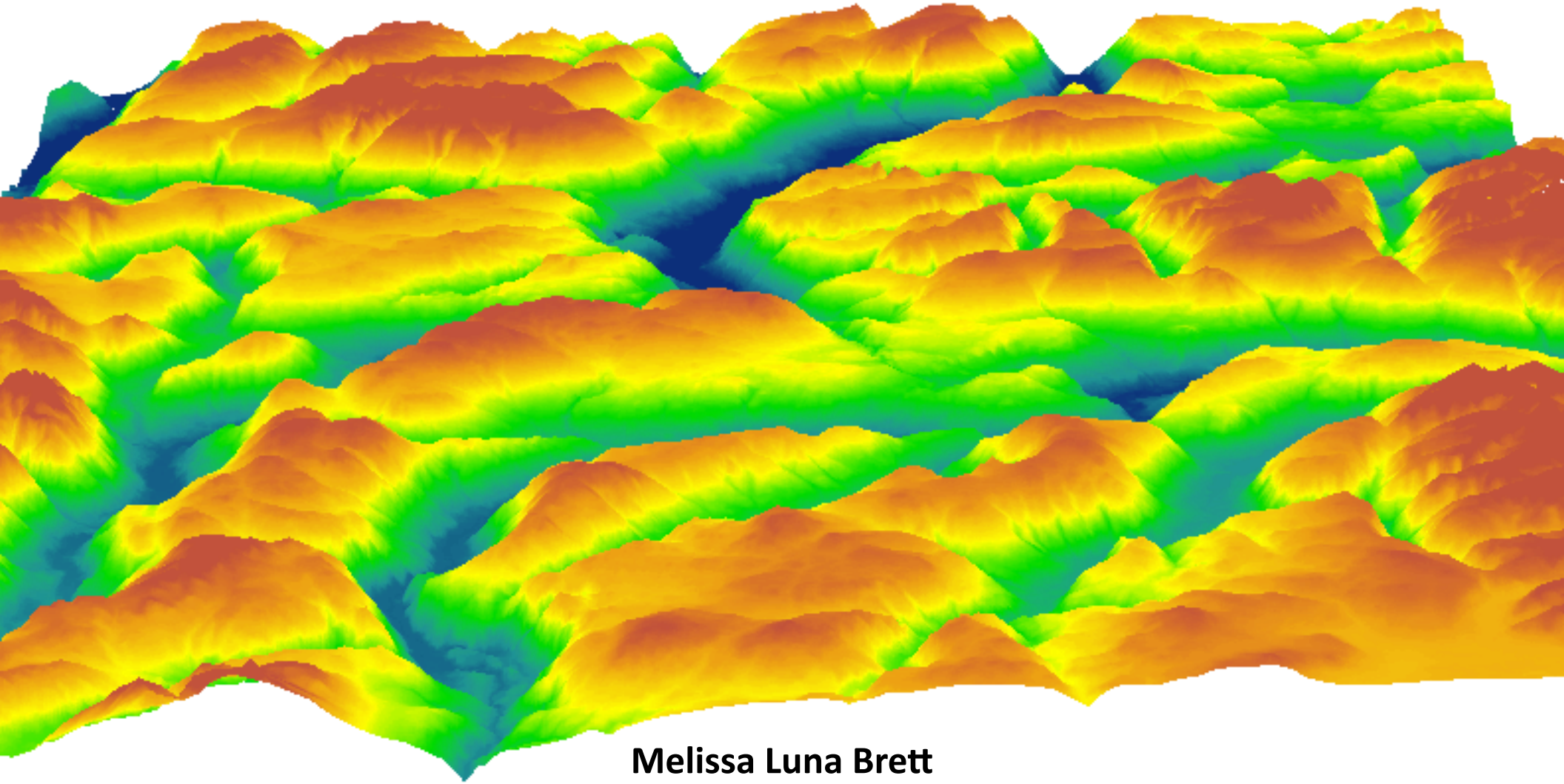
Melissa Luna Brett

Digital Terrain Analysis

Term Project Abstract

Much of the evidence for glacier change in Glacier National Park exists in the qualitative and visual analysis of temporal photographs, taken at or near the same location over two or more time periods. These images serve to show glacier change, and in fact are quite effective given the often dramatic results. This assessment method is important for the public at large and for the Parks Service outreach efforts, to raise awareness of the effects of climate change. However, these analyses are largely qualitative, and lack the numerical assessment necessary for scientific reporting. In order to make a quantitative evaluation of volume change, raster data was collected from the USGS National Elevation Dataset, LiDAR data was collected from Brian Menunous and others from University of Washington, and glacier margins were digitized for the time extent in question. The NED DEM was created from 1966 topographic maps and imagery, and the LiDAR was flown in 2015. This 49-year time interval was assessed for volume change and uncertainty. The 9m NED DEM was resampled and interpolated using cubic convolution, inverse distance weighted, spline, and kriging, in order to create several outcome rasters. These rasters were compared to the original raster in order to determine which method had the least amount of error. The preferred method was cubic convolution, and was used to create 5m, 3, and 1m DEMs. The LiDAR dataset was used to create a 1m, 3m, 5m, and 9m DEM for comparison. Uncertainty results showed that leaving the NED DEN at 9m resolution, and coarsening the LiDAR to 9m to match, was the preferred and most accurate method. These results indicated a volume change for Sperry Glacier of (-) 0.0291 ± 0.0028 km^3. The preferred method was then used for the remaining 8 glaciers with LiDAR coverage in the Park. These results gave a total volume change for the entire Park equal to (-) 0.1424 ± 0.022 km^3. These numbers will soon be compared to studies done by David Shean, Brian Menunous and other from the University of Washington and the USGS.

