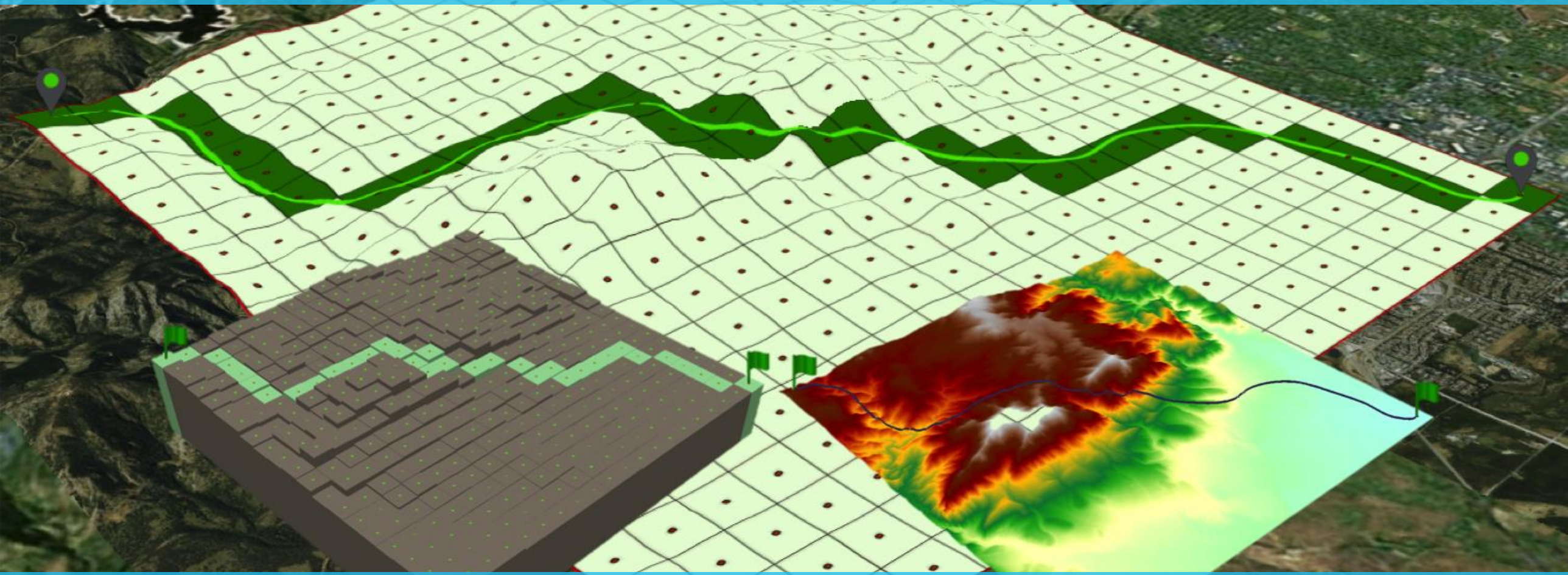
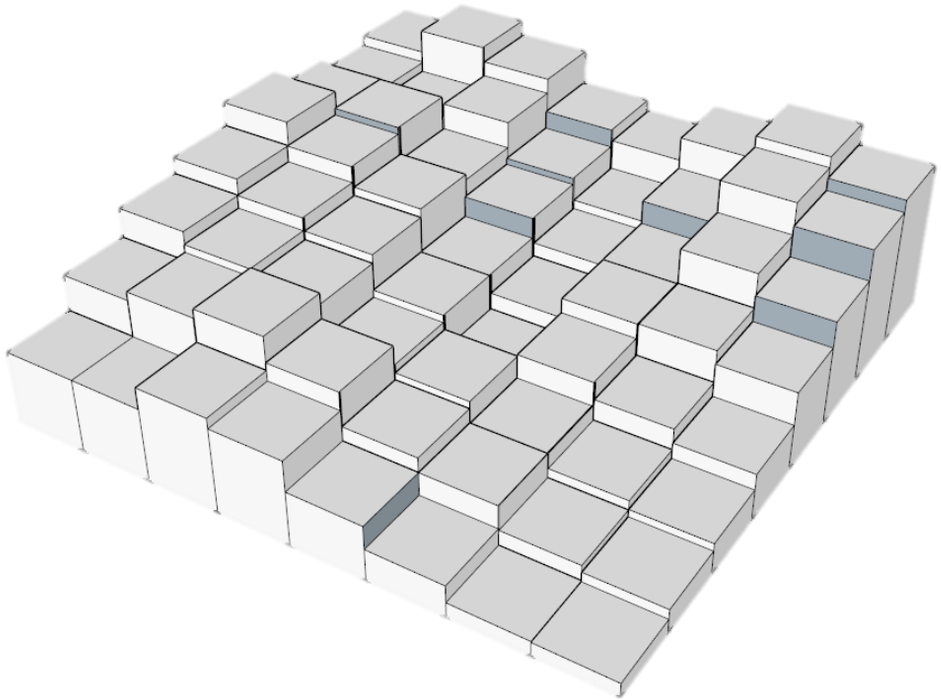
July 7th, 2017

