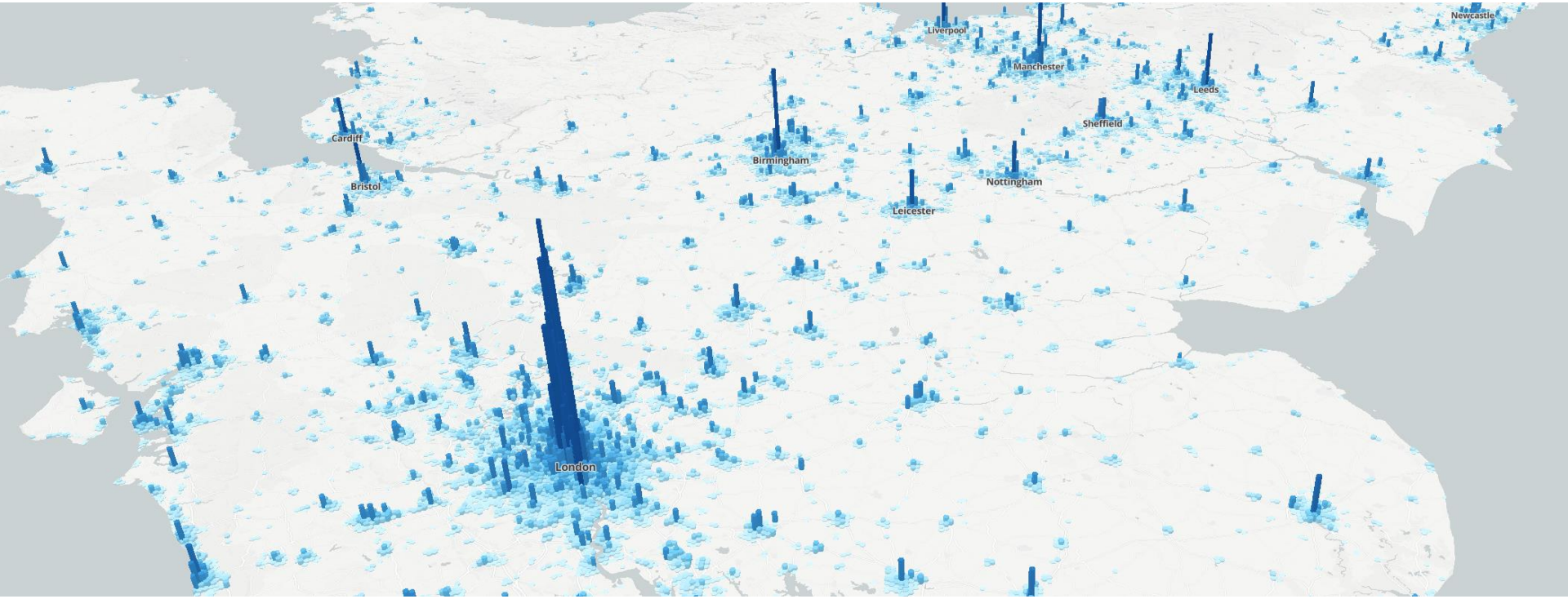
CASA0029: Urban Data Visualisation

Advanced Interactive Mapping: Large Datasets, Animation and 2.5D Visualisation



GB Employment data as hexagon grid, 2011 Census.

Duncan A Smith

Centre for Advanced Spatial Analysis, UCL

Overview

1. **Intro: Advancing Online Mapping**
2. **Large Datasets and Animation**
3. **2.5D/3D Visualisation**

Practical-

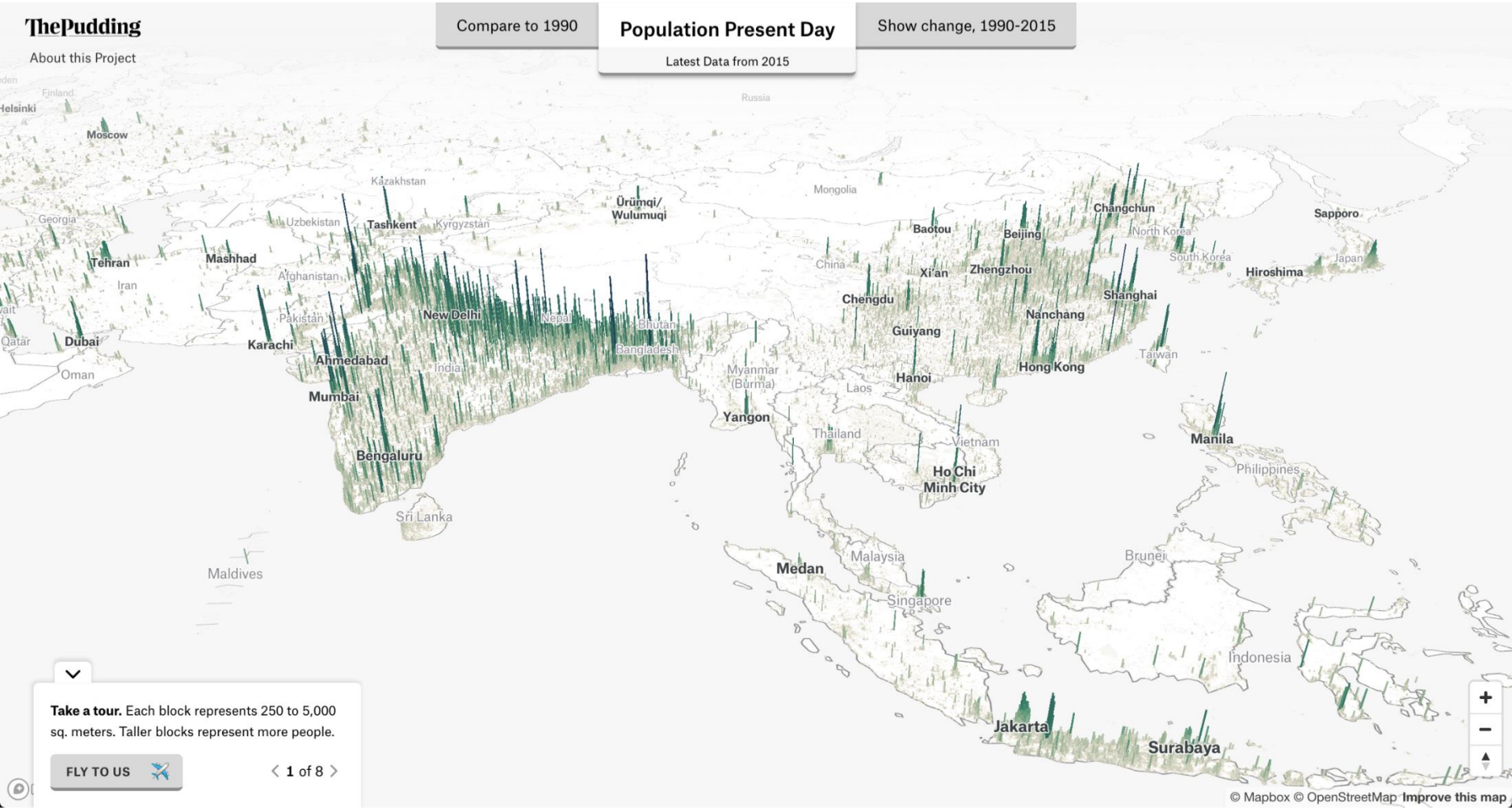
5. 2.5D Visualisation in Mapbox

Intro: Advancing Online Mapping

Various advances in graphics libraries, cloud-services and spatial data creating new possibilities for online spatial data visualisation. Web GL significant advance.

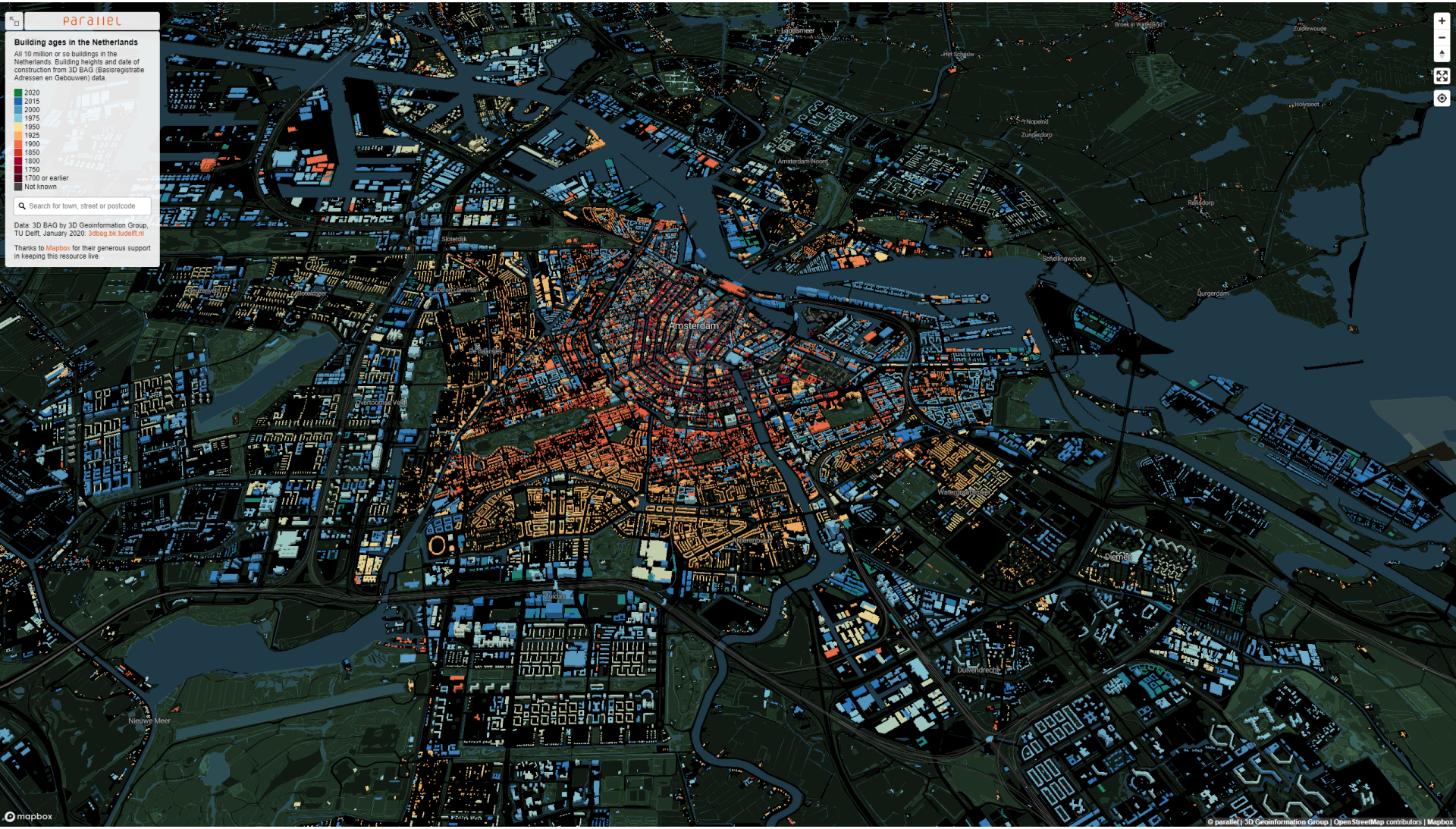
Larger datasets, potential for animation, analytics 2.5D/3D visualisation. Good time for online visualisation experimentation and research…

