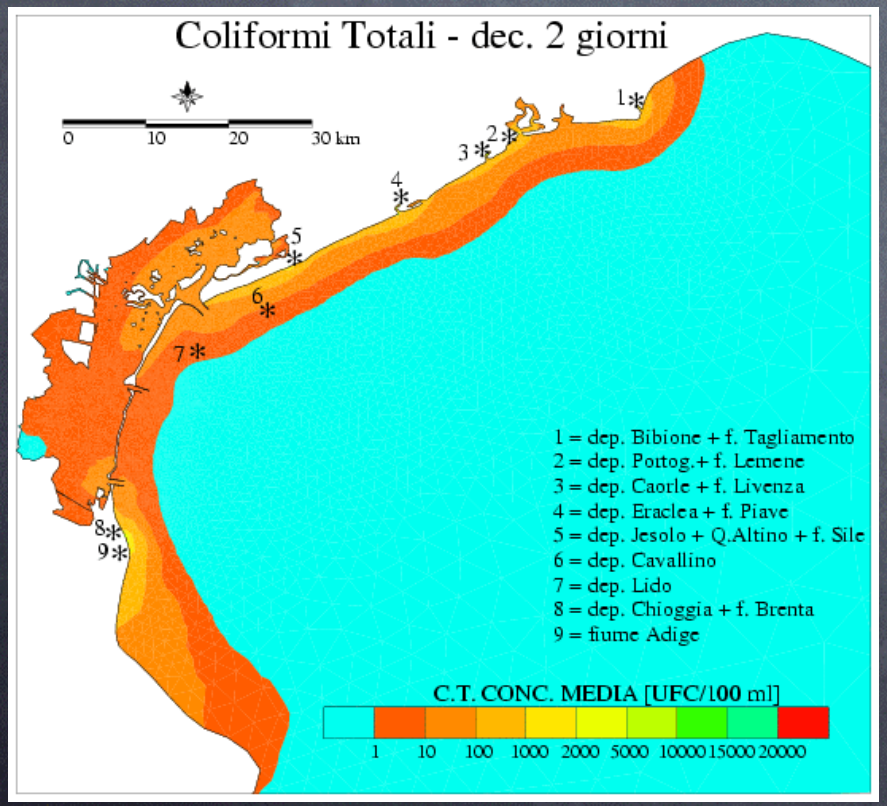


L3

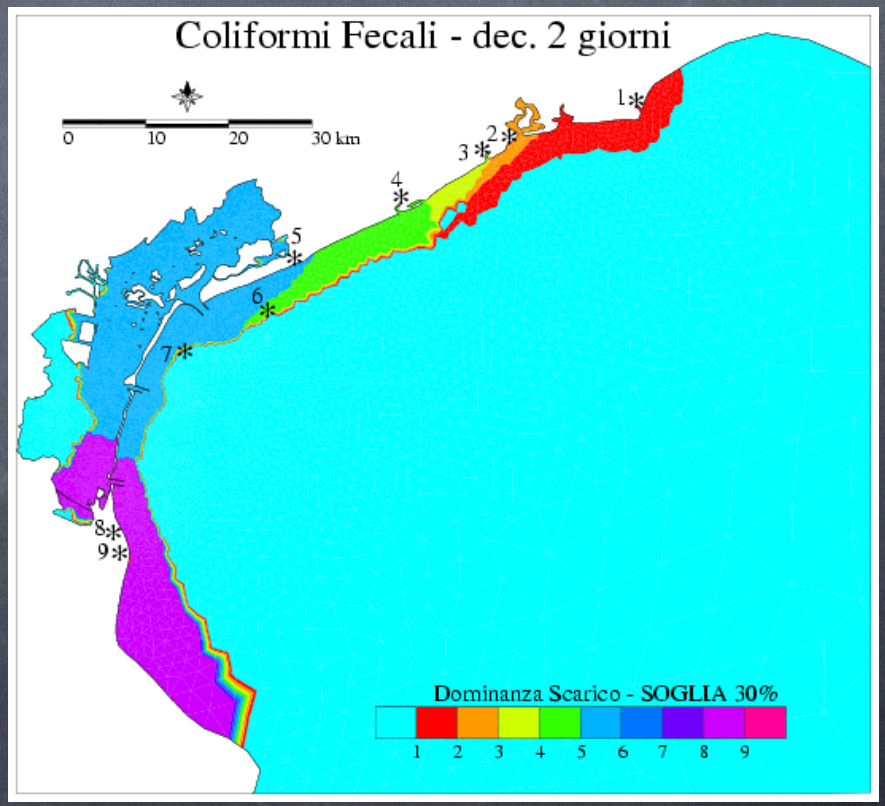


Dealing with Sewage: The BIOPRO Project

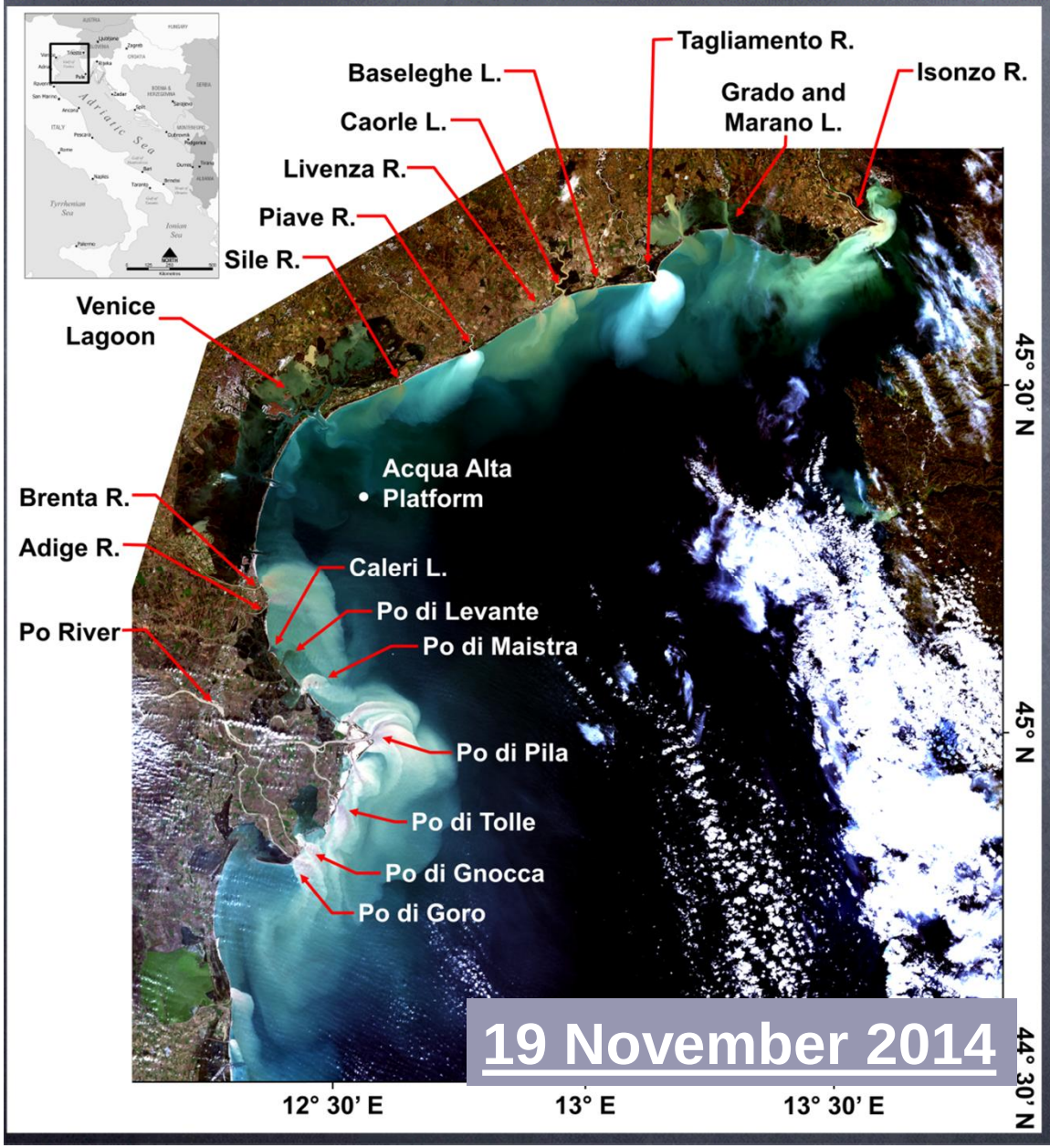
Daily average concentrations

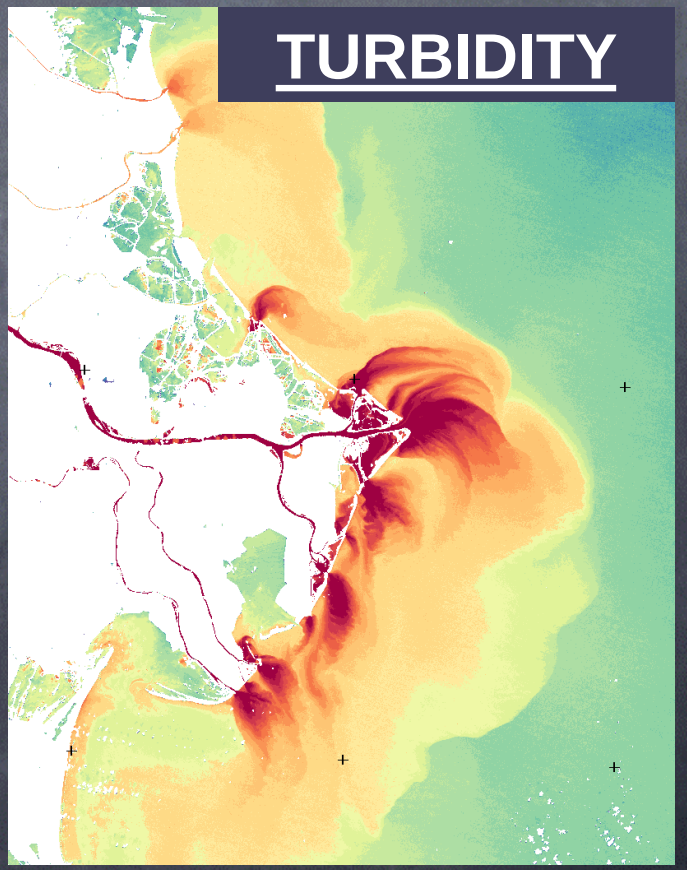


Area of influence

