How Morphological Characteristics Affect the Wake of Swimming Snakes

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Summary

Anguilliform swimmers, like snakes, swim by propagating a traveling wave along their body. While snakes across the ecological spectrum use this mode of swimming we know little about their hydrodynamic differences. We compare volumetric wake measurements of snakes to investigate what makes this swimming style more or less effective.

Introduction

The relatively simple body shape, kinematics and efficiency of anguilliform swimmers like snakes makes them an attractive model for engineering applications [1]. As their body moves it pushes against the water generating vorticity [2]. This vorticity is shed as hairpin vortices each time the midline of their body changes direction [4]. While many animals use this swimming mode, we know little about what characteristics make it more or less effective. Snakes across the ecological spectrum swim this way and provide a wide parameter space to investigate this question. Our preliminary results, presented here, demonstrate the differences in the wake of an aquatic and a non-aquatic snake.

Methods

For each forward swimming trial a live snake is placed in initially still water. The volumetric wake measurements are captured with a 3-component DDPTV setup (see [4] for details) triggered at 14 Hz along with a camera mounted above the water tank to capture the kinematics. The images taken for DDPTV are processed in multiple phases to compute the velocity field and vortex structures are identified by computing the Q-criterion.

The hydrodynamic impulse (J) is a measure of the momentum change to generate a given vortex from a fluid at rest and computed as derived in [3] with,

$$J = \frac{\rho}{2}\int_V x \times \omega \, dV$$

Where, ρ is the fluid density, V is the volume of the vortex, x is the position vector pointing from center of measurement volume to center of vortex, and ω is the vorticity of the identified vortex.

Results and Discussion

The results included here compare two snakes of similar size swimming at similar speeds. One terrestrial (*Xenopeltis unicolor*) and one aquatic (*Acrochordus javanicus*) which flattens its body when swimming.

This morphological difference affects the shed vortex shape (Fig. 1 b and d) and the J signature (Fig. 1 a and c). While the Acrochordus' flatter shape displaces more fluid, the wakes of both snakes contribute a similar amount to the forward movement (seen in the minimum J_x).

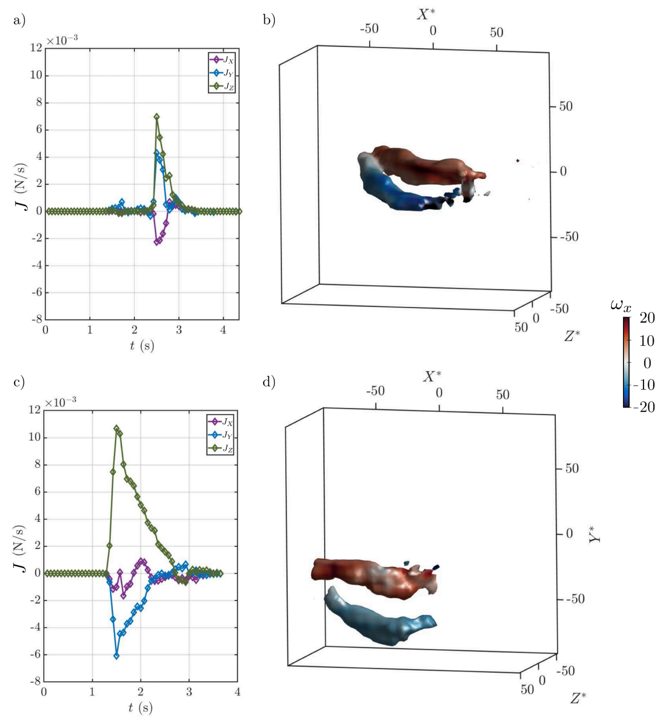

Figure 1: (left) Computed hydrodynamic impulse (see Equation 1) and (right) vortex events at their largest observed size for the (a-b) *Xenopeltis* and (c-d) *Acrochordus*.

Conclusions

Our results indicate that morphological characteristics create identifiable differences in the wake of anguilliform swimmers. We identify differences in the vortex shape, hydrodynamic impulse (J), and the ratio that quantifies how much J is contributing to forward propulsion. In the presentation we will extend this comparison to more snake species and investigate the ratio of vortex force to form drag.

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References

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