

# **Outlooks on acoustics and the study of sediment dynamics**

**Peter D. Thorne: National Oceanography Centre, UK**

**David Hurther: Laboratory of Geophysical and Industrial Flows (LEGI), France**

**Have a look at a number of ongoing developments of acoustic instrumentation for measuring sediment processes**

**Some results from a few studies and recent deployments**

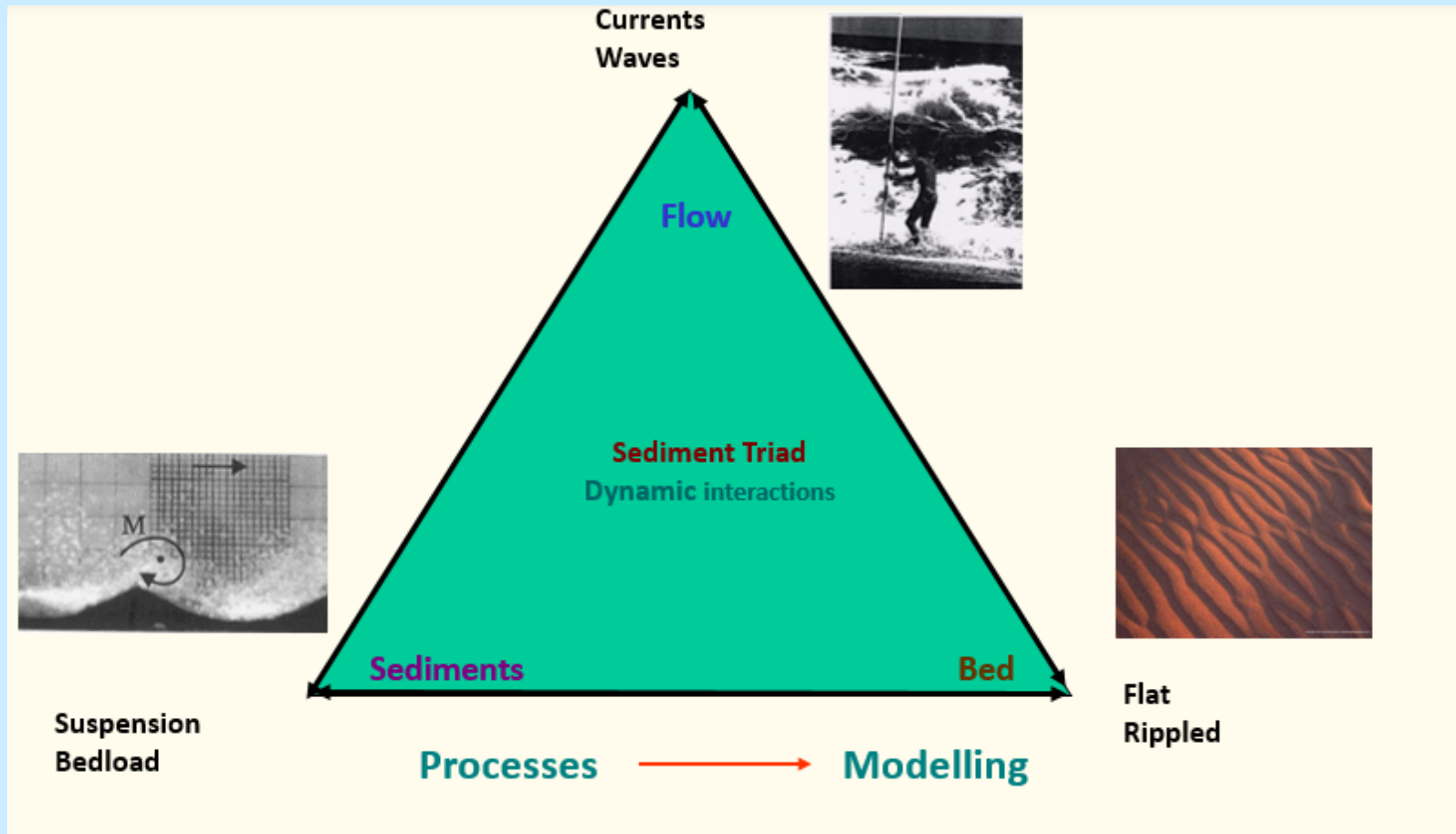
**Provide measurements to advance understanding of nearbed sediment transport dynamics**

**Keynote presentation on Hydralab+ COMPLEX studies at the Third conference of Sea-level and coastal change research group SLACC of the QRA, in Liverpool, UK, 6 - 8 September 2017.**

**Abstract published in the conference programme P1**

Developments have been carried out through EU funding as part of Hydralab programs  
**Provide access to large scale facilities, support staff and instrument development**

Scientific aim Measure fundamental sediment processes



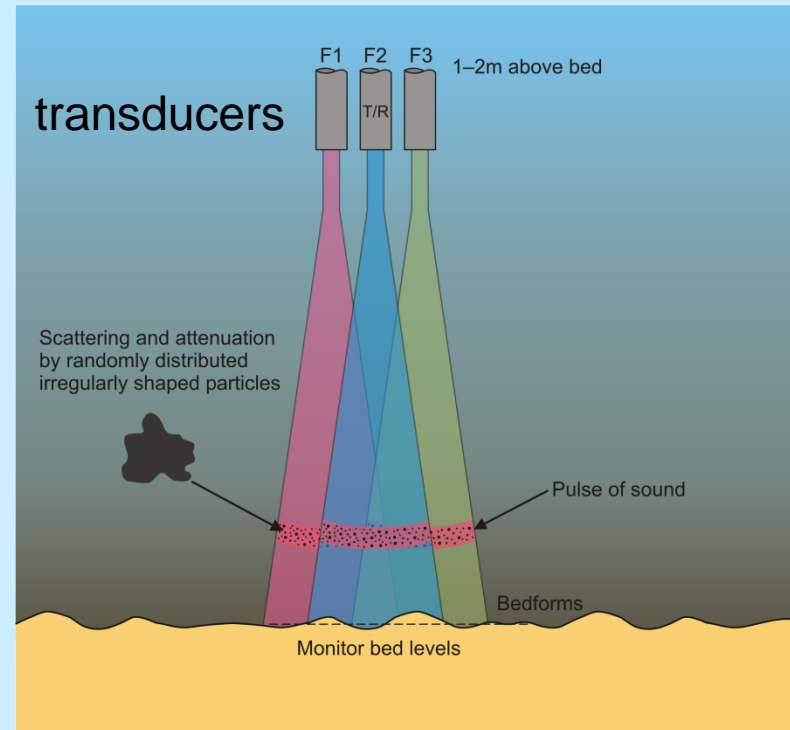
**Simultaneous, co-located measurements of the dynamic interacting sediment triad**

# Concept

Wouldn't it be nice if we could just send a pulse of sound into the water and measure what we need.

## Why acoustics

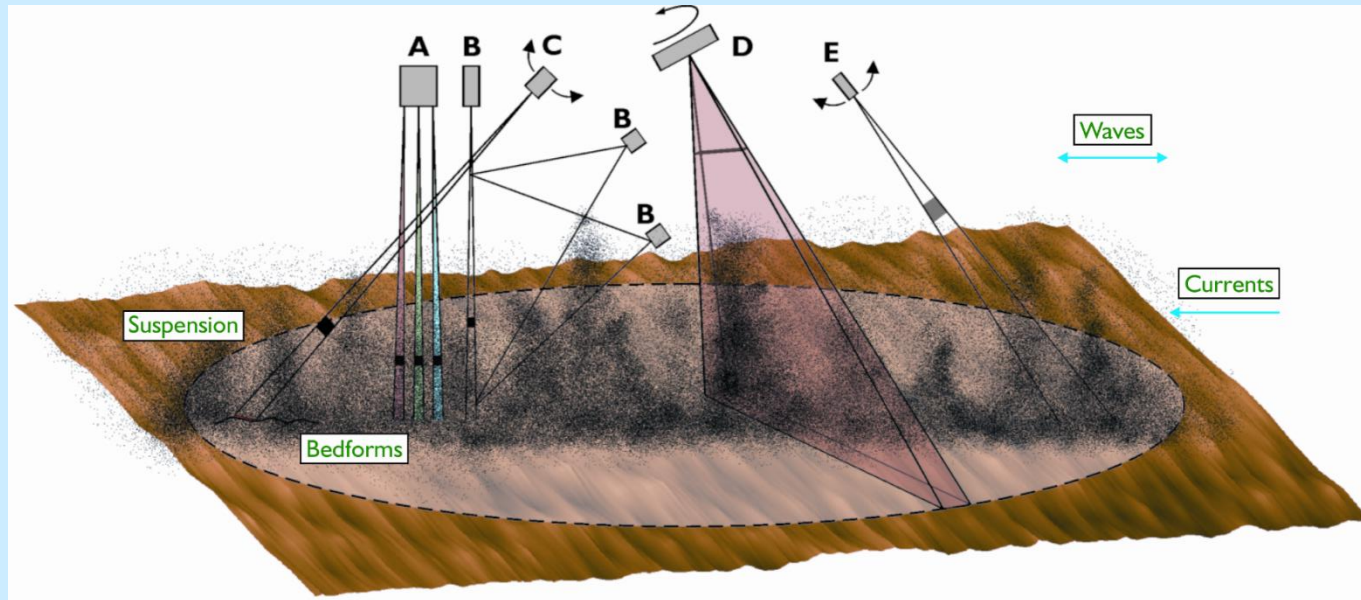
- Non intrusive
- High spatial-temporal resolution
- Provides profiles
- Suspended sediment size & conc
- 3 axis velocity
- bedforms
- bed load



