Local time parameters use in tropical bays:
Understanding of coastal hydrodynamic responses to natural and anthropic physical forcings

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- Introduction

- Material & Methods

- Results

- Conclusions

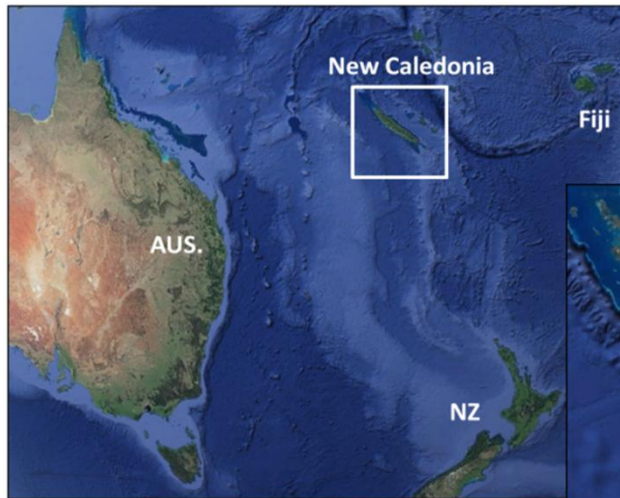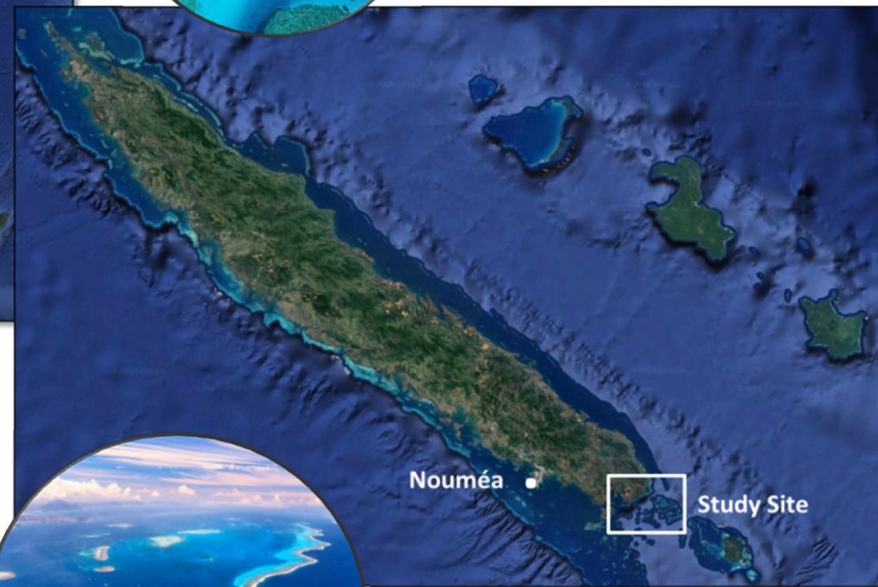○ Introduction

Caledonian context

- A widely known lagoon
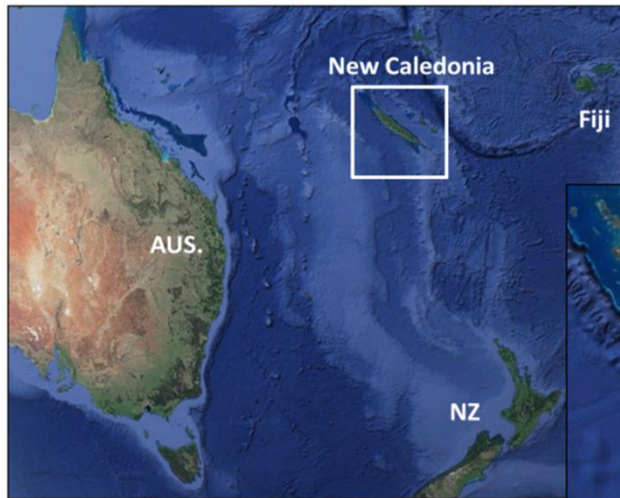
- Second in size after the Great barrier (24 000 km²)

- One of the greatest marine biodiversity

- Unesco site (2008)

