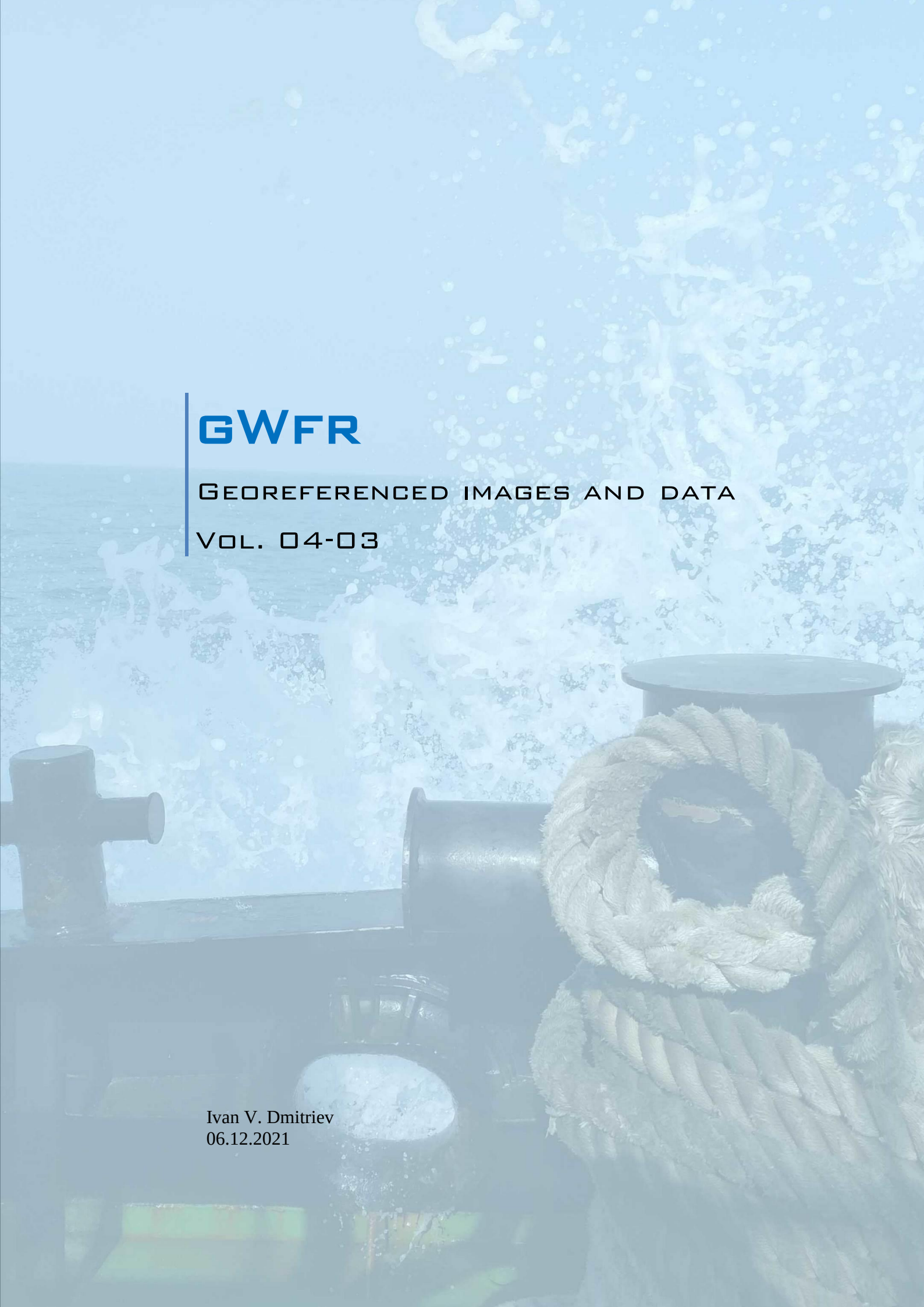

GWFR

Georeferenced images and data

Vol. 04-03

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1. Image-data with world-file and XYZ-data description

The functions set were created for manipulations with SSS mosaic and pts-files (XYZ-gridded-data). There are:

-- resize, cut and merge SSS-mosaic;

-- cut SSS-mosaic image file with world-file in several parts;

-- convert pts-file (MBES grid saved as XYZ) to matrix, apply processing and convert matrix to pts-file back (see ***gWfr*** example).

gWfr lets to do elementary manipulations with raster-image file with world-file (read, write, merge, merge palettes, etc) and convert XYZ-gridded-data to raster-image file with world-file creation.

1.1 XYZ gridded data

This data is gridded in "parallelogram" web-cell (prefer rectangular web-cell with perpendicular grid-lines) and format to three columns: X, Y and Z. The grid web can be rotate relative axis (**Ошибка! Источник ссылки не найден.**).

1.2 World-file name

The world-file name must be same with image name, but extension must be correct: there are three liters; first liters is first liters of image's extension; second liters is last liters of image's extension; third letter is "w". For example: *.tif and *.tfw; *.tiff and *.tfw; *.png and *.pgw.

1.3 World-file main contents

The world file is an ASCII text file, which contains the following lines:

Line1_A: pixel size in the x-direction in map units;

Line2_D: rotation parameter about y-axis;

Line3_B: rotation parameter about x-axis;

Line4_E: pixel size in the y-direction in map units, almost always negative;

Line5_C: x-coordinate of center of upper left pixel;

Line6_F: y-coordinate of center of upper left pixel.

The D and B parameters are not angular rotations and that the A and E parameters do not correspond to the pixel size! Better descriptions of the A, D, B and E parameters are (**Ошибка! Источник ссылки не найден.**):

Line 1: A: x-component of the pixel width (x-scale);

Line 2: D: y-component of the pixel width (y-skew);

Line 3: B: x-component of the pixel height (x-skew);

Line 4: E: y-component of the pixel height (y-scale), typically negative.

(***https://en.wikipedia.org/wiki/World_file***)

The "rotation" is "around" (C,F) point's coordinates.

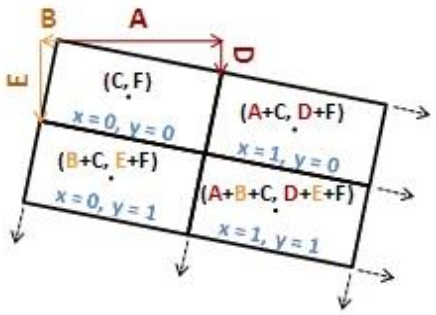


Figure 1.1 World file components

The Coordinates conversion:

Forward conversion: [x';y']=[A B C; D E F]*[x;y;1] or x'=Ax+By+C; y'=Dx+Ey+F;

Reverse conversion: x=(Ex'-By'+BF-EC)/(AE-DB); y'=(-Dx'+Ay'+DC-AF)/(AE-DB);

where,

x,y – column and row raster's number for pixel;

x';y' – pixels coordinates in axis XY (see below)

^+Y

|

----> +X

The left_up_angle of image (Line5_C, Line6_F) is corresponded to column-1 and raw-1 of raster/matrix.

1.4 World-file additional contents

The world-file can include four additional values: [key aS bS BgVal]. These values are used to describe physical values in raster.

Line7_key: 9999999999;

Line8_aS: multiple for image's color value;

Line9_bS: shift for image's color value;

Line10_BgVal: the code of "absent" color (it is means – no data for raster's pixel with BgVal code).

The DataOriginalValue=aS*ColorValue+bS; so, we can convert coded pixels color to its Original Value (for example in meters for bathymetry).

File's example, with additional lines:

Table 1.1 Wold-file's data example

Line from file	Description
0.10001159	x-component of the pixel width (x-scale)
0	y-component of the pixel width (y-skew)
0	x-component of the pixel height (x-skew)
-0.1	y-component of the pixel height (y-scale), typically negative
684083.88367	x-coordinate of center of upper left pixel

Line from file	Description
5887188.48824	y-coordinate of center of upper left pixel
9999999999	the key “below is additional content”
-0.01	the multiple for color value
-38	the shift for color value
255	the code of “absent” color (no data)

1.5 Raster-image type, matrix-image type and XYZ-data type

The follow raster-image types are used:

-- Palette image. 2D-matrix with values from 0 to 255 (usually, values type is uint8), refer to Palette. Palette contained three columns R-G-B, with double numbers from 0 to 1; for some functions means, that Palette is gray (for example gWfrCombineColors). The “absent” color code (values from 0 to 255) set in Head.BgVal field (see description below). When XYZ convert to Palette image (by gWfrMat2Im function), the Head.BgVal=255.

