AUTOMATED ADJUSTMENT OF IMAGE SHARPNESS IN RELIEF SHADING

Master Thesis Presentation
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ETH Zurich

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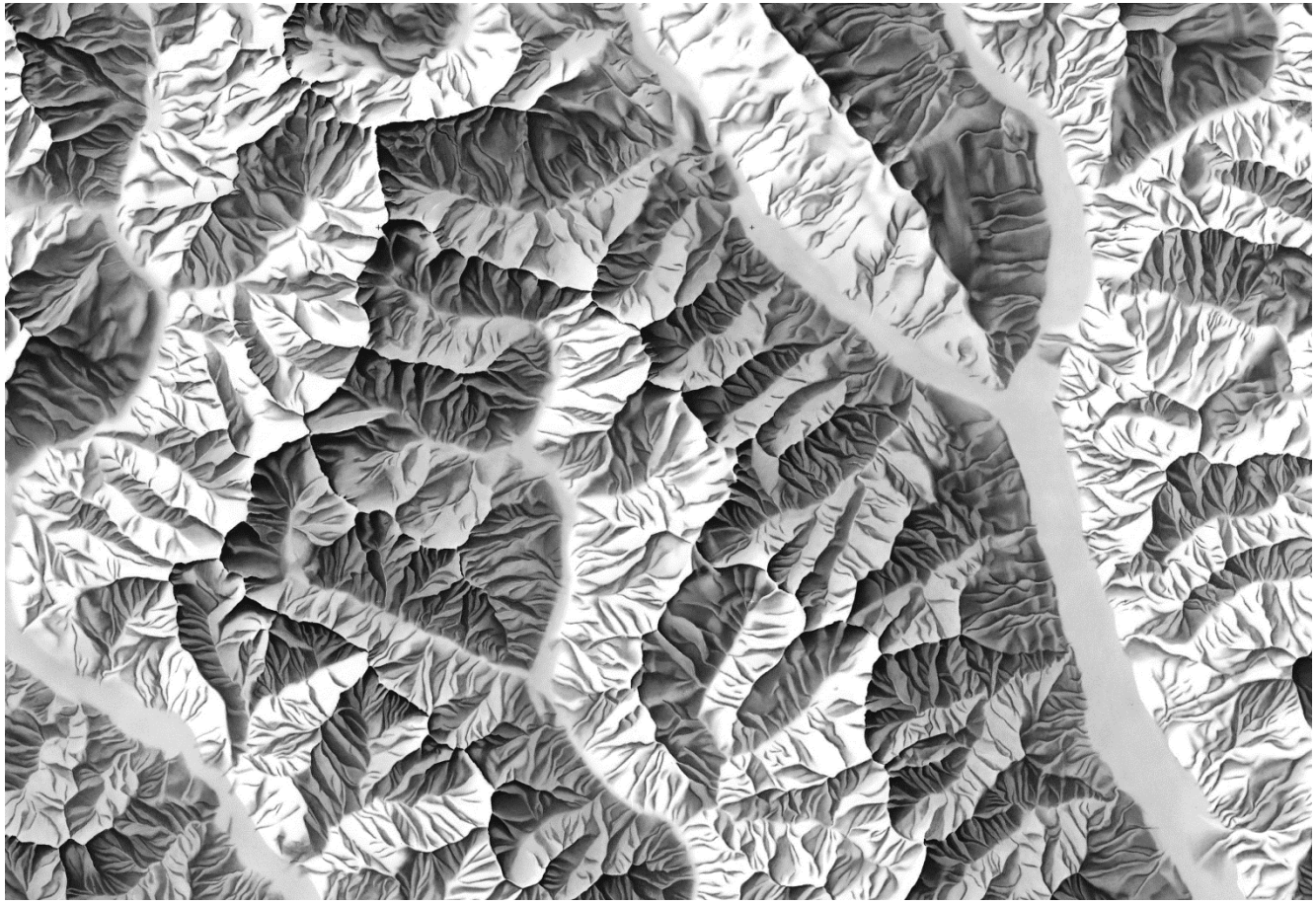
Overview

- Introduction
  - Manual relief shading
  - Analytical relief shading
- Objective
- Methods
  - Implementation in ArcGIS
  - Brassel`s method
  - Jenny`s method
  - Watershed method
- Results
- Conclusion
- References

Relief Shading



Biasca, Ticino, Switzerland, 1:100`000
ETH Zurich (2009)

Manual Relief Shading

Techniques complementing to the Swiss style shading (Imhof, 1982):

- Adjustments of the light direction
- Placement of bright grey tones in flat areas
- Adjustments of brightness and contrast
- Simulation of aerial perspective effect
- Use of colour

Hans Conrad Gyger (1668)
Original map is located in the Haus zum Rechberg Museum, Zurich

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Analytical Relief Shading

- Deployment of Lambert`s Cosine Law (Wiechel, 1878):

Intensity = cos e = cos a cos b + sin a sin b cos c

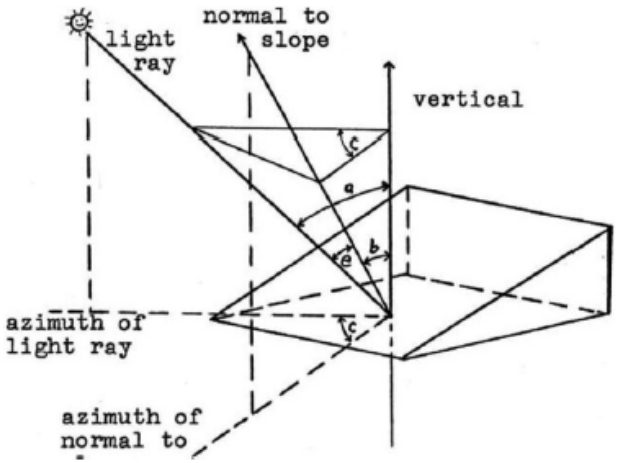


Fig. 1. Wiechel Aalytical Point Illumination 1878 (after Webster)

Moellering (2012)

- Calculating the light intensities in small square areas with fixed azimuth and zenith (Yoëli, 1966)

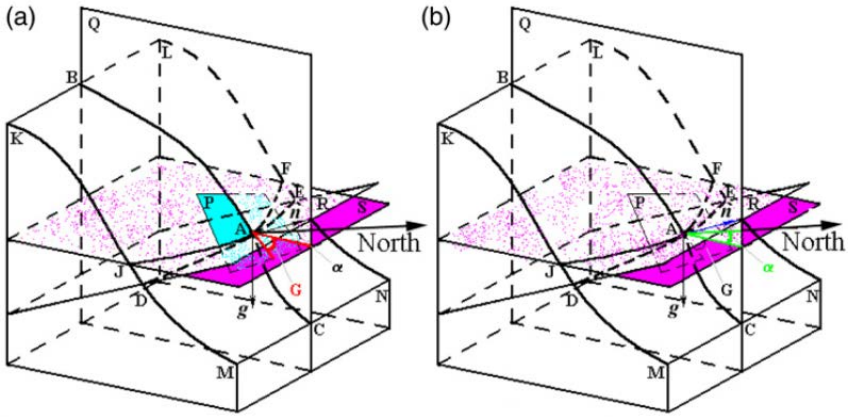
Analytical Relief Shading

slope (a) is an angle between the horizontal plane and a tangent plane at a given point

aspect (b) is a clockwise angle between the North and a projection of the vector normal to the topographic surface onto the horizontal plane

