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Geospatial Data Analysis in Discrete Global Grid Systems

-- Progress & Perspectives

全球离散格网系统中的地理空间数据分析 -- 进程与展望

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University of Calgary

Calgary '88

Calgary 2–4 November 2018 [edit]

Date	Place	Distance	Winner
3 November 2018	Olympic Oval	500m (1)	Wu Dajing
4 November 2018	Olympic Oval	500m (2)	Wu Dajing

Department of Geomatics Engineering

UNIVERSITY OF CALGARY

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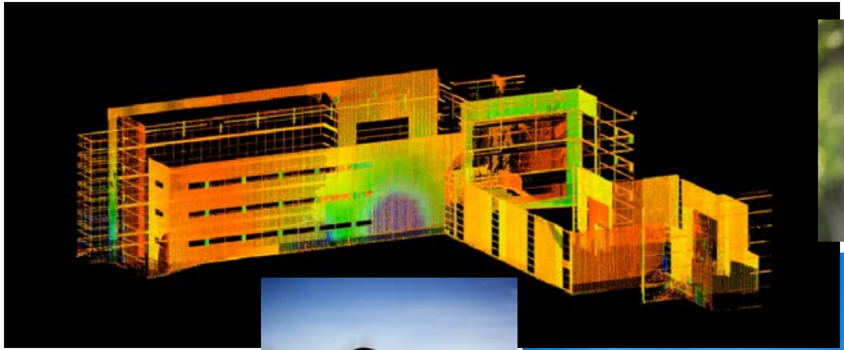
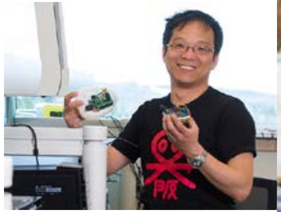
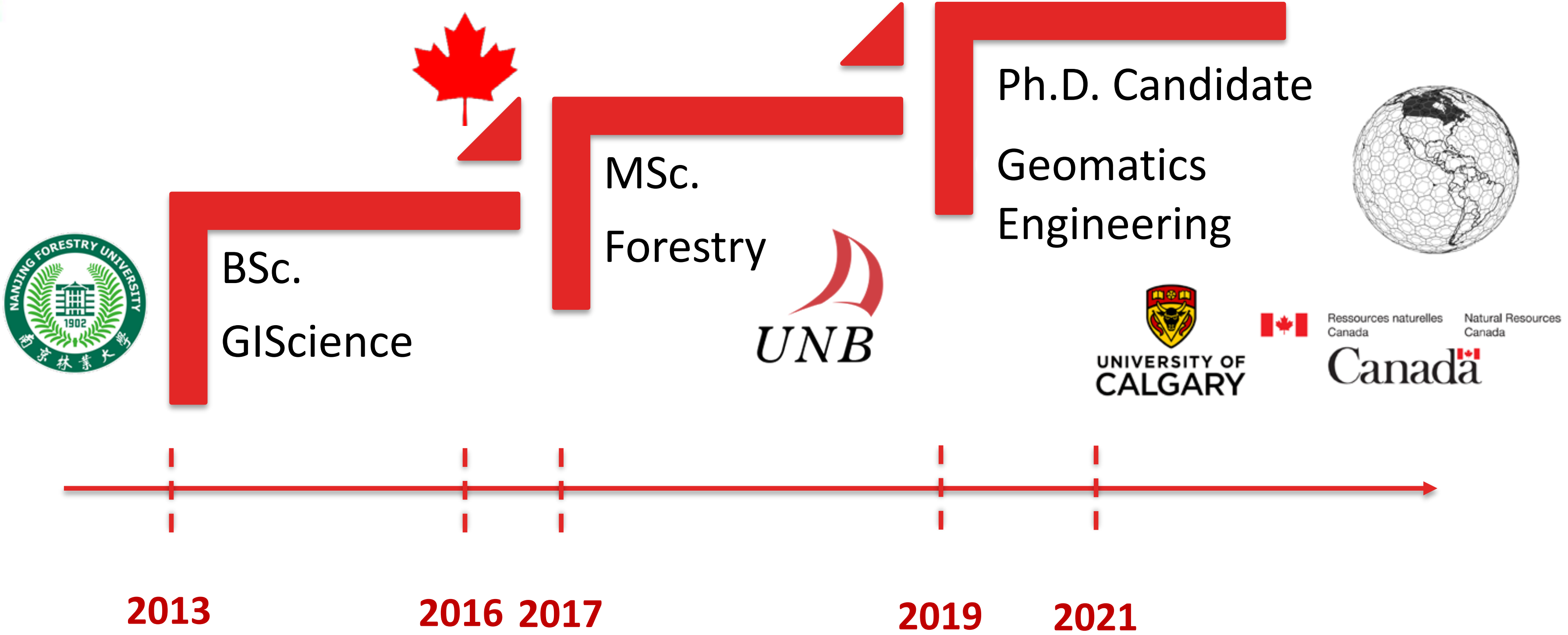
Founded in 1979





