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Geog 493 - Digital Terrain Analysis
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Title
Accuracy assessment of GIS techniques for measuring volumetric loss at Mount St. Helens

Abstract
The 1980 eruption of Mount St. Helens was the most significant volcanic event in modern US history, drastically altering the physical and natural characteristics of the mountain itself and the surrounding landscape. Continuous advances in remote sensing and geographic information systems make it possible to monitor and analyze such changes at the earth's surface with increasing ease. This researcher was curious about how accurate commonly used techniques of volumetric analysis using digital elevation models (DEMs) in a geographic information system are at estimating volumetric loss. By comparing 30m DEMs generated from data collected prior to and following the 1980 eruption, volume loss was calculated using three methods - DEM differencing, Cut Fill and TIN Surface Difference - and compared to the official USGS estimate based on uncompacted deposits. In addition, 10m DEMs were interpolated from the original 30m DEMs to test the effect this would have on the Cut Fill volume calculation. The study found that these techniques produced results between 3 - 3.5% greater than the USGS estimate, within an acceptable range of accuracy for most purposes. Additionally, the use of interpolated surfaces did not have a significant impact on volume calculation. Reasons for discrepancies in estimates include the fact that the post-eruption DEM was generated 24 years after the eruption; this is a significant amount of time for surficial changes to occur through a variety of processes. Also, this researcher was unable to identify the exact study area used by USGS in estimating volumetric loss; as a result, there are almost certainly areas that this study included in its calculations that theirs did not (and vice versa).

Keywords
Mount St. Helens, digital elevation model, volumetric analysis, GIS, remote sensing

Accuracy Assessment of GIS Techniques for Measuring Volumetric Loss at Mount St. Helens

