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DEPARTMENT OF GEOMATICS ENGINEERING

Quantization, Analysis, and Application of Terrain Data Modeled in Discrete Global Grid Systems

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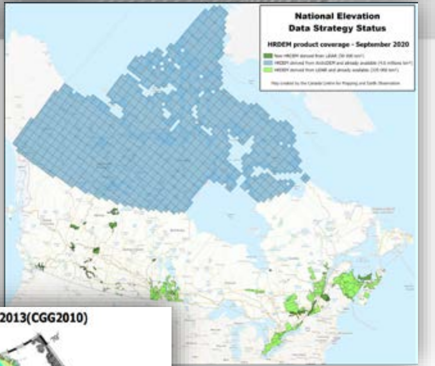
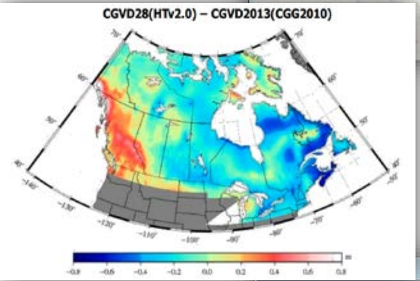
Introduction – Problem statement

- Main open-sourced terrain datasets in Canada
  - Canadian Digital Elevation Model – **CDEM**
  - High Resolution Digital Elevation Model – **HRDEM**



- Main differences (CDEM vs. HRDEM)
  - Coverage
  - Vertical / Horizontal datum
  - Resolution
  - Waterbodies
  - Accuracy



❖ *https://open.canada.ca/data/en/dataset/957782bf-847c-4644-a757-e383c0057995*
❖ *https://open.canada.ca/data/en/dataset/7f245e4d-76c2-4caa-951a-45d1d2051333*

Introduction – Problem statement

From the perspective of Canadian terrain data management

- **Dataset selection (coverage; resolution)**
- **Heavy pre-processing**
- **Inconsistent results**

From the perspective of DGGS applicability

- **Limited development of analytical algorithms**
- **Nascent period of supporting decision-making**

Research Phases

Integration → Analytics → Flood mapping

DGGS Implementations

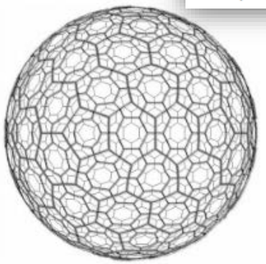
Journal of Geovisualization and Spatial Analysis (2020) 4:26
https://doi.org/10.1007/s41651-020-00066-3

Geospatial Operations of Discrete Global Grid Systems—a Comparison with Traditional GIS

Mingke Li[1] · Emmanuel Stefanakis[1]

Accepted: 18 October 2020

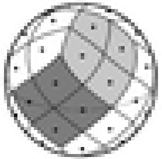
H3



DGGRID version 7.0

dggridR

DIGITAL EARTH GLOBAL ANALYTICS



HEALPix

DGGS Configuration

Icosahedron

Smallest face area

Smallest interior angles

Less angular distortion

❖ *Mahdavi-Amiri et al., 2015*

Orientation

Latitude of the pole (λ) = 37.6895°

Longitude of the pole (ϕ) = -51.6218°

Azimuth (α) = -72.6482°

❖ *Zhou et al., 2020*

ISEA3H

Hexagon

Greatest angular resolution

Optimally compact

Uniform adjacency

❖ *Luczak and Rosenfeld, 1976*

❖ *Sahr, 2011*

Snyder Equal Area projection

Less area and shape distortion

❖ *Snyder, 1992*

❖ *White et al., 1998*

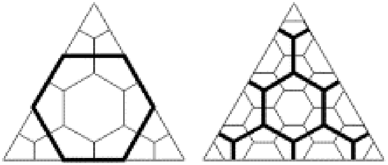
Aperture 3

Smoother transition

Monotonical convergence

❖ *Sahr et al., 2003*

❖ *Mahdavi-Amiri et al., 2015*



Research Objectives

Study 1: Integration of multi-source terrain data in Discrete Global Grid Systems

- Standardize Canadian terrain data at multiple resolutions by using DGGS

Study 2: Analytical functions of terrain data modeled in Discrete Global Grids

- Develop topographical and hydrological functions in a pure DGGS environment
- Extend Tomlin's theory regarding map algebra in 1990s into a DGGS context

Study 3: Flood susceptibility mapping in Discrete Global Grid Systems

- Model flood susceptibility by machine learning in DGGS at multiple resolutions
- Predictor variables: quantized raster data (Study 1), quantized vector data, results of topographical and hydrological analysis (Study 2), climate data, etc.

