Characterisation of an idealised offshore wind farm foundation, under waves and the combination of waves and currents

Isabel García-Hermosa, J. Lebunetel,
N. Abcha, J. Brossard, A. Ezersky, D. Mouazé, G. Perret

Laboratoire Ondes et Milieux Complexes – U. Le Havre
Laboratoire de Morphodynamique Continentale et Côtière – U Caen Basse-Normandie

igarciahermosa@gmail.com

OFELIA www.interreg-ofelia.eu/

Offshore wind farm Foundation EnvironmentaL Impact Assessment

INTERREG IV

Universities of Caen and Le Havre - Plymouth University

RELEVANCE

- Marine renewable energy – meet governmental targets
- Offshore wind tech. from onshore -- deeper/ +ø /+masts

Aims

- Characterise changes in hydrodynamics and sea bed around the cylinder
- Improve understanding of scour processes

Objectives

Experiments to collect data to inform about processes

velocity deficit/ bss/ eddies/ wakes/ turbulence/ scour

Overview

Processes – wave and current + cylinder + sediment (interactions)

Flow structures: Horseshoe vortex
Lee wake vortex

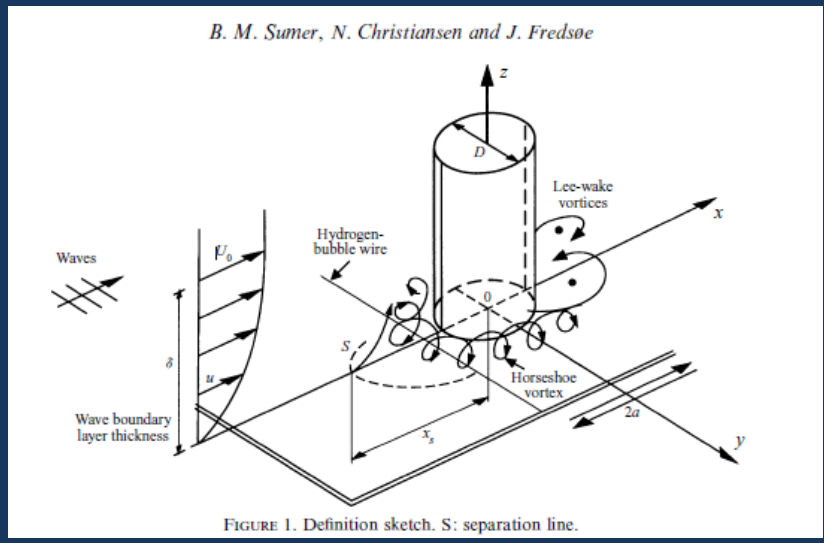


FIGURE 1. Definition sketch. S: separation line.

The *Keulegan-Carpenter* number associated to presence/ absence of horseshoe vortex in oscillatory flows

$$KC = \frac{U_m T}{D}$$

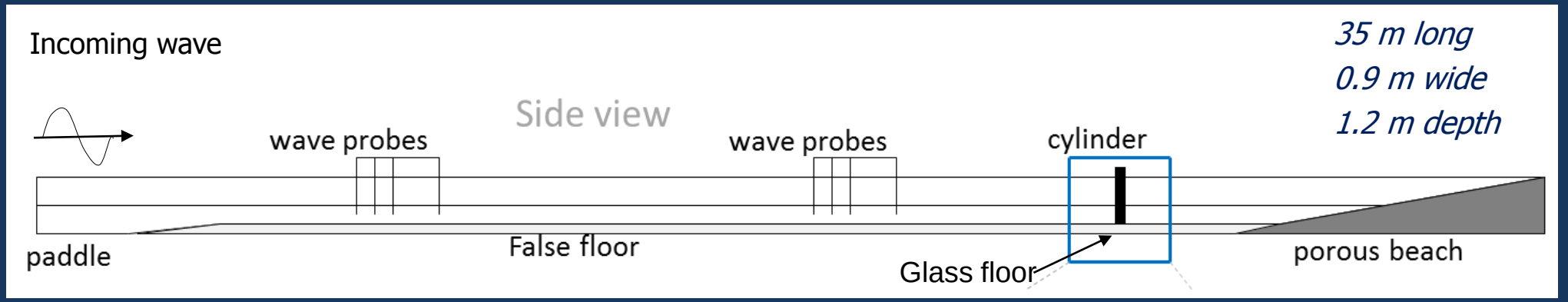
U_m bottom orbital velocity,
T wave period and
D the cylinder diameter.

Sumer & Fresdsoe (1997) and Zanke *et al* (2011) – horseshoe vortex suppressed for KC < 6

Two sets of experiments

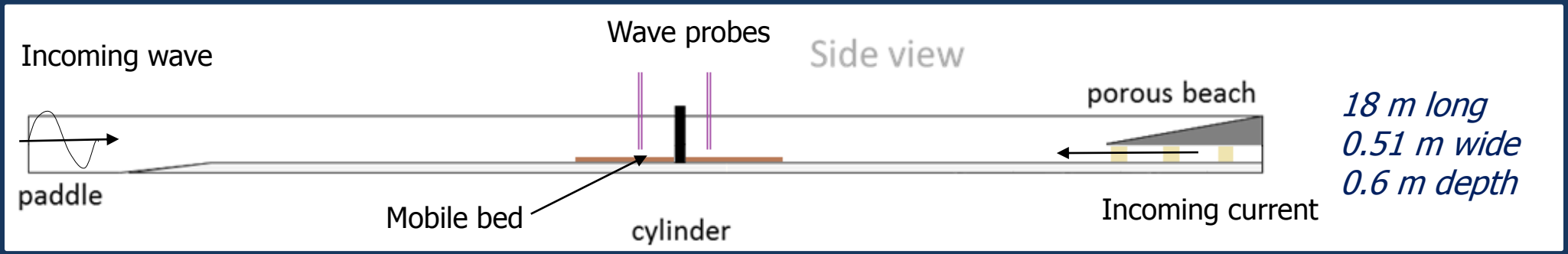
PIV experiments Cylinder + wave + flat immobile bed

Changes of wave properties near the structure



Mobile bed exp Cylinder + *REGULAR* wave + current + mobile bed

Impact of cylinder on waves, currents and mobile bed



PIV experiments

Cylinder + *IRREGULAR* wave + flat immobile bed - Le Havre - wave properties near the structure