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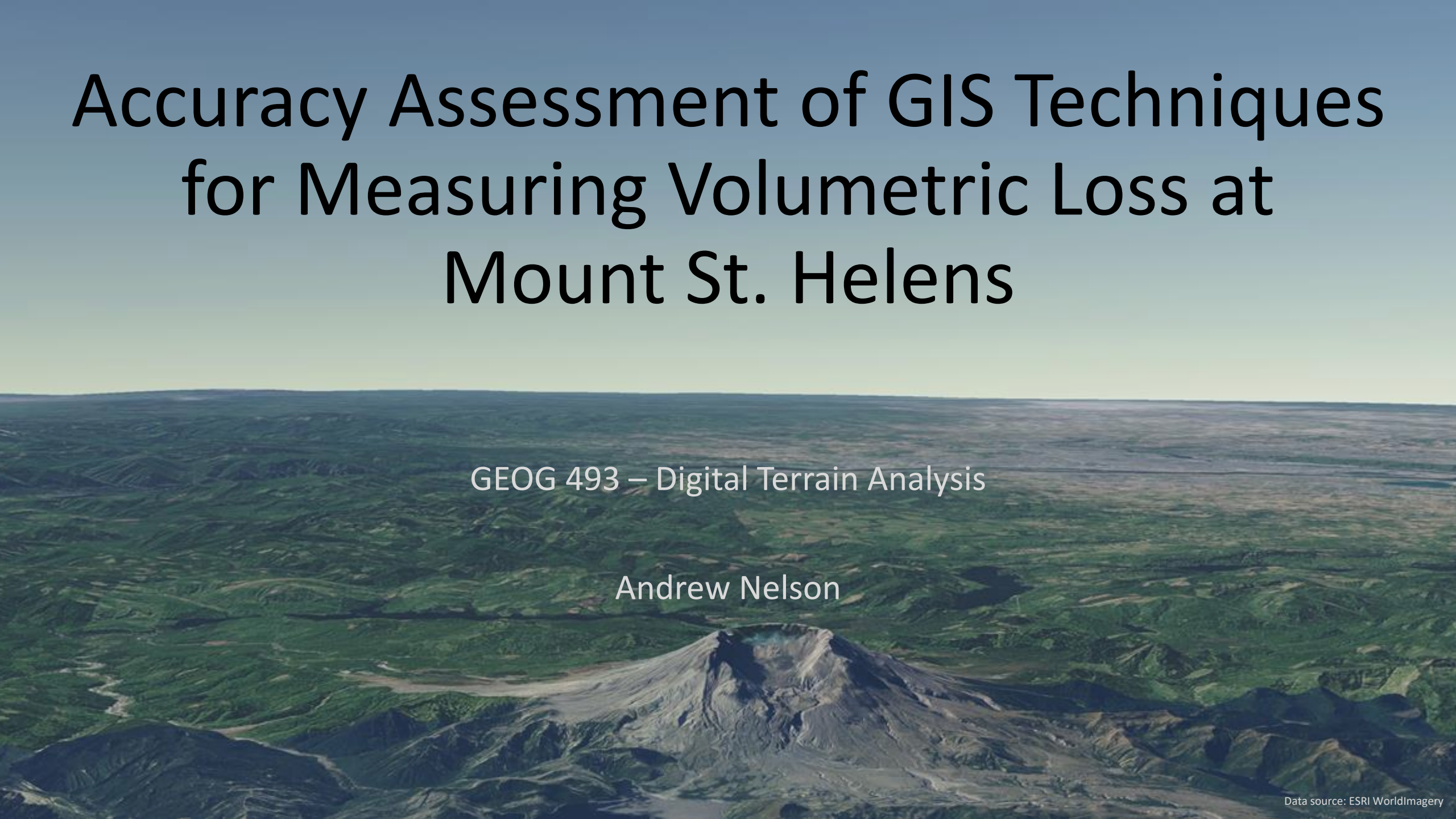
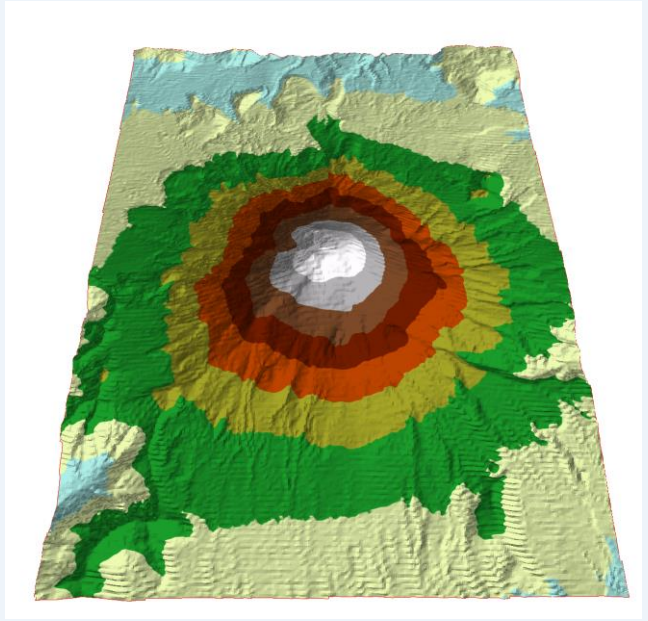
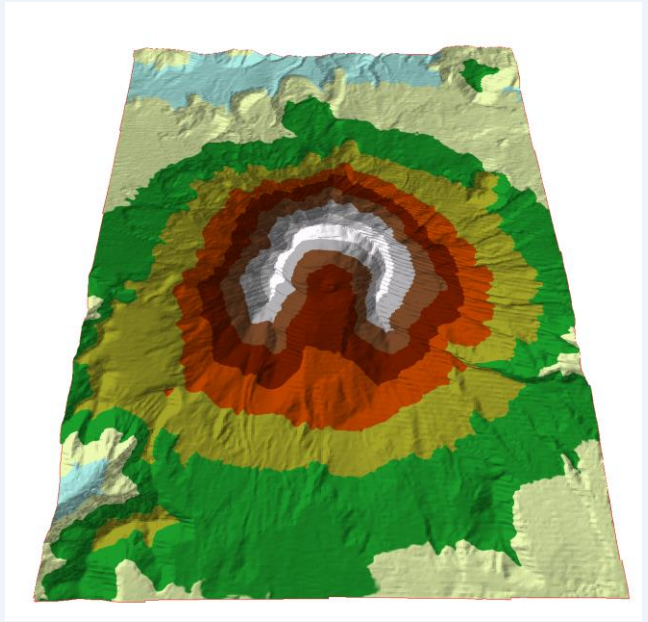


Data source: ESRI WorldImagery

RESEARCH QUESTIONS

- What are the different techniques of performing volumetric analysis using digital elevation models in ArcMap?
- How do the results of these methods compare to volumetric change estimates made using traditional techniques?
- What effect will downscaling DEM resolution using interpolation have on volumetric calculation?



