

DEM DATA OBTAINED FROM THE SHUTTLE RADAR TOPOGRAPHY MISSION – SRTM-3

DANE DEM UZYSKANE Z RADAROWEJ MISJI PROMU KOSMICZNEGO – SRTM-3

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Introduction

One of the crucial problems concerning geospatial data infrastructures, including the ESDI (European Spatial Data Infrastructure), is to fill them with sufficient quality geospatial data meeting user requirements. This problem related to the ESDI is the subject of the study *Environmental Thematic User Needs – Position paper* (INSPIRE-ETC WG, 2002) and of Internet consultations, which took place in 2003 involving the European geoinformation community (INSPIRE-EG, 2003). It results from the analysis performed, that elevation data related to ground surface are one of basic and the most required reference data. In the above mentioned study high priority is assigned to them, as they are frequently a necessary component of many other topic sets: ... *important in modelling of land slides and avalanches, flooding vulnerability, risk to erosion, flow of water and pollutants, spread of air pollution, fires, noise, biodiversity. Used in many sectors, amongst others environment, water supply, energy sector, agriculture and forestry.* In this situation, possibility to use in ESDI the data obtained as a result of the shuttle radar topographic mission (SRTM), performed by NASA, deserves attention.

In February 2000, 11-day mission of space shuttle ENDEAVOUR devoted to radar interferometric scanning of the Earth surface was performed. A measuring set placed in the space shuttle consisted of 60 metre mast with two parallel measuring systems installed on it and operating at X-Band and C-Band frequencies. Each of them included a transmitting antenna and two receiving antennas located on opposite ends of the mast. Registered data stream amounted to 270 Mb/sec. and considerably exceeded possibilities of direct digital transmission to the ground stations. In such situation these data have to be recorded on magnetic storages in

course of scanning on the space shuttle. Due to orbit parameters, scanning covered area between parallels 54°S and 60°N.

Radar interferograms obtained in this way enable producing of a digital elevation model (DEM) for over 80% of Earth surface with exceptionally high resolution expressed by a grid cell size $\Delta\phi = \Delta\lambda = 1'' = 0.00027777^\circ$ in WGS-84 reference system, it means roughly 20 m \times 30 m for the area of Poland.

So that SRTM data could make up a correct, exact and reliable digital elevation model they require long term processing. It is planned to elaborate two versions: SRTM-1 of high resolution as mentioned above and SRTM-3 with three times less linear resolution, i.e. of grid cell size $\Delta\phi = \Delta\lambda = 3''$. Each value in SRTM-3 is average of 9 values of SRTM-1. For the area of Poland it is in approximation a grid cell sized $\Delta x = 60$ m and $\Delta y = 90$ m. Despite the fact that works on those data will be still carried out for a long time, the raw, not verified and not corrected version of SRTM-3 has been released for the entire scanning range. The data made available, despite being raw, make up an extremely valuable research material for scientific purposes and they are provided free of charge for such requirements. But, in order to use them, it is necessary to know their spatial organization, binary encoding format and to have tool software provided for initial elaboration in script task mode. The latter element is especially important as due to their big volume, conversational processing may be applied only to single fragments. Example for area of Poland shows the volume of these data. Such a set consists of 96 files, comprising 1442401 numbers each, which makes up almost 140 million numbers. Detailed description of the radar interferometry method and data obtained in this mission is available at website of Jet Propulsion Laboratory being part of California Institute of Technology, which belongs to NASA (JPL, 2003) and in numerous publications (Moreira et al., 1995; Coltelli et al., 1996; Farr & Kobrick, 2000; GEODETA, 2000; Kurczyński, 2000; Werner, 2001; Rabus et al., 2003; ESA, 2003).

In view of the raw character of SRTM-3 data, there is no information about their accuracy. Only accuracy of the measurement data obtained from radar interferograms is known. In this case, absolute horizontal accuracy is 20 m and absolute vertical accuracy is 16 m. Information about the methods of processing measurement data to SRTM-3 data is not available and, therefore, it is not known to what degree the accuracy can change during the data processing. In the case of SRTM-3 data, only vertical accuracy may be established as it results from the definition of this type of data. On the assumption that during data processing, "total" accuracy has not been changed, we come to the conclusion that vertical accuracy is essentially demoted. However, final accuracy of SRTM-3 data may be improved during data processing, because every number in this data set (for Poland area among others) is a result of recalculation of about 30 measurements made on the shuttle during its mission.

Provisional evaluation shows that relative accuracy, understood here as an accuracy of elevation differences between neighboring cells, is much higher, especially in flat areas. Among other things, the fact that very flat morphological forms and other low elements of terrain surface are clearly observed without any significant disturbances, leads us to such conclusions.

Now, from November 2003, SRTM-3 data for the area of Europe including Poland are available for the public at the address <ftp://edcftp.cr.usgs.gov/pub/data/srtm/Eurasia/>. But Eurasia directory contains 23456 files and finding among them those, which are related to selected area is very inconvenient. Therefore files of Poland area are located at the address <http://netgis.geo.uw.edu.pl/srtm/Poland/> and 1092 files for the area of Europe are at the address <http://netgis.geo.uw.edu.pl/srtm/Europe/>.

