Climate Feedbacks on Smouldering Earth

Moisture deficit and self-heating of organic soils

Dr Guillermo Rein
University *of* Edinburgh

EGU General Assembly 2011

Russian summer, 2010

Dot Earth

ANDREW REVKIN

August 20, 2010, 12:01 PM

The Fire Down Below

By ANDREW C. REVKIN

Last week, after The Times explored the less visible combustion in the region around Moscow — in underground layers of peat — I sent a couple of questions to Guillermo Rein, an expert on such smoldering subterranean fires and an assistant professor at the University of Edinburgh in Scotland.

It turns out that we are connected. He explained that an article I wrote in 2002 about fires, both natural and human caused, smoldering in coal seams around the world, inspired him, while he was completing a doctorate at the University of California, Berkeley, to switch from studying risks posed by smoldering combustion in spacecraft to those back on Earth. (It's kind of gratifying to know that, once in a long while, journalism can have a concrete influence on

Past Errors to Blame for Russia's Peat Fires

James Hill for The New York Times

Firemen and soldiers tried to put out a smoldering fire in a forest planted in a peat field near the town of Elektrogorsk.

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The New York Times

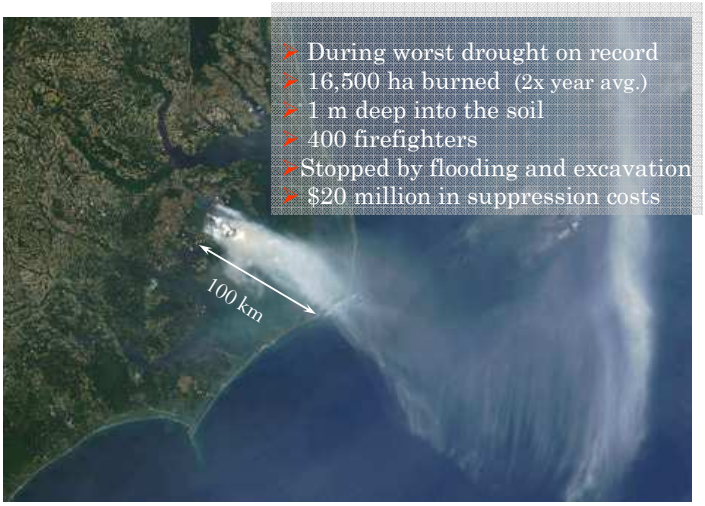
By ANDREW E. KRAMER
Published: August 12, 2010

ELEKTROGORSK, Russia — For two weeks, soldiers with chain saws felled every tree in sight.