Caledonian context

- A contentious mining industry

- 4th Nickel exporter

- Essential to local economy

- Environnemental issues

Objectives

- Assessment of the environmental impacts of human activity through 3D modeling

- Definition of potential risk zones by use of Hydrodynamic times parameters

- Determination of Time Parameters variability depending on physical and meteorological forcings
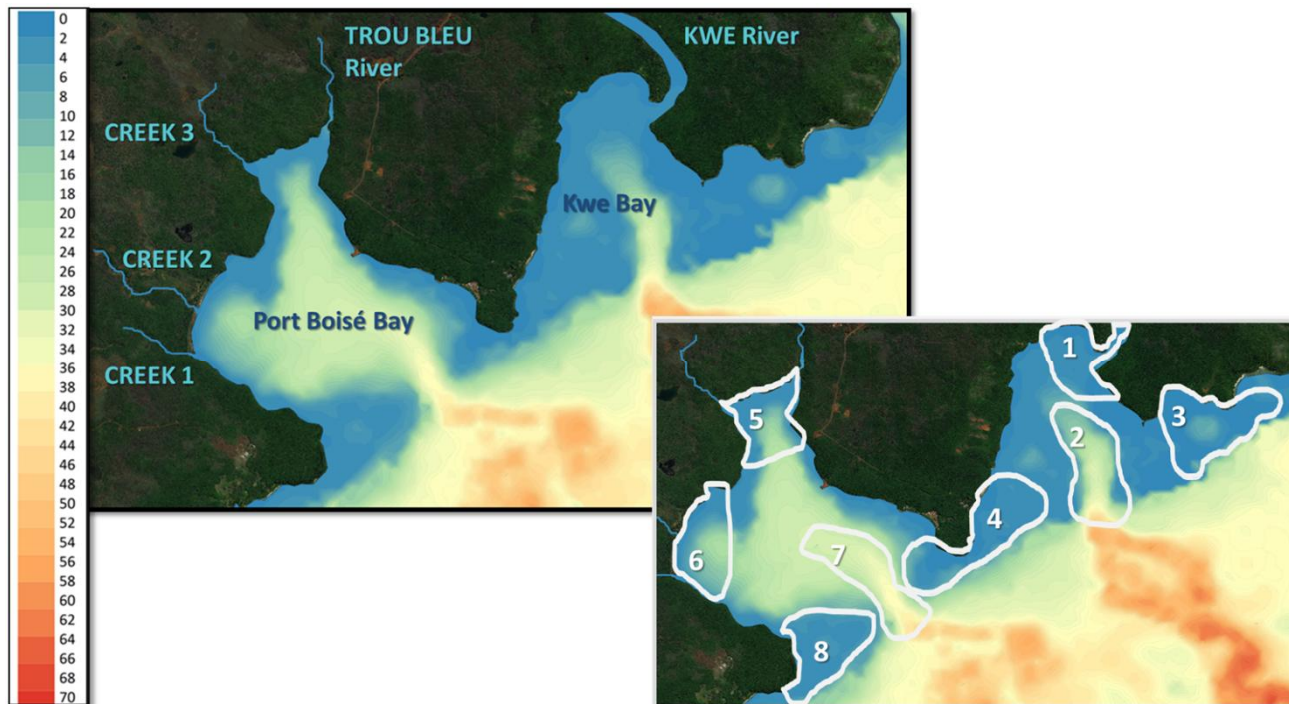
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Study site

- Two bays of similar shape and size (2,5 km²)
- Kwe bay under mining influence
- Port Boisé free from anthropic influence
- Divided in 8 zones of interest

3D Hydrodynamic modeling

○ Model « MARS3D » (Ifremer, Lazure et Dumas 1998)

- Finite differences method

- Governing equations:
  - Conservation of Mass (Continuity equation)
  - Conservation of momentum
  - Energy conservation for incompressible fluids

- Mesh size constant on x & y
- 30 variable sigma layers
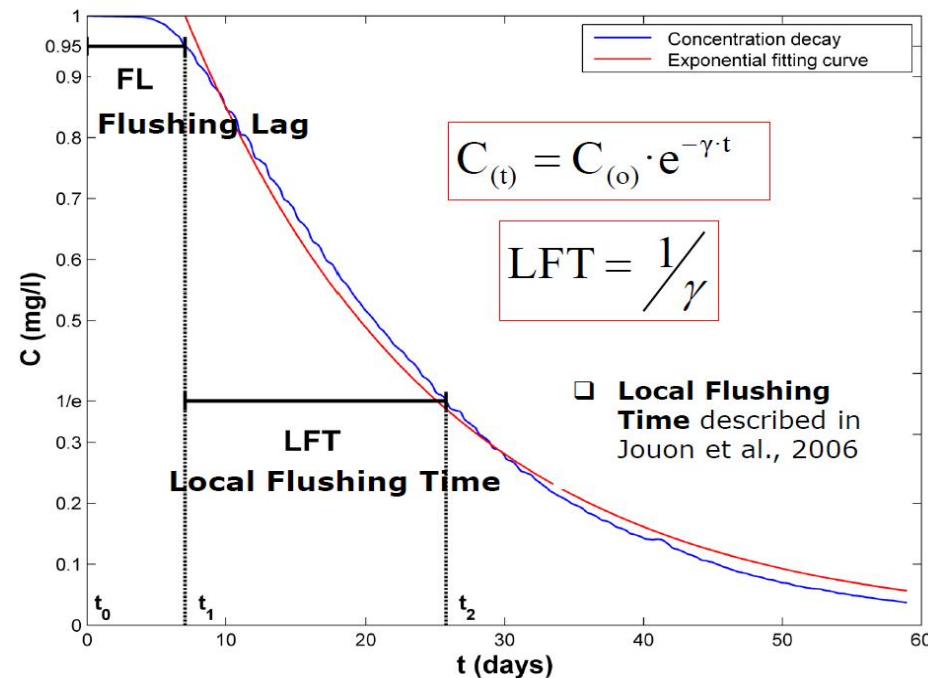- 2 « AGRIF » nested grids
- K-ε turbulence closure
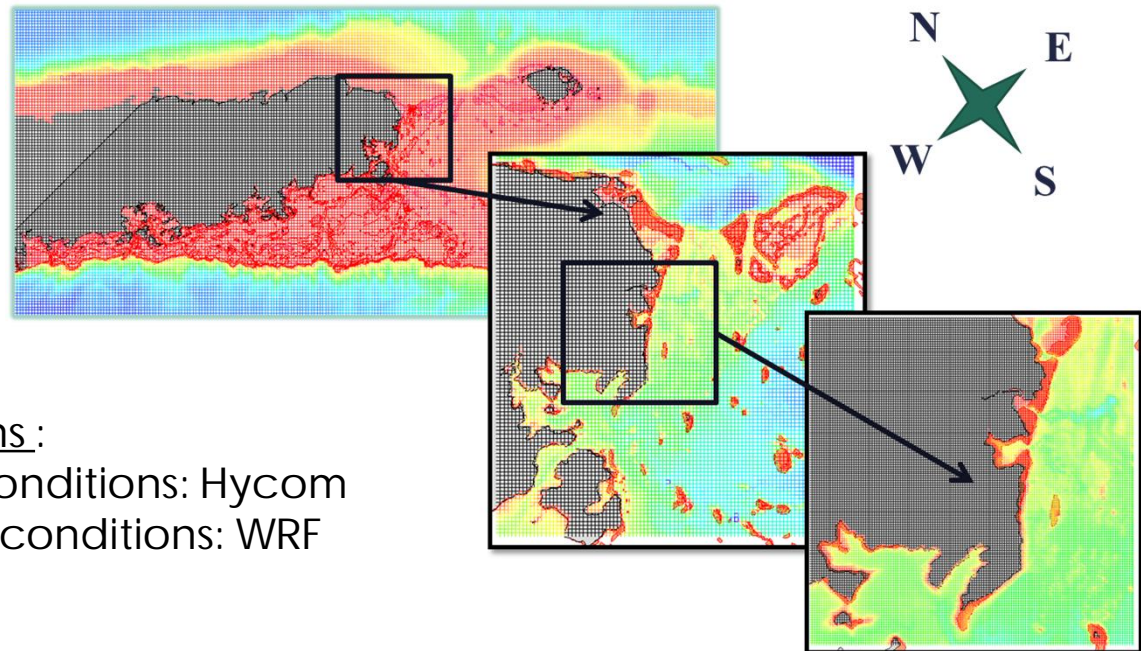
OBC & initial conditions :
- Boundary ocean conditions: Hycom
- Local atmospheric conditions: WRF
- Tidal signal: TPXO8

