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RR06

Experimental and numerical characterisation of smouldering combustion of peat

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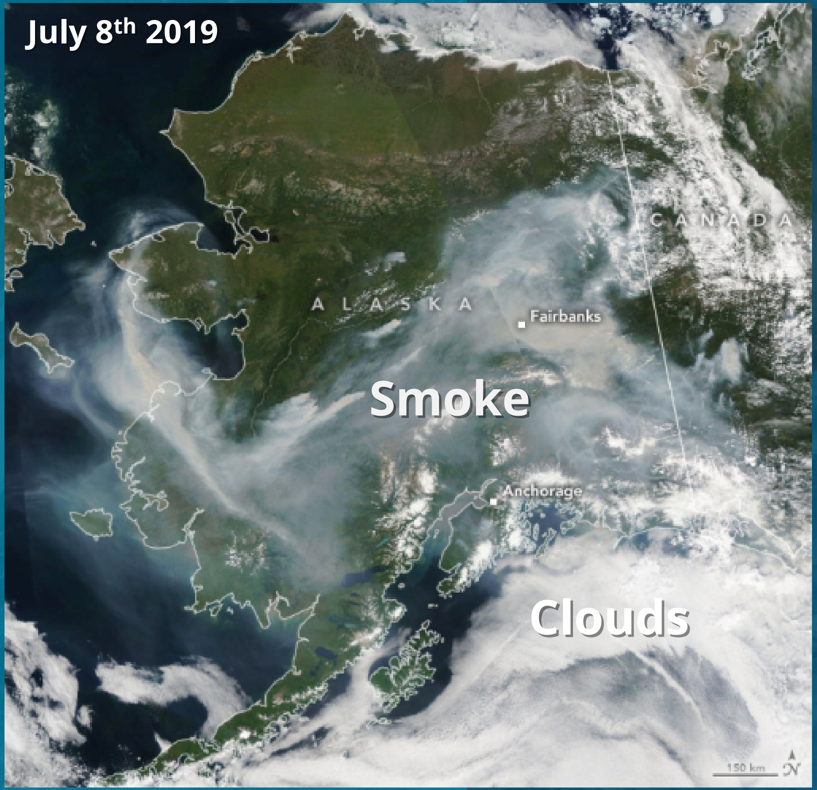

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The Peat Fire Problem

- Peat < 3% of land, but contains 25% of terrestrial carbon
- Peat plentiful in the Arctic and tropical regions
- Fires increase with climate change
- Peat becomes a carbon source
  - Peat fires release substantial CO_2 and other greenhouse gases
  - Difficulty estimating mass of peat consumed creates large uncertainties in predictions of emissions

Research Approach

Motivation: more accurate predictions of greenhouse gas emissions in earth system models

Approach: Address uncertainties in peat fire dynamics and smouldering through an **iterative experimental and modelling process**

Bench top experiments
- Describe pyrolysis and oxidation processes
- Validate model

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Physics-based modeling
- Elucidate physical phenomena
- Explore experimental parameter space over greater range of conditions

