Numerical Modelling in European Environmental Infrastructures

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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

- <u>Measurements</u> 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 the observations (filling in gaps) in space and time

2. Predicting the future evolution of the system

3. Simulating the impacts of non-observed forcing scenarios (what-if scenarios)
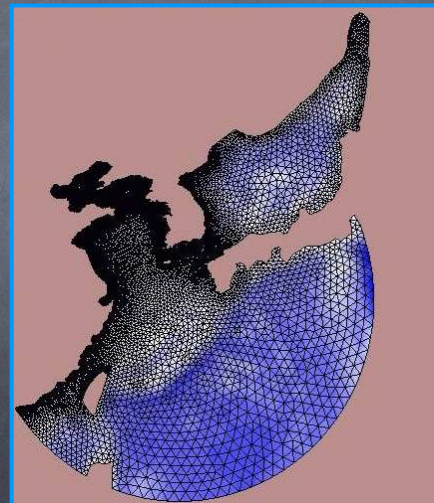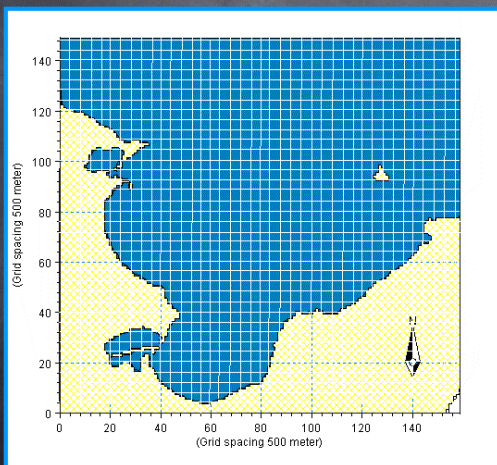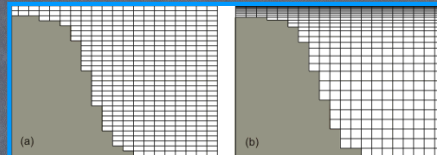
Model dimensions
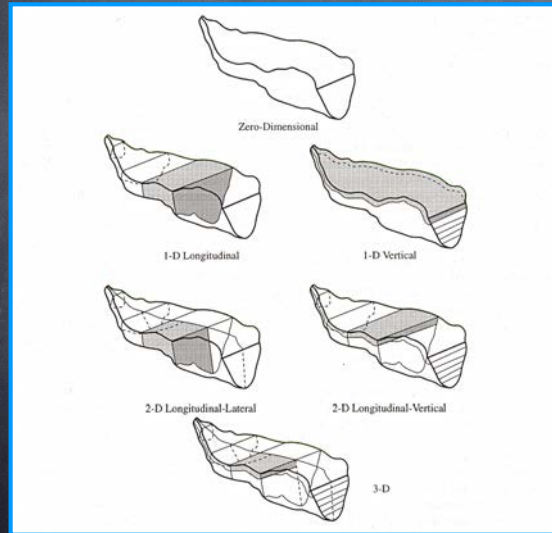
0D
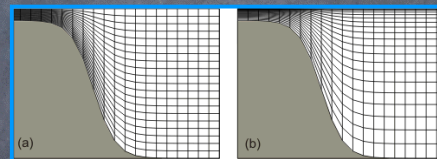
1D

