SPICy (2015-2017)

Toward the implementation of a cyclone-induced coastal hydrodynamics and flooding forecasting system for Reunion Island

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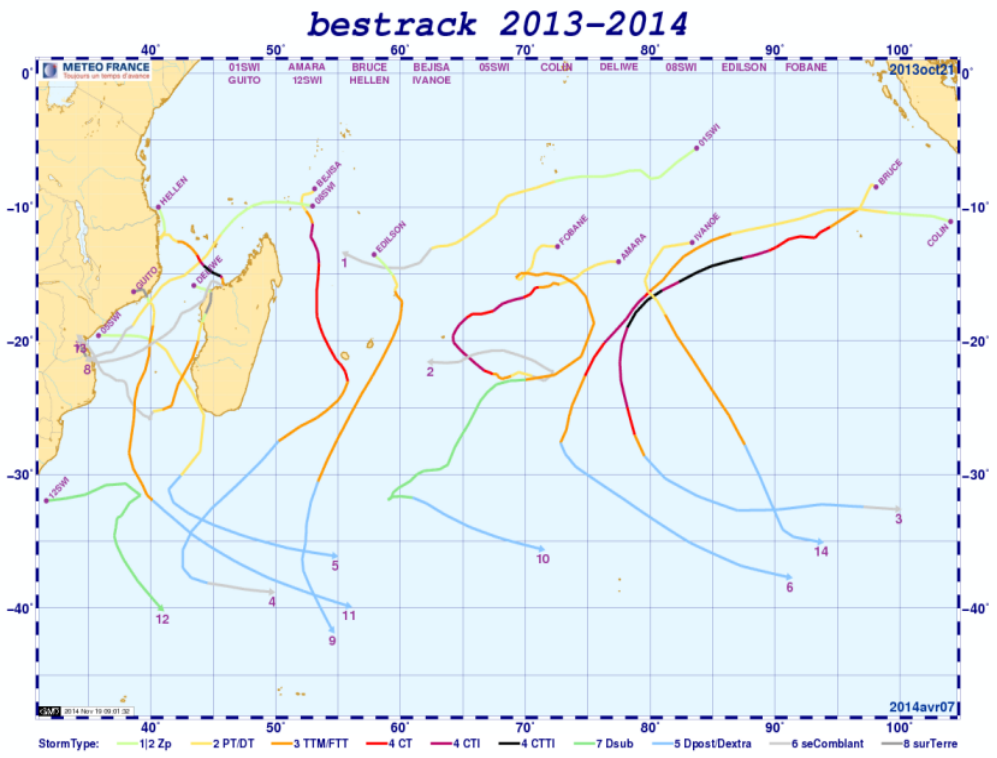
A high exposure to cyclonic events …

- The most exposed among the French Overseas Territories
- 23 cyclones passed within 200km of the island over the last 30 years



… but no coastal surge and wave forecast so far

Main objectives of the Project

- Develop the next generation of cyclone-induced wave, surge (**regional scale**) and flood (**local scale**) forecasting system for the Reunion Island

- Investigate ways for better integration with emergency services to keep in mind the possible operational applications beyond the project

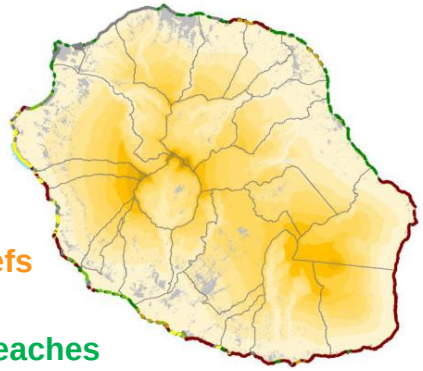
- Produce a demonstrator and inovative products that will be tested within two crisis exercices in 2016 (simulator) and 2017 (on site)

Reunion island presents specific issues ….

Artificial coast

Peeble beaches

Fragmented fringing reefs



Volcanic beaches

Cliffs

> **A small island (Ø ~ 50km)**
  - High uncertainties related to the track

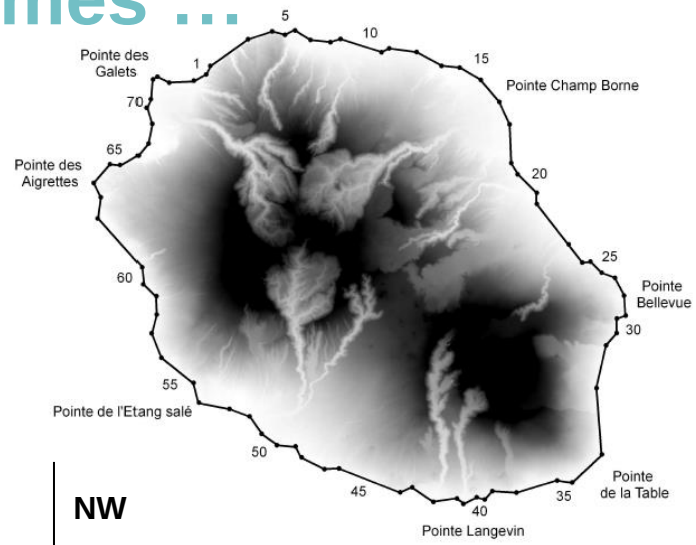
> **No continental shelf associated to a microtidal regime (~0.5m)**
  - Storm surge is not the point
  - …. but waves are