Study 1: Integration – Workflow

Data Acquisition
- CDEM: Geospatial-Data Extraction tool / STAC API
- HRDEM: Download directory / HRDEM Mosaic

Pre-processing
- Standardize horizontal datum: NAD83 CSRS
- Standardize vertical datum: CGVD2013

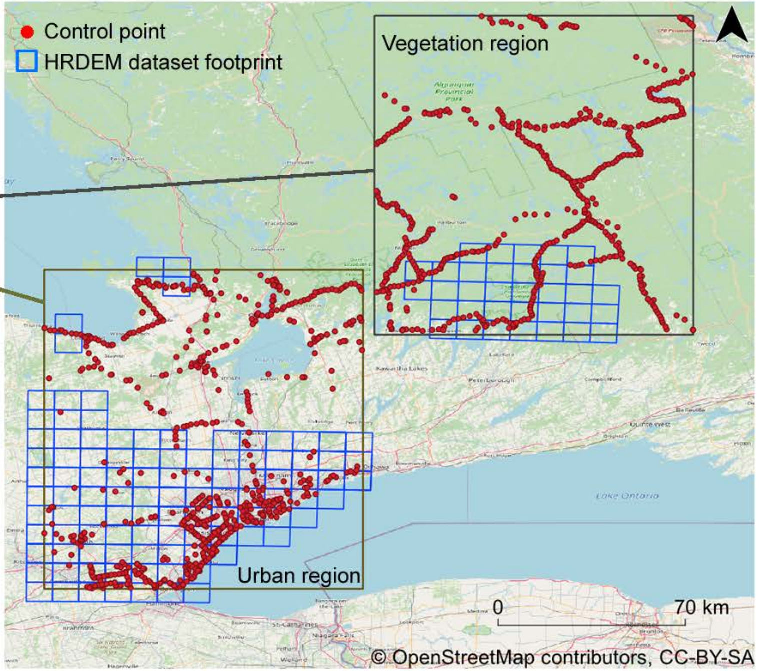
Quantization
- Cell centroids at various levels
- Resample with interpolation; integration

Aggregation
- Mean / max / min

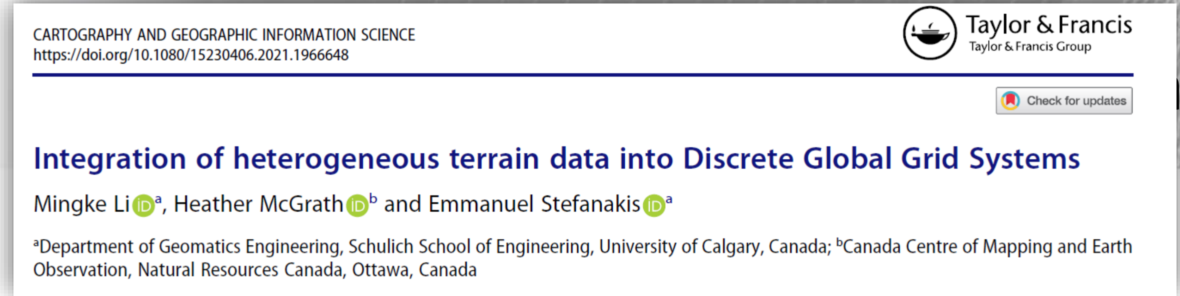
Quality Control
- GCP vs. Pre-DGGS elevations
- GCP vs. Post-DGGS elevations
- Pre-DGGS elevations vs. Post-DGGS elevations

