Métodos Experimentales en Ingeniería

Consideraciones en el modelado experimental de SbN

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Outline

- Introduction
- Approaches at different scales
- Meso-scale examples
  - Posidonia mimics experiments
  - Real saltmarshes experiments
  - Mangrove models

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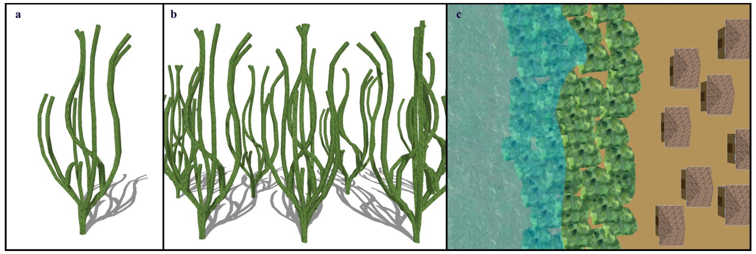
Introduction

- Different scales can be studied:
  - Micro-scale: individual elements
  - Meso-scale: Meadow / community
  - Macro-scale: Different ecosystems



- Approaches to represent individuals
  - Real individuals
  - Mimics

- Hydrodynamics:
  - Scaling
  - Representative of real conditions

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Approaches at different scales

Micro-scale:
- PIV, LDV, LDA
- Load cells
- Laser Scanner

→Turbulence
→ Forces
→ Shear Stresses

Meso-scale:
- ADVs
- Load cells
- Yardsticks, cameras

→Energy attenuation
→ Forces
→Sediment transport

Macro-scale / Field:
- ADCP
- Pressure Sensors
- Aerial Photography

→Coastal protection ecosystem services

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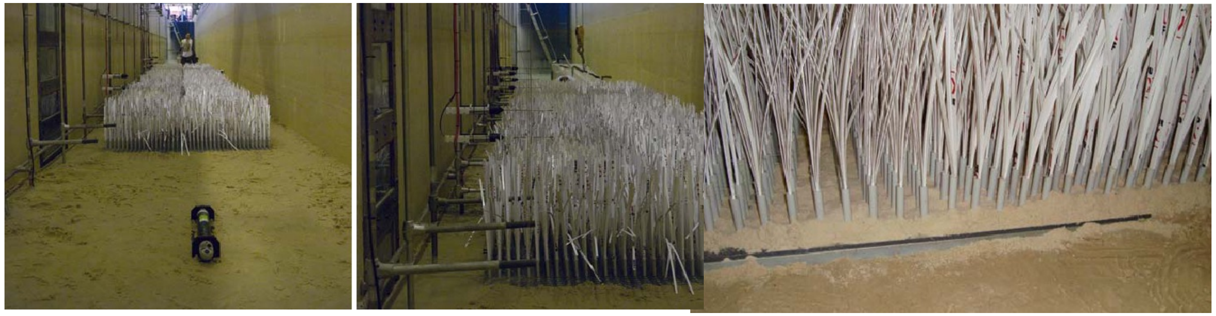
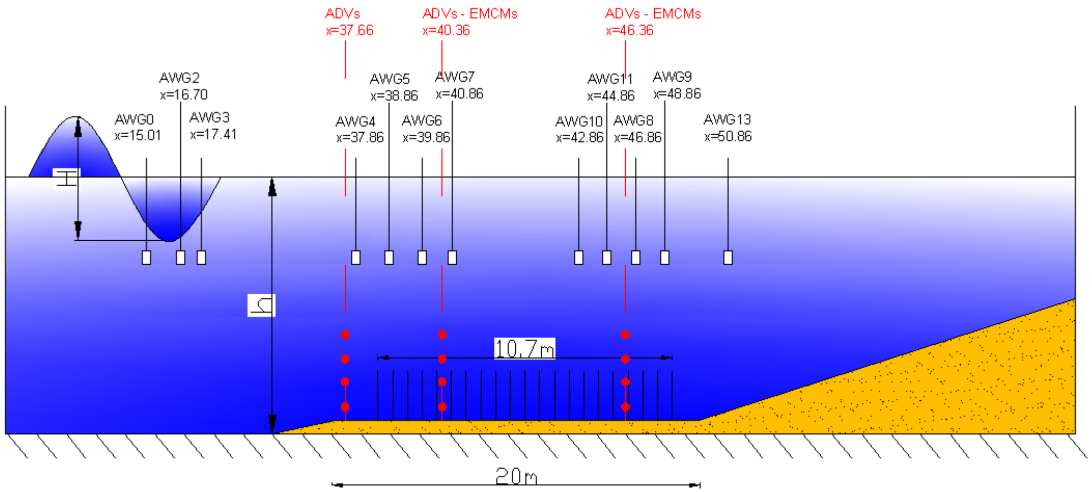
Meso-scale examples

- **Posidonia mimics:**





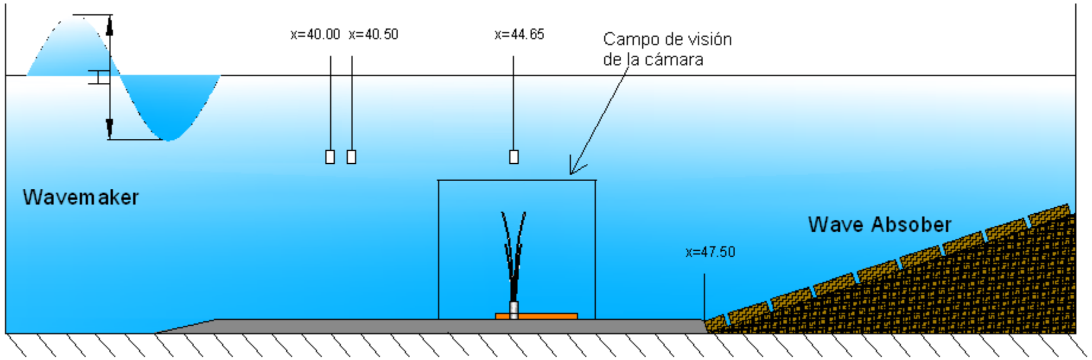
Hydraulic similarity parameter:

