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Improving the accuracy and quality of photogrammetrically derived high-resolution digital elevation models through the development of a raster-based progressive morphological filter

Pete Chirico
USGS
12201 Sunrise Valley Drive
MS 926A, National Center
Reston, VA 20192
pchirico@usgs.gov
703-648-6950

U.S. Department of the Interior
U.S. Geological Survey

High-resolution digital elevation models (DEMs)

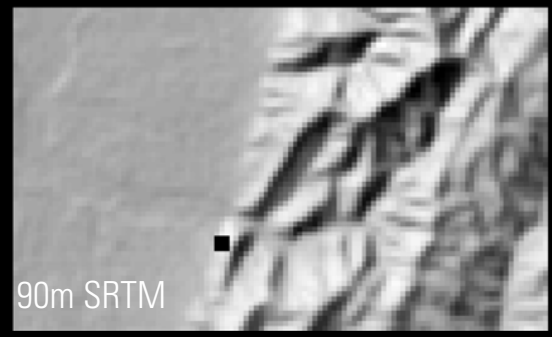
Applications for which absolute* (not relative) DEMs are important:

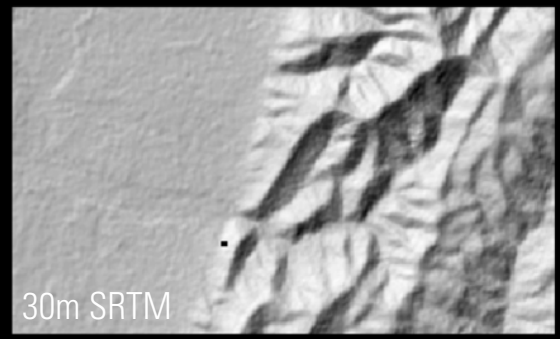
Medium horizontal resolution: 90m -30m
- Geologic Mapping and Interpretation
- Satellite Imagery Terrain Correction

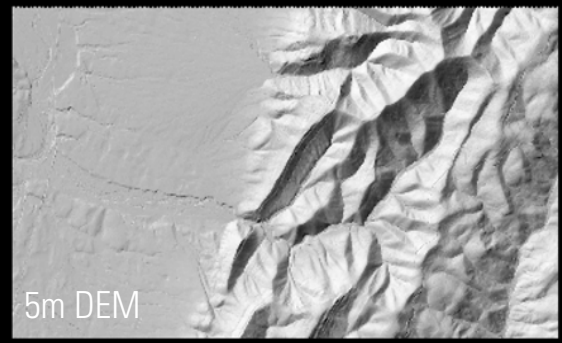
High horizontal resolution: 30m – 5m
- Hydrological Applications
- Geohazard Modeling

Very-high horizontal resolution: 5m - 1m
- Infrastructure Site Selection and Engineering
- Urban Applications

* absolute DEMs are tied to a vertical datum on the ground







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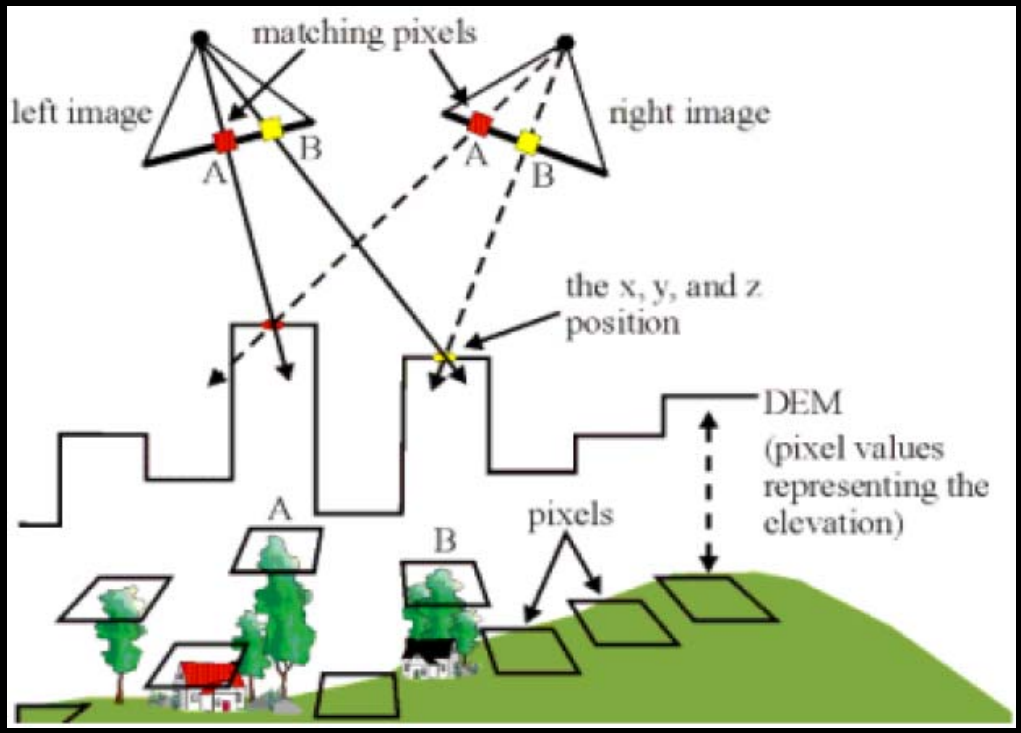
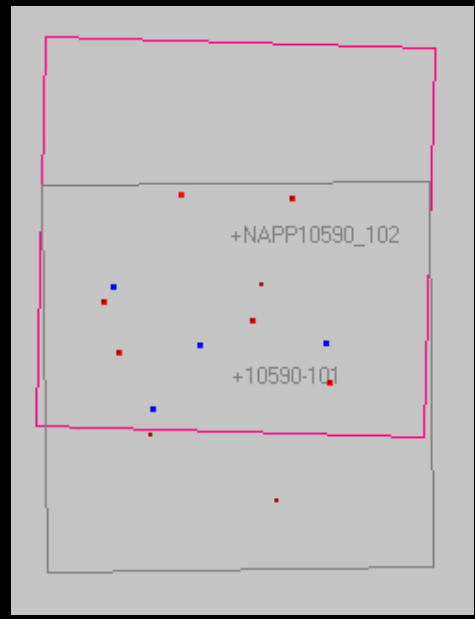
Digital photogrammetry and stereo-autocorrelation techniques

