COMPARISON OF IMPACT OF JPEG 2000 LOSSY COMPRESION WITH ECW LOSSY COMPRESSION TO DIGITAL ELEVATION MODEL

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Abstract: When dealing with a large set of geodata it is always necessary to use compression algorithms to lower their size. There are several algorithms that can be used for aerial (satellite) photos. The algorithms with a best compression ratio are nowadays based on a wavelet technique. Although digital elevation models (DEM) in a GRID form are a bit different to aerial (satellite) photos the wavelet algorithms can be used for a compression of DEM. The compression can be loss or loss less. The paper describes a comparison of two formats based on wavelet algorithm. The first one is well known as JPEG 2000 and the second one is well known as ECW (Enhanced Compression Wavelet). The goal of this research was to determine how the loss compression (high ratio) impacts quality of DEM. OpenJPEG library in GDAL was used to produce JPEG 2000 compressed file and ERDAS ECW SDK was used to produce ECW compressed file. GRASS GIS was used to compare compressed files and the impact of the compression.

INTRODUCTION

There are several articles focused to image data compression based on wavelet technique. For example Vatolin (Vatolin D. et al., 2005) compares several software tools that can compress data according to JPEG 2000 format. In the area of geospatial data are interesting articles from Gladkovaa and Grossberg (Gladkovaa, I., Gottipatia, S., Grossberg, M. 2007; Gladkovaa, I., Grossberg, M., 2006). There are described several compression techniques including JPEG 2000 to MODIS and hyperspectral data. It is quite difficult to find interesting articles about usage of JPEG 2000 or ESW compression applied to DEM (Digital Elevation Model). The papers are often technical specification prepared by software producers. For example Microimages, Inc. describes impact of JPEG 2000 compression to ASTER data (MicroImages, Inc., 2009). In the short article are described results of several compression ratios and their impact to error in the resulting DEM. The impact of the loss compression described in (MicroImages, Inc., 2009) is quite high. The obvious question is if there is another format based on wavelet that can reduce that impact. We have tried to discover if the ECW could be the suitable format. The paper compares JPEG 2000 and ECW impact on quality of loss compression to DEM data.

METHODS AND SOFTWARE

Methods

The research was focused on one main idea: Compare errors in the compressed data to JPEG 2000 format and to ECW format to determine which format is better to use for DEM.

The comparison was based on a simple procedure:

- The original DEM was compressed by loss wavelet compression and stored to JPEG 2000 format and to ECW format with the same (similar) compression ratio.
- The compressed files were uncompressed and compared with original data using simple map algebra (difference=original_dem - compressed_dem).
- For the difference layers were calculated values that represent average error realised by data compression.

The compression has been done in two ratios: 200:1 and 100:1.

JPEG 2000 in GDAL

The GDAL (Geospatial Data Abstraction Library) allows to integrate three different open source libraries for wavelet compression according to JPEG 2000 specification. Unfortunately the only one was used for our research purposes. The table 1 shows problems with each library.

Table 1: Libraries for JPEG 2000 in GDAL

Library	Problem
Libjasper	The compression ratio can be specified, but it has no effect between 10:1 - 500:1. The library specifies the ratio itself.
Kakadu	Compilation process is quite complicated and has not been finished by author of the paper.
OpenJPEG	Some of the tested files were compressed in the results with a lot of noise that was not possible to filter out. This is probably a bug in the library.

The used library was OpenJPEG. There were problems with several tested files, but most of the tested files were compressed correctly. This is probably a bug in the library and should be corrected in the future.
The OpenJPEG library was built from SVN repository to have a latest version of the library.
The basic command for compression to JPEG2000 with OpenJPEG library was:

gdal_translate -of “JP2OpenJPEG” -co "QUALITY=1" -co “BLOCKSIZEX=1024” -co “BLOCKSIZEY=1024” dem.tif dem.tif.j2k

The parameter QUALITY has been set to values: 1, 0.5 to reach the specified compression ratios. Other parameters were used with default values, because they do not have a high impact to a quality of a compression (tested by authors for other purposes - not published yet).

ECW SDK for GDAL

We have used the latest version of ECW SDK available for GNU/Linux.
The basic command for compression was:

gdal_translate -of "ECW" -co "TARGET=80" dem.tif dem_80.ecw

The parameter TARGET has been set to values: 70, 80, 90 to reach the specified compression ratios. Unfortunately we were not able to obtain files with the same size as with OpenJPEG library, but we have tried to have the sizes as much as comparable with the files created with OpenJPEG library. Other parameters were used with default values.

GRASS GIS

GRASS GIS was used for calculating with map algebra and for counting average error.
The command for map algebra was:

r.mapcalc 'dem_dem.tif.j2k.tif=dem-dem.tif.j2k.tif'

DATA

The libraries were tested on five tiles from ASTER DEM version 2. Each tile has a resolution 3601x3601 pixels and spatial resolution about 0.01 deg. In the following table are listed basic characteristics for selected tiles.

