IDENTIFYING AND REMOVING SYSTEMATIC ERRORS IN USGS DEMS

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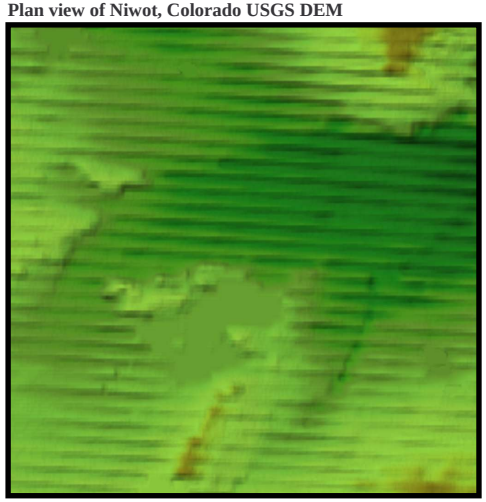
Abstract

Manually profiled USGS Digital Elevation Models (DEMs) are prone to systematic errors which are often referred to as "striping". Striping can be described as successive ridges and troughs, usually oriented approximately E-W, that run through the elevation model. Though these DEMs conform to national map accuracy standards, they cause great frustration to researchers who try to use these data for applications such as slope analysis, watershed delineation, water flow patterns, or landscape rendering. As of April, 1994, over 13,000 USGS DEMs had been produced with the manual profiling process.

Striping renders many DEMs worthless without filtering. The most commonly used stripe suppression method is low-pass filtering. This procedure affects the true terrain, as well as the stripes, and therefore degrades the DEM's resolution. A different method of stripe suppression is presented here. This method utilizes power spectrum estimates for each column in the DEM to identify and suppress the stripes. Assessments of the DEM after the application of the power spectrum technique indicate accuracy improvement over the unfiltered DEMs. In addition, the spatial resolution is less degraded than with low-pass filtering.

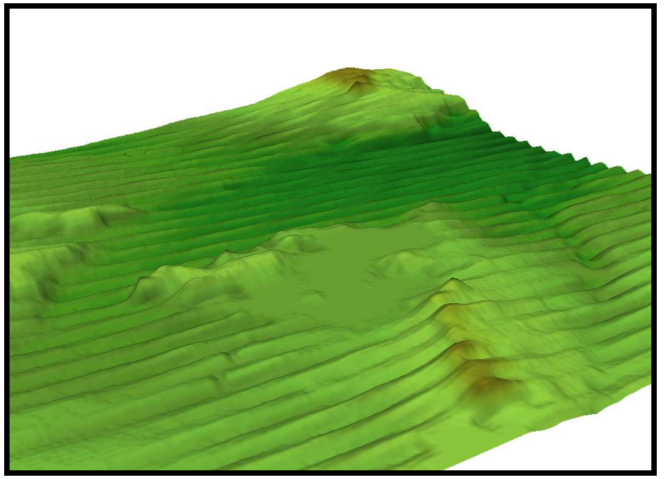
Example of systematic errors found in some USGS DEMs

Plan view of Niwot, Colorado USGS DEM

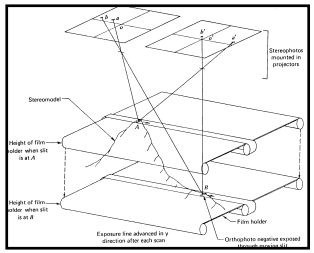


Contour Map generated from Niwot, Colorado USGS DEM

Perspective view looking NE of Niwot, Colorado USGS DEM



What Causes Striping?



