Geophysical Research Abstracts
Vol. 14, EGU2012-4795, 2012
EGU General Assembly 2012
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# Smouldering bog wildfires and possible implications in palaeoenvironmental reconstructions

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Ombrotrophic (i.e., rainwater-fed) peat bogs have been recognized as providing excellent records of past environmental changes over the last millennia. They are well known to provide information on both climatic and vegetational changes, and the deposition of organic and inorganic pollutants from anthropogenic vs. lithogenic sources. Whether they also record well past fire activity is an unresolved issue to date.

Peatland ecosystems are most at risk from smouldering fires, especially in drought conditions. Smouldering fires are slow, low temperature, flameless and the most persistent form of combustion of organic matter (OM) in porous form. It is known to consume dozen of times more peat mass than flaming fires. Importantly, the in-depth oxidation reaction in smouldering leaves few charred remains, which hampers their identification in palaeoenvironmental analyses. Smouldering even consumes the possible pyrogenic char produced by flaming wildfires. Most studies on smouldering peatland fires to date have focused on ignition and carbon losses/emissions, leaving a significant gap in our understanding of OM changes following fires.

In the present work, we present new data which suggest that variations in the chemical signature of OM in peatlands provides a possibility of identifying past peatland fires. In particular, we show results from a laboratory study about the physical, chemical and spectroscopic changes in OM features following a smouldering fire. We initiated a smouldering fire on top of three sphagnum peat columns (26 cm deep) each having a different initial moisture content (MC) designed to reflect dry conditions (55% MC), undisturbed conditions (90% MC), and wet conditions (210% MC). The fires were allowed to propagate downwards until they self-extinguished at some distance from the top. After the fire, we tracked chemical variations in the residual columns to determine the possible signature of natural past smouldering peatland fires.

The analysis shows a consistent variation in the vertical direction of chemical markers below the point at which the fire front propagated the columns. The depth over which the chemical markers vary is apparent down to 5 cm in 55% MC (the whole residual column), and 8 cm deep in 90% MC. No significant variation of any of the chemical parameters was observed in the 210% MC column.

The results of this study show that smouldering fires could occur also when bogs are in undisturbed hydrological conditions (e.g., near 100%MC), and that zone affected by smouldering fire is revealed by the presence of: 1) a strong increases of pH and ash content; 2) higher contents of aromatic and condensed molecules (as suggested by higher C/H values and by fluorescence spectra); 3) higher total N content leading to a decrease in C/N ratio.

These data show potential to track similar variations in cores taken from peat bogs where they may serve as new proxies for the identification of past fire events. Moreover, these findings suggest the possibility that similar chemical and physical signatures detected in previous peatland cores may have been ascribed to the wrong past climatic or hydrological variations, as fire induced changes had not been considered before. In particular, peaks in ash content, such as those observed in our study (e.g.. ca. 13% in the 90% MC residue vs. 3% in the undisturbed peat), have in the past been ascribed to an increase of either dust depositions or mineralization processes typically linked to climatic changes. Similarly, large variations in pH values (e.g., >6 in the 90% MC residue vs. <4 in the undisturbed peat) following a smouldering fire could be wrongly ascribed to a transition from a bog to a fen, which are currently interpreted as indicative of vegetational and hydrological changes. Likewise, variations in C/N ratio as those observed in our experiments have been often ascribed to vegetation and humification changes.

Our new data provides an important addition toward assessing palaeoenvironmental conditions and highlights that smouldering fires may have been overlooked as the cause of both physical and chemical variations observed in peat cores.