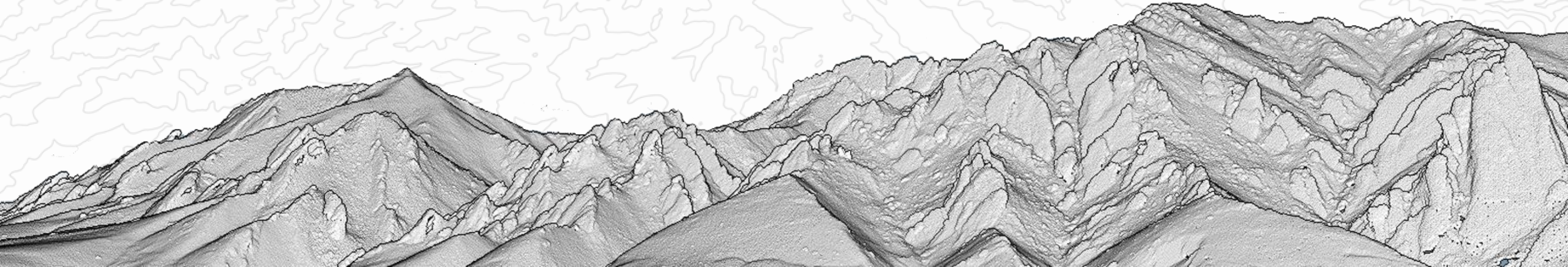
Introduction to OpenTopography Tools for Calculating Change at the Earth's Surface

Cassandra Brigham (ASU)

Christopher J. Crosby (EarthScope)

2025 NSF GAGE/SAGE Community Science Workshop | May 18th, 2025



Short course web page:
https://opentopography.org/workshops/gage-sage-2025-OT-diff

Tentative Agenda:

1:00 pm Welcome and course introduction. Around the room intros. (Brigham & Crosby)

1:30 pm Lecture & activity: Introduction to OpenTopography and short tour of the OT website. Get differencing jobs running via the OT-browser. (Crosby)

2:15 pm Break

2:30 pm Lecture: Differencing and error analysis in OpenTopography (Brigham)

3:30 pm Discussion: Review participants' differencing results (Brigham & Crosby)

3:45 pm Activity: Colab differencing and error exercise. (Brigham)

4:45 pm Discussion

5:00 pm Short Course End

LOGISTICS:

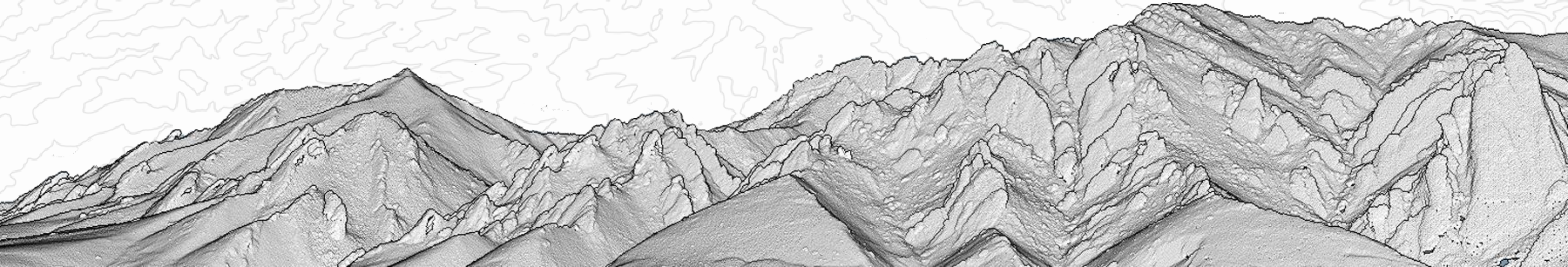
1. Ensure you have a Gmail account and at least 500 MB of Google Drive space
2. Create an OpenTopography account (if you do not already have one) at https://portal.opentopography.org/newUser
3. Bring a laptop capable of connecting to the conference WiFi network, ideally with a webGL enabled browser like Chrome or Firefox

Introductions:

1. Name & affiliation?

2. Your research area / application of high-resolution topography and topographic differencing?

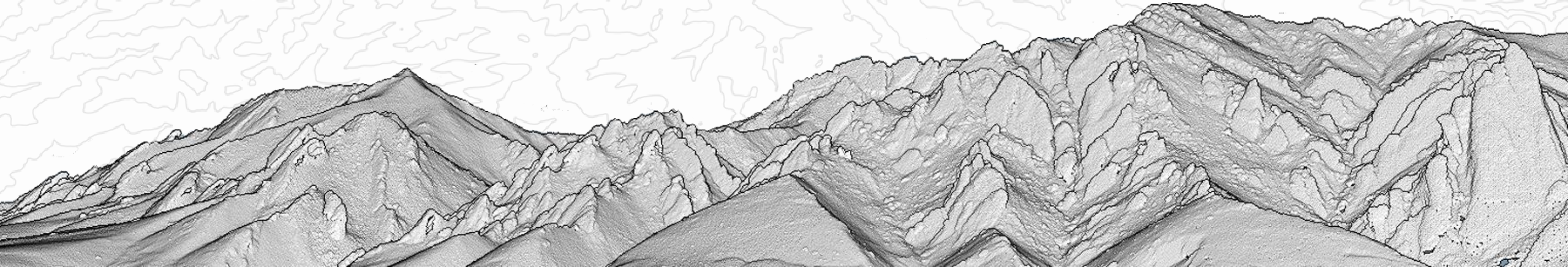
3. Experience with lidar / topographic data and geospatial data analysis?



Introduction to OpenTopography

Christopher J. Crosby (EarthScope)

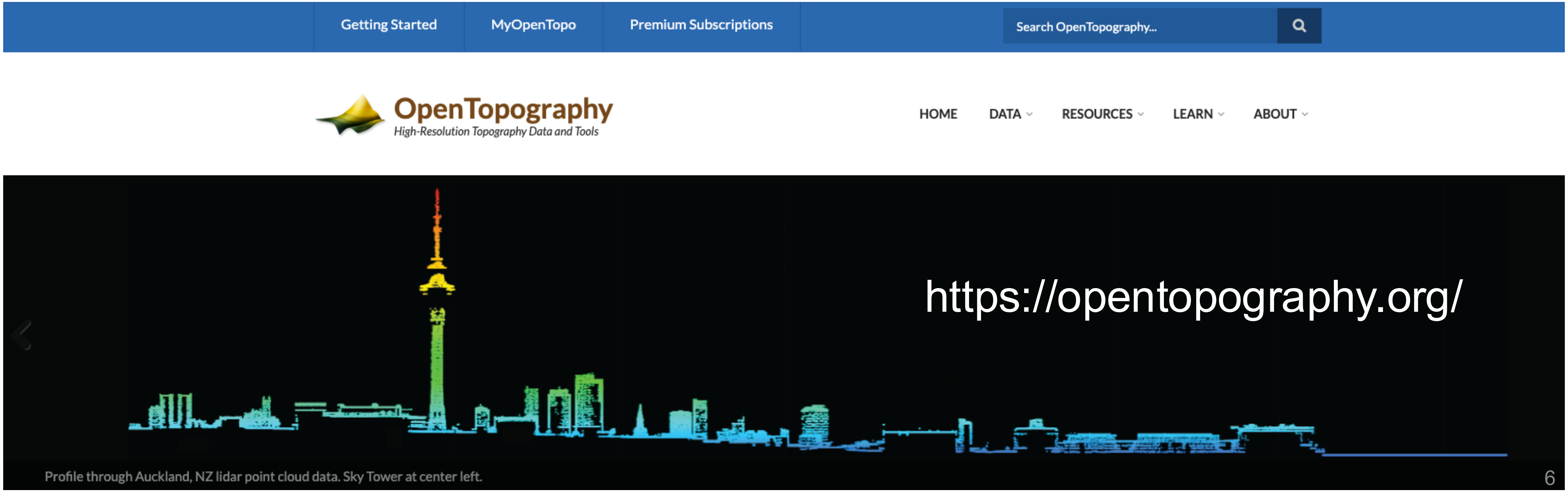
2025 NSF GAGE/SAGE Community Science Workshop | May 18th, 2025



What is OpenTopography?

Democratize online access to *high resolution* topography

Data access (lidar, photogrammetry, satellite) and derived data products



Profile through Auckland, NZ lidar point cloud data. Sky Tower at center left.

Who We Are

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

EarthScope Consortium

ASU Arizona State University








Founded in 2009

Supported by US National Science Foundation (*EAR Award No. 2410799, 2410800 & 2410801*)

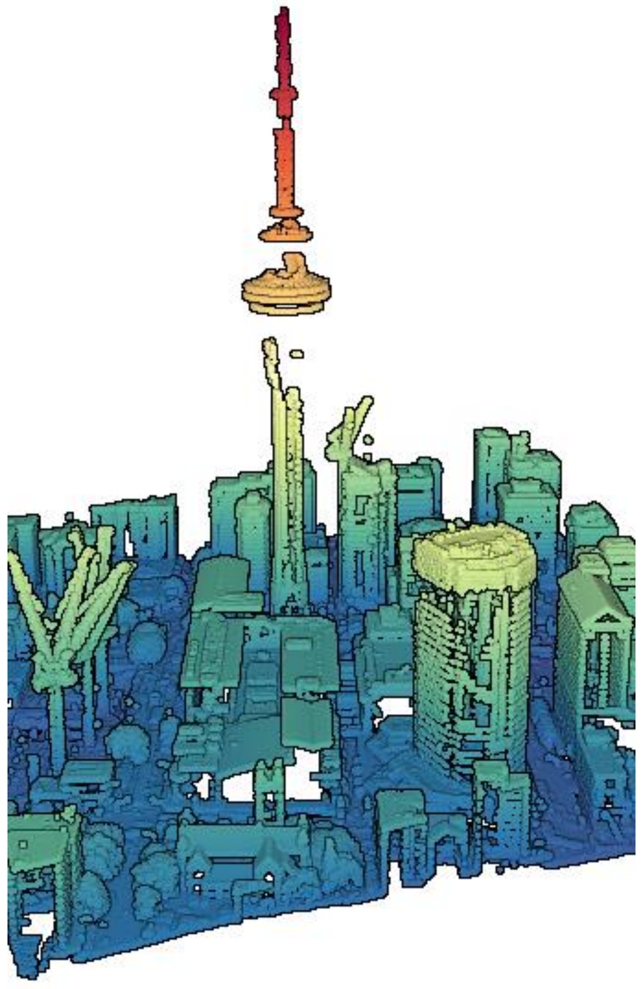
What Do We Do?

Topographic data hosting and distribution

On-demand derived data products and visualizations (DEMs, hillshade, slope, contours, etc.)

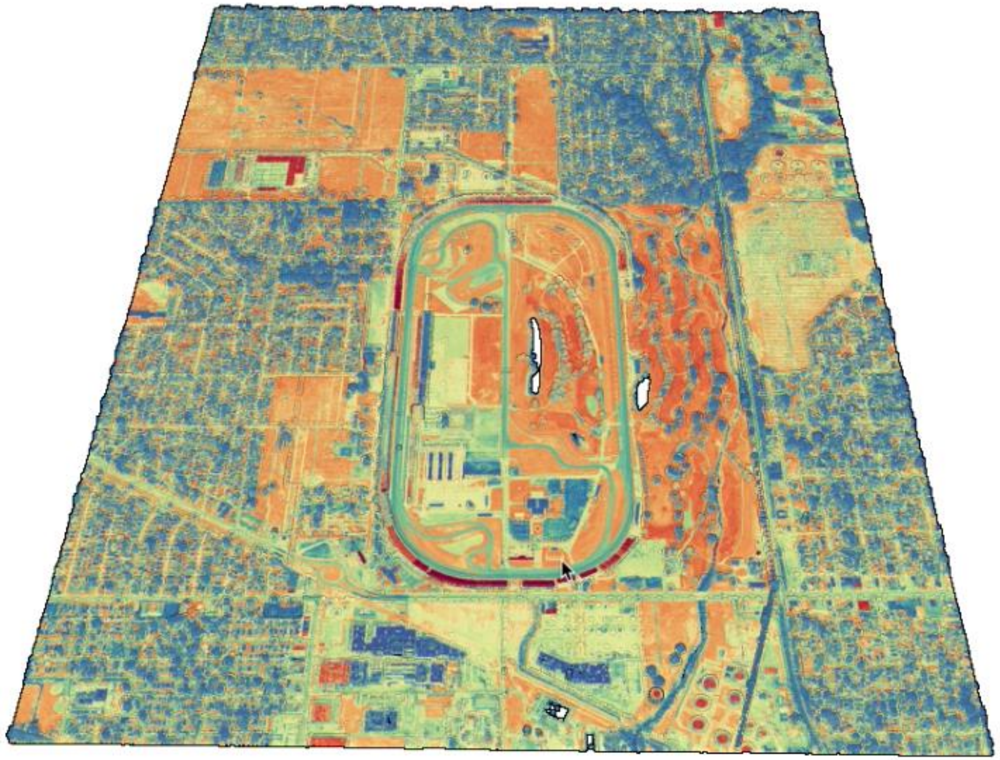
Portal, APIs, cloud native data, notebooks, open source code

Education and training in use of high-resolution topography

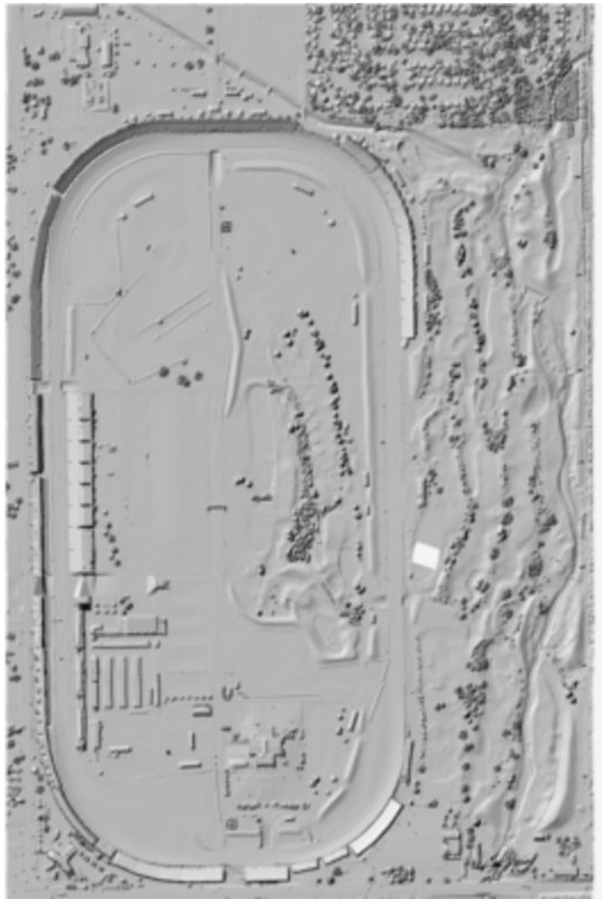


Topographic Data & Derivatives

Indianapolis Motor Speedway



Point cloud



Raster: DEMs, hillshade, slope

Vector: Contours

Data Services

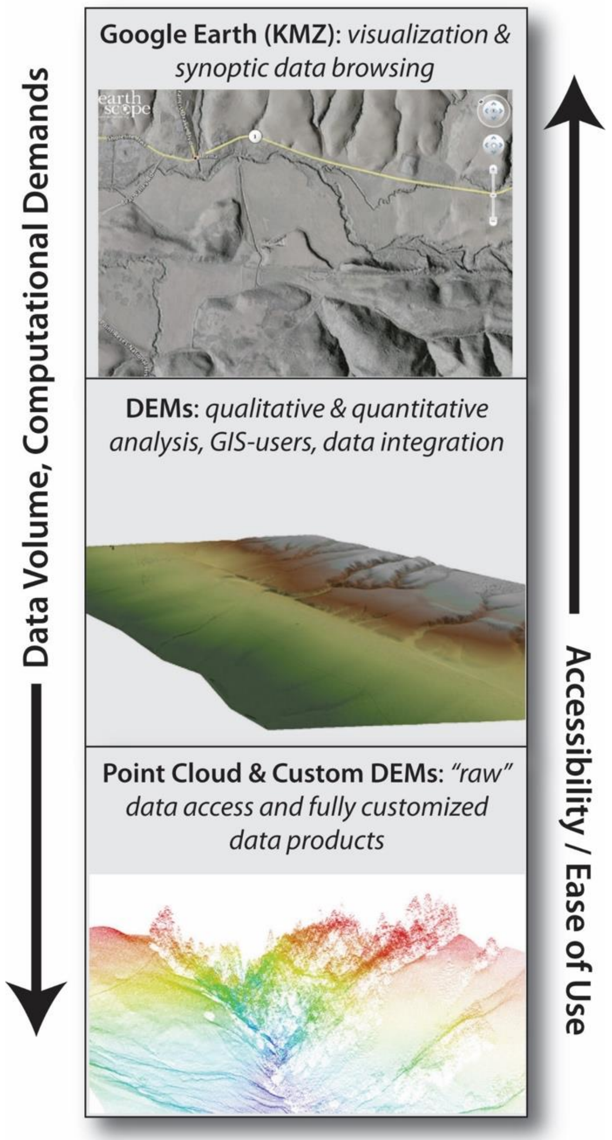
Topography data products and access mechanisms for a diverse user community

Range of available data products:

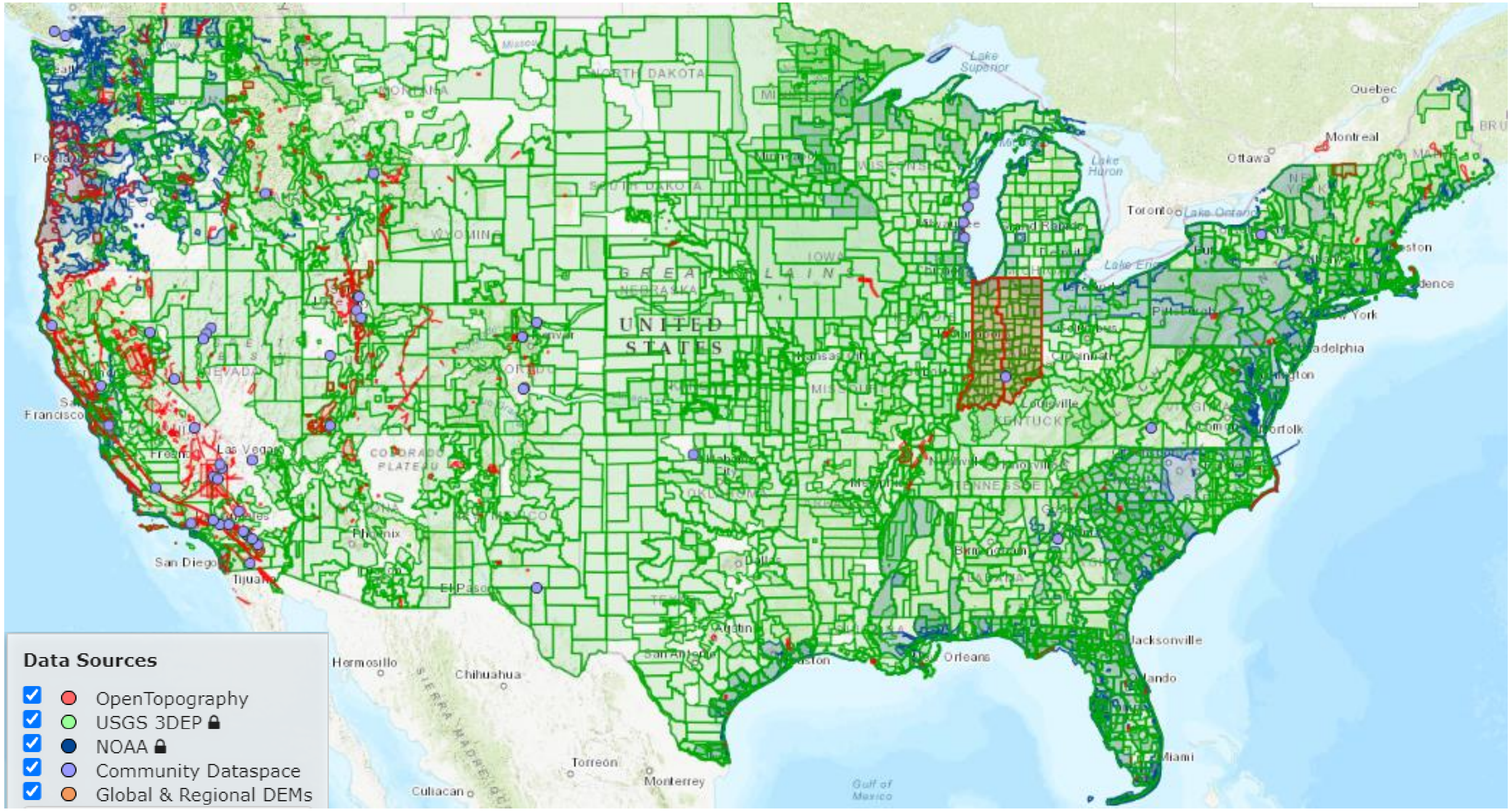
- Easy to access products for browsing and education
    - Browse images, Google Earth, 3D visualization
- Majority of users want a standard gridded product
    - GIS products (e.g. DTM, DSM)
- “Raw” point cloud data for modeling or analysis

Multiple Access Pathways

- Web Portal interfaces, APIs and web services, Bulk Downloads (Cloud Optimized GeoTIFFs - COGs)



The Data



85 trillion points from lidar & photogrammetry

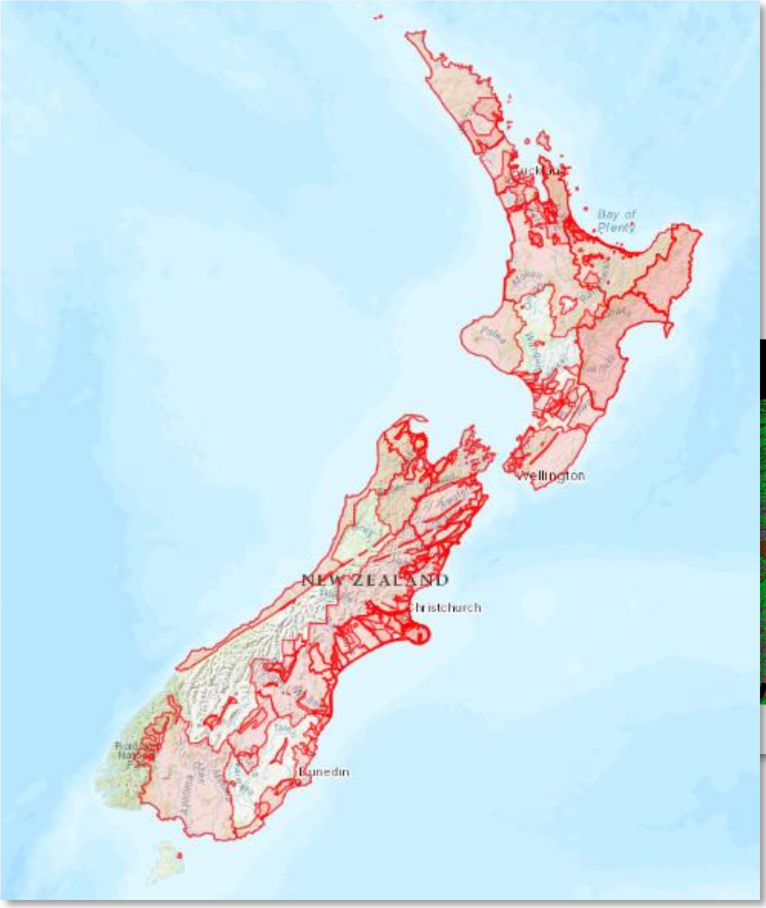
17 global & regional topographic datasets (e.g., SRTM, COP30, USGS 3DEP 10m)

Goal: Streamlined access without the need for specialized software or local compute resources

New Zealand National Lidar Program

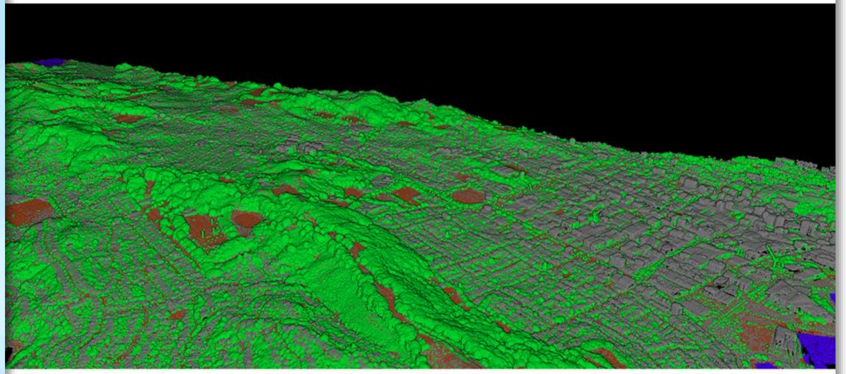
62 lidar point cloud datasets in OpenTopography covering 261,600 sq km (3.1 trillion points)

Land Information New Zealand
Toitū te whenua



LINZ Follow
We make sure NZ has accurate information about where people and places are, people have confidence in property rights and Crown property is well managed.
Oct 16 · 5 min read

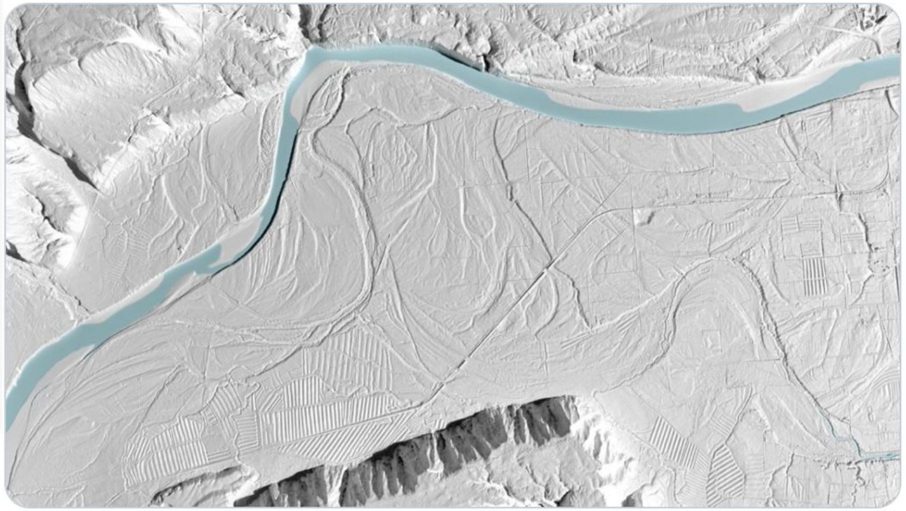
Creating point cloud visualisations with OpenTopography



Stripping down point clouds to bare earth—Wellington, New Zealand

LINZ Data Service
@LINZLDS

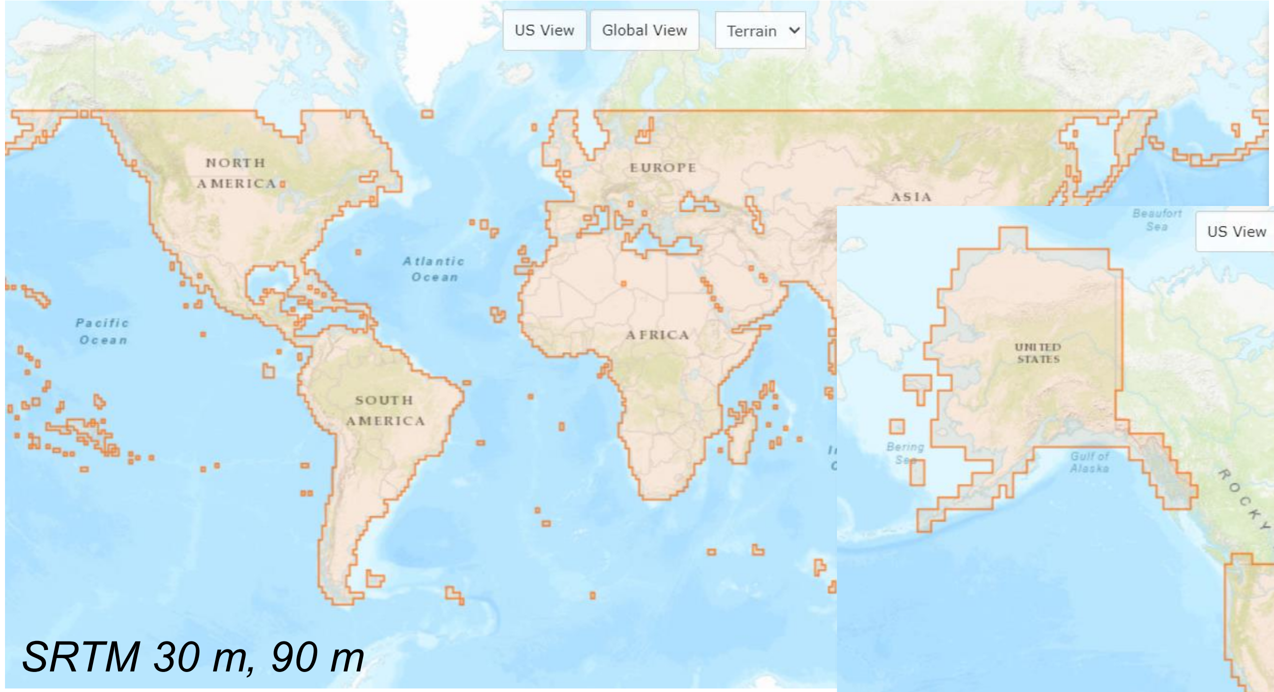
New #LiDAR available! DEM/DSM of Westport data.linz.govt.nz/layer/105446. Point clouds @OpenTopography doi.org/10.5069/G9Z31W…. Check out this image of the Buller River showing land features not easily seen in aerial imagery alone #opendata



Global & Regional Topography Data

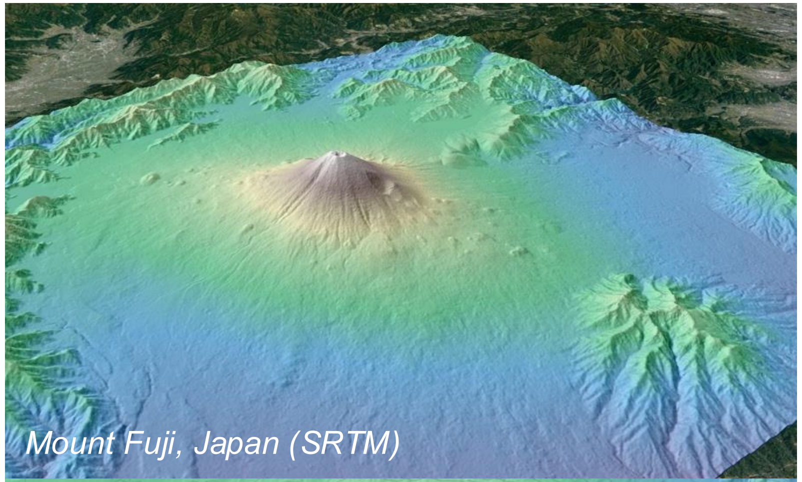
SRTM, NASADEM, ALOS World 3D, Copernicus, GEDI L3, GEBCO, ArcticDEM, REMA, etc.

