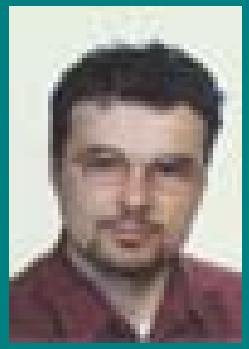
SOME EXPERIENCES IN ANALYTICAL RELIEF SHADING



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CROATIA

INTRODUCTION

- Croatia has a number of mountains
- Shaded reliefs in Croatia were done manually until recent days

- Today, cartography in Croatia is in expansion
  - new series of the official topographic maps
  - national strategy towards tourism has encouraged publishers to provide all kinds of map products

- Increasing need for relief shades

CROATIAN RELIEF (SRTM data)

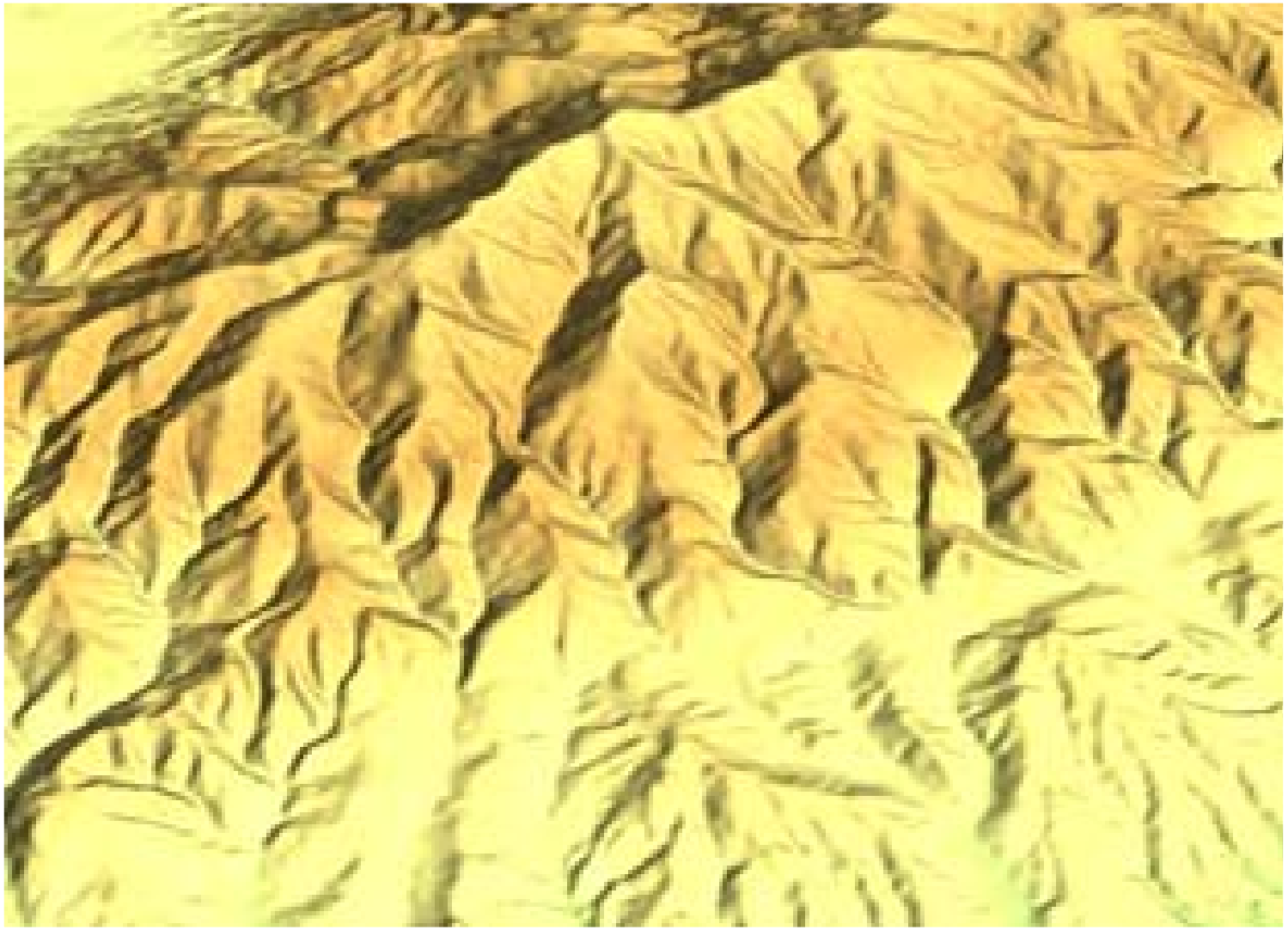
- Geomorphology of Croatian mountains:
  - 95 % sediment
  - 2-4 % metamorphic
  - 1 % vulcanic
- Karst (krš) with it's irregular shape is difficult to present with shades

MEDVEDNICA MOUNTAIN

- Peek – 1035 m – 10 km from Zagreb's main square
- The most visited mountain in Croatia
- The largest number of cartographic representations among Croatian mountains

