Modeling Wildfire Impacts on the Carbon Cycle in the Boreal Biome

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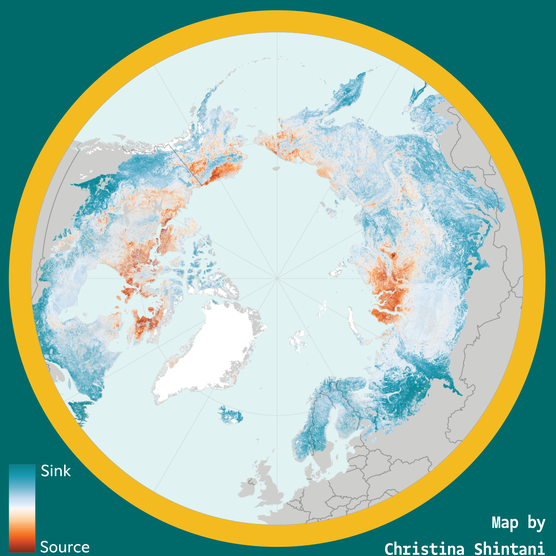
Modeling Wildfire Impacts on Permafrost with Climate Change



Map by Christina Shintani

PERMAFROST PATHWAYS

Prior to Fire

Historically, cold and wet conditions at northern latitudes slowed decomposition and led to the accumulation of soil carbon. This carbon has been preserved in permafrost for **thousands of years**. At present day some permafrost areas remain carbon sinks while others have become sources with rapidly warming climate.

Surface Fire

The leading edge of a wildfire is the **flaming front**, which passes in **seconds to minutes**. The speed and intensity of the stage is driven largely by the quantities and moisture level of finer fuels such as moss, graminoids, and dead foliage, and other litter.

After the flaming front passes some **larger fuels** will continue to burn and smolder for **minutes to days**.

The surface fire rapidly releases carbon stored in litter, dead, and live vegetation to the atmosphere along with other organic gases and smoke particulates.

Crown Fire

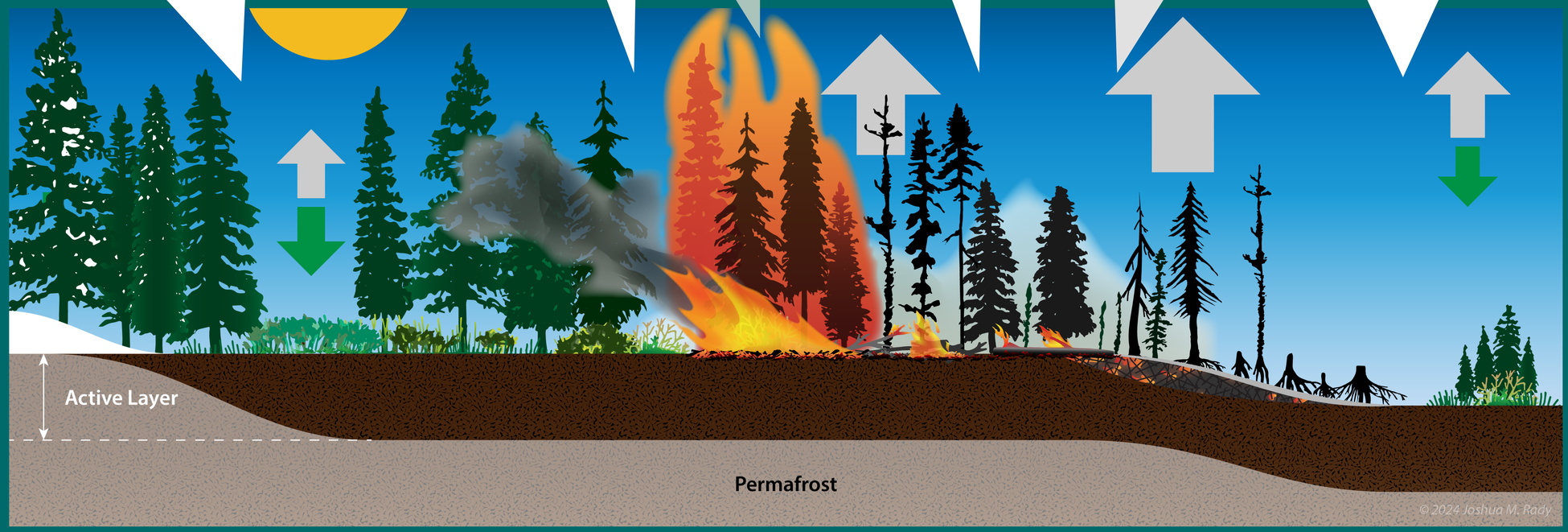
Crown fires increase the fuel involved in a fire and can thereby increase fire intensity. Crown fire initiation depends on vertical vegetation structure, which differs between forest ecosystems in North America and Eurasia.

Ground Fire

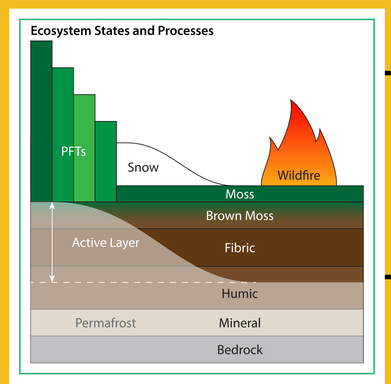
Ground fire starts if the fire drys and heats the organic soil surface to the ignition point. Soil moisture is the critical regulator of ignition. The soil burns by smoldering, more slowly and at lower temperatures than with flaming combustion. The fire moves progressively downward in the soil until fuel is exhausted or the moisture level causes it to go out. This can last from **hours to years** and is responsible for the majority of carbon lost in Arctic and Boreal wildfires where is occurs.

Post-fire Effects

Vegetation productivity can begin to recover quickly after fire but vegetation structure may take **decades** to recover. Alterations to soil structure can be even longer lasting. Decreased organic soil layer thickness following fire reduces insulation of underlying soil. This results in increased active layer depth and **thawing of permafrost**. This in turn can result in additional physical changes such as thaw slumps. The resulting increased erosion and decomposition can lead to elevated emission of ancient stored carbon to the atmosphere for **years** following fire.



DVM-DOS-TEM Model



Fire Front

Prescribed meteorology, simulated fuels, and topology are used to calculate the fire front properties with the Rothermel & Albini fire spread model.

Fire intensity & residence time

Flame height & fire intensity

Crown Fire

The initiation of crown fire is determined by front flame height, fire intensity, and tree crown base height.

Fire radiant heat flux

Fuel Consumption

Combustion of surface fuels is calculated with the Burnup model of Albini.

Radiant heat flux & fire environmental temperature

Ground Fire

We are developing a mechanistic model of ground fire adapted from published equations for the simulation of smoldering combustion of peat. The physical properties of the soil column are supplied by DVM-DOS-TEM. Heat flux into the soil surface is derived from the aboveground fire processes. If energy inputs are sufficient to ignite the soil surface smoldering progress downward (1D) until conditions extinguish the fire.

Emissions

Model vegetation, litter, and soil carbon stocks are updated based on the simulated fire effects. Emissions of carbon dioxide and other gases are calculated based on emission factors.

Permafrost Effects

The altered soil profile changes simulated soil properties and allows the model to predict the effect of the altered thermal regime on permafrost over the long term.