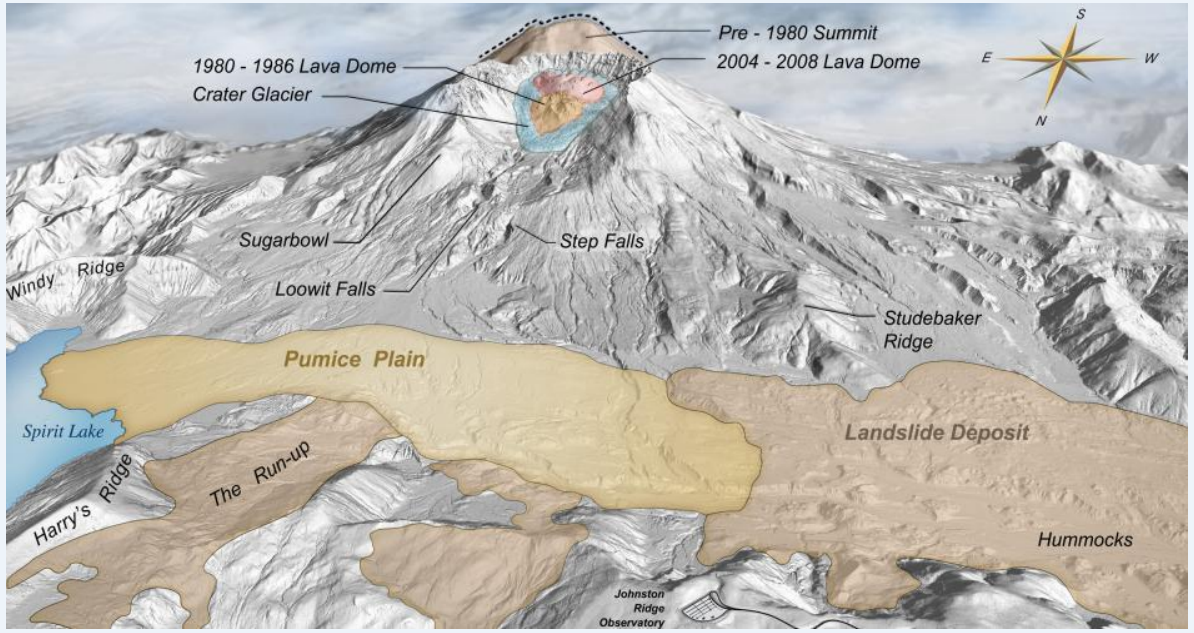


STUDY AREA

Mount St. Helens was chosen as study area due to:

- Large volumetric change from 1980 eruption
- Availability of digital elevation models pre- and post-eruption
- Well-researched, good deal of information available

Many studies target total volumetric change, I am primarily interested in volume removed.



