A NUMERICAL APPROACH FOR UNDERSTANDING THE MAIN PARAMETERS AND PROCESSES INFLUENCING THE SOIL ORGANIC MATTER DECAY DURING WILDFIRES

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Introduction

1) Context:

Climate change → Hotter and drier world → More wildfires

2) Wildfire effects on soils:

High temperatures at soil surface

- Physical effects
- Chemical effects
- Biological effects

Related to loss of Soil Organic Matter (SOM)

3) Knowledge gap:

Although there are models that have a good representation of the soil thermal evolution under extreme heating conditions, they do not incorporate the high-temperature induced SOM decomposition.

4) Objectives:

To understand how wildfires affect SOM and to identify which are the main soil properties involved in this process.

- To develop a numerical model to predict the SOM decay during wildfires.
- To study and identify which are the main parameters that affect SOM decay.

Developed model

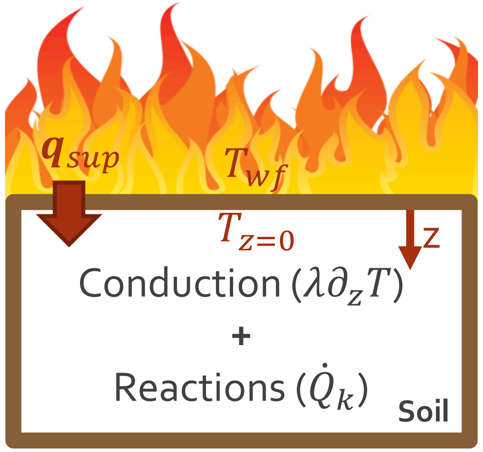

Figure 1: Model diagram.

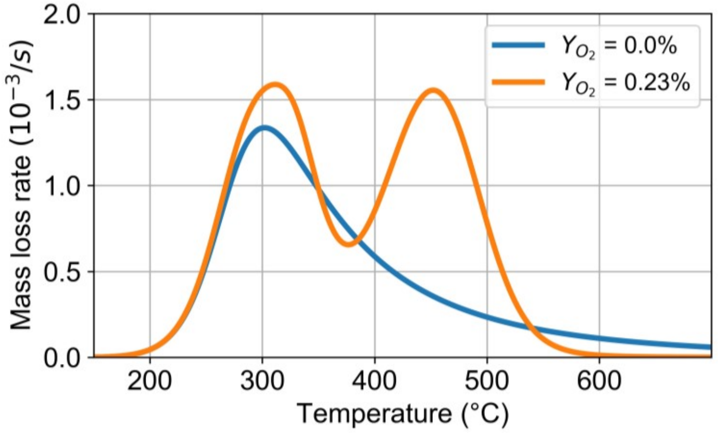

Figure 2: Moss peat thermogravimetric analysis.

Table 1: Model summary.

Sub-Model	Description	Output
Surface condition	Radiative flux boundary condition: $\boldsymbol{q}_{sup} = \varepsilon\sigma\left(T_{wf}^4 - T_{z=0}^4\right)$	SOM and Temperature evolution
Soil heating (Reaction-conduction)*	$\rho c \partial_t T = \partial_z(\lambda \partial_z T) + \sum \dot{Q}_k$ $\lambda(\theta) = \underbrace{\lambda_{soil}(\theta)}_{Lu\ et\ al.,\ 2014} + \underbrace{\lambda_{rad}(T)}_{Massman,\ 2015}$	
Combustion kinetics	$\dot{Q}_k = \Delta H_k \dot{\omega}_{dk}$ $\dot{\omega}_{dk} = m_d^{n_k} Z_k \exp\left(-\frac{E_k}{RT}\right) g(Y_{O2})$ (Huang and Rein, 2016)**	
Water vaporization	Same as combustion but calibrated to represent vaporization ~100°C	

*Fluid movement not considered.
**Moss peat is considered as representative biomass for SOM.

