National Terrain Data Management on Discrete Global Grids in Canada

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OUTLINE

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- Terrain Data sources in Canada
- Research statement
- Research objectives

Methodology

- DGGS configuration
- Workflow
- Study area

Preliminary results and future work

Impact of the research

Take-home messages

Introduction – Understanding of DGGS

- **Discrete Global Grid System**
- Initial polyhedron, cell geom
  projection/spherical subdivision
- Index, reference point, quantization, spatial query, interoperability, (advanced spatial analysis)
- Data integration, multi-scale analysis, consistent observation, accurate analysis, parallel computation
- Potential application domains

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

- *Open Geospatial Consortium (OGC), 2017*
- *Alderson et al., 2020*

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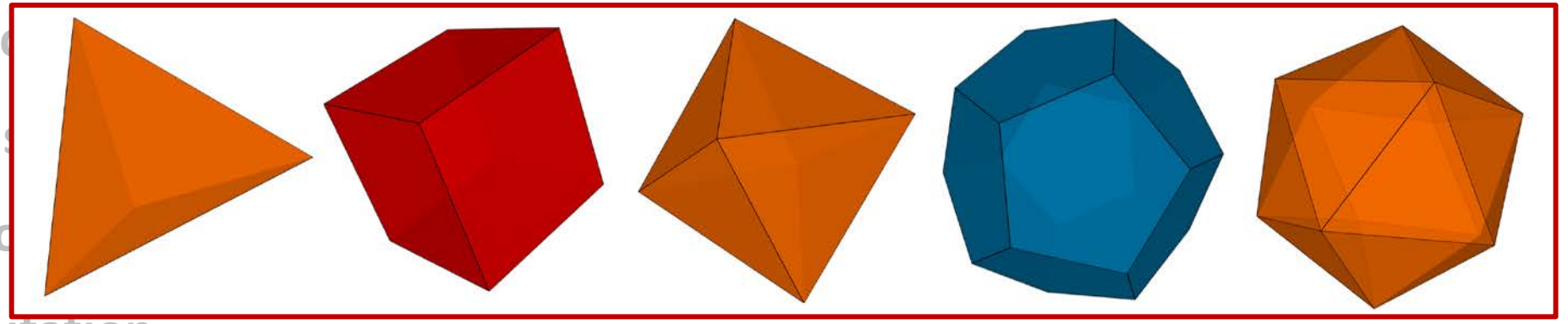

❖ *Sahr et al., 2003*
❖ *Mahdavi-Amiri et al., 2015*

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❖ *Peterson, 2016*
❖ *Goodchild, 2018*

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- **Potential application domains**
  - Multi-source terrain data management
  - Polar-region resource management
  - Multi-source point clouds management
  - Sensor networks' unified management

❖ *Dutton, 1989*
❖ *Goodchild, 2018*
❖ *Sirdeshmukh et al., 2019*
❖ *Purss et al., 2017*

