Simulating Wildfire Spread Using Physically Accurate Models

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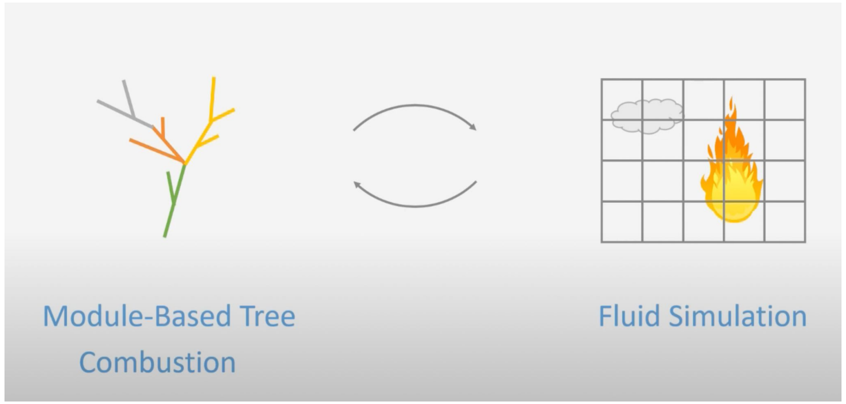
Quick Recap

- Want to simulate and visualize the spread of a wildfire in a virtual forest
- Define and generate a forest for us to burn
  - Grid of cells defining the environment
  - *Module*-level modeling of trees
- Pass forest into CUDA to run simulation
  - Tree **Combustion**
  - **Fluid** Simulation
- Render the forest and see it dynamically change as simulation progresses
  - Tree Rendering
    - Branches
    - Leaves (tentative)
  - Smoke & Fire

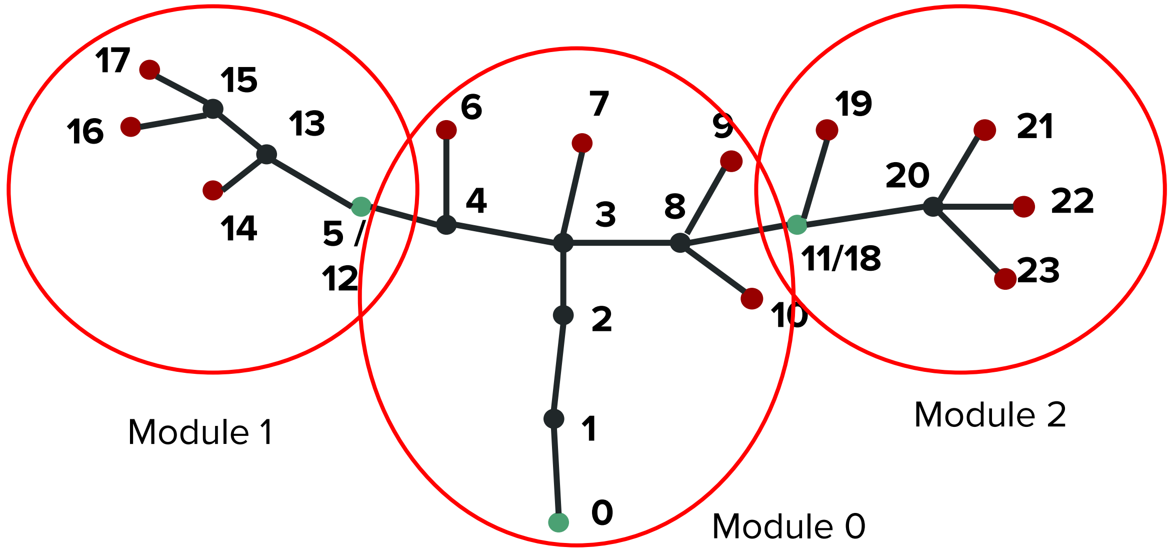
Goals for this milestone

- ✓ Generate a small "forest" to test code
- ✓ Integrate **tree** combustion with **fluid** simulation
- x Render tree and smoke/fire