Information amplitude & phase & frequency

# Acoustic Vision a couple of decades back

Non-intrusive, co-located, simultaneous, high spatial-temporal resolution measurement of the sediment triad



- A- Multi-frequency **A**coustic **B**ackscatter **S**ystem – suspended particle size and concentration
- B - **A**coustic **C**oherent **V**elocity **P**rofiler – 3-axis intra-wave & turbulent velocities
- C - **A**coustic **R**ipple **P**rofiler - transects of the bed profile
- D – **H**igh **R**esolution **S**ector **S**canner – images of the micro-topography
- E – **A**coustic **S**uspended **S**ediment **I**mager – Look at suspended sediment structures

Idea was to develop such instruments and look at the dynamic interaction between the bed, flow and mobile sediments

# **Develop instruments to look at boundary layer sediment transport processes**

**Look at sediment transport processes under waves over rippled sandy beds**

**Impact of ripple slope on entrainment processes**

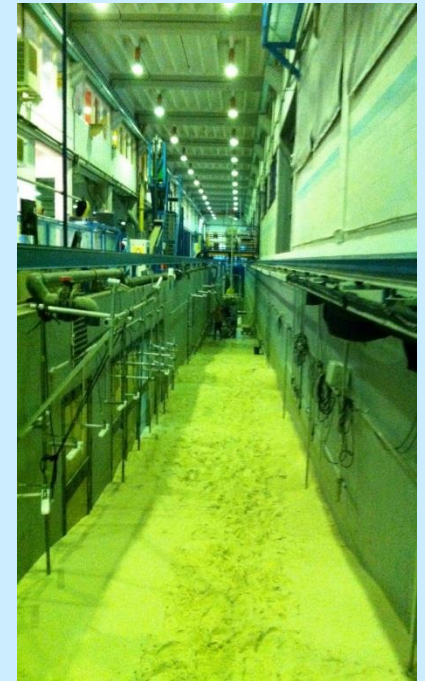
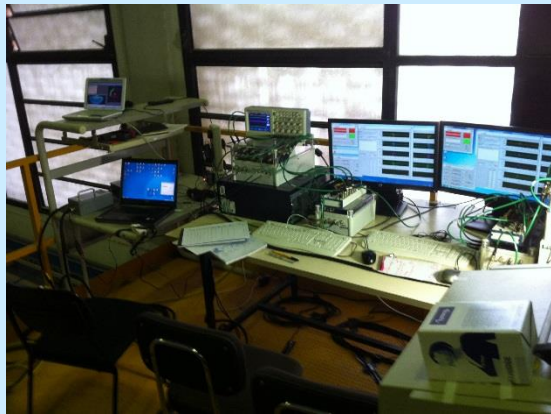
**Influence of wave asymmetry**

**Relative quantities of suspended and bedload**

**Direction of bedload and suspended load transport**



**Typical experiment in the Barcelona Flume: 100 m long, 5 m deep, 3 m wide**  
**Regular waves  $H=0.3-0.5$  m  $T=4.5$  s over 2D-bedforms**



# Instruments

**BASSI** – **B**edform **A**nd **S**uspended **S**ediment **I**mager



**ACVP** – **A**coustic **C**oncentration and **V**elocity **P**rofiler

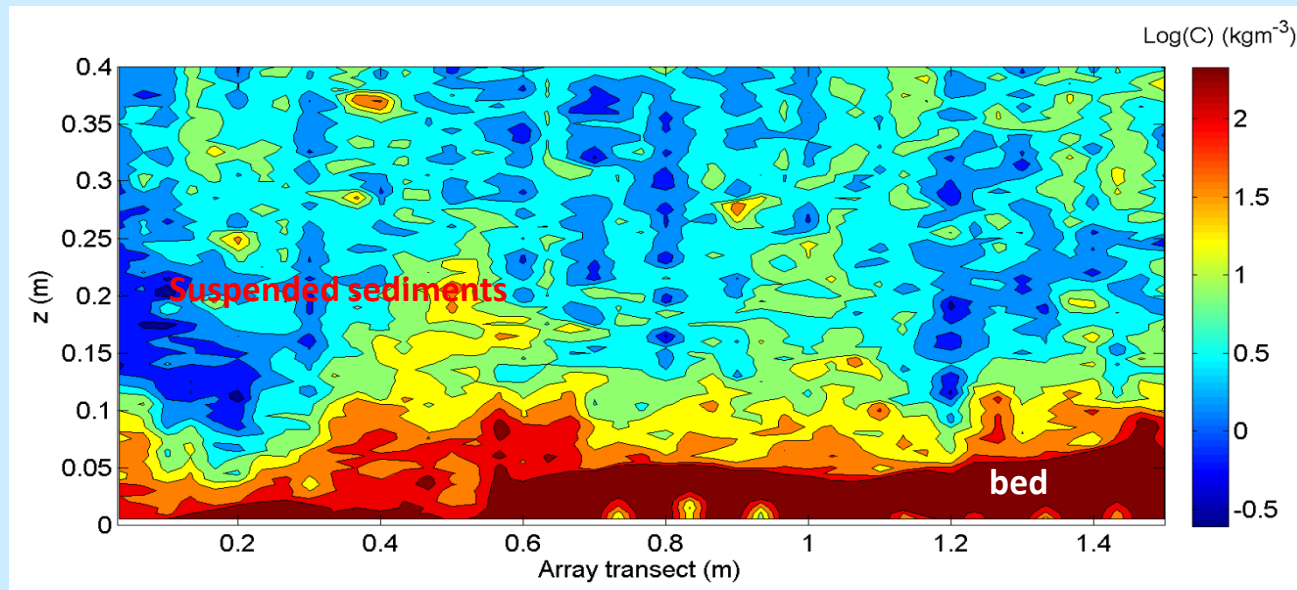
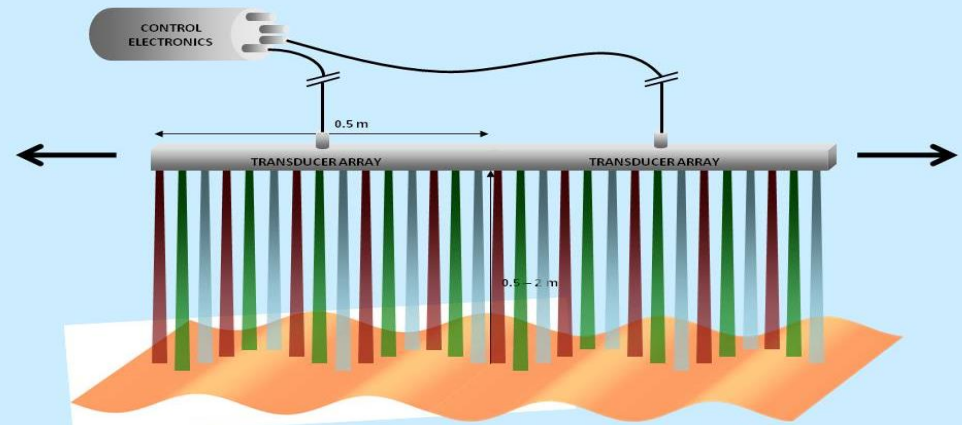