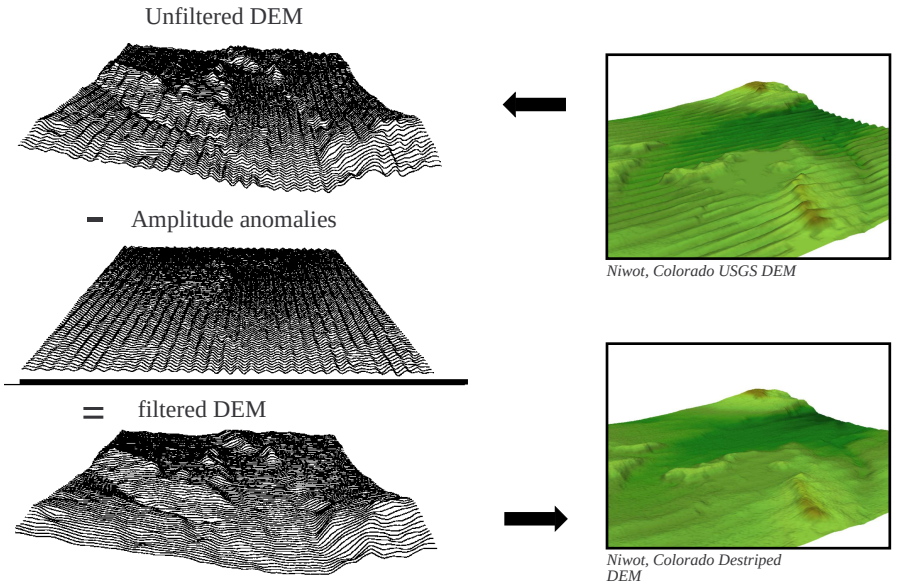
From Remote Sensing & Image Interpretation , Thomas Lillesand and Ralph Kiefer, 1979, p. 324.

F Striping is an artifact of a data collection technique known as **Manual Profiling**

Overview and Implications of Manual Profiling Process

- A floating mark is moved through a stereomodel along a profile (usually E-W).
- The operator keeps the floating mark "on the surface" by adjusting it up or down to account for changes in elevation.
- The traverse direction is alternated from one profile to the next (e.g., left to right, then right to left).
- Points are typically recorded every 30m along profiles, while spacing between profiles is commonly 90m, but may vary.
- The final DEM is interpolated from the collected sample points.
- Stripes may be a "lag" effect in the floating mark adjustment, but this interpretation is uncertain.

Basic Filtering Concept



Niwot, Colorado USGS DEM

Niwot, Colorado Destriped DEM

Stripe Removal Process

Steps

1 Convert spatial profiles into frequency (wavelength) domain on a column by column basis using FFT.

2 Identify frequency regions with anomalous amplitudes.

3 Reduce anomalies to background level using filtering techniques.

4 Convert each column back to the spatial domain.

Fast Fourier Transform (FFT)

FFT is a computer implementation of the Discrete Fourier Transform (given below in 1 dimension):

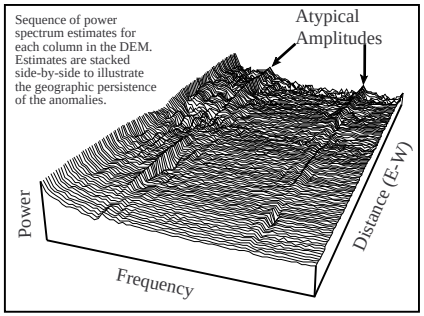
$$Z_n = \sum_{k=0}^{N-1} z_k e^{2\pi i\, kn/N}$$, where

z_k are the samples being transformed (in this case, elevations), N is the total number of samples, Z_n is the resulting (complex) value, and $i=\sqrt{-1}$.

$z_k = z(x_k)$, $x_k = x_o + k\Delta x$, $k = 0,1, \ldots, N-1$

$Z_n = Z(f_n)$, $f_n = \frac{n}{N\Delta x}$, $n = \frac{-N}{2}, \ldots, \frac{N}{2}$

2.



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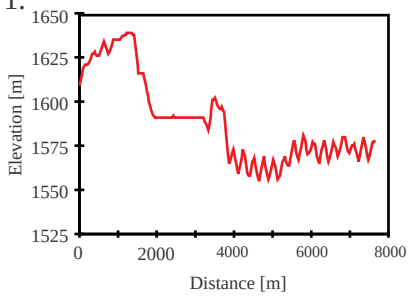

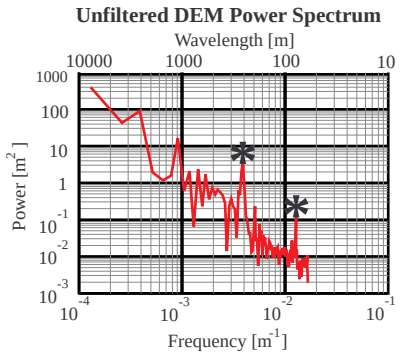

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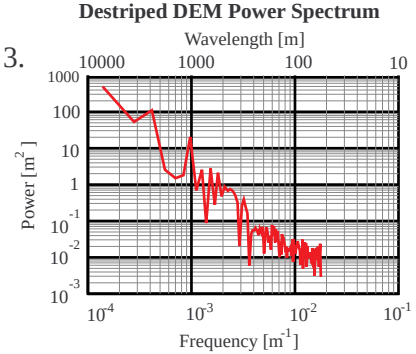