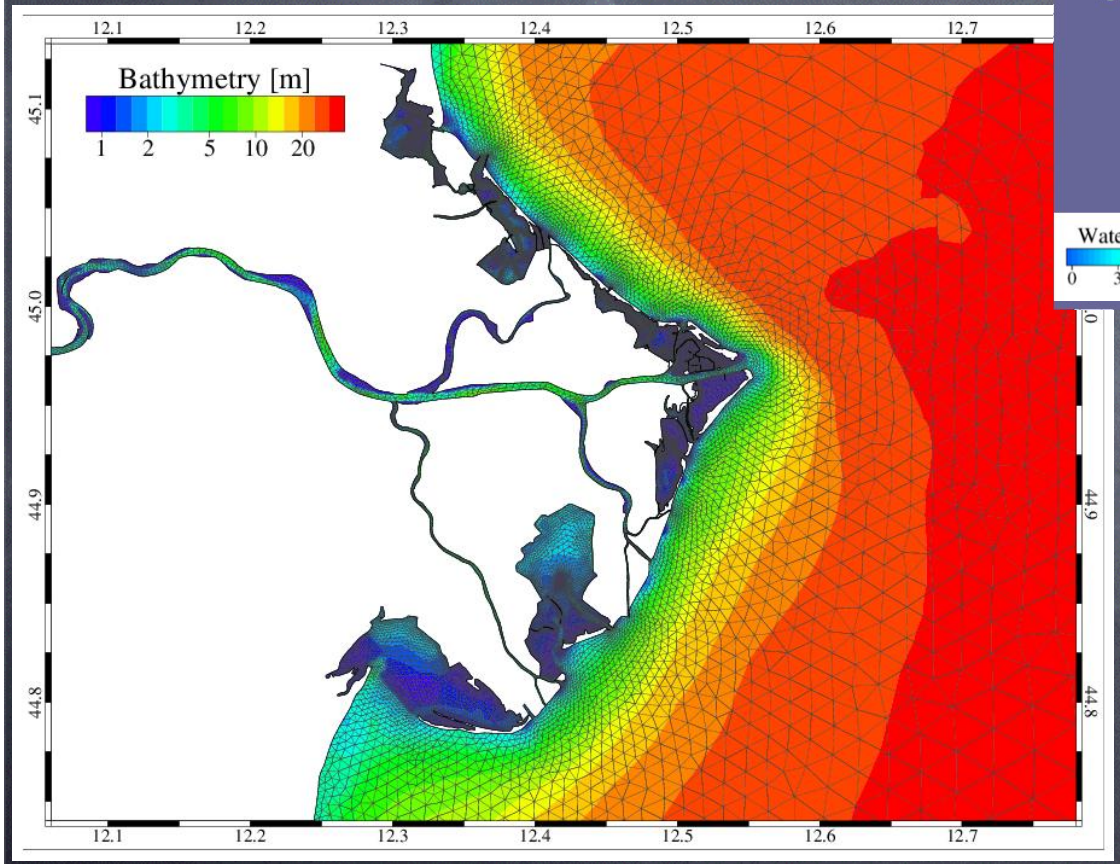


North Adriatic Sea Dynamics

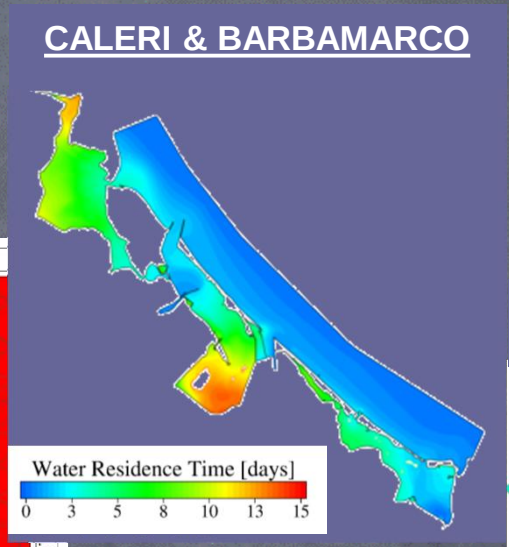




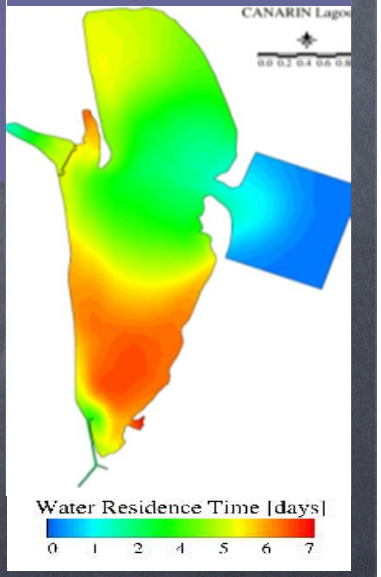
A River-Delta-Sea Model



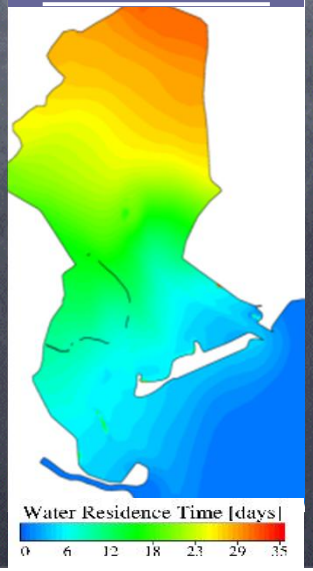
CALERI & BARBAMARCO



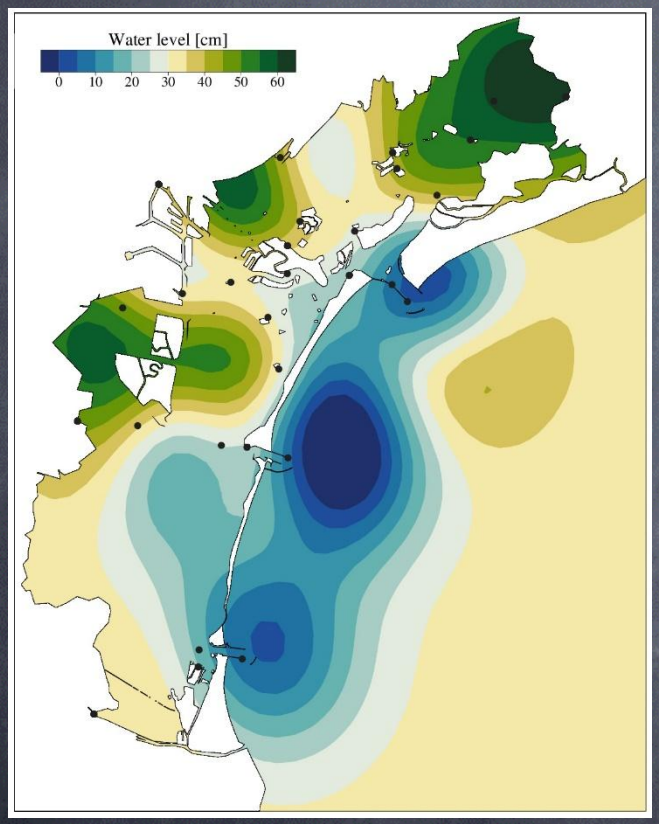