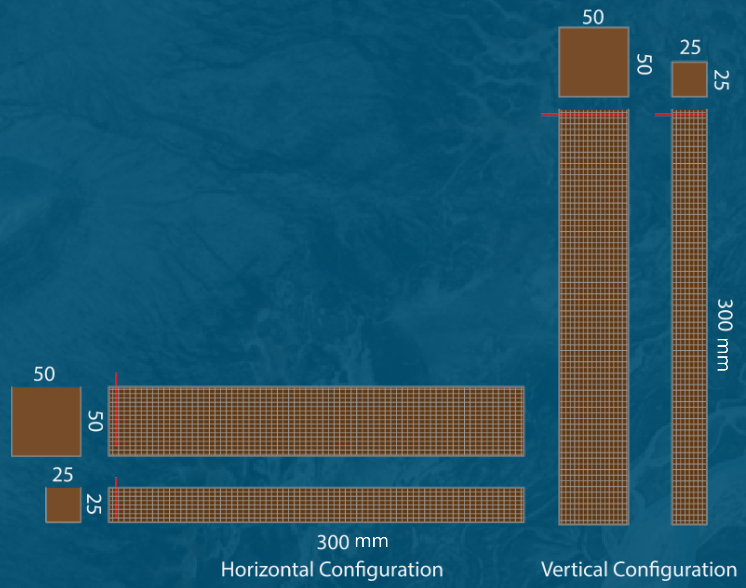
Experimental Methods

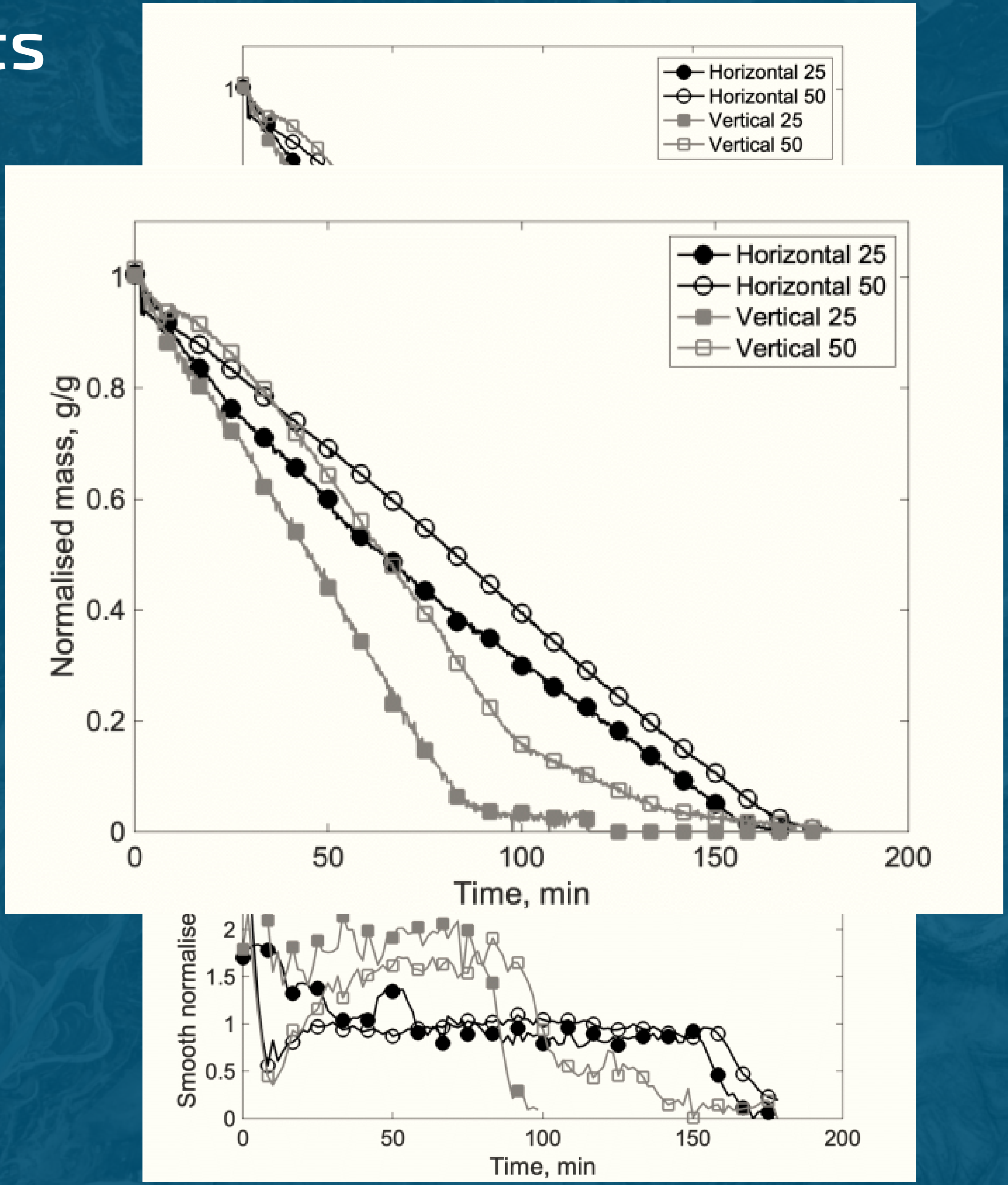
- Cuboidal peat samples with different cross sectional areas
  - Vertical and horizontal orientations
  - Open boundaries constructed by using stainless-steel mesh sample holders
- Commercial sphagnum moss peat dried 48 hr at 80°C
- Ignition: 50 W for 5 min using nichrome wire
- Measurements:
  - Burning rate: Real time mass
  - Pyrolysis front: Centerline temperature (0.25 mm K-type TC)
  - Propagation rate: Time-lapse images