Spatial organization of data

In their current version, the SRTM-3 data are defined in geographic coordinates of WGS-84 reference system. They are divided into segments (tiles), each covering angular square of the Earth surface of dimensions $1^\circ \times 1^\circ$ and, more precisely, an angular square side amounts to 1.00083333° and, as a result, neighboring segments overlap slightly. Data in each segment make up a matrix of numbers corresponding to networks of 1201 rows and 1201 columns consisting of cells with dimensions $\Delta\phi = \Delta\lambda = 3'' = 0.00083333^\circ$. Extreme rows and columns in neighboring segments overlap and contain the same data. Central points of cells located in the segment corners have coordinates expressed in full degrees. *BoundingBox* including one hypothetical segment has coordinates: $(47.99958333^\circ, 17.9995833^\circ)$, $(49.00041666^\circ, 19.00041666^\circ)$. Information on spatial organization and binary encoding format come from documents comprised in USGS servers concerning those data (USGS, 2003; USGS-EROS, 2003).

Binary encoding format

To each segment of spatial structure defined above in SRTM-3 corresponds one binary file with ".hgt" extension. It has been assumed as a rule for names of these files that they include numbers determining the parallel limiting the segment from the bottom and the meridian limiting it from the left side; for instance for the segment defined above, the name of file is N48E018.hgt. Because numbers in the name have no signs, the initial letter N defines the northern hemisphere and in case of southern hemisphere, it is replaced by the letter S. Analogically, three digit numbers of meridians within the range from 0 to 180 are preceded by letters: E for segments located East of meridian 0° and W for those located in the West.

If a segment covers only sea or ocean area (without islands) there is no binary file for such segment. For processing purposes in the script task mode and for complete coverage of selected area, a binary file with proper name containing only zero values may be created for such segment.

All binary files have identical structure and size equal to 2 884 802 bytes. It results from the fact that they include only matrix 1201×1201 of 2-byte signed integers (files have not headings and endings). In primary form, they are compressed and names have additional extensions ".zip", e.g. N48E018.hgt.zip and their average size is within limits from 450 KB to 1600 KB.

Numbers in matrix are placed in rows. The first row concerns cells located the most to the North and the first number in row concerns cell located the most to the West. The last number corresponds to cell located in the South-East corner. Sequence of two bytes is in conformity with IEEE standard (Motorola), it means that the most important is the first byte (*big endian*). Such sequence is assumed in Sun SPARC and Silicon Graphics computers. For PC and DEC Alpha computers, conversion for reverse encoding *little endian* (Intel) is necessary, but often software systems reading such data make this conversion automatically.

In Unix operational systems change of byte sequence can be done by system command: „dd if=inputFileName of=outputFileName conv=swab”. In MS Windows environment simple program in C language should be used:

```
----- conv-swab-1201.c -----
#include <stdio.h>
#include <fcntl.h>
#define NULL 0
#define TABSIZE 1201
int main(int argc, char* argv[])
{
    int i, j; FILE *f1, *f2; int b1, b2;

    if(argc != 3)
        error("Format: conv-swab-1201 inputFileName outputFileName", NULL);
    if(f1 = fopen(argv[1], "r"));
    else error("cp: Could not open %s", argv[1]);
    if(f2 = fopen(argv[2], "w"));
    else error("cp: Could not open %s", argv[2]);
    for( i=0; i<TABSIZE; i++) {
        for( j=0; j<TABSIZE; j++) {
            b1=fgetc(f1); b2=fgetc(f1);
            fputc(b2, f2); fputc(b1, f2);
        }
    }
    fclose( f1 ); fclose( f2 ); exit(0);
}
error(char* s1, char* s2) { printf(s1, s2); printf("\n"); exit(1); }
```

2-byte signed integers have a range from -32768 to 32767, which is sufficient to register elevation (height or depth) expressed in full meters. In SRTM data it was assumed that the extreme negative number -32768 means lack of data.

Initial elaboration of data

The data now available are raw and there are no data (numbers -32768) for many cells. In many cases data have noticeable big errors, which is expressed by occurrence of incredible very big or very small values. Reflection of radar signal from water surface is very weak and therefore, in those places "noise" of numerical values is observed. This effect is very visible in coast line zones, where it is difficult to determine the position of those lines on the basis on these data. For these reasons, it is necessary to carefully edit the data, which for some applications can be performed only partially in automatic way. For other applications concerning flat areas, interesting results can be obtained by casting from integers to floating point numbers that will facilitate the smoothing process, which is frequently necessary in such situations.