2D

3D

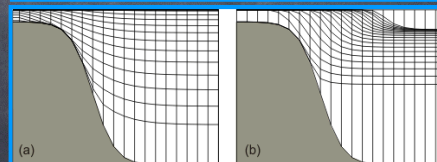# Structured and unstructured grids

Vertical discretization
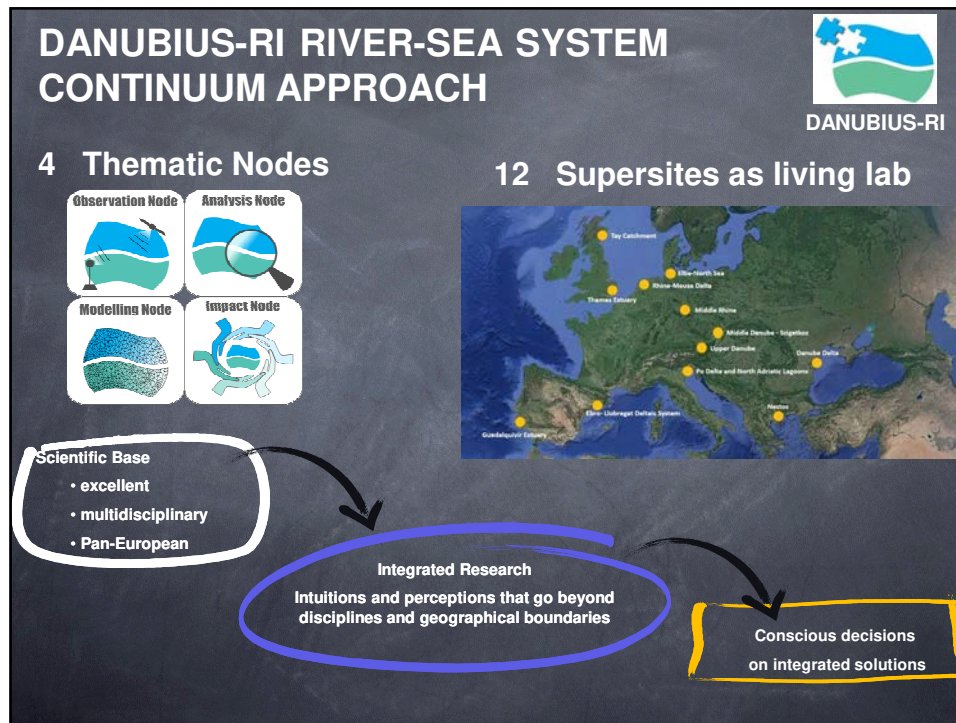
Z - levels

Sigma - levels

Isopycnal - levels

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

DANUBIUS-RI RIVER-SEA SYSTEM CONTINUUM APPROACH

DANUBIUS-RI

4 Thematic Nodes

Observation Node | Analysis Node
Modelling Node | Impact Node

12 Supersites as living lab

Scientific Base
- excellent
- multidisciplinary
- Pan-European

Integrated Research
Intuitions and perceptions that go beyond disciplines and geographical boundaries

Conscious decisions on integrated solutions


Scientific Vision
Advances needed in modelling to address the RS challenges

- **Global simulation models** for surface water, groundwater and hydrology as the basis for regional applications

- **Multi-model simulations** to quantify uncertainty and carry out coupling of models: e.g., hydrodynamics – morphology – vegetation – waves

- **Multi resolution techniques** allow us to scale up and down between global, regional en local models

- **Cloud Computing:** for large model simulations (with big data) made at external computing facilities

- **Fusion of numerical simulation, serious gaming and decision support systems** stimulates stakeholder involvement in modelling

- **Earth Observation Data** (satellite, remote sensing, drones) for system analysis and data-driven modelling
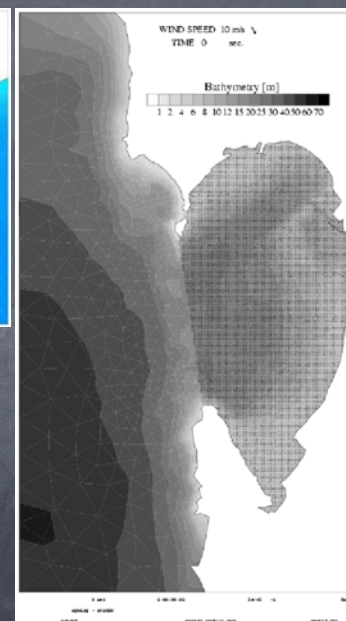
Scientific Vision
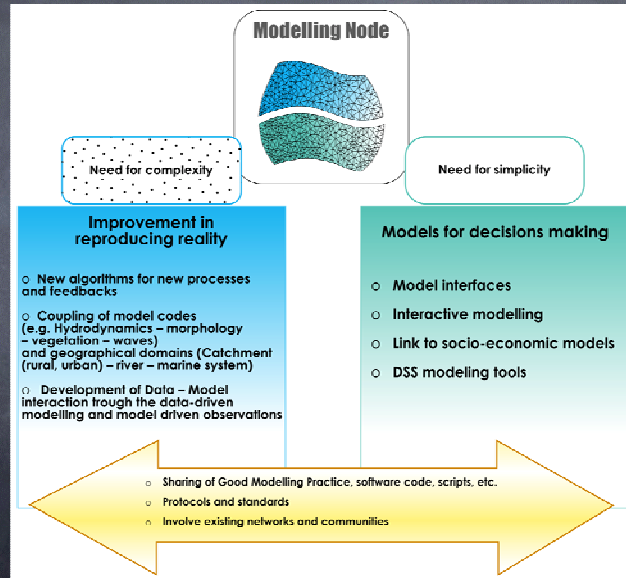


