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Human and climate impacts on Holocene fire activity recorded in polar and mountain ice cores

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Fire is one of the major influences of biogeochemical change on local to hemispheric scales through emitting greenhouse gases, altering atmospheric chemistry, and changing primary productivity. Levoglucosan (1,6-anhydro-β-D-glucopyranose) is a specific molecular that can only be produced by cellulose burning at temperatures > 300°C, comprises a major component of smoke plumes, and can be transported across > 1000 km distances. Levoglucosan is deposited on and archived in glaciers over glacial interglacial cycles resulting in pyrochemical evidence for exploring interactions between fire, climate and human activity.

Ice core records provide records of past biomass burning from regions of the world with limited paleofire data including polar and low-latitude, high-altitude regions. Here, we present Holocene fire activity records from the NEEM, Greenland (77° 27'N; 51° 3'W; 2454 masl), EPICA Dome C, Antarctica (75° 06'S; 123° 21'E; 3233 masl), Kilimanjaro, Tanzania (3° 05'S, 21.2° E, 5893 masl) and the Muztagh, China (87.17° E; 36.35° N; 5780 masl ice cores. The NEEM ice core reflects boreal fire activity from both North American and Eurasian sources. Temperature is the dominant control of NEEM levoglucosan flux over decadal to millennial time scales, while droughts influence fire activity over sub-decadal timescales. Our results demonstrate the prominence of Siberian fire sources during intense multiannual droughts. Unlike the NEEM core, which incorporates the largest land masses in the world as potential fire sources, EPICA Dome C is located far from any possible fire source. However, EPICA Dome C levoglucosan concentrations are consistently above detection limits and demonstrate a substantial 1000-fold increase in fire activity beginning approximately 800 years ago. This significant and sustained increase coincides with Maori arrival and dispersal in New Zealand augmented by later European arrival in Australia. The EPICA Dome C levoglucosan profile is similar to regional charcoal compilations from New Zealand and southeastern Australia.

Evidence from Kilimanjaro demonstrates a major increase in fire activity centered around 800-1000 years ago, corresponding to both increased temperatures and aridity as recorded in regional lake cores. This peak in fire activity is an order of magnitude higher than at any other time in the record including the most recent period. Environmental and anthropological studies suggest that upslope human migrations have occurred in response to the warmer, drier conditions. Kilimanjaro is surrounded by flammable savanna vegetation, yet the Muztagh core is located in an especially arid section of the Tibetan Plateau and consistently contains levoglucosan concentrations that are 100 to 1000 times greater than the mean Kilimanjaro flux. These high concentrations and the lack of available fuel suggest that regional rather than local biomass burning may be the source of the fire products. Biomass burning aerosols are a major component of the South Asian Brown Cloud and may influence the composition and concentration of pyrogenic aerosols across the Tibetan Plateau. The relative impact of human activity versus climate change on Holocene biomass burning varies regionally. Combining ice and sediment core data with model output can help place these regional differences into a global context with implications for a warming climate.