Study 1: Integration – Experiment

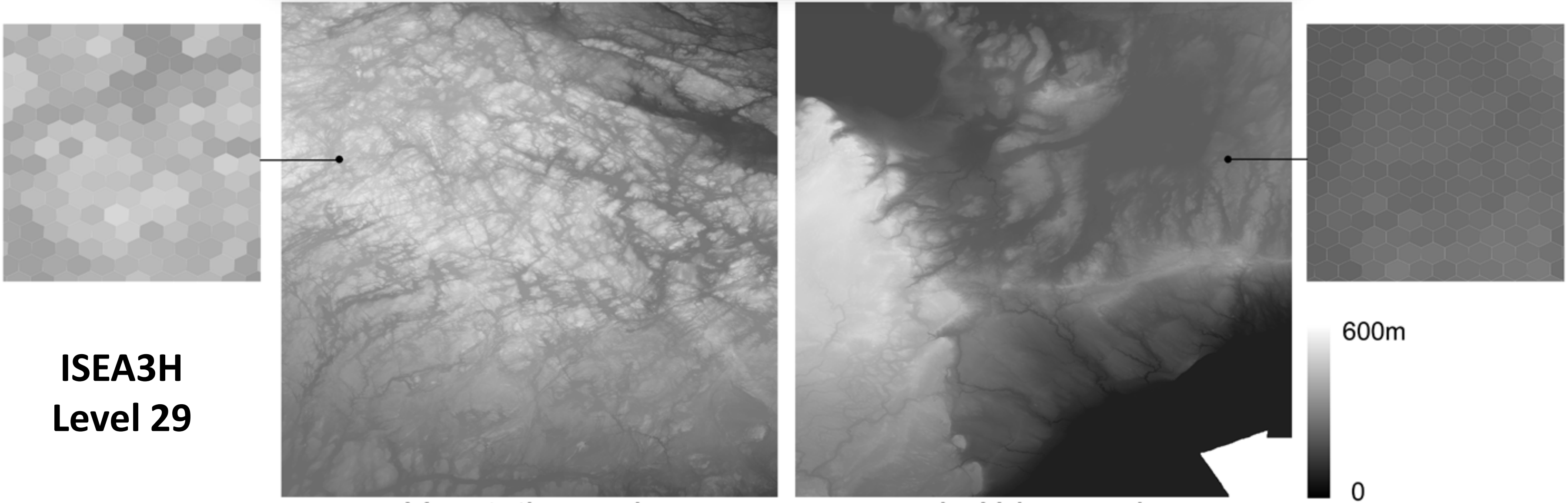
- *Ministry of Natural Resources and Forestry, Ontario* [*https://www.ontario.ca/page/geodesy*](https://www.ontario.ca/page/geodesy)