**3D-ARP** – **3** **D**imensional **A**coustic **R**ipple **P**rofiler

Dynamic interacting triad

# 1. BASSI – Bedform And Suspended Sediment Imager

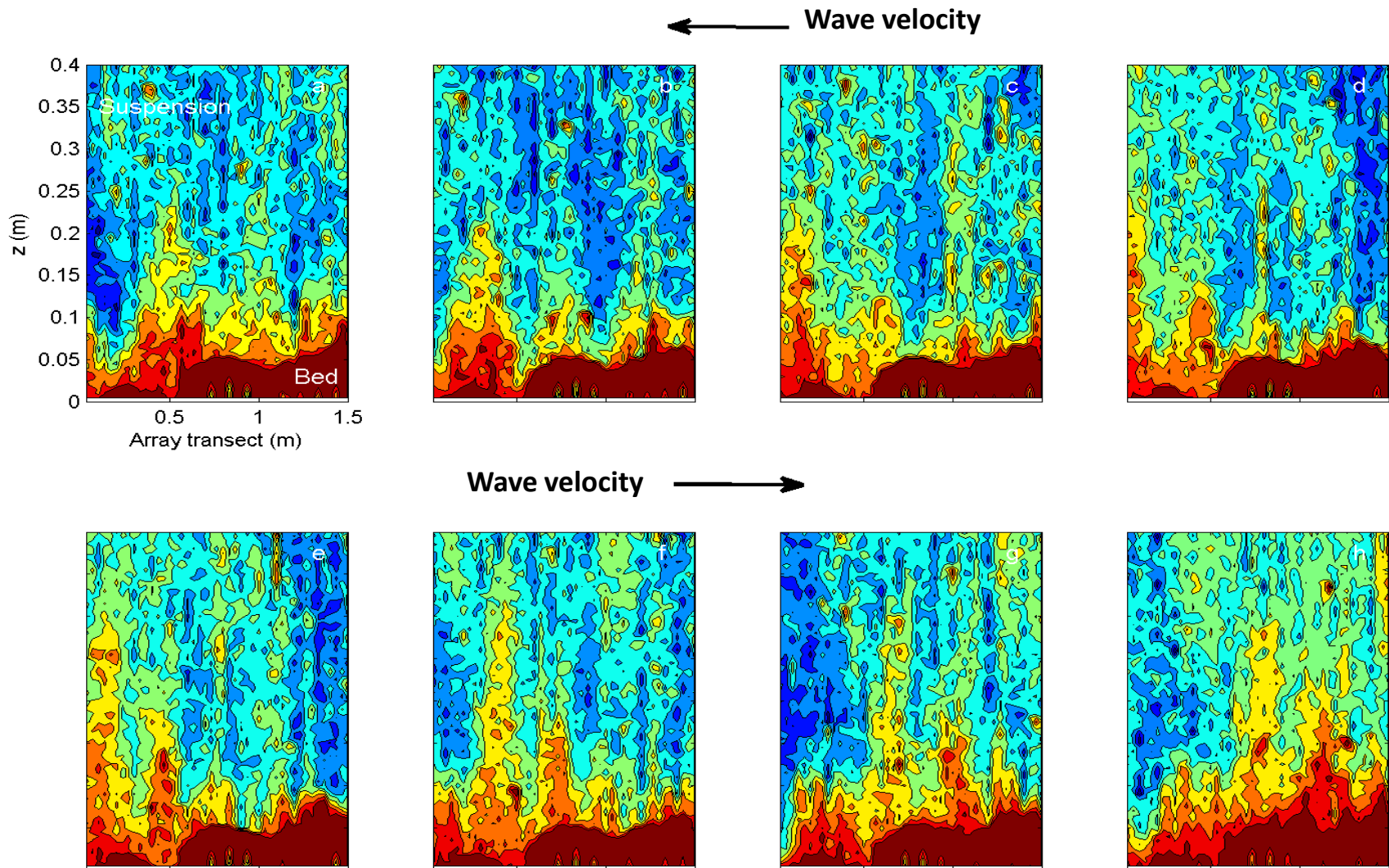
Operates at 0.75, 1.25, 2.5 MHz  
Vertical profile 1m  
Vertical resolution 5 mm  
Horizontal resolution 3.3 cm  
Image rate 10Hz  
15 transducer/array  
4 arrays variable configurations



2DHV Suspension (concentration - particle size), 2D transects of the bed, ripple migration, bedload

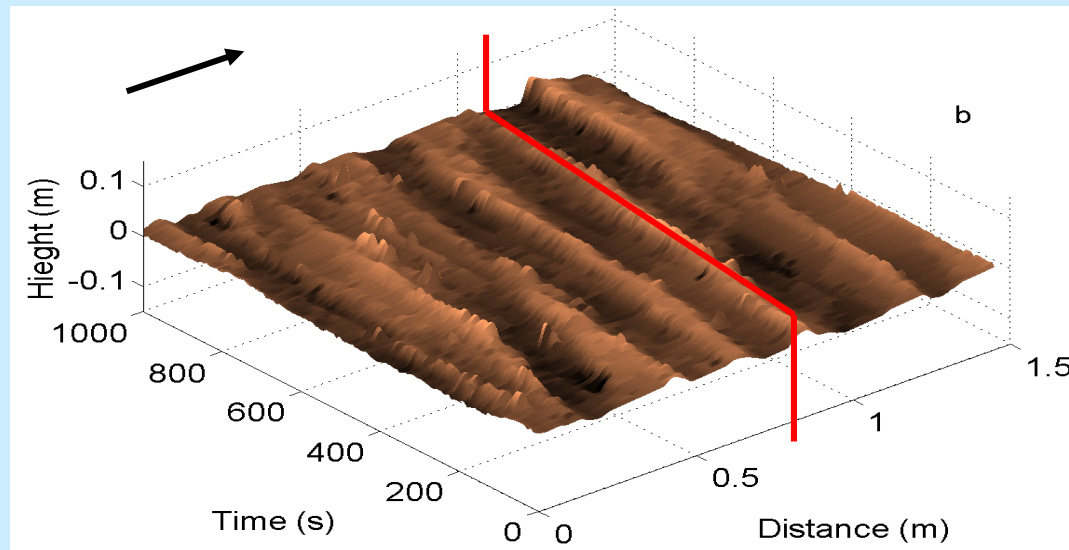
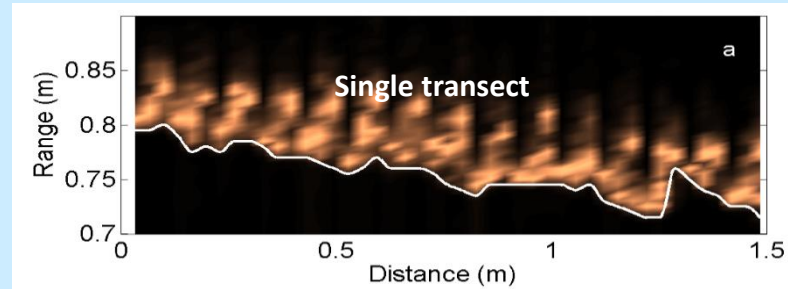