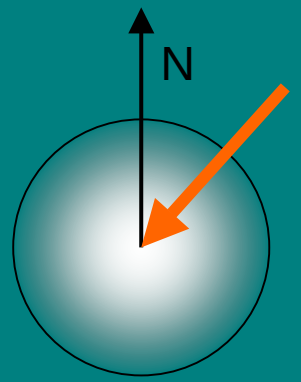
- DEM of Medvednica derived from contours from the topographic map at the scale of 1:25 000 will be used for examples

Perspective view of DEM



The main ridgeline is in SW-NE direction with spurs perpendicular to this direction

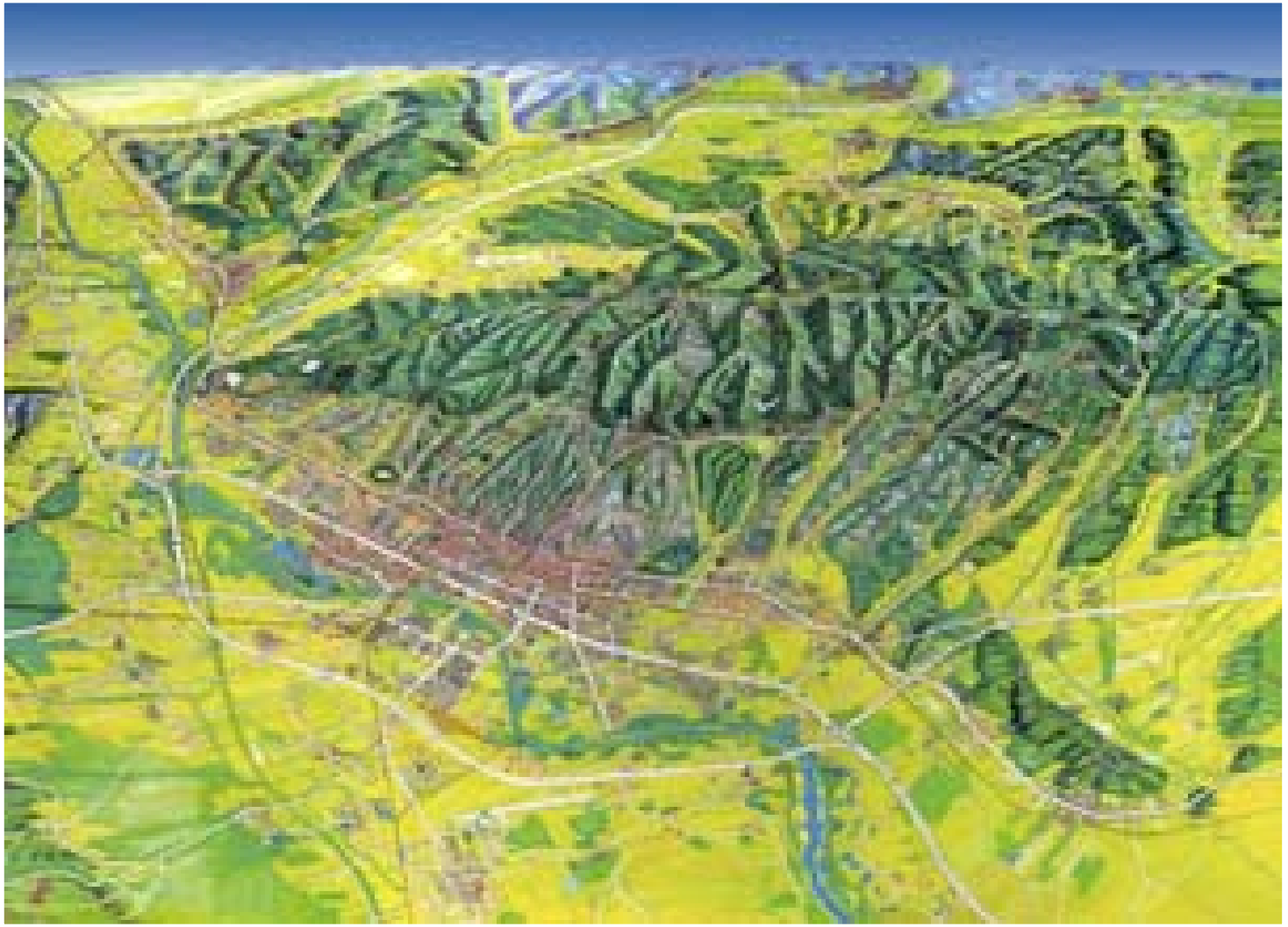
Top of Medvednica (Lovrić, 1993)