lization



ISEA3H
Level 29



a. Vegetation region b. Urban region

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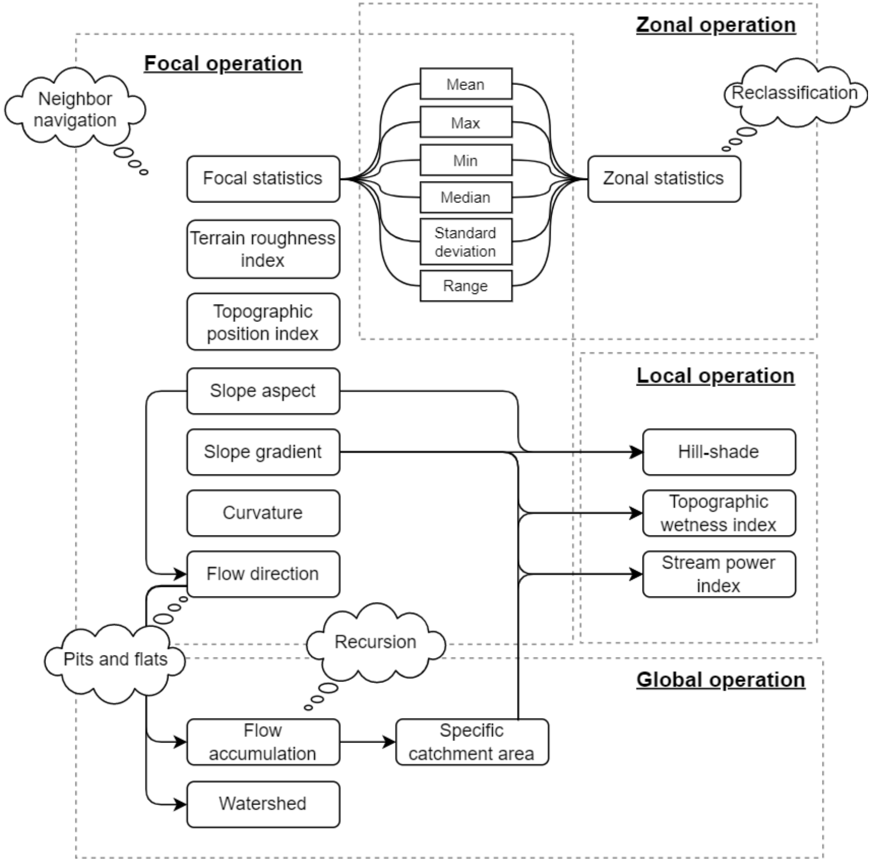
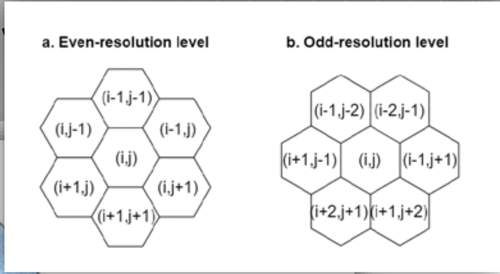
Study 2: Analytical Functions – Classification

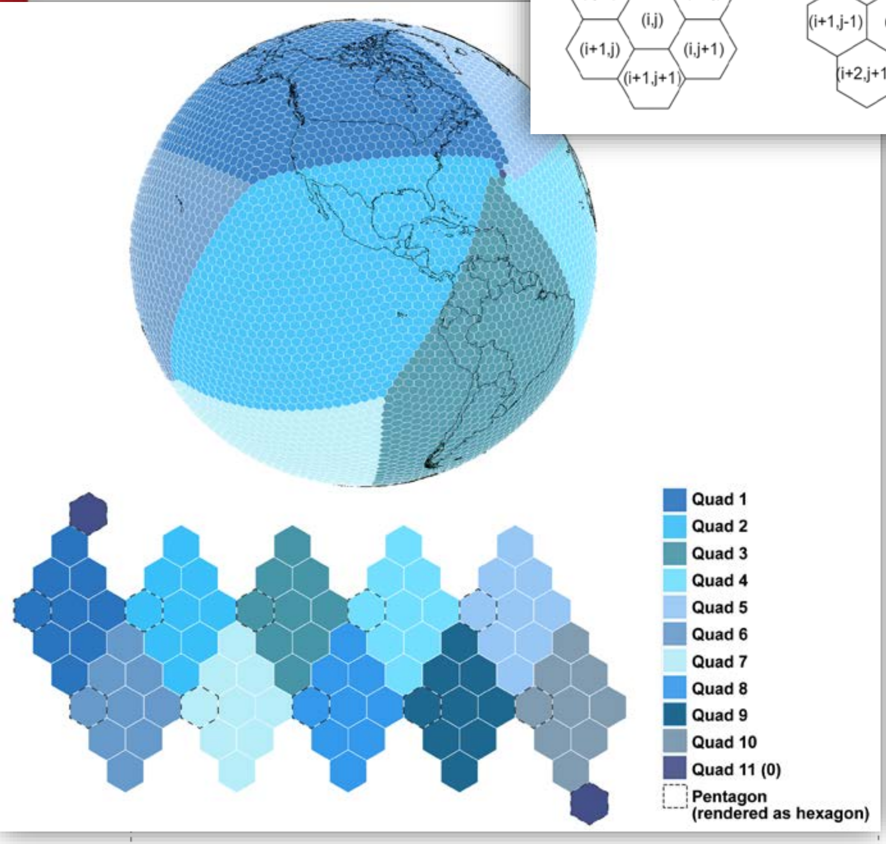


<u>Based on quantized terrain data</u>

- Descriptive statistics
- Topographic analysis
  - Slope gradient and aspect
- Hydrological analysis
  - Flow direction
  - Pits and flat areas (cells)
  - Parallel by branches
- Topographic indices
  - TRI, TPI, TWI, SPI

