DLR

AIRBUS esa

living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

The squared Earth - rethinking global grids

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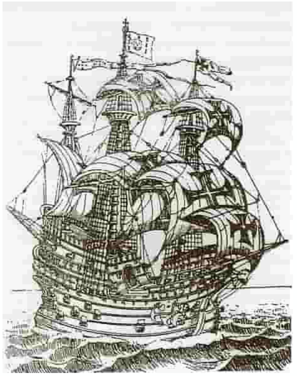
25/May/2022

Introduction or *how the Earth became flat*

… or to bring on a ship in a scale good enough for navigation



Maps provide a way to put a globe onto a sheet of paper (at any scale)

c. 1506

A globe is a good physical model of the Earth… but difficult to fit into your pocket

But computers are not limited to 2D!

Did we miss something along the road?

Are there better ways to represent geospatial data in the digital age?

Conventional GIS puts the map onto a computer screen

Part 1: The view of the data providers

Airbus - Ever Increasing Data Volumes

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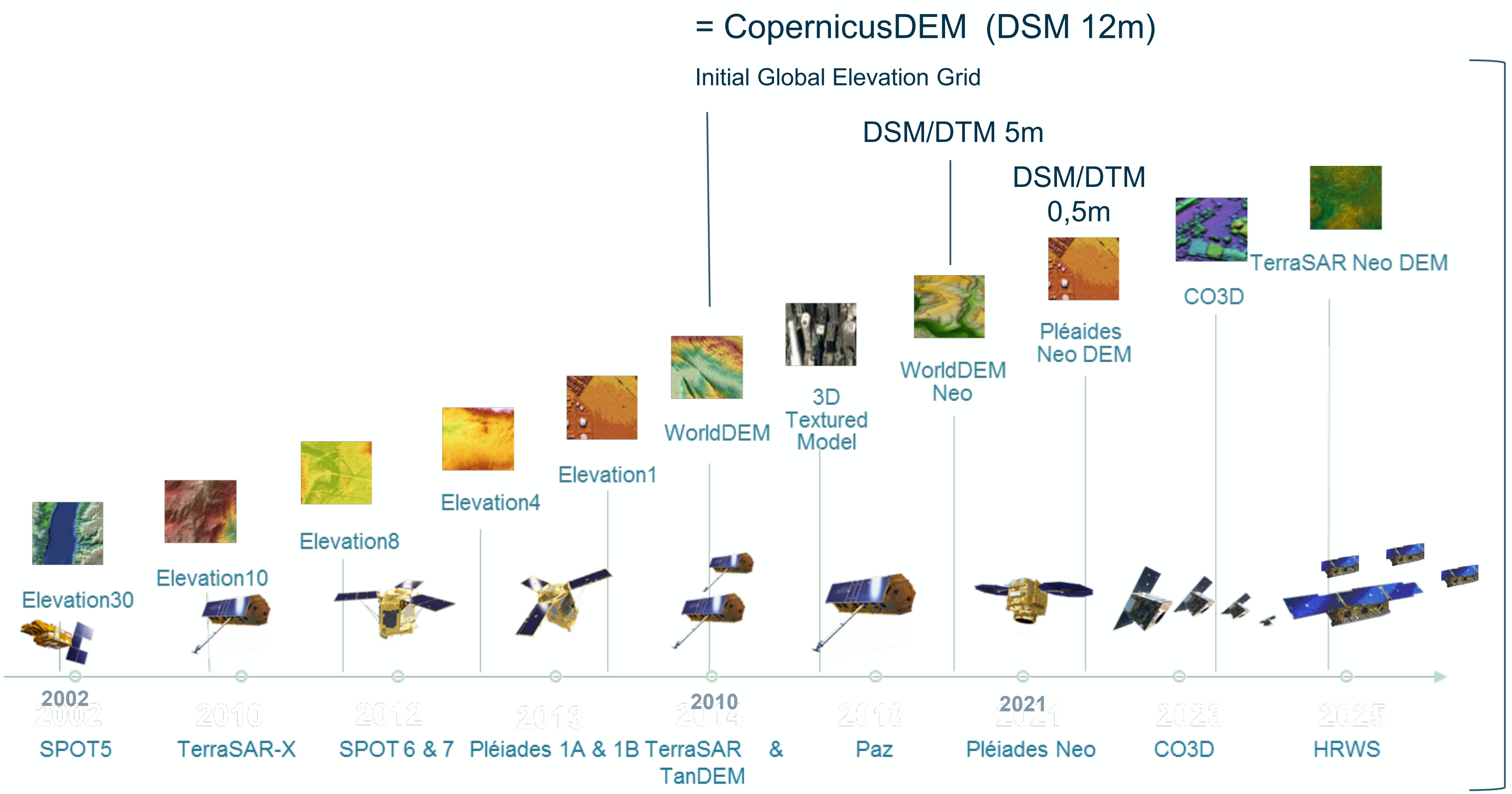
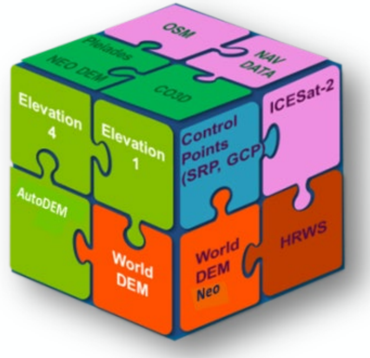


Airbus Elevation 2030

(working title)



Multi-Layered / Multi-Temporal

Elevation Database (DSM/DTM)

Grid Spacing 0,5-5m

EO data and Digital Elevation Models: moving to cloud architecture

- Pléiades Neo imagery - starting with level 1 data
- WorldDEM & WorldDEM Neo (TanDEM Mission and ChangeDEMs) – starting with DLR raw DEMs

Needs

- **host, maintain & process**
  - **global database of DEMs** (DSM/DTM with ≤ 5m grid posting)
  - **containing multiple data sets** with multiple time stamps, resolutions, product variants