Experimenting with Interpolation Methods for Volume Change Analysis



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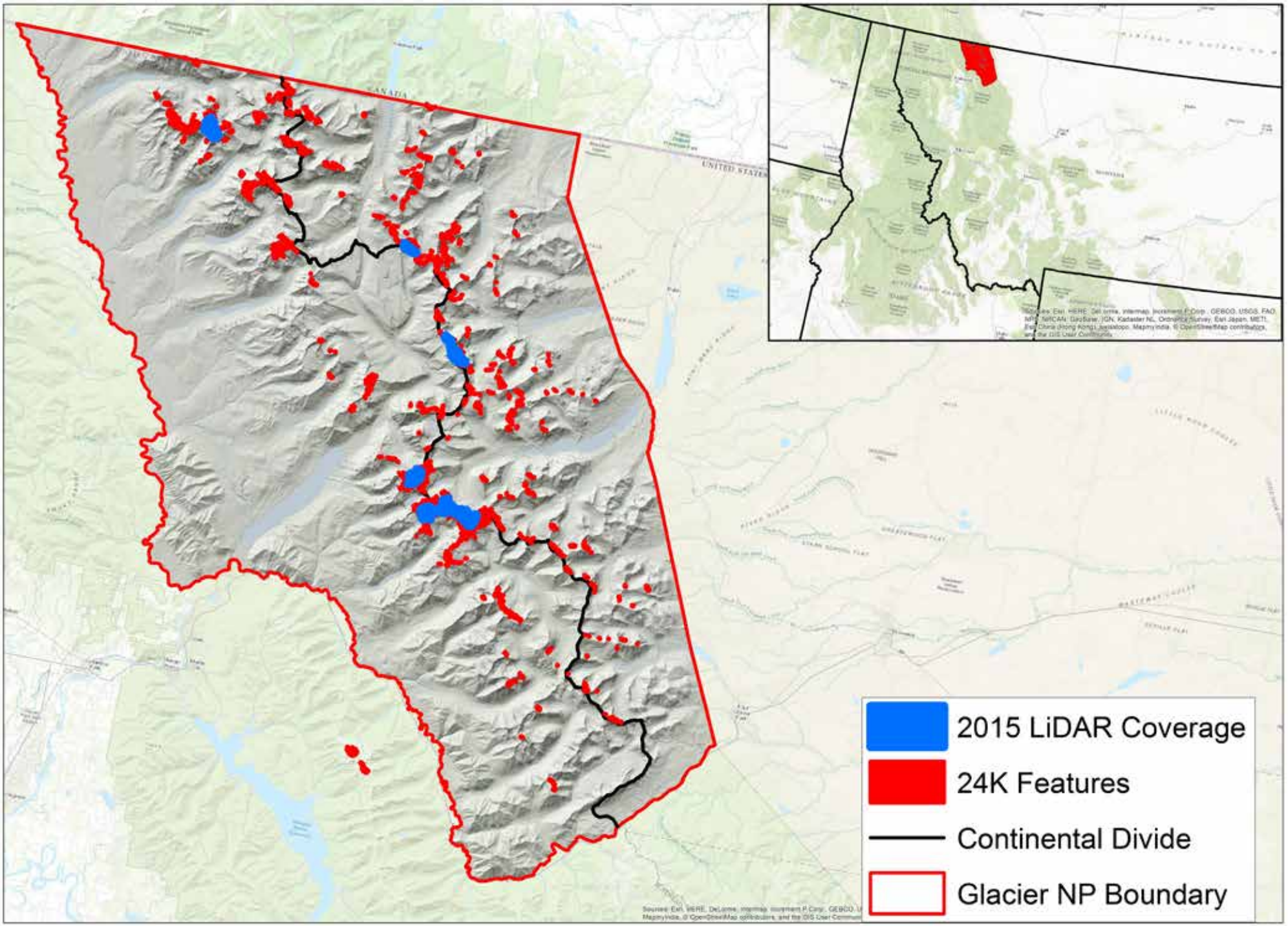
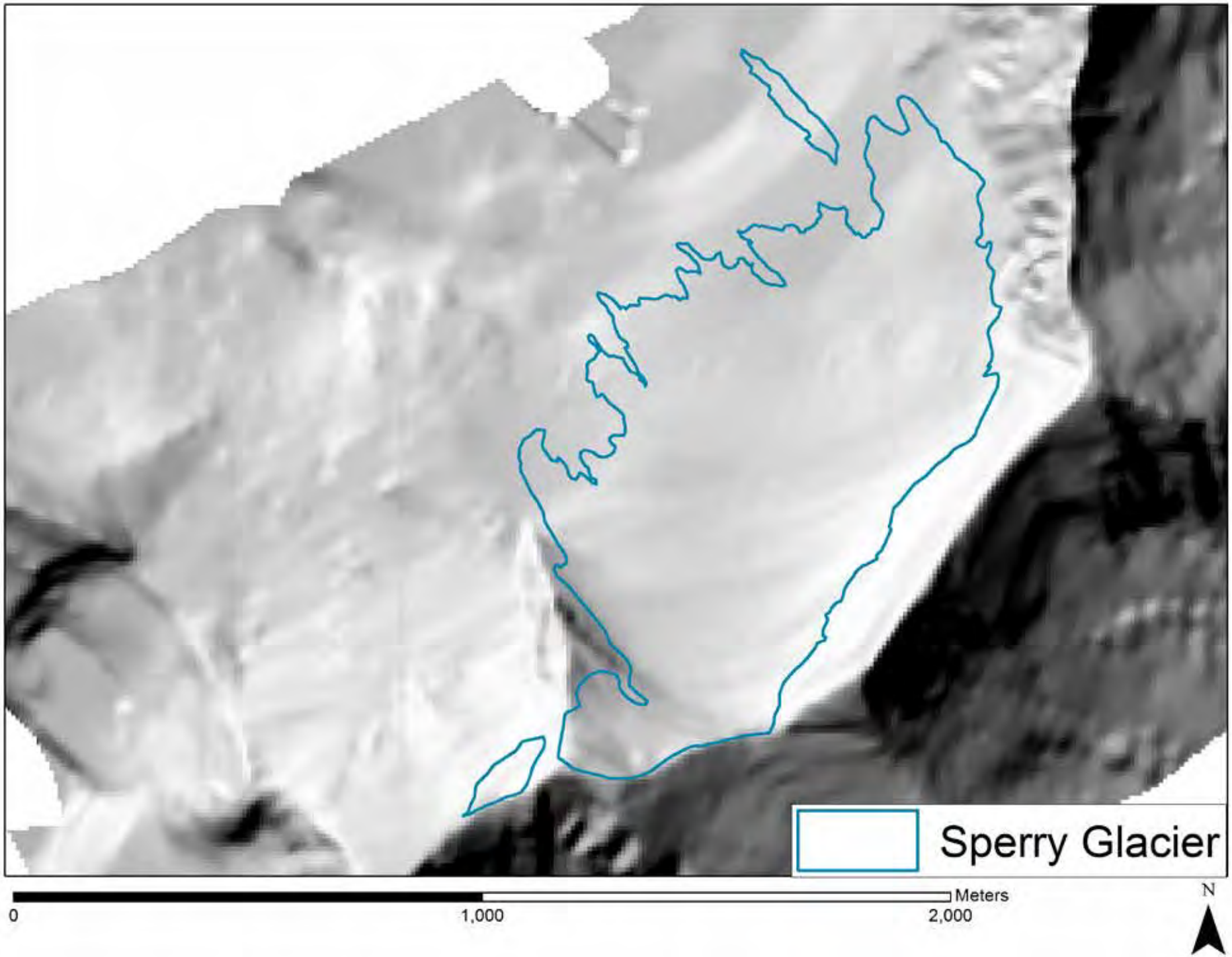
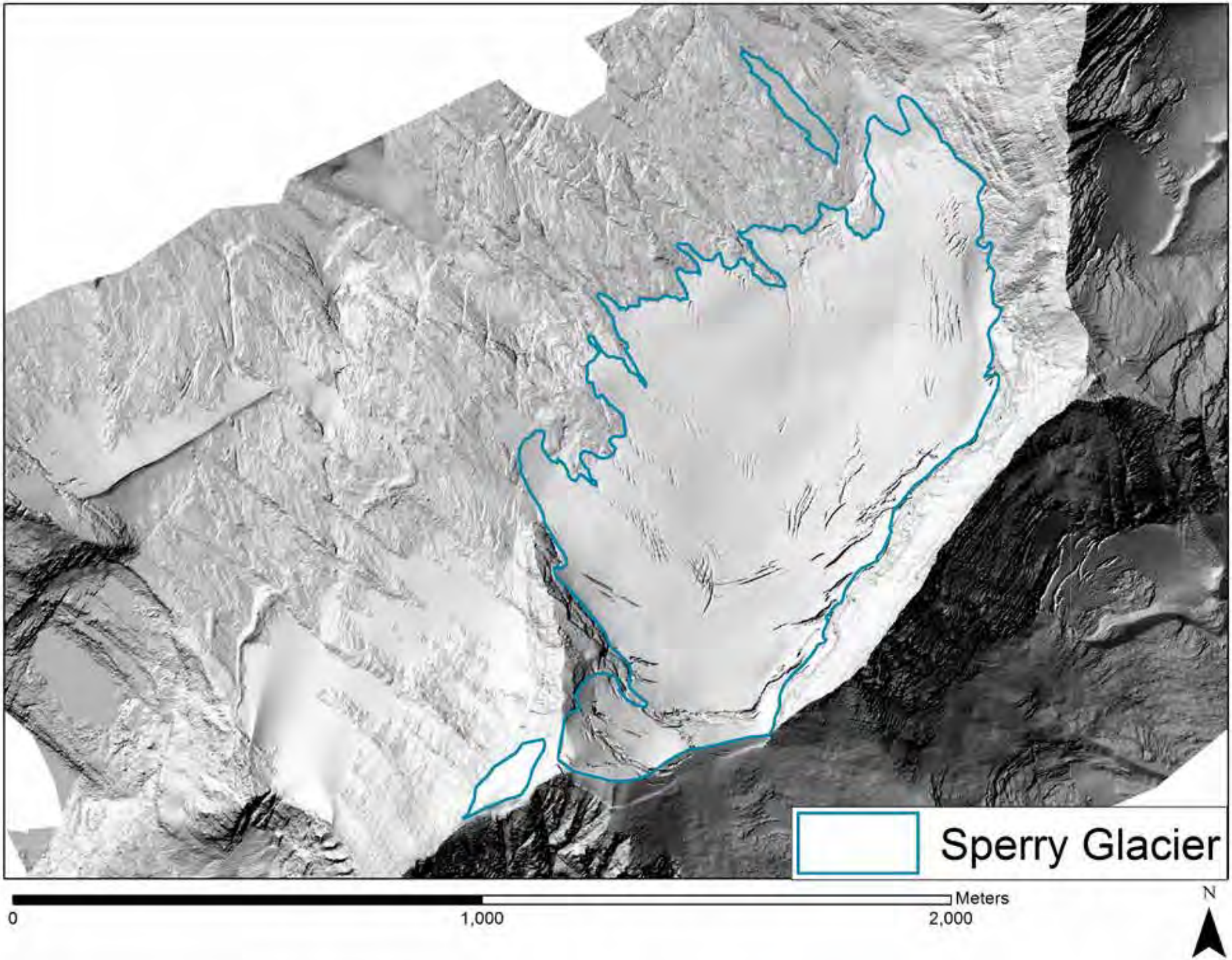