Introduction – Terrain Data sources in Canada

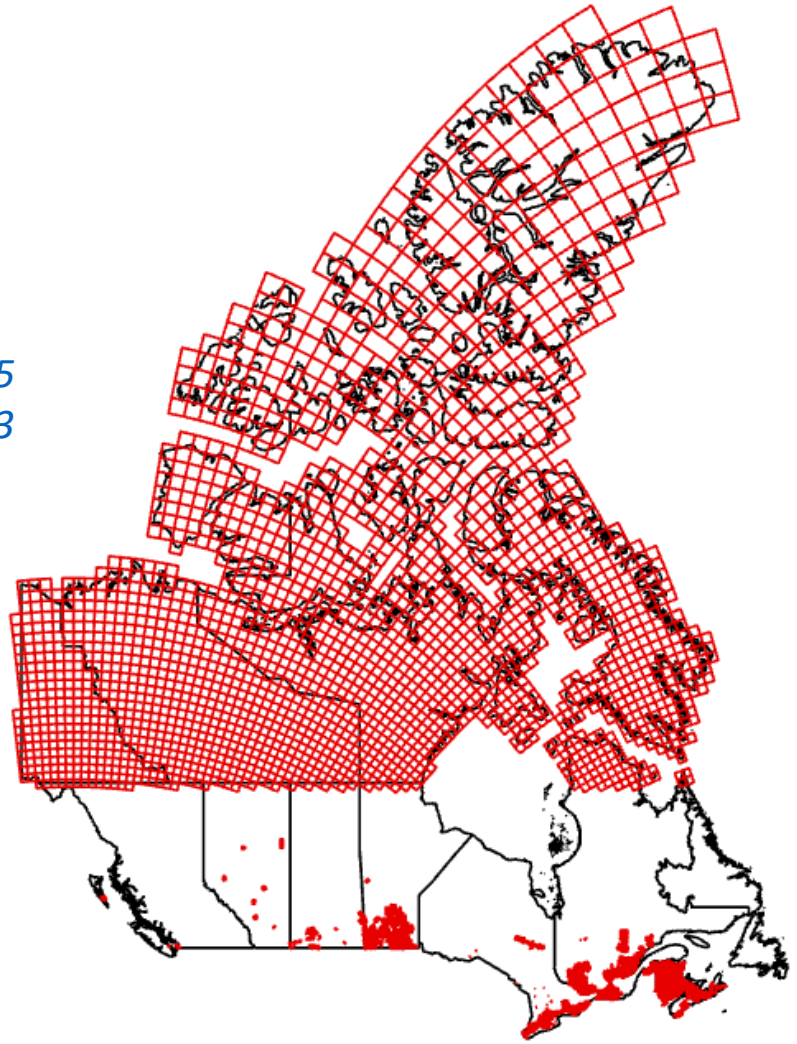
Existing terrain datasets by NRCan

- **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)

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



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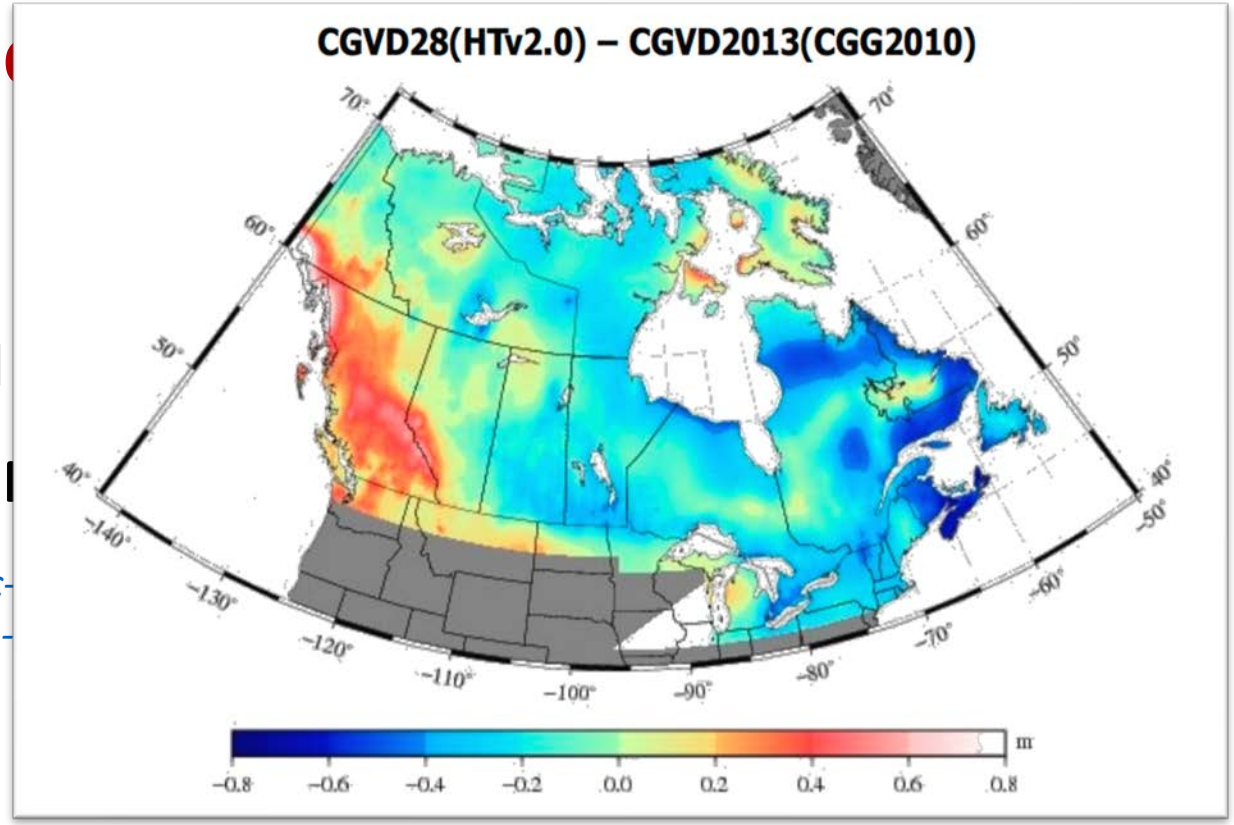

