“Team Second” Report: Temperature-induced Currents

MCEN 5151-001 Flow Visualization, Fall 2025
Emma Wilder, 10/20/2025 (created alone)

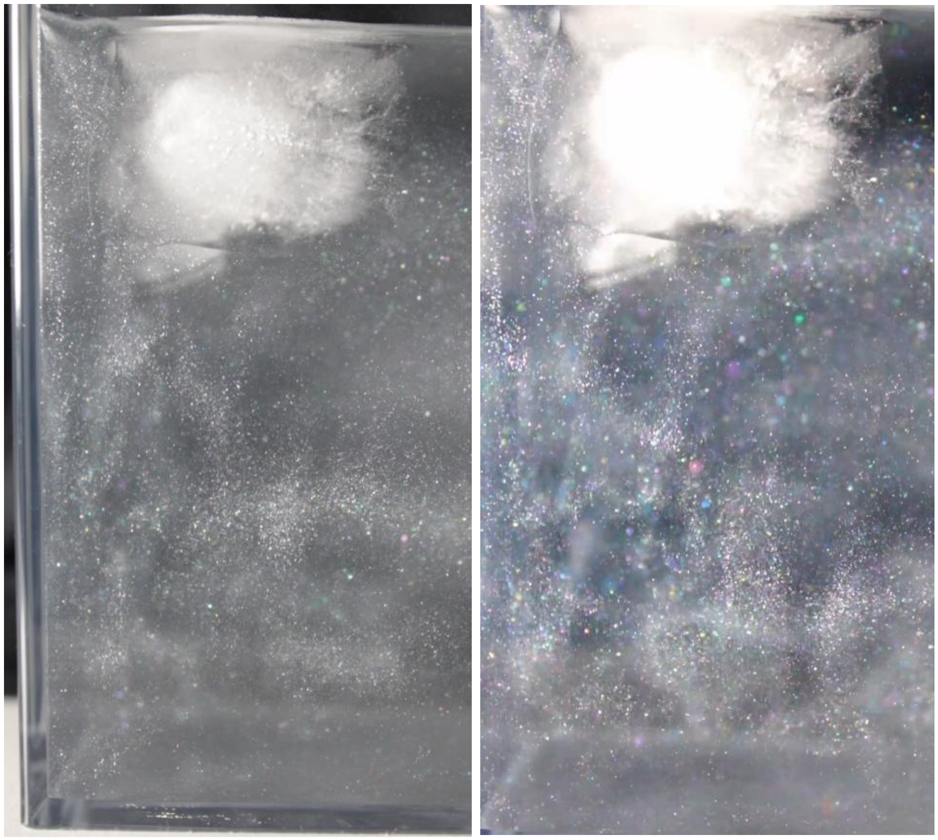

Fig. 1: Thumbnail of (A, left) the unedited video, and (B, right) the edited video.

Introduction

The intent of the video (represented by the thumbnail in Figure 1) was to understand the currents induced by temperature gradients. Ice added to room-temperature water causes differences in temperature and thus density disparities between different parcels of water. The denser, cooler water sinks, forming a current which can be visualized with mica powder. This phenomenon has important implications for ocean currents (Goosse and Fichefet, 1999).

Flow Apparatus

The apparatus included a transparent plastic box (“vessel”) filled with room-temperature tap water and mica powder (EdiGlow Luster Dust). Approximately one gram of powder was added to around 1.5 liters of water. The vessel was left for approximately 10 minutes to still water movement. Two ice cubes were placed in the left-hand side of the vessel on the front side closest to the camera. Around 10 seconds after the ice was added, the recording began to allow the current to develop and to dissipate the movement induced by placing the ice in the vessel. Equipment placements are displayed in Fig. 2a-b, which allowed a close view of the current movements on the small-scale (individual mica particles) and a larger scale.

