Discrete Global Grid Systems (DGGS) and Their Role in Methane Emission Inventories

SENSORUP Lunch and Learn

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Geo Sensor Web Lab
Schulich School of Engineering
University of Calgary

May 16, 2025

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"GIS slices the world into layers of information; DGGS brings that information together again."

Bring It All Down to Earth with DGGS

Why Grid Systems…?

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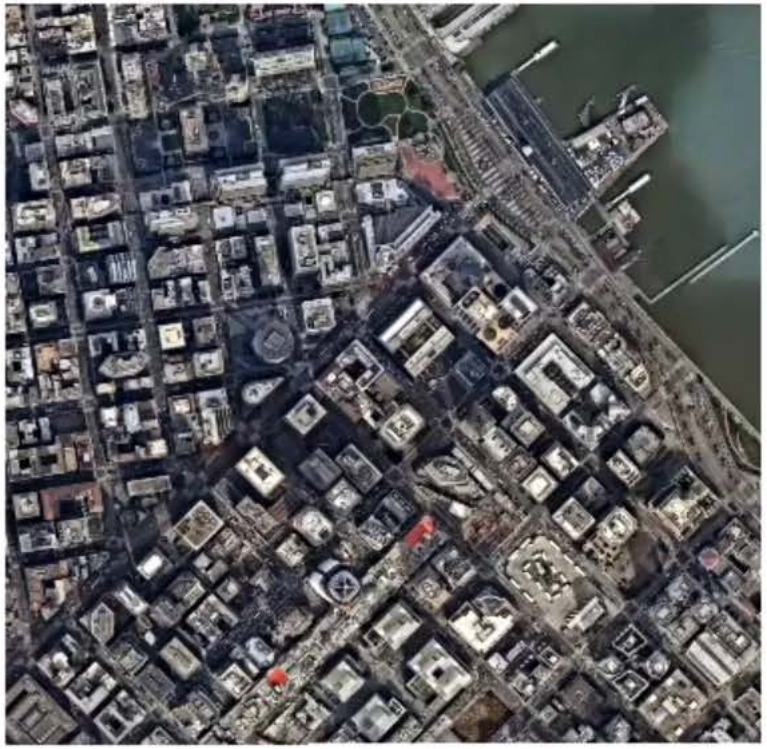
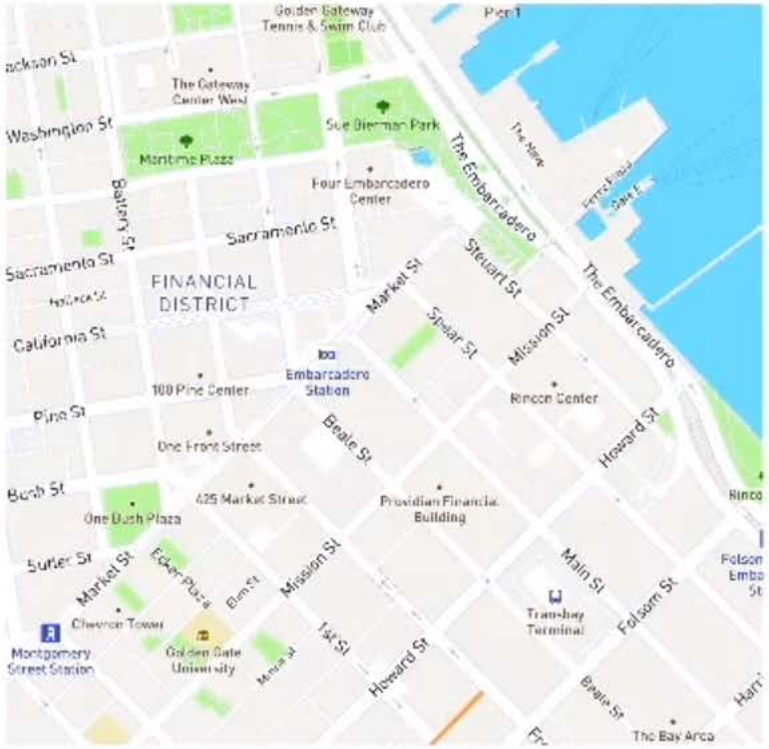
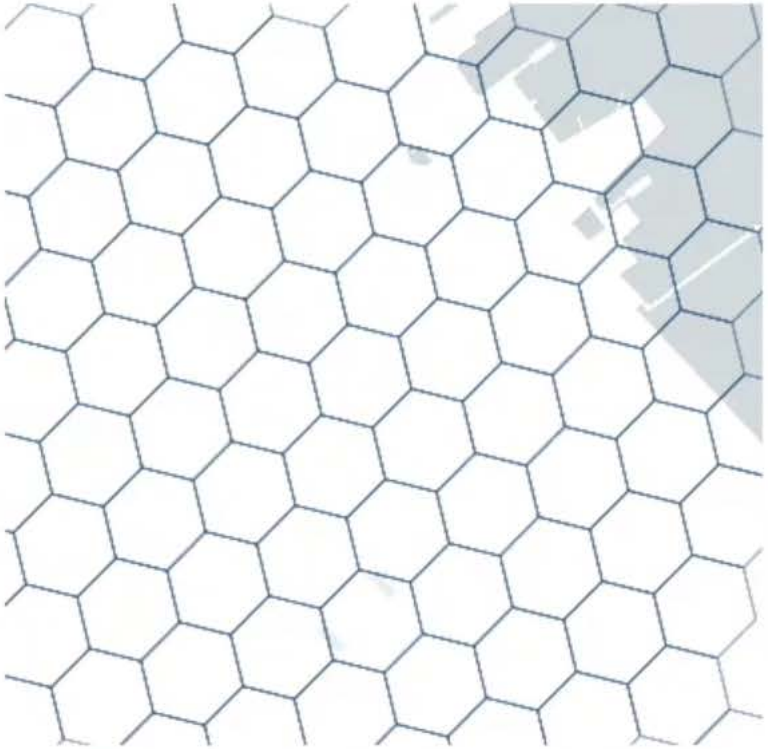
Washington DC ↴







Real world
Hard to model

Map
A common abstraction
But still messy..

Grid System
Clean mathematical space
Partition the world

❖ *https://h3geo.org/#/documentation/community/tutorials*

Why DGGS…?