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❖ *https://www.pxw1.snb.ca/snb7001/e/PDF/presentationANBL-e.pdf*

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GEOGRAPHIC AREA		A (Lat. < 68°)	B (68° < Lat. < 80°)	C (80° < Lat. < 90°)
RESOLUTION (latitude and longitude in arc seconds)	Base:	0.75" x 0.75"	0.75" x 1.5"	0.75" x 3.0"
		1.5" x 1.5"	1.5" x 3.0"	1.5" x 6.0"
		3.0" x 3.0"	3.0" x 6.0"	3.0" x 12.0"
		6.0" x 6.0"	6.0" x 12.0"	6.0" x 24.0"
		12.0" x 12.0"	12.0" x 24.0"	12.0" x 48.0"

Table 1 – Resolution of CDEM Data Based on Geographic Area

Main differences (CDEM vs. HRDEM)

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❖ *http://ftp.maps.canada.ca/pub/nrcan_rncan/elevation/cdem_mnec/doc/CDEM_product_specs.pdf*

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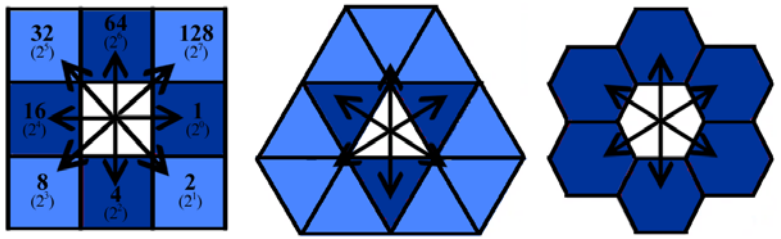
Introduction – Problem statement

From the perspective of DGGS applicability…

- **Insufficient attention in GIS community**
- **Nascent period of supporting decision-making**
- **Limited development of analytical algorithms**
- **Single-resolution usage**



From the perspective of Canadian terrain data management…

- **Multiple sources**
- **Duplicated pre-processing**
- **Inconsistent results**

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From the perspective of Canadian terrain data management…

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Introduction – Research objectives

Objective1

- Standardize Canadian terrain data at multiple resolutions by using DGGS

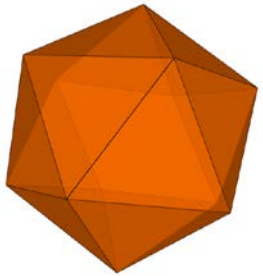
Objective2

- Use in-database DGGS analytics to generate geographical products, focal statistics products, and hydrological products

Objective3

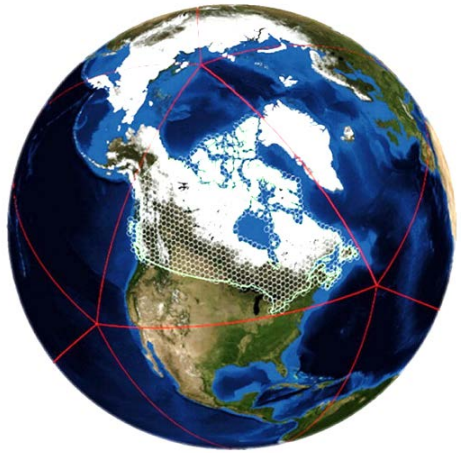
- Apply the terrain data modelled on DGGS to flood susceptibility mapping with different granularities

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*

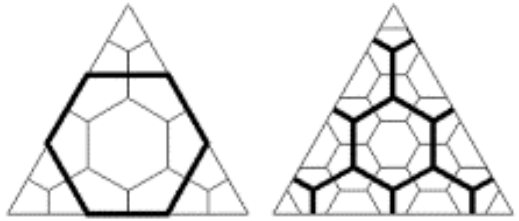


ISEA3H

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

Aperture 3
Smoother transition
Monotonical convergence
❖ *Sahr et al., 2003*
❖ *Mahdavi-Amiri et al., 2015*