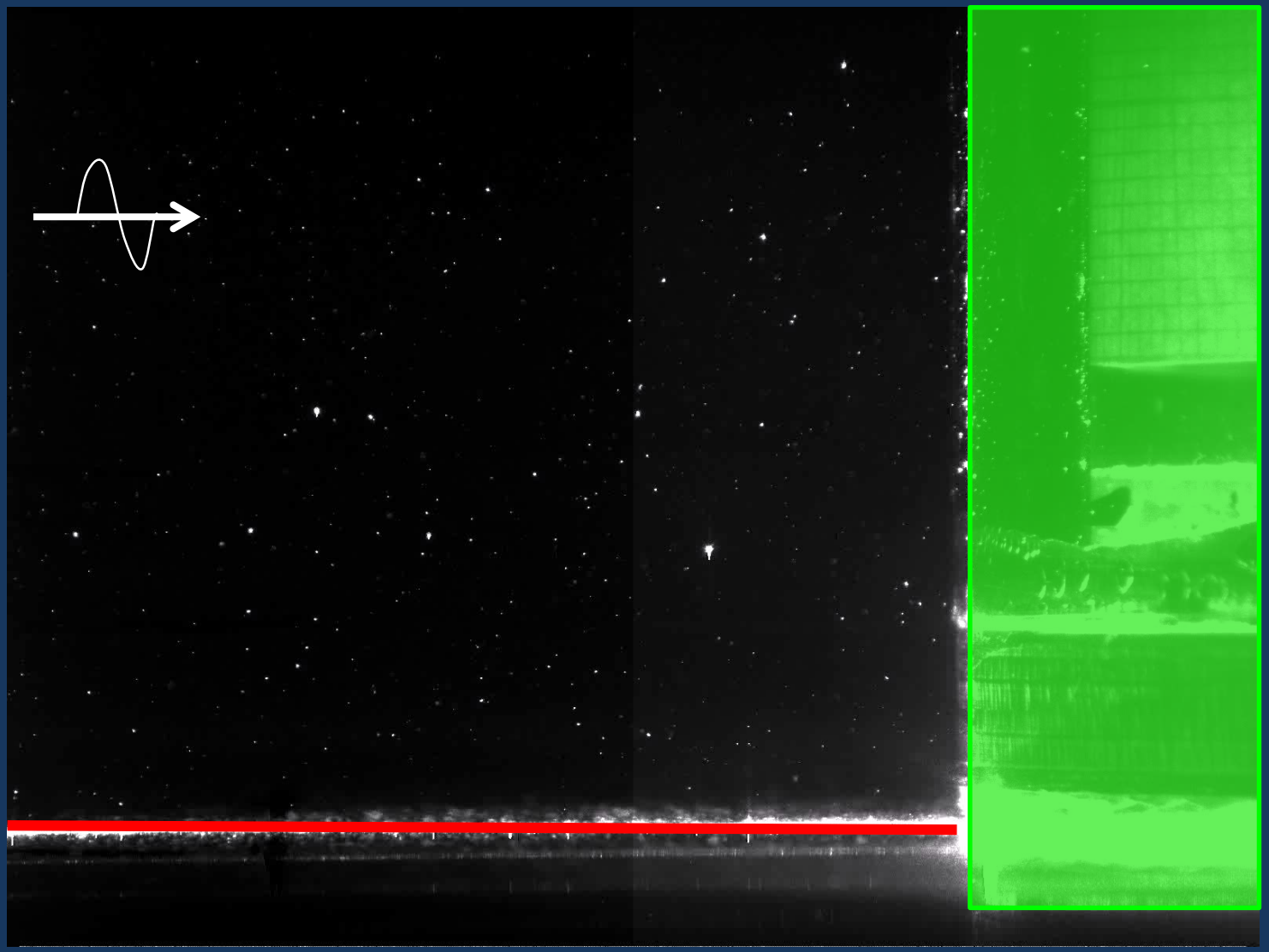
PIV experiments

	Current	Wave	Bed	Flow velocity		Free surface	Bed profile
Le Havre vertical	No	Regular/ Irregular	Fixed/ flat	U_x, U_z	PIV **vertical** plane	Next to	N/A
Le Havre horizontal	No	Regular/ Irregular	Fixed/ flat	U_x, U_y	PIV **horizontal** plane	Next to	N/A
Caen	Yes	Regular	Mobile sand	U_x, U_y, U_z	ADV point	u/s and d/s	laser/ camera