-- Grayscale image. 2D-matrix with values from 0 to 65536 (usually, values type is uint16); there is no palette, the image’s uint16 numbers are code grey colors. The “absent” color code (values from 0 to 65536) set in Head.BgVal field (see description below). When XYZ convert to Grayscale image (by gWfrMat2Im function), the Head.BgVal=65535.

-- Matrix-image. 2D-matrix (values type is double), includes DataOriginalValues. When XYZ convert to matrix (by gWfrXyz2Mat function), the Head.BgVal=nan. Head.K is empty.

-- XYZ-data. There are three rows, which contained X, Y and Z values (type double).

The Data-types and functions for conversion are showed in ***Figure 1.2***.

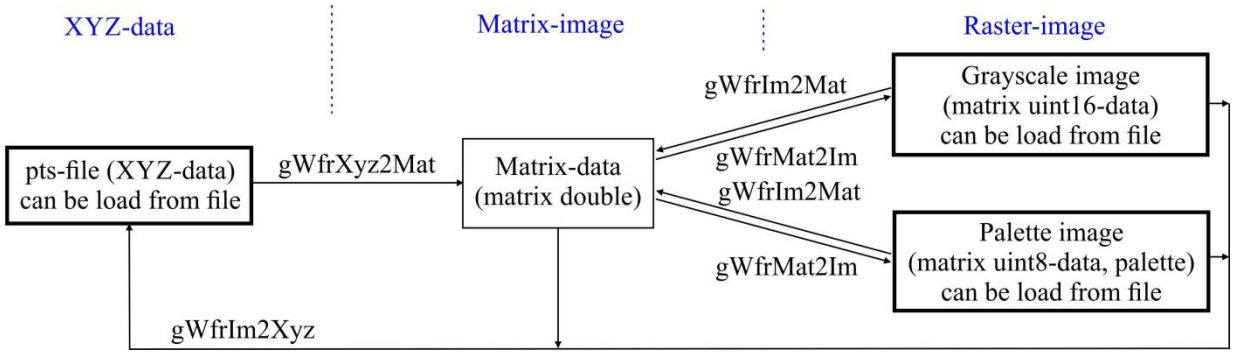


Figure 1.2 Data-types and functions for conversion

1.6 RGB-image type

The functions gWfrRead, gWfrGeotiffRead, gWfrWrite, gWfrDraw can work with R-G-B-image and R-G-B-image with alpha-layer. But, today I have no idea – how the reference to “absolute scale” can be realized with using “multiple for image’s color value” and “shift for image’s color value”. We need table “RGB-color - drawing parameter absolute value” to do it.

Today the MatLab’s functions can used to do it “hardly”:

rgb2gray – convert RGB image or colormap to grayscale;

rgb2ind – convert RGB image to indexed image;

cmunique – eliminate duplicate colors in colormap; convert grayscale or truecolor image to indexed image.

1.7 Palette features

The Palette or Grayscale images, was created by gWfrMat2Im function, have a “linear” colors change (constant step between colors levels). The RGB-palette for some functions means gray (used only first column “Red”).

The DataOriginalValues are calculated, using a) 2D-matrix values for Grayscale image and b) 2D-matrix values and Palette values for Palette image: DataOriginalValue=aS*Color+bS.

1.8 gWfr’s Structures description

The Paletter image or Grayscale image is load to 2D-matrix (uint8 or uint16), named as Data.

The world-file data load to Head structure, which includes:

Head.Color – colormap for raster-image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value";

Head.BgVal – the code of “absent” color (it is means – no data for raster’s pixel with BgVal code).

When used gWfrGeotiffRead, three additional fields can create:

Head.ProjName – the values from geotiff’s GeoAsciiParamsTag;

Head.ProjInfo – the values from geotiff’s GeoDoubleParamsTag;

Head.GeoKeyInfo – the values from geotiff’s GeoKeyDirectoryTag,

These fields are not used in gWfr-functions and created as information only.

2. Functions description

2.1 Read raster-image with world-file

function [Head,Data]=gWfrRead(fname)

Read raster-image file with world-file. Example: *.tif and *.tfw.

Parameters:

fname – image's file name with extension (the world-file extension created as first and last letters of the image's extension and ending with a 'w');

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] –multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image data matrix.

Function Example:

```
>> [Data,Head]=gWfrRead('d:\03_Block-3_SSS_Mosaic\Block-3_2.tif');
```

2.2 Read Geotiff-image file

function [Head,Data,inf]=gWfrGeotiffRead(fname)

Read Geotiff-image file and copy world-file values from tiff's geo-tags.

To extract all geotiff information use: geotiffinfo, geotiffread, geotiffwrite form Mapping Toolbox. See tiff tags description in ***https://www.awaresystems.be/imaging/tiff/tifftags.html***; ***https://www.loc.gov/preservation/digital/formats/fdd/fdd000279.shtml***

Parameters:

fname – Geotif-image file name with geo-tags;

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal=[] – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Head.ProjName – GeoAsciiParamsTag values;

Head.ProjInfo – GeoDoubleParamsTag values;

Head.GeoKeyInfo – GeoKeyDirectoryTag values;

Data – raster-image data matrix.

inf – image information ("imread" function's output).

Function Example:

```
>> [Head,Data,~]=gWfrGeotiffRead('d:\03_Block-3_SSS_Mosaic\Block-3_2.tif');
```

2.3 Write raster-image with world-file

function gWfrWrite(fname,Head,Data)

Write raster-image file with world-file.

Parameters:

fname – image's file name with extension (the world-file extension created as first and last letters of the image's extension and ending with a 'w');

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image data matrix.

Function Example:

```
>> gWfrWrite('d:\03_Block-3_SSS_Mosaic\Block-3_2.tif',Head,Data);
```

2.4 Draw image with world-file's data

function gWfrDraw(Head,Data,figNum,key)

Draw raster-image or matrix-image in world-data axis.

Parameters:

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image or matrix-image data matrix or matrix.

figNum – figure number;

key – drawing method: 1) is image with pixels numbers in axis; 2) is image with axis constructed from Head.Wf (angles must be zero); 3) plot3 with axis constructed from Head.Wf; 4) is surf with axis constructed from Head.Wf.

Function Example:

```
>> [Data,Head.Color]=imread('d:\Ge0MLib_logo3.png'); Head.Wf=[1 0 0 -1 100 50]; Head.K=[1 0]; Head.BgVal=0;
```