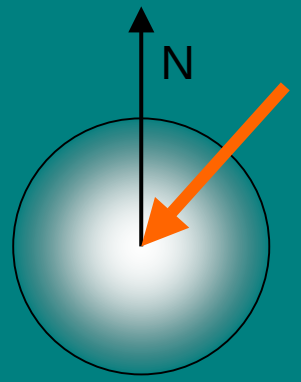


Average direction of light

Shades are drawn manually. Adaptive direction of light

Panoramic view

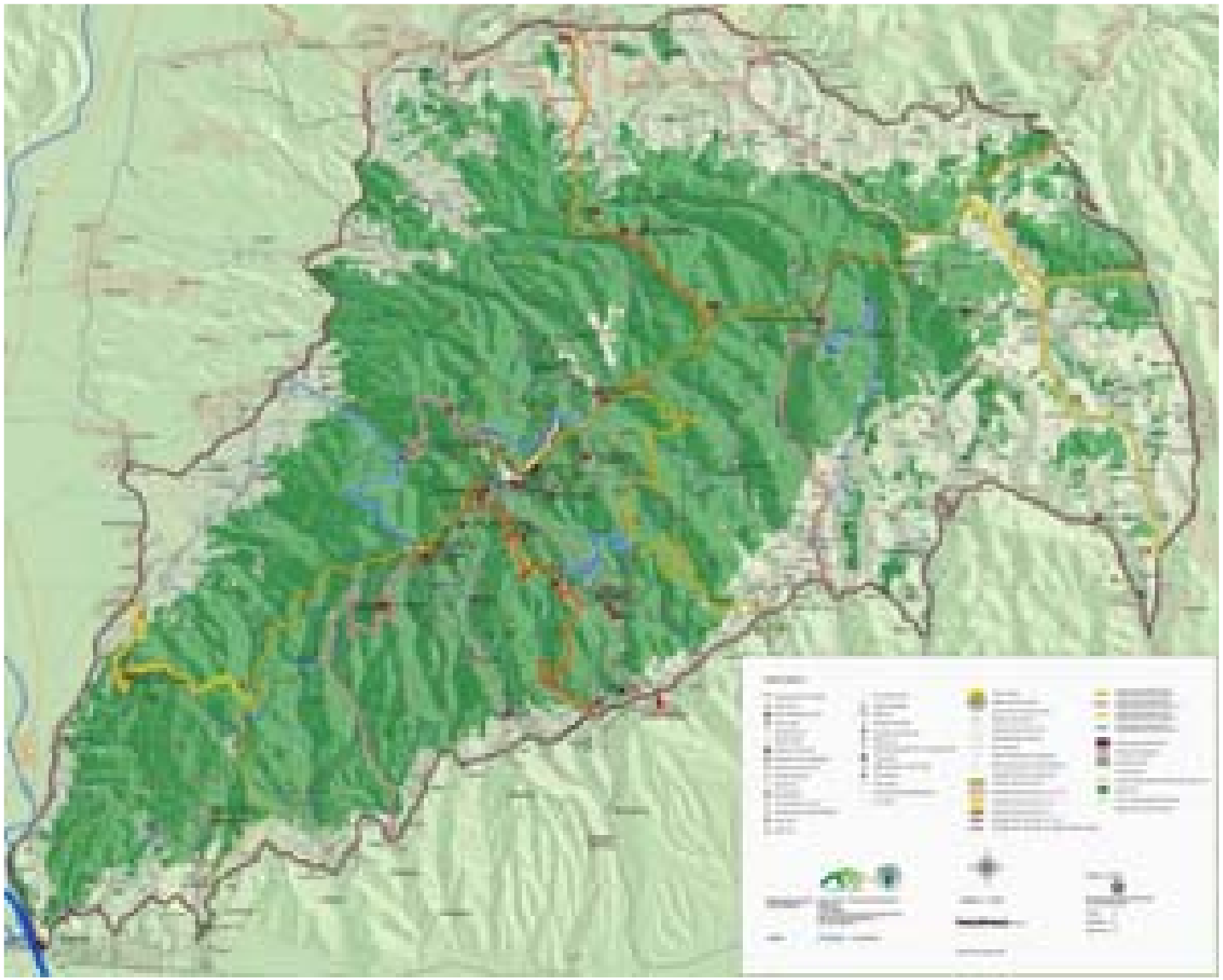


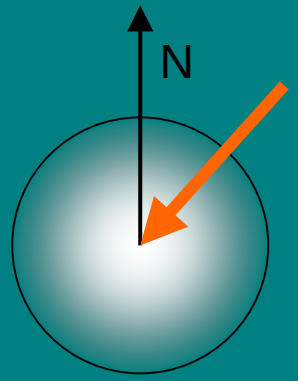


Direction of light

Artistic hand drawing

Bicycle map of Medvednica

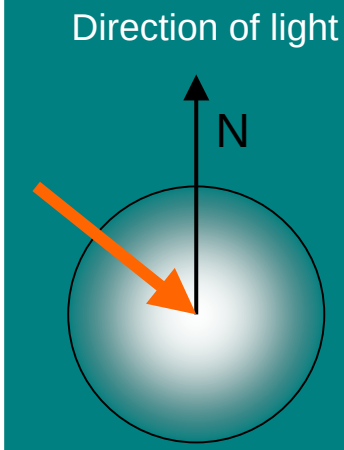




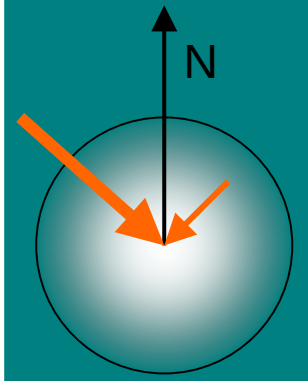
Direction of light

Analytical shading of digital relief model.

