



STORM IMPACT ON A FRENCH COASTAL DUNE SYSTEM

MORPHODYNAMIC MODELING USING XBEACH



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Project STRASS (STORM ATTACK ON COASTAL DUNE SYSTEM)

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JONSMOD, 12-14 May 2014 BRUSSELS



Framework

- > 20% of EU's coastline affected by erosion (EU commission)
 - > France: 35% of sandy coast, half subject to erosion (EuroSION 2004)
 - > Erosion is amplified during storm events and can lead to sudden failures of dune systems due to hydrodynamics and morphodynamics mechanisms
 - > Besides, high stakes are protected by coastal dunes
- ➔ Necessity to assess, anticipate and mitigate coastal flooding due to sand dunes breaches



Aim

- > Understand hydrodynamics and morphodynamics mechanisms at work on sand dunes during storm events
- > Determine the feasibility of modelling sand dunes behavior during storms



Cape cod USA mars 2013, MaggieDu/FlickrR



Contents

1. Breaching processes (hydrodynamics & morphodynamics)
2. Xynthia storm event
3. Description of the studied area and its behaviour
4. Modelling
5. Results

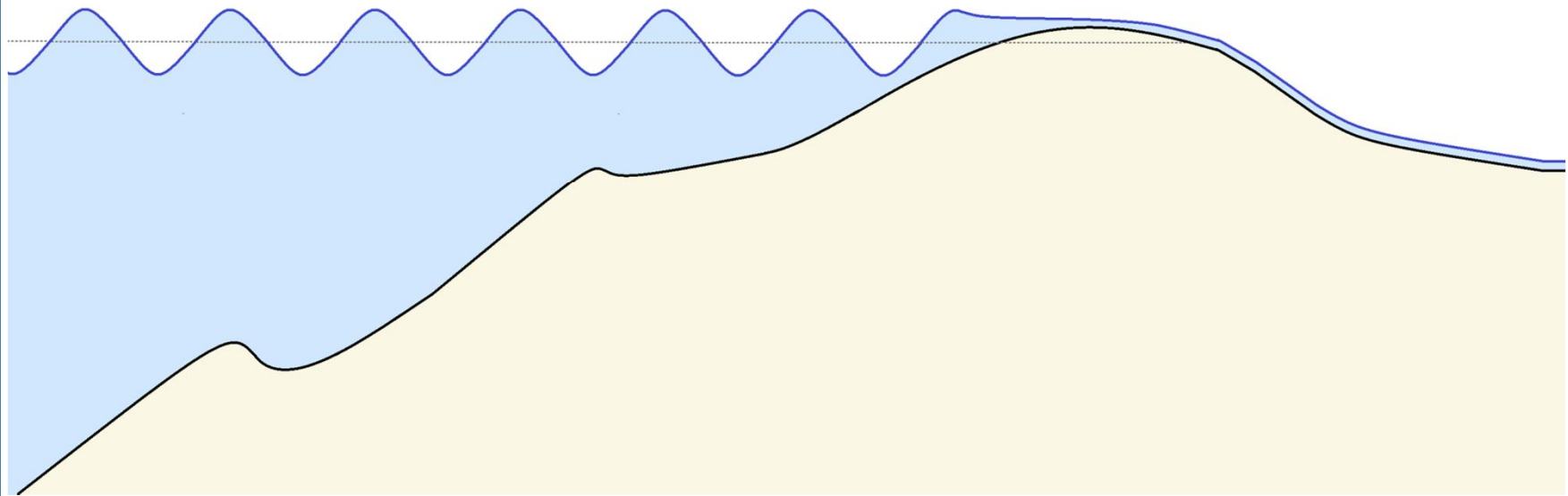


Process leading to breach

Wave impact

Sea side

Land side



