Discrete global grid systems for spatio-temporal aggregation and visualisation

FOSS4G Europe, 2026-06-30, Timișoara

Michael Scholz

DLR

Institute of Transportation Systems

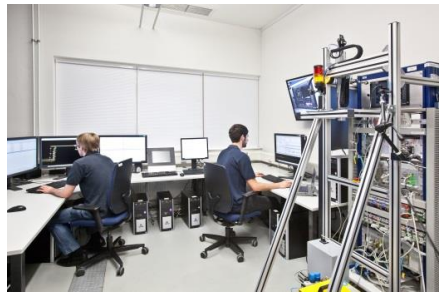
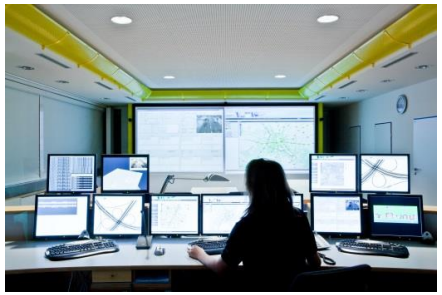
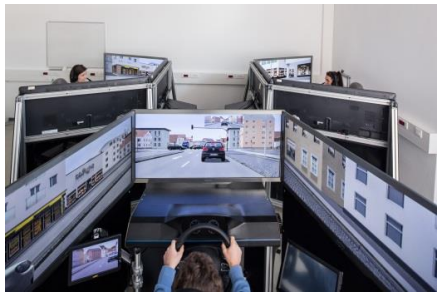
Research infrastructure

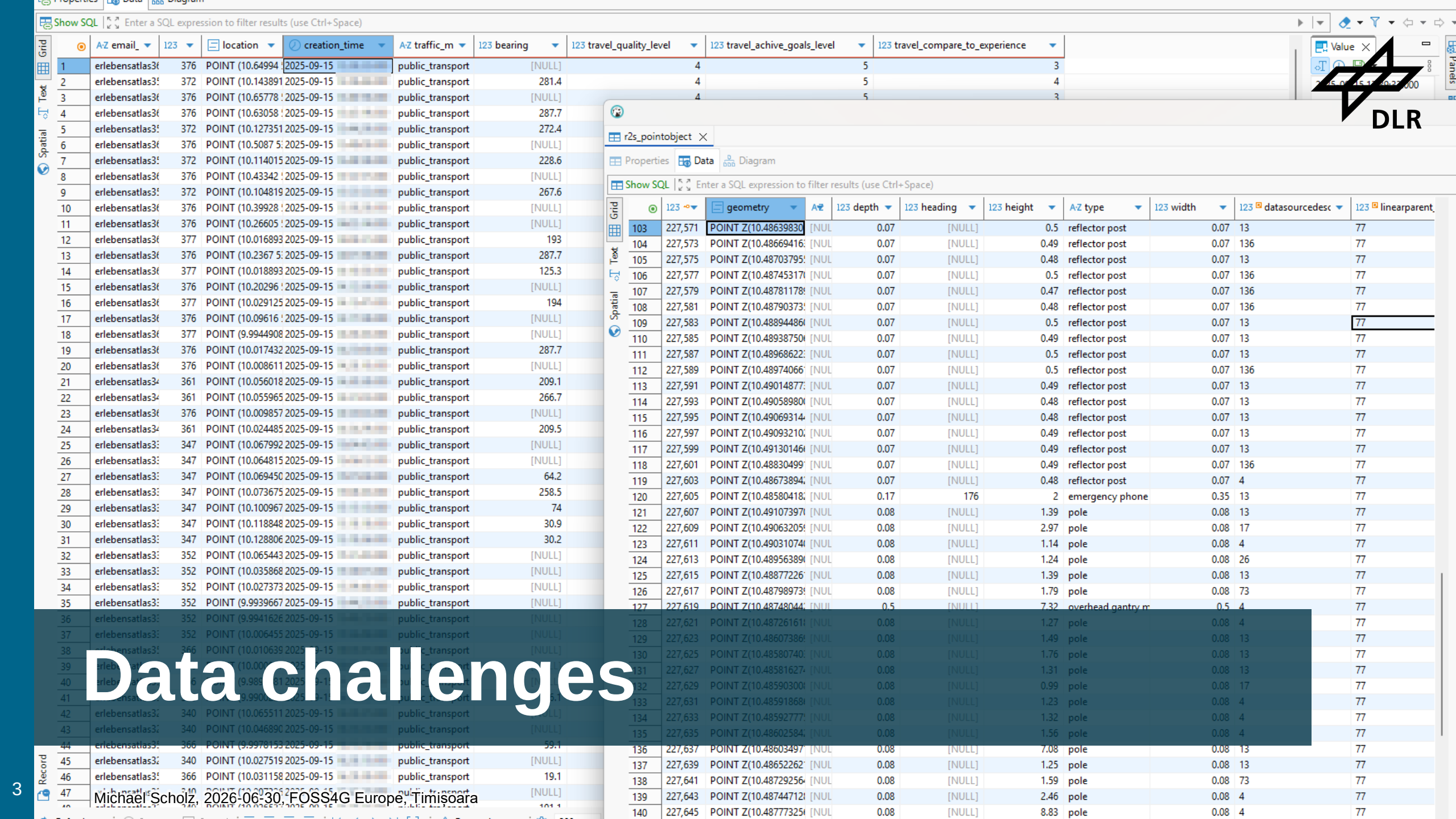








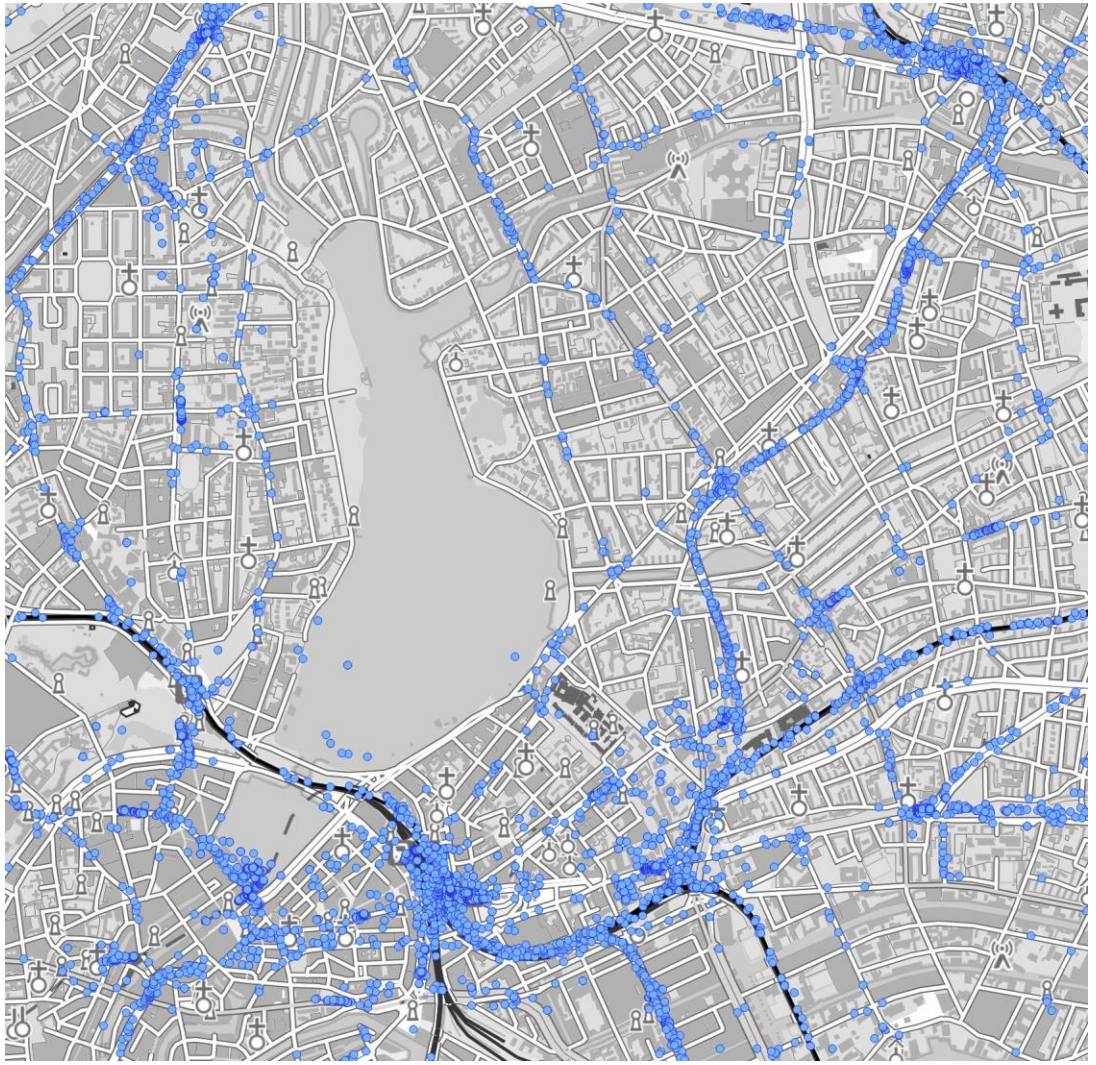





Data challenges

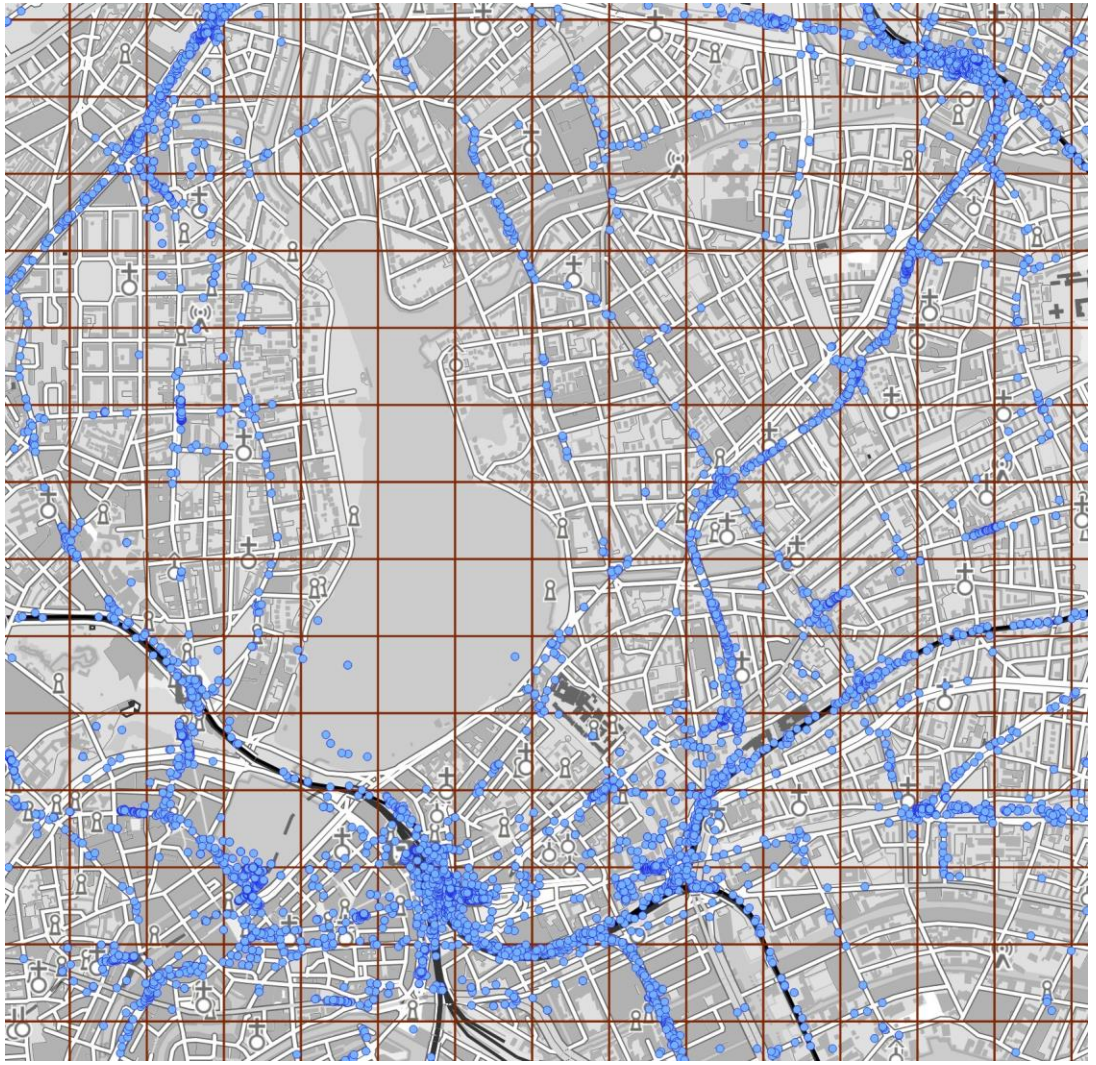
Processing of spatio-temporal event data
Big vector data

