TWO-WAY NESTING TECHNIQUE APPLIED ON MOHID MODELLING SYSTEM

J. Sobrinho[*] , H. De Pablo, F. J. Campuzano, L. Pinto and R. Neves

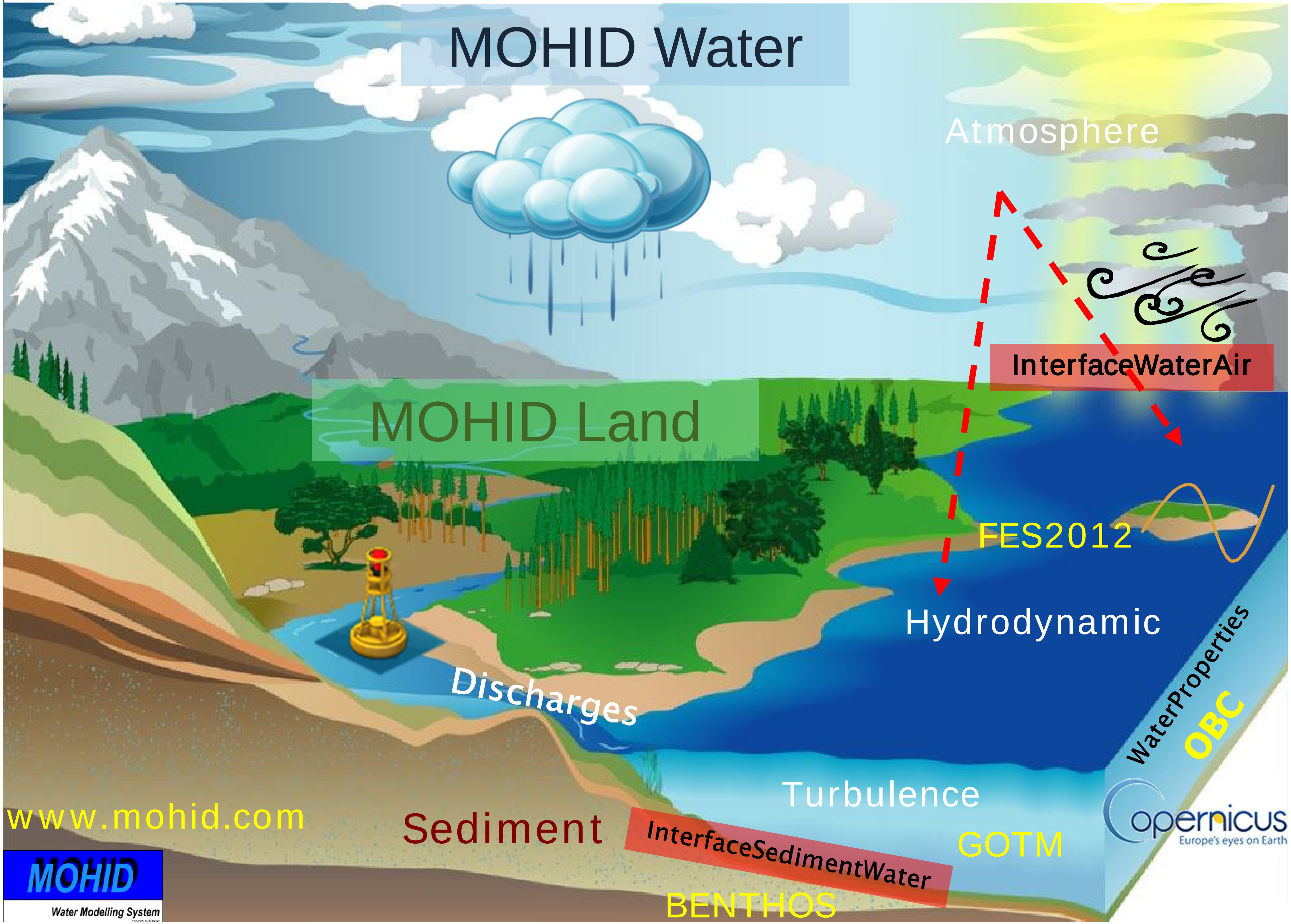
Joao.sobrinho@tecnico.ulisboa.pt
MARETEC, IST, Portugal

JONSMOD, 17-19 October, Florence, 2018

MOHID MODELLING SYSTEM

- Open source modular finite volumes.
- FORTRAN 95 using an object oriented programming philosophy.
- Core numerical models: MOHID Water and MOHID Land.

