Beyond the Graticule: Spatially Explicit Methane Inventories Using Discrete Global Grids

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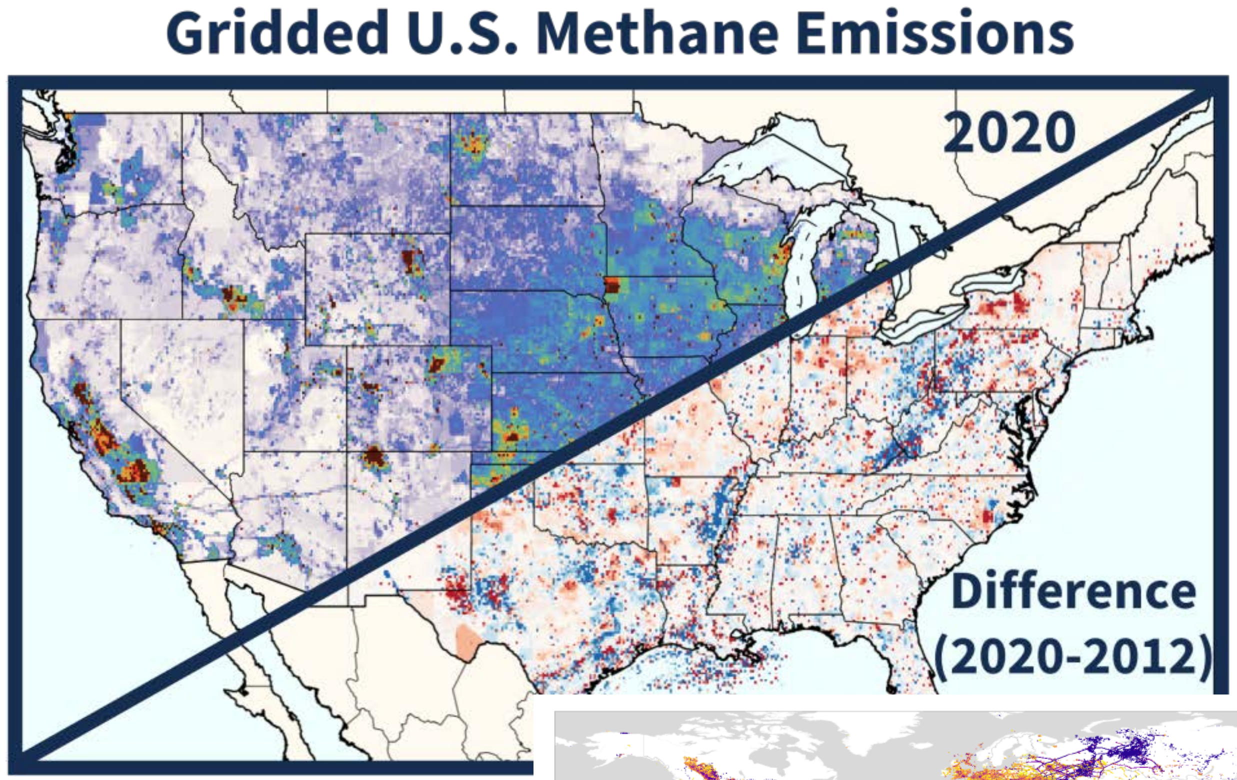
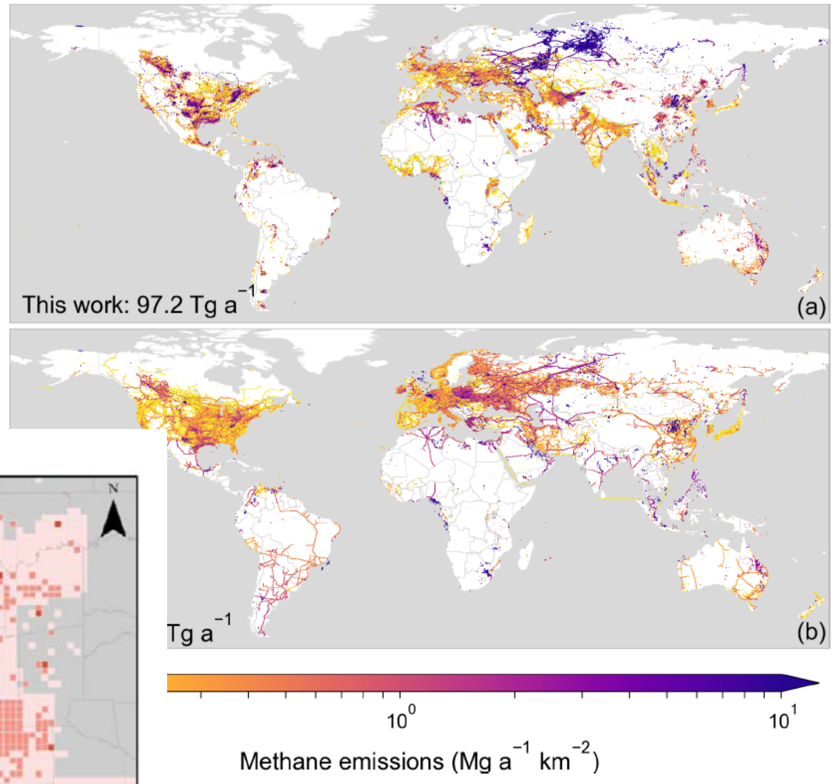
CentroGeo 19°17'30"N 99°13'17"O 2489m

