Sediment transport within submerged model canopies under oscillatory flow

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ECOLOGICAL IMPLICATIONS

Canopy

↓

reduces both waves and currents

↓

Under wave-dominated flows reduce local resuspension and promote the retention of sediment

↓

improve water clarity

↓

increase in productivity

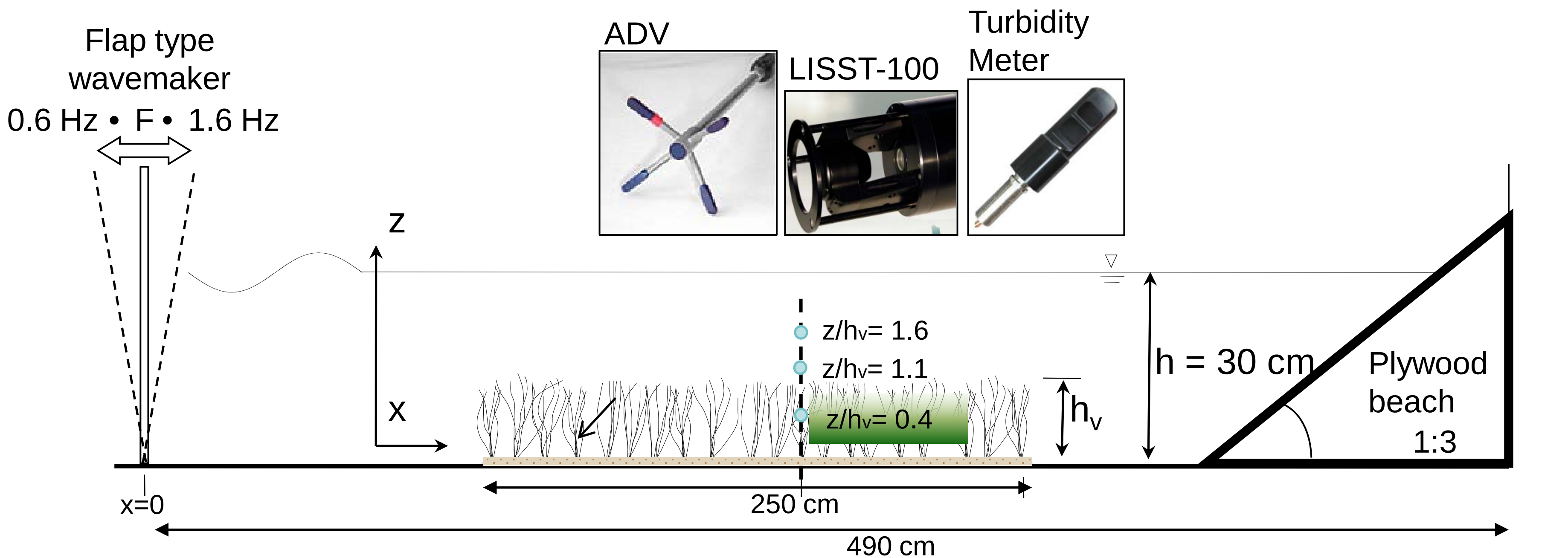
Grupo de Física Ambiental
Departamento de Física
UdG

To study the effect of submerged aquatic vegetation in sediment resuspension under progressive waves:

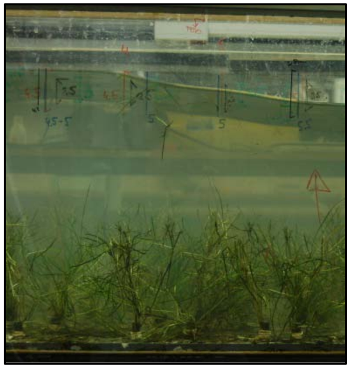
- To determine the impact of plant flexibility and canopy density on the degree of sediment resuspension.

- To test whether different particle sizes behave similar in front of the same hydrodynamics.