RECOMMEND
TWITTER

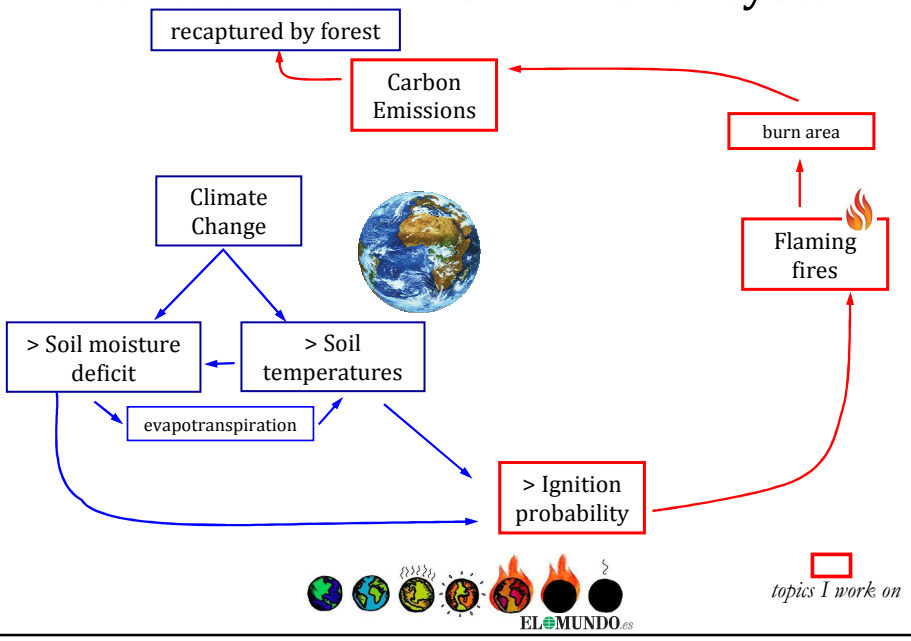
The New York Times

2008 - The Evans Road fire, NC
burned for 7 months

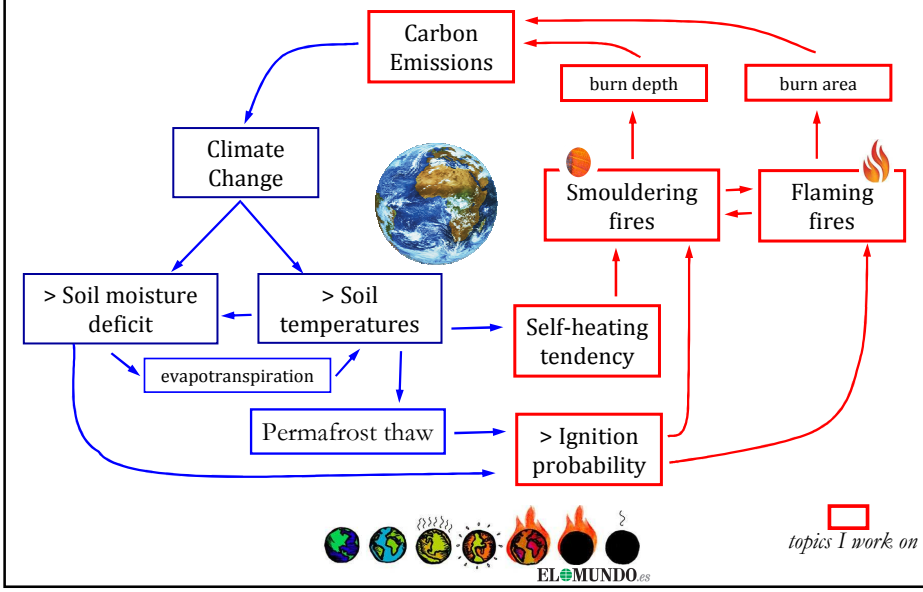


- During worst drought on record
- 16,500 ha burned (2x year avg.)
- 1 m deep into the soil
- 400 firefighters
- Stopped by flooding and excavation
- $20 million in suppression costs

