Analytical operations for terrain data modeled in Discrete Global Grid Systems

CCA | May 25th, 2022

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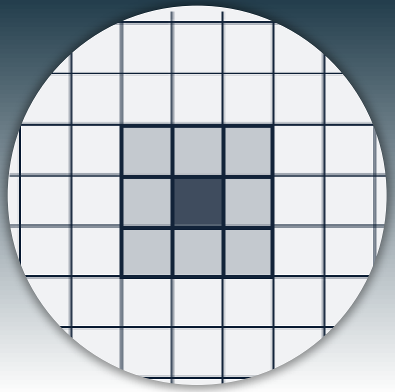
Introduction – Existing research/tools



Map Algebra in Square Grids

- Local
- Focal
- Zonal

❖ *Tomlin, 1990*

Hydrology in Hex Meshes

- HexWatershed

  (Pacific Northwest National Laboratory)

❖ *Liao et al., 2020; 2022*

Development of DGGS

- Open-sourced libraries
- Application in real-world

❖ *Li et al., 2021*

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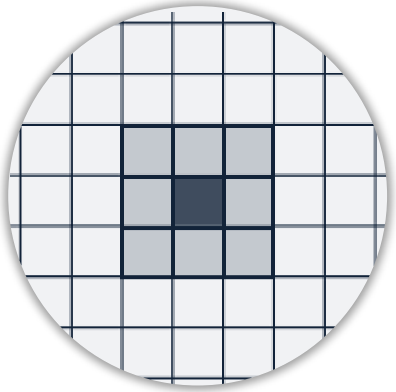

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Introduction – Existing research/tools

Discrete Global Grid Systems

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

❖ *Open Geospatial Consortium (OGC), 2017*

CARTOGRAPHY AND GEOGRAPHIC INFORMATION SCIENCE
https://doi.org/10.1080/15230406.2021.1966648

Taylor & Francis
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Check for updates

Integration of heterogeneous terrain data into Discrete Global Grid Systems

Mingke Li[a], Heather McGrath[b] and Emmanuel Stefanakis[a]

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❖ *Tomlin, 1990*

❖ *Liao et al., 2020; 2022*

Development of DGGS

- Open-sourced libraries
- Application in real-world

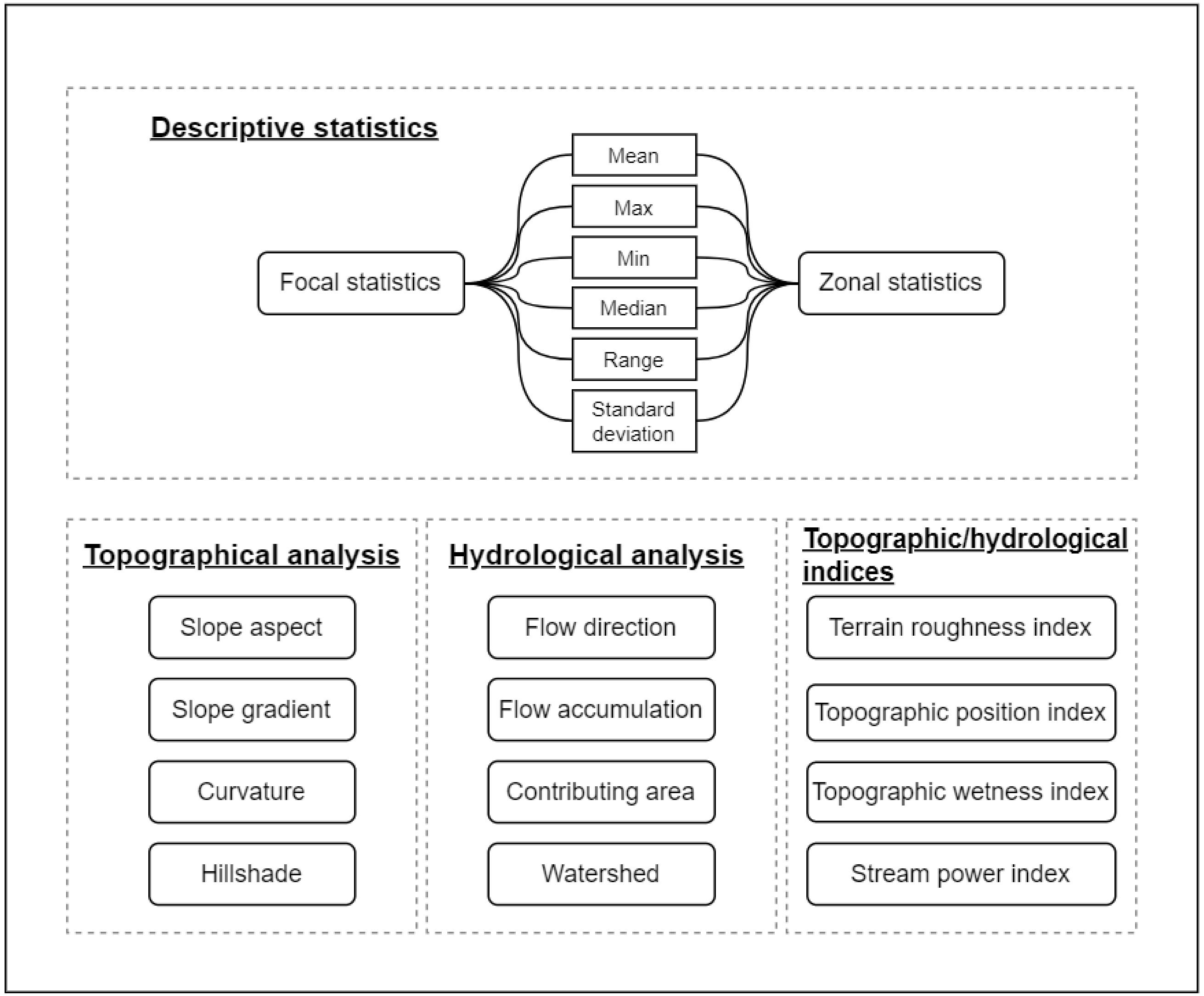
❖ *Li et al., 2021*

Introduction – Objectives

- Develop analytical operations (topographical/hydrological) in hexagonal DGGS.
- Extend Tomlin’s model in a DGGS context.
- Experiment with multiple resolutions and various terrain types.

Introduction – Operation classifications

- **Based on applications**
  - Descriptive statistics
  - Topographical analysis
  - Hydrological analysis
  - Topographic/hydrological indices
- **Based on Tomlin's model in 1990s**
  - Focal / zonal / local
  - Global