https://schulich.ucalgary.ca/geomatics

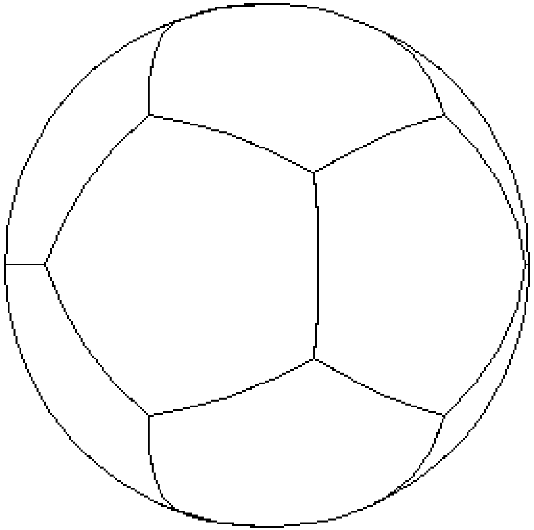
Education background



Geospatial Data Analysis in Discrete Global Grid Systems
-- Progress & Perspectives

1. **Discrete Global Grid Systems (DGGS)**
2. Research Directions (Geo-Data Science Research Group)
3. Research Progress (ML)
4. Future Directions

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*

DGGS – an International Standard

"DGGS infrastructures enable the integrated analysis of very large, multi-source, multi-resolution, multi-dimensional, distributed geospatial data."

Open Geospatial Consortium - Topic 21: Discrete Global Grid Systems Abstract Specification 15-104r5

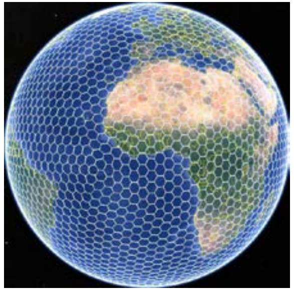
"All Discrete Global Grid Systems are structured for information as distinct from conventional coordinate reference systems originally designed for navigation."

International Standard Organization – ISO 19170-1: Discrete Global Grid Systems Specifications

"DGGS as a Common Geography will ensure that all statistical data is consistently geospatially enabled and that users can discover, access, integrate, analyse and visualise statistical information seamlessly for geographies of interest."

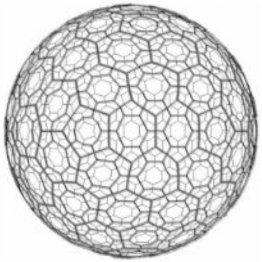
United Nations Committee of Experts on Global Geospatial Information Management - The Global Statistical Geospatial Framework

