Get Wet

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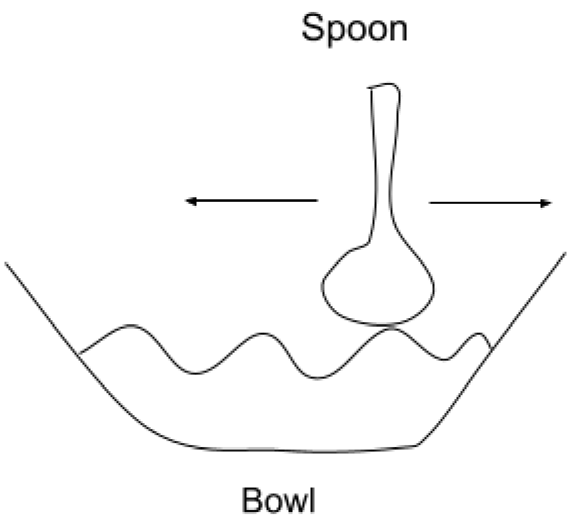
In this image, I am trying to replicate the creation of subaqueous dunes. Whenever you go into the ocean and reach an area with sand fine enough, there will typically be a repeating dune-like pattern along the seafloor. This is created through slow-moving water flowing over the sand, causing it to build up in some areas while leaving lower points in others. On a larger scale, you can see a similar phenomenon in sand dunes, where wind blowing over the sand causes it to accumulate in some areas and reduces accumulation in others. Although sand dunes form on a much larger scale than underwater seabed dunes, the physics behind their formation are similar.



The flow apparatus was simply a bowl and a spoon with water in the bowl. The part of the spoon interacting with the water has an area of roughly 11.8 cm^2 with a length of 5cm and a width of 3cm. The bowl has roughly a volume of 1434 cm^2, with a top diameter of 22.4 cm, bottom diameter of 10.4 cm, and a depth of 6.5 cm. In the sketch, you can see that I would move the spoon back and forth, creating ripples in the water. The water would start as turbulent as I initially move the spoon, then after a couple of seconds the water would start to match the oscillations of the spoon. I then removed the spoon and let the water settle completely.

The motion of the water was mainly caused by the spoon pushing through it and transferring momentum into the flow. As the spoon moved back and forth, pressure on the front of the spoon pushed the water forward, while viscous forces along the surface of the spoon also interacted with the water. Behind the spoon, the pressure field and wake caused surrounding water to move into the area the spoon had just passed through. The bowl also affected the flow because the water could not move through the walls, and the no-slip condition caused the water directly next to the bowl to move much slower than the water farther away from the surface. This created velocity gradients and viscous shear that slowly removed energy from the flow. Within the water itself, faster-moving regions transferred momentum to slower-moving regions through viscosity, causing the overall motion to gradually decay. Gravity acted on the water by pulling the surface back toward its equilibrium position after it was disturbed by the spoon, while surface tension resisted the smaller ripples along the surface. Once the spoon was removed, these effects continued to reduce the motion until the water eventually came to rest. The final shape of the mica at the bottom of the bowl was also affected by how this flow developed and decayed. The dimensions of the bowl controlled the boundaries of the water and affected how the back-and-forth motion oscillated through it, which influenced the overall shape of the deposited patterns. The way I moved the spoon also affected how the mica settled because the fine particles followed the motion imposed on the water while they were suspended. As the water slowed, the mica began settling to the bottom while there was still some remaining motion in the flow, allowing the water to redistribute the particles as they settled. The fineness of the mica also affected the pattern because smaller particles can remain suspended longer and respond more easily to the motion of the water. If the same mass of mica had consisted of larger particles, there would have been fewer particles overall, and they would have settled faster, which likely would have produced a less finely defined pattern. The properties of the water also affected the final result, especially its viscosity, since viscosity controlled how quickly momentum was transferred through the water and how quickly the motion died out

- Finding Reynolds number when the motion of the water was at a peak, $Re = \frac{UL}{v}$, U = 2m/s (An estimate made from my mixing speed compared to a person walking), L = 0.03m (setting the length as the spoon width), $v = 1x10^{-6}\,m^{2}/s.$
  $Re = \frac{2(0.03)}{1x10^{-6}} = 6x10^{4}$
- Finding spatial resolution: Assuming spatial resolution refers to the distance covered by a single pixel, $spatial\ resolution = \frac{field\ of\ view}{pixel\ width\ of\ the\ image}$, FOV = 170mm, Pixel width = 3674. $spatial\ resolution = \frac{170}{3674} = 0.0463\ mm/pixel$