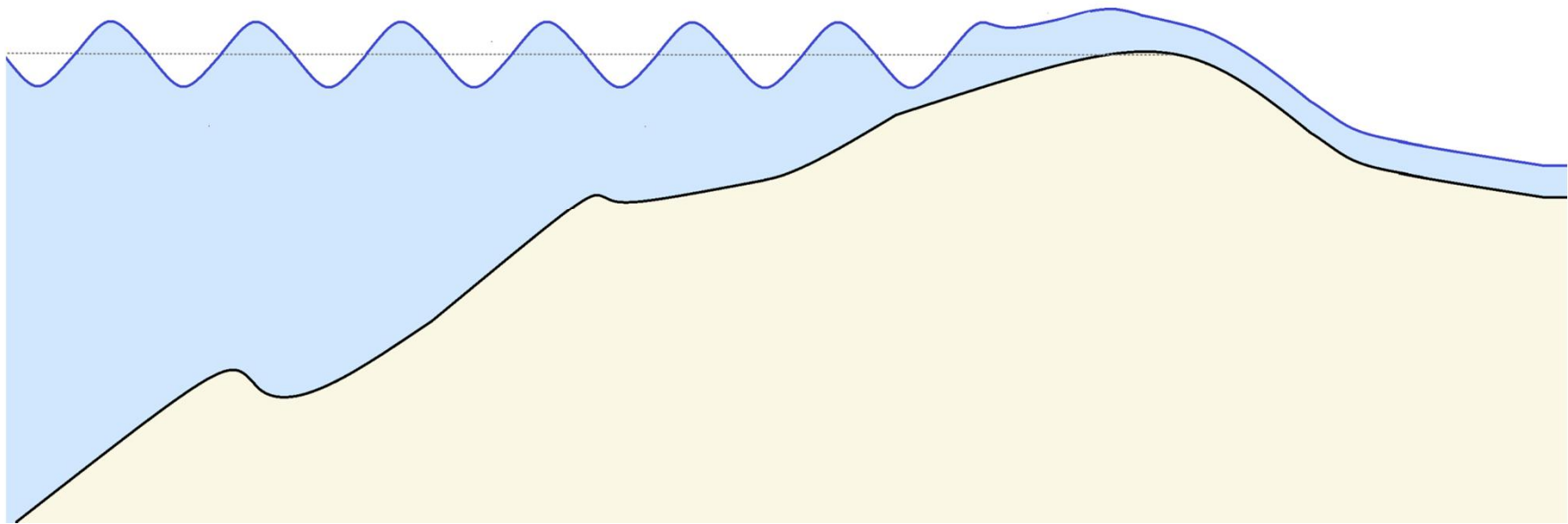


Process leading to breach

Overtopping

Sea side

Land side





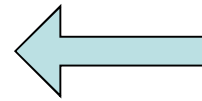
Process leading to breach

Overflowing

During ebb tide

Sea side

Land side



*External erosion
+
Instability*



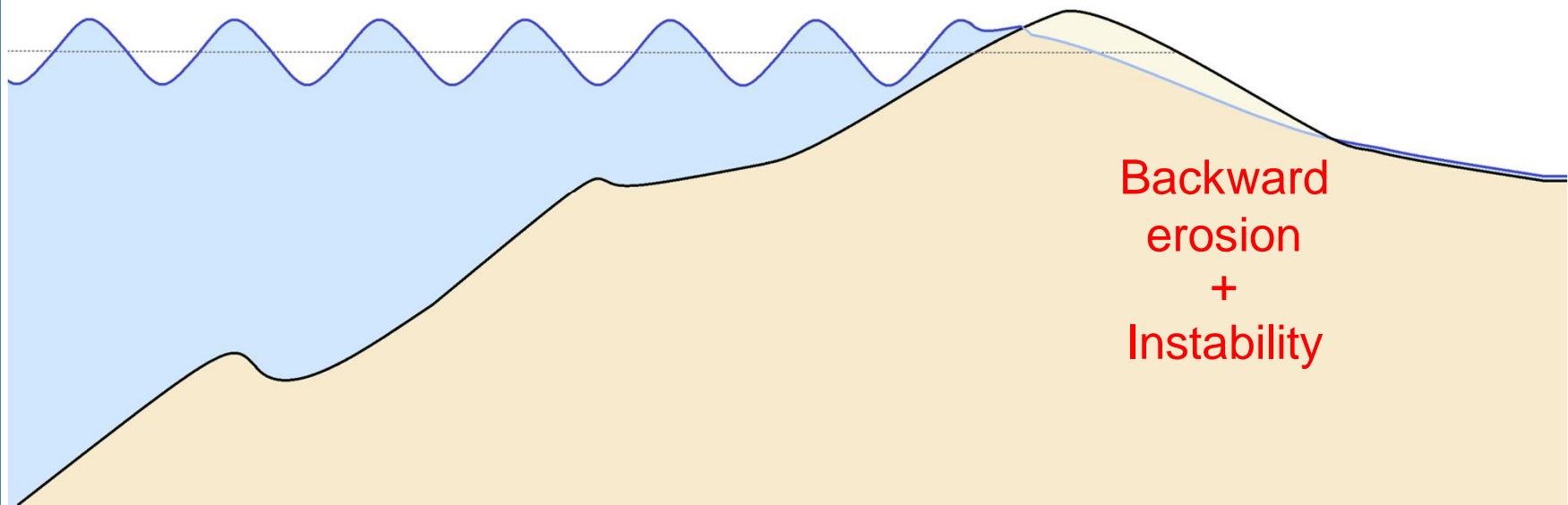


Process leading to breach

Internal erosion

Sea side

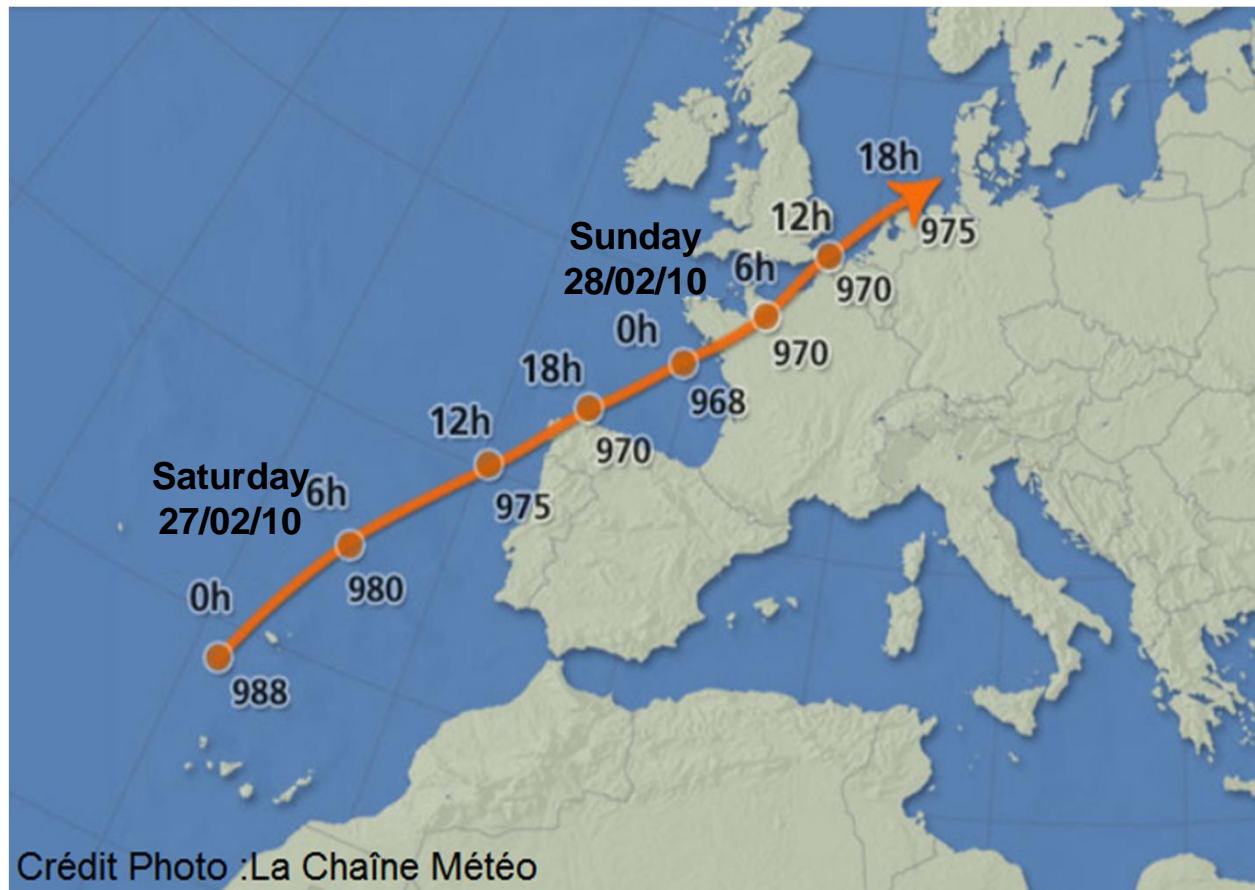
Land side



Backward erosion
+
Instability



Xynthia storm event: 27-28 February 2010



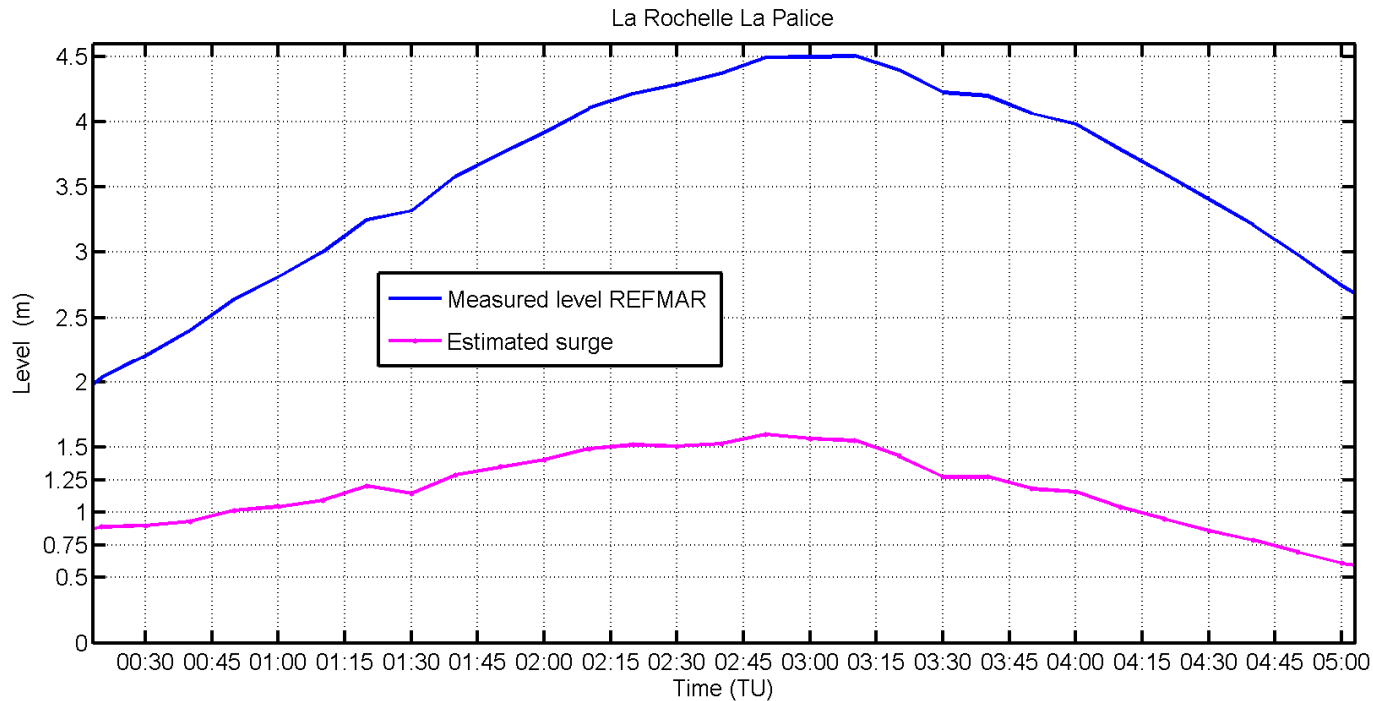
Storm trajectory



Water level during the storm

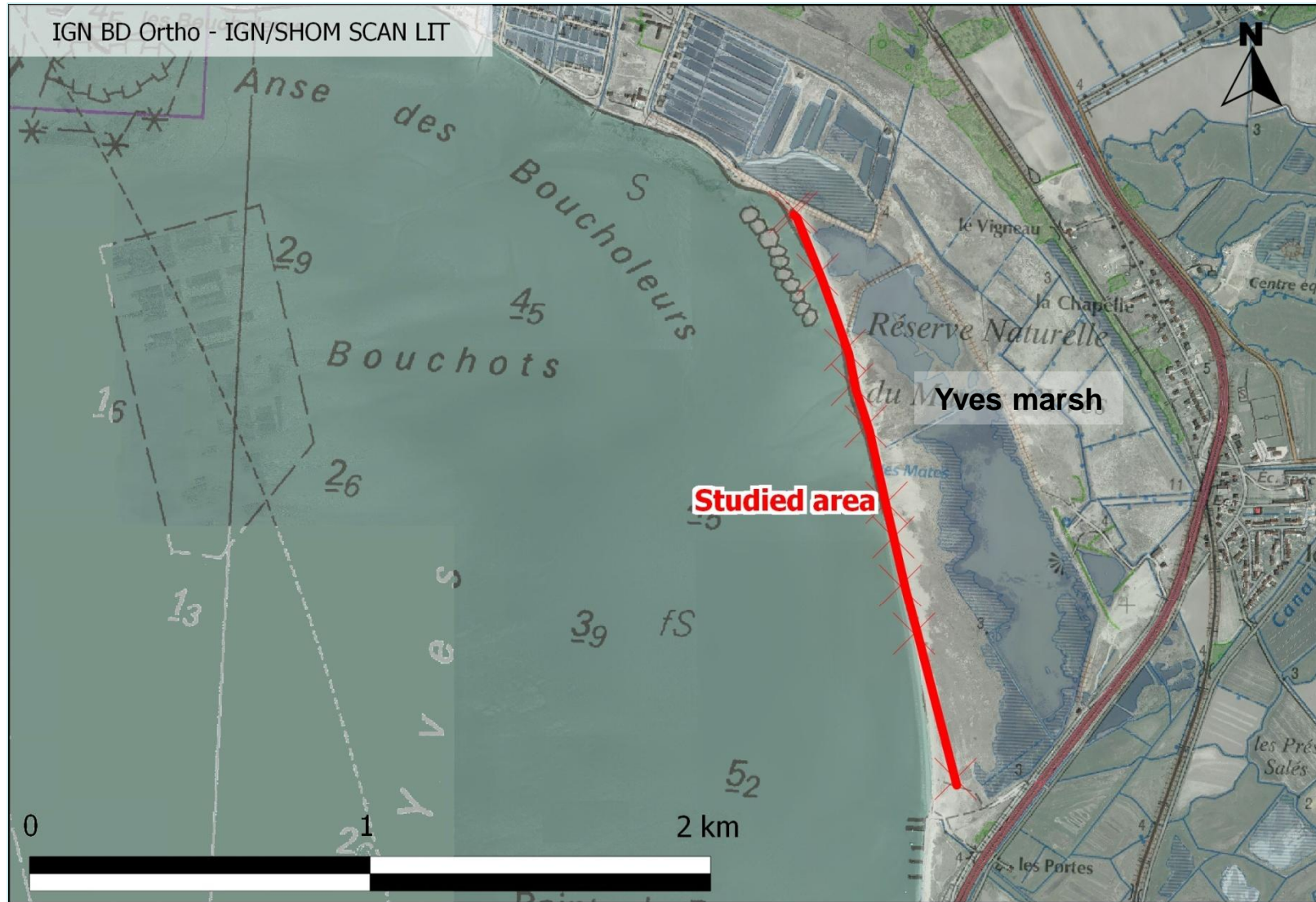
Tide gauge	La Rochelle – la Pallice (SHOM)
Max. Water height during storm	4,51m IGN69
Surge during high tide	1,53m
Water height for a 100-year return period	3,90 – 4,0 m IGN69

CETE de l'Ouest, data from SHOM/CETMEF/ port maritime de Nantes





Studied area : les Boucholeurs



Studied area : les Boucholeurs

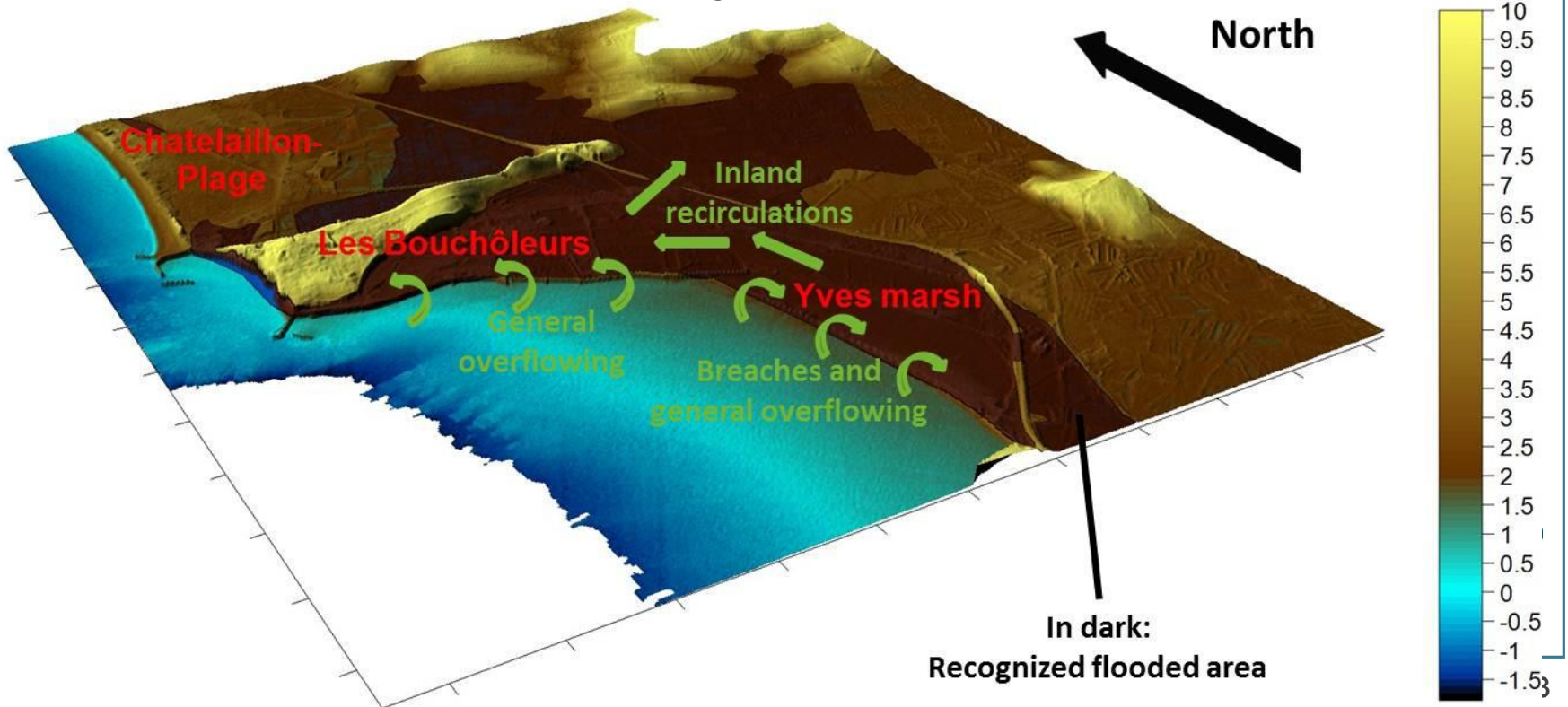
- > Sandy dunes
- > Protecting Yves marshland (natural reserve)
- > On Xynthia trajectory





Les Boucholeurs : storm's effects

- > Submersion of the protected area due to
 - High water level
 - Tide
 - Atmospheric surge
 - Wave setup
 - Erosion and breaching over the Yves marsh dune