Global Human Terrain 2.5D Vector Visualisation



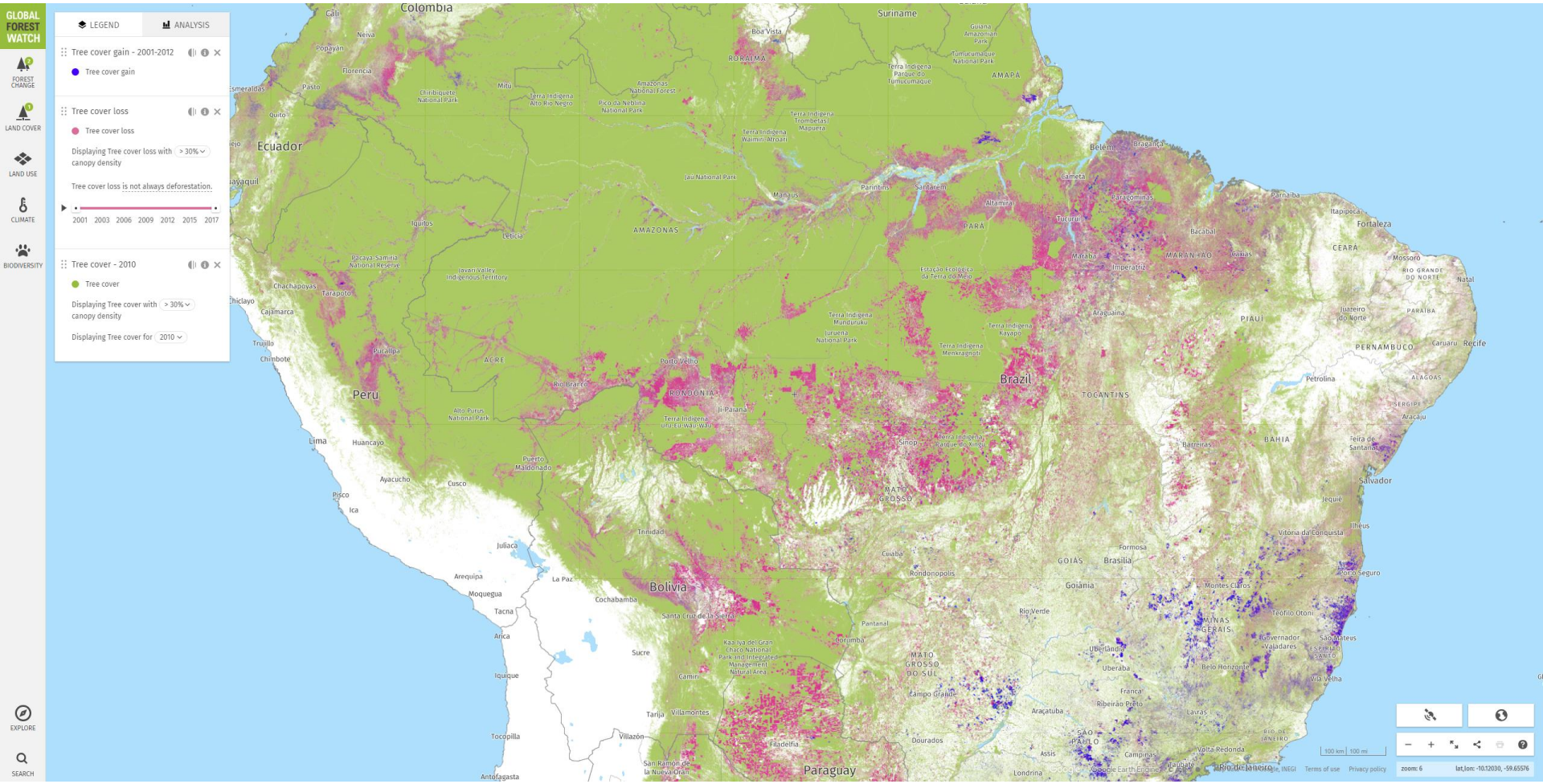
Very large global dataset (Global Human Settlement Layer). Created using Mapbox-
https://pudding.cool/2018/10/city_3d/

Building Level Visualisation



Age of all the buildings in the Netherlands, using Mapbox Vector Tiles. Millions of polygons-
https://netherlands.parallel.co.uk/#13.8/52.365/4.9/0/40 (3D version)
http://code.waag.org/buildings/#52.3605,4.8954,14 (2D version)

Global Environmental Visualisation



Global Forest Watch, important data and analysis on decades of global deforestation- https://www.globalforestwatch.org/

Map and Chart Integration with Narrative

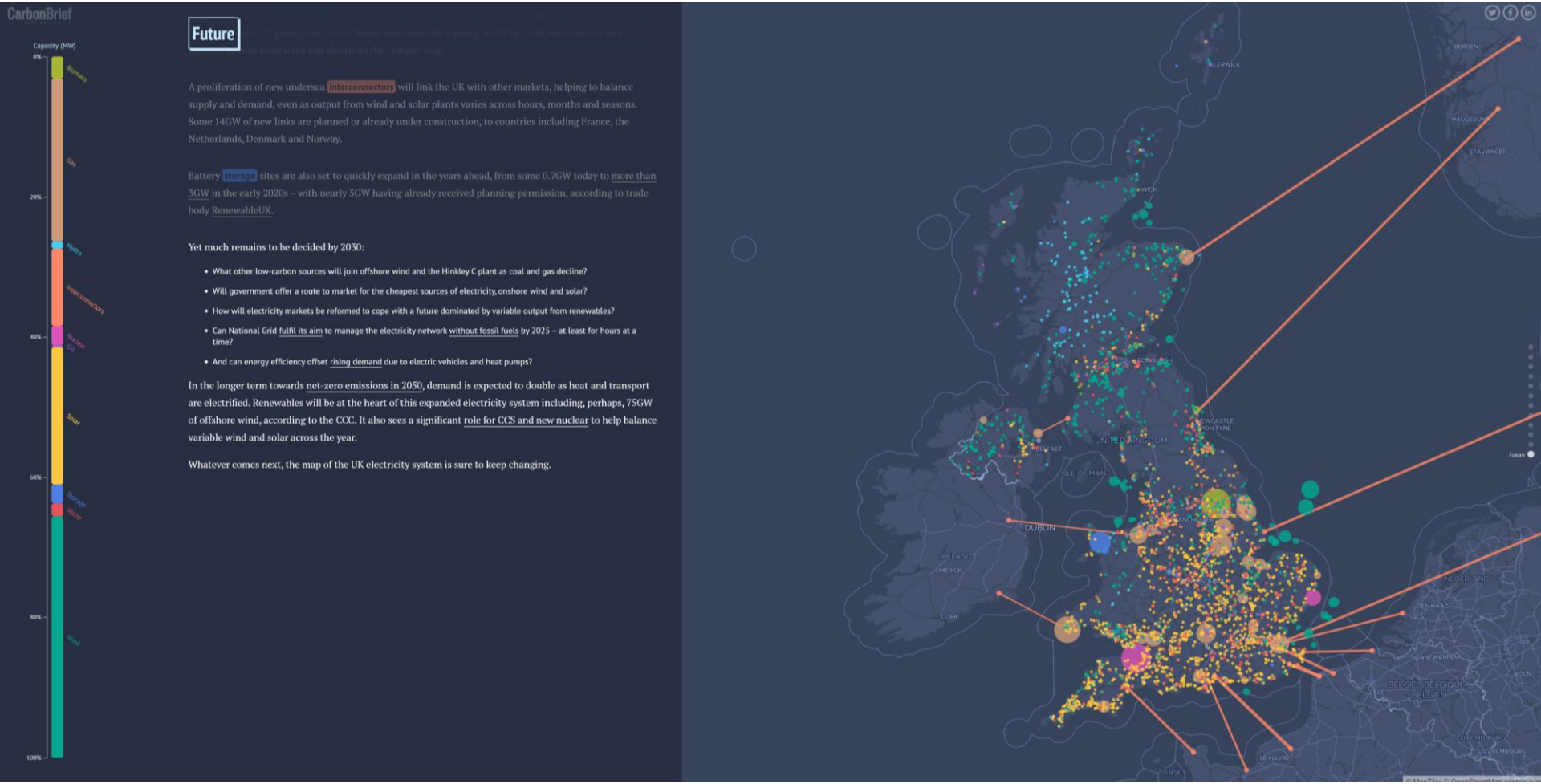


Chart and map integration with linear narrative explanation- https://interactive.carbonbrief.org/how-uk-transformed-electricity-supply-decade/

Some Functionality Still Limited in Web Viz

Spatio-temporal Animation
Not easy to create web animations of lots of transport data points. Trajectory animations still mostly created using desktop software (Unity, Cinema4D…) and shared as movies. Some recent libraries making progress in this area (deck.gl; Carto GL).

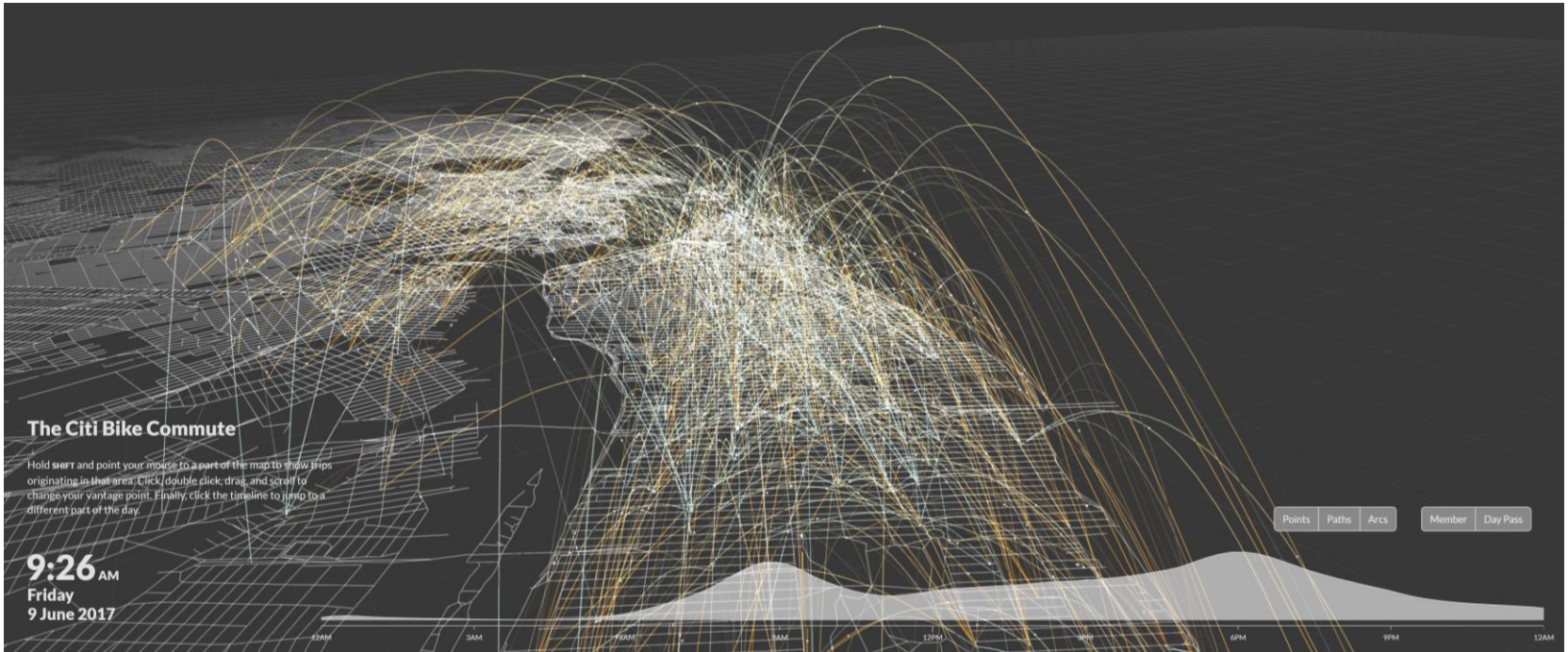
Analytics and Statistics
Basic descriptive stats of features possible. Potential for more advanced combinations of charts and maps providing insightful analysis. Usually requires combining libraries, e.g. mapping & D3.

3D Visualisation
3D web visualisations are improving, but still a very long way from what can be achieved using specialist 3D software.

Avoid Flashy Graphics that Lack Insight

Do not prioritise superficial effects if they fail to help communicate data, promote understanding and insight.

For example, does animation help understanding patterns in NYC Citi Bike?- https://tbaldw.in/citibike-trips/



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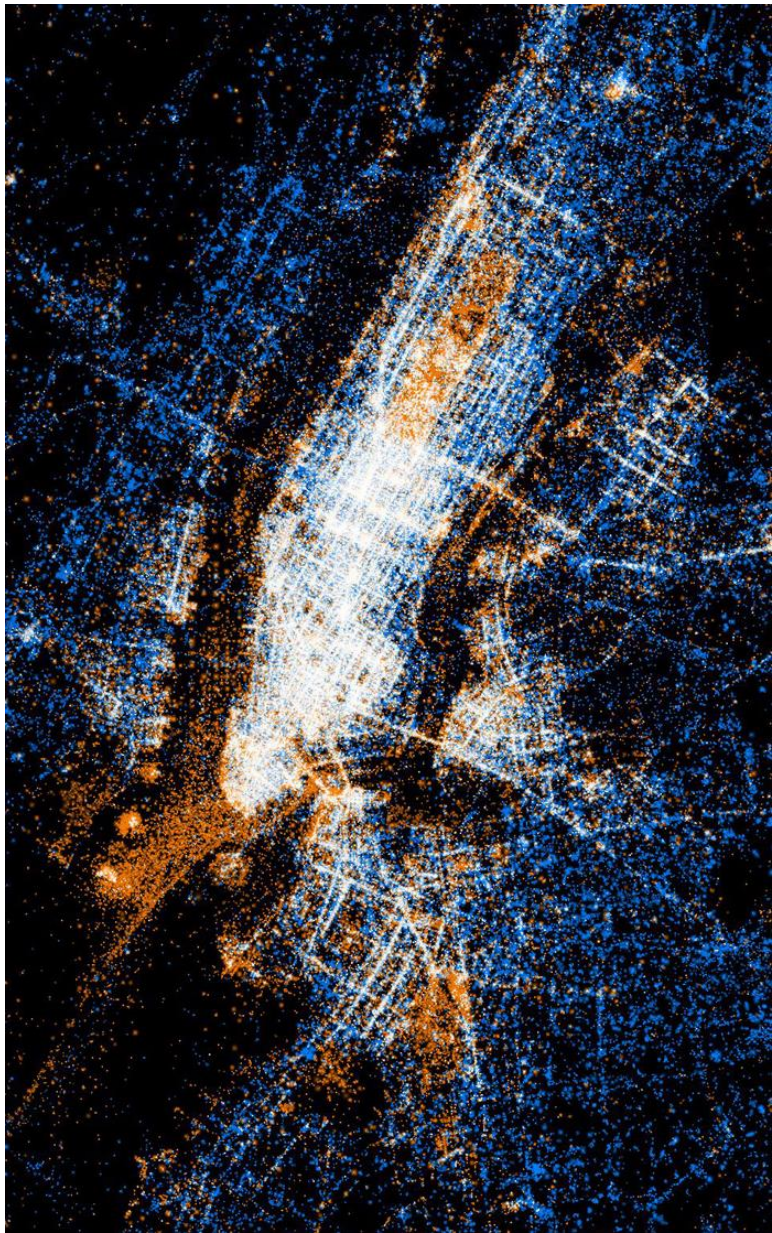
Larger Vector Datasets

Create exploratory sites for larger research datasets- greater level of detail; larger extent; spatio-temporal data.

