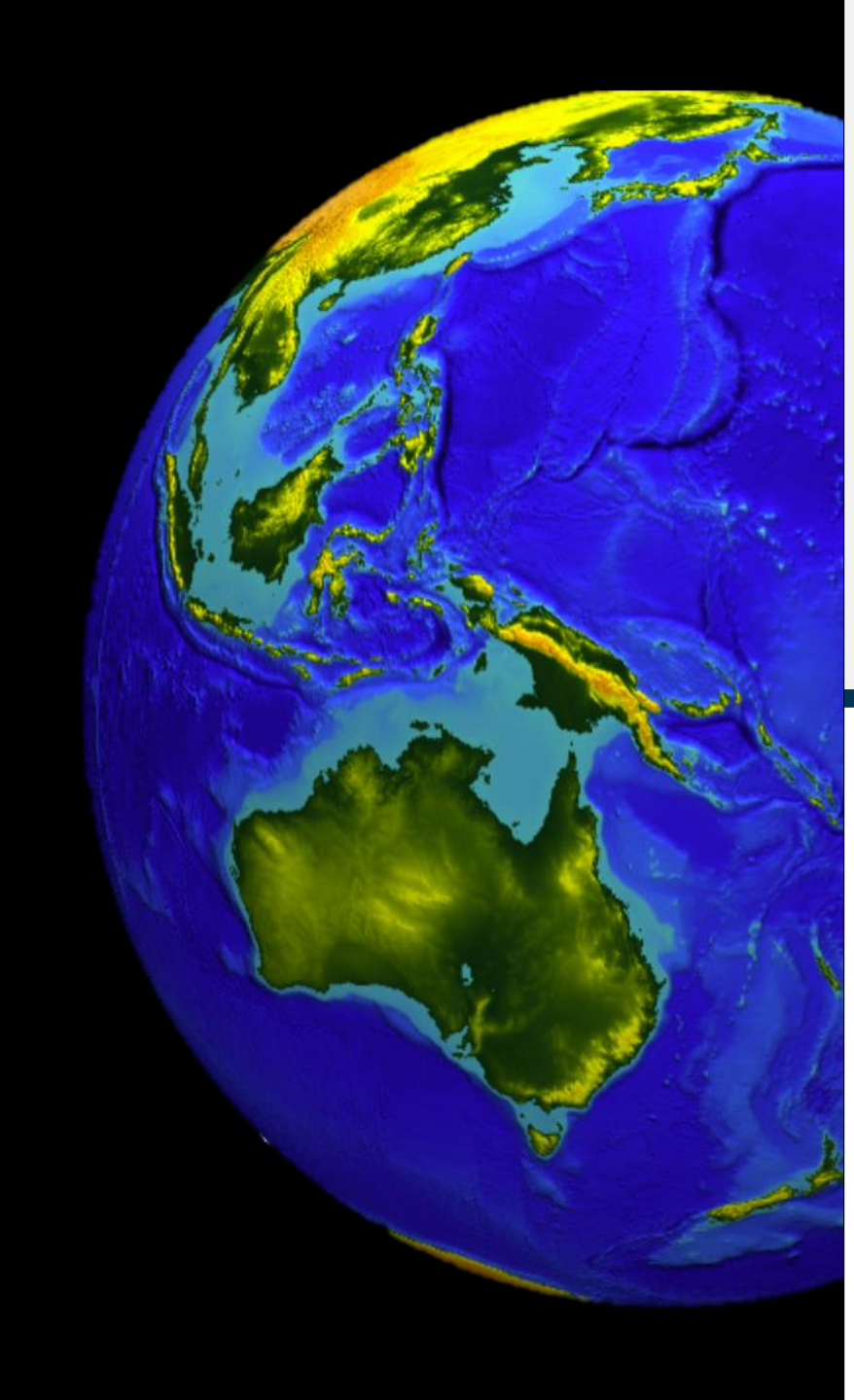


DGGS: Multi-resolution Bathymetry On-Demand

HYDRO 22

5-8 December 2022
Monaco-Grimaldi Forum

Marta Padilla Ruiz, Thierry Schmitt, Perry Peterson, Julien Barbeau, Emmanuel Stefanakis

December 7th, 2022

TELEDYNE
Teledyne Geospatial

UNIVERSITY OF CALGARY

SHOM

Applications Engineer

R&D

Cloud

TELEDYNE
Teledyne Geospatial

Processing automation

Apps

UNIVERSITY OF CALGARY

DGGS

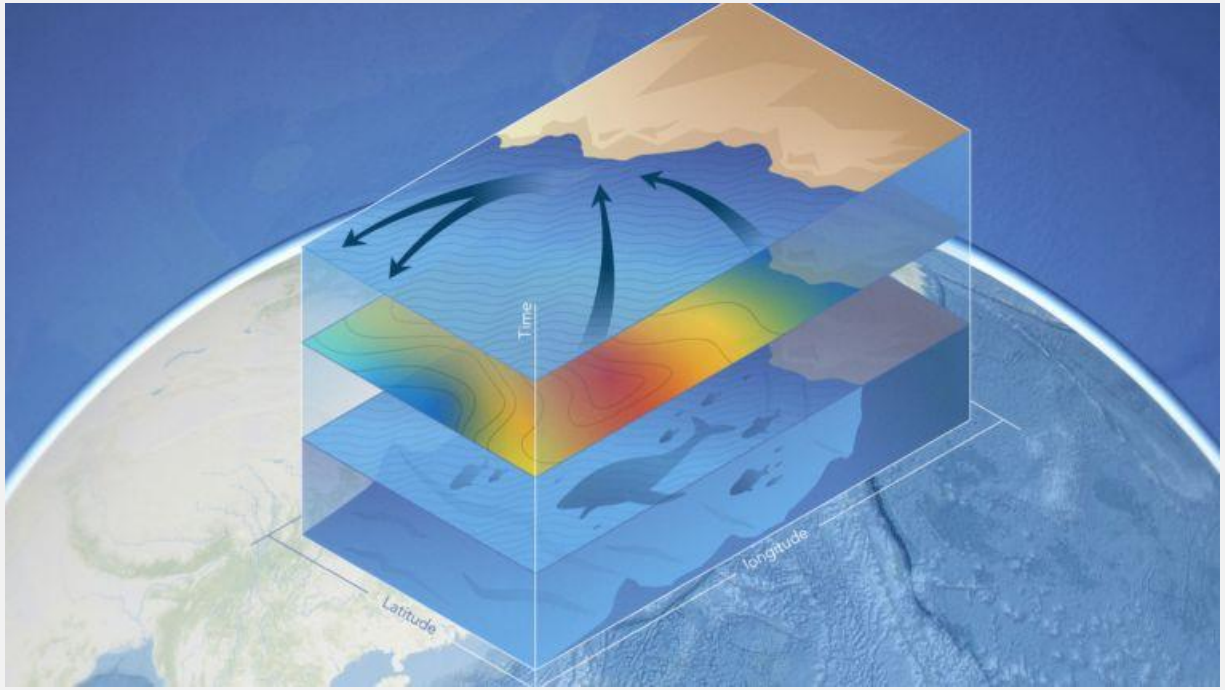
Marine

PhD Student

Marta Padilla Ruiz

Geomatics Engineer – Hydrospatial advocate

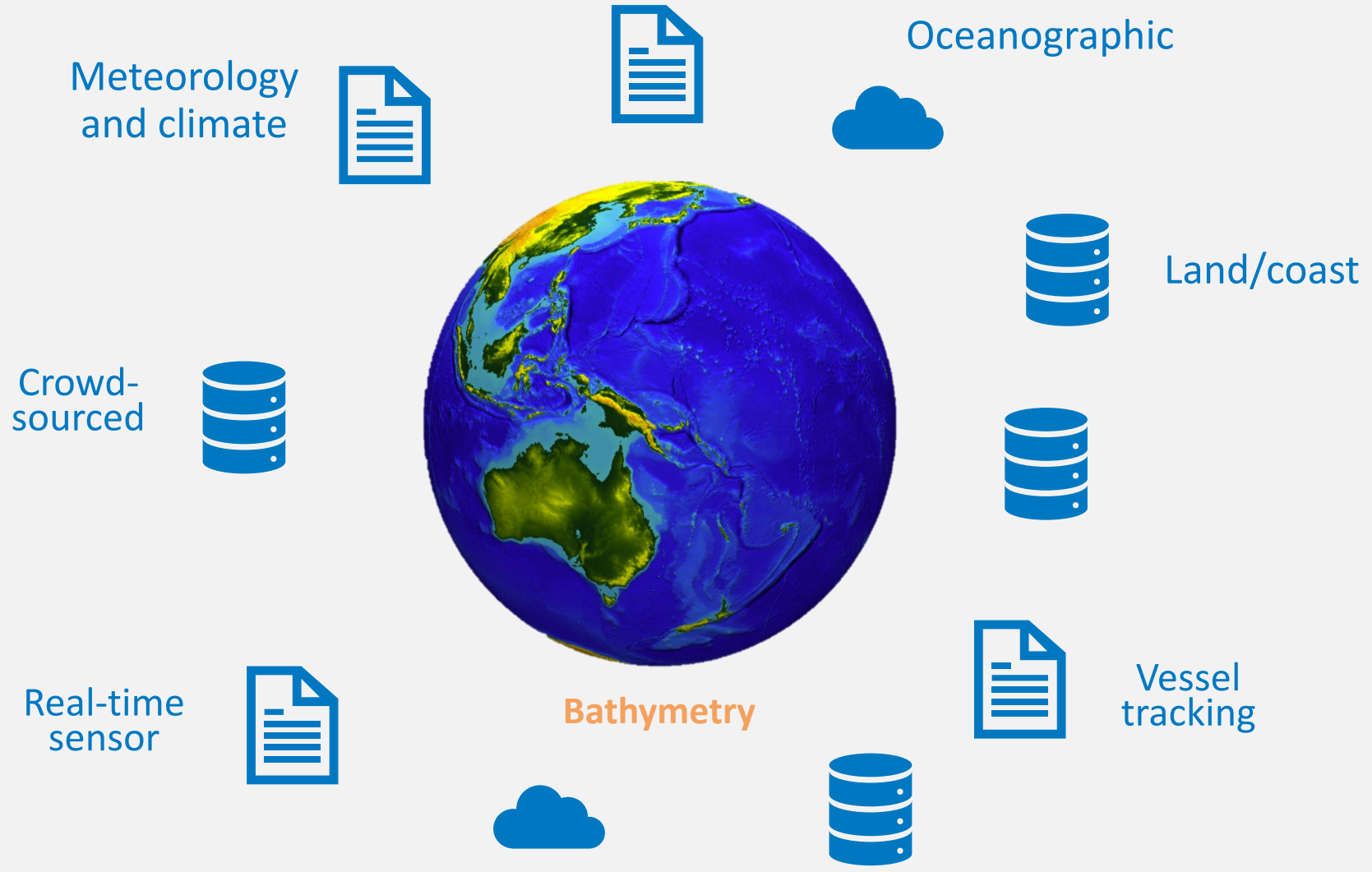
The concept of HYDROSPATIAL



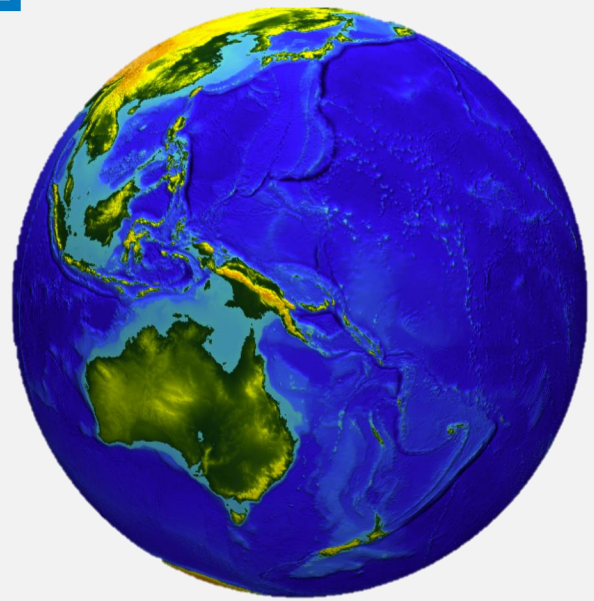
hydrospatial. *adjective*
Relating to hydrospatial sciences or denoting data, information and knowledge that is associated with a particular location and time of the earth's waters and their contiguous zones.

*"We are going through a **marine geospatial** revolution"*

HYDROSPATIAL Data



HYDROSPATIAL Data



Meteorology and climate

Oceanographic

Land/coast

Crowd-sourced

Users

Real-time sensor

Bathymetry

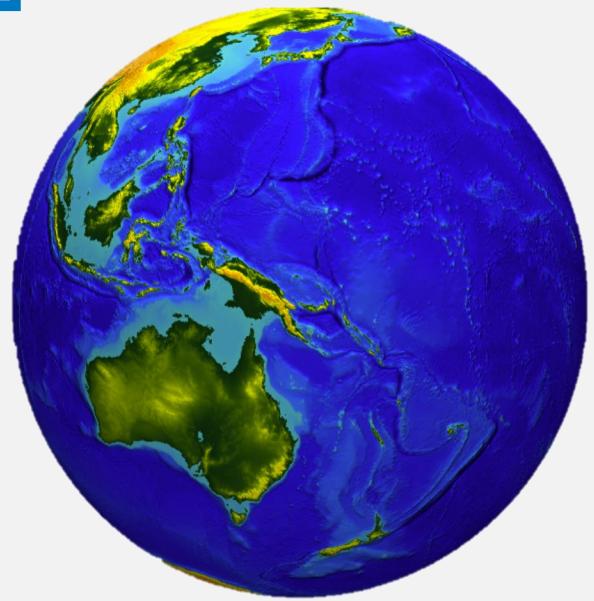
Vessel tracking

HYDROSPATIAL Data

Meteorology and climate

Oceanographic

Hydrospatial Knowledge



Land/coast

Crowd-sourced

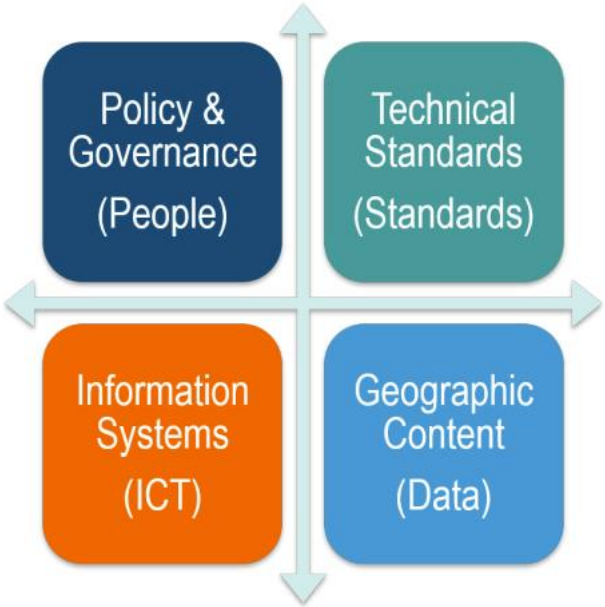
Users

Real-time sensor

Bathymetry

Vessel tracking

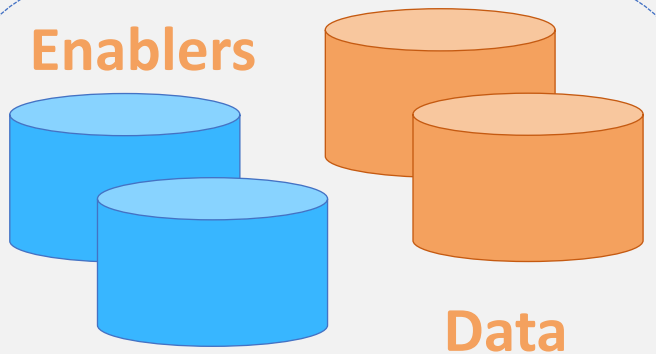
Current paradigm



Current paradigm

Hydrospatial baseline

Enablers



Data

MSDI

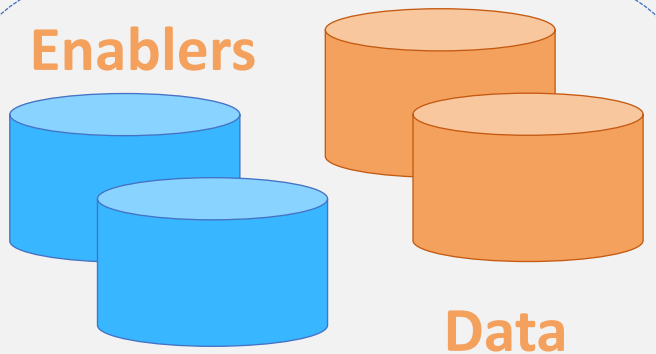
Standards

D

Current paradigm

Hydrospatial baseline

Enablers



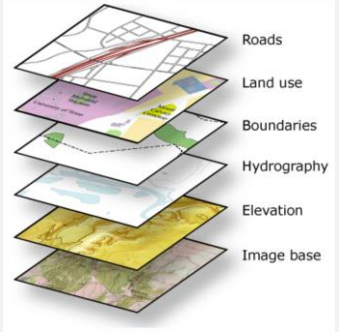
Data

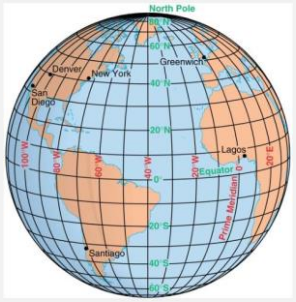
MSDI

Standards

Hydrospatial Information Systems (HIS)