Les Boucholeurs : submersion

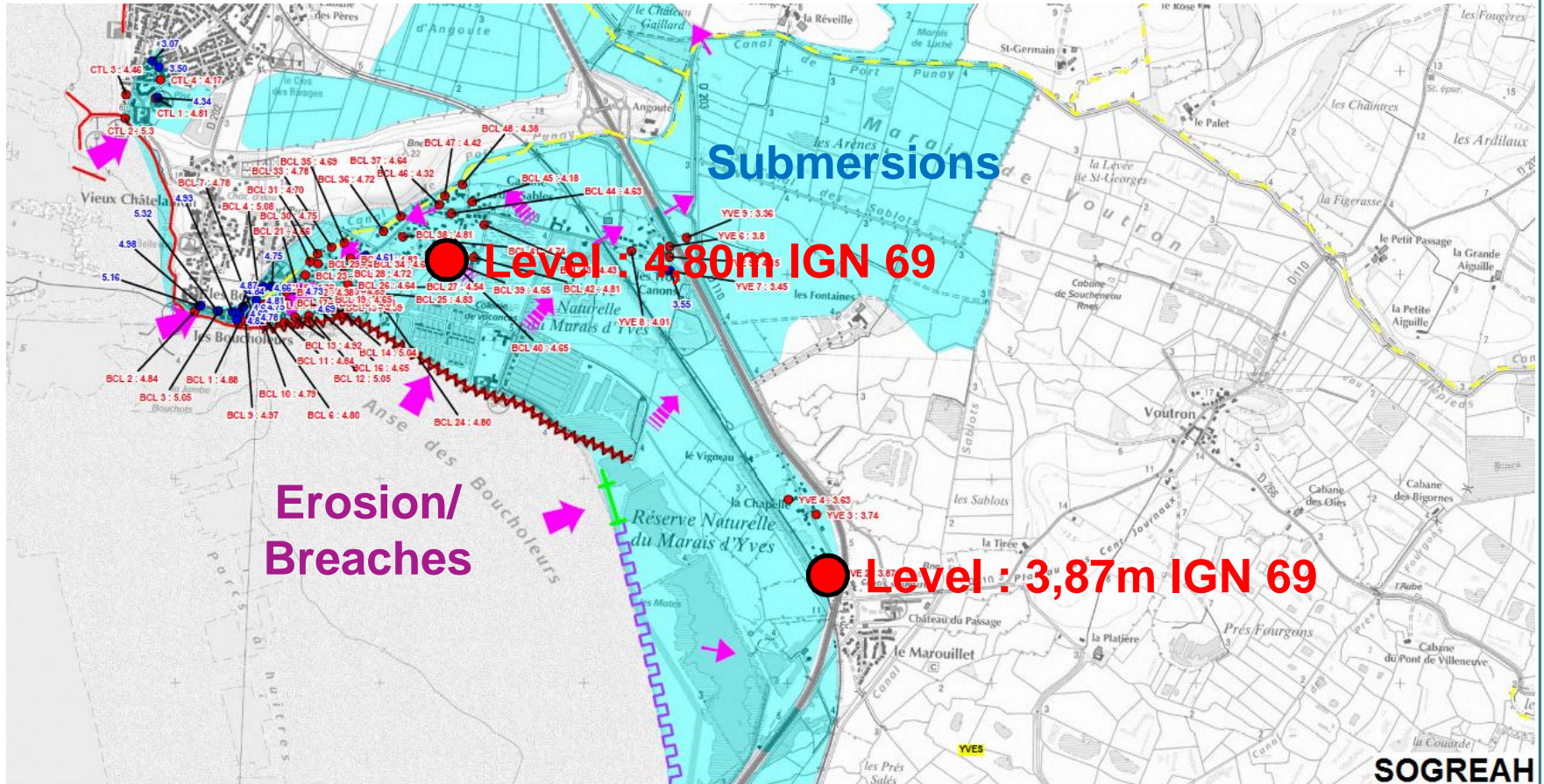


Overview of the flooding

Yann HERMIEU/LPO Report



Les Boucholeurs : submersions



Damages on Boucholeur area



Les Boucholeurs : dune damages



Breach during Xynthia storm

P. Sauvage (CDL)/ LPO Report



Les Boucholeurs : dune damages



Breach during Xynthia storm

ML Cayatte/ LPO Report



Model set up

> Hypothesis

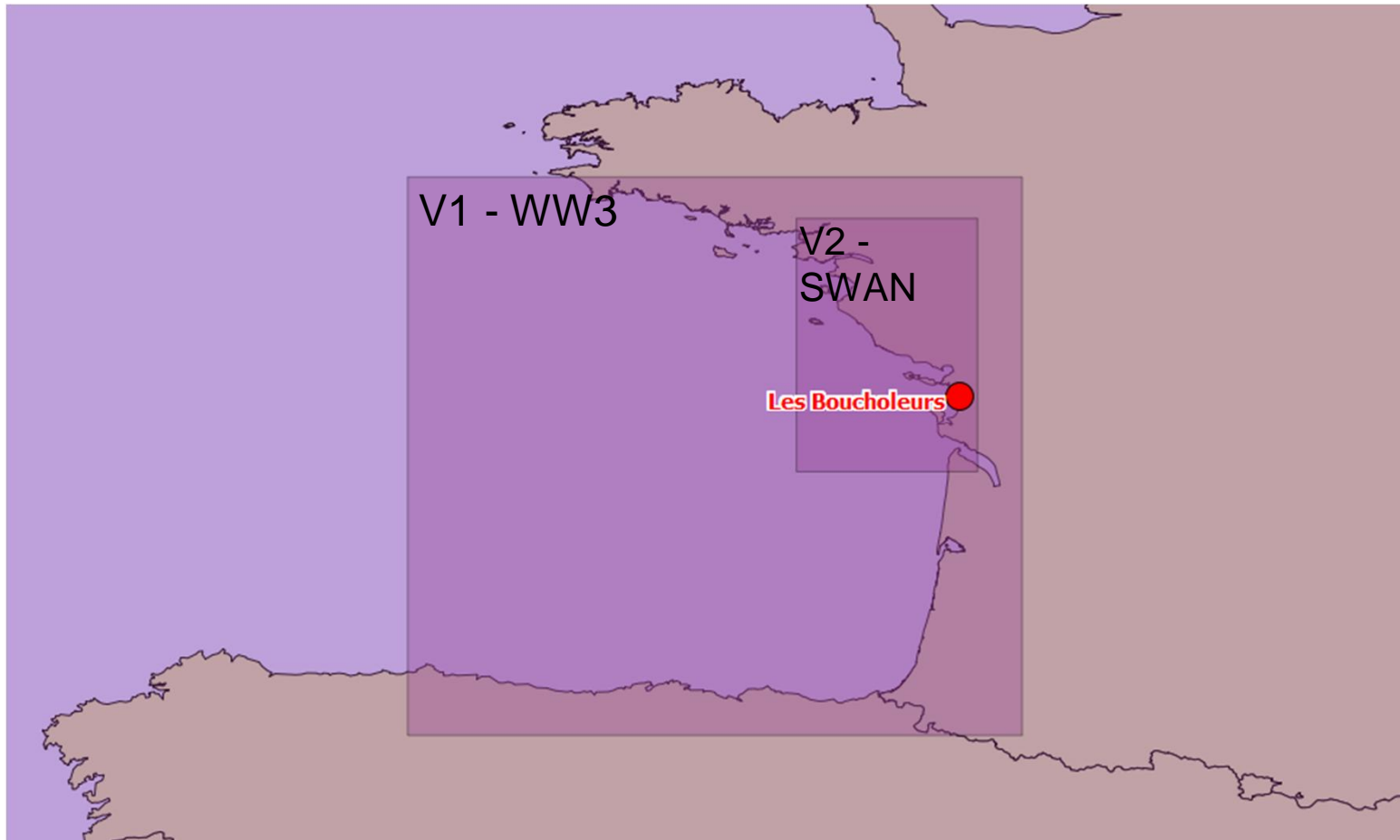
- 2DH approach
- Nearshore circulation & morphodynamics induced by:
 - Waves
 - Water level (tide, atmospheric surge & setup)
- Fine sand $D_{50}=0,2\text{mm}$

> The depth-averaged coupled model : XBEACH (Roelvink et al, 2009)

- Wave action balance
- SW equations + wave forcing terms
- Advection-diffusion equation for suspended transport
- Bed level change equation + avalanching



Embedded waves models



WW3 : Wave Watch III NOAA/NWS/NCEP
SWAN : Simulating WAVes Nearshore TU DELFT





Embedded hydrodynamical models



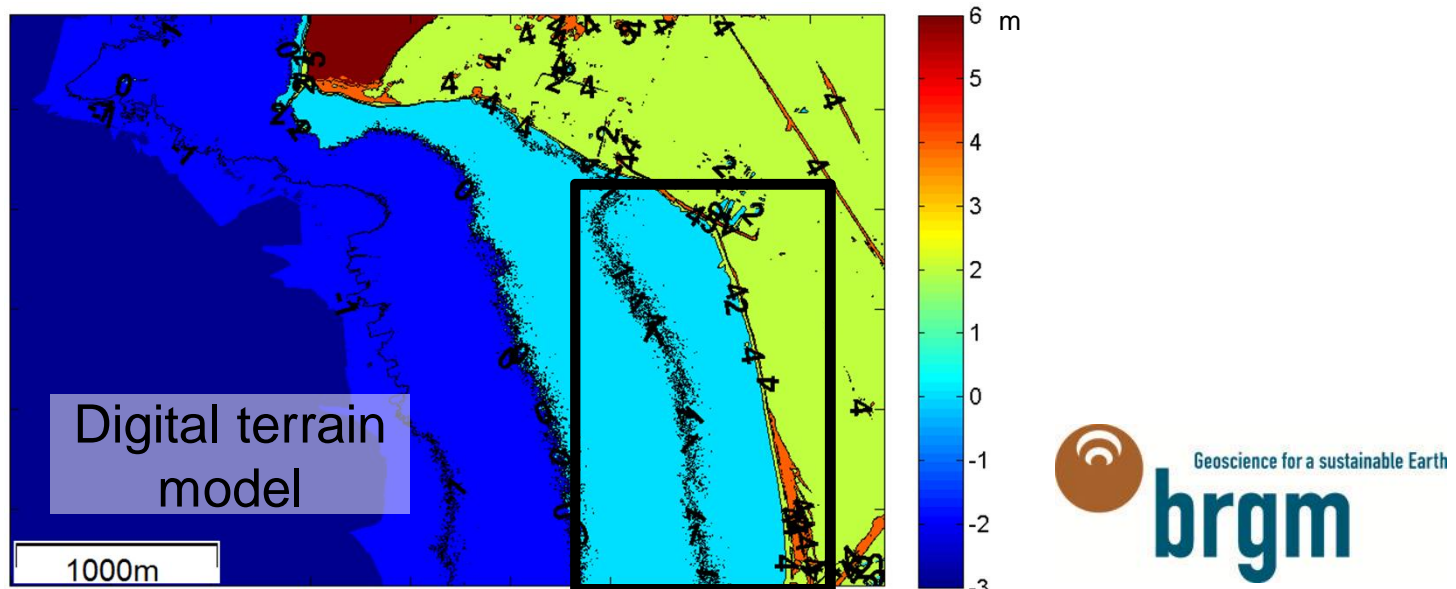
MARS 2D : Model for Applications at Regional Scale IFREMER





Model set up

- > Initial bed level based on:
 - Post-storm LIDAR elevations (after remedial works) 1m X 1m grid
 - HISTOLITT depths (IGN & SHOM)
- > Grid spacing set to 5 m





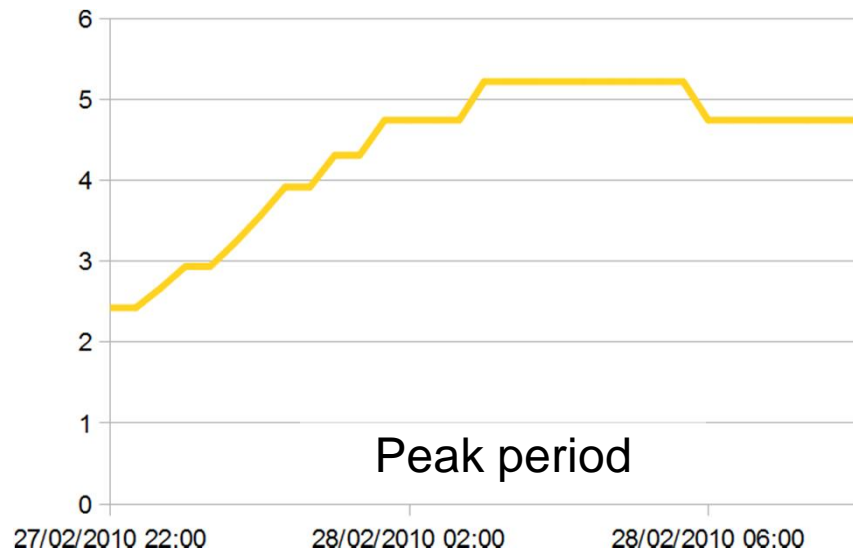
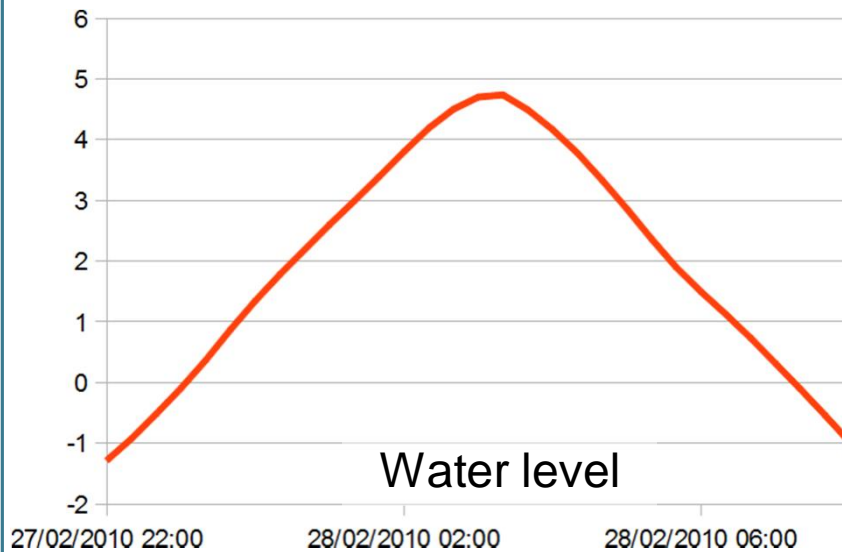
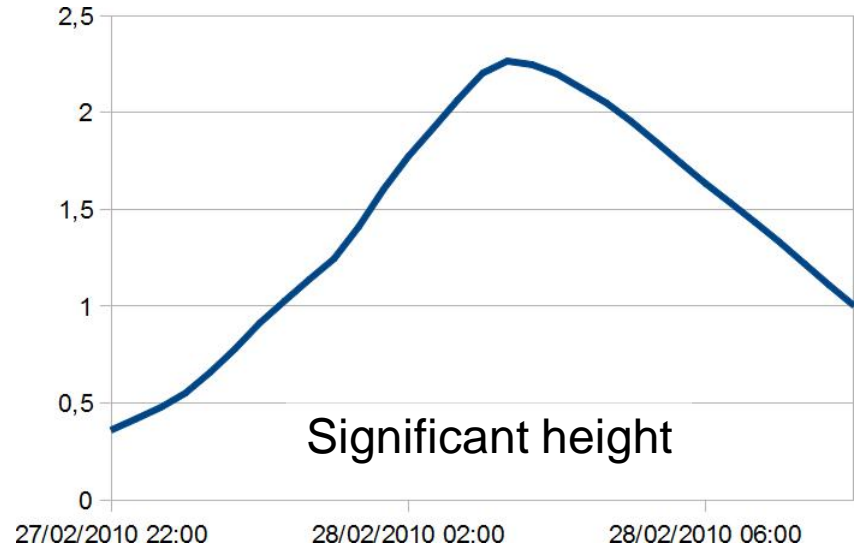
Boundary conditions

