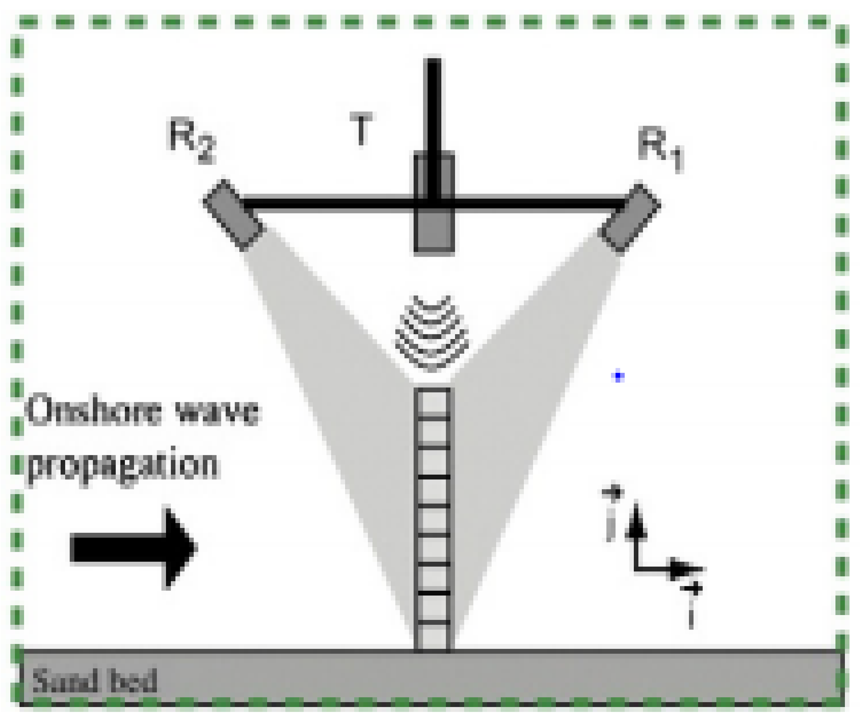
Suspension and bedload transport processes in the wave-driven ripple vortex regime for well-sorted and graded sands

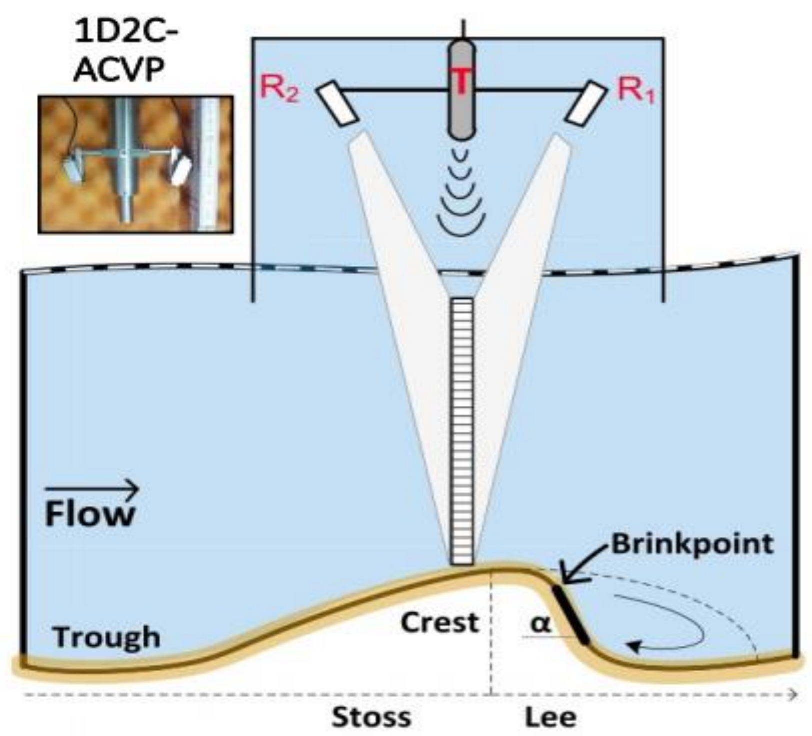
N.Fritsch[1], G.Fromant[1], D.Hurther[2], I.Cáceres[3]

1. Laboratoire d'Informatique Signal et Image de la Côte D'Opale, Calais, France, 2.Laboratory of Geophysical and Industrial Fluid Flows (LEGI), CNRS-Grenoble INP-UGA, Grenoble, France, 3.Laboratori d'Enginyeria Maritima, Universitat Politècnica de Catalunya, Barcelona, Spain.