# Time varying intra-wave intra-ripple suspension processes



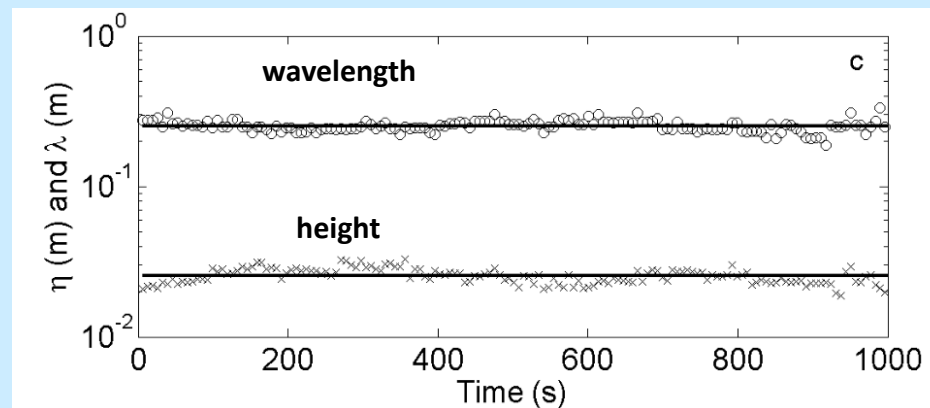
Images 0.5s apart

## Bedforms, ripple migration and bedload



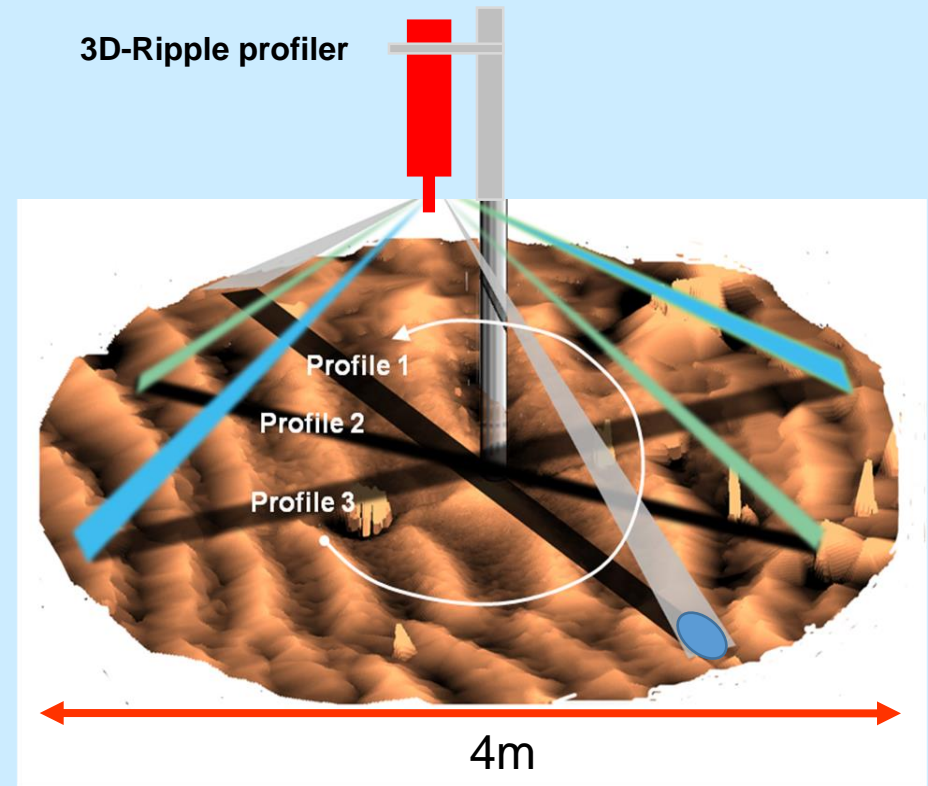
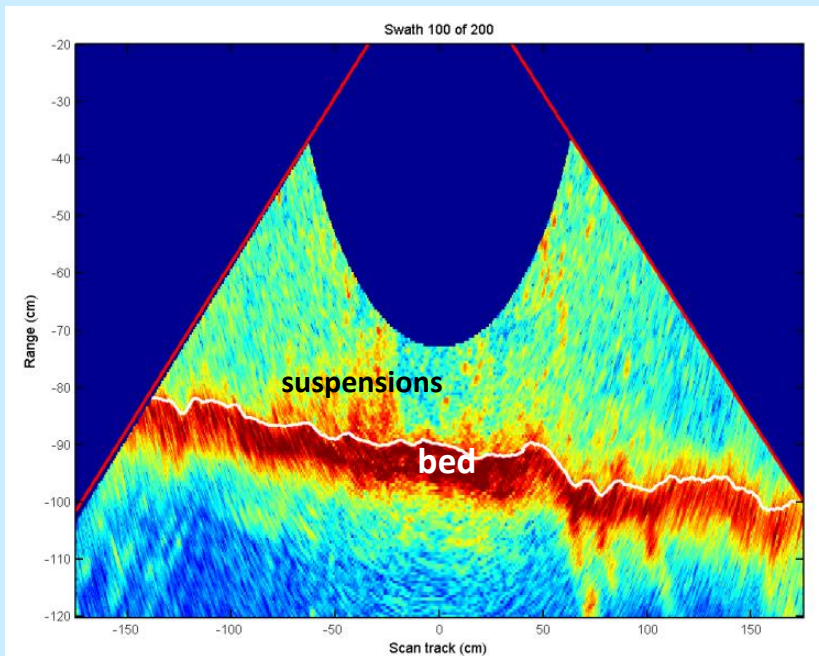
Extract migration rate  
& bedload transport

Nice 2D-Ripples ?



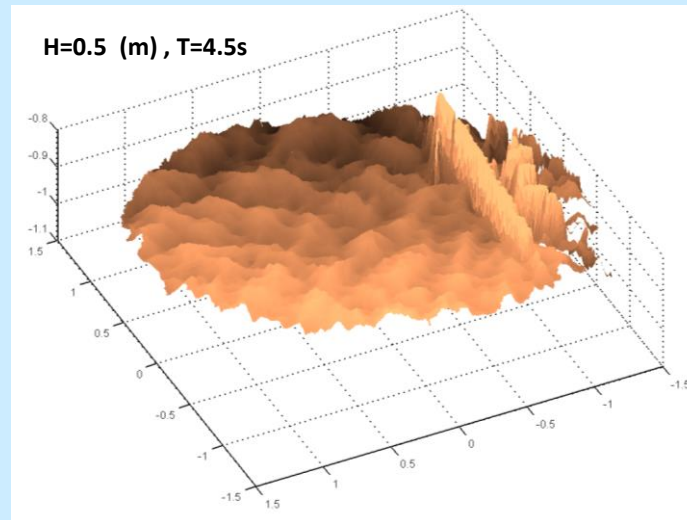
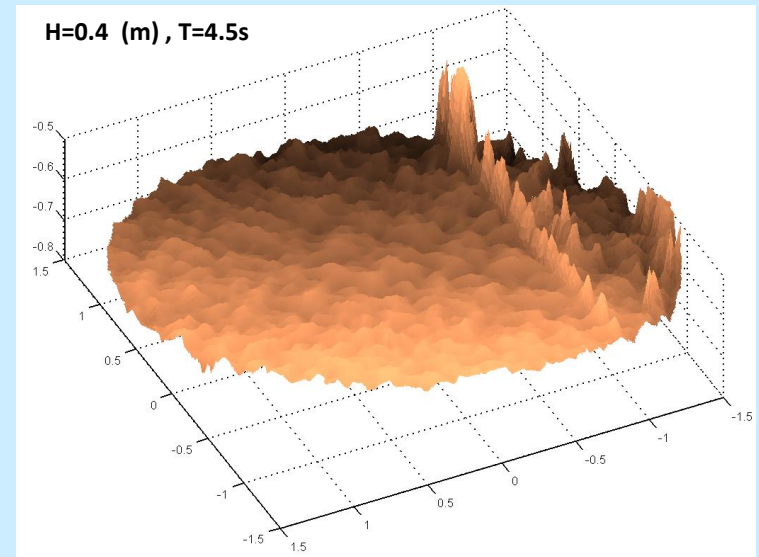
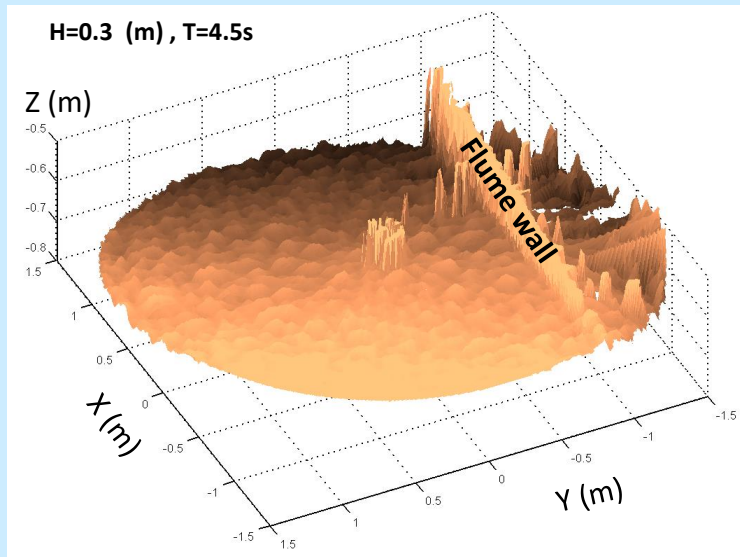
## 2. 3D-ARP – 3 Dimensional Acoustic Ripple Profiler

Operates at 1.1 MHz  
90dB dynamic range  
Variable sector and range  
Variable azimuth rotation,  $0.9^\circ$  -  $9^\circ$   
Variable swath  $0.9^\circ$  -  $9^\circ$   
Variable digitisation, 1-100 us  
Pitch and roll sensors



