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SANDT-PRO: SEDIMENT TRANSPORT MEASUREMENTS UNDER IRREGULAR AND BREAKING WAVES

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SandT-Pro: Wave channel experiments in Barcelona (UPC)

Objectives

General

Improve our understanding and collect a set of high-resolution data of sediment dynamics under large-scale **breaking waves** and **irregular waves**

Focus

Near-bed intra-wave sediment transport processes

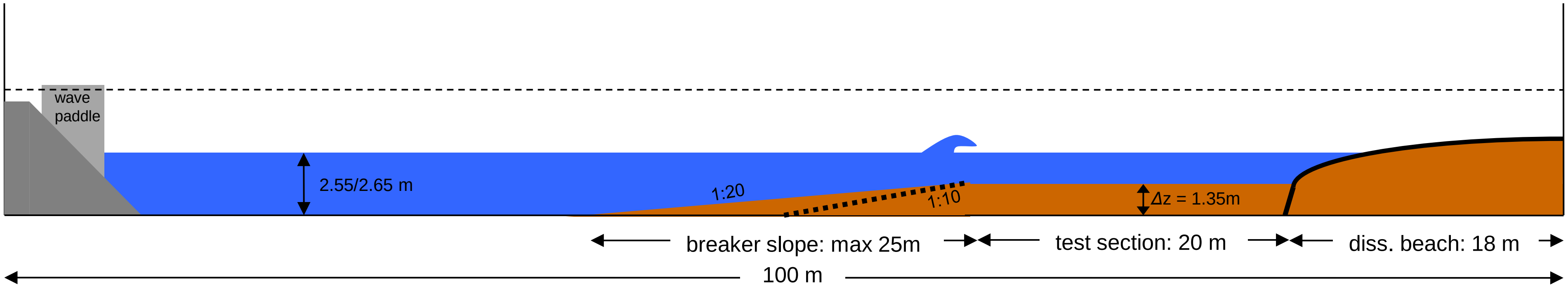
Issues

Breaking-induced turbulent flow and sediment stirring

Time-history effects of suspension under wave groups (sediment pumping)

Sediment fluxes and their components (suspension/bed-load, wave/current..)

Experimental set-up
Barcelona wave flume

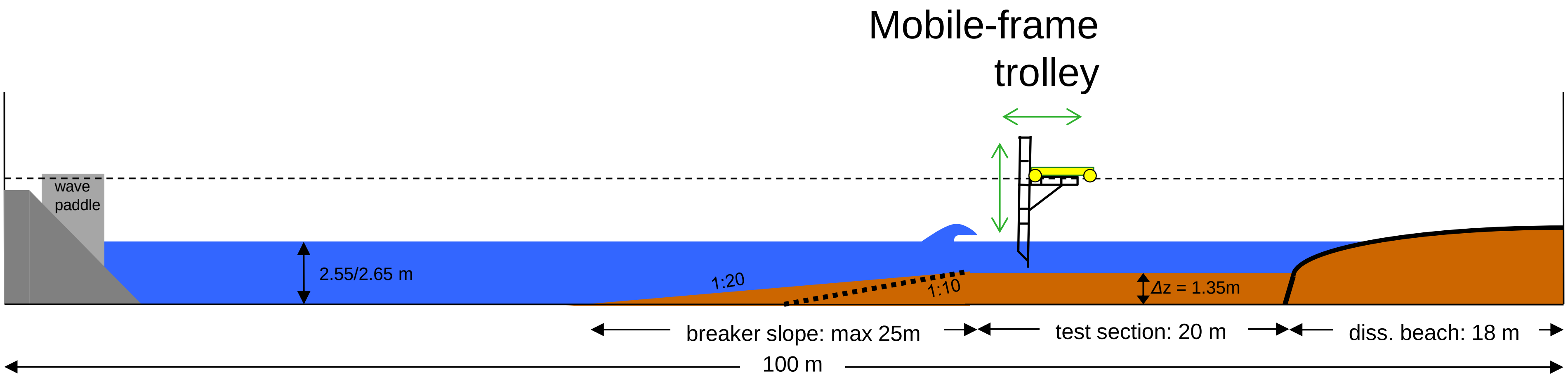


Experiments:

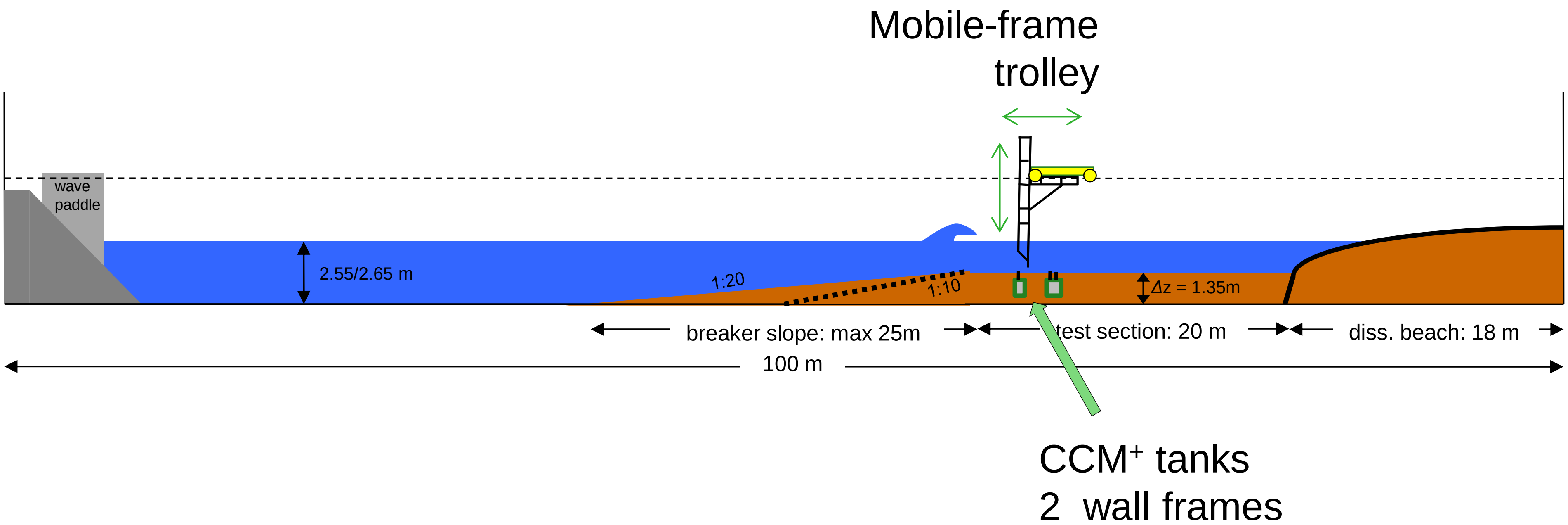
- Regular breaking waves (1) 1:10 slope
- Irregular waves 1:10 slope
- Regular breaking waves (2) 1:20 slope

Sand : D_{50} = 0.24 mm

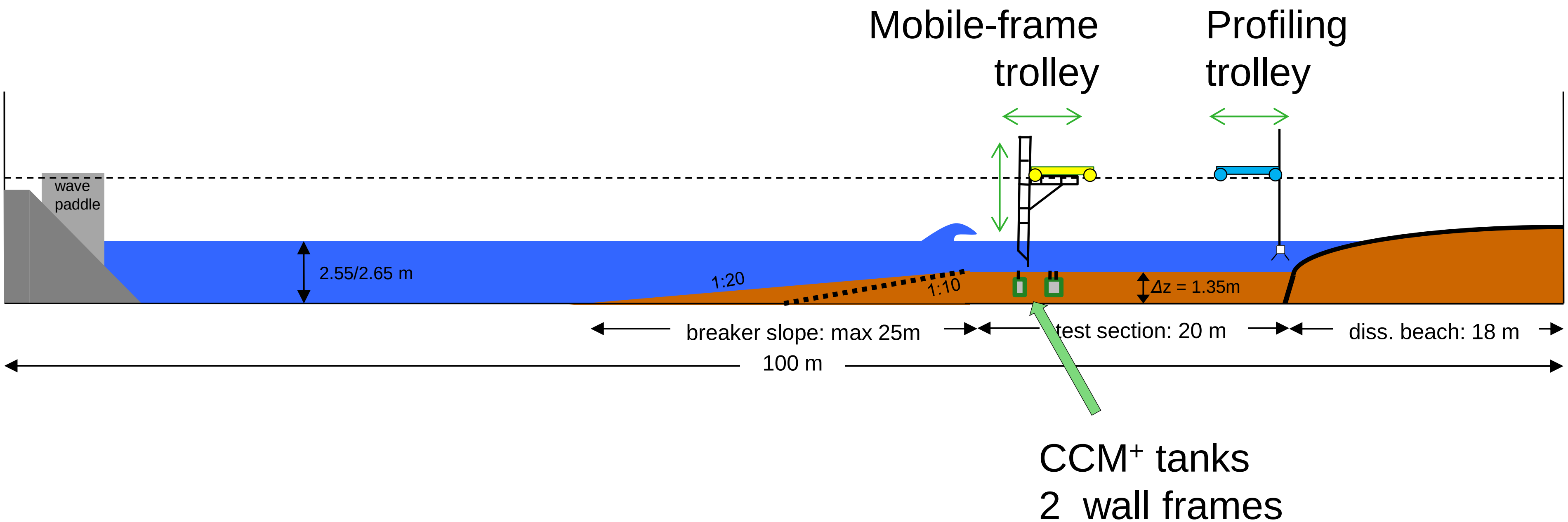
Experimental set-up
Barcelona wave flume



Experimental set-up
Barcelona wave flume



Experimental set-up
Barcelona wave flume

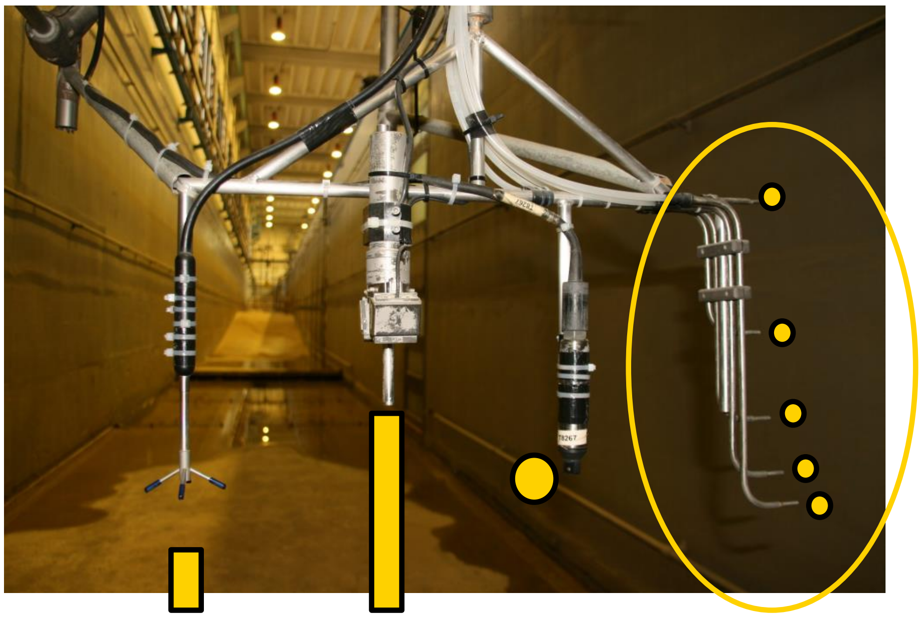


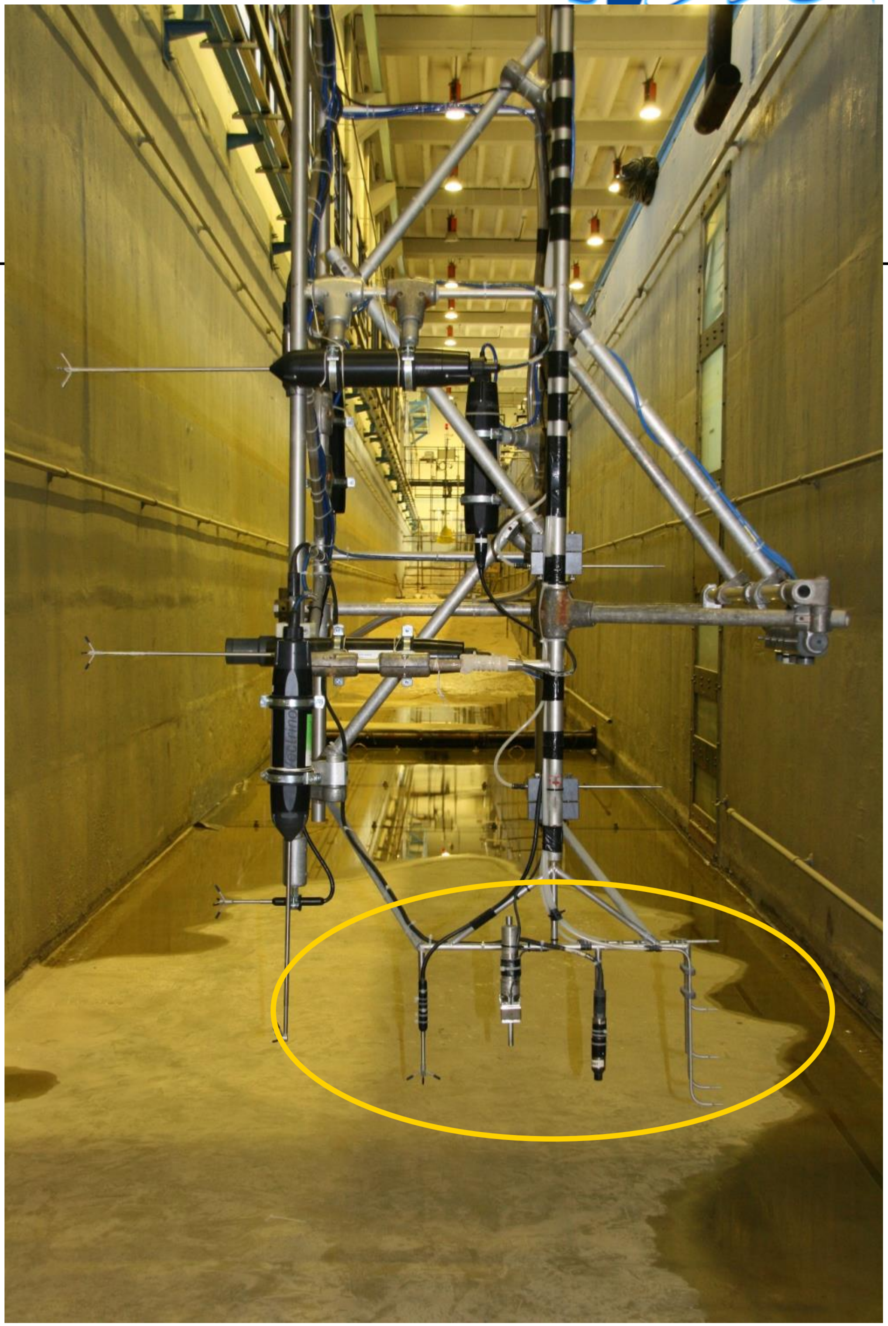
Along the flume: Resistive wave gauges and pressure transducers (surf zone)

Measuring frame

Mini-frame:

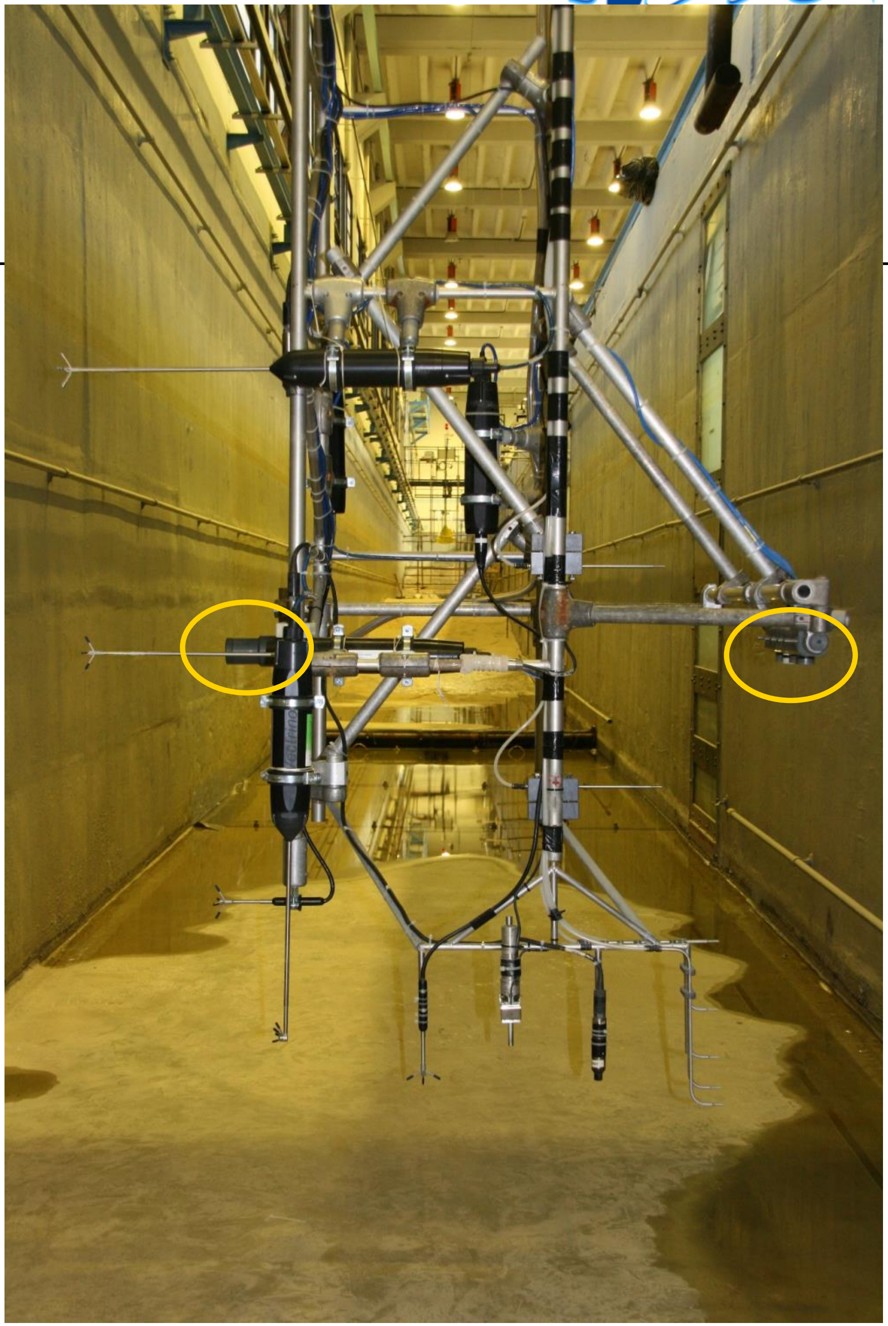
- **HR-ACVP**
- Vectrino Profiler
- Optical Backscatter Sensor
- Transverse Suction System



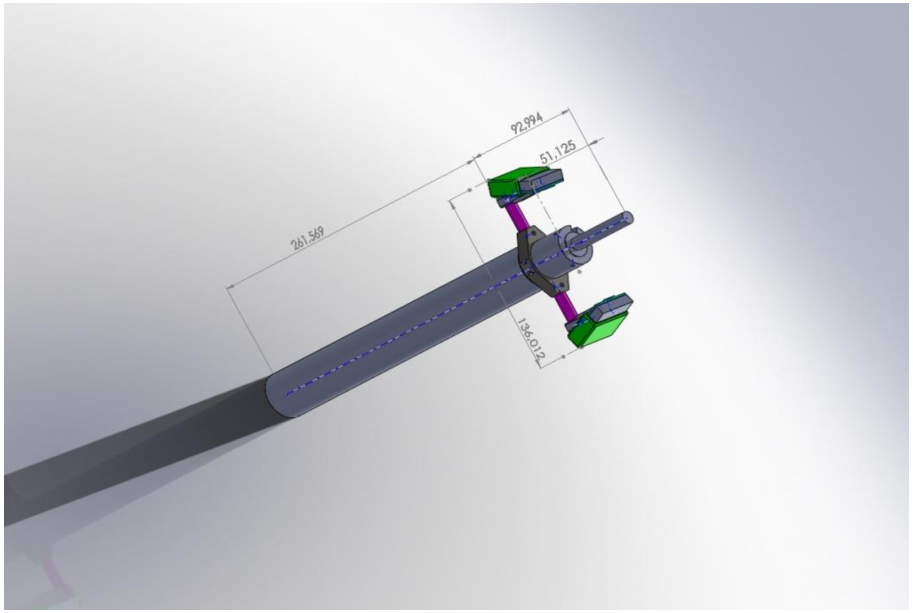


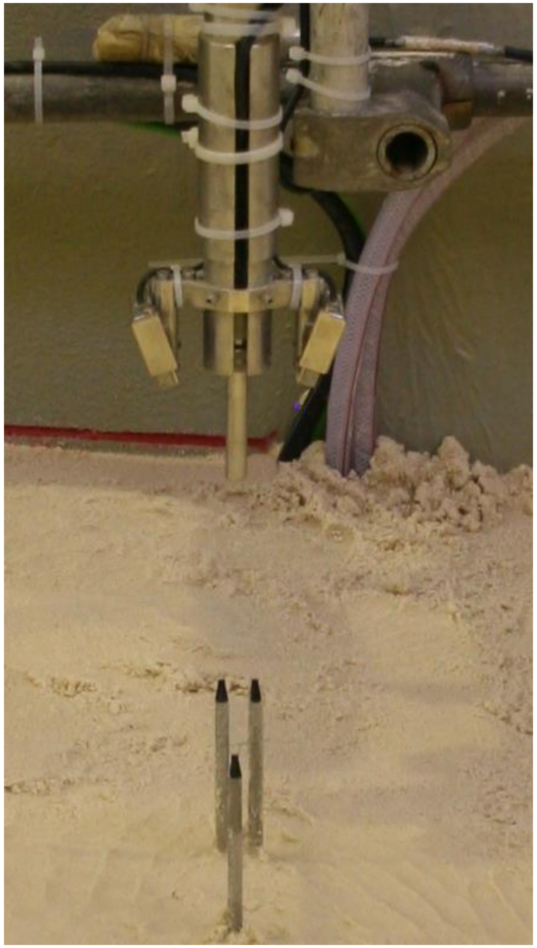
Higher above the bed

- **2D Ripple Scanner**
- **Acoustic Backscatter Sensor**
- + other: ADV's, ..



HR - ACVP





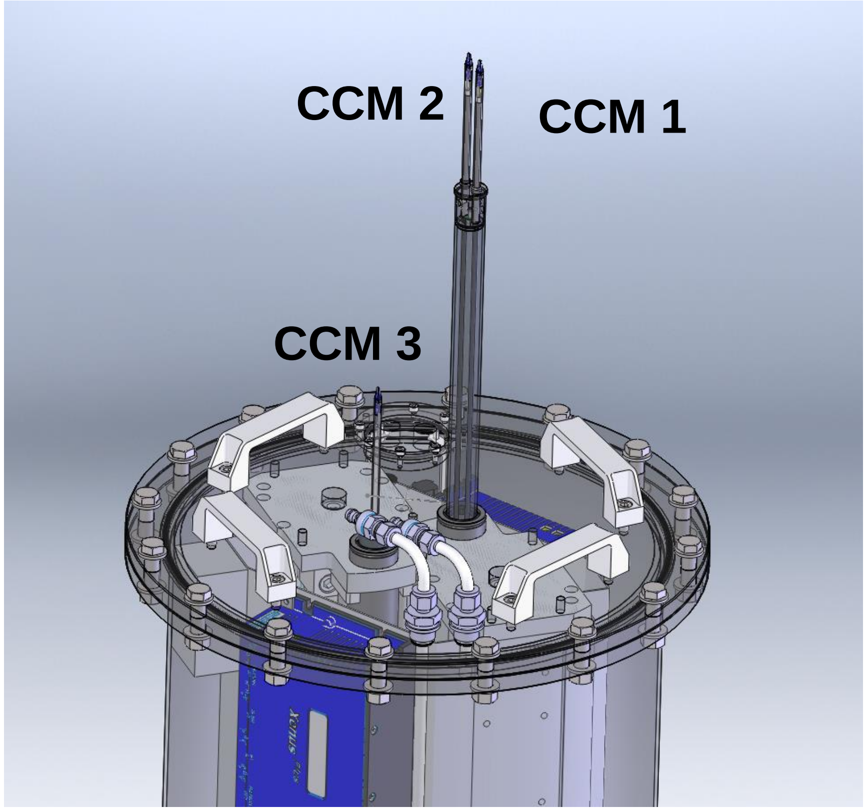
Measuring profile : 20 cm (5 - 10 cm in the bed)
Higher Spatial resolution : 1.5 mm

Hurther, D., Thorne, P.D. (2011). Suspension and near bed load sediment transport processes above a migrating, sand rippled bed under shoaling waves. *J. Geophys. Res.* 116(C07001), 1–17.

CCM+
High concentrations in the sheet flow layer (0-1 cm)

New bed-level tracking system (range 28 cm)

Van der Zanden, J., et al. (2013) New CCM technique for sheet flow measurements and its first application in swash zone experiments, Proc. 6th SCACR, Lisbon.



Wave conditions and procedure

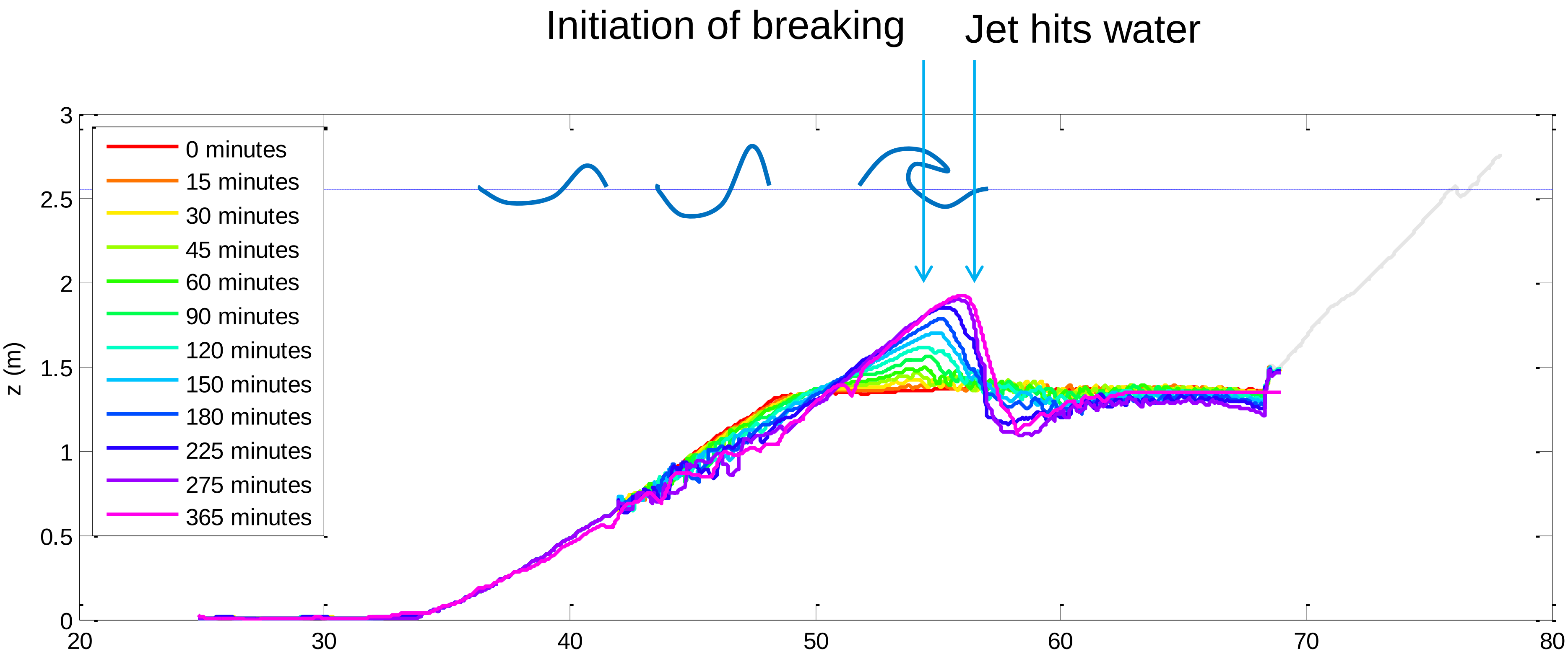
- Conditions:

Case	Slope	d (m)	H (m)	T (s)	Iribarren	Type
RB1	1:10	2.55	0.85	4	0.54	Plunging
RB2	1:20	2.65	0.95	4	0.26	Spilling → plunging

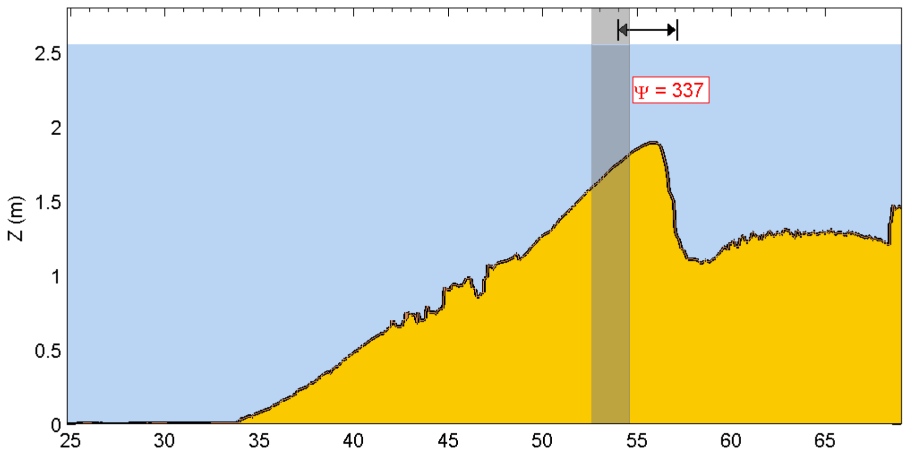
- 15 minute runs

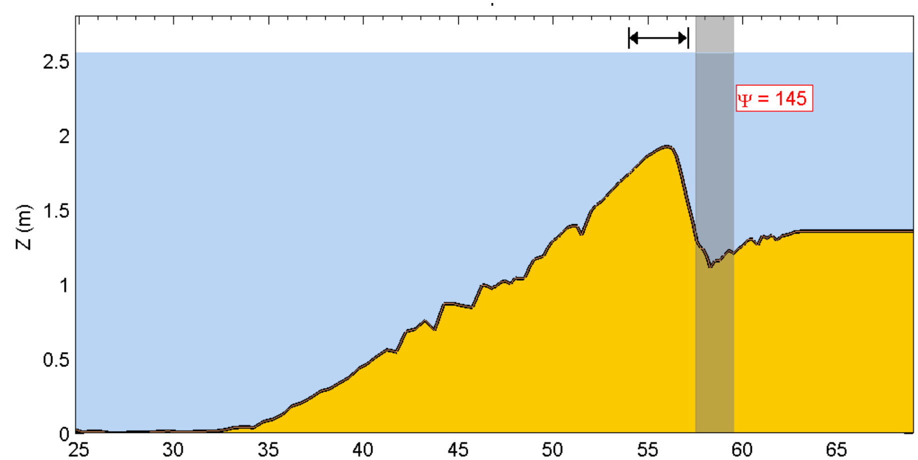
  in between: bed profiling and repositioning mobile measuring frame in the breaker zone

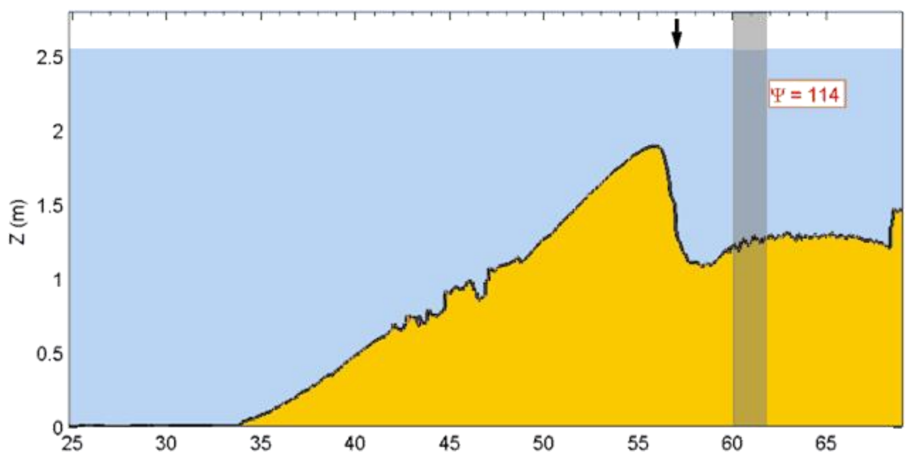
Bed profile evolution
Breaking location (RB1)