Vertical Configuration

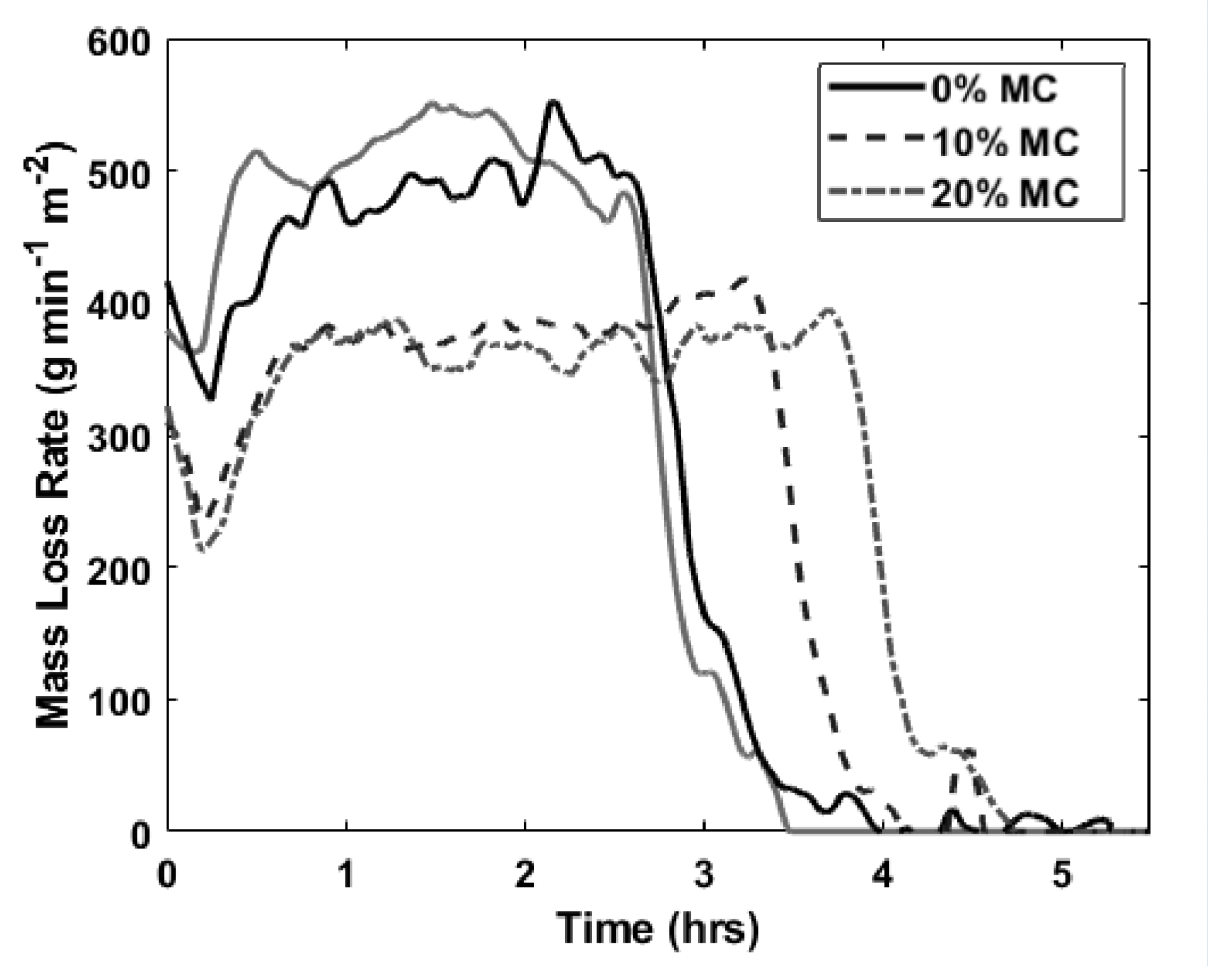
Experimental Mass Loss Results

- Duration of smouldering increases for larger samples
- Propagation direction changes smouldering dynamics
  - Vertical: period of high mass loss rate (MLR) followed by period of lower MLR
  - Horizontal: quasi-steady MLR





