UNIVERSITY OF SOUTH FLORIDA

CroScalar: A Multi-Scale Modeling Framework for Spatio-Temporal Data

Yi Qiang[1], Barbara P. Buttenfield[2], Jinwen Xu[1]

1. University of South Florida, School of Geosciences

2. University of Colorado – Boulder, Department of Geography

COMPASS Lab

NSF

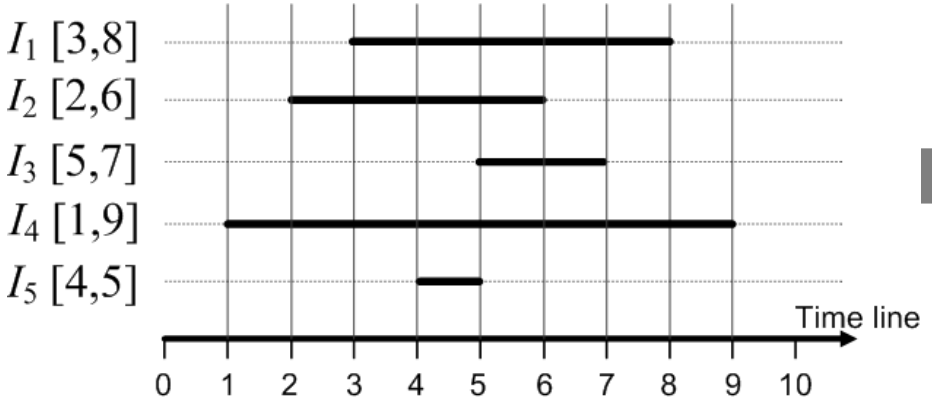
CroScalar: A Multi-Scale Modeling Framework for Spatio-Temporal Data

- Multi-Scale Temporal Analysis (Triangle Model)
- Multi-Scale for Spatial Analysis (Pyramid Model)
- Higher-Dimensional Models for Spatio-Temporal Analyses (CroScalar)

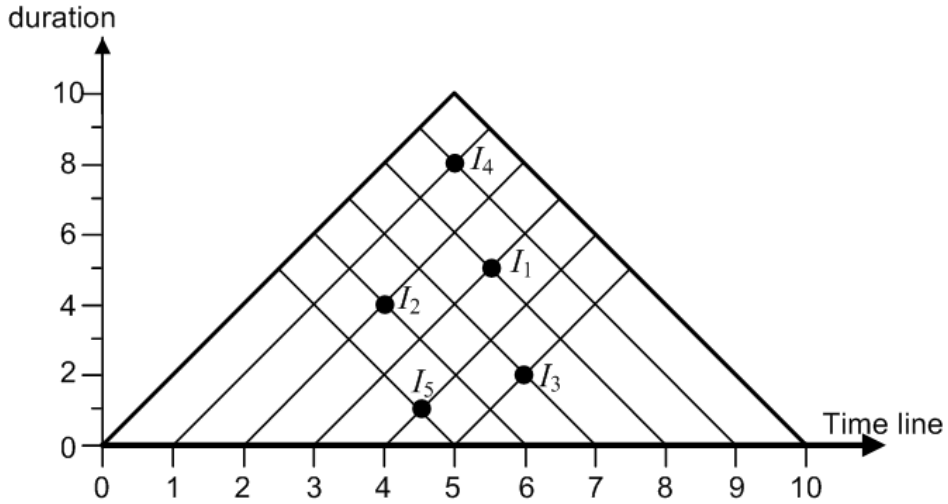
The project is supported by the NSF Methodology, Measurement & Statistics (MMS) Program (Award No. 1853866).

Triangular Model: Mapping Time Intervals in a 2D Space

- Time interval is an extent in time, which is usually represented as linear interval in a 1D linear space
- The linear model is inefficient for data visualization and analysis.
- Alternatively, time intervals can be represented as points in a 2D space



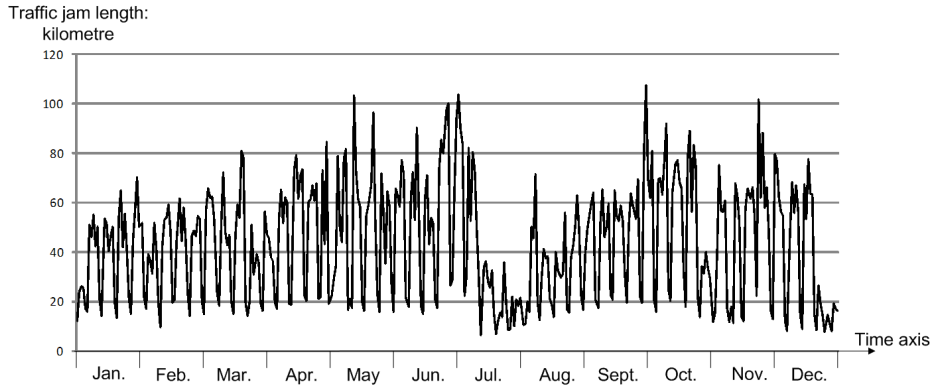
The Linear Model (1D)



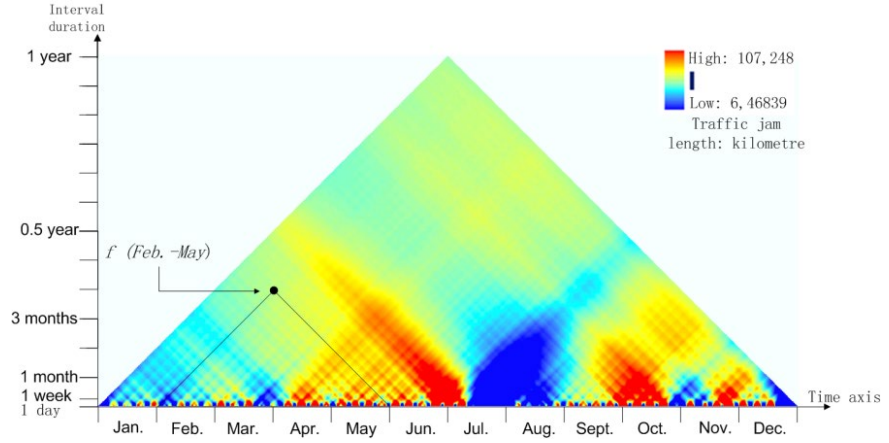
The Triangular Model (2D)

Triangular Model: Mapping Time Intervals in a 2D Space

- Time interval is an extent in time, which is usually represented as linear interval in a 1D linear space
- The linear model is inefficient for data visualization and analysis.
- Alternatively, time intervals can be represented as points in a 2D space



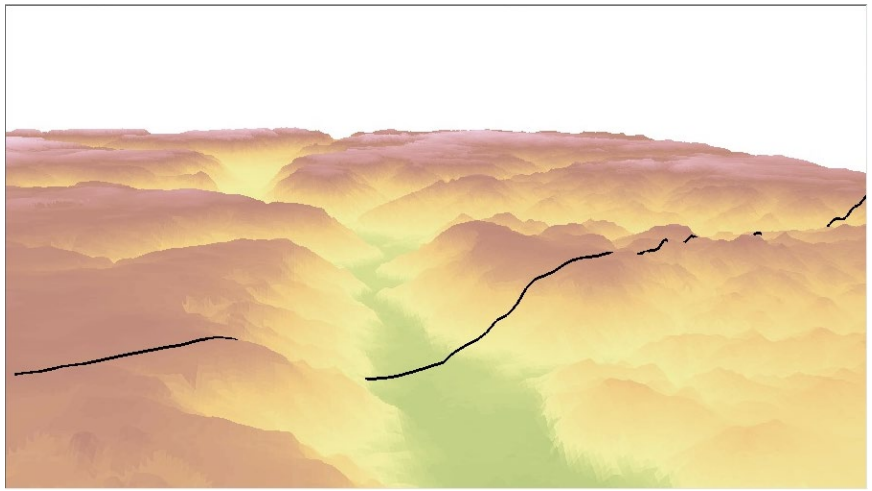
The Linear Model (1D)



The Triangular Model (2D)

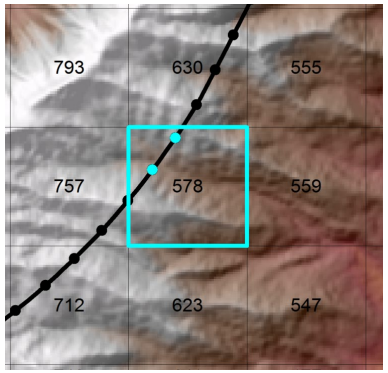
Y. Qiang and N. Van de Weghe, "Re-Arranging Space, Time and Scales in GIS: Alternative Models for Multi-Scale Spatio-Temporal Modeling and Analyses," *ISPRS International Journal of Geo-Information*, vol. 8, no. 2, p. 72, Feb. 2019, doi: 10.3390/ijgi8020072.