Layered model



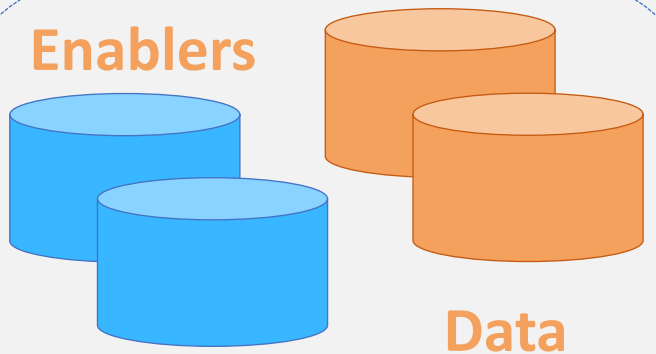


Analog model

Current paradigm

Hydrospatial baseline

Enablers



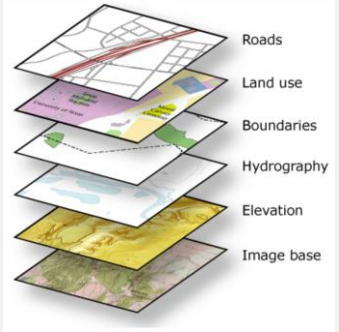
Data

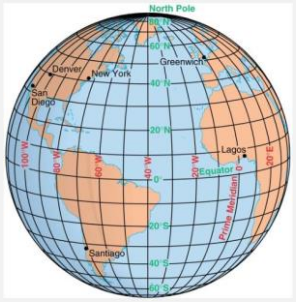
MSDI

Standards

Hydrospatial Information Systems (HIS)

Layered model





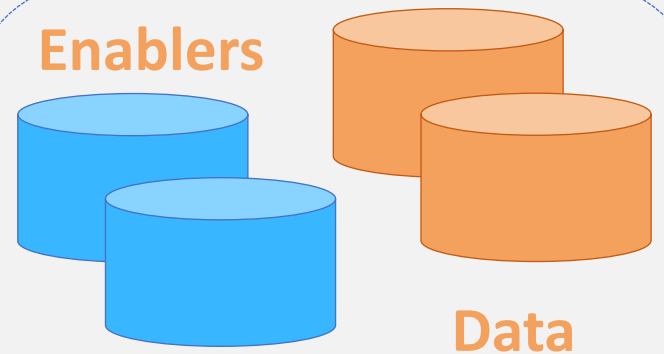
Analog model

Intermediate assistance - Expert

Current paradigm

Hydrospatial baseline

Enablers



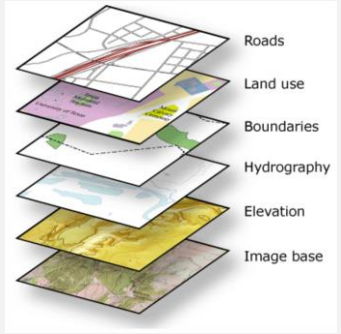
Data

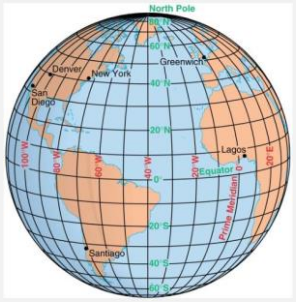
MSDI

Standards

Hydrospatial Information Systems (HIS)

Layered model





Analog model

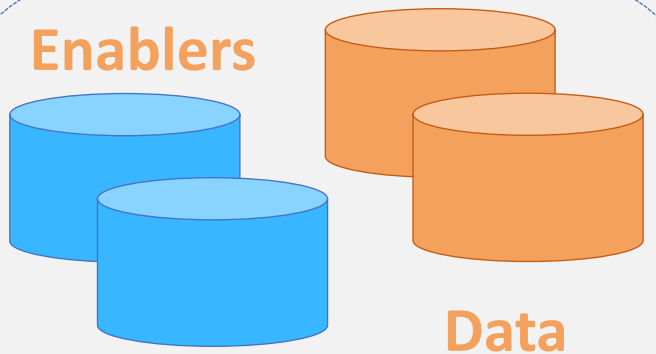
Intermediate assistance - Expert

Services, Products (APIs), Knowledge / Intelligence

Reinventing HIS

Hydrospatial baseline

Enablers



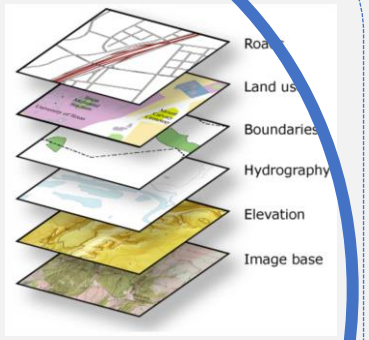
Data

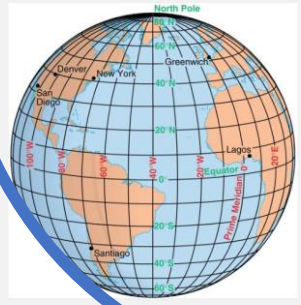
MSDI

Standards

Hydrospatial Information Systems (HIS)

Layered model





Analog model

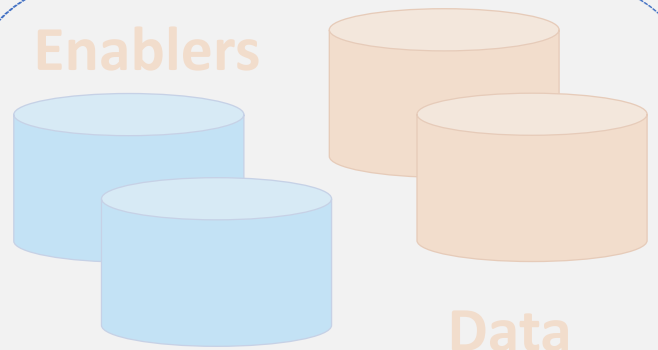
Intermediate assistance - Expert

Services, Products (APIs), Knowledge / Intelligence

Integrated HIMS

Hydrospatial baseline

Enablers



Data

MSDI

Standards

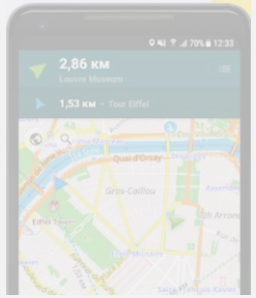
Integrated Hydrospatial Information Management

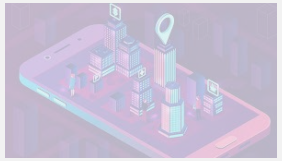
Integrating all types of data

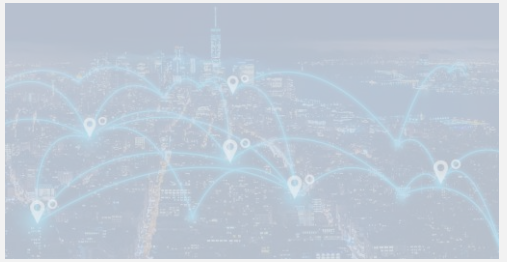
Enable complex decision making and knowledge on demand

Global networks of query-able linked data

Services, Products (APIs), Knowledge / Intelligence







Integrated HIMS

Hydrospatial baseline

Enablers

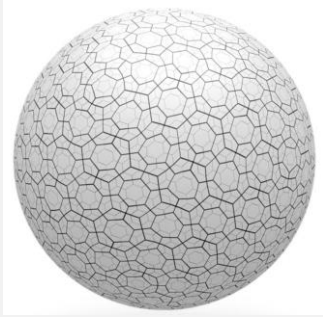
Data

MSDI

Standards

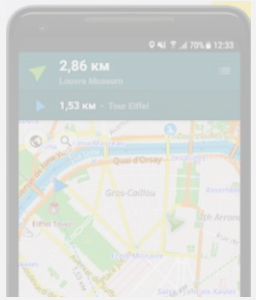
Integrated Hydrospatial Information Management

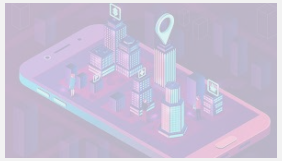
Multi-resolution model

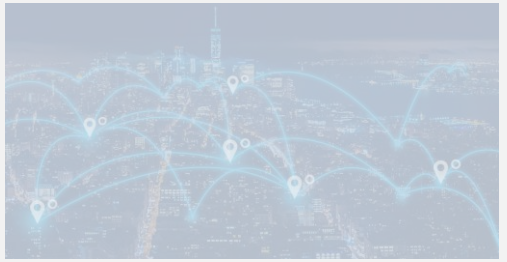


Digital model

Services, Products (APIs), Knowledge / Intelligence

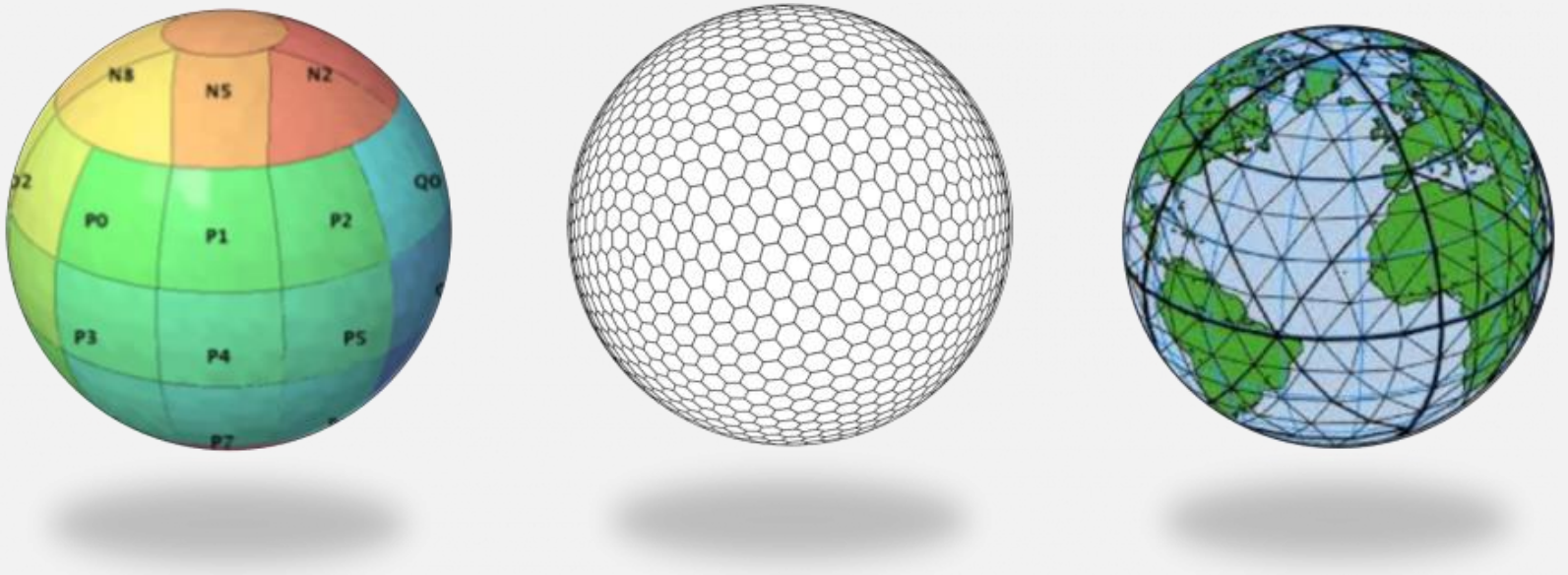






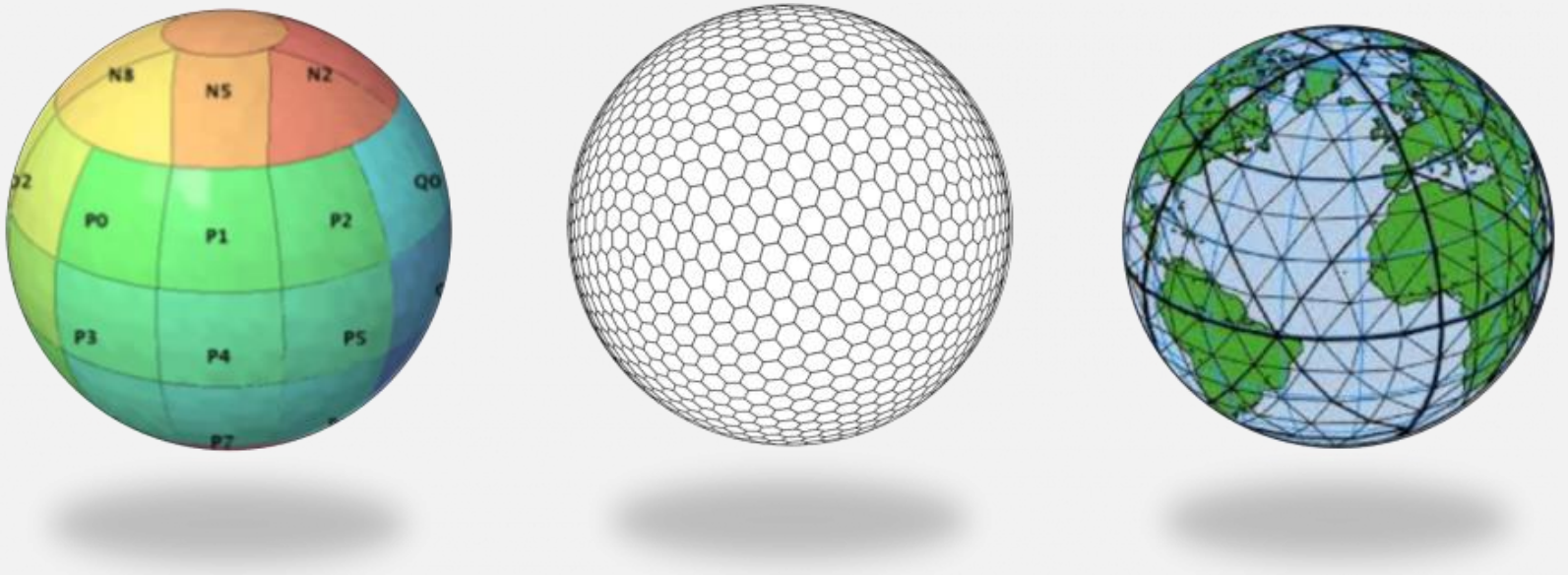
Discrete Global Grid Systems

Discrete Global Grid Systems



*A **Discrete Global Grid System (DGGS)** is a spatial reference system that uses a* **hierarchical tessellation** *of equal area cells to partition and address the globe.*

