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Truc Vert 2008 project

Field measurements of wave celerity in the surf zone, analysis of nonlinear and very low frequency processes

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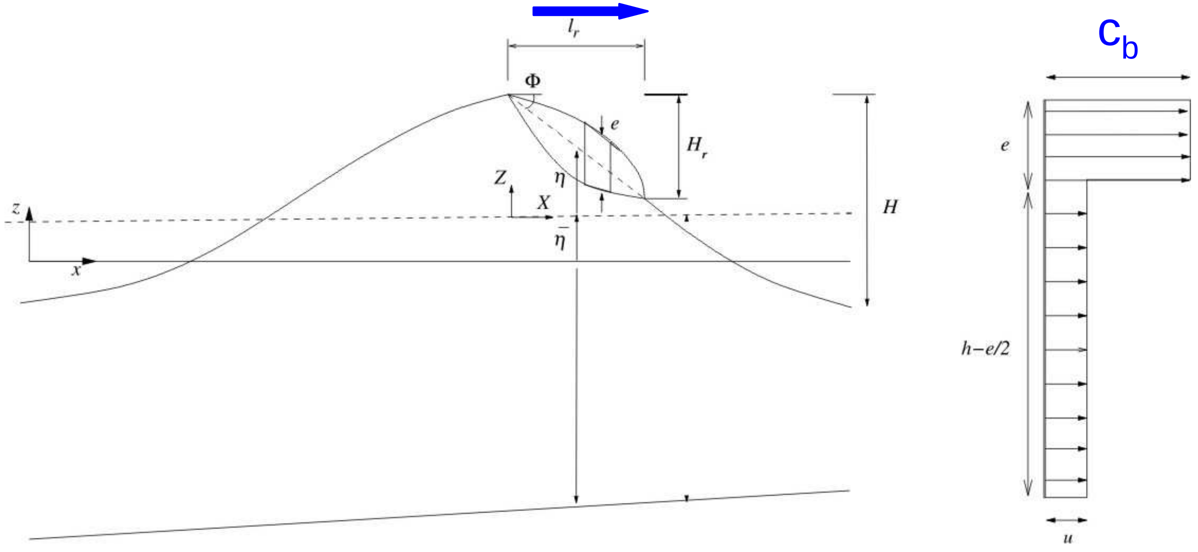
Introduction

Wave celerity is a key parameter for:

- wave propagation models
- remote sensing applications
  - ⇨ estimation of near-shore bathymetry from Radar or Video images

Wave celerity predictors work relatively well before breaking, but not in the surf zone phase-averaged models and most of the Boussinesq-type models are based on the roller concept

c_b: broken wave celerity



Cienfuegos et al. (2004)

- $$c_b = \alpha\sqrt{g\bar{h}}$$

α =1 linear theory

α =1.3 Schäffer et al. (1993)

Boussinesq models

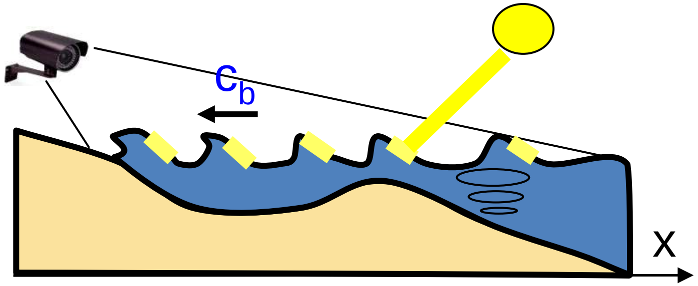
- nonlinear bore theory for phase-averaged approach

Svensen et al (1978, 2003)

SHORECIRC

Depth inversion from video estimation of c_b

e.g. Stockdon and Holman (2000), Catalan and Haller (2008)
or Almar et al. (2008)



Slope of bore trajectories ⇨ c_b

Almar et al. (2008)

c_b=f(h,H,T, …) ⇨ h

Wave celerity in the surf zone

Laboratory experiments :

- monochromatic wave ⇨ Svendsen et al. (1978), Stive (1984), …
- random waves ⇨ Catalan and Haller (2008)

Field experiments :

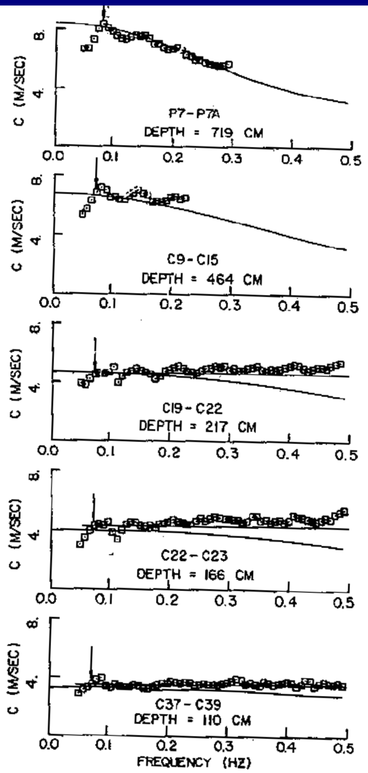
- Suhayda and Pettigrew (1977) : photographing wave poles
- Thornton and Guza (1982): synchronized pressure sensors

$$\left(g\bar{h}\right)^{1/2} < c_b < \left(g\bar{h}\right)^{1/2}\left(1+\frac{H}{\bar{h}}\right)^{1/2}$$

