SRTM Void Area Fill Processes Review

Generated by: Greg Grohman, NGA/PRTT
and George Kroenung, NGA/PLM
15 June 05

Introduction

SRTM is an excellent source for the all-important elevation data that is so critical for today's imagery & geospatial analysis. However much of this data is riddled with small holes (called voids) that wreak havoc on the procedures that are attempting to use the data.

We need to fill these voids so we can proceed. Unfortunately the average analyst doesn't have the capability to model this data if he has a fill source to put in the holes. A contract vehicle is filling this data but not fast enough for our needs. We need to generate a process where an analyst can fix his own data for his own needs.

Following is a review of the current fill process, and a new, better way to fill voids…

The State of the Art…

The current state of the void filling art is relatively unchanged over the past several years.

To take a void area of an elevation model, insert the next best available source (perhaps remove a perimeter bias), and then to feather around the edges of the void to make for a better cosmetic fit has been the only way to go. We simply call this the Fill and Feather (FF) method.

Now everything has changed.

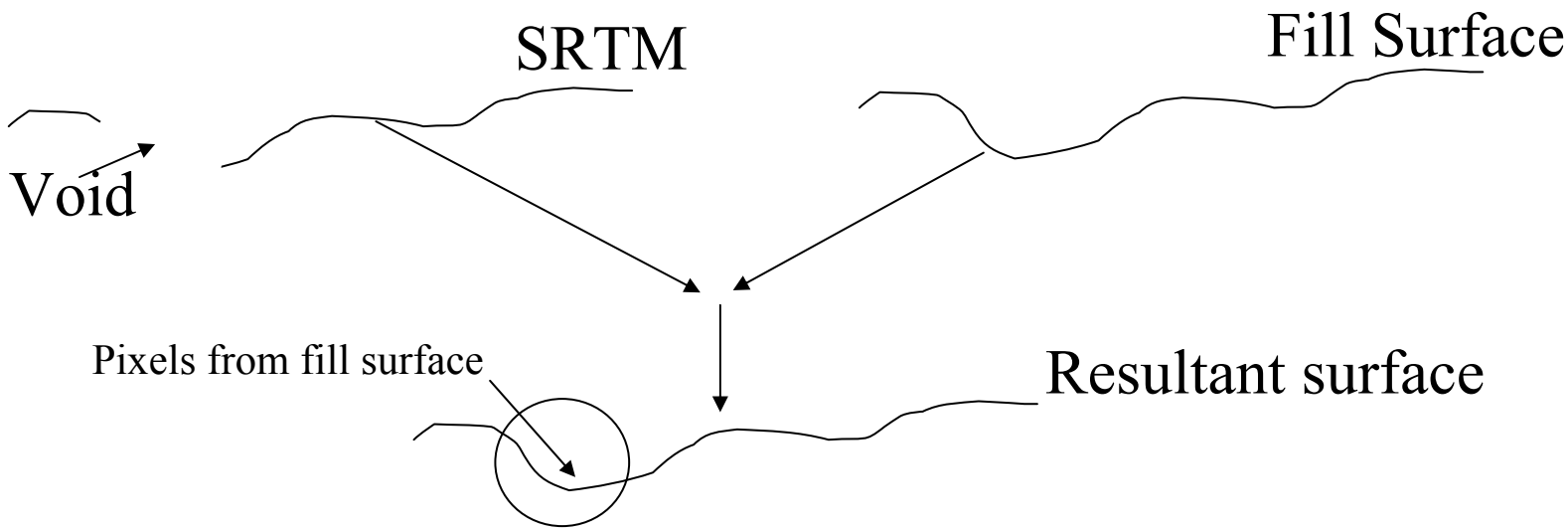
A New Paradigm

Now a new methodology has entered the picture that changes the way we approach this age old problem.

We know we can't simply interpolate across the void.
However we can interpolate the value of the difference between the original surface and the fill, and add those values to the fill surface.
This brings the fill surface up to the original surface in such a way as to better utilize the features in the fill surface around the void area. There will be no need for feathering.

We call this new process the Delta Surface Fill (DSF).

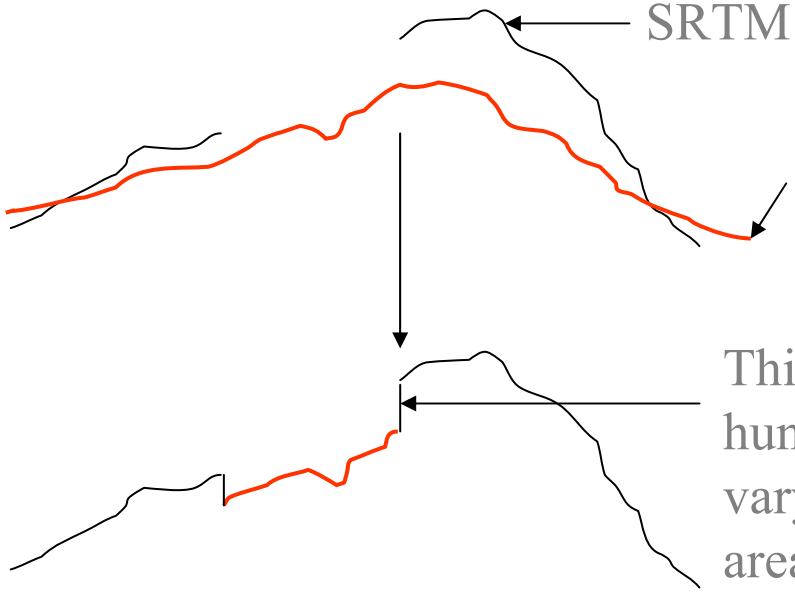
The Current Methodology…



Takes the fill surface and moves pixels to the void area, then "feathers" the void edges so the resultant surface looks nicer.

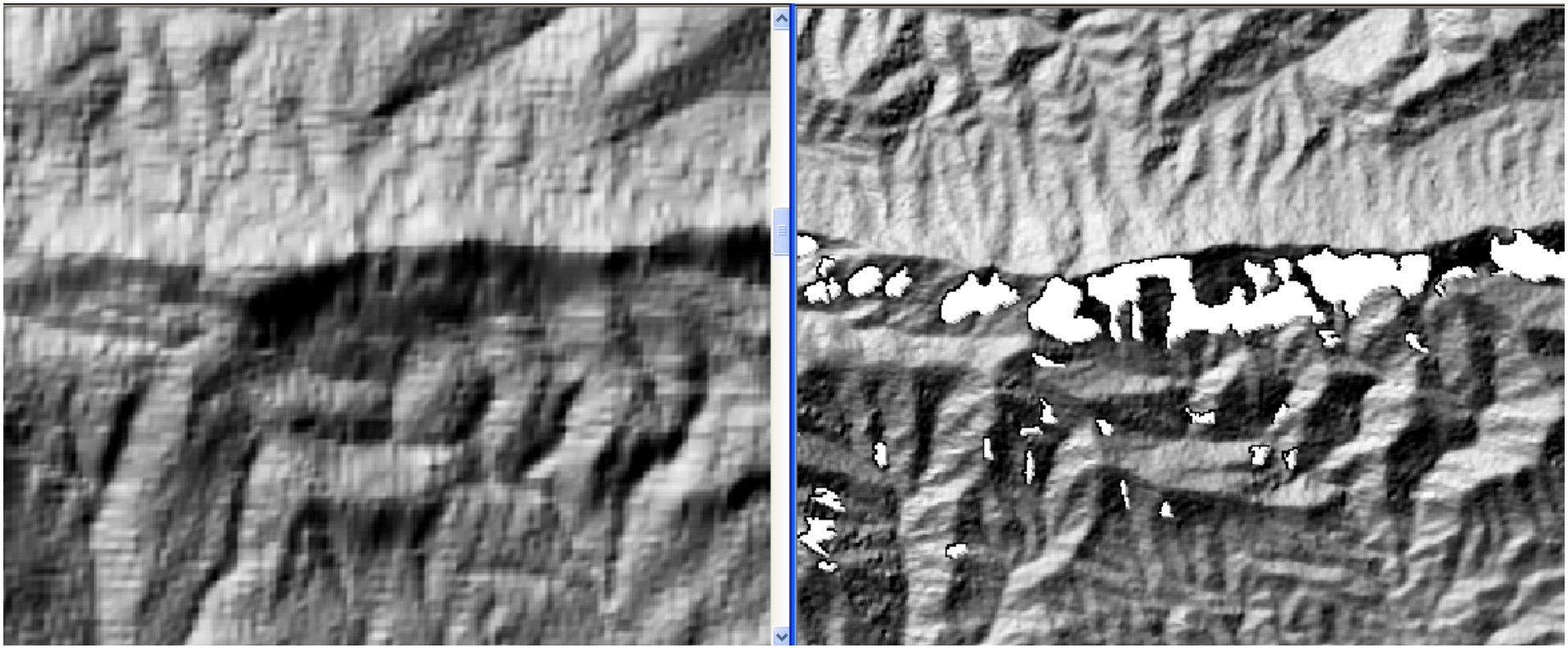
This works nicely when the 2 surfaces are close together and are consistent, with little horizontal or vertical separation (delta) or undulation.

How This Methodology is Challenged…



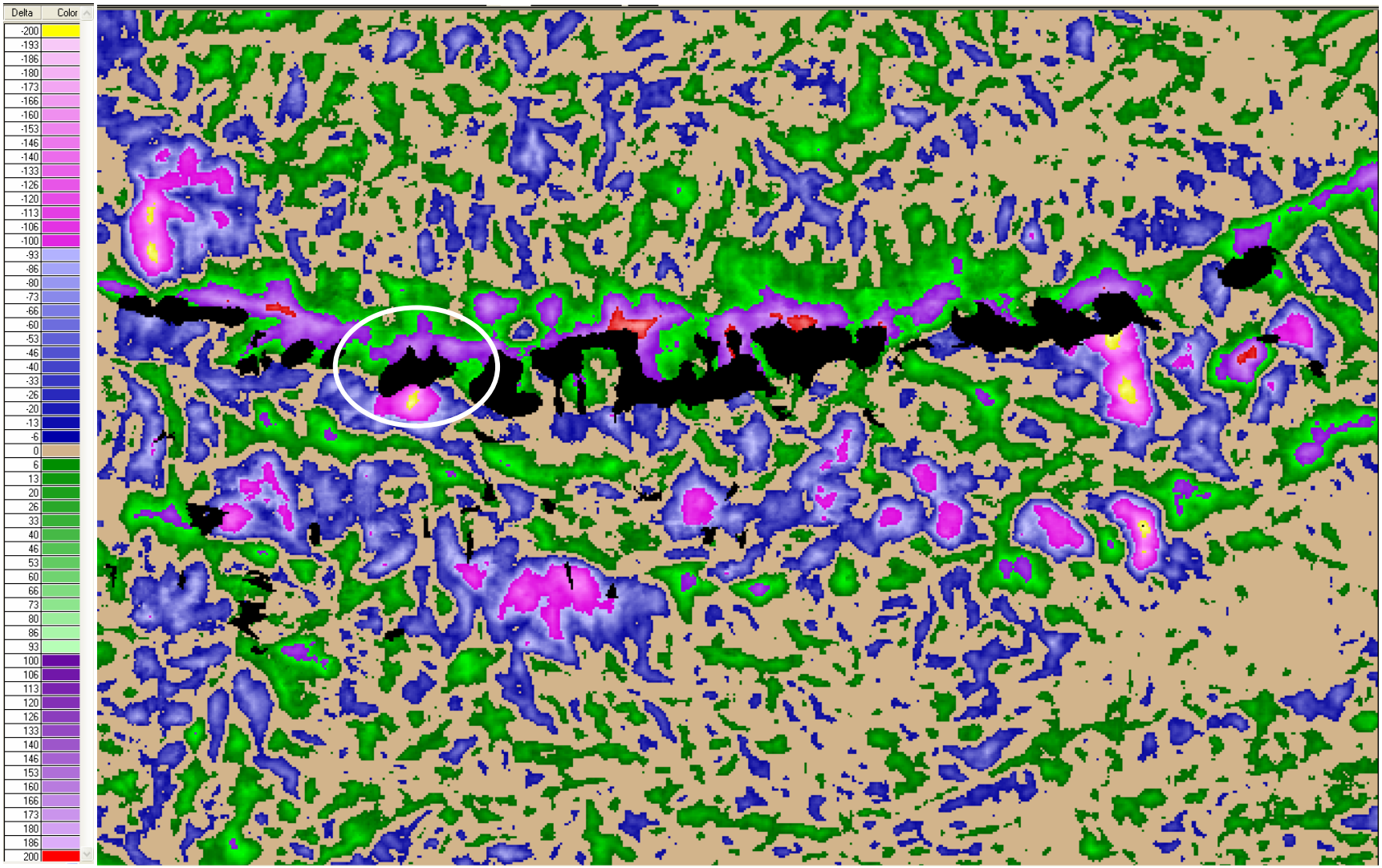
Feathering will be hard pressed to make a proper surface out of these situations, even if the fill surface is somehow lifted (Current contract vehicle does a void-edge mean-based shift.) The artifacts at these void interfaces makes these areas almost unusable in some cases.

