Sound Travels SOFAR in the Ocean

Underwater sound is used by many marine animals to sense their environment, communicate, and find food. Underwater sound is also used by marine scientists to measure ocean depth, track objects in the water, and determine ocean temperature changes. Transmission of sound in the ocean is affected by water temperature, pressure, and salinity. The normal variations in these properties with depth combine to produce a minimum sound speed at a depth of about 1,000 meters. At this depth, sound travels relatively slowly compared to the speed of sound through water at greater and lesser depths. The depth zone centered around this level of minimum sound speed is called the **Deep Sound Channel**, and is also known as the **SOFAR** (sound fixing and ranging) **Channel**. Sound entering this layer tends to be trapped and channeled along it, making this layer extremely efficient in transmitting sound for thousands of kilometers through the ocean.

Objectives

After completing this activity, you should be able to:

- Describe the effect of temperature, pressure, and salinity on the speed of sound in seawater.
- Describe the long range transmission of sound in the Deep Sound Channel.

Investigations

1. On average, sound travels through seawater at about 1,500 meters per second, or more than four times faster than through air. The speed of sound is not constant throughout the ocean, but varies with differences in water temperature, pressure, and salinity. The speed of sound increases with increasing temperature, pressure, or salinity. The speed of sound decreases as temperature, pressure, or salinity (increases) (decreases).
2. On the three graphs provided, plot the temperatures (°C), water pressures (atmospheres), and sound speeds (m/s) respectively as reported in the table. In each graph, draw solid lines through plotted data points to produce temperature, pressure, and sound speed profiles. In the upper most 1,000 m of the ocean, where vertical temperature changes can be relatively large, variations in the speed of sound will be dominated by temperature effects, and to a much lesser extent by salinity and pressure variations. Because of the warmer water above 1,000 m, sound speeds above 1,000 m are relatively (faster) (slower) than those at 1,000 m.
3. Below the uppermost 1,000 m of the ocean, there is typically little variation of temperature or salinity with depth. Pressure changes become the prime cause of sound speed variability. Because of the higher pressures below 1,000 m, with little change in temperature and salinity, sound speeds at depths below 1,000 m (increase) (decrease) with increasing depth.
4. Sound speeds tend to increase upward from the 1,000 m depth due to the warmer water above this level and increase downward from the 1,000 m depth due to the increase of water pressure below this level. Consequently there is a layer of minimum sound speed, called the Deep Sound Channel (DSC), whose center is found in most ocean basins at (0 m) (1,000 m) (4,000 m).
5. Sound waves originating from a source within the DSC, and moving in any direction other than horizontally, will experience changes in their speeds. They will also be bent, or refracted unless they are moving vertically. The result is that sound waves bend, or refract, away from regions of faster sound speed and toward regions of (faster) (slower) sound speed.

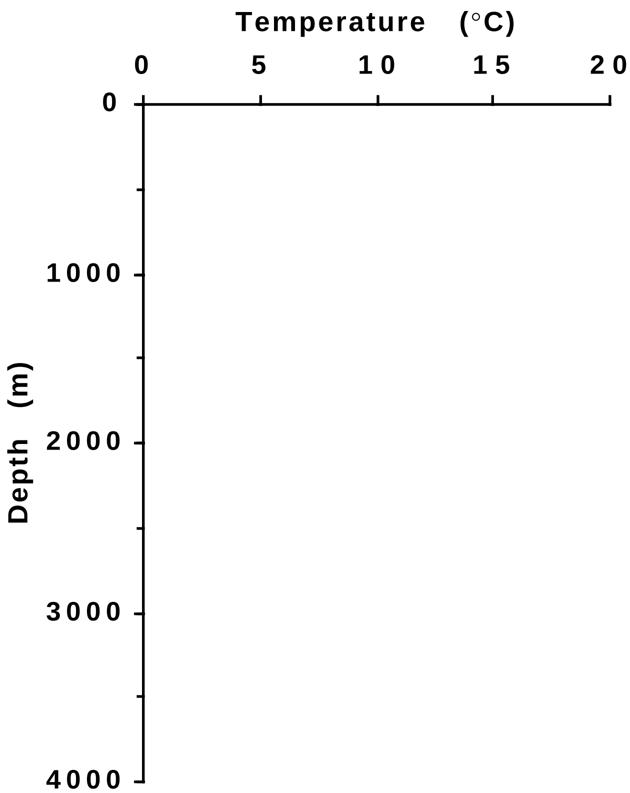
6. A downward moving sound wave approaching the lower boundary of the DSC at a low angle is bent back upward because of the increasing sound speed caused by increasing pressure. An upward moving sound wave approaching the upper boundary of the DSC at a low angle is bent back downward because of the increasing sound speed caused by increasing (temperature) (pressure).
7. The DSC is extremely efficient in transmitting sound, sometimes for thousands of kilometers. Thus, it may be used by people and marine animals to listen to the sounds of distant earthquakes, whales, ships, and submarines. Underwater mountains and the continents, however, may block sound traveling in the DSC. So, whales near the southern tip of South America might be able to hear other whales in the North Atlantic near Nigeria and in the North Pacific near Hawaii. But the whales near Hawaii would probably not be able to hear the whales near (South America) (Nigeria).
8. Scientists are attempting to employ the DSC to determine if the temperature of the ocean is changing over time and, if so, whether or not it is in response to variations in global climate. Data are collected by regularly putting a loud sound into the DSC and measuring the time required for the sound wave to reach various remote listening stations. If the region of the ocean through which the sound travels is warming, then over the next decade or so, the sound speed should (increase) (decrease).

