HIDALGO2

CENTRE OF EXCELLENCE

NCCs Meeting 15th of June 2023

Wildfires pilot

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meteogrid

EuroHPC Joint Undertaking

Grant number: 101093457

Overview: Wildfire Scales in Hidalgo-2 Project

Two **use cases** with two specific **scales**

Scene 1. Landscape level

- To provide simulations of wildfire progression, energy release and coupled atmosphere-fire interactions.
- To estimate perturbation of wind fields.
- To simulate generation of pyro-convective movements.
- To model release and dispersion of smoke and flying embers.
- Calculation domain is **5 x 5 x 3 Km**. Spatial resolution 50 m. Temporal resolution 5-10 min

Scene 2. Settlement level

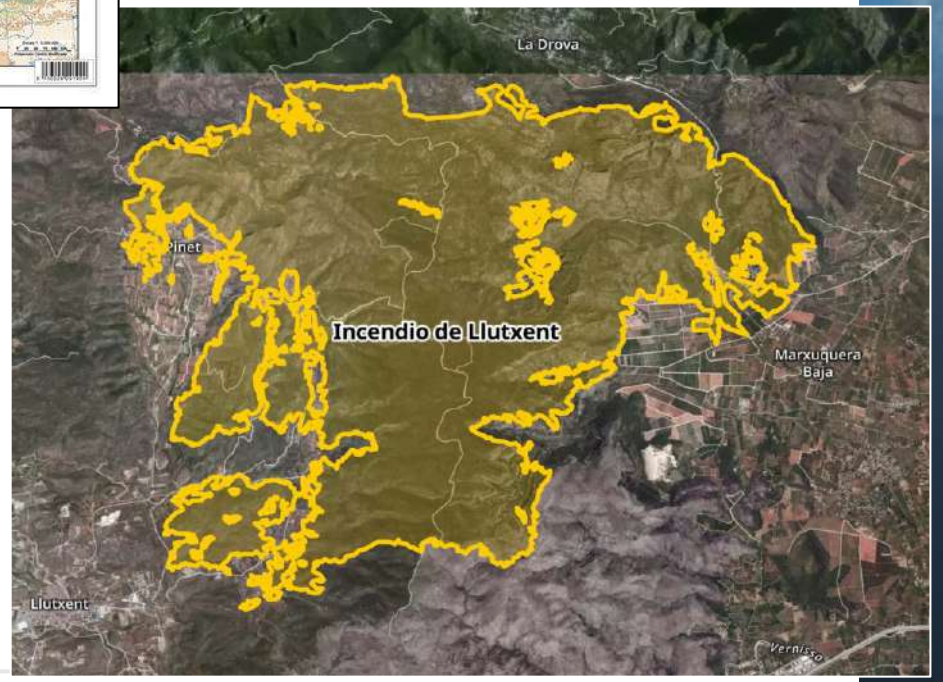
- To provide simulations of the fire behavior and fire-atmosphere interactions
- To estimate local effect of vegetation on air flow and fire behaviour
- To estimate local effect of buildings on air flow and fire behaviour
- To simulate generation, transport and emission of flying embers
- Calculation domain is **1 x 1 x 0.6 Km**; Spatial resolution 1 m; Temporal resolution 1 min

LANDSCAPE Scale

Pilot Site Madrid Region

Pilot Site Valencia Region

Llutxent fire (Aug 2018)
Well documented
Strong atmosphere-fire interactions
Key persons willing to collaborate



Llutxent, August 2018

Challenges and solutions

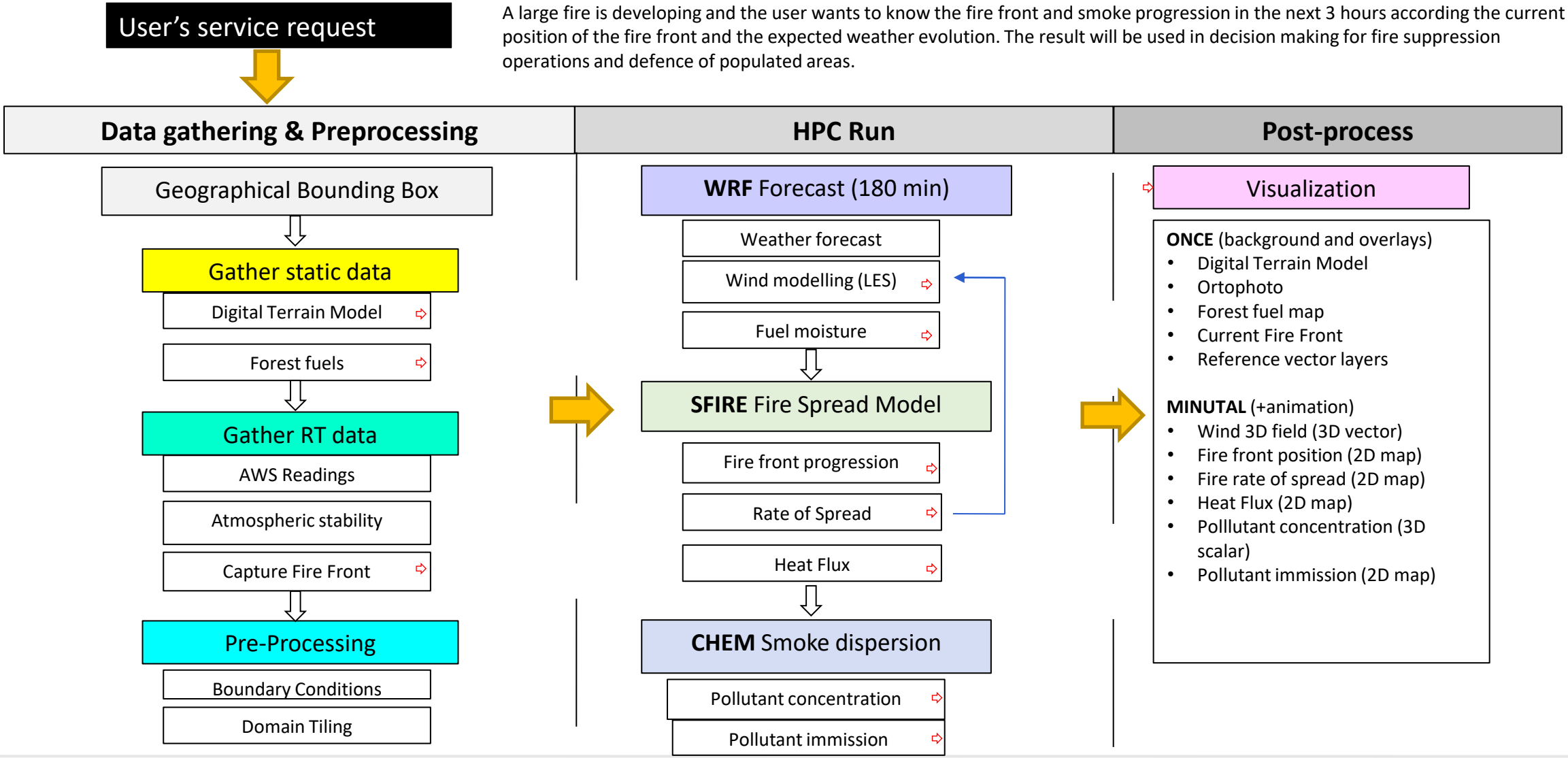
Challenges

Efficient use of the resources offered by EuroHPC servers to improve knowledge on dynamics and **evolution of wildfires** and **atmosphere interactions** for a better prevention, risk awareness and emergency management.

