The hydro-sedimentary impacts of offshore wind turbines monopile foundations: regional numerical modelling

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Plan

1) Context

2) Method

3) Application

- Test-cases
- Real case : Courseulles-sur-Mer

4) Conclusions

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- **Test-cases**
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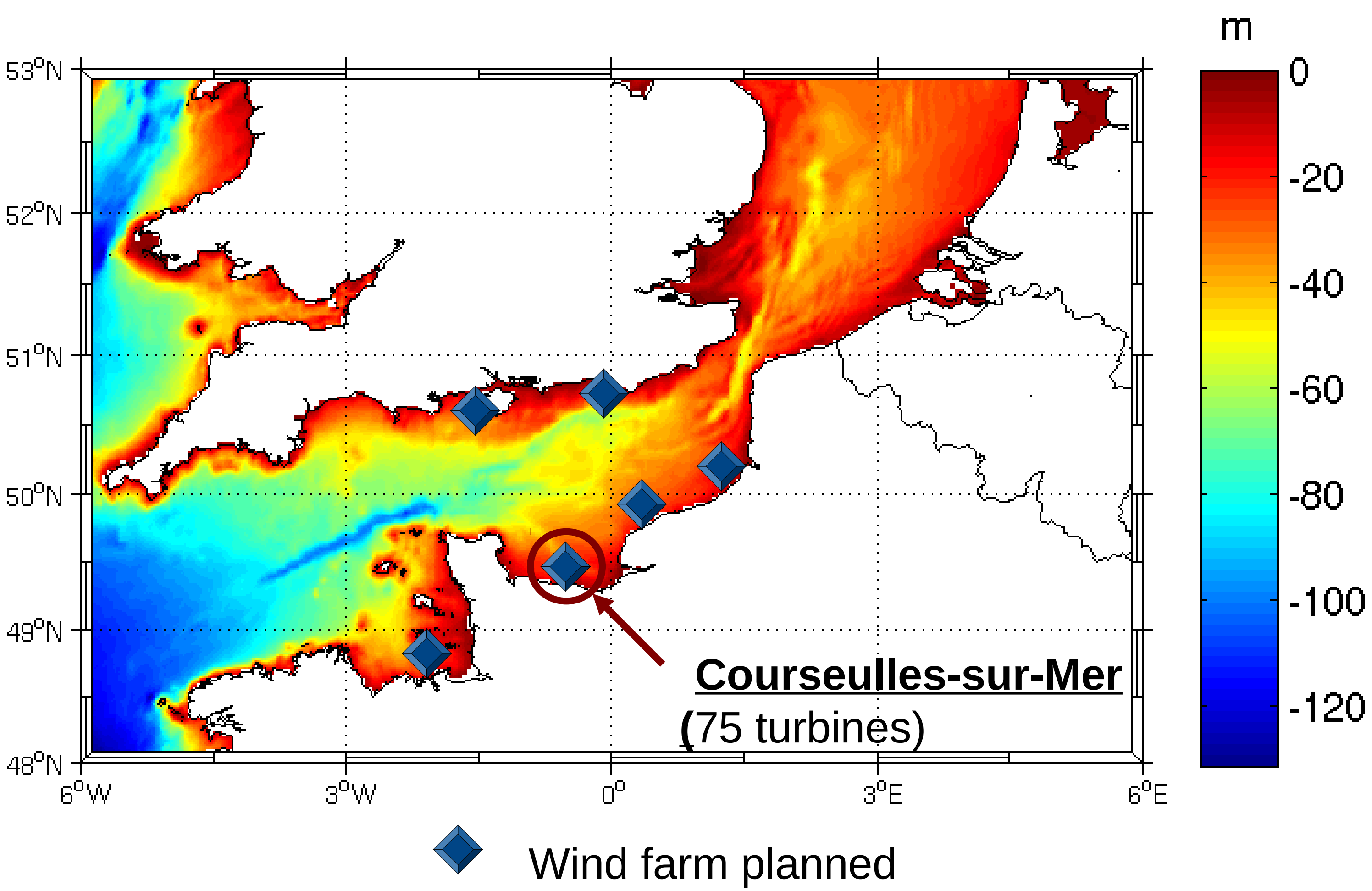
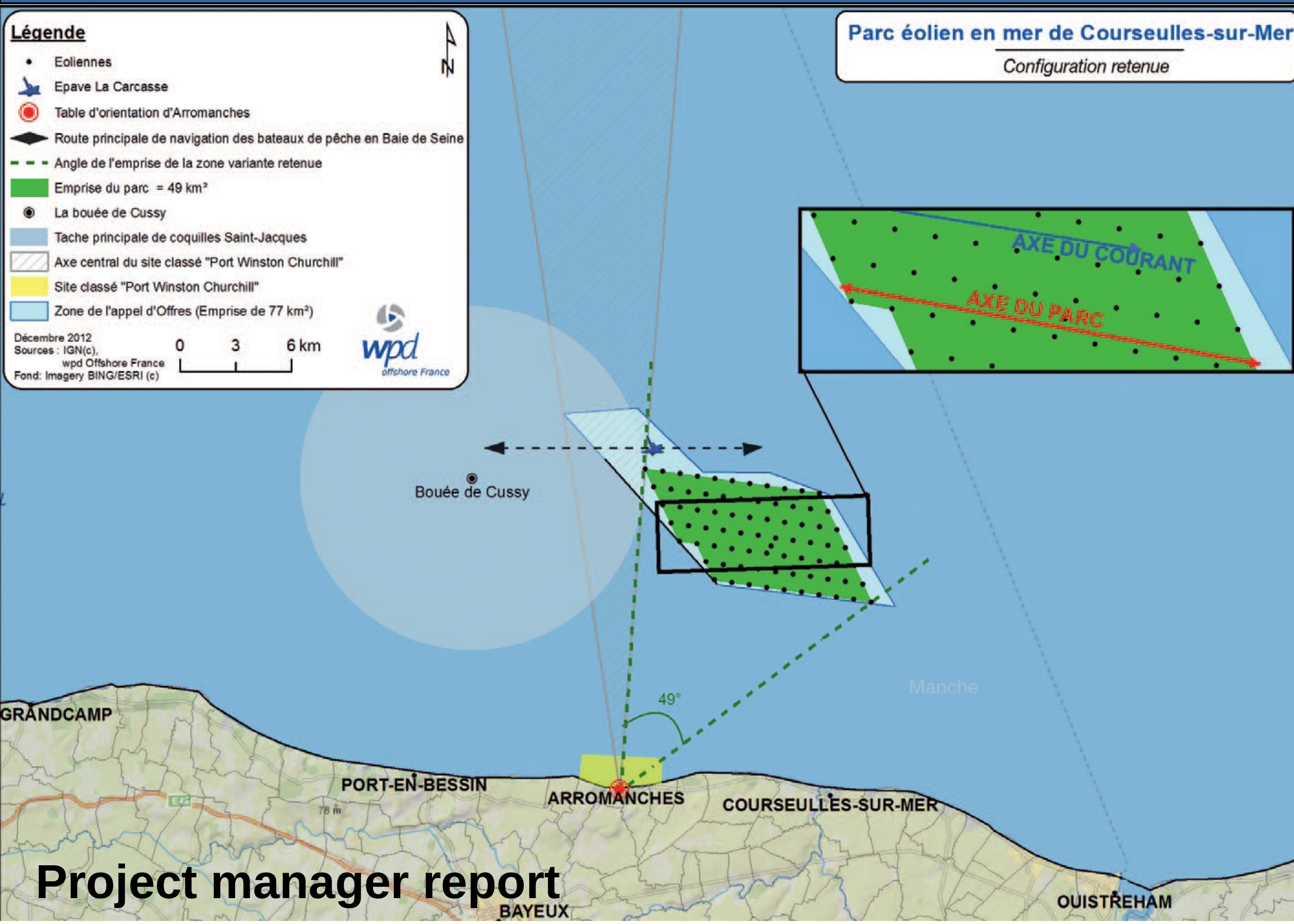
Several wind farms planned in the English Channel



Context: Courseulles-sur-Mer



Project manager report

- This wind farm will be located 10 km offshore

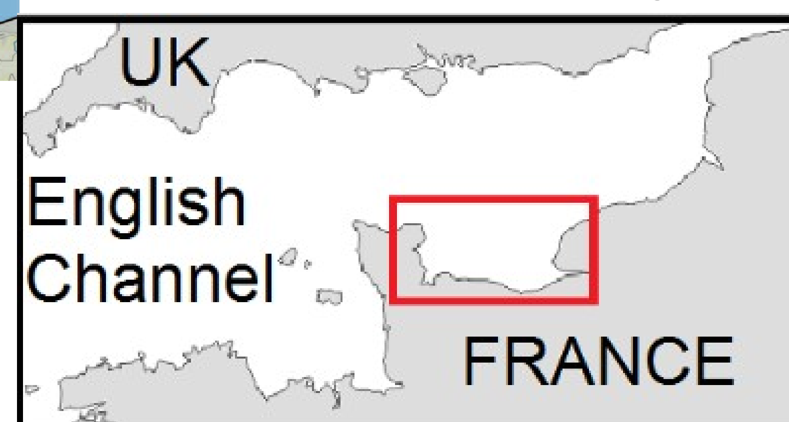
- 7 rows of wind turbines, one turbine every 950 m.