DGGS Implementations



PlanetRisk

OpenEAGGR



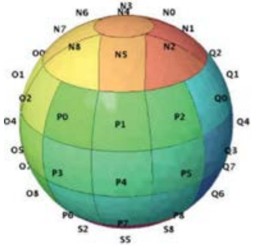
DGGRID version 7.0
dggridR

Solid Earth and Environment GRID

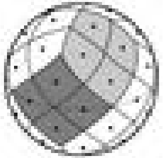
DIGITAL EARTH
GLOBAL ANALYTICS

PYXIS

rHEALPix



H3



HEALPix

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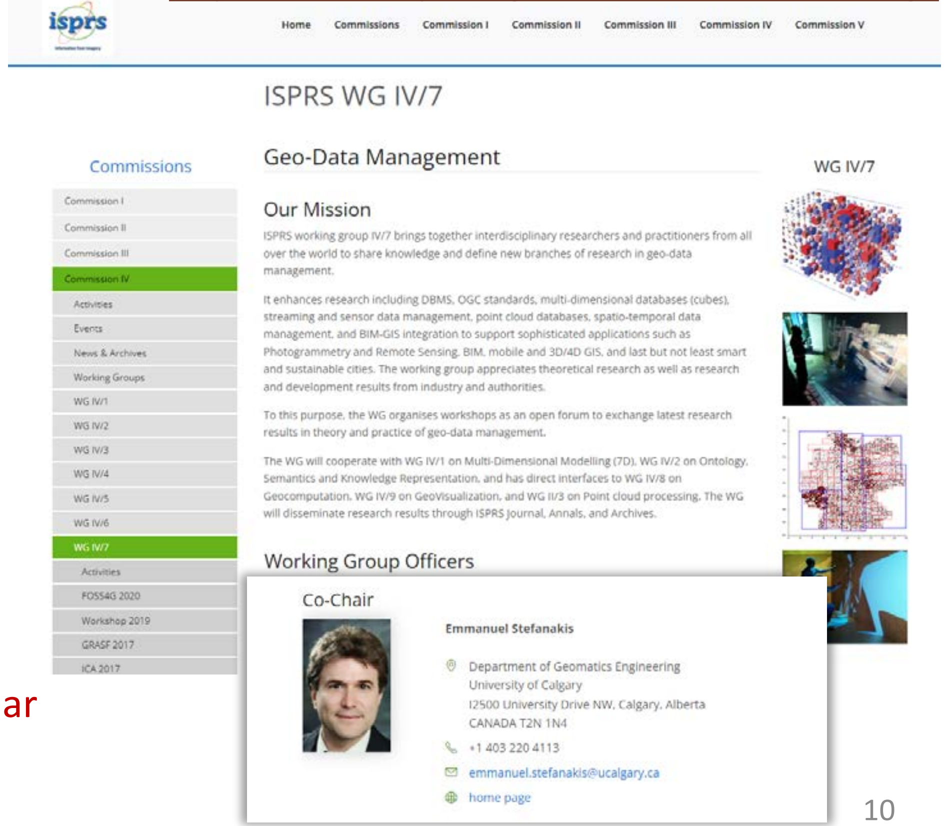
Geo-Data Science Research Group

https://www2.isprs.org/commissions/comm4/wg7







isprs

Home | Commissions | Commission I | Commission II | Commission III | Commission IV | Commission V

ISPRS WG IV/7

Commissions

- Commission I
- Commission II
- Commission III
- Commission IV
  - Activities
  - Events
  - News & Archives
  - Working Groups
  - WG IV/1
  - WG IV/2
  - WG IV/3
  - WG IV/4
  - WG IV/5
  - WG IV/6
  - WG IV/7
    - Activities
    - FOSS4G 2020
    - Workshop 2019
    - GRASF 2017
    - ICA 2017

Geo-Data Management

WG IV/7

Our Mission

ISPRS working group IV/7 brings together interdisciplinary researchers and practitioners from all over the world to share knowledge and define new branches of research in geo-data management.

It enhances research including DBMS, OGC standards, multi-dimensional databases (cubes), streaming and sensor data management, point cloud databases, spatio-temporal data management, and BIM-GIS integration to support sophisticated applications such as Photogrammetry and Remote Sensing, BIM, mobile and 3D/4D GIS, and last but not least smart and sustainable cities. The working group appreciates theoretical research as well as research and development results from industry and authorities.

To this purpose, the WG organises workshops as an open forum to exchange latest research results in theory and practice of geo-data management.

The WG will cooperate with WG IV/1 on Multi-Dimensional Modelling (7D), WG IV/2 on Ontology, Semantics and Knowledge Representation, and has direct interfaces to WG IV/8 on Geocomputation, WG IV/9 on GeoVisualization, and WG II/3 on Point cloud processing. The WG will disseminate research results through ISPRS Journal, Annals, and Archives.

Working Group Officers

Co-Chair

Emmanuel Stefanakis

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CANADA T2N 1N4

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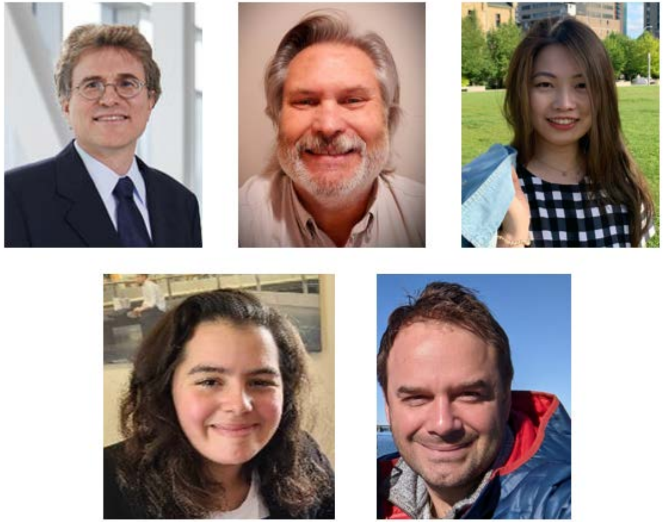
home page

