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Smouldering Combustion of Soil Organic Matter: Inverse Modelling of the Thermal and Oxidative Degradation Kinetics

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Smouldering combustion of soil organic matter (SOM) such as peatlands leads to the largest fires on Earth and posses a possible positive feedback mechanism to climate change. In this work, a kinetic model, including 3-step chemical reactions and 1-step water evaporation is proposed to describe drying, pyrolysis and oxidation behaviour of peat. Peat is chosen as the most important type of SOM susceptible to smoudering, and a Chinese boreal peat sample is selected from the literature. A lumped model of mass loss based on four Arrhenius-type reactions is developed to predict its thermal and oxidative degradation under a range of heating rates. A genetic algorithm is used to solve the inverse problem, and find a group of kinetic and stoichiometric parameters for this peat that provides the best match to the thermogravimetric (TG) data from literature. A multi-objective fitness function is defined using the measurements of both mass loss and mass-loss rate in inert and normal atmospheres under a range of heating rates. Piece-wise optimization is conducted to separate the low temperature drying (<450 K) from the higher temperature pyrolysis and oxidation reaction (>450 K). Modelling results shows the proposed 3-step chemistry is the unique simplest scheme to satisfy all given TG data of this particular peat type. Afterward, this kinetic model and its kinetic parameters are incorporated into a simple one-dimensional species model to study the relative position of each reaction inside a smoulder front. Computational results show that the species model agrees with experimental observations. This is the first time that the smouldering kinetics of SOM is explained and predicted, thus helping to understanding this important natural and widespread phenomenon.