A separate problem of initial processing of data is to integrate separate segments into bigger blocks eliminating rows and columns overlapping on edges of these segments. It may be solved by means of simple software programs developed specially for this purpose. For instance, joining of four selected adjacent segments in corners is realized by program in C language:

```

----- join-4seg-1201.c -----
#include <stdio.h>
#include <fcntl.h>
#define NULL 0
#define TABSIZE 1201

int main(int argc, char* argv[]) {
    int i, j;
    FILE *fi1, *fi2, *fi3, *fi4, *fo;
    int b1, b2;

    if(argc != 6) error(
    "Format: join-4seg-1201 inputFileNW inputFileNE inputFileSW inputFileSE outputFile",
    NULL);
    if(fi1 = fopen(argv[1], "r")); else error("join4: Could not open %s", argv[1]);
    if(fi2 = fopen(argv[2], "r")); else error("join4: Could not open %s", argv[2]);
    if(fi3 = fopen(argv[3], "r")); else error("join4: Could not open %s", argv[3]);
    if(fi4 = fopen(argv[4], "r")); else error("join4: Could not open %s", argv[4]);
    if(fo = fopen(argv[5], "w")); else error("join4: Could not open %s", argv[5]);

    for( i=0; i<TABSIZE; i++) {
        for( j=0; j<TABSIZE; j++) {
            b1=fgetc(fi1); b2=fgetc(fi1);
            fputc(b1, fo); fputc(b2, fo); }
        for( j=0; j<TABSIZE; j++) {
            b1=fgetc(fi2); b2=fgetc(fi2);
            if( j > 0 ) {
                fputc(b1, fo); fputc(b2, fo);
            } } }
    for( i=1; i<TABSIZE; i++) { if( i > 0 ) {
        for( j=0; j<TABSIZE; j++) {
            b1=fgetc(fi3); b2=fgetc(fi3);
            fputc(b1, fo); fputc(b2, fo);
        }
        for( j=0; j<TABSIZE; j++) {
            b1=fgetc(fi4); b2=fgetc(fi4);
            if( j > 0 ) {
                fputc(b1, fo); fputc(b2, fo);
            } } } }
    fclose( fi1 ); fclose( fi2 ); fclose( fi3 ); fclose( fi4 ); fclose( fo );
    exit(0);
}
error( char* s1, char* s2) { printf(s1, s2); printf("\n"); exit(1); }

```

A similar program makes it possible to create files in accordance with SRTM encoding rules, but for any defined area by means of two geographic coordinate pairs (φ_1, λ_1) , (φ_2, λ_2) .

SRTM data processing in GRASS system

Both visualization of SRTM on computer screen and many simple operations on those data may be performed by means of free simple programs operating in MS Windows environment. MICRODEM program worked out by Petera Guth (<http://www.usna.edu/Users/oceano/pguth/website/microdem.htm>) is one of such programs. But more advanced SRTM data processing and complicated analysis within digital elevation model requires software of big capabilities. Such software meeting all necessary requirements is GIS GRASS system (Neteler, Mitasova, 2002).

SRTM-3 data are loaded in GRASS database by command `r.in.bin`; for instance, raster layer for the whole area of Poland can be created by means of one command loading data from one file,:

```
r.in.bin bytes=2 input=/opt/grass-db/srtm/pl/pl.hgt output=pl title=SRTM-3_for_Poland \
north=56.00041666 south=47.99958333 east=25.00041666 west=12.99958333 \
r=9601 c=14401 subst=-32768
```

In other example, separate raster (cellular) layers for those segments are created by means of multiple calls to this program from script in KornShell language for separate files of 96 segments comprising mutually this area:

```
----- in-hgt-1201-pl.ksh -----
#!/bin/ksh
n=48; m13=13; m=0; e0="e0"; e="e"; r="r"; no=0; so=0; ea=0; we=0

while ((n < 56))
do
  integer m=$m13
  while ((m < 25))
  do
    ((no = n + 1)); ((so = n - 1)); ((ea = m + 1)); ((we = m - 1))
    r.in.bin bytes=2 input=/opt/grass-db/srtm/rev/n$n$e0$m$r.hgt \
output=n$n$e$m.d12 title=n$n$e$m.d12 north=$no.00041666 \
south=$so.99958333 east=$ea.00041666 west=$we.99958333 \
r=1201 c=1201 subst=-32768
    ((m = m + 1))
  done
  ((n = n + 1))
done
```

Data loading procedure requires prior creation of place in GRASS database in order to place those data. These places are *location* and *mapset* type directories with WIND file defining environment. Example of WIND file for digital elevation model for area of Poland ($\varphi_1 = 47.99958333^\circ$, $\lambda_1 = 12.99958333^\circ$), ($\varphi_2 = 56.00041666^\circ$, $\lambda_2 = 25.00041666^\circ$):

```
----- WIND -----
proj:      0
zone:      0
north:     56.00041666
south:     47.99958333
east:      25.00041666
west:      12.99958333
cols:      14401
rows:      9601
e-w resol: 0.00083333
n-s resol: 0.00083333
```

As a result, a model compound of 9601 rows and 14401 columns arises. Data loaded to database may be presented in graphic form (visualized) on screen by means of command:

```
d.rast nazwaWarstwyRastrowej
```

But, the image obtained has very reduced resolution resulting from screen resolution and window size, it is approximately 1240×1240 pixels at most. It follows that in average conditions only a fragment corresponding to one segment can be visualized in full resolution