Shaded Relief of Densified DTED®1 Data And SRTM with Voids

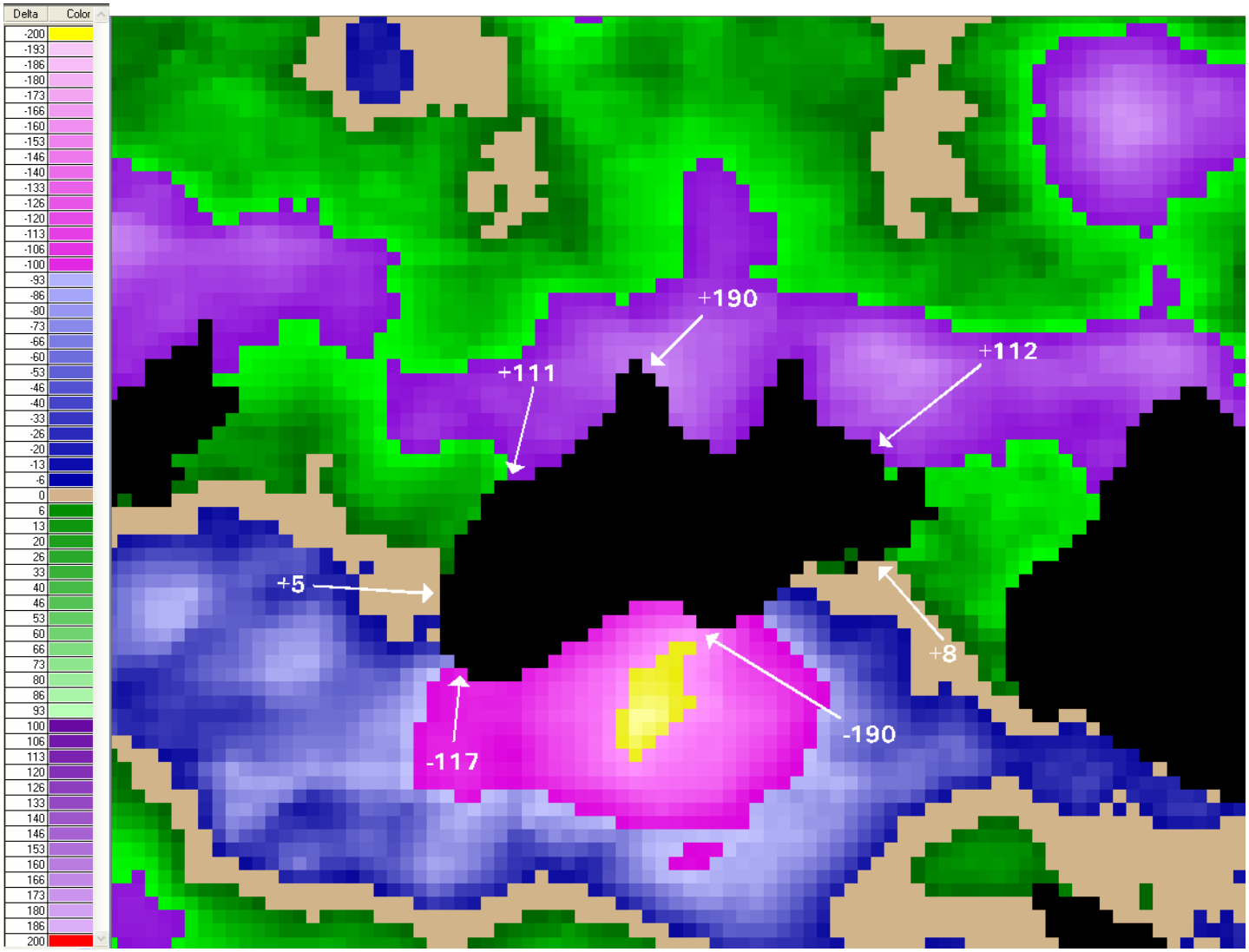


Is there useful data here?

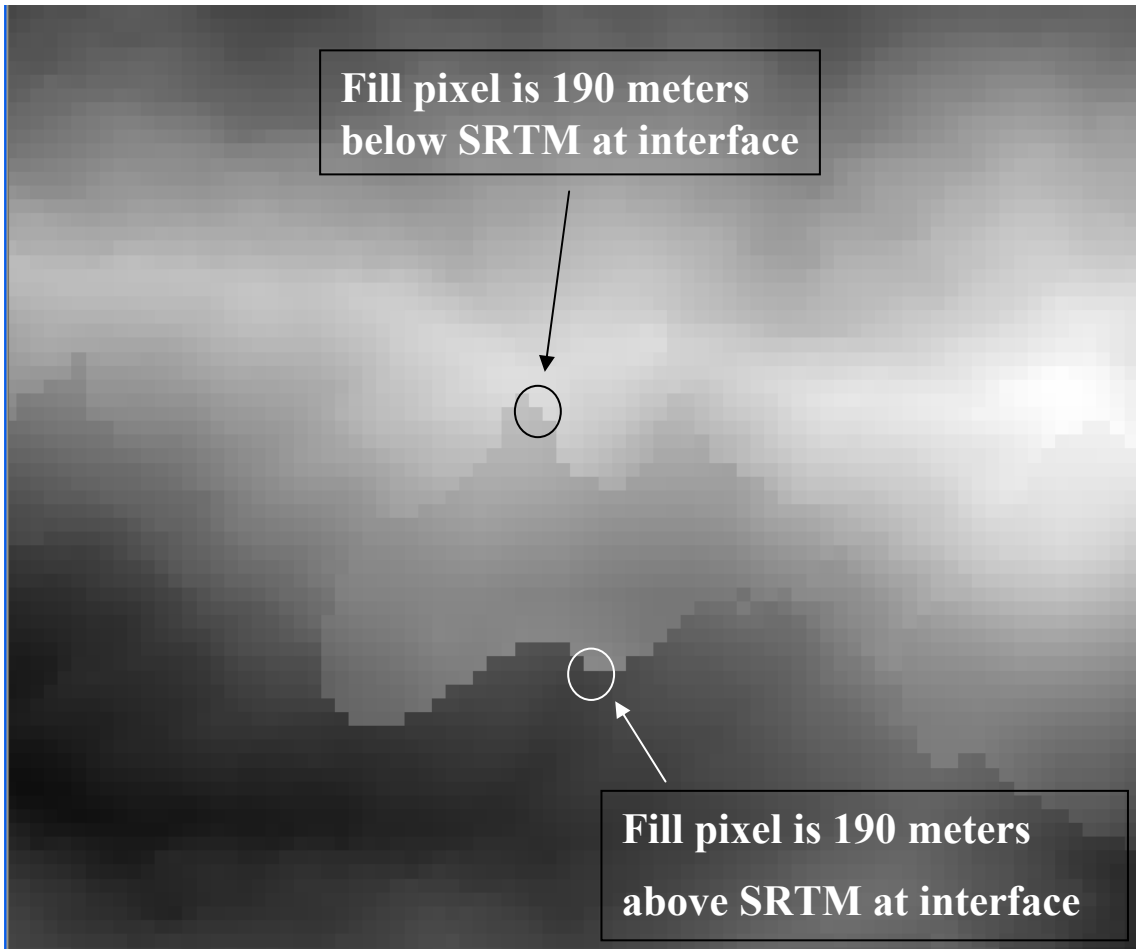
The Delta Surface Showing How the Two Surfaces Vary



The Delta Between SRTM and Densified DTED®1 Around a Particular Void



Current Method Will Require Extensive Feathering to Smooth the Transition from SRTM to Fill Surface

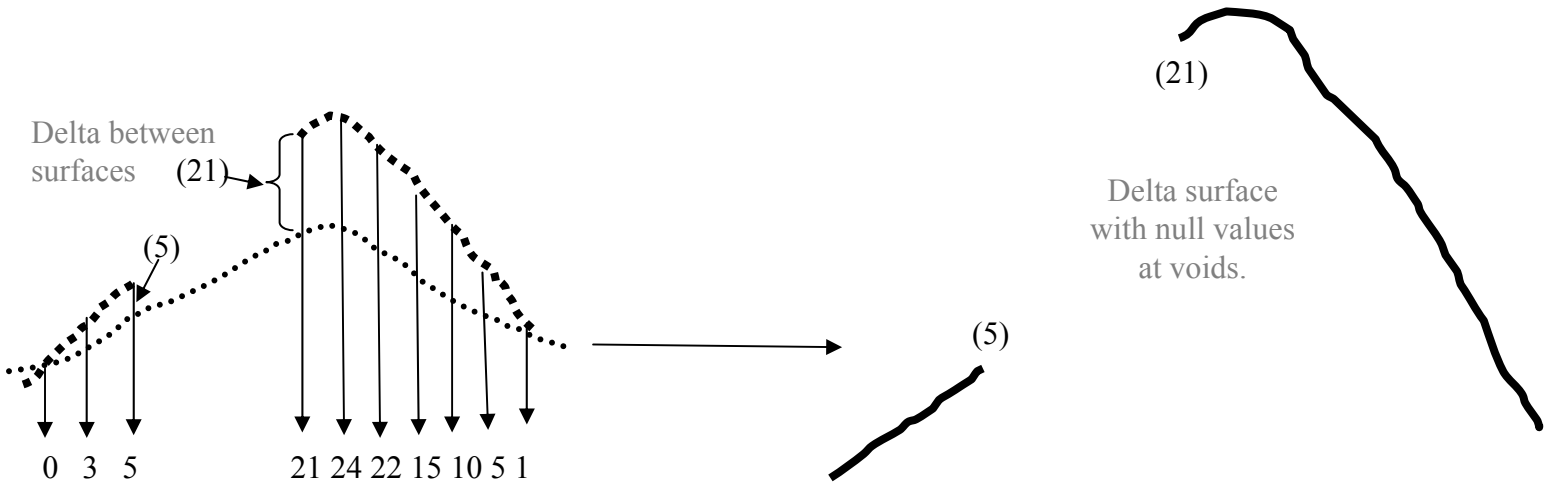


Result will be unacceptable for orthorectification and other uses

We require a process that will "warp" the densified fill surface into place in the SRTM yet conserve the useful data it contains. We trust the SRTM more than the fill source so we need to fit the fill to it.

We know we can't interpolate the SRTM with any kind of accuracy, but we CAN interpolate the surface that is created by the difference between it and the fill (AKA "Delta Surface").

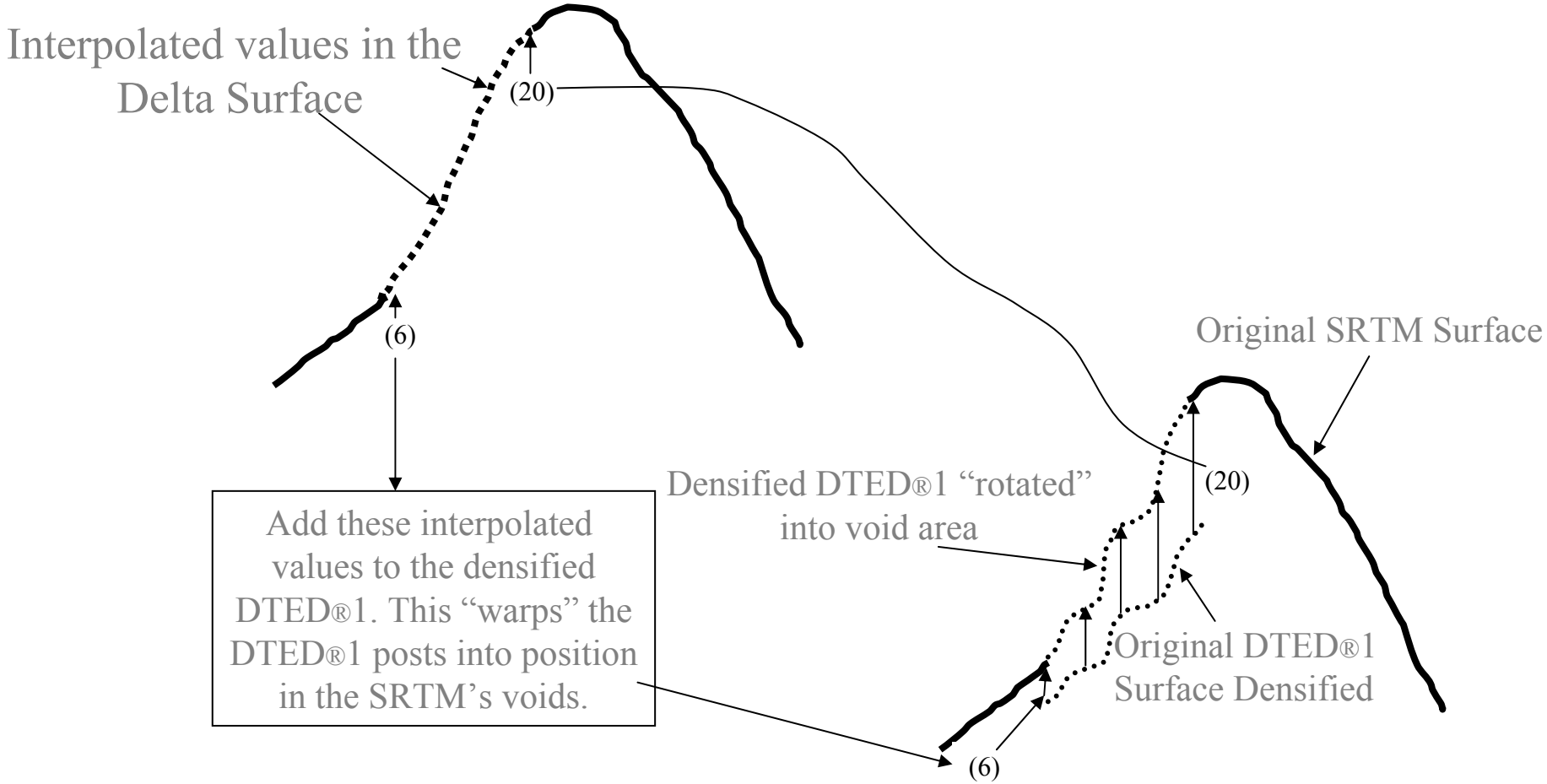
Find the Separation Between the SRTM and the Fill Source at Every Post



