Midterm Exam

1. [2 pt] Circle whether each statement below describes weather or climate.

   (a) A city had a storm with 2 inches of rain ..... weather ..... climate

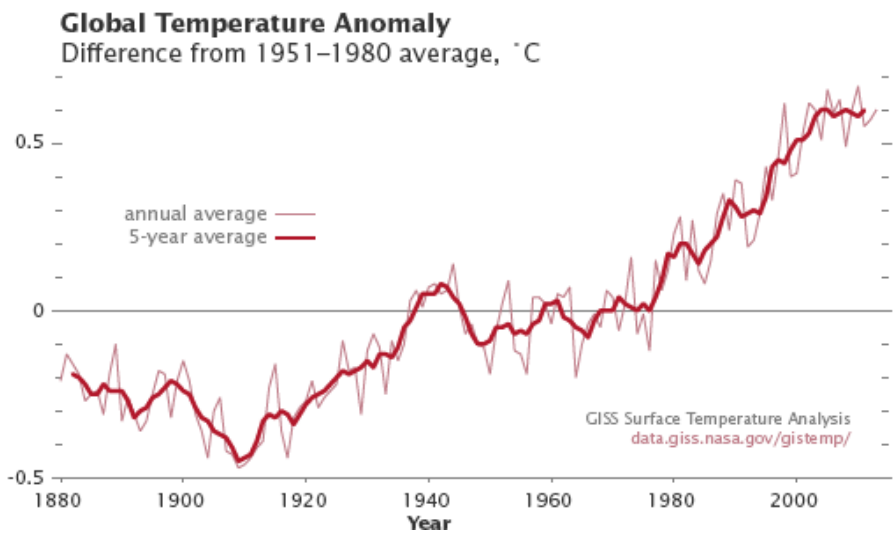
   (b) A city typically gets most of its rain in March ..... weather ..... climate

   (c) A city will have a heat wave starting tomorrow ..... weather ..... climate

   (d) A city rarely gets below freezing in the winter ..... weather ..... climate

2. [2 pt] Someone says, "Weathermen sometimes get forecasts wrong one week in advance, so I do not trust predictions for 50 years in the future." Explain why a weather forecast is different than a climate prediction.

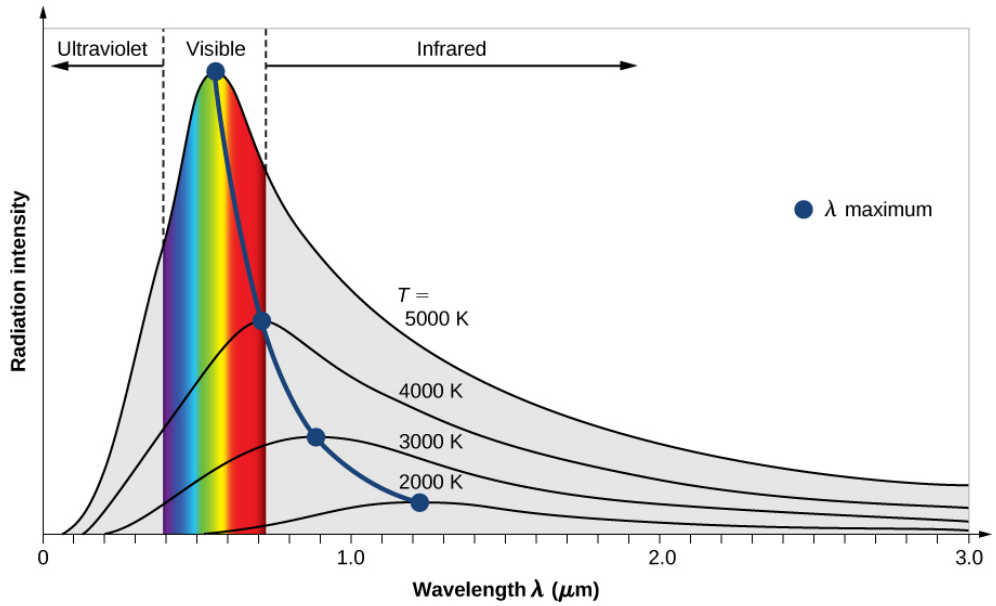
3. [6 pt] Define *temperature anomaly*. Using the graph below, explain why the global temperature anomaly was negative in the period 1880-1940.



4. [5 pt] A global warming advocate tells you that the Earth is now warmer than it has ever been. Is that correct? Explain why or why not.

5. [5 pt] Object A has a higher internal energy compared to Object B. Which object has a higher temperature? Explain your answer.

6. [10 pt] On a clear evening during the winter months, if you happen to be in the Northern Hemisphere and look up at the sky, you can see the constellation Orion (The Hunter). One star in this constellation, Rigel, flickers in a blue color and another star, Betelgeuse, has a reddish color. Which of these two stars is cooler, Betelgeuse or Rigel? Explain your answer. (To answer this question you may use the graph below.)



7. (a) [10 pt] Consider the "Rock planet" model. Draw a diagram and label the fluxes. Derive an expression for the surface temperature using this model (i.e., express T_R in terms of the solar constant (S), albedo of the Earth (α), and Stefan-Boltzmann constant (σ). No need to solve it.

   (b) [5 pt] What would happen to the surface temperature if one layer of the atmosphere is added (i.e, compare T_R with T_{1L}, where T_{1L} is the surface temperature in the "One-layer" model). Answer this question qualitatively, no need for diagrams or systems of equations.

   (c) * [10 pt - extra credit] Now assume that in the "One-layer" model the atmosphere traps only a fraction of the outgoing radiation from the Earth (let's call this fraction ϵ). By definition $\epsilon < 1$. How would it modify the energy balance for the Earth's surface and the atmospheric layer? (i.e., draw a diagram, label fluxes, and write the system of equations for the surface and atmospheric layer. No need to solve this system.)

8. [10 pt] Name and *briefly* describe at least three natural processes that remove carbon from the atmosphere.

9. [10 pt] Briefly describe how a carbon atom in coal could end up in a penguin. You may draw a diagram if you wish.

10. [10 pt] Warming temperatures cause permafrost in Siberia to melt, which causes a release of carbon dioxide and methane (both potent greenhouse gases) that was previously locked underneath the permafrost. Draw a feedback loop that corresponds to the this process, and identify it as a positive or a negative feedback. Is it a slow or fast feedback?

11. [5 pt] What is the difference between climate feedbacks and radiative forcings? And how can they be related?

12. [5 pt] Consider the ice-albedo and lapse-rate feedback mechanisms. In climate science, an effect of a feedback might be expressed using the strength of a feedback g as

$$\Delta T_f = \frac{\Delta T_i}{(1-g)}.$$

Note that the absolute value of g is smaller than one, i.e. $|g| < 1$. Complete the following statement: "For the same initial change in temperature ΔT_i, the final change in temperature ΔT_f is ..... for the ice-albedo feedback compared to the lapse-rate feedback. This is because g for the ice-albedo feedback is ..... and for the lapse-rate feedback is ....."

13. [5 pt] Complete a feedback loop below and determine the sign of the feedback mechanism.