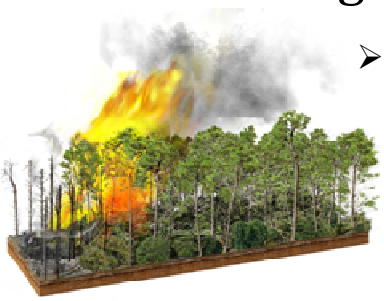
Feedback Mechanism in Earth System



Feedback Mechanism in Earth System



Flaming vs. Smouldering



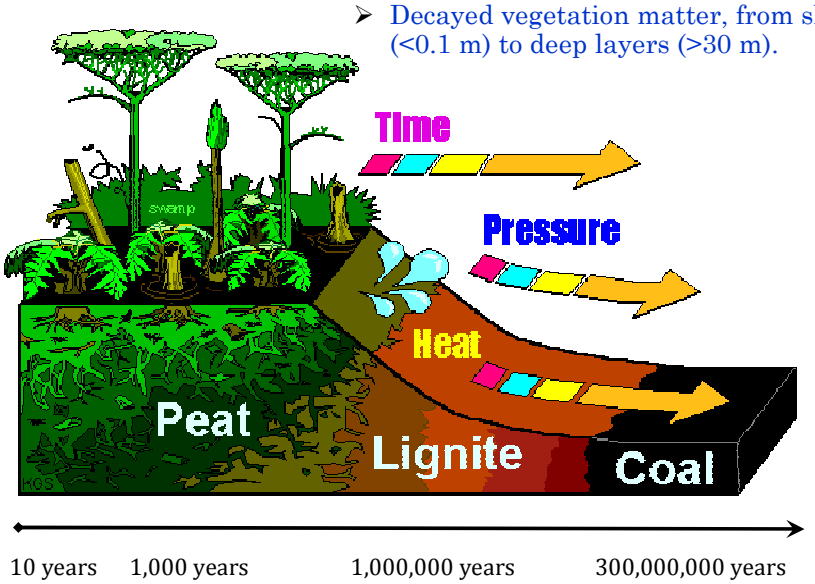
- Flaming fires consume **grasslands**, **shrubs** and **forests**. These take 10-10^2 years to grow back and sequester back the carbon = *Renewable & Carbon Neutral*

- Smouldering fires consume **peat**, organic soils and **coal**. These take 10^4 to 10^8 years to grow again = *Not Renewable & Carbon Positive*

Smouldering fires burn pre-fossil and fossil fuels

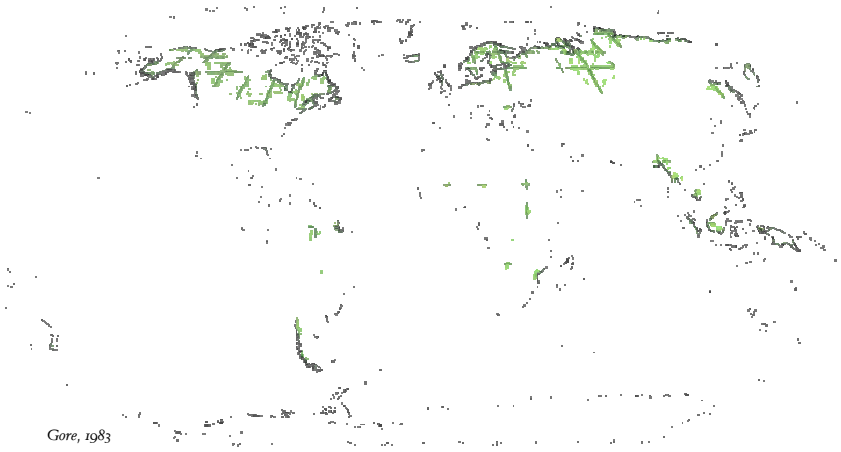
Smouldering Natural Fuels

- Most important: duff, humus, **peat, coal**
- Decayed vegetation matter, from shallow (<0.1 m) to deep layers (>30 m).

