Effect of peat moisture content on smouldering fire propagation

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Smouldering fire

During dry periods, surface fires can ignite the organic material stored in peatlands or in the forest soils and slowly self-propagate to deeper layers.

These fires are difficult to extinguish and significantly damage the ecosystem at the same time as an important amount of carbon emissions are being released.

Introduction

Figure 1. Up) unburned. Down) after the smouldering. Scotland, 2006. G Rein.

The study of smouldering fires has been limited in comparison with flaming wildfire. Moisture content (MC) of the organic layers is known to be one of the most important variables affecting smouldering process (Frandsen, 1987; Rein, 2013) since latent heat of vaporization represents a significant heat sink and decreases the energy available for the pyrolysis front to advance (Reardon et al., 2007; Rein, 2013).

Smouldering ignition limits were established at a peat MC of 110-125% (dry base) but once smouldering is propagating, it can dry layers of organic matter above this established MC limits. The way this happens is not yet well studied.

Understanding how smouldering spreads as well as defining its limiting factors, will be a step to apply research in smouldering propagation to real systems. **Our first results on characterizing the effect of moisture content in smouldering propagation are presented.**

Methodology

Burning experiments were done using commercial sphagnum peat in insulated trays of 20x20 with 5cm depth in order to observe horizontal propagation (figure 2). The ignition method used follows the protocol in Rein et al., 2008. Laboratory experiments allowed the control of variables such as bulk density, peat moisture content and mineral content. With real peat samples all those variables are more difficult to control making the smouldering process harder to analyze.

Infrared camera, thermocouples and weighing scales recorded temperatures of the front, spread rate, burn duration and mass consumption of the peat for MC treatments of 0%, 25%, 50%, 75%, 100% and a heterogeneous mix of 0% and 200% (figure 2).

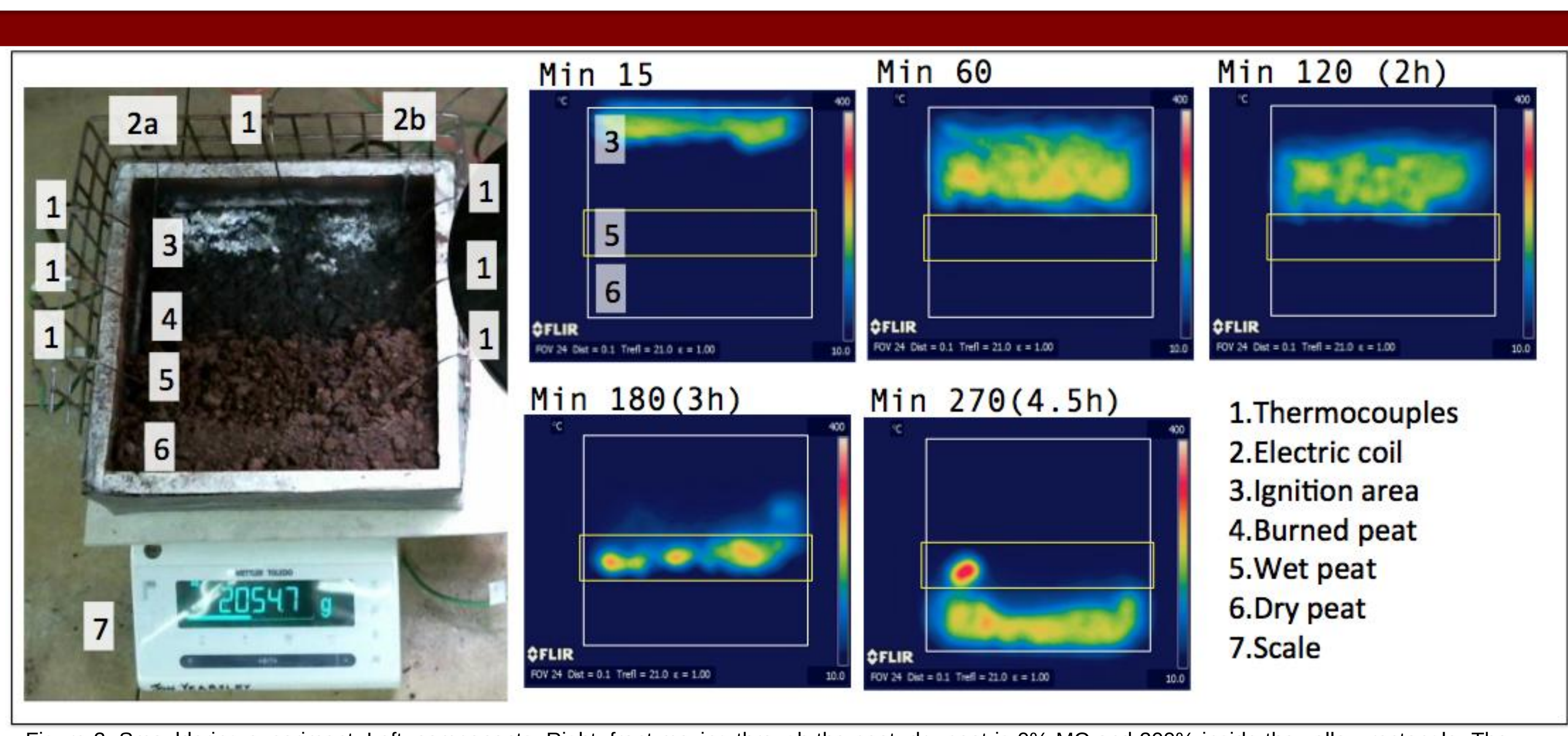

Figure 2. Smouldering experiment. Left, components. Right, front moving through the peat, dry peat is 0% MC and 200% inside the yellow rectangle. The moisture configuration used is for illustrative purposes.