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



Methodology – Workflow

Integration of multi-source terrain data on Discrete Global Grids in Canada

Pre-processing

- Standardize the horizontal datum to NAD83 CSRS
- Standardize the vertical datum to CGVD2013

DGGS modelling

- Construct grids/cell centroids
- Lowest level (28): extract with interpolation
- Upper levels (27-16): extract with interpolation/statistically summary

Quality control

- Quantization of ground control points
- Calculate and compare post-DGGS RMSE & pre-DGGS RMSE

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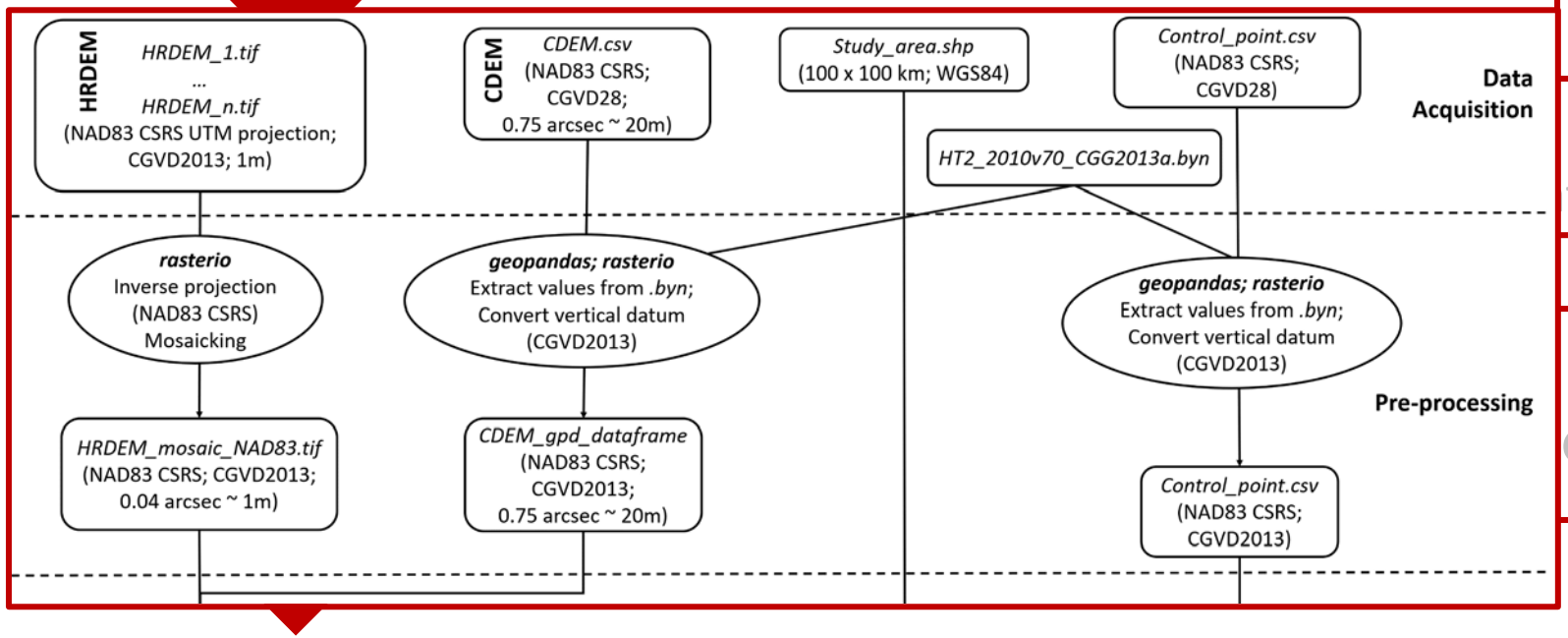

