Integration of Multi-Source Terrain Data on Discrete Global Grids in Canada

CCA | May 26th, 2021

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OUTLINE

Introduction

- Terrain Data sources in Canada – CDEM + HRDEM
- Discrete Global Grid Systems (DGGS)
- Problem statement
- Research objectives

Methodology

- DGGS configuration – ISEA3H
- Workflow

Experiment

- Study area – Ontario
- Results

Impact of the research

Take-home messages

Introduction – Terrain Data sources in Canada

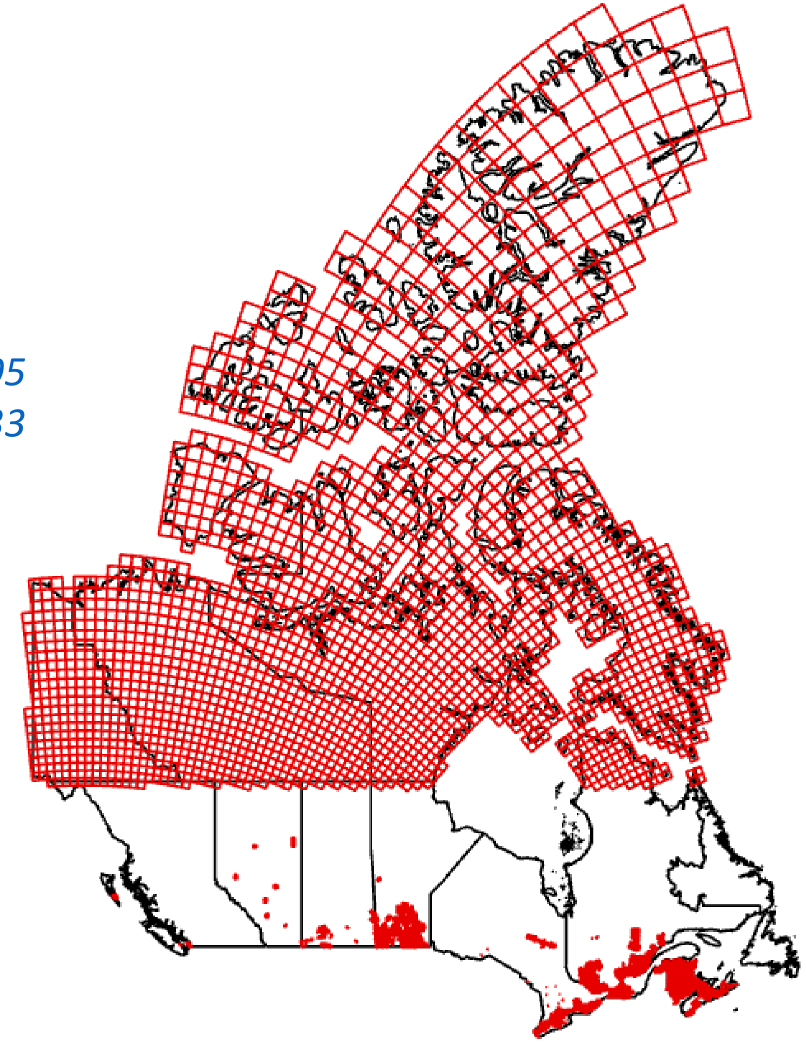
Existing terrain datasets distributed by NRCan

- **Canadian Digital Elevation Model -- CDEM**
- **High Resolution Digital Elevation Model -- HRDEM**

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

Main differences (CDEM vs. HRDEM)

- **Vertical datum – CGVD1928 vs. CGVD2013**
- **Horizontal resolution – 0.75-12 arcsec vs. 1-2m**
- **Waterbodies – estimated elevation vs. void data**
- **Coverage – national wide vs. project footprints**
- **Accuracy – 0-70m vs. ~1m**



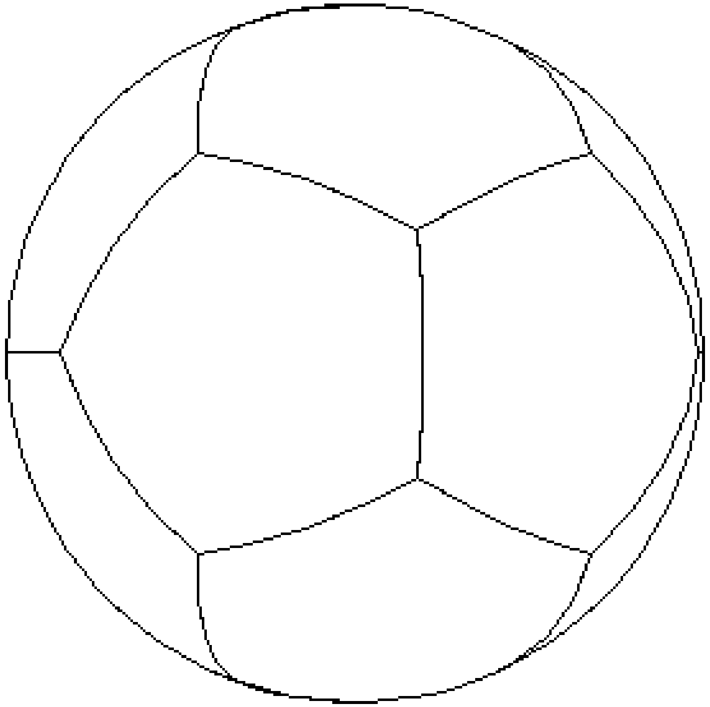
Introduction – Problem statement

From the perspective of terrain data in Canada…

- **Multiple sources (coverage, datum, resolution, waterbody, accuracy)**
- **Time-consuming, duplicated pre-processing**
- **Inconsistent integration results (base) for following analysis**
- **Limited resolution options**

In Canada, an integration solution is highly in need to merge and quality-control the terrain data on a standardized framework

Discrete Global Grid Systems



A Spatial Reference System that uses a Hierarchical Tessellation of cells to Partition and Address the Globe.