Preliminary PIV Results

PIV upstream

jet

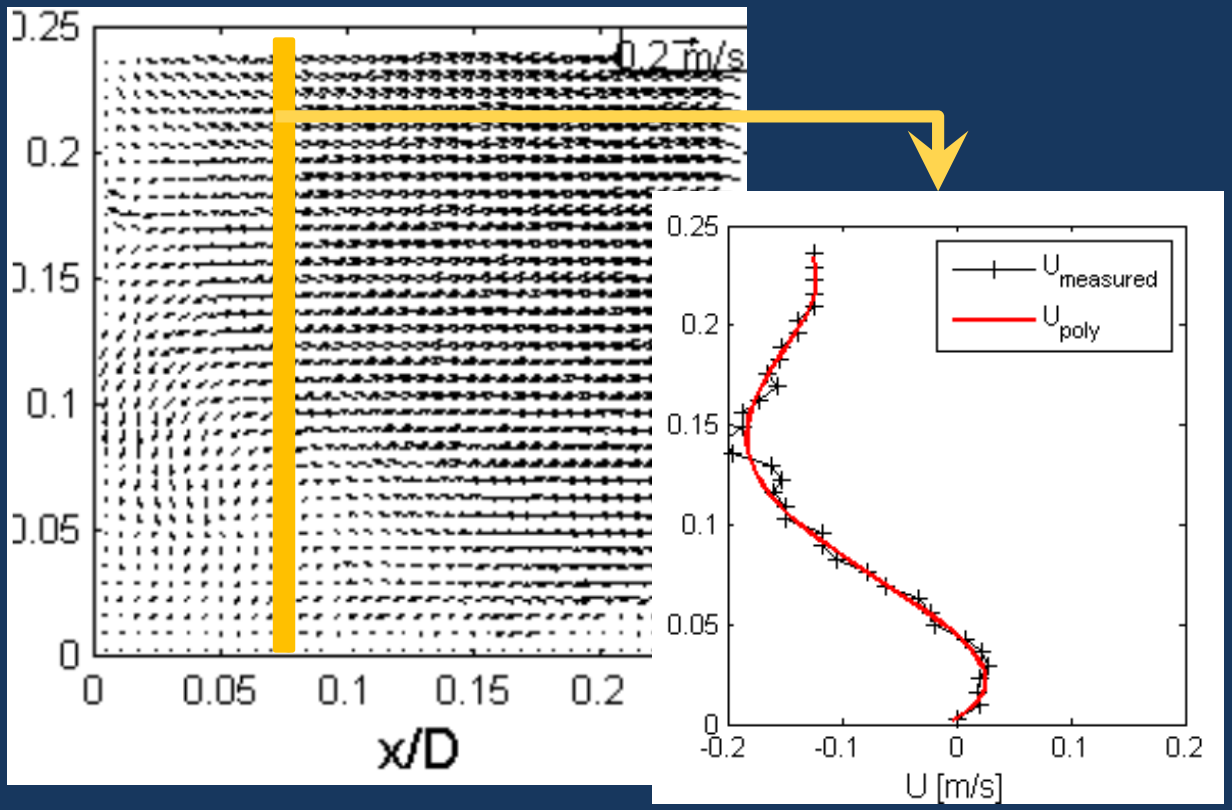


Preliminary Results

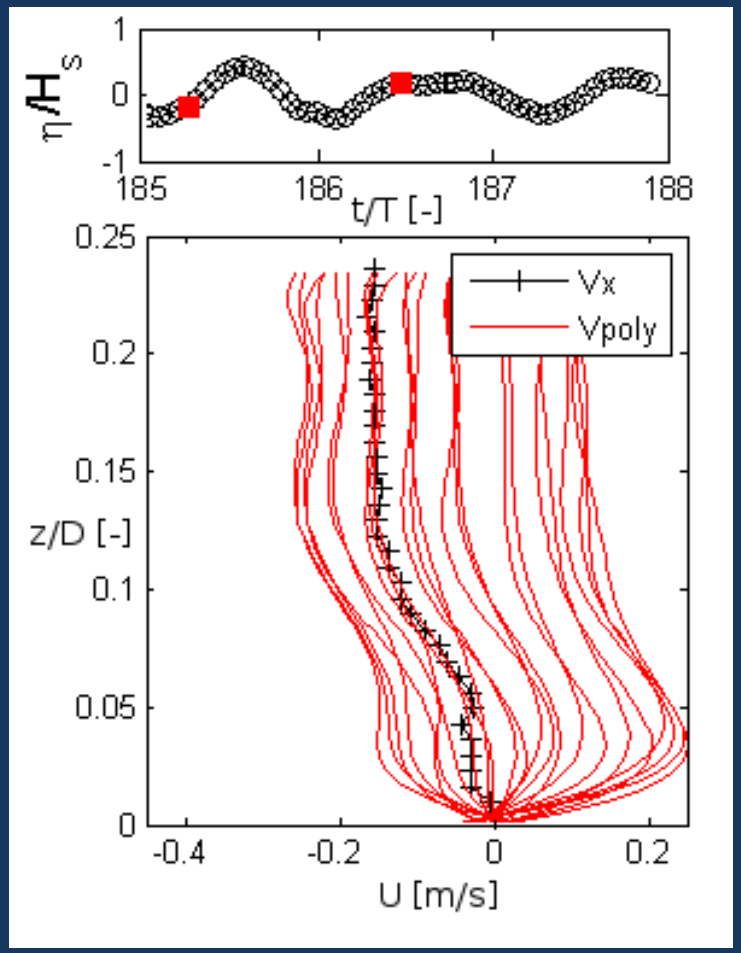
PIV vertical laser plane * downstream

Extraction of vertical line

Smoothing of profile – polynomial to calculate derived variables

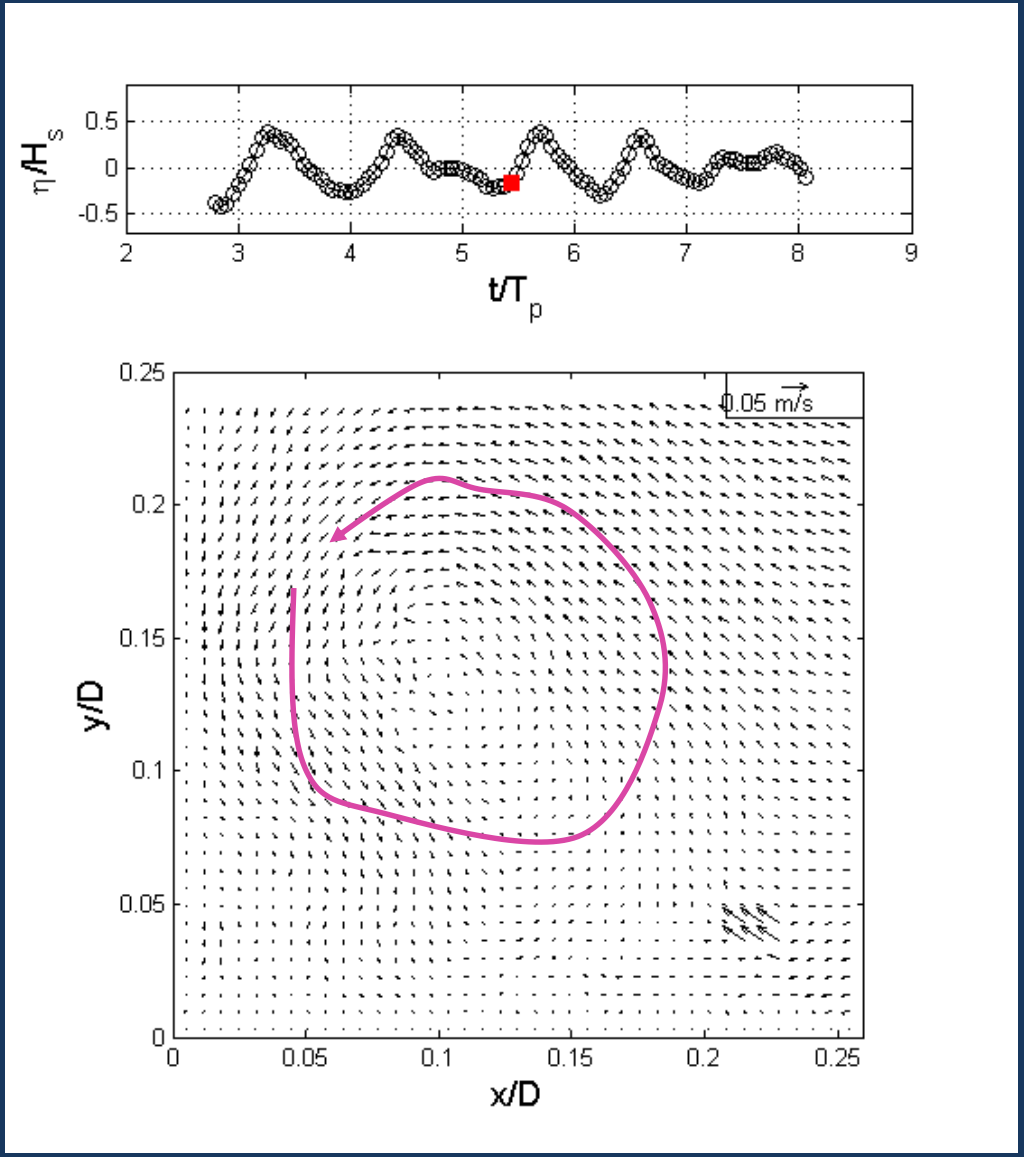


Wave phase velocity



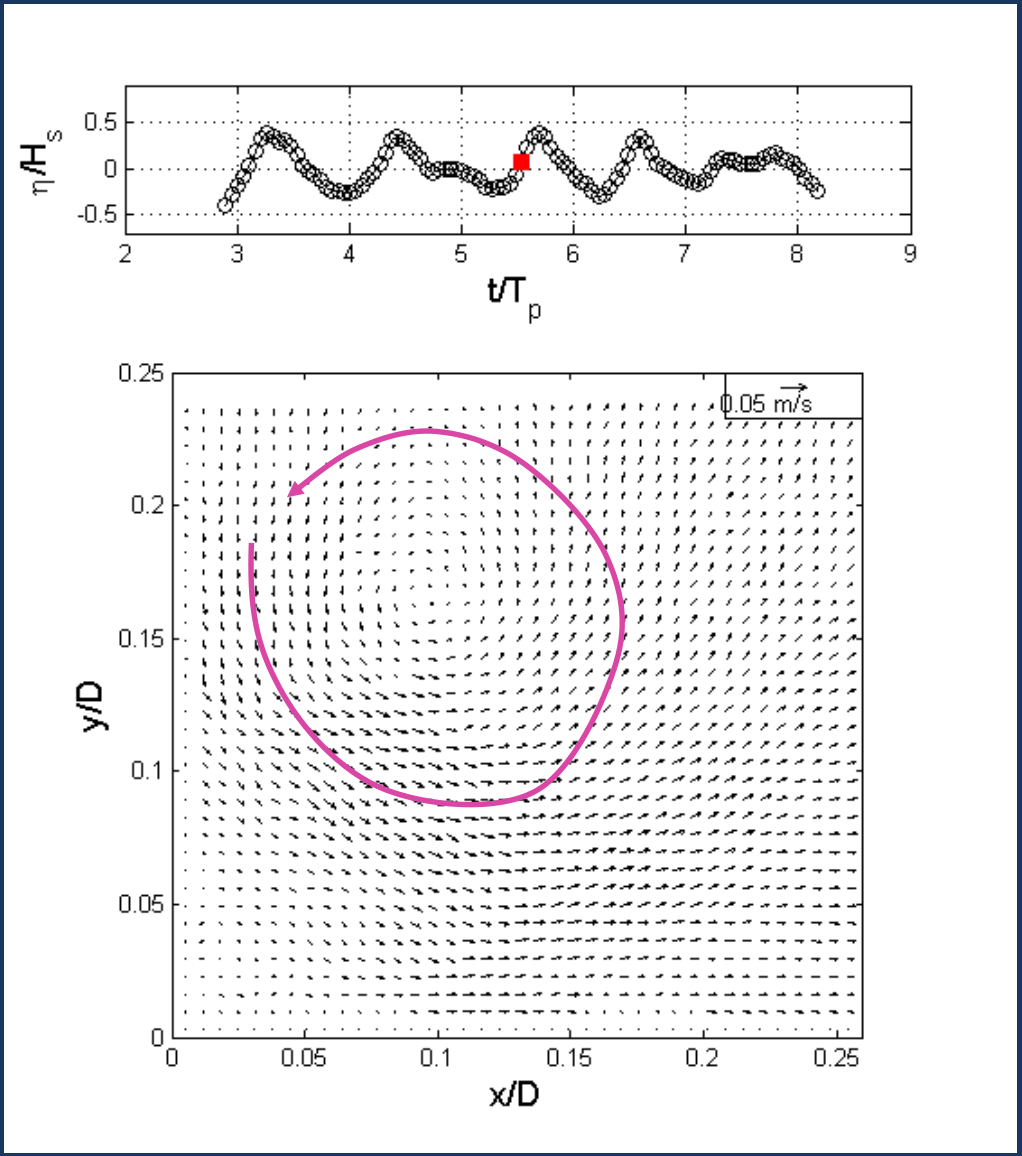
PIV vertical

