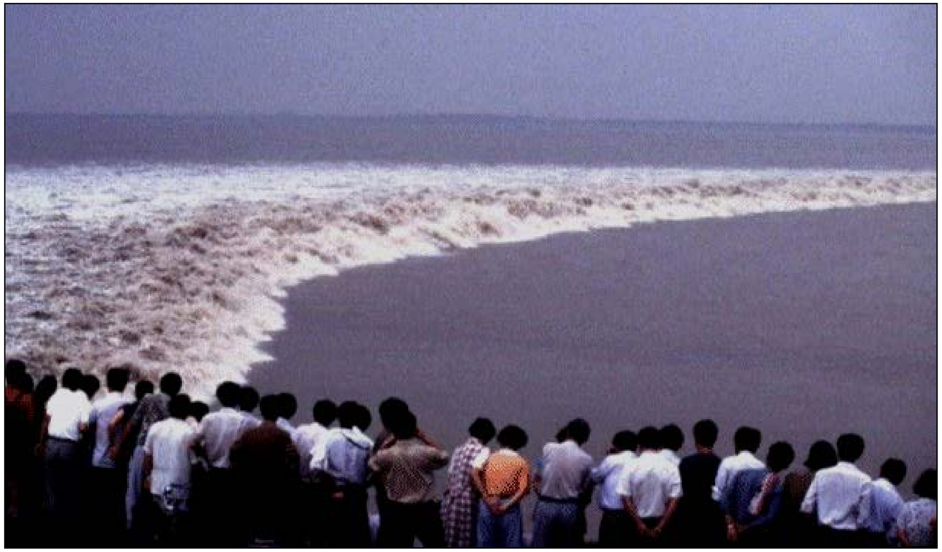
Analysis of non-hydrostatic processes in tidal-bore estuaries

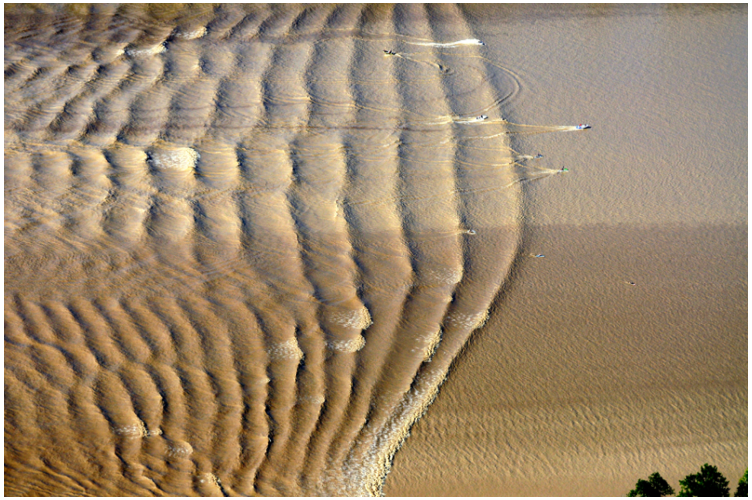
Bonneton P., Sottolichio A., Bonneton N. and Lannes D.

EPOC and IMB - Bordeaux Univ., CNRS

Severn River - England

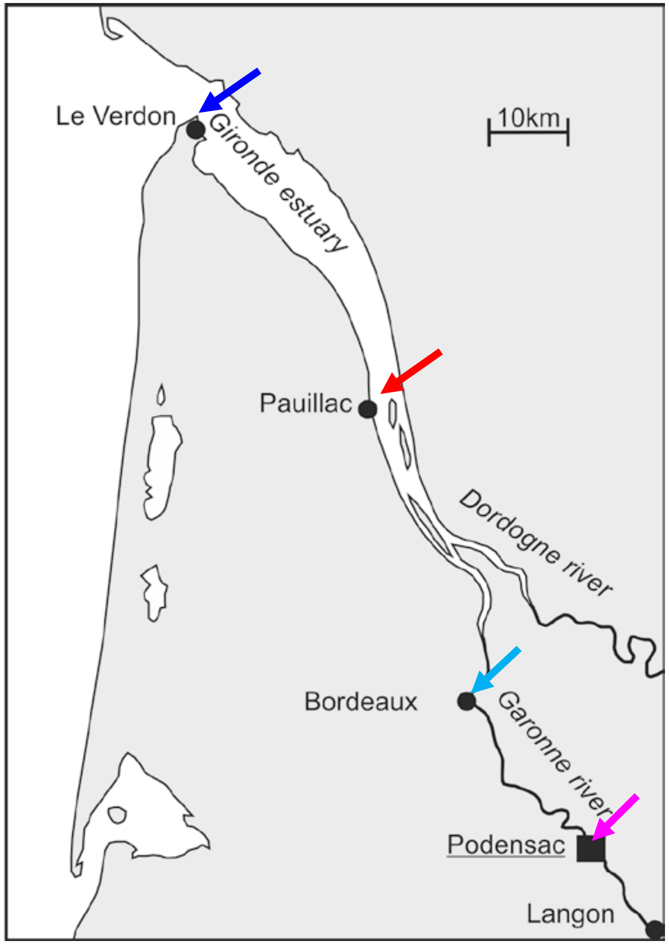


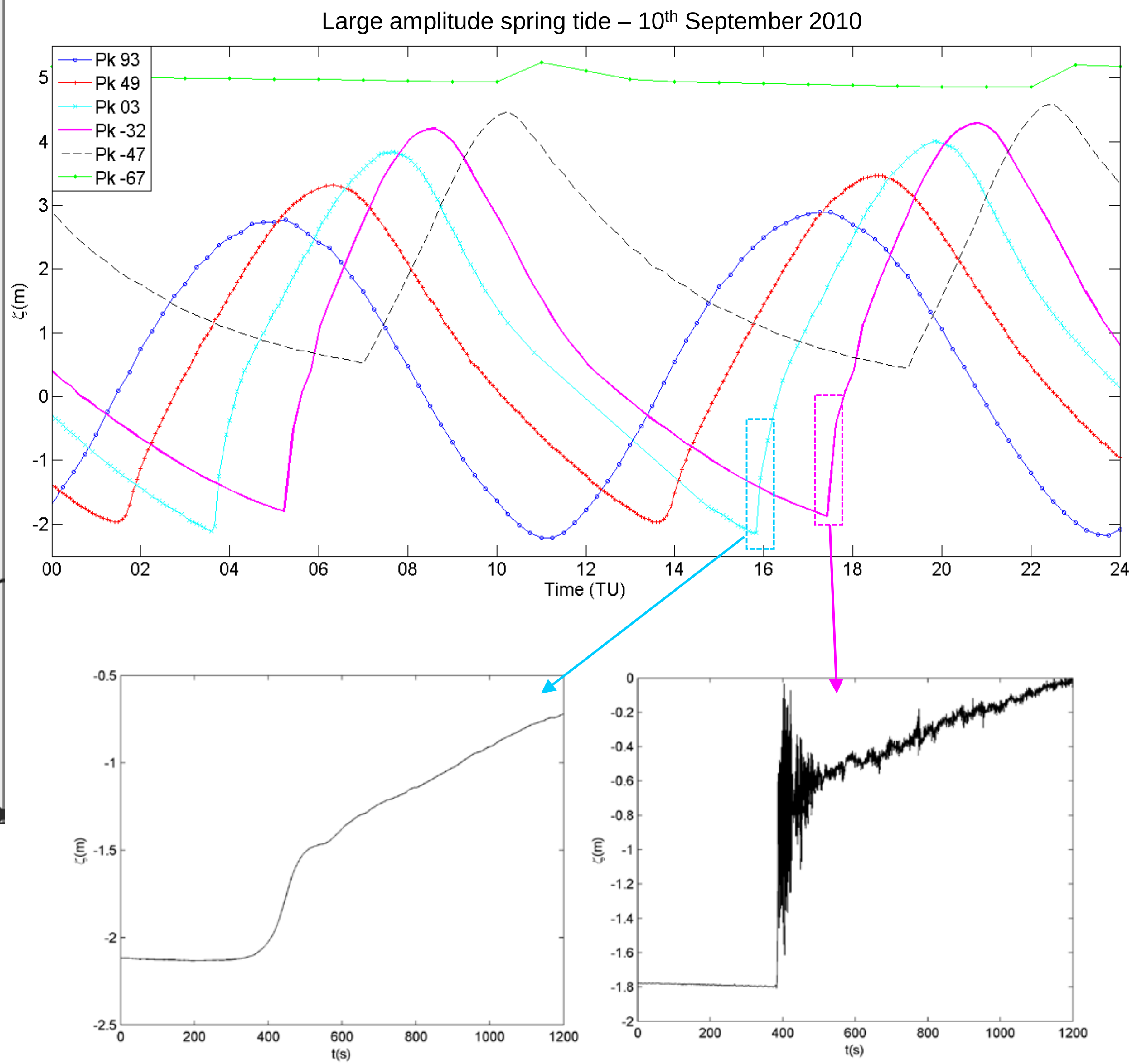
Qiantang River – China



Dordogne River - France

few quantitative observations: *Simpson et al. 2004, Wolanski et al. 2004, Uncles et al. 2006, Bonneton et al. 2011, Chanson et al., 2011*





Bonneton et al. JGR 2015

What are the general conditions which control tidal bore formation in convergent alluvial estuaries?