Cross-Scale Analysis of Sub-Pixel Variations in Digital Elevation Models

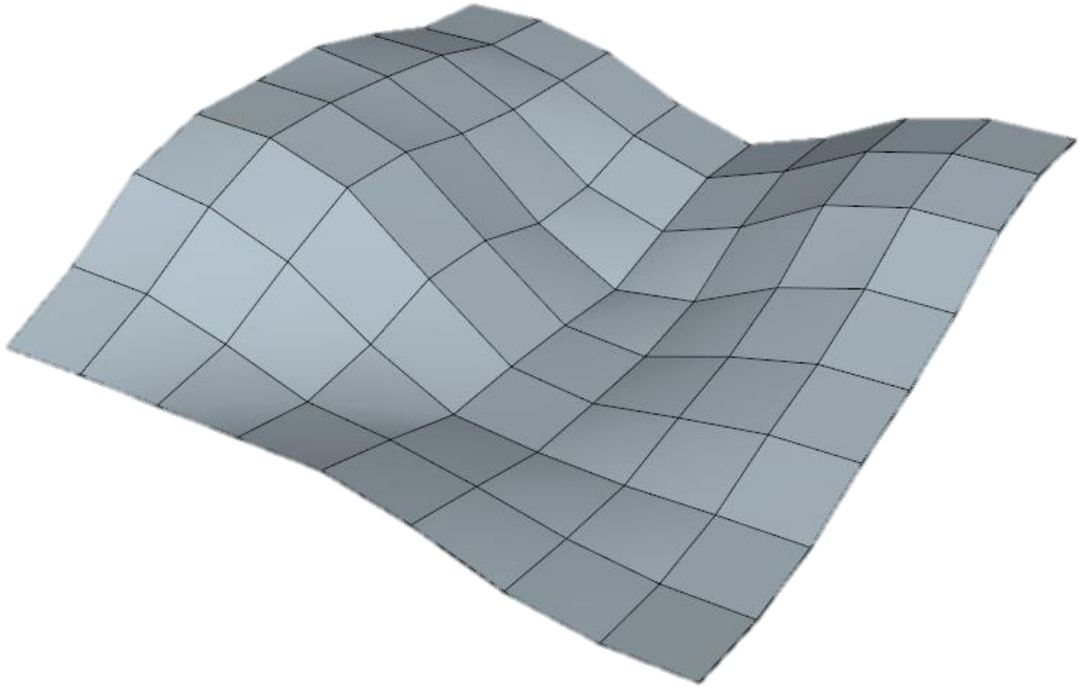


Mehran Ghandehari, Barbara P. Buttenfield, and Carson J. Q. Farmer
Department of Geography, University of Colorado, Boulder
{mehran.ghandehari; babs; carson.farmer} @colorado.edu

