Methods for Surface Configuration (Slope) Analysis from SRTM Data

G. Eric Reasor
Boeing
Integrated Defense Systems
Space & Intelligence Systems
eric.reasor@boeing.com

Slope Product Background

Acronym	Name	Typical Scales	Typical Format
TTADB/PTTADB	Tactical Terrain Analysis Data Base / Planning Tactical Terrain Analysis Data Base	1:50K, 1:100K, 1:250K	Hardcopy Overlay
ITD/PITD	Interim Terrain Data / Planning Interim Terrain Data	1:50K, 1:100K, 1:250K	Digital, Standard Linear Format (SLF)
VITD	Vector Product Interim Terrain Data	1:50K, 1:100K	Digital, Vector Product Format (VPF)
DTOP	Digital Topographic Data	1:50K, 1:100K	Digital, Vector Product Format (VPF)

Slope Methods Background

Manual Methods

Digital Methods

Manual Methods

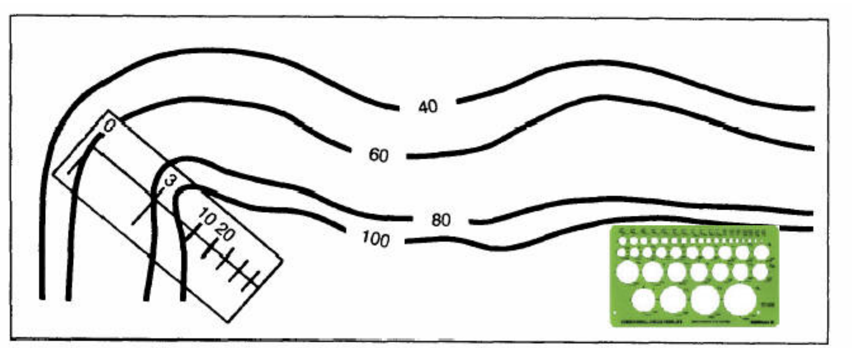
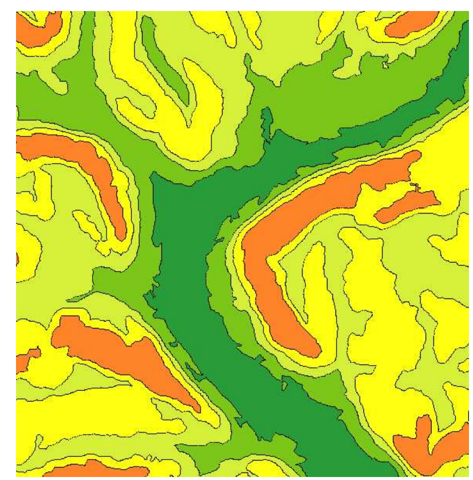


Figure 3-2. Slope example



Digital Methods

Neighbors	Used	Selected Reference
2	z,ze	Batson & others (1975); No aspect
3	z,zn,zne	O'Neill & Mark (1987)
4	zn,zs,ze,zw	Eyton (1991); Carter (1992)
8	zn,zne,ze,zse,zs,zsw,zw,znw	Differential weights (Horn, 1981); Sobel operator (Richards, 1986)
8	zn,zne,ze,zse,zs,zsw,zw,znw	Identical weights (Sharpnack & Akin, 1969)
8	zn,zne,ze,zse,zs,zsw,zw,znw	Heerdegen & Beran (1982)
8	zn,zne,ze,zse,zs,zsw,zw,znw	Local trend surface (Davis, 1973)
9	z,zn,zne,ze,zse,zs,zsw,zw,znw	Steepest Neighbor (Collins, 1975); Only 8 aspects
9	z,zn,zne,ze,zse,zs,zsw,zw,znw	Steepest Downhill Neighbor; Only 8 aspects
9	z,zn,zne,ze,zse,zs,zsw,zw,znw	Average Neighbor; Only 8 aspects

Znw	Zn	Zne
Zw	Z	Ze
Zsw	Zs	Zse

Guth, P.L., 1995, Slope and aspect calculations on gridded digital elevation models: Examples from a geomorphometric toolbox for personal computers: Zeitschrift fur Geomorphologie N.F. Supplementband 101, pp.31-52.