Discrete Global Grid Systems



Multiresolution

Hierarchical tessellations with each cell having a unique identifier or indexing

Cells at the same resolution are **equal area cells**

DGGS as an international standard

"DGGS infrastructures enable the integrated analysis of very large, multi-source, multi-resolution, multi-dimensional, distributed geospatial data."
Open Geospatial Consortium - Topic 21: Discrete Global Grid Systems Abstract Specification 15-104r5

"All Discrete Global Grid Systems are structured for information as distinct from conventional coordinate reference systems originally designed for navigation."
International Standard Organization – ISO 19170-1: Discrete Global Grid Systems Specifications

"DGGS as a Common Geography will ensure that all statistical data is consistently geospatially enabled and that users can discover, access, integrate, analyse and visualise statistical information seamlessly for geographies of interest."
United Nations Committee of Experts on Global Geospatial Information Management - The Global Statistical Geospatial Framework

DGGS characteristics

DGGS are characterized by the properties of their:

- Cell structure
- Indexing
- Quantization strategy
- Associated analytics and algebraic functions

DGGS characteristics

DGGS are characterized by the properties of their:

- Cell structure **Grid definition**
- Indexing
- Quantization strategy
- Associated analytics and algebraic functions

DGGS characteristics

DGGS are characterized by the properties of their:

- Cell structure **Grid definition**
- Indexing **Grid navigation**
- Quantization strategy
- Associated analytics and algebraic functions

DGGS characteristics

DGGS are characterized by the properties of their:

- Cell structure **Grid definition**
- Indexing **Grid navigation**
- Quantization strategy **How to get data into the grid**
- Associated analytics and algebraic functions

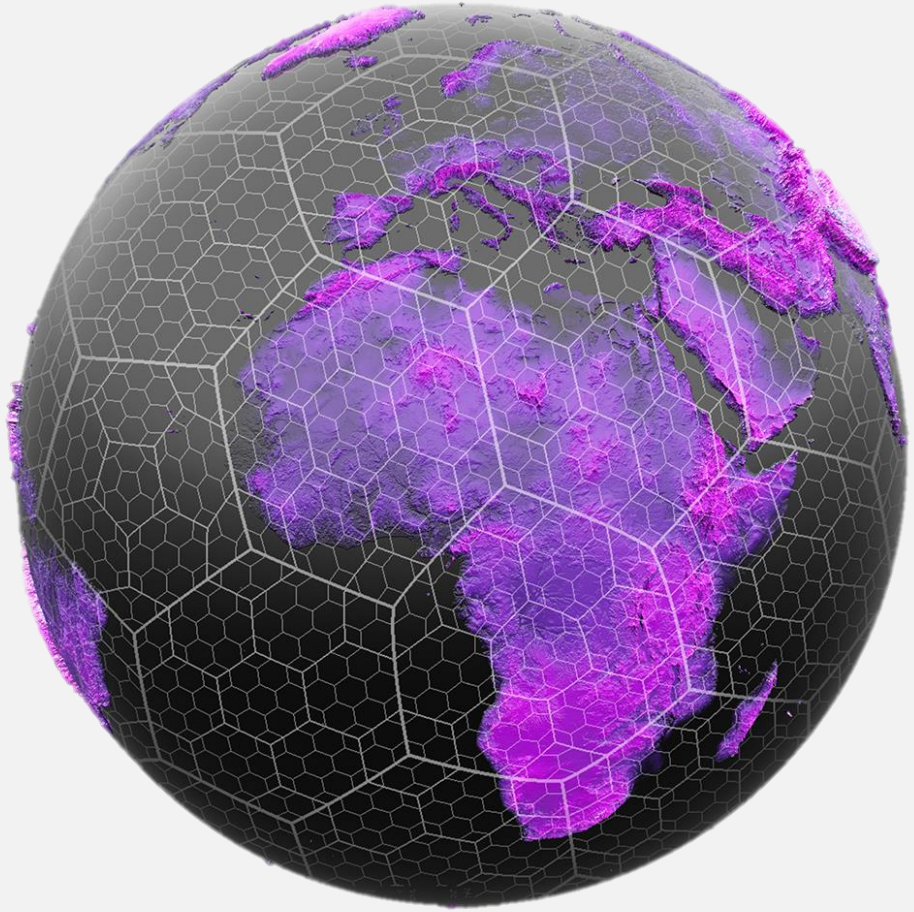
DGGS characteristics

DGGS are characterized by the properties of their:

- Cell structure — Grid definition
- Indexing — Grid navigation
- Quantization strategy — How to get data into the grid
- Associated analytics and algebraic functions — How to perform analytics on the fly

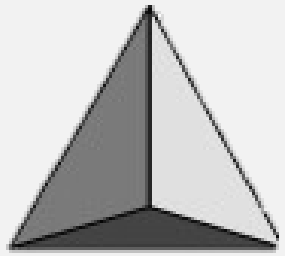
DGGS grid definition

- **Polyhedron** selection
- Polyhedron **Orientation**
- Polyhedron **Partitioning** (cells)
- **Projection** (to/from Earth's surface)

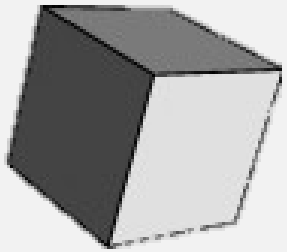


Polyhedron selection

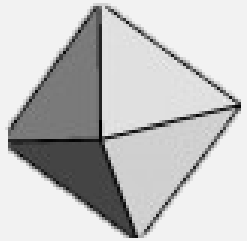
Platonic solids



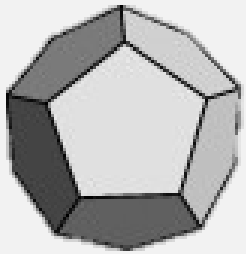
Tetrahedron



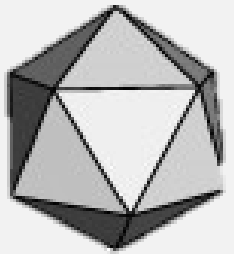
Cube



Octahedron



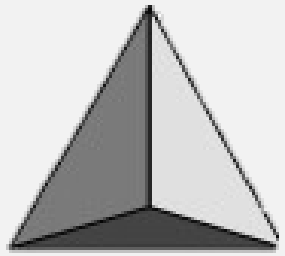
Dodecahedron



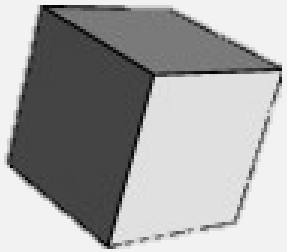
Icosahedron

Polyhedron selection

Platonic solids



Tetrahedron



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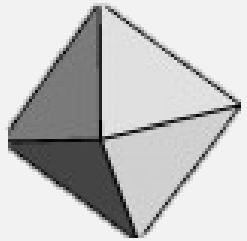
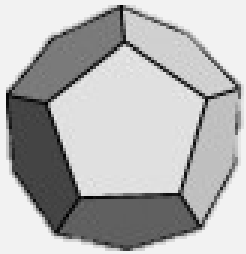
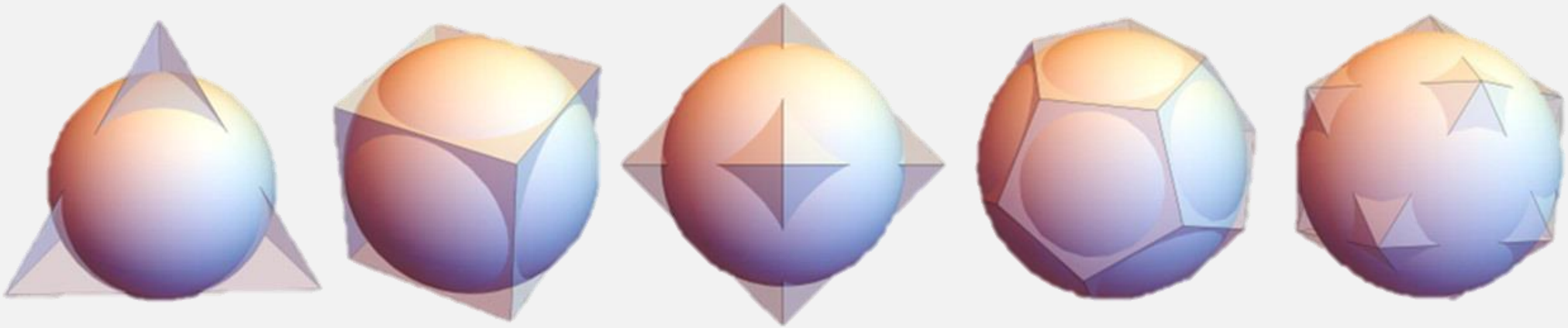