Raster web visualisations of large spatial databases possible for a long time. But vector data has some advantages: retains GIS attributes and geometry- more analytical possibilities and visualisation flexibility than raster tiles.

Some more preparation needed for larger vector datasets.



Map of geolocated tweets (blue) and Flickr photos (orange) for NYC by Erica Fischer->

Vector Tile Data Limits

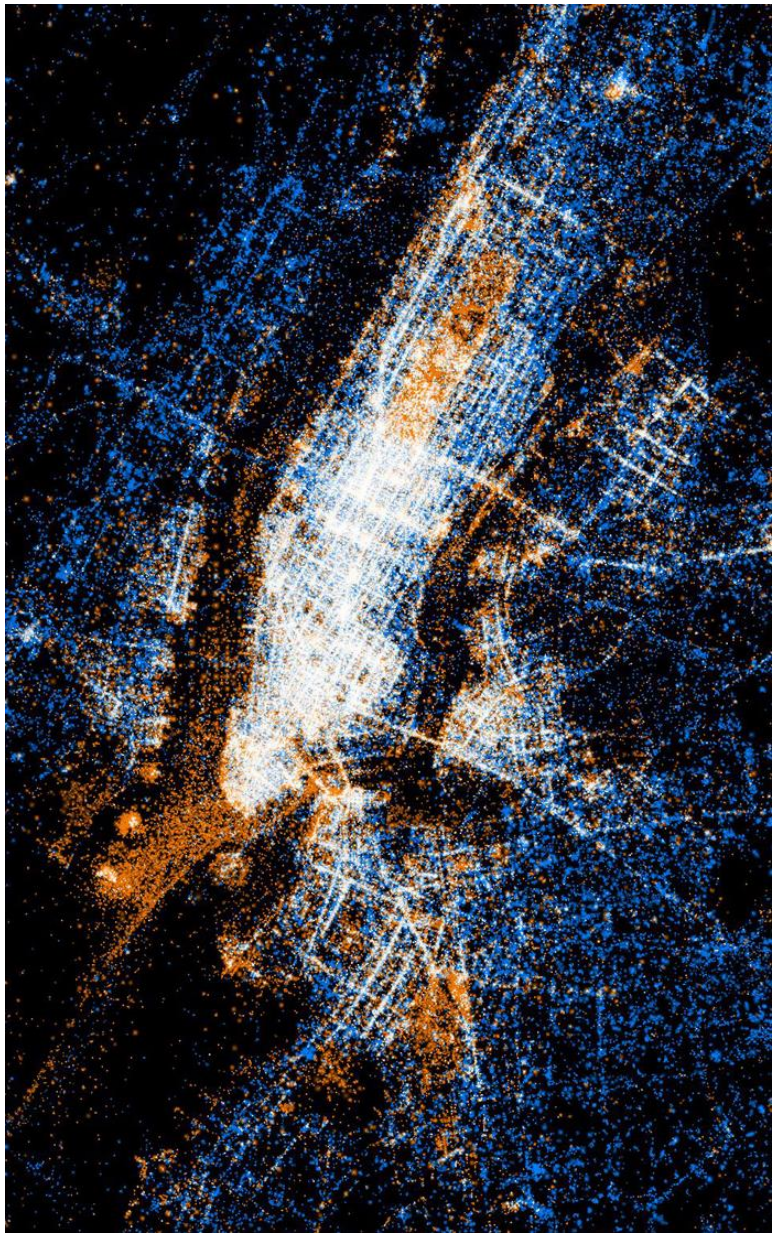
At low zoom levels, potentially millions of features visible: hit memory limits. There is a data limit (500k) for a single vector tile. If there is too much geometry, Mapbox will limit the zoom levels that a Tileset can be viewed at.

Solutions to Vector Tile Limits-

Use Simple Geometry: Points or Regular Grid/Hexagons
Points and tessellations are much smaller to store and less affected by vector tile data limitations.

Generalise (Simplify) the Zone Boundaries
For polygon layers, you can use lower detail zone boundaries. You can change to larger less-detailed zones at low zoom levels. Or you can generalise (simplify geometry) layers. ONS Geoportal also includes generalised zones to download. Or you can generalise yourself in GIS.

Additional free software by Mapbox called Tippecanoe (https://github.com/mapbox/tippecanoe/) can be used to control generalisation of Mapbox Tilesets.



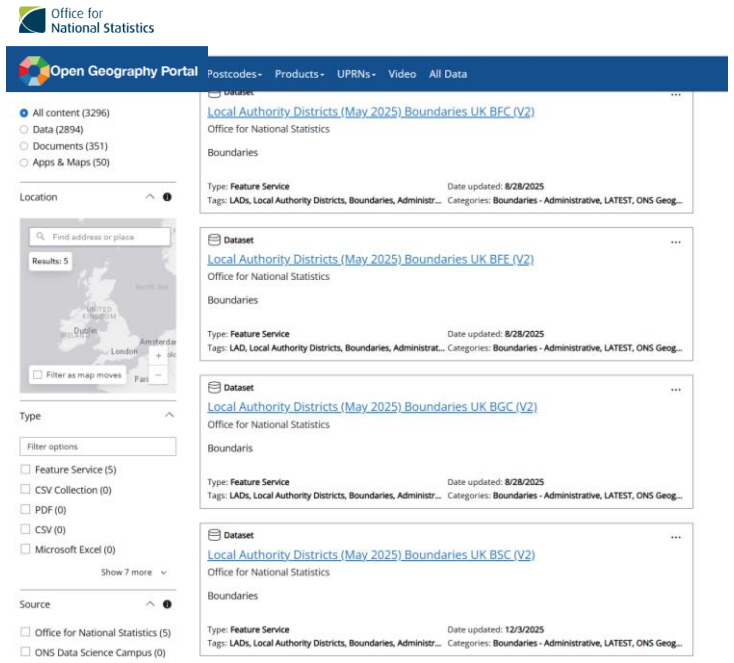
Map of geolocated tweets (blue) and Flickr photos (orange) for NYC by Erica Fischer->

Vector Generalisation of Polygons

Downloading Lower Detail Geometry Layers

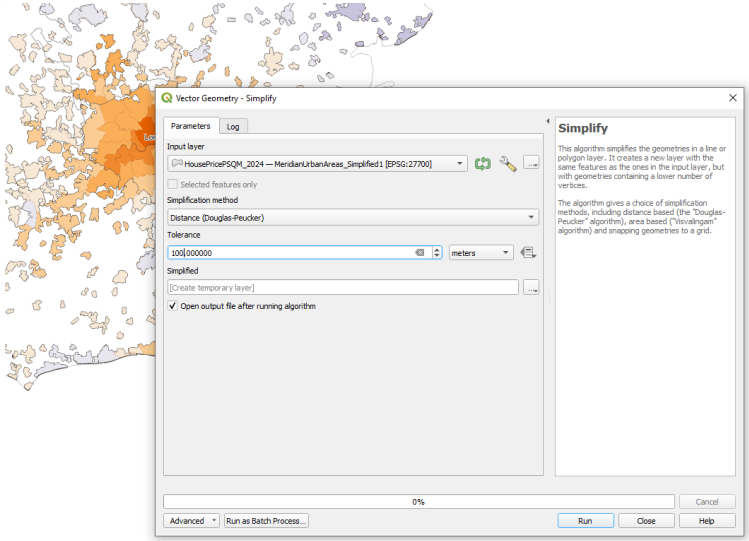
ONS Geoportal offers lots of boundary types. You can choose to map your data at more than one geometry, and use the less detailed option for lower zoom levels. The practical example uses Local Authority boundaries for low zoom levels and switches to MSOA when the user zooms in.

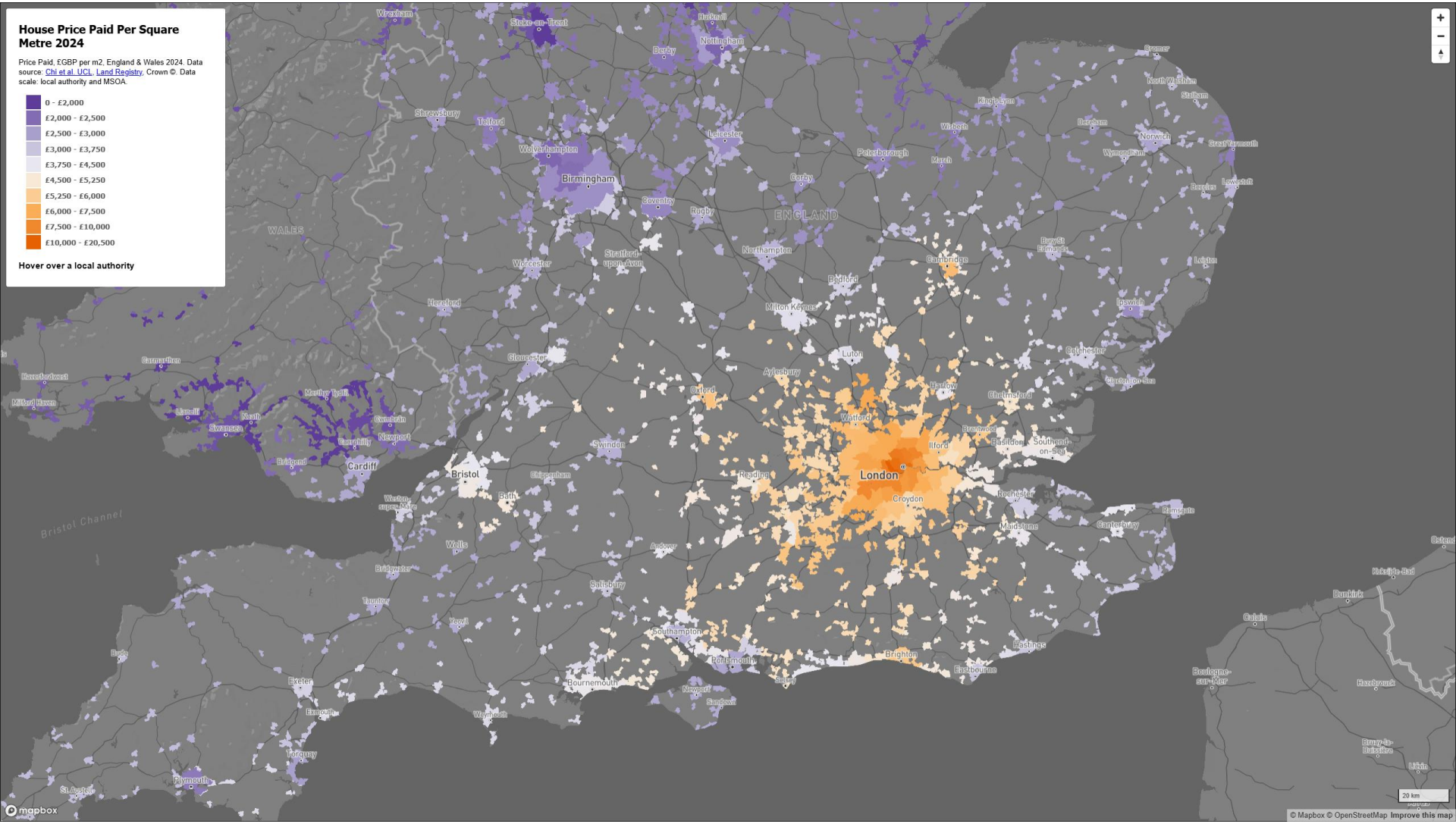
ONS Geoportal also offers two types of generalised layers of UK boundaries. “BGC” is generalised and clipped (to coastal boundaries). “BSC” is super-generalised and the smallest available option.