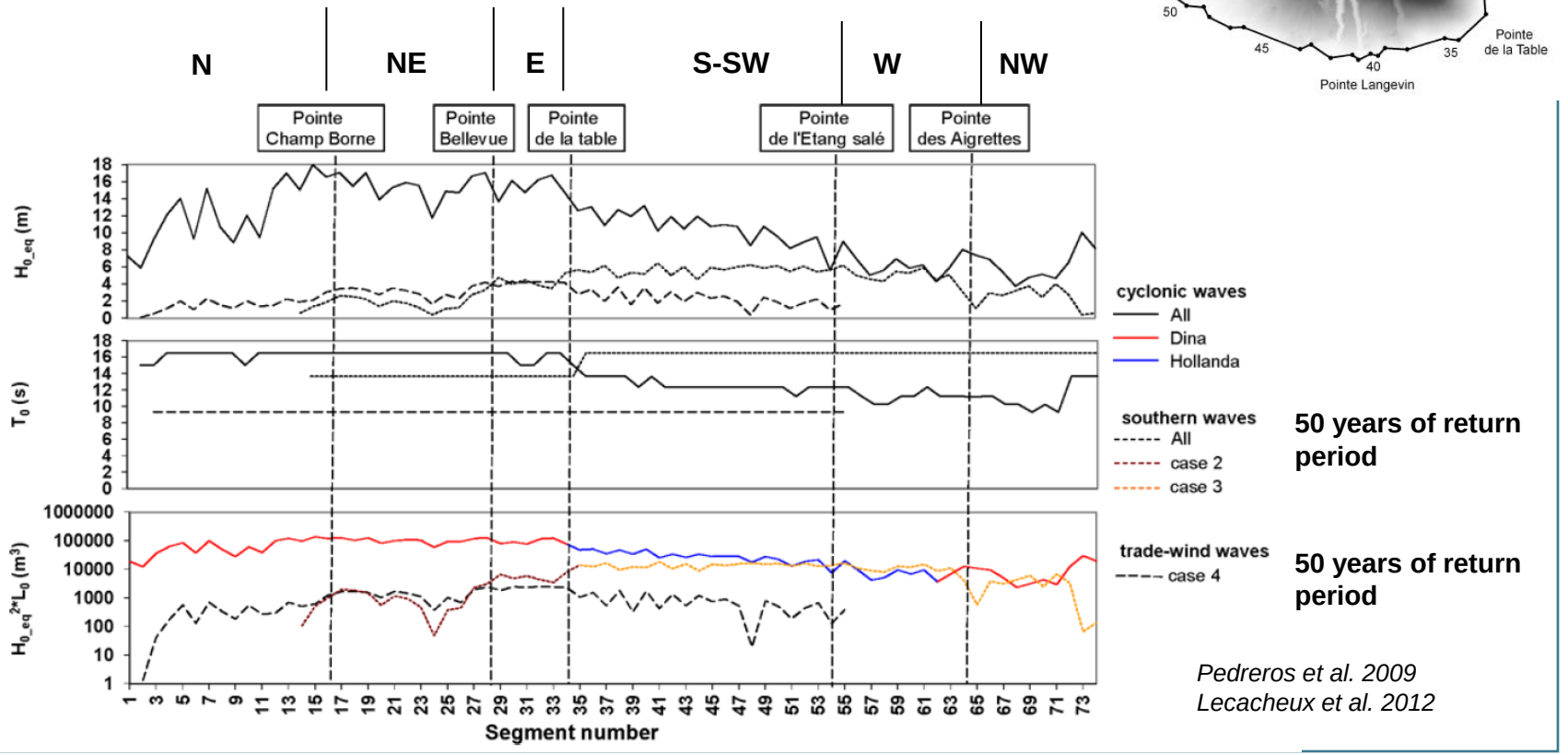
> **Various coastlines types**
  - And as many different behaviours to account for

> **Coastal flooding due to wave overtopping only**
  - Local scale processes are essential

exposed at extreme wave regimes …

- **Cyclonic waves:** all around the island, up to H_{s0} ~18m and Tp ~ 16s in N
- **Southern waves:** S (SW to SE), H_{s0} ~6m and Tp ~ 16s (RP 50 years)
- **Trade-wind wave:** E (NE to S), up to H_{s0} ~4m and Tp ~10s (RP 50 years)





Pedreros et al. 2009
Lecacheux et al. 2012

… that require suitable solutions

- **A probabilistic approach through ensemble simulations is required to account for the high uncertainties**

…. but at the same time :

- **Issue 1 :**

  Classical parametric wind and pressure fields (Holland, 1980) are not adapted to simulate waves because of large-scale environment influence