Processing of spatio-temporal event data



Processing of spatio-temporal event data
Aggregation

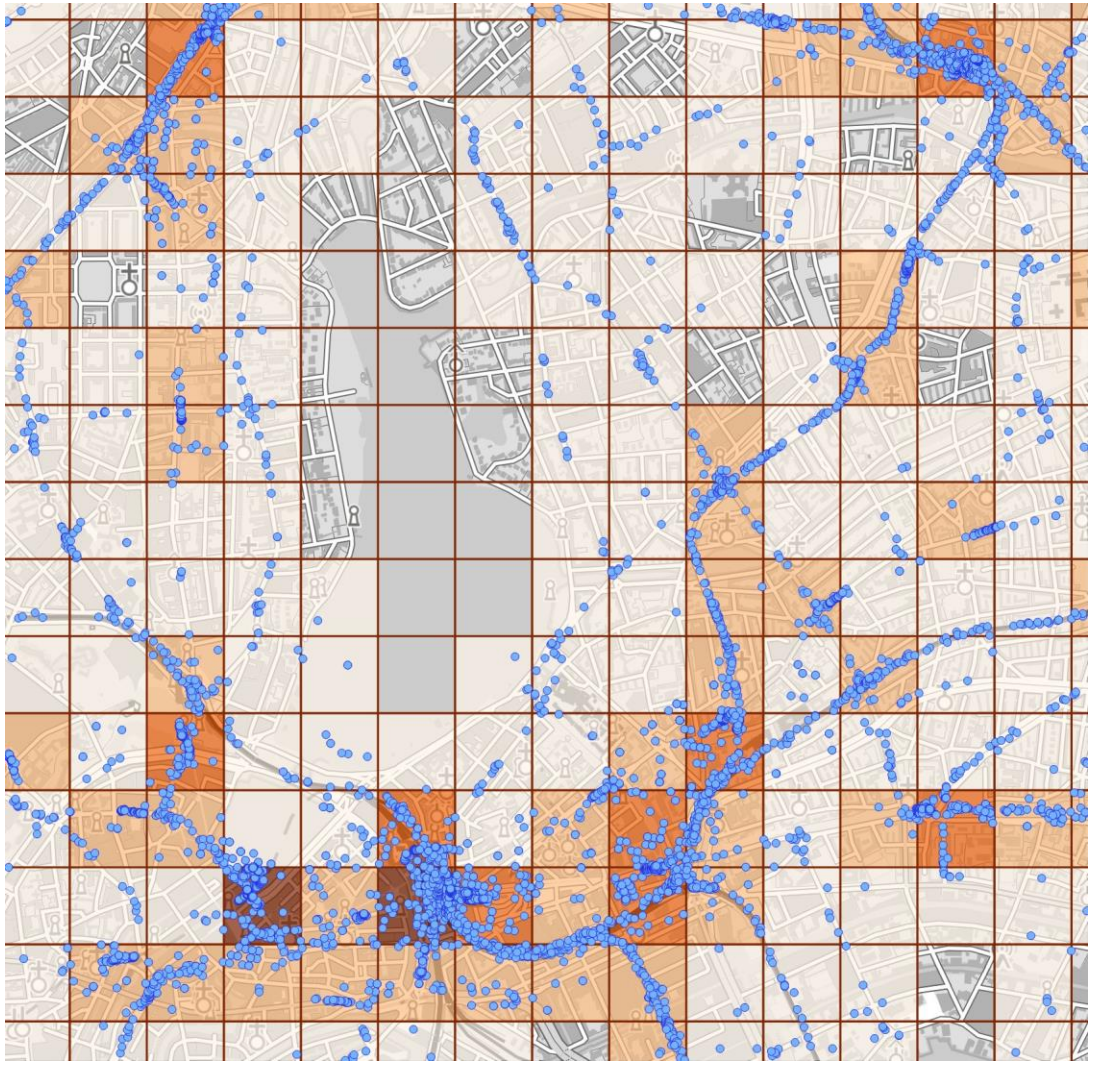
Grid cells



Processing of spatio-temporal event data
Aggregation

Grid cells

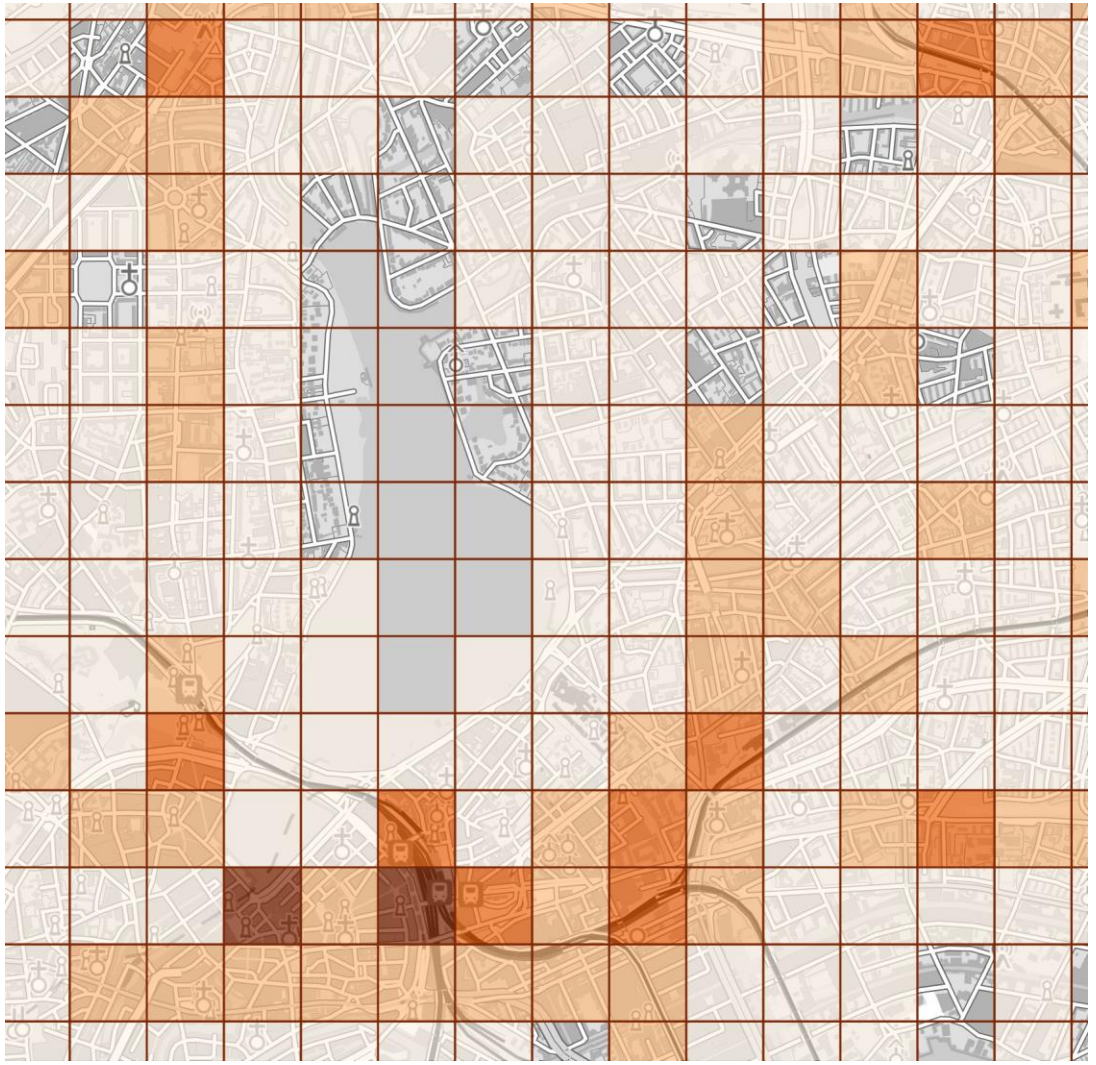
- Binning
  - Collecting all spatial features falling into one cell



Processing of spatio-temporal event data
Aggregation

Grid cells

- Binning
  - Collecting all spatial features falling into one cell

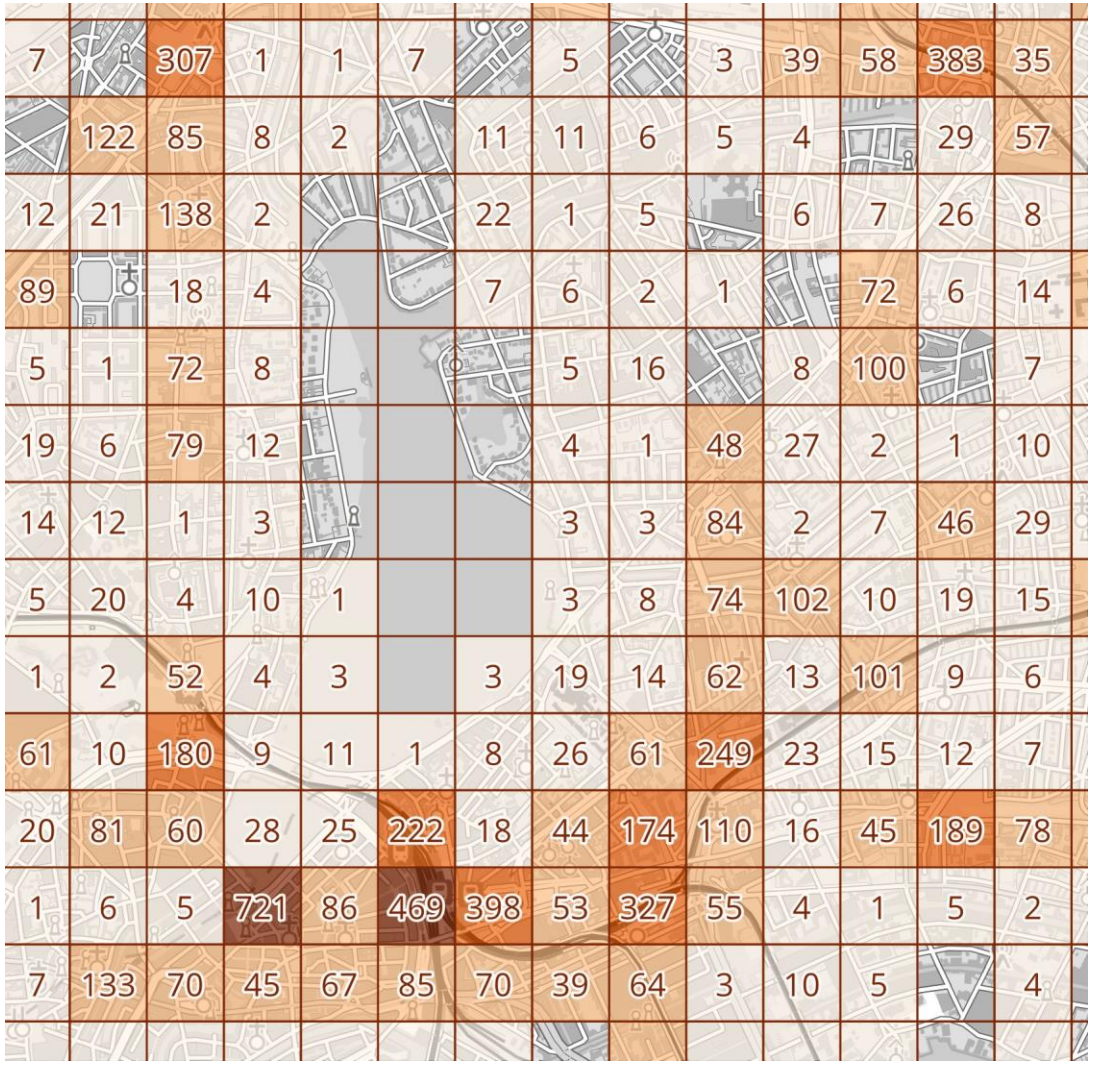


Processing of spatio-temporal event data
Aggregation

Grid cells

- Binning
  - Collecting all spatial features falling into one cell

- With statistical computation
  - `count(feature)`

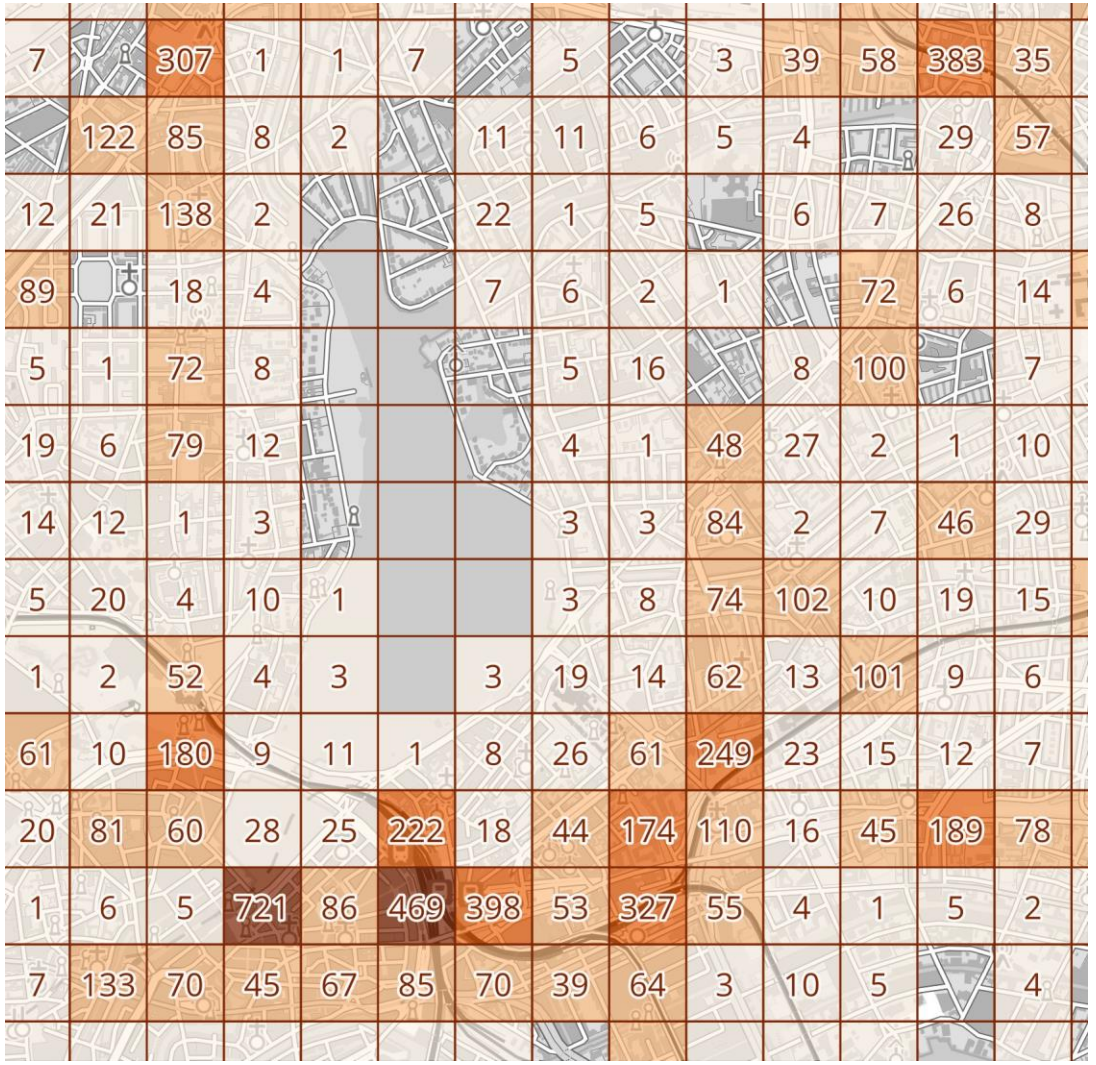


Processing of spatio-temporal event data
Aggregation

Grid cells

- Binning
  - Collecting all spatial features falling into one cell

- With statistical computation
  - `count(feature)`
  - `sum(feature.rainfall)`
  - `avg(feature.temperature)`
  - …
  - `myComplexFunction(val1, val2)`

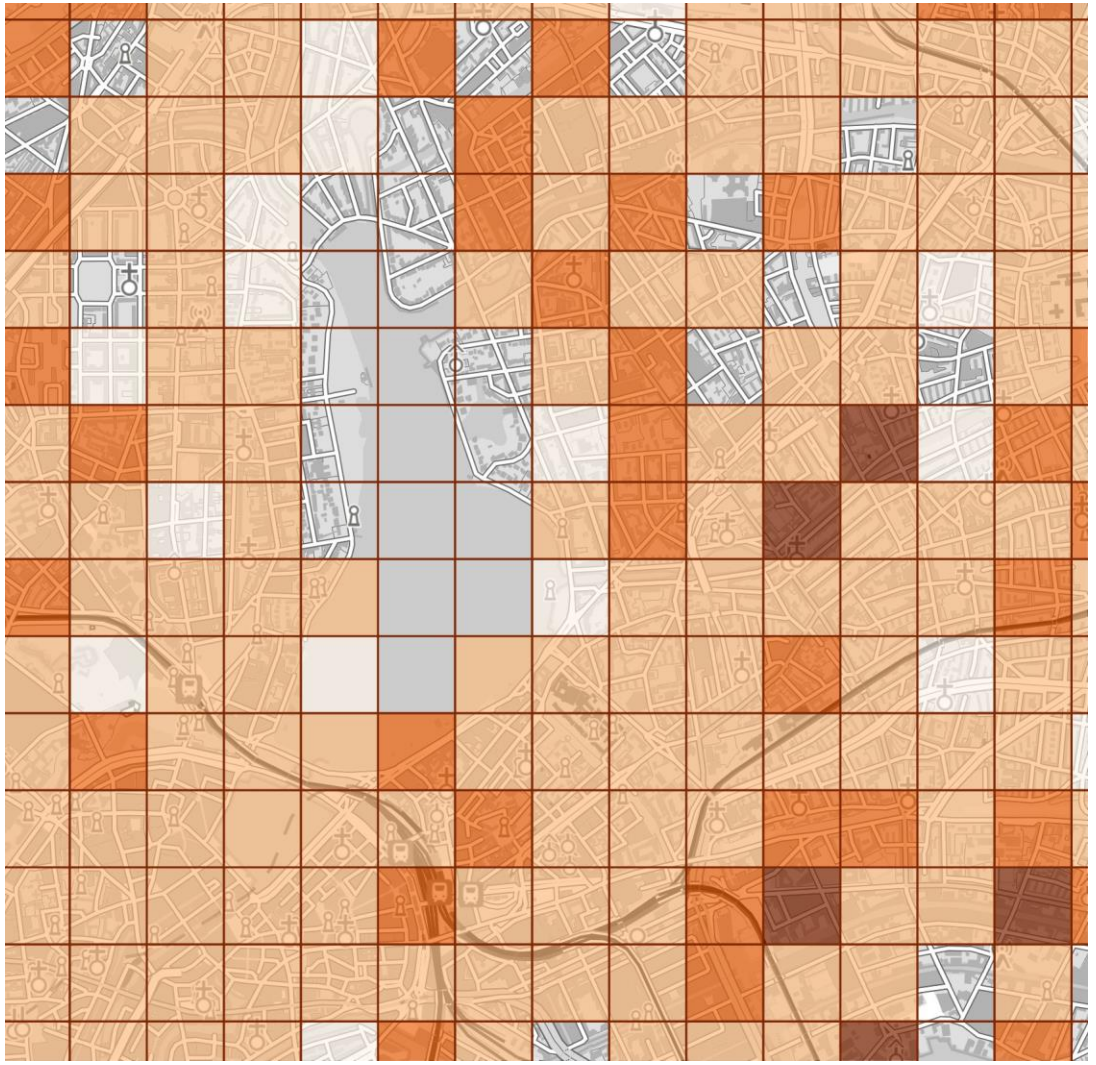


Processing of spatio-temporal event data
Aggregation

Grid cells

- Binning
  - Collecting all spatial features falling into one cell

- With statistical computation
  - `count(feature)`
  - `sum(feature.rainfall)`
  - `avg(feature.temperature)`
  - …
  - `myComplexFunction(val1, val2)`



Processing of spatio-temporal event data
Aggregation

Data protection

- Does aggregation protect individual movement profiles?

Processing of spatio-temporal event data
Aggregation

Data protection

- Does aggregation protect individual movement profiles?