ACVP (Acoustic Concentration and Velocity Profiler) technology



ACVP System [5]

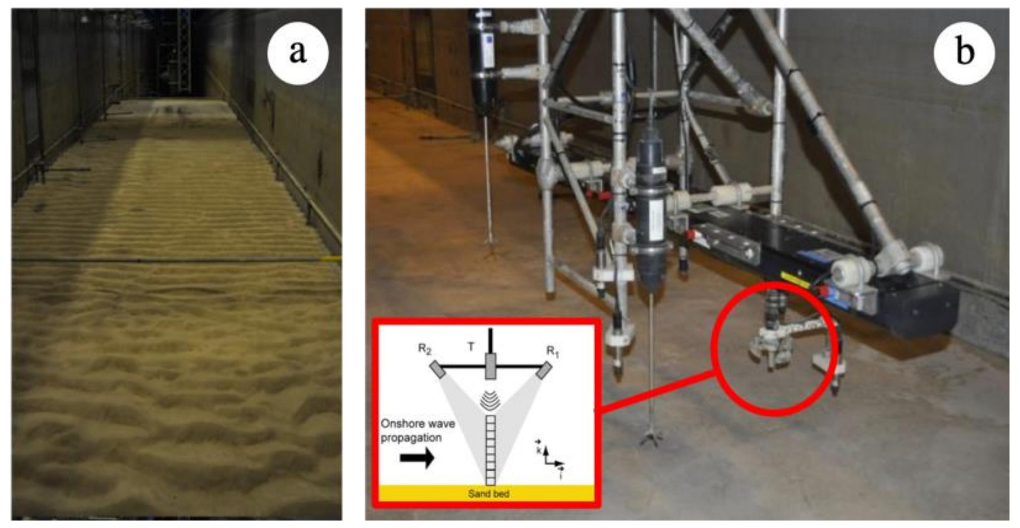


ACVP deployed over rippled bed

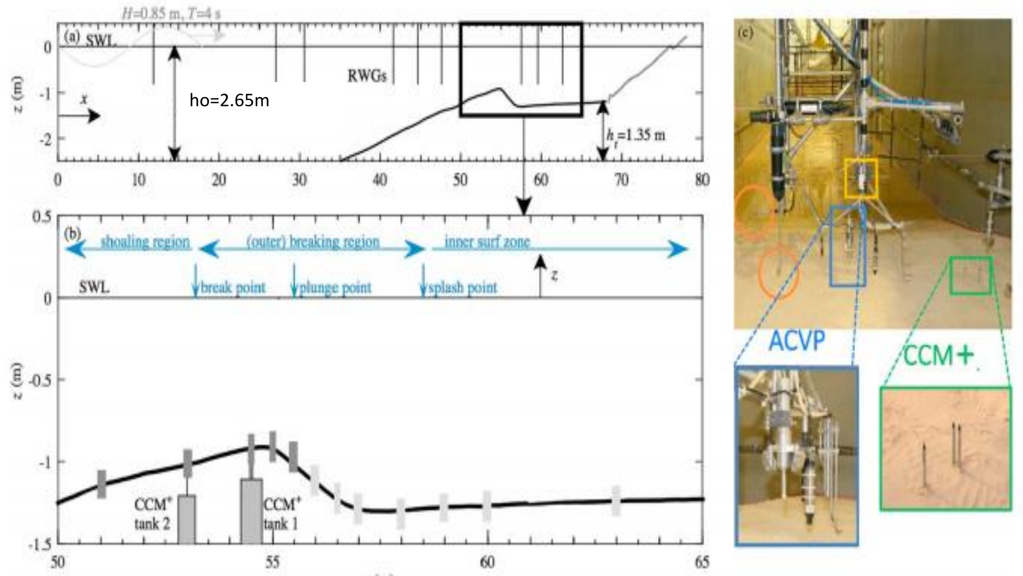
- ACVP : Colocated high-resolution profiling of sediment concentration and velocity fields in the water column [5].
- Hydroacoustic technology
- Developped in LEGI - Grenoble. [5]
- Application to sediment transport and turbulence measurements. [3] [5]

