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A DGGS (Discrete Global Grid System) Datacube Implementation for Sentinel-2

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Introduction

Context:

- Increasing number of open remote sensing data,
- Heterogeneity of the sensors, resolution, georeferencing and data format, ...

Objectives:

- Study and select an appropriate DGGS Framework
- Development of a MPC DGGS demonstrator software handling Sentinel-2 ARD products

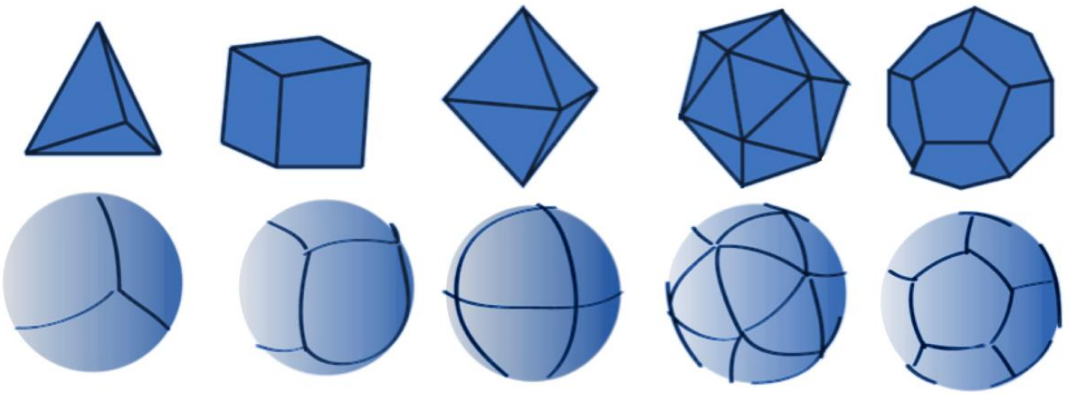
Sentinel-2 Satellite

What IS A DGGS?

Open Geospatial Consortium – OGC:

"A DGGS is a spatial reference system that uses a hierarchical tessellation of cells to partition and address the globe. DGGS are characterized by the properties of their cell structure, geo-encoding, quantization strategy and associated mathematical functions."

- **Base polyhedron**
- Orientation
- Projection
- Cell geometry
- Aperture
- Indexing Strategy



Regular polyhedron (top) and their corresponding initial tessellation (bottom)

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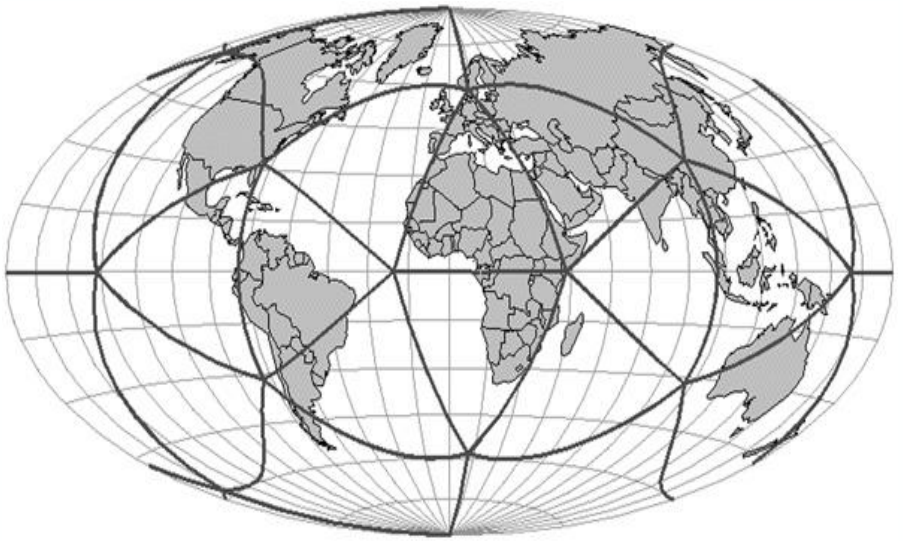
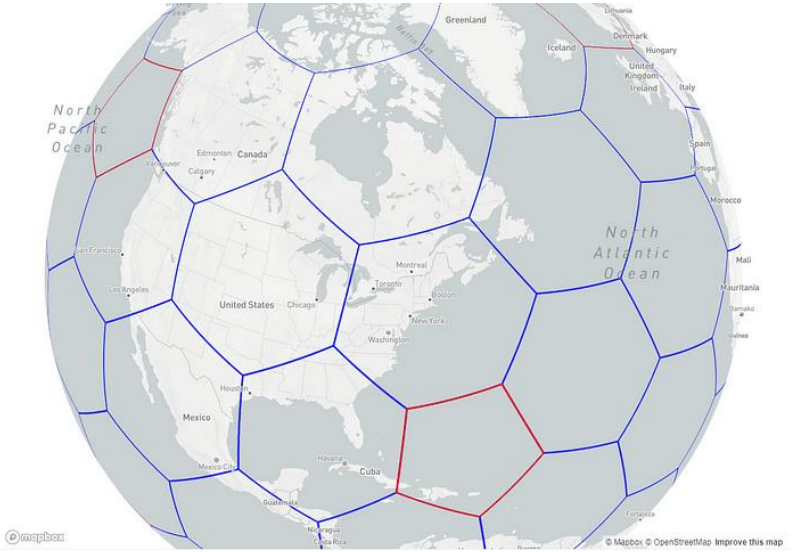