Generalising Layers in QGIS

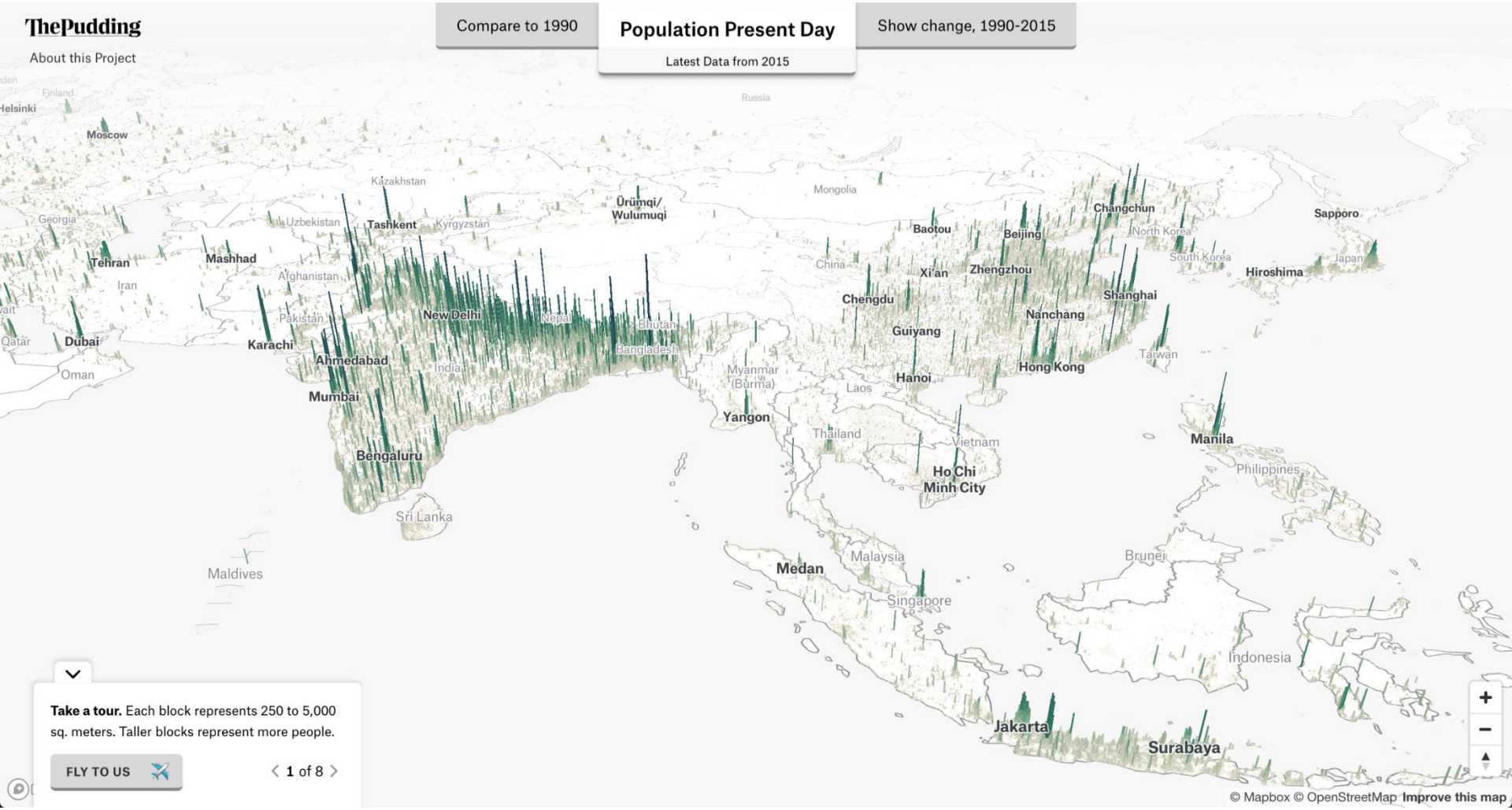
QGIS has a vector geometry tool called Simplify which allows you to reduce the level of detail for polygon layers. You can experiment with different levels of generalisation using the Tolerance option. Again this was used in the practical example to reduce the size of the urban boundaries.





In this example, super-generalised local authority boundaries used for low zoom levels. Also urban boundaries based on low detail Meridian 2 (from Digimap) simplified in QGIS- https://luminocity3d.org/CASATest/PricePSQM2.html

Global Human Terrain 2.5D Vector Visualisation



Very large global dataset (Global Human Settlement Layer). Data on a grid to reduce geometry size. Created using Mapbox and Tippecanoe- https://pudding.cool/2018/10/city_3d/

Animation: Transitions

Transitions are smooth changes from one state to another. Allow greater visual continuity, help viewers understand changes. Advanced transitions with desktop software, more limited currently for web visualisation.

Navigational Transitions

Standard in web mapping libraries to allow ‘flying’ from one location to another. Can be tied together for visual narratives. Smoother with WebGL.

Cartographic Transitions

Some simpler effects possible, such as fading in a new layer. But generally restyling maps involves map disappearing and reappearing without smooth transition.

Geometrical Transitions

‘Morphing’ from one shape to another possible, achievable in some graphics libraries like D3. Only a few good mapping examples such as Carbon Map (cartograms) and What the District?...

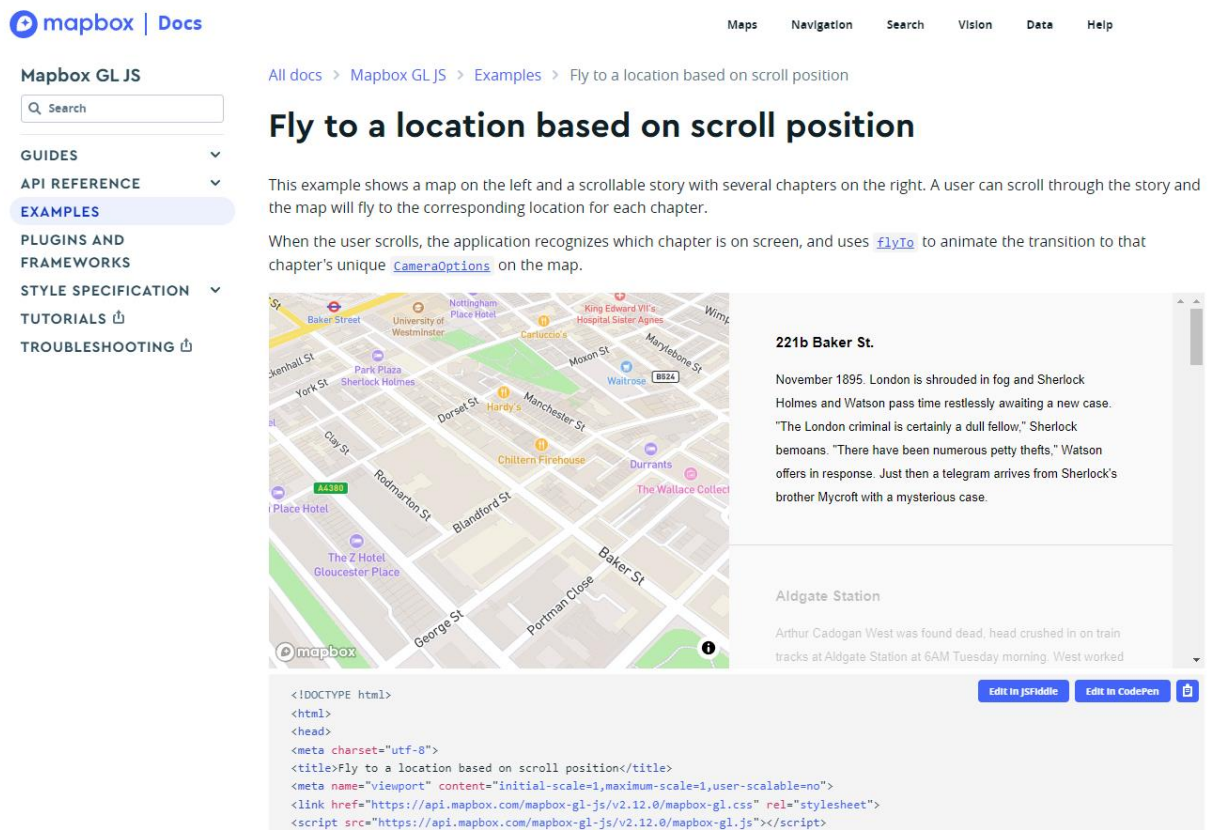
Navigational Transitions

‘Flying’ and zooming from one location to another standard feature in web mapping.

Expanded into ‘story maps’; narratives that guide the user through a map or visualization.

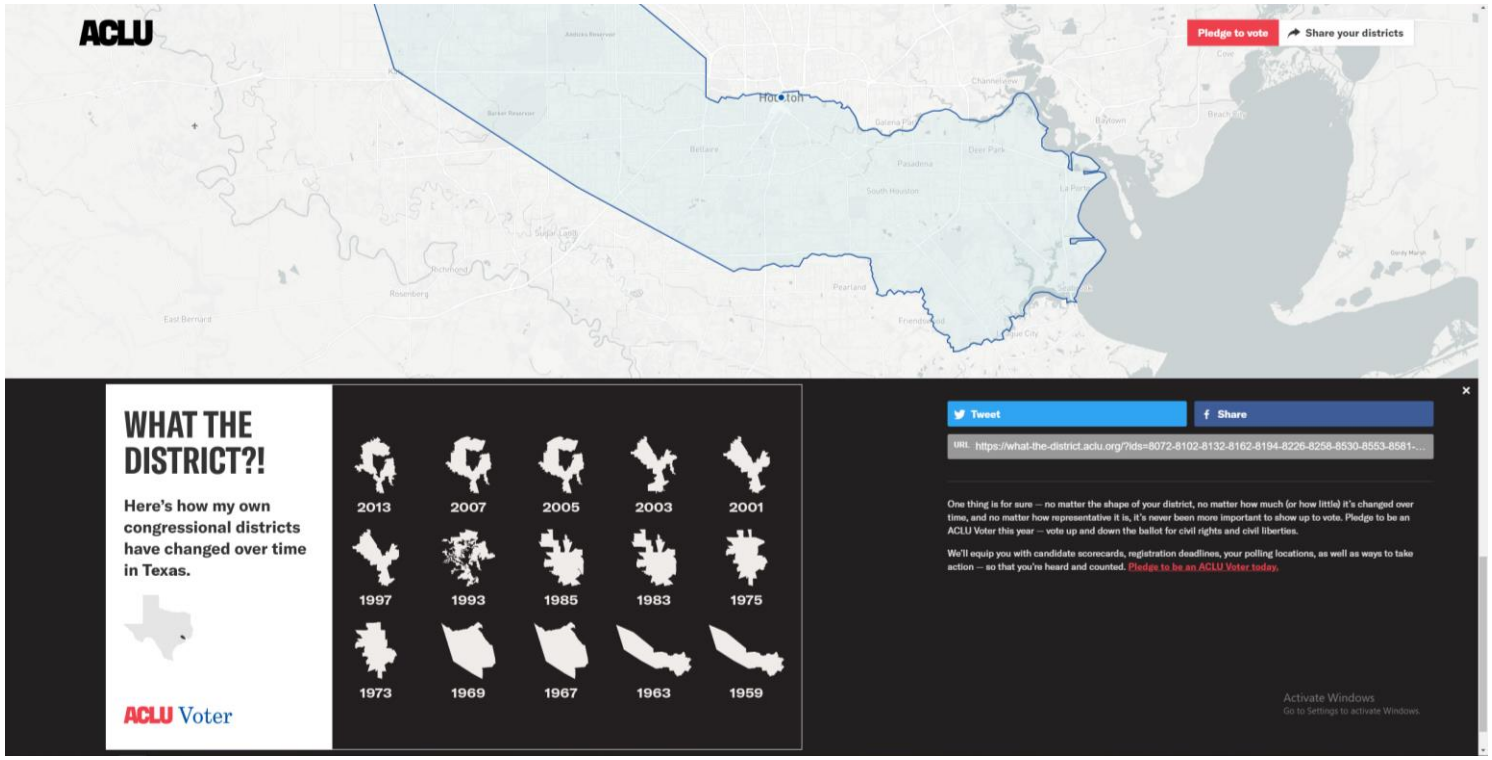
Some good Mapbox GL examples, also ESRI Story Maps examples-