Linear theory

Solitary wave theory

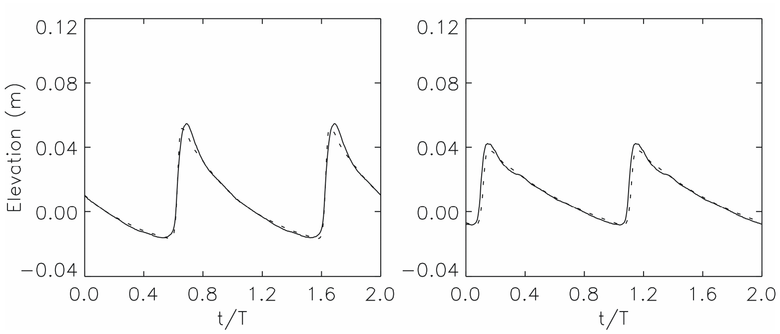
Characterization of c_b

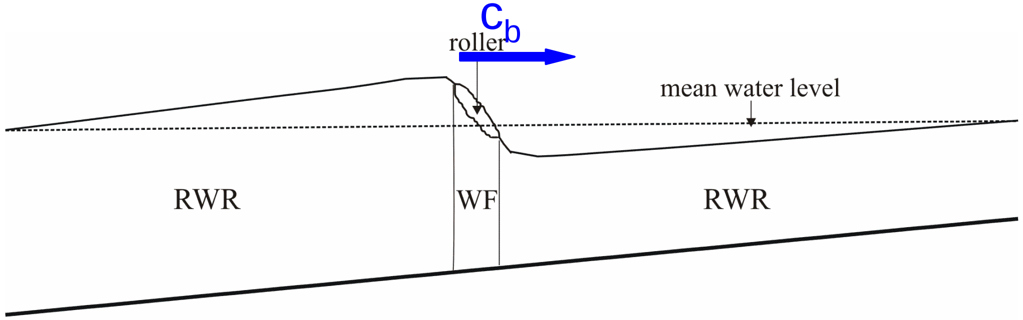


Celerity spectra for relatively high waves with broad energy density spectra on November 12, 1978.

Thornton and Guza (1982)

all the harmonics travel at the speed of the wave front

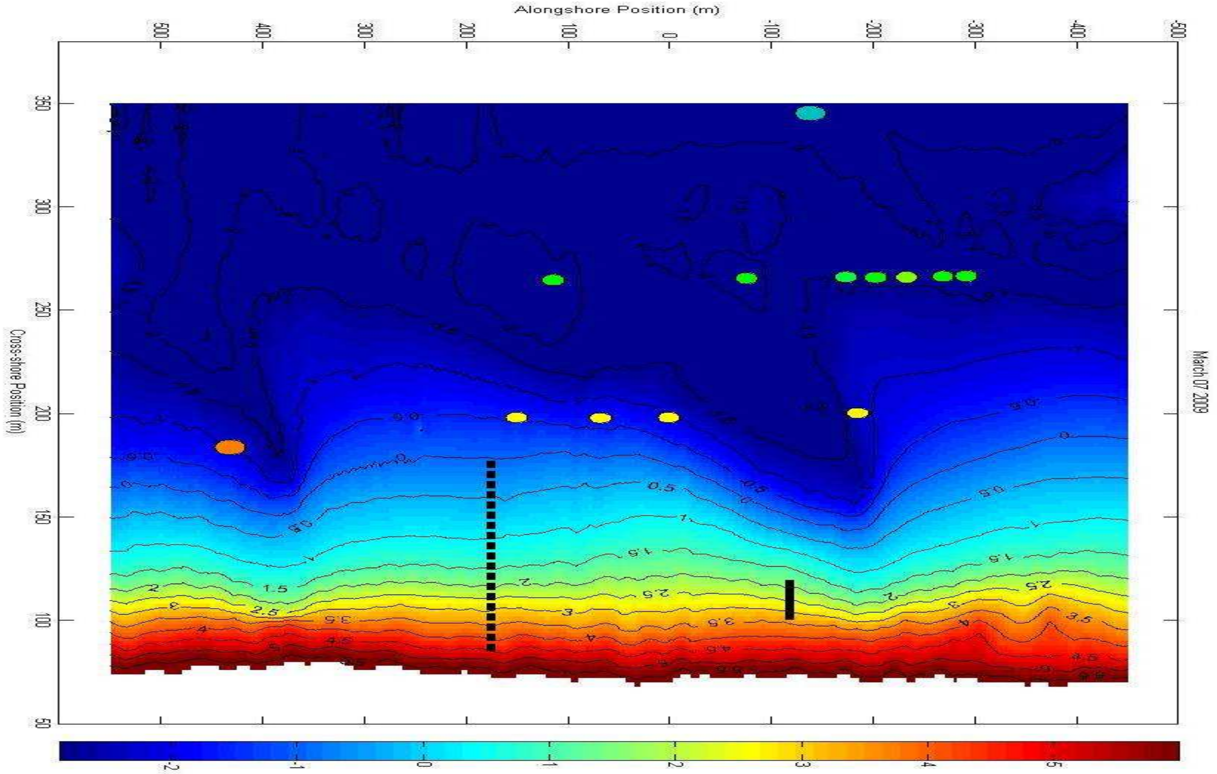




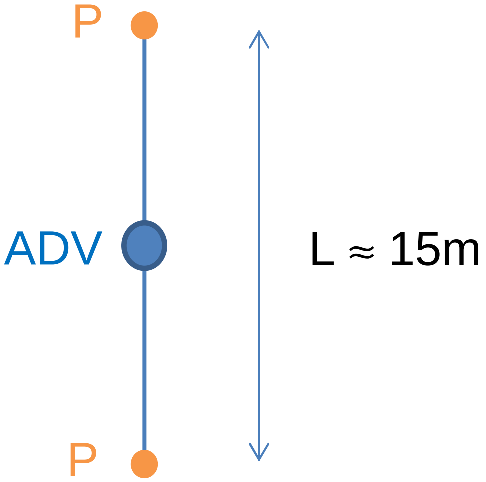
⇨ direct measurements of the broken-wave front celerity c_b