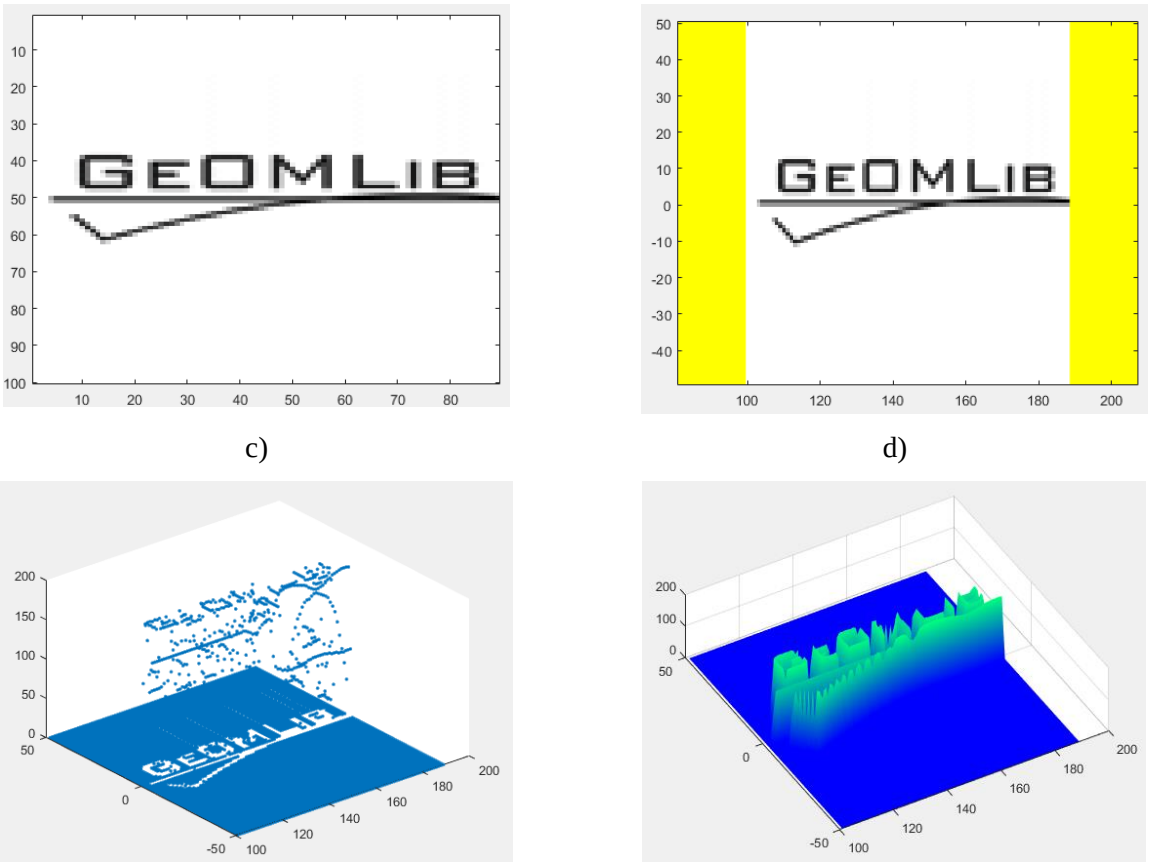
>> gWfrDraw(Head,Data,10,1); % ***Figure 2.1, a***

>> gWfrDraw(Head,Data,10,2); % ***Figure 2.1, b***

>> gWfrDraw(Head,Data,10,2); % ***Figure 2.1, c***

>> gWfrDraw(Head,Data,10,4);colormap('winter'); % ***Figure 2.1, d***

a) b)



c) d)

Figure 2.1 gWfrDraw example results

2.5 Draw image with world-file's data

function gWfrXyzDraw(XYZ,figNum,key)

Draw XYZ-points.

Parameters:

XYZ – X,Y,Z-data in 3-rows-vector;

figNum – figure number;

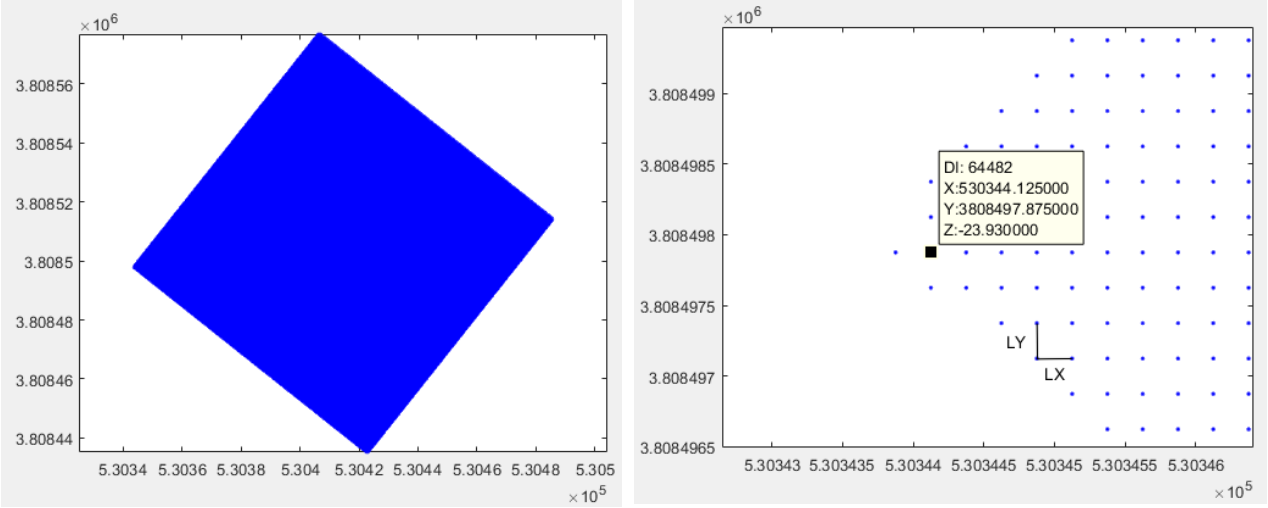
key – drawing method: 1) draw plot(X,Y) in the plane like to postmap, axis equal; 2) draw plot3(X,Y,Z) in 3D, axis not equal;

the "Data cursor" instrument can used to draw X,Y,Z values for point; when drawing, the values X,Y copy to clipboard.

Example:

>> XYZ=dlmread('e:\example1.pts')';gWfrXyzDraw(XYZ,10,1); % ***Figure 2.2***

a) b)



c)

```
>> LX=[530344.125000,3808497.625000,530344.375000,3808497.625000];
>> LY=[530344.125000,3808497.625000,530344.125000,3808497.875000];
>> [Head,Data]=gWfrXyz2Mat(xyz',LX,LY);
>> [Head,Data]=gWfrXyz2Mat(xyz',0.25,0.25);
>>
```

Figure 2.2 gWfrXyzDraw example results

a) post-map for all data;
b) zoomed part; the "Data cursor" instrument using example;
c) LX and LY values formed using "Data cursor" and clipboard (input for gWfrXyz2Mat function).

2.6 Convert XYZ-grid-data to matrix-image

function [Head,Data]=gWfrXyz2Mat(XYZ,LX,LY)

Convert XYZ-data to matrix-image and Head-structure. Z values write to matrix, not existing values set to nan. SkewX and skewY must be zero. Will be changed in future.

Parameters:

XYZ – rows with X,Y-coordinates and Z-data.

LX=const or LX=[lx_x1 lx_y1 lx_x2 lx_y2] is horizontal segment along X axis; see *Figure 2.5* and *Figure 2.2*;

LY=const or LY=[ly_x1 ly_y1 ly_x2 ly_y2] is vertical segment along Y axis; see *Figure 2.5* and *Figure 2.2*;

if grid-web lines parallel to X and Y axis, than can use LX=web-step-along-X, LY=web-step-along-Y.

Head – header structure, which includes:

Head.Color – colormap, empty for matrix image;

Head.Wf – world-file values: [scaleX 0 0 scaleY left_up_angle_X left_up_angle_Y];

Head.K=[] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; Z=DataOriginalValue=a*Color+b;

Head.BgVal=nan – the code of “absent” color (it is means – no data for raster’s pixel with BgVal code);

Data – matrix-image (type double);

Function Example1:

```
>> [Data,Head.Color]=imread('d:\Ge0MLib_logo3.png'); Head.Wf=[1 0 0 -1 100 50]; Head.K=[1 0];
   Head.BgVal=0;
>> XYZ=gWfrIm2Xyz(Head,Data,0,[],1);
>> [Head1,Data1]=gWfrXyz2Mat(XYZ,[0 5 1 5],[5 0 5 1]);
>> gWfrDraw(Head1,Data1,10,2); % Figure 2.3
```

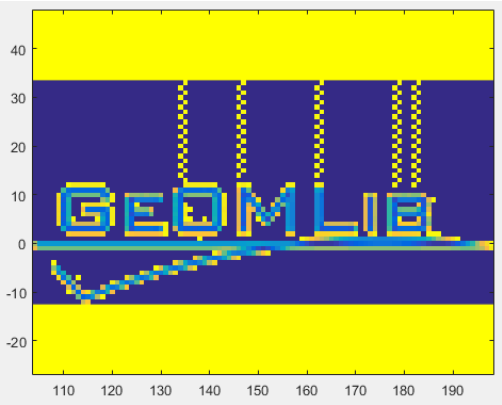


Figure 2.3 gWfrXyz2Mat example1 results (the absetnt points in border was drawn yellow)