Source: USGS CVO

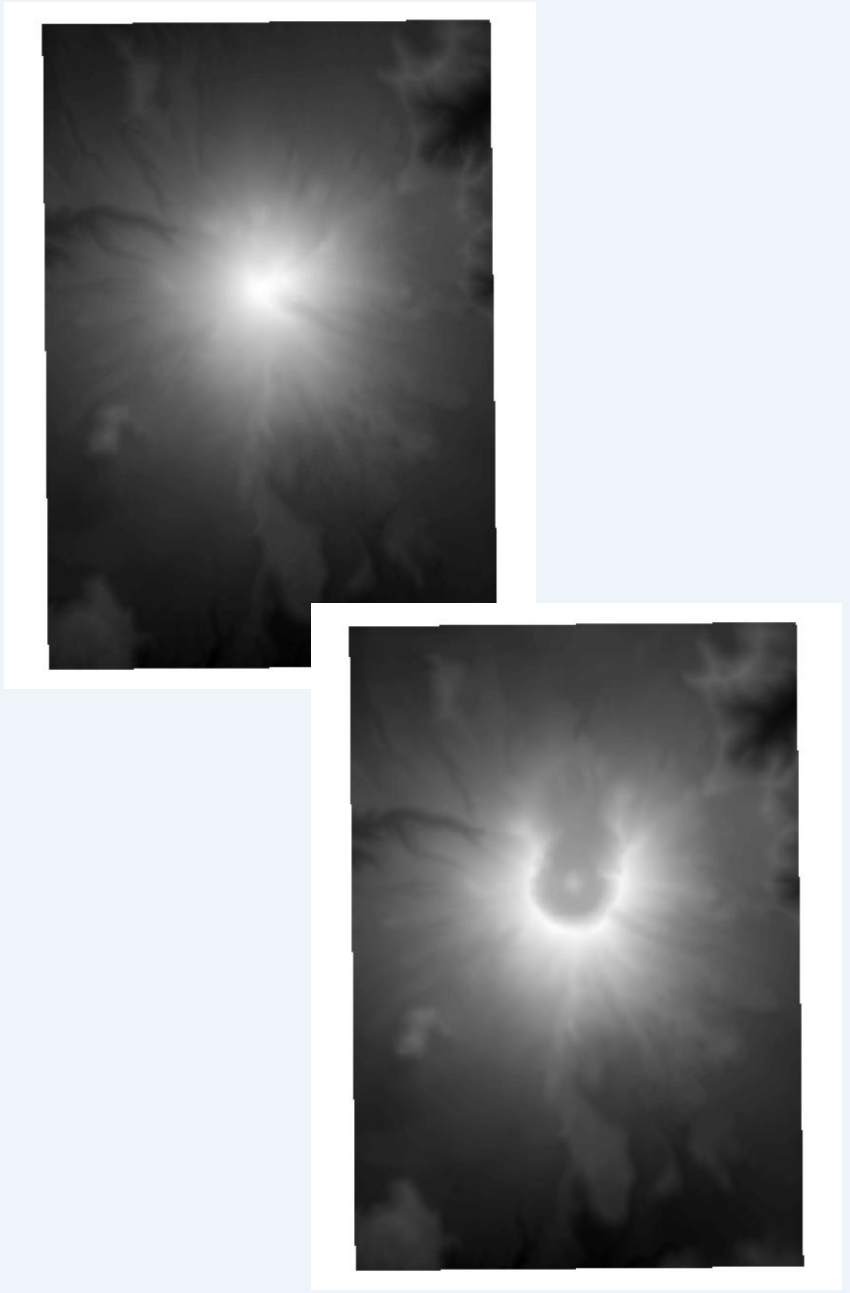
DATASETS

COLLECTED

- 30m Pre-Eruption DEM
- 30m Post-Eruption DEM

CREATED

- 30m Pre- and Post-Eruption Hillshades
- Interpolated 10m Pre- and Post-Eruption DEMs
- Interpolated 10m Pre- and Post-Eruption Hillshades
- Pre-Eruption TIN Model
- Post-Eruption TIN Model



ANALYSIS

DEM DIFFERENCING

- Use Raster Calculator to find elevation difference between pre/post-eruption DEMs
- Output = elevation change; to find volume, multiply this value by area
- Cells with elevation change between -1 and 1 m classed as No Change

Table

DEMDiffINT.tif.vat

OID	Value	Count	Area	Volume
0	-1110	1	900	-999000
1	-1105	1	900	-994500
2	-1099	1	900	-989100
3	-1094	1	900	-984600
4	-1092	1	900	-982800
5	-1091	1	900	-981900
6	-1090	1	900	-981000
7	-1089	1	900	-980100
8	-1088	1	900	-979200

(0 out of 1193 Selected)