[1] T.O'Donoghue et al., The dimensions of sand ripples in full-scale oscillatory flows, 2006
[2] Van der Werf et al., Detailed measurements of velocities and suspended sand concentrations over full-scale ripples in regular oscillatory flow, 2007
[3] D.Hurther, Peter D. Thorne, Suspension and near-bed load sediment transport processes above a migrating, sand-rippled bed under shoaling waves, 2011
[4] D. Wang, J. Yuan, An experimental study of net sediment transport rate due to acceleration-skewed oscillatory flows over rippled seabeds, 2020.
[5] Hurther et al., A multi-frequency Acoustic Concentration and Velocity Profiler (ACVP) for boundary layer measurements of fine-scale flow and sediment transport processes, 2011

Sediment transport processes over ripples under real waves



RIPCOM experiment, 2017, Barcelona CIEM wave flume, 1:1 scale



Mounting of ACVP in Barcelona CIEM wave flume

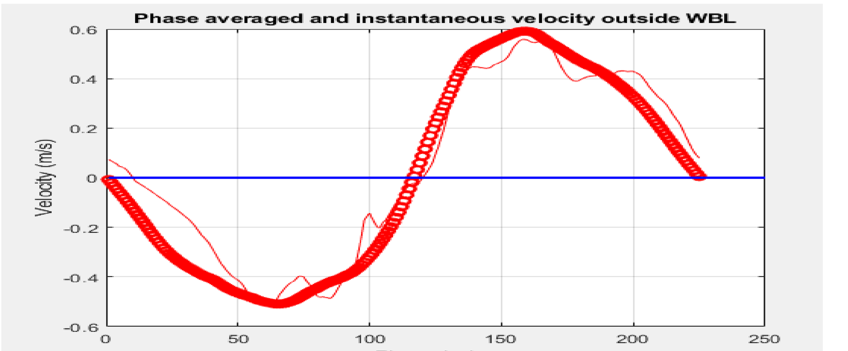
RIPCOM EXPERIMENT (Hydralab+)

Context

- Lack of knowledge and measurements
- Complex interactions between the flow, the bed and the suspended sand → need for high resolution measurements
- DO/D50 = 2000 - 4000 → suborbital ripples [1]

Objectives

- Understanding the morphological behaviour of coastal environments
- Sediment transport processes : influence of grain size → coarse (D50 =0.545mm) and fine (D50=0.246mm) sands
- Improve sediment transport predictive models



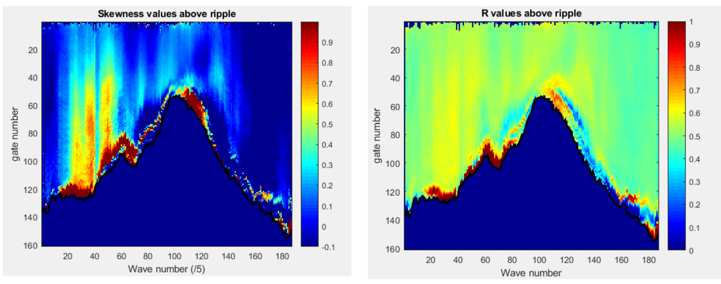
Orbital free-stream cross-shore velocity

Wave conditions

- T=9s
- H=0.3m

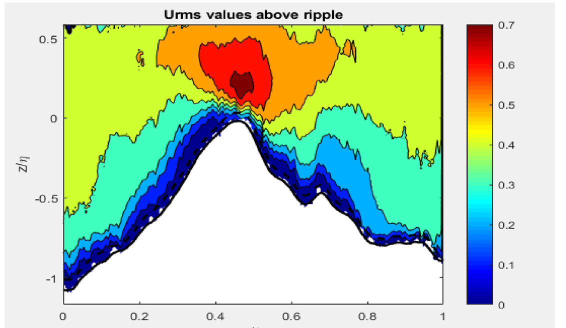
Study interrations between rippled bed and flow