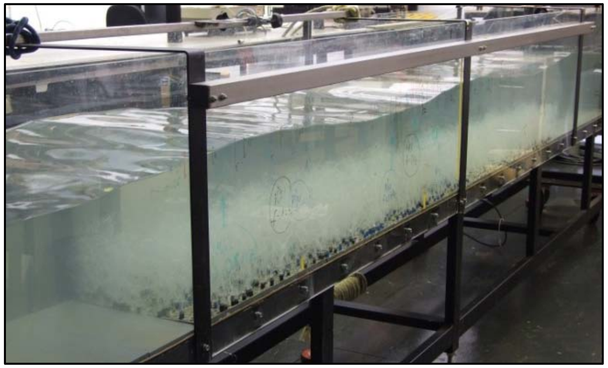
MATERIALS and METHODS



1%, 5%, 7.5% 10%



1%



1%, 5%, 10%

Solid Plant Fraction SPF:

$$SPF(\%) = \frac{n \cdot \pi \cdot (d/2)^2}{A} \cdot 100$$

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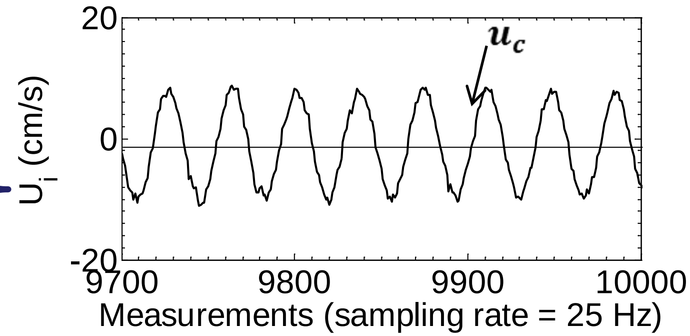
$$\boldsymbol{u_i = u_c + u_w + u'} \rightarrow \boldsymbol{TKE = \frac{1}{2}\rho_w\left(\overline{u'^2} + \overline{v'^2} + \overline{w'^2}\right)}$$

$\boldsymbol{u_i}$: instantaneous velocity

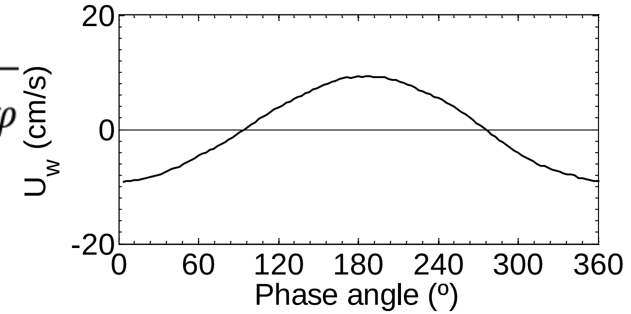
$\boldsymbol{u_c}$: steady velocity $u_c = \frac{1}{2\pi}\int_0^{2\pi} u_i\,(\varphi)d\varphi$



$\boldsymbol{u_w}$: unsteady wave motion

$$u_w^{rms} = \sqrt{\frac{1}{2}\int_0^{2\pi}(u_i(\varphi) - u_c)^2 d\varphi}$$

$\boldsymbol{u'}$: turbulent velocity



$$\Delta\,\boldsymbol{TKE_{z_m}}(\%) = \left(\frac{\boldsymbol{TKE_{canopy} - TKE_{no\ canopy}}}{\boldsymbol{TKE_{no\ canopy}}}\right)\cdot \mathbf{100}$$

$+\,\Delta\boldsymbol{TKE}$: gain of TKE

$-\,\Delta\boldsymbol{TKE}$: reduction of $TKE \Rightarrow$ "**SHELTERING**"