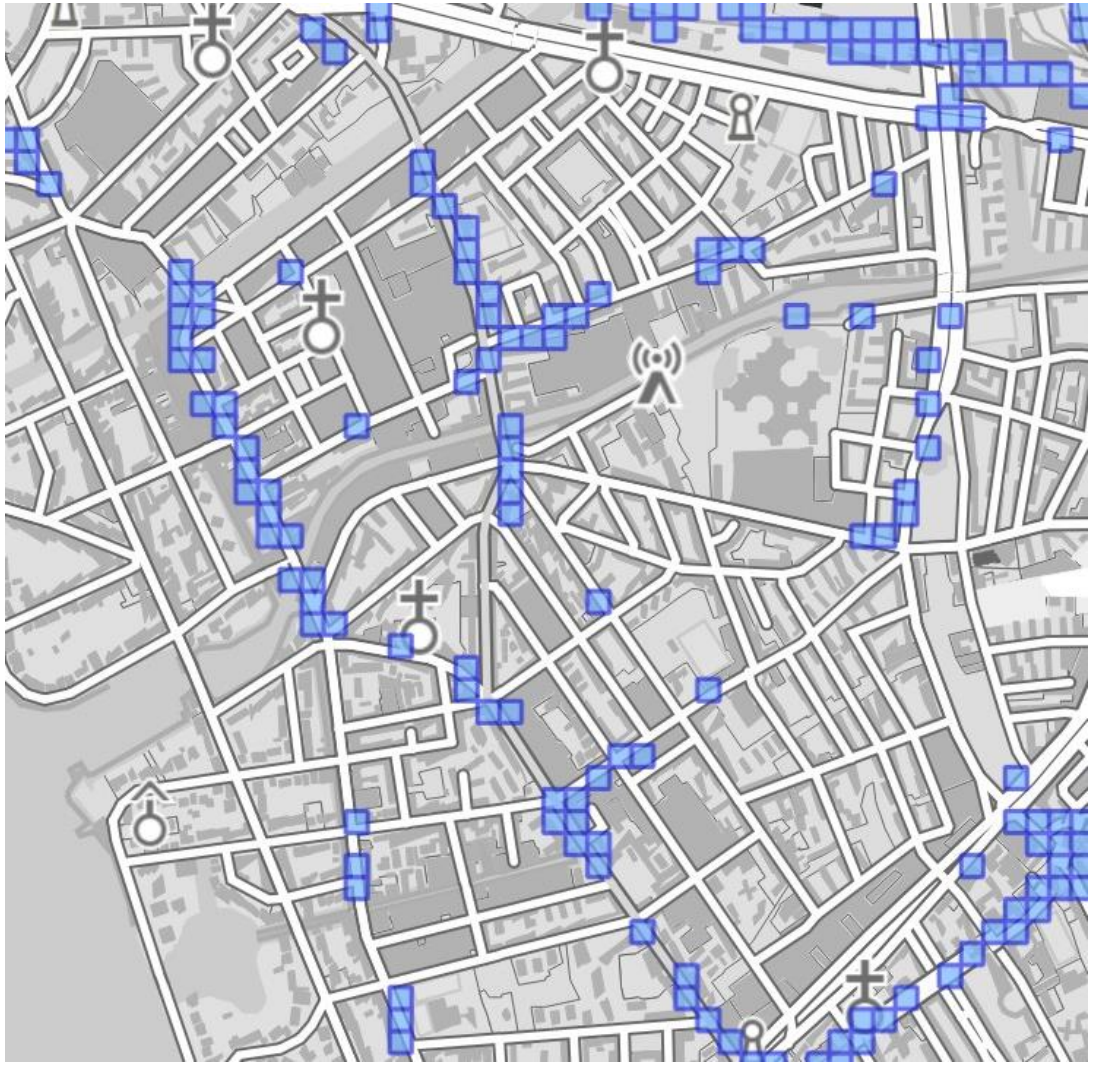
- Well …

Processing of spatio-temporal event data
Aggregation

Data protection

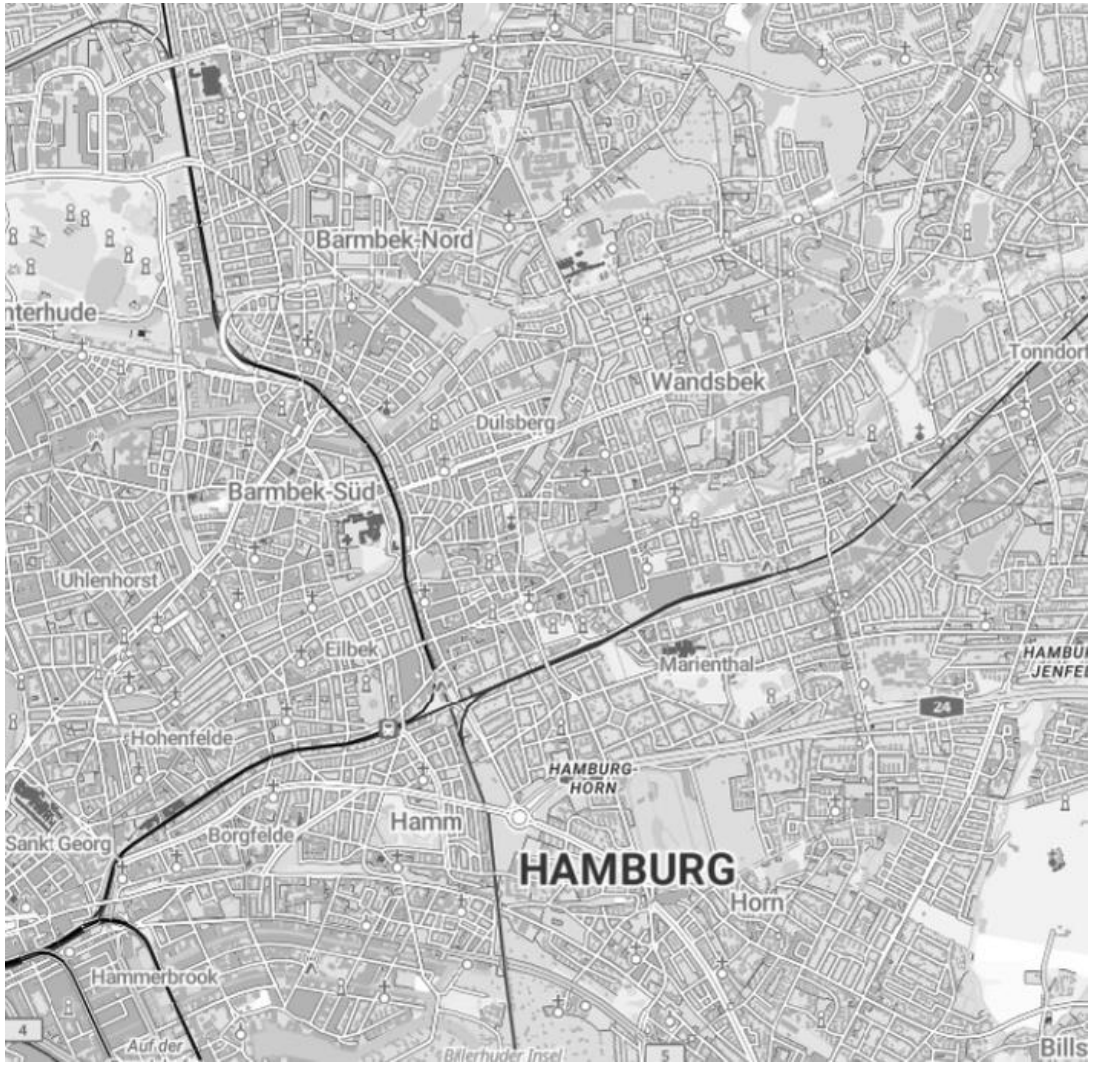
- Does aggregation protect individual movement profiles?

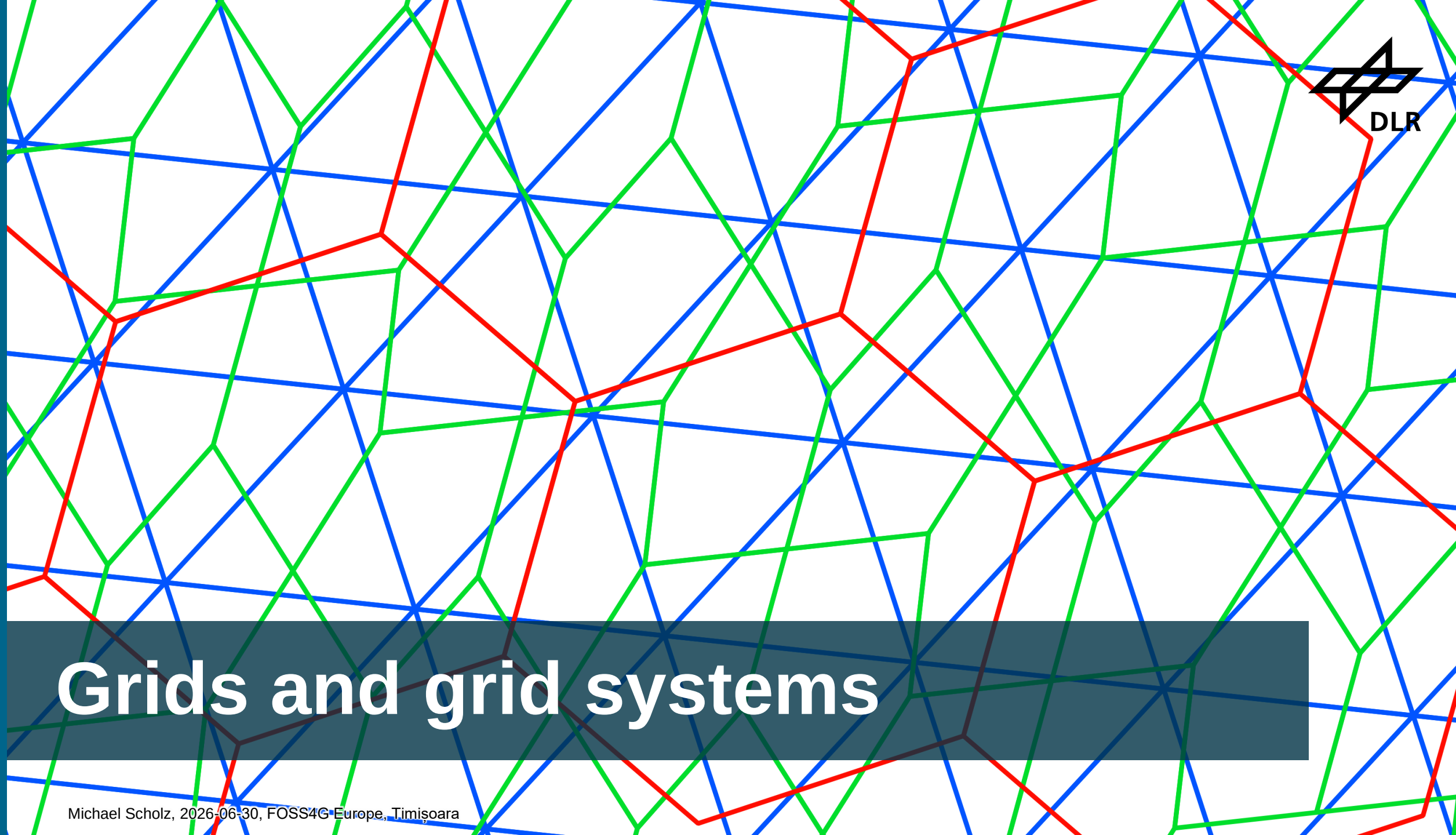
- Well … maybe!
  - Choice of cell size and time window is crucial



Processing of spatio-temporal event data
Common problems

- OGC web services scale poorly with raw data volume
- Rendering performance drops as the volume of data increases
  - Data must first be sent to the client
- Therefore: aggregation in backend
  - But which grid should be used?