Following previous scaling analyses of tidal wave transformation in estuaries by:

Lanzoni and Seminara (1998), Toffolon et al. (2006) and Savenije et al. (2008)

What are the general conditions which control tidal bore formation in convergent alluvial estuaries?

$$\epsilon_0 = \frac{A_0}{D_0} \qquad \Phi_0 = \frac{C_{f0} L_{w0}}{D_0}$$

$$L_{w0} = (gD_0)^{1/2} T_0 / 2\pi$$

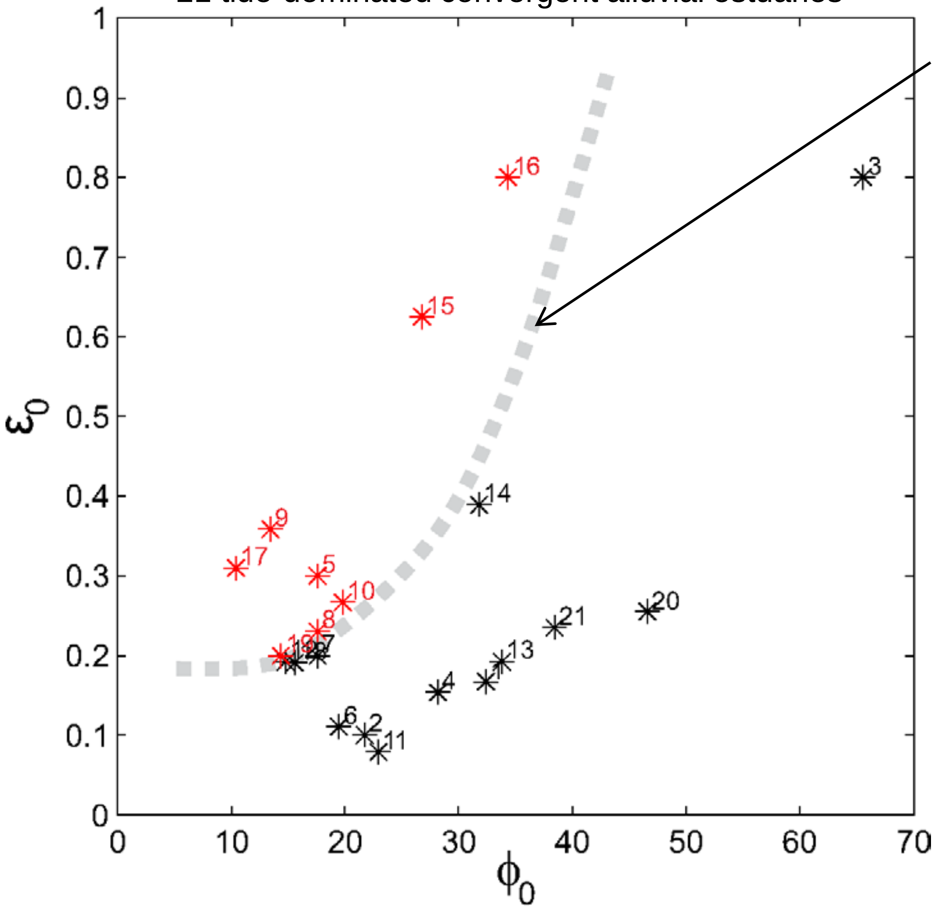
Bonneton et al. ECCS 2016

Tidal bore occurrence in the parameter plane $(\epsilon_0\ ,\ \Phi_0)$

Tidal bores occur when

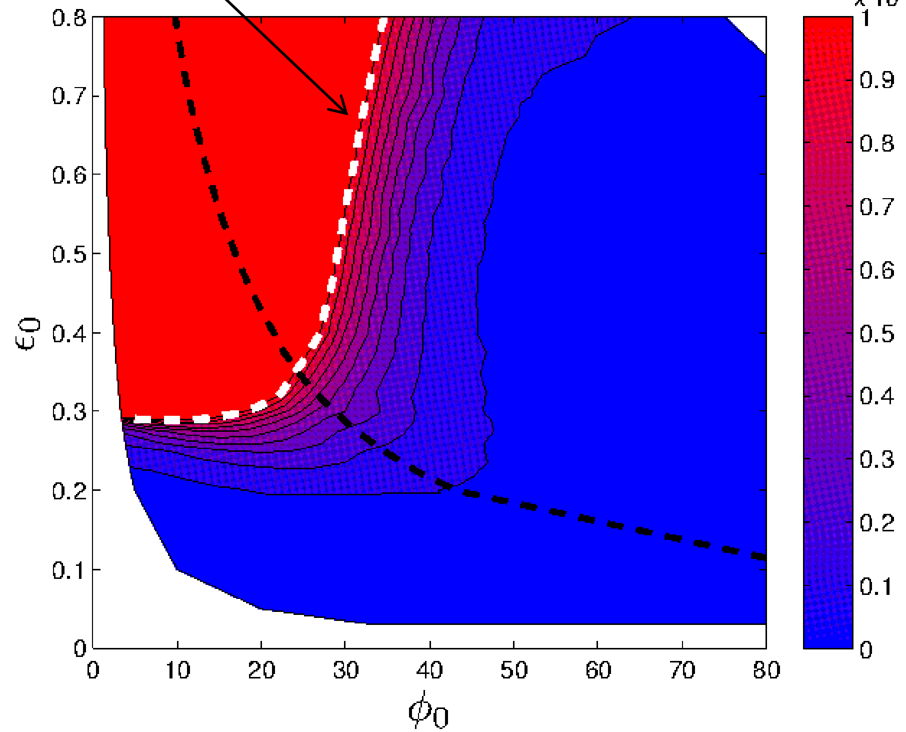
$\varepsilon_0 > \varepsilon_c(\phi_0)$

21 tide-dominated convergent alluvial estuaries

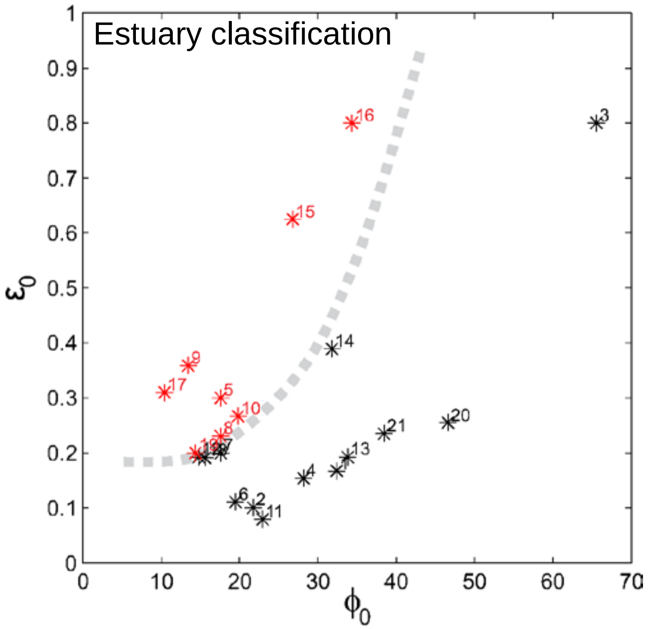


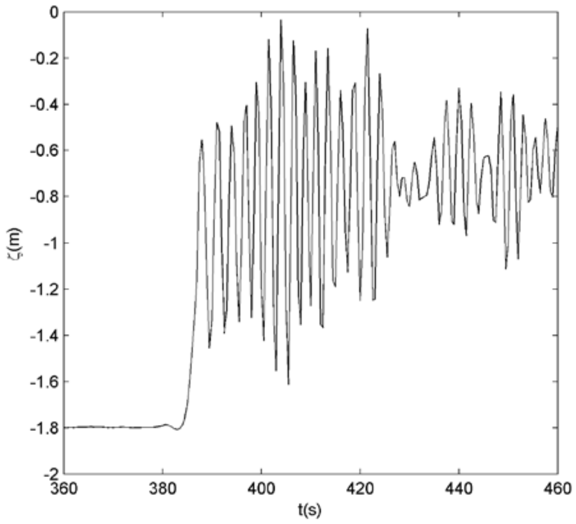
$\varepsilon_c(\phi_0)$

225 numerical simulations



Bonneton et al. ECCS 2016





o a lack of quantitative measurements

o difficulties in measuring this high-frequency process

→ **how to measure and characterize TB**

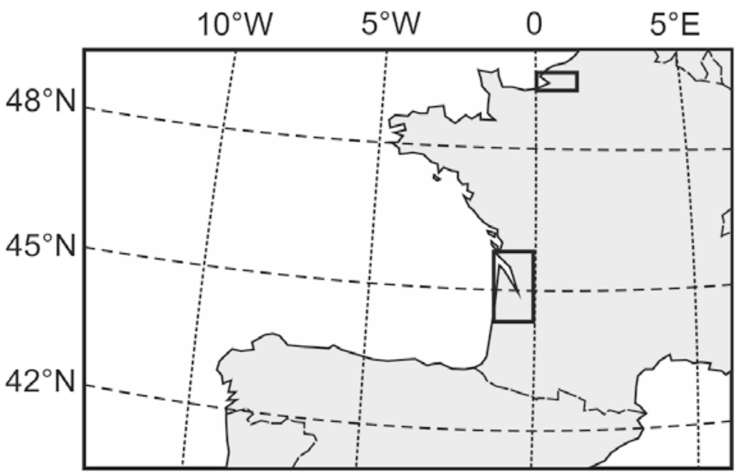
→ **analysis of tidal bore dynamics**

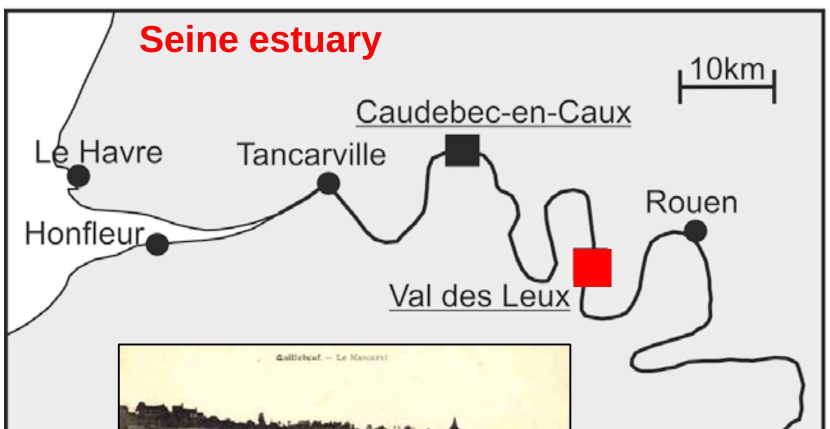
→ **consequences in terms of sediment transport**