- **Services** (hybrid DEM generation, timeline analytics, …) **and future missions** will add to these challenges

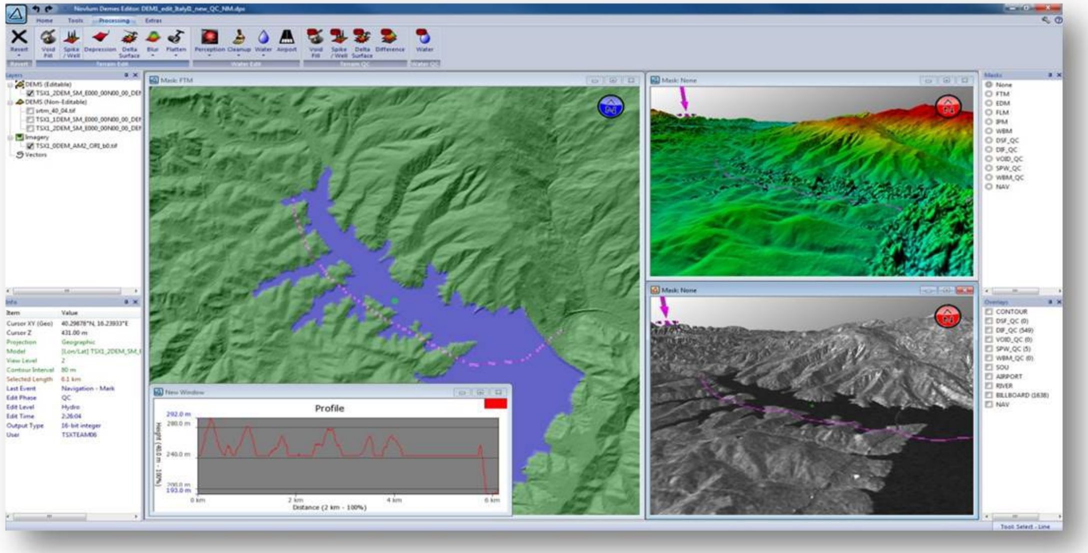
Needs

➢ Need to **harmonise** EO imagery **heterogeneity**;

➢ Necessity to merge data from different sensors (e.g. Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-5P, etc.) in a **global consistent geometry**.

Needs

- **Fast & easy access** for
  - base elevation data
  - instant value-adding processes & analytics
  - on-the-fly visualization



Needs

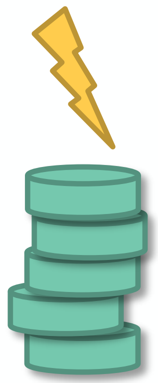
- Need to explore **innovative approaches** to organise, store, manage and analyse remote-sensing imagery.

- Need to offer **flexible data-access** means not based on a fixed granularity.

Needs

- Current roadmaps already lead to challenging requirements for mid-term **high capacity storage and processing upgrades**

- Storage capacities: **Decrease data volume** (e.g. by using intelligent compression without performance impact)



Needs

- ➢ Huge and ever growing EO imagery availability with free and open policy -> **Big Data** handling problem.
- ➢ Need to **rationalise** Sentinels data storage (limiting **data duplication**).

Needs

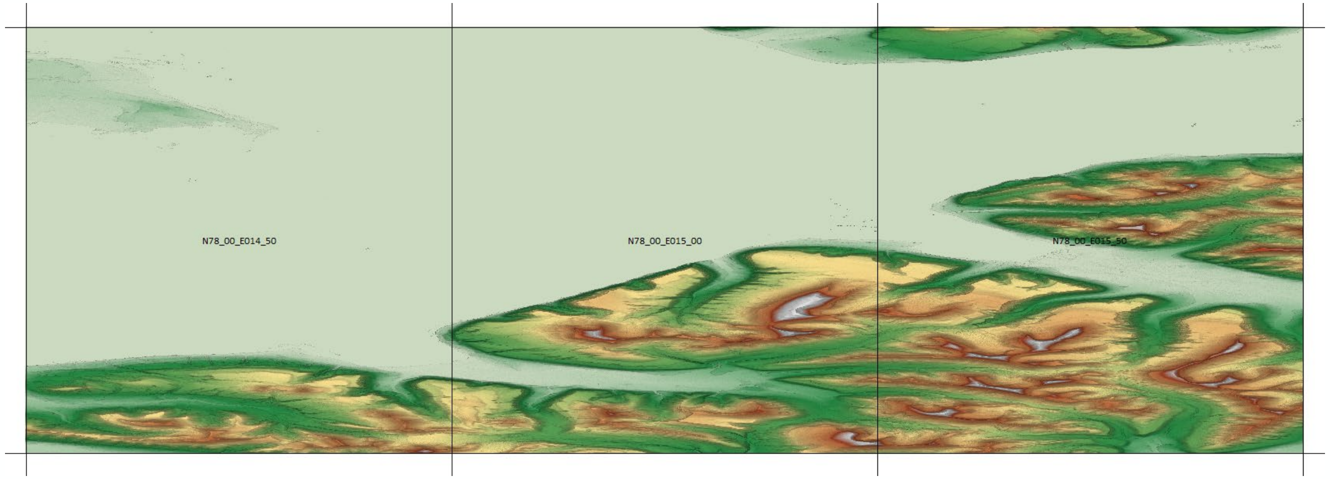
- Enable **fast data analytics on heterogenous data from various sources / with various properties,** e.g. resolution, thematic content

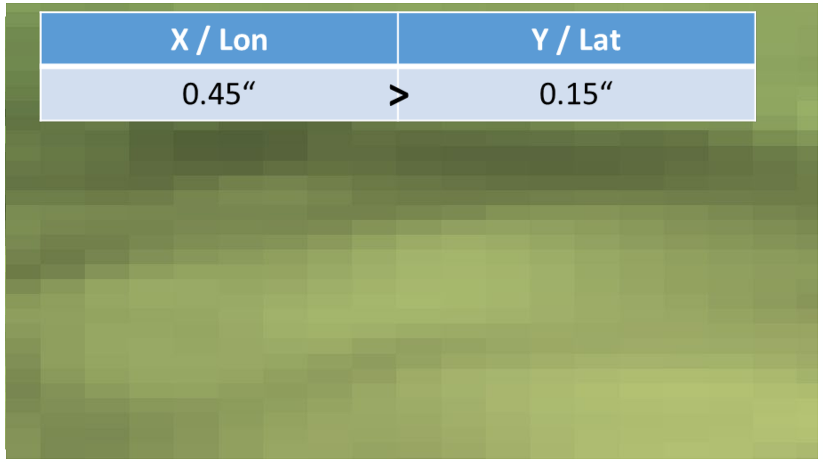
Needs

➢ Expectation to have a **unified framework** for EO data seamless integration, multi source data fusion and cloud computing on a global scale.

