Stability in the Ocean

In the atmosphere, we were able to use potential temperature as a yardstick anywhere in the atmosphere (referenced to 1000mb).

But, no single reference pressure is satisfactory in all cases in the ocean.

- Complicated non-linear equation of state for sea water
- Two water masses as an example:
  - North Atlantic Deep Water (3°C, 34.96 PSU) has a greater potential density (density referenced to temperature at surface pressure) than Antarctic Bottom Water (-2 to -0.4 ^{o}C, 34.66 PSU)
  - NADW is usually found <u>above</u> ABW
  - Temp, salinity variations with compressibility leads to "in situ" density of ABW being greater than NADW.

Seek a stability parameter from empirical data

Stability in the Ocean

- Stability parameter (E)

$$E = -\frac{1}{\rho_{fluid}}\left(\underbrace{\frac{\partial \rho_{fluid}}{\partial S}}_{\mathbf{A}}\underbrace{\frac{\partial S_{fluid}}{\partial z}}_{\mathbf{B}} + \underbrace{\frac{\partial \rho_{fluid}}{\partial T}}_{\mathbf{C}}\underbrace{\left(\frac{\partial T_{fluid}}{\partial z} + \underbrace{\Gamma_{parcel}}_{\mathbf{e}}\right)}_{\mathbf{D}}\right) m^{-1}$$

  - A: $\frac{\partial \rho}{\partial S} > 0$
  - B: term can change sign
  - C: $\frac{\partial \rho}{\partial T} < 0$
  - D: term can change sign
  - e: Γ = 0.1°C/km; i.e. constant

Stability in the Ocean

- Just like in the atmosphere, there are three possible scenarios:
  - $E > 0$ Stable
  - $E = 0$ Neutral
  - $E < 0$ Unstable

- Examples
  - Salty water over less salty water
    - Assume C, D & e are ignored
  - Less salty over salty water
  - Warm over cold water
    - Assume A & B are ignored
  - Cold over warm water

Stability in the Ocean

- Recall the equation of state for sea water

$$\rho \approx \rho_0(1-\alpha_T(T-T_0)+\beta_s(S-S_0)+K(p-p_0))$$

- By neglecting pressure and differentiating wrt z, we can define a stability parameter (assuming no pressure variations in a relatively small range)

$$E=\alpha_T\frac{gT\alpha_T}{c_p}-\frac{1}{\rho}\frac{\partial\rho}{\partial z}\approx-\frac{1}{\rho}\frac{\partial\rho}{\partial z}$$

Ocean Stability = Balance between the density gradient and a non-linear factor combining temperature gradient, gravity and specific heat, **<u>but can be approximated over a small area using the density gradient</u>**