P5 – Final Presentation

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Modelling a military scene using a Discrete Global Grid System

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Today's Agenda

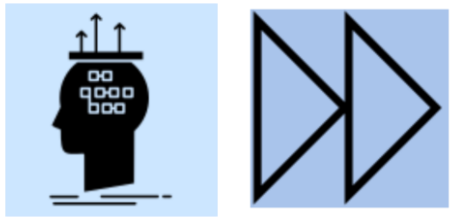
Problem summary

Objectives

Methodology

Implementation

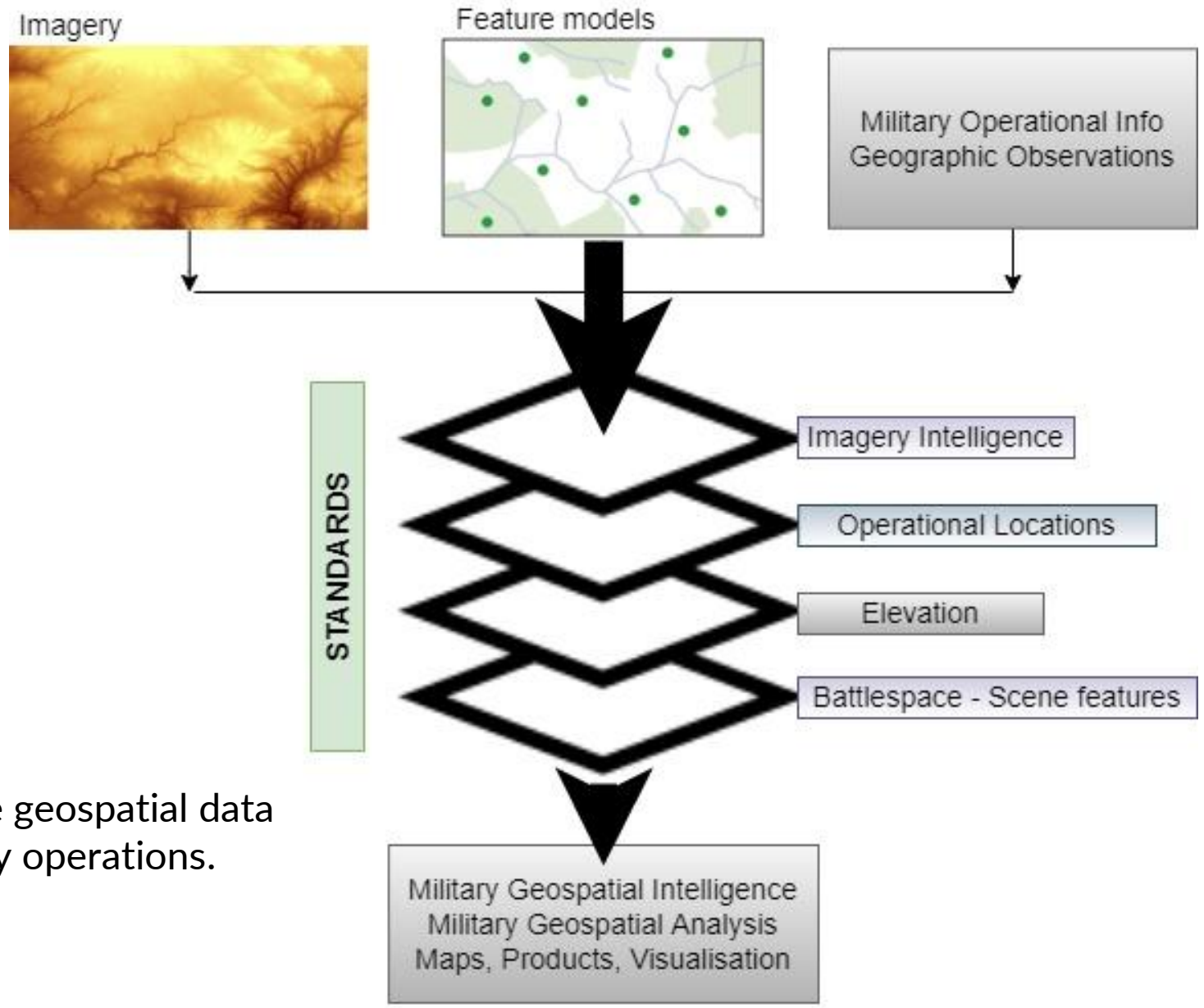
Results



Conclusions

Military geospatial intelligence

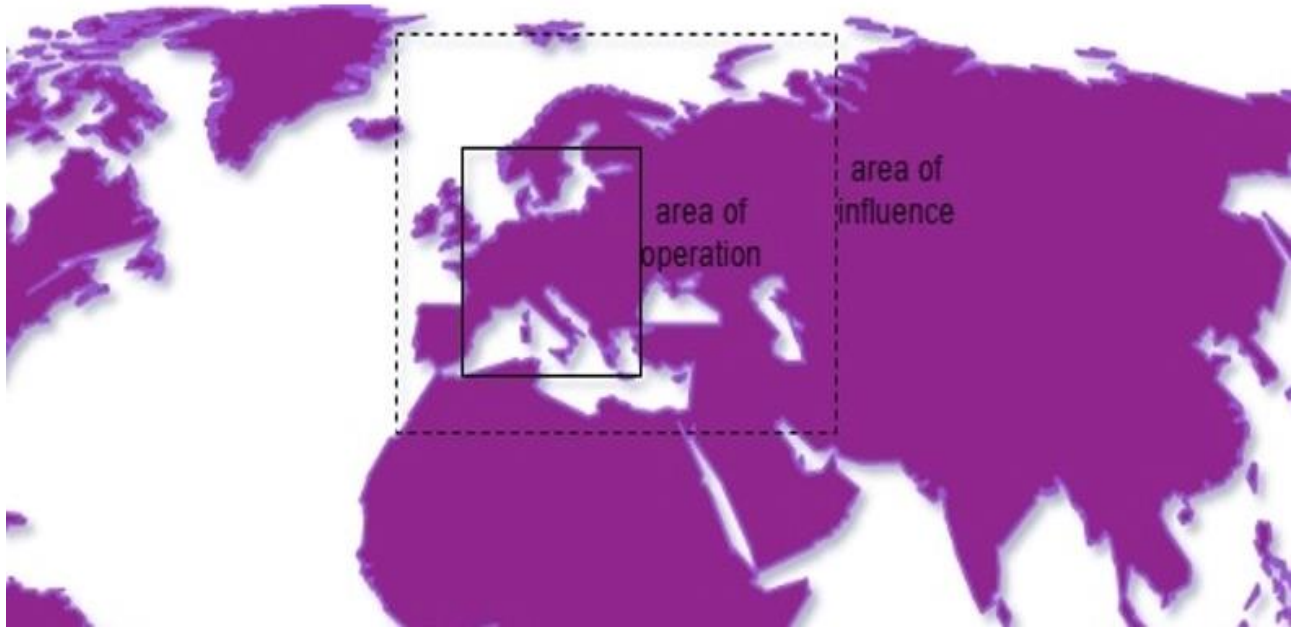
- Commercial off-the-shelf GIS
- Visualization of pure geospatial data products
- Geospatial analysis on frameworks embedded to C3I systems (Command, Control, Communications and intelligence)



create, analyse, visualize & retrieve geospatial data assisting decision making in military operations.

Military operations

- The qualitative spatial perception is an important aspect.
- Discrete thematic raster, vector layers can be ambiguous, being metric and quantitative – they don't provide straightforward connectivity between objects of the scene
- Geospatial data integration can provide high level data driven analysis



Area of operations, Area of influence, Area of coverage

- In military scenes, embedded to the area of coverage concept, the space partitioning is an important aspect, as a base framework for operations.

Problem definition

- Military – combined operations- civil cooperation : air, ground, sea

  → difficulties- geospatial communication
  different data formats, different Coordinate Reference Systems

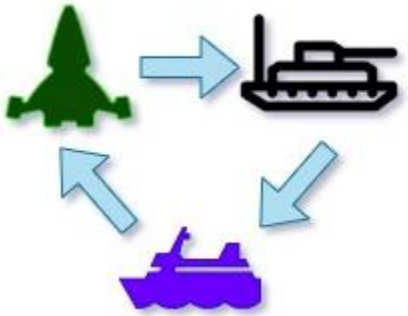
  → referring to different areas of responsibility

  → need for data processing, update

  → need for geospatial data integration to perform analysis

  → distribution of data-security issues

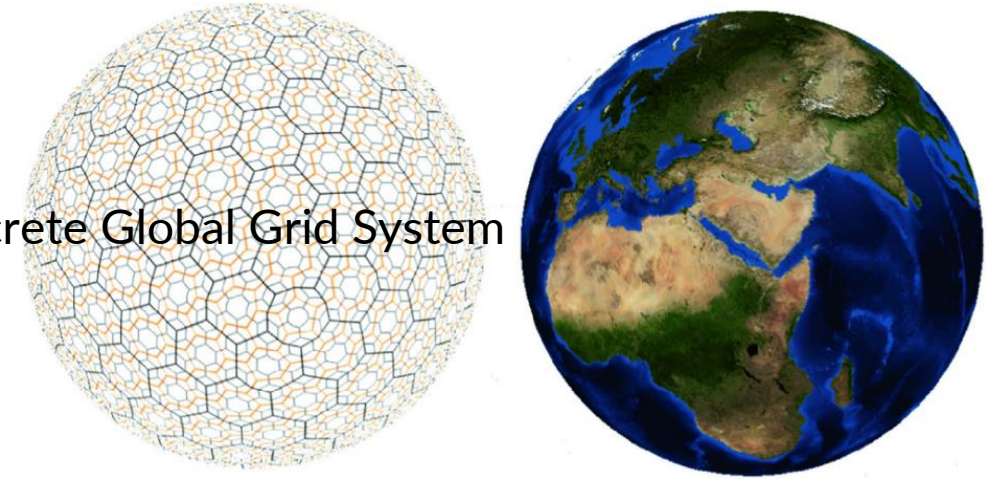
  → Military- civil cooperation: joint operations, disaster management



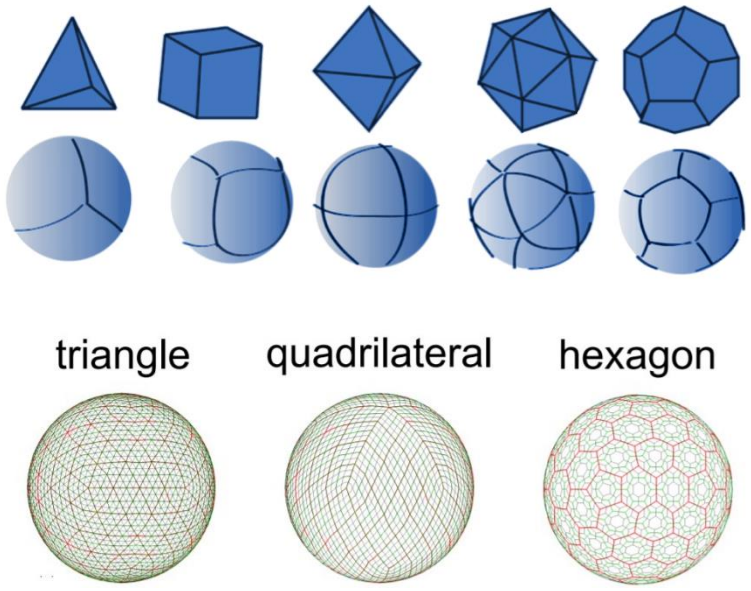
What is a DGGS??

