DGGS as a Spatial Harness for AI Agents

Multi-Agent Querying and Grounded Spatial Reasoning

DGGS · GeoAI · LLM Agent

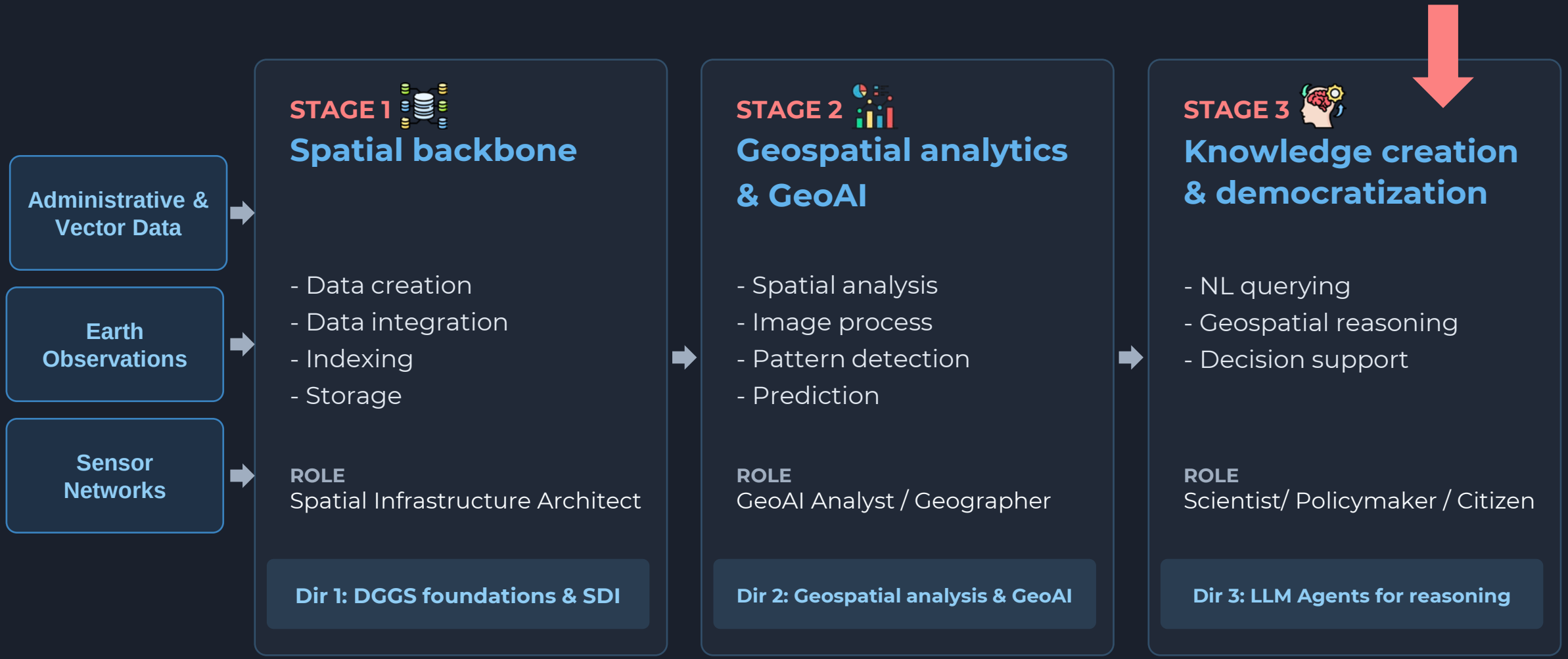
2026 ISPRS Congress – Forum Session

Dr. Erin Li & Dr. Steve Liang
UbiSensing & AI Lab, University of Calgary
mingke.li@ucalgary.ca

isprs 2026 TORONTO
XXV ISPRS CONGRESS
TORONTO, CANADA | 4-11 JULY 2026
FROM IMAGERY TO UNDERSTANDING
47th Canadian Symposium on Remote Sensing
47e Symposium canadien de télédétection
isprs CRSS·SCT
UNIVERSITY OF CALGARY
Ubisensing&AI

Research Roadmap

From Spatial Data Infrastructure to Geospatial Intelligence



Outline

1

DGGS for spatial querying

Multi-Agent Querying System **DGGS-Q**

2

DGGS for spatial reasoning

DGGS-Grounded Multi-Agent System **GridMind**

ongoing

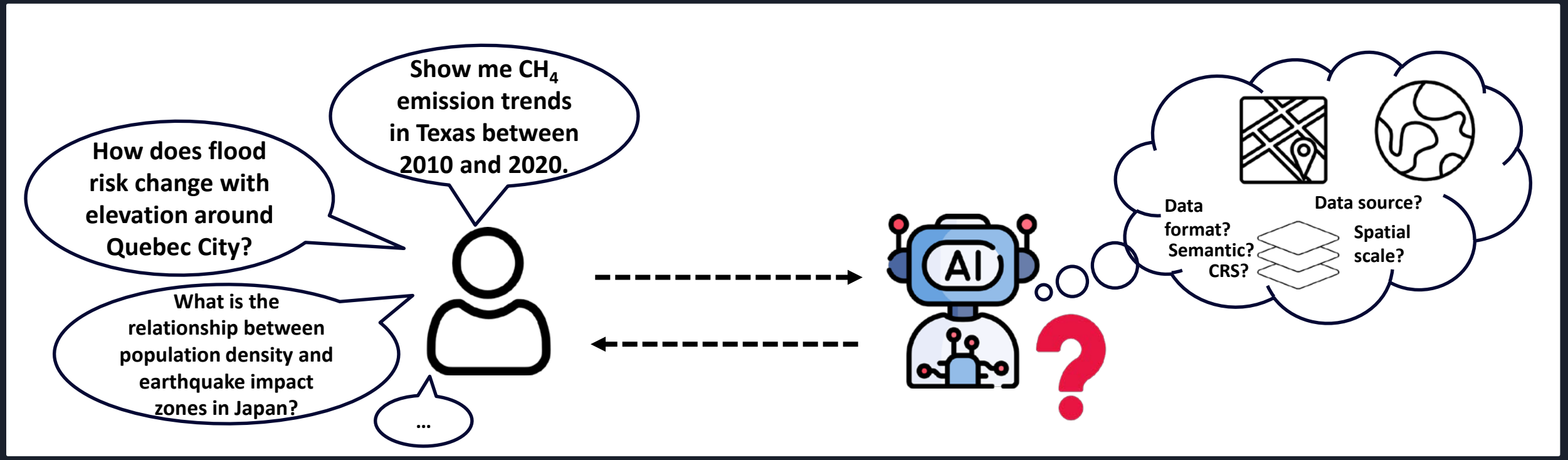
Project 1:
Multi-Agent Querying System DGGS-Q

