AutoBiomes

Procedural Generation of Multi-Biome Landscapes

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CGI, 20-23 October 2020, Geneva

Motivation

The Good Dinosaur [Disney/Pixar]

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Ghost Recon: Wildlands [Ubisoft]

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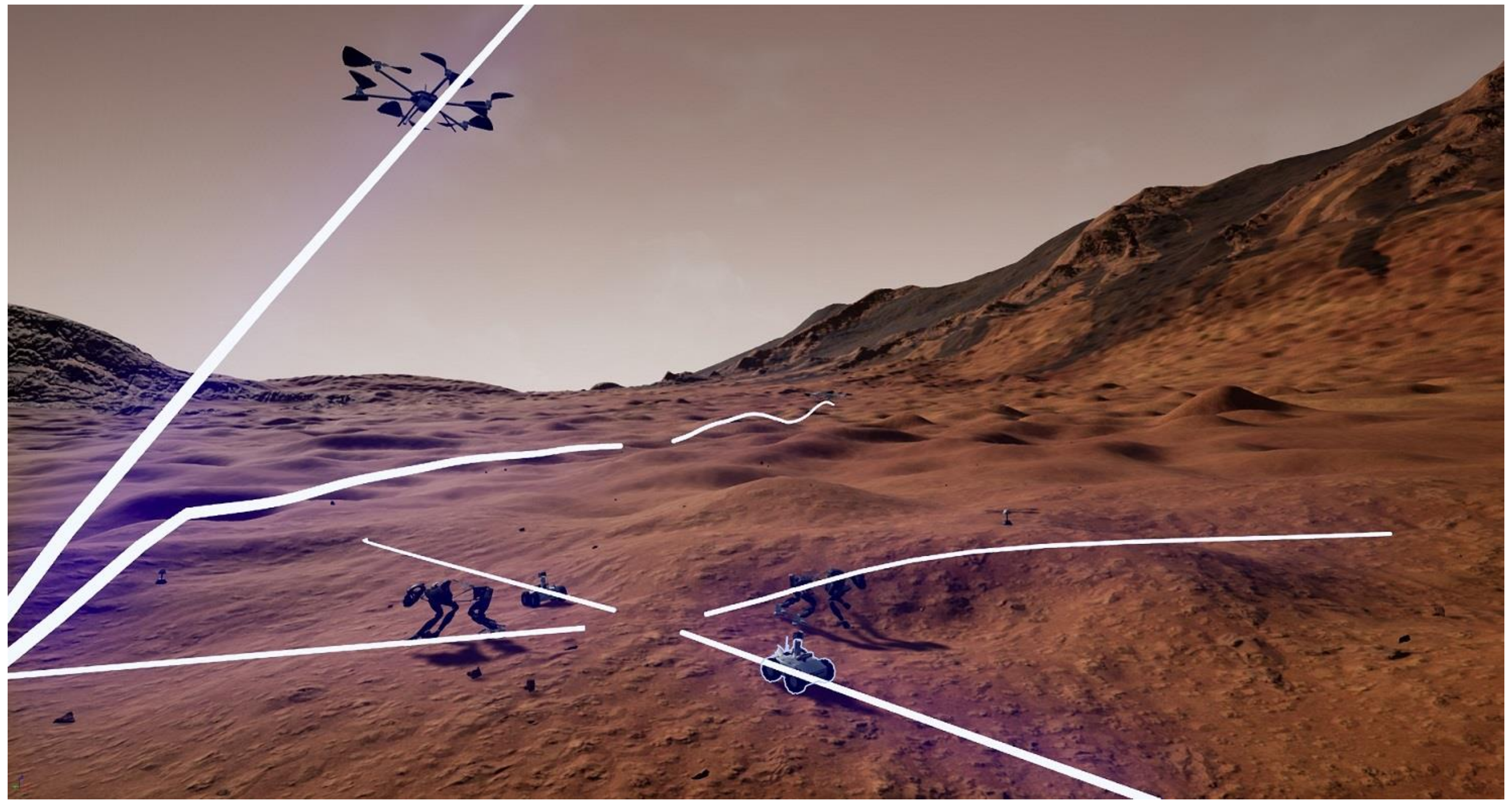

VaMEx-VTB [University of Bremen]

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- Huge landscapes as combination of different biomes

Minecraft

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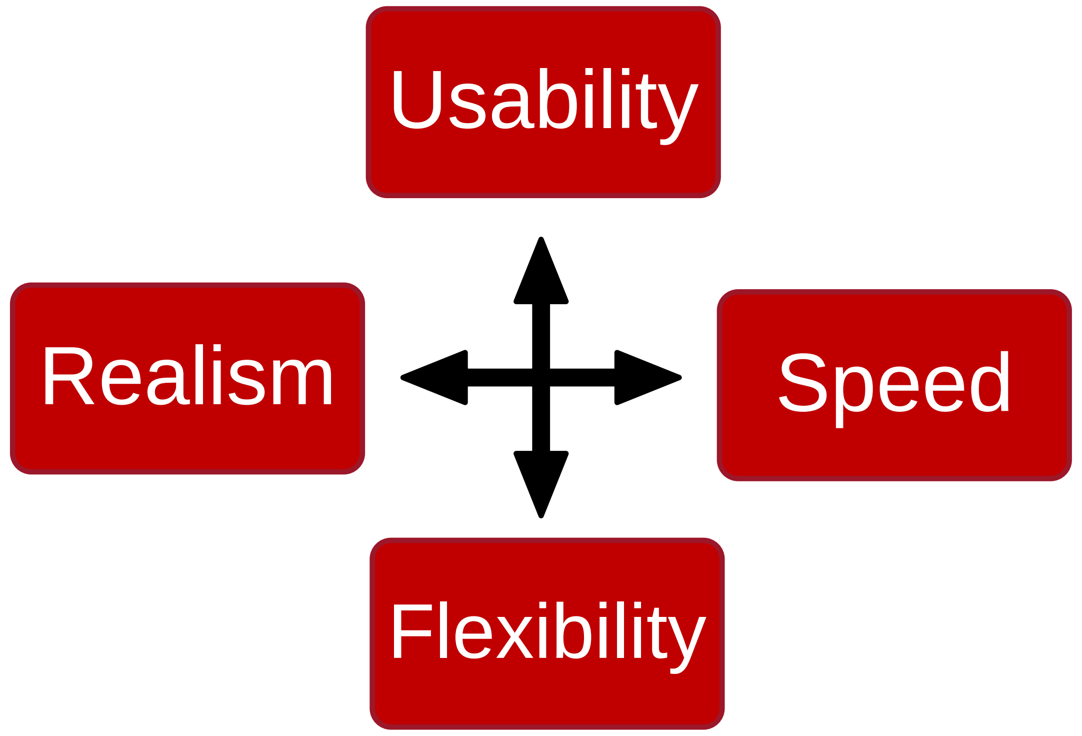
- Populating the terrain with objects
- Manual creation is not an option
- Procedural terrain generation (PTG)
  - Much researched, still open challenges

Minecraft



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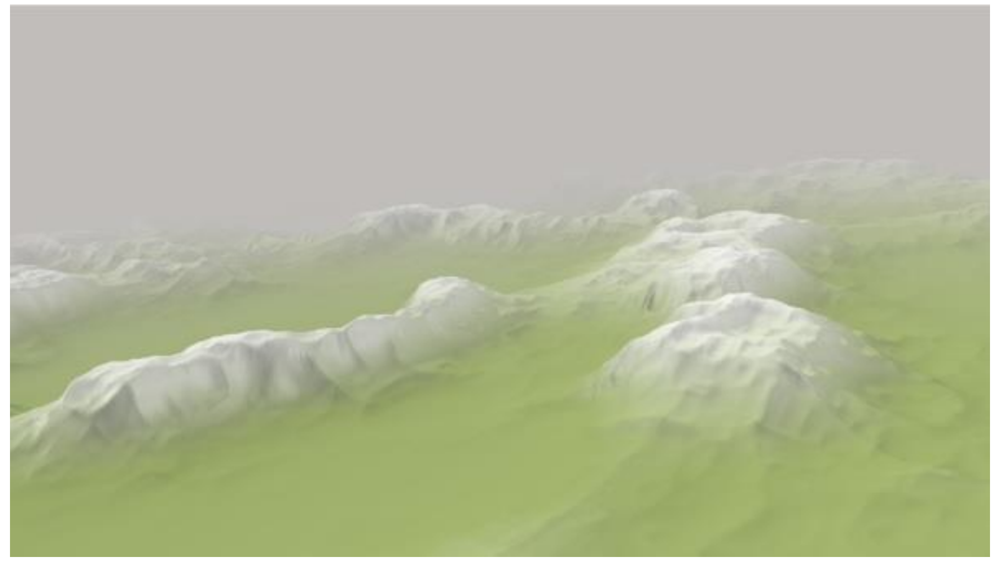
- Main PTG approaches:
  - Synthetic, e.g. noise
    - Fast, unintuitive, hard to get realistic results [Thorimbert18]



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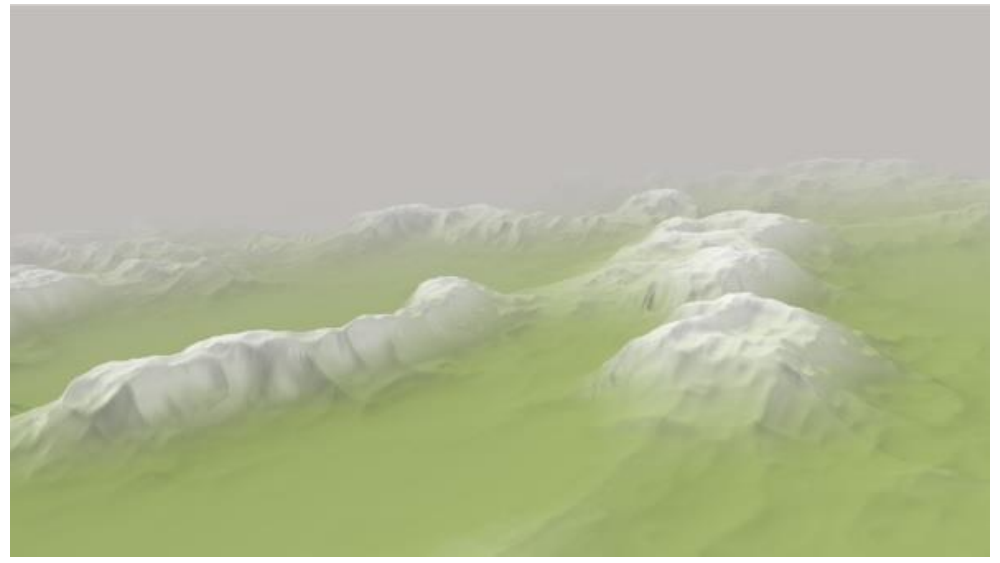

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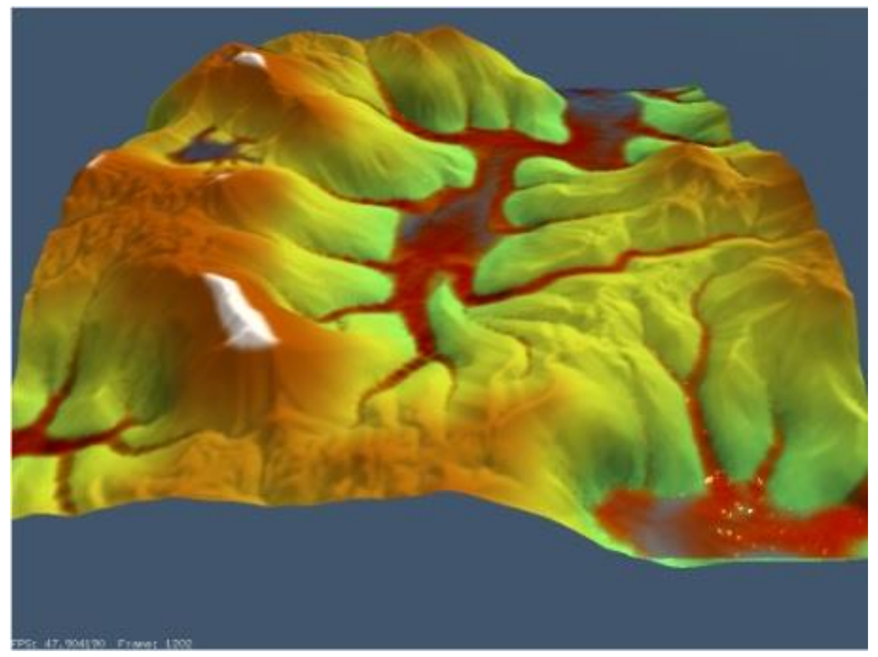

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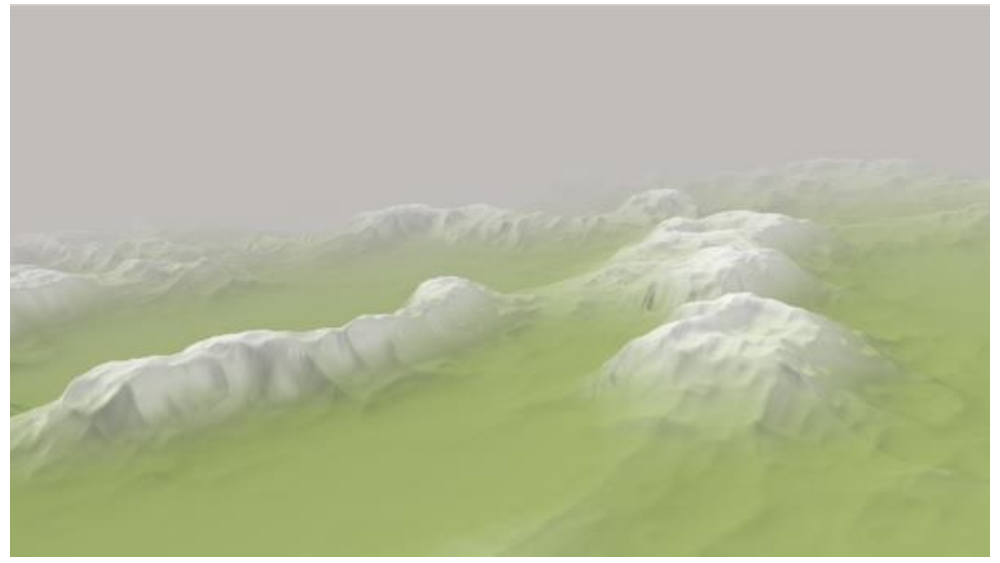

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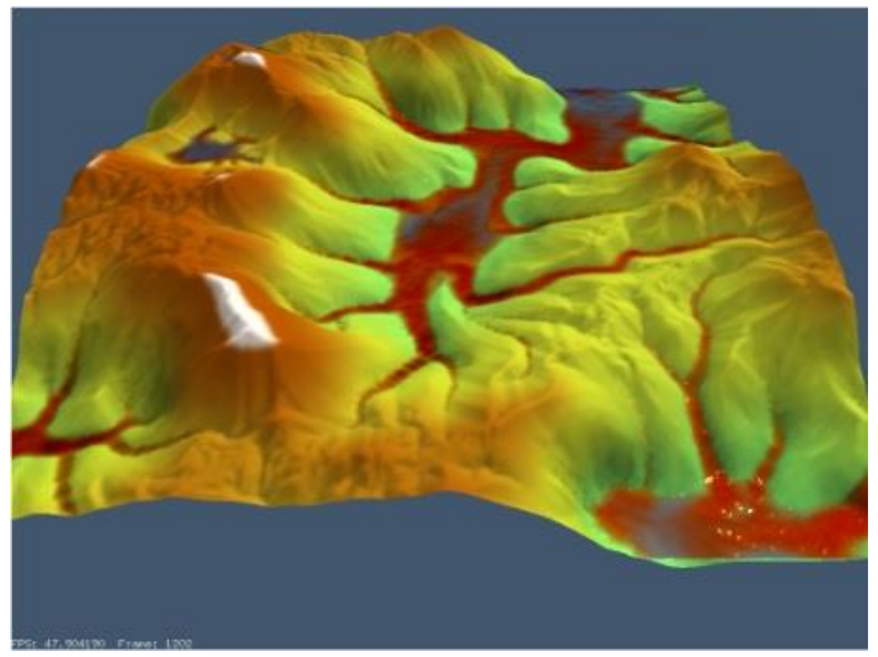

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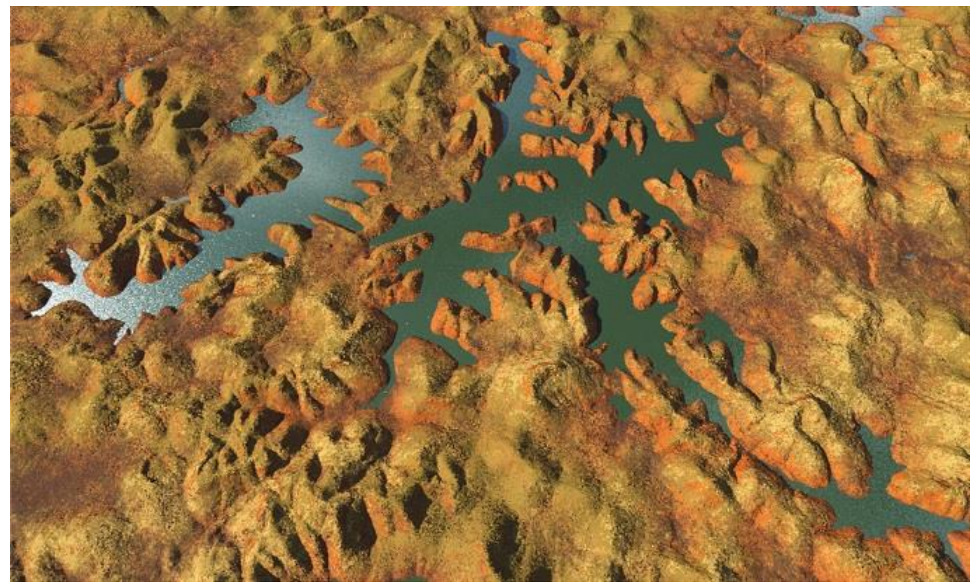

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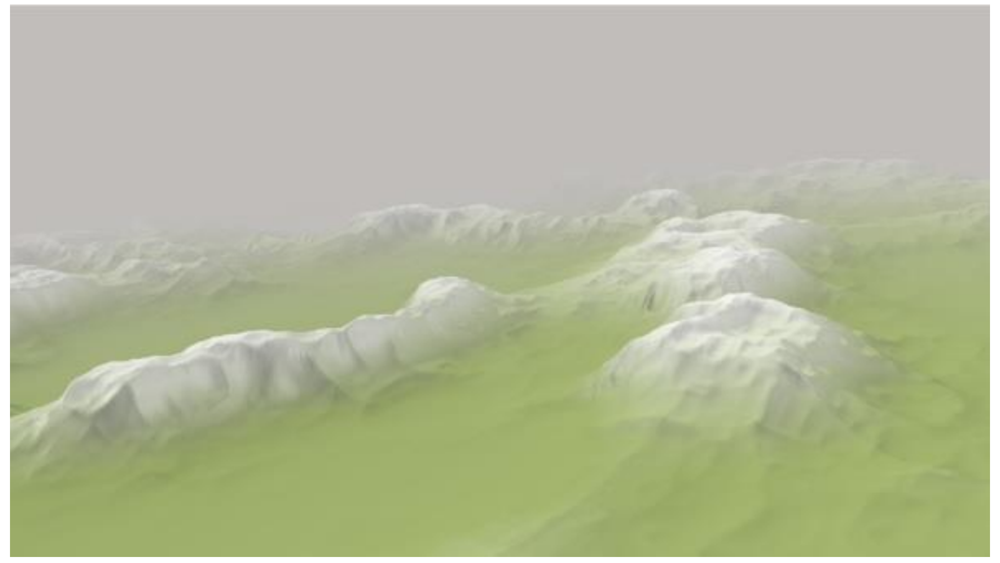
- Also valid for commercial tools (e.g. World Creator, World Machine, Terragen)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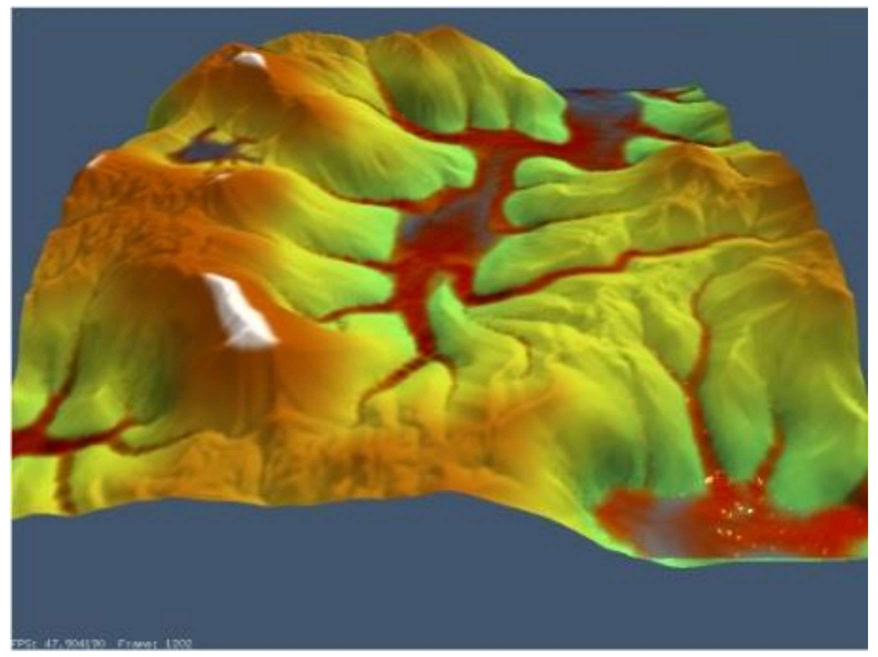
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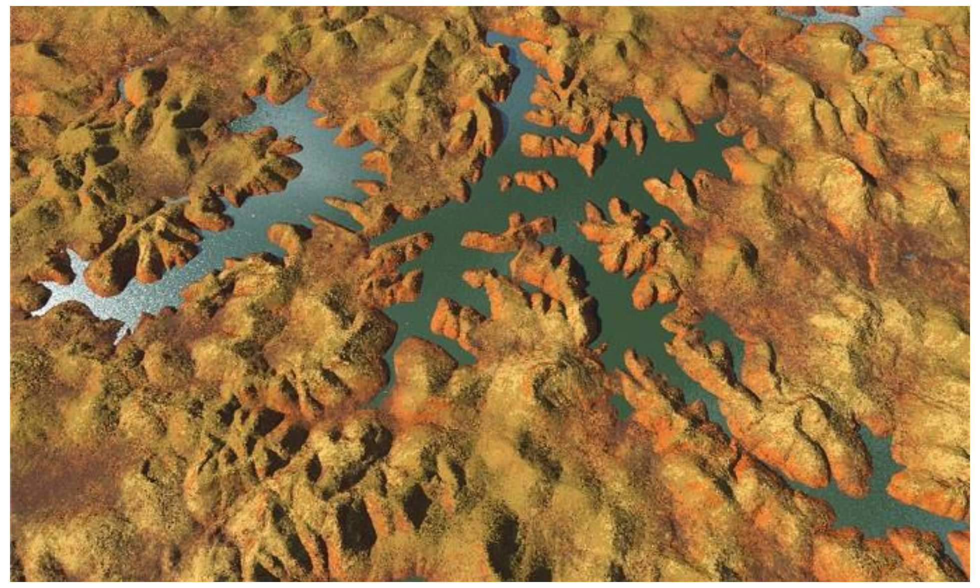
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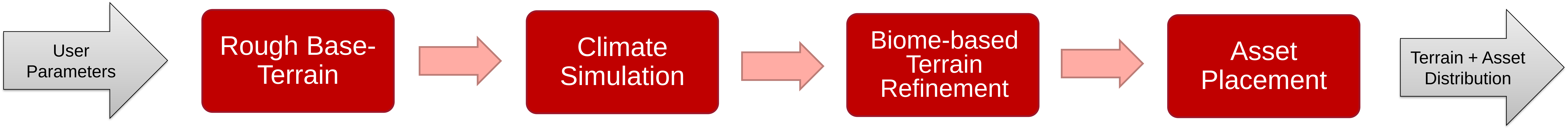
Our PTG Pipeline



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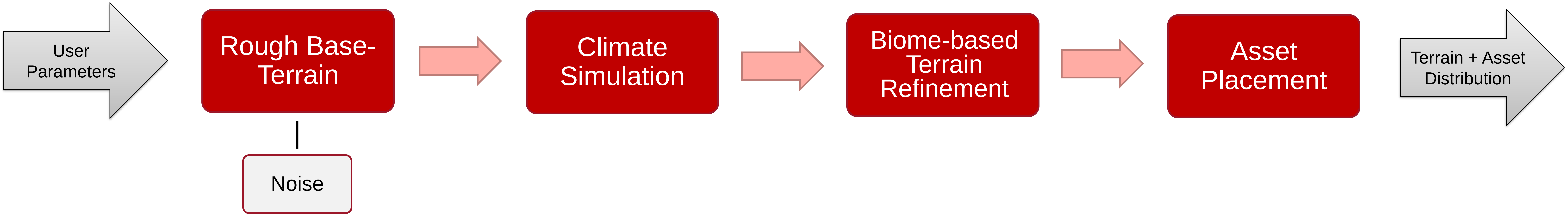

