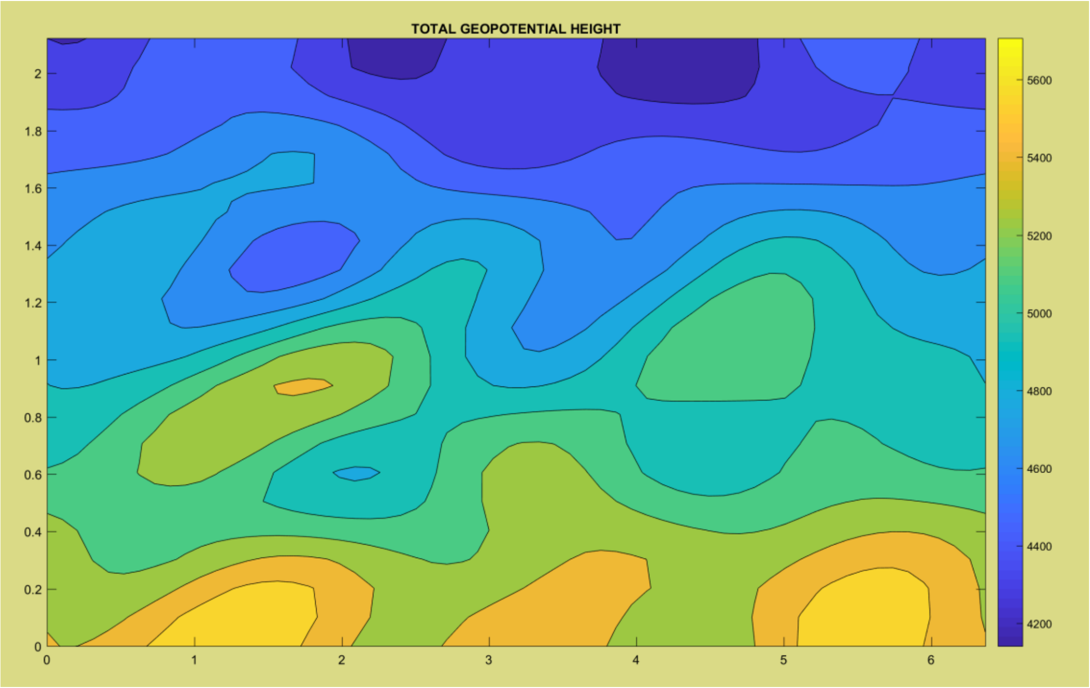
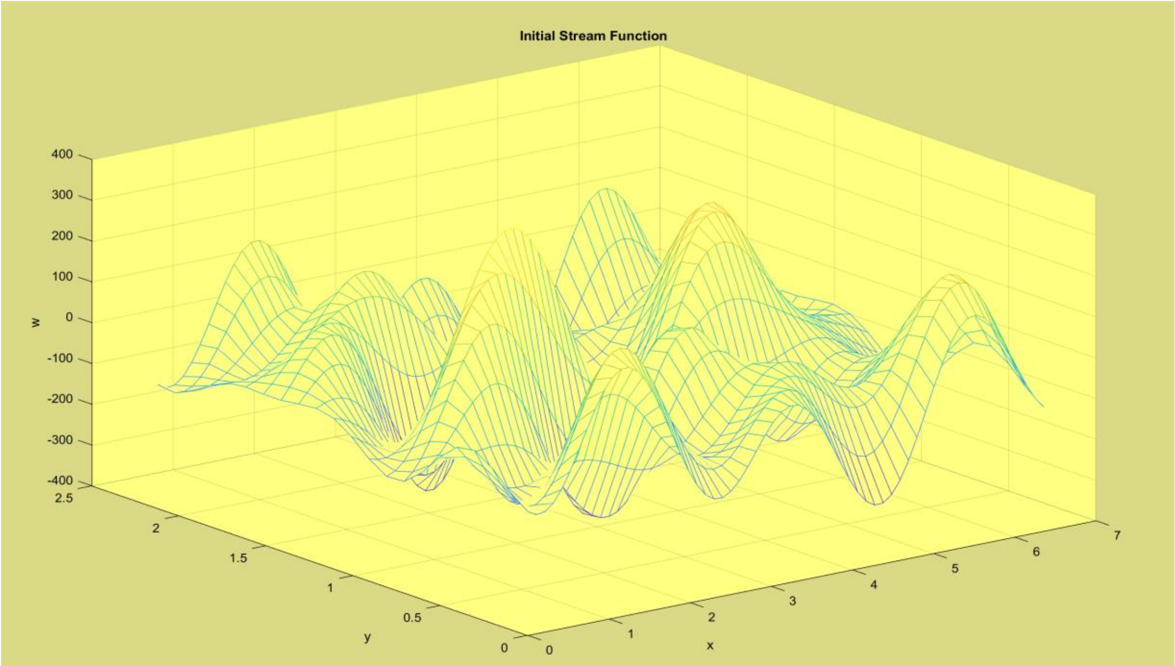
Barotropic Vorticity Equation

$$\frac{d}{dt}(\nabla^2 - F)\psi + \frac{g}{f}J(\psi, \nabla^2\psi) + \beta\frac{\partial}{\partial x}\psi = 0$$

