THE STUDY OF RIVER-SEA SYSTEMS: THE PO DELTA

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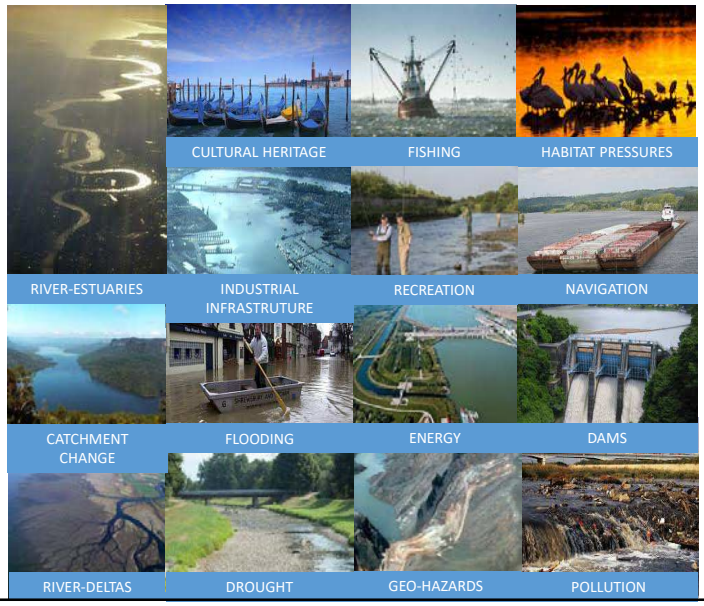
Why River Sea Systems are so important – why to model them?



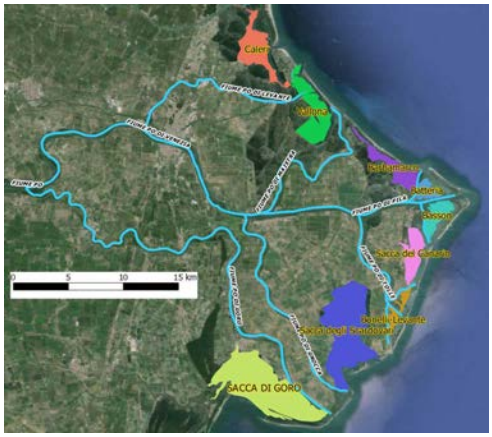
Why these studies?
How identify interactions with the LifeWatch community

- Integrated models to provide baseline for integrative studies – links between hydrodynamics, ecology, water quality…
- Spatial integration – link between the riverine and the marine communities. Starting from the identification of hydrodynamic interactions and feedbacks, quantify the ecological impact

- This typology of studies need:
  - Data for cal/val
  - Interdisciplinary expert support
  - Knowledge about available modeling tools – training

  This is a common field of work between Lifewatch-ERIC and DANUBIUS-RI

Po River Sea System – the delta and its lagoons OVERVIEW



Po River Delta and its lagoon system
Is the perfect example of the complexity of River Sea Systems:
- Several different river branches
- A number of interconnected sub-basins connected with the river branches through natural or regulated connections
- Bathymetric complexity not just along the coast but also along the river branches
- Exposition to spatially varying main forcings

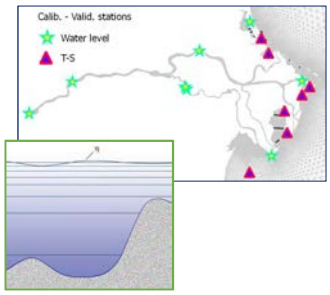
How to study River Sea System from a modeling perspective

The numerical model

- 3D baroclinic finite element
- 1 grid with the 3 different water environments
- The river is modeled 90 km upstream the mouth
- spatial resolution from 5 to 2500 m
- 1 model nesting on the sea boundary

Calibration (6 months, 2009)
- Water level and fluxes in the lagoons and in the river

Validation and analysis (2 years, 2010-2011)
- Water level and fluxes in the lagoons and in the river
- T/S in the lagoons and in the shelf

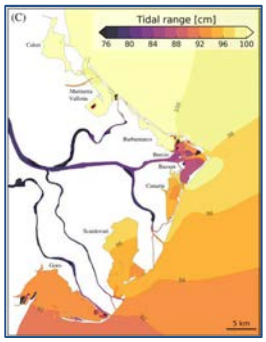


Validation statistics

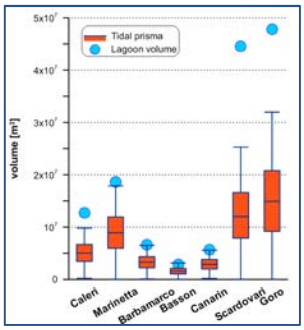
	Marinetta	Basson	Canarin	Scardovari sea	Scardovari internal	Offshore Buoy 6 m
Salinity Bias	-0.2	-5.7	-1.8	-0.6	0.8	-0.9
Salinity RMSE	4.5	7.5	4.6	4.5	2.9	3.4
Temp. Bias (°C)	-0.9	-0.8	-0.8	-0.9	-0.6	-0.7
Temp. RMSE (°C)	2.0	1.2	1.5	1.5	1.4	1.9