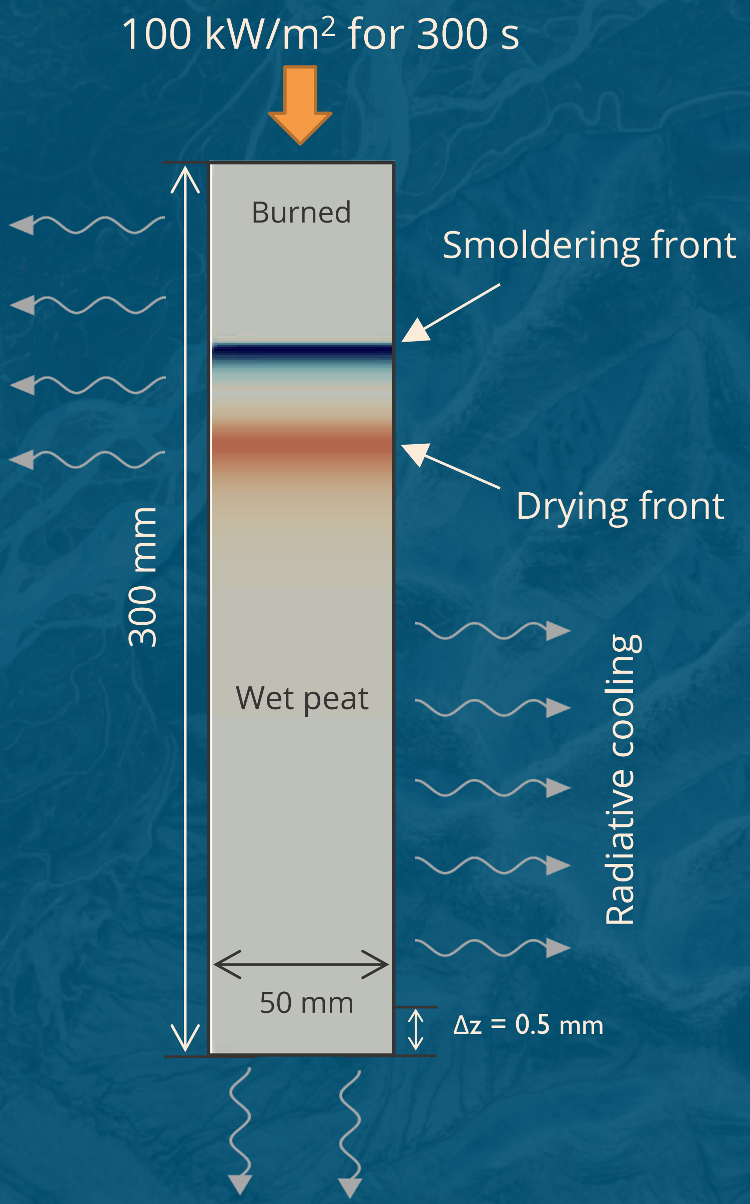
Experimental Moisture Content Results



- Mass loss rate is highest for dry peat
- Negligible differences between 10% and 20% MC

Computational Methods

- 1-D smouldering model
- Implement Huang and Rein's 1D model in Sierra Thermal/Fluids: Aria
  - Including reaction mechanism, reaction parameters, and material properties
- Solves conservation of mass, species, and energy equations in condensed and gas phases
  - Uses Darcy's law for flow through porous media to calculate gas phase velocity
- Solves quasi-static conservation of momentum (to account for collapse)