PIV vertical laser plane * eddy downstream



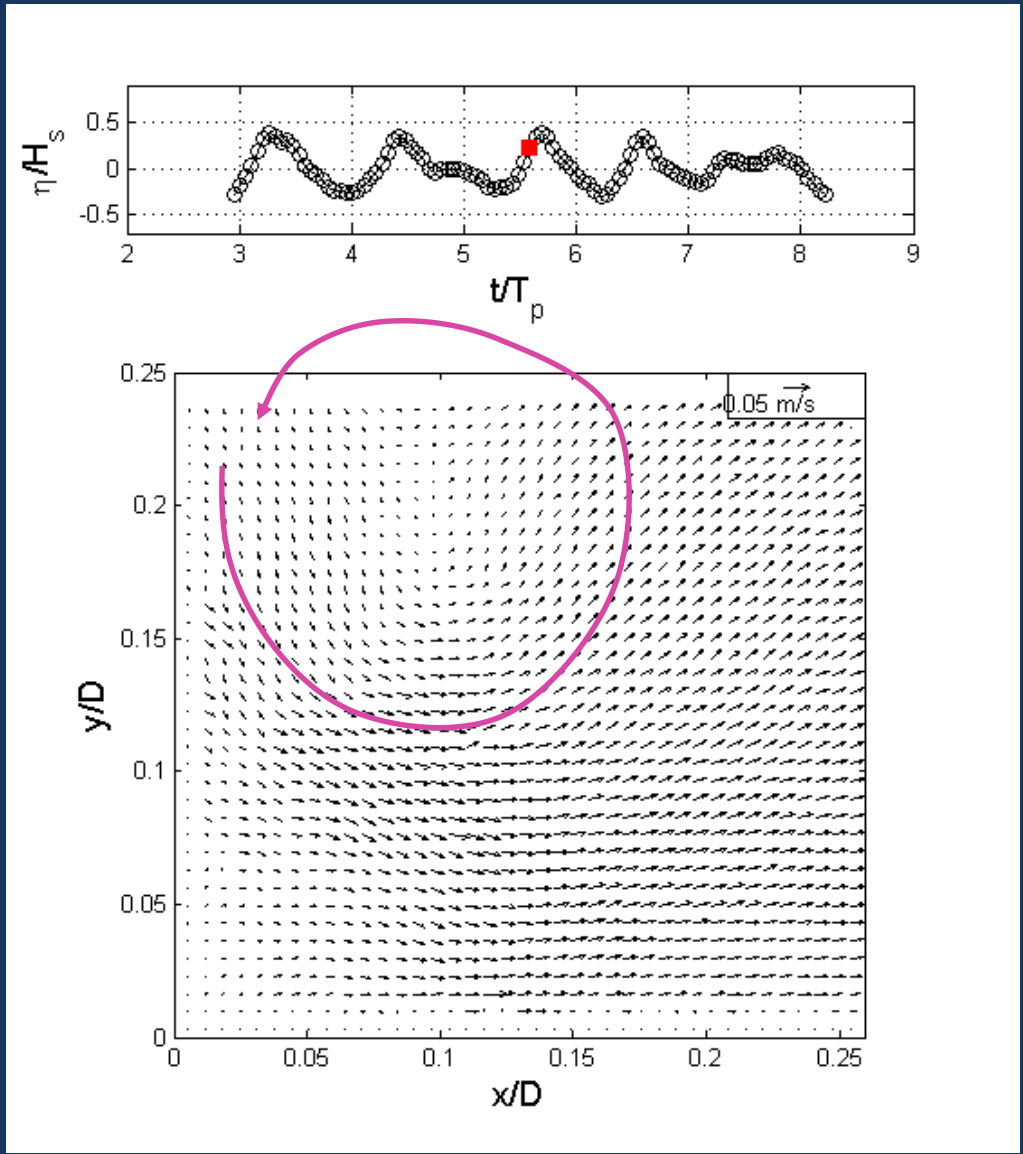
PIV vertical

PIV vertical laser plane * eddy downstream



PIV vertical

PIV vertical laser plane * eddy downstream



Mobile bed experiments

Caen - Cylinder + *REGULAR* wave + current + mobile bed

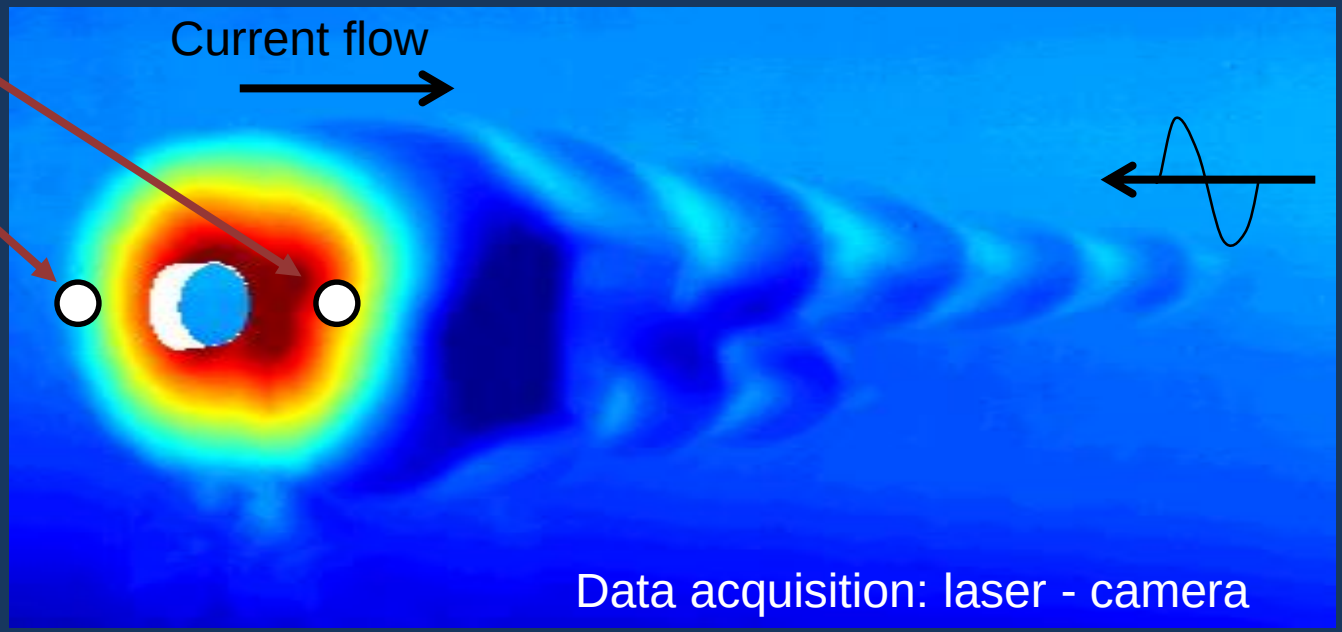
Assessing changes in waves, currents and mobile bed due to the presence of a mast