- *https://www.discreteglobalgrids.org/dggs-resolution/*
- *Open Geospatial Consortium (OGC), 2017*

Introduction – Benefits of DGGS

A uniform data model to integrate geospatial information independent of the original sources

- **Uniform cells**
  - a single consistent framework with constant spatial resolution at each level
- **Spherical cells**
  - hard to define a single projected system that minimizes distortions over a large landscape
  - account for the specificity of the Earth's curvature and avoids potential computational errors over a large landscape
- **Discrete cells**
  - parallel computing
- **Hierarchical structure**
  - multiple resolution options

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From the perspective of DGGS applicability…

- **Insufficient attention in GIS community**
- **Nascent period of supporting decision-making**

Introduction – Research objectives

From the perspective of terrain data in Canada…

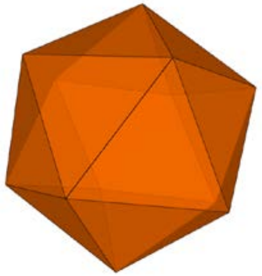
- Multiple sources (coverage, datum, resolution, waterbody, accuracy)

Objectives

- Integrate Canadian terrain data at multiple resolutions by using DGGS
- Set the stage for the national elevation service in future

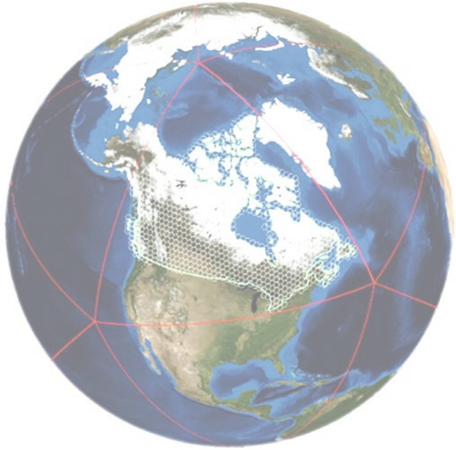
- Insufficient attention in GIS community
- Nascent period of supporting decision-making

Methodology – 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

Snyder Equal Area projection
- Less area and shape distortion
- ❖ *Snyder, 1992*
- ❖ *White et al., 1998*

Hexagon
- Greatest angular resolution
- Optimally compact
- Uniform adjacency
- ❖ *Luczak & Rosenfeld, 1976*
- ❖ *Sahr, 2011*

Aperture 3
- Smoother transition
- Monotonical convergence
- ❖ *Sahr et al., 2003*
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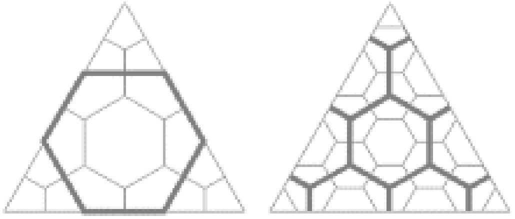

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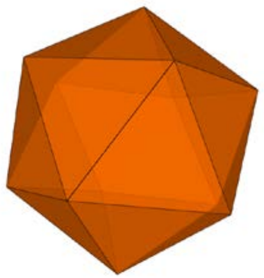

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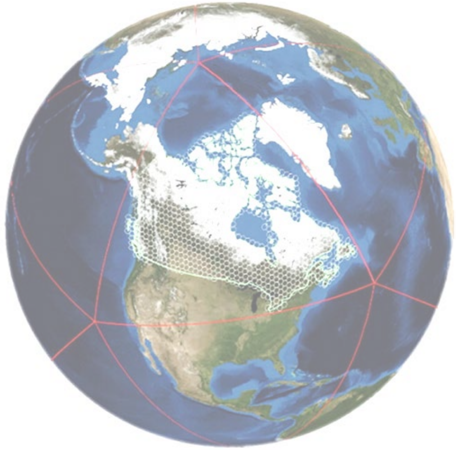

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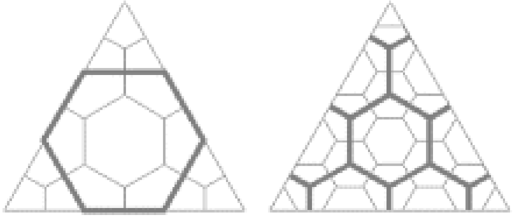

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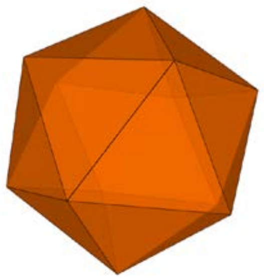

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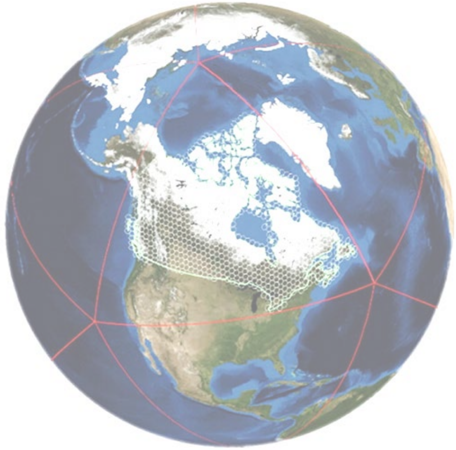