> waves conditions

- Issued from SWAN
- Sequence of wave groups
(direction 250° - 300°)

> Water level as a sum of

- MARS WL (tide +atmospheric surge)
- SWAN wave setup





Model set up

> Key model parameters :

- Morphological acceleration factor $morfac = 1$
- Shields parameter for sheet flow $\theta_{sf} = 1$
(McCall et al, 2010)

$$\theta_{sf} = \frac{v_{cr}}{C^2 \Delta D}$$

v_{cr} Critical velocity

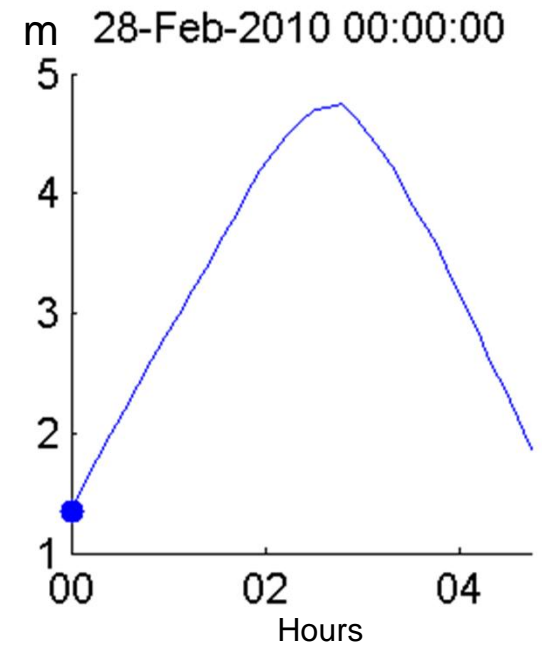
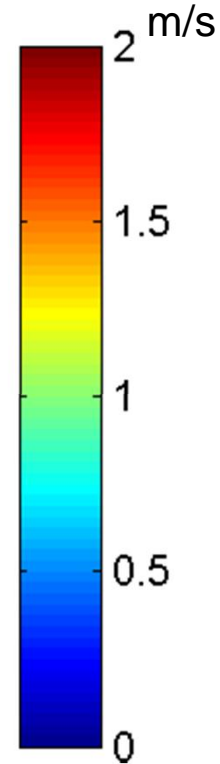
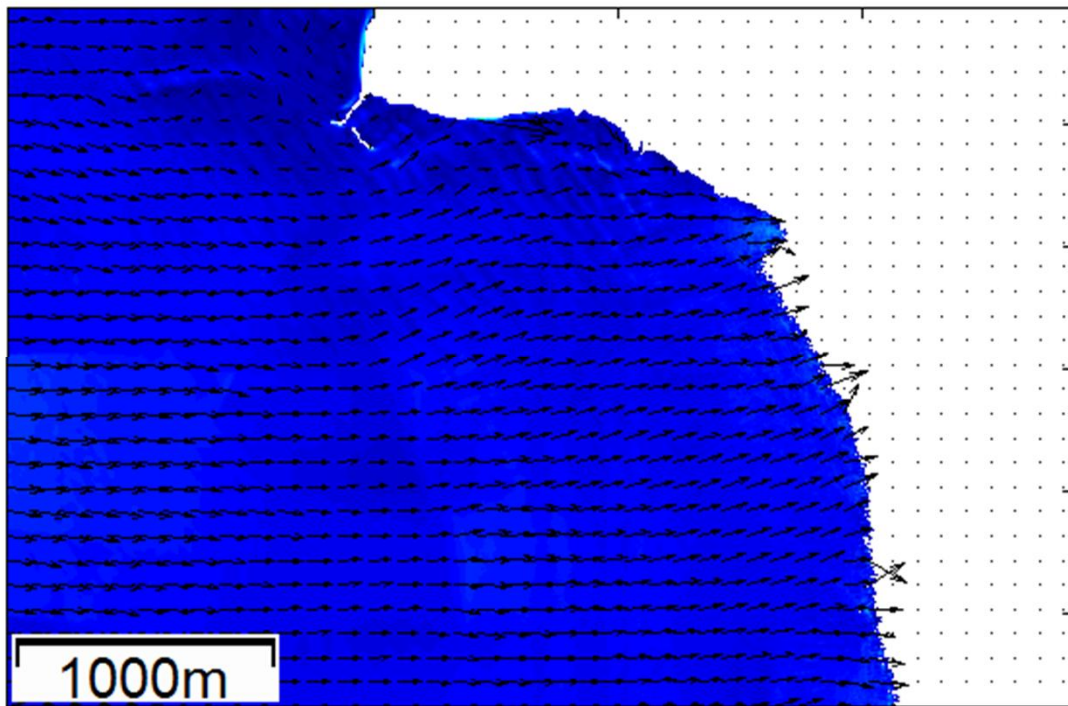
D Median size of materials

Δ Relative particles buoyant density

C Chézy friction coefficient



Results : Currents

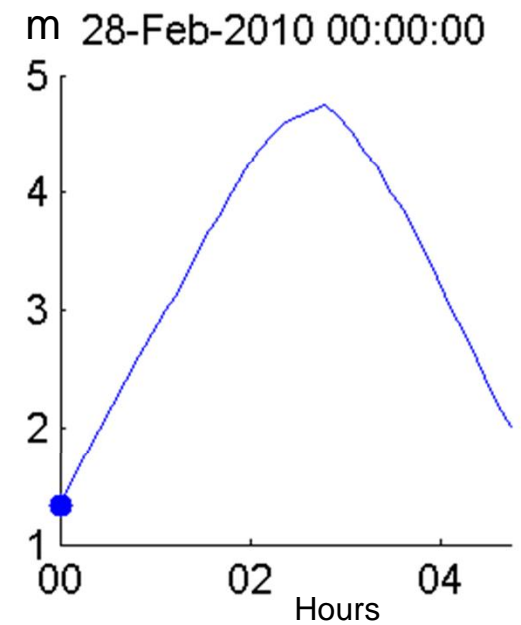
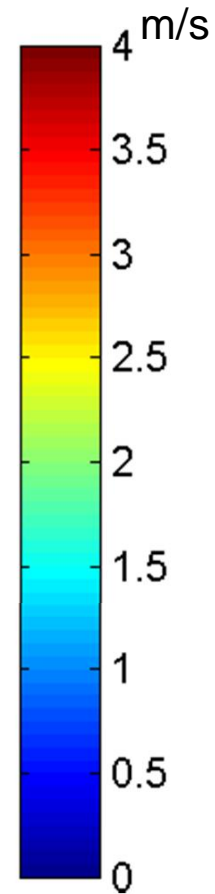
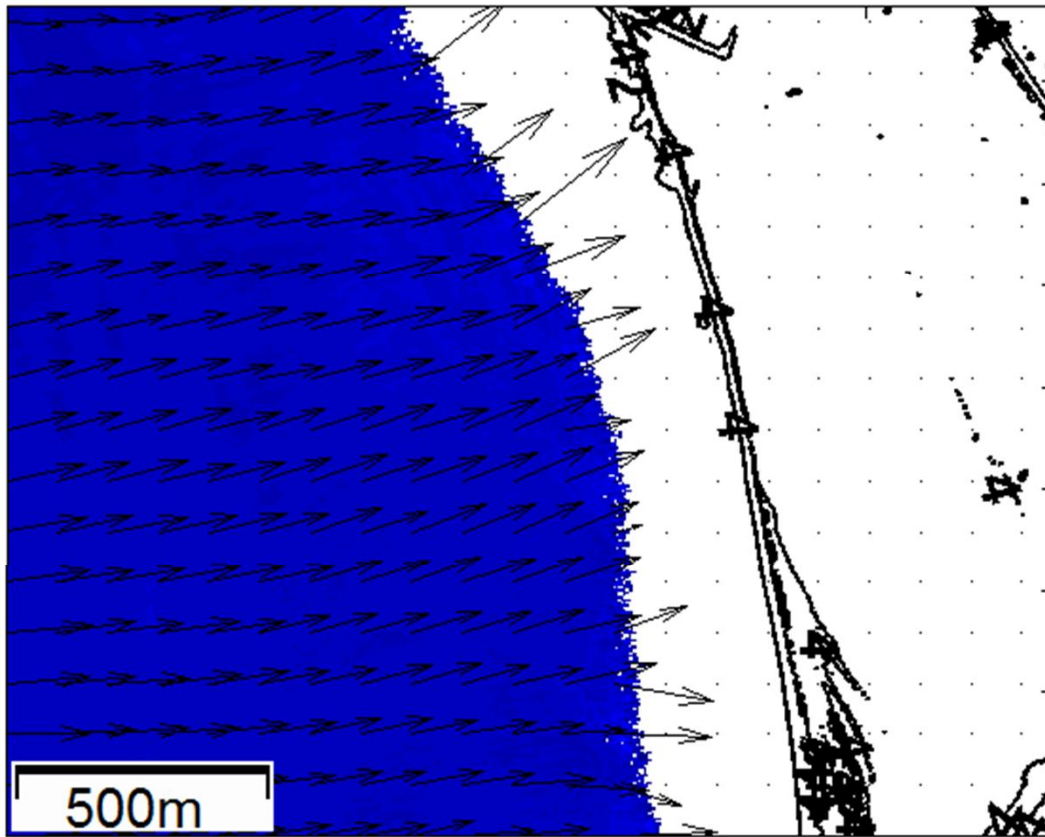