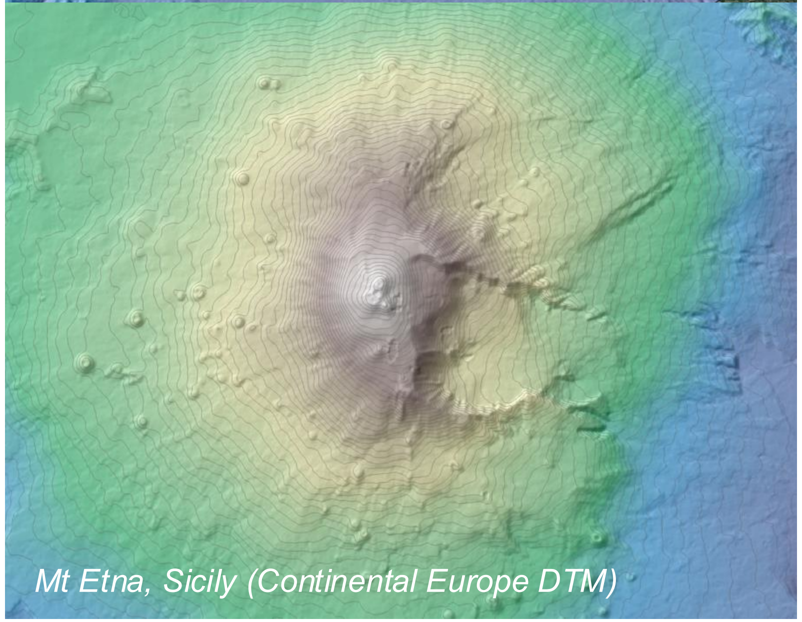
USGS 1m, 10m, 30m



SRTM 30 m, 90 m

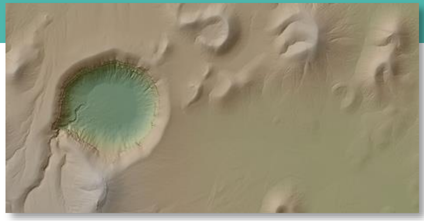
USGS 10 m


Mount Fuji, Japan (SRTM)

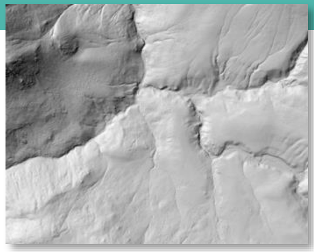

Mt Etna, Sicily (Continental Europe DTM)

Data Services

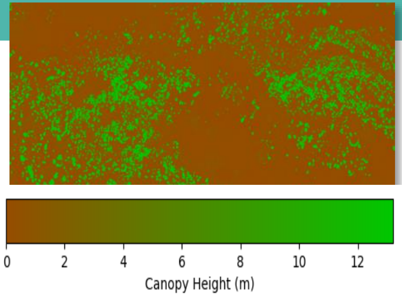
Digital Elevation Models
TIN / Local Gridding



Topographic
Hillshades

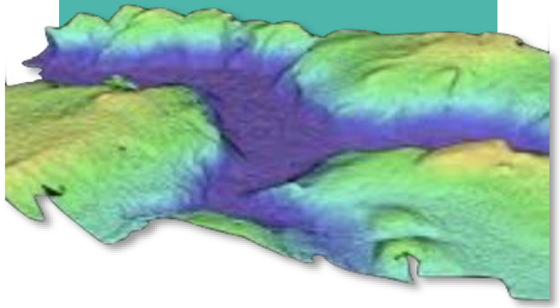


Canopy Height Model



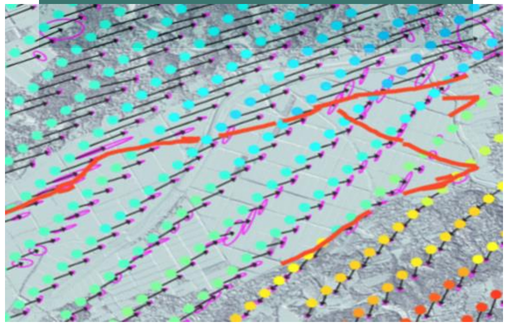
Contour Lines

3D Visualization

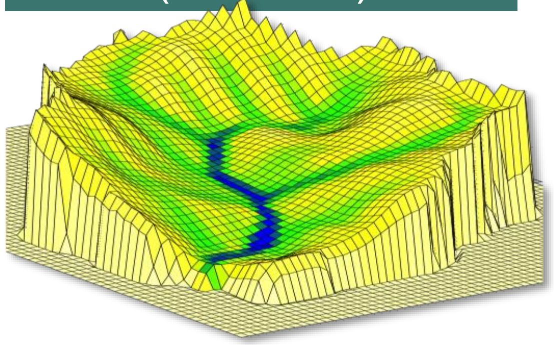


Vertical Differencing

3D Differencing

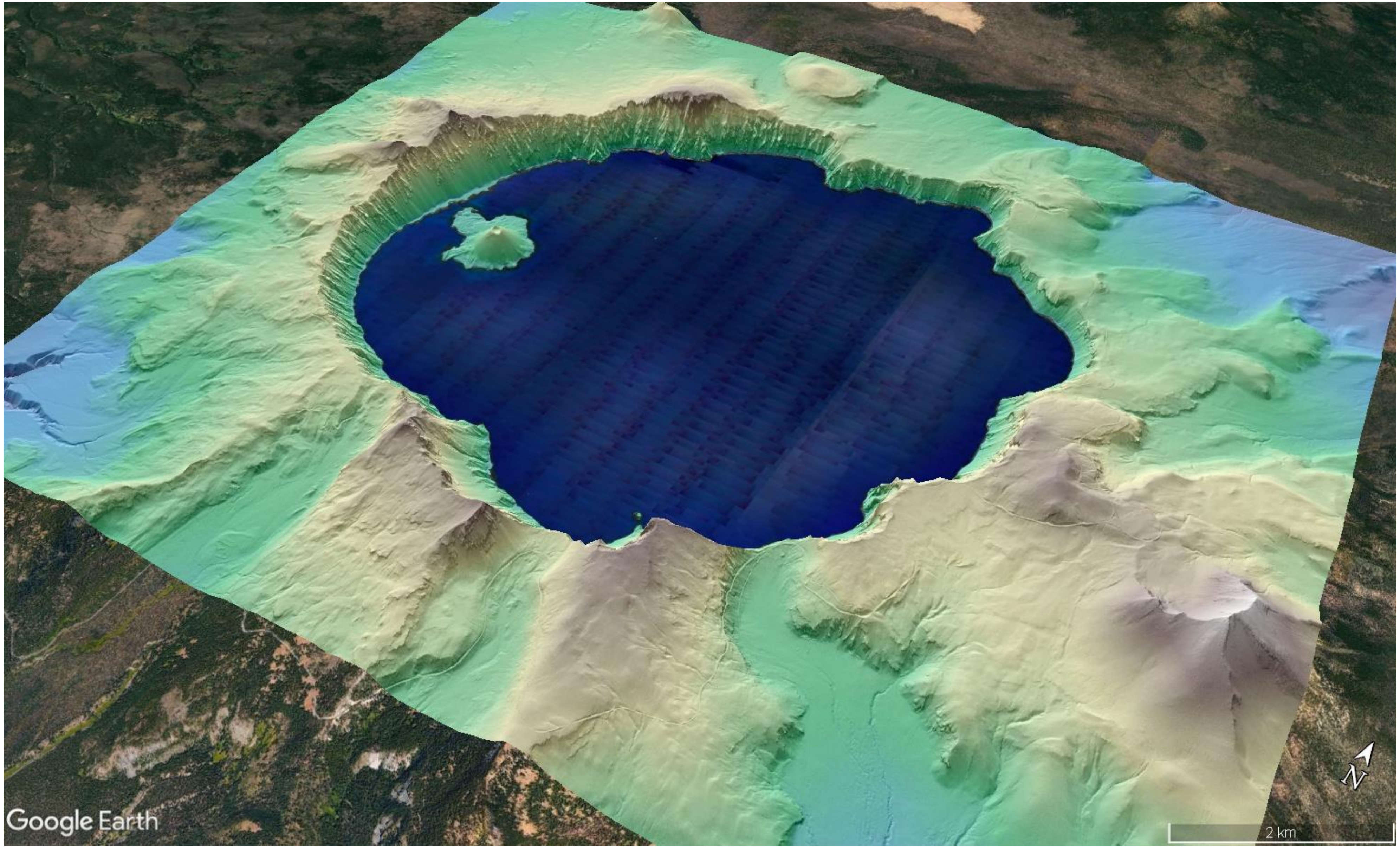


Hydrology Tools
(TauDEM)



Point Cloud Viewer

Visualization Products



Crater Lake colored DTM hillshade overlain on Google Earth imagery

Hydrologic Routing

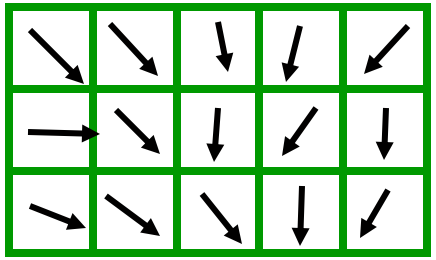
7. Hydrologic Terrain Analysis Products (tauDEM)

- ☑ Hydrologically correct DEM with pits filled
- ☑ D-Infinity Flow Direction
- ☑ D8 Flow Direction:
- ☑ D-Infinity Specific Catchment Area
- ☑ D8 Contributing Area
- ☑ Topographic Wetness Index

Raw DEM

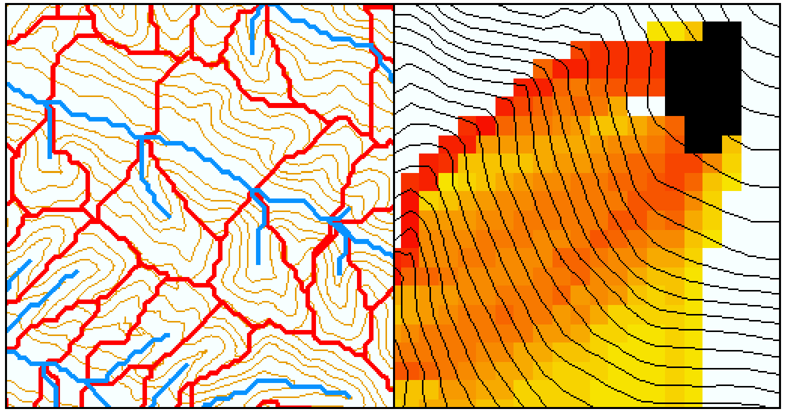
Pit Removal (Filling)

Flow Field



D8
D-Infinity

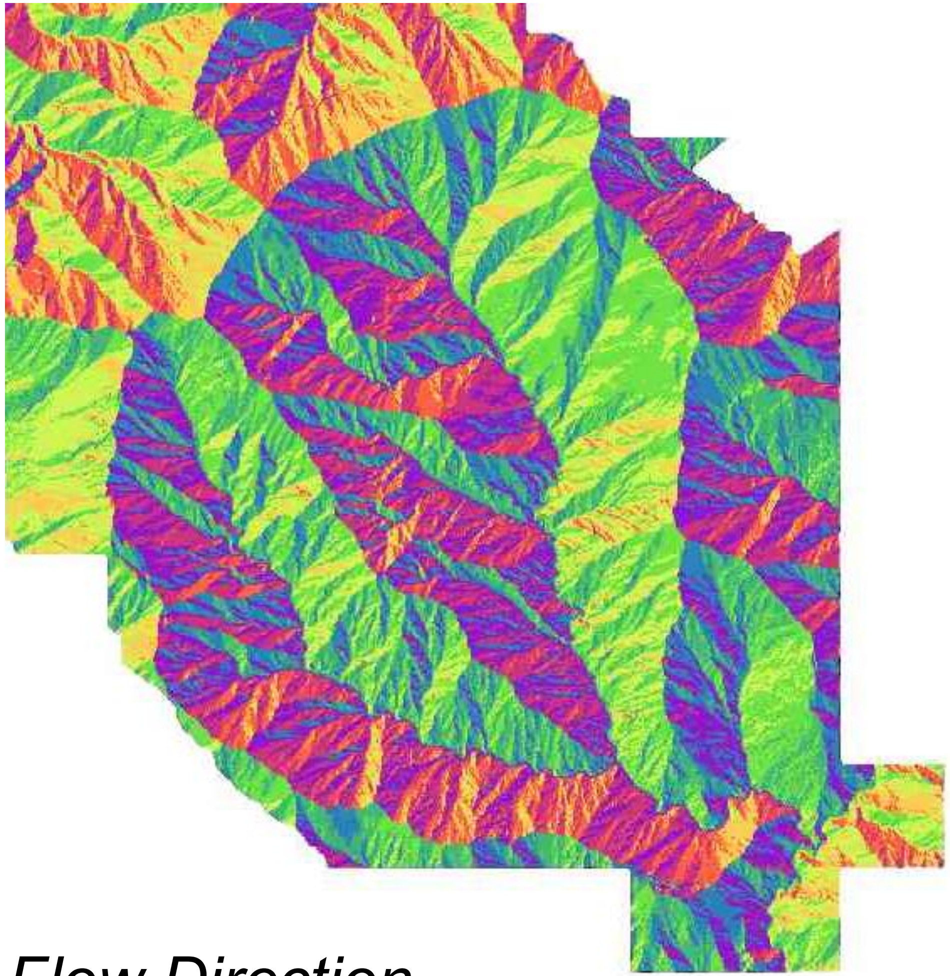
Channels, Watersheds, Flow Related Terrain Information



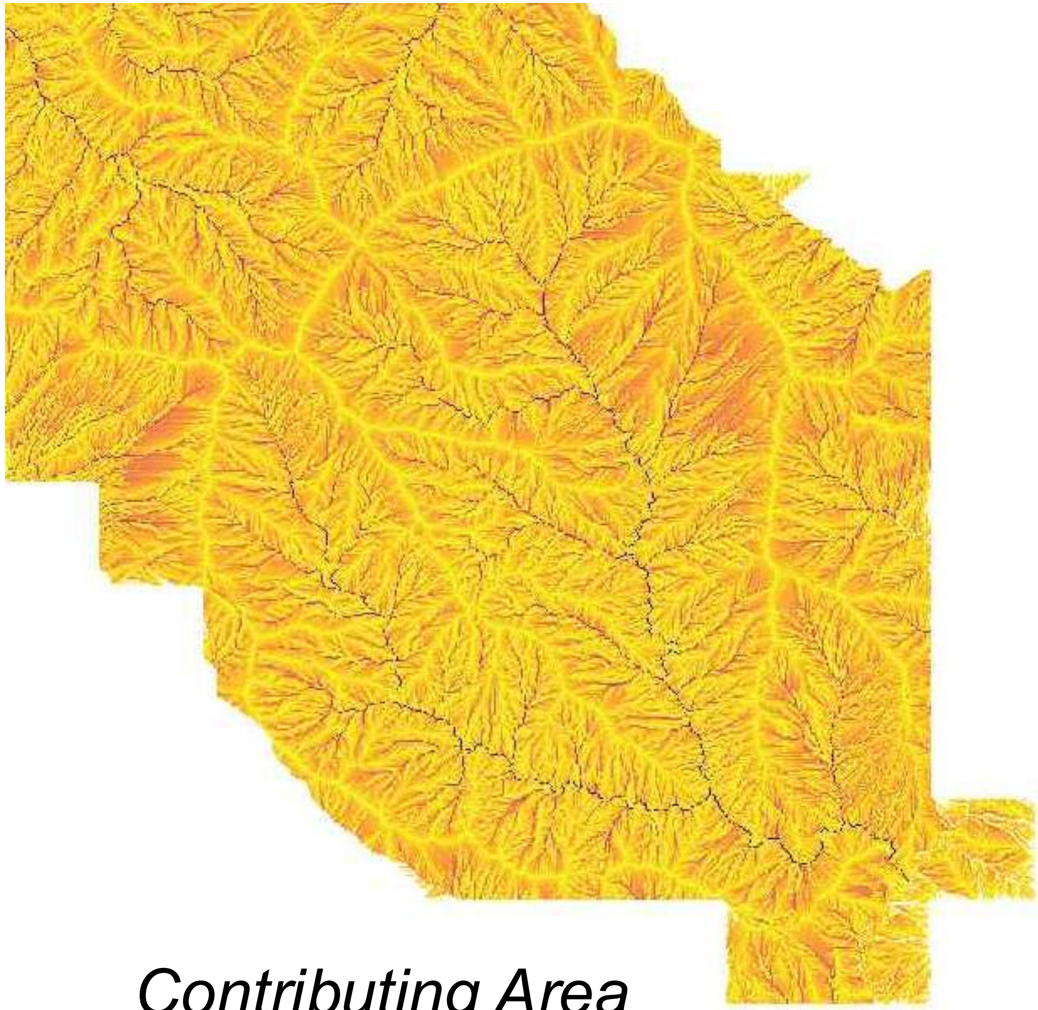
From David Tarboton, USU

Hydrologic Routing

GIS Visualizations



Flow Direction



Contributing Area

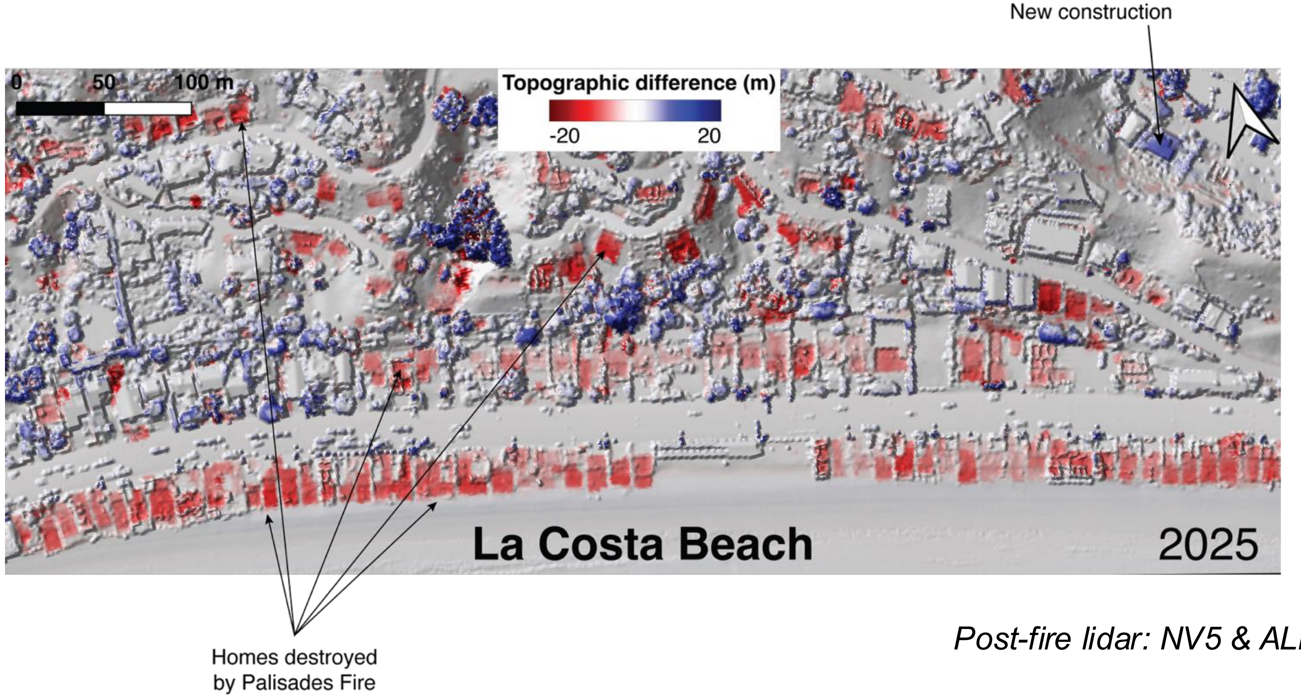
Topographic Differencing

Multi-temporal data comparison / change detection

How do we best utilize the growing availability of multi-temporal topography?

Challenges:

- Methods
- Error assessment
- Data management



LA County Wildfires, January 2025
Palisades Fire

Post-fire lidar: NV5 & ALERT California

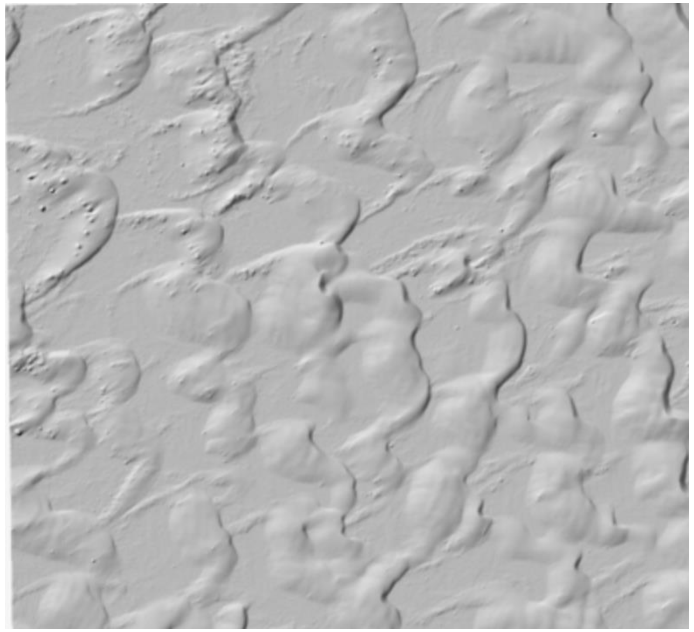
Topographic Differencing

OT High Resolution Topography [3] | USGS 3DEP [6] | NOAA [0] | Community Contributed [1] | Global & Regional DEM [10]

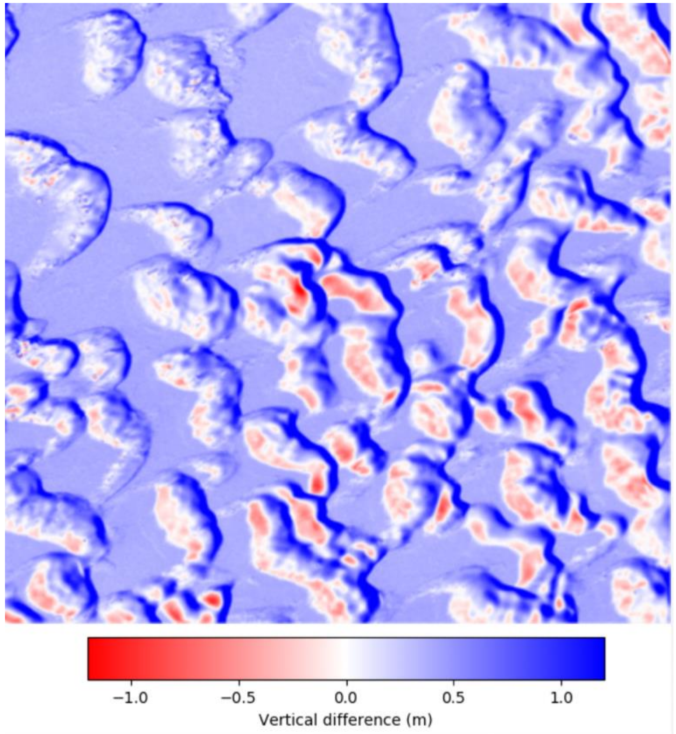
Datasets listed below are hosted by OpenTopography and are available in point cloud format for download and processing (e.g., creating custom DEMs). In some cases derived data products such as raster and Google Earth Image overlays are also available. Click the button to the right of the dataset name to access the available data products.

1 White Sands National Monument, NM: LiDAR Survey of Dune Fields (Sept 2009) Open Data — Differencing — Point Cloud
2 White Sands National Monument, NM: LiDAR Survey of Dune Fields (Jan 2009) Open Data — Differencing — Point Cloud
3 White Sands National Monument, NM: LiDAR Survey of Dune Fields Open Data — Differencing — Point Cloud

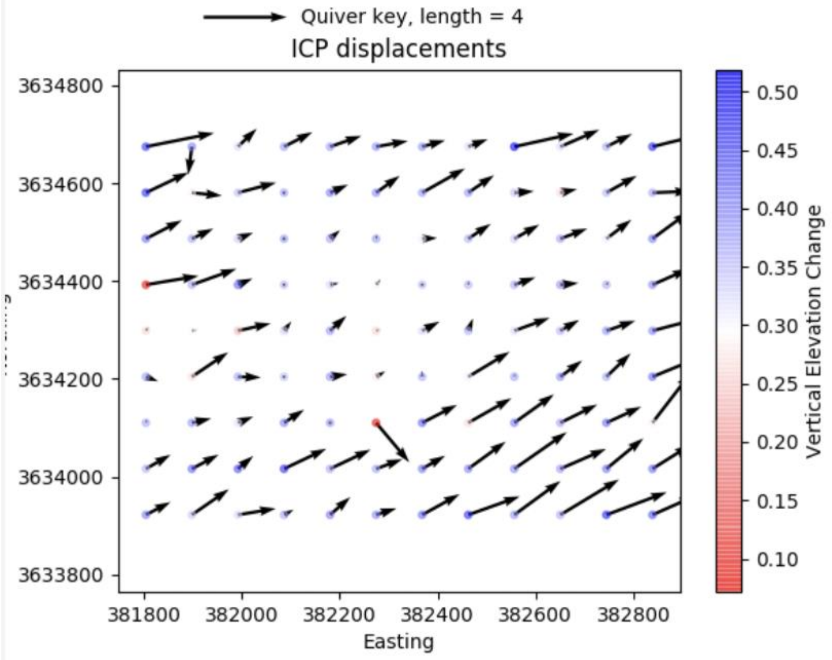
Tools for on-demand comparison of datasets. Change in the vertical or in 3D.



Hillshade



Vertical differencing



3D differencing

OT Community & Impact

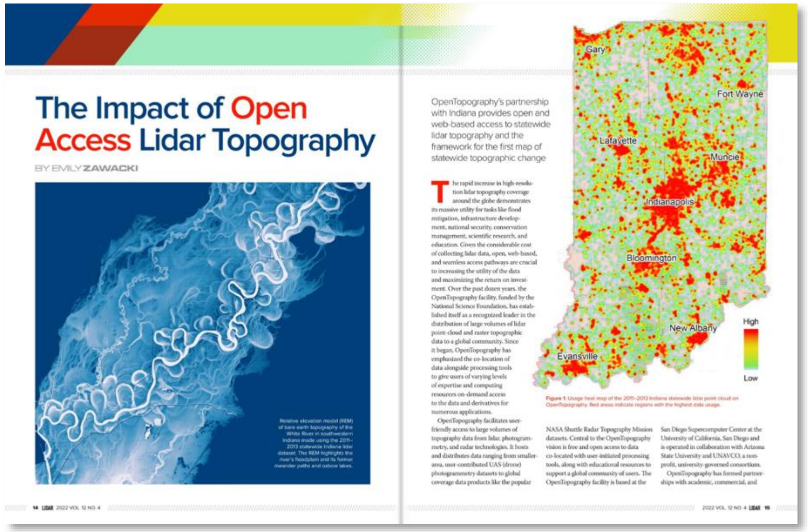
260k registered portal users (2.46M jobs)

141k API users (5.3M API calls)

67k OT mailing list subscribers

Since 2009, OT has enabled 1204 peer-reviewed publications

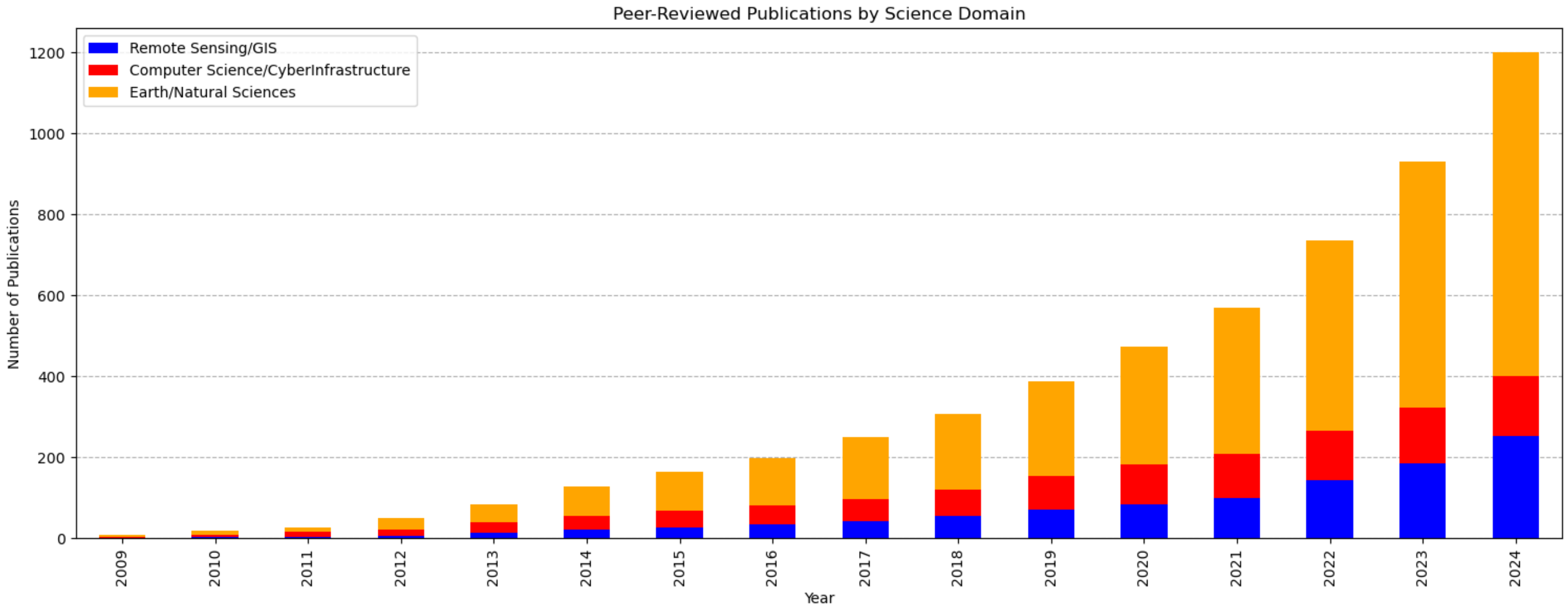
https://opentopography.org/blog/ot-bibliography-2024-review-publications-using-opentopography



The Impact of Open Access Lidar Topography

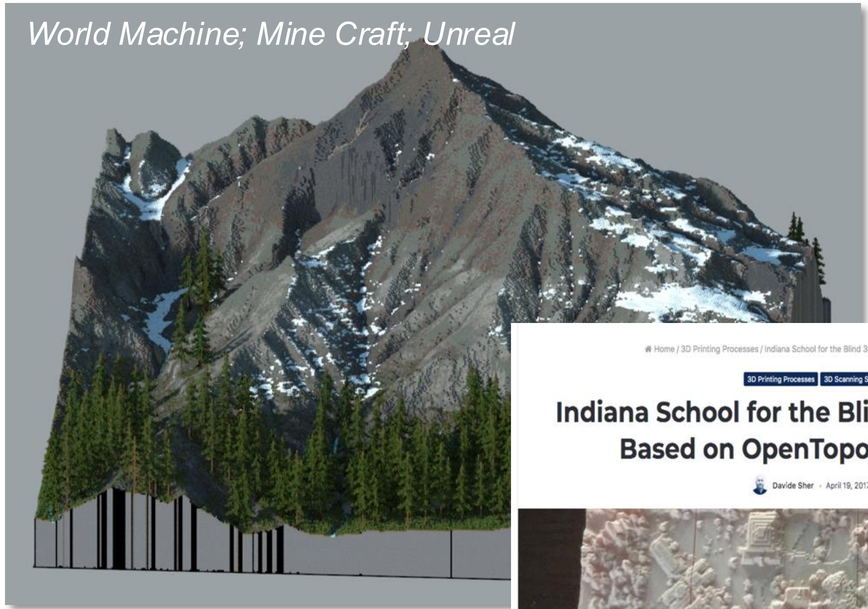
BY EMILY ZAWACKI

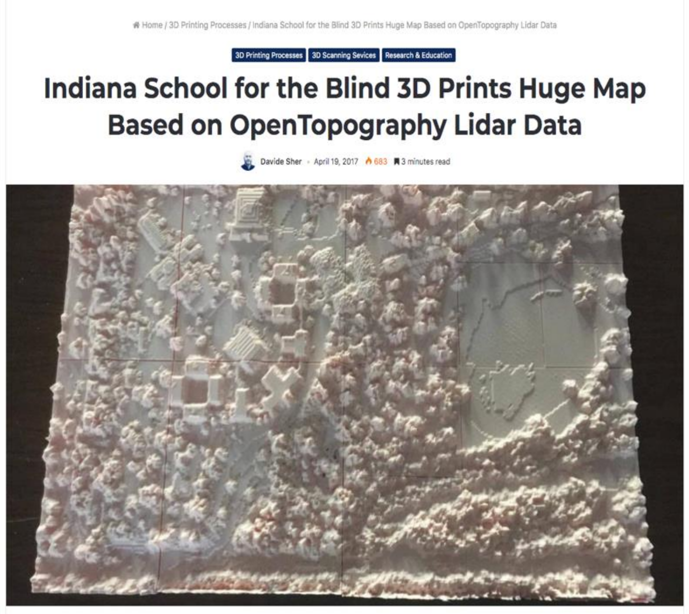
OpenTopography's partnership with Indiana provides open and web-based access to statewide lidar topography and the framework for the first map of statewide topographic change



Diverse Use Cases

- *"…developing a video game and want to experiment with landscapes"*
- *"…make maps for the family ranch"*
- *"…providing training and instruction to land surveyors and engineers"*
- *"…development of Emergency Action Plans"*
- *"…better understand avalanche conditions"*
- *"…generate fault hazard maps for the state of CA"*
- *"…I use these data sets both for teaching and for research"*
- *"…to create orienteering map contours"*
- *"…estimating forest canopy height and density"*

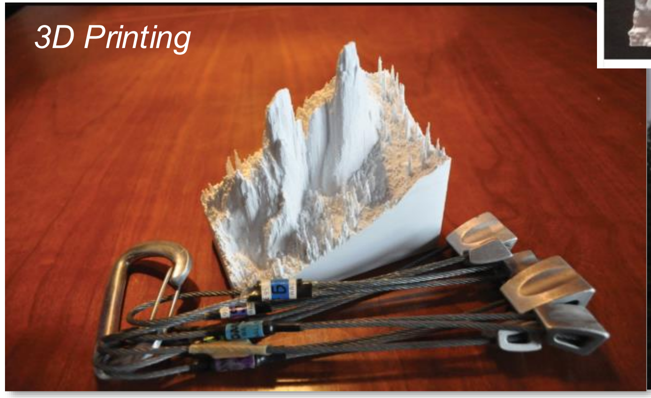



Home / 3D Printing Processes / Indiana School for the Blind 3D Prints Huge Map Based on OpenTopography Lidar Data

3D Printing Processes | 3D Scanning Sevices | Research & Education

Indiana School for the Blind 3D Prints Huge Map Based on OpenTopography Lidar Data

Davide Sher · April 19, 2017 683 3 minutes read

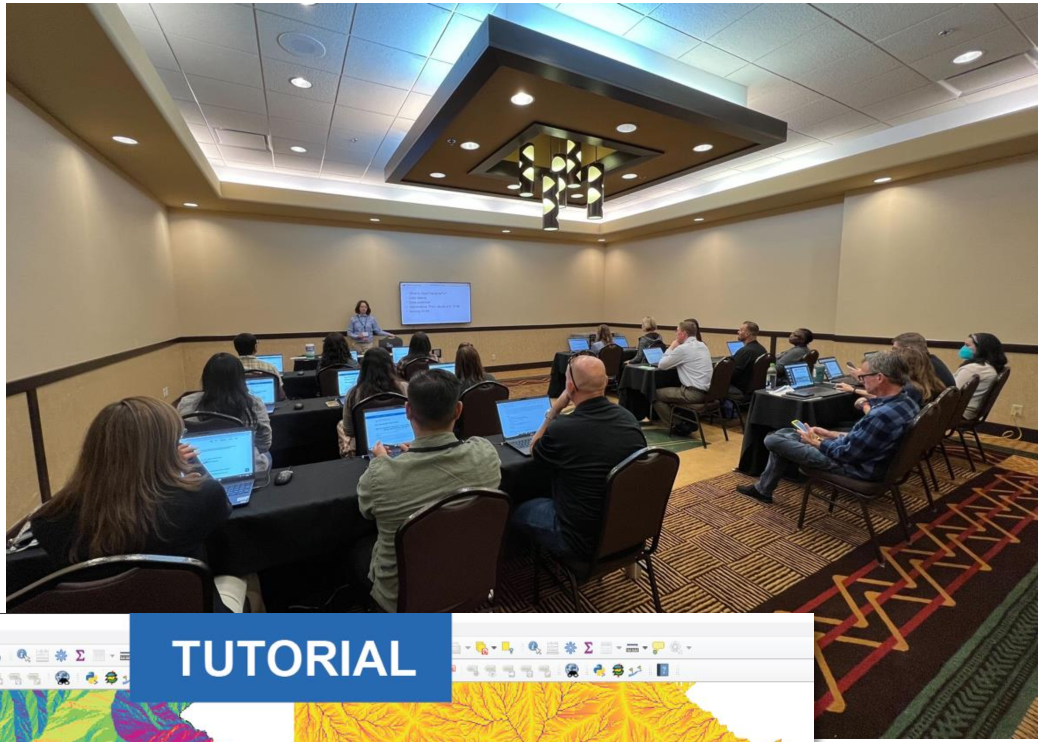


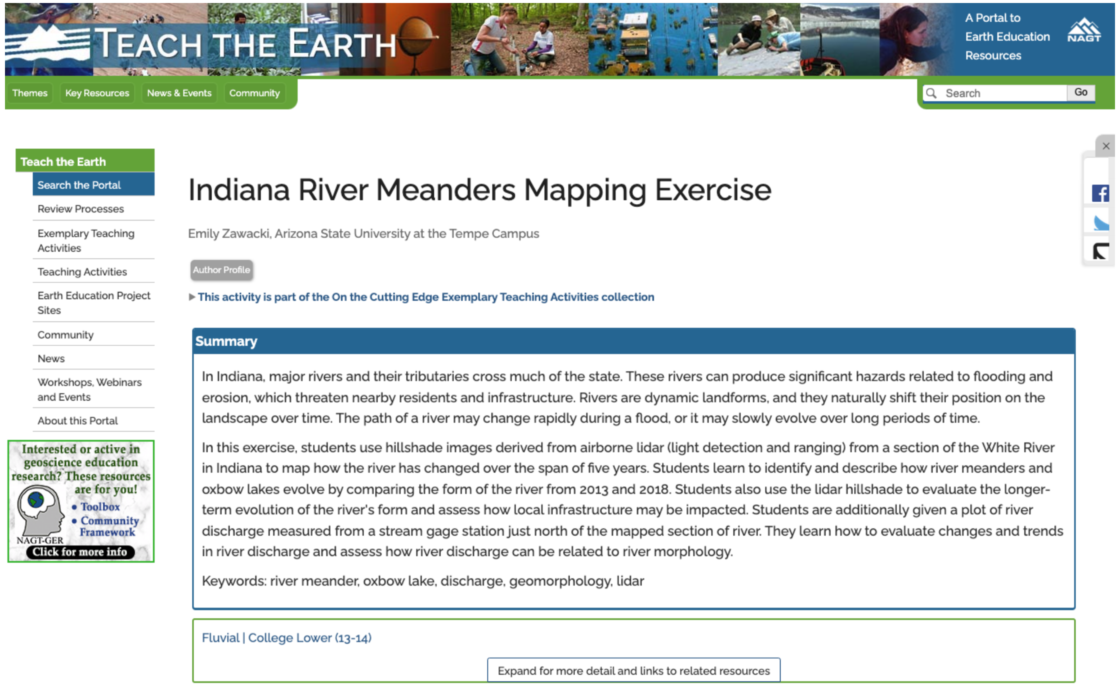
Education and Training

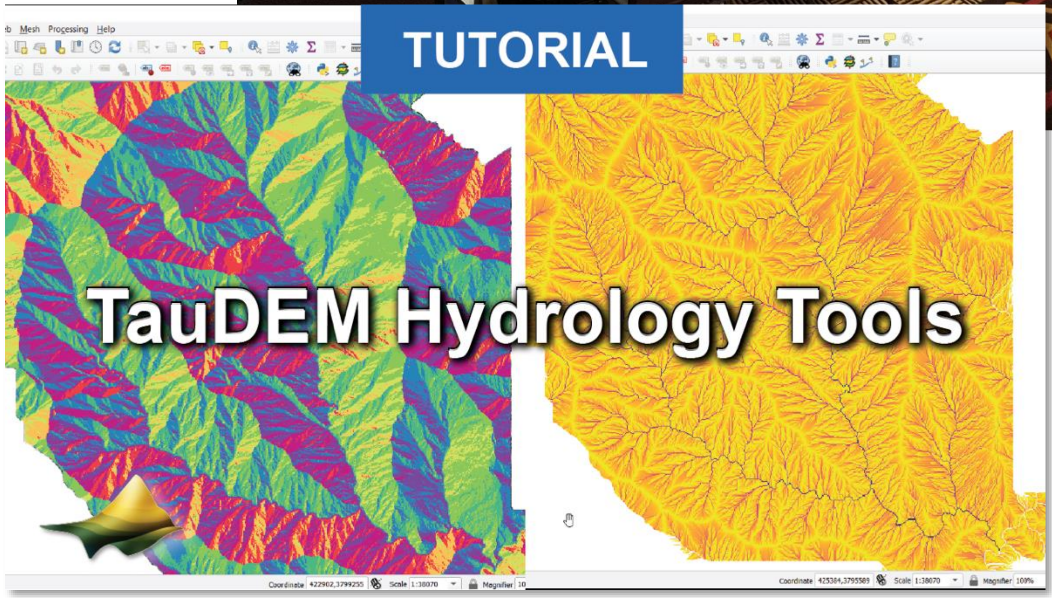
Short courses on lidar technology, data processing and analysis, applications

Video tutorials on OT YouTube channel
https://www.youtube.com/user/OpenTopography

Ready to use classroom activities







Jupyter Notebooks & Code

OpenTopography Facility

Open access to high-resolution, Earth science-oriented topography data, and related tools & resources. US NSF supported.