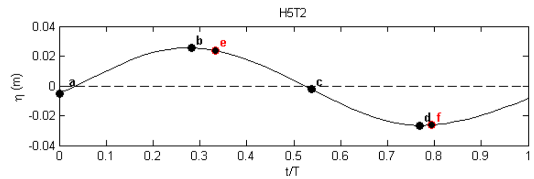
$$\lambda = \frac{(\rho - \rho_m)L^3}{Ea^2}$$

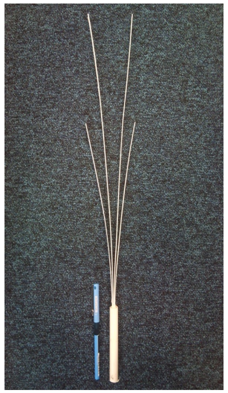
ρ: fluid density
ρ_m: chosen material density
L: mimic's height
E: material modulus of elasticity
a: mimic's thickness

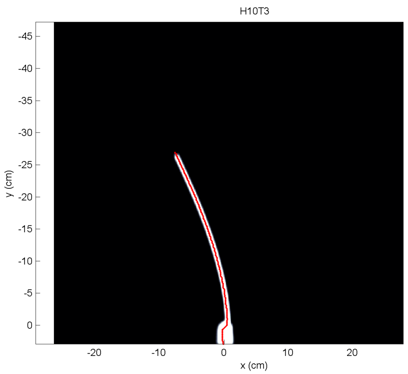
Meso-scale examples

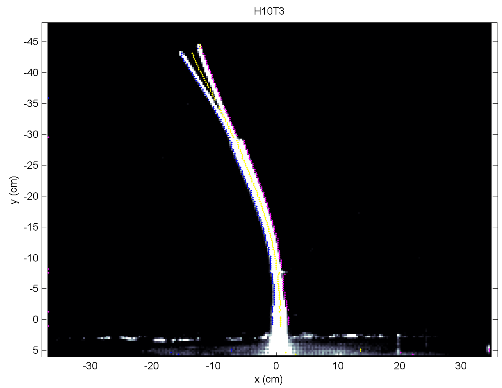
- **Posidonia mimics:**

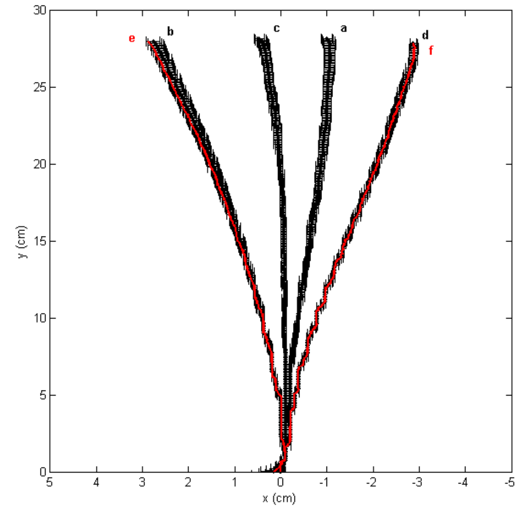












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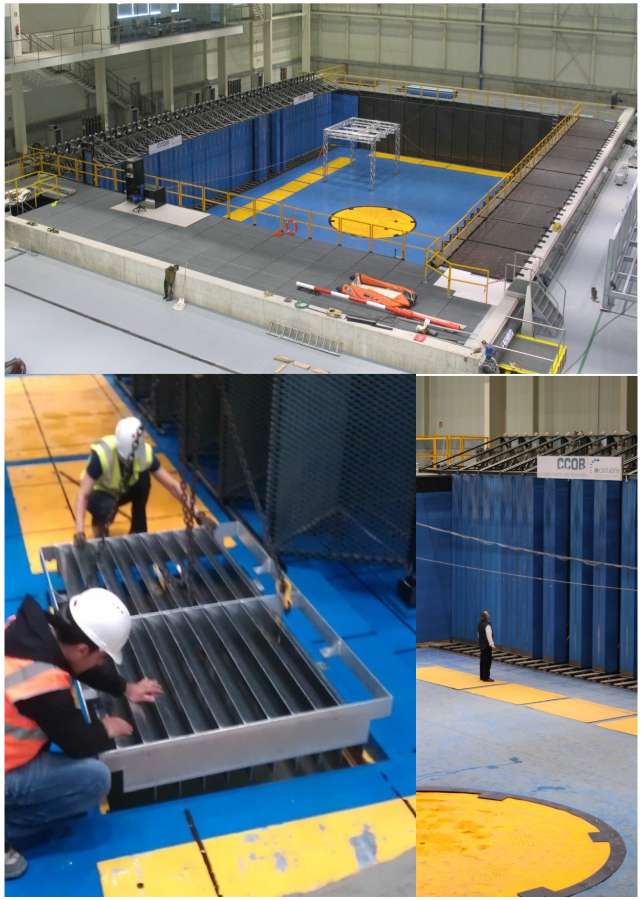