Slope Issues with SRTM Data

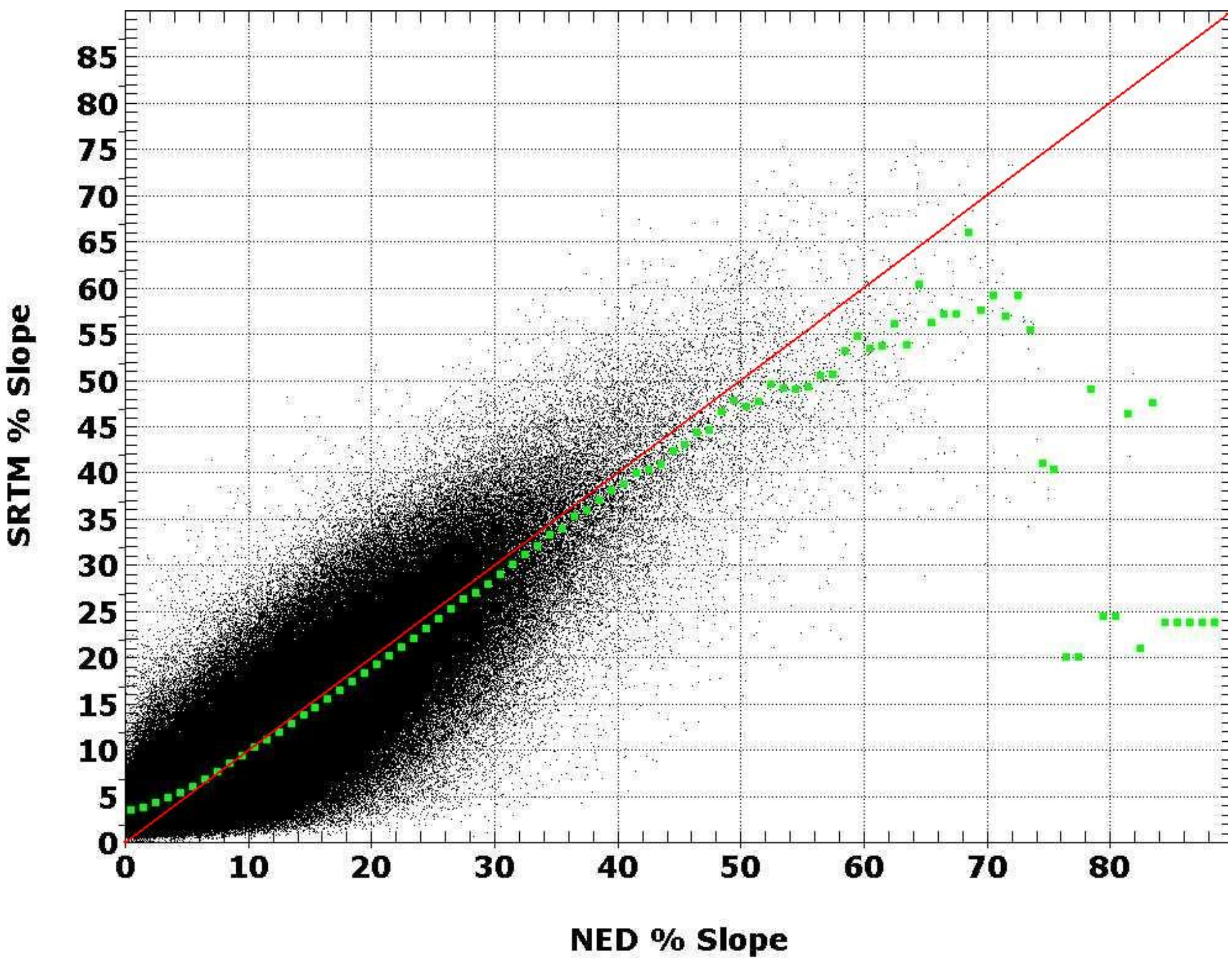
Radar Speckle

Flatter slope areas are evaluated to be too steep.

Smoothing

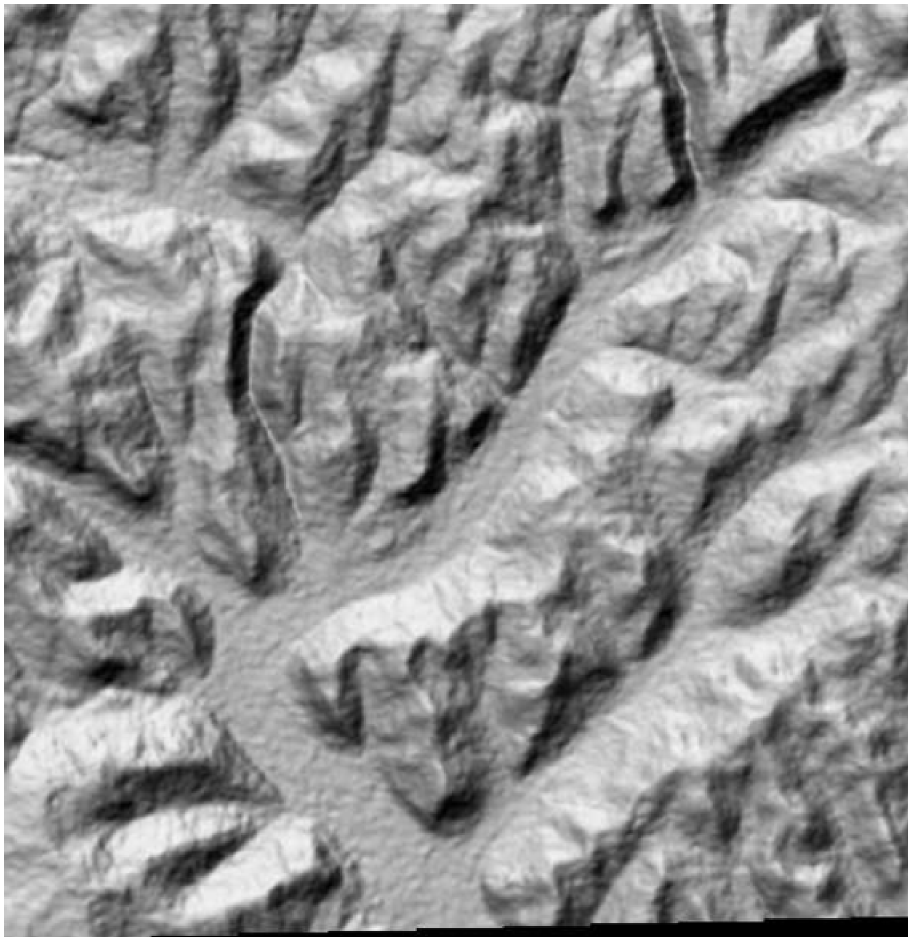
Steeper slope areas are evaluated to be too flat.