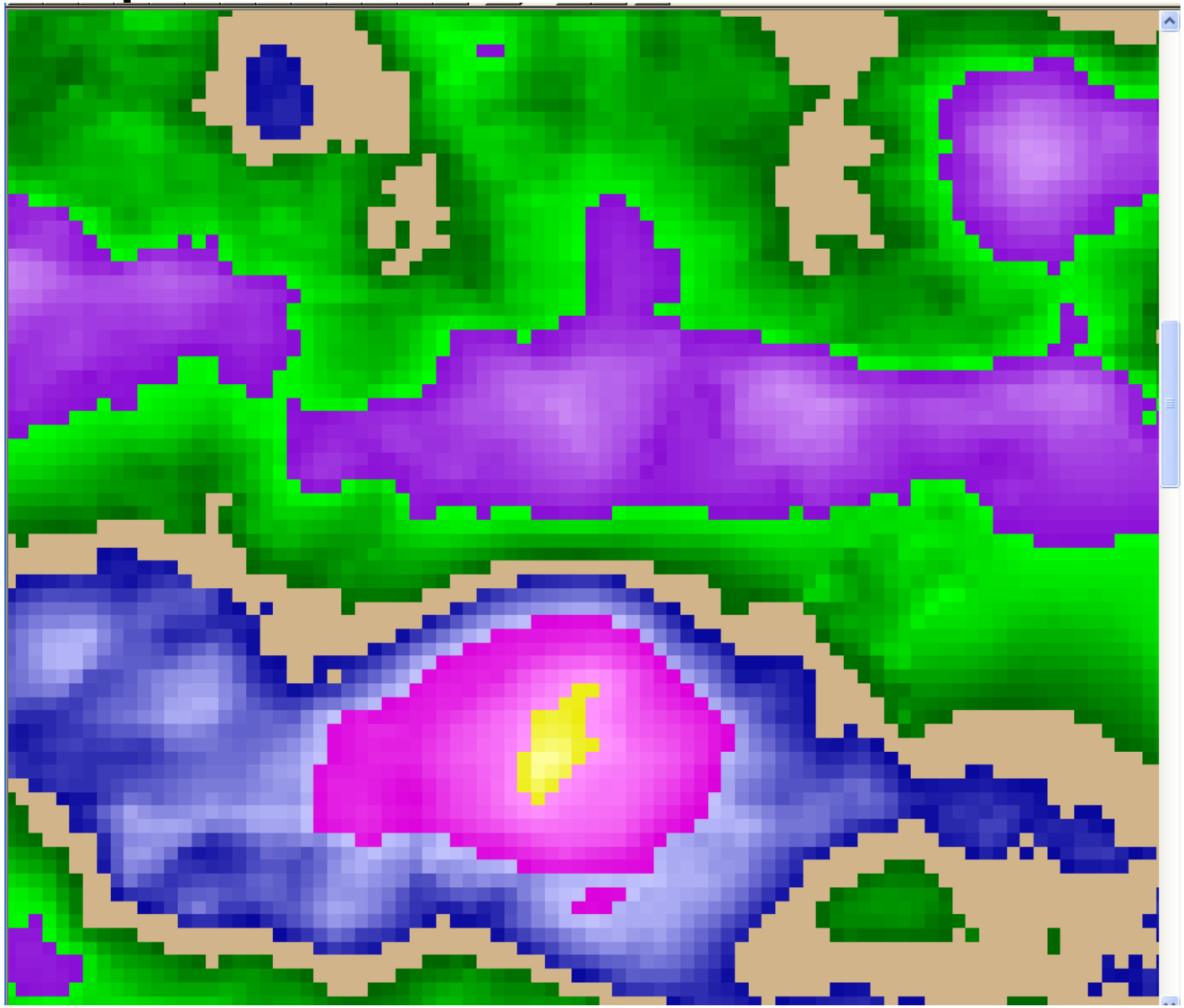
… By definition, the delta's value, when added to the DTED®'s, will equal the value of the SRTM at that post.

SRTM – DTED®1 = delta; delta + DTED®1 = SRTM

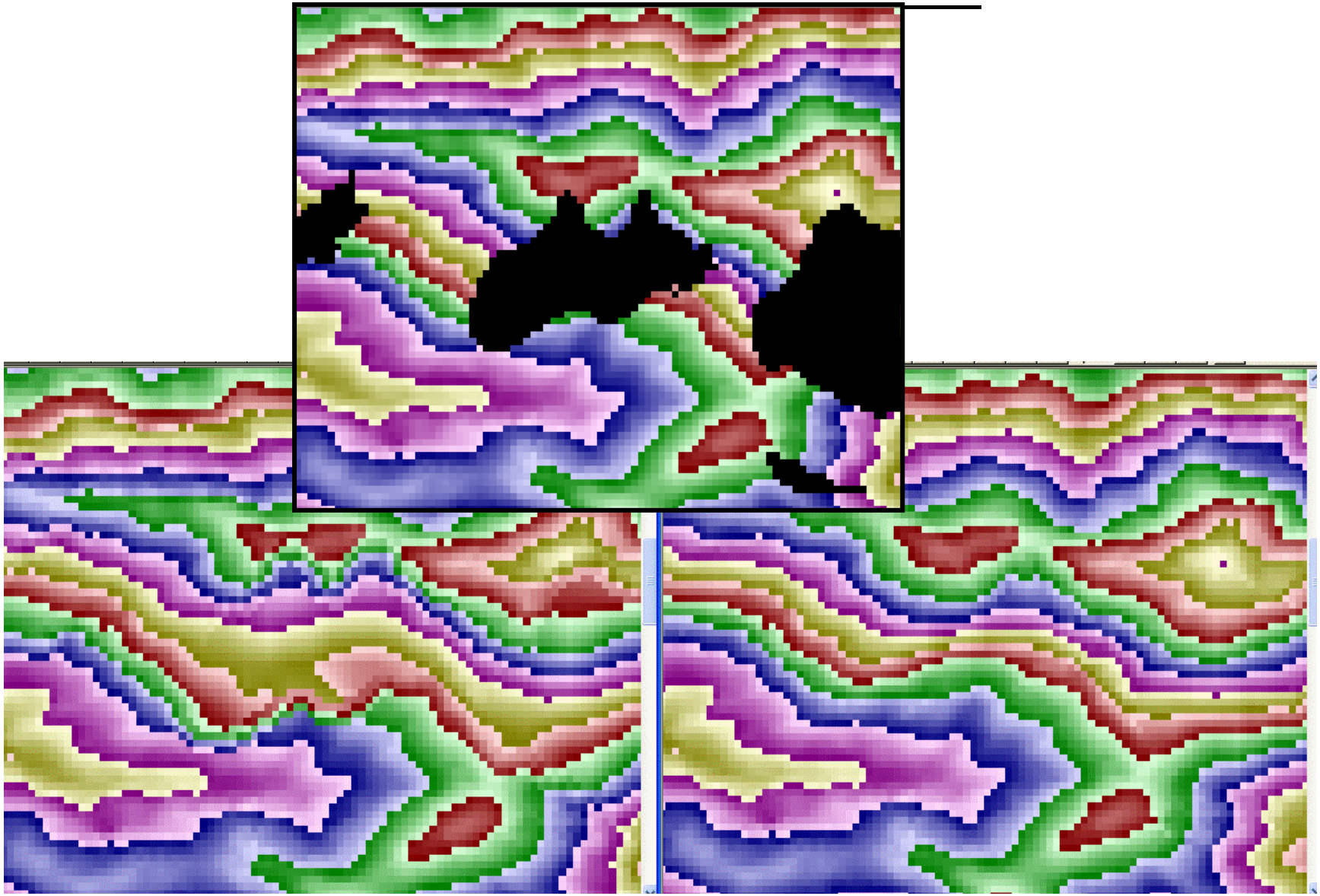
Add the Interpolated Delta Values to the Densified DTED®1 at Every Post in Void



