國立臺灣大學 103 學年度碩士班招生考試試題

Constants/equations you might need:
Earth's radius (R_e) = 6370 km
Mean Sea Level Pressure (P_s) = 1013 hPa
Scale Height (H) = 7.4 km
Universal Gas Constant (R) = 8.314 J $mol^{-1}K^{-1}$
At 1 atm, 298 K, air molecules per cm^3 (N) = 2.5×10^{19}
Molecular Mass of Air (M_a) = 29 g mol^{-1}
Molecular Mass of CO_2 (M_{CO_2}) = 44 g mol^{-1}
GtC = gigaton carbon = 10^{12} kg-carbon
Assume ideal gas for all gases: PV=nRT

1. Figure 1 shows the record of atmospheric CO_2 concentration ($[CO_2]$) measure at the Mauna Loa station.

(a) (6pt) Please estimate the mass increase of CO_2 in unit of GtC from year 1959 ($[CO_2]$ = 316 ppmv) to year 2008 ($[CO_2]$=385 ppmv)

(b) (6pt) Please explain what is the major cause of the annual oscillation of $[CO_2]$ (~5 ppmv peak-to-trough).

(6pt) Please also explain why the peak occurs in Apr-May and the trough in Sep-Oct.

(c) (6pt) The "lifetime" of a molecule is defined as the number of molecules in a reservoir divided by the total flux in or out of the reservoir under steady state. Please estimate the current lifetime of atmospheric CO_2 with respect to the exchange through the annual oscillation described in (b).

(d) (6pt) During the past 50 years, $[CO_2]$ has increased by ~70 ppmv, while the concentration of the halocarbons (e.g., CFCs) has increased by only ~3.5 ppbv (1/20000) in total. However, the radiative forcing due to increase of halocarbons is near 1/3 of that due to the change of $[CO_2]$. Please explain why.

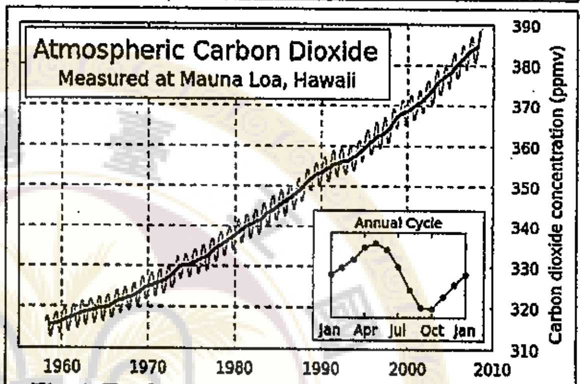

Fig. 1 (Dark grey line is the annual mean value; light grey line is the monthly mean value)

(e) (10pt) Current estimate of climate sensitivity indicates that the doubling of atmospheric CO_2 can lead to an equilibrium global mean surface warming of ~3K. Assume radiative forcing is proportional to $[CO_2]^{0.5}$. For an instantaneous and complete combustion of the Earth's entire fossil fuel reservoirs (~4000 GtC), please estimate how much equilibrium warming would occur. Assume all of the emitted CO_2 stays in the atmosphere. List in detail your equations of estimation.

2. Consider the atmospheric temperature profiles (i), (ii), and (iii) shown in Figure 2.

(a) (6pt) Please pair up each of the three profiles with typical condition in the morning, afternoon, and at night, respectively.

(9pt) Please explain how and why the profiles evolve in the diurnal cycle.

(b) (15pt) Consider a 100-m high smoke stack. Please describe in detail how and why the emitted pollutant might be distributed vertically with each of these profiles (you may draw simple diagrams to help explain).

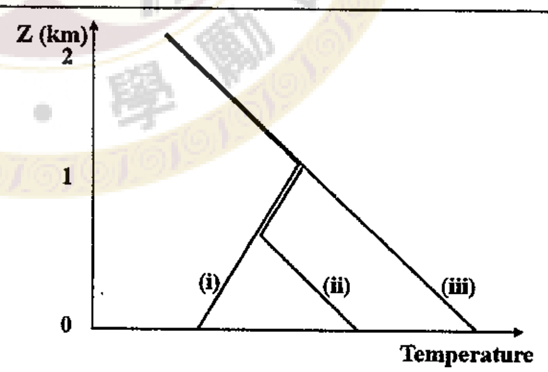

Fig. 2

3. Consider how tropospheric O_3 is controlled by chemical cycling of the NO_x family (NO_2 + NO).

(a) (6pt) Please list all the chemical reactions involved in defining the **photostationary state relation.**

(b) (6pt) Given j_{NO_2}= 0.015 (s^{-1}), k_{NO+O_3}= 1.9×10^{-14} (cm^3 $molecule^{-1}$ s^{-1}), and assume $[O_3]$ = 50 ppb, [NO] = 10 ppb, T = 298 K, and P = 1 atm. Please determine the mixing ratio of NO_2 under the photostationary state.

(c) (6pt) In a typical urban pollution environment with the presence of methane and volatile organic compounds (VOCs), the observed concentration of O_3 is usually much higher than the concentration determined by the photostationary state. Please explain why.

(d) (12pt) Please list three **meteorological** factors that can control the concentration of O_3 near surface and why.

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