Introduction

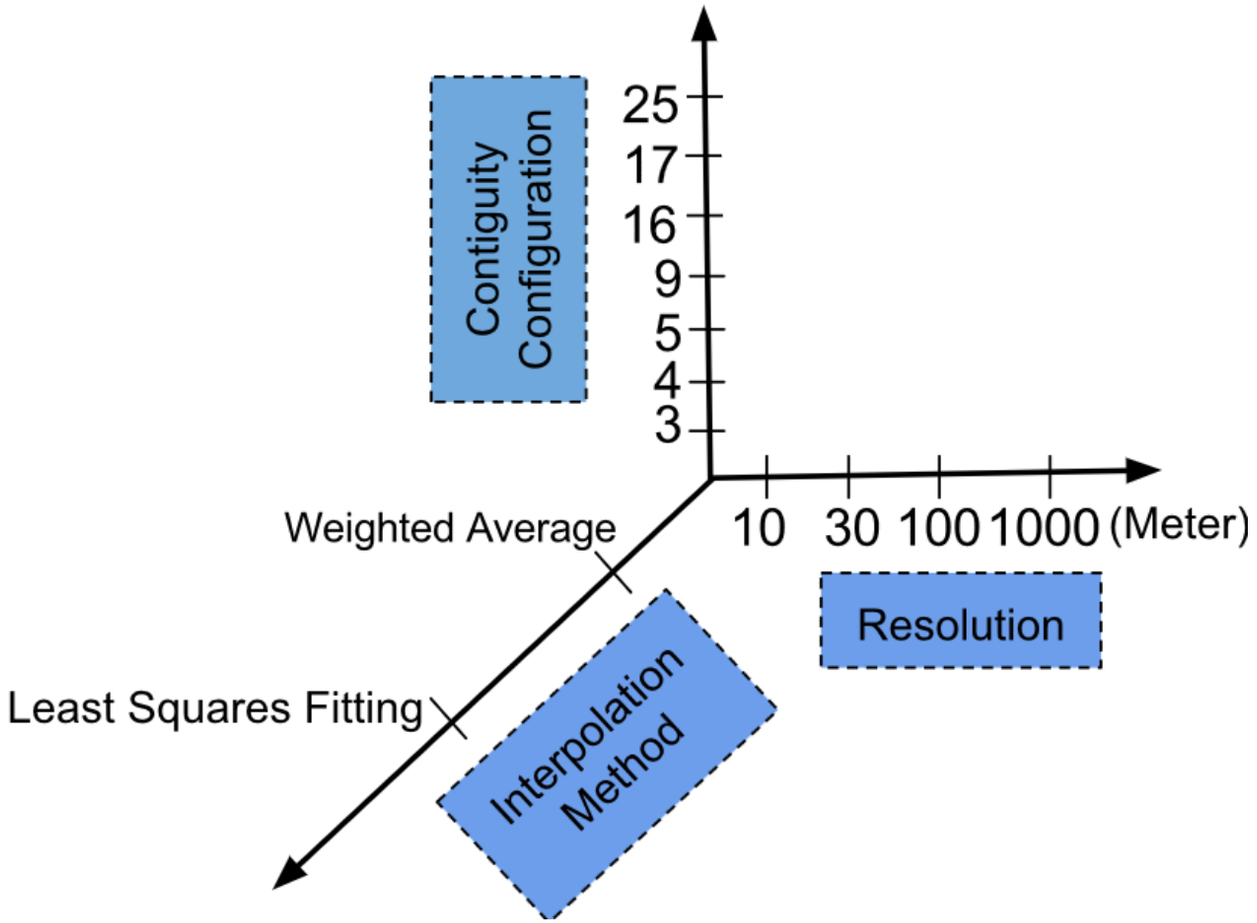


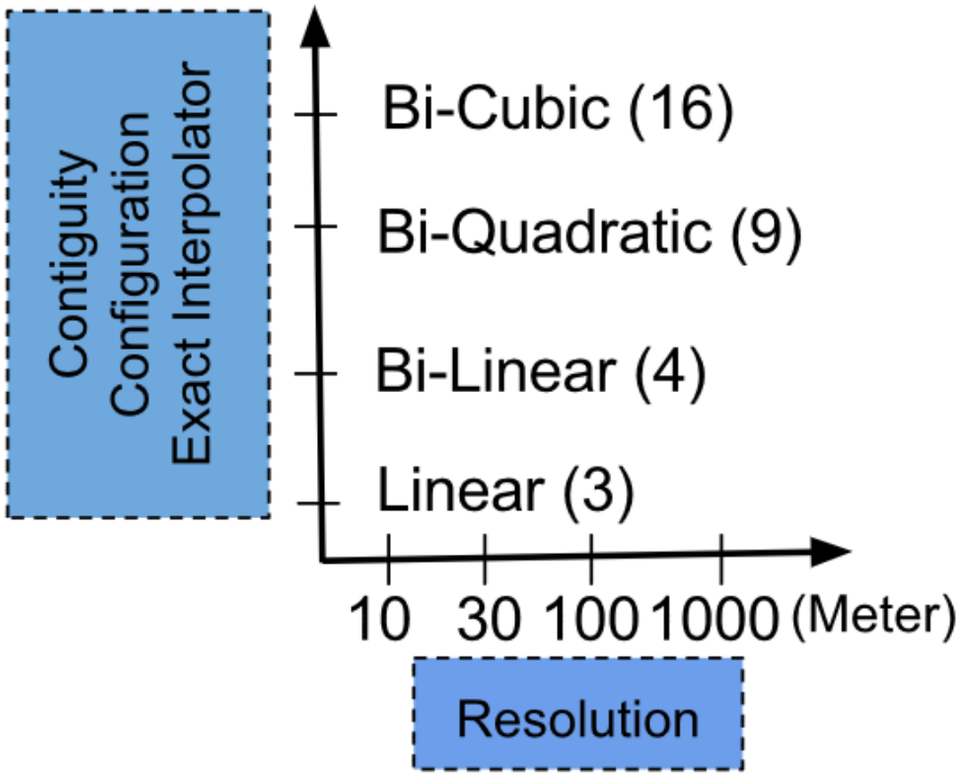
Rigid pixel paradigm



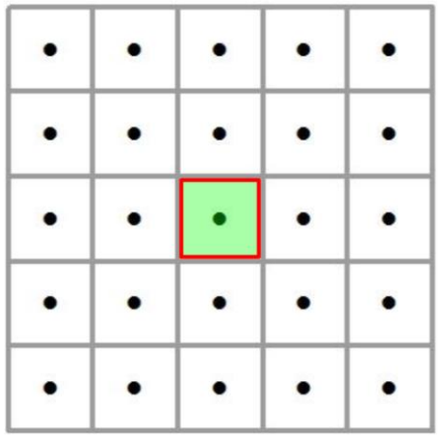
Surface-adjusted paradigm

Methods

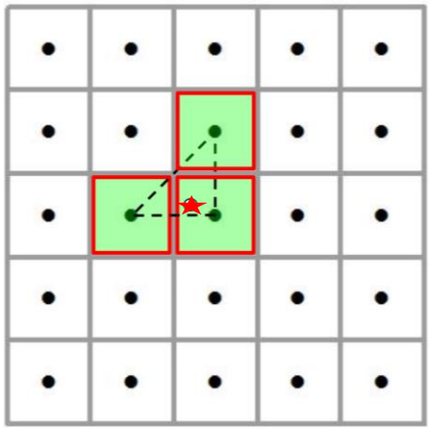

Contiguity Configuration
25
17
16
9
5
4
3
10 30 100 1000 (Meter)
Resolution
Weighted Average