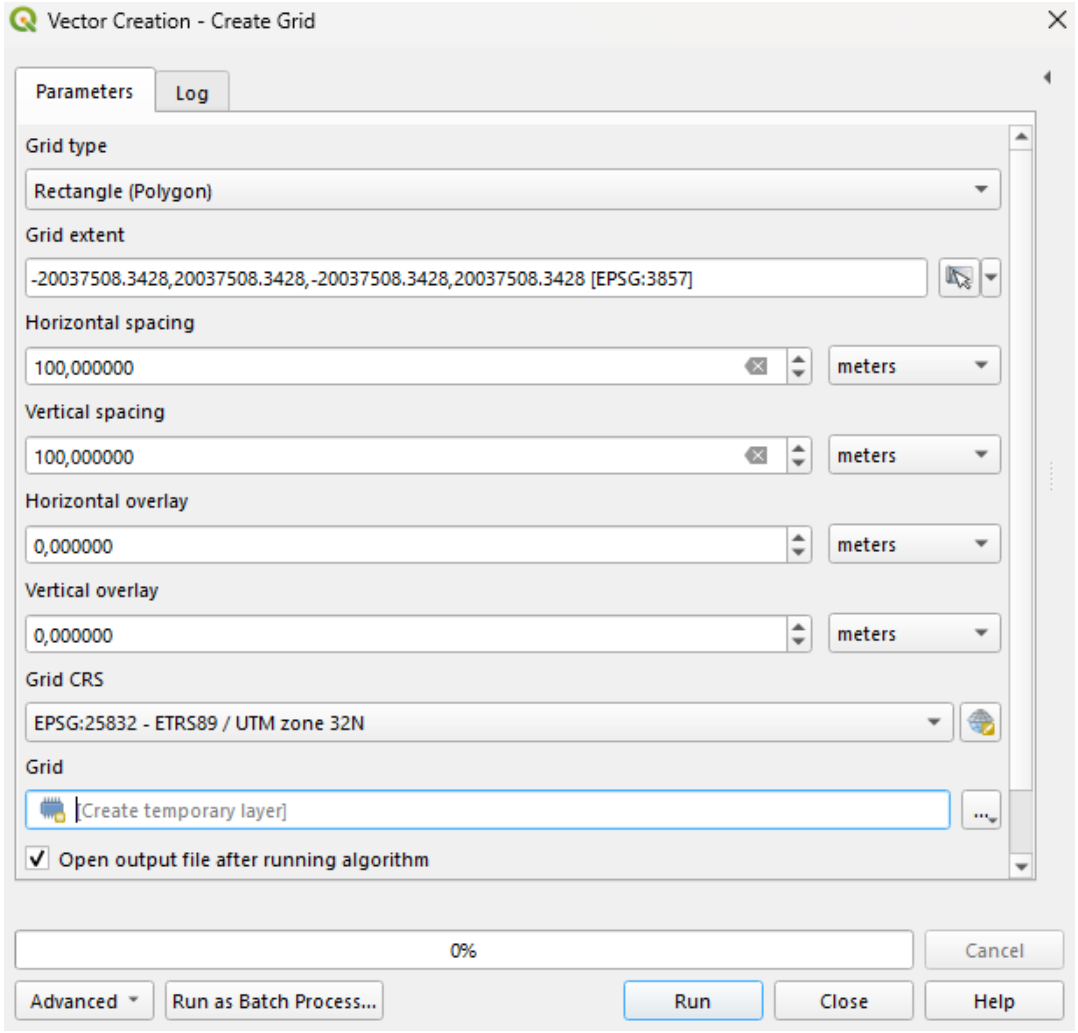


Grids and grid systems

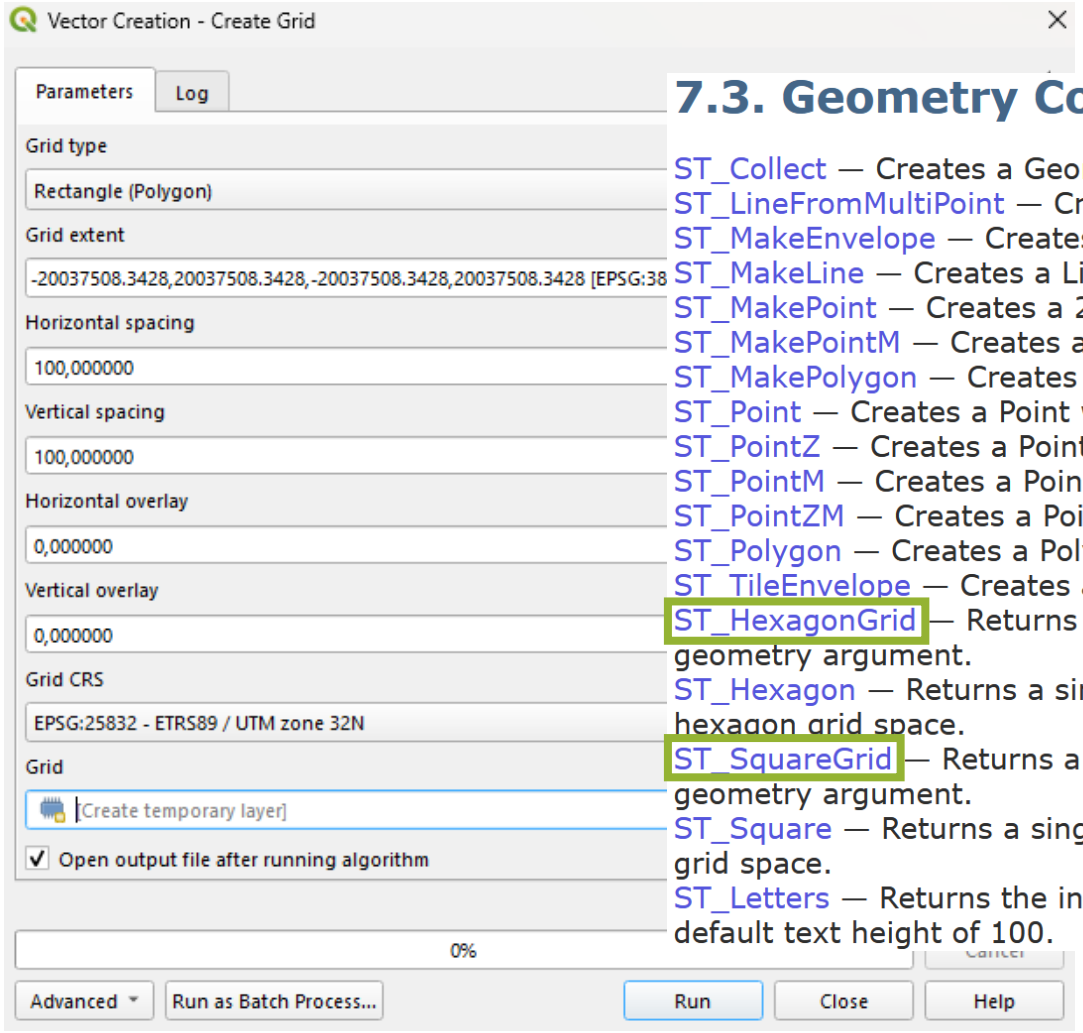
Grids and grid systems

- User-defined grids
- Official, national grids
- Discrete global grids

User-defined grids
Quickly clicked and generated



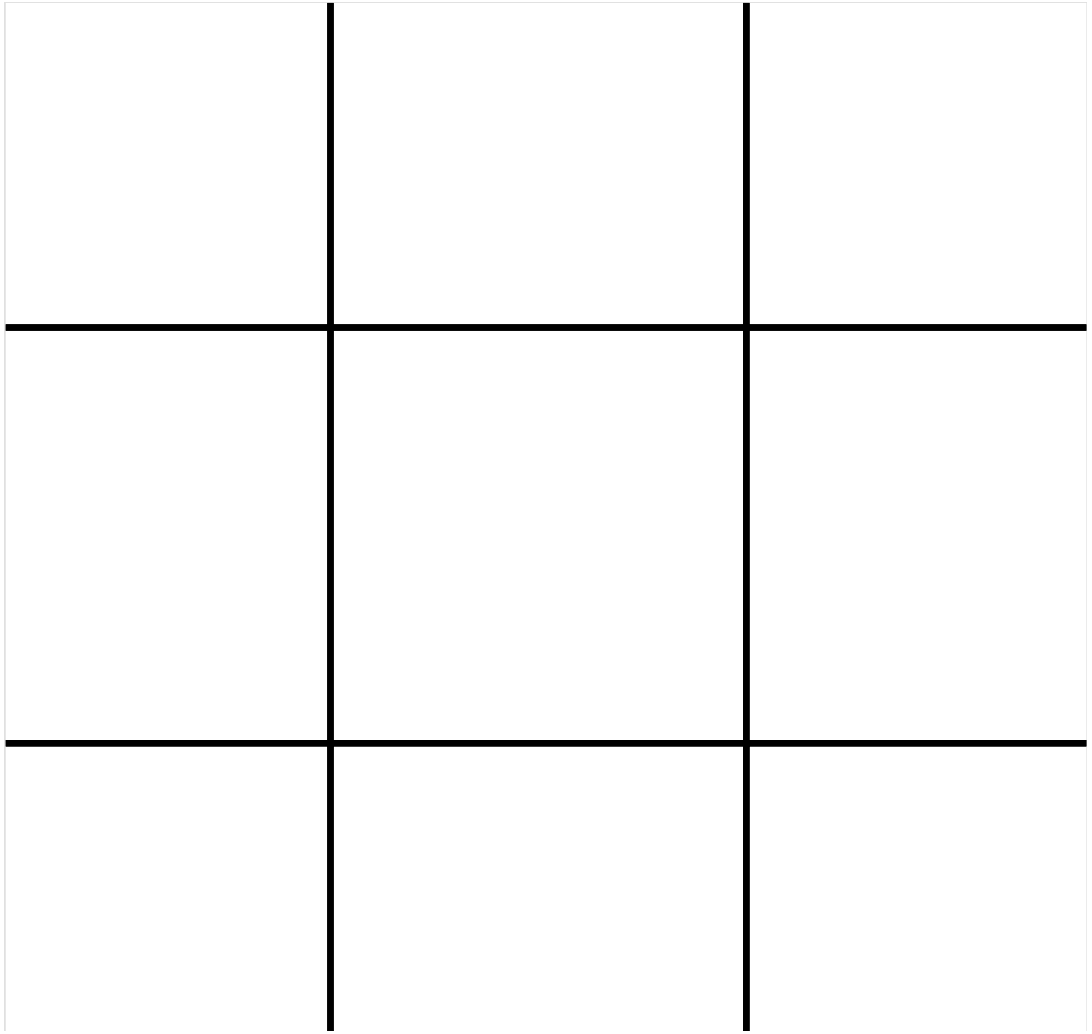
User-defined grids
Quickly clicked and generated



7.3. Geometry Constructors

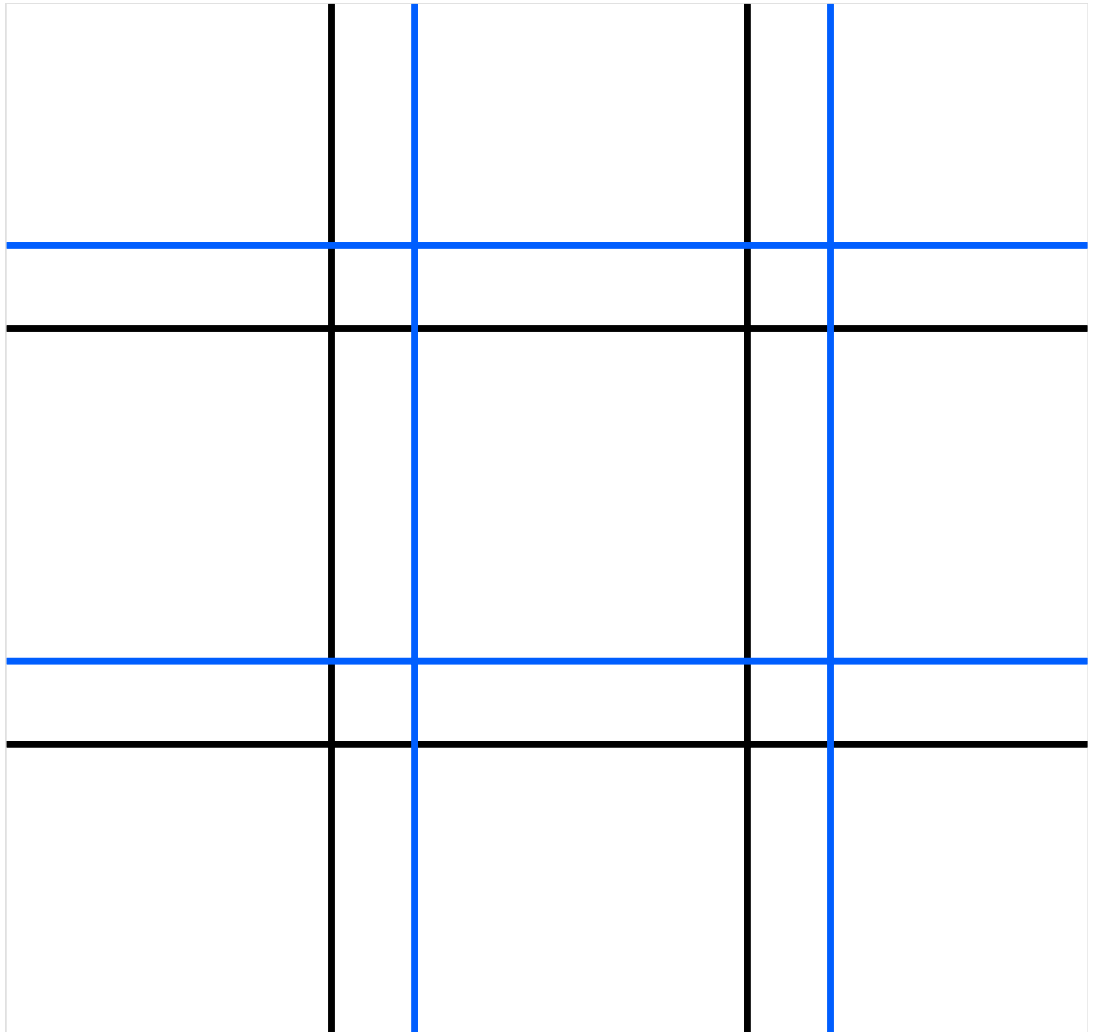
ST_Collect — Creates a GeometryCollection or Multi* geometry from a set of geometries.
ST_LineFromMultiPoint — Creates a LineString from a MultiPoint geometry.
ST_MakeEnvelope — Creates a rectangular Polygon from minimum and maximum coordinates.
ST_MakeLine — Creates a LineString from Point, MultiPoint, or LineString geometries.
ST_MakePoint — Creates a 2D, 3DZ or 4D Point.
ST_MakePointM — Creates a Point from X, Y and M values.
ST_MakePolygon — Creates a Polygon from a shell and optional list of holes.
ST_Point — Creates a Point with X, Y and SRID values.
ST_PointZ — Creates a Point with X, Y, Z and SRID values.
ST_PointM — Creates a Point with X, Y, M and SRID values.
ST_PointZM — Creates a Point with X, Y, Z, M and SRID values.
ST_Polygon — Creates a Polygon from a LineString with a specified SRID.
ST_TileEnvelope — Creates a rectangular Polygon in Web Mercator (SRID:3857) using the XYZ tile system.
ST_HexagonGrid — Returns a set of hexagons and cell indices that completely cover the bounds of the geometry argument.
ST_Hexagon — Returns a single hexagon, using the provided edge size and cell coordinate within the hexagon grid space.
ST_SquareGrid — Returns a set of grid squares and cell indices that completely cover the bounds of the geometry argument.
ST_Square — Returns a single square, using the provided edge size and cell coordinate within the square grid space.
ST_Letters — Returns the input letters rendered as geometry with a default start position at the origin and default text height of 100.

User-defined grids
Quickly clicked and generated



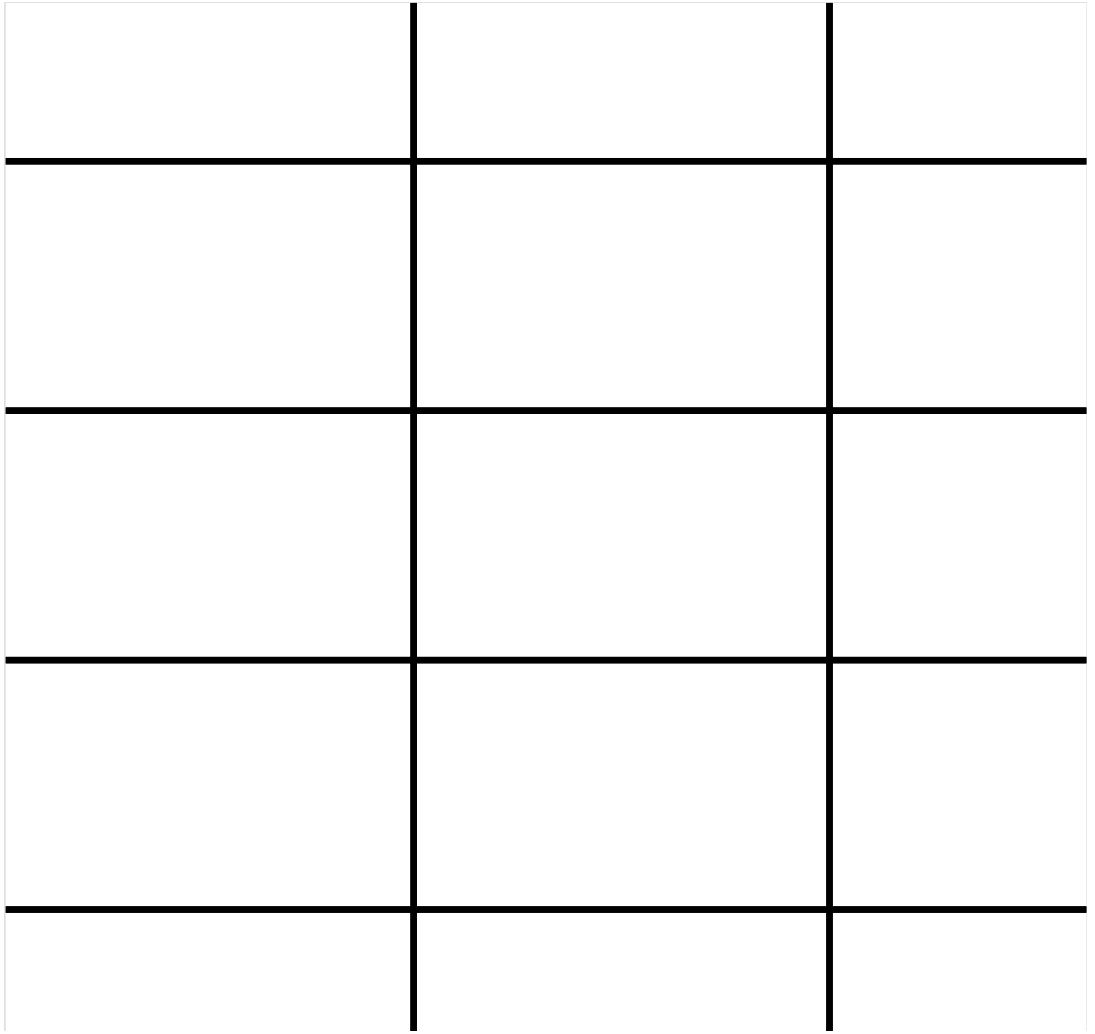
User-defined grids
Quickly clicked and generated

- Flexible geometry
  - Arbitrary coordinate origin
  - User-defined projection



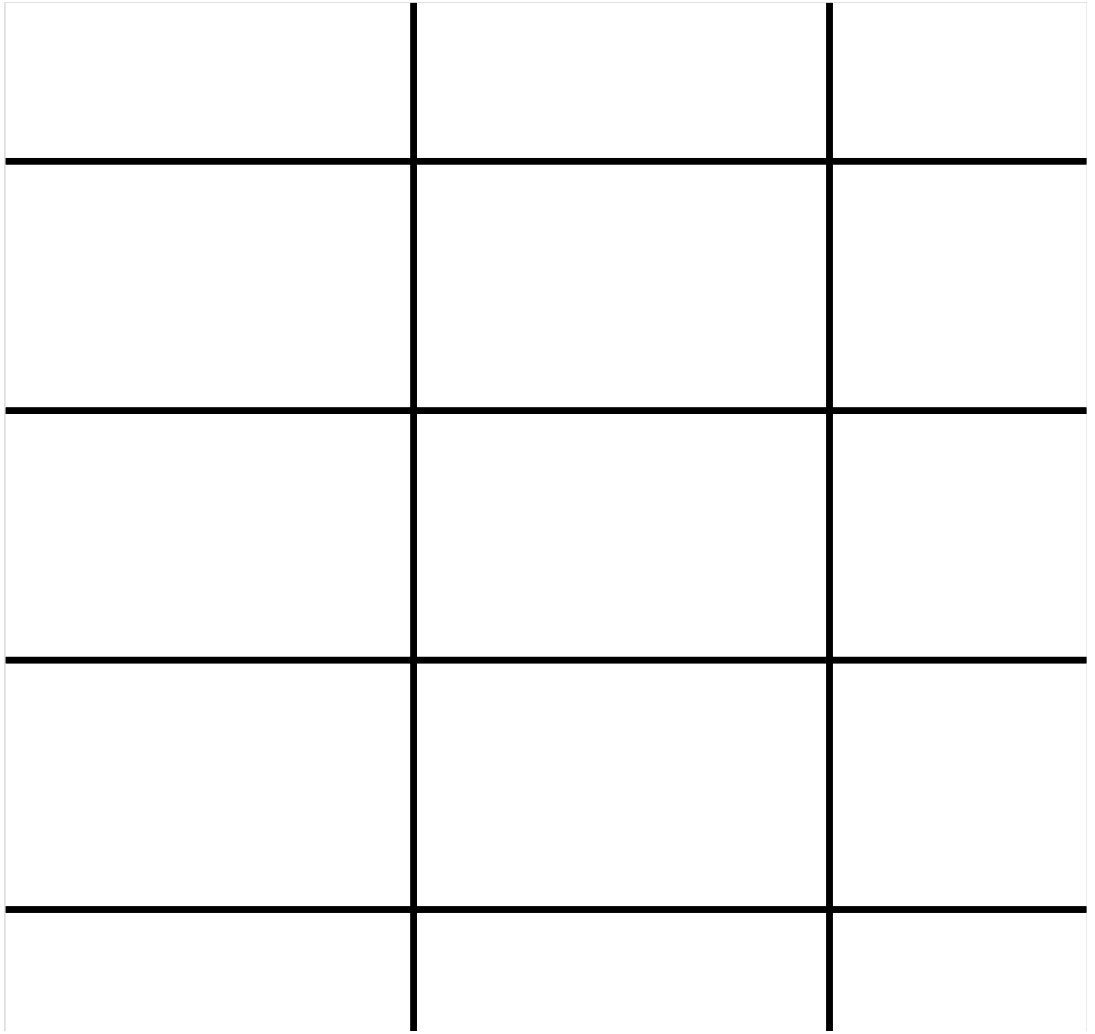
User-defined grids
Quickly clicked and generated

- Flexible geometry
  - Arbitrary coordinate origin
  - User-defined projection



User-defined grids
Quickly clicked and generated

- Flexible geometry
  - Arbitrary coordinate origin
  - User-defined projection
- Not “sustainable”
  - Poor comparability of cell data in user-defined grids



Official, national grids

EEA reference grid for Romania

Official, national grids
EEA reference grid for Romania

- Coordinate reference system
  - ETRS/LAEA, equal area
- Licence: CC BY 4.0

EEA reference grid for Romania (100km), May 2013

The grid is based on proposal at the 1st European Workshop on Reference Grids in 2003 and later INSPIRE ...

EEA reference grid for Romania (10km), May 2013

The grid is based on proposal at the 1st European Workshop on Reference Grids in 2003 and later INSPIRE ...

EEA reference grid for Romania (1km), May 2013

The grid is based on proposal at the 1st European Workshop on Reference Grids in 2003 and later INSPIRE ...

Source: EEA geospatial data catalogue

Official, national grids
EEA reference grid for Romania

- Coordinate reference system
  - ETRS/LAEA, equal area
- Licence: CC BY 4.0
- Resolutions: just 3

EEA reference grid for Romania (100km), May 2013

The grid is based on proposal at the 1st European Workshop on Reference Grids in 2003 and later INSPIRE ...

EEA reference grid for Romania (10km), May 2013

The grid is based on proposal at the 1st European Workshop on Reference Grids in 2003 and later INSPIRE ...

EEA reference grid for Romania (1km), May 2013

The grid is based on proposal at the 1st European Workshop on Reference Grids in 2003 and later INSPIRE ...