A DGGS-grounded multi-agent system that turns natural-language spatial questions into traceable query workflows over harmonized methane emission inventories.

Motivation

Multi-source spatial data fragmentation

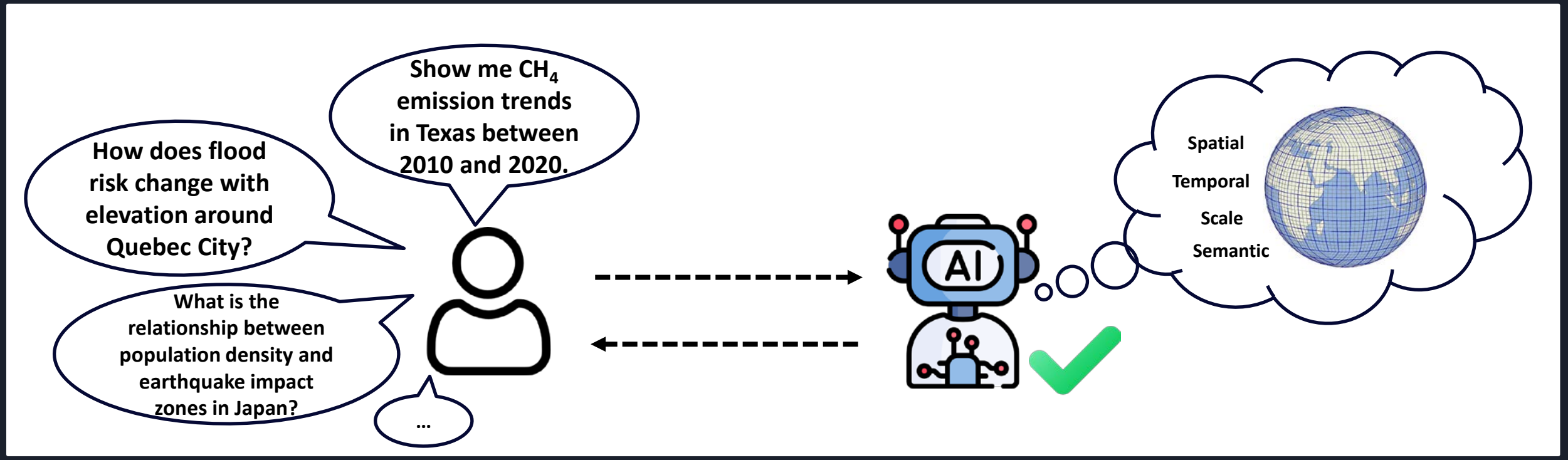
- Spatial data today are scattered across multiple platforms and standards.
- Inconsistent coordinate reference systems, file formats, spatial resolutions, etc.
- Data chaos slows decisions before/during/after events.
- AI models struggle to reason over such inconsistencies.



Motivation

Discrete Global Grid Systems (DGGS) as a standardized reference system

- Spatial: Equal-area global grid unifies coordinate systems.
- Temporal: Enables consistent time-indexed snapshots for change analysis.
- Scale: Multi-resolution hierarchy supports zooming and aggregation.
- Semantic: Common feature schema & attribute alignment.