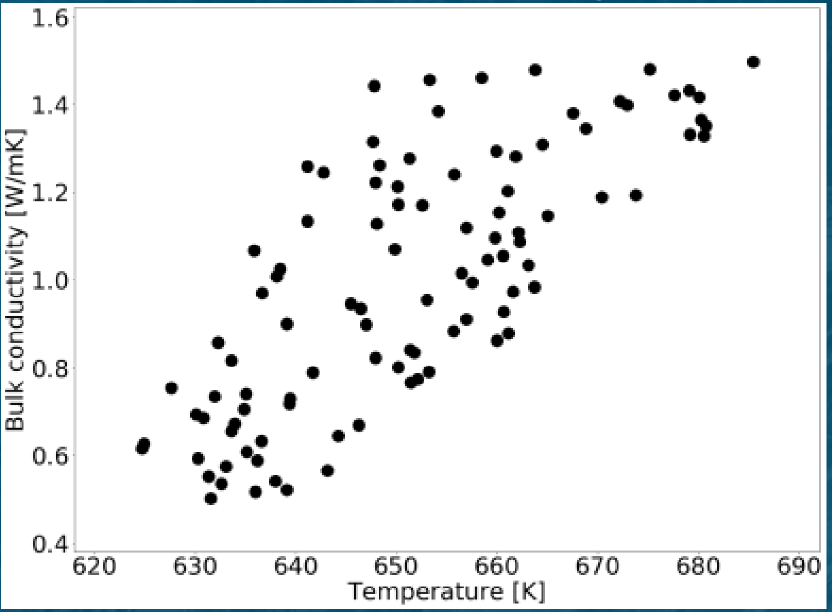


Computational Sensitivity Study of Heat Transfer

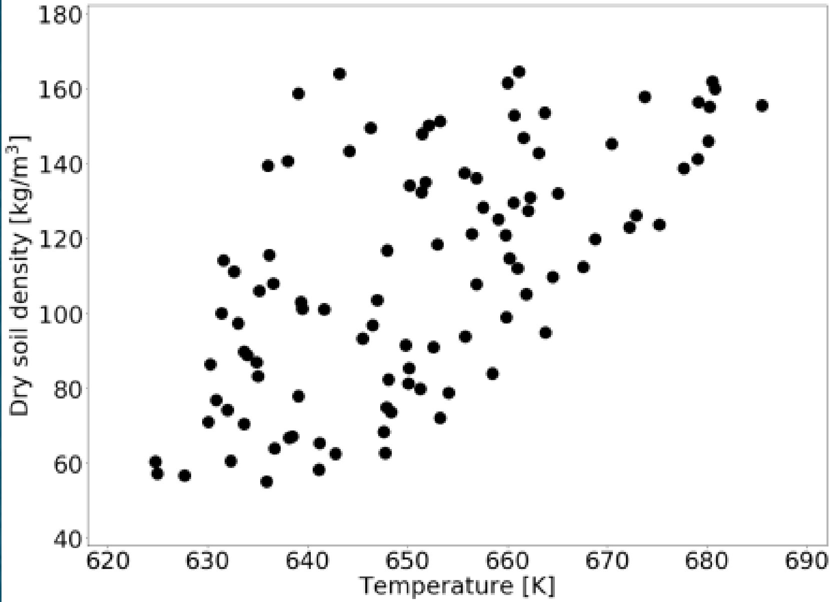
- Considered peat material properties
  - Bulk density
  - Bulk conductivity
  - Molecular weight
  - Solid permeability
  - Young's modulus
  - Poisson's ratio

- Effects of changing **initial** material properties on peat temperature
  - At discrete locations
  - Over time