Spherical icosahedron oriented using Fuller's Dymaxion orientation. All vertices fall in the ocean. Credit: Sahr and al., 2003



Uber H3 —On a globe projection

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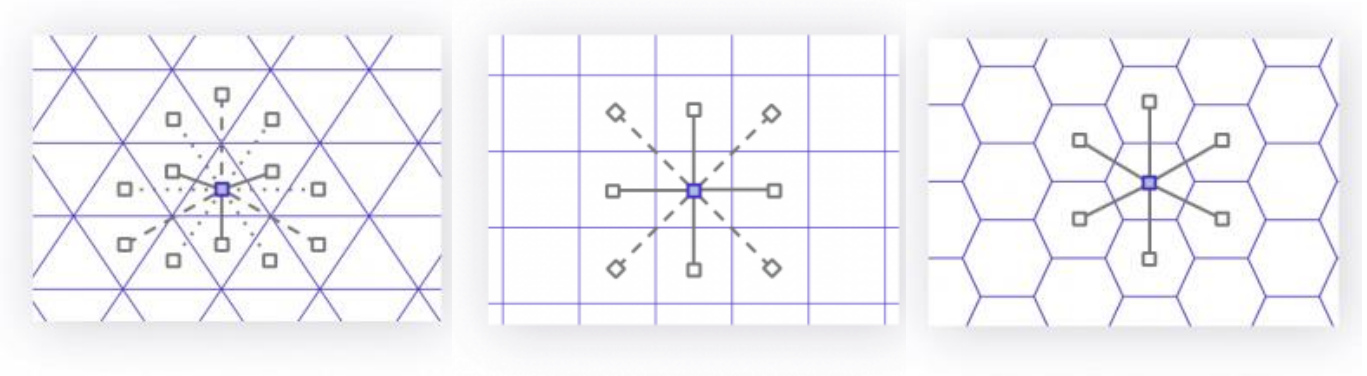

Different grids implementation cell neighbors

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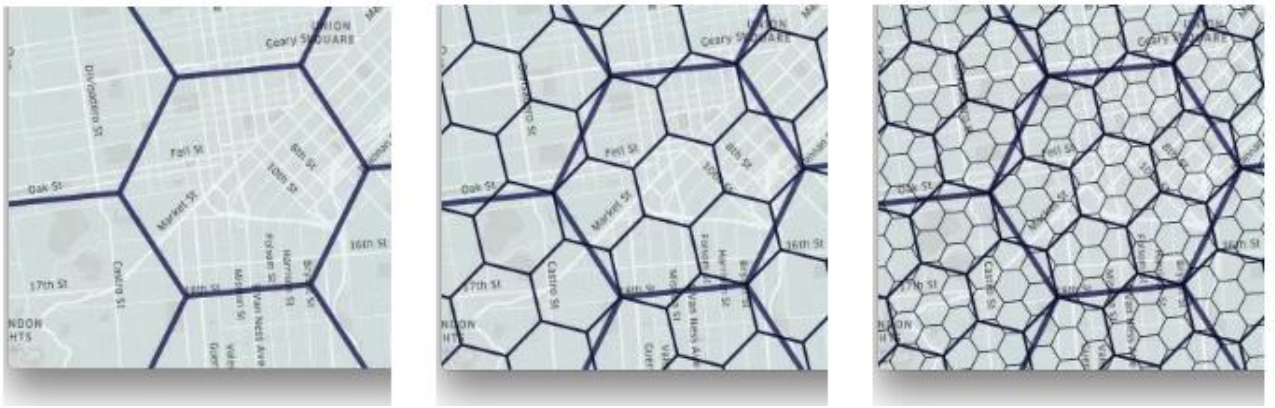