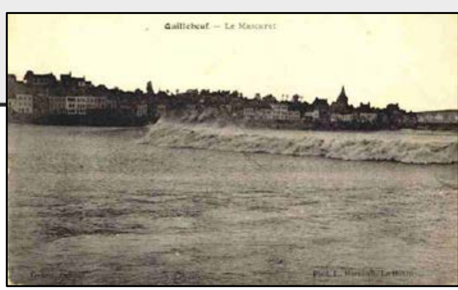
Tidal bore measurements

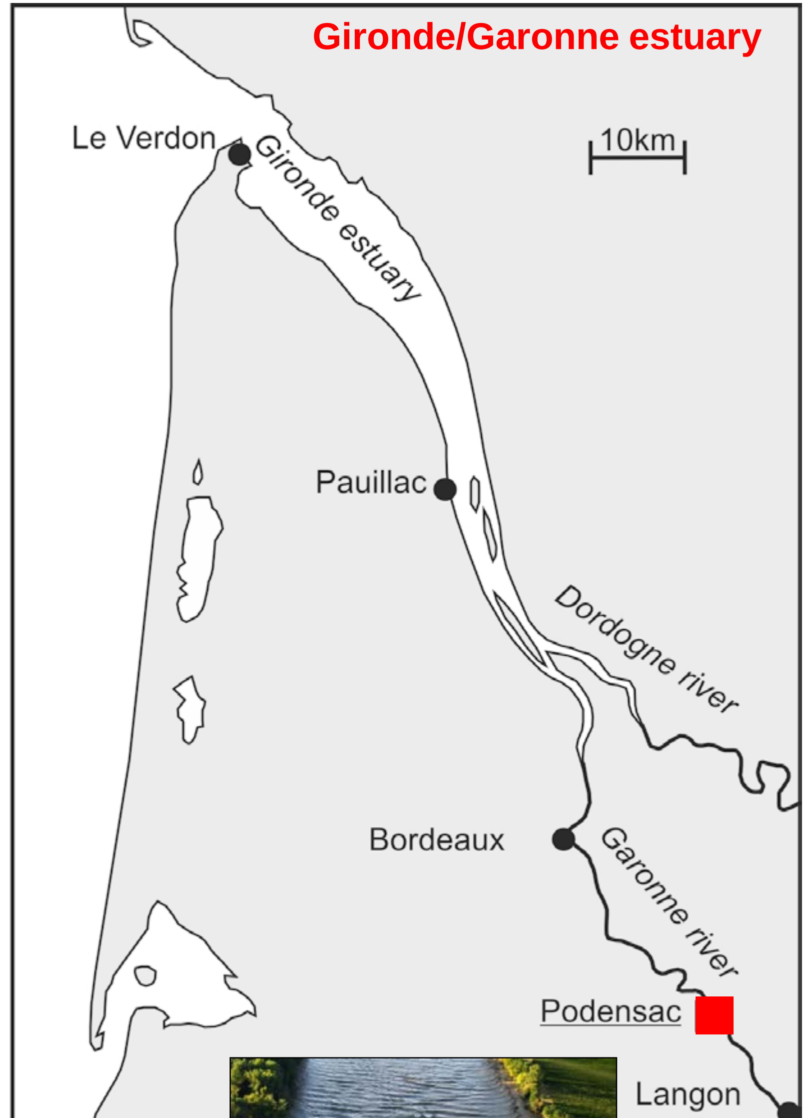
Tidal bore measurements | Field campaigns

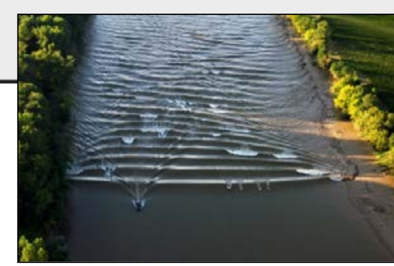
Two French estuaries



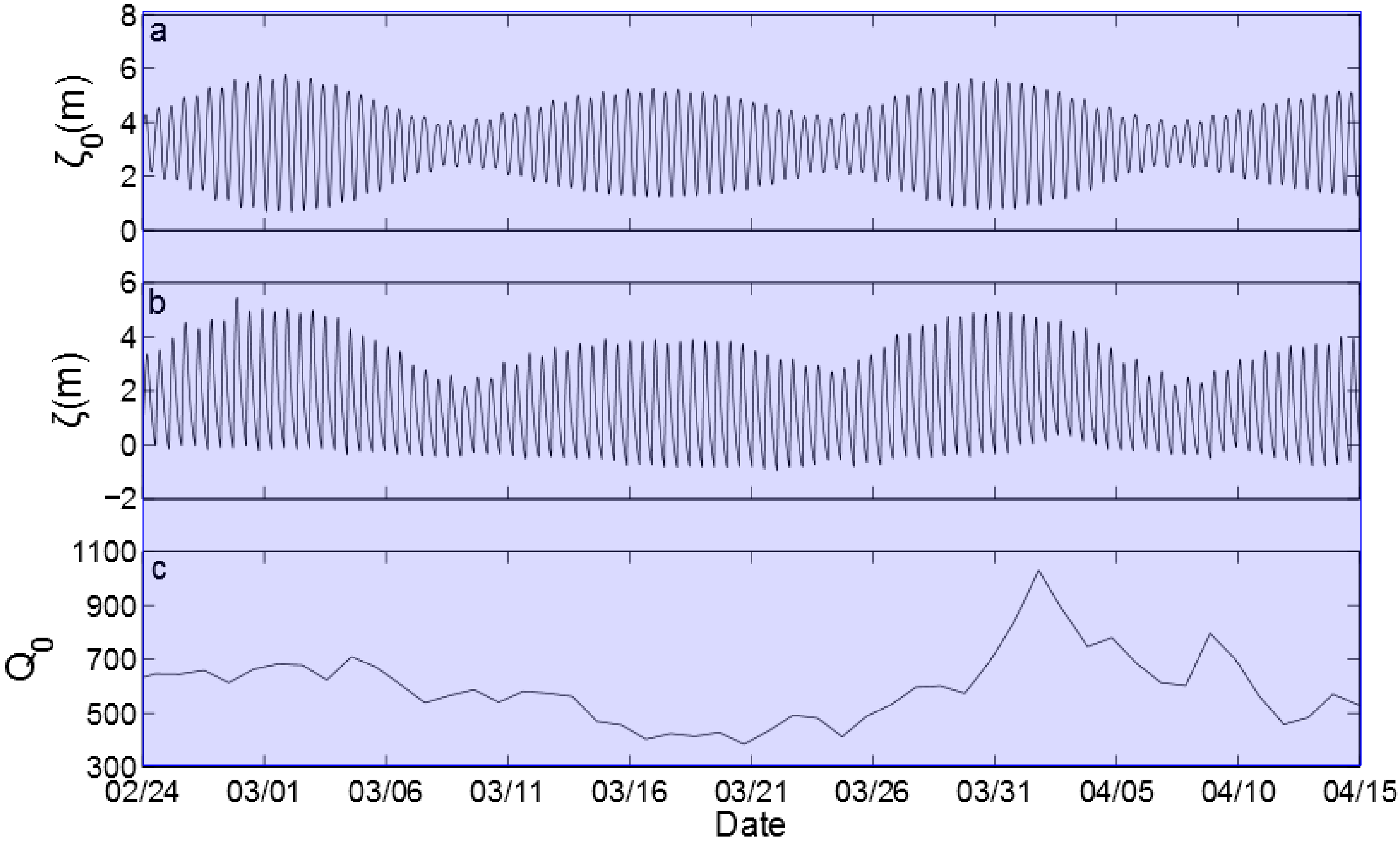




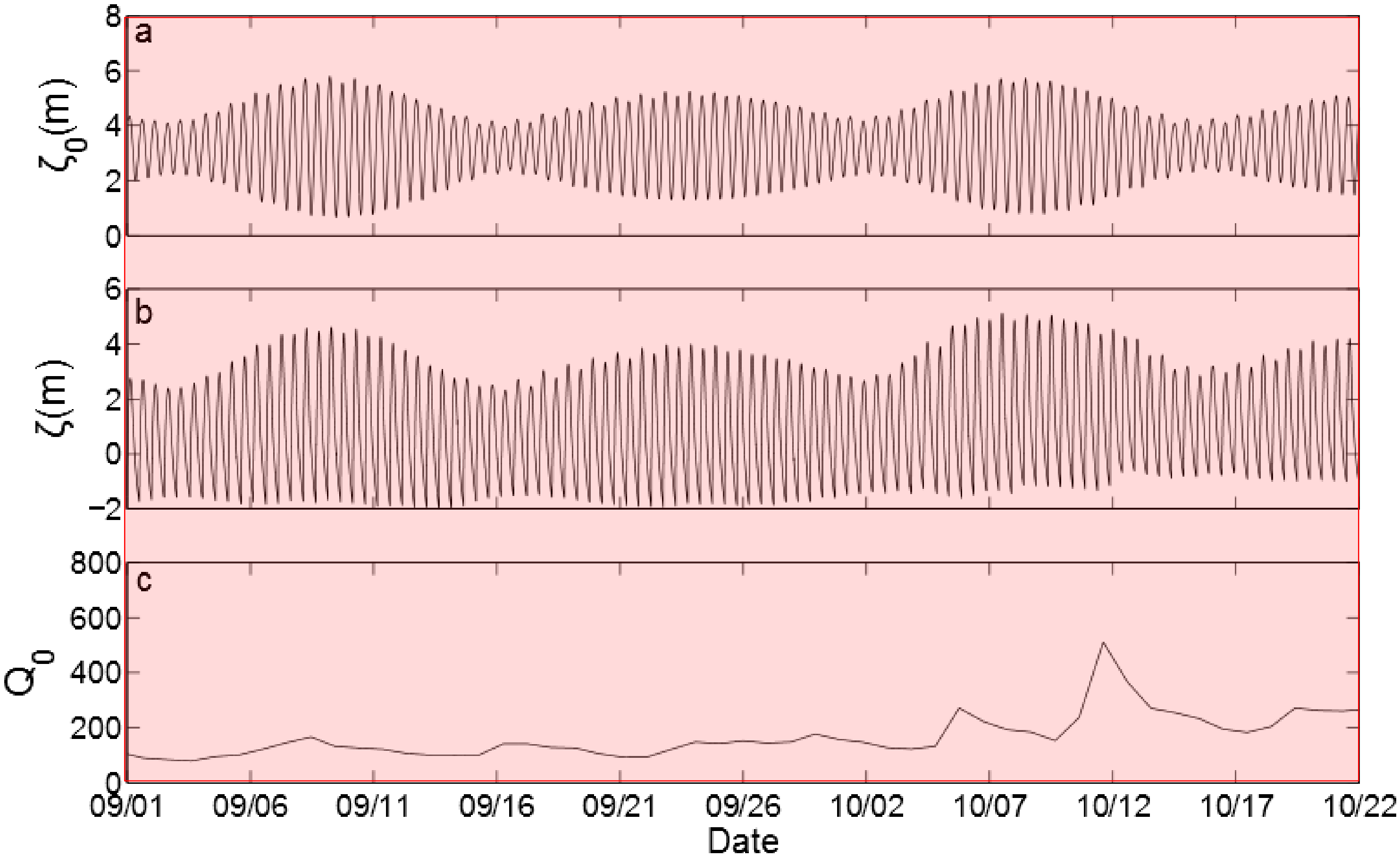




Long-term high-frequency field campaigns
around the **spring** and **autumn** equinox