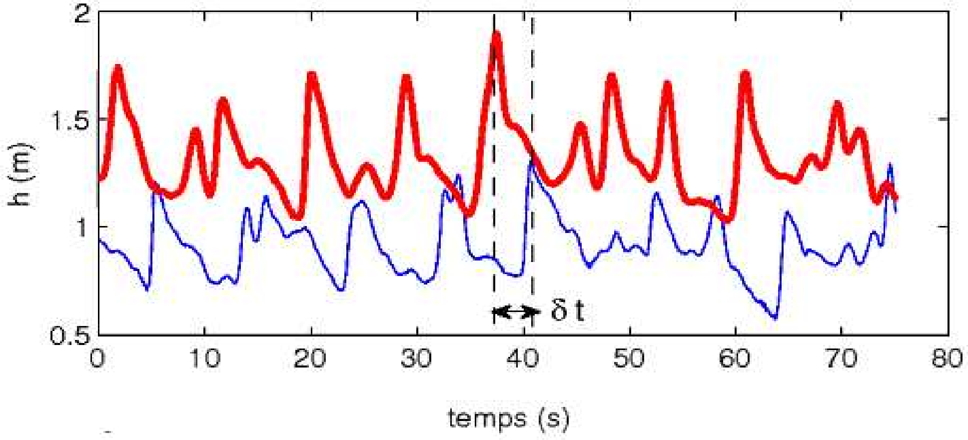
Instrument deployment

Truc Vert beach 2008



Synchronized instruments (f=16 Hz) along a cross-shore line





Cross-shore component of the celerity

$$c_{mx} = \frac{L}{\delta t}$$

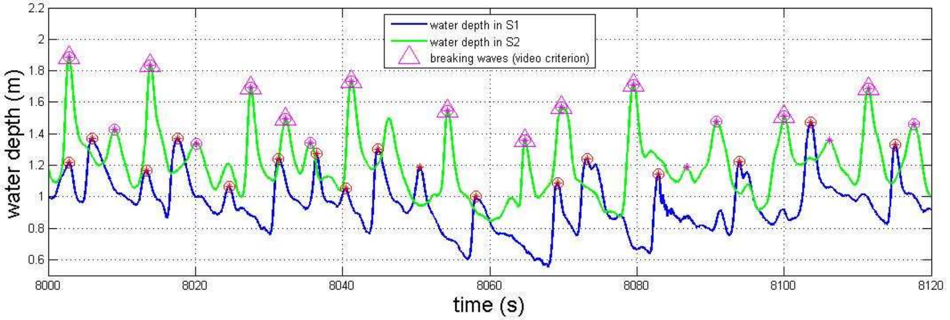
θ<10°⇨ $c_m \approx c_{mx}$

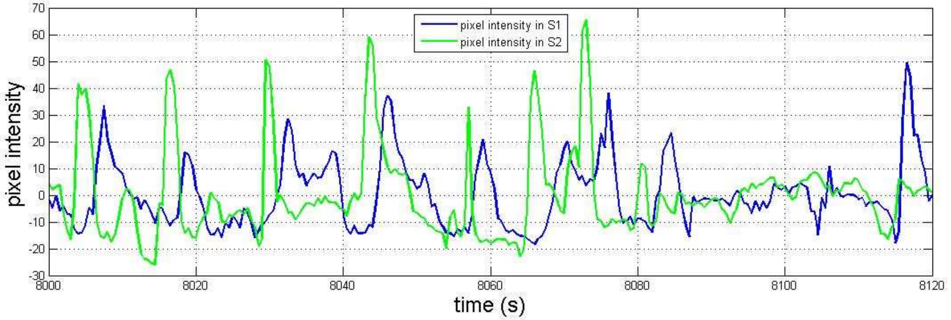
error < 2%

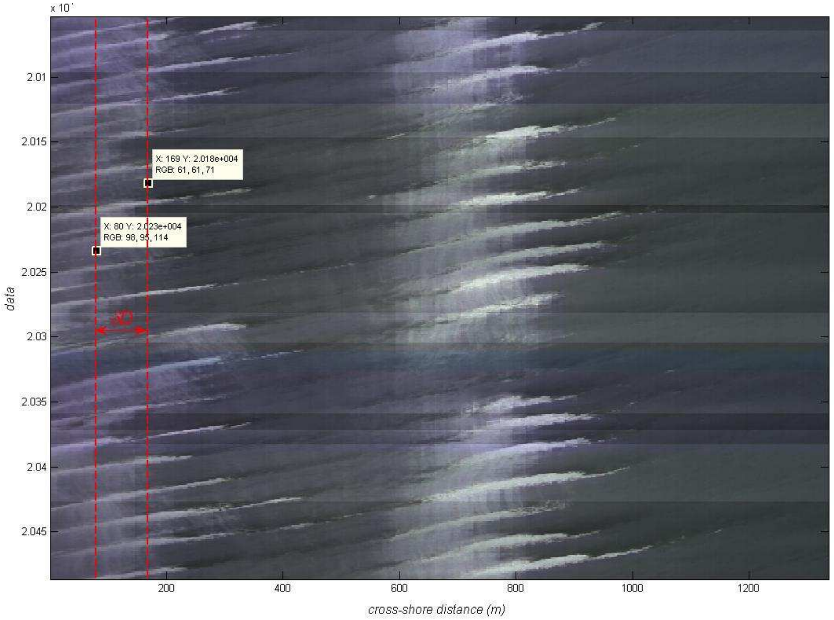
Field experiment | Methods

time lag δt ⇨ cross-correlation over 10 min (*Tissier M.*)

⇨ wave by wave analysis (*Postacchini M.*)