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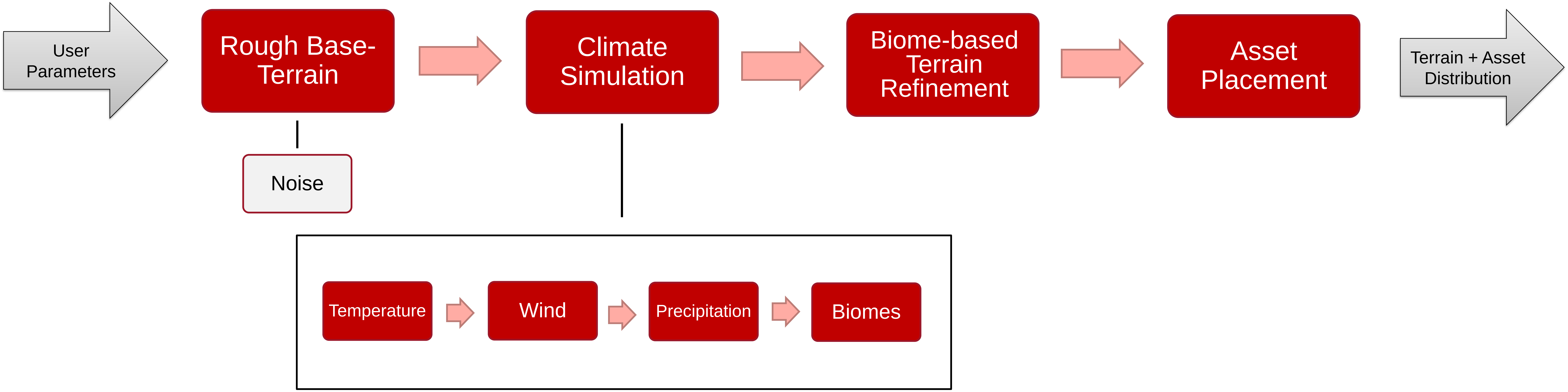

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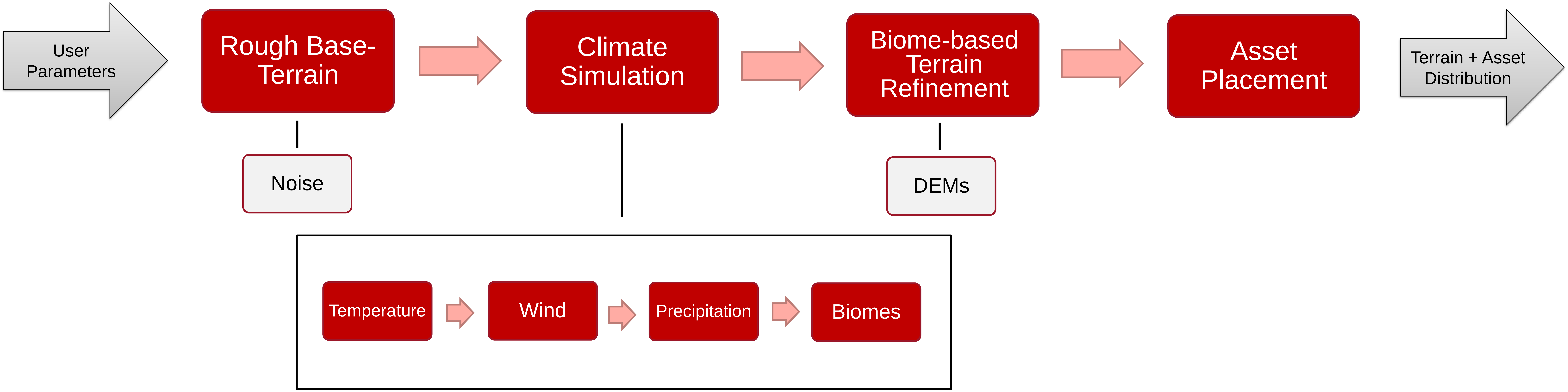

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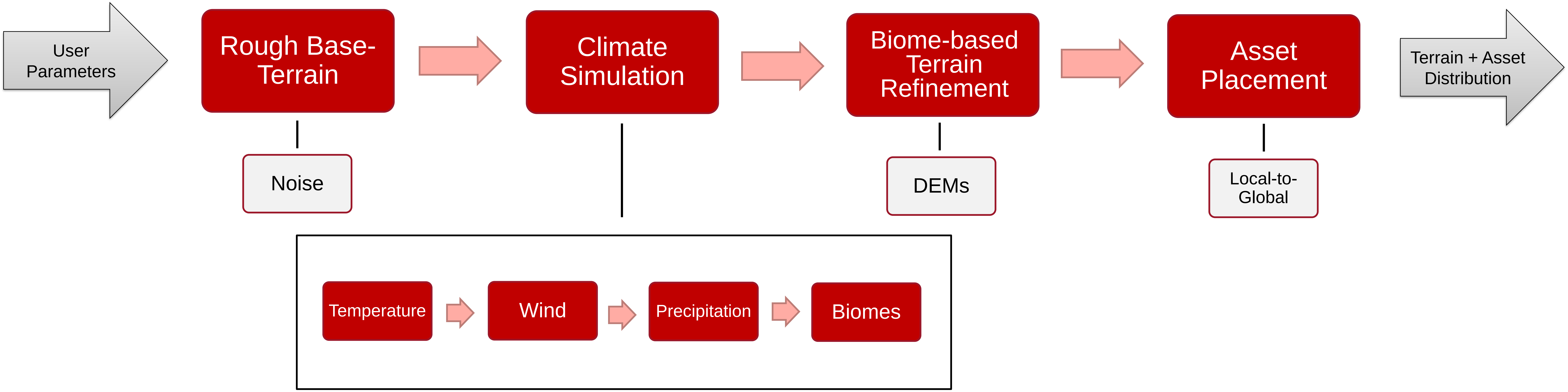

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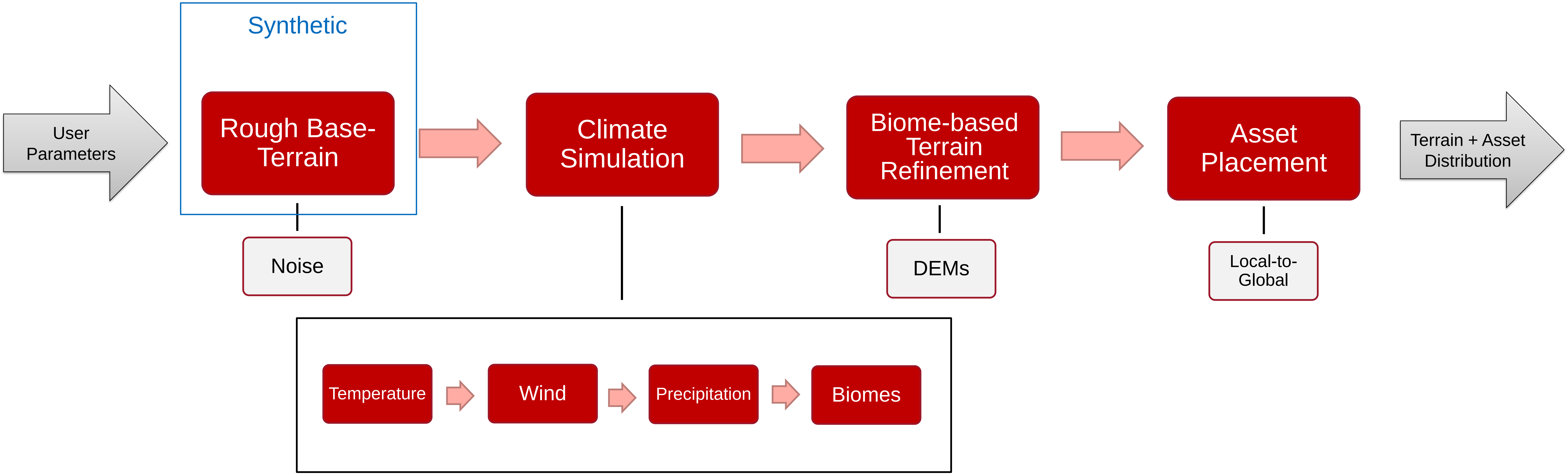

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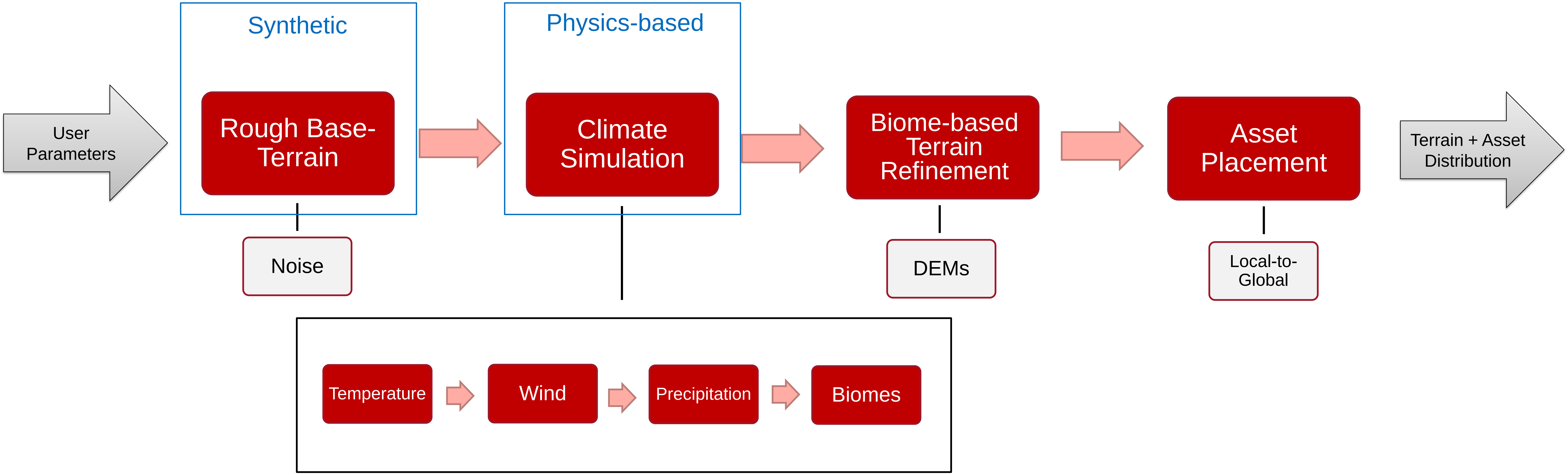

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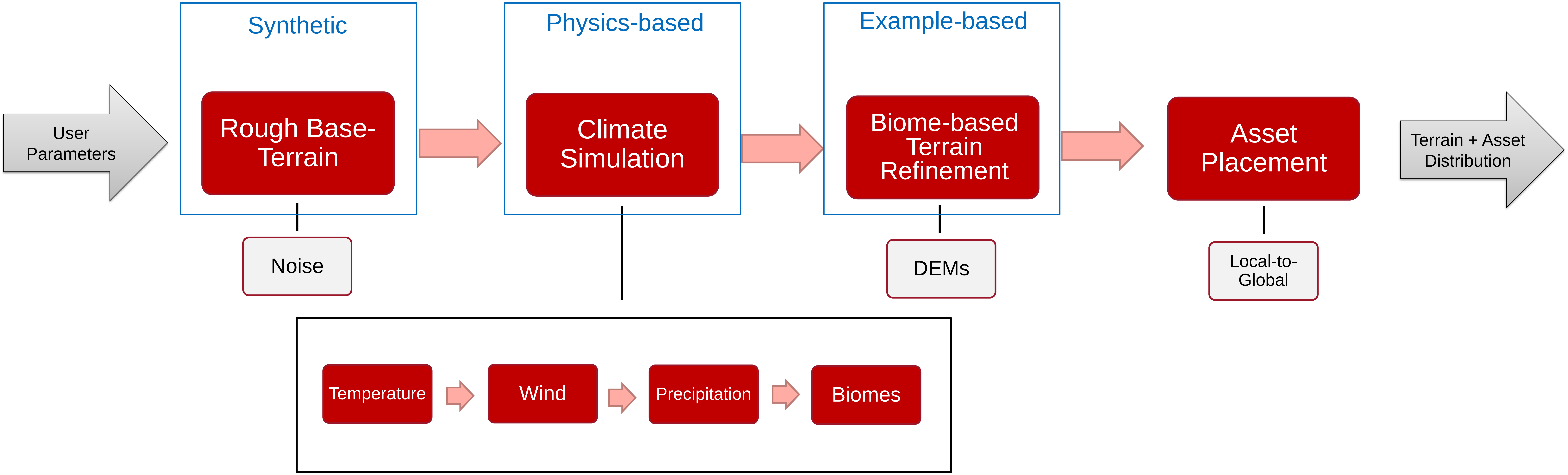

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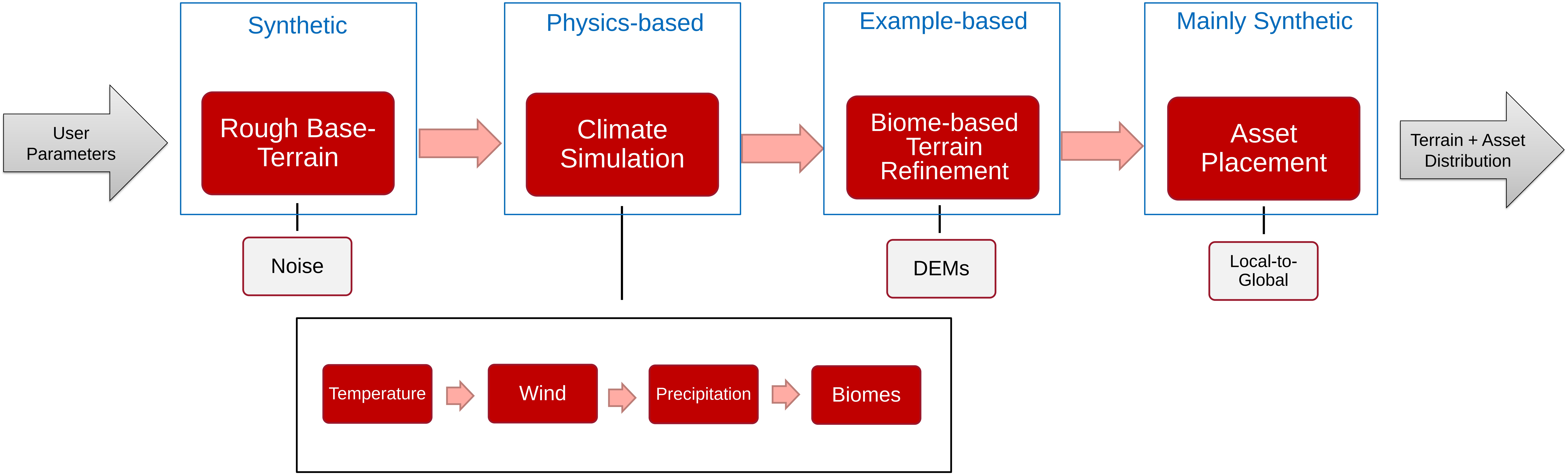

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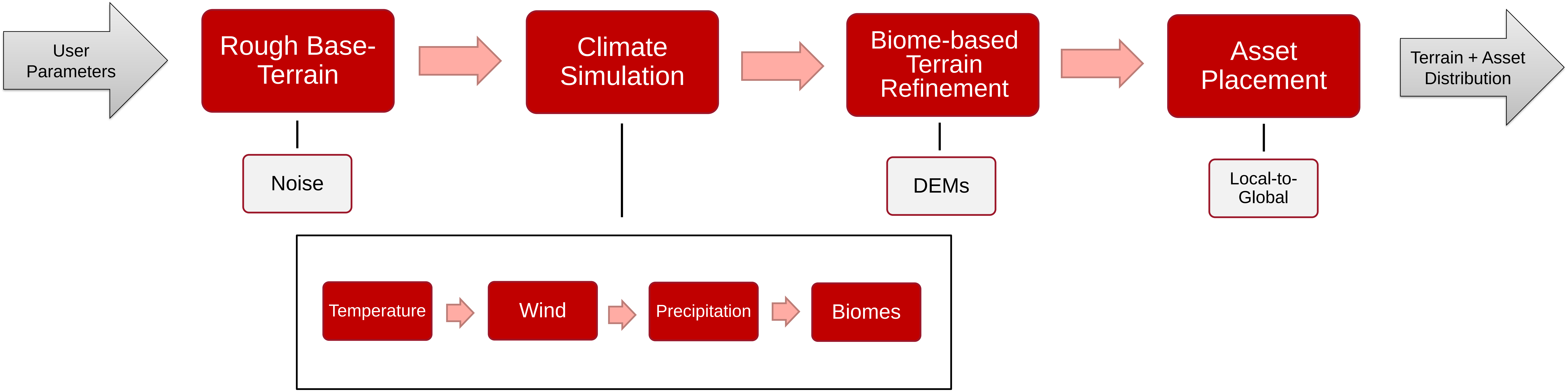

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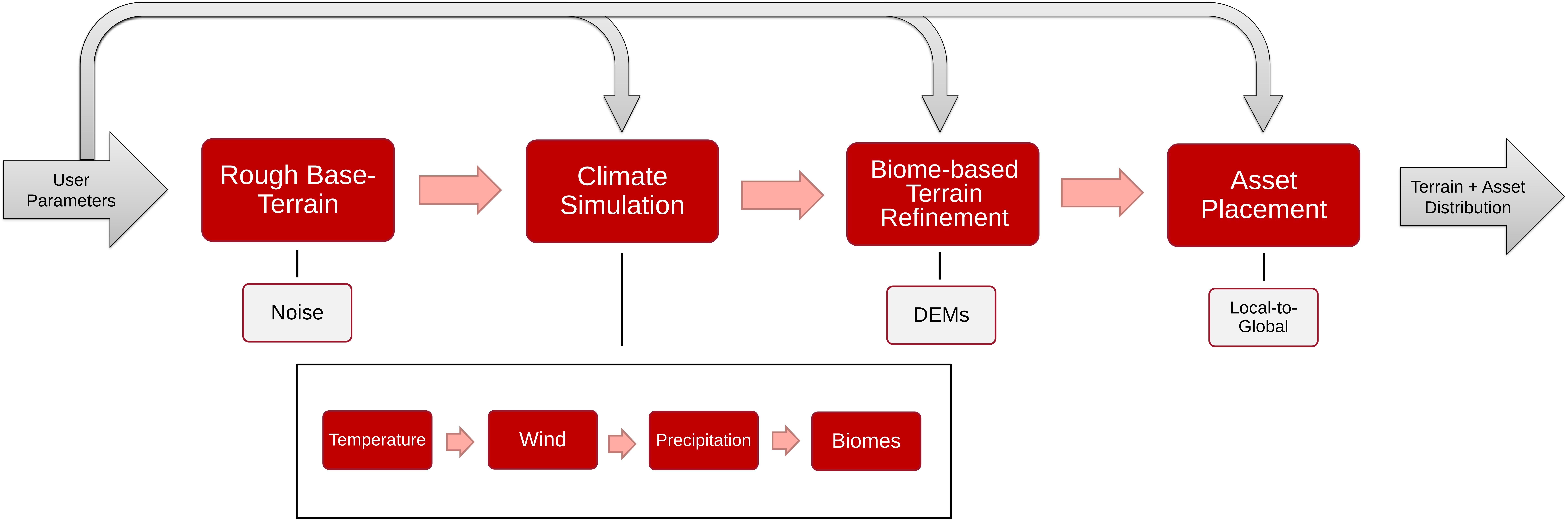

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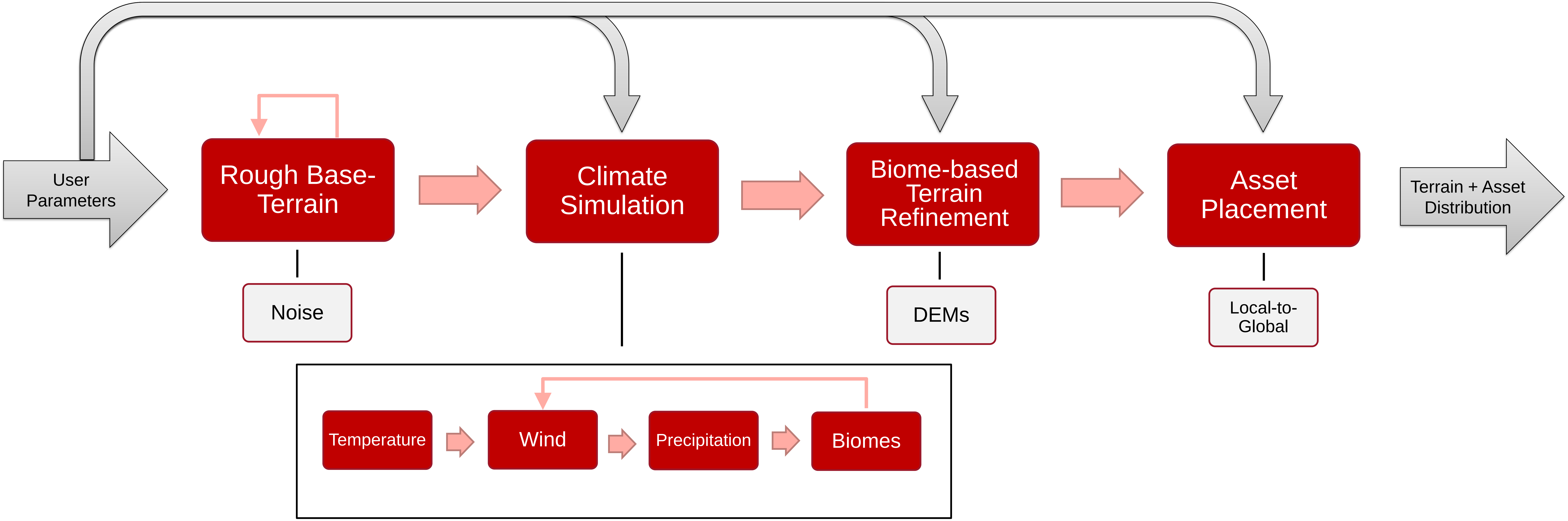

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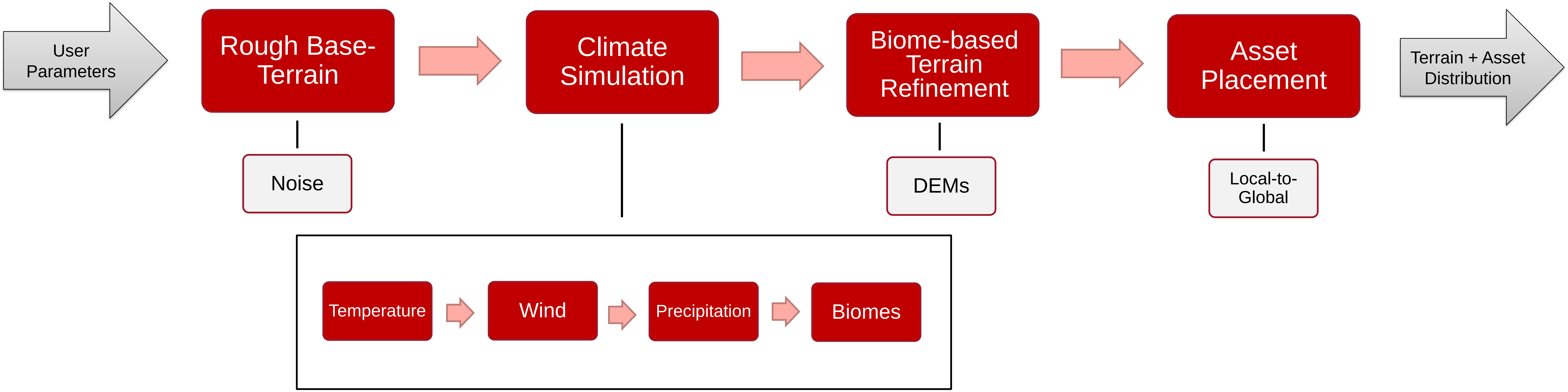

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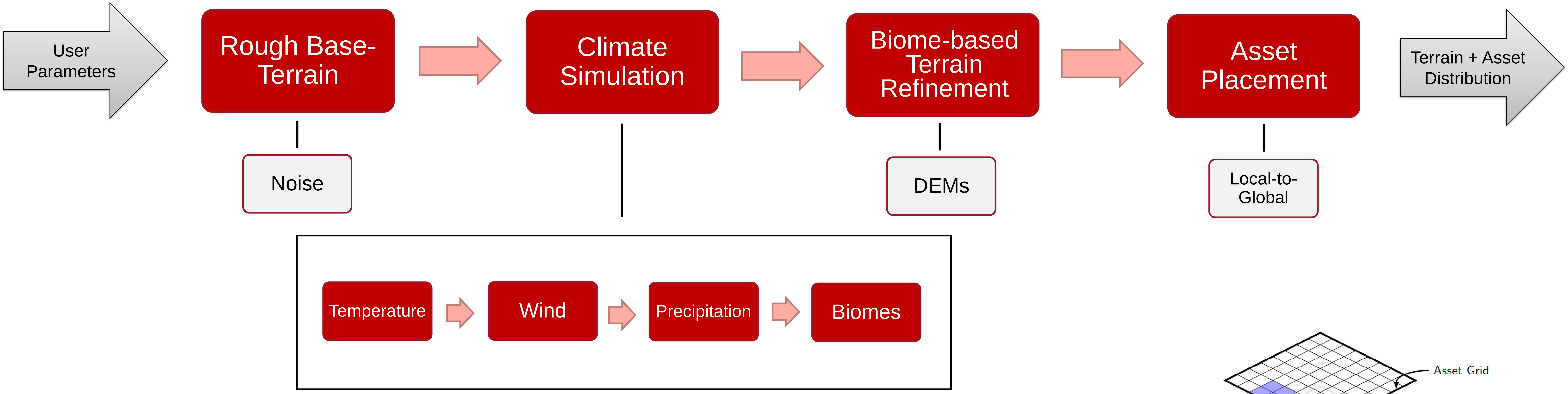

