

NO. B-3 Precise Evaluation of the Greenhouse Effects of CH₄ and N₂O

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Abstract The greenhouse effect of Methane and Nitrous Oxide, which have, per one molecule, larger potential for the global warming than carbon dioxide by several decades, is evaluated. The effect of uncertainties in line parameters, *i.e.*, absorption intensity and half-width, is evaluated for CO₂ and N₂O by calculating variations in radiative forcing due to adding 10 % deviation to or using two different year dataset of line parameters. The uncertainties in line parameters are found to yield, irrespective of strong(CO₂) or weak(N₂O) absorption, variations of nearly the same magnitude in radiative forcing as those of uncertainties. A similar result is obtained for uncertainties in the absorption cross section of CFC-11 and CFC-12.

Key Words Greenhouse Effect, Methane, Nitrous Oxide, Chlorofluorocarbons

1. Introduction

Carbon dioxide is well known for its large greenhouse effect. Methane and nitrous oxide also, at their present concentrations, have nearly comparable greenhouse effects to that of carbon dioxide, while their effects per one molecule exceed that of carbon dioxide by several decades. In addition, these two gases warm the upper troposphere to lower stratosphere in low-latitudes and this warming changes the general circulation through the change in atmospheric stability¹⁾. However, the evaluation of the greenhouse effects of methane and nitrous oxide are not necessarily precise, compared with that of carbon dioxide.

This study is aiming at making an efficient and exact method of radiative calculation, *i.e.*, line-by-line method, and evaluating the greenhouse effects of methane and nitrous oxide with that method. In addition, the greenhouse effect of chlorofluorocarbons, to which line parameters are not yet precisely established because of very narrow line spacing, is also evaluated by incorporating their absorption cross section data into the line-by-line method.

2. Model

In the Meteorological Research Institute there is a computationally fast yet accurate line-by-line method, the efficiency of which is attained by using a dataset of the absorption coefficients calculated beforehand at several temperature and pressure values covering actual atmospheric profiles. In this study, to quickly respond to the update of absorption database, the other line-by-line method directly using molecular absorption database of spectroscopic parameters of significant greenhouse gases and absorption cross section of CFCs, is further improved so as to yield, similarly to the present method, efficient and accurate results. In this method, to exclude empirical method specifying the wavenumber points, the absorption shape function is divided into line center region and wing region whereby different spectral resolutions are used for the two regions. It was demonstrated that this procedure can reduce computation time with holding reasonable accuracy.

3. Result

The effect of variations in the line parameters is investigated quantitatively, by using the line-by-line method, on the variations in radiative forcing. The accuracy of absorption intensity used in this study is 10 % for CO₂, 4-15 % for CH₄, and 2-5 % for N₂O²). For the 15 μm band(560 – 760 cm⁻¹) of carbon dioxide (present concentration 340 ppmv), we calculate the variation in radiative forcing (net radiative flux change at the tropopause) by increasing the absorption intensity and half width by 10 % for all the lines. Table 1 shows the results, in which the radiative forcing is for the concentration change from 340 to 680 ppmv. The variations in intensity and half-width yield about 10 % relative variations in radiative forcing and they are nearly additive.

S/S_o (560 – 760 cm ⁻¹)	α/α_o	F_{trp}^{net} (W cm ⁻²)	$RF^* / \delta RF$ (W cm ⁻²)	δRF (%)
(1 × CO ₂)		29.4410		
1.0	1.0	24.9888	4.4522*	100
1.0	1.1	24.5515	0.4373	9.82
1.1	1.0	24.3890	0.5999	13.5
1.1	1.1	23.9540	1.0341	23.2

Table 1. Effects of variations in absorption intensity and half-width on the net fluxes and radiative forcing of CO₂. S and α represent absorption intensity and half-width, respectively, and the radiative forcing is the net flux changes due to the concentration change from 340 to 680 ppmv.

For nitrous oxide (1100 – 1350 cm⁻¹) of the present concentration 0.310 ppmv, we evaluated the effect of difference in the dataset compilation years on radiative forcing. Table 2 and 3 show the changes in net flux and the comparison of line parameters(intensity, half-width, and line number) between 1982 and 1986 AFGL dataset. When intensity and half-width are varied by 10 % of the same sign, the changes in net flux vary similarly to those for CO₂, as shown in Table 4.