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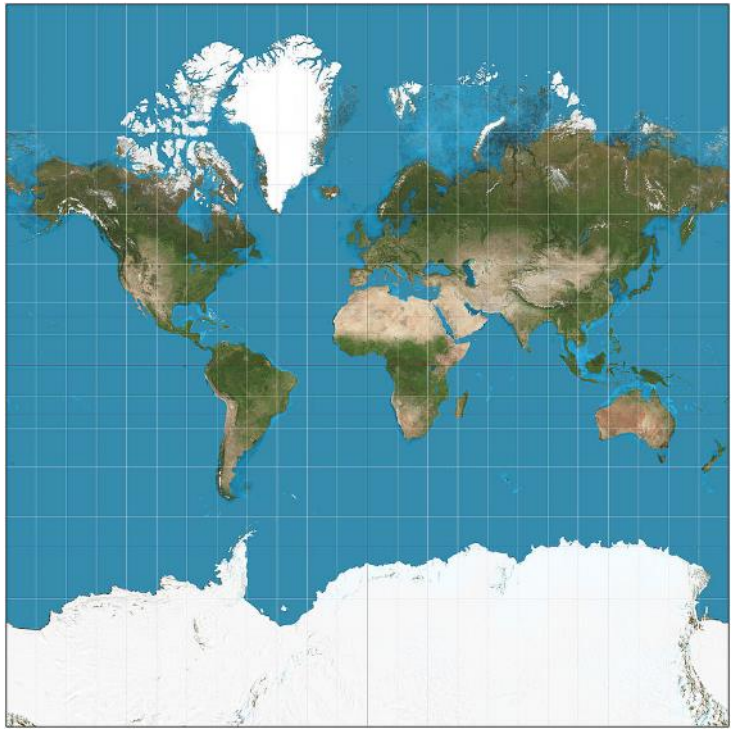
Graticule

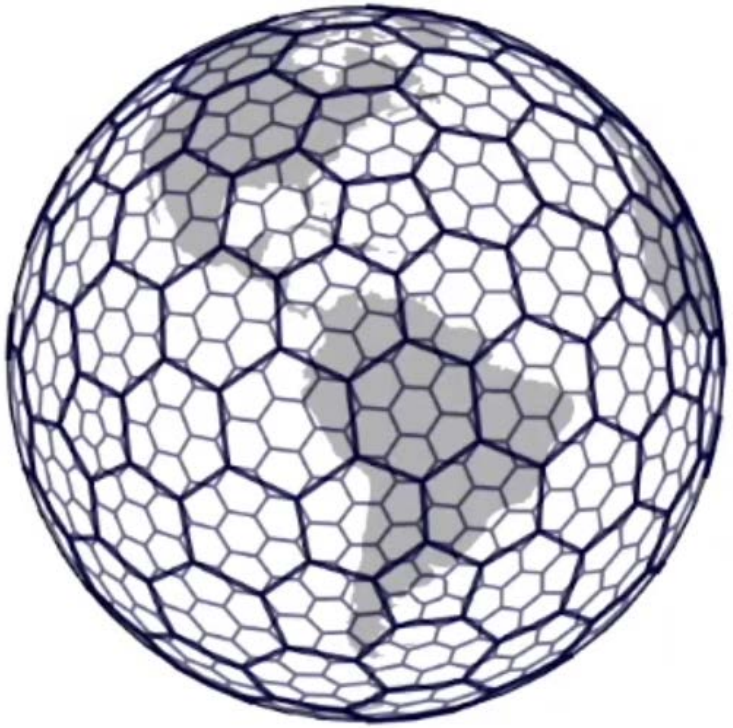
Inconsistent cell unit



Web Mercator Tiles

Inconsistent cell unit

Not a global domain



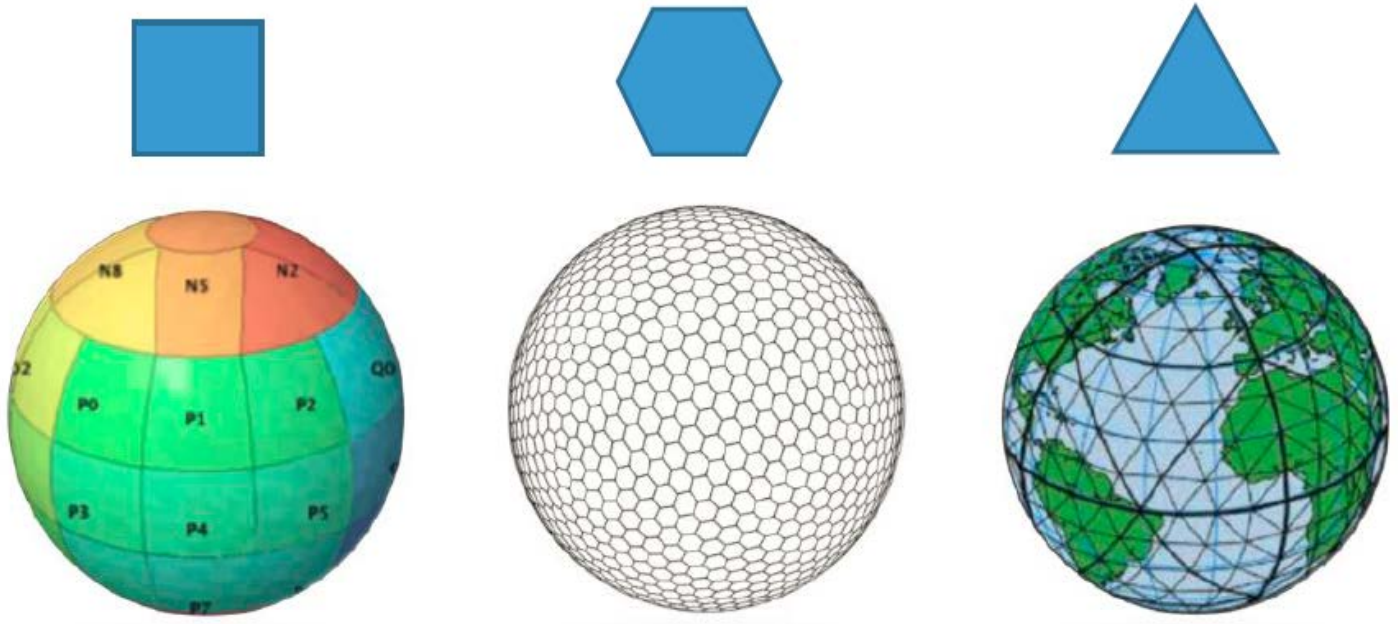
DGGS

✓

- *https://commons.wikimedia.org/wiki/File:Division_of_the_Earth_into_Gauss-Krueger_zones_-_Globe.svg*
- *https://en.wikipedia.org/wiki/File:Mercator_projection_Square.JPG*
- *https://h3geo.org/#/documentation/community/tutorials*