Source: EEA geospatial data catalogue

User-defined and official grids
Disadvantages of both approaches

- Poor comparability of cell data in a global context

User-defined and official grids
Disadvantages of both approaches

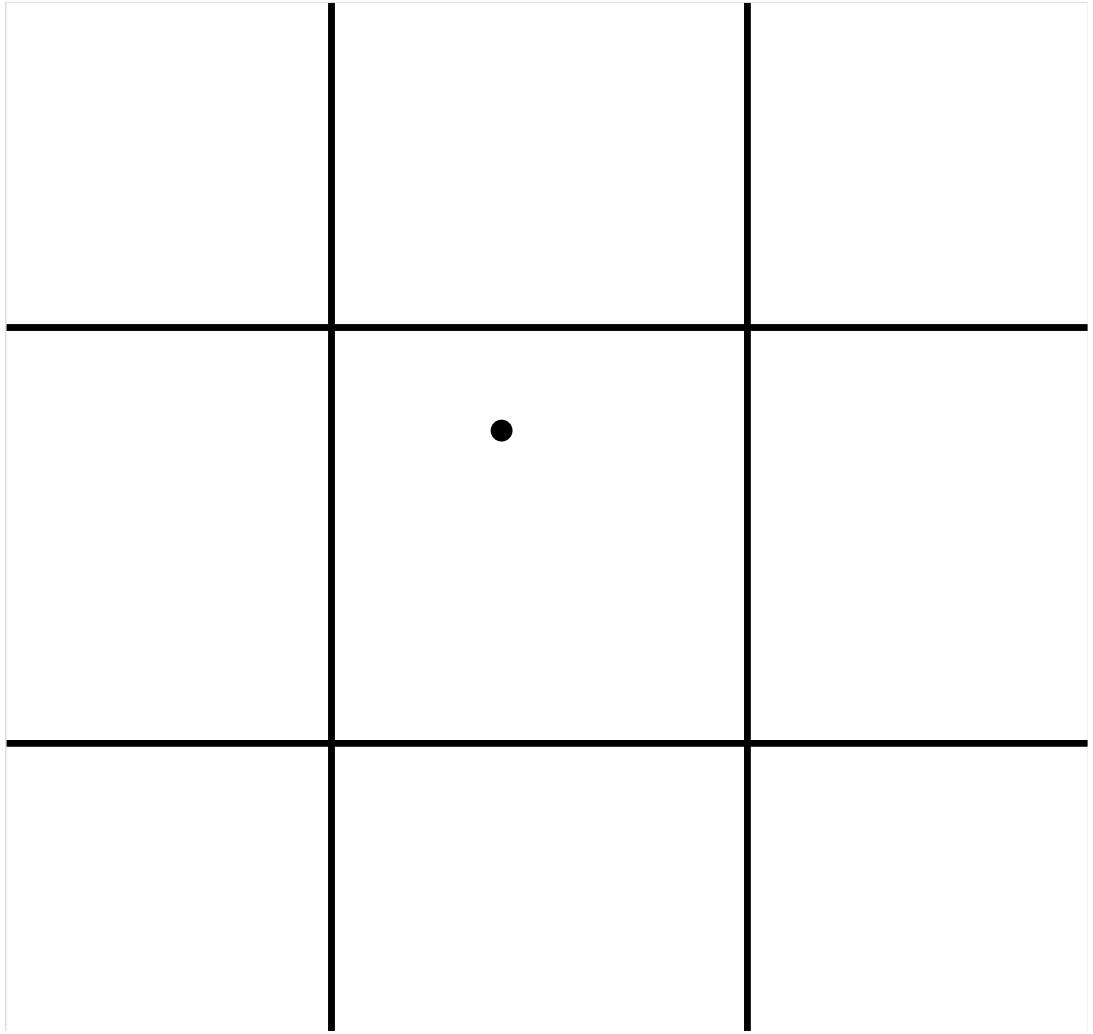
- Poor comparability of cell data in a global context

“[..] Other grids could be also used,
however they need a lot of harmonisation work,
as well as a number of conversion tools. [..]

Source: INSPIRE registry – Geographical grid systems

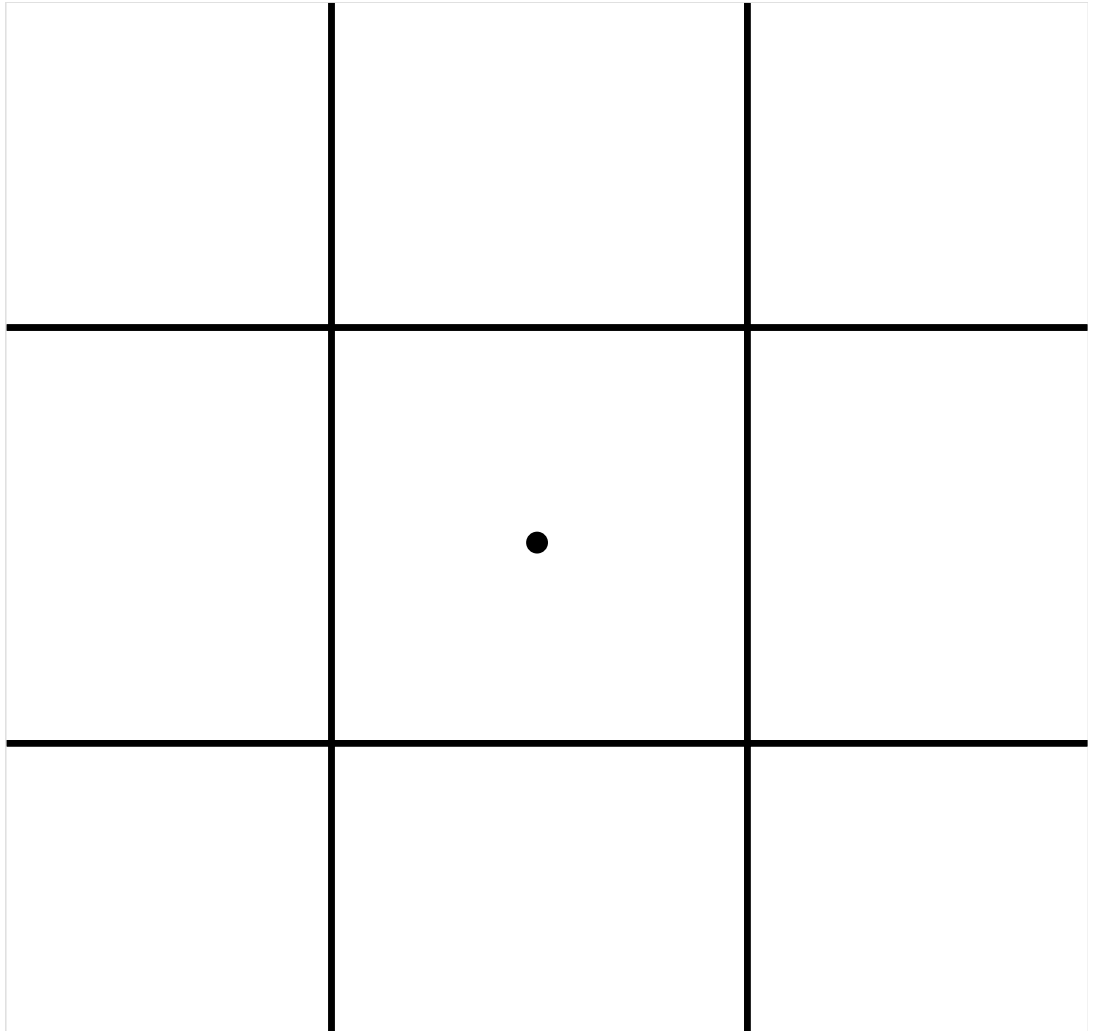
User-defined and official grids
Disadvantages of both approaches

- Poor comparability of cell data in a global context
- Tooling: none
- Cumbersome aggregation (binning)
  - `GROUP BY ST_Intersects(point, cell)`



User-defined and official grids
Disadvantages of both approaches

- Poor comparability of cell data in a global context
- Tooling: none
- Cumbersome aggregation (binning)
  - `GROUP BY ST_Intersects(point, cell)`
  - `GROUP BY ST_SnapToGrid(point, 500.0)`



Discrete global grid systems
DGGS

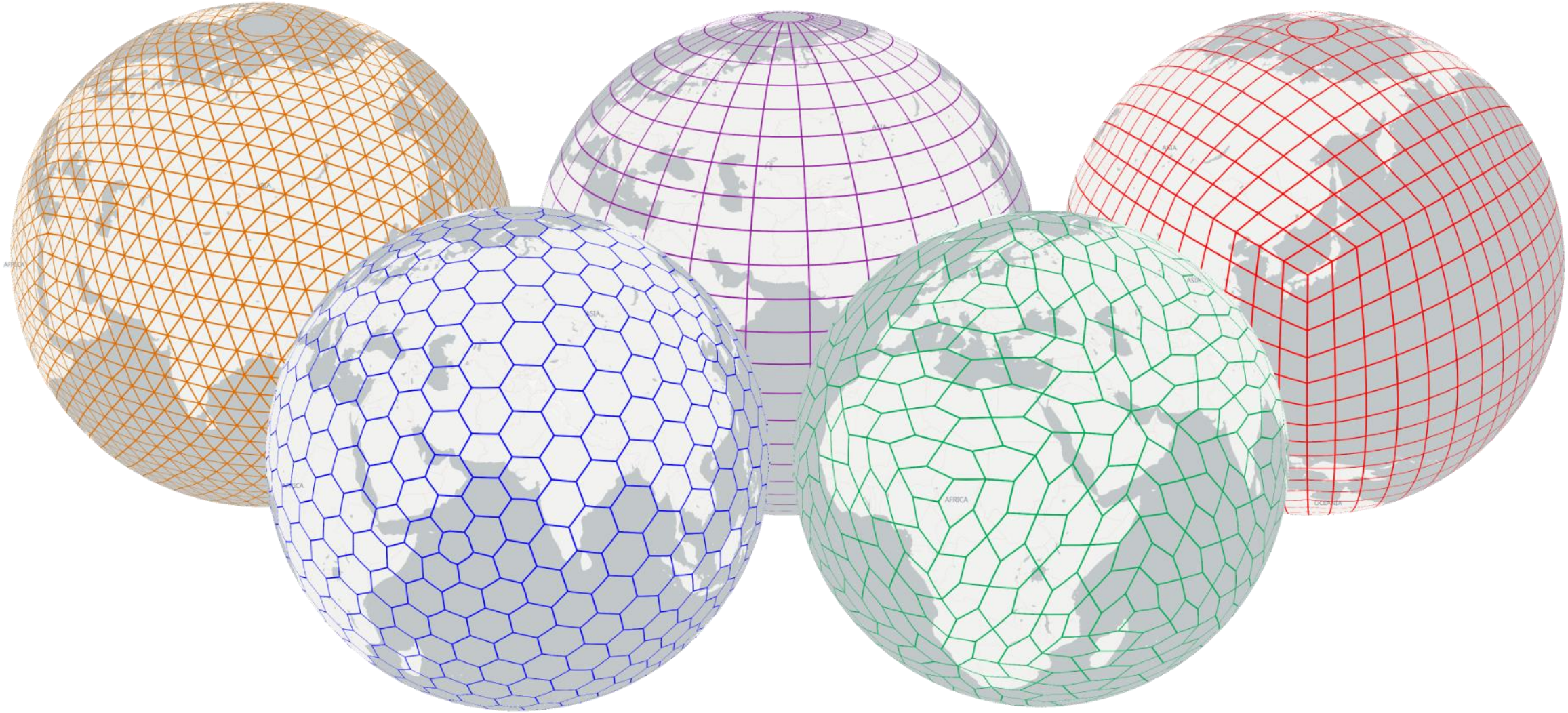


Image source: Varid, © Thang Quach / opengeoshub, MIT licence

Discrete global grid systems

Many different

- Google S2
- Uber H3
- A5
- IGEO7
- HEALPix
- IVEA7H
- Geohash
- …

Discrete global grid systems

Many different

- Google S2
- Uber H3
- A5
- IGEO7
- HEALPix
- IVEA7H
- Geohash
- …

Discrete global grid systems
Key arguments

- Enables global analyses
  - Independent of local projections
  - Wide range of resolution levels

H3

Res	Average edge length (Km)
0	1281.256011
1	483.0568391
2	182.5129565
3	68.97922179
4	26.07175968
5	9.854090990
6	3.724532667
7	1.406475763
8	0.531414010
9	0.200786148
10	0.075863783
11	0.028663897
12	0.010830188
13	0.004092010
14	0.001546100
15	0.000584169

Source: h3geo.org

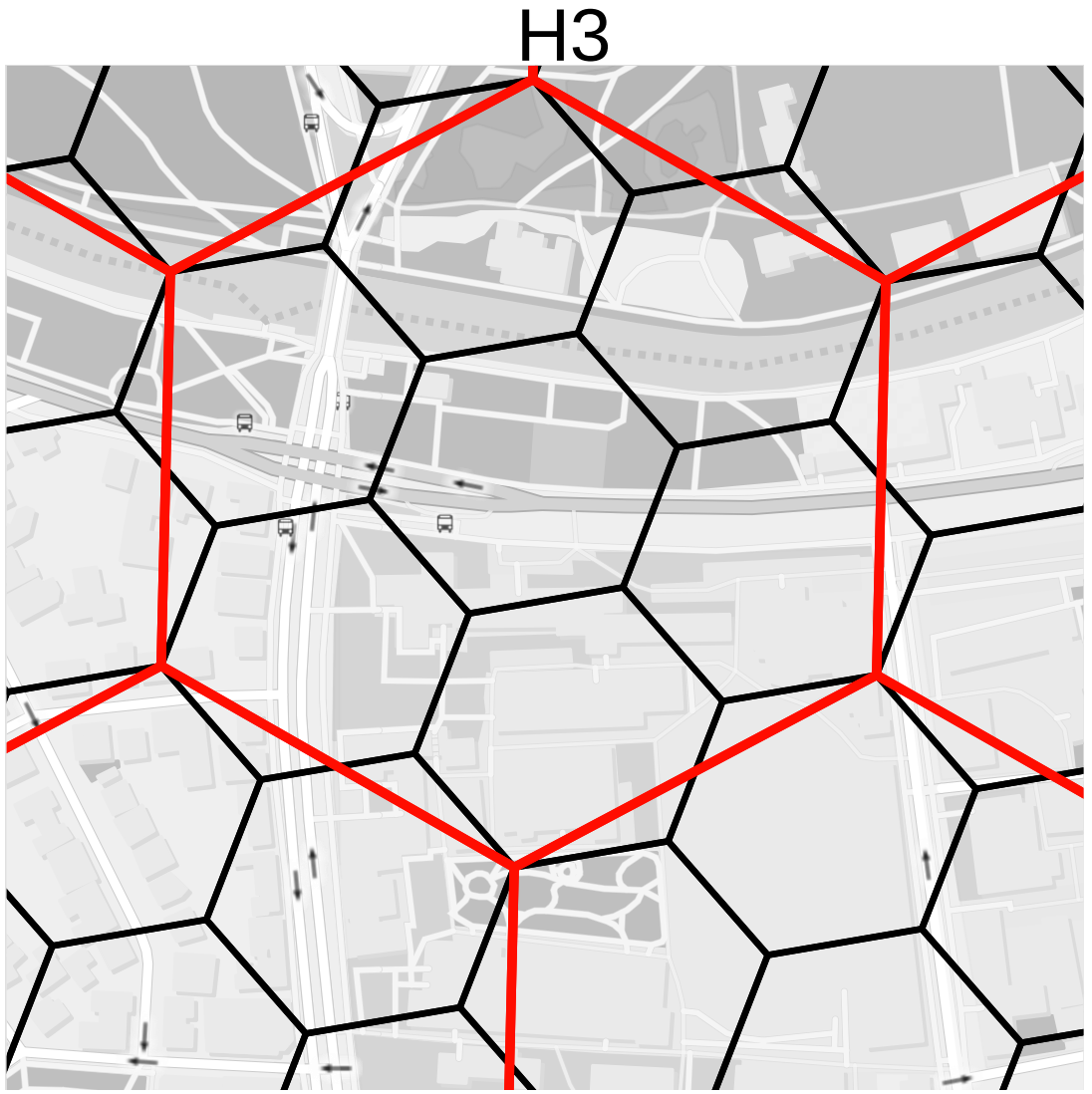
Discrete global grid systems
Key arguments

- Enables global analyses
  - Independent of local projections
  - Wide range of resolution levels
- Hierarchical
  - Defined parent-child relationships
  - Defined conversion between resolution levels

Base map: VersaTiles Graybeard, map data © OpenStreetMap contributors, ODbL

Discrete global grid systems
Key arguments

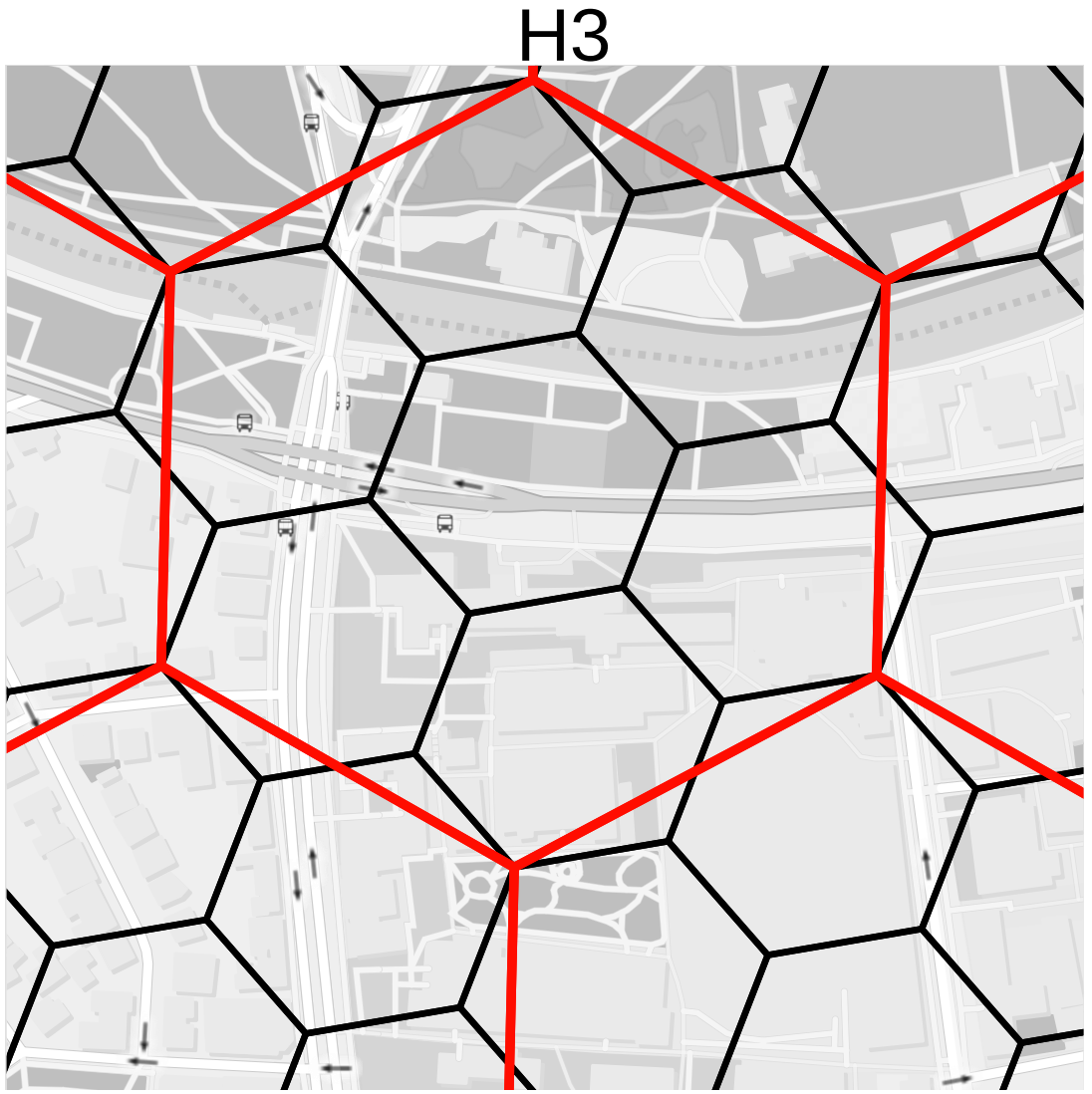
- Enables global analyses
  - Independent of local projections
  - Wide range of resolution levels
- Hierarchical
  - Defined parent-child relationships
  - Defined conversion between resolution levels