Octahedron

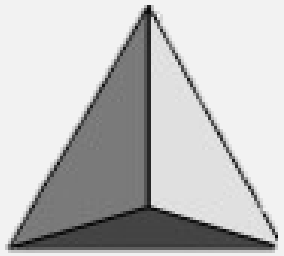


Dodecahedron

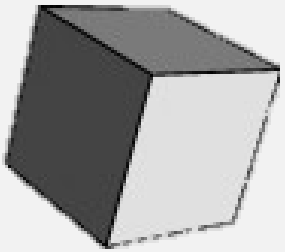
Icosahedron



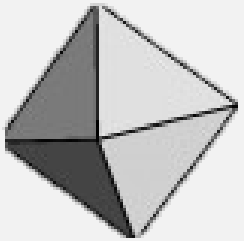
Projection



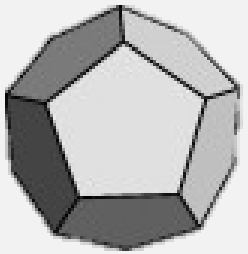
Tetrahedron



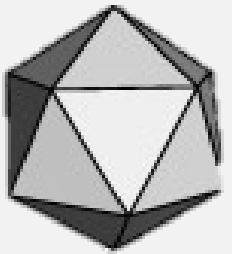
Cube



Octahedron

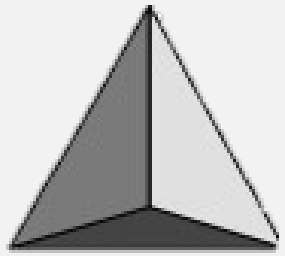


Dodecahedron

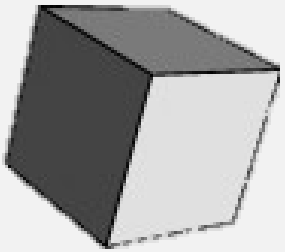


Icosahedron

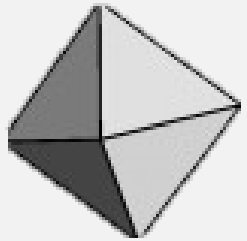
Projection



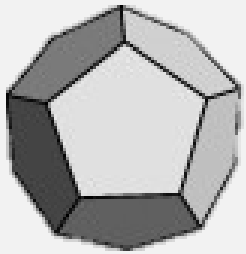
Tetrahedron



Cube



Octahedron

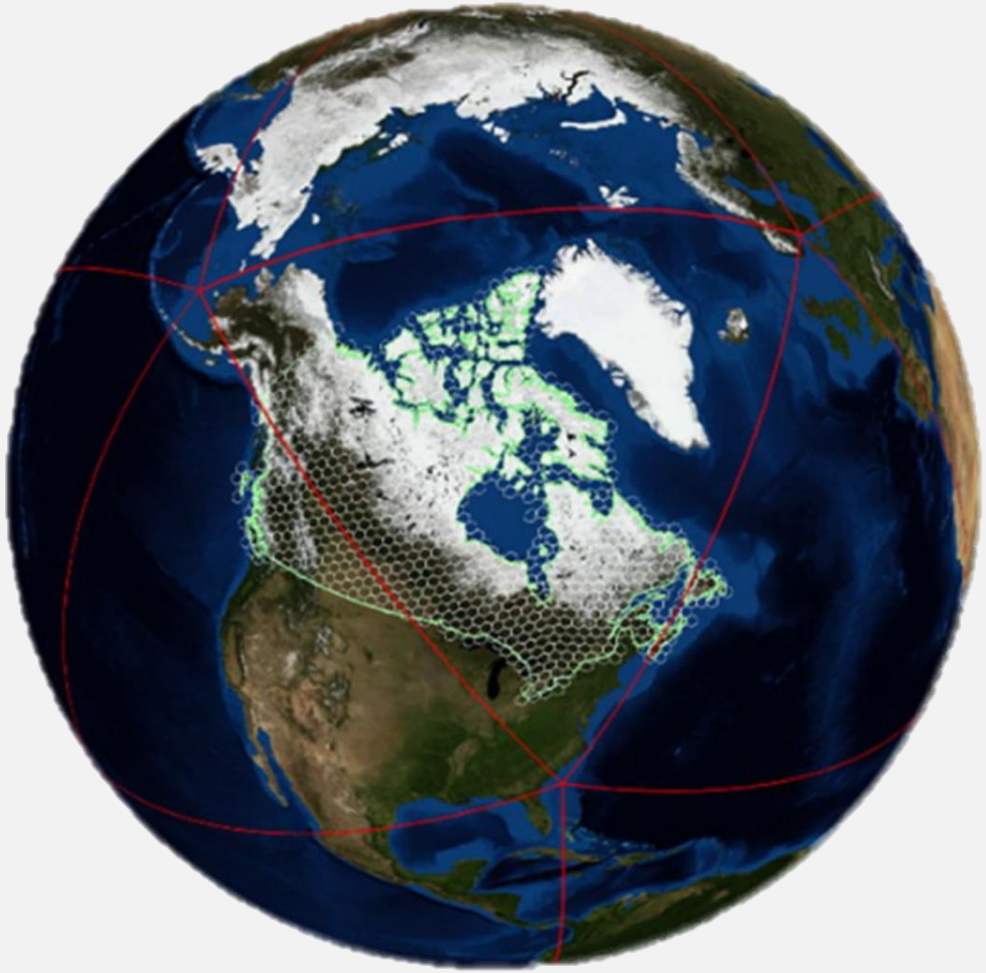


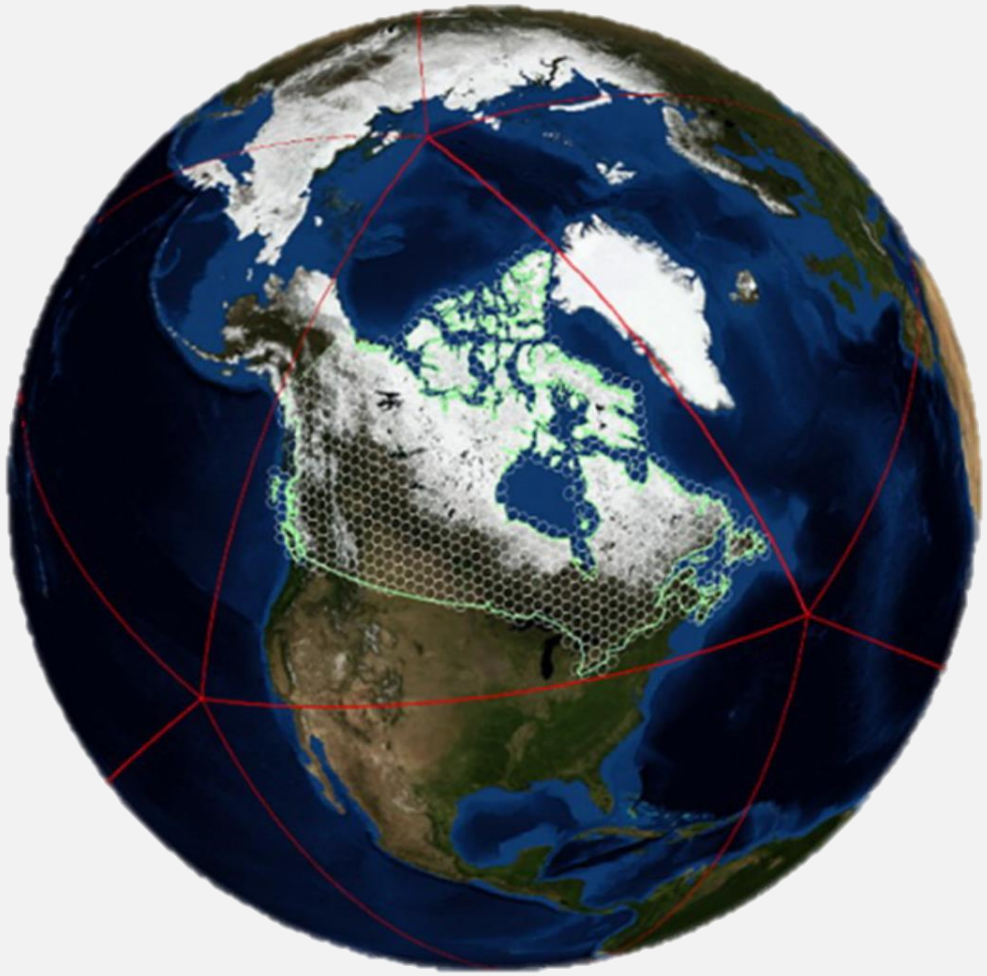
Dodecahedron

Icosahedron

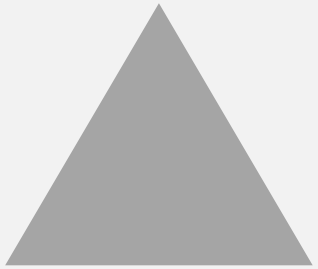
Spherical Equal Area Projection

Polyhedron orientation



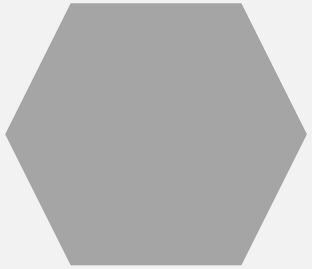


Polyhedron partitioning – Cell tessellation



Triangles

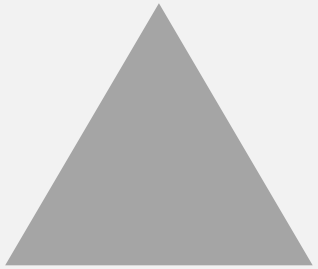
Squares



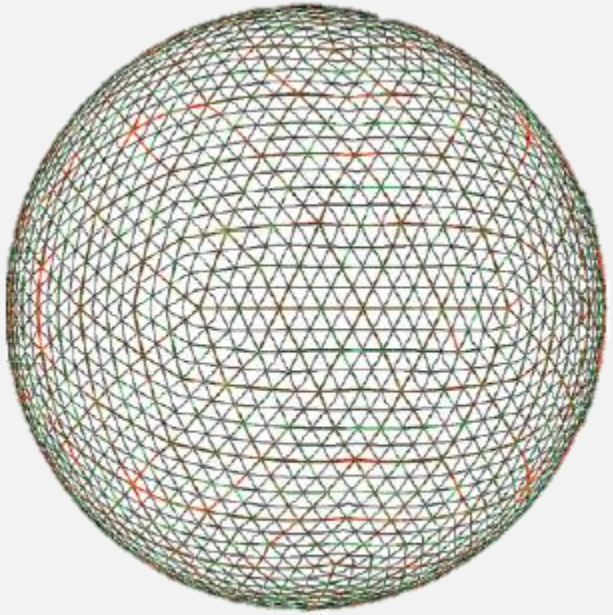
Hexagons

cc

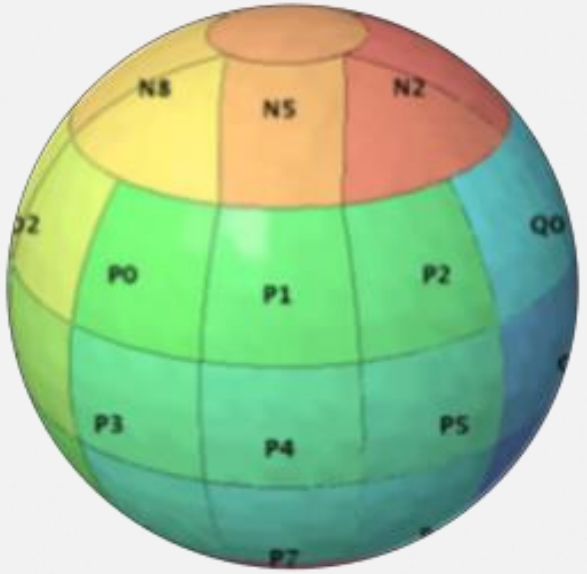
Polyhedron partitioning – Cell tessellation

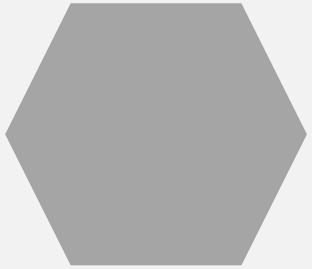


Triangles

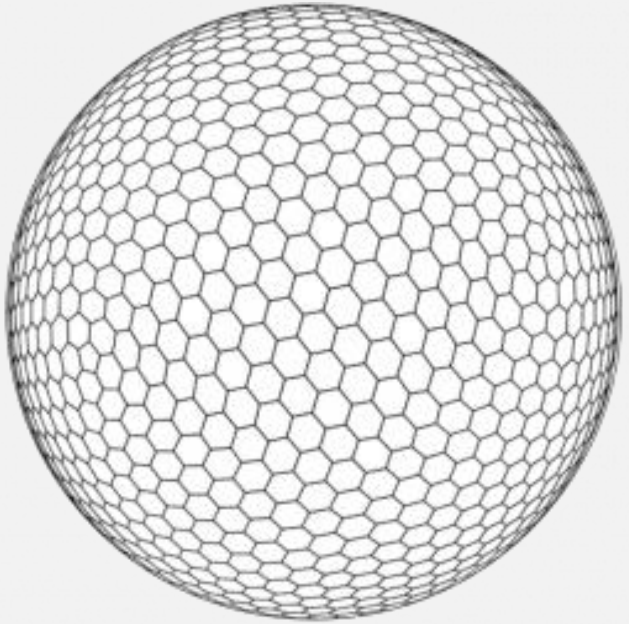


Squares

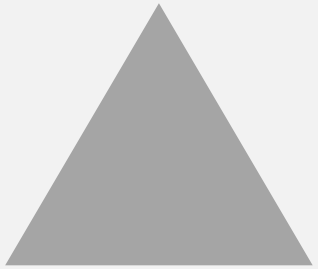




Hexagons

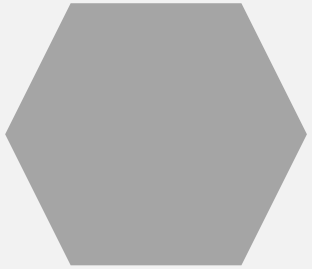


Polyhedron partitioning – Cell tessellation

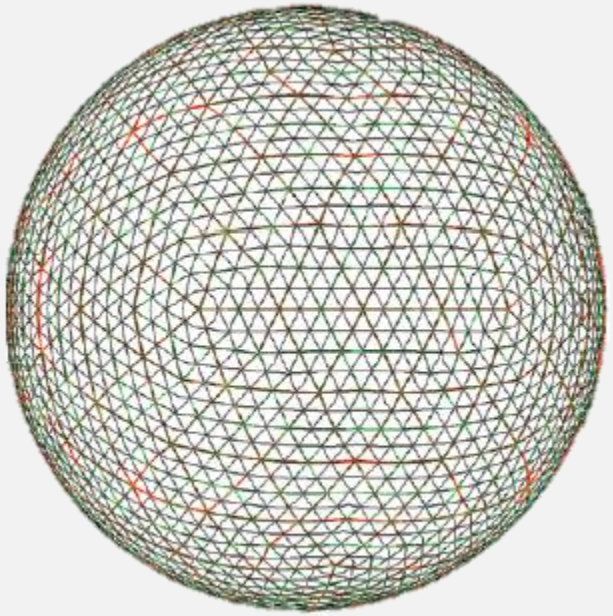


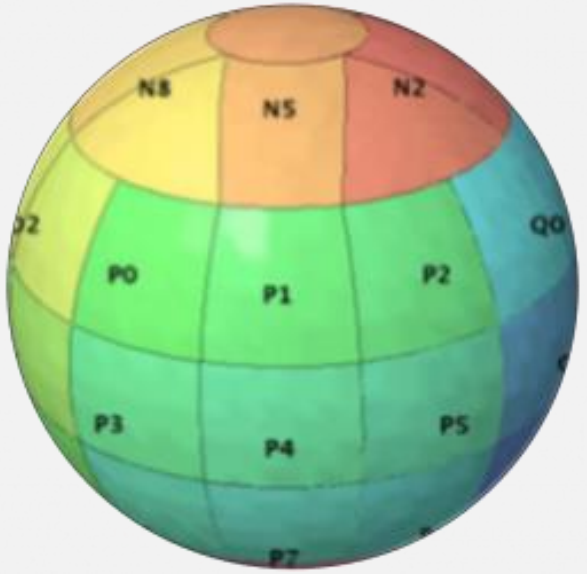
Triangles

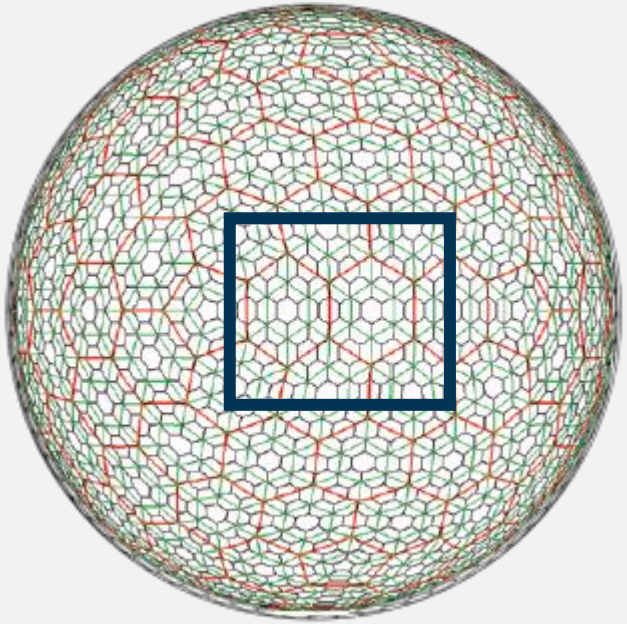
Squares



Hexagons

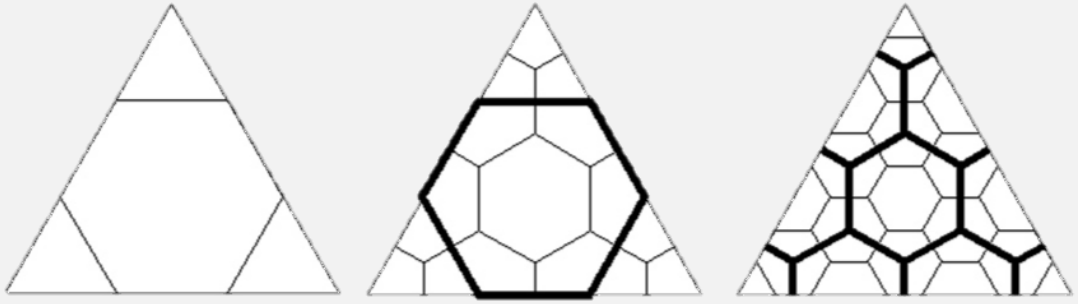




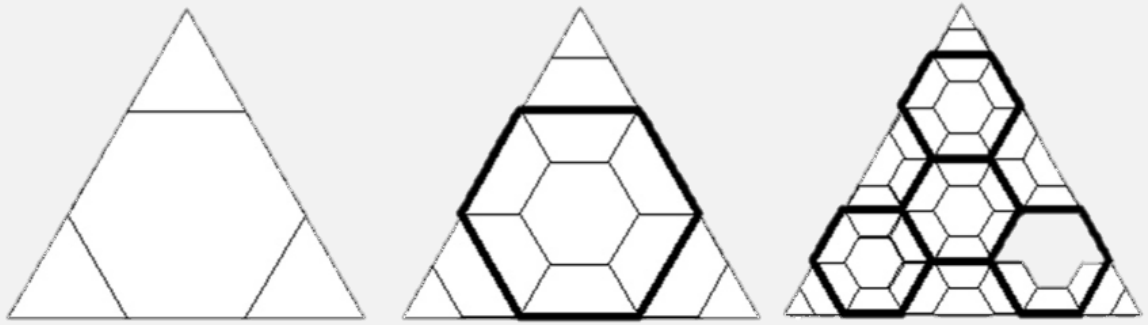


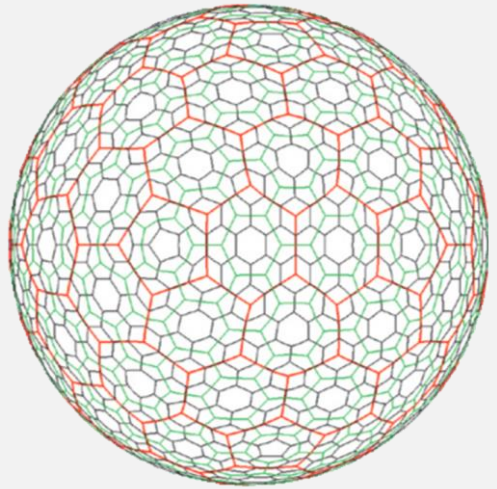
Polyhedron partitioning – Aperture

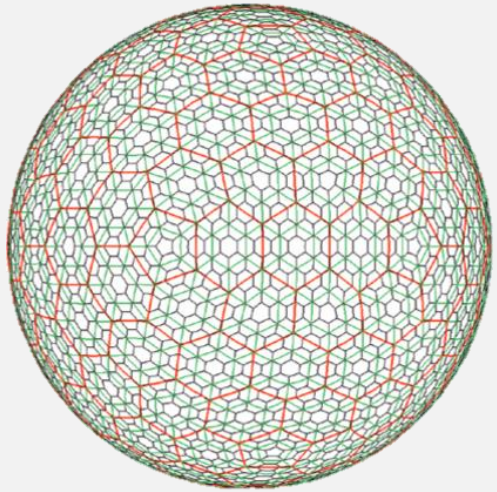
- Aperture 3 hexagons (3 levels)

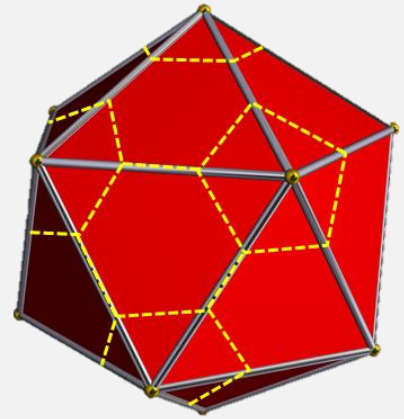


- Aperture 4 hexagons (3 levels)