SINCE 1985 https://github.com/Mohid-Water-Modelling-System/Mohid



MOHID modelling system

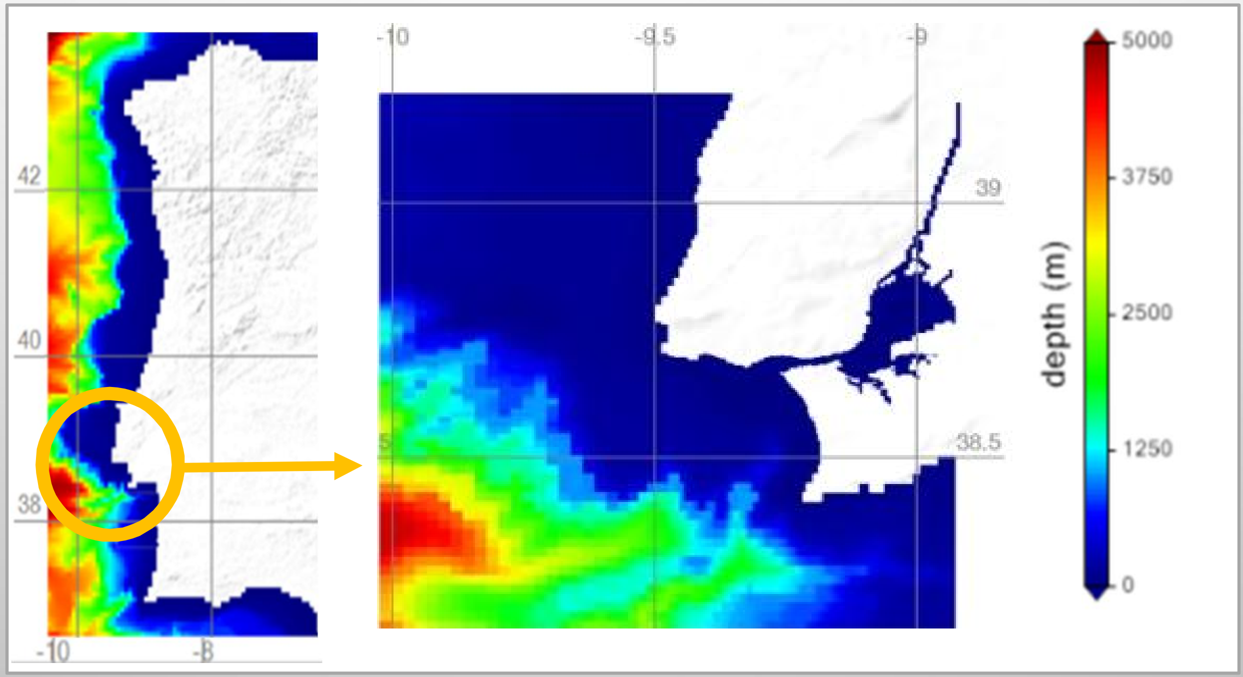
- NUMERICAL CHARACTERISTICS

Spatial discretisation	Finite volumes
Horizontal Grid	Orthogonal
Vertical Grid	Generic coordinates (sigma, cartesian, lagrangian)
Computation points distribution	Arakawa C
Time discretisation	ADI – 2D mass balance; explicit – horizontal momentum; implicit – vertical momentum