Bulk conductivity



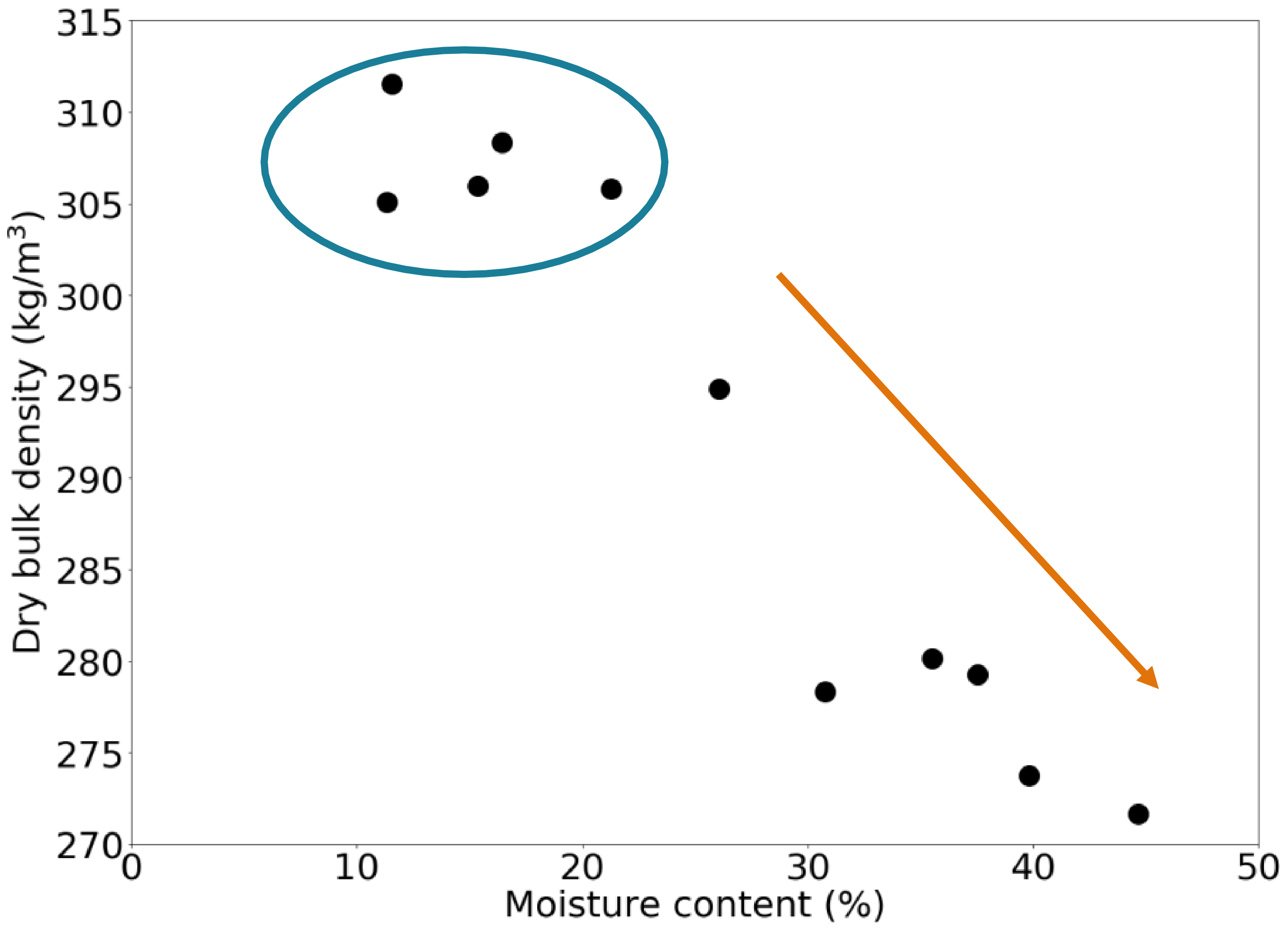
Soil bulk density



Temperature 10 cm below surface at 600 s

Optimal Moisture Content and Bulk Density

- Proctor compaction test
  - ASTM D1557
  - Remove air from peat
- Optimal moisture content:
  - Highest dry density of peat (i.e. most air removed)
- Optimal MC in 10-20% range



Conclusions and Future Work

- Experiments and modeling identified key characteristics of peat smouldering problem
  - Bulk density is critical in model
  - Cross sectional area and sample orientation impact smouldering dynamics, including MLR
  - Optimal MC of 10-20% provides highest dry soil density
- Future work:
  - Validate model with experimental data
  - Consider sensitivity of smouldering soil
  - Investigate relationships between parameters in sensitivity study

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Thank You!

References: Huang and Rein (2014) Combust Flame; Huang *et al* (2015) ProCI; Huang and Rein (2015) IJWF; Huang and Rein (2017) IJWF

Extra Slides

Ranges for sensitivity study

Property	Lower Limit	Upper Limit
Bulk conductivity (W/mK)	0.5	1.5
Bulk density (kg/m^3)	55	165
Molecular weight (kg/mol)	50	150
Poisson's ratio (-)	0.1	0.3
Solid permeability exponent	-12	-9
Young's modulus (N/m^2)	3e5	9e5

