

Using and distributing ECW V2.0 wavelet compressed imagery

Target audience:

This technical white paper is intended for:

- People who want to learn more about wavelet compression technology.
- Organizations that want to distribute imagery on CD-ROM or DVD-ROM.
- People who want to compare the ER Mapper 6.0 Compression Wizard with other compression techniques.

Subjects covered:

Details are provided on:

- Enhancements included in ECW V2.0
- Wavelet image compression technology.
- How to use wavelet image compression.
- Comparisons between different wavelet compression techniques, and older compression technology.
- Using the ER Mapper 6.0 Compression Wizard
- Free ECW compression and decompression utilities
- Free Open Standard ECW Compression and Decompression SDKs
- Distribution of compressed imagery and free software plugins for GIS/CAD/Office applications.
- Advanced compression topics
- Common questions and answers

Summary:

This paper shows you how you can create and distribute royalty-free compressed images using the patent pending ER Mapper ECW Compression facilities and the free plugins for other applications. In particular, it highlights the enhancements brought about by ECW Version 2.0. You can now achieve significant compression ratios with no noticeable deterioration in quality.

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Image compression considerations

New features in ECW V2.0

The following is a summary of the enhancements contained in the recently released ECW Version 2.0. These are discussed more fully in other sections of this document:

- A minor "blue shift" in compressed RGB (not multi-band compressed) images is fixed
- A problem with poor color quality when compressing very small RGB images is fixed. This only affected small (less than 1Kx1K) images.
- Independent blind tests comparing ECW v2.0 with competitors' products show ECW V2.0 to be higher quality.
- You can now increase compression by 50% or more and achieve the same quality as before, or you can use same compression ratio and increase the quality.
- Compression is now 20% to 30% faster on single-CPU machines. The ECW compressor was already very fast, and it is now even faster than other products.
- Multi-CPU compression support speeds up compression by up to 95% on dual-CPU PCs..
- Interactive roaming, zooming, and decompression is up to 400% faster than ECW V1.0.
- The file handle limit of 2,048 compressed images in a single mosaic has been removed, and mosaics with up to 10,000 input images have been tested.
- ER Mapper has been tuned to increase performance and reduce memory requirements when building very large (e.g. 1,000,000 x 1,000,000) mosaics of thousands of files. Producing these sorts of large mosaics (typically algorithms used to create seamless compressed mosaics) is now much faster and uses much less memory.
- The .ERS header file is now optional for .ECW compressed imagery because georeference information is now contained in the .ECW compressed image file as well as in the .ERS file.
- Plugins for ArcView, MapInfo, Autocad MAP, MS Office, ER Viewer, etc have been enhanced to support ECW v2.0 format.
- New free ECW v2.0 plugin for Photoshop and related products enables you to both decompress and *compress* ECW v2.0 images from within Photoshop.
- New ActiveX/ATL control enables full interactive roaming and zooming over compressed imagery.
- Free ECW stand alone Compressor program allows you to compress images up to 500Mb in size.
- Free ECW V2.0 Compression and Decompression SDKs enable you to create your won applications using the ECW V2 libraries.

Working with large images

When working with satellite imagery, airphotos, scanned topographical maps and other types of imagery, the size of image files can become very large. For example, it takes 3TB (3,000GB) of color imagery to take aerial photographs of typical city at 3 inch resolution, and it takes 1.5TB (1,500GB) of color imagery to cover all of California at a resolution of one meter.

The following table demonstrates the reduction in file sizes when compressing imagery using the new ER Mapper *wavelet* based compression technology, which can compress very large images, at high compression rates, with high quality results.

| Image | Dimensions | Uncompressed size | Compression ratio | Compressed size |
|-----------------------|----------------------|-------------------|-------------------|-----------------|
| Color airphoto | 3 x 8,000 x 8,000 | 192MB | 50:1 | 4MB |
| Color airphoto mosaic | 3 x 50,000 x 100,000 | 15,000MB | 25:1 | 600MB |

High compression rates can be achieved on large imagery

Compression of imagery offers several advantages including reduced image file size, faster access, easier distribution and the ability to work with imagery covering larger areas.

What is a compressed image?

A compressed image is one that has been compressed to reduce the image file size, while still providing an almost perfect version of the original. With some compressed formats, such as the ER Mapper Compressed Wavelet (ECW) imagery format created using the ER Mapper Compression Wizard, you can use a compressed image almost anywhere you can use an uncompressed image. This is achieved by automatically selectively decompressing only the portion of the image, at the level of detail currently being viewed or printed.

There are various compression techniques. The most effective technique is *wavelet* based, which is a method of processing, quantizing and then encoding the image in a way that results in very high levels of compression, with an almost perfect reconstruction of the original image.

ER Mapper 6.0 offers wavelet based compression technology to compress images, resulting in very high quality results at very high compression rates. Typically a color image such as an airphoto can be compressed to less than 2% to 5% of its original size (50:1 to 20:1 compression ratio).