Sacca Canarin



Sacca SCARDOVARI



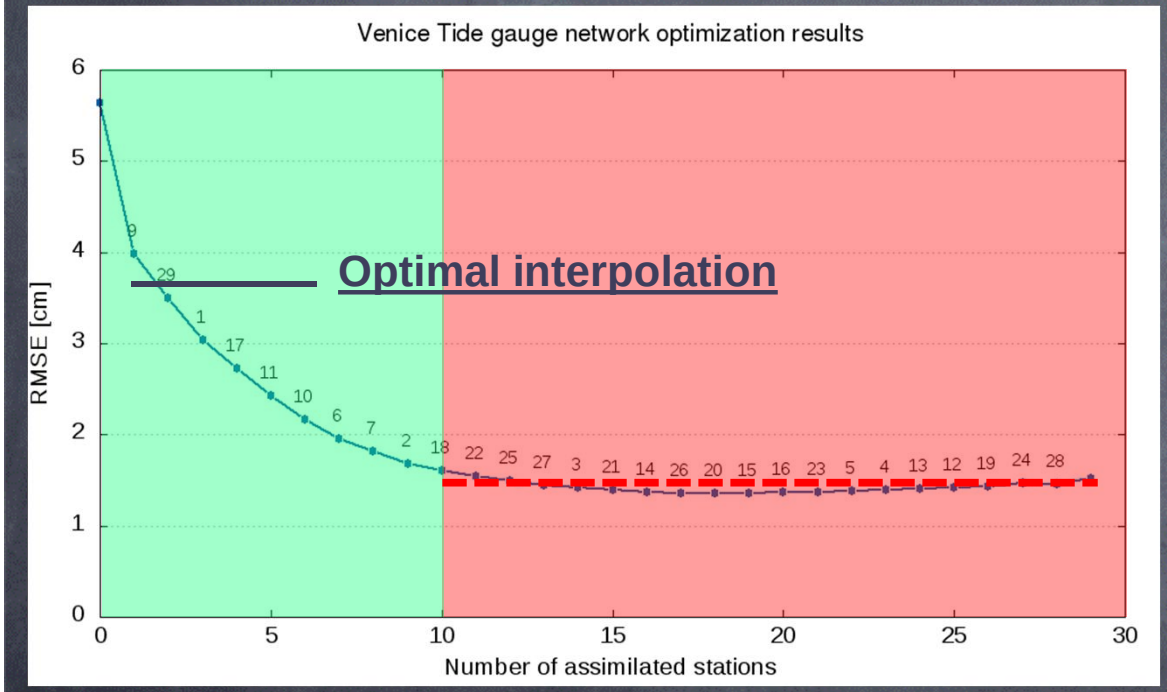
Interpolation versus Assimilation

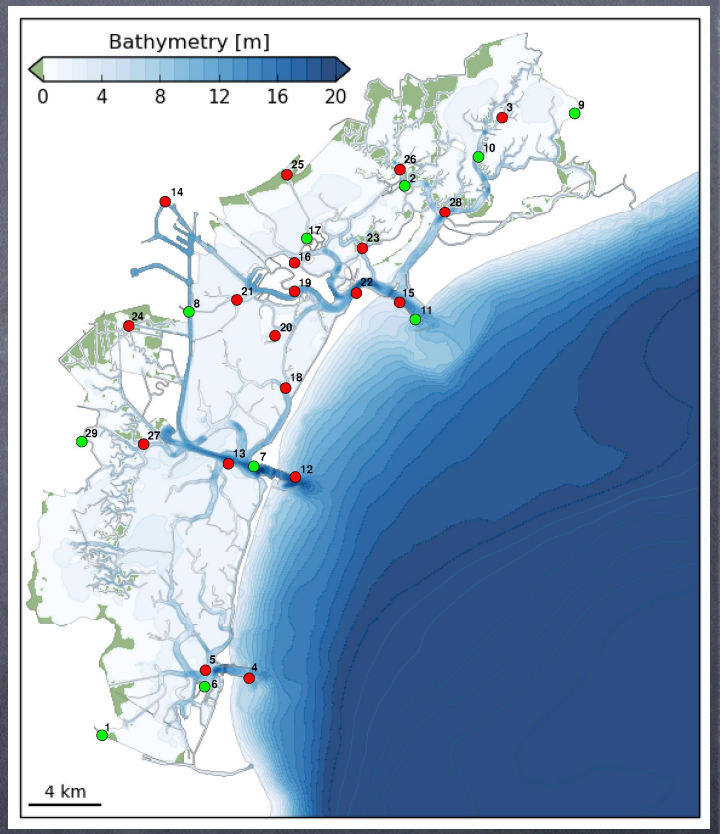


Optimal interpolation of observations (RMSE = 3.75 cm

Model result with assimilation of observations (RMSE = 1.5 cm)