Understanding of DGGS

- **Discrete** -- a finite number of cells
- **Global** -- a grid that completely covers the Earth's surface
- **Grid** -- a tessellation of space into a uniform arrangement of cells
- **System** -- a grid that can be subdivided into smaller cells



rHEALPix **ISEA3H** **QTM**

❖ *Bowater and Stefanakis, 2018*

❖ *Open Geospatial Consortium (OGC), 2017*

A Definition of DGGS by OGC

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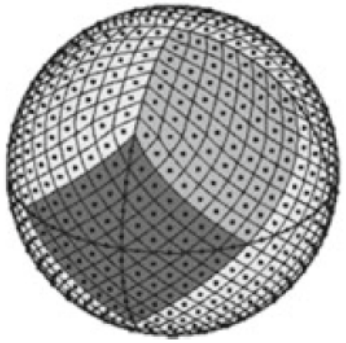
"A Spatial Reference System that uses a Hierarchical Tessellation of cells to Partition and Address the Globe. DGGS are characterized by the properties of their Cell Structure, Geo-encoding, Quantization Strategy and associated Mathematical Functions."

Structural Requirements of DGGS:

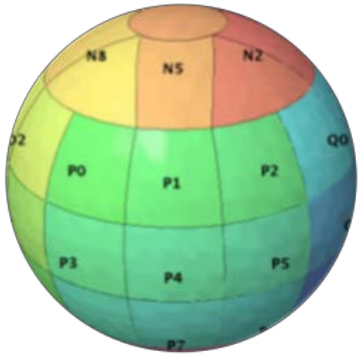
- Preserved globe-tiling without overlapping cells
- Multiple resolution levels
- Initial polyhedral tessellation
- Simple cell geometries
- Equal-area cells
- Unique index for each cell
- Centroid as the reference point for each cell

- *Goodchild, 1994*
- *Kimerling et al., 1999*
- *Open Geospatial Consortium (OGC), 2017*
- *Alderson et al., 2020*

DGGS Alternatives

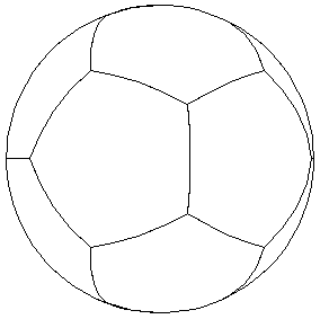


HEALPix

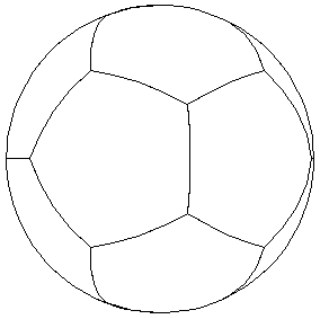


rHEALPix

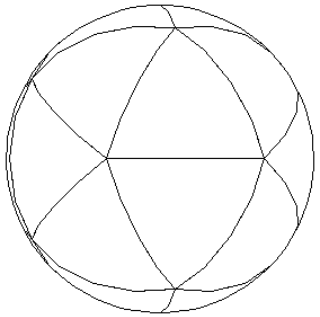
QTM



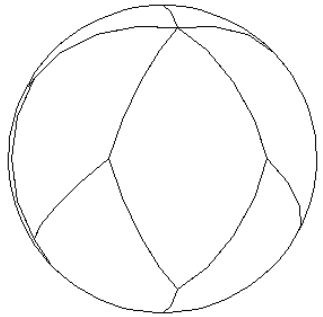
ISEA3H



ISEA4H



ISEA4T



ISEA4D

State-of-the-art DGGS Implementations

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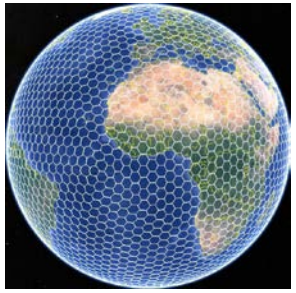
OpenEAGGR