Avoid projected DEM

- Flexibility when handling HRDEM
- Fewer computational errors

tistically summary

GS RMSE

Methodology – Workflow

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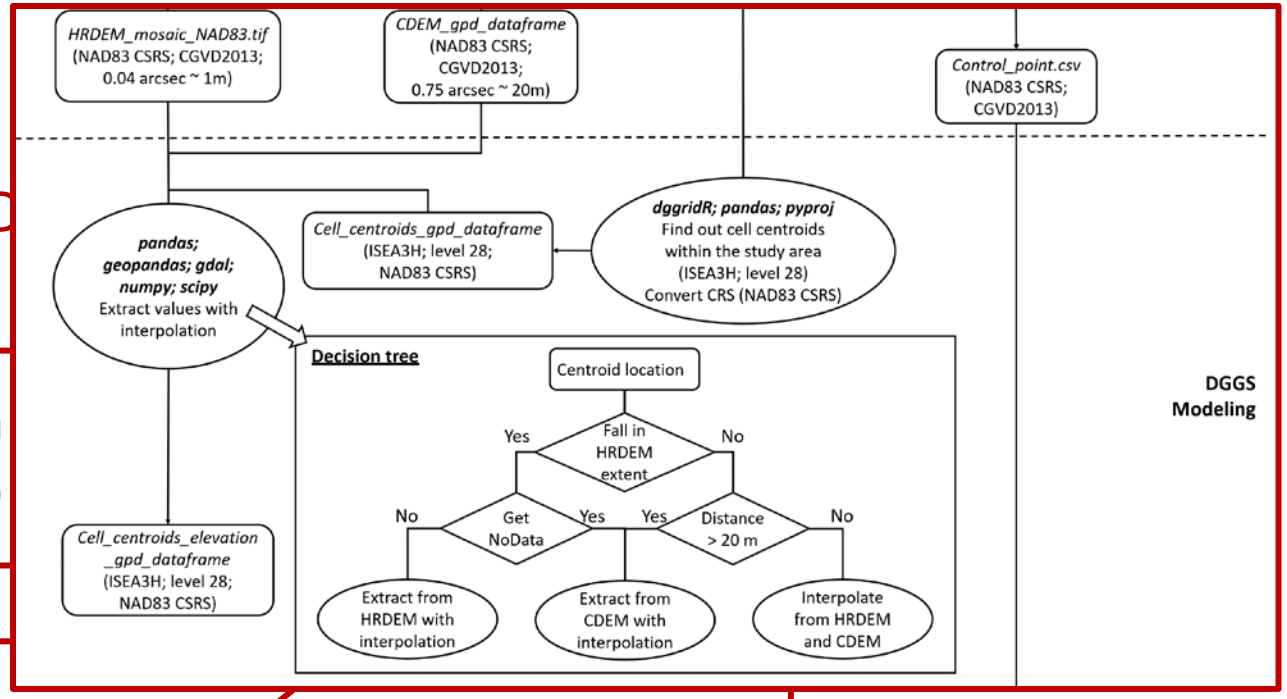