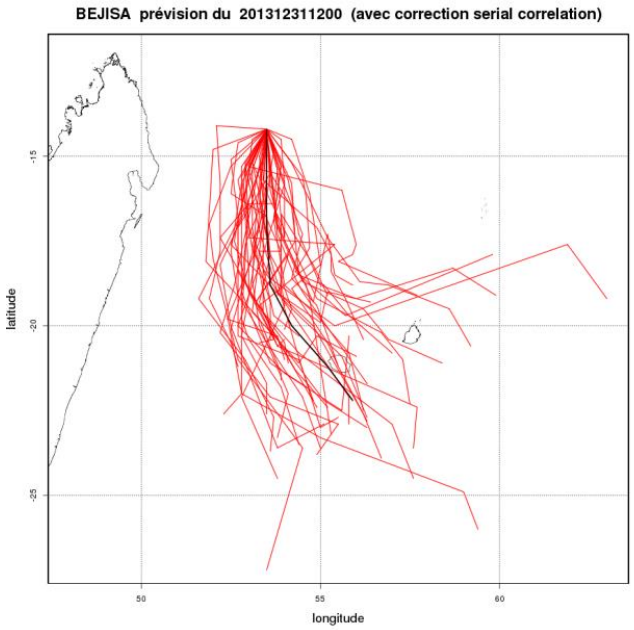
- **Issue 2 :**

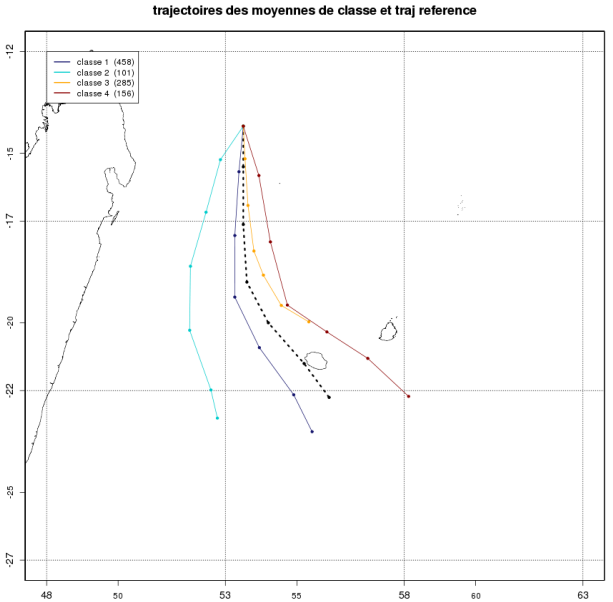
  Classical approaches with overflowing models used in forecast systems (like in the US) can't be applied here

A problem of scale (processes) and computing times!

Our strategy for the meteorological data (1)

- Develop 2 methods to generate ensembles of scenarios accounting for both track and intensity uncertainty
  - Option 1: Based on historical forecast errors statistics (DeMaria et al. 2009)
  - Option 2: Based on the ECMWF ensemble forecasts





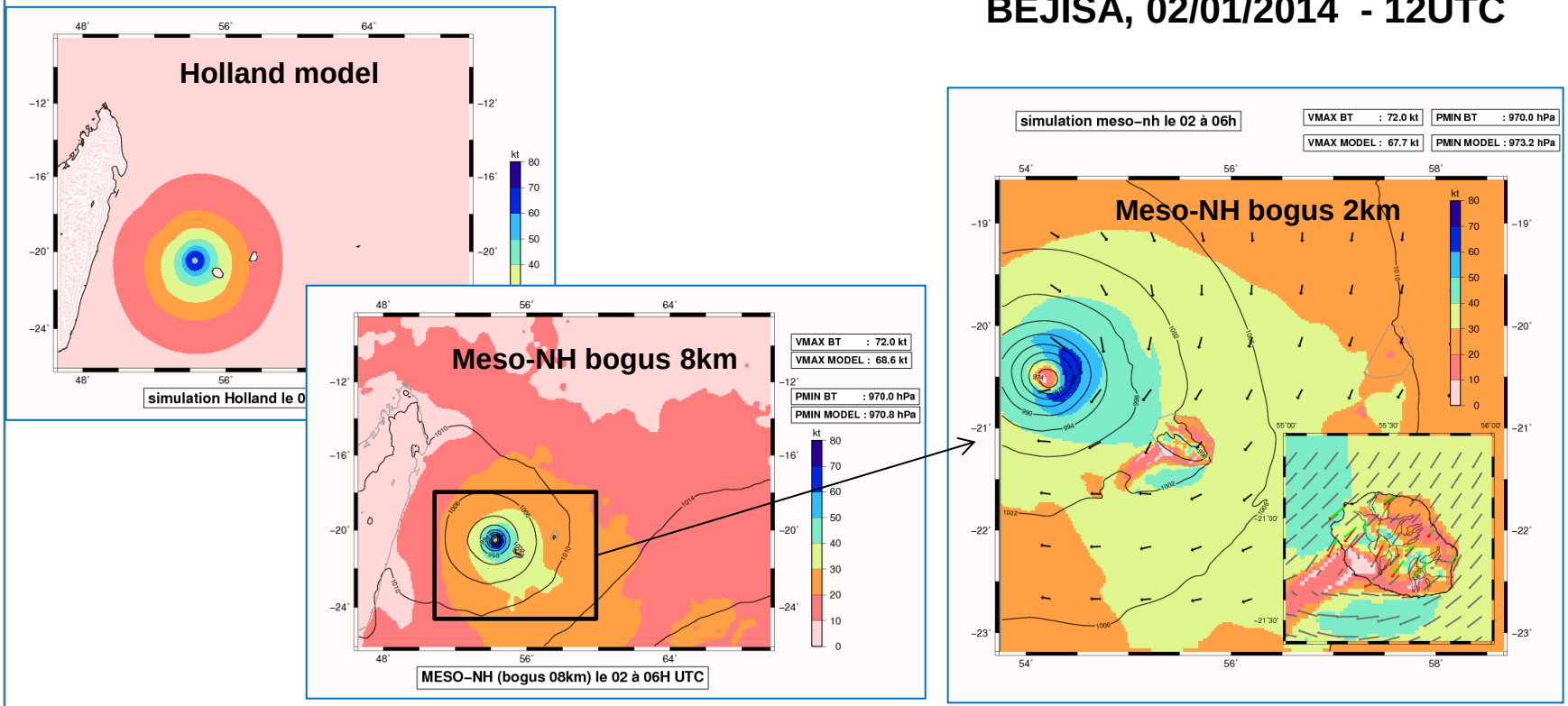
- Apply a clustering to the members to optimize the number of simulation and gain in computing times

