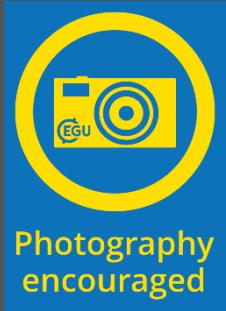




Advanced Image Processing Methods Applied to Enhance the GPR Images



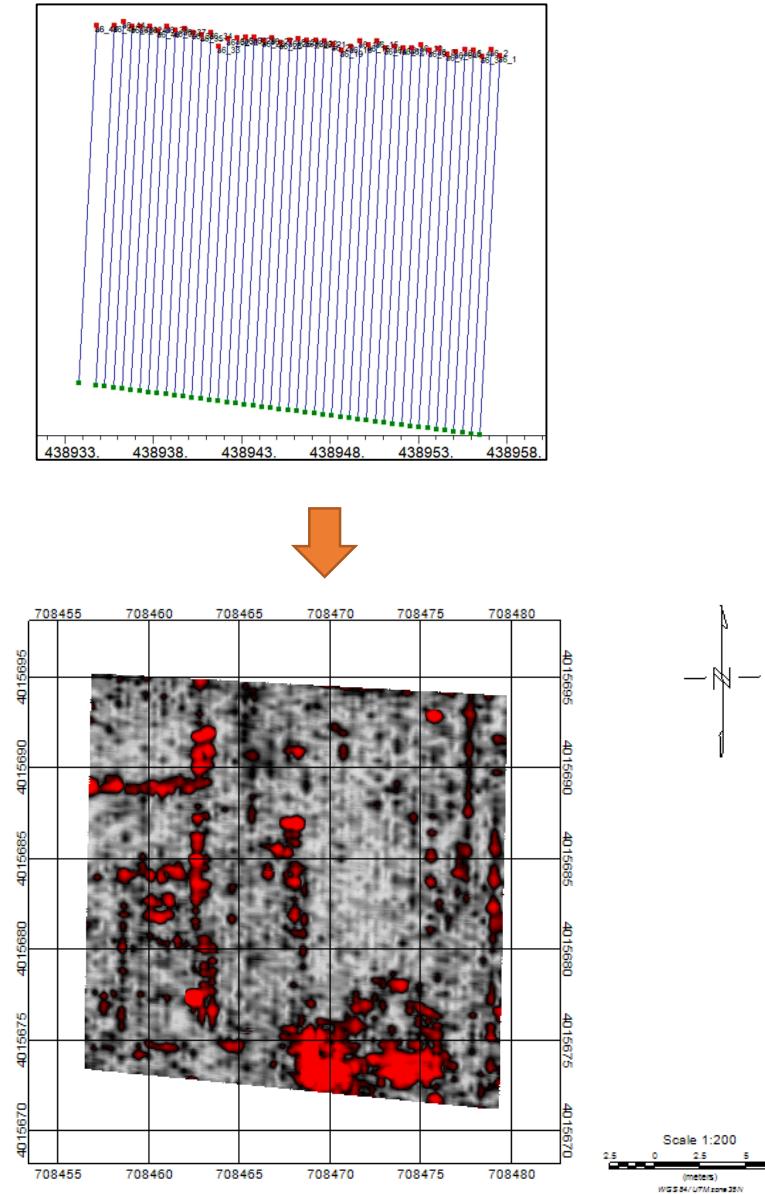
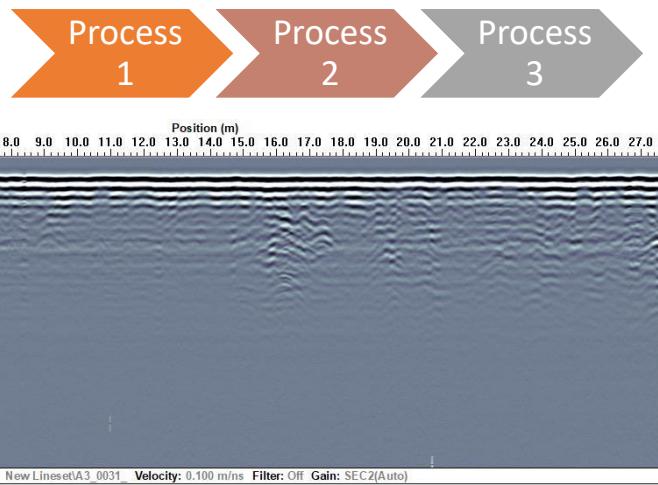
İrfan Akça¹, Çağlayan Balkaya² and Mehmet Ali Kaya³

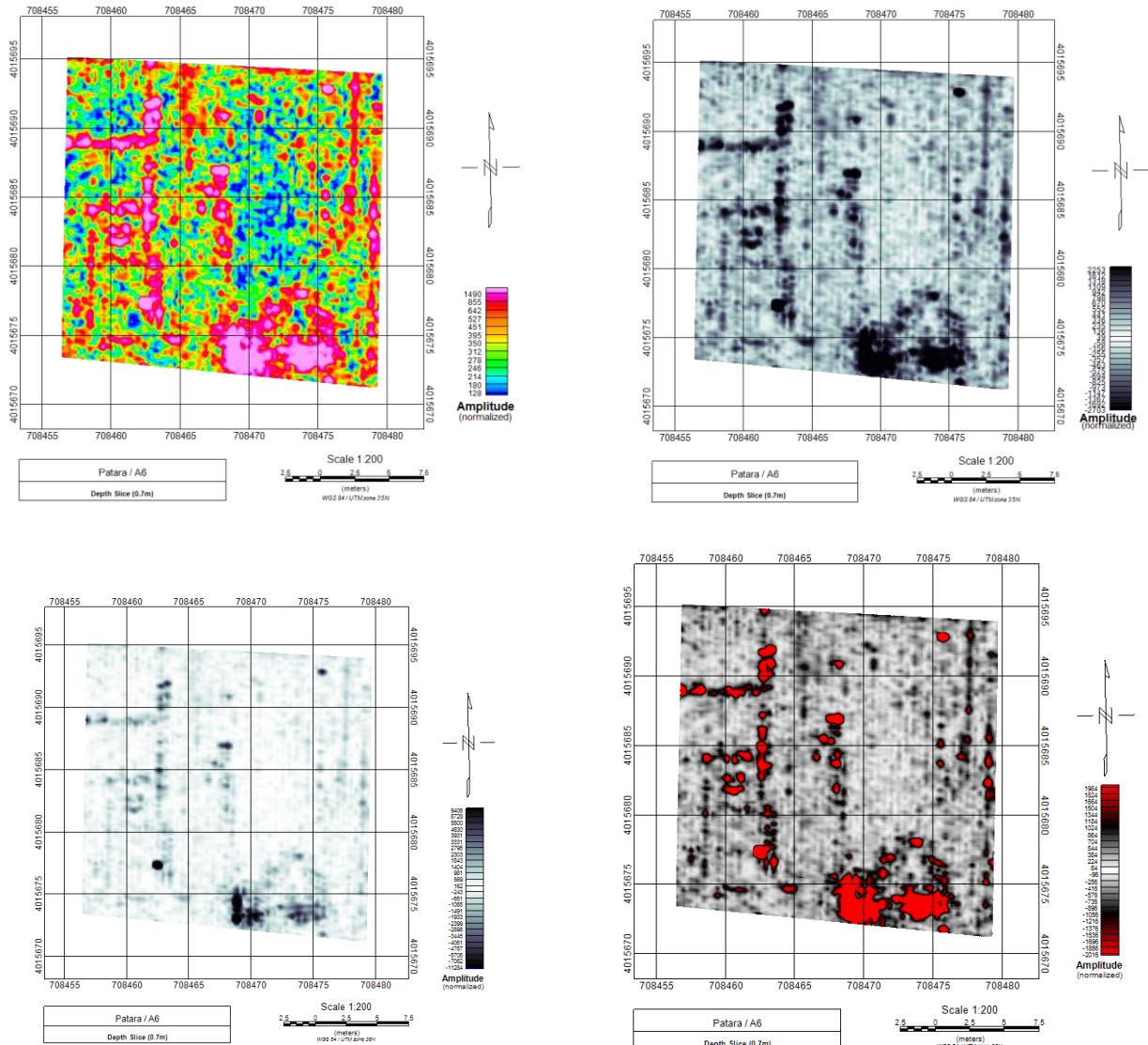
¹Ankara University, Department of Geophysical Engineering, Gölbaşı, Ankara, Turkey