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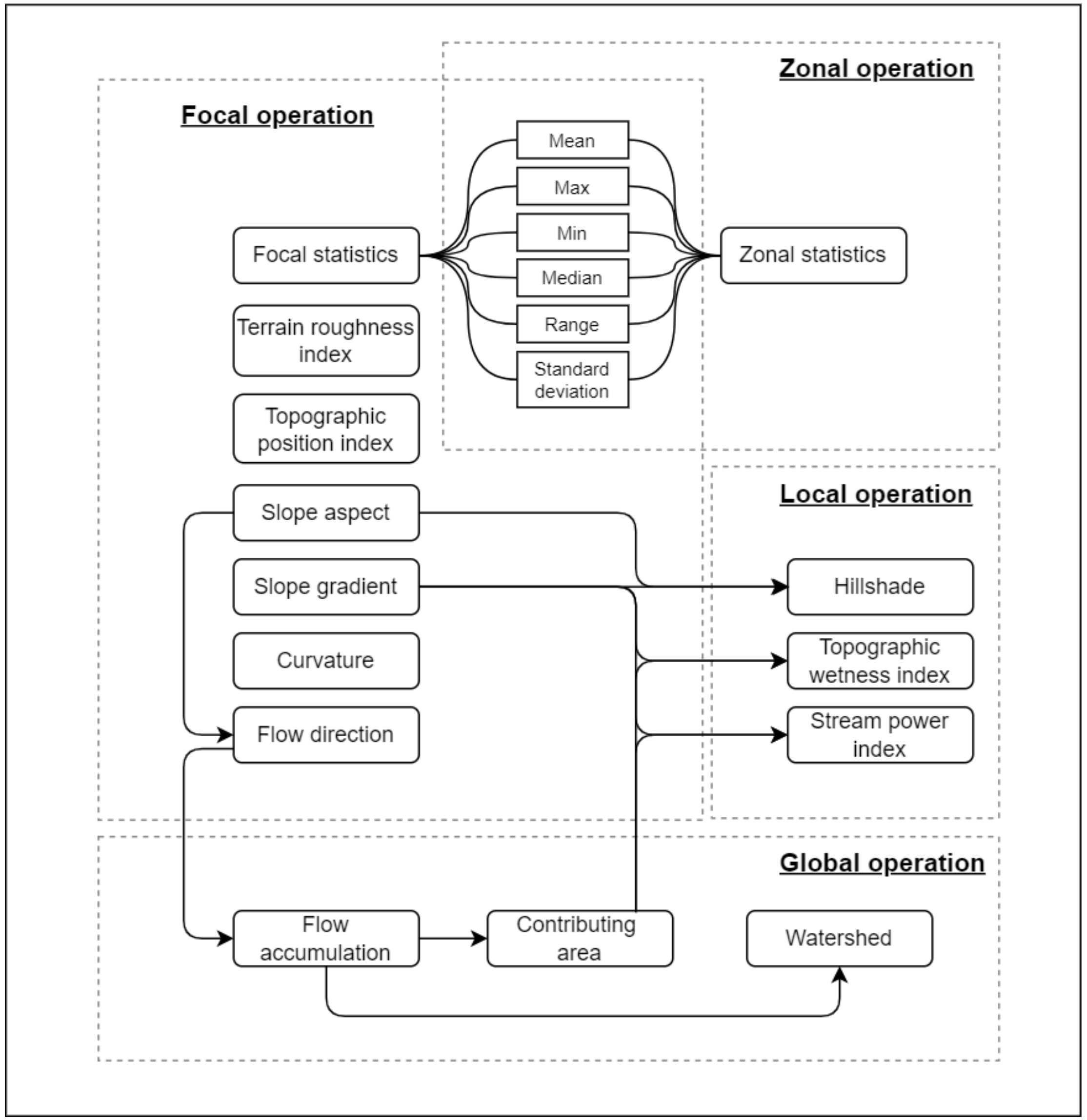
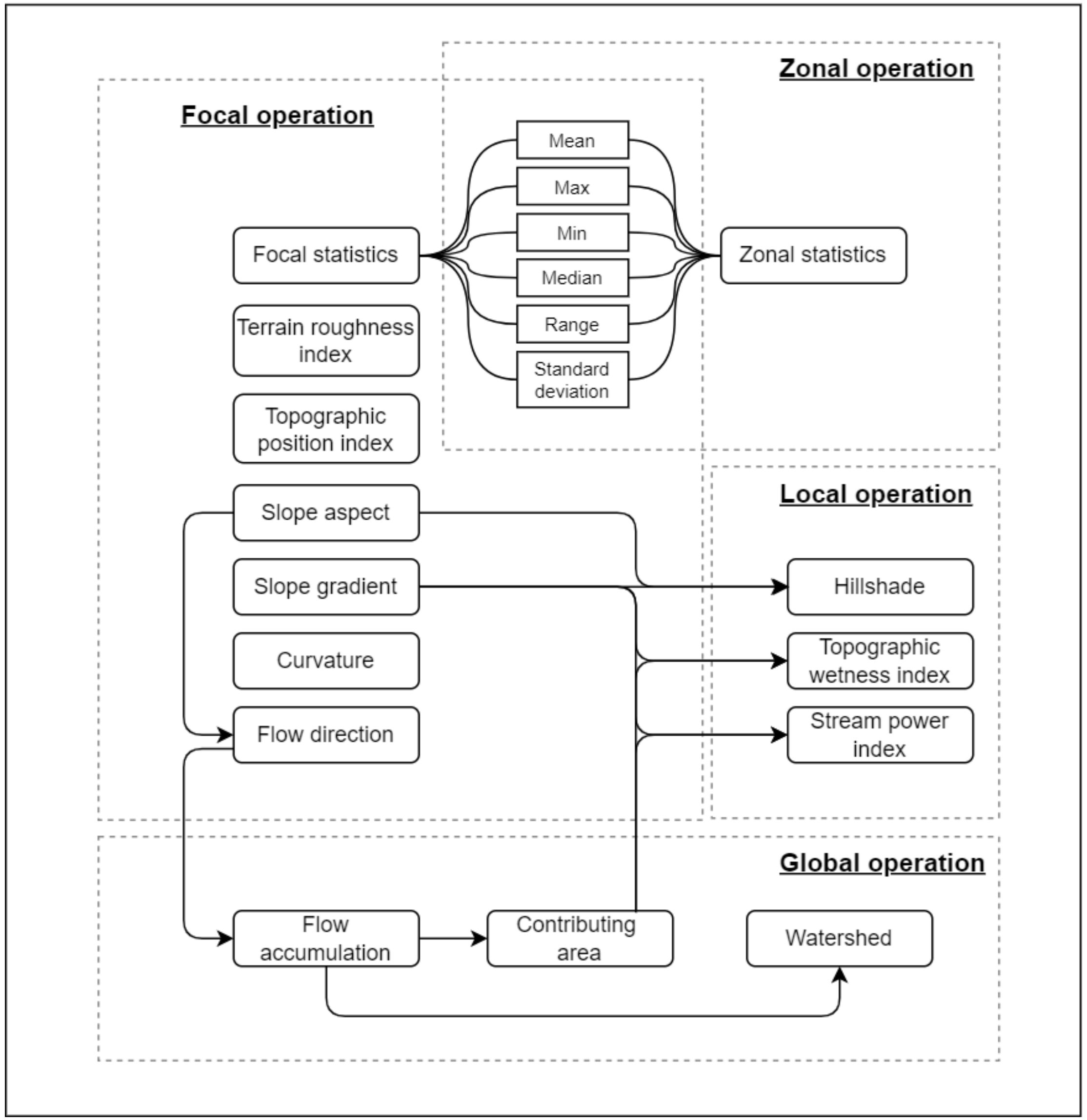


Introduction – Operation classifications

- **Local operations**
- **Focal operations**
  - Neighbor navigation
  - Define neighborhood by #ring
  - Topographic / hydrological analysis – the first ring
- **Zonal operations**
  - Reclassify by zones
- **Global operations**
  - Recursion



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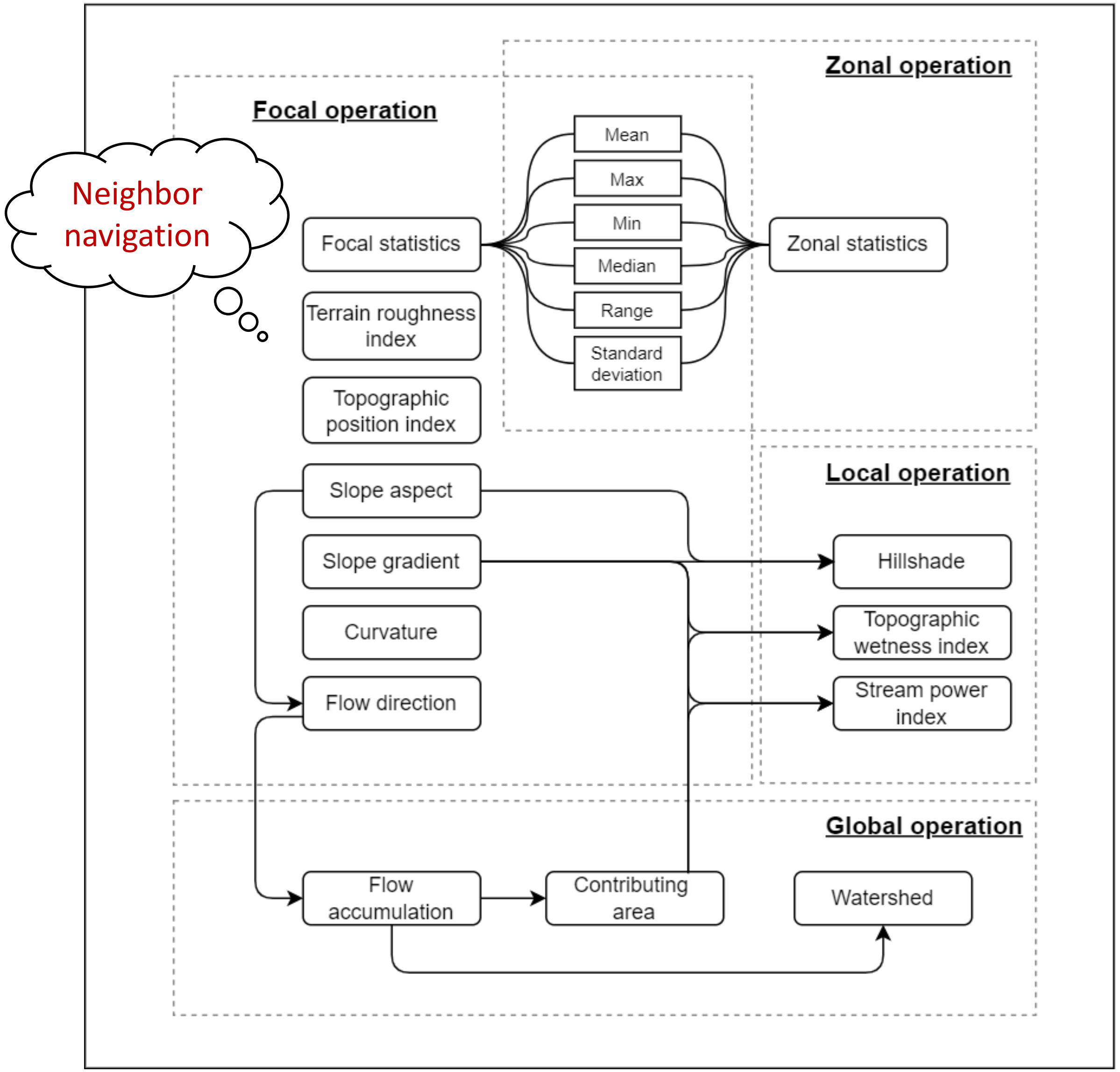

