Pioneer Effect Correction to the Observed Airborne Fraction

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One may wish to compare the observed airborne fraction to that predicted for a model with no biosphere (as in chapter 2), or for a model in which the biosphere is constrained to increase, or decrease, approximately proportional to the fossil fuel CO_2 input (as in the biosphere models employed by Keeling, 1973). However, the biosphere may have been a large source to the atmosphere during the last century due to land clearing – the so called "pioneer effect" (Wilson, 1978; Stuiver, 1978; Freyer, 1979). We wish to point out here that this pioneer effect, if indeed it occurred, would have the effect of reducing the observed airborne fraction by as much as 10% (.06). Since we do not know if the pioneer effect did take place, this may be considered an uncertainty when comparing the observed airborne fraction to that predicted for models that do not include such an effect.

The models are approximately linear up to the present time, so responses to the fossil fuel input and an assumed biospheric input may be added. If the biospheric input during the last century is approximated by an impulse, the atmospheric response is approximately an exponential decrease of the initial impulse with a time constant of several hundred years. The recent response of the atmosphere to the fossil fuel input is approximately an exponential increase with a time constant of about 23 years. The effect of a bisopheric impulse is consequently to cause a subsequent decline in the atmospheric CO_2 base line level so that the apparent increase in atmospheric concentration caused by fossil fuel is reduced.

Corrections for this pioneer effect have been calculated with the box diffusion model (table 1). The fossil fuel source was set to zero and the biospheric source, γ_b, represented by a Gaussian function:

$$\frac{dn_b}{dt} = \gamma_b = -\frac{Q}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2}\left(\frac{t - t_c}{\sigma}\right)^2} \qquad (1)$$

where n_b is the biospheric perturbation, Q is the total source, σ is the width, and t_c is the central year of the source.

The corrections are proportional to the size of the source, as they must be in a linear model. The correction is larger with the Gaussian input centered on the year 1850 than centered on 1800, because the atmospheric input has then decayed for a shorter time. With the input centered on 1900, the correction is sensitive to the width. If the width parameters σ is set to 50 years, the atmospheric concentration continues to rise until 1970, and as a consequence, the correction to the airborne fraction is negative. This correction would effect all stations approximately equally because of the long time involved compared to the time for atmospheric mixing, and consequently, have little effect on differences between them.

Table 1. Corrections to be added to the observed airborne fraction if the pioneer effect is believed but the model does not include it. These corrections have been calculated by use of the box diffusion model (Oeschger *et al.*, 1975) with the biospheric source represented by a Gaussian function. The parameters of the model are as given by Oeschger *et al.* except for the following: depth of ocean = 4198 m, depth of surface layer = 100 m, depth of ocean with carbon equivalent to preindustrial atmosphere = 69 m, diffusion constant K = 4900 m^2/yr, CO_2 buffer factor = 9.64.

The central year, total source, and width refer to parameters in equation (1).

Central Year	Total Source (gt)	Width (σ, year)	Correction
1800	100	50	.022
	200	50	.023
	200	25	.040
1850	100	50	.027
	200	50	.054
	200	25	.060
1900	100	50	−.001
	200	50	−.002
	200	25	.104

REFERENCES

Freyer, H.D. (1979). On the ^{13}C record in tree rings. Part I. ^{13}C variations in northern hemispheric trees during the last 150 years, Tellus, *31,* 124–137.

Keeling, C.D. (1973). The carbon dioxide cycle: reservoir models to depict the exchange of atmospheric carbon dioxide with the oceans and land plants. In Rasool, S.I. (Ed.) Chemistry of the Lower Atmosphere, 251–329. Plenum Press, New York.

Oeschger, H., Siegenthaler, U., Schotterer, U., Gugelmann, A. (1975). A box diffusion model to study the carbon dioxide exchange in nature, Tellus, *27,* 168–192.

Stuiver, M. (1978). Atmospheric carbon dioxide and carbon reservoir changes, Science, *199,* 253–258.

Wilson, A.T. (1978). Pioneer agriculture explosion and CO_2 levels in the atmosphere, Nature, *273,* 40–41.