²Süleyman Demirel University, Department of Geophysical Eng. West Campus, Isparta, Turkey

³Trakya University, Vocational College of Technical Sciences Edirne, Turkey







User defined display settings

Type of display

Interpolation methods
intervals in x, y and z (cell sizes)

Color scale

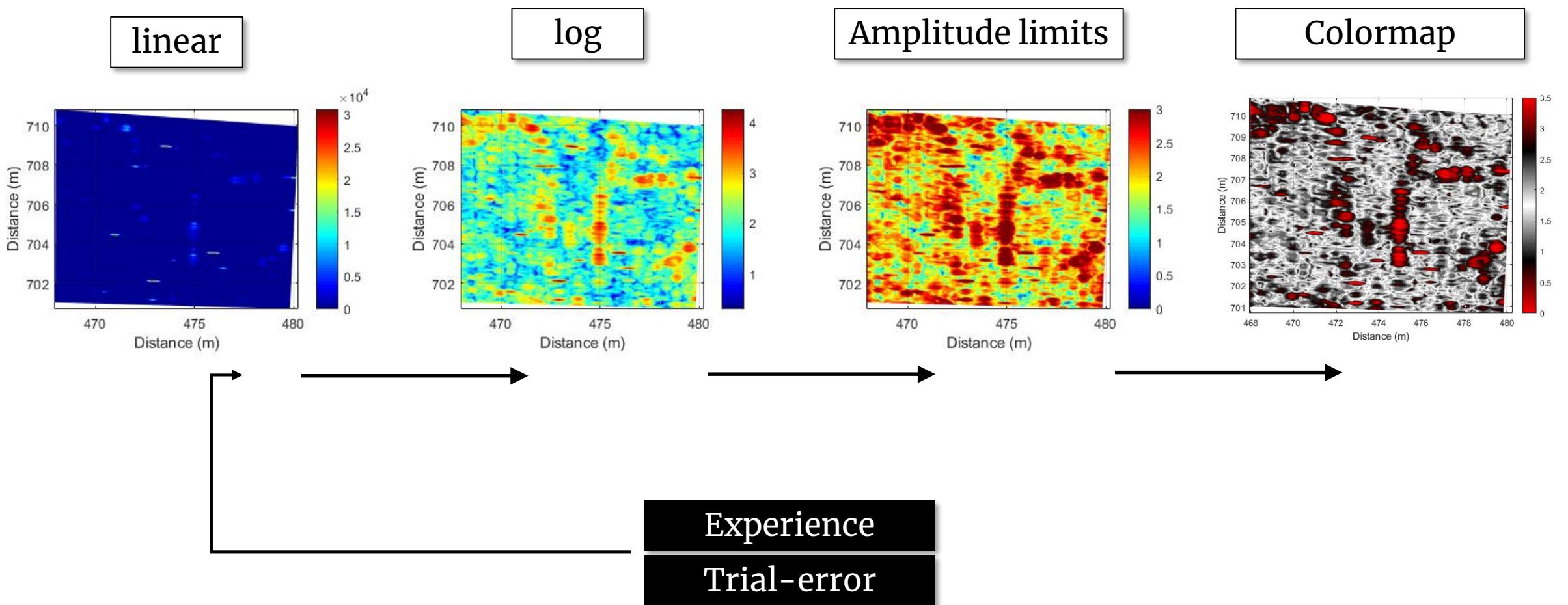
Colorspace HSV,RGB,Diverging,Lab...
Number of colors
Color range

...

Type of data

Linear
Logarithmic
Normalized
Absolute value

...



Standardized color scales, parameter range, presentation type?

An automated colorscale-range-filter selector?

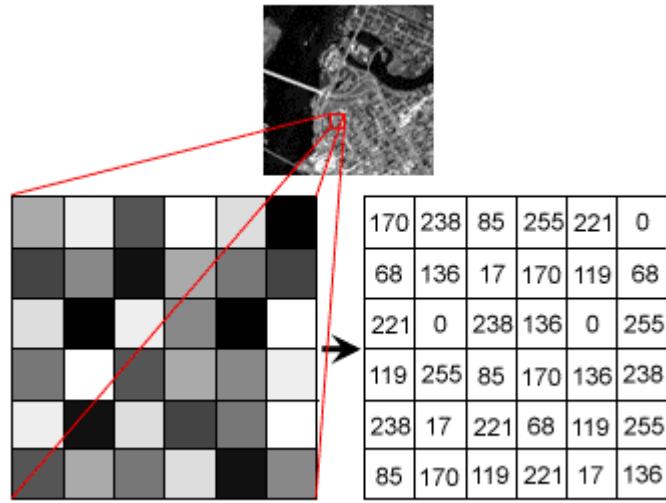
Machine learning / Neural networks?

Apply image processing filters to maps / sections /models

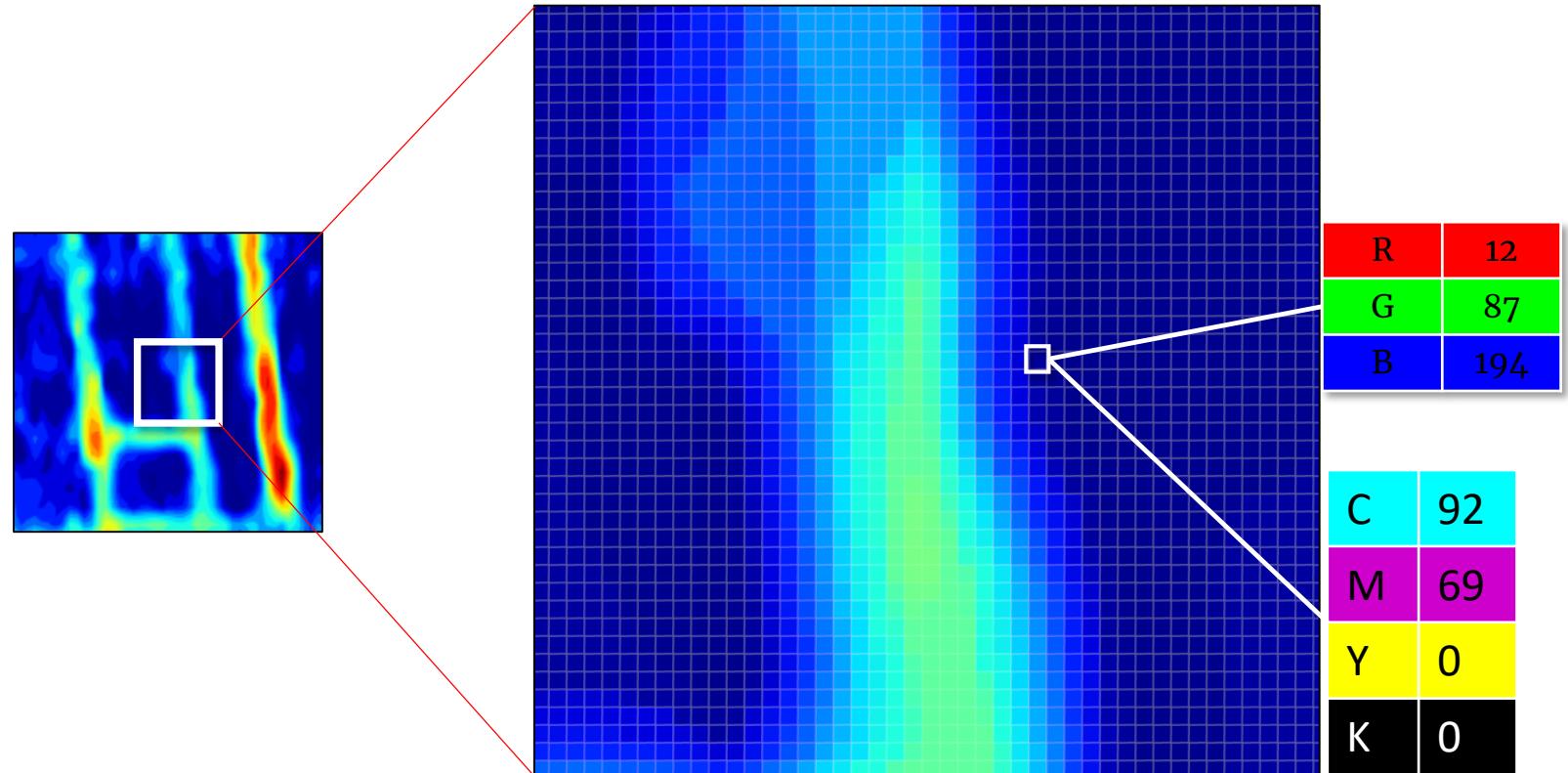
to enhance the geophysical images
to emboss desired attributes, structures or linearities
to suppress noise or unwanted features