SRTM and NED Slope Comparison

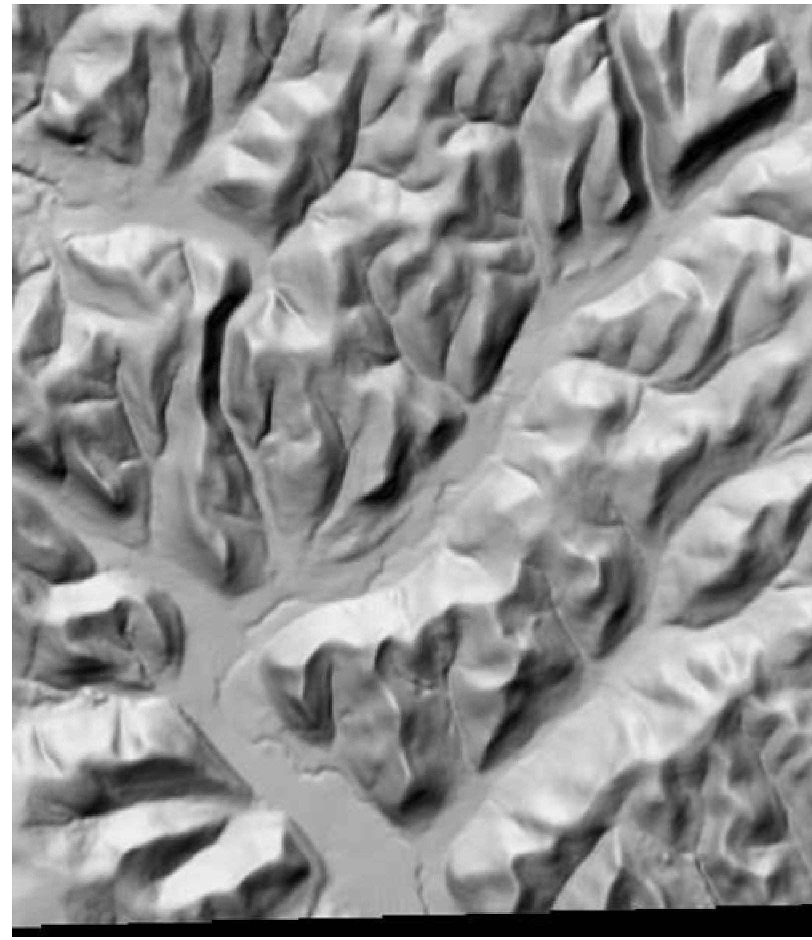


Radar Speckle in Valley Floor

SRTM



NED



Objectives of Slope Method

- Fully Automated
- Maximize cartographic appeal
  - Remove less important details that may obscure more important aspects of analysis.
  - Process raw data into actionable intelligence
- Biggest SRTM Issue: remove radar speckle at low slopes
- Watch out for misrepresentation or incorrect analysis

Inspiration from Past and Present

- Past – Manual Methods
  - Manual compilation of slope overlay from contours for TTADB product.
  - Circular templates with diameters calculated according to contour intervals

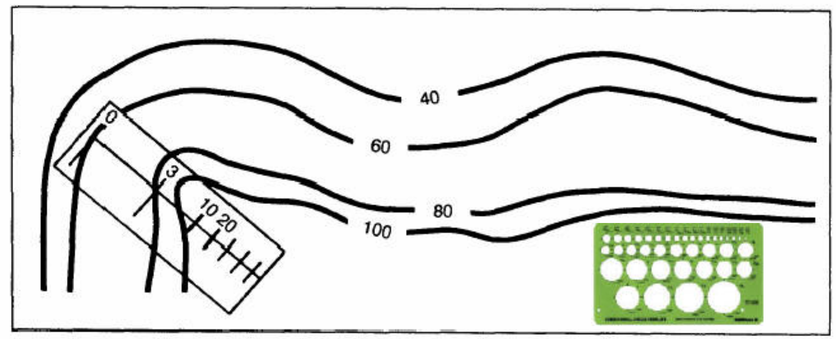


Figure 3-2. Slope example

- Present – LIDAR and RBFs
  - Smooth surface reconstruction of LIDAR data (noisy range data)
  - RBF – Radial Basis Functions
  - Adaptively vary smoothing to preserve sharp edges and corners
  - J. C. Carr, R. K. Beatson, B. C. McCallum, W. R. Fright, T. J. McLennan, and T. J. Mitchell. *Smooth surface reconstruction from noisy range data*. In Proceedings of Graphite 2003, pages 119--126, 2003.

(a) c=10mm, 45,988 centres (b) c=20mm, 28,950 centres

Figure 14: Removing unwanted detail from a surface reconstructed from LIDAR data with low pass filtering and then fitting an RBF with fewer centres to the smoothed data.

Evolution of Idea

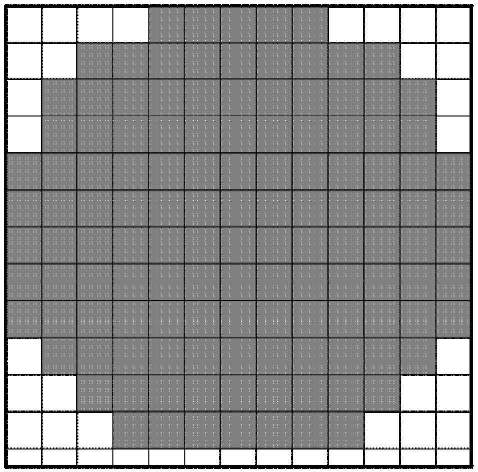
- Early Idea
  - Create contours from SRTM
  - Create new DEM from those contours
  - Determine slopes from the new DEM.

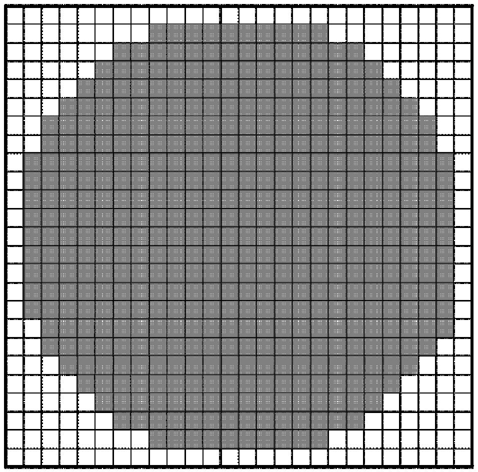
- Issues Encountered
  - Choice of contour
  - Choice of method for generating DEM from contours
    - IDW, Spline, TOPOGRID
  - Performance
  - Lost slope detail near drainage
  - Blunders / Anomalies in generated DEM
  - Removal of small areas

Improvements and Refinements

- Initial re-sampling of DEM
- Use of circular focal function
- Iterative removal of small areas

Initial Re-Sampling of DEM



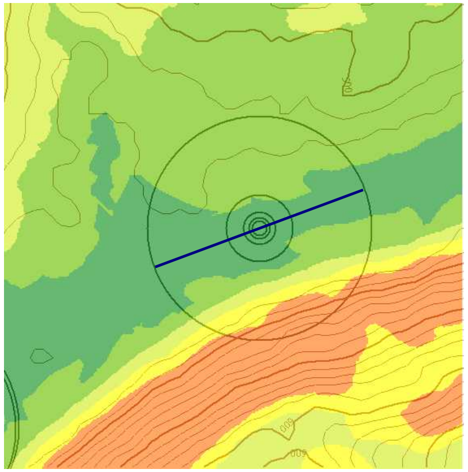


- Benefits
  - Initial re-sampling of SRTM DEM to a higher resolution
  - Allows for better estimation of circles in raster calculations
  - Improved cartographic characteristics (stair steps from lower resolution)
- Implementation Details
  - Choice of interpolation method: Bilinear
  - Choice of resolution: 5m

Circular Focal Function

▪Drop intermediate creation of DEM

▪Use various size radius and look for particular ranges of elevation



Benefits:

▪All data in SRTM DEM is considered (not just contours)

▪Flexibility to combine different combinations of radius statistics

▪Raster calculations (performance, parallelizable)

▪Cartographic aggregation to some degree in all slope categories

▪Essentially a highest non-weighted slope method over a larger circular area that assumes the high and low of elevation range are near edges of the circular analysis area.