Visualization of digital elevation model

Other problem of visualization is sufficiently exact presentation of elevation variability by means of colors. Obtaining of image presenting all subtle relief in full details requires elaboration of special table of mapping elevation to colors. Example of such table for the area of Poland:

```
----- colors-for-pl -----
% -5 2600
nv:0
-5:160:160:192    0:160:160:192
 0:160:160:192    0.5:224:160:255
0.5:224:160:255   5:255:255:255
 5:255:255:255   15:144:144:255
15:144:144:255   25:112:128:144
25:112:128:144   45:112:192:224
45:112:192:224   60:232:248:255
60:224:255:255   70:112:196:196
70:112:196:196   80:112:144:112
80:112:144:112   90:96:224:192
90:96:224:192   100:232:255:248
100:232:255:248  110:128:216:96
110:128:216:96  130:80:128:80
130:80:128:80   150:128:208:128
150:128:208:128 160:240:255:240
160:248:255:232 170:192:224:0
170:192:224:0   190:128:128:64
190:128:128:64  220:240:224:0
220:240:224:0   250:255:255:224
250:255:255:232 320:255:160:0
320:255:160:0   400:160:128:112
400:160:128:112 500:255:96:96
500:255:96:96   600:255:240:240
600:255:240:240 700:255:64:160
700:255:64:160  800:128:80:112
800:128:80:112 1000:255:128:255
1000:255:128:255 1600:255:255:255
1600:255:255:255 2600:128:128:255
```

In this table the first line defines coordinate range and the second one defines color for cells not containing data (number -32768). Remaining lines define colors for assumed elevation ranges by determination of extreme values of those ranges. These values are defined by means

of four numbers in scheme elevation:red:green:blue, for instance for height 1600 m white color was assumed, that gives record 1600:255:255:255. Colors for values inside those ranges are interpolated linearly on the basis of extreme values.

For correct and exact visualization, color selection in the table cannot be incidental and it requires careful elaboration for big areas including simultaneously low-laying and mountain regions. In case of the whole area of Poland this scale should include about 2600 distinguished colors. Solution of this question provides the use of extended scale, specially developed here for this task and taking into consideration not only particular colors, but also color intensity degree, that is illustrated in Fig. 1 as white solid broken line. In such color scale passing over from one color to another occurs either in bright value zone or dark value zone that increases considerably the number of available colors. Such a scale is named here "extended color scale" (ECS). For images illustrating not only elevation but also relief in the form of shadows the extended color scale cannot be applied and in such a case it is necessary to use "narrow color scale" (NCS) presented in Fig. 1 in the form of white straight dashed line.

In the GRASS system, problems connected with the loss of horizontal resolution and "vertical resolution" (color resolution of image) in visualizing model data can be solved by generating image in PNG (Portable Network Graphics) format by means of graphic driver provided for such kind of graphic images. Prior to the use of such a driver, it is necessary to define values of series of environmental variables, which affect its operation. Therefore, the most convenient solution is to code all commands to script in KornShell language:

```
----- disp-png-pl.ksh -----
#!/bin/ksh
# definitions of environmental variables for GRASS system and PNG driver
GRASS_WIDTH=1401
export GRASS_WIDTH
GRASS_HEIGHT=9601
export GRASS_HEIGHT
GRASS_PNGFILE=pl.png
export GRASS_PNGFILE
GRASS_BECKGROUNDCOLOR=000000
export GRASS_BECKGROUNDCOLOR
GRASS_TRANSPARENT=FALSE
export GRASS_TRANSPARENT
GRASS_TRUECOLOR=TRUE
export GRASS_TRUECOLOR
# activation and selection of PNG driver
d.mon start=PNG
d.mon select=PNG
# creating of image for raster layer "pl"
d.rast pl
# stopping PNG driver
d.mon stop=PNG
```

The result file received with the name pl.png, taking into consideration proportion correction (14401 × 14401 pixels), is illustrated in Fig. 2, but unfortunately only in much reduced horizontal resolution.

Another method of visualization of digital elevation model is based on two number parameters of graphic image, hue parameter and intensity parameter. In such a case hue parameter serves to present elevation and intensity parameter to illustrate relief at assumed sun position determined by azimuth and height angle. This way of visualization provides an image containing more information about ground surface shape. But presentation of elevation by means of hues provides lower vertical resolution, since color scale (NCS – white straight dashed line in Fig. 1) is considerably shorter than in the method presented before (ECS – white broken solid line in Fig. 1).