ENHANCEMENT

1. To improve the subjective quality of an image for human viewing.
2. To modify the image in such a way as to make it more suitable for further analysis and automatic extraction of its contents.

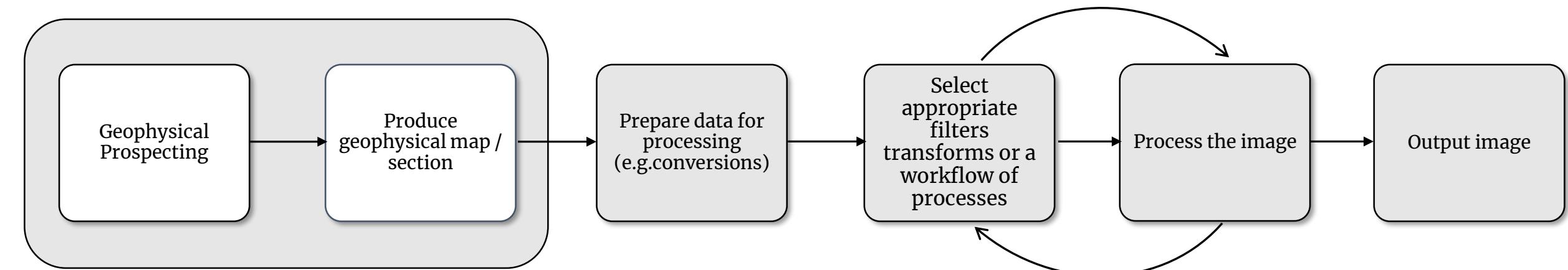


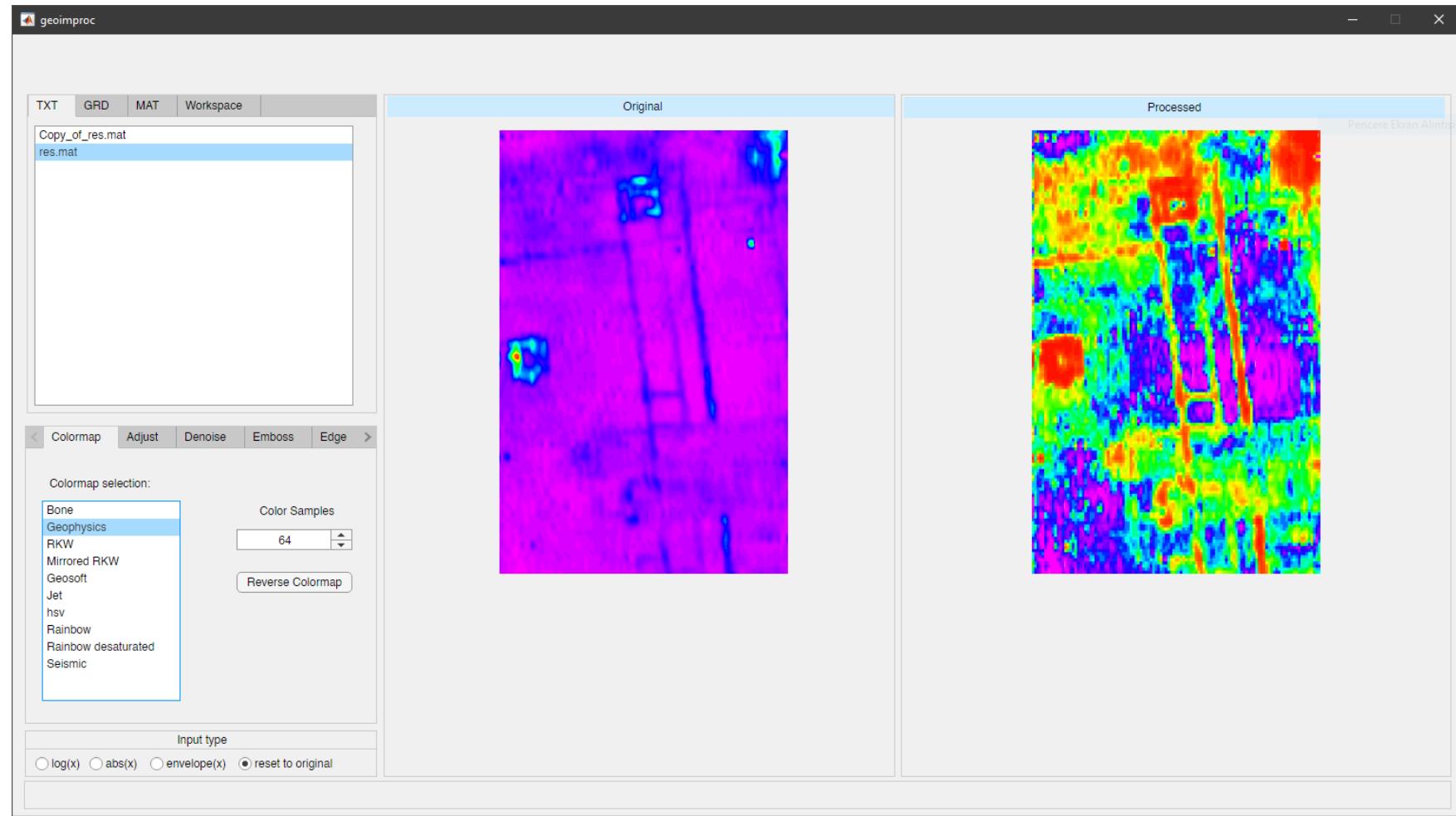
Monochrome (grayscale)



Color image

- 1 Restoration / Smoothing / De-noising
- 2 Contrast adjustment / Sharpening
- 3 Histogram equalization
- 4 Directional derivatives / Edge detection
- 5 Shading & lighting



