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Downhill and uphill diffusion of gases with temperature inversions in the atmosphere

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Abstract: In this study, downhill and uphill diffusion of gases with temperature inversions in the atmosphere has been studied, discussed and applied to study the increase in CO_2-pollution with temperature inversions in Incheon (INC), Korea; Ho Chi Minh City (HCM), Vietnam; Alpine (ALP), France; Shanghai (SHA), China; Colorado (COL); Alaska (ALA), USA; Fukuoka (FUK), Japan; Ny Alesund (NYA), Norway; and High Arctic (ARC). Results have shown that: (i) In temperature inversions, the downhill and uphill diffusion of gases can occur, in which diffusion flux depends on the gradient of concentration and the difference of temperature. (ii) The downhill and uphill diffusion of carbon dioxide with temperature inversions can make CO_2-pollution in the layer under the temperature inversion layer increase stronger or decrease slower than that without temperature inversions. (iii) The temperature inversion can make the CO_2-concentration in the High Arctic increase up to 6.5 times greater than that without temperature inversions.

Keywords: Downhill diffusion; Uphill diffusion; Temperature inversions; CO_2-concentration

1. Introduction

1.1. The downhill and uphill diffusion

The diffusion is a mass transfer process, which can be described by Fick's laws that postulates a linear relationship between the flux of a component and its own concentration gradient and the component diffuses down the concentration gradient. This is normal diffusion or Fickian diffusion [1]. Non-Fickian diffusion is the diffusion processes that do not obey the Fick's laws. Downhill diffusion and uphill diffusion are two diffusion types that are non-Fickian diffusion. In the downhill diffusion, the diffusion flux goes from the higher concentration area to the lower concentration area, which is similar to Fickian diffusion in direction of diffusion flux. In the uphill diffusion, the diffusion flux goes from the lower concentration area to the higher concentration area, which is opposite to Fickian diffusion [2–12]. The downhill diffusion and uphill diffusion often occur in multicomponent systems and the cause is the diffusion coupling effect (the diffusion flux of any components couples strongly to that of its partner components) [2–12]. In this paper, the downhill diffusion and uphill diffusion of gases occurring in single-component systems or in multicomponent systems without the diffusion coupling effect are studied and presented.

1.2. The temperature inversions in the atmosphere

Normally, the temperature decreases with height, when it increases with height, this is the temperature inversion, it means the temperature in the temperature inversion layer (IL) is greater than that in the layer under the temperature inversion layer (UL) [13–15]. The temperature can be increased from 0.5 to 7.69 °C for every 100 m [14]. Especially in Antarctica, the temperature at the height of 10 m can be 25 °C greater than at the surface [15]. The temperature inversion suppresses the air pollutant by acting as a "cap," and makes the air pollutants concentration in UL cannot decrease. Moreover, in temperature inversions, the downhill and uphill diffusion can make the air pollutants concentration in UL increase. This subject has been studied and discussed, which will be presented in the following.

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In summary: The CO_2-transfer in the atmosphere with temperature inversions can be determined by the diffusion equation of gases [Eq. (13)]. Moreover, this equation can be developed to determine the transfer of some gases (such as CO, NO_2, NO, SO_2 …) in the atmosphere and can lead to the possibility to employ short-term predictions of the pollution concentration, which is similar to the super statistical approach to air pollution statistics [36].

5. Conclusions

Downhill and uphill diffusion of gases can occur in the atmosphere with temperature inversions, which is described by a partial differential equation (diffusion equation of gases). The diffusion flux of gases depends on the concentration gradient and the difference of temperature. The diffusion equation of gases can be applied to determine the diffusion flux of carbon dioxide that moves between the temperature layers and the layer under temperature layers. The downhill and uphill diffusion with temperature inversions makes the CO_2-pollution in INC, HCM, ALP, SHA, NYA, ARC, ALA, FUK increase stronger than that without temperature inversions. The downhill diffusion makes the CO_2-pollution in COL decrease slower than that without temperature inversions. In particular, the downhill diffusion with temperature inversions can make the CO_2-concentration in ARC increase up to 6.5 times greater than that without temperature inversions.

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