Needs

- **Significant reduction / avoidance of spatial distortions**





X / Lon		Y / Lat
0.45“	>	0.15“

Needs

➢ Need to have a global grid which **minimises geometric distortions**;

➢ It should be as close as possible to the S2 sensor geometry (i.e. L1B) so that distortions are **less impacting**.

Needs

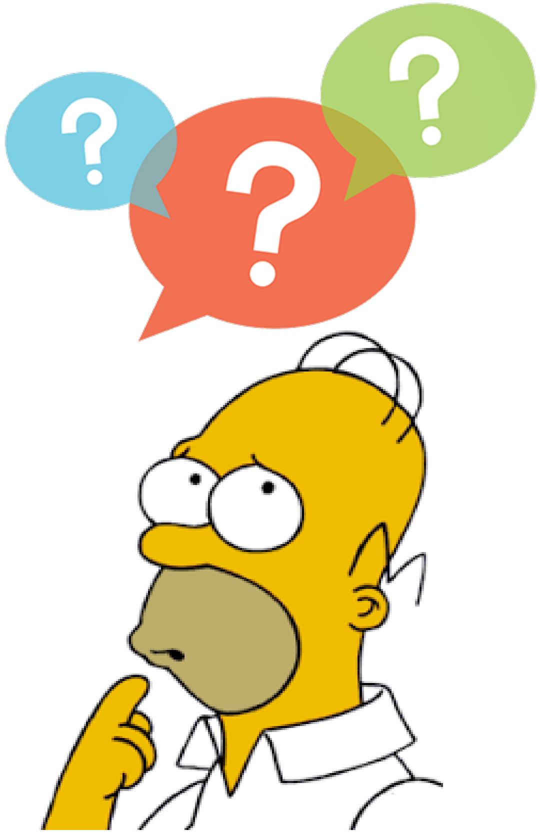
- Reduced information loss by **maintaining highest possible posting** (irregular grids?)
- **Pre-defined cell sizes, potential for multiple parallel grids** (do we want that)?

Questions

➢ Which **DGGS resolution** level is better for each Sentinel?

➢ Will users care about **discrete resolution levels**?

➢ Can DGGS projections **preserve** original satellite **radiometry**?

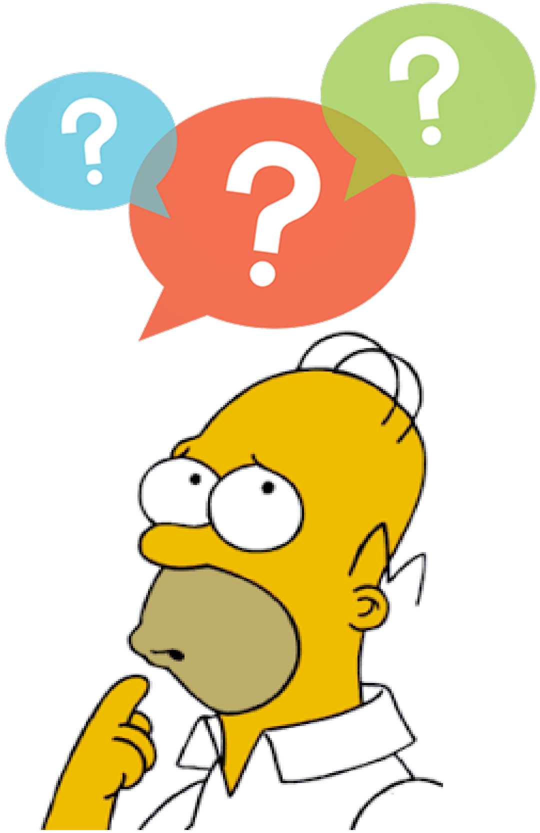


Needs

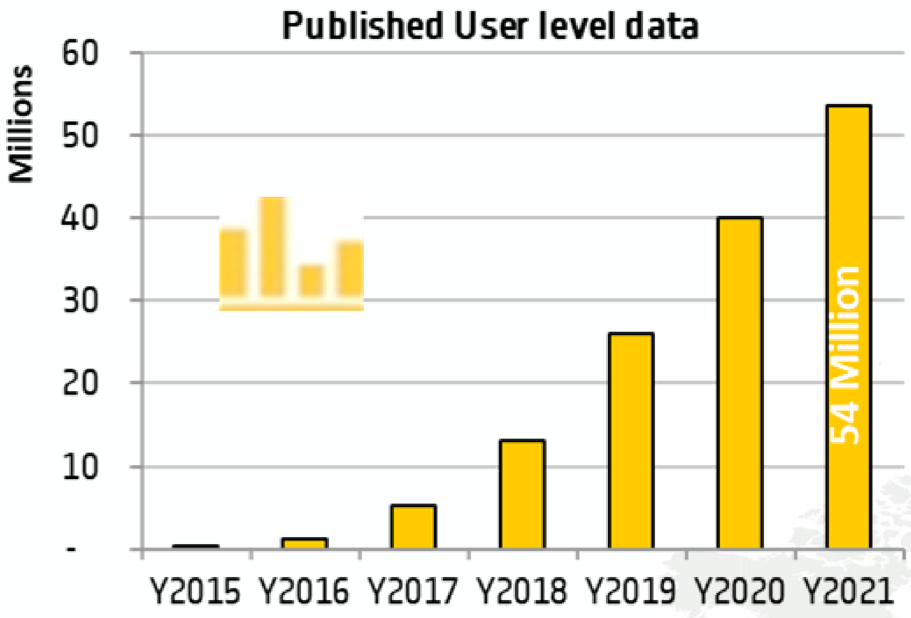
- **Ideal DGGS world**: starts with sensor geometry and is delivered as such to end users
- **The reality check**: when does the system realistically start (ground segment, operational production environment) and where does it end (just before delivery to users)