Stud… nctions – Classification



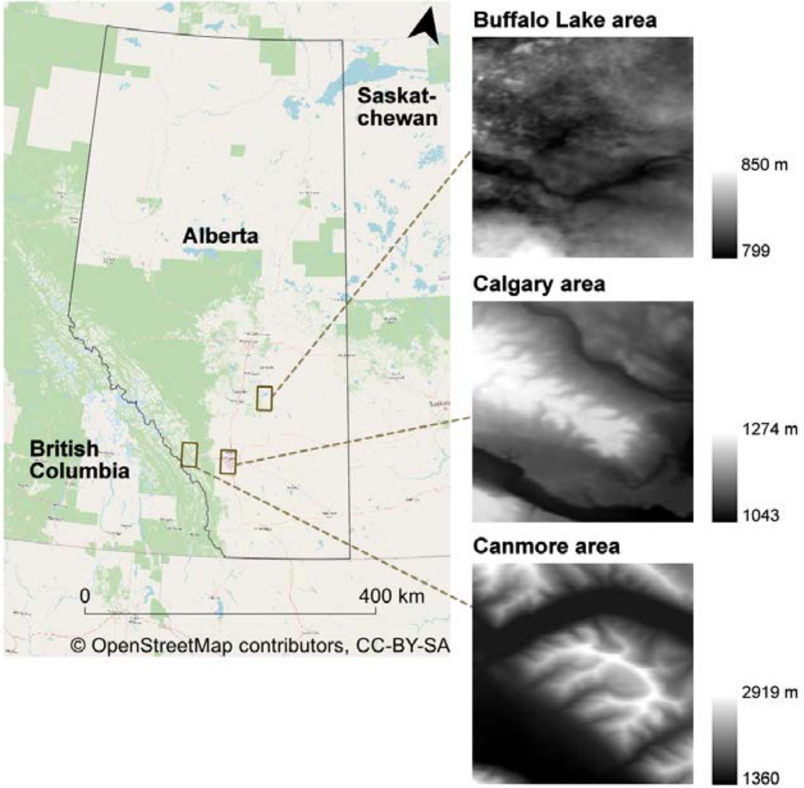


<u>Extending Tomlin's model into DGGS</u>

- Local operations
- Zonal operations
- Focal operations
  - Neighbor navigation – Q2DI
- Global operations
  - Recursion