Traditional Contour Intervals

c. A guide for the selection of contour intervals at the 1:50,000 scale follows. It is based on uniform slope and is largely reliant on observation and experience.

Relief Category	Slope %	Contour Interval
Low	0 - 5	10 m w/5 m supplements
Low-medium	5 - 20	10 m
Medium	20 - 45	20 m
High	45 and greater	40 m

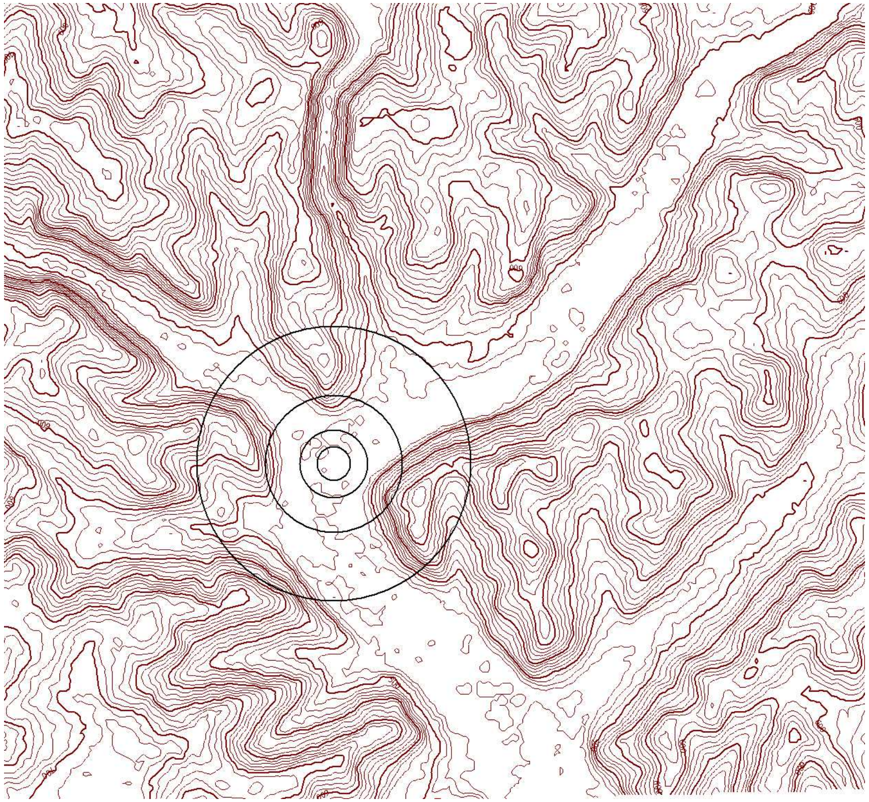
- MIL-T-89301A Section 3.16.3.1.c

Slope Calculations for Common Contour Intervals

Slope		Calculated Diameter for Intervals / Ranges (all values in meters)			
Category	Percent	5m	10m	20m	40m
1	0-3%	166.7	333.3	666.7	1333.3
2	3-10%	50.0	100.0	200.0	400.0
3	10-20%	25.0	50.0	100.0	200.0
4	20-30%	16.7	33.3	66.7	133.3
5	30-45%	11.1	22.2	44.4	88.9
6	>45%	Everything else not classified.			

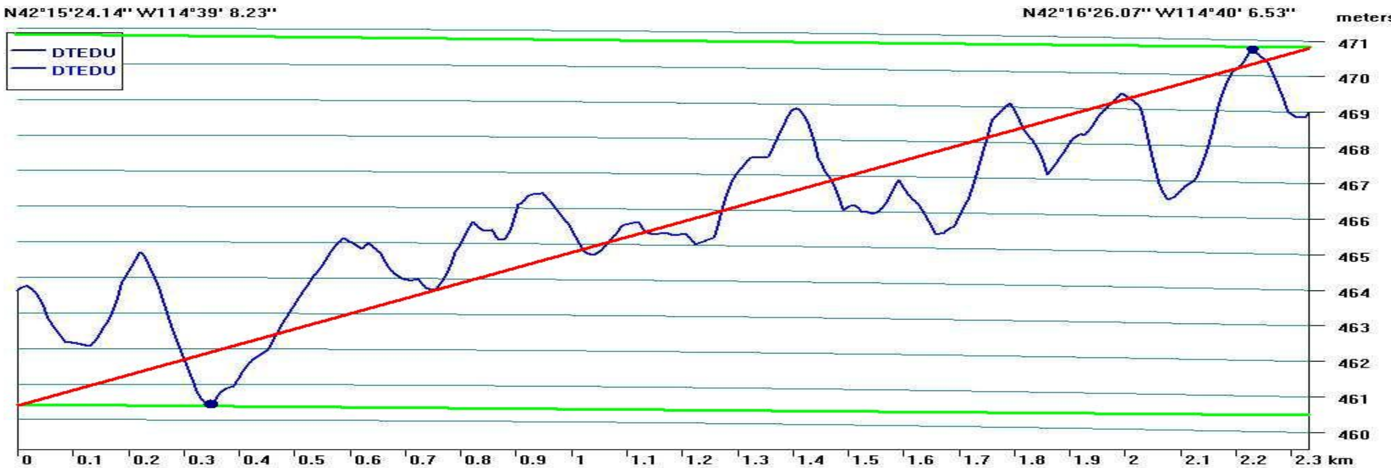
Combining Multiple Radius

- Smaller is Better for Detail
  - For flatter slopes it would be better to have a smaller contour interval (radius) to get more cartographic detail.
- Larger is Better for Radar Speckle Removal
  - To remove radar speckle in flatter slopes it would be better to have a larger contour interval (radius).
- Solution is to Combine
  - Not restricted to one choice of contour interval (radius) so use multiple values and combine the results.