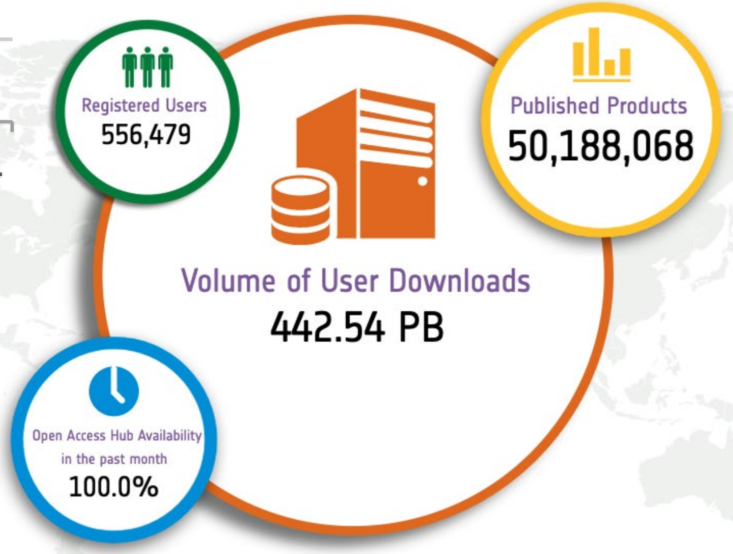
Questions

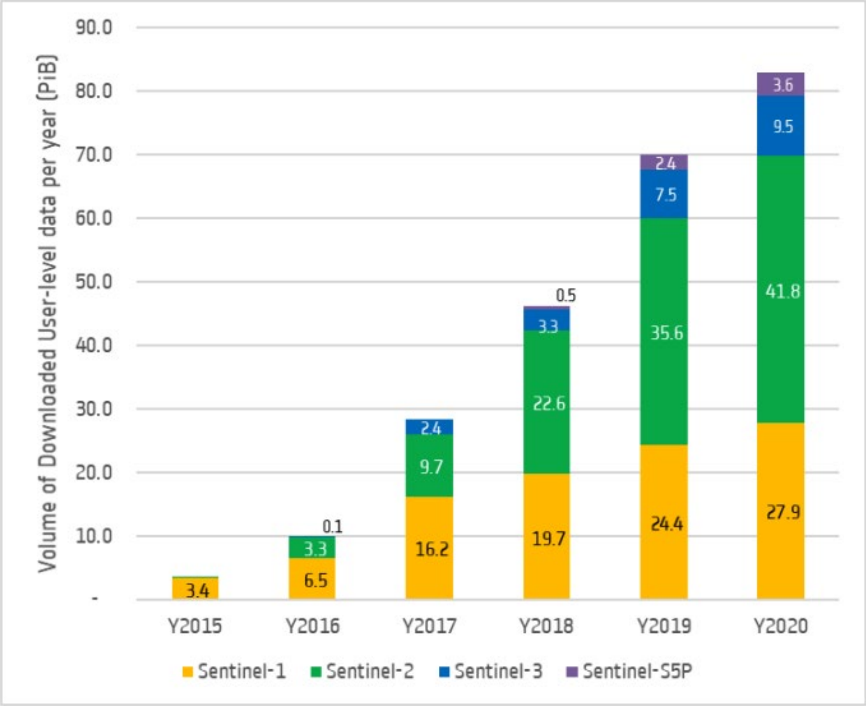
- Can DGGS **facilitate interoperability** best practices, automatization, systemization, visualization, and **on-the-fly processing** through integrated web-services?



Some Statistics - Copernicus Sentinels







From **Sentinel Data Dashboard**: https://dashboard.copernicus.eu/

Some Statistics – Airbus Global Elevation Data

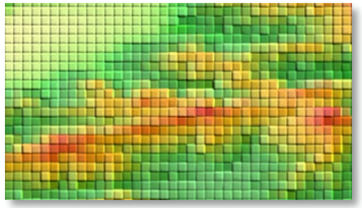
149Mio km²

WorldDEM
0,4” (12m)

WorldDEM Neo
0,15” (5m)

Elevation 2030
0,5 - 5 m

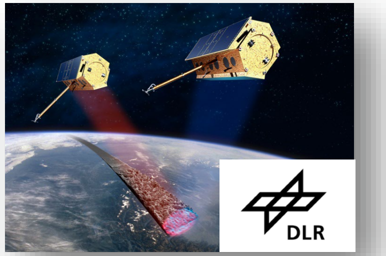
Data Tiling
26.400 geocells
(1x1 deg)



Data Tiling
105.600 ¼-cells
(0.5x0.5 deg)

Data Tiling
tbd

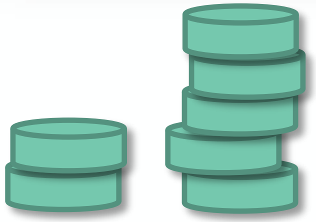
Data Aqcuisition
TanDEM-X Mission
2010-2014



Data Aqcuisition
Change DEMs
2017-2021

Data Aqcuisition
Pléiades, PNeo
2020 - …

Data Volume
DEM 6TB
Incl. AUX 7,5TB



Data Volume
DEM 23,5TB
Incl. AUX 69,5TB

Data Volume
DEMs ???TB
Incl. AUX ???TB

Expectations / Questions (Summary)

- Expectation to have a **unified framework** for EO data seamless integration, multi-source, multi-resolution data fusion and cloud computing on a global scale.