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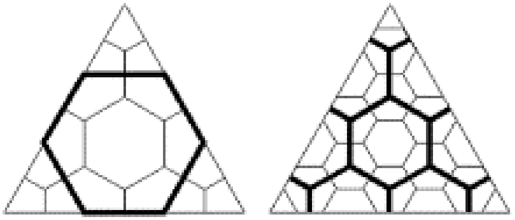

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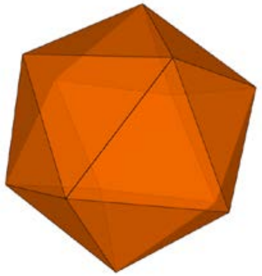

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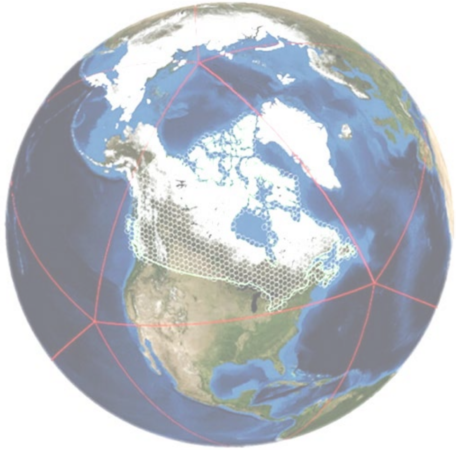

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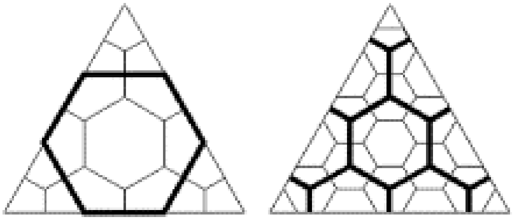

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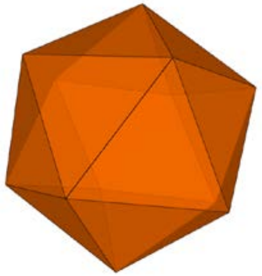

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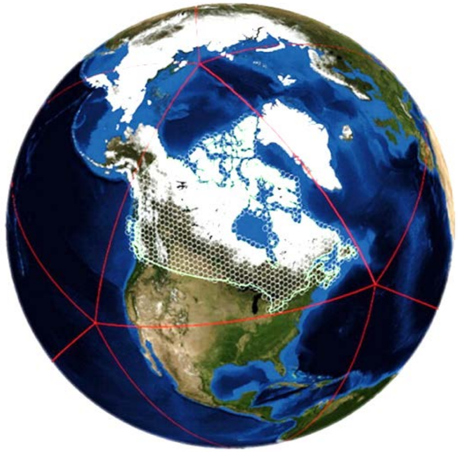

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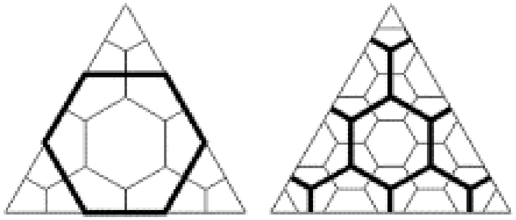

Methodology – Workflow

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

Pre-processing
- Horizontal datum: NAD83 CSRS
- Vertical datum: CGVD2013

Quantization
- Cell centroids
- Levels 29-16: Resample with interpolation; integration

Aggregation
- Levels 28-16: mean / max / min

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

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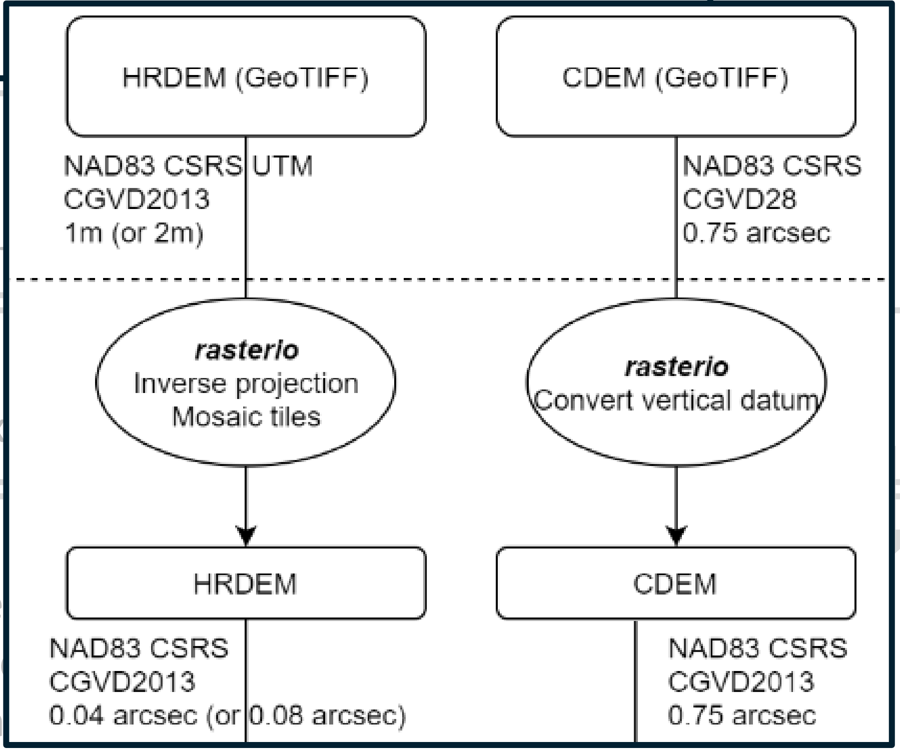
- GCP vs. Post-DGGS
- Pre-DGGS elevation



