Midterm Exam #1 Study Guide
METR 4403/5403 – Spring 2025

The first midterm exam will cover all class material from 1/13 to 3/10.

When and where:
Exam: Friday March 14, 9:30 am-10:20am in NWC 1350.
Review session: Wednesday March 12, 9:30 am -10:20am 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)
- A number of multiple choices, and short-answer questions.
- 2-3 multipart questions that may involve sketches, descriptions and use of equations/terms.
- No detailed 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. Instability (EML climatology and advection)
   c. Lift (synoptic QG source/jet streaks; mesoscale front/outflow/dryline)
   d. Moisture (BL moisture large and deep; return flow; vertical mixing; evapotranspiration)
   e. Vertical wind shear (synoptic influences; deepening cyclones; jet streaks; LLJ; lee cyclogenesis)

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?

8. **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. Storm relative wind vectors on hodographs
    e. Streamwise and crosswise vorticity
    f. Calculation of Storm Relative Helicity

g. Significance of streamwise vorticity on updraft evolution
h. Environmental storm-relative helicity (SRH) over different depths
i. Graphic representation of SRH on hodograph
j. Forecasting supercell motion/Bunker's supercell motion.

9. **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 thunderstorms.
   d. Be familiar with the evolution/structure of supercell thunderstorms.
   e. 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.

10. **Hail Forecasting**
    a. Be familiar with the basic ingredients for severe hail forecasting (hail embryo, moderately strong updraft, moisture/saturation)
    b. Be familiar with the properties of thermodynamic/kinematic profiles favorable for severe hail
       - Moderate to strong mid-level shear
       - Upper-level flow not too strong to limit residence time.
       - Strong enough low-level SRW to support broad updraft and supercells.
       - But not too strong to displace hail embryos.
       - Weaker low-level shear compared to tornadic cases but still significant overlap.
    c. Be familiar with the properties of thermodynamic/kinematic profiles not favorable for hail.
    d. Be familiar with the storm modes more favorable for severe hail.

11. **Supercell Pressure Perturbations**
    a. Origin of mid-level rotation in supercells (linearized vorticity equation)
    b. Be familiar with the diagnostic pressure perturbation equation and physically explain each of the terms.
    c. Be familiar with linear and non-linear dynamic forcing.
    d. Be able to explain the processes involved in splitting supercells, cell propagation, and why left or right splits are favored given certain wind profiles.