Function Example2:

```
>> xyz=dlmread('e:\example1.pts')'; gWfrXyzDraw(xyz,10,1);
>> LX=[530344.125000,3808497.625000,530344.375000,3808497.625000]; % use gWfrXyzDraw
>> LY=[530344.125000,3808497.625000,530344.125000,3808497.875000]; % use gWfrXyzDraw
>> [Head,Data]=gWfrXyz2Mat(xyz,LX,LY);
>> [Head,Data]=gWfrXyz2Mat(xyz,0.25,0.25); % the grid-lines are parallel to X&Y axis, see Figure 2.2
>> gWfrDraw(Head,Data,10,2); % Figure 2.4
```

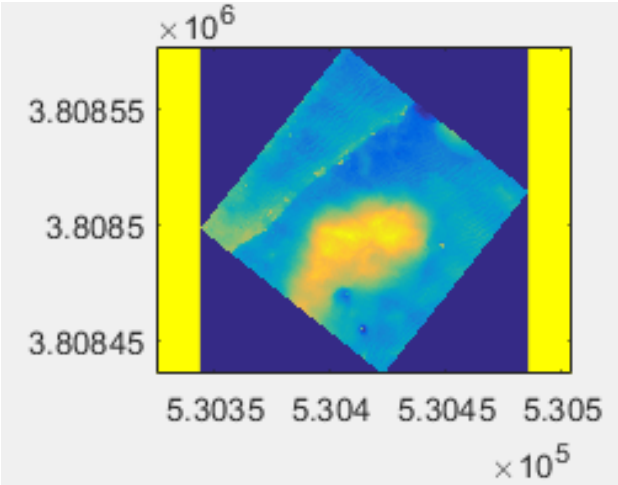
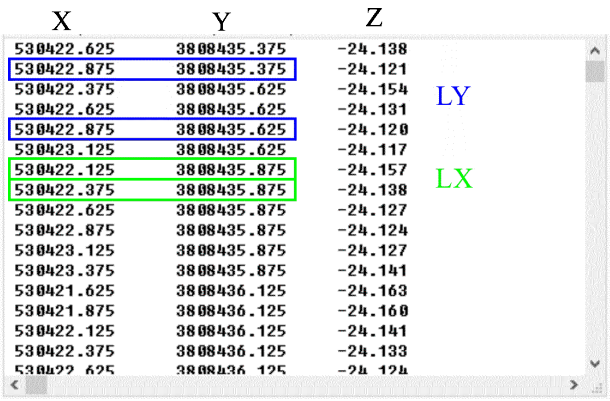


Figure 2.4 gWfrXyz2Mat example2 results (the absetnt points in border was drawn yellow)



LX=[530422.125, 3808436.125, 530422.375, 3808436.125];
LY=[530422.875, 3808435.375, 530422.875, 3808435.625];

Figure 2.5 gWfrXyz2Mat LX and LY handle forming

2.7 Convert image to XYZ-grid-data

function XYZ= gWfrIm2Xyz(Head,Data,BgVal,K,SortKey)

Convert raster-image or matrix-image and Head-structure to XYZ-data. The value of color (first palette's column for palette image) is used for Z creation.

Parameters:

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; Z=DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image or matrix-image data matrix;

K – forced multiple (a) and shift (b) for "Data Original Value" calculation from Color; if K==[], then used Head.K;

BgVal – forced code of "absent" color; if BgVal==[], then used Head.BgVal; it can set to NaN (for matrix with type double); excepted in XYZ;

SortKey – if 1 than sort along Y (values along X change quick), else sort along X (values along Y change quick);

XYZ – rows (type double) with X,Y-coordinates and Z-data without BgVal value; if Head.K is not empty, then Z=a.*Head.Color+b.

Function Example:

```
>> [Data,Head.Color]=imread('d:\Ge0MLib_logo3.png'); Head.Wf=[1 0 0 -1 100 50]; Head.K=[1 0]; Head.BgVal=0;
>> XYZ=gWfrIm2Xyz(Head,Data,0,[],1);
>> figure(2);plot3(XYZ(1,:),XYZ(2,:),XYZ(3,:),'.');axis xy; % Figure 2.6
```

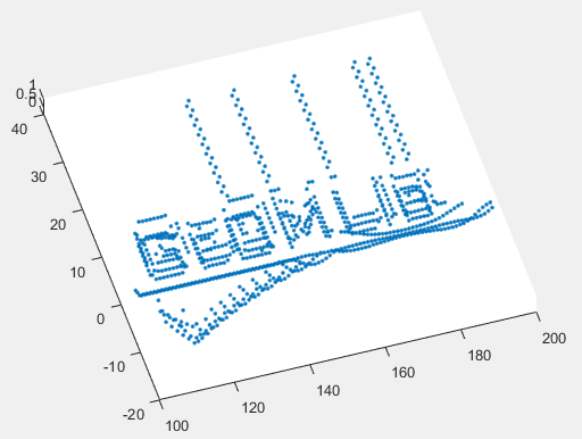


Figure 2.6 gWfrIm2Xyz example results

2.8 Convert matrix-image to raster-image

function [Head,Data]= gWfrMat2Im(Head,Data,MinMax,BgVal,imType)

Convert matrix-image to raster-image: palette (254 levels + "absent" color=255, grey paletter) or grayscale (65534 levels + "absent" color=65535).

Parameters:

Head – input header structure, which includes:

Head.Color=[] – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal=nan – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – input matrix-image (type double);

MinMax – minimal and maximal values link to level-0 and level-254/65534; if empty, than min and max will calculate from Data;

BgVal – code of "absent" color for palette (palette image only);

imType – raster-image type: 'uint8' or 'palette'- palette, 'uint16' or 'grayscale' - grayscale without pallete;

Head – output header structure, which includes:

Head.Color – linear palette for palette-image or empty for grayscale-image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value"; DataOriginalValue=a*Color+b;

Data – output raster-image data matrix. Function Example 1:

```
>> [Head1,Data1]=gWfrMat2Im(Head,Data,[],1,'palette');
```

Function Example 2:

```
>> [Data,Head.Color]=imread('d:\Ge0MLib_logo3.png'); Head.Wf=[1 0 0 -1 100 50]; Head.K=[1 0];
   Head.BgVal=0;
```

```
>> XYZ=gWfrIm2Xyz(Head,Data,0,[],1);
>> [Head1,Data1]=gWfrXyz2Mat(XYZ,[0 5 1 5],[5 0 5 1]); % input “background” to Data1 as nan
>> [Head3,Data3]=gWfrMat2Im(Head1,Data1,[],1,'palette'); % set “background” color level-255  [1 1 1];
>> gWfrDraw(Head,Data,10,2); % Figure 2.7, a
>> gWfrDraw(Head3,Data3,11,2); % Figure 2.7, b
```

a) b)

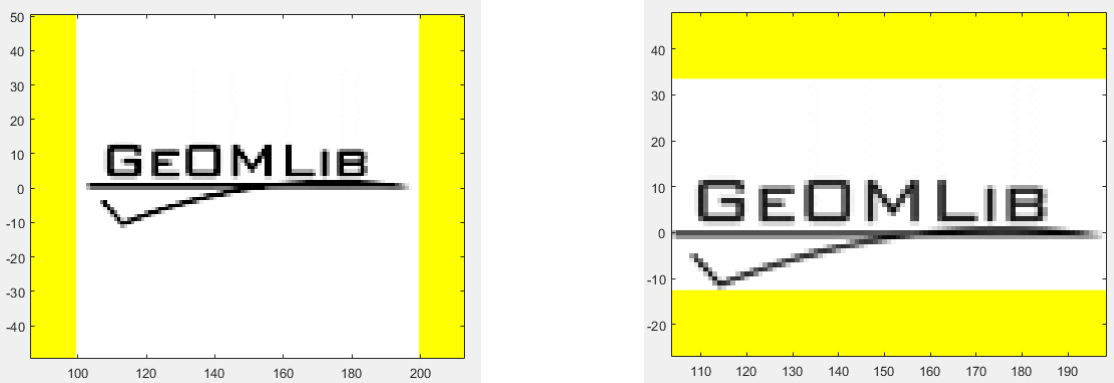


Figure 2.7 gWfrMat2Im example results

2.9 Convert raster-image to matrix-image

function [Head,Data]=gWfrIm2Mat(Head,Data,BgVal,K)

Convert raster-image (palette or grayscale) to matrix-image (type double).

Parameters:

Head – input header structure, which includes:

Head.Color – palette for palette-image or empty for grayscale-image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value"; DataOriginalValue=a*Color+b;

Data – input raster-image data matrix.