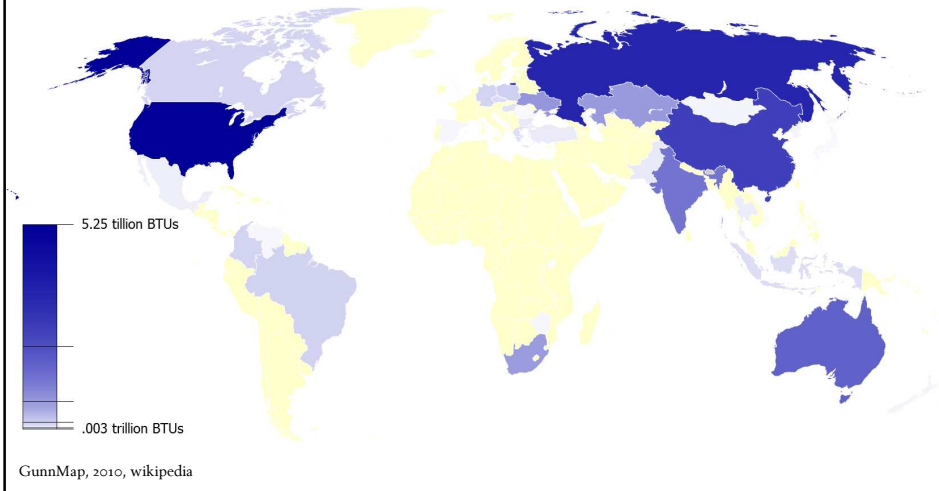


World Map of Peatlands

- Contain more terrestrial carbon than the forests or the atmosphere

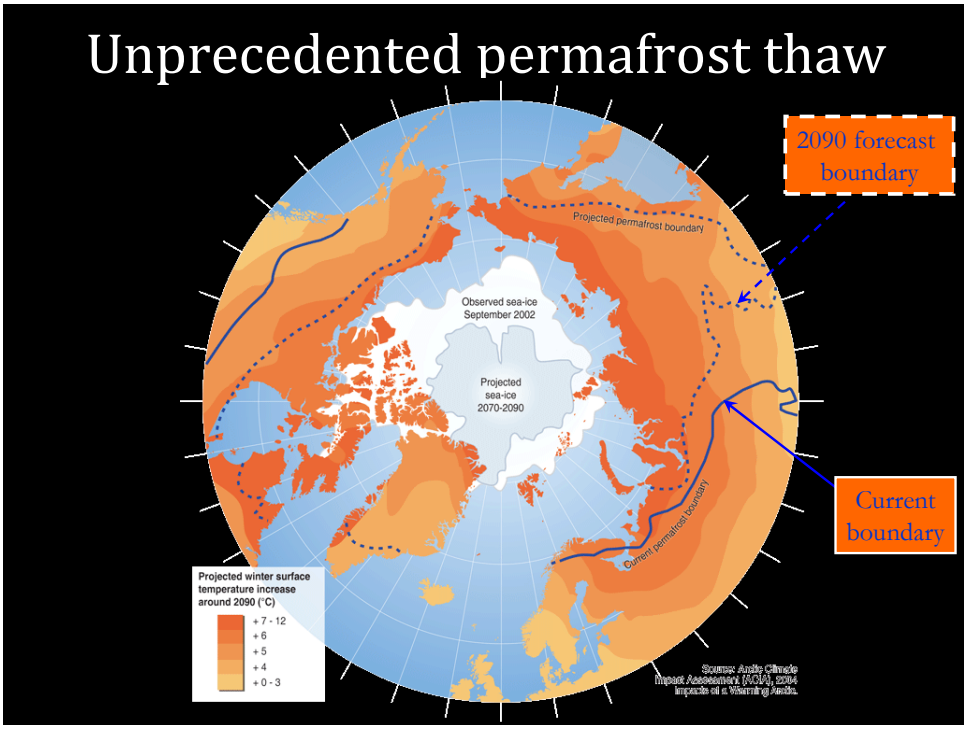


World Map of Coal Deposits



GunnMap, 2010, wikipedia

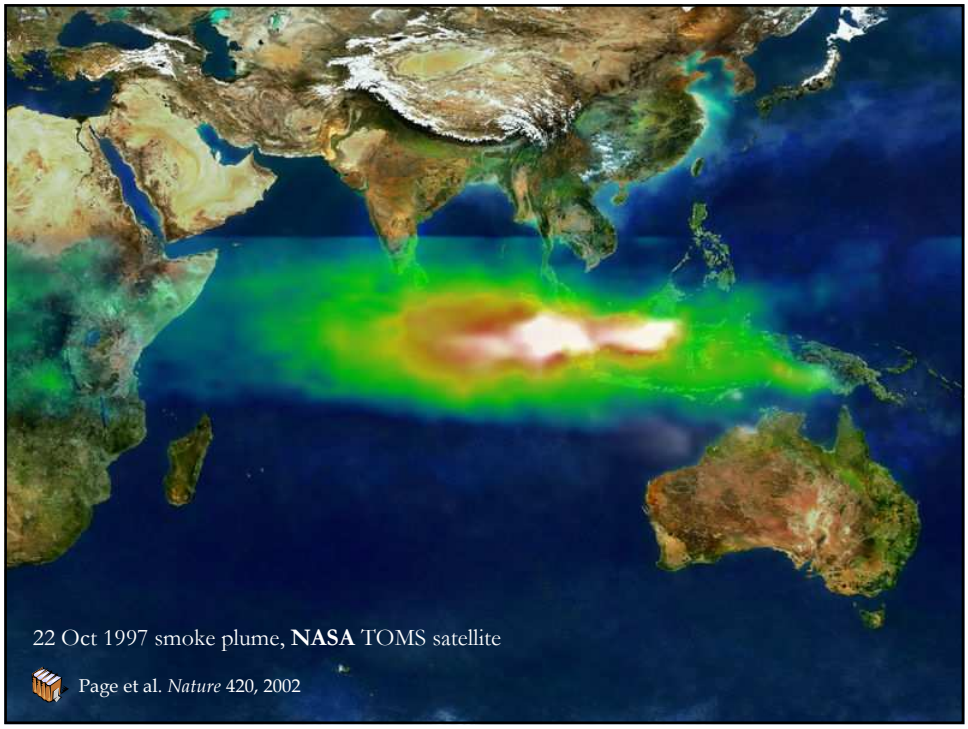
Unprecedented permafrost thaw



2009, Las Tablas de Daimiel National Park, Spain

salvemoslastablas.blogspot,
Tomás Beldad, 2009

- Peat moisture <20% dry weight
- More than 50 ha were burning
- Depth down to 5 m
- Lasted from Aug 2009 to Feb 2010
- Emitted ~ 10 ton of $CO+CO_2$ per day



22 Oct 1997 smoke plume, **NASA** TOMS satellite