Results

Smouldering self-propagates in all experiments done with different MC, reaching temperatures over 400ºC (figure 3a), but while the smouldering front in dry peat (0% MC) can maintain the temperatures, wet peat (100% MC) temperatures slowly decay to extinction. For dry peat the velocity of propagation is 10cm/h (figure 3b) while for other moisture treatments the velocity of the front is <6cm/h, due to the fact that water has to evaporate before smouldering front can advance.

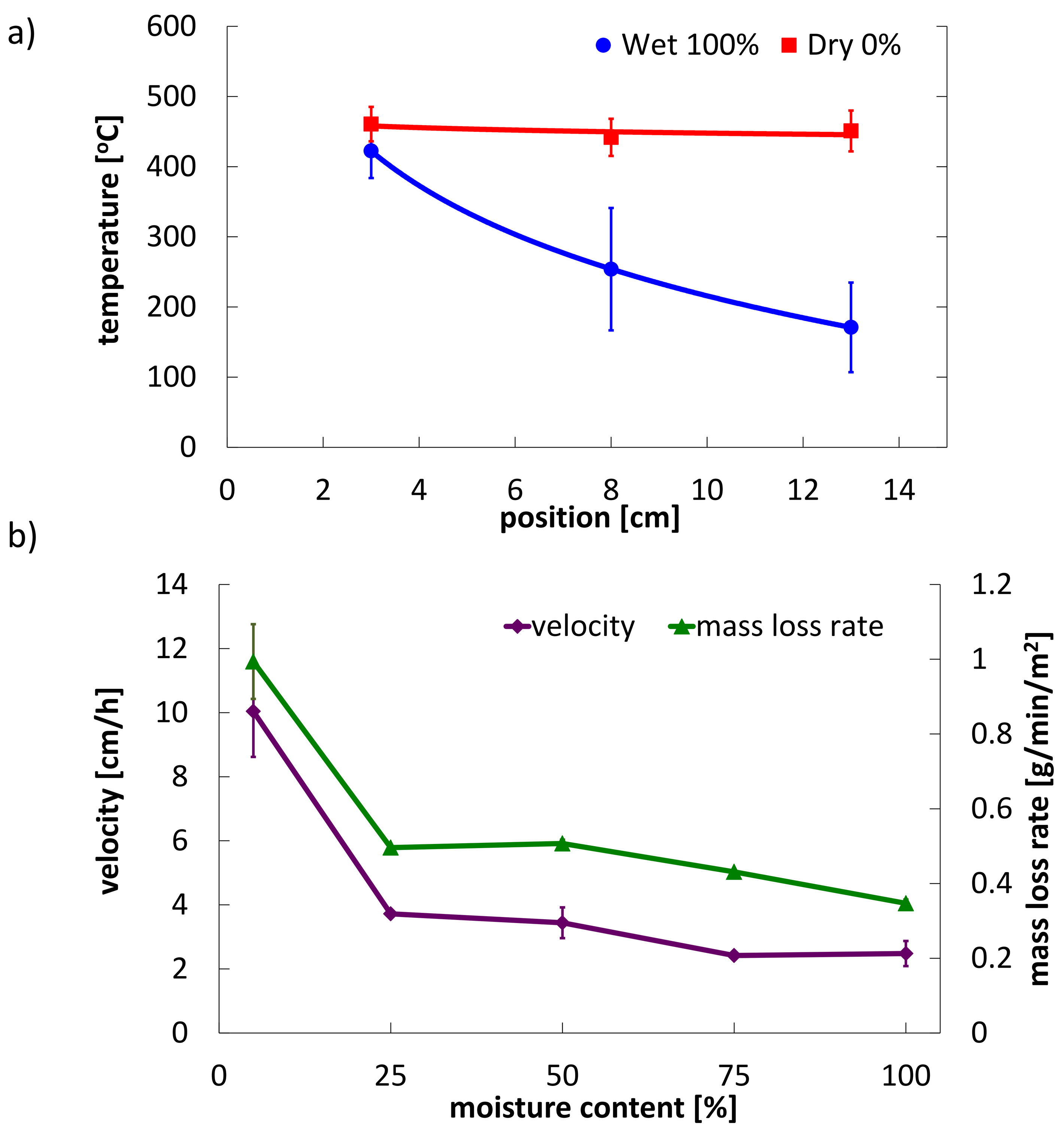

Figure 3. a) Maximum temperatures measured for peat in distance from the igniter. b) Velocity of the front and mass loss rate for different peat moisture content treatments. Error bars are standard deviations.