Photograph of the relief model (source unknown)



Hand drawn shades, by Ante Čala



Direction of light

MOTIVATION

- Absence of people specialized for manual relief shading
- Shades prepared for one map usually cannot be reused for other maps
- Investigate analytical relief shading and modify it to better serve the purpose for topographic and thematic maps

METHODOLOGY

- Brassel's work "Ein Modell zur automatischen Schräglichtschattierung", 1974.
- Modification of the azimuth, height and length of the vector of light
- The goal: Weight of shades on the map: as small as possible while preserving the best perception of the relief

Weight of shades

R_{mn} - raster matrix of shaded relief with values [0,255]

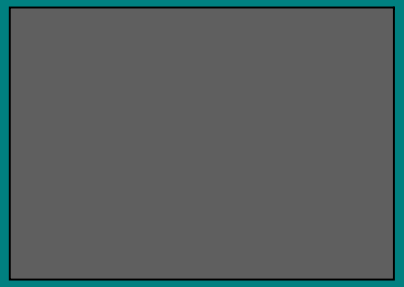
$$W = \frac{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left(1 - \frac{R_{ij}}{255}\right)}{m \cdot n} \cdot 100\,[\%]$$

calculated weight by this equation have relative meaning and does not represent final weight on printed map.

Weight calculated by equation $$W = \frac{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left(1-\frac{R_{ij}}{255}\right)}{m \cdot n} \cdot 100\,[\%]$$

100%

0%



50%

DIFFUSE SHADING

$\vec{r}_{ij}$ - normal vector of relief surface

$\vec{l}_{ij}$ - vector of light

Cosine of the angle between vectors $\vec{r}_{ij}$ and $\vec{l}_{ij}$.

$$D_{ij} = \frac{\vec{l}_{ij} \cdot \vec{r}_{ij}}{\left|\vec{l}_{ij}\right| \cdot \left|\vec{r}_{ij}\right|} \qquad i = 0,1,\ldots,m \qquad j = 0,1,\ldots,n$$

Linear transformation from $[\min(D_{ij}),\max(D_{ij})]$ to $[0,255]$

$$R_{ij} = \frac{255}{\max(D_{mn}) - \min(D_{mn})}\left(D_{ij} - \min(D_{mn})\right)$$

Vector of light

$$\vec{l}_{ij} = x_{ij}\vec{i} + y_{ij}\vec{j} + z_{ij}\vec{k}$$ triple x_{ij}, y_{ij}, z_{ij} defining the radius vector

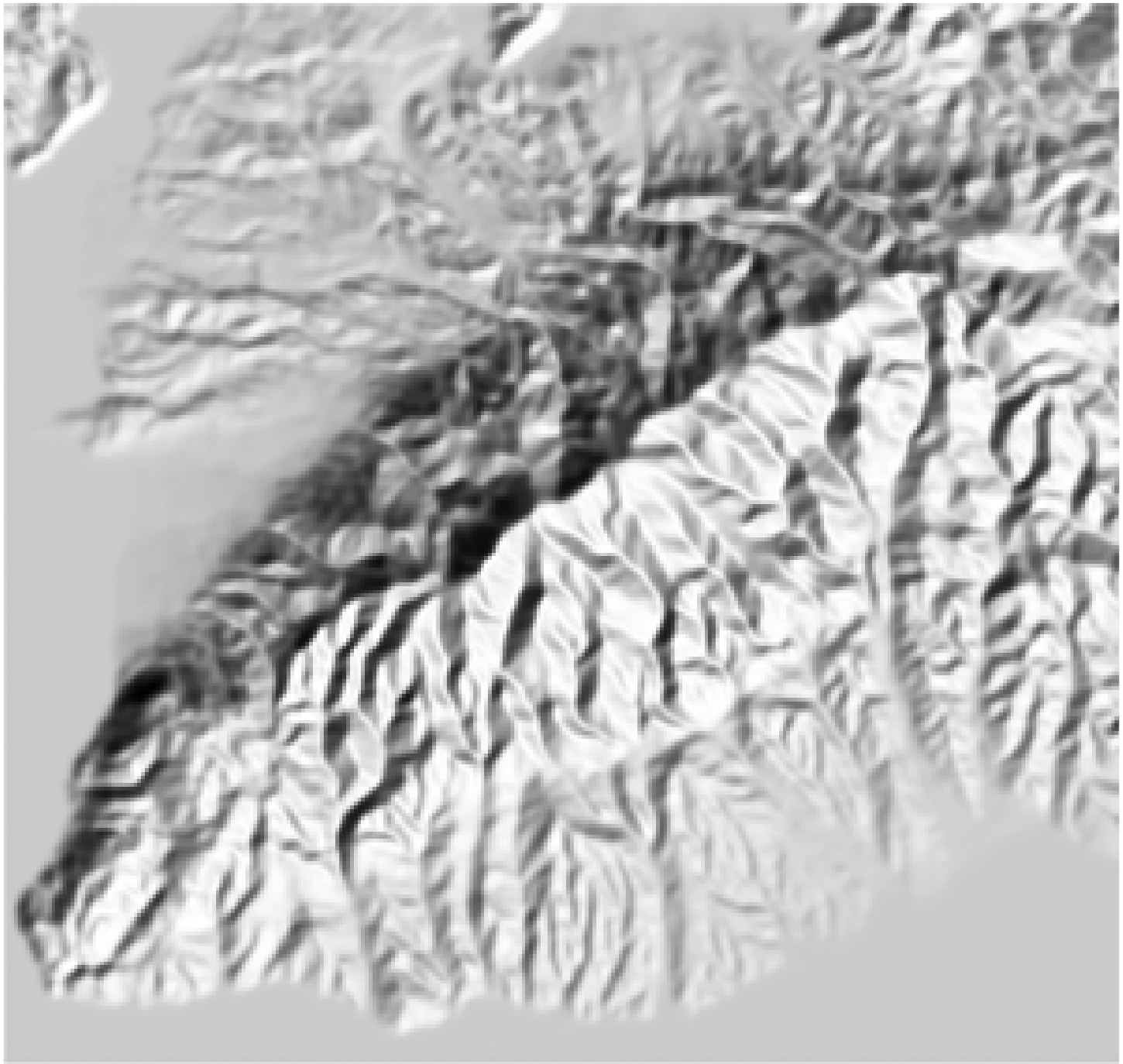
$$H_{ij} = \arctan\left(\frac{z_{ij}}{\sqrt{x_{ij}^2 + y_{ij}^2}}\right)$$ height above horizon

