Energy and Climate

Coursework problems

Questions 7 and 10 will be assessed.

Answers to question 7 to be handed in before 6 March 1998
Answers to question 10 to be handed in before 27 March 1998

1. Calculate the difference (expressed as a percentage of the mean) between the average solar radiation incident on the top of the Earth's atmosphere at perihelion and aphelion when the Earth-Sun distance is respectively 147×10^6 km and 152×10^6 km. The mean distance is 149.6×10^6 km. Calculate the change in the radiative equilibrium temperature of the Earth which would result from such changes in the incident radiation, assuming a mean equilibrium temperature of 256 K.

2. Neglecting the absorption of radiation by the atmosphere and transport of heat by the atmospheric and oceanic circulation, show that the radiative equilibrium temperature of the Earth's surface varies with latitude, θ, as $T_e = \overline{T_e}\frac{4}{\pi}\cos\theta$, if the solar declination is assumed to be 0°. Hence show that, if the surface becomes totally covered by ice with an albedo of 0.8 following a reduction in the solar constant, the situation is likely to persist even when the solar constant has returned to it's former value.

3. By calculating the solar energy (assuming that the Sun radiates as a black body at 6000 K) at wavelengths of 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4 and 12.8 μm, obtain an estimate of that fraction of the solar energy which is in the visible range (0.4 to 0.7 μm).

4. A new glass is transparent to sunlight but absorbs 80% of radiation emitted from the ground. Show that in a greenhouse covered with this glass, the total radiant energy incident on the surface of the earth is $5S/3$ where S is the incident flux of solar radiation.

5. Consider a model of the atmosphere consisting of three concentric isothermal shells. Each layer completely absorbs all of the long wave radiation emitted by an adjacent layer or surface but absorption within the emitting layer may be neglected. Calculate the temperature of each layer in terms of the temperature of the surface.

6. The measured effective surface temperatures of Earth and Venus are 250 K and 230 K respectively, while the measured surface temperatures are 280 K and 750 K. Calculate the optical thickness of the atmospheres of Earth and Venus.

7. Approximately 48% of the mean incoming solar flux at the top of the atmosphere (340 W m^{-2}) is absorbed at the surface, and 16% is lost by net radiation from the surface. The annual average conduction into the surface is negligible the net absorption of energy at the surface is balanced by latent and sensible heat transfer into the atmosphere. The processes accounting for approximately 70% and 30% of the net absorbed radiation.

Calculate the mean annual precipitation over the surface of the Earth.

Assuming that water vapour has a mean density of 3 g m^{-3} in the troposphere, estimate the average residence time of a water molecule in the troposphere which may be assumed to be 10 km deep.

8. Air, originally at rest with respect to the rotating Earth, is moved slowly northwards from the equator, while it's angular momentum is conserved. What zonal velocity will the air have at 45°N, relative to the Earth? Comment on the result.

9. The mean poleward transport of energy by the Earth-atmosphere system at 50°N is 5×10^{15} W. 60% of this heat is carried by the atmospheric circulation, and the mean meridional temperature gradients in the upper and lower troposphere at this latitude are respectively -4×10^{-6} K m^{-1} and -6×10^{-6} K m^{-1}. Derive an estimate of the mean meridional velocity in the lower part of the troposphere, assuming this layer to be 3 km deep, necessary to transport this heat, assuming a direct meridional circulation extending over a meridional distance of 1000 km. Comment on how this circulation compares with that which is observed.

10. The mean density of the Earth is 5.5×10^6 g m^{-3}. Calculate the ratio of the angular momentum of the atmosphere to that of the Earth, assuming that the atmosphere is at rest relative to the Earth. If the atmosphere has a uniform angular velocity relative to the Earth, calculate the effect on the length of the rotation period of the Earth of an increase in the mean zonal wind speed at the equator of 5 m s^{-1}.