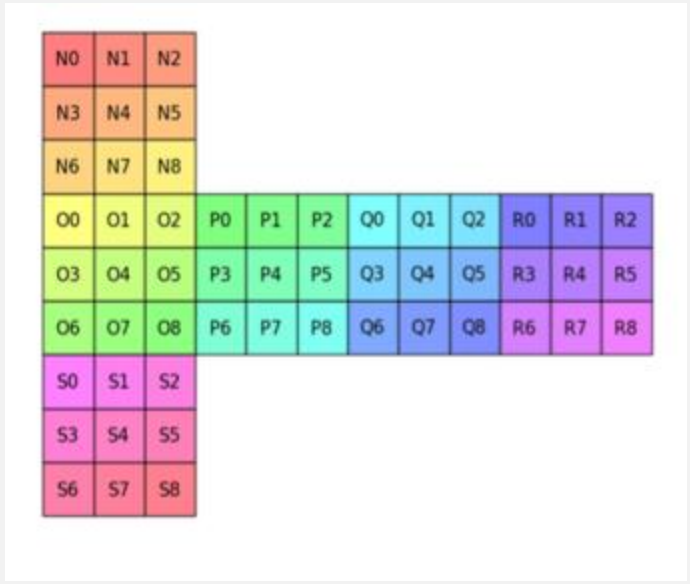


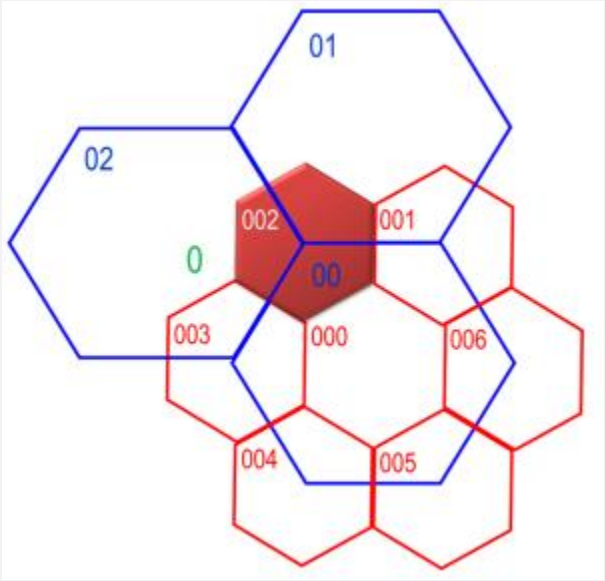




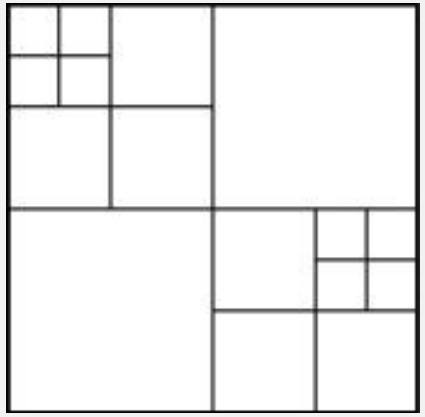


DGGS - Cell indexing

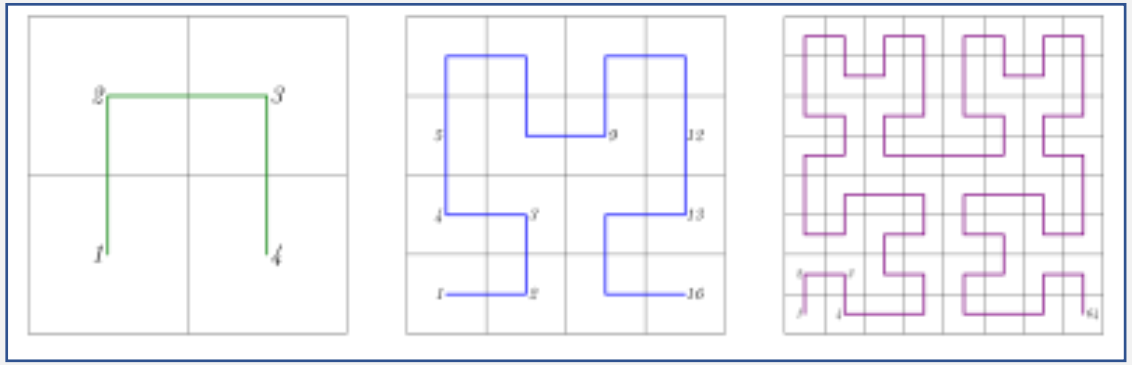




Quad-tree

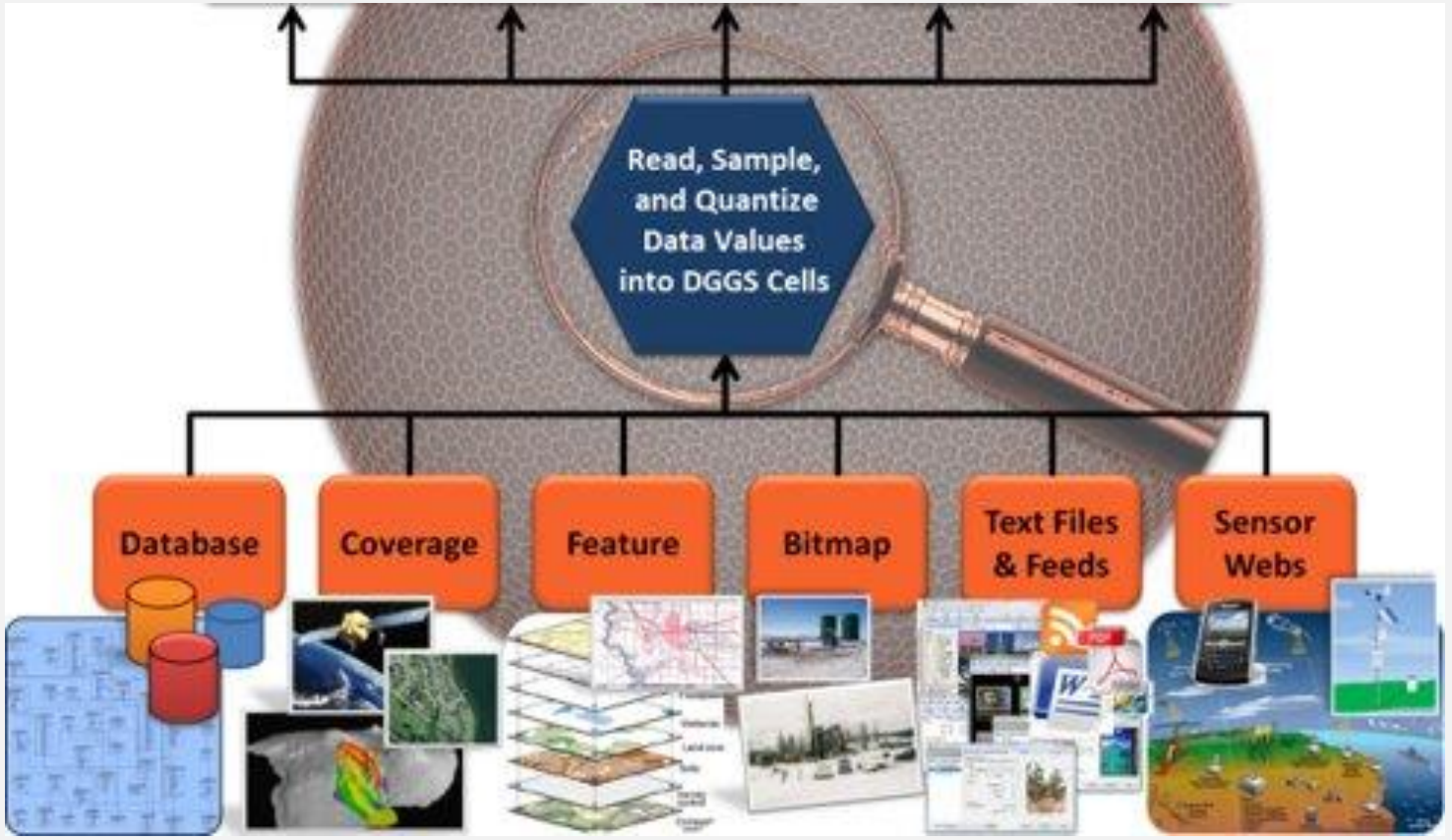


Space Filling Curves

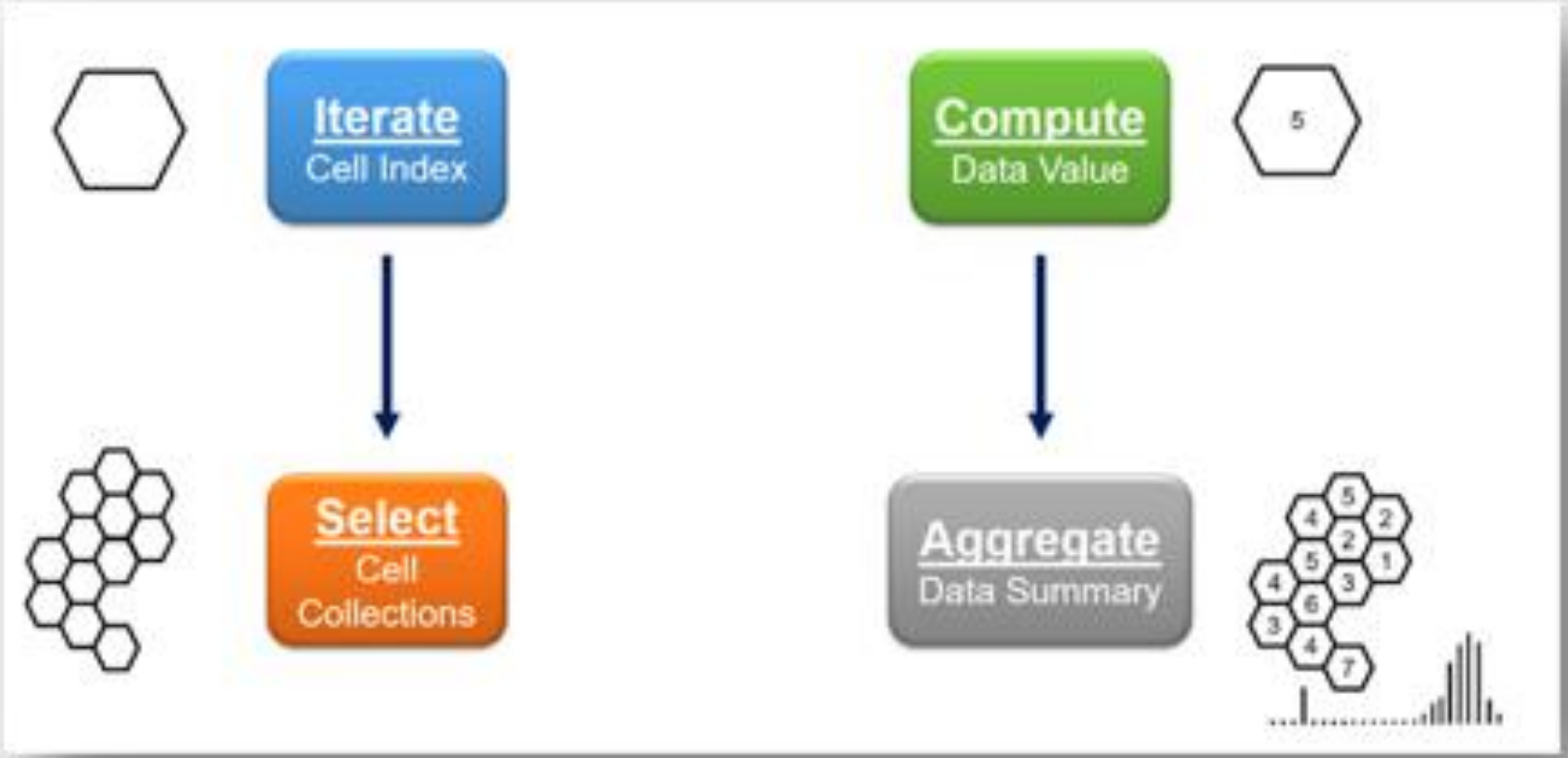


DGGS – Quantization

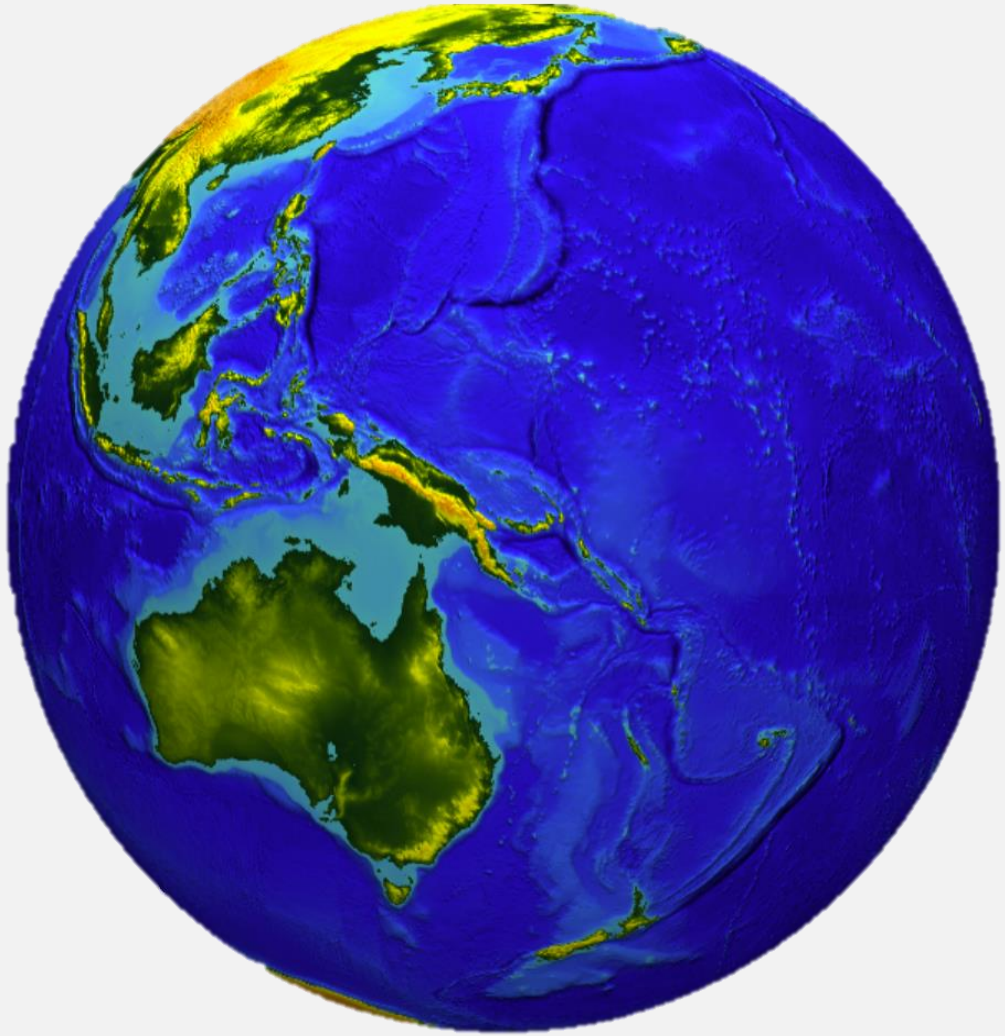
- Populating DGGS cells with data.
- Methods for both raster and vector data.
- Different strategies for sampling data preserve the resolution of the original data.
- Following of the principles of high-fidelity digital signal processing.