2015 LiDAR Coverage
24K Features
Continental Divide
Glacier NP Boundary
Kilometers
0
25
50
N

ORIGINAL NED (1/3 arc-second resolution or approx. 9m)

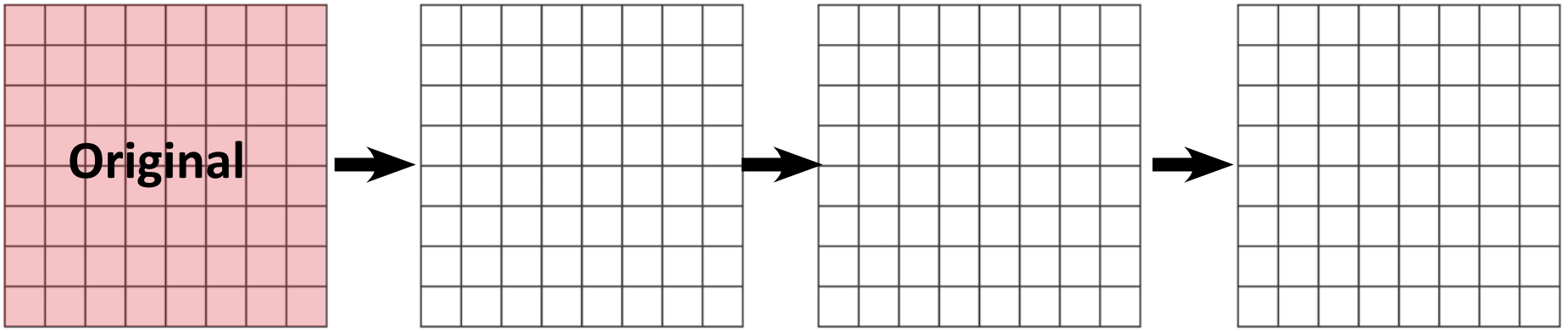


1meter DEM Created from LiDAR

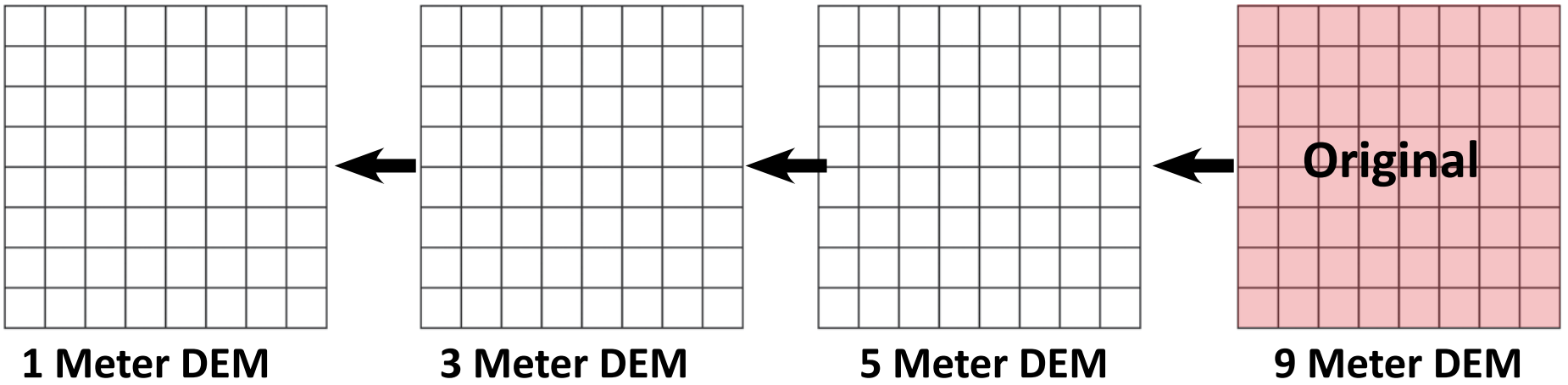


Creating Raster Data

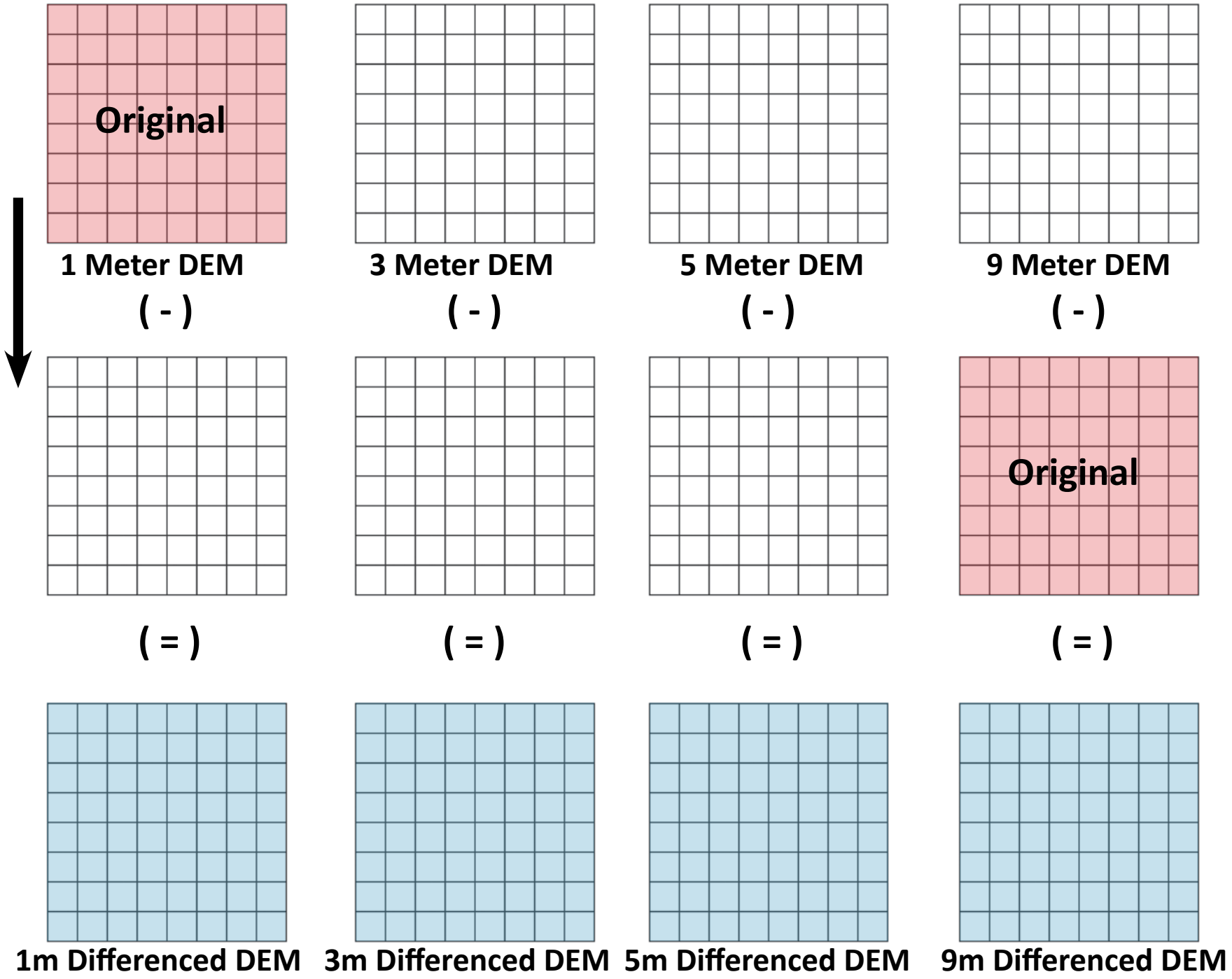
Option 1: Interpolating the LiDAR data to courser resolution