Our strategy for the meteorological modelling (2)

> Create corresponding 2D wind and pressure fields by introducing the scenarios into the model **Meso-NH** (Global model coupling) through a bogusing scheme to :

- take into account the large-scale circulation in wave modelling applications
- reconstruct a wind circulation consistent with the local orography when the cyclone is in the vicinity of the Island

BEJISA, 02/01/2014 - 12UTC



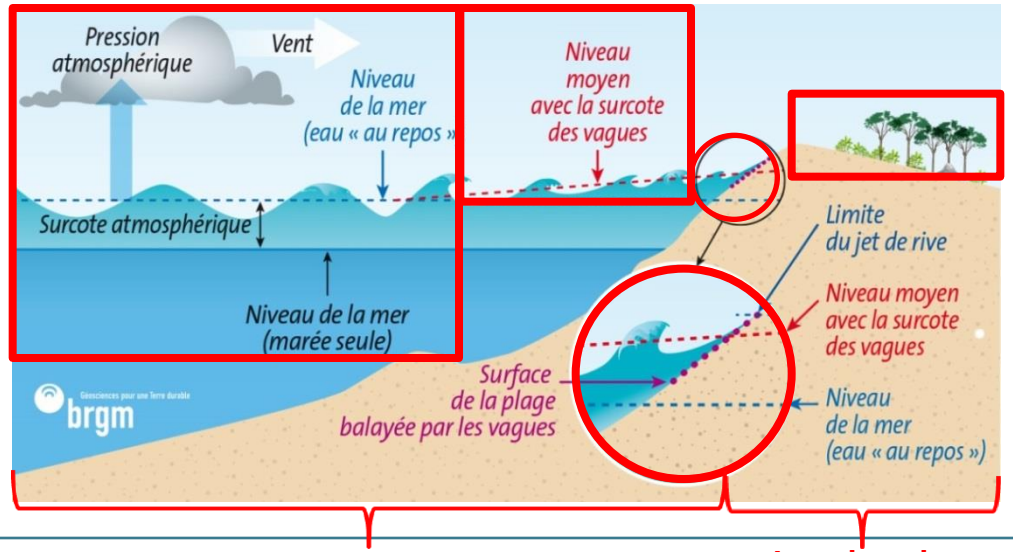
Our strategy for the hydrodynamic modelling (1)

> **Implement an optimized modelling platform comprising** :

- ✓ 2D spectral wave model (WW3) and NLSW model (MARS-2D: tide, storm surge, currents) until a resolution of 100-300m
- ✓ 1D spectral wave model profiles (SWAN) on homogeneous coastal segments to compute the wave-induced setup at 10m resolution all around the island
- ✓ 2DV non-hydrostatic free surface model profiles (SWASH) to fully simulate wave overtopping with at 1m resolution (topo-bathymetry lidar data)
- ✓ 2D NLSW model (MARS-Flood) to propagate the water flow with a resolution of 4m enabling a realistic representation of urban areas (wet-dry interface, spatial distribution of friction, river discharge, runoff, culvert and urban drainage)