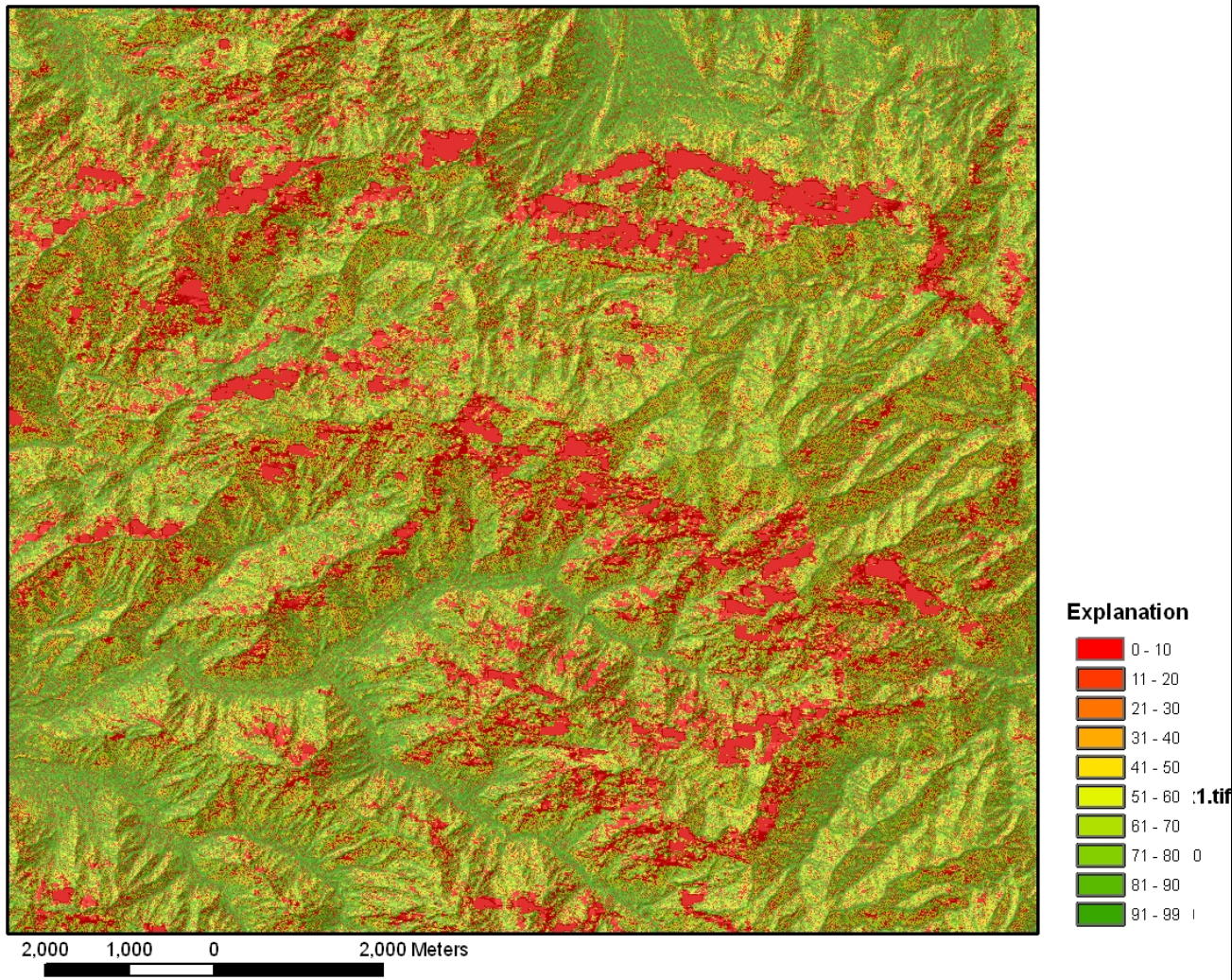




Stereo auto-correlation algorithms measure the amount of parallax and calculate elevation values on a pixel-by-pixel basis for all pixels matched in a set of stereo images