Least Squares Fitting
Interpolation Method


Contiguity Configuration Exact Interpolator
Bi-Cubic (16)
Bi-Quadratic (9)
Bi-Linear (4)
Linear (3)
10 30 100 1000 (Meter)
Resolution

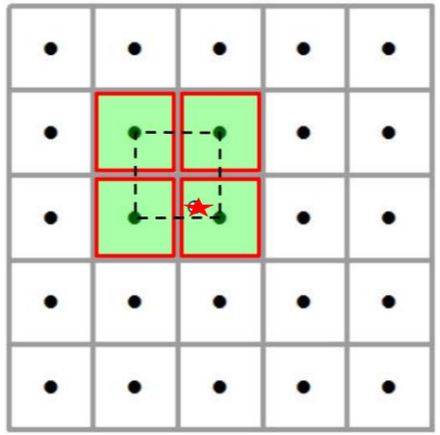
Methods: Contiguity Configurations



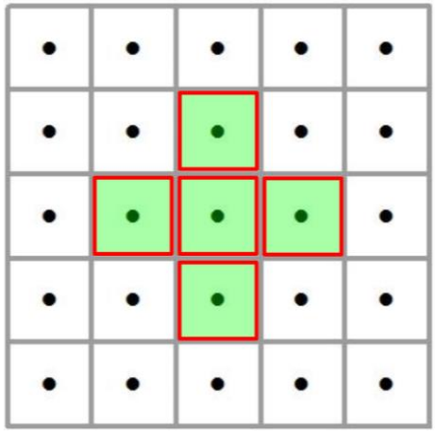
(a) Nearest Neighbor (1)