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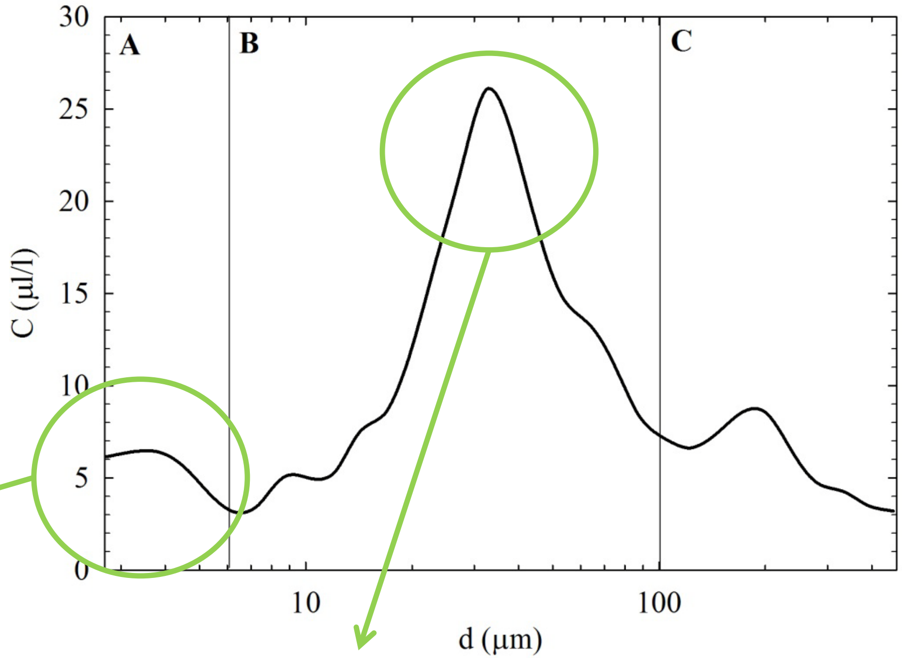
Particle Size Distribution



clay
very fine silts

↓

very cohesive

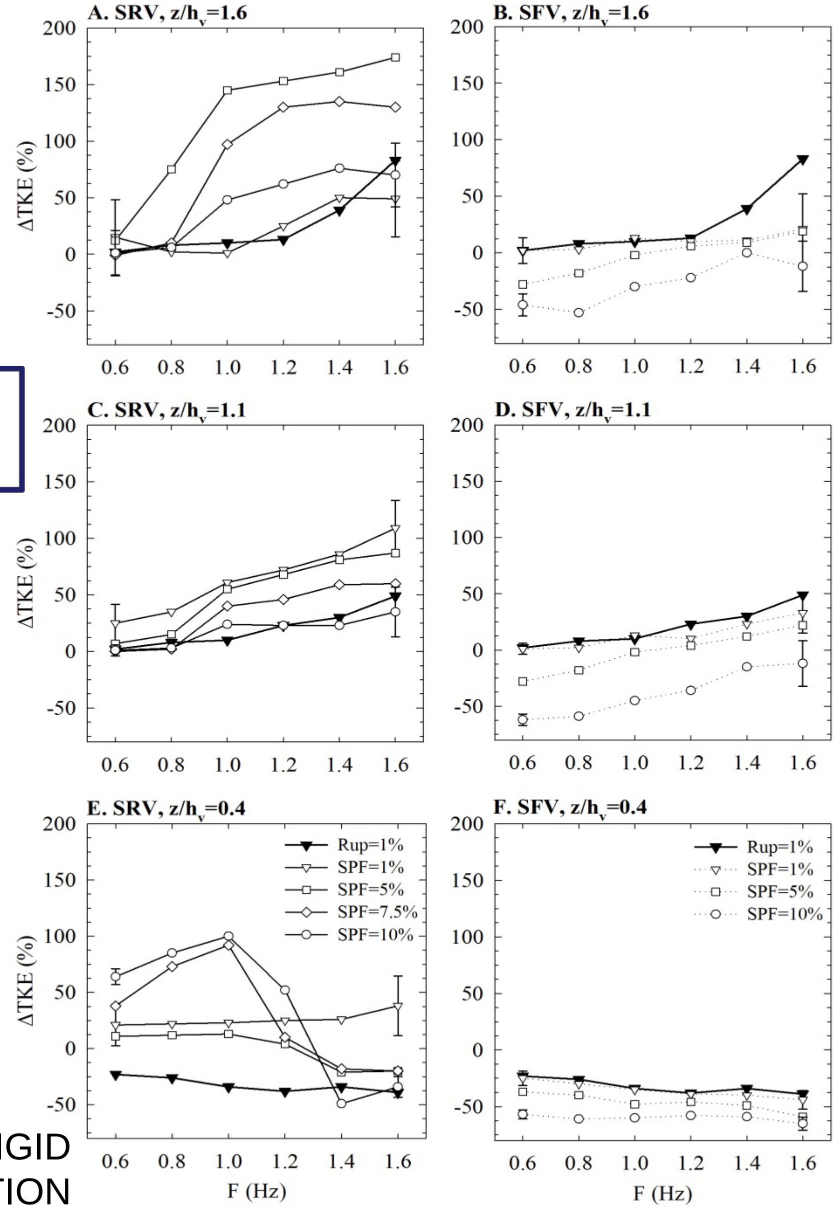
fine to coarse silts
small sand particles