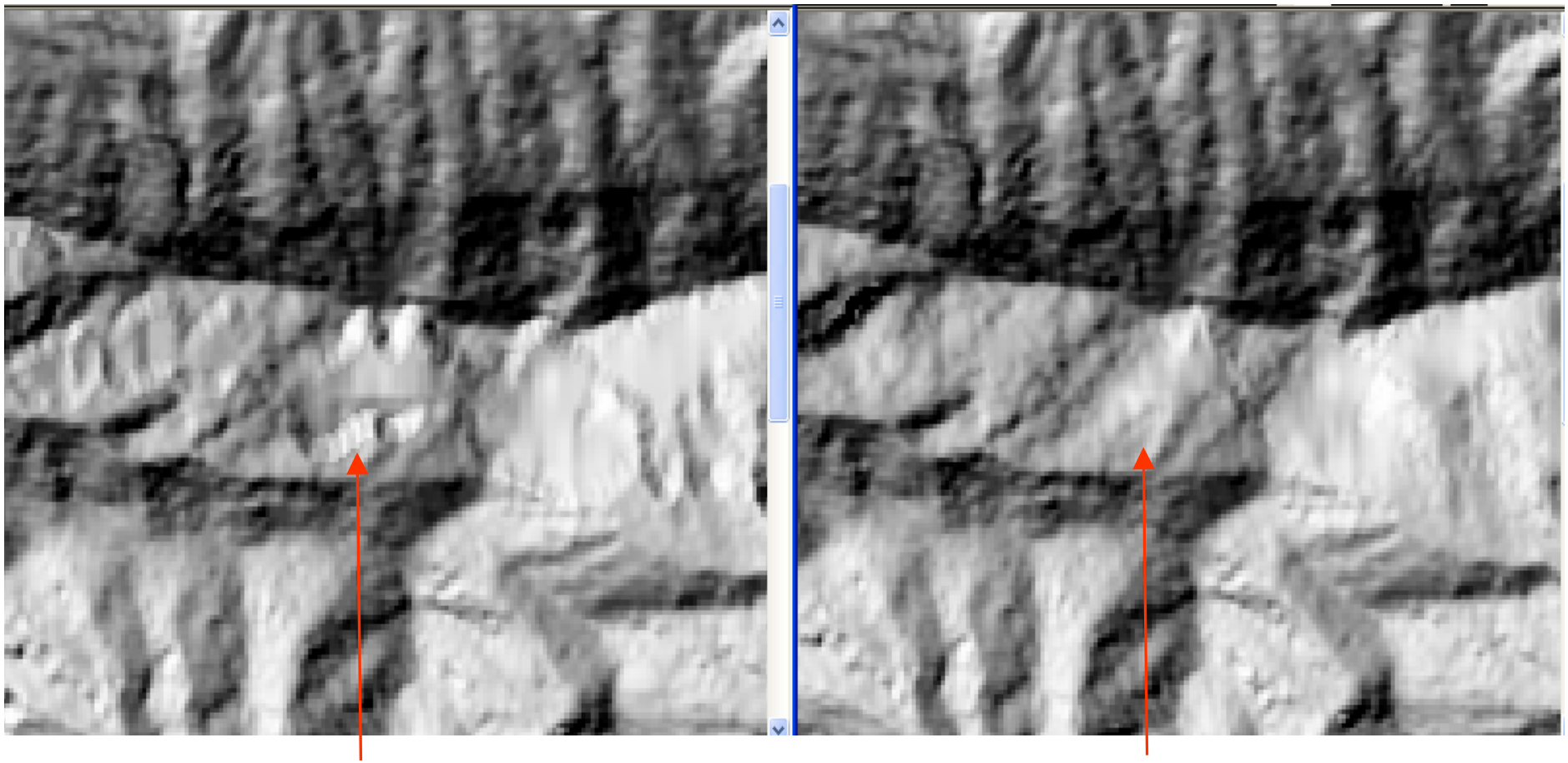
Interpolated Delta Values Across Voids



Color Contours of FF and DSF SRTM



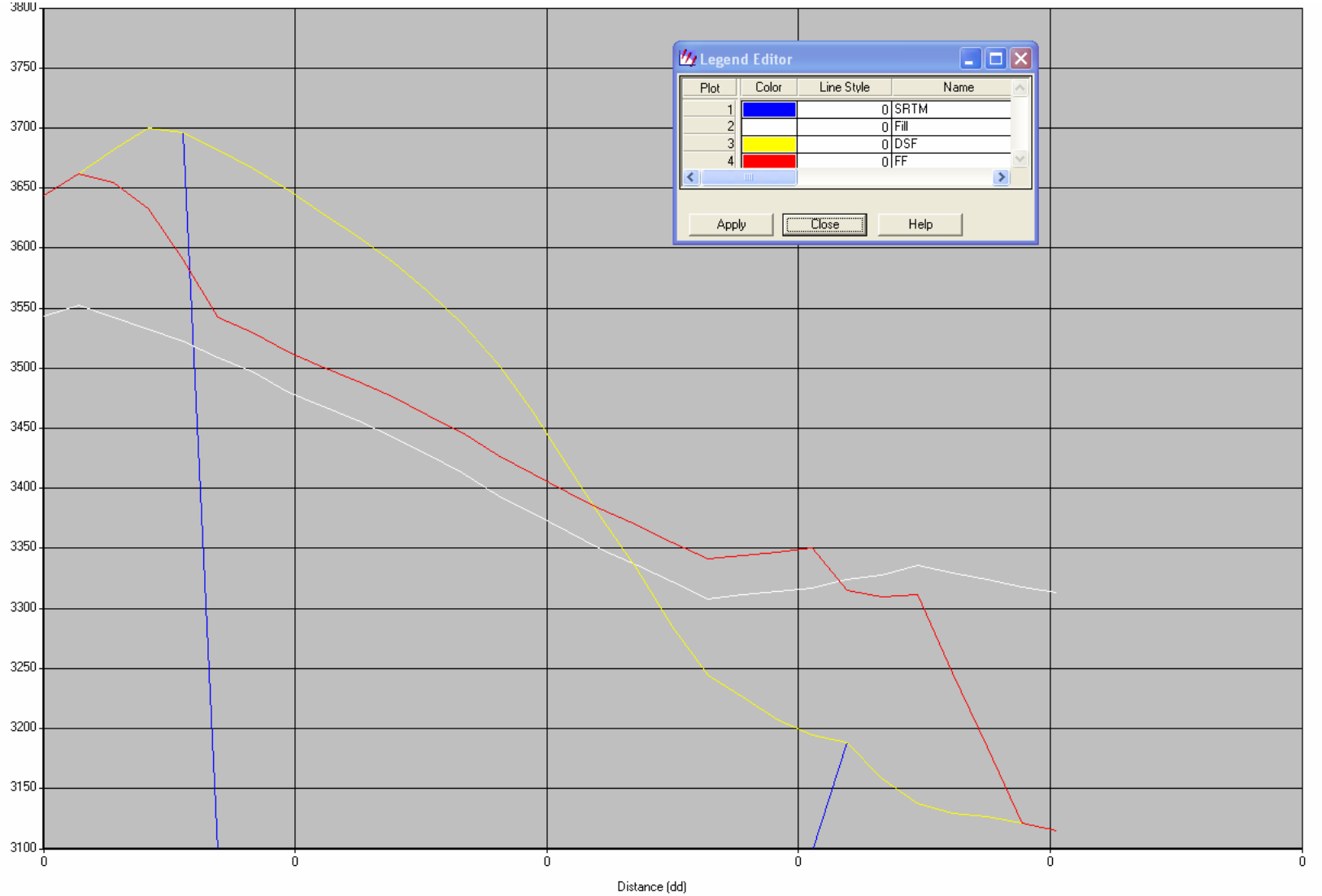
Shaded Relief of Fixed SRTM



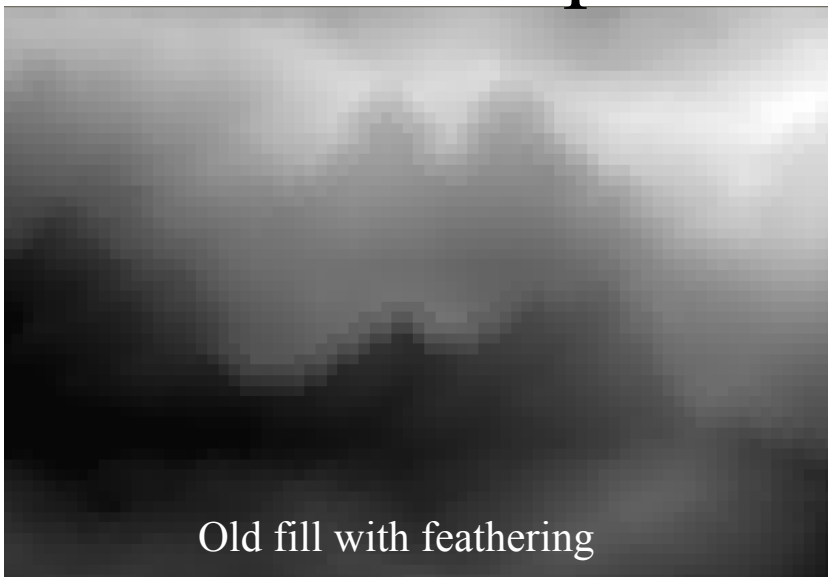
FF: Notice Feather Region

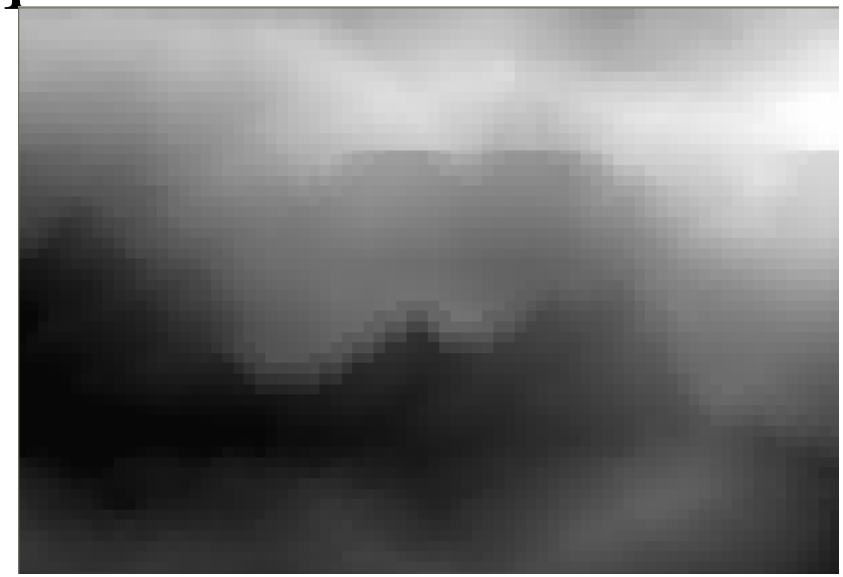
DSF: Fill blends in

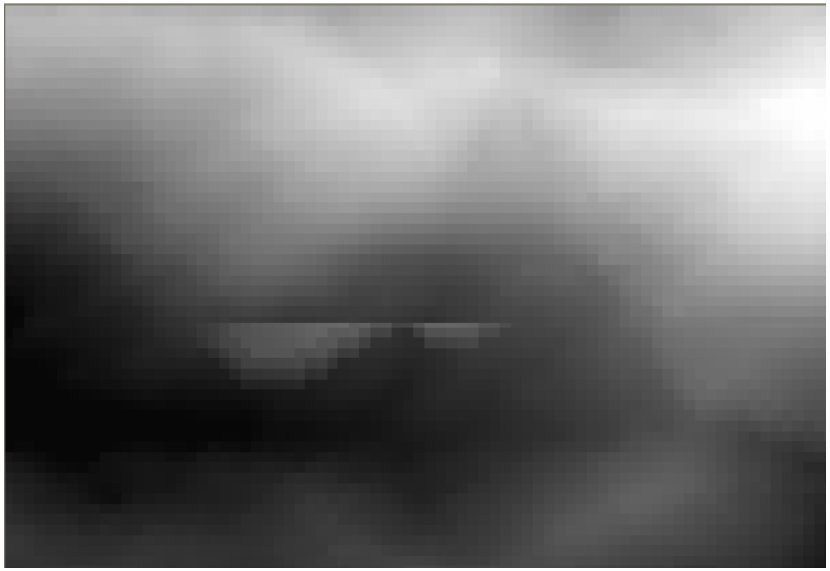
Profile of Fixed SRTM

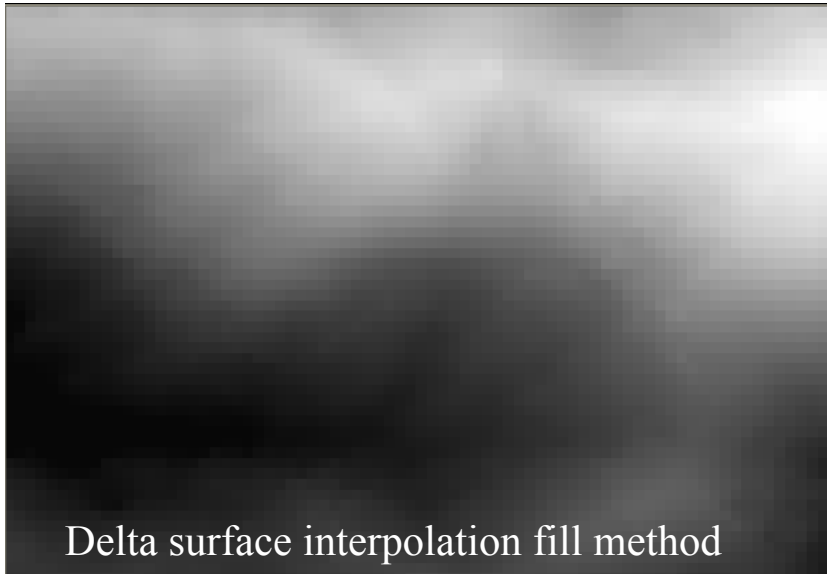


Vertical Swipe Comparison of the 2 methods







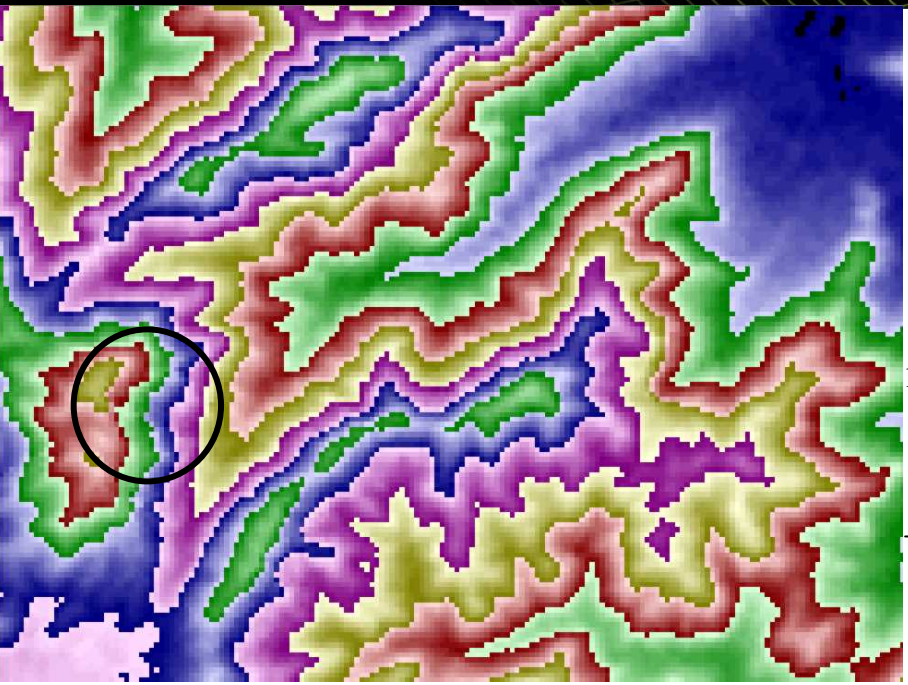


Process Test Methodology

We wish to test the two processes against each other to get statistics on them over the same areas.

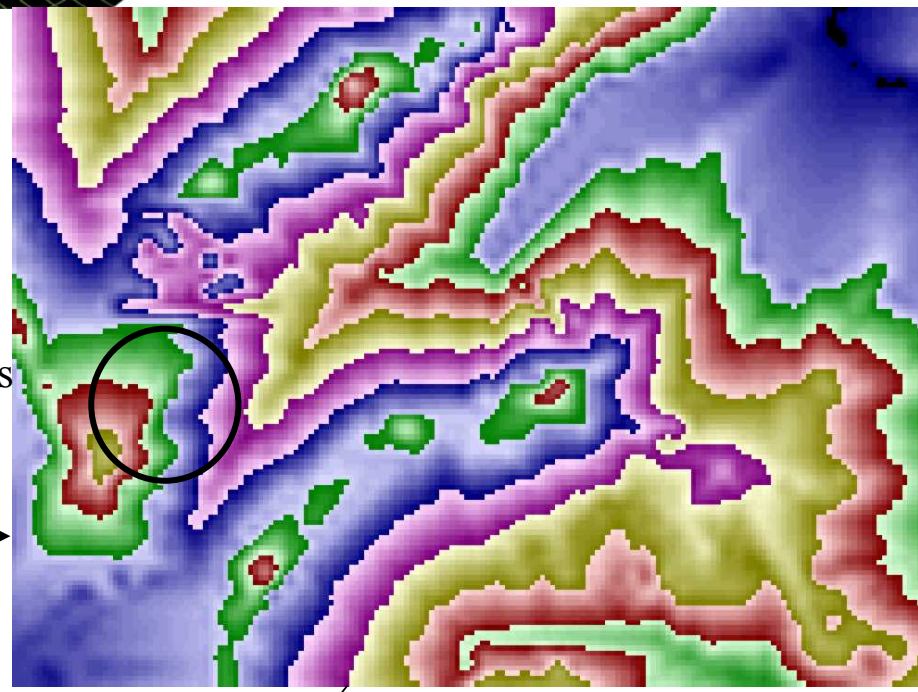
We will start by taking areas with known data and removing areas to create artificial voids that typify real-world examples. We will then fill these voids using both methods and compare them back to the original.

