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Impact of extreme wildfires on stratospheric aerosol and gaseous composition

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The severity of wildfires has remarkably increased over the last years in both Northern and Southern hemispheres and there is an emerging realization of their effect on climate and ozone layer. Intense wildfires release tremendous amounts of heat into the atmosphere, which gives rise to extreme thunderstorms termed Pyrocumulonimbus (PyroCb). These storms, augmented by the energy of combustion, can generate vigorous convective updrafts injecting smoke and other combustion products into the stratosphere, where the residence time of aerosols is not limited by cloud scavenging and precipitation. A number of recent studies have put in evidence that the effects of strong PyroCb events on the global stratosphere rival those of moderate volcanic eruptions in terms of magnitude and duration whilst exceeding them in terms of radiative forcing (e.g. Khaykin et al., 2020). Furthermore, the PyroCb injections into the stratosphere were shown to generate persistent synoptic-scale anticyclones (SCV – Smoke-Charged Vortex), lofting confined bubbles of combustion products and moisture deep into the stratosphere due to solar heating of carbonaceous aerosols, which prolongs their atmospheric residence time and radiative effects.

Here we use ground-based lidar records in France (ATOLL, SIRTa, OHP) and New Zealand (Lauder) together with global observations by MLS, OMPS, CALIPSO satellite missions to characterize and quantify the planetary-scale impact of wildfires on stratospheric gaseous composition and aerosol burden as follows. First, we identify the wildfire events during the last two decades with a measurable stratospheric impact and classify them into four categories ranging from 1 (e.g. Alberta 2023) to 4 (Australian Black Summer 2019/20) based on the magnitude and longevity of their stratospheric impact. Using a combination of nadir and limb observations along with ERA5 analysis, we explore the spatiotemporal evolution and dynamics of the smoke plumes. Then, we quantify the aerosol and gas mass fluxes into the stratosphere for each event.

We show evidence for the geographical and seasonal extension of wildfire events. By using long-term ground-

based and satellite lidar observations of depolarization, we point out the longevity of fine smoke particles in the stratosphere.

Finally, a particular focus is made on the anomalous 2023 Boreal wildfire season and its impact on the lowermost stratosphere. Using multiwavelength fluorescence lidar observations (Veselovskii et al., 2023), we point out contrasting properties of smoke aerosols in the free troposphere and upper troposphere/lower stratosphere.

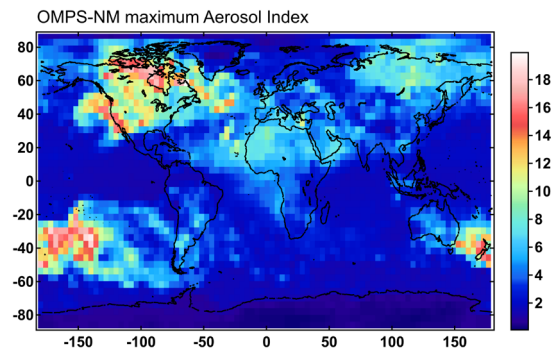


Figure 1. Primary source regions of wildfire smoke in the UTLS as inferred from OMPS-NM Aerosol Index: North America, Australia and Siberia.

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