Long-term high-frequency field campaigns around the spring and autumn equinox

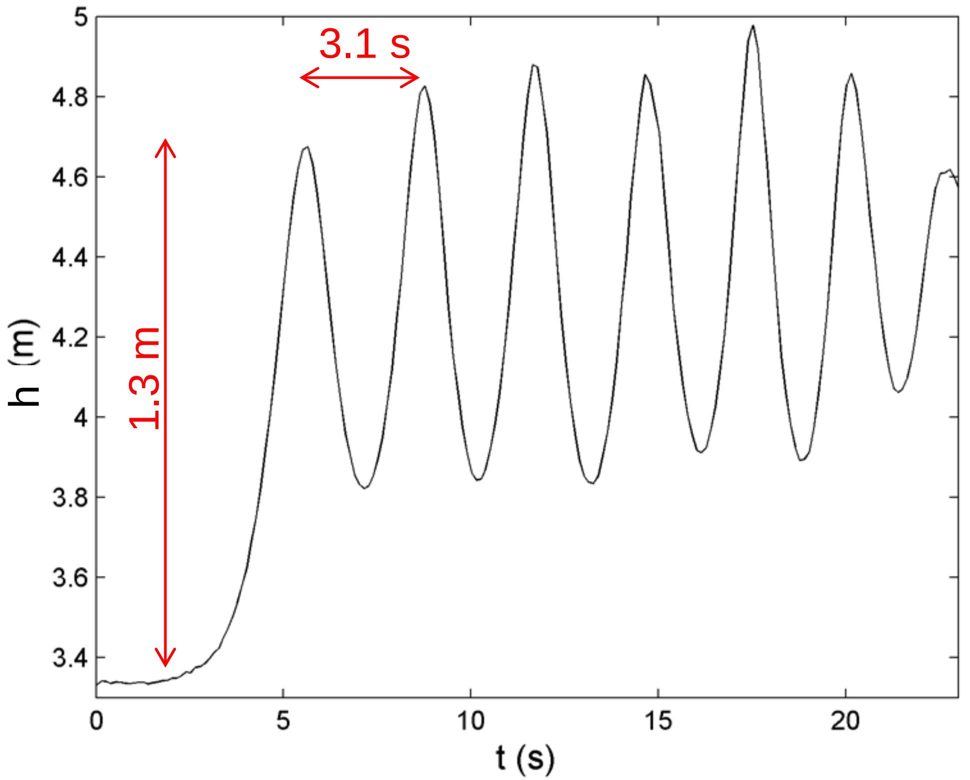


⇒ **large range of tidal ranges and freshwater discharges**

High-frequency (8 Hz) direct acoustic surface tracking measurements

Nortek ADCP, Signature 1000 → expensive in terms of memory

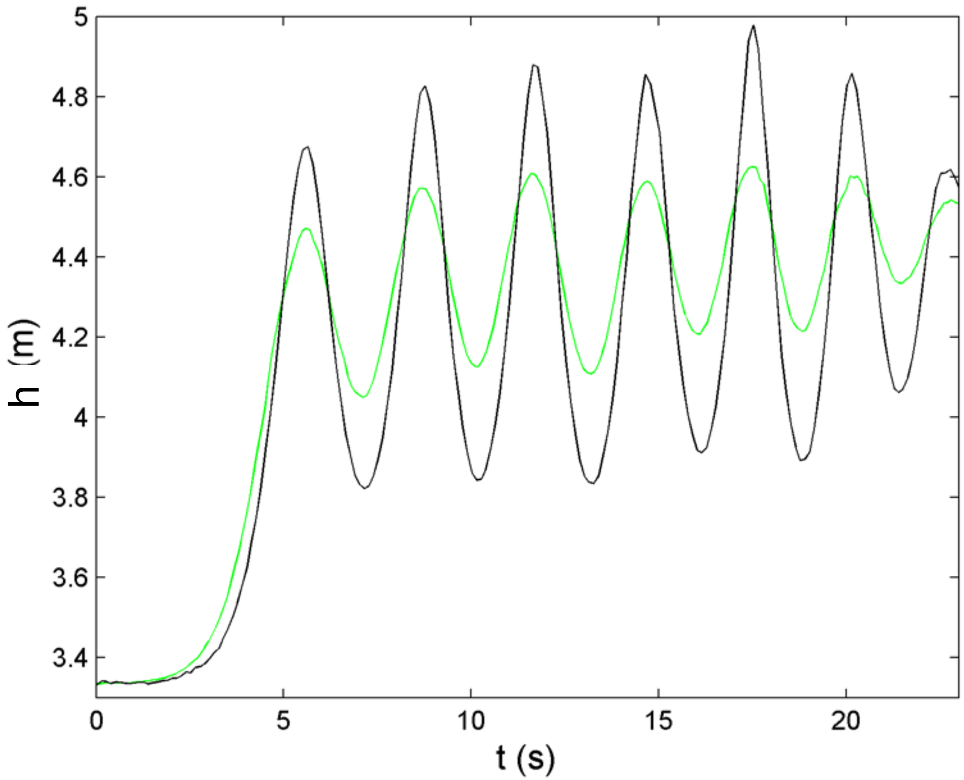
→ bottom pressure sensors



Garonne River, 31/08/15, Tr=6.6 m, Fr=1.28

High-frequency (8 Hz) pressure measurements

→ hydrostatic reconstruction

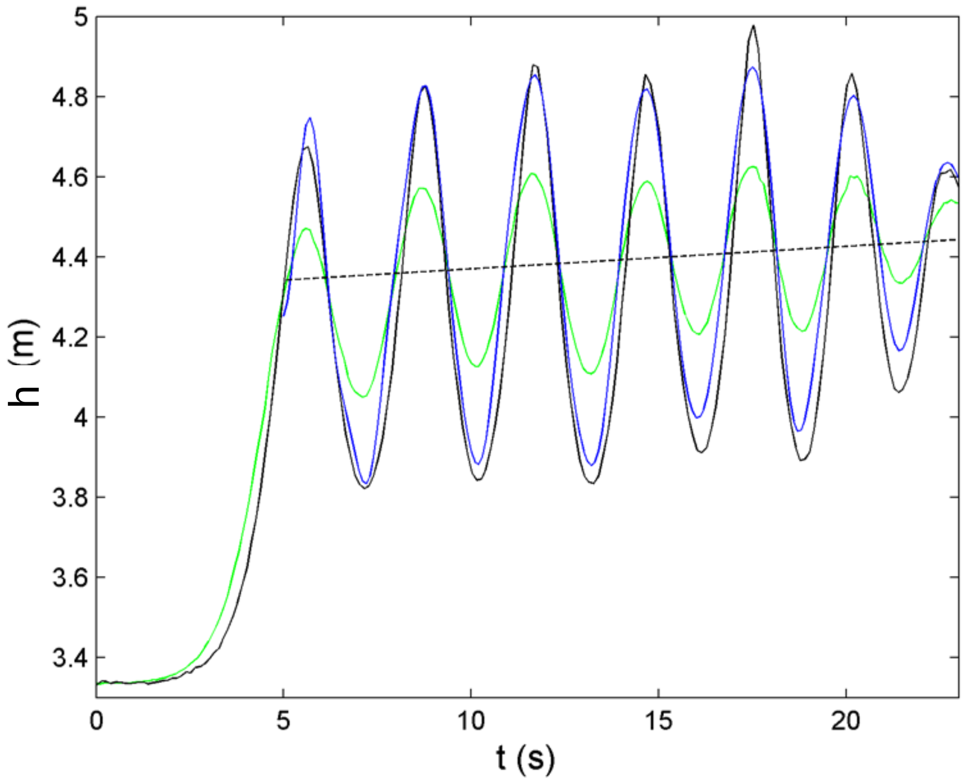


High-frequency (8 Hz) pressure measurements

→ **hydrostatic reconstruction**

→ **linear non-hydrostatic reconstruction,**

$$\zeta_{\mathrm{NH}} = \mathcal{F}^{-1}\left(\frac{\cosh(k\bar{h})}{\cosh(kz_{\mathrm{P}})}\mathcal{F}(\zeta_{\mathrm{H}})\right)$$