Solid Earth and Environment GRID

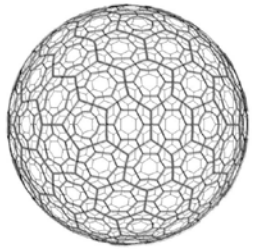
AusPIX



PlanetRisk

H3

STCL

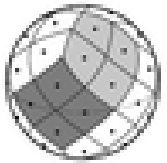


DGGRID version 8.1b

PYXIS

DIGITAL EARTH GLOBAL ANALYTICS

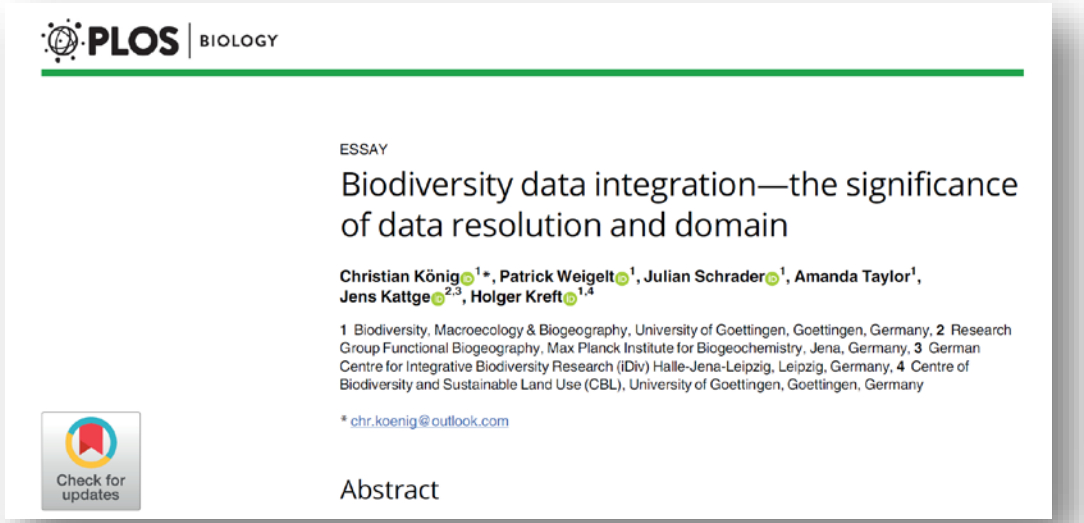
S2Geometry



HEALPix

Application of DGGS in previous literature

I. Spherical cell bins to aggregate geospatial data without spatial bias



PLOS BIOLOGY

ESSAY

Biodiversity data integration—the significance of data resolution and domain

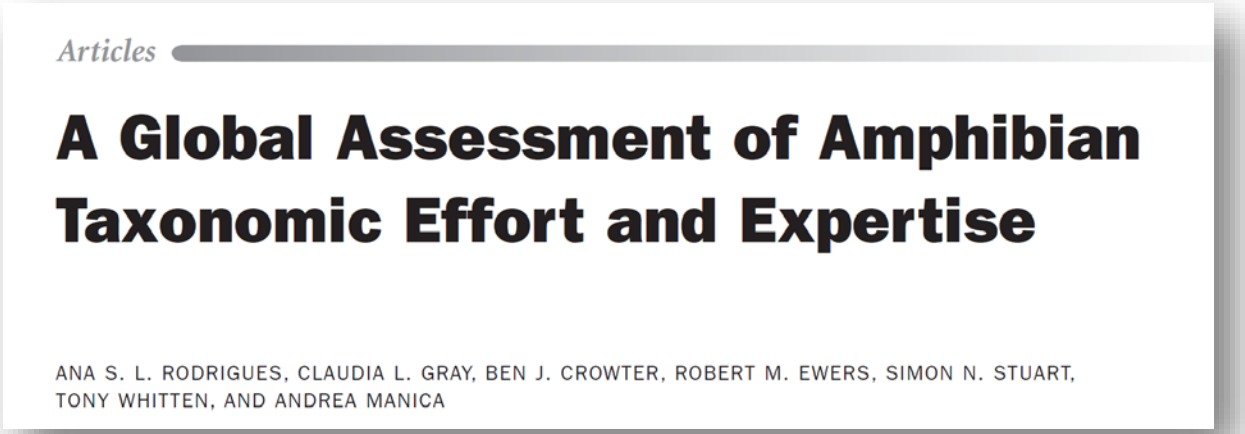
Christian König[1]*, Patrick Weigelt[1], Julian Schrader[1], Amanda Taylor[1], Jens Kattge[2,3], Holger Kreft[1,4]

1 Biodiversity, Macroecology & Biogeography, University of Goettingen, Goettingen, Germany, 2 Research Group Functional Biogeography, Max Planck Institute for Biogeochemistry, Jena, Germany, 3 German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Leipzig, Germany, 4 Centre of Biodiversity and Sustainable Land Use (CBL), University of Goettingen, Goettingen, Germany

* chr.koenig@outlook.com

Check for updates

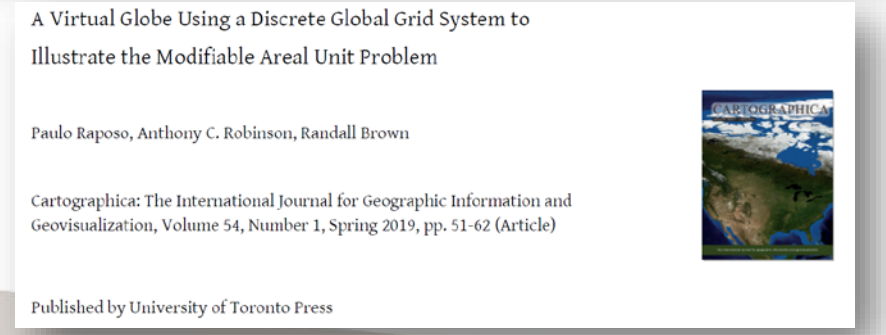
Abstract



Articles

A Global Assessment of Amphibian Taxonomic Effort and Expertise

ANA S. L. RODRIGUES, CLAUDIA L. GRAY, BEN J. CROWTER, ROBERT M. EWERS, SIMON N. STUART, TONY WHITTEN, AND ANDREA MANICA

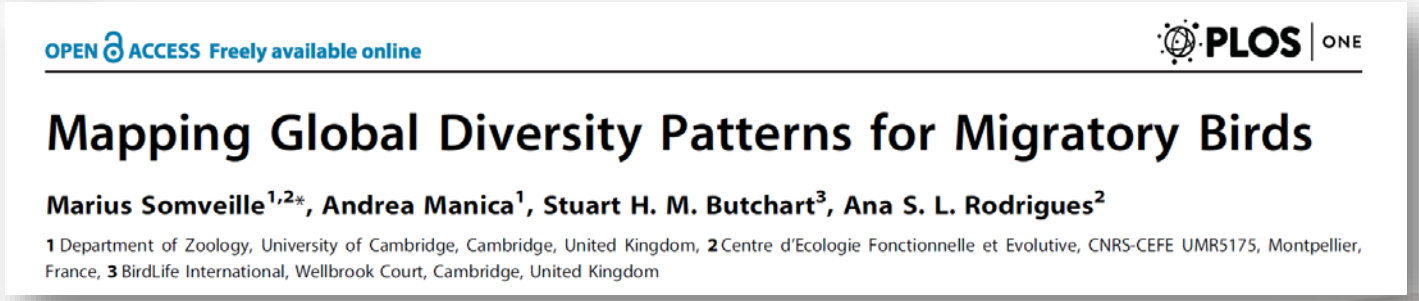


A Virtual Globe Using a Discrete Global Grid System to Illustrate the Modifiable Areal Unit Problem

Paulo Raposo, Anthony C. Robinson, Randall Brown

Cartographica: The International Journal for Geographic Information and Geovisualization, Volume 54, Number 1, Spring 2019, pp. 51-62 (Article)

Published by University of Toronto Press



OPEN ACCESS Freely available online

PLOS ONE

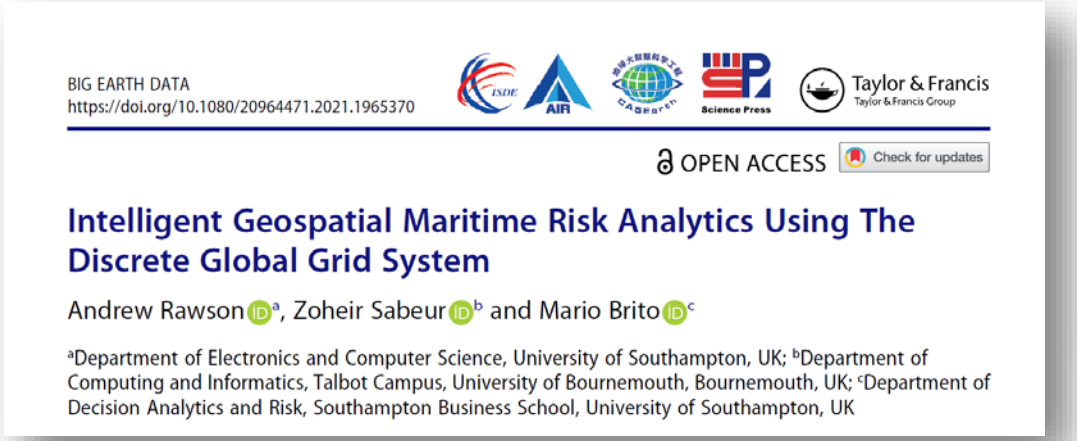
Mapping Global Diversity Patterns for Migratory Birds