Page et al. *Nature* 420, 2002

Rothiemurchus Wildfire, July 2006

- Lodgepole pine plantation
- 3 days of flaming fire
- 40 days of smouldering fire

Aviemore, Scotland

by G Rein, 2006

Smouldering around the Globe

Growing Global Phenomena

Accidental burning of fossil fuels

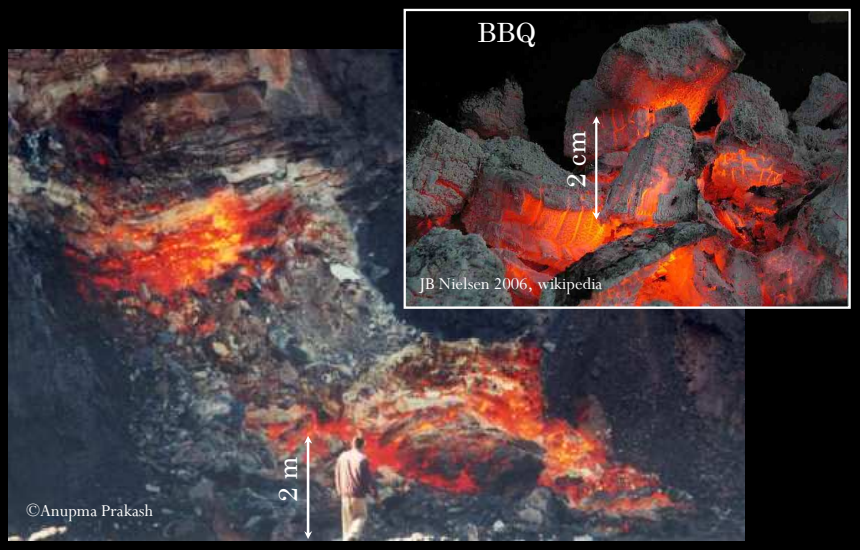
- Burning of natural deposits of coal and peat, and organic soils

  - Consuming of energy resources
  - Destruction of environmental resources
  - Emitting greenhouse gases and pollutants

"Think of it as one giant charcoal briquette. It will ignite and the fire will sink into the soil"

