

MEA444: Mesoscale Analysis and Forecasting

Lab Exercise 5: Solutions

[100 pts total]

Pre-lab 5

B. "Cloud Modeling" section

1. Idealized/simplified; they provide only a simplified picture of the real atmosphere; Excluded are: pre-existing boundaries and other horizontal variations in the environmental conditions, which can have a significant impact on storm evolution
2. Convective cells are triggered using an ellipsoidal bubble of warm air with a maximum temperature excess of 2°C specified at the center of the bubble.
3. Controlled experiments in simple environments; view storm evolution without the complexities inherent when observing storms in the real world

C. "Background Concepts" section

Conceptual Models:

1. Ordinary cells → short-lived small
2. This pattern of cell evolution is a distinguishing characteristic of an organized multiple cell system; Period redevelopment, usually on the downshear side of the cold pool where the lift is the greatest (continual preferred-flank cell regeneration).
One of the more distinctive cloud features found in some organized multiple cell systems is a well-defined shelf cloud. Such a cloud will have a crisp, flat base indicating an active updraft. Sometimes the cold pool will surge ahead of the developing cells, and a separate arc cloud will form along the leading edge.
3. Quasi-steady; rotation; the mesocyclone itself is located within the notch of the hook echo; storms that propagate away from the mean wind, exhibit mid-level mesocyclones, and show hook echo patterns.
4. Curvature → govern RM/LM split favored; cyclonic/anticyclonic

Physical Processes:

1. CAPE (moisture and instability); LFC height; evap cooling; precip loading
2. Orientation of the shear vectors; Theta-e (strength & depth of cold pool) / strength & depth of environmental shear
3. Bulk Richardson number (BRN) → CAPE/shear
*BRN is calculated by dividing CAPE by shear, where shear is defined as half the square of the vector difference between the 0-6 km mean wind and a representative surface layer wind. Vertical wind shear mainly acts to distribute rainfall downshear of the updraft. A more significant impact of vertical wind shear on a convective updraft is the generation of mid-level rotation. In strongly sheared environments, this can lead to the production of a long-lived supercell storm.
 - a. strength and orientation of the horizontal vorticity present in a vertically sheared environment can be represented with a vorticity vector

In-Class Lab 5

1. **[40 pts] (see below)**

2. **[10 pts] Describe and briefly explain the storm type versus shear and buoyancy relationships revealed by your shear/buoyancy diagram.**

Ordinary cells are found at the weak-shear end of the spectrum; multiple-cell systems occur for intermediate values of shear, while supercells are found only for stronger values of shear. This relationship is primarily due to the organizing influence of the shear, with multiple-cell systems requiring some low-level shear to help regenerate new cells along the gust front, and supercells requiring stronger vertical wind shear to promote the development of significant mid-level mesocyclones that are necessary for the supercell processes. There is some dependence on buoyancy as well, with multiple cells extending more into the supercell shear range for larger instabilities. This is due to the large instability cases producing stronger cold pools, which can move away too quickly from an incipient supercell updraft, cutting it off from the warm low-level environment air early in its evolution.

3. **[10 pts] Examining the matrix views, describe the influence of variations to the buoyancy (stability) profiles on overall storm structure and evolution?**

Increasing the instability increases the size, depth, and strength of the individual convective cells, and also tends to increase the size and strength of the resulting convective system as a whole.

4. **[10 pts] For a given hodograph and magnitude of vertical wind shear, what is the role of dry mid-level air on storm evolution?**

By comparing the simulations for the two High CAPE soundings, which have nearly identical CAPEs but differ in that the High, Dry sounding has much drier mid-level conditions, we find that dry mid-level air seems to weaken the storm system. However, the dry mid-level air does enhance the surface cold pools in some cases. The reason is that dry mid-level air is entrained into both the updrafts and downdrafts, decreasing potential updraft buoyancy, but increasing the potential downdraft negative buoyancy. These modeling results do not support the common misconception that dry mid-level air always enhances storm severity, or that dry mid-level air is necessary for supercell development.

