EARTH SCIENCES SCIENTIFIC BACKGROUND ASSESSMENT

Exercise 1:

**Solar radiation and the temperature of the Earth**

In this exercise, we will make some crude estimates of the temperature of planet Earth, which is determined by the heating from the Sun and the cooling by the Earth emission of infrared radiation.  Refer to the table below for useful astronomical data and physical constants.

**1. Astronomical context**.

**1.1.** Knowing the Sun’s power (Tab.1), compute the solar constant S0, i.e. the solar energy flux [Wm-2] at the location of the Earth’s orbit.

**1.2**. Compute the total solar energy incident on Earth per unit time.

**1.3.** The solar radiation that hits a given unit of the Earth’s surface depends on many factors like season, time of the day and geographical location (section 4). Considering a constant albedo (see Tab.1), show using a simple approach that the average daily mean solar energy flux absorbed by a unit surface of the Earth is equal to $\frac{S\_{0}}{4}(1-α)$.

**2. Radiative balance.**

For a constant climate, the Earth’s mean temperature isn’t increasing nor decreasing with time, and all the absorbed solar radiation must be balanced by outgoing terrestrial radiation. In other words, the Earth can be seen approximately as a blackbody in radiative equilibrium with the sun.

The blackbody energy lost per unit surface is given by the Stephan-Boltzmann law:

E = σT4,

where σ is the Stephan’s constant (value listed in tab.1), and T is the surface temperature in degrees Kelvin.

**2.1** Compute the equilibrium temperature of the Earth’s surface in the blackbody approximation, using the solar energy source computed at point 1.3.

**3. Comment.**

The temperatures computed at point 2 is normally called the emission temperature. Is it a good approximation of the actual surface temperature of the Earth? If not (too warm, too cold) comment on the physical reasons that determine this difference.

**4. Latitudinal variations**

**4.1**. Suppose that the Earth’s rotation axis is normal to the Earth-Sun axis (as for the equinoxes). By considering the solar flux incident on a latitude belt bounded by latitudes $(φ, φ + dφ),$ show that F$(φ)$, the daily averaged solar radiation per unit area [Wm-2] of the Earth’s surface, varies with latitude as:

F$(φ)$ = $\frac{S\_{0}}{π}\cos(φ)$

**4.2** Using the result at point 4.1, suppose that, separately at each latitude, the radiation budget can be represented by black-body approximation and that the albedo is the same for all regions of the Earth. Determine how surface temperature varies with latitude.

**4.3** Calculate the surface temperature at the equator, 30◦, and 60◦ latitude.

Table 1: Useful astronomical and physical constants

|  |  |
| --- | --- |
| Sun Power  | Ps = 3.9 1026 W |
| Average distance Earth-Sun  | R = 1.496 1011 m |
| Earth Radius  | a = 6.371 106 m |
| Stephan’s Constant | σ = 5.67 10−8 W m−2 K−4 |
| Average Albedo  | α = 0.3 |