CutFill_30m | DEMDiffINT.tif.vat

ANALYSIS

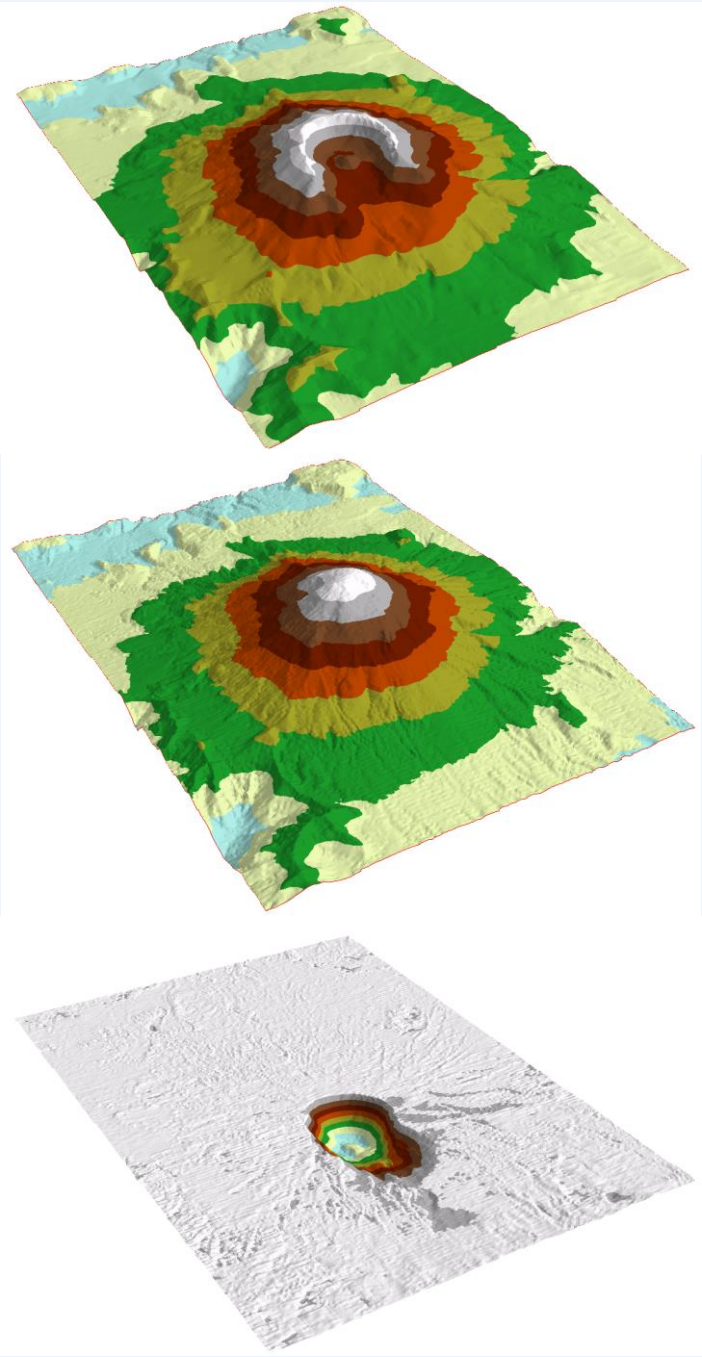
CUT FILL

- Spatial Analyst toolbox
- Calculates areas and volumes of change
- Output = positive values represent areas of “cut” (volumetric loss) negative values represent areas of “fill” (volumetric gain)
- Cells with volume between -900 and 900 m^3 classed as “No Change”

