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THE QUANTIFICATION OF INERTIAL EFFECTS ON FLOATING OBJECTS IN A LABORATORY SETTING

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Introduction

- The ocean has long been populated with floating objects from sea ice and *Sargassum* to man made trash and oil spills (Ebbesmeyer & Scigliano, 2009).
- The ability to model the behavior of floating objects can be beneficial in various ways. Some examples include tracking trash in the ocean, assisting in marine search and rescue operations and tracking the progression of Sargassum along the coasts and its subsequent beaching.
- While the most common factors of floating objects movement are known to be the presence of ocean currents and wind, how these factors interact with the debris is a complicated matter (Mendez-Tejeda & Jiménez, 2019). Numerous studies have been conducted to study the behavior of specific floating debris such as the impact of ocean currents and object properties on the movement of *Sargassum* (Brooks et al., 2019).

Objective

- This paper seeks to quantify the effect of inertial particle buoyancy on a drifter through multiple current, wind and wave conditions in a laboratory setting to create a general model for the movement of floating objects in the ocean.

Methods

Laboratory Work

- Several drifters underwent various wind, current and wave conditions in the Air-Sea Interaction Saltwater Tank at the SUSTAIN lab at Rosenstiel School of Marine and Atmospheric Science (See Table 1)

Case	Water Current Speed (cm/s)	Wind Speed at Sea Surface (cm/s)	Wave Conditions (Freq. (Hz), Volt. (V), K value)
A	12	0	None
B	12	570	None
C	12	1190	None
D	0	0	1.5, 1.25, 0.1

Table 1. The four cases of water speed, wind speed and wave conditions simulated in ASIST.

- Four drifters of varying density ($\rho_{particle}$) were constructed out of filling a rubber ball with varying amounts of water. A CARTHE drifter was also used as the control in this experiment. The inertial particle buoyancy will be referred to as delta (δ) and can be found by the following:

$$\delta = \rho_{water}/\rho_{particle}. \quad (1)$$

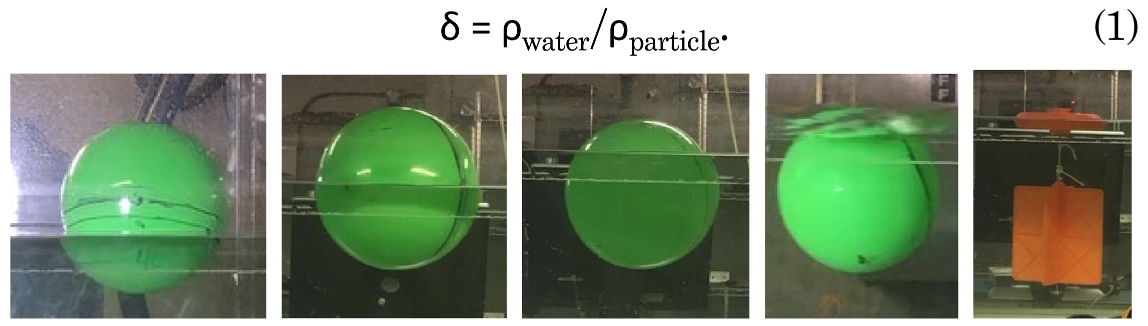


Figure 1. The four rubber ball drifters of increasing delta values as well as the control CARTHE drifter.

- For cases A-C, the drifters underwent five trials to find their velocity v_p. For case D, only one trial was conducted for drifters with a submerged height to total diameter ratio of 0.33 and 0.5 while the remaining drifters underwent two trials.
- An estimation for the leeway factor α can then be found as:

$$\alpha = (v_p - v_{water})/(v_{air} - v_{water}) \quad (2)$$

Methods Cont.