125 followers · San Diego Supercomputer Center, ... · http://www.opentopography.org · @opentopography.org · info@opentopography.org

Follow

Popular repositories

RiverREM (Public)
Forked from klarrieu/RiverREM
Make river relative elevation models (REM) and REM visualizations from an input digital elevation model (DEM).
Python · 150 stars · 25 forks

points2grid (Public)
Points2Grid is a robust and scalable tool for gridding LIDAR point cloud data to generate Digital Elevation Models (DEM). Points2Grid uses a local gridding method to compute grid cell elevation usi...
C++ · 88 stars · 36 forks

OT_3DEP_Workflows (Public)
Forked from cmspeed/OT_3DEP_Workflows
Jupyter Notebook-based workflows for programmatically accessing, processing, and visualizing 3D Elevation Program (3DEP) lidar data
Jupyter Notebook · 77 stars · 17 forks

OT_BulkAccess_COGs (Public)
OpenTopography has recently converted its entire global dataset collection to COGs. This notebook example highlights the power of Cloud Optimized GeoTIFFs (COGs) and how they can be used to reduce ...
Jupyter Notebook · 41 stars · 5 forks

3D_Differencing (Public)
3D differencing in OpenTopography - Author: Chelsea Scott cpscott1@asu.edu
Python · 21 stars · 10 forks

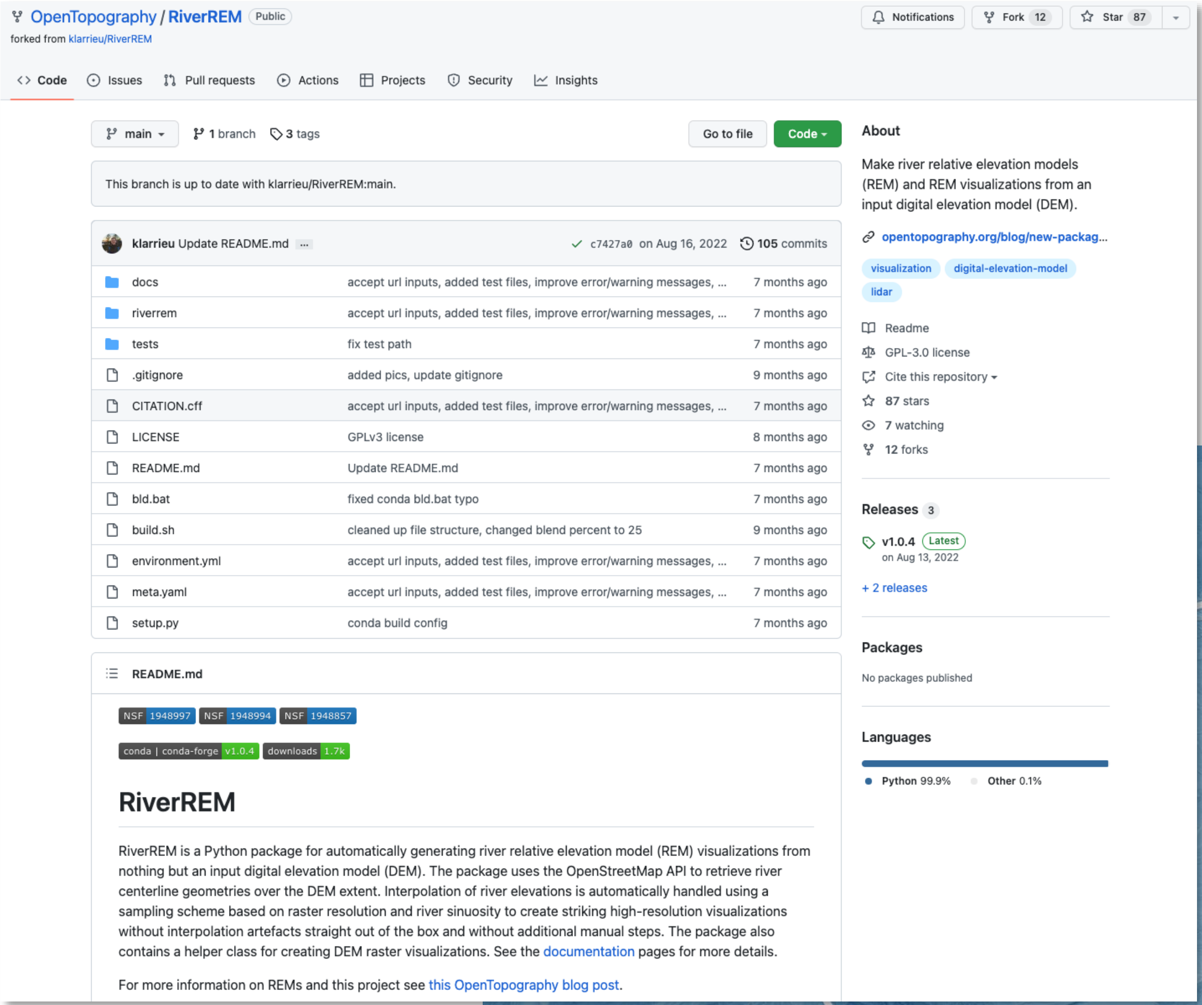
PointCloud_to_STL (Public)
This notebook uses a Voxel subsampling method for point cloud data thinning. After the point cloud has been thinned, triangulation is computed to create a mesh which can be exported as a STL file a...
Jupyter Notebook · 19 stars · 5 forks

People

Invite someone

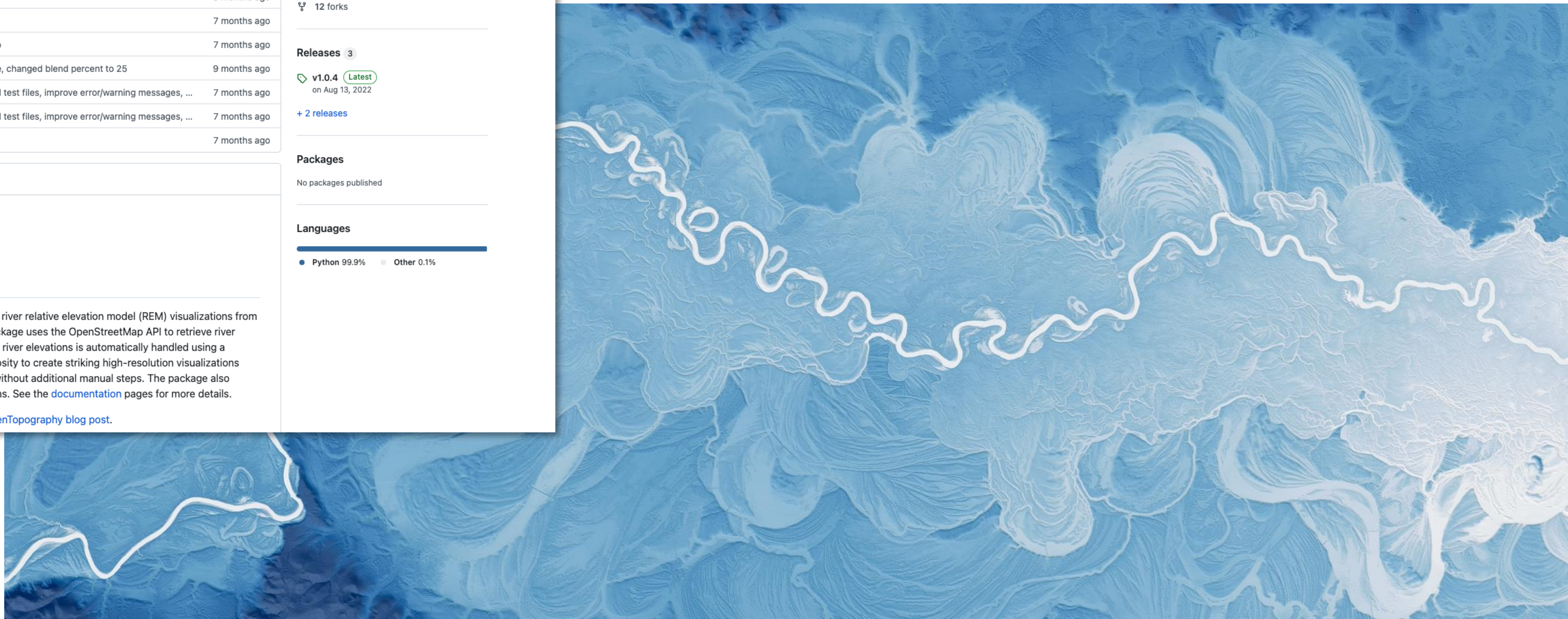
Top languages

RiverREM



Python package for the automated generation of relative elevation models (REMs) in fluvial environments.

Open source package built by OT intern Kenny Larrieu summer 2022.



Topography for 3D Printable Models

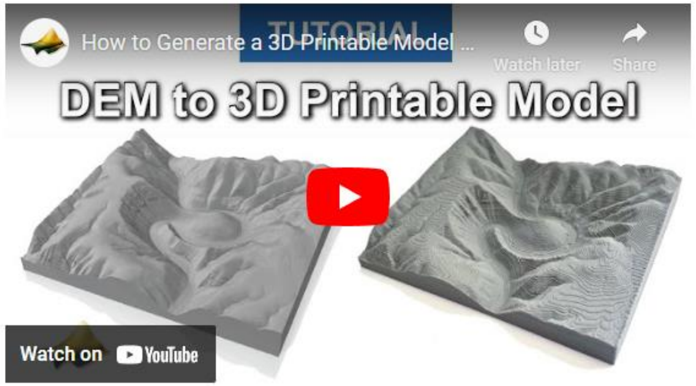
OpenTopography
High-Resolution Topography Data and Tools

HOME DATA RESOURCES LEARN ABOUT

3D Printing Digital Elevation Models

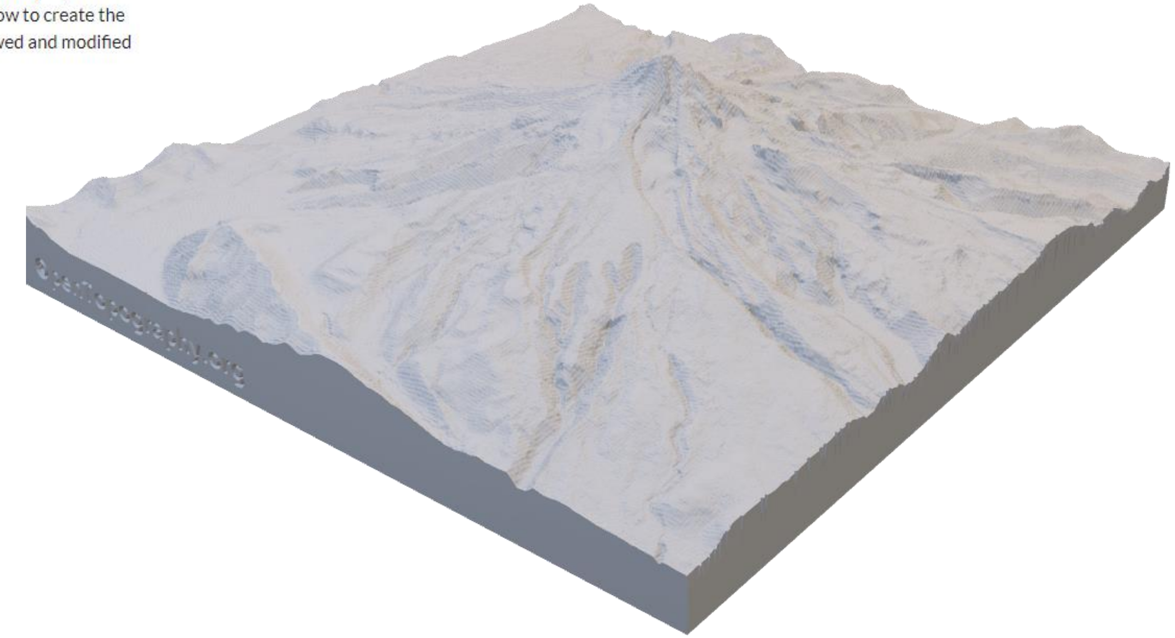
Have you ever wanted to make a 3D print of your favorite mountain peak, city-scape, or tourist destination? OpenTopography's video tutorial demonstrates how to prepare a digital elevation model (DEM) for 3D printing. Each software package in the tutorial is freely available for download. In the tutorial, we describe step-by-step how to create the standard triangle language (STL) file that is commonly used in 3D printing. We use the DEMto3D plugin in QGIS to generate the STL file, which can then be viewed and modified using the 3D Builder software. You can find a number of pre-made STL files for 3D printing on our OpenLandform Catalog.

This YouTube video tutorial explains how to create a 3D printable model from a DEM downloaded from OpenTopography:



3D Printing Terrain Workflow

You can find topography data via OpenTopography's portal to download high resolution digital elevation models (DEMs). 3D prints can be made using a digital terrain model (DTM), which depicts just the bare Earth surface, or a digital surface model (DSM), which depicts vegetation, buildings, and other structures at Earth's surface. DTMs are preferable when printing topographic landforms, and DSMs are preferable when printing urban environments.



Mount Hood 3D Model

https://opentopography.org/learn/3D_printing

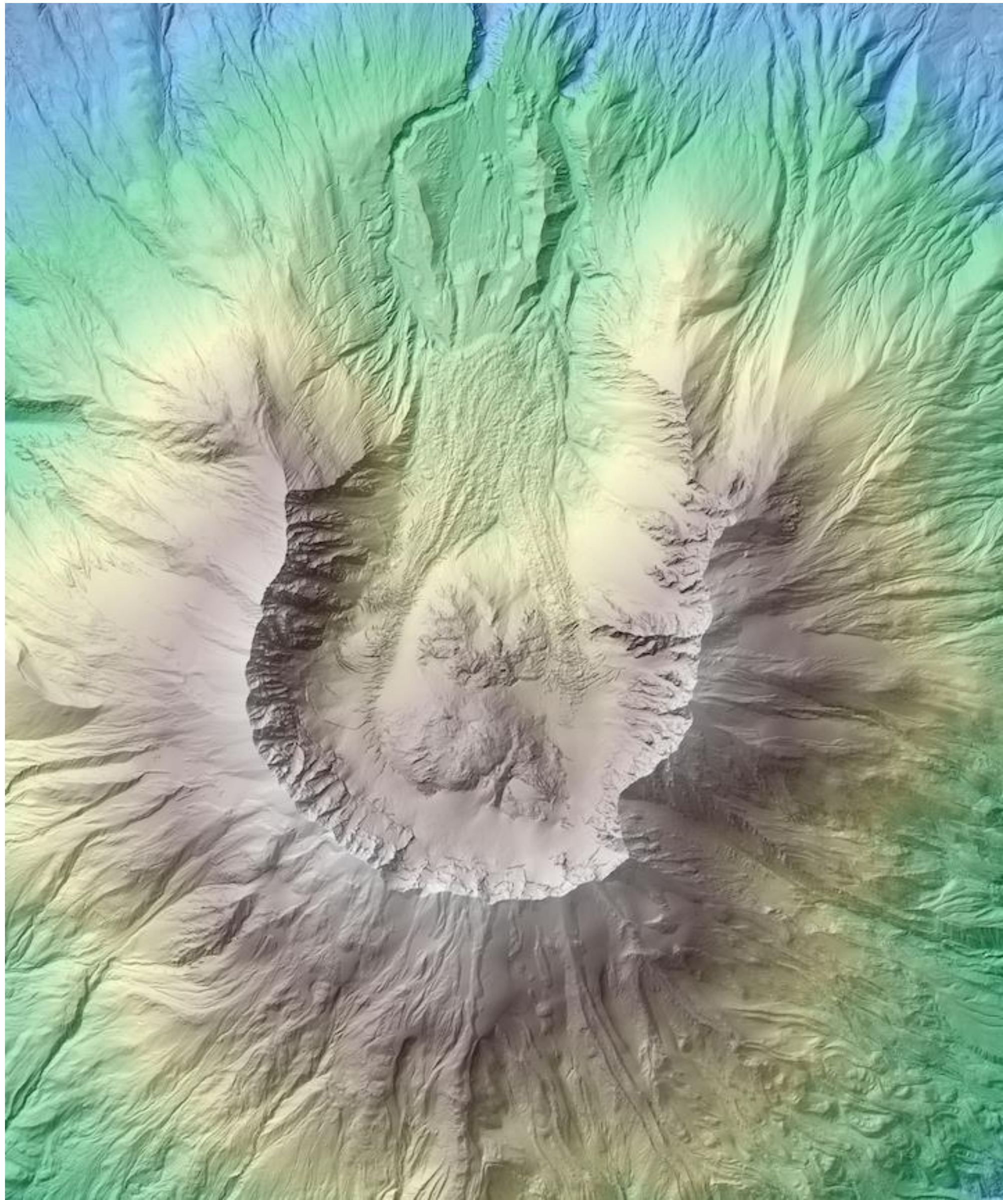
Conclusions

OT provides easy access to high resolution and global/regional topographic data and derived products

Most comprehensive source of topographic data on the internet

Education and training resources for self-paced learning

State and national-scale datasets present massive opportunities for advanced processing and analysis




White River, IN

OpenTopography

NSF

Thank you!

www.opentopography.org

Contact: **info@opentopography.org**

Socials: **@OpenTopography**

SDSC

EarthScope Consortium

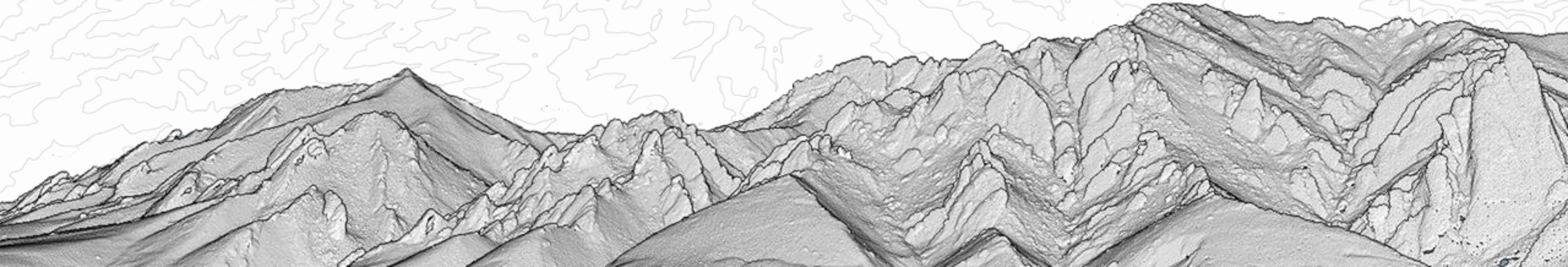
ASU

Demo: OpenTopography data discovery and access

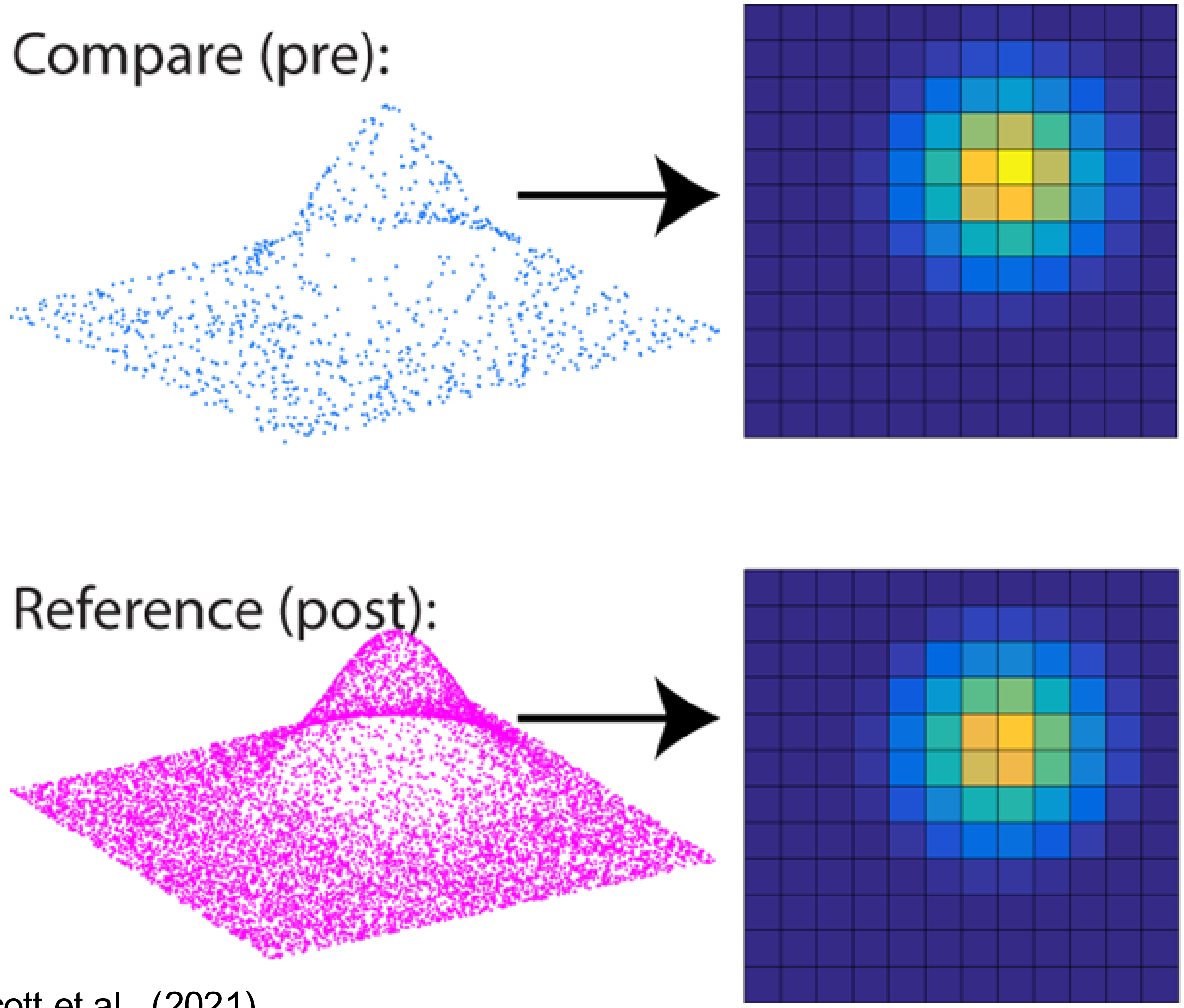
Introduction to OpenTopograhy Tools for Calculating Change at the Earth's Surface

Cassandra Brigham & Christopher Crosby

2025 NSF GAGE/SAGE Community Science Workshop



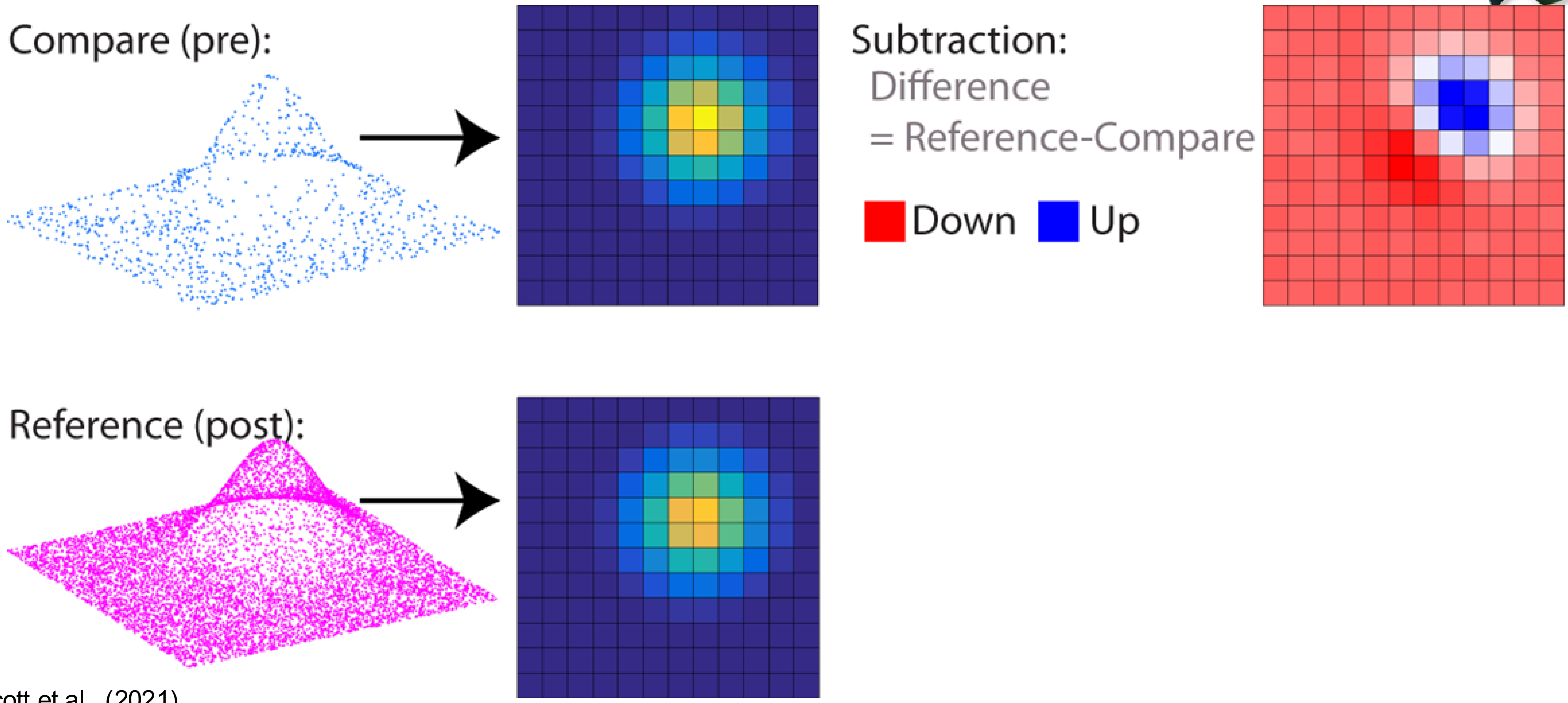
Vertical Topographic Differencing



Scott et al., (2021)

Identical grid for pre and post event topography

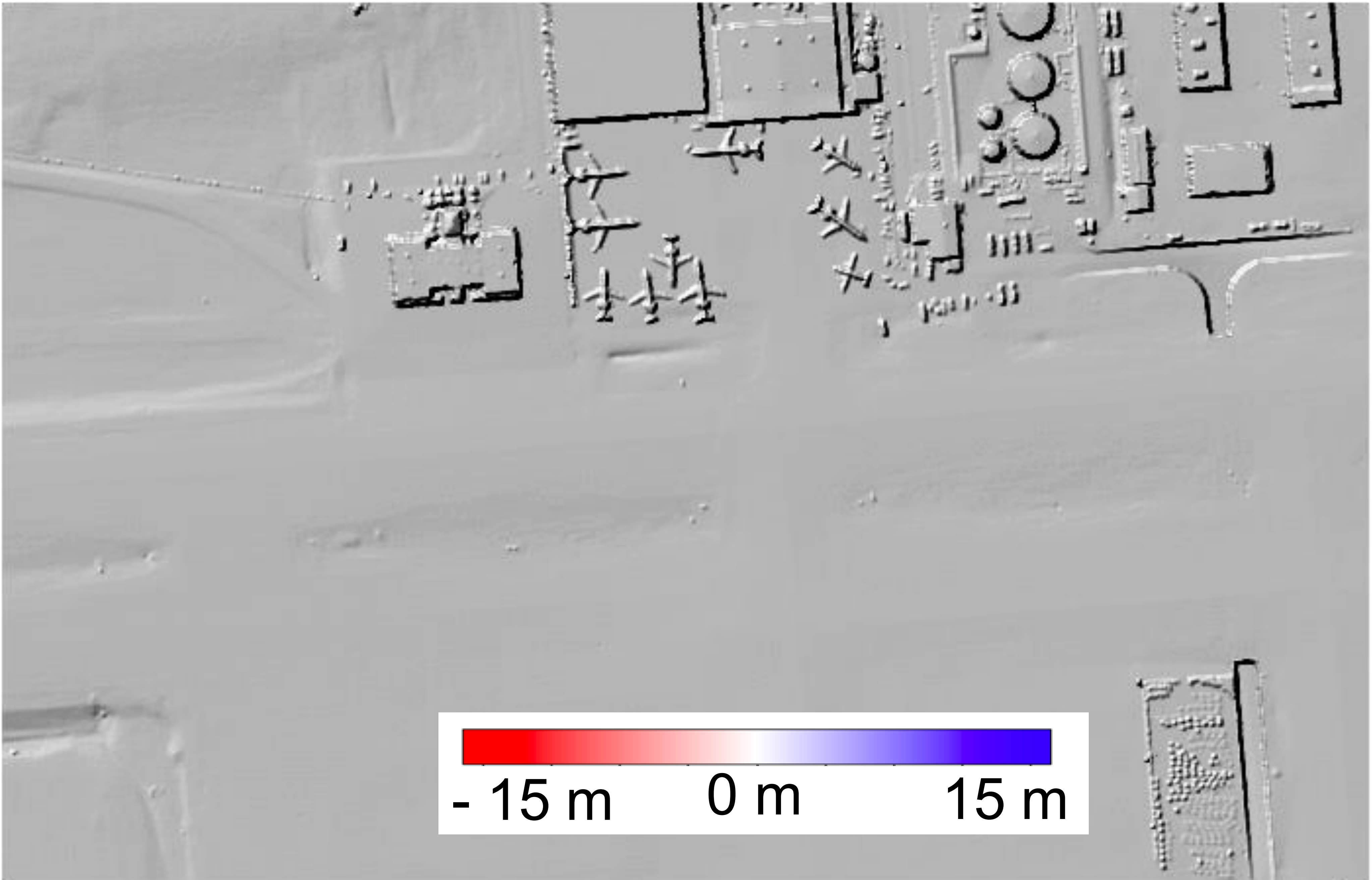
Vertical Topographic Differencing

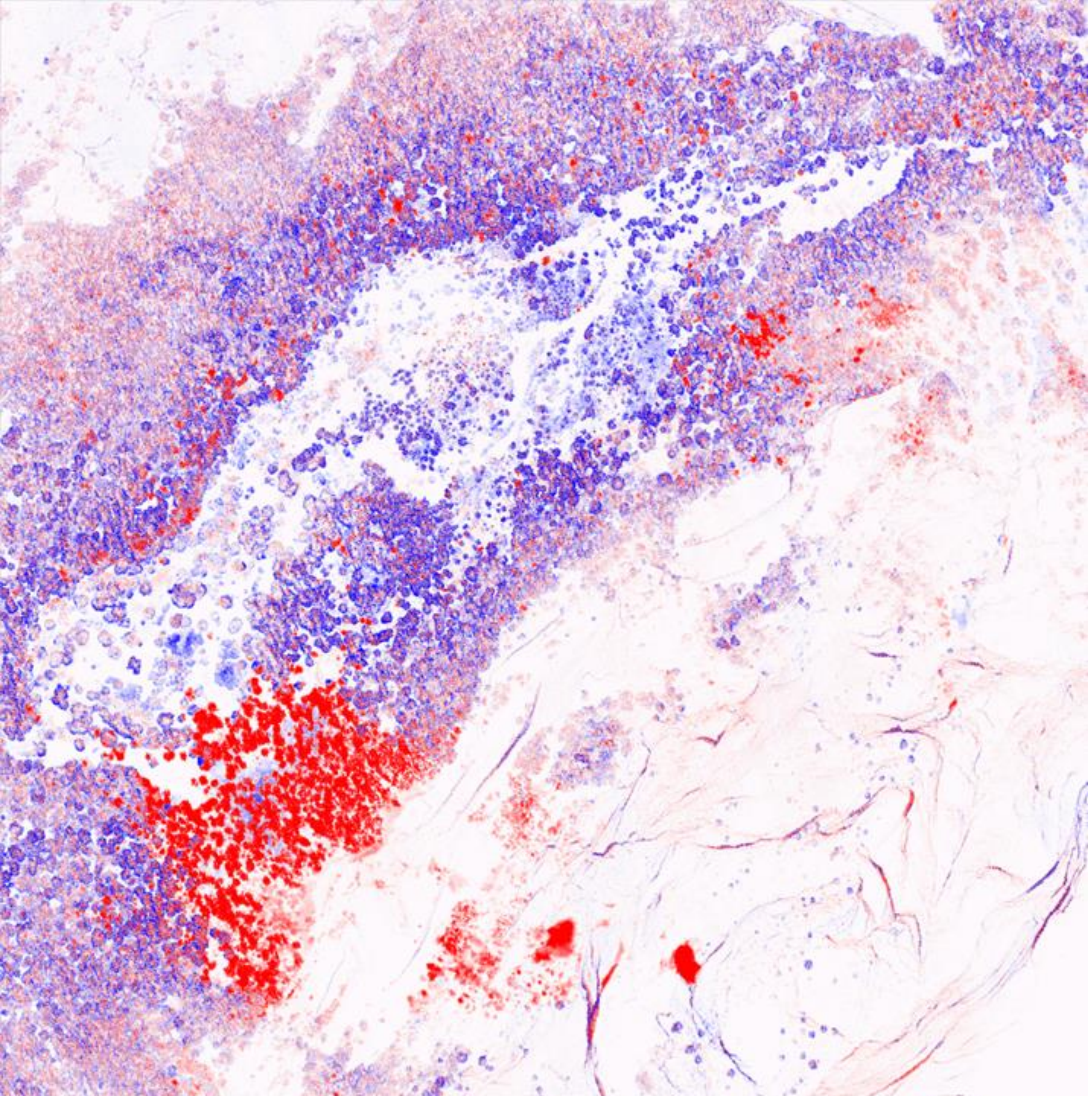


Scott et al., (2021)

Raster subtraction

Salt Lake City Airport



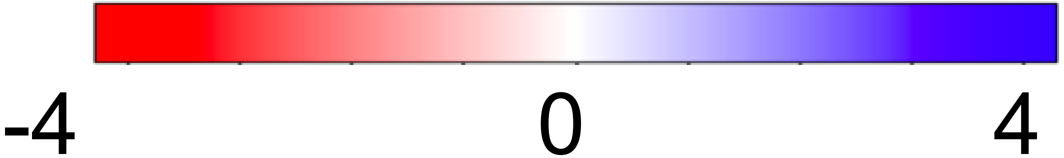


Yosemite, California

2006-2010

Salt Lake City, Utah

Vertical Difference (m)



On-demand Topographic Differencing

What?