Hydrodynamic time parameters

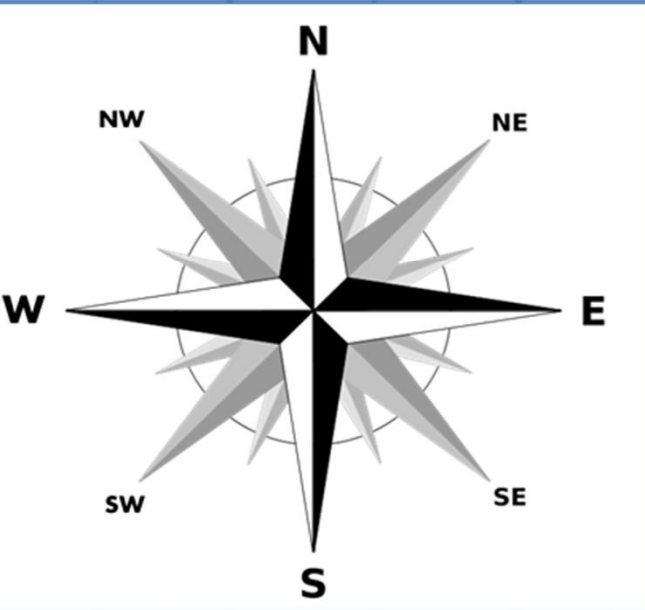Lagrangian « *Residence Time* » vs Eulerian « *Local e-Flushing Time* »

$$C_{(t)} = C_{(o)} \cdot e^{-\gamma \cdot t}$$

$$LFT = \frac{1}{\gamma}$$

❑ **Local Flushing Time** described in Jouon et al., 2006

Advantages of local e-Flushing times (eFTs):

Help identify potential stagnation zones by highlightening spatial contrast in small scale areas
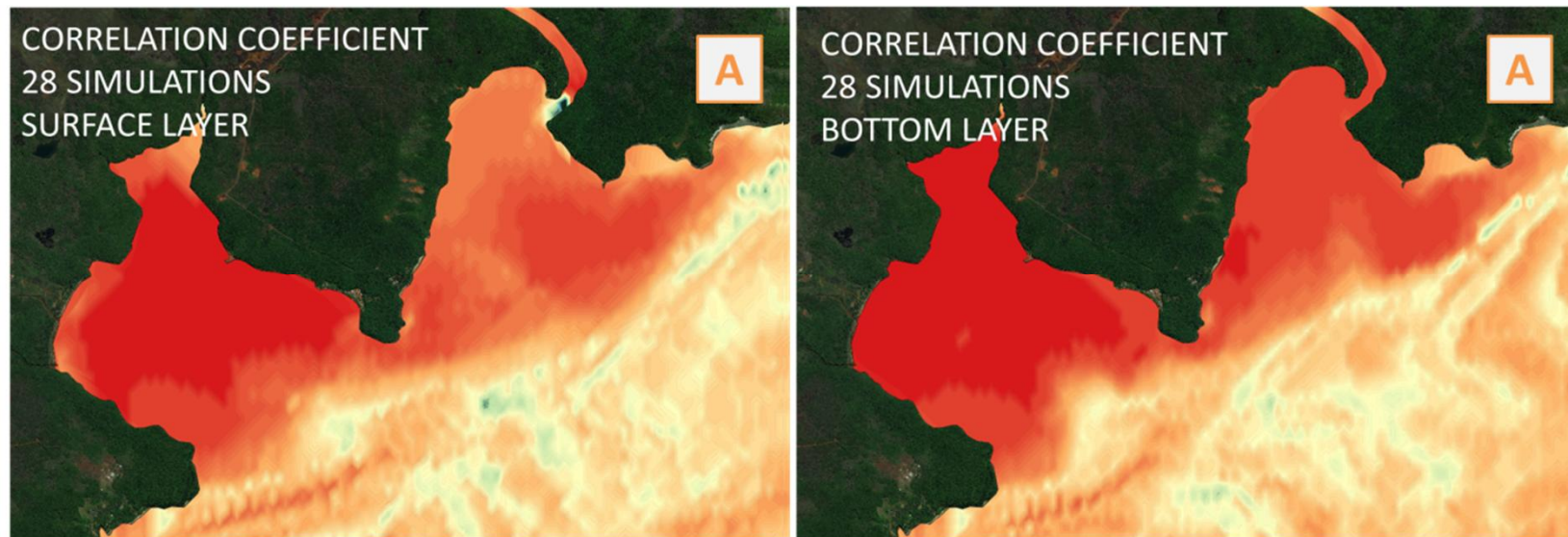
Wide simulation panel