Water level

Currents on the whole area



Results : Currents



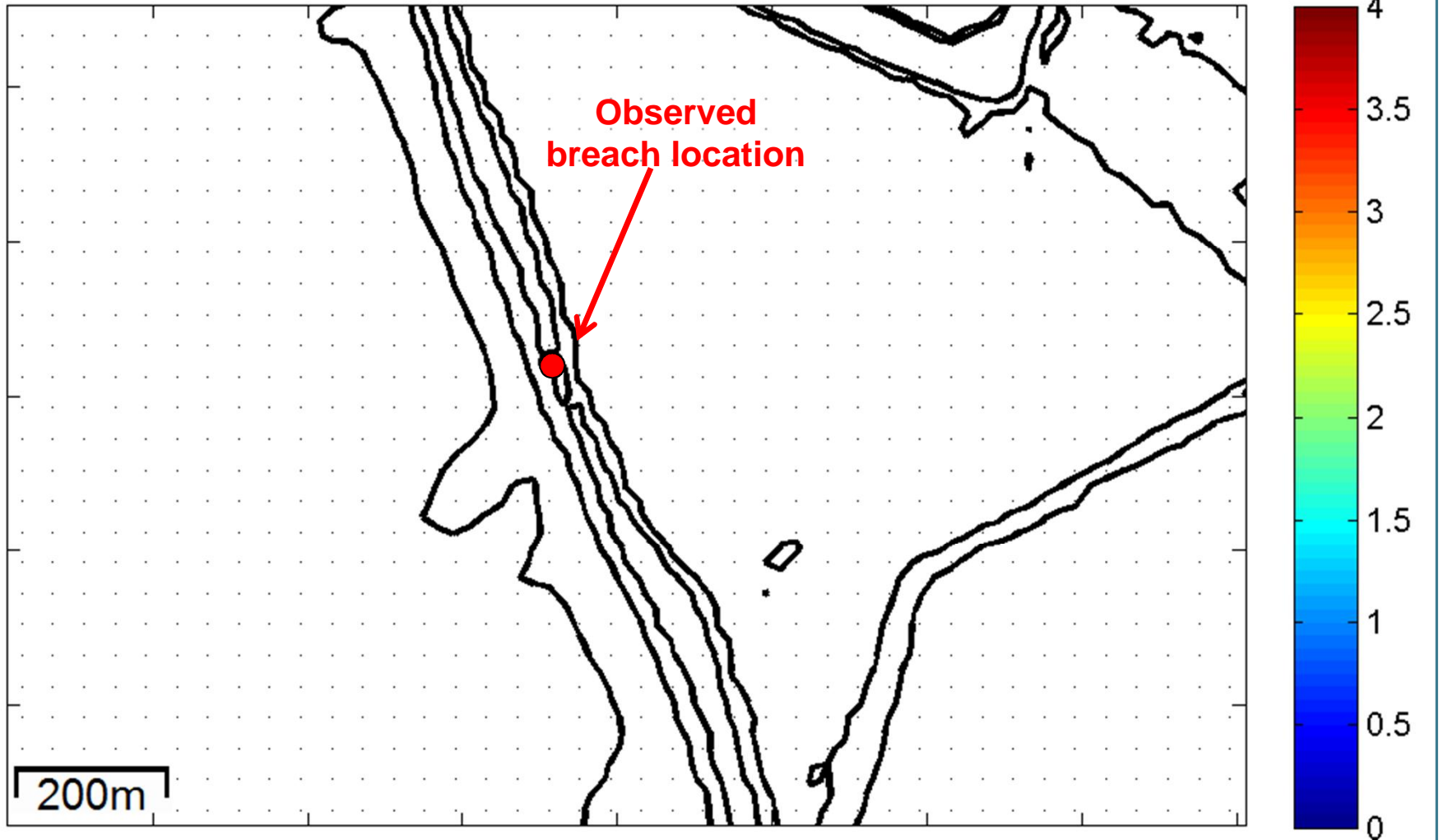
Water level

Currents on Yves marsh



Results : Currents

28-Feb-2010 00:00:00



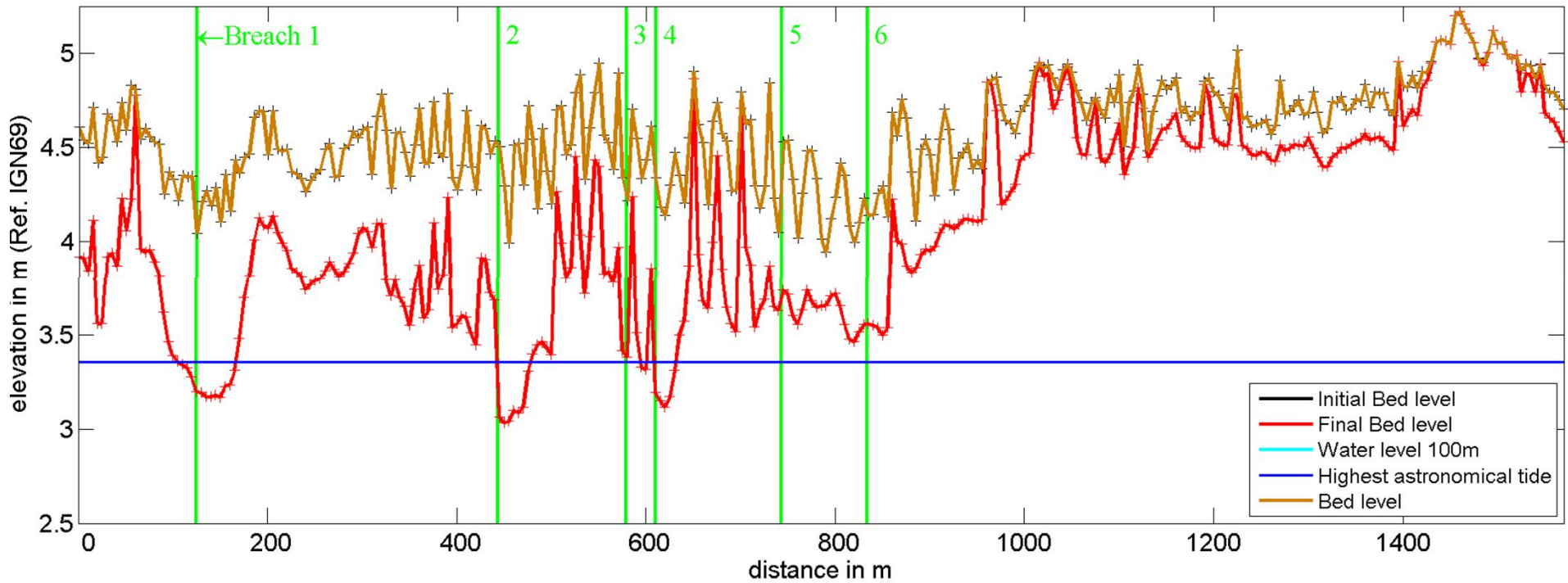
Currents on a breach



Results : Dune level



crest line 28-Feb-2010 00:00:00



Long shore profile of dune crest



Comparison to observations

> Submersion on Yves marsh

3,87 m measured VS 3,82 m model (IGN 69)