2DHV suspension, 3D- beforms, ripple migration  
bed load

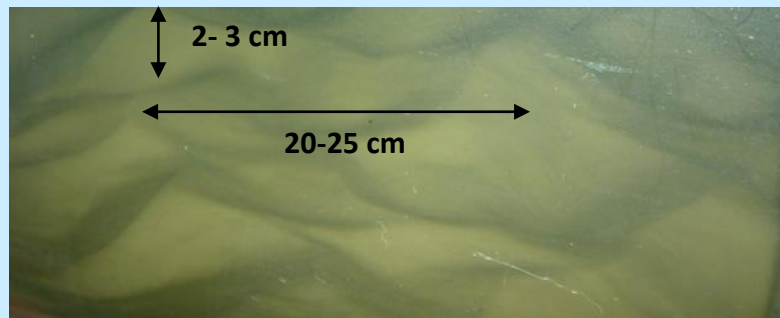
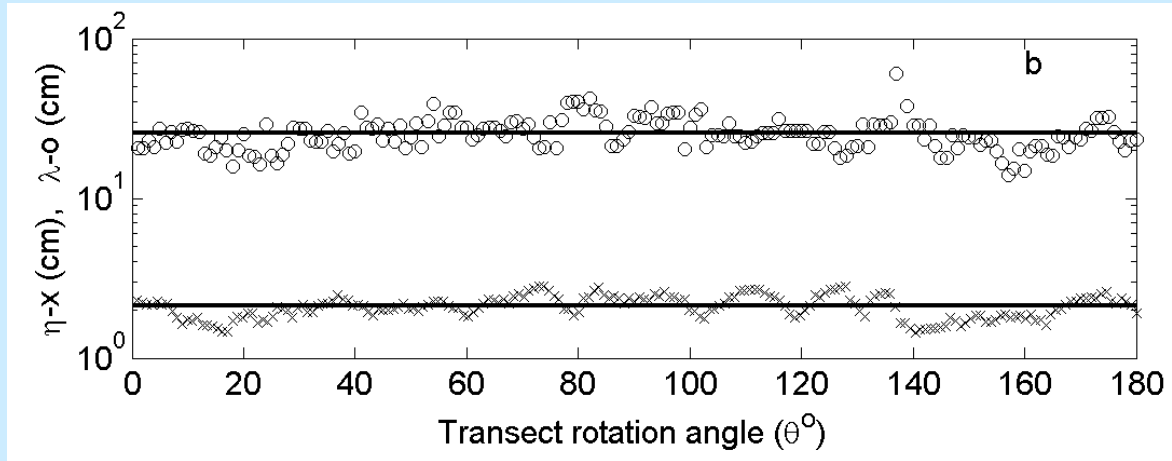
## 3D-ARP measurement of the bed – was expecting 2D ripples



Not very 2D was the system working ok!

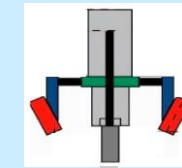
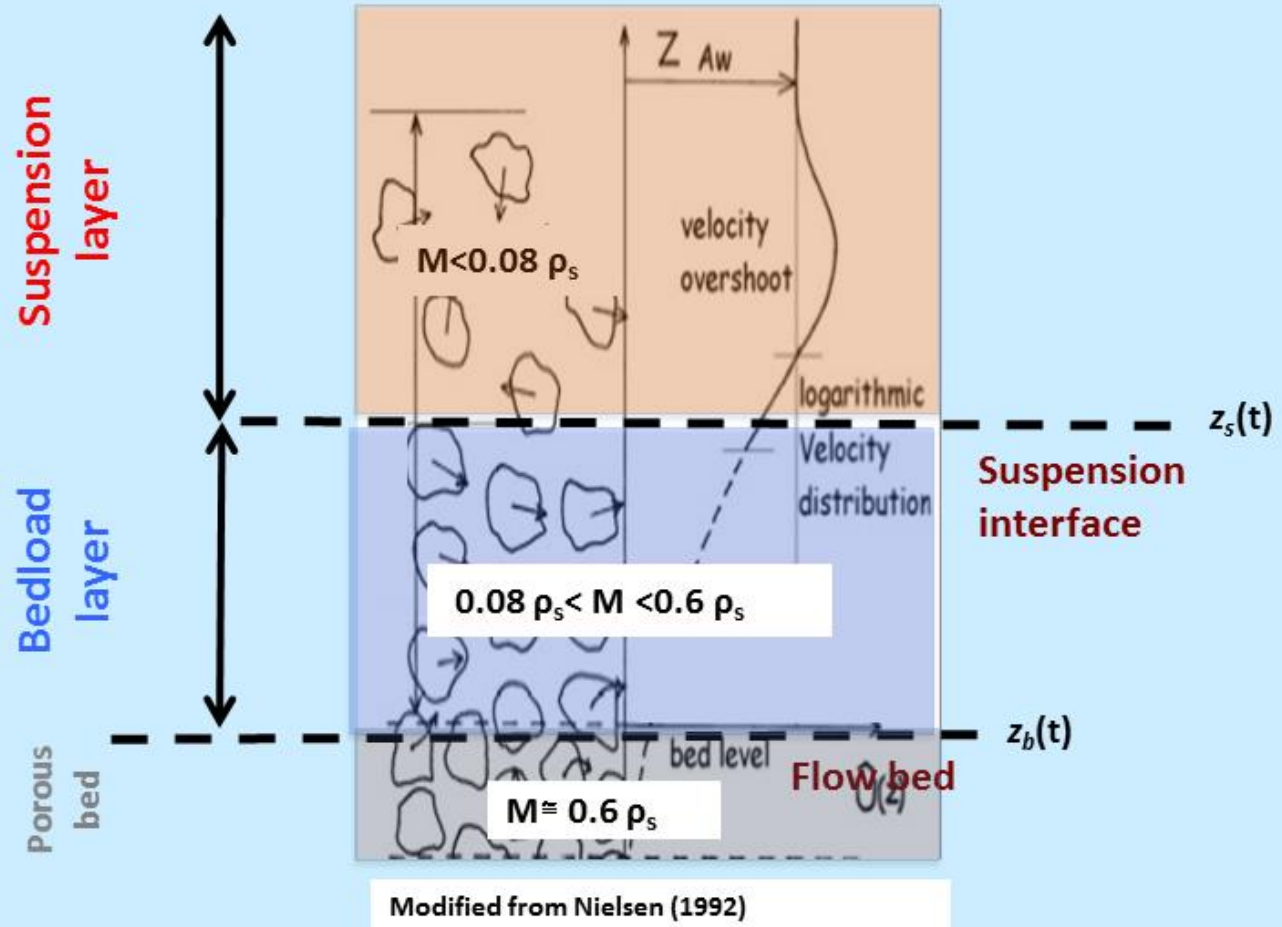