Thermal evolution validation (Campbell et al., 1995)

- The model has a good agreement with the measured temperatures.
- The main features of the soil thermal evolution are simulated.
- Errors are attributed to underestimations of the soil thermal conductivity.
- The radiative term compensates the underestimations on the thermal conductivity. Adjusted volumetric pore radius ranged from 1 mm to 2 mm.

$$\lambda_{rad}(T) \approx 3.8\sigma \underbrace{R_p}_{\text{Volumetric pore radius}} T^3$$

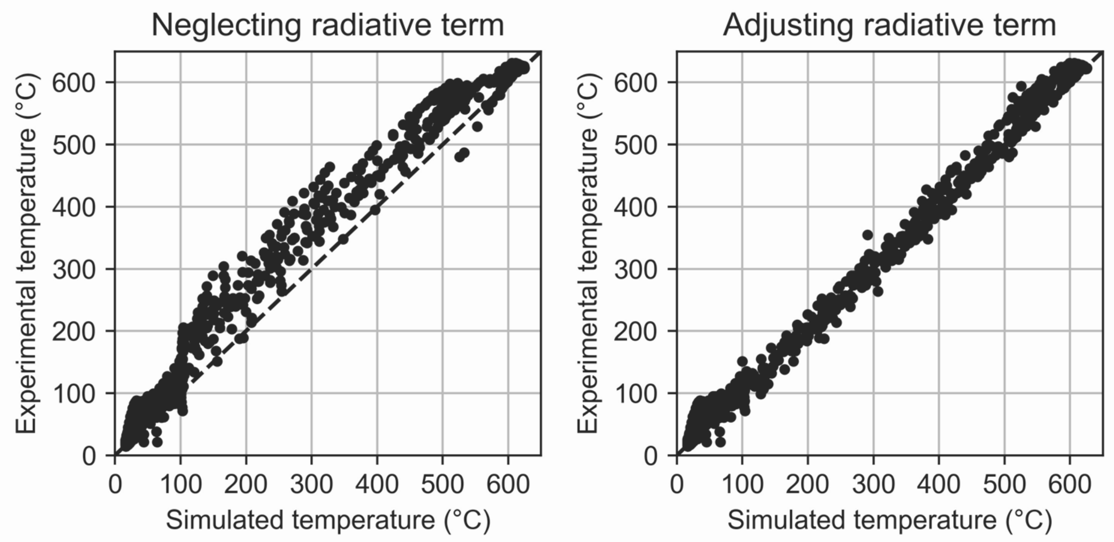

Figure 3: Thermal evolution validation results.

Model parameters analysis

Table 2: Model parameters and range in which they were tested.

Class	Parameter	Values
Soil description	Texture (1)	Sand and clay variations in a soil texture
	Texture (2)	Centroid of each soil texture
	Bulk density	0.8 g/cm^3 to 1.6 g/cm^3
	Volumetric pore radius	0.0 mm to 4.0 mm
Initial conditions	Soil water content	Dry – θ_{1500} – θ_p – θ_{33} – Sat.
	Soil organic matter	0% to 8%
	Initial temperature	20°C to 40°C

$^*\theta_p=(\theta_{33}+\theta_{1500})/2$

- Heating source temperature ranged from 200°C to 1000°C
- Maximum exposure time was of 6 hours.

- SOM decay increases with:
  - Lower water content
  - Higher sand fraction and lower clay fraction
  - Higher volumetric pore radius
- Low-influential parameters over SOM decay:
  - Uncertainty within a soil texture
  - Initial temperature
  - Bulk density
- SOM decay is almost proportional for any initial SOM content.
- Water plays a primary role as a heat absorber.
- Effect of texture over SOM decay is related to the initial water content (Average between FC and PWP).

Conclusions

About the model:

- The model underpredicts the soil thermal evolution but can be enhanced by adjusting the volumetric pore radius with values between 1 mm to 2mm.
- The developed model represents the main features of the thermal evolution during extremes events.
- The coupled soil heating-SOM combustion model is a novel approach:
  - To understand how SOM is affected after wildfire events.
  - To represent vaporization without the need of additional empirical relationships.

Take-~~home~~ lab (or field) messages:

- When studying high-temperatures induced SOM decay, variations in the following parameters could be omitted:
  - Initial temperature
  - Bulk density
  - Uncertainty within a soil texture
- SOM decay is proportional for any initial SOM.
- Water plays a main role as a heat absorber.

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