> Breaches locations and breaches dimensions

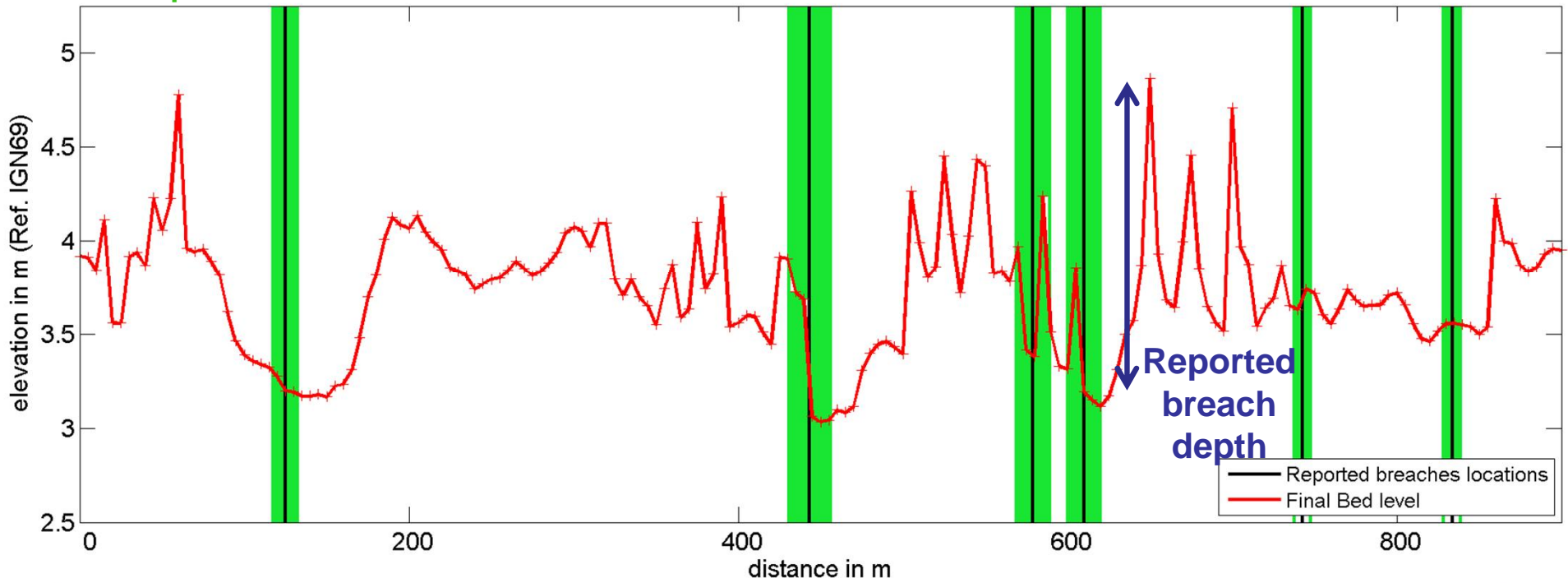


Comparison to observations



crest line 28-Feb-2010 05:40:00

Reported breaches width



**Reported locations of breaches
on long shore profile**

1,5 m VS 1,7 m
Observed model

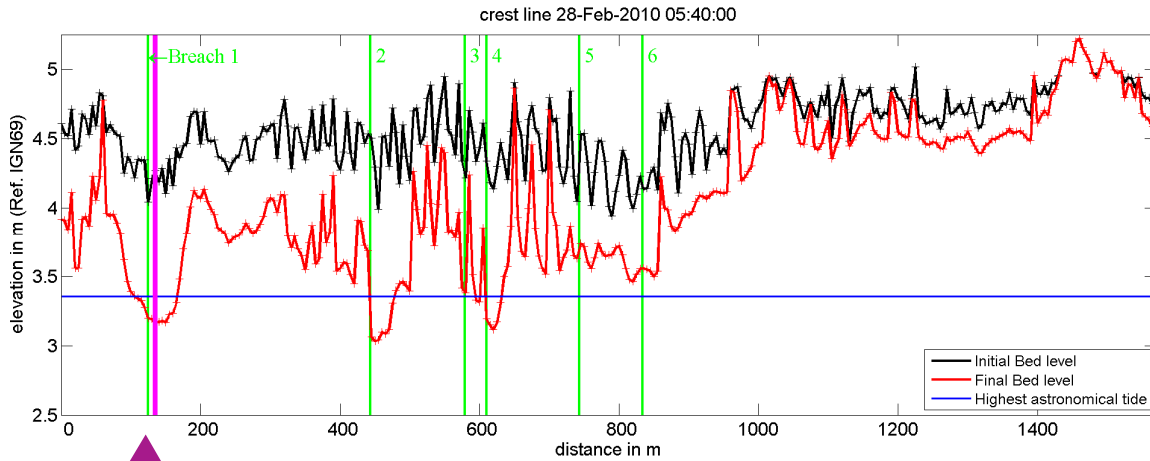


Comparison to observations

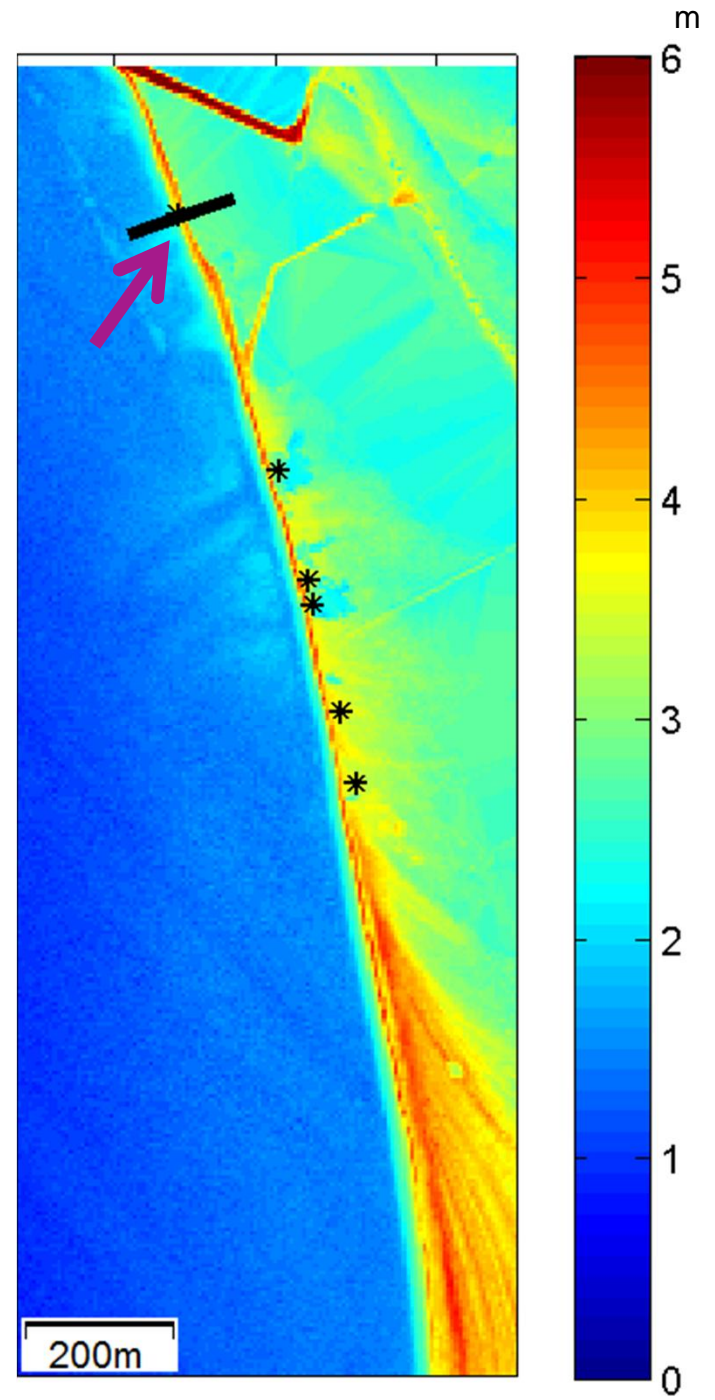
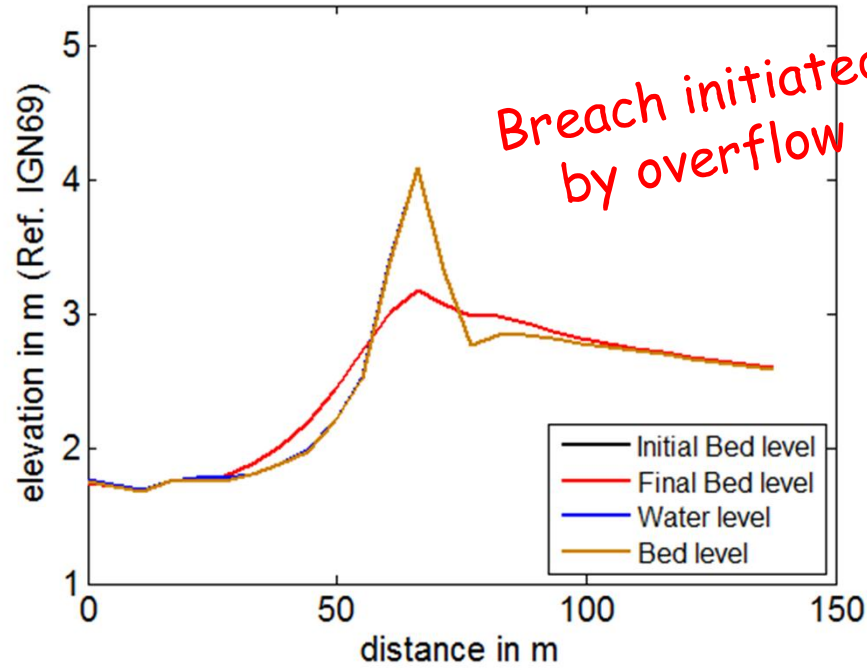
- > Submersion on Yves marsh
3,87 m measured VS 3,82 m model (IGN 69)
 - > Breaches locations and breaches dimensions
 - > Observations during recovery
- ➔ Few metadata available**



Breach profile 1

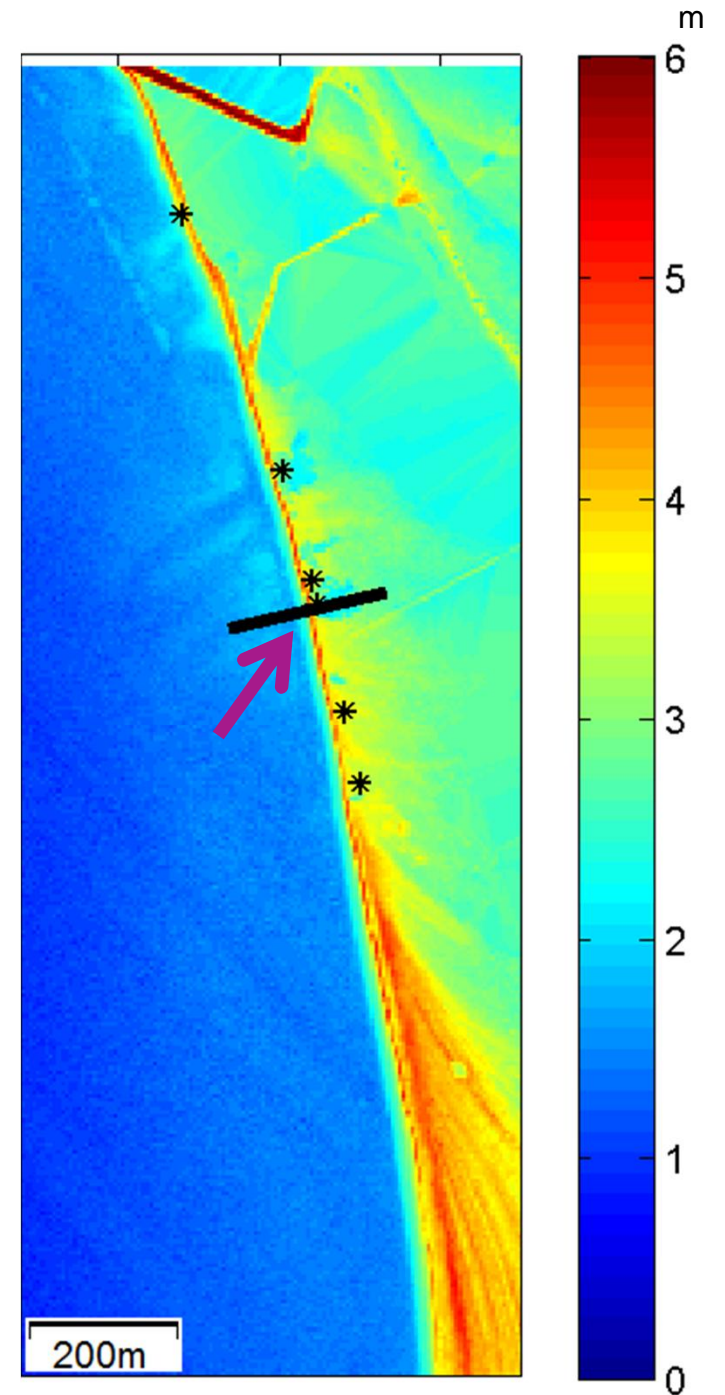
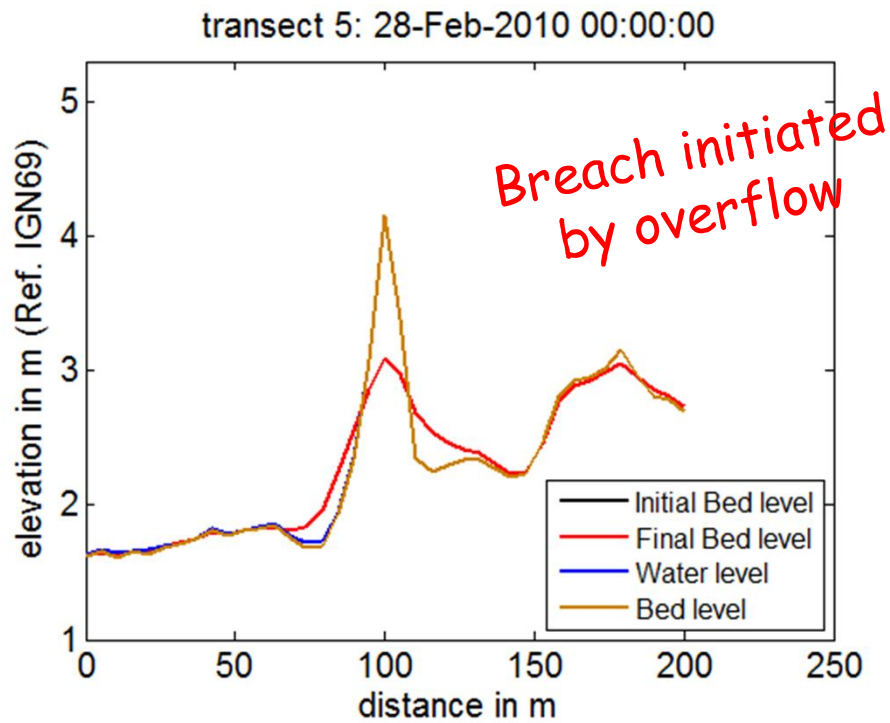
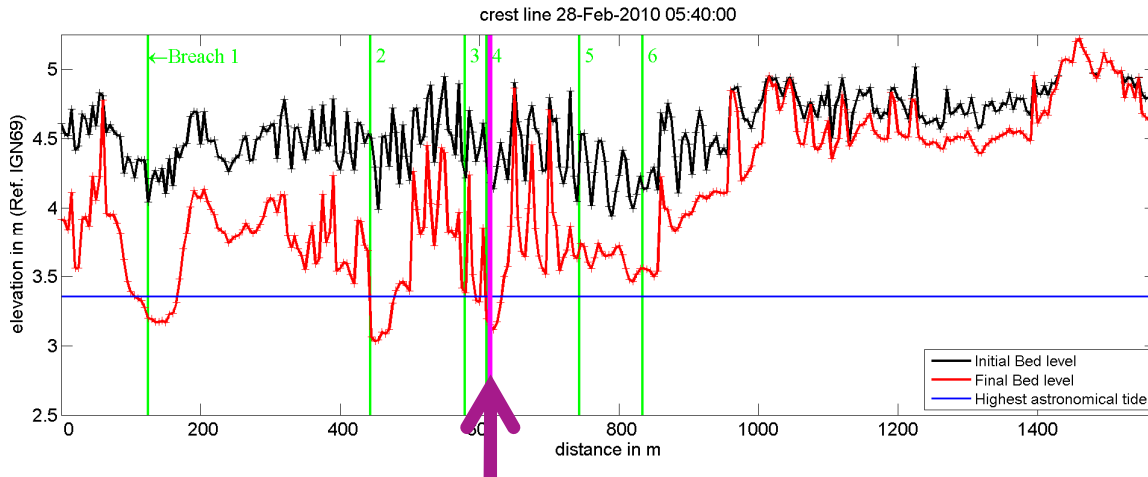