Absorbers (1100 – 1350 cm ⁻¹)	F_{trp}^{net} (W cm ⁻²)	$RF^* / \delta RF$ (W cm ⁻²)	δRF (%)
(H ₂ O, CO ₂ , O ₃) ₈₆	31.6864	0	–
(H ₂ O, CO ₂ , O ₃) ₈₆ , (N ₂ O; n=0.50) ₈₆	30.1028	-1.5837*	0
(H ₂ O, CO ₂ , O ₃) ₈₆ , (N ₂ O; n=0.50) ₈₂	29.9705	+0.1323	8.4
(H ₂ O, CO ₂ , O ₃) ₈₆ , (N ₂ O; n=0.75) ₈₂	29.9470	+0.1558	9.8

Table 2. Effects of variations in absorption intensity and half-width on the net fluxes and radiative forcing of N₂O. The number of subscript 86 and 89 represent the years of AFGL dataset 1982 and 1986, respectively, and n is the power law temperature dependence of half-width. The radiative forcing is the net flux changes due to the concentration change from 0 to 0.310 ppmv.

We evaluated the effect of absorption cross section of CFC-11(present concentration 300 PPT) and CFC-12(500 PPT) on radiative forcing by adding 10 % deviation. Table 5 and 6 show the results, in which the concentration change of 10 % corresponds to 10 % deviation of cross section.

Also in this case, radiative forcing varies by about 10 %.

Comparison of AFGL '82 and '86 datasets for N₂O

Band (1100 - 1350 cm ⁻¹)	'82	'86	('82 - '86)/'86
$\sum S_i$	0.105 × 10 ⁻¹⁶	0.976 × 10 ⁻¹⁷	7.58%
$\bar{\alpha}_L = \frac{1}{N} \sum \alpha_{L_i}$	0.0794	0.0741	7.15%
N	3163	4997	

Table 3. Comparison of line intensity, half-width, and line number of N₂O between the AFGL dataset of 1982 and 1986.

Changes in net flux and radiative forcing of 2 × N₂O

S/S_o (1100 - 1350 cm ⁻¹)	α/α_o (1100 - 1350 cm ⁻¹)	F_{trp}^{net} (W cm ⁻²)	$RF^* / \delta RF$ (W cm ⁻²)	δRF (%)
(1 × N ₂ O)		30.1028		
1.0	1.0	29.2645	0.8381*	100
1.0	1.1	29.2015	0.0631	7.53
1.1	1.0	29.1272	0.1374	16.4
1.1	1.1	29.0609	0.2038	24.3

Table 4. As in Table 1 except for N₂O (1100 - 1350 cm⁻¹, 0.310 ppmv).

Changes in net flux and radiative forcing of F11 (800 - 860 cm⁻¹)

Concentration (PPT)	F_{trp}^{net} (W cm ⁻²)	$RF^* / \delta RF$ (W cm ⁻²)	δRF (%)
0	9.6825	0.0755	103.6
300	9.6070*	0	-
600	9.5341	0.0729*	100
330 (1.1 × σ)	9.6000	0.0074	10.1

Table 5. Effects of variations in absorption cross section on the net fluxes and radiative forcing of CFC-11(800-860 cm⁻¹). The radiative forcing is the net flux changes due to the concentration change from 300 to 600 PPT.

Changes in net flux and radiative forcing of F12 (860 - 940 cm⁻¹)

Concentration (PPT)	F_{trp}^{net} (W cm ⁻²)	$RF^* / \delta RF$ (W cm ⁻²)	δRF (%)
0	23.9177	0.1233	103.2
500	23.7944*	0	-
1000	23.6750	0.1194*	100
550 (1.1 × σ)	23.7823	0.0121	10.1

Table 6. As in Table 5 except for CFC-12(860-940 cm⁻¹) and the radiative forcing is the net flux changes due to the concentration change from 500 to 1000 PPT.

References

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