..a hierarchical tessellation of equal area cells that both partition the entire Earth at multiple levels of granularity and provide a global spatial reference frame..

As defined by the DGGS standard, OGC.



- A DGGS is designed as a framework for information as distinct from conventional coordinate reference systems originally designed for navigation.



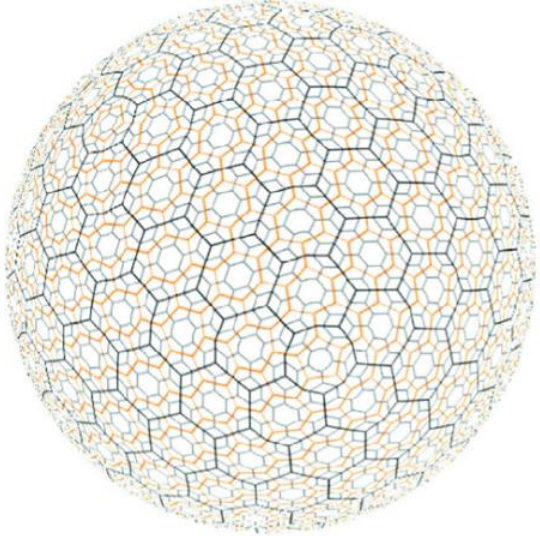
Different space partitioning methods

Discrete Global Grid Systems:

- Offer the area subdivision while having the ability to integrate different geospatial data formats.

- Globally unique cell indices
- Can provide connectivity relations – info given as key/value pairs

DGGS



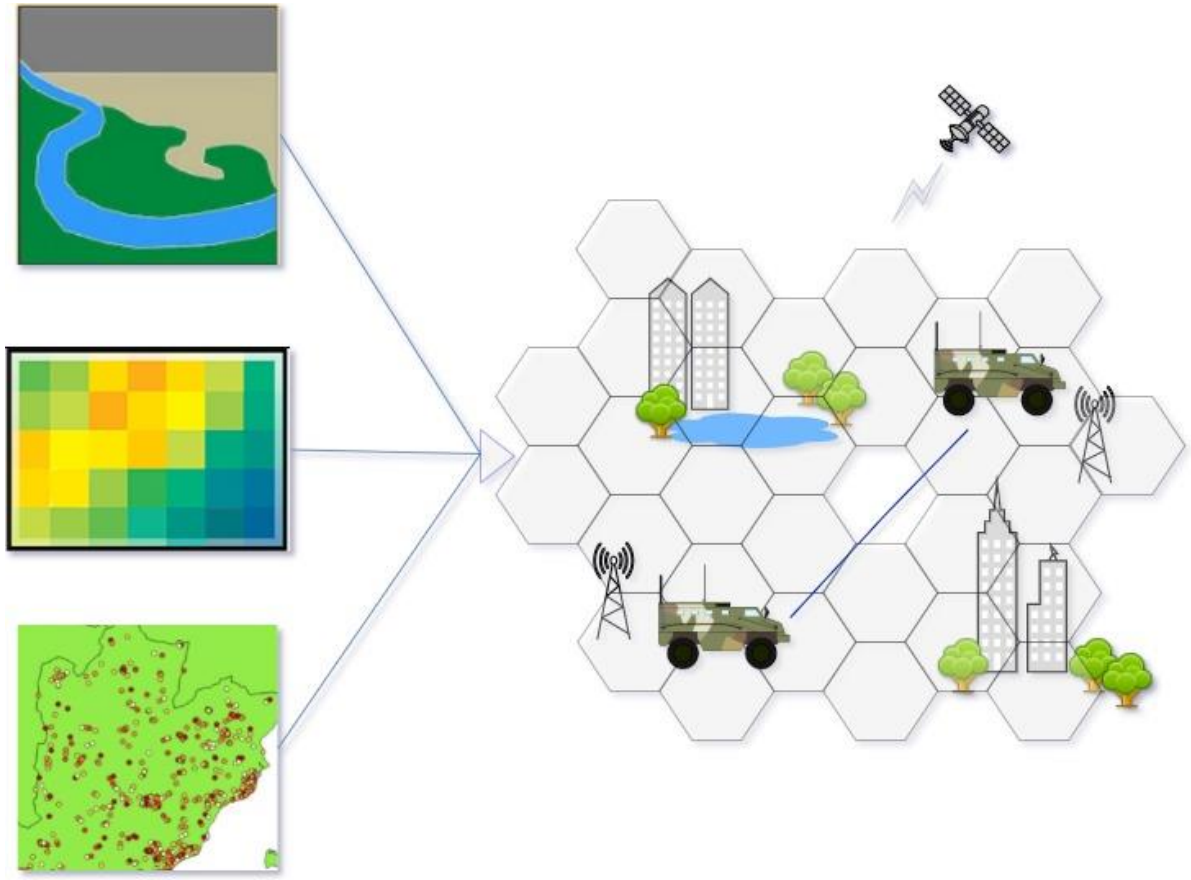
- OGC DGGS Abstract Specification

Open Geospatial Consortium

- Related research
  - **Rawson et al. (2021)** Intelligent geospatial maritime risk analytics using the discrete global grid system.
  - **J. Bousquin. (2021)** Discrete global grid systems as scalable geospatial frameworks for characterizing coastal environments.
  - **Robertson et al. (2020)** An integrated environmental analytics system (ideas) based on a dggs.

Objectives & Methodology

- Application of a DGG system
- Integration of different datasets (vector, raster) of military interest
- Demonstrate the integration and storage procedure and identify the potential of this approach to model a military scene
- Military case study (ranging) using the DGGS system



NATO OTAN

Current military geospatial standards

OGC Abstract Specification

Open Geospatial Consortium

Discrete Global Grid Systems

Use of an existing DGGS implementation: [H3: Uber's Hexagonal Hierarchical Spatial Index]

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Datasets

3 vector 2D datasets, 1 raster elevation dataset

Vector datasets:

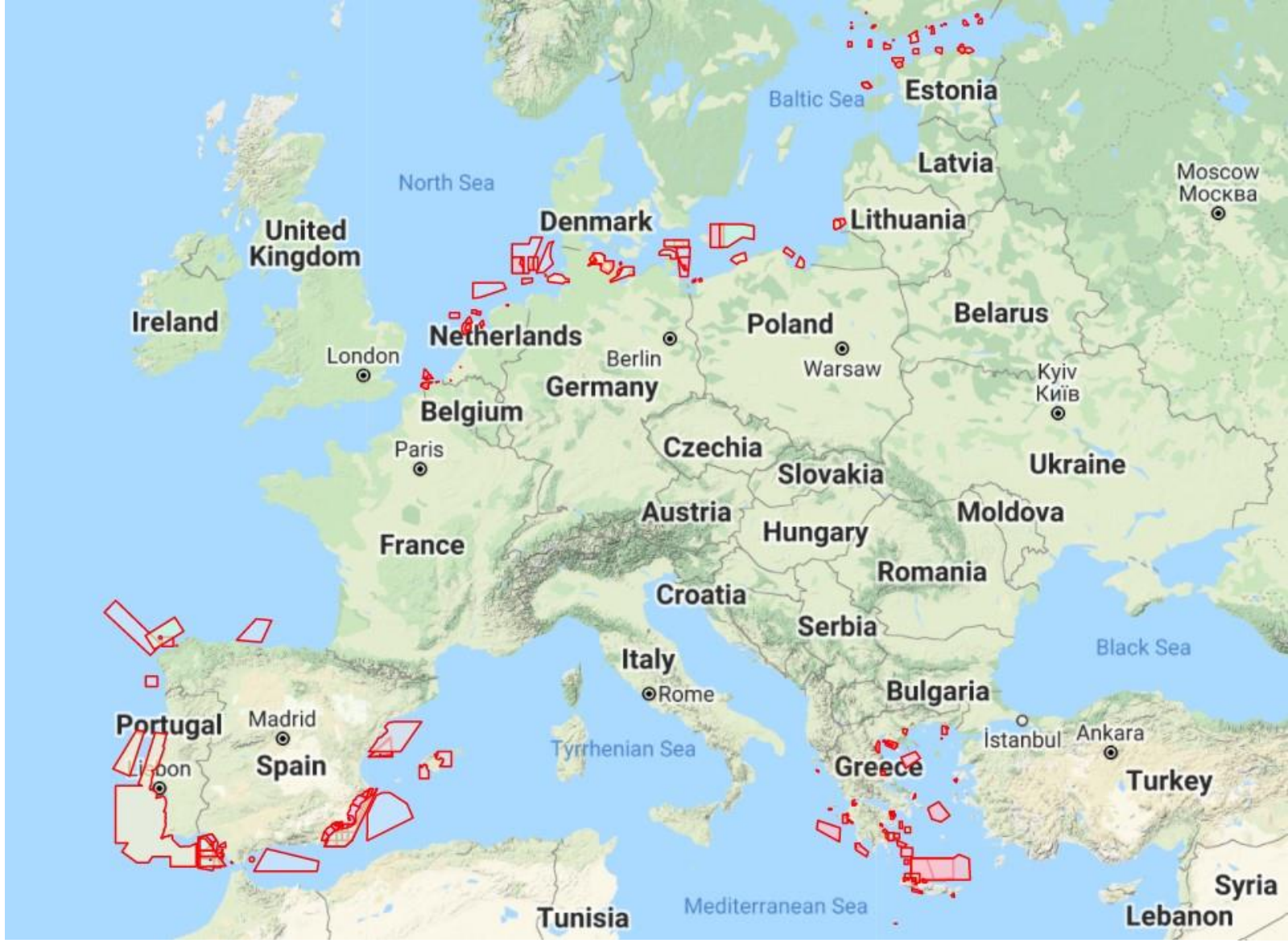
EMODdnetHAMilitaryAreas20210201.shp

EMODdnetHAMilitaryAreas20210201.shp, Offshore military areas in the EU.