$$A_{ij} = \arctan\left(\frac{y_{ij}}{x_{ij}}\right)$$ azimuth

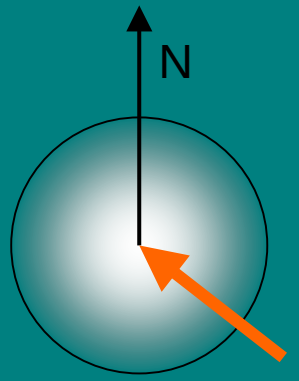
$$I_{ij} = \sqrt{x_{ij}^2 + y_{ij}^2 + z_{ij}^2}$$ length

$$\vec{l}_{ij} = \{H_{ij}, A_{ij}, I_{ij}\}$$

$$\vec{l}_{ij} = f(\vec{r}_{ij}) \neq \overrightarrow{const.}$$



Diffuse shading
A=135°
H=45°
I=1



Direction of light

Weight: 27%

Modification of azimuth

Calculate the aspect a_{ij}

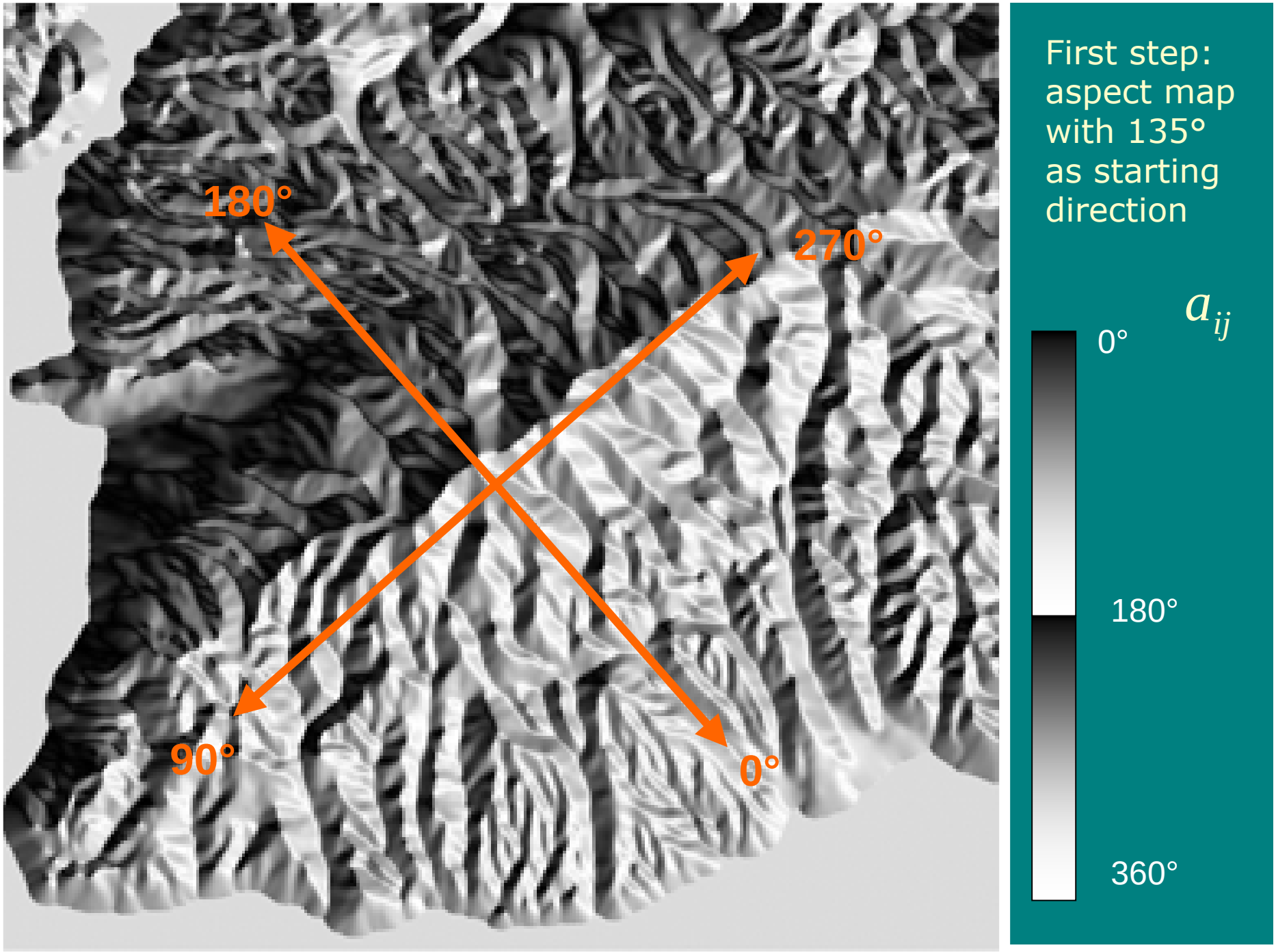
with starting direction $A_{ij} = A_{const.}$ (135°)