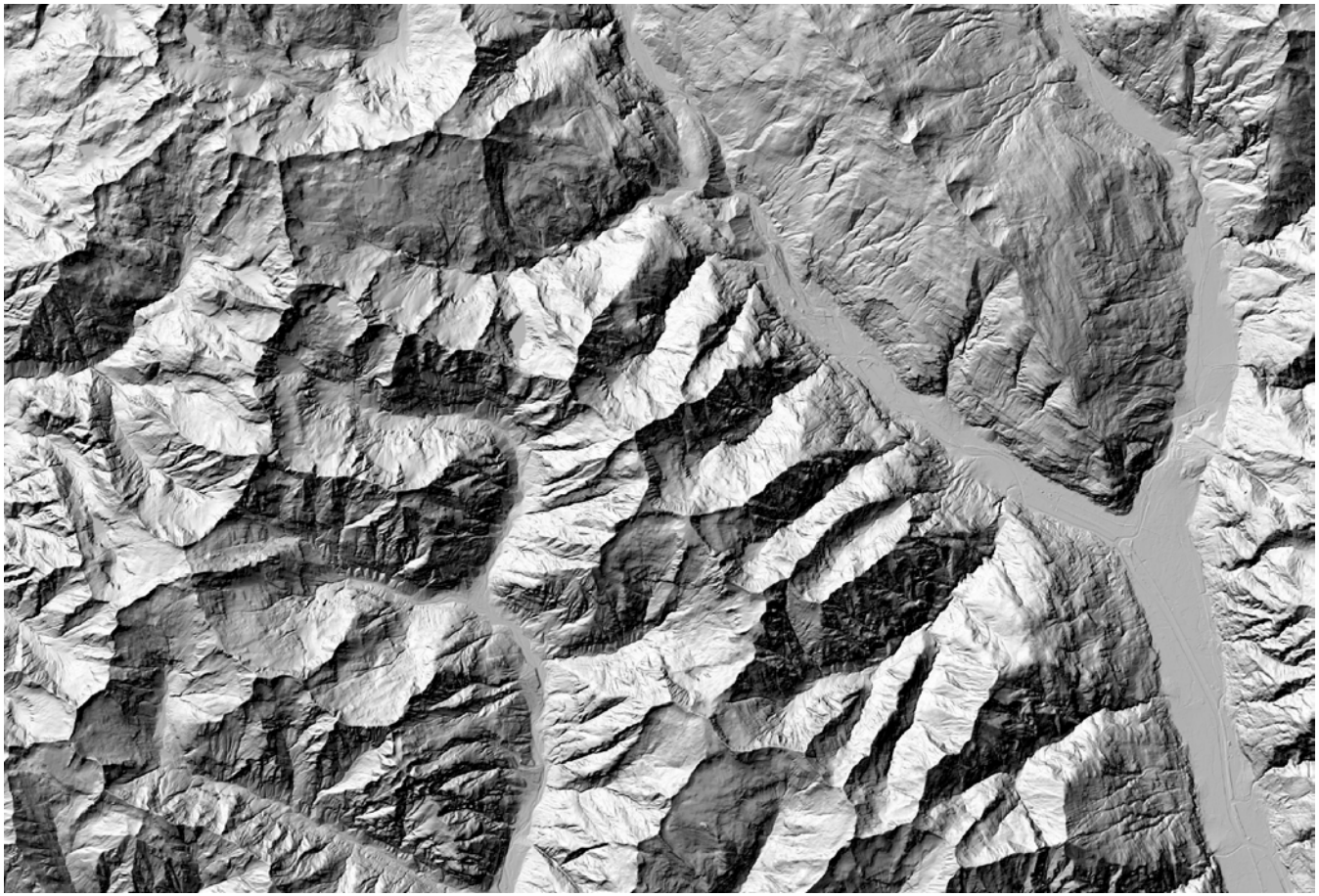
- Analytical Hillshading Equation:

Intensity = cos(Zenith)cos(Slope) + sin(Zenith)sin(Slope)cos(Azimuth - Aspect)



I.V. Florinsky (2012)

Analytical Relief Shading



I.V. Florinsky (2012)

Methods to Generate and Enhance Analytical Relief Shading

- Techniques within GIS packages (Buckley, 2008; Mark, 1992)
- Tonal changes (Brassel, 1974; Jenny, 2001; ArcGIS, 2008)
- Local adjustments of light direction (Yoëli, 1967; Zhou, X. and Dorrer, E., 1995, Jenny, 2001, Orzan et al, 2013)
- Applying more than one light source (Mark, 1992)
- Employing multidirectional visibility index (Podobnikar, 2012)
- Applying generalization (Brassel, K.E. and Weibel, R., 1988; Weibel, 1999; Leonowicz, A.M., Jenny, B. and Hurni, L., 2010)
- Photogrammetry and remote sensing (Horn, B.K.P. and Sjoberg, R.W., 1979; Horn, 1981; Hobbs, 1999)
- Filtering, texturizing, and colorizing by means of graphic software (Patterson, Tutorials, 2014; Jenny, B. and Hurni, L., 2006)

Objective

Improvement and automation of aerial perspective effect in ArcGIS

1. Implementation and comparison of existing methods
   → Visualization of influence of weights and parameters applied

2. Development of a new method to simulate aerial perspective effect within ArcGIS
   → Fully automated, implemented as ArcGIS tool

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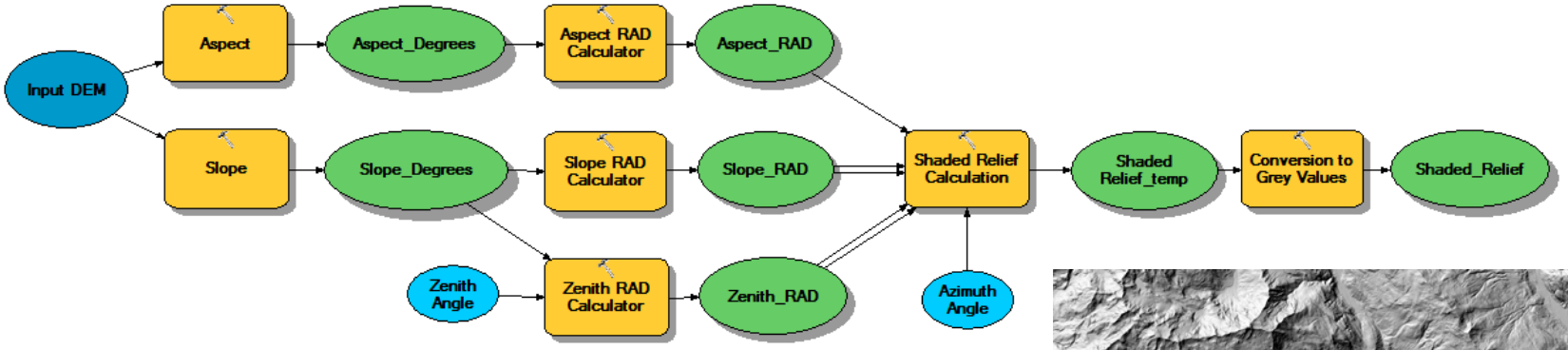
ArcGIS Hillshade Function

calculates illumination by setting a position for a hypothetical light source and calculating illumination values for each raster cell:

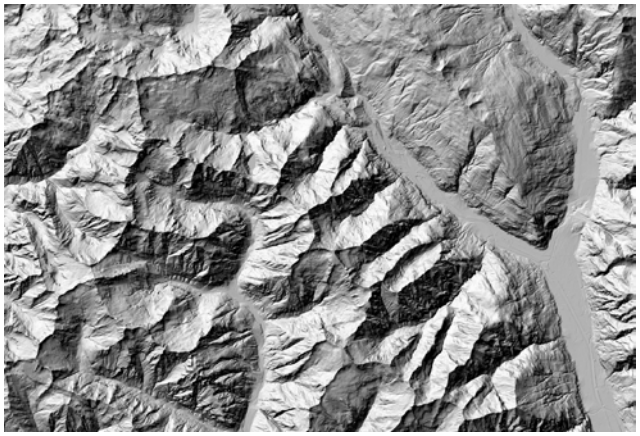
Hillshade= 255.0*((cos(Zenith_rad)*cos(Slope_rad))+(sin(Zenith_rad)*sin(Slope_rad)*cos(Azimuth_rad-Aspect_rad)))



a	b	c
d	e	f
g	h	i

(ESRI, 2011)