Bedform regime : Sheet flow , Ripples







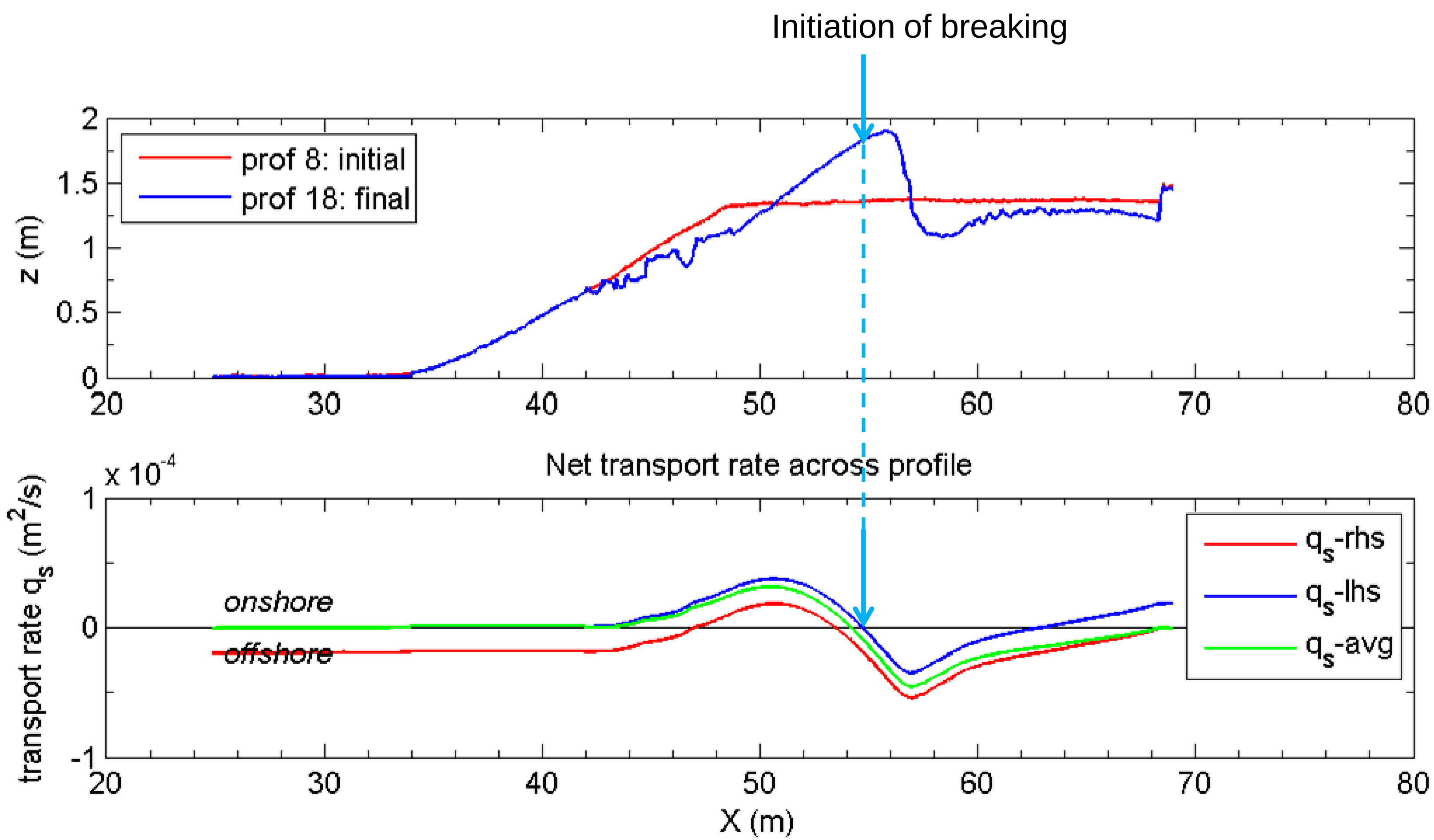
Sheet flow on breaker bar : ψ > ~ 200

(Mega) ripples on offshore slope

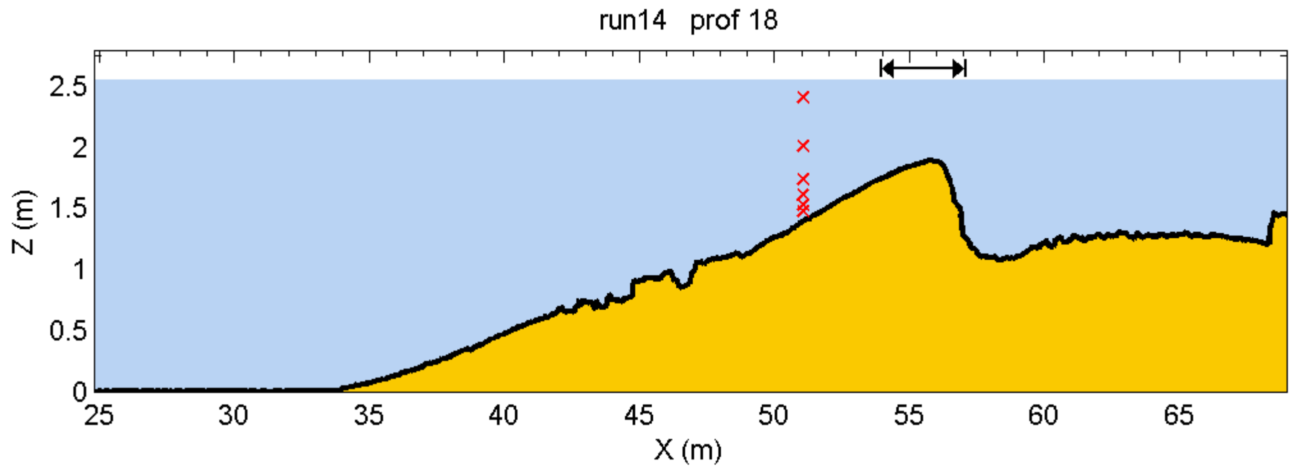
and in the surf zone : ψ < ~200

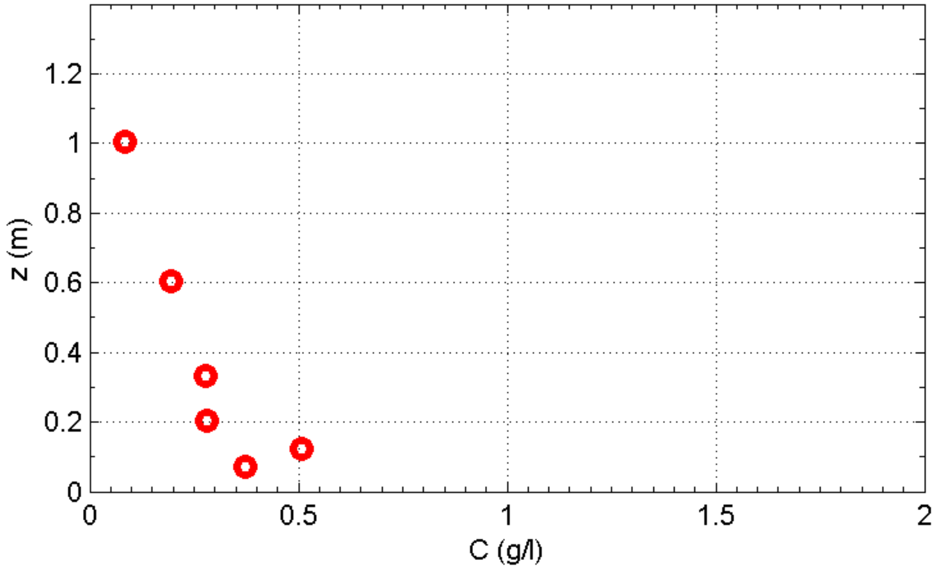
Agrees with ripple predictor O'Donoghue et al. (2001)

Net transport rates

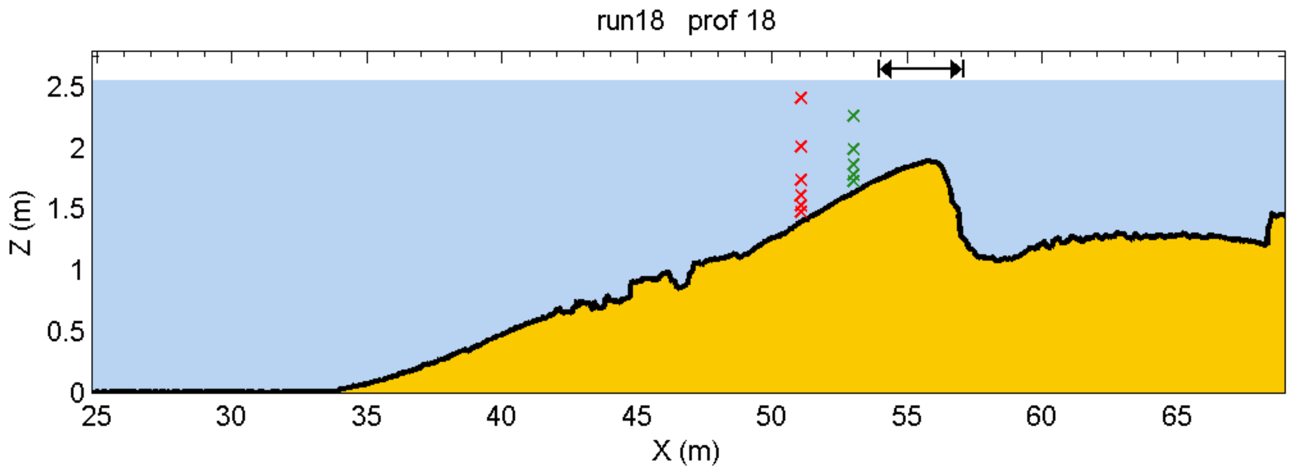


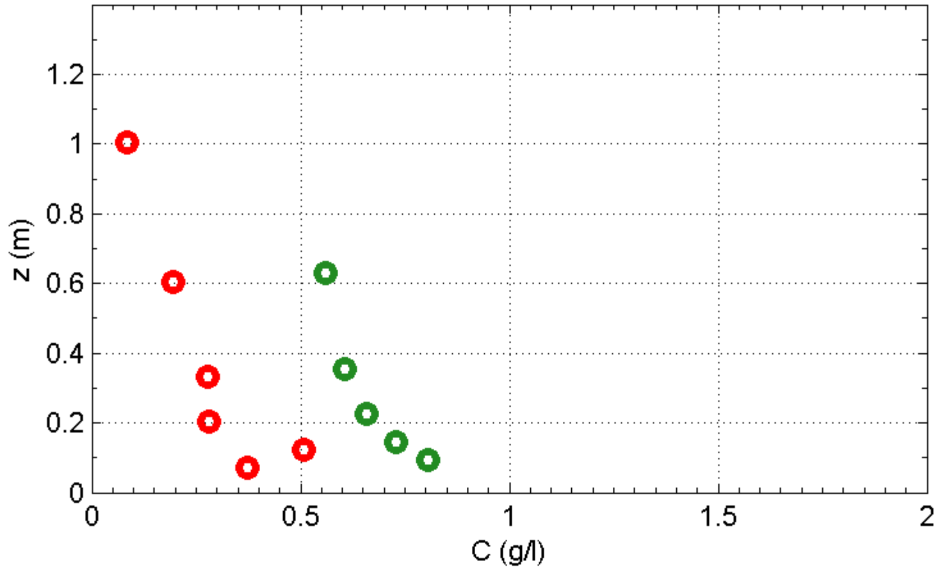
Suspension profiles pre-break (TSS)



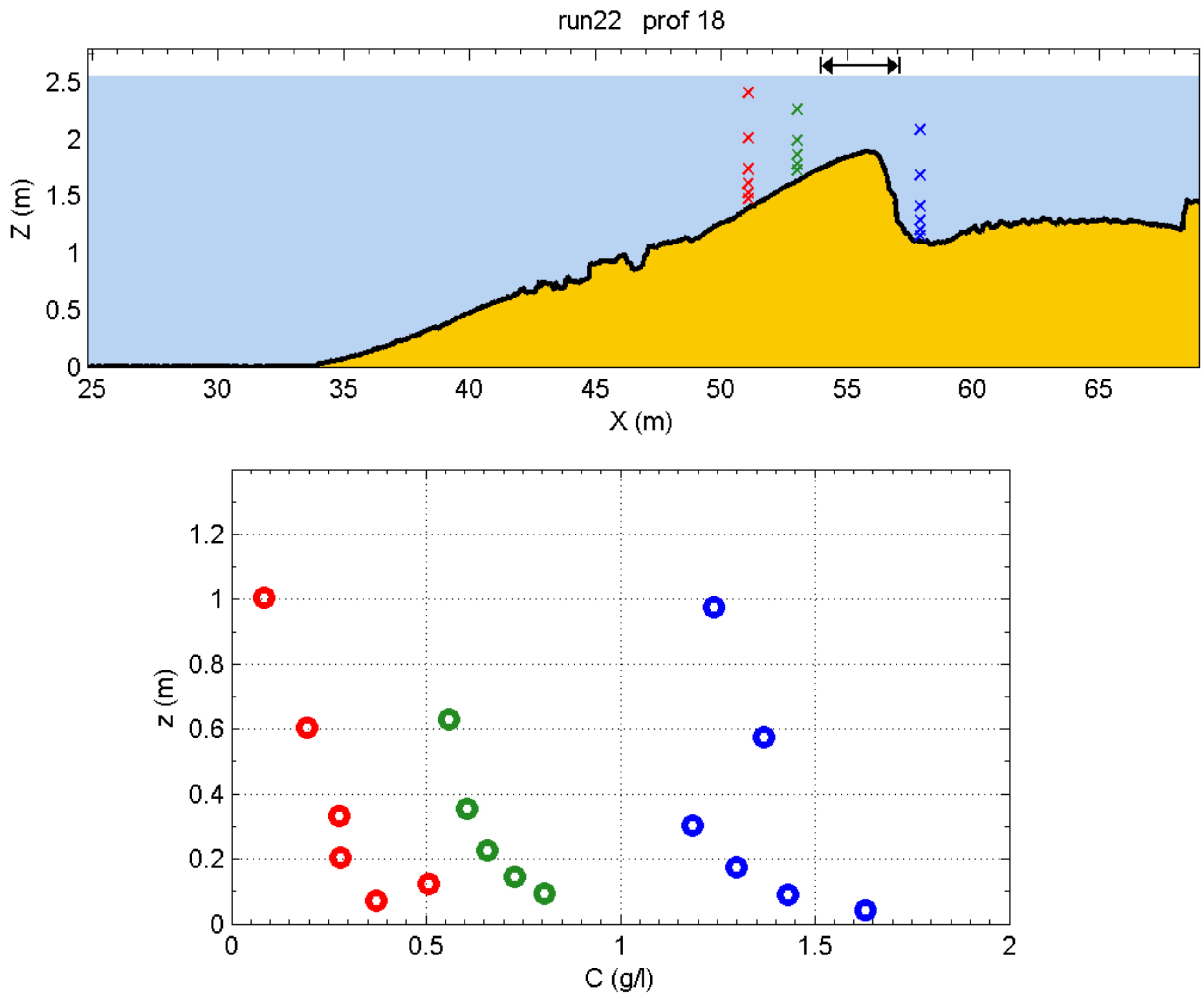


Suspension profiles pre-break (TSS)