AirportsEU.shp, Transport Networks-Airports-EU, Eurostat

Raster datasets:

ETOPO5 5-minute gridded elevation data, was generated from a digital data base of land and sea-floor elevations on a 5-minute latitude/longitude grid, cropped for EU.



Offshore military areas in the EU was created in 2020 by CETMAR for the European Marine Observation and Data Network (EMODnet)

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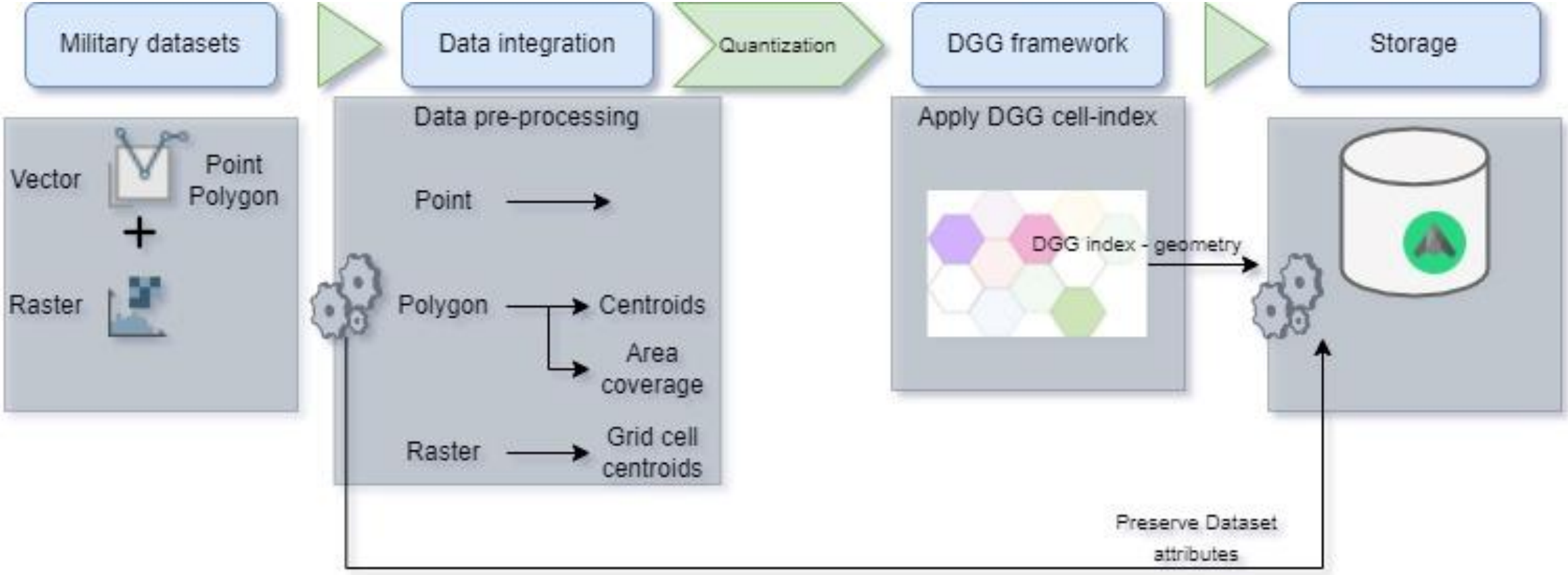
Methodology

- 2D + elevation geospatial datasets (different formats) integration under the same DGGS framework
- Storage in files, database



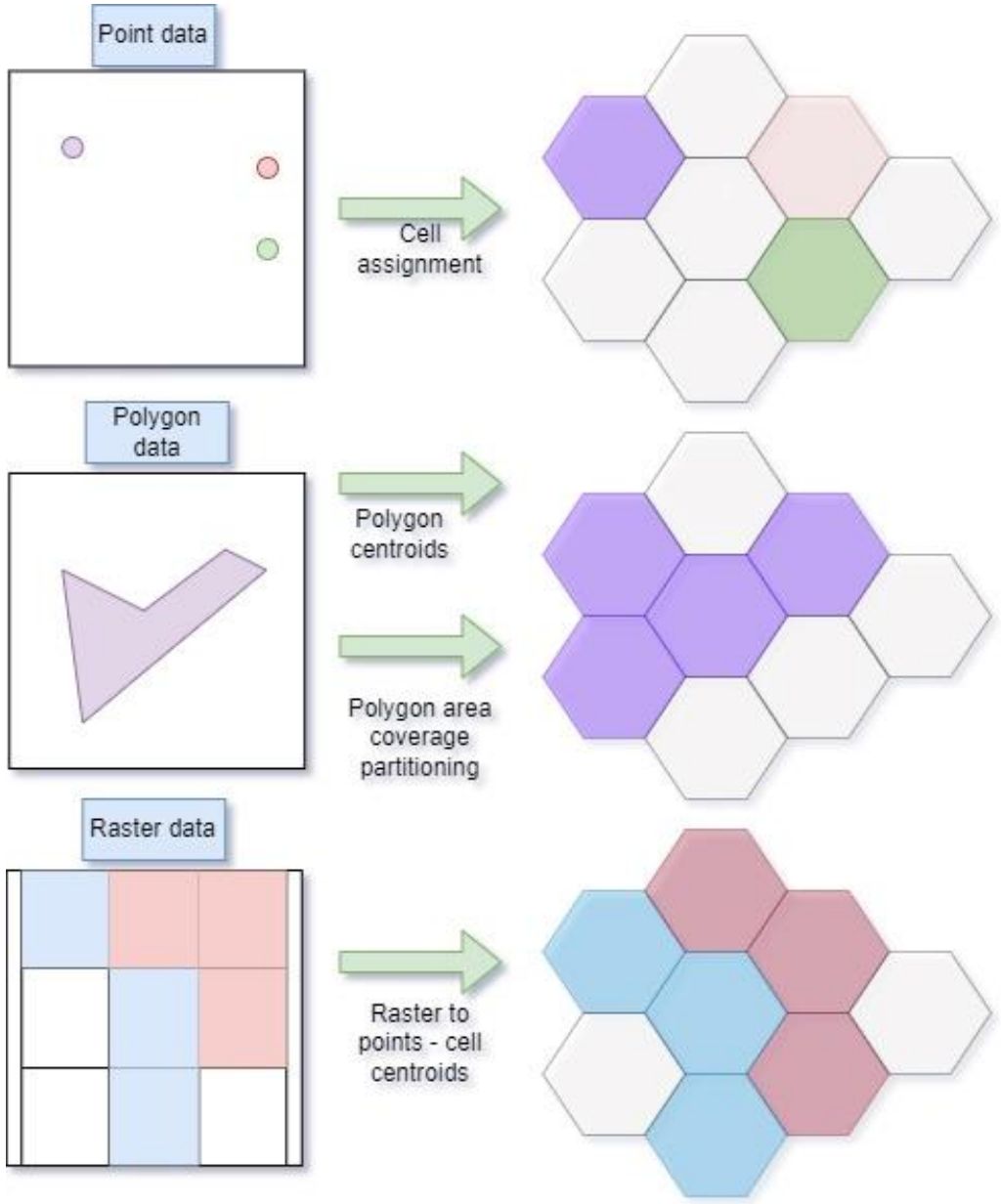
Methodology

Different APIs per data format

- Raw data → quantization → DGGS cell index data transformed/binned in the DGGS framework

- Testing different quantization approaches
- Testing different resolutions

- Assessment after conversion-data integration : Distortions and errors, topology validity, geometric coherence, position displacement