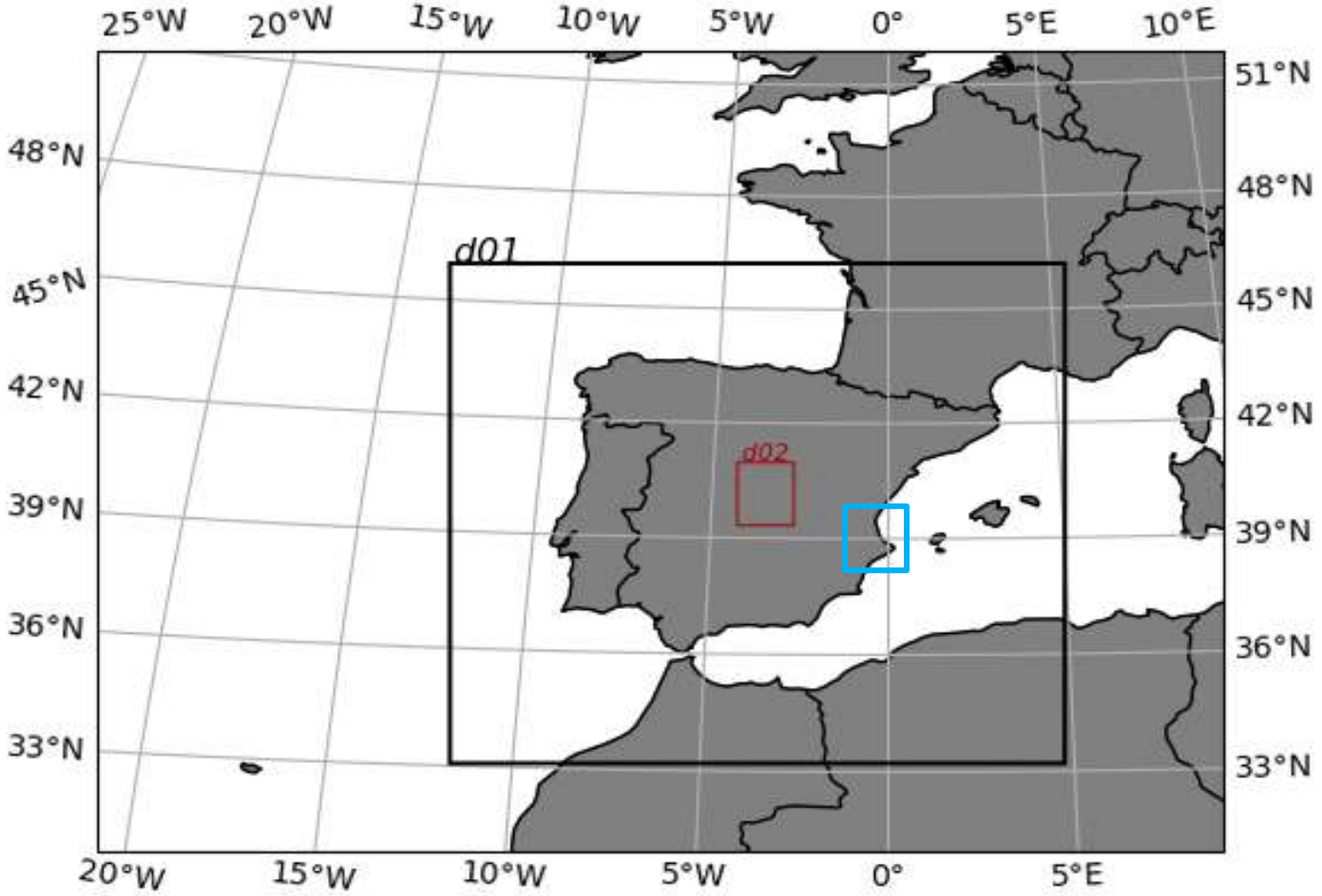
- **Downscaling** of weather data at different scales, local wind fields
- Use of **physical models**, complex fire-fuel and fire-atmosphere interactions
- Detailed (high-resolution) description of the governing factors at several scales
- Demanding calculations of the highly turbulent thermo fluid dynamics involved
- Currently the CFD solvers partially calculate these phenomena
- Modeling of **lower atmosphere dynamics** and the interaction with large fire fronts
- Modeling of local winds and pyro-convective events
- Modelling **smoke** production and dispersion
- Integration of models under a common, interoperable framework
- Use of **advanced visualization** for analysis, context training and risk awareness

Operational simulation of large fires

A large fire is developing and the user wants to know the fire front and smoke progression in the next 3 hours according the current position of the fire front and the expected weather evolution. The result will be used in decision making for fire suppression operations and defence of populated areas.



WRF Domain nesting



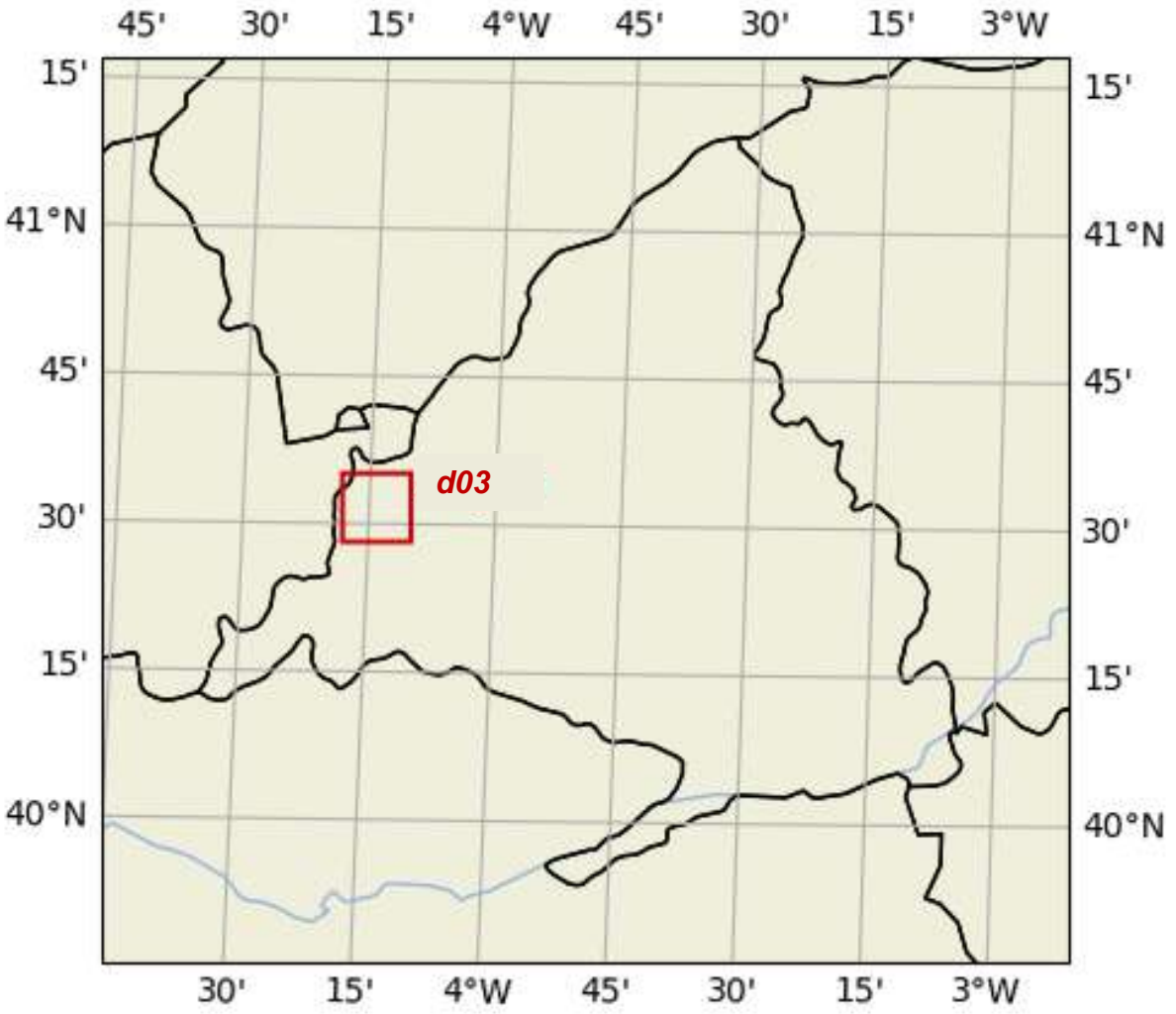
WRF-ARW
(Advanced Research WRF)

Model initialization with GFS data at 0.25 degrees of resolution

Two nested domains

d01: 5.54 km (Spain)
d02: 1.85 km (Center)