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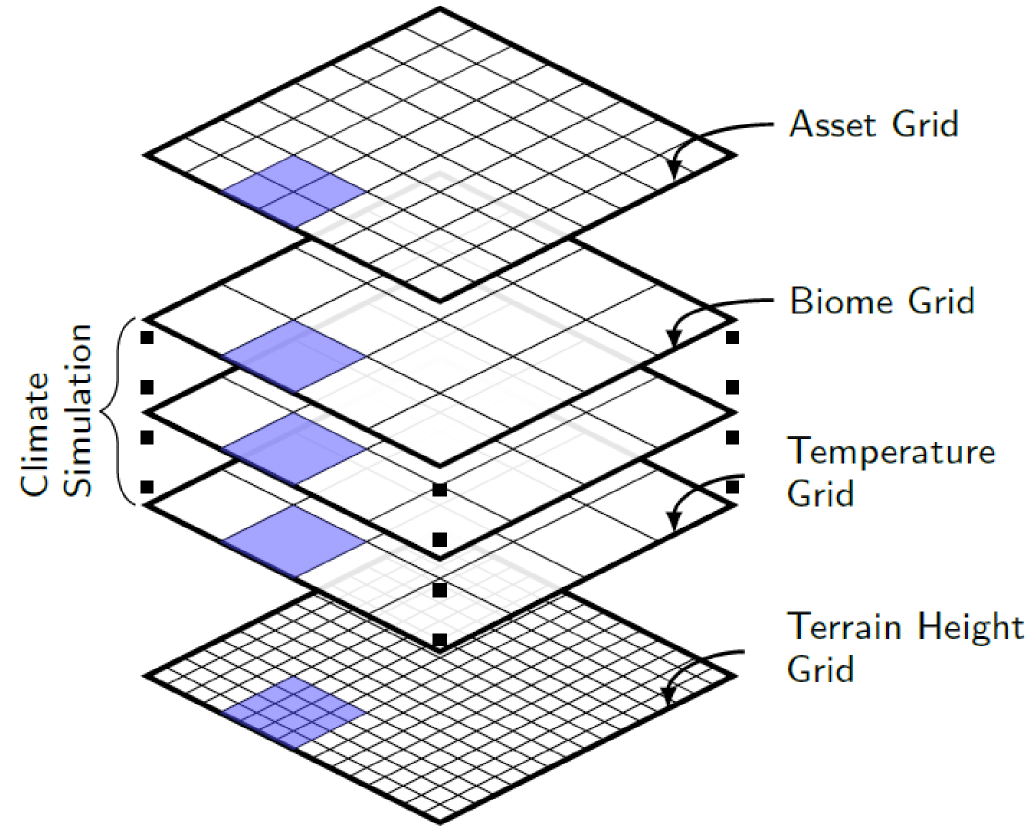
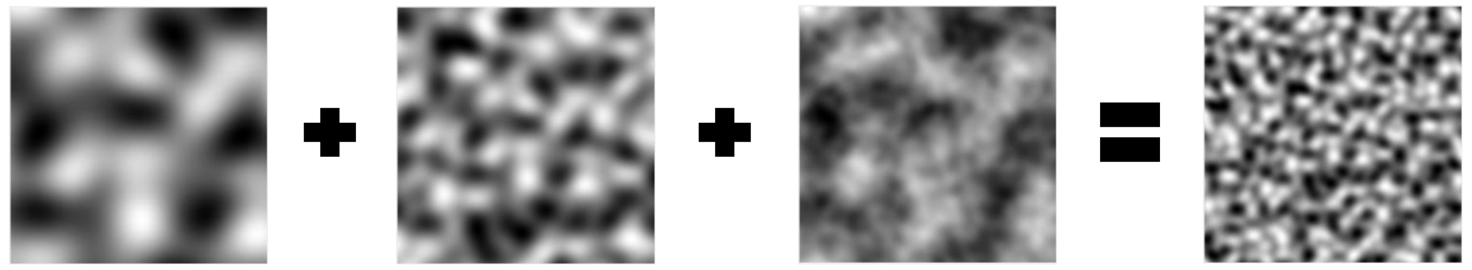


Base Terrain Generation

- Multiple octaves of simplex noise



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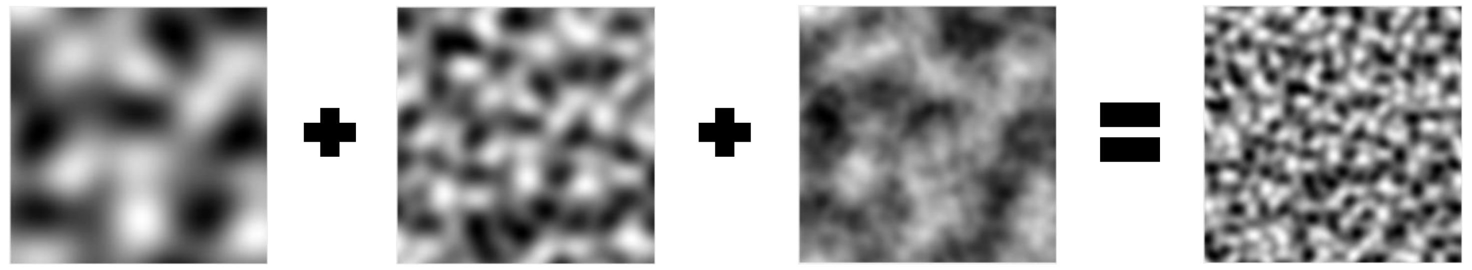

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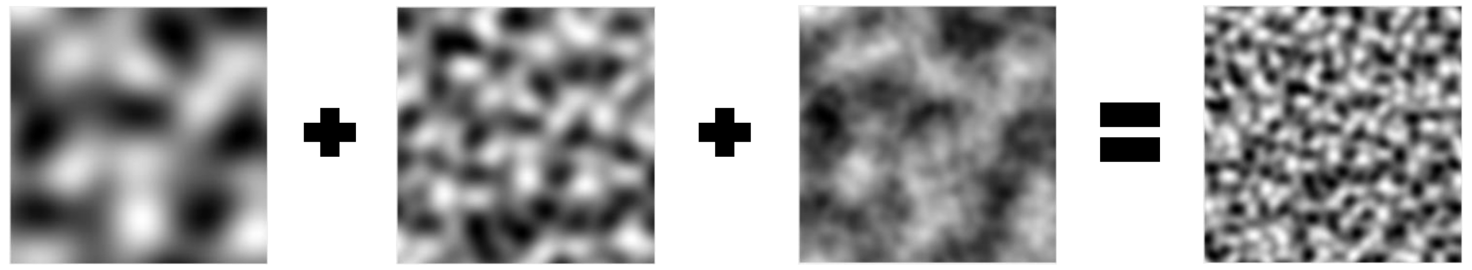

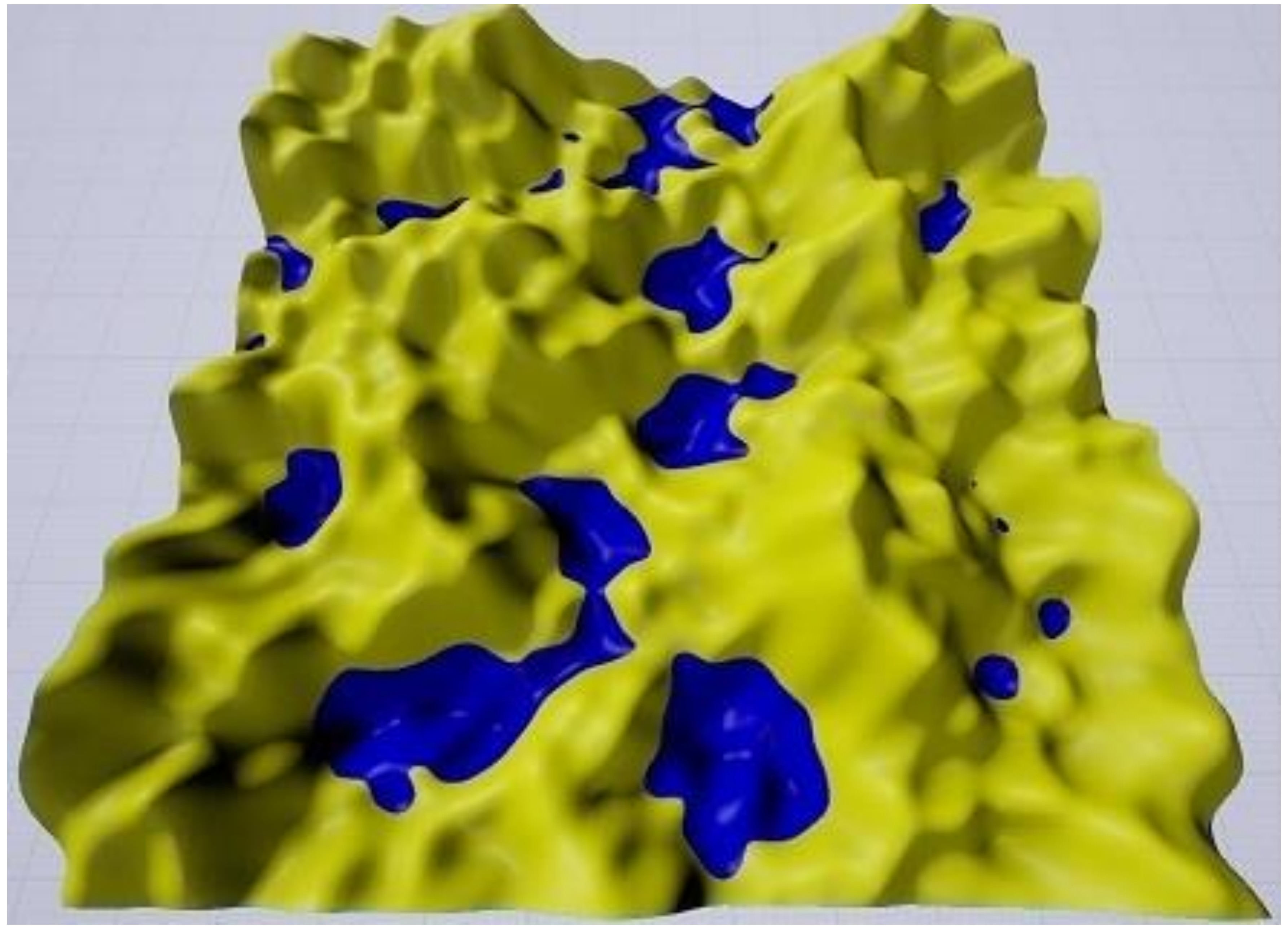

Base terrain, water bodies in blue

Base Terrain Generation

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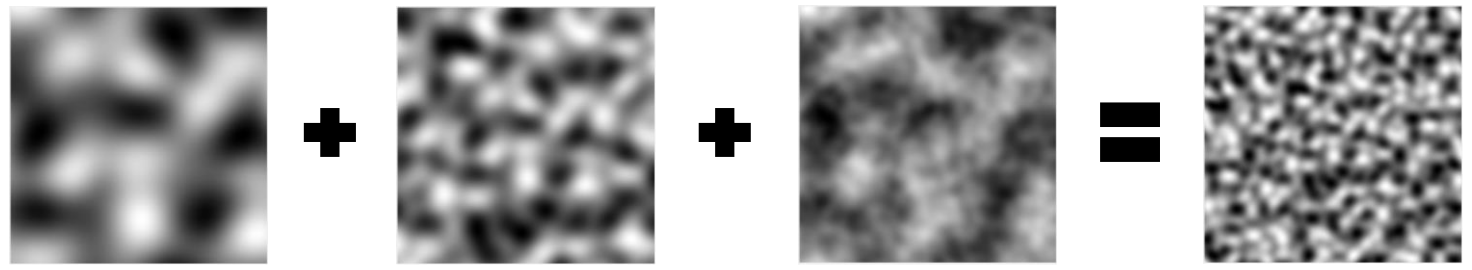
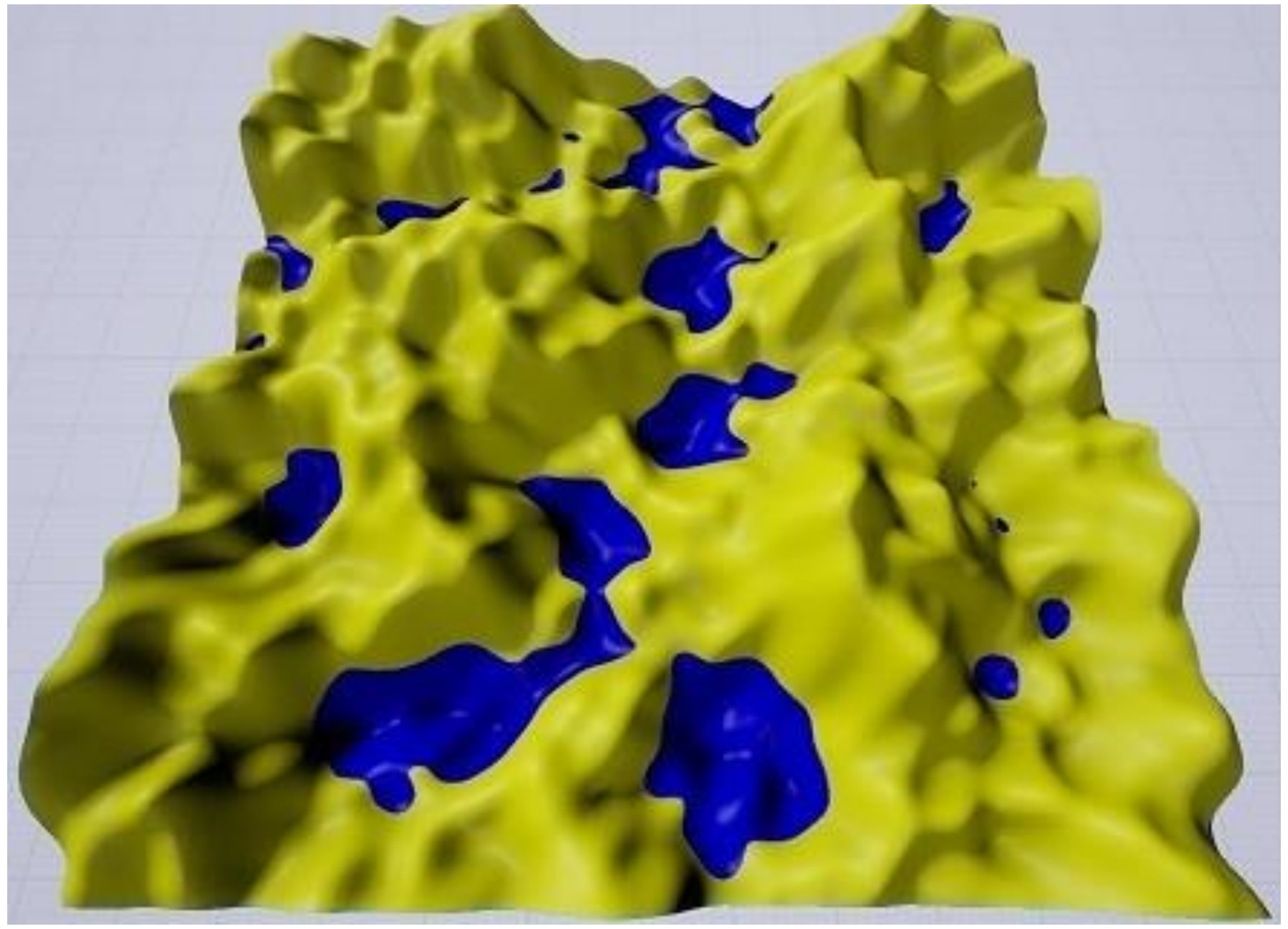
- Easily extendable with sketch-based editing techniques





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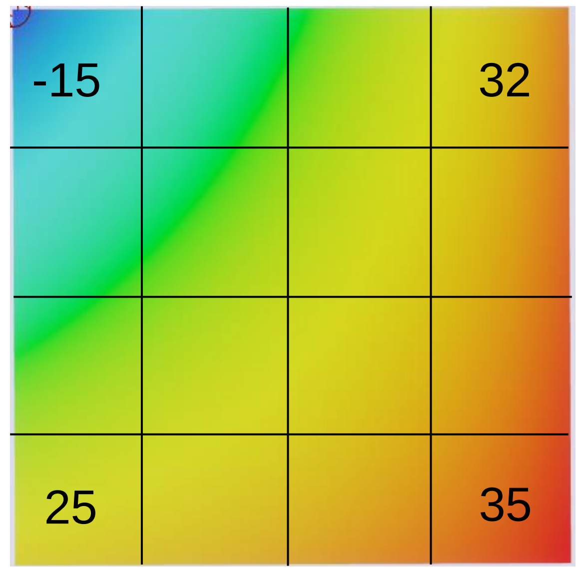
Climate Simulation - Temperature

- Two adjustable interpolation modes:
  - Bi-linear interpolation



Temperature, blue = cold, red = hot

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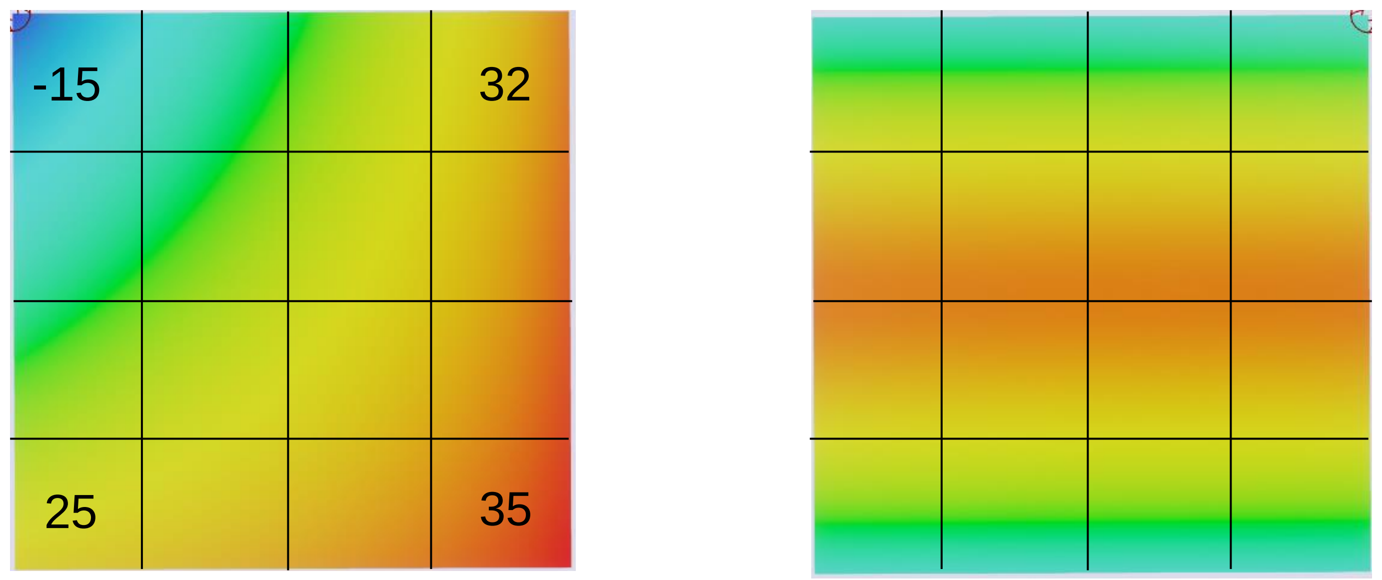

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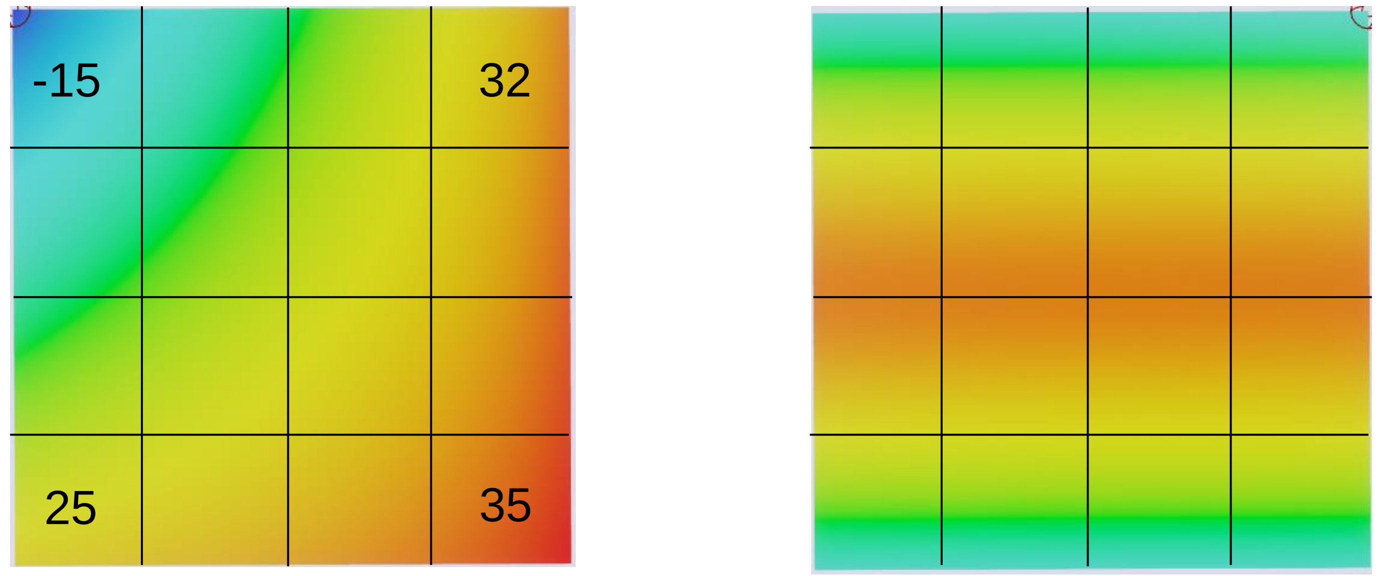
  - Sine-based interpolation
- Adjustable altitude-based decline



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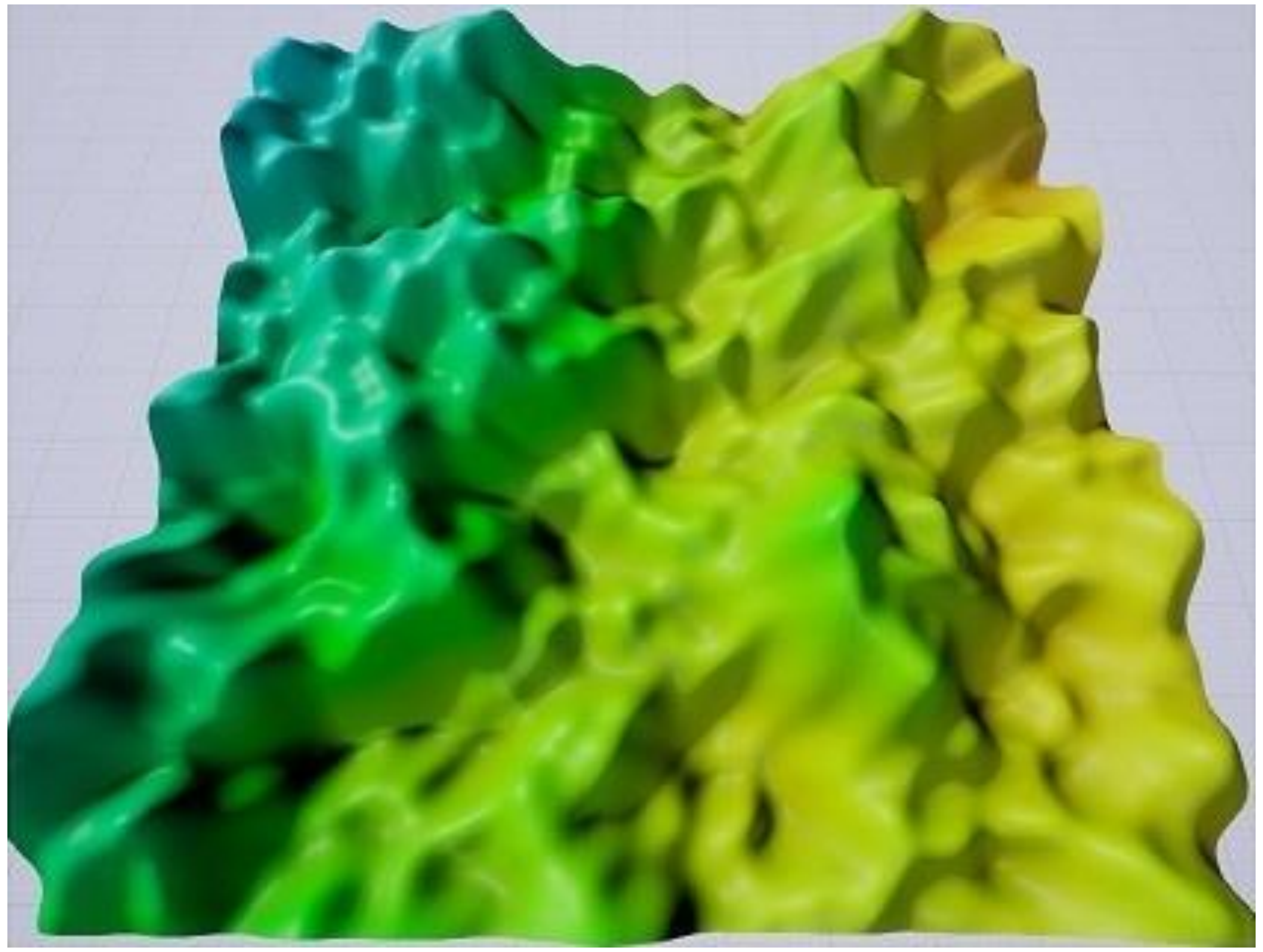

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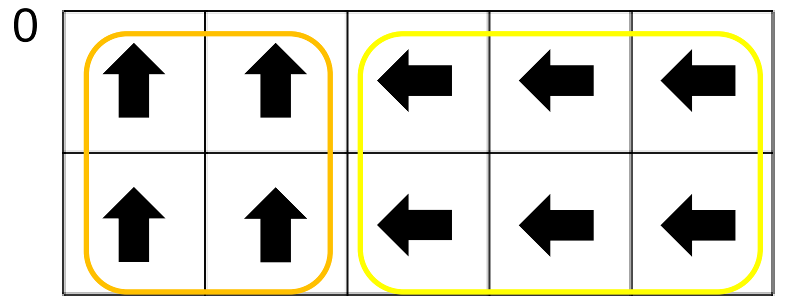

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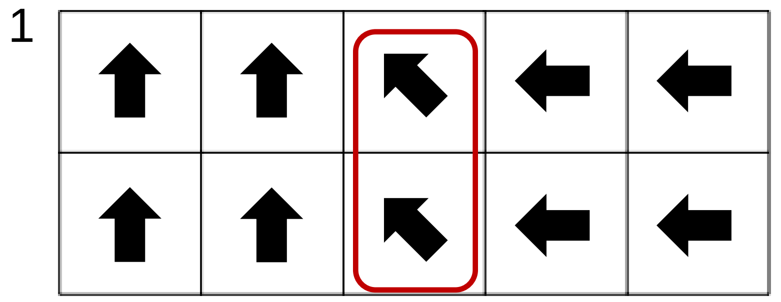