Uncertainty Assessment of Distance Measurement

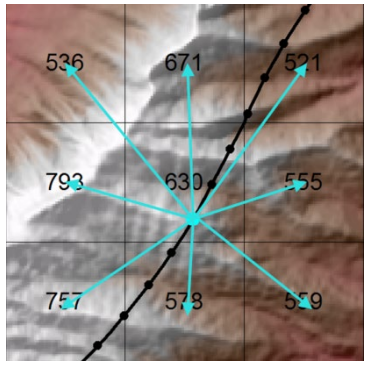


Distance Measurement in 3D terrain

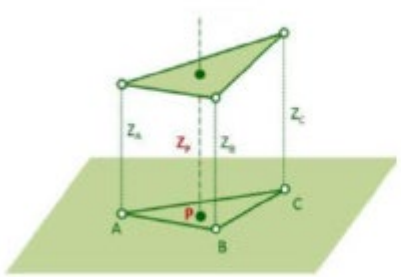
- Closest centroid



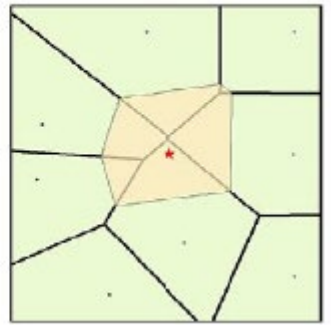
- Weighted Average



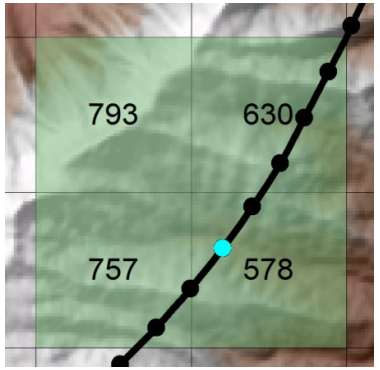
- TIN



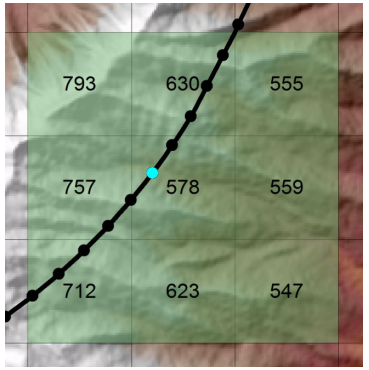
- Nearest Neighbor



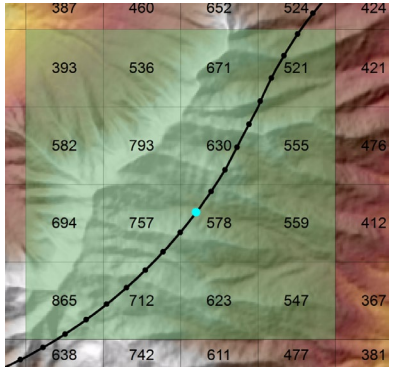
- Bi-Linear



- Bi-Cubic

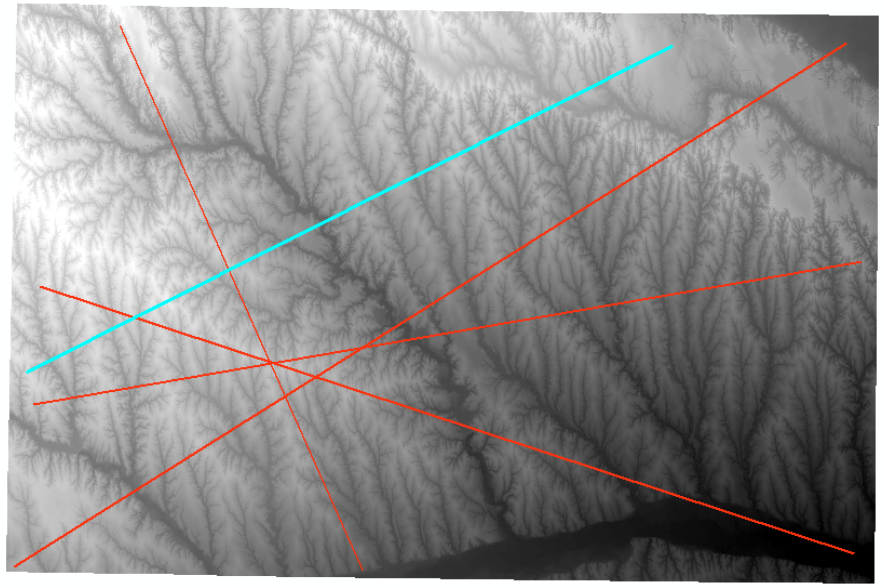


- Bi-Quadratic

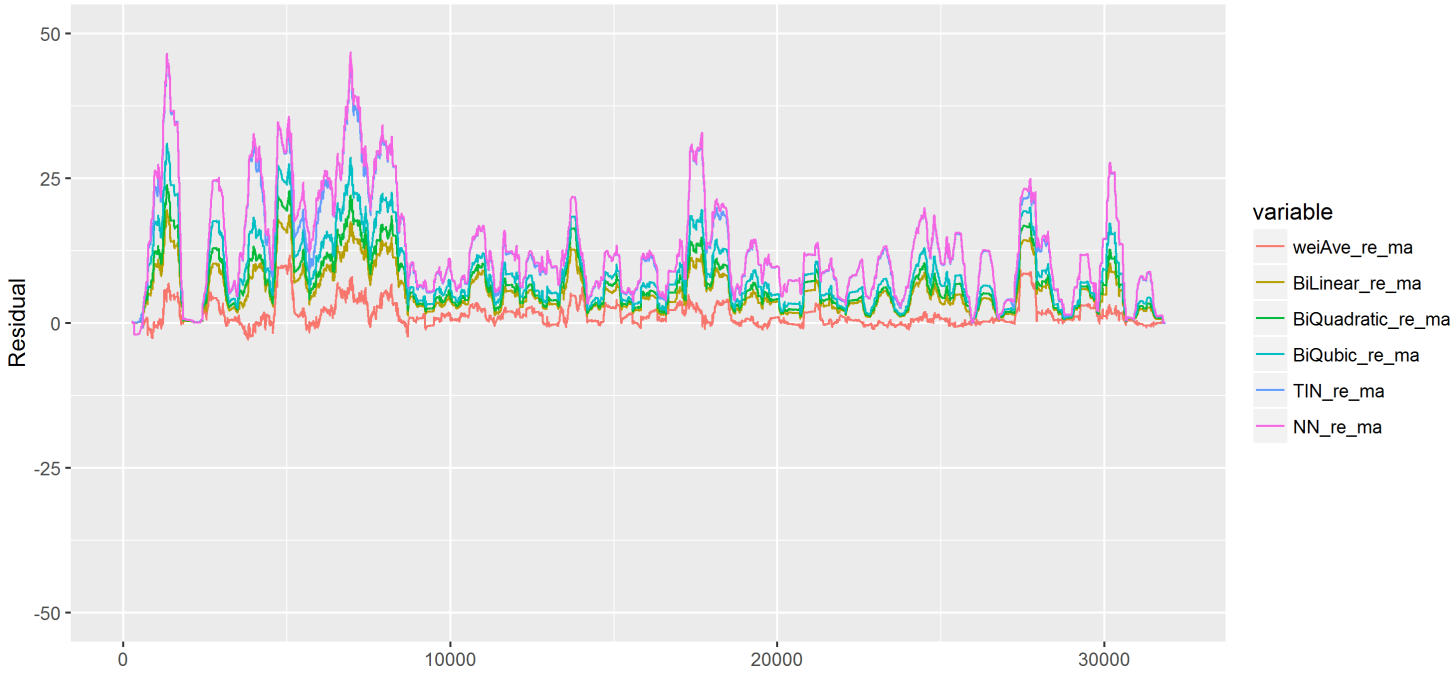


Surface-Adjusted Distance Measurement

Uncertainty Assessment of Distance Measurement

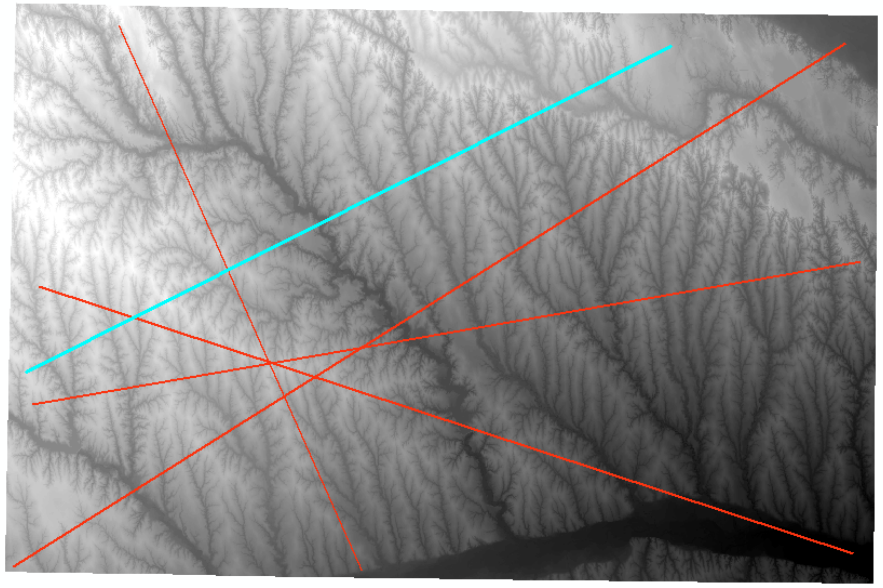


Transects in a study area in Nebraska

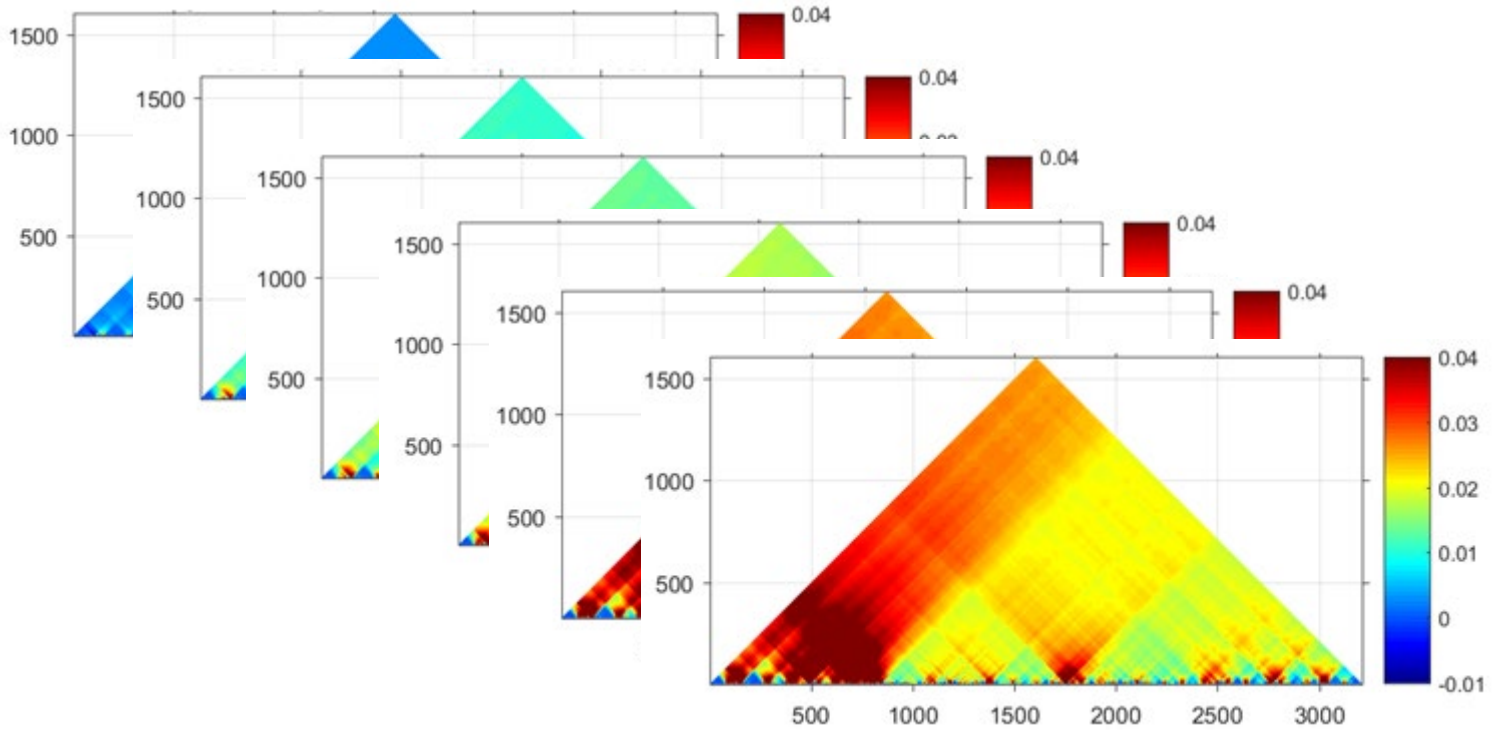


Measurement residuals in 9-meter intervals

Uncertainty Assessment of Distance Measurement

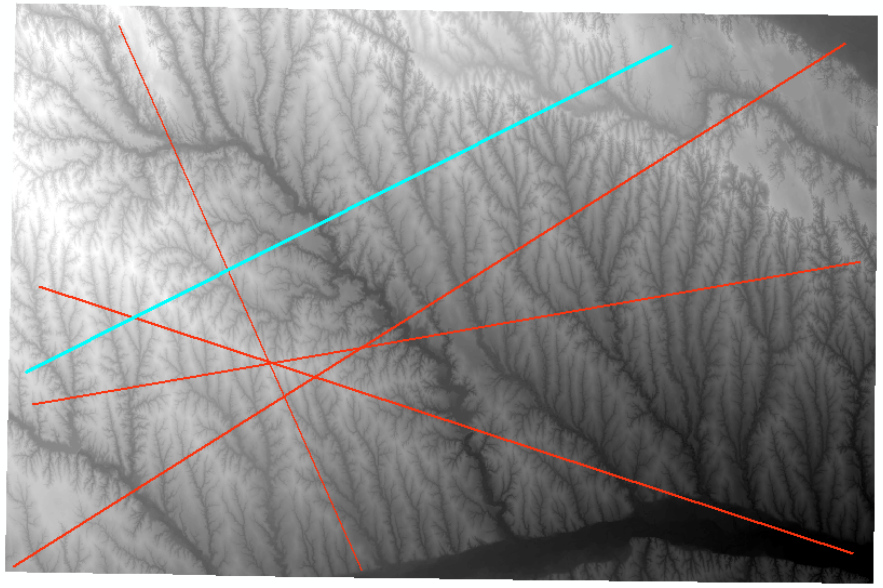


Transects in a study area in Nebraska



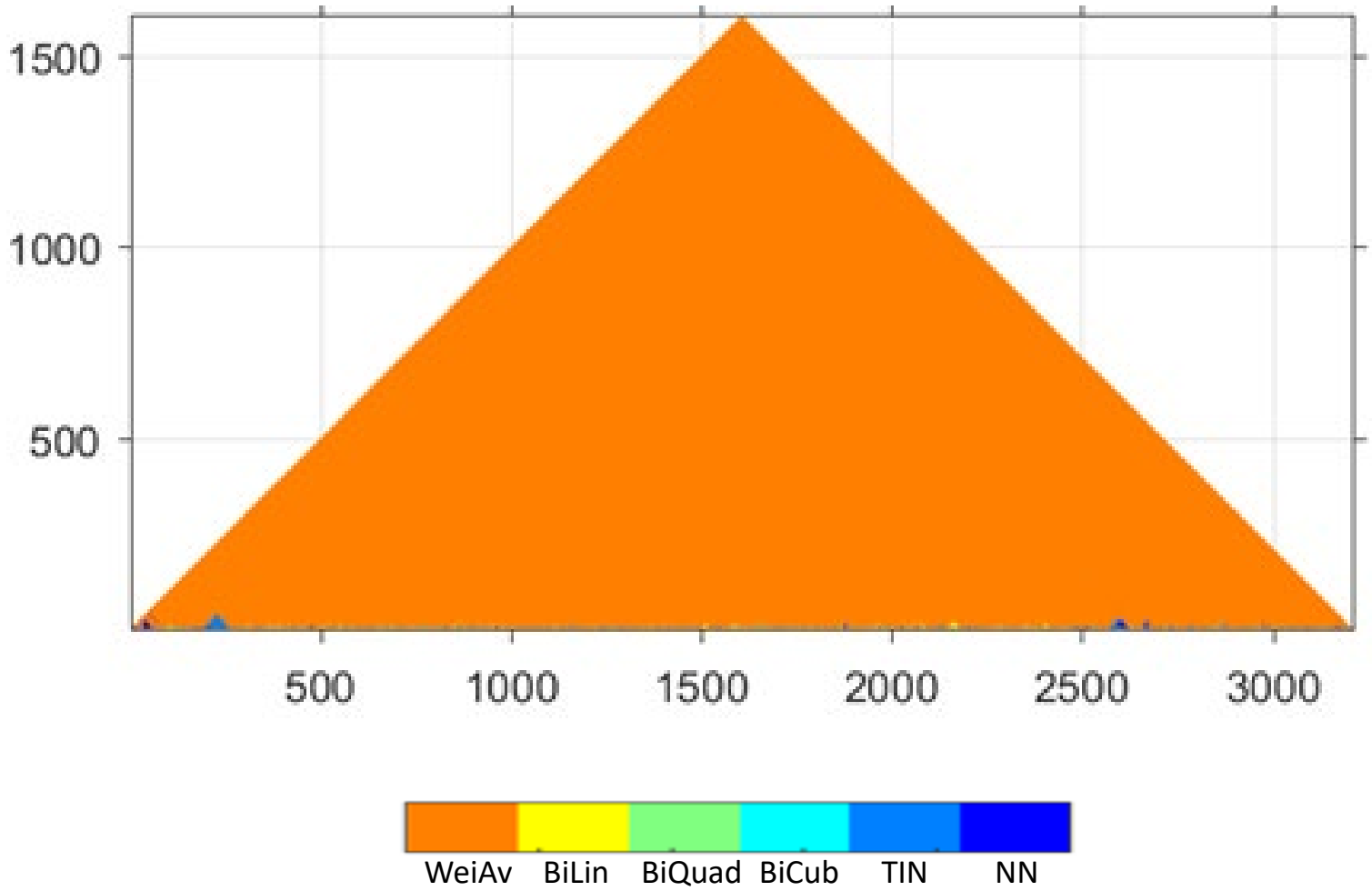
Triangle Models of residuals at different intervals