Two-Part Work Structure

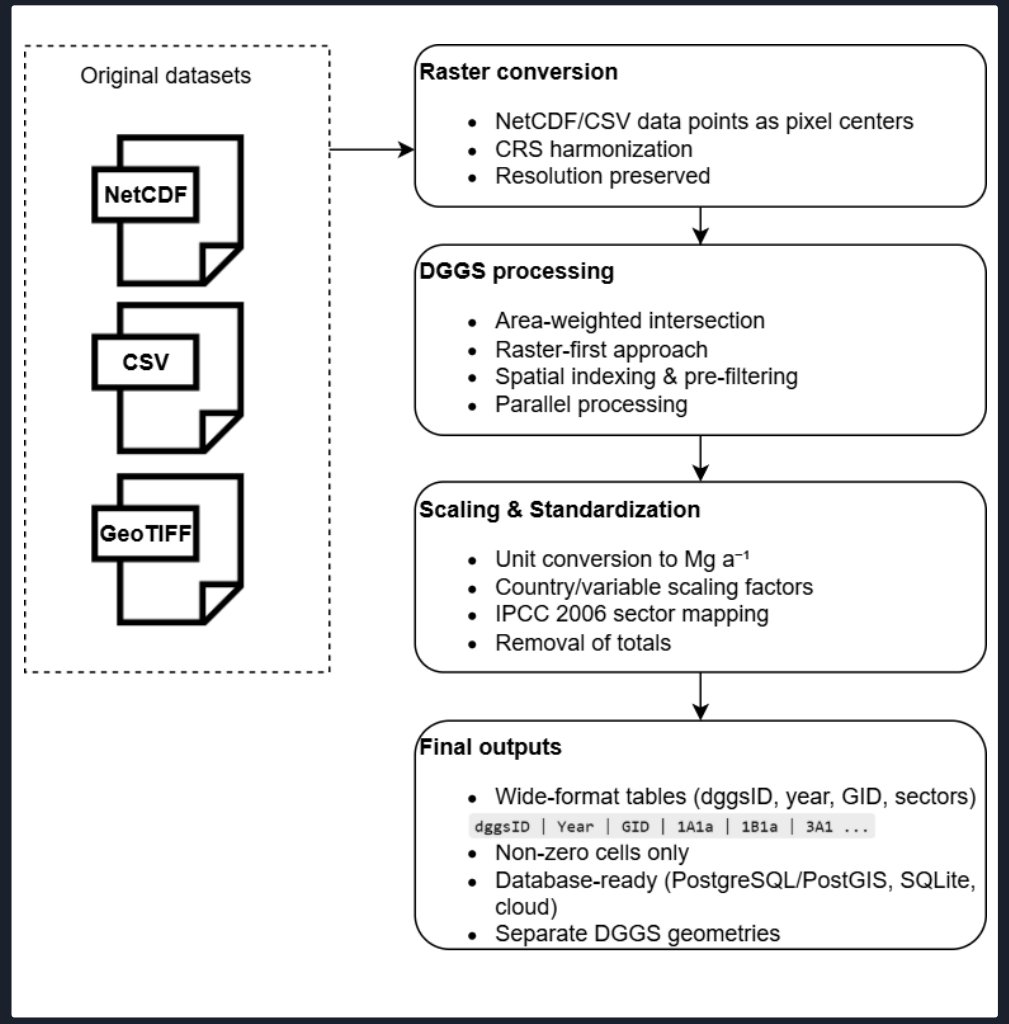
Part 1 – Data harmonization

- Convert 15 emission inventories onto rHEALPix DGGS using DGGAL (https://github.com/ecere/dggal).

- Standardize spatial structure, sectoral semantics (to IPCC 2006 scheme), and reporting units (to Mg a^{-1}).
- Apply scaling factor (close to one) to ensure conservation of total emissions.
- Store data in DGGS-indexed relational backend.

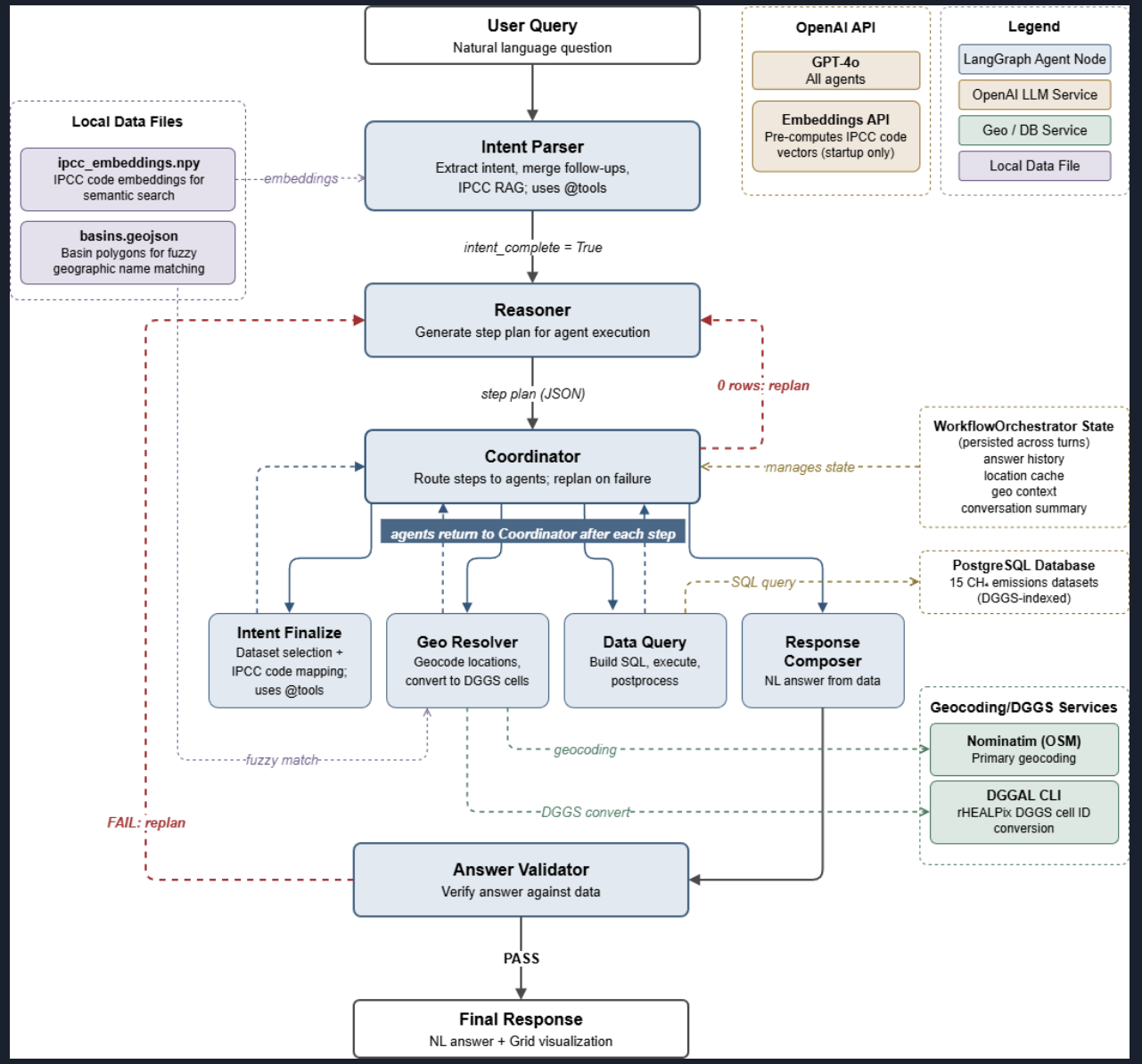
➢ Li, M., & Liang, S. (2025). Harmonized Global to Regional Gridded Methane Inventories on rHEALPix DGGS (V1.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.17362125