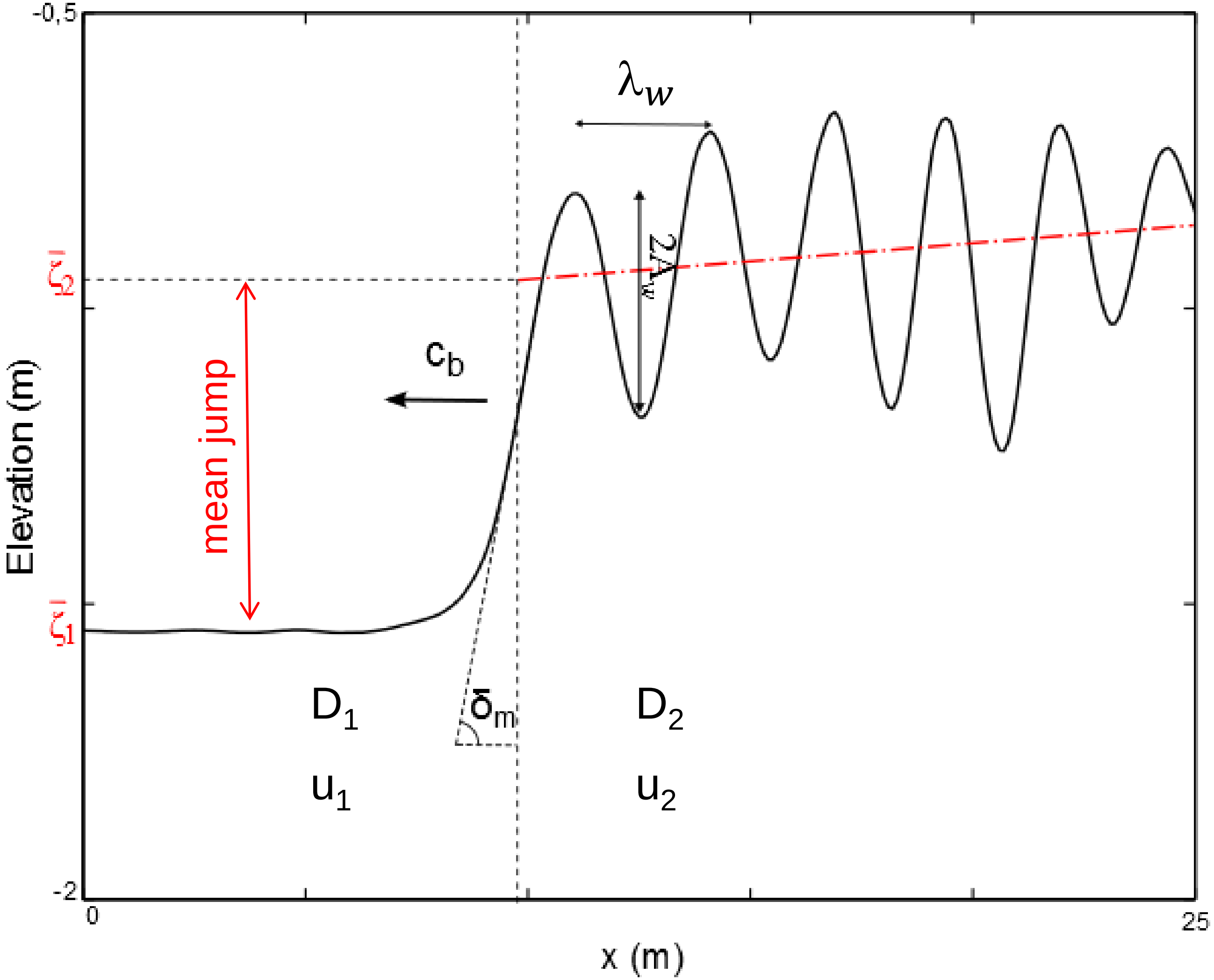


→ nonlinear non-hydrostatic reconstruction, *Bonneton and Lannes, submitted*.

Tidal bore dynamics

Tidal bore dynamics

- mean jump
- secondary wave field



$$F_r = \frac{c_b - u_1}{\sqrt{gD_1}}$$

Local nonlinearity parameter

$$\varepsilon = \frac{T_R}{D_1}$$

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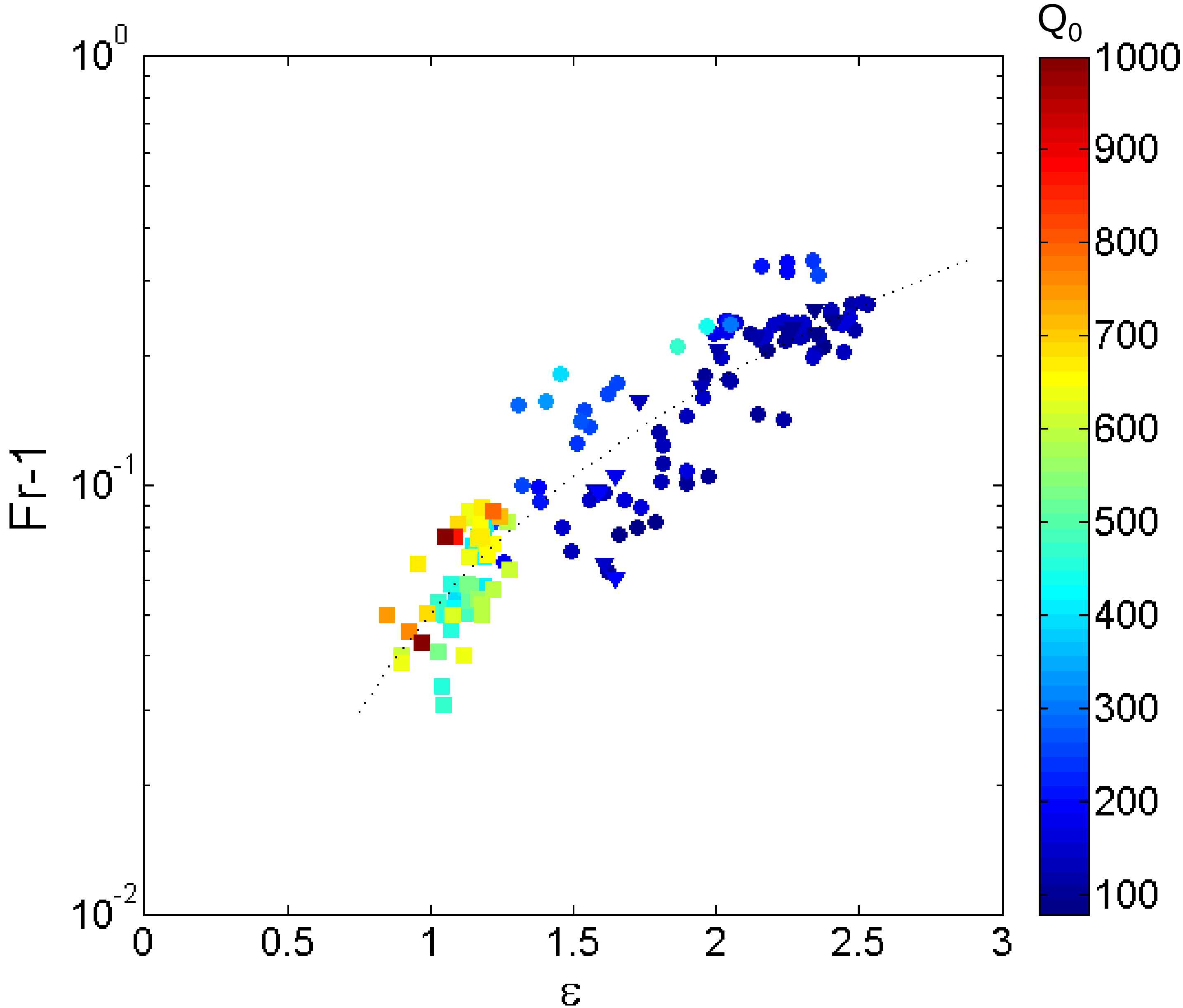
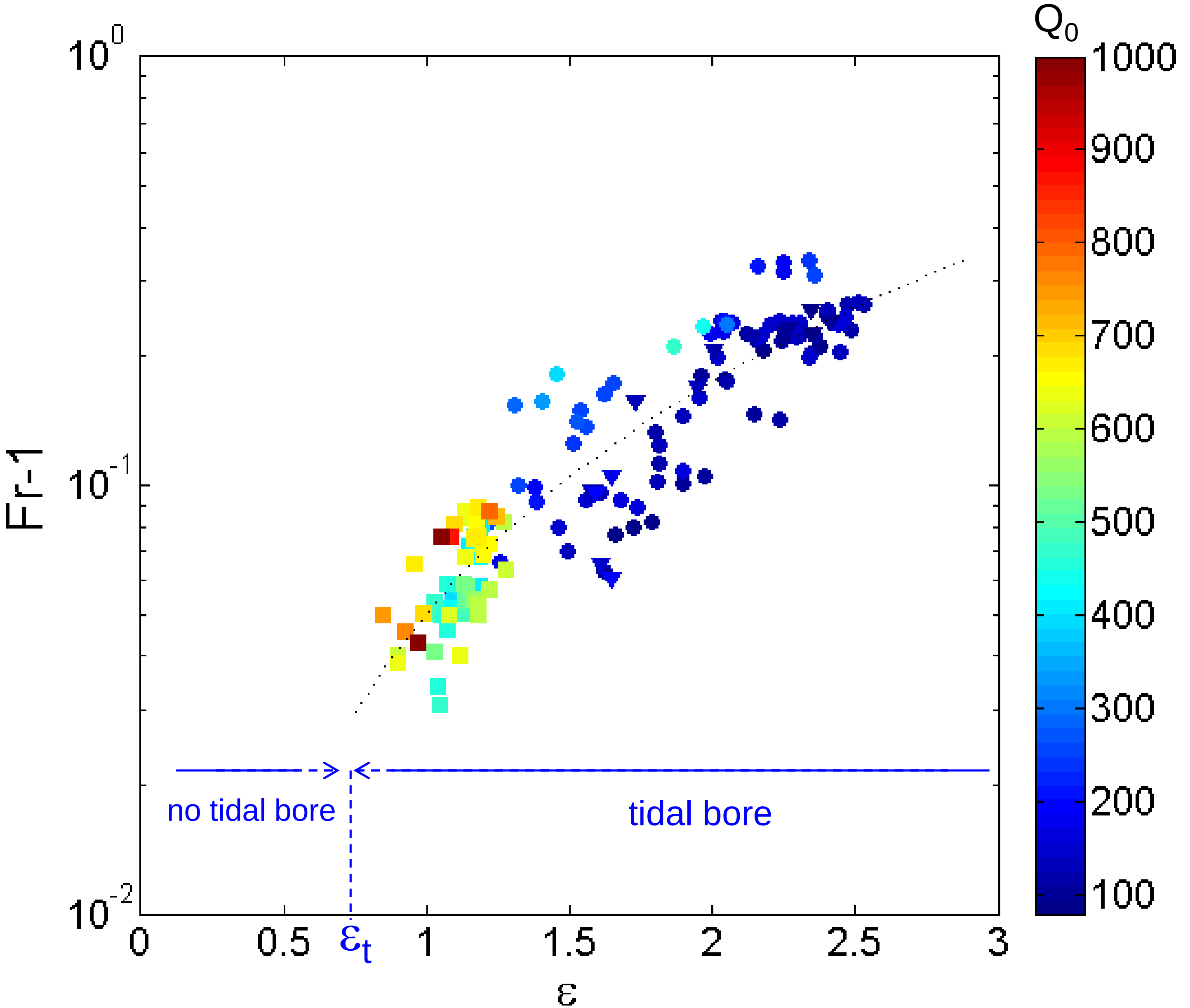
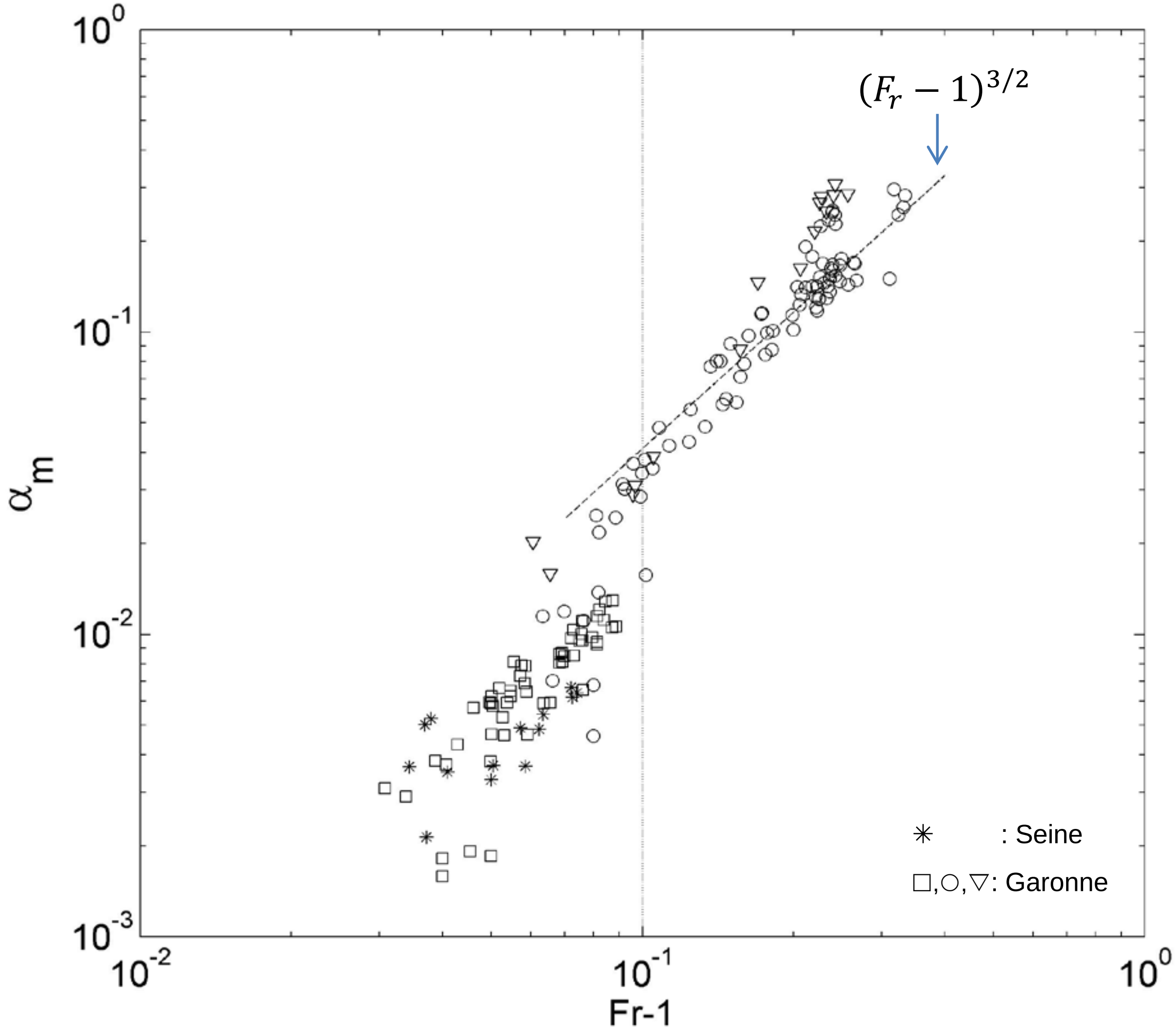
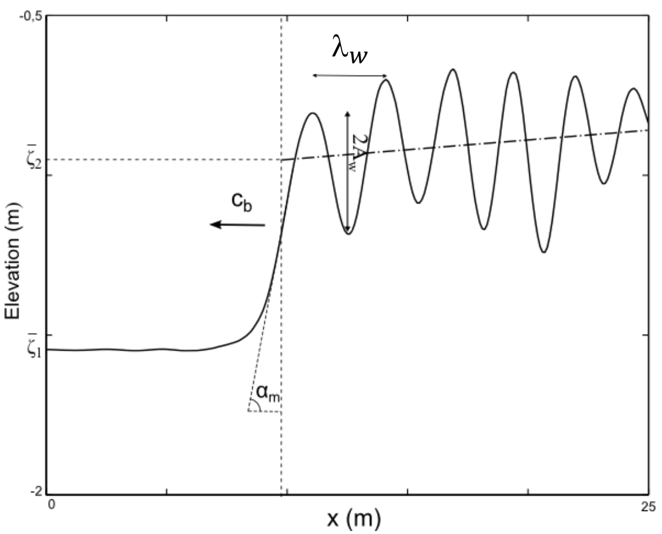