In this method of visualization, beside elevation model also a relief model is required presented in the form of shadows obtained at defined sun position. To determine lighting and shadow model, script `shade.rel.sh` of GRASS system may be used, in which calculation algorithm coded in the form of command for program `r.mapcalc` provided for calculation from field of *mapalgebra*:

```
#————algorithm of script shade.rel.sh in system GRASS:—————
# ewres(), nsres(), isnull(a) and null() - internal GRASS functions
shd="pl.shd"
elev="pl"
scale=1.
alt=30.
az=270.
r.mapcalc << EOF
$shd = eval(\\
x=($elev[-1,-1] + 2*$elev[0,-1] + $elev[1,-1] \\
-$elev[-1,1] - 2*$elev[0,1] - $elev[1,1])/(8.*ewres()*$scale) , \\
y=($elev[-1,-1] + 2*$elev[-1,0] + $elev[-1,1] \\
-$elev[1,-1] - 2*$elev[1,0] - $elev[1,1])/(8.*nsres()*$scale) , \\
slope=90.-atan(sqrt(x*x + y*y)), \\
a=round(atan(x,y)), \\
a=if(isnull(a),1,a), \\
aspect=if(x!=0||y!=0,if(a,a,360.)), \\
cang = sin($alt)*sin(slope) + cos($alt)*cos(slope) * cos($az-aspect), \\
if(cang < 0.,0.,100.*cang), \\
if(isnull(cang), null(), 100.*cang))
EOF
```

In order to achieve a graphic image which is a combination of elevation model with relief model in script `disp-png-pl.ksh` presented before, command `d.rast pl` should be replaced by command `d.his h_map=pl and_map=pl.shd`. Raster layer with the name `pl` (as before) includes elevation model, and raster layer `pl.shd` includes relief model obtained from realization of script `shade.rel.sh`.

Summary

For the first time, we are dealing with very detailed geospatial data for almost entire Europe, which are available free of charge for the general public. Although these are raw data, their value for research purposes is undoubtedly great. Wider dissemination of those data should be supported by dedicated geo-information server cooperating with a database and a subsystem making data available in various forms together with metadata. Such server may be and should be one of the components of the European Spatial Data Infrastructure (ESDI).

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STRESZCZENIE

Istotnym problemem infrastruktur geoinformacyjnych, w tym także ESDI (European Spatial Data Infrastructure), są dane geoprzestrzenne o dostatecznej dokładności i spełniające potrzeby użytkowników. Zagadnienie to w odniesieniu do ESDI jest tematem prac zespołu ekspertów inicjatywy INSPIRE (Infrastructure for Spatial Information in Europe). W raportach zespołu przyznaje się tym danym wysoki priorytet, ponieważ są podstawą różnych analiz przestrzennych w wielu dziedzinach działalności praktycznej i badawczej. W tej sytuacji na uwagę zasługuje możliwość wykorzystania do takich zastosowań w ESDI danych uzyskanych z radarowej topograficznej misji promu kosmicznego (SRTM) zorganizowanej przez NASA. Misja ta odbyła się w lutym 2000 i jej celem było interferometryczne radarowe skanowanie powierzchni Ziemi. Zainstalowany na promie zestaw pomiarowy składał się z 60-metrowego masztu i zainstalowanych na nim dwóch równoległych układów pomiarowych (X-band i C-band). Skanowanie objęło obszar Ziemi zawarty pomiędzy równoleżnikami 54°S i 60°N.

Dane SRTM, aby mogły stanowić poprawny i zweryfikowany model powierzchni terenu, wymagają wieloletnich prac. Opracowywane są dwie wersje: SRTM-1 o pełnej rozdzielczości (moduł próbkowania 1") i SRTM-3 o rozdzielczości liniowo trzykrotnie mniejszej (moduł 3"). Rzędne terenu SRTM-3 są średnimi z 9 wartości SRTM-1. Pomimo, że prace nad tymi danymi będą jeszcze trwały długo, obecnie została udostępniona surowa (nie zweryfikowana, nie poprawiona) wersja SRTM-3 dla całego zasięgu skanowania. Udostępnione dane stanowią dla celów naukowych niezwykle cenny materiał. Jednak, aby móc je wykorzystać trzeba znać ich organizację, format zapisu binarnego i dysponować oprogramowaniem do wstępnej ich obróbki w trybie zadań skryptowych. Ten ostatni element jest szczególnie istotny, ponieważ ze względu na wielką objętość przetwarzanie konwersyjne jest bardzo pracochłonne. O objętości tych danych świadczy przykład dla obszaru Polski – zestaw taki składa się z 96 segmentów i stanowi to łącznie 138 milionów liczb.

Organizacja przestrzenna danych

Obecnie dostępne dane SRTM-3 są określone w układzie odniesienia WGS-84. Podzielone są na segmenty obejmujące wycinki powierzchni Ziemi o wymiarach 1.00083333° na 1.00083333°, a moduł siatki rozmieszczenia poszczególnych segmentów jest określony w pełnych stopniach. W rezultacie sąsiadujące segmenty nieznacznie na siebie nachodzą – skrajne wiersze i kolumny w sąsiadujących segmentów pokrywają się, a centralne punkty narożnych komórek mają współrzędne wyrażone w pełnych stopniach. Prostokąt obejmujący jeden przykładowy segment ma współrzędne: (47.99958333°, 17.99958333°), (49.00041666°, 19.00041666°).

