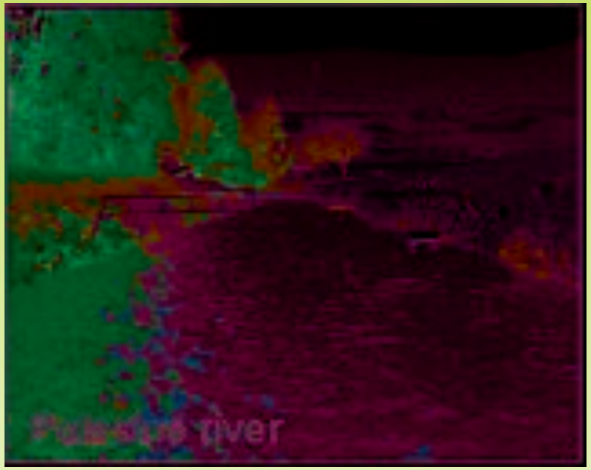
Exploring boundary layer and sediment transport processes under waves and currents using sound scattering

Coastal nearshore flows

Waves / currents

River / estuary



Streams

LEGI
LABORATOIRE DES ECOULEMENTS GEOPHYSIQUES ET INDUSTRIELS

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cnrs dépasser les frontières

Atelier Fluide, OSUG, 18 Avril 2012

APPROACH and METHODOLOGY

Combine

physical modelling of sediment transport processes in high-performance experimental facilities (LEGI channel & flumes, european large-scale Hydralab facilities: CIEM-UPC, GWK Hannover)

- **-under controlled flow forcing conditions**
- **-at moderate to full-scale forcing conditions (waves, currents, susp., beload, sheet flow transport)**

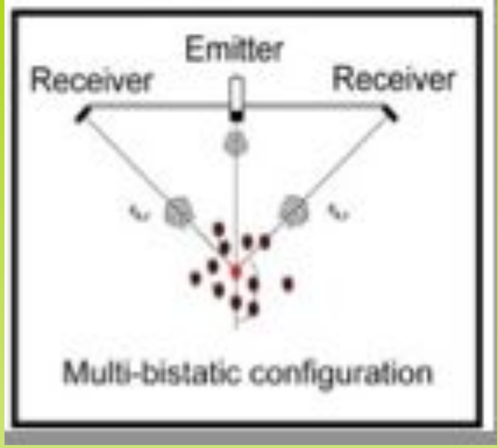
High-resolution acoustic measurements of the multi-scale flow processes involved in the Sediment transport triad

Provide

physical models of sediment transport predictions (sed. Conc., sed flux) versus flow controlling parameters (flow bed vel, bed slope, bed shear, flow acceleration,…)

Fine-scale data for comparison / validation of numerical data of sediment transport under waves and currents

Acoustic scattering system (ABS, ADV, ADVP, ADCP, UVP,..)



Pressure scattered by a single sediment particle

$$p = A(r_{k,i}, r_{k,r}, a_p, \theta)\exp\left[i\omega_c t + ik_c\left(r_{k,i} + r_{k,r}\right)\right]$$

$$A = \frac{p_0 r_0}{2} a_p f_p\left(\theta, a_p\right) \frac{D_i D_r}{r_{k,i} r_{k,r}} \exp\left[-\alpha\left(r_{k,i} + r_{k,r}\right)\right]$$

Acoustic intensity scattered by a cloud of suspended sediments

$$\hat{p}^2 = \frac{3\left(p_0 r_0\right)^2}{16\pi}\left(\frac{\int_0^\infty a_p^2 \left|f_p\left(\theta_0, a_p\right)\right|^2 n\left(a_p\right) da_p}{\rho_p \int_0^\infty a_p^3 n\left(a_p\right) da_p}\right) C \iiint_V \left(\frac{D_i D_r}{\hat{r}_i \hat{r}_r}\right)^2 \exp\left[-2\alpha\left(\hat{r}_i + \hat{r}_r\right)\right] dV$$