Option 2: Interpolating the NED data to finer resolution

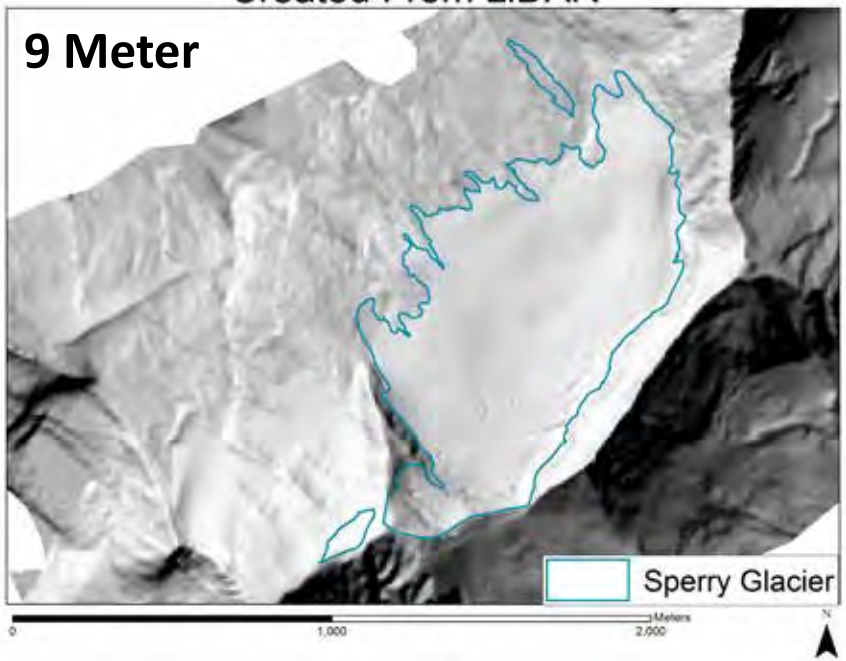


Use Raster Calculator to subtract older DEM *FROM* newer DEM (new - old)