Uncertainty Assessment of Distance Measurement

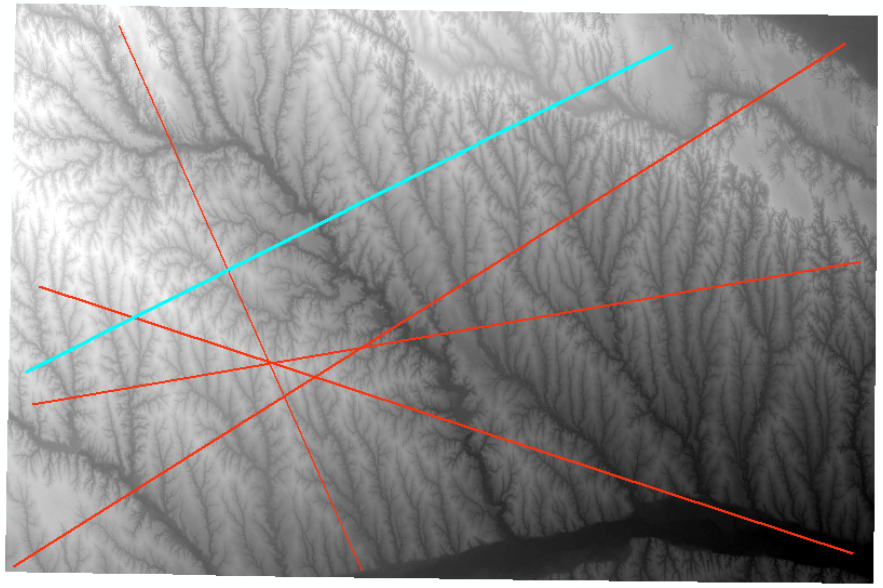


Transects in a study area in Nebraska

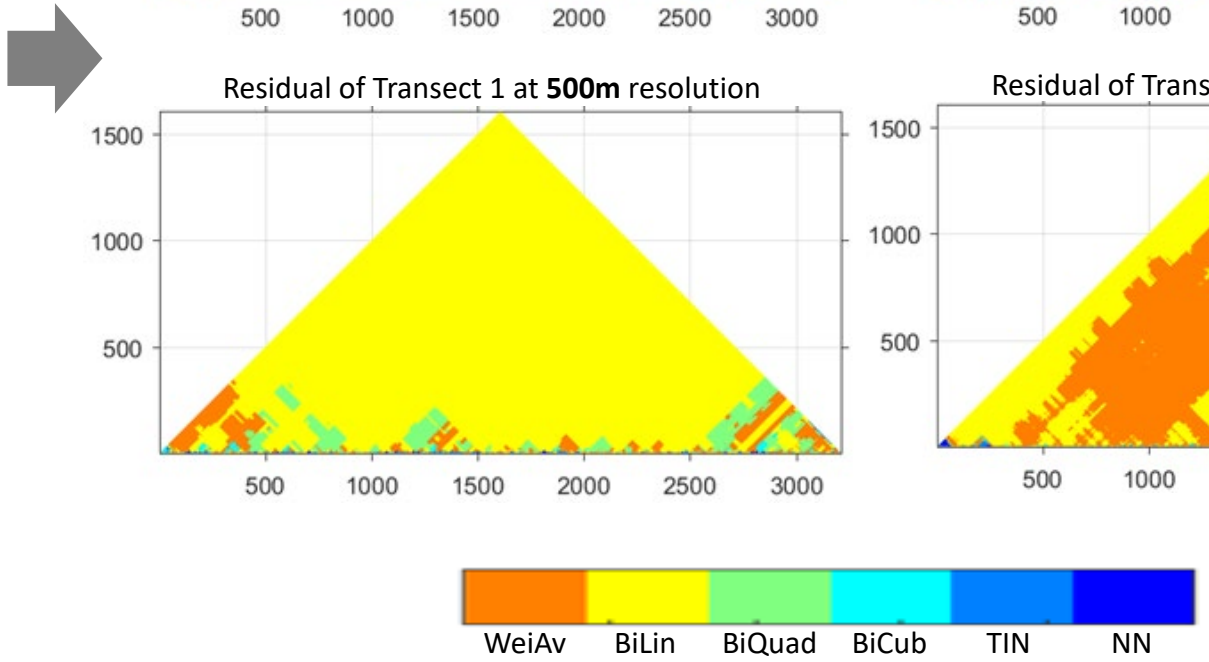
Residual of Transect 1 at 10m resolution DEM



Uncertainty Assessment of Distance Measurement



Transects in a study area in Nebraska



Pyramid Model

- Pyramid Model (PM): **Multi-scale representation** for 2D spatial data
- Similar concept as Image Pyramid
- Integrating the scale dimension (z) with the spatial (x,y) dimension

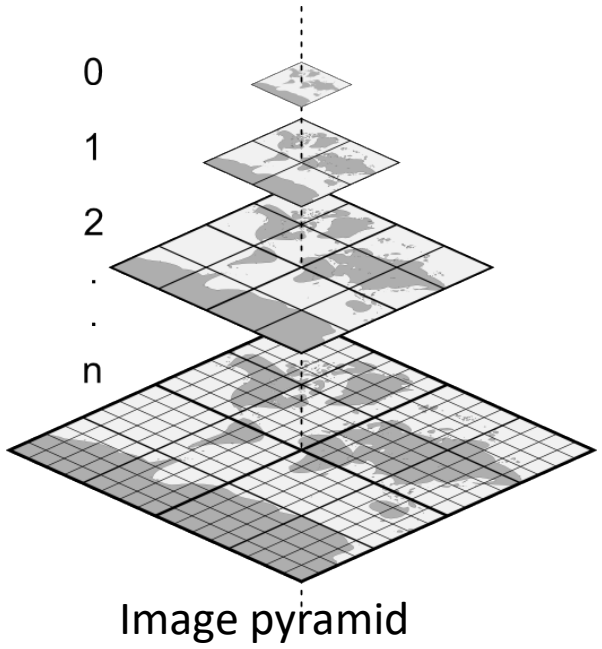
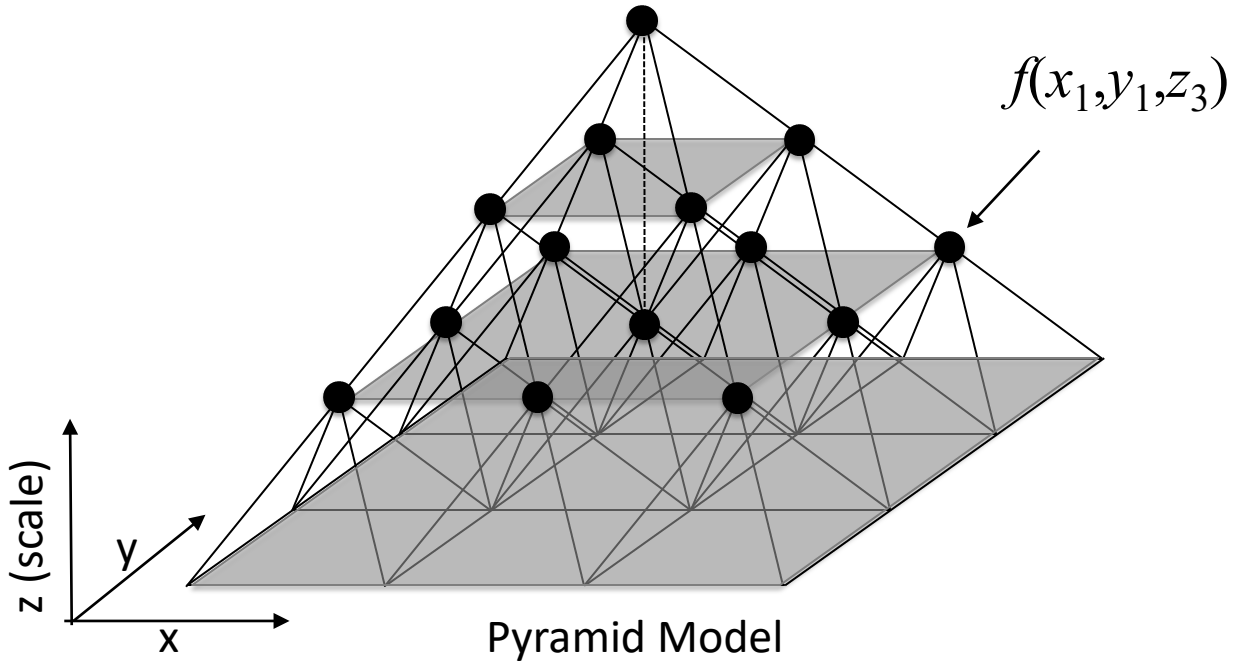


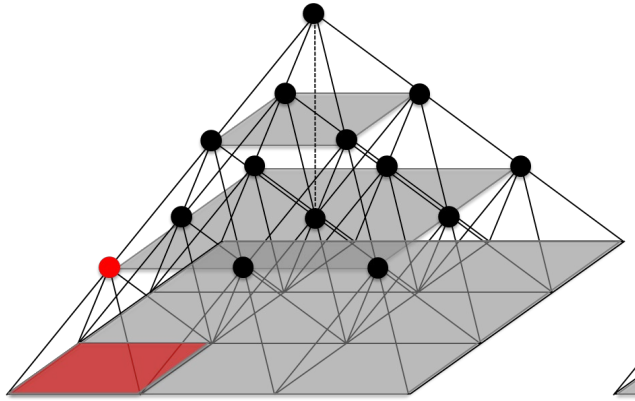
Image pyramid



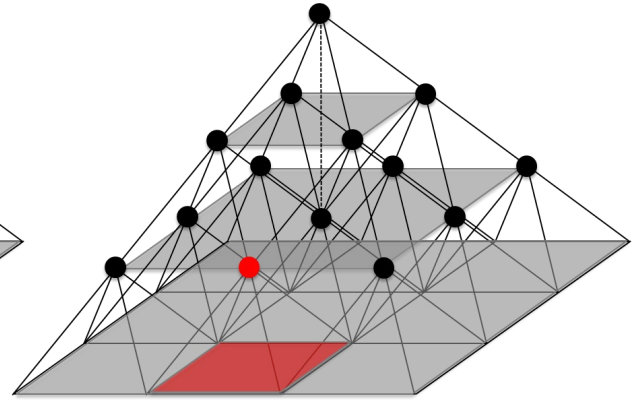
Pyramid Model

Pyramid Model

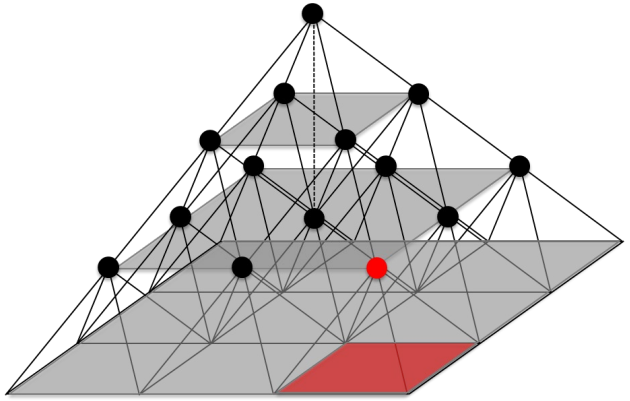
Each node (voxel) represent a specific cell in the tessellation in the base layer