Tidal network optimization

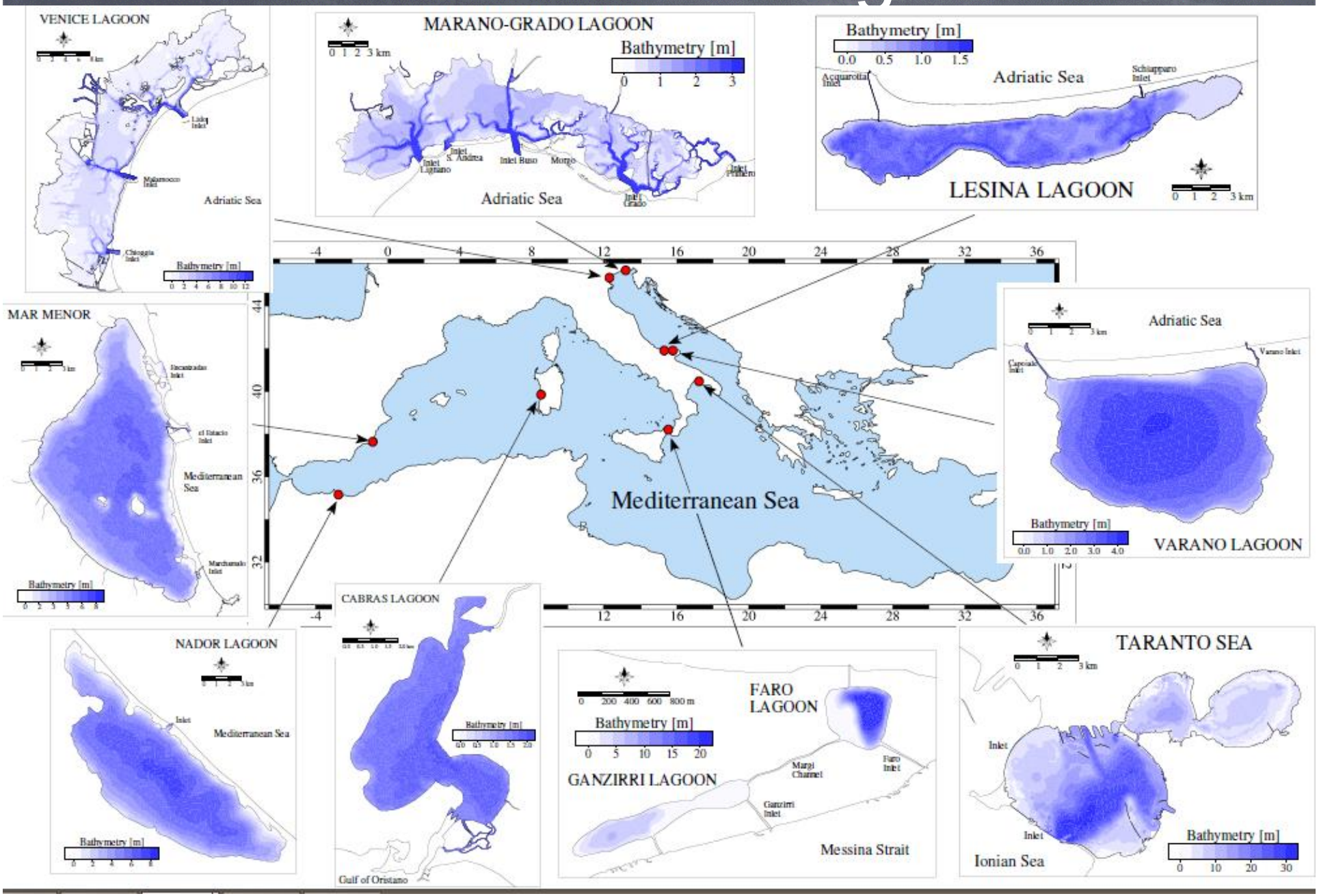


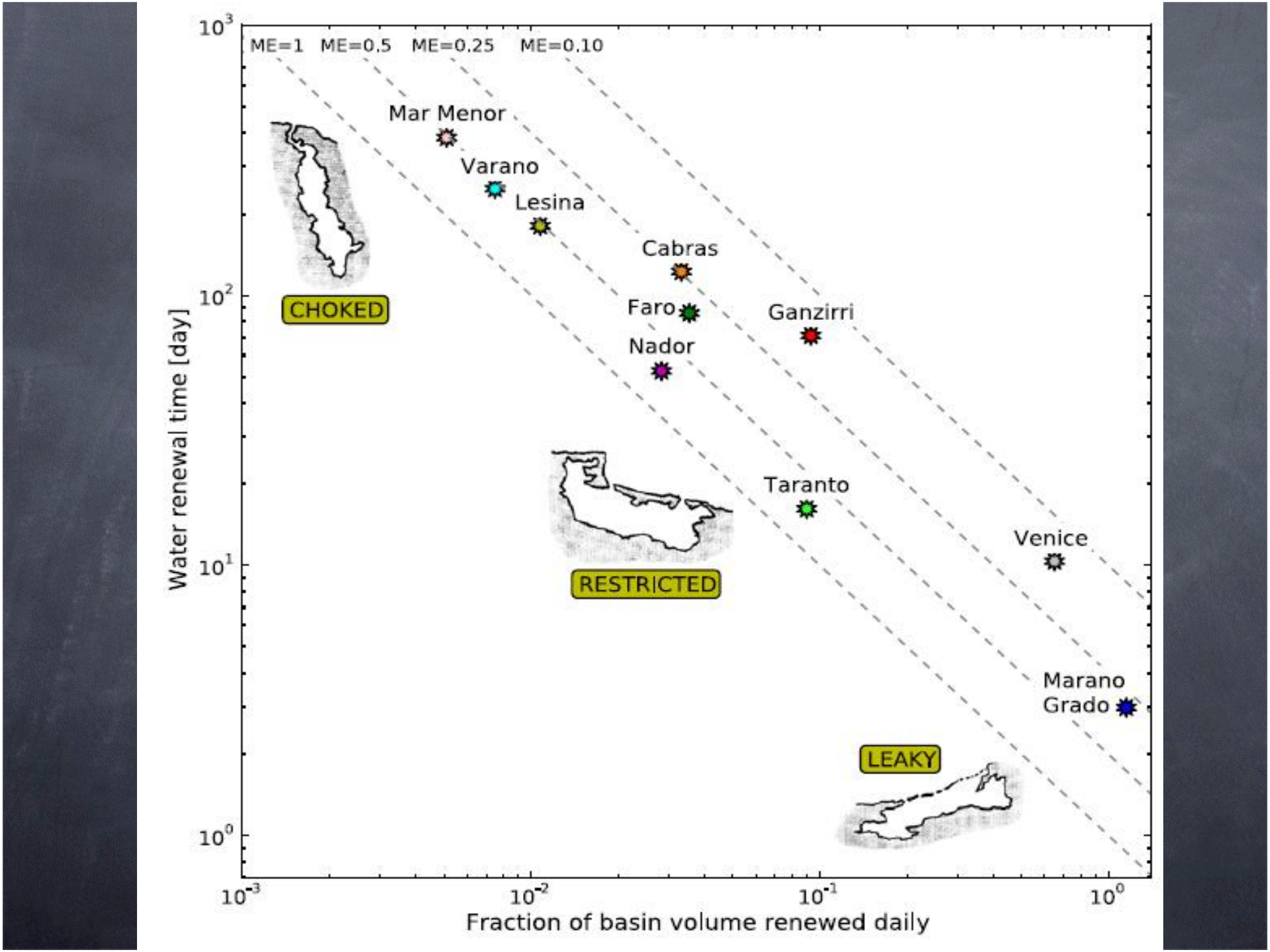