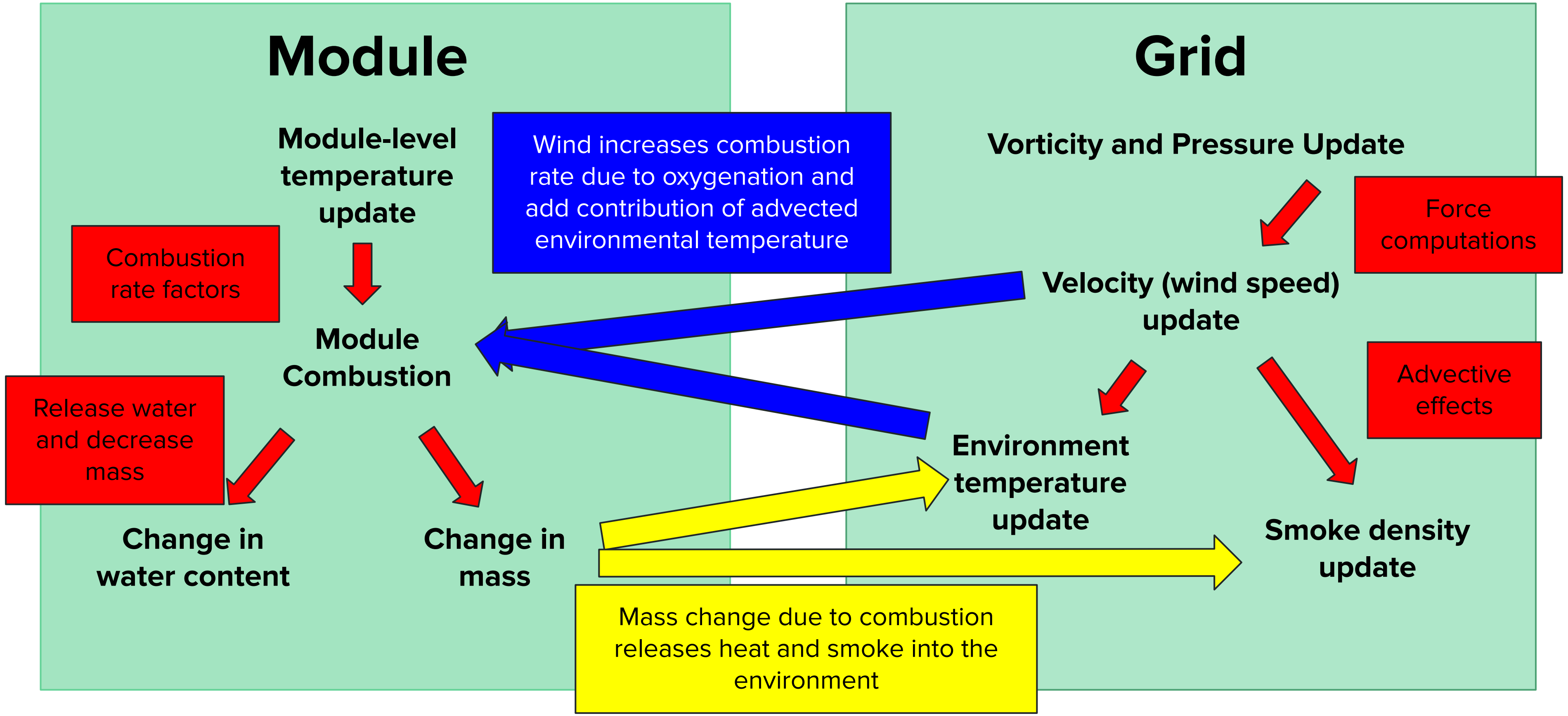


Forest

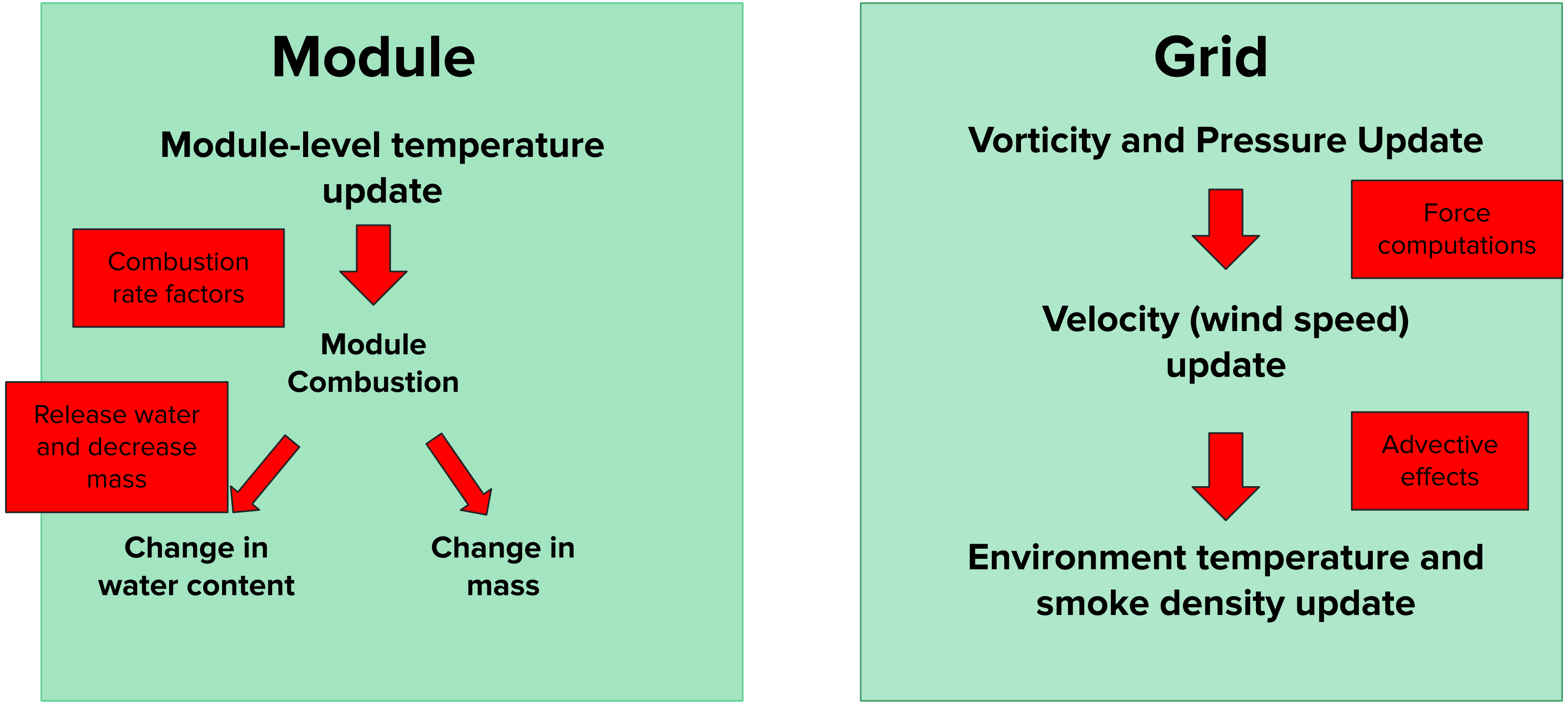
- **20x20x20 grid** containing our initial demo sandbox **(8000 grid points)**
- **2 trees** spawned in our sandbox
  - Each tree has **3 modules** for us to test on **(6 modules total)**



Module to Grid


Module
Grid
Module-level temperature update
Combustion rate factors
Module Combustion
Release water and decrease mass
Change in water content
Change in mass
Wind increases combustion rate due to oxygenation and add contribution of advected environmental temperature
Vorticity and Pressure Update
Force computations
Velocity (wind speed) update
Advective effects
Environment temperature update
Smoke density update
Mass change due to combustion releases heat and smoke into the environment

Module to Grid


Module
Module-level temperature update
Combustion rate factors
Module Combustion
Release water and decrease mass
Change in water content
Change in mass
Grid
Vorticity and Pressure Update
Force computations
Velocity (wind speed) update
Advective effects
Environment temperature and smoke density update

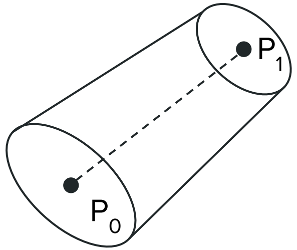
What we’re seeing

$$\begin{tikzcd}