Zenith Angle_deg = 90 – Altitude

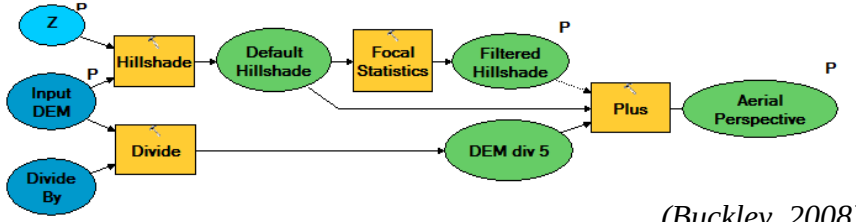


Shaded relief generated using hillshade function

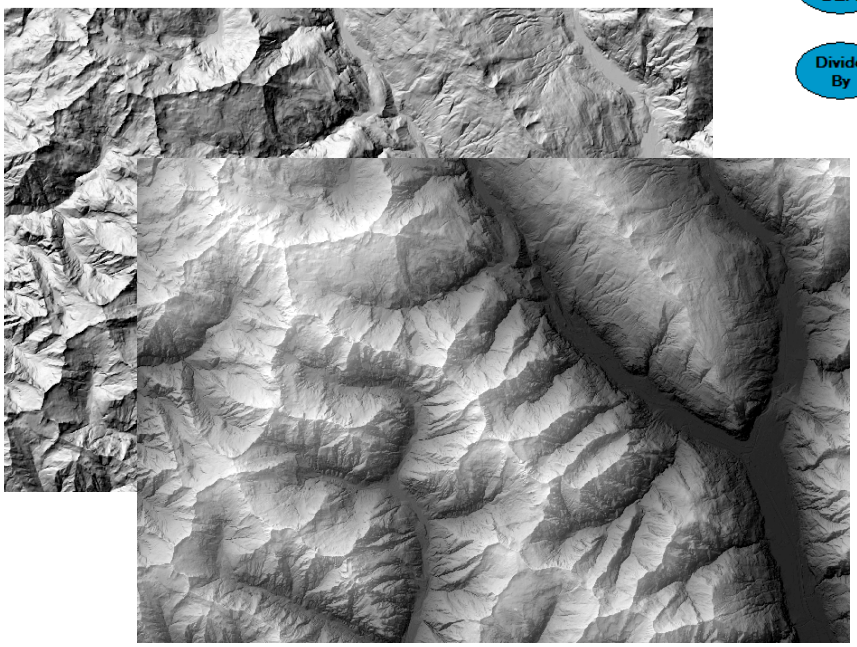
ArcGIS Hillshade Toolbox (2008)

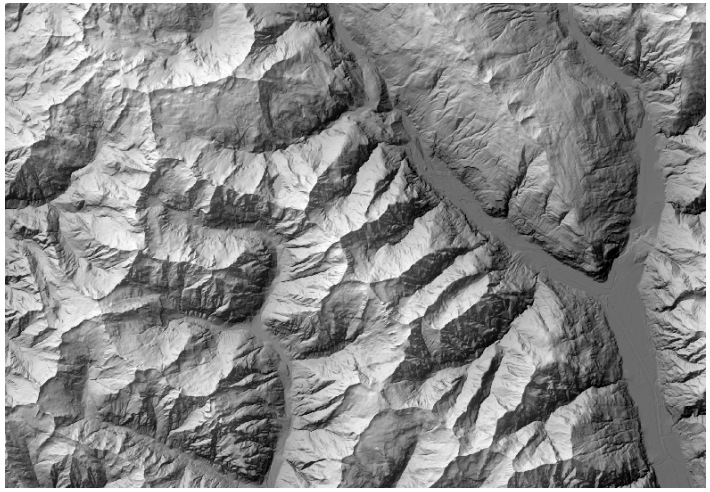
The Swiss Hillshade model outputs:

- generalized (smoothed) hillshade produced by using a median filter;
- a modified hillshade simulating aerial perspective effect in an inverse way (higher elevations lighter, lower darker).



(Buckley, 2008)



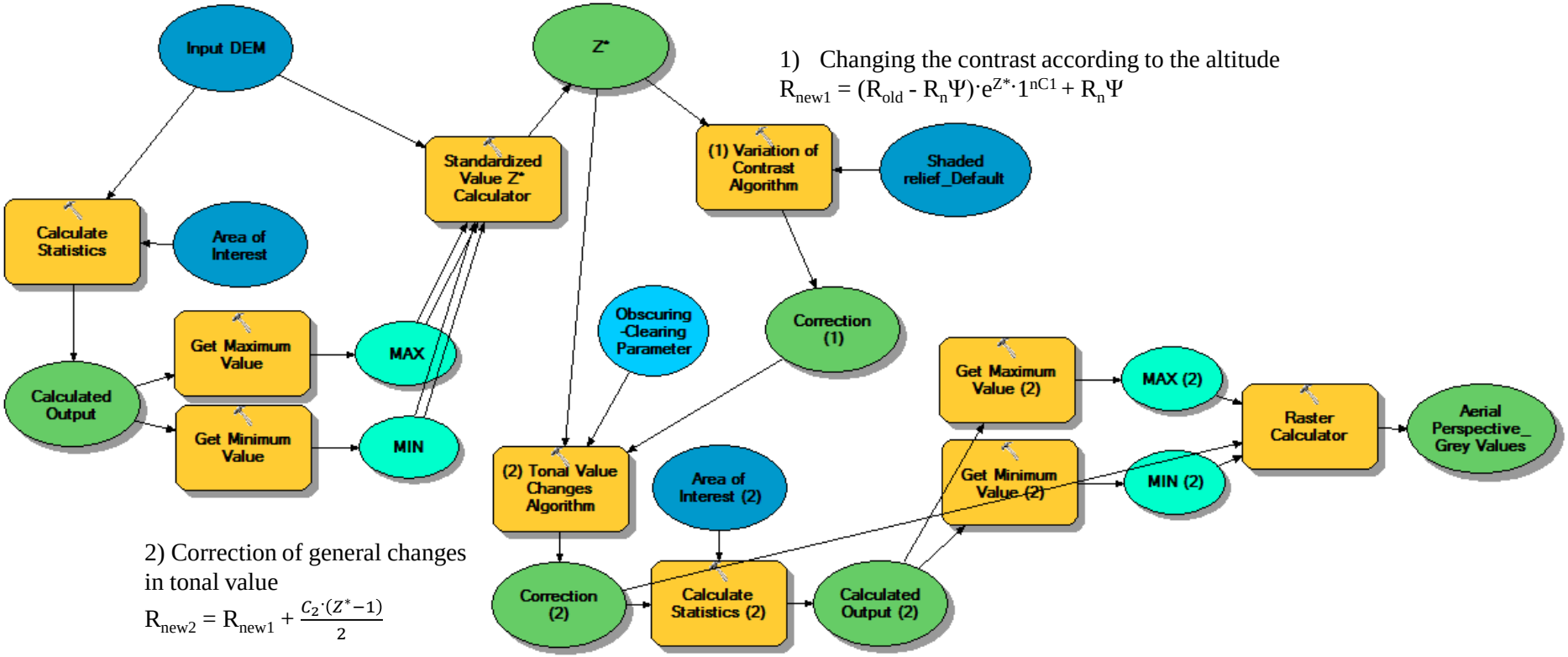


Shaded relief generated using the Swiss Hillshade model

Brassel`s Method (1974) in ArcGIS

Weight for the altitude of the grid cell

$Z^* = (Z - \frac{Z_{max}+Z_{min}}{2}) / \frac{Z_{max}-Z_{min}}{2}$



1) Changing the contrast according to the altitude

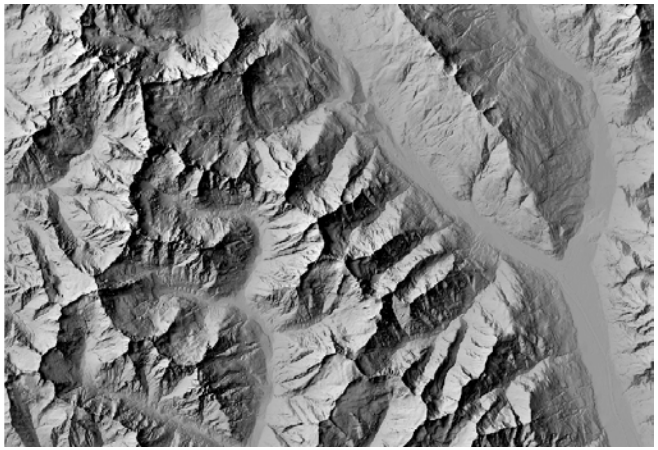
$R_{new1} = (R_{old} - R_n\Psi)\cdot e^{Z^*\cdot 1^{nC1}} + R_n\Psi$

2) Correction of general changes in tonal value

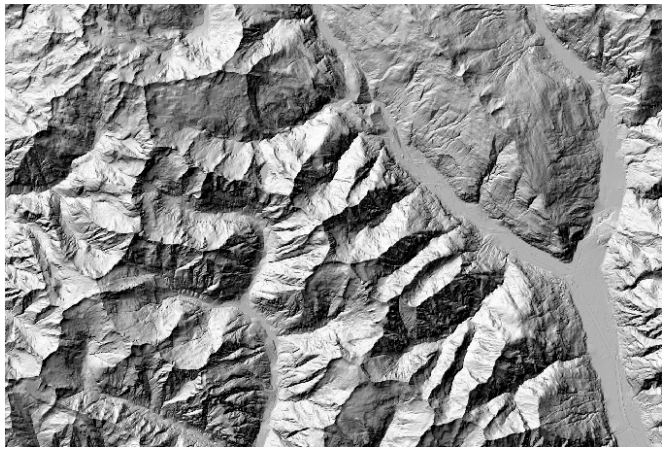
$R_{new2} = R_{new1} + \frac{C_2\cdot(Z^*-1)}{2}$