- Rows distant from 900 m, oriented in current direction.

- Diameter of the monopiles : 6m

- Bathymetry: 20-30m

- Seabed : mix of sand and gravel

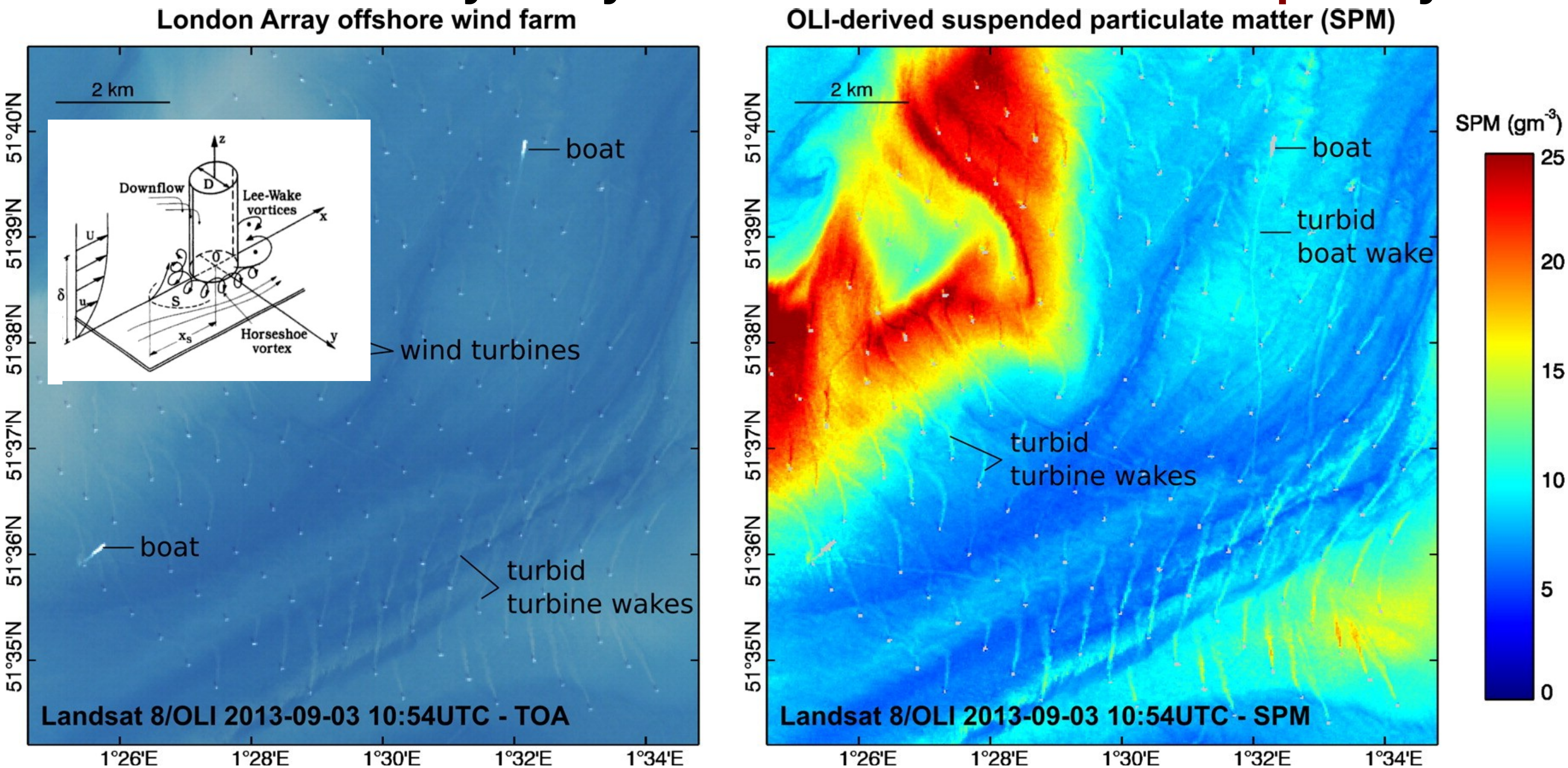


Tidal current (vertically averaged)
Spring tide (95) : 1m/s
Neap tide (45) : 0,4m/s

Waves :
Bottom orbital velocity : Maximum in 2013 = 0,16 m/s
Mean = 0,045 m/s

Context

Modification of hydrodynamics and sediment transport by monopile



Turbid turbine wakes observed by remote-sensing at London Array (Vanhellemont et al., 2014)

Aims of the study:

- Estimate monopile effect on hydrodynamics and sediment transport using regional model
- Find a parametrization which is able to reproduce properly these modifications

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Method

Numerical model **MARS** (Model for Applications at Regional Scales)
Developed by IFREMER

Hydrodynamical module 3D (Lazure & Dumas, 2008)

- Primitive equations solver

Sediment transport module (Le Hir et al., 2011)

- Advection-diffusion equations solver

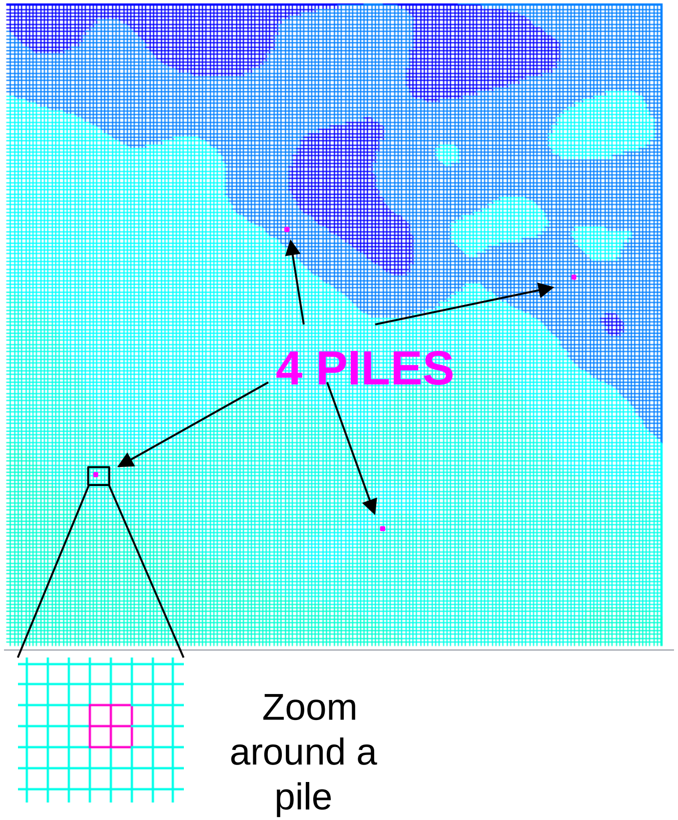
Method

Strategies to model wind turbines

2 approaches

Take into account monopiles in the mesh

- Monopiles are represented as dry points



Zoom around a pile

Use of a sub-grid parametrization method

- Adding drag force term in **momentum equations**

$$Fu_d(z) = -0{,}5 \frac{\rho_0 C_d(z) D}{\Delta x \Delta y} \|\boldsymbol{U}_\infty(\boldsymbol{z})\| U_\infty(z)$$

$$Fv_d(z) = -0{,}5 \frac{\rho_0 C_d(z) D}{\Delta x \Delta y} \|\boldsymbol{U}_\infty(\boldsymbol{z})\| V_\infty(z)$$

Cd(z) : Drag coefficient, could vary vertically
D : Diameter of the pile
U_∞(z)=(U_∞(z),V_∞(z)) : undisturbed current velocity upstream the pile (taken 90 m upstream)

- Adding source terms of turbulence in **k-ε turbulence model equations.**

$$P_k = F_d \|\overrightarrow{U}(z)\|$$
$$P_\varepsilon = c_{2\varepsilon} \frac{\varepsilon}{k} P_k$$