transect 2: 28-Feb-2010 00:00:00



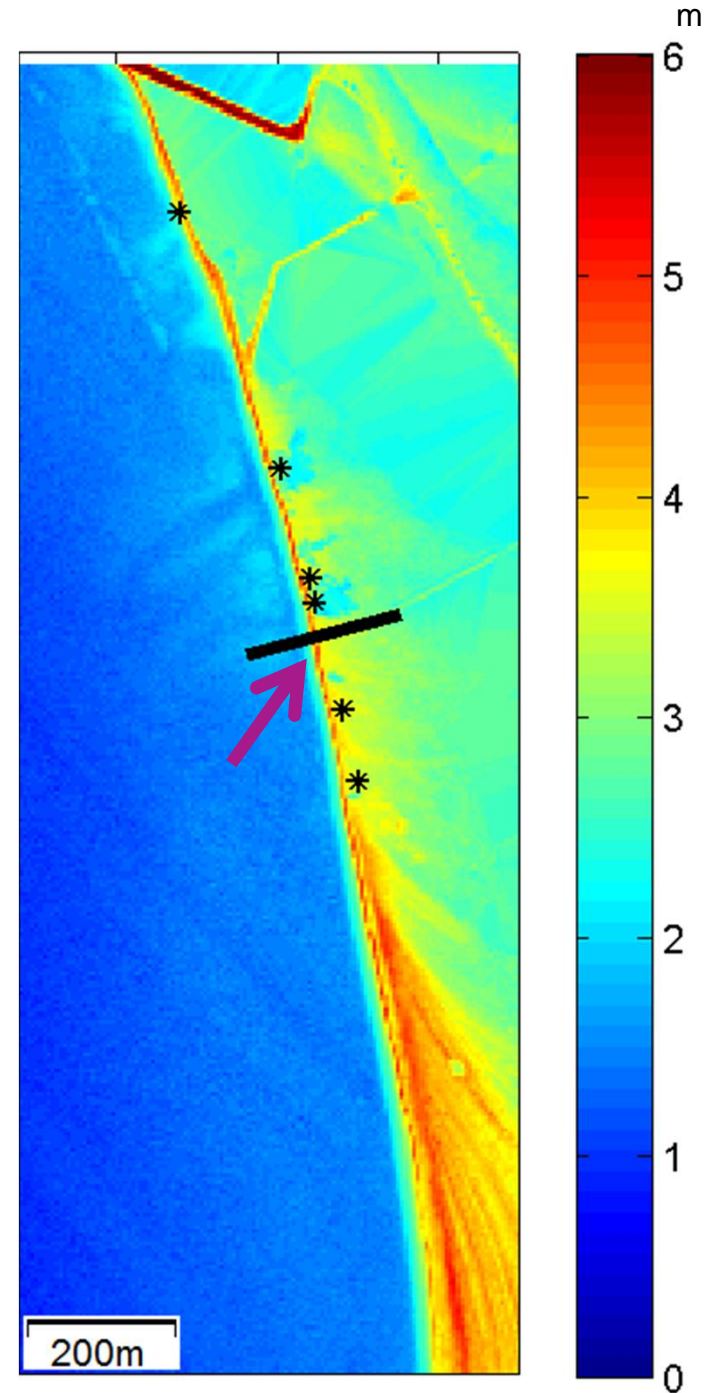
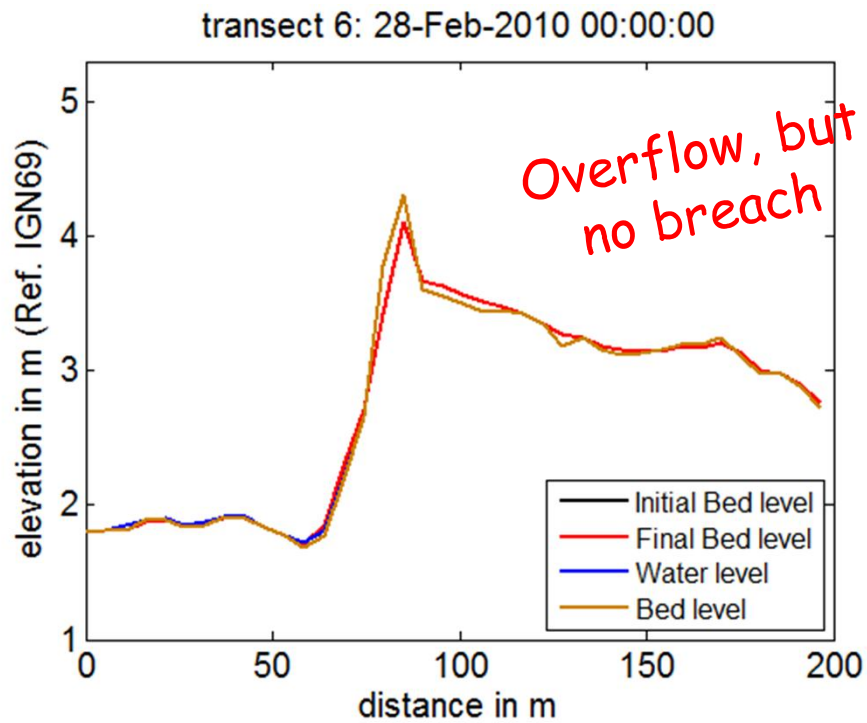
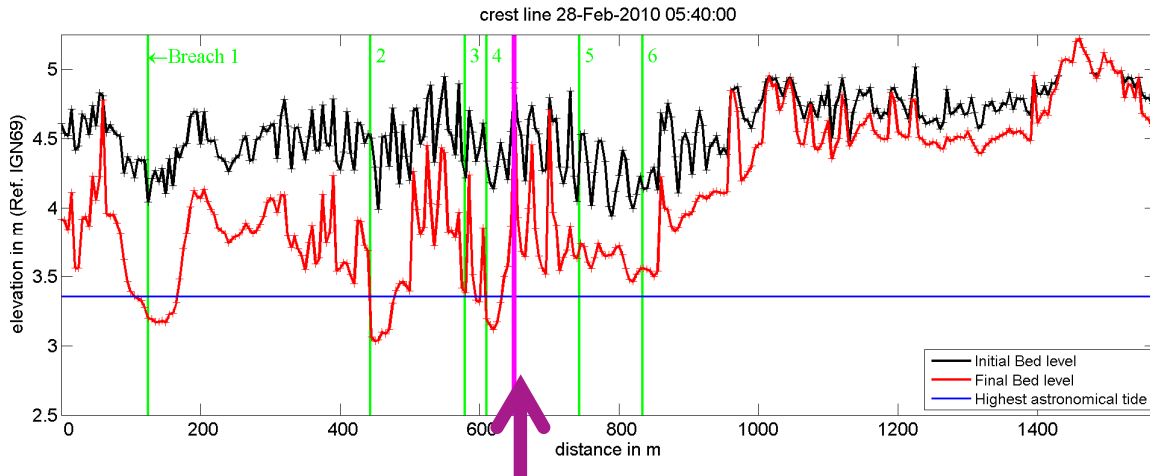


Breach profile 4



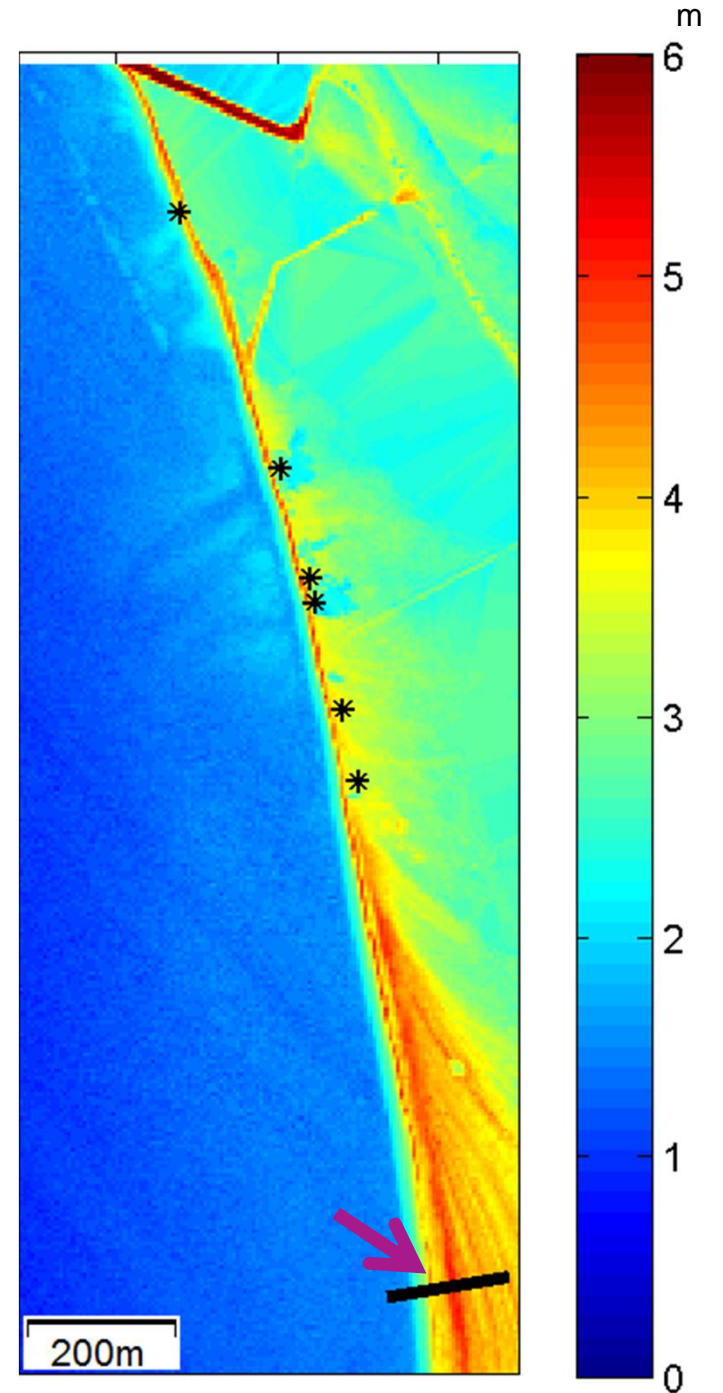
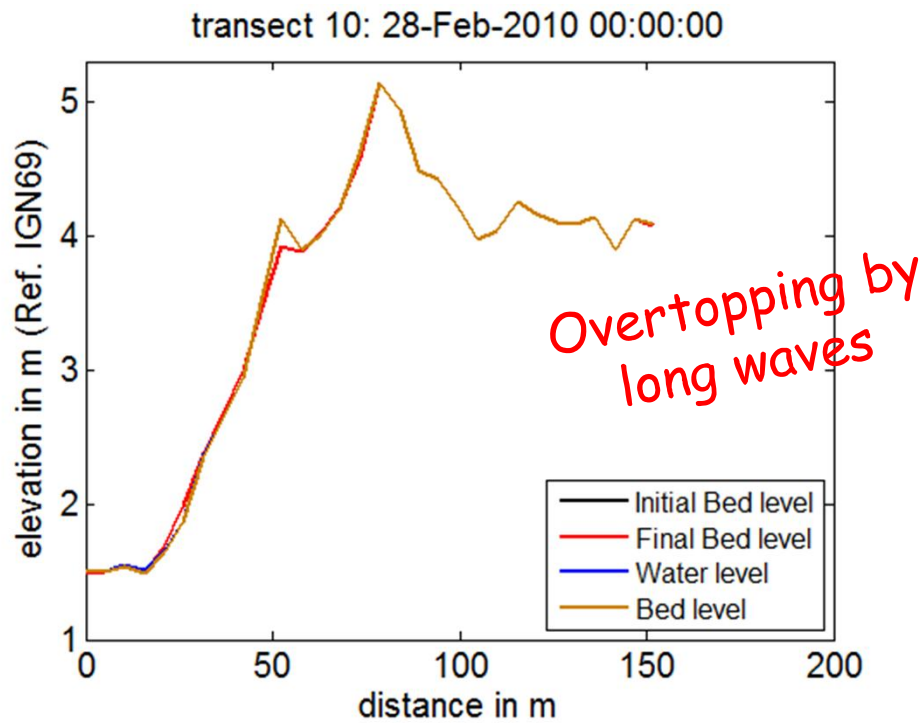
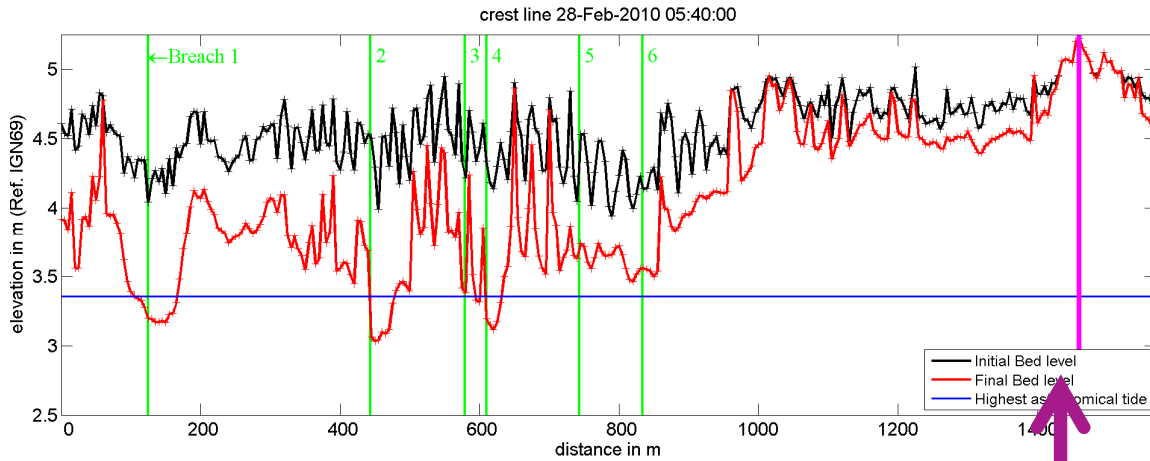