This means that, at 20:1 compression, 10GB (10,000MB) of color imagery will compress down to 500MB, which is small enough to fit on to a single CD-ROM. Where your source image has less information content, such as scanned topographic maps or airphotos over areas with less land change, higher compression rates may actually be achieved - 100:1 or more is not uncommon for compressed scanned topographic maps.

You can include free imagery plugins for GIS and office applications with your compressed data. These plugins read the compressed imagery in a wide range of software applications such as ArcView, AutoCAD MAP, MapInfo, ER Mapper, ER Viewer, Photoshop, Microsoft Office and Excel, and other software applications. There is no data royalty fee when using the ER Mapper Compression Wizard to compress images. You can also use the free ECW compression and decompression SDKs to create your own applications that can open, read and write compressed images.

Because the compressed imagery is constructed of multi-resolution wavelet levels, you also enjoy fast roaming and zooming on the imagery - even from slow media such as CD-ROM.

Lossless versus lossy compression

There are two types of image compression: Lossless, and lossy.

Lossless compression, as the name implies, results in a compressed image that can be perfectly reconstructed to be identical to the original image. The main advantage of lossless compression is this perfect reconstruction. The main disadvantage is that lossless compression is typically limited to about 2:1 compression. For example, at 2:1 compression, a 500MB airphoto mosaic compresses down to 250MB, being 50% of its original size.

Lossy compression throws away some information content, in order to achieve much higher compression rates than is possible with lossless compression. The most effective form of compression today comes from using wavelet based image encoding. This technique is very effective at reducing information content, thus making the compressed file very small, without throwing away important information.

Unlike JPEG, which uses a block based Discrete Cosine Transformation (DCT) on blocks across the image, modern wavelet compression techniques enable compression of 20:1 or more without visible degradation of the original image.

Wavelet compression can also be used to generate lossless compressed imagery, although the compression rate falls back to 2:1 to 3:1.

When compression should and should not be used

You should consider using compression when you need to meet one or more of the following requirements:

- Easy distribution of large amounts (10MB to multi TB) of imagery
- Fast access directly from CD-ROM
- Imagery is airphotos, orthophotos, satellite or scanned topographic maps.

You should not use compressed imagery, or should use a lower compression factor, when one or more of the following criteria are important to your application:

- Hyperspectral signature analysis is being carried out.
- Important information is represented as subtle secondary changes to the data.
- Your application is “mission critical”, for example navigation systems using DEM data.

You can still use compression for the above applications, by:

- Using a lower compression rate. For example, a compression rate of 3:1 results in imagery that is very close to identical to the original image, while still offering faster access rates on slower CD-ROM media.
- Producing compressed “views” of the source data, for example producing a compressed imagery which is a color shaded view of a DEM.

Interactive image decompression

An important consideration when dealing with large images is the ability to:

- Interactively decompress a subset region of a compressed image. For example, although the compressed image might cover all of a city, you may want to zoom in to examine only one city block. It is important that only the area covering your region of interest is decompressed.
- Interactively decompress to a level of detail (LOD) of a compressed image. For example, the compressed image might be 200,000 x 300,000 pixels in size, yet your viewing window might cover 800x600 pixels on screen. In this case, it is important to decompress only the top levels of detail, down to 800x600 pixels in resolution, as that is all the information that can be displayed at the current level of detail on screen.

Doing interactive image decompressing using ER Mapper Compressed Wavelet (ECW) images is simple - your software application automatically decompresses the portion of the image currently being viewed, at the level of detail required, on the fly. This is managed by the ER Mapper decompression engine, which manages the display of the imagery within the application such as WORD, ER Mapper or AutoCAD MAP.

You open a compressed image just as you would open a normal .ERS, .TIF or any other file. If you have a compressed image called “compressed_image”, you will see that there are two files, being “compressed_image.ers” and “compressed_image.ecw”. The “compressed_image.ers” is an optional header file, and you use ER Mapper 6.0 File Open or one of the wizards to open this file as you would any other file. In the same way, you can drag and drop the “compressed_image.ecw” into a WORD document (if you have previously installed ER Viewer), to roam and zoom through the image, from within WORD. Use the free ER Mapper imagery plugin extension for your GIS product to use the compressed image within MAP, World, ArcView, MapInfo and other GIS products. Alternatively, your applications can link to the Open Standard ECW library to decompress and compress images.

ER Mapper ECW V2.0 compressed images maintain the full geocoding and locational information about the file. This means that compressed images will be automatically registered with other imagery and vector data, just like an uncompressed file.

Compressed images do have some restrictions: You can't do point profile on a compressed image, and you must use an uncompressed image when using image rectification tools. Thus, you should geocode your image to the desired map projection before compressing it. These same restrictions apply to the use of any image format other than the native uncompressed ER Mapper image format.

Full real time roaming, zooming and panning is supported in ER Mapper for compressed images, and all the normal algorithm capabilities, such as selecting imagery within a vector polygon, or using statistics, all operate fully.