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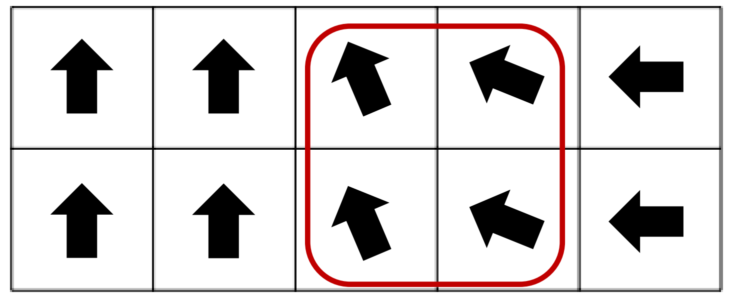

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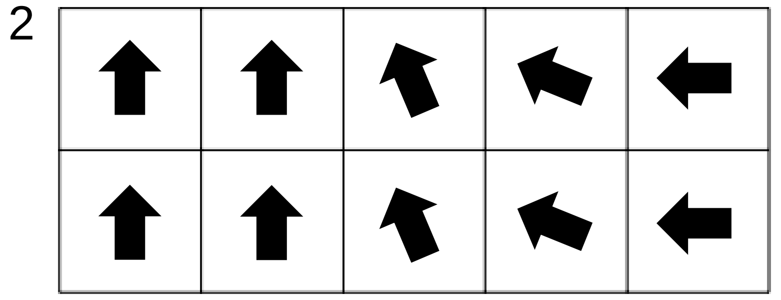
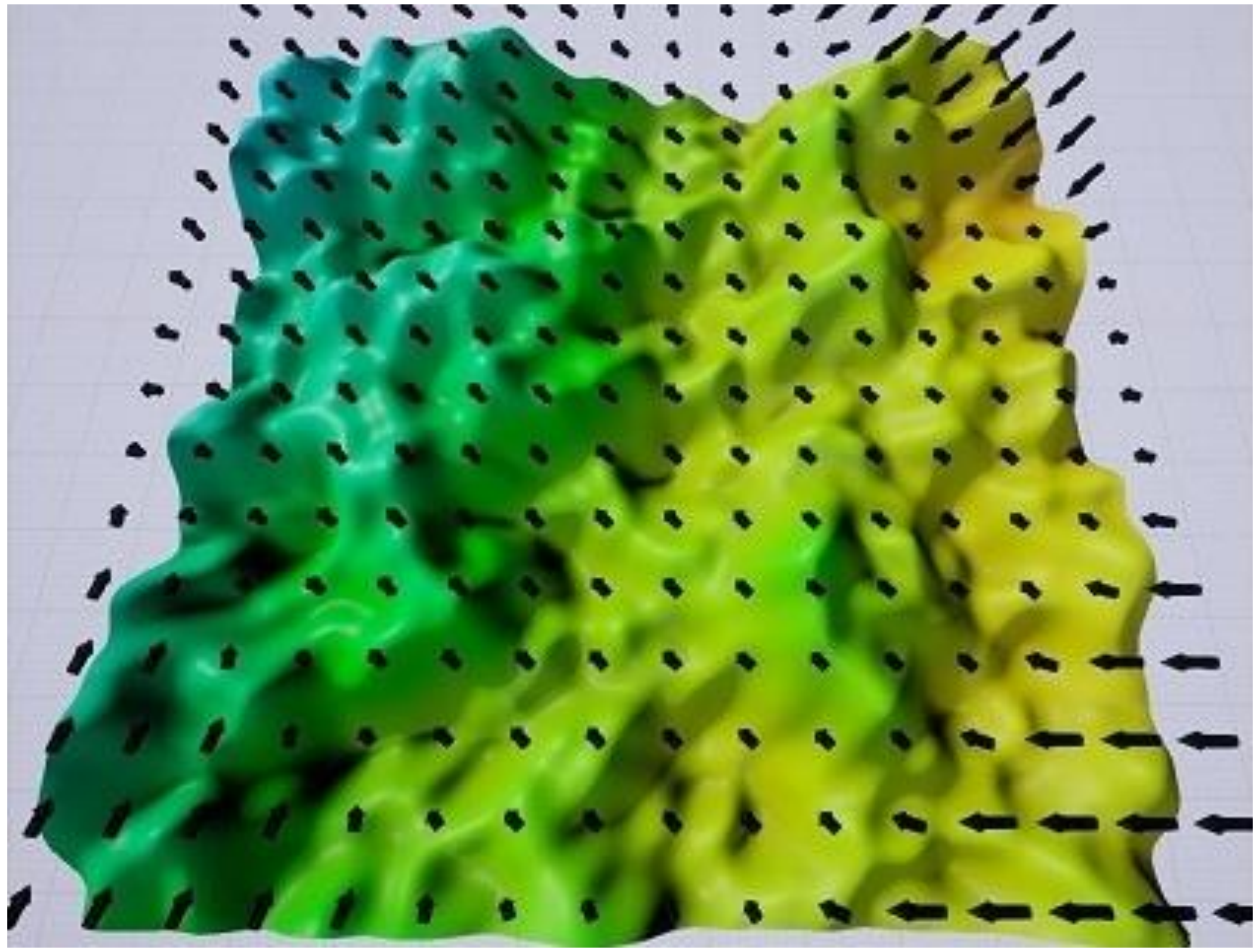
    - Iteratively averaging wind vectors with adjacent ones in forward direction
  - Enables creation of smooth, believable prevailing wind currents





Wind vector field

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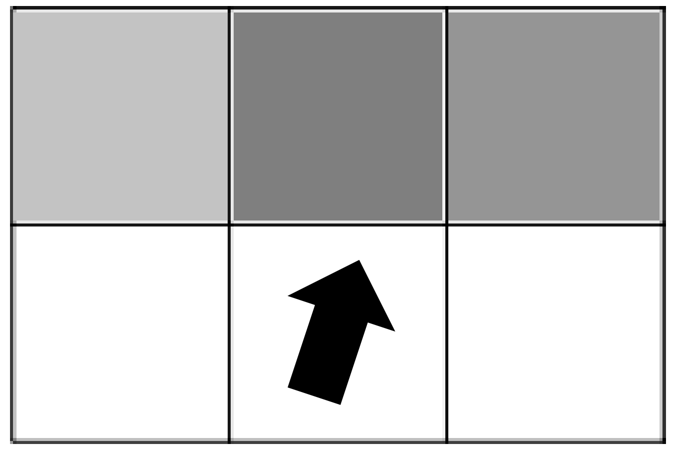

Grey indicates receiving moisture amount

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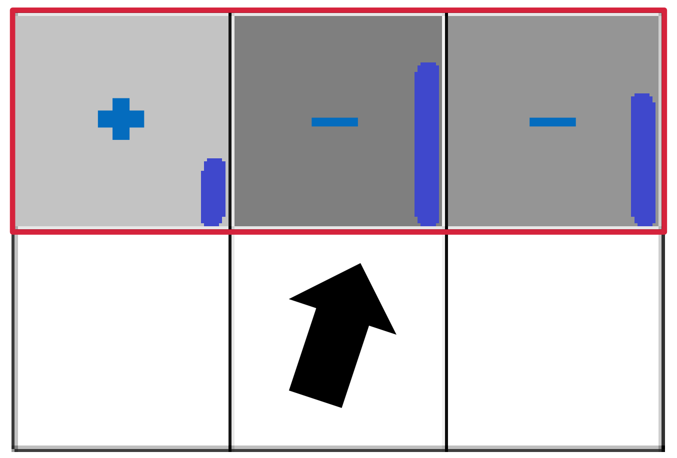

Diffusion based on current moisture

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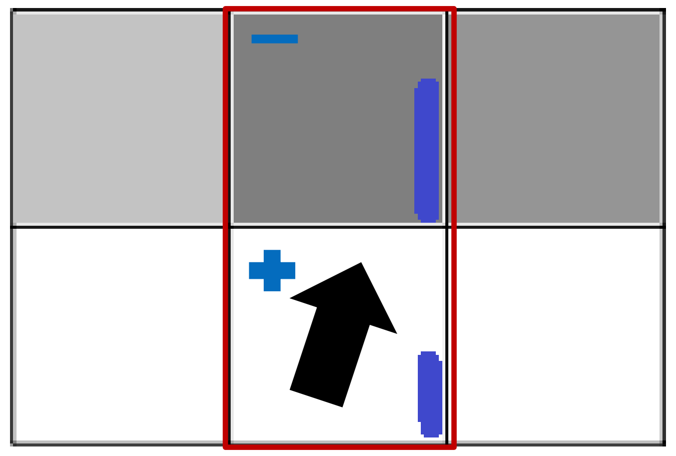

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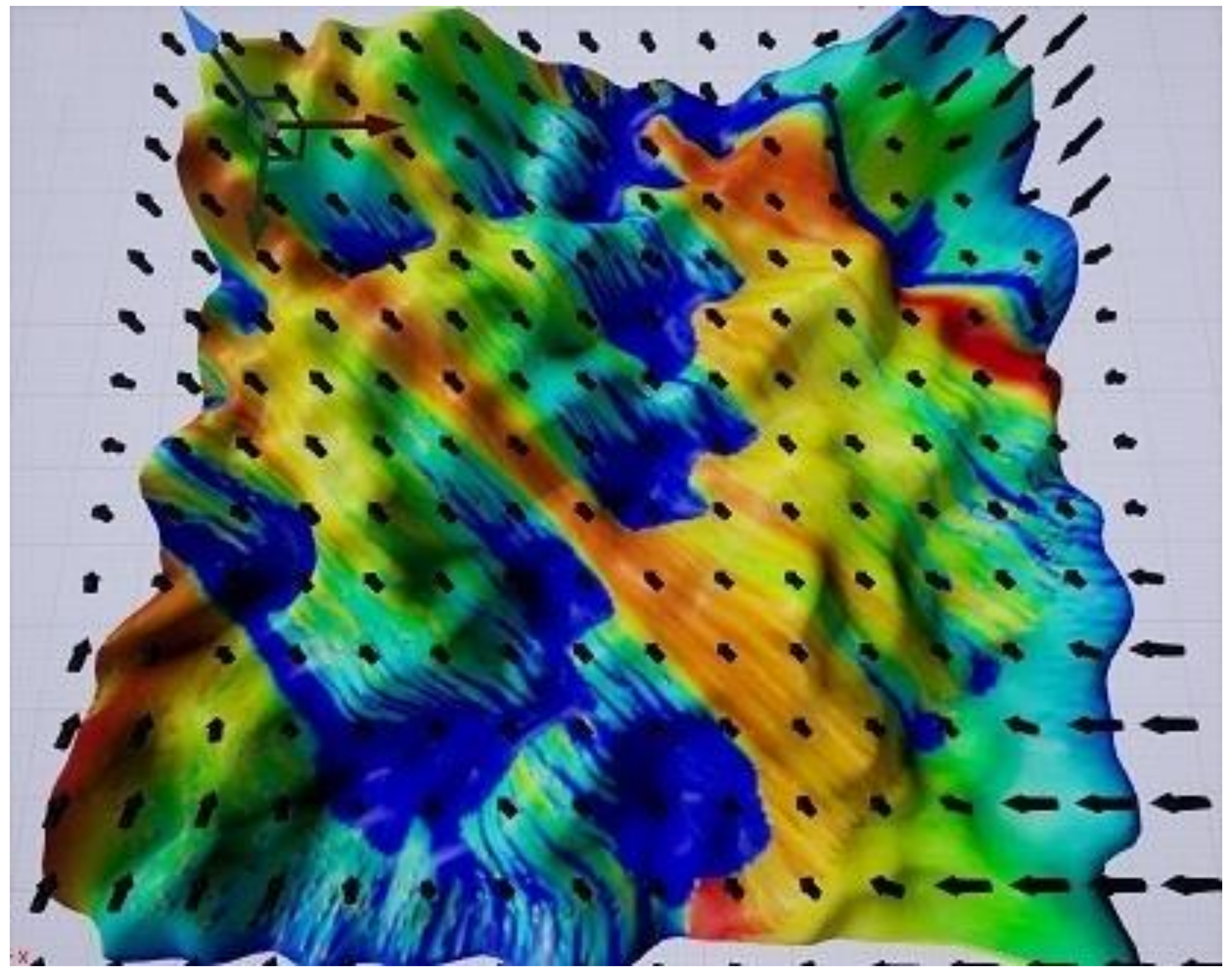

Moisture, low = red, high = blue

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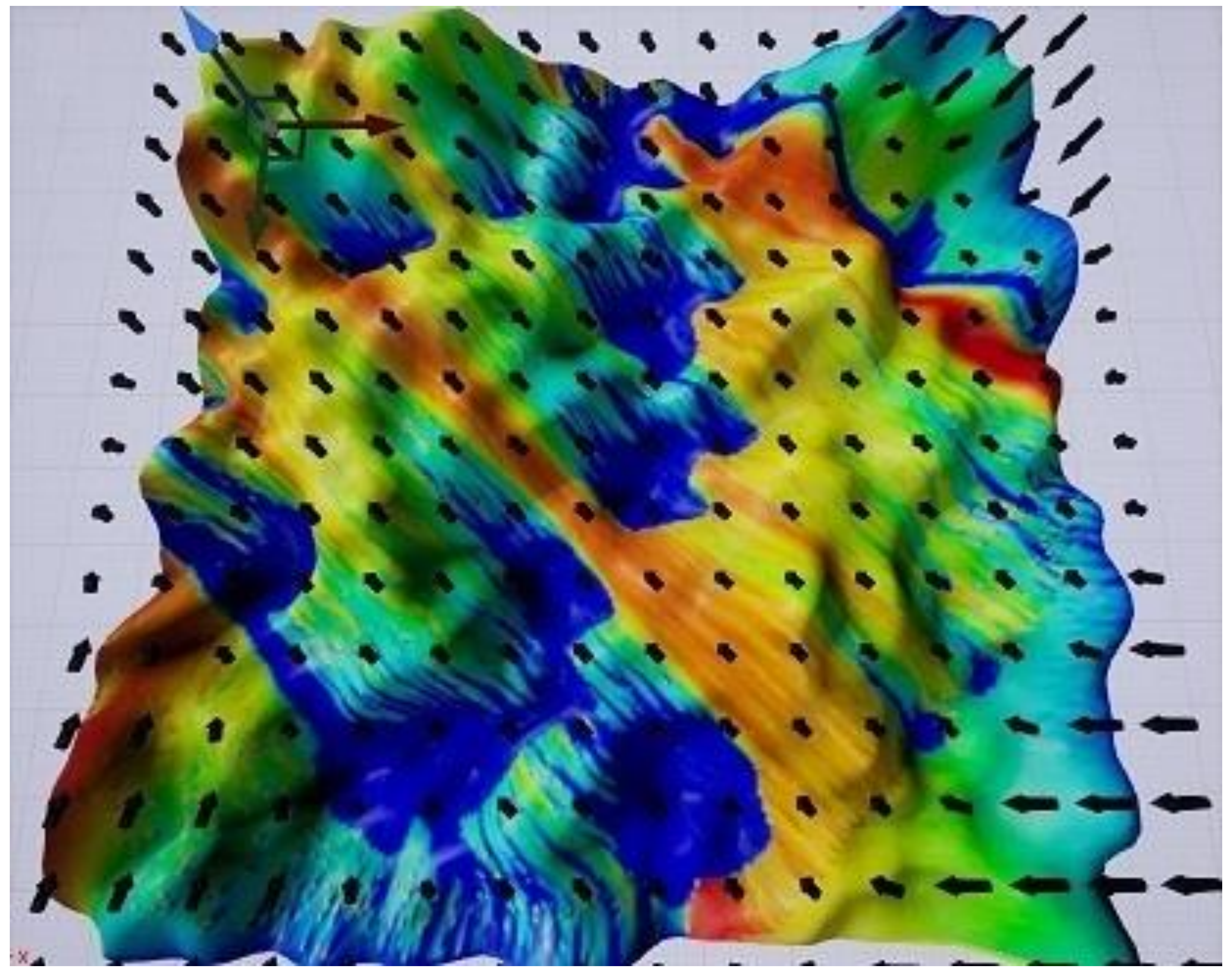
- Temperature and moisture-dependent precipitation



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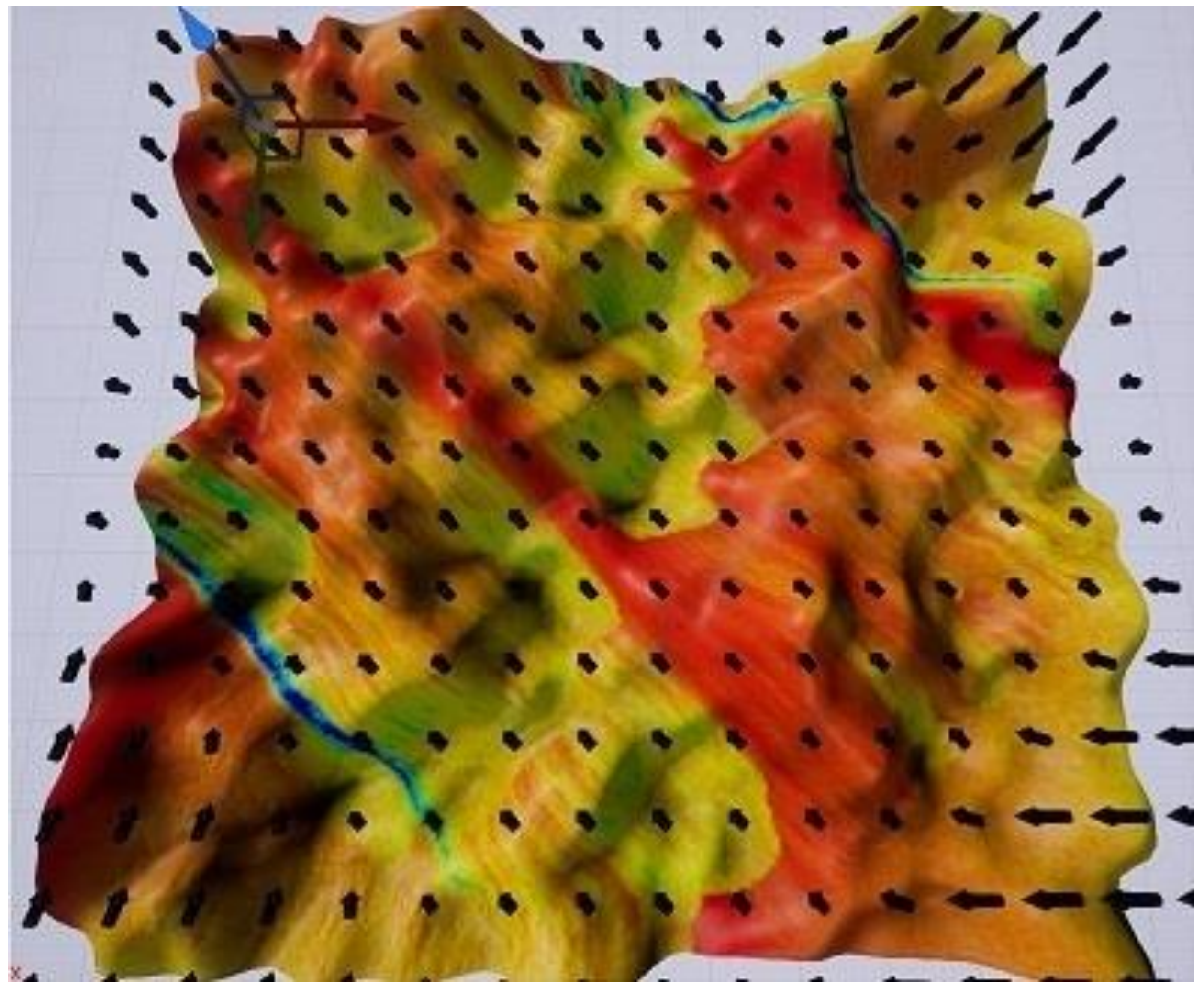

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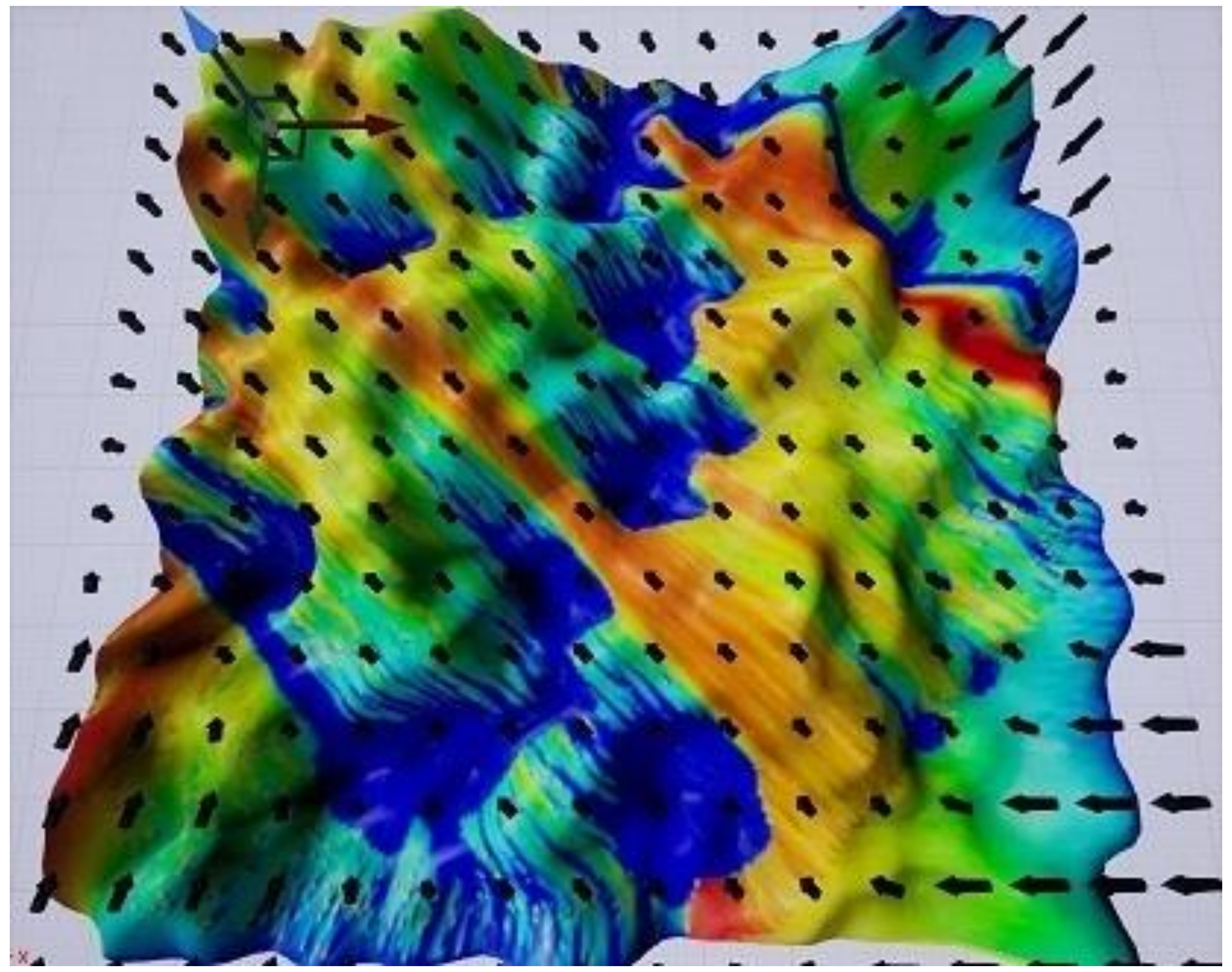
  - Dispersion and equalization
- Temperature and moisture-dependent precipitation
- Enables phenomena like rain shadows



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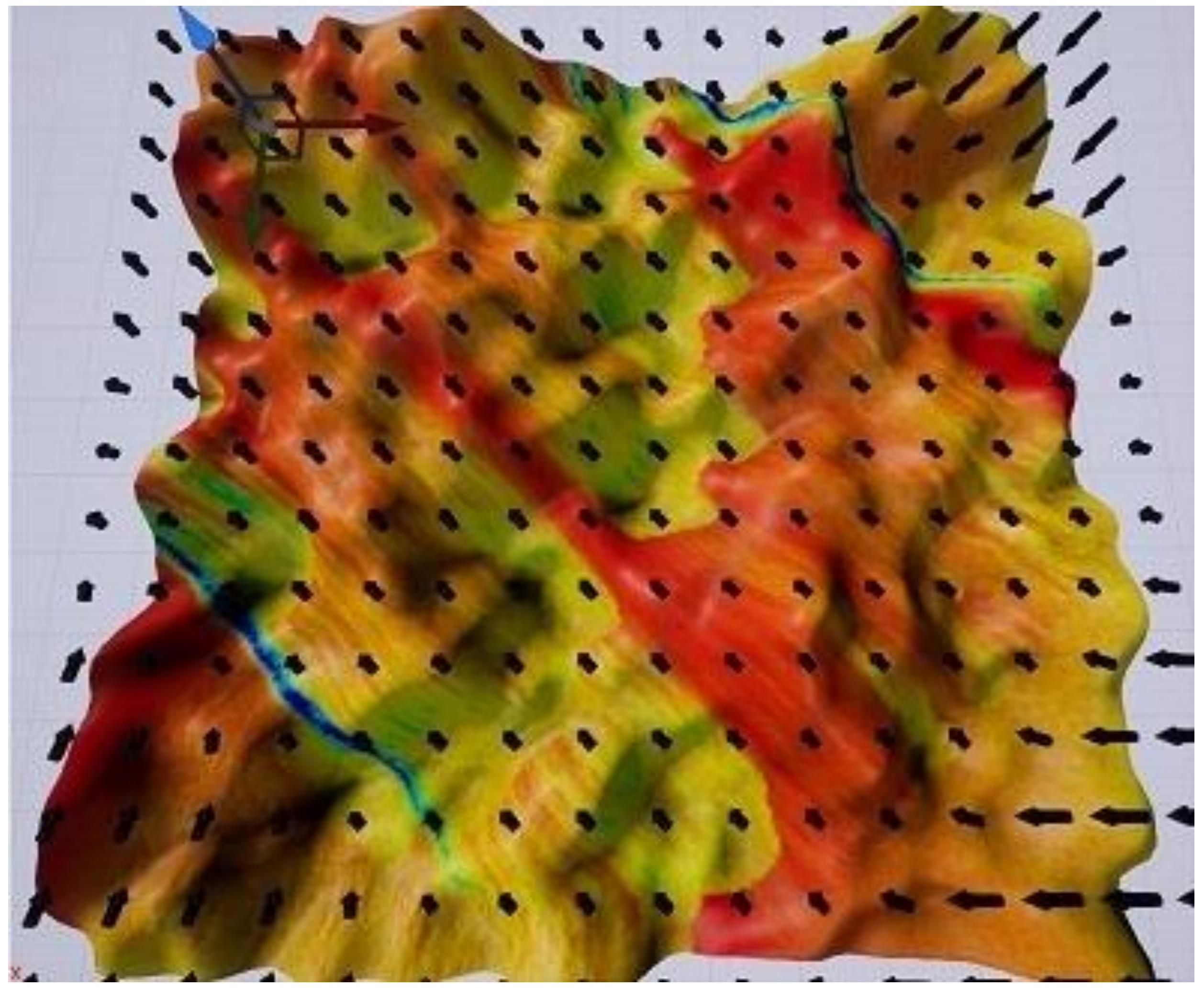

