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Laboratory study of smouldering peat fires: dynamics and emissions

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Smouldering combustion of natural fuel layers such as peatlands leads to the largest fires on Earth and posses a possible positive feedback mechanism to climate change. In this work, we use an experimental methodology to study the smouldering combustion of samples of peat under a wide range burning conditions, i.e. different thermal boundary conditions and oxidizer flow rates. This allows the smoulder reaction to be studied under a range of conditions expected in natural peat. This is an important step in translating laboratory studies to real peat fires. Vertical peat samples (30 mm deep and 125 mm in diameter) were ignited by radiation on the top, free surface and a smouldering front allowed to propagate downward against a forced flow of oxidizer.The effect of the external heat flux and oxidizer flow rate on the smoulder reaction is studied through mass loss measurements and analysis of the emissions.

A consistent reaction framework is observed across the range of burning conditions studied. Two regimes of smouldering are observed – the first is a period of peat smouldering characterized by high mass loss rate (a function of the thermal boundary conditions, ranging from 4 to 6 $g•s^{-1}•m-2$) where pyrolysis is significant. In the second regime the char produced by the pyrolysis reactions is oxidized to form ash and the mass loss rate is lower (approximately 1.5 $g•s^{-1}•m-2$ and less dependent on the thermal boundary conditions). These two regimes represent the global smoulder process. This framework is confirmed by analysis of the sample composition throughout the experiment. CO and CO_2 emissions are studied as a function of burning conditions and regimes. The yields (emission factors) of CO and CO_2 are 0.12–0.18 and 0.25–0.6 $kg•kg^{-1}$ during the peat smouldering regime and increase to 0.4 and 2 $kg•kg^{-1}$ during the char oxidation regime. The CO/CO_2 ratio was found to be0.2–0.3. Comparison is made with experiments in which flaming combustion was initiated. It is found that the flux of CO_2 increases 3.8 times and CO decreases 0.75 times compared to the corresponding time during smouldering, showing that these modes of combustion are driven by different chemical processes. The CO/CO_2 ratio for flaming is less than 0.1. Because flaming is limited to the surface of the peat and smouldering can propagate into the peat, the smouldering phase of the combustion was shown to dominate the CO and CO_2 emissions releasing 97% and 85% of these species respectively. Results of FTIR analysis of the combustion products show thathydrocarbons are emitted in greater quantities during the first regime compared to the second.

This is the first time that smoulder dynamics and emissions from peat have been quantified in terms of the smouldering conditions. This has resulted in a robust set of data on smoulder dynamics and emissions taking into account a range of possible conditions under which real smouldering fires occur. This is a significant step forward in allowing lab-scale results to be applied in real-scale smouldering fires.