Measured intensity for concentration / sediment size profiling

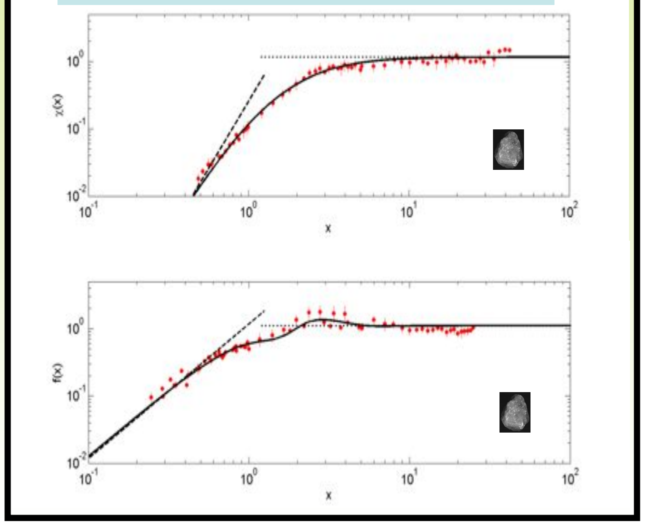
$$\langle I \rangle = (RT)^2 \hat{p}^2 = A_{bi} A_s C \exp\left(-4\int_{\hat{r}} \xi_s C d\hat{r}\right)$$

A_{bi}: instrument constant

with

$$A_s = \frac{3}{4\rho_s} \frac{\left\langle a_s^2 f^2(\theta = \pi, x)\right\rangle}{\left\langle a_s^3 \right\rangle} \qquad \xi_s = \frac{3}{4\rho_s} \frac{\left\langle a_s^2 \chi \right\rangle}{\left\langle a_s^3 \right\rangle}$$