- Evolution of velocity non-linearities as approaching the ripple bed
- Acceleration skewness in the flow changes the ripple dimensions and shapes. [4]



Values of R and beta, quantification of acceleration and velocity skewness

- Mostly turbulent at the ripple crest



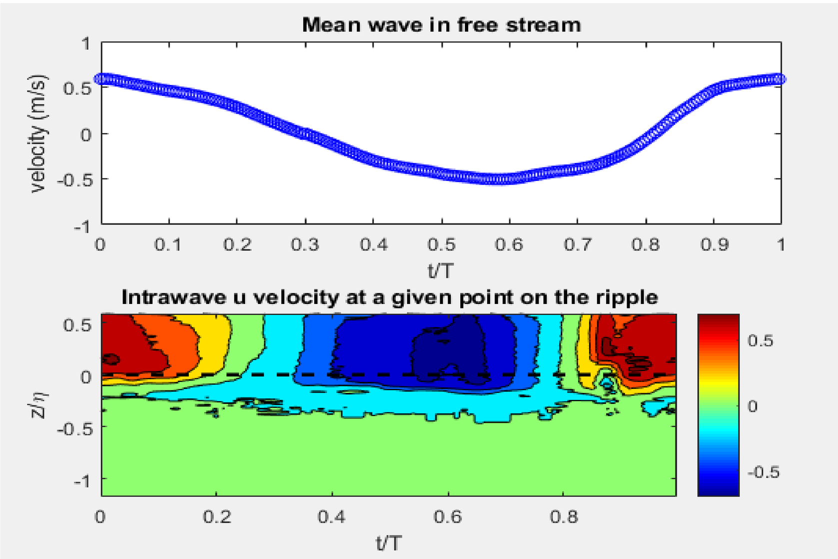
Rms cross-shore velocity above coarse sand ripple bed

Hydrodynamics

Pulse-to-pulse coherent Doppler Velocity measurements

$$\begin{cases} v_D^+ = \dfrac{2v_0}{c}(u\sin\alpha + v\cos\alpha) \\ v_D^- = \dfrac{2v_0}{c}(v\cos\alpha - u\sin\alpha) \end{cases} \quad \begin{cases} u = \dfrac{c}{4v_0\sin\alpha}(v_D^+ - v_D^-) \\ v = \dfrac{c}{4v_0\cos\alpha}(v_D^+ + v_D^-) \end{cases}$$

vD+ and vD- : Doppler frequencies at receivers
u, v : cross- and longshore velocity components



Intrawave cross-shore velocity (u) for coarse sand ripple (m/s), RIPCOM experiment