$$\varepsilon = \frac{T_R}{D_1}$$

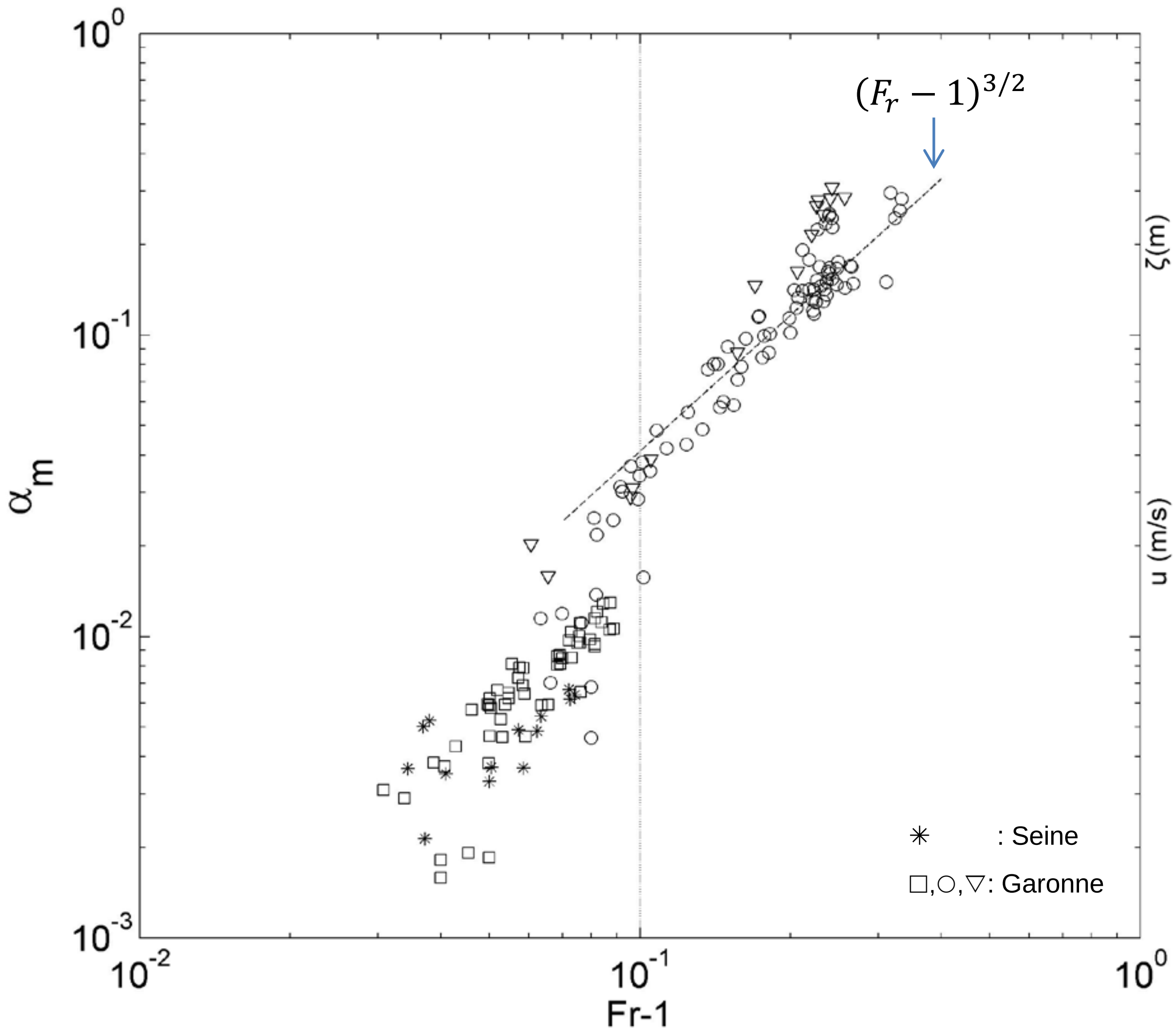


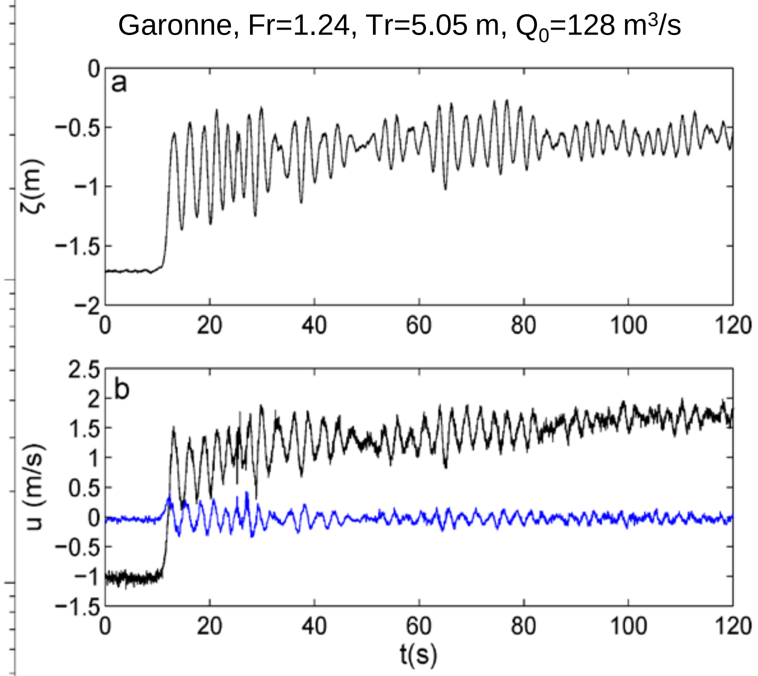
Tidal bore dynamics | Secondary wave field