Sediment form and attenuation functions

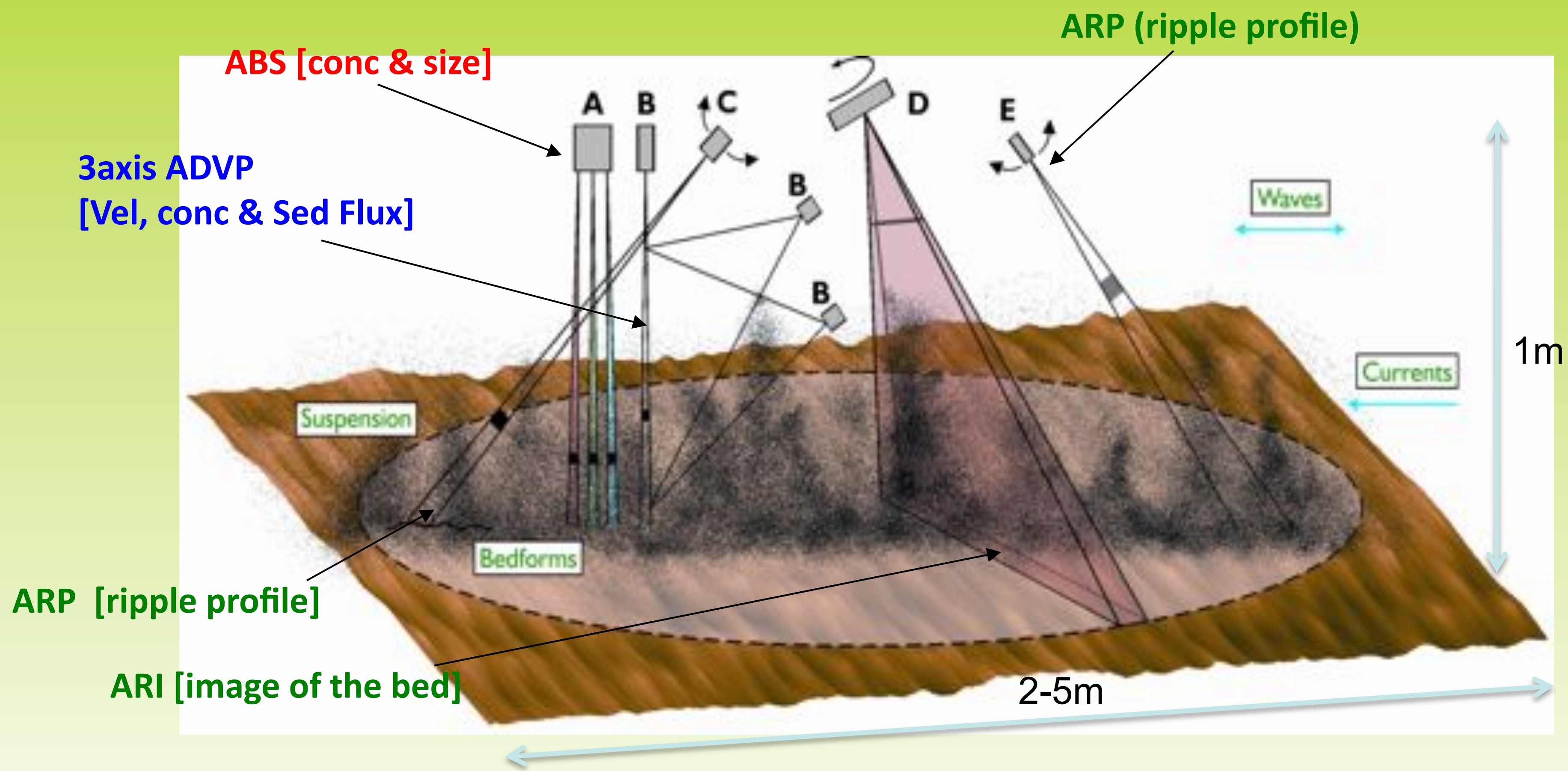


Why Acoustics

- ➔ Applicable in opaque / turbid / sediment laden flows (up to 100 $kg.m^{-3}$)
- ➔ Acoustic scattering theory by natural sediments (100µm-1mm) becomes accessible and reliable
- ➔ Coherent scatt. and incoherent Rayleigh scattering are combined for fine-scale meas. of velocity, sed concentration, sed size meas., bedforms and nearbed interfaces
- ➔ Robust and relatively "cheap" technology (sensors, electronics, processing time)
- ➔ Adapted for laboratory and field studies of sediment transport

Acoustic measurement objective: the Hydralab4-WISE project (LEGI, NOC-L, UPC, EPFL)

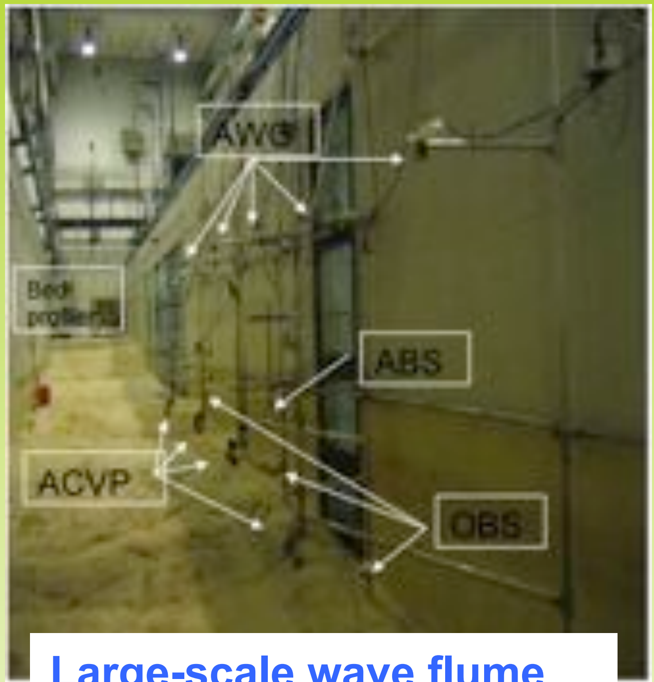
Provide an unprecedented acoustic vision of sediment transport triad



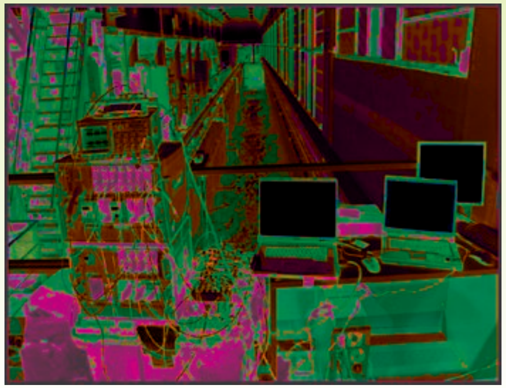
A complete set of novel acoustic flow measuring instrumentation for: flow (velocity, ADVP), sediment transport (sed. conc., ADVP ABS sed. Flux ADVP, sed. Size, ACVP ABS) , bedforms (bed interface tracking, ARP, ARI)