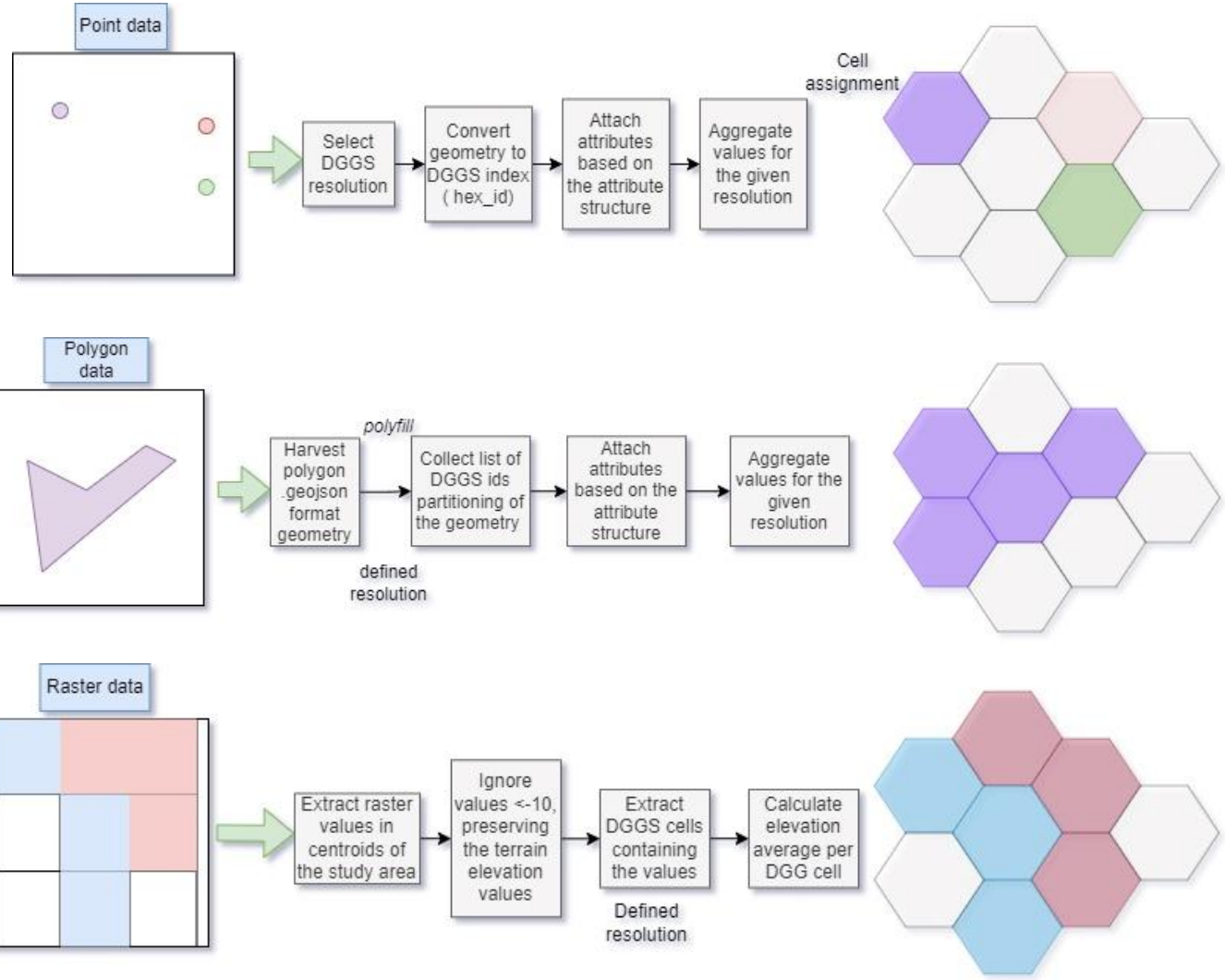
Implementation

APIs

- Point to DGGS ✓
- Polygon to DGGS ✓
- Raster to DGGS ✓

Integrated model

Info from multiple data sources/ formats under a common DGGS framework



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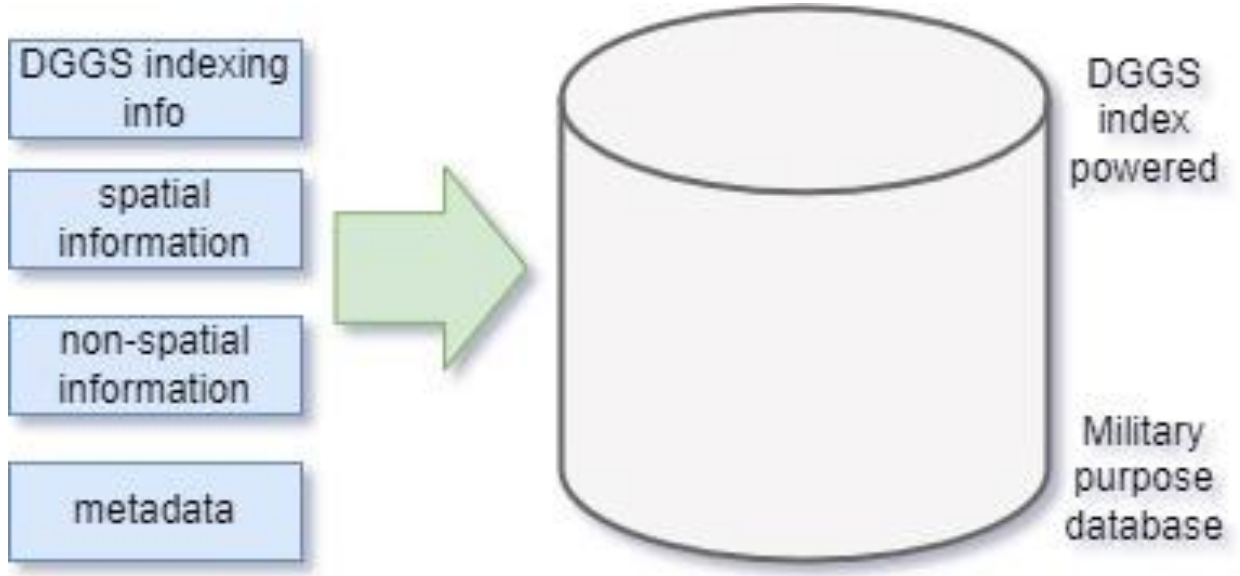
Database

- Military purpose database
- Storage of the integrated datasets – DGGS index
- Transform them in a fashion ready for spatial analysis, to designate the accessibility and interoperability of a military database
- The integrated dataset's attributes are preserved and stored, data loss minimization
- Construction of an integrated attribute structure model, fitting the different datasets' qualitative and quantitative scene related properties



hex id	country	status	type	area	coast dist	elevation	value

Database

hex_id: contains info regarding the geometry, resolution, geocoding

Results

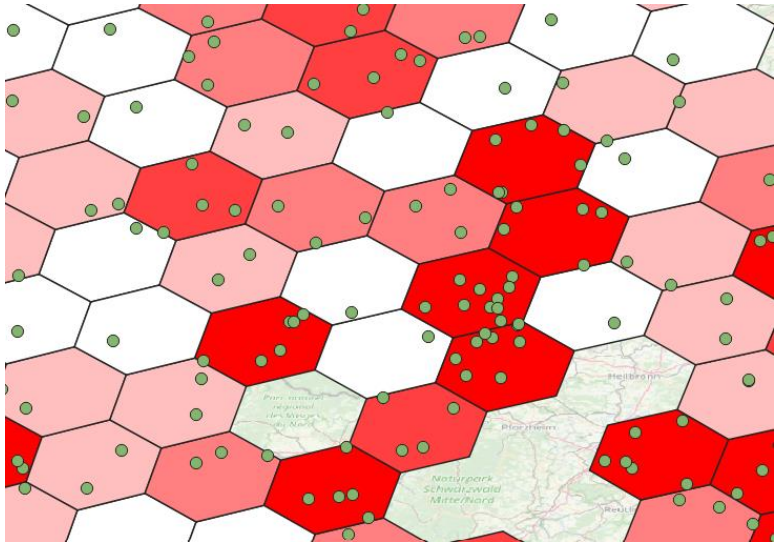
> Aggregation on a given resolution

> Data binning on a given resolution

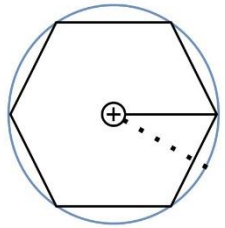
> Hierarchical – neighborhood connectivity

> Original spatial uncertainty dependent

> Storage efficiency neglecting geometry

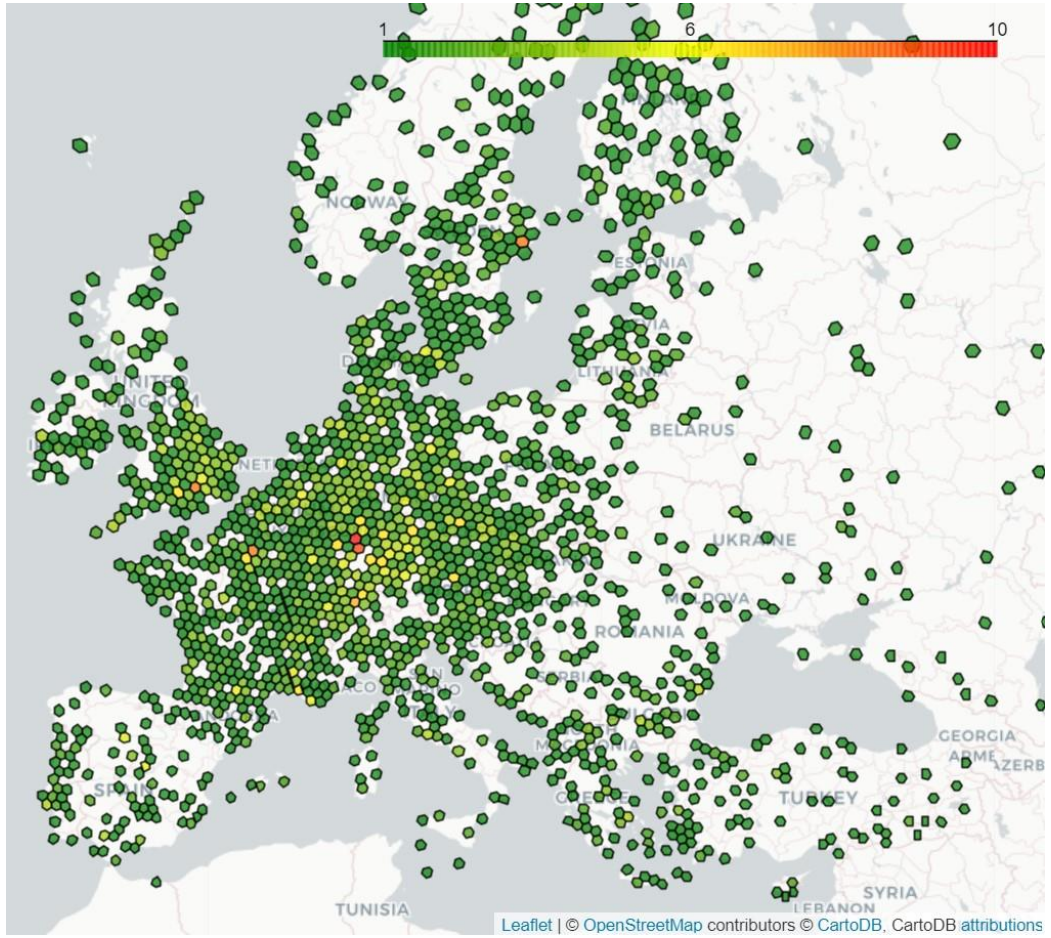


The original positional uncertainty of point data can be used to define the modelling resolution under the DGGS framework – Margin of error after quantization lies within cell boundary