In a few mouse clicks, users can run vertical and 3D differencing on OT

Why?

Standardize approach

Democratize access to tools

Solve issues, like CRS projections

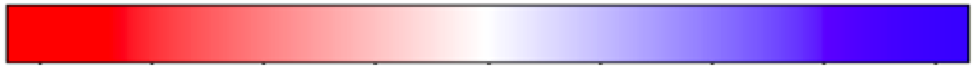
Challenges:

Legacy & Hybrid data

Algorithms: On-demand

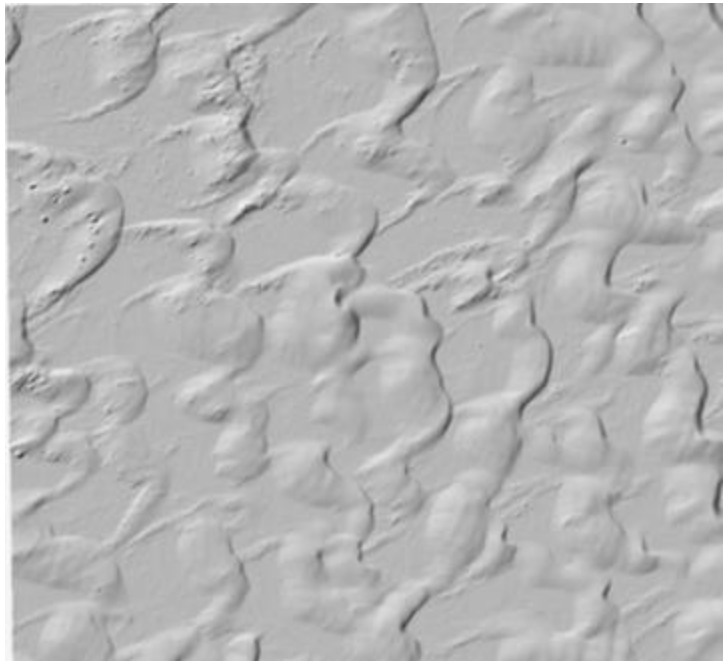
Cyber-infrastructure & HPC

Iowa City, Iowa: 2008-2014

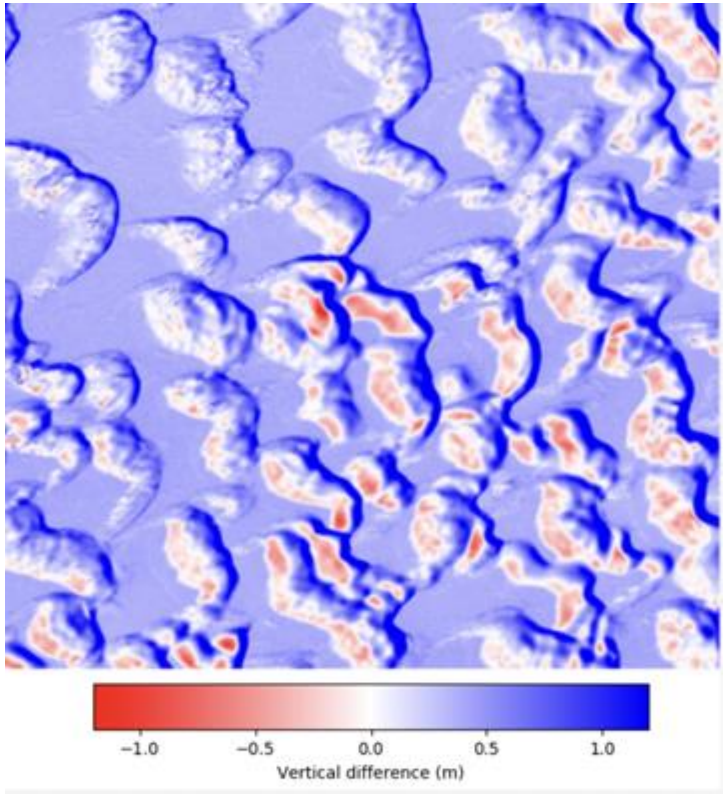


Scott, C., Phan, M., Nandigam, V., Crosby, C., Arrowsmith, R. (2021). Measuring change along the Earth's surface: On-Demand vertical and 3D topographic differencing hosted by OpenTopography. *Geosphere*. https://doi.org/10.1130/GES02259.1

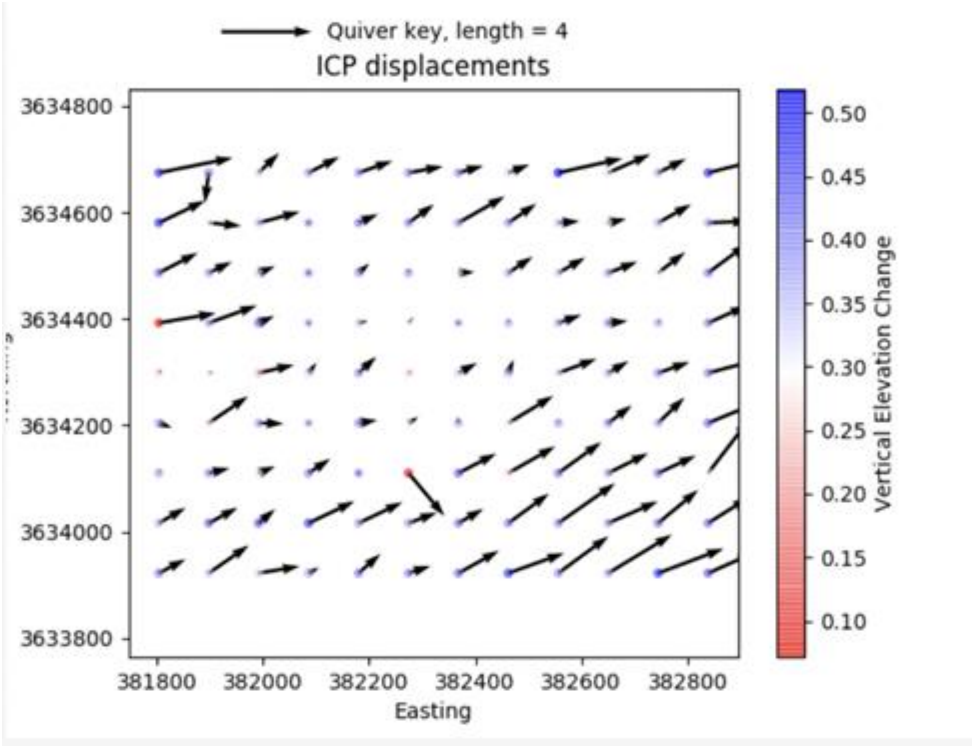
White Sand National Monument, NM



Hillshade

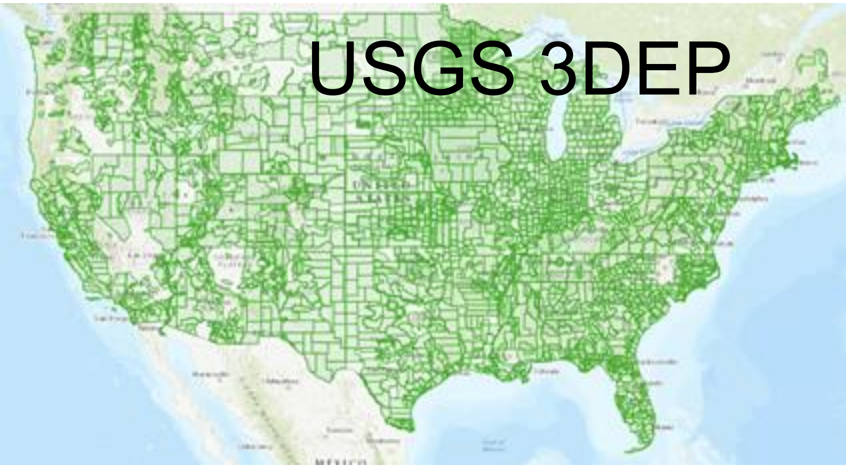


Vertical differencing



3D differencing

Differencing in OT



New Zealand

Perform differencing on (many) overlapping datasets

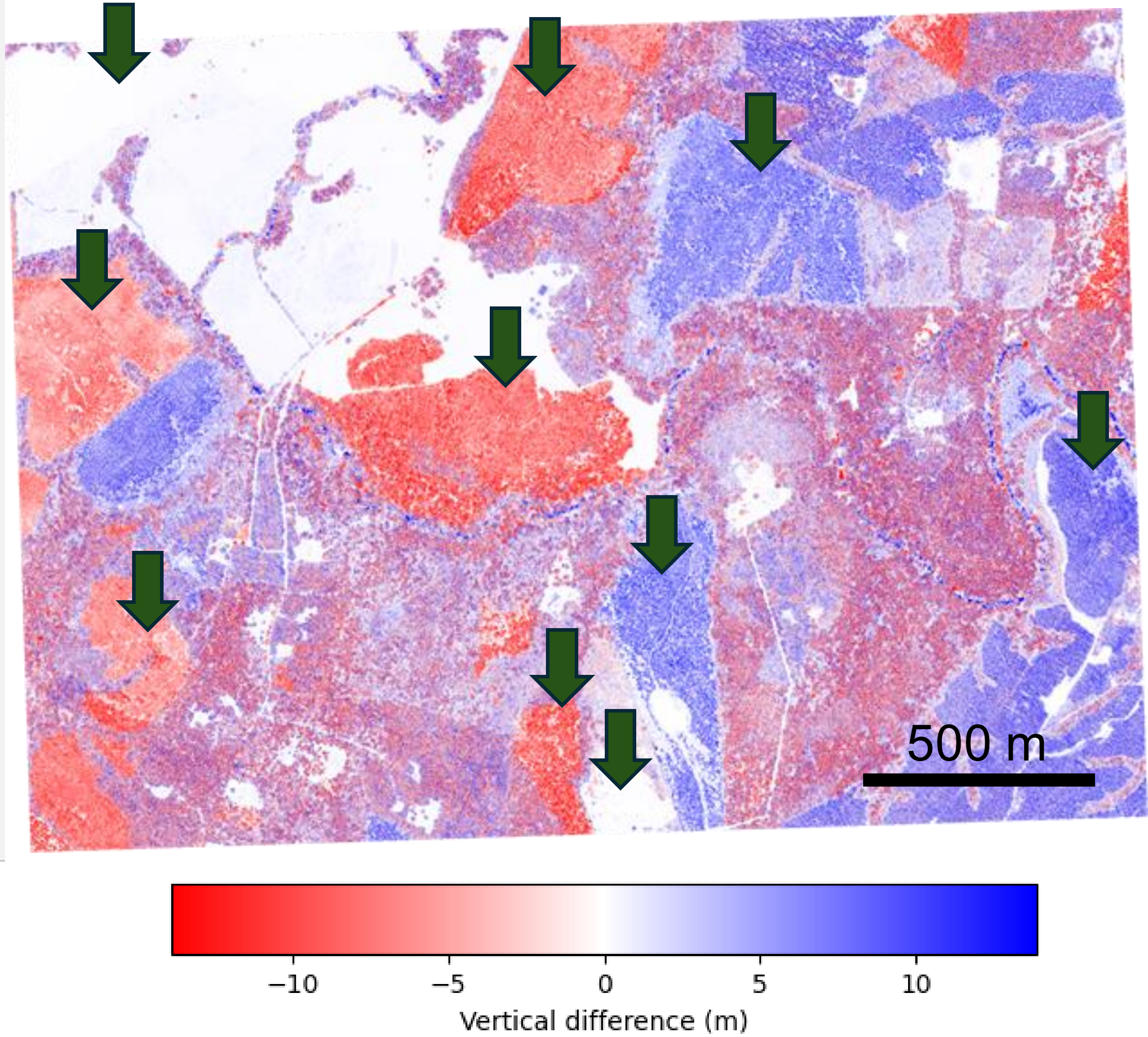
~3000 datasets covering over 20% of lower 48

Many datasets in New Zealand

Record many processes

Uncertainty in Vertical Differencing

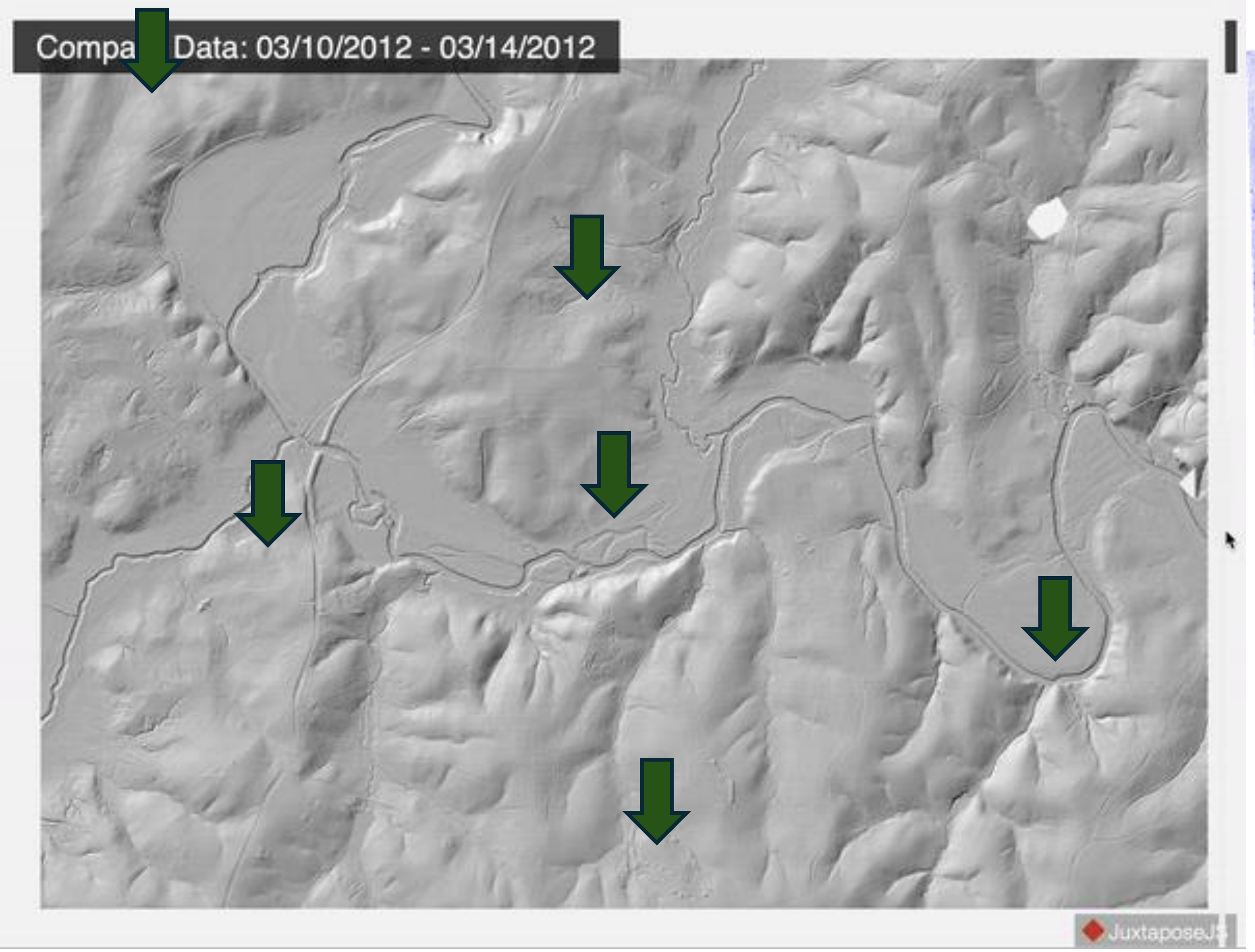
DSM differencing

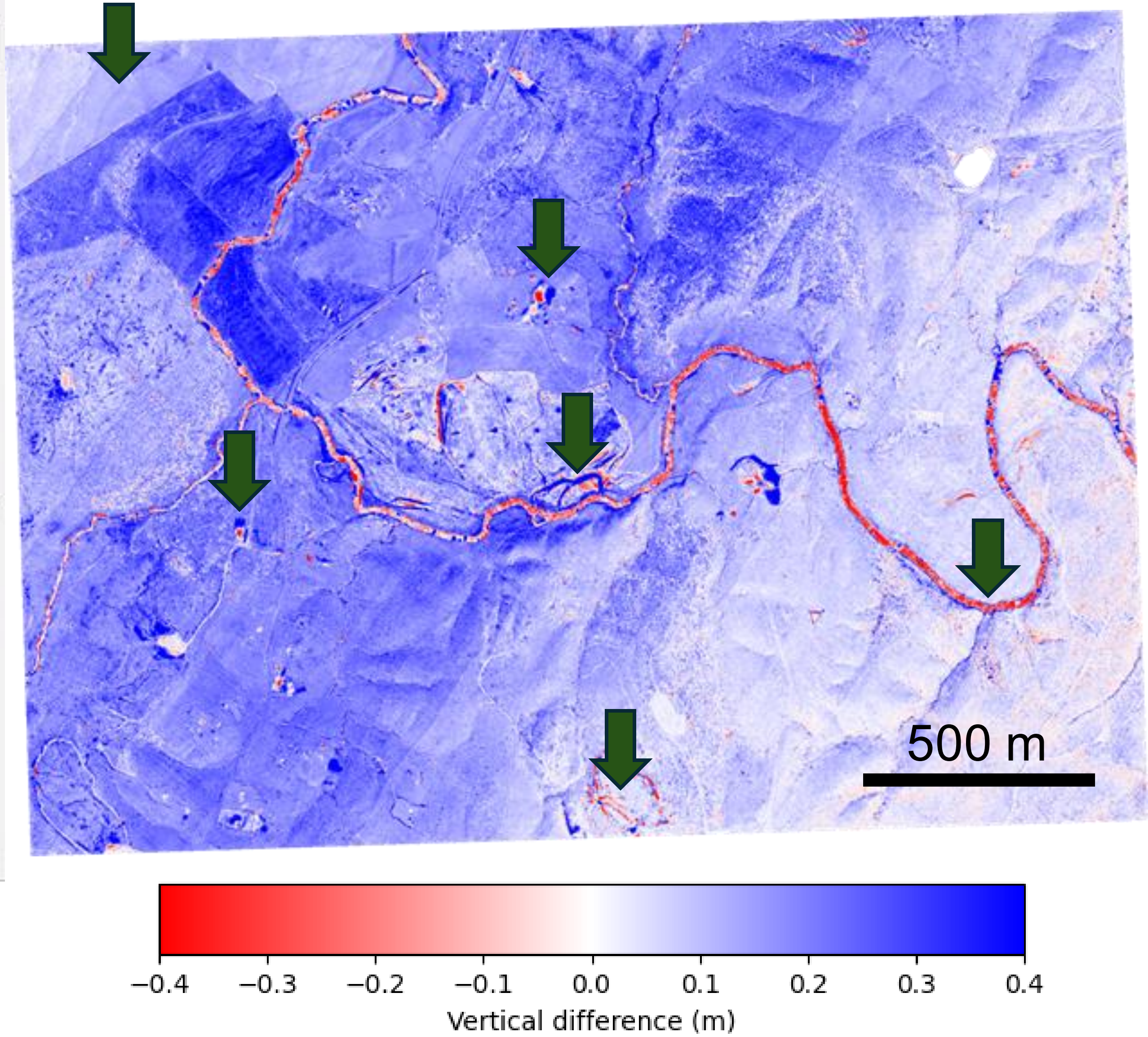


Roundabout Creek, VA
2012 - 2019

Uncertainty in Vertical Differencing

DTM differencing





Roundabout Creek, VA
2012 - 2019

Why care about uncertainty in differencing?

Errors related to dataset acquisition, processing and metadata recording are accentuated in differencing results - critical to understand and quantify the impact of these errors

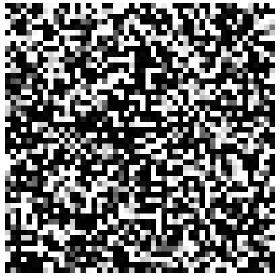
Essential component of the mapping and monitoring system envisioned by this working group

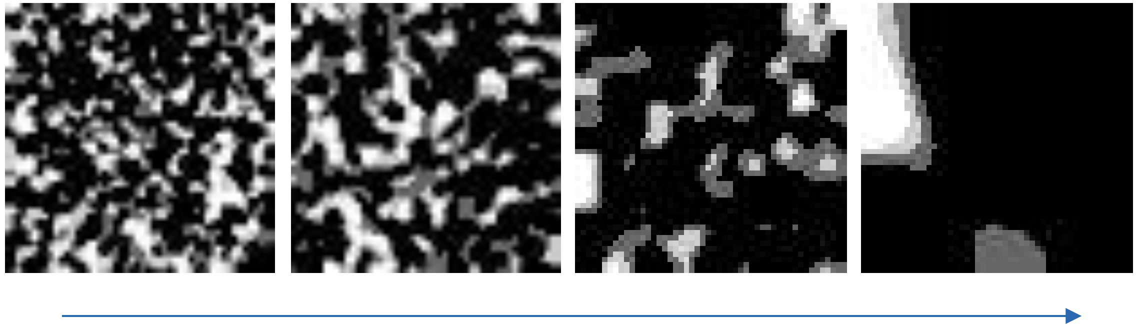
Easily communicate the presence of different error types of varying orders of magnitude to non-expert users and guide them towards a better understanding of error

Uncertainty in Vertical Differencing

Properties and spatial patterns of error

Random		Systematic
Spatially uncorrelated	Spatially correlated	

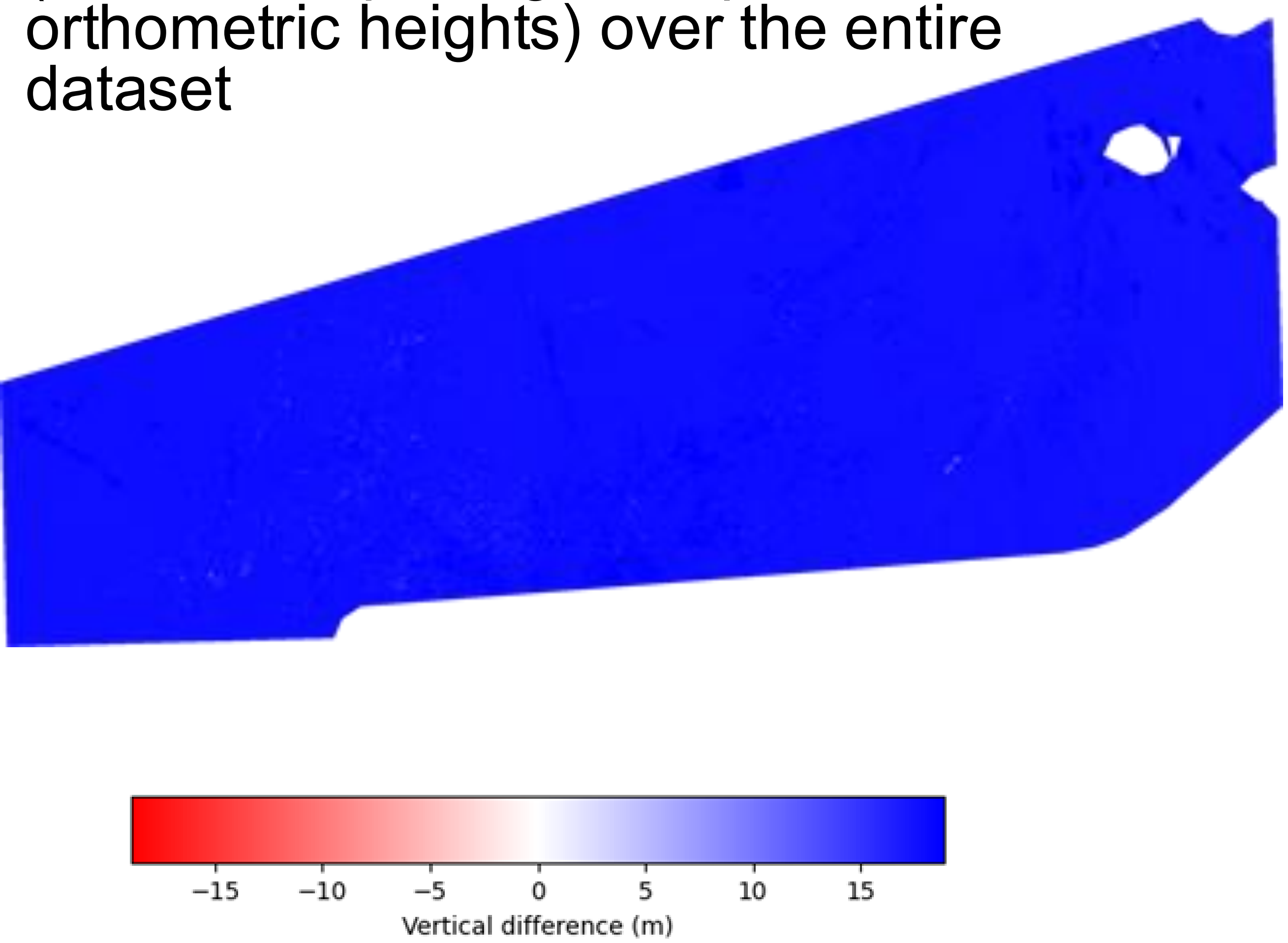


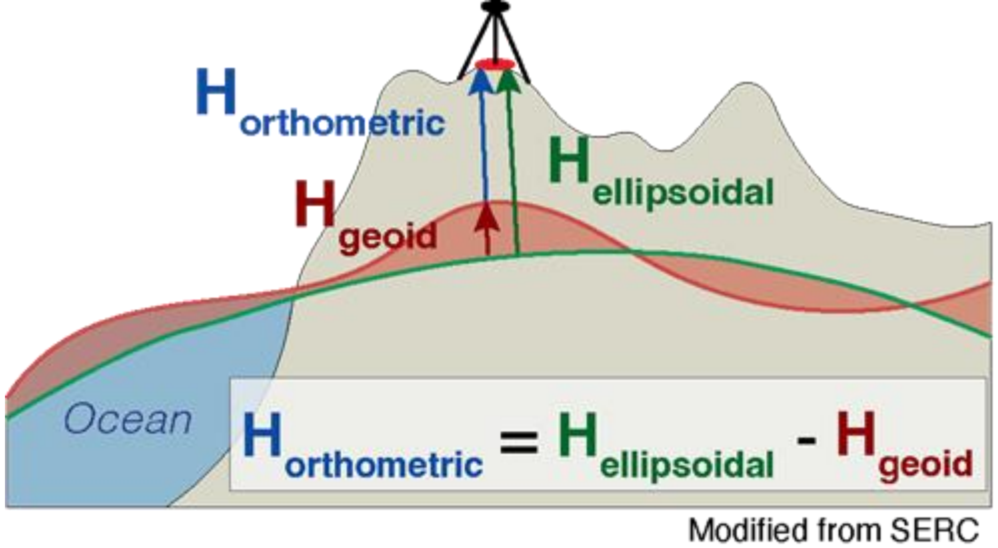


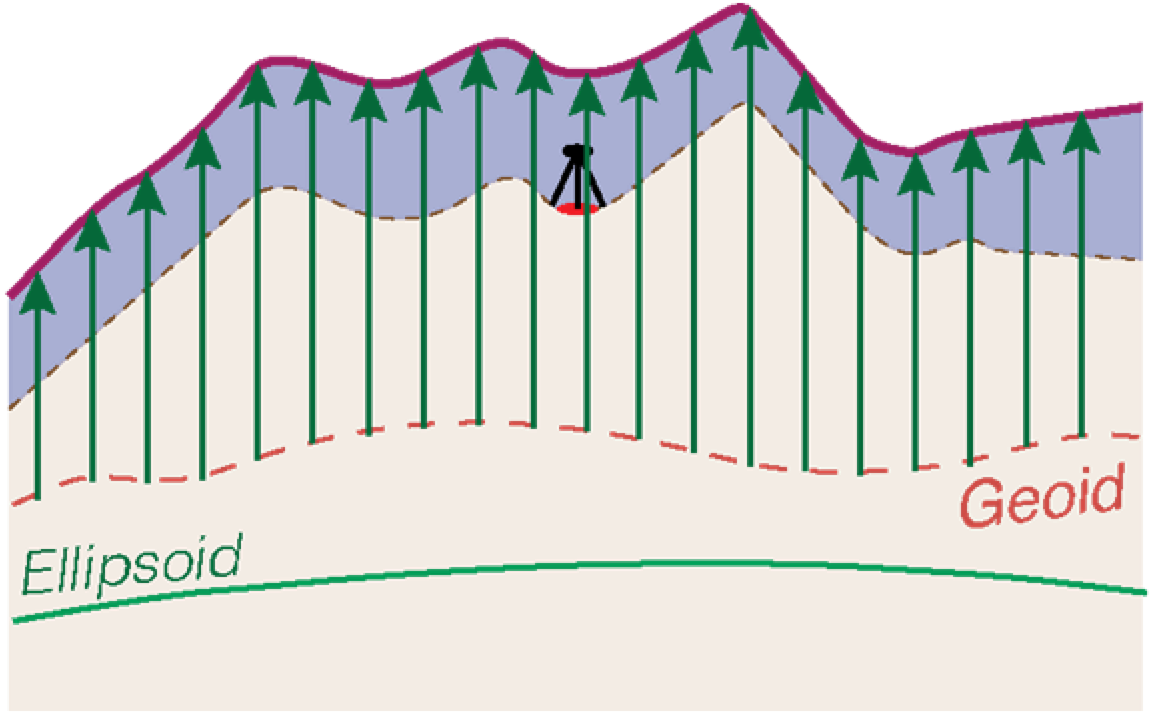
Increasing correlation range length

Systematic long-range error due to metadata errors

Apparent vertical changes from 10-20 cm (incorrect geoid) to a few tens of meters (incorrect reporting of ellipsoidal and orthometric heights) over the entire dataset

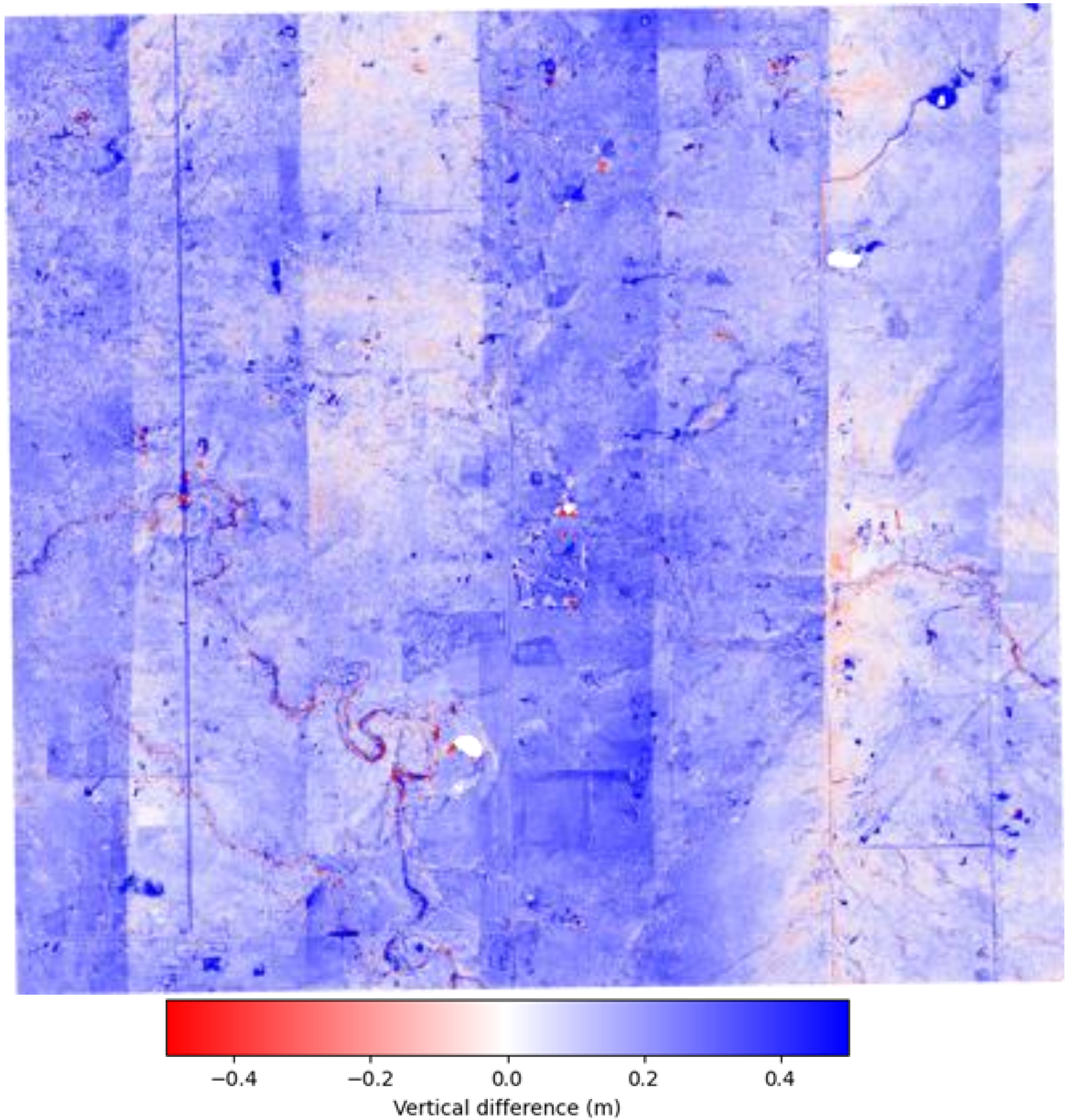






Long-range: km+ scale

Flight line error



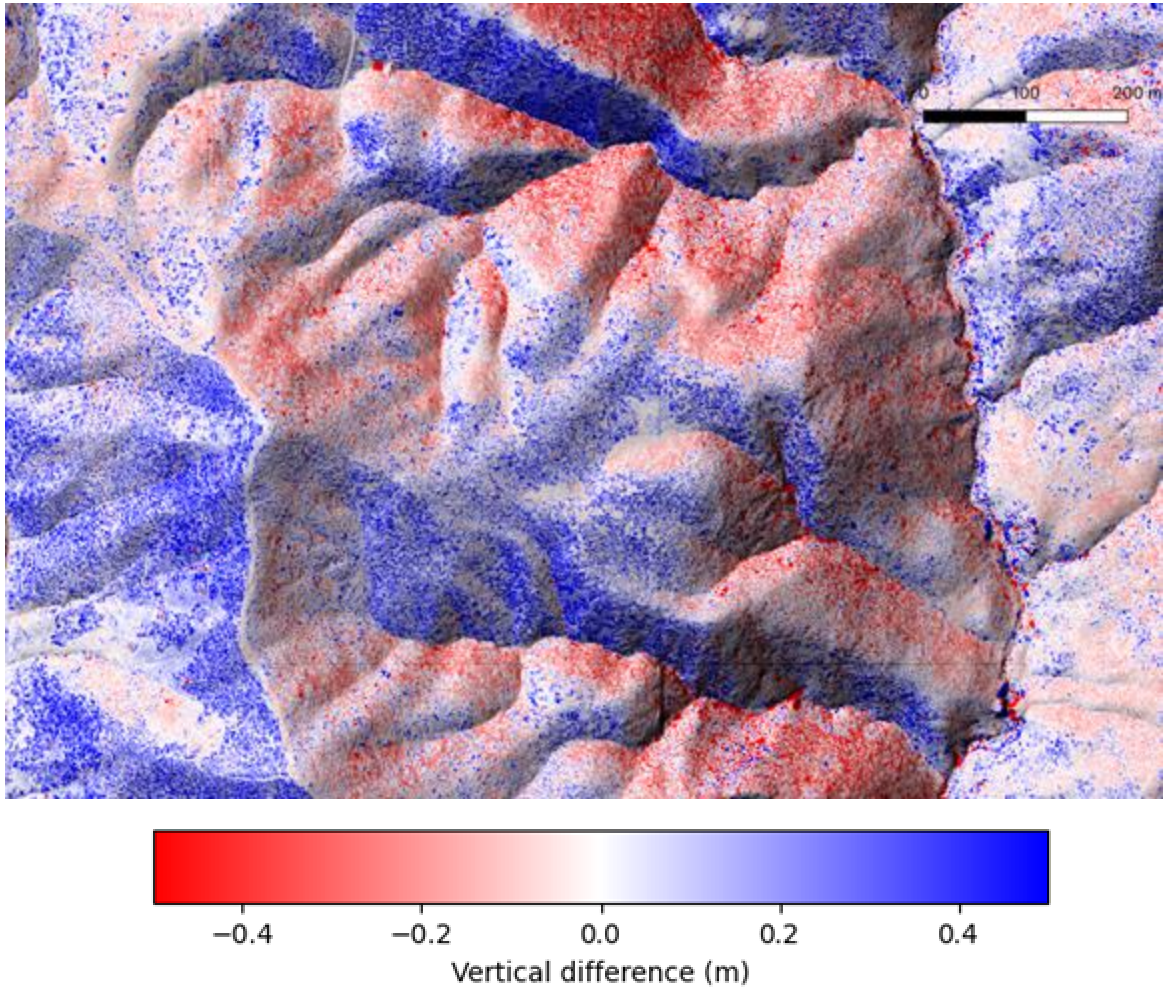
Georeferencing errors of the flight lines make linear, swath-to-swath artifacts