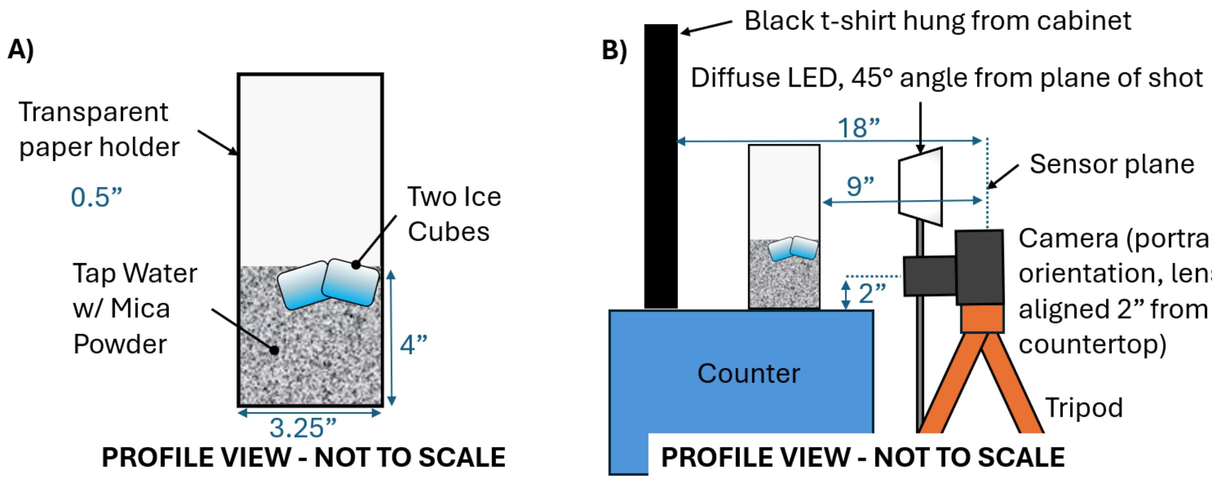

Fig. 2: Profiles of experimental setup including (A) a close up of the vessel, & (B) entire setup.

Scientific Explanation

The density of water changes slightly with temperature; at 1°C, water density is 999.90 kg/m^3, but at room temperature (e.g., 20°C), it is 998.21 kg/m^3 (Tanaka et al., 2001). Since ice cools water down through both convection and conduction, (Adrian, 1975), and melting ice produces cold liquid water, introducing ice to a room-temperature liquid creates a temperature gradient, and thus a density gradient. Denser, cooler water sinks in water that is warmer than it, but when this happens, the bulk water must replace the water that has sunk, leading to relatively warmer and less dense water coming from elsewhere (Fig. 3). Since the ice cubes are in the left side of the vessel, closest to the camera, warmer water from the back of the vessel and to the right fill in for the cold water that has sunk. Therefore, a current forms which is counter-clockwise for the water coming from the right hand side, and the mica particles in the back of the vessel (shown by the out of focus bokeh) are also rising.

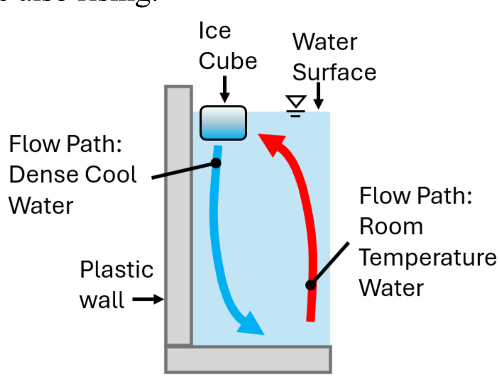

Fig. 3: Diagram of flow path.

Estimation of Velocities and Non-Dimensional Scales

To estimate the fluid velocity for non-dimensional scales such as the Reynolds number (Re), the field of view and particle tracking can be used. The field of view for this image was around 4 inches vertically. Tracking a mica particle that has been caught in the downwards cold current, it appears to cross around half the field of view (i.e., 2 in. or 5.1 cm) in 2.5 seconds.