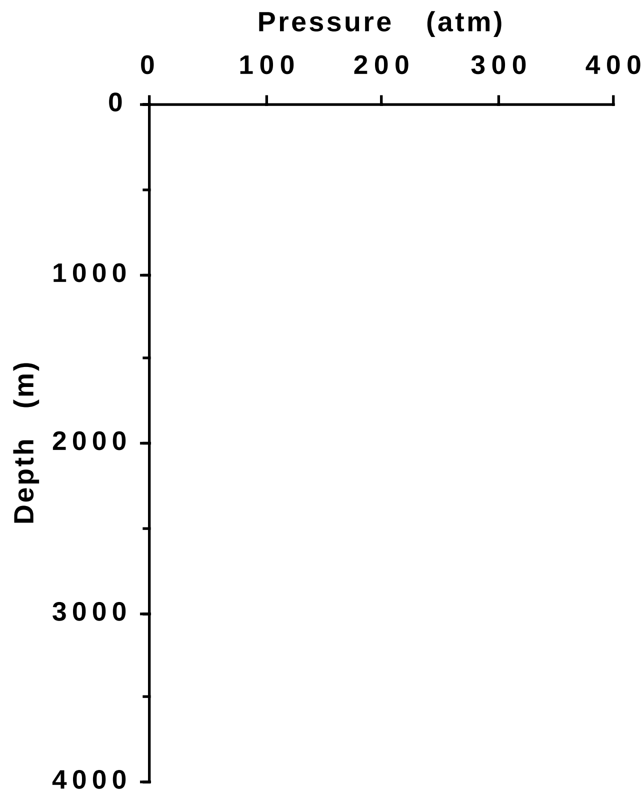
Source

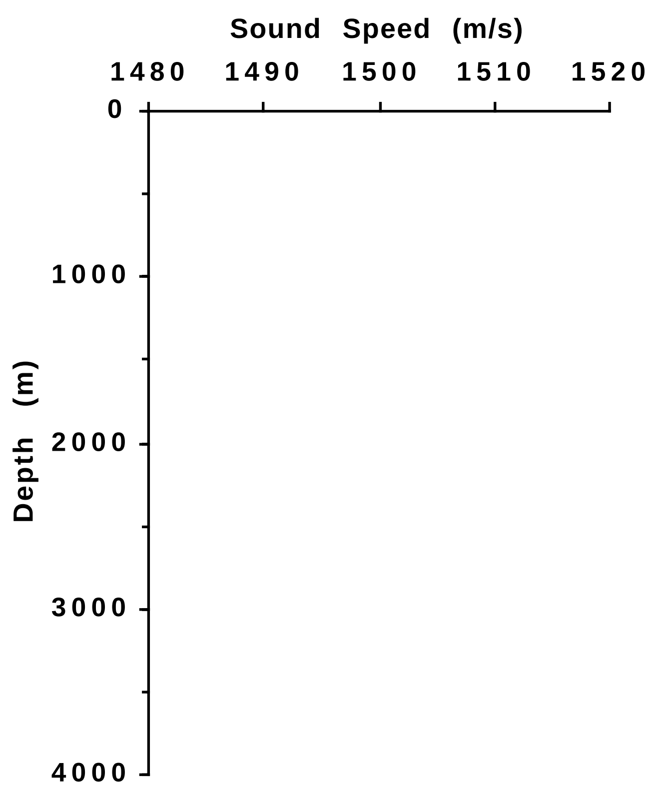
The Maury Project, American Meteorological Society

Depth Table

Depth (m)	0	500	1000	1500	2000	3000	4000
Temperature (° C)	18	12	4	3	2	2	2
Water Pressure (atm)	0	50	100	150	200	300	400
Sound Speed (m/s)	1498	1486	1482	1484	1488	1502	1516


Temperature (°C)
0 5 10 15 20
Depth (m)
0
1000
2000
3000
4000


Pressure (atm)
0 100 200 300 400
Depth (m)
0
1000
2000
3000
4000


Sound Speed (m/s)
1480 1490 1500 1510 1520
Depth (m)
0
1000
2000
3000
4000