Low or failed correlation: pits, spikes, and void areas

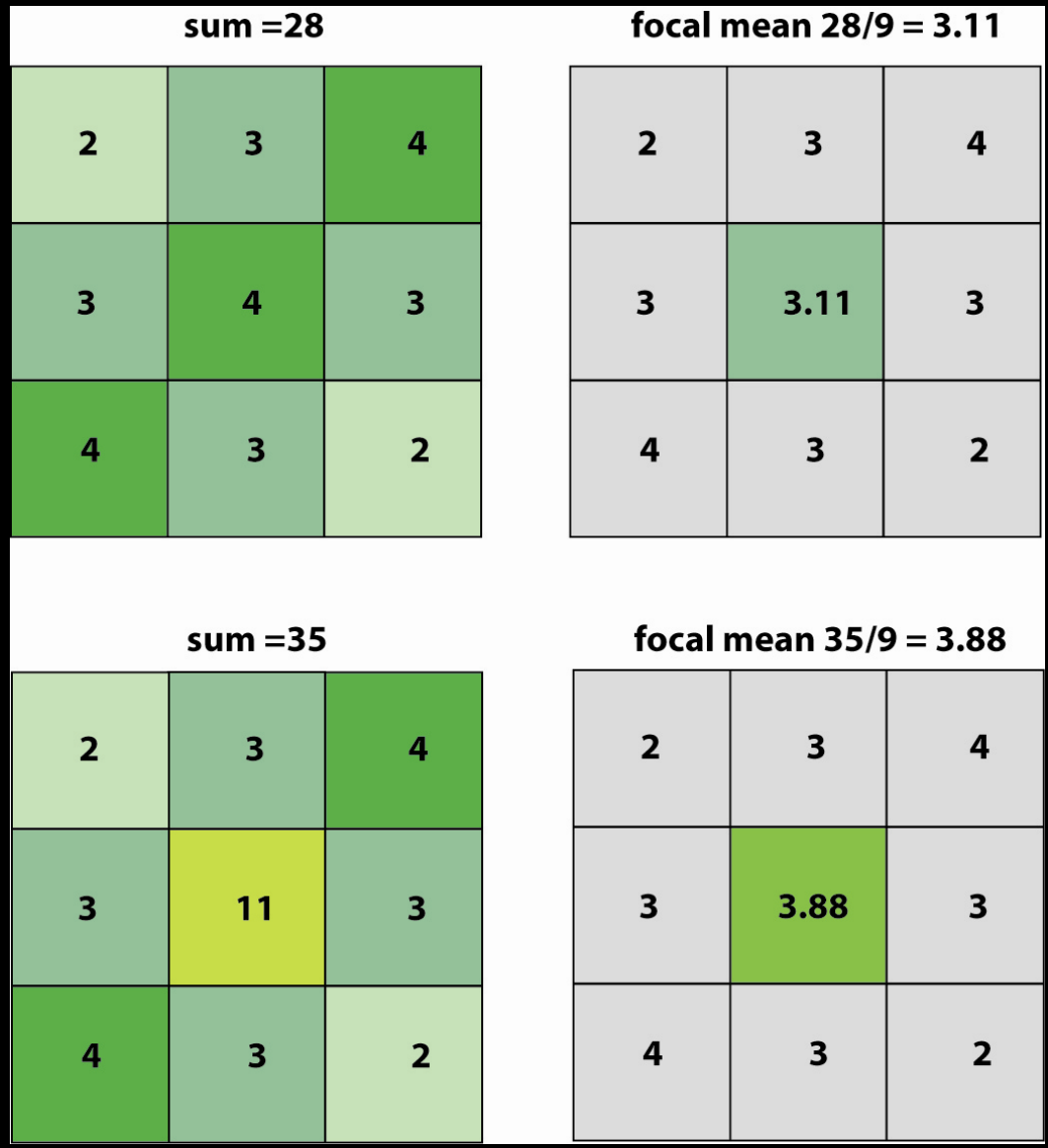
Poorly matched pixel values result in erroneous elevation values or failed values which are exhibited in the output DEM as pits, spikes, and void areas.



Traditional solution is a low pass filtering technique

To improve the quality of output DEMs, most software routines employ a low pass filtering technique to smooth elevation values. This technique reassigns a mean elevation value for a 3x3, 5x5, or 7x7 pixel window around all cell values. Calculating a mean elevation in a window containing a large pit or spike biases the values of all cells within that window and reduces, but does not eliminate the erroneous value.

Also, errors in raster based DEMs are not normally individual cell value spikes, instead they are often collections of pixels and form mounds, blisters, or excavations.



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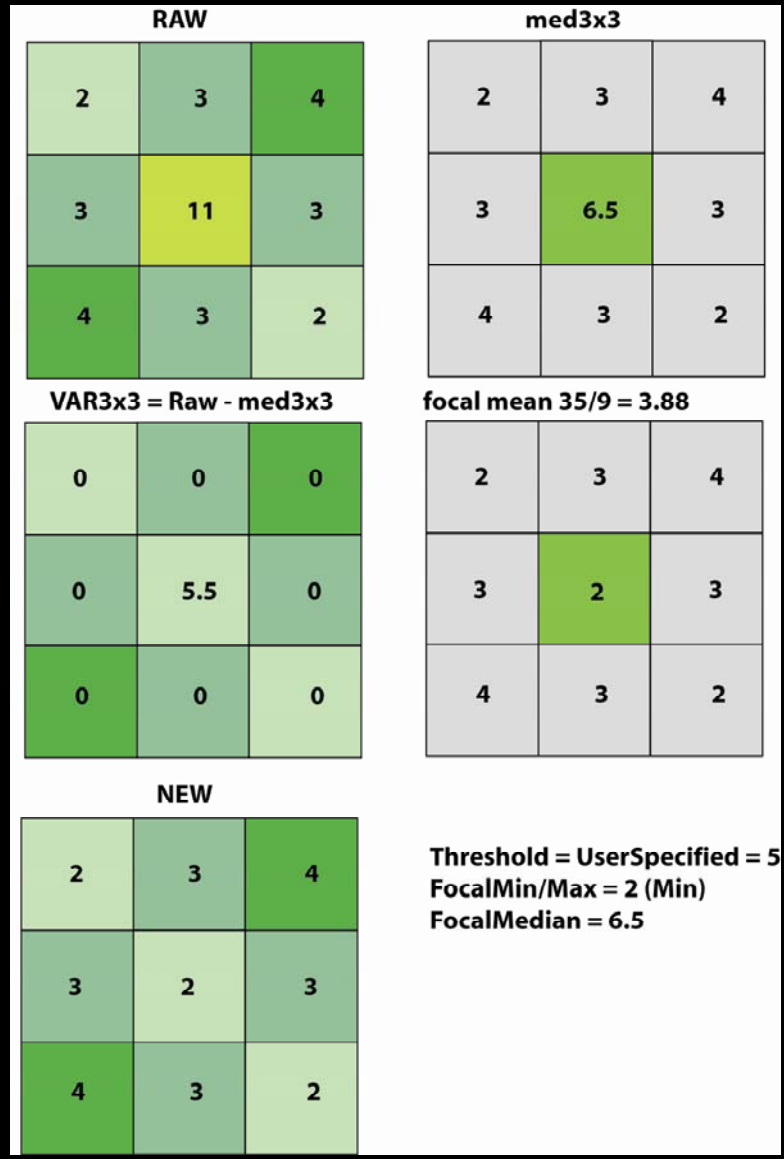
A new approach: the Progressive Morphological Filter