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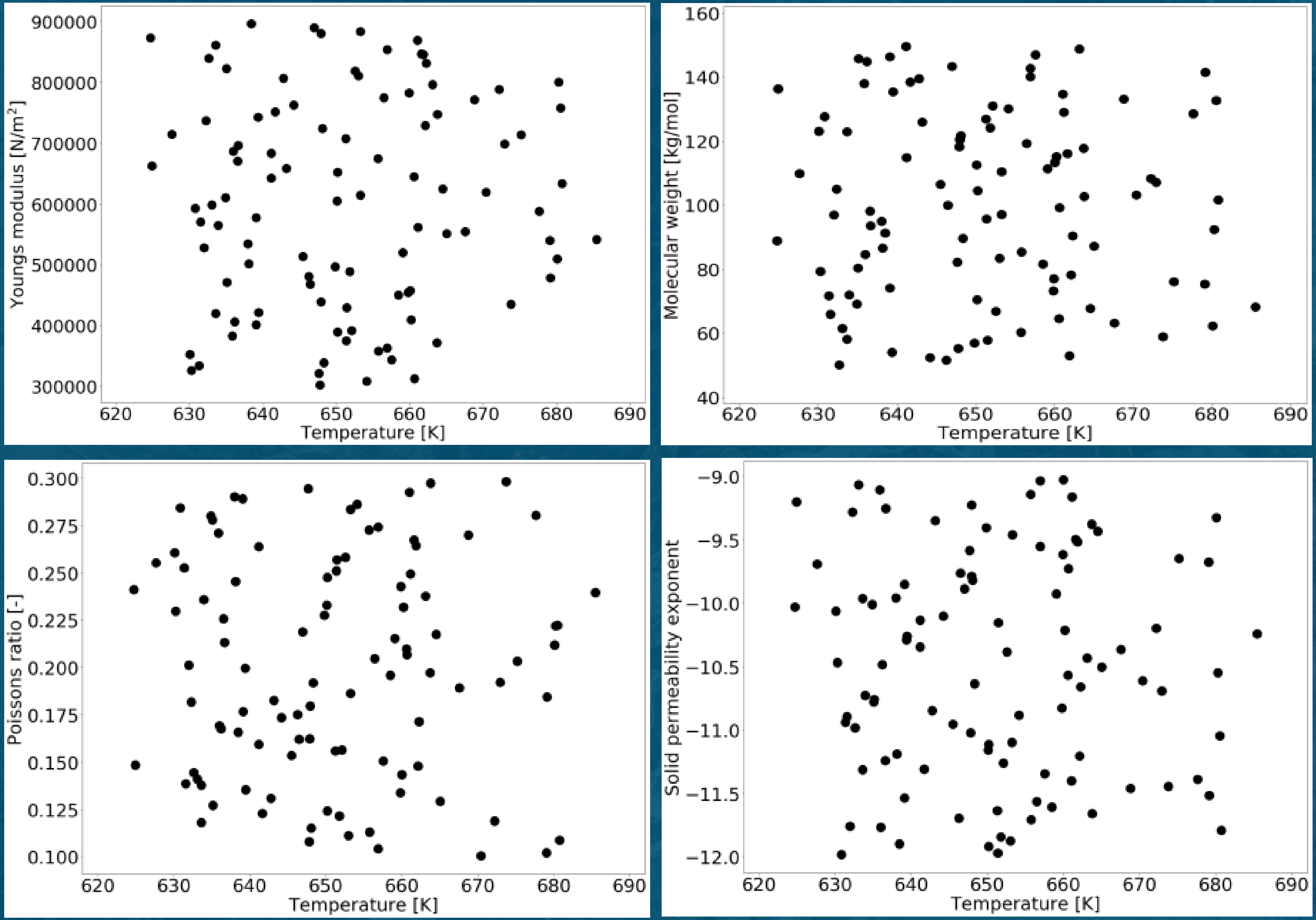
Sensitivity of other material properties at t = 600 s