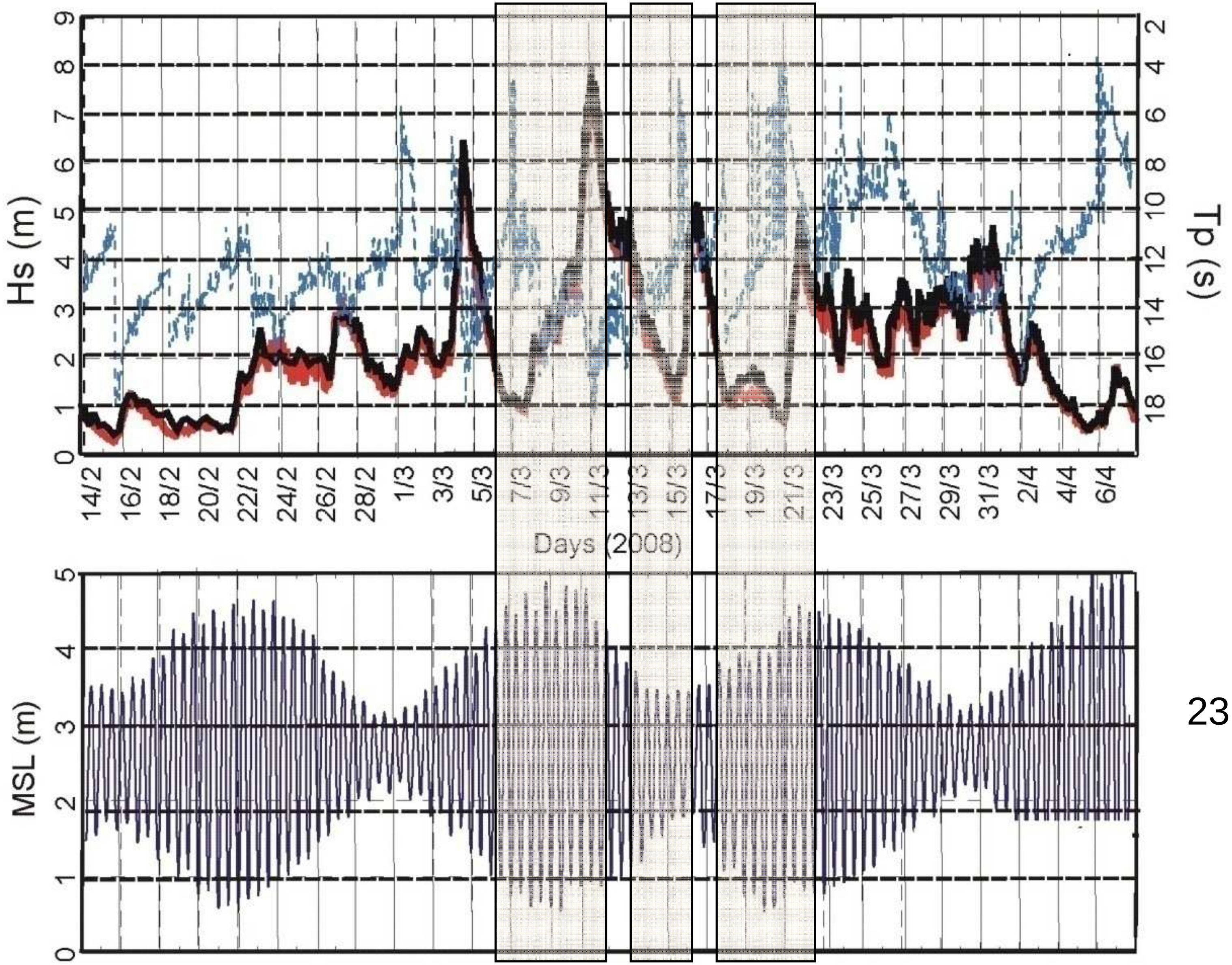






(Almar R.)