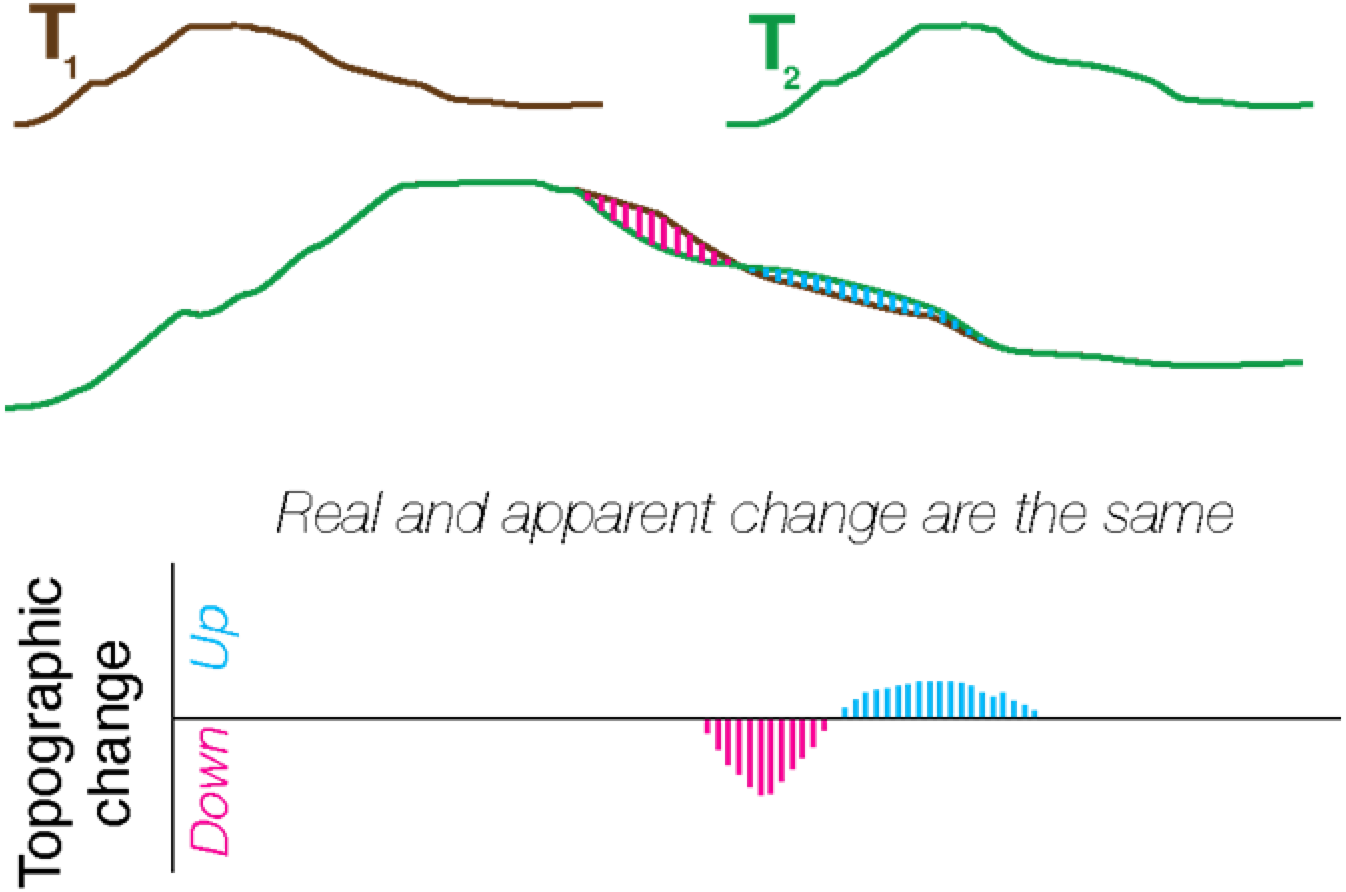
10’s of centimeters (or less)

Interfere with linear patterns (e.g., roads, faults, canals) of surface change.

Long- to mid-range: kms - 100s of m

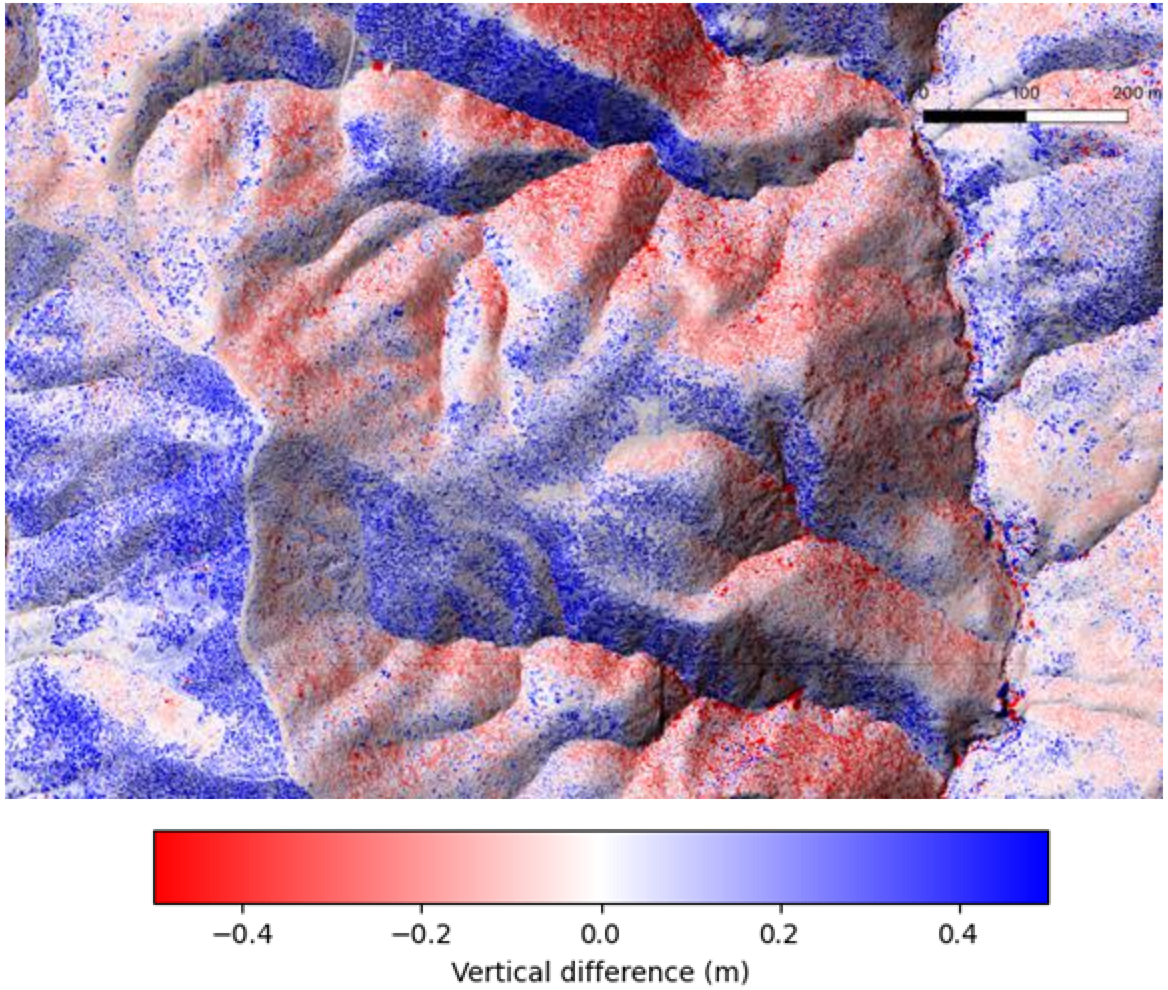
Horizontal georeferencing error

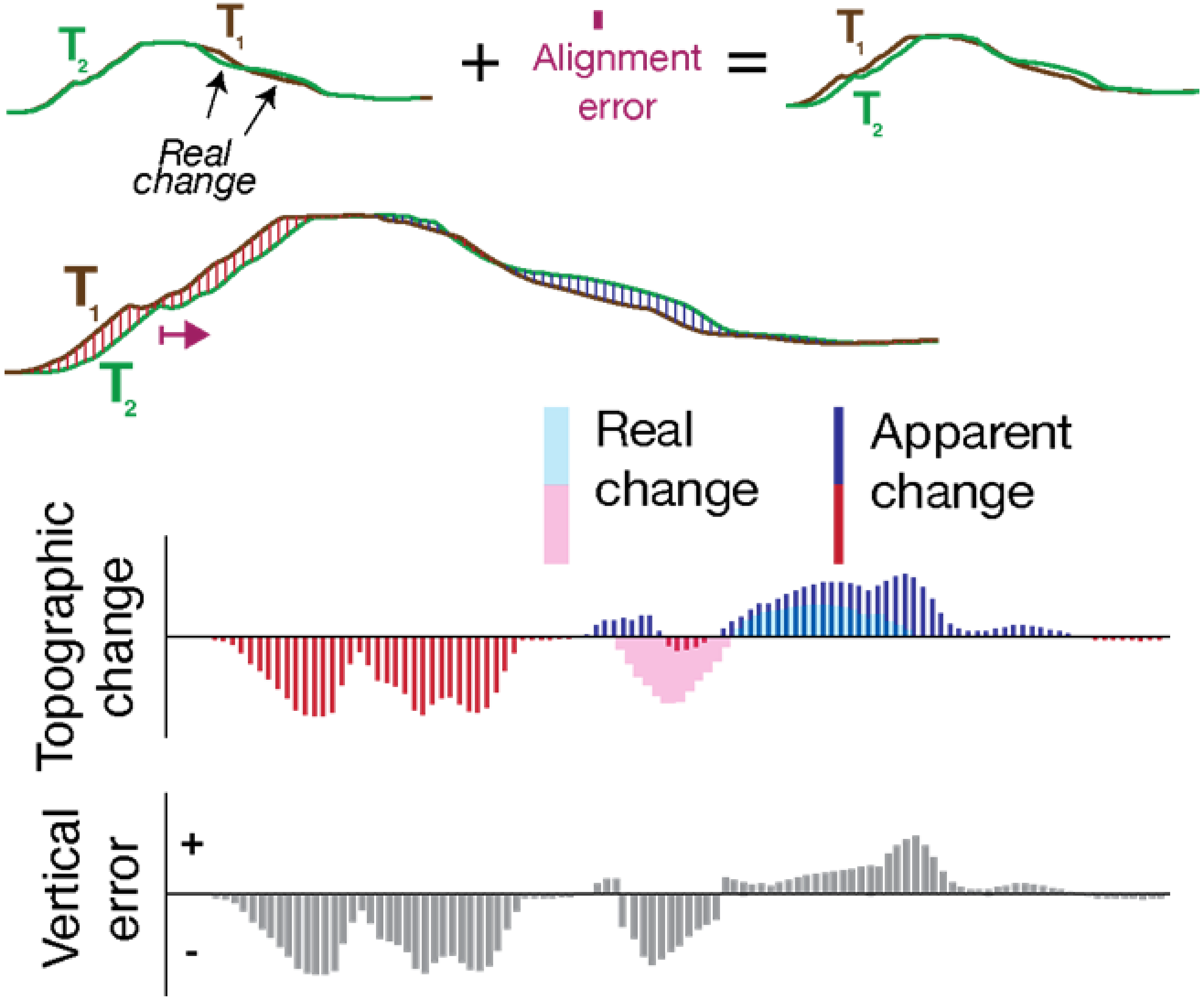




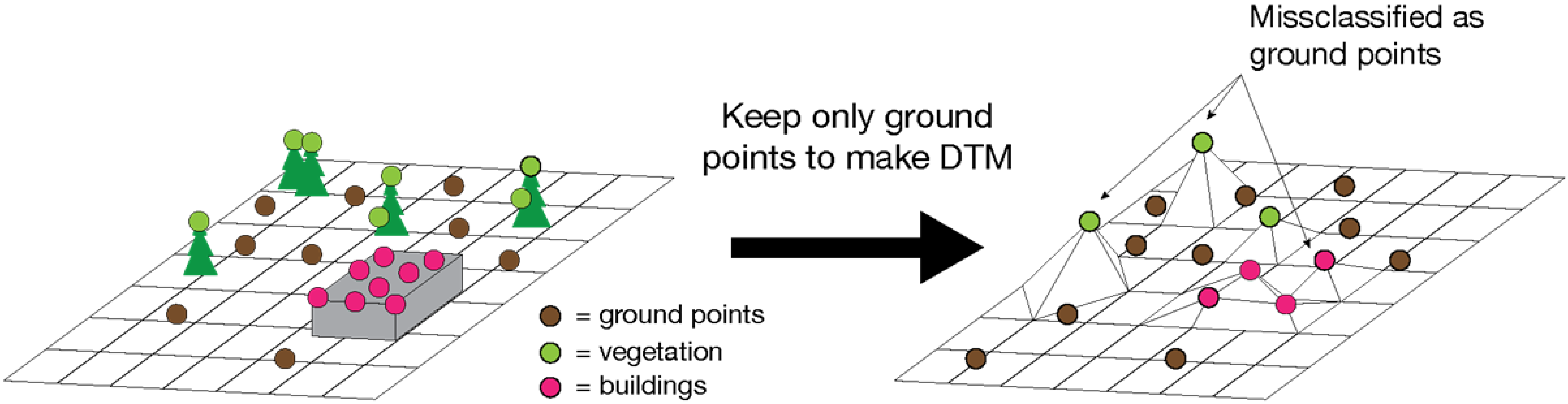
Mid-range:
10s to 100s of m

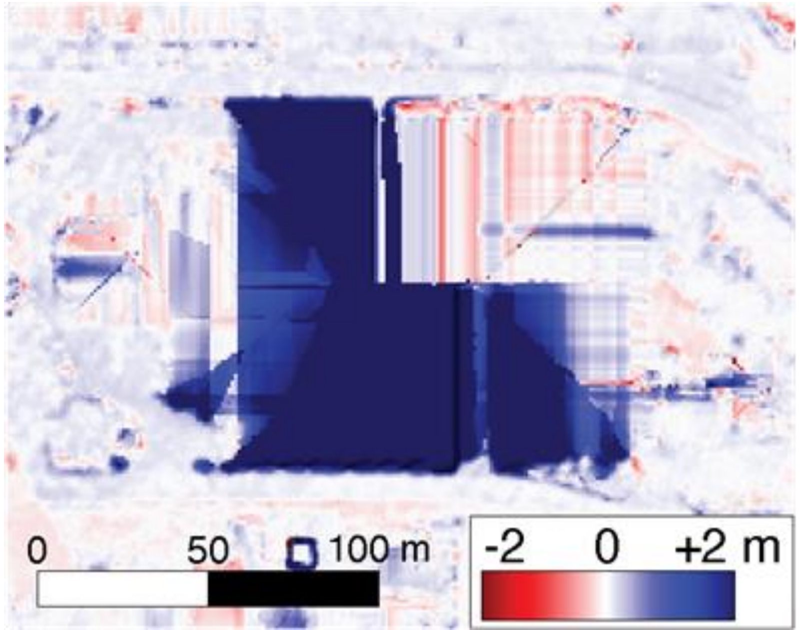
Horizontal georeferencing error





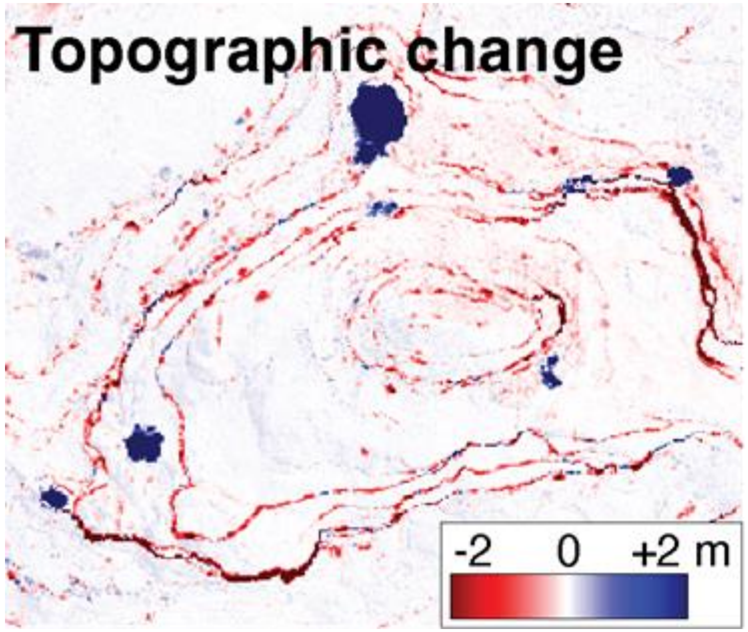
Misclassification error

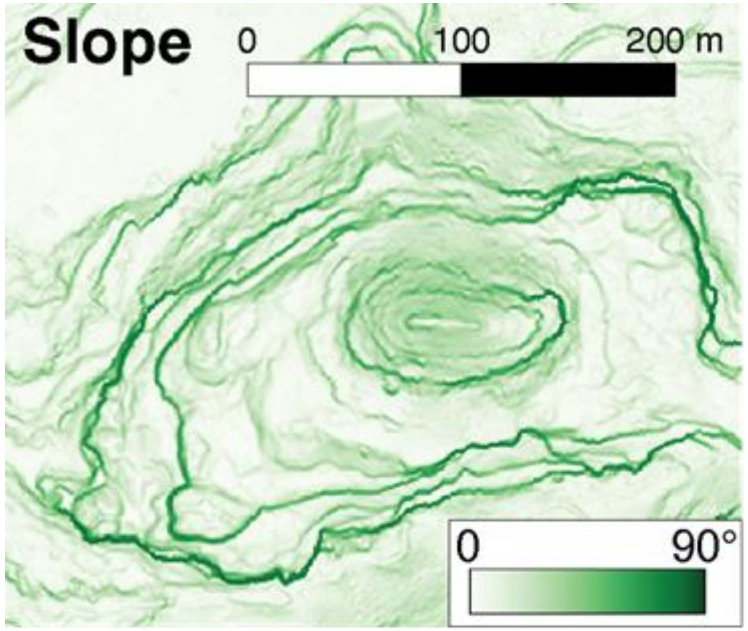


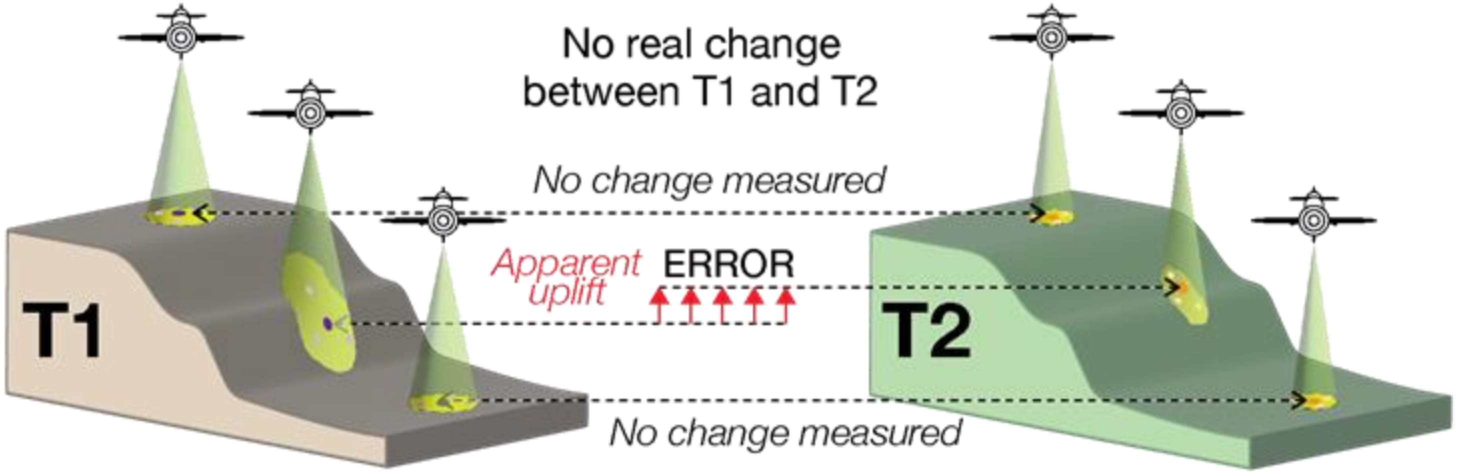


Short-range : meters to 10s of m

Geometric distortion





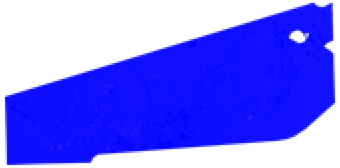


A lidar sensor oblique to the ground surface leads to greater artificial horizontal offsets.

This geometric distortion is particularly acute over steep slopes.

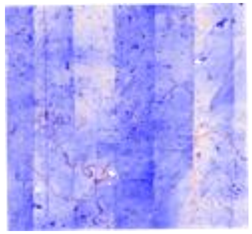
Short-range : meters to 10s of m

Uncertainty in Vertical Differencing

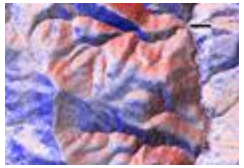


Very long range → **Vertical bias**

– 0.4 m



Long range



Mid range

Short range

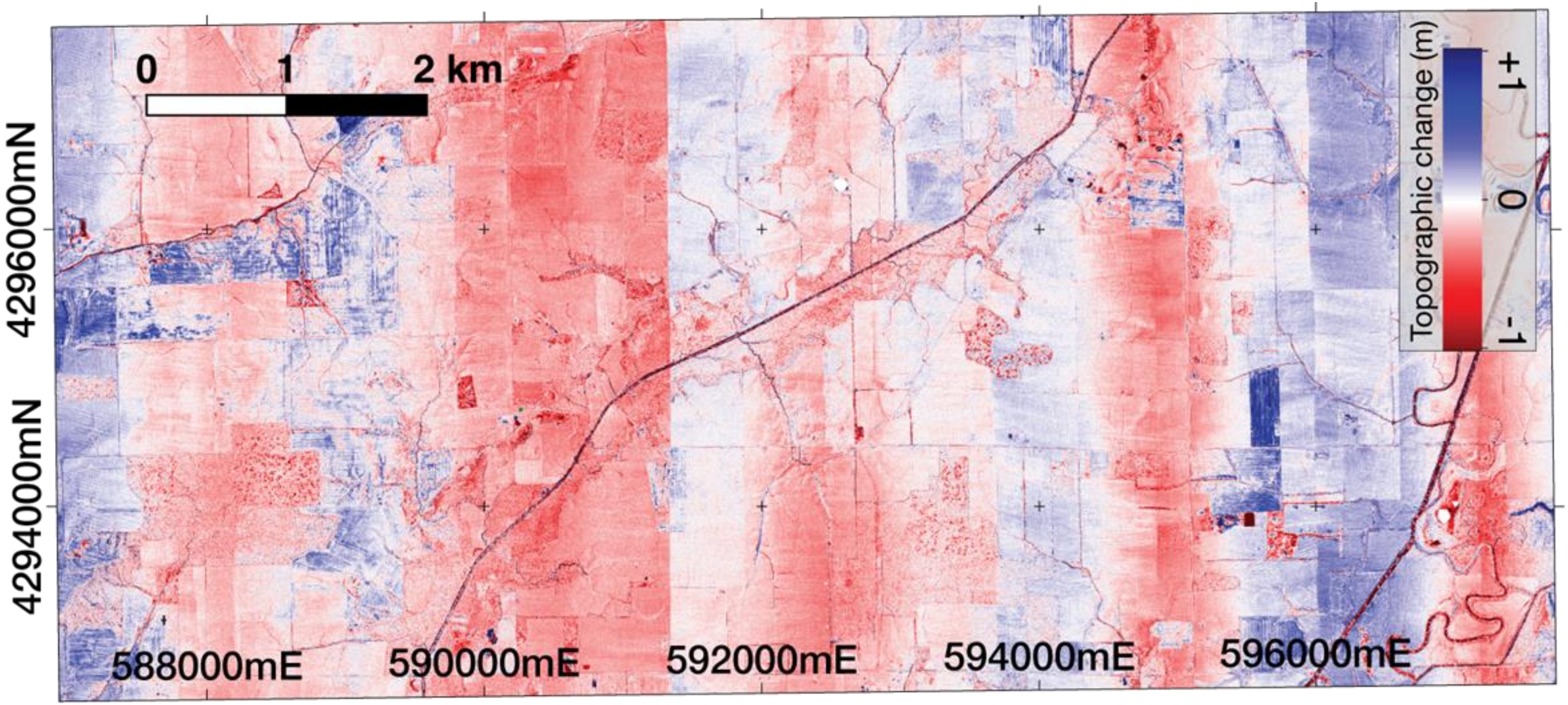
→ **Mean correlated uncertainty values over three length scales**

Very short range → **Mean uncorrelated uncertainty**

Total mean uncertainty

± 0.004 m

Uncertainty in Vertical Differencing



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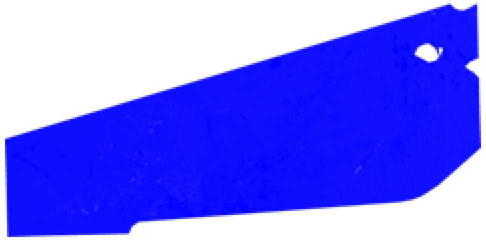
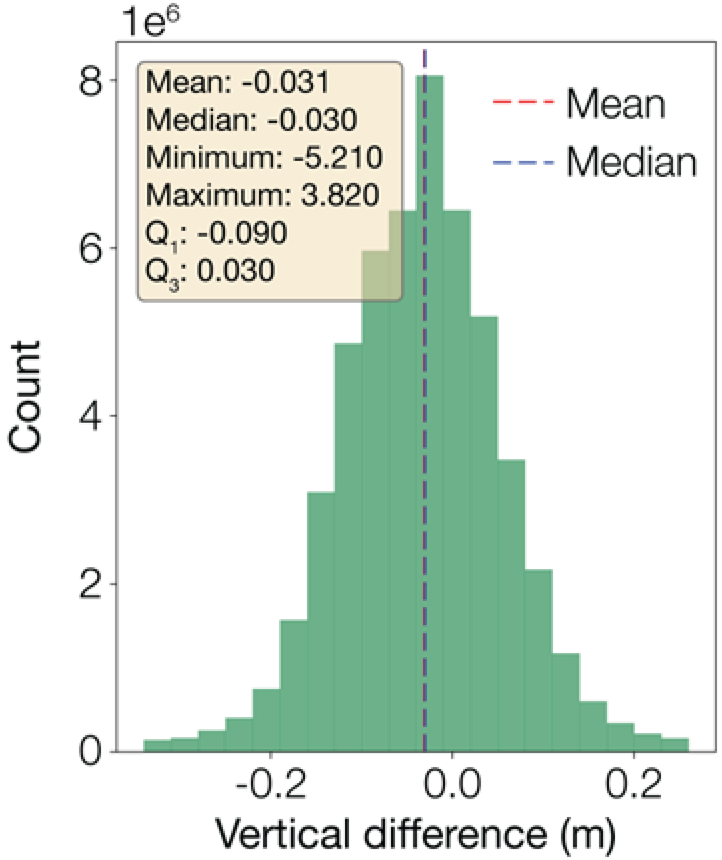


Very long range → **Vertical bias**

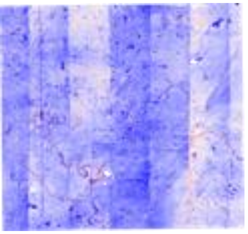
e.g. – 0.4 m

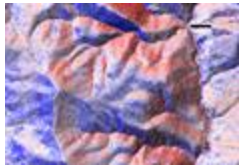


Area: **52.3 km²**

Vertical bias: **- 0.030 m**

Uncertainty in Vertical Differencing



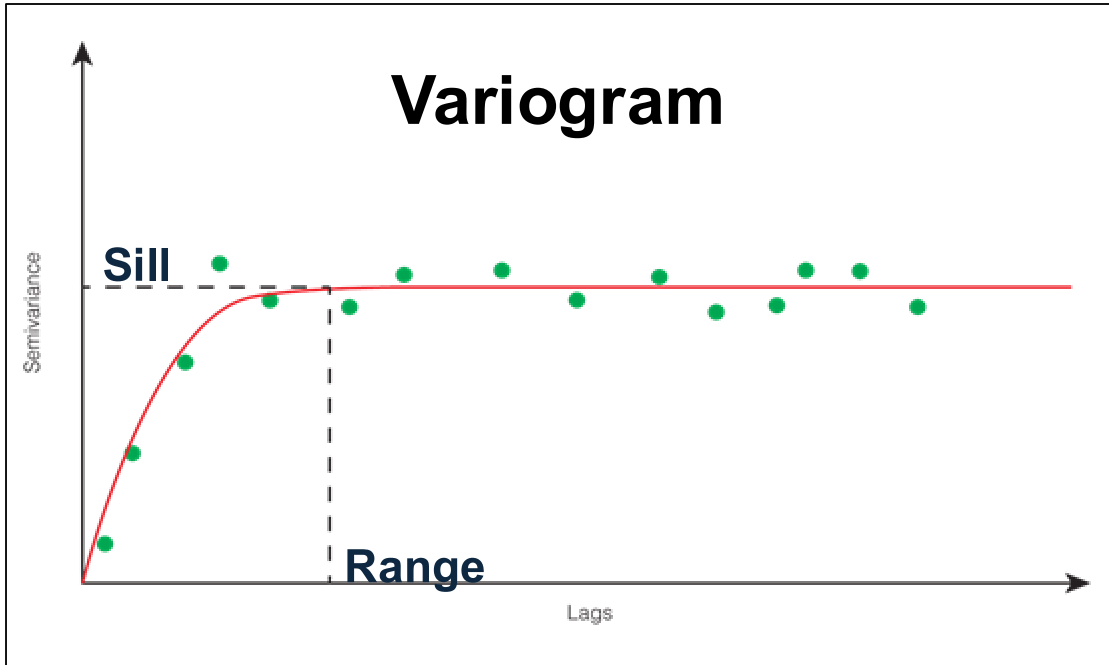


Long range

Mid range

Short range

→ **Mean correlated uncertainty values over three length scales**



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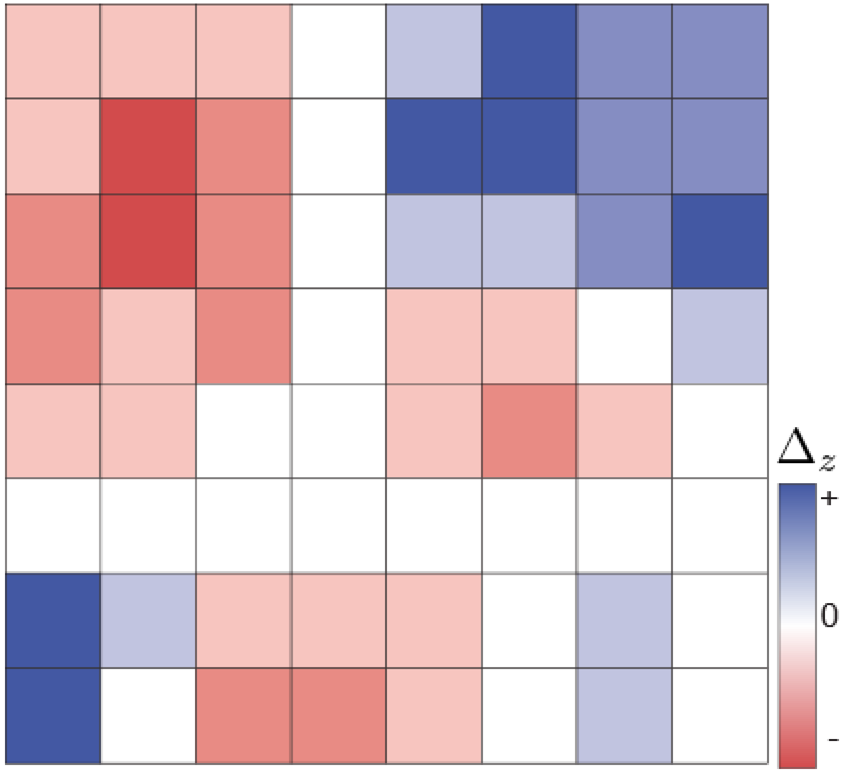

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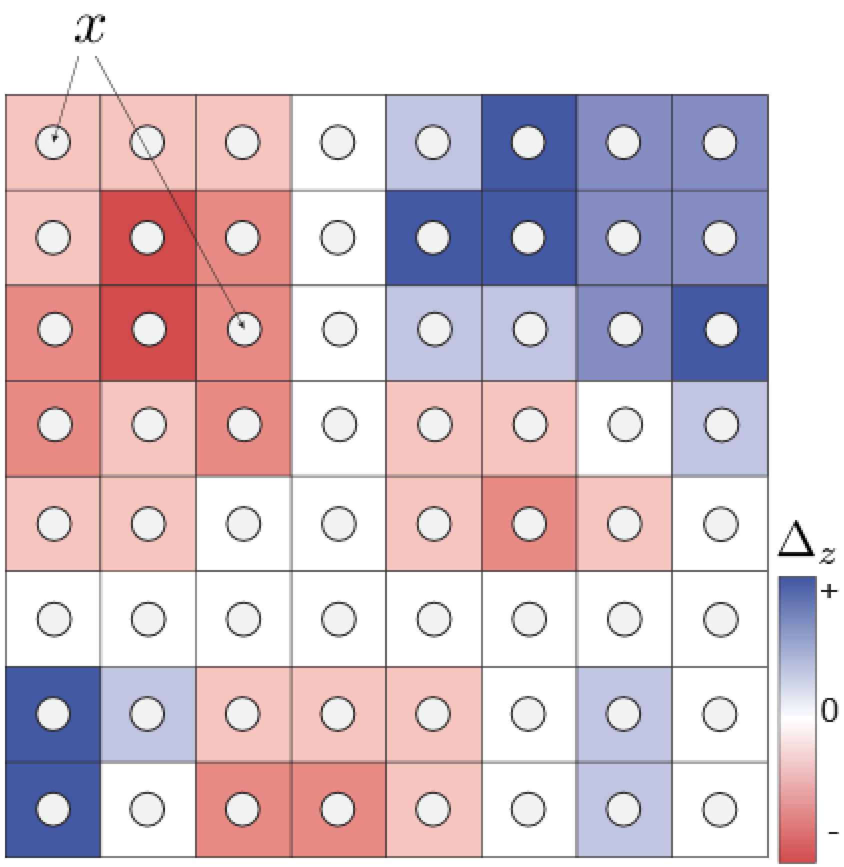