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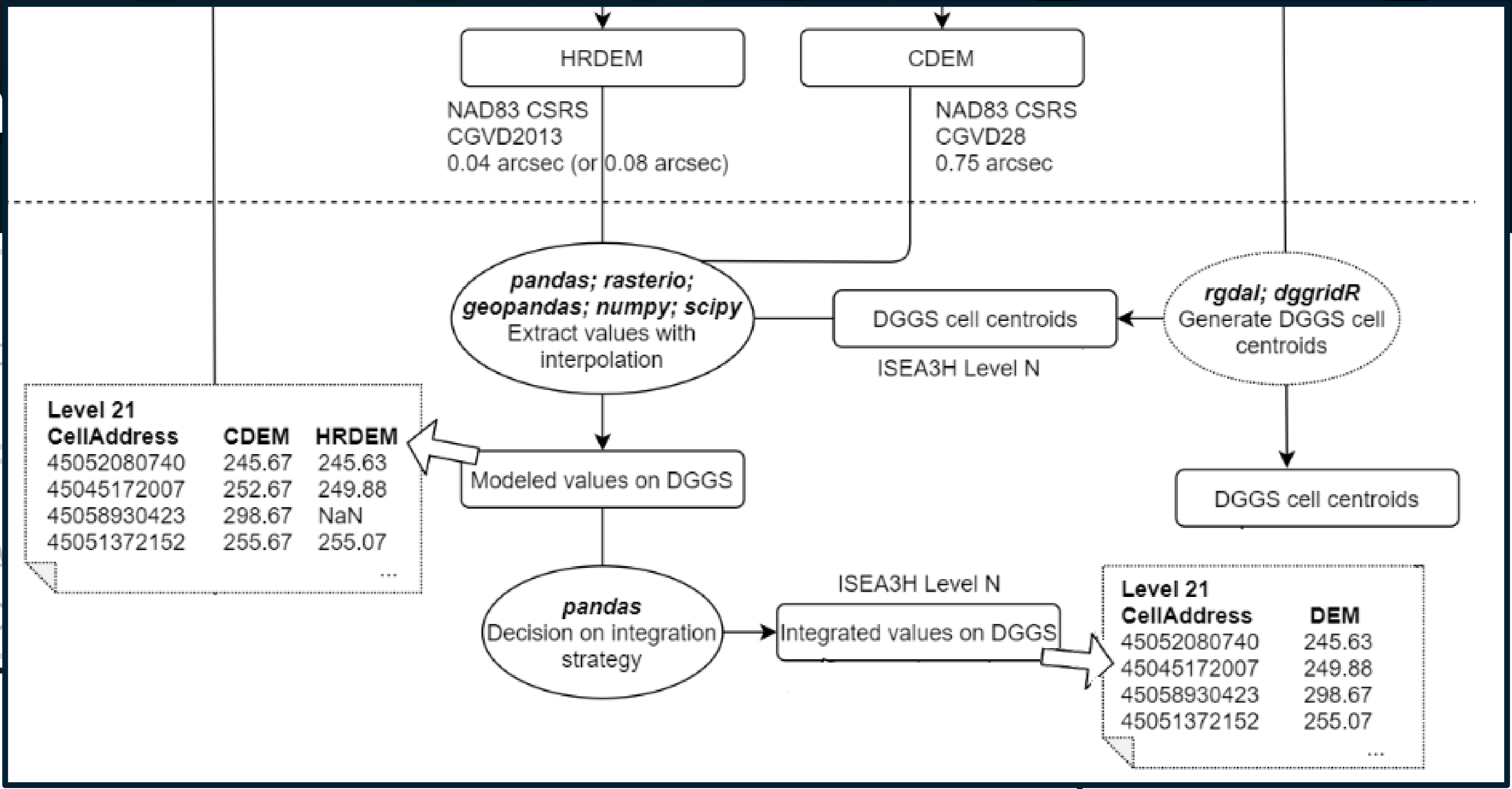


Data Acquisition
- CDEM: Geospatial-Data Ext
- HRDEM: Download directo

Pre-processing
- al datum: NA
- datum: CGVD

Level 29 ~ 0.74 m²
Level 16 ~ 1.2 km²

Quantization
- Cell centroids
- Levels 29-16: Resample with interpolation; integration

