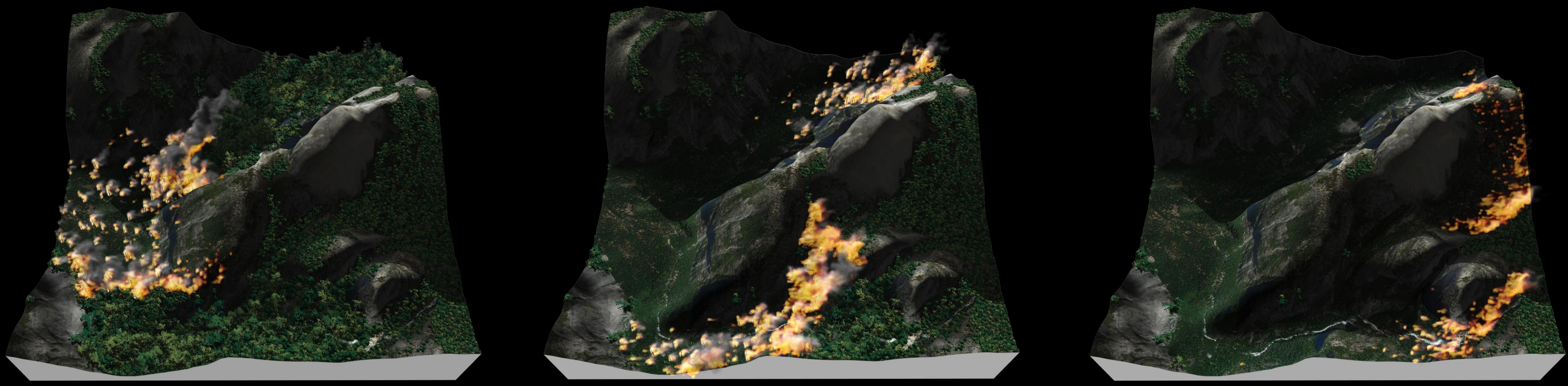
Fire in Paradise: Mesoscale Simulation of Wildfires