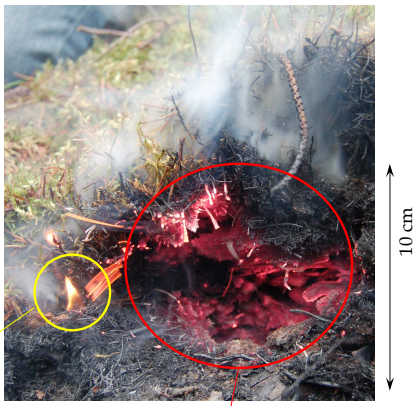
State Forest Manager
NC, 2008

Smouldering fuel



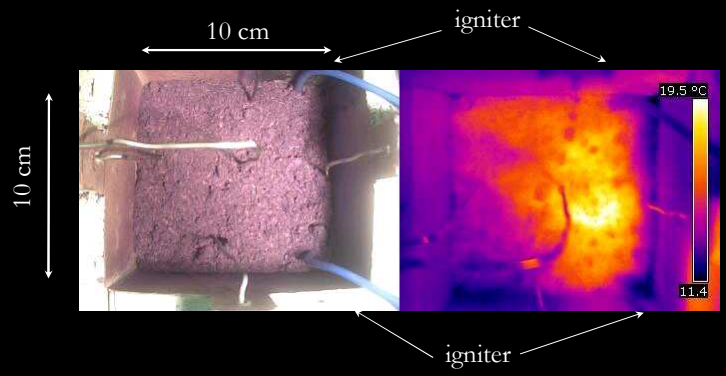
Smouldering Combustion

- Flameless combustion
- Low peak temperature:
  ~500-700 °C
- Low heat release rate:
  ~8 kJ/g (1/3 of flaming)
- Creeping spread rate
  ~ 1-5 cm/h



Rein, *International Review of Chemical Engineering*, 2009

Smouldering propagation in peat



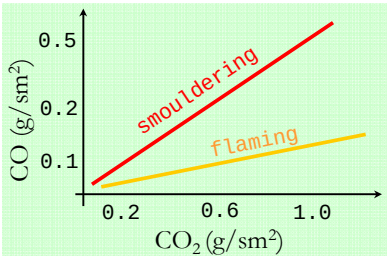
(video speeded up 1,200 times)

Smouldering Emissions

- Combustion reaction is typically incomplete:

$$C^s + O_2 \rightarrow CO_2 + H_2O + CO + \sum(CH_4,\ C_3H_8,\ NH_3,\ CH_3OH\ldots) + Char^s$$

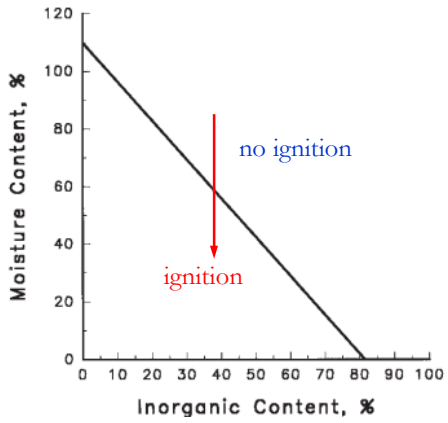
- CO/CO_2 smouldering is 0.43 ± 0.12. Typical values for flaming combustion is ~0.1