Marius Somveille[1,2]*, Andrea Manica[1], Stuart H. M. Butchart[3], Ana S. L. Rodrigues[2]

1 Department of Zoology, University of Cambridge, Cambridge, United Kingdom, 2 Centre d'Ecologie Fonctionnelle et Evolutive, CNRS-CEFE UMR5175, Montpellier, France, 3 BirdLife International, Wellbrook Court, Cambridge, United Kingdom

Application of DGGS in previous literature

II. A data fabric for heterogeneous data integration and multi-scale data queries



BIG EARTH DATA
https://doi.org/10.1080/20964471.2021.1965370

Taylor & Francis
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Intelligent Geospatial Maritime Risk Analytics Using The Discrete Global Grid System

Andrew Rawson[a], Zoheir Sabeur[b] and Mario Brito[c]

[a]Department of Electronics and Computer Science, University of Southampton, UK; [b]Department of Computing and Informatics, Talbot Campus, University of Bournemouth, Bournemouth, UK; [c]Department of Decision Analytics and Risk, Southampton Business School, University of Southampton, UK

CARTOGRAPHY AND GEOGRAPHIC INFORMATION SCIENCE
https://doi.org/10.1080/15230406.2021.1966648

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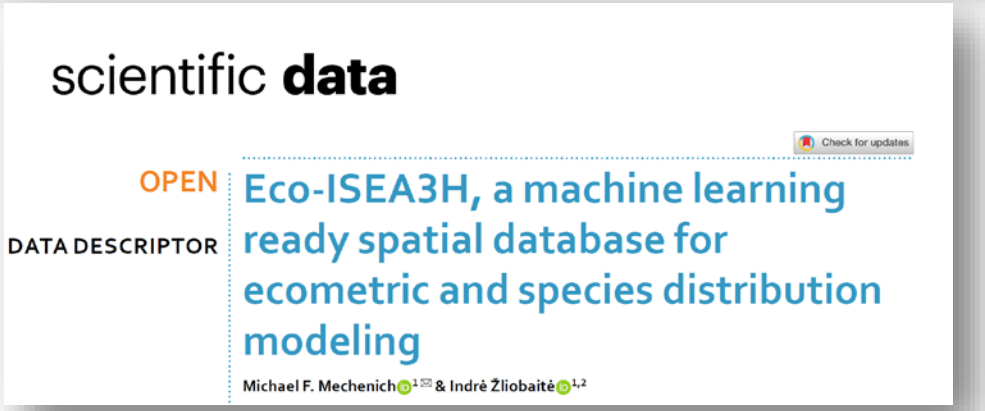
Integration of heterogeneous terrain data into Discrete Global Grid Systems

Mingke Li[a], Heather McGrath[b] and Emmanuel Stefanakis[a]

[a]Department of Geomatics Engineering, Schulich School of Engineering, University of Calgary, Canada; [b]Canada Centre of Mapping and Earth Observation, Natural Resources Canada, Ottawa, Canada



scientific data

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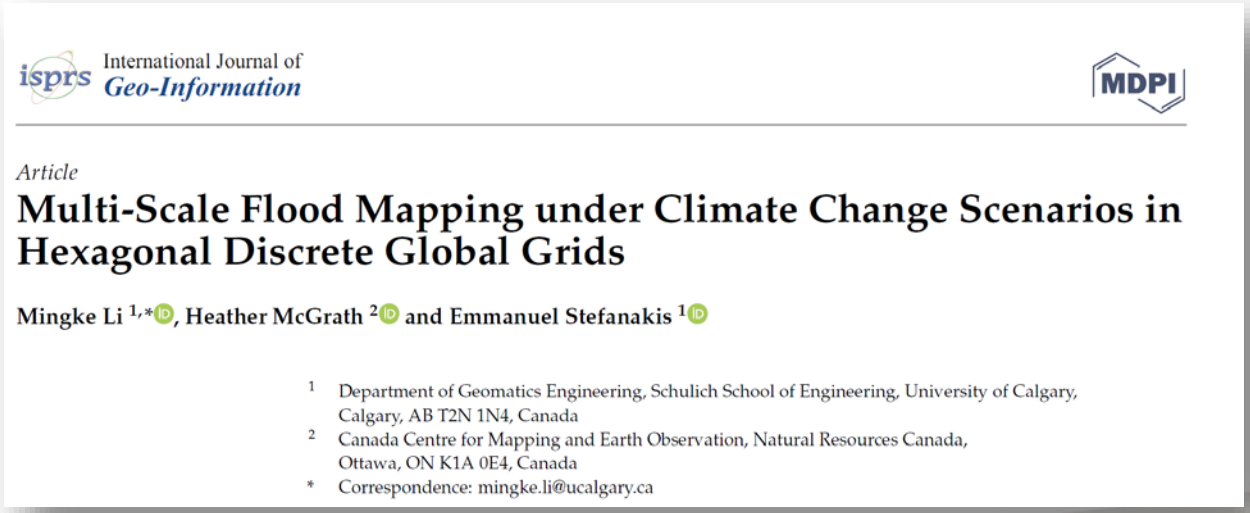
OPEN

DATA DESCRIPTOR

Eco-ISEA3H, a machine learning ready spatial database for ecometric and species distribution modeling

Michael F. Mechenich[1] & Indrė Žliobaitė[1,2]