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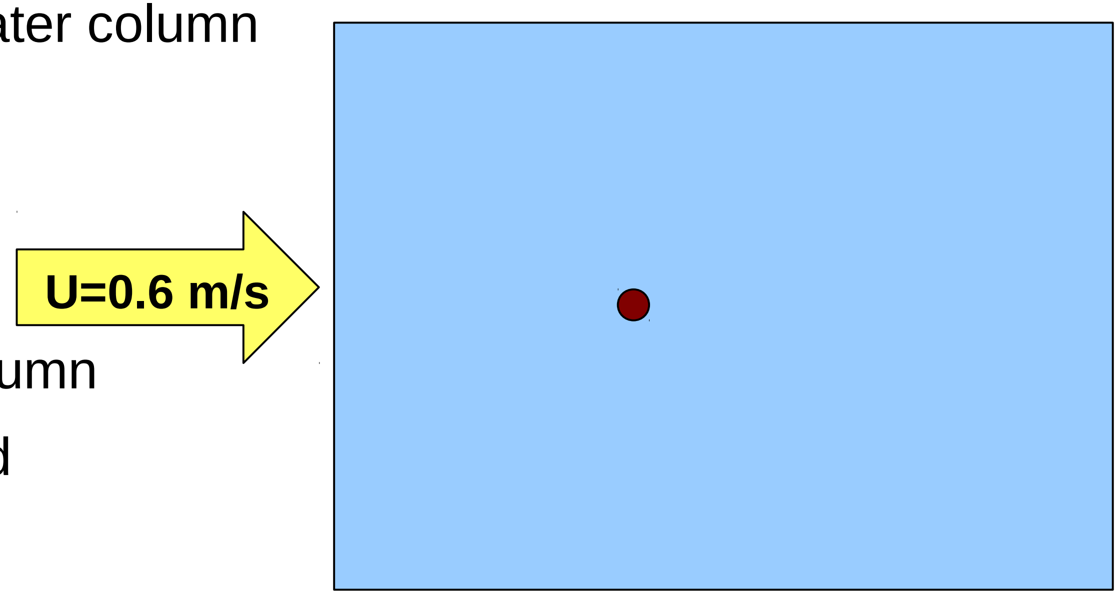
Application

First test

- Fixed current of 0.6 m/s
- Horizontal resolution of 3 m
- 15 uniforms levels in the water column
- Water depth : 30 m
- Diameter of the pile : 6 m
- Drag coefficient
  - Cd=0.65 in the water column
  - Cd=3.25 close to the bed
- Sediment :
  - Diameter : 250 µm
  - Initial thickness : 1 m



Application: Hydrodynamics

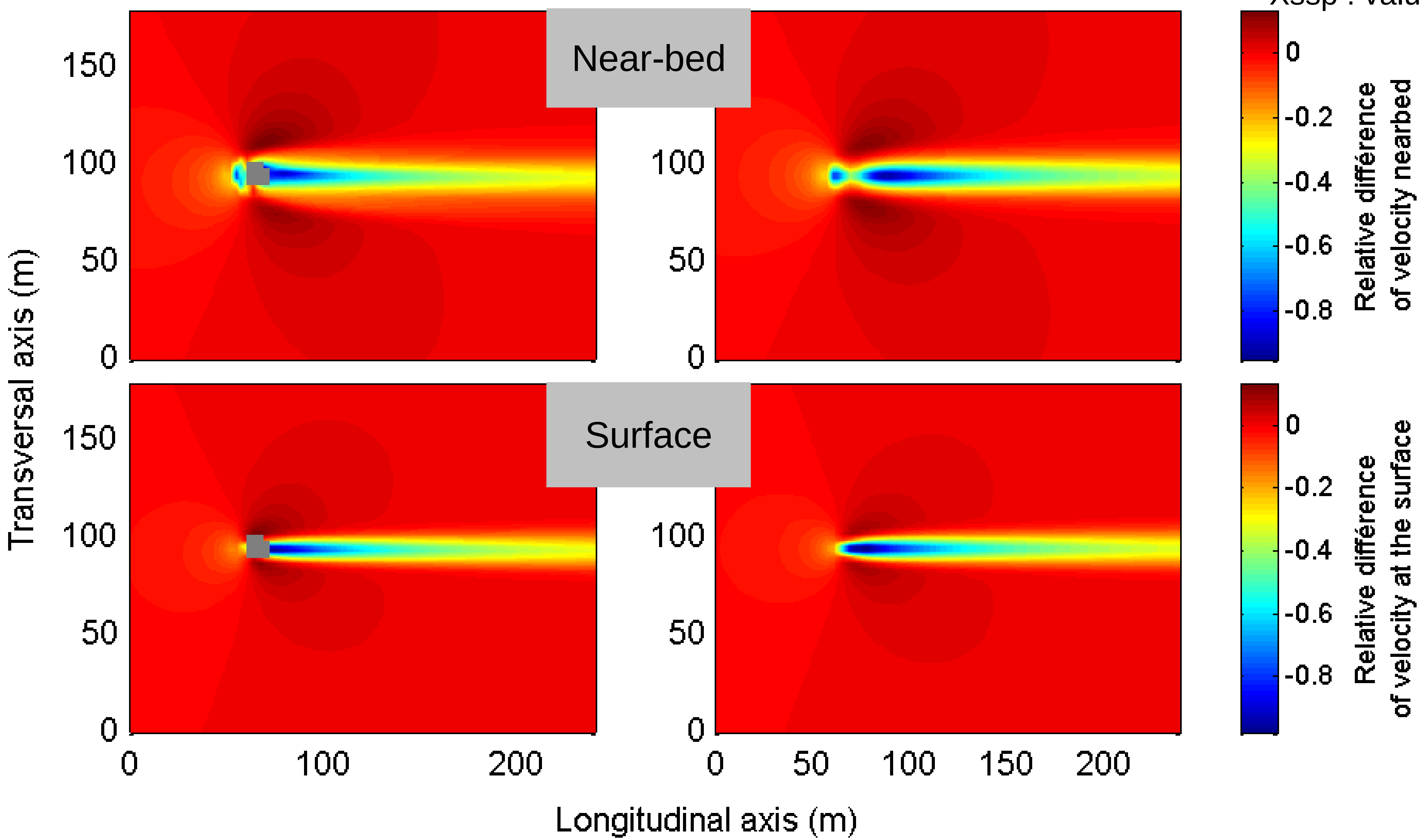
Relative difference of current velocity (m/s)

Relative difference : $\frac{X_p - X_{ssp}}{X_{ssp}}$

Xp : value with pile

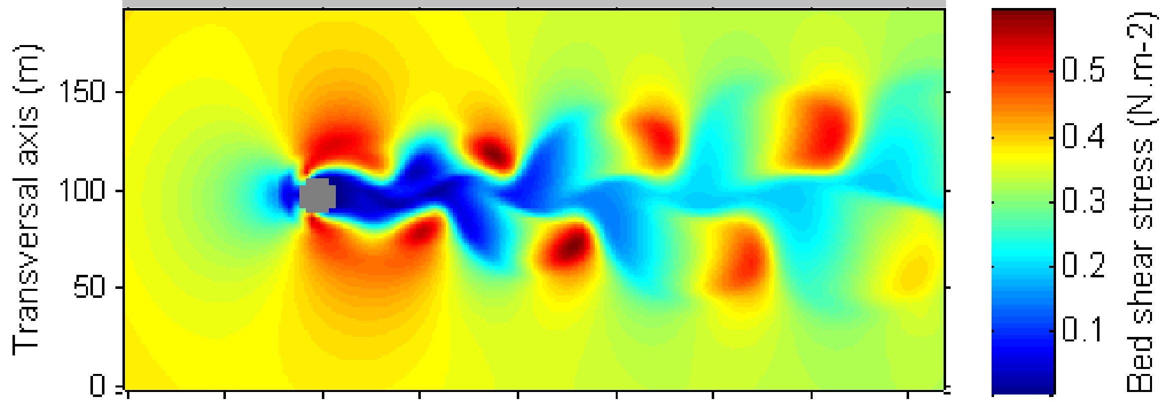
Xssp : value without pile

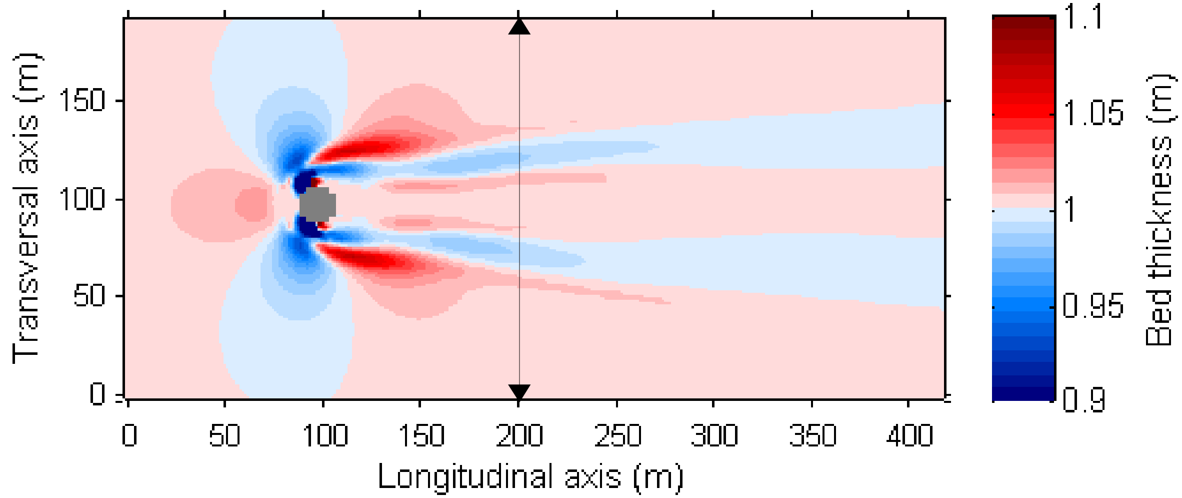
First test



Second test:
Diameter of the monopile : 15 m
Magnitude of fixed current : 0.5 m/s
Water colum divided by 25 uniform levels
Diameter of sand : **250 µm, initially only in the bed** (Bed thickness: 1 m)