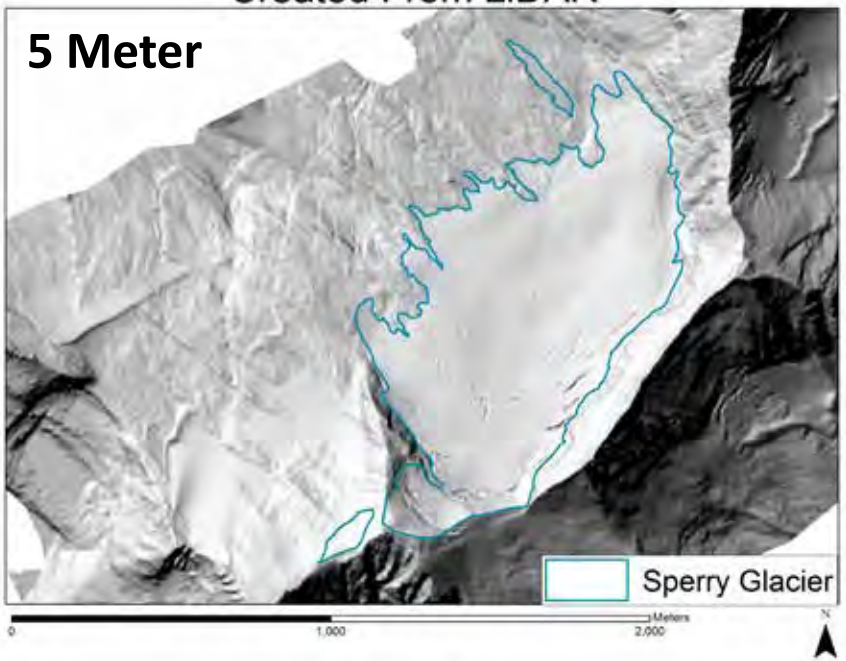
Created From LiDAR

9 Meter



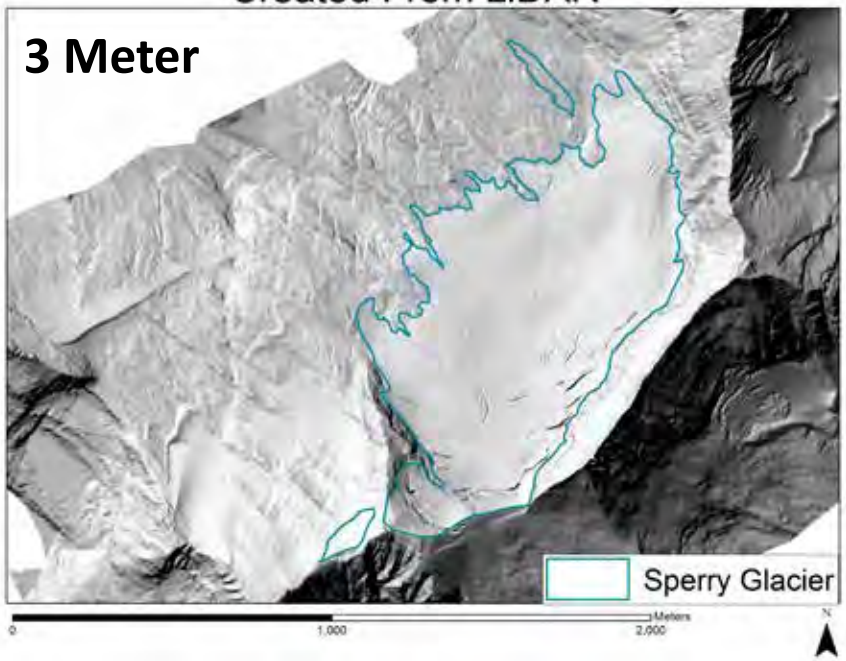
Created From LiDAR

5 Meter



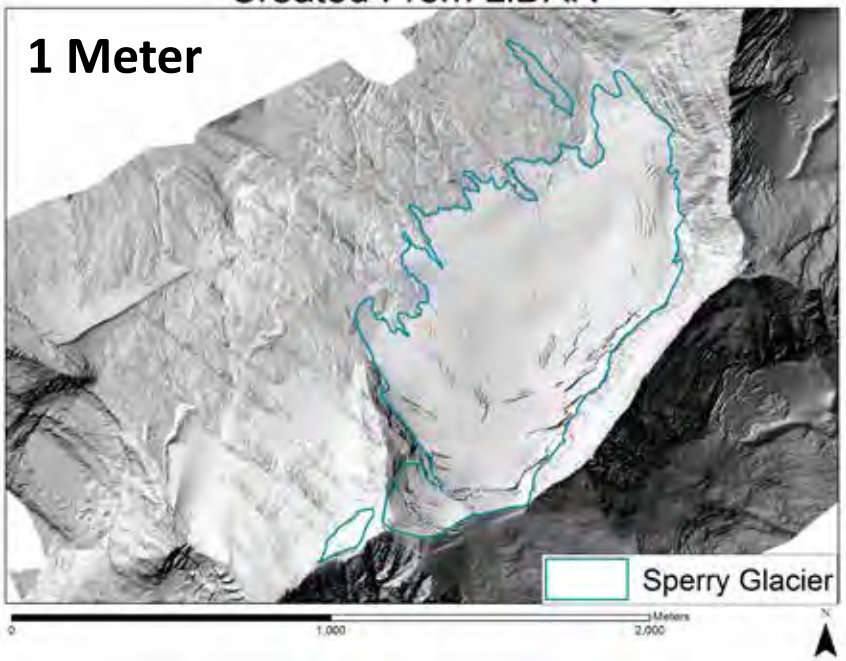
Created From LiDAR

3 Meter

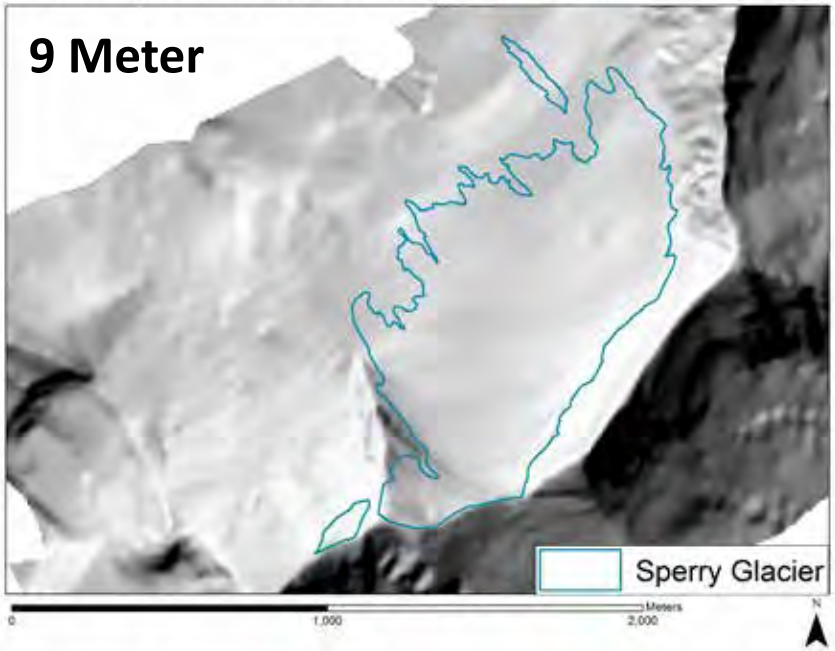


Created From LiDAR

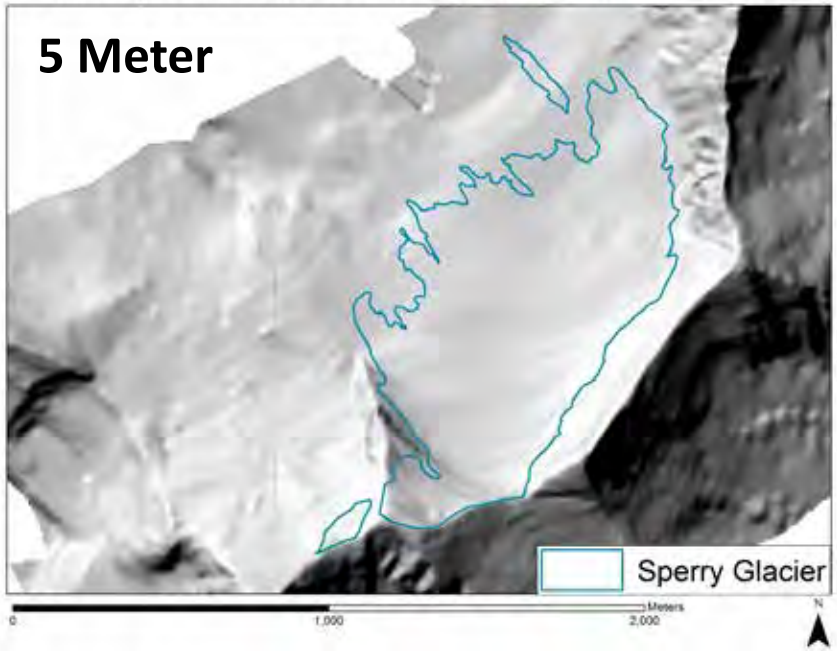
1 Meter



Created by Cubic Convolution Interpolation From 9m NED DEM



Created by Cubic Convolution Interpolation From 9m NED DEM



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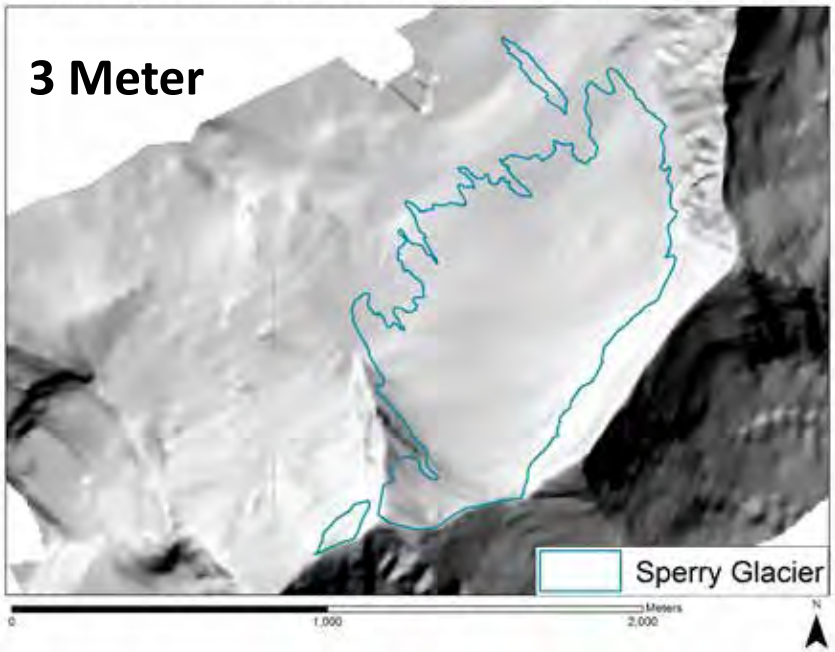
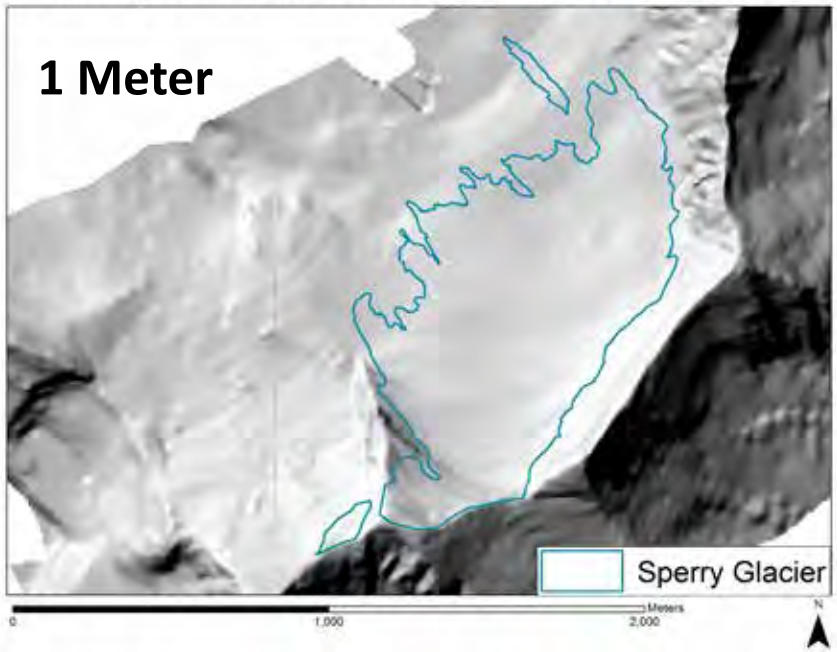
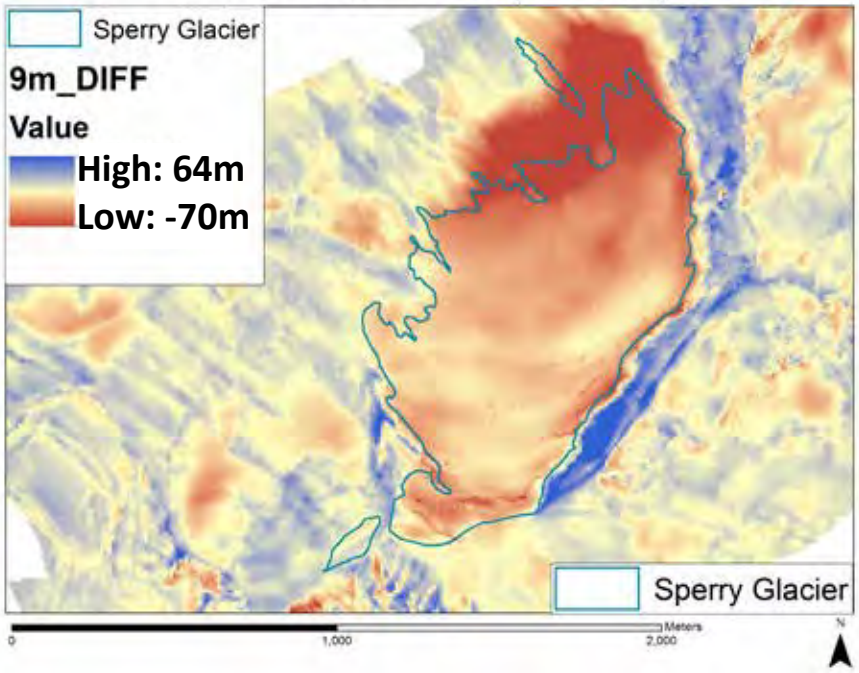


