San Francisco State University Name _____
Department of Earth & Climate Sciences Spring 2018

ERTH 260: Homework #10
Climate Change and Severe Thunderstorms
(Due Wednesday 2 May 2018; 100 points)

Please answer in complete sentences in coherent paragraphs.

1. Meteorologists and climate scientists interested in how global warming have conclusions about the impact warming will have on thunderstorm frequency and severity. Thunderstorm frequency (related to the slope of the environmental lapse rate) is not expected to change, but the severity of thunderstorms is expected to increase. The latter is related to the expected increase in the amount of water vapor in the boundary layer.

   The skew T/log P diagram (Fig. 1) below has three soundings at a location in which global warming uniformly heats the sounding at all levels, with the initial sounding shown at left, the sounding at an intermediate time shown in the middle, and the sounding in the far future shown at right. Note that the slope of the environmental lapse rates $(\Delta T/\Delta z)_e$ for each sounding is identical. Assume that the increase in water vapor at this location is such that the surface temperature and dew point are the same; saturated conditions occur at the base of each sounding.

   Indicate the LCL, LFC, and EL on each sounding and indicate the area of CAPE by red shading. How do your results illustrate that if cumulonimbus clouds occur for all three cases, the case on the right (with the warmest temperatures and highest mixing ratios) would have the severest thunderstorms? (50 points)

   Since global warming is expected to affect all levels of the troposphere equally, then the slope of the environmental lapse rate will be the same. However, if this warming in lower levels is matched by an increase in actual mixing ratios (more water vapor and higher dew points), then the CAPE would be expected to increase dramatically. For the case shown, the LCL and LFC for all three scenarios are the same; a cloud base would be found at the ground and the soundings are absolutely unstable. However, the CAPE for the warmest case would be extremely large.

   CAPE is a measure of the vertical acceleration due to buoyancy. Since hail size and downdraft wind strength are directly proportional to CAPE, average hail diameters would increase and so would the strength of the downdraft winds. A greater percentage of hail stones would meet the definition of severe hail, perhaps giant hail, and the number of cases with straight line winds greater than 57 mph would increase.

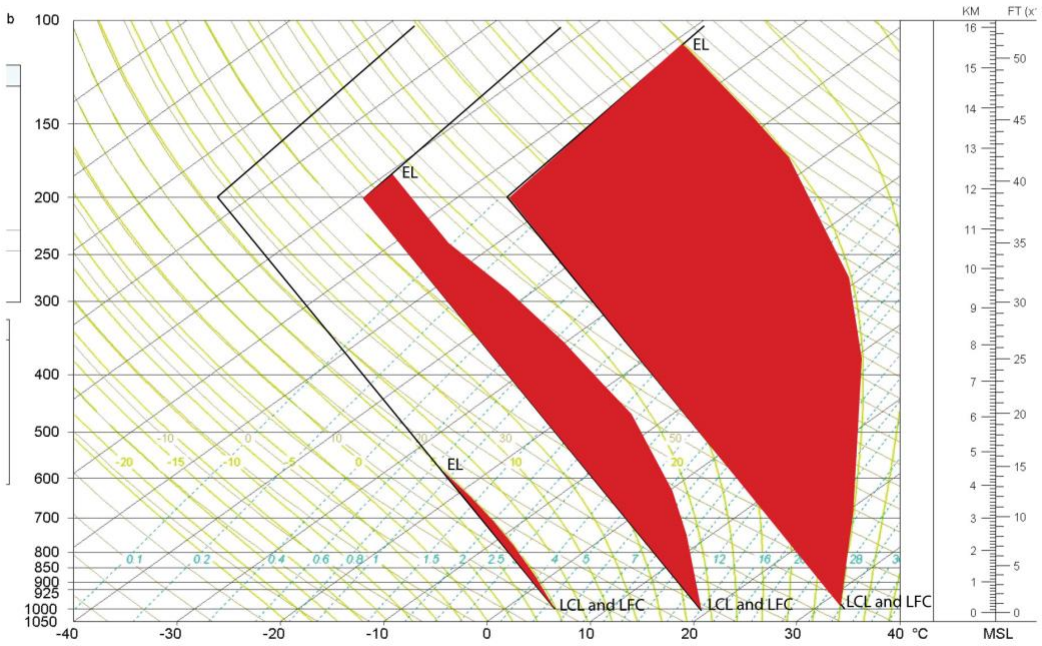

Fig. 1: Skew-T/log p diagram with an initial sounding (far left) and then two soundings progressively associated with increasing mean temperatures due to Global Warming. Note that the environmental lapse rate, $(\Delta T/\Delta z)_e$, is identical in all three cases. Fig. 1 is duplicated in larger format at the end of the Homework.