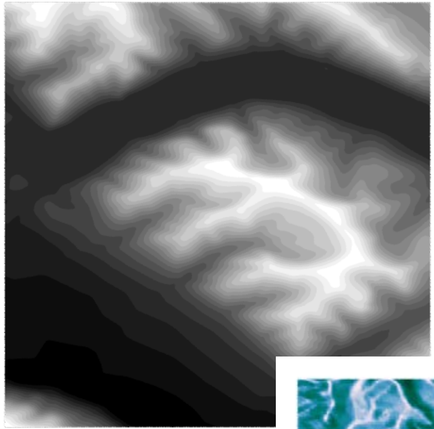
❖ *Sahr, 2019*

Study 2: Analytical Functions – Experiment

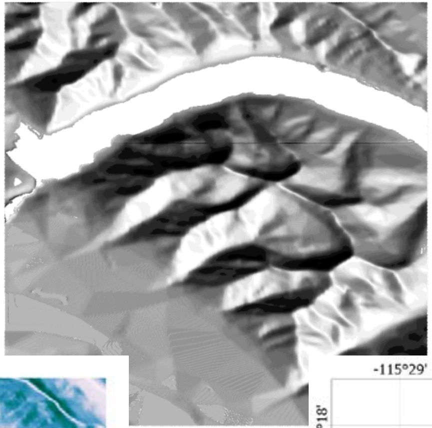


Study 2: Analytical Functions – Visualization

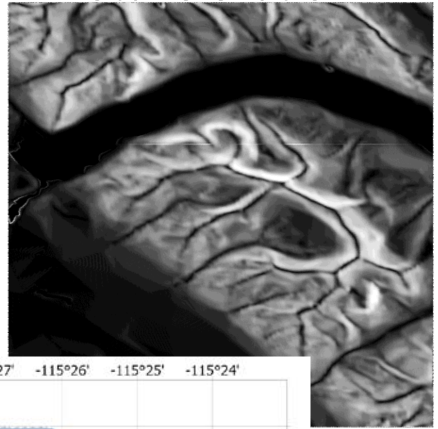
Mean elevation

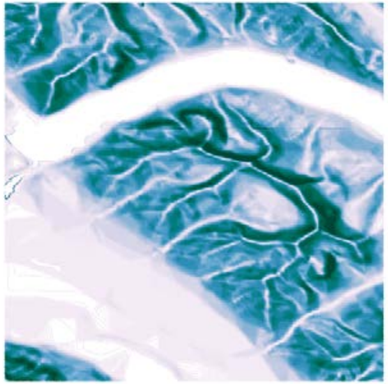


Hill shade

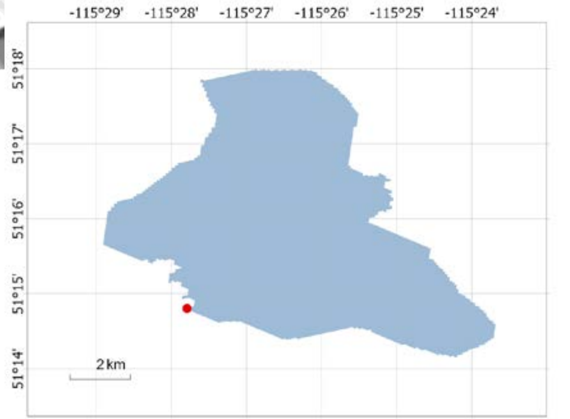


Std. elevation





Slope gradient



Watershed

Canmore area
ISEA3H
Level 24

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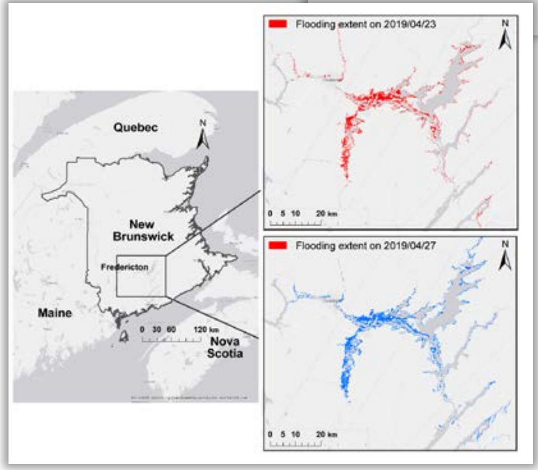
Study 3: Flood mapping – Workflow

Study area → Sample points → Predictor variables → Model training → Flood susceptibility maps

Flooded + non-flooded points in 2018
Flooded + non-flooded points in 2019
70% training + 30% testing



<u>Topographical factors</u>
Elevation, slope, aspect
TWI, TRI, SPI
Proximity to river

<u>Climate factors</u>
Weekly average precipitation
Weekly average temperature
Total winter precipitation

<u>Anthropogenic factors</u>
Proximity to road
Land-use classifications

<u>Analysis scale</u>
ISEA3H level 28 (~1.5 m)
ISEA3H level 24 (~13.3 m)
ISEA3H level 20 (~119.5 m)

<u>Machine learning methods</u>
Support Vector Machine
Random Forest
Gradient Boost Machine

<u>Model performances</u>
F-score
Cohen’s kappa index

<u>Parallel analysis with traditional GIS</u>

Predict flooding areas
Multiple scales

Research Impact

- **Utility of DGGS as an integration platform of multi-source data**
  - Potential for a national elevation service for Canada
- **Analytical functions developed in a pure DGGS environment**
  - Migrate square-based algorithms to hexagonal grids
- **DGGS-driven decision making**
  - Flood mapping by machine learning

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