Feedbacks in modeling
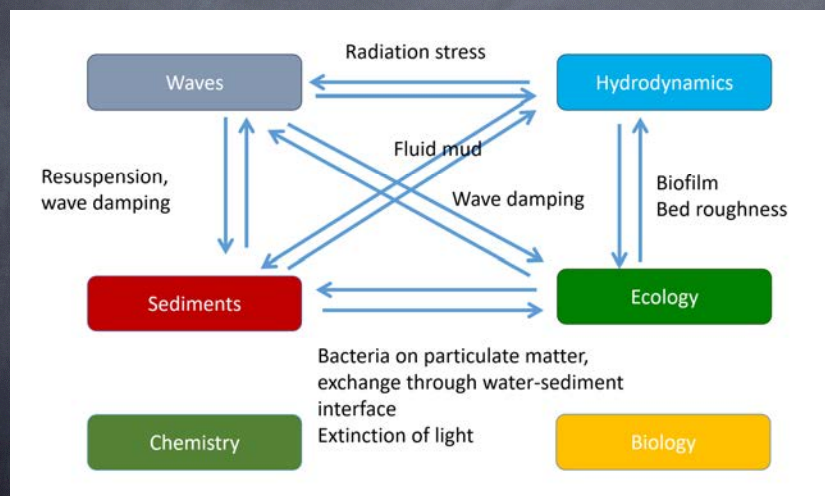
Various topics in modeling

- Connectivity
- Climate change versus anthropogenic activities
- Feedbacks between lagoons and the open sea
- Interpolating with models
- Storm surge: forecasting, assimilation, and uncertainty
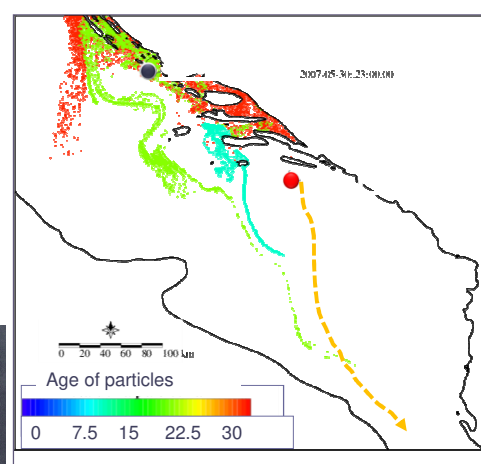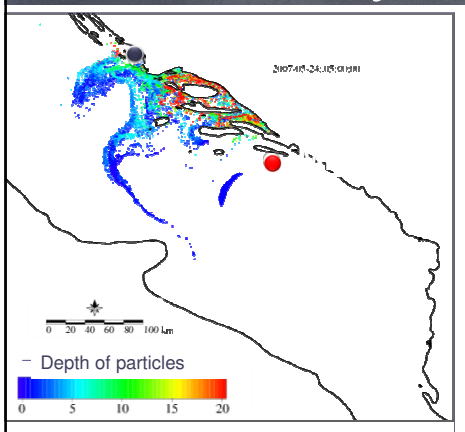
Residence times and turn over time