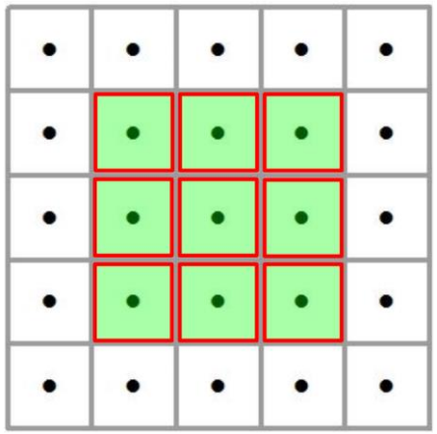
(b) Linear (3)



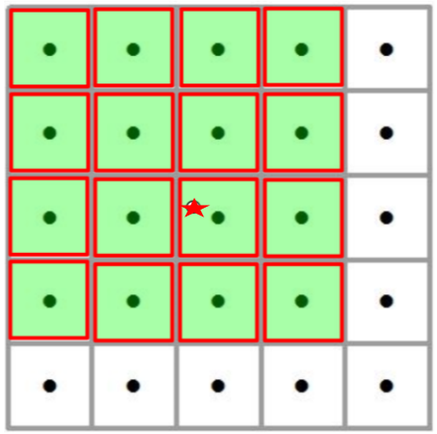
(c) Bi-Linear (4)



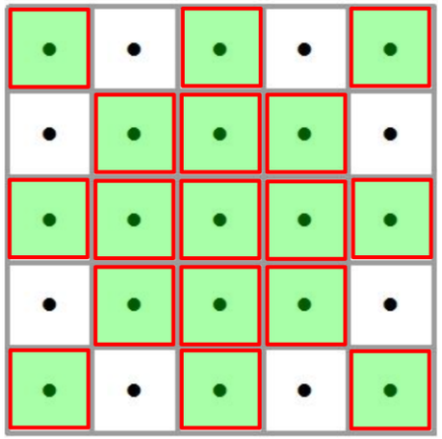
(d) 5



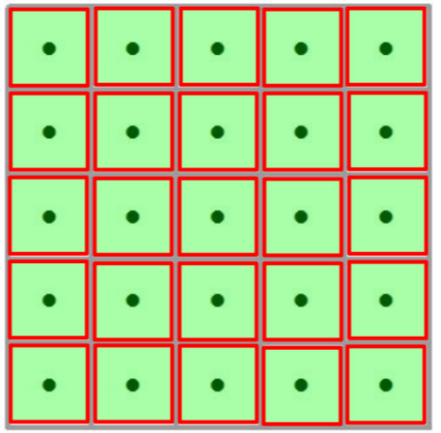
(e) Bi-Quadratic (9)



(f) Bi-Cubic (16)