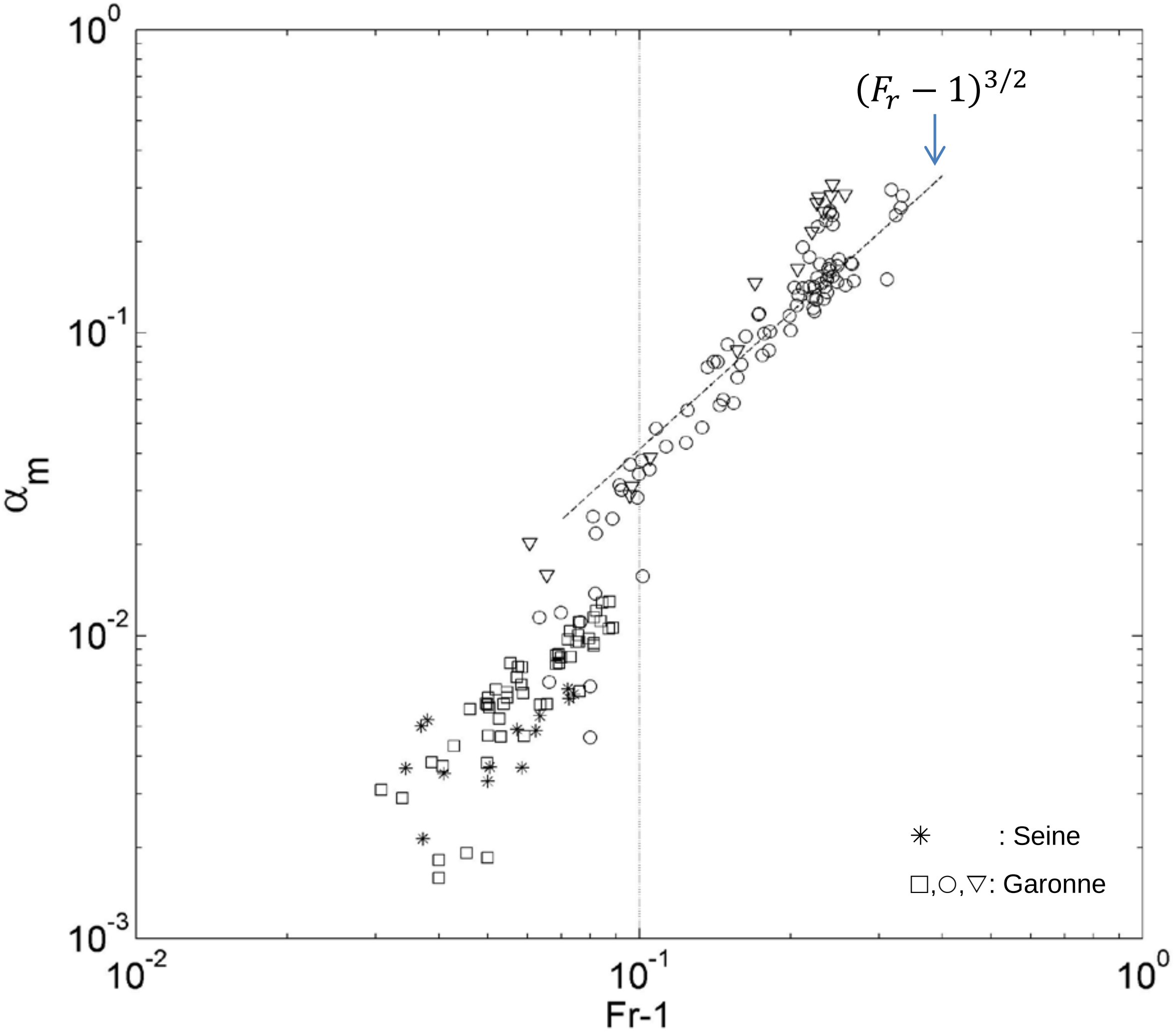


Secondary wave field





high steepness
secondary wave regime
→ ***mascaret***

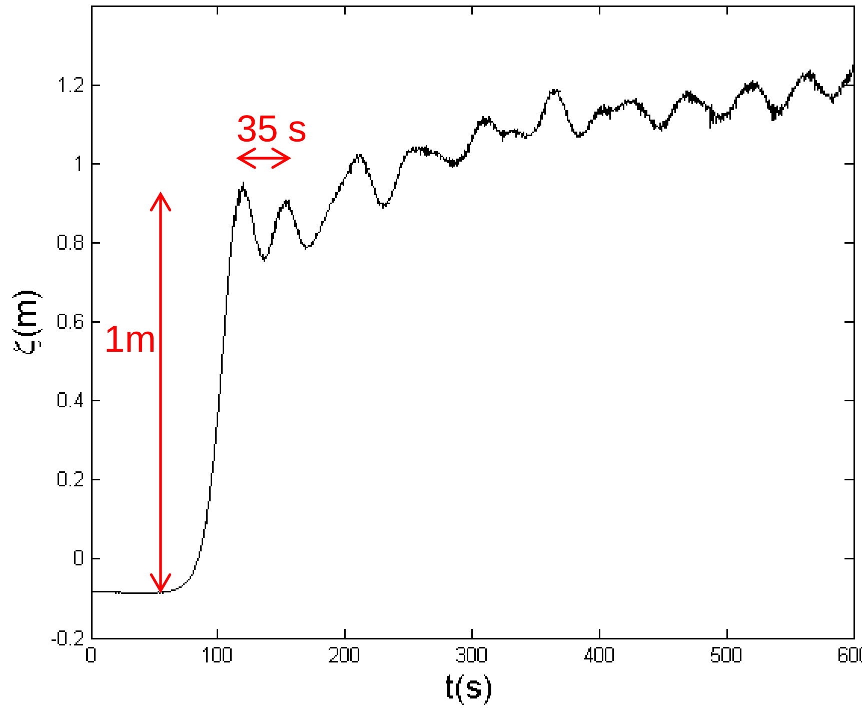


Low steepness
secondary wave regime
→ **not visually observable**

high steepness
secondary wave regime
→ ***mascaret***

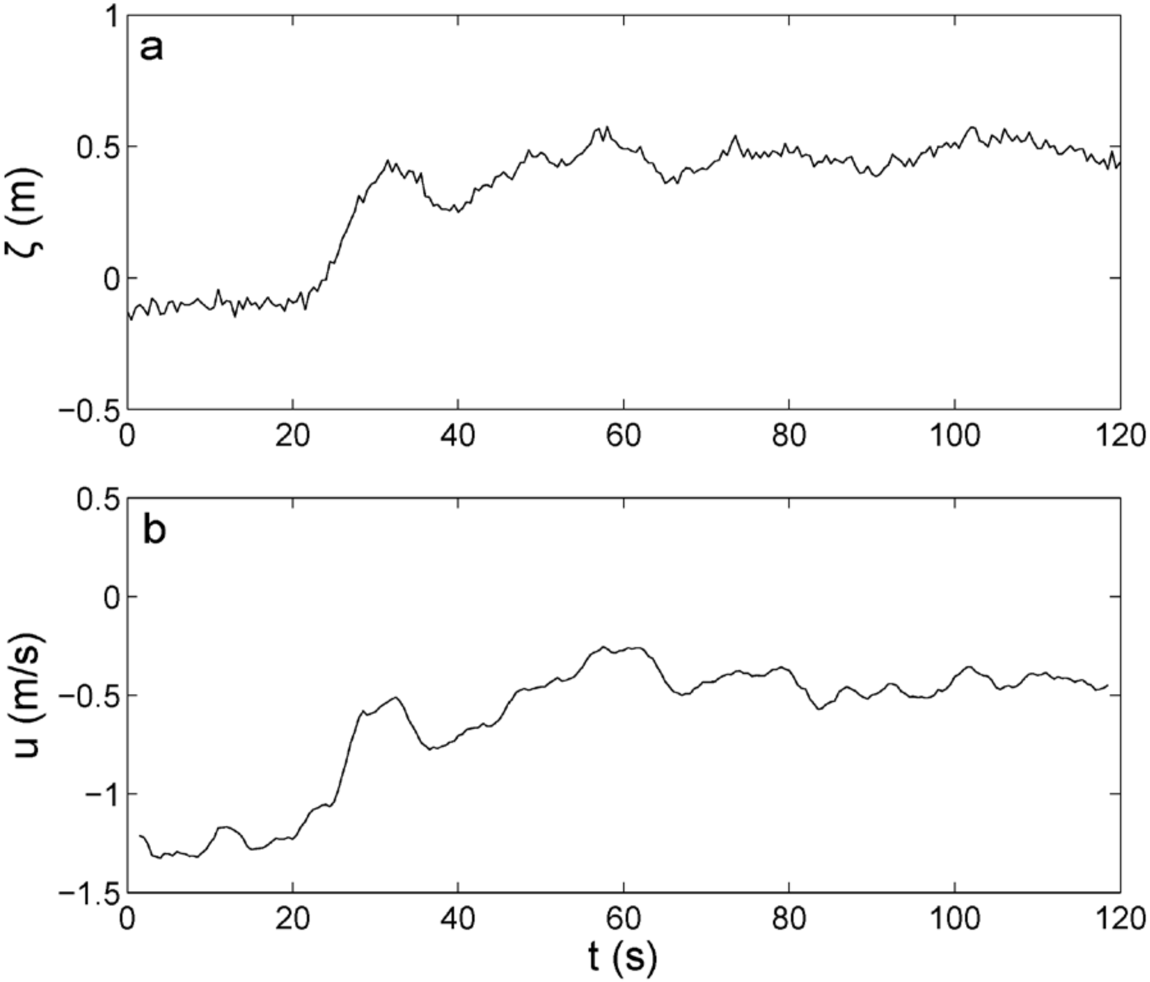
Seine estuary

Field site
100 km from the estuary mouth



Bonneton et al., CR Geosci. 2012

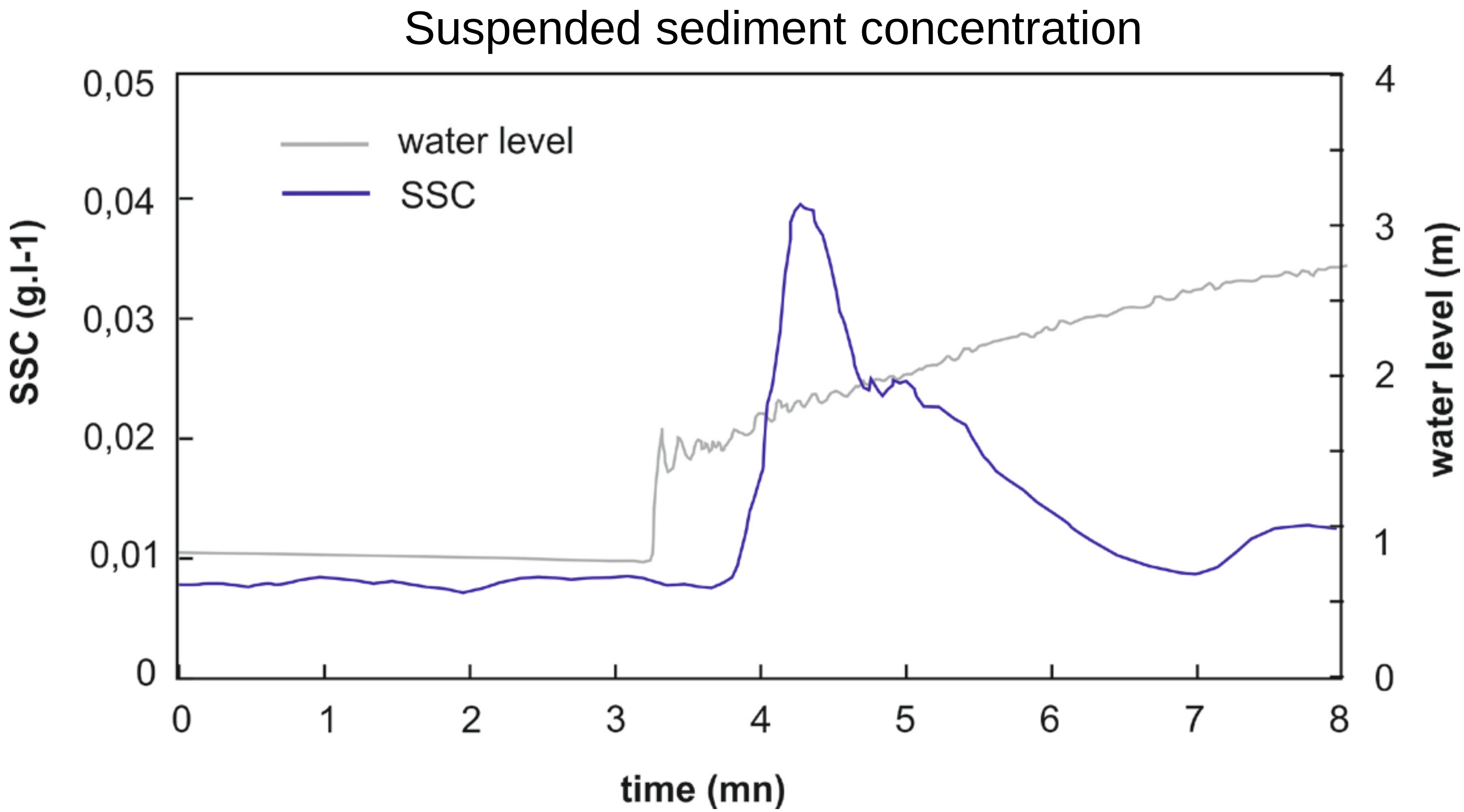
Garonne River



acceleration: 0.18 m/s^2

Garonne, Fr=1.08, Tr=5.05 m, Q_0=681 m^3/s, depth averaged velocity

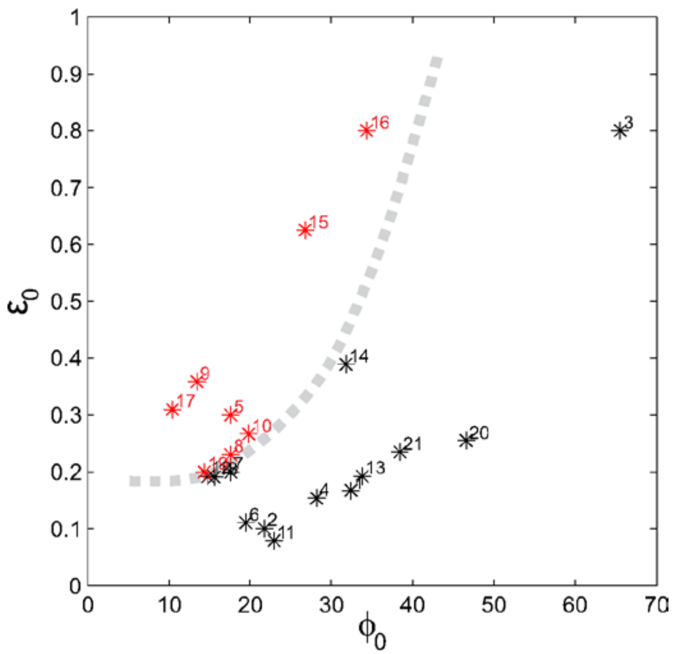
Garonne River



Conclusion

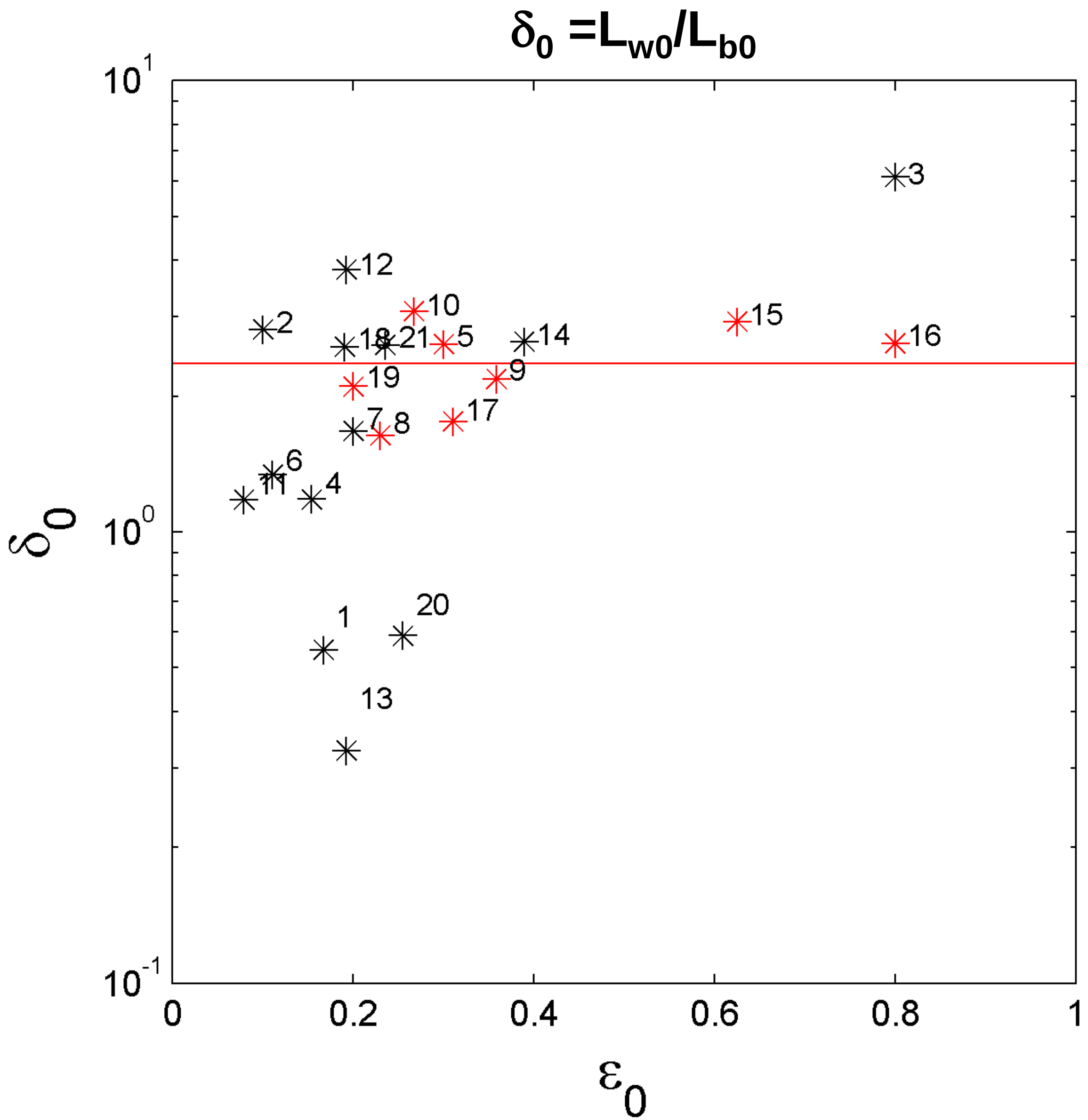
Conclusion

- Tidal bore dynamics → a complex non-hydrostatic process
- Low-steepness tidal bore regime (Fr<1.1)
  - → significant in terms of flow and sediment dynamics
  - → not visually observable
  - → makes it difficult to identify (e.g. Seine estuary)
- A need to reassess <u>tidal bore occurrence</u> and dynamics in meso and macro-tidal estuaries <u>worldwide</u>



1	Chao Phya	Thailand
2	Columbia	USA
3	Conwy	UK
4	Corantijn	USA
5	Daly	Australia
6	Delaware	USA
7	Elbe	Germany
8	Gironde	France
9	Hooghly	India
10	Humber	UK
11	Limpopo	Mozambique
12	Loire	France
13	Mae Klong	Thailand
14	Maputo	Mozambique
15	Ord	Australia
16	Pungue	Mozambique
17	Qiantang	China
18	Scheldt	Netherlands
19	Severn	UK
20	Tha Chin	Thailand
21	Thames	UK

Conditions for tidal bore formation | Field data



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Tidal bore estuaries: $\delta_0 \approx 2.4$ $\rightarrow$ 2D parameter space (ε_0 , ϕ_0)