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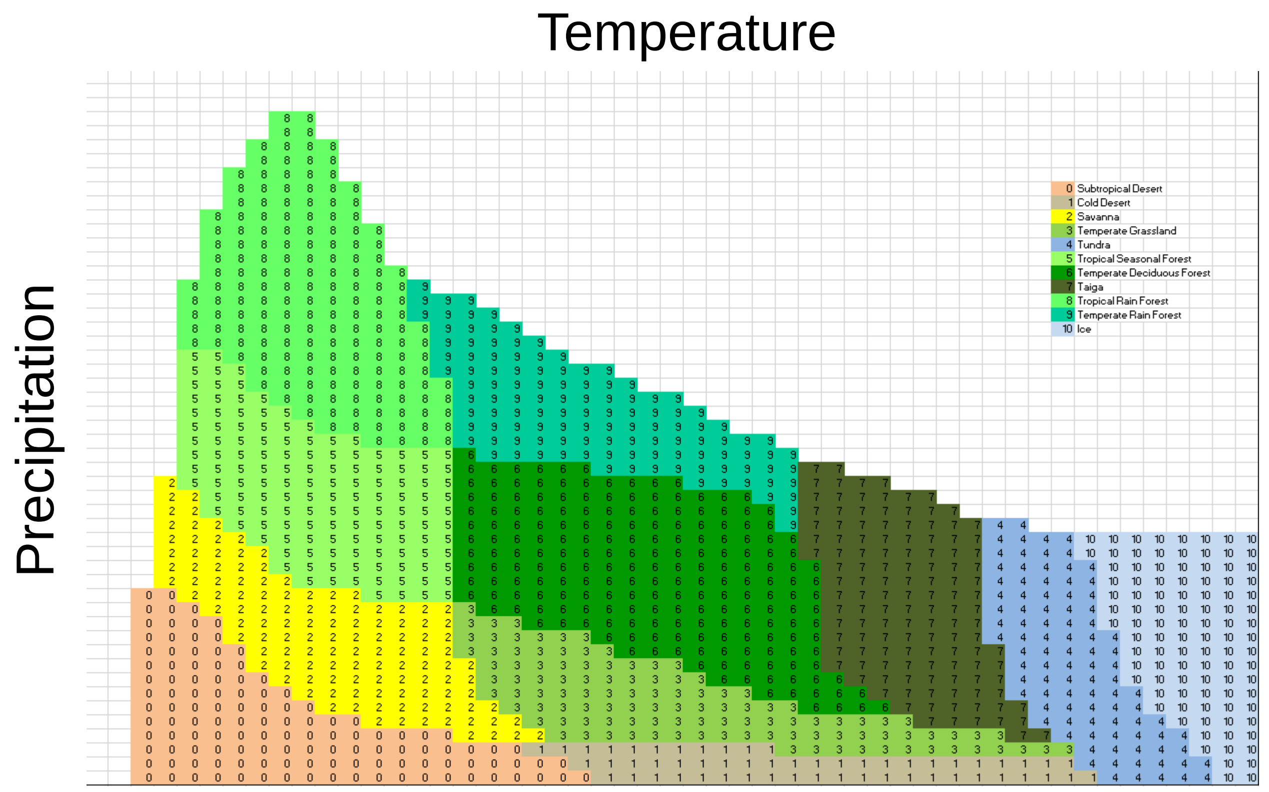

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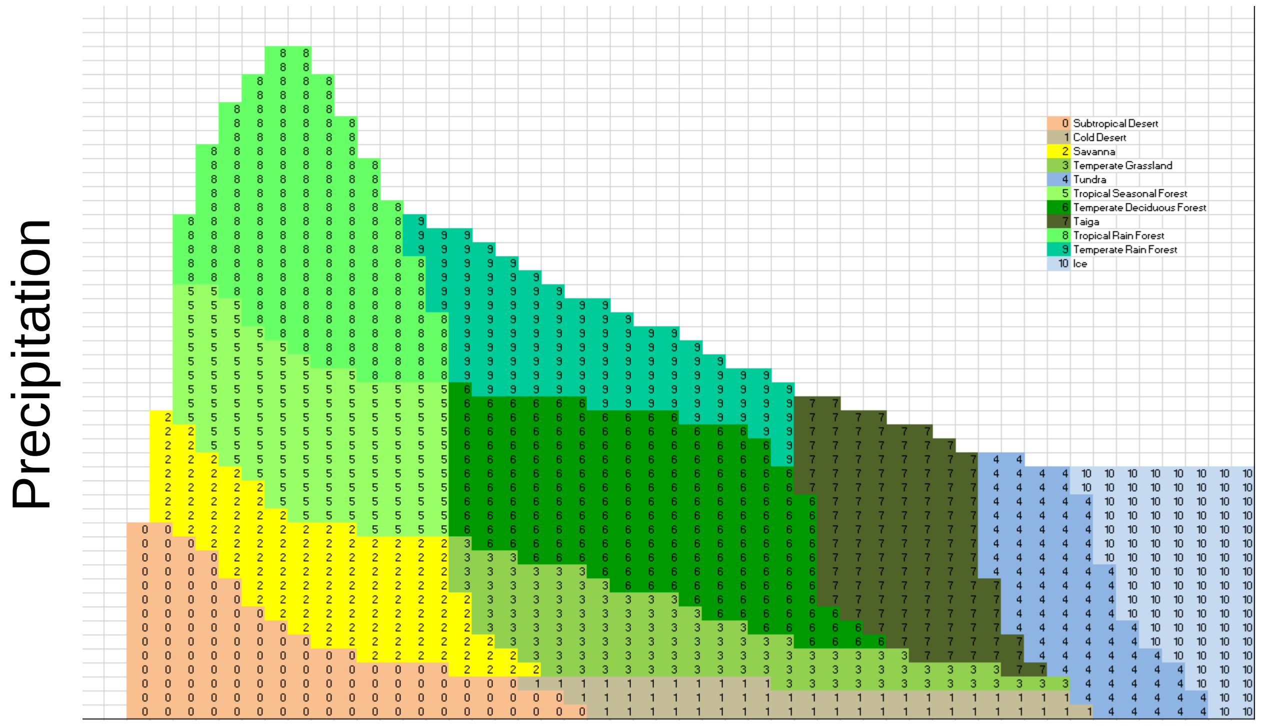
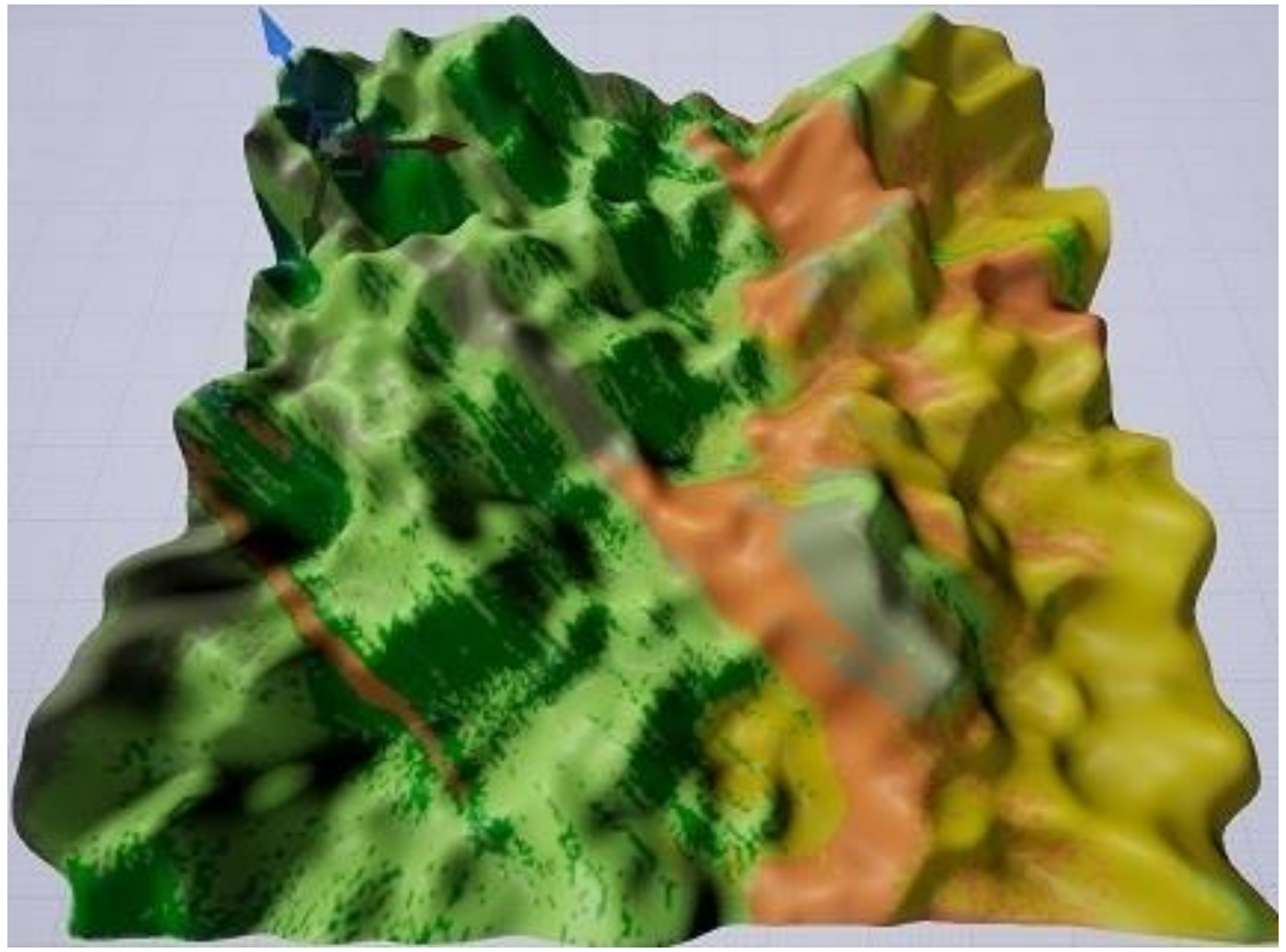
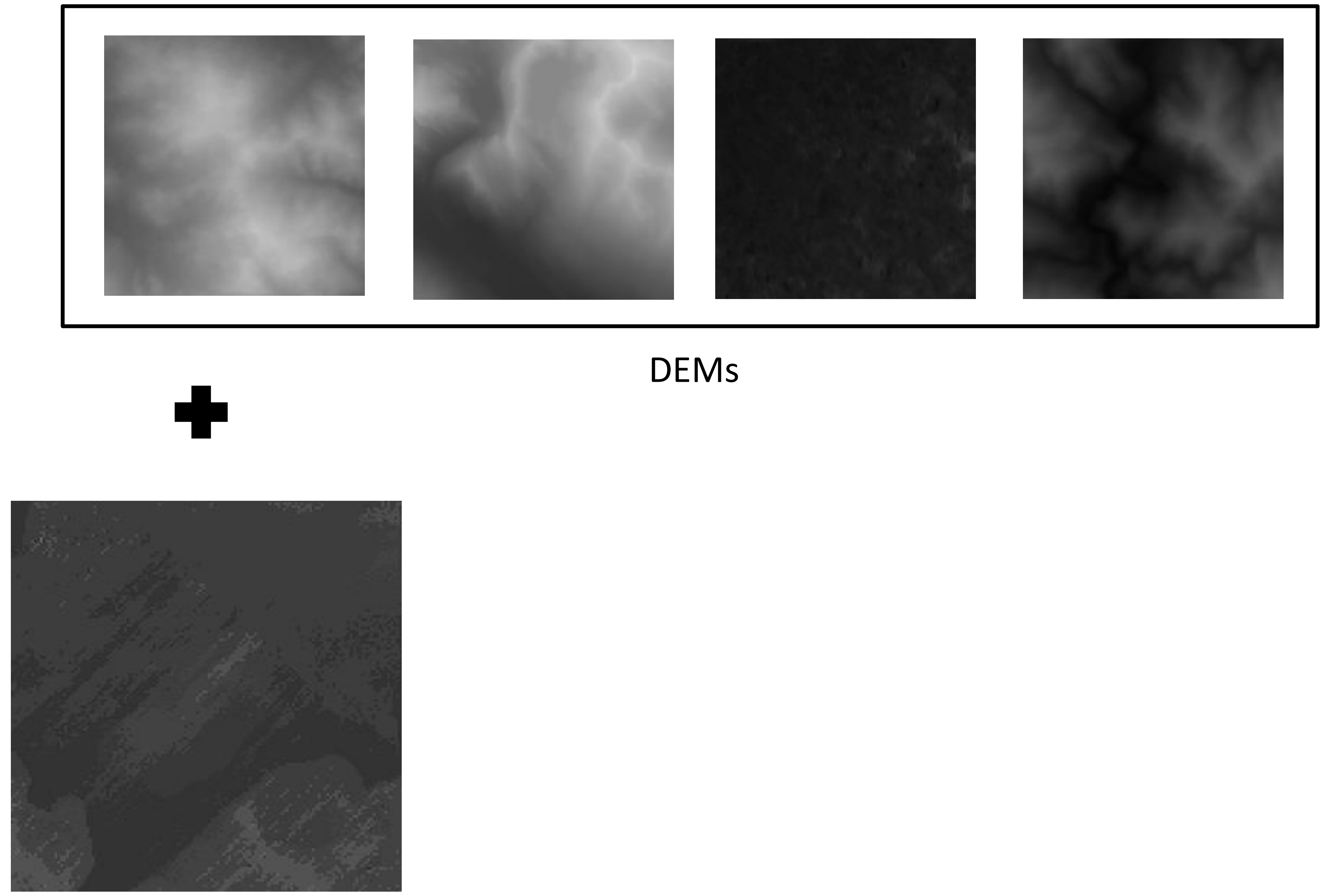




Biome map

Biome-Based Terrain Refinement

- Adds biome-specific structures
- DEMs as examples, inherently realistic



DEMs

Biome map

Biome-Based Terrain Refinement

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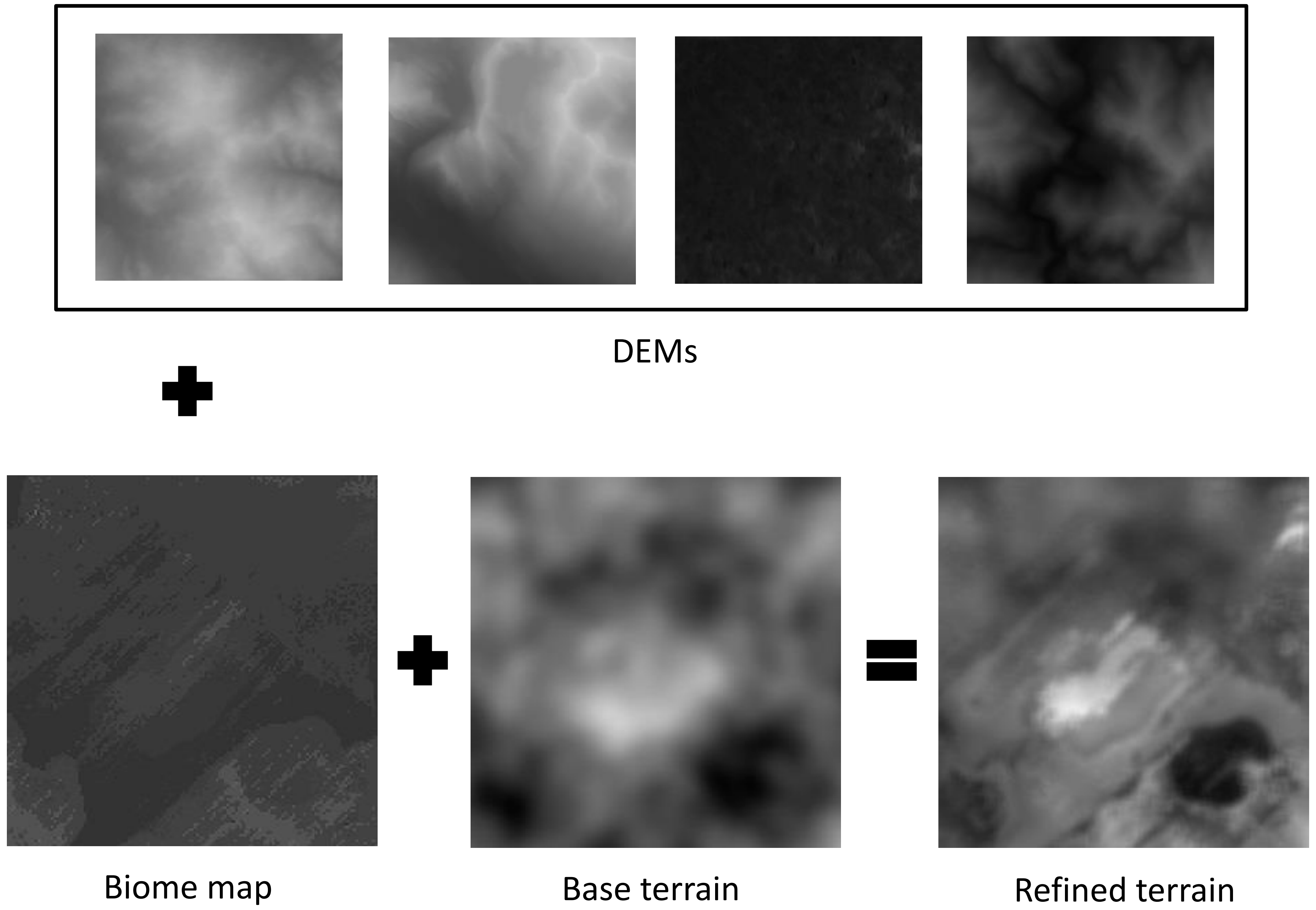

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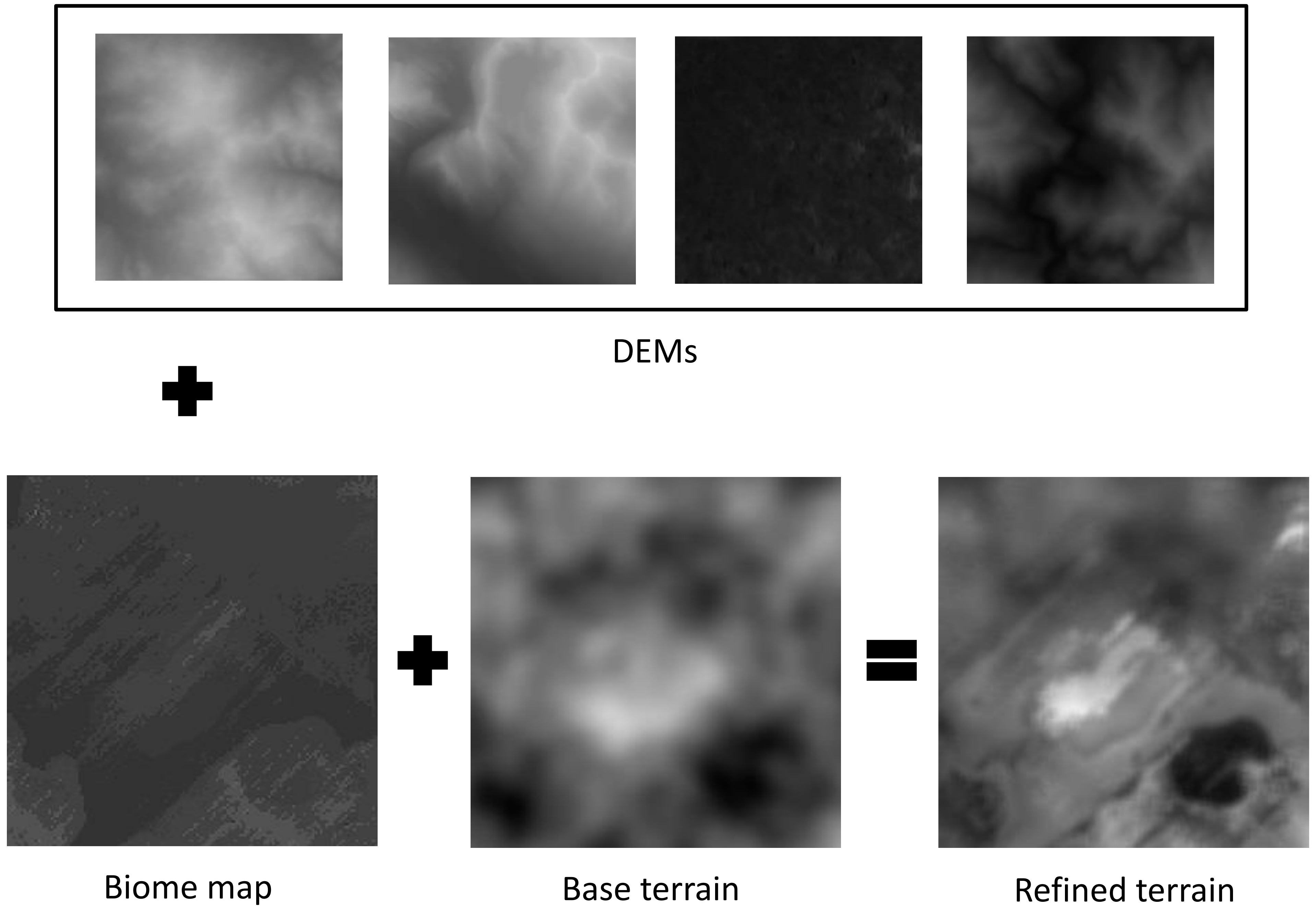

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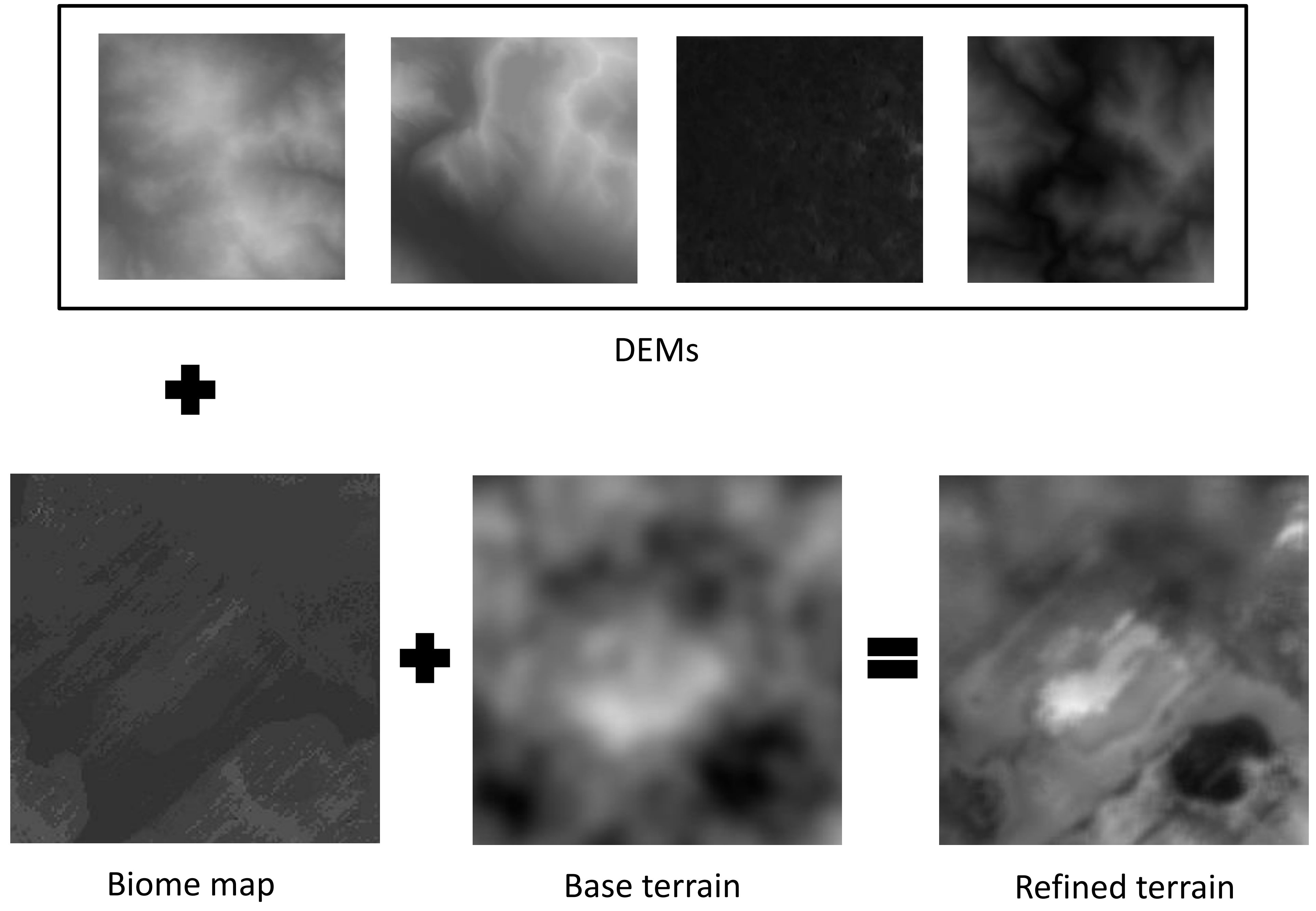

