Density of Seawater

Equation of State: $\rho = \rho(T, S, p)$

T = Temperature

- units: °C
- ocean range: -2°C to 30°C

Potential Temperature

- if we raise water without changing heat content
  - ==> pressure decreases
  - ==> temperature decreases
- convenient to use *potential temperature* θ
  - $\theta = T$ water would have at surface
  - $\theta < T$
- difference pretty small....
  - $\theta \approx T - .5$°C for 5 km
  - BUT important effect for deep water
- Accurate formula for θ can be found in Gill
- My approx formula: $\theta = T - Ap - Bp^2$
  - $A = .04(1 + .185T + .035[S - 35])$
  - $B = .0075(1 - T/30)$
  - T in deg C, p in "dynamic km"
  - For $30 \leq S \leq 40$, $-2 \leq T \leq 30$, $p \leq 6$ km,
  - $\theta - T$ good to about 6%
    - (except for some shallow values w/ tiny $\theta - T$)

S = Salinity = mass of salt (gm) dissolved in 1 kg seawater

units: ppt or psu

kind of salt the same everywhere in sea

(ocean mixes up in time it takes to dissolve)

55% chlorine

31% sodium

8% sulphate

4% magnesium

1% potassium

S can go from 0 (coast) to about 40psu (Red Sea)

BUT 90% is between 34 and 35 psu

P = pressure = force/area

for ocean, use *hydrostatic* approximation:

pressure = weight of fluid above

MKS units: Newton/m^2 = Pascal

atmospheric weight $\approx 10^5$ N/m^2 $\equiv$ 1 bar

ocean weight $\approx$ 1 bar every 10 m depth of water

==> ocean depth in dbar $\approx$ depth in meters

ocean pressure measured relative to surface (ignore atm)

Rules About Density

1) Density hardly changes

$\rho \approx 1000\text{kg/m}^3 = 1\ \text{gm/cm}^3$

2) Density increases when pressure increases

z	ρ
0	1028.1
1000	1032.8
4000	1046.4

$(S = 35\text{psu},\ T = 0°\text{C})$

3) Density increases when salinity increases

S	ρ
0	999.8
35	1028.1

$(T = 0,\ z = 0)$

4) Density decreases as T increases

5) BUT the *amount* it changes depends on T,p

colder water: *less* sensitive to T

deeper water: *more* sensitive to T

6) Variations due to T and S are small but **very important**

Accurate formula for $\rho(T, S, p)$ can be found in Gill appendix

My Approximate Density Formula:

$$\rho = C(p) + \beta(p)S - \alpha(T,p)T - \gamma(T,p)(35 - S)T$$

units: p in "km", S in psu, T in ° C

$C = 999.83 + 5.053p - .048p^2$

$\beta = .808 - .0085p$

$\alpha = .0708(1 + .351p + .068(1 - .0683p)T)$

$\gamma = .003(1 - .059p - .012(1 - .064p)T)$

For $30 \le S \le 40$, $-2 \le T \le 30$, $p \le 6$ km:

good to .16 kg/m^3

For $0 \le S \le 40$, good to .3 kg/m^3

cabelling

nonlinear T dependence, so mixing changes density

thermobaric effects

α depends on p, so

density ordering depends on depth

Potential Density

sigma-t: $\sigma_t = \rho(T, S, 0) - 1000$

potential density: $\rho(\theta, S, 0)$

$\sigma_\theta = \rho(\theta, S, 0) - 1000$

$\sigma_1 = \rho(\theta, S, 1\text{km}) - 1000$