H3 grid cell aperture (size and shape) at different levels

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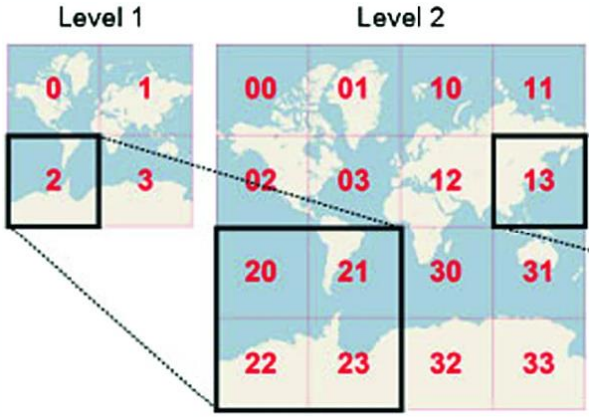
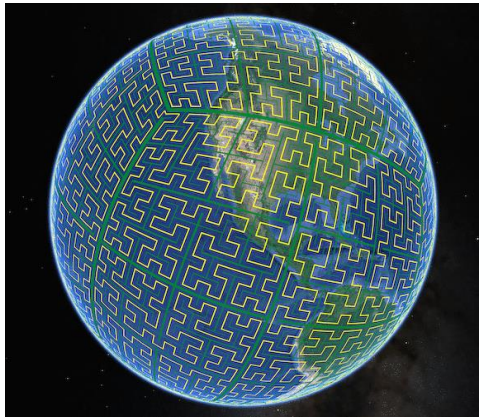


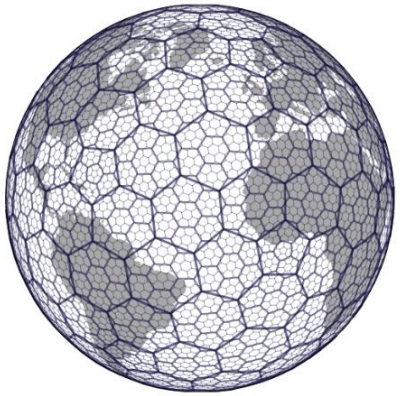
Classic Hierarchical index

Coordinates examples:
Level 0: **0**
Level 1: **2**
Level 2: **23**
Level 3: **231**
Level 4: **2312**
Level 5: **23120**



Space-filling curve (Google S2)

Coordinates examples:
fff1000...000000000 # Level 0 cell ID
fffpp**10...000000000** # Level 1 cell ID
[...]
fffpppp...pppp**10000** # Level 28 cell ID
fffpppp...pppppp**100** # Level 29 cell ID
fffpppp...pppppppp**1** # Level 30 cell ID



H3

Coordinates examples (ESRIN)
Level 0: **8053fffffffffff**
Level 1: **8152bffffffffff**
Level 2: **82528ffffffffff**
Level 3: **83528dfffffffff**
[...]
Level 12: **8c528d0e1cb1dff**
Level 13: **8d528d0e1cb1d3f**

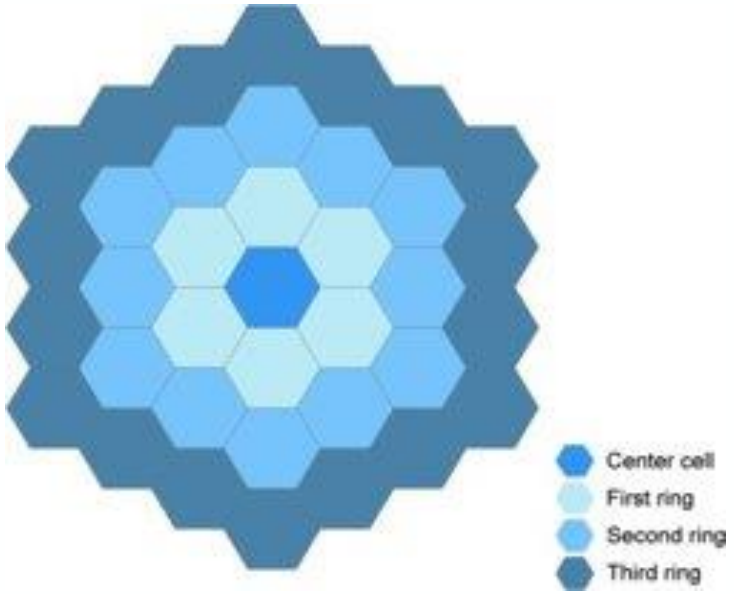
DGGS for Sentinel-2 – Key Aspects

Mission sensors resolution vs discrete resolution

- DGGS resolution level fitting the sensors characteristics but limiting the data volume,
- Enabling the interoperability with other missions