Theoretical Work

- The BOM set (Beron-Vera, Olascoaga and Miron, 2019) is an adaptation of the Maxey-Riley set (Maxey and Riley, 1983) for a small spherical particle of radius a that floats at the air-sea interface. Given uniform wind and ocean conditions, the velocity v_p of such particles is given by

$$v_p = (1- \alpha)\, v_{water} + \alpha\, v_{air}. \quad (2)$$

- This alpha is ultimately found to be

$$\alpha := \gamma\Psi/[1 + (1-\gamma)\Psi] \quad (3)$$

where

$$\gamma = \mu_{water}/\mu_{air} \quad (4)$$

is the ratio between the dynamic viscosity of the fluids and

$$\Psi= \pi -1 \cos -1 (1 - \Phi) - \pi -1 (1 - \Phi) *\surd (1 - (1 - \Phi) 2)$$

which gives the particle's projected (in the flow direction) area as $\pi\Psi a2$.

In eq. 5,

$$\Phi = (i \sqrt{3} / 2) * (1/ \phi - \phi) - 1 /(2\phi) - \phi /2 + 1 \quad (5)$$

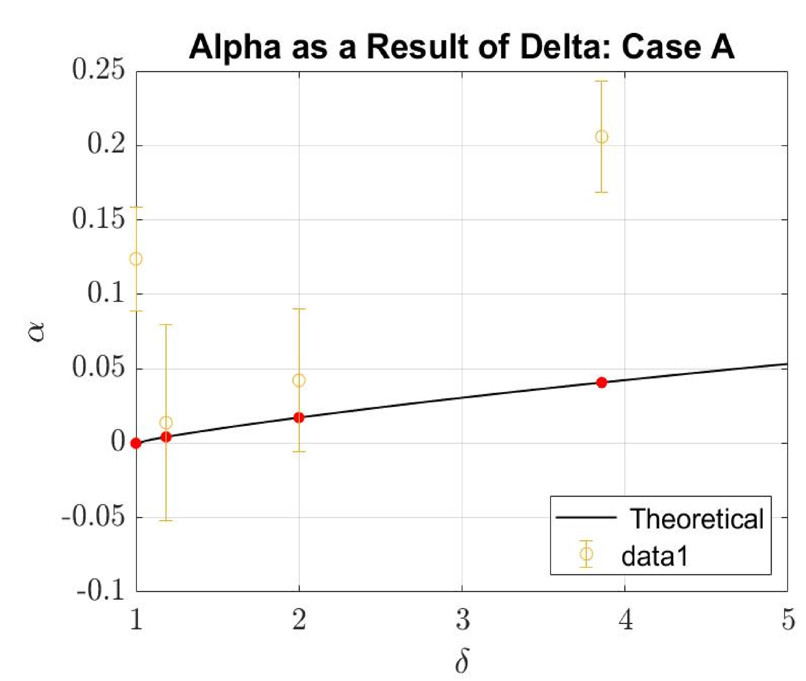
where $\phi^3 = i *sqrt(1 - (2\delta -1 - 1) 2) + 2\delta-1$.

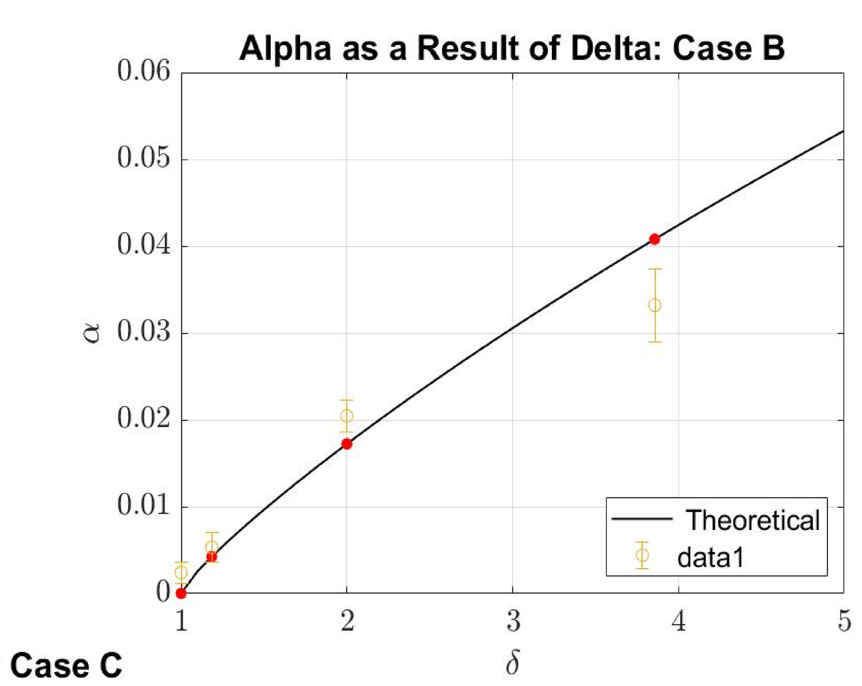
(6)

