Numerical and Experimental Comparisons of Oceanic Overflow

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ABSTRACT.

Overflows in the ocean occur when dense water flows down a continental slope into less dense ambient water. These density driven plumes occur naturally in various locations in the global ocean, but it is important to study idealized and small-scale models which allow for stronger confidence and control of parameters.

The work presented here is a direct qualitative and quantitative comparison between physical laboratory experiments and lab-scale numerical simulations.

Physical parameters are varied, including the Coriolis parameter, the inflow density anomaly, and the inflow volumetric flow rate. Laboratory experiments are conducted using a rotating square tank and high resolution camera mounted on the table in the rotating reference frame. Video results are digitized in order to compare directly to numerical simulations. The MIT General Circulation Model (MITgcm), a three dimensional, full physics ocean model, is used for the numerical simulations. These simulations are run under the full range of physical parameters corresponding to the specific laboratory experiments.

EXPERIMENTAL METHODS.

High-quality video is obtained to use as qualitative data to compare to numerical simulations. Our experiment is modular in that we can vary relevant parameters to observe different effects on the dense water plume.

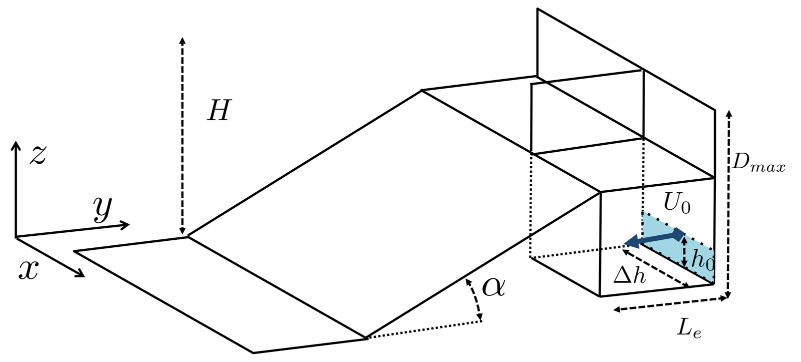

Figure 1: Experimental schematic of overflow slope.