5. **[10 pts] What is the role of shear *depth* in controlling resulting storm structure?**

The strong, shallower shear environments are less likely to produce long-lived supercells than the strong, deeper shear environments, but are more likely to produce strong, long-lived lines of convective cells than the deeper shear cases. Strong, shallow shears tend to promote very strong cold pools, which can move away from the supercell updraft cutting off its supply of warm low-level environmental air. The strong cold pools also create deep cold pool lifting, which promotes regular ordinary cell redevelopment along the gust front. Weaker, shallow shear environments and weaker, deeper shear environments both produce similarly weaker convective systems.

6. [10 pts] What is the role of hodograph *curvature* in controlling resulting storm structure and evolution for strongly-sheared environments?

Strongly-sheared, straight hodographs produce mirror-image, splitting supercell storms (simulations D2, D4, E2, E4). Clockwise-curved hodographs enhance the right-moving, cyclonic supercell (simulations G1-3, H1-4, I1-4, L1-3, M1-4, P1). Counterclockwise-curved hodographs enhance the anticyclonic, left-moving supercells (simulations J1-4).

7. [10 pts] Can you find other significant storm structures as you further explore the matrix? Look for shallow (mini) supercells, HP supercells, and storm systems conducive to producing straight-line winds, such as bow echoes.

Note which simulations display these structures.

Simulations G1, H1, I1, J1, L1, M1, O1, and P1 are all supercells that have a smaller horizontal and vertical scale. These simulations suggest that conditions of relatively low CAPE, high moisture, and strong low-level wind shear will support shallow supercells.

Simulations M2, P3 (south end), L2, and L3 (borderline) show radar patterns and evolutions that have been associated with HP supercells.

Simulations P2-4, which are cases with very strong low-level vertical wind shear and moderate to high instability, exhibit large regions of strong near-surface winds throughout the four hours of simulation. These cases also exhibit bow-echo patterns, which are often observed in association with strong straight-line wind events.

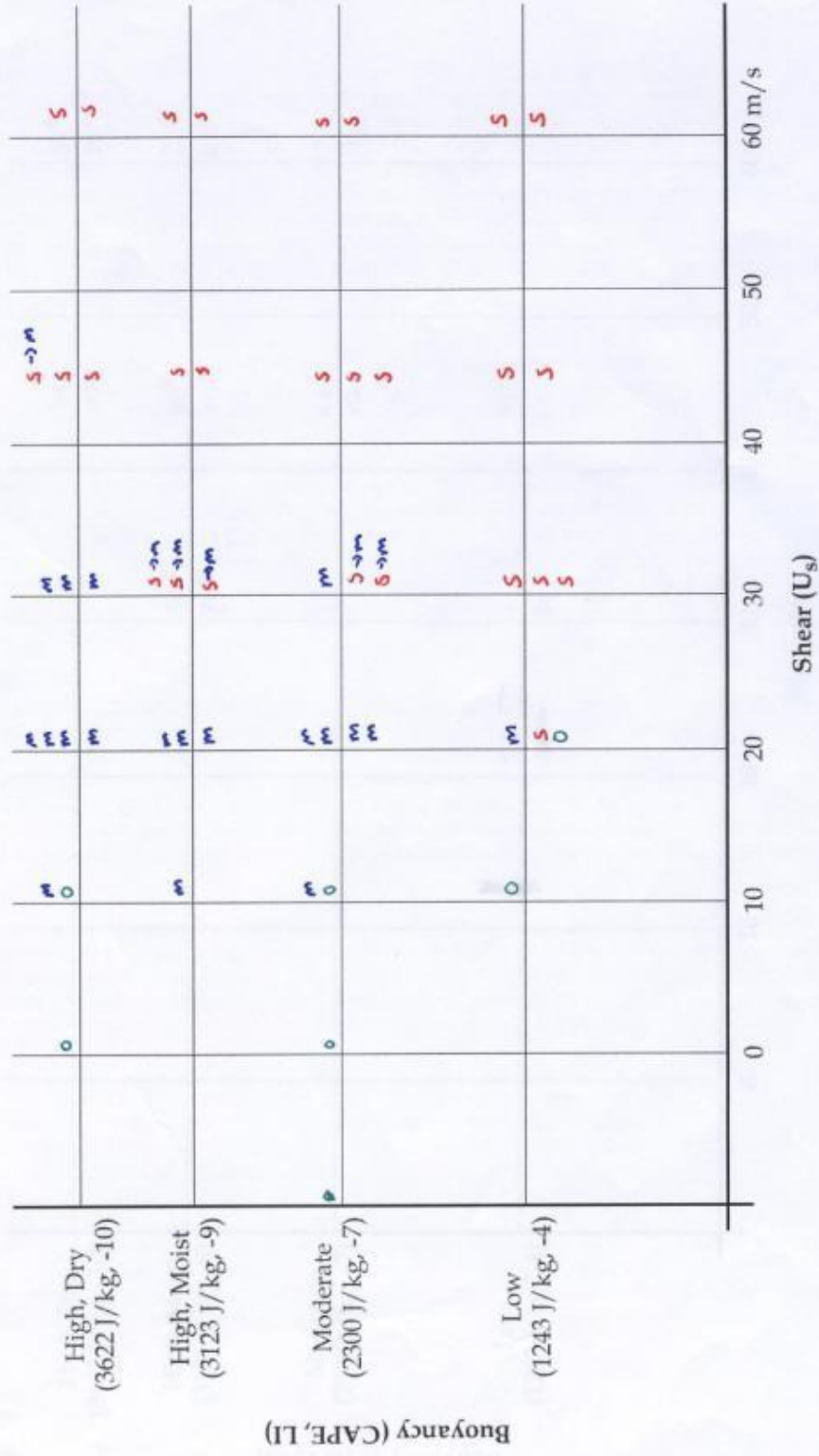
A Convective Storm Matrix Answer Worksheet