https://docs.mapbox.com/mapbox-gl-js/example/scroll-fly-to/



Geometrical Transitions

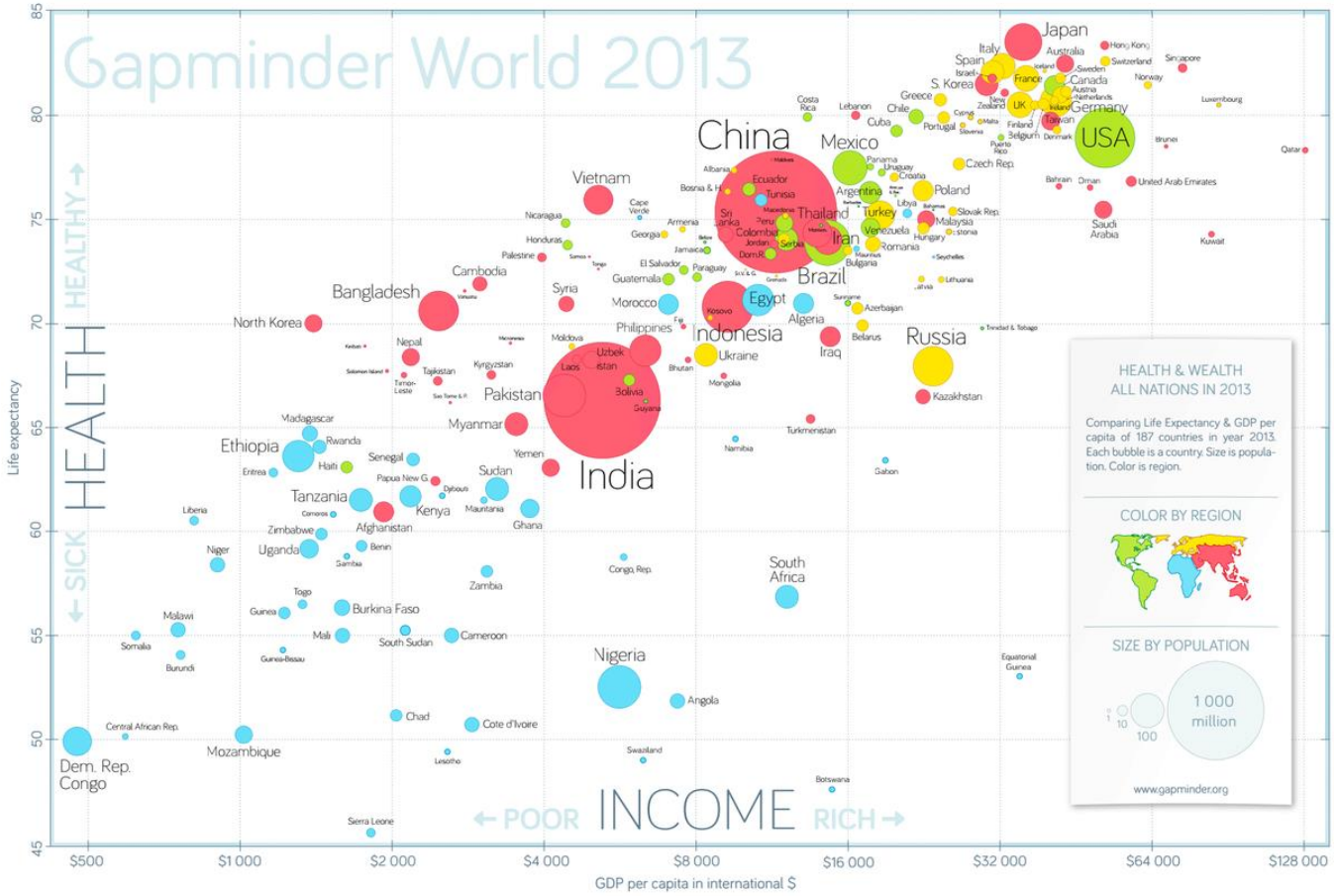
Not standard functionality on web maps. Can do simple animations of single points, but generally limited.
More advanced geometrical transitions relevant to more specialist visualisations such as Cartograms.



Uses geometrical transitions to highlight gerrymandering in US congressional districts- https://what-the-district.aclu.org/

Transitions in Interactive Charts

Used to represent change over time, and for changes in axis dimensions. Gapminder (Hans Rosling) is a famous example of demographic change over time (discuss more next week)- https://www.gapminder.org/tools/



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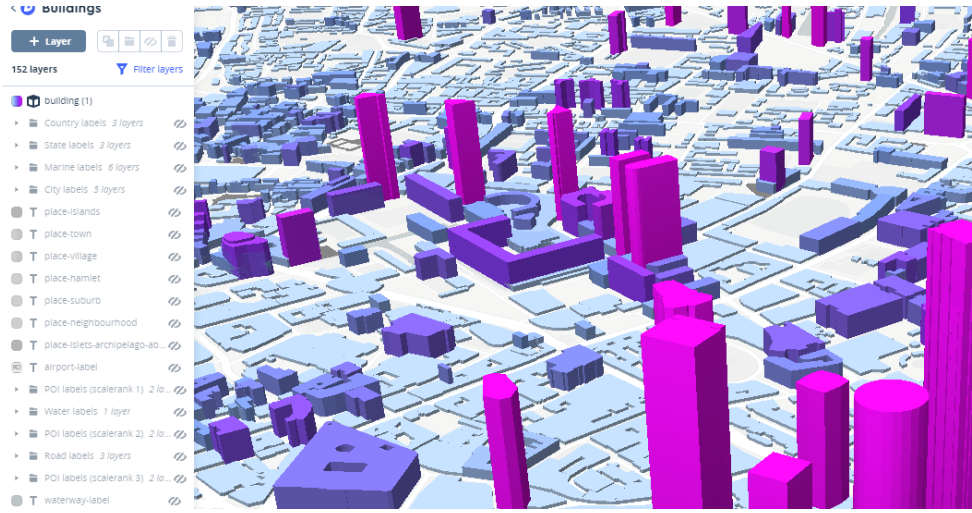
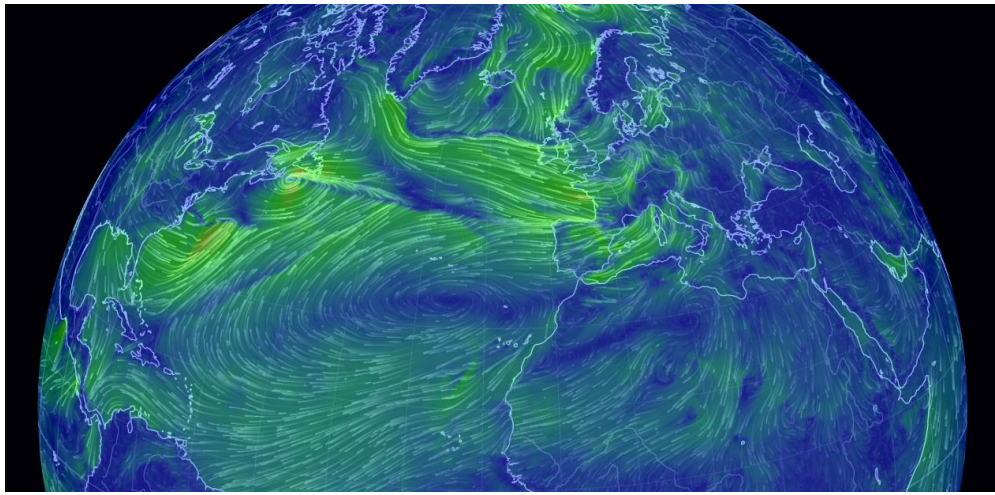
2.5D & 3D Visualisation

WebGL libraries offering many new possibilities for 3D visualisation. Mapping WebGL libraries often 2.5D rather than full 3D functionality.



There are a series of JS libraries with full 3D graphics capabilities, such as Three.js and Cesium.js. Expanding capabilities of web visualisation.



3D Visualisation Applications

Lots of specialist areas use 3D. Some areas compatible with interactive web visualisation approaches, others more complicated, movie-based visuals. Will discuss 3D further in later lecture with Valerio

1. 2.5D/3D Thematic Mapping

Communicating density, magnitude, multiple layers. Global environmental data on 3D globes. Increasingly possible in web browsers.

2. Architectural Rendering- Communicating Built Form

Often use photo-realism techniques for architectural renders. Web vis libraries cannot compete with specialised 3D graphics tools. Increasingly AR/VR applications.

3. Analytical 3D City Models

Developing research area, used for example in energy modelling, pollution, real estate. Traditionally desktop software based, but web possibilities using more abstract / diagrammatic visualisation styles.

1. Thematic Mapping 2.5D

Useful addition to traditional 2D thematic mapping:

Communicate Magnitude
Extrusion of 2D polygons can show variables like density in an engaging and legible way. Arguably viewer can appreciate variation in magnitude more accurately than via colour alone.

Show Multiple Data Layers
'Stack' data layers to show relationships; compare data with urban form

Challenges with 2.5D
Can create occlusion problems; need to be careful (some data viz. researchers argue should avoid).

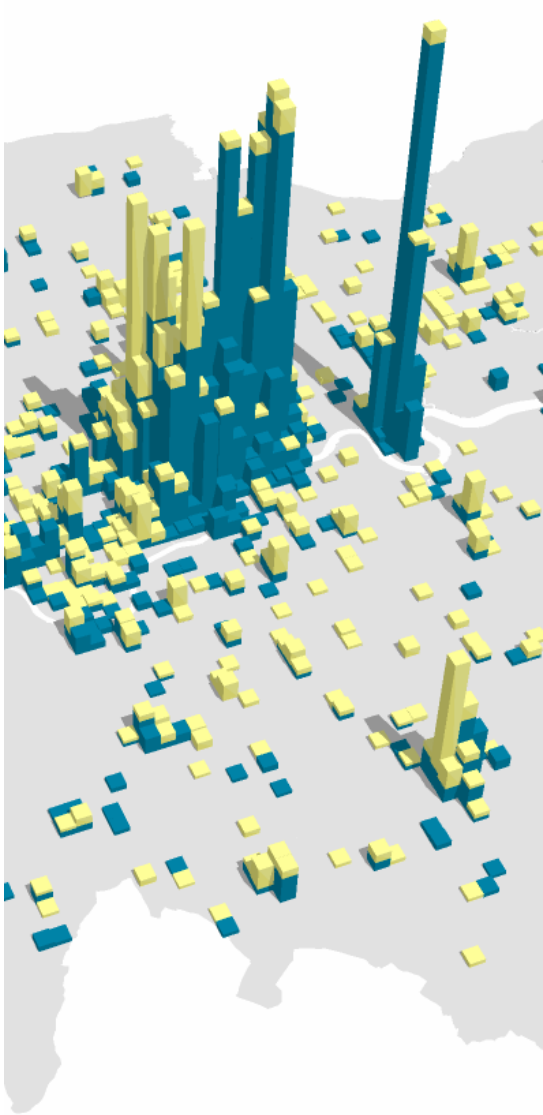
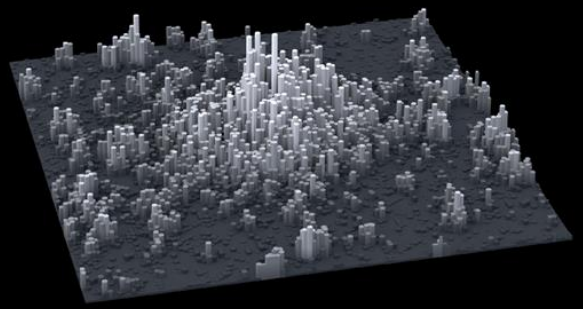
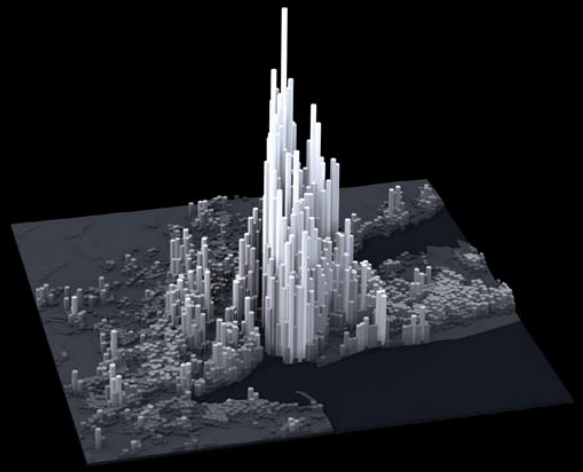


Image created for LSE Cities, using ArcScene and Artlantis (architectural renderer)

