METR 4133 – Dynamics III
Fall 2012

Final Exam Review Guide

Listed below are some of the topics, concepts, and capabilities for which you will be responsible on the final exam. The purpose of the guide is to help you review the materials. Please note that the absence of a topic from this sheet does not imply that it will be absent from the exam. The final exam is comprehensive covering all topics discussed from the beginning to the end of the semester.

Review of Dynamics and Thermodynamics

1. Understand the term "synoptic meteorology" and which events occur on the synoptic scale versus other scales.
2. Know the geostrophic and hydrostatic equations, be able to determine the geostrophic wind direction and speed given a height field, and know under what conditions geostrophic and hydrostatic approximations are valid.
3. Understand the ageostrophic wind and its relationship to the geostrophic and observed winds as well as divergence and vertical motion.
4. Know the direction of the ageostrophic wind relative to the acceleration vector.
5. Understand and be able to apply the thermal wind equations.
6. Understand the relationship between thickness and thermal wind.
7. Know the physical and mathematical differences between barotropic and baroclinic atmospheres.
8. Understand and be able to write down and apply the mass continuity equation in pressure and height coordinates – including both compressible and incompressible forms.
9. Understand and be able to apply the thermodynamic energy equation in pressure coordinates.
10. Understand the concept of vorticity and be able to explain physically, and work mathematically with, the vertical vorticity equation and all of its terms individually in height and pressure coordinates. You will not need to memorize the vorticity equations, though you must know the *expression* for vertical vorticity.

Quasi-Geostrophic Theory and Application

1. Understand and be able to apply simple wave forms to scale analysis of the equations of motion, vorticity equation, thermodynamic energy equation, and mass continuity equation.
2. Know the order of magnitudes of vertical vorticity, horizontal divergence and Earth's vorticity.

3. Be able to explain physically and mathematically all terms in the QG vorticity and thermodynamic energy equations (Lagrangian and Eulerian forms) and be able to apply them to physical examples.
4. Know the approximations applied to the QG vorticity and thermodynamic energy equations.
5. Understand the relationship between vertical z-velocity (w) and vertical p-velocity (ω) and the general magnitudes of each in the free atmosphere.
6. Understand the relationship between the ageostrophic wind and vertical motion via the mass continuity equation.
7. Know the relationships between temperature and geopotential, between vertical relative vorticity and geopotential, and between the height tendency and geopotential.
8. Be able to explain mathematically and physically all terms in the QG omega equation and be able to apply it to physical situations.
9. Be able to explain mathematically and physically all terms in the QG height tendency equation and be able to apply it to physical situations.
10. Be able to use QG omega and QG height tendency equations to understand and explain formation and movement of surface pressure system
11. Be able to use QG omega and QG height tendency equations to understand and explain formation and movement of upper level system
12. Be able to apply QG theory to analyze the typical life cycle of a mid-latitude system

Linear Perturbation Theory and Waves

1. Know and be able to explain the difference(s) between transverse and longitudinal waves.
2. Know how we apply the linear perturbation theory to arrive at the frequency equ. (dispersion relation) for acoustic wave, external gravity wave, internal gravity wave, and Rossby wave
3. Be able to define basic states and perturbations and then use them to linearize a set of nonlinear equations.
4. Be able to derive the frequency equation, or dispersion relationship from linearized equations.
5. Understand the difference between a dispersive and non-dispersive wave
6. Understand and be able to compute and explain the phase speed
7. Be able to explain physically and mathematically the conservation of absolute vorticity and its application to Rossby waves