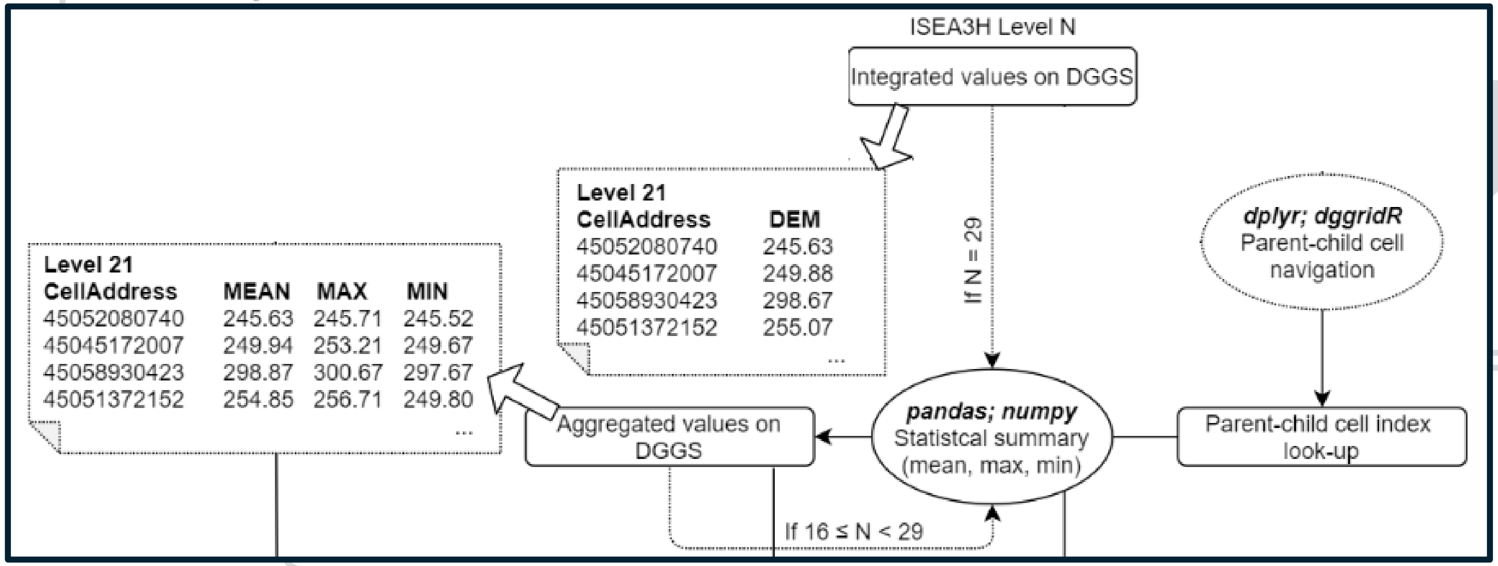
Aggregation
- an / max / min

Levels 28-16
Reduce vertical resolution

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

Methodology – Workflow

Data Acquisition



Different application purposes

Aggregation

- Levels 28-16: mean / max / min

Quality Control

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Methodology – Workflow

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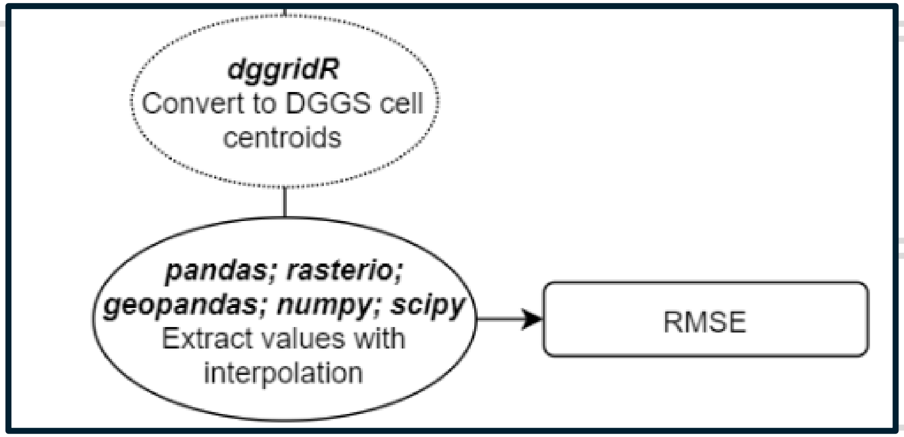
- HRDEM: Download directory / HRDEM Mosaic