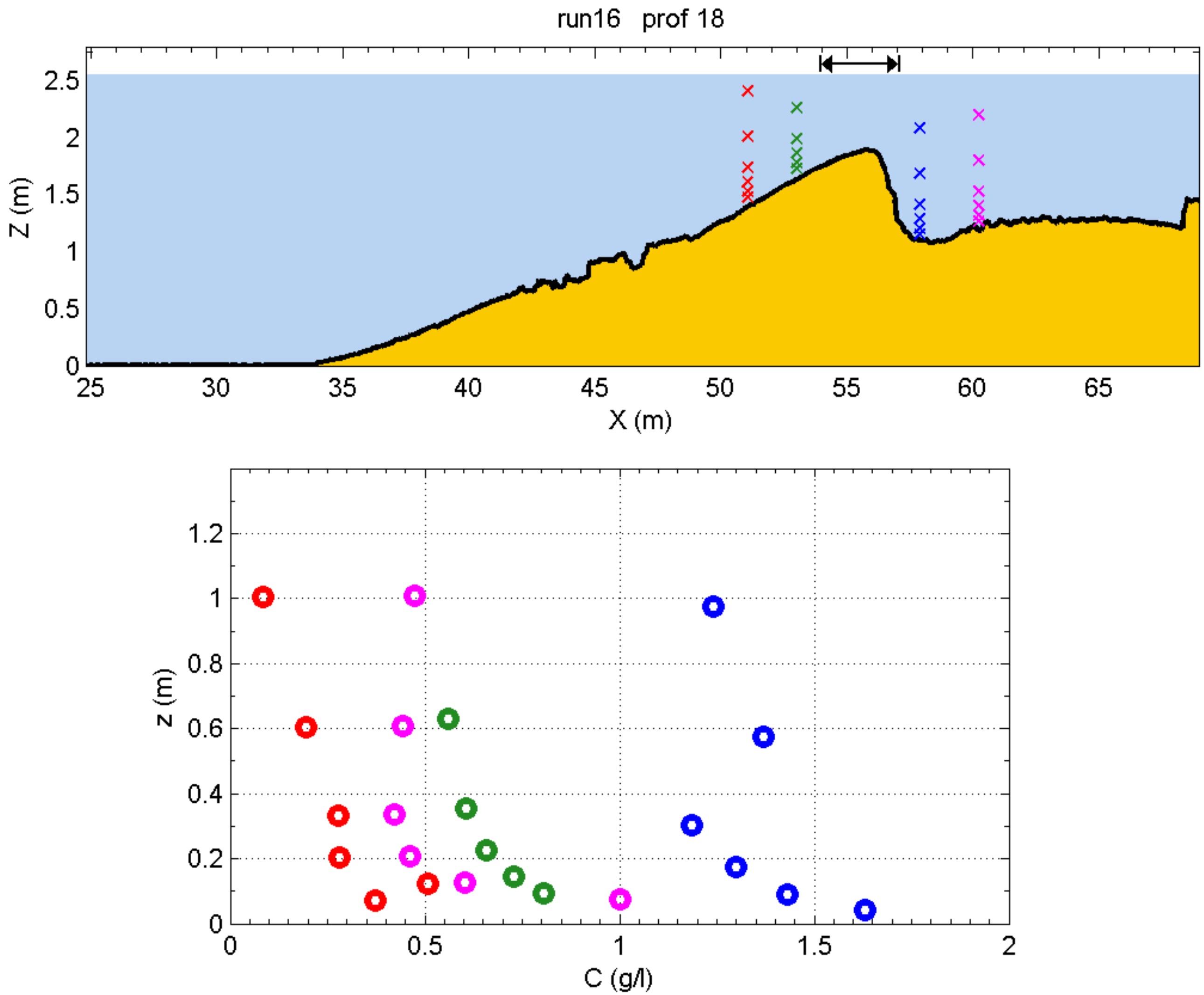




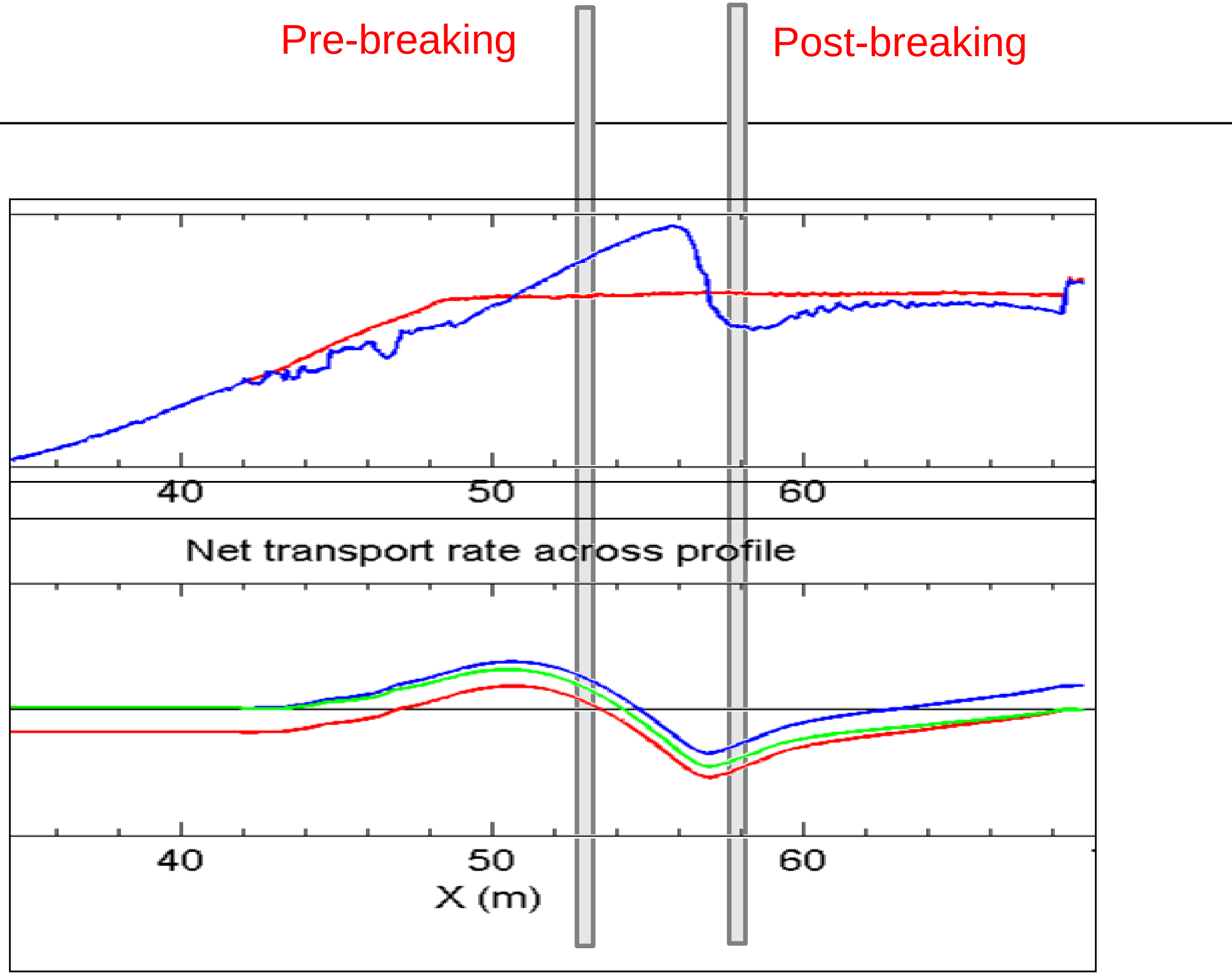
Suspension profiles pre-break and post-break (TSS)



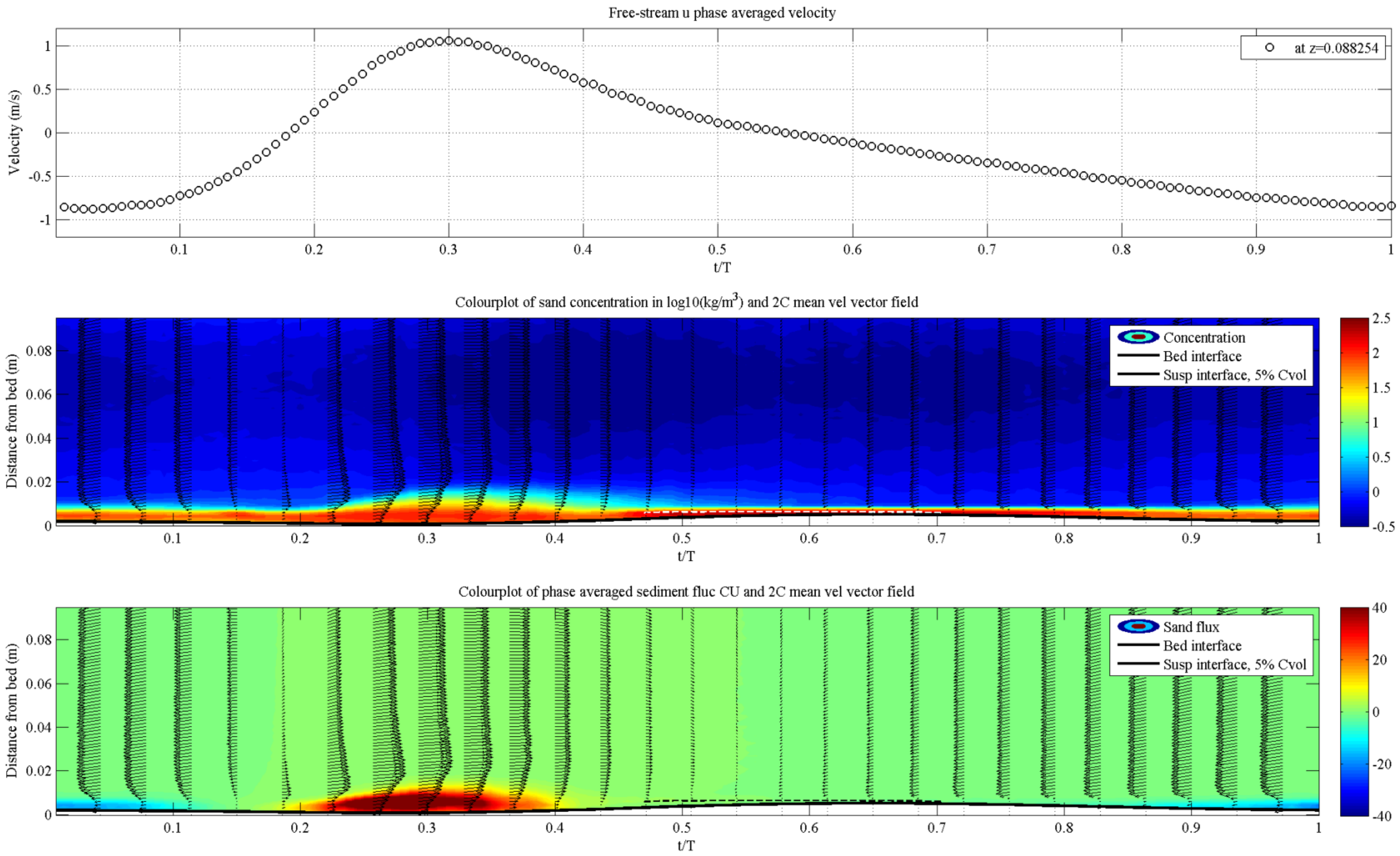
Suspension profiles pre-break and post-break (TSS)



Results of detailed near-bed measurements at 2 selected example locations

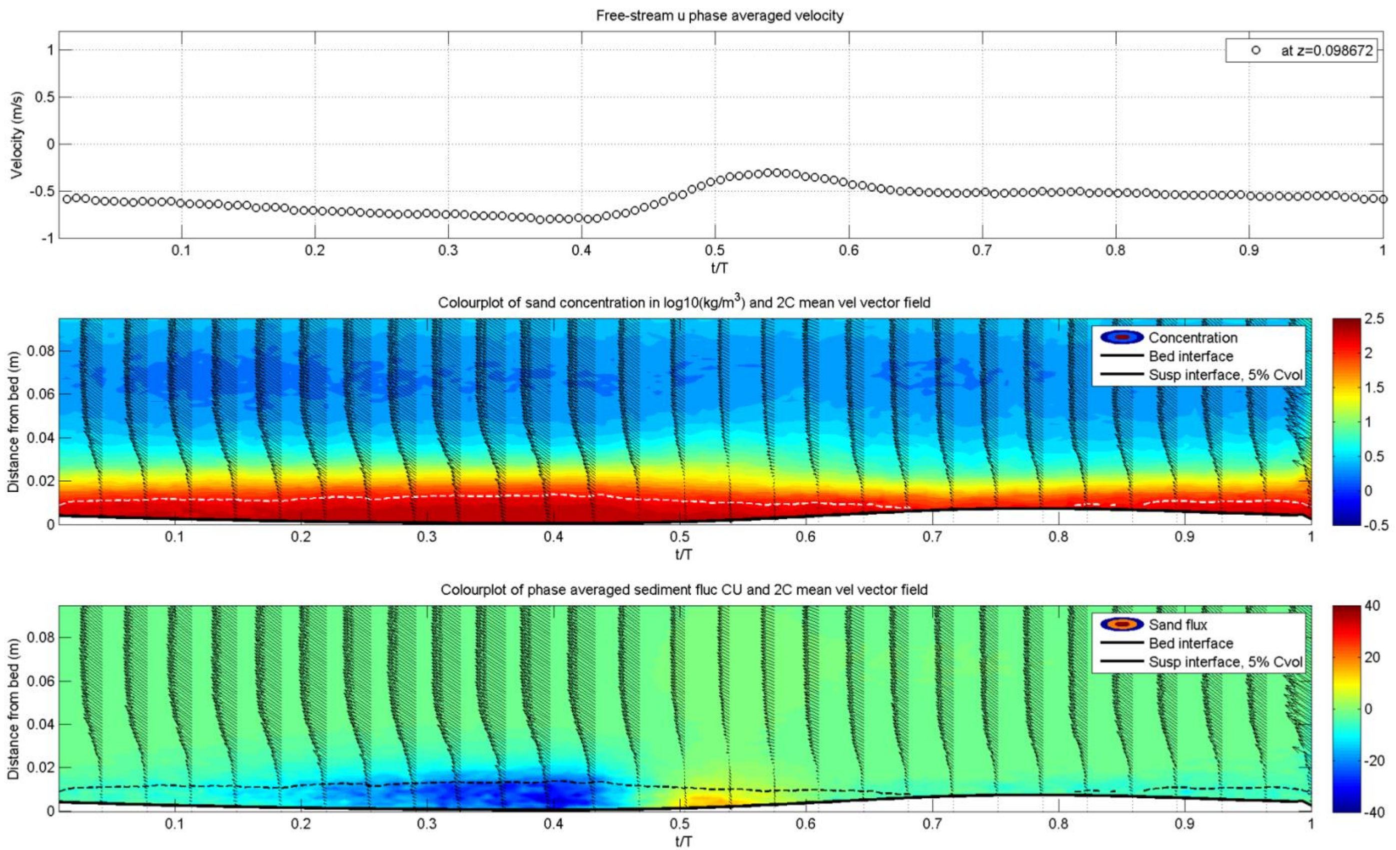


Pre-breaking: ACVP velocities, concentrations and fluxes near the bed (0 -> 9 cm)



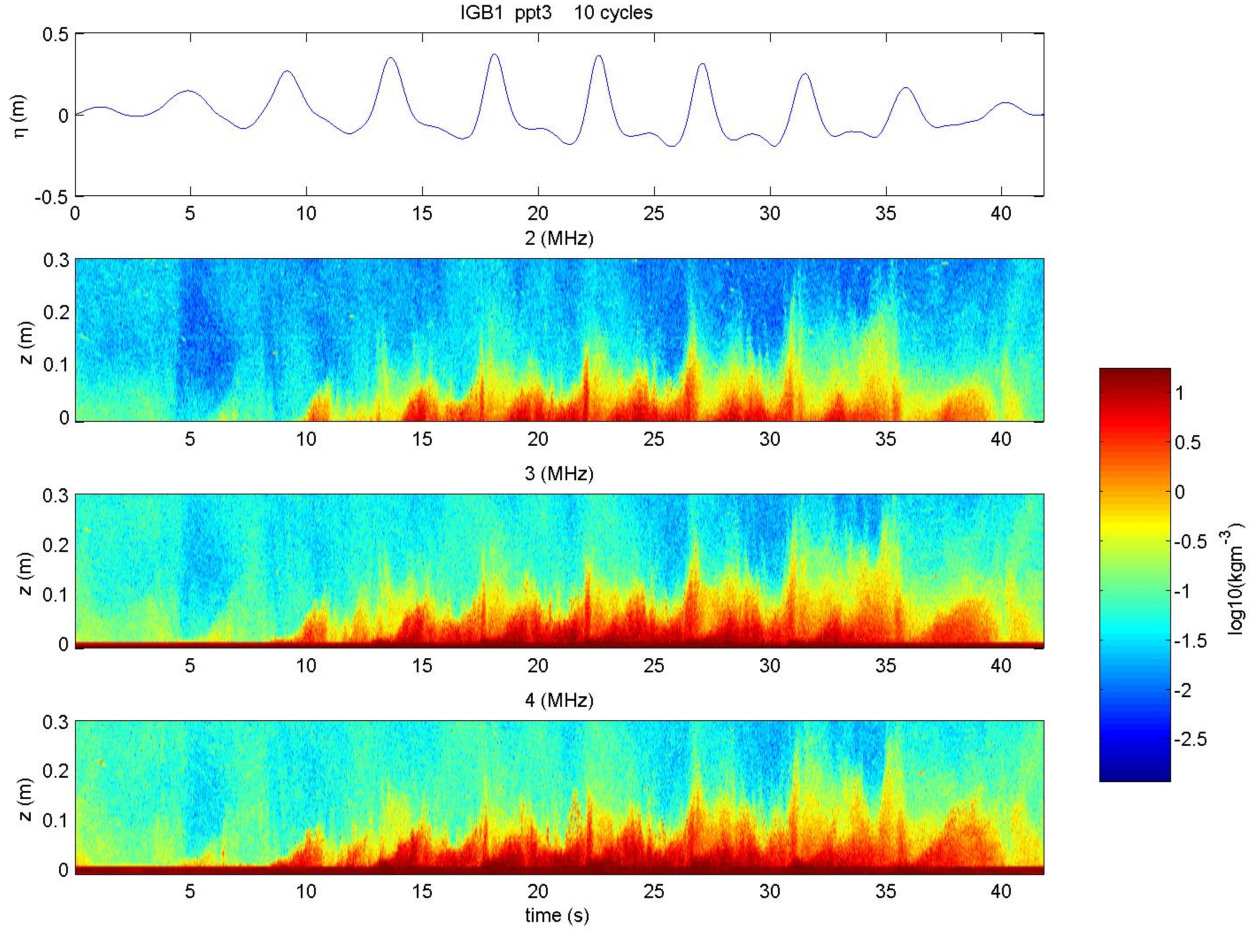
- Dominance of sediment fluxes in the sheet flow layer (0 - 1 cm) inside the WBBL (0 – 4 cm)
- Quasi-steady sediment behaviour: in phase with free-stream flow
- Onshore net sediment transport

Post-breaking: ACVP velocities, concentrations and fluxes near the bed (0 -> 9 cm)



- Undertow dominates , no flow reversal
- Near-bed fluxes in the sheet flow layer still dominate
- Dominant offshore sediment flux and net offshore sediment transport
- Small onshore flux under wave crest

Irregular non-breaking waves: ABS suspension



- Final waves show higher concentrations (phase-lag of suspension, wave pumping ? ,see also Vincent and Hanes, 2002)
- Intra-wave suspension variations until 25 cm above the bed (rippled bed !)

