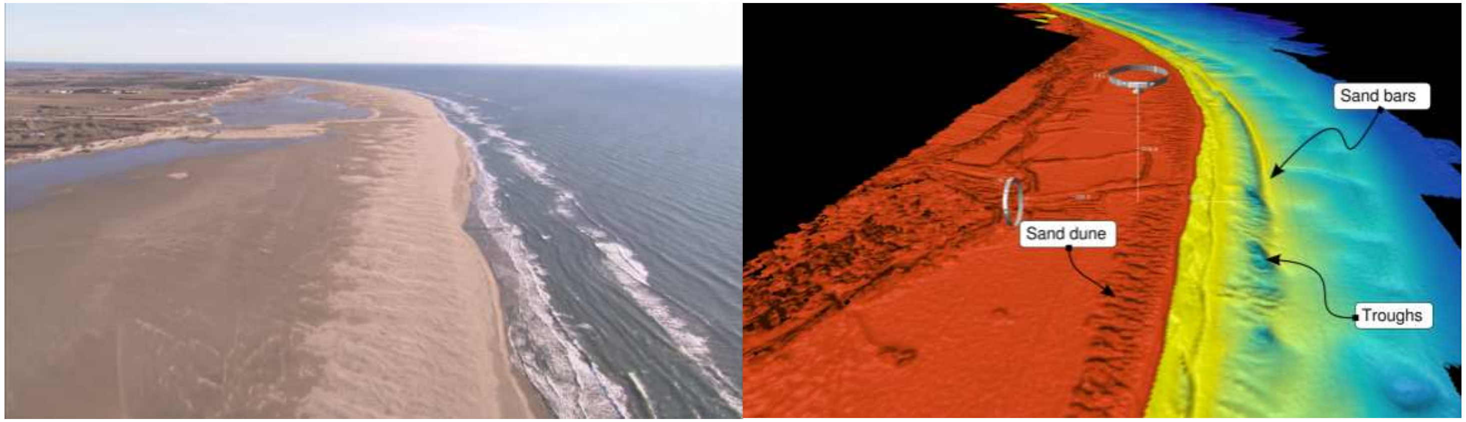


Nearshore simulation & design platform

Ingredients

+ Morphodynamics by minimization principle

+ Design of defense structures and coastal engineering

+ Uncertainties on bed characteristics & wave definition

+ Uncertainties on the state

+ Extreme scenarios

+ Deep Convolutional Neural Network

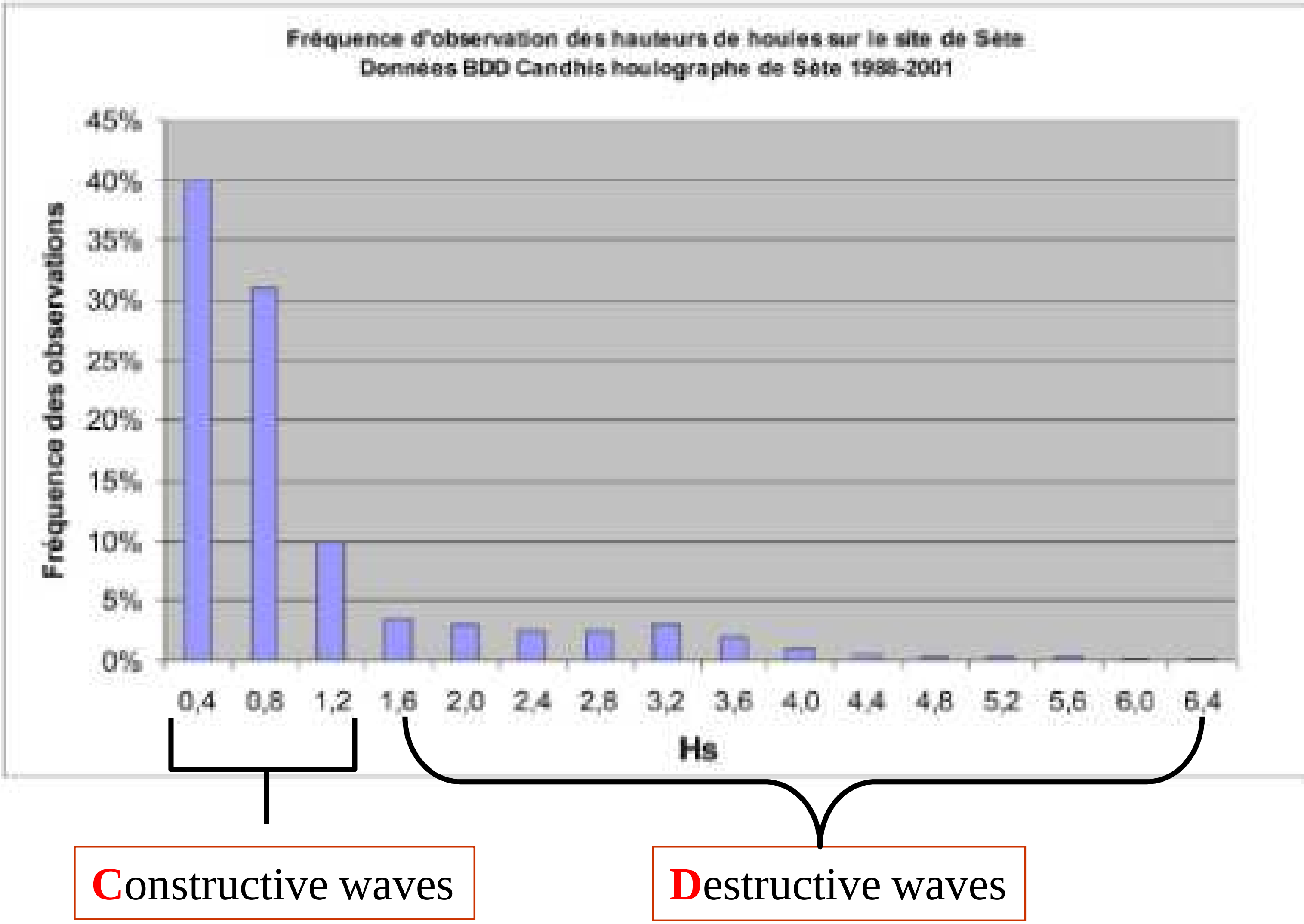
Platform features :

-Saint-Venant+ variational bathy dynamics
-Optimization of defense stuctures
(Automatic adjoint by INRIA/Tapenade)
-Introduction of Equivalent Orbital Velocity
- Link with infragravity waves
-Extremes events (Quantiles)
-Direct & Inverse UQ

This year remarks :

-Links with Exner/Fowler models
- 2 applications for Total
-Application to hazard quantification in oil transport by seas
by either ships or coastal pipelines
(estimation of buried oil in the intertidial beaches)
-Risk for nearshore infrastructures due to wave concentration
-CNN

Waves



-Coastal engineering to preserve C and remove D

-Morphodynamics in the presence of C

Variational Fluid/Bottom model

Dependency chain: $\psi \rightarrow \{\mathbf{U}(\psi,\tau), \tau \in [0,T]\} \rightarrow J(\psi,T)$

Flow state equation: $\mathbf{U}_t + F(\mathbf{U},\psi) = 0, \quad \mathbf{U}(0) = \mathbf{U}_0(\psi)$

Cost fct: $J(\psi,T) = \int_{(0,T)} j(\psi,\mathbf{U}(\psi,t))$

Bed motion: $\partial_t \psi = -\rho(t,x)\nabla_\psi J, \quad \psi(t=0,x) = \psi_0(x) =$ given,

Bed time and space variability through its response to flow perturbations.
Aleatory uncertainties also present in initial and boundary conditions.
Epistemic uncertainties due to model & numerics.

→ Same platform used to design beach protection devices (geotube, sand dune, groyne, etc).