Mobile sediment

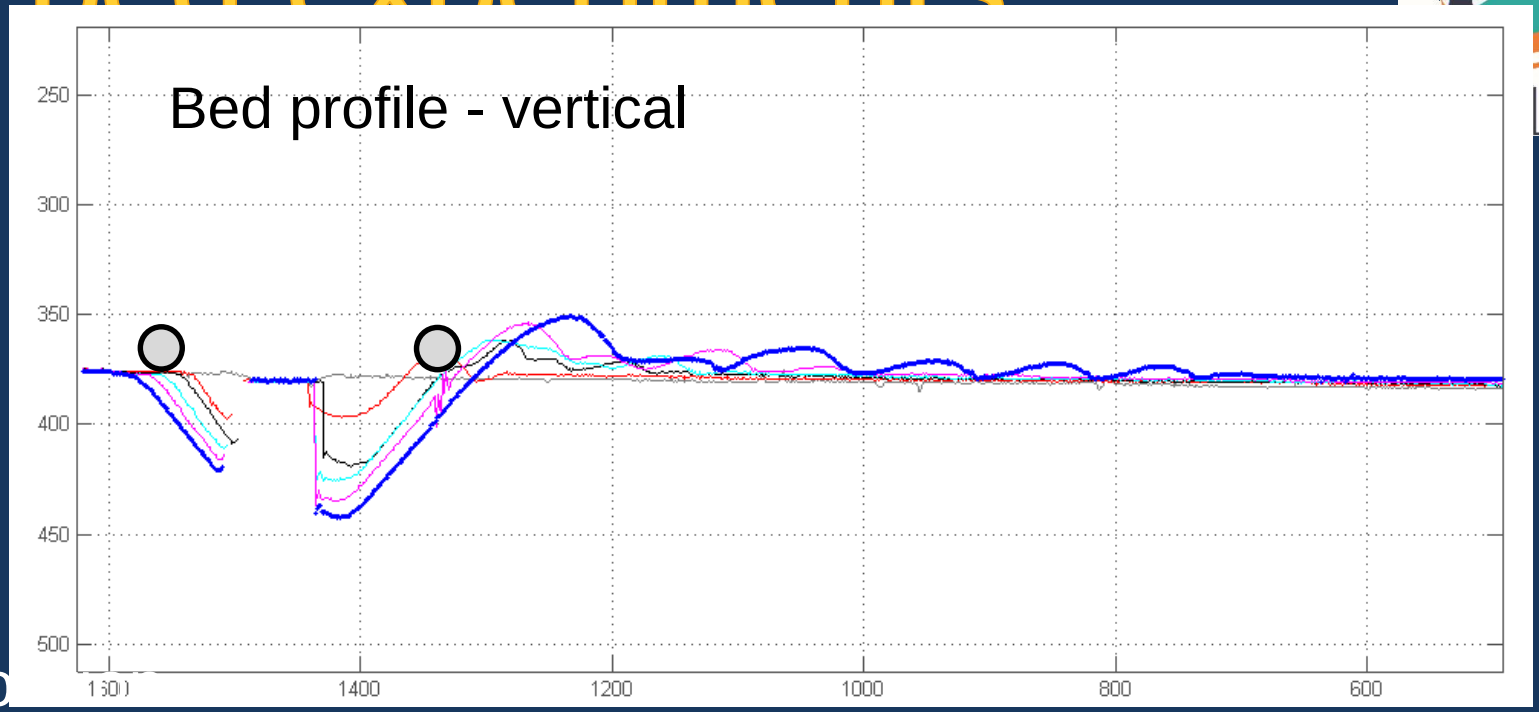
	Current	Wave	Bed	Flow velocity		Free surface	Bed profile
Le Havre vertical	No	Regular/ Irregular	Fixed/ flat	U_x, U_z	PIV **vertical** plane	Next to	N/A
Le Havre horizontal	No	Regular/ Irregular	Fixed/ flat	U_x, U_y	PIV **horizontal** plane	Next to	N/A
Caen	Yes	Regular	Mobile sand	U_x, U_y, U_z	ADV point	u/s and d/s	laser/ camera

