ATM S 211 **Climate and Climate Change**

Assignment 3: Faint Sun and Greenhouse Effect Due 21 October 1999

1. Astrophysicists believe that 3 billion years ago the sun's power output was only 75% of today's solar energy output.

   a) Assuming that the albedo of Earth was the same 3 billion years ago as now, what would have been the emission temperature of the Earth then? Show the calculation. (3pts)

$$T_{emission} = \sqrt[4]{\frac{\frac{S_0}{4}(1 - albedo)}{\sigma}} \qquad \sigma = 5.67\text{x}10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$$

   Hint: $\sqrt[4]{0.75} = 0.93$

   b) Today the emission temperature is 255K and the surface temperature is 288K. The difference between these two numbers is a measure of the greenhouse effect of the atmosphere. What would be a good guess of the surface temperature 3 billion years ago, if the greenhouse effect and the albedo were the same then as now? Explain your answer or show the calculation. (2pts)

   c) If the surface temperature reached the value given in b) above, would there have been an ice-albedo feedback effect? What would this do to the temperature? What do you think the surface conditions would be like? Explain. (2pts)

   d) The geological record shows that the Earth has probably never frozen over (Actually this is now in dispute, but assume that Earth was never frozen over). Can you think of one or more ways to reconcile the fact that Earth's surface never completely froze over with the fact that the early Sun was much less powerful than today's? Explain. (3pts)

2. Write a short essay (1-2 pages), intended for a general reader who has not taken this or a similar course, explaining how the atmospheric "greenhouse effect" works, and why it would change if the concentrations of certain atmospheric gases change. (10 points)