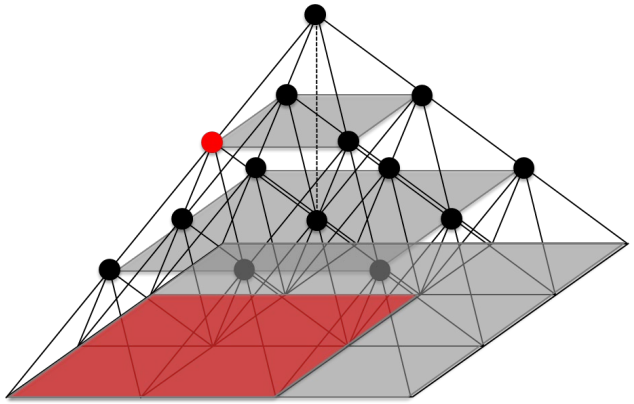
$f(x_1,y_1,z_1)$



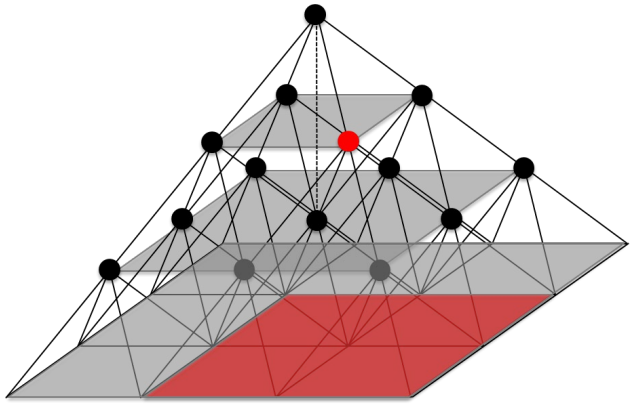
$f(x_2,y_1,z_1)$



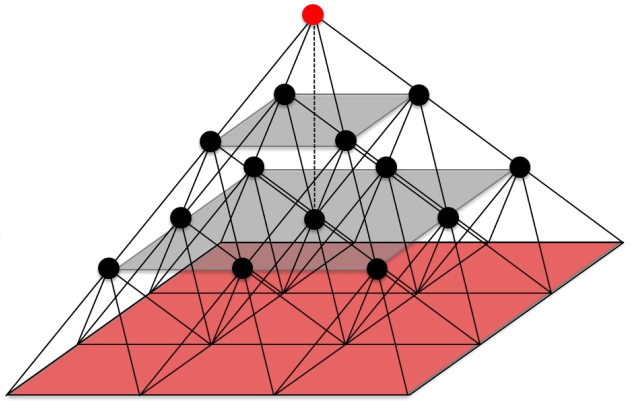
$f(x_3,y_1,z_1)$



$f(x_1,y_1,z_2)$

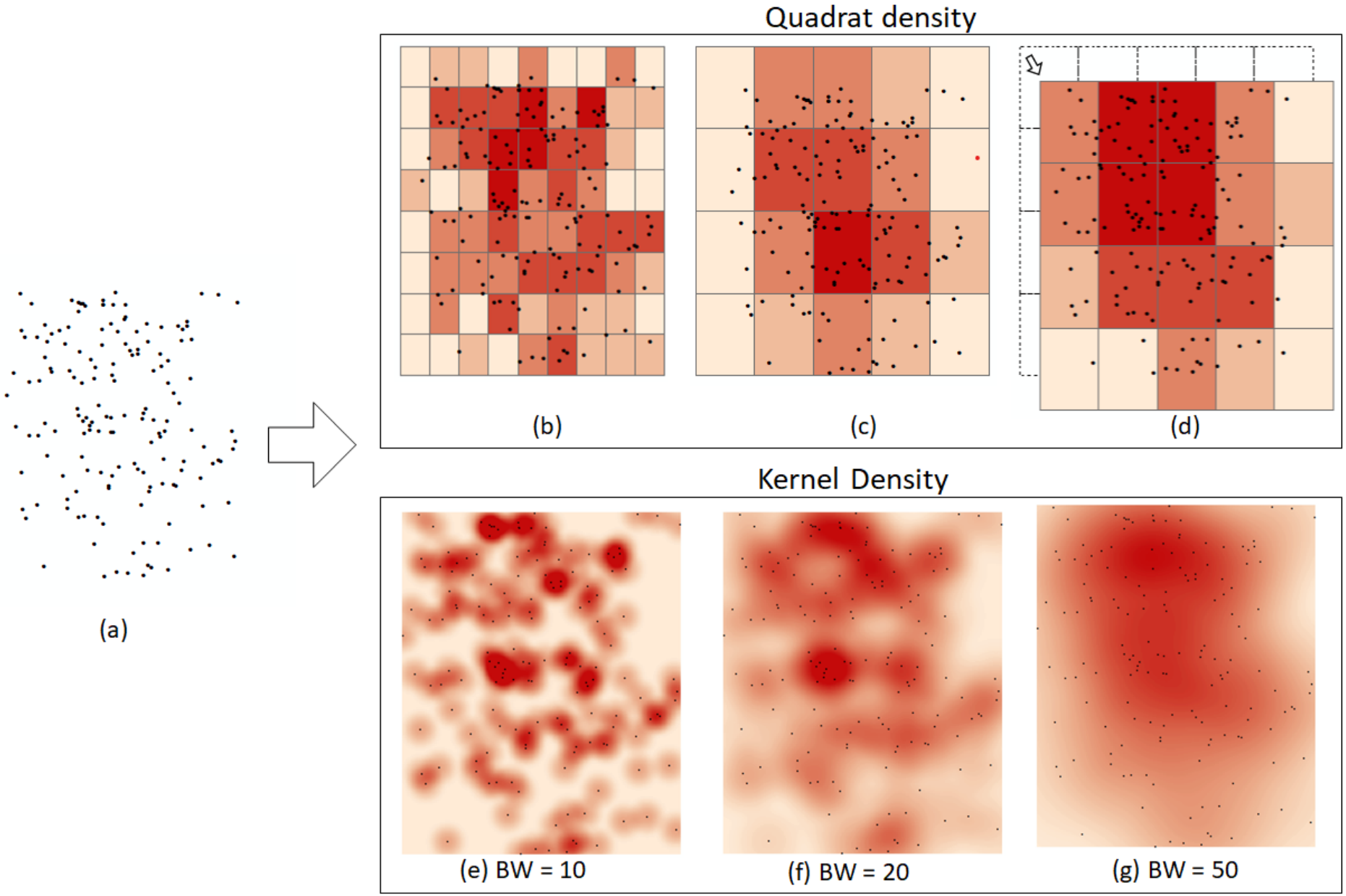


$f(x_2,y_1,z_2)$

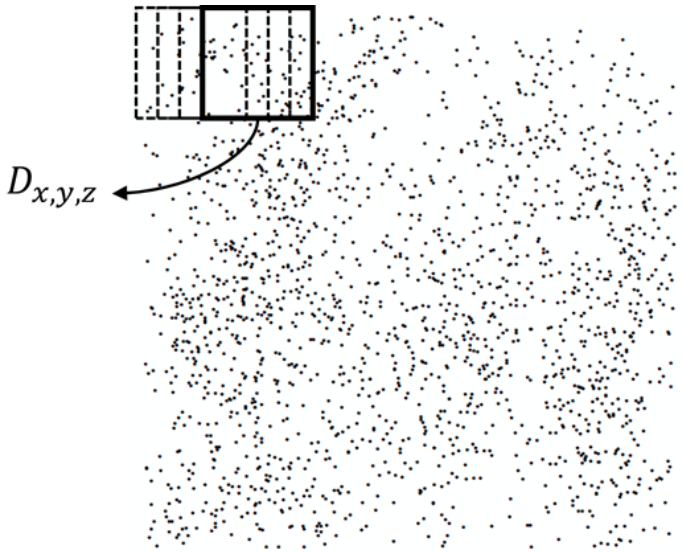


$f(x_1,y_1,z_3)$

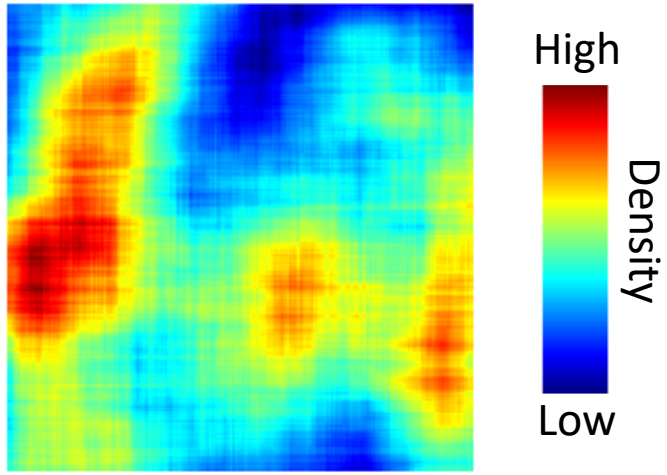
Scale Issue in Point Pattern Analysis



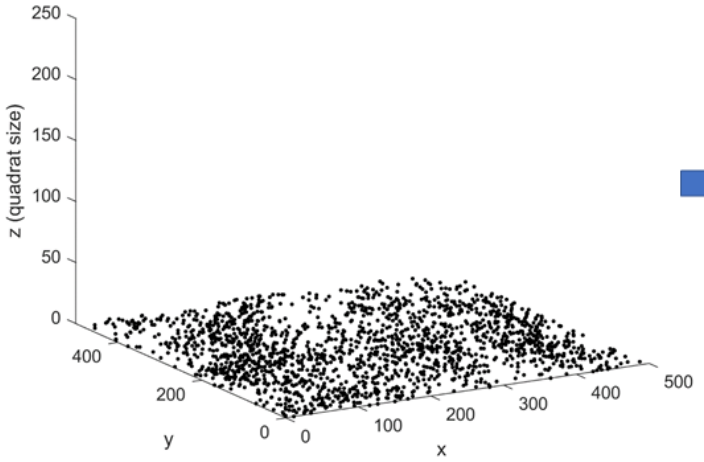
Multi-Scale Quadrat Density in PM



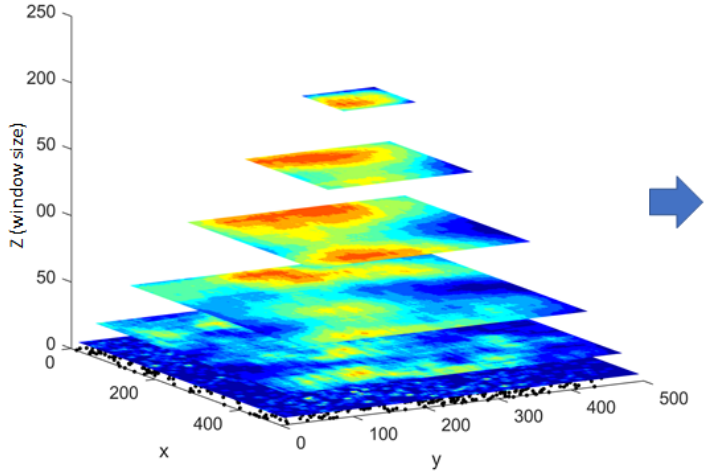
(a) Moving window rolling through a point set



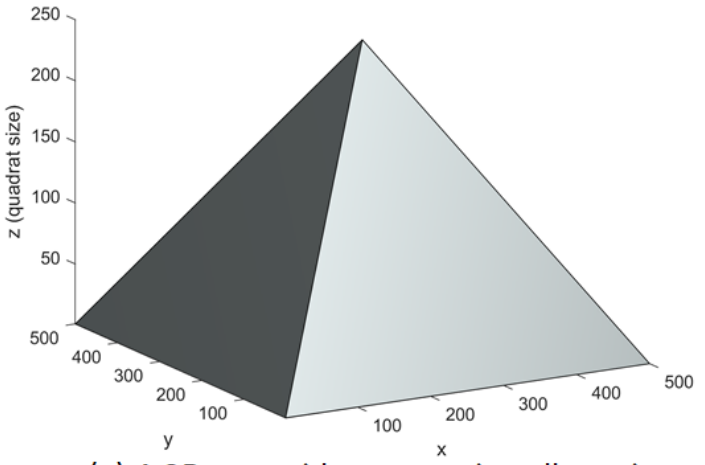
(b) Color-coded point density in moving windows