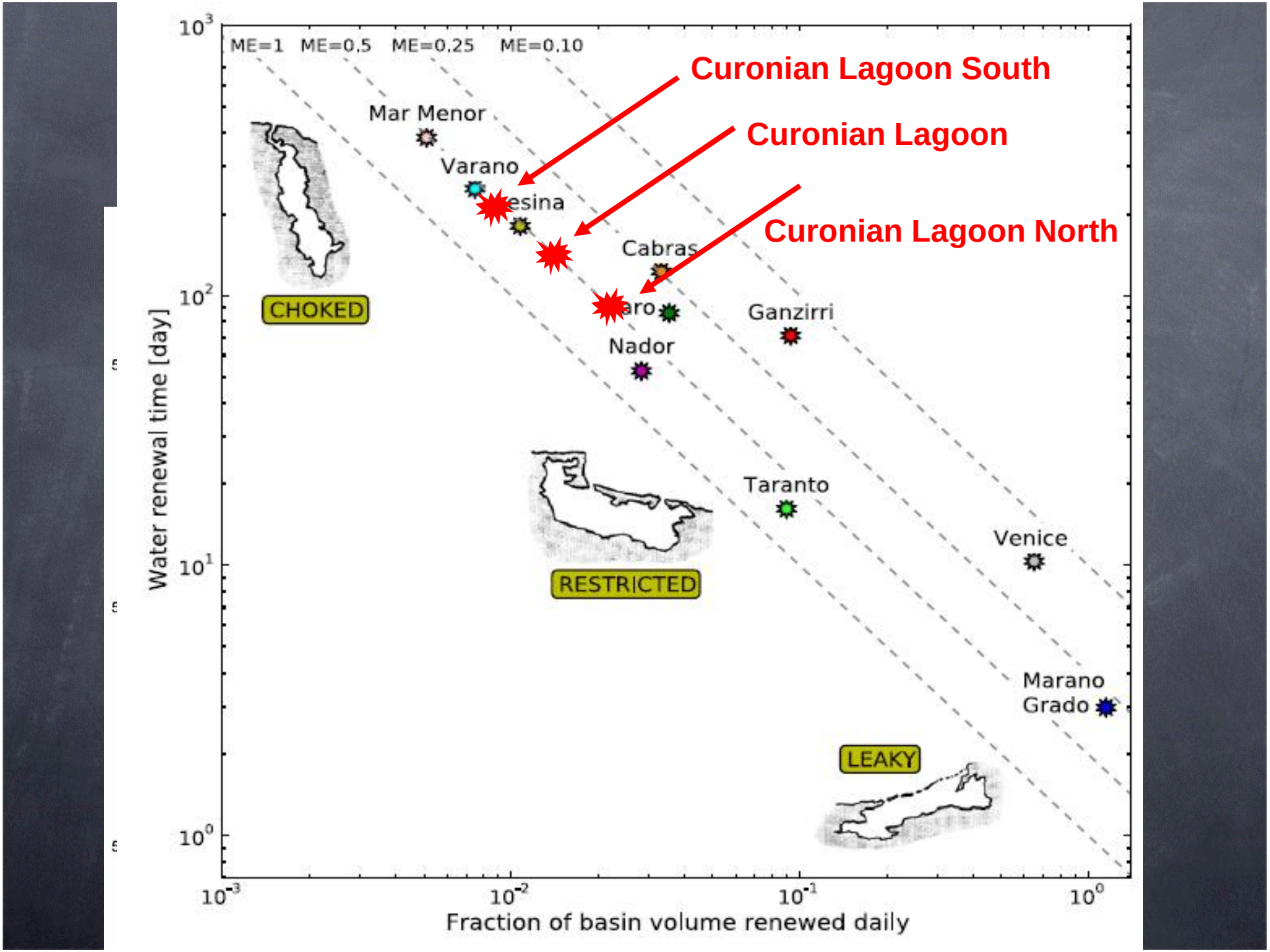
1 station maintenance cost ≈ 3500 € / yr