→ Long term experience with automatic differentiation in reverse mode

Ansatz

The bed adapts in order to reduce water kinetic energy with 'minimal' sand transport

We do not know details of microscopic mechanisms.
We are interested by macroscopic features.

Example of functional

for beach morphodynamics simulations

T: Time interval of influence
Ω *:* observation domain

$$J(U(\psi)) = \int_{t-T}^{t} \int_{\Omega} \left(\frac{1}{2}\rho_w g \eta^2 + \rho_s g (\psi(\tau) - \psi(t-T))^2\right) d\tau d\Omega$$

$$\eta(\tau, x, \psi) = h(\tau, x, \psi) - \frac{1}{T}\int_{t-T}^{t} h(\tau, x, \psi) d\tau$$

Phd Afaf Bouharguane

Link with the Exner eq in 1D

$$\psi_t = -\frac{1}{1-\lambda} q_x = -\rho \nabla_\psi J$$

with $0 \le \lambda < 1$ the bed porosity

hard bottom : $\lambda, \rho \to 0$

soft bottom : $\lambda \to 1, \rho = \frac{1}{1-\lambda} \to \infty$

Increasing depth : $q, \nabla_\psi J \to 0, x \to -\infty$

$$q(x) = \int_{-\infty}^{x} \nabla_\psi J \, d\xi$$

But, on a closed domain $x \in [0, L]$:

$$q(x) = q(0) + \int_0^x J_\psi \, d\xi$$

Basin or channel experiment means

$J_\psi = 0$ for $x < 0$ and $q(0) = 0$

Minimization based dynamics similar to using non local fluxes

Example in 1D

$$J(\psi) = \frac{1}{2}(\partial_x u)^2 \quad \text{and} \quad q(x) = \int_{-\infty}^{x} \nabla_\psi J d\xi$$

$$q(x) = -\int_{-\infty}^{x} \partial_{\xi\xi} u \partial_\psi u d\xi + \partial_x u(x) \partial_\psi u(x)$$