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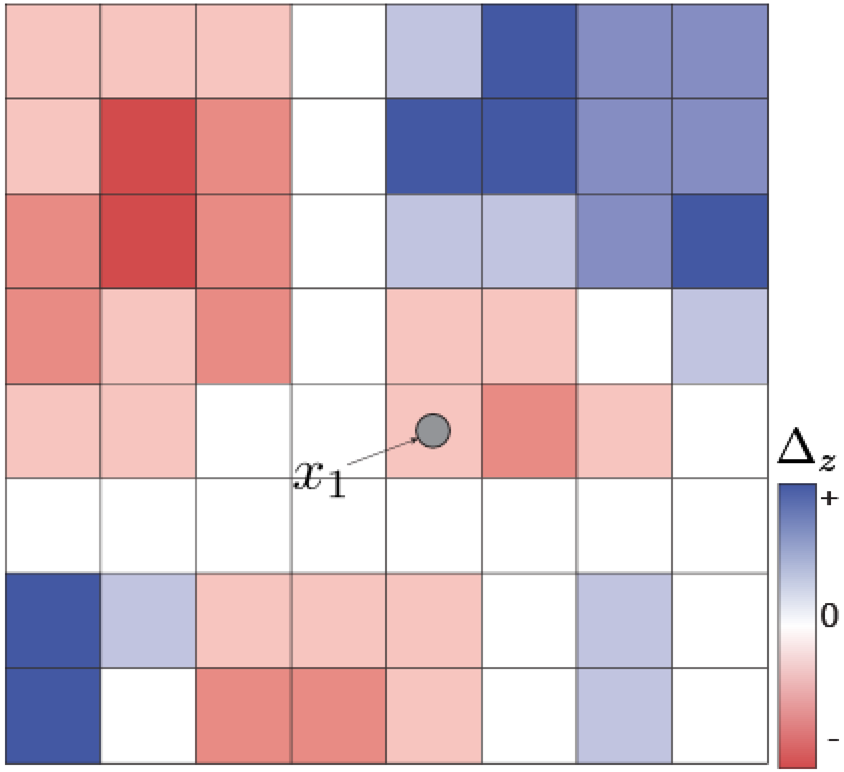

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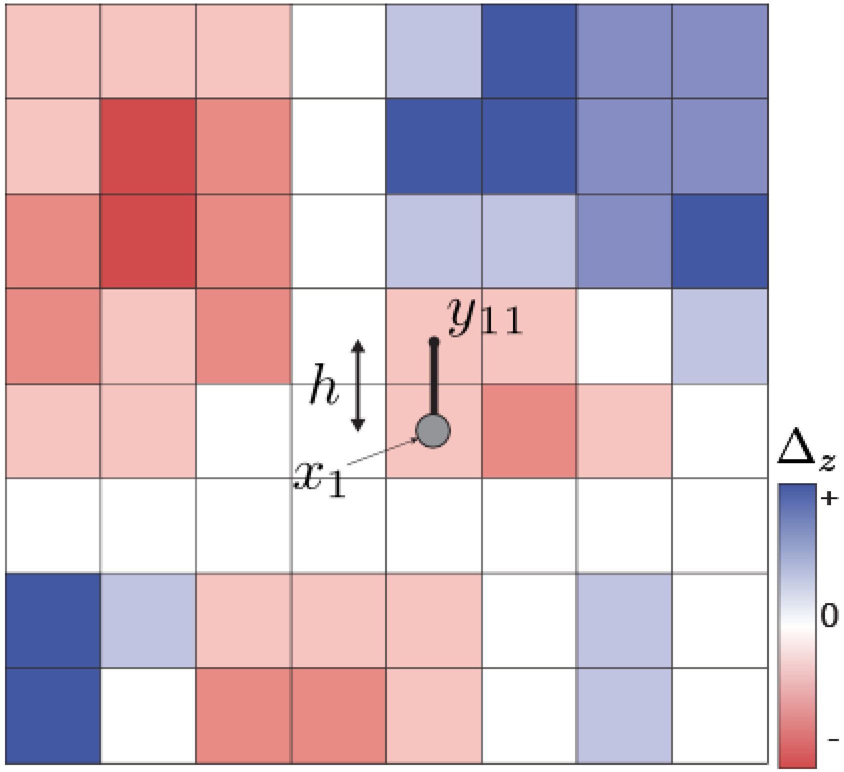

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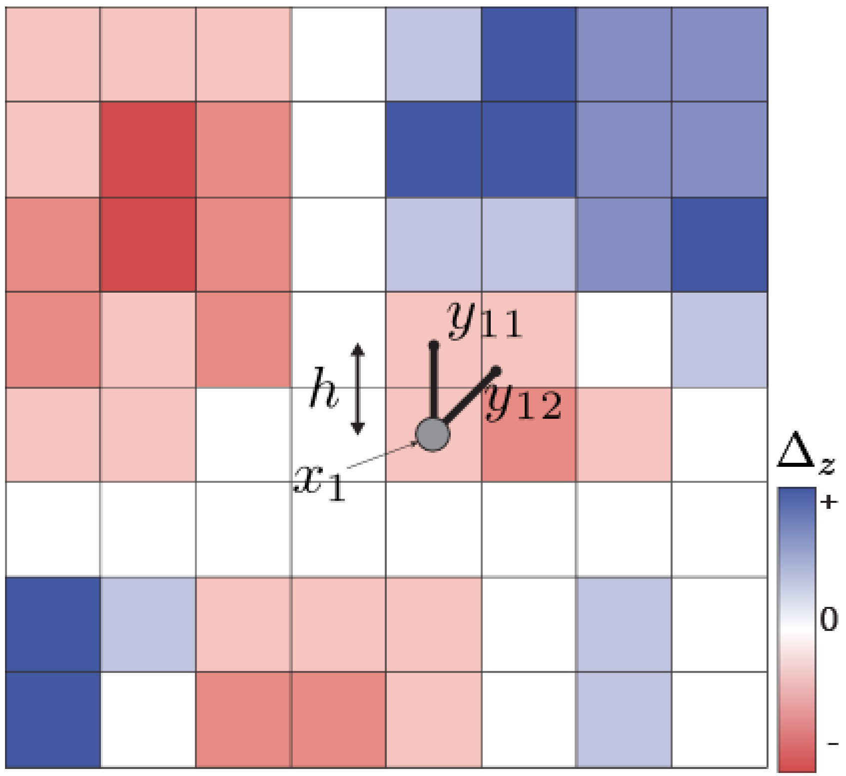

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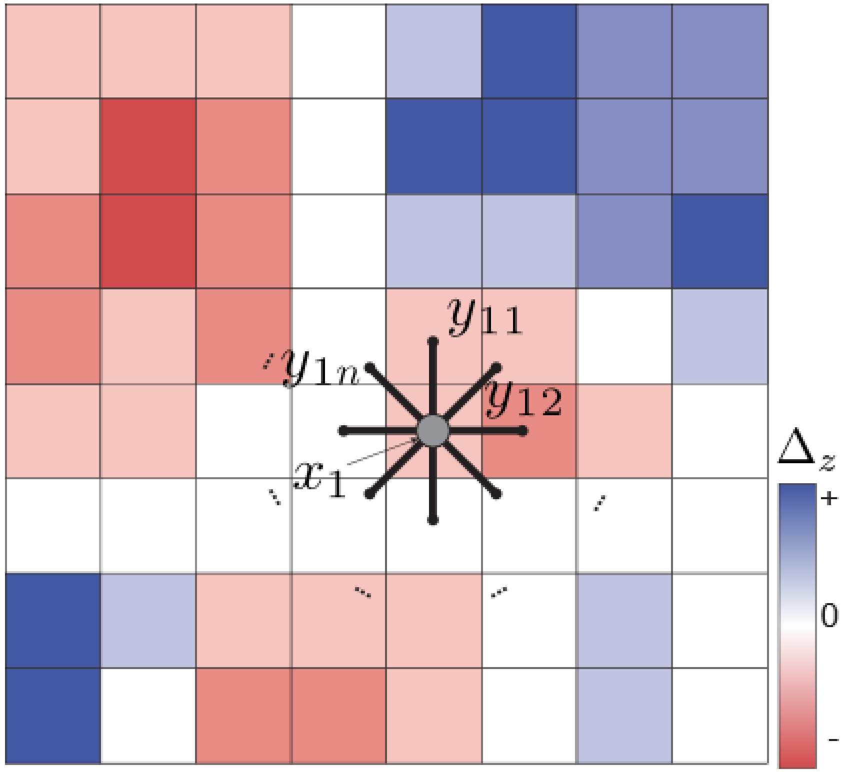

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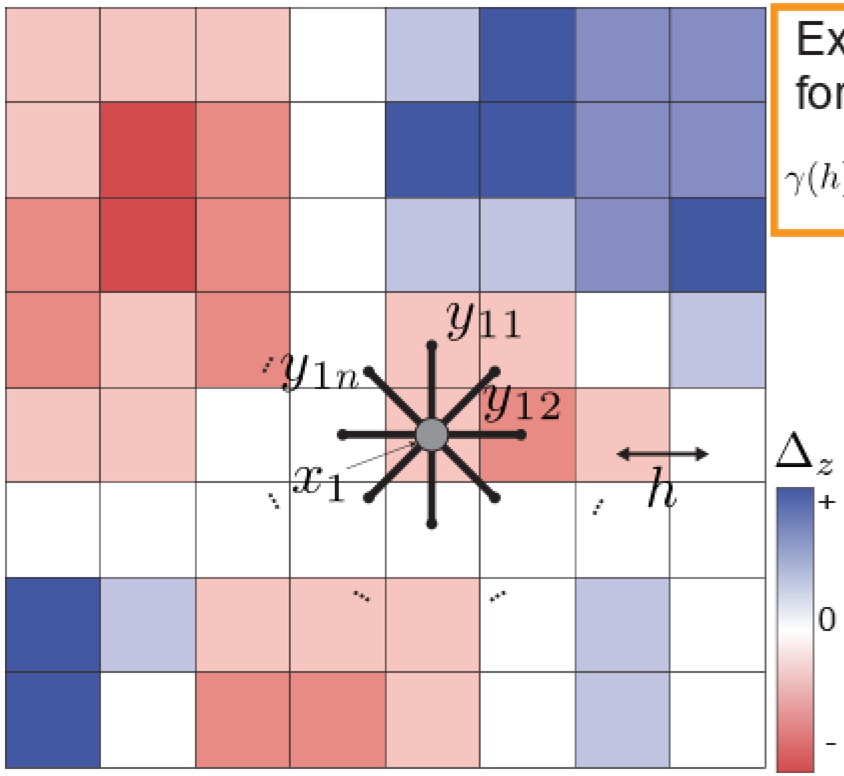
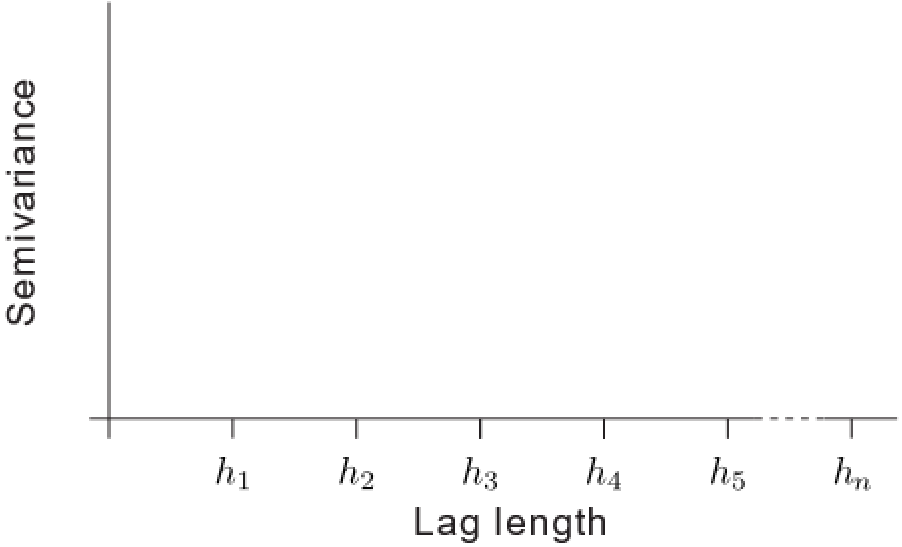


Experimental semivariance calculation for a given lag h , calculated in n directions for m samples :

$$\gamma(h) = \frac{[\Delta_z(x_1) - \Delta_z(y_{h1})]^2 + [\Delta_z(x_1) - \Delta_z(y_{h2})]^2 + ... + [\Delta_z(x_2) - \Delta_z(y_{h1})]^2 + ... + [\Delta_z(x_m) - \Delta_z(y_{hn})]^2}{2mn}$$



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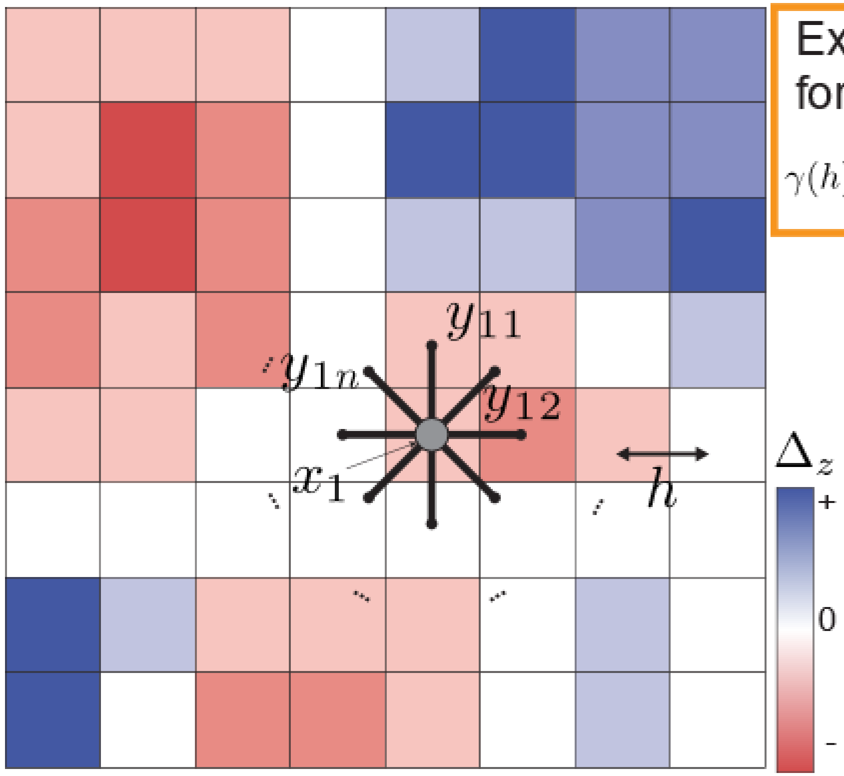

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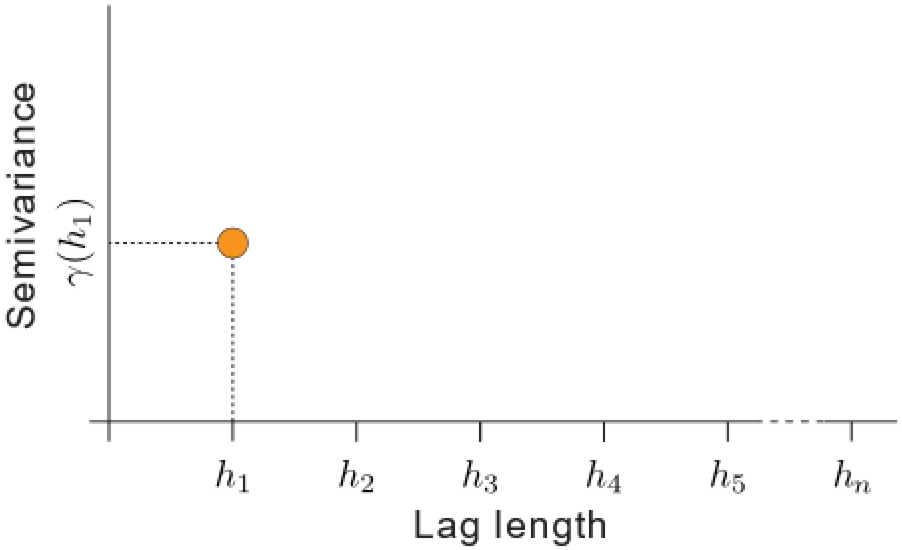

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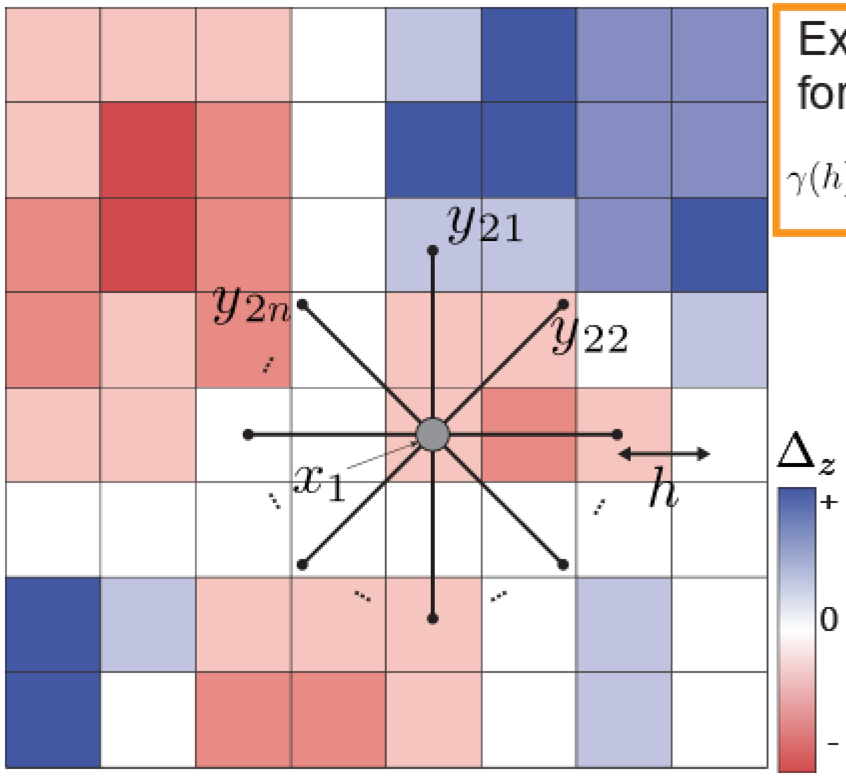

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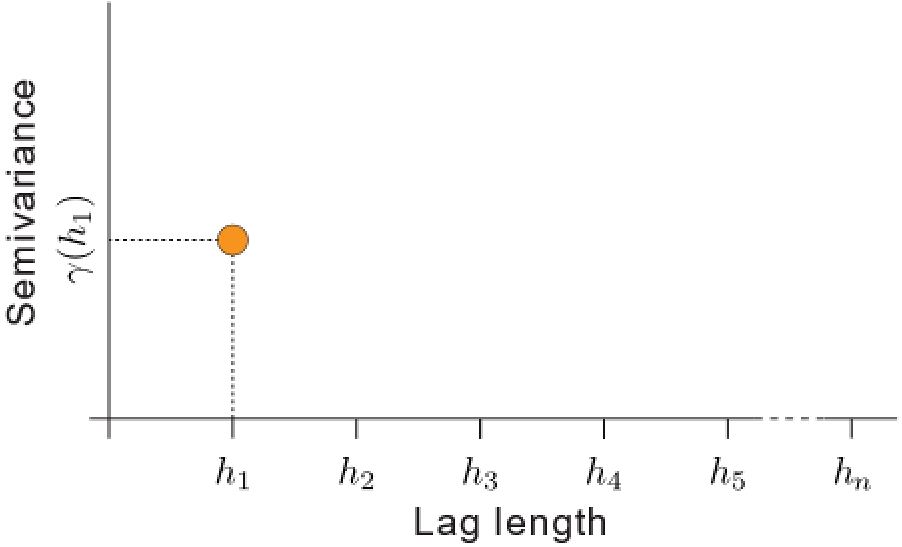

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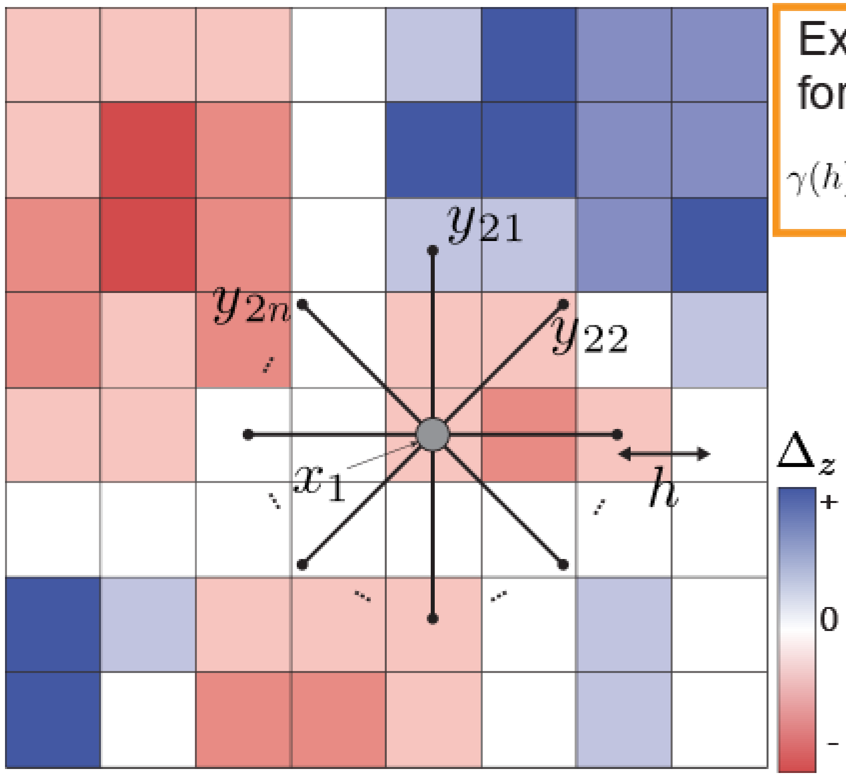

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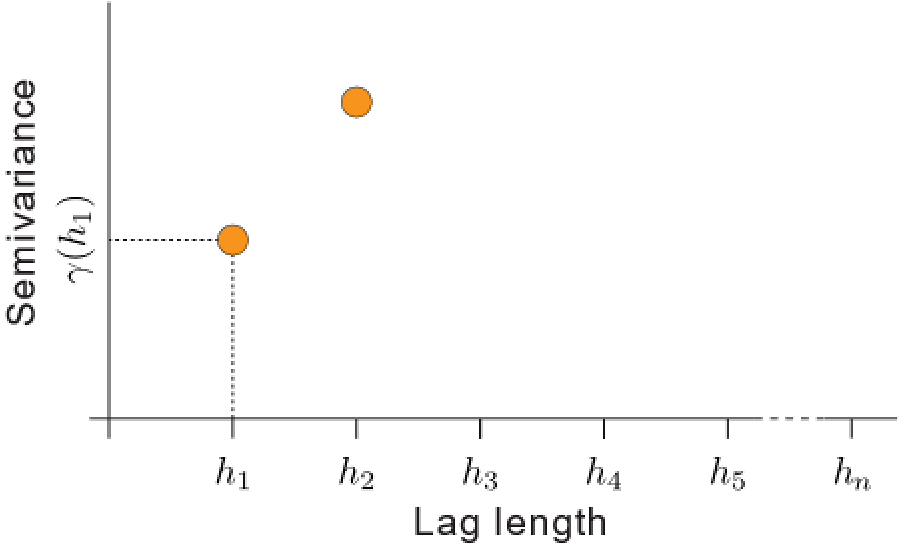

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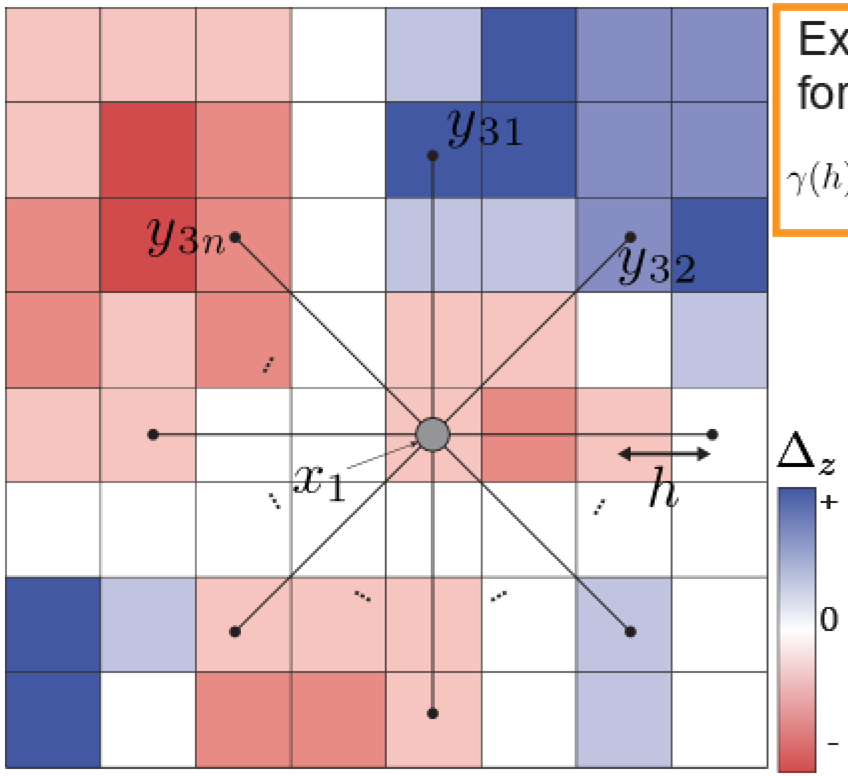

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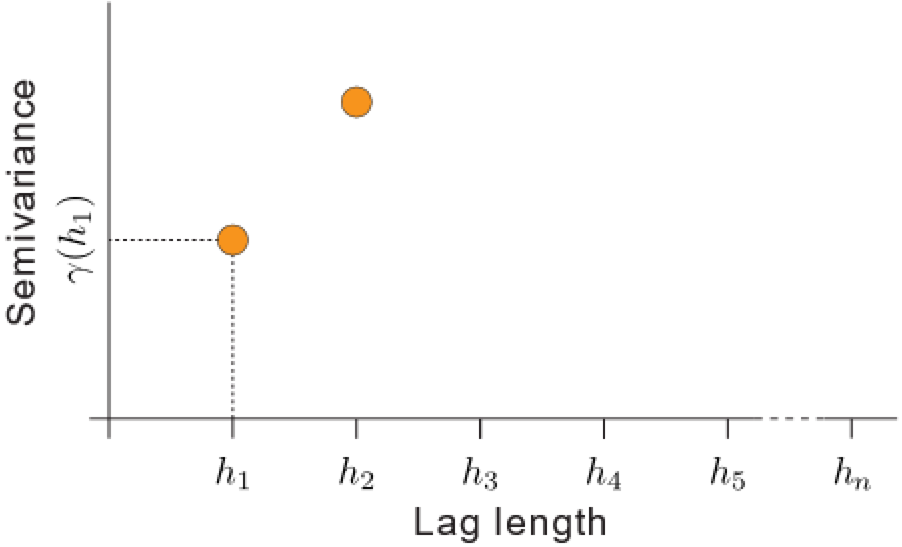

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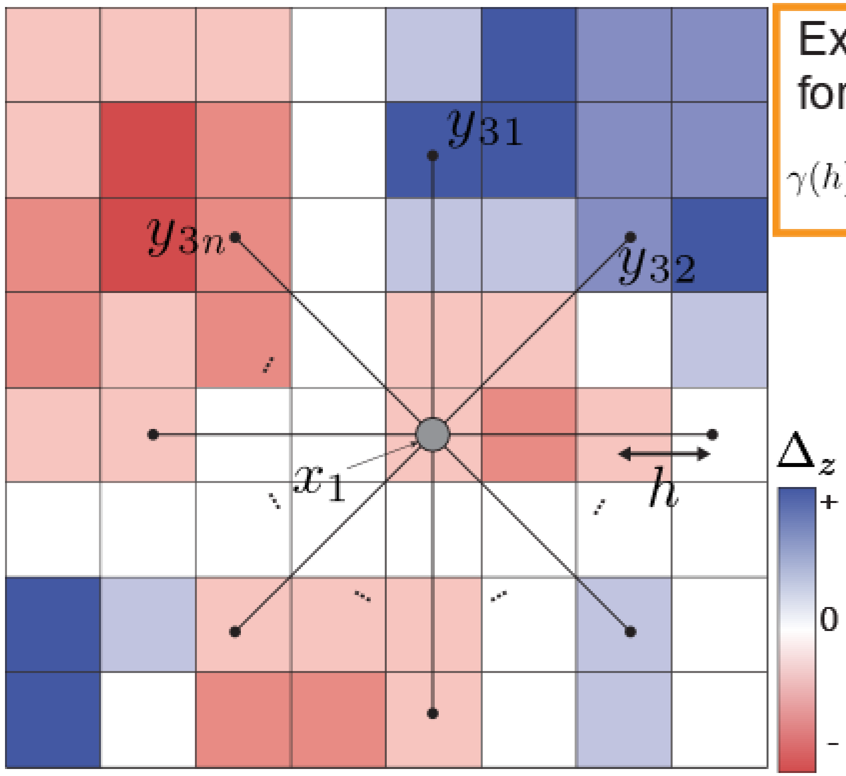

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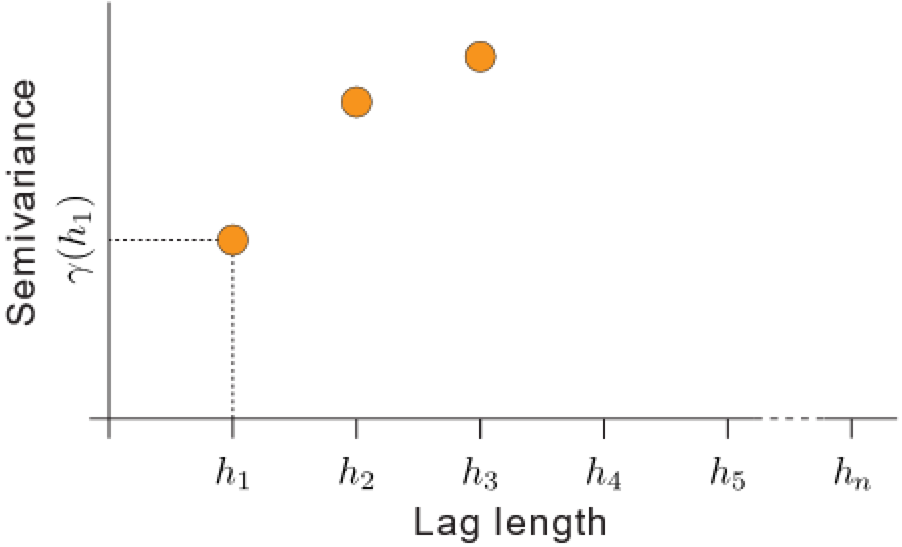

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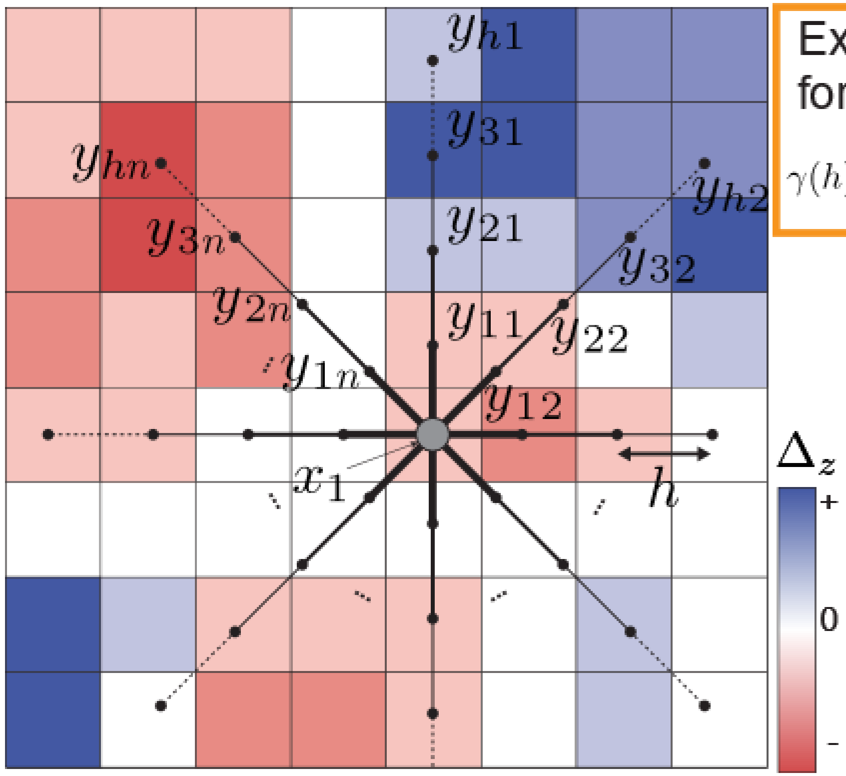

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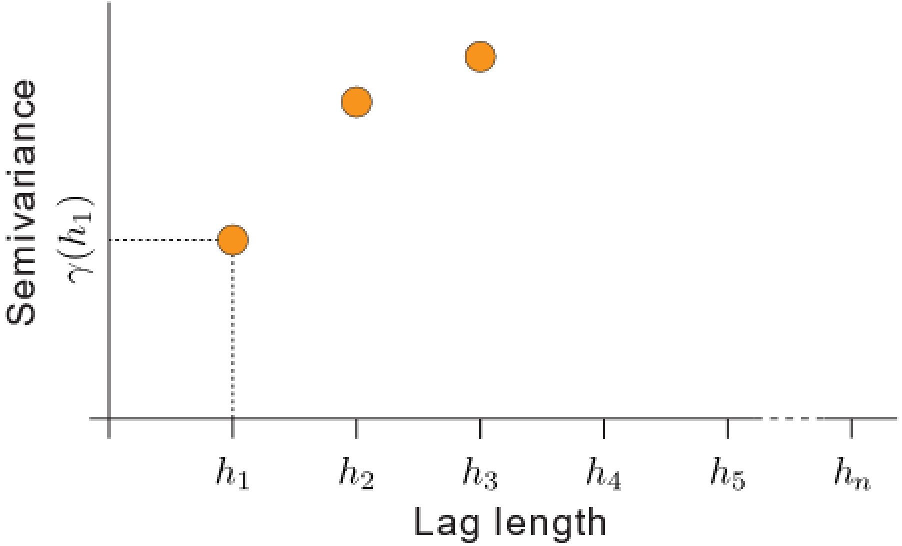