Format zapisu binarnego

Każdemu segmentowi odpowiada jeden plik binarny z rozszerzeniem „.hgt”. Dla nazw tych plików przyjęto zasadę, że zawierają liczby określające równoleżnik ograniczający ją od południa i południk ograniczający segment od zachodu, na przykład plik dla segmentu określonego powyżej ma nazwę N48E018.hgt. Ponieważ liczby w nazwie nie mają znaków, litera N określa półkulę północną, a S południową. Numery południków (0 do 180) również poprzedzone są literami E lub W.

Dla segmentów obejmujących wyłącznie obszary morskie nie ma plików binarnych. W takim przypadku dla potrzeb przetwarzania można utworzyć plik o odpowiedniej nazwie i wypełniony zerami.

Wszystkie pliki binarne mają identyczną budowę i wielkość 2 884 802 bajtów, ponieważ zawierają jedynie macierz 1201 × 1201 2-bajtowych liczb całkowitych ze znakiem.

Liczby w macierzy ułożone są wierszami – pierwszy wiersz dotyczy komórek położonych najbardziej na północ i pierwsza liczba w wierszu dotyczy komórki położonej najbardziej na zachód. Kolejność dwóch bajtów zawierających liczbę odpowiada standardowi IEEE, czyli bardziej znaczący bajt jest pierwszy („big-endian”, np. komputery Sun SPARC i Silicon Graphics). Dla komputerów PC i DEC-Alpha potrzebna jest konwersja do odwrotnego zapisu „little-endian”, lecz często programy czytający same dokonują tej konwersji. W systemach unixowych zamiana kolejności bajtów może być dokonana programem systemowym, jednak w środowisku MS Windows trzeba samemu opracować odpowiedni program.

Przyjęte w danych SRTM całkowite liczby 2-bajtowe ze znakiem mają zakres od -32768 do 32767

i w zupełności wystarczą do zapisania wysokości wyrażonej w całkowitych metrach, a wartość – 32768 oznacza w tym przypadku brak danych.

Wstępna obróbka danych

Obecnie udostępnione dane są surowe – dla wielu komórek brak jest danych, a także w wielu przypadkach dane mają widoczne błędy. Odbicie sygnału radarowego od powierzchni wody jest słabe i w tych miejscach obserwuje się „szum” wartości liczbowych. Jest to widoczny w strefach linii brzegowych, gdzie trudno jest ustalić przebieg tych linii.

Oddzielnym zagadnieniem wstępnej obróbki danych jest łączenie ze sobą poszczególnych segmentów w większe bloki z eliminacją pokrywających się na brzegach wierszy i kolumn. Można to rozwiązać przy pomocy prostych programów specjalnie do tego celu opracowanych.

Przetwarzanie danych w systemie GRASS

Zarówno wizualizację danych SRTM na ekranie komputera, jak i wiele prostych operacji na tych danych można wykonać przy pomocy prostych programów działających w środowisku MS Windows. Jednak bardziej zaawansowane przetwarzanie danych SRTM i skomplikowane analizy powierzchni terenu wymagają oprogramowania o dużych możliwościach. Takim oprogramowaniem jest coraz bardziej ostatnio doceniany system GIS GRASS. Dane SRTM-3 są wprowadzane do bazy GRASS-a programem r.in.bin, jednak wymaga to wcześniejszego utworzenia miejsca na umieszczenie tych danych w postaci katalogów typu location i mapset wraz z definiującym środowisko plikiem WIND.

Wizualizacja modelu powierzchni terenu

Wprowadzone do bazy systemu GRASS dane SRTM mogą być zobrazowane na ekranie przy pomocy polecenia d.rast, jednak o bardzo zredukowanej rozdzielczości wynikającej z rozdzielczości ekranu i wielkości okna – jest to najczęściej około 1240 × 1240 pikseli. Z tego wynika, że w pełnej rozdzielczości, biorąc pod uwagę korektę proporcji $\Delta x/\Delta y = 1,5$, można przedstawić na ekranie jedynie fragment jednego segmentu. Wyświetlenie na ekranie całego modelu dla obszaru Polski (9601 wierszy i 14401 kolumn) powoduje 12-krotną redukcję rozdzielczości.

Innym problemem zobrazowania jest dostatecznie dokładne przedstawienie zmienności wysokości przy pomocy barw. Uzyskanie obrazu przedstawiającego w pełni wszystkie subtelne detale rzeźby terenu wymaga opracowania specjalnej tabeli odwzorowania rzędnych na kolory. W takim przypadku można zastosować metodę polegającą na stopniowym przechodzeniu poprzez poszczególne kolory, uwzględniając dodatkowo zmienność jasności. Tak opracowana tabela dla dużego zakresu wysokości pozwala przedstawić różnice wysokości wynoszące zaledwie kilka metrów.

W systemie GRASS problemy wizualizacji związane z rozdzielczością poziomą i pionową można rozwiązać przez wygenerowanie pliku typu PNG za pomocą sterownika graficznego przeznaczonego dla tego typu obrazów graficznych. Przed użyciem tego sterownika trzeba jednak określić wartości szeregu zmiennych środowiskowych, które wpływają na sposób jego działania.