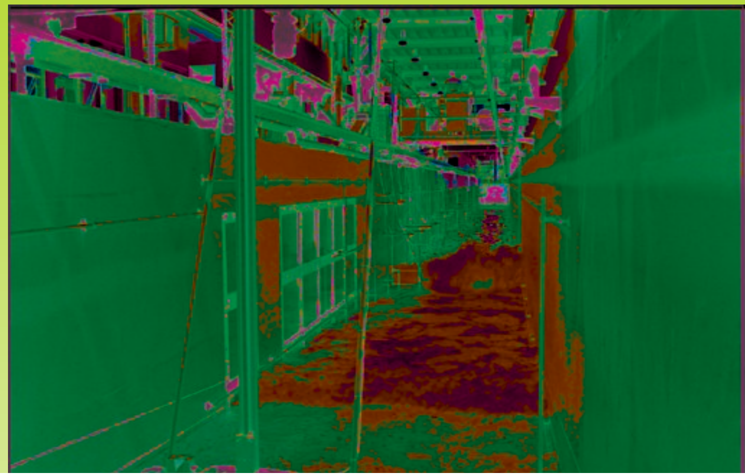
Some application examples

SAND TRANSPORT UNDER COASTAL NEARSHORE BREAKING WAVES

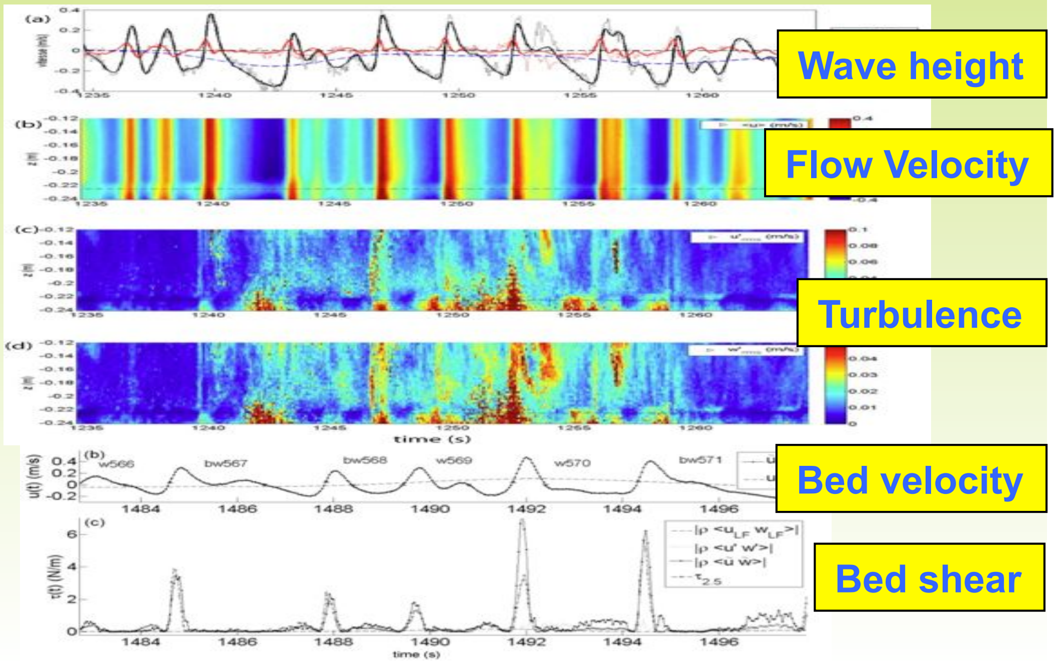


Large-scale wave flume experiments at UPC-CIEM



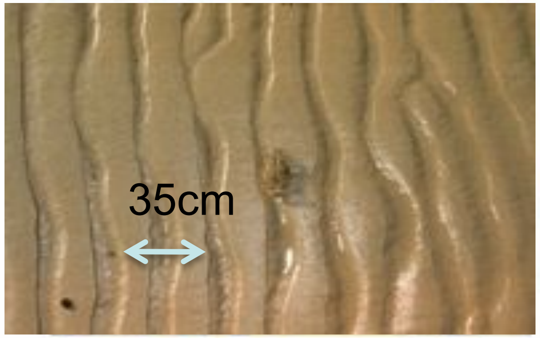


Acoustic measurements below breaking waves

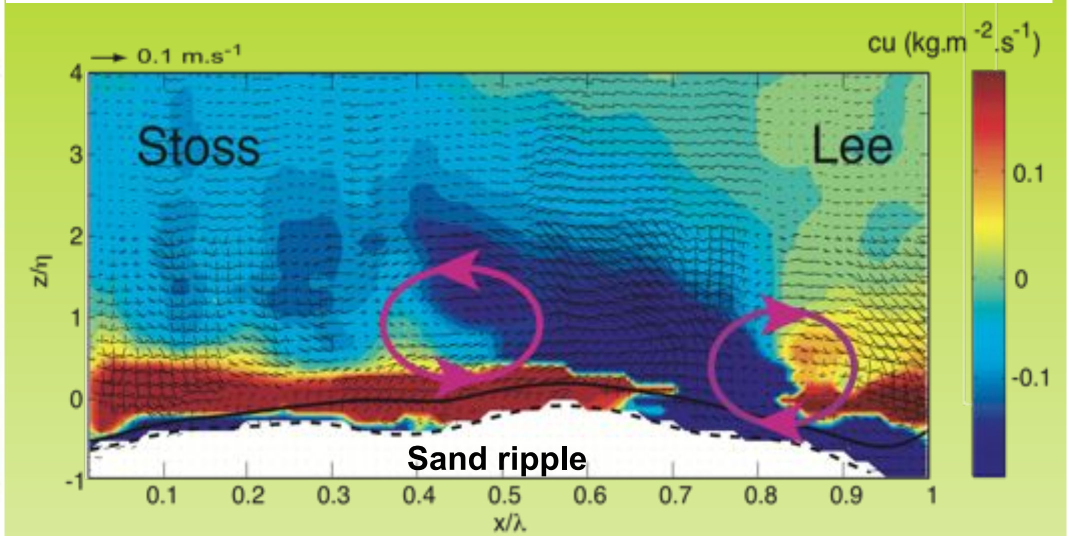


Suspended and bedload transport above ripples and dunes