isprs International Journal of *Geo-Information*

MDPI

Article

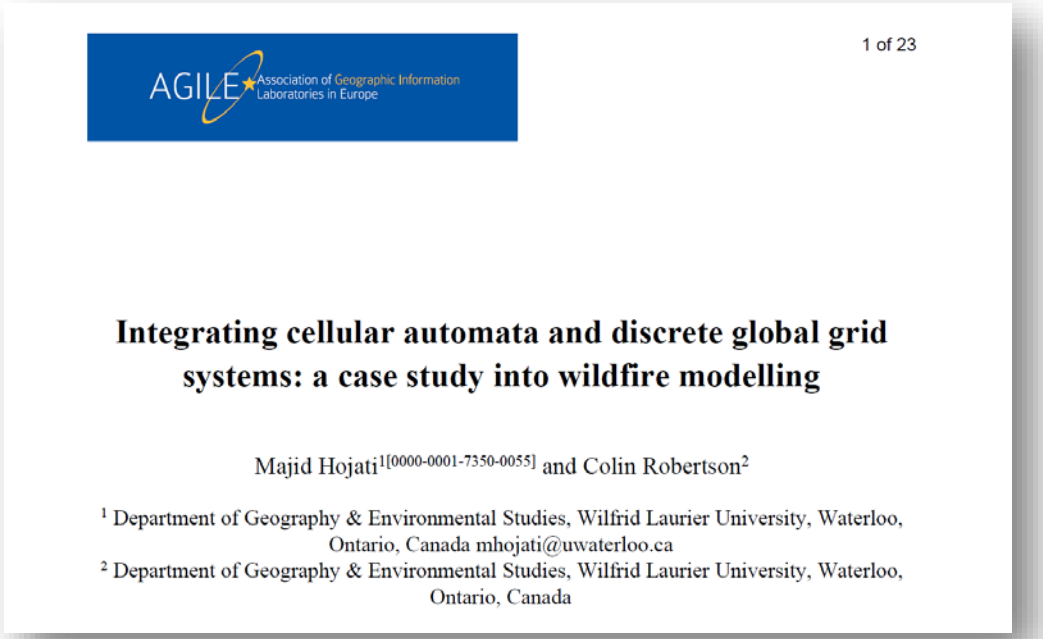
Multi-Scale Flood Mapping under Climate Change Scenarios in Hexagonal Discrete Global Grids

Mingke Li [1,*], Heather McGrath [2] and Emmanuel Stefanakis [1]

[1] Department of Geomatics Engineering, Schulich School of Engineering, University of Calgary, Calgary, AB T2N 1N4, Canada
[2] Canada Centre for Mapping and Earth Observation, Natural Resources Canada, Ottawa, ON K1A 0E4, Canada
* Correspondence: mingke.li@ucalgary.ca

Application of DGGS in previous literature

III. Bottom-up predictive models



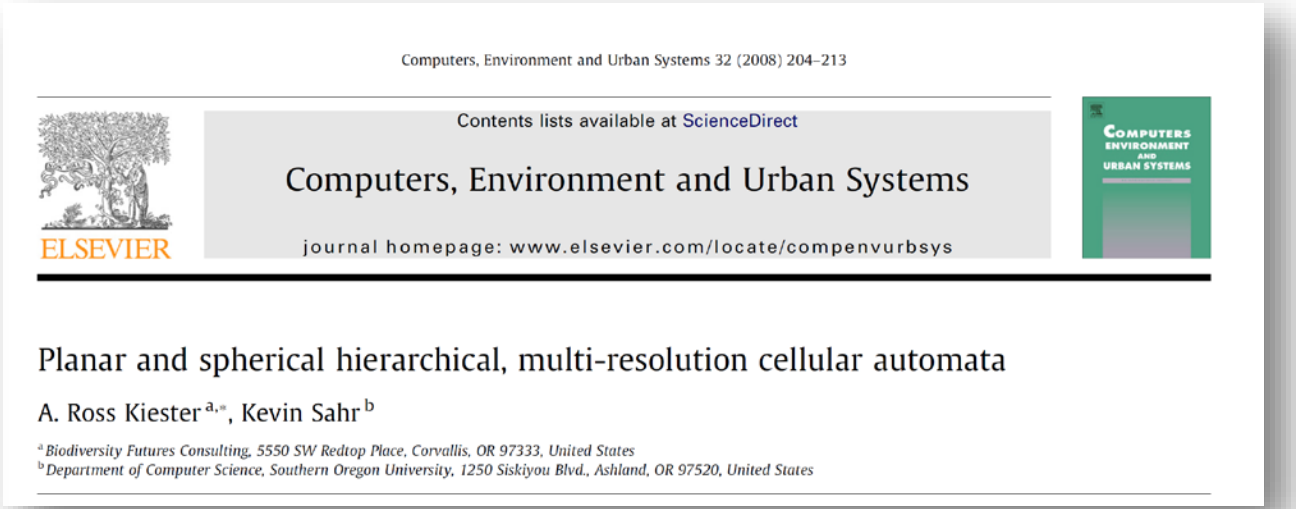
AGILE Association of Geographic Information Laboratories in Europe

1 of 23

Integrating cellular automata and discrete global grid systems: a case study into wildfire modelling

Majid Hojati[1][0000-0001-7350-0055] and Colin Robertson[2]

[1] Department of Geography & Environmental Studies, Wilfrid Laurier University, Waterloo, Ontario, Canada mhojati@uwaterloo.ca
[2] Department of Geography & Environmental Studies, Wilfrid Laurier University, Waterloo, Ontario, Canada



Computers, Environment and Urban Systems 32 (2008) 204–213

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

journal homepage: www.elsevier.com/locate/compenvurbsys

Planar and spherical hierarchical, multi-resolution cellular automata

A. Ross Kiester [a,*], Kevin Sahr [b]

[a] Biodiversity Futures Consulting, 5550 SW Redtop Place, Corvallis, OR 97333, United States
[b] Department of Computer Science, Southern Oregon University, 1250 Siskiyou Blvd., Ashland, OR 97520, United States

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How could DGGS help with GHG monitoring, reporting, and mitigation planning?

Inadequate Spatial Grids Limit Action

Existing GHG inventories are:

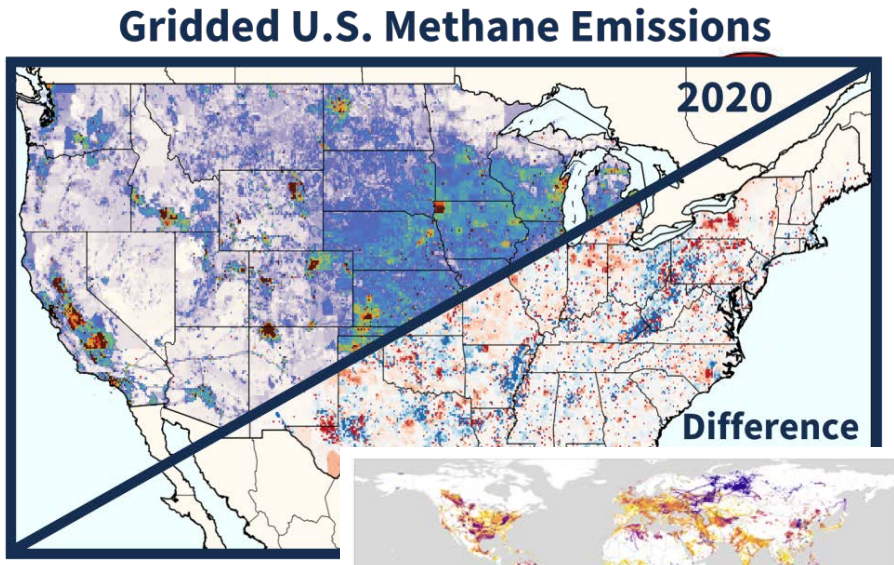
- **Spatially inconsistent**
- **Poorly georeferenced**
- **Difficult to integrate**