- 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
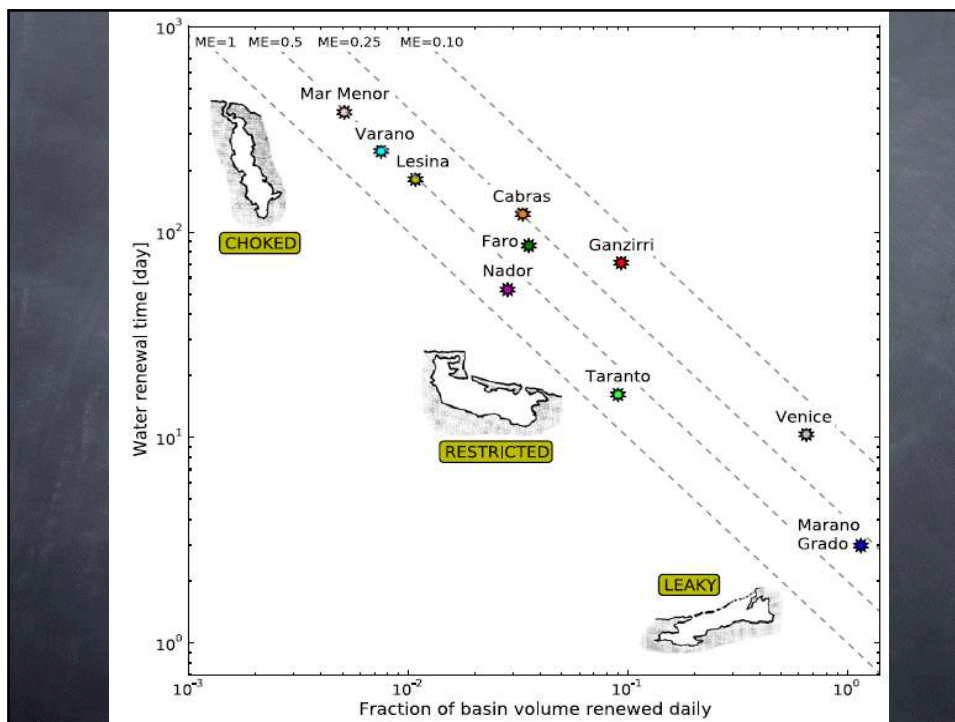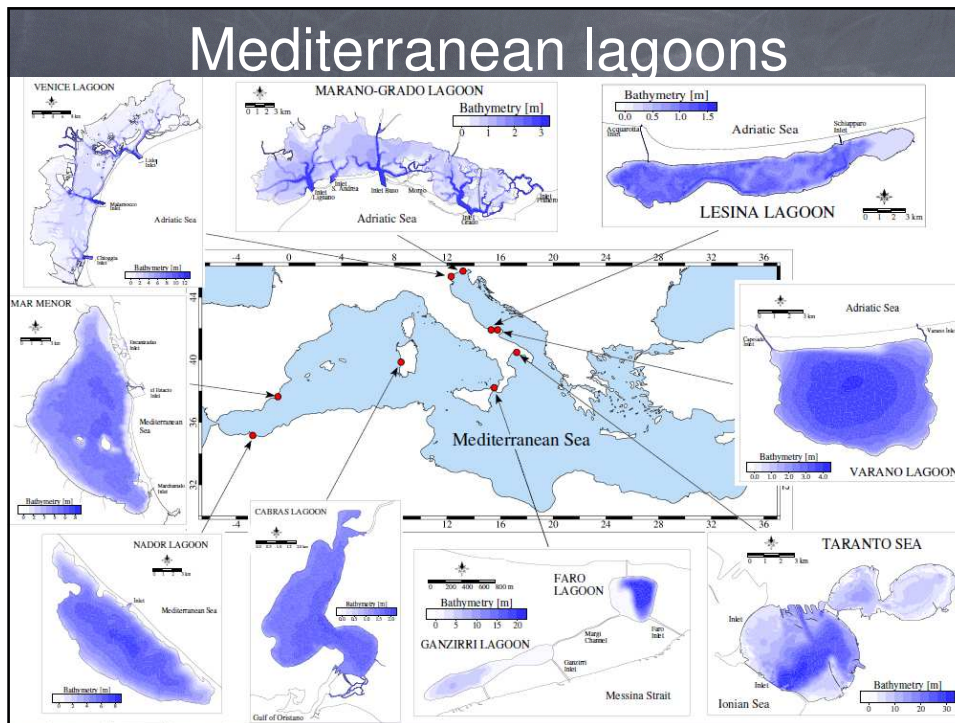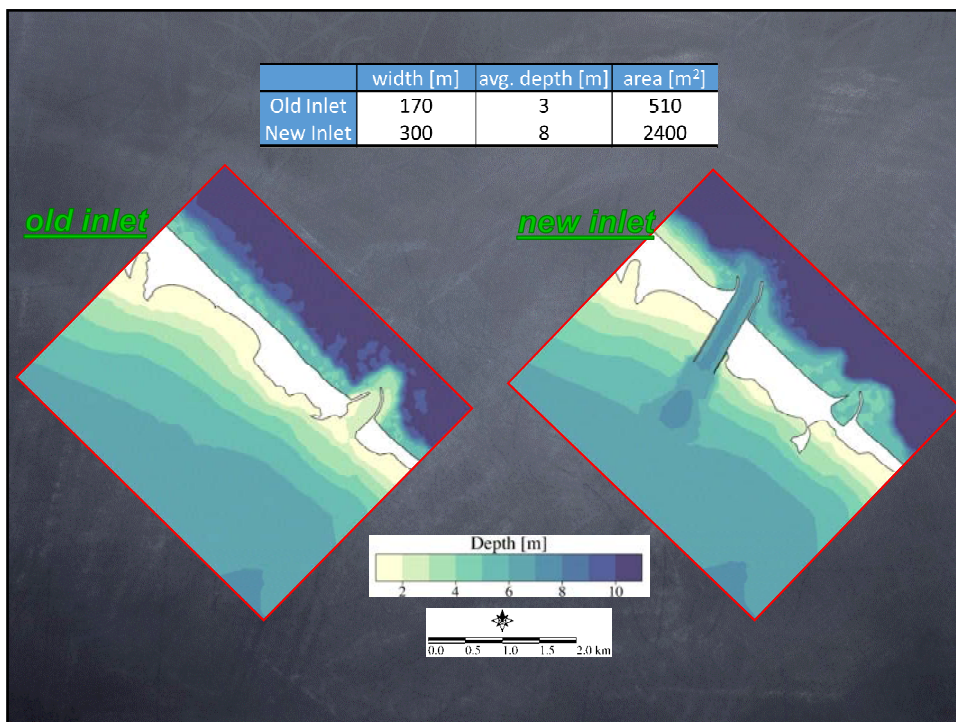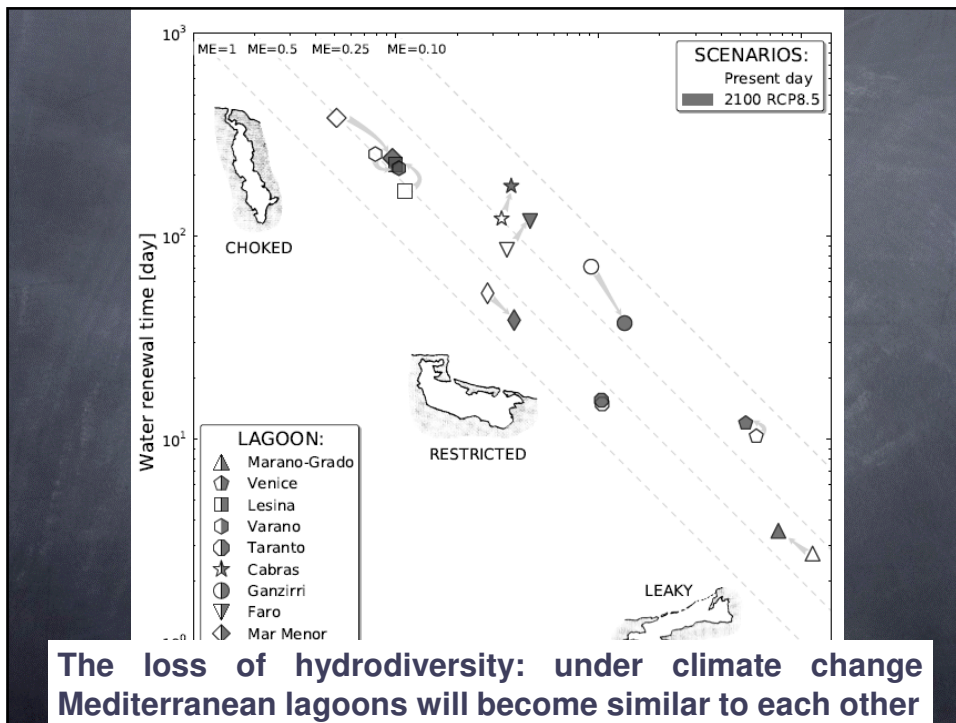
Mechanisms of connectivity
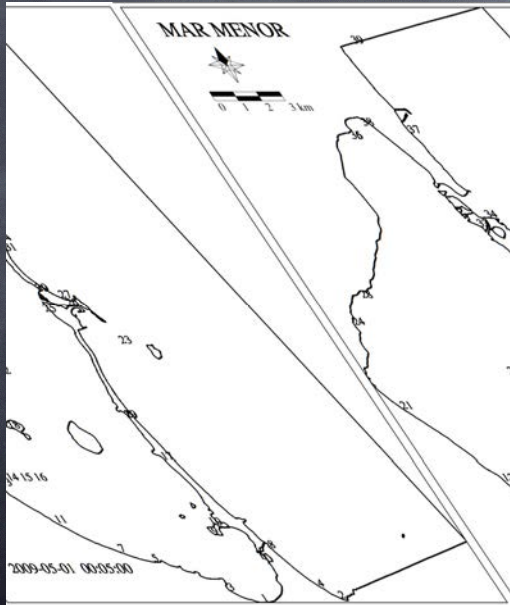
- **A bridge to preserving biodiversity (UNEP 2019)**
- **Land–sea connectivity encompasses biological migration, hydrological cycling, nutrient transport, and climatic adaption (migration corridors), which are vital to both coastal and global ecosystems**
- **Free-flowing river systems work to connect aquatic, avian, and terrestrial communities**