WRF Domain nesting



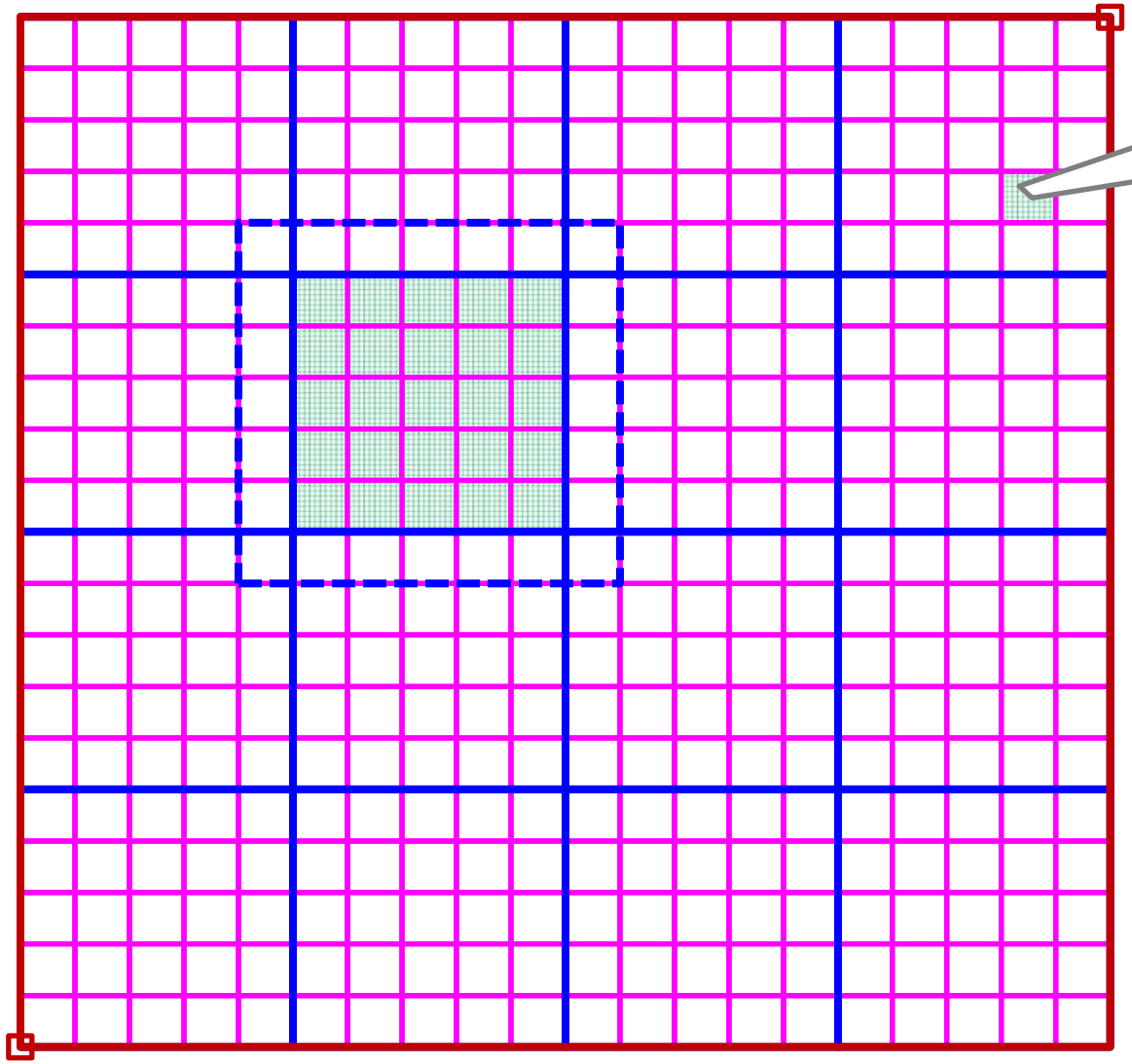
Domain d03

HR Domain for **WRF_LES** at 0.62 km resolution

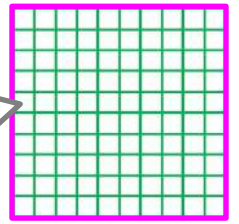
Used for forest fire simulation (**SFIRE**)
and smoke dispersion (**CHEM**)

Sampling at this resolution to feed the numerical CFD solution (Open Foam)
at even higher resolutions

MPI_CART_CREATE = To create this division into tiles
MPI_CART_SHIFT =To enable communication between tiles