Pre-processing
- Horizontal datum: NAD83 CSRS
- Vertical datum: CGVD2013



Data accuracy indicators in metadata

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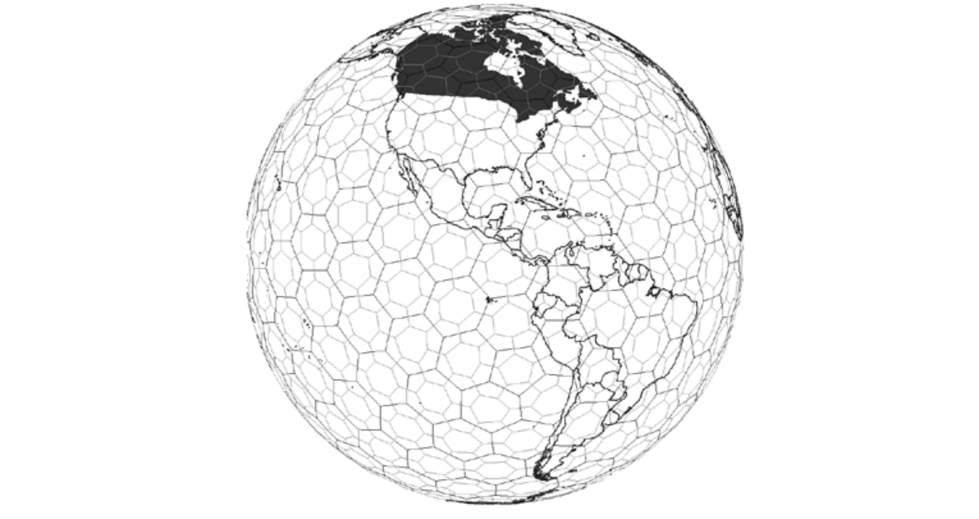
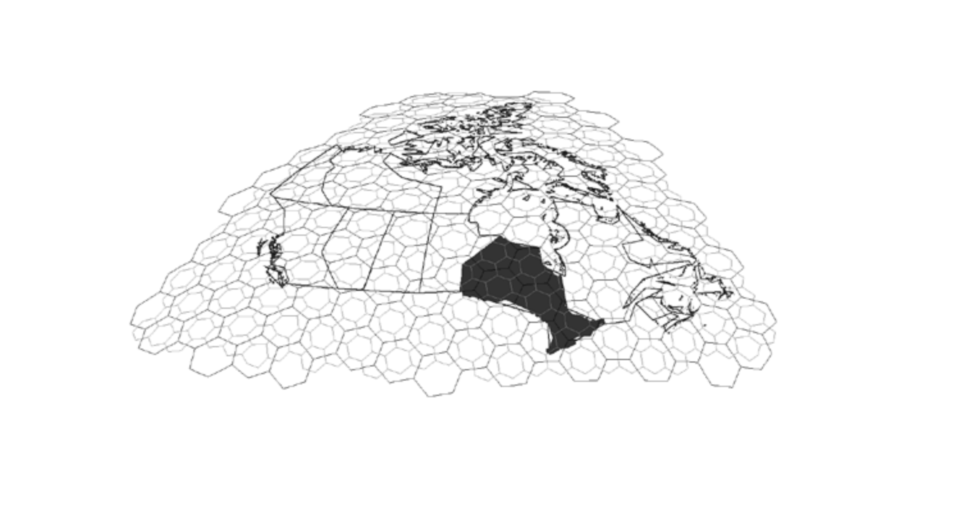
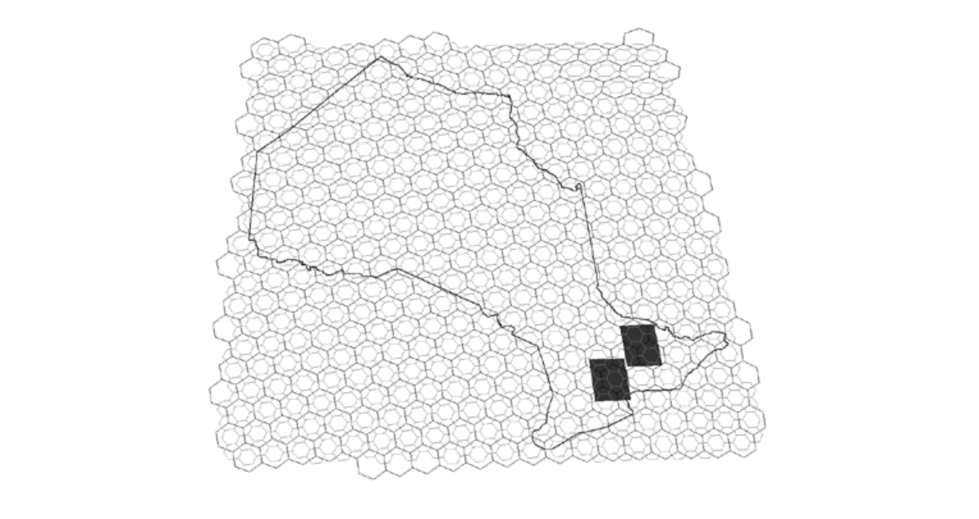
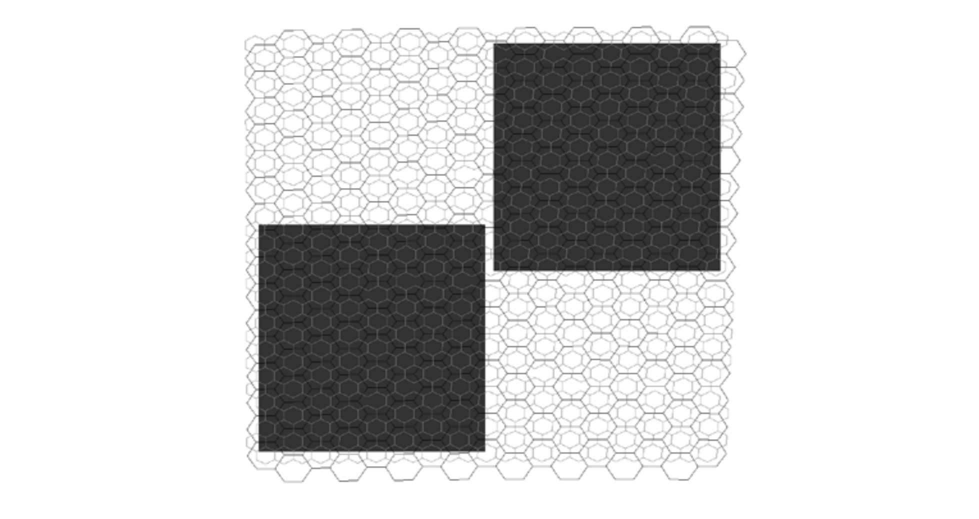
- Pre-DGGS elevations vs. Post-DGGS elevations