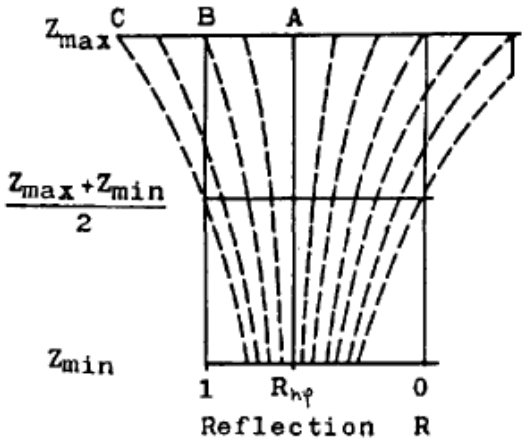
Output of Brassel`s Method

1) Changes of the contrast according to the altitude: $R_{new1} = (R_{old} - R_n\Psi)\cdot e^{Z^*\cdot 1^{nC1}} + R_n\Psi$



Default shaded relief, calculated with hillshading equation in ArcGIS





Variation of contrast (Brassel, 1974)

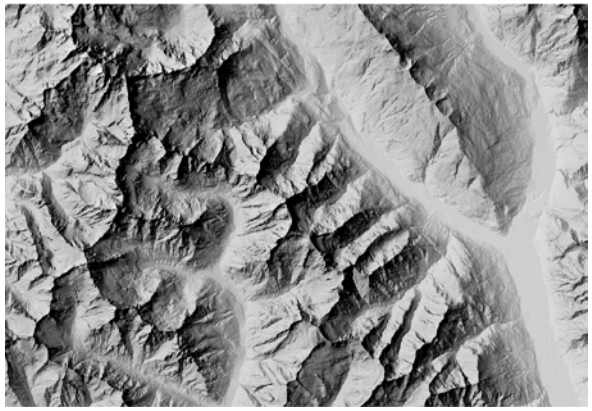
Output of Brassel`s Method

2) General changes of grey values according to the altitude $R_{new2} = R_{new1} + \frac{C_2 \cdot (Z^* - 1)}{2}$, where parameter C_2 defines the extent of maximum obscuring ($0 < C_2 \leq 1$) or clearing ($-1 \leq C_2 < 0$).

C_2=1

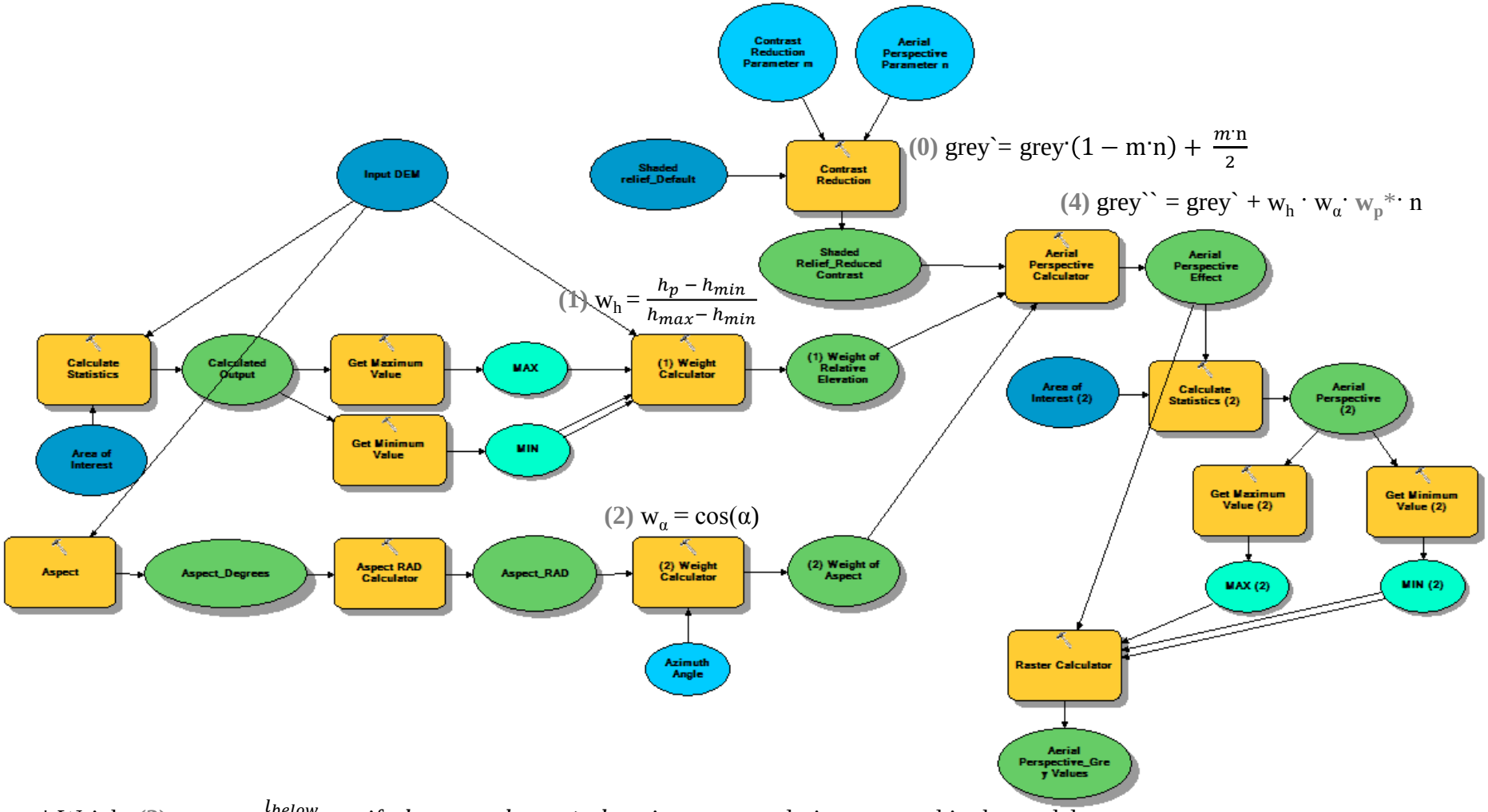
C_2= -1

C_2= $-\frac{1}{2}$



C_2= $-\frac{1}{3}$

Jenny`s Method (2001) in ArcGIS



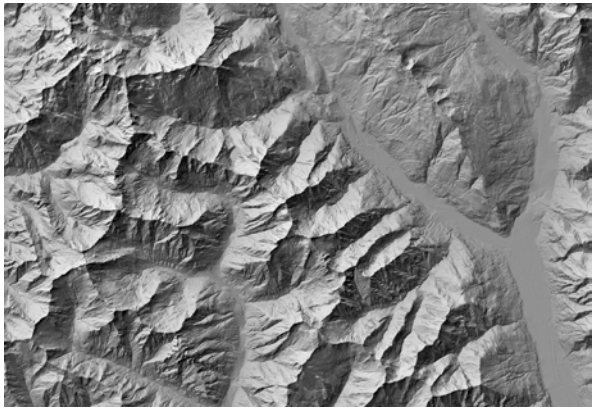
* Weight (3) $w_p = \frac{l_{below}}{l_{above} + l_{below}}$, if $l_{above} + l_{below} \geq l_{min}$ is not currently incorporated in the model

Output of Jenny's Method

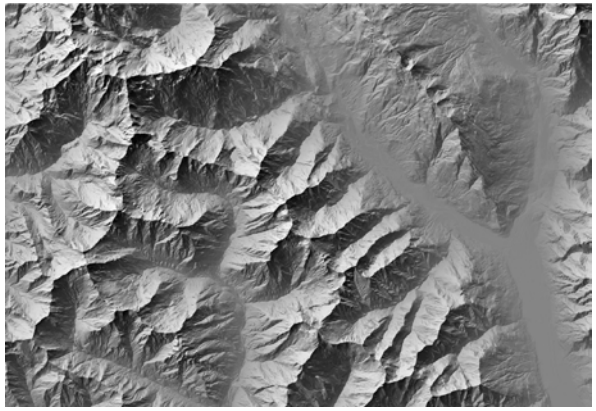
Grey values with aerial perspective effect: **(4)** $grey`` = grey` + w_h \cdot w_\alpha \cdot w_p^* \cdot n$

Aerial perspective parameter *n* is included in the contrast reduction to prevent contrast reduction in case aerial perspective is not applied (i.e. when n = 0).