The progressive morphological filter iteratively compares individual raw elevation values to a set of focal neighborhood statistics and a user defined threshold value. Elevation differences between the raw value and the neighborhood statistics are compared to the threshold value.

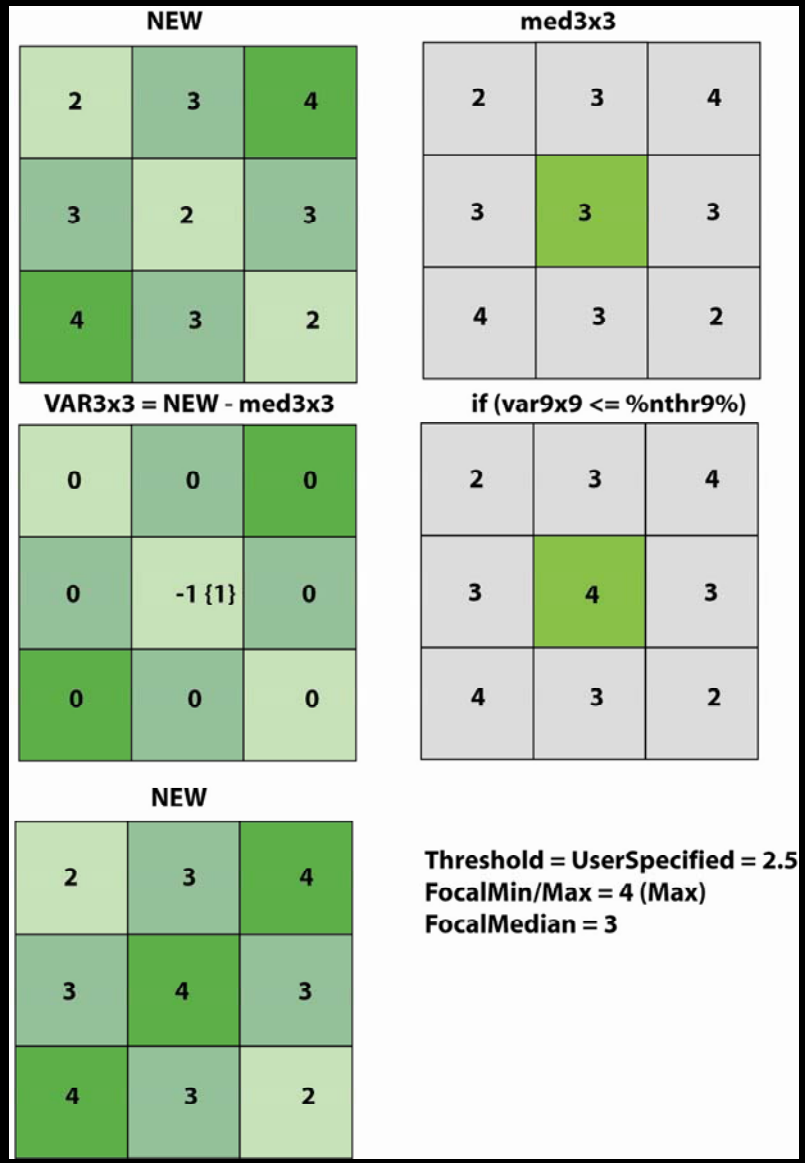
A new approach: the Progressive Morphological Filter

Raw values that exceed the threshold are replaced with a focal minimum, focal maximum, or focal median value based on the characteristics of the elevation value in question.



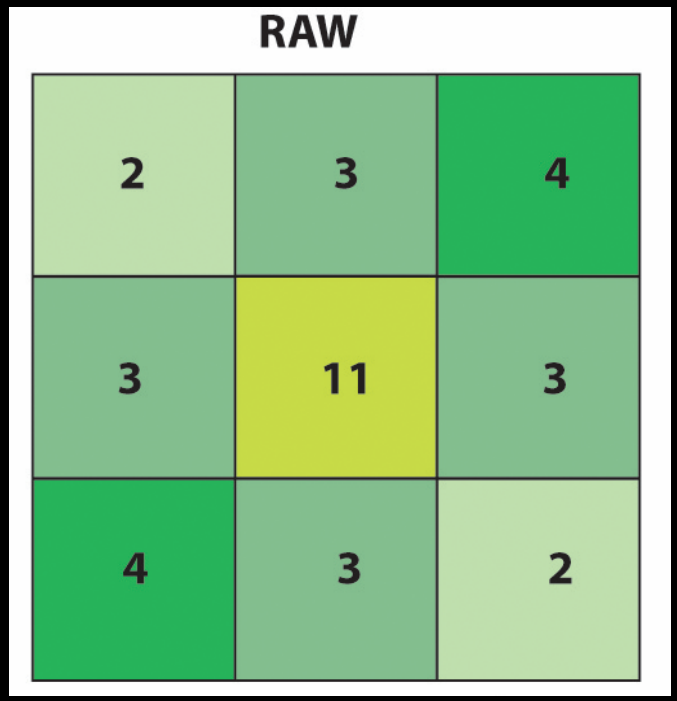
Four progressive stages of neighborhoods and threshold values