DGGS – Operations

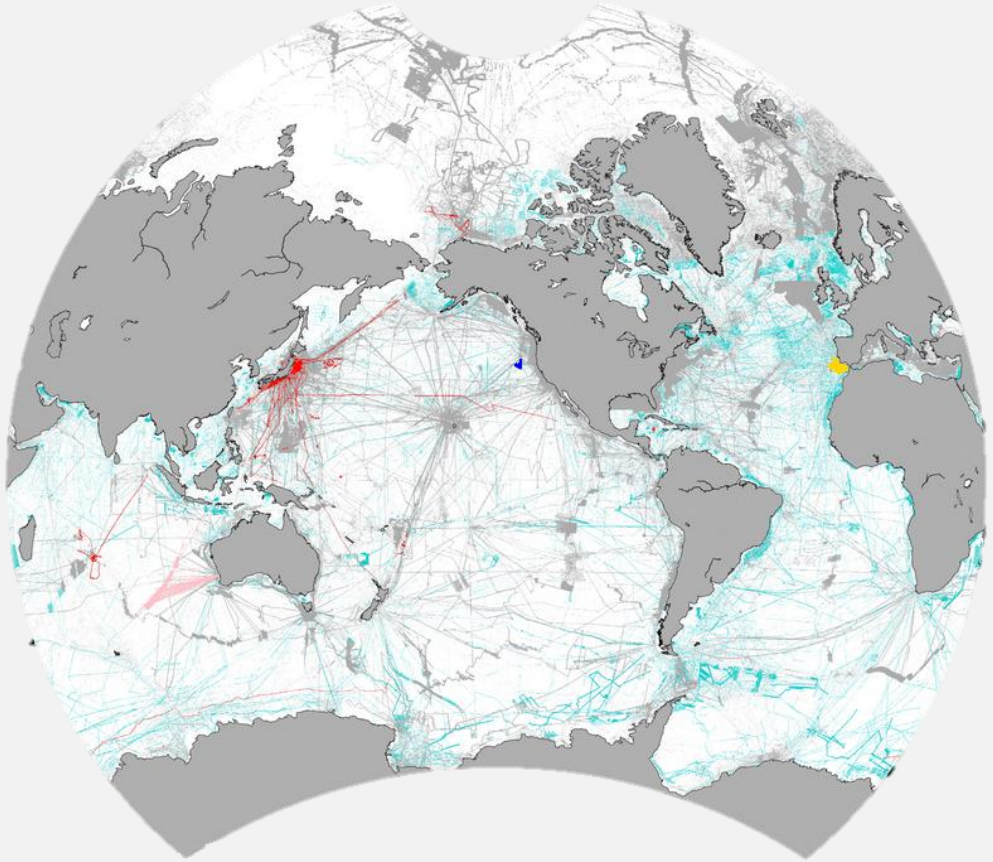


DGGS to manage Multi-resolution Bathymetry



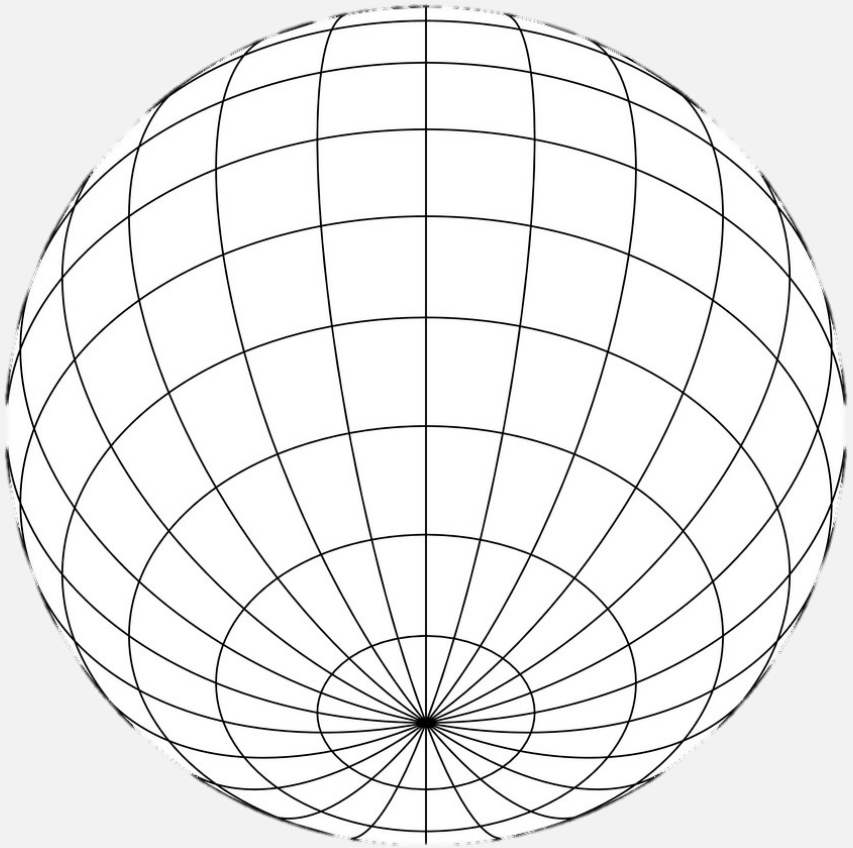
DGGS is an ideal candidate to handle **global multi-resolution bathymetry integration** from different sources and its integration with other **Hydrospatial datasets**

Bathymetry integration paradigm



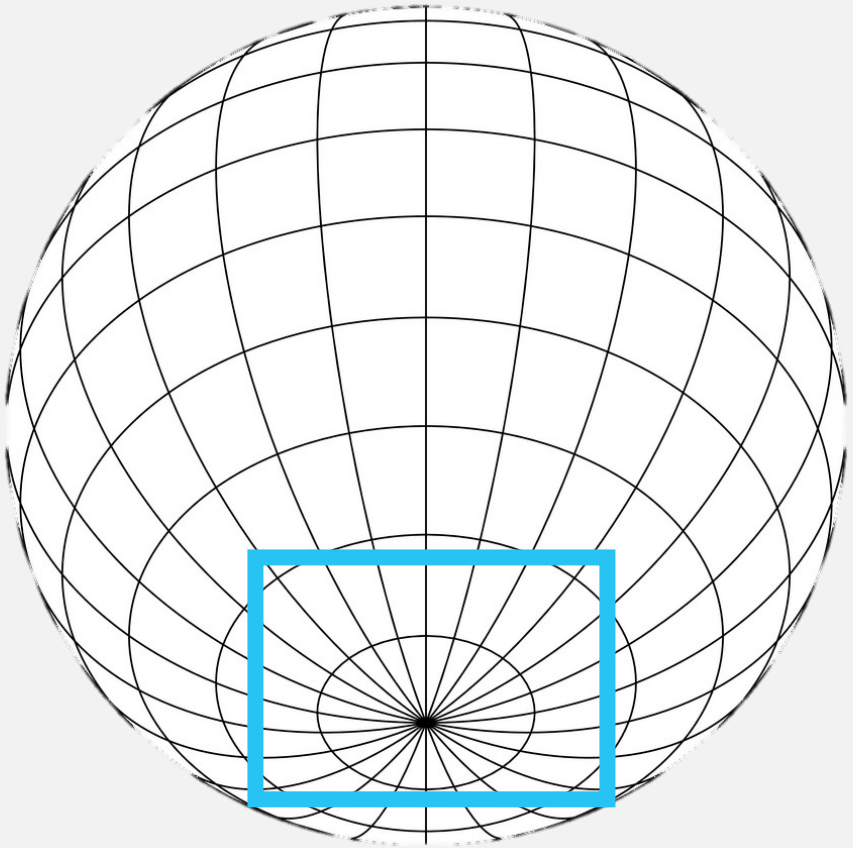
Current methods require **pre-integration** of regional and global data sources using a **conventional grid** to produce a static single resolution global bathymetry model

The problem with conventional grids



Conventional geographic coordinates, well suited for navigation and analytical geometry, are insufficient for handling the volume, variety, and velocity of current data demands.

The problem with conventional grids



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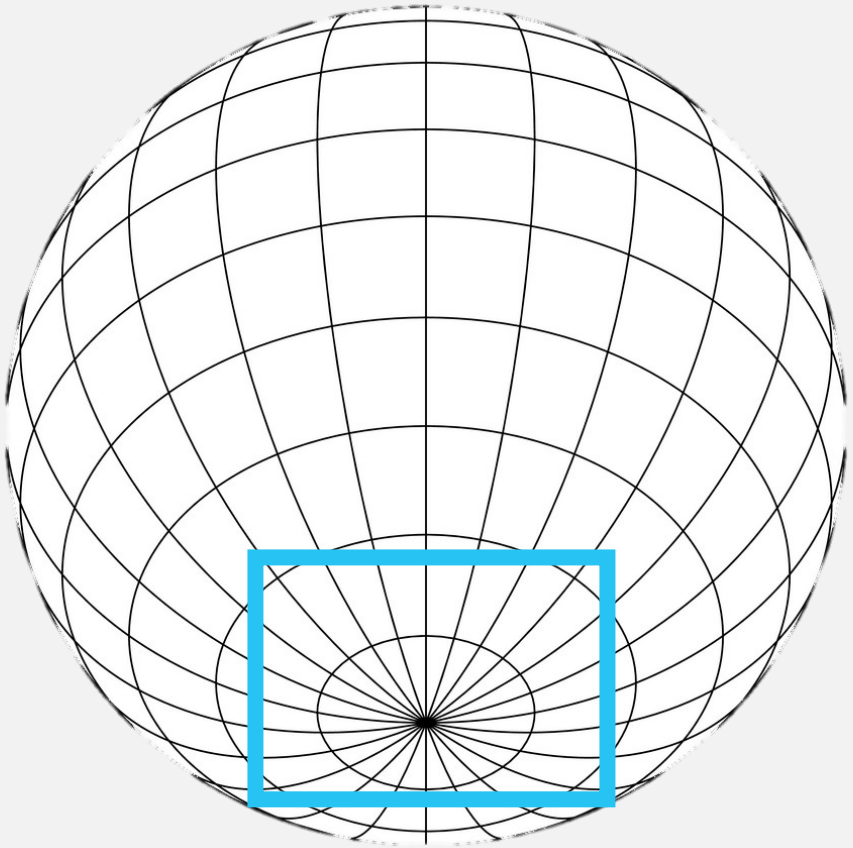

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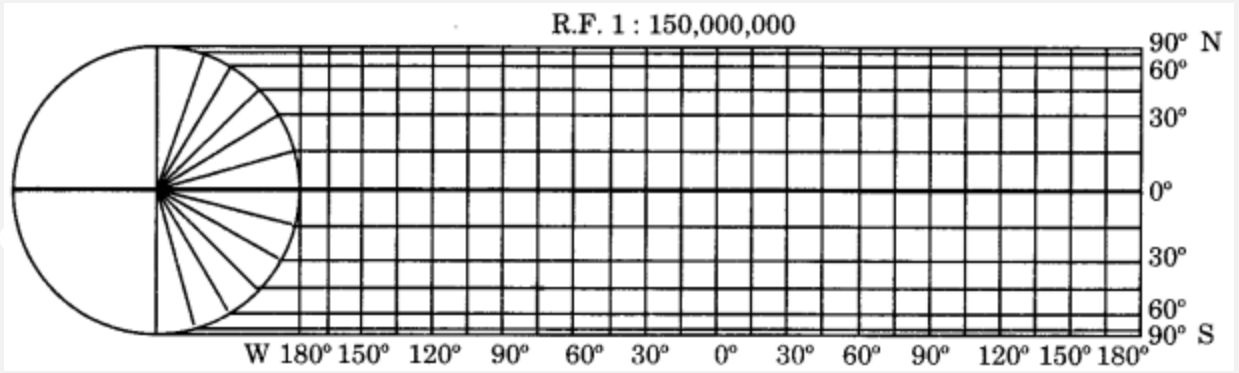
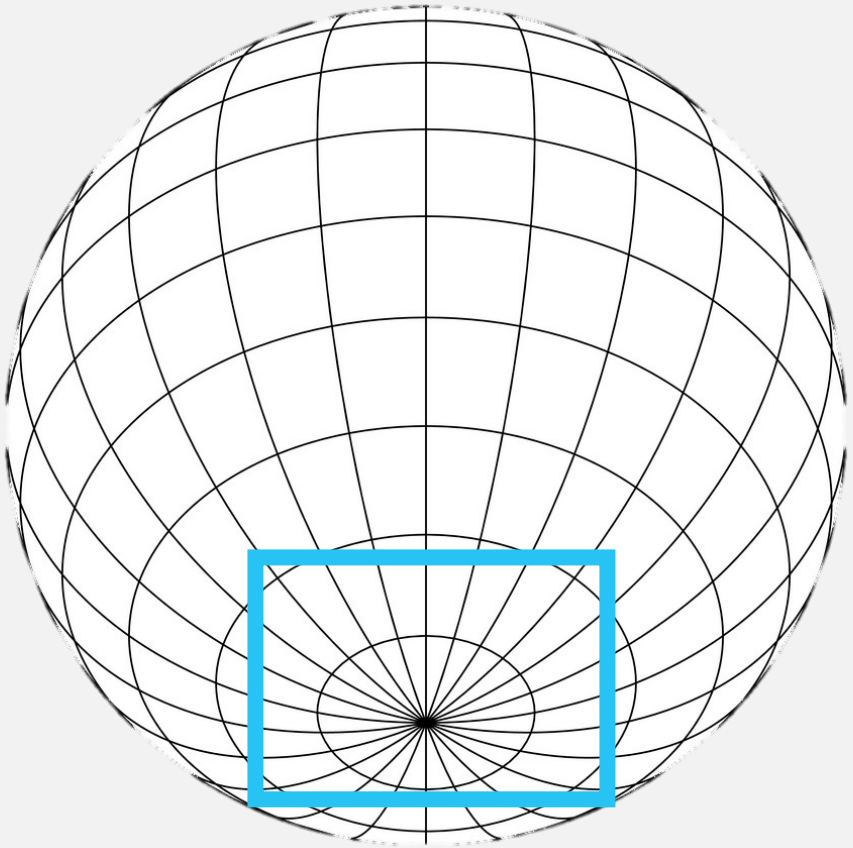


