Soft corals Vortex-Induced Dynamics

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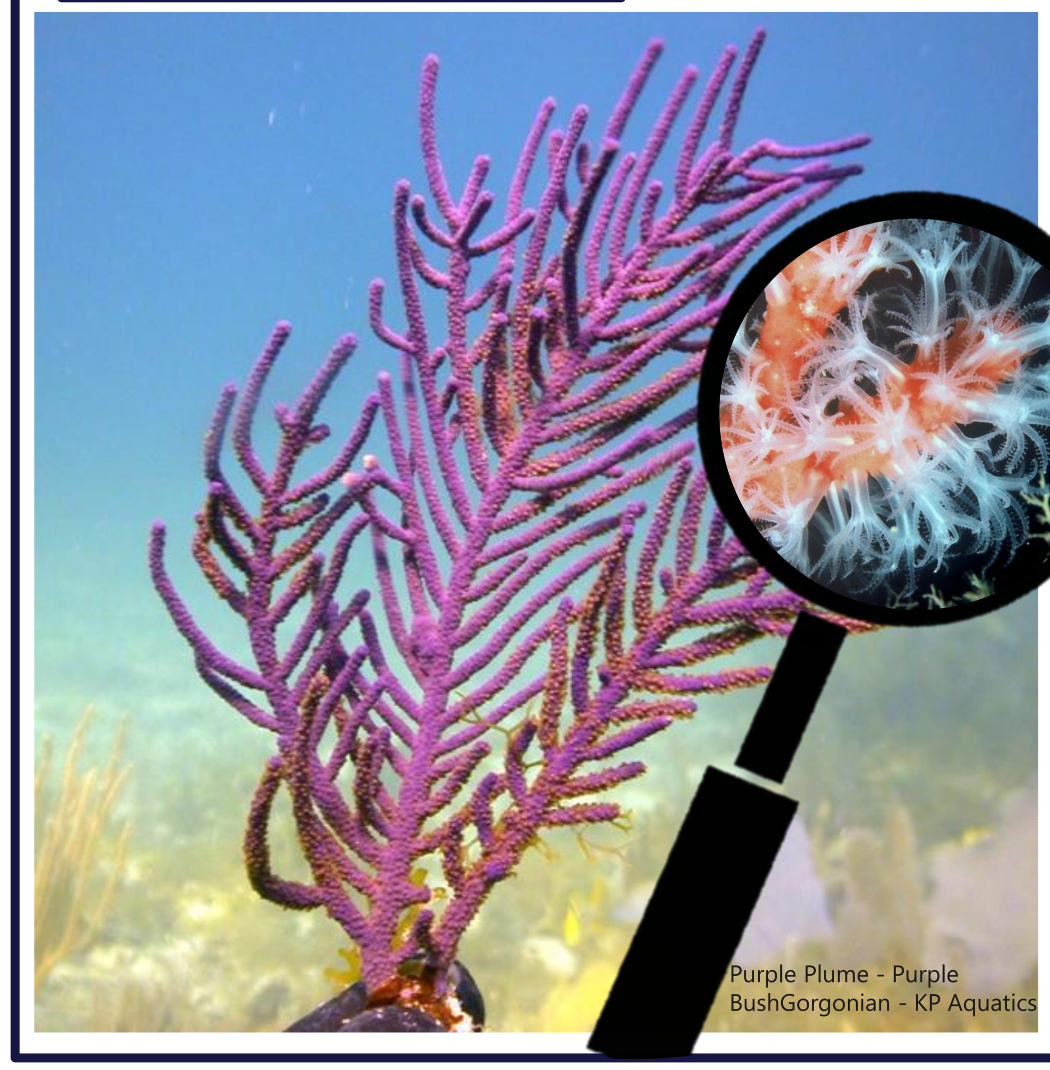
STUDIED SYSTEM