ISPRS WG IV/7 (Geo-Data Management) Webinar

https://www.youtube.com/watch?v=FWGl4lSrIyA

Geo-Data Science Research Group



ISPRS WG IV/7 (Geo-Data Management) Webinar
https://www.youtube.com/watch?v=FWGl4lSrIyA

- rHEALPix DGGS (D.B.)
  - Orientation to suit local scale
  - Latitudinal data analysis (population/CO_2 emission/GDP etc.)
  - Mobility networks at the urban scale
- PYXIS DGGS (P.P. & M.R.)
  - OGC pilot project
  - Marine data management
- DGGRID/dggridR (M.L.)
  - Terrain modeling
  - Flood susceptibility

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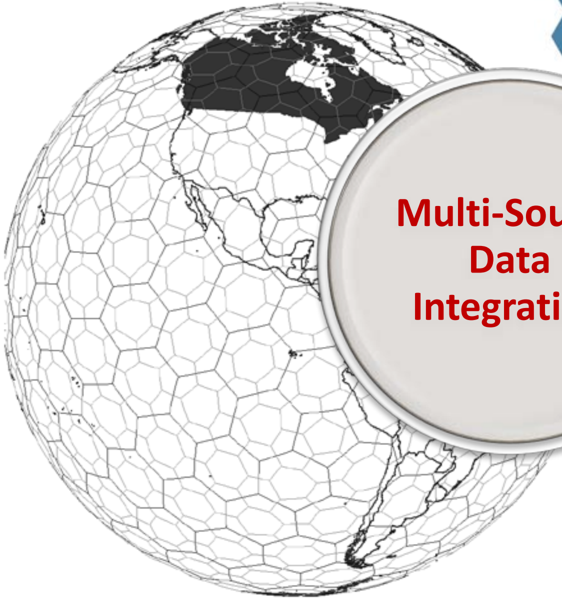
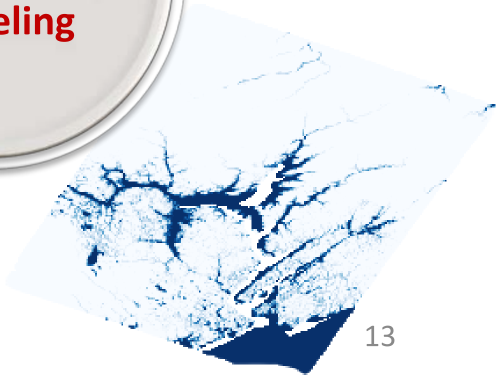
Research Phases