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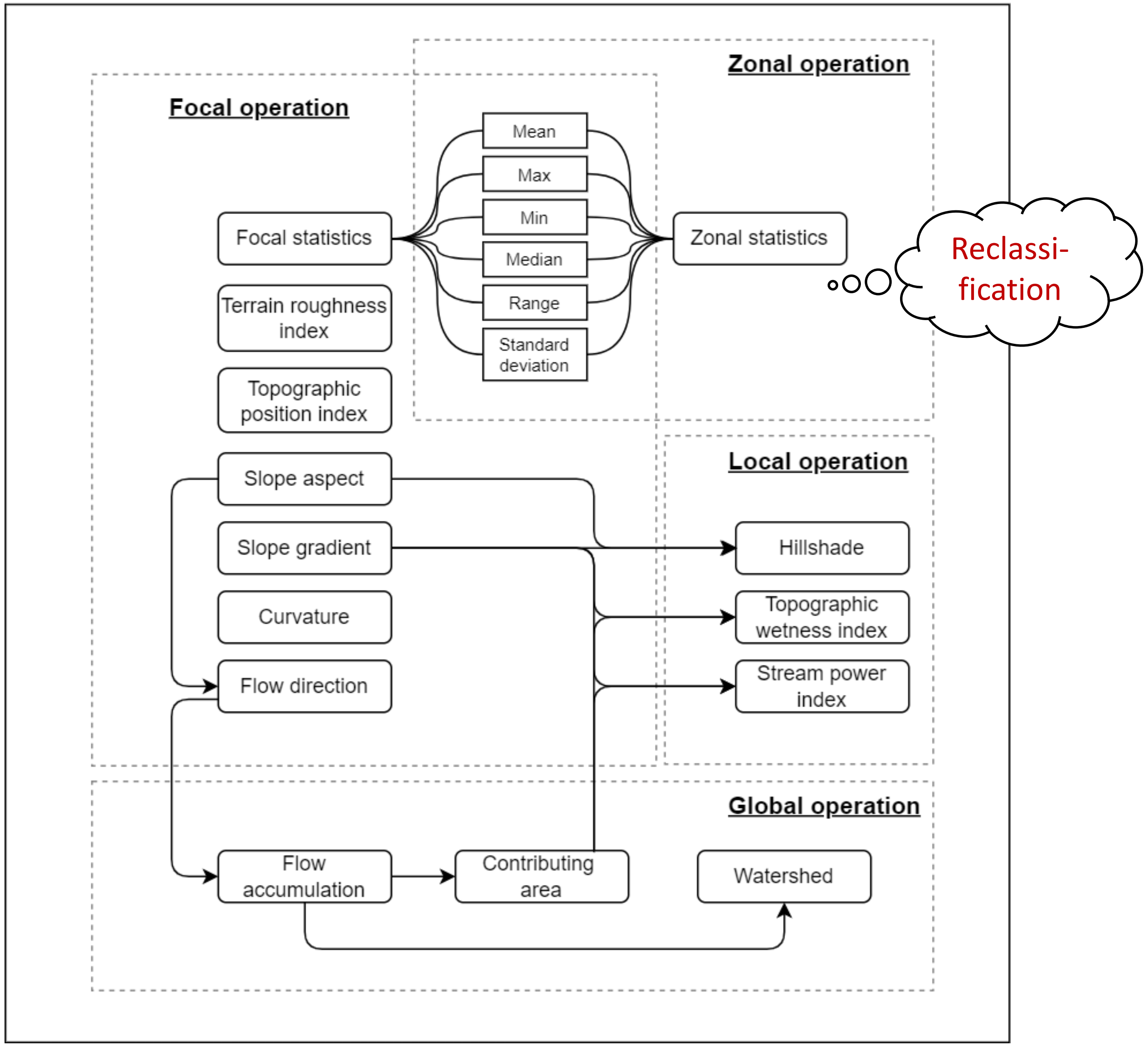

