ATM 562 – Some potential final exam questions

Fall, 2018 – Fovell

A representative, rather than exhaustive, list. More questions concerning Chapter 8 may be added later.

1. I claim to have a finite difference scheme for solving the 1D wave equation that will converge on the true solution as Δt and Δx approach zero, with $\frac{\Delta t}{\Delta x}$ fixed. Discuss conceptually how would you verify my claim, without coding it and running a simulation. Define the requirements for convergence, define your terms, and explain your procedures.

2. Compare and contrast the upstream and leapfrog schemes for solving the 1D wave equation. What does each scheme do well, and do poorly, and why?

3. What is the computational mode in time, which schemes possess one and why, and how might it be manifested in a numerical solution? What can be done to suppress the computational mode?

4. Design a scheme that is centered in time but lacks a computational mode, and is not always absolutely unstable. Describe it. How does it avoid a computational mode?

5. Briefly define linear and nonlinear instability, and compare and contrast them.

6. Your simulation blew up. How would you determine whether linear or nonlinear instability was the cause?

7. Consider damping terms added to the model to control nonlinear instability. Your goal is to suppress $2\Delta x$ waves while limiting the damping applied to longer wavelengths. Will a zero-order damper accomplish this? Why or why not?

8. Consider this forward-time, center-space approximation for the 1D wave equation. Is it consistent with the differential equation $u_t + u_x = 0$?

$$\frac{u_j^{n+1} - u_j^n}{\Delta t} = -\frac{u_{j+1}^n - u_{j-1}^n}{2\Delta x}.$$

9. Can you show that this scheme is absolutely unstable? If it is unstable, how would you alter the scheme to make it stable?

$$\frac{u_j^{n+1} - u_j^{n-1}}{2\Delta t} = -u_j^n.$$

10. What is buoyancy pressure? What is dynamic pressure? Provide examples of how high and low buoyancy and dynamic pressure could be created.

11. Figure 1 shows the pressure perturbations, p', about a pool of cold air. Two areas of high perturbation pressure are identified as “X” and “Y”. For each location, and referring to buoyancy and dynamic pressures, discuss the most likely reason why $p' > 0$ and justify your answers.

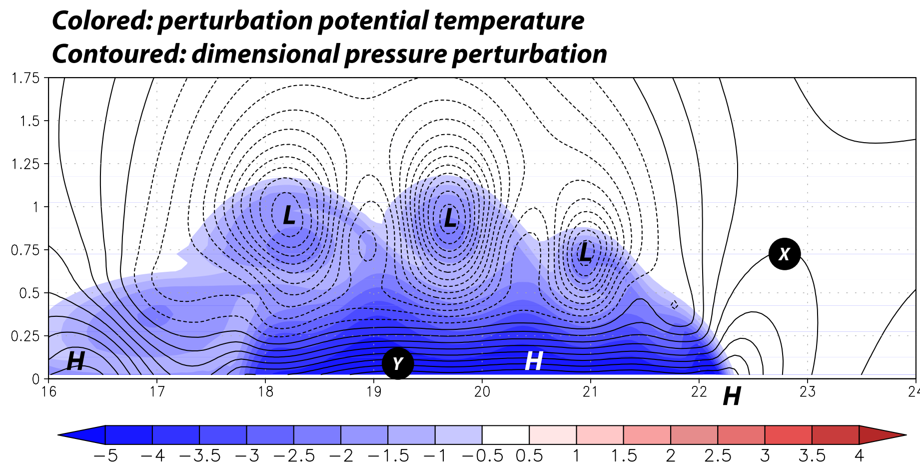

Figure 1: Pressure perturbations about a cold air pool.

12. Using your discussion relating to Figure 1, explain why a positively buoyant thermal cannot rise as quickly as the buoyancy force alone suggests it should.

13. Referring to Kessler’s autoconversion parameterization, briefly explain why this results in a simulated cloud producing surface rain too quickly.

14. Briefly explain the concept behind the Kessler equation for accretion of cloud water by raindrops, $\bar{\rho} k_2 q_c q_r^{7/8}$.