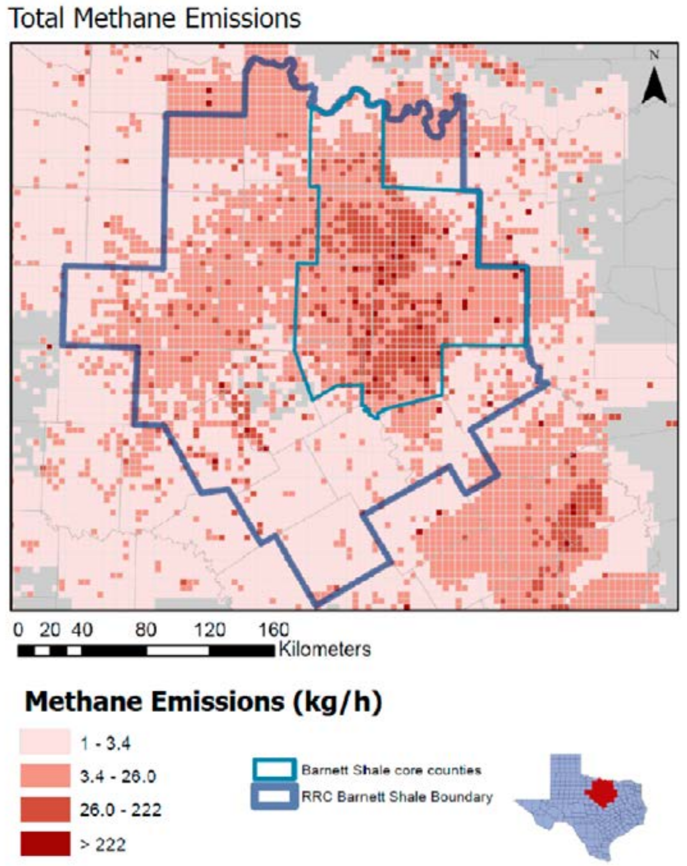
INEGI

Why do we need gridded GHG inventories?

- Supports Inverse Atmospheric Analyses: Provide a prior estimate for inverse atmospheric analyses.
- Simulates Large Emission Events: Provide baseline emission data to simulate large, short-term emission events.
- Enhances Local Emission Estimates: Assists in estimating and comparing emissions for localized studies.
- Provides Seamless Coverage: Offers consistent data across boundaries (county, basin, province, etc.).
- Engages Non-Technical Audiences: Presents emissions data in an intuitive, accessible format.







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

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
- Spatial disaggregation of national totals can result in misallocations

Graticule

Web Mercator Tiles

A Global, Uniform Spatial Framework for GHG Data

What if emissions from every facility, basin, region, or country could be georeferenced to a single, equal-area, and hierarchical space-time grid?

Such a framework would unlock:

- Seamless reconciliation of bottom-up inventories and top-down observations
- Precise source attribution across spatial and administrative boundaries
- Consistent integration of multi-source and multi-temporal data

Think of it not just as a grid, but as a spatially intelligent container for all related data (facility characteristics, equipment type, operational history, environmental conditions, etc.)