As a further analysis, we will break down the statistics into regions of the voids; those being the first 10 posts into the void, the remaining posts in the void, and all the void taken as a whole.



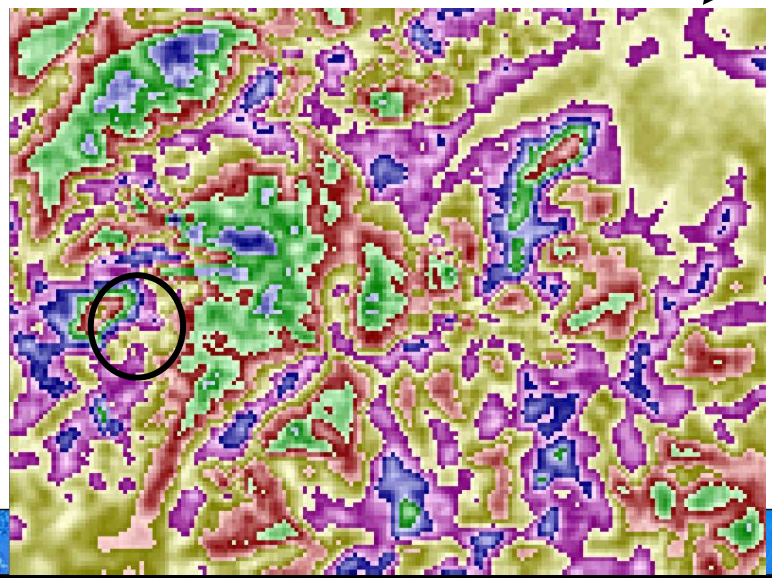
SRTM

minus



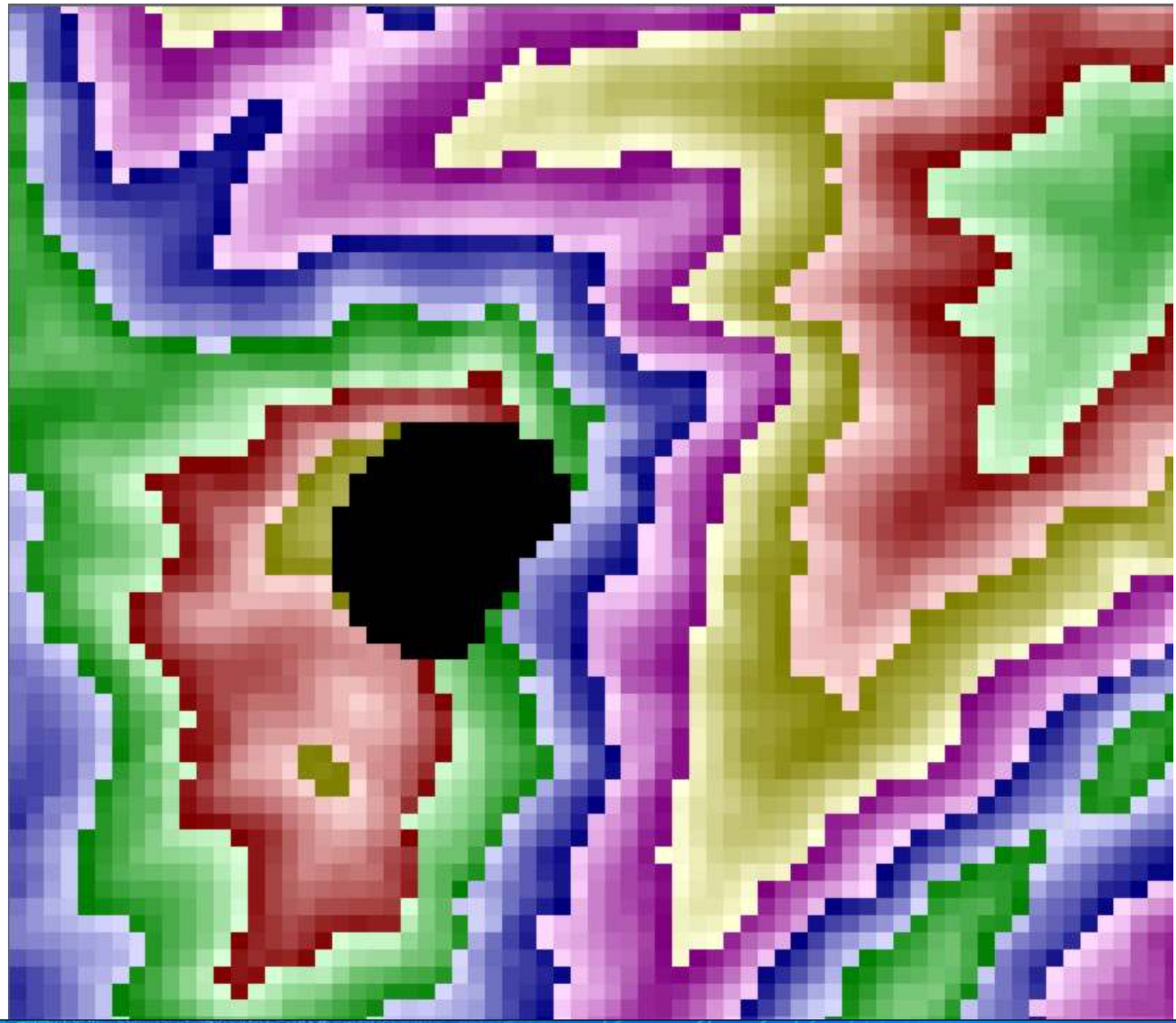
Densified DTED®1

// equals

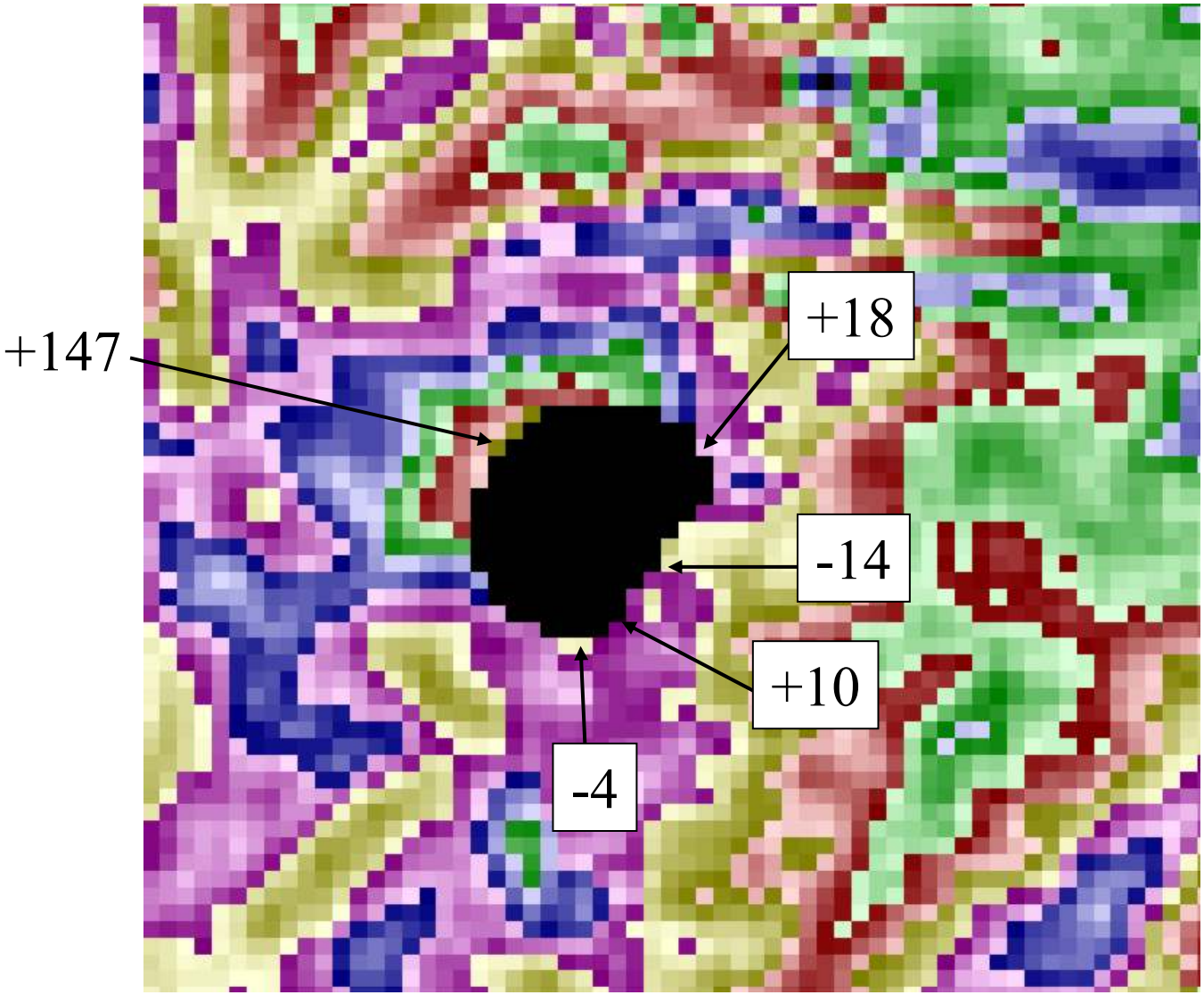


Delta Surface

The Test Void Area in the SRTM Data



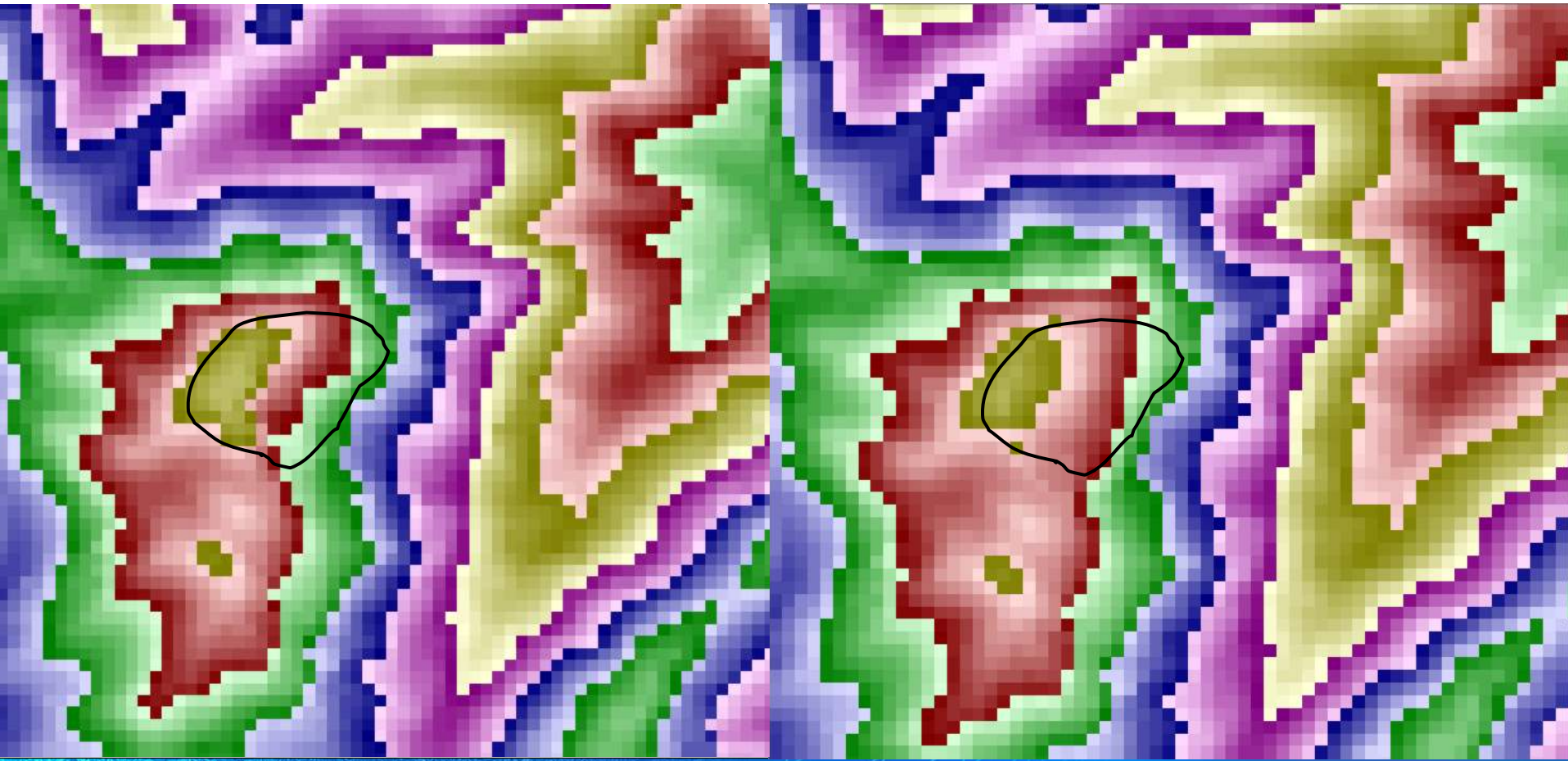
The Test Void Area in the Delta Surface



Original SRTM data with void outlined, next to DSF result

SRTM

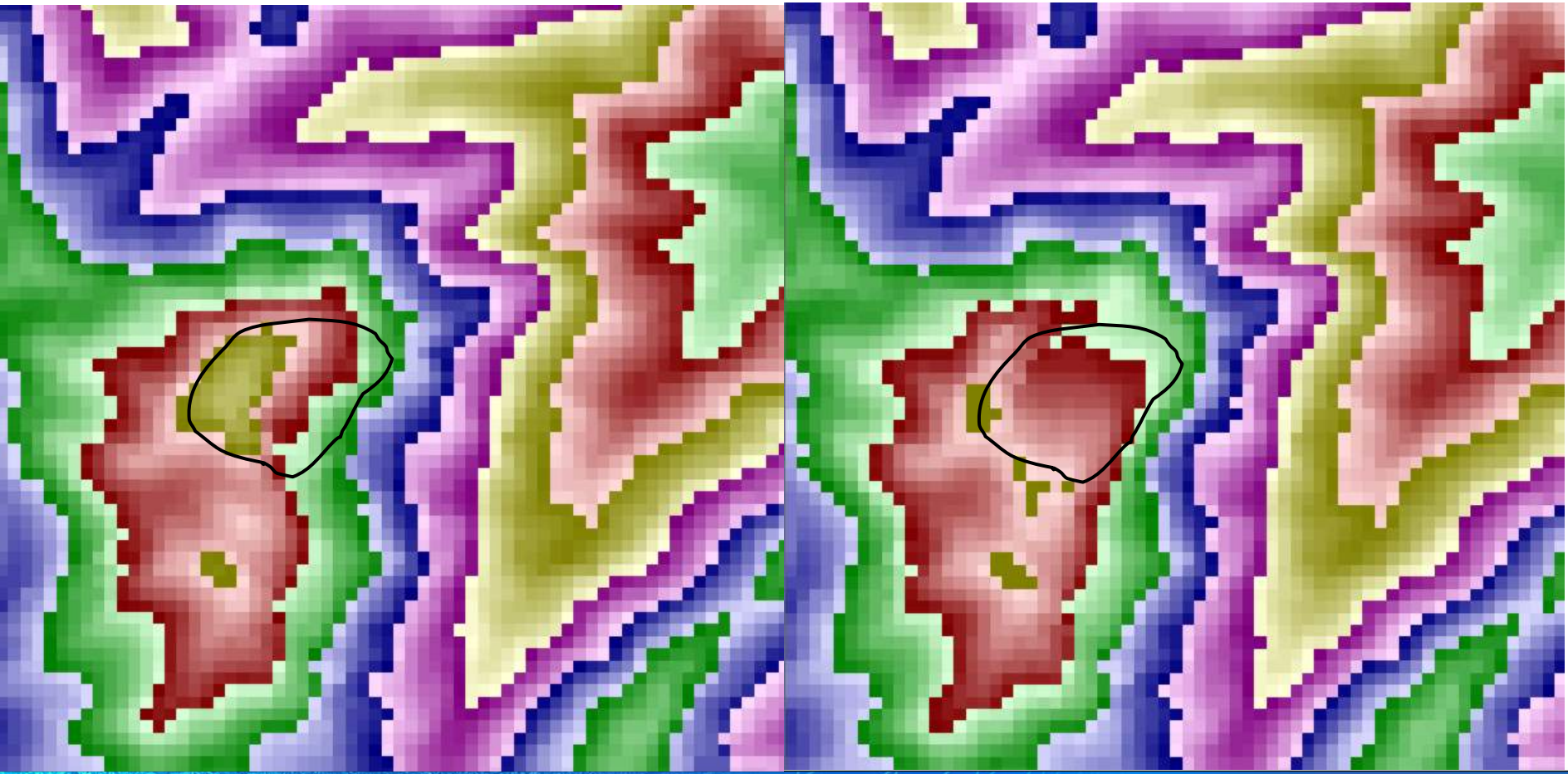
Delta Surface Filled SRTM



Original SRTM next to old void fill&feather result

SRTM

Fill&feather (VF) result



Statistical Results from this Test

Process: DSF

min: -45	max: 40	std dev: 20.6
		2 sigma: 34.0

Process: FF