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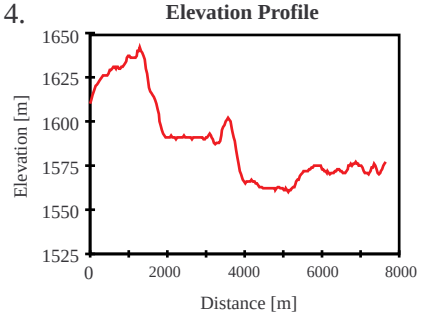
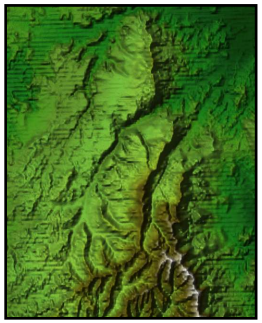


Comparisons of Unfiltered vs Destriped DEMs

Los Indios Canyon, NM
Unfiltered DEM

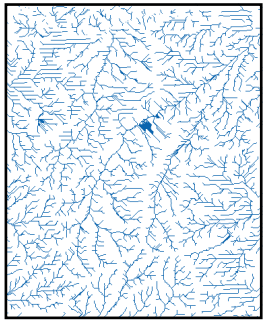
Los Indios Canyon, NM
Destriped DEM

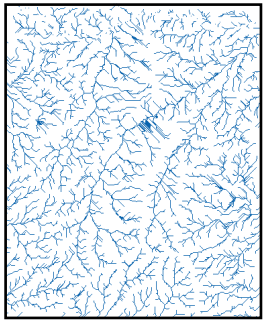
Shaded Relief Elevation



Slope

Derived Water Flow Pattern



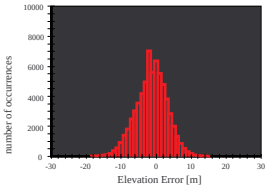


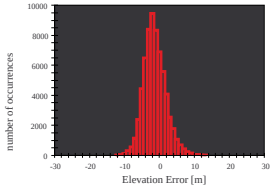
Accuracy Assessment

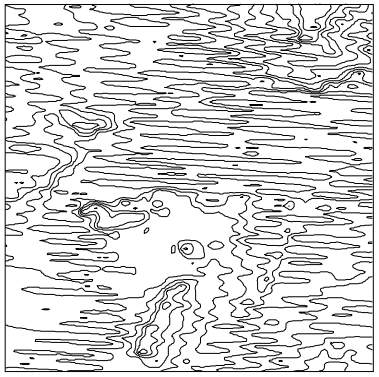
The USGS has produced two DEMs for the Niwot, Colorado 7 1/2 - minute quadrangle - one with the older manual profiling technique, and one with the newer contour-to-grid (CTOG) interpolation technique.

One way to assess the effectiveness of the destriping technique is to compare the unfiltered and destriped DEMs to the newer, more accurate, contour-based DEM. This was done for the Niwot quadrangle with the results presented below. The destriped DEM had a similar maximum error and a lower root mean square error (RMSE).

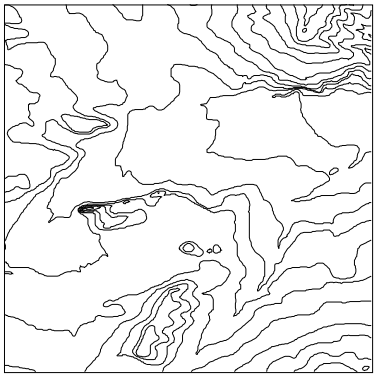
	Unfiltered	Destriped
Maximum error	26 m	27 m
RMSE	4.43 m	3.18 m



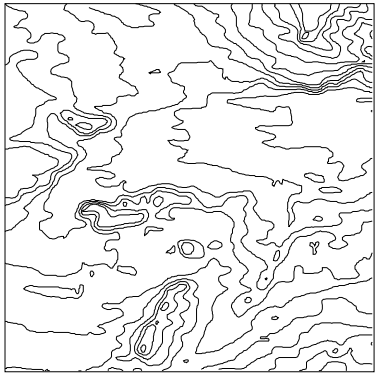




*Contours generated from unfiltered **manually profiled** DEM*



*Contours generated from **CTOG** DEM, "true" surface*



*Contours generated from **destriped** DEM*