Soft coral: Bipinnate sea plume with polyps

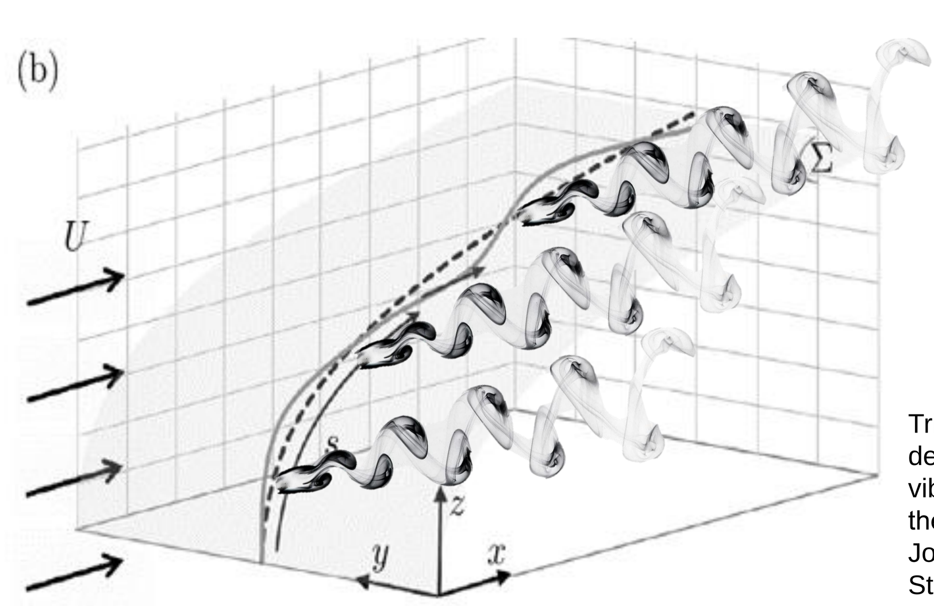
OBSERVATIONS

High frequency vibrations of the branches perpendicular to the flow

Boudina, M., Gosselin, F., & Étienne, S. (2021). Vortex-induced vibrations: A soft coral feeding strategy? *Journal of Fluid Mechanics, 916*, A50.

HYPOTHESIS

Vortex shedding in the wake of the branches creates high frequency vibrations transverse to the flow allowing the coral to capture more nutrients.



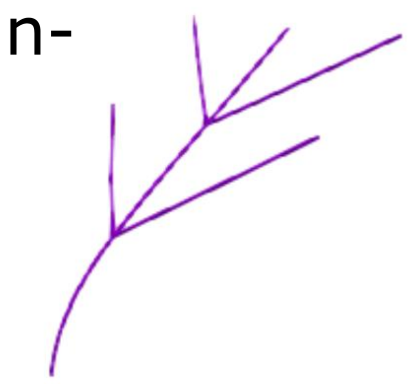
Tristan Leclercq, Emmanuel de Langre, *"Vortex-induced vibrations of cylinders bent by the flow"* Journal of Fluids and Structures, vol. 19, no. 2, pp. 123–140, March. 2018.

OBJECTIVES

1. Implement a 3D finite elements methods solving the vortex induced dynamics of the coral.
2. Validate the model with litterature results and experiments

METHODOLOGY

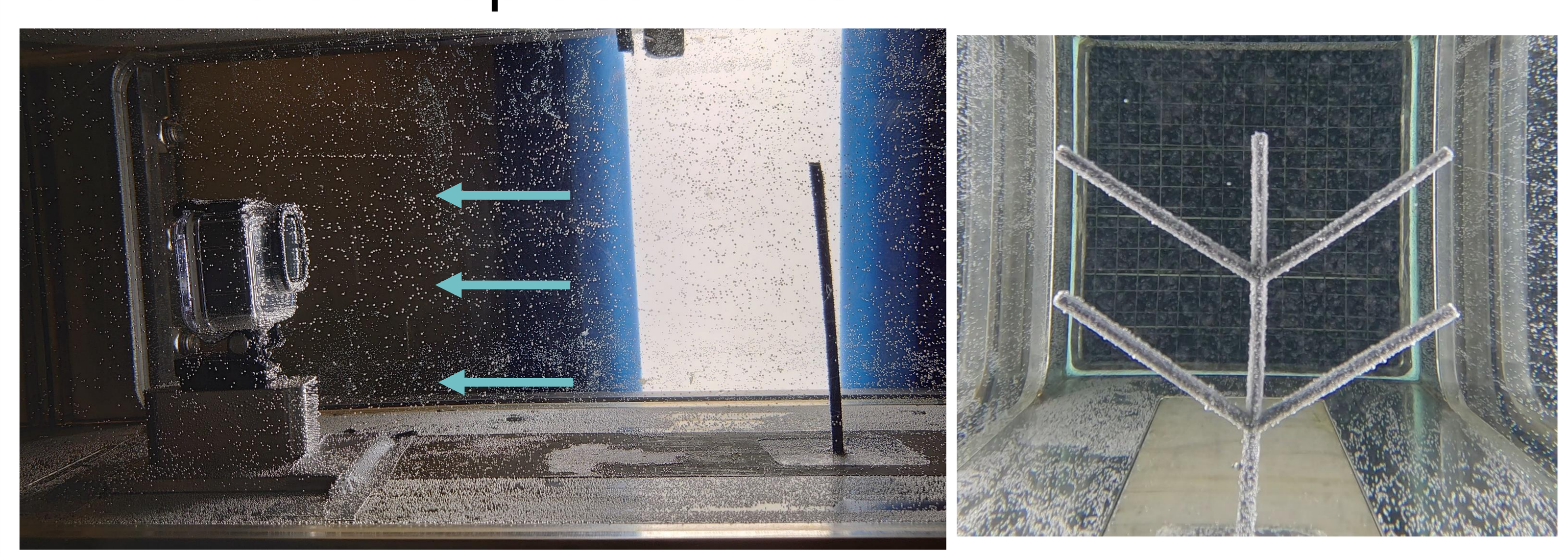
1. Implement the cross-flow and in-line wake oscillator model:



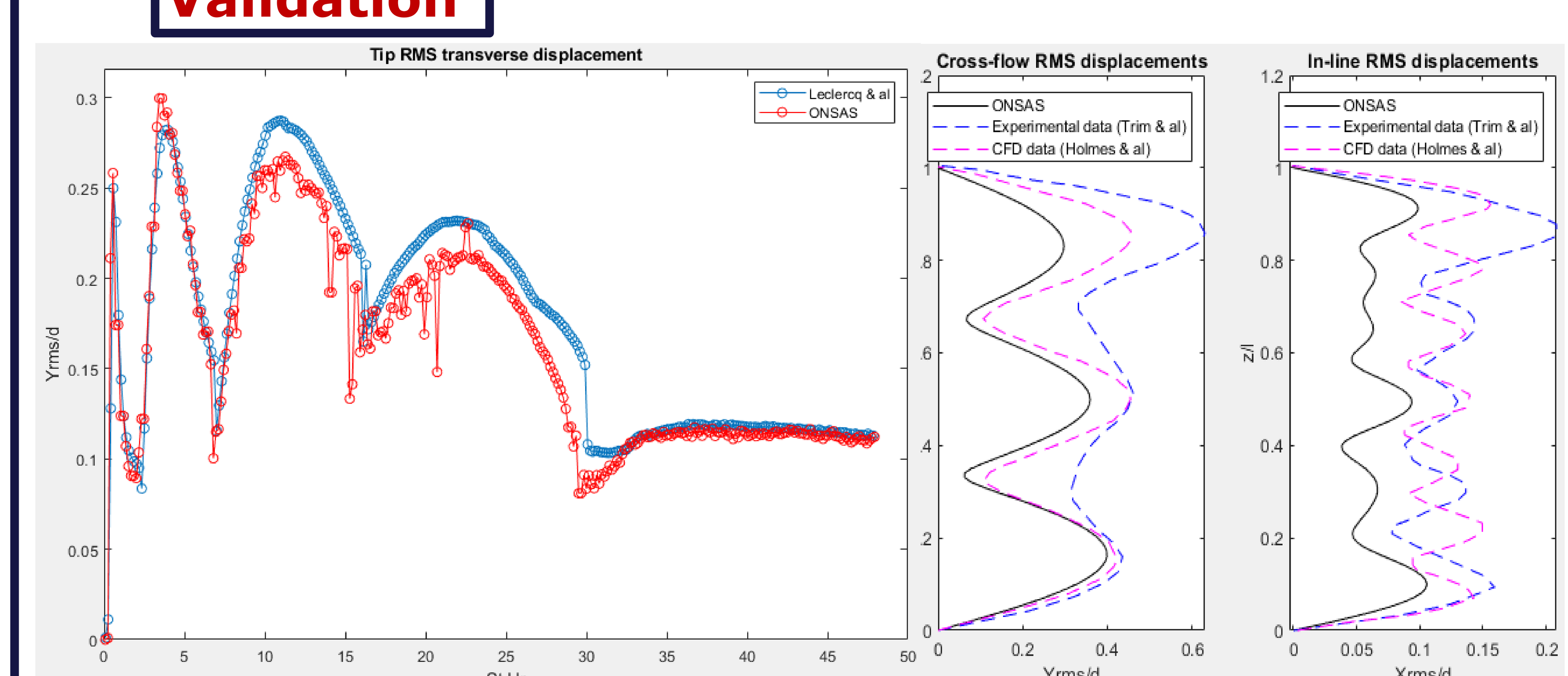
$$f_{\mathrm{Lift}} = \frac{1}{2}\rho\frac{C_L^0 q}{2} D^2 U^2$$

$$\ddot{q} + \varepsilon\left(2\pi\frac{S_t U}{D}\cos\theta_0\right)\left(q^2-1\right)\dot{q} + \left(2\pi\frac{S_t U}{D}\cos\theta_0\right)^2 q = A\frac{\ddot{Y}}{D}.$$

2. Record coral vibrations and extract transverse displacements



Validation



Cross-flow RMS displacement validation against Leclercq, T., & de Langre, E. (2018) wake oscillator.