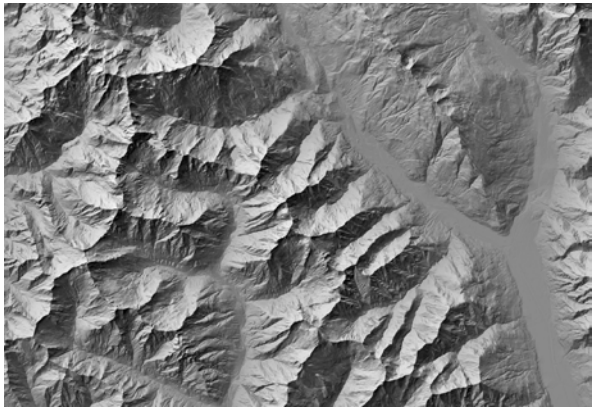
$m = 0{,}1$
$n = 0{,}1$



$m = 0{,}9$
$n = 0{,}9$



$m = 0{,}5$
$n = 0{,}9$



Default shaded relief

New Approach

Brassel's and Jenny's models:

✓ weights applied accentuate local peaks and diminish contrast in the lowlands

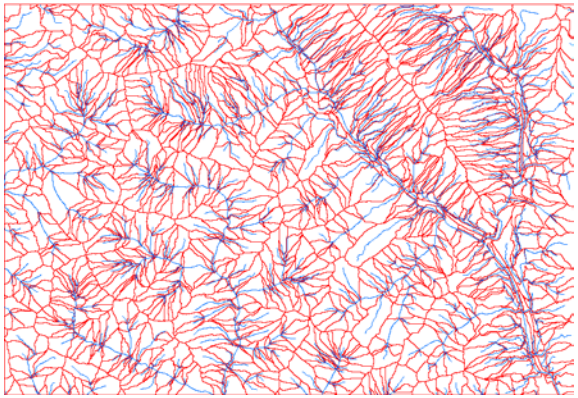
✗ major landforms within which points are located are not emphasized

→ Dividing terrain by **watersheds**:

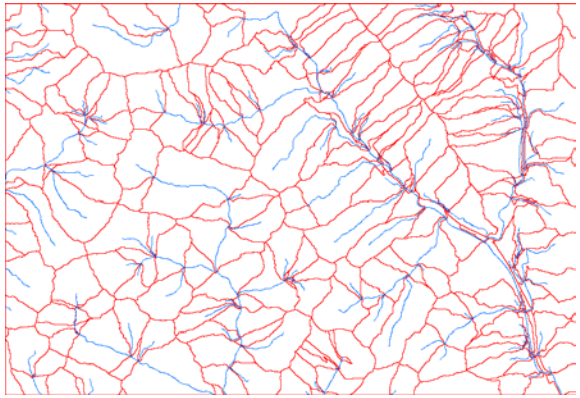
- constraining the tonal values to an area of a watershed
- taking into consideration major landforms
- treating every single watershed area separately as it is done in manual relief shading
- applying both global (the whole image) and local (landform) approaches

Extraction of Watersheds in ArcHydro

- ArcHydro tools
- Hydrology network data
- Choice of the proper parameters/scale



1: 2000



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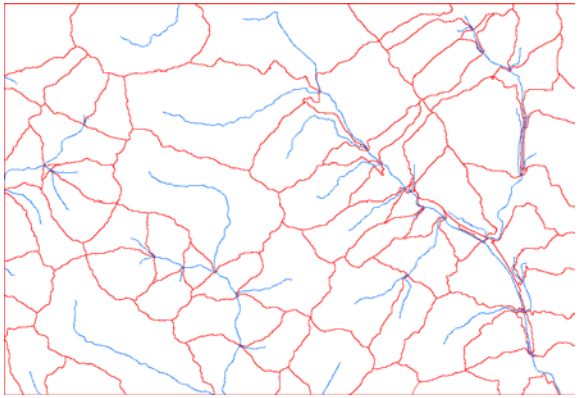
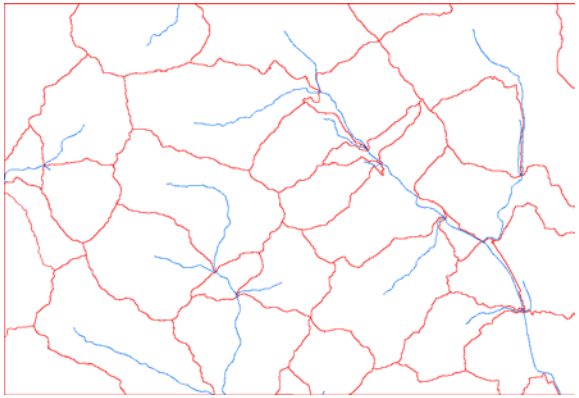
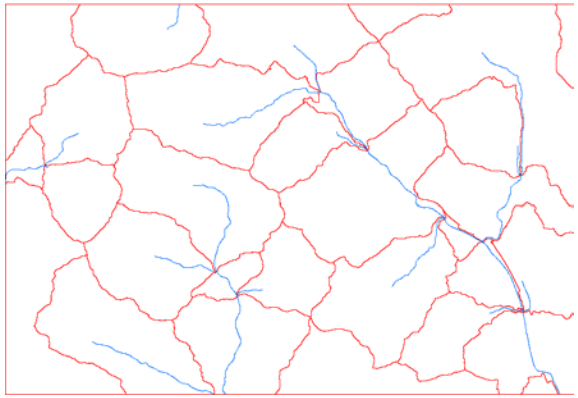


