RADIATIVE FORCING FROM A BOREAL FOREST FIRE

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ABSTRACT

We report measurements of energy and carbon fluxes from a boreal forest fire chronosequence. Taking into account greenhouse gas emissions and post-fire changes in the surface radiation budget, a boreal forest fire in interior Alaska caused the climate to cool. This result suggests that management of forests in northern countries to preserve carbon sinks may have the opposite effect on climate as that intended.

INTRODUCTION

Recent increases in fire activity within boreal ecosystems have released carbon dioxide and other greenhouse gases to the atmosphere that promote global warming [*Kasischke and Stocks*, 2000]. Simultaneously, within burn perimeters, post-fire changes in ecosystem structure cause atmospheric cooling, primarily from increased snow cover during winter and spring [*Chambers and Chapin*, 2002; *Liu et al.*, 2005]. Quantitative comparison of these two effects on climate has been limited in the past, in part, because of challenges in obtaining annual carbon and radiation measurements from the same sites. Here we report carbon and surface radiation observations from a boreal fire that was accidentally set by humans in interior Alaska. We use these observations to compute the net radiative forcing of the fire event, considering both greenhouse gas emissions and post-fire changes in the surface radiation budget.

METHODS

The Donnelly Flats fire occurred during 13-20 June 1999 in interior Alaska (63°, 55'N; 145°, 44'W). The crown fire burned approximately 7600 ha of black spruce (*Picea mariana*). The fire was intense, causing stand-replacing mortality of the black spruce within the burn perimeter and consuming much of the soil organic matter above the mineral horizon. Soil C emissions were estimated by sampling 200 m transects within the fire perimeter and in a nearby undisturbed black spruce forest that served as a control [*Neff et al.*, 2005]. Aboveground C emissions were estimated by comparing tree density and biomass at similar sets of paired sites. Total carbon emissions were converted to greenhouse gases using emission factors from Andreae and Merlet [2001]. Greenhouse gases were converted into estimates of radiative forcing using equations developed by *Myhre et al.* [1998]. Eppley precision spectral pyranometers were used to directly measure upwelling and downwelling solar radiation during July and August of 1999, and then continuously from October 1999 through September 2004 [*Chambers and Chapin*, 2002; *Liu et al.*, 2005].

RESULTS

During the fire, 1700 ± 600 g C/m^2 was emitted to the atmosphere. For a 1 m^2 atmospheric column, the emitted CO_2, CH_4 and N_2O caused approximately 7.2 W/m^2 of radiative forcing. CO_2 contributed to 85% of the total radiative forcing from the fire-emitted greenhouse gases, followed by methane (14%) and N_2O (1%). Soil respiration during the following year contributed another ~200 g C/m^2/yr. Weighting the amount of soil respiration by the time it remained in the atmosphere during the first year, this flux contributed to another 0.5 W/m^2 of positive radiative forcing. The sum of positive radiative forcing from emissions and respiratory losses -that would drive global atmospheric warming- was approximately 8 W/m^2.

Observations of reflected (outgoing) shortwave radiation from within the burn perimeter and the control site during the 5 year period from 2000 to 2004 provide a means to estimate the effect post-fire changes in vegetation structure and composition on the surface radiation budget. During this period, the recent burn reflected more shortwave radiation back into the atmosphere than the control, with an annual mean difference between the sites of 21 W/m^2. Seasonally, the largest difference in outgoing shortwave radiation was during spring (Fig. 1).

FIGURES

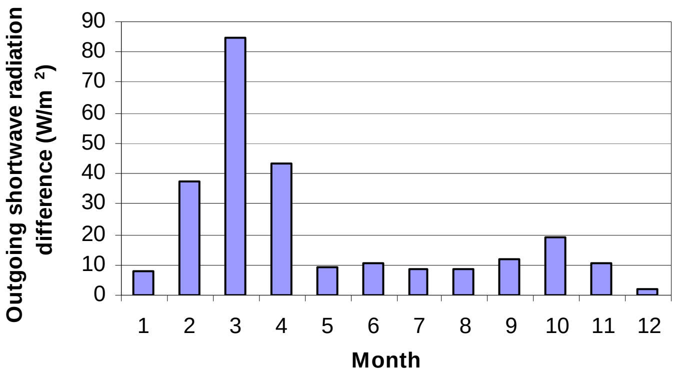

Fig. 1. The difference in outgoing shortwave radiation between the burn and control sites. The high snow albedo in the recent burn caused much more radiation to be reflected back into the atmosphere during spring as compared with the mature black spruce forest that served as the control.

DISCUSSION AND CONCLUSIONS

For this fire, the cooling from the increased surface albedo was approximately twice as large as the warming caused by the release of greenhouse gases, as compared in terms of radiative forcing. A more complete assessment of the net effect of this fire on climate would also consider the effects of emitted aerosols on atmospheric radiation and the subsequent deposition of soot on snow and ice albedo. In addition, the decrease surface outgoing shortwave radiation needs to be further adjusted for cloudiness at our sites using a radiative transfer model, to directly compare with the greenhouse gas radiative forcing estimates that were presented at the height of the tropopause.

Our results suggest that for northern countries, including Canada, Norway, Russia, and Sweden, management of forest fires to preserve carbon sinks may have the opposite effect on climate as that intended by international treaties such as the Kyoto Protocol. This finding is consistent with recent modeling work on carbon sequestration and land use change [*Betts*, 2000] and requires a more nuanced view of the societal value of a northern hemisphere carbon sink.

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