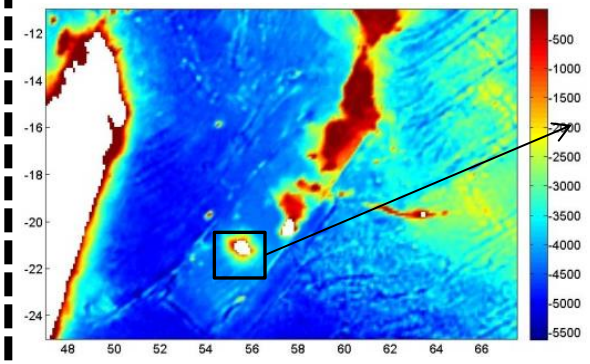
Regional scale

Local site

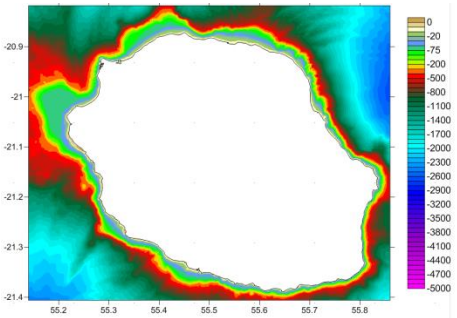


Our strategy for the hydrodynamic modelling (2)
Regional scale

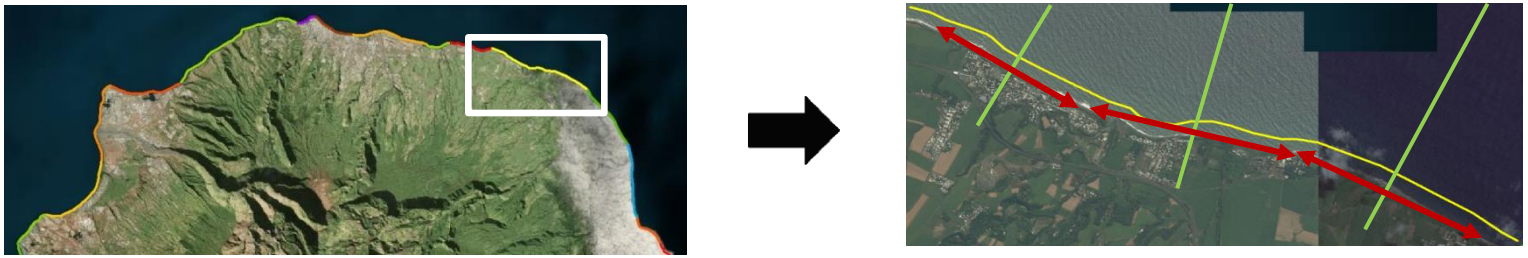
Wavewatch 3 two-way nested grids (10km => 300m)



MARS-2DH grid (100m)



Coastline segmentation and 10m resolution 1D SWAN profiles



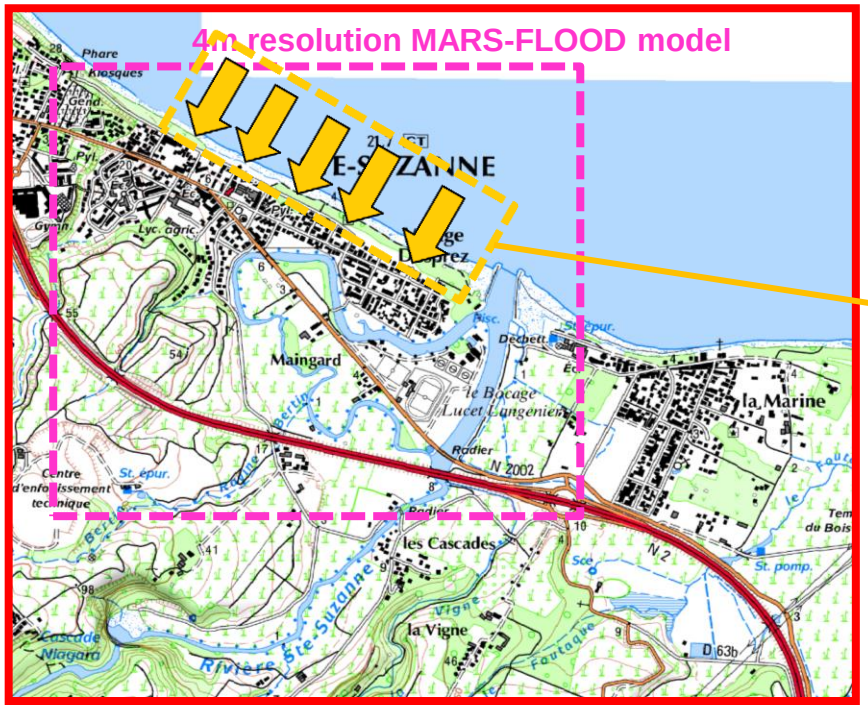
Computing time ~ 25min on 24 CPU for 24h simulated : OK!

