METEO 470 Climate Dynamics **Spring 2008**

PROBLEM SET #4

GLOBAL ENERGY BALANCE; EL NINO/SOUTHERN OSCILLATION

1. The equilibrium climate sensitivity is often defined by the so-called '*2xCO_2*' equilibrium sensitivity, defined as the temperature increase (in ^oC) resulting from a doubling of atmospheric CO_2 levels to approximately 560ppm from their pre-industrial value of approximately 280ppm (the current level is approximately 365ppm). Approximate the longwave radiative forcing due to increased greenhouse gases by an equivalent change in shortwave radiation received by the earth's surface, with $\Delta Q=4W/m^2$ for CO_2 doubling.

a. Calculate the '*2xCO_2*' equilibrium sensitivity using the general definition of equilibrium sensitivity provided in class, applied to a *black body* earth.

b. Same as 'a', but for *gray body* earth

c. How does your answer compare with the typically quoted values of equilibrium climate sensitivity? Discuss briefly.

2. In 1991, Dr. James Hansen made a famous prediction back in 1991 when he tested the reliability of global climate models by predicting that global mean surface temperatures would cool for several years in response to the explosive Mt. Pinatubo eruption. Using the numerical ©Matlab zero-dimensional EBM model used in class and available at
http://www.math.nyu.edu/caos_teaching/physical_oceanography/numerical_exercises/ebm/zero_dim_ebm.html
with the standard *gray body* parameter values, make your own prediction of the post-Pinatubo global mean cooling. You are given that the eruption was associated with a decrease in average shortwave radiation received by the earth of approximately 4W/m^2 over a duration of 2 years [*hint*: express this change in terms of an equivalent fractional change in the solar constant, but be careful to distinguish carefully between the *solar constant* ($S_0 \approx$1370 W/m^2) and the *average* shortwave radiation *received by the earth's surface*].

3. Consider a simple dynamical model for ENSO. The relationship between the zonal wind anomaly *U* (positive for easterlies that are stronger than their 'normal' value, and negative for a weakening of the easterlies) and the eastern tropical Pacific temperature anomaly *T* (positive for an El Nino, and negative for a La Nina) is as follows:

$$dU/dt = -\alpha T \qquad (1)$$

$$dT/dt = -\beta T + kU \qquad (2)$$

where α, β and k are positive constants

a. Provide a physical interpretation of the ‘feedbacks’ represented in each of the three terms in (1) and (2) on the right hand sides of the equations

b. Find the general time-dependent solution for the temperature ***T*** **[hint: you may find it useful to review the introductory physics problem of a damped spring].** Briefly interpret your solution.

c. Suppose that α=1 m yr^{-2} K^{-1}, β= 0.5 yr^{-1}, and *k*=1.5 K m^{-1}. What is the period of the oscillations? What is the damping ("e-folding") timescale of the oscillations, i.e. how long does it take for the amplitude of the oscillations to become negligibly small? Are these numbers realistic based on what you know about El Nino?