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 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
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 and 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

- Waves
- Radiation stress
- Resuspension, wave damping
- Hydrodynamics
- Fluid mud
- Wave damping
- Biofilm, Bed roughness
- Sediments
- Bacteria on particulate matter, exchange through water-sediment interface
- Ecology
- Extinction of light
- Chemistry
- Biology
- Extinction of light
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

[Map of Mediterranean lagoons]

[Graph showing water renewal time (day) vs. fraction of basin volume renewed daily]
The loss of hydrodiversity: under climate change Mediterranean lagoons will become similar to each other.
Anthropogenic interventions are much stronger than climate change.

- 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 feedback of lagoons on the open sea:

About 150,000 triangular elements.
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
The city of Venice

The pavement level in the city is low with respect to the sea level. Therefore even moderate surge can produce flooding in the city.

### Acqua Alta

<table>
<thead>
<tr>
<th>Sea level</th>
<th>Flooded surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>190 cm</td>
<td>100%</td>
</tr>
<tr>
<td>140 cm</td>
<td>90%</td>
</tr>
<tr>
<td>130 cm</td>
<td>69%</td>
</tr>
<tr>
<td>120 cm</td>
<td>35%</td>
</tr>
<tr>
<td>110 cm</td>
<td>12%</td>
</tr>
<tr>
<td>100 cm</td>
<td>4%</td>
</tr>
</tbody>
</table>

Pavement lower than 90 cm

### Storm Surge Forecast in Venice

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

From Stoffelen, 2014 (eSurge training course)
Statistical Results

<table>
<thead>
<tr>
<th>Configurations</th>
<th>RMS error [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>REF</td>
<td>16.3</td>
</tr>
<tr>
<td>SCATT</td>
<td>10.2</td>
</tr>
<tr>
<td>ALT</td>
<td>14.2</td>
</tr>
<tr>
<td>SCATT+ALT</td>
<td>9.0</td>
</tr>
</tbody>
</table>

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