Summary of first results

Wave breaking

- Breaker bar built up by sand coming from both sides: Offshore net transport in surf zone (undertow), onshore net transport before breaking (wave skewness)
- Sediment transport is dominated by the near-bed fluxes (0 -1 cm), also in the breaker zone (is a first impression and needs further study)

Wave iregularity

- Non-breaking wave group experiments seem to show suspension phase-lag effects (further study)

Future work (SINBAD)

- Validation and further analysis of the new dataset

  suspended versus bedload fluxes, flux profiles, wave-/current related fluxes, ..
- 2 new series of breaking wave experiments at UPC (2014)

  fixed-bed: PIV + LDA measurements
- Numerical modeling using the new experimental data
- Further development of a practical sand transport model (SANTOSS model)

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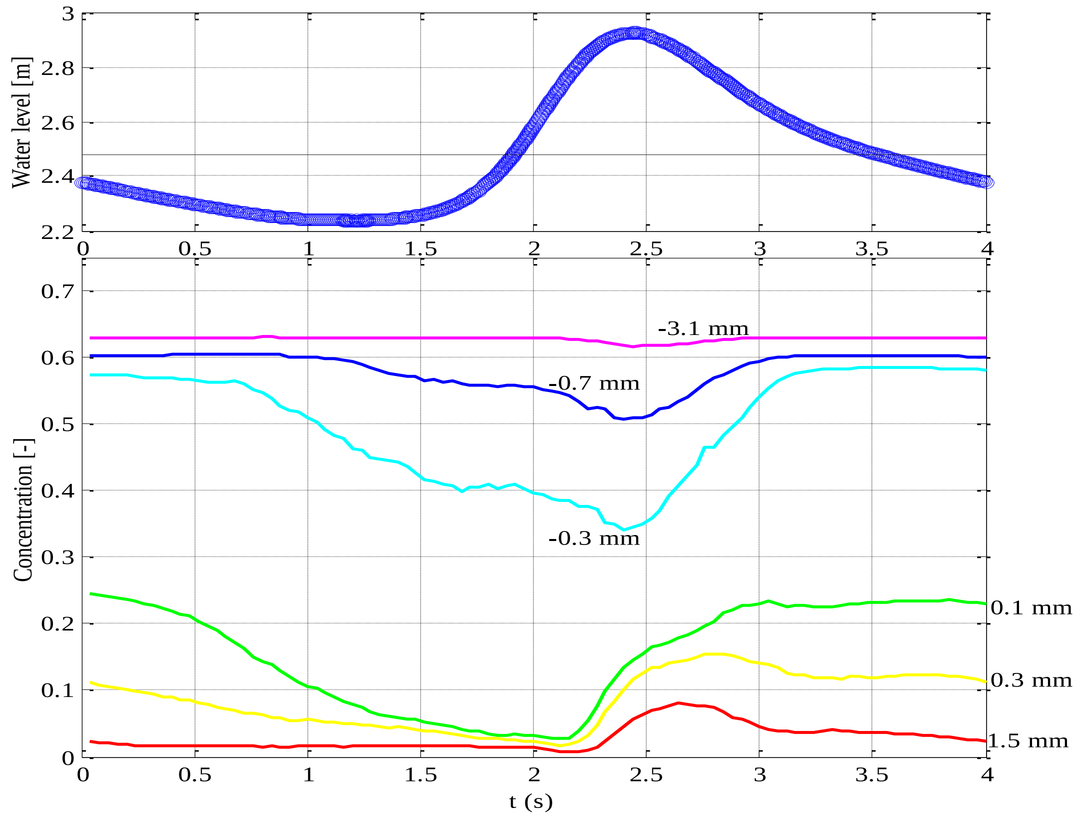
THANK YOU !

Pre-breaking: shoaling waves over a sloping bed
CCM concentrations in the sheet-flow layer

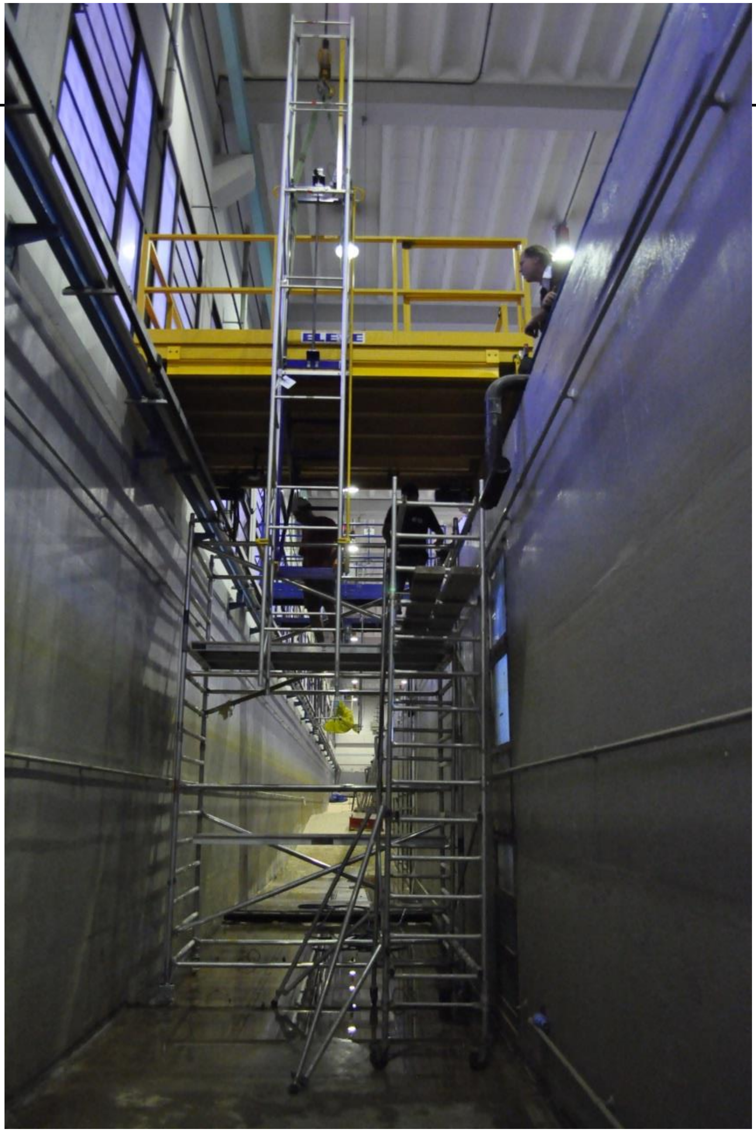


Asymmetric and skewed wave

- Quasi-steady behaviour in pick-up layer and upper sheet flow layer
- Comparable sheet flow behaviour as for uniform waves over horizontal bed

(Schretlen, 2012; Dohmen-Janssen and Hanes, 2002)

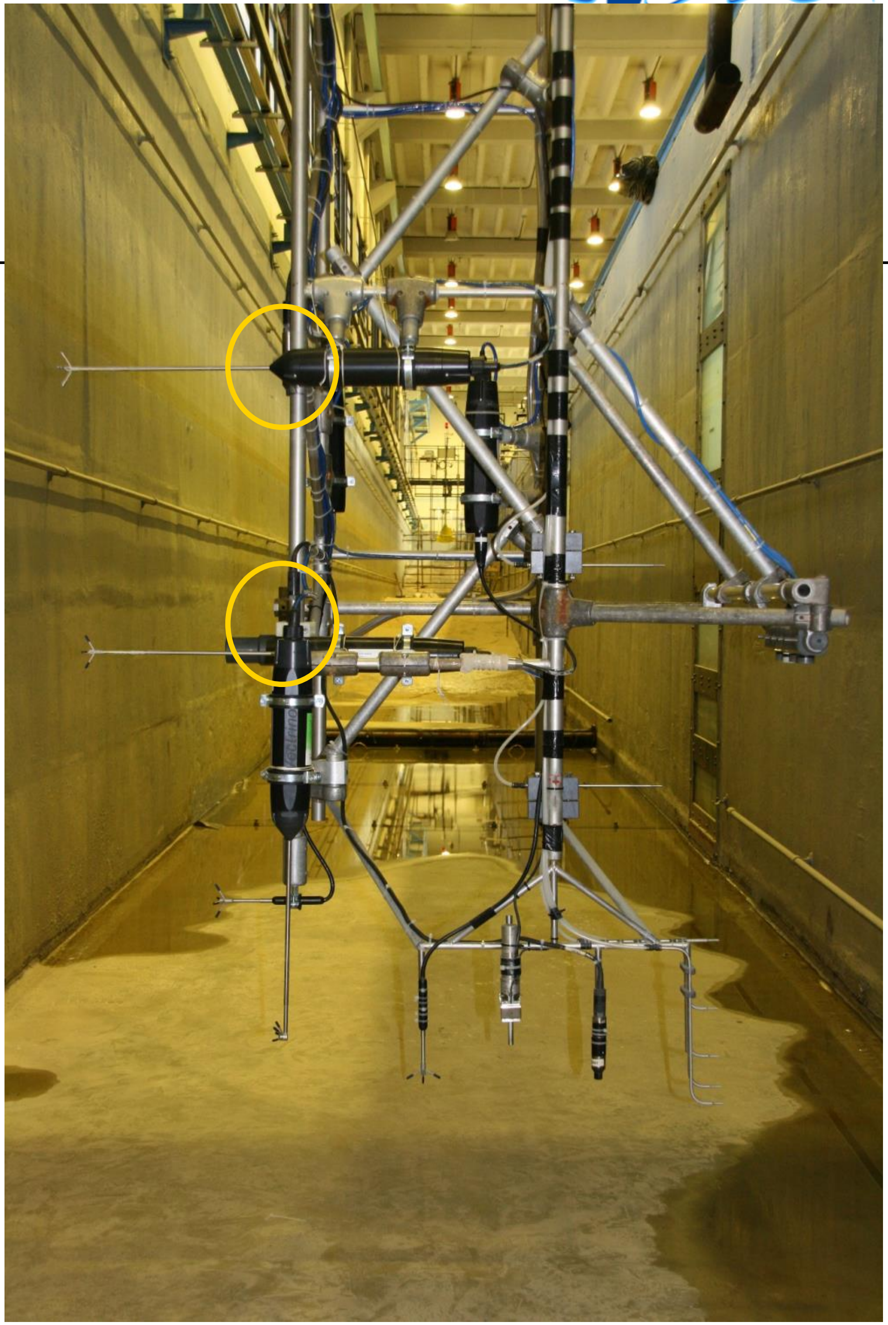
Mobile-frame deployment



Mini-frame:

- Vectrino Profiler
- HR-ACVP
- Optical Backscatter Sensor
- Transverse Suction System

- 2D Ripple Scanner
- Acoustic Backscatter sensor
- 4 ADV’s
- 2 OBS’s



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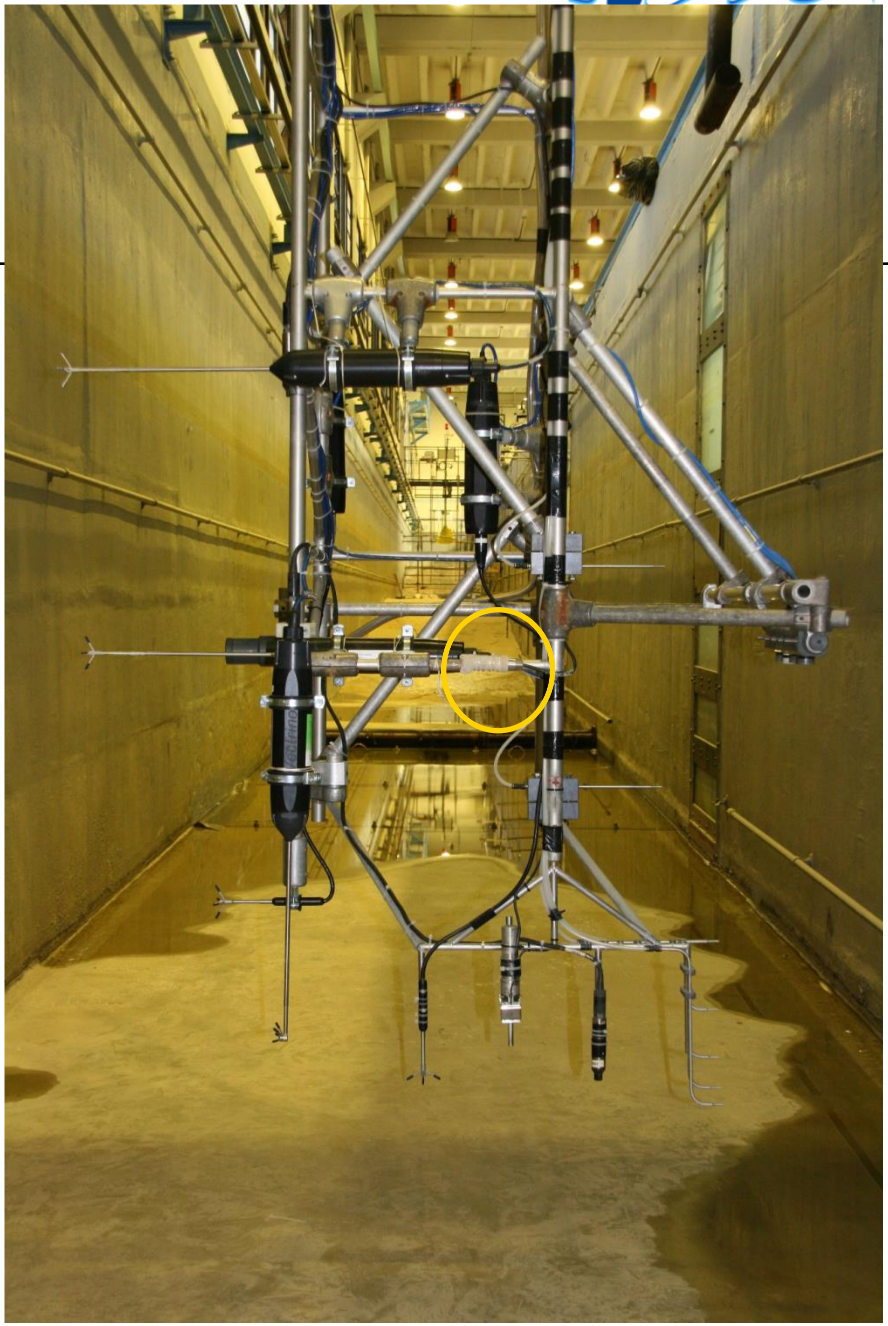
- 4 ADV’s
- 2 OBS’s
- Pore pressure transducer



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- 2D Ripple Scanner

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- 2D Ripple Scanner
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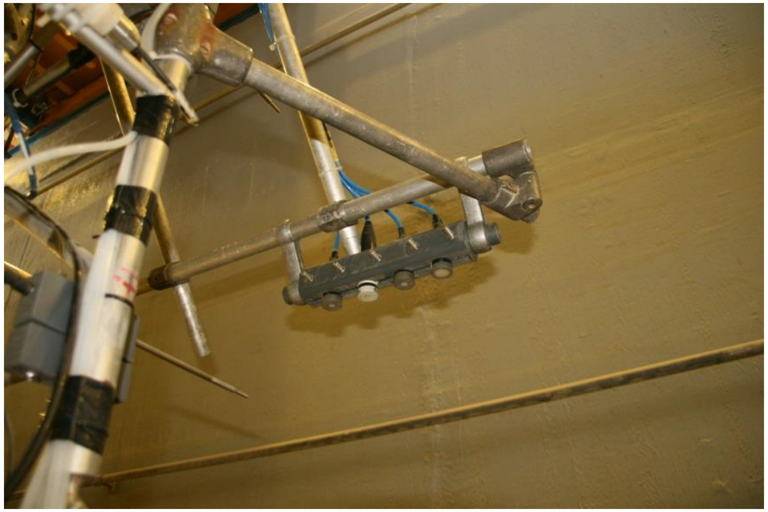