(To help you prepare your graphs, make notes in the spaces provided.) ← from strong
pool

	Hodo	Low Buoyancy	Moderate Buoyancy	High Buoyancy, Moist	High Buoyancy, Dry
A			Ordinary ✓ A2		Ordinary ✓ A4
B			Ordinary ✓ B2		Ordinary ✓ B4
C			Multicell (weak) ✓ C2		Weak multicell ✓ C4
D			Supra → multi-line ✓ D2		Supra → multicell ✓ D4
E			Supra ✓ E2		Supra ✓ E4
F		Ordinary ✓ F1	Multicell ✓ F2	Multicell ✓ F3	Weak multi ✓ F4
G		Mini supra ✓ G1	Cyclonic supra → multicell ✓ G2	Cyclonic supra → multicell ✓ G3	Multicell ✓ G4
H		Shallow RM supra ✓ H1	RM supra ✓ H2	Strong RM supra ✓ H3	Strong RM supra ✓ H4
I		Shallow RM supra ✓ I1	Strong RM supra ✓ I2	Strong RM supra ✓ I3	Strong RM supra ✓ I4
J		Shallow LM supra ✓ J1	Strong LM supra ✓ J2	Strong LM supra ✓ J3	Strong LM supra ✓ J4
K		Weak multicell ✓ K1	Weak multi ✓ K2	Multi ✓ K3	Weak multi ✓ K4
L		Weak, shallow RM supra ✓ L1	RM supra → multicell ✓ L2	RM supra → multicell ✓ L3	Multicell ✓ L4
M		Shallow RM supra ✓ M1	RM supra ✓ M2 → HP supra → bow echo	RM supra ✓ M3	RM supra ✓ M4 → multi
N		Ordinary ✓ N1	Weak multi ✓ N2	Multi ✓ N3	Weak multi ✓ N4
O		Weak shallow supra ✓ O1	Multi ✓ O2	Multi ✓ O3	Multi ✓ O4
P		Shallow supra ✓ P1	Multicell ✓ P2 → bow echo	Supra/multi ✓ P3 → bow	Multi → bow ✓ P4