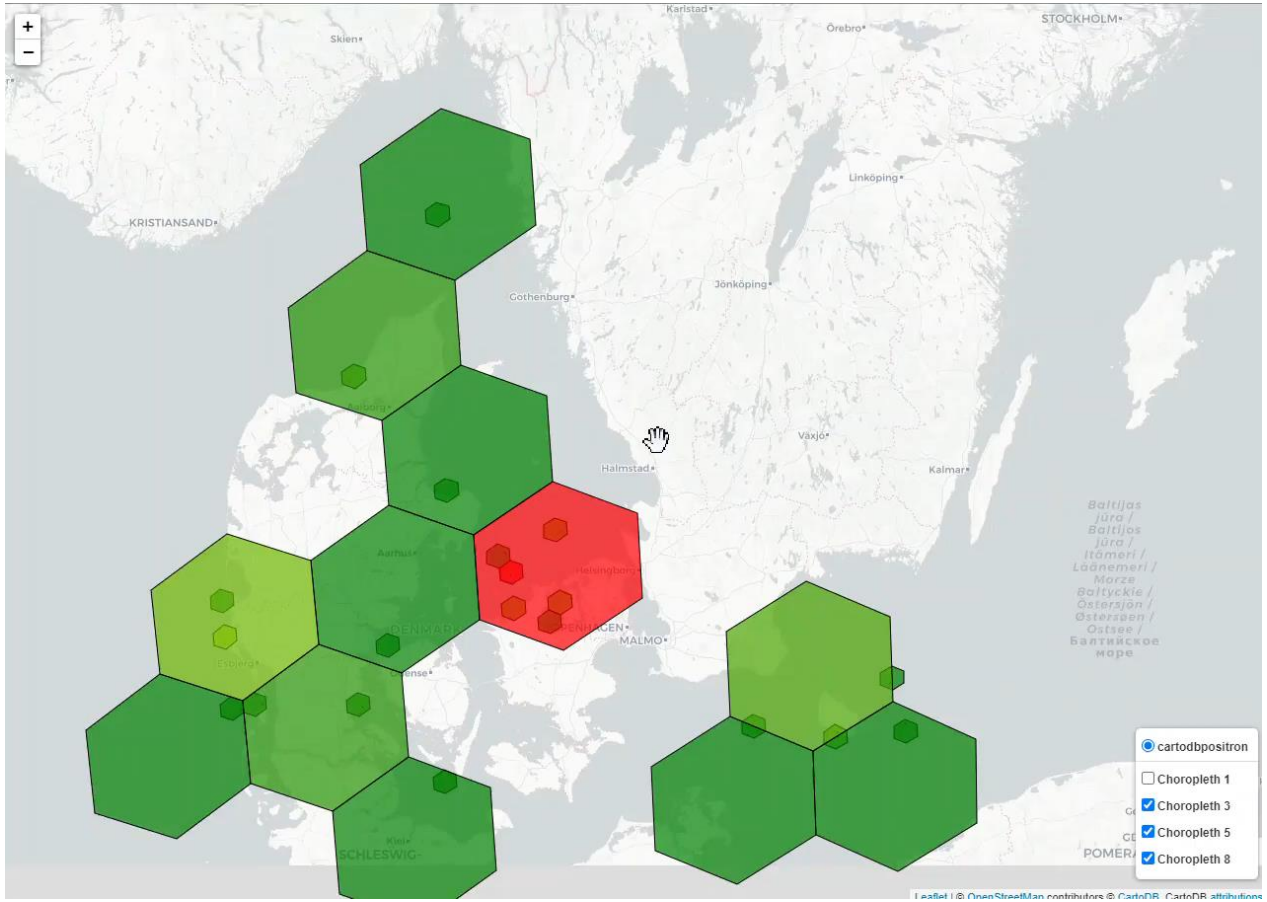


Results

Point to DGGS ✓ APIs



Resolution 4



Multiresolution

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Results

> Aggregation on a given resolution

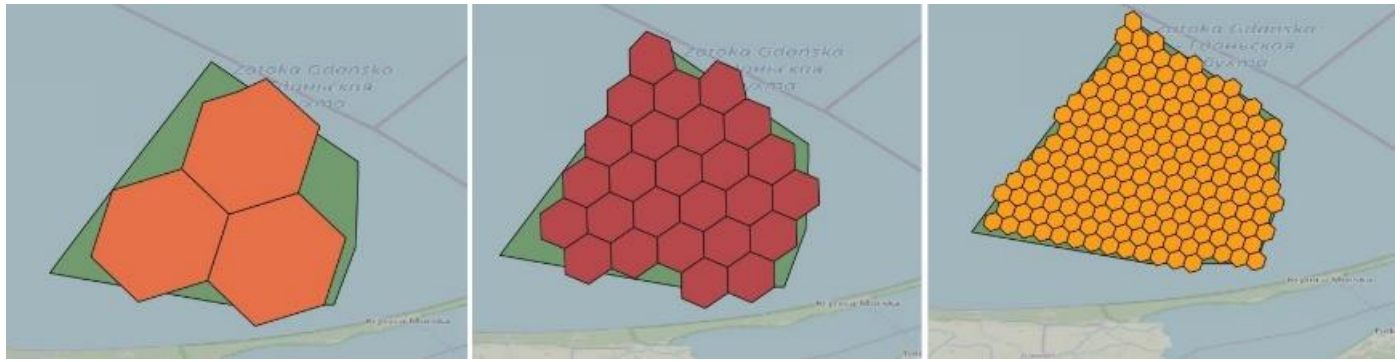
> Data binning on a given resolution

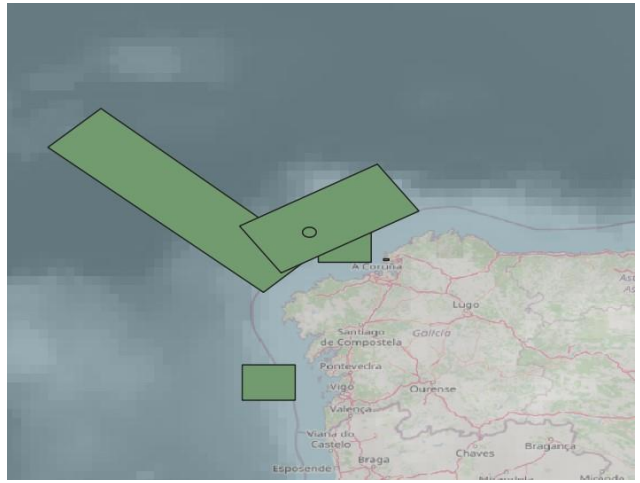
> Hierarchical – neighborhood connectivity