(c) A point set in the 2D space

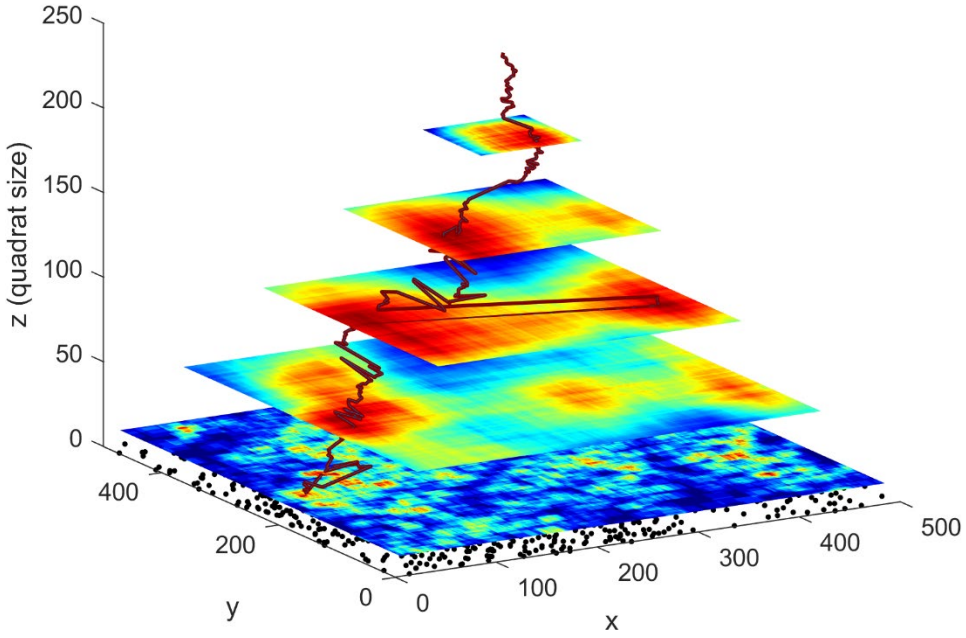


(d) Point density in different sizes of moving windows

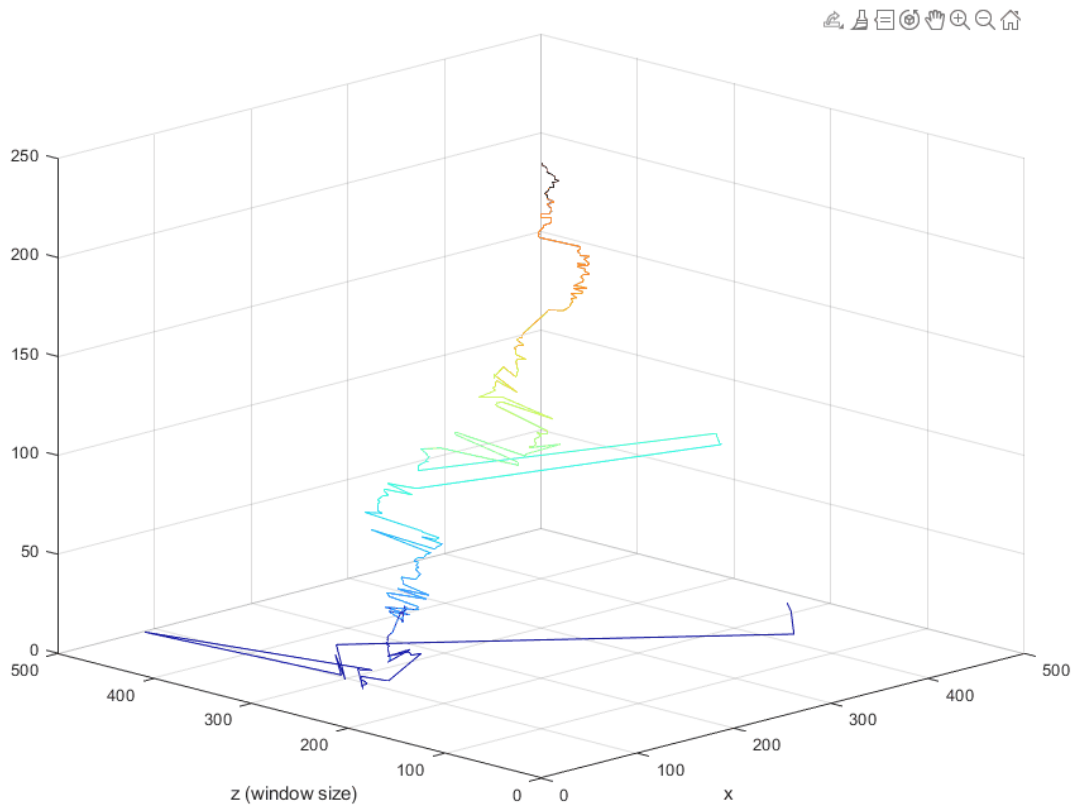


(e) A 3D pyramid representing all moving windows

Global Peaks of Quadrat Density

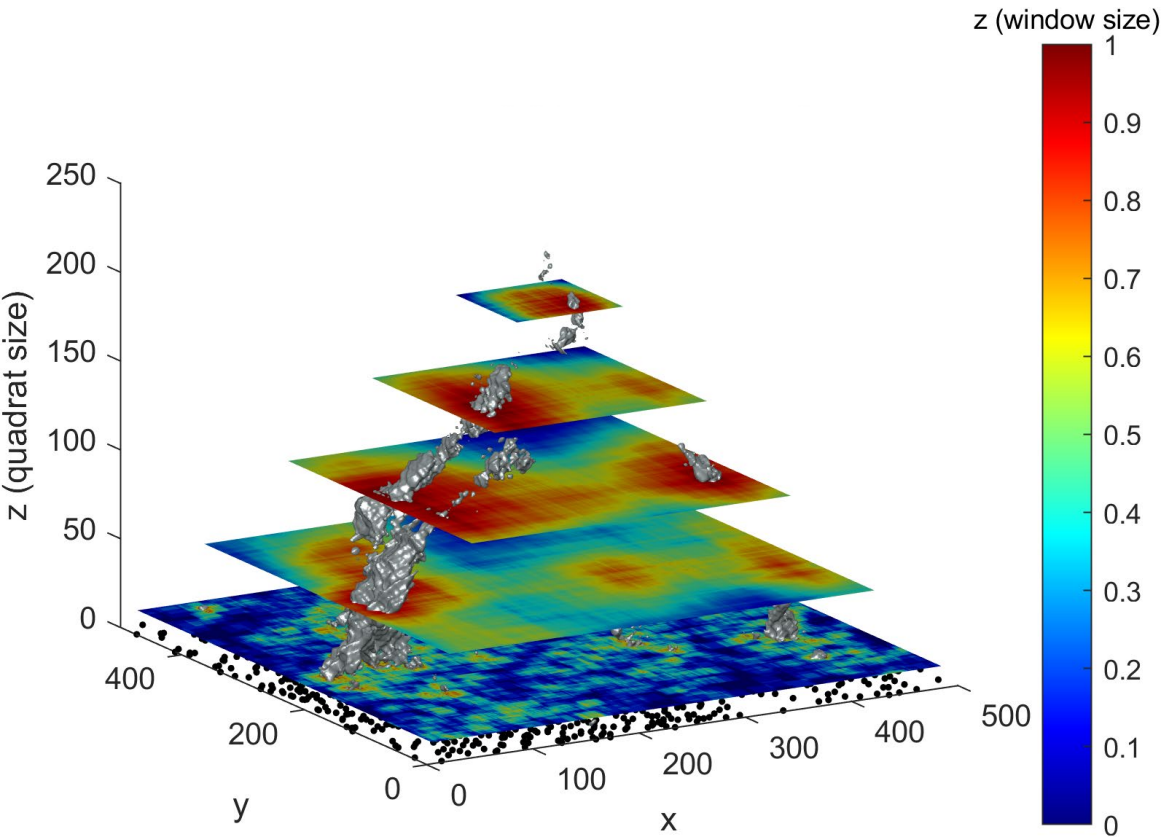


Global density peaks at different scales

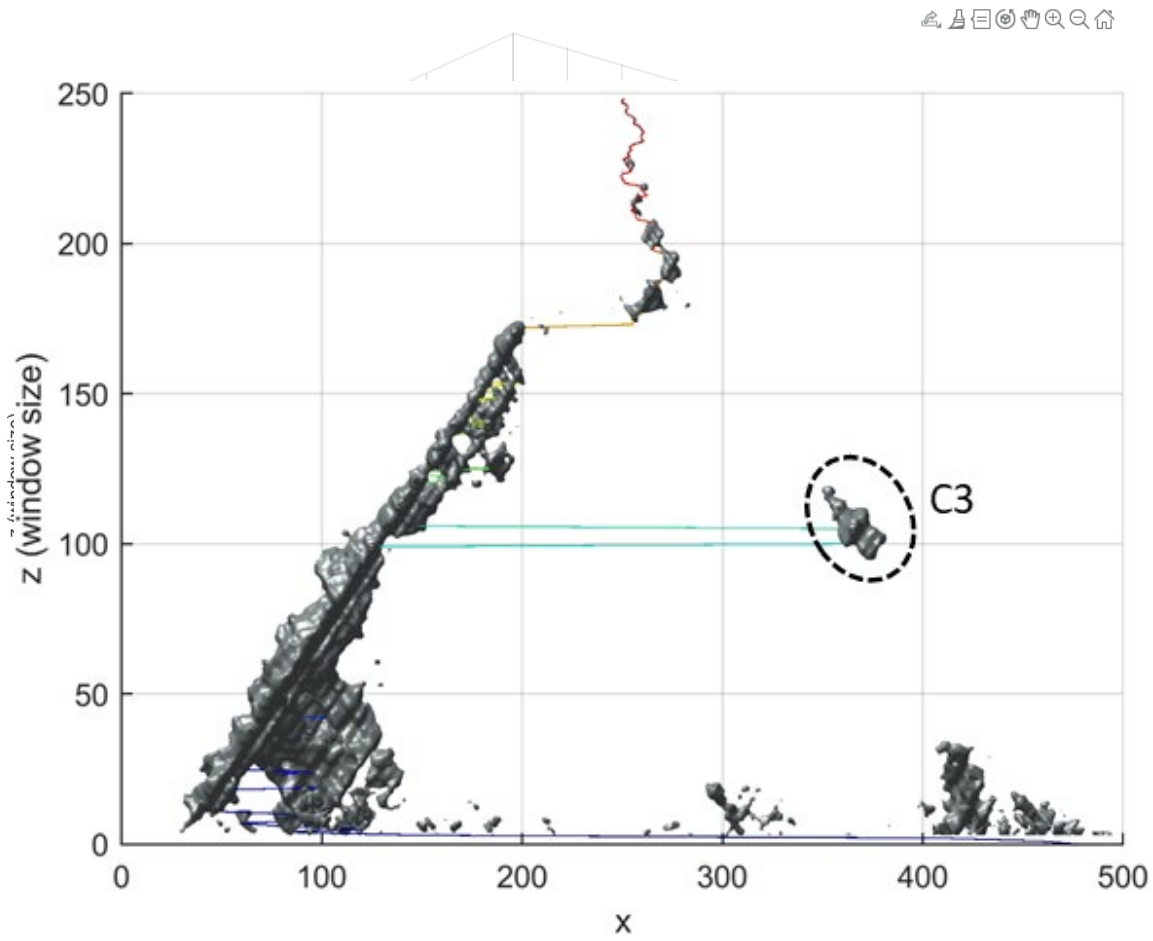


Global density peaks viewed from different angles

Isosurface of Quadrat Density

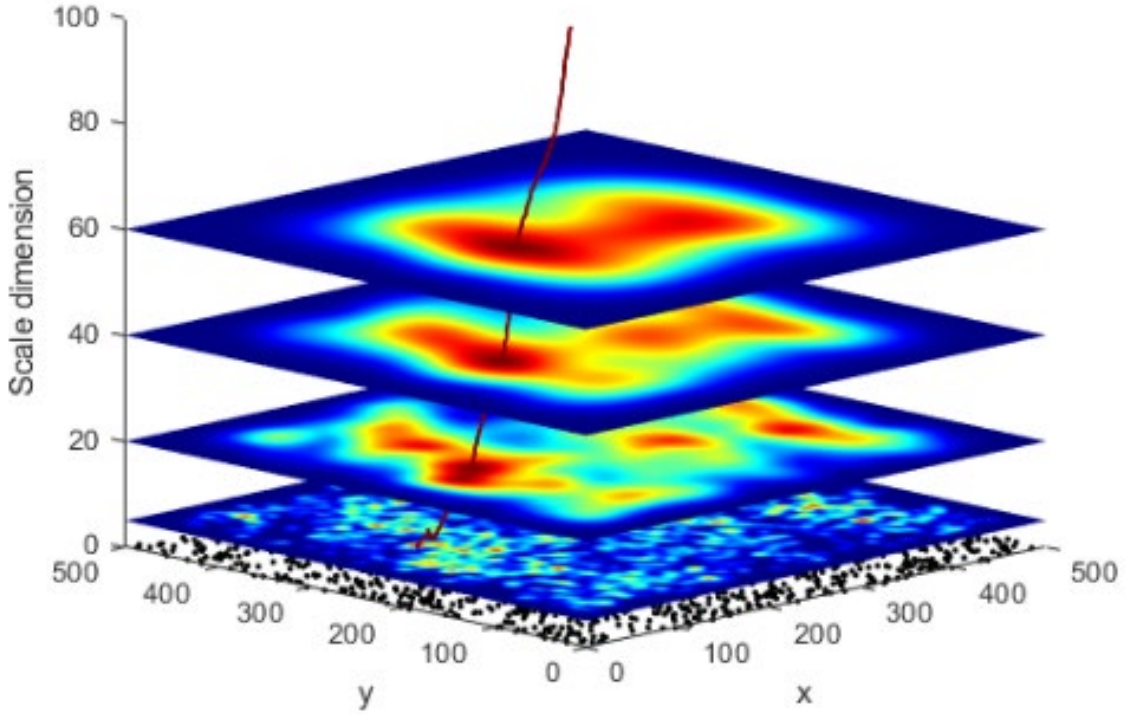


High density (99th percentile) voxels across scales