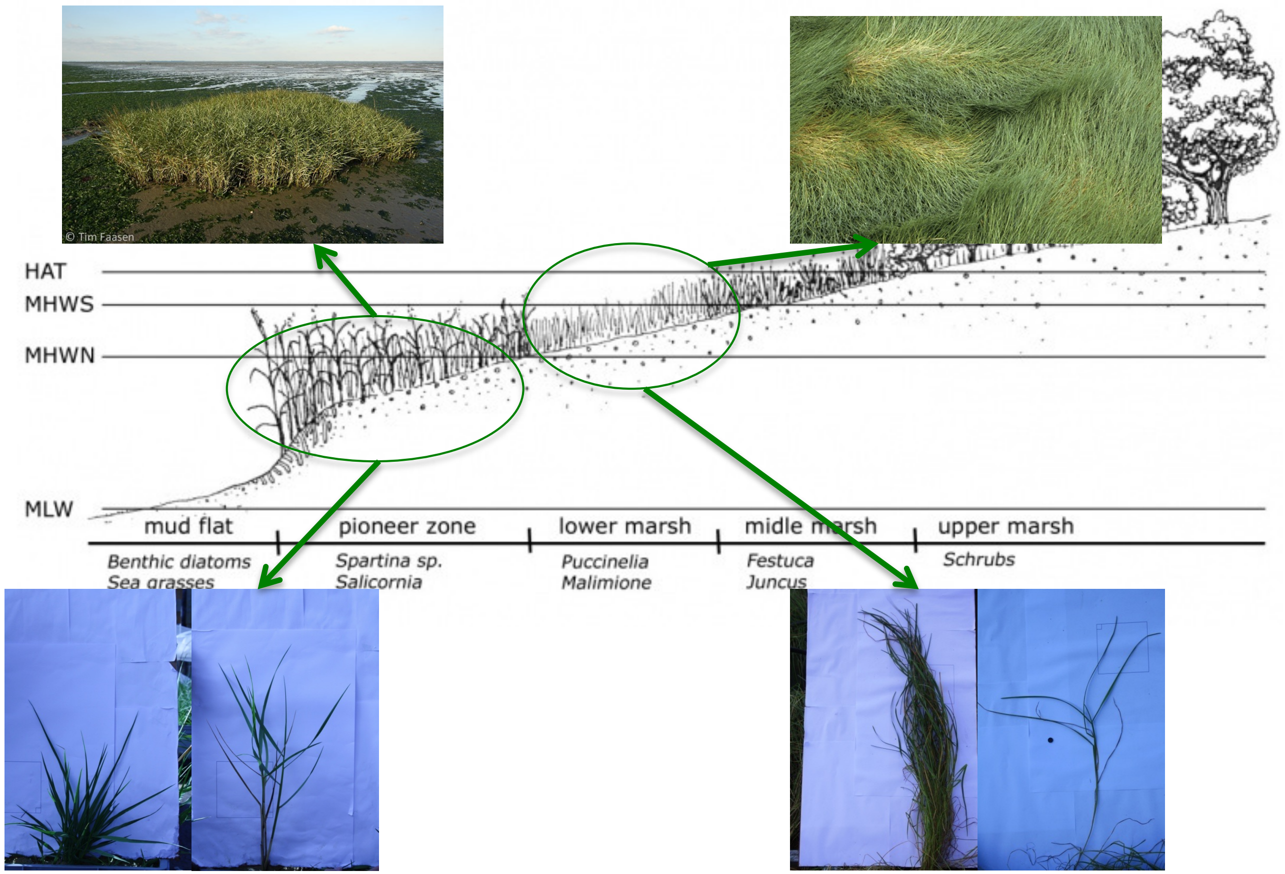
Meso-scale examples

- **Real saltmarshes:**
  - Evaluate the effect of:
    - shoot stiffness
    - vegetation density
    - standing biomass
    - wave conditions
    - current + waves
    - water depth



Meso-scale examples

- **Real saltmarshes:**



Meso-scale examples

- **Real saltmarshes:**
  - Growing plants from seeds
  - Waves and currents and different water depths
  - Flow and vegetation characteristics