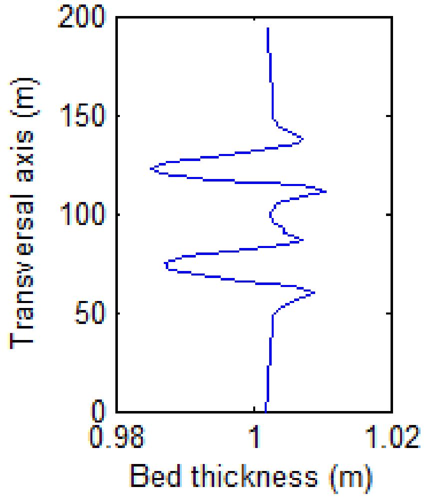
Simulation using dry points methods



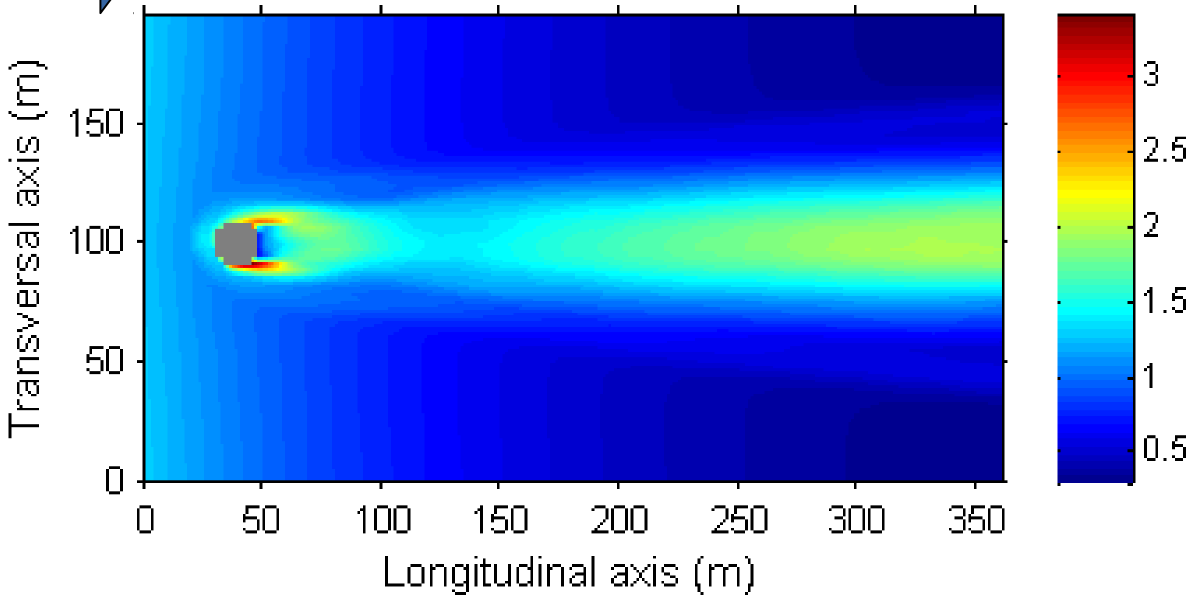


After 12 hours of simulation

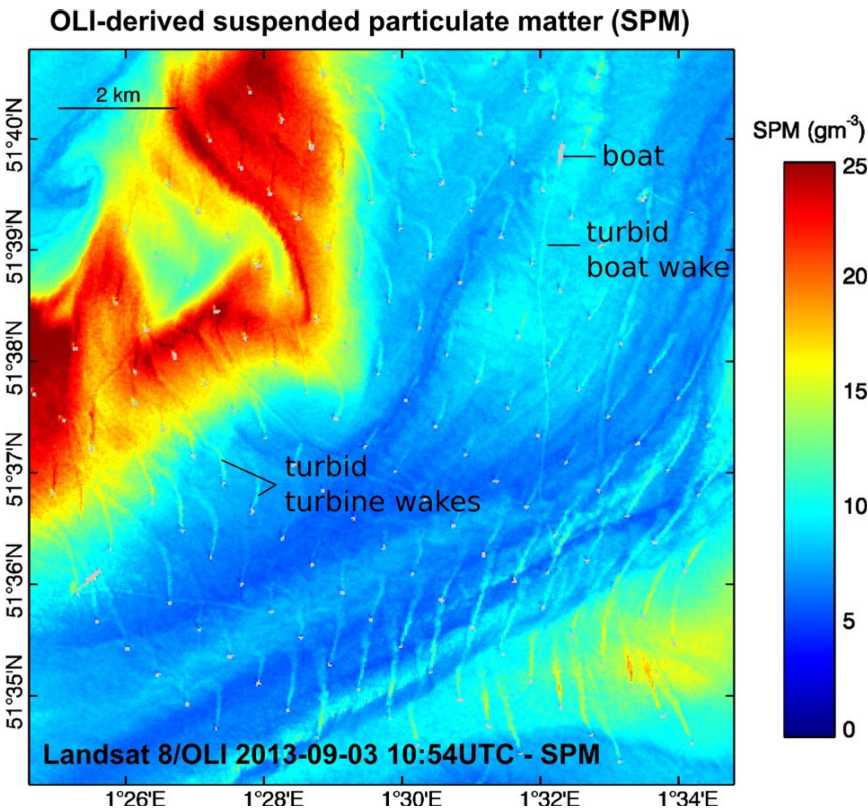
Experiment in Caen University



Third test: Very fine sand



Suspended sediment concentration at the surface (mg/l)



(Vanhellemont et al., 2014)

Diameter of the monopile : 15 m
Magnitude of fixed current : 0.5 m/s
Water colum divided by 25 uniform levels
Diameter of sand : **65 µm, initially only in the water column and forced at boundaries (5 mg/l)**

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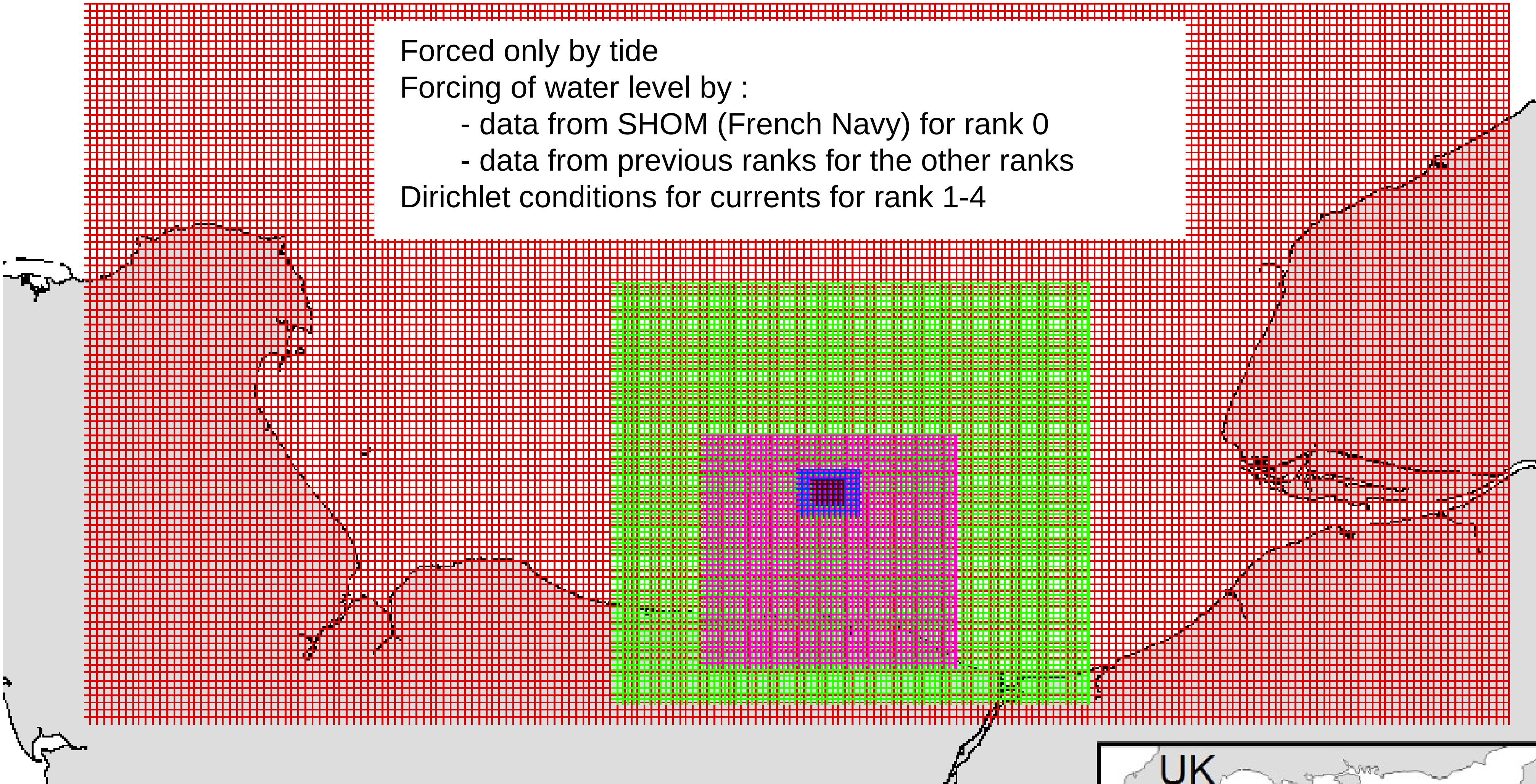
Application: Courseulles-sur-Mer