Radiometry preservation (e.g. PSF, MTF)

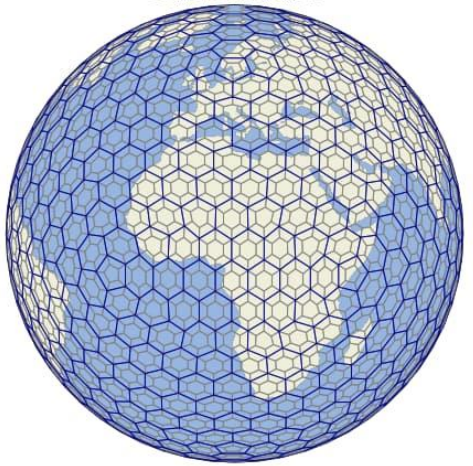
To assess the radiometry vs the cell shape



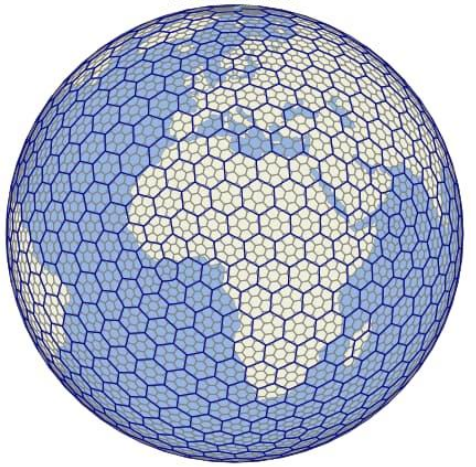
DGGS implementations comparison

- ✓ ISEA7H (Hexagons)
  Icosahedral Snyder Equal Area
- ✓ H3 (Hexagons)
- ✓ rHealPix (Multiple-Quadrilater)
- ✓ ISEA4T/D (Tringles/Diamonds)

DGGRID ISEA4H L4 and L5

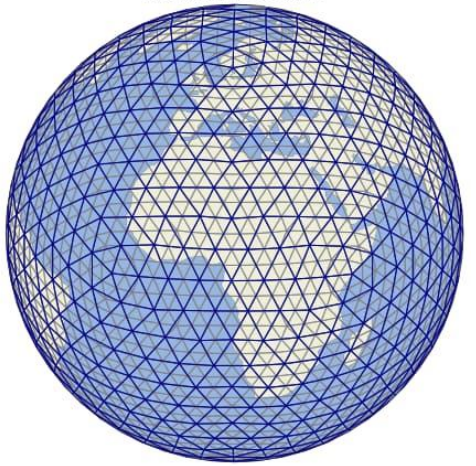


Uber H3 L1 and L2



Landcare rHEALPix L2 and L3

DGGRID ISEA4T L3 and L4



DGGS comparison

	H3	rHealPix	ISEA7H	ISEA4T/D
Cell	Hexagon	Multiple	Hexagon	Triangle/Diamond
Aperture	7	9	7	4
Projection	Gnomonic	Custom (EA)	ISEA	ISEA
Shape/Area preservation	Great shape preservation High area distortions	Good shape preservation by shape group Very low area distortion	Great shape preservation Great area preservation	Low shape preservation (lower than ISEA7H see Figure 7) Great area preservation
indexing	Dual indexing: Axis and hierarchical	Z space filling curves	Sequential id	Sequential id
Orientation	Dimaxion	custom	customizable	customizable
Software support	Excellent (Multi-language support, DBs support, Cloud extensions, ...)	Limited (implemented in the Proj.4 Cartographic Library)	Good (DGGRID + bindings)	Good (DGGRID + bindings)

- **ISEA7H and rHealPix** are good candidates regarding shape and area preservation.
- **ISEA7H** brings the benefits of an equal area projection, high compactness and great neighbours' relation.
- **rHealPix** is by design suitable for raster processing specially in the mid latitudes (square faces) and provides some unique features useful for multiresolution handling.

- **H3** is subject to high area distortion but also the most used DGGS and by far the most supported. A good support and user experience are key to the adoption of DGGS. This makes **H3** the go-to grid for practical application.