K – forced multiple (a) and shift (b) for "Data Original Value" calculation from Color; if K==[], then used Head.K;

BgVal – forced code of “absent” color; if BgVal==[], then used Head.BgVal;

Head – output header structure, which includes:

Head.Color=[] – colormap, empty for matrix image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal=nan – the code of “absent” color (it is means – no data for raster’s pixel with BgVal code);

Data – output matrix-image (type double);

Function Example:

```
>> [Head1,Data1]=gWfrIm2Mat(Head,Data,[],[]);
```

2.10 Cut rectangular zone from image

function [Head,Data]=gWfrCut(Head,Data,LimS)

Cut rectangle from raster-image or matrix-image and correct world-data; cutting zone input in pixels.

Parameters:

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; Z=DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image or matrix-image data matrix;

LimS – limits for cut zone [minX maxX minY maxY] in pixels.

Math:

Line1_A: pixel size in the x-direction in map units;

Line2_D: rotation parameter about y-axis;

Line3_B: rotation parameter about x-axis;

Line4_E: pixel size in the y-direction in map units, almost always NEGATIVE;

Line5_C: x-coordinate of center of upper left pixel;

Line6_F: y-coordinate of center of upper left pixel.

x'=Ax+By+C; y'=Dx+Ey+F.

Function Example:

```
>> [Data,Head.Color]=imread('d:\Ge0MLib_logo3.png'); Head.Wf=[1 0 0 -1 100 50]; Head.K=[1 0];
   Head.BgVal=0;
>> [Head1,Data1]=gWfrCut(Head,Data,[20 80 10 90]);
>> gWfrDraw(Head1,Data1,10,2); % Figure 2.8
```

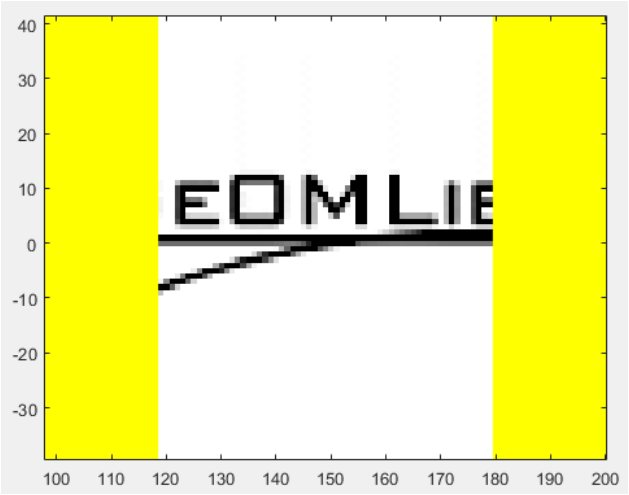


Figure 2.8 gWfrCut example results

2.11 Adds/cut borders to image

function [Head0,Data0]=gWfrAdd(Head,Data,AddLim,BgVal)

Adds/cut borders for raster-image or matrix-image and correct world-data; borders value set in pixels.

Parameters:

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; Z=DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image or matrix-image data matrix;

AddLim – adds for image border in pixels [addX_left addX_right addY_up addY_down] in pixels; positive values are added, negative - are cut;

BgVal – forced code of "absent" color; if BgVal==[], then used Head.BgVal; it can set to NaN (for matrix-image with type double);

Math:

Line1_A: pixel size in the x-direction in map units;

Line2_D: rotation (skew) parameter about y-axis;

Line3_B: rotation (skew) parameter about x-axis;

Line4_E: pixel size in the y-direction in map units, almost always NEGATIVE;

Line5_C: x-coordinate of center of upper left pixel;

Line6_F: y-coordinate of center of upper left pixel.

x'=Ax+By+C; y'=Dx+Ey+F.

Function Example:

```
>> [Data,Head.Color]=imread('d:\Ge0MLib_logo3.png'); Head.Wf=[1 0 0 -1 100 50]; Head.K=[1 0];
   Head.BgVal=0;
>> [Head1,Data1]= gWfrAdd(Head,Data,[-20 -20 30 0],0);
>> gWfrDraw(Head1,Data1,10,2); % Figure 2.9
```

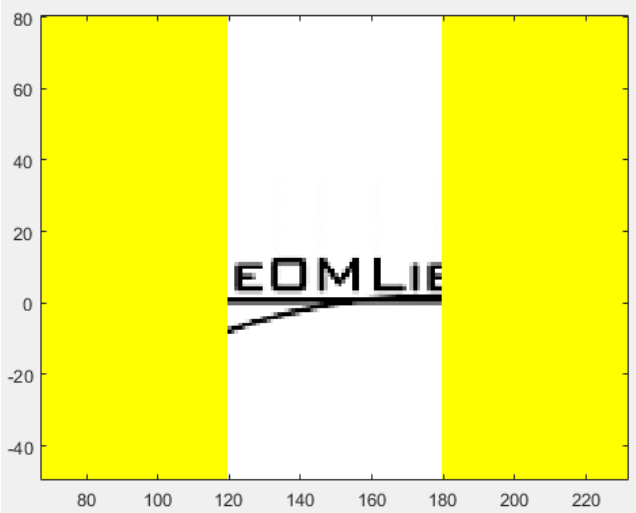


Figure 2.9 gWfrAdd example results

2.12 Resize image

function [Head,Data]=gWfrResize(Head,Data,divXY,rFl)

Resize raster-image or matrix-image with world-data correction.

Parameters:

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image or matrix-image data matrix.

divXY – divider [divX divY] for [scaleX skewY skewX scaleY];

rFl – resize method name: 1) repeat or delete values - 'Wfr'; 2) use "imresize" function from Image Processing Toolbox with methods 'nearest', 'bilinear', 'bicubic', 'box', 'triangle', 'cubic', 'lanczos2', 'lanczos3'.

Function Example 1:

```
>> [Head1,Data1]=gWfrResize(Head,Data,[2 2], 'Wfr');
```

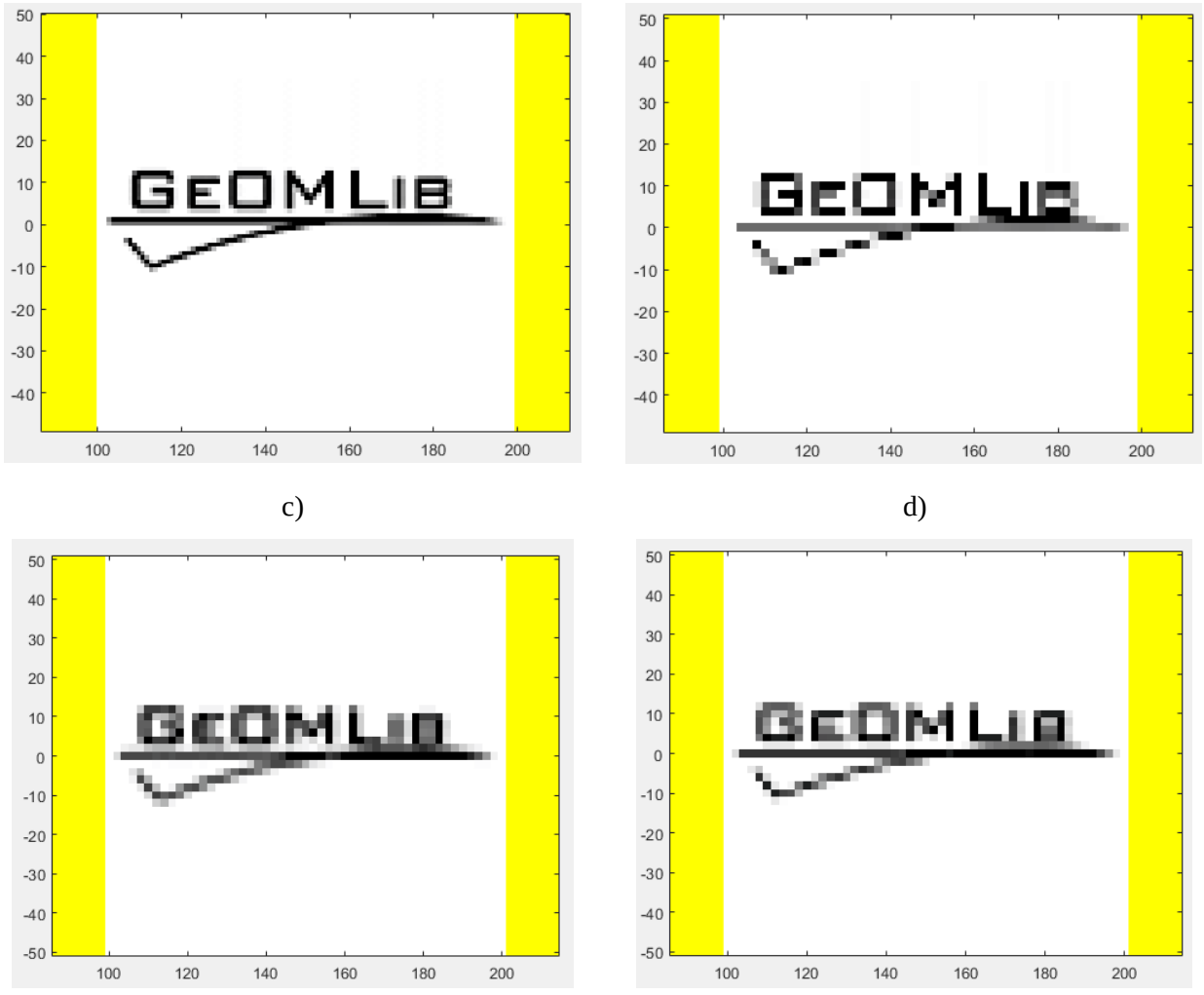
Function Example 2:

```
>> [Head2,Data2]=gWfrResize(Head,Data,Head0.Wf([1 4])./Head.Wf([1 4]),'Wfr');
```