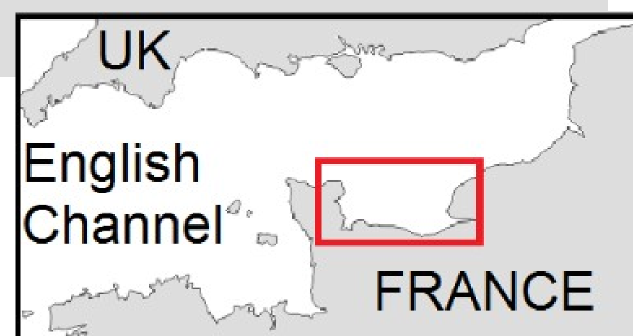
Forced only by tide
Forcing of water level by :
- data from SHOM (French Navy) for rank 0
- data from previous ranks for the other ranks

Dirichlet conditions for currents for rank 1-4



- Diameter of sediment : 250 µm
- Bed thickness : 1m

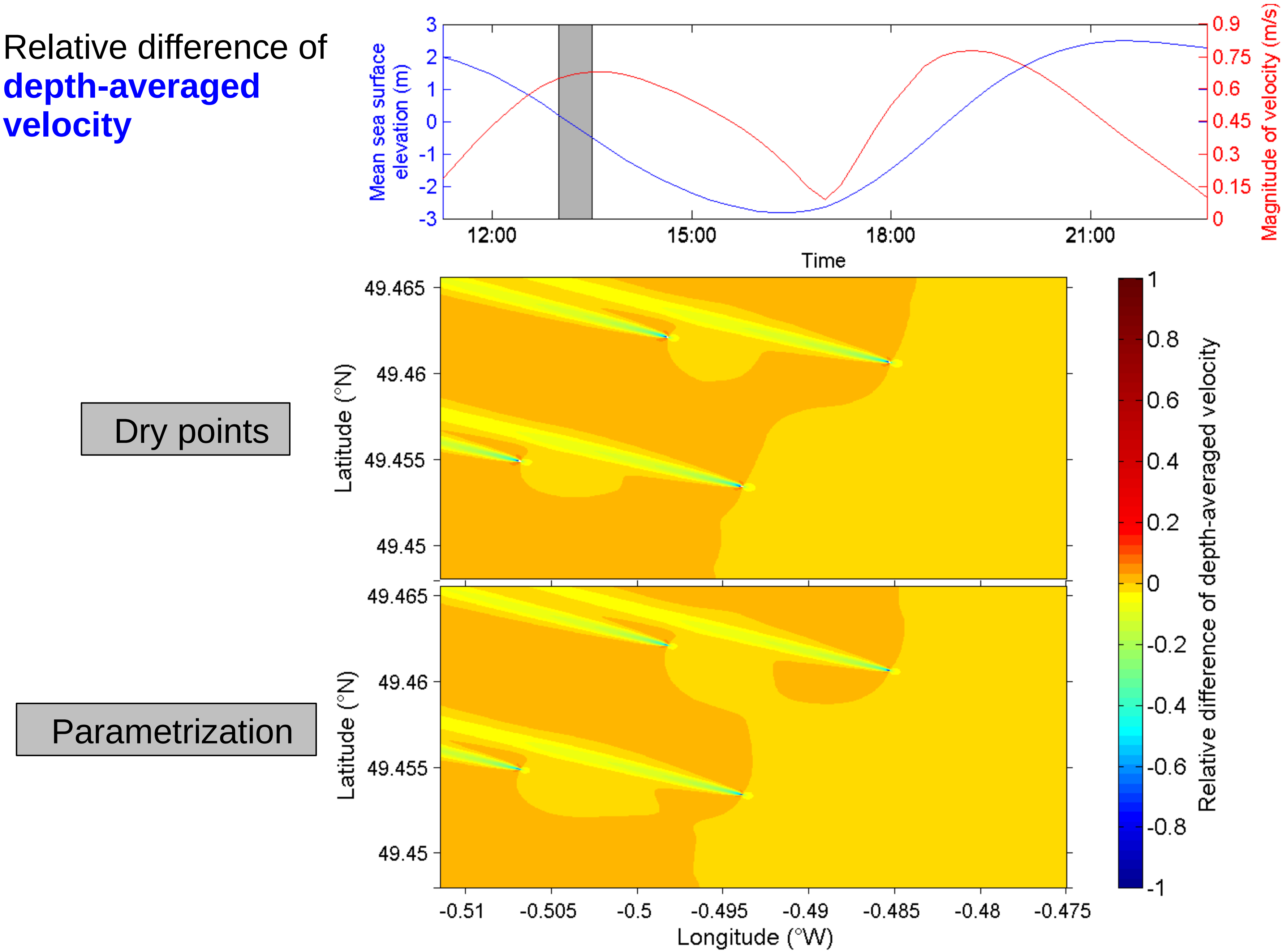
Rank 0 (Δx=243m)
Rank 1 (Δx=81m)
Rank 2 (Δx=27m)
Rank 3 (Δx=9m)
Rank 4 (Δx=3m)



Application the 11/11/2011 :

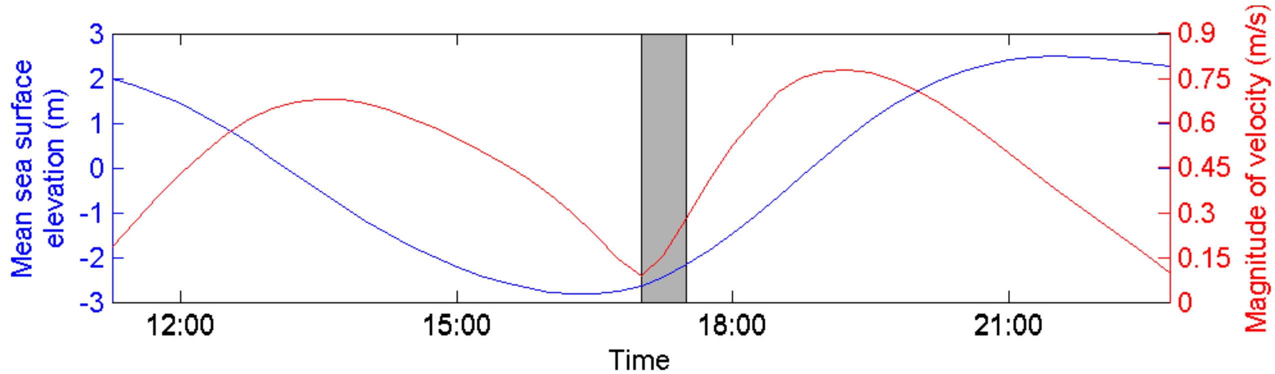
- medium tide (tidal coefficient of 79)
- weak waves