Meso-scale examples

- **Real saltmarshes:**

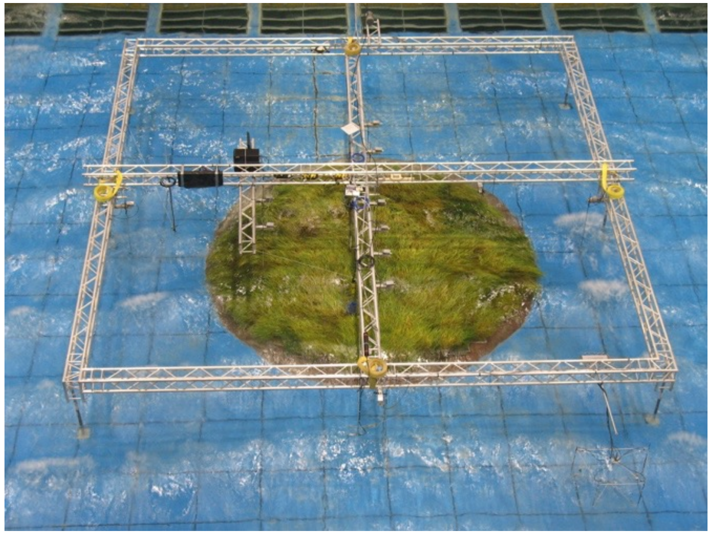
+ Current

Waves

- Current

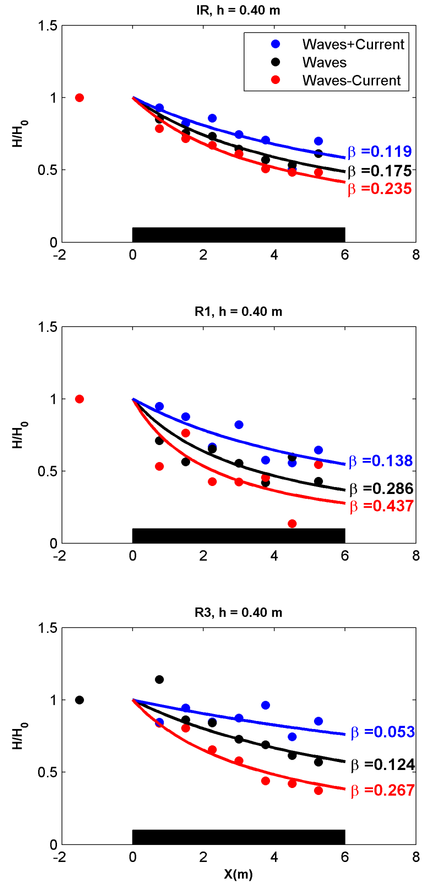
$$\frac{H}{H_0} = \frac{1}{1+\beta x} \quad \text{(Dalrymple et al., 1984)}$$

$$\frac{H_{rms}}{H_{rms,0}} = \frac{1}{1+\beta' x} \quad \text{(Méndez and Losada, 2004)}$$



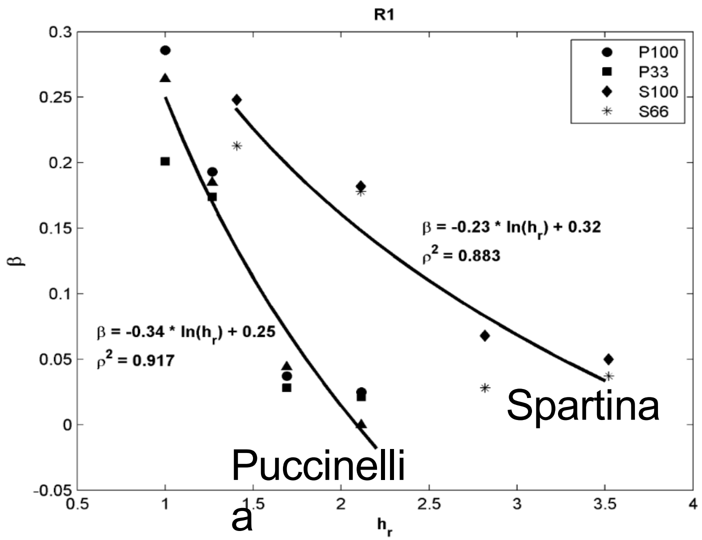
- Currents flowing in the **same direction** as waves **decrease** dissipation

- Currents **opposing** waves **increase** dissipation



Meso-scale examples

- **Real saltmarshes:**



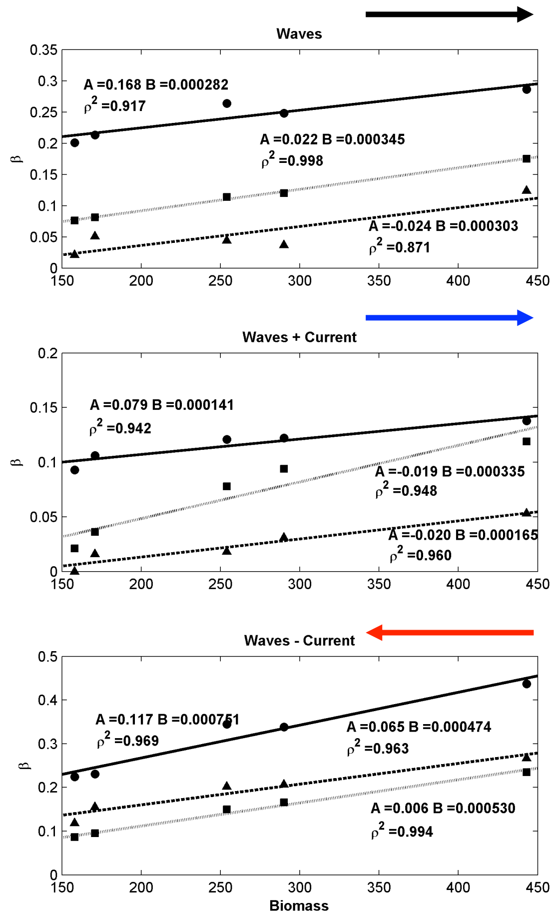
Relative water depth:

$$h_r = h/h_v$$

h.- water depth

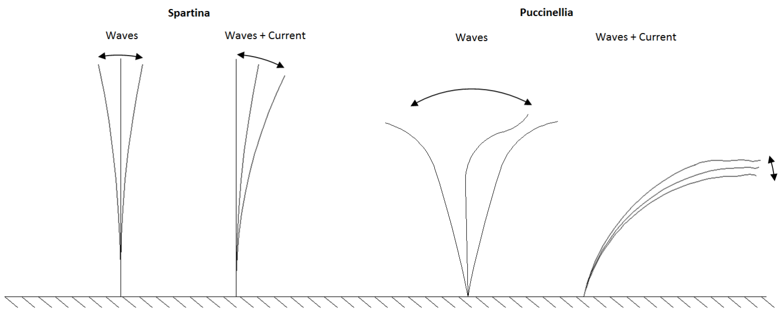
h_v.- vegetation heigth

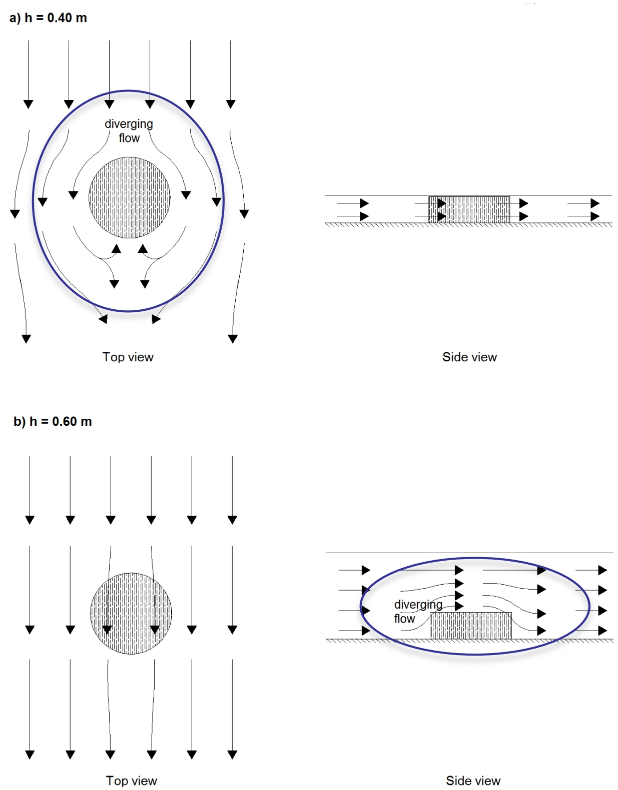
Biomass: Damping coefficient relates to biomass linearly



Meso-scale examples

- **Real saltmarshes:**
  - Analytical study
    - New formulation for wave attenuation with waves and currents
    - Waves and currents in the same and opposite direction
    - Deflected length and dense conditions





Meso-scale examples

- **Real saltmarshes:**
  - Conservation of ene

$$\frac{\partial E_{wc} c_{g_{wc}}}{\partial x} = -\varepsilon_{D_{wc}}$$

  - Irrotational and uniform wave-current field:

$$c_{g_{wc}} = \frac{\partial \sigma_{wc}}{\partial k} = U_0 + \frac{1}{2}\left(1 + \frac{2kh}{sinh2kh}\right)\left(\frac{g}{k} tanhkh\right)^{1/2}$$

$$(\sigma_{wc} = \sigma - U_0 k)$$

  - Depth integrated and time-averaged energy flux density of wave-current field:

$$E_{wc} = \frac{\rho}{16} g \left(1 + \frac{2kh}{sinh2kh}\right)\left(\frac{g}{k} tanhkh\right)^{1/2} H^2 + \frac{\rho}{16} g U_0 \left(3 + \frac{4kh}{sinh2kh}\right) H^2 + \frac{3\rho}{16} k U_0^2 \left(\frac{g}{k} cothkh\right)^{1/2} H^2 + \frac{\rho}{2} h U_0^3$$

Meso-scale examples

- **Real saltmarshes:**
  - Depth integrated and time-averaged energy dissipation:

$$\varepsilon_{D_{wc}} = \overline{\int_{-h}^{-h+l_D} F_{wc} u_{wc} dz}$$

$$F_{wc} = \frac{1}{2}\rho C_{D_{wc}} a N u_{wc} |u_{wc}|$$

  - Considering doppler effect and dense meadow conditions:

$$u_{wc} = \frac{gk}{2\sigma_{wc}} H \frac{coshk(h+z)}{coshkh} sin(kx - \sigma t)$$

  - Solving, the energy dissipation rate is:

$$\varepsilon_{D_{wc}} = -\frac{2}{3\pi}\rho C_{D_{wc}} a N \left(\frac{gk}{2(\sigma - U_0 k)}\right)^3 \frac{sinh^3 kl_D + 3sinhkl_D}{3kcosh^3 kh} H^3$$

Meso-scale examples

- **Real saltmarshes:**
  - Dalrymple et al. (1984) was the first using this conservation of energy

$$A_0 = \frac{2}{3\pi}\rho C_{D_{wc}} aN\left(\frac{gk}{2(\sigma - U_0 k)}\right)^3 \frac{sinh^3 kl_D + 3sinhkl_D}{3kcosh^3 kh}$$

$$H = \frac{H_0}{1+\beta_{wc}x}$$

$$B = \left[\frac{\rho g}{8}\left(1+\frac{2kh}{sinh2kh}\right)\left(\frac{g}{k}tanhkh\right)^{\frac{1}{2}} + \frac{\rho g}{8}U_0\left(3+\frac{4kh}{sinh2kh}\right) + \frac{3\rho k}{8}U_0^2\left(\frac{g}{k}cothkh\right)^{\frac{1}{2}}\right]\left[U_0 + \frac{1}{2}\left(1+\frac{2kh}{sinh2kh}\right)\left(\frac{g}{k}tanhkh\right)^{\frac{1}{2}}\right]$$

$$\beta_{wc} = \frac{A_0 H_0}{B}$$

  - The drag coefficient can be expressed as:

$$C_{Dwc} = \frac{3\pi}{2aN\left(\frac{gk}{2(\sigma - U_0 k)}\right)^3 H_0}\frac{3kcosh^3 kh}{sinh^3 kl_D + 3sinhkl_D}\left[\frac{g}{8}\left(1+\frac{2kh}{sinh2kh}\right)\left(\frac{g}{k}tanhkh\right)^{\frac{1}{2}} + \frac{g}{8}U_0\left(3+\frac{4kh}{sinh2kh}\right) + \frac{3k}{8}U_0^2\left(\frac{g}{k}cothkh\right)^{\frac{1}{2}}\right]$$

$$\left[U_0 + \frac{1}{2}\left(1+\frac{2kh}{sinh2kh}\right)\left(\frac{g}{k}tanhkh\right)^{\frac{1}{2}}\right]\beta_{wc}$$