Velocities vary between peat samples of different MC ($F_{4,7}$ = 39.33, p<0.001). The only observed difference is between dry peat and the other MC (Tukey HSD, p<0.001). Differences in the mass loss give a similar picture to the velocities of propagation (figure 3b, table 1), after ignition mass loss rate for dry peat shows a higher peak (figure 4), while the wet peats (50-100% MC) have a more constant rate during the whole burning.

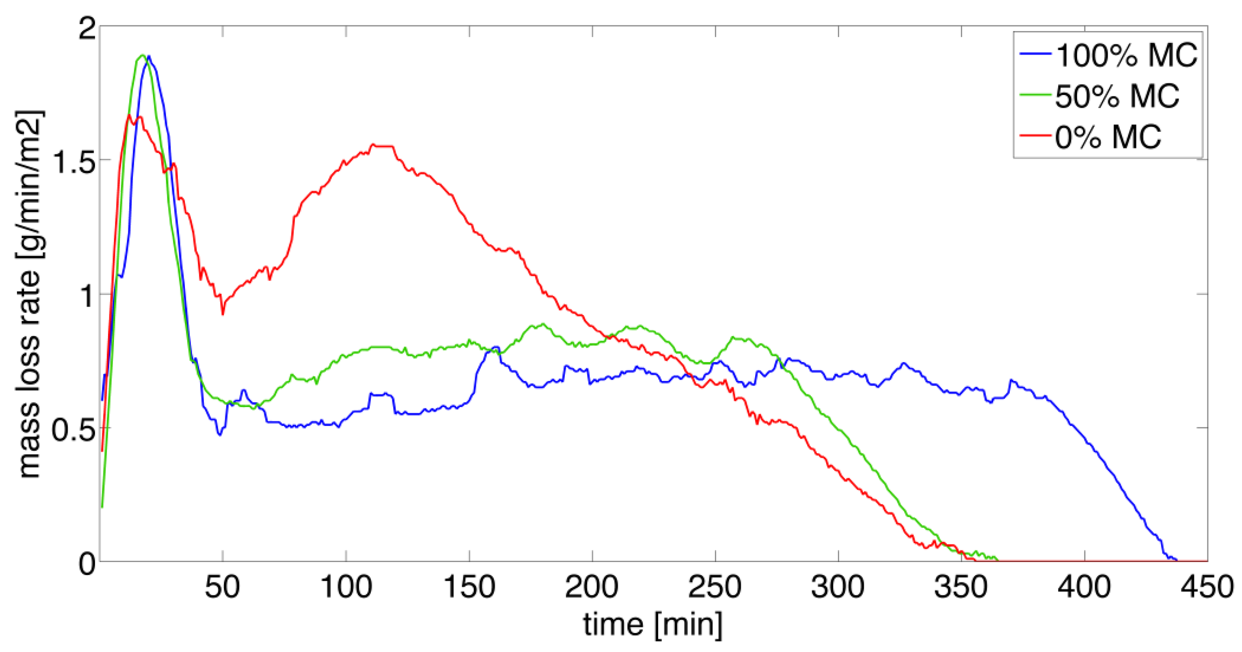

Figure 4. Evolution of mass loss rate during the burning, three different moisture content treatments are compared.

Peat with heterogeneous configuration which includes 200% MC, burns at 6.6cm/h after a long preheating where water in the peat is evaporated (figure 2), although the temperatures are the lowest recorded for a self-sustaining propagation.

Peat moisture	Velocity	Front Temp	Mass consumed	Mass loss rate	Burn duration	replicates
%	cm/h	ºC	%	g/min/m²	min	num.
0	10.0±1.4	446±27	93.7±2.1	0.99±0.10	300±40	5
25	3.7	458	94.7	0.50	403	1
50	3.4±0.5	438±29	89.3±2.9	0.51±0.01	386±19	5
75	2.42	414	82.4	0.43	460	1
100	2.5±0.4	212±85	84.3±4.9	0.35±0.01	430±41	5
0/200	6.6±0.1	207±33	-	-	-	2

Table 1. Average measurements of smouldering fire propagation for peat under different MC treatments.

Conclusions

Our results confirm earlier studies by showing that MC of the peat has a strong effect on the propagation of the smouldering (Reardon et al., 2007; Rein et al., 2008). Wet peat is dried and heated enough to sustain self-propagation.

Novel experiments are presented looking at horizontal propagation of self-sustaining combustion and being a step from laboratory experiments to a more realistic natural scenario since peatlands have heterogeneous distributions of moisture. How smouldering propagates in realistic configurations is not well studied.

Our project will study heterogeneous configurations. Data will be used to validate a smouldering propagation model (FIREOX3 by Jon Yearsley). This information will be useful for ecosystems management and fire services.

References

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