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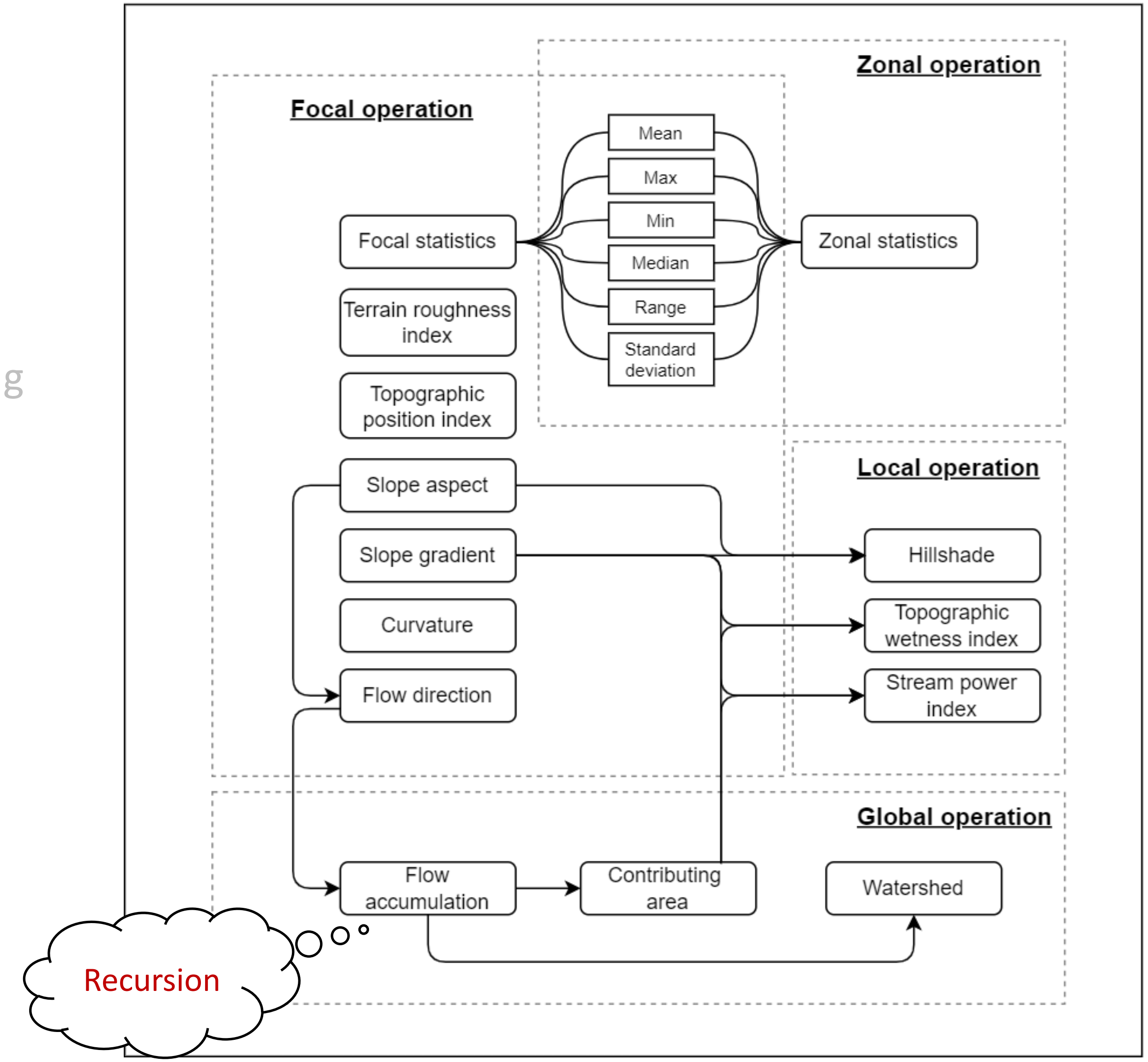
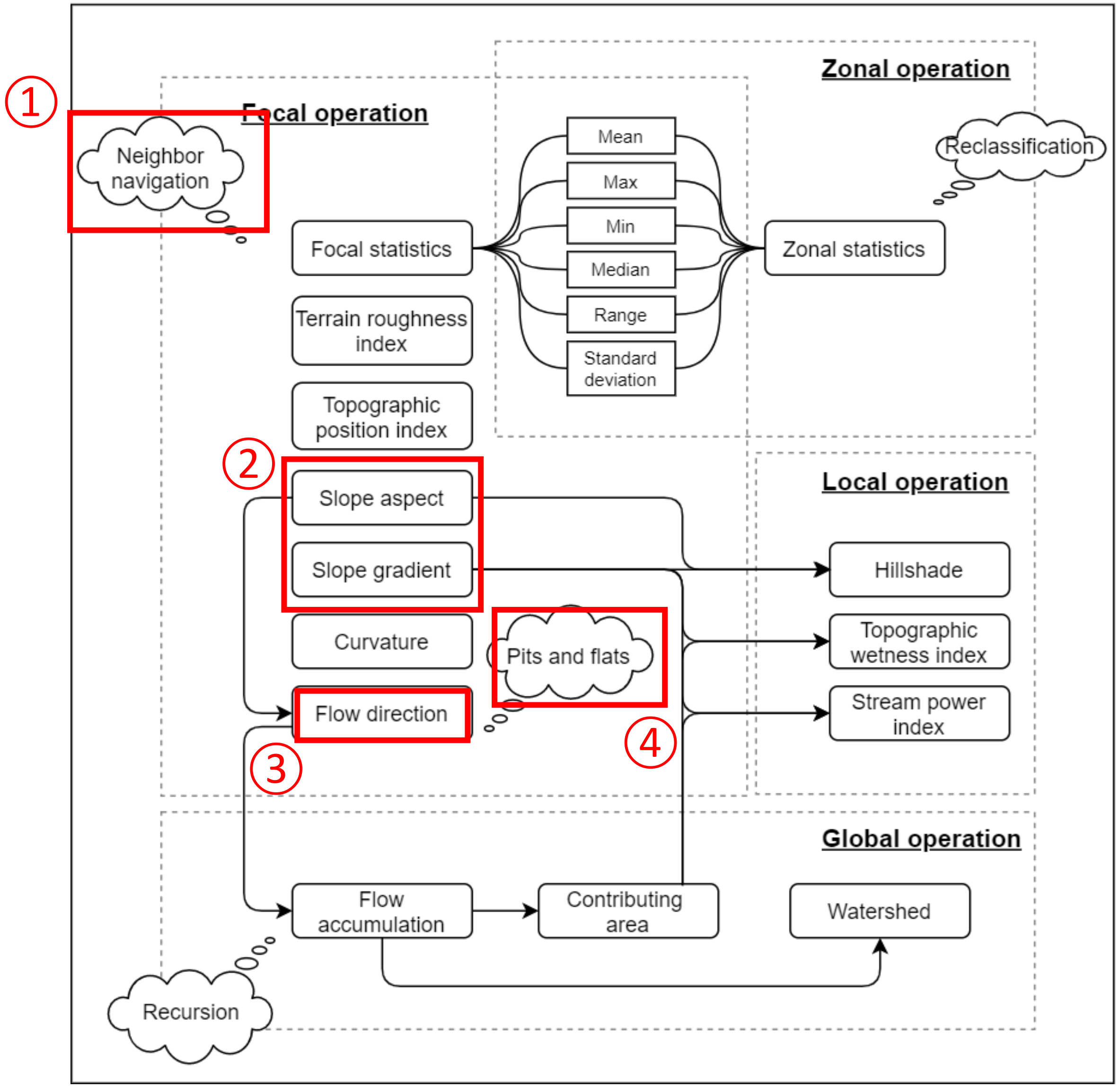