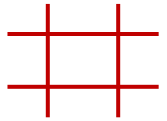


Sfire Grid

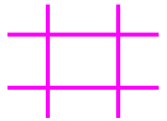


Digital Terrain Model
Forest Fuel Models

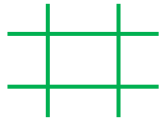
Domain d03
12500 x 12500 m



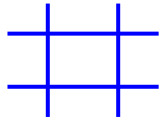
Atmospheric Grid
625 m resolution



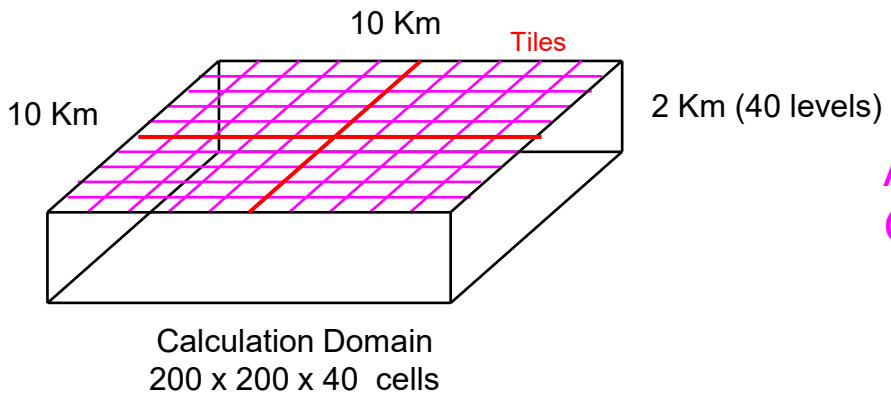
Sfire Grid
62,5 m resolution



Tiles
5 x 5 Atm. Cells



Halo
1 Atm. cell

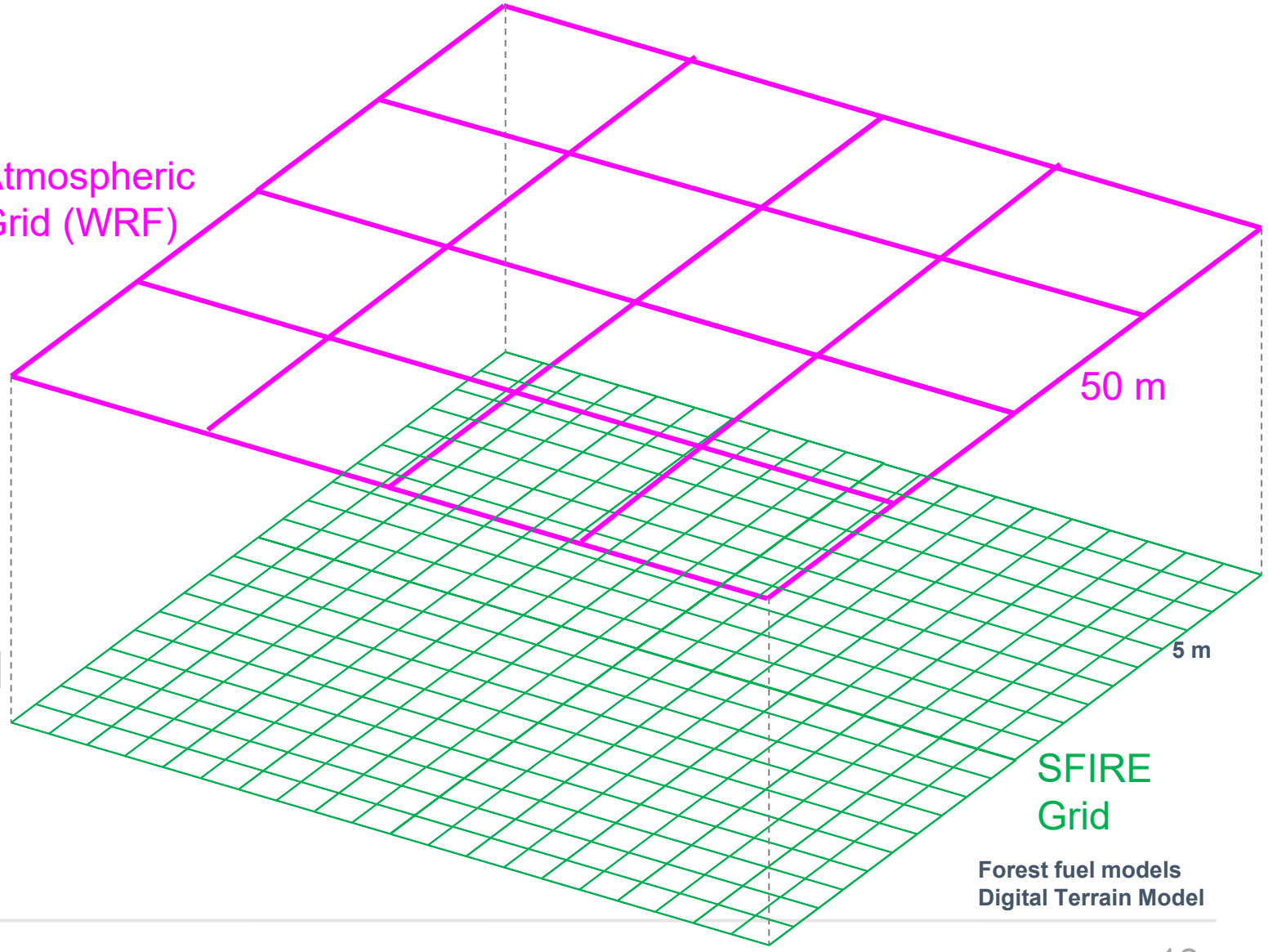


Calculation Domain
200 x 200 x 40 cells

250 x 250m Tiles
40 x 40 = 1600 Tiles

Fire-Atmosphere Interaction

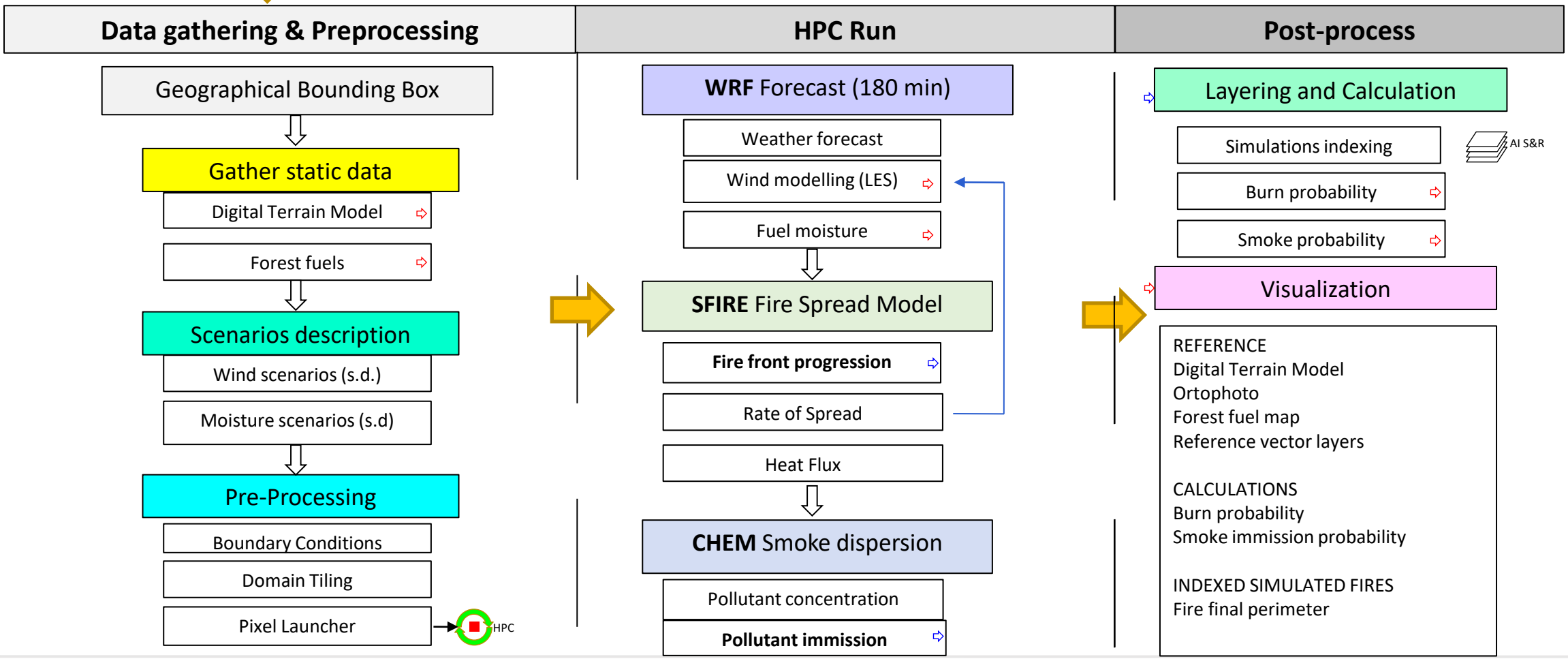
360 min simulation
1 min iteration



Scenario multiple simulation, burn and smoke probability

User's service request

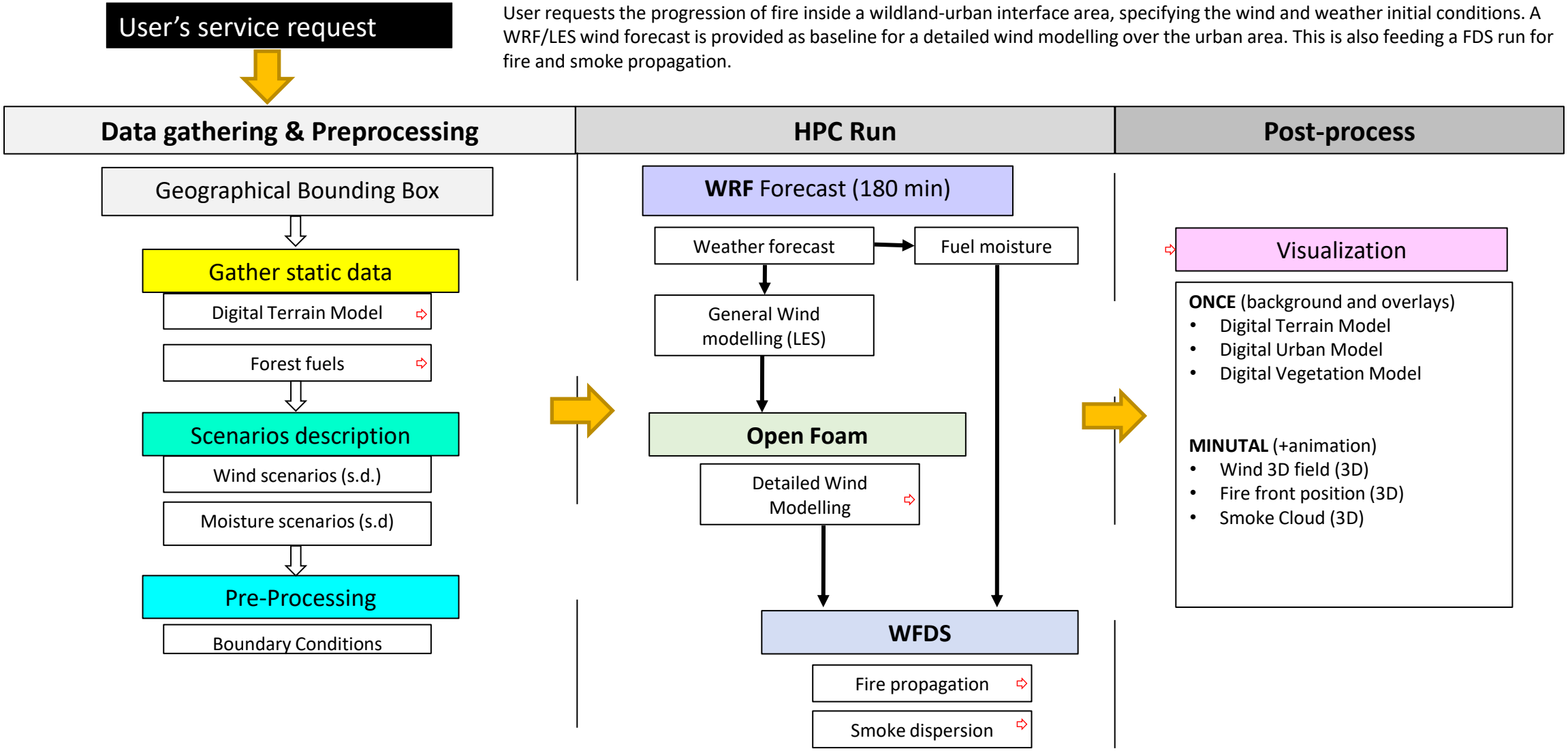
A large fire is developing and the user wants to know the fire front and smoke progression in the next 3 hours according the current position of the fire front and the expected weather evolution. The result will be used in decision making for fire suppression operations and defence of populated areas.



SETTLEMENT Scale

Detailed simulations of buildings and installations

User requests the progression of fire inside a wildland-urban interface area, specifying the wind and weather initial conditions. A WRF/LES wind forecast is provided as baseline for a detailed wind modelling over the urban area. This is also feeding a FDS run for fire and smoke propagation.