min: -79	max: 102	std dev: 53.2
		2 sigma: 87.8

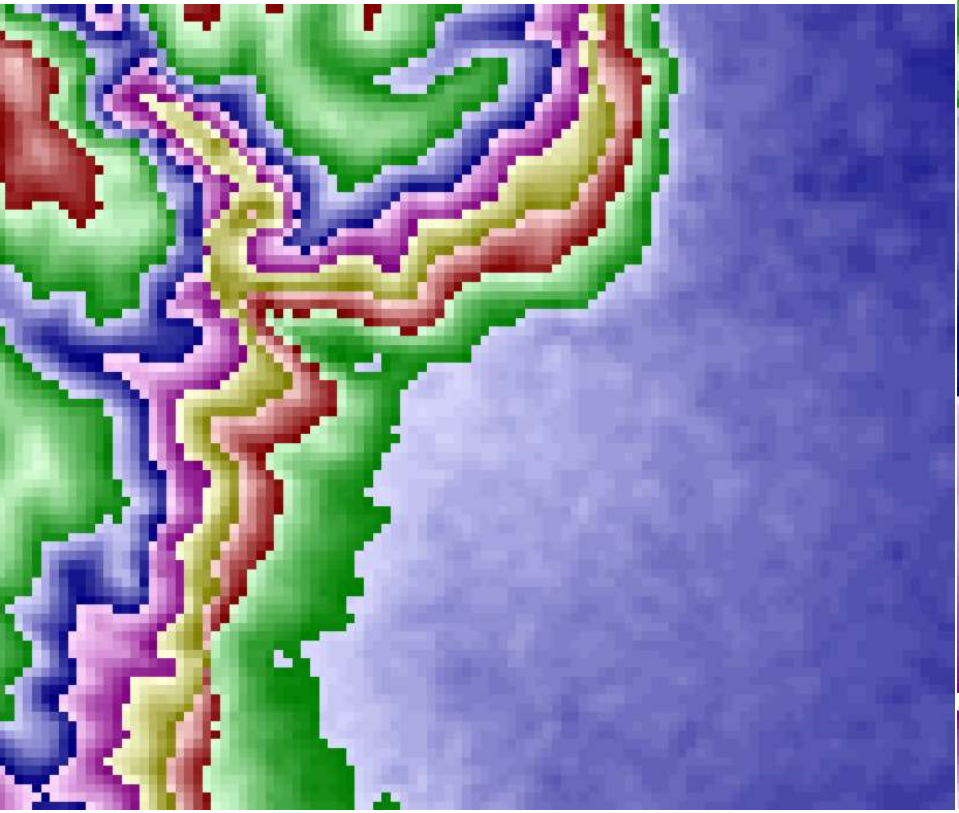
Results of delta of all pixels within void fill area

We can see in this test that the DSF method is superior both cosmetically and statistically.

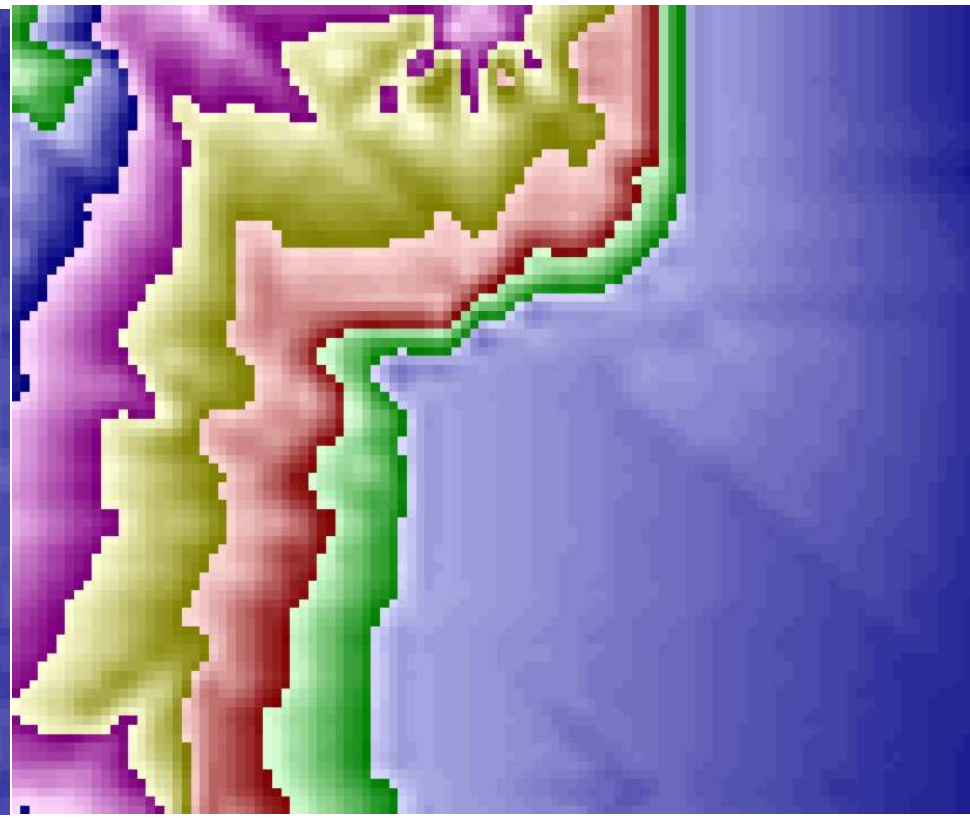
Results from other test areas…

Note the smoothing of the DTED®1
with respect to the SRTM

SRTM



Densified DTED®1



SRTM

Results:
DSF: min: -36; max:66
Sigma:19.7
FF: min: -95; max:118
Sigma:61.5

DSF

FF

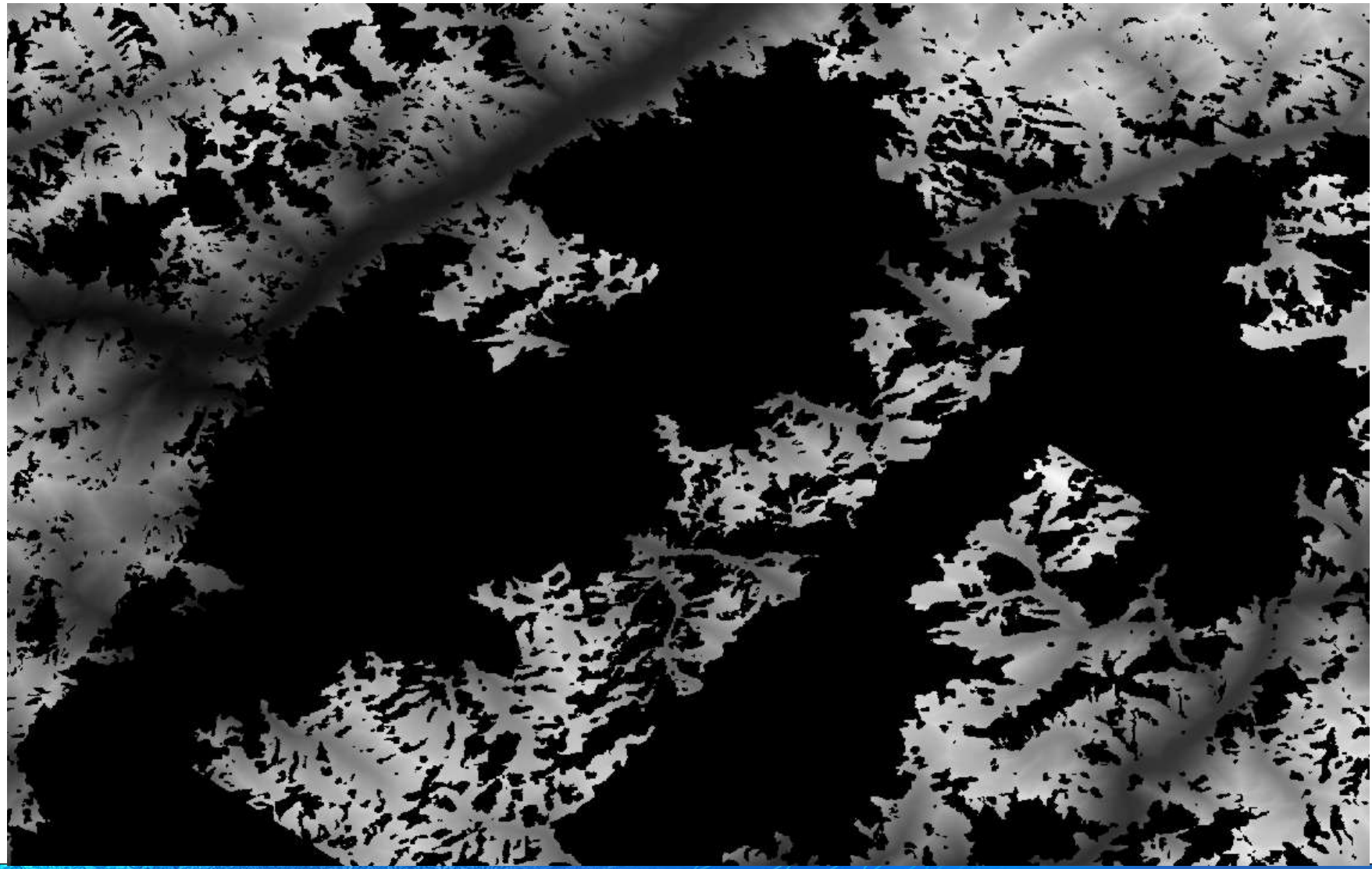
DSF has "tilted" The DTED®1 into place

- Due to the continuous nature of terrain data, this process works very well at the edges of voids. Small to medium voids fill wonderfully. As we get far away from the edges our confidence in the interpolated delta, or 'just what to add to the DTED®1', lessens.