Category 1 (0-3%) Radius for 5, 10, 20, and 40m contours on 10 m contour background.

Possible Issues with Circular Focal Range



A degree of continuity of terrain is assumed inside the radius

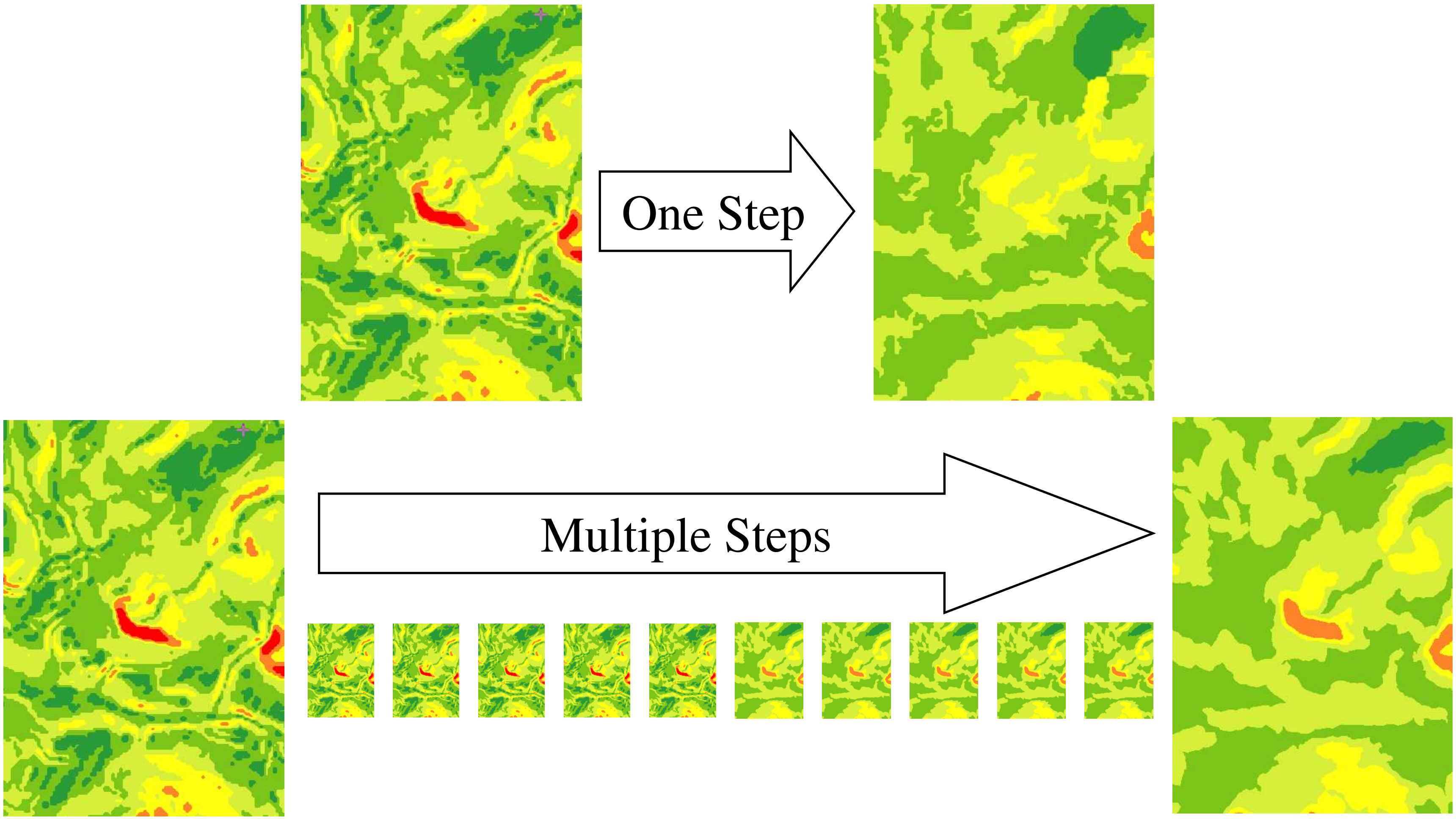
Karst or highly distorted surface area could be classified as flat if the detail occurs below the radius/threshold used.

But this phenomena is essentially indistinguishable from radar speckle (the phenomena trying to be ignored)

Iterative Removal of Small Areas

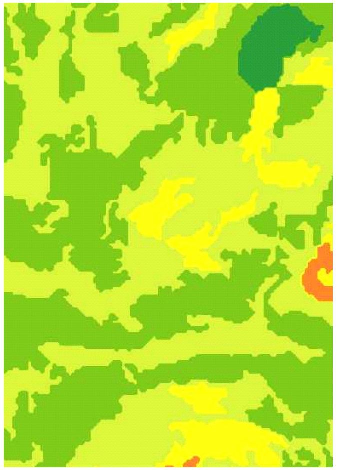
- Remove small areas in steps
  - Remove very small areas
  - Have adjacent classifications nibble into those areas
  - Increase size and repeat
  - Stop when minimum size is reached

Iterative Removal of Small Areas

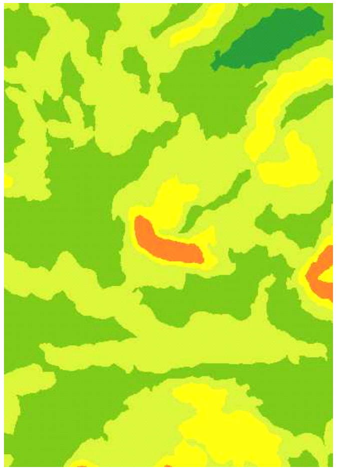


Iterative Removal of Small Areas

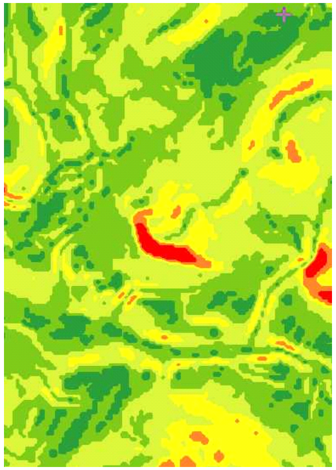
Non-iterative



Iterative



NED



Benefits

- Can retain important slope features that may be entirely dropped out if not iteratively removed.