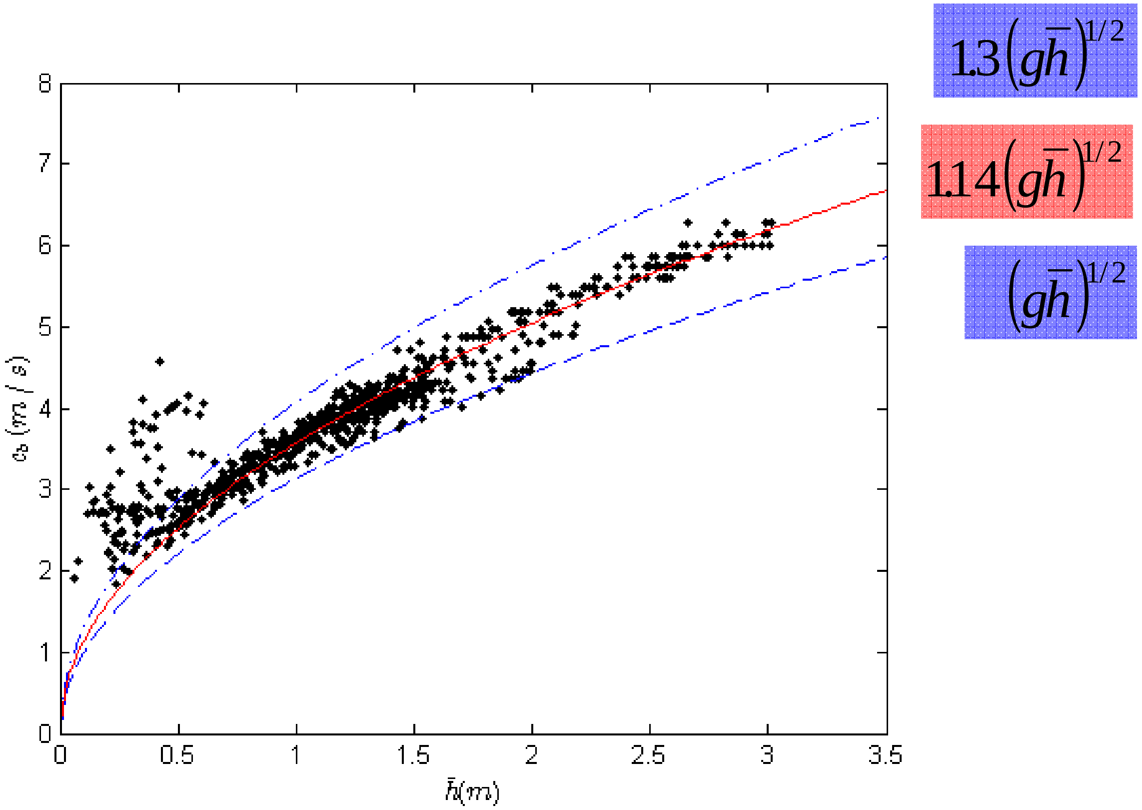
Field experiment | **Data set**



23 tidal cycles

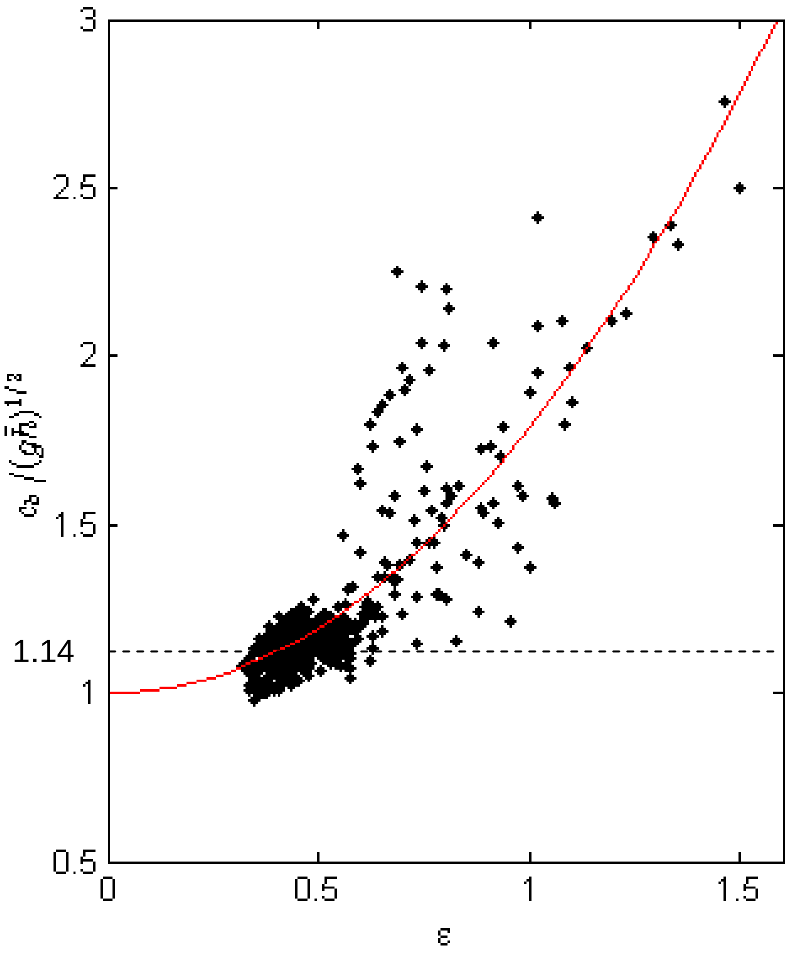
Broken-wave celerity measurements

Celerity calculated by cross-correlation between 10-min long signals



Results | Broken-wave celerity measurements

the non-dimensionalized broken-wave celerity is mainly controlled by ε=H/h



$$c_m/(g\bar{h})^{1/2} = 0.8\varepsilon^2 - 0.014\varepsilon + 1$$

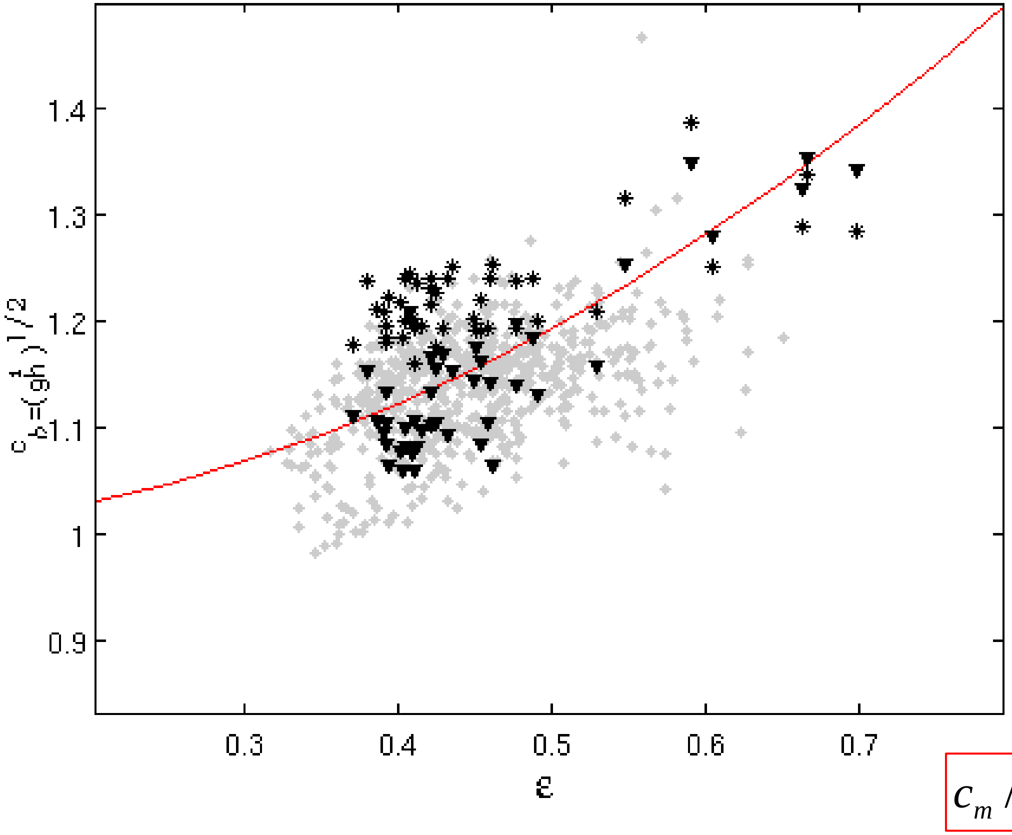
Mean current effects

$$\boxed{c_m = c_r + U_e}$$

$$U_e = \frac{1}{h}\int_{-h}^{0} U(z)dz$$

(Kirby and Chen (1989))

- for most of the data (22 tides over 23) : undertow current with $U_e/C_m<2.5\%$
- for one tide : onshore-directed current with $U_e/C_m\approx15\%$



$$\boxed{c_m/(g\bar{h})^{1/2} = 0.8\varepsilon^2 - 0.014\varepsilon + 1}$$

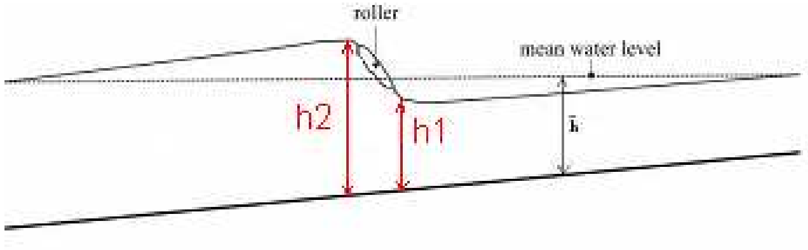
Results | Nonlinear broken-wave celerity predictors

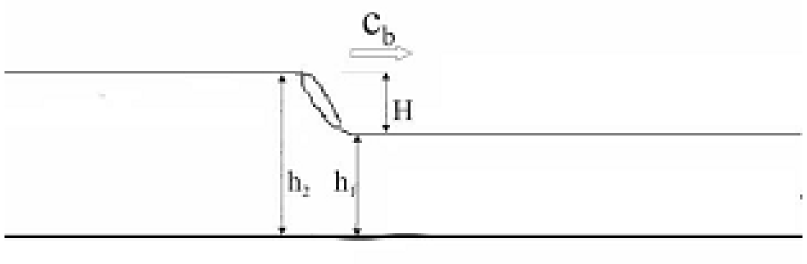
- solitary wave theory

$$c_b = \sqrt{g\bar{h}(1+\varepsilon)}$$

- bore model (Svendsen et al. 1978)

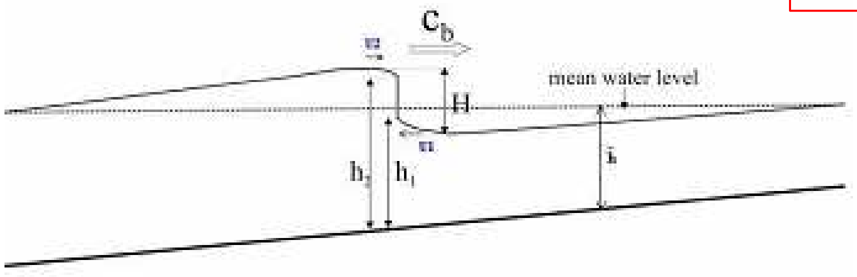
$$c_b = \left(\frac{g h_1 h_2 (h_1 + h_2)}{2\bar{h}^2}\right)^{1/2}$$





