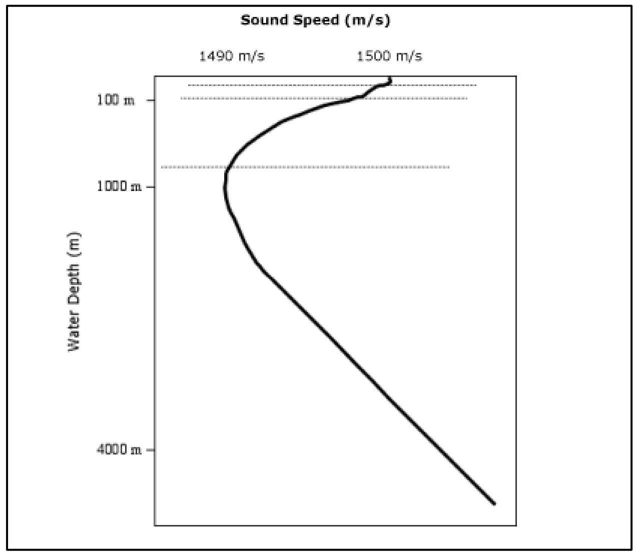
Estimation of the Ocean Sound Velocity Profile

By Mike Kalmbach

This article leads to an estimation of ocean sound velocity, from the end of a surface cast down to full ocean depth. Without further ado …

The ocean has three primary 3 sound velocity zones.

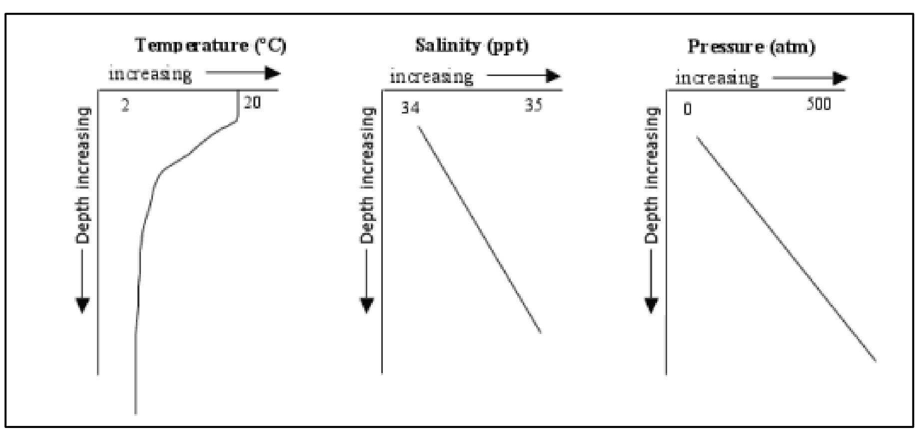
- **Surface / Seasonal:**
  Surface: 0 to 100 m
  Seasonal: 100 to 200 m
  A highly variable layer.
- **Main thermocline:**
  Decreasing SV to 1000 meters due primarily to decreasing temperature.
- **Deep isothermal layer:**
  Below 1000 meters. Water temperature approaches two degrees C, and sound speed increases only due to pressure.



Sound speed is at a minimum at roughly 1000 m of water. (Note: This creates the channel allowing sound to travel great distances in the ocean.)

Sound velocity is a function of temperature, salinity and pressure (depth).

- **Temperature** varies greatly from the surface to the end of the main thermocline then steadies out.
- **Salinity** is measured in Practical Salinity Units (PSU). 1 PSU = approximately 1 part per thousand. Salinity changes from 34 near the surface to 35 near the bottom.
- **Pressure** is typically measured in decibars. One decibar pressure increase corresponds to 1 meter of water depth.