- 100 times larger emissions per unit area than flaming fires

Rein et al, *Proc. Comb. Inst.* 32, pp. 2489-2496, 2009

Smouldering Ignition Limits



Frandsen, *Can. J. For. Res.* 1997

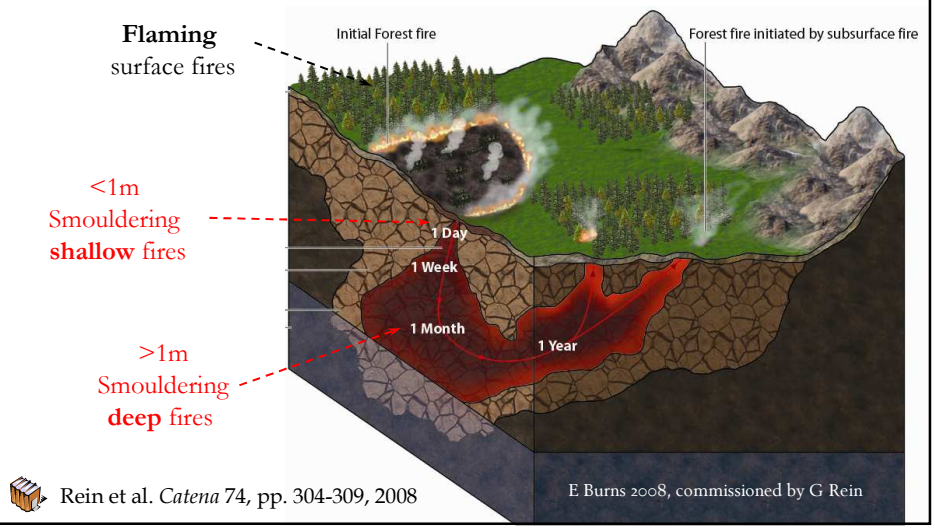
Most persistent fires

- **Smouldering is easiest to ignite**
  - Lower heat fluxes for ignition (8 vs. 15 kW/m^2)
  - Self-heating at room temperatures <30 ºC
- **Smouldering is most difficult to suppress**
  - much larger amounts of water
  - much longer smothering hold-on times
- Indeed, the **oldest** continuously burning fire on Earth, a smouldering coal seam in Australia, is at least >6,000 years old

Rein, *International Review of Chemical Engineering*. 1, 2009

Controlling Mechanisms

0. Composition – *organic, water, inert*
1. Oxygen availability – *free surface, cracks/channels, galleries*
2. Heat losses – *convection, radiation, conduction*



Rein et al. *Catena* 74, pp. 304-309, 2008

Conclusions

1. Accidental burning of fossil fuels
2. Destruction of valuable energy and environmental resources
3. Equivalent to 10-40% of man-made global emissions
4. Positive feedback mechanism between Smouldering fires and Climate Change

- Current research effort in smouldering is not proportional to the threat
- New opportunities for engineering in the Earth System – low level intervention Geoengineering

Go Geoengineering

- The Royal Society defines Geoengineering as

  "deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming"

- I propose we start with the simpler task, one with a low level of geointervention:

  Deliberate large-scale suppression of smouldering fires on the Earth System

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Climate Feedbacks on Smouldering Earth: Enchantment of Moisture deficit and self-heating of fossil and pre-fossil soils

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Global smouldering phenomena, the slow, low-temperature, flameless burning of organic soils, is the most persistent type of combustion phenomena and the longest continuously fires on Earth (>6,000 years).
It take place since deep times and in many ecosystems, special boreal and tropical ones. These are accidental sources of carbon emissions that during millennia have been slowly burning fuels with zero energy efficiency, consuming large amounts of fossil energy resources (coal seams), destroying natural ecosystems (peatlands) and emitting greenhouse gases and pollutants. The global problem has grown in the last decades to an estimated release varying between 10 to 40% of the man-made carbon emissions, and a coal consumption rate at least 5 times that of Germany.

Because it involves the burning of fossil and pre-fossil fuels, this is the only carbon-positive wildfire phenomena. This creates feedbacks in the climate system because moisture deficit and self-heating of organic soils are enchanted under warmer climate scenarios and would lead to more frequent smouldering fires. Warmer temperatures at high latitudes are resulting already in more Artic fires and unprecedented permafrost thaw exposing large soil carbon pools to smouldering for the fist time since millennia.

While flaming fires have been a central focus in fire research, smouldering fires are as important in terms of ecosystem damage, atmospheric emissions and socioeconomic threats but have received little attention. Moreover, these fires are difficult or impossible to detect with current remote sensing methods because the chemistry is significantly different, their thermal signature is much smaller, and the plume is much less buoyant.