Up in smoke

Where there is smoke, there are radiative feedbacks. With wildfires becoming a growing problem in the Anthropocene, we need to better understand the influence of fire on the climate system.

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Climate change and human activities have driven changes in wildfire activity across the globe in recent decades. Following the bushfires that ravaged Australia earlier this year, in the western United States masks are being worn in response not only to COVID-19, but to poor air quality caused by numerous intense wildfires. The hazy orange skies photographed over San Francisco in September are a reminder that increasing wildfire activity is not just a consequence of climate change, but an active participant: wildfire emissions influence the Earth's radiative balance and thus fire is an active driver of the climate system. As demonstrated by several papers in this issue, we need to better understand how fire regimes around the globe are changing because of the potentially large fire-related feedbacks within our planet's climate system.

Wildfires burn biomass and emit large quantities of greenhouse gases and aerosols into the atmosphere. From 1997 to 2016, carbon emitted by fire was equivalent to about 22% of the global carbon emissions from fossil fuel consumption during that same time period[1]. The problem is particularly acute in some of the world's most vulnerable regions: in a Comment, McCarty et al. highlight fires that smoulder in carbon-rich peat in the Arctic for months or years. Arctic fires released 35% more CO_2 in 2020 compared to the previous year[2] and emissions of greenhouse gases have direct radiative effects that warm the climate. Recent changes to fire regimes in peat-rich regions underline the urgency to better constrain greenhouse gas emissions from fire.

Fires also emit reactive gases that affect radiative forcing indirectly. For example, in the Article featured on this month's cover, Theys et al. find from satellite observations that nitrous acid is enhanced in wildfire plumes due to chemical reactions that occur within the smoke. The nitrous oxide then breaks down in the atmosphere to form hydroxyl radicals, which in turn enhance ozone production at the regional scale.

Biomass burning is estimated to be responsible for a substantial fraction of global black carbon (soot) and primary organic aerosol emissions[3]. Whereas greenhouse gases act to warm the climate, aerosols can have the opposite radiative effect and lead to cooling. Furthermore, the fallout of soot on glaciers and ice sheets can enhance melting due to reduced albedo[4].

In last month's issue, Schill et al.[3] reported airborne measurements of aerosols produced by biomass burning in the troposphere at the global scale. They found that these particles were ubiquitous, if too dilute to be readily detected by satellite remote sensing. Yet they found that the dilute smoke was so pervasive globally that it contributed about the same total direct radiative effect as the contribution from dense smoke plumes.

There are indirect radiative effects of aerosols as well. Soot particles act as nuclei for water droplet and ice crystal formation in clouds and thus influence the structure of clouds that in turn modulate the Earth's radiation balance. In an Article, Lohmann et al. find that rising soot emissions following future climate warming could reduce the formation of reflective low level clouds and enhance cloud formation at high altitudes, enhancing the greenhouse effect and surface warming.

The past also informs our understanding of how fire can influence the climate system. One particularly dramatic scenario is the suggestion that emissions from global wildfires ignited by the Chicxulub impact event 65 million years ago[5] contributed to the devastating global climatic changes that followed. And in another Article in this issue, Boudinot and Sepúlveda present geochemical evidence that points to feedbacks between atmospheric oxygen concentrations and forest fires about 94 million years ago that in turn led to an enhanced flux of nutrients and deoxygenation of the oceans, ultimately resulting in a large carbon cycle perturbation.

The atmospheric consequences of fire go beyond regional air pollution to the workings of the global climate system. The exact climatic consequences of wildfire emissions depend on many factors, including their distribution and transport and complex chemical reactions. Observational datasets with sufficient spatial and temporal coverage are needed to understand these factors. As wildfires become increasingly common and more intense in some parts of the world, we need to better understand these feedbacks. ❐

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