The rates of sound velocity increase with increasing temperature, salinity and pressure:

T: +1 degree C = +4.0 m/sec
S: +1 PSU = +1.4 m/sec
P: +1 km = +17 m/sec

A simplified formula to calculate velocity as a function of temperature, salinity and pressure:

To look at the temperature and salinity effects, consider Wilson's formula for sound velocity (simplified):

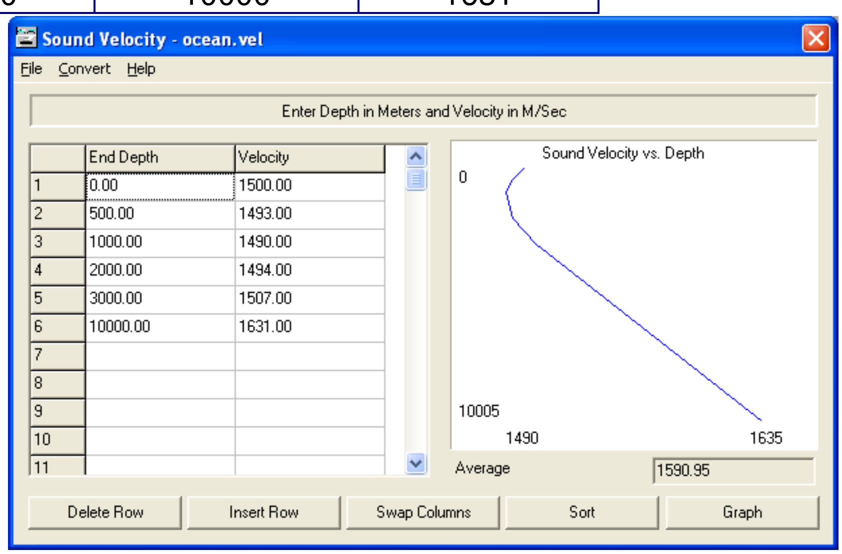
$$c = 1449 + 4.6T - 0.055T^2 + 0.0003T^3 + (1.39 - 0.012T)(S - 35) + 0.017Z$$

where c = sound velocity (ms^{-1})
T = Temperature (°C)
S = Salinity
Z = Depth (dbars) [*Not* measured up in this case!]

The goal here is to estimate SV beyond the reach of a surface cast. The problem is we don't know the water temperature and temperature has a large effect on velocity. That's where estimation comes in.

The table below gives calculations of SV using approximate temperature and salinity values, providing a reasonable profile to full ocean depth.

T (deg C)	S (PSU)	Z (dbar)	SV (m/sec)
9	34.0	500	1493
6	34.1	1000	1490
3	34.2	2000	1494
2	34.3	3000	1507
2	35.0	10000	1631



Detailed equations for calculating pressure. The estimation is 1 meter = 1 decibar.

$$D = C_1 P + C_2 P^2 + C_3 P^3 + C_4 P^4$$

$$\langle g \rangle = g(\theta) + \frac{1}{2} \gamma P$$

Parameter	**Value**	**Units**
P	Measured gauge pressure	[decibar]
C_1	9.72659	[J/kg/decibar]
C_2	-2.2512 E-5	[J/kg/decibar^2]
C_3	2.279 E-10	[J/kg/decibar^3]
C_4	-1.82 E-15	[J/kg/decibar^4]
$g(\theta)$	Local gravity at latitude θ	[m/s^2] - see formula below
γ	2.226 E-6	[m/s^2/decibar]

The standard ocean depth formula is derived using a water density profile at a salinity S = 35, a temperature T = 0 [deg C], and a compressibility correction of second order.

Latitude θ	**0 [deg]**	**30 [deg]**	**45 [deg]**	**60 [deg]**	**90 [deg]**
Gravity	9.780318	9.793240	9.806190	9.819169	9.832177

Pressure/Latitude	**θ = 0 [deg]**	**θ = 30 [deg]**	**θ = 45 [deg]**	**θ = 60 [deg]**
500 [decibar]	496.65 [m]	496.00	495.34	494.69
1000	992.12	990.81	989.50	988.19
2000	1979.55	1976.94	1974.33	1971.72
5000	4915.04	4908.56	4902.08	4895.60
10000	9725.47	9712.65	9699.84	9687.03

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