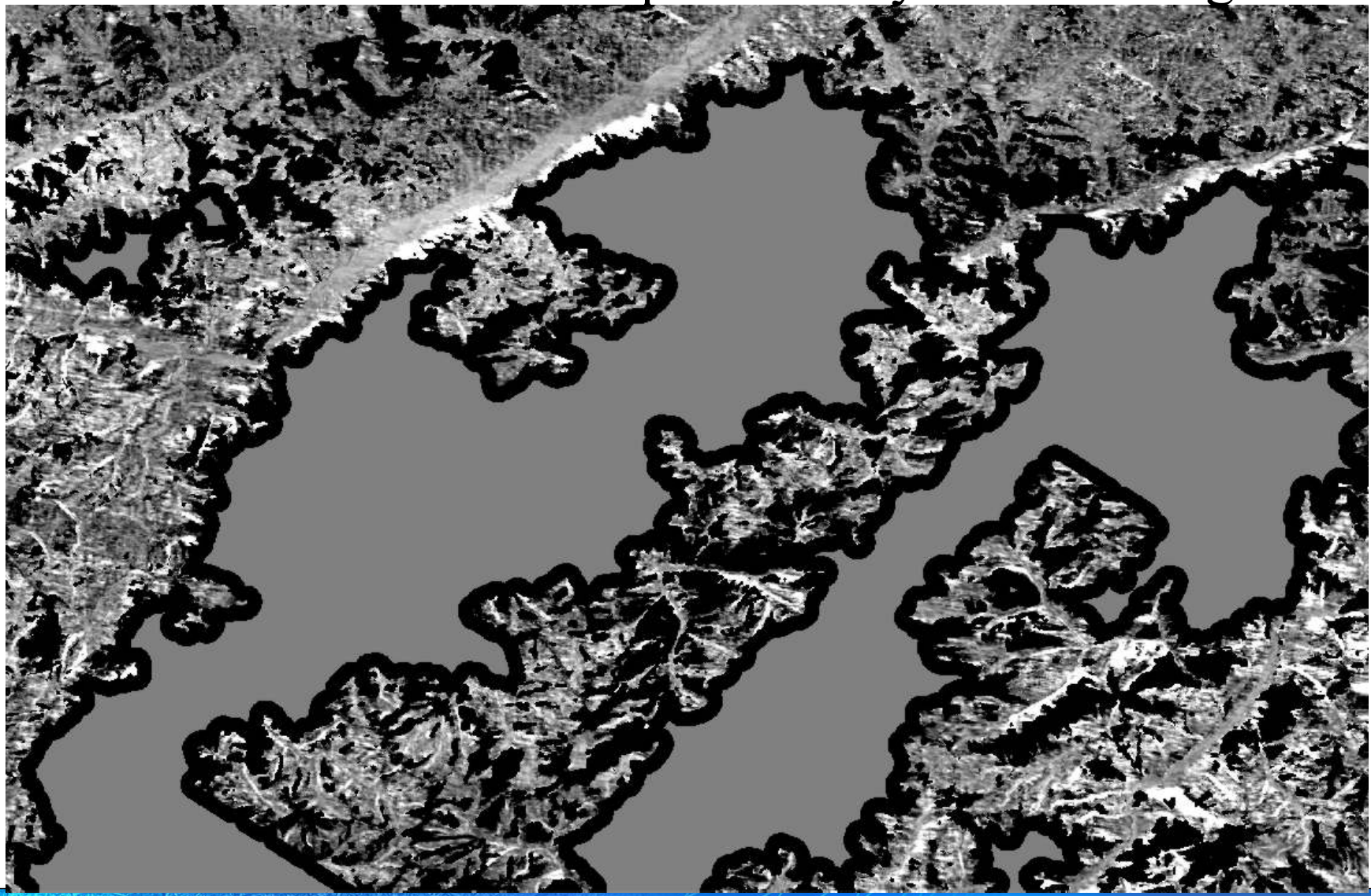
So what can we do with BIG voids?

Here we will simply remove the mean from the densified DTED®1.

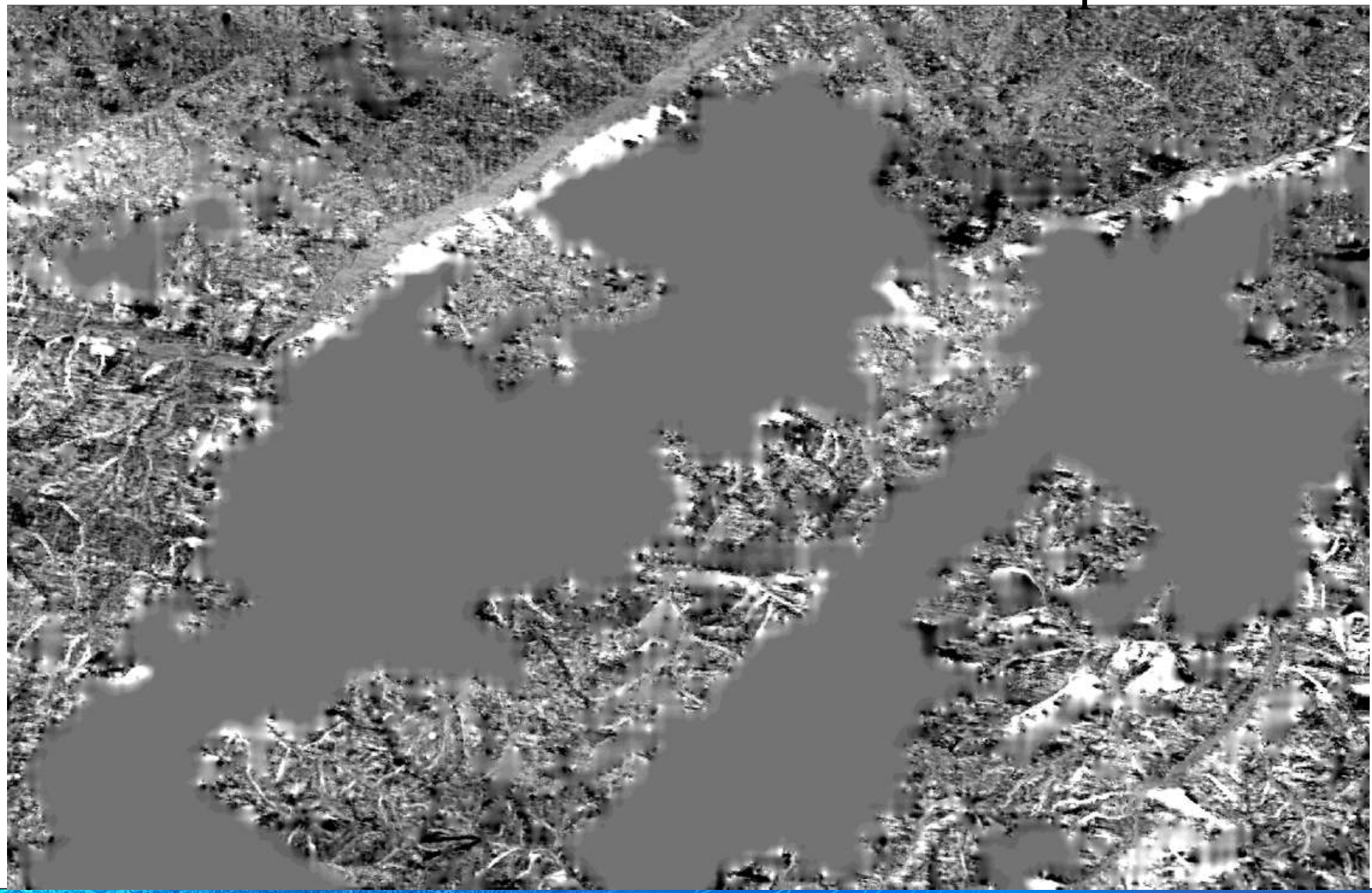
These SRTM voids are over 25 miles long and 14 miles wide



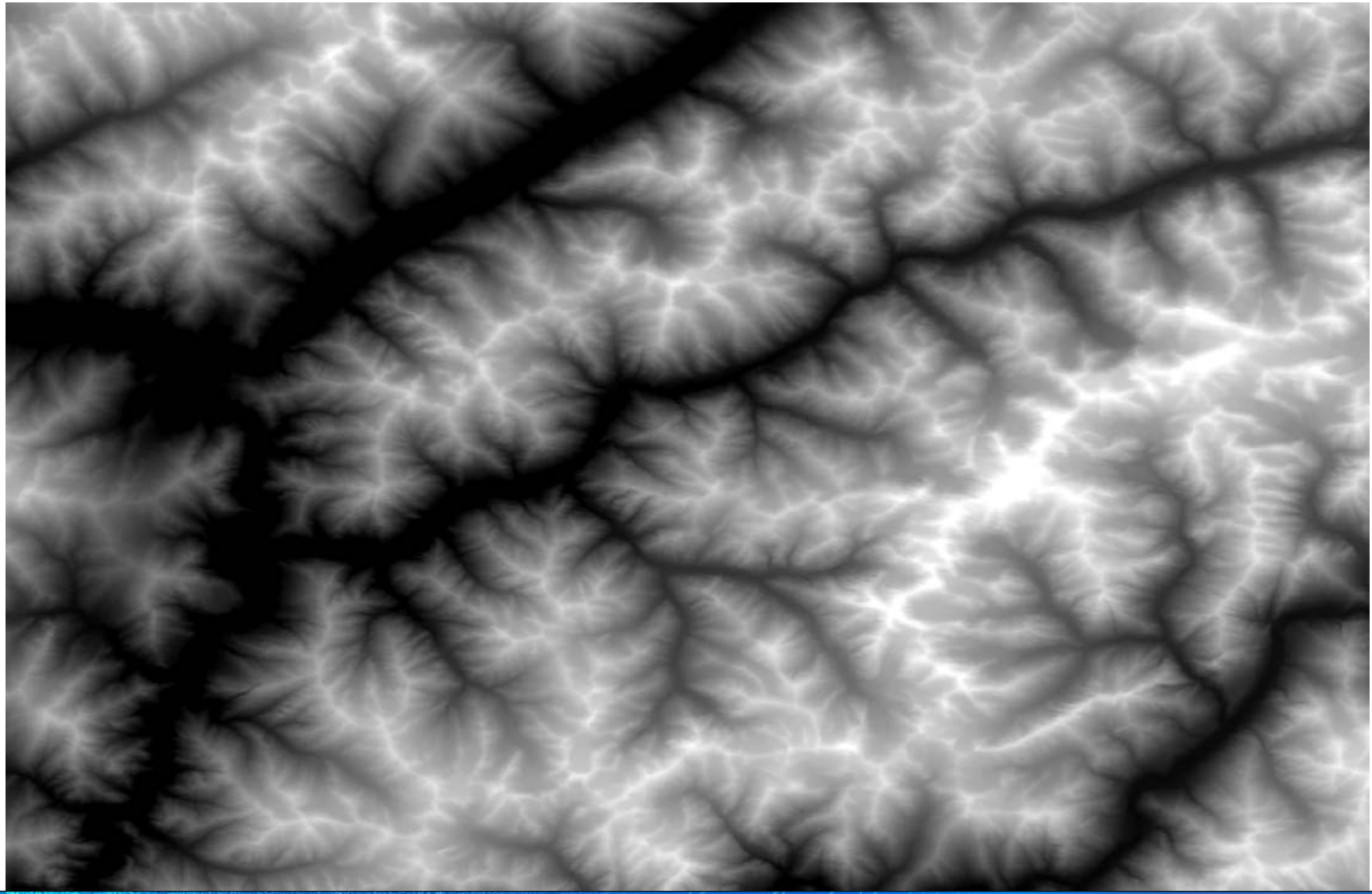
This delta surface has a value of "mean" everywhere in the void that is >30 pixels away from the edge.