102 simulations launched:

- 2 river flow conditions
- 3 tidal ranges

- 8 wind directions
- 3 wind intensities (1 null)

River condition	Wind intensity	Tidal range	Wind directions
Low River Flow	8 m/s	Low	
		Medium	
		High	
	5 m/s	Low	
		Medium	
		High	
Medium River Flow	8 m/s	Low	
		Medium	
		High	
	5 m/s	Low	
		Medium	
		High	

Precision of Local Flushing time formulation

→ Testing the accuracy of the exponential decreasing equation linking tracer concentration and local flushing time
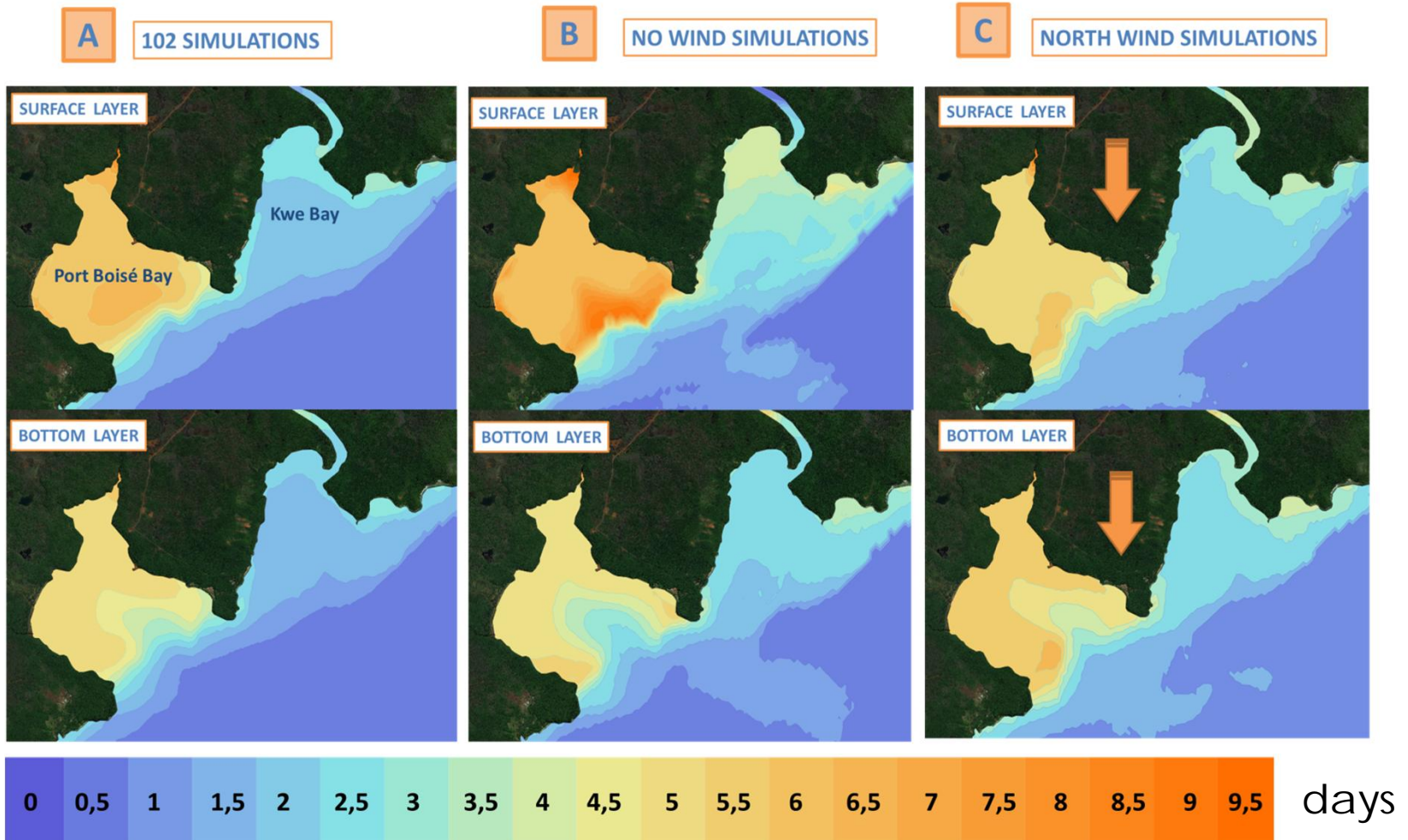