ANALYSIS

SURFACE DIFFERENCE

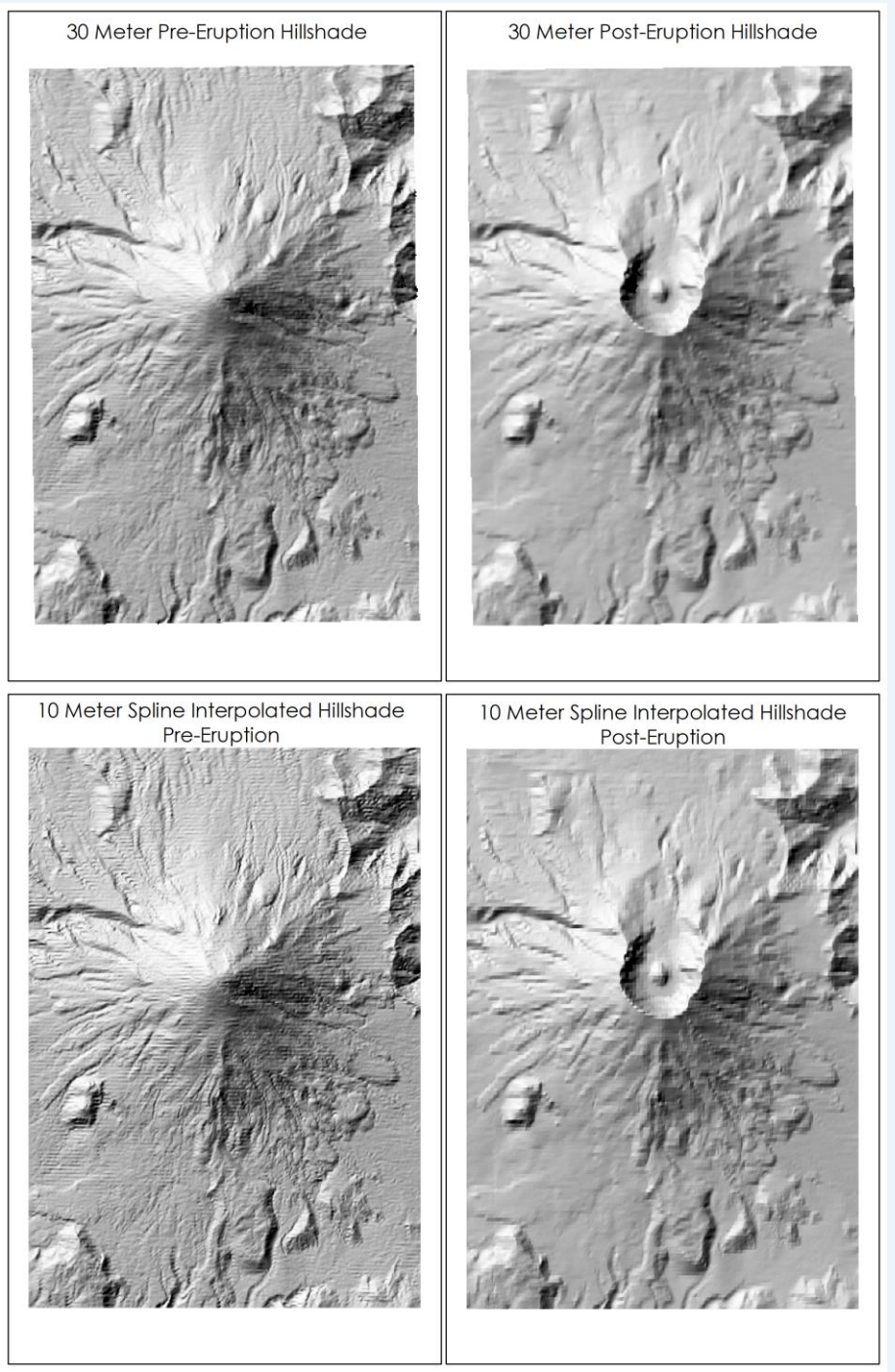
- 3D Analyst toolbox -> Triangulated Surface
- Similar to Cut Fill but performs analysis on TIN models
- Output = areas above/below reference model (in this case, post-eruption)
- Cells with volume between -900 and 900 m^3 classed as “No Change”