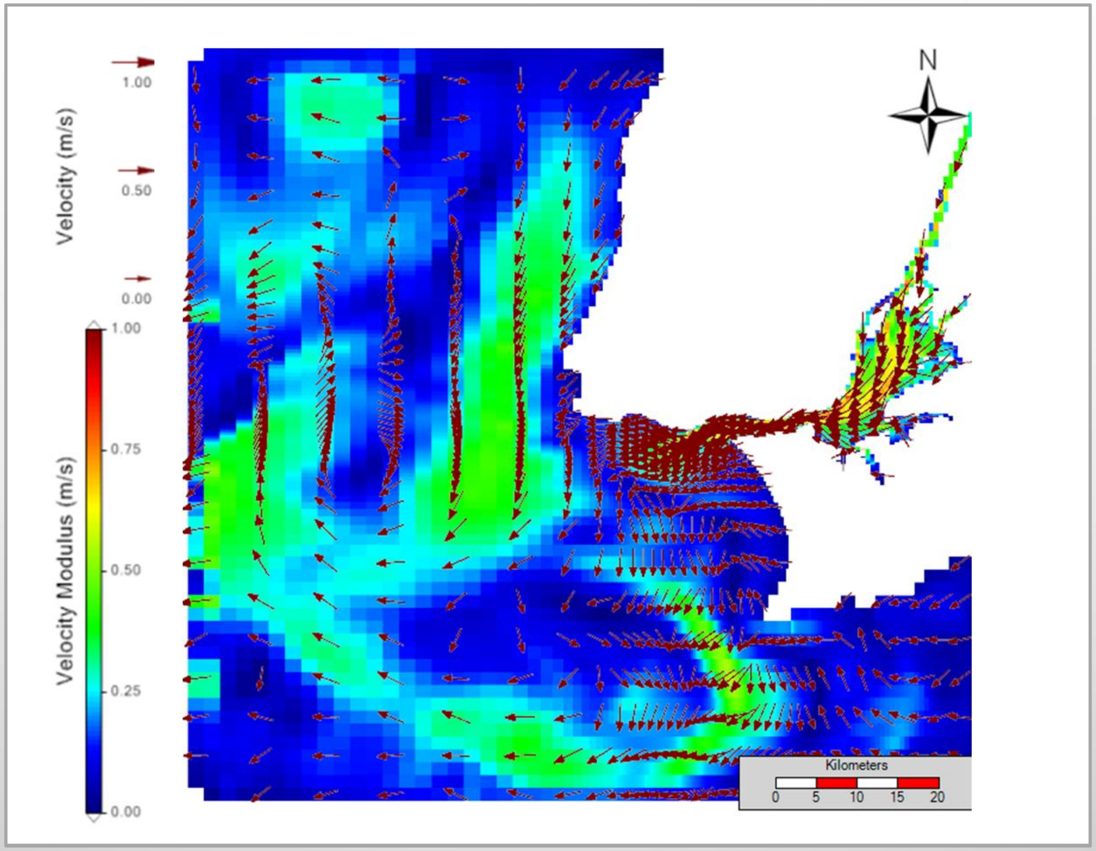
- APPROXIMATIONS
  - Boussinesq
  - Hydrostatic flow

FROM REGIONAL TO LOCAL

- When the objective is to study coastal areas with more detail, a downscalling methodology is applied, where a child domain gets its open boundary condition from its parent domain.



FROM REGIONAL TO LOCAL



- Child solution similar to parent solution near the boundary of the two domains.
- Flux relaxation scheme, and in some cases a sponge barrier may be necessary to eliminate reflections.

ONE-WAY OPTIONS

- This means, for the case of an estuarine discharge, two options could be considered:

  1. Implementing the fresh water discharge from the estuary in both domains – less accurate, and most likely incorrect in regards to biogeochemical processes.

  2. Having a bigger local domain than the study area to avoid strong divergence near its open boundary condition with the parent (regional) domain.

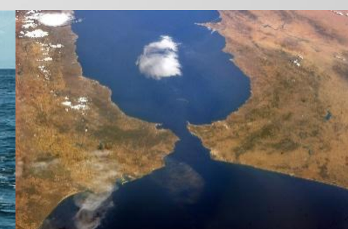
EMERGING PROBLEMS

- Improving computational power promotes higher resolution regional domains, but still cannot accomodate the estuaries.
  - Nested domains for estuaries, islands, etc are still needed.

- Demand for higher resolution will increase computational time for local domains (which will still need to be larger than the focus area).

- More frequent studies on ocean renewable energies and aquaculture, etc, which affect local hydrodynamics and biogeochemical parameters should also be included in intermediate regional domains without too much diffusion.





TWO-WAY NESTING SYSTEM

- With a Two-Way coupling system, one can improve the parent domain solution by:
  - Reducing diffusion;
  - Circulation correction due to local bathymetric features;
  - Adition of fresh water plumes with higher precision, in applications with a transition from open ocean to an estuary.

- And the child domain by:
  - Providing a smoother transition in the open boundary condition, as a result of a more accurate parent solution.

TWO-WAY NESTING SYSTEM
IMPLICATIONS

- It is critical that the child domain is well computed, as inconsistencies will be absorbed by the parent solution;

- Increased computation size when compared to a traditional one-way system, compensated in part by the possibility of having smaller child domains;

CONCEPT

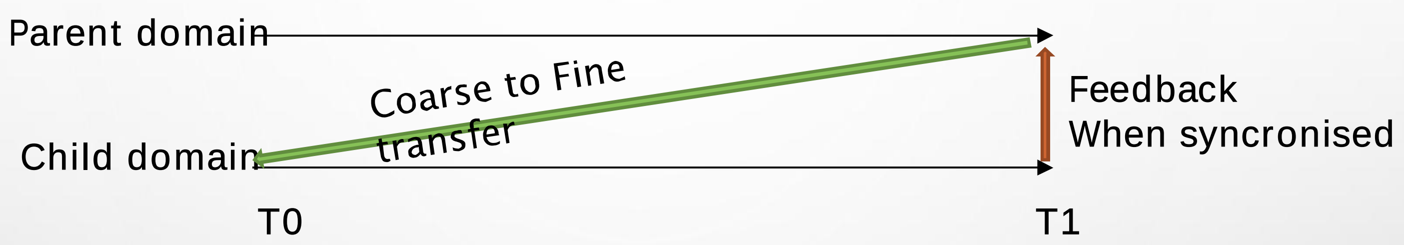
- Nudging of the parent domain (coarser grid) towards the child domain (finer grid) using:

$$P = P^{Cg} + (P^{Fg} - P^{Cg}).\frac{\Delta t}{T_d}$$

- *Cg* coarser grid
- *Fg* finer grid
- T_d decay time in seconds

- This nudging is made for all the main hydrodynamic variables:
  - Velocities
  - Temperature
  - Salinity
- Any other property the user wants to feedback into the coarser domain