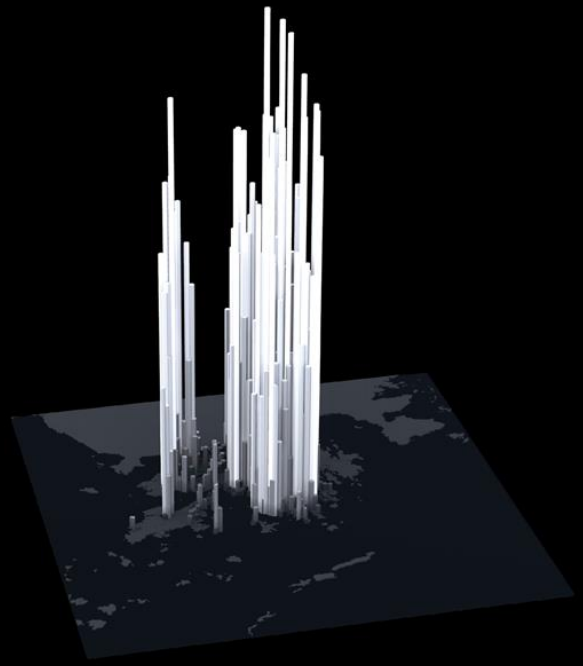
Global Diversity of Urban Form



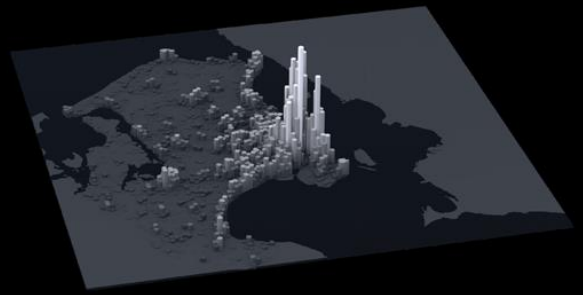
LONDON peak 27,100 pp/km²



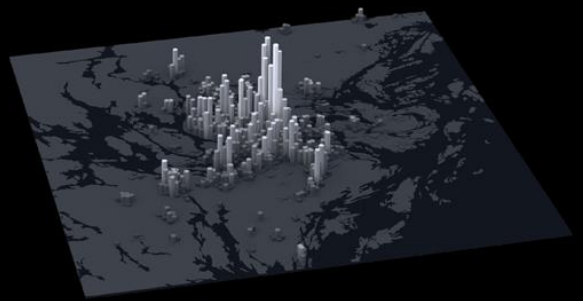
NEW YORK peak 59,150 pp/km²



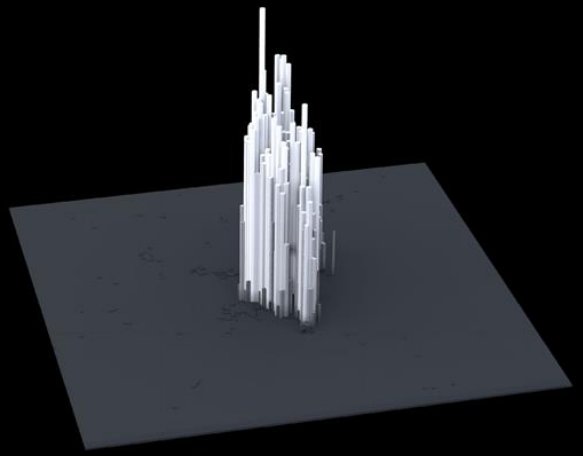
HONG KONG peak 111,100 pp/km²



COPENHAGEN peak 24,050 pp/km²

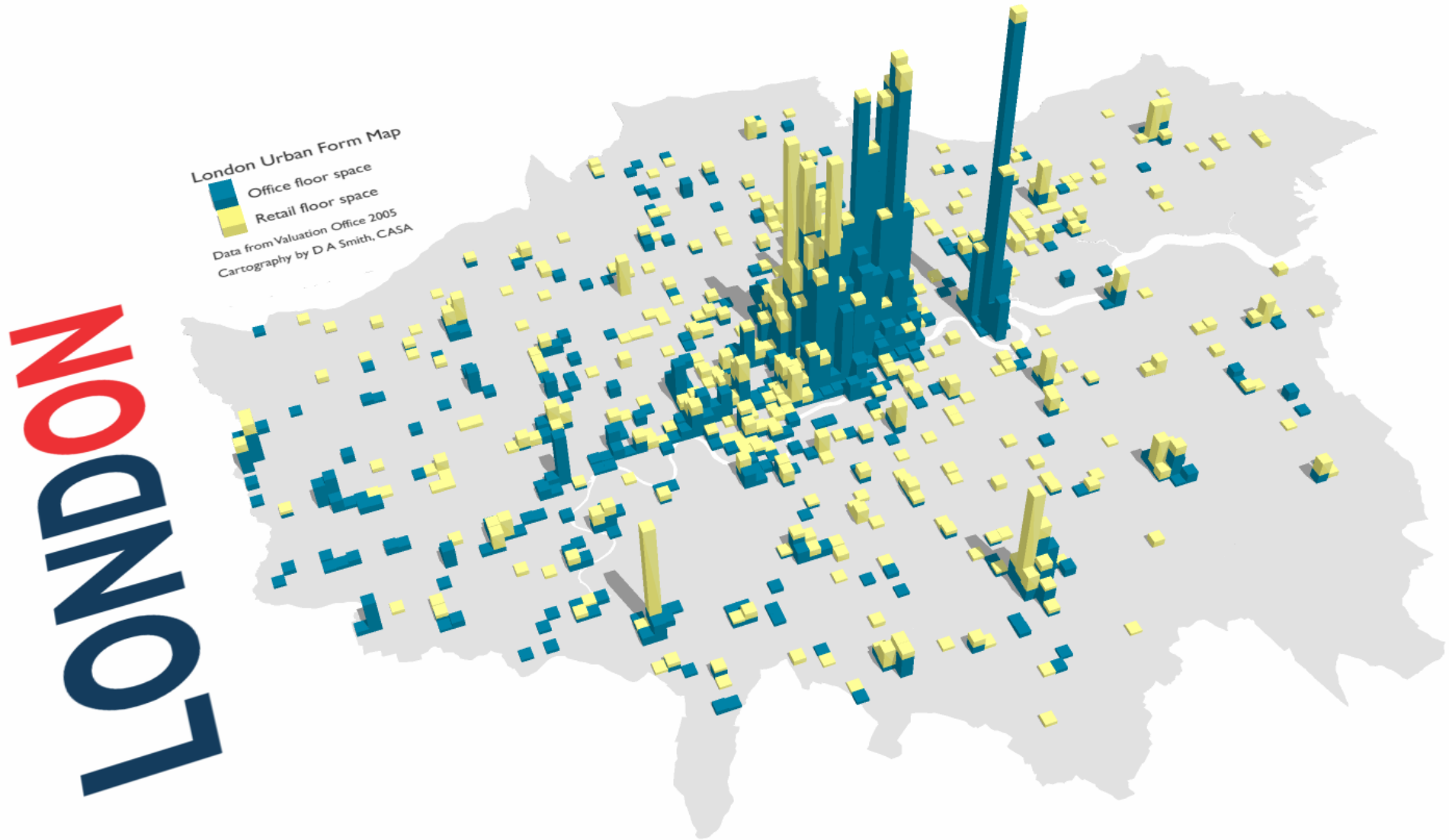


STOCKHOLM peak 24,900 pp/km²

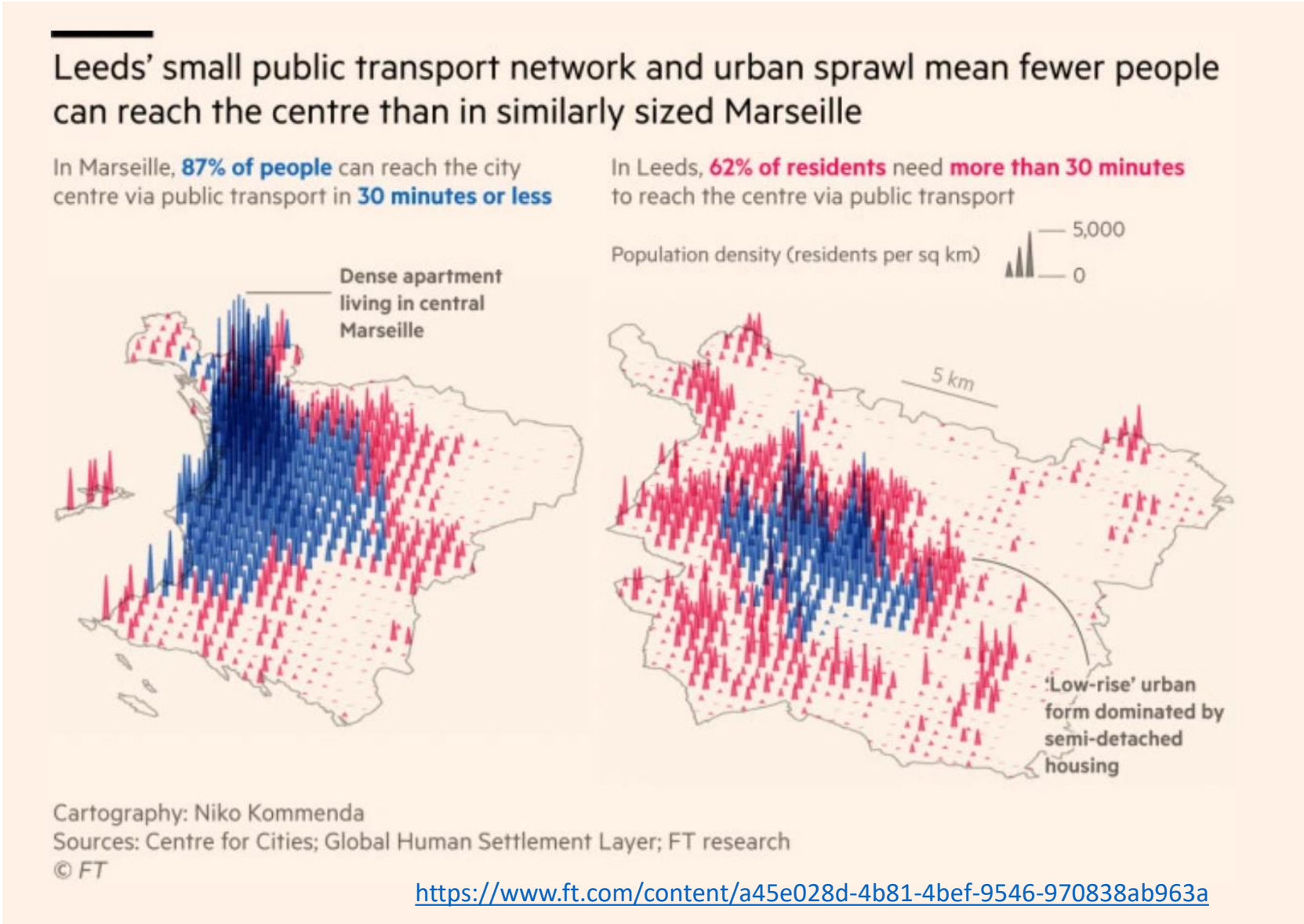


BOGOTA peak 55,800 pp/km²

Geometry created using GIS and Sketchup for rendering.



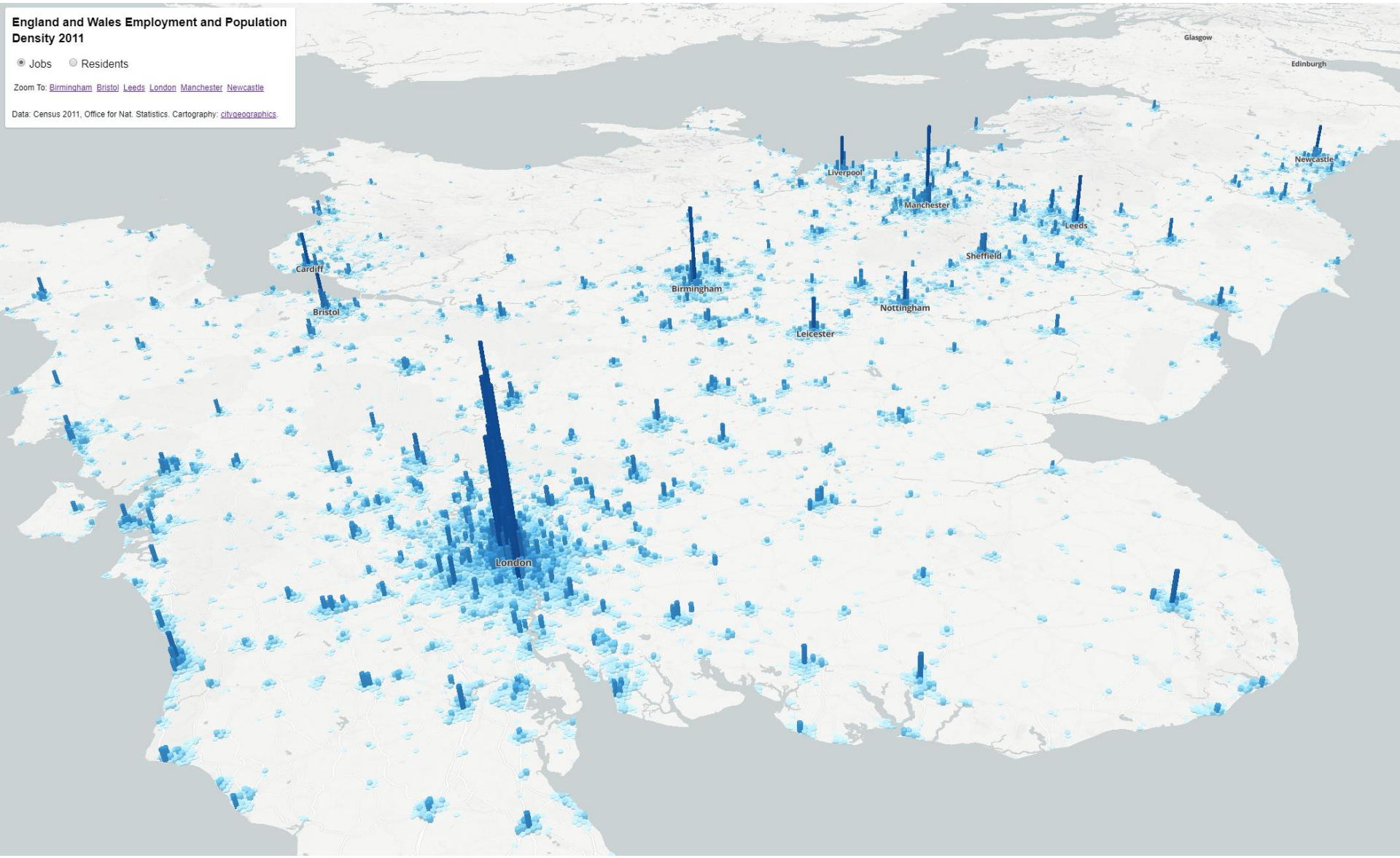
Possible to map more than one variable together in 2.5D.
Example from Financial Times below, density and accessibility-



https://www.ft.com/content/a45e028d-4b81-4bef-9546-970838ab963a

England and Wales Density Hex Map Mapbox

Extrusion helps to communicate density. Hexagon approach simplifies geometry and helps with generalisation issue discussed earlier.