Our strategy for the hydrodynamic modelling (3) Local scale

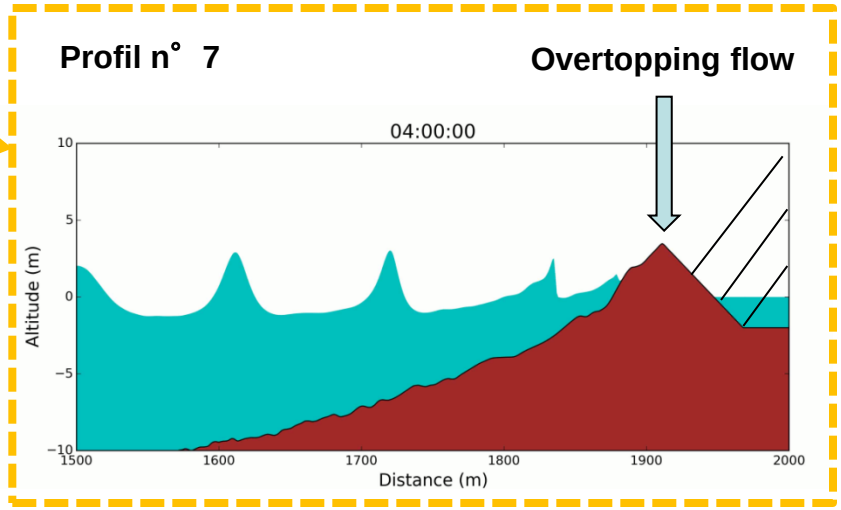
- Inputs from regional models (waves and waterlevels time series)

Sainte-Suzanne city

10m resolution MARS-FLOOD model



1m resolution SWASH profiles



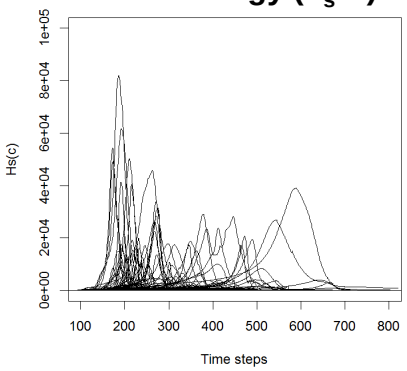
Computing time ~ 20 min on 24 CPU for 24h simulated : OK!

Computing time ~ 2h30 on 24 CPU for 24h simulated : Too long!

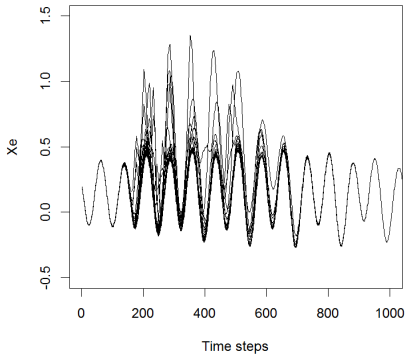
Our strategy for the hydrodynamic modelling (4)
Using meta-models for wave overtopping

> Given a database of 100 scenarios computed with full 2DV process model :

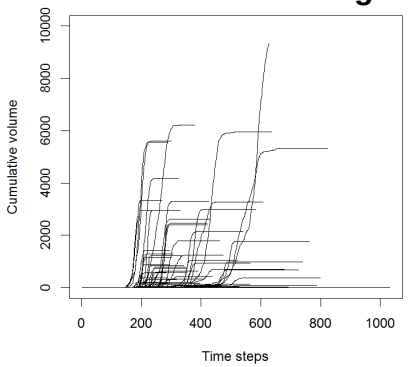
Wave energy ($h_s^2 L$)



Water level



Cumulated discharge



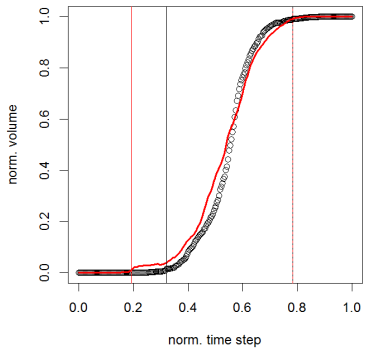
> Develop meta-models (approximations) that compute in a few seconds :

Option 1: Approximate characteristics of the time series (start/end of overtopping and max. discharge) with regression methods

Option 2: Approximate the full time series with advanced mathematical methods like Generalized Boosted Regression Models

Work still in progress but first results are promising !

Application with Dina (2002)