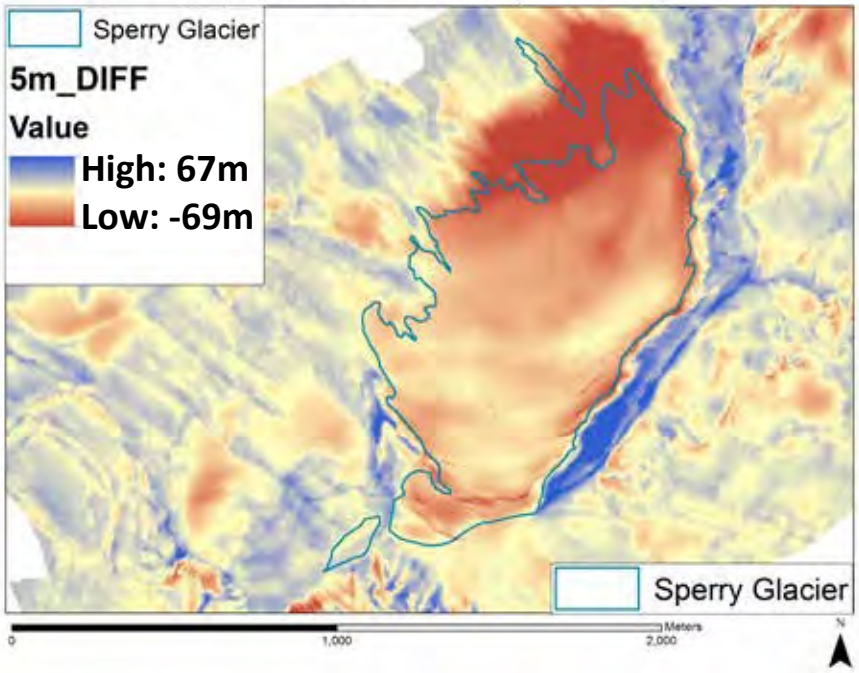
Created by Cubic Convolution Interpolation From 9m NED DEM



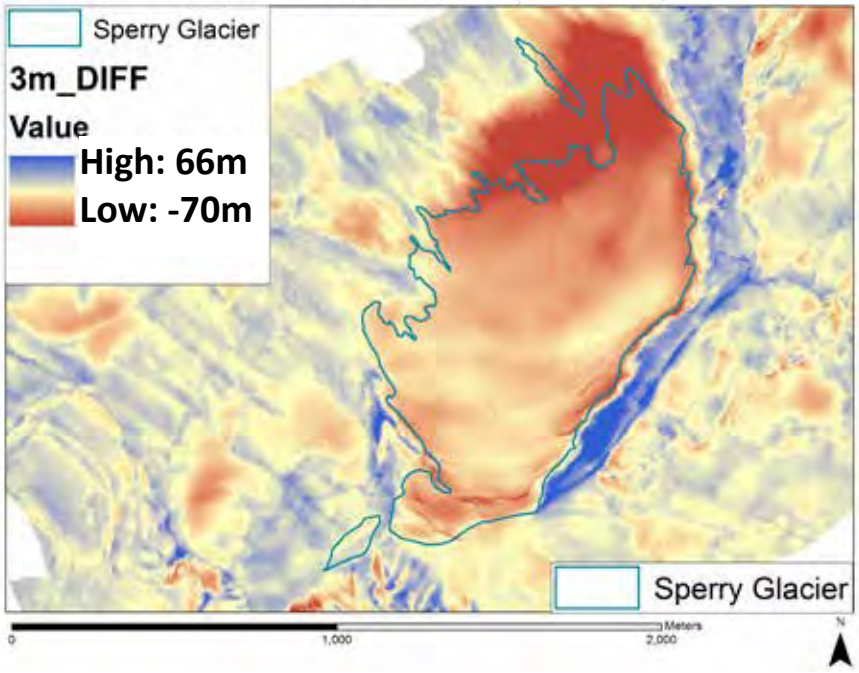
Differenced DEMs (9 Meter)



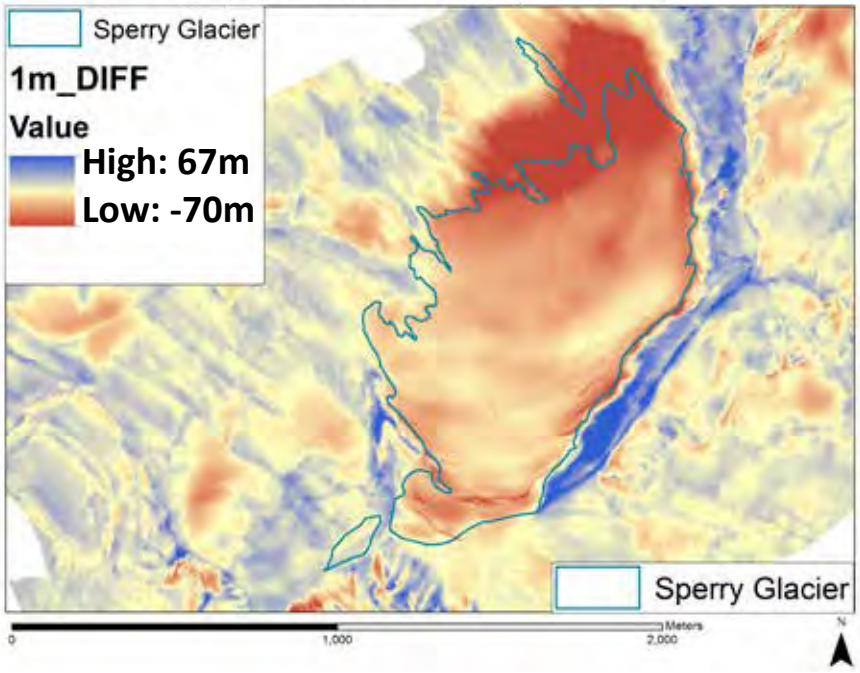
Differenced DEMs (5 Meter)