↓

weakly cohesive

Vertical distribution of ΔTKE:

$$\Delta\, TKE(\%) = \left(\frac{TKE_{canopy} - TKE_{no\ canopy}}{TKE_{no\ canopy}}\right) \cdot 100$$



Above canopy z/hv=1.6

Above Top Canopy z/hv=1.1

Inside Canopy z/hv=0.4

RIGID VEGETATION

FLEXIBLE VEGETATION

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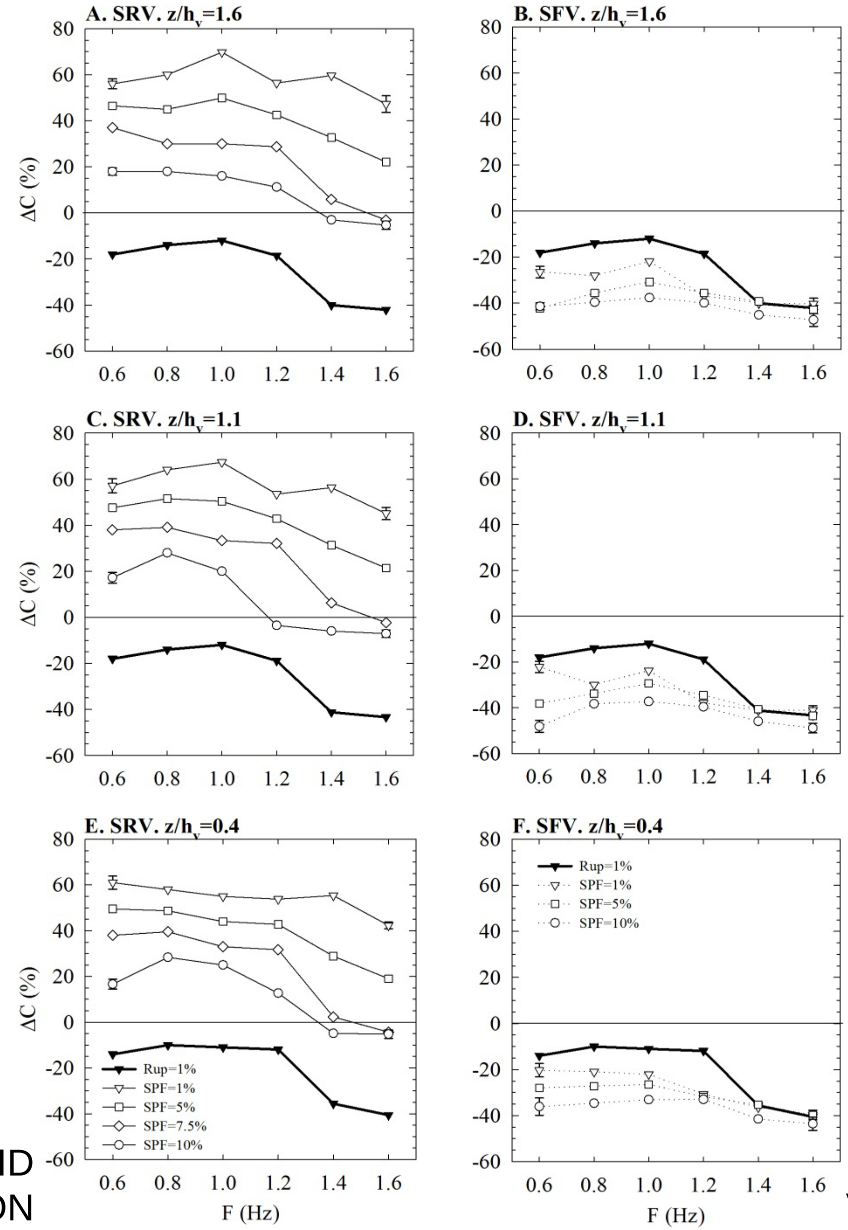
Vertical distribution of Δ C
(small particles: 2.5 μm • ϕ • 6 μm)

$$\Delta C(\%) = \left(\frac{C_{canopy} - C_{no\ canopy}}{C_{no\ canopy}}\right) \cdot 100$$