Multi-Source Data Integration

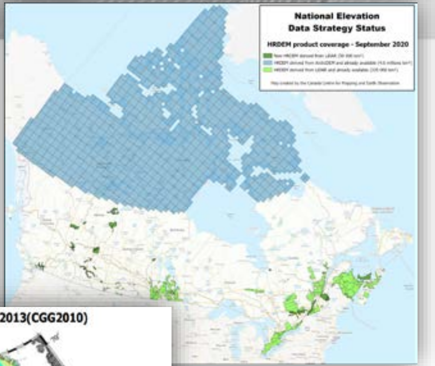
Analytical Operation Development

Flood Susceptibility Modeling

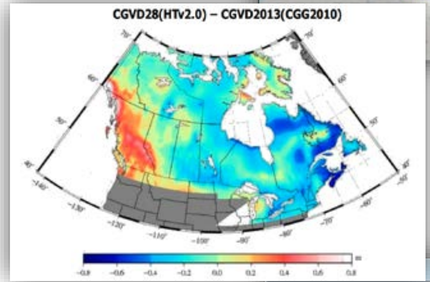


Introduction – Problem statement

- 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**

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

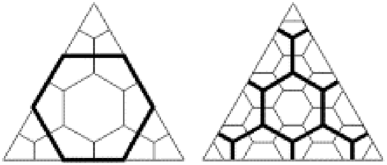
- *Snyder, 1992*
- *White et al., 1998*

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

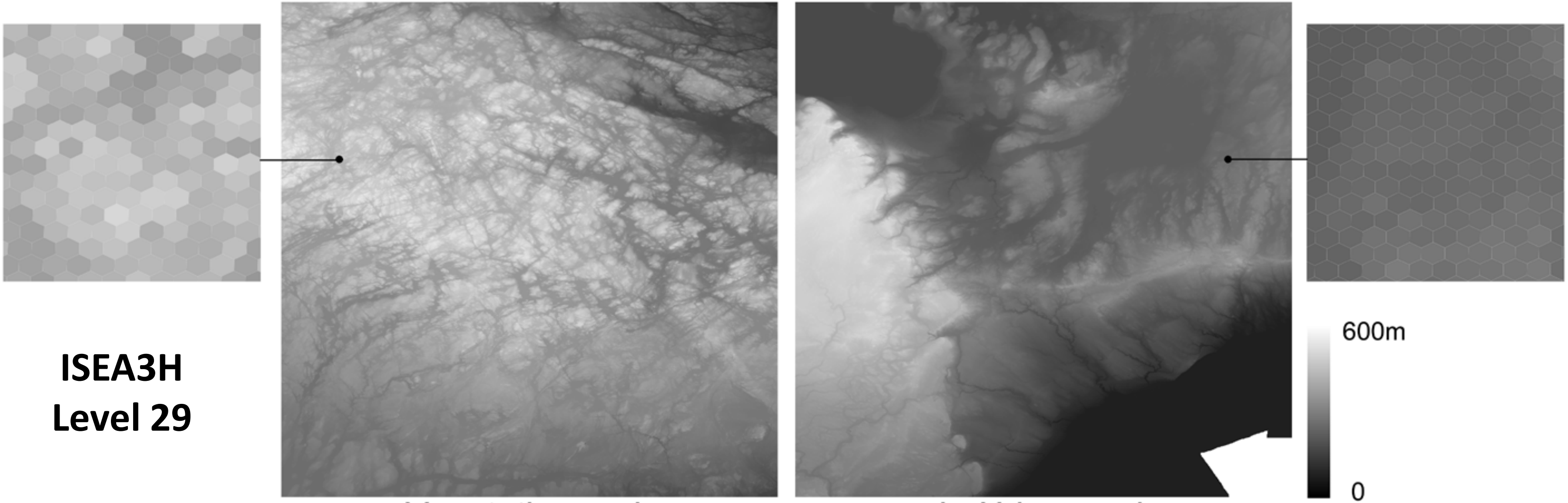
Quantization
- Cell centroids at various levels
- Resample with interpolation; integration

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 – Visualization

ISEA3H
Level 29



a. Vegetation region   b. Urban region

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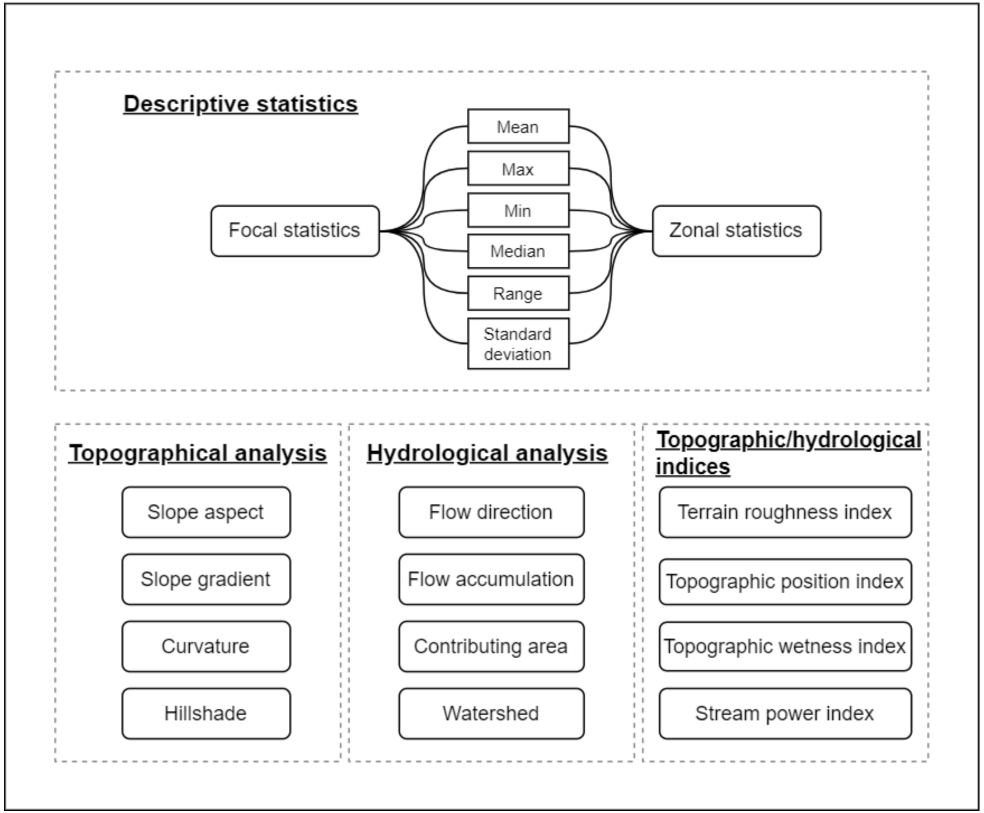
Study 2: Analytical Functions – Classification