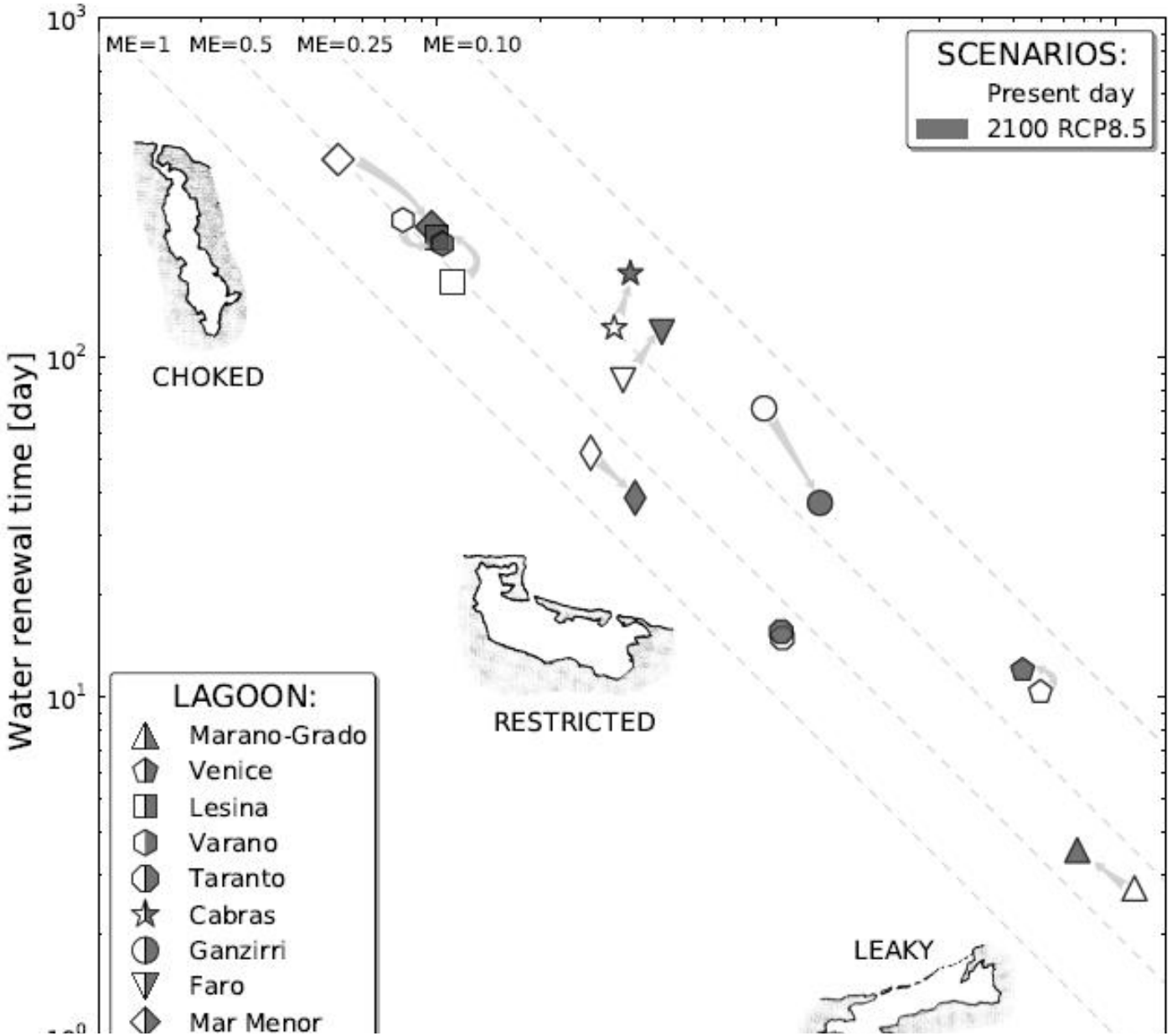
SAVE 66,500 € / yr

Mediterranean lagoons



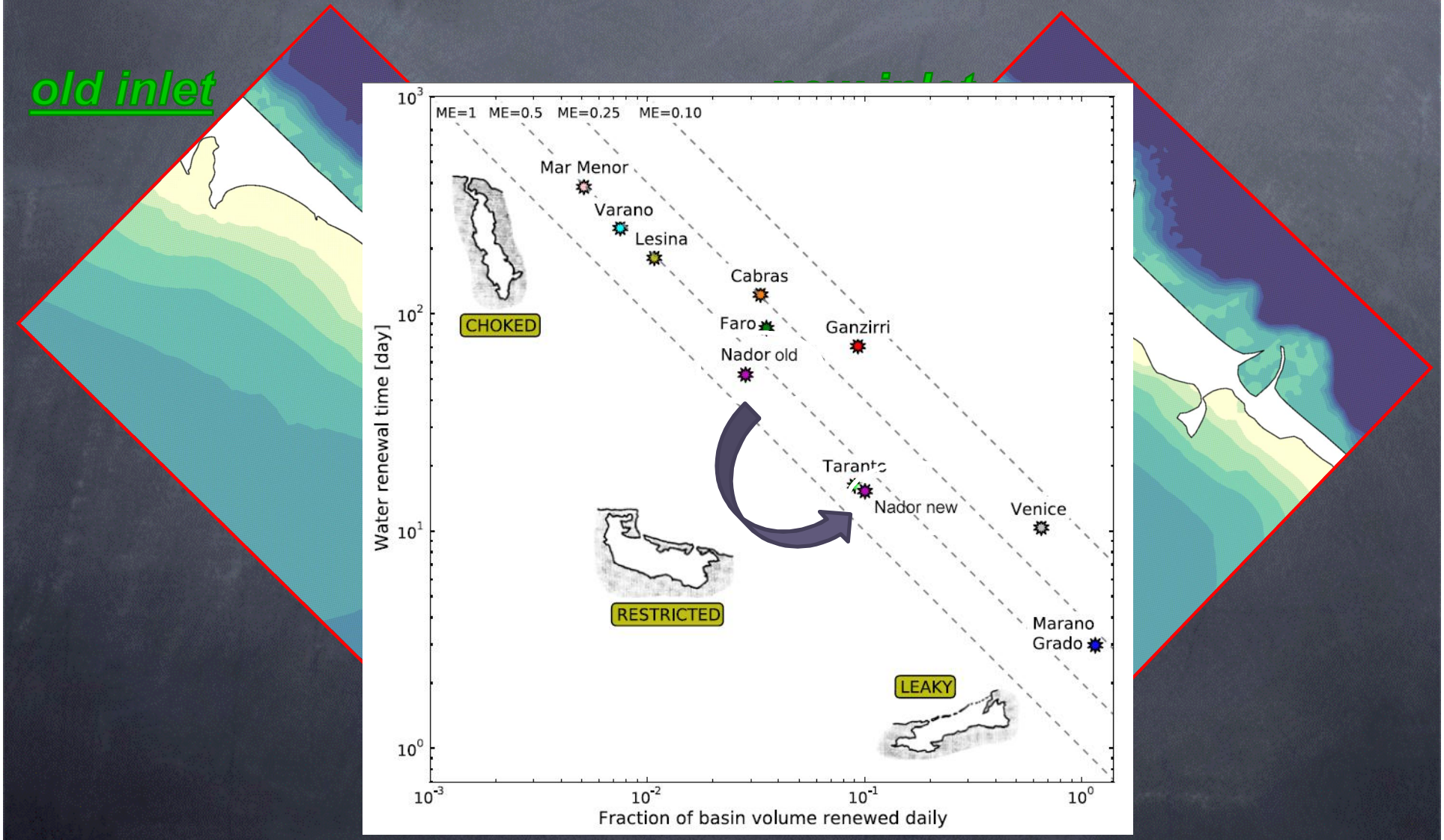

ME=1
ME=0.5
ME=0.25
ME=0.10
Mar Menor
Varano
Lesina
Cabras
Faro
Ganzirri
Nador
Taranto
Venice
Marano
Grado
CHOKED
RESTRICTED
LEAKY
Water renewal time [day]
Fraction of basin volume renewed daily
10^3
10^2
10^1
10^0
10^{-3}
10^{-2}
10^{-1}
10^0


ME=1
ME=0.5
ME=0.25
ME=0.10
Curonian Lagoon South
Curonian Lagoon
Curonian Lagoon North
Mar Menor
Varano
esina
Cabras
aro
Ganzirri
Nador
Taranto
Venice
Marano
Grado
CHOKED
RESTRICTED
LEAKY
Water renewal time [day]
Fraction of basin volume renewed daily
10^3
10^2
10^1
10^0
10^{-3}
10^{-2}
10^{-1}
10^0



The loss of hydrodiversity: under climate change Mediterranean lagoons will become similar to each other

The Nador Lagoon



Acknowledgements

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- A. Cucco, I. Scroccaro
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- P. Zemlys, A. Razinkovas-Baziukas, J. Mezine, N. Cercasova, A. Erturk
- A. Perez-Ruzafa
- A. Stanica, I. Dinu
- S. Zecchetto, F. De Biasio
- V. Koutitonsky

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International Center for advanced studies on River-Sea systems

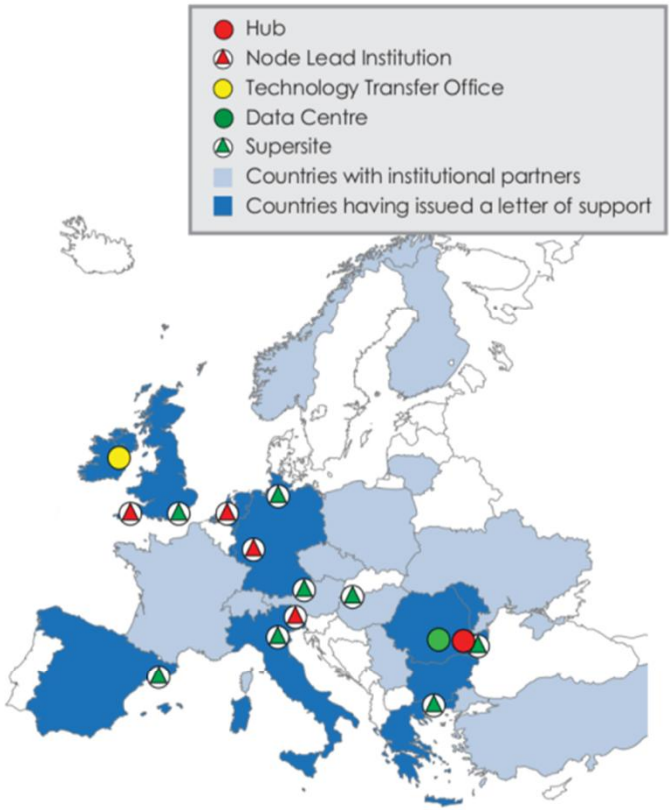
Addressing societal challanges related to river-sea systems requires new approaches to world leading research, spanning traditional disciplines

DANUBIUS-RI a distributed, pan-european RI, led by Romania

DANUBIUS RI challenge

Better understanding of freshwater-marine systems & transitional environments (e.g. delta, estuary, lagoon), ensuring a comprehensive approach - integrative study of River – Sea (RS) systems and fulfilling societal demands

DANUBIUS-RI was included in the 2016 ESFRI Roadmap
and is a **EUSDR** Flagship Project (EU Strategy for the Danube Region)



DANUBIUS-PP

Preparatory Phase for the pan-European Research Infrastructure DANUBIUS–RI "The International Centre for advanced studies on river-sea systems"