The filter progresses through four stages whereby elevation values are compared to increasingly smaller neighborhoods and a progressively reduced threshold value. The result is that only elevation values that exceed the defined parameters are replaced; all other values remain unchanged and the overall output quality is improved without degrading the high resolution fidelity of the DEM.



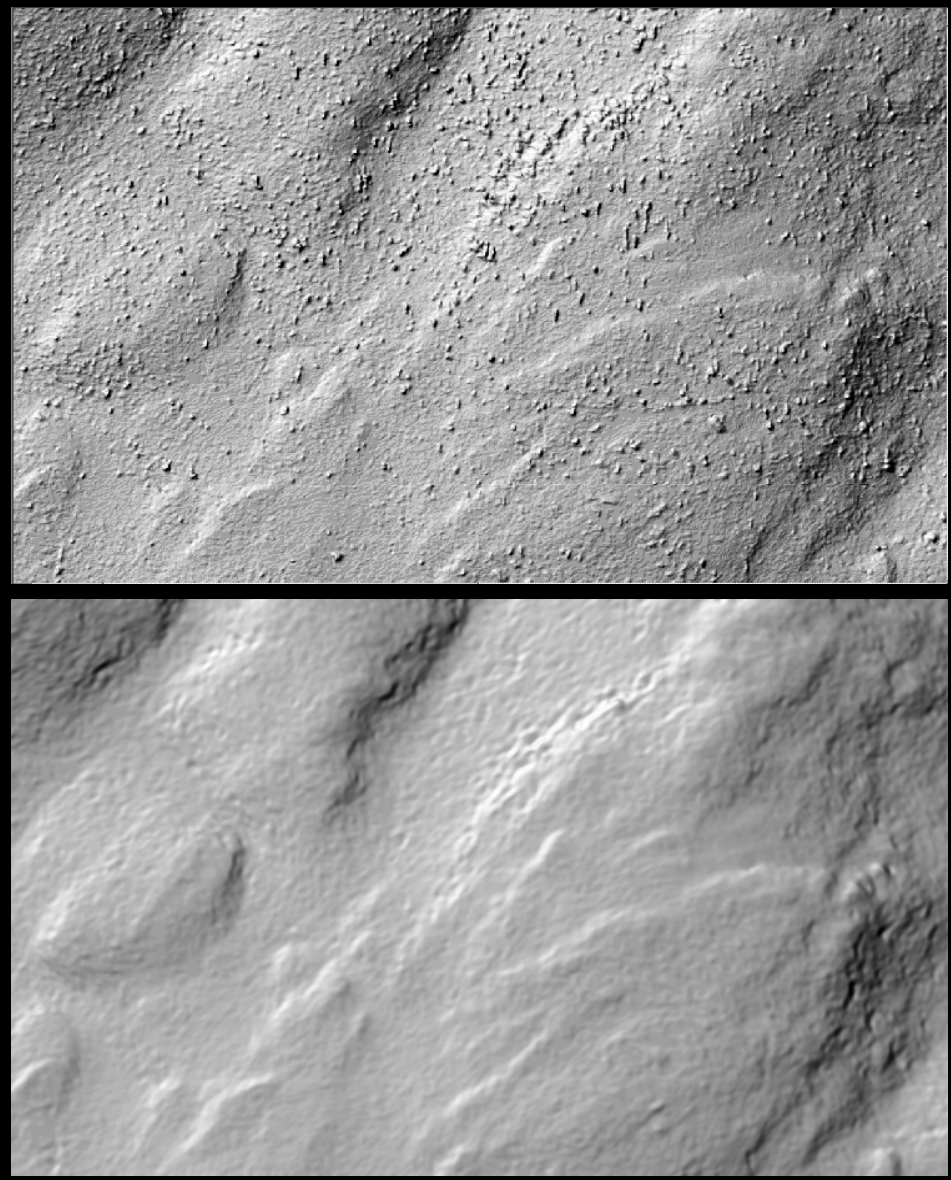
Filter targets and modifies only values outside of threshold

The result is that only elevation values that exceed the defined parameters are replaced; all other values remain unchanged and the overall output quality is improved without degrading the high resolution fidelity of the DEM.



Example: Aerial Photography Derived DEM

Pre-Filter and Post Filter example of photogrammetrically derived DEM (stereo-autocorrelation process) from 1:40,000 scale aerial photographs. Horizontal DEM resolution is 2.3m.

