Weather prediction model

$$\frac{\partial \zeta}{\partial t} = -\frac{\partial}{\partial x}\left[u(\zeta + f)\right] - \frac{\partial}{\partial y}\left[v(\zeta + f)\right]$$

$$\psi = \frac{g}{f_0}\Phi \qquad \zeta = \nabla^2 \psi \qquad u = -\frac{\partial \psi}{\partial y} \qquad v = \frac{\partial \psi}{\partial x}$$

$$\zeta_{i,j}^{n+1} = \zeta_{i,j}^{n-1} + 2\Delta t \left(\frac{\partial \zeta}{\partial t}\right)_{i,j}^{n}$$

$$\left(\frac{\partial \zeta}{\partial t}\right)_{i,j}^{n} = -\frac{\left[F_{i+1,j}^{n} - F_{i-1,j}^{n}\right]}{2\Delta x} - \frac{\left[G_{i,j+1}^{n} - G_{i,j-1}^{n}\right]}{2\Delta x}$$

$$f = 2\Omega \sin\theta \approx f_0 + \beta y \qquad F = u(\zeta + f) \quad G = v(\zeta + f)$$

Assignment

- What will the weather be next Tuesday?
  Make a 5-day weather forecast from Thursday using the non-divergent barotropic vorticity equation on a beta plane.

- Initialize with observed 500 hPa geopotential height
- Output predicted geopotential height, vorticity and u and v wind components.

- Choose a grid of nlon=64 and nlat = 16, with a 500 km spacing and a time step of 1 hour.
- Domain is cyclic in longitude, and bounded ($v = 0$) on the north and south boundaries.
- Choose boundary condition ψ=mean at N and S edges.

Model schematic

- Calculate streamfunction from geopotential
- Calculate vorticity from for streamfunction

1. Given vorticity, obtain streamfunction
2. Calculate *u* and *v* wind from streamfunction
3. Evaluate advection as voriticity flux diveregence
4. Predict evolution of vorticity … loop for 5 days

Code elements (suggested subroutines):

- Finite difference X and Y derivatives (e.g., fddxc, fddys)
- Finite difference Laplacian (e.g., fdlaps)
- Finite difference Poisson solver (invert Laplacian)

Suggested coding plan

- Start with stub, configure to run for 1 step

1. Read initial geopotental and get streamfunction
   - Compute vorticity
   - Compute u and v
   - Check the output is correct
2. Build Poisson solver subroutine (*most of the work today*)
   - Convince yourself that can recover the input streamfuction from your calculated vorticity.
3. Try more steps with the Rossby wave test
4. Try the real initial conditions

- *Optionally add drag and horizontal diffusion*

Possible starting point

- Code stub:
  ~dcn/ATOC7500/week07/ndbvmstub.f90
- And, a IDL plotting script:
  ~dcn/ATOC7500/week07/bplot.pro
- Also (same directory) a “test” initial conditions (z500test_64x16.txt), and the real initial conditions (z500inic_64x16.txt).