➢ https://doi.org/10.31223/X5F48V



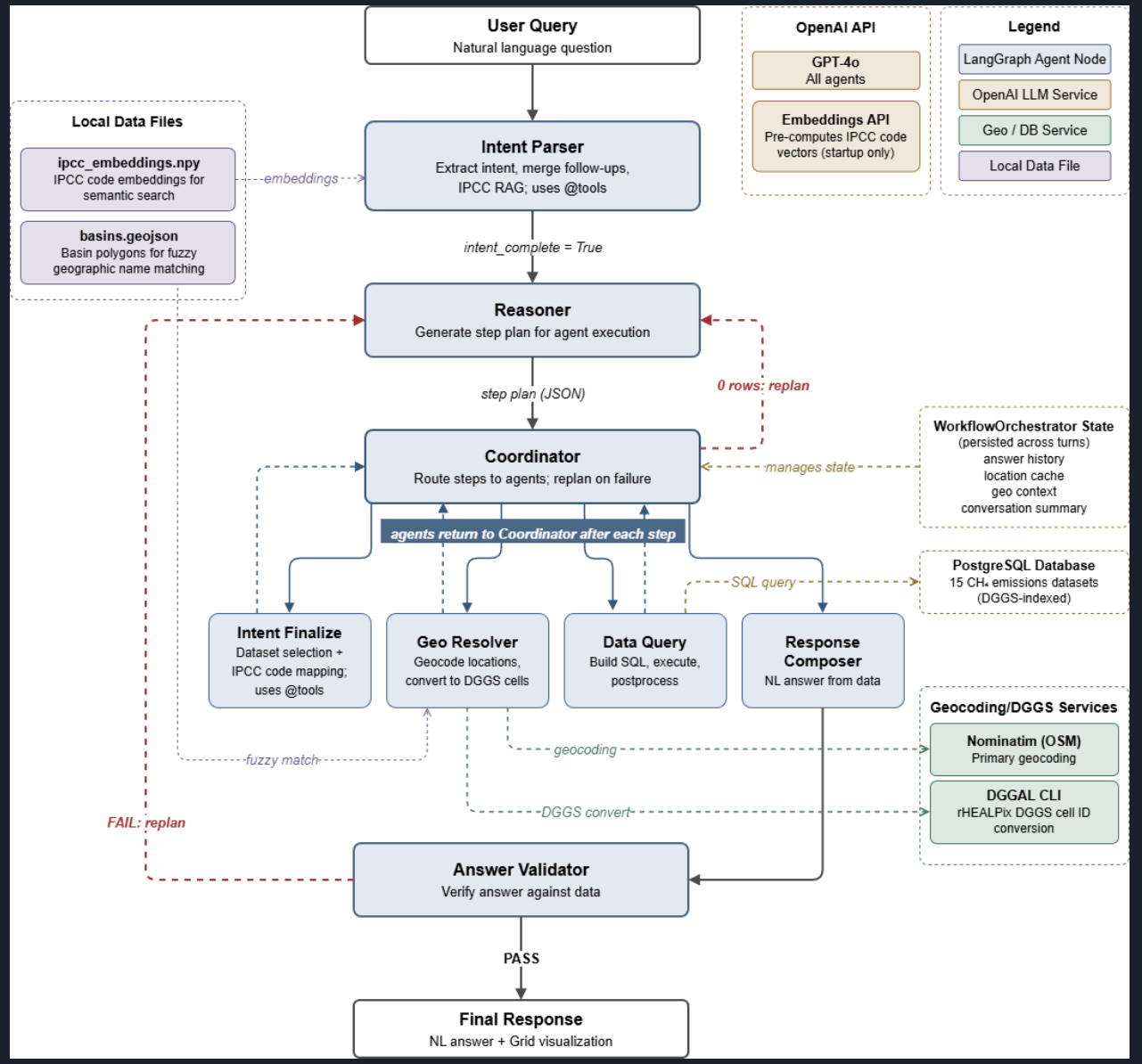
Part 2 – Multi-agent query system

- Reasoner generates execution plan
  - Creates a step-by-step JSON
  - Replans using failure feedback
- Coordinator routes agents + manages execution
  - Sends each step to the right agent
  - Manages state and recovery
- IntentParserAgent extracts task + variables
  - Human-in-the-loop
  - In-session memory