Experiment – Study area



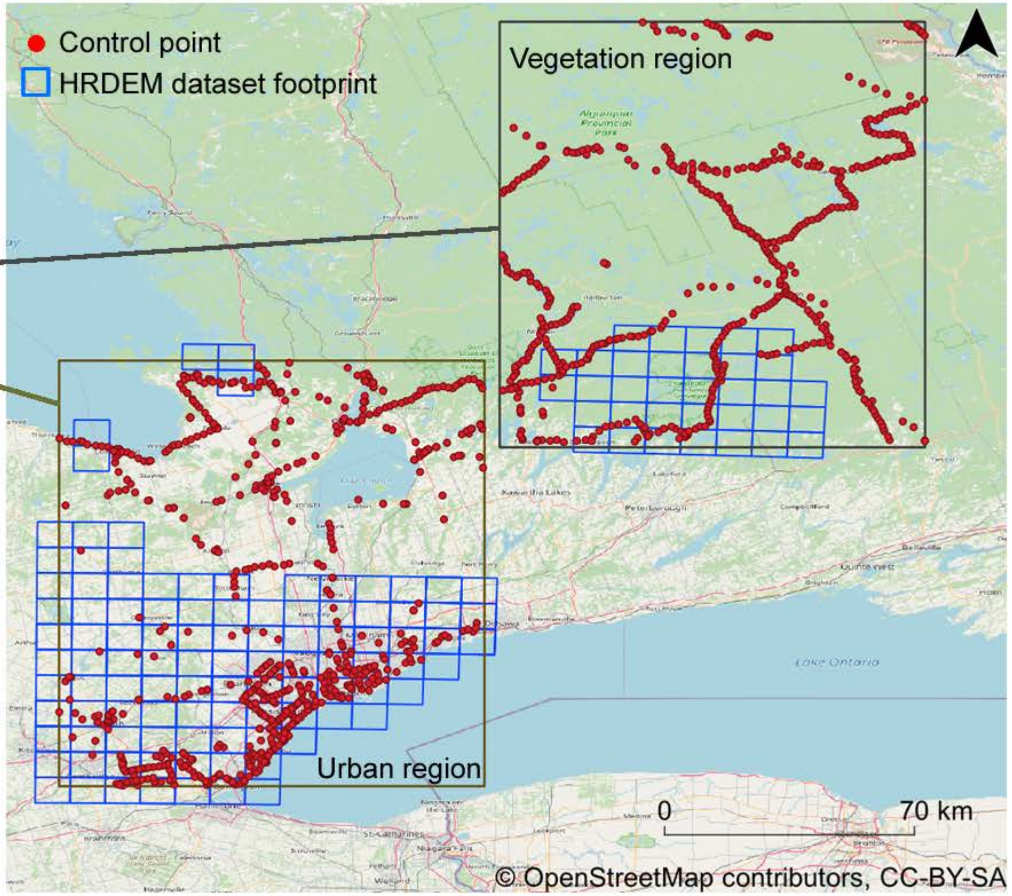






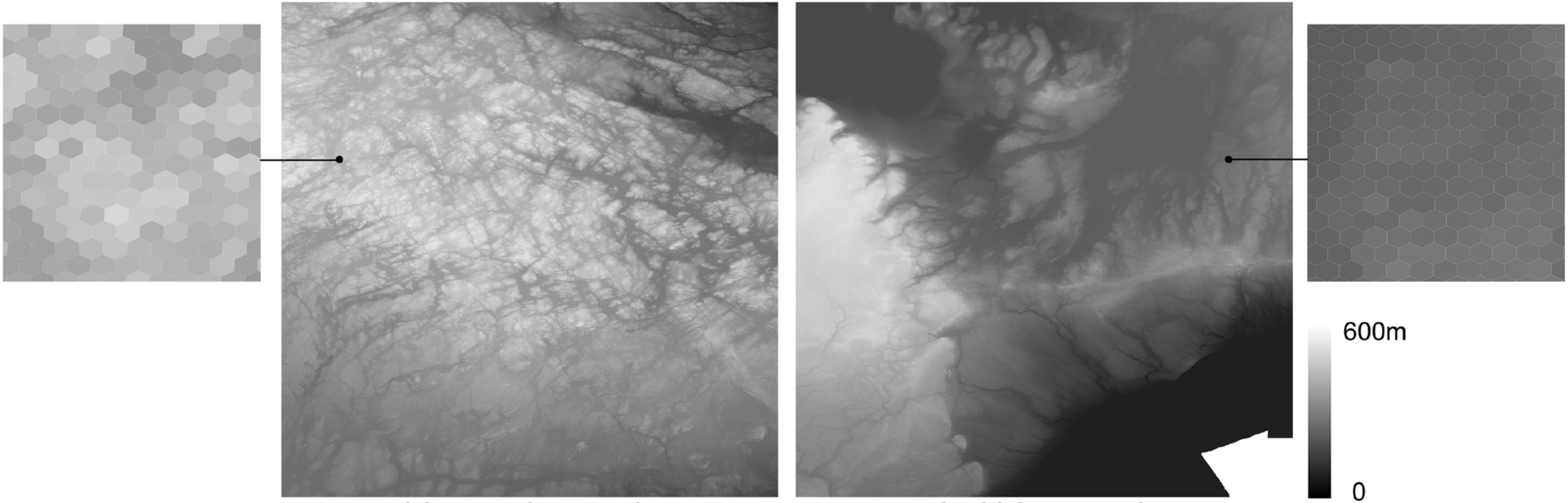
Experiment – Study area

- ❖ *Ministry of Natural Resources and Forestry, Ontario*



Experiment – Results (quantization)