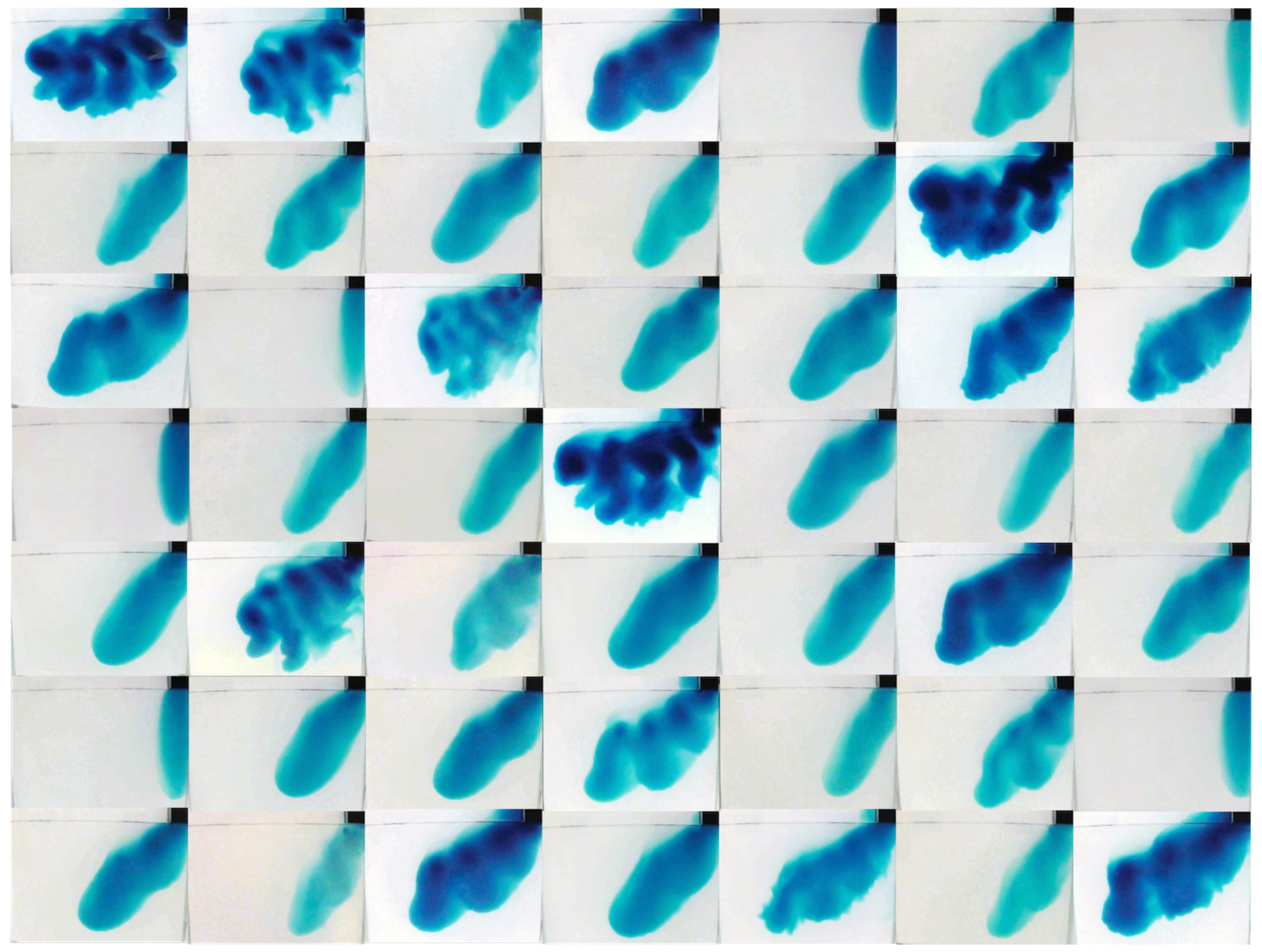

Figure 2: Assortment of experimental overflows to display visual plume diversity.

NUMERICAL METHODS.

The numerical model used for the simulations of the lab experiments is the general circulation model developed at the Massachusetts Institute of Technology (MITgcm). The MITgcm solves the governing equations using the finite volume method with an Arakawa C-grid discretization scheme for placement of the model's physical control volumes.

RESULTS.

Two different physical cases are presented here, compared directly to numerical simulations at five different resolutions (25^3, 50^3, 100^3, 200^3, 400^3). Figures 3 (more eddies) and 4 (less eddies) show a snap shot at the same time for all five resolutions and the experimental results are in the bottom right corner. Figure 5 shows plume path and final plume area for both cases.