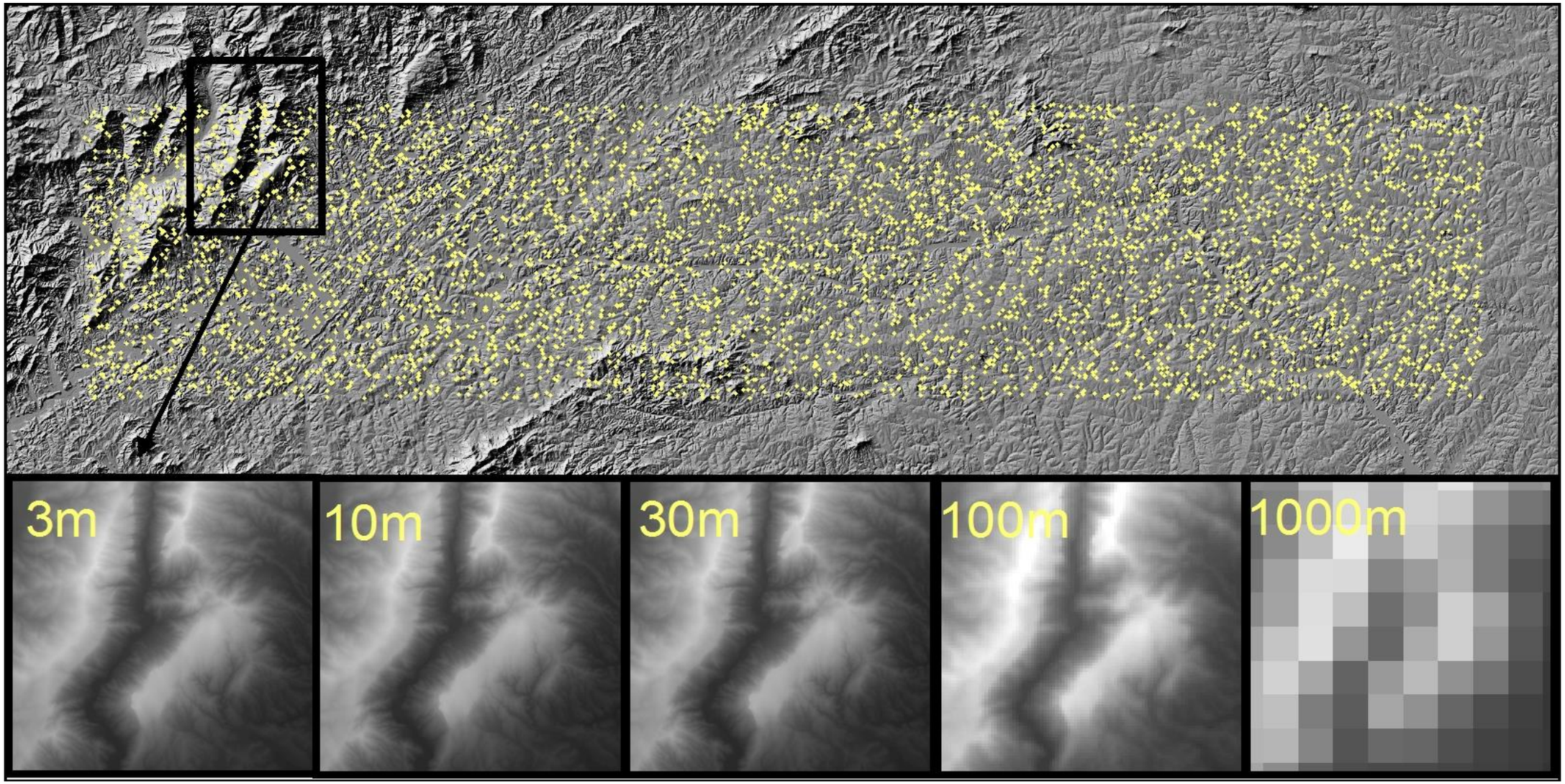


(g) 17



(h) 25

Methods: Data Sets and Study Areas



Methods: Workflow and Processing

01 Load 4 Input DEMs (DEM10, DEM30, DEM100, DEM1000)

02 Load benchmark (DEM3)

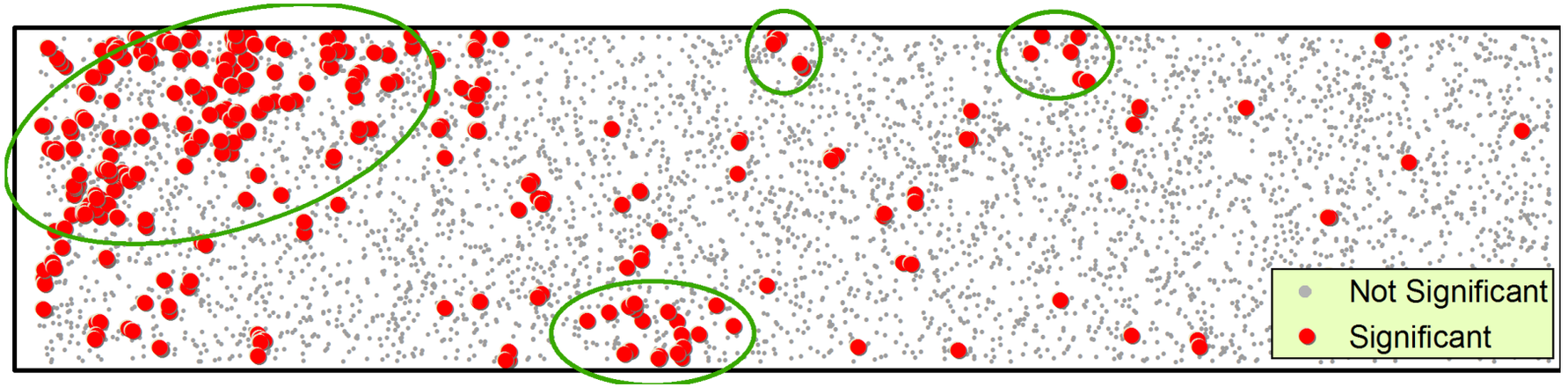
03 Generate sample of 20,000 random points in the study area

