Fluids Lab
COESSING 2020
Waves Beneath the Surface

Motivation

The ocean's density varies in depth (stratification) and can be modeled as a fluid with many discrete layers each with a different density. A very simple model of ocean stratification is a two-layer fluid composed of light water near the surface and dense water at depth. In a two-layer fluid the density difference can be due to temperature changes, salinity changes, or both. An extreme example of a two-layer fluid is the atmosphere-ocean system, where air makes up the top layer and water makes up the bottom layer with the sea surface acting as the interface between the two layers. The waves that form along the surface of the air-sea interface are often the first thing that we visualize when we think about the ocean. A similar type of phenomena- internal waves- also form along the internal density layers in the ocean. Internal waves drive the transport of energy and in some cases mass throughout the ocean's interior. Internal waves are also a source of energy for turbulent mixing, which helps exchange fluid properties like heat and nutrients between stratification layers.

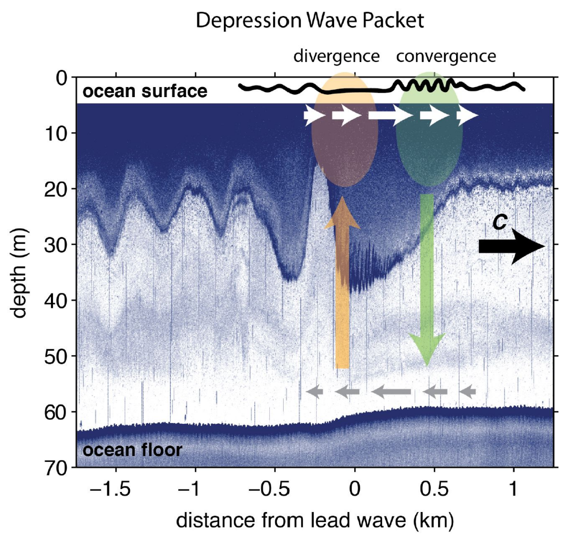

Figure 1: Acoustic backscatter showing the structure of internal waves offshore the US east coast. These data are collected using an instrument that sends out an acoustic pulse and then listens for the return echo. Zooplankton in the upper ocean are good reflectors of sound (dark blue at top of figure). The fluctuations in this upper layer show a passing internal wave. The deeper ocean layer has few scatterers with a weak echo (light colors).The dark blue at the bottom marks the ocean floor's sediment.

Experiment

Supplies: Cooking oil, water, dye, bowl and a spatula.

Procedure:

1. Fill the bowl with cooking oil. Pick a bowl that isn't too big. Best if it is clear, like glass or clear plastic.
2. Then, **slowly** pour the water with food coloring on one side of the bowl.
3. Once the two fluids have settled, with the spatula, create a wave on one side of the bowl by disturbing the oil / water interface.

Watch the slow wave that forms on the interface between the oil and water layers. In contrast, see how the top surface of the oil layer is completely still and not showing any wavy motion. Link to youtube video: https://www.youtube.com/watch?v=Wr49Hk0YmE0.

This video shows internal waves following a density current released from a central location in the bowl. The bowl is filled with freshwater. The mold in the center of the bowl serves as a way to release salt water. Watch the waves forming at the interface of the 2 layers once the turbulence of the density current dies down.
Link to second video: https://www.youtube.com/watch?v=HNHQrmIFd4Y.

Thinking More

1) Can you estimate the speed of the wave in your bowl?
2) Can you estimate the wave period of the wave in your bowl?
3) What do you think controls the wave period and speed of the wave in your bowl?

During the experiment, you may have noticed that the interface between the water and oil supported very large amplitude disturbances while the interface between the water and the surface had relatively small amplitude disturbances. A similar phenomenon happens in the ocean-- internal waves with amplitudes of 10's-100's of meters have a very small surface signature (10's of centimeters). What is the amplitude of the largest wave in Figure 1? How does this compare to the height of your home?

More information: Watch this awesome documentary about famous oceanography Walter Munk and his studies of waves on the ocean's surface.

**Many of these activities were inspired by Mirjam Glesser's Kitchen Oceanography projects found at https://mirjamglessmer.com/kitchen-oceanography/. This lab also contains material from Oregon State University's Fluid Earth class (OAS530).*