Introduction – Challenges



Methods – DGGS configuration

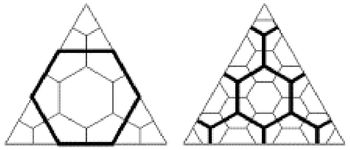
Icosahedron

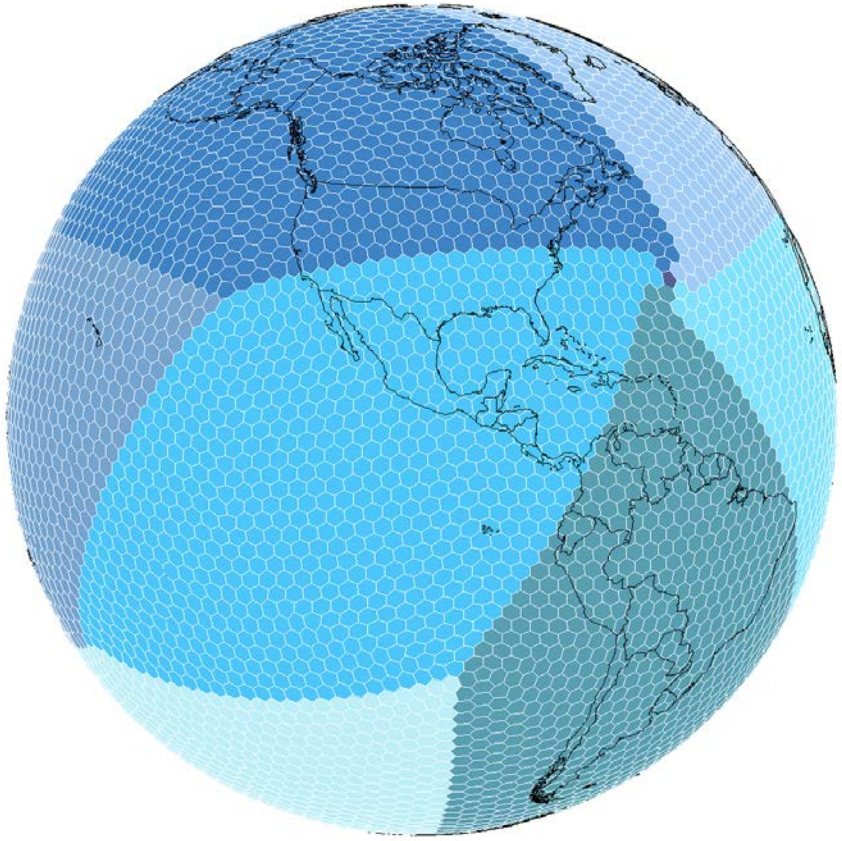
Snyder Equal Area Projection

ISEA3H

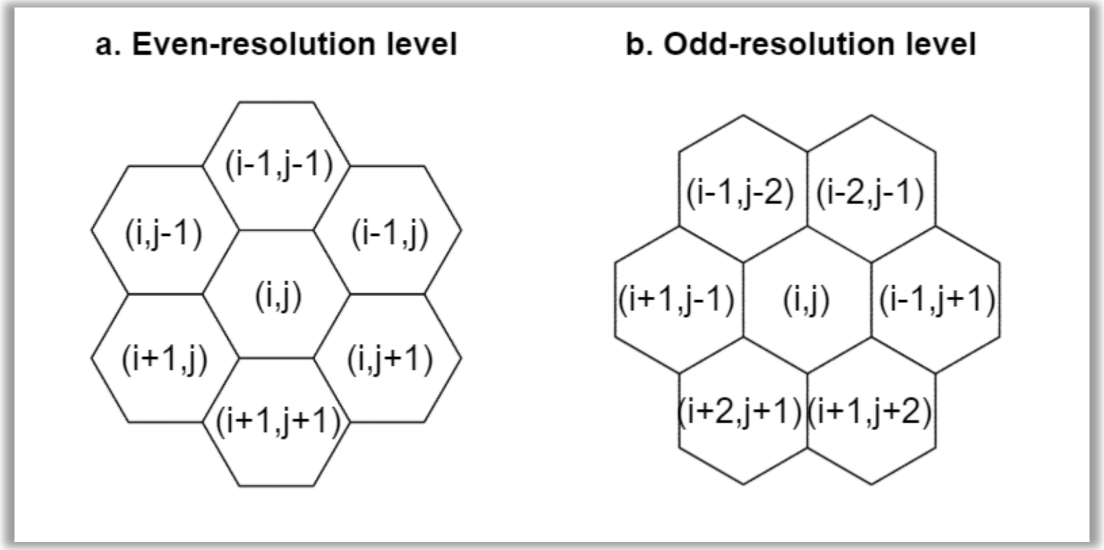
Aperture 3

Hexagon





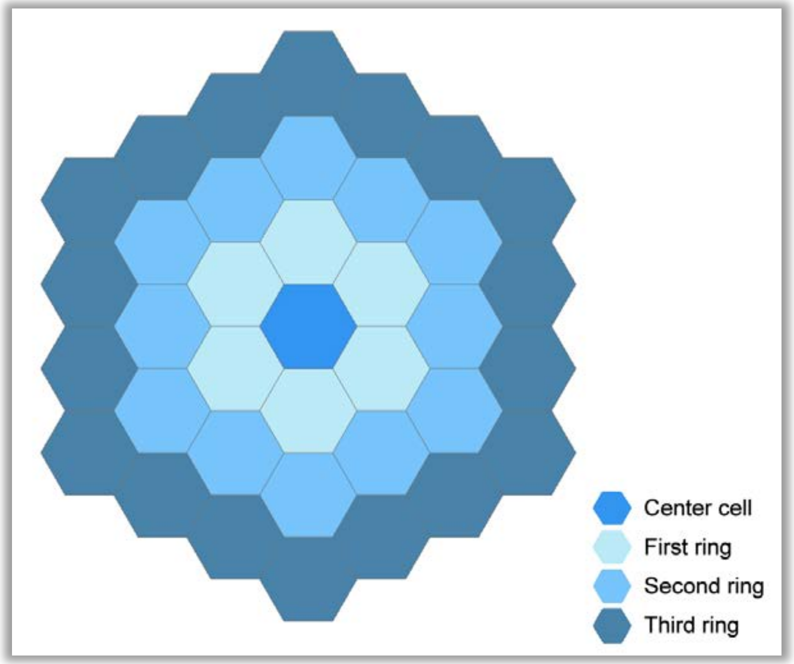
Methods – Neighbor navigation



<u>Q</u>uadrilateral <u>2</u>-<u>D</u>imensional <u>I</u>nteger (Q2DI) indexing

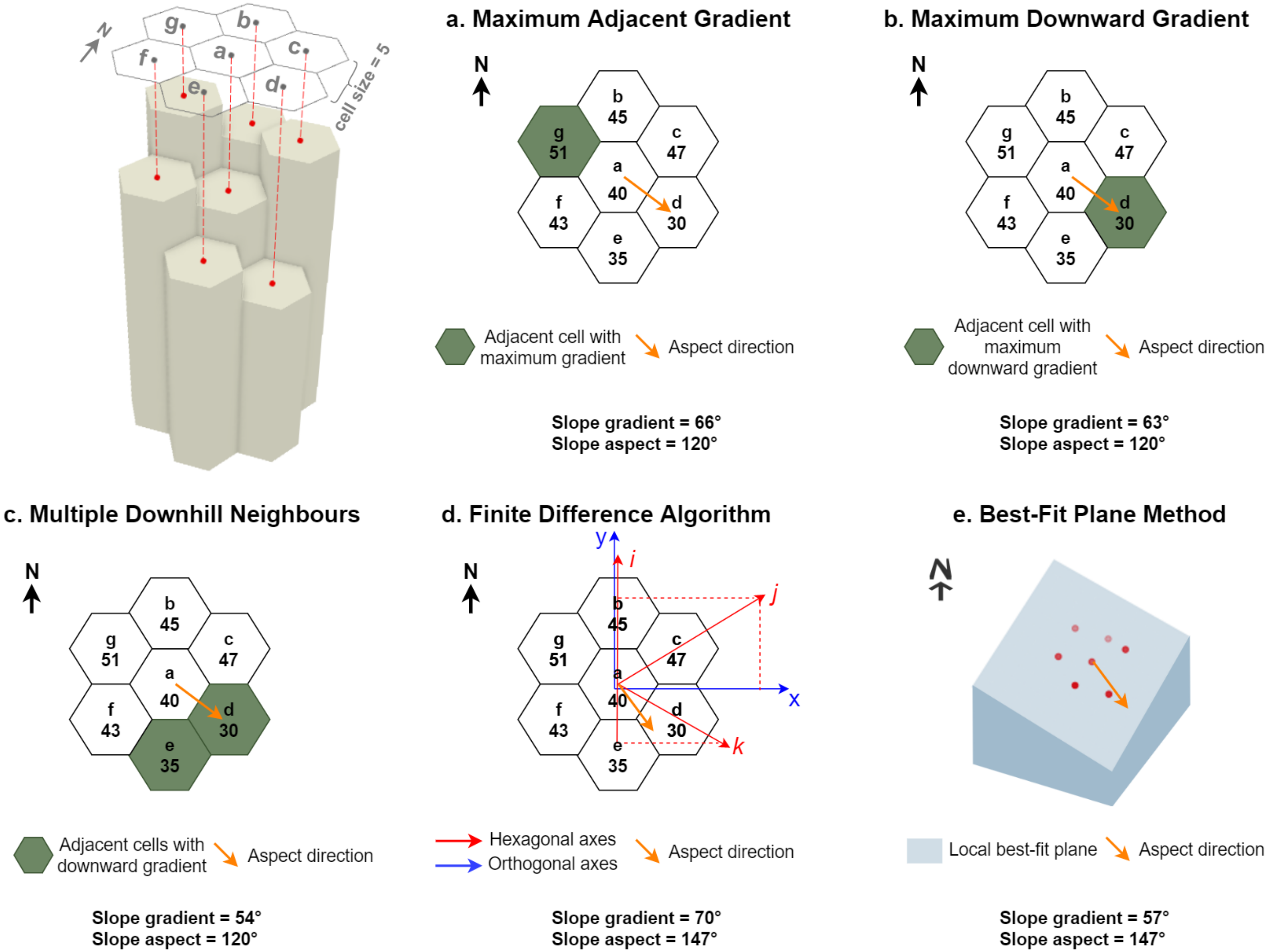
dggridR/DGGRID

❖ *Sahr, 2008; 2019*



Neighborhood by #ring

Methods – Slope, Aspect & Flow direction



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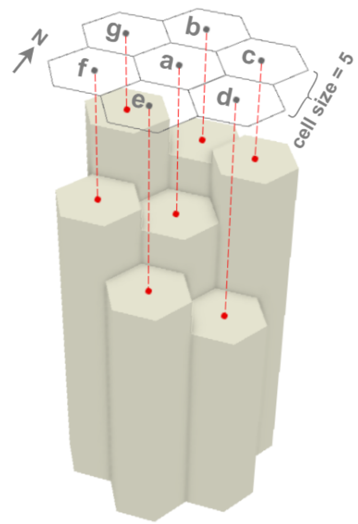
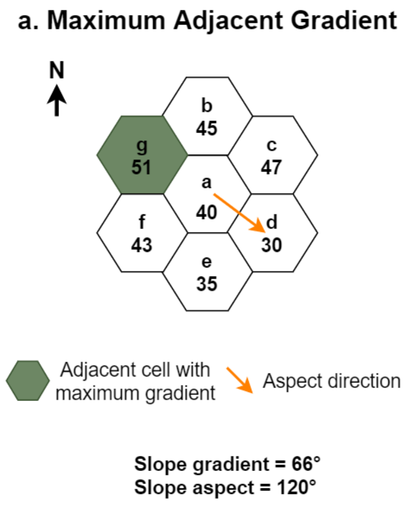
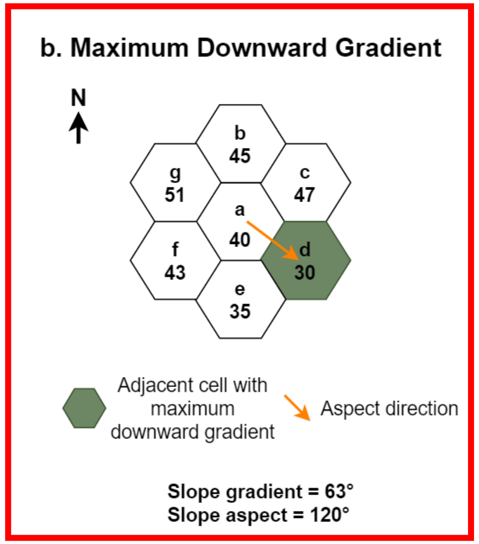