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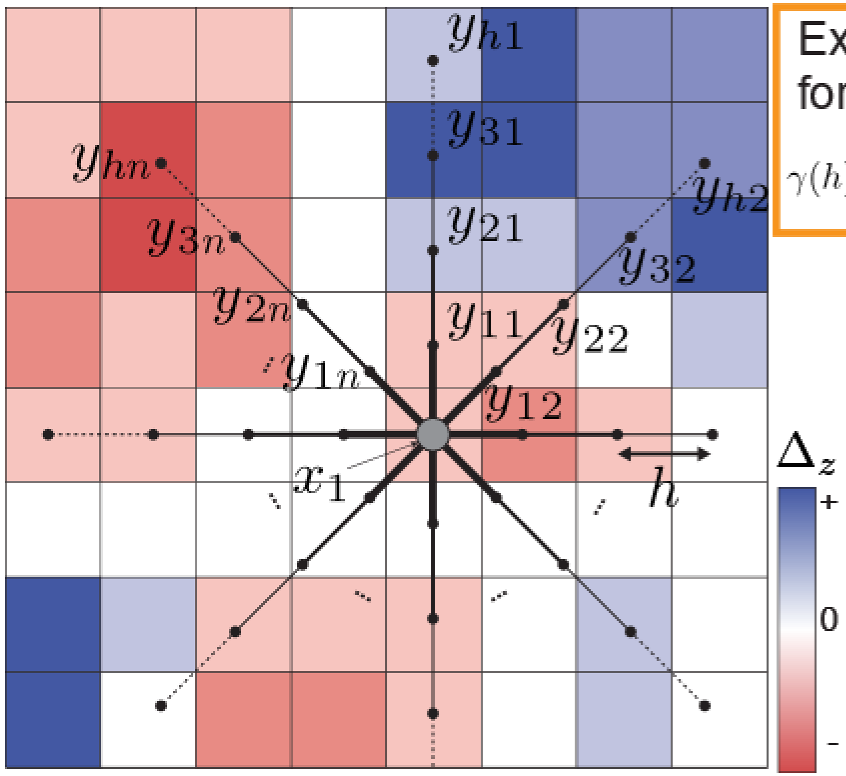

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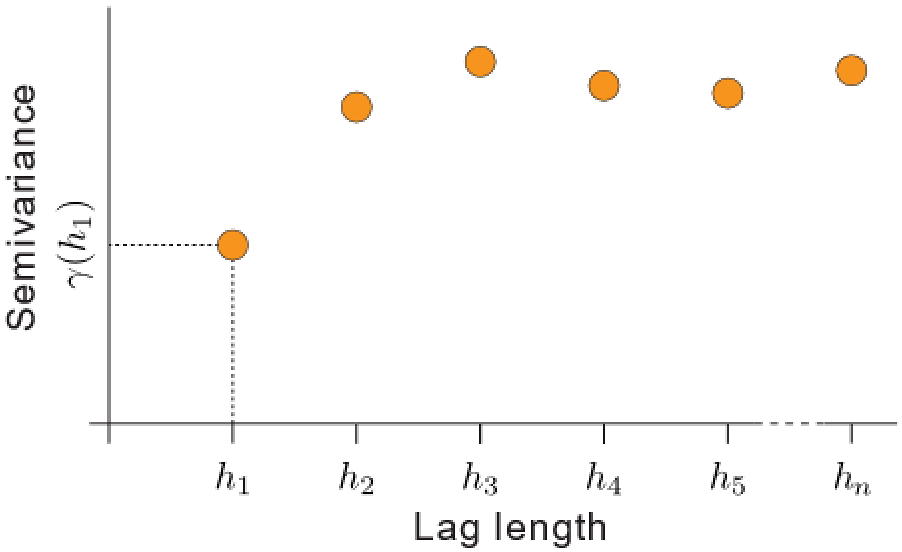

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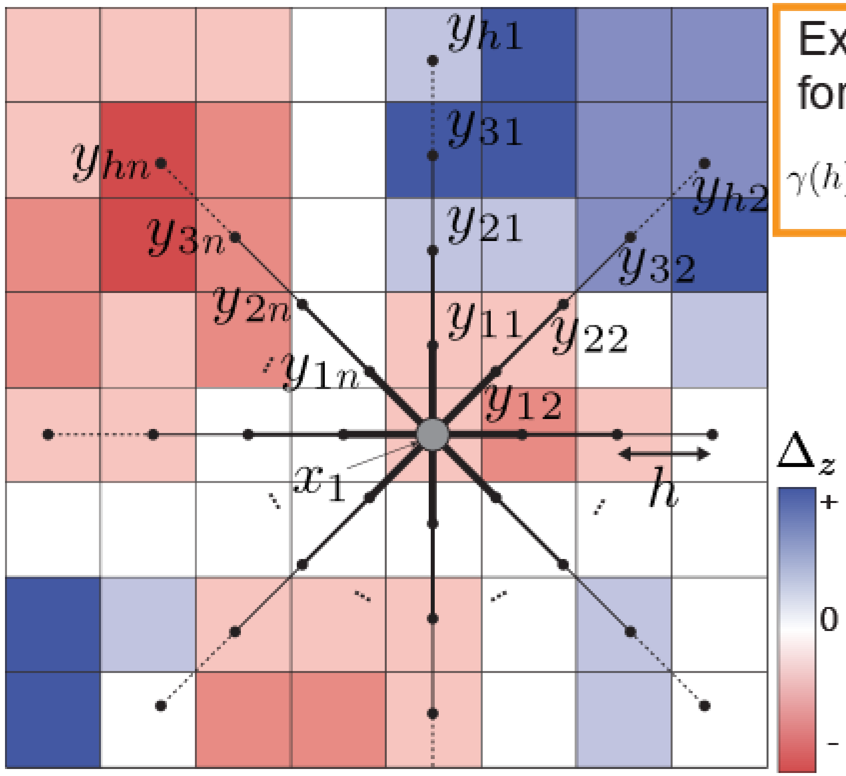


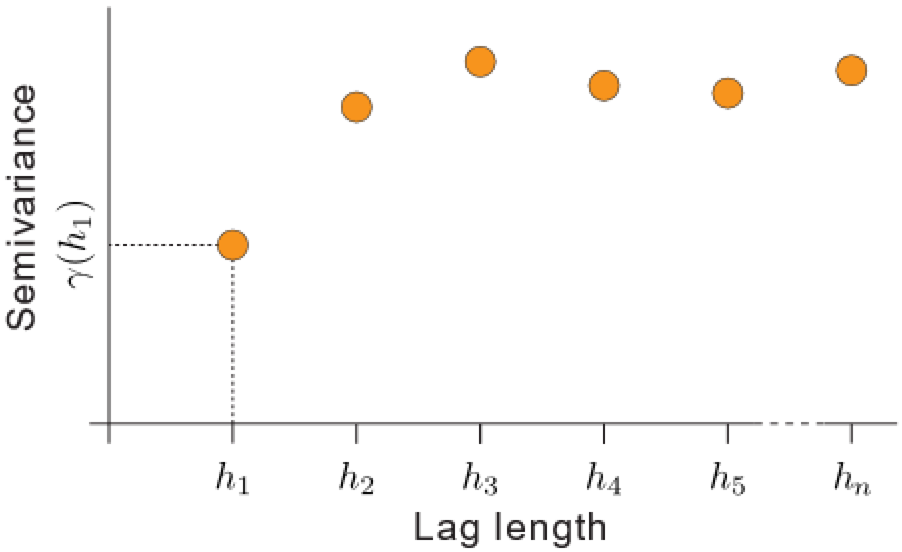
Experimental semivariance calculation for a given lag h, calculated in n directions for m samples :

$$\gamma(h) = \frac{[\Delta_z(x_1) - \Delta_z(y_{h1})]^2 + [\Delta_z(x_1) - \Delta_z(y_{h2})]^2 + \ldots + [\Delta_z(x_2) - \Delta_z(y_{h1})]^2 + \ldots + [\Delta_z(x_m) - \Delta_z(y_{hn})]^2}{2mn}$$

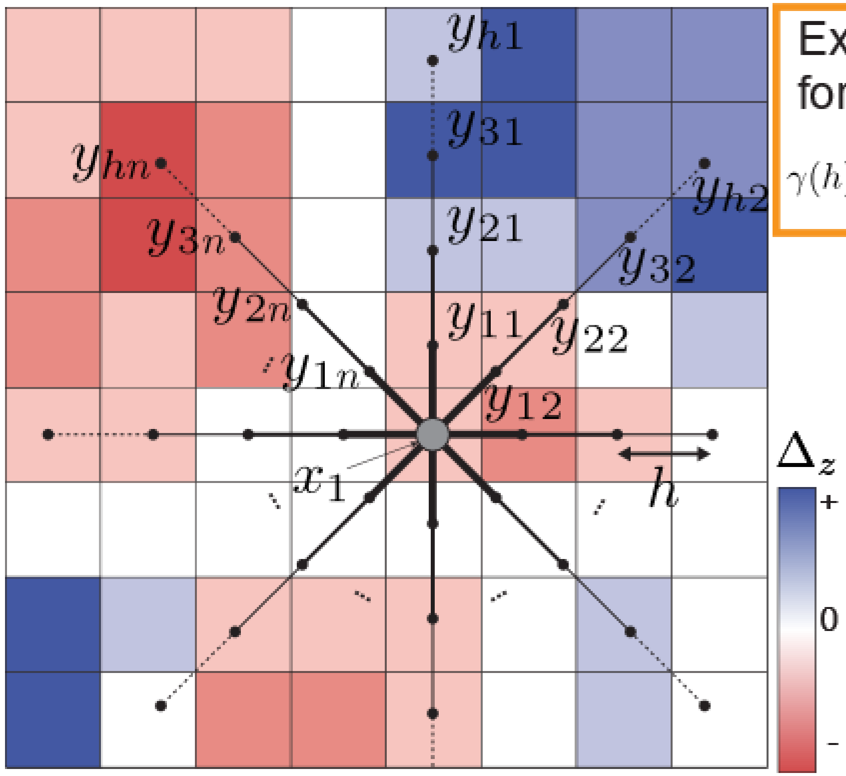
Semivariance modeled with spherical model of range a and sill c :

$$\gamma(h) = \begin{cases} 0, & h = 0 \\ c_0 + (c - c_0)\left[\frac{3h}{2a} - \frac{1}{2}\left(\frac{h}{a}\right)^3\right], & 0 < h \leq a \\ c, & h > a \end{cases}$$

c_0 represents the nugget effect, equal to 0 in this example.



Uncertainty in Vertical Differencing



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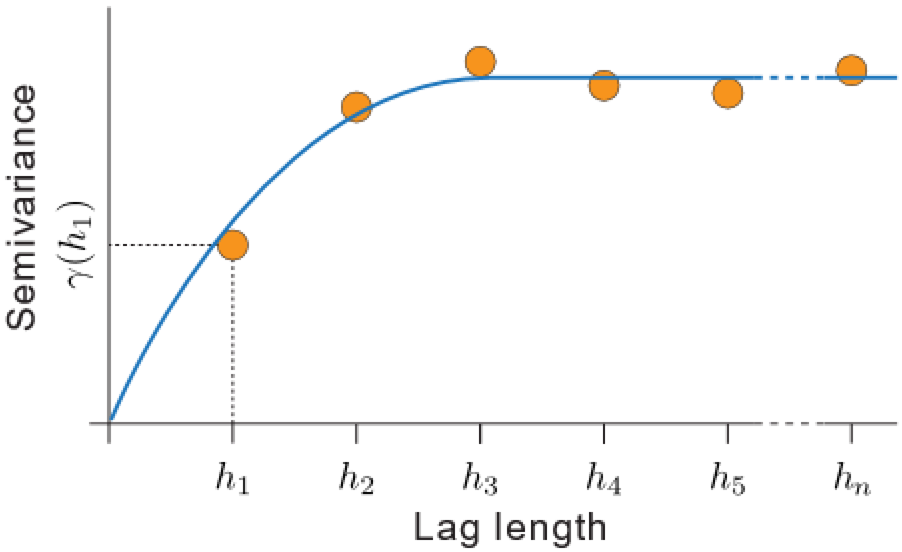

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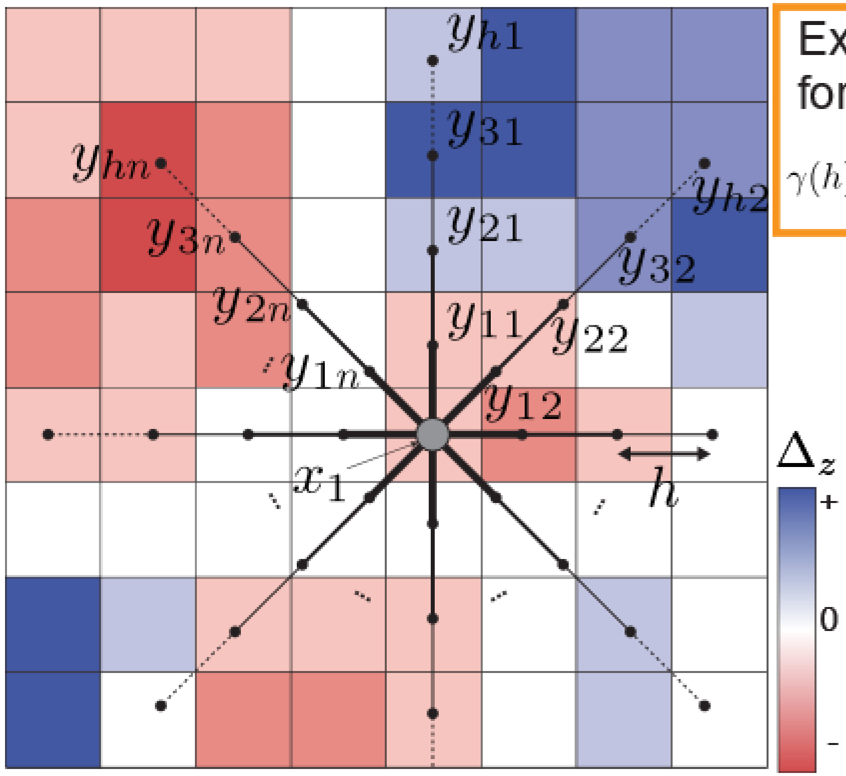

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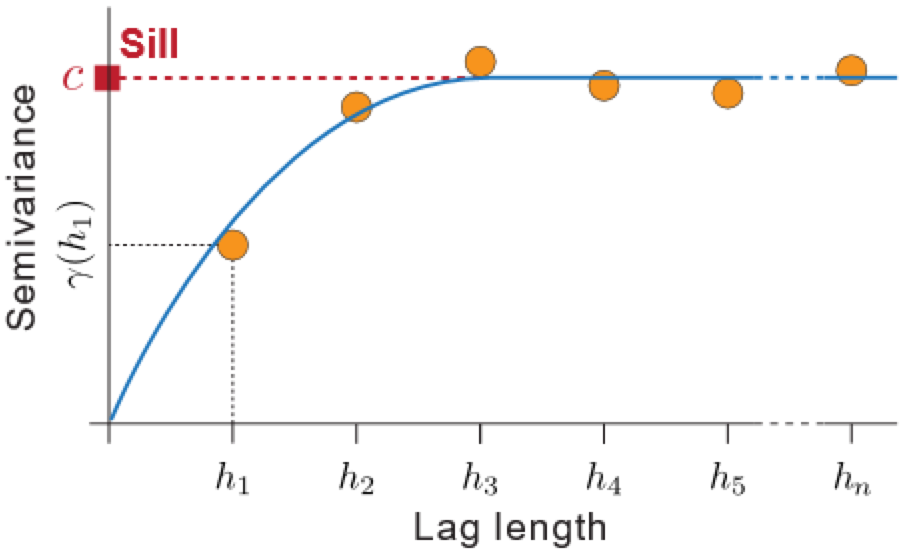

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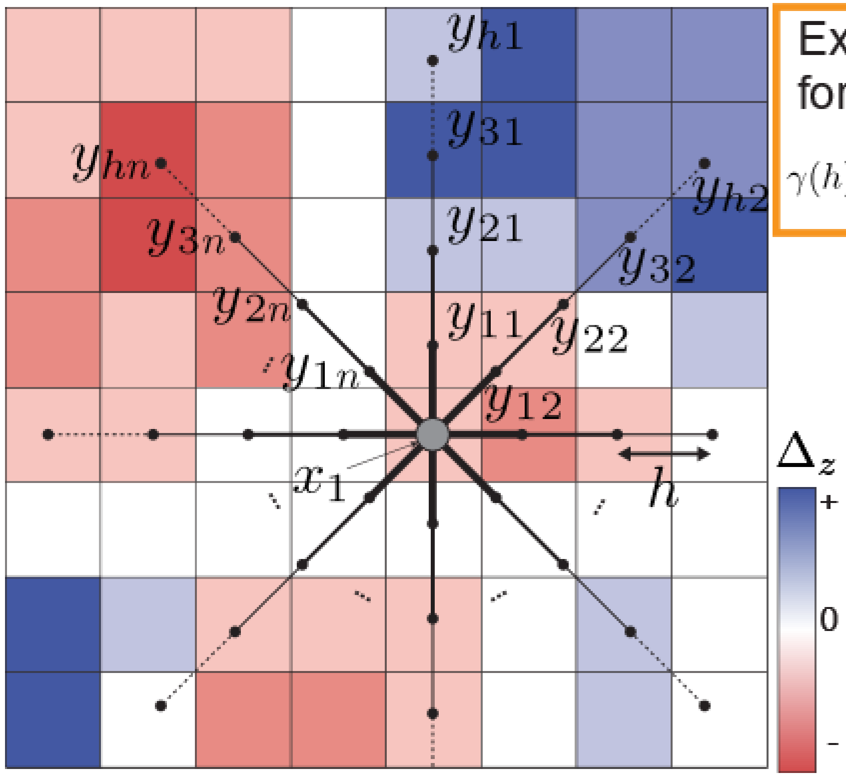

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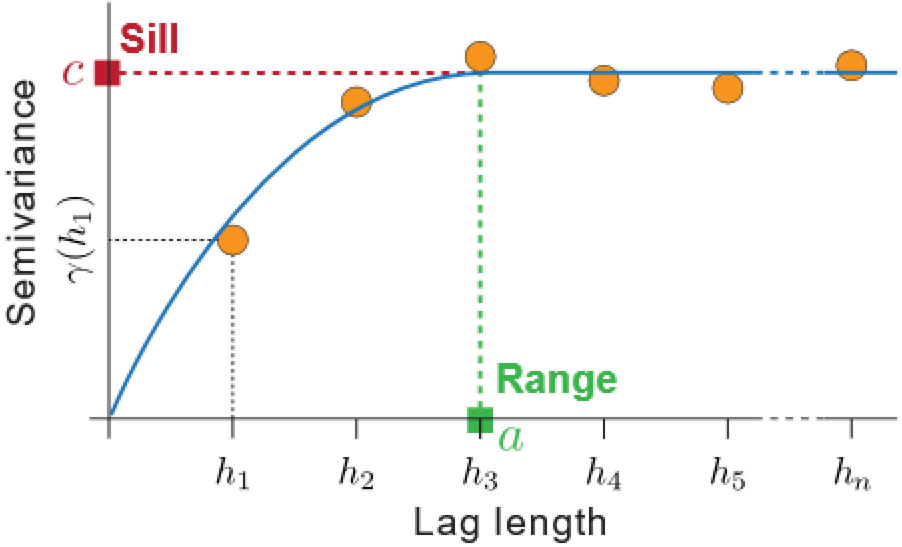

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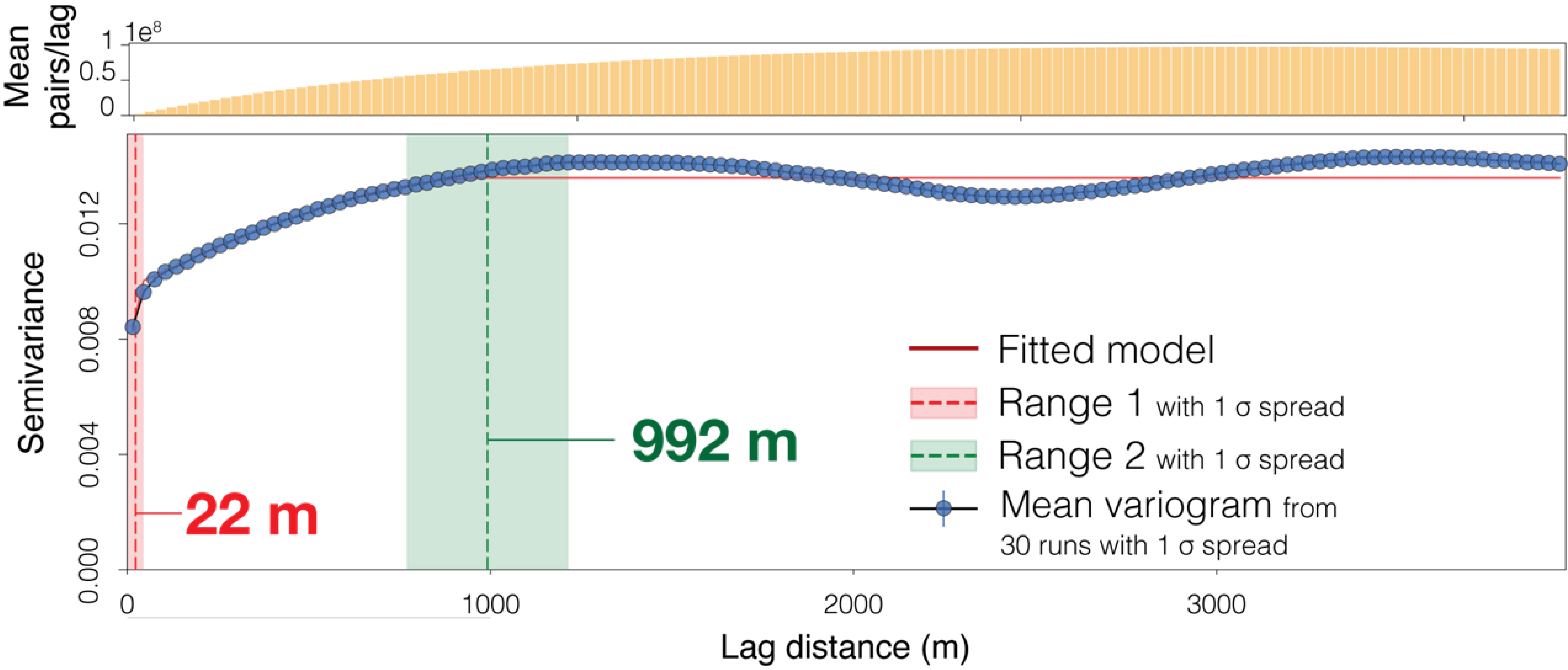
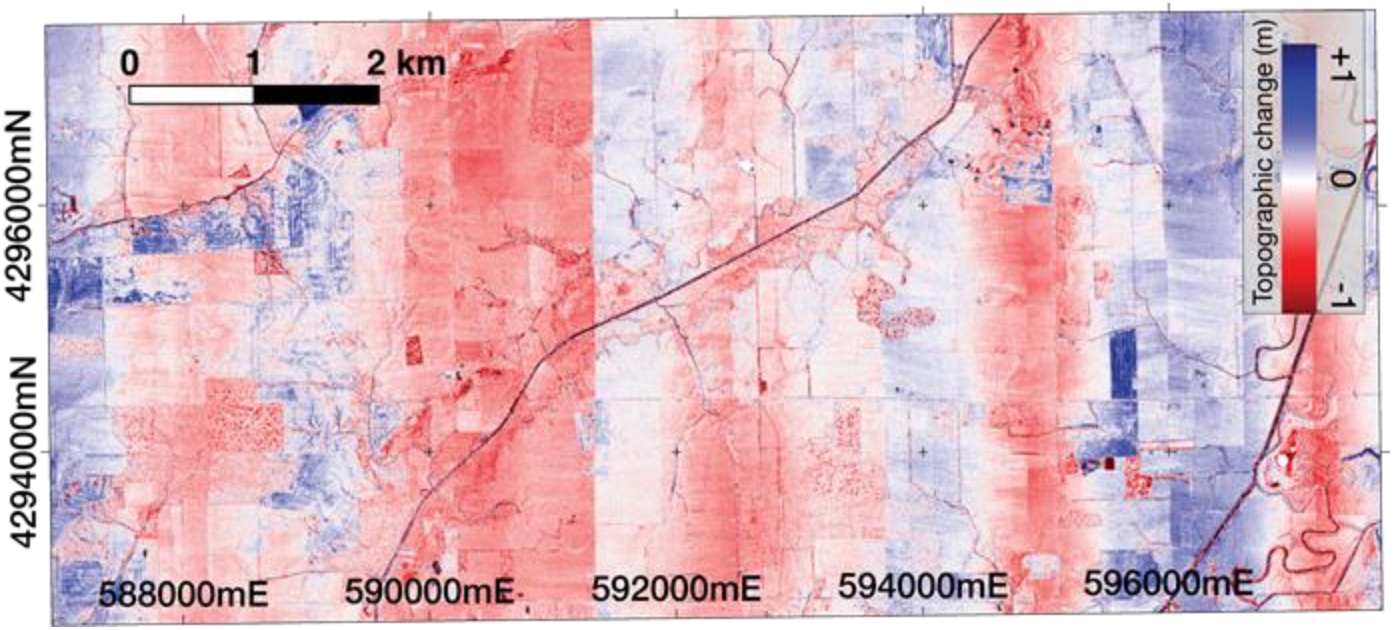


Uncertainty in Vertical Differencing



Area: **52.3 km²**

Vertical bias: **- 0.030 m**

Propagated uncertainty:

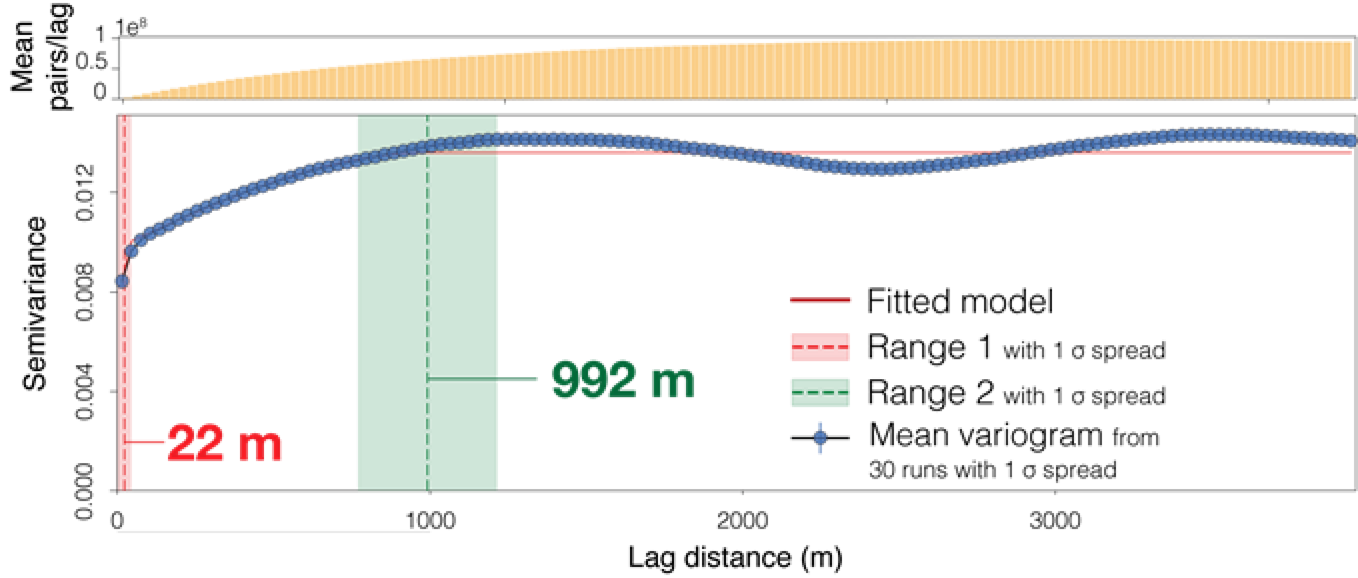
Random, uncorrelated: < 0.001 m

Random, correlated:

Range 1: **± 0.001 m**

Range 2: **± 0.009 m**

Total: **± 0.009 m**



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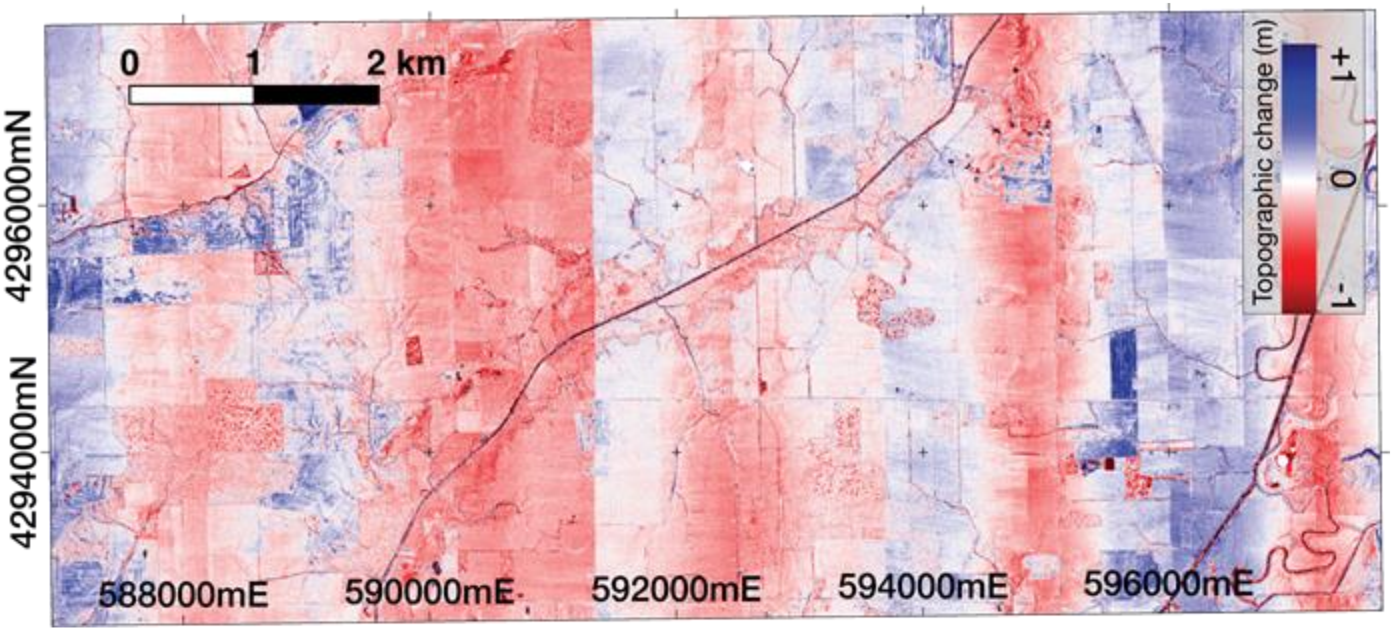

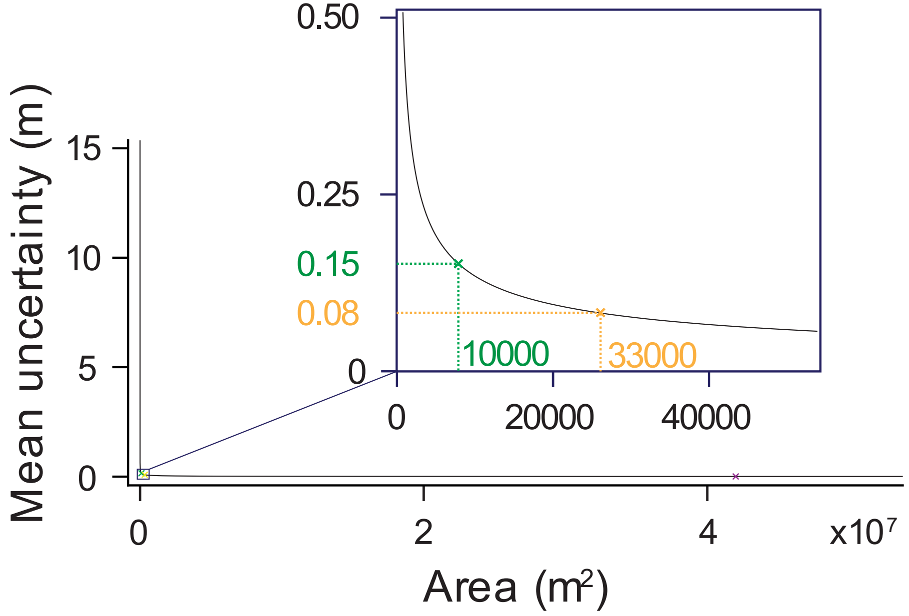

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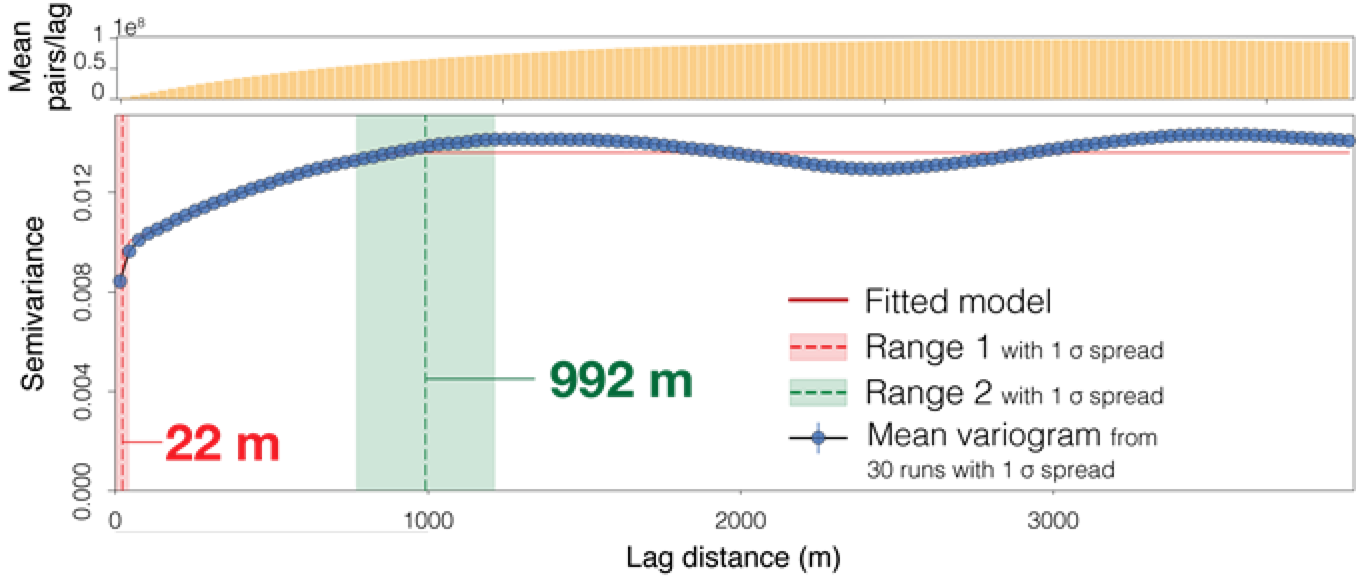
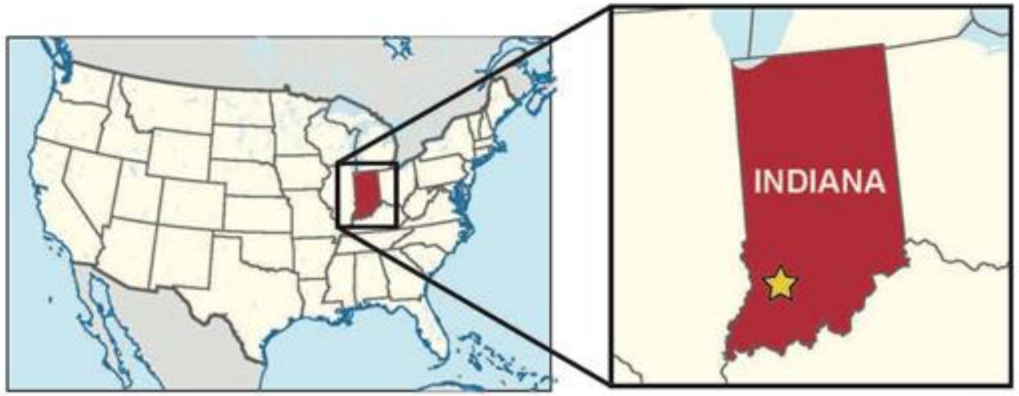
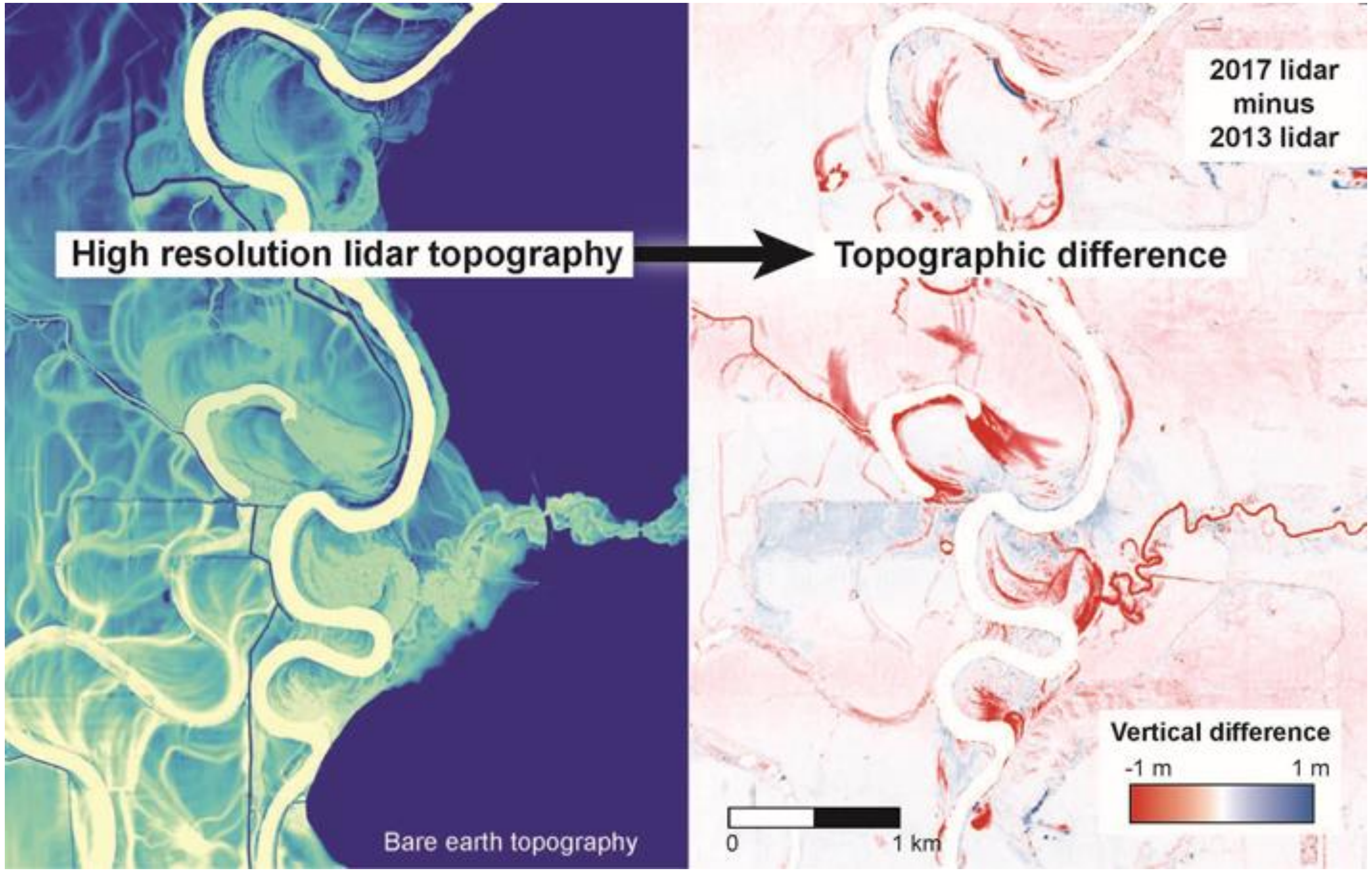