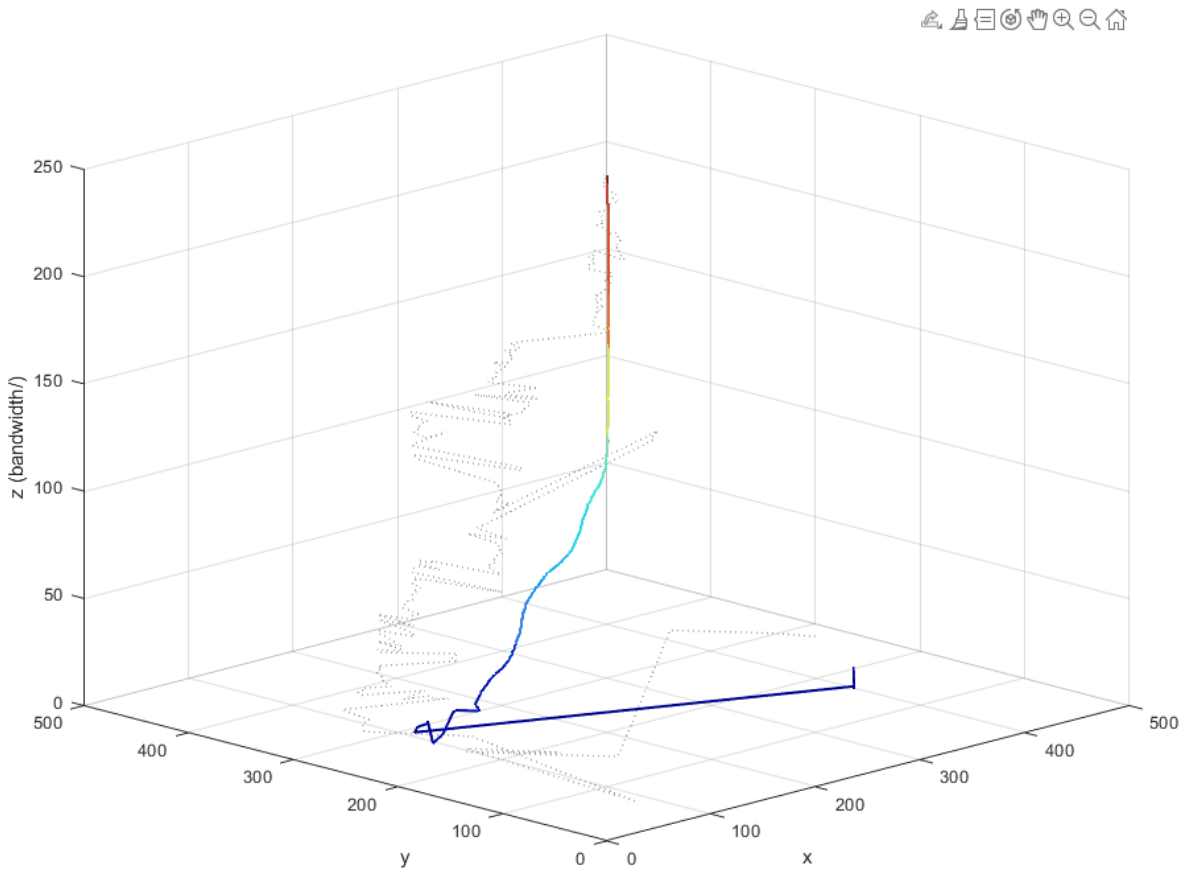


Voxels of density at the 99th percentile

Global Peaks and Isosurface of Kernel Density

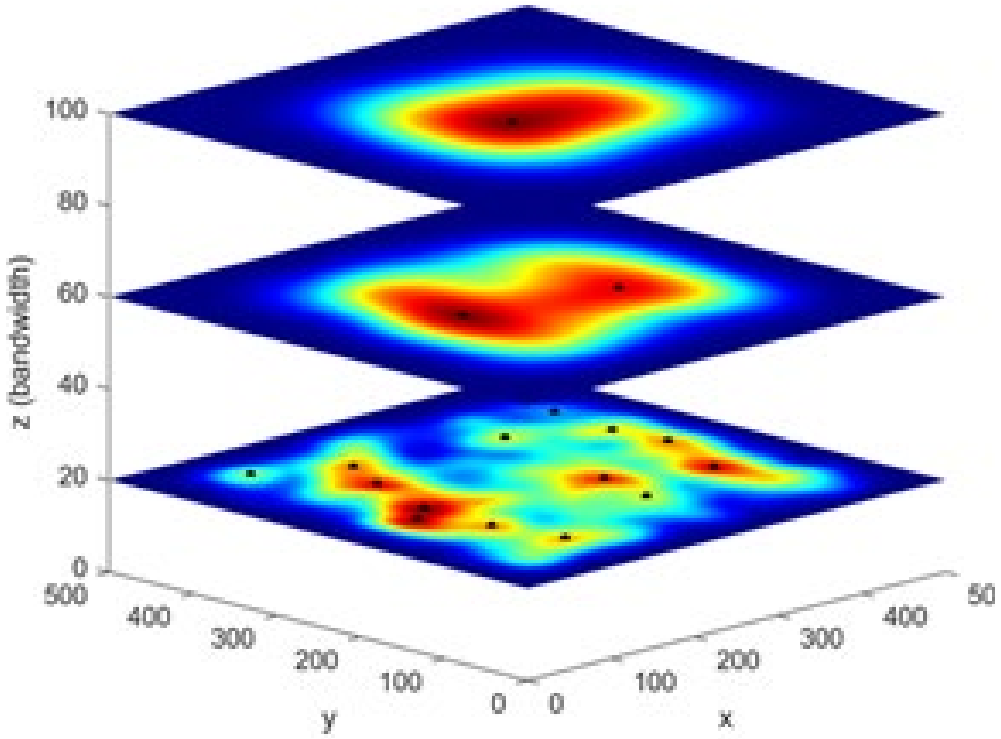


Linking global peaks of kernel density at different scales

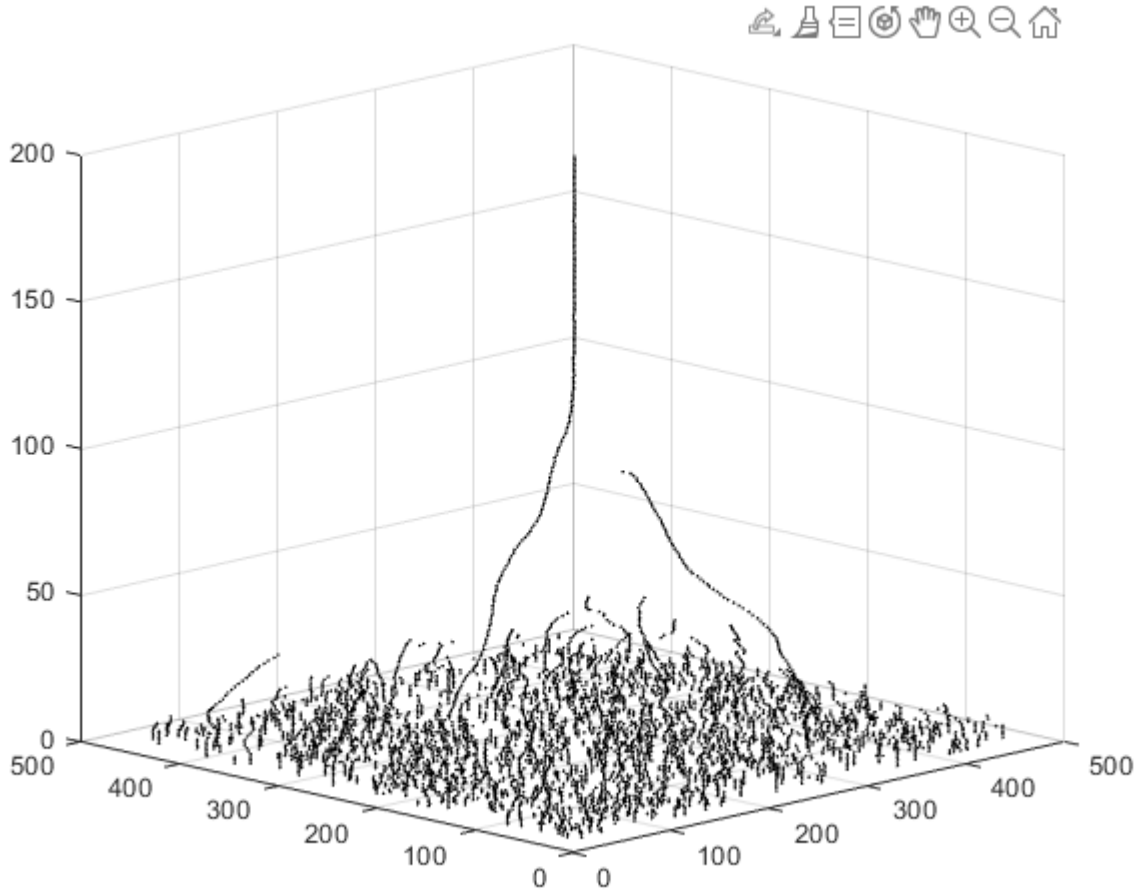


Global density peaks viewed from different angles

Local Peaks

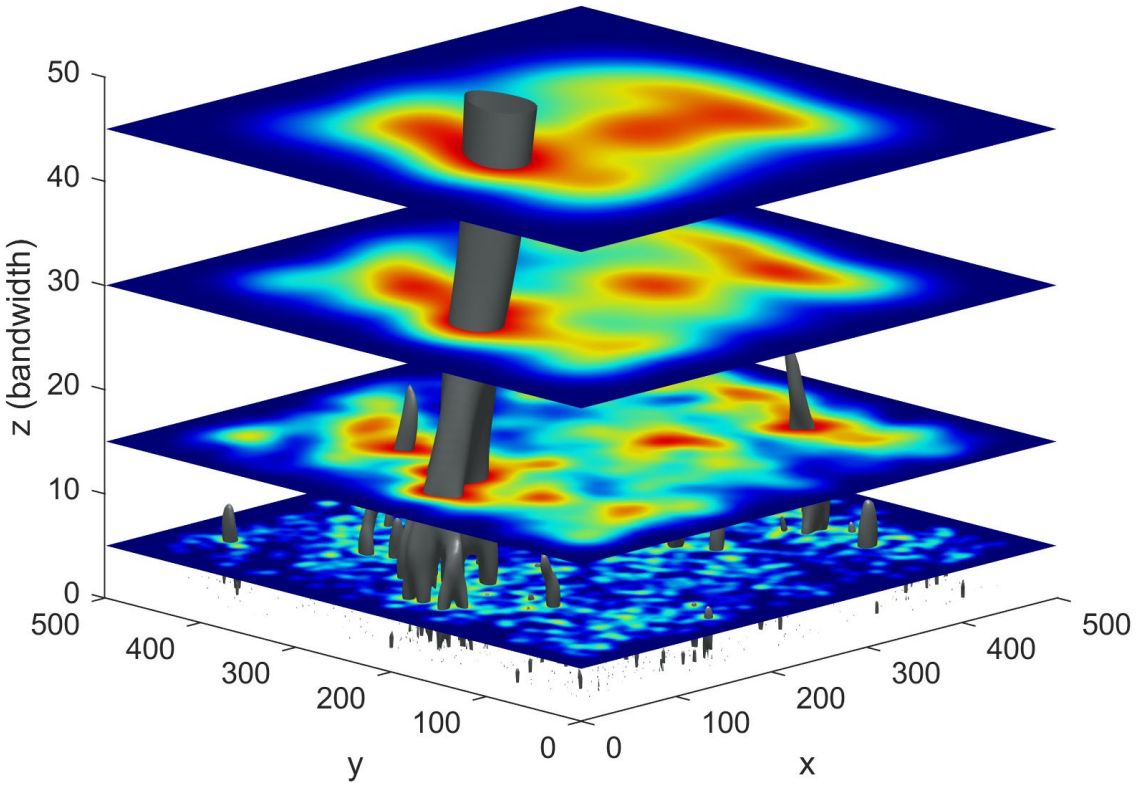


Local peaks detected at different scales

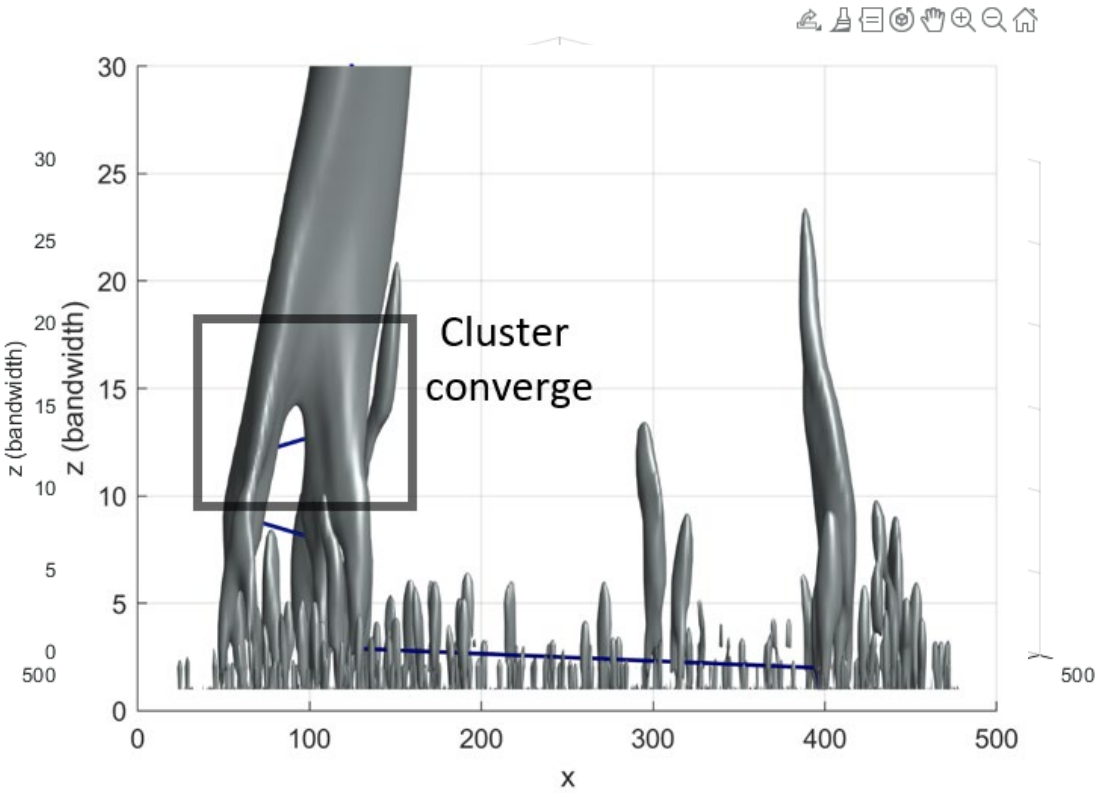


Local density peaks viewed from different angles