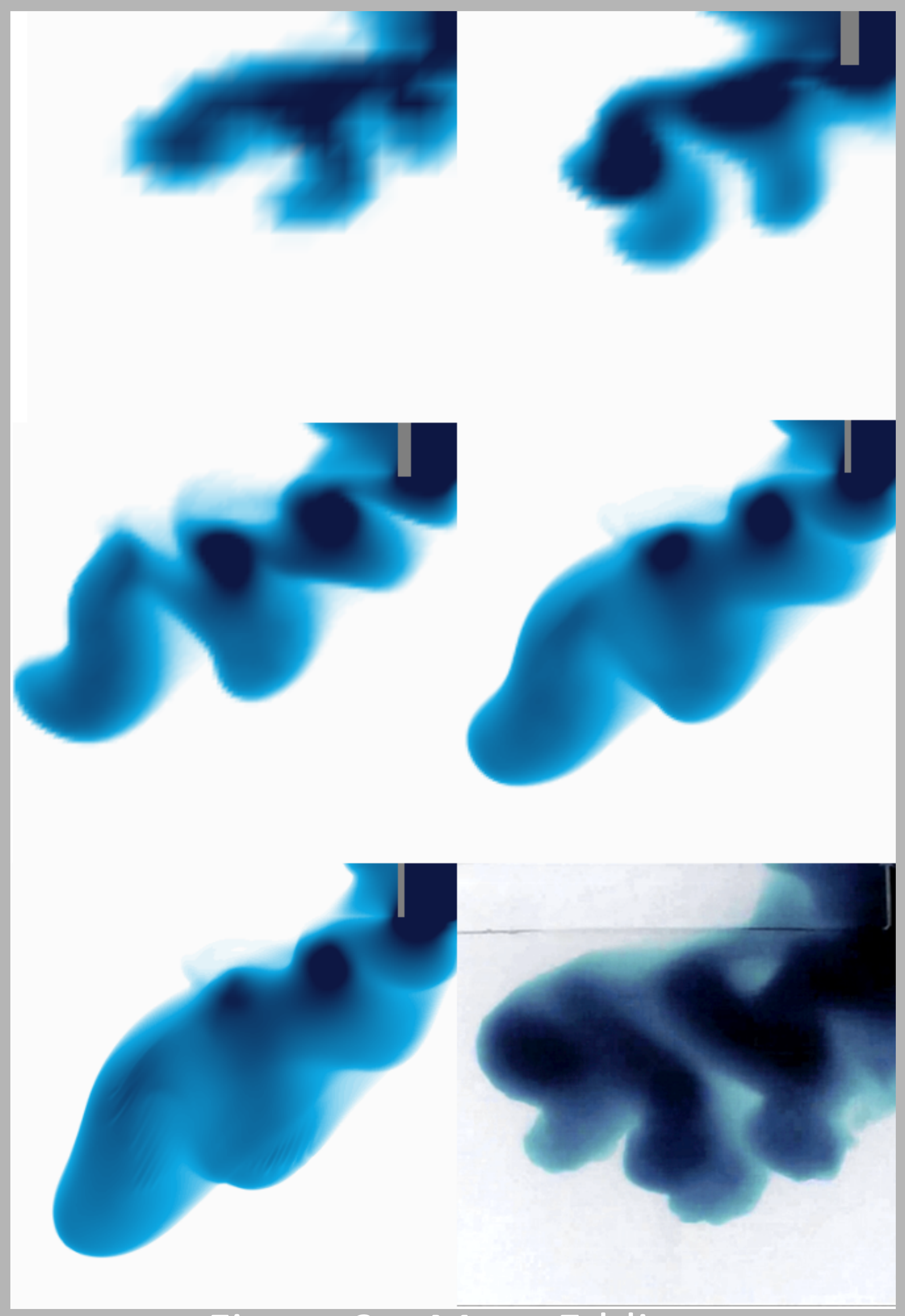

Figure 3 – More Eddies

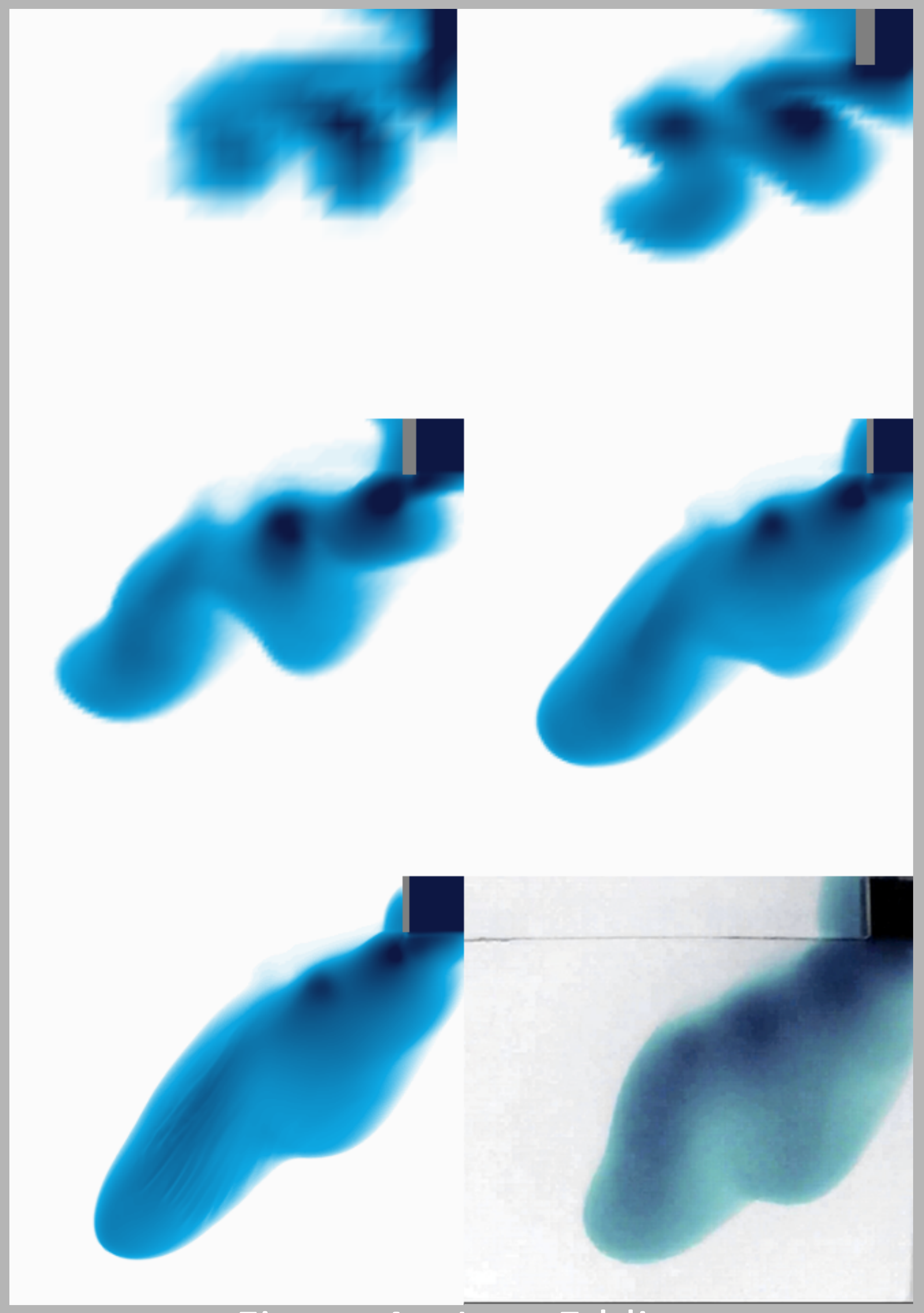

Figure 4 – Less Eddies