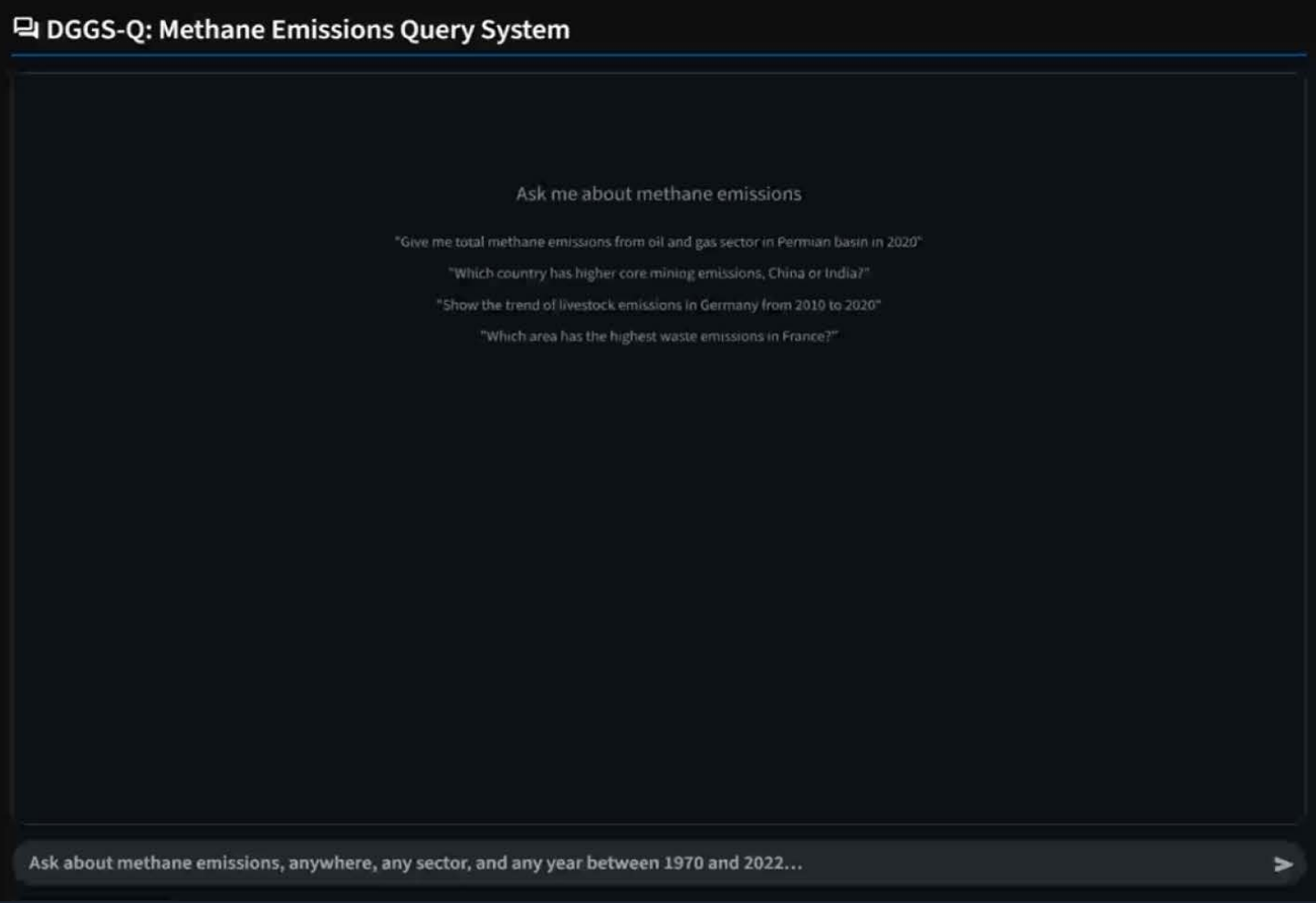
Part 2 – Intelligent query system

- GeoResolverAgent maps text location → DGGS IDs
  - Nominatim API
  - On-the-fly DGGS conversion by DGGAL
- DataQueryAgent generates SQL → retrieves results
  - SQL writing with *@tool*
  - DGGS prefix matching
- AnswerValidatorAgent checks answer against data
  - Detects numerical inconsistencies
  - Flags unsupported claims
  - Triggers replan when needed



DGGS-Q Demo

Aggregation | Comparison | Trend | Extremum | Multi-round queries



Key contributions

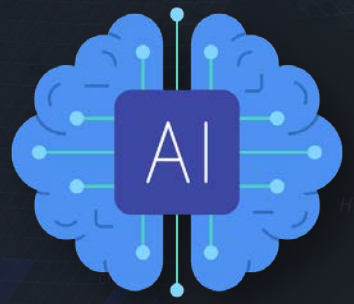
01 **Introduces DGGS-Q as an explainable multi-agent framework** for natural-language querying over DGGS-indexed geospatial data.

02 **Uses DGGS prefix matching for spatial filtering**, making query execution more reproducible and auditable.

03 **Agentic architecture through reasoner-coordinator orchestration**, creating inspectable query workflows.

04 **Produces traceable audit artifacts**, including structured intent, execution plan, DGGS cells, SQL, results, and validator verdict.

05 **Improves robustness over single-agent reasoning**, showing that structured multi-agent design supports more trustworthy geospatial AI.