Meso-scale examples

- **Real saltmarshes:**
  - Drag coefficient as a function of the deflected Reynolds number:

This new Re includes the the **biomechanical** plant properties indirectly

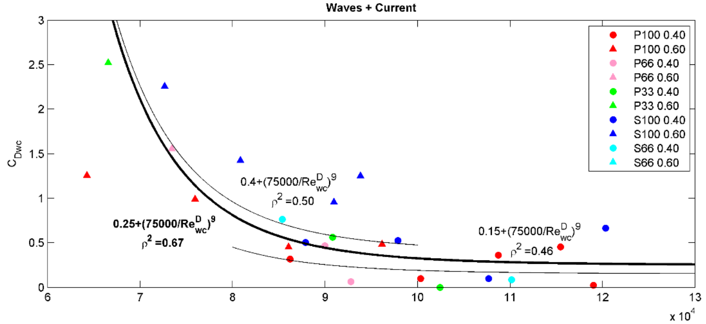
$$Re^D = \frac{l_D V_c}{\nu}$$

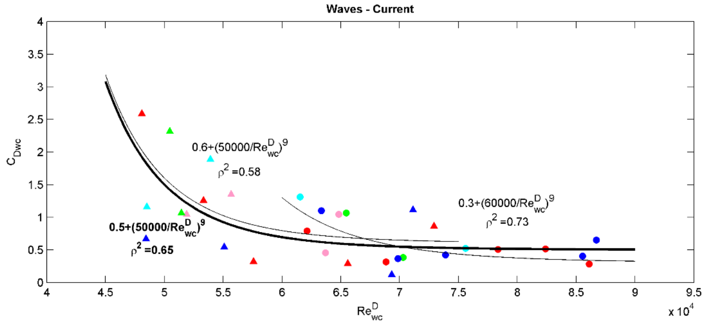
$$Re^D_{wc} = \frac{l_D |u_{wc}|}{\nu}$$

$$C_D = 0.08 + \left(\frac{50000}{Re^D}\right)^{2.2} \quad \textit{regular waves}$$

$$C_{Dwc+} = 0.25 + \left(\frac{75000}{Re^D_{wc}}\right)^{9} \quad \textit{regular waves + currents}$$

$$C_{Dwc-} = 0.50 + \left(\frac{50000}{Re^D_{wc}}\right)^{9} \quad \textit{regular waves − currents}$$





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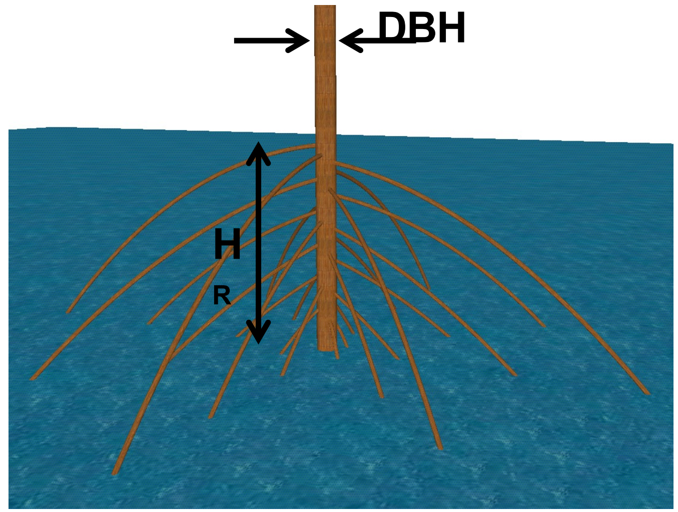
Meso-scale examples

- **Mangrove models:** Rhizophora
  - Experimental set-up: unidirectional flow
    - Mangrove geometry: Ohira et al. (2013):
      - DBH = 0.20 m: mature mangroves
      - H_R = 2.012 m
      - 24 roots
      - Roots diameter: from 0.033 to 0.042 m