Young's Modulus

Molecular Weight

Poisson's Ratio

Solid Permeability Exponent



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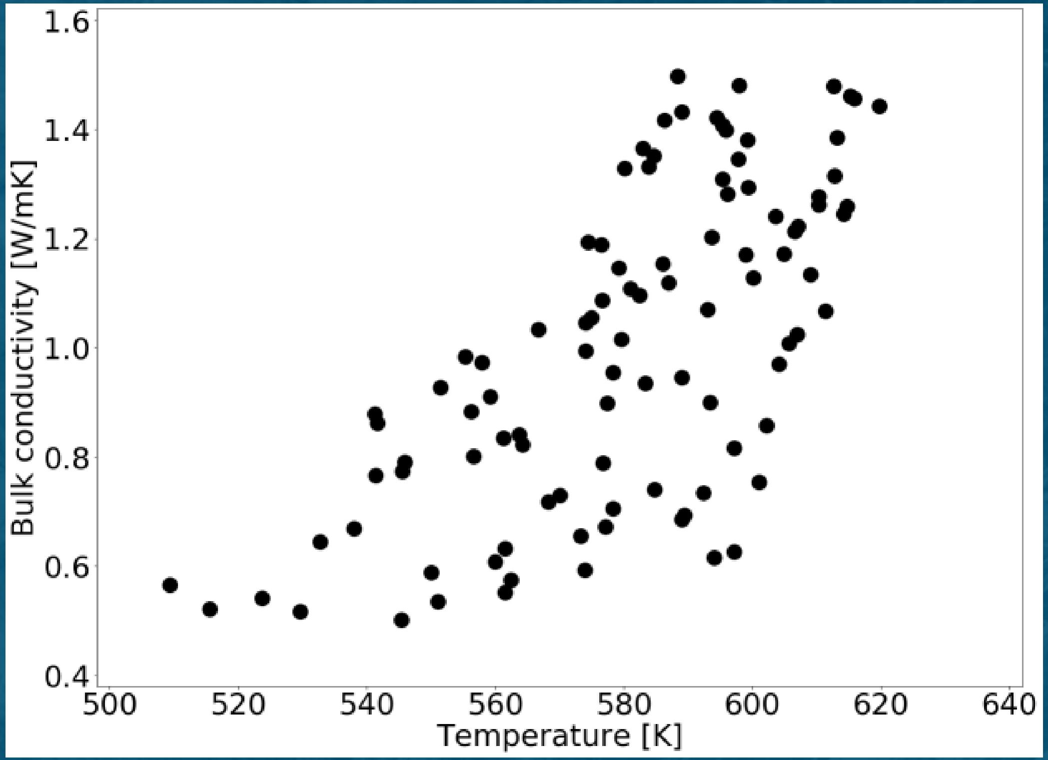
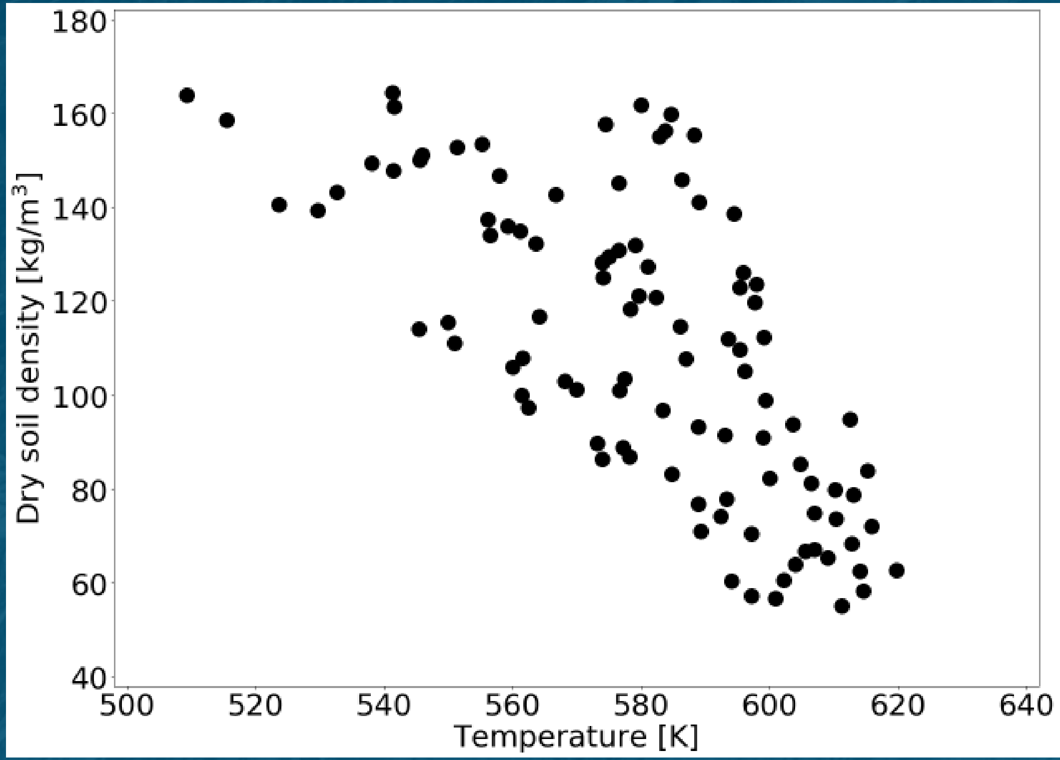
Sensitivity of key material properties at t = 100 s

Bulk conductivity



Soil bulk density



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Compaction diagram

- Compaction
  - Increases the shear strength and
  - Reduces the settlement of soil by mechanical means