ALGORITHM



- **METHODS INCLUDED**:
  - Volume weithed average with a radious of search dependent on the coarser grid space in order to account for variable grids.
  - Inverse weithed distance method also with the possibility of using a search radious.

ALGORITHM

- The final velocity equation computed by the parent domain now becomes:

$$\underbrace{\frac{\partial u_i}{\partial t}+\frac{\partial (u_i u_j)}{\partial x_j}}_{\text{Advection}}=\underbrace{-\frac{1}{\rho_{\sup}}\frac{\partial p_{atm}}{\partial x_i}}_{\text{Atm P}}\underbrace{-g\frac{\partial \eta}{\partial x_i}}_{\text{Barotropic}}\underbrace{-\frac{g}{\rho_{face}}\int_{x_3}^{\eta}\frac{\partial \rho'}{\partial x_i}dx_3}_{\text{Baroclinic}}+\underbrace{\frac{\partial}{\partial x_j}\left(\nu\frac{\partial u_i}{\partial x_j}\right)}_{\text{Difusion}}\underbrace{-2\varepsilon_{ijk}\Omega_j u_k}_{\text{Coriolis}} \longrightarrow u_i^*$$

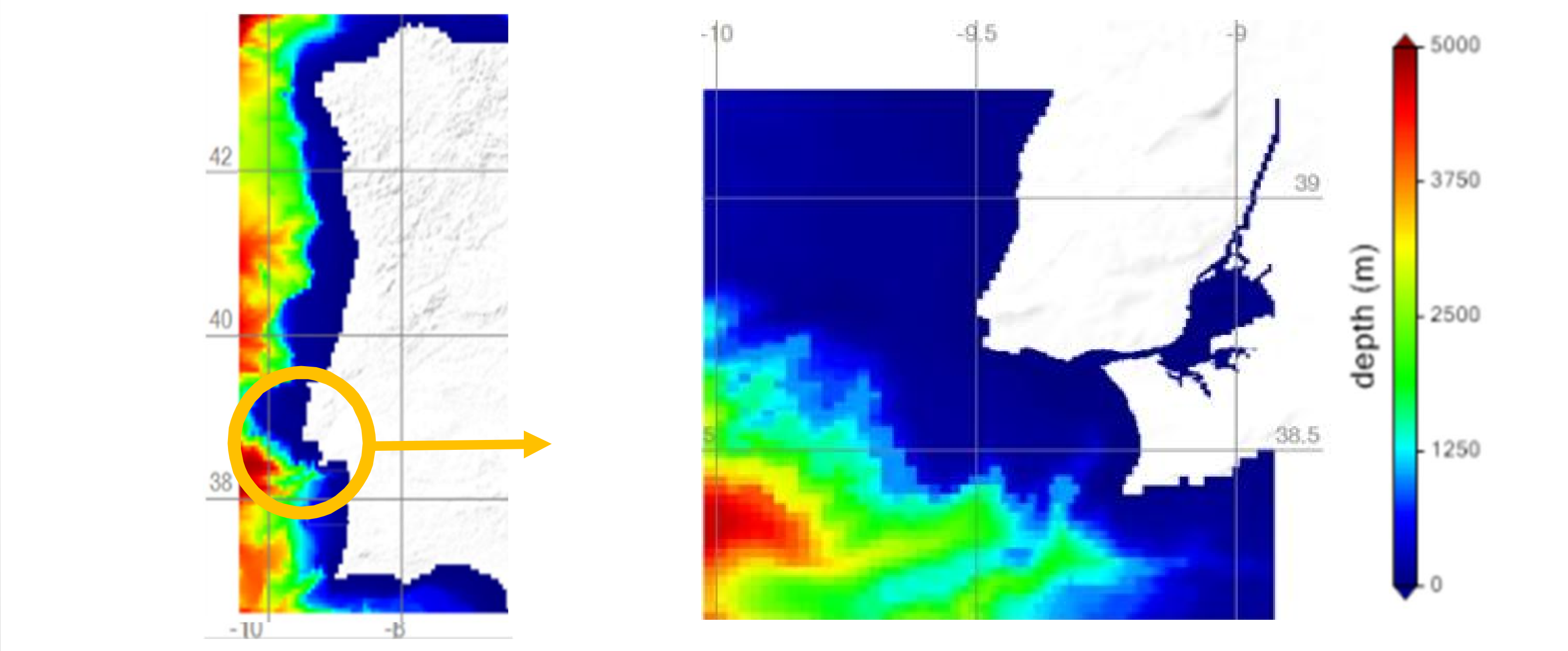
$$u_i = u_i^* + \frac{\left(u_i^{Child} - u_i^*\right) * \Delta t}{T_d}$$