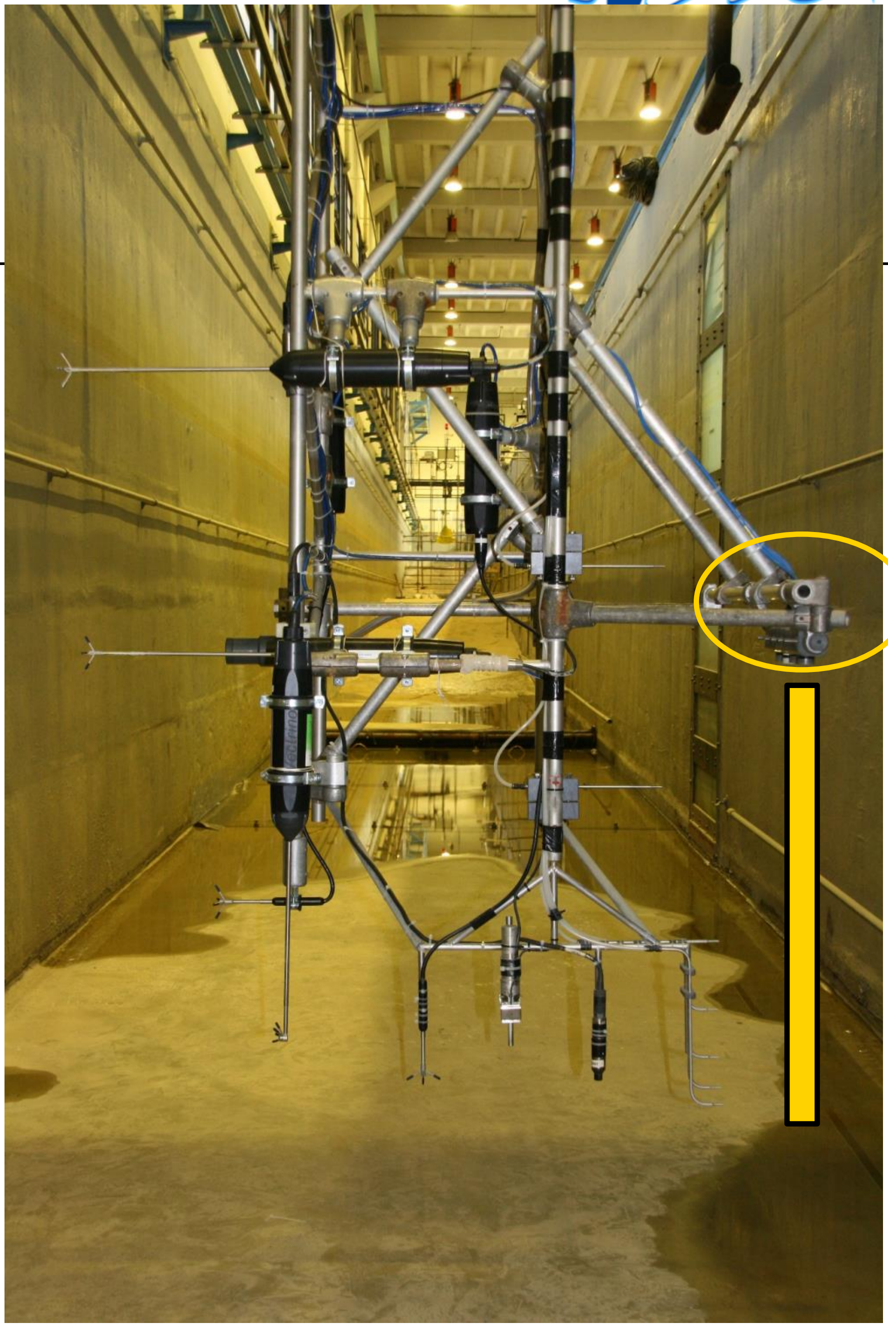

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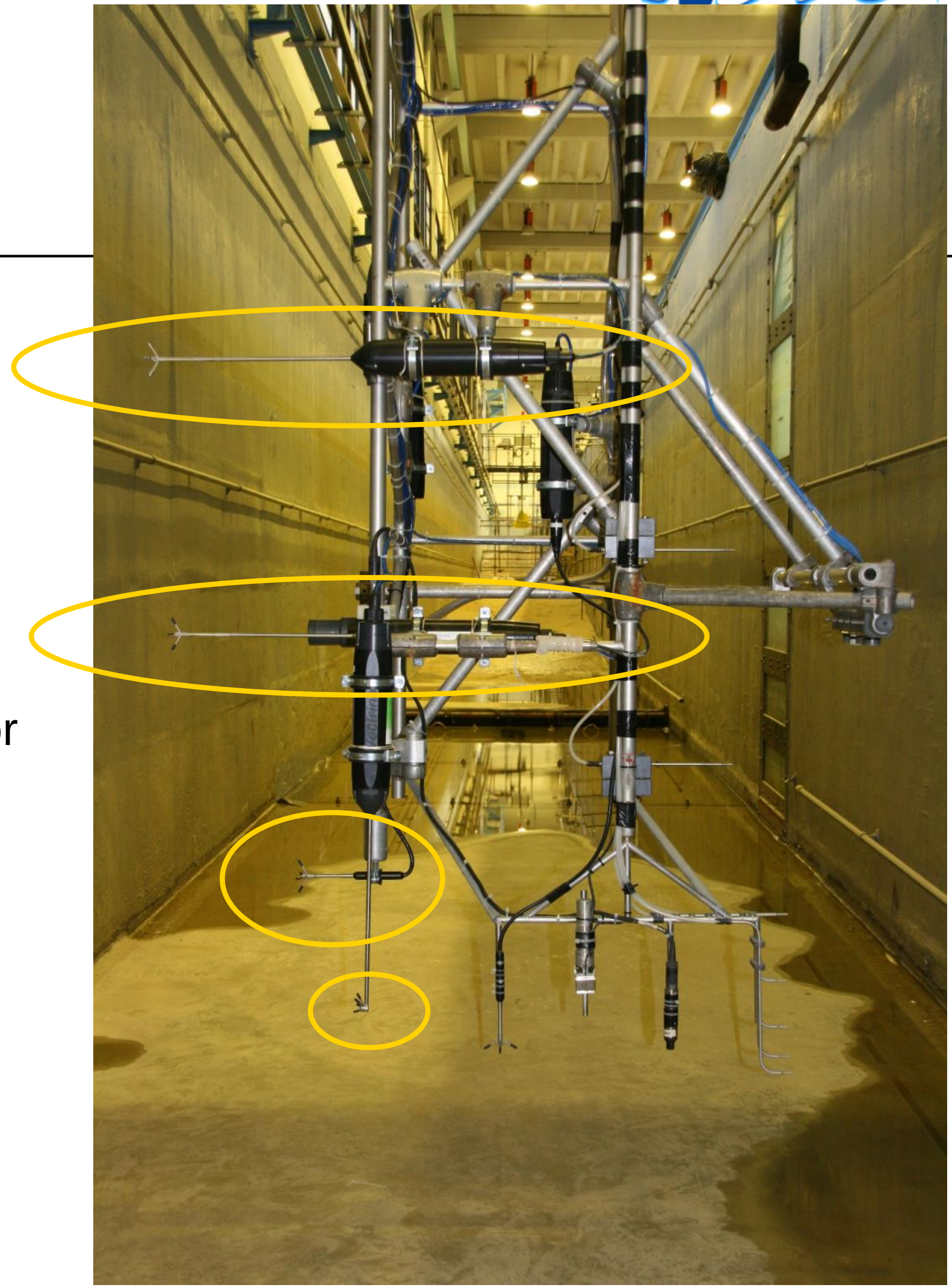
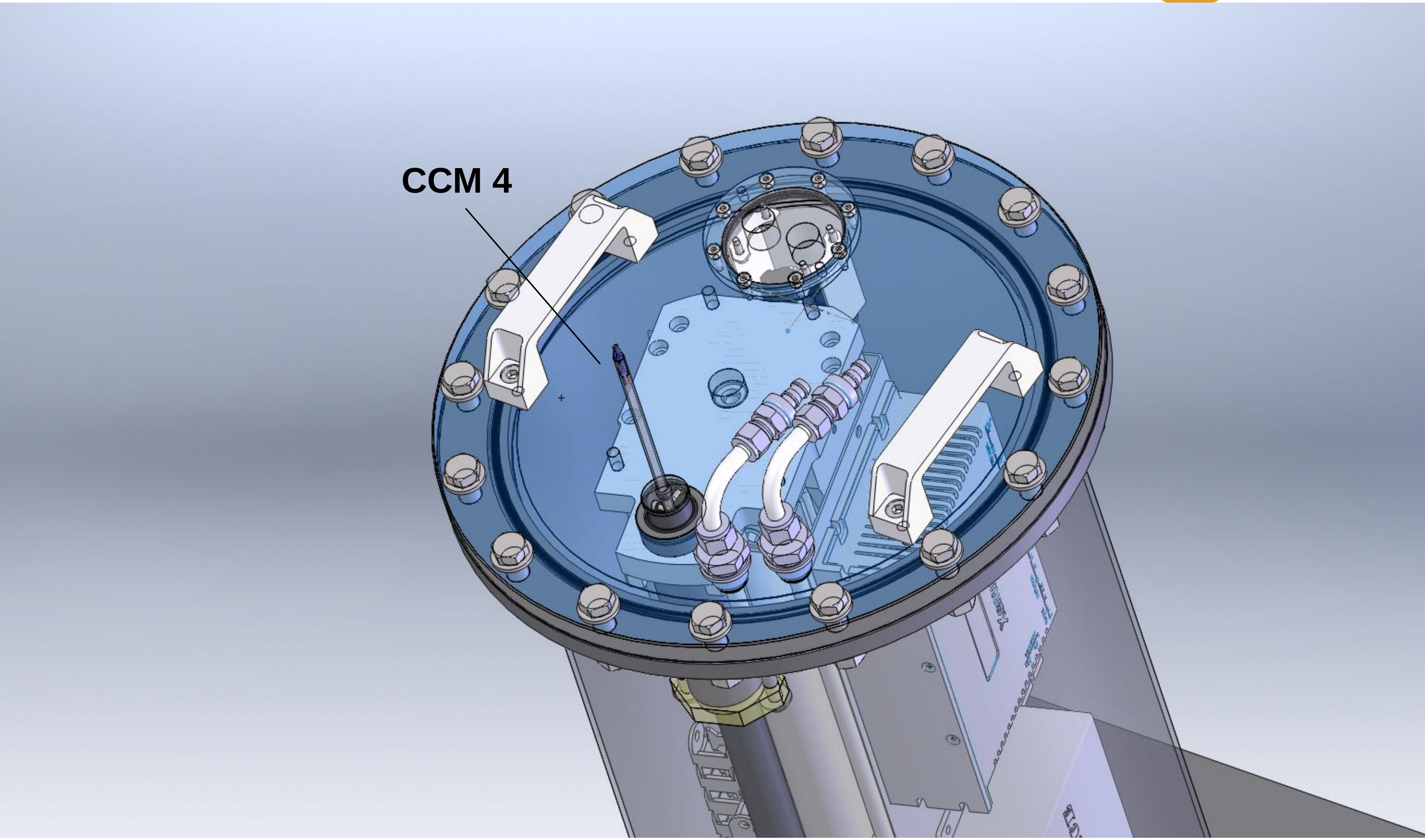



CCM 4

ACVP

Left to right:

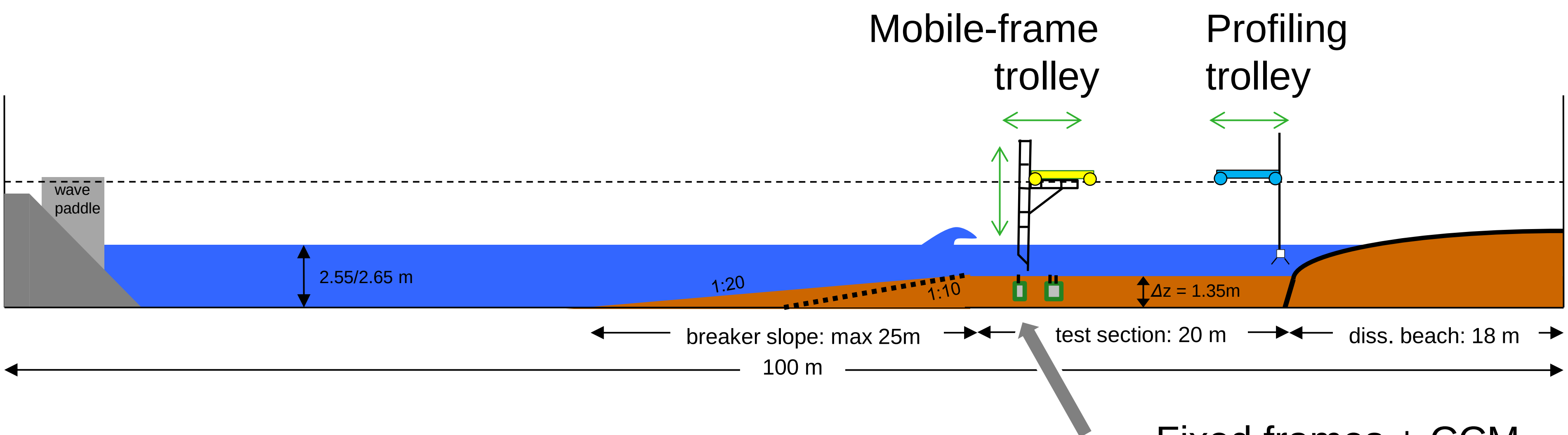
Mobile frame

- Vectrino Profiler (not shown)
- ACVP
- OBS
- TSS nozzles

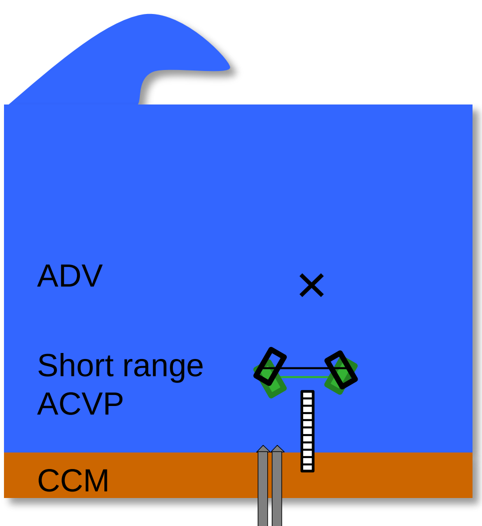
Fixed frame

- CCM probes
- ACVP

Experimental set-up
Barcelona wave flume



Fixed frames + CCM

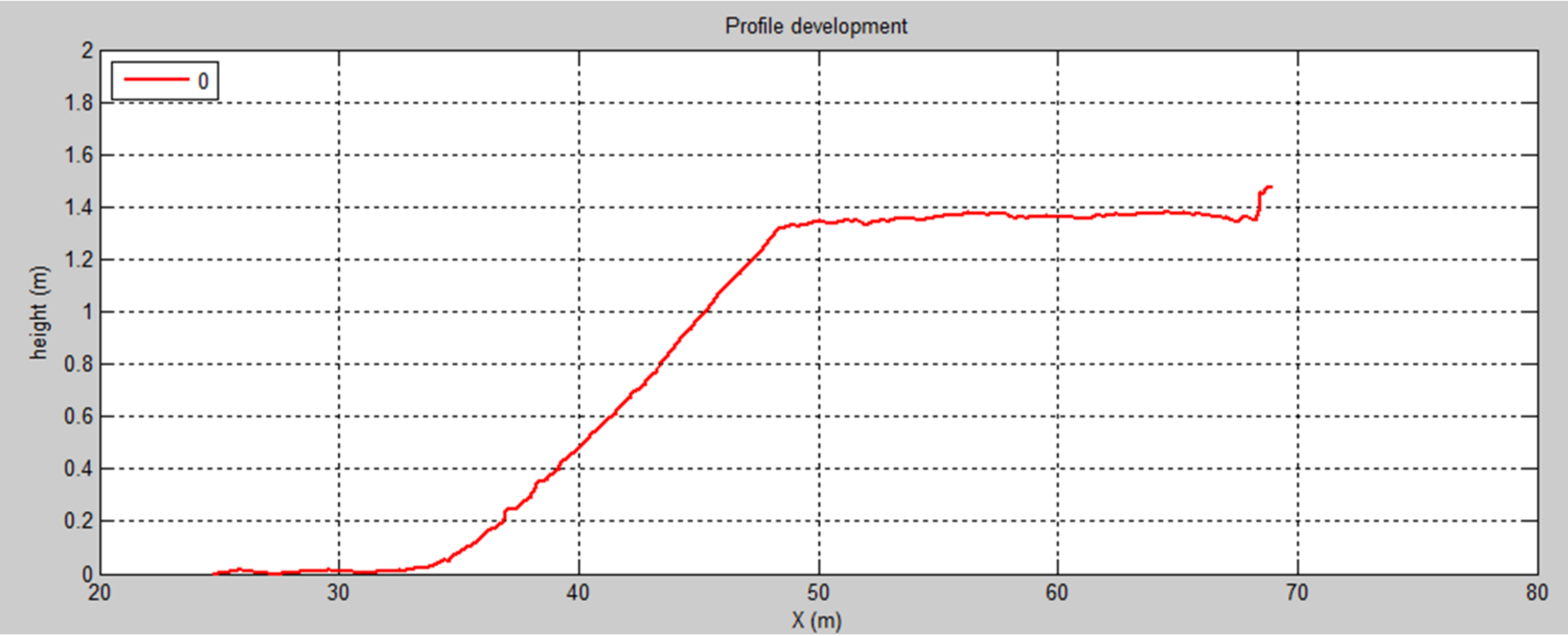


Experiments:

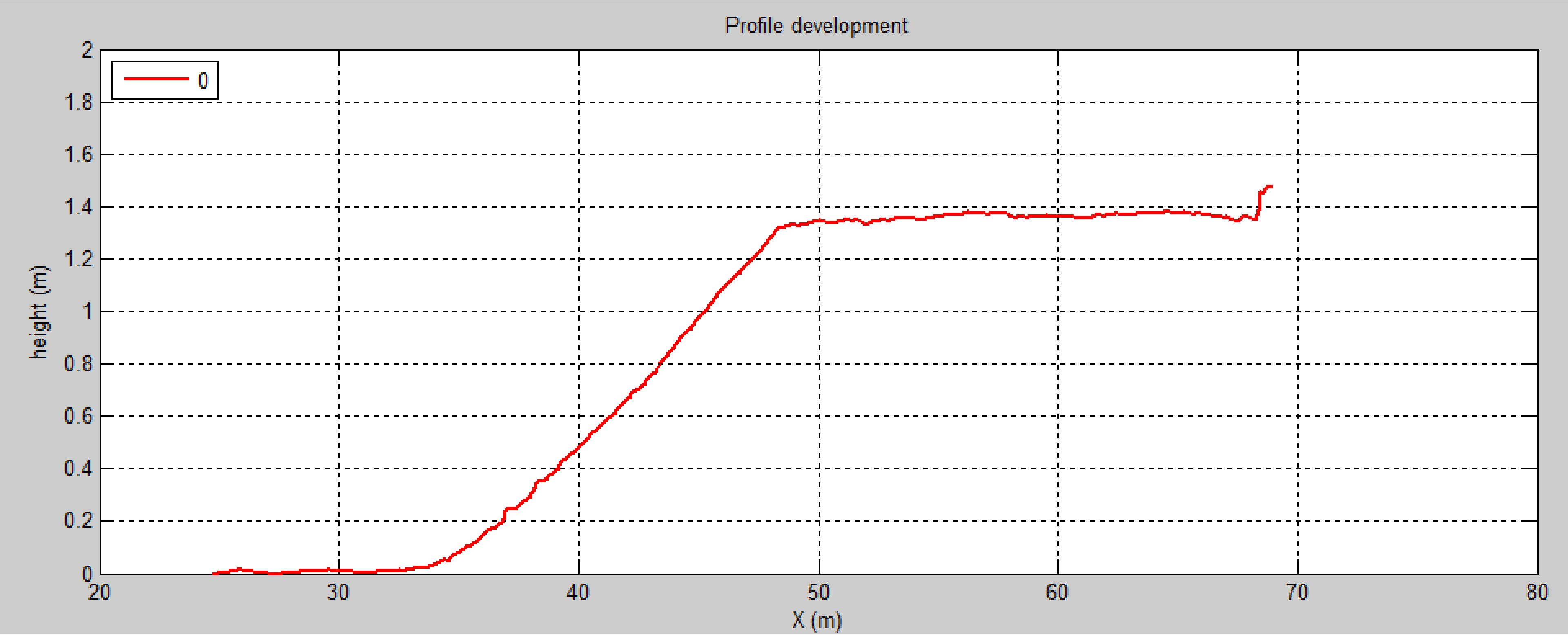
- Regular breaking waves (1) 1:10 slope
- Irregular waves 1:10 slope
- Regular breaking waves (2) 1:20 slope

D50 = 0.24 mm

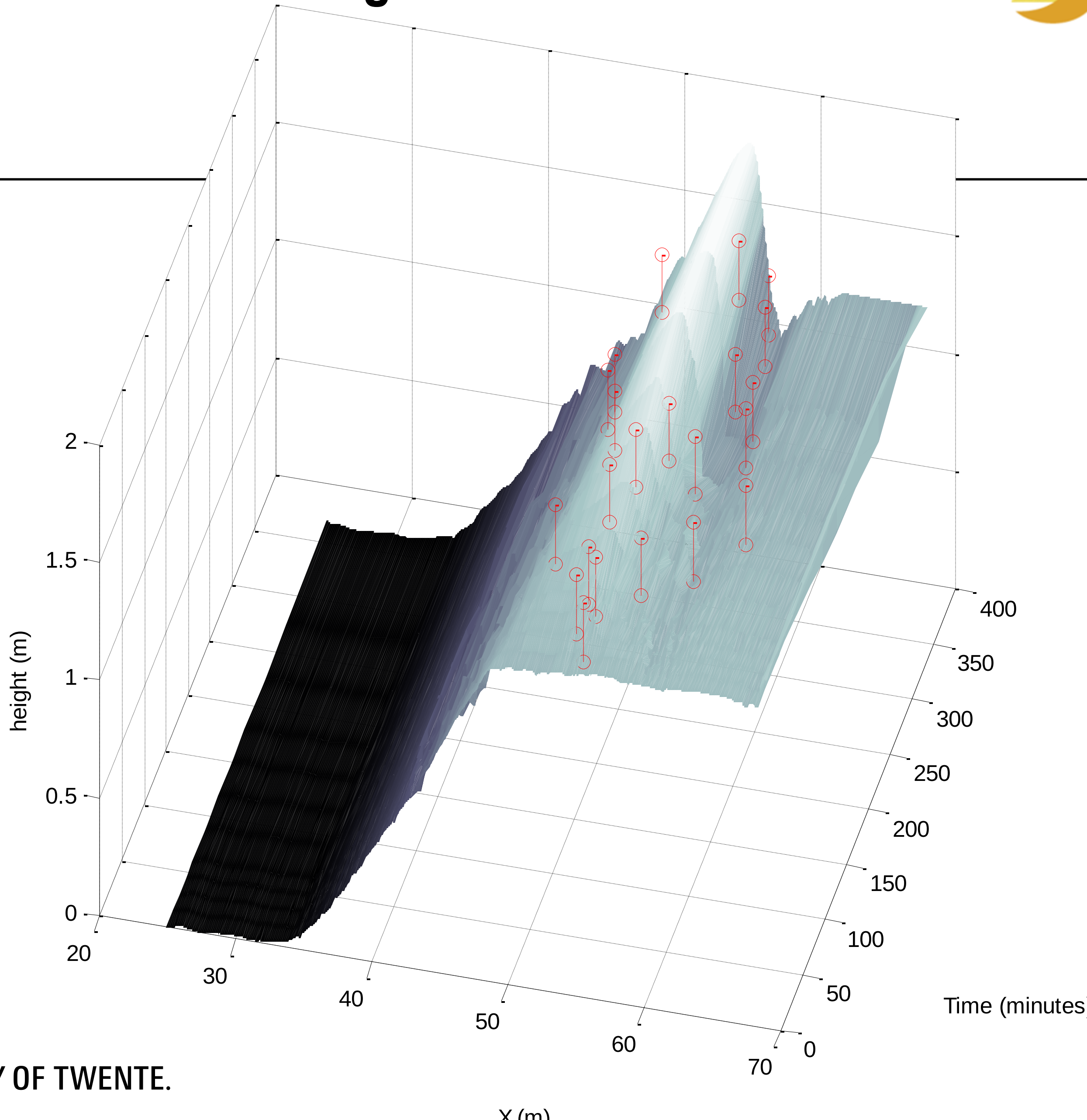
Results: bed profile evolution



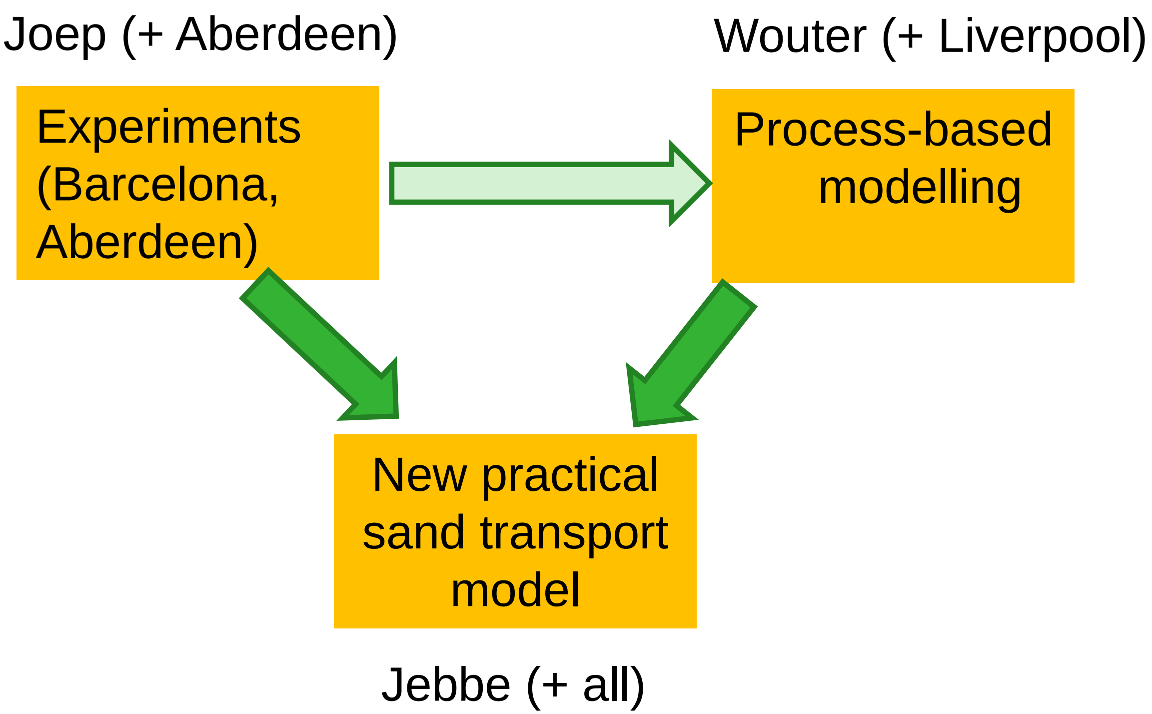
Results: profile evolution



Mobile frame measuring locations



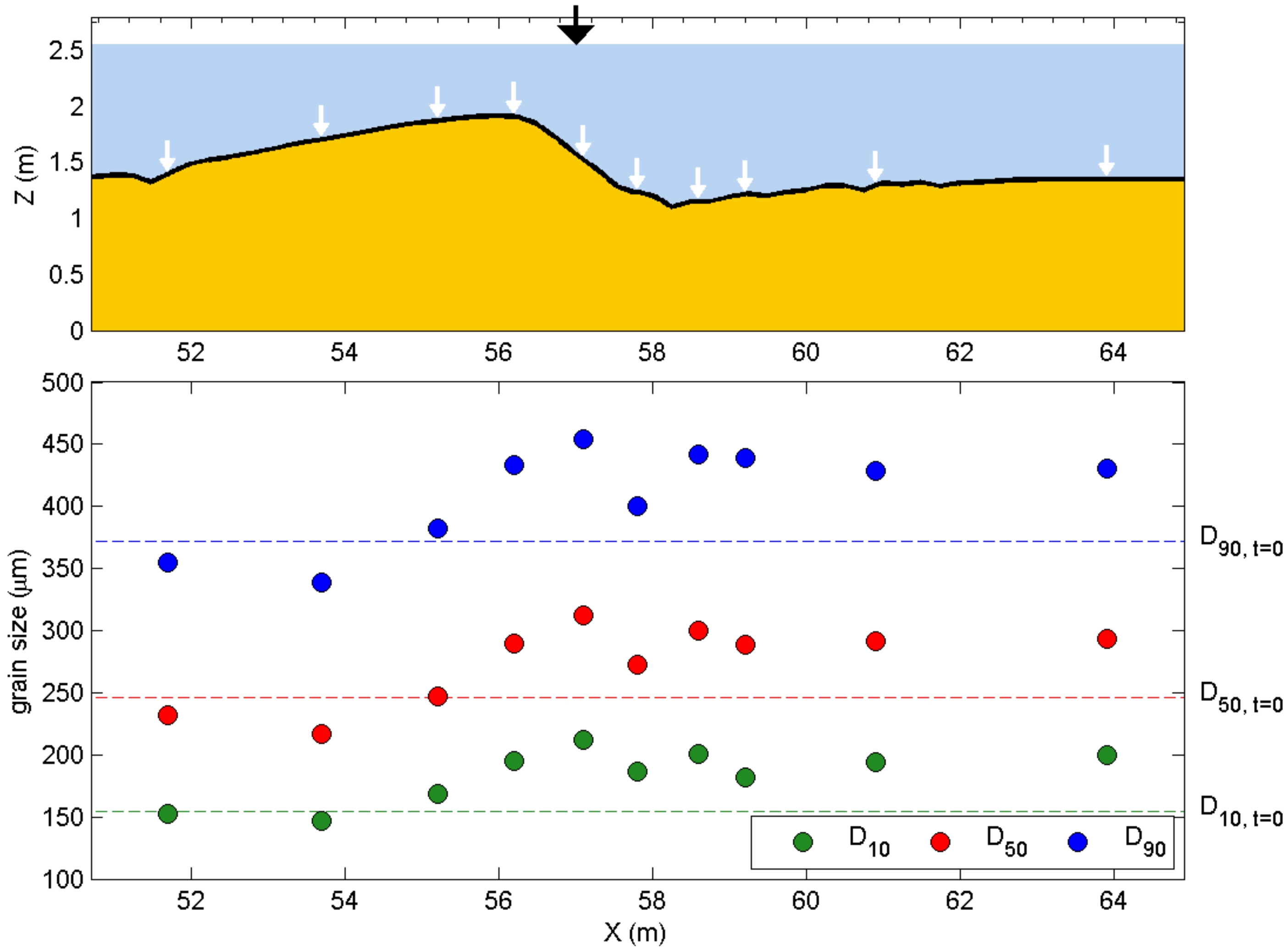
SINBAD: activities



Outline

- Research objectives
- Experimental set-up
- Results breaking-wave experiments
- Resutls Irregular-wave experiments
- Closure

Grain-size sorting bed



UN

SINBAD: UK-Dutch collaboration project 2012 -2016

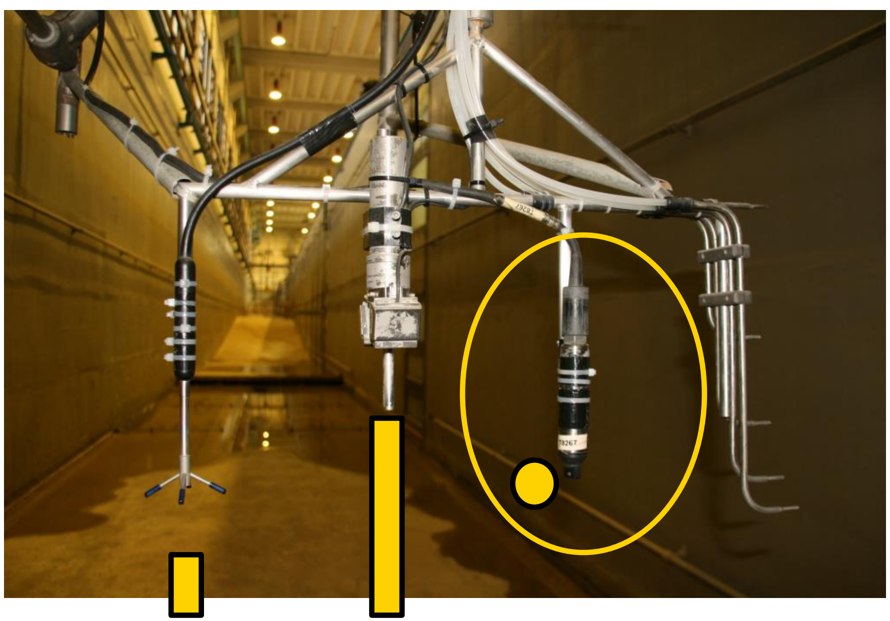
- Objectives: Study the effects of
  1. Wave breaking
  2. Wave irregularity