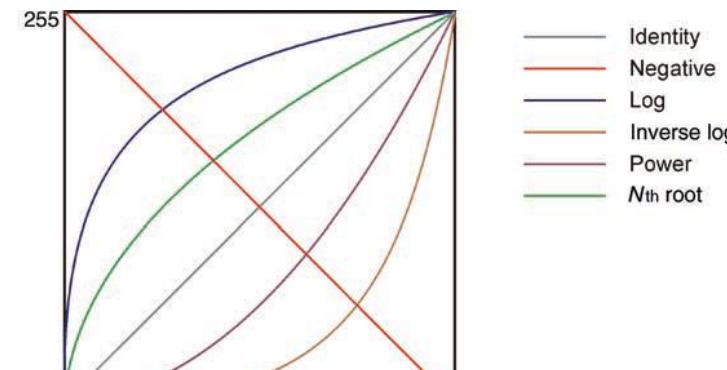


Convolution with a filter

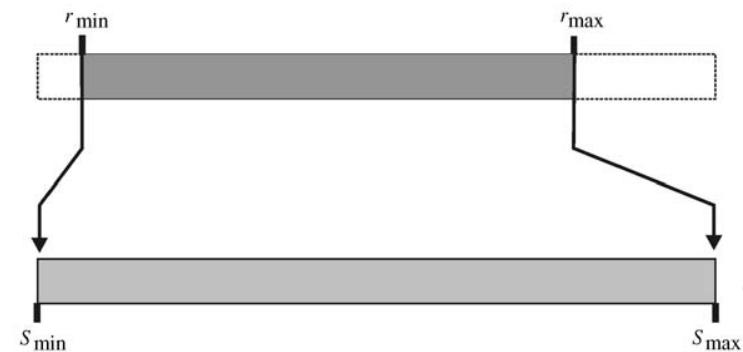
$$g(x, y) = h * f(x, y)$$

$$h = \begin{bmatrix} 0.075 & 0.124 & 0.075 \\ 0.124 & 0.204 & 0.124 \\ 0.075 & 0.124 & 0.075 \end{bmatrix}$$

Transforms



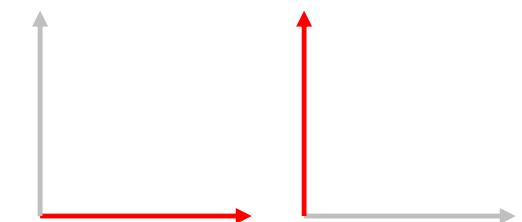
(Marques., 2011)

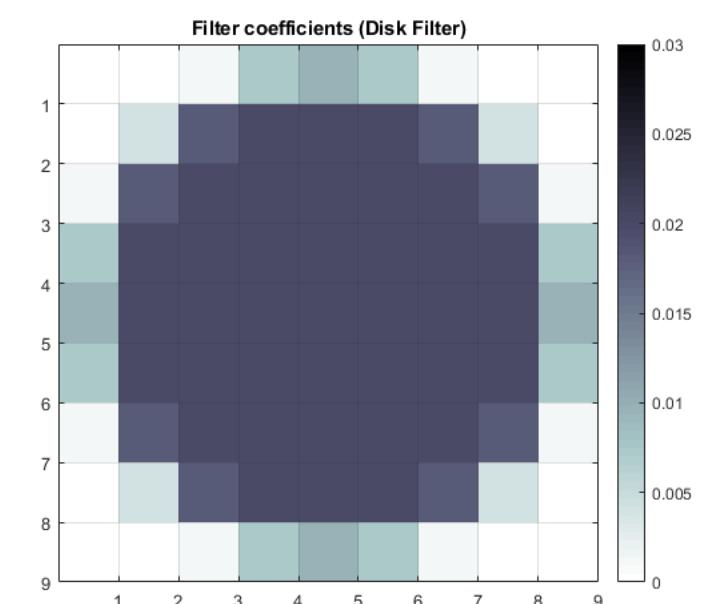
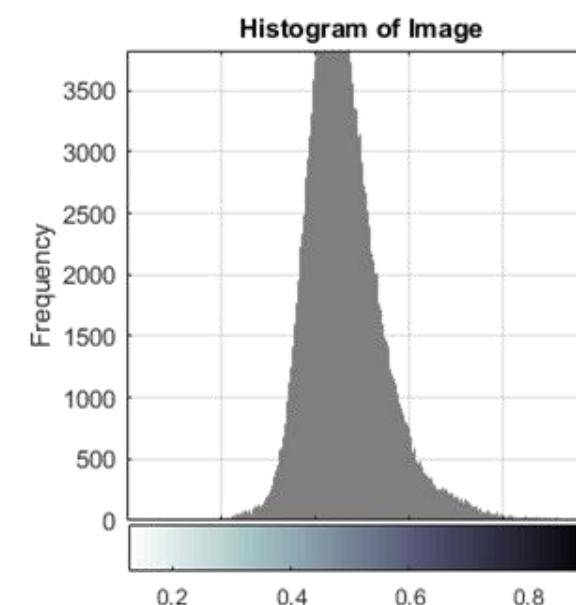
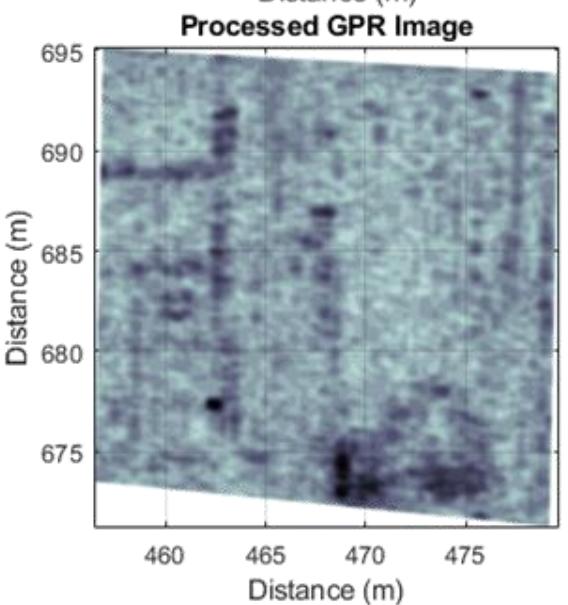
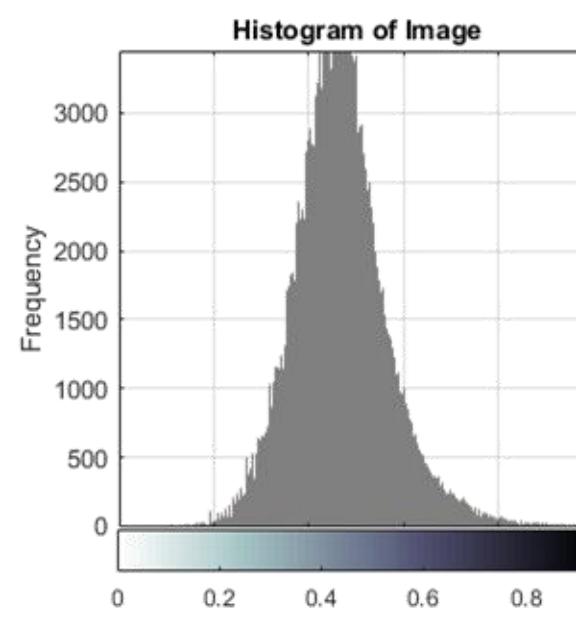
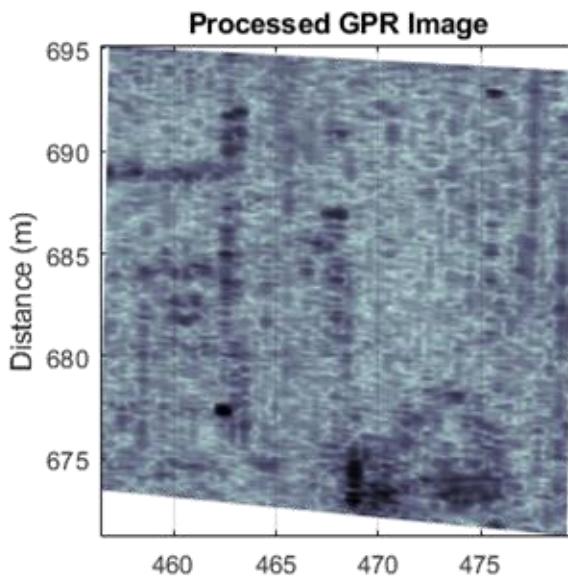