- This way, all forces are correctly nudged to the parent domain as they were previously computed by the child domain considering its own forces in play.

- Water level is not nudged.

VALIDATION

PORTUGUESE COAST (PCOMS) – TAGUS SOLUTION



- 50 vertical layer (7 sigma)
- Horizontal resolution (5.7km)

Atmospheric forcing MM5

OBC WI tide Model & MyOcean

- 50 vertical layer (7 sigma)
- Horizontal resolution (300m – 2km)
- River flow (15´)

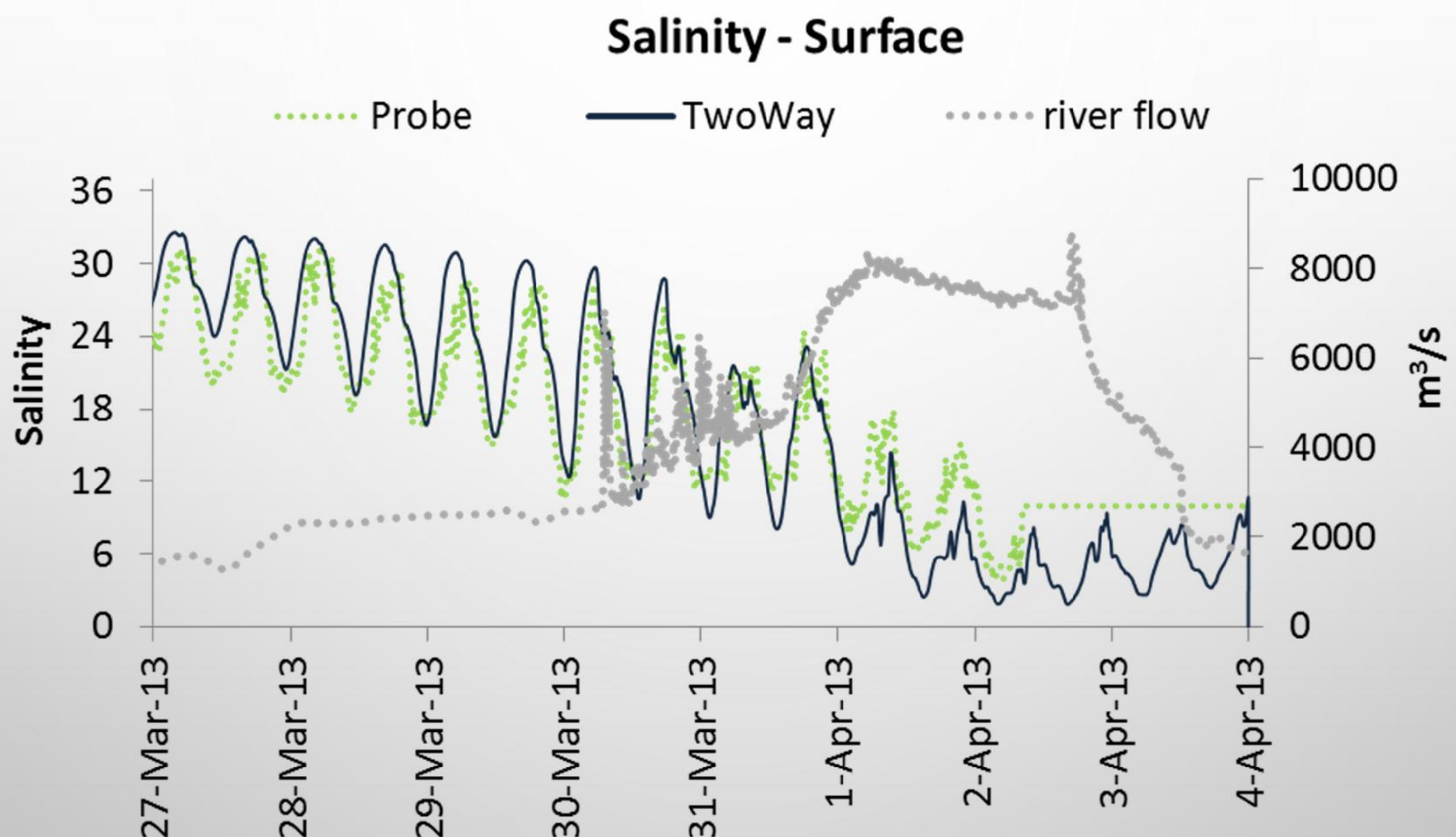
Atmospheric forcing MM5

OBC from PCOMS (15')