- Which DGGS resolution level is better for Sentinel-2?
- Will the users care about discrete resolution levels?
- Can DGGS projections preserve original satellite radiometry?
- Can DGGS facilitate interoperability best practices, automatization, systemization, visualization, and on-the-fly processing through integrated web-services?

Part 2: What is a DGGS?

DGGS take-aways:

Part 3: Where do we go from here?

Open questions:

- Do we need more or fewer global representation solutions?
- Do we have the right ones in place?
- Should global providers strive for more harmonisation in their products incl. gridding?
- Which cell geometry would you consider most apt for storing/analysis of future ‘big EO data’: triangles, squares, or hexagons
- What max difference in cell area (or ‘aperture’) would you consider tolerable in your work: 1:4, 1:7, or 1:9

Open questions:

“choice is the enemy of interoperability”

So, what should drive system design in the future?

Summary

Which road to take: **Continuous** (point-clouds) or **discrete** (grids)?

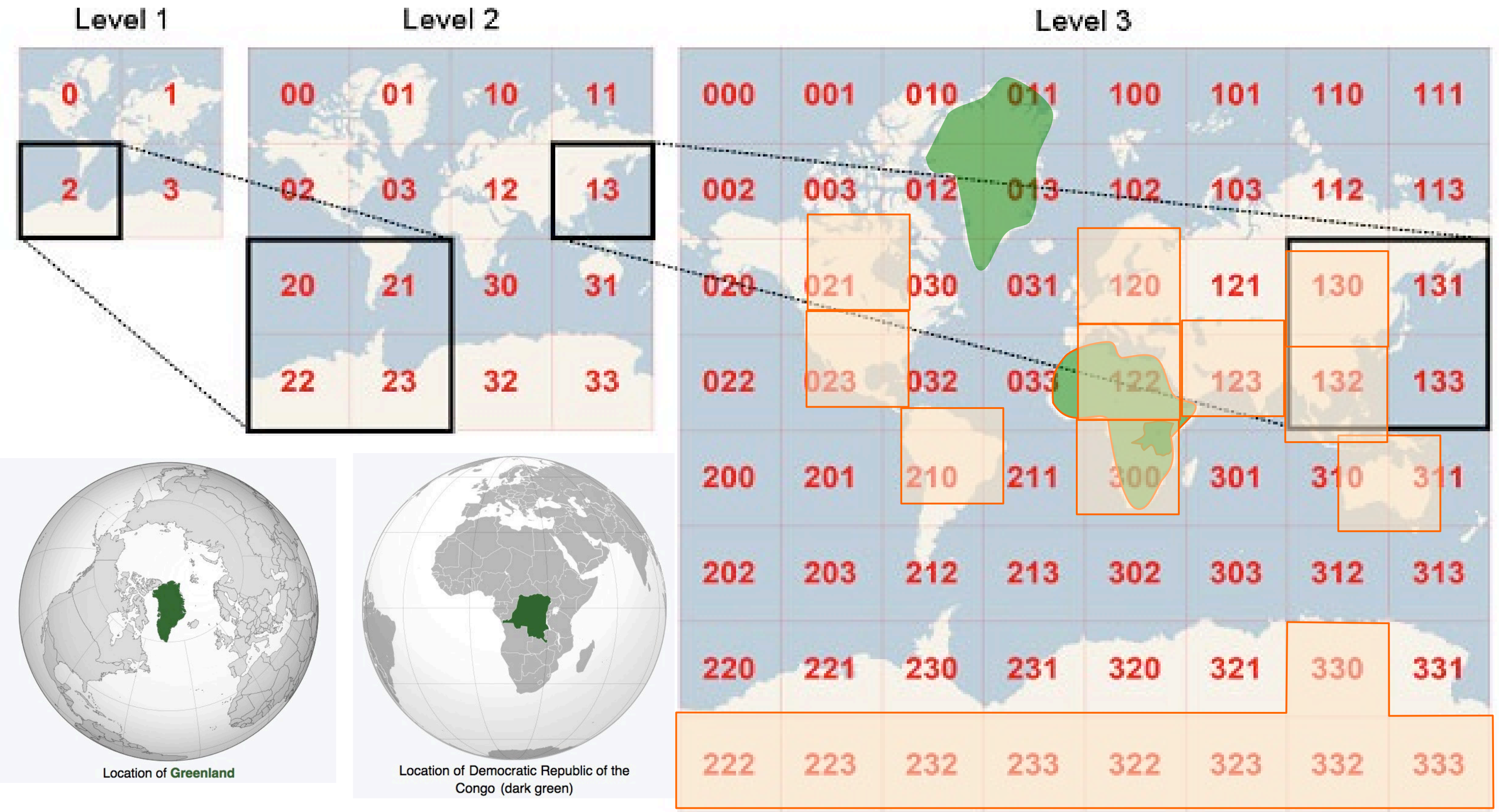
*If **grids** then:*

- Global or continental, mono-resolution or hierarchical?
- Which criteria for 'good' global grids? (e.g. Goodchild/Kimerling)
- Main candidate global grid(system)s?
- Individually or together?

