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METR 3133 – Mesoscale Meteorology
Fall 2016

Exam #3 Study Guide

Below are listed the principal topics, concepts, and capabilities for which you will be responsible on the first exam. The absence of a topic from this sheet does NOT imply that it will be absent from the exam!

Vector Equation of Motion (worth 5% of the test grade but you must write it down EXACTLY as shown, including vector symbols)

$$\frac{d\vec{V}}{dt} = -\frac{1}{\rho}\nabla p + \vec{g} - 2\vec{\Omega}\times\vec{V} + \nu\nabla^2\vec{V}$$

Hydrostatics, Vertical Coordinates, Reference Frames, Derivatives

1. Memorize, know the variables within, and be able to apply the equation of state (ideal gas law).
2. Understand the hydrostatic equation and be able to apply it.
3. Know the consequence of a hydrostatic atmosphere on the vertical acceleration.
4. Understand and be able to give examples of hydrostatic versus dynamic pressure.
5. Know how to derive and use the hypsometric equation.
6. Know the physical definition of geopotential and geopotential height.
7. Understand why the mean temperature of a layer in the atmosphere is related to the geopotential thickness.
8. Know the meaning of scale height and where it comes from.
9. Understand the concept of e-folding time or distance.
10. Understand pressure as a vertical coordinate and the advantages of it relative to height (z) as a vertical coordinate.
11. Know the difference between Lagrangian and Eulerian reference frames and be able to give physical examples of each.
12. Know the difference between a total and a local derivative.
13. Know the definition and physical meaning of flux, including mass flux and heat flux.
14. Know the definition and meaning of enthalpy and entropy.
15. Know how to utilize a Taylor series expansion and the consequences of neglecting terms in it.
16. Know how to expand a total derivative into the local derivative and fluid transport terms.
17. Know how the total derivative of a vector in a rotating reference frame leads to curvature and Coriolis terms (you do not need to memorize the equations).
18. Know how Newton's gravitational acceleration is combined with the centrifugal force to yield gravity.
19. Understand the basic principles of the equations of motion in spherical coordinates.
20. Be able to expand the vector equation of motion into its component equations.

Equations of Motion, Scale Analysis, Approximate Forms of Equations

1. Understand the concept of scale analysis and why we use it.
2. Know the characteristic length scales for synoptic scale flow.
3. Be able to apply scale analysis to the equations of motion and thermodynamics if the equations are provided to you.
4. Understand the geostrophic and hydrostatic equations in terms of approximations made by applying scale analysis.
5. Understand the difference between diagnostic and prognostic equations.
6. Be able to explain physically the ageostrophic wind.
7. Understand the relationship (no need to memorize the equation) between the ageostrophic wind and the acceleration of the wind.
8. Understand why we sometimes write the dependent variables as the sum of a basic or reference state and a perturbation on top of it.
9. Be able to apply the concept in item 8 above to any equation, remembering the products of perturbation quantities are small and can be neglected.

Conservation of Mass and Energy, First Law of Thermodynamics, Buoyancy and Static Stability

1. Understand the concept of mass conservation and the mass continuity equation.
2. Be able to distinguish among various forms of the mass continuity equation if provided with them (e.g., compressible, incompressible, anelastic).
3. Understand physically what approximation leads to an incompressible or anelastic atmosphere.
4. Be able to apply scale analysis to any form of the mass continuity equation.
5. Understand what is meant by the Boussinesq approximation.
6. Understand the concept of internal energy and know how it is defined and used.
7. Understand the concept of entropy and know how it is defined and used.
8. Understand the concept of enthalpy and know how it is defined and used.
9. Understand the concept of a thermodynamic system.
10. Understand total energy and how it is comprised of the internal and kinetic energies.
11. Understand the principle of energy conservation and diabatic heating.
12. Understand and be able to apply the concept of an adiabatic atmosphere.
13. Understand the concept of energy balance (kinetic and mechanical energy).
14. Be able to utilize the first law of thermodynamics in its two principal forms, understanding physically the meaning of each term.
15. Understand the concept of an isentropic atmosphere and how it relates to both entropy and potential temperature.
16. Know the difference between a diabatic and an adiabatic process.
17. Know how to apply scale analysis to the thermodynamic energy equation.
10. Know the meaning and origin of buoyancy and be able to utilize it in the vertical equation of motion.
18. Understand the buoyancy frequency and its importance in the atmosphere.
19. Understand and be able to apply the concept of static stability.
20. Understand how static stability relates to lapse rate.
21. Be able to explain the Brunt-Vaisalla frequency