Function Example 3:

```
>> [Data,Head.Color]=imread('d:\Ge0MLib_logo3.png'); Head.Wf=[1 0 0 -1 100 50]; Head.K=[1 0];
   Head.BgVal=0;
>> [Head3,Data3]=gWfrResize(Head,Data,[0.5 0.5],'Wfr');
>> gWfrDraw(Head3,Data3,10,2); % Figure 2.10, a
>> [Head3,Data3]=gWfrResize(Head,Data,[2 2],'Wfr');
>> gWfrDraw(Head3,Data3,11,2); % Figure 2.10, b
>> [Head3,Data3]=gWfrResize(Head,Data,[2 2],'bicubic');
>> gWfrDraw(Head3,Data3,11,2); % Figure 2.10, c
>> [Head3,Data3]=gWfrResize(Head,Data,[2 2],'box');
>> gWfrDraw(Head3,Data3,11,2); % Figure 2.10, d
```

a) b)



c) d)

Figure 2.10 gWfrResize example results

2.13 Combine colors/palettes for raster-image1 and raster-image2

function [Head1n,Data1n,Head2n,Data2n]=gWfrCombineColors(Head1,Data1,Head2,Data2, MinMax,imType)

Combine colors/palettes for raster-image1 and raster-image2 using Head.K field (renew colors/raletter are linear).

Parameters:

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX skewY skewX scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; Z=DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image or matrix-image data matrix;

Head1,Data1,Head2,Data2 – input Data and Header;

Head1n,Data1n,Head2n,Data2n – output Data and Header; Head1n.K==Head2n.K; the Head.BgVal will be set 255 for palette-image and 65535 for grayscale-image; BgVal value for palette is [0 0 0];

imType – forsed output raster-image type: 'uint8' or 'palette'- palette, 'uint16' or 'grayscale' - grayscale without pallete;

MinMax – minimal and maximal values link to level-0 and level-254/65534; if empty, than min and max will calculate from Data.

Algorithm: 1) convert raster-image to matrix-image; 2) find [min max] for matrix-images; 3) convert matrix-image to raster-image.

Function Example 1:

```
>> [Data1,Head1.Color]=imread('d:\Ge0MLib_logo3.png'); Head1.Wf=[1 0 0 -1 100 50]; Head1.K=[1 0]; Head1.BgVal=0;
>> Data2=Data1;Head2=Head1; Head2.K=[4 0];
>> [Head1n,Data1n,Head2n,Data2n]=gWfrCombineColors(Head1,Data1,Head2,Data2,[],[]);
>> image(Data1n);colormap(Head1n.Color); % Figure 2.11, a
>> image(Data2n);colormap(Head2n.Color); % Figure 2.11, b
>> Head1n
Head1n =
     Wf: [1 0 0 -1 100 50]
  Color: [256x3 double]
      K: [3.9843137254902 0]
  BgVal: 255
>> Head2n
Head2n =
     Wf: [1 0 0 -1 100 50]
```

Color: [256x3 double]

K: [3.9843137254902 0]

BgVal: 255

a) b)

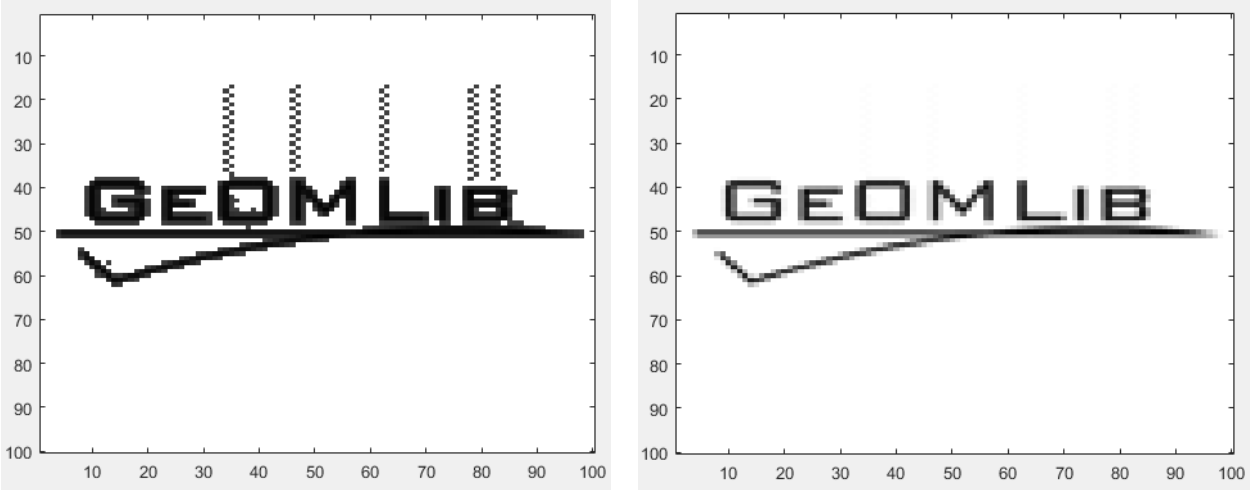


Figure 2.11 gWfrCombineColors example results

2.14 Merge Image1 and Image2 using world-data

function [Head3,Data3]= gWfrMergeData(Head1,Data1,BgVal1,Head2,Data2,BgVal2,IntKey)

Merge Image1 and Image2 using world-data. The features: a) Image2 is cover up Image1; b) world file's Line2_D (skewX) and Line3_B (skewY) must be zero.

Parameters:

Head – header structure, which includes:

Head.Color – colormap for palette image;

Head.Wf – world-file values: [scaleX 0 0 scaleY left_up_angle_X left_up_angle_Y];

Head.K=[a b] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – raster-image or matrix image;

Head1,Data1 – input underlying images;

Head2,Data2 – input overlying images;

BgVal1, BgVal2 – forsed code of "absent" color for Image1 and Image2; the OutputImage.BgVal=BgVal1; if empty, then Head.BgVal values are used;

IntKey – key for colormap correction; if 0 than OutputImage.Color palette and OutputImage.K will be coped from Head1.Color.

Head3,Data3 – output merged image.

Additional features.

0) SkewX and skewY are zero. Will be changed in future.

1) If IntKey==1:

-- try to Combine Colors using Head1.K and Head2.K values;

-- else try to find overlap area for Image1 and Image2 and calculate Head.K.

2) Means that palette for palette-image is gray - for calculations used Head.Color(:,1) column only.

3) Means that Head1.Wf(1)==Head2.Wf(1), Head1.Wf(4)==Head2.Wf(4); the OutputImage.Wf(1)=Head1.Wf(1), OutputImage.Wf(4)=Head1.Wf(4).