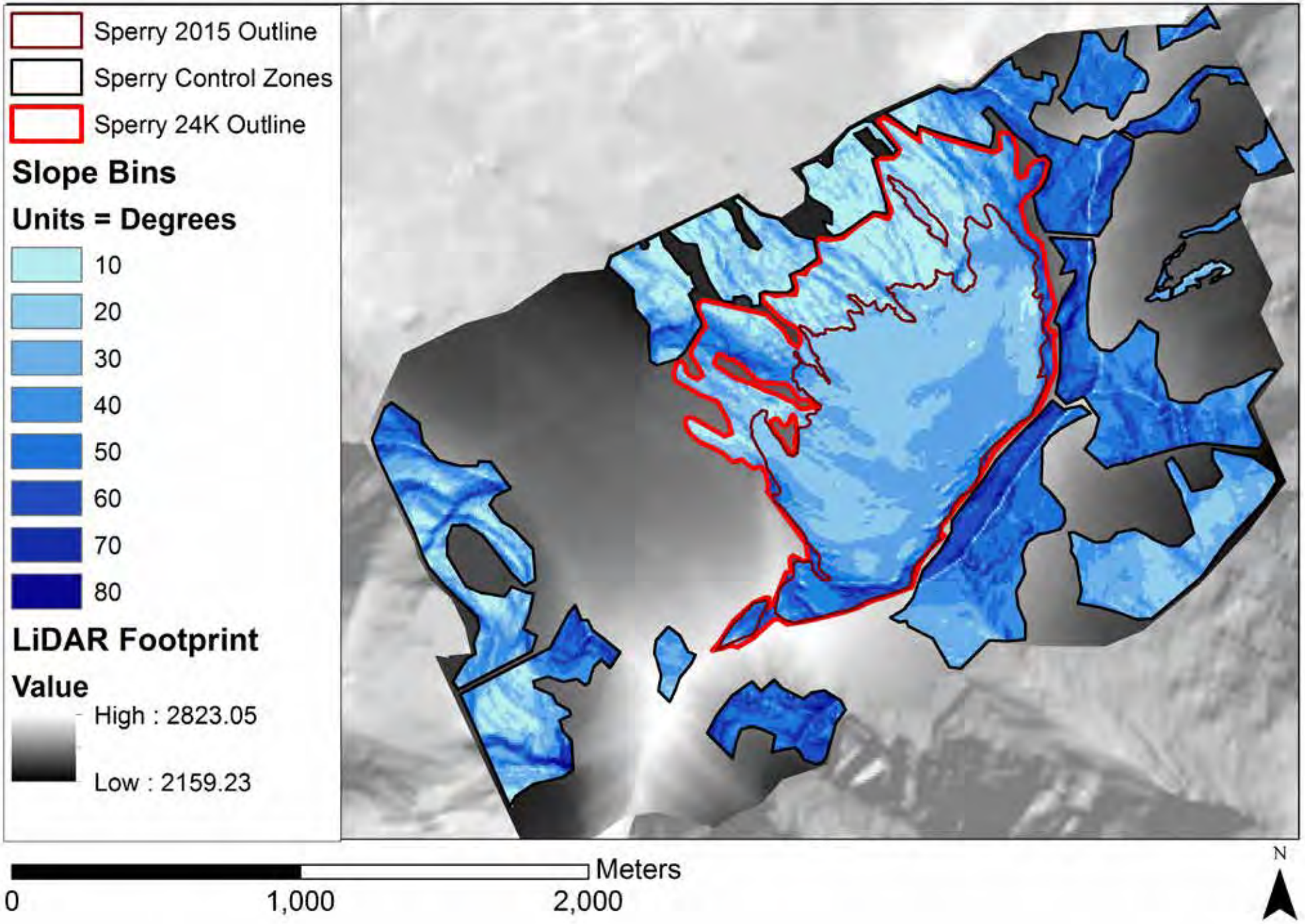
Differenced DEMs (3 Meter)



Differenced DEMs (1 Meter)



Sperry Glacier LiDAR Footprint and Control Zones



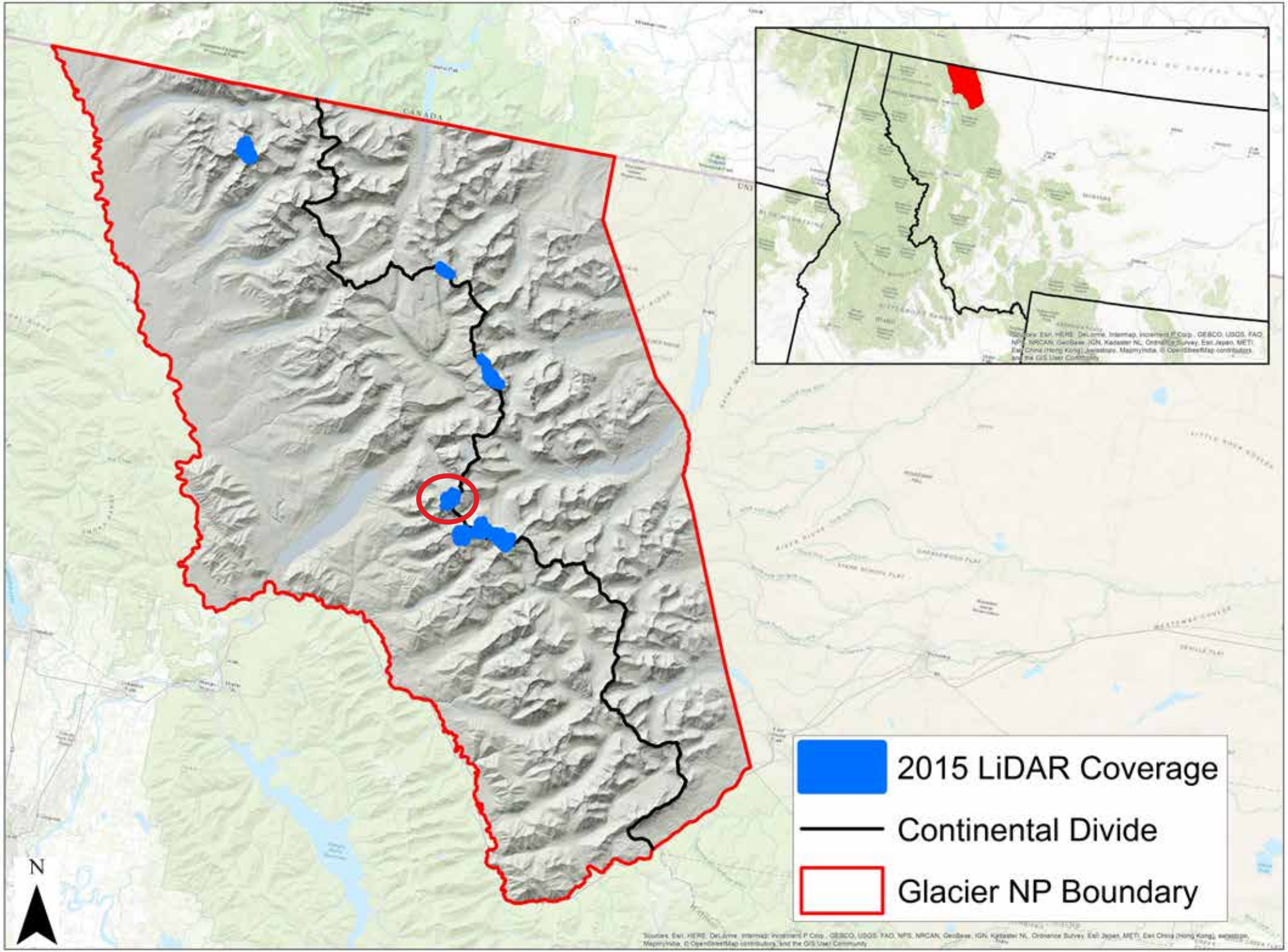
Calculating Volume Change & Uncertainty

$$\Delta V_j = A \sum_{i=1}^{n} \Delta Z_{ij}, \qquad R_j = \sqrt{\frac{\sum_{i=1}^{n} (\Delta Z_{ij})^2}{n}}, \qquad F = \frac{R_c}{R_g}. \qquad U = \pm \frac{|\Delta V| * F}{2}.$$