Gradients

$$g_x(x, y) \approx f(x + 1, y) - f(x - 1, y)$$

$$g_y(x, y) \approx f(x, y + 1) - f(x, y - 1)$$

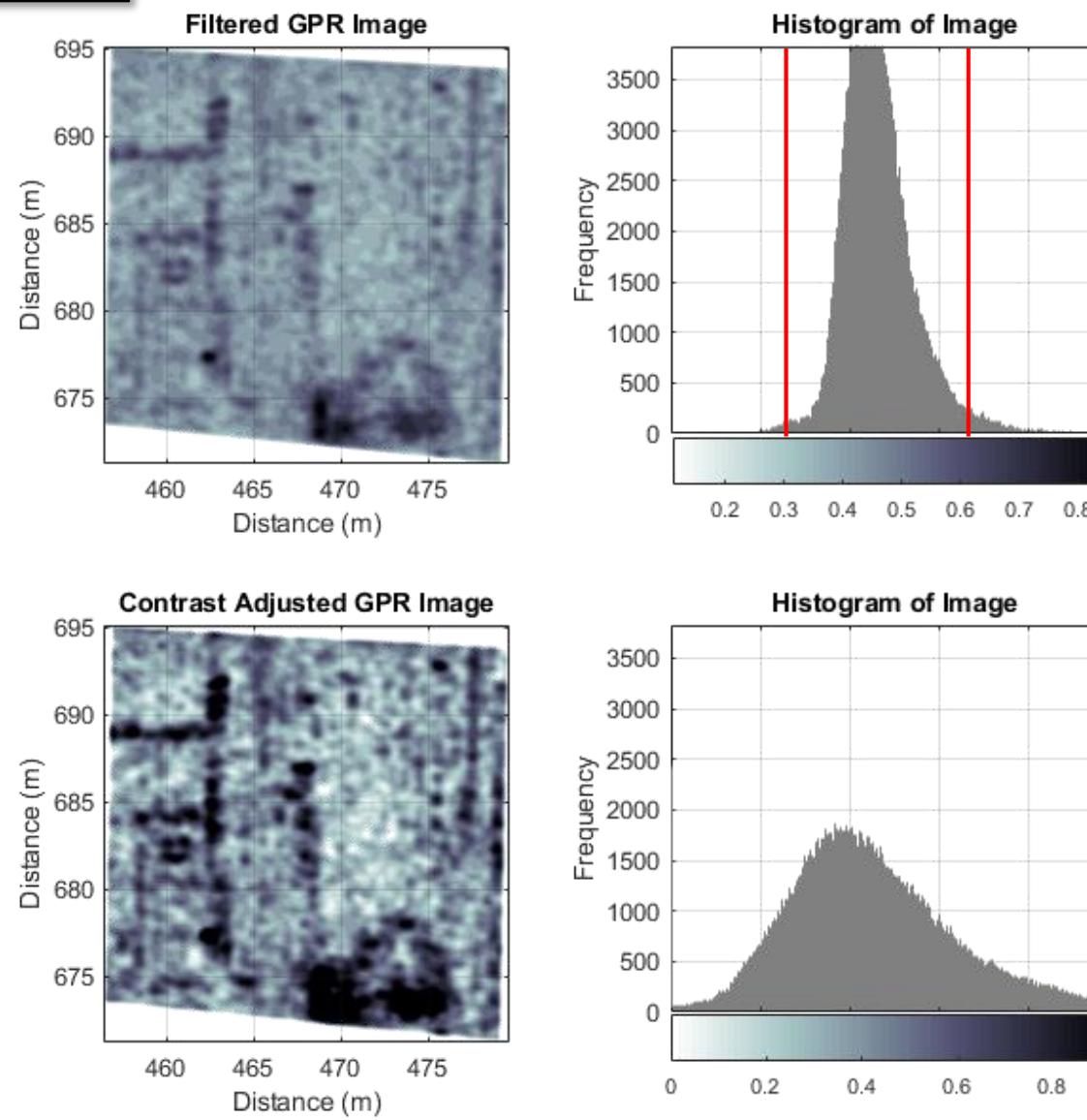




```
h = fspecial('average',hsize);  
h = fspecial('disk',radius);  
h = fspecial('gaussian',hsize,sigma);  
h = fspecial('laplacian',alpha);  
h = fspecial('log',hsize,sigma);
```

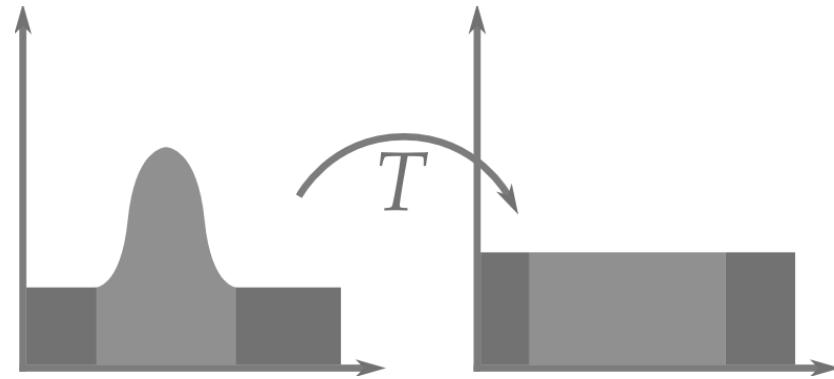
```
S = conv(R,h);
```

CONTRAST ADJUSTMENT



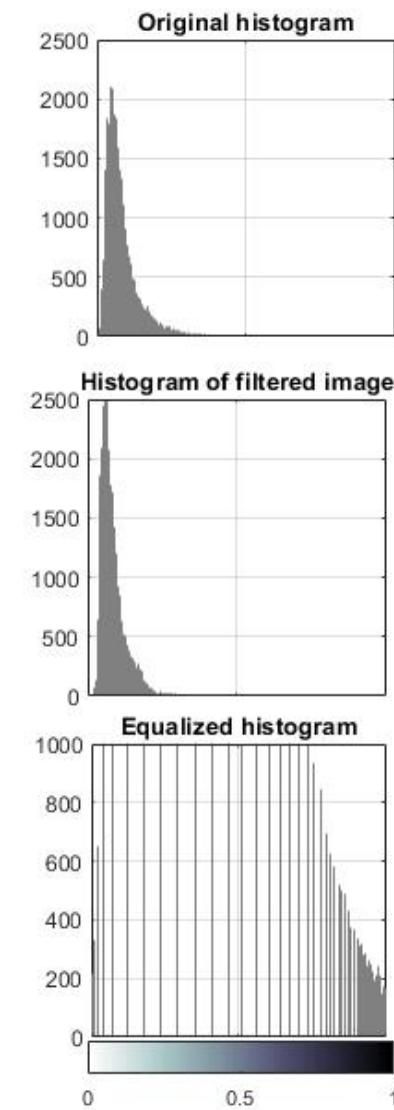
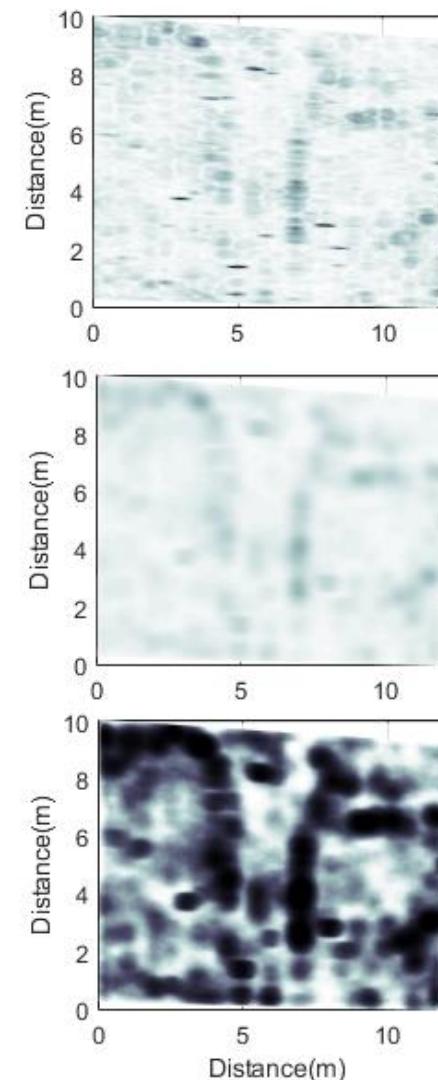
```
low_in=0.3;  
high_in=0.62;  
S = imadjust(R,[low_in high_in]);
```