- **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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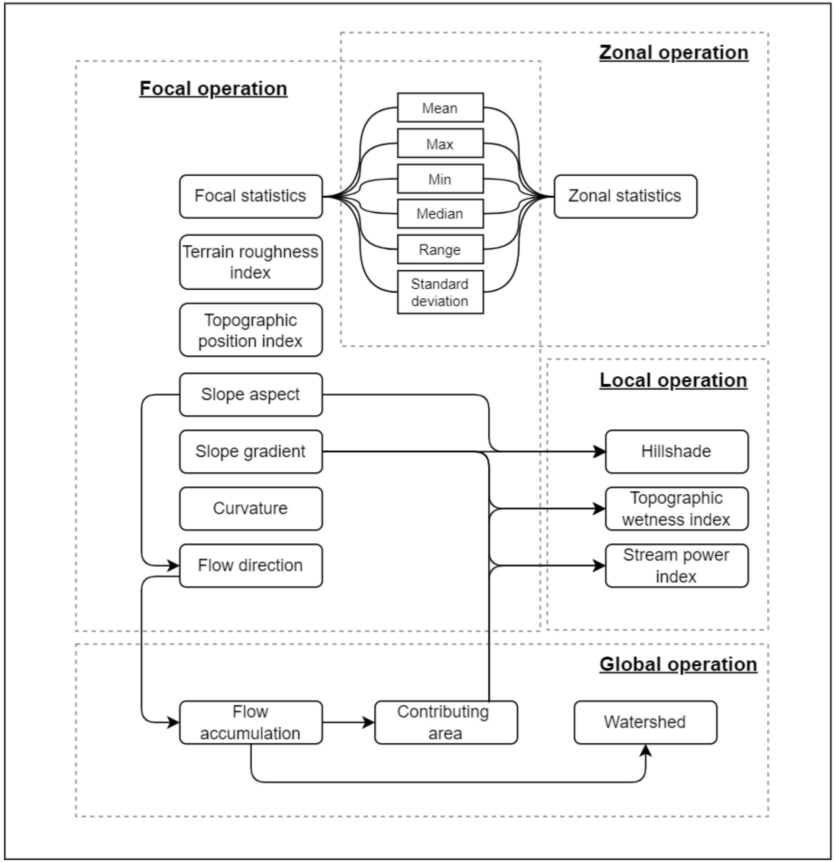
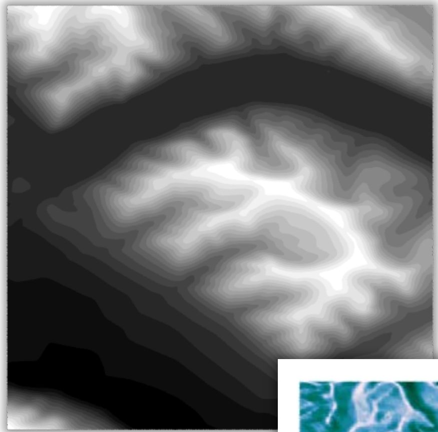
❖ *Tomlin, 1990*