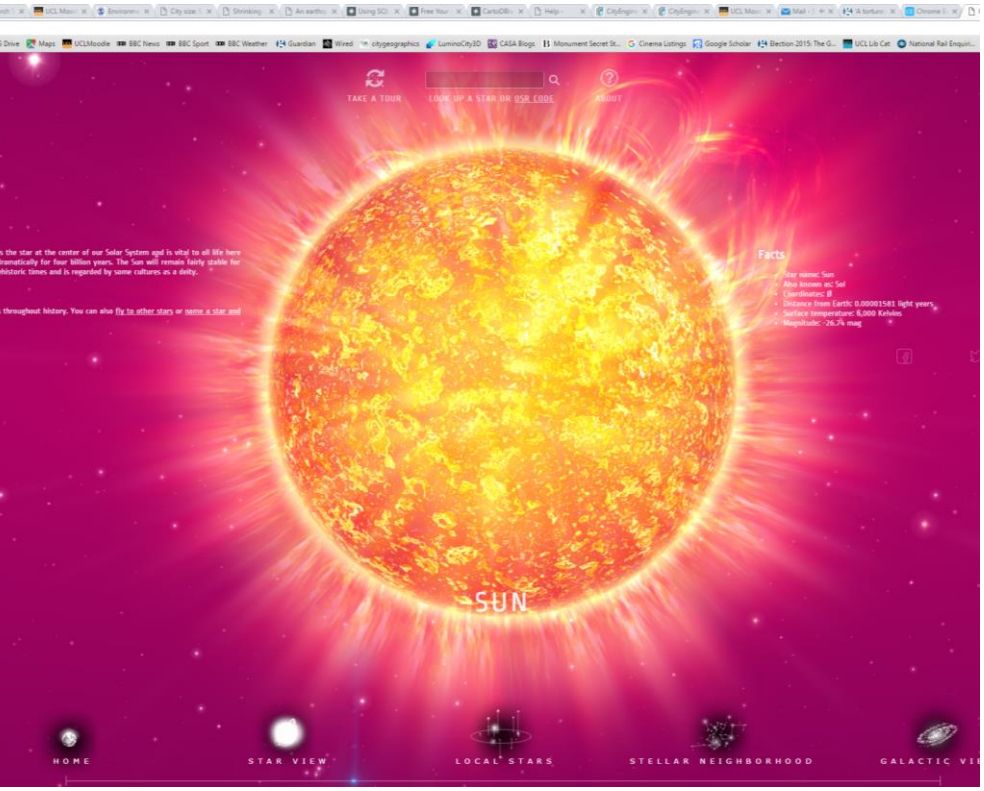


Be Careful with Variable Zone Sizes

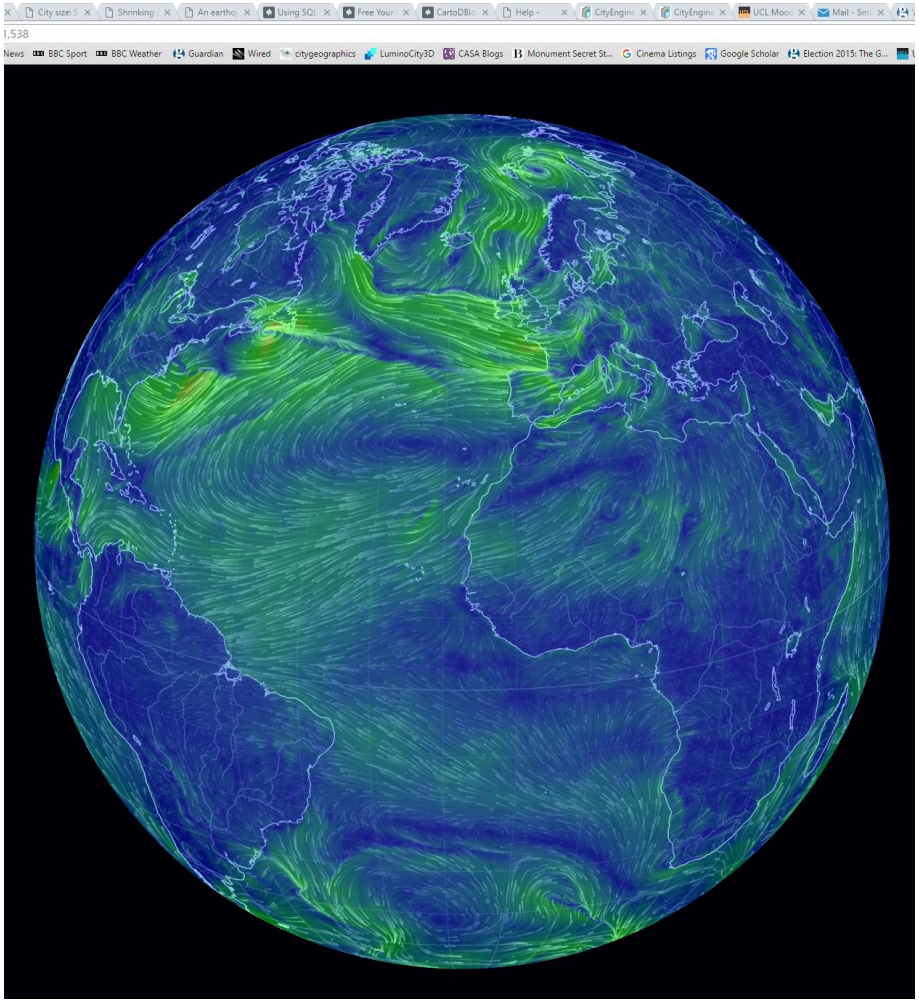
Previous examples use regular grids. This means that cell height & volume is proportional to the variable mapped for each cell.

If zone sizes are variable, then this can make the comparison more confusing. Feature volume will typically not be proportional to the variable being displayed. Example below emphasises large suburban zones. Should extrude by density, not absolute population, and ideally have regular zones-
https://kepler.gl/#/demo/nyc_census

3D Globe Visualisations (WebGL)



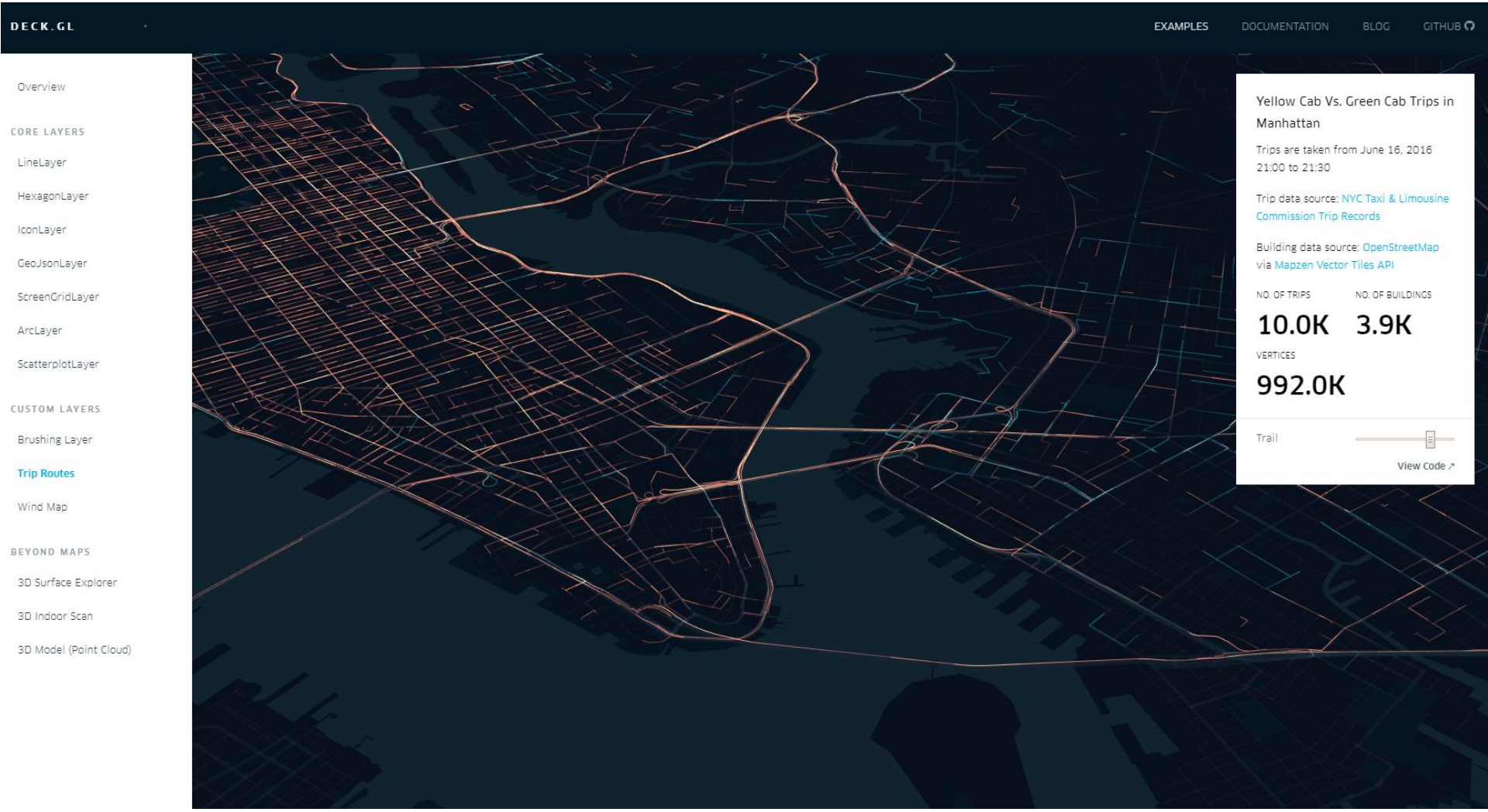
http://osr.org/oms/



http://earth.nullschool.net/#current/wind/surface/level/orthographic=-17.41,20.31,538

2D Models in 3D Viz Environment

Deck.gl (WebGL library from Uber) example of 2D flows in 3D environment.



2.5D and Full 3D

Many GIS datasets described as 3D are really 2.5D. This means that they have 2D geometry with the addition of height/extrusion attributes.

Possible to do a lot with 2.5D. Buildings outlines with a height attribute classic example. Used for extruded models. Attributes for buildings and tunnels in network datasets. We will do some 2.5D visualisation with Mapbox.

Limitations of 2.5D

Ultimately this approach is not a full 3D dataset, either in terms of more complicated 3D geometry (roofs, facades, textures, interiors) or 3D attributes (multiple buildings levels, underground, bridges, materials…).

Full 3D GIS data is expensive to produce. 2.5D data can be used as a base for 3D urban models.

Example of full 3D architectural model of London by Vu City- https://www.youtube.com/watch?v=2RnkyieHiKs

Conclusions

Technical Advances Expanding Possibilities for Web Visualisation
Expanding functionality for visualisation of larger vector datasets; incorporating animated transitions; and greater cartographic flexibility.

Focus on Improving Insight and Clarity, Rather than Flashy Graphics
Animation and 3D does not inherently improve a visualisation. Can make it weaker and confusing. Plan carefully where these elements most effective.

2.5D / 3D Visualisation Can be Powerful for Particular Applications
3D particularly good for urban form visualisation (e.g. massing, function, energy); communicating density; more immersive experiences.

Urban Modelling and Web Visualisation
Traditionally 3D visualisation uses various specialist desktop software. Some more basic 3D visualisation possible online, particularly for more abstract visualisations.

Group Discussion- Web GL Possibilities

Web GL can help visualise very large datasets. Have a look which visualises global population density at high resolution-
https://pudding.cool/2018/10/city_3d/
3D visualisation being used to help explore a large statistical dataset using extrusion. What does 3D add here? Does it make the visualisation more engaging? Does it create any legibility problems? Here is a more traditional 2D visualisation of the same dataset for comparison-
https://luminocity3d.org/WorldPopDen/

Another advantage of Web GL is that it allows smooth animations, such as flying between locations on the map. In the Pudding 3D density map above, try using the map guide feature at the bottom left, which guides you through some examples in the map. What does this feature add to the map? How might this help users understand the visualisation?
It is also possible to use animation and narrative to explain change over time in a complex dataset. Here is an example to discuss-
https://interactive.carbonbrief.org/how-uk-transformed-electricity-supply-decade/

Practical

Individual Visualisation is Due Monday Next Week

Individual Visualisation due Monday 9th Feb. You should have chosen the dataset you want to visualise and be working on creating this visualisation. ***Ask Duncan, Huixin and Kayla for help.***

Individual visualisation example and guide are on Moodle. Your visualisation should run in VS Code using Live Server. You also need to include a short 500 word report discussing your visualisation design and the techniques you used. Again example is on Moodle.

Practical – Examples Advanced Interactive Mapping

Examples of advanced mapping, and different techniques to show large spatial datasets using vector tiles.