ANALYSIS

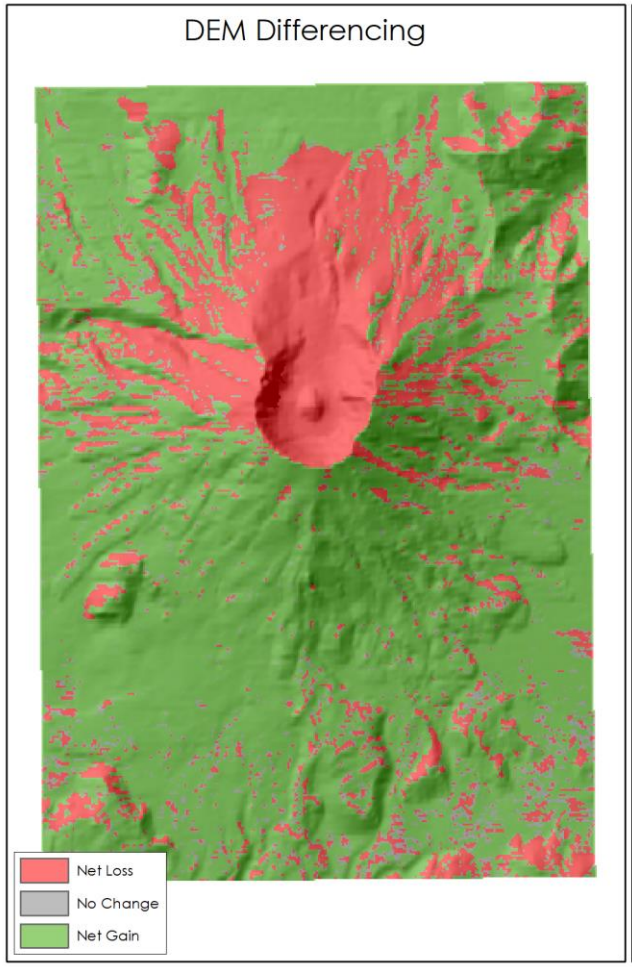
CUT FILL – INTERPOLATED 10m DEM

- Extraction -> Sample
- Interpolated 10m pre/post eruption DEMs using Spline
- Performed Cut Fill using these DEMs as input

