# Documentation of Oceanographic and Acoustic Models

## 1 Seawater Attenuation Coefficient (`alphaAinslieMcColm`)

**Description:** Computes the acoustic attenuation coefficient $\alpha$ in seawater (in dB/km) as a function of frequency and oceanographic parameters.

**Function Signature:**

```
alphaAinslieMcColm(f, T, S, D, pH)
```

**Arguments:**

- $f$: Frequency in Hz
- $T$: Temperature in degrees Celsius (°C)
- $S$: Salinity in PSU (Practical Salinity Units)
- $D$: Depth in meters
- pH: Acidity level

**Returns:**

- $\alpha$: Attenuation coefficient in dB/km

**Model Components:**

- **Boric acid contribution:**

$$A_1 = 0.106 \cdot \exp\left(\frac{\text{pH} - 8}{0.56}\right), \quad f_1 = 0.78\sqrt{\frac{S}{35}} \exp\left(\frac{T}{26}\right)$$

$$\alpha_{\text{boric}} = \frac{A_1 f_1 f^2}{f^2 + f_1^2}$$

- **Magnesium sulfate contribution:**

$$A_2 = 0.52\left(\frac{S}{35}\right)\left(1 + \frac{T}{43}\right), \quad f_2 = 42\exp\left(\frac{T}{17}\right), \quad P_2 = \exp\left(-\frac{D}{6000}\right)$$

$$\alpha_{\text{MgSO}_4} = \frac{A_2 P_2 f_2 f^2}{f^2 + f_2^2}$$

- **Pure water contribution:**

$$A_3 = 0.00049\exp\left(-\left(\frac{T}{27} + \frac{D}{17000}\right)\right), \quad \alpha_{\text{H}_2\text{O}} = A_3 f^2$$

**Total attenuation:**

$$\alpha = \alpha_{\text{boric}} + \alpha_{\text{MgSO}_4} + \alpha_{\text{H}_2\text{O}}$$

**Reference:** M. A. Ainslie and J. G. McColm, "A simplified formula for viscous and chemical absorption in sea water," *J. Acoust. Soc. Am.*, vol. 103, no. 3, pp. 1671–1672, 1998. `https://doi.org/10.1121/1.421258`

## 2 Meridional Arc Length (`ArcLengthOfMeridian`)

**Description:** Computes the distance from the equator to latitude $\phi$ (in radians) using the WGS84 ellipsoid model.

**Function Signature:**

```
ArcLengthOfMeridian(phi)
```

**Returns:**

- Distance (in meters) from the equator to latitude $\phi$

**Model:**
Let $a = 6378137.0$ m, $b = 6356752.314$ m, and $n = \frac{a-b}{a+b}$. Then:

$$M(\phi) = \alpha\phi + \beta\sin(2\phi) + \gamma\sin(4\phi) + \delta\sin(6\phi) + \epsilon\sin(8\phi)$$

with:

$$\alpha = \frac{1}{2}(a+b)\left(1 + \frac{n^2}{4}(1 + \frac{n^2}{16})\right)$$

$$\beta = -\frac{3}{2}n\left(1 + \frac{3}{4}n^2\left(1 - \frac{n^2}{6}\right)\right)$$

$$\gamma = \frac{15}{16}n^2\left(1 - \frac{1}{2}n^2\right)$$

$$\delta = -\frac{35}{48}n^3\left(1 + \frac{9}{16}n^2\right), \quad \epsilon = \frac{315}{512}n^4$$

## 3 Convert Raw Depth to True Depth (`convert_true_depth`)

**Description:** Converts digitized sonar depth values to true physical depth in meters.

**Function Signature:**

```
convert_true_depth(depth, data; ping=1)
convert_true_depth(depth, Q; ping=1)
```

**Arguments:**

- `depth`: Raw depth (integer or float)
- `data`: Structure containing `Q[ping]` sample interval and sound velocity
- `Q`: Vector of sonar sample parameters
- `ping`: Ping index (default = 1)

**Computation:**

$$\text{true\_depth} = \text{depth} \times (0.5 \times \text{sampleInterval} \times \text{soundVelocity})$$

## 4 Speed of Sound in Seawater (`velocityUNESCO`)

**Description:** Computes the speed of sound in seawater using the UNESCO 1995 polynomial formulation.

**Function Signature:**

```
velocityUNESCO(T, S, D; pH=nothing, f=nothing)
```

**Arguments:**

- $T$: Temperature in ˚C
- $S$: Salinity in PSU
- $D$: Depth in meters (used to estimate pressure)

**Returns:**

- $c_s$: Speed of sound in m/s

**Computation Steps:**

1. Convert depth $D$ to pressure $P$ in bar:

$$P = 1.013 + 10^{-5} \cdot (1023.6 \cdot 9.80665 \cdot D)$$

2. Evaluate temperature-dependent polynomials:

$$C_w = C_0(T) + C_1(T)P + C_2(T)P^2 + C_3(T)P^3$$

$$A = A_0(T) + A_1(T)P + A_2(T)P^2 + A_3(T)P^3$$

$$B = B_{00} + B_{01}T + (B_{10} + B_{11}T)P$$

$$D_f = D_{00} + D_{10}P$$

3. Compute final sound speed:

$$c_s = C_w + AS + BS^{3/2} + D_f S^2$$

**Reference:** G.S.K. Wong and S. Zhu, "Speed of sound in seawater as a function of salinity, temperature and pressure," *J. Acoust. Soc. Am.*, vol. 97, no. 3, pp. 1732–1736, 1995.