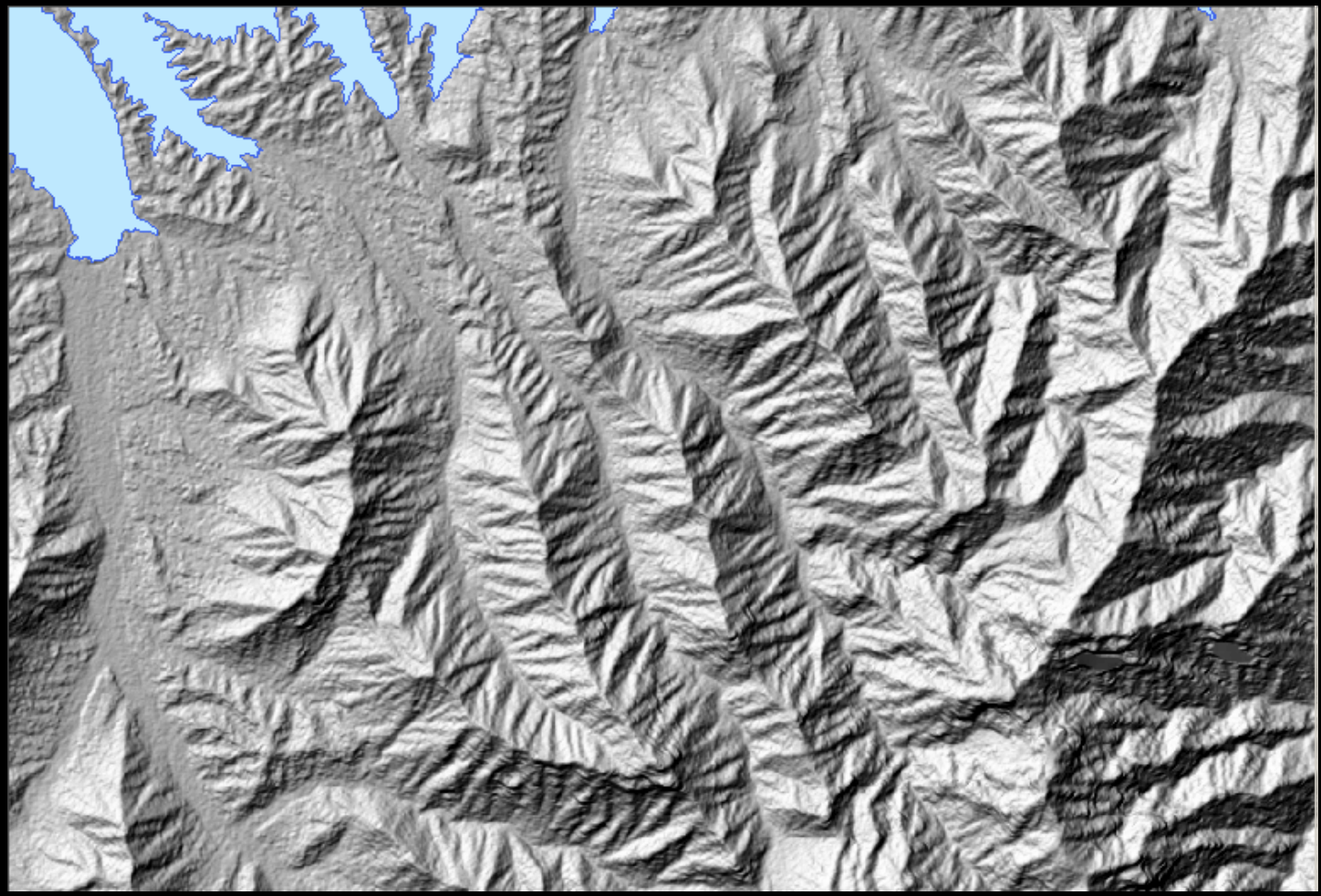


Example: Aerial Photography Derived DEM

PID	ELEVATION	CATOFINAL_M	SQ_DIFF	CATOPRE_M	PRE_SQ_DIFF	USGS_DEM_M	USGS_SQ_DIFF
JV1827	238.2700	237.6980	0.327	237.0000	1.613	236.3190	3.806
JV7213	476.2000	477.0040	0.646	477.0000	0.640	475.7710	0.184
JV4193	573.0000	572.9610	0.002	573.0000	0.000	572.5640	0.190
JV7244	319.9000	319.5040	0.157	319.0000	0.810	319.0730	0.684
JV1824	320.7620	320.6180	0.021	319.0000	3.105	320.6690	0.009
JV1825	257.3580	255.1440	4.902	255.0000	5.560	255.8650	2.229
JV1828	222.1950	222.1910	0.000	223.0000	0.648	216.6630	30.603
		AVG_SQ_DIFF	0.865	1.768			5.386
		RMSE	0.930	1.330			2.321

Pre-Filter and Post Filter examples of RMSEz for the photogrammetrically derived DEM (stereo-autocorrelation process) from 1:40,000 scale aerial photographs. Horizontal DEM resolution is 2.3m.