Implementation Details:

- Gave priority to flatter categories of slope in case of a ties.
- Small areas removed in 10 iterations to minimum size.
  - 5,000 sq. meters to 50,000 sq. meters

Summary of New Method

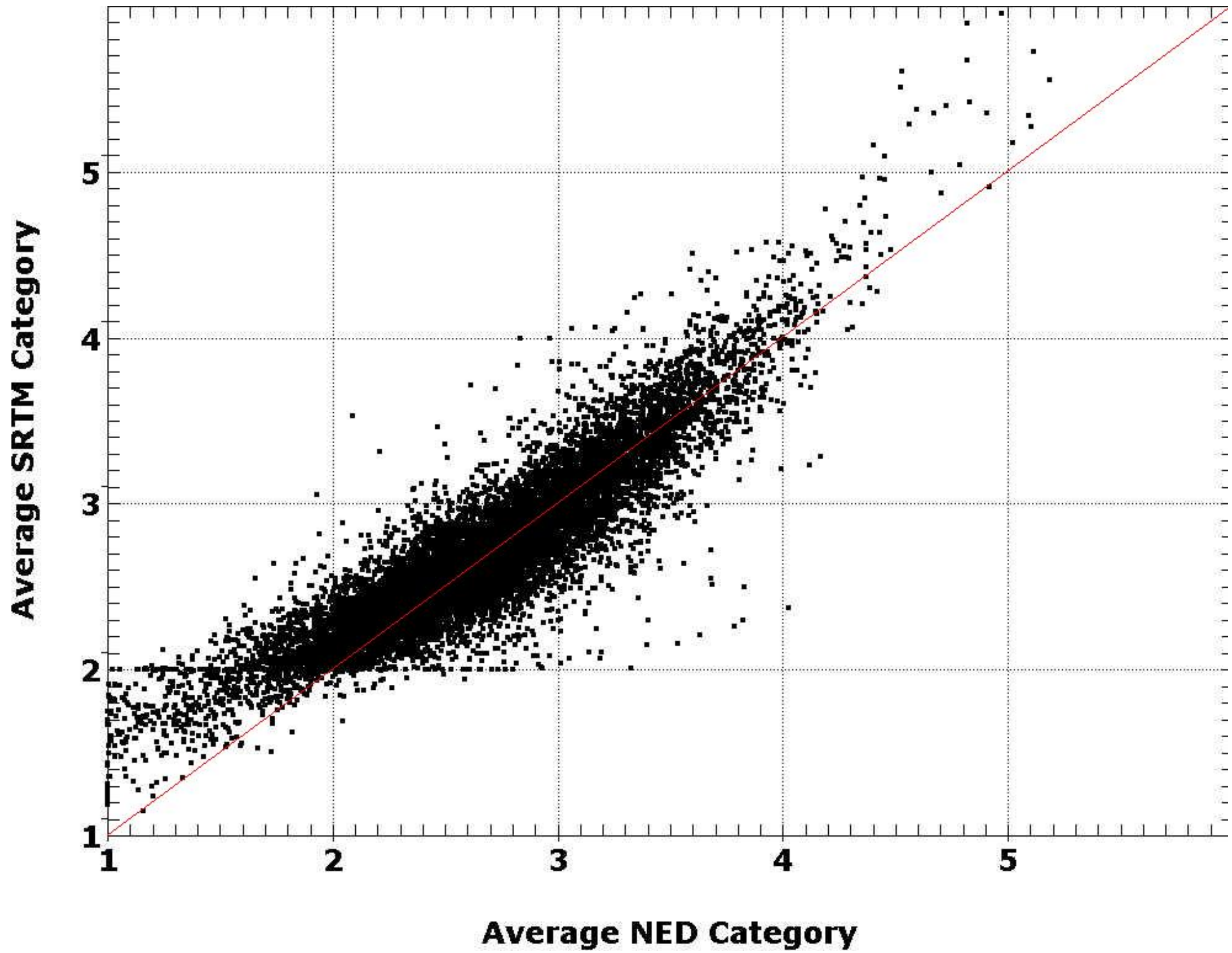
Resample SRTM DEM to higher resolution

Generate focal range statistics using a circular area and a variety of diameters.

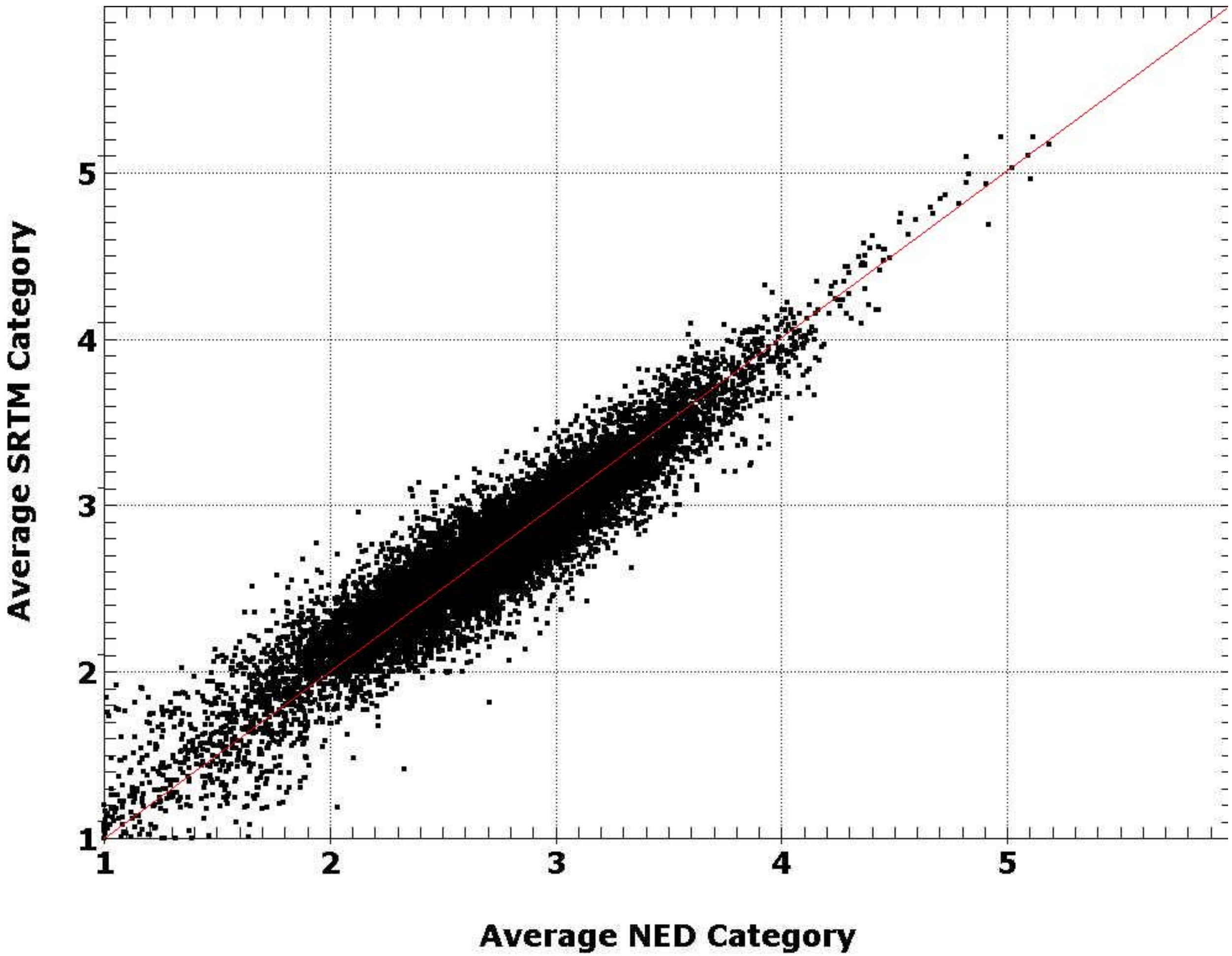
Combine and classify focal range statistics to create an initial slope classification.