Mobile bed experiments

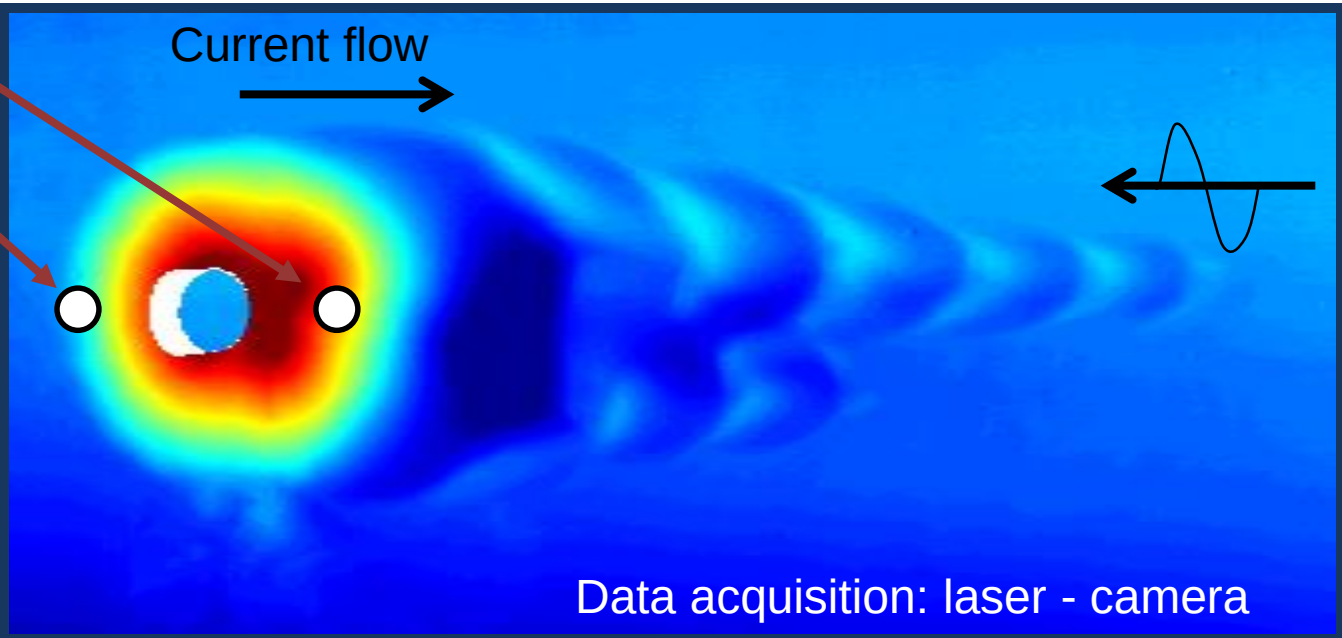
Approximate position of ADV vertical velocity profiles