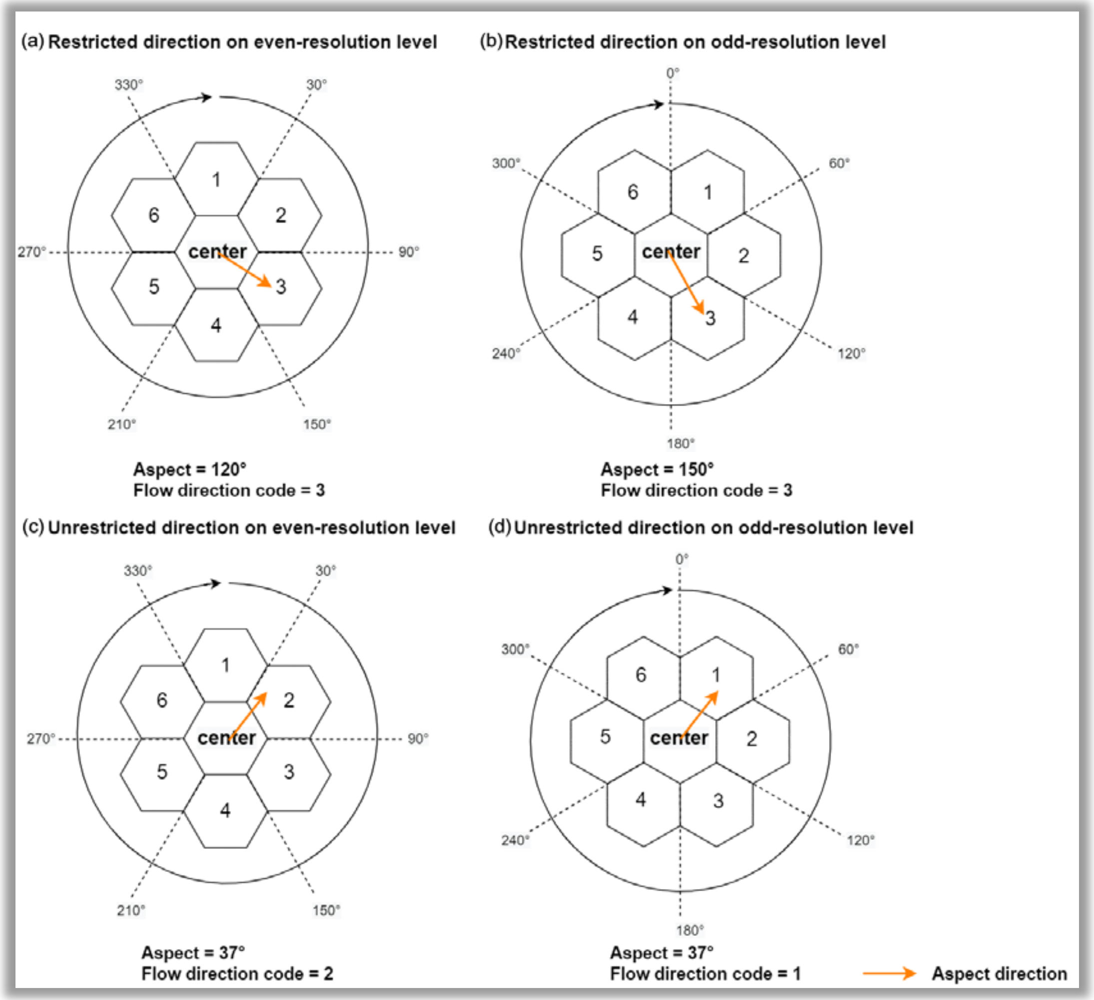
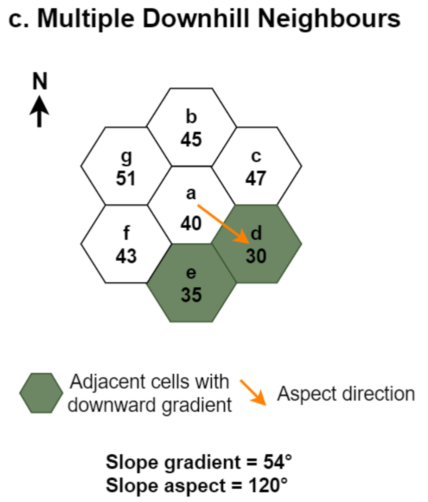
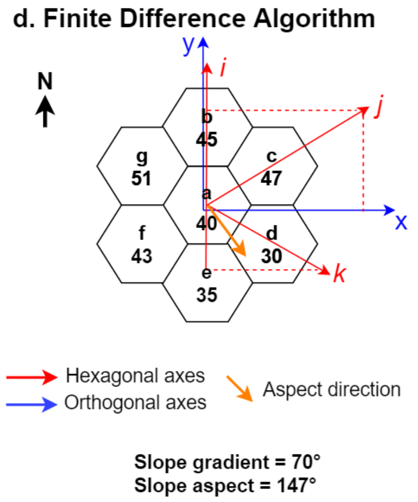


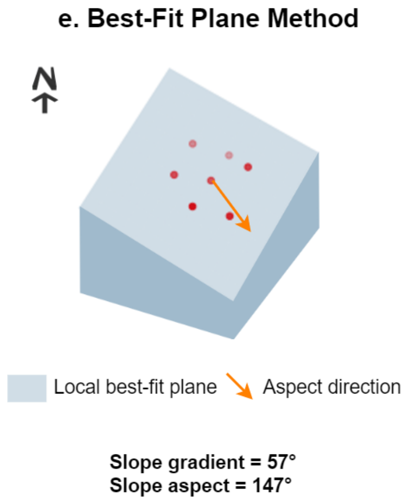












Methods – Pit filling & Flat removal

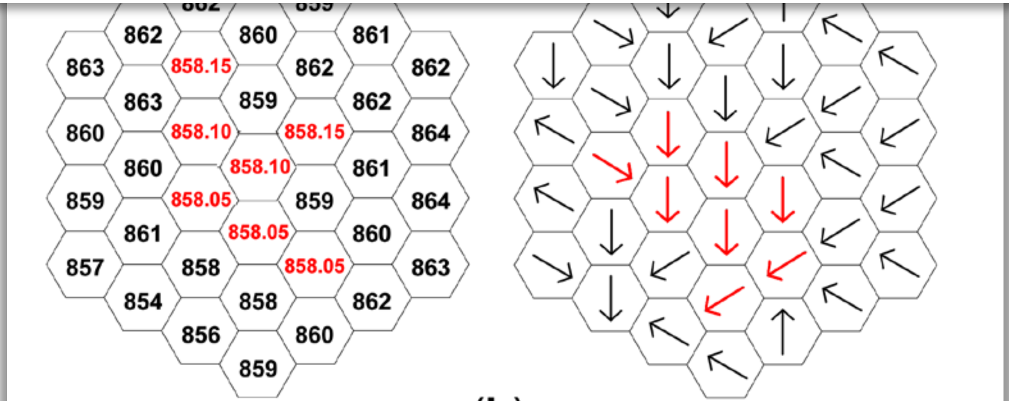
geographies MDPI

Article

Geovisualization of Hydrological Flow in Hexagonal Grid Systems

Mingke Li [1,*], Heather McGrath [2] and Emmanuel Stefanakis [1]

[1] Department of Geomatics Engineering, Schulich School of Engineering, University of Calgary, Calgary, AB T2N 1N4, Canada; emmanuel.stefanakis@ucalgary.ca
[2] Canada Centre of Mapping and Earth Observation, Natural Resources Canada, Ottawa, ON K1A 0E4, Canada; heather.mcgrath@canada.ca
* Correspondence: mingke.li@ucalgary.ca