Relative difference of **depth-averaged velocity**



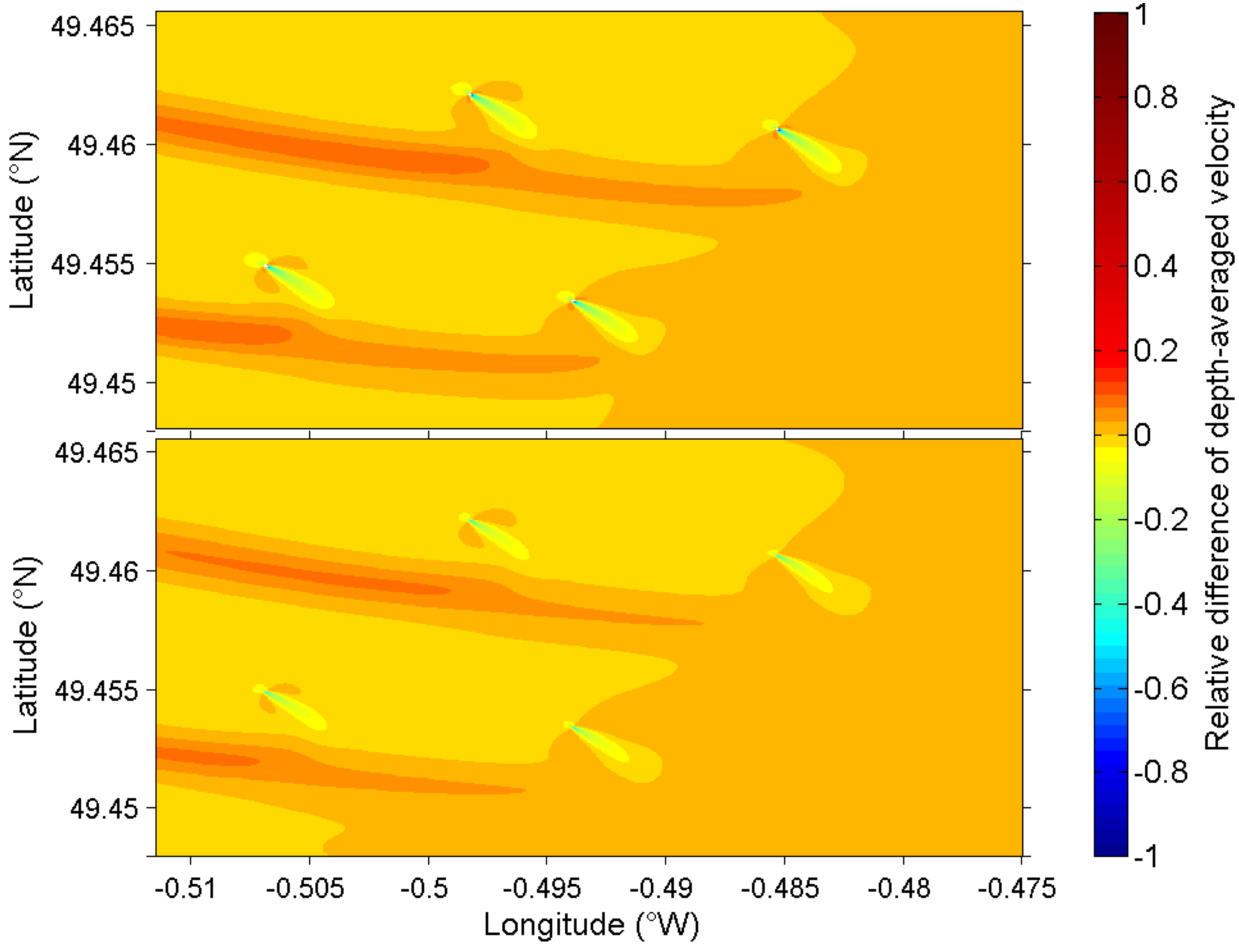
Application: Courseulles-sur-Mer

Relative difference of **depth-averaged velocity**



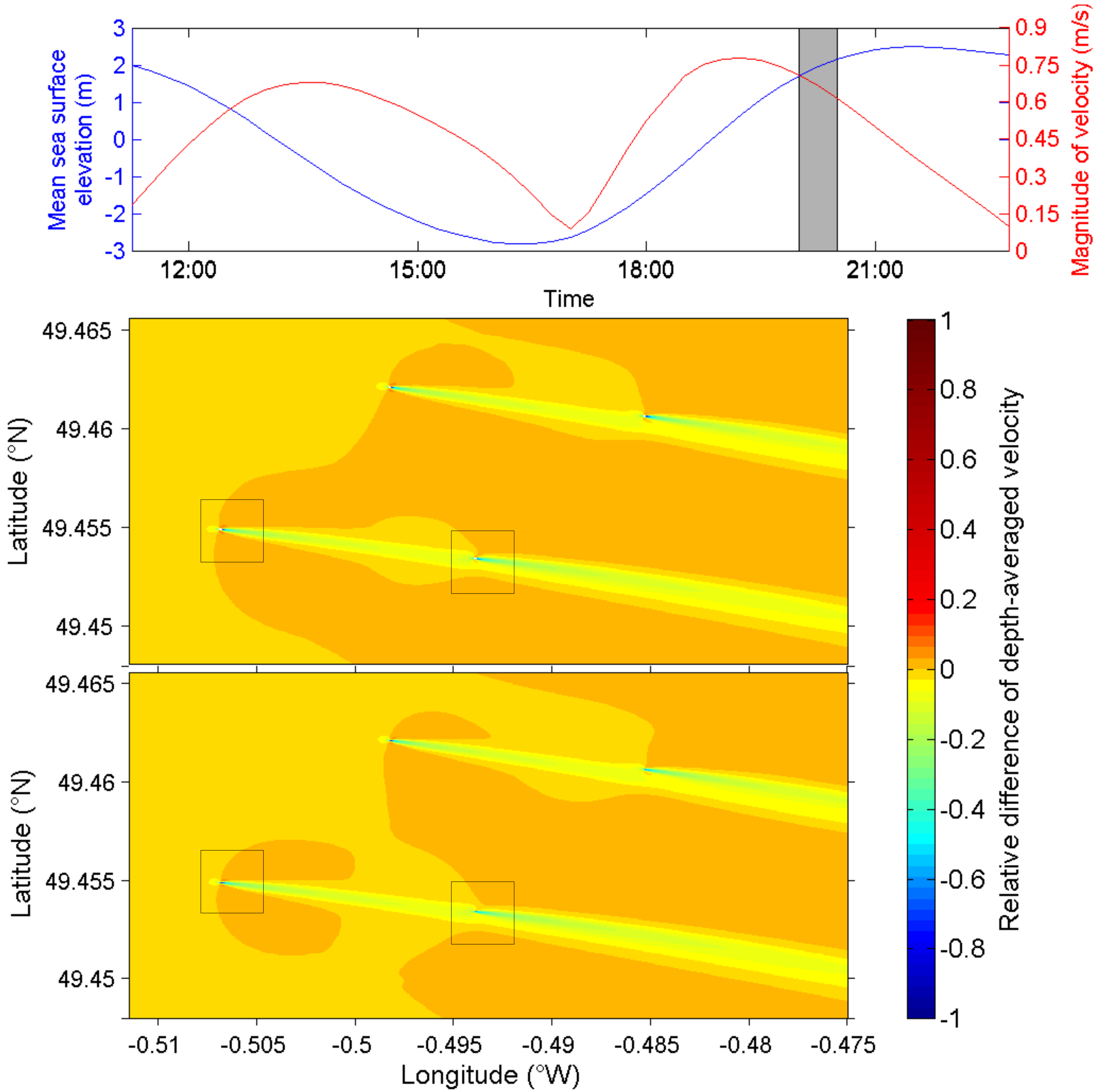
Dry points

Parametrization



Application: Courseulles-sur-Mer

Relative difference of **depth-averaged velocity**