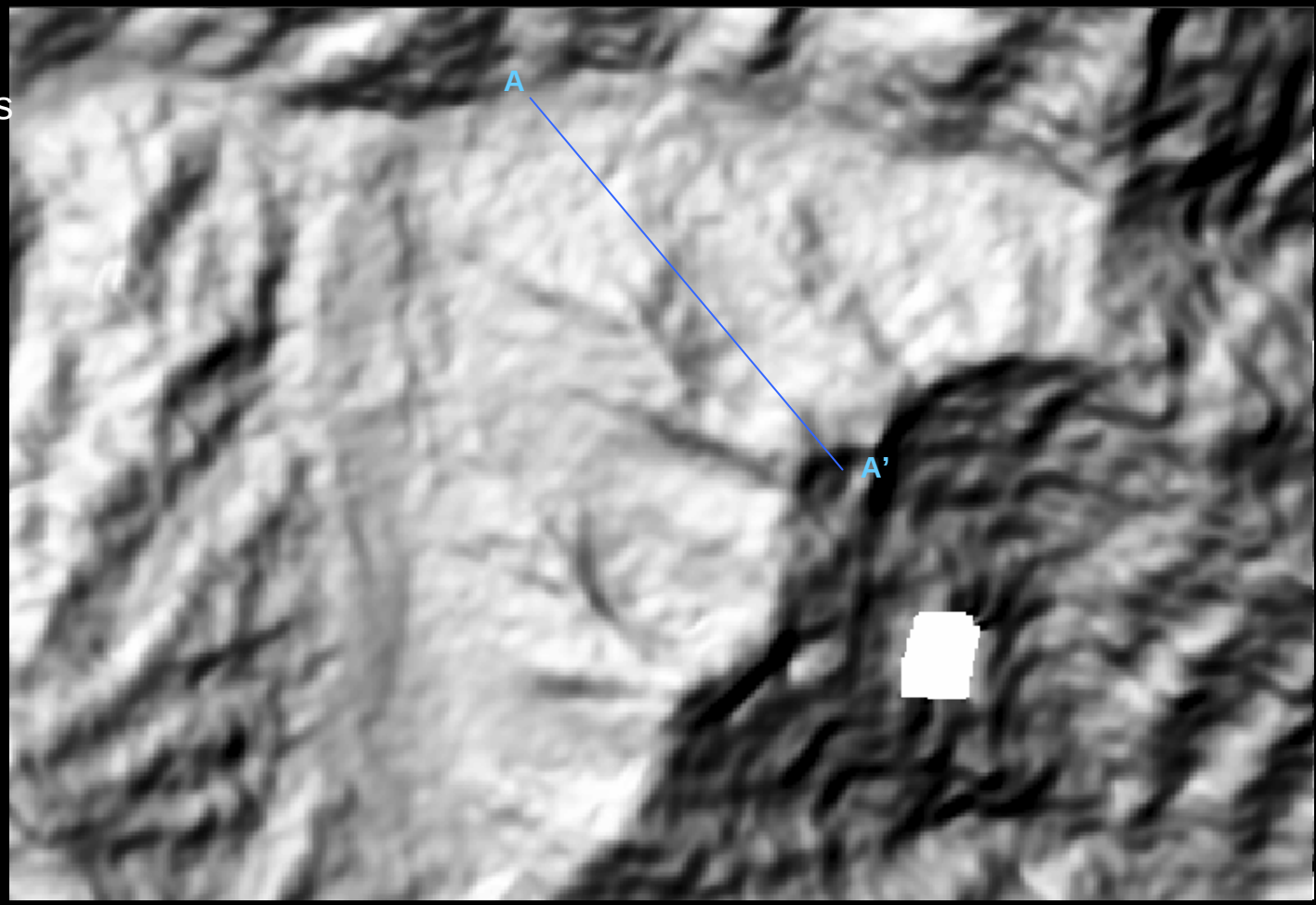
Example: SPOT 5 HRG Derived DEM



ASTER DEMS: Progressive Morphological Filter Development

Low stereo auto-correlation results in “pits and spikes” throughout ASTER DEM.

A progressive morphological filter was developed and applied to edit these values while leaving the remainder of the DEM alone.



