## PHYS/OCEA 4595 Atmospheric Chemistry Quiz 1, October 2, 2024

1. We discussed a calculation showing that, in principle, the ocean could uptake all but 3 % of the carbon dioxide emitted by fossil fuel burning. However, this calculation made two assumptions which, in practice, significantly restrict the ability of the ocean to uptake carbon dioxide. Briefly, what are these two assumptions? (8 points)

Fart - Ocean pH assumed constant - Atmospheric equilibrium CO2 5 ocean

2. What are two important mechanisms by which humans have modified the nitrogen cycle in the last 100 years? (8 points)

- inceased nitrogen fixation from Ofossil fuel burning Dindustrial fertilizer, or 3 nitrogen fixing crops.

**3.** Give a rough estimate for each timescale.

(i) Timescale for vertical overturning in the troposphere. (2 points)

(ii) Timescale for interhemispheric exchange in the troposphere. (2 points) 6 months ~ Yr

(iii) Timescale for an air parcel in the troposphere to go into the stratosphere. (2 points)

(iv) Timescale for an parcel in the stratosphere to go into the troposphere. (2 points) Z years

(v) Timescale for parcel to be dispersed globally in the east-west direction. (2 points) 2 weeks

(vi) Timescale for mixing within a hemisphere. (2 points) 4-6 Mentus

4. (i) The burning of methane  $(CH_4)$  in the presence of  $O_2$  produces  $CO_2$  and  $H_2O$ . Show how many O<sub>2</sub> are consumed in the burning of one methane molecule by showing the balanced stoichiometry of this reaction. (6 points)

> Need 240 to Balance CH4  $CH_4 + 20_3 \rightarrow CO_3 + 2H_2O$

(ii) Suppose that a sufficient amount of methane was burned that it would increase the CO<sub>2</sub> mixing ratio in the atmosphere by 5 ppmv (i.e., if all of the CO<sub>2</sub> produced were to remain in the atmosphere). In this case, by how much would you expect the  $O_2$  mixing ratio to decrease (if this were the only process occurring in the atmosphere)? (4 points)

Decrease by iOppmu

Suppose that, as a result of this methane burning, the actual CO<sub>2</sub> mixing ratio increased by 2 ppmv, and the O<sub>2</sub> mixing ratio decreased by 8 ppmv. Assume that the only other two processes affecting the mixing ratios of  $CO_2$  and  $O_2$  in the atmosphere are uptake of  $CO_2$  by biomass and dissolution of CO<sub>2</sub> in the ocean. A diagram may help in answering the two questions below.

(iii) What was the effect of land uptake on the mixing ratios of  $CO_2$  and  $O_2$ ? (6 points) Suppose L = Land CO2 uptake O = Ocean CO2 uptake obs change CO2 Then  $(5,-10) + (-0_{c,0}) + (-1,1) = (2,-8)$ (11.2)

CH4Burn Ocean uptake Need L=2 ppm v CO2

(iv) What was the effect of ocean uptake on the mixing ratios of  $CO_2$  and  $O_2$ ? (6 points)

From above  $5 - O_c - L = 2$   $1 \quad C$   $occain \quad L = 2$  from above obtaine Need Oc= 1 ppmv O2 5. (i) The global mean mixing ratio of  $N_2O$  in the preindustrial atmosphere was 285 ppbv. How many moles of  $N_2O$  were in the atmosphere? (6 points)

$$Na = \frac{Ma}{Ma} = 1.8 \times 10^{20}$$
 moles in the atmosphere.  
 $N_{20} = C_{N_{20}} = N_a = 5.1 \times 10^{13}$  moles  $N_{20}$ 

(ii) N<sub>2</sub>O is destroyed (mostly in the stratosphere) with a global mean first order loss rate of k = 0.004 (year)<sup>-1</sup>. The main source is emission from the surface. Using a global mean box model in which the preindustrial N<sub>2</sub>O mixing ratio was in steady state, estimate the preindustrial number of moles of N<sub>2</sub>O emitted from the surface every year. (10 points)

Steady State means 
$$\frac{d N_{20}}{dt} = 0$$
  
 $\frac{d N_{N_{20}}}{dt} = E - L$  (Grbbal so no transport  
 $0 = E - K N_{N_{20}}$   
 $E = K N_{N_{20}}$   
 $= 204 \times 10^{4}$  moles  $N_{20}/year$ 

(iii) Measurements indicate that  $N_2O$  is increasing at a rate of 1 ppbv per year, and that its current mixing ratio is 315 ppbv. Using a global box model, estimate the current emission of  $N_2O$  from the surface in moles per year. (14 points)

$$\frac{d N_{N_{20}}}{dt} = (1 \times 10^{-9}) N_{a} = 1.8 \times 10^{41} \text{ moles } N_{20}/yr$$

$$\frac{d N_{20}}{dt} = E = K N_{N_{20}}$$

$$E = 1.8 \times 10^{41} \frac{\text{moles } N_{20}}{yr} + (0.004) (315 \times 10^{-9}) (N_{a})$$

$$= 4.07 \times 10^{41} \frac{\text{moles } N_{20}}{yr}$$

6. (i) Assume that the global mean precipitation rate is 2 mm/day. What is the global volume of rainfall reaching the surface in one year (in m<sup>3</sup>)? (8 points)

Volume rain = 4TT R2. (0,002m) - 365 days lyr  $= 3,75 \times 10^{14} m^3$ 

(ii) Suppose that lighting was a source of  $1 \times 10^{12}$  moles of HNO<sub>3</sub> per year (after oxidation from NO and NO<sub>2</sub>). Assume that all of this nitric acid in the atmosphere dissolves in rain, and that each nitric acid molecule dissociates to produce one H<sup>+</sup>. Estimate the mean pH of rainfall. (Note:  $pH = -log_{10}[H^+]$ ). (12 points)

$$[H^{+}] = \frac{1 \times 10^{12} \text{ moles } H^{+}}{3.75 \times 10^{14} \text{ m}^{3} \cdot 1000 \, \theta/m^{3}} = 2.67 \times 10^{5} \text{ moles}/\rho$$
  
$$\rho H = -\log_{10} [H^{+}] = 5.6$$