Project 2 (ongoing):
DGGS-Grounded Multi-Agent System GridMind

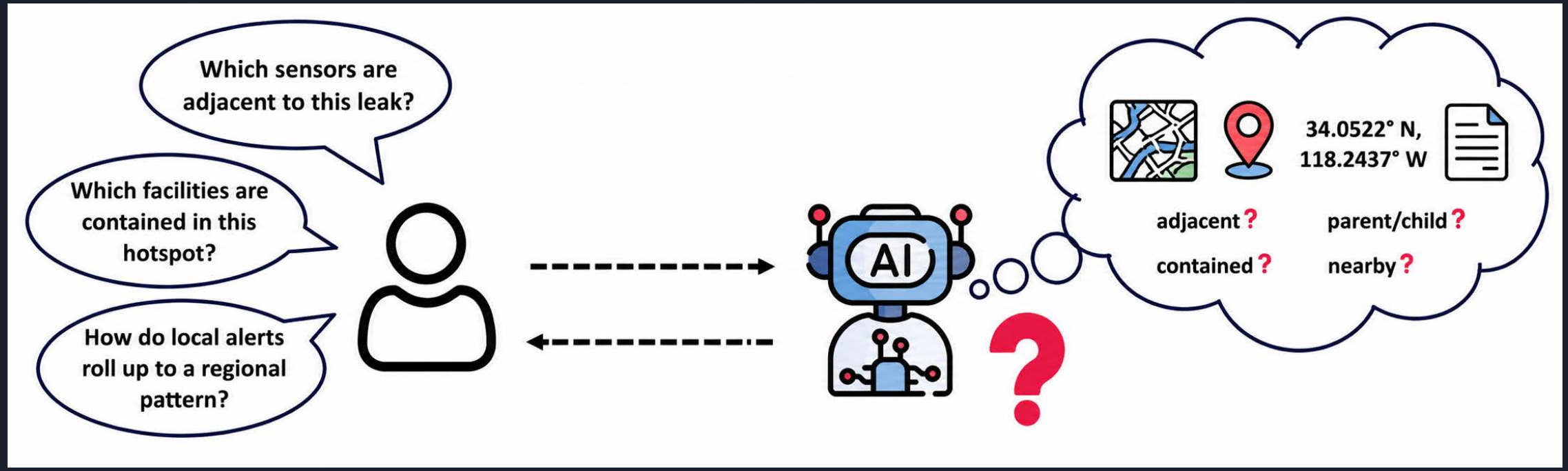
A DGGS-grounded agent substrate where grid cells and spatial features reason through hierarchy, adjacency, and containment.

Motivation: LLMs need spatial grounding

- **Spatial reasoning** derives new spatial facts or decisions from known **relations** such as:
  - Adjacency
  - Containment
  - Hierarchy
  - Proximity
- LLMs are not reliable when these relations must be inferred from coordinates, maps, or text.

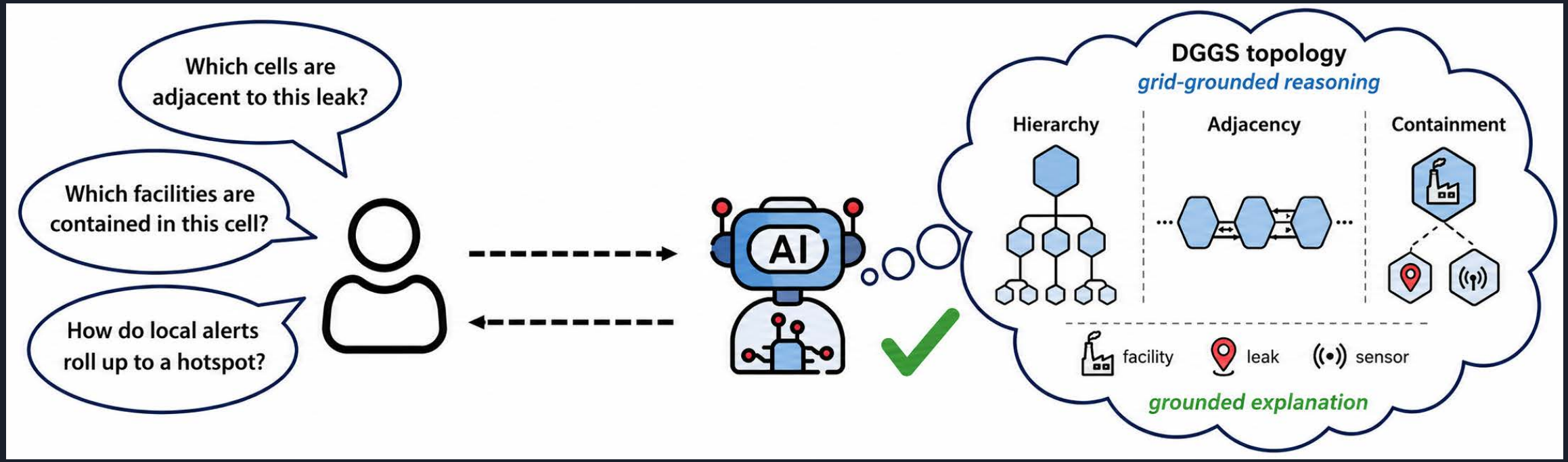
** LLMs violate the first law of geography??*

Everything is related to everything else, but near things are more related than distant things.



