

**ATOC 7500: The Art of Climate and Environmental Modeling**  
**Week 4 Lab Assignment**  
**One-dimensional linear advection**

Advection is one of the most important aspects of geophysical fluid flow. The linear advection (the velocity  $u$  does not depend on the advected quantity,  $q$ ) equation in one dimension is:

$$\frac{\partial q}{\partial t} = -u \frac{\partial q}{\partial x}$$

Construct a finite difference model to test the dependence on the model accuracy on the details of the scheme. Test sensitivity of the model to:

- the Courant number (each of  $u$ ,  $\Delta x$ , and  $\Delta t$ )
- strength of time filter (zero is a good starting place)
- different shaped initial distributions of  $q$

In constructing your model, you must first choose appropriate model geometry (grid spacing, time step, etc.). You will also need to define appropriate experiments, and diagnostics that measure the error.

**Things to consider**

- What type of finite difference scheme?
- What are the boundary conditions?
- What output do you need?
- How can you measure errors?
- What is “truth”?

**Question for discussion and experiments:**

- 1) Does the scheme conserve mass?
- 2) Does the scheme conserve variance?
- 3) Is the system positive definite?
- 4) Do errors grow indefinitely?
- 5) Is an error in phase as much if a problem as an error in amplitude?
- 6) Are errors dependent on the shape you are advecting?
- 7) Can you separate the computation and physical modes?

Consider plotting “errors” as a function of time to help guide your discussion.

Extra question: Repeat experiments for the non-linear case. How are the results different?

$$\frac{\partial u}{\partial t} = -(u_0 + u) \frac{\partial u}{\partial x}$$

Please add discussion of these on the wiki, since there are answers that will depend on the various assumptions made in the model building and details of experiment construction. Remember to explain in the discussion how your results may be caused by these assumptions.