Some Useful Equations (They will be provided in the last page of the exam)

$$\frac{\partial \zeta}{\partial t} = -u\frac{\partial \zeta}{\partial x} - v\frac{\partial \zeta}{\partial y} - w\frac{\partial \zeta}{\partial z} - \beta v - (\zeta + f)\delta + \left(\frac{\partial p}{\partial x}\frac{\partial \alpha}{\partial y} - \frac{\partial p}{\partial y}\frac{\partial \alpha}{\partial x}\right) - \left(\frac{\partial w}{\partial x}\frac{\partial v}{\partial z} - \frac{\partial w}{\partial y}\frac{\partial u}{\partial z}\right)$$

$$\vec{V}_g = \frac{1}{f}\hat{k}\times\nabla\Phi \qquad \frac{\partial T}{\partial t} = -\vec{V}\cdot\nabla_p T + \frac{\omega\sigma p}{R} + \frac{\dot{Q}}{C_p} \qquad -\frac{\partial \vec{V}_g}{\partial p} = \frac{R}{fp}\left(\hat{k}\times\nabla_p T\right)$$

$$\vec{V}_a = \frac{1}{f}\hat{k}\times\frac{D\vec{V}}{Dt}$$

$$u_g = -\frac{g}{f}\frac{\partial Z}{\partial y} = -\frac{1}{f}\frac{\partial\Phi}{\partial y} = -\frac{1}{\rho f}\frac{\partial p}{\partial y} \qquad v_g = \frac{g}{f}\frac{\partial Z}{\partial x} = \frac{1}{f}\frac{\partial\Phi}{\partial x} = \frac{1}{\rho f}\frac{\partial p}{\partial x}$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0$$

$$\left(\nabla_p^2 + \frac{f_o^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega = -\frac{f_o}{\sigma}\frac{\partial}{\partial p}\left[-\vec{V}_g\bullet\nabla_p\left(\zeta_g + f\right)\right] - \frac{R}{\sigma p}\nabla_p^2\left[-\vec{V}_g\bullet\nabla_p T\right]$$

$$\left(\nabla_p^2 + \frac{f_o^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\chi = f_o\left[-\vec{V}_g\bullet\nabla_p\left(\zeta_g + f\right)\right] - \frac{f_o^{\,2}}{\sigma}\frac{\partial}{\partial p}\left[\frac{R}{p}\left(-\vec{V}_g\bullet\nabla_p T\right)\right]$$

$$\zeta_g = \frac{1}{f_o}\nabla_p^2\Phi = \frac{g}{f_o}\nabla_p^2 Z \qquad \chi = \frac{\partial\Phi}{\partial t} \qquad \frac{\partial\Phi}{\partial p} = -\frac{RT}{p}$$

$$\frac{\partial\zeta_g}{\partial t} = -\vec{V}_g\bullet\nabla_p\zeta_g - \beta v_g - \delta f_o$$

$$\frac{\partial T}{\partial t} = -\vec{V}_g\cdot\nabla_p T + \omega\sigma p/R$$

$$\zeta_T = \zeta_g(above) - \zeta_g(below)$$

$$\xi' = \tilde{\xi}e^{i(kx+ly+mz-\omega t)}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + \frac{1}{\rho}\frac{\partial p}{\partial x} = 0$$

$$\frac{\partial \rho}{\partial t} + u\frac{\partial \rho}{\partial x} + \rho\frac{\partial u}{\partial x} = 0$$

$$\frac{d\theta}{dt} = 0$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + g\frac{\rho_1 - \rho_2}{\rho_1}\frac{\partial h}{\partial x} = 0$$

$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} + h\frac{\partial u}{\partial x} = 0$$

$$\frac{\partial\zeta}{\partial t} + u\frac{\partial\zeta}{\partial x} + v\frac{\partial\zeta}{\partial y} + \beta v = 0$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}+\frac{1}{\rho}\frac{\partial p}{\partial x}=0$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+w\frac{\partial w}{\partial z}+\frac{1}{\rho}\frac{\partial p}{\partial z}+g=0$$

$$\frac{\partial u}{\partial x}+\frac{\partial w}{\partial z}=0$$

$$\frac{\partial \theta}{\partial t}+u\frac{\partial \theta}{\partial x}+w\frac{\partial \theta}{\partial z}=0$$