  …on sediment transport processes
- Methodology: Laboratory experiments (Aberdeen, UPC Barcelona) and Process-based 1DV/3D numerical modelling (Twente, Liverpool, Bangor)
- End-product: a new practical sand transport model
  (to be used in morphological models e.g. Delft3D)

Mini-frame

Mini-frame:

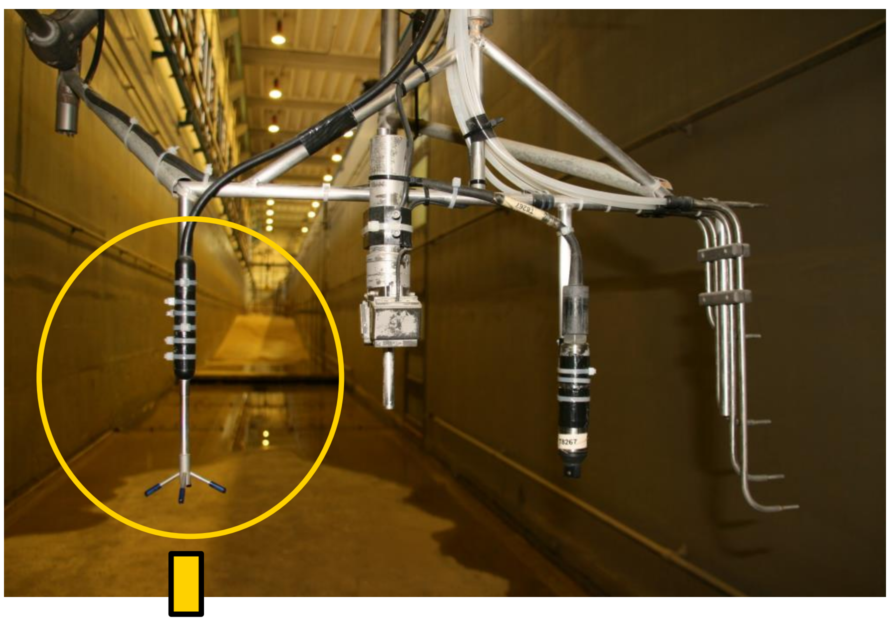
- Vectrino Profiler
- HR-ACVP
- Optical Backscatter Sensor



Mini-frame

Mini-frame:

- Vectrino Profiler



Mini-frame

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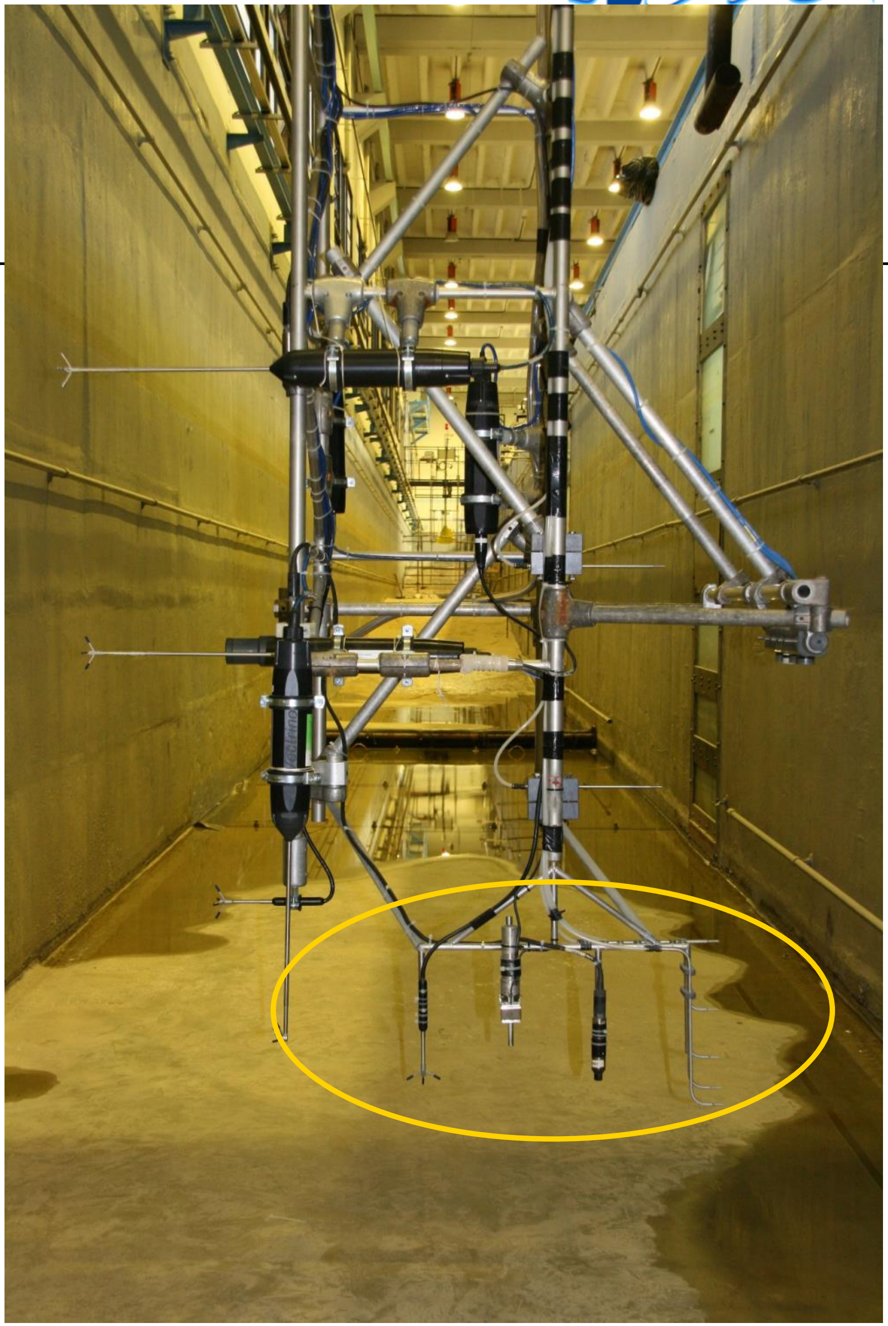
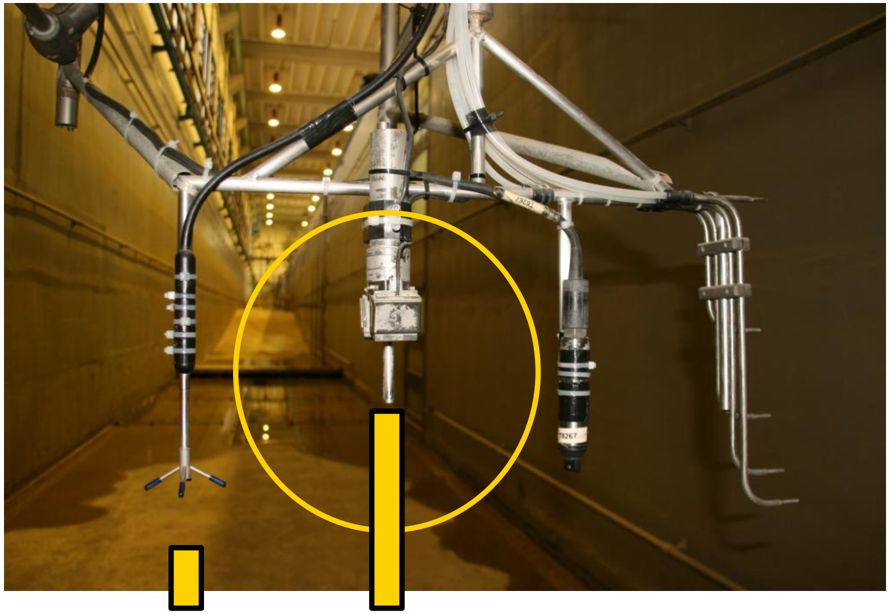
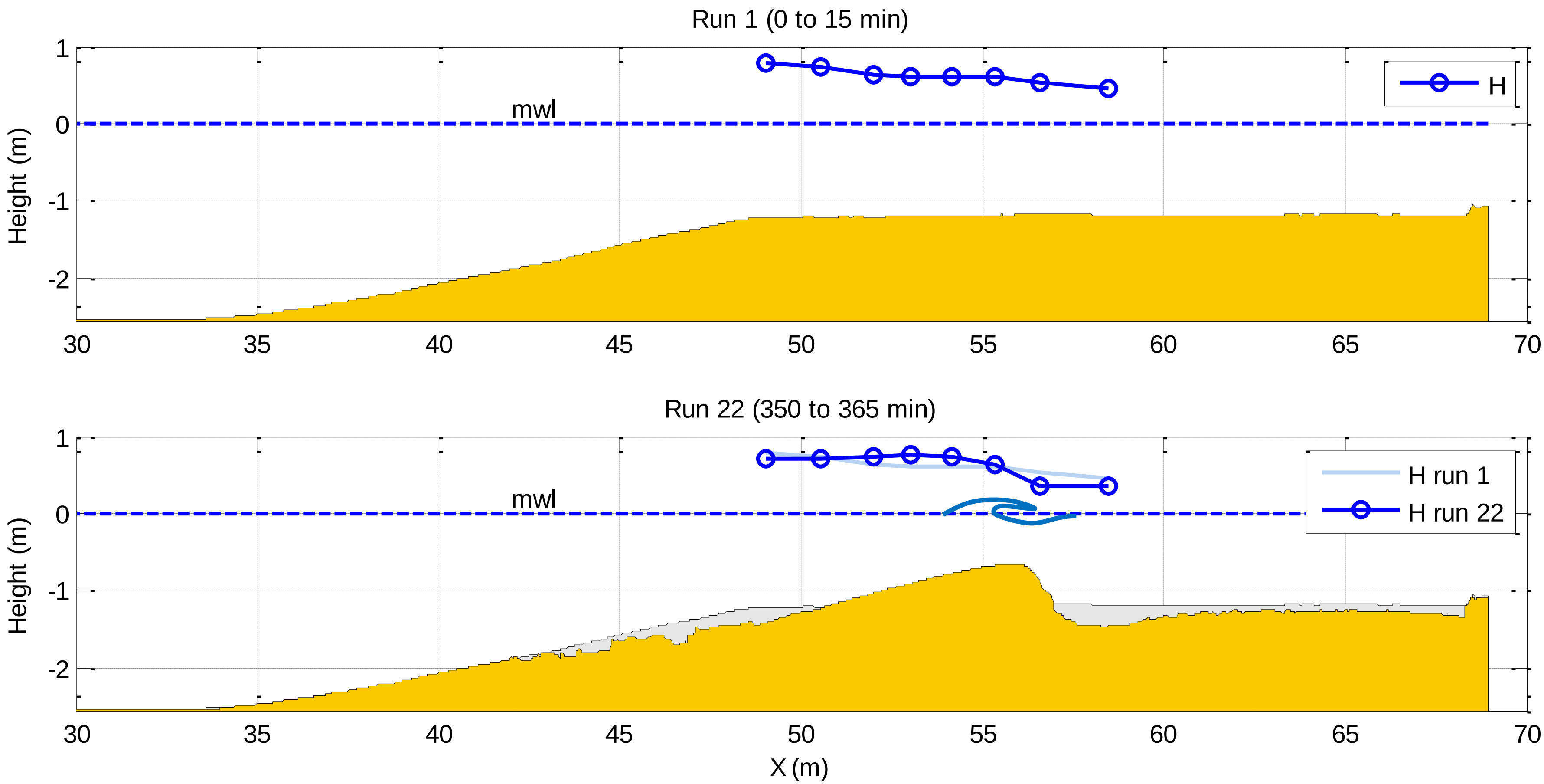


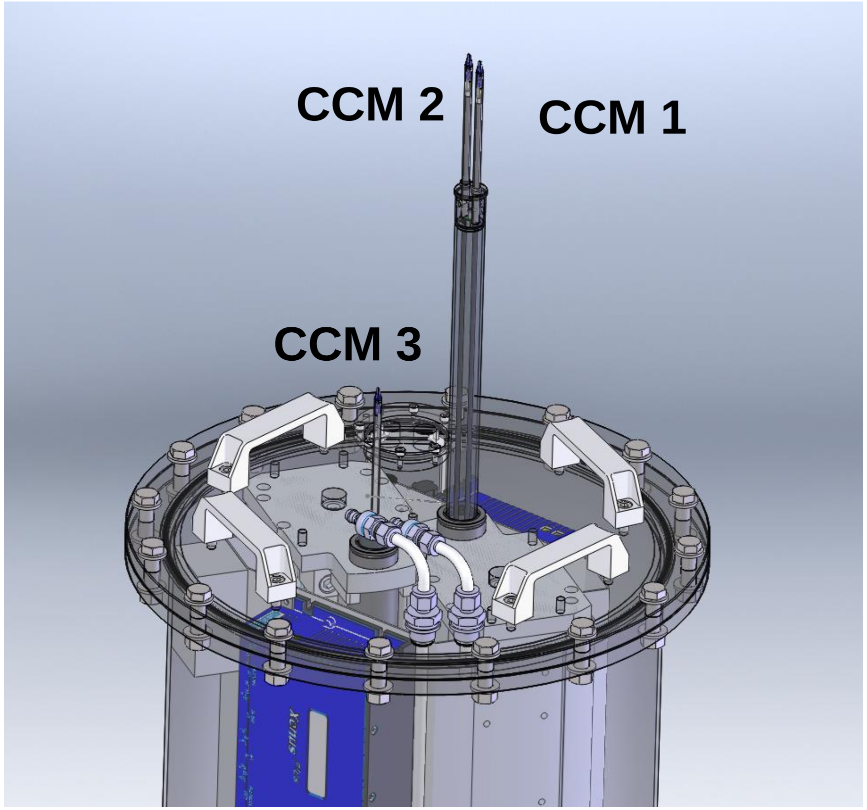


Shoaling and breaking during bar development



CCM+

CCM probe



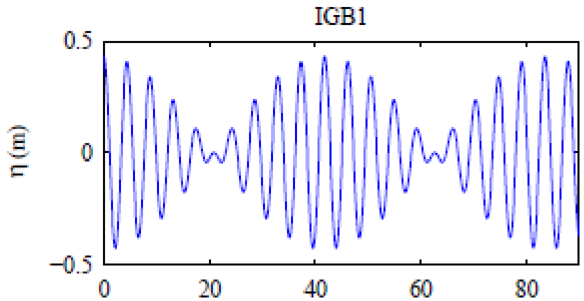
Concentration range: 5 – 60 %
Spatial resolution: ca. 1 mm
New bed-level tracking system (range 28 cm)

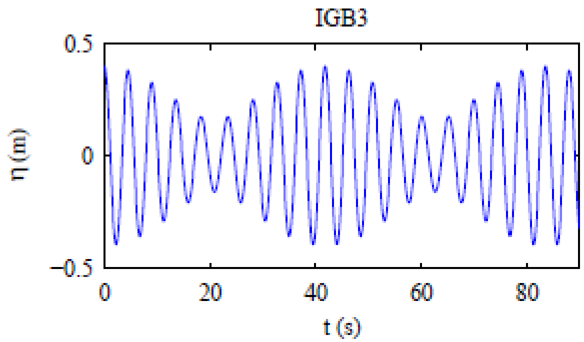
Van der Zanden, J., et al. (2013) New CCM technique for sheet flow measurements and its first application in swash zone experiments, Proc. 6th SCACR, Lisbon.

Irregular wave experiments

Wave conditions and experimental procedure

Grouped waves							
test #	T_m	H_{rms}	H_s	H_{max}	T_g	N	Remark
IGB1	4.40	0.49	0.69	0.69	41.8	10	bichromatic, fully modulated
IGB2	4.40	0.49	0.69	0.69	28.6	7	bichromatic, fully modulated
IGB3	4.40	0.49	0.69	0.62	41.8	10	bichromatic, partial modulated
IGM1	4.40	0.49	0.69	0.79	44	10	waxing, fully modulated
IGM2	4.40	0.49	0.69	0.79	44	10	waning, fully modulated





- 2.5hr measurements per condition
- 1 measurement location in the centre of horizontal bed