CORRELATION COEFFICIENT
28 SIMULATIONS
SURFACE LAYER
A

CORRELATION COEFFICIENT
28 SIMULATIONS
BOTTOM LAYER
A

| <70 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 |

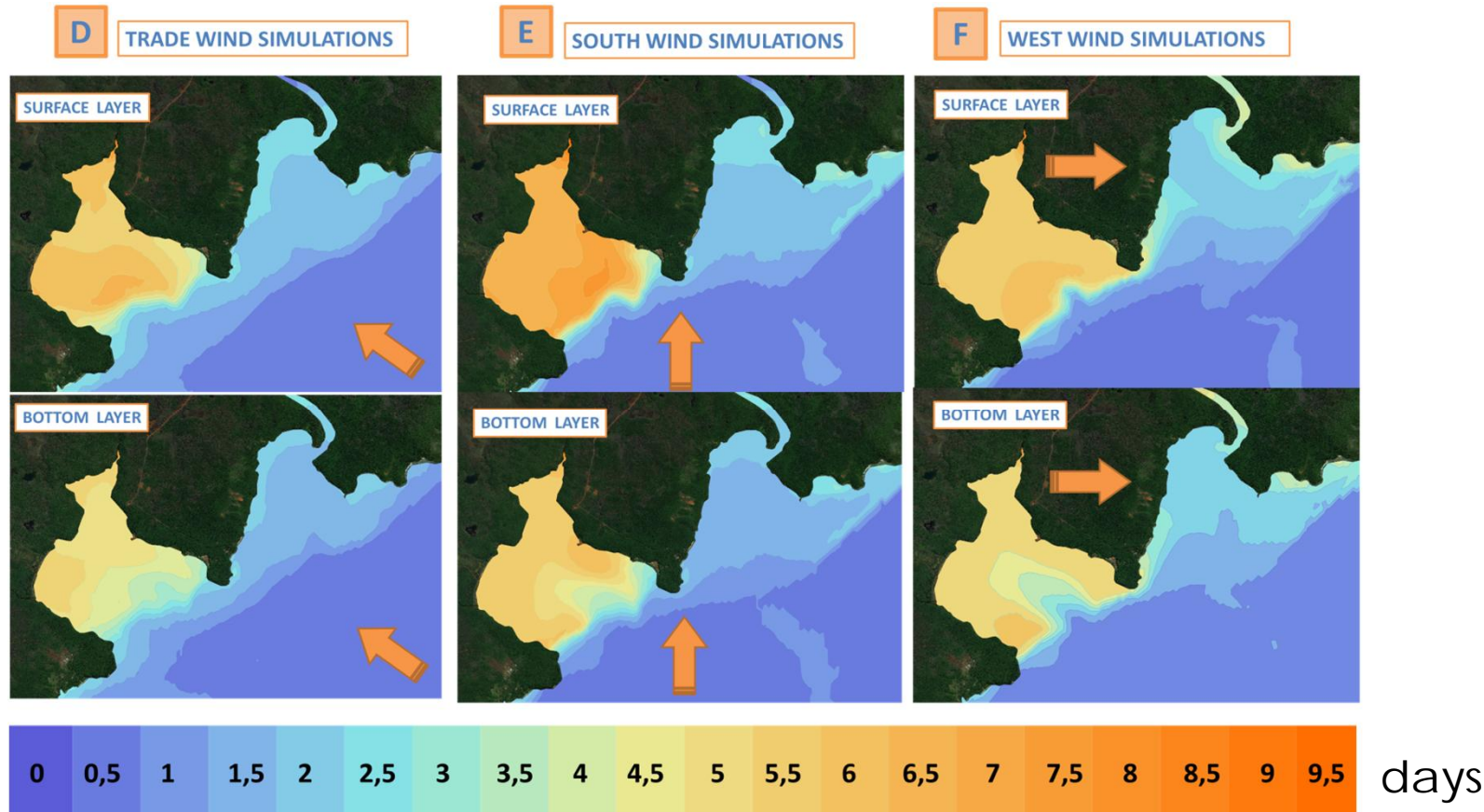Correlation Coefficient > 0,94 within the bays

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Results
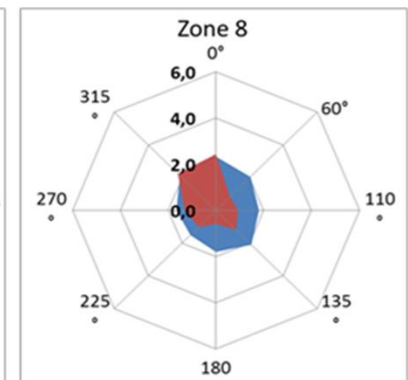
Averaged Flushing time distribution, by wind direction :

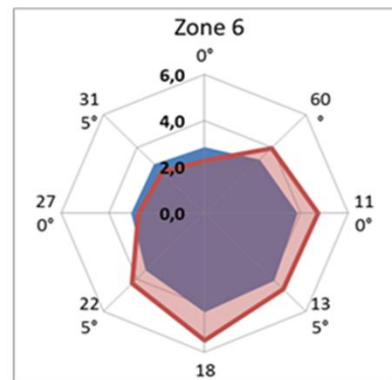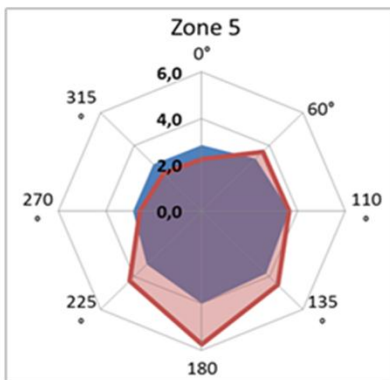**A** 102 SIMULATIONS   **B** NO WIND SIMULATIONS   **C** NORTH WIND SIMULATIONS