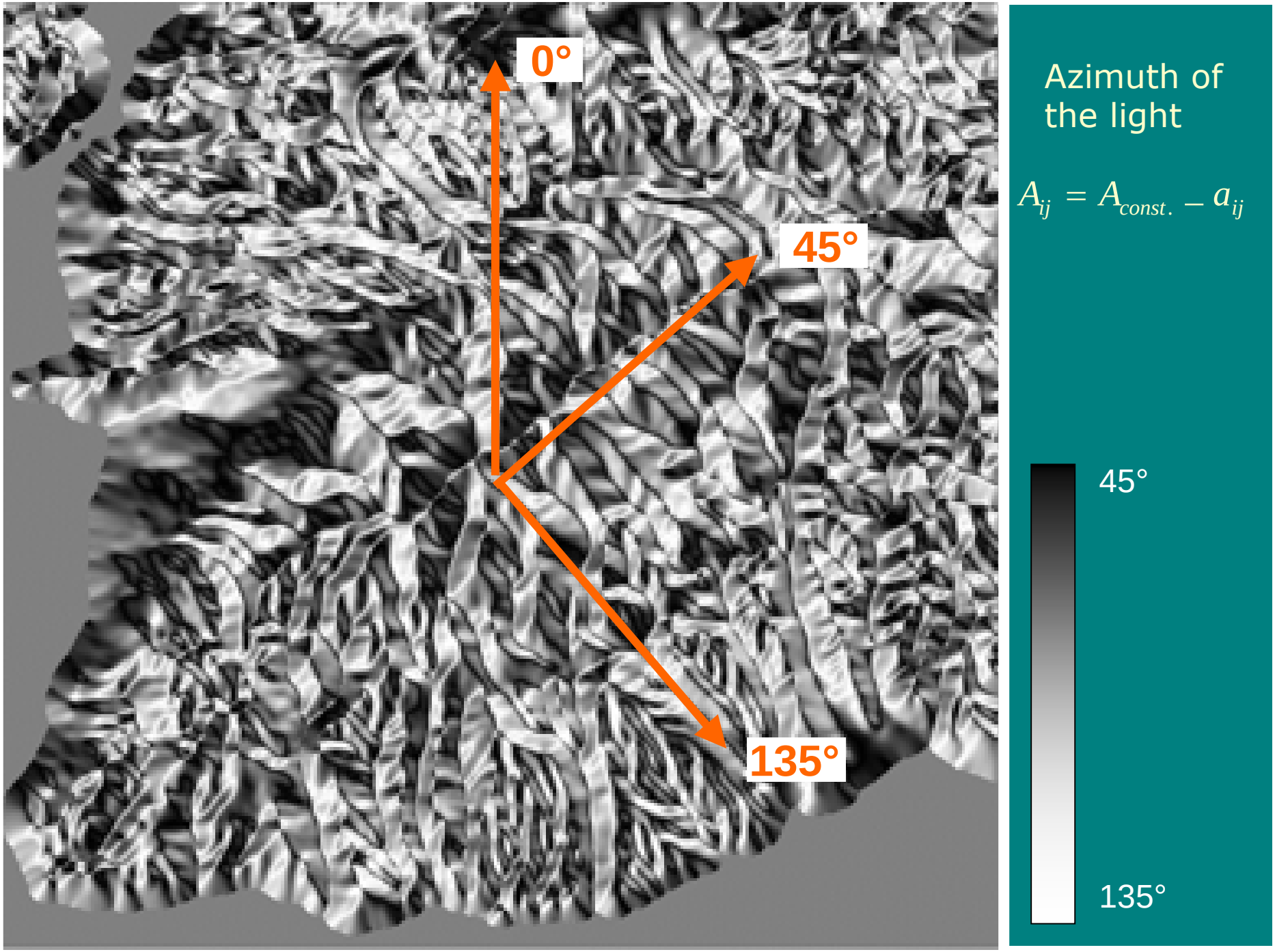
Transformation to the first quadrant:

$$a_{ij} = \arcsin\left(\left|\sin\left(a_{ij}\right)\right|\right)$$

Final azimuth of the light:

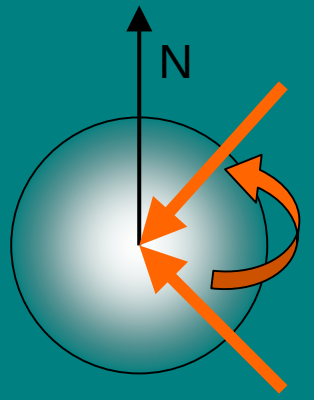
$$A_{ij} = A_{const.} \pm a_{ij}$$


180°
270°
90°
0°
First step: aspect map with 135° as starting direction
a_{ij}
0°
180°
360°