Base map: VersaTiles Graybeard, map data © OpenStreetMap contributors, ODbL

Discrete global grid systems
Key arguments

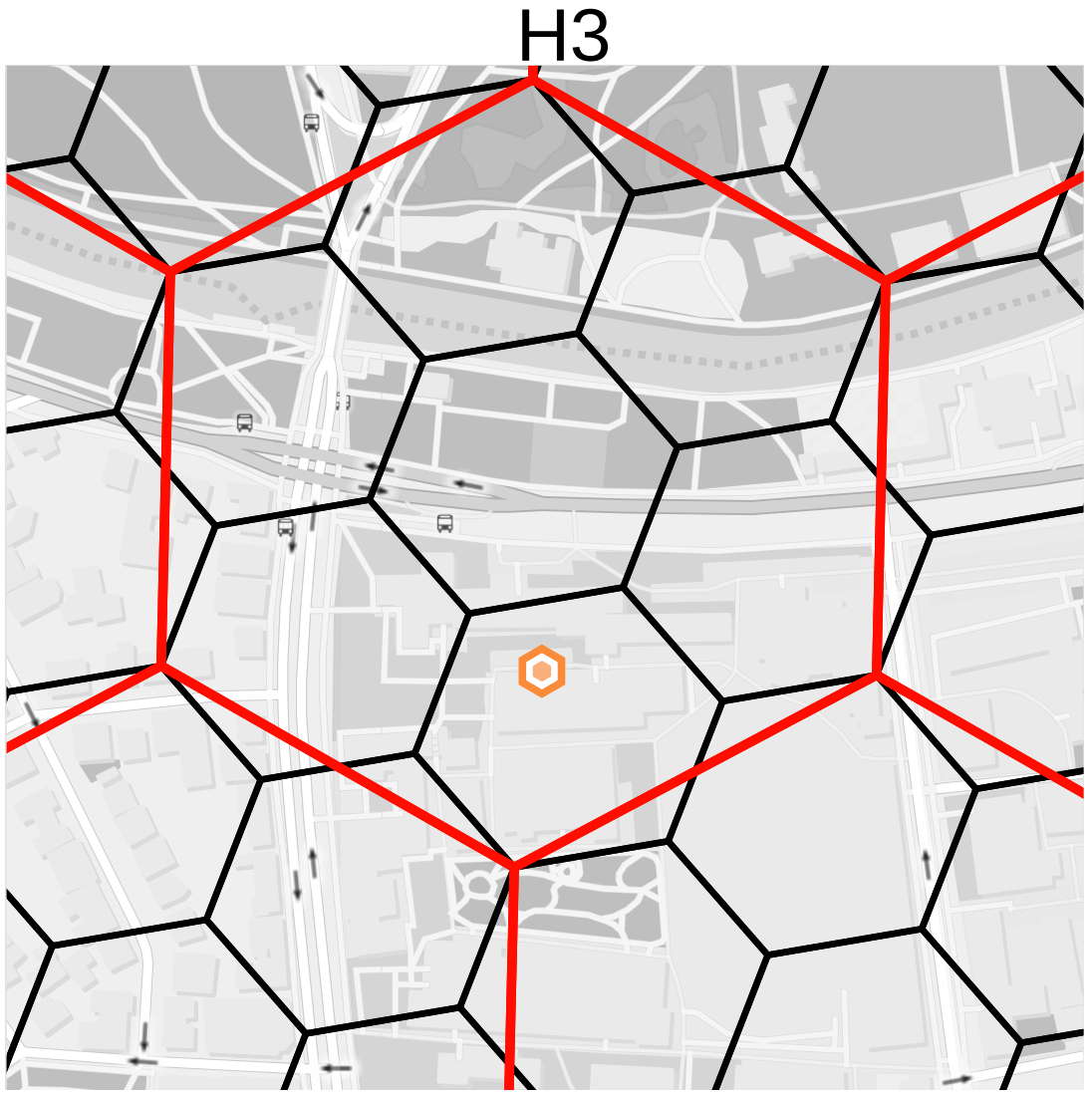
- Unique cell IDs as indices
  - Comparability and “portability”
  - Stability of algorithms



Base map: VersaTiles Graybeard, map data © OpenStreetMap contributors, ODbL

Discrete global grid systems
Key arguments

- Unique cell IDs as indices
  - Comparability and “portability”
  - Stability of algorithms
- Tooling for diverse software stacks
- `latLngToCell(lat, lng, res)`
  - `latLngToCell(45.747, 21.227, 10)`



Base map: VersaTiles Graybeard, map data © OpenStreetMap contributors, ODbL

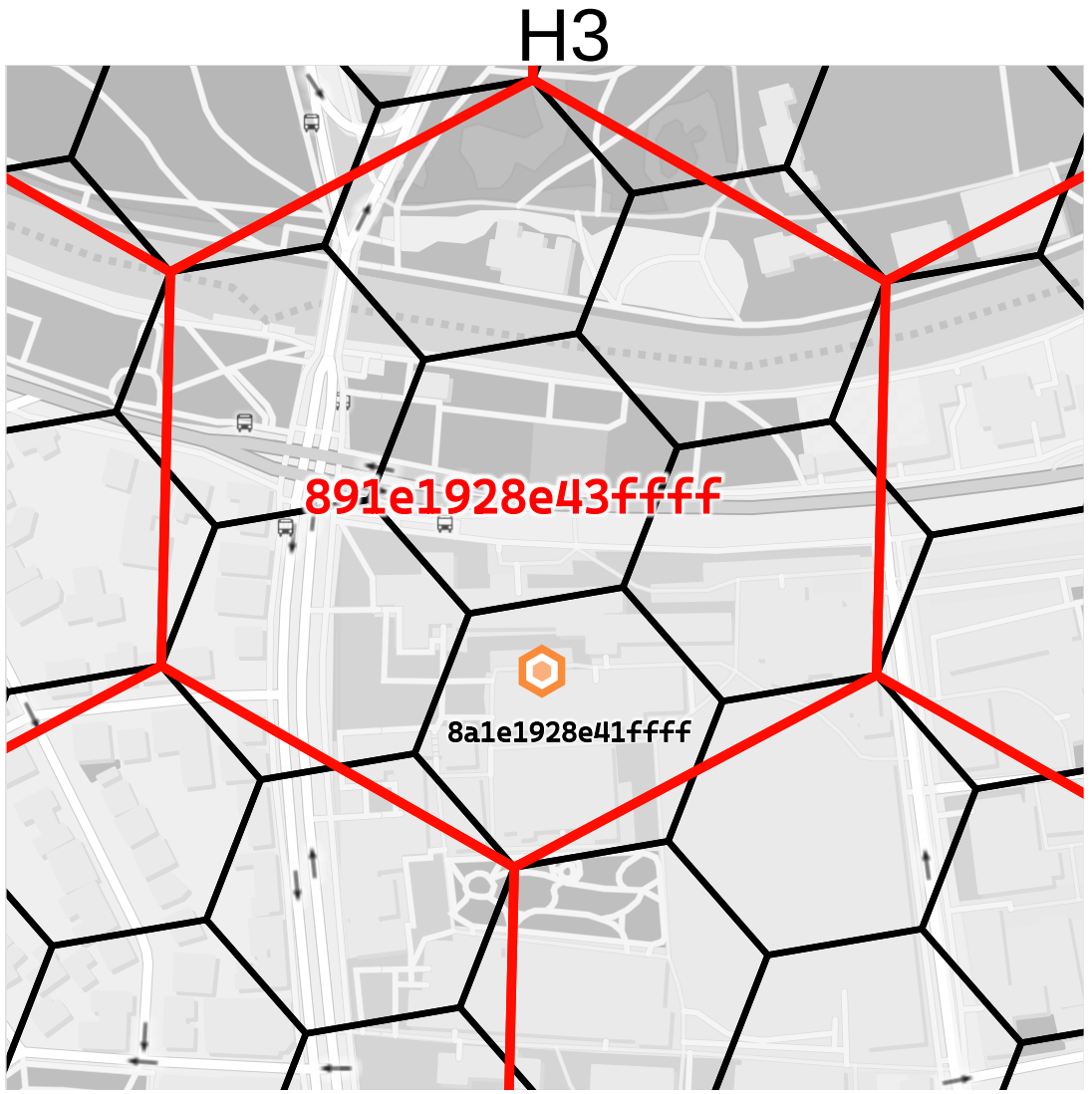
Discrete global grid systems
Key arguments

- Unique cell IDs as indices
  - Comparability and “portability”
  - Stability of algorithms
- Tooling for diverse software stacks
- `latLngToCell(lat, lng, res)`
  - `latLngToCell(45.747, 21.227, 10)`
    `-> cellID` **`8a1e1928e41ffff`**

H3

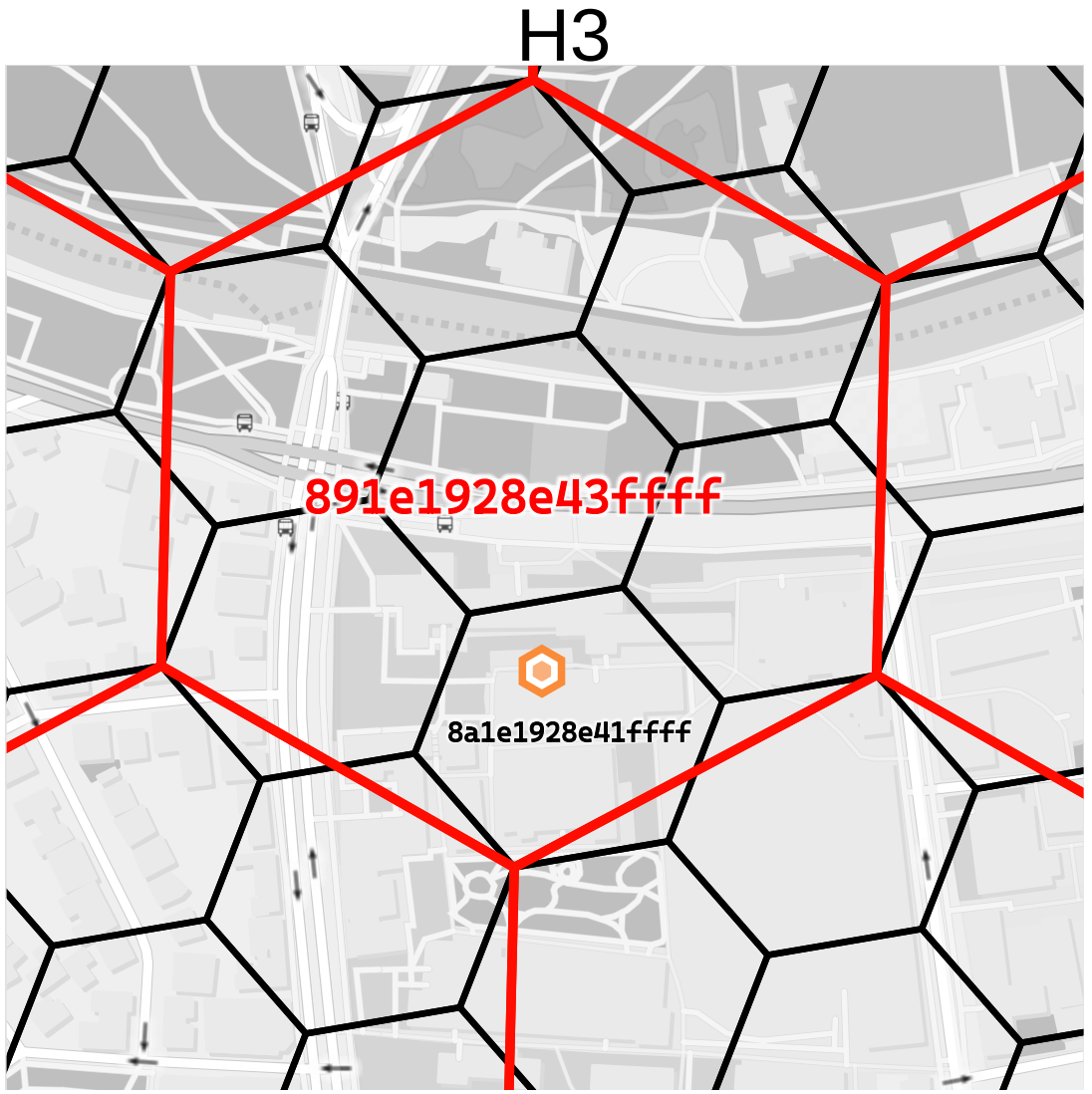
Discrete global grid systems
Key arguments

- Unique cell IDs as indices
  - Comparability and “portability”
  - Stability of algorithms
- Tooling for diverse software stacks
- `latLngToCell(lat, lng, res)`
  - `latLngToCell(45.747, 21.227, 10)` `-> cellID` **`8a1e1928e41ffff`**
  - `latLngToCell(45.747, 21.227, 9)` `-> cellID` **`891e1928e43ffff`**



Discrete global grid systems
Key arguments

- Unique cell IDs as indices
  - Comparability and “portability”
  - Stability of algorithms
- Tooling for diverse software stacks
- `latLngToCell(lat, lng, res)`
  - `latLngToCell(45.747, 21.227, 10)` `-> cellID` **`8a1e1928e41ffff`**
  - `latLngToCell(45.747, 21.227, 9)` `-> cellID` **`891e1928e43ffff`**
- `GROUP BY cellID`



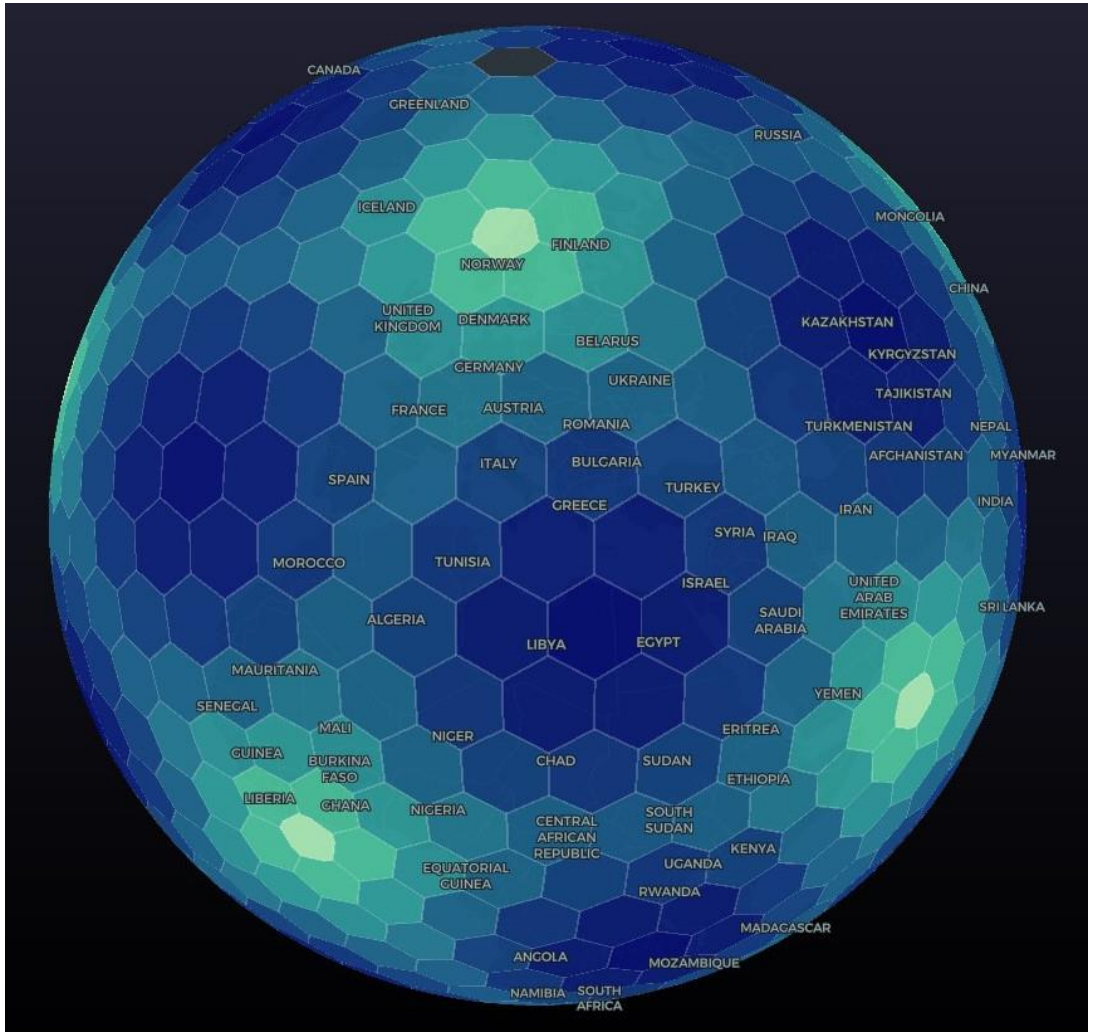
Discrete global grid systems
Brief comparison

Property	INSPIRE grid	S2	H3
Region of application	RO, EU	Global	Global
Working coordinate reference system	Projected 2D, LAEA	WGS84 (internally, cube faces projected on sphere)	WGS84 (internally, icosahedron faces projected on sphere)
Geometry	Square	“Square“, quadtree-like	Hexagon
Resolution levels	3	31	16
Finest resolution	100 m	~ 1 cm	~ 58 cm
Stability of hierarchy	Good	Good (×4)	Average (~×7)
ID codes the hierarchy	Implicit	Yes	Yes
Open-source ecosystem	Small	Medium	Large
Licence	CC BY 4.0	Apache 2.0	Apache 2.0

Discrete global grid systems
Glorifying H3?