- shock wave model (Bonneton, 2004)

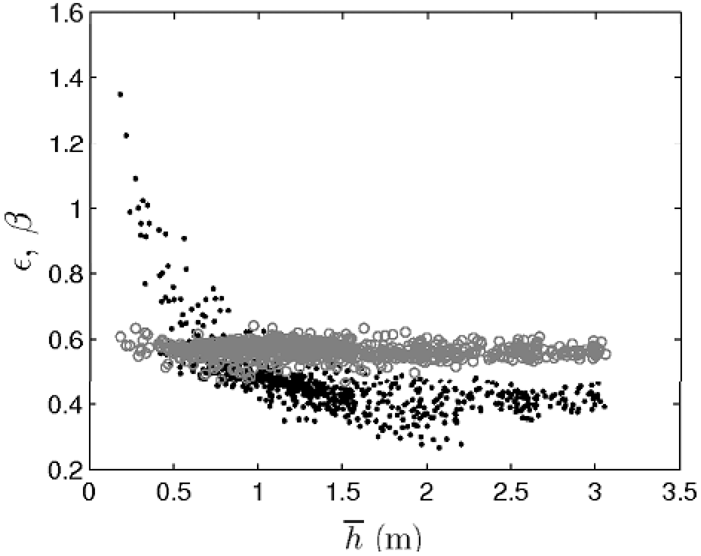
$$c_b = -2(g\bar{h})^{1/2} + 2(g h_1)^{1/2} + \left(\frac{g h_2 (h_1 + h_2)}{2h_1}\right)^{1/2}$$

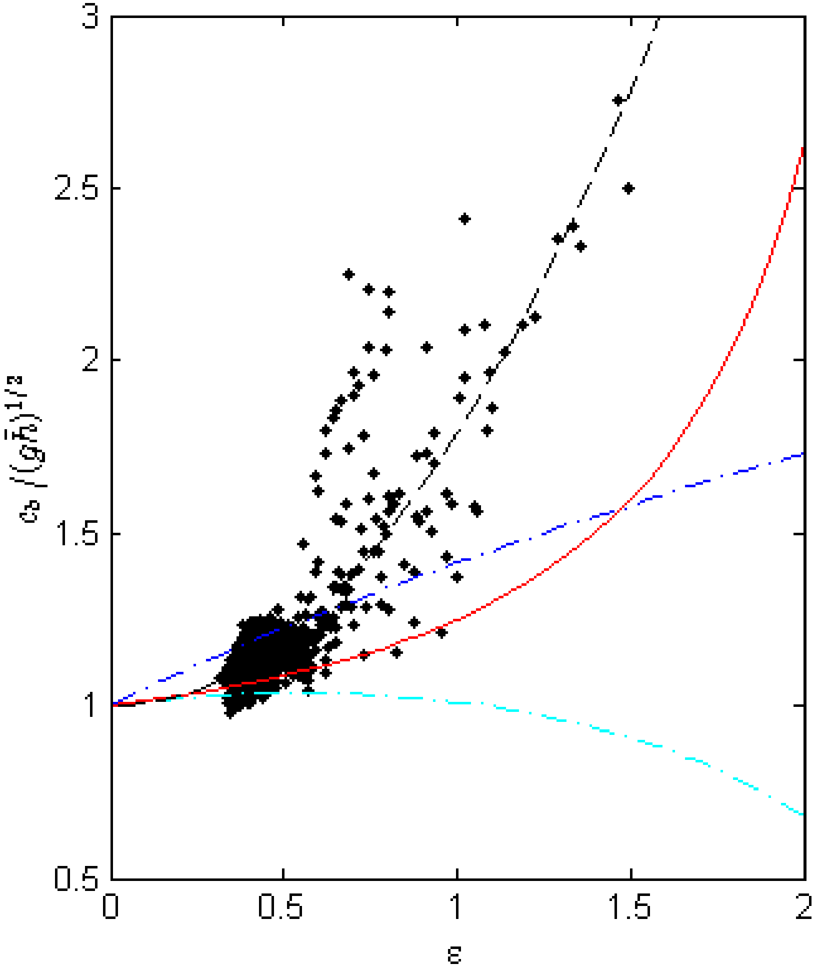


Broken-wave celerity predictors

$$\boxed{\frac{c_{th}}{(g\bar{h})^{1/2}} = f(\varepsilon, \beta)}$$

$$\beta = \frac{\zeta_c}{H}$$

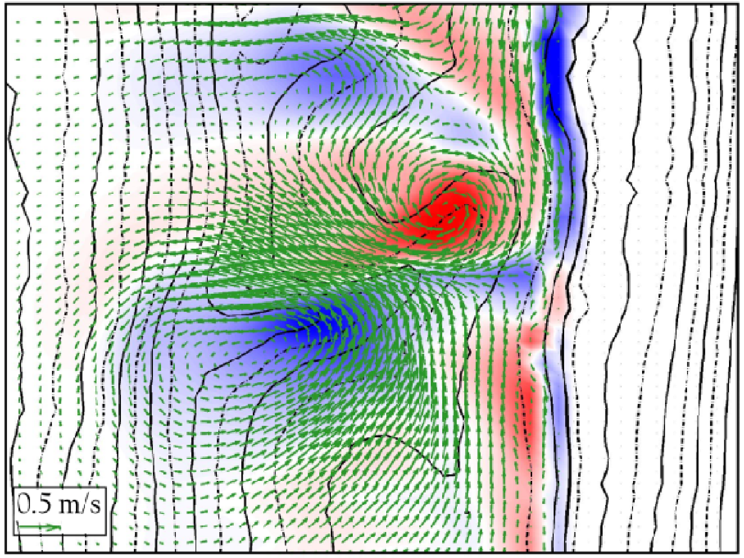


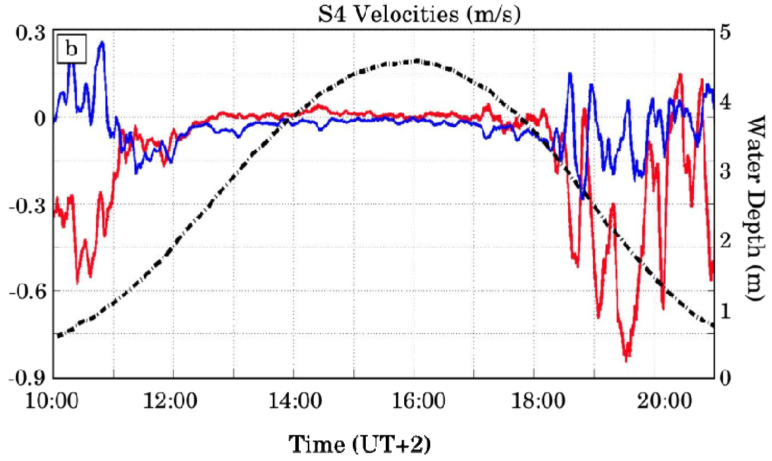


Tissier et al. (EJM/B, 2010)