Table 2: Used tiles

Tile	Minimal elevation	Maximal elevation
N23E026	409	1098
N33E081	4342	6375
N49E017	88	1163
N51E021	1	341
S24E125	295	477

The data were available in GeoTIFF format without compression, with encoding of values using range of UInt16 domain. The size of each tile in original format was about 28 MB.

RESULTS

The following six tables show the results of calculations. The results are discussed in the chapter discussion and conclusion. The results are described by average error that was counted as sum of errors for each individual pixel divided by number of pixels and maximal error.

Table 3: Impact of JPEG 2000 and ECW compression to tiles

Tile	Format	Compression ratio (approx)	Average error (m)	Max. error (m)
N23E026	JPEG 2000	200:1	3.02	70
N23E026	ECW	200:1	29.75	150
N23E026	JPEG 2000	100:1	2.01	40
N23E026	ECW	100:1	10.04	60
N33E081	JPEG 2000	200:1	9.25	130
N33E081	ECW	200:1	31.80	190
N33E081	JPEG 2000	100:1	6.76	90
N33E081	ECW	100:1	30.90	170
N49E017	JPEG 2000	200:1	5.04	60
N49E017	ECW	200:1	30.48	180
N49E017	JPEG 2000	100:1	3.95	50
N49E017	ECW	100:1	10.58	70
N51E021	JPEG 2000	200:1	3.50	60
N51E021	ECW	200:1	29.82	160
N51E021	JPEG 2000	100:1	2.86	50
N51E021	ECW	100:1	9.91	70
S24E125	JPEG 2000	200:1	3.14	30
S24E125	ECW	200:1	9.40	50
S24E125	JPEG 2000	100:1	2.82	30
S24E125	ECW	100:1	9.41	50

The average error can be used for several purposes, but for other several purposes can be important distribution of the error in the whole DEM. The tables 4 - 8 show distribution of errors.

Table 4: Error distribution for the tile N23E026 (number of pixels with the error in the specified interval).

Error (m)	JPEG 2000, 200:1	ECW, 200:1	JPEG 2000, 100:1	ECW, 100:1
0-9	9184335	1477335	10384137	2752222
10-19	3662865	3155327	2565054	7616682
20-49	119923	5640655	18010	2597996
>=50	78	2693884	0	301

Table 5: Error distribution for the tile N33E081 (number of pixels with the error in the specified interval).

Error (m)	JPEG 2000, 200:1	ECW, 200:1	JPEG 2000, 100:1	ECW, 100:1
0-9	4440190	1457910	5628647	1506232
10-19	5825228	2794141	6041859	2896342
20-49	2585156	4259297	1287173	4324281
>=50	116627	4455853	9522	4240346

Table 6: Error distribution for the tile N49E017 (number of pixels with the error in the specified interval).

Error (m)	JPEG 2000, 200:1	ECW, 200:1	JPEG 2000, 100:1	ECW, 100:1
0-9	6981412	1511068	8026620	3138934
10-19	5464409	2970914	4763386	6408995
20-49	519842	4333892	177093	3396340
>=50	1538	4151327	102	22932

Table 7: Error distribution for the tile N51E021 (number of pixels with the error in the specified interval).

Error (m)	JPEG 2000, 200:1	ECW, 200:1	JPEG 2000, 100:1	ECW, 100:1
0-9	8579372	1497022	9319832	2950247
10-19	4242626	3132185	3592172	7382160
20-49	144937	4330046	55155	2627177
>=50	266	4007948	42	7617

Table 8: Error distribution for the tile S24E125 (number of pixels with the error in the specified interval).

Error (m)	JPEG 2000, 200:1	ECW, 200:1	JPEG 2000, 100:1	ECW, 100:1
0-9	8942700	2981922	9332178	2955083
10-19	3970966	7876472	3610642	7902694
20-49	53535	2107048	24381	2108249
>=50	0	1759	0	1175

DISCUSSION AND CONCLUSION

From tables 3-8 is obvious that the files created with JP2OpenJPEG library in JPEG 2000 format contain smaller errors than files created with ECW SDK in ECW format. The differences between average errors are higher than expected (we have expected similar errors for both formats). For example the tile N23E026 has average error about

3 m in JPEG 2000 format and about 30 m in ECW format in compression ratio 200:1. The smallest difference in average error generally is for S24E125 tile that has the smallest variance in heights.

The test should be done for more tiles of ASTER data and for another DEM data as well, but even from presented results we can conclude, that when are DEM data (from ASTER source) compressed into JPEG 2000 format with OpenJPEG library that the results are significantly better that in compression with ECW SDK.

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