Mobile bed experiments

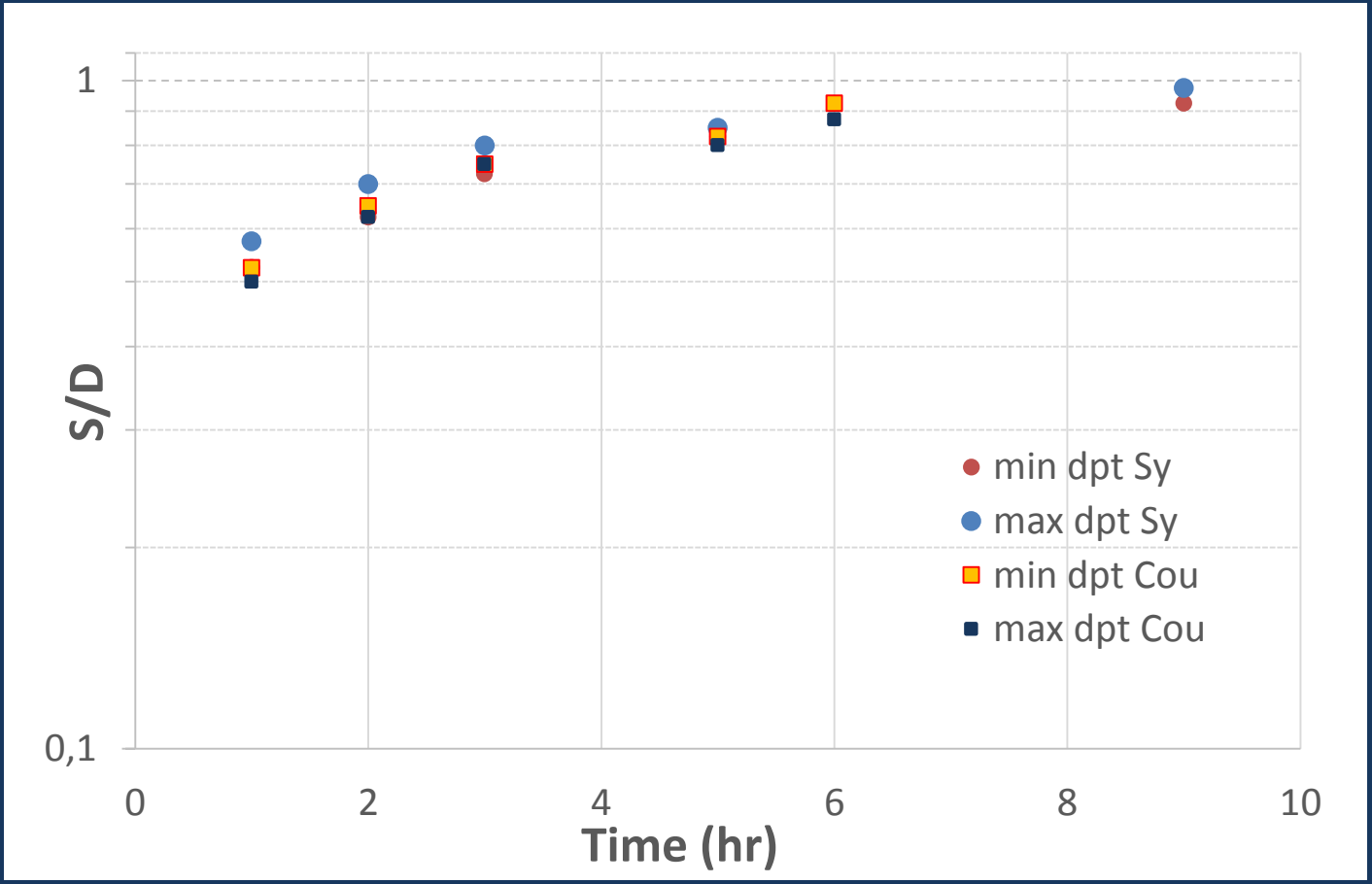


Approximate po
of ADV vertical
velocity profiles



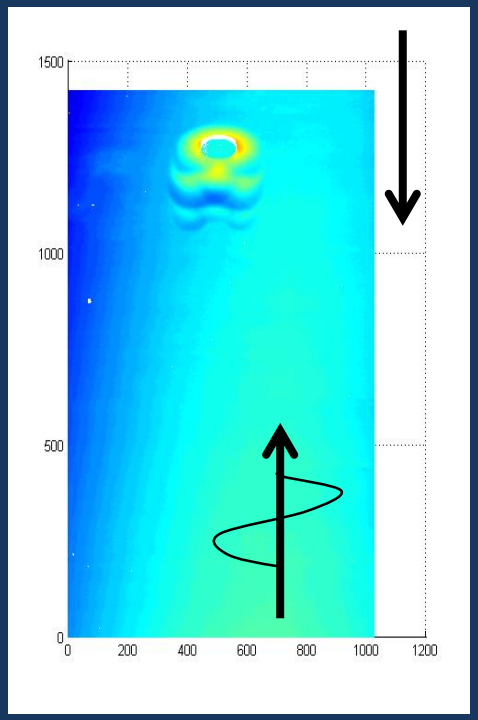
Time evolution scour depth

Courseulles sur mer & resonance cases



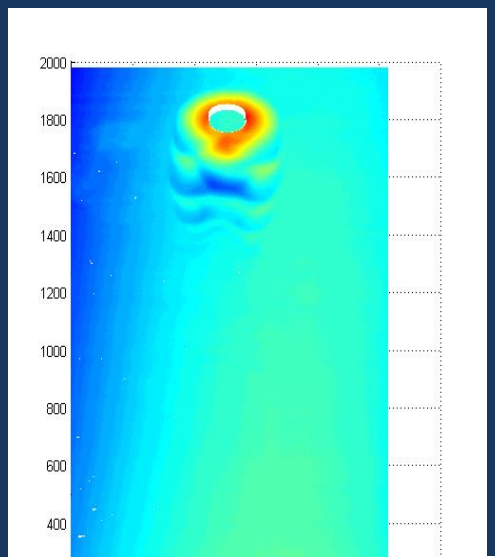
Model time

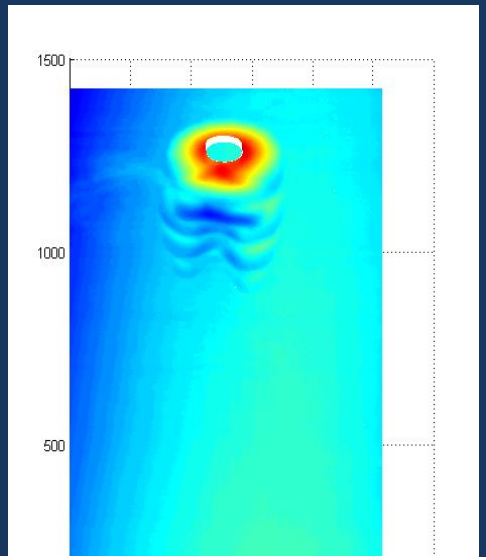
Morphological changes



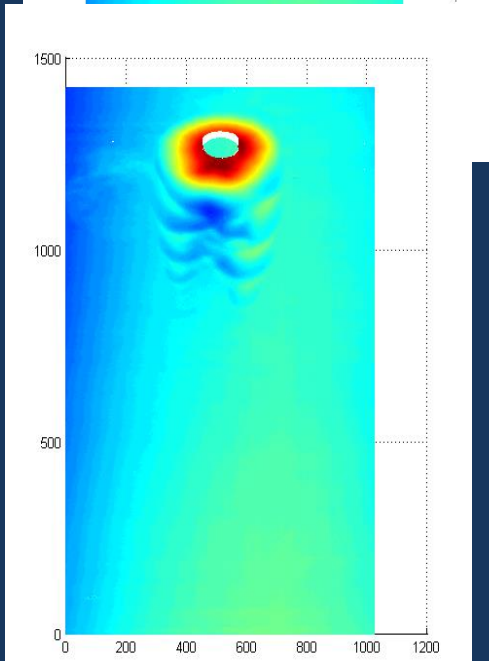
Top view

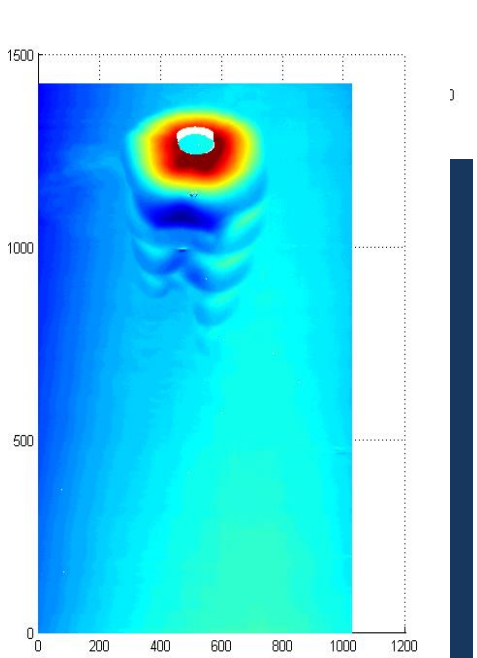
Data acquired with laser/camera method

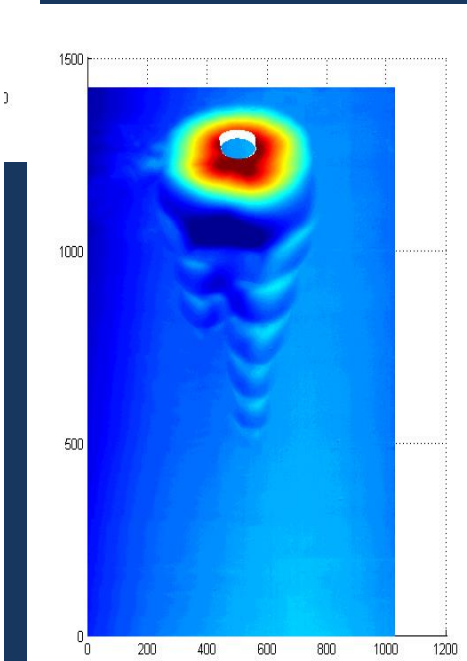




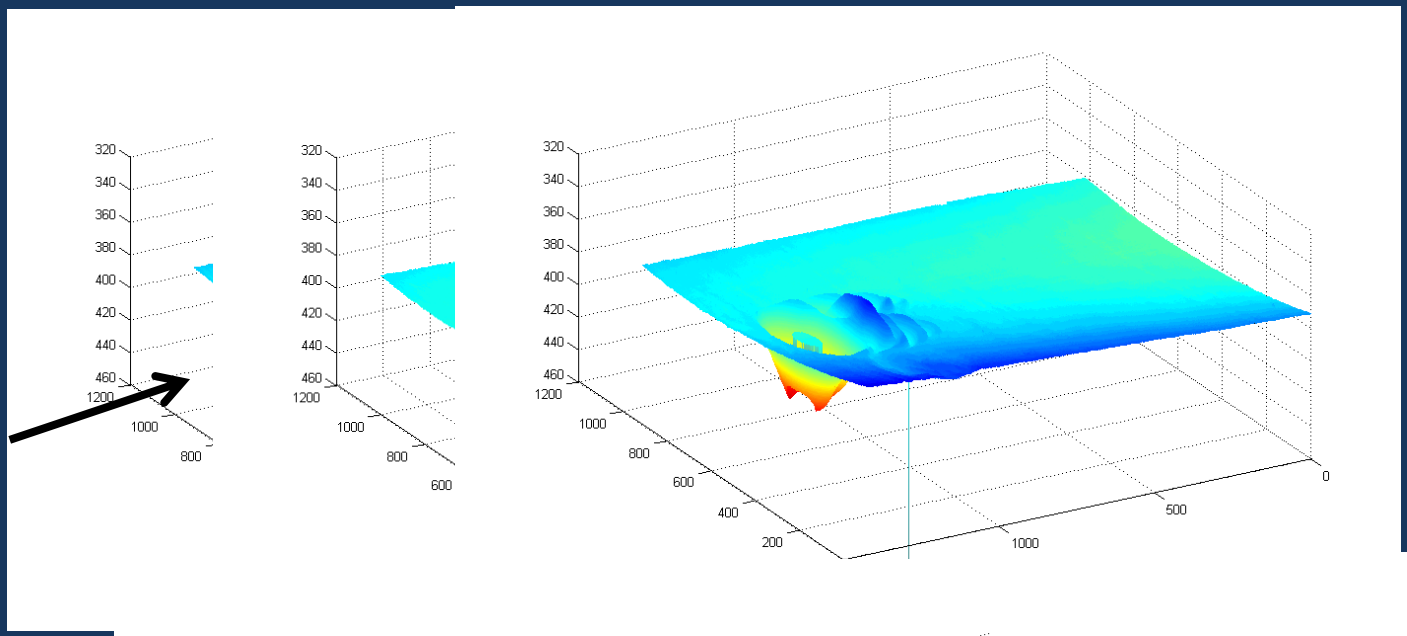
Increase scour depth and extent







Morphological changes



Side view

Bed evolution with time

Summary

Data collated for wave/wave + current to characterise changes in flow field around cylinders;

PIV exp

- Velocity fields and free surface - for regular irregular waves
- Encouraging - flow structures observed: vortices, jets @ low KC;
- Observed structures associated to scour processes;
- Eddy presence not continuous -> Causes prelim. wave history

Mobile bed exp

- Detailed bathymetries @ regular intervals; point velocity, free surface
- Clear water scour regime
- S/D converges with time

Further work

- Analysis and post-processing is on-going
  PIV and mobile bed
- Relate changes in bed and velocity responses