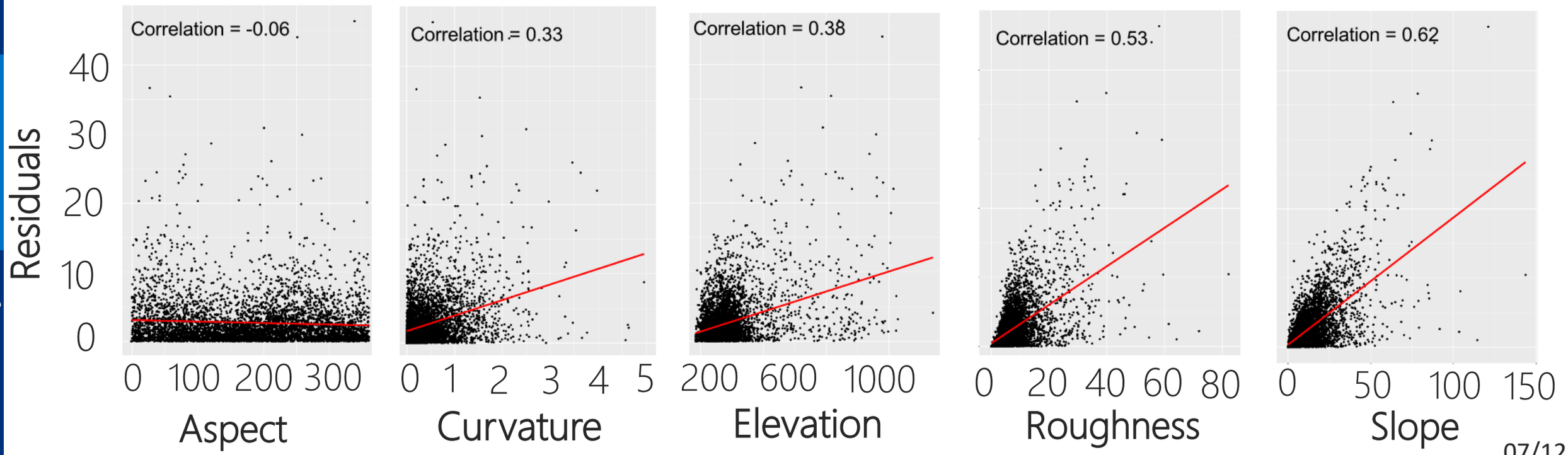
04

For i in 20,000 random points:
For j in 4 Input DEMs:
For k in 6 interpolation methods:
- Interpolate the elevation of point i based on the DEM resolution j using interpolation method k ($Elev_{ijk}$)
- Compute $Residual_{ijk} = Elev_{ijk} - Elev_i$ of benchmark