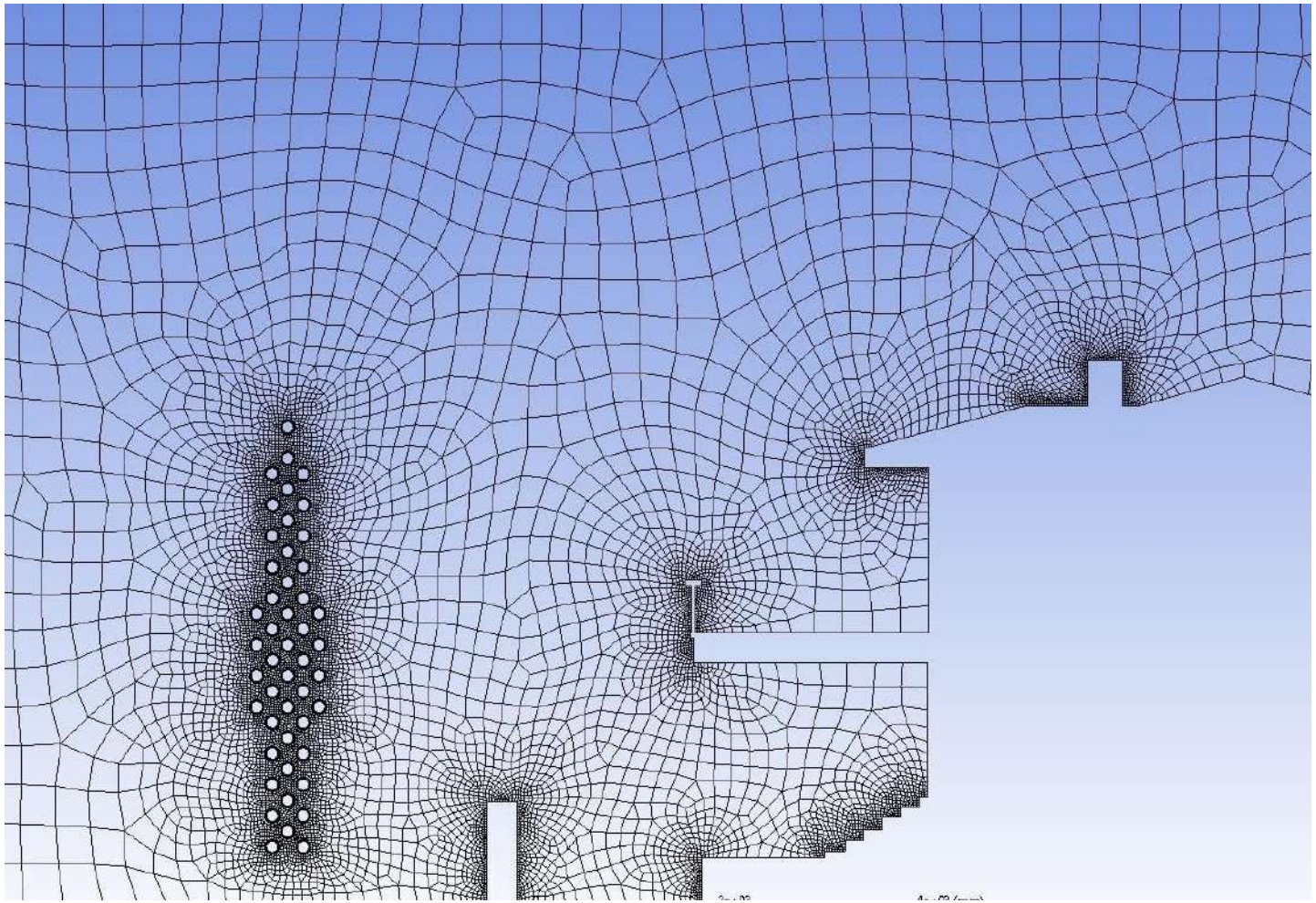
OpenFoam/FDS simulation – Data and Setup

- **Geographical extent**= 1 Km x 1 Km x 0.5 Km
- **Data availability** from other pilot sites (i.e. Barcelona area)
  - Ortophoto
  - Detailed LiDAR point cloud dataset
  - Tailored drone photogrametric products (photo, pointcloud) high resolution
- **No topography** (flat terrain) for FDS model
- **Boundary conditions from WRF-LES** model HPC simulations
  - Wind vector field at 100 m resolution
- Available **3D models** of urban-vegetation scenarios
  - 3D model of buildings = Facets for CFD simulations (contour)
  - Vegetation as porous media = local array of 3D spherical objects
  - Produced automatically from 3D vegetation point cloud
- Detailed m**eshing** of 3D models
  - Meshing of 3D models of buildings (actually done in Ansys Fluent Mesher)
  - Meshing of array of spherical objects
- Simulation domain description (inlet, outlet, walls, floor)

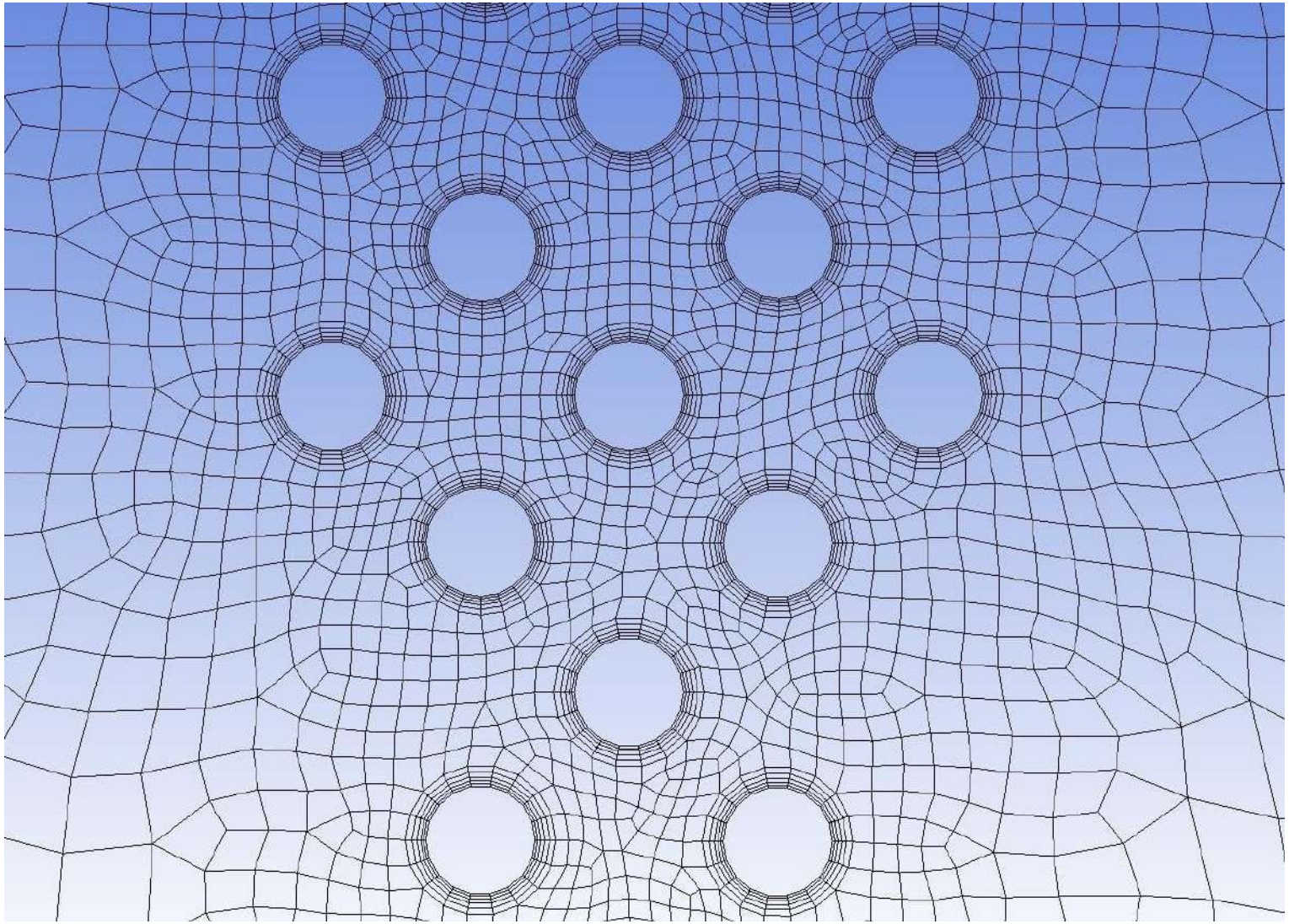

Perspective
Lit
Show
10
10°
0,25
4

OpenFoam/FDS simulation – Experience (2D)