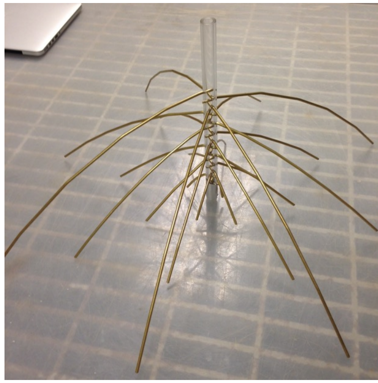


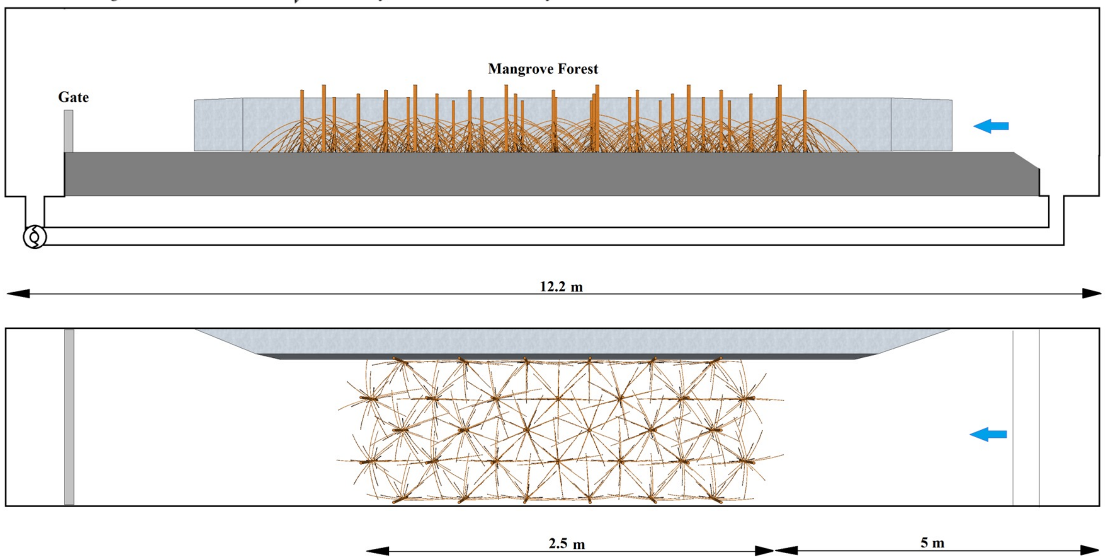
Meso-scale examples

- **Mangrove models:** Rhizophora
  - Scale: 1/12, 32 mangroves

$$\frac{\text{Inertia force}}{\text{Gravity force}} = \frac{F_i}{F_g} \propto \frac{\rho U^2 L^2}{\rho g L^3} = \frac{U^2}{gL}$$

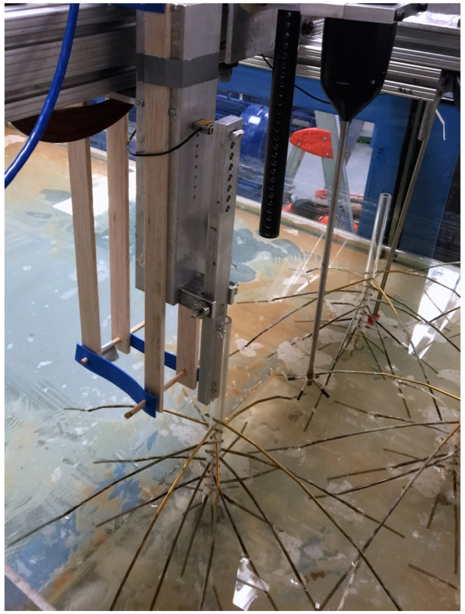
$$\frac{\text{Inertia forces}}{\text{Viscous forces}} = \frac{F_i}{F_v} \propto \frac{\rho U^2 L^2}{\mu U L} = \frac{\rho U L}{\mu} = \frac{UL}{\nu} = Re$$