05 Accuracy Assessment (RMSE, Standard Deviation, etc.)

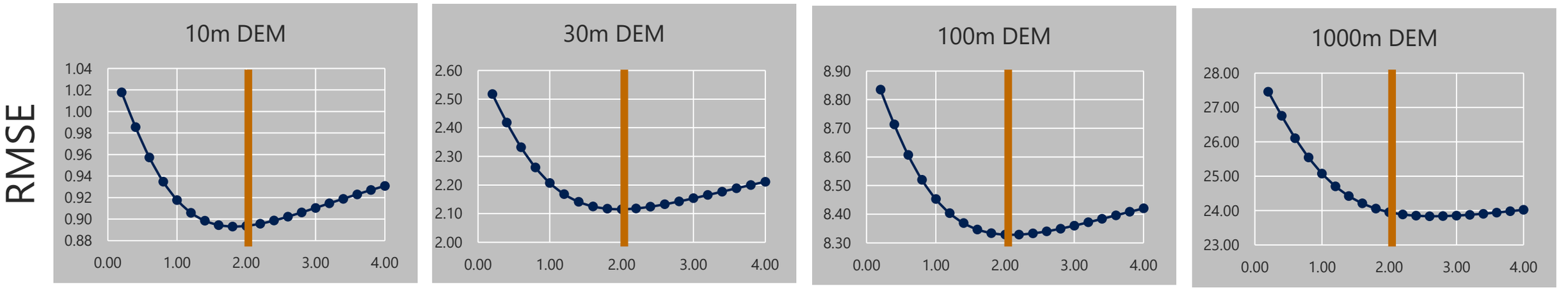
Results: Analysis of Residuals





Optimal Configuration for Weighted Average Interpolator (RMSE values)

Contiguity Configuration	10m	30m	100m	1000m
WA3	0.90	2.14	8.36	23.86
WA4	0.89	2.12	8.33	23.96
WA5	0.92	2.22	8.50	24.94
WA9	0.91	2.20	8.52	25.63
WA16	0.90	2.21	8.58	26.63
WA17	0.91	2.24	8.62	26.64
WA25	0.93	2.31	8.75	27.69



Optimal Configuration for Least Squares Fitting (RMSE values)

Polynomial order	Contiguity Configuration	10m	30m	100m	1000m
1	4	0.88	2.10	8.34	24.08
	5	0.88	2.17	8.51	26.48
	9	0.90	2.33	8.83	29.84
	16	0.97	2.74	9.51	34.70
	25	1.09	3.26	10.25	38.48
2	9	0.89	2.22	8.60	25.65
	16	0.92	2.48	10.13	29.10
	17	0.93	2.52	9.67	30.82
	25	0.99	2.81	10.28	32.65
3	9	0.89	2.22	8.71	26.00
	16	0.92	2.46	8.97	28.17
	17	0.93	2.50	9.06	29.77
	25	0.99	2.79	9.49	31.88
4	16	0.92	2.46	8.97	27.54
	17	0.93	2.50	9.06	29.46
	25	0.99	2.79	9.49	30.41

Comparing Surface-Adjusted Methods (RMSE Values)

	Li3	BiLi4	LSqF4	WA4	BiQ9	BiC16
10m	0.88	0.88	0.88	0.89	0.90	0.97
30m	2.10	2.10	2.10	2.12	2.33	2.74
100m	8.34	8.34	8.34	8.33	8.83	9.51
1000m	24.03	24.08	24.08	23.96	29.85	34.72

	WA4	Li3	BiLi4	LSqF4	BiQ9	BiC16
Run time for 20,000 sample points (seconds)	2.48	6.79	7.35	7.44	9.12	16.52

Summary

Cross-scale analysis of elevation estimates across resolutions shows varying amounts of error and processing speed.

- Error magnitudes vary with DEM resolution and interpolation method
- General increase in the residuals at coarser resolutions
- RMSE values are very close for 10m DEM: hard to distinguish optimal value for any single method
- Bi-Cubic: highest magnitude errors
- Weighted Average, Linear, Bi-Linear, and Best Fit: lowest RMSE
- Weighted Average shows nearly lowest or lowest RMSE and fastest computations

Ongoing and Future Work

- Other terrain types (Flat, Hilly, Mountainous, Uniform, Non-Uniform)
- Other metrics (Distance, Area, Volume) adjusting for (Slope, Curvature)
- Modeling applications (Flow Accumulation, Flood inundation, Debris Flows, Earthquakes, etc.)