## Ripple dimensions independent of orientation -3D bedforms

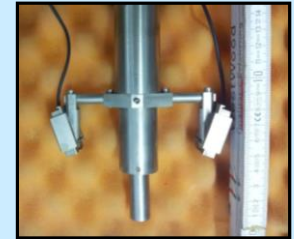


**3D-ripples !**

# HR-ACVP - High Resolution Acoustic Concentration and Velocity Profiler



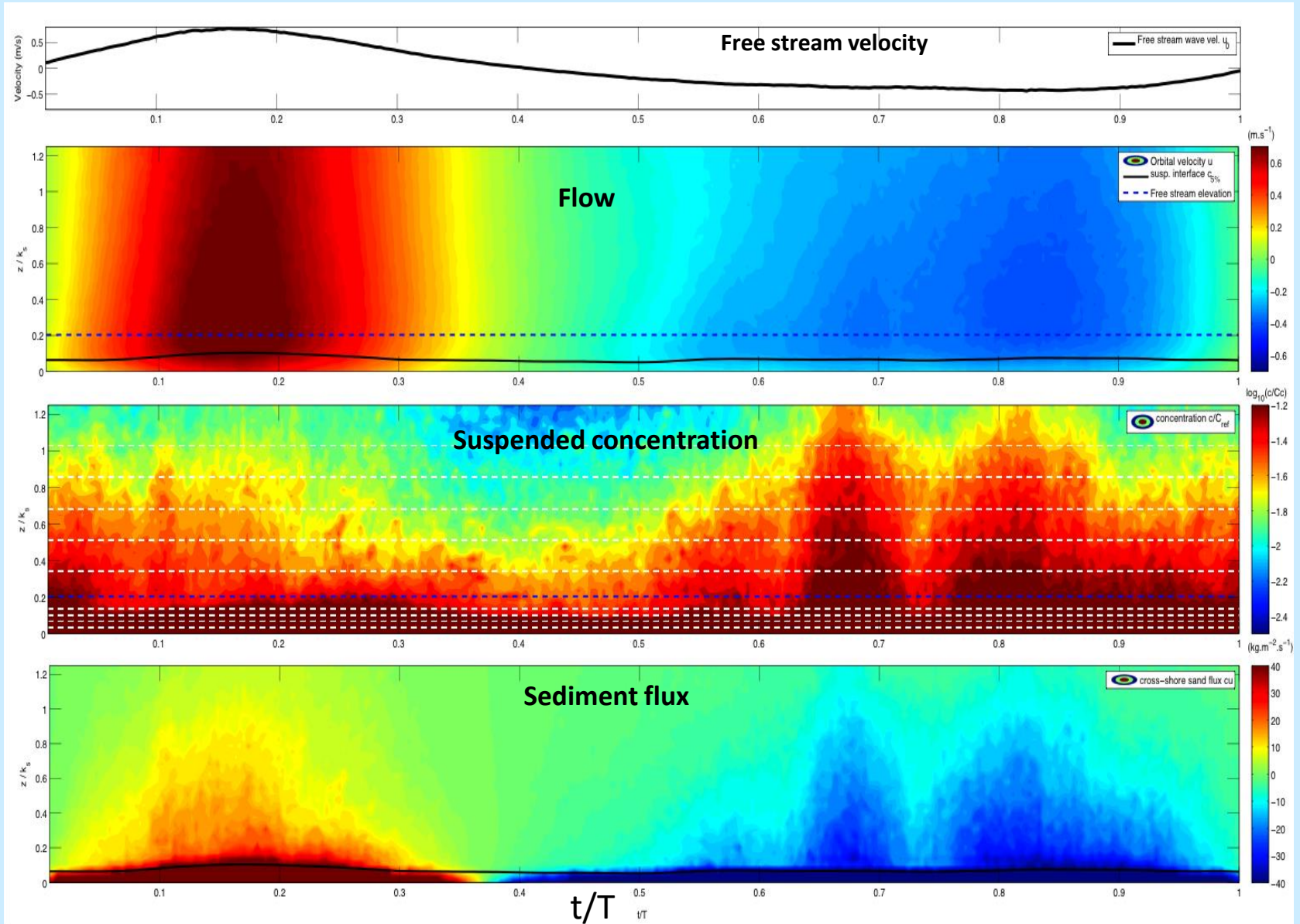
10 - 20 cm



**Dual freq**  
**Resolution 1 mm**  
**Vel 100 Hz - u,w**  
**Conc 10 Hz**

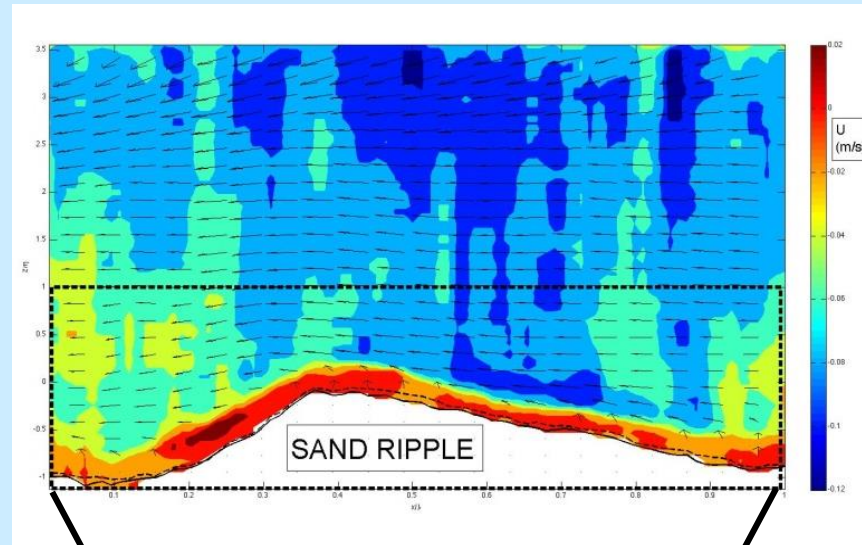
**Suspension (concentration and particle size), 2 component velocity, bedload, bottom tracking**

# Measurements of flow, suspended concentration and sediment flux under waves over a ripple bed



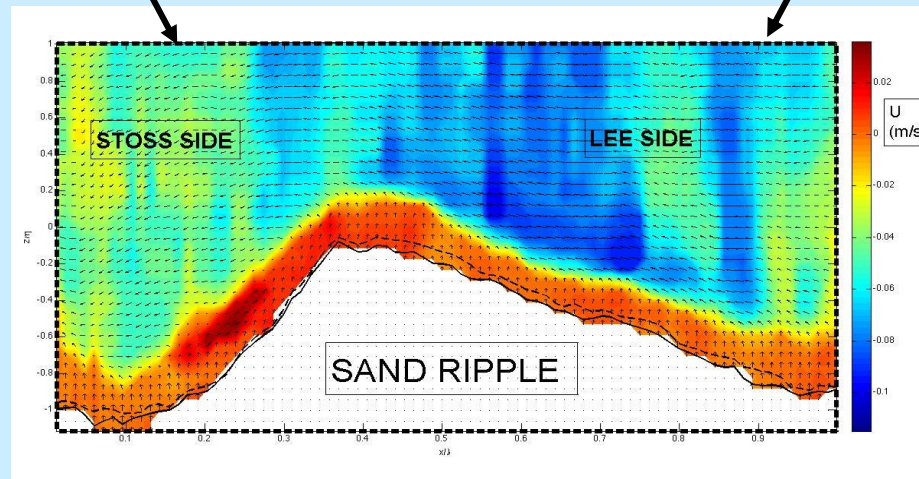


## Averaged velocity over a ripple and streaming vectors



Blue - offshore

Red onshore

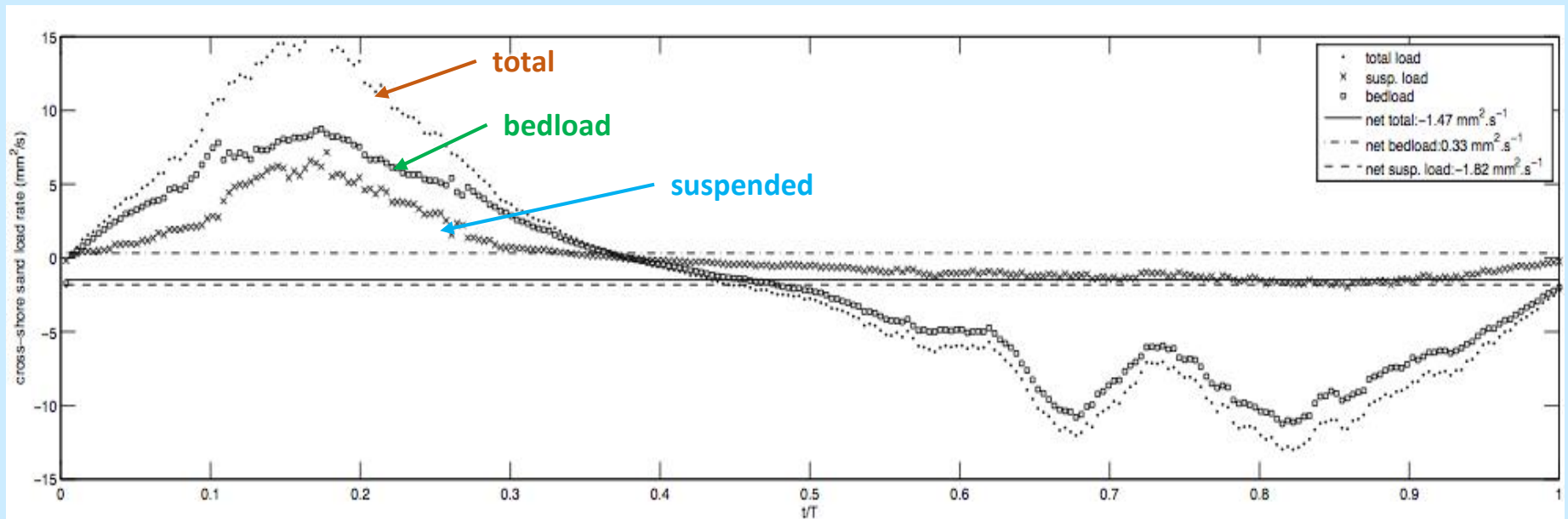
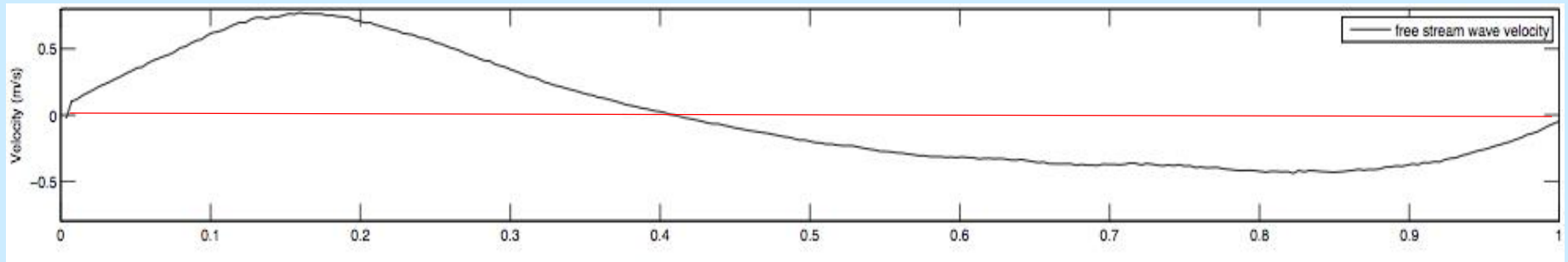