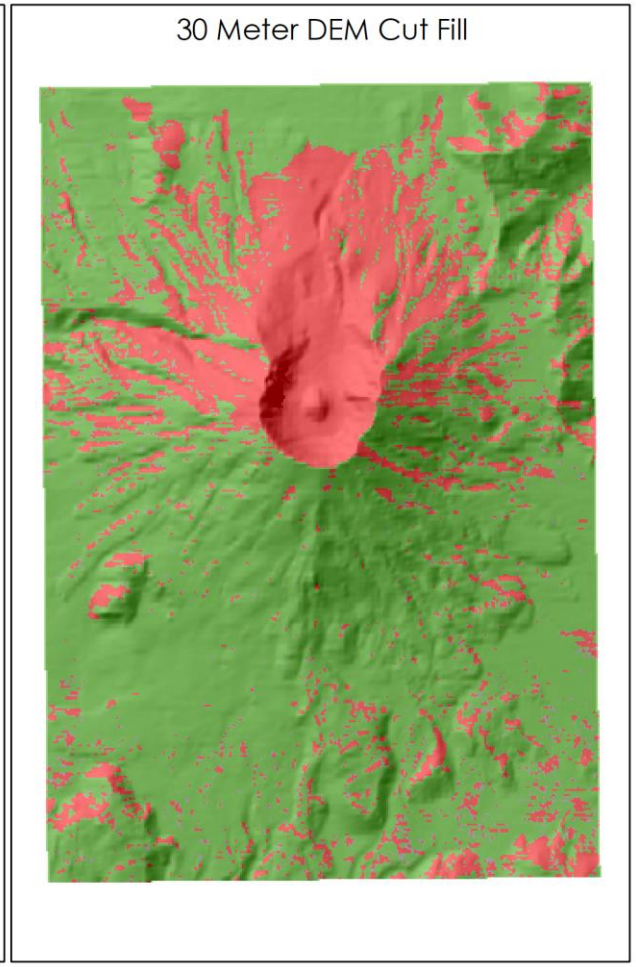


RESULTS

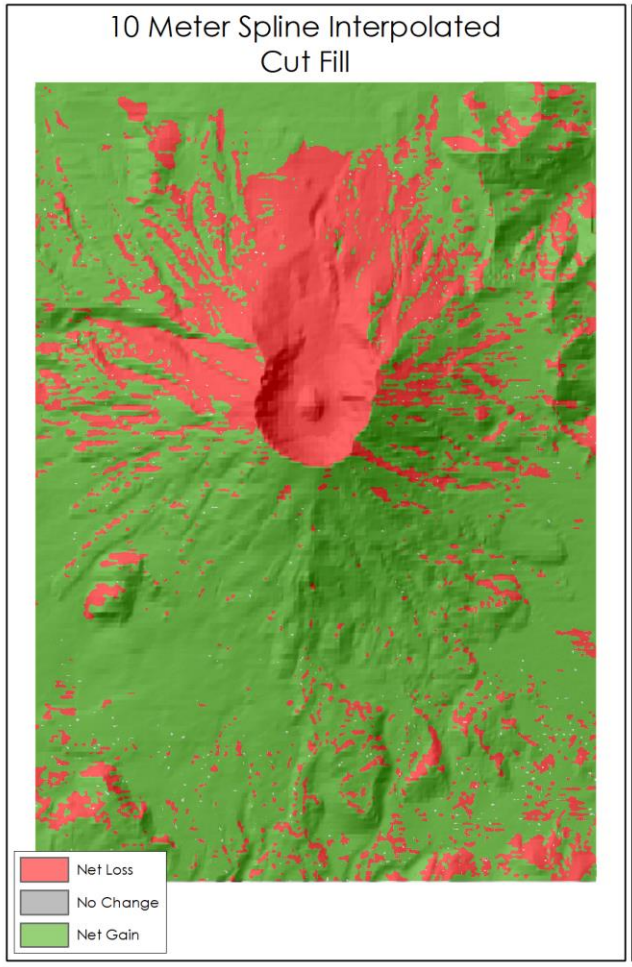
DEM Differencing



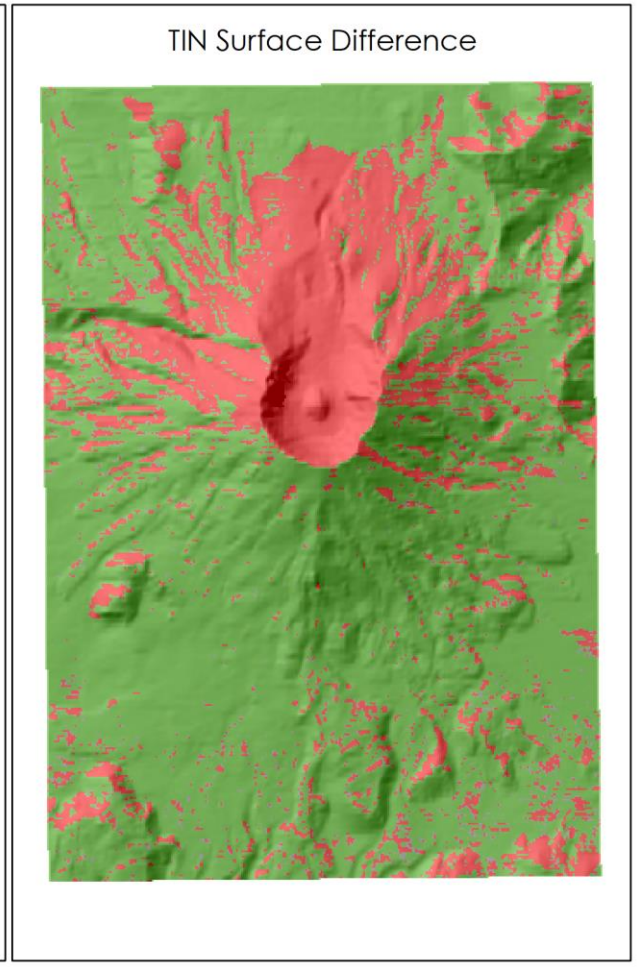
30 Meter DEM Cut Fill



10 Meter Spline Interpolated Cut Fill



TIN Surface Difference



RESULTS

	USGS	30m DEM Difference	30m DEM Cut Fill	TIN Surface Difference	Interpolated 10m DEM Cut Fill
Estimated Volume Removed (m^3)	2,828,852,974.54	2,927,595,864.52	2,927,391,300.00	2,914,970,838.87	2,926,926,309.63
Difference (m^3)		98,742,889.98	98,538,325.46	86,117,864.33	98,073,335.09
Percent Difference		3.49	3.48	3.04	3.47

- Each DEM-based technique resulted in volumetric loss of about 2.93 billion m^3
- TIN Surface Difference was slightly lower at 2.91 billion m^3, closest to USGS estimate
- Little difference in appearance of output rasters produced by each method
- Interpolation did not have significant effect on volume calculations

RESULTS

Reasons for discrepancies

- Study Area
- Post-Eruption DEM too recent
- DEM resolution – too coarse
- Pre-Eruption DEM not LiDAR-derived
- Information-loss during conversion/interpolation (raster-to-TIN)

SOURCES

- University of Washington Department of Earth and Space Sciences, http://gis.ess.washington.edu/data/raster/thirtymeter/mtsthelens/

- USGS Mount St. Helens Fact Sheet https://pubs.usgs.gov/fs/2000/fs036-00/fs036-00.pdf