Map Projections

The problem with conventional grids



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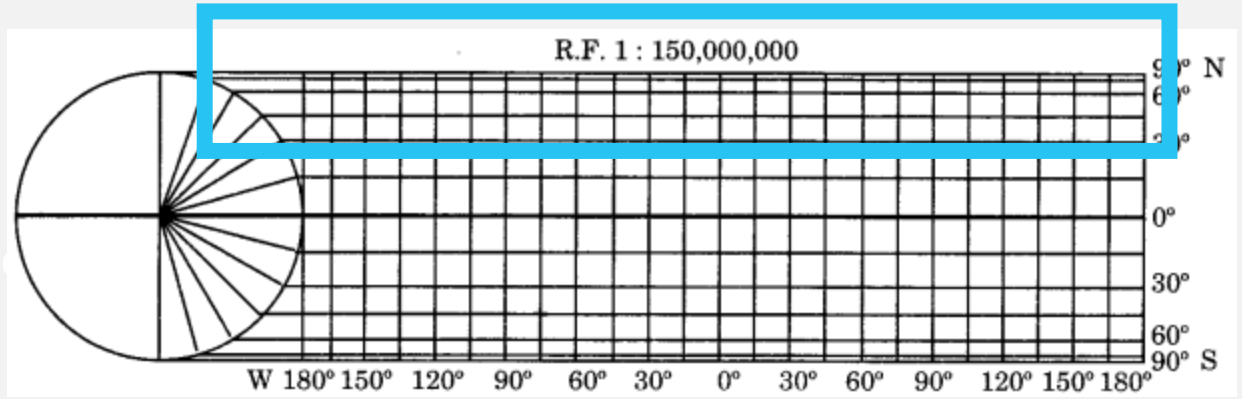
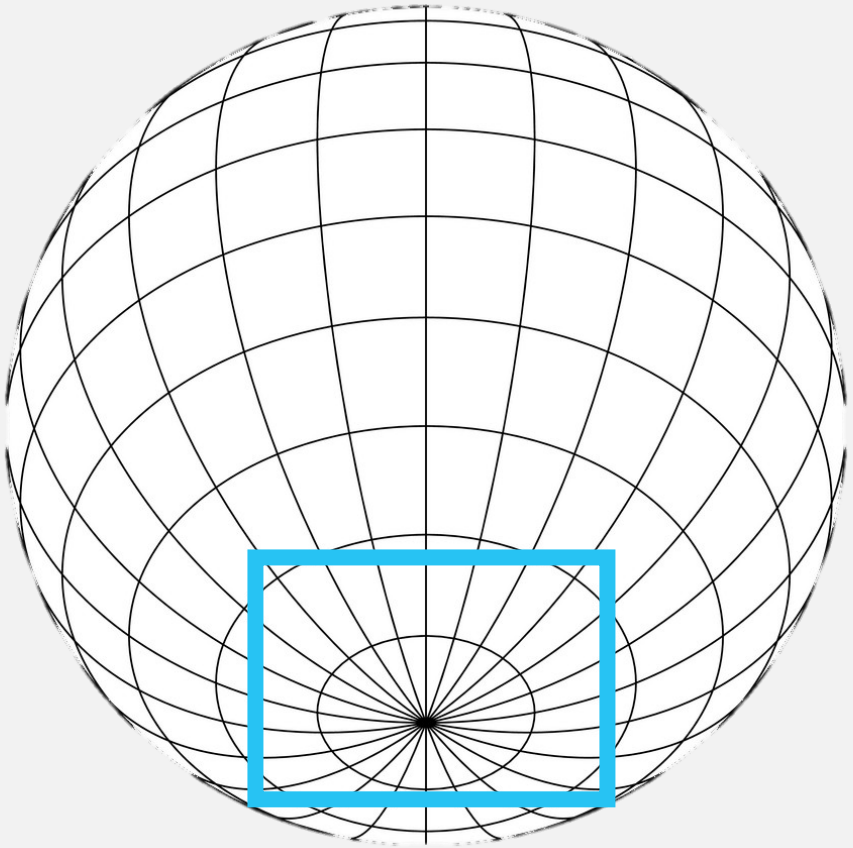


Map Projections

The problem with conventional grids



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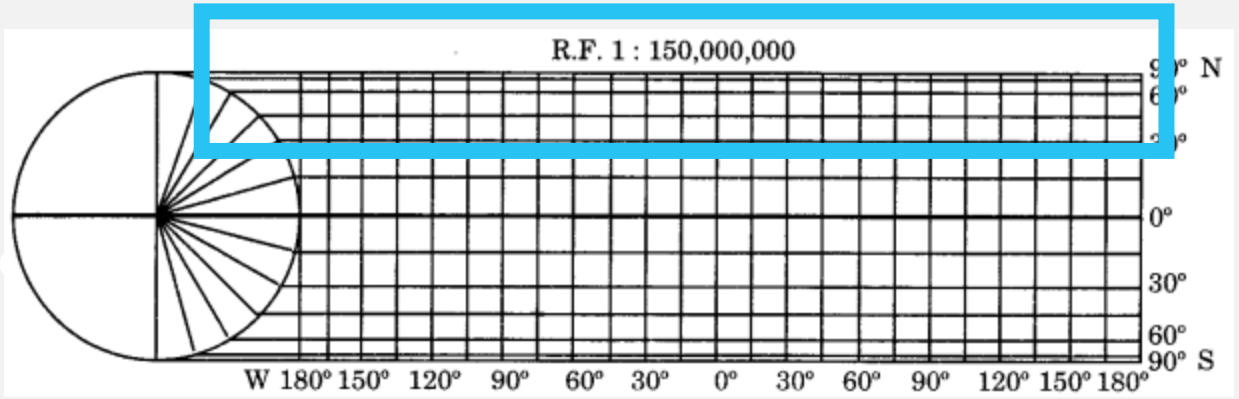


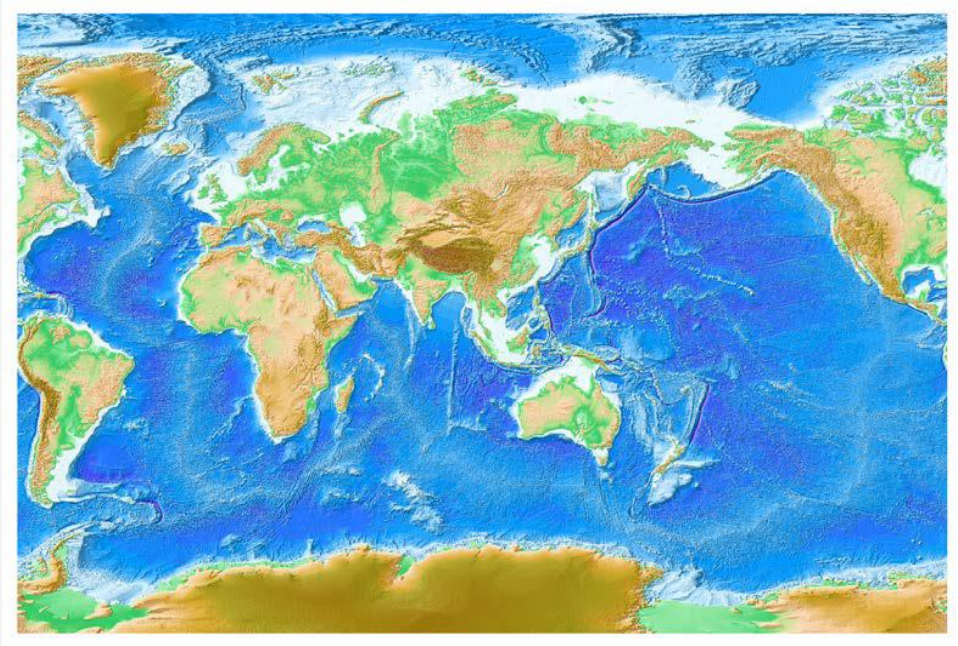
Map Projections

Complicates statistical analysis and discrete simulations on these grids

Bathymetry integration paradigm

GEBCO Grid

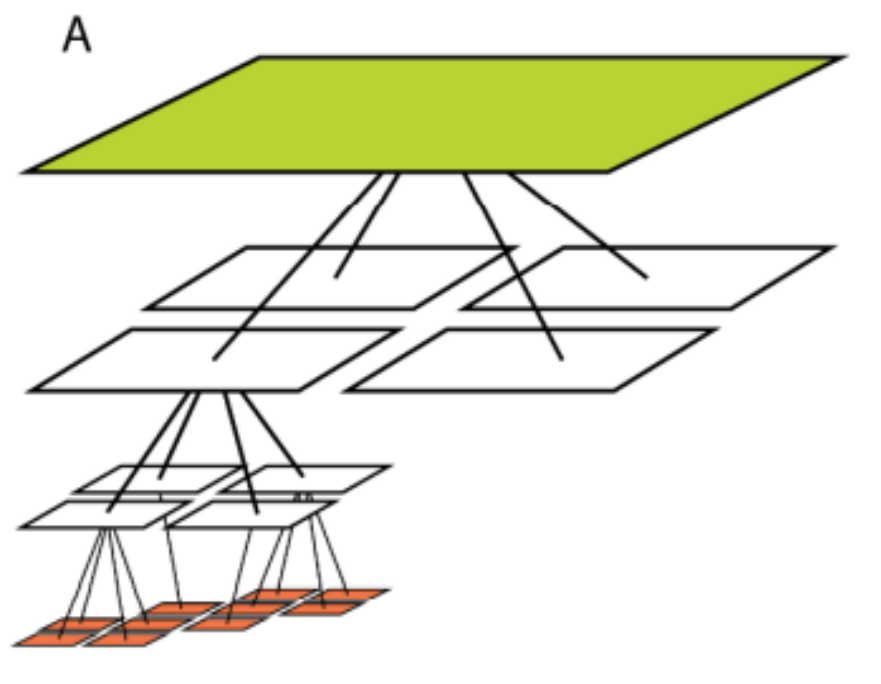
A Global Bathymetry Chart of the Oceans



Definitive map of the world ocean floor by 2030

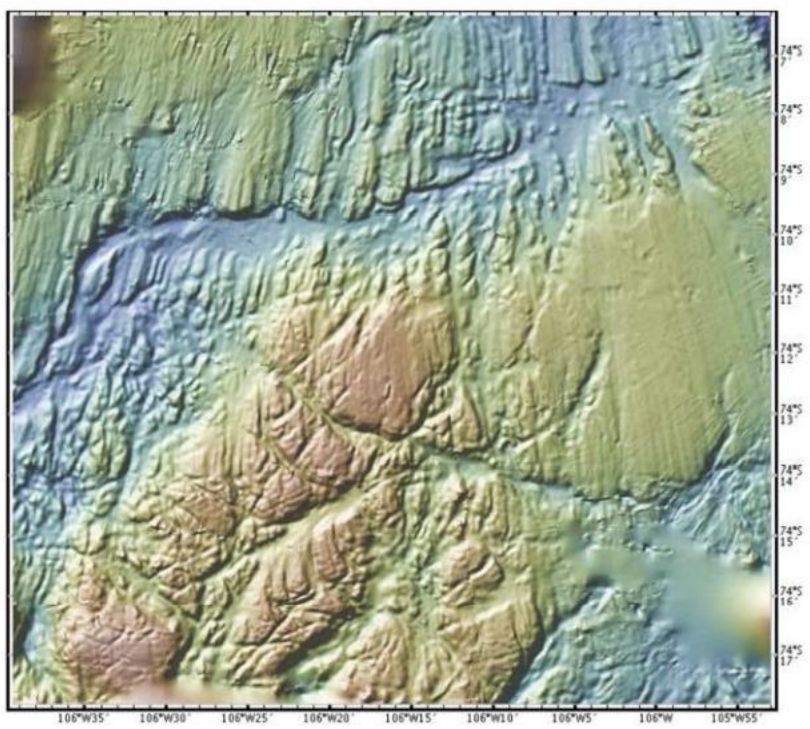
Uses a latitude/longitude grid and the polar regions have been integrated to it

Bathymetry integration paradigm



Hierarchical coordinate structures improve efficiency but still **introduce distortions** and fail to provide allowance for additional heterogeneous data integration.

Bathymetry integration paradigm



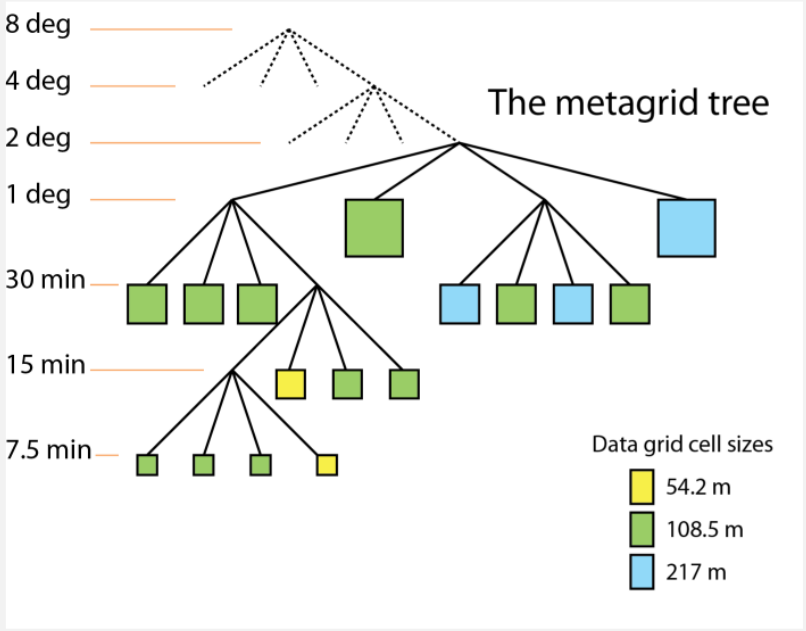
GMRT

It integrates bathymetry in a multi-resolution model based on a quad-tree over the Mercator projection.

It accommodates global coverage by maintaining 3 parallel tile sets – Mercator, South Polar, and North Polar; all of them on different coordinate systems.

There is an added problem of accessing polar data combined with the rest of the world due to the need of using different CRS.

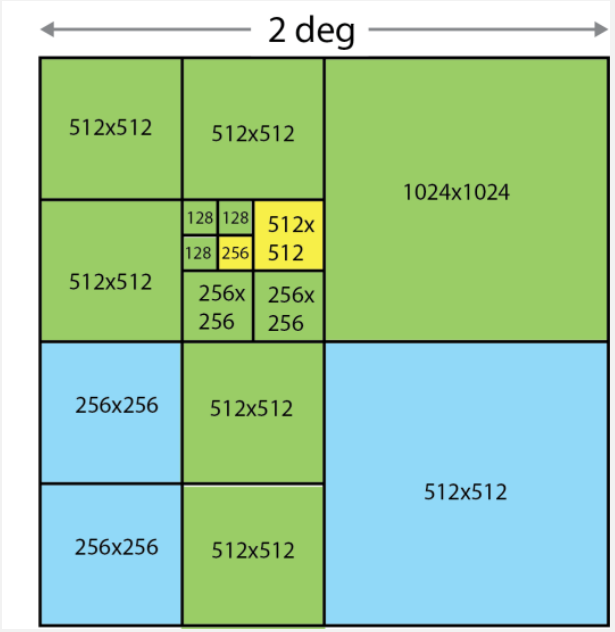
Bathymetry integration paradigm



Global GGS

Combines the advantages of GMRT and GEBCO.

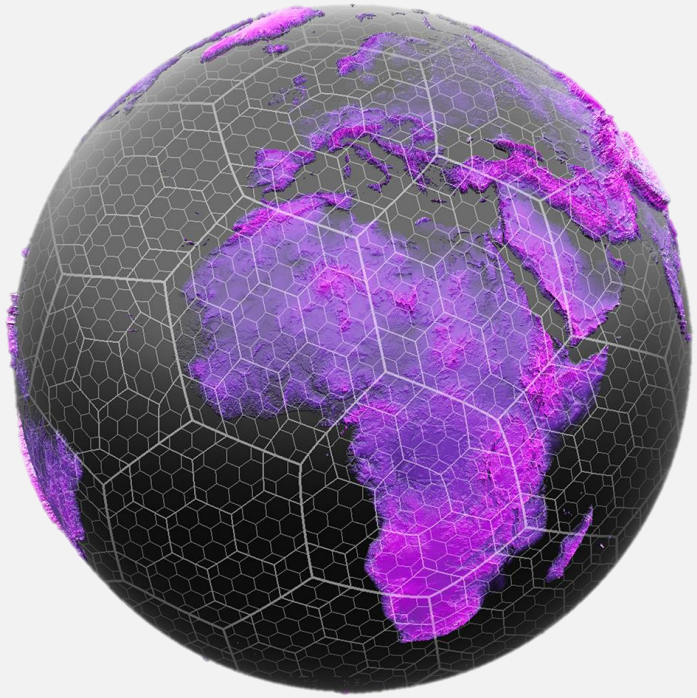
It is defined in geographic coordinates, uses a single scheme and projection, and incorporates a quadtree hierarchy, enabling data of any resolution to be represented.



Global GGS avoids the sampling asymmetries of GEBCO.

On the fly analysis and integration of other datasets would be complicated to perform in this kind of grid. The cells still get distorted near the poles and the cells are not equal area.