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Reduce vertical resolution

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Methodology – Study area

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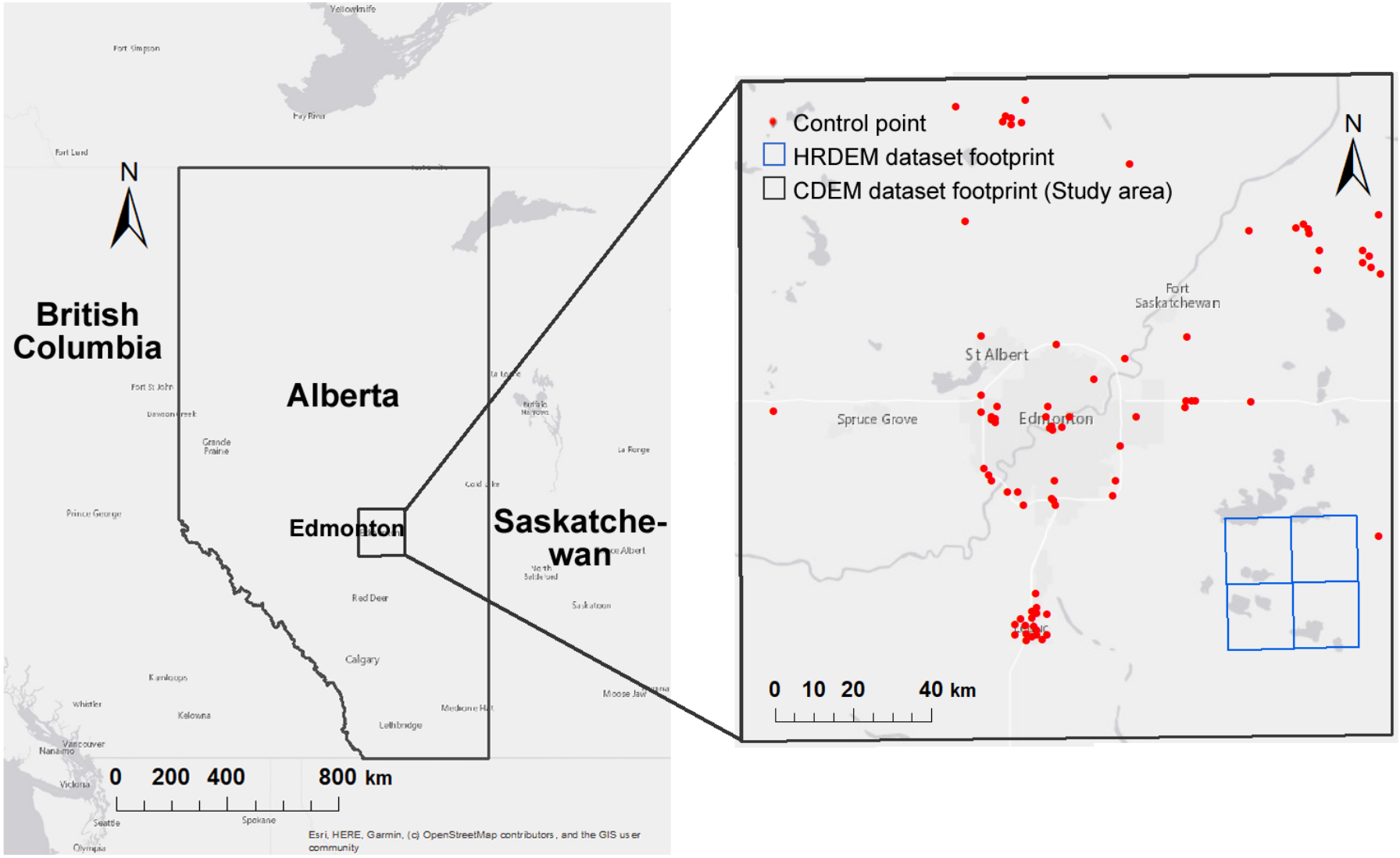


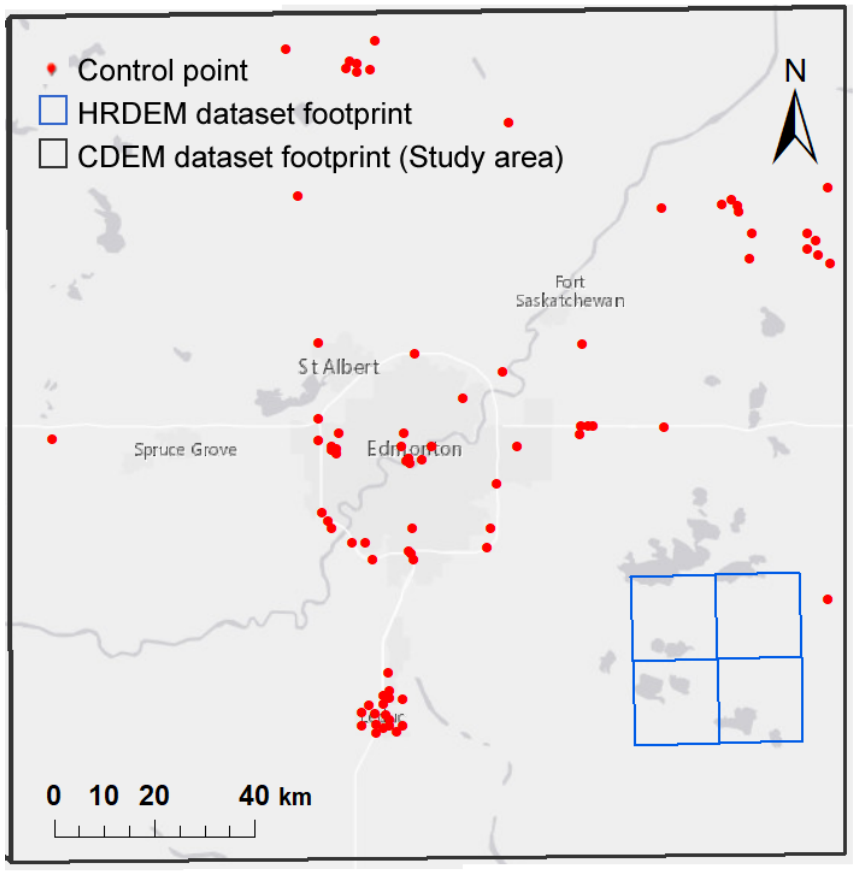
Preliminary results and future work

Preliminary results

- **Resolution level 28**
- **82 control points**
- **Post-DGGS RMSE = 9.04 m**
- **Pre-DGGS RMSE = 9.10 m**