T. Hädrich[1], D. T. Banuti[2], W. Palubicki[3], S. Pirk[4], D. L. Michels[1]
[1]KAUST, [2]UNM, [3]UAM, [4]Google AI

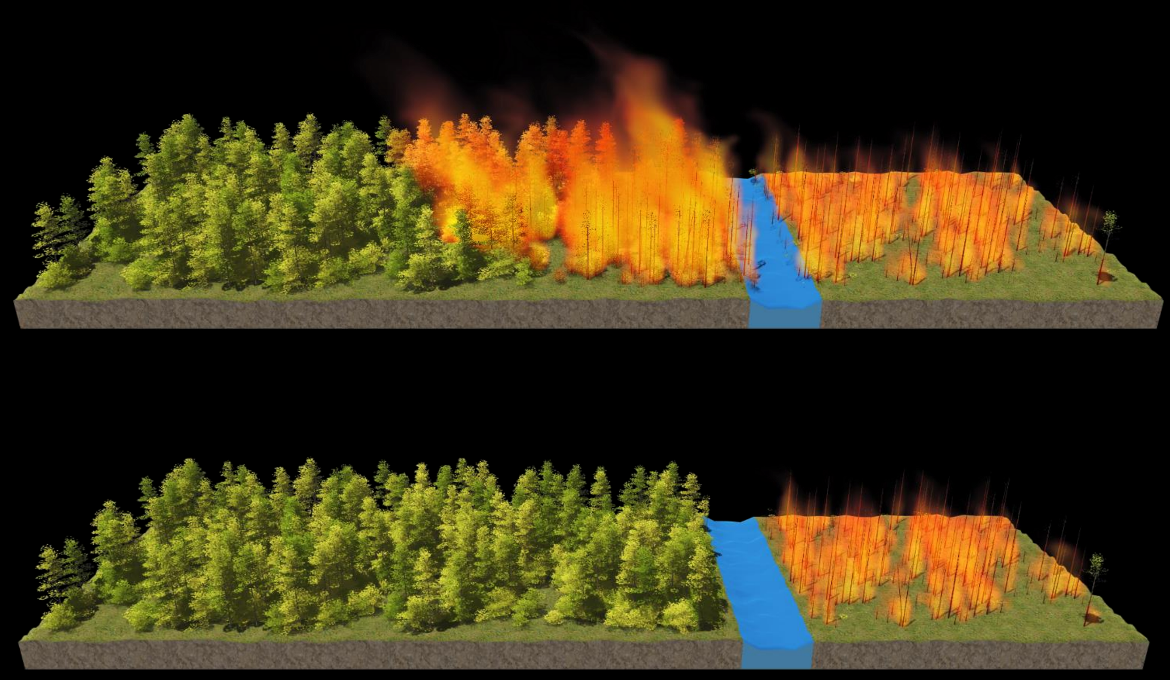


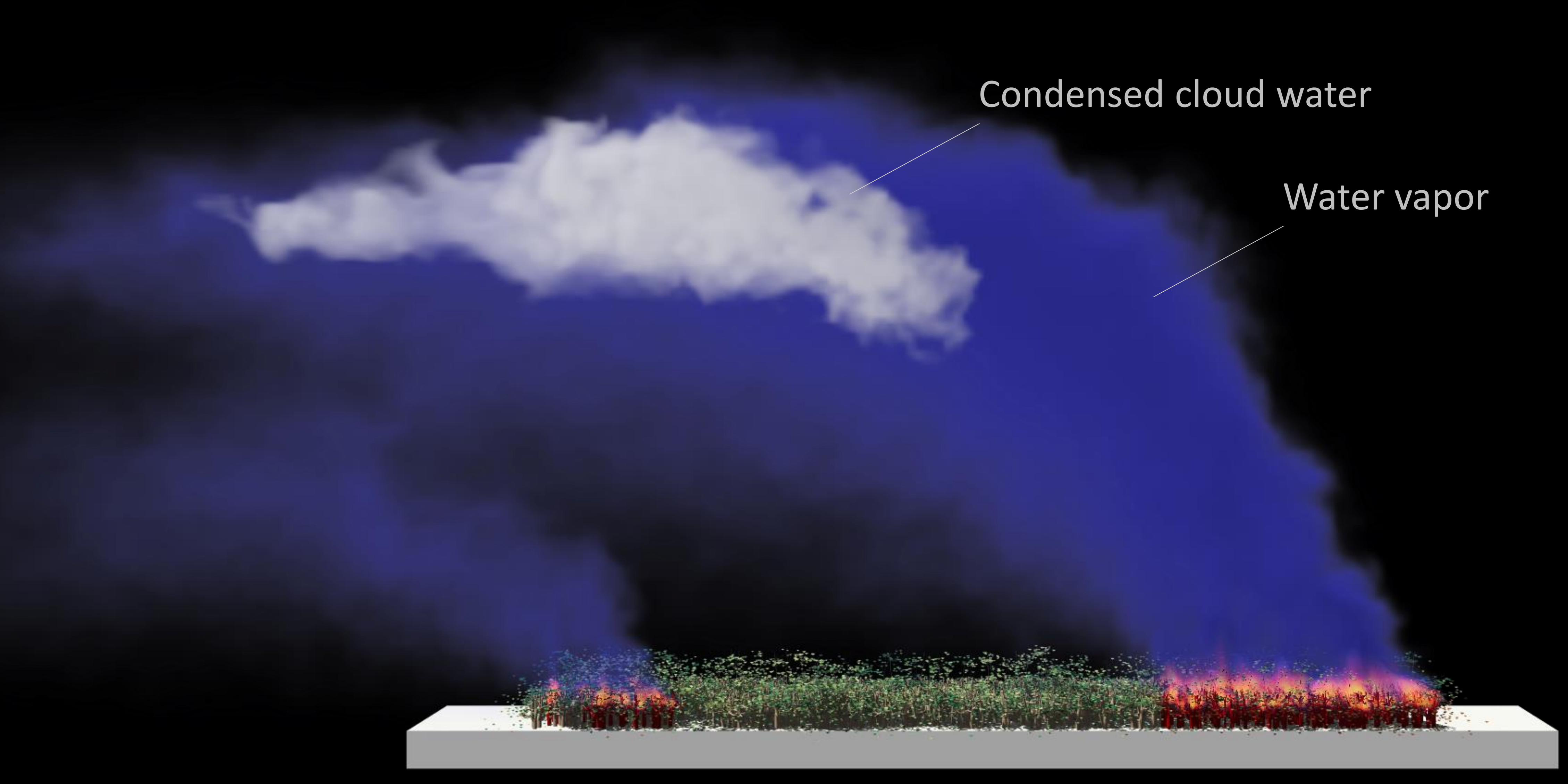
Wildfires are an existential threat across various countries around the world. Moreover, the frequency of forest fires is expected to further increase as a result of changing climatic conditions. The complex dynamics paired with their often rapid progression renders wildfires an often disastrous natural phenomenon that is difficult to predict and to counteract. We present a novel method for simulating wildfires with the goal to realistically capture the combustion process of individual trees and the resulting **propagation of fires at the scale of forests**. We rely on a state-of-the-art modeling approach for large-scale ecosystems that enables us to represent each plant as a detailed 3D geometric model.

Each tree in our simulation is composed of a number of connected **branch modules**, where each module consists of a collection of branches. We employ an **Eulerian fluid solver** to simulate fire and to model its propagation through the ecosystem. This way, fire can be transferred from module to module and – in turn – from tree to tree. The use of detailed branch geometry allows us to realistically capture the three-dimensional fire spread, which cannot be easily covered with other representations or statistical models. For example, when a tree underneath another tree is burning, fire can spread vertically. This would not occur in simplified spatial representations such as statistical models.

Our model allows us to simulate the effect of wind for wildfires. A constant wind velocity, for example, leads to fire propagation in the dominant wind direction. Moreover, we simulate an increased concentration of oxygen due to wind, which accelerates the combustion process.

Our simulation runs at interactive rates and thereby provides a convenient way to explore different conditions that affect wildfires, ranging **from terrain elevation profiles** and **ecosystem compositions** to various measures against wildfires, such as **cutting down trees as firebreaks, the application of fire retardant, or the simulation of rain**. In the Figure on the right side, two simulations with fire breaks of different sizes are set up, and fire is initiated on the right side. If the fire barrier is too narrow, the fire is able to spread to the other side. If the fire break is sufficiently large, the fire spread is prohibited.





Flammagenitus clouds are dense grayish to brown cumuliform clouds which potentially emerge from wildfires or volcanic eruptions. Burning wood releases large amounts of water that supersaturate the air above a fire. Flammagenitus clouds can condense, resulting in rainfall contributing to potentially extinguishing the fire. The Figure on the left side shows a simulation of a wildfire scenario from which a flammagenitus cloud emerges whose rainfall finally extinguishes the fire on the left side.