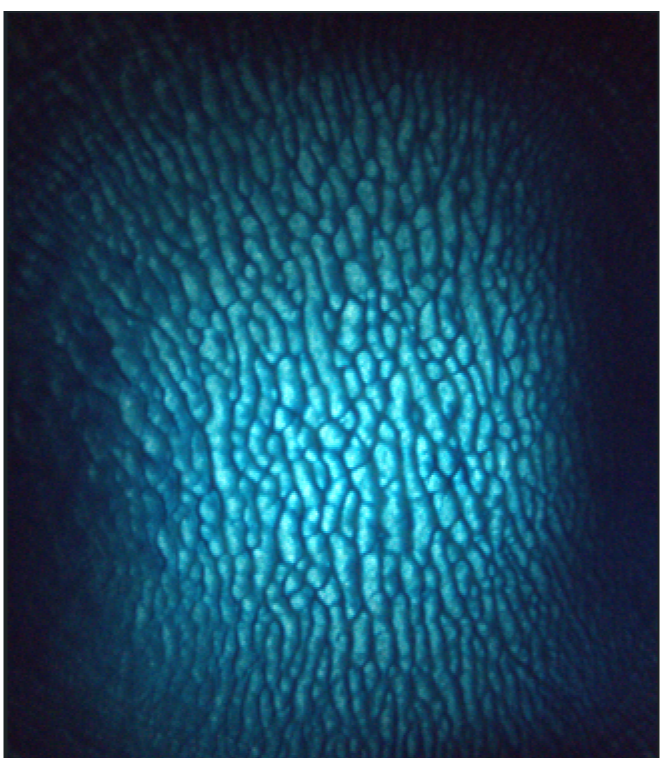
- In this case, time resolution doesn’t apply because, by the time I took the picture, all the water was still. The idea of the experiment was to let the water settle to let the powder fall to the bottom of the bowl. Nothing is moving in the picture.

The main visualization technique used in this experiment was the use of blue mica powder in a bowl of water. In the bowl, I put roughly 3 cups of water, which is equal to 0.71 L, and added about ⅓ of a gram of mica powder to the bowl. This gives roughly a dilution of 0.46 g/L of mica powder to water. The only environmental condition that affected this experiment is the requirement for it to be nighttime, or at least the experiment must be done in a room with nearly total darkness. That’s foundational to the lighting because you’re going to really overexpose the camera if you are in a bright room. You’re also more likely to get light bouncing off the surface of the water, which you want to eliminate at all costs. Reducing the light that reflects off the surface of the water and hits the camera will increase the clarity of the shot through the water into the bottom of the bowl. My only sources of light came from below the bowl. The lighting setup was very rudimentary. Overall, my set included a wide bowl(to hold the water), two similarly sized bowls, a large glass tray, an LED lantern, an LED flashlight(with a long light strip), a single sheet of paper towel, and a spoon for the mixing. The wide bowl(must be slightly translucent) would sit inside the glass tray; then place the two similarly sized bowls on either side of the LED lantern, placing the flashlight with the light strip facing towards and above the lantern. Put the single paper towel sheet on top of the lantern and flashlight to spread out the light, then place the glass tray(with the wide bowl already on it) on the two similarly sized bowls. This will elevate the glass tray and the wide bowl above the light source and allow the light to come through the bottom of the bowl.

In all honesty, there wasn't much intentional use of photographic tech; a lot of the settings I changed through trial and error. The only three I used intentionally were shutter speed 1/400s, focal length of 5.56 mm, and ISO6400. I also had an f/1.9, but that was not intentional. The camera was roughly 9 cm away from the bottom of the bowl. With the ISO, I was trying to make the picture as bright as possible, with 6400 being the highest setting on my phone. Then I played around with shutter speed to get a sharp image with large contrast between bright and dark spots. And I set the focal length at 5.56mm so that the bottom of the bowl is in focus. Otherwise, all I did was play with post-processing settings. The settings I changed during post-processing are:

- Flipped the image 90 degrees, then rotated the image 2.8 degrees to the right
- Reduced exposure by -36
- Increased contrast by 18
- Increased vibrance by 100
- Increased saturation by 41
- Increased highlights by 29
- Reduced shadows by -17
- Reduced warmth by -5
- Increased sharpness by 100
- Reduced white point by -49
- Increased black point by 13
- Increased grain by 58

Below is the picture before post-processing:



The image shows ripples in the powder after settling at the bottom of the bowl. Interestingly, some sections are long, tube-like ripples, and other sections are circular. This difference may have been caused by the small starting vortices that are generated each time I change the direction of the spoon. But a majority of the ripples are long and rest along the bowl perpendicular to the motion of the spoon. I like the image a lot, but I wish the lighting were more circular. The LED lantern forced the lighting to be long and have a rectangular shape to it, and I would have liked it more if I had a ring light to put below the bowl. So that it more evenly illuminates the entire bottom of the bowl and lets us see the behaviour of the settling powder as we get towards the edges of the bowl. I don't think it shows the fluid physics very well because it a image of the powder after everything settled. It's a remnant of the fluid physics, but I don't feel as though it shows the physics itself. Similarly to how a river can carve away at a mountain given enough time, those features are results of the physics but not the physics themselves. It leaves a lot of room for interpretation. Although I'm happy with the result, this photo was not my original intent. I set up the experiment with the intent to swirl the water around in a circle to try to get traces of the powder moving slower near the walls of the bowl and faster towards the center. It turned out my camera/ set up was good enough to capture what I had in mind, leaving me with blurry blue pictures of faint swirling structures. So I sat down for a while to think about what new thing I could try. After a couple of minutes, I walked back over to my setup and noticed the powder had settled at the bottom, and it reminded me of the dunes that from under water in rivers or oceans. I then decided to change my intention from capturing swirling traces to ripples at the bottom of the bowl. The two things I would improve about the experiment are my camera quality and getting a ring light to evenly illuminate the bottom of the bowl.

References:

Use of AI - used generally for grammar, fluidity throughout the report, and brainstorming.
Sand Dunes reference - used when considering the factors that affect the shape of the ripples