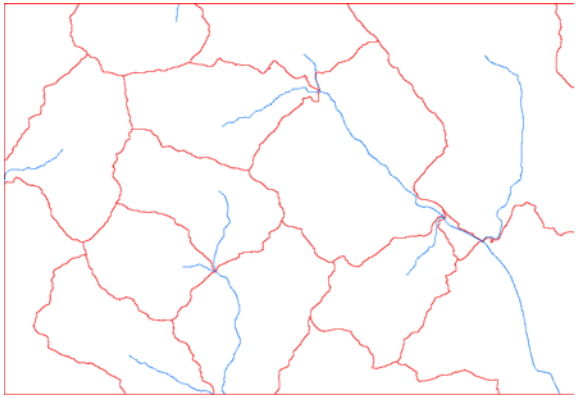
1: 30000



1: 75000



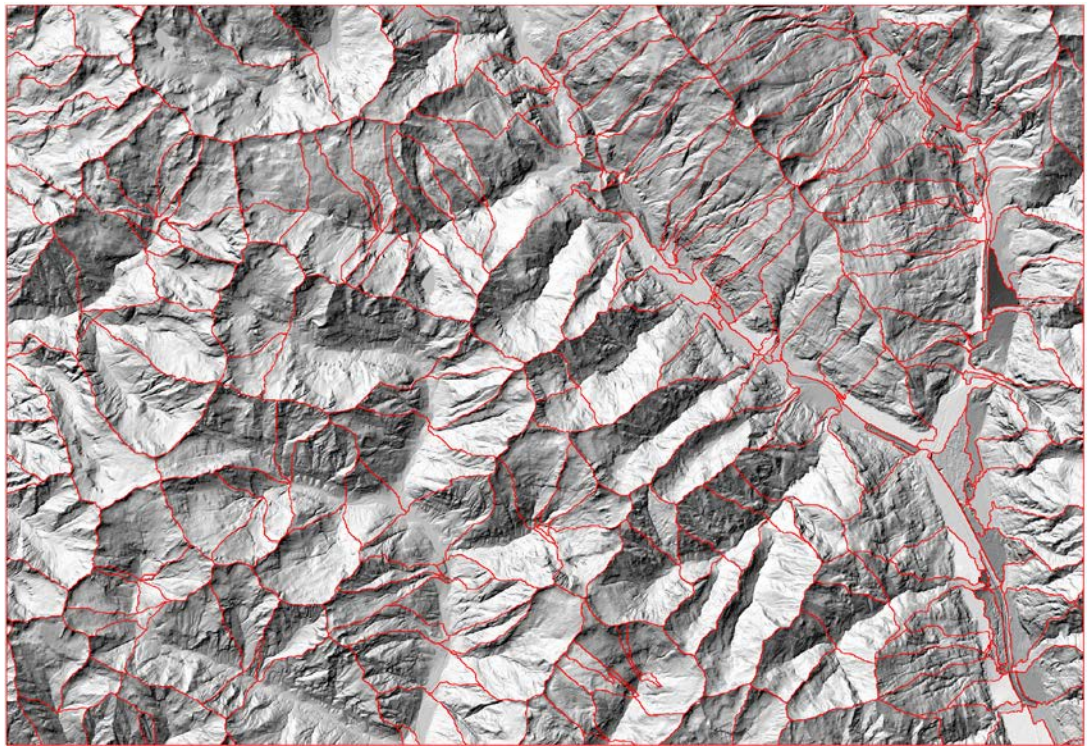
1: 100000

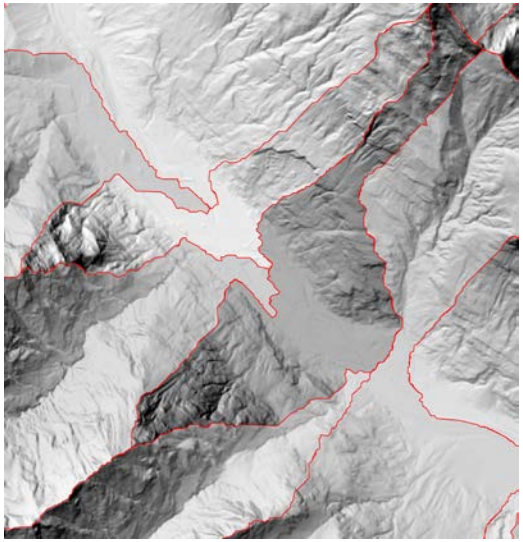


1: 150000

Extraction of Watersheds in ArcHydro

Shaded relief with altitude weight applied within watersheds, 1:10000



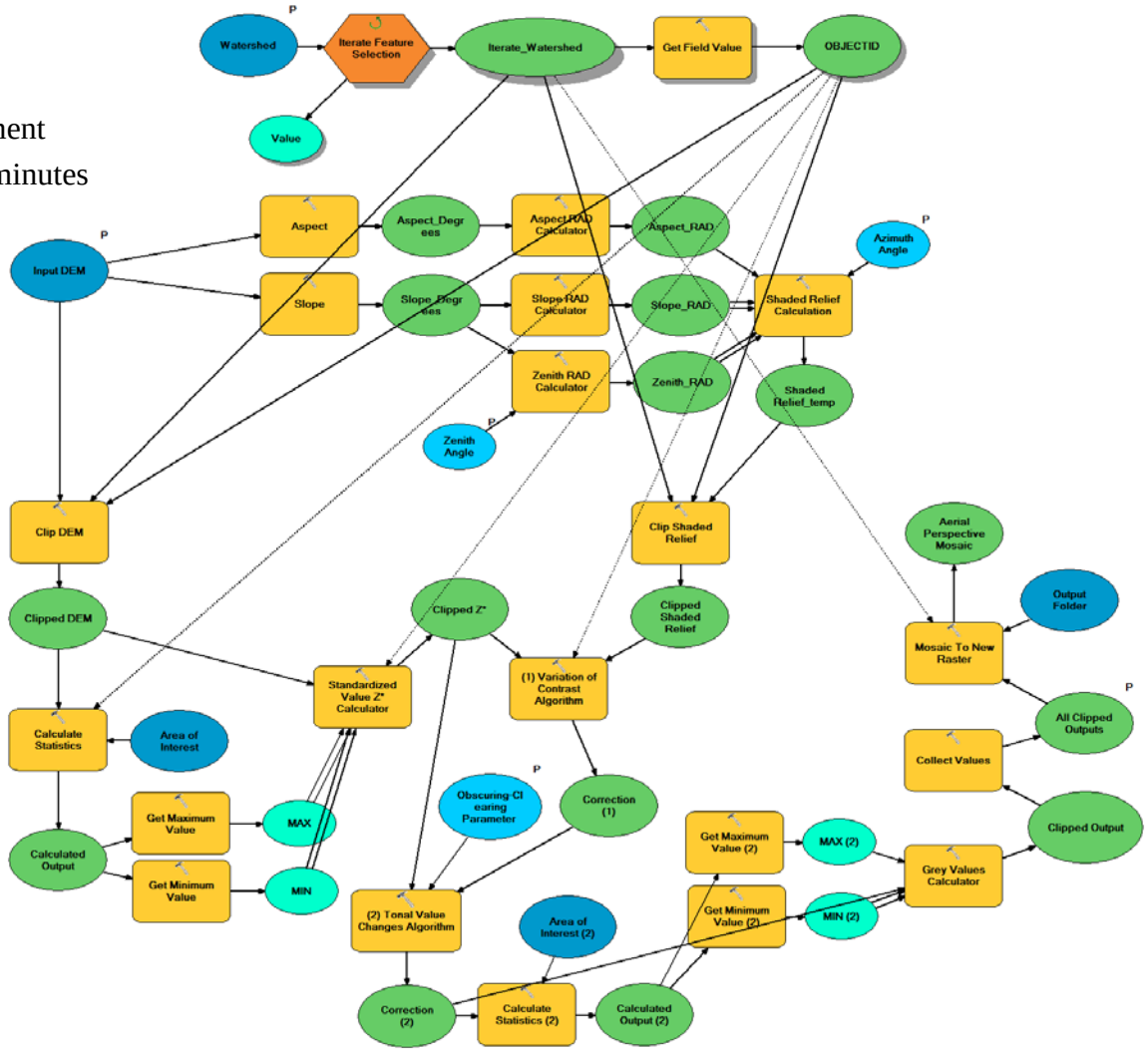


Transitions between tonal values of adjacent watershed areas due to weights applied within every particular watershed, 1:50000

Watershed Model (Brassel)

Watershed Tool:

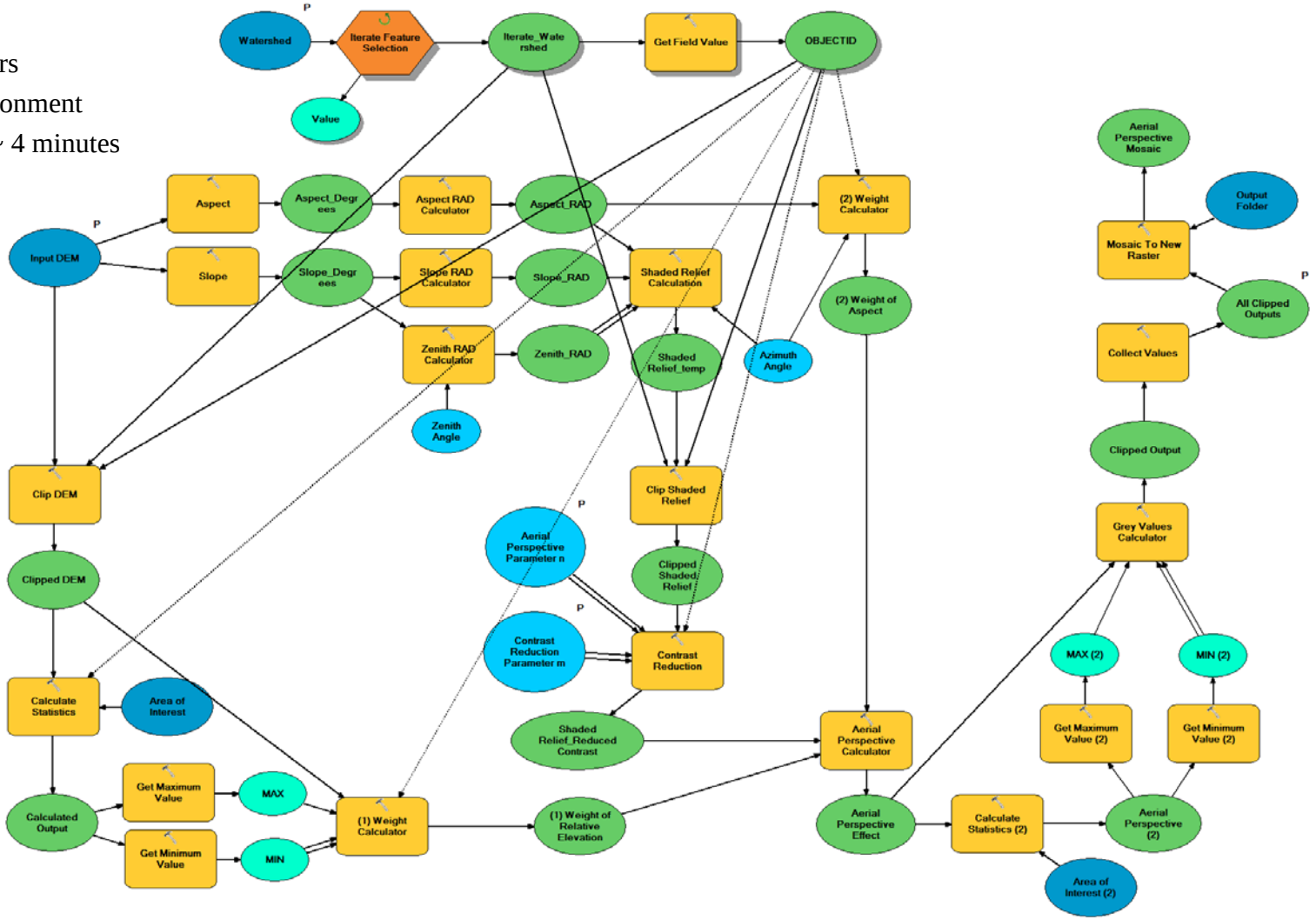
- 3 input parameters
- Workspace environment
- Execution time ~ 4 minutes