Above canopy z/hv=1.6

Above Top Canopy z/hv=1.1

Inside Canopy z/hv=0.4

RIGID VEGETATION

FLEXIBLE VEGETATION

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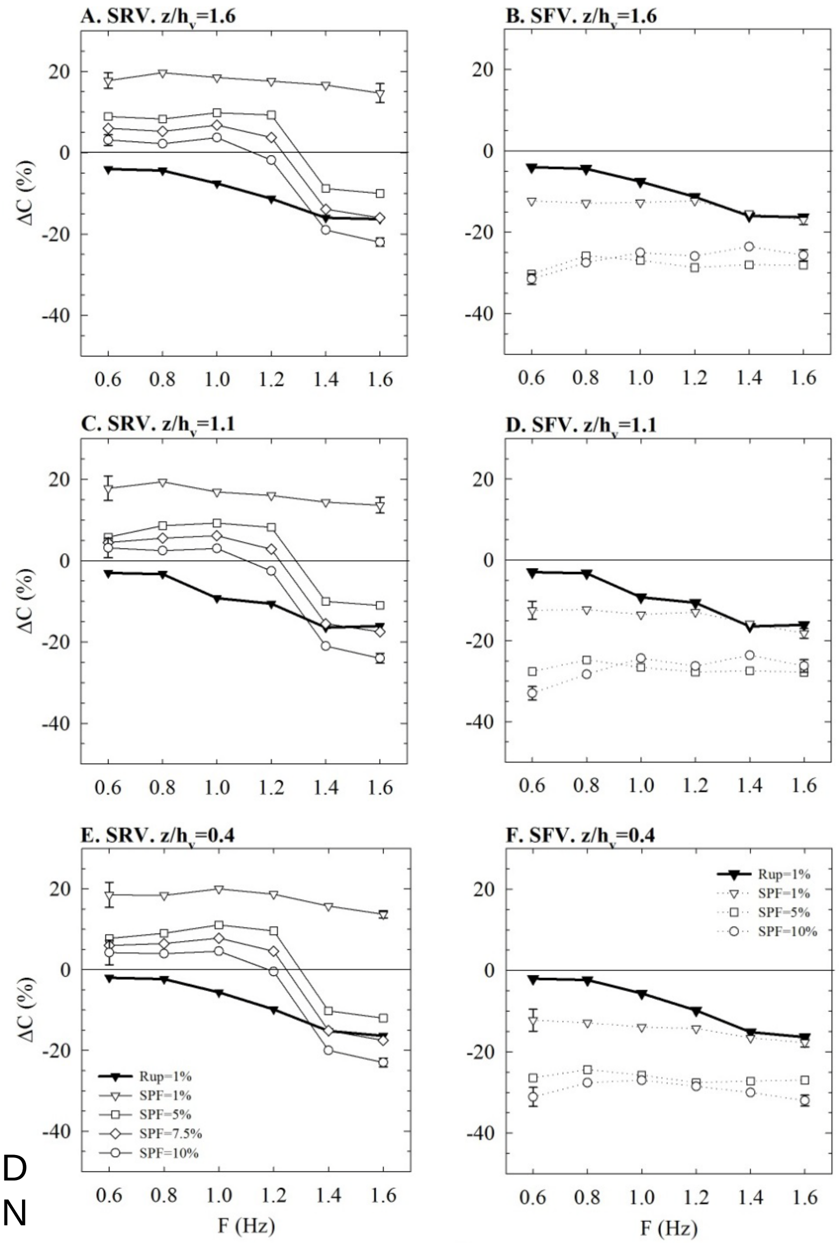
RESULTS