Concentration measurements

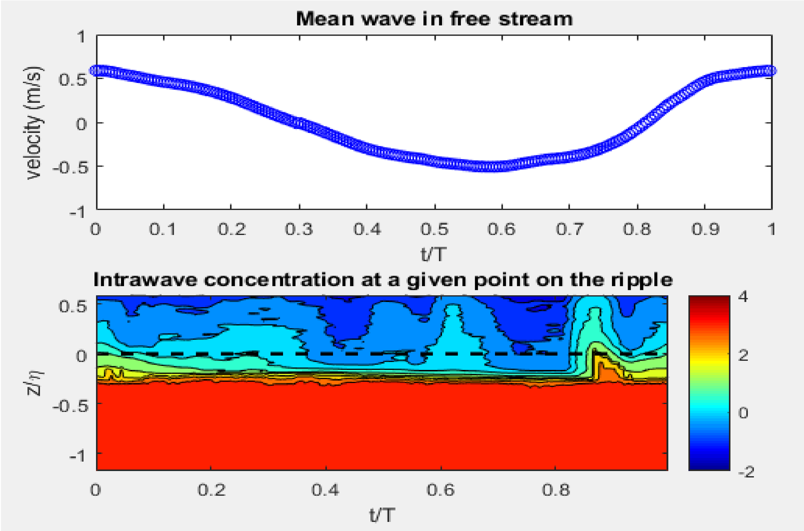
Mass concentration

Attenuation parameter

$$I = M.Aj.As.e^{-4\alpha}$$

Backscattered intensity

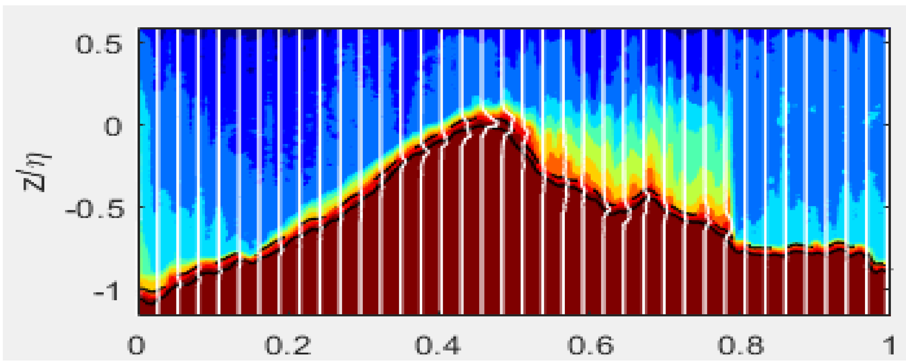
Backscattering model



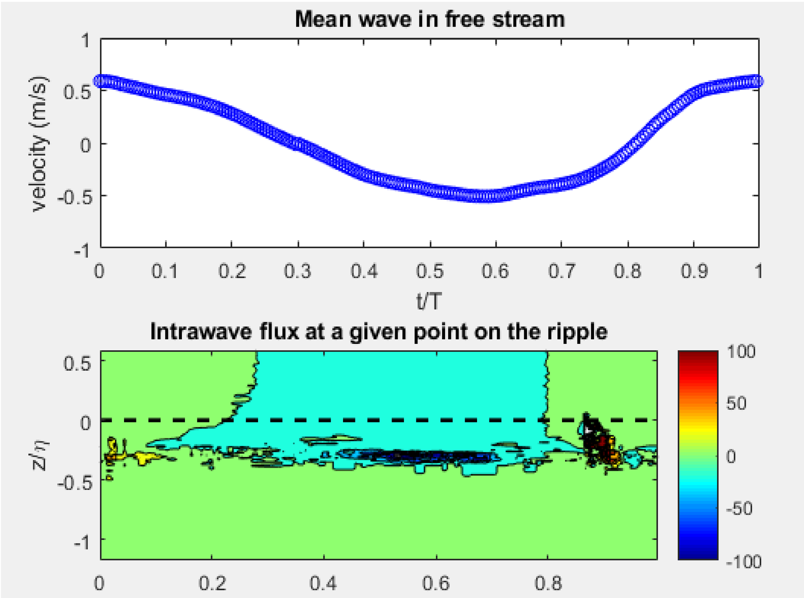
Intrawave concentration for coarse sand ripple (g/L), RIPCOM experiment

Quasi instantaneous flux

- Q = M.U
- Flux direction and value : crucial information for coastal engineering → how can we predict it ?