Iteratively remove small areas

Typical Method SRTM – NED Comparison



New Method SRTM – NED Comparison

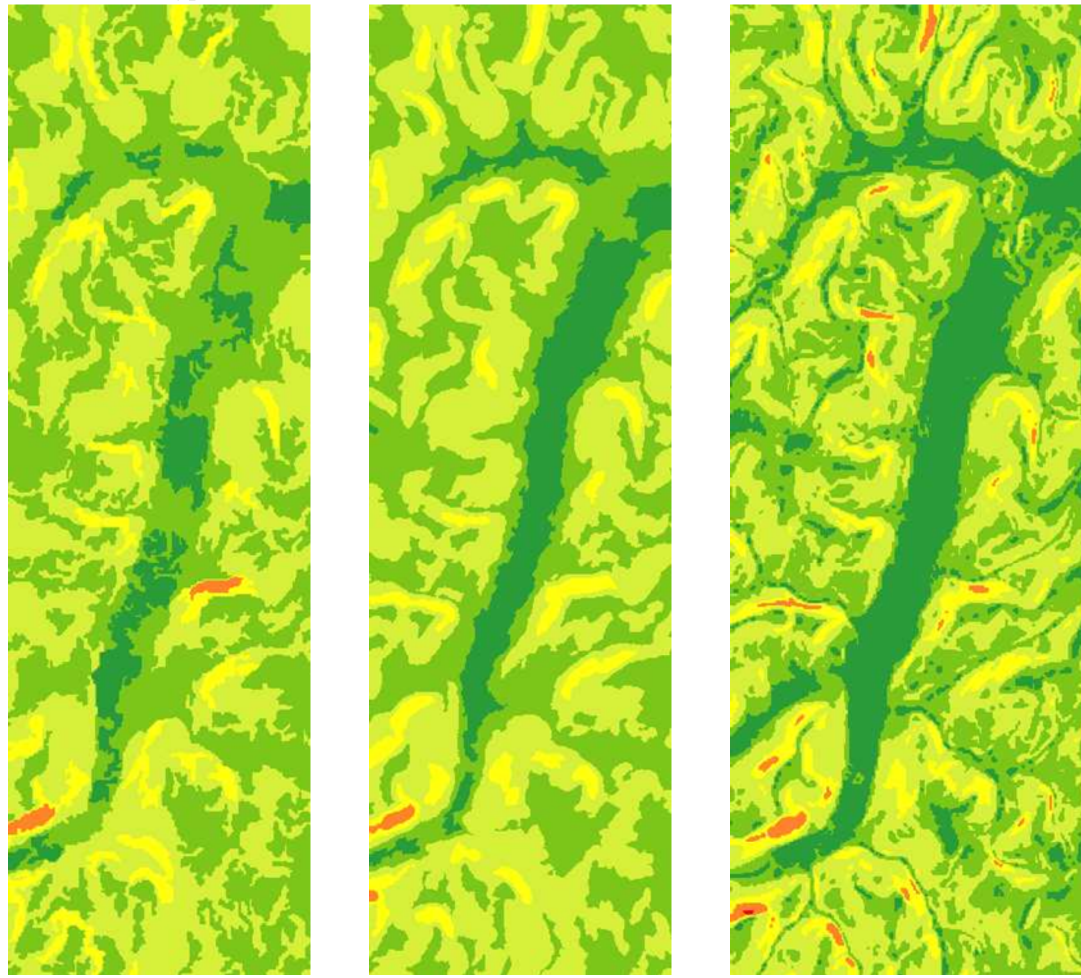


Example - Smooth Valley Floor

Images (Left to Right)

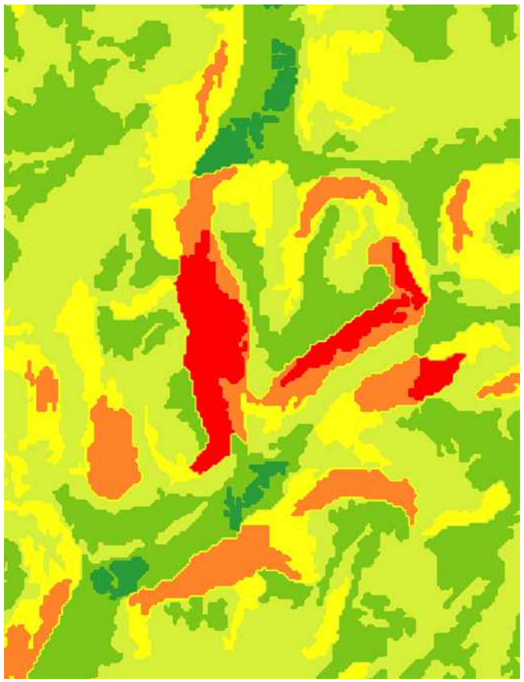
- SRTM Typical method
- SRTM New method
- NED for comparison