0°
45°
135°
Azimuth of the light
$A_{ij} = A_{const.} - a_{ij}$
45°
135°

Modificaton
of azimuth

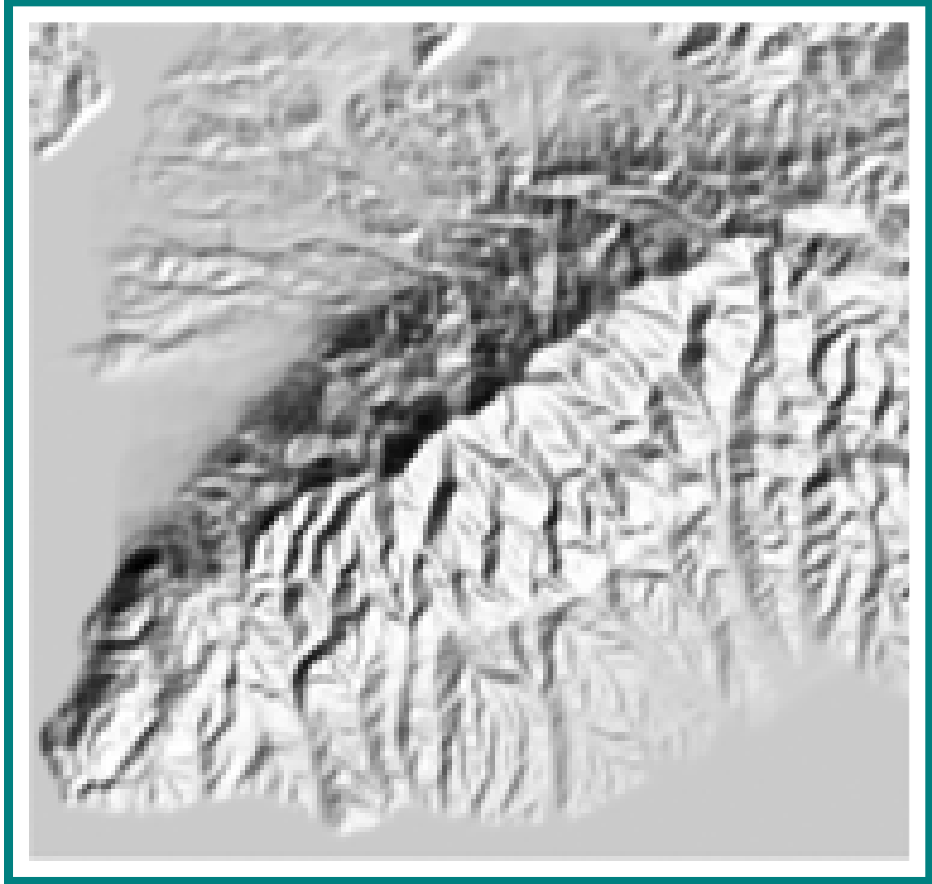
$$A_{ij} = A_{const.} - a_{ij}$$



Direction of light

Weight: 28%

Comparison



Modification of height

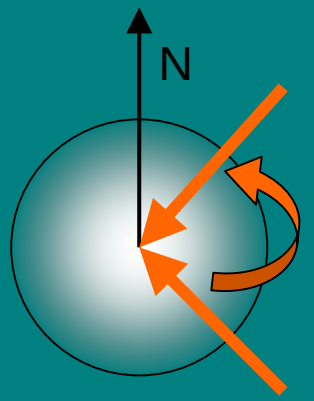
Calculate the slope of relief S_{ij}

Let the height be perpendicular to the slope:

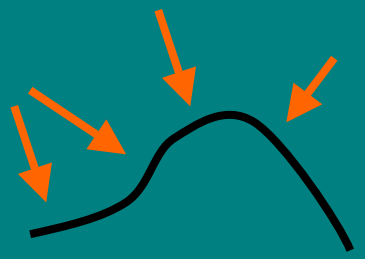
$$H_{ij} = 90° - S_{ij}$$


0°
Slope
90°
0°
Height
90°

Modification of azimuth and height



Direction of light



Height of light

Weight: 14%

Modification of the length of vector

$I\left(\min\left(R_{mn}\right)\right)=1$ - length of the light vector for minimum elevation

$I\left(\max\left(R_{mn}\right)\right)=k$ - length of the light vector for maximun elevation

Linear relationship between the length and elevation

$$I_{ij}=\frac{k-1}{\max\left(R_{mn}\right)-\min\left(R_{mn}\right)}\left(R_{ij}-\min\left(R_{mn}\right)\right)+1$$