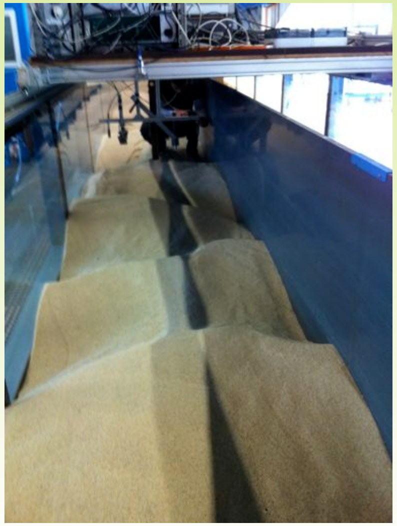
Migrating orbital Ripples under waves

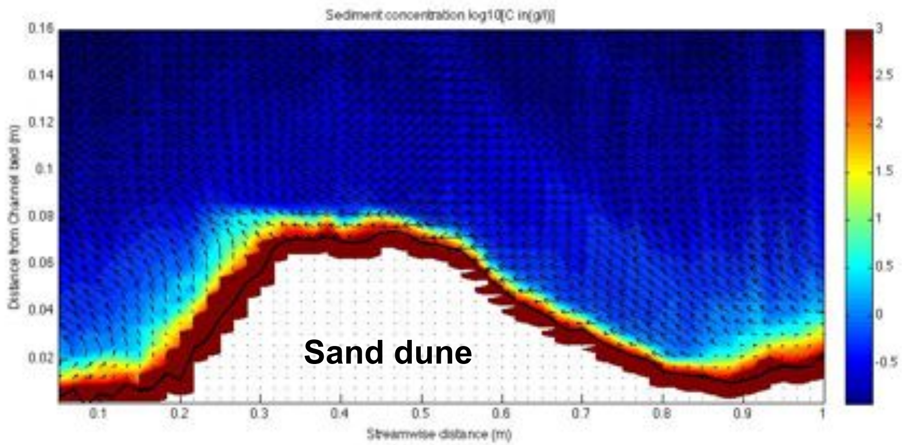


Acoustic flow and sediment flux above a ripple



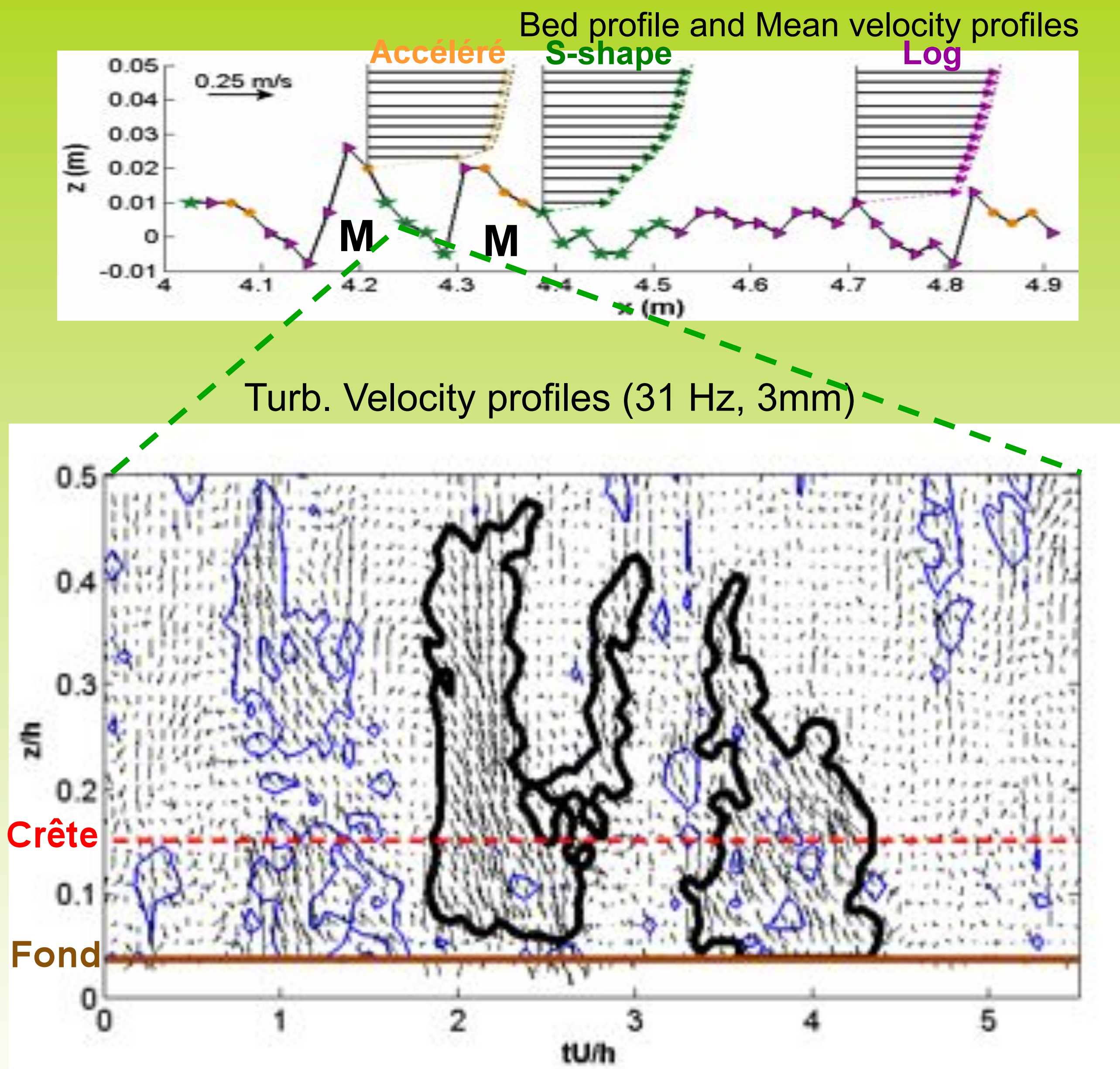
Migrating dunes under river flooding conditions





Gravel-bed flows: Nearbed turbulence structure

Gravel-bed channel (LEGI)



-Direct estimation of Double averaged (DA) momentum and TKE budgets

-Local flow characterization (mixing layer type analogy)

-Coherent flow structure dynamics and organization

Improvements in sediment transport rely on our capability to perform fine-scale measurements across the Water Interface with Sediments (WISE)

Thanks for your attention

FP6

FP7

hydralabIII-SANDS

hydralabIV -WISE

-SANDS