Motivation: DGGS topology as an agent substrate

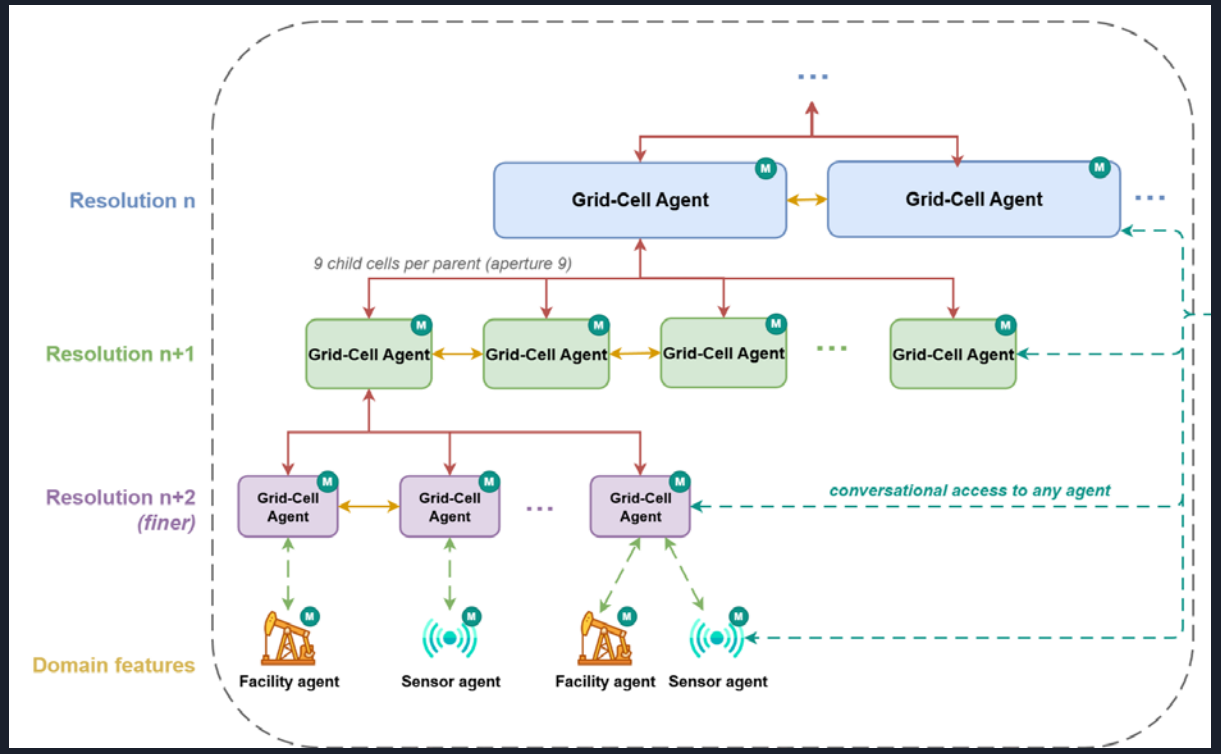
- Space is indexed with **rHEALPix DGGS** cells. Cell identifiers encode spatial structure.
- Spatial relations are derived from DGGS topology:
  - Parent and child cells from **hierarchy**
  - Neighboring cells from **adjacency**
  - Features linked to containing cells (**containment**)
- The LLM explains behavior but does not invent/infer the spatial relationships.



GridMind – cells and features as agents

** Demonstrated in an oil and gas facility asset management scenario*

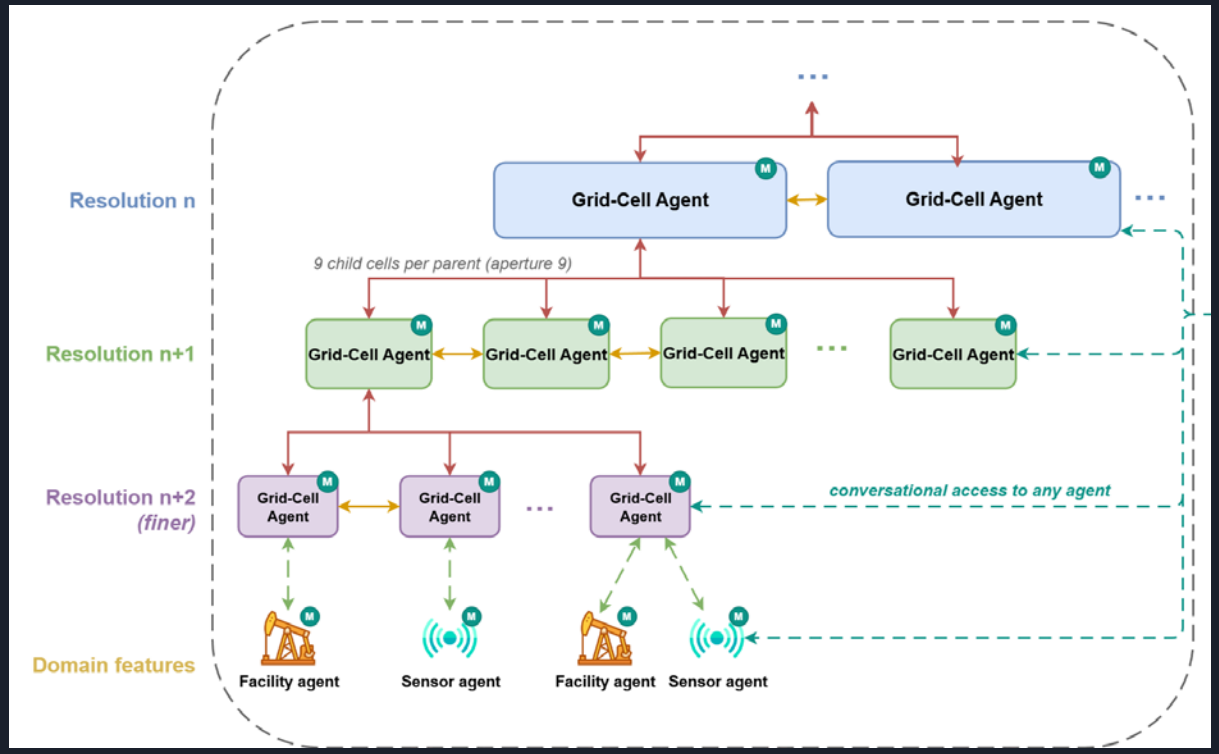
- **Grid-cell agents** represent spatial units at multiple resolutions and summarize local and regional conditions
- **Feature agents** represent domain entities, such as facilities, leaks, sensors, or repairs, and are bound to their containing DGGS cells
- Each agent has **local memory** and responds to events that reach it.
- **Event-driven system** where dormant cells/features remain inactive until triggered (e.g., a leak event, a sensor reading, a neighbor message, or a user question).