Isosurface of Kernel Density



High density (99th percentile) voxels across scales

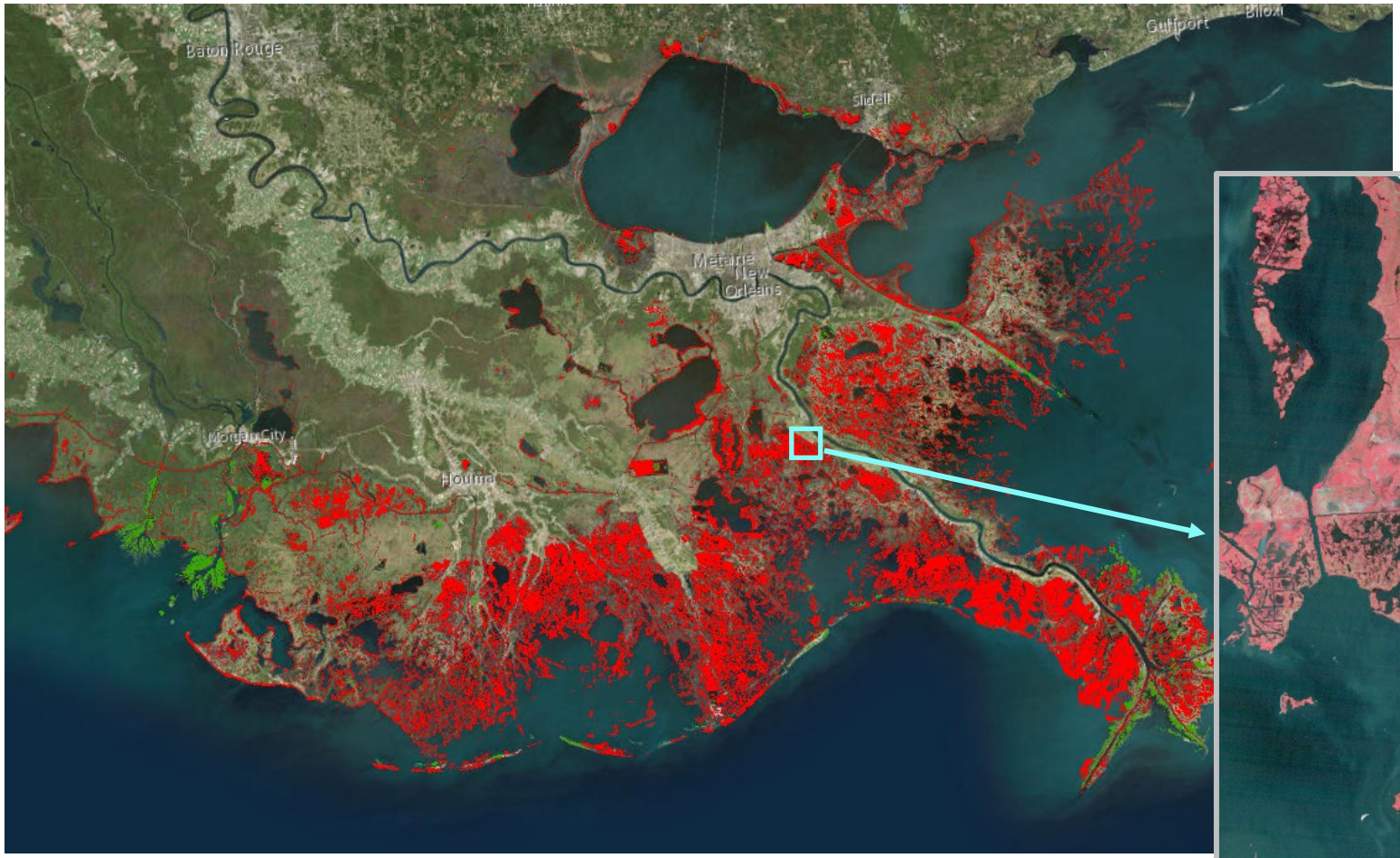


(d) Azimuth: 0° Altitude: 0°

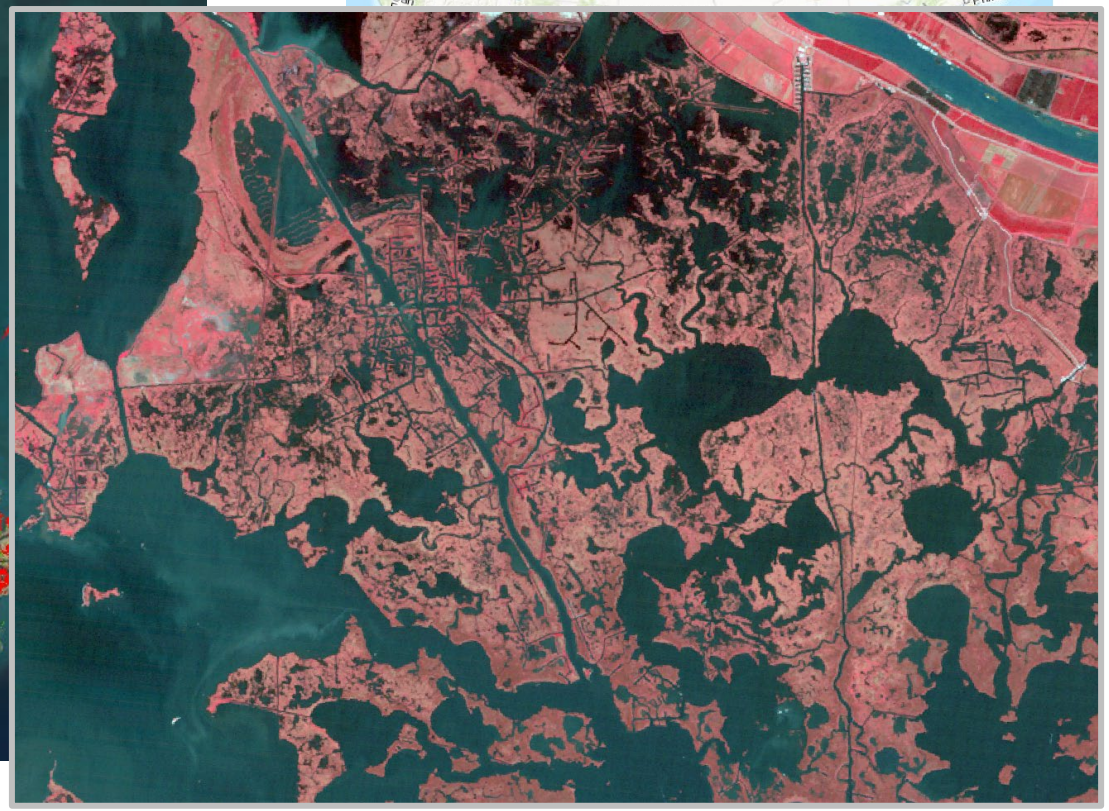
Voxels of density at the 99th percentile

Land Cover Change Analysis

Land cover change detection and modeling are scale-dependent

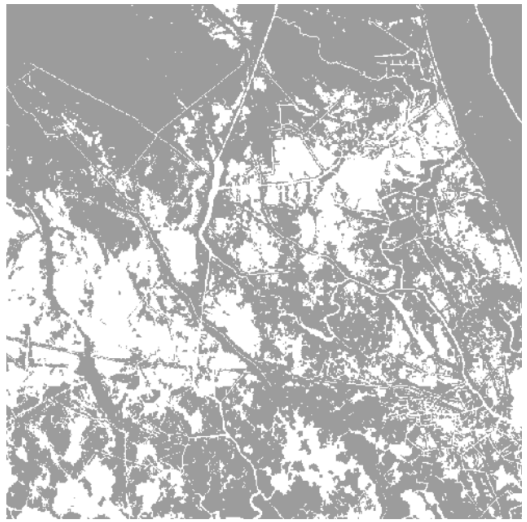


Land loss and gain from 1930 – 2010 in Mississippi Delta



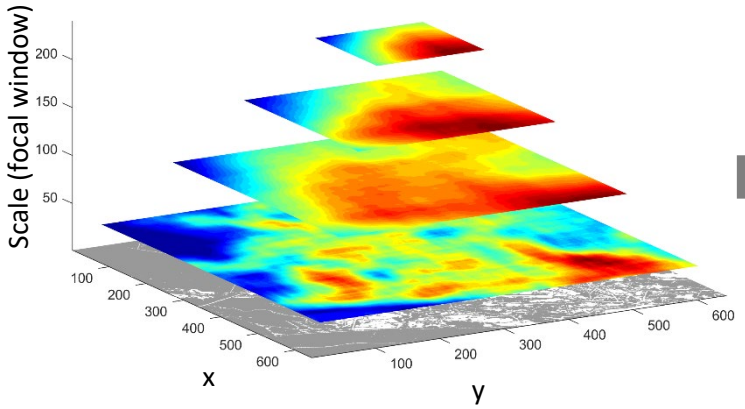
Wetland fragmentation is a driving factor of land loss