\boxed{\text{Modules losing mass over time}} \arrow[d] & \boxed{\text{Temperature and smoke in affected grids increases}} \arrow[d] & \boxed{\text{Temperature and smoke in neighboring grids increases and spreads out over time}} \arrow[d] \\
\boxed{\text{Wood is combusting in our simulation}} & \boxed{\text{Combustion is properly affecting the environment}} & \boxed{\text{Fluid is advecting and the fire is spreading throughout the simulation space}}
\end{tikzcd}$$

Rendering

Tree Rendering

1. Iterate over every branch (edge) of graph and update **VBOs** using **CUDA kernels**
2. Use **geometry shader** to render triangles needed to render cone

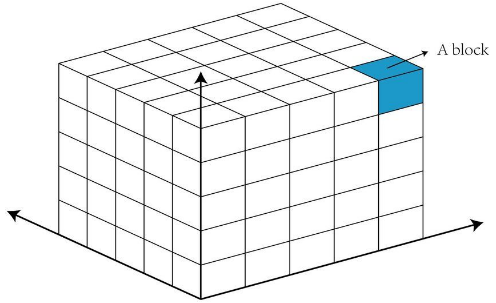


A truncated cone is represented by ***two vec4's****, with the* <u>*xyz*</u> *representing it's position in world, and* <u>*w*</u> *representing its radius.*

Smoke + Fire Rendering

VBO data computed in two passes using kernels:

1. **Rays** from light source pass through **smoke density field** to compute **light intensity** for each **voxel** (grid from simulation)
2. Cast **ray from viewpoint** and **accumulate light intensity** from first pass as the ray traverses the scene



Next Steps

1. **TOP PRIORITY:** Get simulation rendered! (we have everything we need…)
2. Sanity check the simulation
3. Expand sandbox
    a. Increase simulation dimensions
    b. Add more trees