- ψ is stream function, $\psi = \frac{g}{f}\Phi$, Φ=Geopotential Height
- g is gravity, f is Coriolis parameter: $2\Omega\sin(\text{latitude})$, Ω is planetary rotation rate
- F is a regional average flow

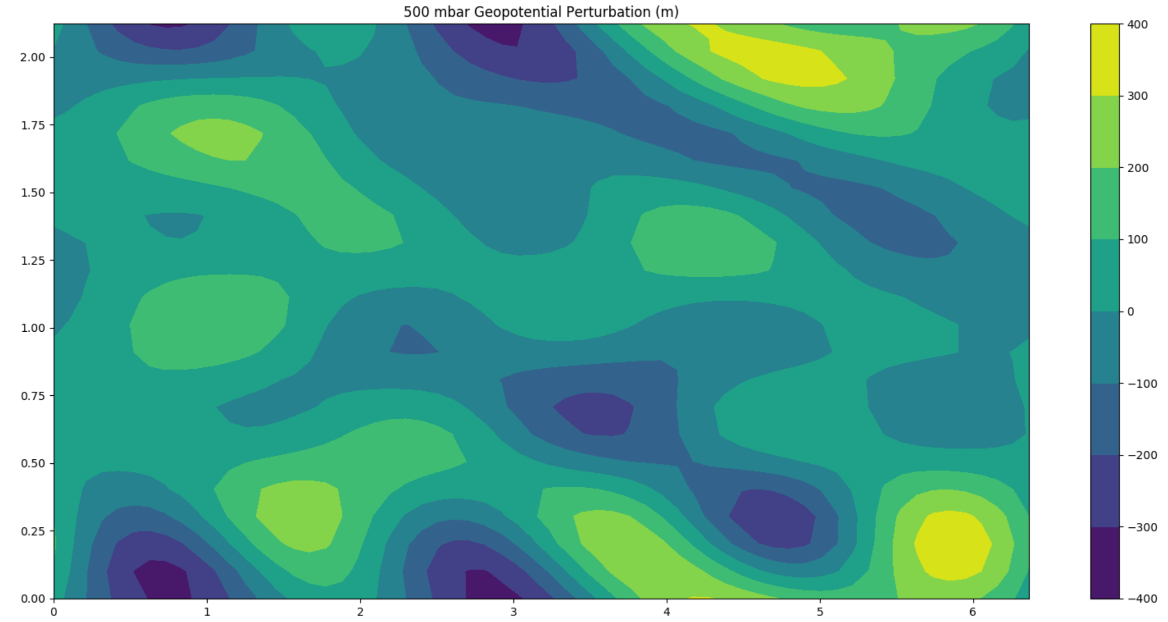
- $\beta = \frac{2\Omega\cos(\text{latitude})}{Radius\ of\ Earth}$
- $J(\psi, \nabla^2\psi)$ is the Arakawa Jacobian, $J(\psi, \nabla^2\psi) = \frac{\partial\psi}{\partial x}\frac{\partial(\nabla^2\psi)}{\partial y} - \frac{\partial\psi}{\partial y}\frac{\partial(\nabla^2\psi)}{\partial x}$





Solving the Equation

- Generate an initial field, i.e. Geopotential Height/Stream Function




```python
#set seed for same initial conditions every time
seed(a=2)

#randomize seed for different initial conditions
seed()


Z_0 = zeros((nx+1,ny+1));
 # Set the incoming values.
Nwavex = 3
Nwavey = 3
Nwaves = (2*Nwavex+1)*(2*Nwavey+1)


for kwave in range(-Nwavex,Nwavex+1):
    for lwave in range(-Nwavey,Nwavey+1):
        Amplitude = (2000.0*2*(random()-0.5)) / Nwaves
        phase= 2*pi*(random()-0.5)
        term = cos(2*pi*(kwave*(XX/xlen)+lwave*(YY/ylen)+phase))
        Z_0 = Z_0 + Amplitude*term
```

- Take derivatives using finite difference method
- Solve the equation
- End up with solving Helmholtz equation over and over
- Adaptation of Leapfrog and Spectral methods (want something that preserves energy)