Lessons learned until now

- It is not cost optimized to store high resolution (10m) S2 in a DGGS database.
- Only light information should be stored, such as **simplified quality masks or low resolution overviews** (either the bands data, or computed indexes NDVI...)
- To be relevant, the link with the full resolution rasters should be maintained (i.e the database can be used as **product catalogue**).

With such an approach the main interest of the DGGS is:

1. To overlap low res information (from various sources) for global statistics computation
2. To enable **efficient and precise** data queries based on **metadata**.

USE CASE: Indexation with binary masks

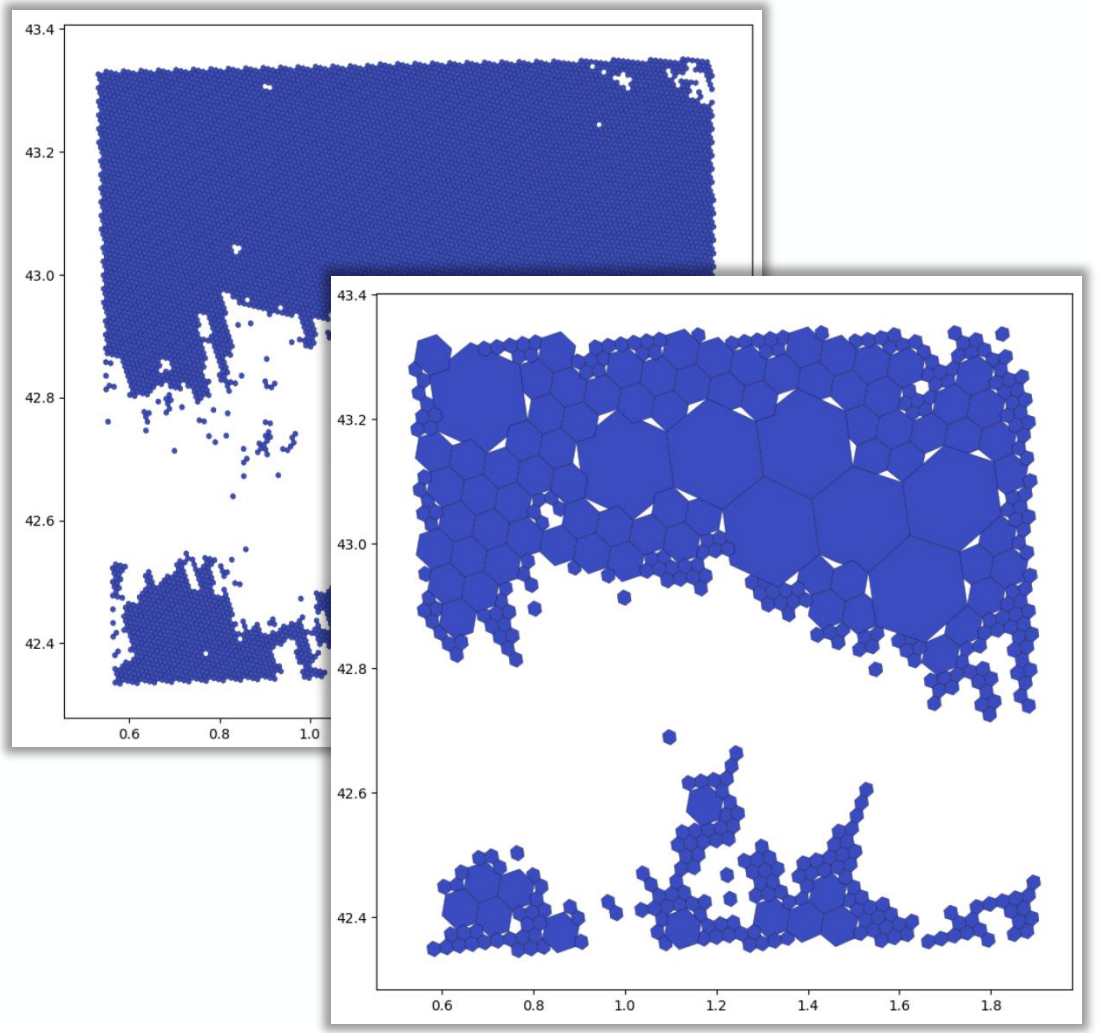
✓**Product indexing**: using H3 for fast Sentinel-2 products indexing can be an efficient way of querying satellite imagery.

›Example with cloud mask. It then becomes possible to precisely filter clear sky data at a specific location.

✓Pictures shows S2 cloud filtering using the L2A SCL layer on H3.