Function Example 1:

```
>> [Head3,Data3]=gWfrMergeData(Head1,Data1,[],Head2,Data2,[],0);
```

Function Example 2:

```
>> [Data1,Head1.Color]=imread('d:\Ge0MLib_logo3.png'); Head1.Wf=[1 0 0 -1 100 50]; Head1.K=[1 0]; Head1.BgVal=0;
>> Data2=Data1;Head2=Head1; Head2.K=[4 5]; Head2.Wf=[1 0 0 -1 120 60];
>> [Head3,Data3]=gWfrMergeData(Head1,Data1,[],Head2,Data2,[],0);
>> gWfrDraw(Head3,Data3,10,2); % Figure 2.12, a
>> [Head3,Data3]=gWfrMergeData(Head1,Data1,[],Head2,Data2,[],1);
>> gWfrDraw(Head3,Data3,10,2); % Figure 2.12, b
```

a) b)

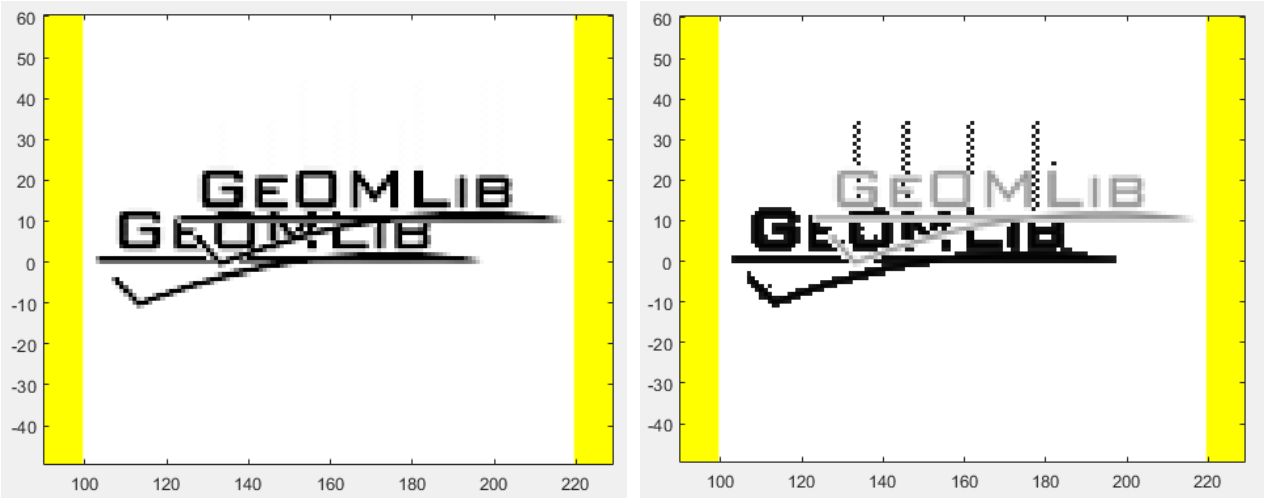


Figure 2.12 gWfrMergeData example results

2.15 Dip angles calculation (matrix-data)

function Data1=gWfrMatAngles(Head,Data,directCode)

Calculate dip-angles for matrix-data (topography or bathymetry grid), using a number of methods. Warning! SkewX and skewY are zero (will be changed in future).

Parameters:

Head – header structure, which includes:

Head.Color=[] – colormap for palette image;

Head.Wf – world-file values: [scaleX 0 0 scaleY left_up_angle_X left_up_angle_Y];

Head.K=[] – multiple (a) and shift (b) for "Data Original Value" calculation from Color; DataOriginalValue=a*Color+b;

Head.BgVal=nan – the code of "absent" color (it is means – no data for raster's pixel with BgVal code);

Data – input matrix-image (type double; nan is code of "absent" data);

directCode – the direction of max-angle estimation: 2- calculate dx and dy; 4- calculate dx,dy,dxy,dyx.

Data1 – output matrix with "angles" (see calculation method description below).

Function Example 1:

```
>> Data1=gWfrMat2Im(Head,Data);
```

Math description

The function with directCode=2 is calculate diff function along column and along rows. The last row (for diff along row) and last column (for diff along column) are duplicated to keep Data size. The results are used for two sets of angles calculation. The function result is maximal angle from two sets.

The function with directCode=4 is calculate diff function along column and along rows and calculate diff in two matrix diagonals. There are duplicated to keep Data size:

-- last row for diff along row,

-- last column for diff along column,

-- last column and first row for diff in diagonal 1,

-- last column and last row for diff in diagonal 2.

The results are used for four sets of angles calculation. The function result is maximal angle from four sets.

The difference calculation direction is shown in ***Figure 2.13***. The black points are the grid nodes (along rows and columns); the magenta point is the point used for angle calculation. The used two or four directions.

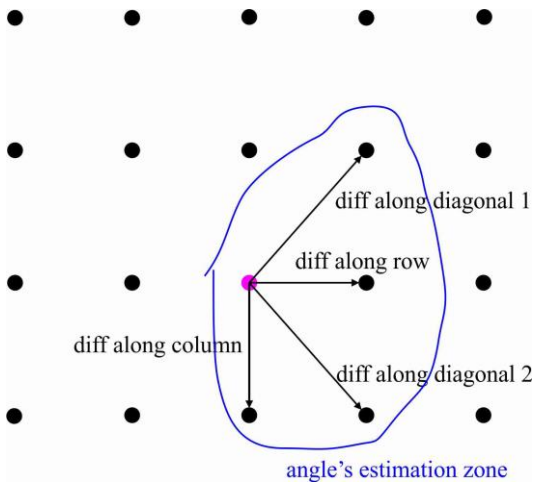


Figure 2.13 gWfrMatAngles calculation – the difference direction

The comparison of calculation results for noisy bathymetry data is shown in ***Figure 2.14***. The palette is used: 0-3 degrees is white; 3-5 degrees is gray; 5-90 degrees is red; “no data” is blue.

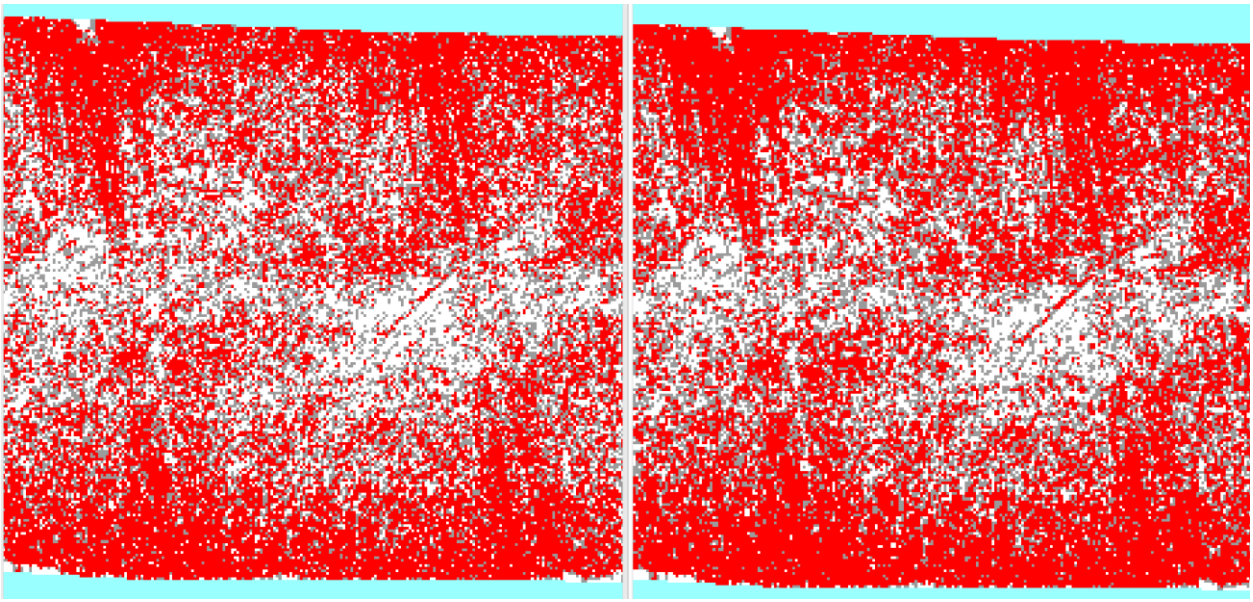


Figure 2.14 gWfrMatAngles example results for directCode=2 (left) and directCode=4 (right)