Podsumowanie

Po raz pierwszy mamy do czynienia z bardzo szczegółowymi danymi geoprzestrzennymi dla prawie całej Europy bezpłatnie dostępnymi publicznie. Pomimo, że są to obecnie dane surowe, ich wartość dla celów badawczych jest niewątpliwie wielka. Szersze upowszechnienie tych danych powinno być wsparte dedykowanym serwerem geoinformacyjnym współdziałającym z bazą danych i podsystemem udostępniania danych w różnych postaciach wraz z metadanymi. Serwer taki może być i powinien być jednym ze składników Europejskiej Infrastruktury Geoinformacyjnej (ESDI).

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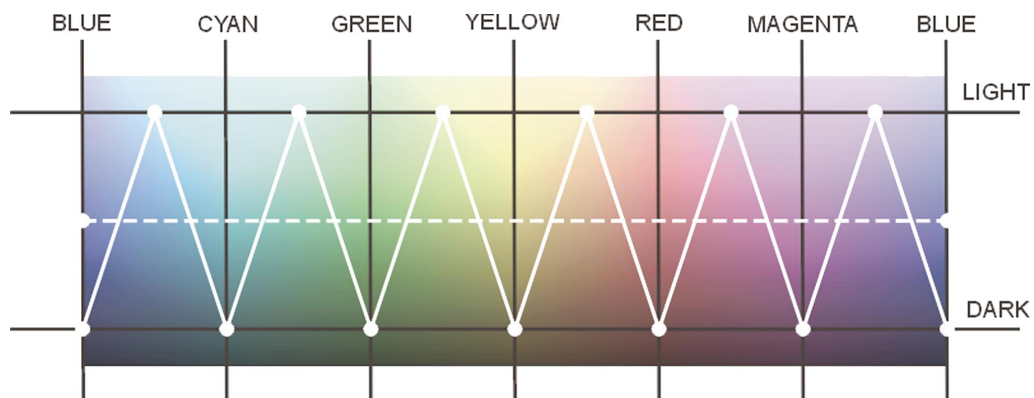


Fig. 1. Two types of color scale for presentation of a digital elevation model of ground surface. White straight dashed line defines „narrow color scale” (NCS) and white solid broken line defines „extended color scale” (ECS). The figure shows only schemes of models and, for particular applications, positions of nodal points may be selected arbitrarily, in order to present as much information as possible

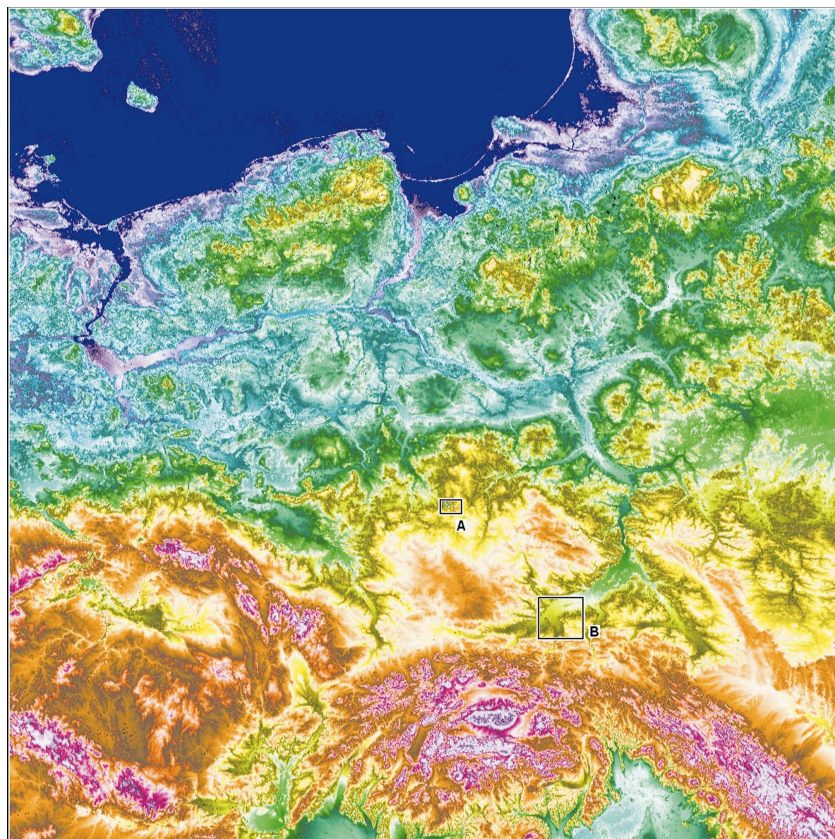


Fig. 2. Visualisation of the digital elevation model of Poland at an extended color scale (ECS) to represent high resolution data, without paying much attention to other cartographic aspects of this approach. It is an image reduction of dimensions 14401×14401 pixels, record of which in TIFF format is file of 830 MB. Rectangle marked with letter A comprises region of Belchatow strip mine and it is illustrated in fig. 3. The second rectangle (B) includes fragment of Vistula river valley in region of Dunajec river mouth (fig. 4)