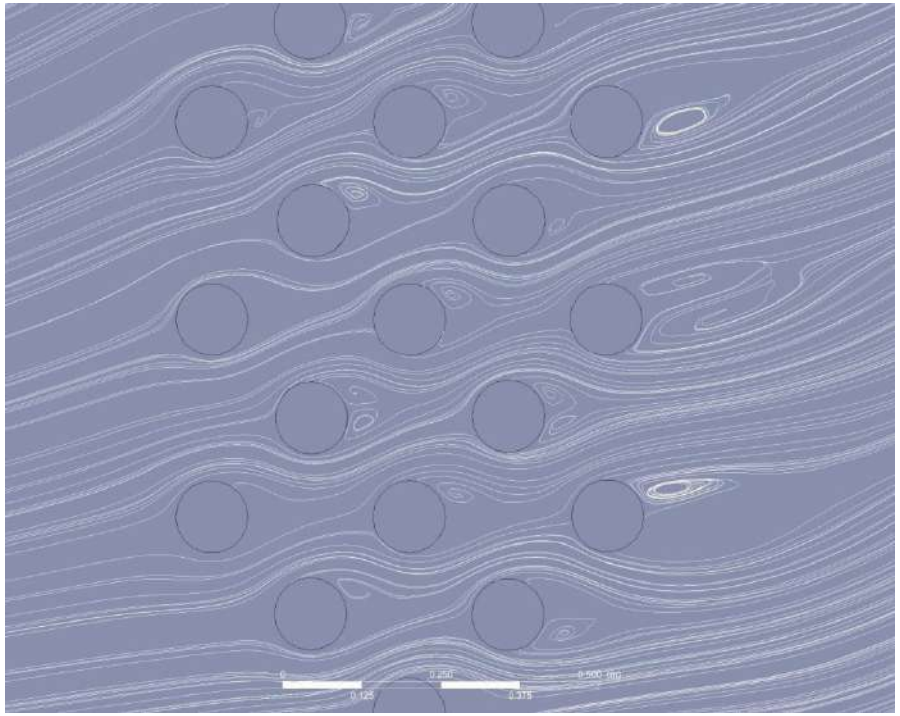
- Approach followed for the calculation of wind flow around buildings surrounded by vegetation (Navier-Stokes 2D model in **Ansys Fluent** Academic License)
- A single input wind vector (horizontal component)



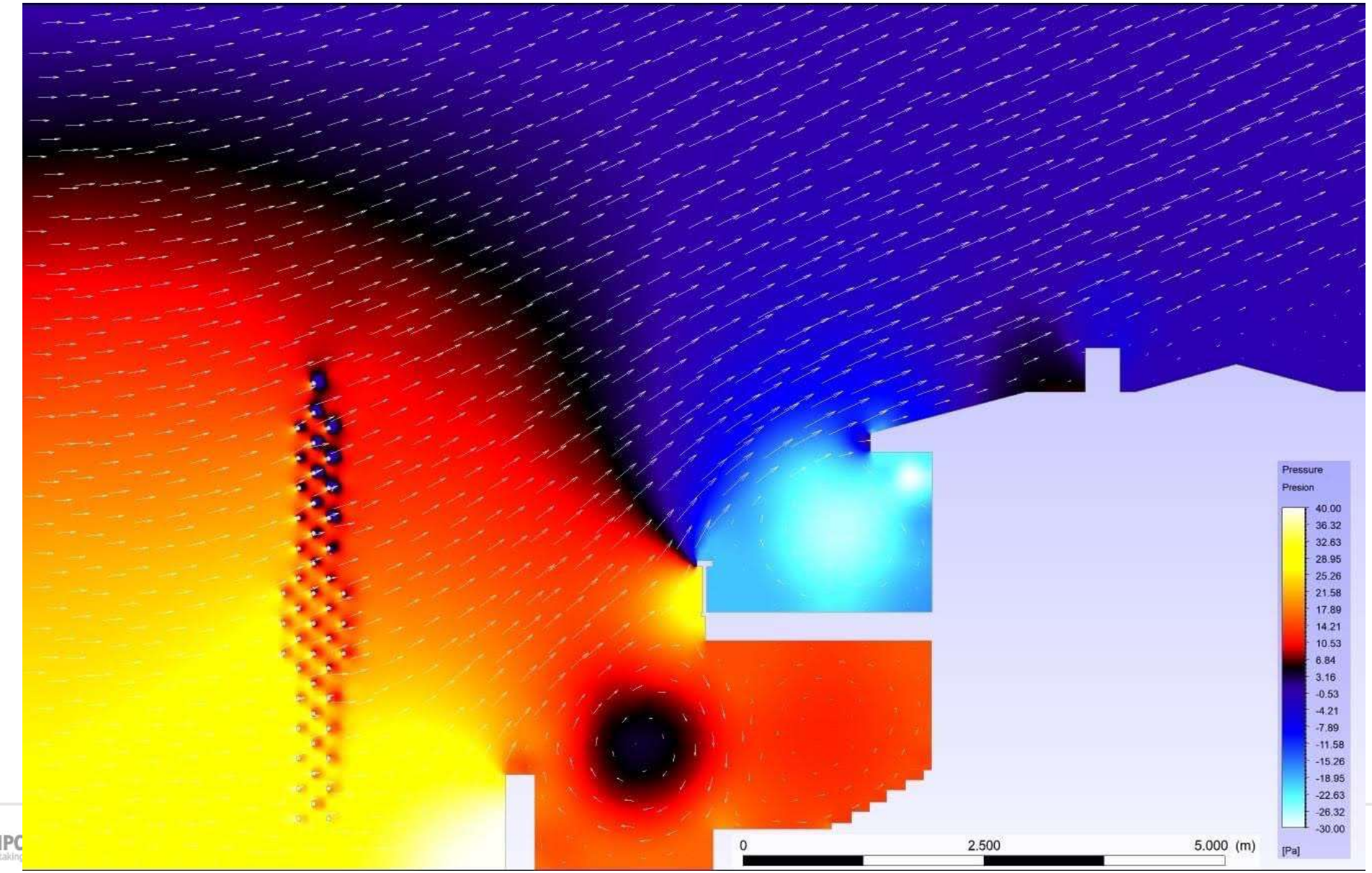
OpenFoam/FDS simulation – Experience (2D)



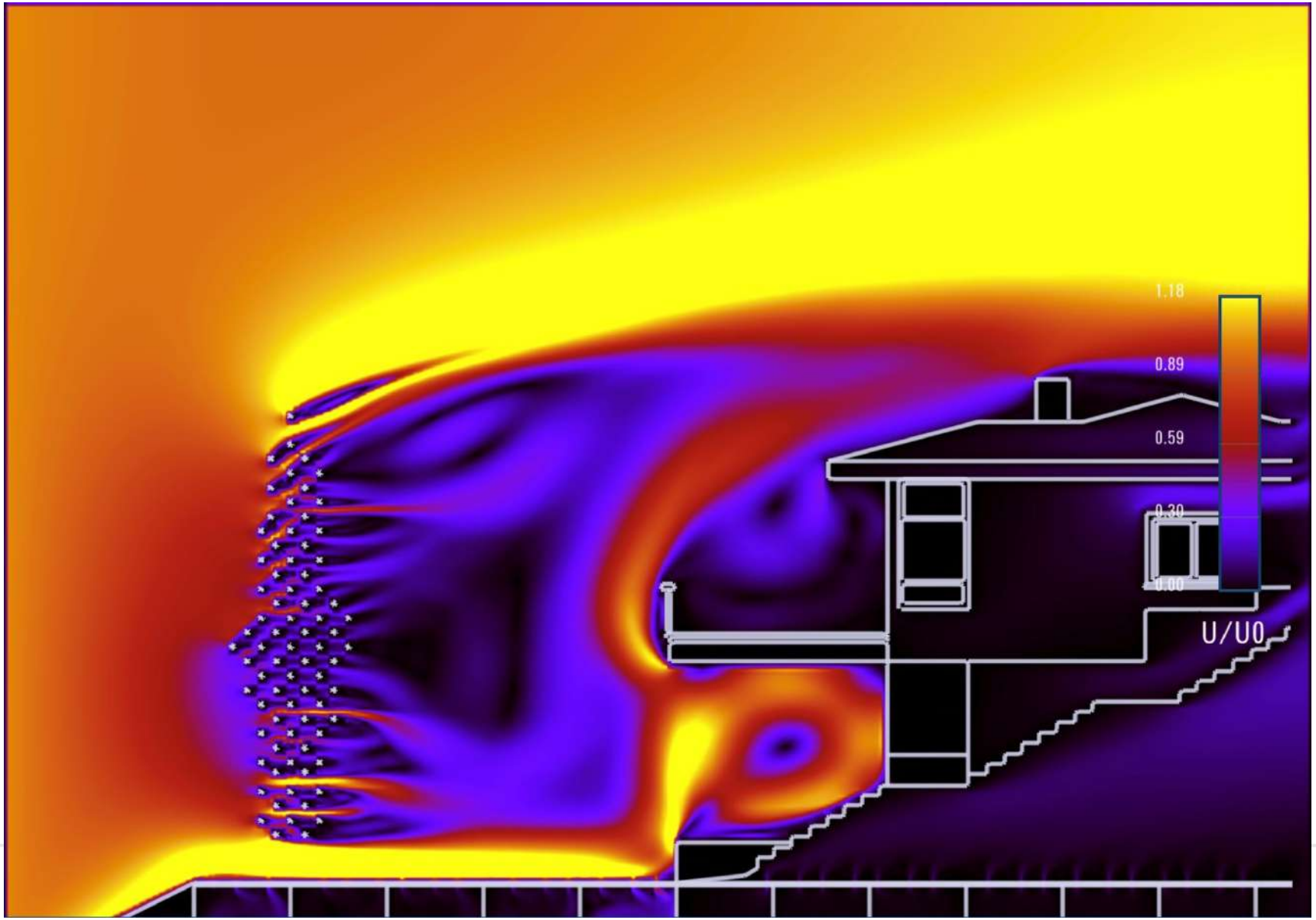
- Detailed meshing of porous media (vegetation)