Simulated with SWASH 2DV

Approximated

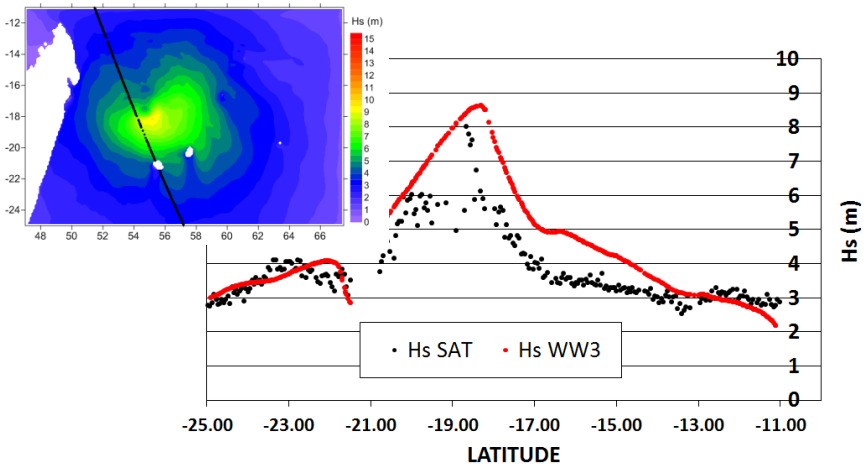
Discharge_max (SWASH): 8625 m^3

Discharge_max (approximated): 7626 m^3

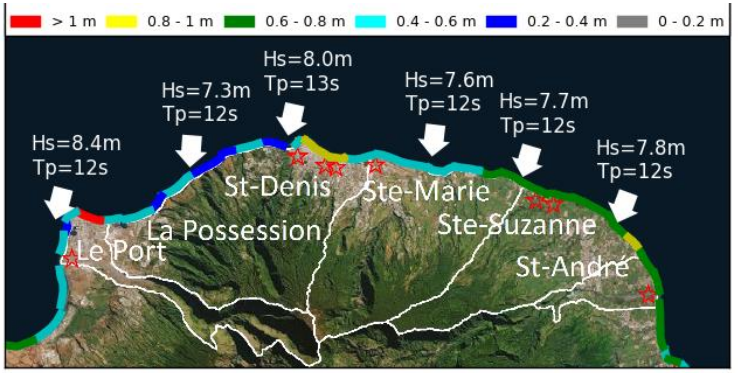
Example of reconstitution of historical events (2)
The case of Dumile (Jan. 2013) at regional scale

> Input Data : Best-track Dumile+ bogusing in Meso-NH (8km-2Km)

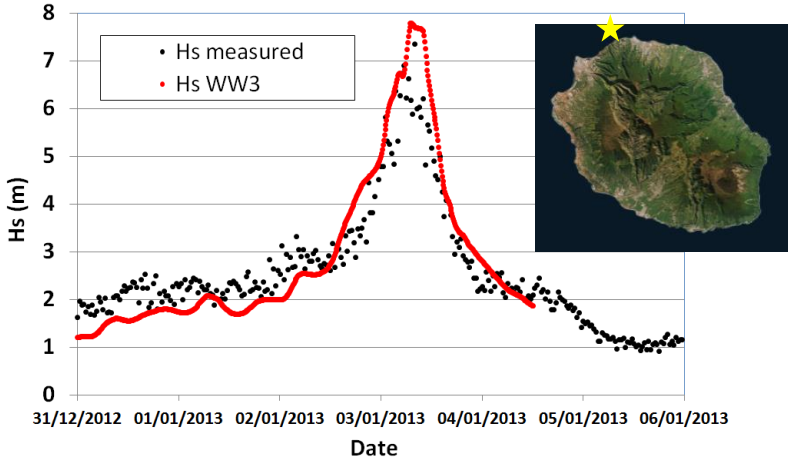
Comparison with satellite altimetry observations

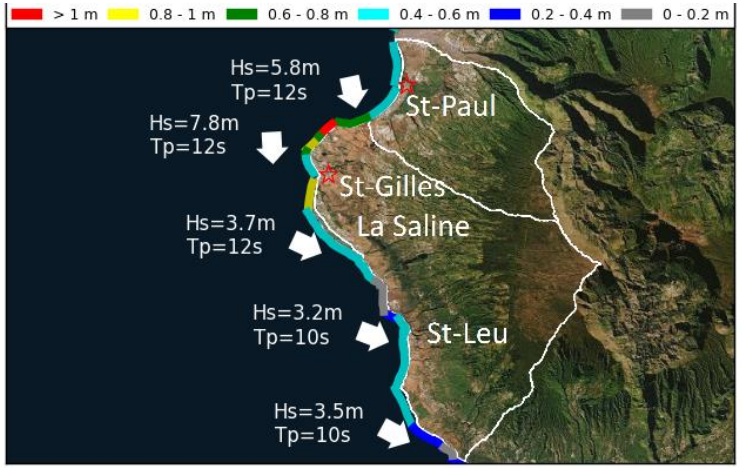


Storm surge (including wave setup)



Comparison with buoy measurements (AWAC)

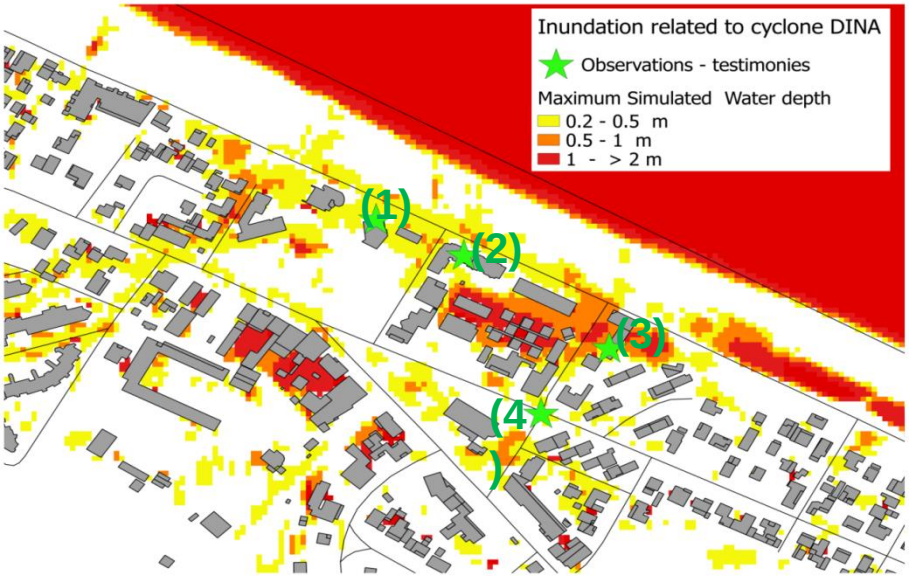




Example of reconstitution of historical events (3) The case of Dina (Jan. 2002) on Sainte-Suzanne

