2024_57_MechEng_SN: Modelling of Artic and Boreal Large Scale Wildfires

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Wildfires, or wildland fires, are becoming more frequent due to the adverse effects of climate change. This surge in wildfire activity has significant consequences, especially in Arctic and boreal regions like Canada, Alaska, Siberia, and Greenland. These latitudes are of particular concern because they contain old vegetation and ancient organic soils that would contribute substantially in a wildfire to the release of CO_2, exacerbating global warming through a positive feedback loop. Additionally, wildfires can affect thawing permafrost and release stored carbon and methane, amplifying greenhouse gas emissions. These wildfires disrupt old ecosystems, leading to significant changes in carbon dynamics and plant communities. Compounding these challenges is the remote nature of these regions, making it difficult for firefighting crews to reach wildfires quickly. There is an urgent need to deepen our understanding of wildfires in these areas to design effective mitigation measures and model their future impact on the climate.

Wildfires are complex phenomena influenced by vegetation type/density, local atmospheric conditions, and topography. The underlying dynamics involve fluid mechanics, heat transfer, radiation, solid combustion, and chemistry. These processes cover a vast range of scales, from kms down to embers in cm, making the problem inherently turbulent and resistant to direct simulation. Moreover, hot gases rise into the atmosphere, potentially creating complex weather feedback. Understanding how fast a fire propagates is critical to determine the affected area. On the ground level, "spotting" is crucial, where burning vegetation(firebrands) is transported ahead of the fire potentially igniting new fronts. The motion of firebrands is affected by both local/global conditions. There is a major research gap regarding firebrands, which needs to be addressed to understand wildfires dynamics.

The PhD aims to develop an open-source tool for modelling firebrands in large wildfires within realistic terrain and vegetation. The approach will incorporate stochastic modelling to simulate the dispersion of firebrands while accounting for turbulent flow and local temperature/density variations, progressively incorporating complex physics and may ultimately integrate with large-scale atmospheric models. The project's effectiveness will be assessed by comparing with data from well-studied wildfires and satellite imagery.

Ultimately, the model will not only enhance our fundamental understanding of wildfire behaviour but also provide a practical tool that can be integrated into various aspects of fire safety in remote regions, helping to design effective mitigation measures.

This project will combine expertise in coupled reactive flow physics, vegetation and solid combustion, and stochastic modelling, creating a novel approach that sheds new light on wildfires, contributing to our ability to combat these increasingly prevalent and destructive natural disasters.