ANSWER KEY

Part I: Locating Geographical Features

1. The National Weather Service’s Storm Prediction Center (www.spc.noaa.gov) has issued a tornado watch on a warm spring day. The watch covers a large area believed to be at risk for severe weather, including tornadoes. Late in the afternoon, Storm Spotter A sees a storm that has numerous updrafts oriented in a perfectly upright fashion. Storm Spotter B sees a storm with a single, rotating updraft that tilts downwind. Which, if either, of the storm spotters should interpret their storms as an immediate threat? What type of thunderstorms did Spotter A and Spotter B view?

An ordinary thunderstorm (sometimes referred to as an “air mass thunderstorm”) is characterized by one or more updrafts that are typically oriented in an upright fashion. The supercell thunderstorm is characterized by single dominant, rotating updraft that tilts downwind. Hence, Spotter A is looking at an ordinary, multi-cell thunderstorm, whereas Spotter B is looking at a supercell. Given that supercells are the most prolific producers of severe weather, Spotter A’s storm is not an immediate threat (though it could become a supercell later), whereas Spotter B’s storm is.

| Type of storm viewed by Spotter A | Ordinary, multi-cell thunderstorm |
| Type of storm viewed by Spotter B | Supercell thunderstorm |

2. Thunderstorms form after rising air cools sufficiently for water vapor to condense, forming a cloud. Based on this requirement, what is the name of the level where you would expect to find the base of a typical thunderstorm?

Level of base of thunderstorm the Lifting Condensation Level (LCL) or Convective Condensation Level (CCL)

3. Thunderstorms require rising air for their development. Name three sources of rising motion for thunderstorm development.

| Source of rising air (#1) | Fronts, drylines, or outflow boundaries |
| Source of rising air (#2) | Solar heating |
| Source of rising air (#3) | Orographic lift (i.e., terrain) |
4. Both a cold front and a dryline are prominent in Figures 6 and 7 — plots of temperature, dew point, and wind data from 2:00 PM CST (2000 UTC) on 10 November 2004. Identify the location of the cold front and dryline. On the appropriate maps, draw the cold front with a blue line and the dryline with a brown dashed line. Also, identify any circulations in the wind field and label them appropriately.

Figure 6 – Air Temperature (in °F) and Wind Vectors for 10 November 2004 at 11:00 AM CST (1700 UTC), as Measured by the National Weather Service

Figure 7 – Dewpoint Temperature (in °F) and Wind Vectors for 10 November 2004 at 11:00 AM CST (1700 UTC), as Measured by the National Weather Service
5. Thunderstorms often form along surface boundaries such as drylines, cold fronts, and warm fronts. Generally, one boundary alone can be favorable for storm development, and the intersection of multiple boundaries is even more favorable. Based on this statement and your results from question 4, identify and label on Figure 6 or 7 the location where you believe storms will form initially. In addition, identify and label the larger region where you believe storms may occur within the next hour. Briefly explain your choice of locations. (Note: Thunderstorms formed within 30 minutes of the time the data used in Figures 6 and 7 were collected. Do not worry about the movement of the boundaries with time.)

Thunderstorms will form initially where there is strong surface convergence, sufficient moisture ($T_D > 55^\circ F$), and warm temperatures. Thunderstorms will develop in regions with sufficient moisture, warm air, and moderate convergence.

6. At your local surface observation station, a thunderstorm with frequent lightning approaches from the west. At the same time, the station reports easterly surface winds. This thunderstorm likely is in what stage of its life cycle? Justify your answer.

If the storm is moving from the west toward the observer, the main updraft is to the west of the observer. It is possible that the updraft is immediately overhead. Either way, easterly winds imply that air is moving into the storm before being lifted into the updraft. Thus, the storm cannot be dissipating. Because frequent lightning is accompanying the storm, it must be well-established. The thunderstorm is likely in its mature stage.

7. One of the prominent features of the typical thunderstorm is the outflow at the surface created by the thunderstorm’s downdraft. Based on the temperature and wind data from 6:30 PM CDT on 17 August 1994 (Figure 8), circle the region where you expect thunderstorm activity to be located. Explain how you made your decision. Also, how does your selected location compare to the radar reflectivity data (Figure 9) from KTLX (the NEXRAD radar near Oklahoma City) at 6:30 PM CDT?

Thunderstorm activity is located in south-central Oklahoma, as identified by a cold pocket of air that exists across that location. Thunderstorm activity should be located north and east of Lawton based on the pure divergent signature in the Mesonet wind field. Comparing this to base reflectivity data from the KTLX radar, storms are in south-central Oklahoma. They seem to be displaced from the center of the temperature minimum. This spatial separation results from the fact that the storms have moved southward, and thus are on the leading edge of the temperature minimum.

Figure 8 – Air Temperature (in °F) for 17 August 1994 at 6:30 PM CDT (2330 UTC), as Measured by the Oklahoma Mesonet
8. Using the information provided in Figures 8 and 9, what stage in their life cycle are the thunderstorms southwest of KTLX? Explain your reasoning.