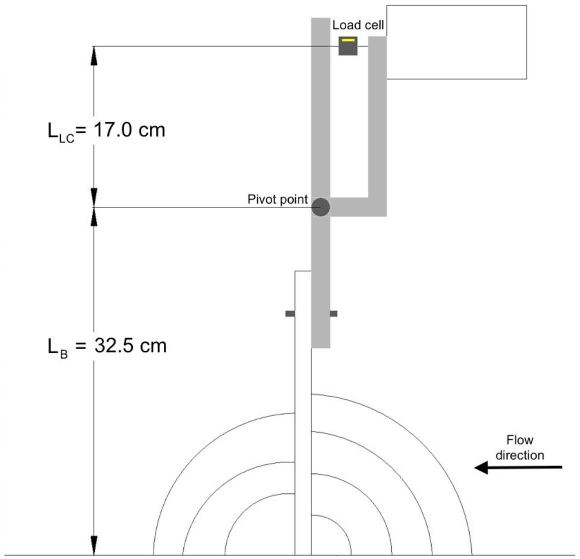


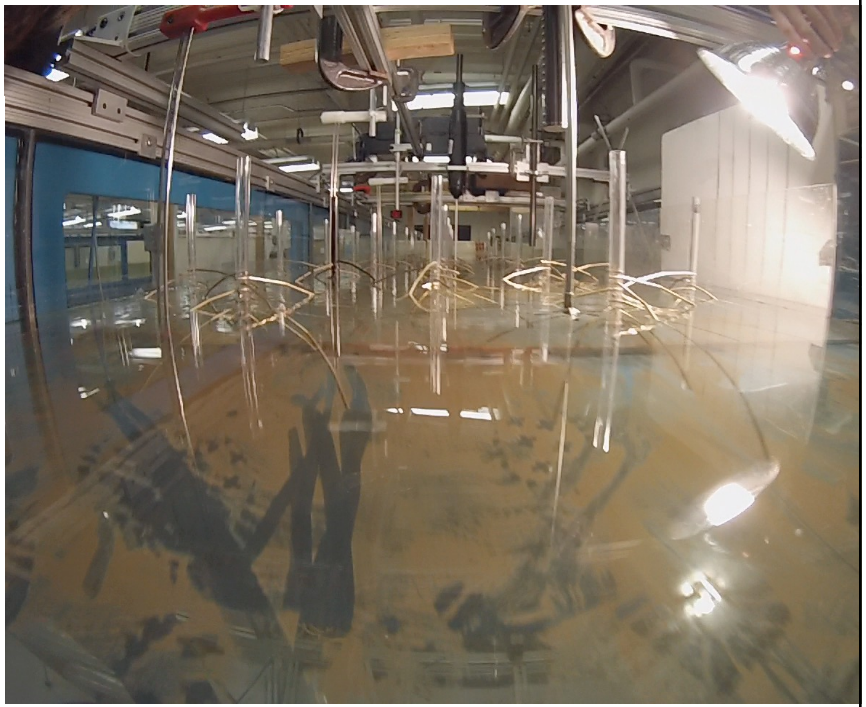


Meso-scale examples

- **Mangrove models:** Rhizophora
    - Forces and velocity profiles







Meso-scale examples

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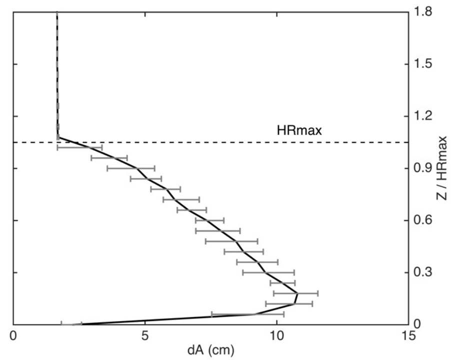

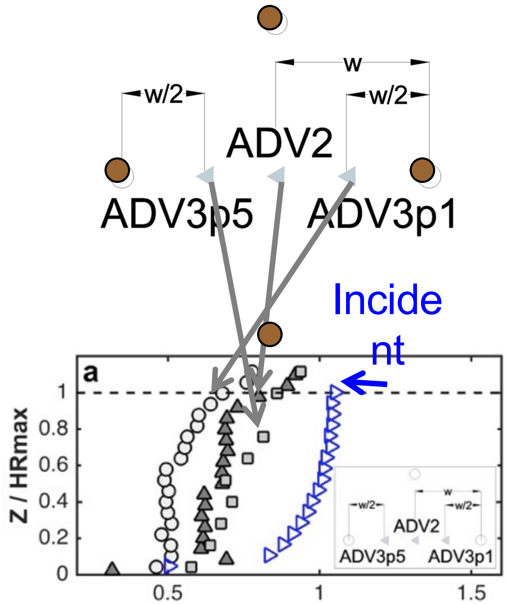

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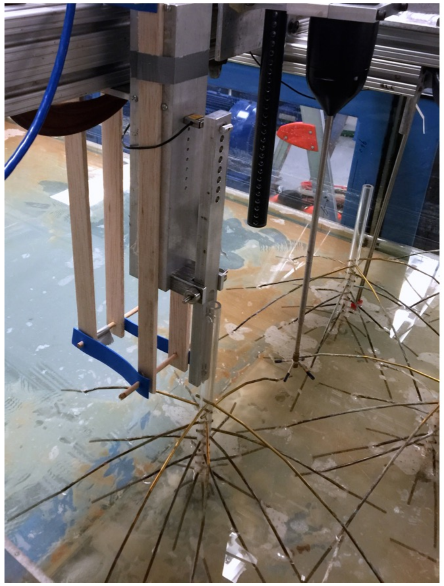

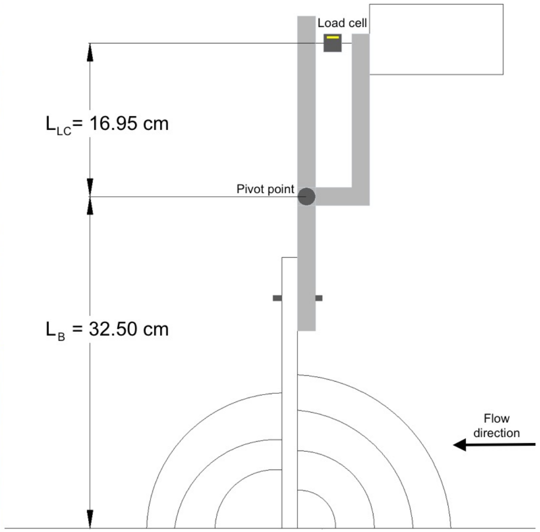

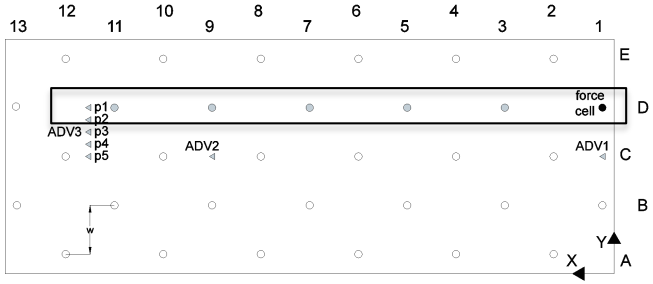

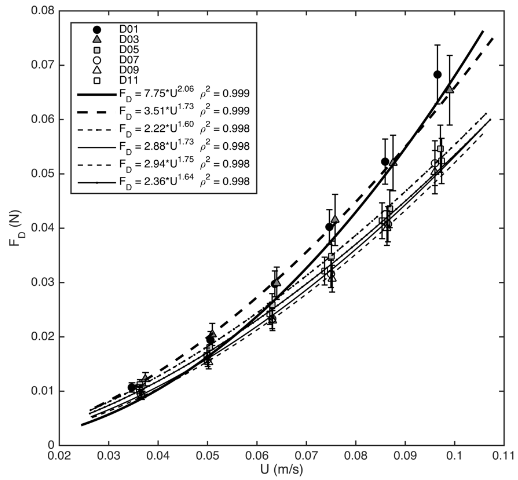

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