Demo

Statewide Topographic Differencing of Indiana



Scott, C. P., Beckley, M., Phan, M., Zawacki, E., Crosby, C., Nandigam, V., & Arrowsmith, R. (2022). **Statewide USGS 3DEP Lidar Topographic Differencing Applied to Indiana, USA**. *Remote Sensing*, *14*(4). https://doi.org/10.3390/rs14040847



Statewide Topographic Differencing of Indiana

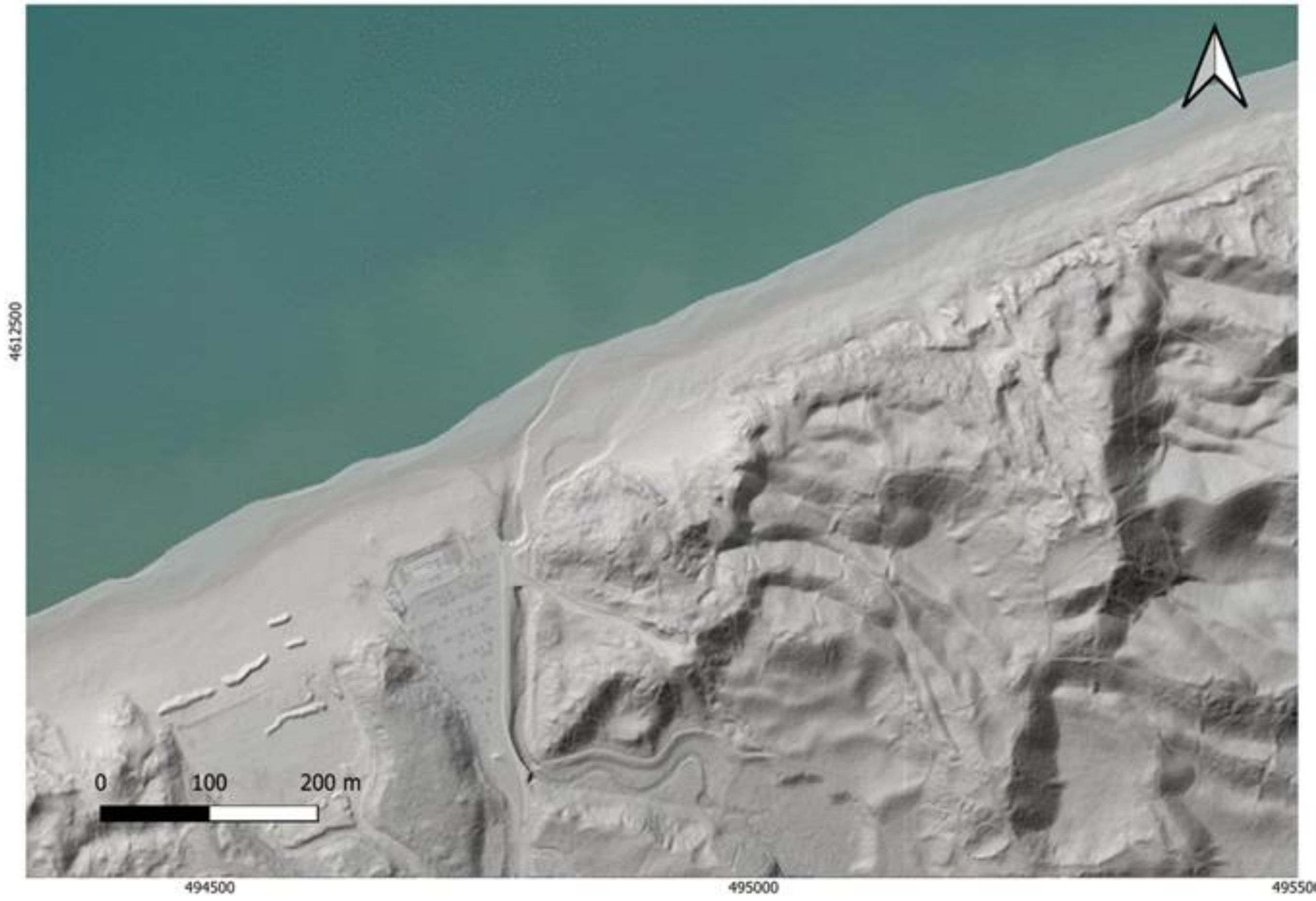
Motivation:
Large-scale topography processing
What does a decade of change look like across a state?

Why Indiana:

Two statewide datasets

Anticipated interesting change

Data-hosting partnership between OT and Indiana



Indiana Dunes National Park

Statewide Topographic Differencing Challenges

Big data: Indiana is 10^2-10^3 larger than the area of large past differencing studies

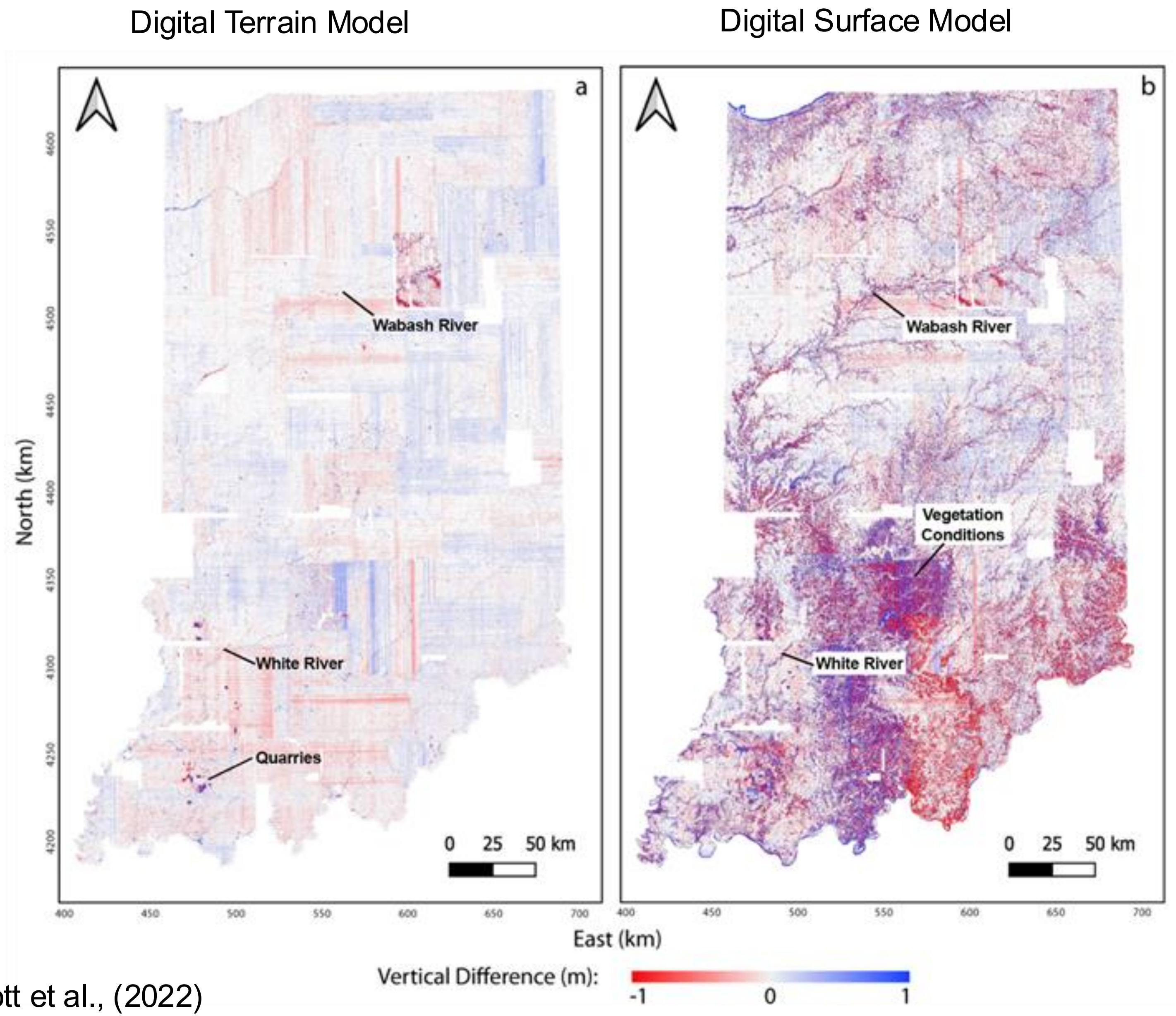
Computation:

- Need high performance computing (HPC) resources
- Memory needs, especially for point cloud to raster/grid
- Final products are ~4 TB

Noise: Sources? Correct at the state-scale?

Visualize the results?

Indiana Topographic Differencing



Fluvial and riparian

Vegetation (correlations with season of data acquisition)

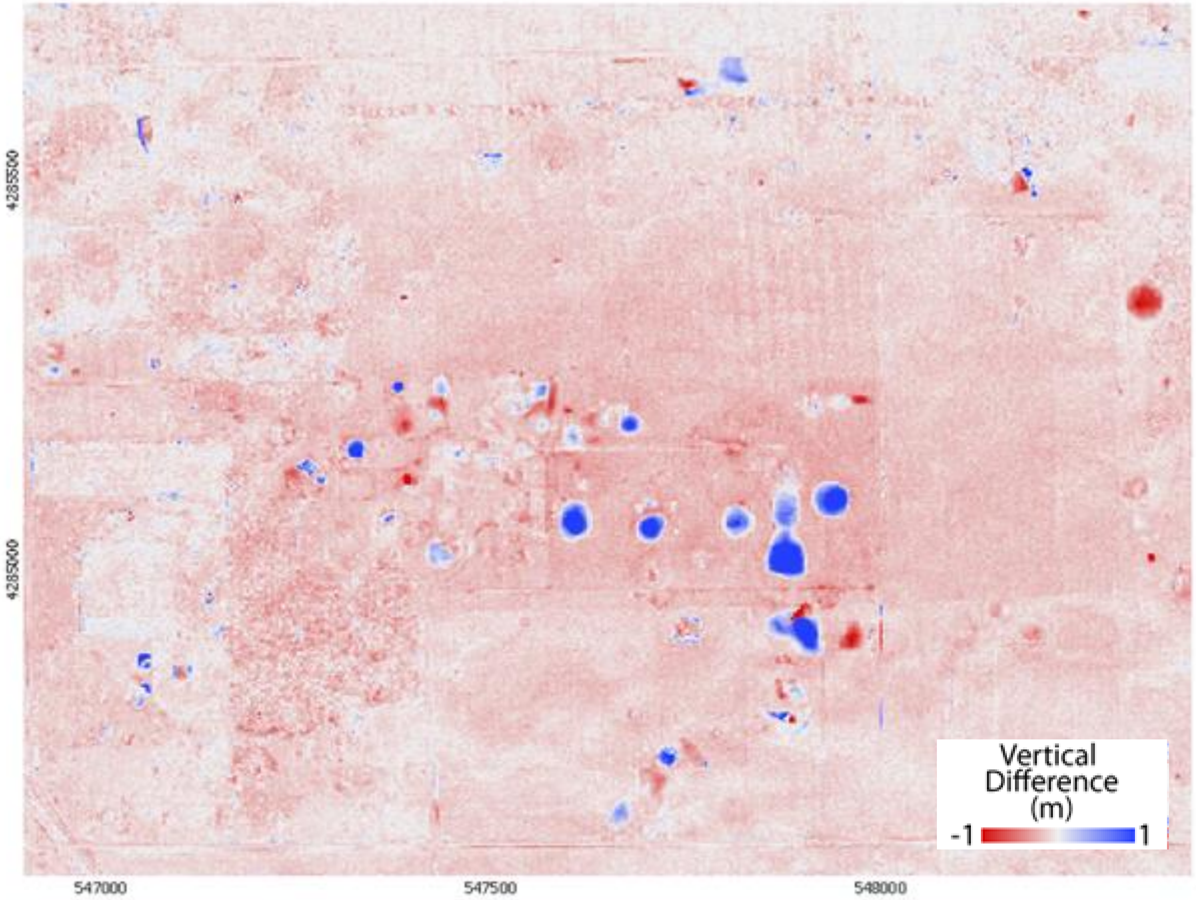
Quarries and mining

Flight alignment errors

Browsable map:
portal.opentopography.org/indiana

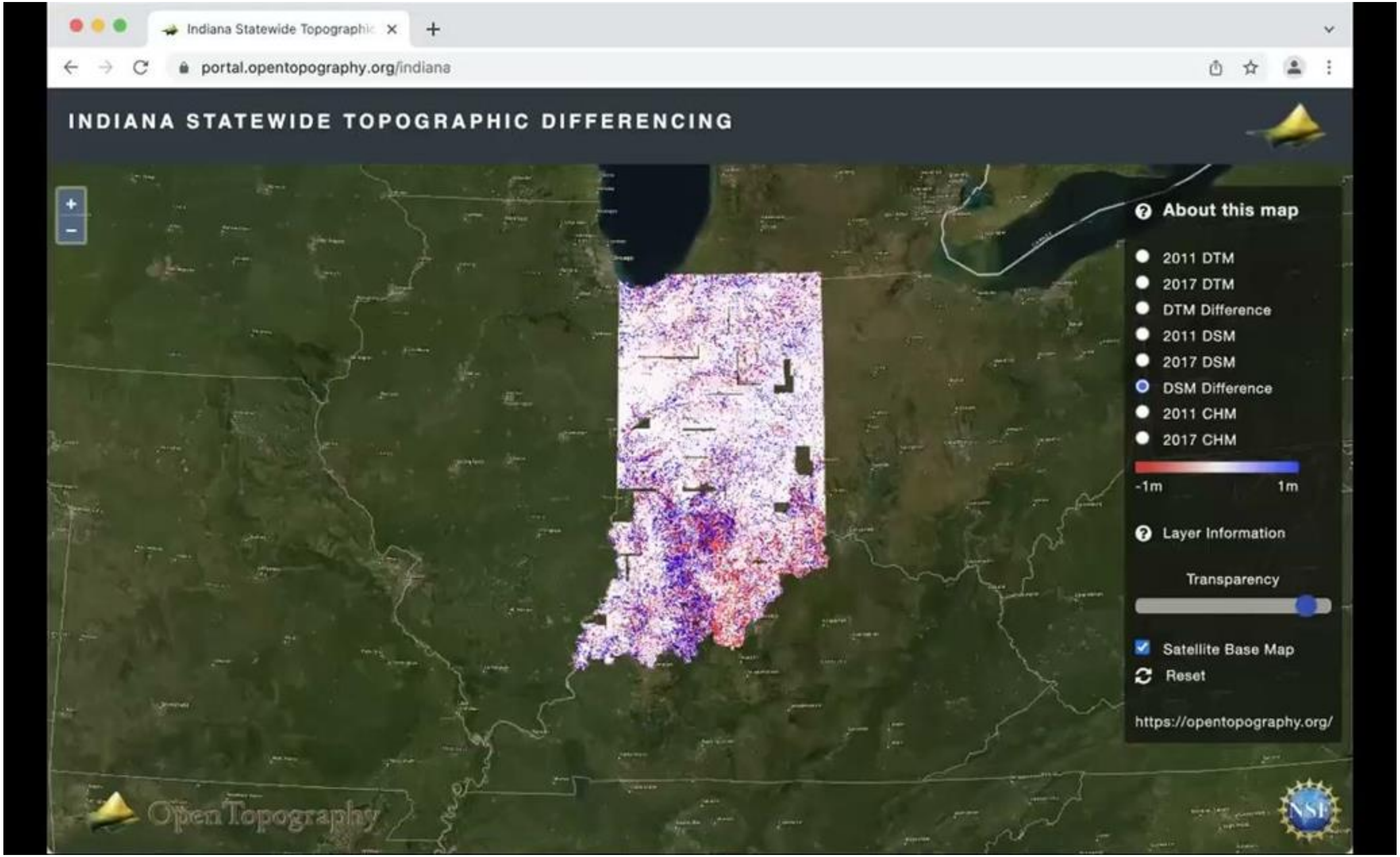
Scott et al., (2022)

Sinkholes

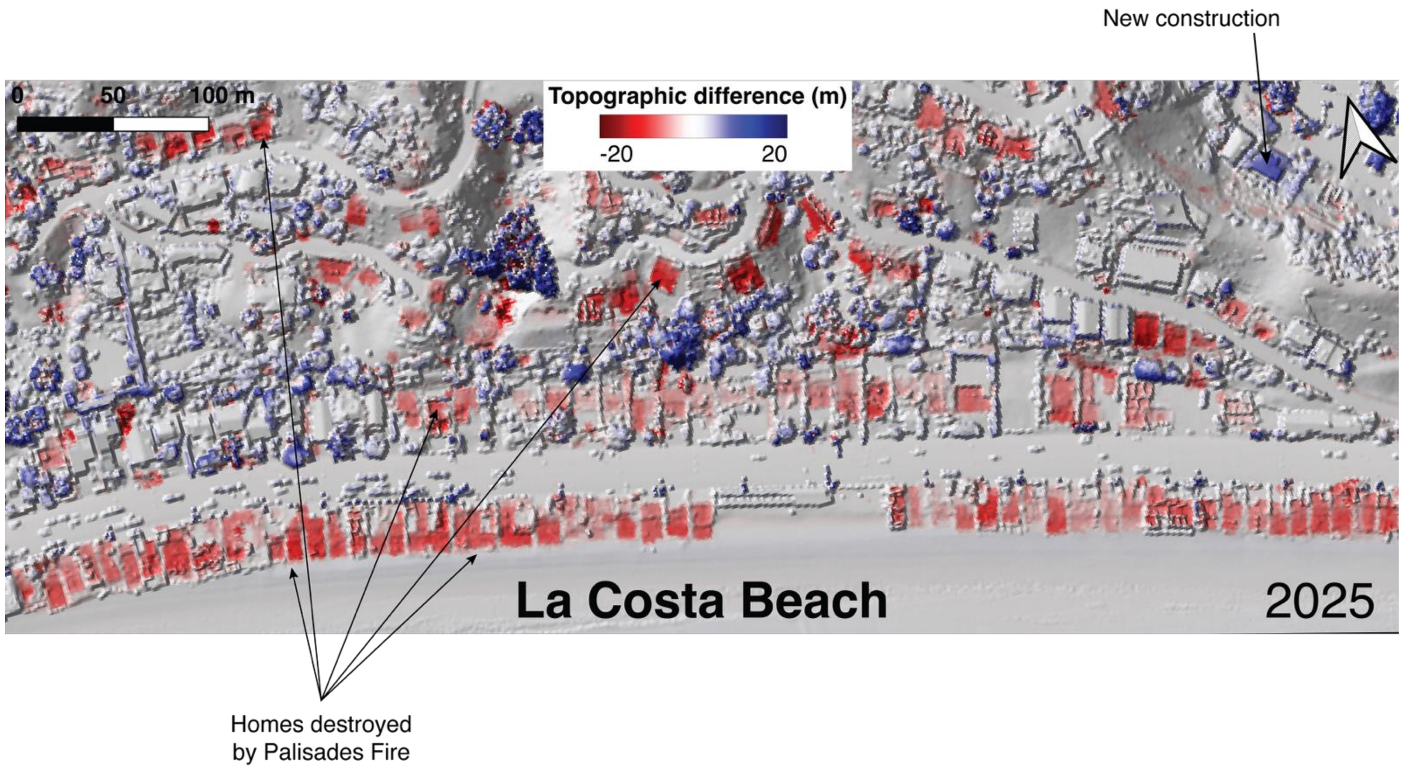


Scott et al., (2022)

Visualize: https://portal.opentopography.org/indiana



Differencing shows the impacts of the 2025 LA Fires

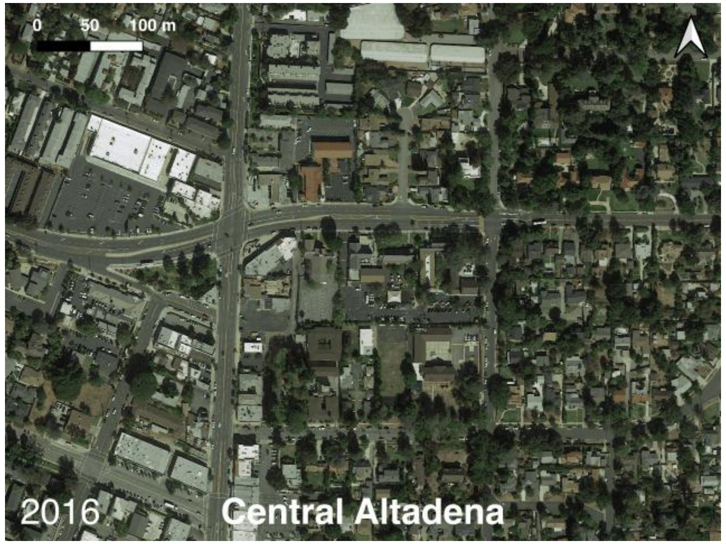


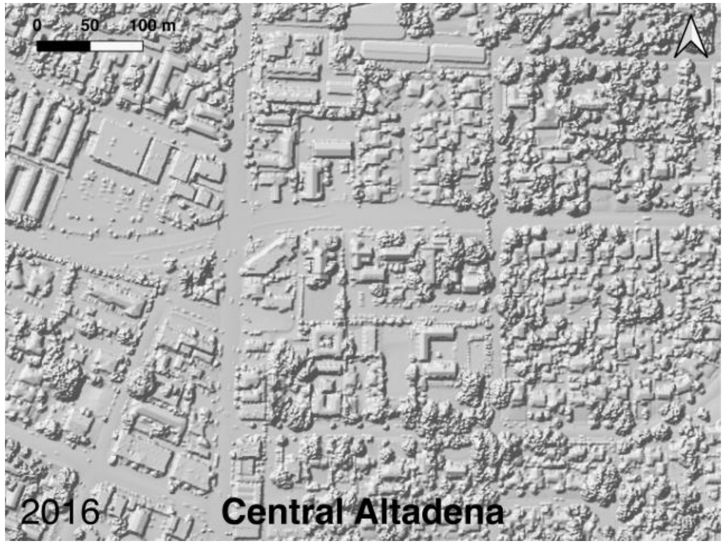
Palisades Fire

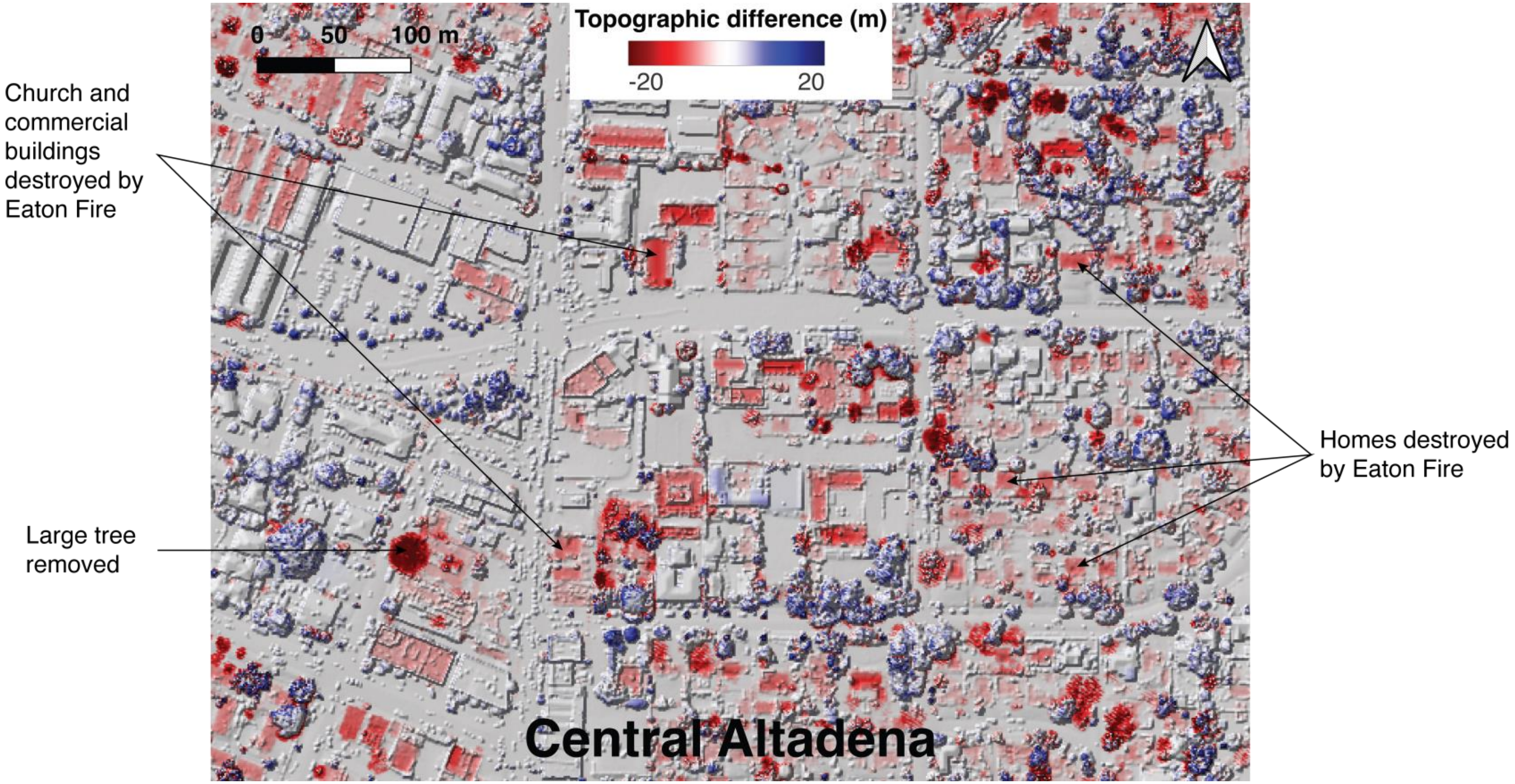
Blog post: https://opentopography.org/blog/using-lidar-understand-impacts-2025-palisades-and-eaton-fires-los-angeles-ca

Data portal: https://portal.opentopography.org/lafires

Differencing shows the impacts of the 2025 LA Fires







Eaton Fire

https://opentopography.org/blog/using-lidar-understand-impacts-2025-palisades-and-eaton-fires-los-angeles-ca

Resources: Self-paced Learning

https://opentopography.org/learn/differencing

Blog posts with differencing examples and error discussion

Video tutorials: Differencing on OT, 3D differencing on Matlab

Conference presentations

Github links to differencing code

Undergraduate differencing exercise

Resources: Peer-reviewed Open Access Publications

Software Contribution

GEOSPHERE

GEOSPHERE, v. 17, no. 4

https://doi.org/10.1130/GES02259.1

12 figures; 2 tables

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Measuring change at Earth's surface: On-demand vertical and three-dimensional topographic differencing implemented in OpenTopography

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ABSTRACT

Topographic differencing measures landscape change by comparing multitemporal high-resolution topography data sets. Here, we focused on two types of topographic differencing: (1) Vertical differencing is the subtraction of digital elevation models (DEMs) that span an event of interest. (2) Three-dimensional (3-D) differencing measures surface change by registering point clouds with a rigid deformation. We recently released topographic differencing in OpenTopography where users perform on-demand vertical and 3-D differencing via an online interface. OpenTopography is a U.S. National Science Foundation–funded facility that provides access to topographic data and processing tools. While topographic differencing has been applied in numerous research studies, the lack of standardization, particularly of 3-D differencing, requires the customization of processing for individual data sets and hinders the community's ability to efficiently perform differencing on the growing archive of topography data. Our paper focuses on streamlined techniques with which to efficiently difference data sets with varying spatial resolution and sensor type (i.e., optical vs. light detection and ranging [lidar]) and over variable landscapes. To optimize on-demand differencing, we considered algorithm choice and displacement resolution. The optimal resolution is controlled by point density, landscape characteristics (e.g., leaf-on vs. leaf-off), and data set quality. We provide processing options derived from metadata that allow users to produce optimal high-quality results, while experienced users can fine tune the parameters to suit their needs. We anticipate that the differencing tool will expand access to this state-of-the-art technology, will be a valuable educational tool, and will serve as a template for differencing the growing number of multitemporal topography data sets.

Chelsea Scott https://orcid.org/0000-0002-3884-4693

INTRODUCTION

Topographic differencing measures landscape change from urban growth, flooding (Wheaton et al., 2009; Izumida et al., 2017), coastal processes (Brock et al., 2001; Bull et al., 2010), earthquakes and creeping faults (Oskin et al., 2012; Nissen et al., 2012, 2014; Clark et al., 2017; Scott et al., 2018a; Wedmore et al., 2019; Barnhart et al., 2019; Scott et al., 2020), volcanic eruptions (Albino et al., 2015), and landslides (Lucieer et al., 2014), among other events. Interest in this technique is growing as more regions are surveyed with multitemporal topography data. Vertical differencing is the subtraction of raster-based digital elevation models (DEMs) and can be performed on original raster topography or grids generated from point cloud data, as shown in Figure 1. Three-dimensional (3-D) differencing resolves the best rigid deformation during an event of interest and is performed with a windowed implementation of the iterative closest point (ICP) algorithm (Besl and McKay, 1992; Chen and Medioni, 1992), as illustrated in Figure 2.

The 3-D differencing method, in particular, often requires an expert to dedicate substantial effort to customize processing, and there is little standard methodology or documentation available. As multitemporal topography coverage increases, more data types with variable characteristics are differenced, and results are used to respond to natural disasters and study phenomena altering Earth's surface. In this paper, we describe our implementation of on-demand vertical and 3-D differencing on topography data available via OpenTopography (opentopography.org). A major challenge in 3-D differencing is to select the appropriate differencing algorithm and the resolution of derived displacements, which depend on data resolution, noise, and landscape characteristics. We compared several differencing algorithms and incorporated metadata (e.g., point density) into the default processing settings. Our workflow quickly produces quality differencing results and offers default options that can be further tailored for individual data sets by more advanced users. Deployment of these tools in OpenTopography expands access to state-of-the-art technology for scientists, geospatial professionals, and students. Additionally, our tools can become a reference that contributes to the standardization of topographic differencing, which is lacking in the geosciences.

OpenTopography is a U.S. National Science Foundation–funded facility that enables discovery and access of high-resolution topography data sets and provides on-demand processing tools. OpenTopography is built on a scalable-system–oriented architecture that supports a range of downstream processing tools that derive common science products from hosted raw data (Krishnan et al., 2011). As of October 2020, the 341 point cloud data sets hosted by OpenTopography cover more than

https://doi.org/10.1130/GES02259.1

remote sensing

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Article

Statewide USGS 3DEP Lidar Topographic Differencing Applied to Indiana, USA

Chelsea Phipps Scott [1,*], Matthew Beckley [2], Minh Phan [3], Emily Zawacki [1], Christopher Crosby [2], Viswanath Nandigam [3] and Ramon Arrowsmith [1]

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Academic Editor: Luke Wallace

Abstract: Differencing multi-temporal topographic data (radar, lidar, or photogrammetrically derived point clouds or digital elevation models—DEMs) measures landscape change, with broad applications for scientific research, hazard management, industry, and urban planning. The United States Geological Survey's 3D Elevation Program (3DEP) is an ambitious effort to collect light detection and ranging (lidar) topography over the United States' lower 48 and Interferometric Synthetic Aperture Radar (IfSAR) in Alaska by 2023. The datasets collected through this program present an important opportunity to characterize topography and topographic change at regional and national scales. We present Indiana statewide topographic differencing results produced from the 2011–2013 and 2016–2020 lidar collections. We discuss the insights, challenges, and lessons learned from conducting large-scale differencing. Challenges include: (1) designing and implementing an automated differencing workflow over 94,000 km^2 of high-resolution topography data, (2) ensuring sufficient computing resources, and (3) managing the analysis and visualization of the multiple terabytes of data. We highlight observations including infrastructure development, vegetation growth, and landscape change driven by agricultural practices, fluvial processes, and natural resource extraction. With 3DEP and the U.S. Interagency Elevation Inventory data, at least 37% of the Contiguous 48 U.S. states are already covered by repeat, openly available, high-resolution topography datasets, making topographic differencing possible.

Keywords: lidar; topographic change; USGS 3DEP; Indiana; vertical differencing

https://doi.org/10.3390/rs14040847

White River, IN

OpenTopography

Thank you!

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Socials: @OpenTopography

SDSC

EarthScope Consortium

ASU