Hydrodynamic interaction

Lagoons – Sea



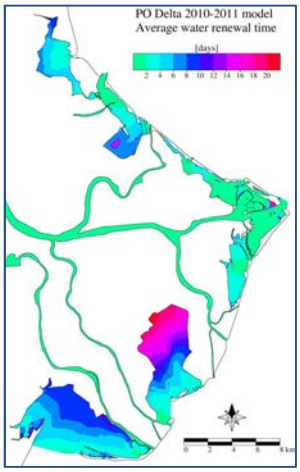
Tidal range
- Damping along coast due to tidal propagation in the Northern Adriatic Sea
- Almost similar between sea and lagoons



Tidal prims are
- in the order of the lagoon volumes
- lagoons are hydrodynamically active

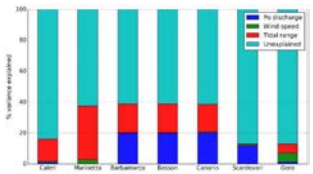
The water flushing time is in the order of a few days and correlated with tidal range

Advection and mixing: Water Renewal Time



The WRT is the time needed to lower the concentration of a passive tracer from 1 to 0.33 (Takeoka, 1984), is a general descriptor of the lagoons dynamics.
WRTs were calculated in the analysis simulation every 30.5 days (24 maps).

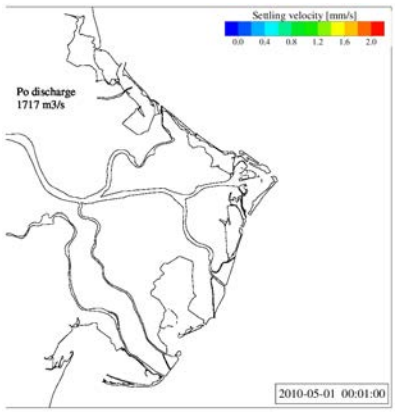
- WRTs are generally low (5 days avg.)
- WRTs locally are lowered by freshwater inputs
- Marked season variability (twice values in summer)
- Limited spatial variability (except Scardovari Lagoon)



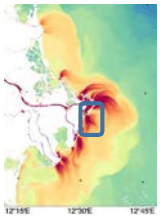
- The tidal forcing influences more the WRTs of the smaller lagoons
- The wind is not influencing the WRTs because of their limited area
- The high percentage of WRTs variance unexplained is due to the non-linear characteristics of the PO RDS system and interaction between the forcings

Mixing interaction: River - Sea

Lagrangian parcels from river branches

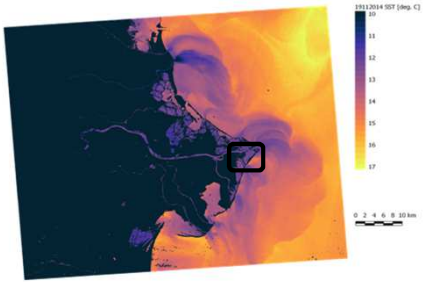


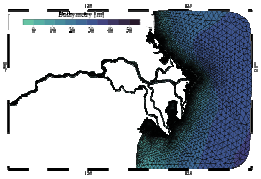
Modeling coastal mixing in multiple river-mouth deltas



Limited coastal areas, between the river branches, with higher temperature. Thermohaline characteristics closer to marine waters.

Use of EO images, in situ measurements and a set of model runs to understand the process.



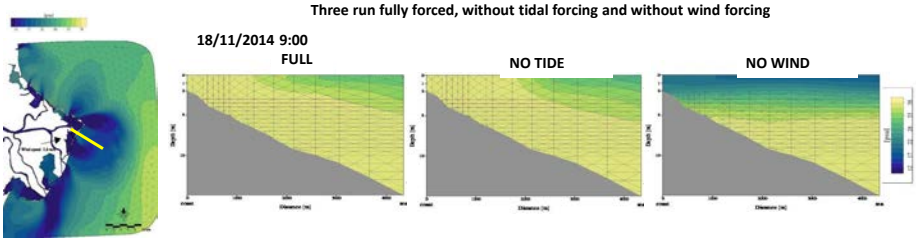


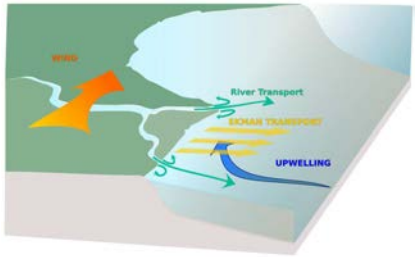
- Coastal warmer and saltier bulges between river branches due to upwelling
- Process occurrence due to upwelling induced by tidal straining and wind
- The water bulges modulate thermohaline characteristics of Po Delta lagoons