Higher resolution

Close to the bed flow onshore while above offshore



## Bedload, suspended load and total load



Net suspended load offshore

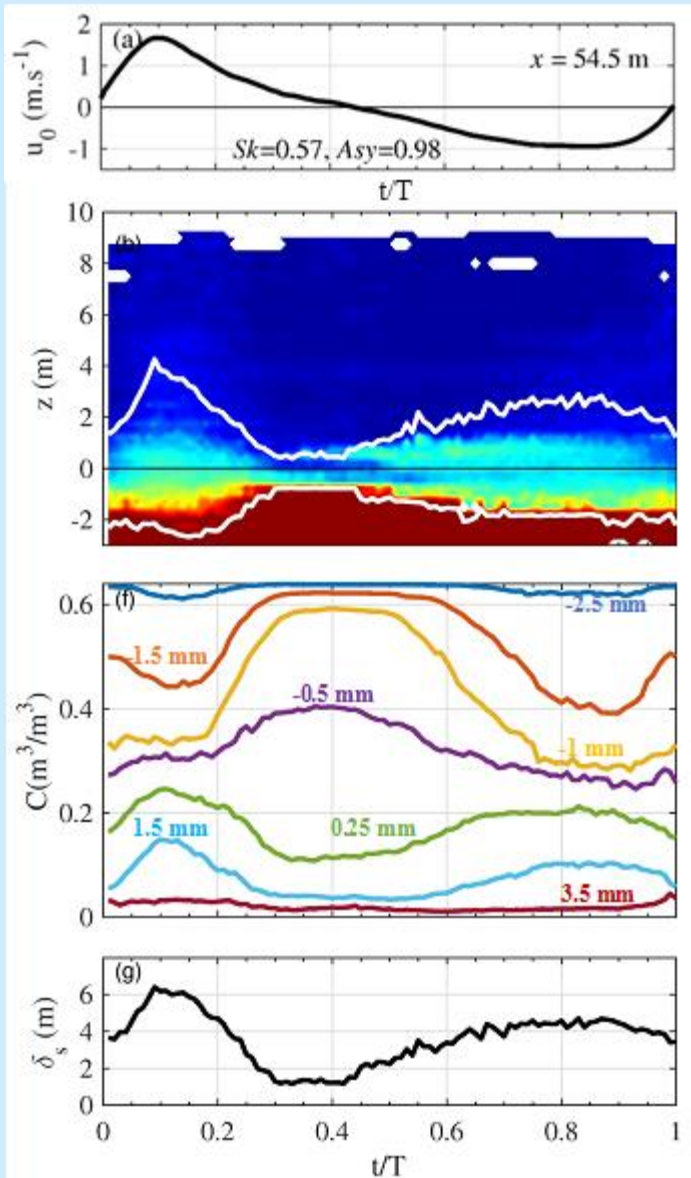
Net bedload onshore

Total load offshore

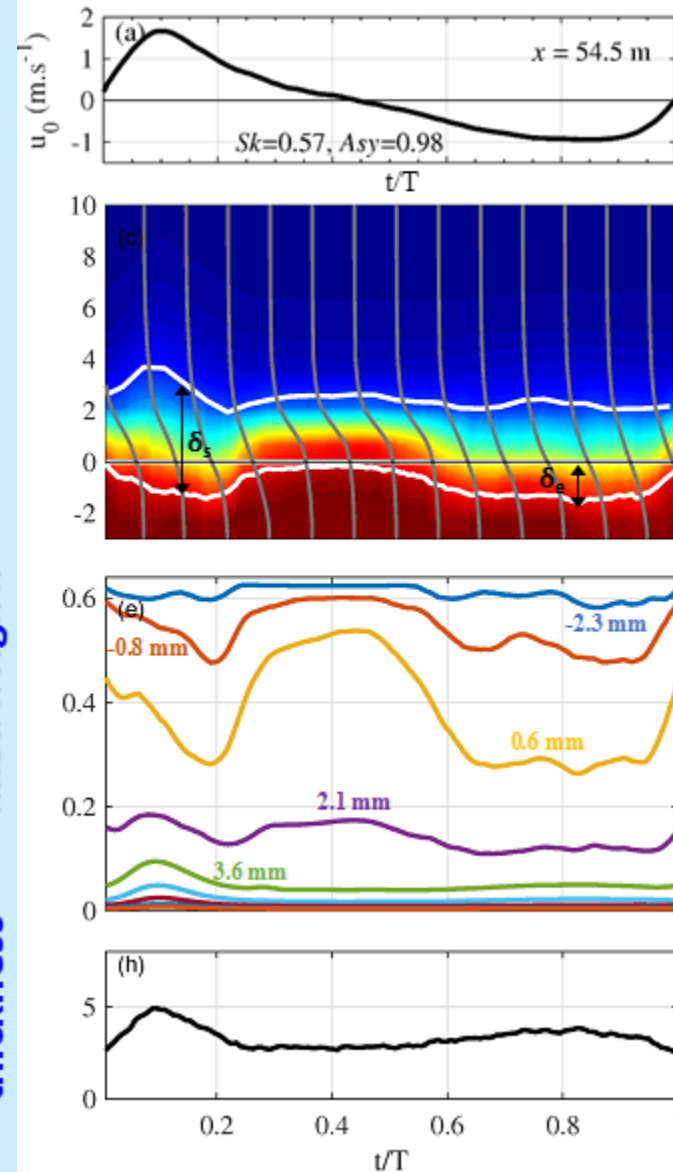
# Wave-driven sheet flows in the wave breaking region

G. Fromant, J. van der Zanden

CCM-3p



ACVP



$u_0$   
 Concentration field  
 Concentration at fixed heights  
 Sheet Flow thickness

$\delta_s$  sheet flow layer

$\delta_e$  erosion depth

Vol conc

$\delta_s$  sheet flow layer

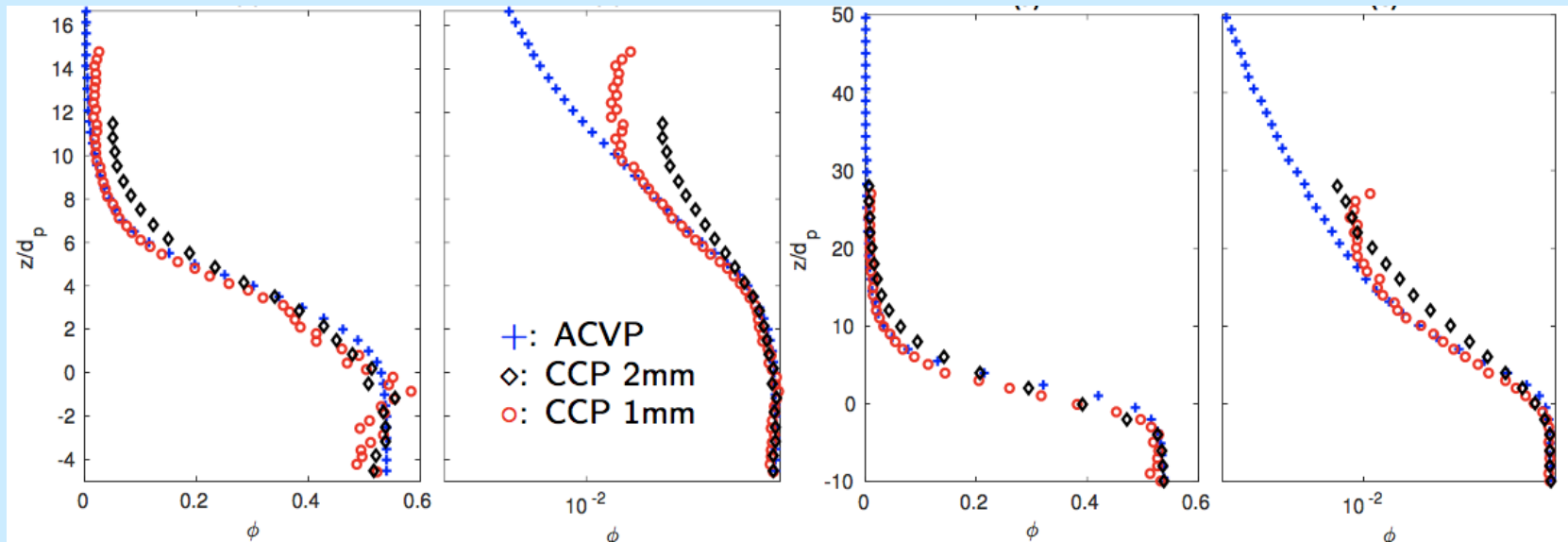
# Current-driven Sheet Flows

J. Chauchat, G. Fromant, T. Revil-Baudard, R. Myeras, J. Puleo

## Bedload measurements: comparison of ACVP & CCProfiler measurements

Large particle (3 mm)