SURFACE LAYER

Kwe Bay

Port Boisé Bay

BOTTOM LAYER

| 0 | 0,5 | 1 | 1,5 | 2 | 2,5 | 3 | 3,5 | 4 | 4,5 | 5 | 5,5 | 6 | 6,5 | 7 | 7,5 | 8 | 8,5 | 9 | 9,5 | days |

Results: Local eFTs

D	TRADE WIND SIMULATIONS
E	SOUTH WIND SIMULATIONS
F	WEST WIND SIMULATIONS

SURFACE LAYER
BOTTOM LAYER

0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7 7,5 8 8,5 9 9,5   days

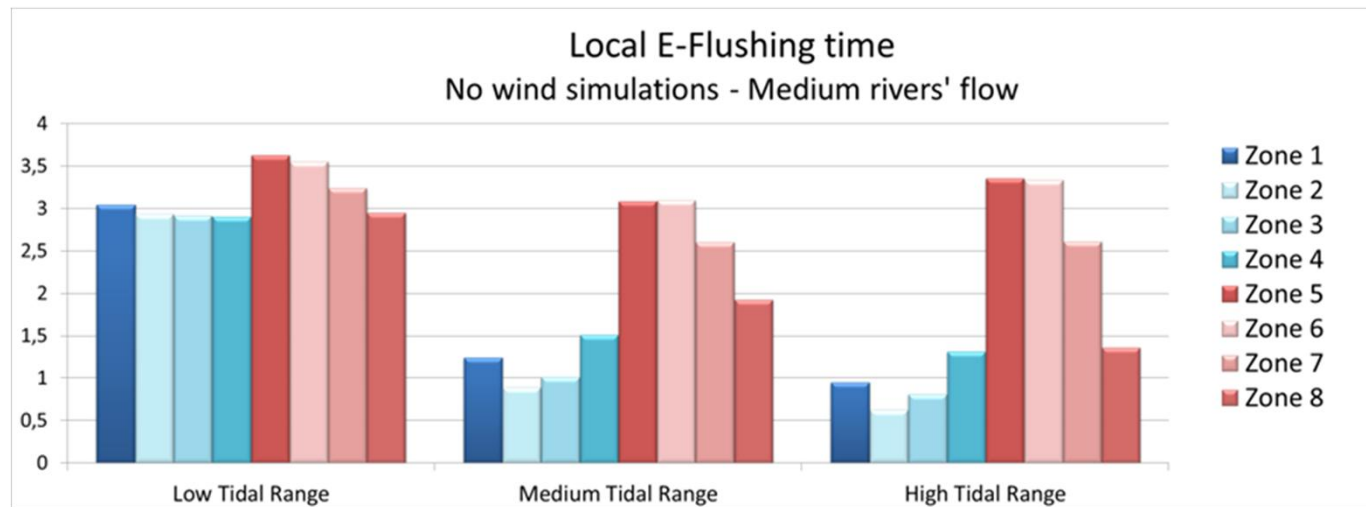| Mean e-Flushing Time	Kwe Bay	Port Boisé	Difference	Multiplication Factor
No Wind	1,78	3,19	1,41	1,79
North Wind	1,34	2,82	1,48	2,10
Trade wind	1,29	3,36	2,07	2,60
South Wind	1,39	4,09	2,69	2,93
West Wind	1,23	2,61	1,38	2,13
All 102 simulations	1,33	3,15	1,82	2,37

Local e-flushing times by zone, with medium rivers' flow radars
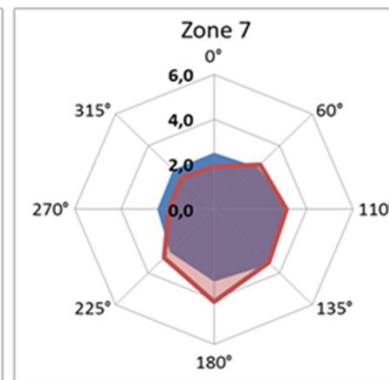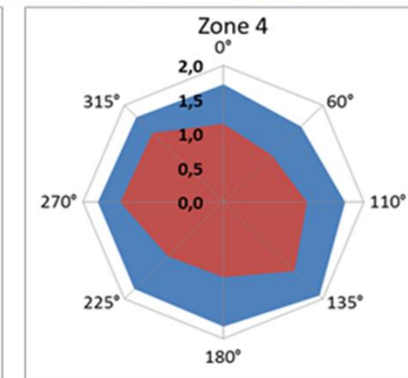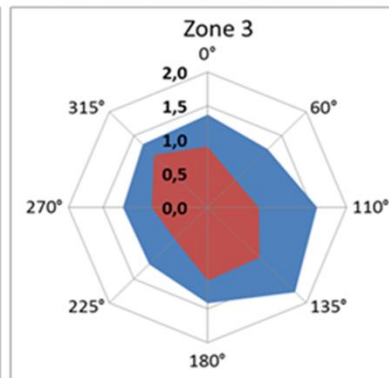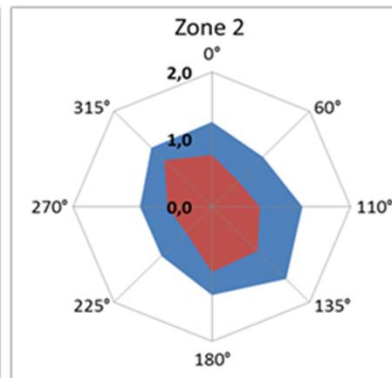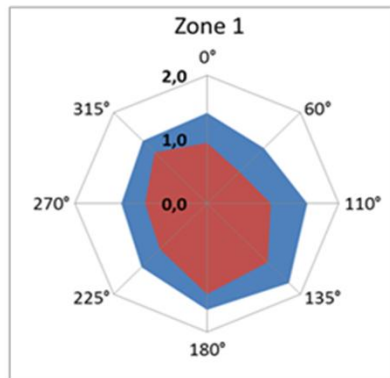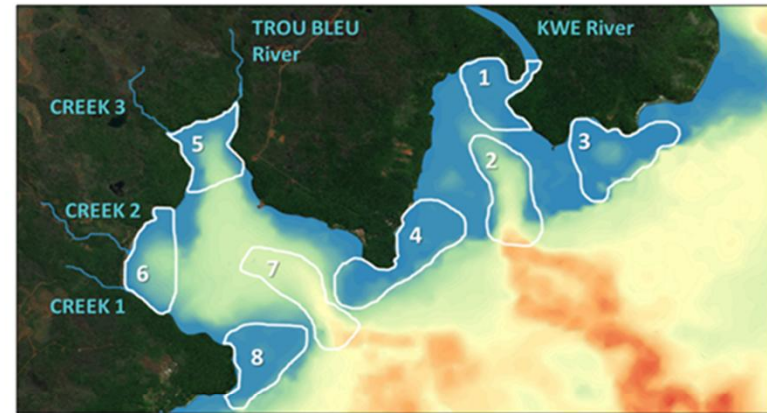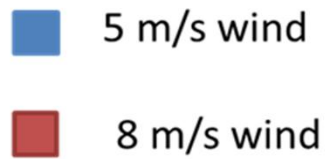
Variability of Flushing Times with the tidal range