Connectivity in the Adriatic Sea

Mediterranean lagoons

The loss of hydrodiversity: under climate change Mediterranean lagoons will become similar to each other
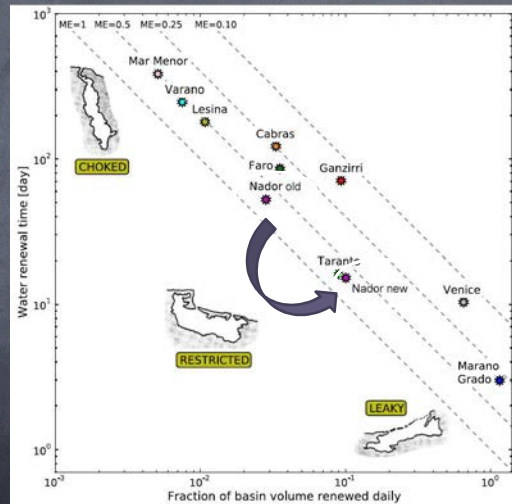
# Anthropogenic interventions are much stronger than climate change

# The feedback of lagoons on the open sea

About 150.000 triangular elements

- **The only sea open boundary is the Otranto Strait (OA line).**

- **The main lagoons and the Po Delta is included in the numerical grid.**

- **To resolve the river-sea continuum, the unstructured grid also includes the lower part of the major rivers**
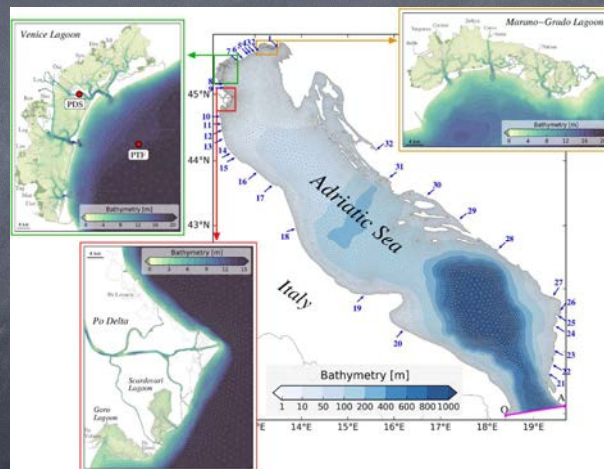
The influence of lagoons: tidal range
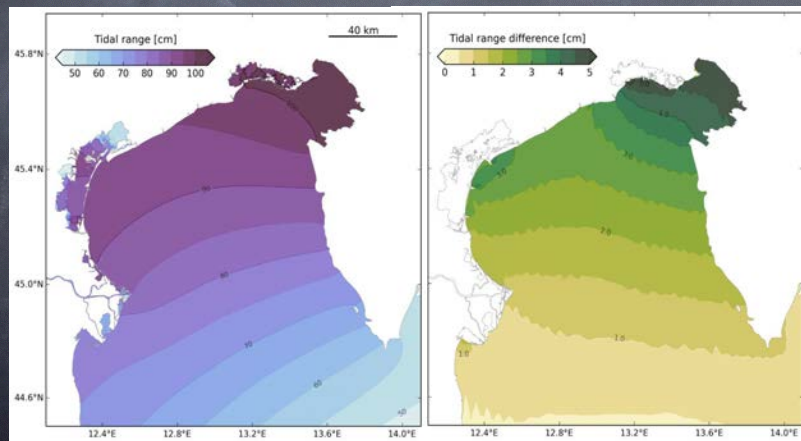
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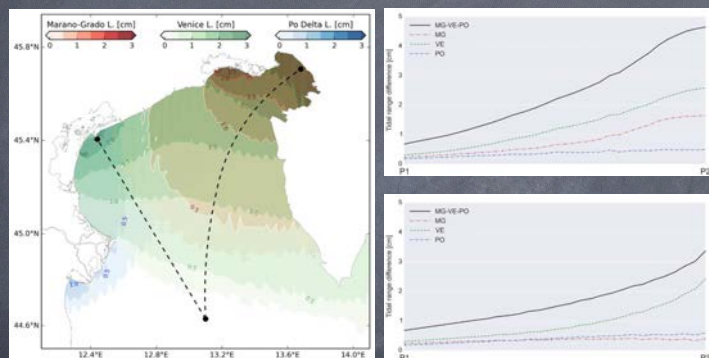
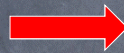**Tidal wetlands have two functions affecting tidal energy:**

- **STORAGE: they store the tidal energy during flood tides, and release it during ebb tides**
- **DISSIPATION: they dissipate more tidal energy on bottom friction and horizontal diffusion than other water regions**
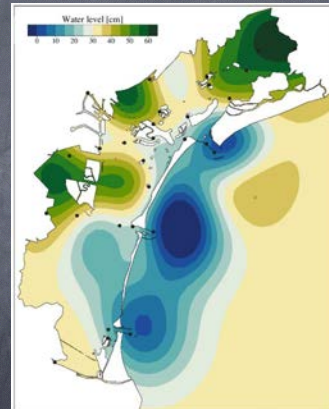
The Venice Lagoon tidal gauge network
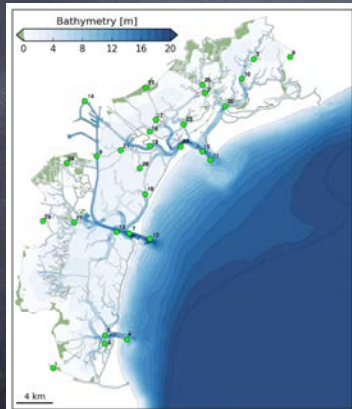
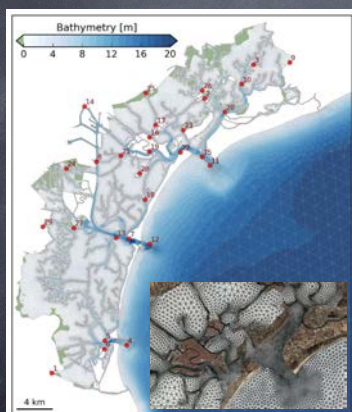**OPTIMAL INTERPOLATION of observations**

Is this the real representation of the parameter?