Transformation to the grayscale

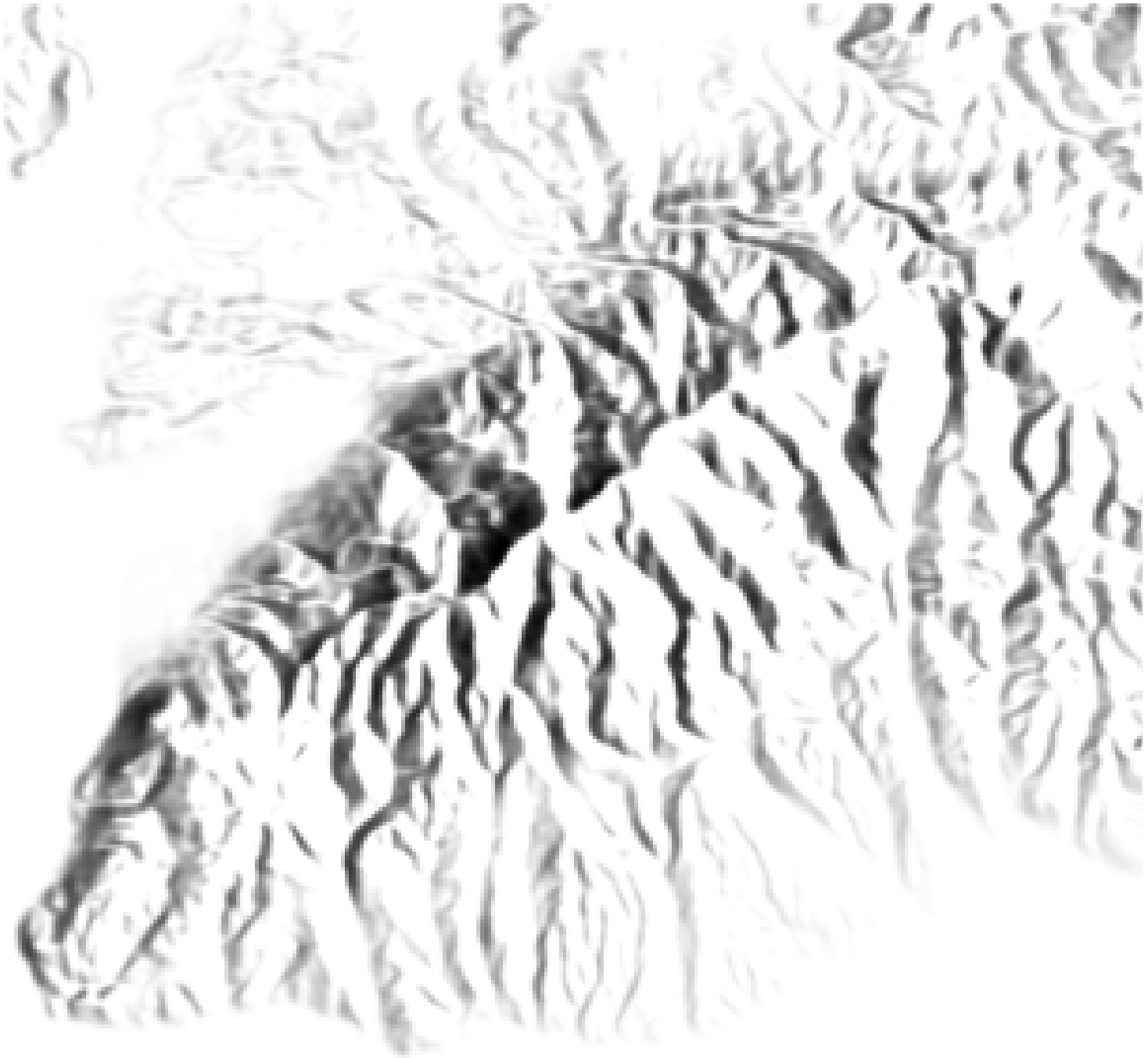
$$R_{ij}=\frac{255}{D_{flat}-\min\left(D_{mn}\right)}\left(D_{ij}-\min\left(D_{mn}\right)\right)$$

If

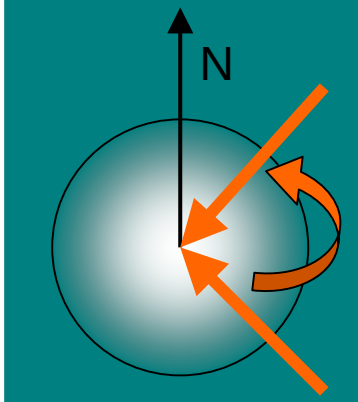
$R_{ij}>255$

then

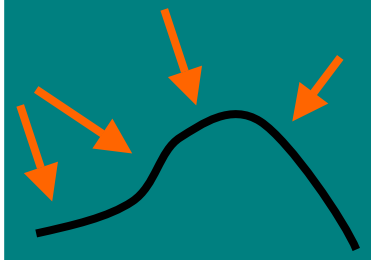
$R_{ij}=255$



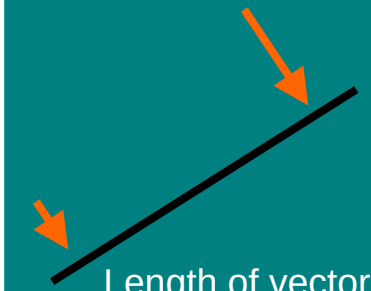
All three modifications



Direction of light



Height of light



Length of vector

Weight: 9%

CONCLUSION

- Light vector as function of relief model can give different results
- Presented modifications are simple and easy to interpret, and applicable to any relief model
- Modificated results can be used for easier creation of final shades

Overlay of the shades on the map

Standard diffuse shading

Modification of the azimuth and height of the light (our approach)

Thank you!