> Original spatial uncertainty dependent

> Original geometry segmentation

> Fusion of overlaps





Results

Polygons to DGGS ✓

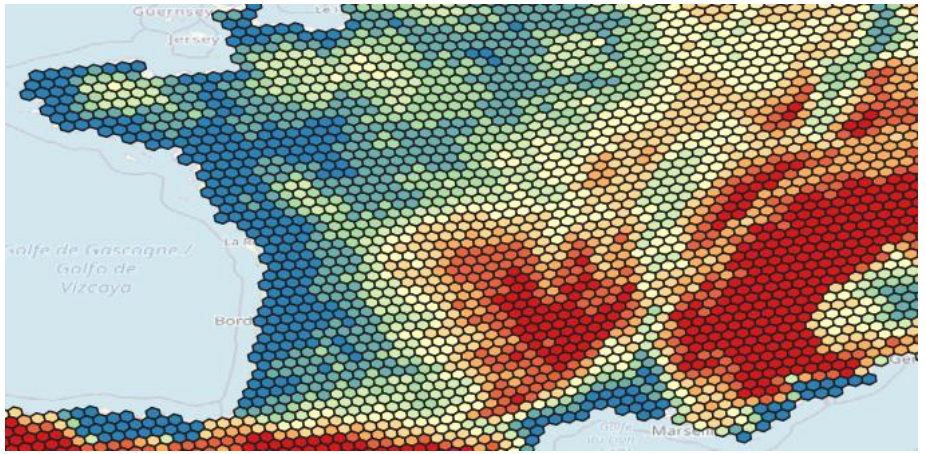
APIs

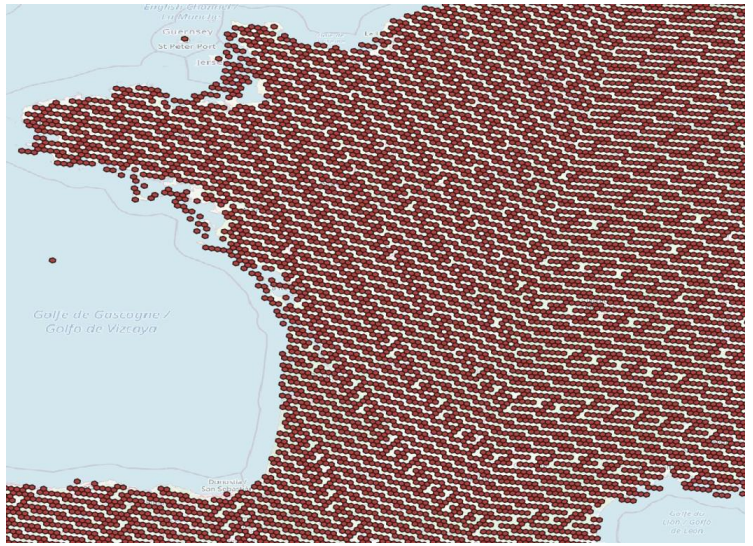
Results

> Optimal resolution based on original raster resolution

> Hierarchical – neighborhood connectivity

> Up sampling capabilities - aggregation

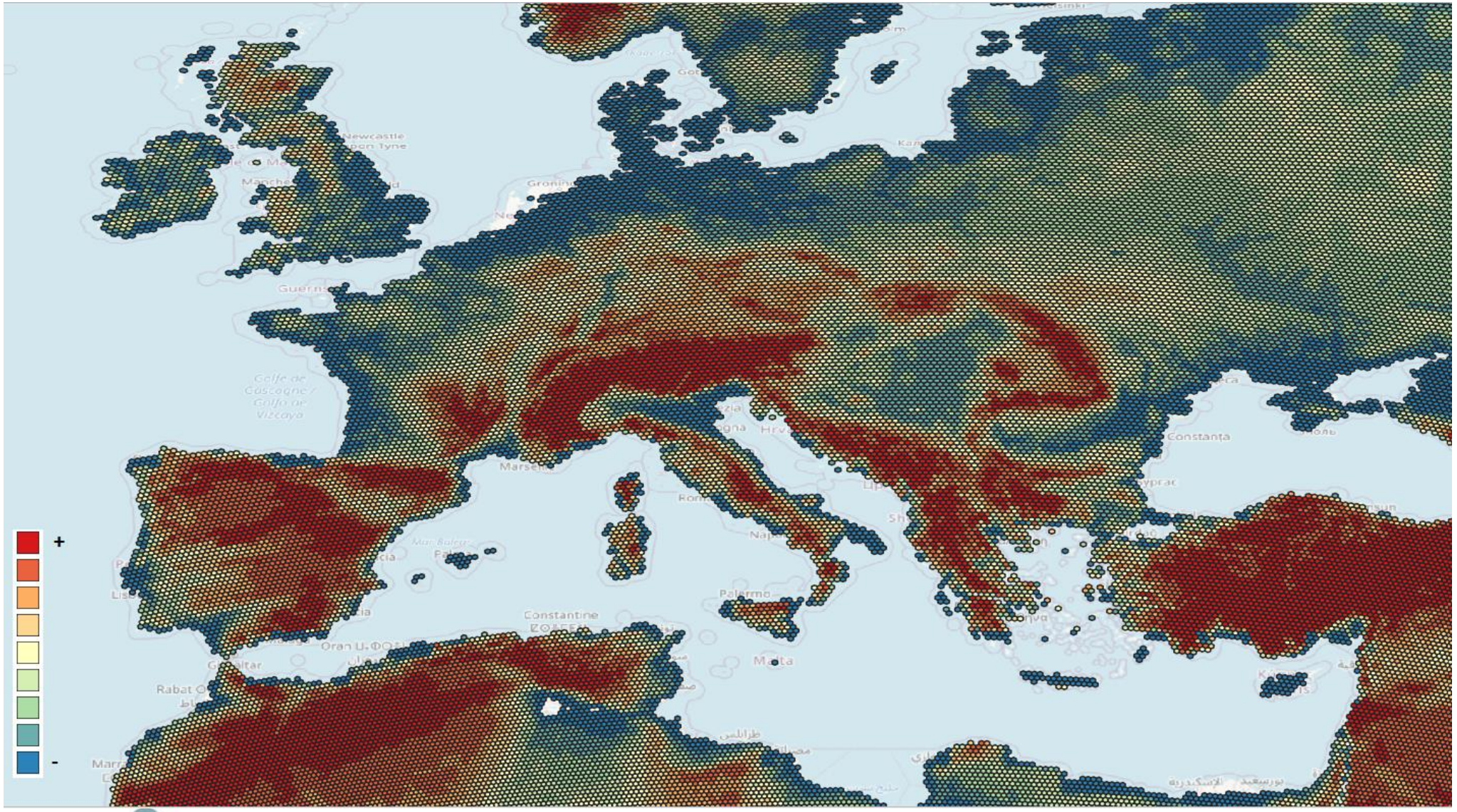




Results

Raster to DGGS ✓

APIs



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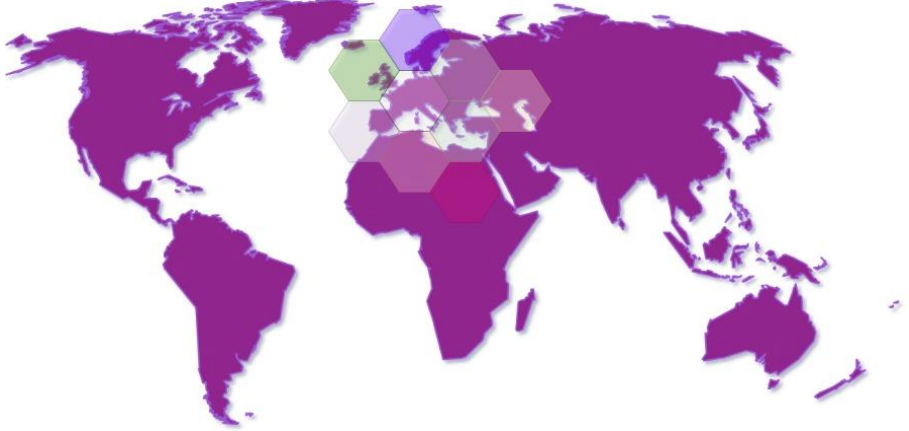
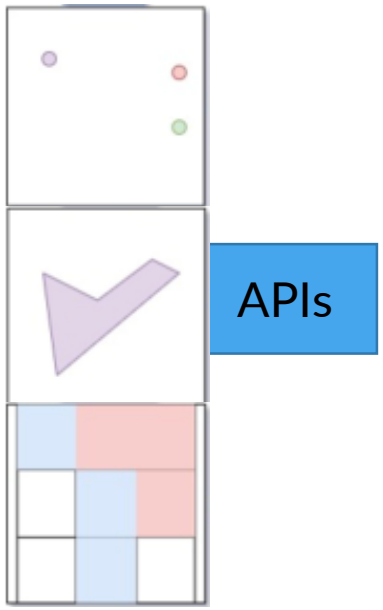
Results



>Uniform resolution
>Cells/Objects connectivity
>Aggregated information
>Terrain elevation info – 2.5D approach
>Local & DB storage



Integrated model ✓

Info from multiple data sources/ formats under a common DGGS framework

Models exported in : .Geojson, .csv, dataframes

- In-database integration
- Visualization: online & offline
  Qgis, folium, pydeck, KeplerGL, GlobeGL
- Can be used in GIS & Database environments for analysis

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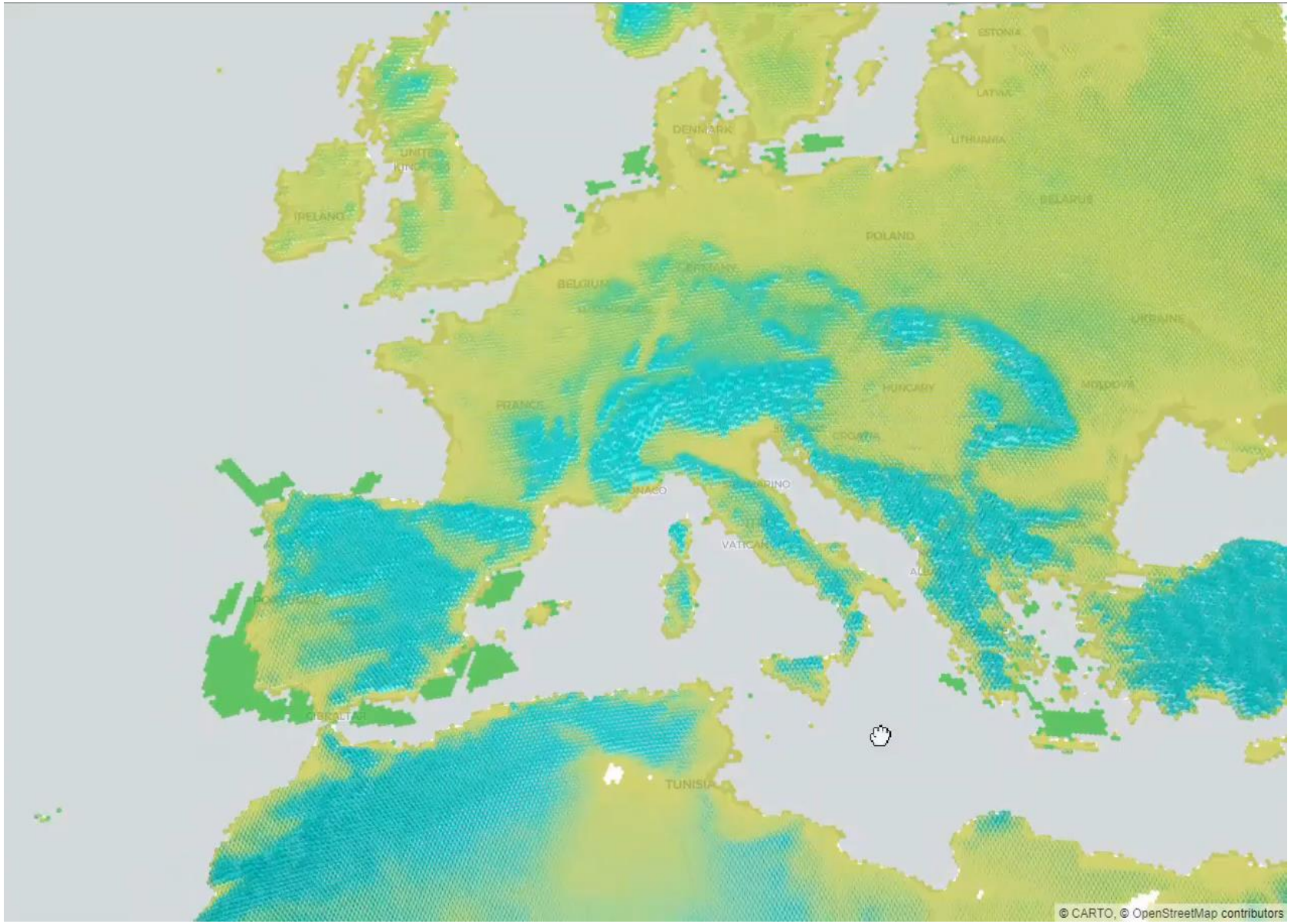
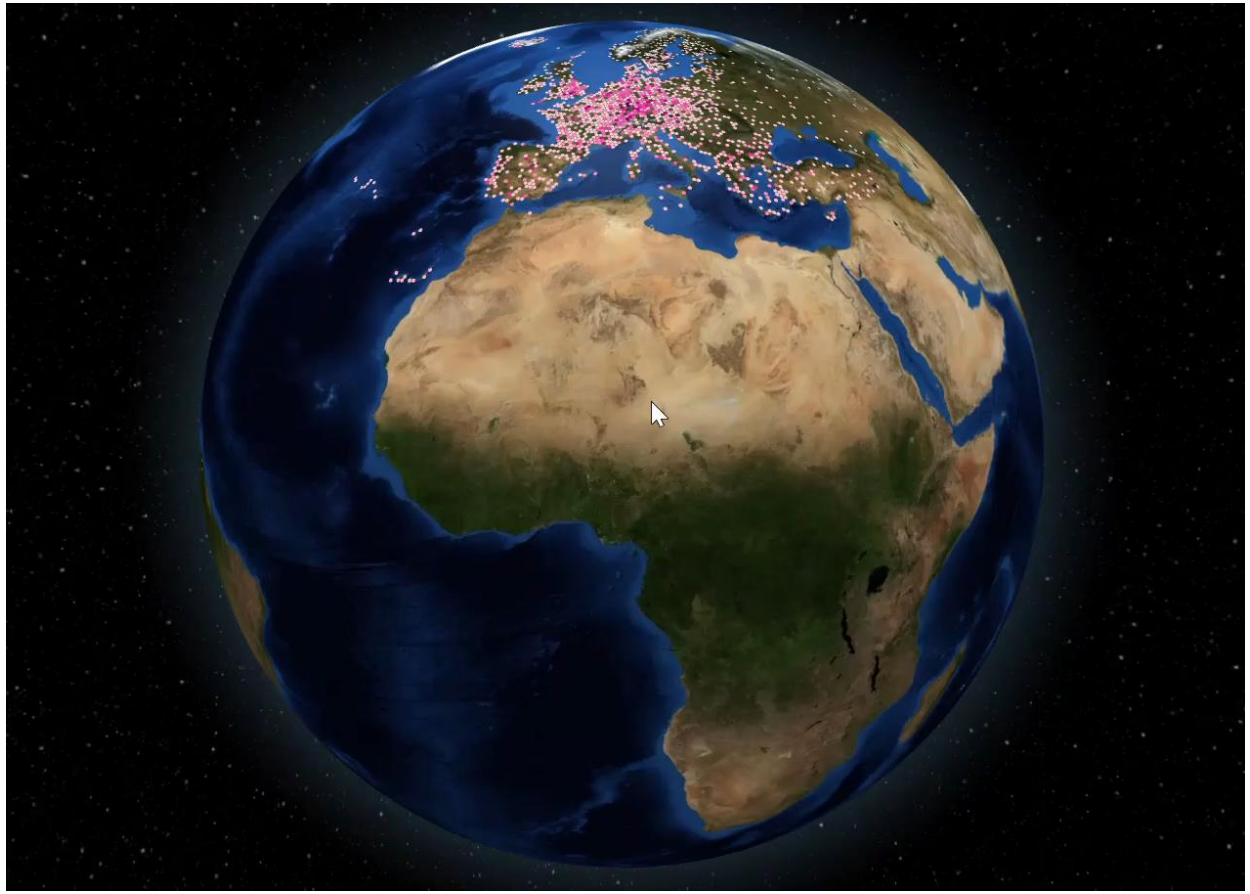
Results

