Assignment 6 Solutions

1. Ordinary air mass thunderstorms require a triggering mechanism to cause updrafts of air and a conditionally unstable atmosphere. Triggering mechanisms include sea breeze fronts, mountain valley circulations, and differential heating of the land surface. The first stage of the life cycle is known as cumulus stage or growth stage. Warm, moist air rises and cools to form a cumulus cloud. The cloud will continue to grow forming a towering cumulus cloud in just a few minutes. As the cloud builds well above the freezing level, the particles grow bigger and heavier and begin to fall. The drier air from the cloud is drawn into it in a process called entrainment. This makes the air colder and heavier and it begins to descend as a downdraft, which forms the gust front of the thunderstorm as it hits the surface. This marks the beginning of the mature stage. The thunderstorm is most intense during this stage. After the storm enters the mature stage, it begins to dissipate in about 15 to 30 minutes. The dissipating stage occurs when the updrafts weaken as the gust front moves away from the storm and chokes off the updraft. The whole process takes less than an hour to complete. Air mass thunderstorms form in regions where there is limited wind shear (where the wind speed and wind direction do not abruptly change with increasing height above the surface). More severe and organized thunderstorms require wind shear because this helps keep the updraft effectively separated from the downdraft. Therefore the updraft is not choked off and the thunderstorm has a sustained source of warm moist air to continue to grow and develop.

2. The Central Plains region is most susceptible to tornadoes because it often provides the proper atmospheric environment for the development of compact, rotating supercell thunderstorms, particularly in the spring season. Near the surface, there is warm, humid maritime tropical air transported on the southerly winds from the Gulf of Mexico. Warm, dry continental tropical air from the Mexican Plateau overlays this warm, moist surface air. This provides a shallow stable layer, or “cap”, through which only the strongest updrafts can penetrate. In the upper-levels of the atmosphere above the cT air mass, cold, dry continental polar air is transported on westerly to northwesterly winds from Canada. The cold dry, air increases the instability in the upper atmosphere. The strong vertical wind shear causes air to rotate in the horizontal. A strong updraft twists this rotation in a vertical direction, causing the formation of a rotating supercell thunderstorm capable of spawning tornadoes. Because of our mountainous terrain and dry climate, Arizona typically does not have the right combination of air masses and vertical wind shear to create strong supercell thunderstorms, but they do happen on very rare occasions.

3. In a region where there is strong vertical wind shear, the thunderstorm may form in such a way that the outflow of cold air from the downdraft never undercuts the updraft. In such a storm, the wind shear may be so strong to create horizontal spin, which, when tilted into the updraft, causes it to rotate. A large, long-lasting thunderstorm with a single violently rotating updraft is called a supercell—and tornadoes often form in the area of the rotating updraft. This type of storm is fairly compact, usually on the order of 10 km or less. A weather forecaster would typically look at two pieces of information in to determine if a supercell thunderstorm is tornadic and a tornado warning should be issued. First, tornadic supercells have a characteristic shape on a radar reflectivity image. They consist of a relatively large area of high reflectivity (red and orange colors) in a front flank downdraft, where most of the heavy rain and hail occurs. Behind the front flank downdraft, there is a smaller area of high reflectivity that forms a hook echo in the reflectivity. The "hook" defines the rear flank downdraft. The notch of the hook is where the rotating updraft is located and where the tornado occurs. Second, weather radar can also be used to detect wind velocity with respect to the radar position. Tornadoes are clearly indicated by compact areas of strong winds moving toward and away from the radar beam that would indicate rapid rotation.

4. Tornadoes are most likely to occur in the central United States during late spring and early summer (specifically April and May) as those months are most ideal for the clash of the three air mass types necessary for supercell thunderstorms (see question #2). The safest course of action would be to try to seek shelter in a ravine and get as low as possible. Seeking shelter under an underpass would be a bad idea because the underpass would channel the winds at that point if the tornado passed directly over—blowing you away. Trying to outrun the tornado is also not smart because tornadoes can move very quickly and you might drive right through its path.

5. Ice phase processes are necessary in convective clouds for lightning to occur. In maritime convective clouds there is very few Ice condensation nuclei and cloud condensation nuclei, so these are mostly warm clouds with a relatively few number of big water droplets and nearly no ice crystals. Hence lightning occurs over or very near to large islands and continents, and not over the open ocean.