(b)

m

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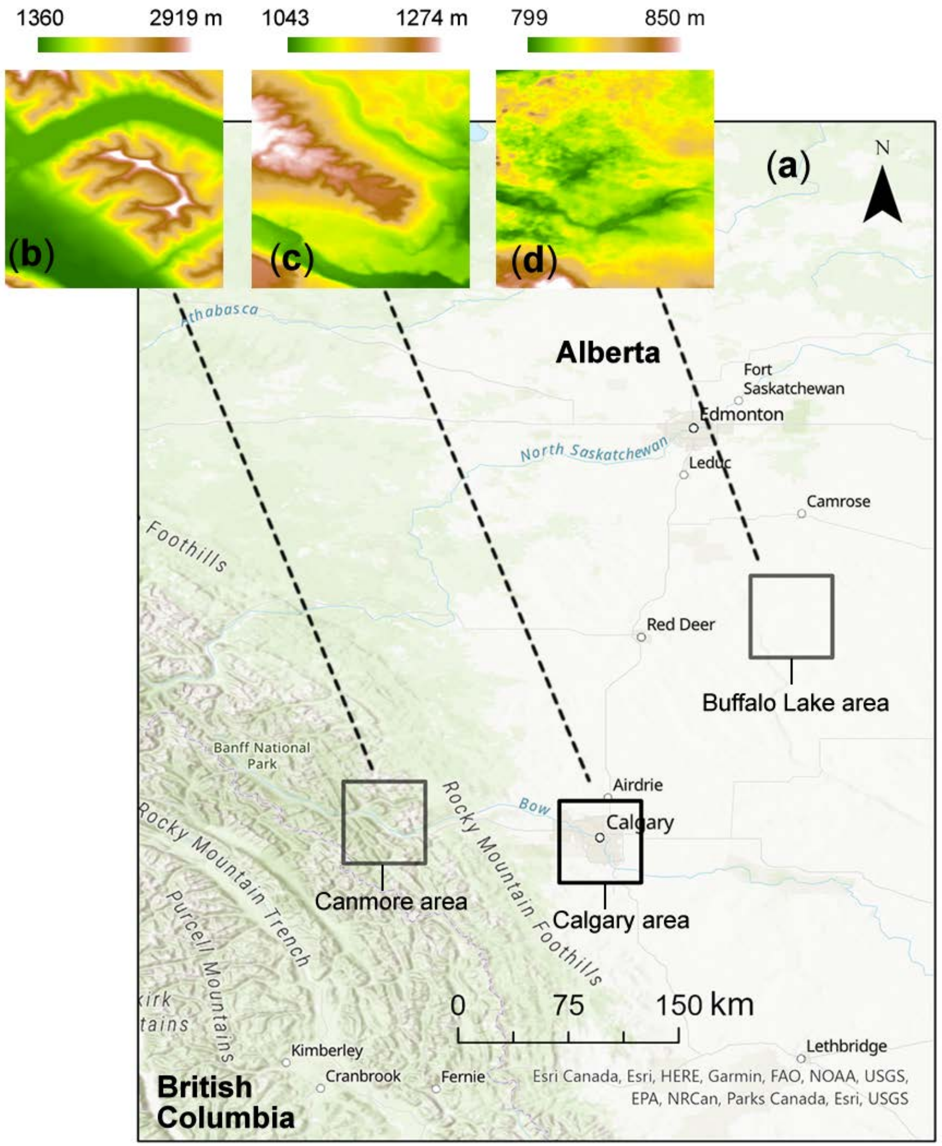
Implemen-tations

(RichDEM) / HexWatershed / PyFlowLine

- Barnes, 2018
- Liao et al., 2020; 2022

Experiment process

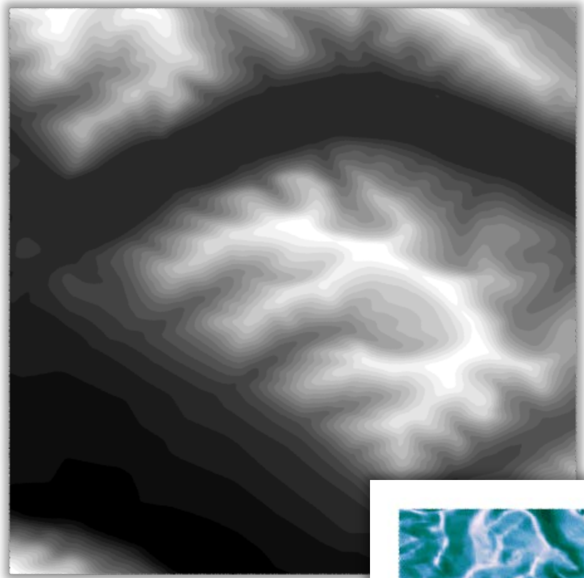


- 3 areas in Alberta, Canada
- 3 levels of roughness
- 5 resolutions: level 20-24 (0.015 km^2 to 180.599 m^2)
- Elevation resource: Canadian Digital Elevation Model
- Quantization: bilinear interpolation over centroids
- Compute topographical/hydrological parameters
- Cell-based comparison among 5 algorithms by Pearson correlation coefficients