House Price Choropleth Map Example

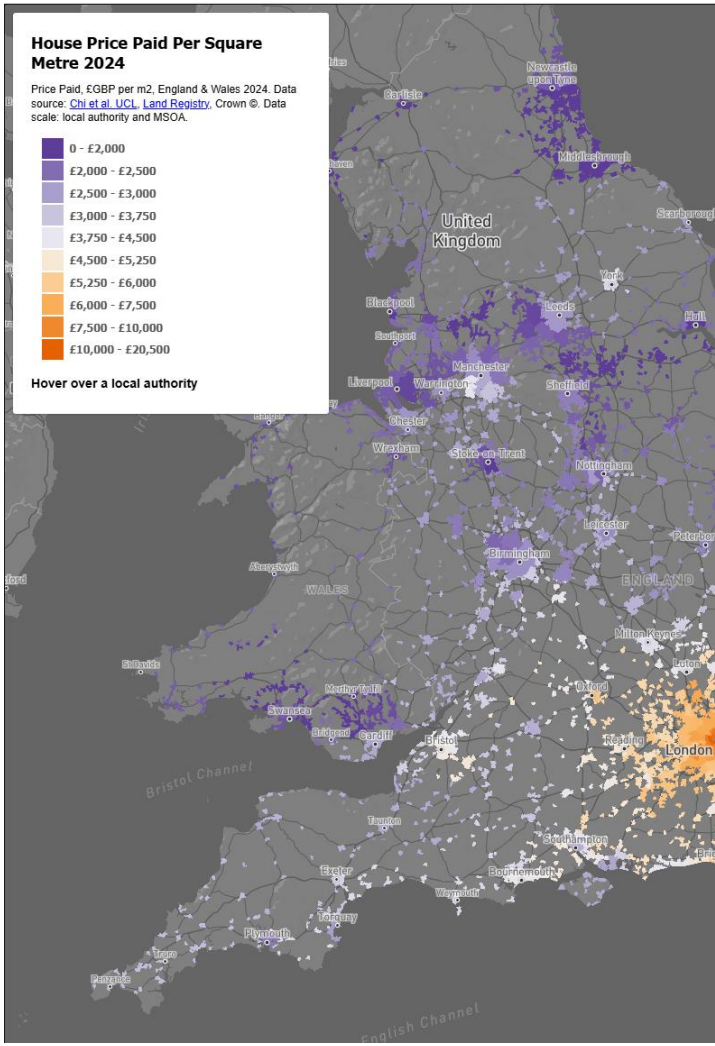
Uses low detail local authority layer, and simplified geometry in QGIS. Switches between local authority and MSOA data. Map created in Mapbox Studio. Interactivity in Mapbox.gl JS with invisible interactive layer overlaid on basemap.

Hex Map Jobs Density Map Example

Hexagon layer created in QGIS using spatial join with census data. Mapped in Mapbox.gl JS using the 'fill extrusion' layer type.

3D Buildings Map Example

Data comes from Digimap Building Heights layer. Combined with Valuation Office data to get building primary function. Uploaded as a Mapbox Tileset. Style by building function in Mapbox Studio.

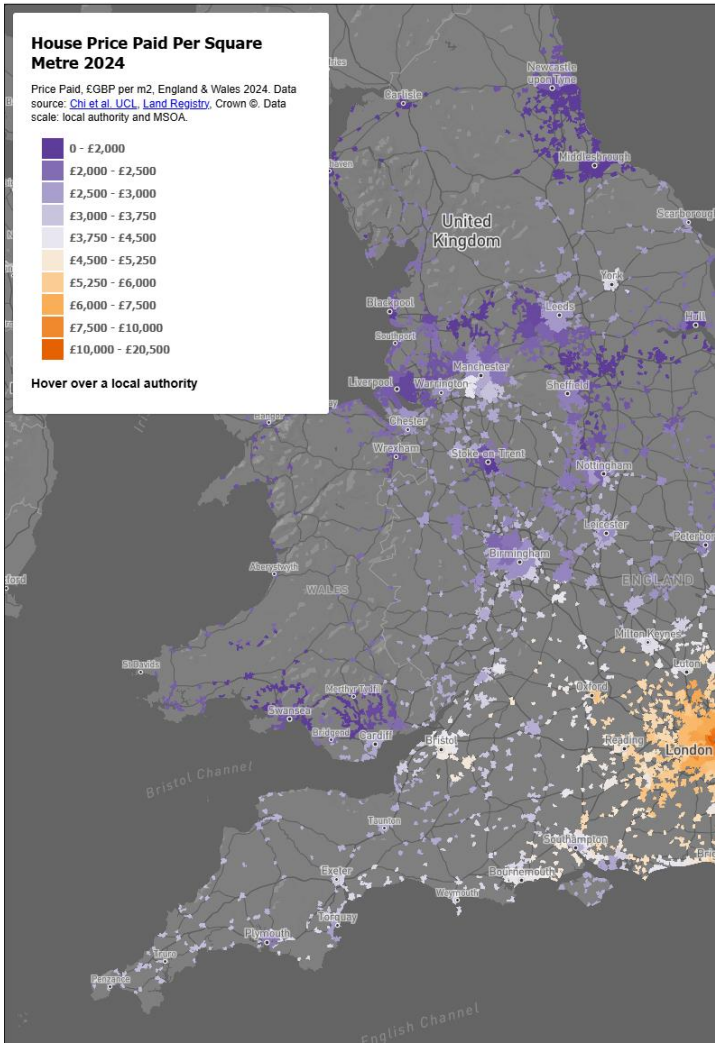


England and Wales House Price Map Example

Code and data on Moodle, also online- http://luminocity3d.org/CASATest/PricePSQM2.html

Original data is house price per square metre, created by combining Land Registry and Energy Performance Certificate data by researchers at UCL - https://data.london.gov.uk/dataset/house-price-per-square-metre-in-england-and-wales-epo9w/

Example of generalised geometry techniques. Uses low detail local authority layer, and simplified geometry in QGIS. LA and MSOA layers uploaded as Tilesets. Switches between local authority and MSOA data at zoom level 7. Map created in Mapbox Studio. Interactivity in Mapbox.gl JS with invisible interactive layer overlaid on basemap.



England and Wales Density Hex Map Example

Code and data on Moodle, and online- http://luminocity3d.org/mapbox/Mapbox_example9_3Ddata.html

Original data layers created in GIS from census data using area-weighted spatial join- https://citygeographics.org/luminocity/luminocity3d-spatial-analysis/

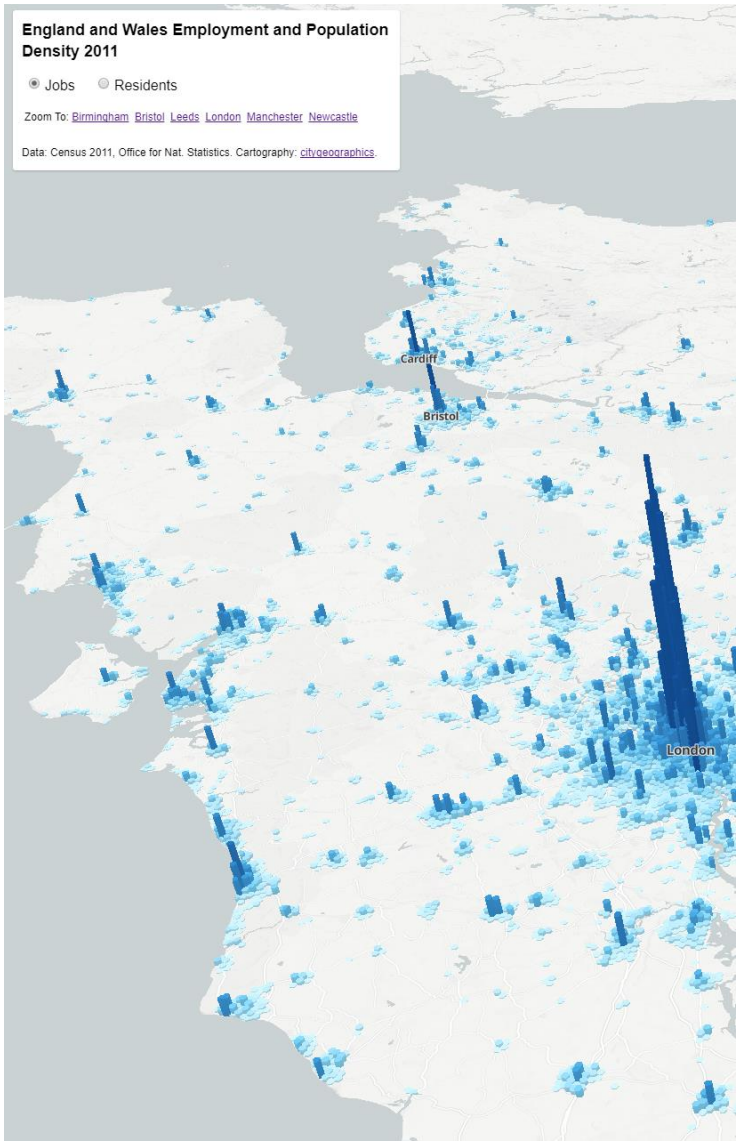
Equal area hexagons help legibility and reduces polygon count compared to irregular zones. Final shapefiles uploaded to Mapbox as Tile Layer.

Points to note in the code-

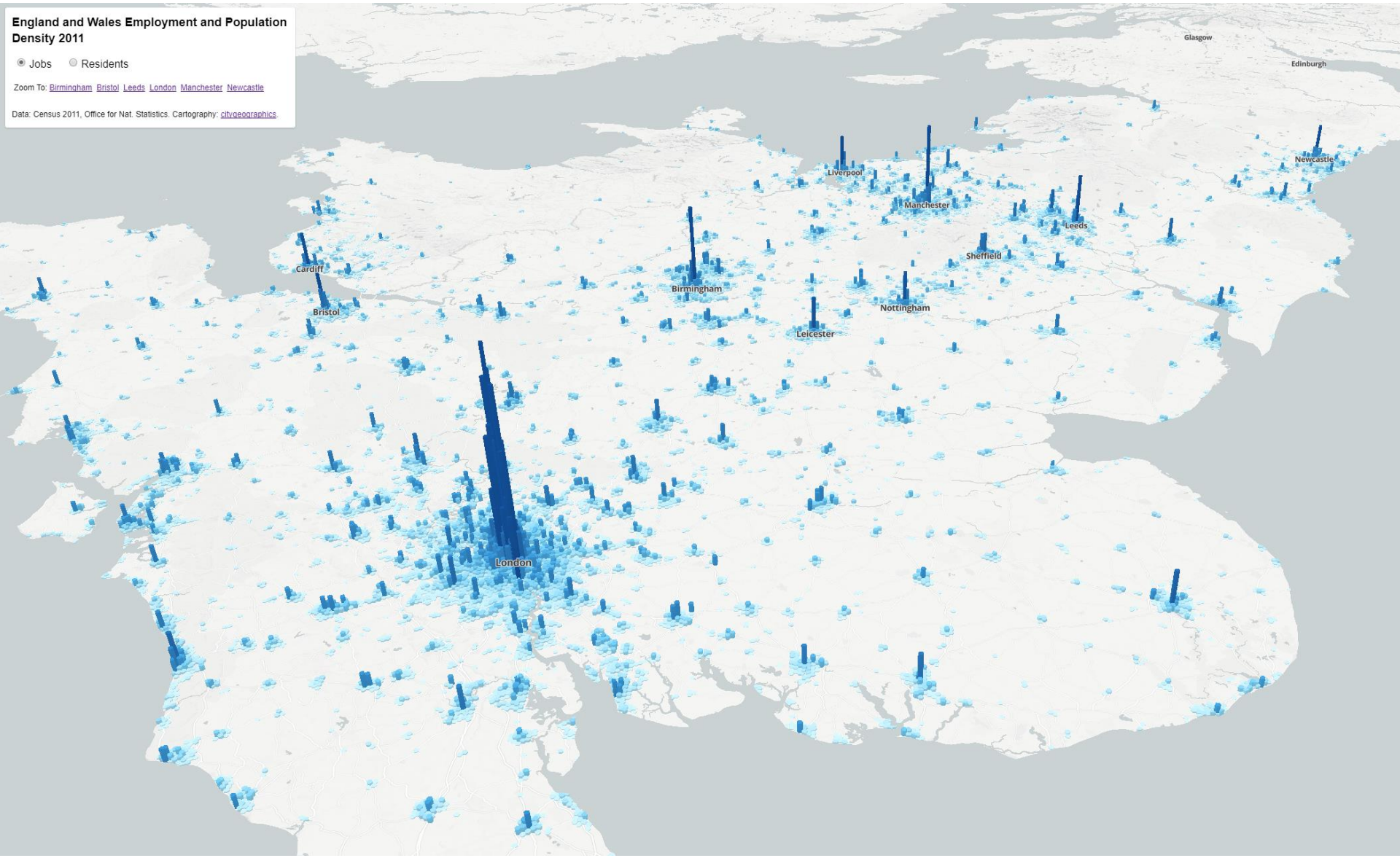
Layer Transitions
3D layers added on client-side for flexibility. Opacity transition when switching between jobs and population layers using 'fill-extrusion-opacity-transition' property.

'Zoom to' Navigational Buttons
Smoothly zoom to city locations with map.flyTo command. Can control speed of transition, and location, rotation and pitch of final viewpoint.

Labels Overlay
Labels in the background style would not be visible behind 3D layer. So labels for major cities added on the client-side. Labels rotate with the user viewpoint.



England and Wales Density Hex Map Example



2.5D Buildings in Mapbox

Mapbox Studio has OpenStreetMap data with heights pre-loaded, and landmark buildings. Can be used for basemaps. But OSM has few building properties.

Adding Your Own 2.5D Buildings

Can also upload your own 2.5D data layers. Set them as ‘fill-extrusion- type’, then extrude and colour polygons using attributes.

Practical example uses Digimap Ordnance Survey data (Building Heights layer) combined with Valuation Office data to get building function. Can be used to create a simple 3D building function map. Tippecanoe used to improve generalisation of layer at lower zoom levels.