> Input Data : Best-track Dina + bogusing in Meso-NH (8km-2km)

SPICy « simplified » strategy (Zoom)



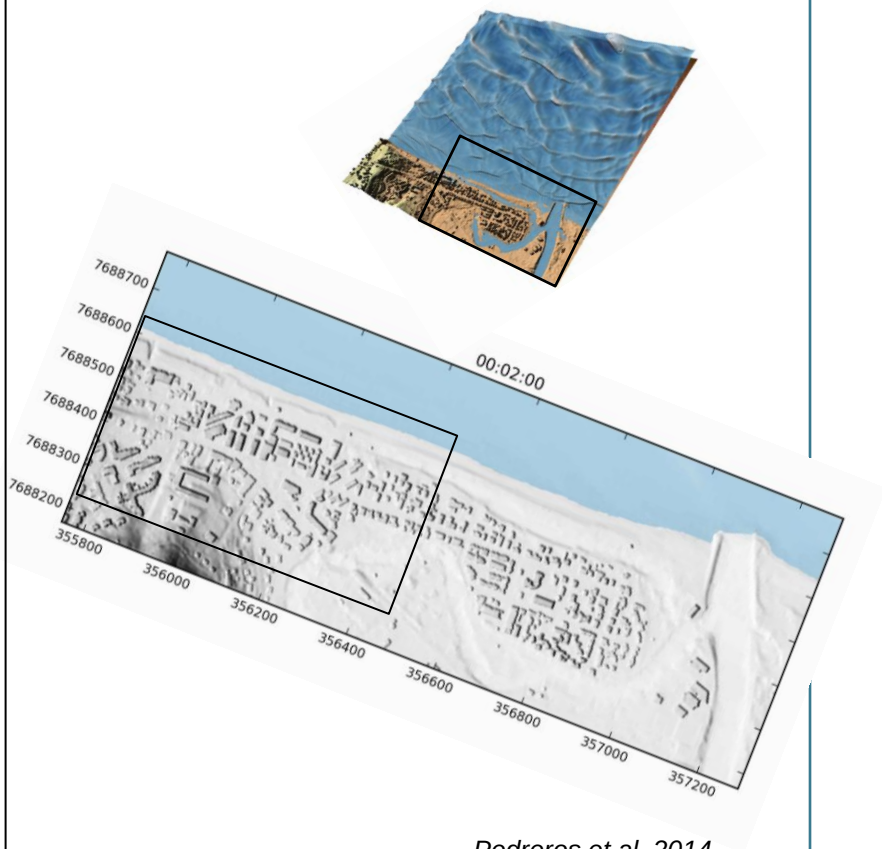
(1) « Building destroyed by waves »

(2) « Six flats inundated at street level »

(3) « Firestation inundated »

(4) « Street Desprez and post station is inundated »

Comparison with a « full processing modelling » (SWASH 3D, 2m resolution)

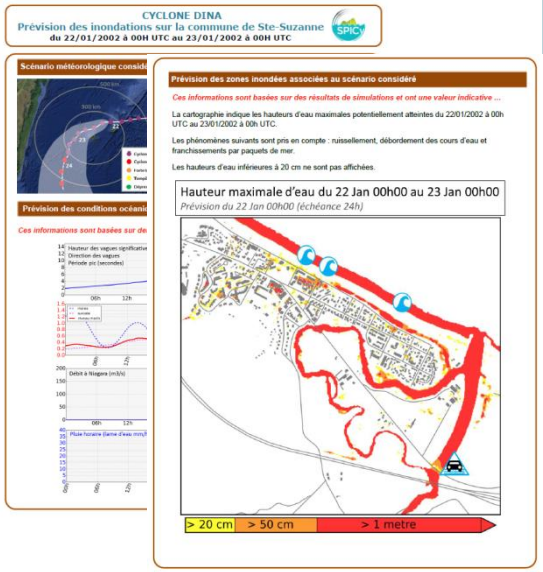


Pedreros et al. 2014

Next steps, next questions

> Test the tools with ensemble forecasts

- Qualification of the forecast : Scoring? Reliability diagrams. Talagrand diagrams?
- Optimization of the number of tracks to simulate
- How to represent results in an intelligible and useful manner for emergency managers ?
- …….



> First crisis exercise in June 2016

To follow the project …

THANKS!

http://spicy.brgm.fr : in english very soon, with (un)like buttons!