Project Timeline		
Start: December 2016	Duration: 36 months	End: November 2019

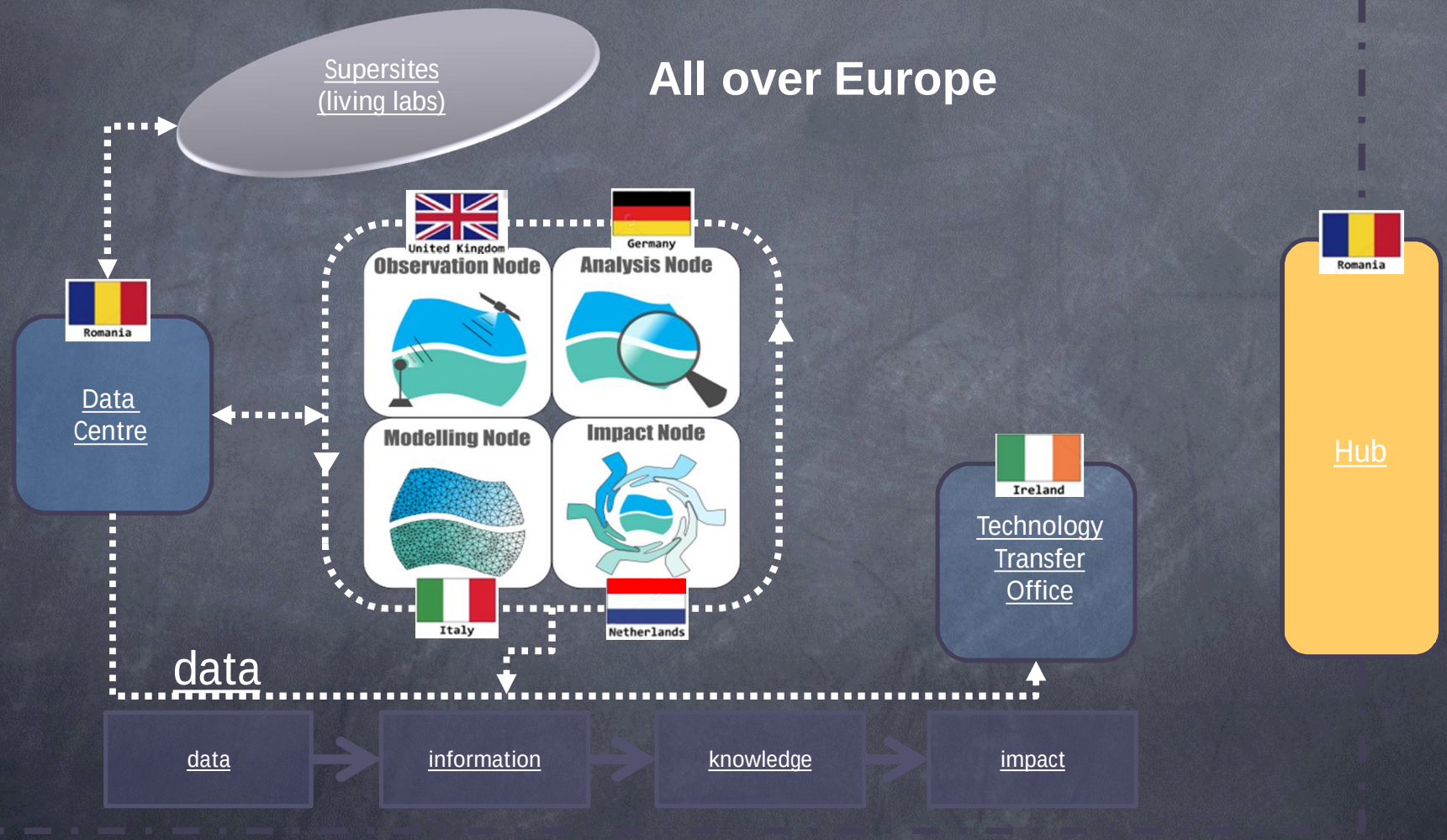
DATA

INFORMATION

KNOWLEDGE

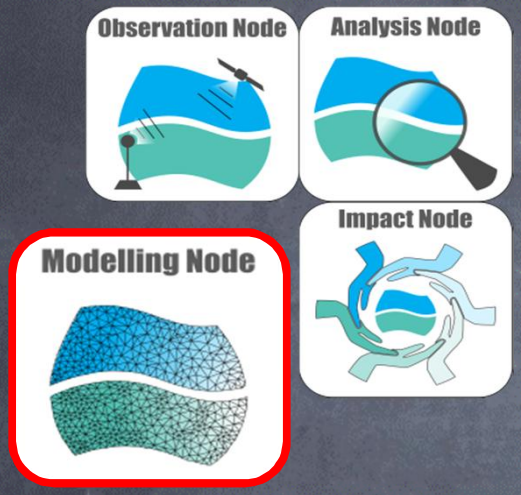
WISDOM

The DANUBIUS-RI components

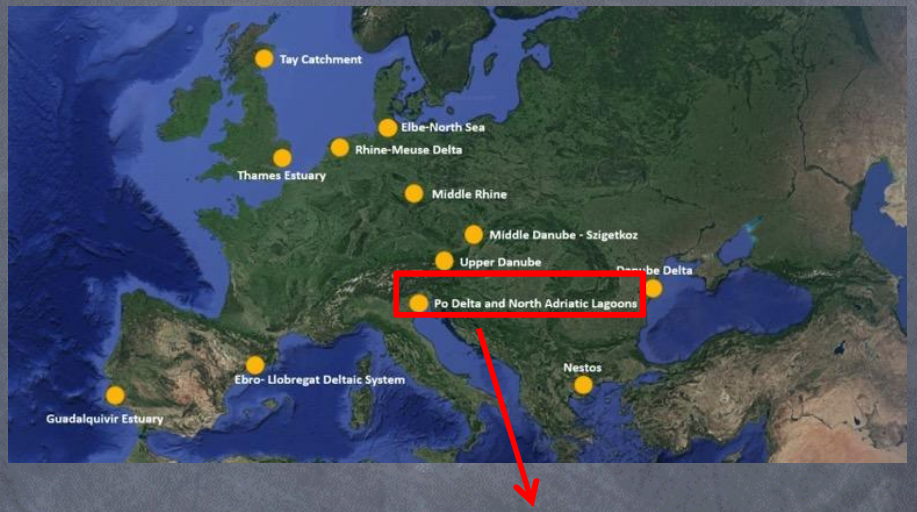


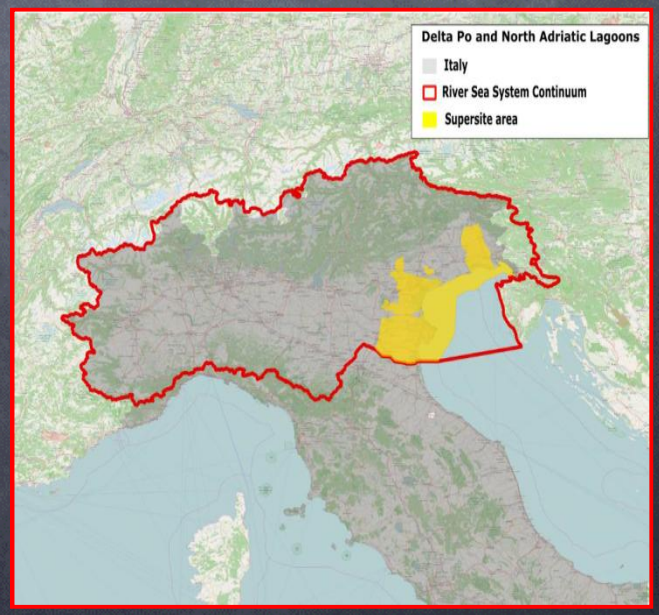
Italy in DANUBIUS-RI components

4 Thematic Nodes



12 Supersites as living lab





Modelling Node

Po Delta and North Adriatic lagoons Supersite

Observation Node

Leading Inst.: Plymouth Marine Laboratory (PML) and University of Stirling, UK

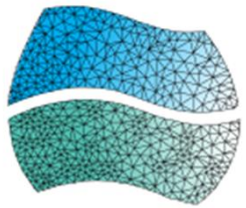
Real time observation tools and instruments, new sensors, satellites, automated data processing, quality control and visualization

Analysis Node

Leading Inst.: Federal Institute of Hydrology (BfG), Germany

laboratories, instrumentation and highly innovative methodologies for samples analysis.

Modelling Node



Leading Inst.: Institute of Marine Sciences (CNR-ISMAR), Italy

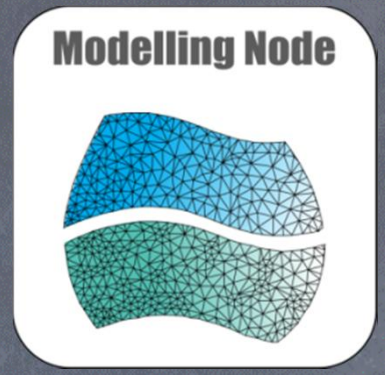
Development of new modelling tools in terms of new algorithm, data-models interaction, interfaces, link with socio-economic modelling.

