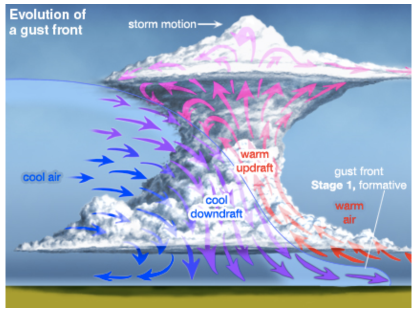
# Homework–Module 4 Name:

1) We learned in Module 3 that adiabatic compression always works to warm sinking air. Yet the thunderstorm downdraft beneath the base of the cloud is usually much colder than the air surrounding it. Explain the apparent paradox using concepts in Chapter 11 of H&P and material in Module 3.

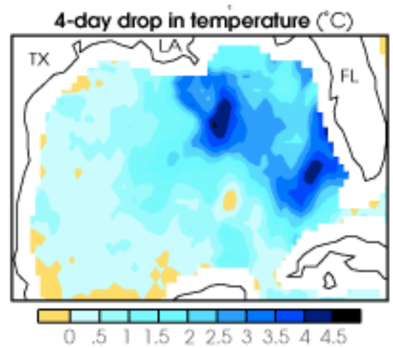
   There is a 600-character limit for all questions.

   *Schematic of the cool downdraft in a severe thunderstorm. Figure Credit: Encyclopedia Briannica.*[1]




[1] https://media1.britannica.com/eb-media/32/24032-004-75D4F911.jpg

2) Explain why the surface (skin-layer) water temperatures are so much cooler after the passage of an intense hurricane. It turns out that most of the cooling is not due to sensible heat transport and evaporation of seawater, important processes that account for a smaller portion of the net cooling. (Hint: Consider what strong hurricane winds would do to the surface water and water a few tens of meters below the surface. You may want to revisit material in Module 1 on how wind affects the formation of the nighttime surface inversion and Fig. 9.19 of H&P to infer on how ocean temperatures vary with depth.)




*Satellite estimates of the change in surface water temperature in the wake of Hurricane Katrina, four days after its passage. Surface cooling of up to 4˚C occurred in regions where Katrina passed. Figure Credit: NASA* [2]

[2] https://earthobservatory.nasa.gov/IOTD/view.php?id=6223

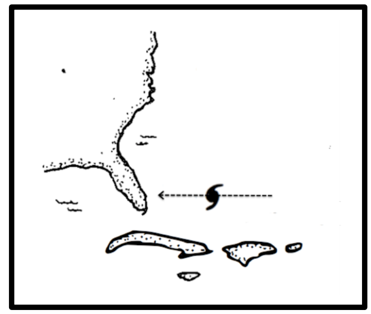
3) Describe four meteorological factors that frequently occur together during summer and early fall over the Los Angeles Basin that set the stage from a major buildup of photochemical smog, being certain to explain how each factor would contribute to a buildup. You can neglect seasonal differences in the input of primary pollutants that are the ultimate cause of photochemical smog.

Los Angeles Basin shrouded by smog.
*Photo: Robert S. Donovan*

4) Paleoclimate data reveal that recent ice ages in the northern hemisphere coincide with climate regimes having colder summers in high latitudes. Explain why periods of glacial advance in the higher latitudes of the Northern Hemisphere tend to occur with colder summers, but not necessarily with colder winters.


Glacial maximum 15,000 years ago

5) You are on the beach of Miami, Florida, facing due east, and Hurricane Esteban is moving due west toward you. The storm is expected to make landfall with a forward speed of 35 knots. (See figure to the right.) Which one of the two scenarios, a) or b), would you expect to bring faster winds at your location? Explain your answer.
   a) Esteban making landfall as a minimal Category 1 hurricane (64 knots) just to your south.
   b) Esteban making landfall as a minimal Category 3 hurricane 96 knots) just to your north.



The categories are based on the Saffir-Simpson Hurricane Wind Scale[3], which rates intensity according to the storm's maximum sustained wind speed. The region of maximum winds is located on the hurricane's forward flank (to the right of the storm) where the rotational winds point in the same direction that the center of the hurricane is moving. (See to Figs. 12.6, 12.7 and 12.11d of the H&P). It may help to sketch a diagram, similar to Fig. 12.11d, where you show your location relative to the center of the hurricane, the rotational speed of the vortex, and the forward speed of the hurricane.

[3] http://www.nhc.noaa.gov/aboutsshws.php

6) As noted in the prior question, recent ice ages in the northern hemisphere coincide with colder summers. Which orbital extremes would be most conductive in producing colder summers in the northern hemisphere.

a) When obliquity is at its largest (24.5˚) or smallest value (22.1˚)?

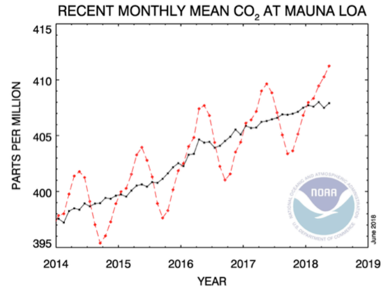
b) When aphelion or perihelion occurs during summer?

c) When eccentricity is at its largest (0.058) or smallest (0.0034) value?

Explain your answers in terms of radiative equilibrium and deviations from it.


[Glacial maximum 15,000 years ago]

7) The figure shows monthly mean CO2 levels (ppm) at the NOAA Mauna Loa laboratory over the period Jan 2014 to May 2018 (4 years, 5 months). The red line gives monthly values that include seasonal variations; the black curve gives the long-term trend with the seasonal cycle removed. Dots are the mean for the month. Click the figure caption to see a larger readable version of the graph, and use the larger figure to answer the following questions.




CO2 levels at the top of Mauna Loa HI. Units are in parts per million (ppm). Click link to get most recent graph.

a) What was the average annual rate of increase in CO2 in ppm per year for the period 1 Jan 2014 to 1 Jan 2018?

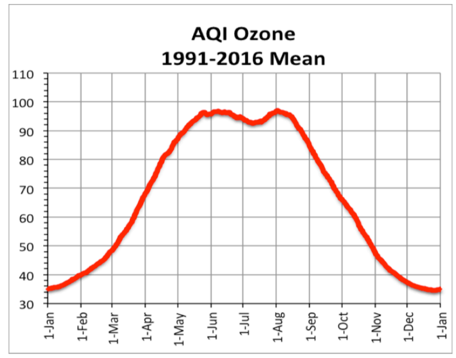
b) How large is the seasonal increase in CO2 (to the nearest whole ppm) at its peak value from its value 6 months earlier? How large is the seasonal decrease from its value 7 months earlier? Your answers must be consistent with your answer in part a).

c) In which month is the average CO2 concentration the highest? In which month is it the lowest?

d) What is the physical cause for a seasonal cycle of CO2? Explain. (Research the answer yourself.)

8) The graph to the right shows the daily average value of the Air Quality Index (AQI) for ozone, the primary irritant in photochemical smog, for Phoenix, Arizona. Describe two meteorological reasons why average ozone levels are two-times higher during the four calendar months (May-June-July-August) than the four months (Nov-Dec-Jan-Feb), being certain to explain how each factor contributes to the buildup. (The answers are not related to seasonal changes in the input of primary pollutants from auto emissions that are the ultimate cause of photochemical smog.)

What is the meteorological reason for the dip in the AQI in July?




*Air Quality Index (AQI) for ozone at Phoenix, Arizona. Data are from the Environmental Protection Agency.*