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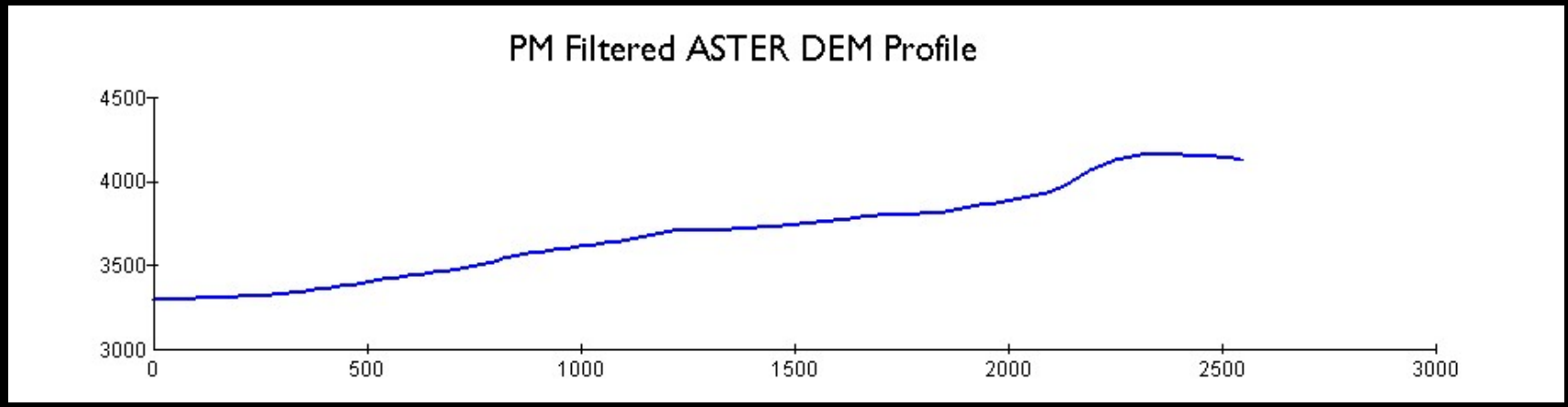
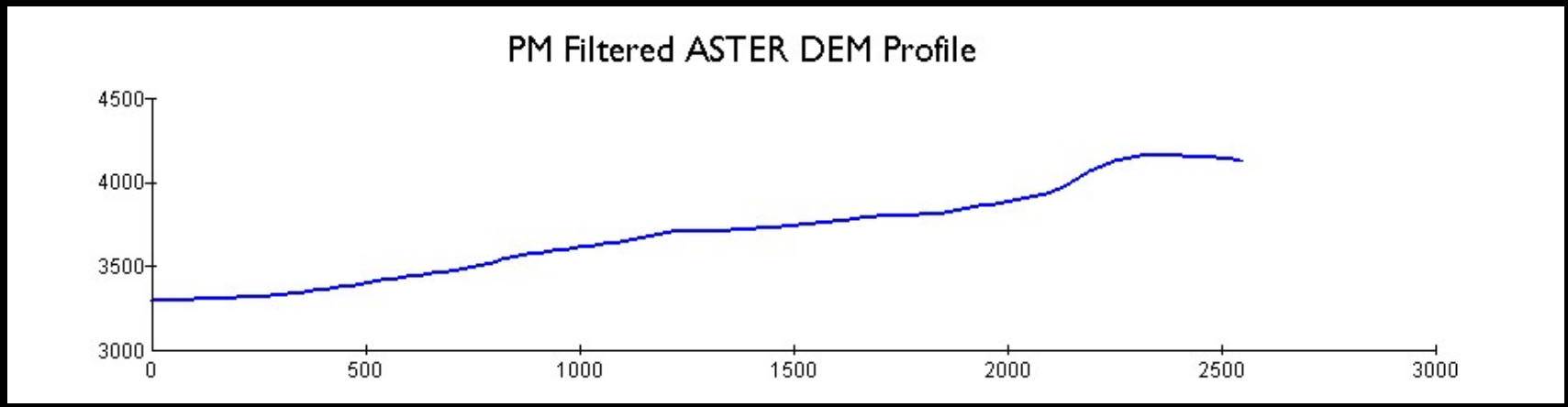
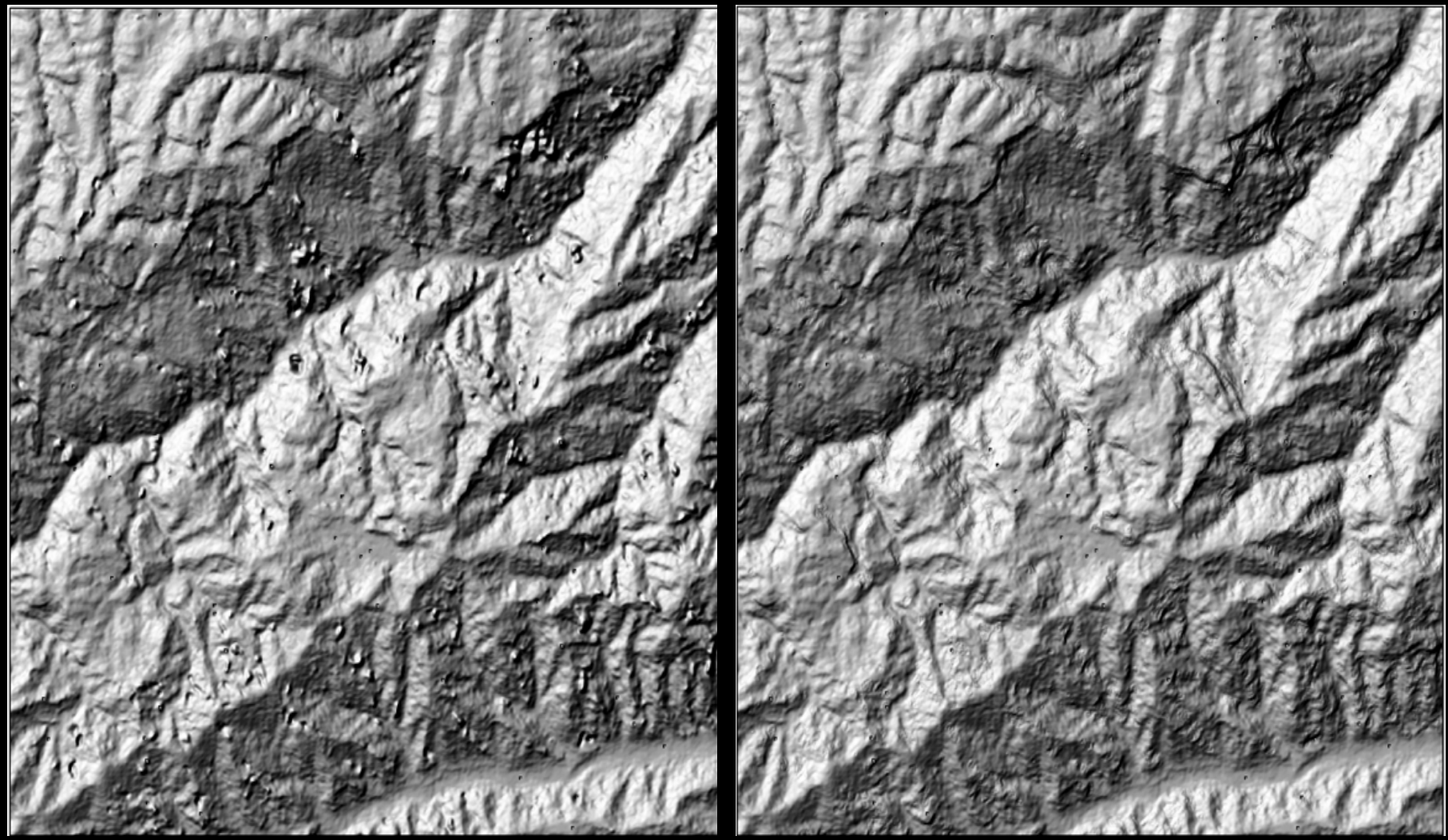




Example: ASTER Derived DEM



Pre and Post-Filter example of absolute ASTER DEM (stereo-autocorrelation process).
Horizontal DEM resolution is 30m.

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CONCLUSION

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