Assuming that the particle moves with the same velocity as the water (which is likely true because the mica particles are small), the cold water velocity is approximately 2.0 cm/s. For density and viscosity figures used, a temperature of 1°C is assumed (Eq. 1). The diameter of the flow can be visually estimated at around half the vertical field of view (2 in. or 5.1 cm). Using these figures with Eq. 1, Re can be estimated at 578, which is in the laminar range. This result agrees with the somewhat predictable flow path, although the currents change slightly with time, which may be due to the shape and size of the ice cube changing over time.

$$Re = \frac{\rho v D}{\mu} = \frac{(999.9\ kg/\ m^3)\left(\frac{0.020\ m}{s}\right)(0.051\ m)}{(0.00173\ Pa * s)} = 578 \qquad \text{Equation 1}$$

Visualization and Photographic Technique

The visualization technique is a mixture between particle tracking (individual mica particles) and to a lesser extent in this video, refractive index technique since mica has multiple indices of refraction. The lighting used was a nine-inch diffuse LED light panel (NEEWER) which was pointed towards the vessel at a 45° angle and was 20 inches away from the vessel. The highest brightness setting was used (100%, full 10 Watt power) at a color temperature of 5600 K for white light, and the light was placed to avoid glare.

The photographic technique was developed to allow for calculations of flow velocity, to see the flow path, and to aesthetically appreciate this phenomenon. Since half of the field of view is crossed in around 2.5 seconds (see section above), the flow crosses is around 20% of the field of view per second, Therefore, the shutter speed used of 1/80 s would result in a movement of less than 0.3% of the image over the exposure time, which is adequate to capture the flow detail while still allowing for typical motion blur near a 180 degree shutter angle. The camera used was a Canon EOS Rebel T7 (digital DSLR) with an EF-S 18-55mm IS II Kit lens. A 35 mm focal length and 9 in. distance from the sensor to the vessel was used to see individual particles following the cold current while also including the context of the flow around it. The video was recorded at 30 frames per second with a portrait orientation to stress the downwards flow of the cold current. Most of the video was played back at 30 frames per second (i.e., real time), but the second part of the video was played back at 10x speed (equivalent of one frame every 1/3 s of real time, or playing back the video recorded at 300 frames per second). The camera shoots at a resolution of 1920 x 1080 pixels, which was also the final dimensions of the video, but was zoomed in slightly to crop out distracting elements (Fig. 1a-b). An aperture of f/4.5 was used to have a lower depth of field to have separation from the mica particles in the back of the vessel that tended to flow upwards. To achieve the expose to the right exposure technique, ISO was 800. The shot was composed to fill the frame, to see details while showing the larger scale shape of the current, and to exclude elements like the plastic wall and background. Post-processing was performed in DaVinci Resolve and included enhancing saturation (to bring out bokeh color for artistic effect) and increasing contrast with the RGB curve (to better see currents) (Fig. 1a-b). The spatial resolution is such that it allows the discernment of individual mica particles. Some particles are represented by a couple pixels, and given the resolution of 1920 x 1080 pixels, the spatial resolution is around 3 orders of magnitude, meaning 3 decades of scales are able to be resolved, which is sufficient for this laminar flow. Since the field of view is 4 inches (or 102 mm) over 1920 pixels, which means there are around 19 pixels per mm.

Conclusion

The video reveals the impacts of temperature gradients on water currents, fulfilling the intent of the visualization. I like that the image reveals the smaller and medium scale currents. I wish that I could also include the larger scale currents across the whole with of the vessel while also capturing detail. What makes the tracking of particles difficult is that when particles change orientation, they do not reflect the light as well, so the particle can get lost. Using different particles (for example, spherical and symmetrical particles that reflect light evenly) could improve this issue.

References:

Adrian, R. J. Turbulent Convection in Water over Ice. *J. Fluid Mech.* **1975**, *69* (4), 753–781. https://doi.org/10.1017/S002211207500167X.

Goosse, H.; Fichefet, T. Importance of Ice-Ocean Interactions for the Global Ocean Circulation: A Model Study. *Journal of Geophysical Research: Oceans* **1999**, *104* (C10), 23337–23355. https://doi.org/10.1029/1999JC900215.

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