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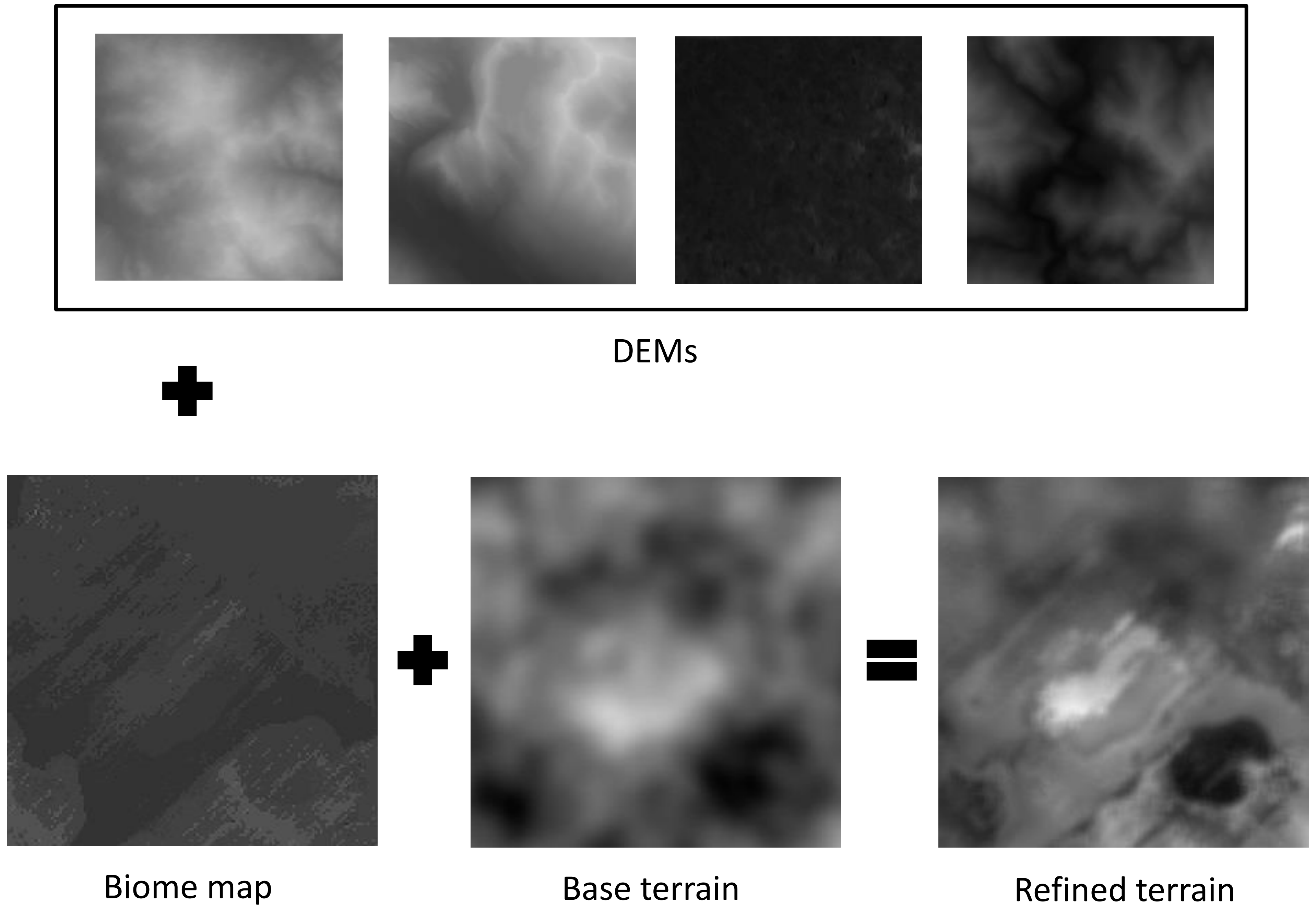

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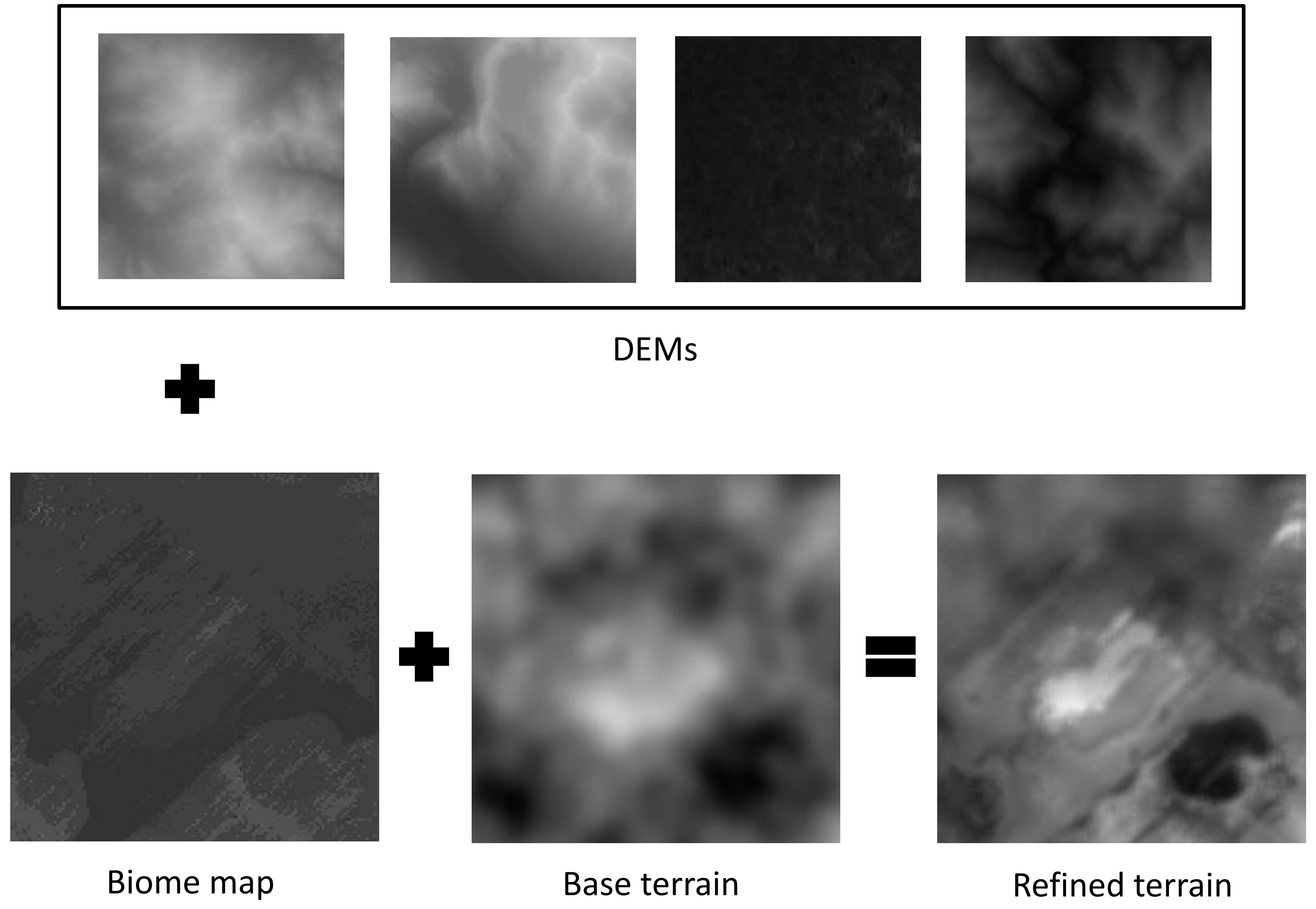

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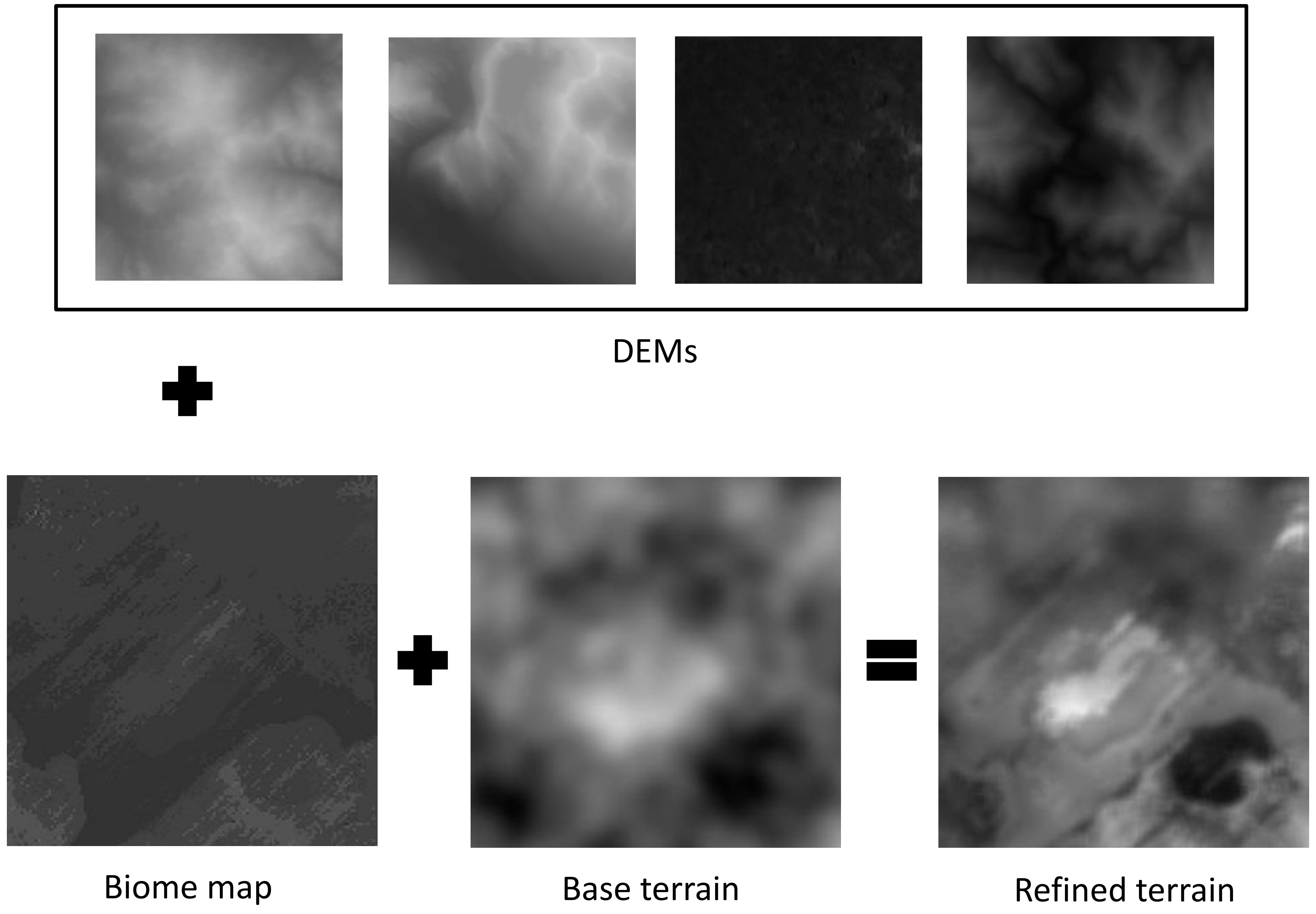

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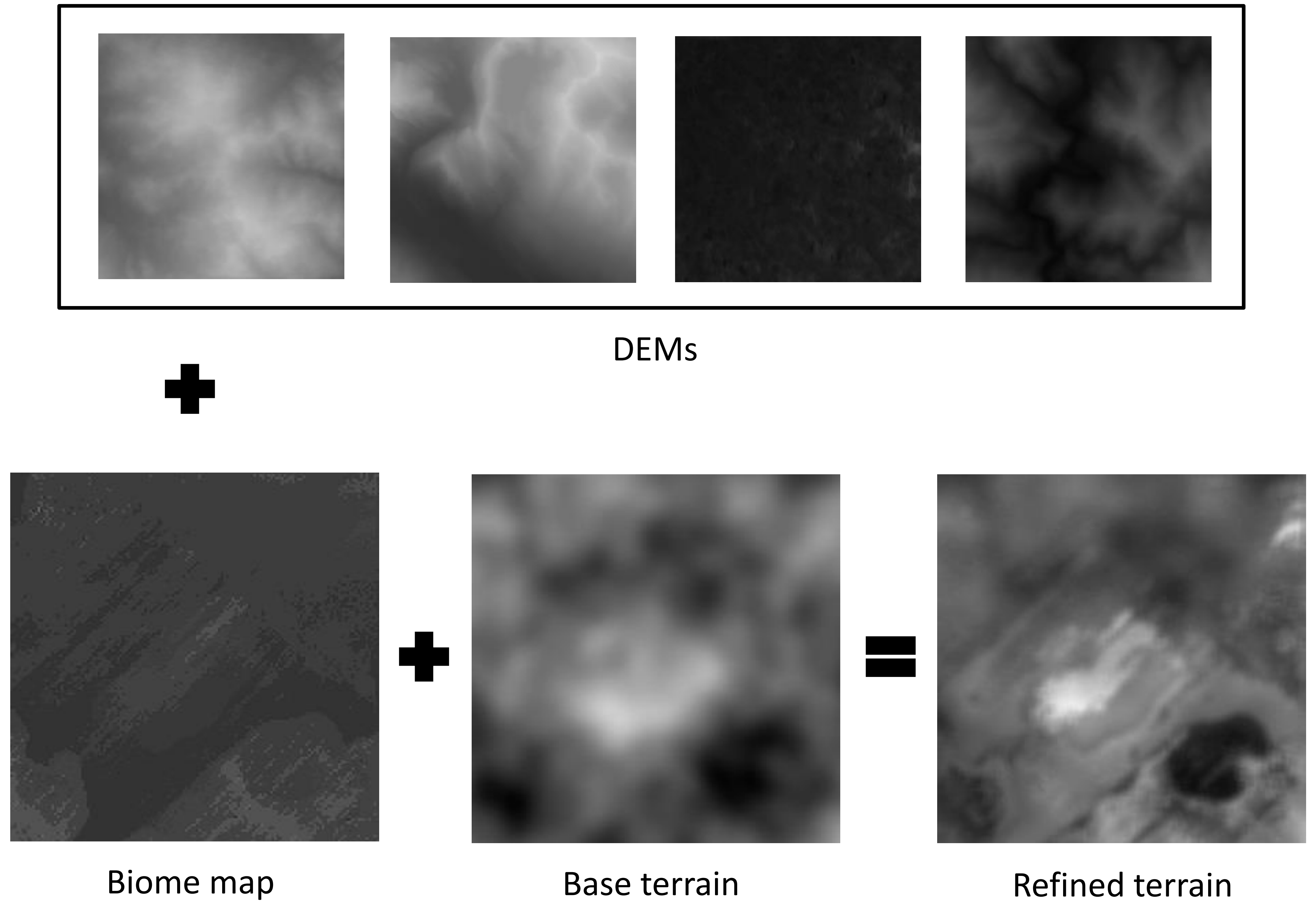

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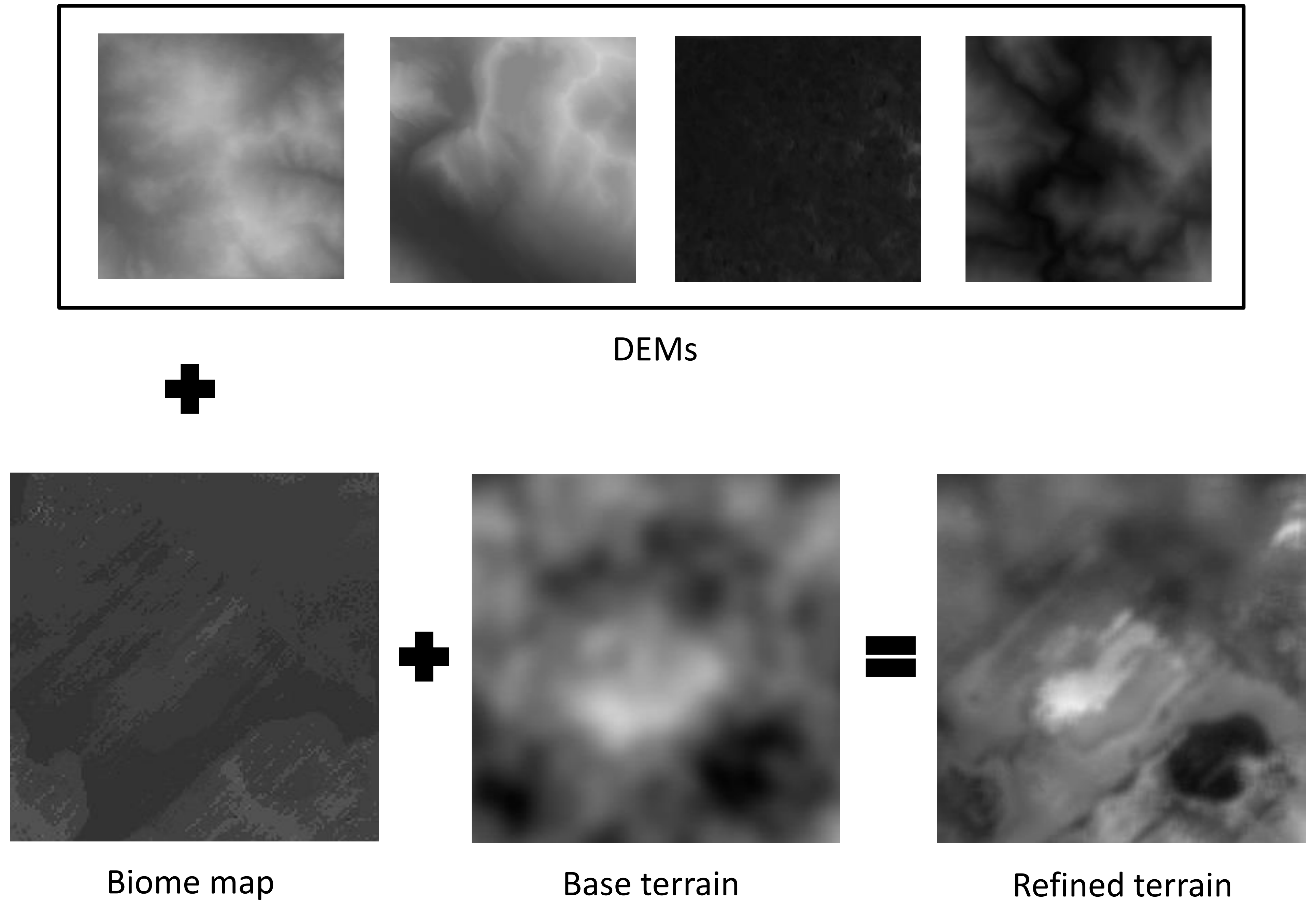

$$h(p) = w_b \cdot h_b(p) + w_d \cdot \sum_{i=1}^{n} w_i \cdot h_{di}(p)$$

Procedural Asset Placement

- Iterative, rule-based local-to-global model

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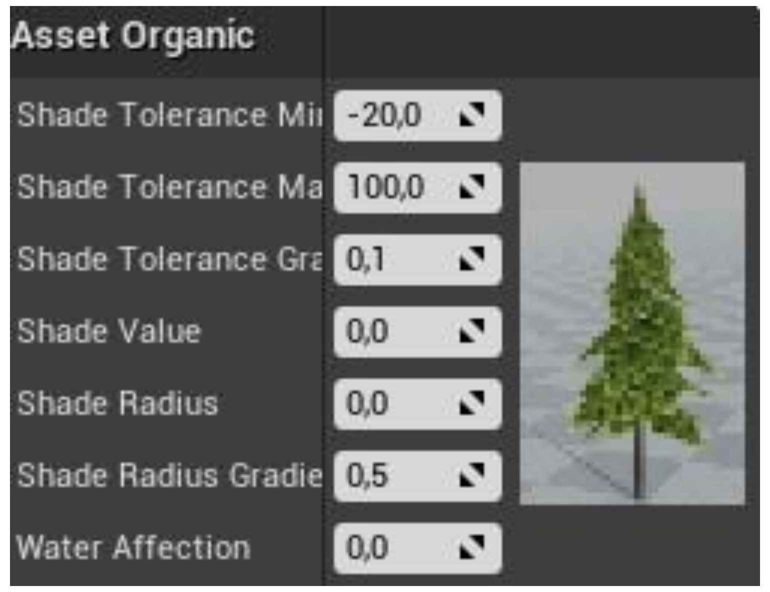
Procedural Asset Placement

- Iterative, rule-based local-to-global model
  - Assets with bilateral placement rules



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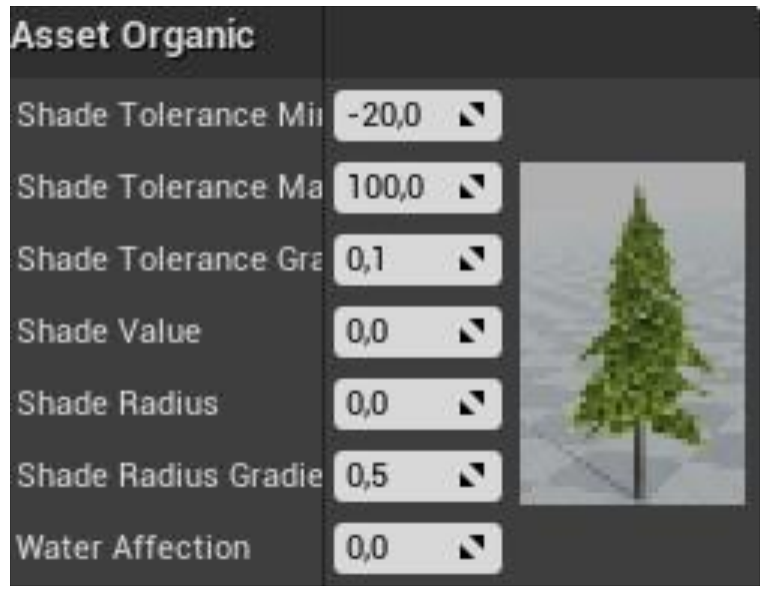

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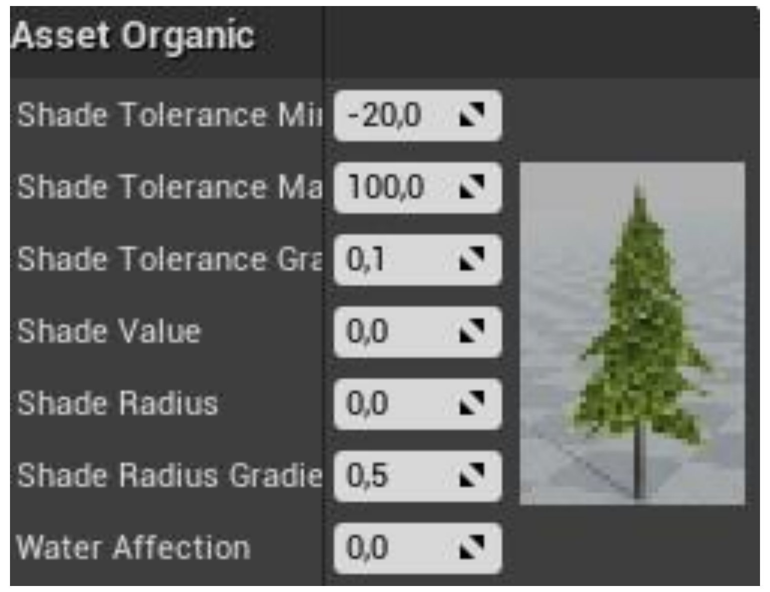

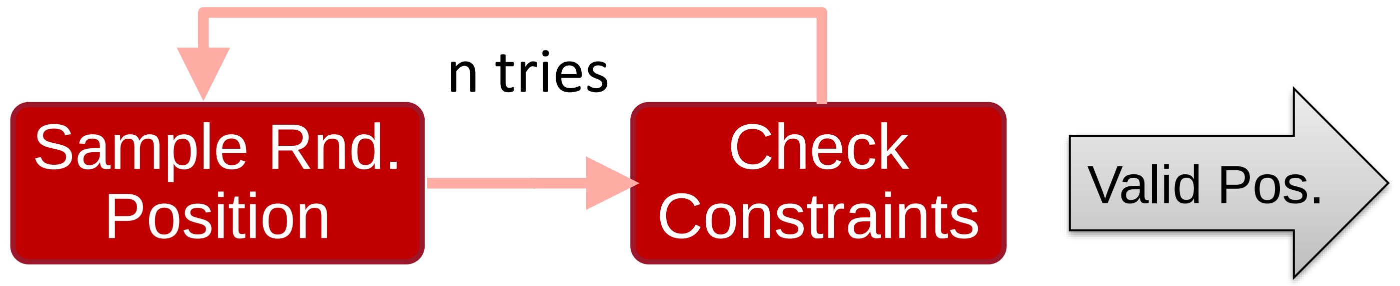

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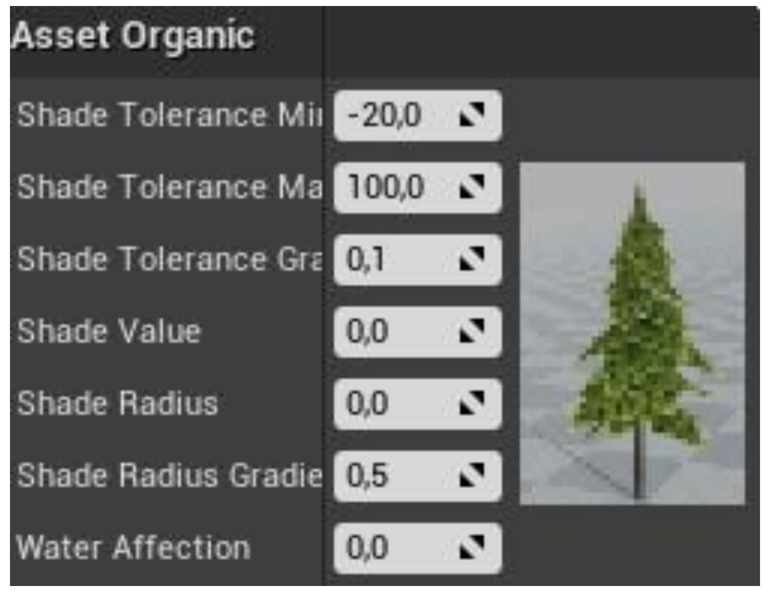