Multi-Scale Modeling of Land Loss



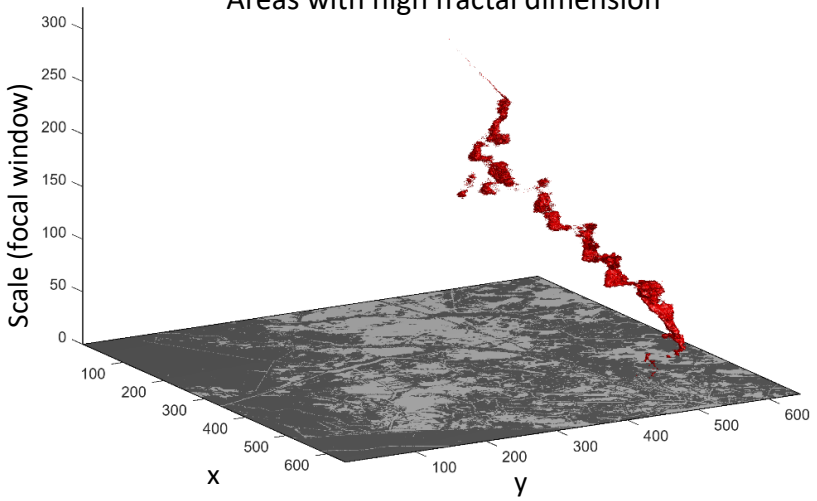
Land
Water

Land cover 2001

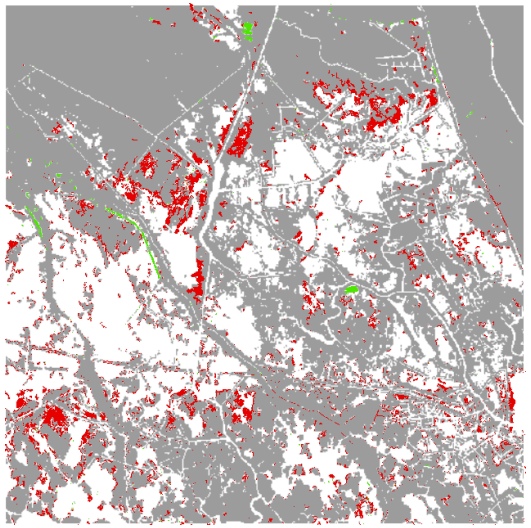


Multi-scale fractal dimensions in PM

Areas with high fractal dimension

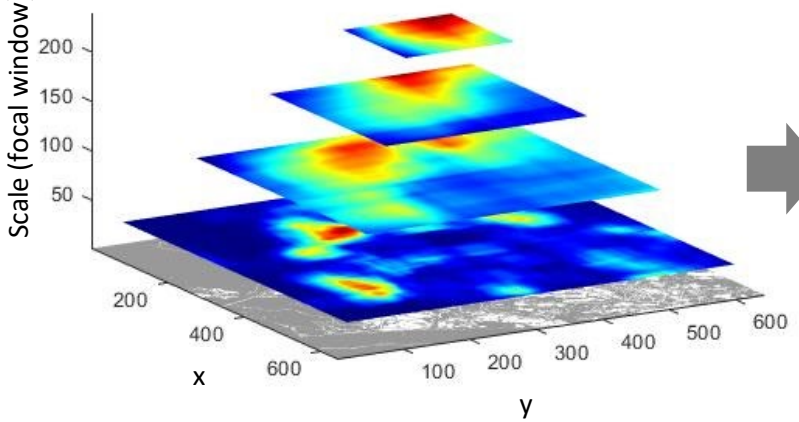


Visual analytics



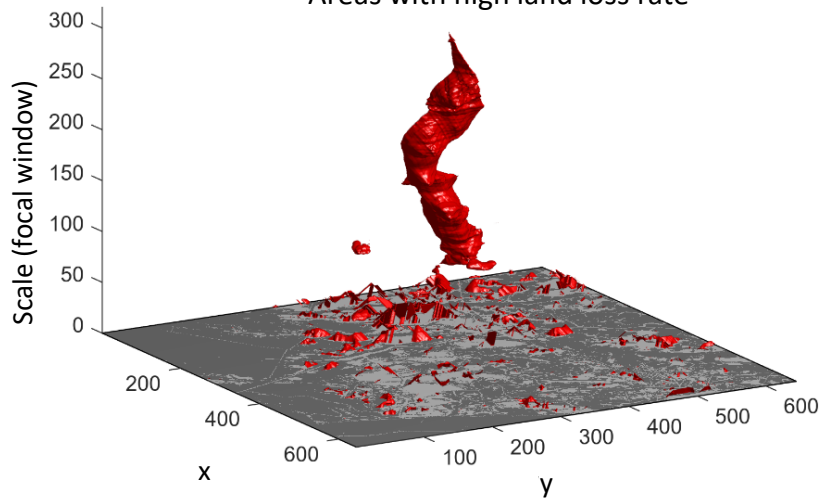
Land
Water
Land loss

Land loss 2001 - 2016



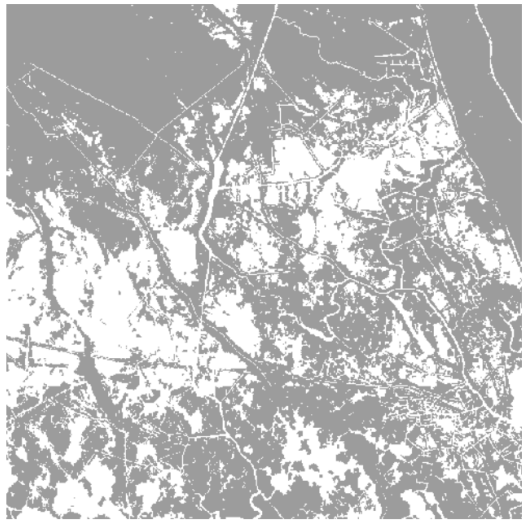
Multi-scale land loss ratio in PM

Areas with high land loss rate

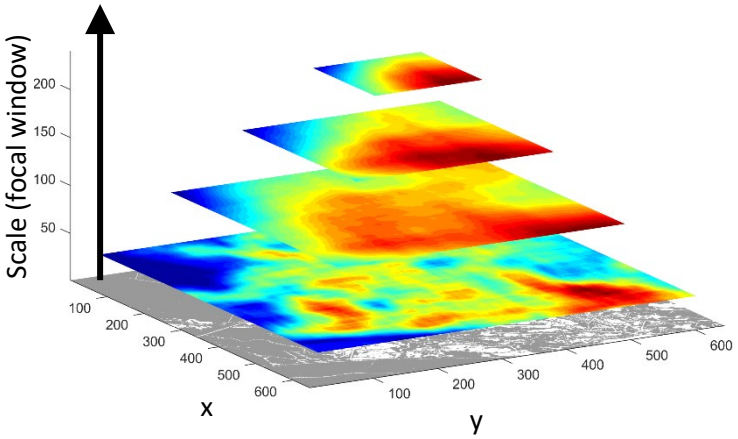


Visual analytics

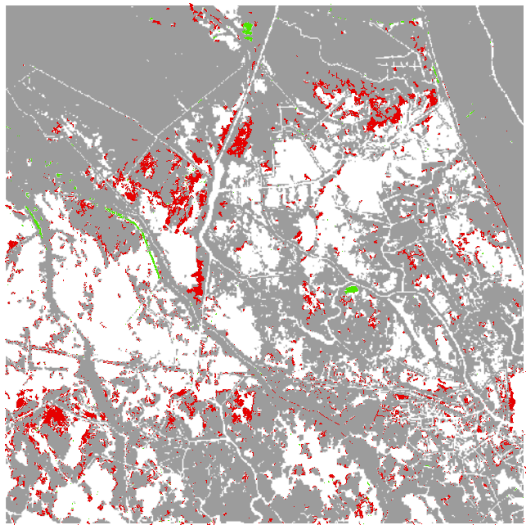
Multi-Scale Modeling of Land Loss



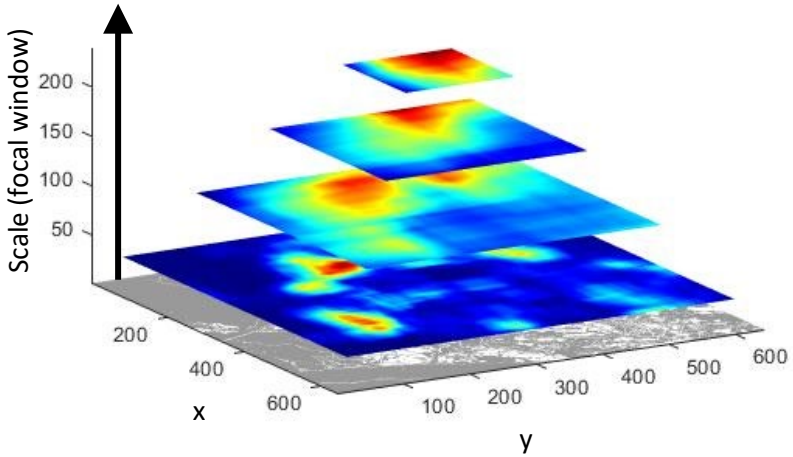
Land cover 2001



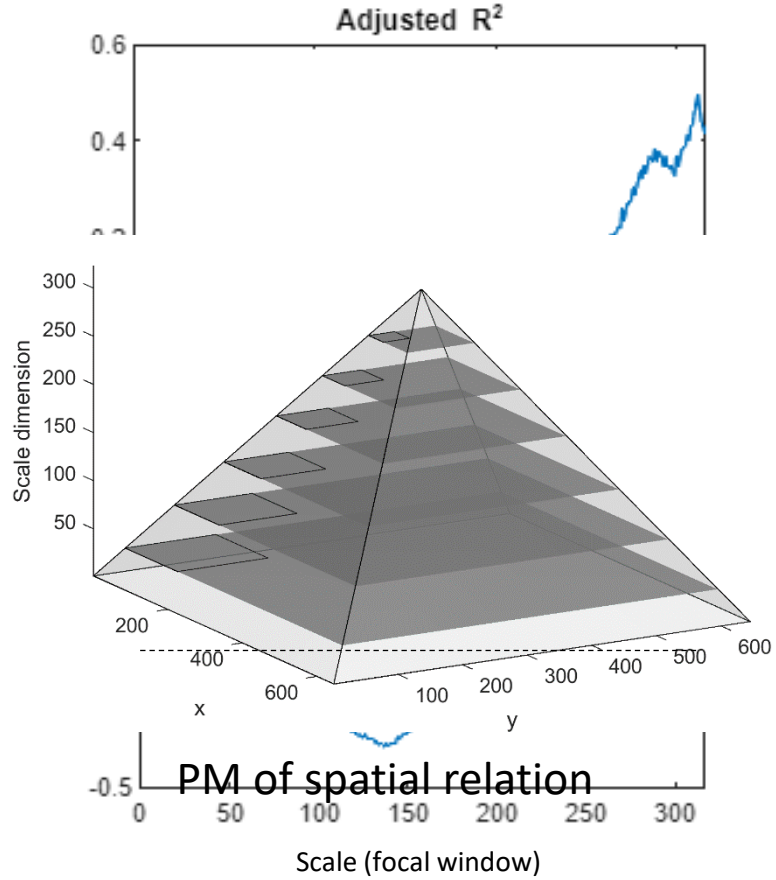
Multi-scale fractal dimensions in PM



Land loss 2001 - 2016



Multi-scale land loss ratio in PM



PM of spatial relation

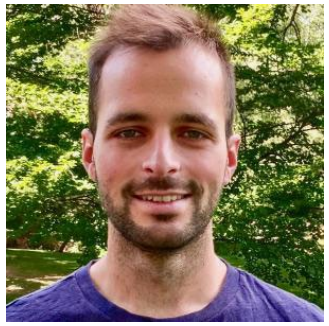
CroScalar: A Multi-Institution Collaboration

Yi Qiang, Assistant Professor
University of South Florida

Barbara (babs) Buttenfield, Emeritus Professor
University of Colorado - Boulder

Nodari Sitchinava,
Associate Professor
University of Hawaii - Manoa

Jinwen Xu (PhD candidate)
University of South Florida



Georgios (George) Charisoulis
(PhD candidate)
University of Colorado - Boulder

Kate Carlson
(MA, graduated in 2021)
University of Colorado - Boulder

Katie Tyler
(MA, graduated in 2022)
University of Colorado – Boulder

Thank you!

Reference

Y. Qiang, B. Buttenfield, and J. Xu, “Analyzing multi-scale spatial point patterns in a pyramid modeling framework,” *Cartography and Geographic Information Science*, pp. 1–14, Apr. 2022, doi: 10.1080/15230406.2022.2048419.

Y. Qiang, B. P. Buttenfield, and M. B. Joseph, “How to Measure Distance on a Digital Terrain Surface and Why it Matters in Geographical Analysis,” *Geographical Analysis*, vol. 53, no. 3, pp. 588–622, 2021, doi: 10.1111/gean.12255.

Qiang, Y. and Van de Weghe, N. (2019) “Re-Arranging Space, Time and Scales in GIS: Alternative Models for Multi-Scale Spatio-Temporal Modeling and Analyses”, *ISPRS International Journal of Geo-Information*. vol: 8(2). DOI:10.3390/ijgi8020072

Funding Source

This article is based on work supported by the NSF Methodology, Measurement & Statistics (MMS) Program (Award No. 1853866).

Website: https://croscalar.github.io