Future work

- Other DGGS configurations
- Quantization at upper levels
- Test the algorithms on a study area
- Spatial analysis algorithms in DGGS
- Application in the real-world



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slope aspect hill-shade	max min median range standard deviation	depression filling flow direction flow accumulation
Topographic analysis 1	Focal statistics 2	Hydrological analysis 3

Future work

Objective1
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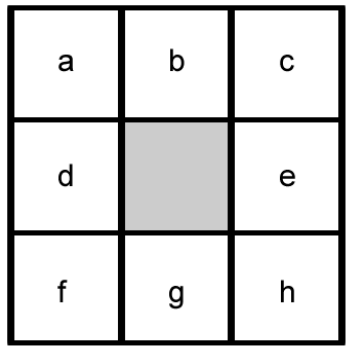
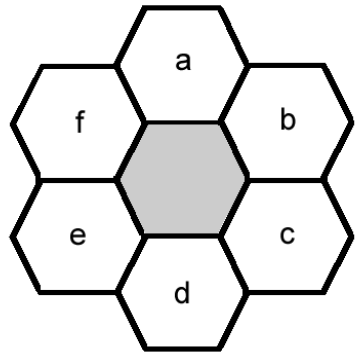
Objective2 ← • **Spatial analysis algorithms in DGGS**

Objective3 ← • Application in the real-world





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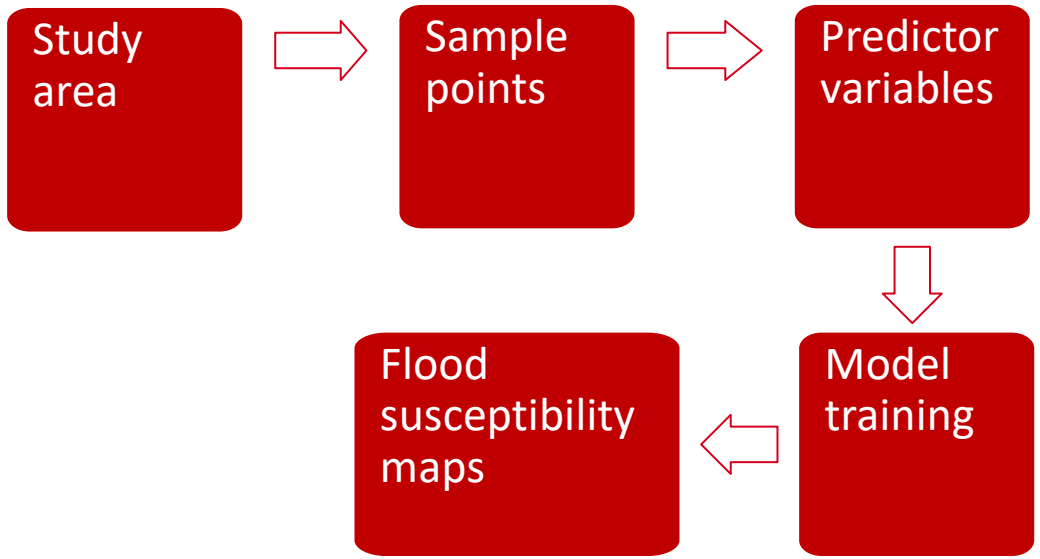

Impact of the research

From the perspective of DGGS applicability…

- **integrate multi-source data**
- **archive multi-resolution data**
- **conduct in-database analytics**
- **support real-world decisions**

From the perspective of Canadian terrain data management…

- **complete coverage over the country**
- **improve the data quality than the pure CDEM data**
- **saves end-users' time on pre-processing**
- **provides consistent base terrain data**
- **multi-resolution options**
- **avoid the projected terrain rasters**
- **no voids over the waterbody**

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Take-home messages

1. CDEM and HRDEM are integrated on DGGS at multiple resolutions, which will benefit the end users.
2. Quality control is done by calculating RMSE between the modelled elevation values and the ground survey elevations.
3. Applicability of DGGS is explored in solving real-world problems and supporting decision-making.
4. Other explorations and the rest of the work are in progress.

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Question?

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