They appear to be in the decaying stage because (1) cool, outflow air is apparent on the Mesonet temperature map and (2) the storms do not exhibit high reflectivity (i.e., 50 dBZ and lower).

9. Use one sentence to state the primary impact of thunderstorms on the vertical distribution of temperature in the atmosphere. (Hint: How does the vertical temperature profile within a thunderstorm compare to the vertical temperature profile of the ambient environment?)

The thunderstorms act to stabilize the atmosphere because the vertical temperature profile of the atmosphere surrounding the storms is conditionally unstable, whereas inside the storms the lapse rates have become moist adiabatic.

10. Violent tornadoes are significantly more likely to develop from supercell thunderstorms as opposed to other types of thunderstorms. Explain why you think this is the case.

Tornadoes are generated, in part, by rotation in a thunderstorm. The stronger and longer lasting the storm rotation, the higher likelihood that a tornado will be violent. Supercell thunderstorms always rotate and, in many cases, they exhibit strong rotation over several hours. Thus, violent tornadoes are more common in supercell thunderstorms than other thunderstorms.

11. Many people assert that the reason that the Southern Great Plains has so many tornadoes during the springtime is because cool air from the north meets warm air from the south. Explain why this statement is incorrect, using the knowledge that tornadoes are rare in California, where cool air from the Pacific Ocean meets warm air from farther inland (e.g., Death Valley).

Conditions that are favorable for the development of severe thunderstorms include strong instability resulting from the presence of abundant surface moisture and steep lapse rates. These conditions occur when warm, moist air is near the surface with cold, dry air aloft. This scenario occurs frequently in the Southern Great Plains because of the influence of tropical moisture from the Gulf of Mexico (i.e., winds advect moisture northward) and cold, dry air from the Rockies (i.e., upper-level westerlies). In California, on the other hand, surface air from the Pacific Ocean is modified by the cool, California current that is offshore. Thus, an oceanic breeze provides cool moist air (i.e., a lower moisture content because of its temperature and saturation vapor pressure). A breeze from farther inland (e.g., Death Valley) is almost always dry. Thus, the strong instability necessary to produce severe thunderstorms rarely occurs in California. As a result, few tornadoes occur in this region.

12. (Advanced Students/Meteorology Majors) In a short paragraph, explain why a Southern Plains dryline tends to move eastward during the day but westward during the night.

Without significant synoptic forcing, the Southern Plains dryline tends to move eastward during the day and westward during the night. The terrain in this region slopes upward toward the west and separates warm, dry air that moves off the elevated terrain of the southern Rockies and Mexican Plateau from Gulf moisture that moves inland around the western side of the Bermuda High during the spring. During the day, solar radiation begins the process of convective mixing with the drier air aloft – especially west of the dryline where skies often are clear. The mixing process results in the erosion of the shallow moist layer by dry air. The effect is to give the impression that the dryline is moving eastward when, in reality, it is ‘developing eastward’ because of a slow erosion of the moist layer. After sunset, with the end of convective mixing and dry air entrainment, the dryline stalls. Because surface winds tend to become more southeasterly during the late afternoon into the evening hours, the moist layer returns and deepens westward, giving the impression that the dryline is retreating.
13. **(Advanced Students/Meteorology Majors)** Describe (or sketch) a vertical profile of temperature and moisture that would provide an excellent environment for a heatburst to occur.

   An excellent environment includes warm, moist air at the low levels to support convection, weak wind shear throughout the troposphere (so that storms have time to develop raindrops aloft), and a significant layer of dry air in the mid-levels. The layer of dry air is important for the raindrops to completely evaporate and for compressional warming of the evaporated air to occur before the downdraft reaches the ground.

14. **(Advanced Students/Meteorology Majors)** Thunderstorms that form in a warm, moist, tropical environment often are characterized by torrential rainfall and a minimum of lightning. Explain why you think this may be the case.

   Torrential rainfall is made possible by the fact that a maritime tropical atmosphere is likely very warm and very moist. Lightning requires the buildup of large differences in electrical charge in a cloud. Typically, these large charge differences require the presence of ice crystals in the cloud. In the tropics, however, showers and thunderstorms form with few or no ice crystals because of the very warm nature of the atmosphere.

15. **(Advanced Students/Meteorology Majors)** Drylines often serve as a focus for convection — that is, storms tend to form along a dryline when one is present. Explain why drylines have this characteristic.

   A wind shift across a dryline acts to increase convergence and vertical motion. In turn, the formation of storms becomes more likely.

16. **(Advanced Students/Meteorology Majors)** Several stations in the Oklahoma Mesonet measured a large heatburst on 23 May 1996. Use the temperature and dew point maps from 1:30 AM CDT (Figures 10 and 11) to determine where you would expect a heatburst to be located. Outline and label the area you selected. For a heatburst to occur shortly after midnight, what physical process likely was responsible for the unusually high temperatures?

   The heatburst is located southwest of Oklahoma City (near Chickasha, OK). Given the time of day, solar heating is zero. Based upon a map of dewpoint temperature, the likely culprit for the abnormally high temperatures would be warming (and drying) resulting from the adiabatic compression of a downdraft from a collapsed thunderstorm.