Topology-defined communication channels

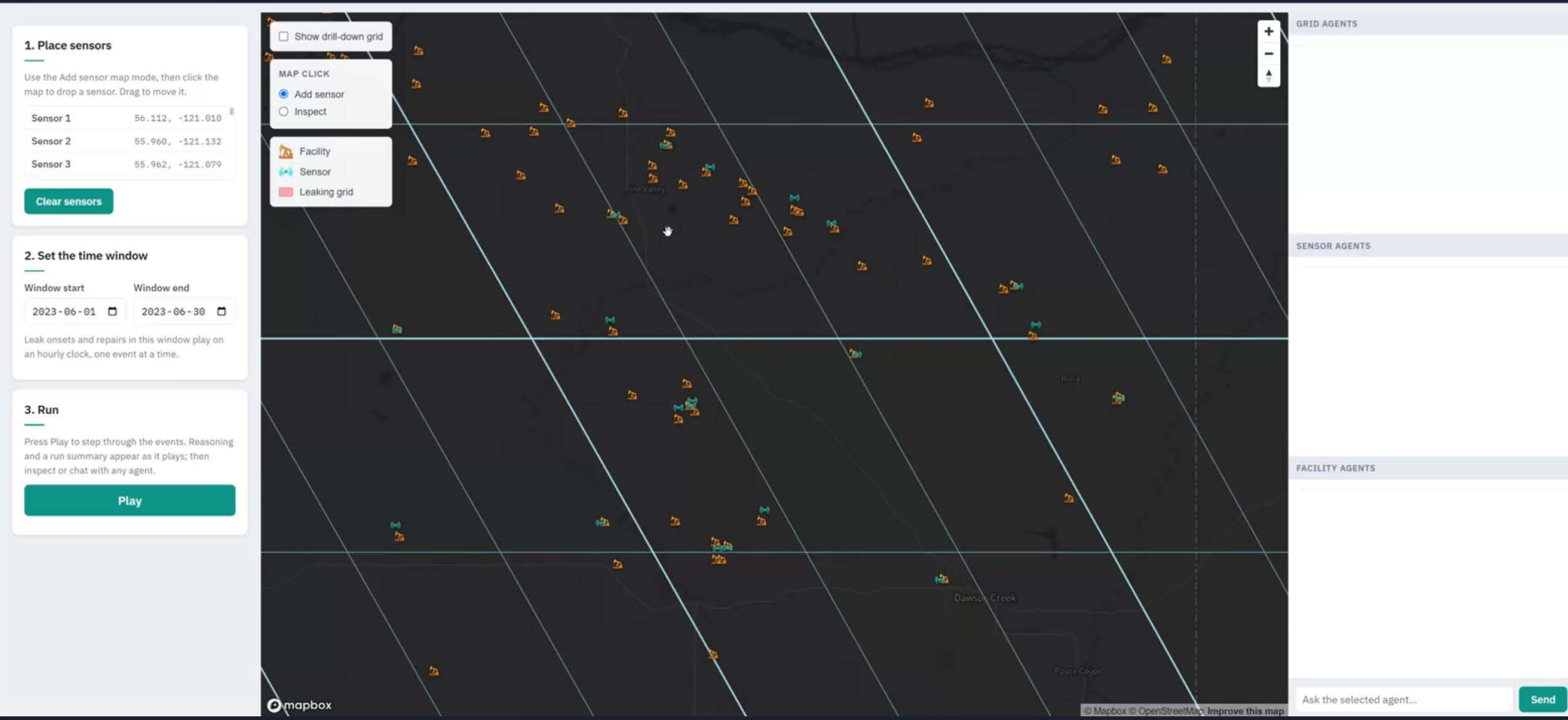
** Demonstrated in an oil and gas facility asset management scenario*

- **Vertical –** parent and child cells, supporting cross-resolution reasoning
  - Fine-level cells can roll up to coarse regional summaries
  - Coarse cells can drill down to local details
- **Lateral –** neighboring cells at the same level, supporting propagation and pattern detection
- **Inward –** feature and containing cell, supporting a facility or sensor to report its status to the cell agent it belongs to



GridMind Demo

GridMind: A DGGS-Grounded Multi-Agent Sandbox for Asset Management



Key contributions

01 **Grounds spatial reasoning in DGGS topology**, rather than relying on LLM-inferred spatial relations.

02 **Uses cell identifiers to derive adjacency, hierarchy, and containment** in a stable and verifiable way.

03 **Models grid cells and spatial features as agents**, creating a geography-organized agent system.

04 **Defines topology-based communication channels** for feature-to-cell, neighbor-to-neighbor, and parent-child reasoning.

05 **Provides grid-grounded agent memory**, allowing agents to explain why they acted.

Take-home message: DGGS as a Spatial Harness for AI Agents

** AI Agent = LLM + Harness*

1

Data

DGGS standardizes fragmented spatial datasets across space, scale, time, and semantics.

2

Querying

DGGS-Q makes natural-language geospatial queries traceable, explainable, and auditable.

3

Reasoning

GridMind uses DGGS topology to ground adjacency, hierarchy, and containment.

4

GeoAI

LLMs provide interaction, planning, and explanation, while DGGS provides the spatial structure.

Thank You

Dr. Erin Li
Postdoctoral Associate
UbiSensing & AI Lab, University of Calgary

mingke.li@ucalgary.ca