EAPS 53600: Intro to General Circulation of the Atmosphere
Lab 03: Waves in a 1-layer shallow-water model

In class we have shown theoretically how a single shallow layer of fluid of constant density can exhibit various types of waves. Specifically, we have considered this fluid 1) without background rotation ($f = 0$); 2) with constant background rotation ($f = f_0$); and 3) with varying background rotation ($f = f_0 + \beta y$).

These waves are also found in stratified fluids (with variable density), such as our atmosphere and ocean. In such cases, the waves are conceptually identical, but the math is a bit more complex (including accounting for vertical scale/propagation).

Theory is not truth... it's a hypothesis that should be tested! In this lab, you will use a computer model of a 1-layer shallow fluid to develop and test hypotheses based on this bed of theory.

Code basics:

- Two different codes for a numerical one-layer shallow water model are provided on the course website: one in MATLAB and one in python. You may choose based on your own preference; the MATLAB code is a bit more user-friendly.
- First and foremost: try out the code yourself and see what happens! There are parameters at/near the top of the code that you can modify – take some time to see what these are and understand what they mean. *Pro tip: if something breaks and you can't fix it, download the original code and start again.*

Tasks:

1. Below are two scientific statements. For each statement: 1) Using the theoretical equations learned in class, rephrase the statement in the form of a specific hypothesis; 2) Design and describe a set of experiments to test the hypothesis; 3) Execute your experiments and make a single plot that quantitatively evaluates your hypothesis; 4) State your conclusions, including any surprising results you found (if any).
   (a) Non-rotating gravity waves move at different speeds for different fluid depths.
   (b) The energy of a Rossby wave will move differently at different latitudes.
2. The equator acts as a dynamical barrier (though not true physical barrier) for waves, called a **waveguide**. As a result, numerous types of waves can emerge simultaneously when a forcing is applied at or near the equator. These equatorial waves may be

modeled by setting up the shallow water as an **equatorial beta plane** – i.e. a beta plane with $f_0 = 0$ (for the Northern Hemisphere). Set up your model as an equatorial beta plane initialized with a localized height perturbation on the equator.

(a) Based on the theory, propose a hypothesis: what types of wave responses will there be and how will they move?

(b) Design and execute an experiment to test your hypothesis above. Describe the evolution of the wave responses, including images from your experiment as evidence.

(c) Based on the theory, propose a hypothesis: how will the wave response change with increasing equatorial deformation radius, $L_{d,EQ} = \sqrt{\frac{c_{GW}}{\beta}}$?

(d) Design, execute, and analyze experiments to test your hypothesis above.

(Note: the steady response to a continuous near-equatorial forcing – a height perturbation in shallow water, analogous to a heating source in the atmosphere – has an analytical solution called the "Matsuno-Gill model"; see class notes.)