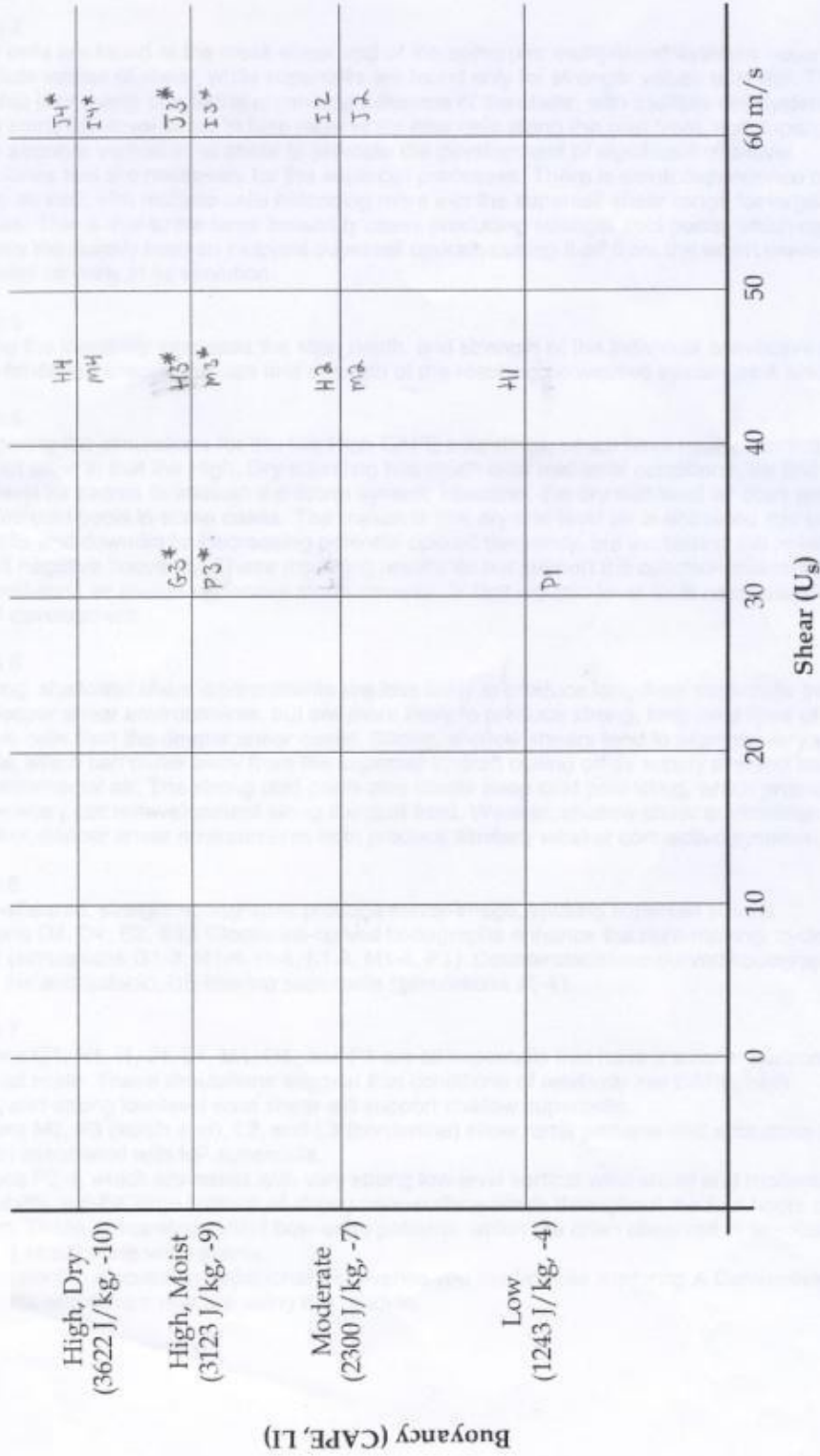
Question 1A Answer Worksheet

Shear (U_s) vs. Buoyancy



Plot all simulations using storm-type symbols (O, M, S).

Question 1C Answer Worksheet Low-Level Mesocyclones



Plot the simulations which produce the strongest low-level mesocyclones. Use matrix box labels (A1, B1, etc.). Add an asterisk for low-level occlusions.

only recorded
"strong" = significant
see vol.