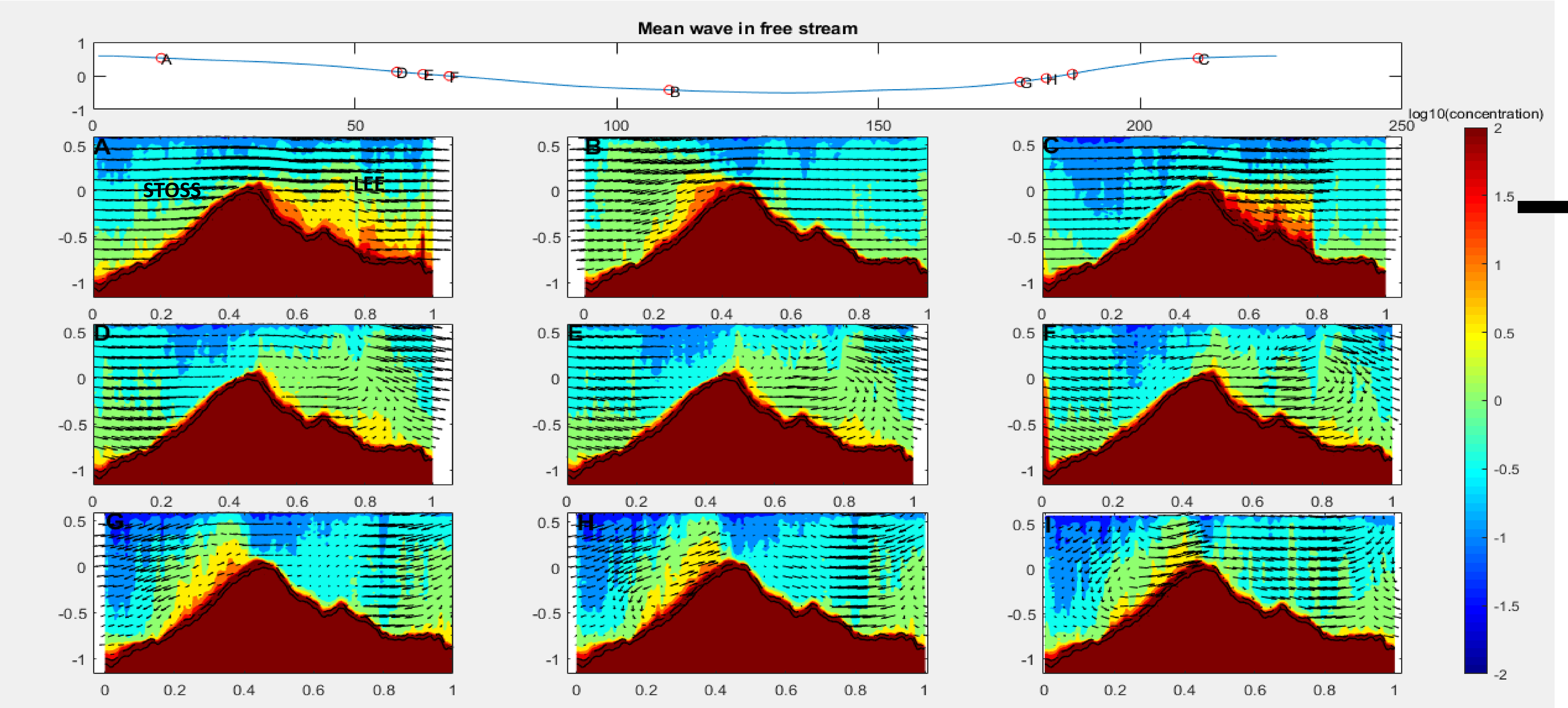


Concentration contours and flux profiles above ripple, RIPCOM experiment



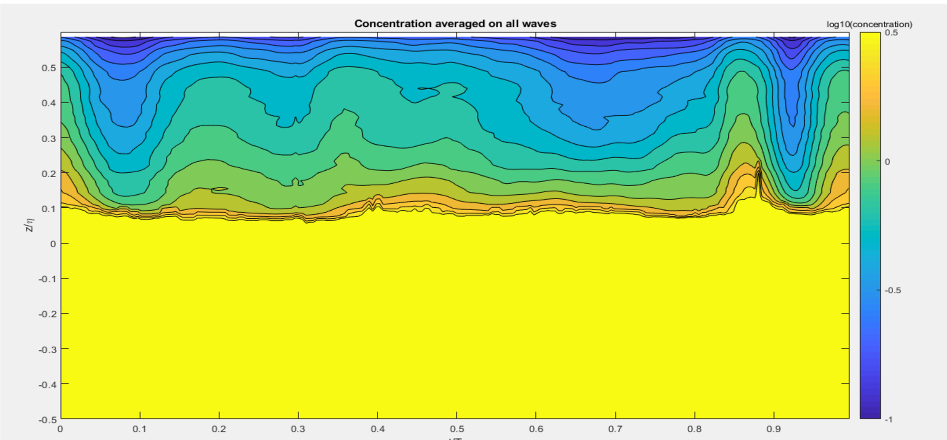
Intrawave flux for coarse sand ripple (m^2/s), RIPCOM experiment

