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Black carbon and organic carbon emissions from wildfires in Mexico

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RESUMEN

En México se registran alrededor de 7650 incendios anuales, con un promedio de 263 115 hectáreas afectadas. Los incendios forestales generan, además del impacto en la degradación del suelo, la deforestación, la degradación de los ecosistemas y la proclividad al cambio de uso de suelo, emisiones tóxicas para el medio ambiente, tales como ácido cianhídrico, carbono negro y carbono orgánico, entre otros. El carbono negro es un contaminante de efecto invernadero de vida corta. Asimismo, promueve el derretimiento de la nieve y el hielo, y una disminución de las precipitaciones. Se ha estimado que tiene un potencial de calentamiento global cercano a 5000.[1] Se presenta una estimación de las emisiones de carbono negro y carbono orgánico de los incendios forestales en México, desde 2000 hasta 2012. El promedio de los resultados obtenidos es de 5955 Mg/año de carbono negro y 62 085 Mg/año de carbono orgánico. Una correcta gestión de los incendios forestales podría evitar alrededor de 14 888 Gg de CO_2 equivalentes por año. Por otra parte, la mejoría en la calidad del aire, la conservación de los ecosistemas, la mejora de la visibilidad y el mantenimiento del uso del suelo son algunos de los beneficios colaterales. Mitigar las emisiones de carbono orgánico forestal, que son diez veces superiores a las emisiones de carbono negro, podría prevenir la morbilidad y mortalidad debido a estos compuestos orgánicos tóxicos en el medio ambiente.

ABSTRACT

In Mexico, approximately 7650 wildfires occur annually, affecting 263 115 hectares of land. In addition to their impact on land degradation, wildfires cause deforestation, damage to ecosystems and promote land use change; apart from being the source of emissions of toxic substances to the environment (i.e., hydrogen cyanide, black carbon and organic carbon). Black carbon is a short-lived greenhouse pollutant that also promotes snow and ice melting and decreased rainfall; it has an estimated global warming potential close to 5000.[1] We present an estimate of the black carbon and organic carbon emissions from wildfires in Mexico from 2000 to 2012 using selected emission factors from the literature and activity data from local agencies. The results show average emissions of 5955 Mg/yr for black carbon and 62 085 Mg/yr for organic carbon. Black carbon emissions are estimated to be 14 888 Gg CO_2 equivalent (CO_2 eq) per year on average. With proper management of wildfires, such emissions can be mitigated. Moreover, improved air quality, conservation of ecosystems, improvement of visibility and maintenance of land use are a subset of the related co-benefits. Mitigating forest organic carbon emissions, which are ten times higher than black carbon emissions, would also prevent the morbidity and mortality impacts of toxic organic compounds in the environment.

Key words: Black carbon, organic carbon, wildfires, Mexico, emissions.

[1] El potencial de calentamiento global (GWP, por sus siglas en inglés) se calcula como la relación entre el potencial de calentamiento global absoluto (AGWP) de un gas o contaminante dado respecto al AGWP del CO_2. El AGWP tiene unidades Wm^{-2} g^{-1} año.
[1] The GWP is calculated as the ratio of the Absolute Global Warming Potential (AGWP) of a given gas to the AGWP of CO2. The AGWP has units of Wm^{-2} g^{-1} yr.

1. Introduction

Wildfires are events described by the burning of biomass fuels. Krawchuk *et al.* (2009) have added that a wildfire "is an ecological disturbance process that has a heterogeneous global distribution controlled by the coincidence of three basic requirements: vegetative resources to burn, environmental conditions that promote combustion, and ignitions". Wildfires impair the air visibility, causing health problems for people and animals and destroy vegetation and ecosystems. Wildfires also emit toxic by-products to the environment, such as hydrogen cyanide, organic carbon and black carbon (Yokelson *et al.*, 2007), among others. Deaths from smoke inhalation from wildfires number 350 000 per year worldwide (Johnston *et al.*, 2012).

