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!

Definitions of Mesoscale

1. Be able to explain various approaches (e.g., dynamical, phenomenological) for defining atmospheric “scales” (e.g., synoptic, meso, storm).
2. Understand the atmospheric energy spectrum and its role in helping define the mesoscale.
3. Be able to explain the concept of energy cascade and its role in the atmosphere.
4. Be able to explain how the mesoscale differs dynamically from other scales in the atmosphere.
5. Be able to perform a scale analysis of the equations of motion and know the principal time and space scales for planetary, synoptic, meso- and storm-scale motions.

Linear Perturbation Theory and Gravity Waves

6. Understand the physical and mathematical differences between a linear and nonlinear operator, like advection, or a physical system, like a cloud growing in a conditionally stable atmosphere.
7. Understand the term “nonlinear steepening” and its origin in nonlinear advection.
8. Understand and be able to explain the concept of an eigenvalue.
9. Be able to classify a given mathematical operator as linear or nonlinear using equations.
10. Understand how nonlinear processes involve feedback or, in the case of waves, involve creating multiple waves from a single one.
11. Know and be able to explain the difference(s) between transverse and longitudinal waves.
12. Be able to list and explain the physical relevance of all steps and assumptions associated with linear perturbation theory as applied to wave motion.
13. Be able to work with complex exponential functions and know their relationship, in the context of waves, to the more standard sine and cosine formulations (see handout).
14. Be able to define basic states, and perturbations from them, as directed, and then use them to linearize a set of nonlinear equations. You will NOT be expected to come up with a list of equations that describe a particular type of wave, though you may be asked to explain why a given set of equations is appropriate for representing various pure wave types.
15. Be able to derive the frequency equation, or dispersion relationship, for all of the pure wave types discussed in class.
16. Understand the difference between internal and external gravity waves.
17. Understand the buoyancy frequency and its relevance in gravity waves.
18. Understand how the orientation of internal gravity waves affects their frequency relative to the intrinsic buoyancy frequency.
19. Understand the conditions of vertical stratification in which internal gravity/buoyancy waves occur.
20. Know and be able to explain the Boussinesq approximation.
21. Understand the concept of a wavenumber vector and how it relates to wave propagation and wave structure.
22. Be able to compute numerical values of phase speed for all wave types using order of magnitude estimates for relevant physical quantities.

Mountain Wave Dynamics and Downslope Wind Storms

23. Know the general characteristics of mountain waves and the conditions necessary for their formation.
24. Be able to explain the Froude number both physically (i.e., its role in mountain wave dynamics) and mathematically.
25. Understand the physical difference between supercritical and subcritical flow in the context of mountain waves.
26. Understand the concept of linear perturbation theory and how it is applied to mountain waves.
27. Be able to define mathematically and explain the buoyancy frequency.
28. Be able to Linearize the equations governing mountain waves and derive the dispersion relation.
29. Given the dispersion relation for mountain waves, be able to explain wave characteristics (e.g., vertically propagating, trapped, evanescent).
30. Know the physical characteristics and presumed mechanisms associated with the formation of downslope wind storms.
31. Understand the application of shallow water wave theory to downslope windstorms and the assumptions made.
32. Understand the physical difference between supercritical and subcritical flow in the context of downslope wind storms.
33. Understand and be able to explain and apply the two flow constraints for nonlinear theory applied to downslope wind storms for cases in which the Froude number is less than, greater than and equal to unity.

Atmospheric Instability Theory

34. Understand the concept of instability and be able to give meteorological and non-meteorological examples of it.
35. Be able to explain the physical characteristics of: static/gravitational instability, centrifugal instability, inertial instability, and symmetric instability.
36. Understand the importance of conserved variables in instability theory.
37. Be able to utilize equations for the above types of instability to diagnose whether a given atmosphere (e.g., on a map or diagram) is stable, neutral, or unstable.
38. Be able to provide examples of where the instabilities listed above most commonly occur in the atmosphere.
Equations to Be Provided on the Exam
(note that others may be provided for given problems)

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} = -\frac{1}{\rho} \frac{\partial p}{\partial x} + f_y
\]

\[
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial v}{\partial z} = -\frac{1}{\rho} \frac{\partial p}{\partial y} - f_x
\]

\[
\frac{\partial w}{\partial t} + u \frac{\partial w}{\partial x} + v \frac{\partial w}{\partial y} + w \frac{\partial w}{\partial z} = -\frac{1}{\rho} \frac{\partial p}{\partial z} - g
\]

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

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

\[
\frac{dw}{dt} = -\frac{1}{\rho} \frac{\partial p}{\partial z} + g \frac{\theta'}{\theta}
\]

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

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

\[
\omega = u_o k \pm \sqrt{gH} \quad \omega = u_o k \pm \frac{Bk}{\sqrt{k^2 + m^2}} \quad Fr = \frac{u^2}{c^2}
\]

\[
(1 - Fr^2) \frac{\partial D}{\partial x} = -\frac{\partial h_i}{\partial x} + \left( \frac{\partial^2 w'}{\partial x^2} + \frac{\partial^2 w'}{\partial z^2} \right) + \left( \frac{B^2}{u^2} - \frac{1}{u} \frac{d^2 \bar{u}}{dz^2} \right) w' = 0
\]

\[
l^2 = \left( \frac{B^2}{u^2} - \frac{1}{u} \frac{d^2 \bar{u}}{dz^2} \right)
\]

\[
M \equiv vr \quad M \equiv u - f_y \quad M_g \equiv u - f_y \quad \frac{dv}{dt} = -f(M - M_g) = -fM'
\]

\[
\frac{d^2(\Delta z)}{dt^2} = g T_o \left( \gamma - \Gamma_d \right) \Delta z \quad \frac{d^2(\Delta r)}{dt^2} = -\frac{1}{r_o^3} \frac{dM}{dr} \Delta r \quad \frac{d^2(\Delta y)}{dt^2} = -f \left( f - \frac{\partial u}{\partial y} \right) \Delta y
\]

\[
\frac{d^2(\Delta s)}{dt^2} = \left\{ f \frac{\partial M_g}{\partial z} \left[ \left( \frac{\Delta z}{\Delta y} \right)_{\text{tube}} - \left( \frac{\Delta z}{\Delta y} \right)_{u_x} \right] \cos(\alpha) + B^2 \left[ \left( \frac{\Delta z}{\Delta y} \right)_\theta - \left( \frac{\Delta z}{\Delta y} \right)_{\text{tube}} \right] \sin(\alpha) \right\} \Delta s \cos(\alpha)
\]