DGGS
- Grid ID
- Resolution

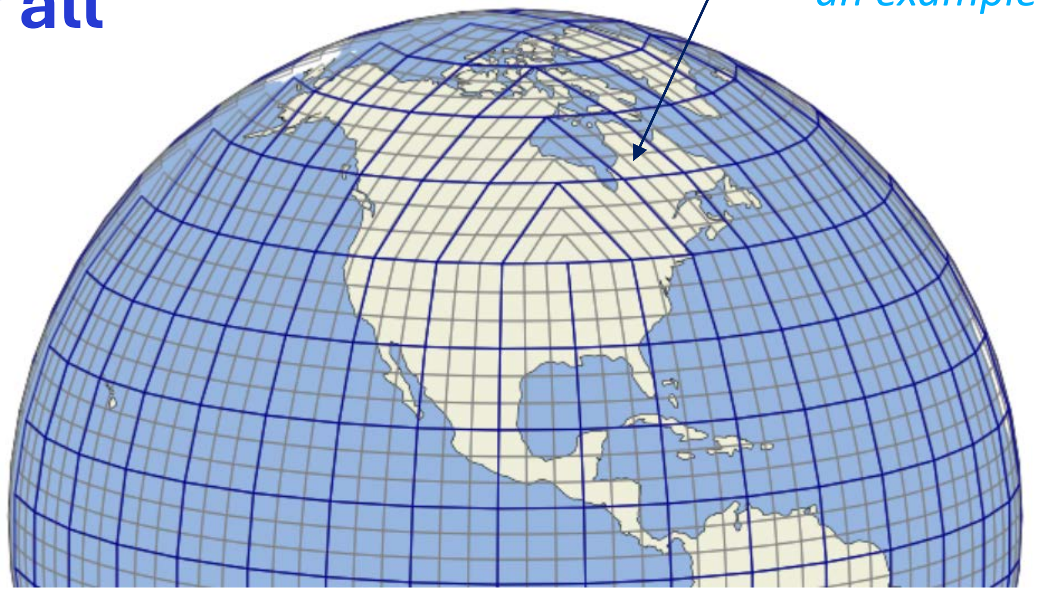
Facility
- Facility type
- Facility age
- Facility operator

Equipment
- Equipment type
- Emission rate
- Pipe material

Operational history
- Maintenance record
- Blowdown event

Environmental conditions
- Wind speed
- Atmospheric pressure

an example of O&G..



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

Equal Area

- Defines consistent and quantitative spatial resolution
- Enables true emission intensity comparisons across space/time
- Ensures spatial integrity and consistency in visualizations

Hierarchical

- Allows consistent aggregation (facility/basin/national scale)
- Supports multi-level analysis and reporting

Unique Index

- Acts as a standard data bucket for facility/emission data management

Fixed Grid Location

- Facilitates precise hotspot tracking and temporal trend monitoring
- Supports monitoring design, including optimized aerial survey and satellite observation planning

Global Coverage

- Allows for standardized monitoring designs across jurisdictions
- Supports global methane strategy, e.g., Arctic permafrost region tracking

Multi-Source Integration (Cross-cutting benefit)

- Facilitates top-down and bottom-up reconciliation
- Integrating activity and emissions data at their native resolution can prevent misallocations

Our Recent Study

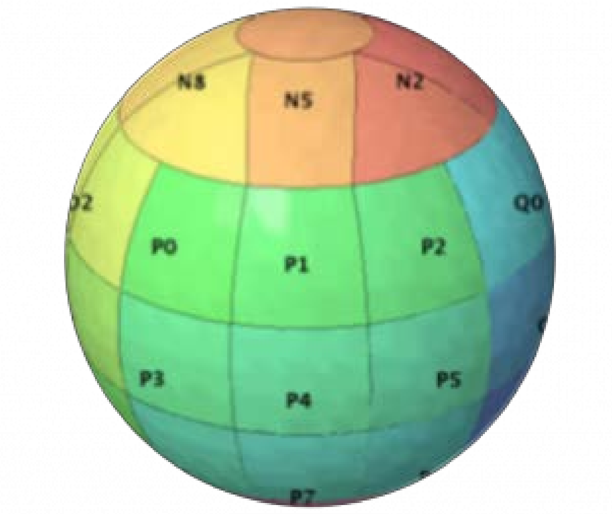
Spatially Explicit Methane Emissions from Alberta Upstream Oil and Gas Operations with Equal-Area Grid Systems