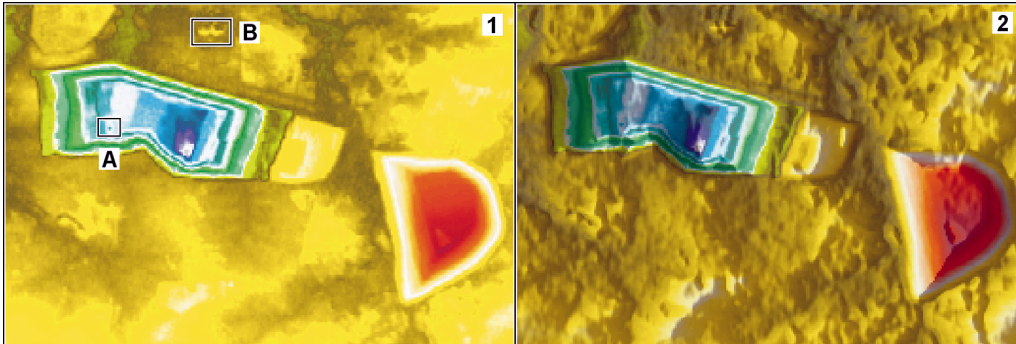


Fig. 3. Region of Belchatow strip mine. On the left side the strip mine is visible and on the right side a dumping ground is visible. 1 – image presenting only elevation data, 2 – visualization of elevation data and relief by means of shadows (illumination from left side). A – outline of excavator on the bottom of the strip mine, B – outline of the Belchatow power plant.

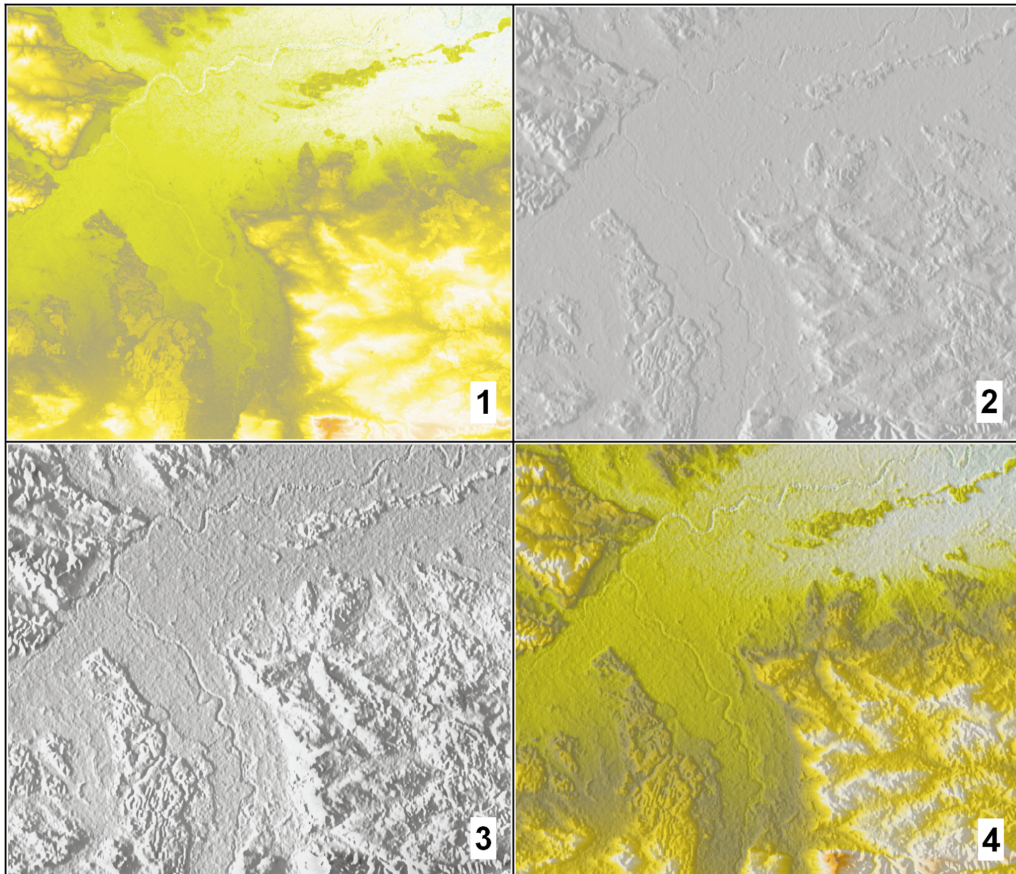


Fig. 4. Fragment of Vistula river valley in region of Dunajec river mouth. There are visible beds of meandering rivers: Vistula river and Dunajec river, 1 – image presenting only elevation data by means of color scale, 2 – image presenting only relief with illumination from left side, 3 – also only relief, but with more expressive grey scale, 4 – combination of image 1 with image 3 by means of color description model based on HIS (*Hue, Intensity, Saturation*) parameters.