2. We know that the propensity for thunderstorms to rotate is related to the vertical shear in the environment within which such thunderstorms develop. The vertical shear is related to how strong the jet stream, say at 500 mb, is relative to the surface winds.

   Meteorologists and climate scientists studying the impact of global warming predict that most of the warming will take place at higher latitudes while the temperatures in the equatorial regions would change the least. This will result in a weaker equator-to-pole temperature gradient than exists today.

   Using the concept embedded in the hypsometric relation, will the weaker equator-to-pole temperature difference result in smaller or greater vertical shear in the middle latitudes? Explain in detail.

   The schematic cross section in Lab 7 (the first diagram) will help you in

visualizing this, and you might consider providing some drawings. (50 points)

The strength of the polar jet stream is related to the height gradient found in middle latitudes, with higher 500 mb heights to the south and lower middle latitude heights to the north, and the slope of the isobaric surfaces in the middle latitudes. If the temperatures in the equatorial regions stay the same, while temperatures in the higher latitudes increase, this height gradient and isobaric slopes will get weaker, and so will the average strength of the polar jet stream.

Vertical wind shear in the middle latitudes is related to the (generally) increase in wind speeds with height found in that region. Since the winds at the ground are always weak, a decrease in the 500 mb wind speed (weaker jet stream) will result in a decrease in vertical wind shear.

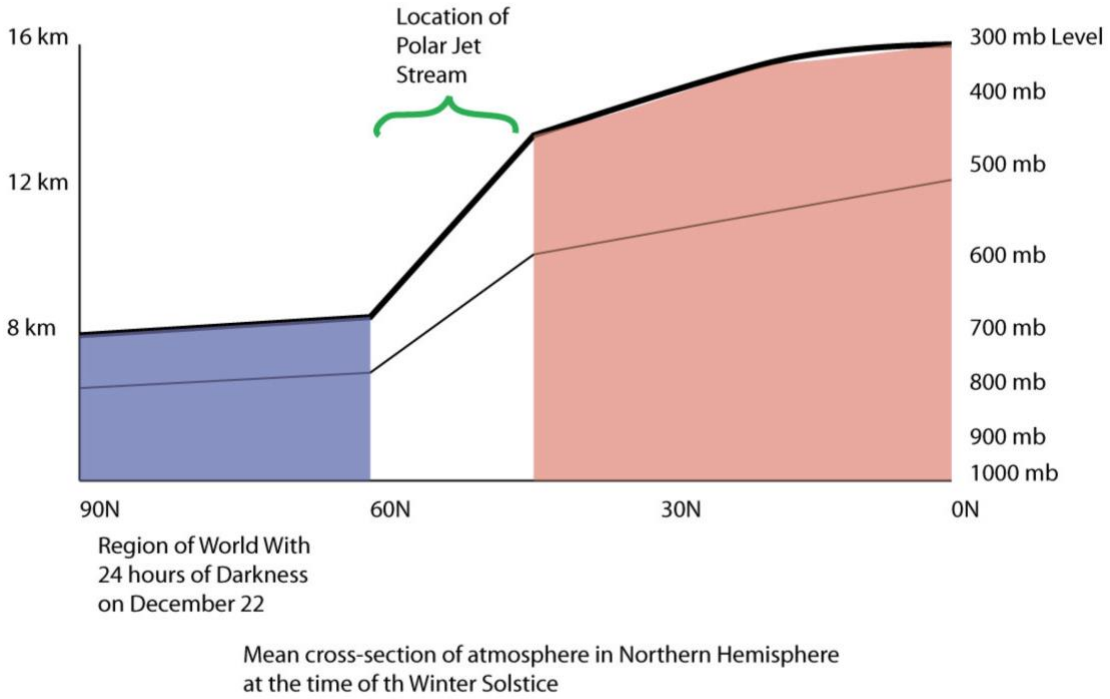

Fig. 2: Schematic cross-section of the Troposphere at the time of the winter solstice in the Northern Hemisphere. This is taken from Lab 10.