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

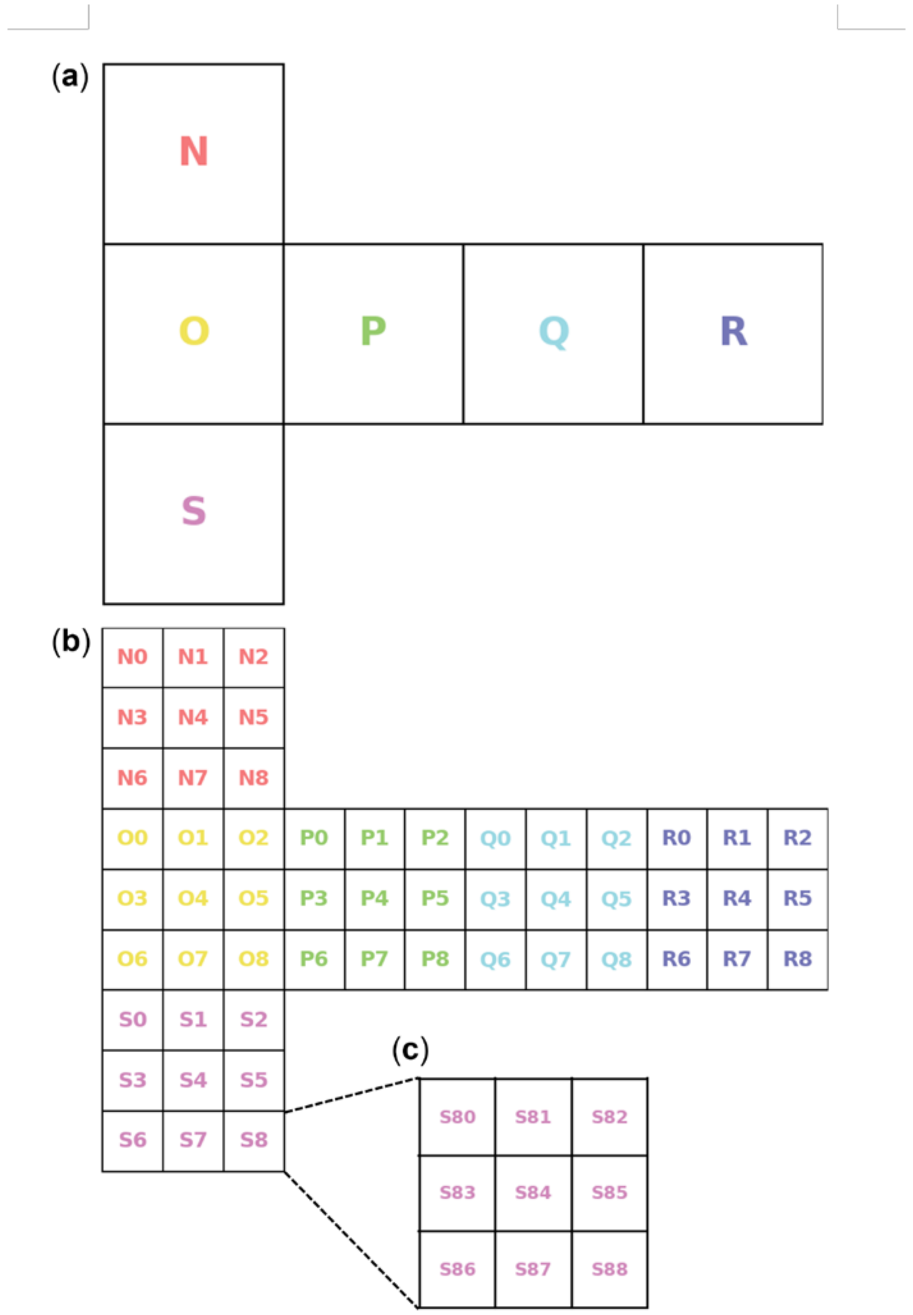
What we did: An initiative study on Alberta upstream O&G emissions

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

Oil and Gas Infrastructure Mapping (OGIM) database



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



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

Demo

Looking Ahead: Aligning with OGC DGGS Standards and AI Potential

Aligning with OGC DGGS API standards

- Expose emission data via OGC DGGS API
  - Serve the rHEALPix methane inventory using standardized endpoints
  - Support web-based queries and analytics on spatially explicit methane zones
- Conform to standardized data encoding
  - Encode methane emissions and facility attributes using DGGS-JSON, enabling compatibility with other OGC-compliant systems and clients.

Augmenting with AI

- Spatiotemporal hotspot prediction: Train AI models to detect and forecast high-emission zones over space and time using DGGS-indexed data.
- Inference of missing emissions: Use zone-level contextual patterns (e.g., Facility type, history, surrounding emissions) to estimate gaps in self-reported or incomplete data.
- Automated emissions data pipeline with LLM-based AI agents to:
  - Extract raw emission factor and activity data from diverse sources
  - Auto-transform data into DGGS-compliant structures and support data queries and analysis

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THANK YOU

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