Small particle (1 mm)



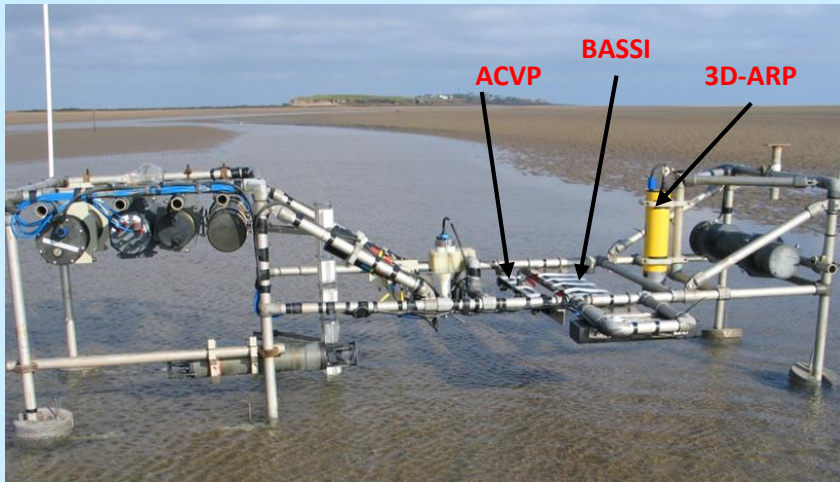
- Good agreement between CCP probes and ACVP
- CCP do not measure concentrations below  $\phi < 0.01$



## Secured major funding at least in part due to acoustic systems

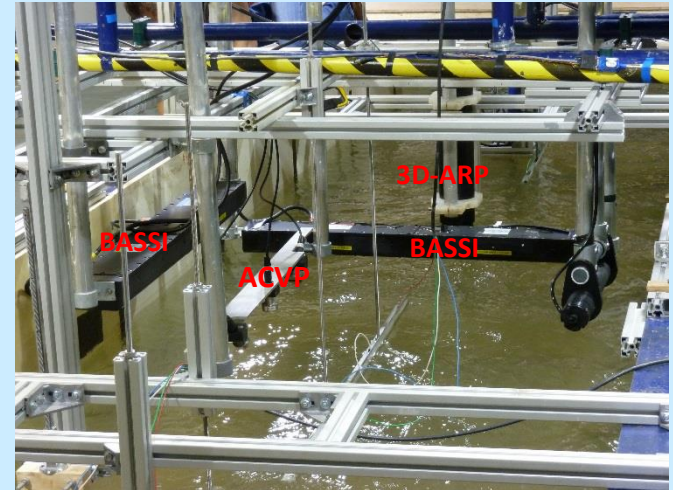
### COHBED - NERC

Study ripple formation over physically and biologically cohesive beds



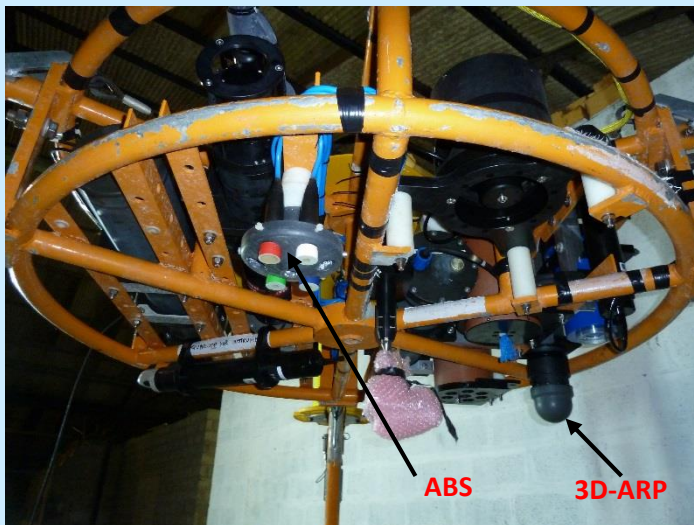
### INSTRON - EPSRC

Model tidal stream turbine studies



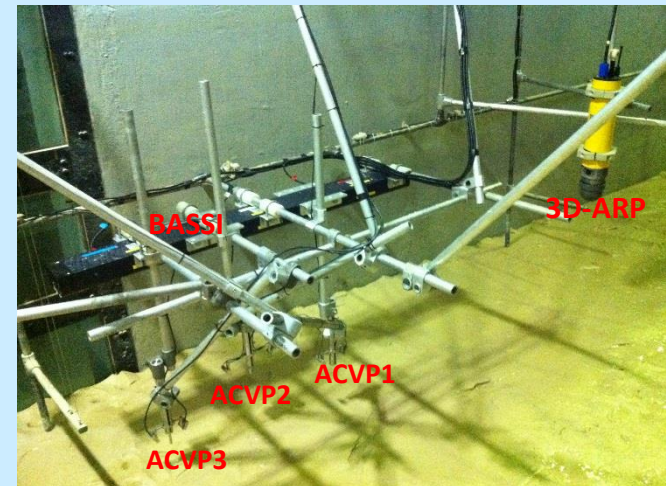
### BLUEcoast – NERC

Physical and biological dynamic coastal processes and their role in coastal recovery



### Hydralab – EU

Water interface sediment experiment

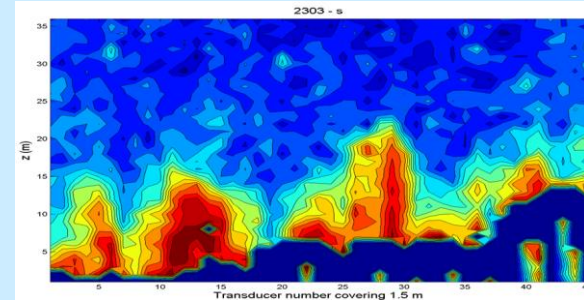




# Conclusions

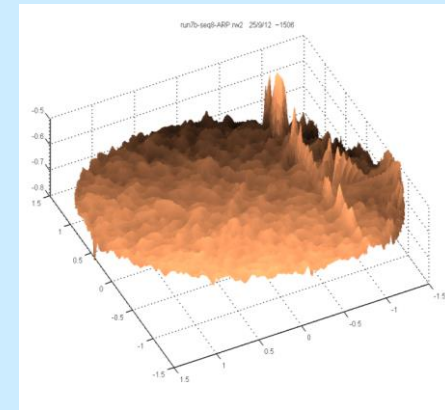
## BASSI

2DHV images of suspended conc/size  
Intra-wave intra-ripple suspended sediments  
Transects of bedforms  
Ripple dimensions  
Ripple migration can be measured



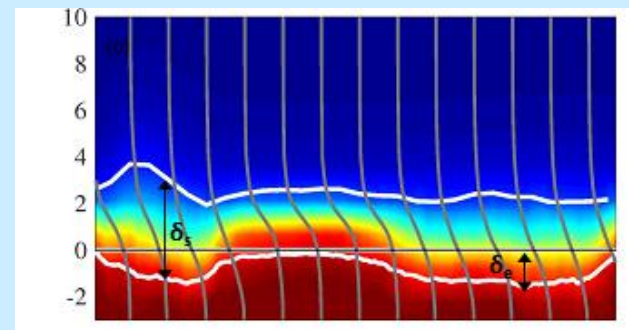
## 3D-ARP

Individual transects of the bed  
3D images of the bedforms  
Ripple dimensions  
Ripple migration  
Suspended sediment can be measured



## HR-ACVP

particle size & concentration  
velocity profiling & bed interface tracking  
Suspended sediments & bedload fluxes  
Bedform measurements on mobile beds



Made significant progress since the vision. What does the future hold ?