How anthropogenic forest fires may have impacted Earth's climate over 10 000 years ago

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Recently paleoclimatologist William Ruddiman suggested that humans may have had a significant impact on the Earth's climate already thousands of years ago—through carbon and methane emissions originating from biomass burning and deforestation associated with early agriculture. The EARLYHUMANIMPACT project set out to verify this hypothesis.

Whilst global warming means more forest fires, the opposite is also true. Forests store about 30 percent of the carbon found on the planet's surface, and each forest fire not only releases this carbon into the atmosphere but also other climate-impacting substances such as aerosols. The impact of these aerosols on climate change, however, is not yet well understood.

The EARLYHUMANIMPACT project builds upon the idea that the answer might lie in Earth's history books. Over 10 000 years ago, human agriculture started to thrive at the expense of forests, and the project team believes that anthropogenic aerosols resulting from this process may have altered the global climate system for thousands of years.

To verify this, Prof Carlo Barbante and other researchers from the University of Venice examined data from ice and lake core climate records of seven continents and compared it with parallel histories of fire regimes. They used a new technique for determining a specific molecular marker of biomass burning—known as levoglucosan—which can record past fire in ice cores and lake sediments. With the project soon coming to an end, Prof Barbante discusses the process and the main outcomes of his work.

Why did you choose to focus your research on fire reconstruction?

The role of aerosols in the climate system is still poorly understood and even less is known about the relative role of biomass burning.

Fire affects the climate system by releasing carbon, which would otherwise be stored in woody vegetation. It contributes to the levels of several aerosols and atmospheric gases in the air and is an important cause of their variability over the years. It also influences regional and global climate through the emission of greenhouse gases, mainly carbon dioxide and methane.

The decrease in the spatial extent of forests which started around 7 000 to 5 000 years BP may be related to early agricultural activity, including forest clearance through burning which should leave a quantifiable signal in climate proxies. Under this ERC Advanced Grant, we are aiming to provide essential insight into the interplay between climate and human activity, especially with the advent of agriculture, as well as the role of aerosols through time.

How do you explain that we know so little about aerosols' past influence on climate change?

Anthropogenic and natural aerosols may have altered the global climate system for thousands of years as suggested by comparing late-Holocene greenhouse-gas (GHG) concentrations to those from previous interglacial periods. Now, human activities including fossil fuel burning are currently altering the composition of the atmosphere and the global climate system at rates faster than ever recorded in geologic time.

The problem is that, for most of the climatic and environmental archives that paleoclimatologists study (e.g. three rings, marine and terrestrial records), it is difficult to find the right transfer functions that link the concentration of a specific marker in the record with its atmospheric occurrence in the past. It is therefore of paramount importance to look at past atmospheric composition through the use of paleoclimatic records and appropriate proxies for which the cause/effect relationship is known.

How did you proceed to verify Ruddiman's hypothesis?

His hypothesis is centred on the observation that atmospheric carbon dioxide and methane levels were at their minima around 7 000 to 5 000 years before the present day, respectively, and then slowly increased until the rapid rise in GHGs caused by the Industrial Revolution. The increase in methane is attributed to biomass burning and rice cultivation in the tropics. The carbon dioxide increase is more difficult to ascribe to human activity, but Ruddiman argues that deforestation and biomass burning may be a primary factor.

Ice and lake core proxy records provide quantifiable data on past fire regimes across all possible spatial and temporal scales. We aim to quantify the temporal and spatial changes in Holocene biomass burning in ice and lake core records from seven continents which correspond with centres of the origin of agriculture. We have developed for this a novel technique for measuring a globally-present molecular marker of biomass burning (levoglucosan, 1,6-anhydro-β-D-glucopyranose) in ice cores and lake sediments. We supplemented these pyrochemical analyses with palynological evidence of the impact of past fire regimes.

What are the main takeaways from the project so far?

For example, recent studies of the Greenland ice sheet have shown that climate changes including summer North Hemisphere insolation and temperature affect boreal fire activity over millennial timescales.

Our results on fire reconstruction in the Holocene show an important peak in fire activity 3–2 ka year ago. However Northern Hemisphere temperatures and especially summer fire season temperatures remain stable or decrease between 3 and 2ka. Therefore, major climate parameters and environmental changes alone cannot explain the levoglucosan flux reaching Greenland during the middle to late Holocene.

Given the lack of a plausible climate control for this pattern, coupled with the absence of paleoclimate evidence for any synchronous global climate change at this time, we argue that human activity associated with agriculture and land clearance provides the best explanation for observed trends in fire activity during the late Holocene. Extensive deforestation in Europe between 2.5 and 2 ka is synchronous with the Greenland levoglucosan fire peak, demonstrating a quantifiable early human impact on the environment beginning about 4 000 years ago.

Did you manage to differentiate between natural and anthropogenic fires?

This is certainly one of the most challenging tasks of the whole research project and we are working on this. The links between biomass burning and increased agriculture (and therefore increased GHGs including carbon dioxide and methane) and the prolongation of interglacial climate are only valid if measured increases in burning demonstrate a quantifiable relationship with increased temperature, as can be measured in ice cores. In addition, lake cores contain necessary palynological evidence for human-induced fires such as the anthropological pollen index, pollen indicators of slash-and-burn cultivation, the presence of fire-tolerant species suggesting frequent fire activity, and changes in the arboreal pollen influx.

The multi-proxy nature of ice and lake cores makes them the perfect material to investigate the linkages between early agricultural activity and climate change, as temperature, palynologic evidence, and levoglucosan are measured from the same depth and time within the surrounding matrix.

What are you planning to do until and after the end of the project?

We are actually concentrating on a part of the project that was not originally foreseen in the implementation of the proposal. Novel organic molecular proxies are proposed for the reconstruction of fire events in association with anthropic activities. Namely, faecal sterols and a suite of polycyclic aromatic hydrocarbons were individuated and tested as suitable molecular markers of human presence and fire activity, in addition to the levoglucosan that we already use. These are very promising proxies in paleoclimatic reconstructions and we aim to pursue on this research direction in the near future. This ERC grant has been a great opportunity to study a poorly understood and often neglected part of the climate system.

More information: Project page: cordis.europa.eu/project/rcn/99498

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