Spring 2026 EEPS1820
Homework 4, due Mar 6, 11:59PM

COVERING: Vallis 4, 5; Oceananigans.jl; Jupyter Notebooks

Setting up your computer

Again we will be using julia, a computer language similar to python and matlab but much faster (like C++ or FORTRAN). We will also be using jupyter notebooks, to make it easy to visualize, annotate and share julia code and outputs.

Getting the jupyter notebook working

Finding the PS04.ipynb Notebook

The jupyter notebook is here. You can download it directly and then save it for editing. You will be editing the PS04 jupyter notebook to complete your homework assignment, but not sending it back into the class repository.

Opening the PS04.ipynb Notebook

You can open jupyter however you like and then open the notebook you just downloaded, or you can go to the directory where it is at the command line and type

```
>> jupyter notebook PS04.ipynb
```

Execute the steps in the notebook one at a time, by hitting Shift-Return or clicking on the play button at the top. Note the output that comes back from each step! When you reach the end of the notebook, you will be asked to upload particular figures to canvas and explain them.

1 Describe the balance of the initial conditions

1.1 Initial buoyancy distribution

Write the initial buoyancy distribution as a function of x, y, z. It describes an initial front between dense and buoyant waters that penetrates the whole depth. There is also vertical stratification that is uniform. Hint: the buoyancy is piecewise linear in y.

1.2 Balance?

Is this initial condition in thermal wind balance? geostrophic balance?

1.3 Put it in balance

What could we do to make the flow in thermal wind balance without affecting the buoyancy distribution? Specify functions for u, v, w, b that would get this done.

Hint: Recall the following formula for Thermal Wind from Vallis:

$$f\frac{\partial v_g}{\partial z} = \frac{\partial b}{\partial x}, \qquad f\frac{\partial u_g}{\partial z} = -\frac{\partial b}{\partial y}. \qquad (3.38a,b)$$

Is this the only possibility for these functions? Could they be changed by a constant?

2 After the Movie

Execute the notebook down until it reads "End Tutorial". Open the movie that results and answer the following questions.

2.1 First 2 seconds of video

Examine the velocity shading in the lower left panel showing the cross-front velocity u. Explain the red & blue pattern in terms of along-front shear in the front. Is this shear geostrophic? Is this shear (approximately) oscillatory?

2.2 Last 3 seconds of video

The last 3 seconds of the video show growing baroclinic instabilities on the front. We haven't discussed these much yet, but they are a bit like unstable Rossby waves. Describe the baroclinic instabilities in terms of potential vorticity. They have relative vorticity (upper right panel). Does the initial conditions have PV? How do the instabilties affect the PV of the initial conditions?

2.3 Restart the video with no noise

Go up to where the initial noise ϵb is set. Change its value to 0. The original noise was to trigger the growth of the baroclinic instabilities, so setting this to zero will eliminate the instabilities and let us see the zonally-symmetric front adjust. Move the output files (.jld2, .mp4, .png) to a subdirectory, restart the kernel of the notebook, and run the whole notebook with zero noise.

2.3.1 Are the oscillations for the first 2 seconds still there? Why?

2.3.2 Instead of the unstable front, something else happens. Describe it and the balances it implies.

2.3.3 Compare this final flow to your answer to problem 1.3.

2.3.4 Can you explain why the net momentum of the adjusted front is near zero?

3 Figures!

3.1 Upload the final 3D buoyancy volume plots in the noisy and no-noise cases.