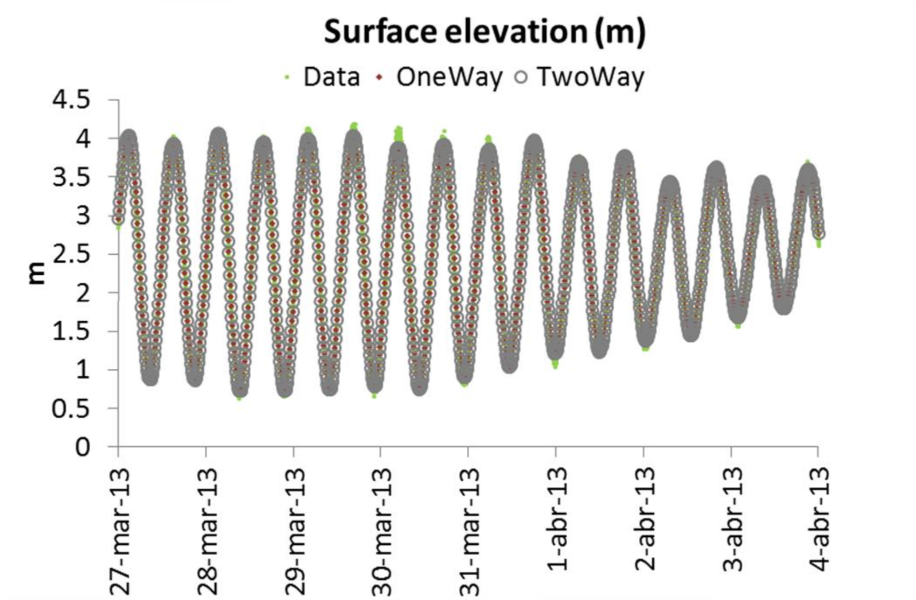
VALIDATION METHODOLOGY

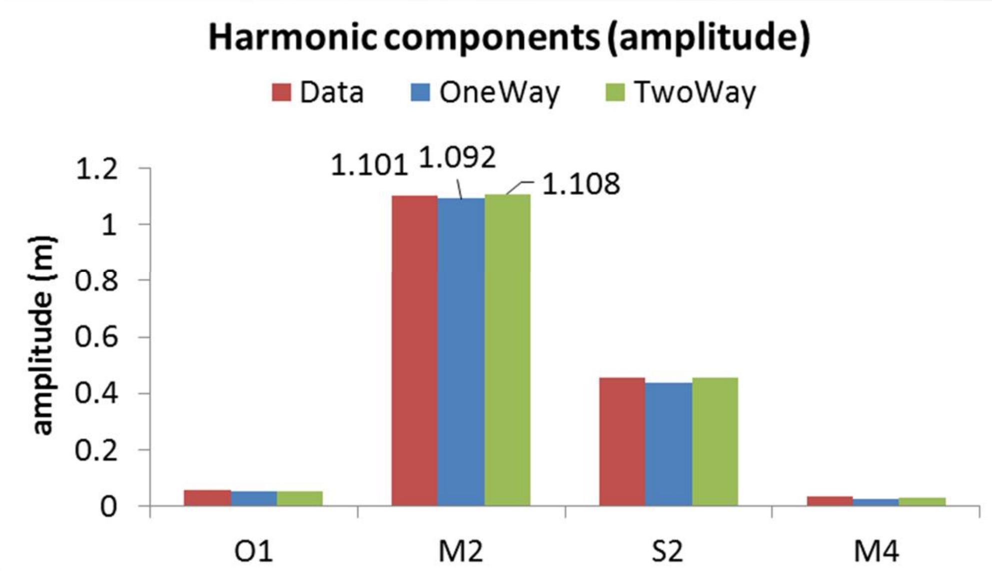
- A comparison was made considering three methodologies:
  - Tradicional One-Way (operational in MARETEC);
  - TwoWay solution.
- In the TwoWay scenario, the time decay for the feedback was 120s (2 x Parent DT).
- Temperature and salinity.
- Tide gauge at the mouth of the estuary was used to compute harmonics and validate surface elevation.