✓Cells can store cloud percentage for each resolution

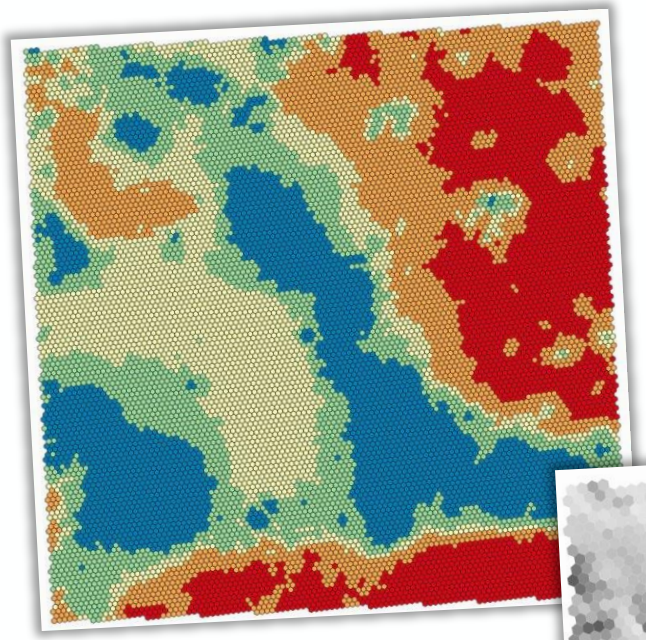
✓Other masks could also be included in the data model: snow mask, quality mask, etc.



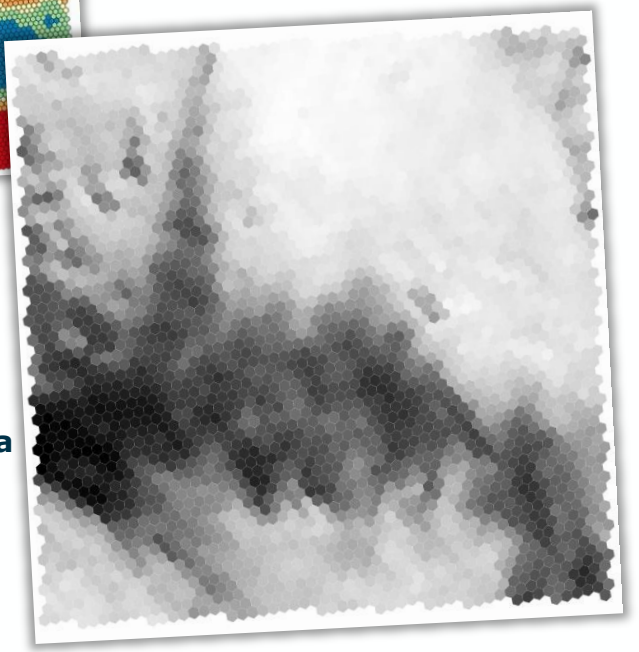
SCL cloud pixels indexation and H3 DGGS simplification

DGGS USE CASE: DATACUBE creation

- ✓ **Data Integration**: The key application for DGGS is enabling multi-source geospatial analysis. We can combine data from multiple sensors using the same grid.
- ✓ Using the **same code base,** we can populate DGGS grid with Sentinel-2 data, Copernicus DEM or other EO data.
- ✓ Results in **Multi-source and Multi-resolution** overlapping datasets
- ✓ Same DGGS cells' footprints for all datasets