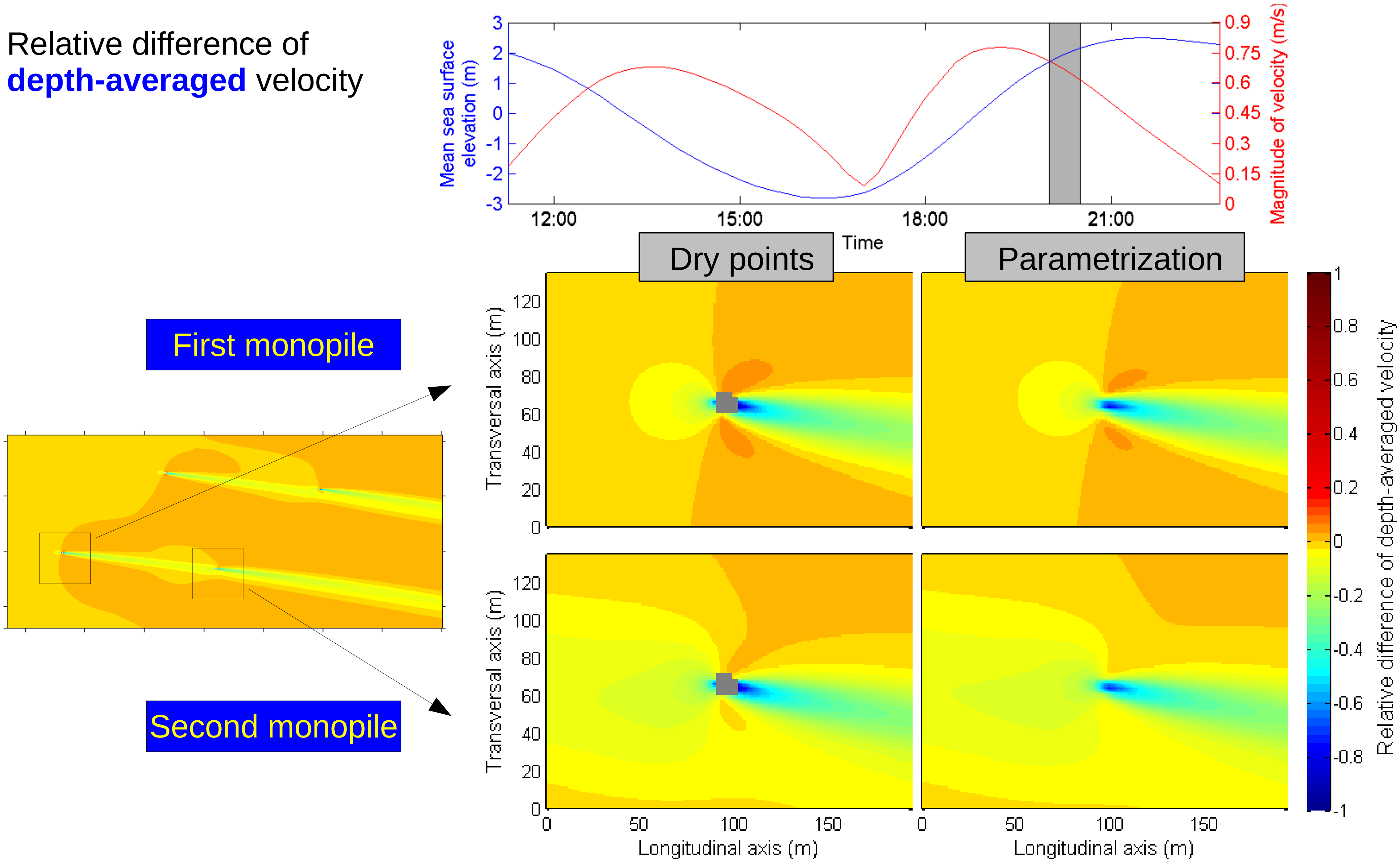


Dry points

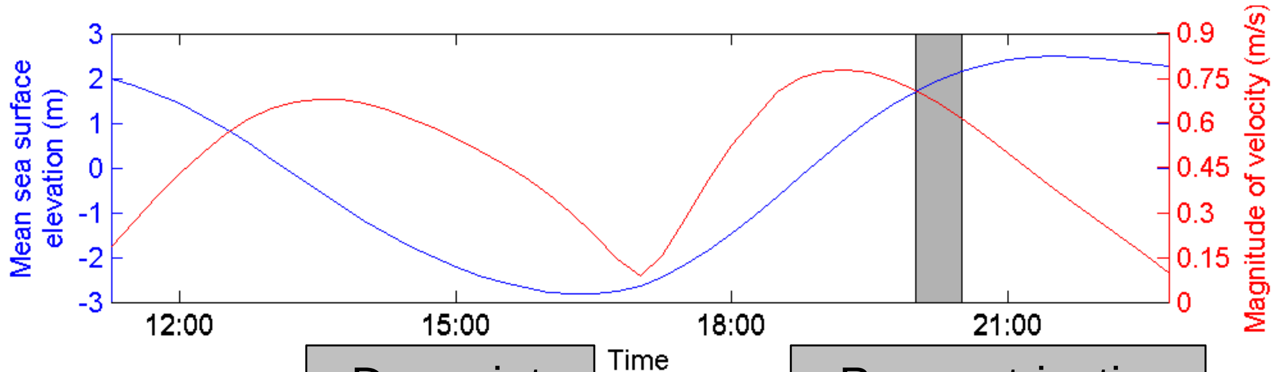
Parametrization

Application: Courseulles-sur-Mer

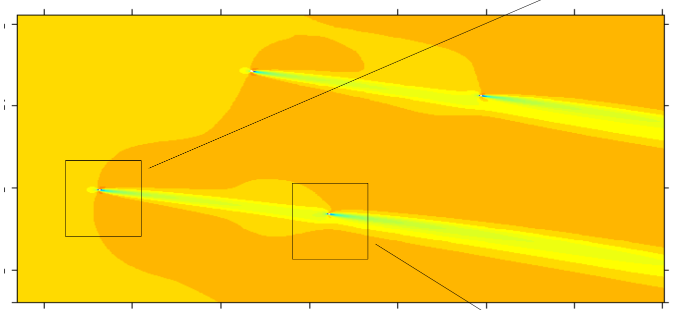
Relative difference of **depth-averaged** velocity



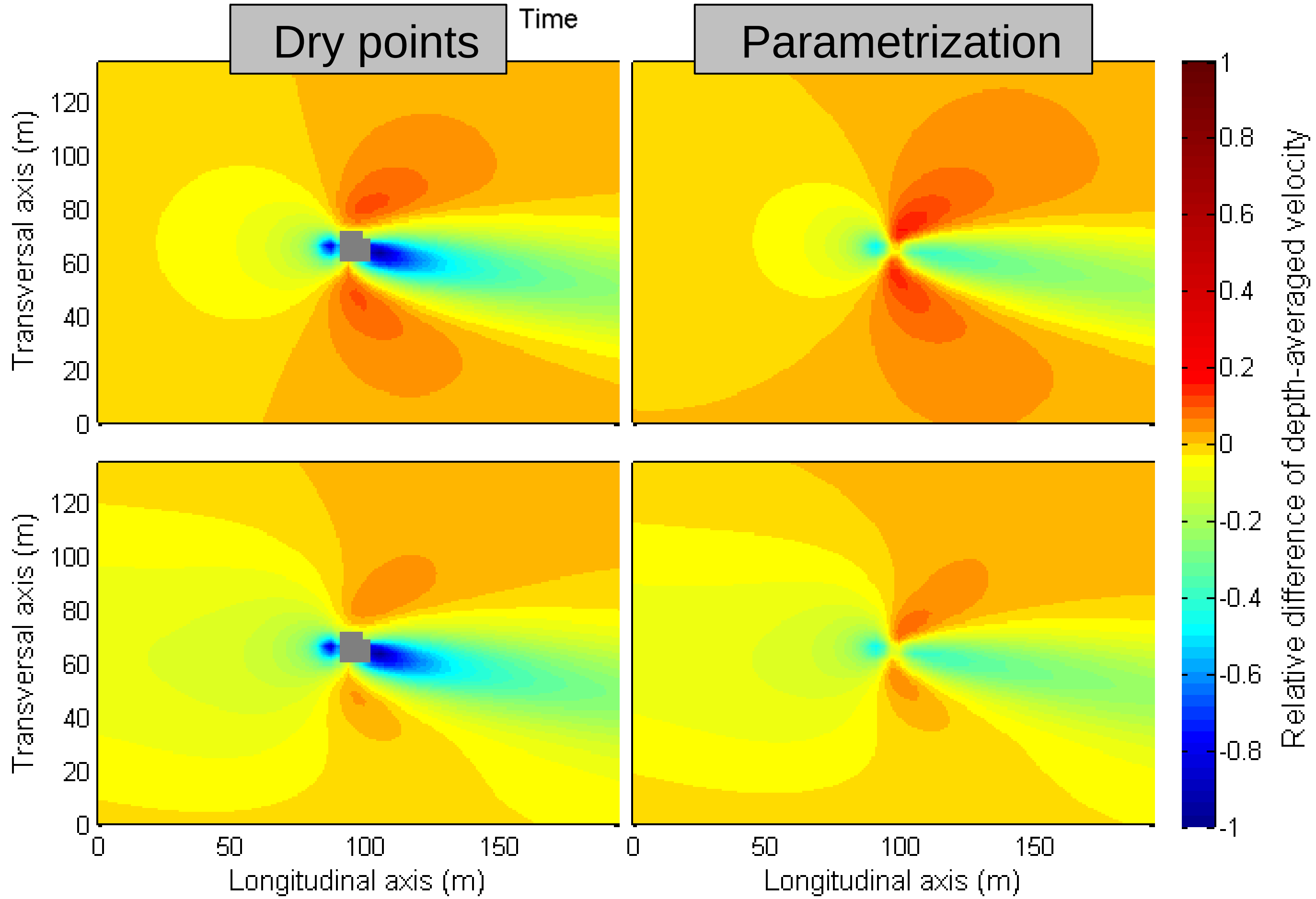
Relative difference of **near-bed** velocity