29 stations

Model results with assimilation

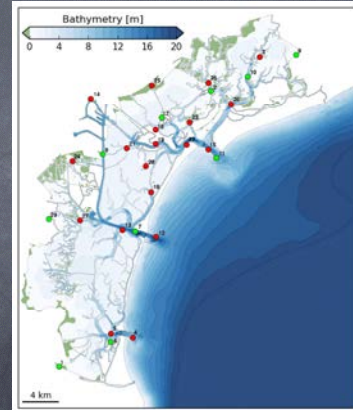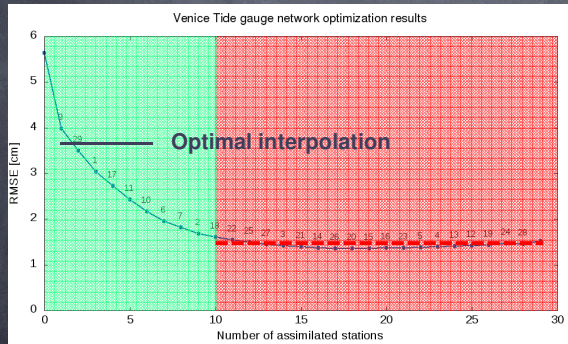**MODEL RESULTS with assimilation of observations**

Are all stations needed?

The tidal network optimization process

1 station maintenance cost ≈ 3500 € / yr ➙ **SAVE 66,500 € / yr**

The Acqua Alta Phenomenon

Acqua Alta

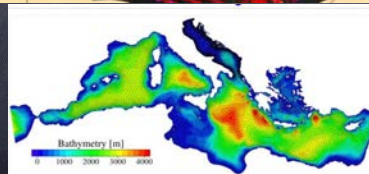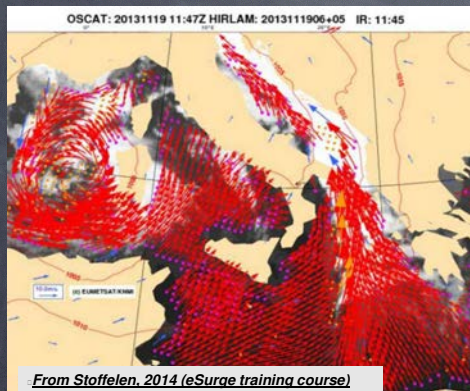| Sea level	Flooded surface
190 cm	100%
140 cm	90%
130 cm	69%
120 cm	35%
110 cm	12%
100 cm	4%

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**

The city of Venice

(http://gisportal.insula.it)

Storm Surge Forecast in Venice

OSCAT: 20131119 11:47Z HIRLAM: 2013111906+05   IR: 11:45

From Stoffelen, 2014 (eSurge training course)

Bathymetry [m]

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

Jason-1 20041030 05:35 GMT Track: 0196

● **Tide gauge**
++ **Altimeter track**
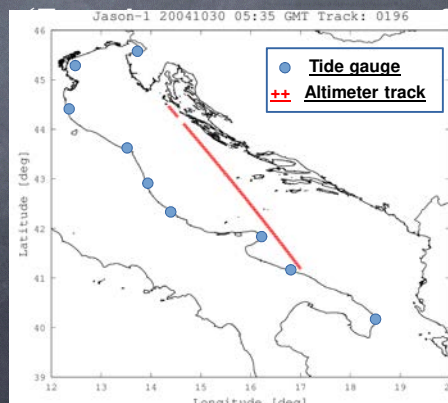
Statistical Results

Configurations	RMS error [cm]
REF	**16.3**
SCATT	10.2
ALT	14.2
SCATT+ALT	**9.0**

The RMS error on the estimation of the maximum surge peak reduces by 44% using both methodologies
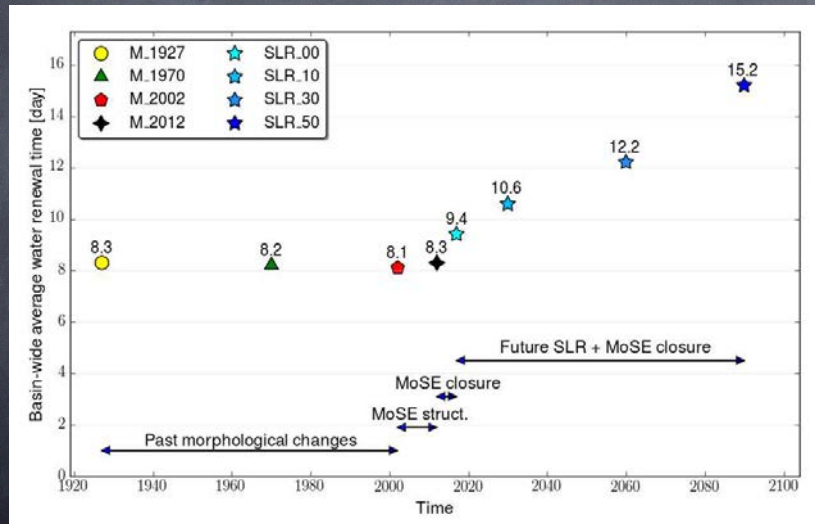
The mobile barriers MOSE