“Resistant” profile 1



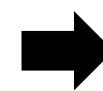
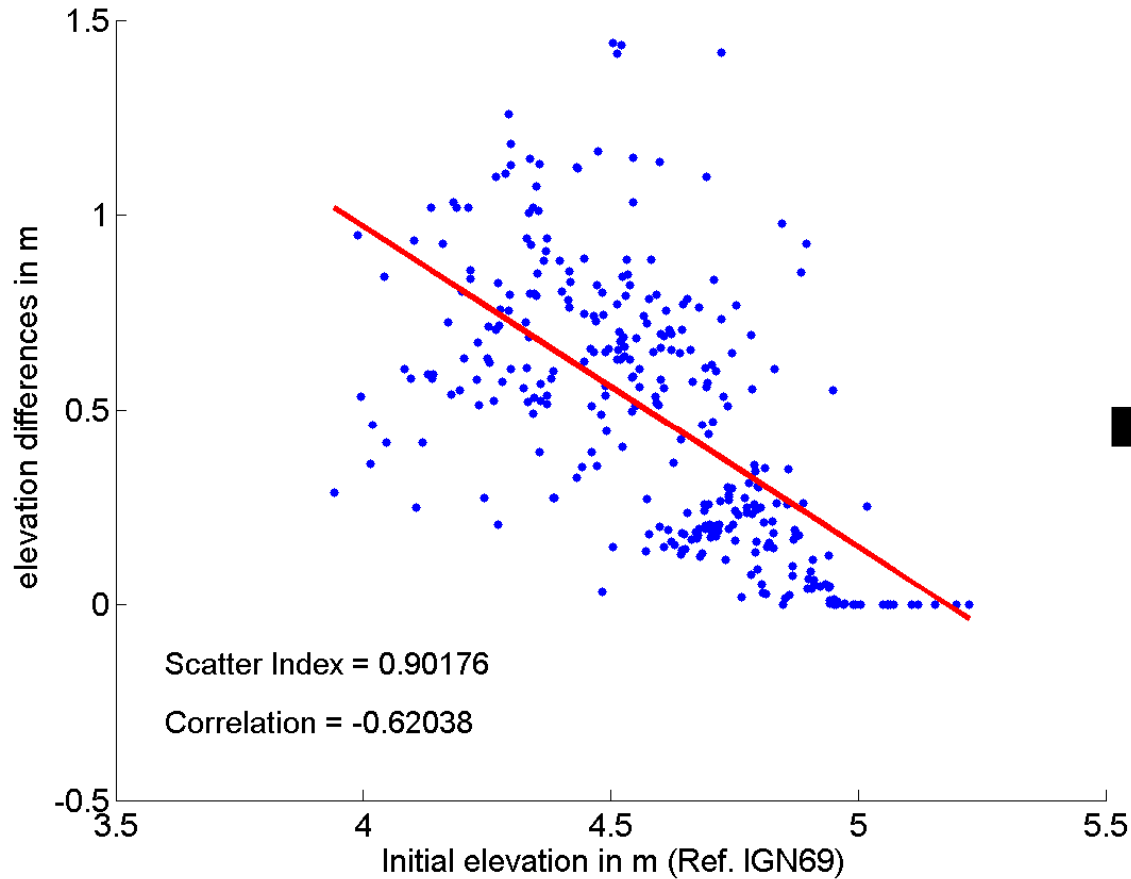


“Resistant” profile 2





Preliminary quantitative results



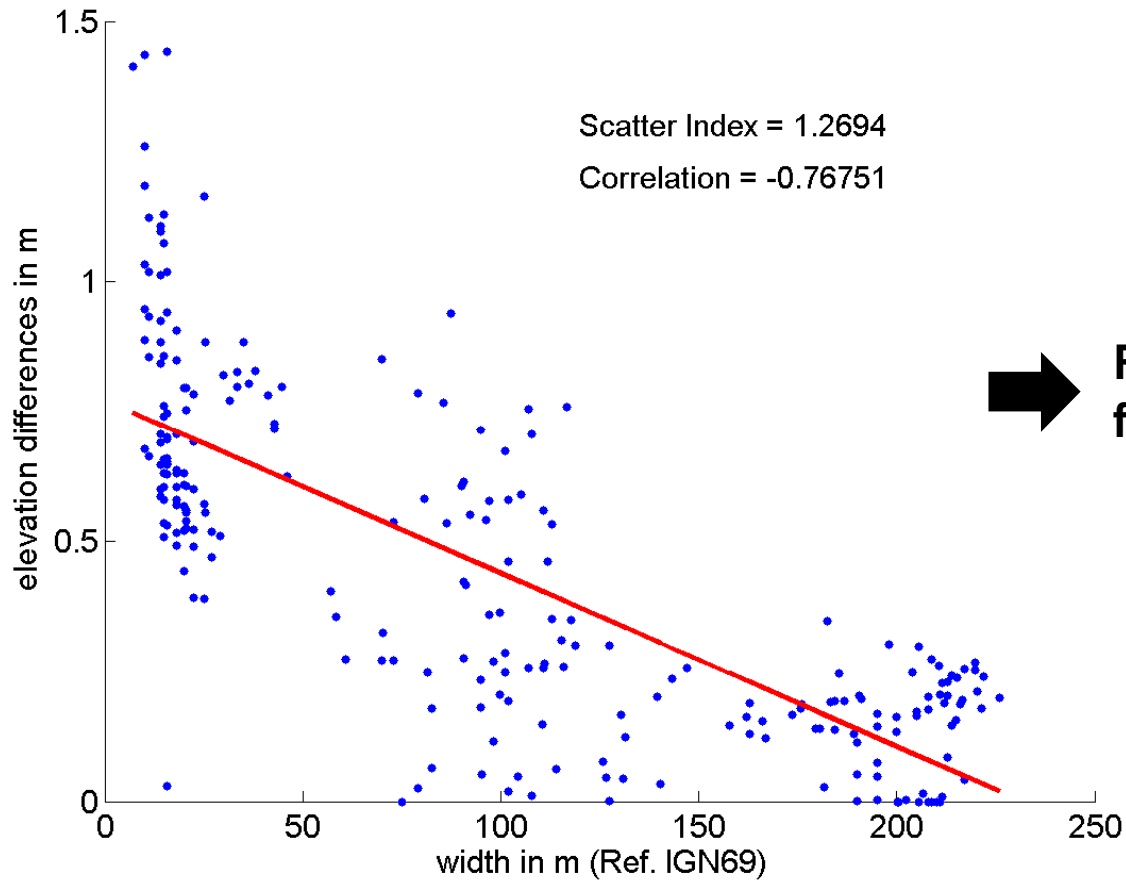
**Amplified erosion
on low profiles**

Correlation between dune initial height
and elevation difference





Preliminary quantitative results



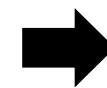
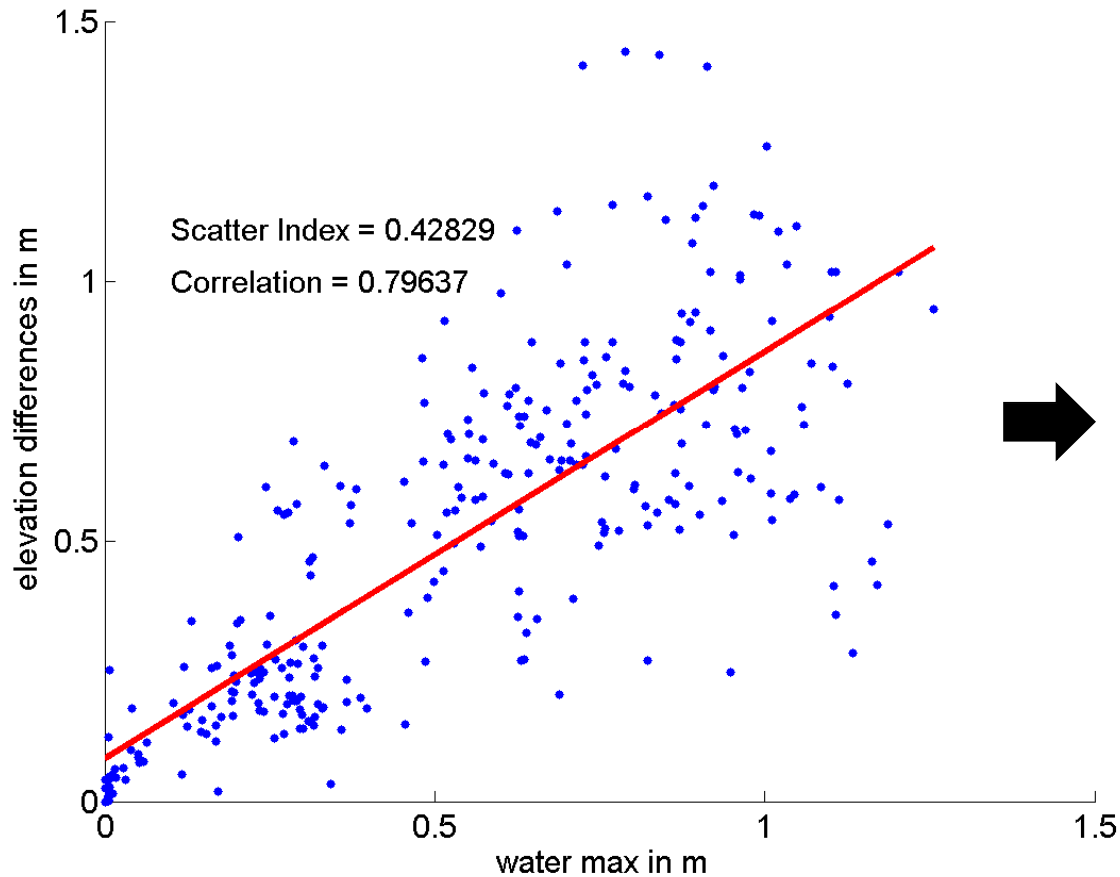
➔ Reduced height loss for larger profiles

Correlation between dune width and elevation difference





Preliminary quantitative results



Erosion related to the height of submersion

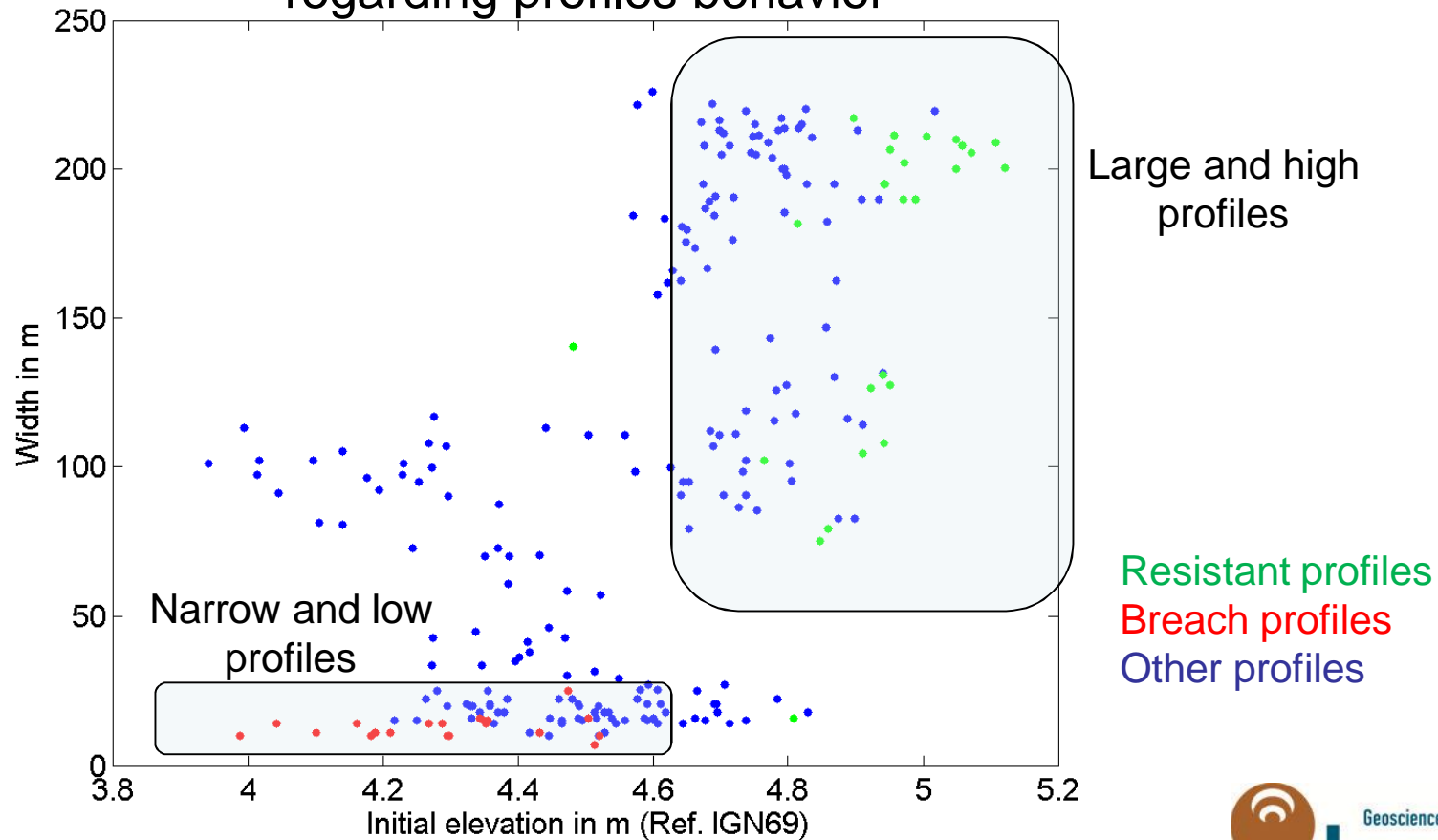
Correlation between maximum water level and elevation difference





Preliminary quantitative results

initial elevation and dune width
regarding profiles behavior





Conclusions and perspectives

- > Good reproducibility of the event
(water level over Yves marsh, breaches locations)
- > Opportunities for dynamic flood modeling including morphological evolution
- > Perspectives:
 - Improvement on breach and flooding modeling thanks to :
 - Increased cross shore resolution
 - Introduction of vegetation cover
 - Improvement of the bed erodability (non erodable layers)



Potential applications

> Reliability assessments

> Improvements design

> Predictions and emergency management