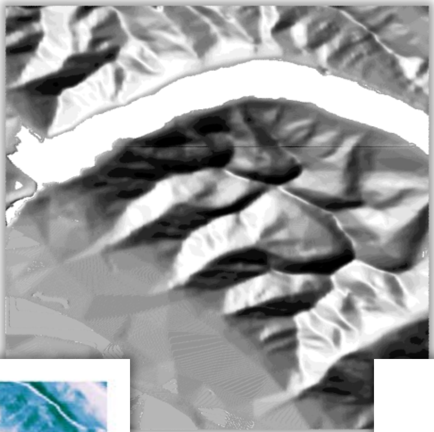


Study 2: Analytical Functions – Visualization

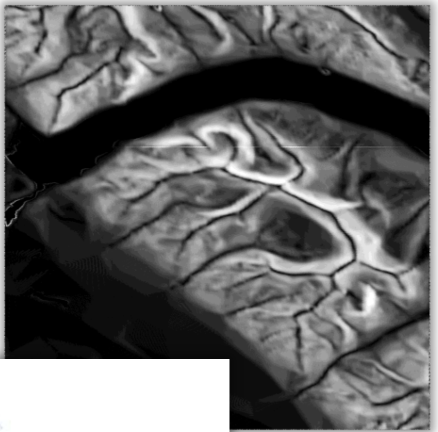
Elevation



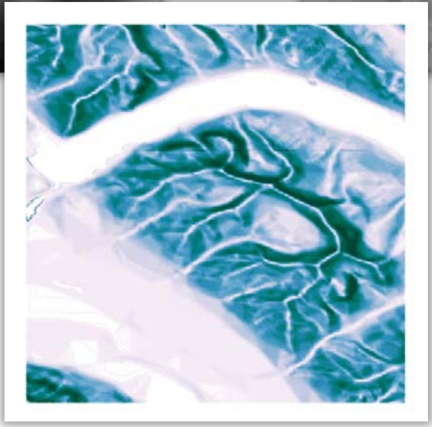
Hill shade



Std. elevation



Canmore area
Level 24



Slope gradient

Flow accumulation

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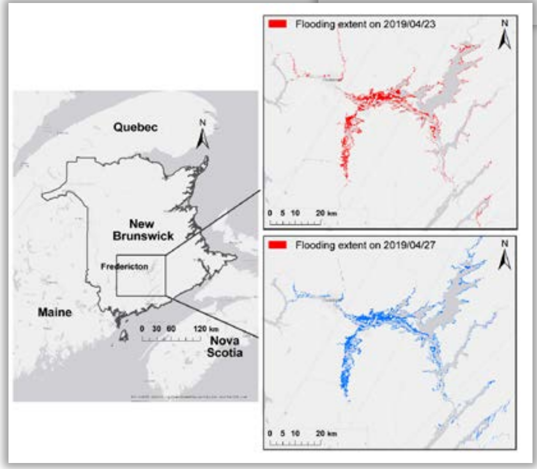
- Predictor variables: quantized raster data (Study 1), quantized vector data, results of topographical and hydrological analysis (Study 2), climate data, etc.

Study 3: Flood mapping – Workflow (on-going)

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

Sample points

2000 pts
Flooding events in four years
70% training + 30% testing



Predictor variables

<u>Topographical/Geomorphic factors</u>
Elevation, slope, aspect, roughness,
Soil types, land use, NDVI,
TRI, TPI, etc.

<u>Hydrological factors</u>
Flow direction/accumulation
Proximity to river
TWI, SPI

<u>Meteorological factors</u>
Precipitation, temperature,
Snow depth, wind speed, etc.

<u>Anthropogenic factors</u>
Proximity to road
Impervious areas

Model training

<u>Analysis scale</u>
ISEA3H level 23 (~542 m^2)
ISEA3H level 21 (~4876 m^2)
ISEA3H level 19 (~43886 m^2)

<u>Machine learning methods</u>
Random forest (RF)
Artificial Neural Networks (ANNs)
Multilayer Perceptron (MLP)
Adaptive Neuro-Fuzzy Inference System (ANFIS)
Support Vector Machine (SVM)

<u>Parallel analysis</u>
ABM

Flood susceptibility maps

Spatial-temporal mapping

Forecasts under different climate change scenarios

Multiple scales

https://storymaps.arcgis.com/stories/f2317e6814d0455a8ea4f2d4af2b0255

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Future research directions

- ➢ Uncertainties of data modeling
- ➢ Topology b'w spatial objects / DGGS cells
- ➢ Data I/O, storage, interoperability, etc.