SRTM Typical | SRTM New | NED

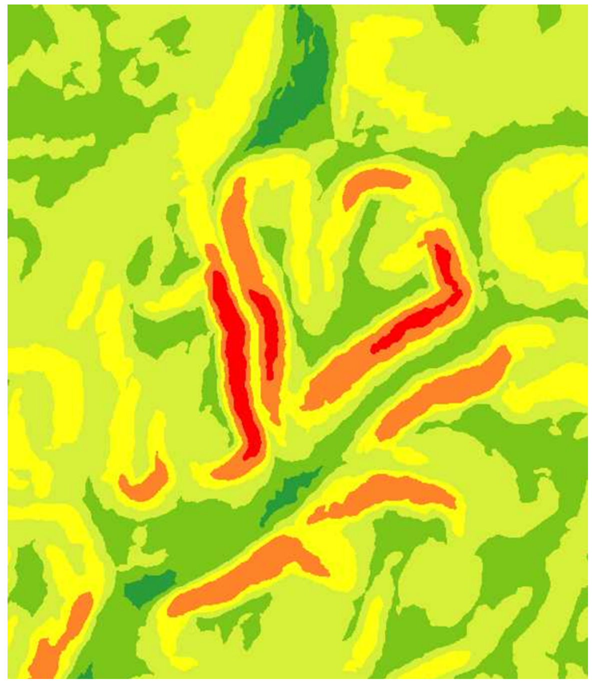


Example - Narrow Pass

SRTM Typical



SRTM New



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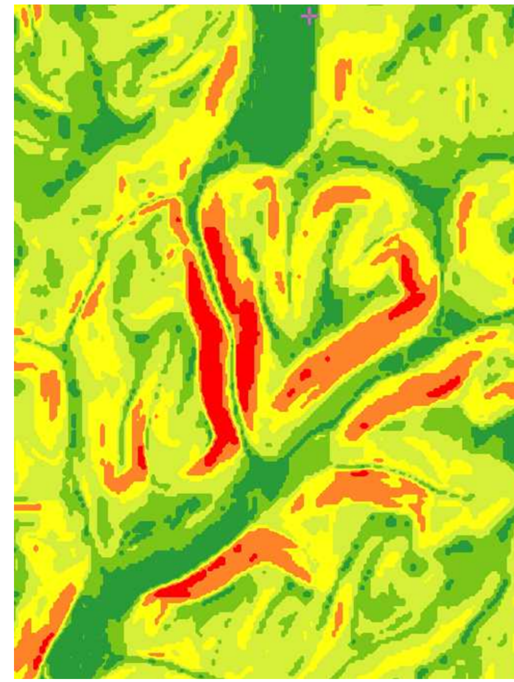
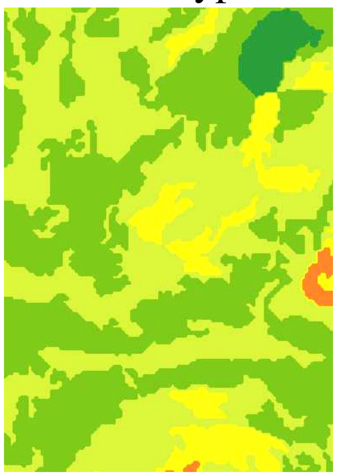


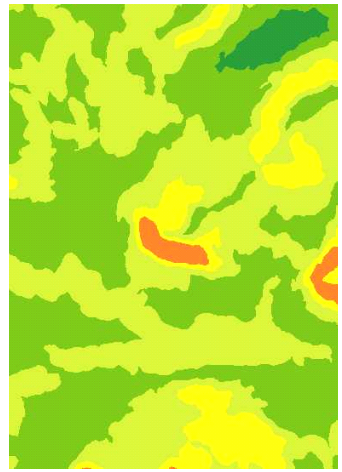
Images (Left to Right) – SRTM Typical Method, SRTM New Method, NED

Example – Important Feature Retained

SRTM Typical



SRTM New



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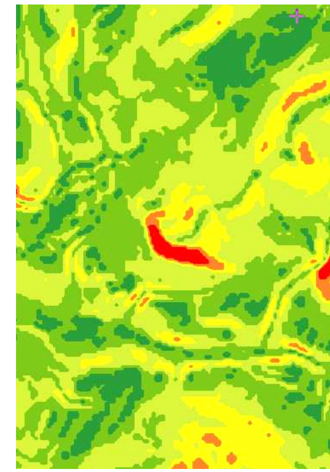

- Previous example showing benefit of Iterative small area removal.
- Can retain important slope features that may be entirely dropped out if not iteratively removed.

Other Important Issues

- Vegetation in SRTM
- Remaining phase unwrap anomalies below detection thresholds of Phase 2 production.

Other Methods

- Intermediate DEM
  - A method closer to the original idea with the generation of an intermediate DEM from contours may also have good or even better results and the added benefit of a DEM with the radar speckle removed.
- Sample SRTM DEM
  - A method where only the more significant points are sampled from the SRTM DEM and then interpolated to a new DEM hopefully leaving out the radar speckle. (ESRI VIP)

Future Work

- Use method on a larger variety of terrain and objectively measure performance. (Issue of availability of accurate and cartographically appealing slope maps for comparison)
- Experimentation with adjustable parameters in method (re-sample resolution, diameter/range combinations, number and area size in iterative small area removal)
- Integration of water features into process to make an improved and consistent slope product.
- Methods for enhancement of ridges that may be smoothed in SRTM.
- Methods for removal of vegetation in SRTM which can effect slope.
- Alternative methods and generation of DEMs with radar speckle removed.
- Slope is key input into CCM (Cross-Country Movement) analysis. Improve automation of other key inputs for a better total analysis package (vegetation, soils).

References / Acknowledgements

Boeing – SRTM production and void fill programs

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NGA

NGA home page: http://www.nga.mil

ESRI

ESRI home page: http://www.esri.com