HISTOGRAM EQUALIZATION



T is usually a cumulative density function (CDF)

```
radius=6;  
h = fspecial('disk',radius);  
F=imfilter(I,h);  
H=histeq(F,256);
```



HISTOGRAM EQUALIZATION

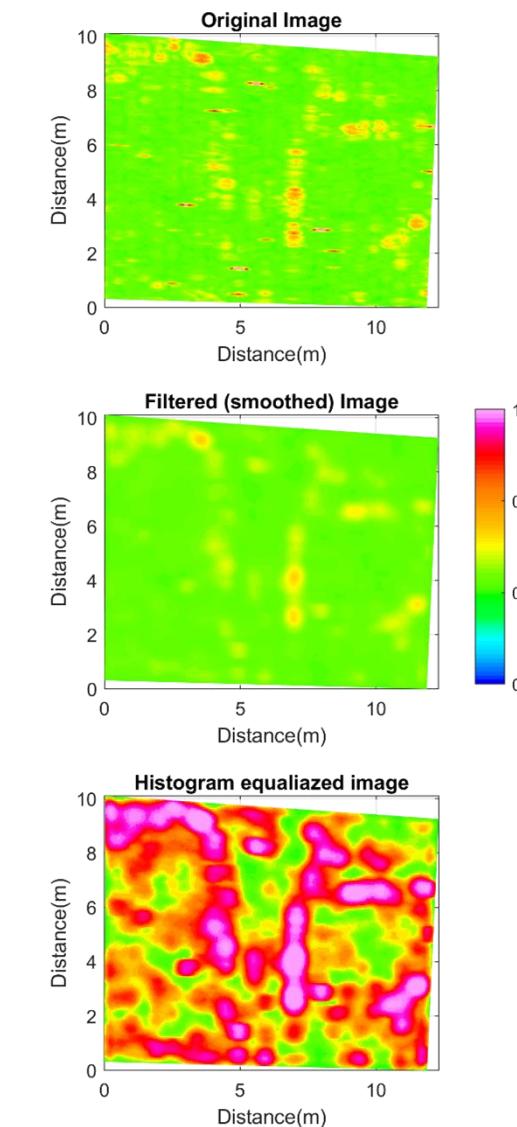
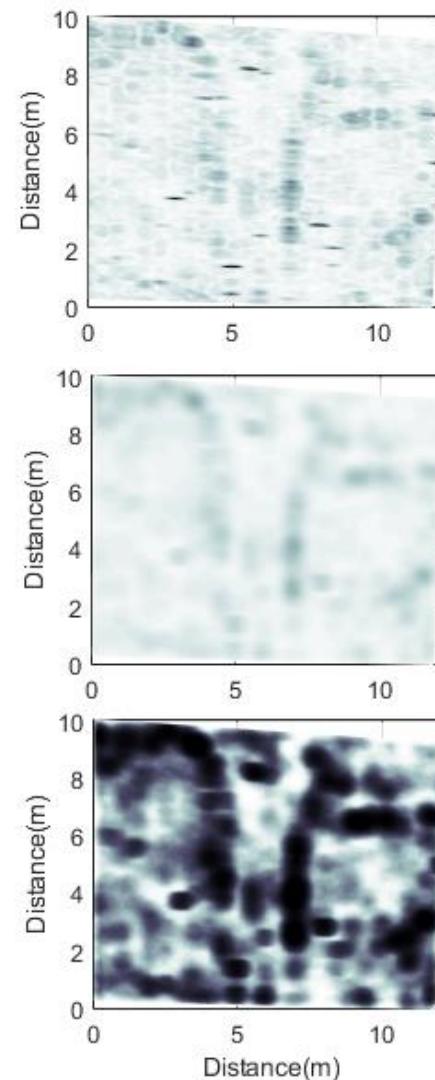
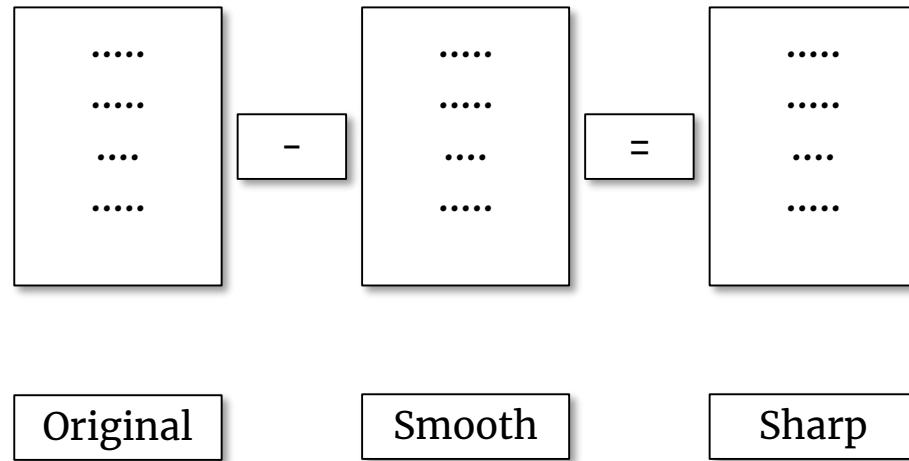


IMAGE SHARPENING

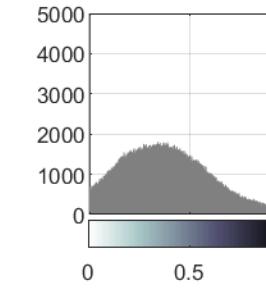
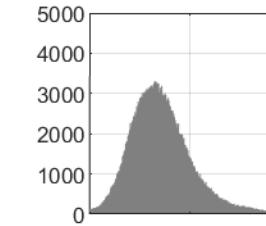
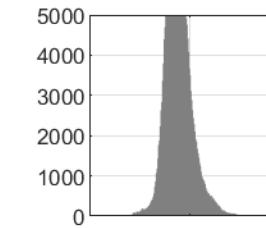
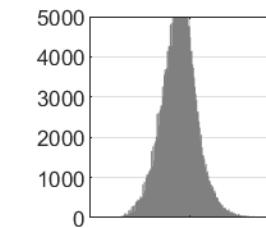
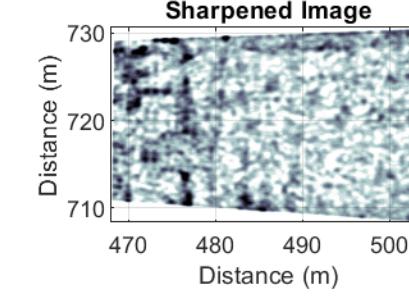
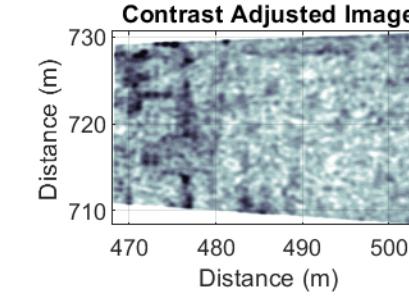
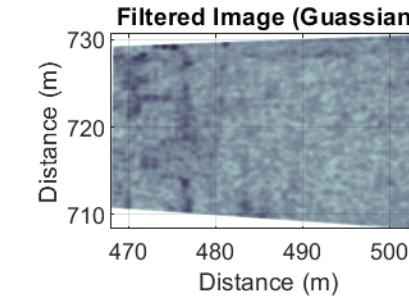
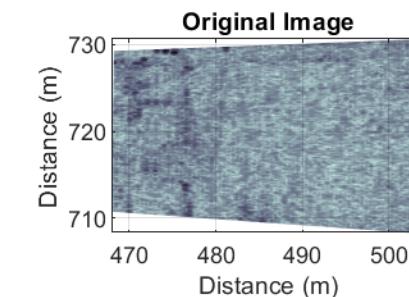
Unsharp Masking