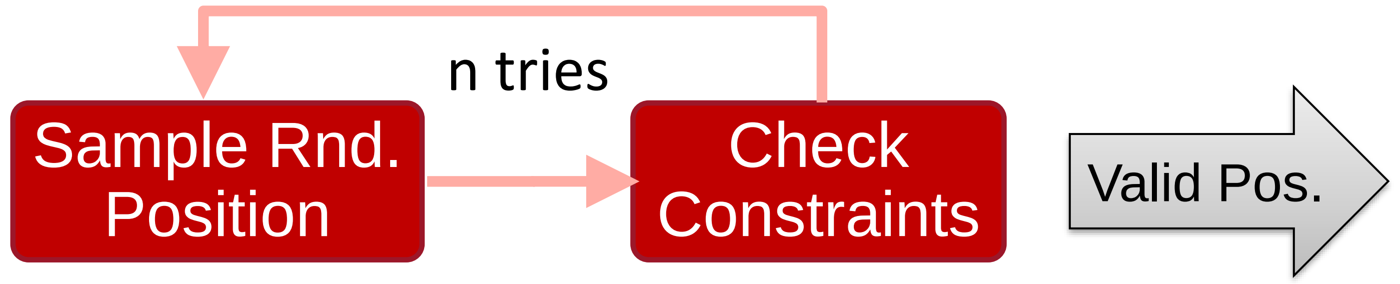

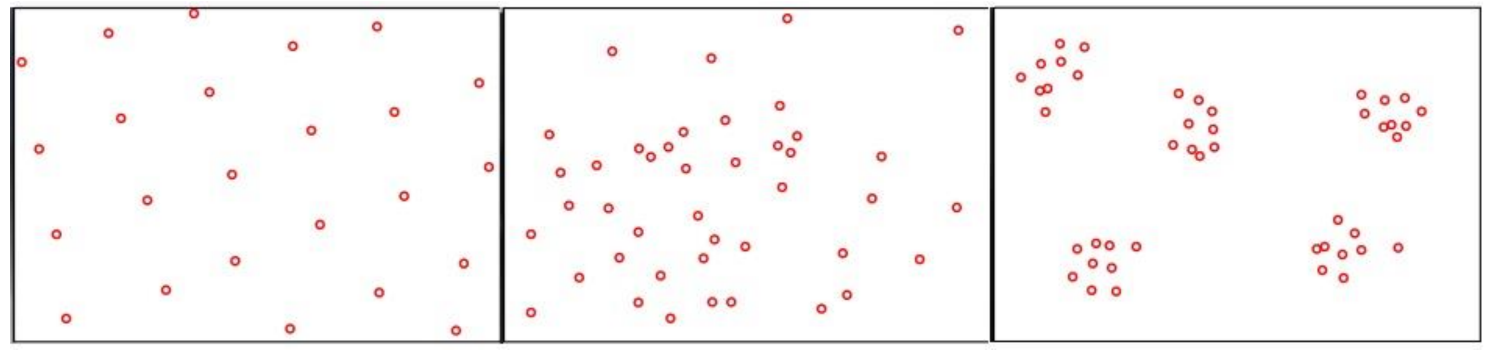

Procedural Asset Placement

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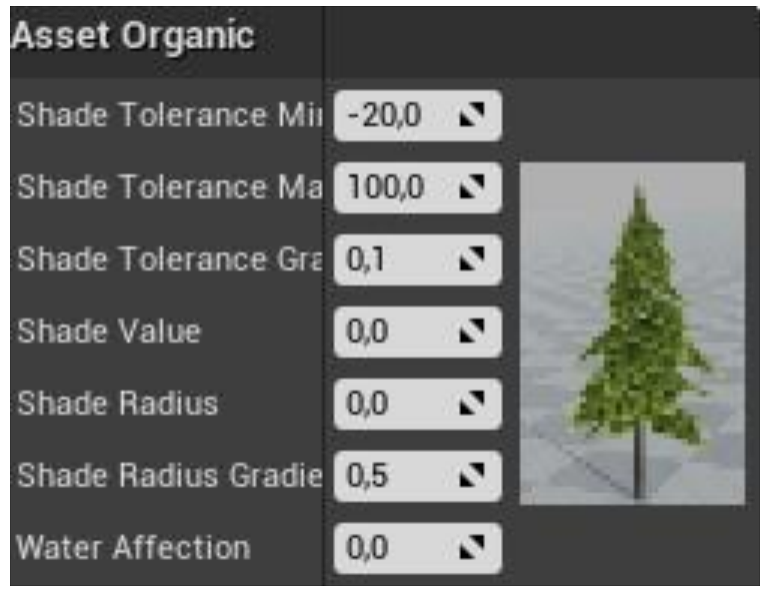
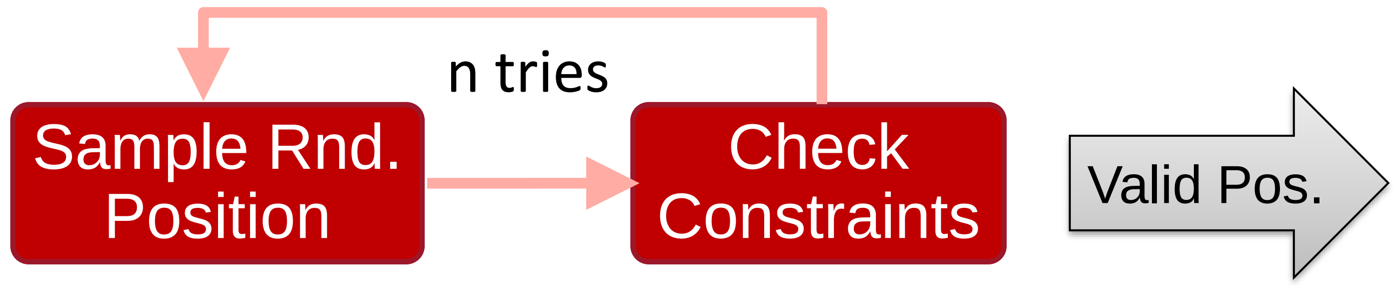
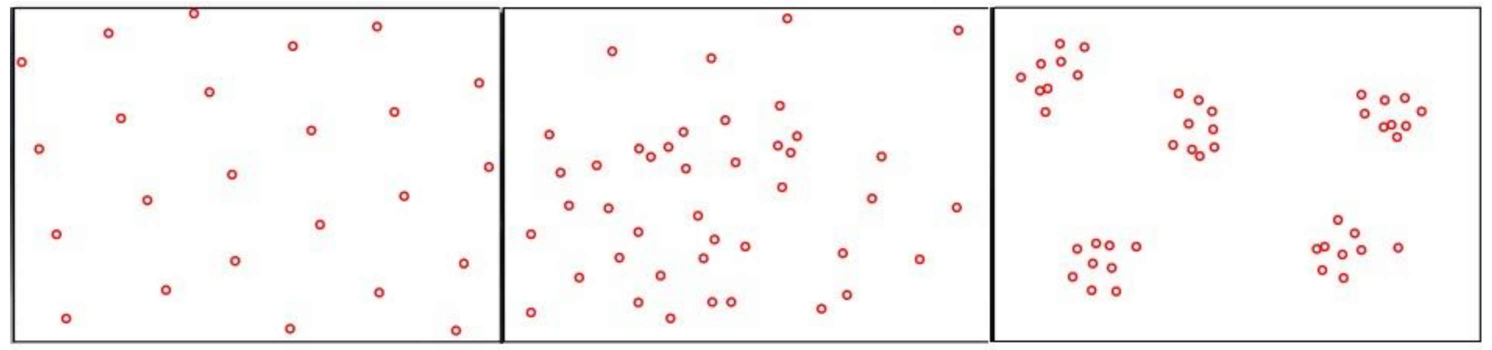
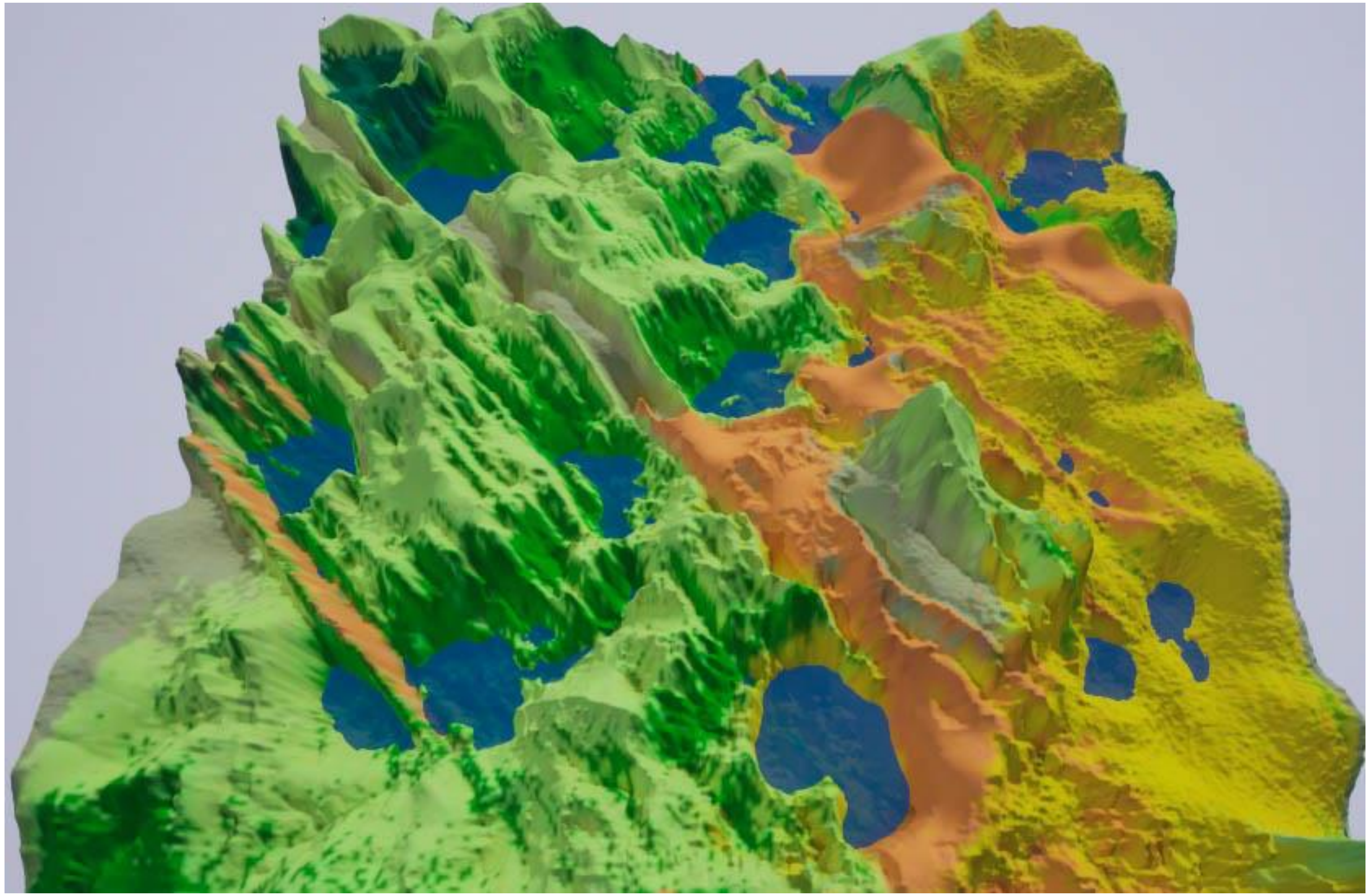
  - Constrained-based placement via dart throwing
- Enables emergent multi-object distributions
- All seasons with one placement
  - Switching asset variants







Result: Proxy View of Final Terrains



Represents $1600\ km^2$

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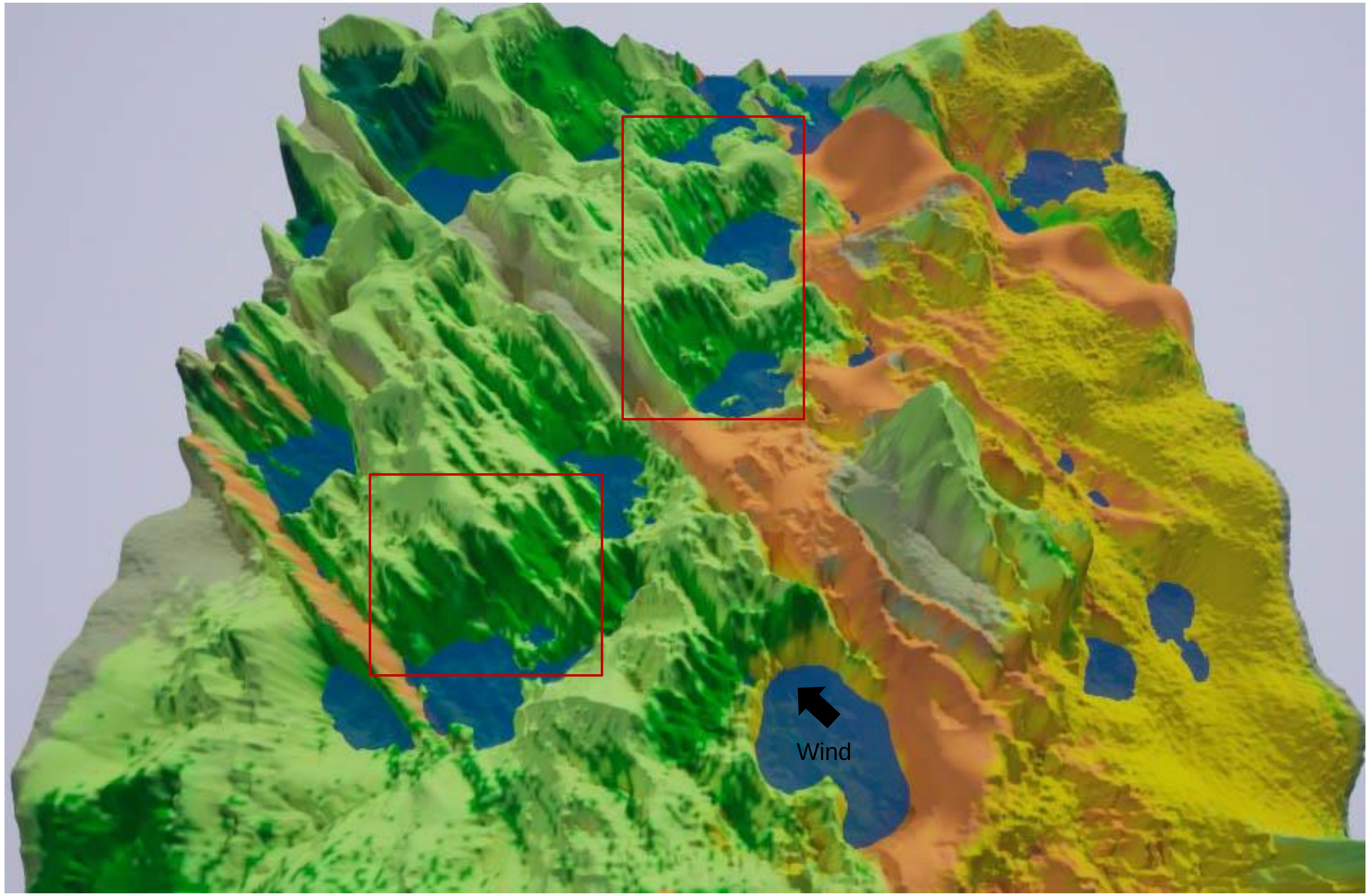

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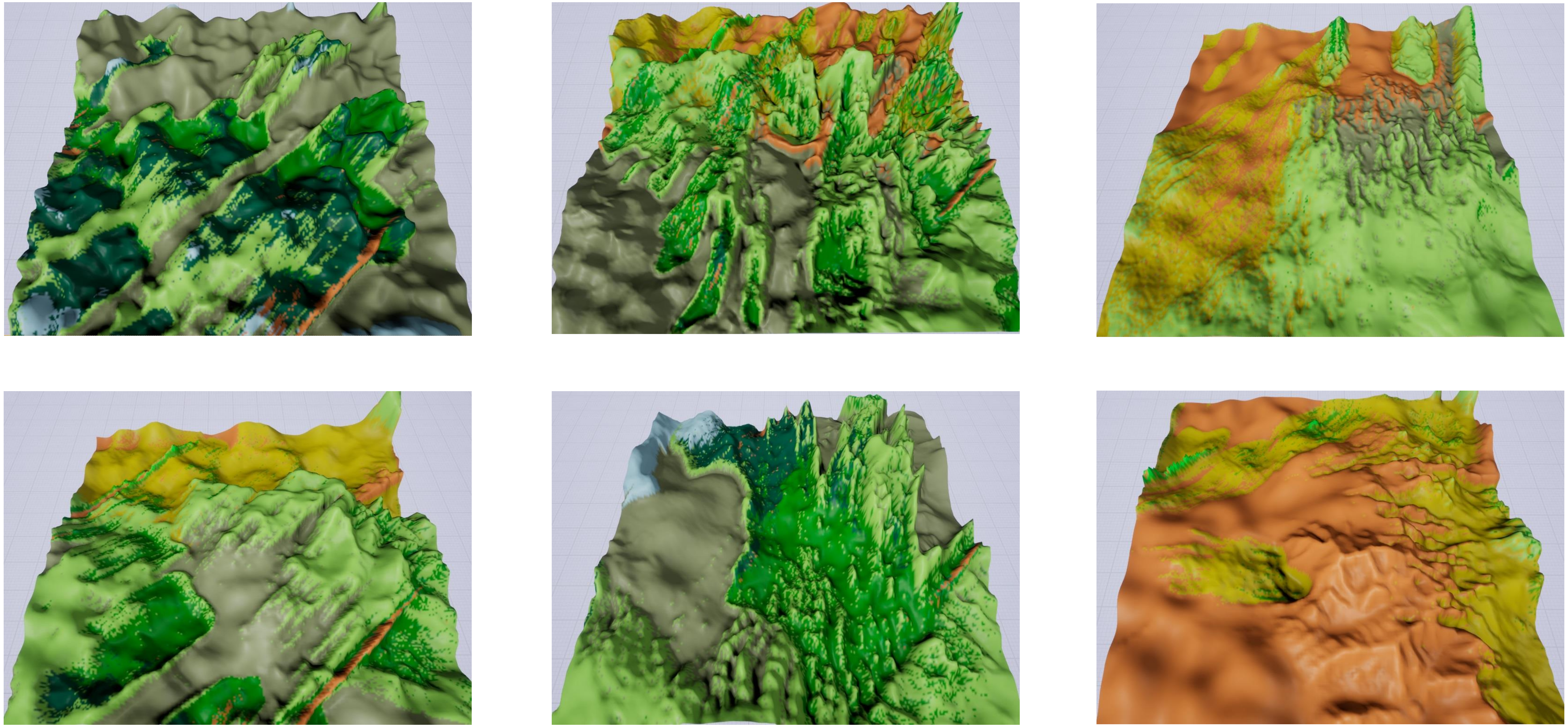

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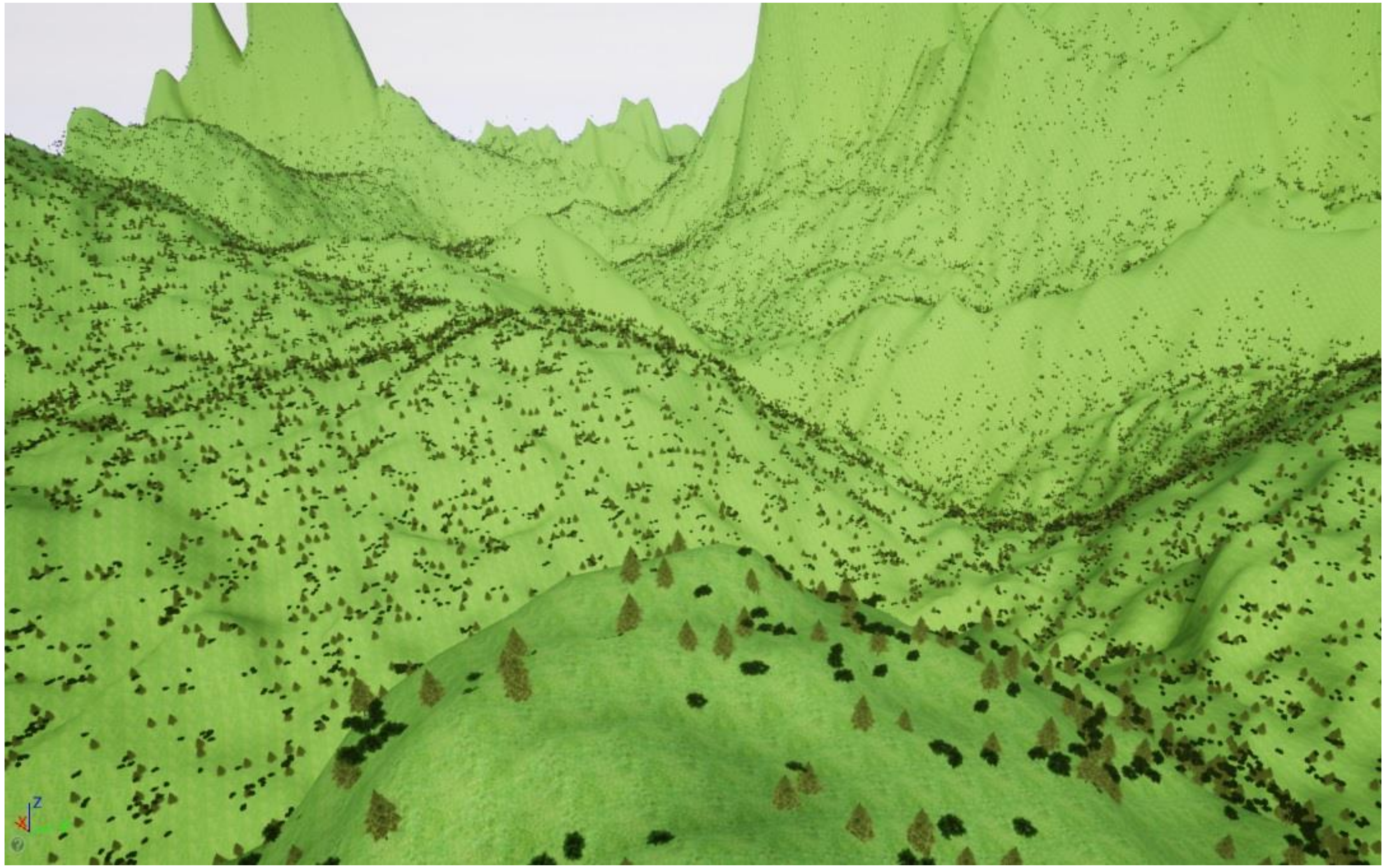


~ 200,000 instances on final terrain

Result: Asset Placement

Shrubs exclusively in shadow of dense tree clusters

Tight clusters of shrubs in open spaces between trees

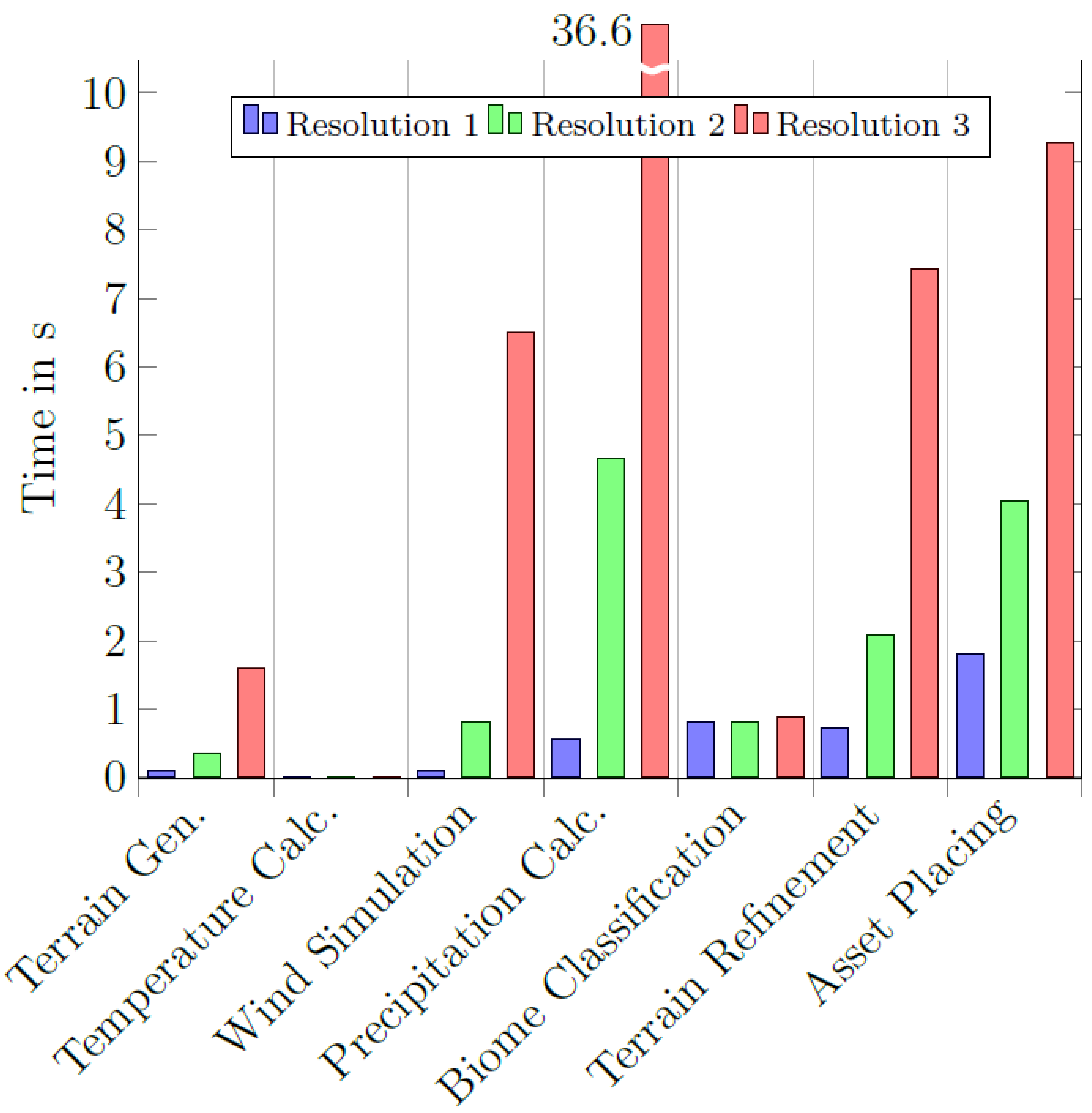
Dense, clumped shrubs around loosely grouped trees

