PROBLEMS

8. 1 Residence times of aerosols

The radioisotopes ^{210}Pb and ^{7}Be are often used to determine the atmospheric residence times of aerosols.

1. Lead-210 is produced by radioactive decay of ^{222}Rn emitted from soils, and condenses immediately on preexisting aerosol particles. The ^{222}Rn emission flux is 1.0 atoms cm^{-2} s^{-1} from land (30% of Earth's surface) and zero from the oceans. The only sink of ^{222}Rn is radioactive decay (half-life 3.8 days), producing ^{210}Pb. Removal of ^{210}Pb is by radioactive decay (half-life 23 years) and by aerosol deposition. The total mass of ^{210}Pb in the troposphere is estimated from observations to be 380 g. Derive the residence time against deposition of ^{210}Pb-carrying aerosols in the troposphere. You should find a value of 8 days.

2. Beryllium-7 is produced by cosmic rays in the stratosphere and upper troposphere. Similarly to ^{210}Pb, it condenses immediately on preexisting aerosol particles. The global source of ^{7}Be is 150 g yr^{-1}; 70% of that source is in the stratosphere and 30% is in the troposphere. Removal of ^{7}Be is by radioactive decay (half-life of 53 days) and by aerosol deposition (in the troposphere only). We assume that the troposphere and stratosphere are well-mixed reservoirs, that ^{7}Be is at steady state in each of these reservoirs, and that the transfer rate constant from the stratosphere to the troposphere is k_{ST} = 0.8 yr^{-1}. The total mass of ^{7}Be in the troposphere is estimated from observations to be about 3 g. Derive the residence time against deposition of ^{7}Be-carrying aerosols in the troposphere. You should find a value of 24 days.

3. Why are the lifetimes of ^{210}Pb-carrying aerosols and ^{7}Be-carrying aerosols in the troposphere so different?

4. Since most of the ^{222}Rn emitted at the surface decays in the troposphere, one might expect ^{210}Pb concentrations to be much lower in the stratosphere than in the troposphere. In fact the opposite is observed. How do you explain this observation?

[To know more: Koch, D.M., et al., Vertical transport of aerosols in the troposphere as indicated by ^{7}Be and ^{210}Pb in a chemical tracer model, *J. Geophys. Res., 101,* 18651-18666, 1996]

8. 2 Aerosols and radiation

We examine here the effects of different types of idealized aerosols on the surface temperature T_o of the Earth.

1. Sulfate aerosols scatter solar radiation (no absorption), and do not absorb or scatter terrestrial radiation. What effect would an increase in sulfate aerosol

concentrations have on T_o?

2. Soot aerosols absorb solar and terrestrial radiation (no scatter). Discuss briefly how the effect of a soot layer on T_o depends on the altitude of the layer.

3. Desert dust aerosols scatter solar radiation (no absorption) and absorb terrestrial radiation (no scatter). Consider our simple greenhouse model where the gaseous atmosphere consists of a single thin layer that is transparent to solar radiation but absorbs a fraction f of terrestrial radiation. We add to that layer some desert dust so that the planetary albedo increases from A to $A + \varepsilon$, and the absorption efficiency of the atmospheric layer in the terrestrial radiation range increases from f to $f + \varepsilon'$. Assume that ε and ε' are small increments so that $\varepsilon << A$ and $\varepsilon' << f$. Show that the net effect of desert dust is to increase T_o if

$$\frac{\varepsilon'}{\varepsilon} > \frac{F_S}{2\sigma T_o^4} \approx 1.8$$

and to decrease T_o otherwise. Here F_S is the solar constant and σ is the Stefan-Boltzmann constant.

[To know more: Tegen, I., et al., Contribution of different aerosol species to the global aerosol extinction optical thickness: estimates from model results, *J. Geophys. Res., 102,* 23,895-23,915, 1997]