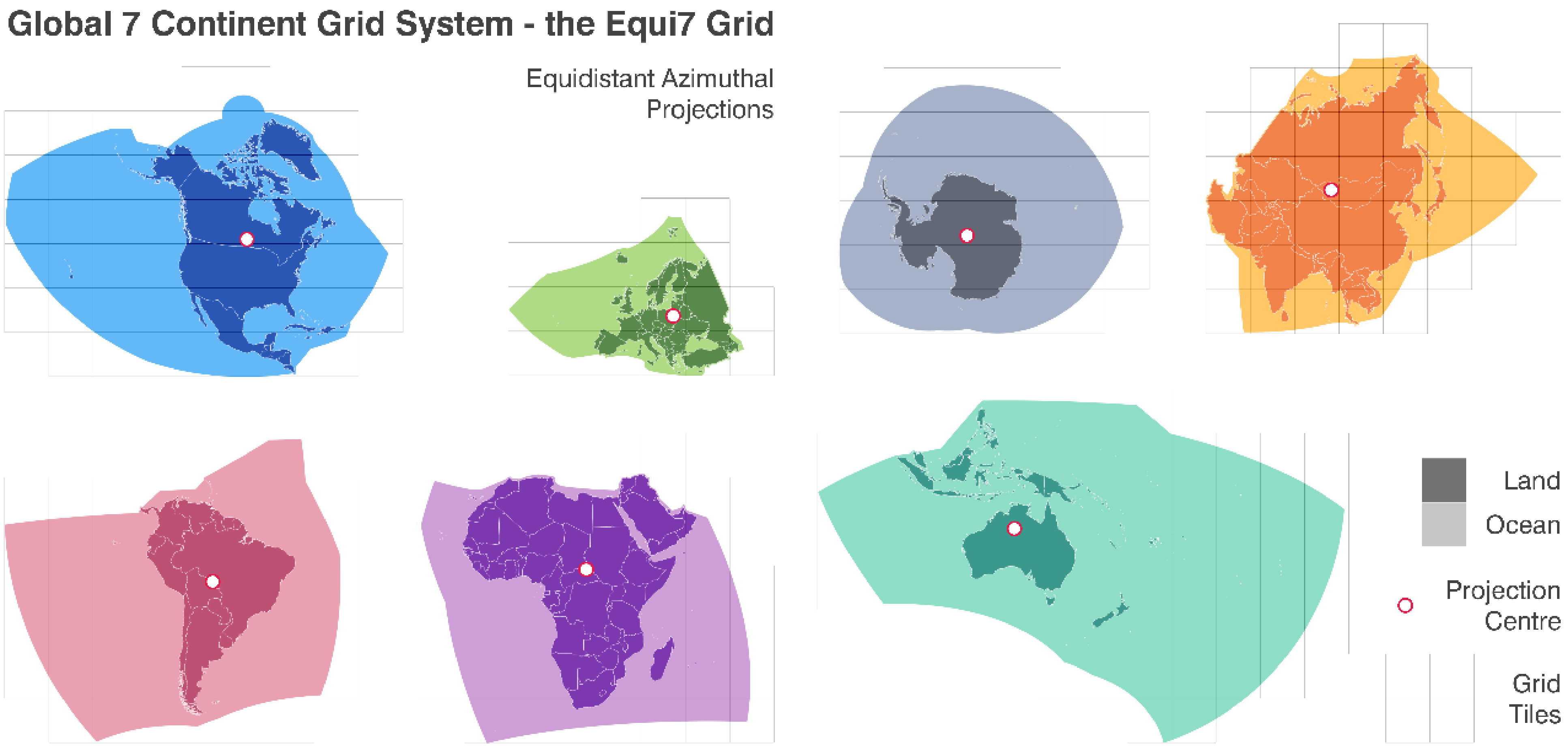
M. Goodchild (2019):
So, in the final analysis, the big-picture question for DGGSs remains the same as it has been for more than two decades:
how do we use the compelling arguments for these multi-resolution systems to persuade the larger scientific community to adopt them, in preference to the distorted representations of digital maps?
https://doi.org/10.3138/cart.54.1.preface

Backup slides

The WMTS standard (base EPSG:3857)



The EQUI7 grid (TU Vienna)