Local E-Flushing time
No wind simulations - Medium rivers' flow

Legend: Zone 1, Zone 2, Zone 3, Zone 4, Zone 5, Zone 6, Zone 7, Zone 8

X-axis: Low Tidal Range, Medium Tidal Range, High Tidal Range

- Tidal currents intensity vary correspondingly to the tidal range

→ The more important tidal currents are, the more heterogeneous the eFTs values between the bays and within the bays

→ In Port Boisé, highest currents trigger longer eFTs in Zones 5 and 6

Variations of Flushing times (in %)
- from the averaged eFTs for a same wind direction
- Due to changes in wind intensity and tidal range
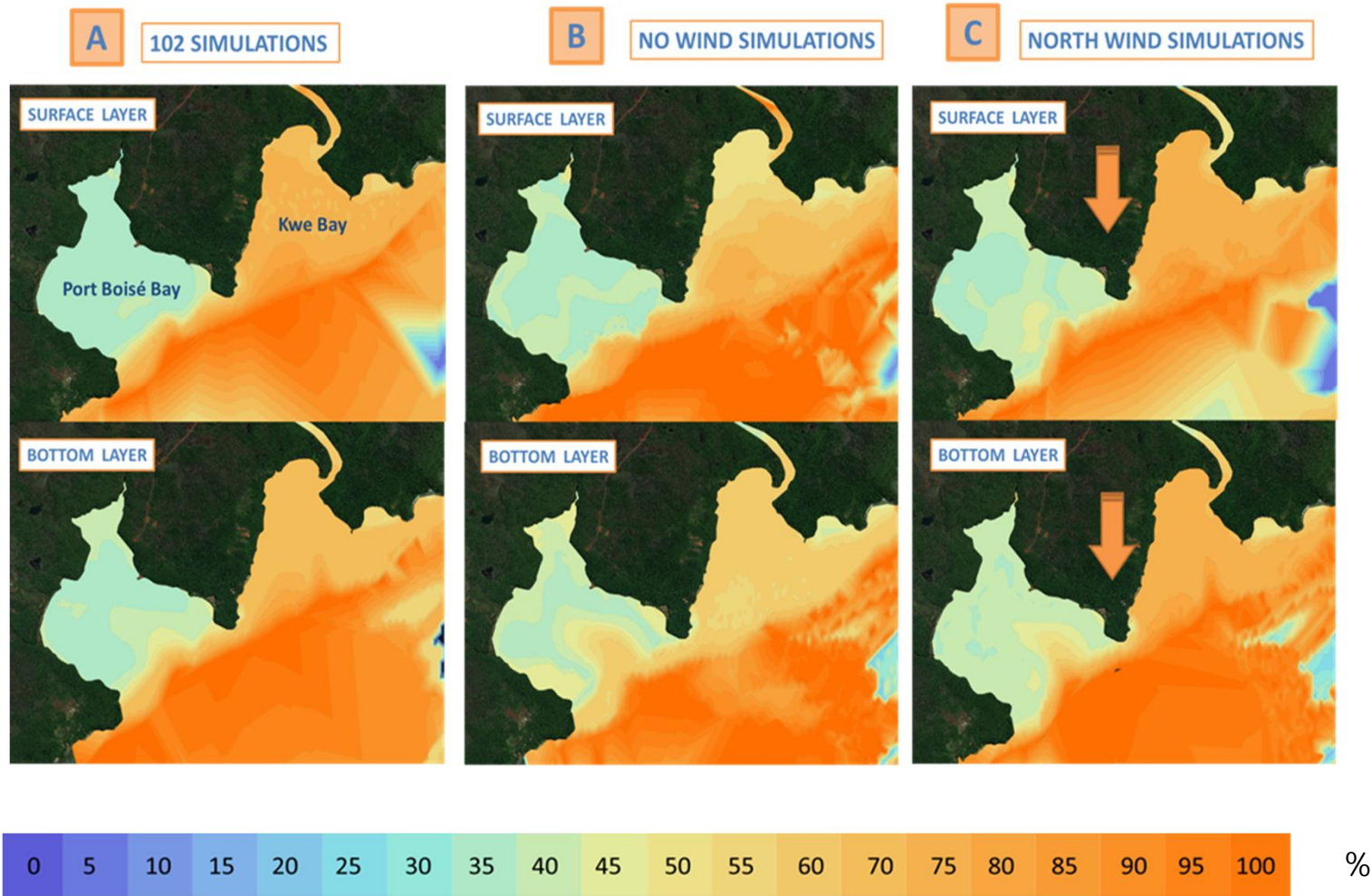
Variations of Flushing times (in %)
- from the averaged eFTs for a same wind direction
- Due to changes in wind intensity, river flows and tidal range
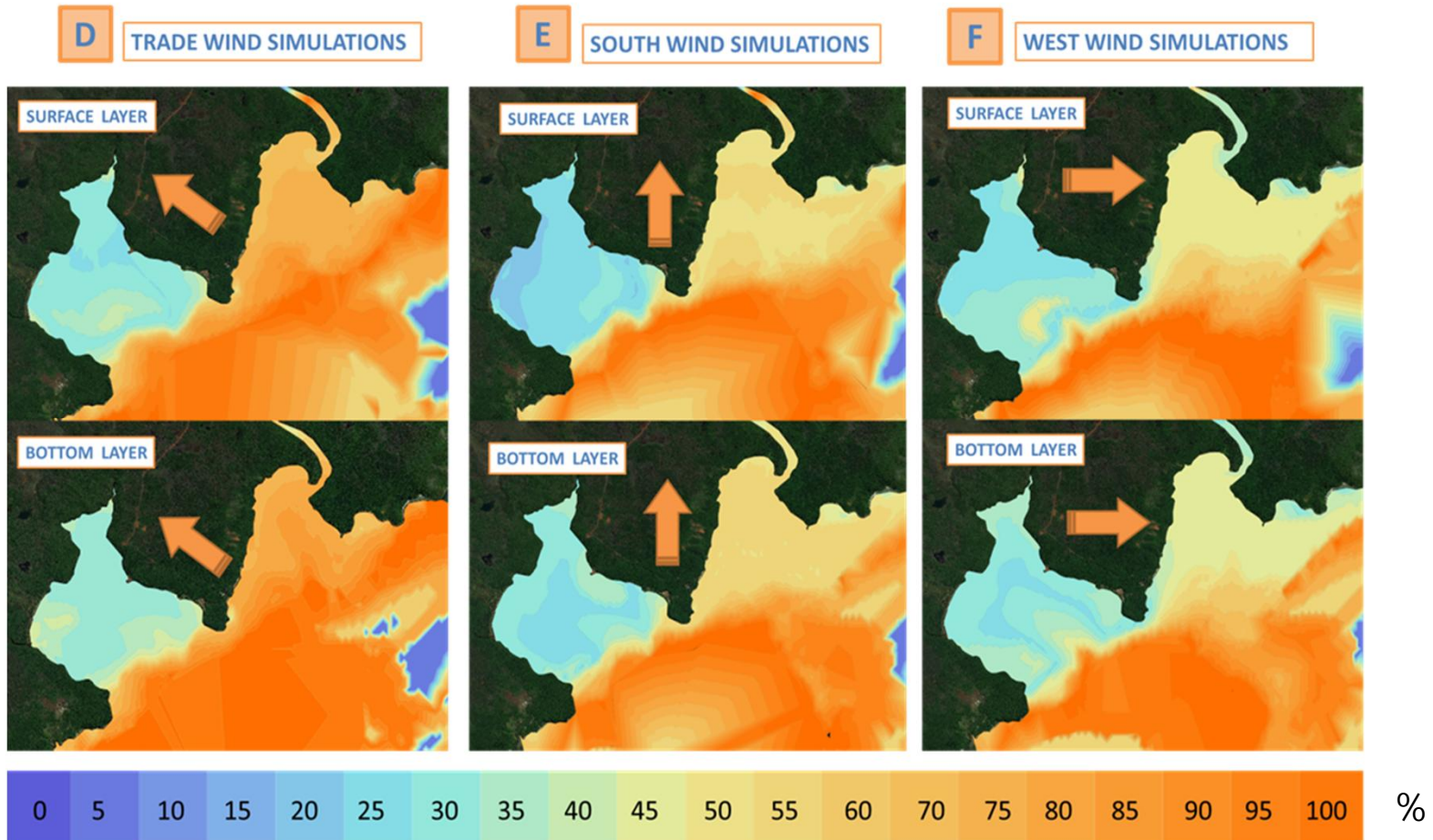
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- Two similar bays can have completely different deposition and stagnation risk levels
  → Local time parameters help identify these disparities and allow their classification

- EFTs values does not only depend on turbulence level
  → Passing zones, concomitant or opposite effects, accumulation phenomenon highlighted by this parameter

- EFTs values significantly change according to physical forcings such as Wind intensity and direction, tidal range, and river inputs
  → meteorological forcings variability must be taken into account for eFTs calculation rather than averaged weather conditions

- Differences in eFTs values also exist upon the vertical
  → For complete evaluation of risk, there will be a need of distinguishing eFTs depending on the depth

Thanks for your attention !

Port Boisé bay