Black carbon is a 0.1-0.5 μg cluster of different compounds produced by the incomplete burning of fossil fuels (primarily oil, diesel and fuel oil) and biomass (wood, coal, etc.) and is structured with an elemental carbon core surrounded by volatile organic compounds in the form of gaseous- and liquid-phase molecules. Certain sulfates and carbonates are emitted as complex chain structures, which tend to collapse as the particles age, thereby modifying their optical properties (IPCC, 2007). Due to the complex nature of their components as well as weather conditions (e.g., presence of moisture), the physical characteristics (e.g., on the surface or in the atmosphere) of the environment and the type of emission sources (biomass fuel combustion internal engines), the nature of black carbon forcing changes with its lifetime.

Unlike volatile organic compounds that form a component of the structure of black carbon that is transparent to the human eye, black carbon absorbs visible light and is therefore responsible for diminished visibility in the air. For compounds that are emitted into the atmosphere, black carbon is the main substance that absorbs solar radiation (Bahadur *et al.*, 2011). By absorbing solar radiation, the pollution decreases the incidence of radiation on the surface, but the net effect on the earth-atmosphere system (known as radiative forcing) represents an increase in the surface and atmospheric temperatures (IPCC, 2007).

Black carbon is an important short-lived climate forcing species whose global warming potential is estimated to be up to 5000 times that of carbon dioxide (EPA, 2012), positioning it as the second or third climate driver behind CO_2 on a global scale (Bachmann, 2009; Shindell and Faluvegi, 2009). The main global emission sources of black carbon are found in the transport sector from diesel-driven vehicles (Bond *et al.*, 2004; Woodcock *et al.*, 2009) and in the burning of biomass in the rural households of developing countries (Wilkinson *et al.*, 2009; Ruiz-Mercado *et al.*, 2011).

Carbon dioxide, which is the most abundant component of the so-called greenhouse gases (GHG), has a long lifetime (IPCC, 2007). Certain other 'Kyoto basket' GHGs are composed of gases with shorter and more stable lifetimes, such as methane. However, other GHG, despite their anthropogenic origins and significant contribution to global warming, are not included. These gases include species that lead to the formation of tropospheric ozone (i.e., carbon monoxide [CO], non-methane volatile organic compounds [NMVOC] and nitrogen oxide [NOx]) and aerosols and their precursors (i.e., sulfur dioxide [SO_2], black carbon [BC] and organic carbon [OC]) (Rypdal *et al.*, 2005).

Wildfire emissions are composed primarily of carbon dioxide, many organic species and black carbon (Yokelson *et al.*, 2007); their shares are dependent on the meteorological conditions, type of vegetation, humidity, and topography of the terrain, among other factors. Organic compounds emitted by fires are reactive species that play a role in the formation of ozone and secondary organic aerosols in addition to many other organic compounds, such as benzene and toluene, degradation products from biopolymers, *n*-alkanes, *n*-alkenes, *n*-alkanoic acids, *n*-alkanols, monosaccharide derivatives from cellulose, steroids and terpenoid biomarkers, and polycyclic aromatic hydrocarbons (primarily retene) (Yokelson *et al.*, 2007; Evtyugina *et al.*, 2013), which are known to be toxic to human health. Excluding agricultural burning, recent estimates suggest that wildfires account for approximately half of the global BC and CO emissions and two-thirds of OC emissions (UNEP and WMO, 2011). However, no global black carbon emission inventory is available from the United Nations Framework Convention on Climate Change (UNFCCC).

Mexico has a land area of ca. 1.9 million square kilometers. In 1993, land use was distributed as follows, tropical and temperate forests (36%), shrublands (27%) and developed areas with activities such as agriculture and pasture (22%) (de Jong *et al.*, 2010). Currently, land use change has been incremented due to uncontrolled urban growth, abandonment of