- Open question: how these processes can affect ecosystem, nutrients dispersal/stagnation, presence/absence of fish stocks

Modeling coastal mixing in multiple river-mouth deltas

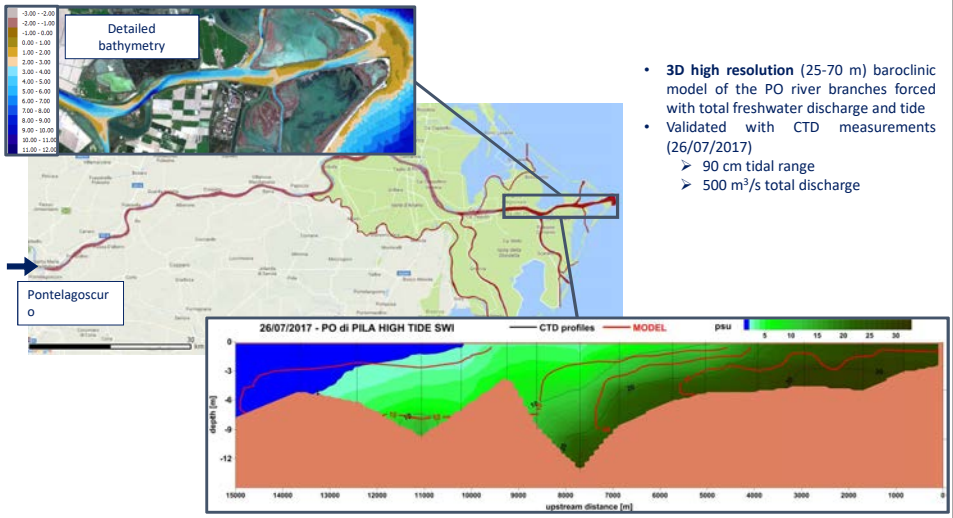
Three run fully forced, without tidal forcing and without wind forcing





- Winds from the land and along the coast drive the upwelling through Ekman mechanism.
- The presence of river discharge enhances the water column stratification.
- Tidal action follows the tidal straining theory and ebb to flood phase can favor upwelling processes.
- Both processes are identified in the results justifying the surficial presence of the warmer and saltier water bulges.

River- Sea interaction: Salt Wedge Intrusion

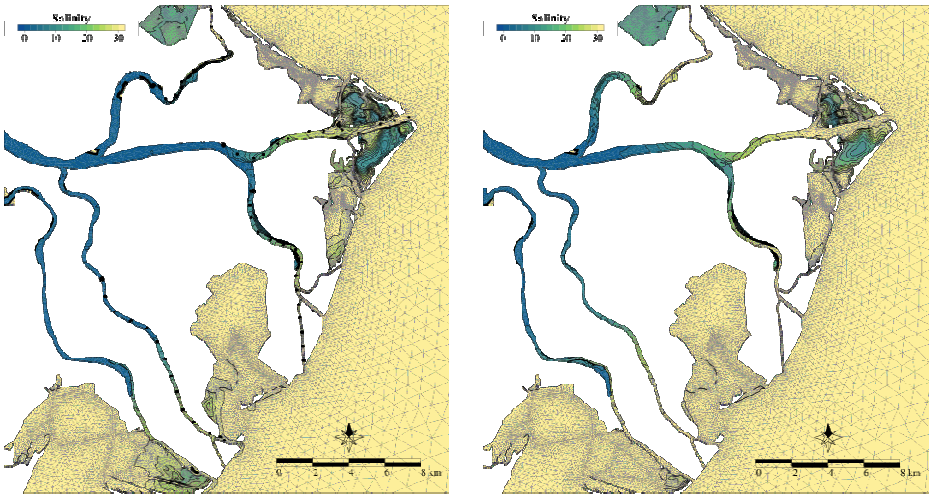


- **3D high resolution** (25-70 m) baroclinic model of the PO river branches forced with total freshwater discharge and tide
- Validated with CTD measurements (26/07/2017)
  - 90 cm tidal range
  - 500 m^3/s total discharge

Salt Intrusion

Present Situation – snapshot July 2017

Climate Scenario RCP 8.5 – snapshot 2080-2100



Larger extension inland of salty water → changes in the riverine environment – impacts on ecosystems

Conclusions

3D hydrodynamic models for RDS systems can provide the baseline for the studying interactions of

- *river-sea*
- *lagoon-sea*
- *river-lagoon*

These tools can be deeply integrated with ecological studies, both for present state investigations and scenarios. Examples are:

- *Hydrodynamic models with habitat suitability models*
- *Investigate interactions and feedbacks*
- *Provide scenarios in the climate change perspective in order to quantify environmental impacts*