Influence of current fluctuations

Wave breaking over complex bathymetries induces the generation of circulation cells which are not-stationary ⇨ **Very Low Frequency (VLF) motions** (f<0.04 Hz)





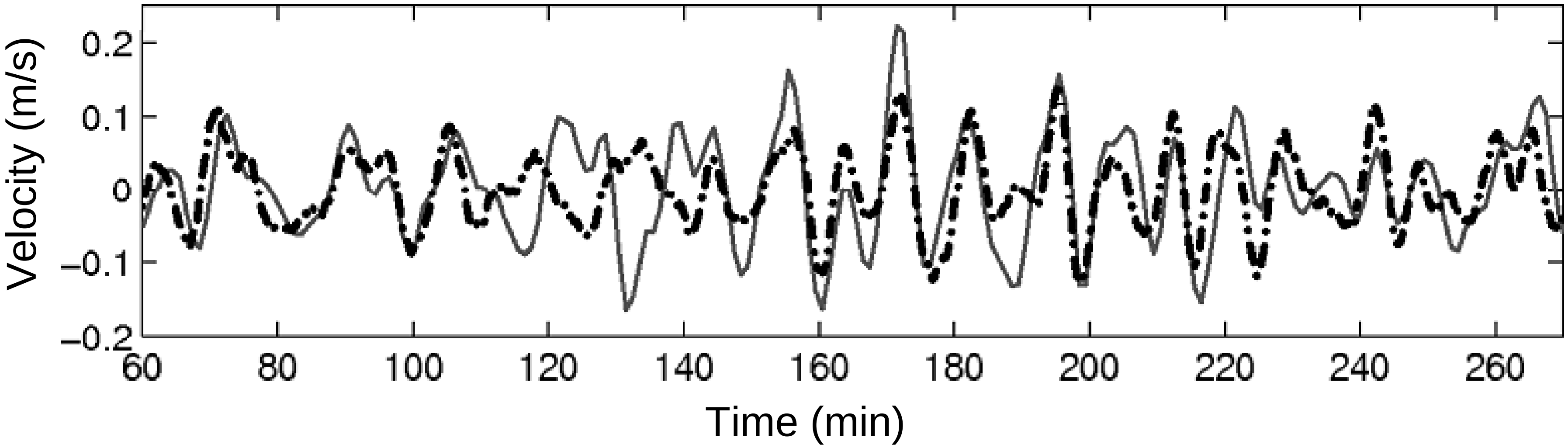
Bruneau et al. (2009)

How these VLF motions can influence wave celerity ?

Results

VLF motions

$c_m = c_r + U_e$ VLF oscillations of the velocity ⇨ VLF oscillation of c_m

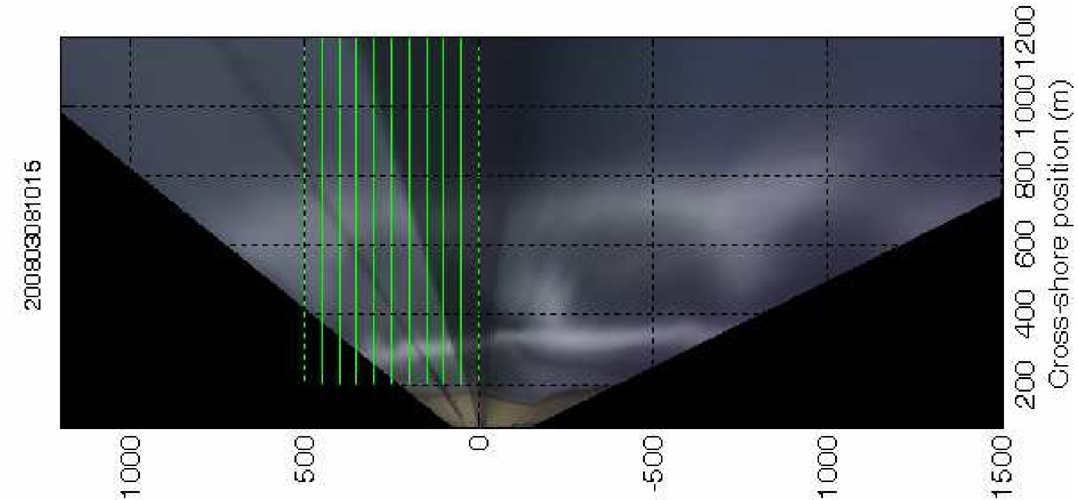


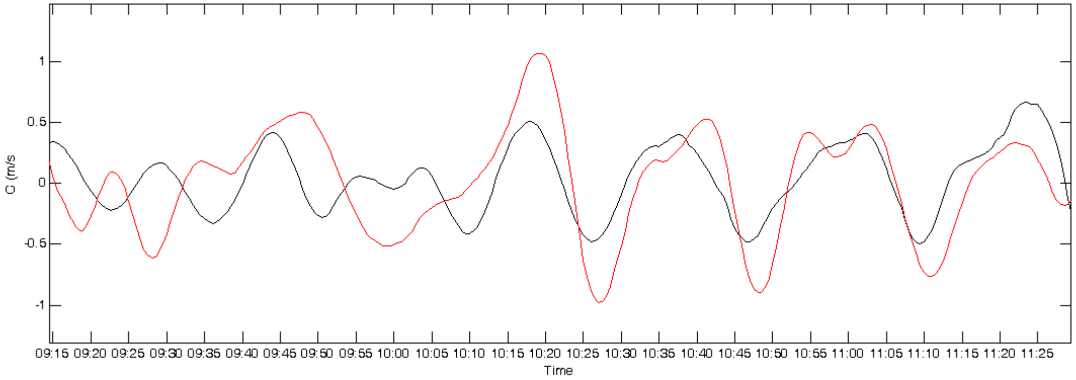
- · - · wave celerity computed on 3-min long periods

—— 3-min averaged cross-shore current (ADV measurements)

This phenomenon can be used as a proxy to analyze, from high frequency wave-celerity video observations, the spatial structure of VLF motions.