6. Following is the sequence of events: a) Formation of stepped leader (negative charge near the bottom of the cloud begins to flow). b) As the electrons approach the ground, a region of positive charge moves up into the air through any conducting object. c) A bright return stroke is formed when the downward flow of electrons meets the upward surge of positive charge. Thunder occurs due to the rapid heating of the air that causes a

rapid change in pressure, inducing a sound wave. Because light waves travel faster than sound waves, so the sound of thunder normally occurs after the flash.

7. Thunderstorms would form at the location that is nearest the cold front, so the best answer is location #2.

8. In this case, the safest course of action would be to seek shelter in a structure that would conduct a lightning strike around your body. Of the options given, a parked car is best because the car is a metallic conducting surface. A lightning bolt hitting a car would travel through the metallic cage of the car and probably blow out the car tires, but the insulating surfaces within the interior of the car, such as cloth or vinyl seats and carpeting, would provide a good level of protection for the person inside. Seeking shelter under a tree would be bad because the upward protruding tree will act as a charge collector and is therefore more prone to being struck by lightning. Laying low in an open space would be the second best option if a car was not available, but lightning may still directly strike you. Jumping in pond would be a bad idea because water acts as a conductor, so lightning striking the pond would electrocute you. For the same reason, it is probably not a good idea to be in the shower or taking a bath during a thunderstorm. This situation would most likely happen in Tucson during monsoon season. Monsoon thunderstorms in Tucson typically approach from an easterly direction, after they roll off the mountains surrounding the city in late afternoon.

9. Narrow mountain canyons act to channel water from heavy rainfall events that occur over the mountains. During these events, if the thunderstorm is nearly stationary over the mountains it may produce copious amounts of rain. For example, in the Sabino Canyon flood, the recorded rainfall was over 10 inches! As all this water is channeled in the narrow mountain canyon very quickly, causes a lot water to move at very high speed. The force of the moving water is sufficient to move very large, heavy objects. If caught in a mountain canyon during such an event, you should immediately try to seek higher ground.

10. A hurricane derives its energy from the latent heat of condensation, as warm moist air condenses in cumulonimbus clouds. This heat is then converted into kinetic energy. A mid-latitude cyclone, on the other hand, derives its energy from the large-scale temperature gradient, so does not necessarily require warm sea surface temperatures to sustain it. When mid-latitude cyclones pass over warm water, the extra latent heat provided by the warm moist air helps intensify them. A good example is Nor'esters that form on the East Coast of the United States.

11. For their formation hurricanes require: 1) A fuel source: Warm water and very conditionally unstable air that releases lots of latent heat when water condenses, 2) A spark: A pre-existing area of disturbed weather, such as a cluster of thunderstorms. When this disturbance grows to a sufficient size, it starts to feel the effects of the Coriolis force and rotate clockwise or counterclockwise, depending on the hemisphere. 3) A good exhaust: Little vertical wind shear will allow the developing storm to have a good outflow circulation at the top. If the upper level winds are strong, the outflow will be choked off and the storm will weaken. Additionally, per condition #2, the pre-existing disturbance must be far enough away from the equator (about 5 degrees latitude) so the Coriolis force is strong enough to cause the cluster of thunderstorms to rotate and organize into a tropical cyclone.

12. Florida and Jamaica are both susceptible to strong hurricanes because: 1) they are surrounded by very large, warm ocean with water temperatures above 80 degrees F; 2) they are sufficiently far enough away from the equator so tropical cyclones will develop; 3) the passage of the intertropical convergence zone provides areas of disturbed weather (clusters of thunderstorms) mostly during the warm season. For this reason, hurricane season in the Atlantic basin is from June through November. Southern California does not experience hurricanes because the waters off the Pacific coast are too cold to support strong tropical cyclones. Costa Rica is too near the equator to experience tropical cyclones, though Central American countries immediately to the north like Nicaragua, Honduras, Guatemala, and Belize certainly do (Hurricane Mitch is an infamous example).

13. Cyclones hitting the north coast of Australia typically track due south or southwest. The "strong" side of the storm, where the highest winds and storm surge is experienced, is where the wind direction is in the same direction as the storm motion. Since the cyclone rotates in a clockwise direction, the east side of the storm would be the strong side. So the greatest amount of damage would be experienced if the eye storm passed just to the west of a city on the northern coast of Australia, like Darwin. Cyclone season in northern Australia occurs during late summer and fall in southern hemisphere, so the peak of the season there is about from February to April (equivalent to August to October maximum in hurricanes in the North Atlantic).