BIG EARTH DATA
https://doi.org/10.1080/20964471.2021.2012912
Taylor & Francis
OPEN ACCESS Check for updates

GIScience research challenges for realizing discrete global grid systems as a Digital Earth

Majid Hojati[a], Colin Robertson[a], Steven Roberts[a] and Chiranji Chaudhuri[b]

[a]Department of Geography and Environmental Studies, Wilfrid Laurier University, Waterloo, ON, Canada; [b]Coldwater Laboratory, University of Saskatchewan, Canmore, AB, Canada

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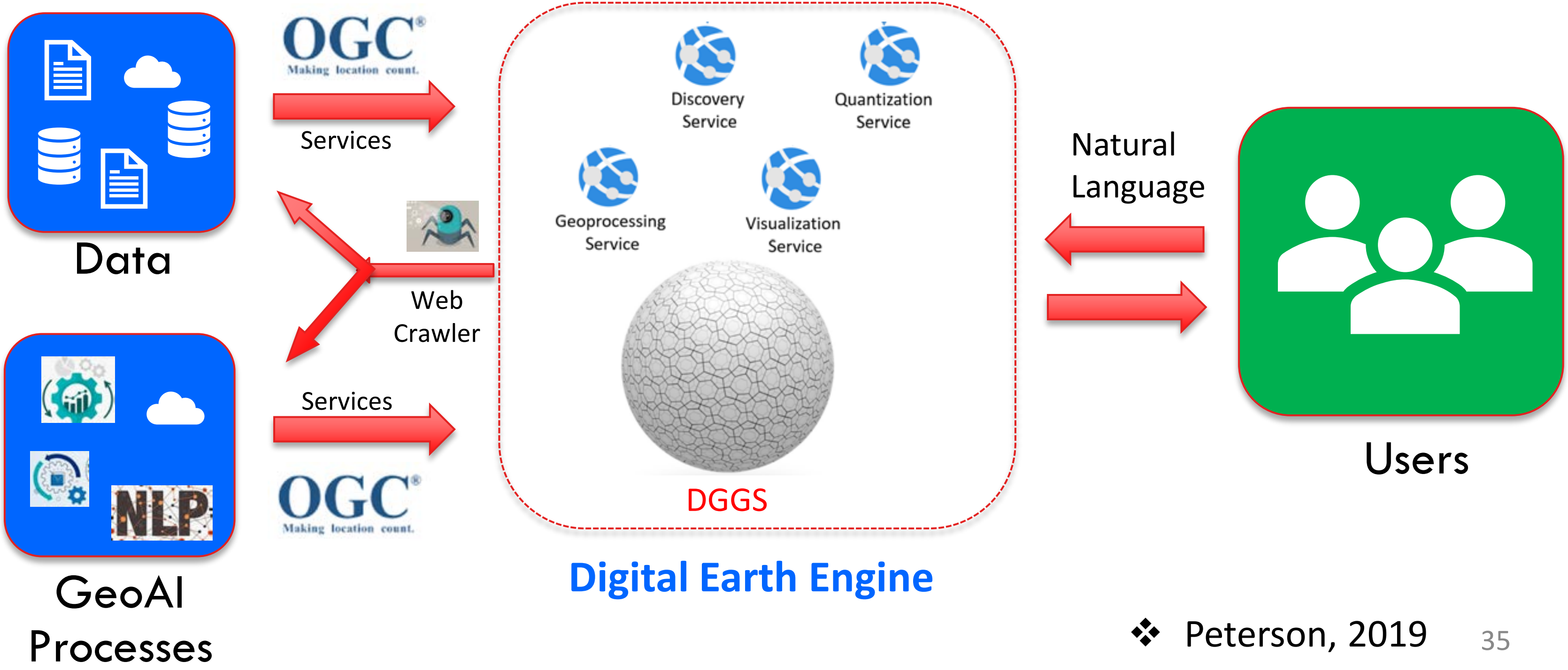
- ➢ DGGS-powered datacubes
- ➢ Big data management through DGGS and cloud computing
- ➢ Application of DGGS to sensor networks / IoT
- ➢ Handling point clouds by DGGS

Vision: Discovery-based analysis

- Digital Earth can serve as an **agnostic data & processing** engine
- **Non-GIS experts** are unable to apply sophisticated data analytics



❖ Peterson, 2019

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Q & A

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