Preliminary VLF study from video imagery





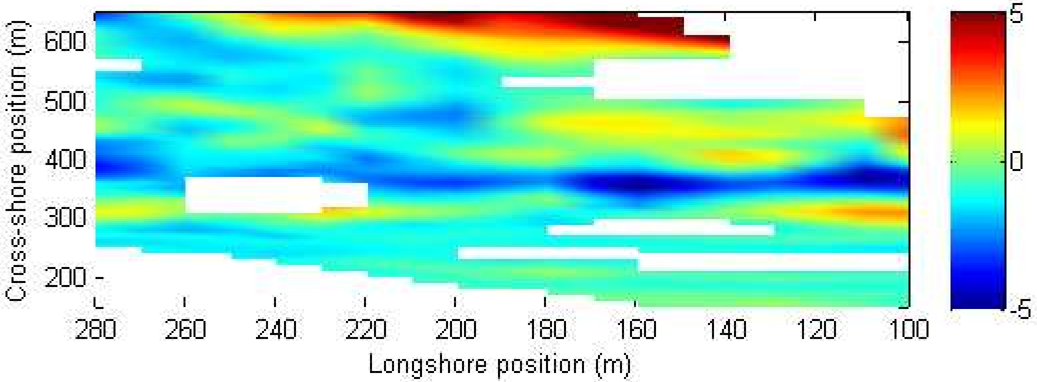
C_m (pressure sensors)

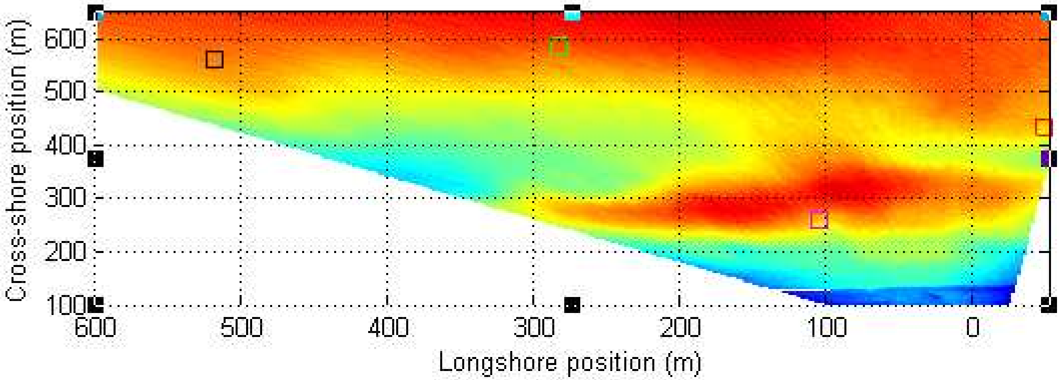
C_m (video)

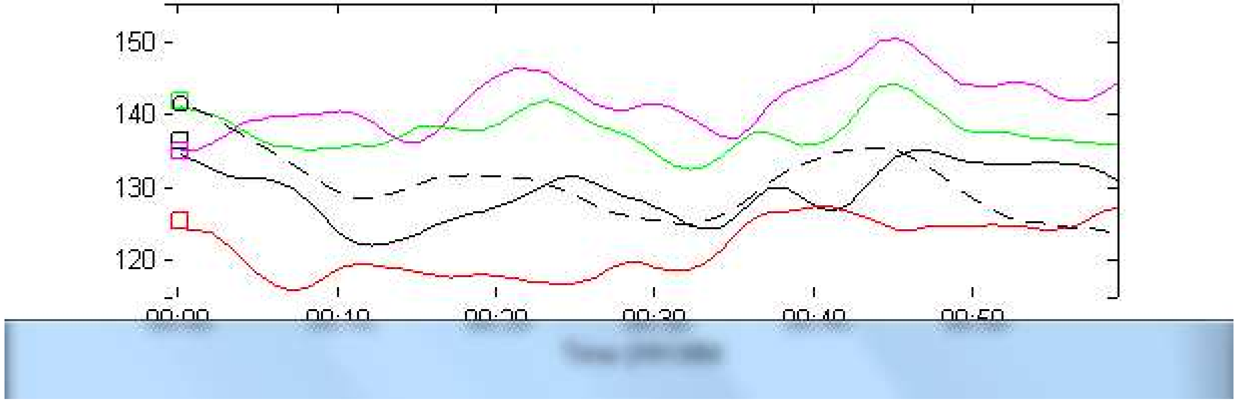
Almar et al. (2010)

Preliminary results

High-energy storm event
11th March 2008







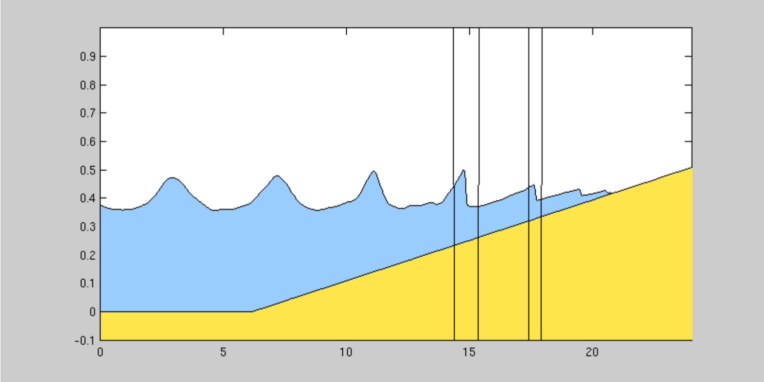
Almar et al. (2010)

Conclusion

- The influence of non-linearities on wave celerity has been quantified

- The classical nonlinear bore model is inappropriate in the vicinity of the swash zone

- Nonlinear celerity models have to be improved for video-based depth inversion applications ⇨ ex.: fully nonlinear Boussinesq models (shoaling and surf zones)



Bonneton et al. (EJM/B, 2010)
Tissier et al. (ICCE 2010)

- Preliminary results show that video imagery can be successful in mapping the spatial variability of VLF motions associated with topographically-controlled rip current systems.

Thank you for your attention