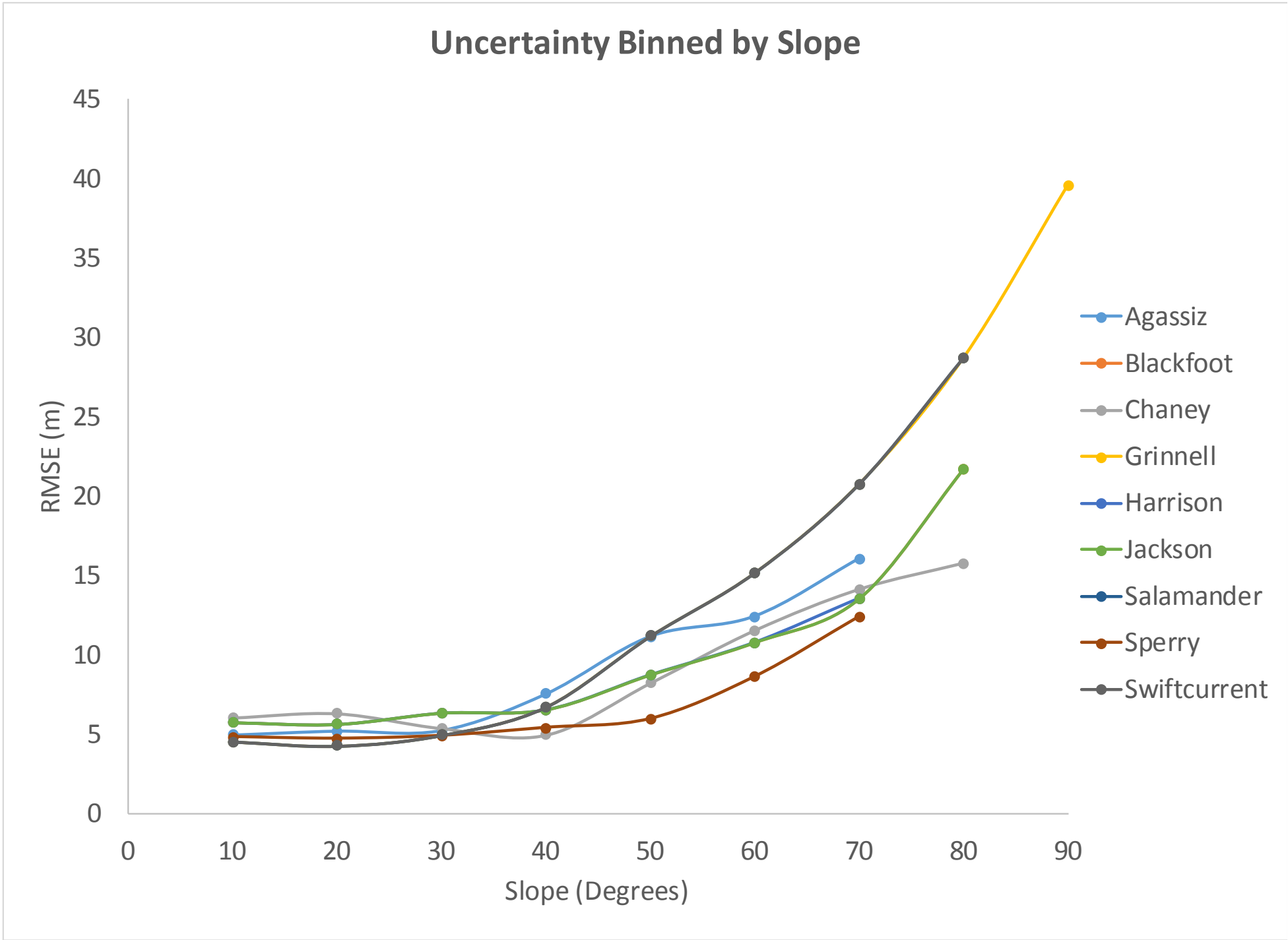
	Cell Area (m^2)	Volume Change (m^3)	RMSE_c/RMSE_g	Uncertainty (m^3)
Sperry Glacier	1270537.567	-29118490.83		2803618.551
10	154904.9994	-4170121.12	0.151278971	315425.8164
20	541963.6863	-13135531	0.17334757	1138506.188
30	373579.6805	-7810031.601	0.207385041	809841.8632
40	111715.5341	-2386509.084	0.225647497	269254.9011
50	61508.26434	-1137272.391	0.291127909	165545.8664
60	22532.69478	-406129.7944	0.414588701	84188.41192
70	4332.707313	-72895.83875	0.57220013	20855.50419

Choosing a Method

	Original LiDAR 1m (-) 1m interpolated FROM NED	3m interpolated FROM LiDAR (-) 3m interpolated FROM NED	5m interpolated FROM LiDAR (-) 5m interpolated FROM NED	9m interpolated FROM LiDAR (-) 9m Original NED
Volume Change	(-) 0.036 km^3	(-) 0.033 km^3	(-) 0.031 km^3	(-) 0.029 km^3
Uncertainty	18%	16%	13%	10%
Prefered Method				

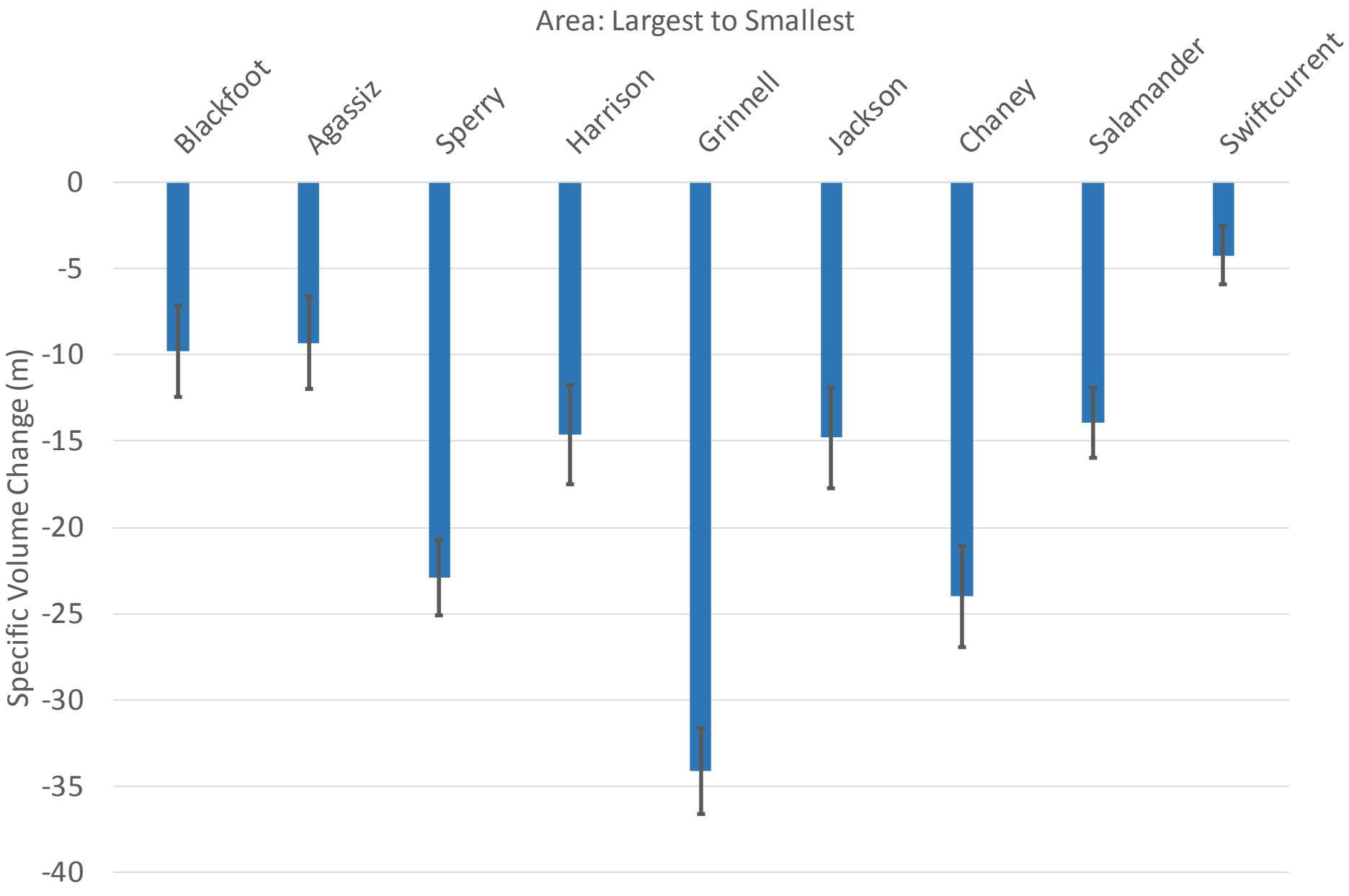

2015 LiDAR Coverage
Continental Divide
Glacier NP Boundary
N
0
25
50
Kilometers

Uncertainty for all 9 Glaciers



Preliminary Results

Specific Volume Change



Conclusions

Total Volume Change for all 9 Glaciers

Glaciers	Volume Change (km^3)	Uncertainty (km^3)	Percent Uncertainty
Blackfoot	-0.0170	0.004627272	27%
Agassiz	-0.0144	0.004117312	29%
Sperry	-0.0291	0.002803619	10%
Harrison	-0.0185	0.003624238	20%
Grinnell	-0.0340	0.002454611	7%
Jackson	-0.0131	0.00258095	20%
Chaney	-0.0127	0.001551397	12%
Salamander	-0.0028	0.000411498	15%
Swiftcurrent	-0.0007	0.000286567	39%
	Total Loss = -0.1424 ± 0.022		

That's equal to roughly 380,000 ± 58,000 Olympic Swimming Pools!


Questions?