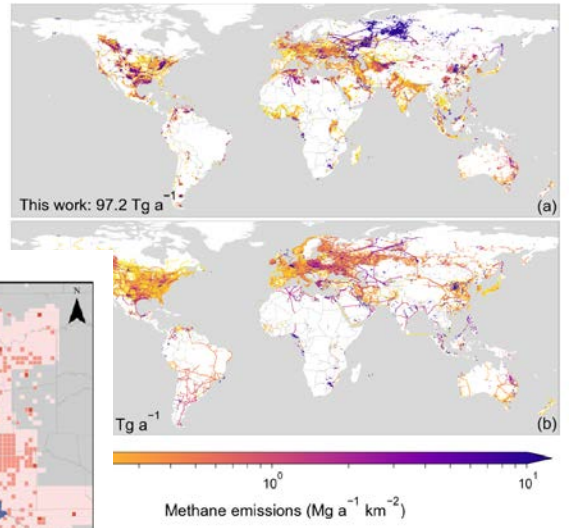
Gridded methane inventories often use **latitude–longitude grids** (graticule), where cell size and shape vary with latitude. This leads to several problems:

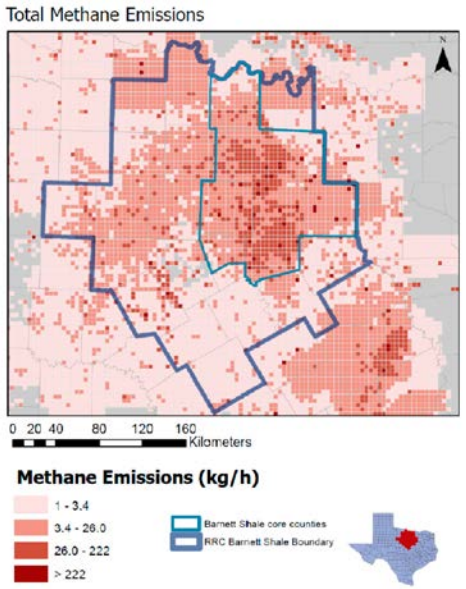
- **Inflate emission densities in high-latitude regions**
- **Complicate direct inter-cell comparisons and integration**
- **Distort visualization and interpretation**

Other issues:

- **Definition of spatial scales is not clear (site/facility/urban/etc.)**
- **Data from multiple satellites/sensors/sources needs to be integrated**







- Scarpelli et al. 2020
- EDGAR 2023
- Maasakkers et al. 2023
- Crippa et al. 2024

If used to manage GHG data, a DGGS can at least benefit…

A Global, Uniform, Hierarchical Spatial Framework for GHG Data

- Integration of multi-source data
- A standard data bucket for facility/asset data management (unique index)
- True emission intensity comparisons across space and time (equal area)
- Spatial integrity and consistency of the conveyed information when visualized
- Quantitative spatial resolution (equal area)
- Consistent aggregation at any scale, e.g., facility, basin, and national (hierarchical)
- Multiple analysis and reporting granularity (hierarchical)
- Precise hotspot tracking and trend monitoring over time (fixed grid location)
- Informed monitoring design, including optimized aerial survey and satellite observation planning
- Global vision – permafrost methane monitoring in the Arctic (global coverage)

Our recent study

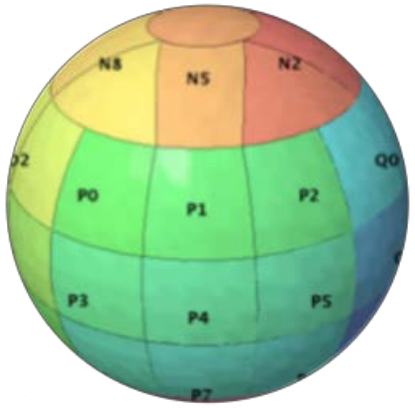
Spatially Explicit Methane Emissions from Alberta Upstream Oil and Gas Operations with Equal-Area Grid Systems

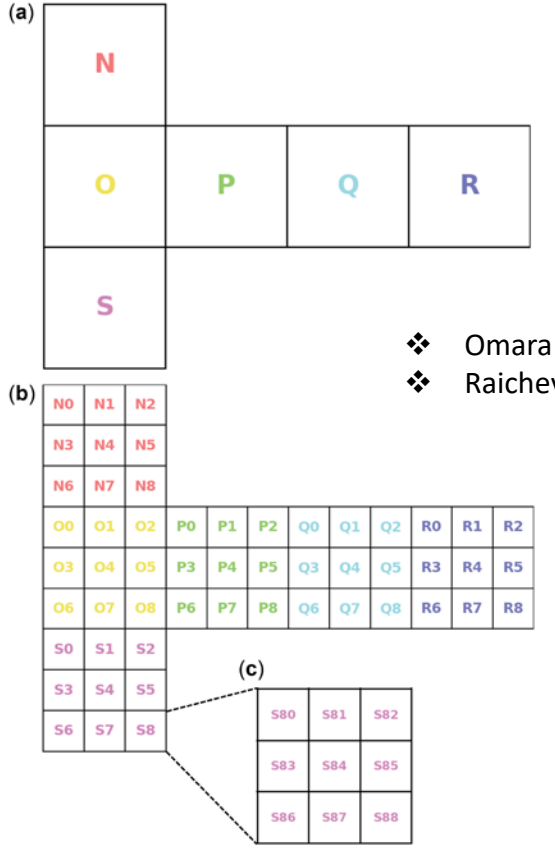
What we adopt: rHEALPix DGGS (rHEALPixDGGS-py library)

What we did: An initiative study on **Alberta upstream O&G** emissions

Data we used: 2020-2023 Petrinex Conventional Volumetric Data (Fuel, Flare, Vent)