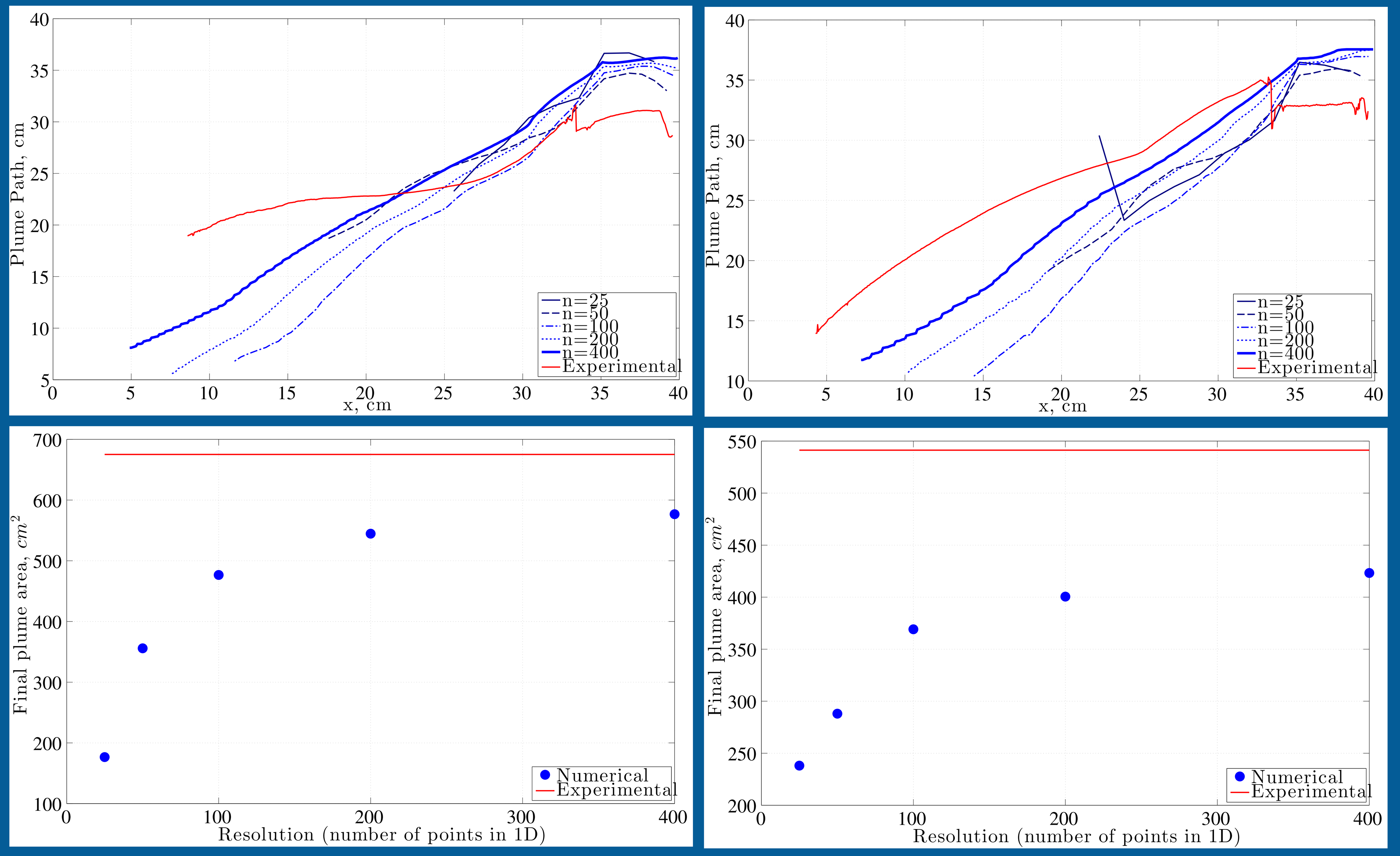

Figure 5 – Plume path and final plume area plots for a case with more eddies (left) and less eddies (right)

ANALYSIS.