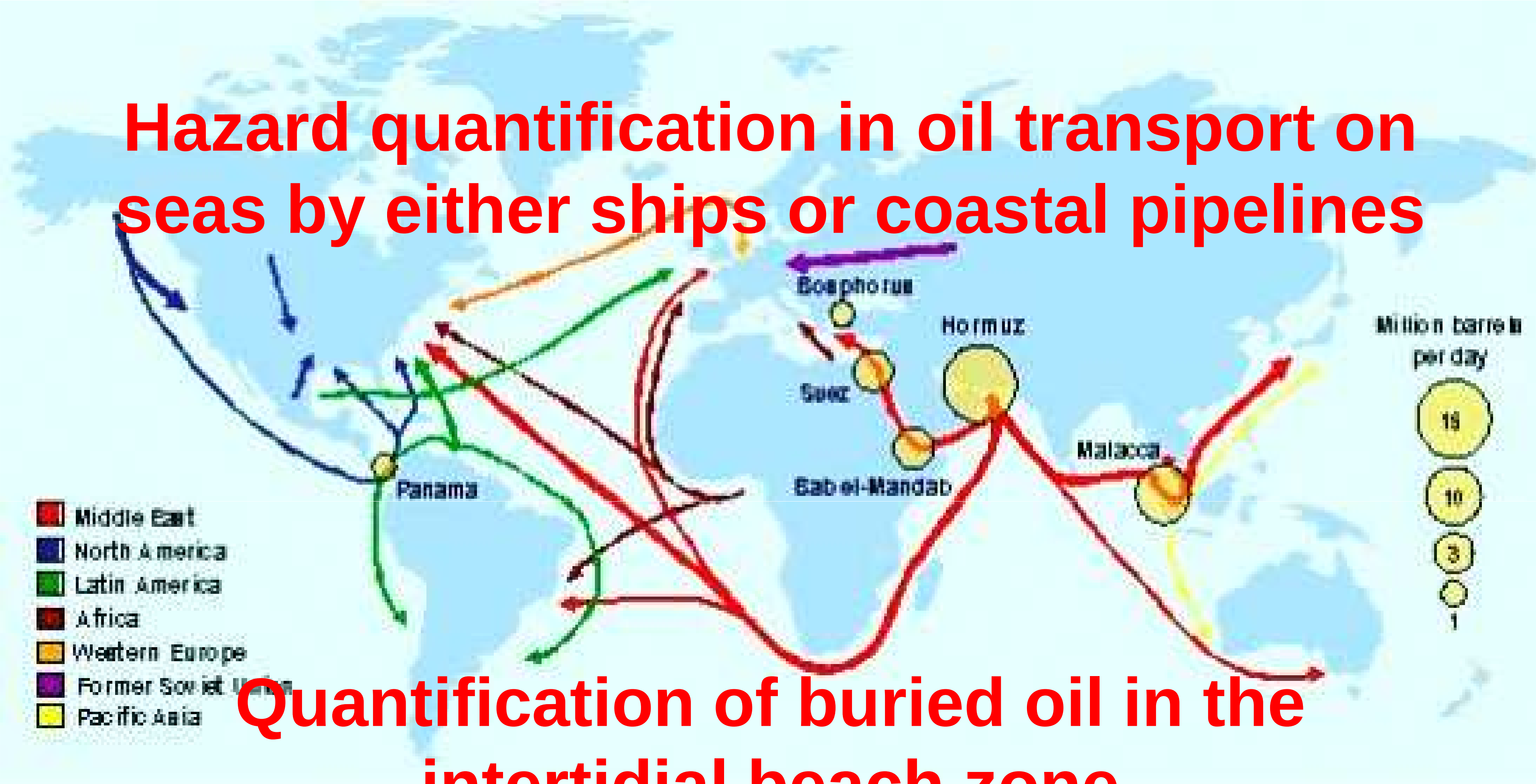
$$q(x) = \int_{0}^{+\infty} \partial_{\xi\xi} u(x-\xi) \partial_\psi u(x-\xi) d\xi + \partial_x u(x) \partial_\psi u(x)$$

$$\psi_t + \frac{1}{1-\lambda} q_x = 0$$

$$Fowler: q(x) = \int_{0}^{+\infty} |\xi|^{-1/3} \partial_{\xi\xi} u(x-\xi) d\xi + \partial_x u(x) u(x)$$