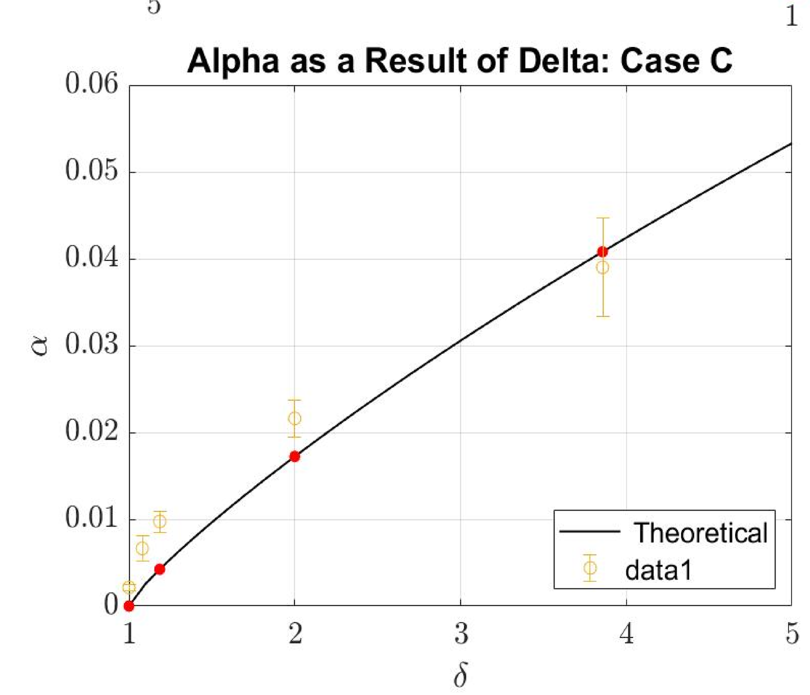
Results

b.

Figures 1-3 show the resulting average α values calculated for cases A-C overlaid with the theoretical alpha value as a function of delta(which can be found in Table 2). The error bars present in the plots represent one standard deviation of the data collected over the five trials per case. No experimental alpha measurements were conducted for Case D as velocity measurements were inconclusive due to reflection in the tank interfering with the drifter's movement.







Figures 2-4: The theoretical alpha value as a function of delta was superimposed with the average alpha values for each delta tested in cases A-C.

Submerged cap height to diameter ratio	0.33	.50	.75	1
Delta	3.857143	2	1.185185	1
Alpha	0.040804	0.017225	0.004241	0

Table 2. The delta and theoretical alpha value for various drifters.

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Discussion

Errors

- An issue with the accuracy of particle velocity measurement became evident when the control drifter did not reflect the current velocity in Case A. The error in measuring the velocity would create a margin of error for calculating the alpha from experimental data. As the length L was fixed, it can be assumed there was human error in measuring the time (ΔT). Therefore, the error in the velocity can be found as follows:

$$\Delta v_p= L^*\Delta T/T2 . \quad (7)$$

From there, the change in α as a result of Δvp is found to be

$$\Delta\alpha= \Delta v_p / (v_{air} - v_{water}) \quad (8)$$

- The error in the estimation of α in Cases A-C are: 15%, 0.34% and 0.16%, respectively.

Conclusion

Were this study to be extended, different methods of measuring water velocity must be used to minimize the error from this data collection. Albeit the mishap with measurements in case A, cases B and C can be deemed useful in better understanding how floating objects can behave in high wind situations such as storms. No quantitative work was done for case D as the results were inconclusive due to reflection in the wave tank interfering with the drifter movement. Further work to be conducted can be to attempt Cases A through C with different wave conditions so that particle movement can better reflect how it would naturally behave in open ocean exposed to varying degrees of all three factors.

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