# Urban Terrain Rendering Using WebGPU with Geoclipmap Level-of-Detail

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## 1. Background and Motivation

Large-scale, high-resolution terrain visualization is critical for urban planning and geospatial analysis. Traditional uniform-grid rendering is memory-intensive and inefficient for web delivery. With the advent of WebGPU, it is now feasible to implement advanced GPU-driven level-of-detail (LOD) techniques directly in the browser. This project will leverage geometry clipmaps (Hoppe 2004) to achieve efficient real-time terrain rendering, and extend it to support urban overlays such as roads and parcels derived from OpenStreetMap (OSM).

## 2. Objectives

- Implement a WebGPU-based terrain renderer using the geoclipmap LOD algorithm.
- Integrate OSM vector features (roads, parcels, buildings) by conforming them to the terrain mesh in real time.

## 3. Approach

### Phase 1 – Terrain LOD Core

- Ingest elevation tiles (OSM-derived DEMs).
- Construct nested clipmap grids centered on the viewer.
- Use WebGPU compute/vertex shaders (WGSL) for vertex displacement, normal computation, and seamless LOD transitions.

### Phase 2 – Vector Overlay Adaptation

- Load OSM urban elements data (roads, parcels, buildings).
- For roads and parcels, use GPU-based draping: project vector vertices onto the underlying terrain heights and render them as textured polylines/polygons conforming to slope.
- For buildings, drape the footprint polygon onto terrain, then extrude vertically in shaders to generate flat-roofed/non-warped top, with walls adjusted to local ground variation.

## 4. References

1. Hoppe, H. (2004). Geometry clipmaps: Terrain rendering using nested regular grids. https://hhoppe.com/geomclipmap.pdf
2. Asirvatham, A., & Hoppe, H. (2005). Terrain Rendering Using GPU-Based Geometry Clipmaps. *GPU Gems 2*. https://hhoppe.com/gpugcm.pdf
3. Over, B., Zipf, A., Neis, P., & Lauer, M. (2010). Generating web-based 3D City Models from OpenStreetMap: The current situation in Germany. *Lecture Notes in Geoinformation and Cartography*, 57-71. https://www.sciencedirect.com/science/article/pii/S0198971510000402?via%3Dihub
4. Ruiz, L. A., & Maiz, M. (2018). Real-time Screen-space Geometry Draping for 3D Digital Terrain Models. *ResearchGate*. https://www.researchgate.net/publication/335428761_Real-time_Screen-space_Geometry_Draping_for_3D_Digital_Terrain_Models
5. NASA Earthdata Search. https://search.earthdata.nasa.gov/search
6. OpenStreetMap. https://www.openstreetmap.org/
7. Digital Elevation Model (DEM) generated from Cartosat-1 Satellite Data of India. https://www.data.gov.in/catalog/digital-elevation-model-dem-generated-cartosat-1-satellite-data-india