Discrete global grid systems
Glorifying H3?

- Area variance as (huge) drawback
  - *“H3 cells vary in size across the globe, with the ratio between the largest and smallest cell areas being roughly 2”*

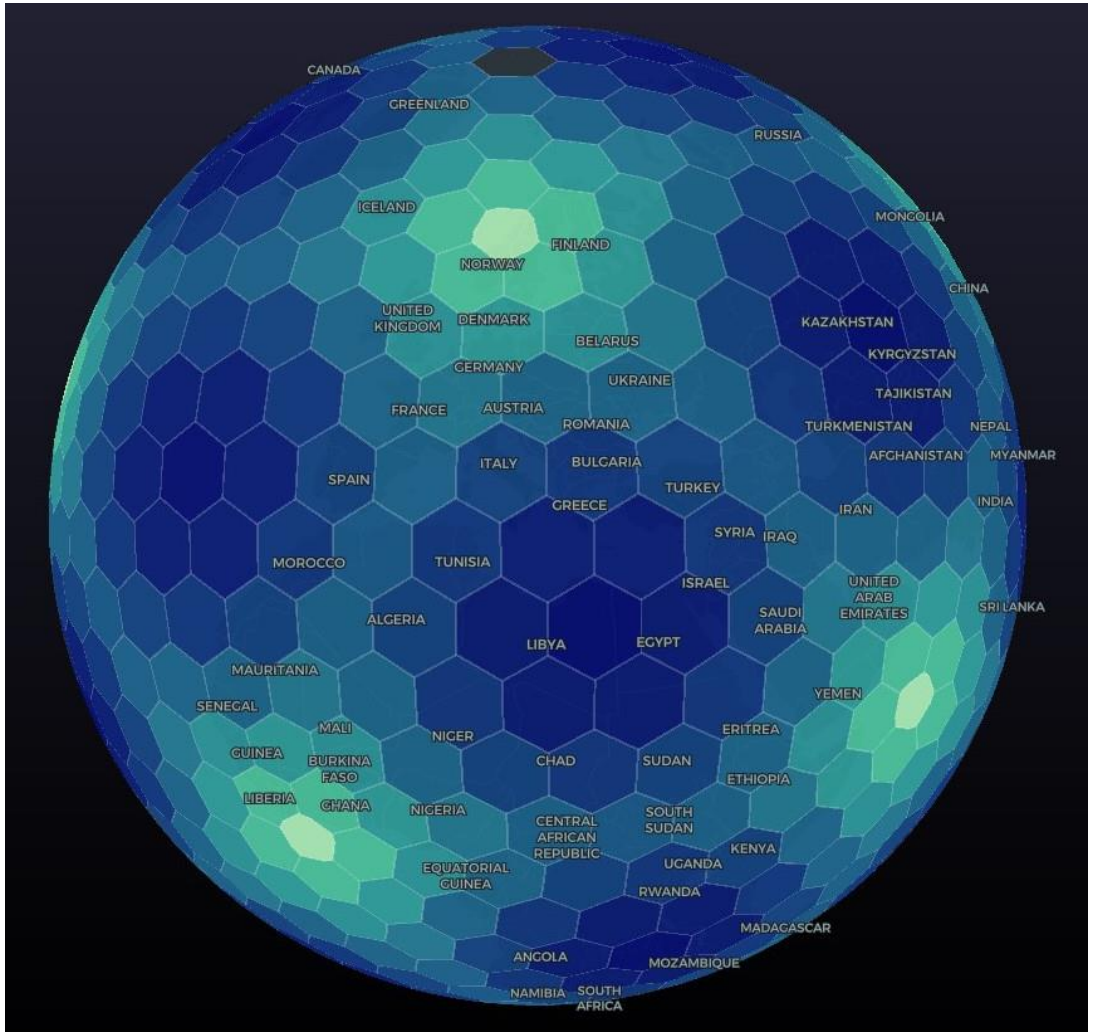


Source: a5geo.org, Apache-2.0 licence

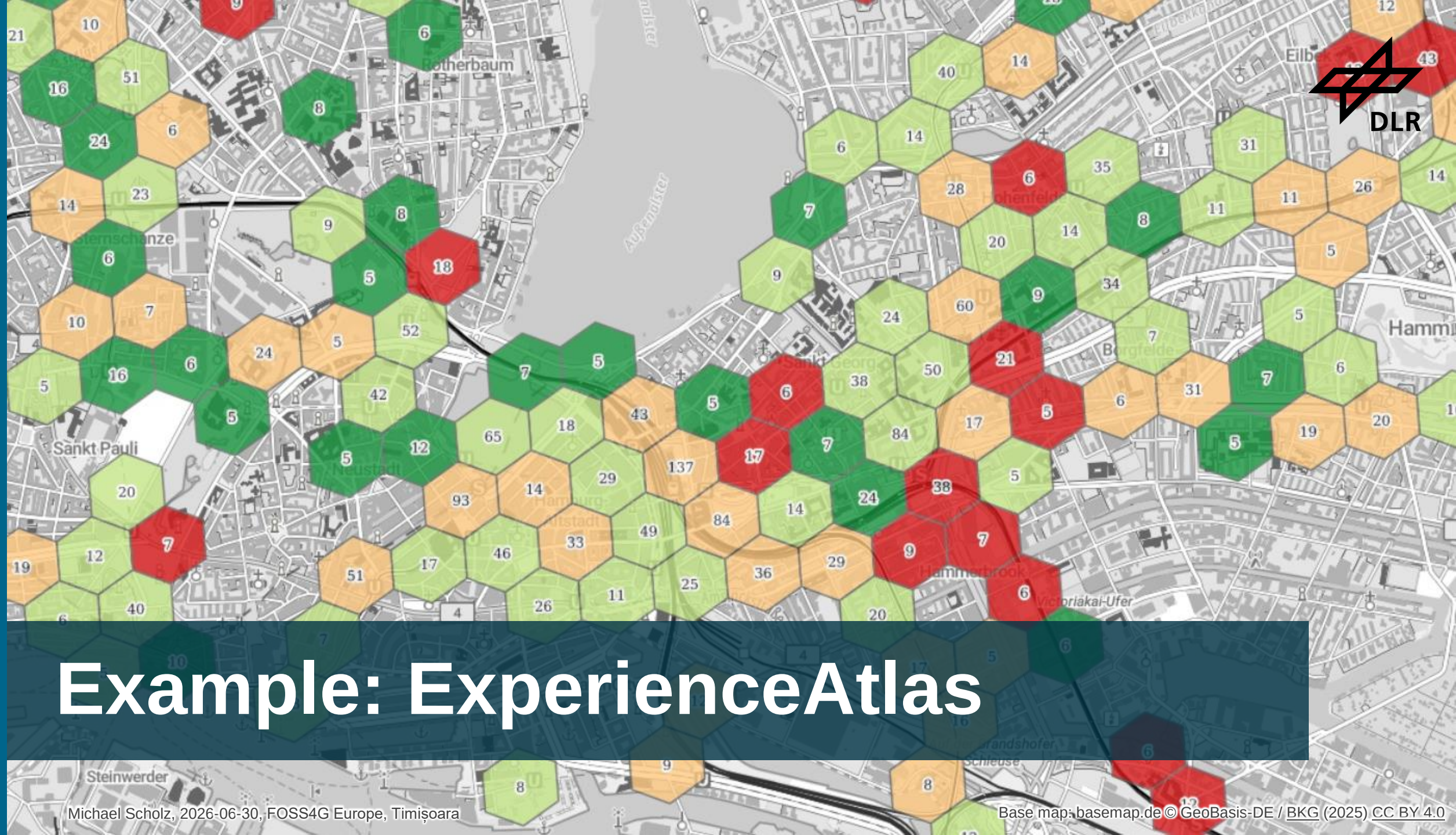
Discrete global grid systems
Glorifying H3?

- Area variance as (huge) drawback
  - *“H3 cells vary in size across the globe, with the ratio between the largest and smallest cell areas being roughly 2”*

