1. The amount of energy that is required to raise the temperature of the atmosphere and oceans depends on their physical properties (heat capacity for air Cp = 1004 J $K^{-1}kg^{-1}$ and for liquid water Co = 4218 J $K^{-1}kg^{-1}$) and the depth of ocean surface layer that communicates with the mass of atmosphere (use $P_s = 10^5$ Pa) [1 Pa = 10^{-5} bar = N m^{-2} , 1 J = 1 N m]
   a. If the top ocean warms by 1°C during a 3-month summer period, what is the average rate of net energy flow into the ocean during this period in units of Wm^{-2}? You need to specify a reasonable depth of the top ocean for the estimation (5%)
   b. If the atmosphere warms by 1°C during the same period, what is the average rate of net energy flow into the atmosphere (5%)
   c. please compare the thermal capacity of the ocean relative to the atmosphere (10%)

2. Please write down the energy balance equation at Earth surface. Discuss the energy balance in the tropics, subtropics, and polar latitudes over land and ocean regions (give values if you can, or compare the relative magnitudes based on you understanding about dominant factors that determine the value of surface energy fluxes) (20%)

3. Please describe physically and quantitatively Hadley circulation in terms of conservation of energy, mass, and angular momentum, and the role of baroclinic eddies (20%)

4. From the global energy balance at the top of the atmosphere $S(H_2O, I, C) = R(T, H_2O, \log_2 CO_2, C)$, we can derive the response of warming (dT) in response to doubling of CO_2 ($d\log_2 CO_2$) while holding water vapor, cloud and ice content (H_2O, C, I) fixed as follows

$$\frac{dT}{d\log_2 CO_2} = -\frac{\partial R}{\partial \log_2 CO_2} / \frac{\partial R}{\partial T} \equiv \Delta_0 \approx 1K \text{ (i.e. doubling CO}_2 \rightarrow \text{1K warming).}$$

   Following the above dT, if H_2O is changed as a function of T, we can obtain

$$\frac{dT}{d\log_2 CO_2} = \Delta_0 / (1-\beta_{H_2O}),$$ Please derive β_{H_2O} (5%).

   CO_2 warming experiments in GCMs indicate that β_{H_2O} is about 0.4. What does the above expression tells you ? why ? (10%)
   What if you allow cloud and ice content to change as well ? (5%)

5. Please describe the spatial structure and responsible dynamics of ocean gyre circulation (20%).

試題隨卷繳回