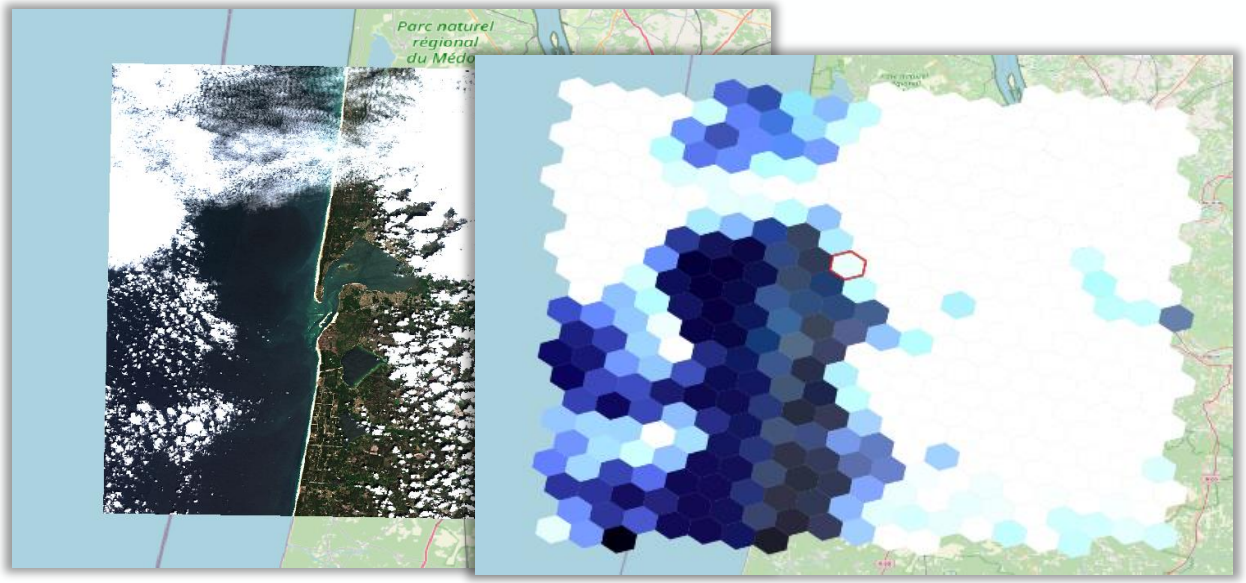
Copernicus DEM



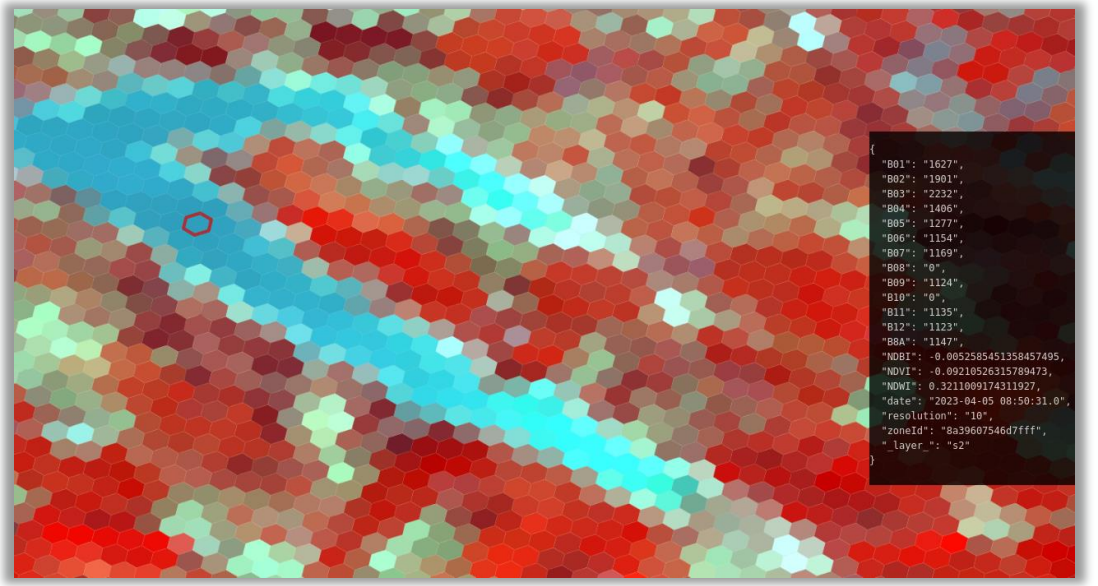
S3 LST data

DGGS USE CASE: DATACUBE creation

- ✓ **Multispectral bands analysis**: Storing the pixels bands values is another great capability. We can combine data from multiple spectral bands in order to calculate “on the fly” remote sensing indicators (NDVI, NDBI, etc.) but also reproduce RGB visible or false colors maps.
- ✓ Some **limitations** however regarding the required storage for such use case: only low (60m) or medium (20m) resolution should be considered.



cloudy Sentinel-2 image converted to H3, and dispalayed at low res level of DGGS grid