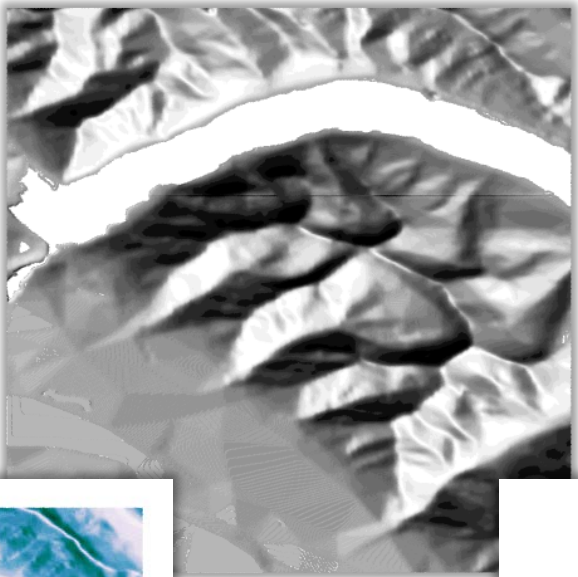
❖ *Li et al., 2021*

❖ *https://open.canada.ca/data/en/dataset/7f245e4d-76c2-4caa-951a-45d1d2051333*

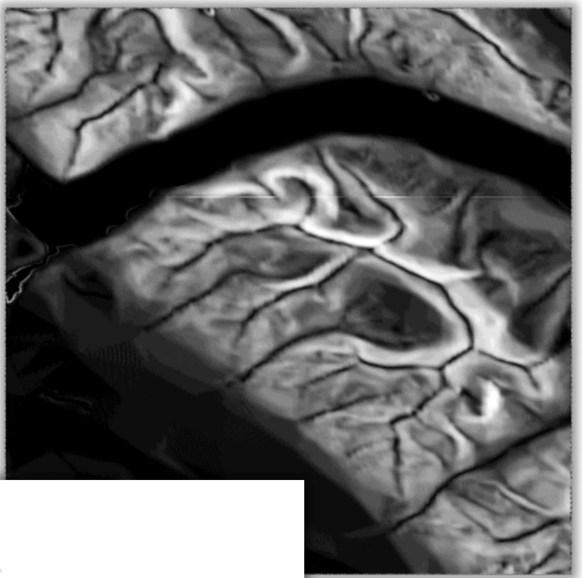
Visualization



Elevation

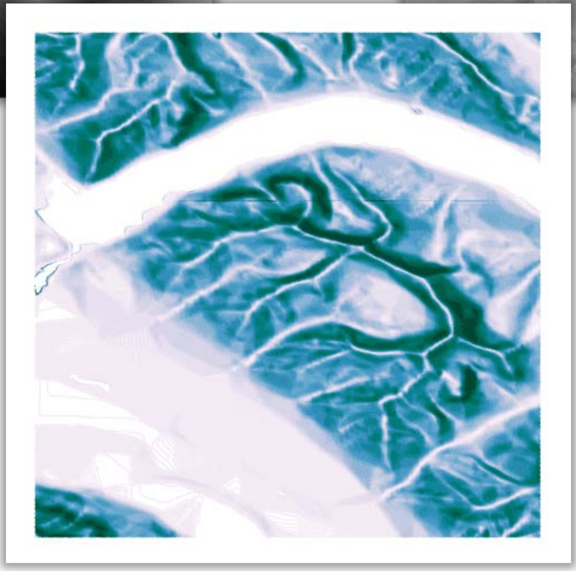


Hill shade

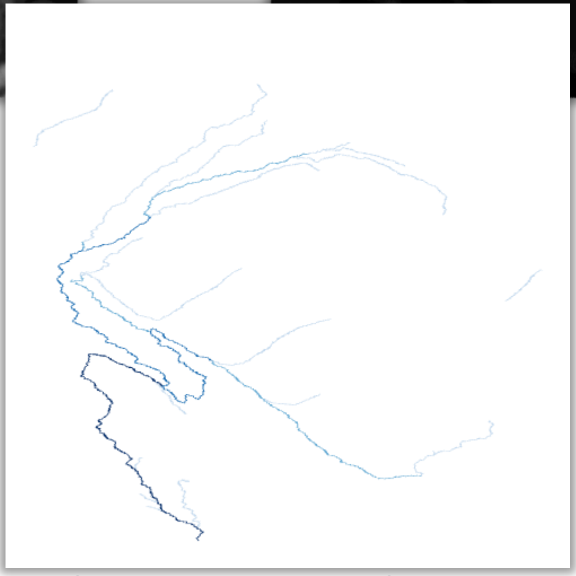


Std. elevation

Canmore area
Level 24



Slope gradient

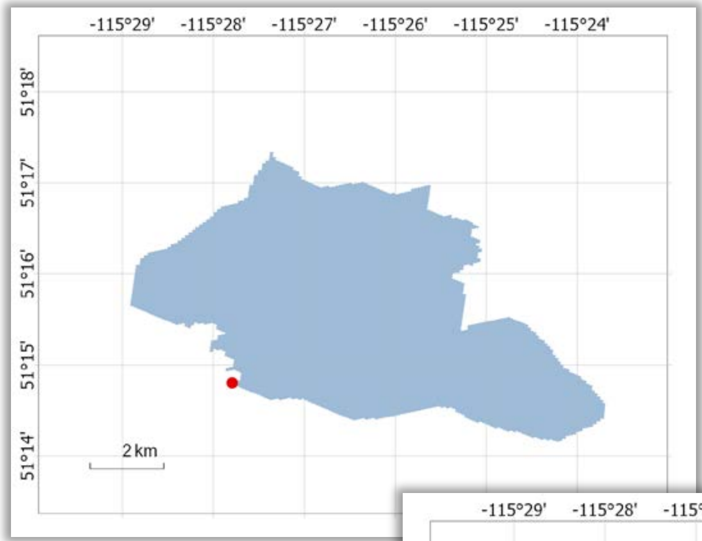


Flow accumulation

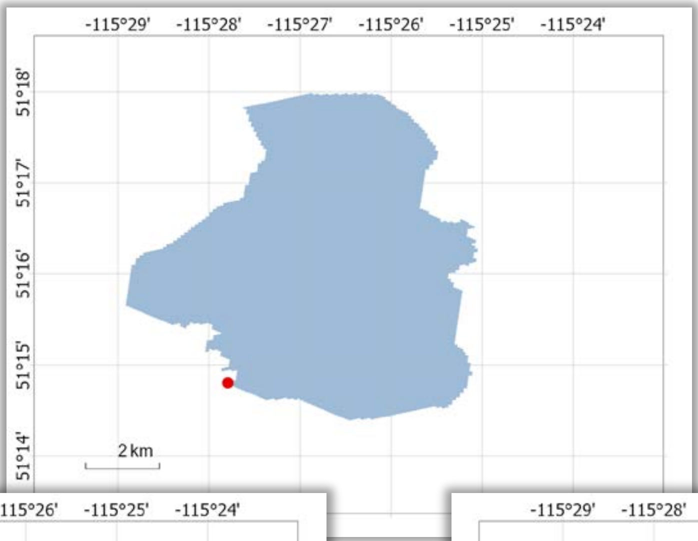
Main results

- **Slope gradient showed strong positive relationships between various algorithms.**
  - Buffalo Lake area: $r > 0.9$; Calgary and Canmore areas: $r > 0.8$
- **Grid resolution and terrain roughness influenced topographic parameters.**
  - The maximum gradient/curvature was greater at finer resolutions, most evidently in Buffalo Lake area
  - Higher absolute TPI/TRI values were observed at coarser resolution levels in more rough areas
- **Flow direction can vary among different approaches, and the impact of such variation can propagate to flow accumulation, TWI, SPI, etc.**
  - Wide range of *r* among resolutions/areas (flow accumulation/TWI/SPI)
  - Geovisualization of delineated watershed above an outlet

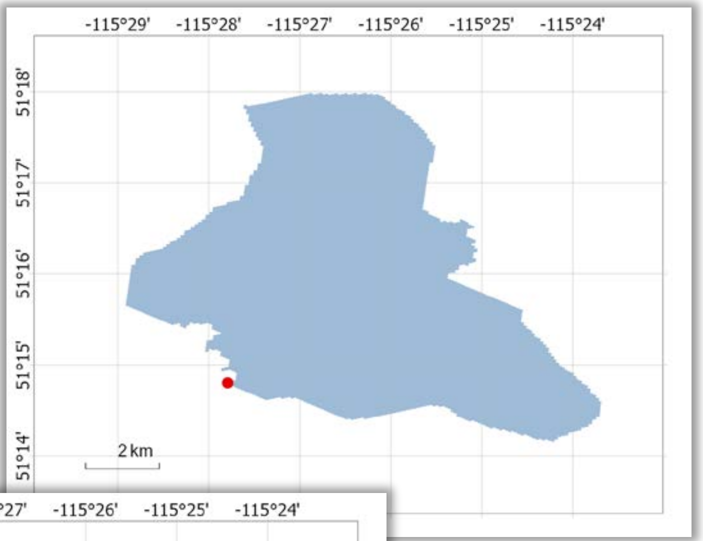
MAG



MDG

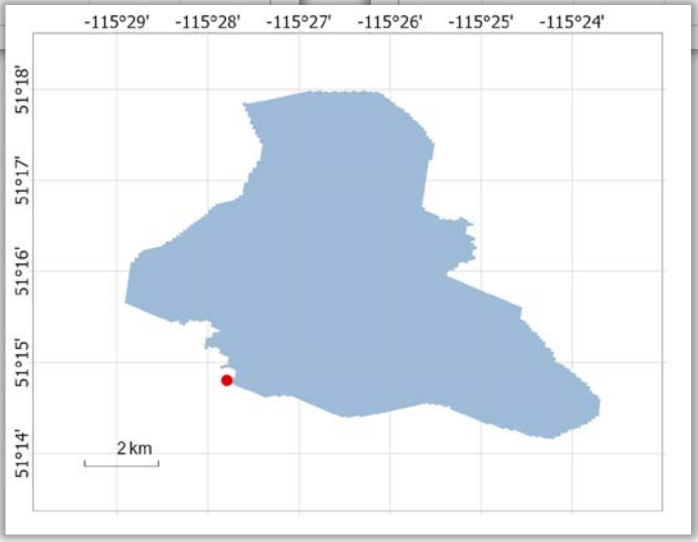


MDN

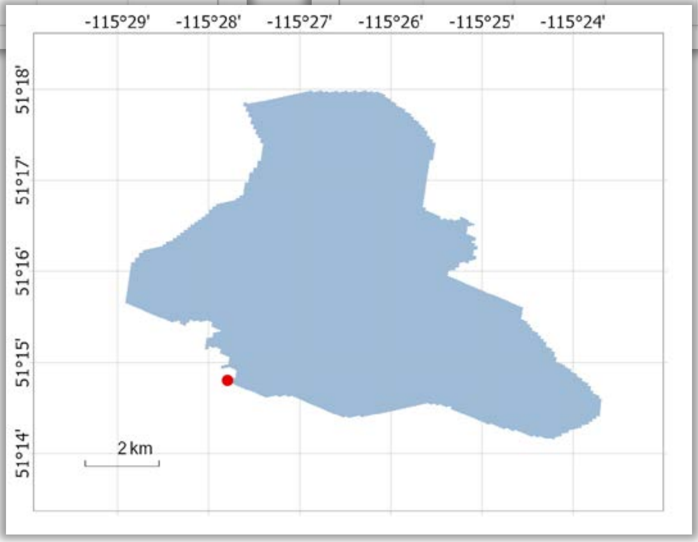


Canmore area
Level 24

Outlet Watershed



FDA



BFP

Impact of the research

- **Extended Tomlin's theory** into a DGGS context.
- The first attempt to develop **topographical** operations in a pure ISEA3H DGGS environment.
- Explored **hydrological** parameters production in DGGS.
- A guide for future **flood inundation modeling** or **flood susceptibility modeling** (on-going project).
- Bridge the gap between the existing DGGS implementations and **DGGS-driven decision-making** in the real world.

References

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Question?

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