Oil and Gas Infrastructure Mapping (OGIM) database



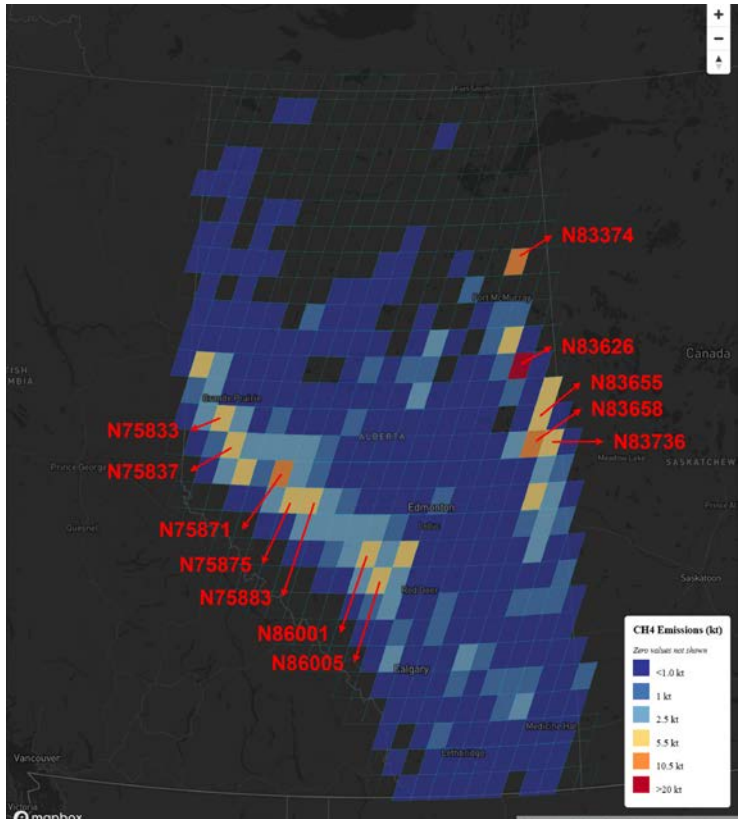


- Omara et al. 2024
- Raichev et al. 2020

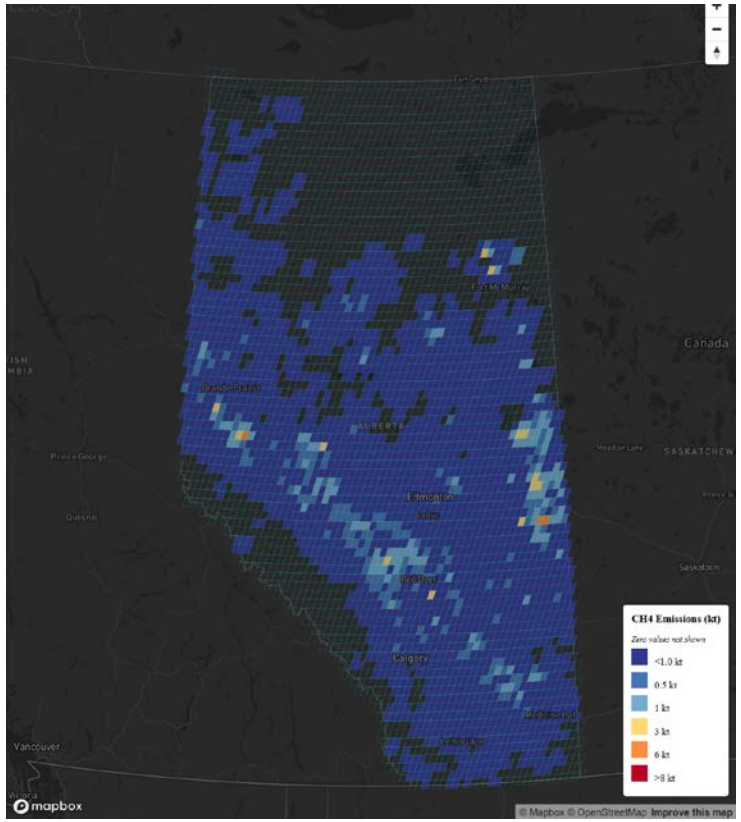
rHEALPix = **r**earranged **H**ierarchical **E**qual **A**rea iso**L**atitude **Pix**elization
DGGS = **D**iscrete **G**lobal **G**rid **S**ystems

Our recent study

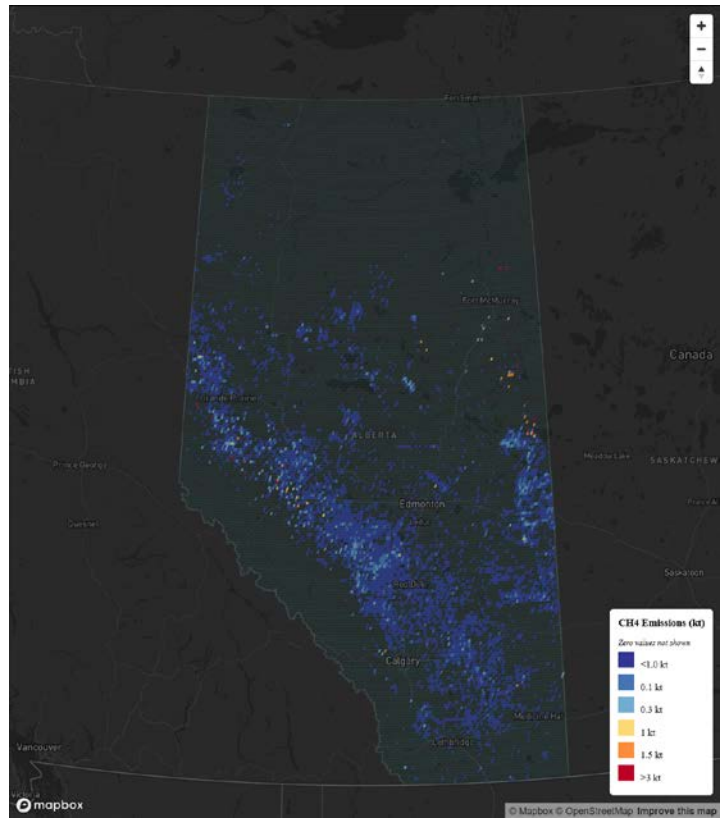
Year 2020



Resolution 5



Resolution 6



Resolution 7

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Demo

Questions

- What if each facility's equipment, emissions, and metadata were managed within a grid cell that has a globally unique, standardized identifier -- how would that change your current workflows?
- Any use cases where managing facility assets or emissions using a spatially-fixed, equal-area grid would add value?
- Do you currently struggle with integrating data from different sources (e.g., satellites, field inspections, sensors)? Would a common spatial reference like DGGS make this easier?
- Could a DGGS help to track methane reduction performance by consistently comparing "emission per grid cell" across time or space?
- If each grid cell could serve as a standard "container" for regulatory reporting (e.g., all emissions within Cell X), would that improve clarity?

Thank you!

Q&A

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University of Calgary

May 16, 2025