Watershed Model (Jenny)

Watershed Tool:

- 4 input parameters
- Workspace environment
- Execution time ~ 4 minutes



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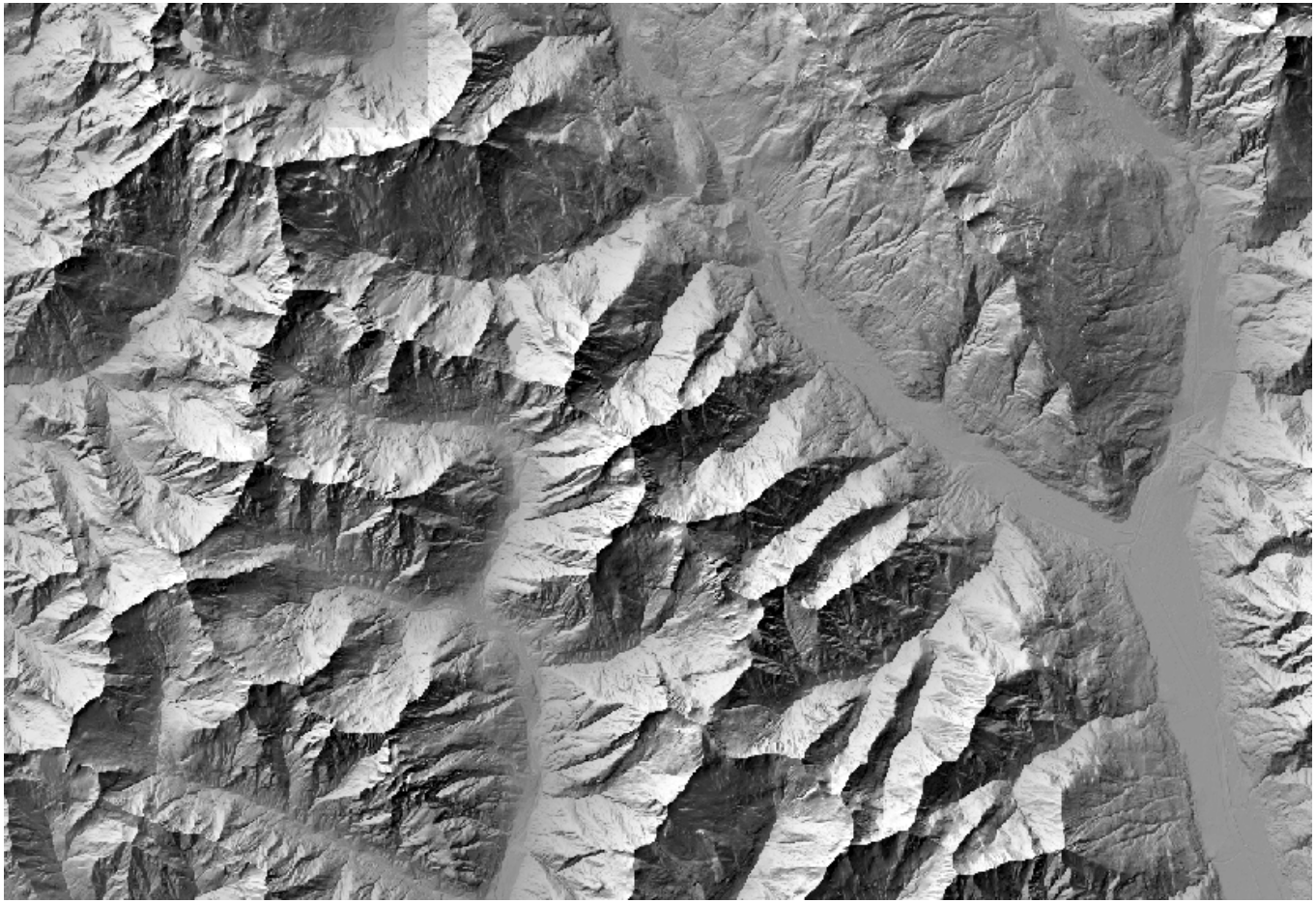
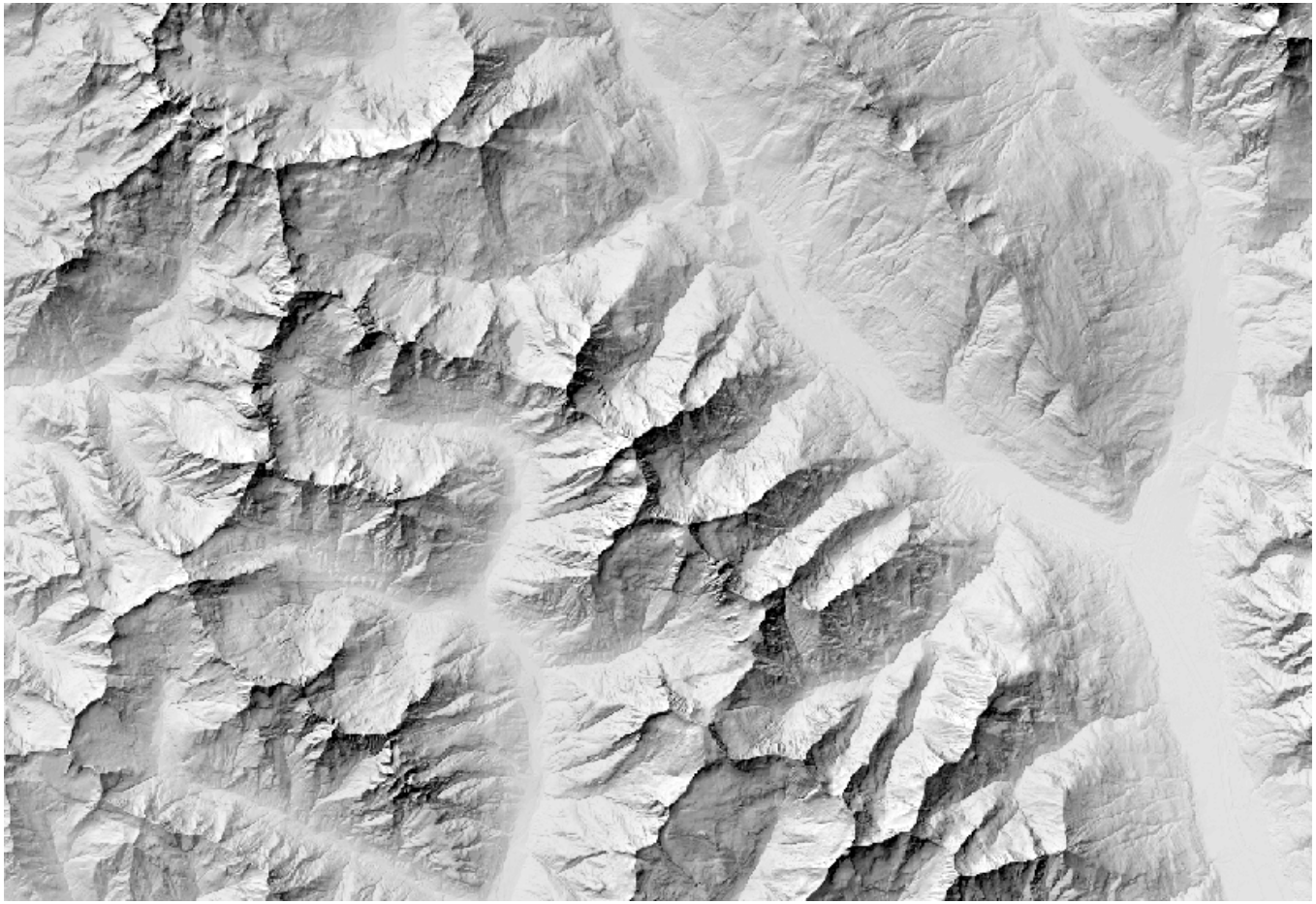
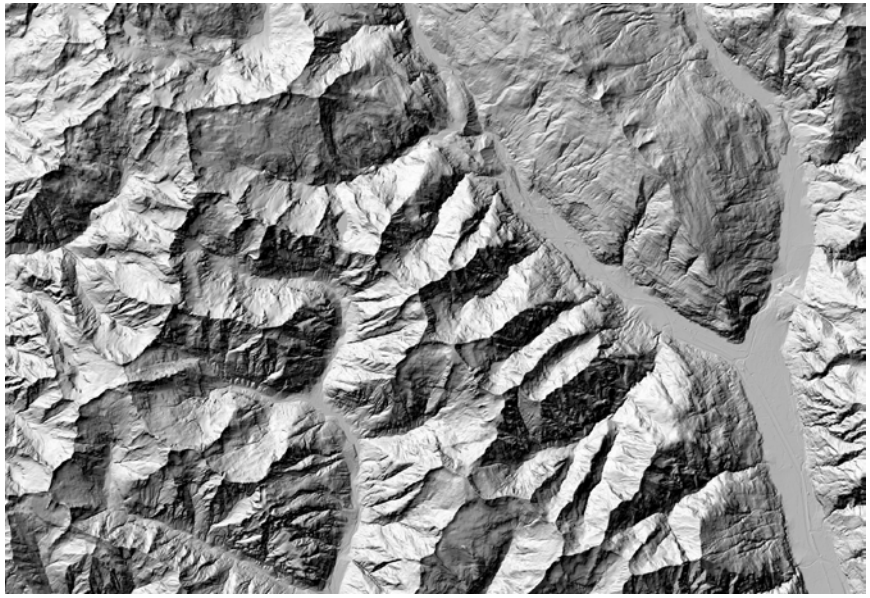
Results of the Watershed Method (Jenny)