Integrated model ✓

- Interactive visualization
- 2.5D approach
- Tooltip capabilities

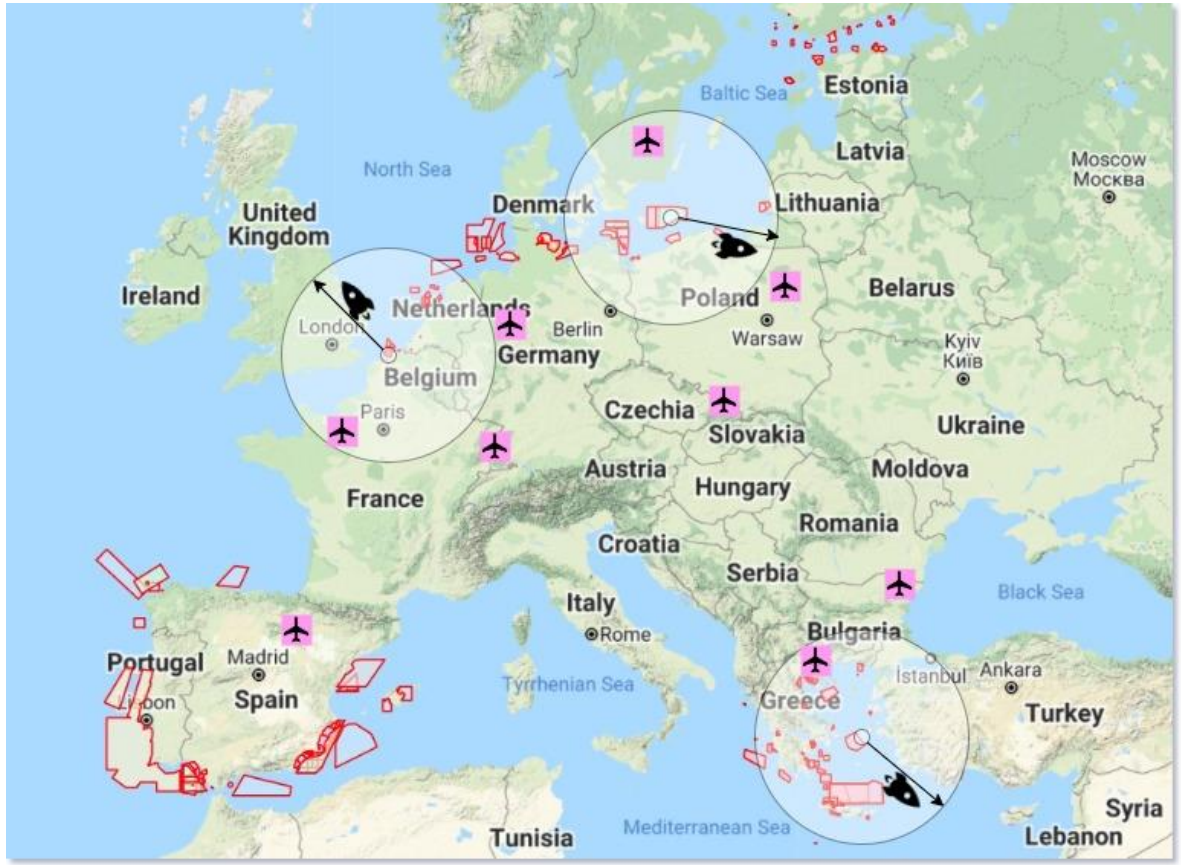


Results

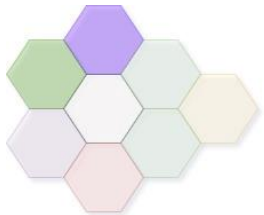


Military case study

- Joint military operation scenario
- Use of the integrated model for analysis
- Detection of civil European airport domains potentially affected by a missile firing of a 250 km range.

