Influences of boreal fire emissions on Northern Hemisphere atmospheric carbon and carbon monoxide

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Received 24 May 2004; revised 19 November 2004; accepted 20 December 2004; published 16 February 2005.

[1] There were large interannual variations in burned area in the boreal region (ranging between 3.0 and 23.6 $\times$ 10^6 ha yr^{-1}) for the period of 1992 and 1995–2003 which resulted in corresponding variations in total carbon and carbon monoxide emissions. We estimated a range of carbon emissions based on different assumptions on the depth of burning because of uncertainties associated with the burning of surface-layer organic matter commonly found in boreal forest and peatlands, and average total carbon emissions were 106–209 Tg yr^{-1} and CO emissions were 33–77 Tg CO yr^{-1}. Burning of ground-layer organic matter contributed between 46 and 72% of all emissions in a given year. CO residuals calculated from surface mixing ratios in the high Northern Hemisphere (HNH) region were correlated to seasonal boreal fire emissions in 8 out of 10 years. On an interannual basis, variations in area burned explained 49% of the variations in HNH CO, while variations in boreal fire emissions explained 85%, supporting the hypotheses that variations in fuels and fire severity are important in estimating emissions. Average annual HNH CO increased by an average of 7.1 ppb yr^{-1} between 2000 and 2003 during a period when boreal fire emissions were 26 to 68 Tg CO^{-1} higher than during the early to mid-1990s, indicating that recent increases in boreal fires are influencing atmospheric CO in the Northern Hemisphere.

Citation: Kasischke, E. S., E. J. Hyer, P. C. Novelli, L. P. Bruhwiler, N. H. F. French, A. I. Sukhinin, J. H. Hewson, and B. J. Stocks (2005), Influences of boreal fire emissions on Northern Hemisphere atmospheric carbon and carbon monoxide, *Global Biogeochem. Cycles*, *19*, GB1012, doi:10.1029/2004GB002300.

1. Introduction

[2] Biomass burning has long been recognized as a significant source of a number of important trace gas species and particulate matter to the atmosphere [*Seiler and Crutzen*, 1980; *Lavoue et al.*, 2000; *Andreae and Merlet*, 2001]. Initially, fire emissions calculations were based on assessments of average burned area (using data reported by fire management agencies or best guesses) combined with average biomass levels (for different regions/biomes) and estimates of fraction of biomass consumed during fires. This procedure produced estimates of 2.55 Gt C yr^{-1} from global wildland fires and 3.86 Gt C yr^{-1} from all biomass-burning sources (including combustion of biofuels and charcoal and charcoal production) [*Andreae and Merlet*, 2001].

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0886-6236/05/2004GB002300$12.00

[3] Availability of satellite-based fire products has improved emission estimates from wildland fires. Three basic approaches are used: (1) hot spot detection [*Arino et al.*, 2001; *Giglio et al.*, 2000; *Justice et al.*, 2002; *Sukhinin et al.*, 2004], (2) burn scar mapping [*Tansey et al.*, 2004; *Simon et al.*, 2004], and (3) observation of atmospheric aerosols from fires [*Duncan et al.*, 2003a]. While hot spot products are the most widely available products and cover the longest time periods, caution must be exercised in using these data to estimate emissions [e.g., *Schultz*, 2002] because of sampling biases [*Eva and Lambin*, 1998; *Kasischke et al.*, 2003]. In some cases, hot spot data have been scaled to burned-area estimates by using other burned-area information [*Van der Werf et al.*, 2003].

[4] The new satellite data products are being used to estimate spatial and temporal patterns of burned area and are combined with data sets depicting spatial variations in biomass and fuel load to estimate emissions. Using a combination of satellite fire products, *Van der Werf et al.* [2004] estimated that an annual average of 3.53 Gt C yr^{-1} were released from wildland fires from 1997 to 2001, while *Ito and Penner* [2004] and *Hoelzemann et al.* [2004] estimated that 1.43 and 1.78 Gt C, respectively, were released from wildland fires in 2000.

[5] In this paper we present the results from a study aimed at (1) quantifying the effects of spatial and temporal