In-line RMS displacement validation against experimental and CFD data

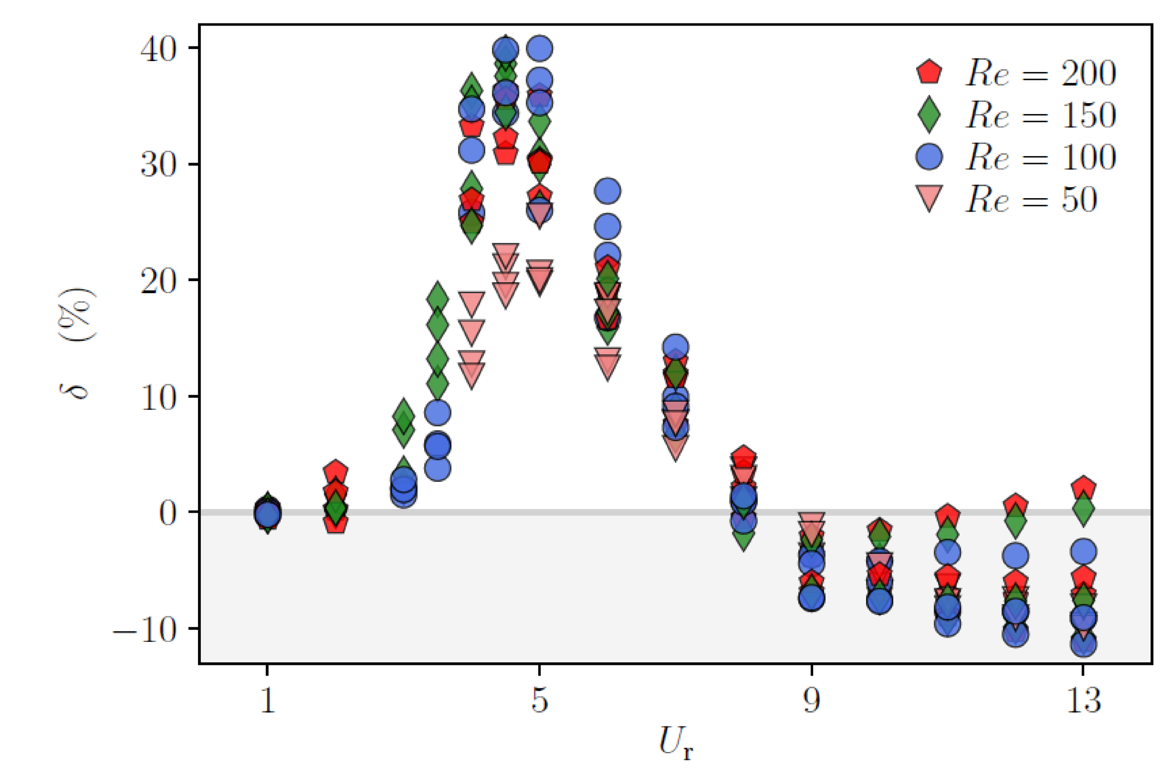
FIRST RESULTS (Boudina 2020 thesis)

Capture efficiency of a fixed cylinder:

$$\langle\eta\rangle_{\mathrm{fixed}} = 0.38R^{2.09}Re^{0.52}$$

Capture efficiency of a vibrating cylinder:

$$\delta = \frac{\langle\eta\rangle - \langle\eta\rangle_{\mathrm{fixed}}}{\langle\eta\rangle_{\mathrm{fixed}}}$$



CONCLUSION (Boudina 2020 thesis)

- VIV are at the origin of the observed high frequency vibrations
- VIV allow up to 40% increase in capture efficiency

NOMENCLATURE

- A: coupling constant in the wake-oscillator model
- C_L^0: constant lift coefficient
- C_L: lift coefficient
- D: branch diameter
- ϵ: coupling constant in the wake-oscillator model
- $\langle\eta\rangle fixed$: capture efficiency of a fixed cylinder
- $\langle\eta\rangle$: capture efficiency of a cylinder with VIV
- Γ: branch aspect ratio
- K_c: Keulegan Carpenter number
- q: oscillating parameter(bidisperse case)
- R: particles radius
- Re: Reynolds number
- S_t: Strouhal number
- θ_0: flow incidence angle
- U: constant flow velocity
- $\ddot{Y}$: branch acceleration transverse to the flow

ACKNOWLEDGMENTS

FONCER

GPS Génie par la simulation SBES Simulation - Based Engineering Science