Realtime data analysis example

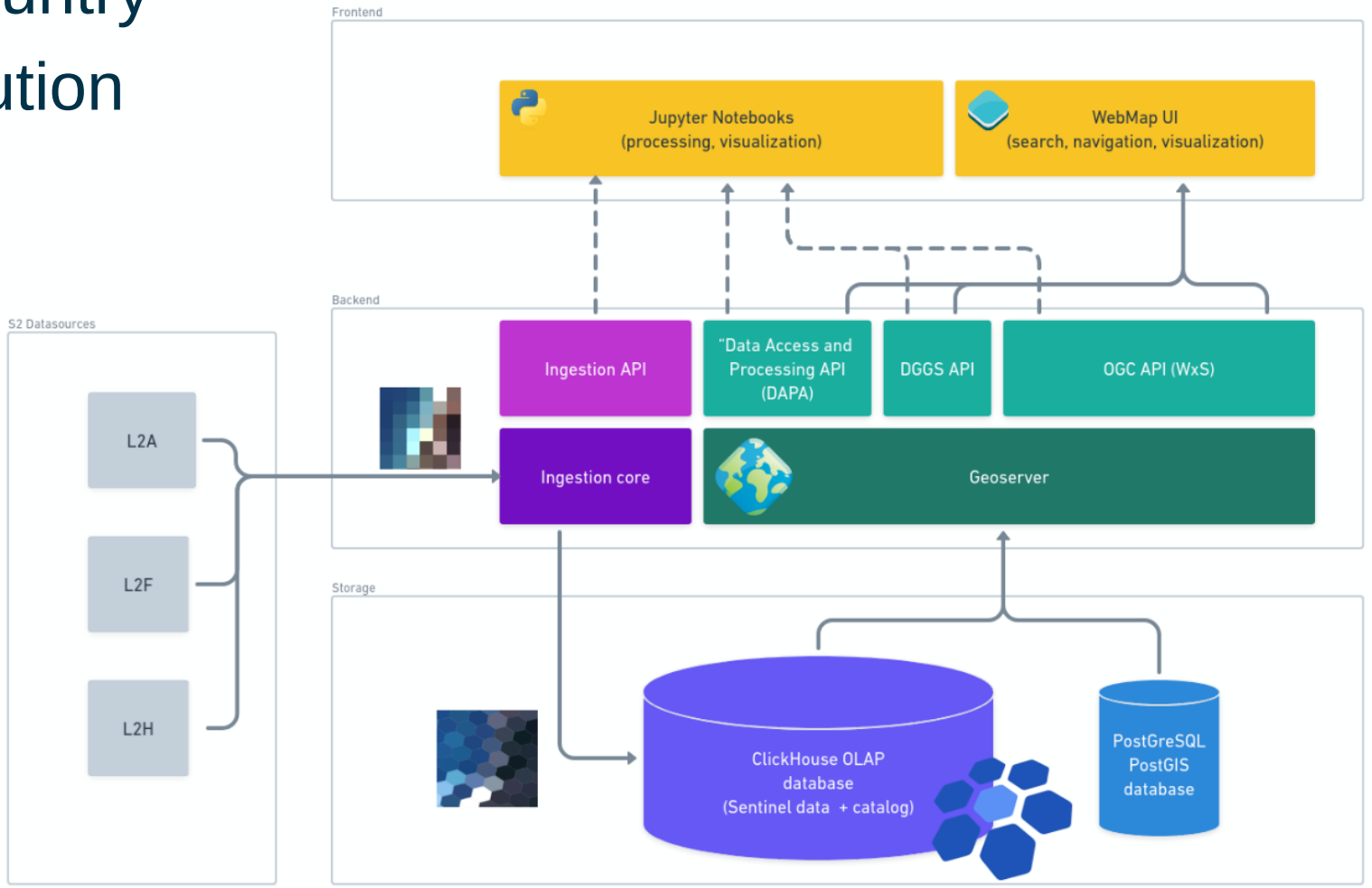
DGGS USE CASE: DATACUBE creation

- ✓ The DGGS demonstrator will be **limited at mid-resolution at a country-level**.
- ✓ As DGGS technology continues to advance, it is expected that handling full products using DGGS grids may become more viable in the future, further enhancing the capabilities and applications of geospatial data analysis.

Comparison of H3 DGGS level 11 and original 60m/px S2 image

MPC S2 - DGGS Demonstrator overview

- Development of POC at country scale, storing for low resolution bands (20m maximum)
- Demonstrate efficiency in term of product indexing
- Support of native S2 (L2A) and Sen2Like products (L2F, L2H)



Conclusion and way forward

✓A perfect DGGS does not exist;

✓Almost no current EO application relies on DGGS. Mainly actively used in some commercial projects (e.g. Uber and PokemonGo);

✓Beside Uber H3, almost no well-maintained open-source tools are available, while based on the selection criteria ISAE7H and rHEALPix are better options for Sentinel-2 ARD data;

✓Promising capabilities considering data indexing;

✓Large scale application is conditioned by performant conversion (Raster to DGGS grid) and storage tools (Clickhouse/ElasticSearch/PostgresSQL).