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.
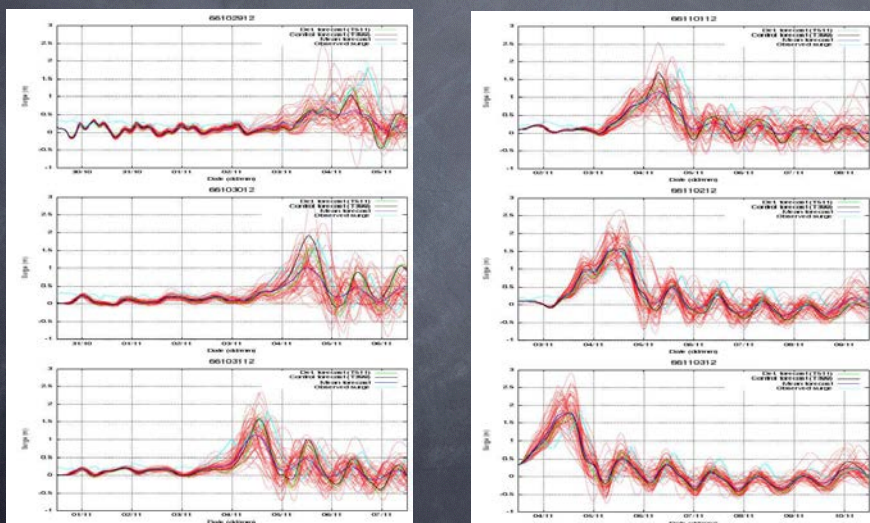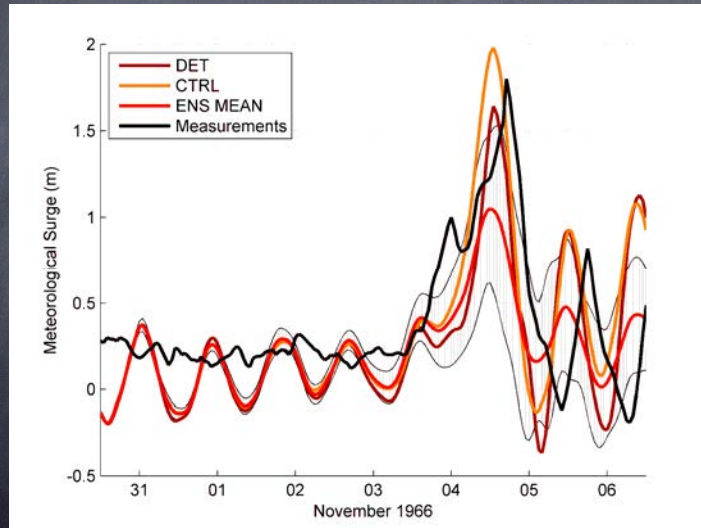
Changes in water renewal time
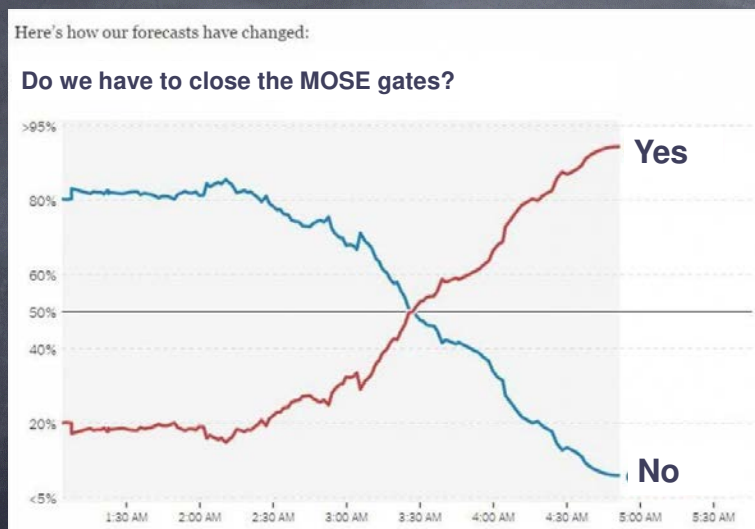

Ensemble forecast

50 ensemble forecast + 1 control forecast + 1 deterministic forecast

Estimating uncertainty with the ensemble forecast

Forecasting is difficult

"Prediction is very difficult, especially if it's about the future."
Nils Bohr, Nobel laureate in Physics