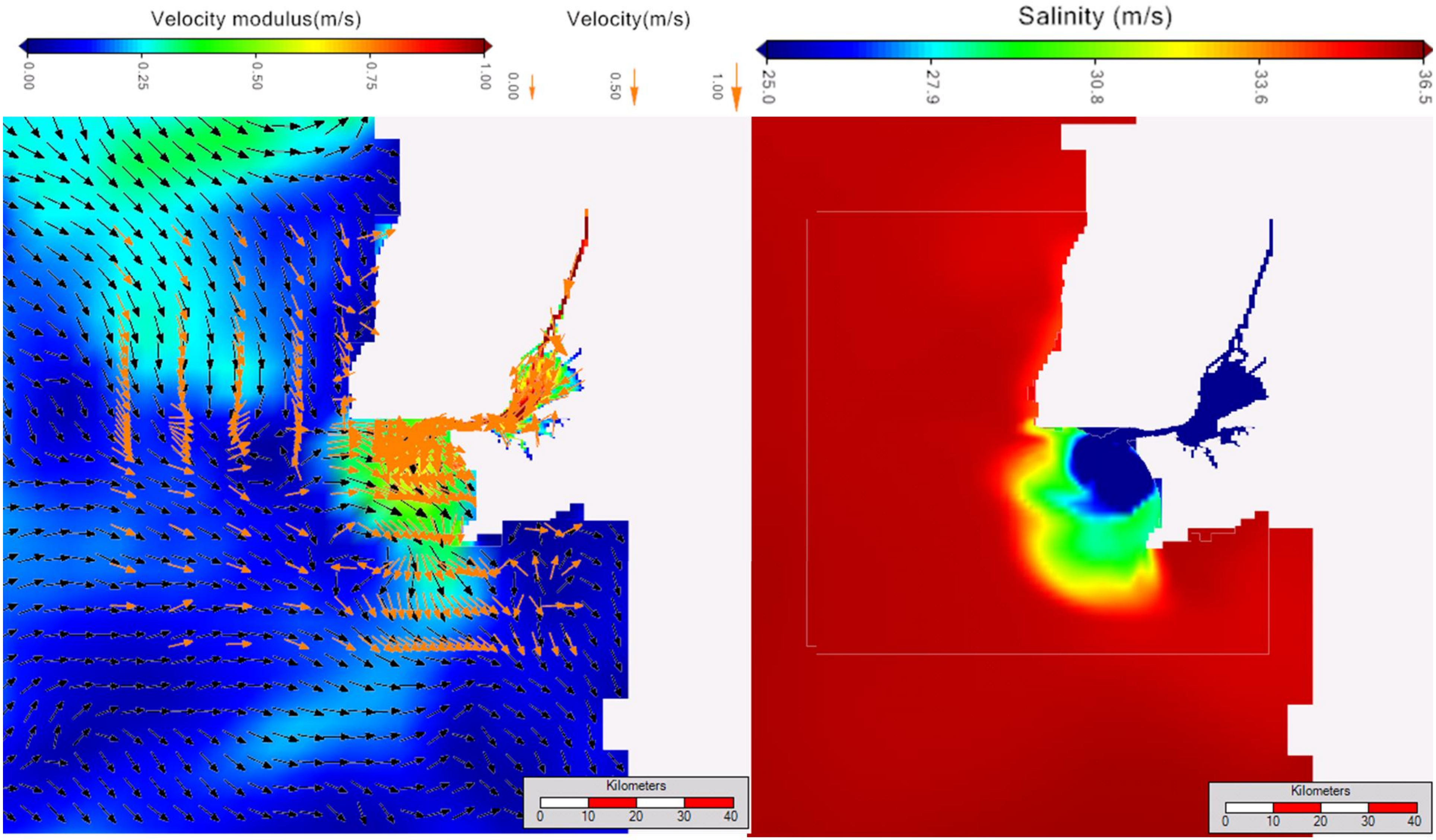
VALIDATION

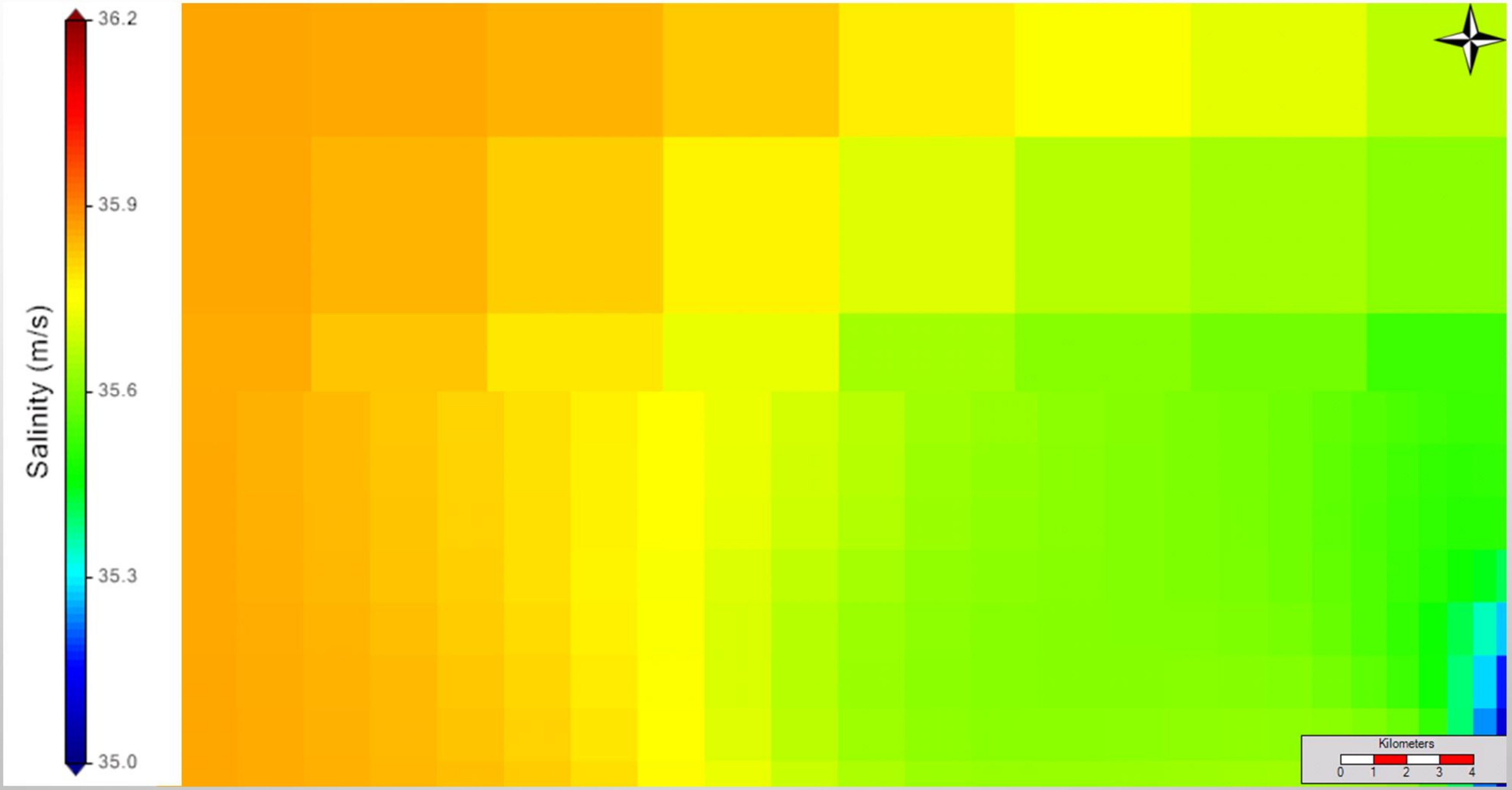

Salinity - Surface
Probe
TwoWay
river flow
Salinity
36
30
24
18
12
6
0
10000
8000
6000
4000
2000
0
m³/s
27-Mar-13
28-Mar-13
29-Mar-13
30-Mar-13
31-Mar-13
1-Apr-13
2-Apr-13
3-Apr-13
4-Apr-13

VALIDATION


Surface elevation (m)
Data
OneWay
TwoWay
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
m
27-mar-13
28-mar-13
29-mar-13
30-mar-13
31-mar-13
1-abr-13
2-abr-13
3-abr-13
4-abr-13


Harmonic components (amplitude)
Data
OneWay
TwoWay
1.2
1
0.8
0.6
0.4
0.2
0
amplitude (m)
1.101
1.092
1.108
O1
M2
S2
M4


Velocity modulus(m/s)
0.00
0.25
0.50
0.75
1.00
Velocity(m/s)
0.00
0.50
1.00
Kilometers
0
10
20
30
40
Salinity (m/s)
25.0
27.9
30.8
33.6
36.5
Kilometers
0
10
20
30
40


36.2
35.9
35.6
35.3
35.0
Salinity (m/s)
Kilometers
0 1 2 3 4

FUTURE WORK

- Validation of the algorithm on a real case for a longer period.

- Definition of the best option for relaxation:
  - Should the relaxation include the boundary cells between child and parent domains as well as the entire domain? Or should it be only in the interior?

- Improvement of coupling in interface between ocean and estuaries (momemtum discharges).
- Connection to MOHIDLand.