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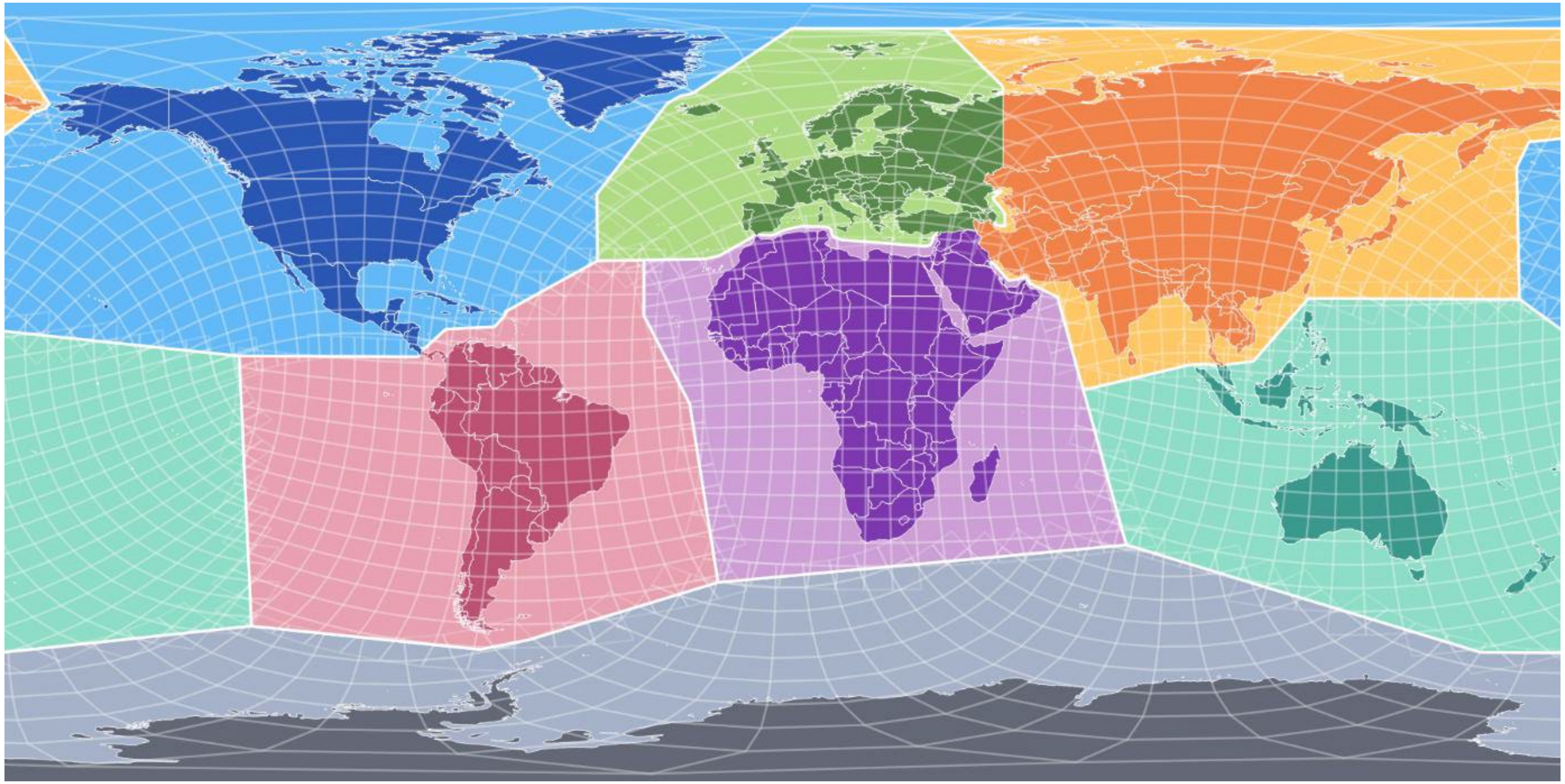
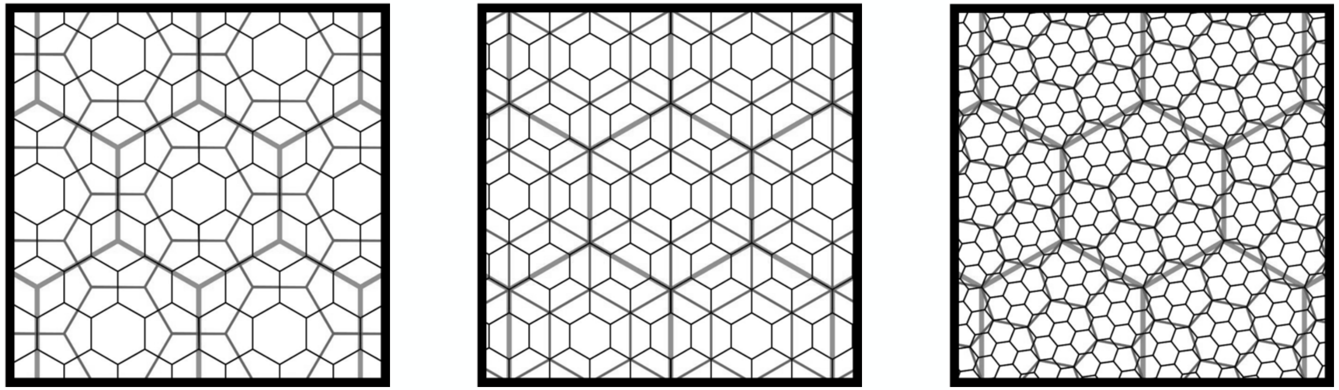


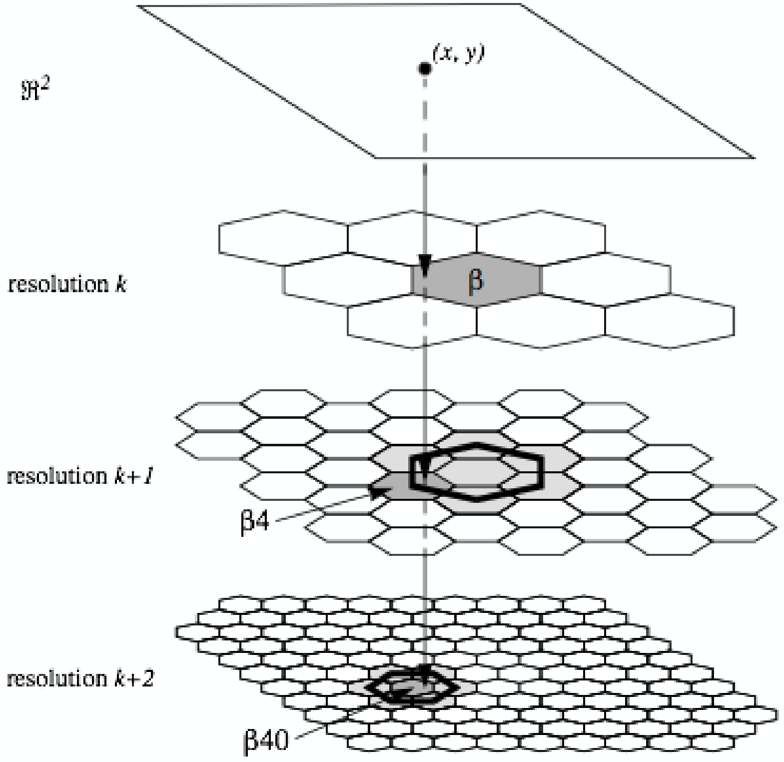
B. Bauer-Marschallinger, Optimisationof global grids for high-resolution remote sensing data, Computers & Geosciences, 2014
doi:10.1016/j.cageo.2014.07.005

Discrete Global Grid and Sentinel Products

- It is often useful to assign to each hexagon a linear code or index. The most useful indexes are hierarchical **prefix codes**, where the cell being indexed is considered to be at a specific resolution in a multi-resolution structure, and each digit in the index corresponds to a location at a single resolution relative to a hierarchical parent's index.

