

Eddy Flow



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Introduction

This report documents the techniques used to capture a video of an eddy current in nature. It will also describe some of the physics and fluid properties involved.

This project is the last of three team projects for the Flow Visualization Course at the University of Colorado at Boulder in the spring of 2012. The purpose of the assignment was to team up engineers and art students, and combine their disciplines, in order to visually produce a fluid phenomenon and capture it using the photographic technique of their choice.

Flow Apparatus

This video was captured on April 7th, 2012 at 1:00pm on a section of South Boulder Creek, near Walker Ranch in Boulder County, Colorado. Walker Ranch is part of a conservation effort called Boulder County Open Space and is one of several parks and areas monitored, maintained, and conserved by Boulder County. Boulder County prioritizes the conservation of open space lands for the protection of critical wildlife habitats, protecting farms and ranches and creating quality recreational experiences ^[1]. The area is open to the public free of charge, and occupants can partake in activities including hiking, fly-fishing, horseback riding, and mountain biking.

The video displays a current flow found and left undisturbed in nature. The tracing particles seen in the film, as white in color, are of an unknown substance. The author simply discovered the flow visualization while hiking in the area, and captured the flow by using the technique seen in **Figure 1**.

Analysis

The water flow seen in the video is known as an eddy current, characterized by turbulent flow creating a reverse current as it flows past an obstacle. This is often seen in flowing rivers, atmospheric jet streams, and oceanic currents. As the flow passes an obstacle the flow begins to separate behind itself. The separation creates a void causing the fluid to flow around the edge of the obstacle often creating a vortex, rotating back towards the obstacle. A description of eddy flow written by Leonardo da Vinci, from the sixteenth century, describes it best "...the smallest eddies are almost numberless, and large things are rotated only by large eddies and not by small ones, and small things are turned by small eddies and large." ^[2]

The small eddies receive the kinetic energy from slightly larger eddies. The slightly

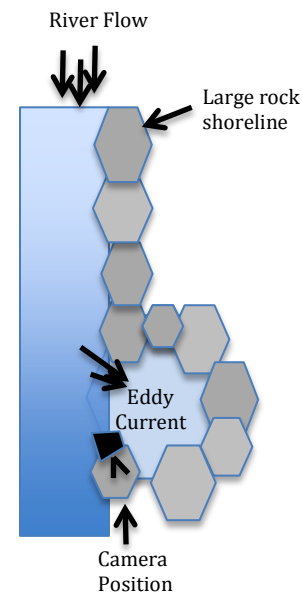


Figure 1: River flow and Camera position

larger eddies receive their energy from even larger eddies and so on. The largest eddies extract their energy from the mean flow. This process of transferred energy from the largest turbulent scales (eddies) to the smallest is called *cascade process* [3]. It is known that any flow near a corner consists of an infinite series of eddies with decreasing size and intensity as the corner point is approached [5].

Turbulent flow is irregular, random and chaotic involving many scales and many variables, including eddy sizes, flow depth, jet width, and viscous forces, which are dissipated into internal energy [2] making it very difficult to compute mathematically. The best ways to measure eddy flow is by using a technique known as large eddy simulation (LES)[4]. LES aims to solve for only the large-scale flow characteristics and neglects the smaller scale eddies involved. These simulations use a combination of the Navier Stokes equation and the Reynolds number (Re). The Reynolds number is a dimensionless ratio of inertial forces to the viscous forces and can be calculated using the following formula:

$$\mathbf{Re} = \frac{U_d L}{\nu}$$

Where U_d is the velocity, L is a typical length scale and ν is the viscosity of the water. The Reynolds number for this eddy flow is estimated to be between 180- 350 and varies greatly by area and time of the video. The Navier-Stokes equation can be written in terms of Re as follows [3]:

$$U_t + U \cdot \nabla U = -\nabla P + \frac{1}{\mathbf{Re}} \Delta U + F_b$$

Where U is the velocity vector, P is the Kinematic pressure, F_b is a dimensionless body force (closely related to a Grashof number or Froude number).

Photographic Technique

An 18.1-mega pixel DSLR camera was used and captured the 1280x720 pixel resolution video. The camera was a Canon EOS Rebel T2i body, housing the high resolution CMOS sensor, with a Canon EFS 18-55mm f/3.5-5.6 IS II lens [3]. The camera was focused manually and the camera used automatic exposure settings. The camera's focal length was 18.0mm. Only natural sun light was used to light the frame. The screen shot of the original video can be found in **Figure 2**.



Figure 2: RAW video screen shot

Post processing was done using Windows Movie Maker and adjustments were performed to enhance subtle qualities and produce the final video. Once the video was imported into Movie Maker, the video was turned to gray scale increasing the contrast between the visible flow and the yellowish color of the water. The entire film was then darkened using a darkening algorithm imbedded in the software. This removed some glare and also increased the contrast in the flow. Next, title and credit transitions were applied to the beginning and the end of the video. The video was then played back at “half speed” (according to Windows Movie Maker); this created a calmer, soothing feeling for the video. The author chose to add music for an added effect, obtaining permission by the musician to use for this video. The song was written and performed by Adam Richardson, a close friend of the author, and is titled “Do You Dream”. (More of Adam’s music can be found at: adamrichardsonmusic.com)

Conclusion

The final video effectively reveals the fascinating turbulent eddy flow physics in a unique and intriguing way. The author’s intent was achieved and the post processing effects creates a video that is calming and easy to watch. I would like to further research eddy flow and the computational methods for turbulent flow. Additional imaging techniques could be applied, including different camera angles and enhancements in post processing techniques.

References:

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