Function Example 2:

```
>> A=dlmread(name); % read xyz-data (pts-file for MBES)
>> [Head,Data]=gWfrXyz2Mat(A',5,5); % convert to matrix-data with step 5 meters
>> Data1=gWfrMatAngles(Head,Data, 4); % calculate dip angles
>> [Head1,Data1]=gWfrMat2Im(Head,Data1,[0 90],1,'palette'); %convert to image-data
>> for n=1:9;Head1.Color(n,:)=[255 255 255]./255;end; for n=10:15;Head1.Color(n,:)=[155 155 155]./255;end; for n=16:255;Head1.Color(n,:)=[254 0 0]./255;end; Head1.Color(256,:)=[153 255 255]./255; % direct correction of palette
>> gWfrDraw(Head1,Data1,100,1);axis equal; % draw image (Figure 2.14)
>> gWfrWrite([name '.tif'],Head1,Data1); % save image to geo-referenced tiff file
```

3. gWfr example

```
%script gPts2DFilt
%2D filtration for pts-file (XYZ bathy data); warning! the skewX and skewY are zero
for pts-file.
%Coordinate axis:
%^+Y (N)
%|
%|
%----> +X (E)

%========Read pts-file and convert it to matrix-image==========
XYZ=dlmread('d:\Reglam\For_ID.txt');
dE=[####47.875 ####026.875 ####48.125 ####026.875]; %dE=[lx_x1 lx_y1 lx_x2 lx_y2] is
horizontal segment along X axis;
dN=[####48.125 ####026.875 ####48.125 ####027.125]; %dN=[ly_x1 ly_y1 ly_x2 ly_y2] is
vertical segment along Y axis;
[Head,Data]=gWfrXyz2Mat(XYZ',dE,dN); %Data is "matrix-image" contane grid
gWfrDraw(Head,Data,1,1); %Figure 3.1, a
%========Find holes and prepare mask==========
B=uint8(~isnan(Data)); %convert to black&white image;
B=bwmorph(B,'close'); %use Image Processing Toolbox -- fill small "holes";
B=bwmorph(B,'dilate',10); %use Image Processing Toolbox -- add 10 pixels to black-area
borders
figure(2);imagesc(B); %Figure 3.1, b
%========Prepare triangulation web==========
dx=dE(3)-dE(1);dy=dN(4)-dN(2); %use [stepX 0 0 stepY left_up_angle_X left_up_angle_Y]
Bo=scatteredInterpolant(round((XYZ(:,1)-min(XYZ(:,1)))./dx)+1,round((max(XYZ(:,2))-
XYZ(:,2))./dy)+1,XYZ(:,3),'natural','linear');
%========Interpolate data for holes==========
L=isnan(Data);
[L2,L1]=find((B==1)&L);L3=(B==1)&L;
Data2=Data;Data2(L3)=Bo(L1,L2);
gWfrDraw(Head,Data2,3,1); %Figure 3.1, c
%========2D filtration==========
F=zeros(21,21);F(11,11)=1;%create emulation of filter
Data3=gData2DFilt(Data2,F,1); %make filtration with normalization
gWfrDraw(Head,Data3,4,1); %  Figure 3.1, d
[Head2,Data4]=gWfrAdd(Head,Data3,[-5 -5 -5 -5],nan);%cut 5-pixels borber
gWfrDraw(Head2,Data4,5,1); %Figure 3.1, e
%========Write new pts-file==========
XYZ2=gWfrIm2Xyz(Head2,Data4,nan,[1 0],1);
dlmwrite('d:\Reglam\For_ID2.txt',XYZ2','precision','%.3f');

%mail@ge0mlib.com 19/06/2018
```

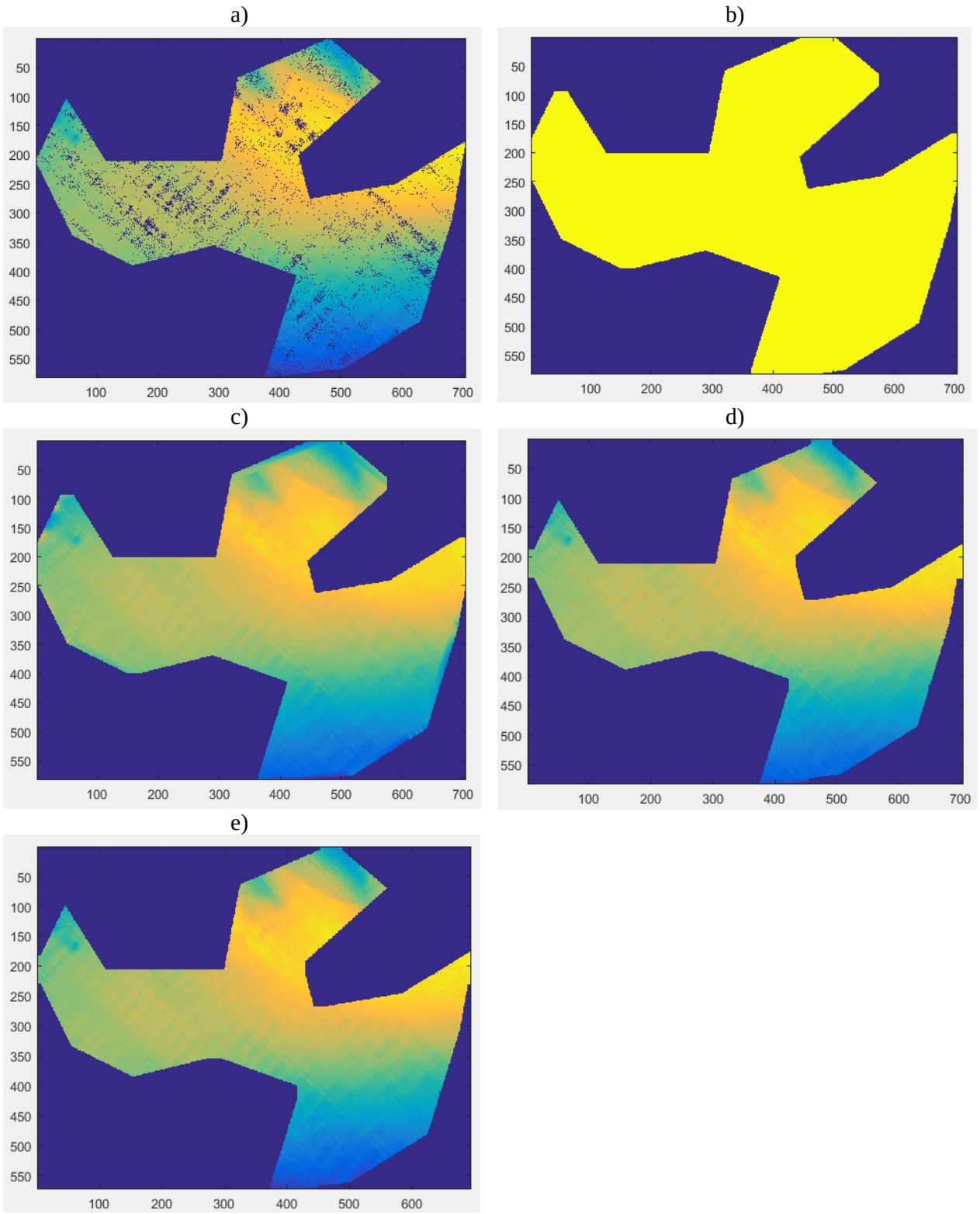


Figure 3.1 gPts2DFilt script's steps

a) original pts-file converted to matrix-image (grid);
b) mask for holes interpolation;
c) interpolated matrix-image;
d) filtered matrix-image, using 2D filter;
e) matrix-image with 5-pixels cut.

Citation

1) https://support.esri.com/en/technical-article/000002860
2) http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/world-files-for-raster-datasets.htm
3) https://en.wikipedia.org/wiki/World_file
4) https://www.awaresystems.be/imaging/tiff/tifftags.html;
5) https://www.loc.gov/preservation/digital/formats/fdd/fdd000279.shtml