Level 29

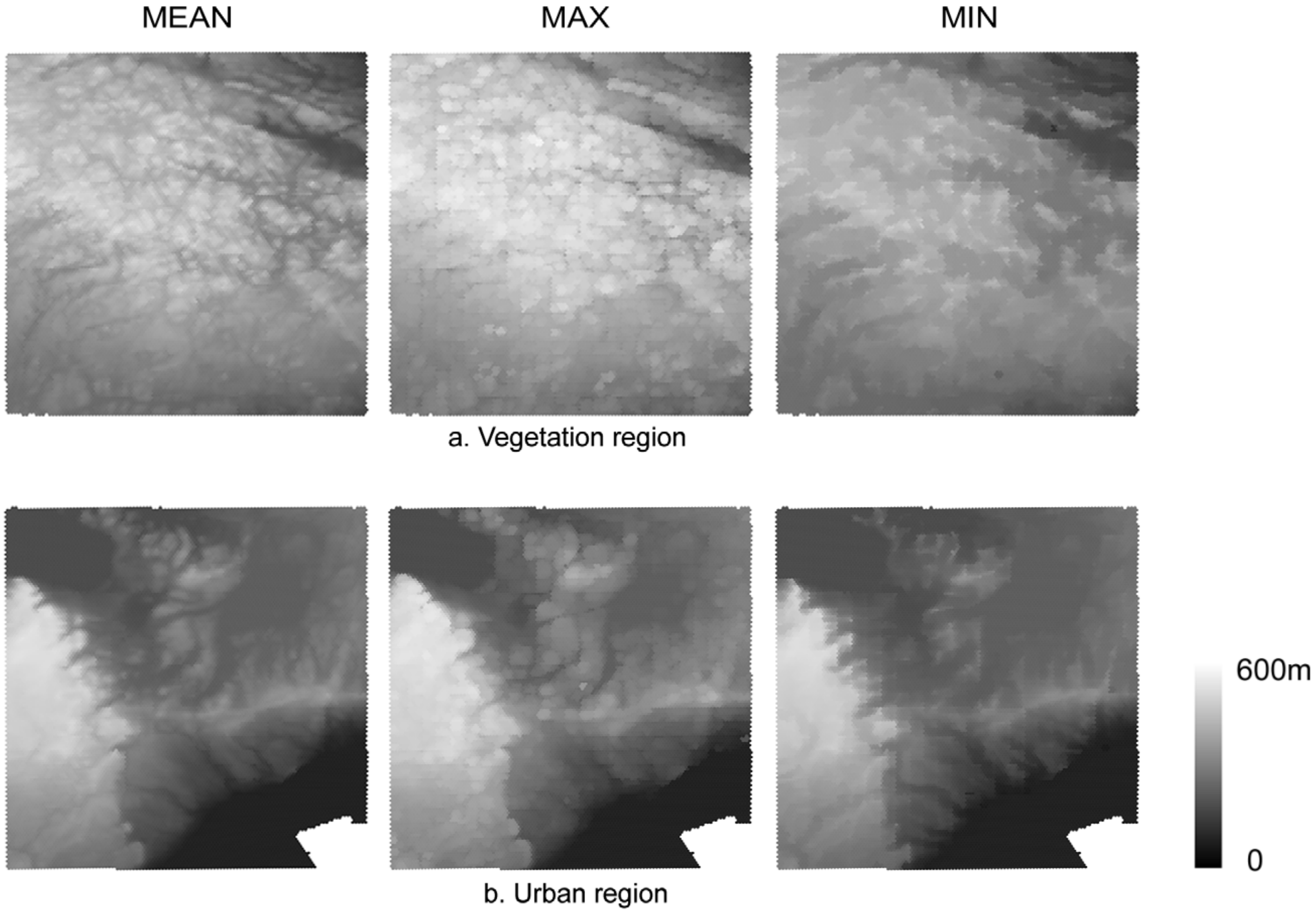


a. Vegetation region

b. Urban region

Experiment – Results (aggregation)

Level 16



Experiment – Results (RMSE)

<u>GCP vs Pre-DGGS</u>

Vegetation area

- HRDEM ~ 4.9m (n = 72/510)
- CDEM ~ 6.4m (n = 438/510)

Urban area

- HRDEM ~ 3.7m (n = 429/746)
- CDEM ~ 3.8m (n = 317/746)

Resolution Level	GCP versus Post-DGGS		Pre-DGGS versus Post-DGGS	
	Vegetation	Urban	Vegetation	Urban
16	14.679	9.625	14.440	9.203
17	12.026	6.517	12.091	5.824
18	9.492	4.762	7.655	3.608
19	7.973	3.944	5.345	2.725
20	6.767	4.075	3.391	1.902
21	6.233	3.862	2.227	1.351
22	6.374	3.737	1.366	0.985
23	6.310	3.842	1.039	0.657
24	6.371	3.745	0.759	0.487
25	6.258	3.773	0.142	0.276
26	6.265	3.750	0.072	0.178
27	6.261	3.762	0.052	0.140
28	6.264	3.754	0.073	0.099
29	6.258	3.745	0.051	0.039

Impact of the research

Set the stage for a national elevation service across various scales for Canada

- Complete coverage over the country
- Improve the data quality than the pure CDEM data
- Save end-users' time on pre-processing
- Provide consistent base terrain data
- Multi-resolution options
- Avoid the projected terrain rasters
- No voids over the waterbody

Take-home messages

1. Exploring the utility of DGGS for enabling a national elevation service for Canada
2. DGGS are advantageous because of discrete, uniform, spherical, and hierarchical cells
3. Future work includes analytical functions in DGGS, DGGS-powered datacube, support decision-making

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Question?

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