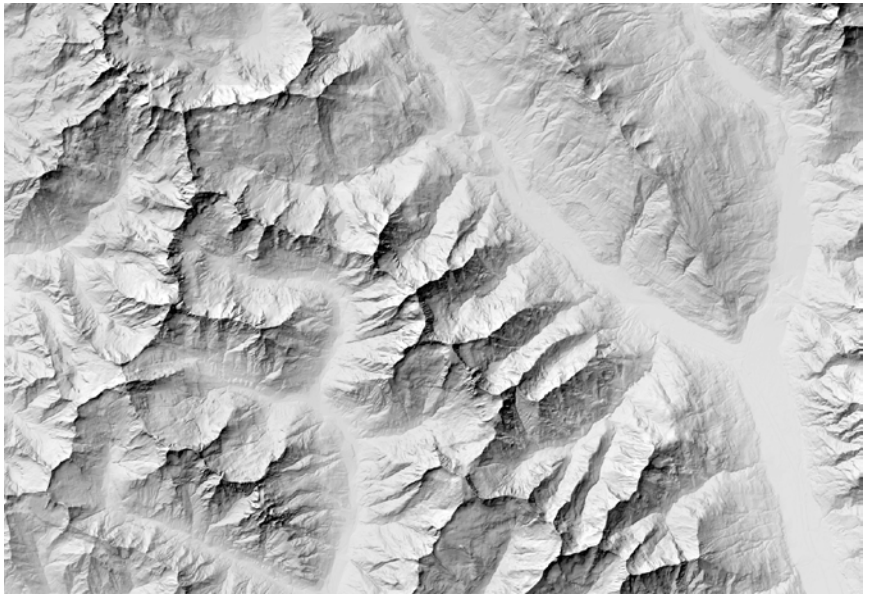
Results of the Watershed Method (Brassel)



Results

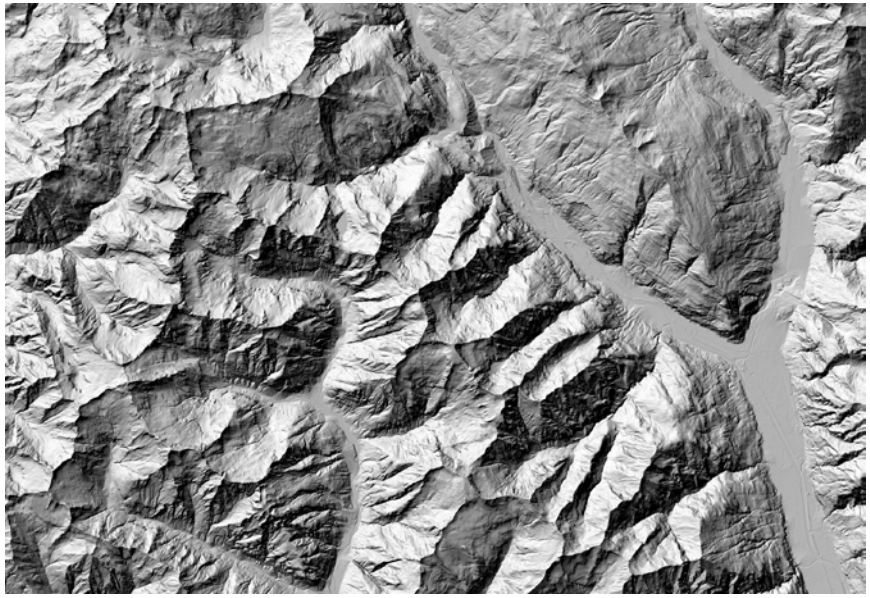


Shaded relief generated using hillshade function with default parameters

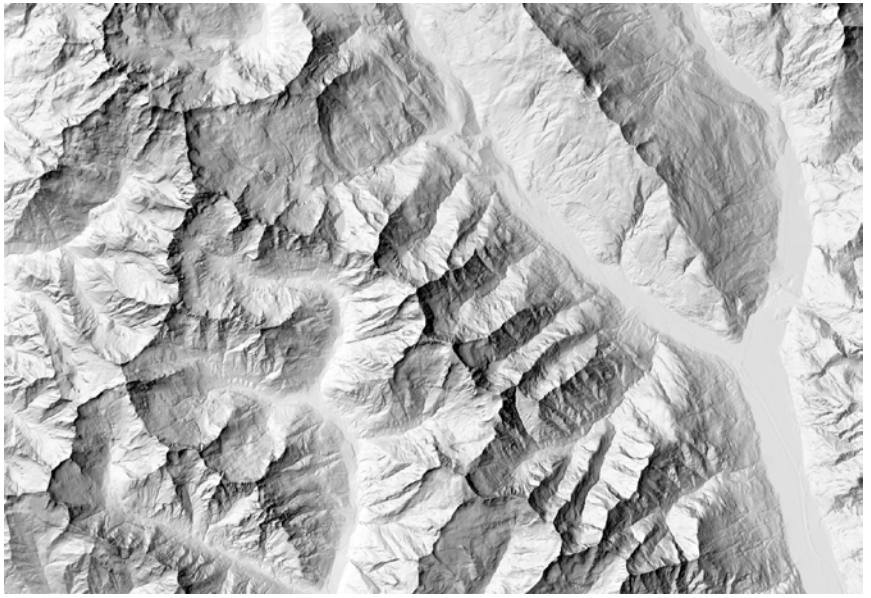


Shaded relief generated using hillshade function combined with aerial perspective effect calculated for watersheds using Brassel's equations

Enhanced Results



Shaded relief generated using hillshade function with default parameters



Shaded relief generated using hillshade function combined with aerial perspective effect calculated for watersheds using Brassel's equations and light changes within watersheds with two light sources

Conclusion

Limitations of the method:

- Choice of parameters for the algorithm in ArcHydro tools

Results:

- Implementation of the aerial perspective effect calculated by two methods in ArcGIS (global)
- Constraining the aerial perspective effect to watersheds in ArcGIS (local)
- Implementation of a new approach within a single ArcGIS tool in a **quantitative**, **consistent, reproducible** in GIS, **automatic** way

Thank you for your attention!

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- Cover image. Source: ETH Zurich (2009). ETH Geodata Portal. Retrieved from https://geodata.ethz.ch/geovite/geovite_index.jsp (last accesed: 16.06.2014)