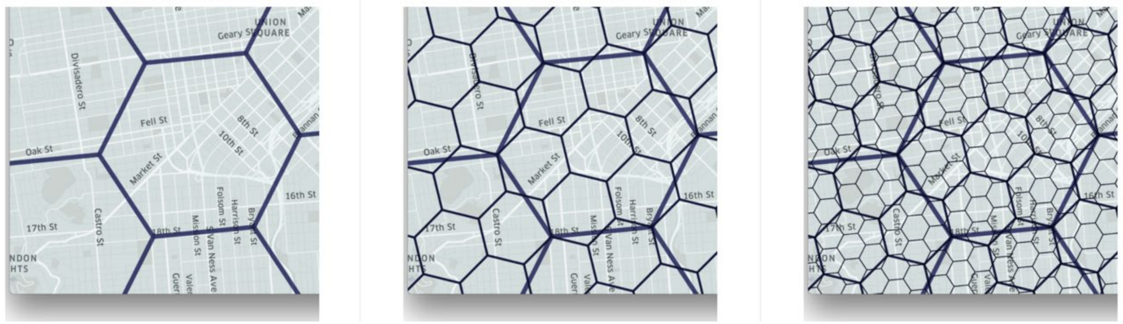


Hierarchical partition of space using hexagon apertures 3 (left), 4 (middle) and 7 (right) (Sahr, 2013).



Alternative

- Uber developed H3, their grid system based on hierarchic hexagons, for efficiently optimizing ride pricing and dispatch, for visualizing and exploring spatial data.



- The H3 grid is based on a icosahedron projection and is constructed by laying out 122 base cells over the Earth, with ten cells per face. Some cells are contained by more than one face. Since it is not possible to tile the icosahedron with only hexagons, they chose to introduce also twelve pentagons, one at each of the icosahedron vertices. Such pentagon vertexes are located over water.

- H3 supports sixteen resolutions. Each finer resolution has cells with one seventh the area of the coarser resolution. Hexagons cannot be perfectly subdivided into seven hexagons, so the finer cells are only approximately contained within a parent cell.

- The basic functions of the **H3** library are for indexing locations, which transforms **latitude** and **longitude** pairs to a 64-bit H3 index, identifying a grid cell.

- H3 is now open and free: https://github.com/uber/h3

DGGS optimization

After the main choices, i.e.:

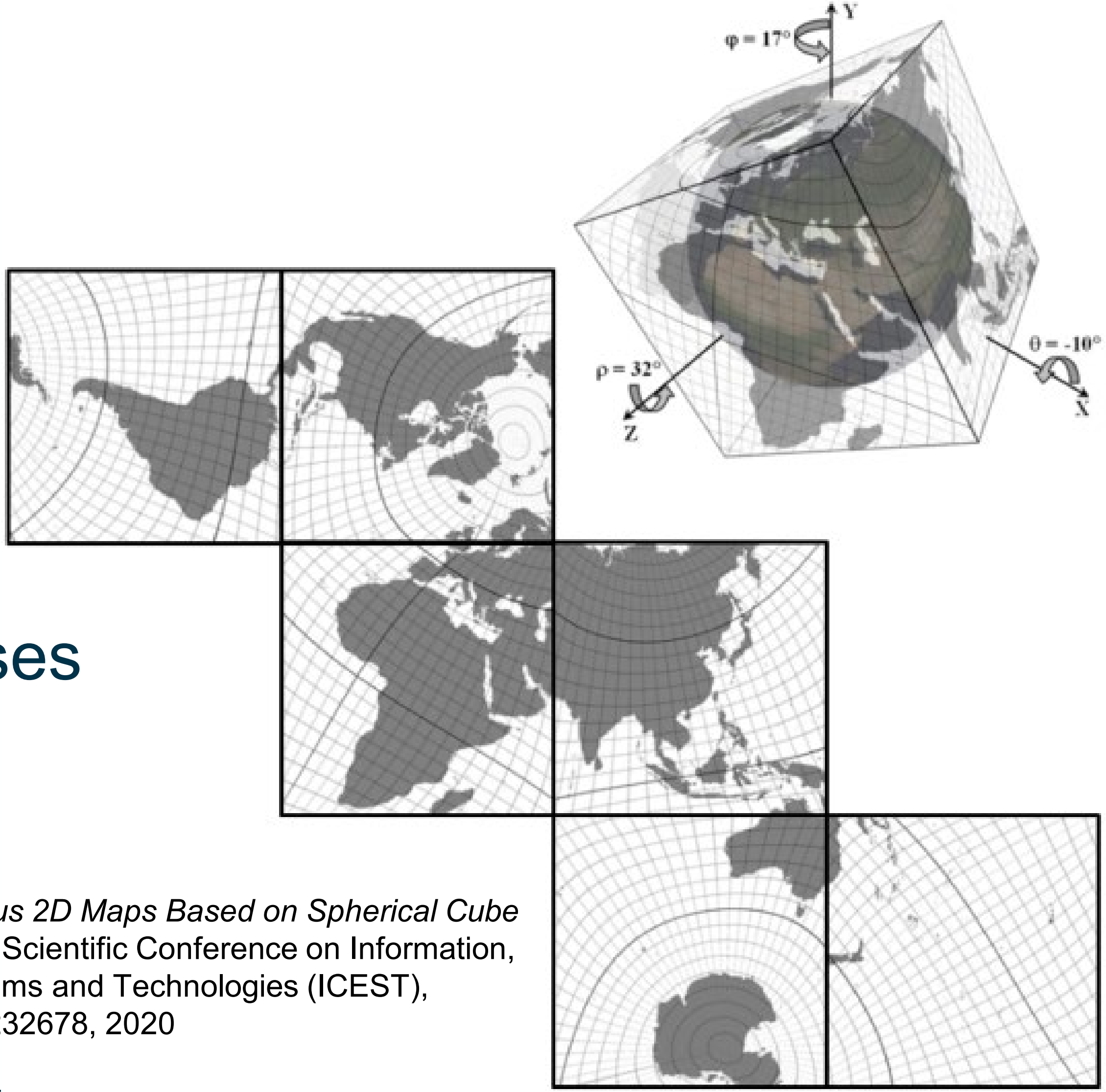
shape (”square”)

Refinement ratio (4 - quadtree)

- “cube-sphere mapping”

Cube sphere mapping can be optimized

to reduce distortions e.g. over land masses



Dimirijevic A., Strobl P., *Continuous 2D Maps Based on Spherical Cube Datasets,* Proc. 55th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST), doi:10.1109/ICEST49890.2020.9232678, 2020