First monopile

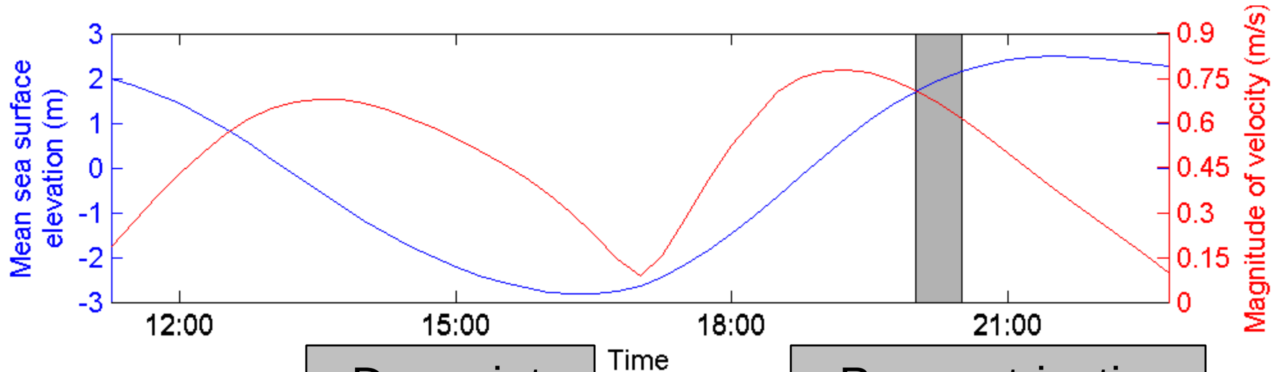


Second monopile

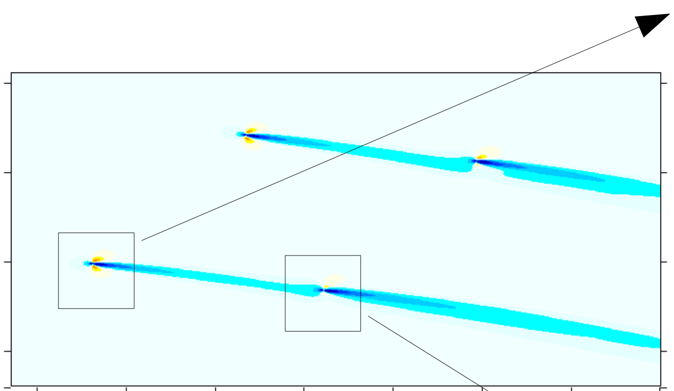


Application: Courseulles-sur-Mer

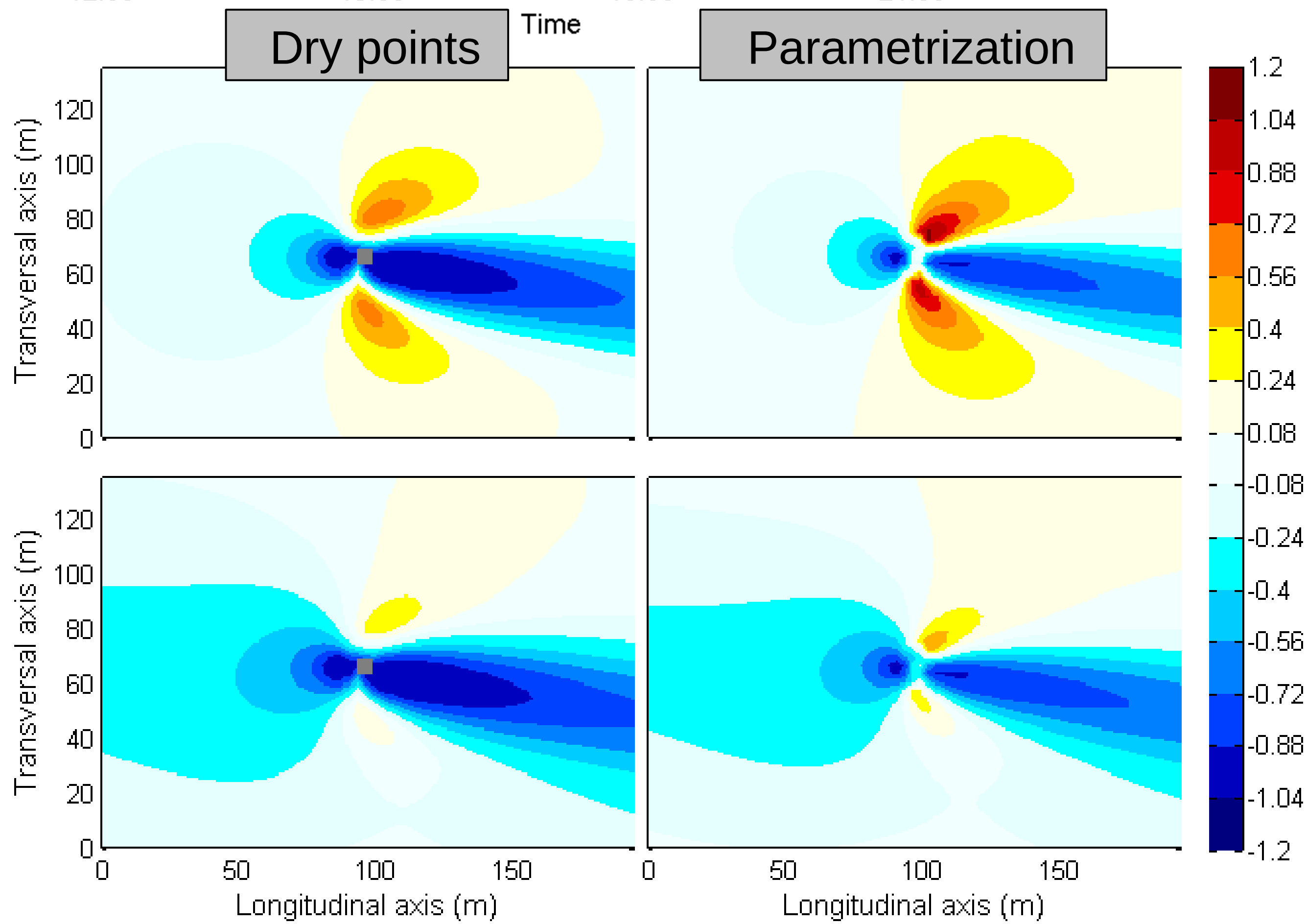
Relative difference of suspended sediment concentration near-bed



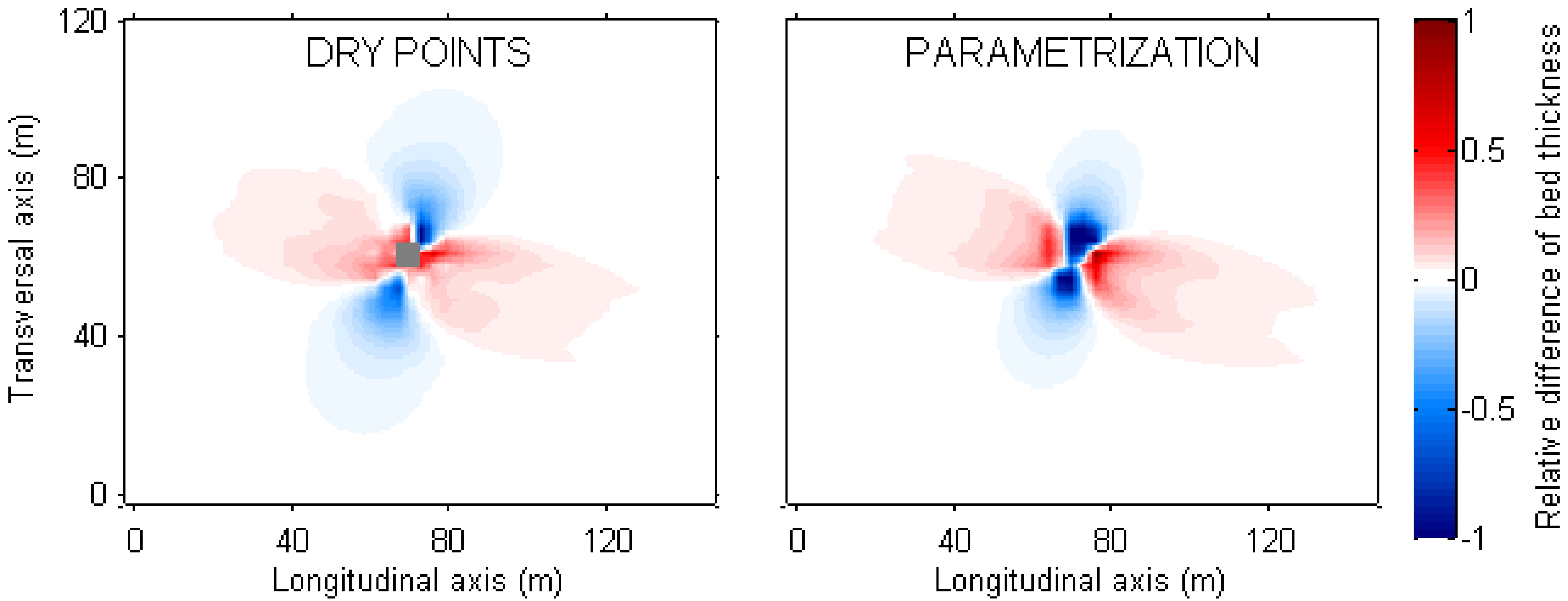
First monopile



Second monopile



Relative difference of bed thickness after one tidal cycle around the first monopile



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Conclusions

•Two approaches were tested to model offshore wind turbine foundations
•Impacts of monopile on hydrodynamics are well reproduced with both strategies

•Sand resuspension and erosion occur where bed shear stress increases due to monopile.
•Turbid wake observed dowstream monopile are reproduced using very fine sand

• Interactions between monopiles are modelled in the regional application.

•**Possible perspectives**

• Introduction of waves in the model

•Use of a morphodynamic module

•More comparison with experimental and in-situ measurements

OFELIA
OFFSHORE FOUNDATIONS' ENVIRONMENTAL IMPACT ASSESSMENT

France (Manche Channel) England interreg

European Regional Development Fund
The European Union, investing in your future

Fonds européen de développement régional
L'Union européenne investit dans votre avenir

Thank you for your attention

Questions?

The OFELIA project was selected under the European cross-border cooperation programme INTERREG IV A France (Channel) - England, co-funded by the ERDF.