Text exam ENV-320, Part Schmale

Question 1 (3 pnts)

Verify the following by showing all steps of your own calculation: The insolation in cloud-free conditions is about 1000 W m^{-2}, if the troposphere absorbs 50 % of it, then the tropospheric temperature will increase by 0.36 K h^{-1}.

Use the following values, while remembering that a Watt is defined as Joule per second:

- thickness of troposphere: 10 km
- average density of troposphere: 0.5 kg m^{-3}
- heat capacity of air: cp = 1005 J kg^{-1} K^{-1}

Solution 1:

$$\frac{dT}{dt} = -\frac{1}{\rho c_p}\frac{dF(z)}{dz}$$

$$\frac{dT}{dt} = -\frac{1}{1005\ J\ kg^{-1}\ K^{-1} * 0.5\ kg\ m^{-3}}\ \frac{0 - 1000 * 0.5\ W\ m^{-2}}{10000\ m} = 0.36\ K\ h^{-1}$$

Question 2 (2 pnts)

Figure Q2 shows Earth's averaged outgoing longwave radiation. High clouds can be found along the equator, where the outgoing longwave radiation is relatively lower.

a) Explain in no more than 3 lines why high clouds are responsible for the relatively lower radiation (think of the Stefan-Boltzmann Law).

High clouds are colder, because the temperature in the upper troposphere is colder. A colder black or grey body emits less radiation compared to a warmer body or cloud close to the surface.

b) Do high clouds cool or warm Earth?

High clouds warm Earth, because they radiate less longwave radiation to space than lower clouds or compared to the Earth's surface.

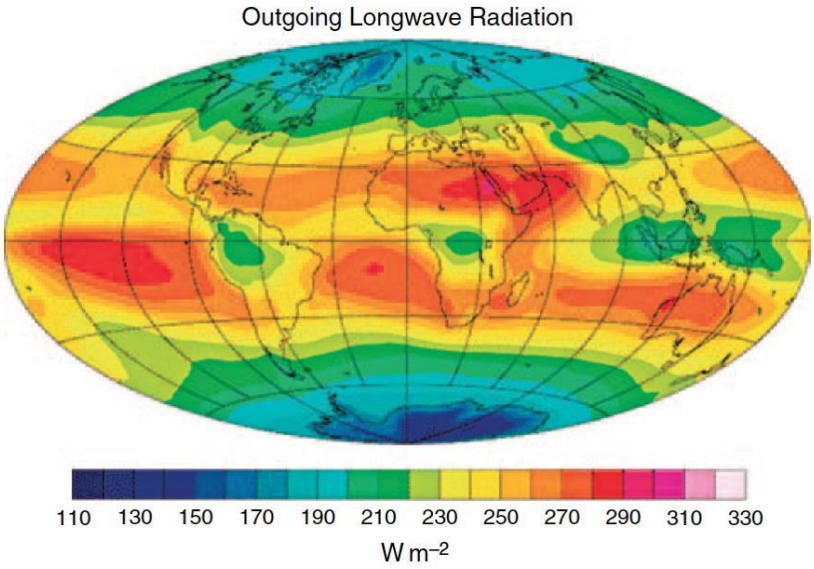

Figure Q2: Average outgoing longwave radiation from Earth in W m^{-2}.

Question 3 (2 pnts)

Why can sulfate aerosol, formed from SO_2 emitted from volcanoes into the stratosphere, remain there for years while the lifetime of sulfate aerosol in the troposphere is only several days? Answer in no more than 5 lines.

The main atmospheric removal process is wet deposition. In the stratosphere there are no clouds, so removal happens via dry deposition only. If the sulfate aerosol is small (only a few micrometer or less) sedimentation is a very slow process.

Question 4 (3 pnts)

a) Why is it so difficult to reduce ozone pollution in cities? Hint, make sure to include NO_x and VOCs in your argument. 5 lines

Ozone can be formed from NO_x and VOCs oxidation whereby the ozone yield of the reactions is highly non-linear. The ratio of NO_x to VOCs is critical and depending on that ratio reduction of either NO_x (in the NO_x limited regime) or VOCs (in the VOC limited regime) leads to less ozone production. However, just reducing both or either of them does not necessarily lead to an overall ozone reduction.

b) The rate of production of OH in the atmosphere depends on how $O(^1D)$ reacts further, i.e. it is quenched back to ground state or yields 2 OH from reaction with H_2O. The yield (εOH) can be calculated as in EQ1. Calculate εOH based on three different humidities, whereby ξH2O = 0.0167*RH:

k_4	$2.2*10^{-10}$ cm^3 $molecule^{-1}$ s^{-1}
k_3	$2.9x10^{-11}$ cm^3 $molecule^{-1}$ s^{-1}
RH1	20 %
RH2	50%

RH3	80%

$$\varepsilon OH = \frac{2k_4 \xi H_2O}{k_3}$$ EQ1

RH20	0.05
RH50	0.13
RH80	0.20

c) If our atmosphere were to become more humid, how would the lifetime of CH_4 with respect to OH change?

More OH would be produced and hence CH4 would react faster, so the lifetime decreases.

Question 5 (1.5 pnts)

Figure Q5 shows two aerosol number concentration size distributions. Answer the following questions by focusing on the red boxes:

a) How many modes are there on 3 April?

one

b) How many modes are there on 15 April?

two

c) Are there more or less particles on 15 April compared to 3 April?

There are more on the 15th.

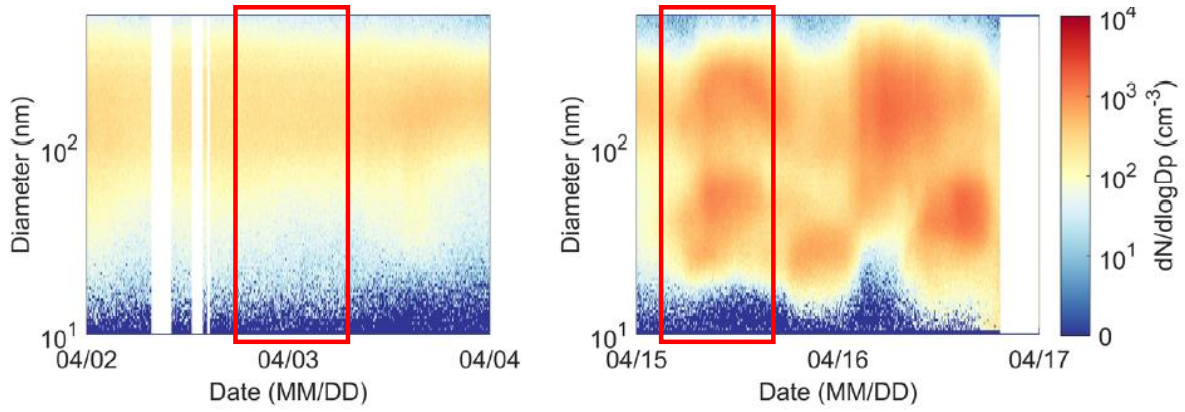

Figure Q5: Aerosol number concentration size distribution in the central Arctic in April 2020.