Impact Node

Leading Inst.: Deltares, Netherlands

interface between natural and social sciences developing methodologies and tools that will help to solve problems in highly complex dynamic RS systems. Identifying causal relation between knowledge development and impact: from data to information to knowledge

Modelling Node: Role in the Research Infrastructure

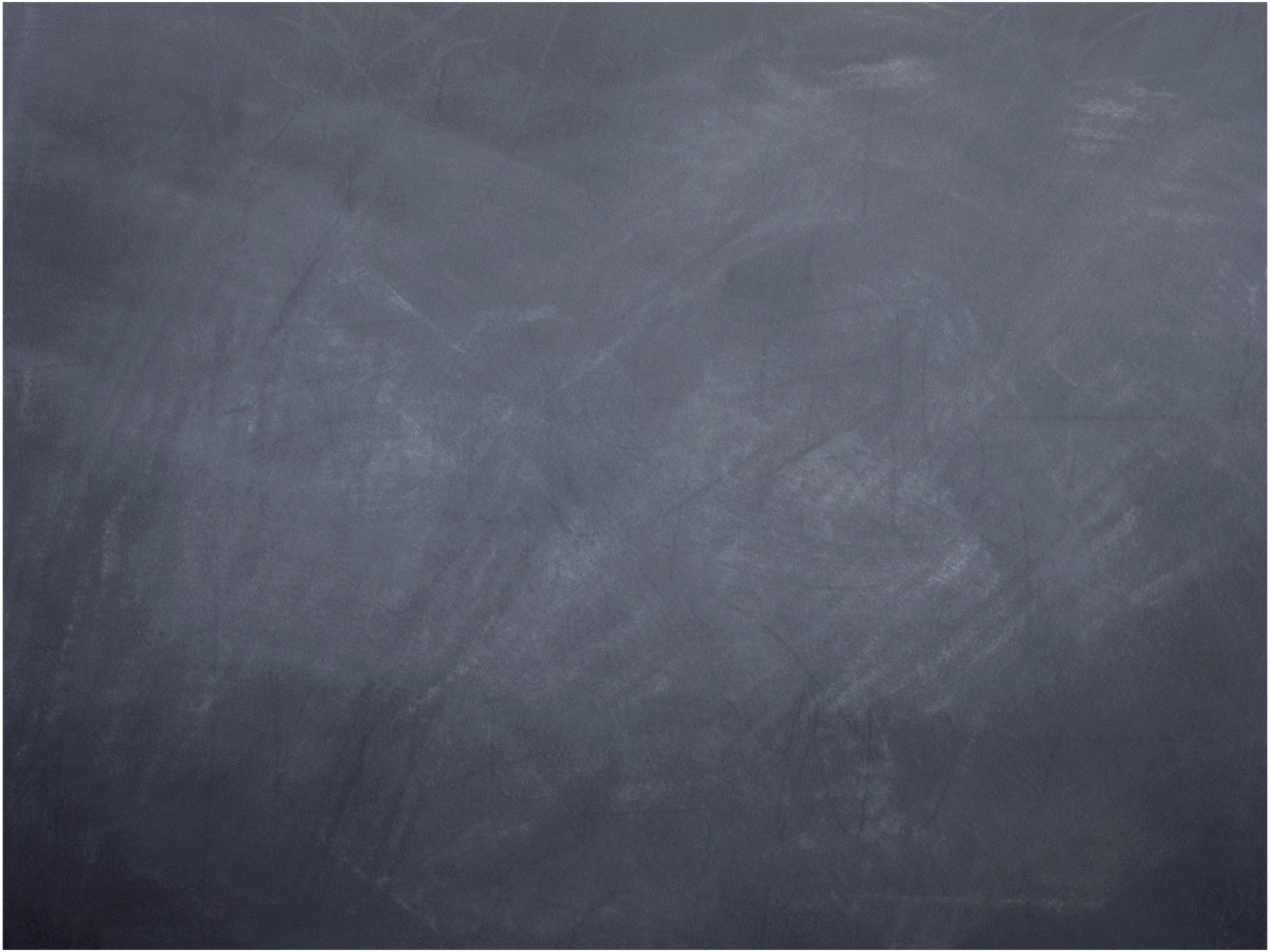


Coordination to focus the modelling effort and create critical mass on River-Sea (RS) modelling topics to facilitate calls from EU on these

Work done by the Modelling Community through Research Projects

Modelling Node Services provided through RI to researchers

Core Codes and test cases
Expert Support
Visualization tools
Standards
Training



Applications in Italy

Garda lake

Lagoons of the Po Delta

Orbetello Lagoon

Bonifacio strait

Cabras Lagoon

Marano-Grado Lagoon

Venice Lagoon

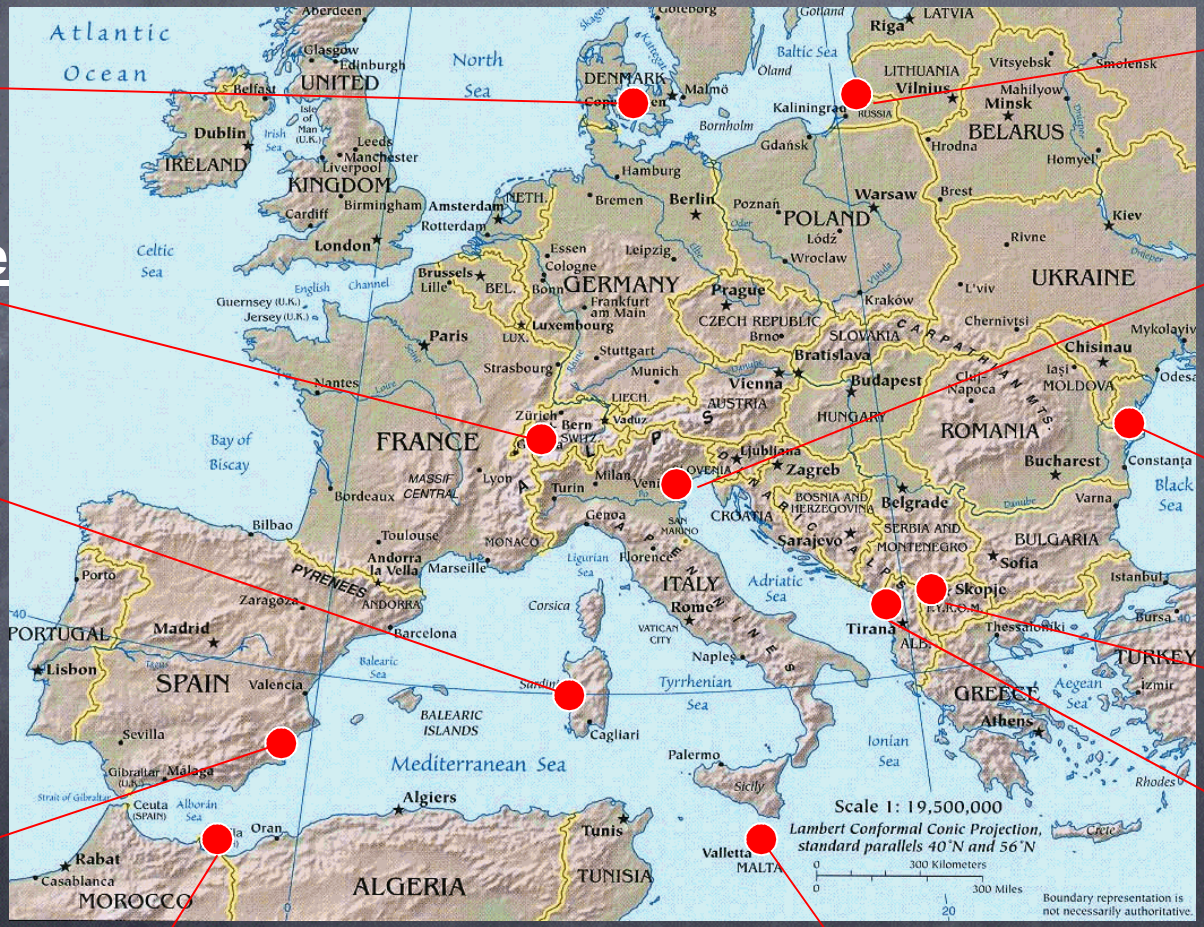
Lagoons of Lesina and Varano

Alimini Lake

Sea of Taranto

Ganzirri and Faro Lagoons

Applications in Europe



Roskilde Fjord, Denmark

Ginevra lake

Cabras Lagoon

Mar Menor, Spain

Nador Lagoon, Morocco

Curonian Lagoon, Lithuania

Venice Lagoon

Danube Delta

Skadar lake

Kotor Bay

Mellieha Bay, Malta

Conclusions

- Modeling techniques can be efficiently applied to the coastal zone and lagoons
- Modeling approach is needed for coastal zone management and sustainable development
- Some parameters can not be measured and can be quantified only through modeling (residence time)
- With modern computer codes the spatial resolution can be pushed to limits adequate to resolving coastal scale processes