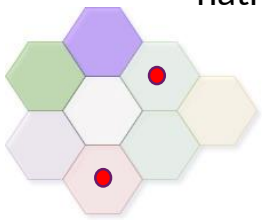


Integrated model

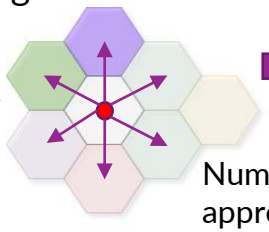


Res = 5

Find Firing Areas



Find neighbours using k-ring native indexing

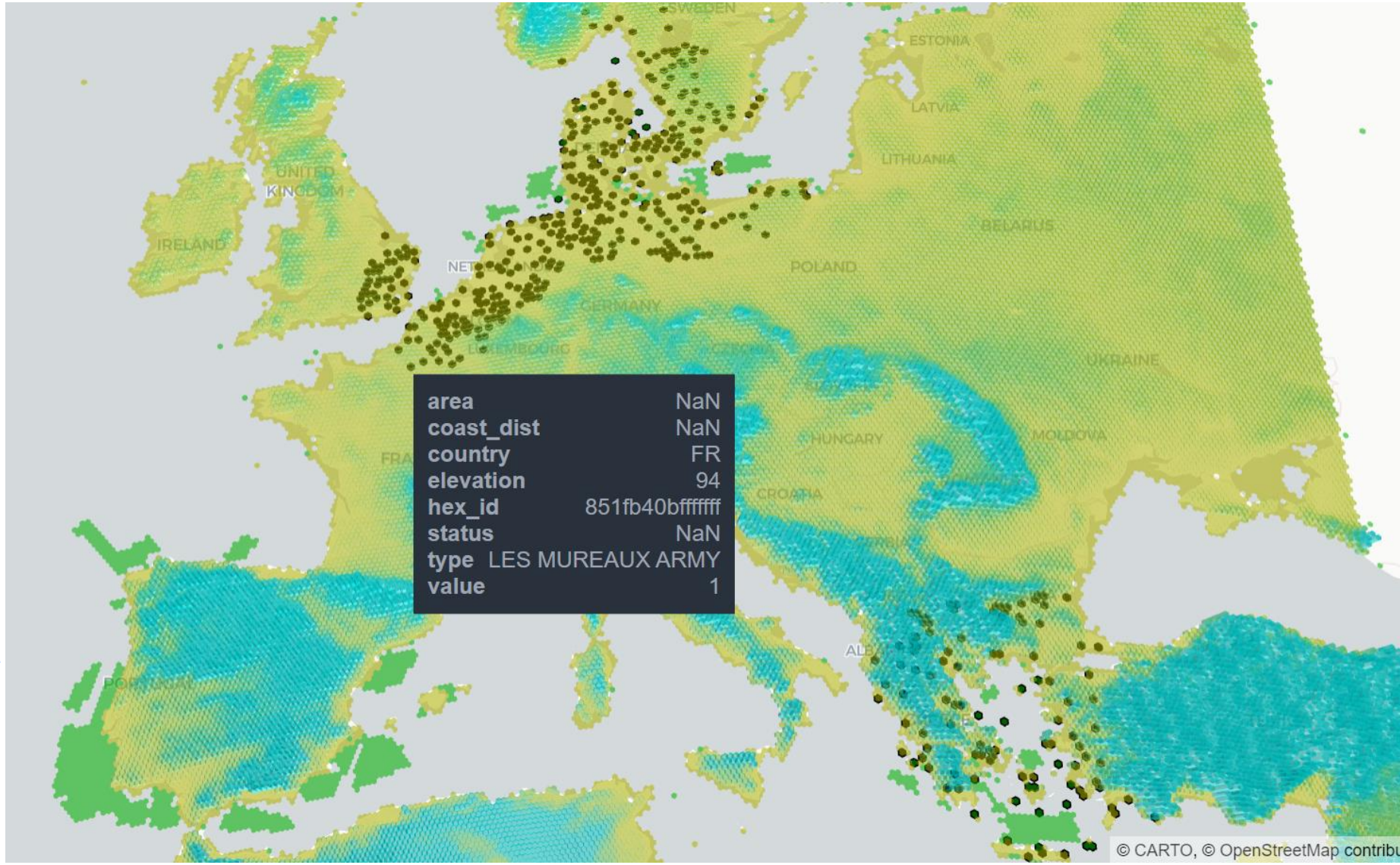


Number of rings: 250 km range approximation based on hexagons area, edge length

Filter & select civil airports

Result + according properties

Military case study



GitHub

https://github.com/tpapakostas/Military_scene_model

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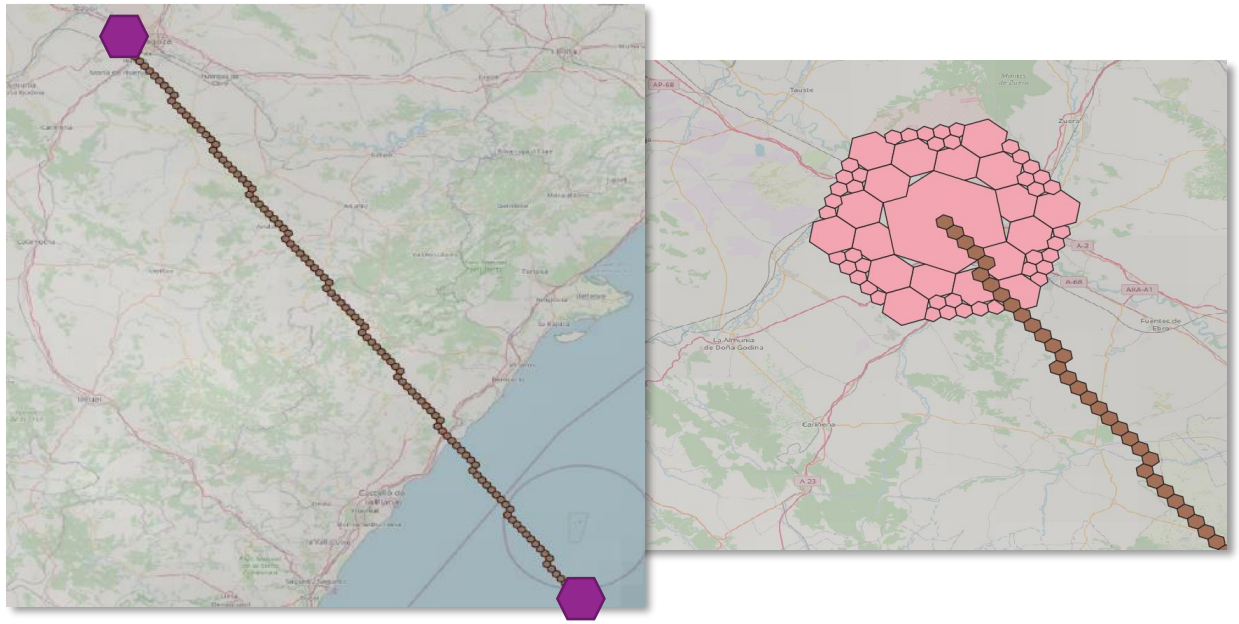
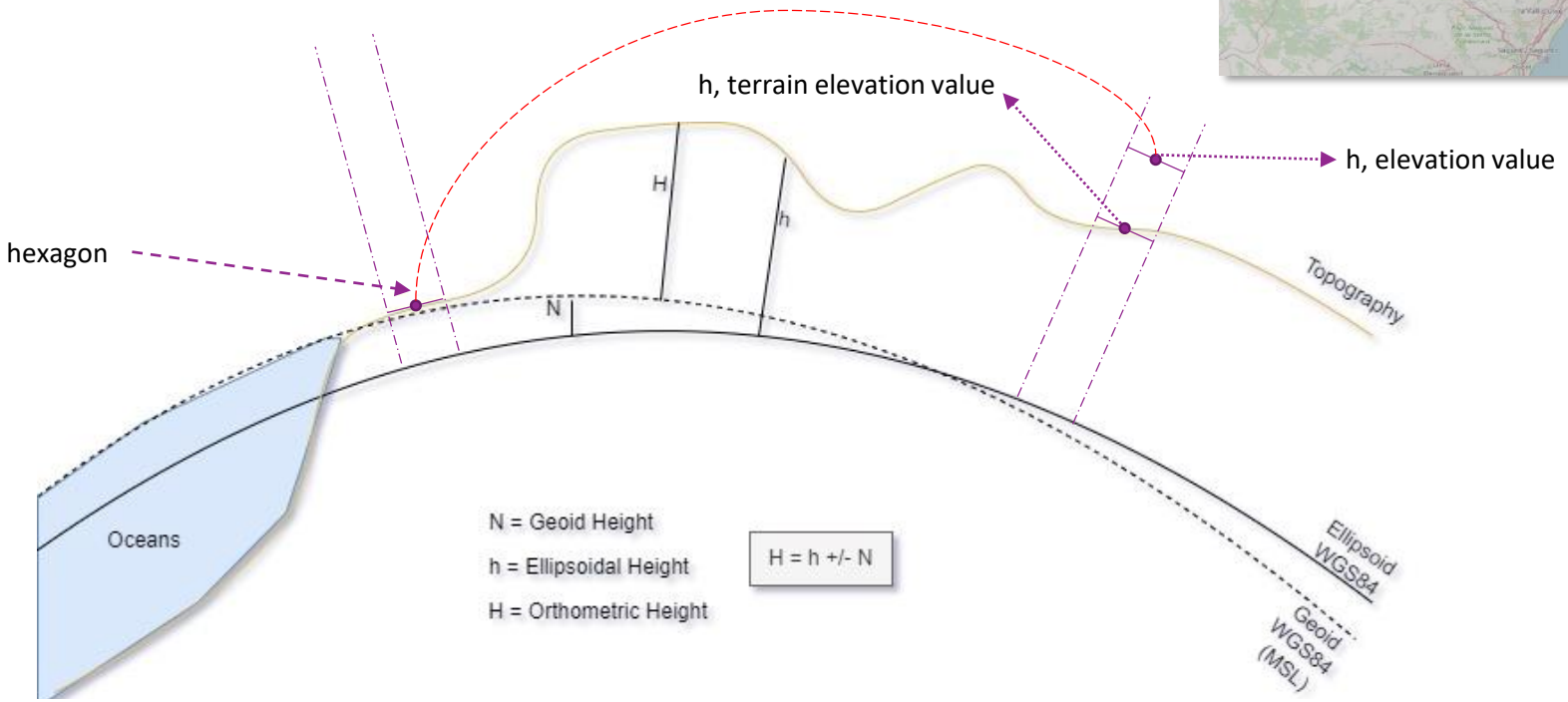
Military case study

Missile trajectory

Given a missile's firing start location, target location:

- Trajectory path as a sequence of DGGS cells of the integrated model





- 3rd dimension : 2.5D approach
- Elevation values on the center of each consecutive DGGS cell, uniform elevation on each DGGS cell area
- Absolute geometric heights in WGS84 or relevant to the terrain geometric heights in WGS84

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Conclusions - Overview

Research question:

To what extent can a Discrete Global Grid System assist in modelling military scenes in one integrated way?

Sub-questions:

- What are the benefits of using a DGGS when modeling a military scene, in comparison with the current state of the art?
- How to achieve integration and storage of different format geodatasets of military interest (vector, raster) using a DGGS?
- How to use a database, exploiting different format DGGS indexed datasets for geospatial analysis of a military scene?
- What are the different visualisation alternatives of DGGS indexed datasets assisting in military analysis?

Conclusions

Strengths

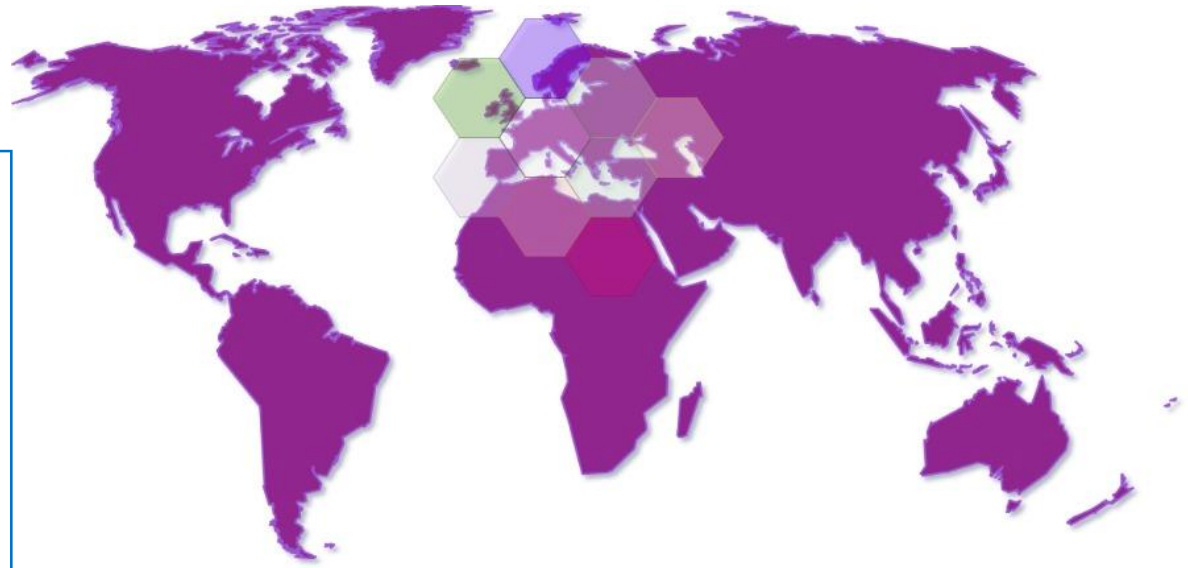
- Uniform framework, representing the Earth surface, fixed area-based, augmenting communication and cooperation
- Advanced integration, aggregation, segmentation, data binning capabilities, assisting monitoring and analysis of continuous military interest observations in one integrated way
- Integration of 3rd dimension elevation values in a 2.5D approach
- Augments the qualitative perception of a military scene - connectivity relations between objects – analysis
- Interactive, Intuitive visualization
- Capable of handling military operations (i.e. ranging)
- Advanced geocoding capabilities

Weaknesses

- Quality of the results highly dependent of the original data accuracy/spatial uncertainty, as well as the demanded precision requirements of the scene's coverage
- Cannot be seamlessly treated as a reference frame with positional value, due to resolution constraints
- Not fully 3D – DTM not DSM
- Current distributed DGGS implementations are not mature yet to support high spatial accuracy results and geometric calculations/operations.

Limitations

- Lack of pure military data
- Data cleaning, not fully automatic
- Custom attribute structure model, not based on conventional military patterns
- Modelling quality is dependent on the original data accuracy/spatial uncertainty and the scene's coverage – Uniform resolution
- APIs call for optimization, automation
- Case study, not optimal runtimes for real or quasi real time



Recommendations & Future work

- Military DGGS standardization
- Research using pure military data, patterns, military model assessment
- Research with large military datasets, Big data analysis, Assessment of computational strength
- Machine learning approaches using DGGS for war gaming/prediction modelling of military scene scenario

- Application of different data formats (vector lines, point clouds) for military scenario
- Multi-resolution approach and optimization / automation for variable military scene coverages
- Profiling of conventional spatial analysis algorithms for military operations using a DGGS (terrain analysis, geology, topography, hydrology, meteorology)
- Different area subdivision approach (rectangular, triangular, rhombus)

Thank you!