Intermediate test Geochemical Cycles (Geo2-1207) October 3, 2016

15:15 - 17:00 pm

Ruppert B / Ruppert C

Name and studentnumber

Question 1 (20 points)

a) Why is the air sinking at ~20-30° latitude on both hemispheres (and also in the polar regions) while it rises at equatorial latitude and the polar fronts at ~60° latitude (again on both hemispheres)?

b) Why are these 20-30° latitudinal bands characterized by deserts? It less well-known but also the polar regions are very dry.

Question 2 (30 points)

At the equator, the average flux of solar radiation absorbed by the surface mixed layer of the ocean is 700 W m^{-2} (Note: 1 W = 1 J s^{-1}). The average temperature of equatorial surface water is 25°C. The latent heat of evaporation of water is 2.25 x 10^6 J kg^{-1}. The surface area of the oceans = 3.61 x 10^{14} m^2.

a) Use the Stefan-Boltzmann equation ($I_0 = \sigma (T_s)^4$ with I_0 being the incoming radiation and T_s the absolute temperature) to calculate the radiative flux from the equatorial ocean to the atmosphere. (Note: $\sigma = 5.8 \times 10^{-8}$ W m^{-2} K^{-4}) How does this energy loss from the surface mixed layer compare with the solar energy input?

b) Assuming that the average yearly temperature of the surface mixed layer does not change and evaporation is the only other mechanism by which the sea loses heat, calculate the amount of water that would be evaporated at the equator per m^2 per year.

Question 3 (25 points)

In the figure below the concentrations of the gases CFC-11 ($CFCl_3$) and CF_4 in the atmosphere are provided as a function of altitude. Table 2.3 from the text book is reproduced on the next page.
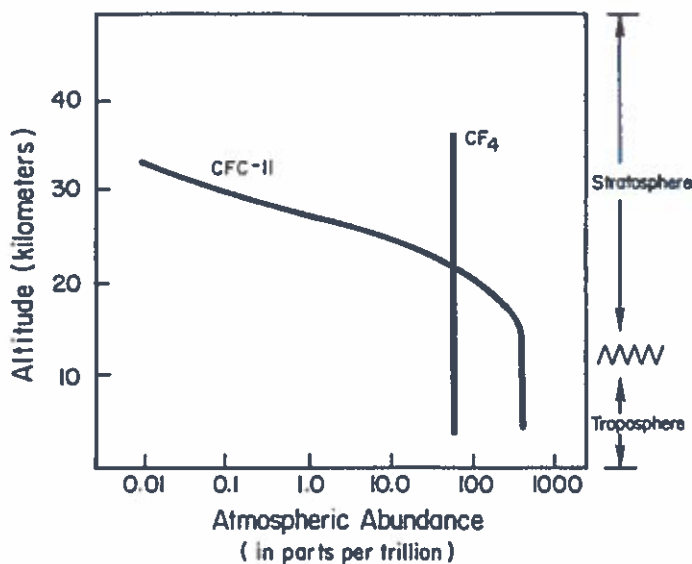
a) Explain the processes that result in the vertical distribution of CFC-11 ($CFCl_3$) in the troposphere.

Table 2.3 Extra trapping of infra-red radiation ΔQ (positive radiative forcing) by excesses of trace atmospheric gases above their pre-industrial concentration

Trace Gas	Preindustrial concentration 1750 ppm	Conc.[a] 2007–2005 ppm	ΔQ (watts/m^2)	% total ΔQ	Life (yr)[b]
CO_2	~280	384	1.66±0.17	55%	
CH_4	0.715[c]	1.774	0.48±0.05	16%	9
N_2O	0.270	0.319	0.16±0.02	5%	114
Strat.H_2O[d]			0.07±0.05	2%	
Halocarbons-total[e]			0.34±0.03	11%	65–130
CFC 12			(0.17)		100
CFC 11			(0.063)		45
CFC 113			(0.024)		85
Trop.O_3[f]	—	—	0.35	12%	short
Strat. O_3 loss[g]	—	—	−0.05±0.10	−2%	
Total			3.01		

Source: After Solomon et al. 2007, chap. 2 and table 2.1, p. 141.

[a] 2007 CO_2 Raupach et al. 2007; rest 2005.

[b] From IPCC 2007; removal of CO_2 involves a range of processes that can span long time scales.

[c] Ice core data; ice core range (up to 650,000 years ago) 0.32–0.79.

[d] Stratospheric water vapor from methane oxidation.

[e] In addition to CFCs include HCFCs (see Solomon et al. 2007 Table 2.1, p. 141).

[f] Tropospheric O_3 range of ΔQ = 0.25 to 0.65.

[g] Net negative forcing from stratospheric O_3 destruction by CFCs 1750–2005.

b) If CFC-11 and CFC-12 (CF_2Cl_2) had been produced at exactly the same rate since their introduction into the atmosphere, what would you expect the vertical profile of CFC-12 to look like in comparison to CFC-11? Concisely explain your answer and draw the two profiles on your answer sheet.

c) What can you say about the chemistry, in terms of reactivity, of carbon tetrafluoride (CF_4) in the atmosphere? Will its residence time be shorter or longer than that of the CFCs? Why?

Question 4 (25 points)

Consider the simple H_2O-CO_2 model for clean rain discussed in class as starting point. This involves rain water in equilibrium with atmospheric CO_2. There are two equilibrium reactions describing this clean rain ($CO_2(g) = (CO_2(aq))$). $CO_2(aq) + H_2O = H_2CO_3$ and $H_2CO_3 = H^+ + HCO_3^-$, with equilibrium constants K_1 and K_2 respectively. Numeric value for K_1 is $10^{-1.47}$ and that for K_2 is $10^{-6.35}$. pCO_2 in the atmosphere is $10^{-3.5}$ bar.

Let 0.35 mg L^{-1} of $CaCO_3$ (calcite) dissolve in this model rain. It dissolves completely. What will be the resulting Ca^{2+} concentration? What will be the pH? *Hint*: start by writing the appropriate chemical reaction describing H^+ consumption when $CaCO_3$ dissolves.