Midterm Exam #1 Study Guide METR 4403/5403 – Spring 2026

The first midterm exam will cover all class material from 1/21 to 3/9.

When and where:
Exam: Friday March 13, 10:30 am-11:20am in NWC 1350.
Review session: Wednesday March 11, 10:30 am -11:20am in NWC 1350.

Format:
- Closed notes (like traditional in-class exam), closed everything (e.g., phones, etc.).
- Everyone is expected to take exam in person in NWC 1350
  (except for special situations)
- Several multiple choices, fill-in-the-blank, or true-false questions.
- 3-4 multipart questions.
- No calculations. There may be simple derivations starting from equations given. A list of equations will be provided to you on the last page of the exam.

Materials needed:
- Pencils. You may find color pencils to be helpful as well. Paper will be provided.

Topics we covered:

1. **Basic ingredients for severe convection**
   a. Be able to identify the four primary ingredients for severe thunderstorms (instability, lift, moisture, shear)
   b. Be familiar with:
      - The Elevated Mixed Layer
      - Moisture return patterns
      - Common sources of lift (synoptic v.s mesoscale)

2. **Surface Analysis**
   a. Be familiar with conducting a typical surface analysis to identify air masses, boundaries, etc…

3. **Skew-T & Parcel Theory**
   a. Be familiar with lines on a Skew-T/Log-P diagram and their physical meanings.
   b. Be able to identify important convective layers such as the LCL, LFC, EL, etc…
   c. Be familiar with how the buoyancy of an air parcel is calculated.
   d. CAPE/CIN calculations and their various forms (MUCAPE, MLCAPE, etc…).
   e. The assumptions made in parcel theory, especially when computing CAPE/CIN.
   f. How to find the theoretical maximum updraft velocity.
   g. Factors ignored by parcel theory that can cause it to over-estimate maximum vertical velocity
   h. The influence of diurnal mixing on low-level temperature, lapse rates, moisture, etc…

4. **Lapse Rate Tendency**

   a. Be familiar with the lapse rate tendency equation and be able to physically explain each of the terms in the equation.
   b. Be familiar with the difference between absolutely unstable, conditionally unstable, and absolutely stable lapse rates.
   c. Be able to explain the influence of lapse rates on convection.
   d. Be able to explain physically what the Elevated Mixed Layer is and why it is important for severe thunderstorm forecasting.

5. **Quasi-Geostrophic Height Tendency Equation**

   a. Be familiar with mass continuity, the QG thermodynamic equation, and the QG vorticity equation.
   b. Be familiar with the QG height tendency equation, and be able to explain physically how each term contributes to heights falling or rising.
      • Know how the vorticity advection term works to change geopotential height at different levels within trough-ridge systems, and able to apply the knowledge.
      • Know how the differential temperature/thermal advection term works to change geopotential height at different levels within trough-ridge systems, and able to apply the knowledge.
      • Know how diabatic heating can cause height change at different levels.
      • Which term is responsible for propagation and which is responsible for intensity change?

6. **Quasi-Geostrophic Omega Equation**
   a. Be familiar with the QG Omega equation and be able to explain physically how each term contributes to vertical motion.
      - Know how the differential absolute vorticity advection term works to produce vertical motion at different parts of mid-level trough-ridge systems, and near upper-level jet streak, and able to apply the knowledge.
      - Know how thermal advection term works to produce vertical motion at different parts of mid-level trough-ridge systems, and able to apply the knowledge.
   b. Also, be familiar with jet streaks and regions of ascent/descent and the concept of lee cyclogenesis.

7. **Vertical wind shear**
   a. Sources of vertical wind shear (geostrophic and ageostrophic)
   b. Influence on convection
   c. How to measure? Bulk wind differences. Effective inflow layer.
   d. Effective bulk shear. What layer to use to calculate?
   e. How to forecast vertical wind shear change?
   f. LLJs and how they affect shear?

8. **Convective Mode**
    a. What values of deep-layer (i.e. 0-6 km) BWD are considered weak, moderate, or strong for organized convection and what storm modes they favor.
    b. Be familiar with the life cycle of single-cell thunderstorms.
    c. Be familiar with the evolution/structure of multicell and supercell thunderstorms.
    d. Be familiar with the methodology for determining storm mode based on:
        • Boundary type/forcing for ascent
        • Storm motion
        • Deep-layer wind shear and anvil-level storm-relative wind vectors.

9. **Hodographs and related concepts/quantities**
    a. Hodographs – be able to plot them
    b. Layer vertical wind shear vector and horizontal vorticity based on hodographs
    c. Straight and curved hodographs, the direction of curvature.
    d. Forecasting supercell motion/Bunker's supercell motion.
    e. Storm relative wind vectors on hodographs
    f. Streamwise and crosswise vorticity
    g. Shape of low-level hodograph/effect on streamwise vorticity
    h. Storm Relative Helicity (SRH) and its definition/calculation
    i. Significance of streamwise vorticity on updraft rotation
    j. Environmental storm-relative helicity (SRH) over different depths
    k. Graphic representation of SRH on hodograph