Vertical distribution of Δ C
(large particles: 6 μm • ϕ • 100 μm)

$$\Delta C(\%) = \left(\frac{C_{canopy} - C_{no\ canopy}}{C_{no\ canopy}}\right) \cdot 100$$



Above canopy z/hv=1.6

Above Top Canopy z/hv=1.1

Inside Canopy z/hv=0.4

RIGID VEGETATION

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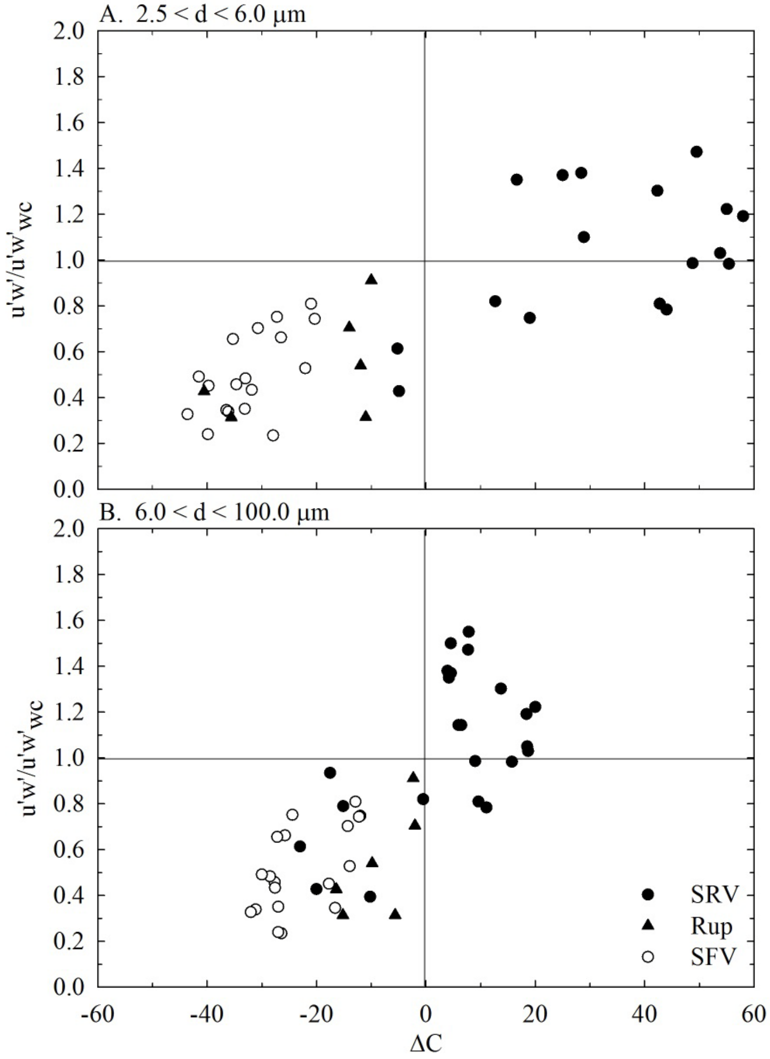
Ratio of Reynolds stress

$$\frac{u'w'_{canopy}}{u'w'_{no\ canopy}}$$



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CONCLUSIONS

- Plant flexibility control wave induced turbulence within the canopy and consequently, the exposure of the substrate sediment bed to stress:
  - Above rigid model, TKE increases relative to the non-vegetated case. Inside the rigid canopy model high frequencies and high densities promote larger canopy sheltering.
  - The TKE inside the flexible canopy progressively lessens with wave frequency and canopy density (blades dissipate the turbulence).
- Flexible canopies and densest rigid canopies diminish sediment resuspension and therefore diminish erosion, especially for larger particles and wave frequencies above 1.2 Hz. Therefore, these wave frequencies were found to promote erosion of small particles, that is a tendency to bed sandification.
- For small particles, TKE reduction correlates well with the amount of resuspended particles. For large particles, this correlation is also positive, although at a larger intensity.
- At high frequencies (F = 1.4,1.6 Hz), ΔC for the *R. maritima* bed is similar to the flexible bed (at the same density), while at low frequencies, F<1.4 Hz, ΔC for *R. maritima* is similar to that for rigid canopies.