Assignment 1

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1 Problem 1

Install python 2.7. on your computer and become familiar with the it. For Linux users it should be already installed. Make sure you know how to install packages which might be not installed, but needed in later assignments. For windows users we suggest installing Anaconda or Miniconda which already include a lot of useful packages, i.e. `numpy`, `matplotlib` and `netCDF4`. In addition, it comes with a nice editor called spyder. You should be able to:

-use while loops and if clauses

-create an n-dimensional array and fill it with values you want

-define and use a function

-be able to do 1-D and 2-D plots

-read data from an ASCII-file (.txt)

2 Problem 2

(a) Consider a stratified ocean of depth $H = 1000$m with a density profile $\rho(z)$ of arbitrary form. Derive a formula for the pressure $p(z)$ starting from the hydrostatic approximation:

$$\frac{\partial p}{\partial z} = -\rho(z)g. \tag{1}$$

(b) Assume a linear density profile of the form

$$\rho(z) = \rho_0 - A \cdot z, \tag{2}$$

and write down $p(z)$ for this case. A is a constant.

(c) Write a python function which can compute the pressure profile of an arbitrary density profile. The function could look like:

```
compute_pressure(z,density,p_atm)
```

In python, create an array for depth and for corresponding density using the density profile from eq.(2). Use your written function to compute (1) the pressure profiles from (b) with $\rho_0 = 1000\text{kg/m}^3$ and $A = 0.03\text{kg/m}^4$ and (2) the pressure profile from a measured density profile you can download at `https://www.io-warnemuende.de/ml-teaching.html`. The data has the format: depth [m], temperature [°C] and density [kg/m^3]. Note that $z = 0$ is at the surface of the ocean and $p(z = 0) = p_{atm}$ with $p_{atm} = 1000$hPa. The data comes in the order: depth, temperature and density anomaly which is simply the density minus 1000 kg/m^3.

3 Problem 3

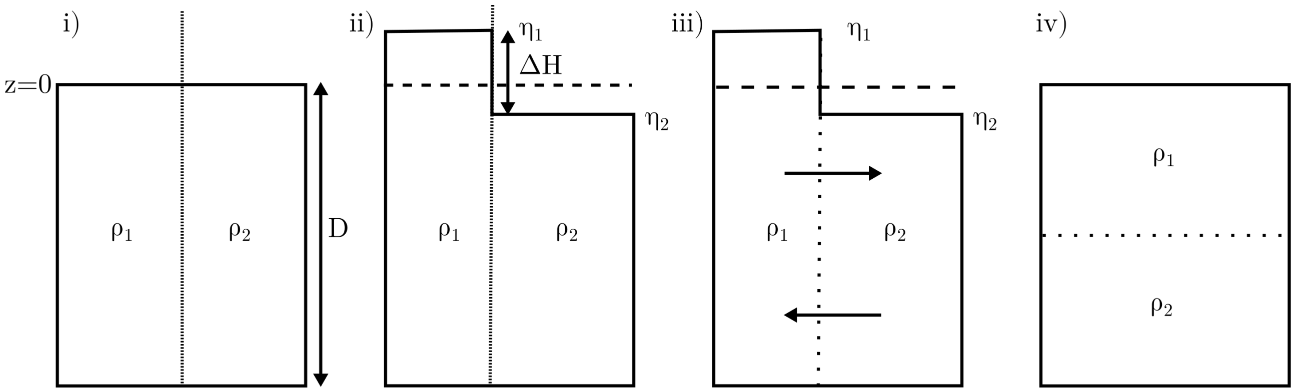

Figure 1: Schematic of the process of stratification which shows the different time scales of sea level and density related pressure gradients.

In this problem we investigate the different roles of sea level and density related pressure gradients. Both act on different time scales. Processes related to sea level related pressure differences are about 100 times faster then those related to density related pressure differences. Consider a gedankenexperiment of two water bodies of densities ρ_1 and ρ_2 with $\rho_1 < \rho_2$ as shown in figure 1 i). Both bodies are separated by a movable barrier, denoted by the dotted lines in i) and ii). Since mixing processes have smaller timescales than the density related pressure differences we neglect mixing in the following.

(a) Write down the corresponding pressure functions of depth for both water columns and compute the vertical integrated pressure difference $\Delta P = P_1 - P_2$ with P_i being the vertically integrated pressure.

$$P_i = \int_D^0 p_i(z)\, dz, \tag{3}$$

with D being the water depth. Assume there is no atmospheric pressure.

(b) Since the pressure difference is not zero, there must a pressure gradient. This pressure gradient causes the water columns to adjust as seen in ii) so that the integrated pressure gradient vanishes. Compute the pressure profiles for ii) and compute the height difference $\Delta H = \eta_1 - \eta_2$ between the two water columns by integrating both water columns vertically:

$$P_1 = \int_D^{\eta_1} p_1(z)\, dz, \qquad P_2 = \int_D^{\eta_2} p_2(z)\, dz \tag{4}$$

For simplicity we assume that $\eta_2 = -\eta_1$. Note that here the boundary conditions $p_i(z = 0) = 0$ are shifted to $p_1(\eta_1) = 0$ and $p_2(\eta_2) = 0$. Use the following numbers: $D = -1000\text{m}$, $\rho_1 = 1000\text{kg/m}^3$, $\rho_2 = 1030\text{kg/m}^3$.

(c) The integrated pressure is now equal in both water columns, but both pressure profiles differ as you saw in (b). Plot both pressure profiles and the pressure difference as a function of z from the bottom to the surface of the smaller water column. You can and should use/adjust your code from Problem 2. Use the numbers from (b)

(d) In our simple experiment there is a water level step which would not occur in nature. This results in a singularity in the pressure gradient. If one assumes some distance Δx between the two water bodies, one can solve this infinity problem. What form would the resulting velocity profile caused by the pressure gradient have if we take out the barrier? The arrows in iii) give you already a hint. Can you approximate the time needed for the stratification process from iii) to iv)? Assume Δx by a number you can choose and give insight of your choice.