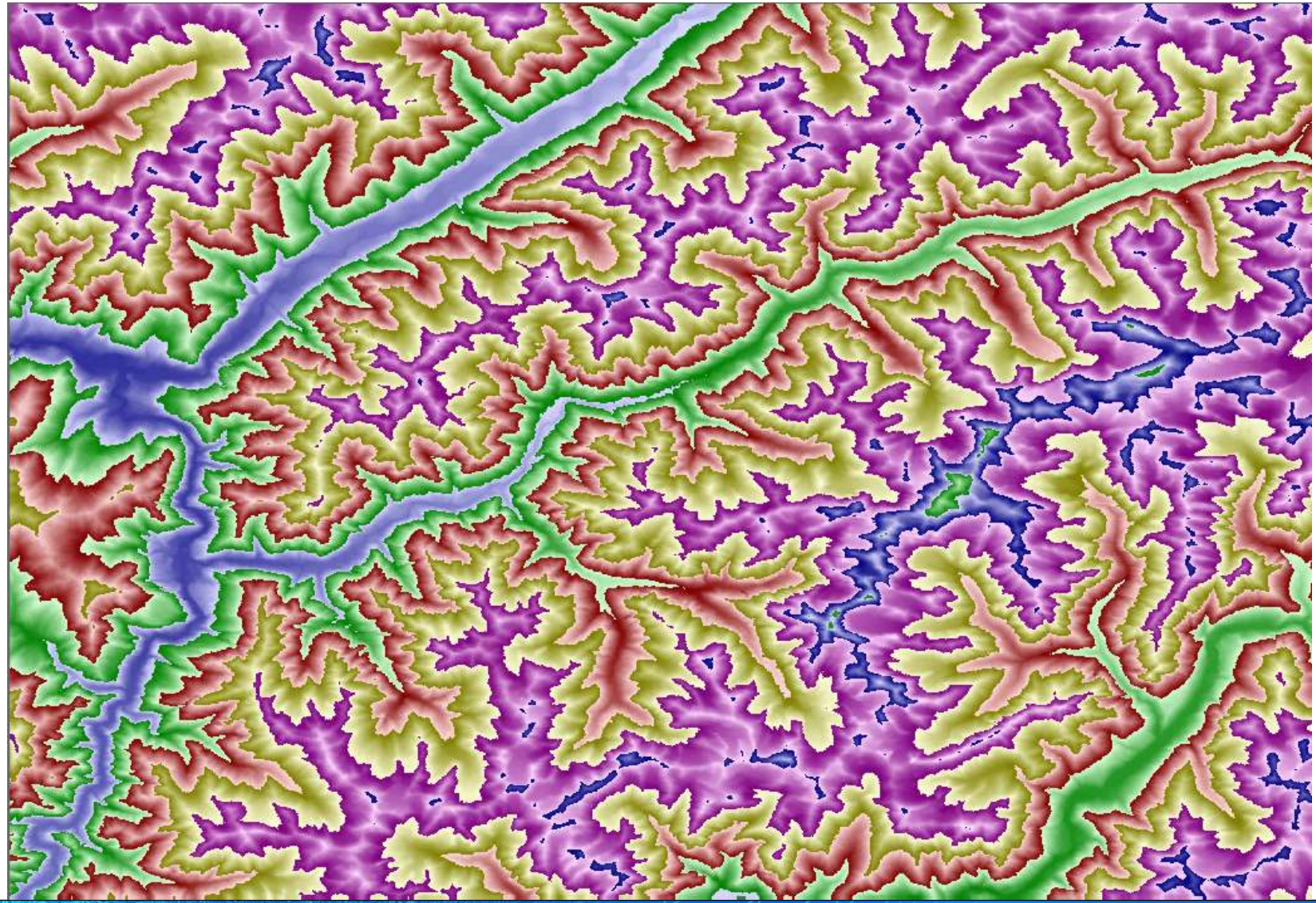
Now we interpolate the delta surface, either across the smaller voids or over to the mean plane…



The result of adding the mean-plane added delta surface to the densified DTED®1 in the voids…



The result of adding the mean-plane added delta surface to the densified DTED®1 in the voids…



Overall Test Results for DSF vs VF

For first 10 cells/voids smaller than 20 posts across:

DSF average standard deviation = 19.2m

FF average standard deviation = 47.2m

(a total of 11 test cases in two different geographic regions)

For those test cases that had voids larger than 20 posts across, here is how the remainder (middle portion) did:

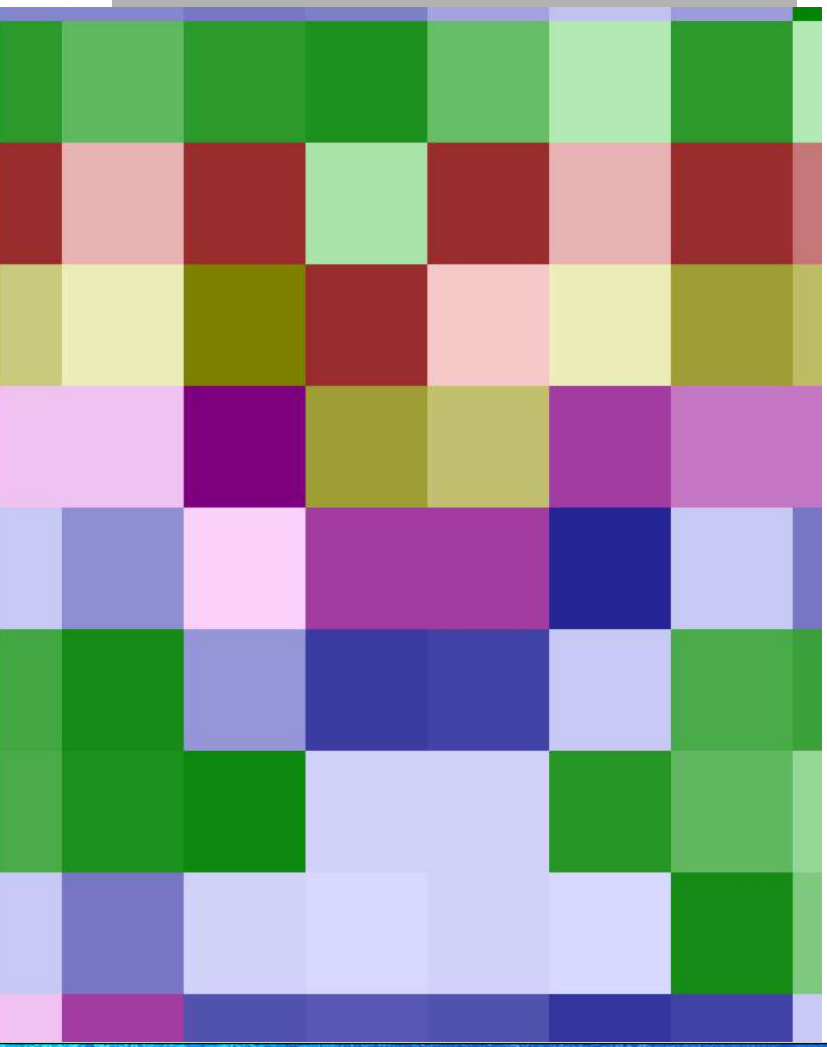
DSF average standard deviation = 18.0m

FF average standard deviation = 22.3m

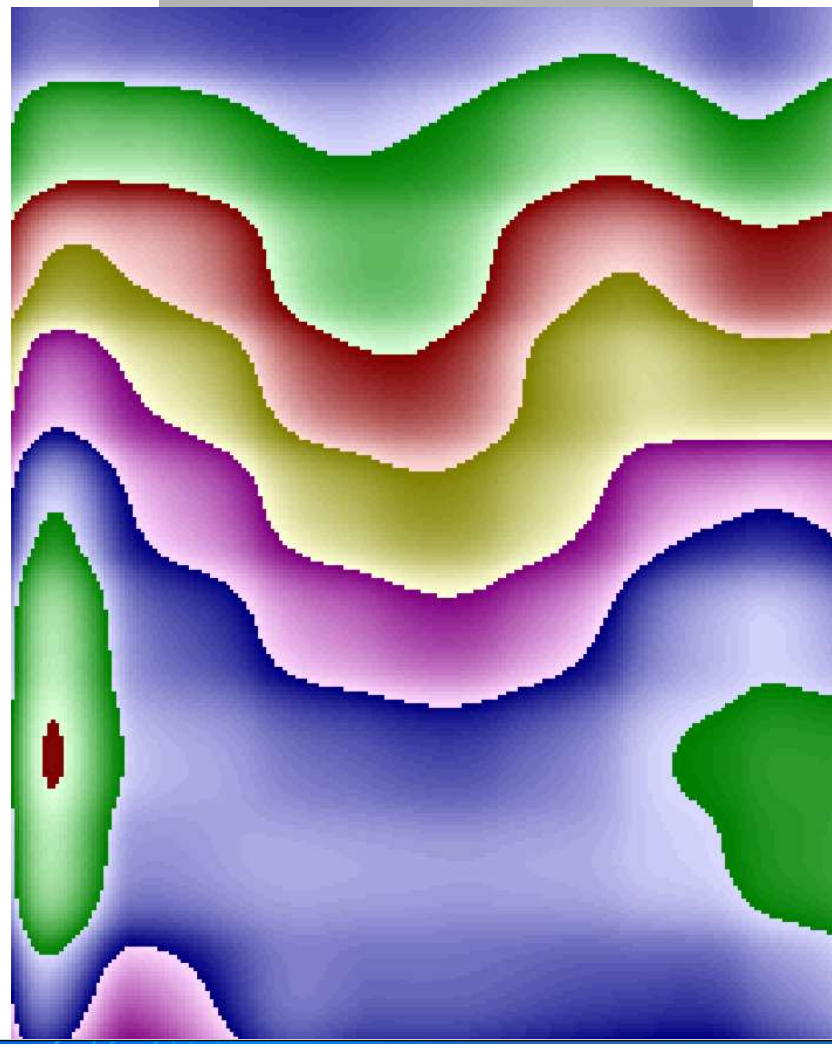
(a total of 5 test cases in two different geographic regions)

What if all I have is DTED®0?

DTED®0 over void areas



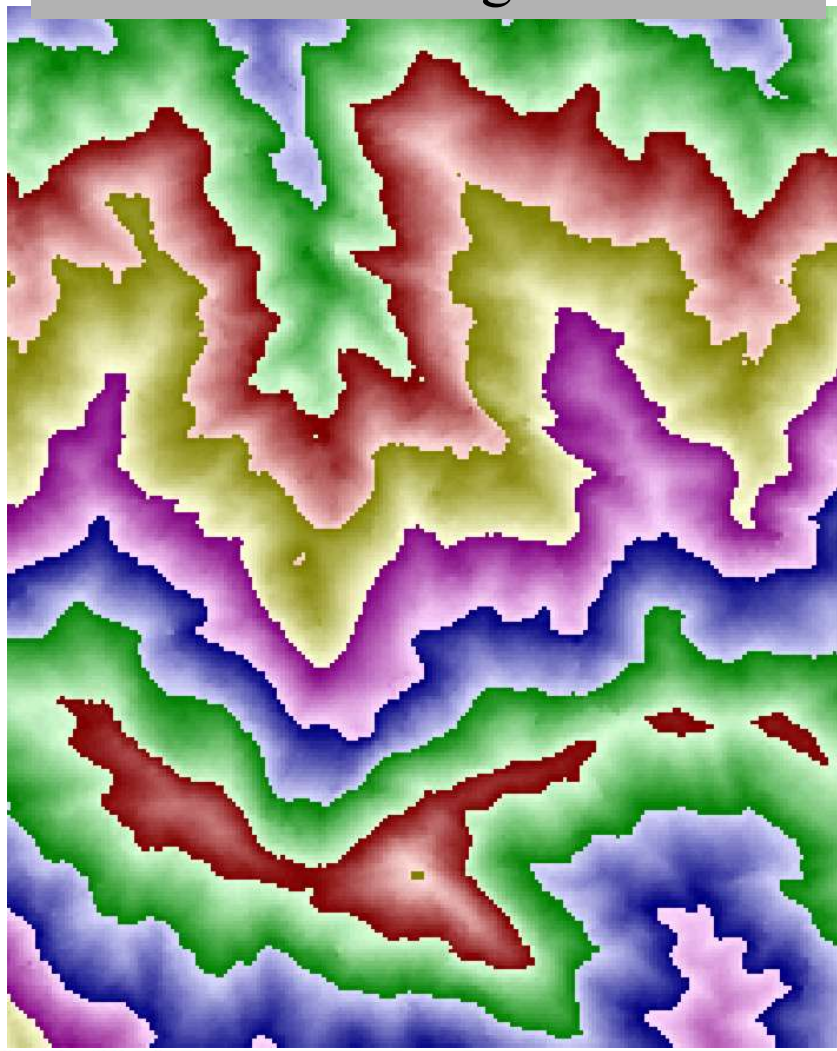
Densified DTED®0



Test Results of DTED®0 for fill:

SRTM with actual voids

DSF SRTM using DTED®0



Observations

*The DSF process does a superior job of making the DTED®1 "look" more like the underlying ground truth, both statistically and cosmetically. This is especially true if the DTED®1 is "less than perfect".

*Once you are more than 300 meters (10 posts) from the edge of the void, the two processes are not too different, with the DSF only slightly better than the older FF.

*"Garbage in equals garbage out." Neither process can handle a bad input data set very well once you are away from the void edge. The middle of large areas will reflect the accuracy of the fill source, as expected.

Summary

The Delta Surface interpolation method conserves SRTM and utilizes the densified DTED®1 data better than the fill/feather process currently in place.

The feathering can be so extensive in high delta areas that the resultant surface will be unusable there. This is not an issue with the Delta Surface method.

The Delta Surface method will use the SRTM data everywhere it exists and has been deemed useful*.

*The Delta Surface method has the added benefit of helping to identify problem areas in the SRTM (such as phase unwrap error), and can easily accommodate the simple voiding of these areas.

Summary

The Delta Surface Fill (DSF) method of SRTM void filling is superior both statistically (with smaller standard deviations compared to ground truth) and cosmetically (land forms look more realistic). An analyst may even overcome minor void obstacles if only DTED®0 is available for fill.

The DSF method is fast, and more appropriately models what is actually to be expected on the Earth's surface at that void.

NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

Know the Earth…Show the Way

SRTM Void Area Fill Processes Review

Generated by Greg Grohman, PRTT
and George Kroenung, PLM

Comments and questions...