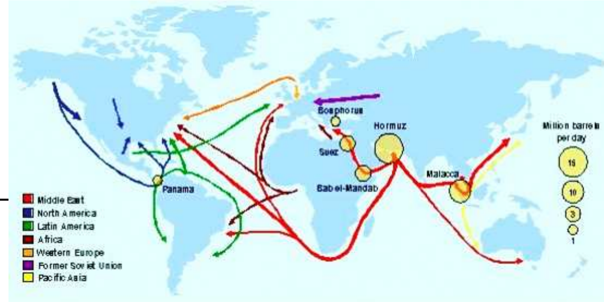
Littoral erosion & extreme events

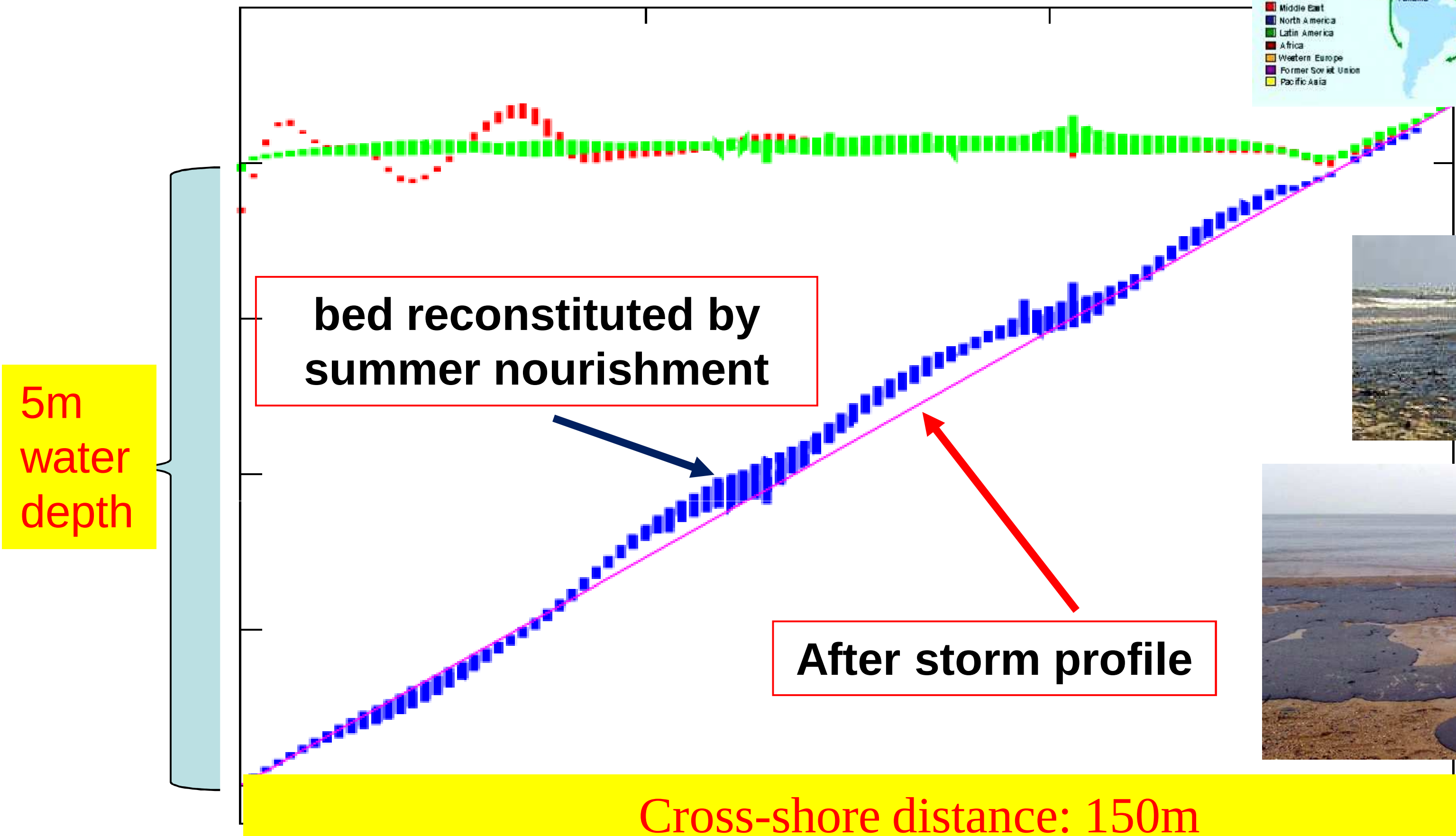
Hazard quantification in oil transport on seas by either ships or coastal pipelines



Quantification of buried oil in the intertidial beach zone

Hazard quantification in oil transport on seas
Quantification of buried oil in intertidal beach zones !





Cross-shore distance: 150m
Oil might be covered by 40cm of sand in some area, corresponding to on site observations (Prestige oil spill)
It can reappear next winter !
Pertinent with strong tidal coefficient (Saint-Malo 28-116)
(Piriac 40-100)

On site observations of oil buried between clean sand by wave action

INTERNATIONAL TANKER OWNERS POLLUTION FEDERATION (ITOPF)
Tech Paper No. 6
RECOGNITION OF OIL ON SHORELINES

Layering of oil below cleaned surface
Pensacola Beach, Fl, USA
Photo: Markus Huettel