- For hexagonal area equality
  → IGEO7

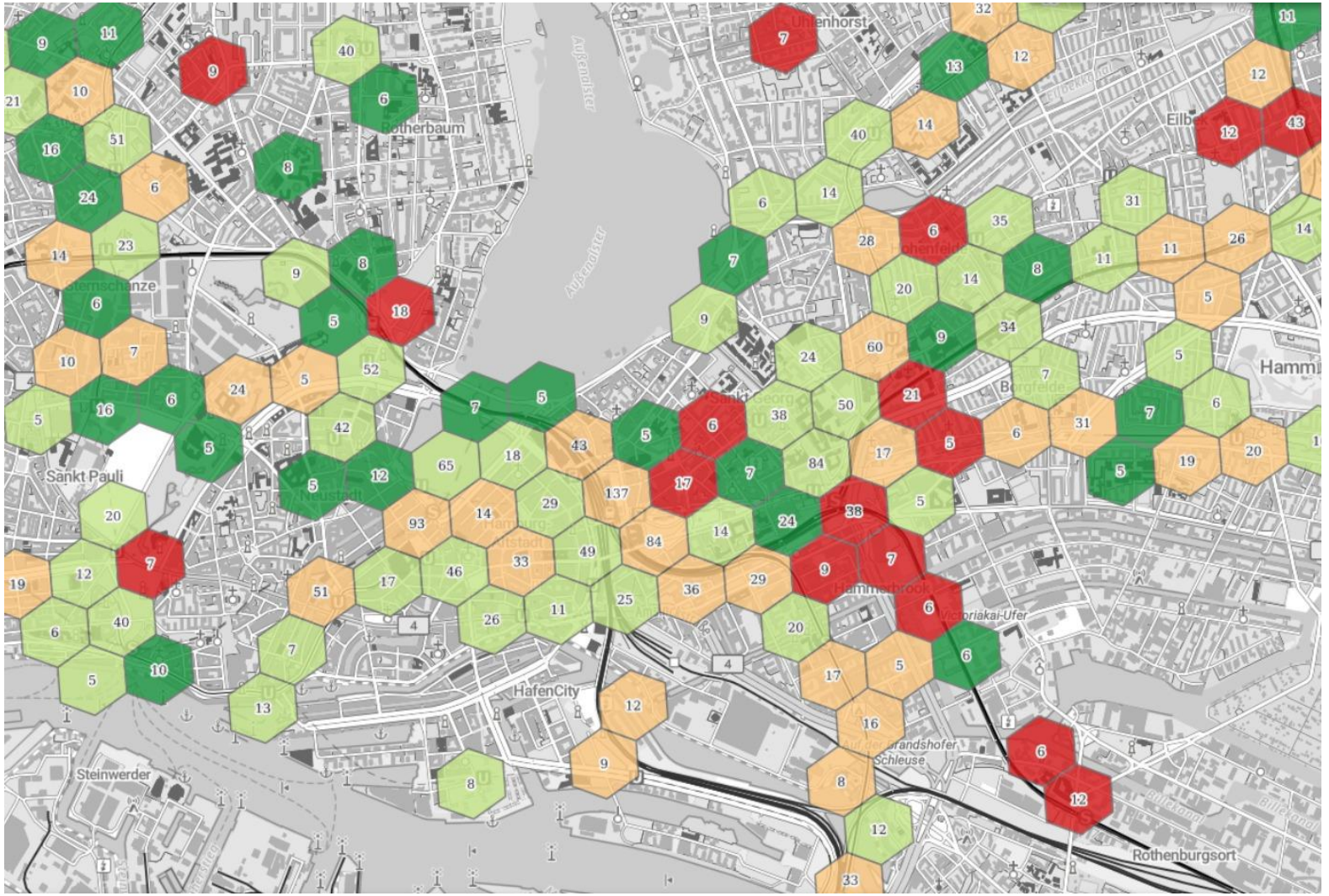


Source: a5geo.org, Apache-2.0 licence

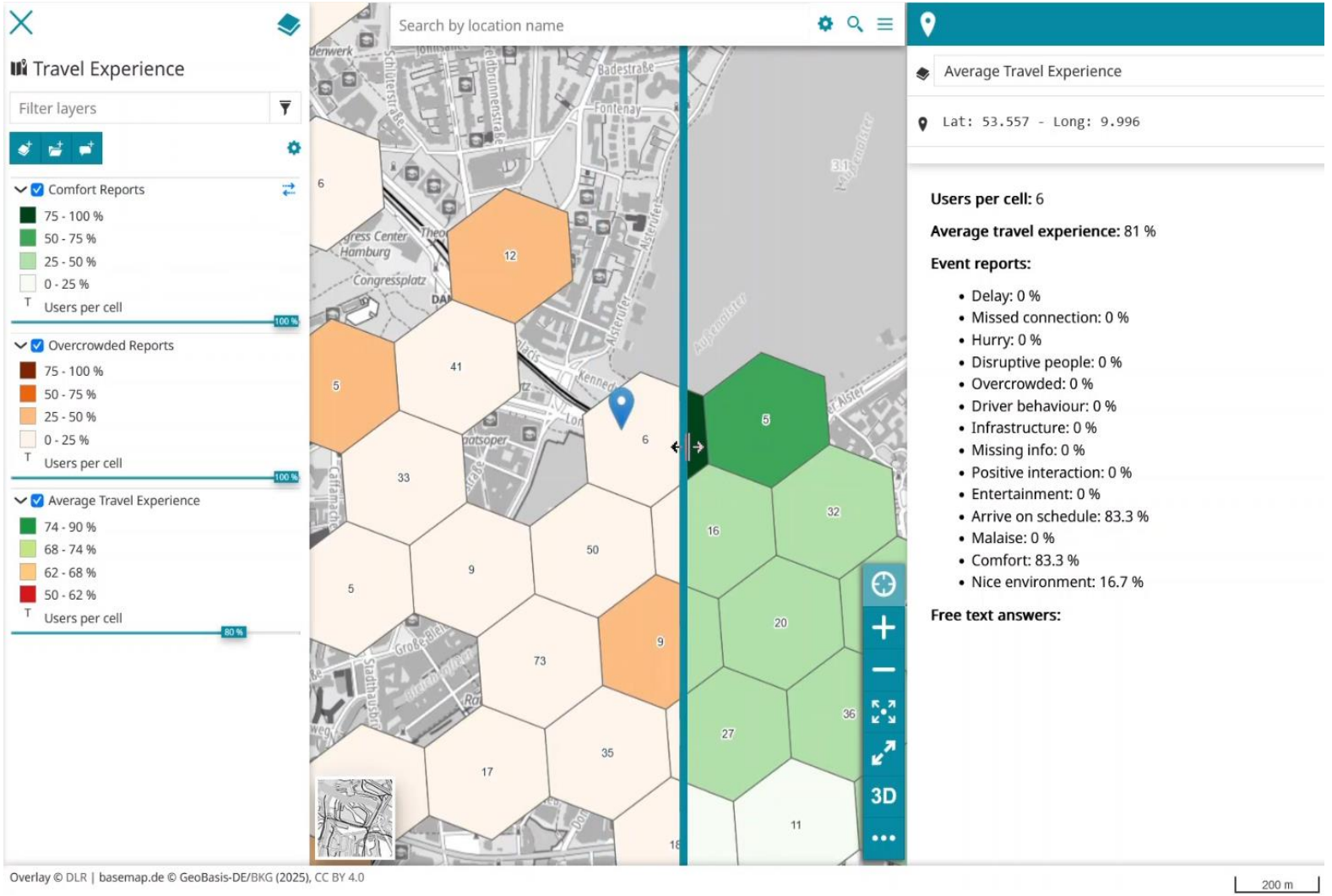


Example: ExperienceAtlas

Project ExperienceAtlas
Demo as web map and video

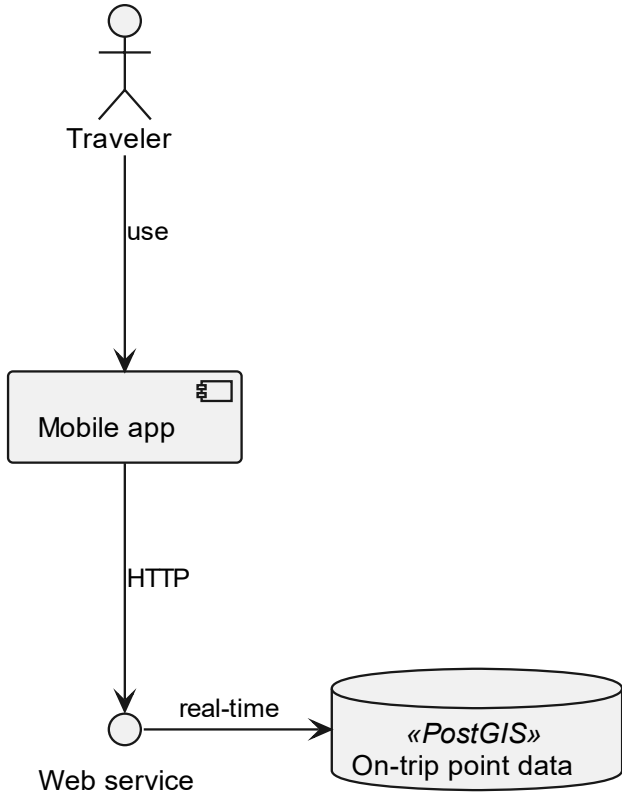


Project ExperienceAtlas
Demo as web map and video



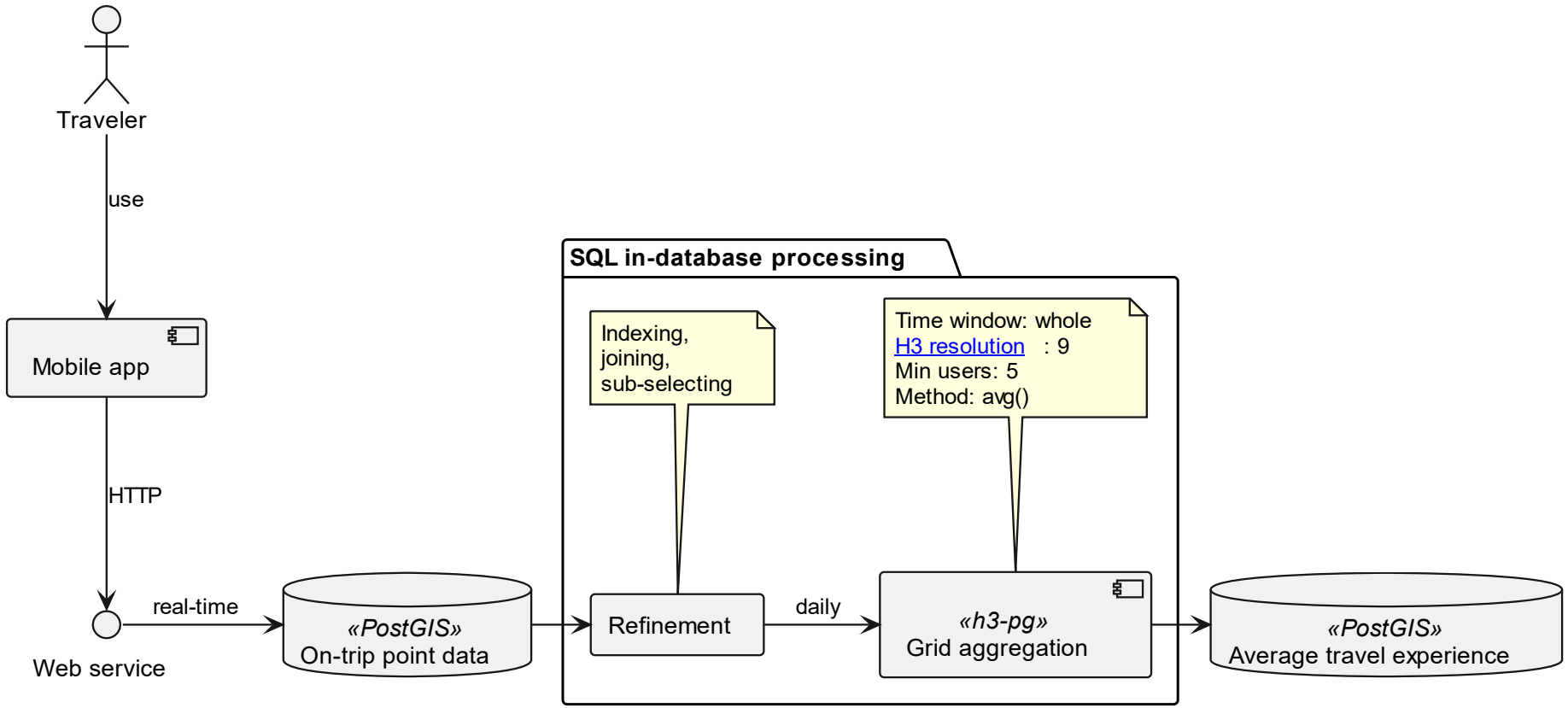
Project ExperienceAtlas

System architecture



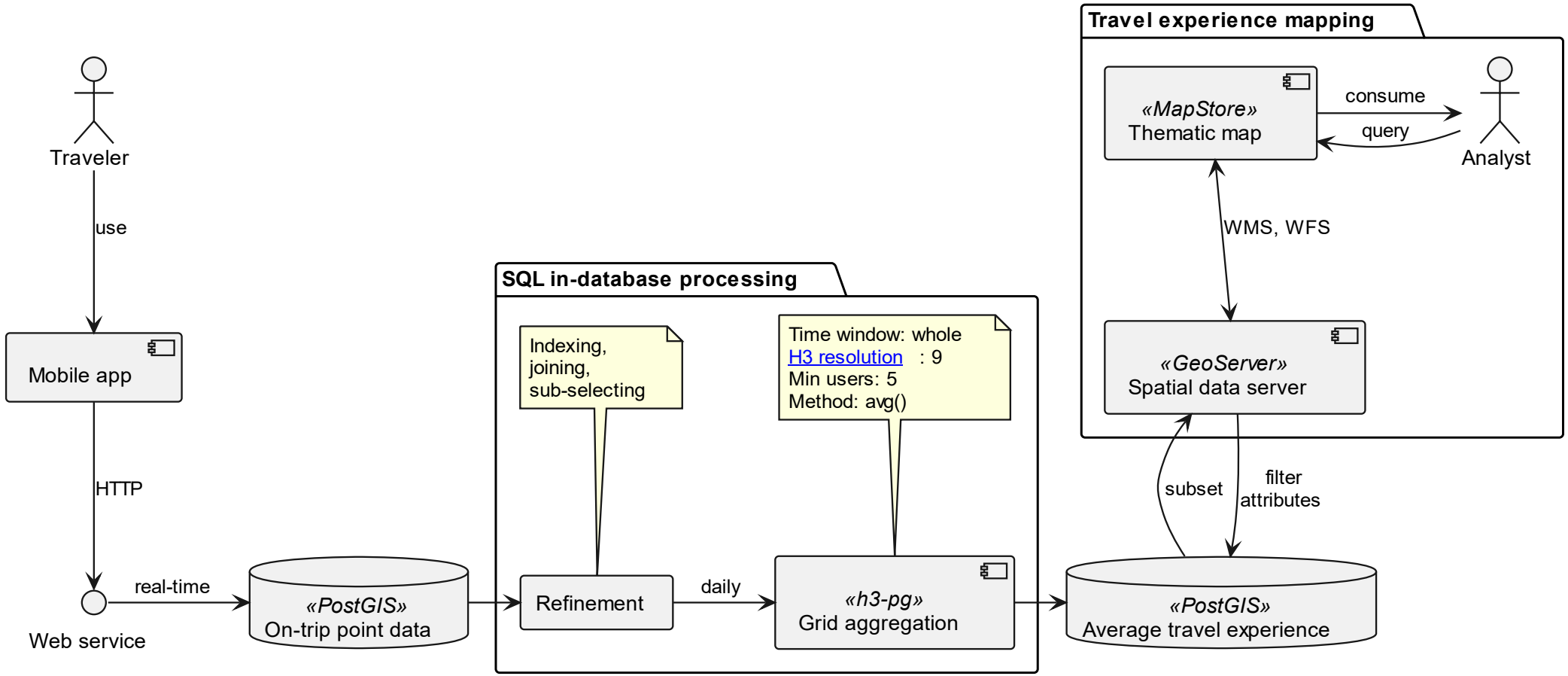
Project ExperienceAtlas

System architecture



Project ExperienceAtlas

System architecture



Outlook and OGC activities

OGC AI-DGGS Pilot
“Spatial tokens“ as common spatial language

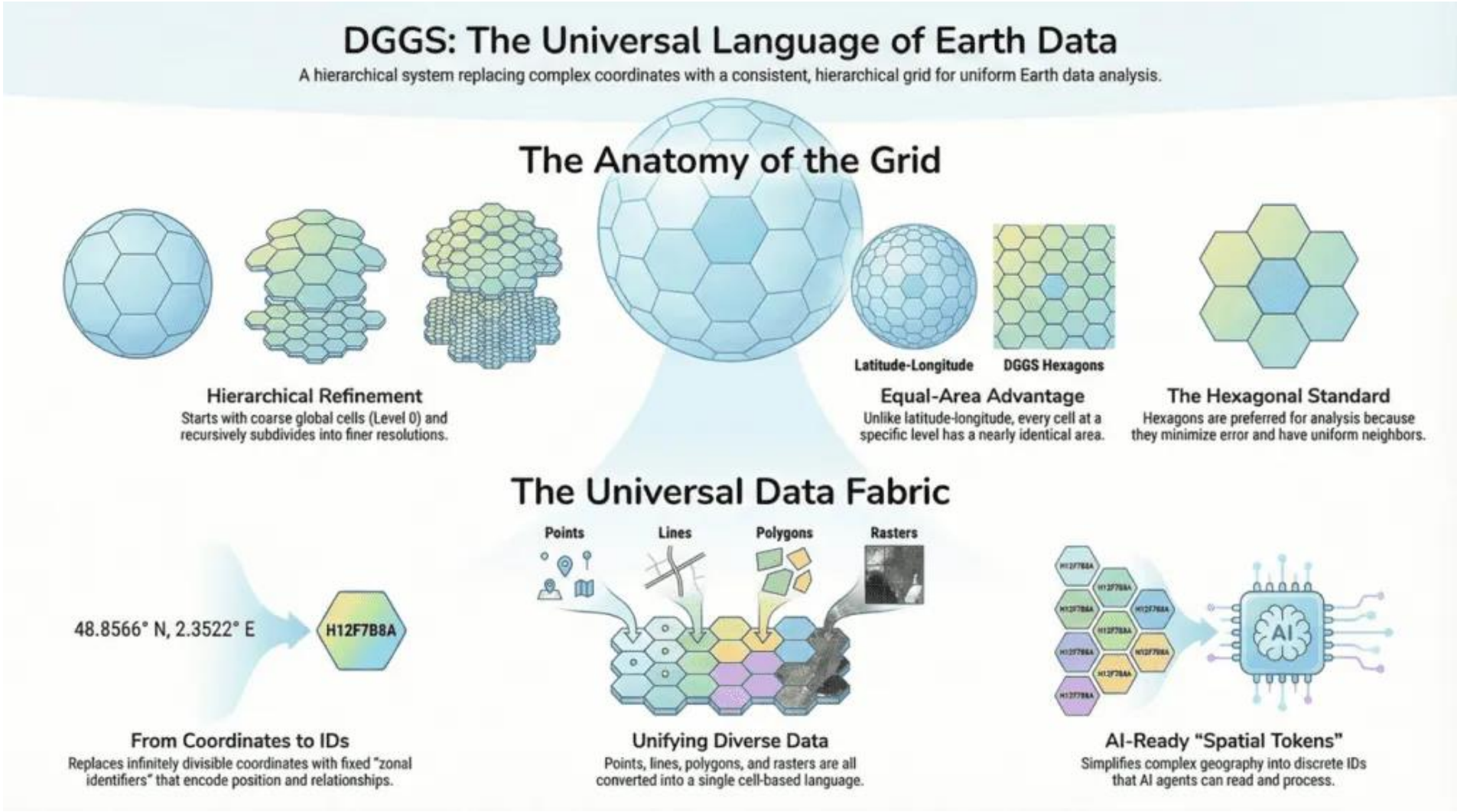


Image source: OGC blog post

OGC AI-DGGS Pilot

“DGGS cells are to geospatial AI
what tokens are to language models”

Sources and resources:

- From chat to map: How DGGS + Agentic AI turn geodata into verifiable decision-making bases
- AI-DGGS Pilot for Disaster Management
- Video recording of OGC’s AI-DGGS workshops

Tooling

- DGGAL, the Discrete Global Grid Abstraction Library
  - Implements OGC API – DGGS standard
  - Provides uniform functions on different DGGS

- Vgrid as Python library and as Vgrid plugin for QGIS
  - Creation of different grid geometry layers
  - Binning functions

- GeoPlegma

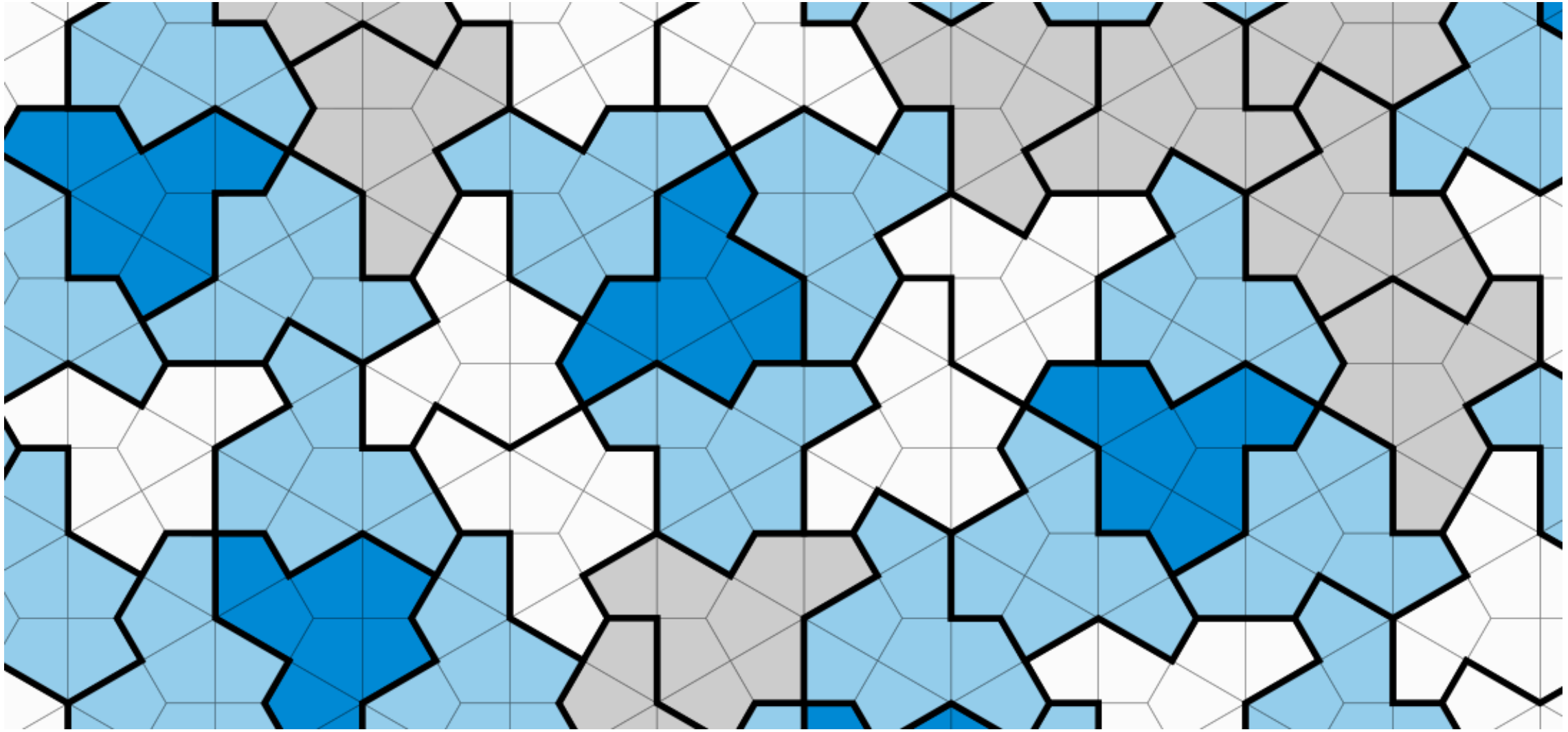
Additional resources

- The Shape That Actually Wins at Everything 🐝
- Hexbin vs. H3
- IGEO7 vs. H3
- IGEO7 vs. S2
- A5 vs. H3: Visualises area variance of H3
- Alexander Kmoch et al.: *Area and shape distortions in open-source discrete global grid systems,* https://doi.org/10.1080/20964471.2022.2094926

Other DGGS-related talks on this conference

- Efficient Neighbourhood Computation and Cloud-Native Storage for the IGEO7 DGGS Using the Z7 GBT Indexing
- Tiling the Earth: Interactive HEALPix in the Browser
- Asking a Province a Question: LLMs, H3, and Open Dutch Geodata
- Storing your Satellite in a DGGS
- Indexing with Hexagons: GBT Explained

If the structure stays the same, your algorithms stay the same 🤗



Imprint

Topic:	**Discrete global grid systems for spatio-temporal aggregation and visualisation**
	FOSS4G Europe, Timișoara
Date:	2026-06-30
Author:	Michael Scholz
Institute:	Transportation Systems
Licence:	All content and media „© CC BY-NC-ND 3.0“, unless otherwise stated