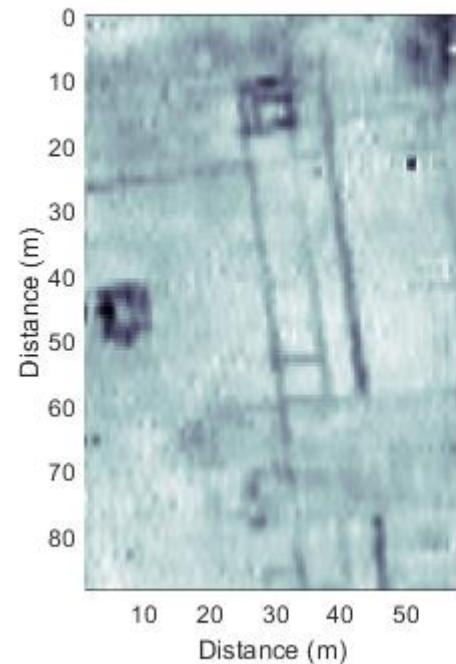
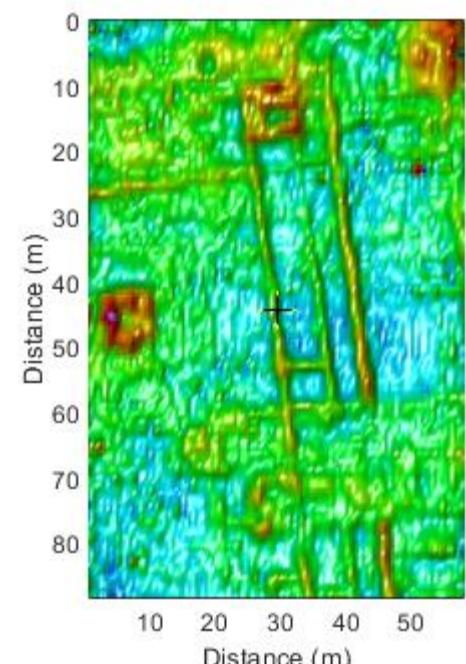
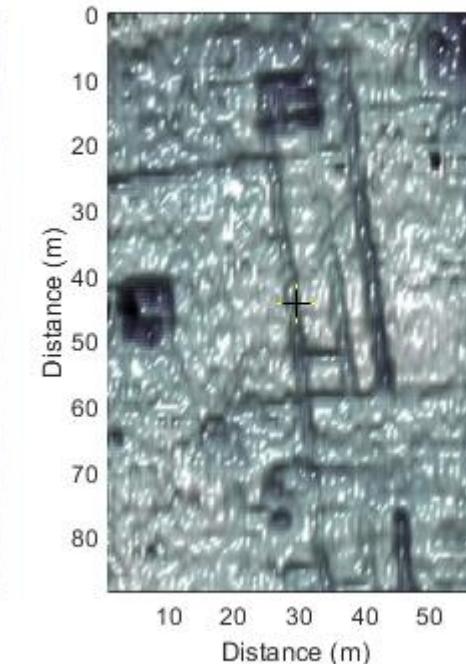
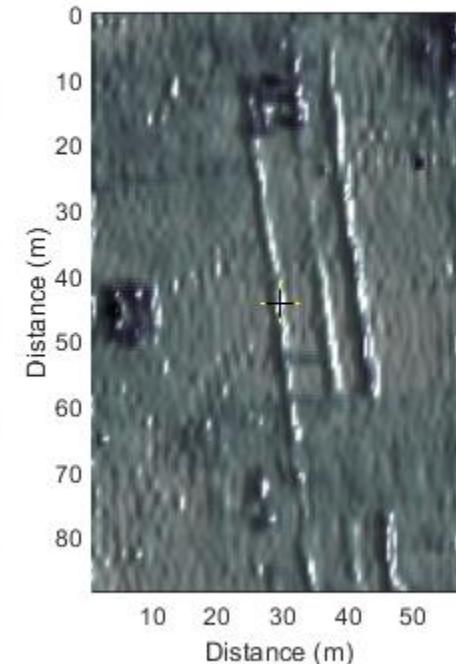
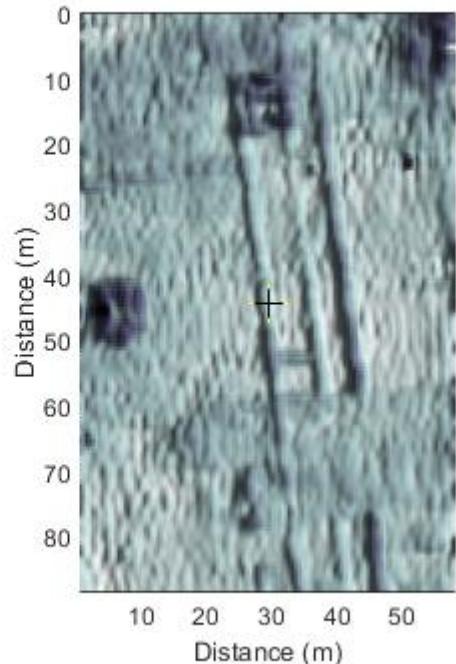
```
S=imsharpen(I, 'Radius', 5, 'Amount', 2);
```

Radius: Standard deviation of the Gaussian lowpass filter

Amount: Strength of the sharpening effect [0 2]



SHADING

`shadem('shiny' , [90 35])``shadem('ui')`

GRADIENTS

Roberts

$$h_x = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$



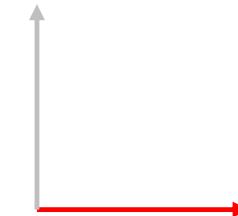
$$h_y = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$



Prewitt

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

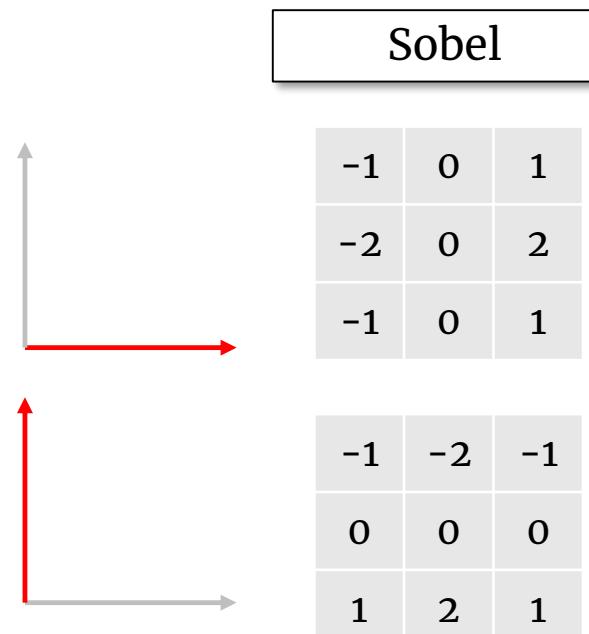
$$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$