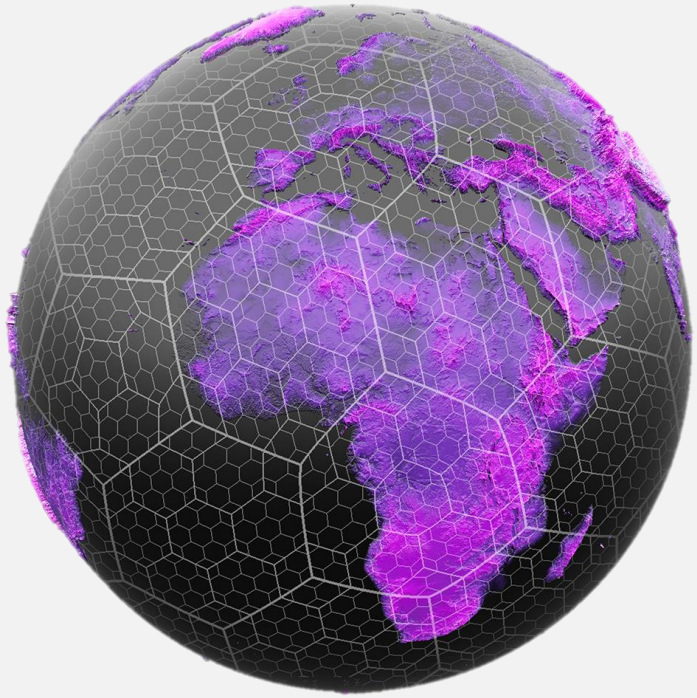
DGGS to manage Multi-resolution Bathymetry



ISEA3H

ISEA3H is equal area, produces the **least area distortion**, and the spatial data associated with a cell is **aligned and integrated** in subsequent resolutions.

DGGS to manage Multi-resolution Bathymetry



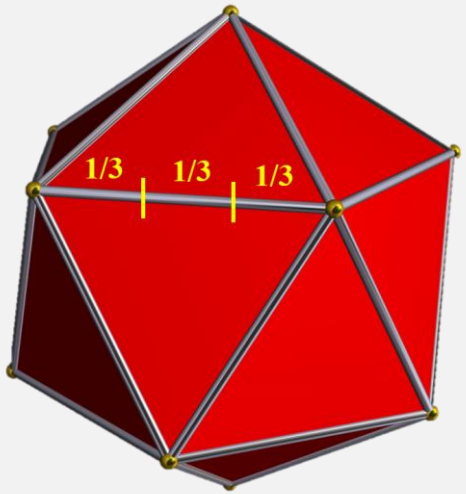
ISEA3H

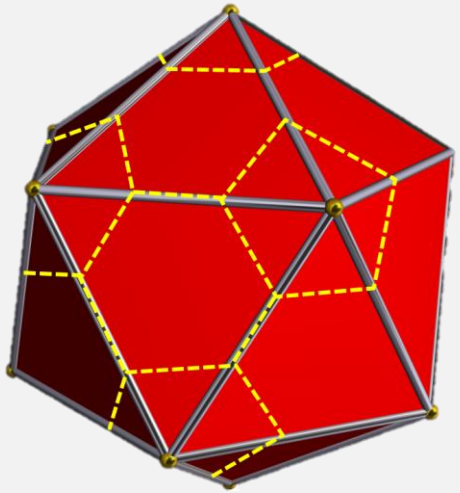
ISEA3H is equal area, produces the **least area distortion**, and the spatial data associated with a cell is **aligned and integrated** in subsequent resolutions.

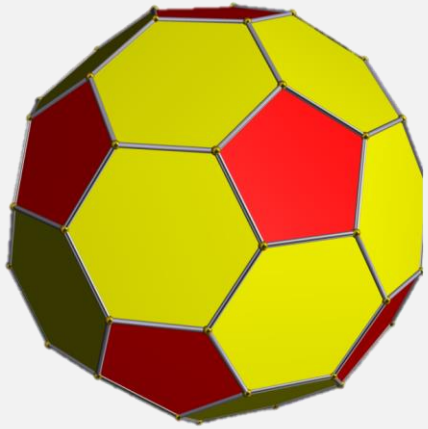
Its usefulness has already been proven for the integration of terrain data models and for multi-resolution topographical analysis

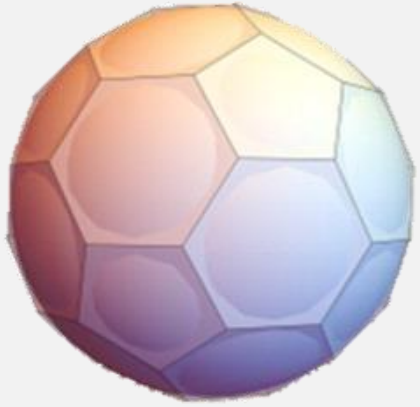
Truncated Icosahedron

Platonic icosahedron → truncate the 12 vertices

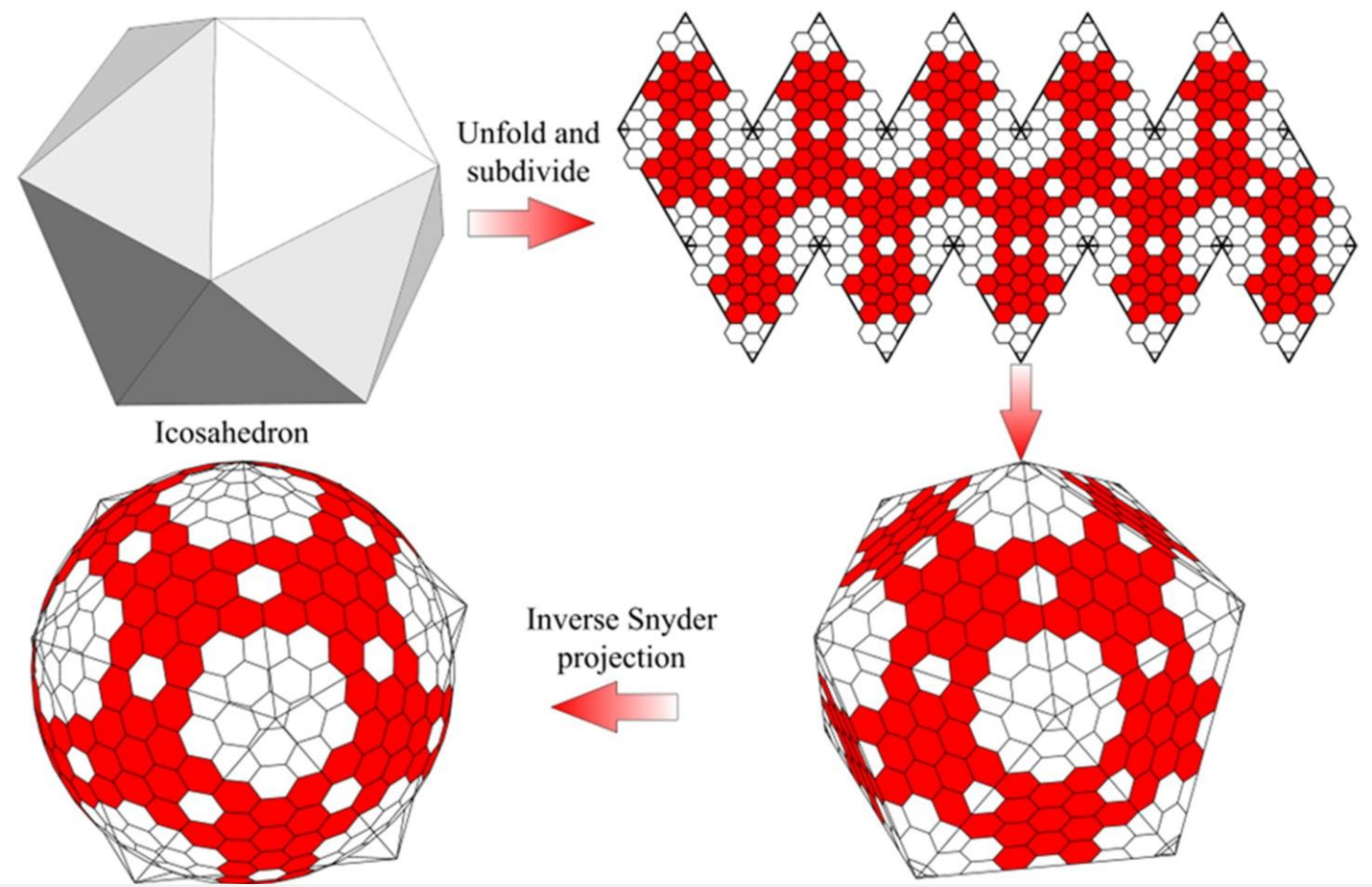




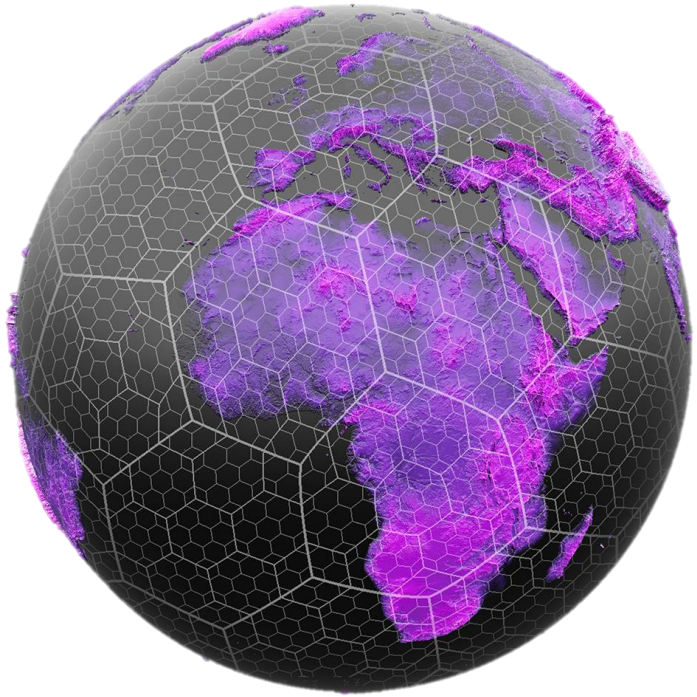




Hexagonal cells



DGGS to manage Multi-resolution Bathymetry

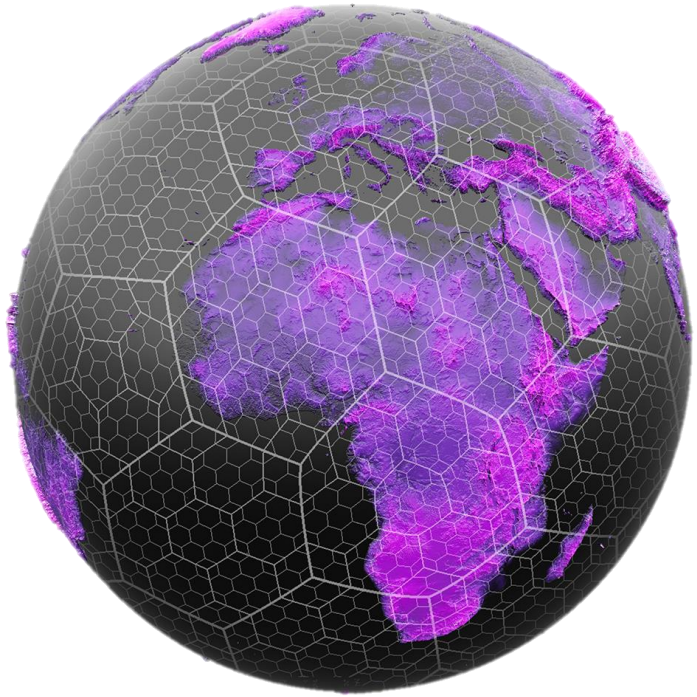


ISEA3H

Alternative grid model for bathymetry data integration that meets all the goals of:

- global model,
- rapid data integration,
- multi-resolution,
- no distortion near the poles,
- optimized for parallelization in cloud computing environments

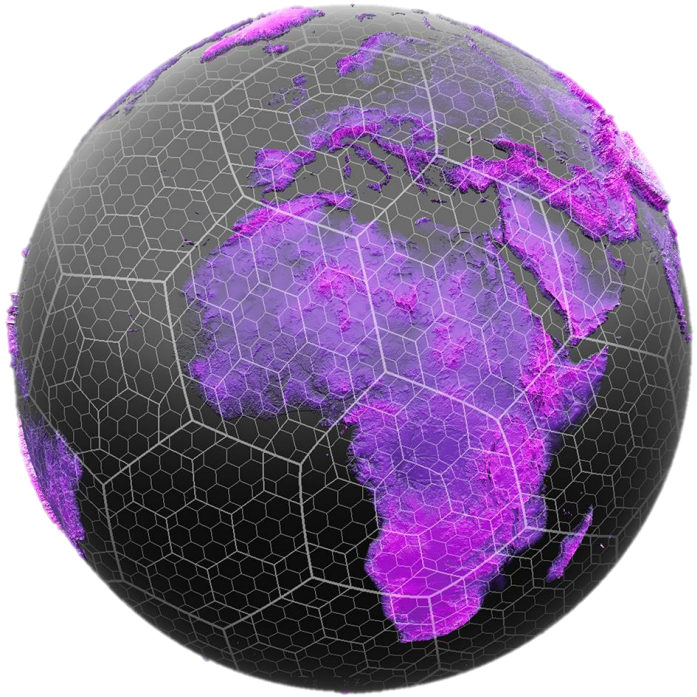
DGGS to manage Multi-resolution Bathymetry



ISEA3H

Ideal candidate to manage global multi-resolution bathymetry and handle integration and analysis of other hydrospatial data on the fly.

DGGS to manage Multi-resolution Bathymetry



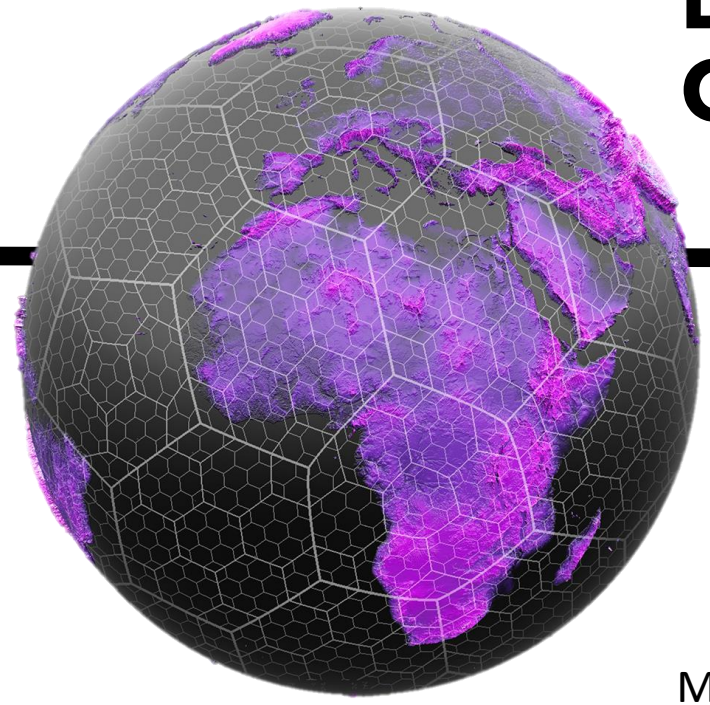
ISEA3H

DEMO

TELEDYNE Teledyne Geospatial

UNIVERSITY OF CALGARY

SHOM



DGGS: Multi-resolution Bathymetry On-Demand

HYDRO 22

5-8 December 2022
Monaco-Grimaldi Forum

Marta Padilla Ruiz, Thierry Schmitt, Perry Peterson, Julien Barbeau, Emmanuel Stefanakis

December 7th, 2022

TELEDYNE
Teledyne Geospatial

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