Another example of the impact of erosion onTotal infrastructures

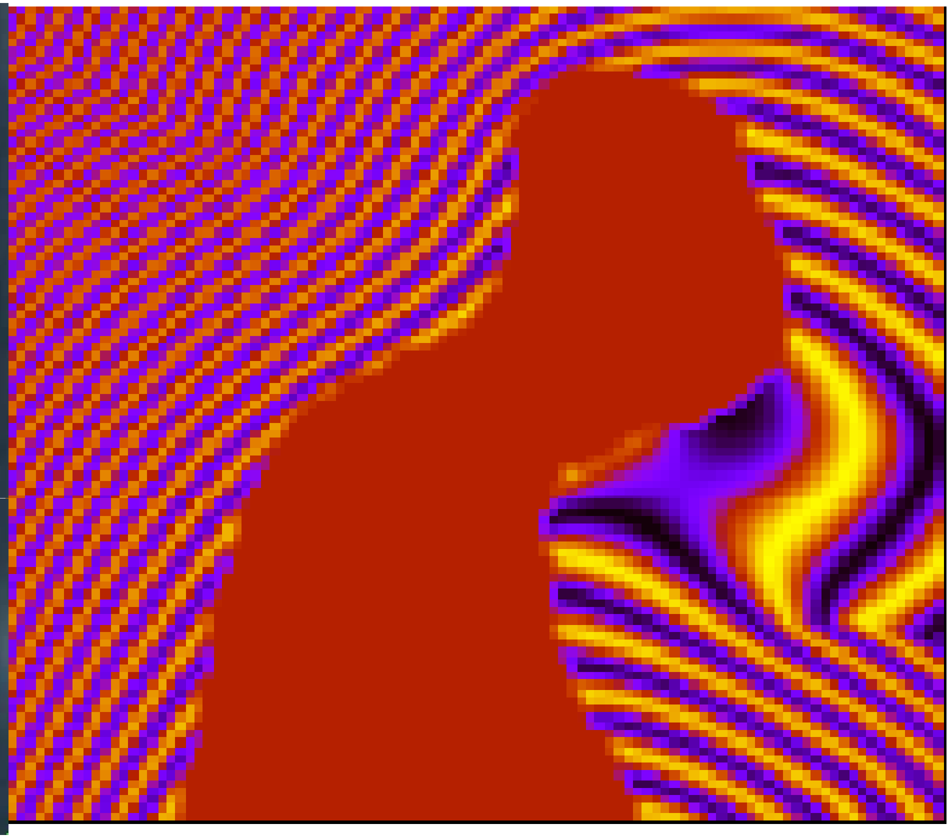
-high tide
-sandy beaches

Phenomenology

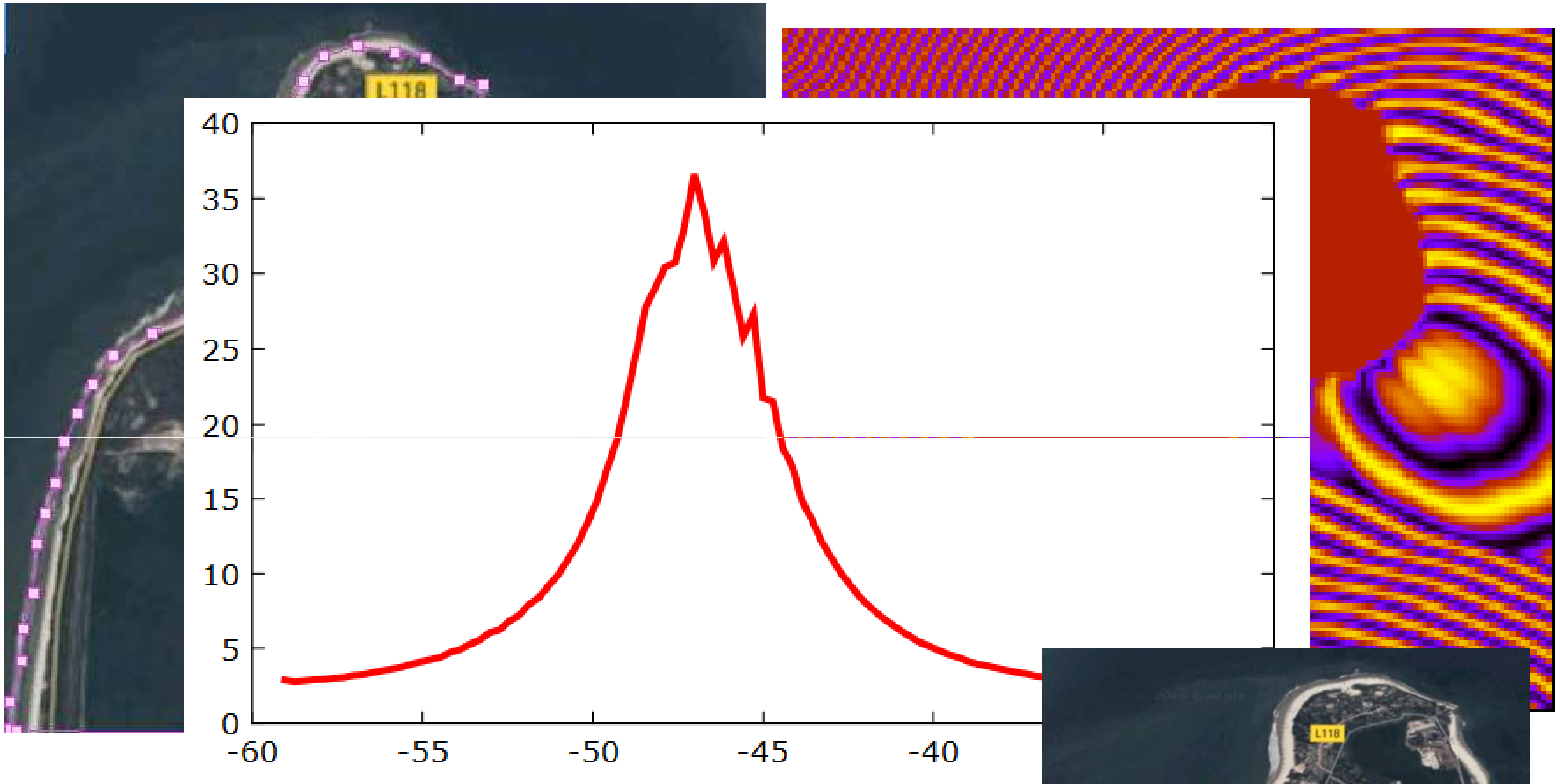
- Reflection : *waves bounce back on emerged structures.*
- Refraction : *approaching waves turn parallel to the beach*
- Diffraction : *geometric due perturbations in shadows.*
- Shoaling : *waves entering shallow water (h<L/2), C and L decrease and H increases with T constant.*
- Dispersion : $h_x < 0 \Rightarrow C_x=(L/T)_x < 0$ *with T constant* $\Rightarrow L_x < 0$ *(wavelength decreases). Superposition of monochromatic waves will spread, each wave slowing.*

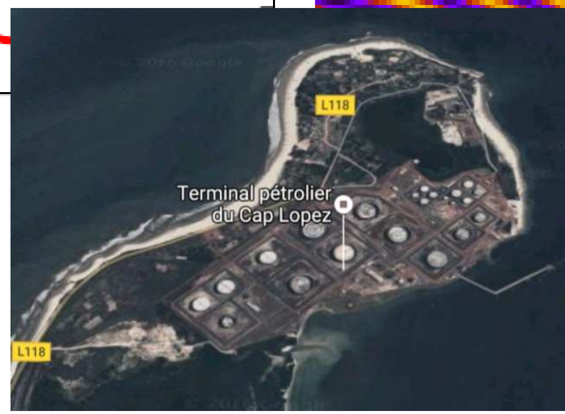
How much complexity should we account for ?

Refraction + Diffraction



Refraction + Diffraction





Identification of worst-case scenario wave direction