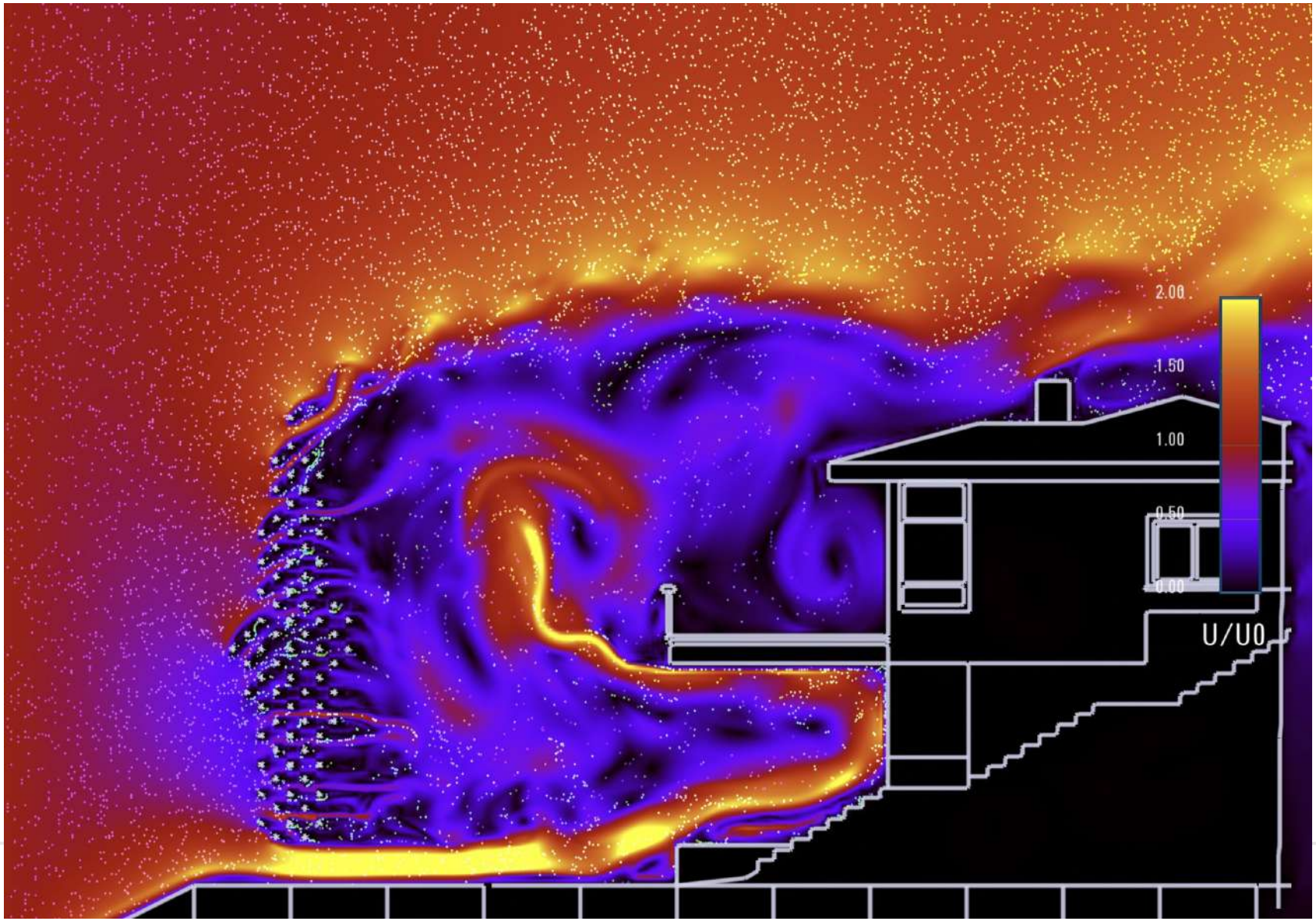
OpenFoam/FDS simulation – Experience (2D)

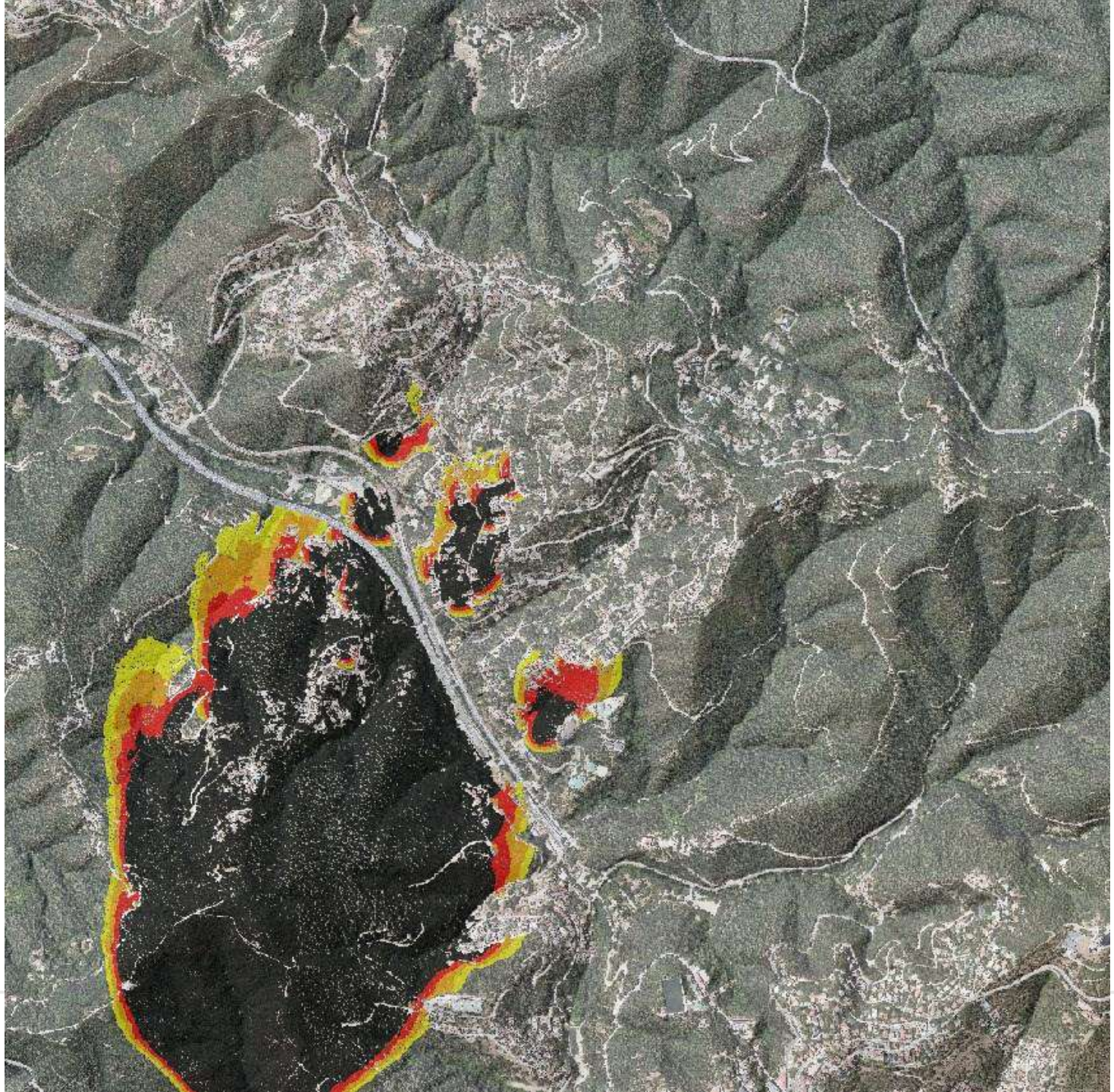


OpenFoam/FDS simulation – Experience (2D)