Result: Asset Placement - Seasons

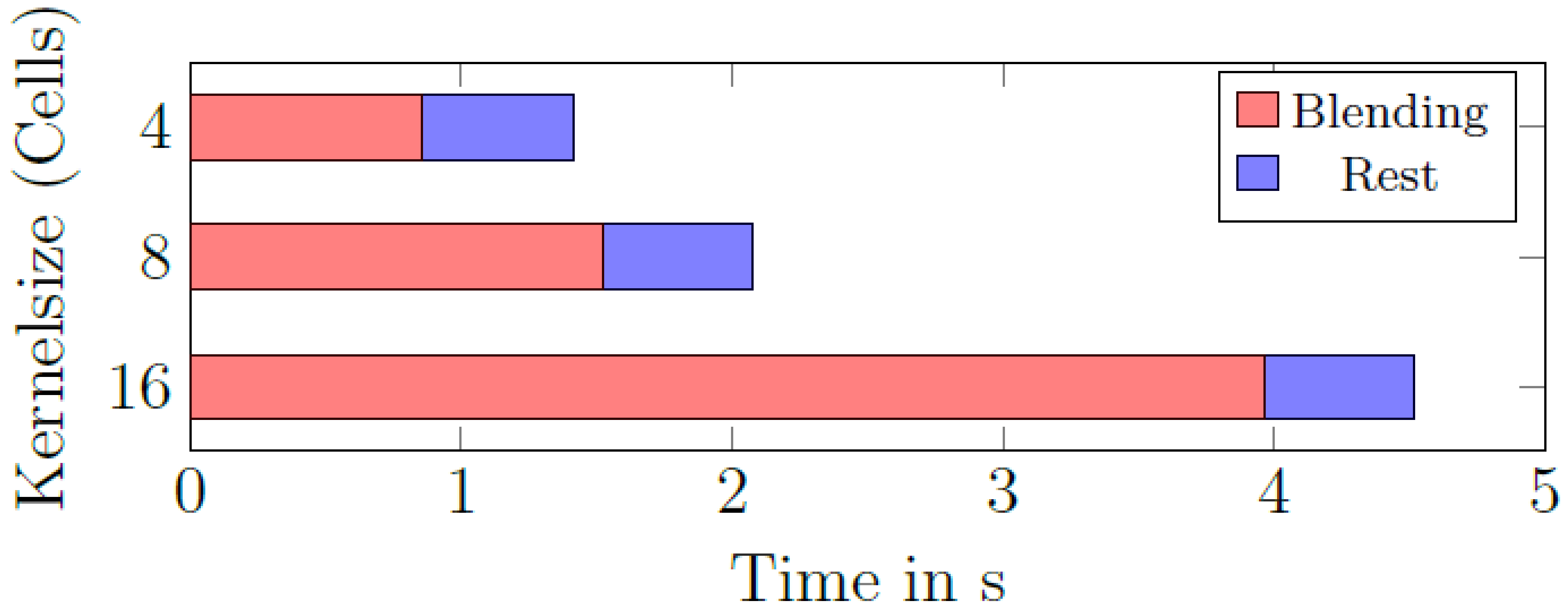
Result: Performance

Complexity:
$O(N \cdot k)$ - N: # cells
k: # iterations

Pipeline Step	Res. 1	Res. 2	Res. 3
Terrain Gen.	1024	2048	4096
Asset Placing	30	60	120
Rest	128	256	512



Result: Terrain Refinement Performance



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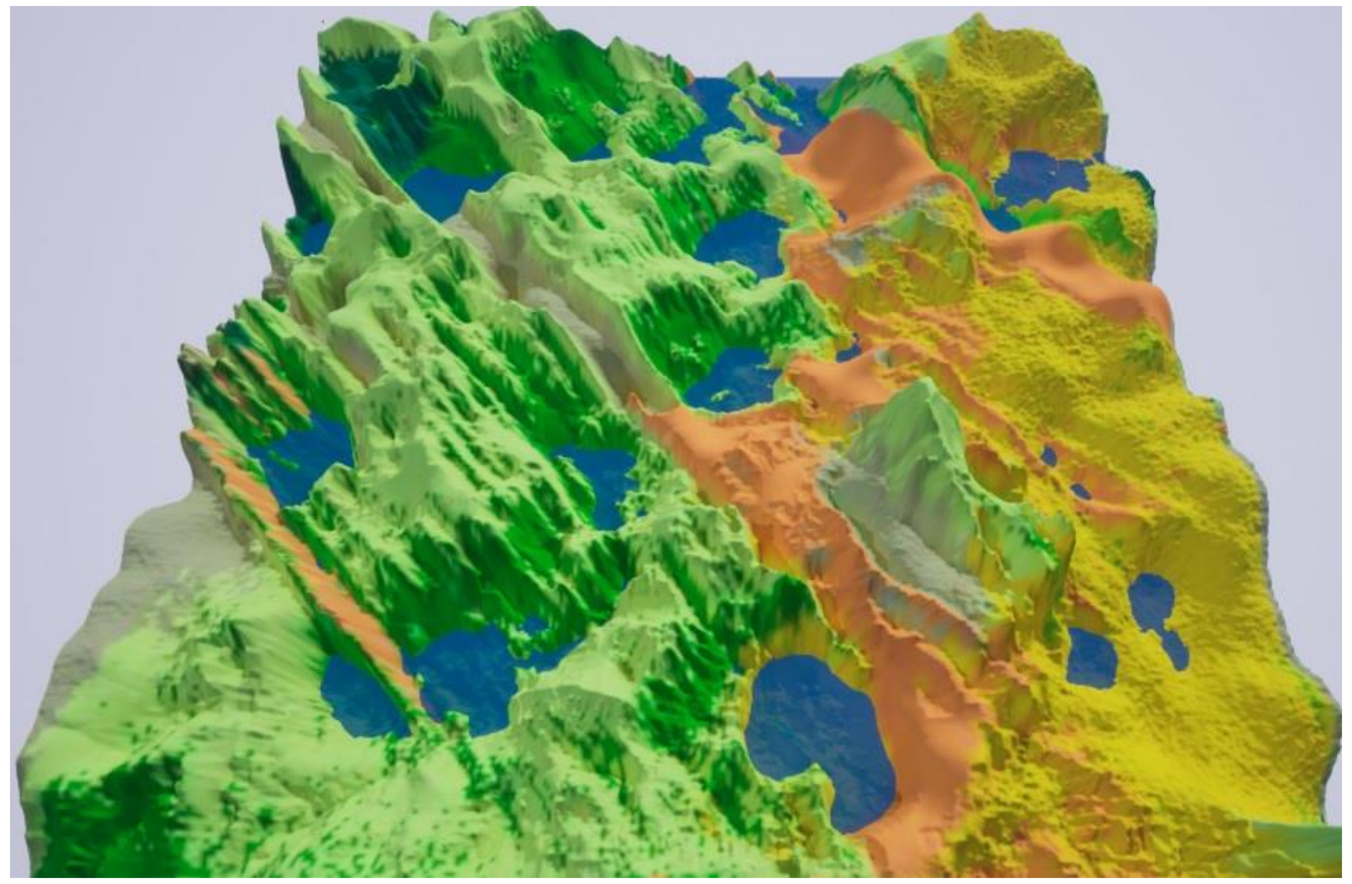

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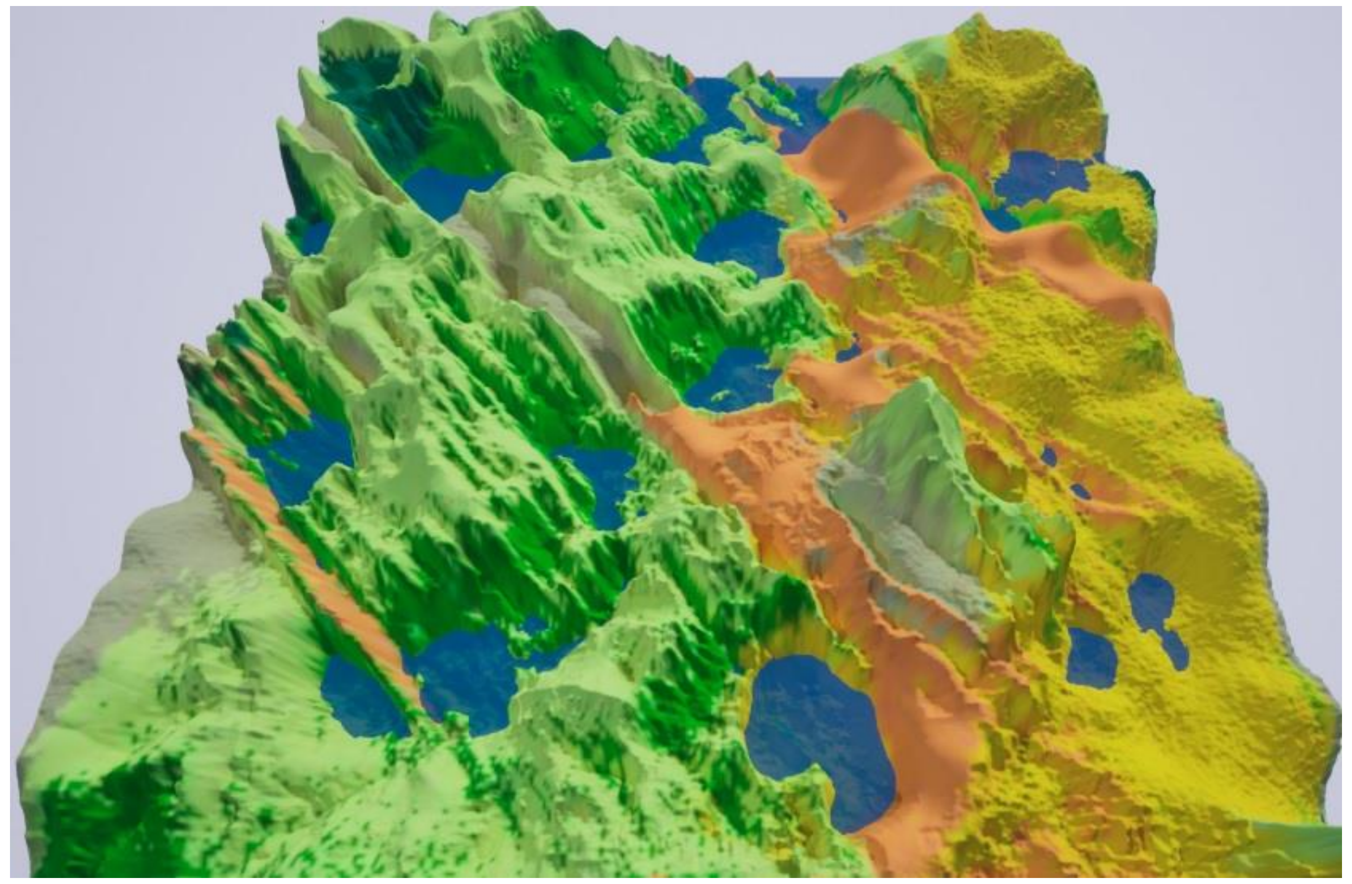

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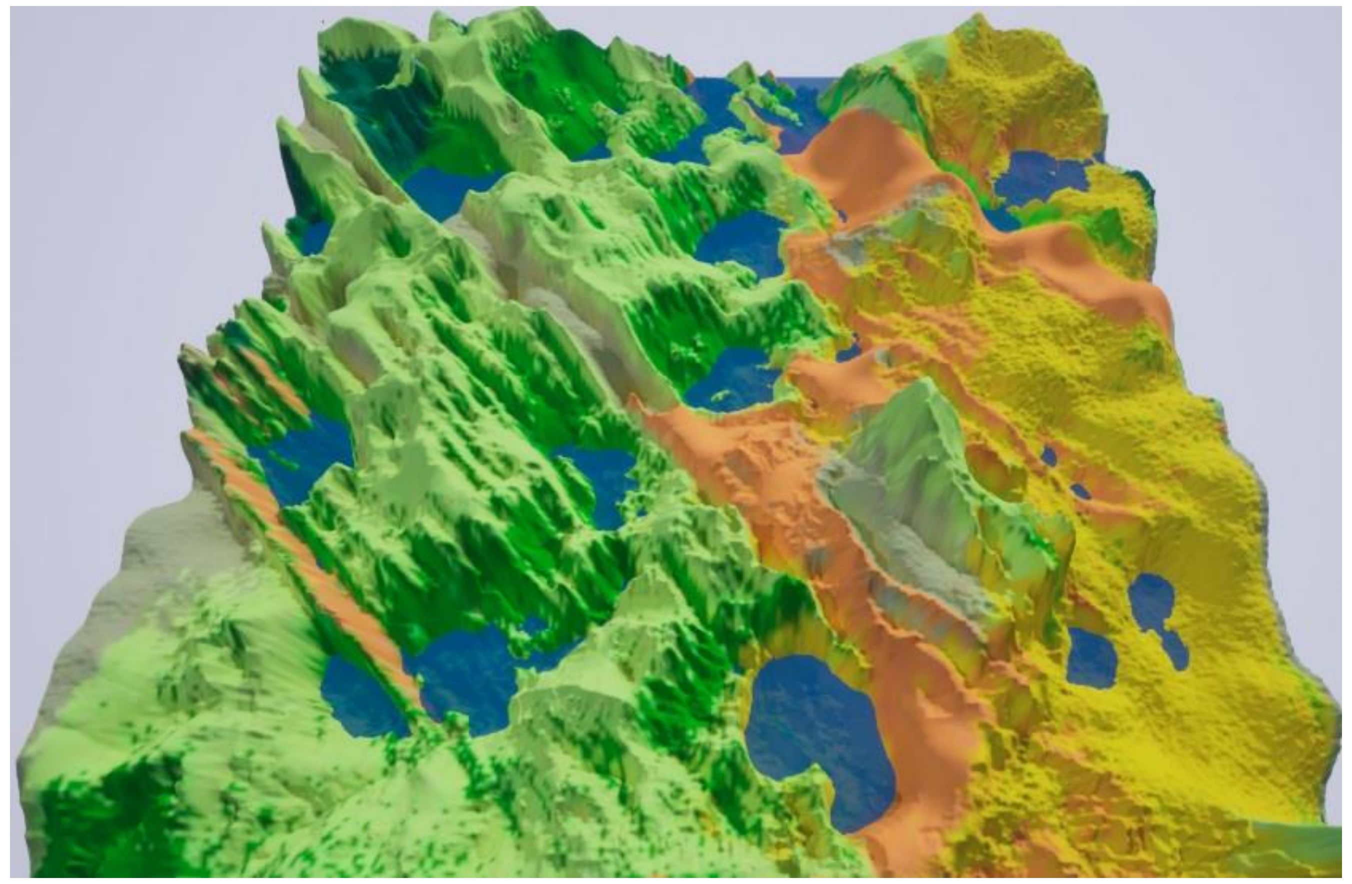

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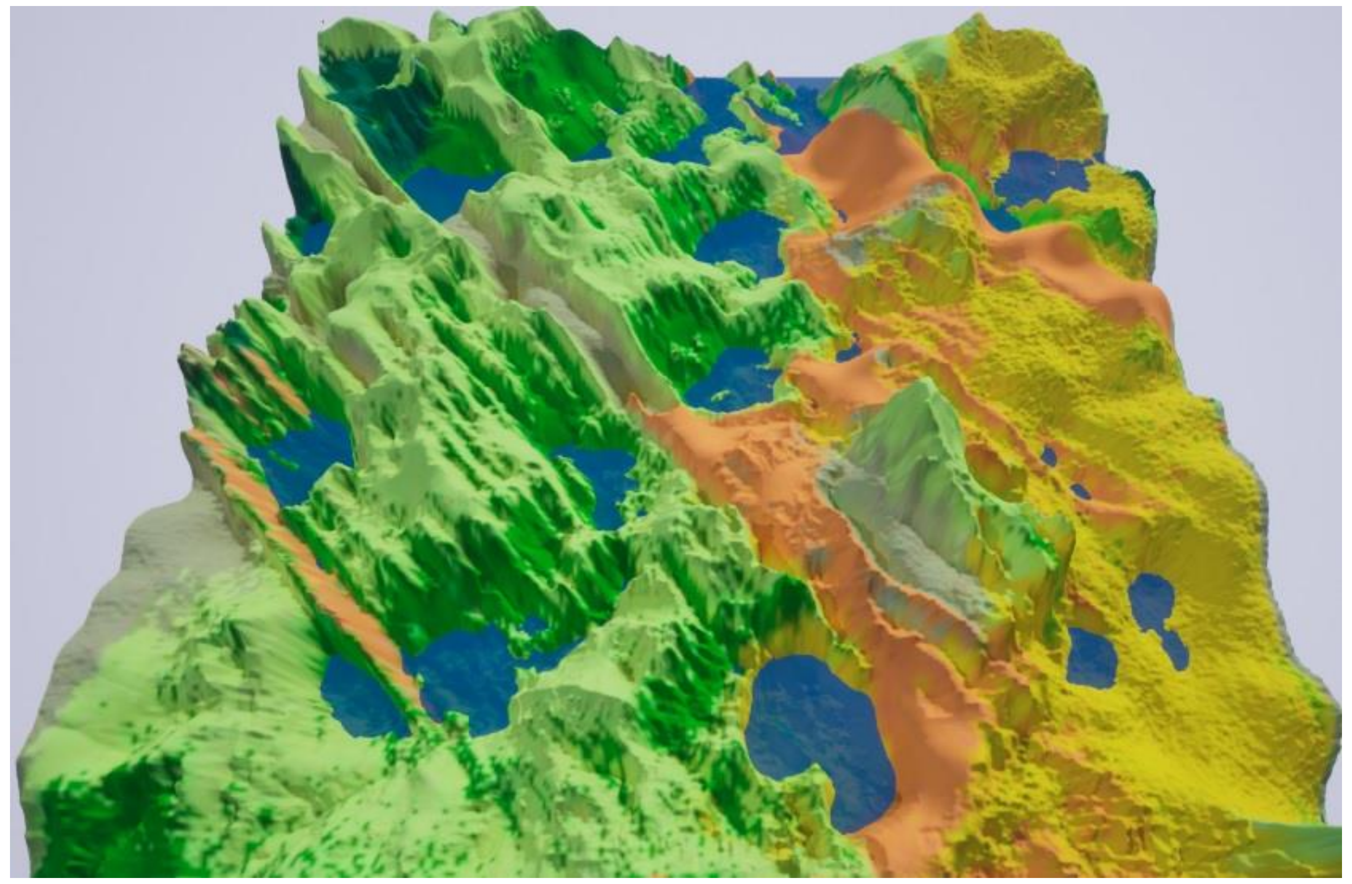
- Unreal Engine 4 integration



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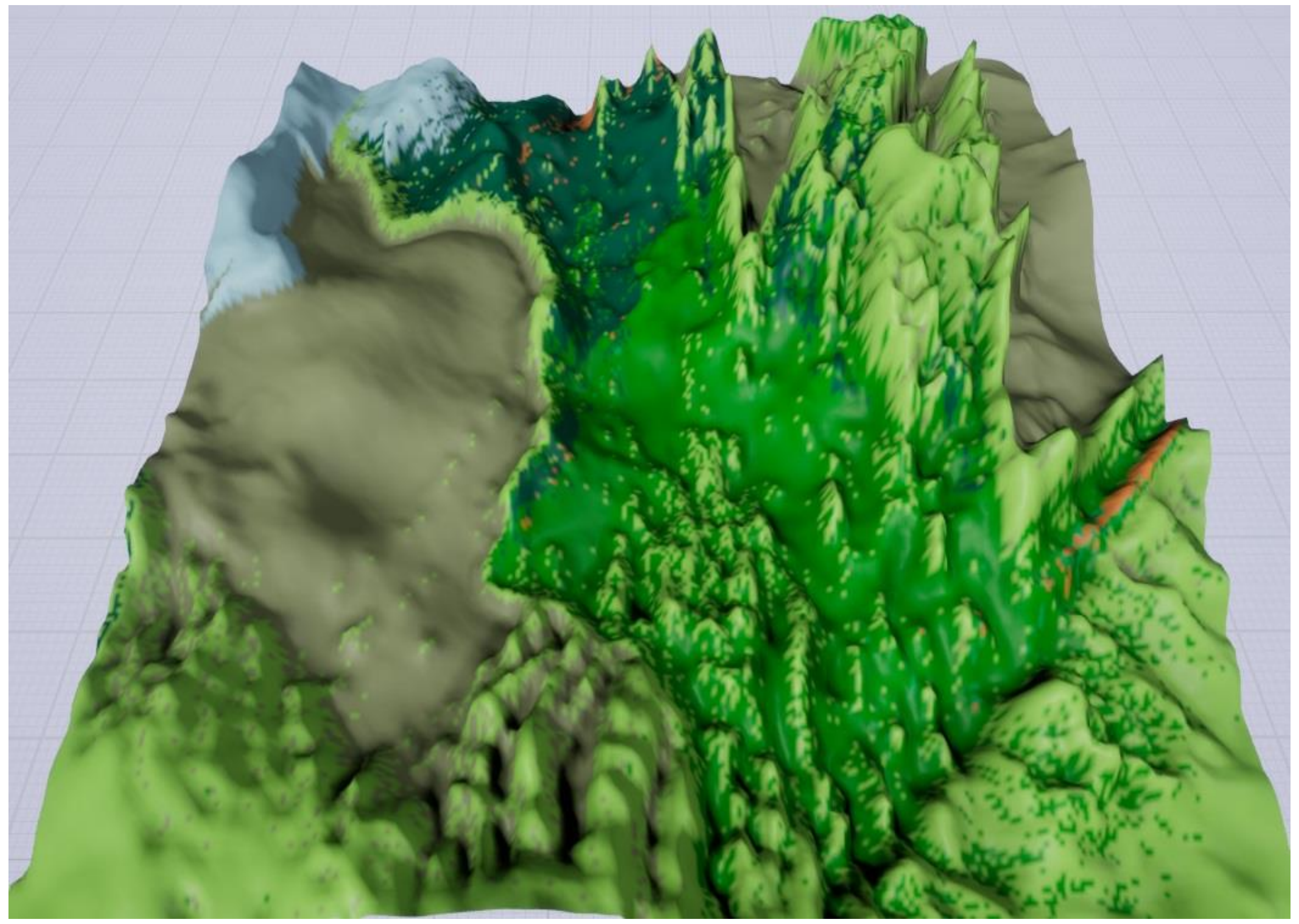
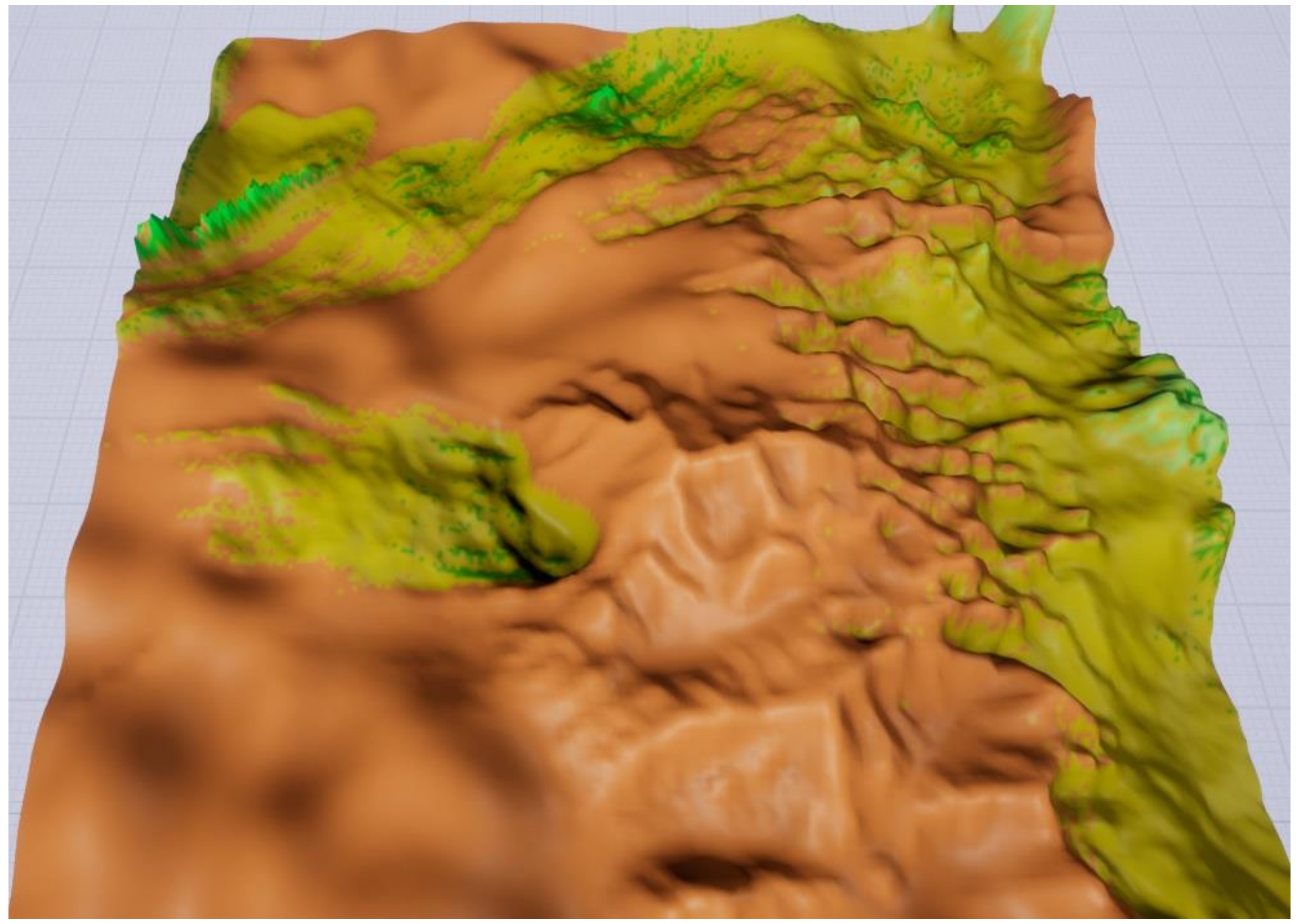
- Improve efficiency, e.g. multi-threading

Bremen

Thank you!

Questions?





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