Several analysis metrics have been used to compare numerical results to the experimental results. All results use the vertical view of the plume, which is equivalent to the vertical sum in the numerical results. These metrics include plume velocity, plume area, and tracer weighted plume path. Plume velocity is fairly steady through time and compares well across cases. Plume area is defined as the area where the tracer is greater than some threshold value. The plume path is defined as,

$$Y(x) = \frac{\int y\tau(x,y)dy}{\int \tau(x,y)dy}$$

This metric is time independent and also not dependent on the threshold value cutoff for the tracer. The initial angle of descent can also be calculated using this plume path, as a single metric for comparison.

Figure 6: Sample of Plume Tracing

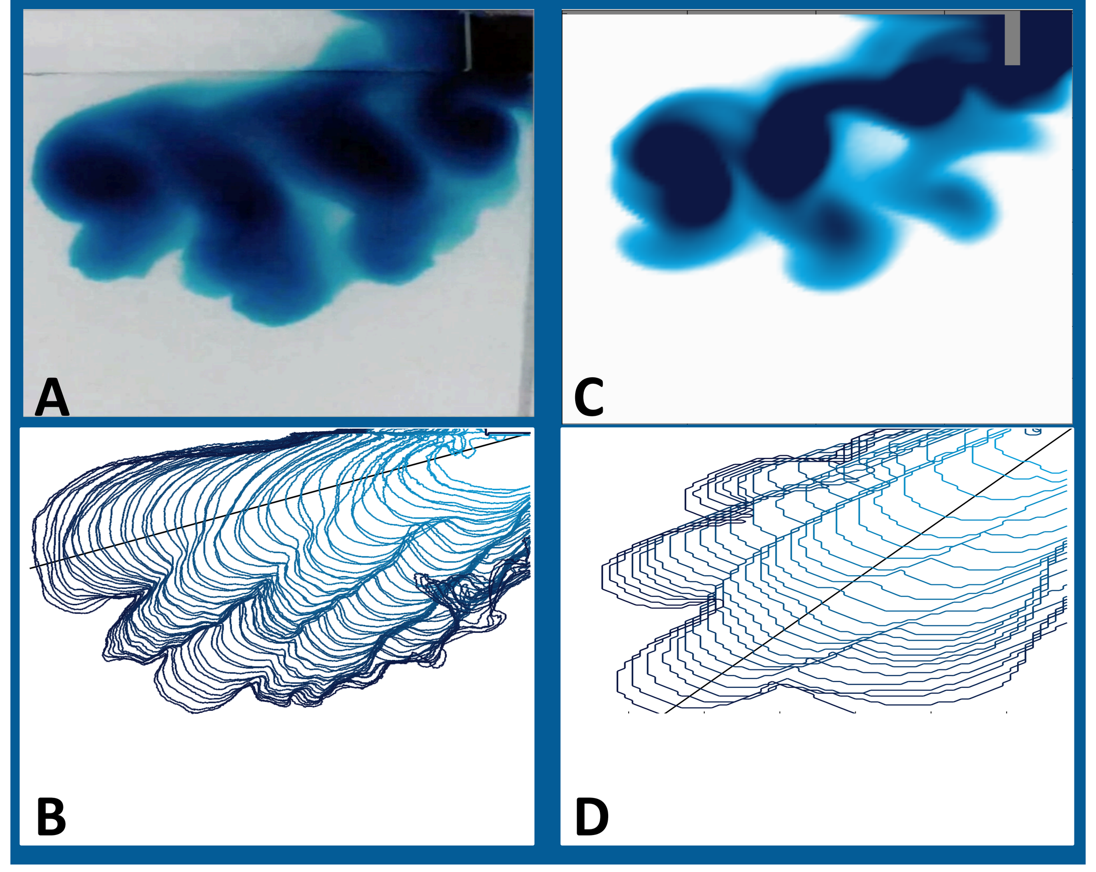

Figure 6: A) Final frame from experiment. B) Plot of plume front every 5 seconds from experiment. C) Final frame from numerical model. D) Plot of plume front every 5 seconds from numerical model

CONCLUSIONS.

A resolution of 200x200x200 is adequate. Results show that the MITgcm results match experiments better for cases that are more laminar with less eddies. Overall, the MITgcm is under predicting the plume area. For cases with eddying behavior, the MITgcm does not have enough mixing so plume descends too far down slope.

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