Results for coarse sand ripples



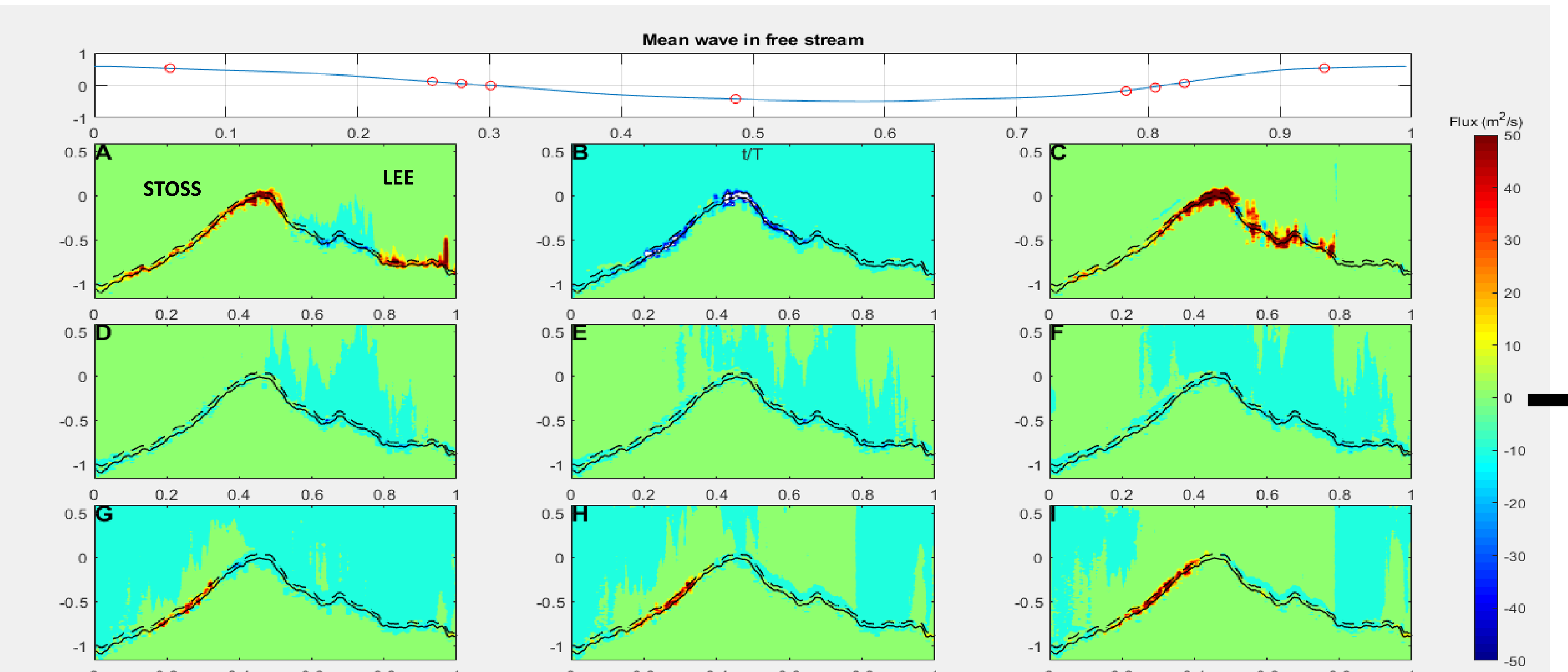
Velocity vectors and concentration contours above the ripple at observed at different phases of the orbital free-stream velocity

- **First flow reversal** : clockwise vortex on the lee side of the ripple, associated with high concentration events as observed by [2]-[3].
- **Second flow reversal** : counter-clockwise vortex on the stoss side of the ripple, associated with high concentration events as observed by [2]-[3].
- **Maximum onshore velocity** : velocity field directed onshore.
- **Maximum offshore velocity** : velocity field directed offshore.



Intrawave concentration for coarse sand ripples

- 4 concentration events observed as expected in oscillatory flows [2]



Flux contours above the ripple at observed at different phases of the orbital free-stream velocity

- Sediment transport mainly occurs as **bedload**.
- Offshore flux during first flow reversal.
- Onshore flux on the stoss during second flow reversal.
- Vortex signatures during flow reversals
- **Ripple averaged net sediment transport rate** : $1.4088.\ 10^{-5}\ m^2/s$ → positive net as observed for acceleration skewed flows [4]