OpenFoam/FDS simulation – Experience (2D)





Advanced visualization techniques

- Import vector and scalar fields from HPC simulations
- Visual simulation of 3D wind vector fields
- Visualization of scalar fields (smoke, pollutant concentration, temperature …)
- Realistic visualization of flames and smoke (Ray marching techniques)
- Implementation in immersive VR environments

Visualization of fire propagation and smoke – Atmospheric stability

Visualization of fire propagation and smoke – Atmospheric stability

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Visualization of fire propagation and smoke – Atmospheric stability


Perspective
Lit
Show
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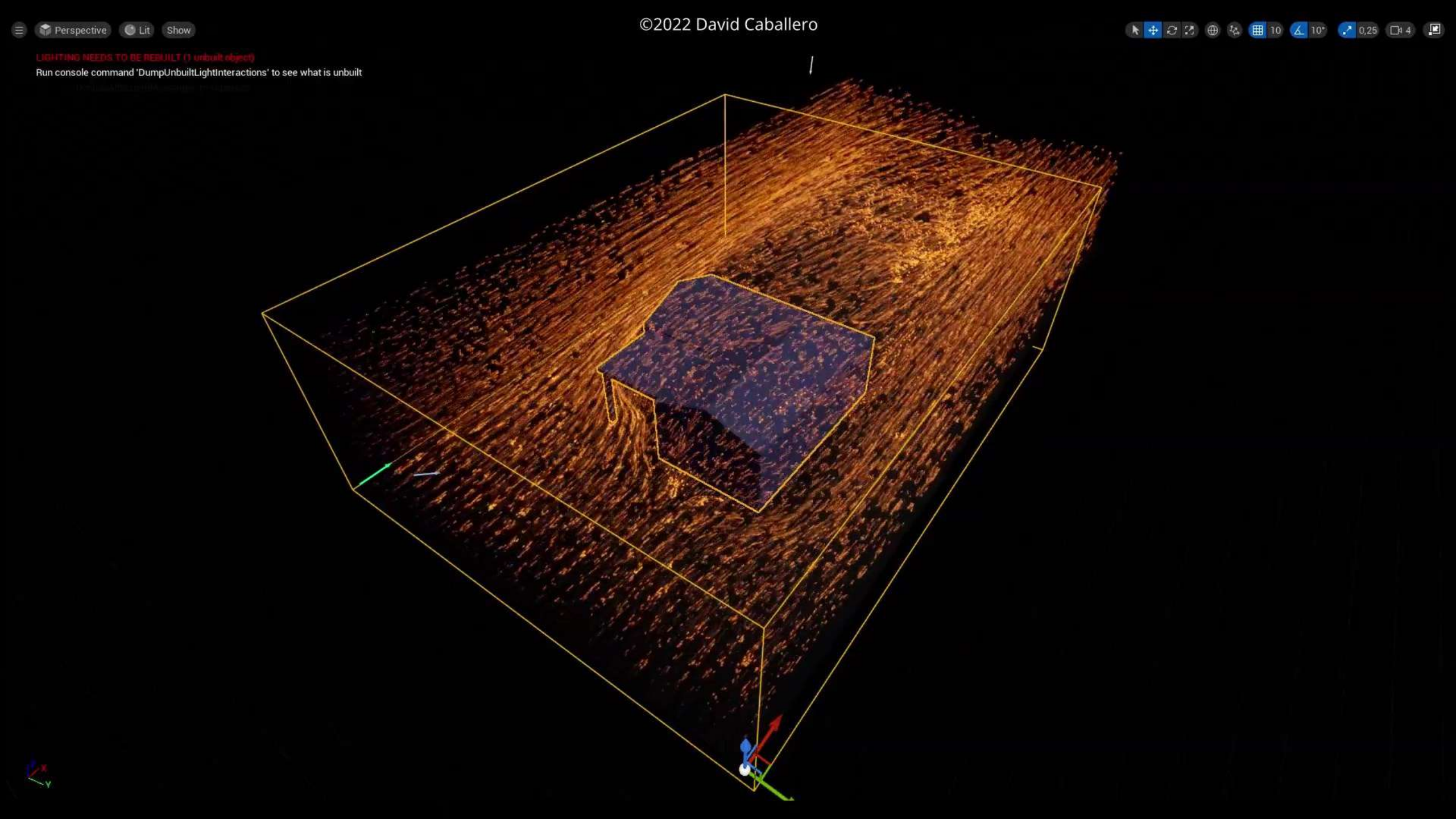
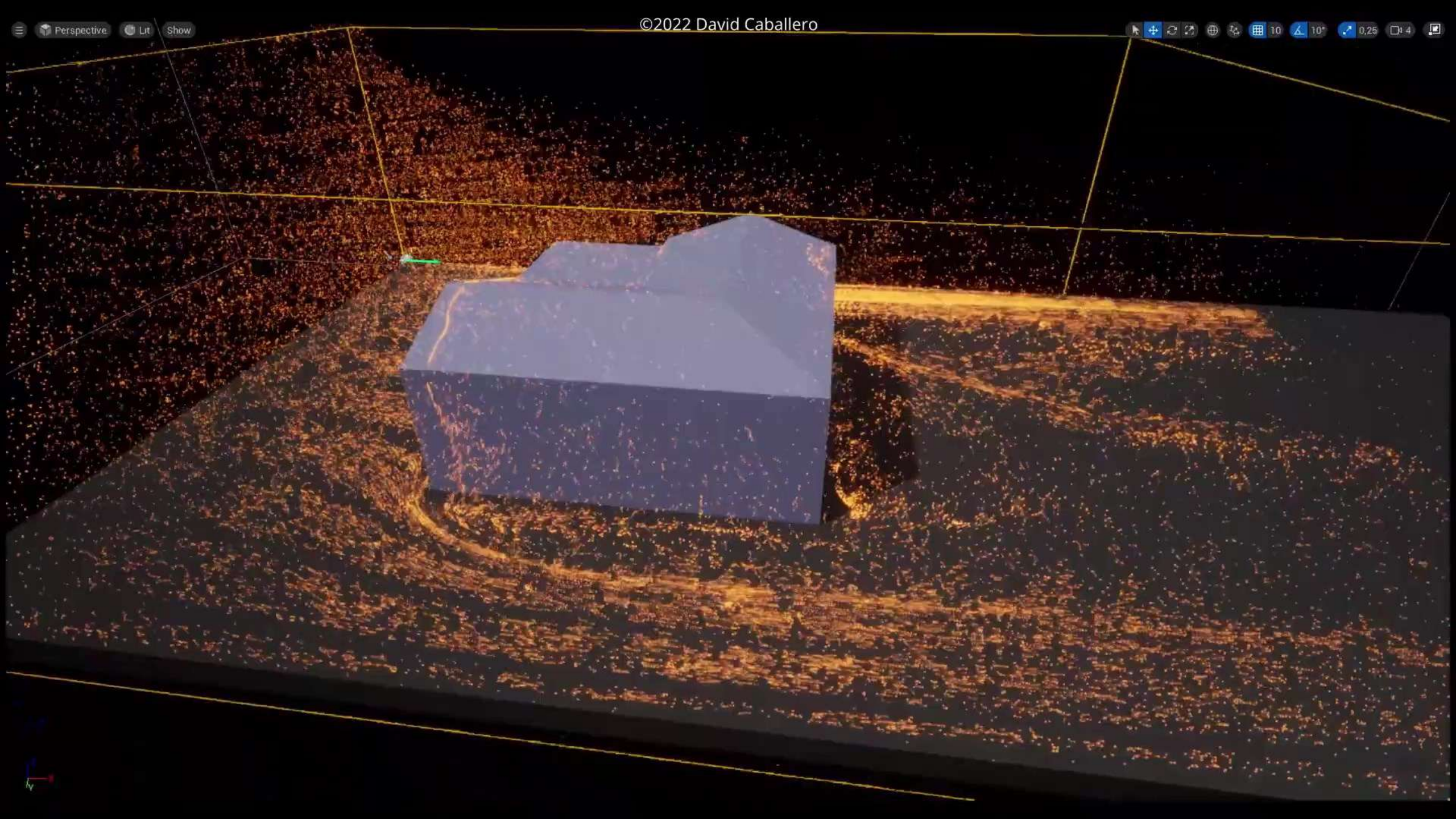
10°
0.25
4


REFLECTION CAPTURES NEED TO BE REBUILT (1 unbuilt)

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Perspective
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