- Estimate of turbulent kinetic energy and bed shear stress from vertical velocity profiles
- Compare measured scour depth to empirical formulae and scour models
- Derive and implement parametrisation into models

Thank you!

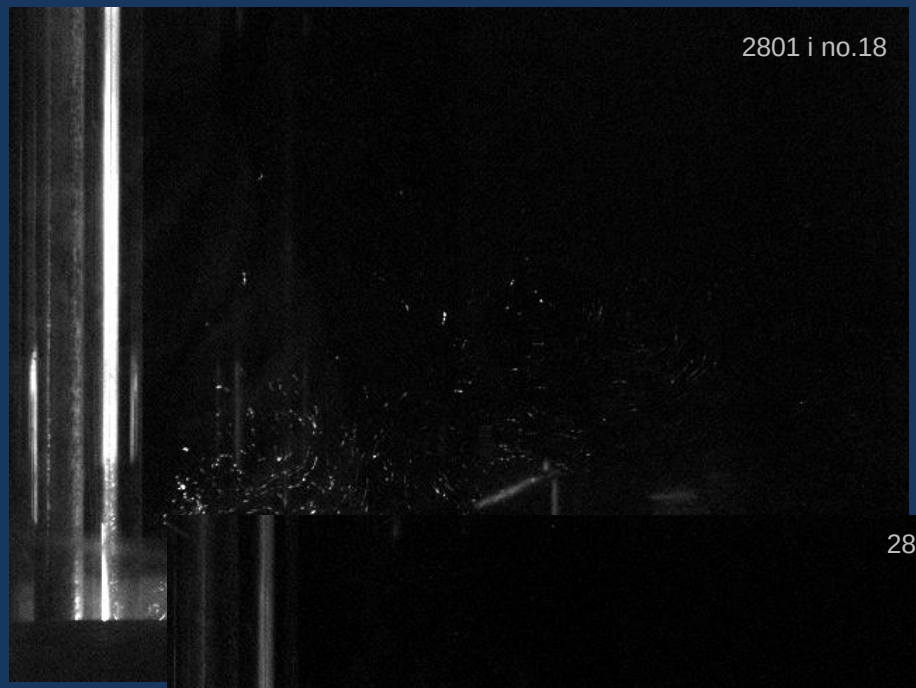
Associated Posters

Ezersky *et al.* Laboratory modelling of resonant wave-current interaction in the vicinity of wind farrm masts. B45

Rivier *et al.* Assessment by regional modelling of the impact of monopile foundations on the on the hydrodynamics and sediment transport: case of Courseulles sur mer (France) wind farm. Y249

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

Morphological changes



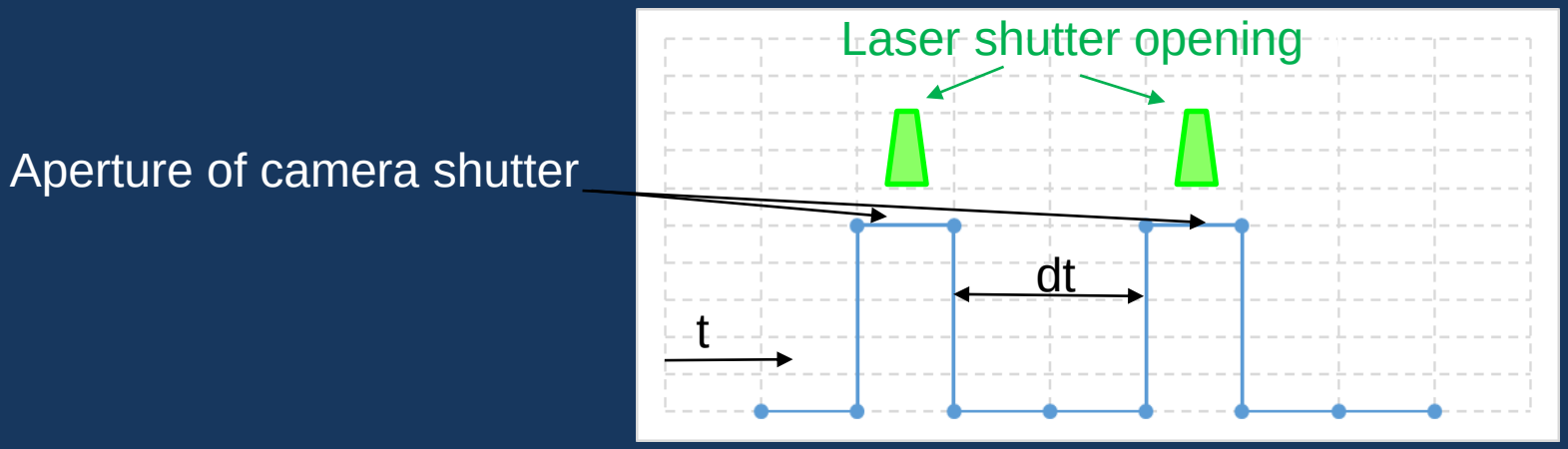
Visualisation, video laser with high suspension

Courseulles conditions – re suspension up to mid depth

PIV measurements

Particle Image Velocimetry (PIV)

- Synchronised laser and camera;
- Laser illuminates particles in area of interest at two consecutive instants (dt << 1 s);
- Camera captures two consecutive images (dt << 1 s) @instant when laser is illuminating the field;



Analysis - Pair of images – Particle displacement – Calibration (pixel to mm) - – Particle velocity

PIV Experiments

Field of view captured

Extent of lase sheet