Sobel

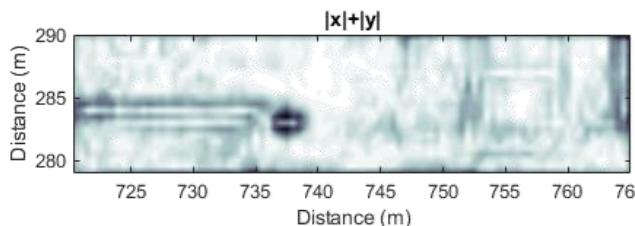
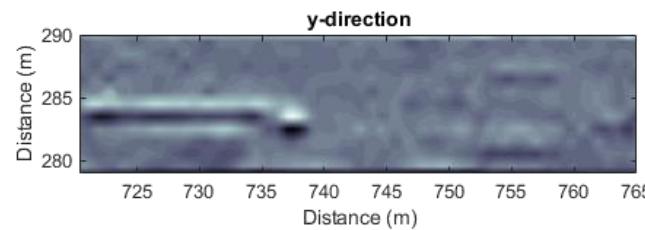
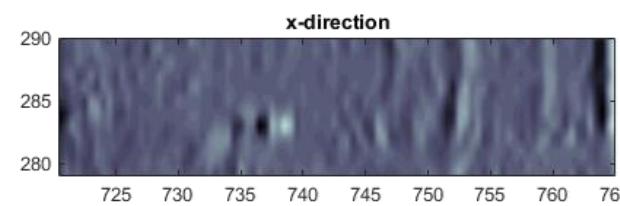
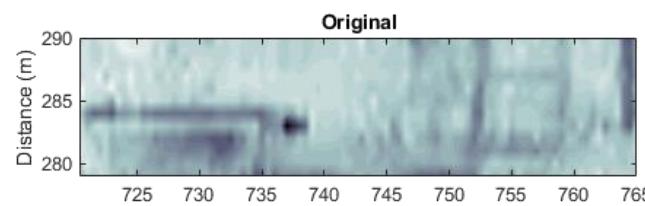
$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

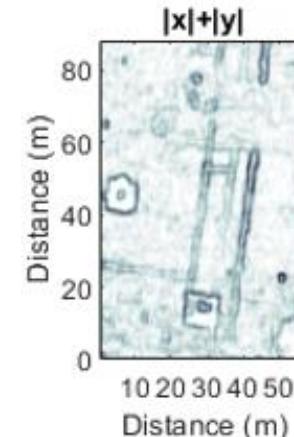
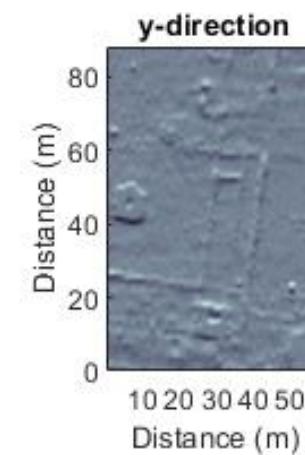
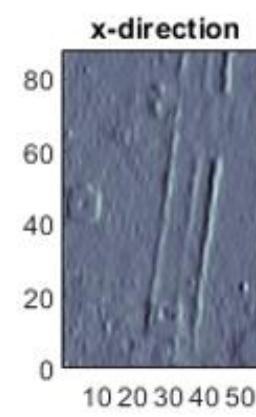
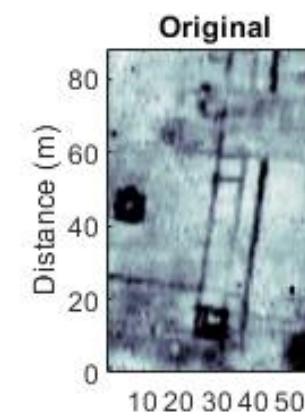


GRADIENTS

Prewitt

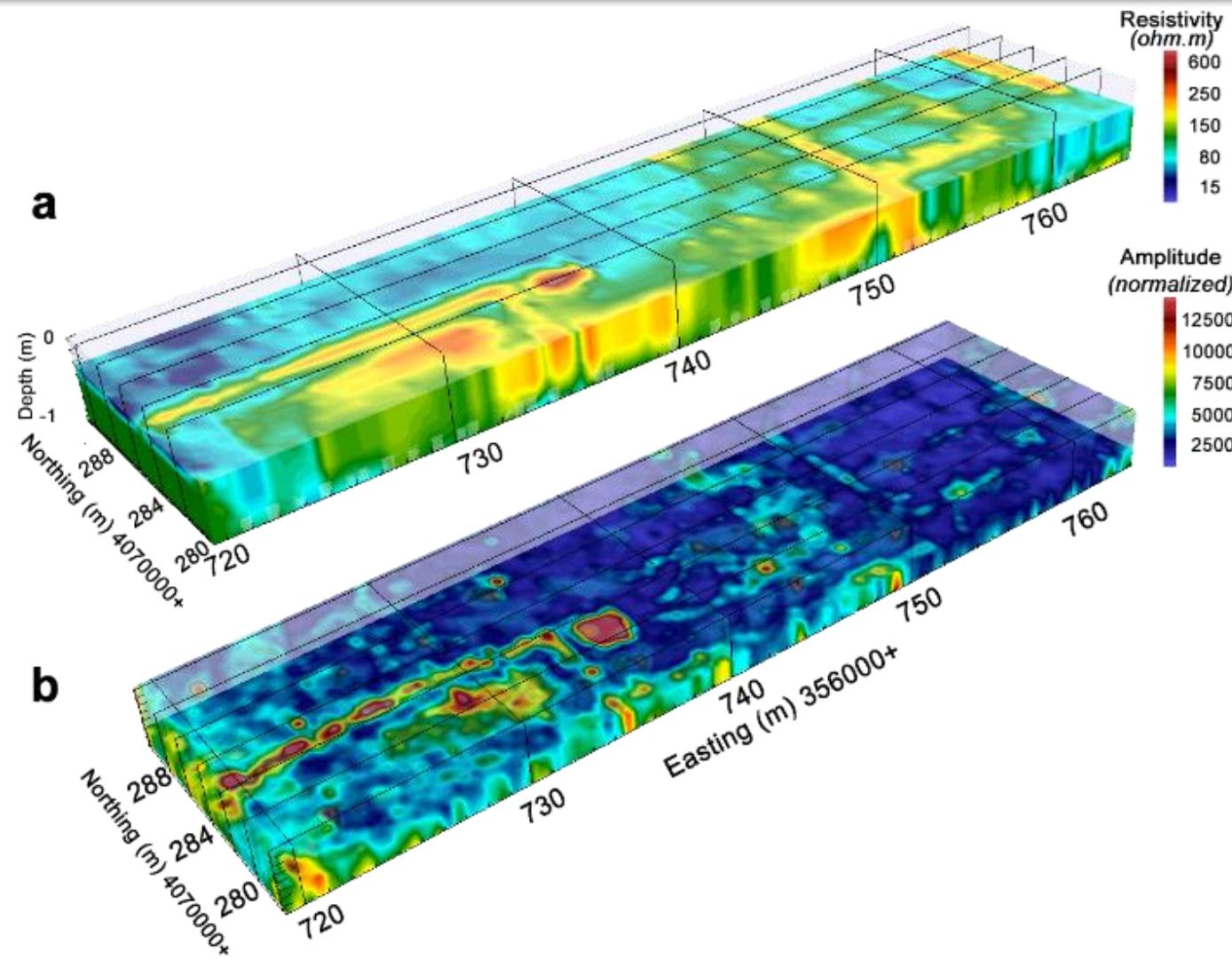


Sobel



1. Image processing methods should be used as an auxiliary tool to enhance geophysical images
2. Image processing may be incorporated directly into geophysical processing
3. Histogram of a geophysical image tells us much about the presentation of results
4. Linear anomalies seen in GPR images such as the buried archaeological structures, pipelines and similar shallow targets may be emphasized by image processing methods
5. Image processing methods make GPR images more suitable for further analysis and automatic or visual extraction of its contents.
6. This process should be an interactive process since there exist also several user dependent settings in image processing

Further research and investigation: 3D filtering and image processing procedures



Thank you for your attention



- Akca, I., Balkaya Ç., Pülz, A., Alanyalı H. and Kaya M.A. 2019. Integrated geophysical investigations to reconstruct the archaeological features in the episcopal district of Side (Antalya, Southern Turkey). *Journal of Applied Geophysics*.
- Marques, O. 2011. Practical image and video processing using MATLAB. Wiley,
- MATLAB, Image Processing Toolbox.
- Mathworks File Exchange.
- Ronne, A.J., Witter, B. J. And Thompson G.R. 2010. Exploration of Four Geothermal Properties in Nevada. World Geothermal Congress, Bali, Indonesia, 25-29 April 2010.