Wavelet compression performance gains

Over the last ten years, disk drive speeds have increased by a factor of 10, yet CPU speeds have increased by a factor of 100.

With the rapidly increasing size and usage of digital imagery, disk input/output (IO) rates have become a significant bottleneck. To make matters even worse, CD-ROM and DVD-ROM access speeds are even slower than hard disk access speeds. For example, a typical hard disk drive has an average seek time of 10ms (the time taken to seek across 1/3 of the disk drive), where as CD-ROM drives have an average seek time of about 100ms to seek across 1/3 of the CD-ROM.

The slow seek time means that a computer can only request about 100 widely scattered pieces of information per second from a hard disk, and only about 10 widely scattered pieces of information per second from a CD-ROM.

Consequently, modern computers displaying or using imagery spend most of their time waiting for the data to be retrieved from the disk drive. As the size of digital imagery increases, this problem gets worse.

In addition to the advantages of smaller files, compression of digital imagery offers higher performance, because compressed imagery trades slower disk speeds against faster CPU speeds. Compression is “compute bound” rather than “disk bound”, meaning that decompression is limited by CPU speed rather than by disk IO or seek speed.

Furthermore, modern compression techniques, such as the ER Mapper Compressed Wavelet (ECW) imagery format, cluster related areas of imagery on the disk. This improves the performance even further by dramatically reducing the number of seeks required.

A 10GB image that has been compressed down to a 500MB ECW compressed image file can be read as quickly from a CD-ROM as the uncompressed imagery can be read from hard disk. This makes distribution and use of imagery directly from CD-ROM a practical reality.

RAM requirements during interactive viewing / decompression

The ER Mapper Compressed Wavelet (ECW) format has a very low memory footprint during imagery decompression. About 2MB of RAM will be used during interactive decompression of imagery, thus compressed imagery can be used even on quite small computers with limited amounts of RAM – the ER Viewer will view compressed imagery on a machine with a total of 16MB of RAM.

See the Advanced Topics section for more information on memory requirements for compressing imagery.

Comparing different compression techniques

Wavelet versus older compression techniques

Over the years, considerable effort has been spent in compressing information in order to make it easy to distribute, and to reduce storage requirements.

Techniques used by common compression program such as ZIP, or by older compression formats such as JPEG or TIFF, suffer from sever disadvantages when trying to compress large digital images. These problems include:

- **Limited compression rates.** Because ZIP and related methods are lossless techniques (it is important that a compressed program is exactly decompressed), they don't take advantage of the lossy compression techniques that result in much higher compression rates for digital imagery. Typically a "ZIPped" image file will be 50% smaller than the original image, whereas a wavelet compressed image will be 95% smaller than the original image.
- **All or nothing decompression.** It is essential to be able to selectively decompress a portion of digital imagery while viewing the image, and to selectively decompress the image at different levels of detail (as the user zooms in or out of the image view). Older techniques used by ZIP, TIFF, JPEG and other image compression formats, were not designed with selective decompression of imagery in mind. This means that they can not effectively be used when working with images larger than about half computer memory size, which is significantly smaller than the typical size of digital imagery today.
- **Artifacts and visible errors in the data.** Older techniques, for example as currently used by the JPEG compression process, compress the image as a series of blocks. This is because older techniques were memory based, so they needed to limit the size of each block. Because of this, JPEG and related formats suffer from significant and visible degradations when higher compression ratios are used. Recent breakthroughs in wavelet processing (such as the patent pending method used by ECW) have removed memory limits from image compression. This means that large imagery can be compressed efficiently, without introducing visible artifacts into the compressed image.
- **No geographic coordinates.** Older image formats do not have, or have very limited, geographic information stored with the compressed image. This is because older formats were designed for graphics art imagery rather than earth related digital imagery such as airphotos or satellite images. Because of this, many formats don't support geographic information, or only do so in a very limited way.
- **Slow speed.** In order to work effectively with large digital images, the user needs to be able to view any sub-section of the image, at any zoom factor, with sub-second response times. Older formats do not achieve adequate response rates for several reasons:
 1. Many formats require decompressing of the entire image, rather than a selected subset at a select level of detail.
 2. Many formats assume the image will be smaller than computer RAM, making them very slow to access large images.
 3. Most formats do not employ "clustering" of imagery information to reduce disk seeks.

Wavelet based image compression and decompression

Wavelet compression involves a way of analyzing an uncompressed image in a recursive fashion, resulting in a series of higher resolution images, each “adding to” the information content in lower resolution images.

The primary steps in wavelet compression are performing a Discrete Wavelet Transformation (DWT), quantization of the wavelet-space image subbands, and then encoding these sub bands.

Wavelet images by and of themselves are not compressed images, rather it is the quantization and encoding stages that do the image compression. Image decompression, or reconstruction, is achieved by carrying out the above steps in reverse and inverse order. Thus, to restore the original image, the compressed image is decoded, dequantized, and then an inverse-DWT is performed.

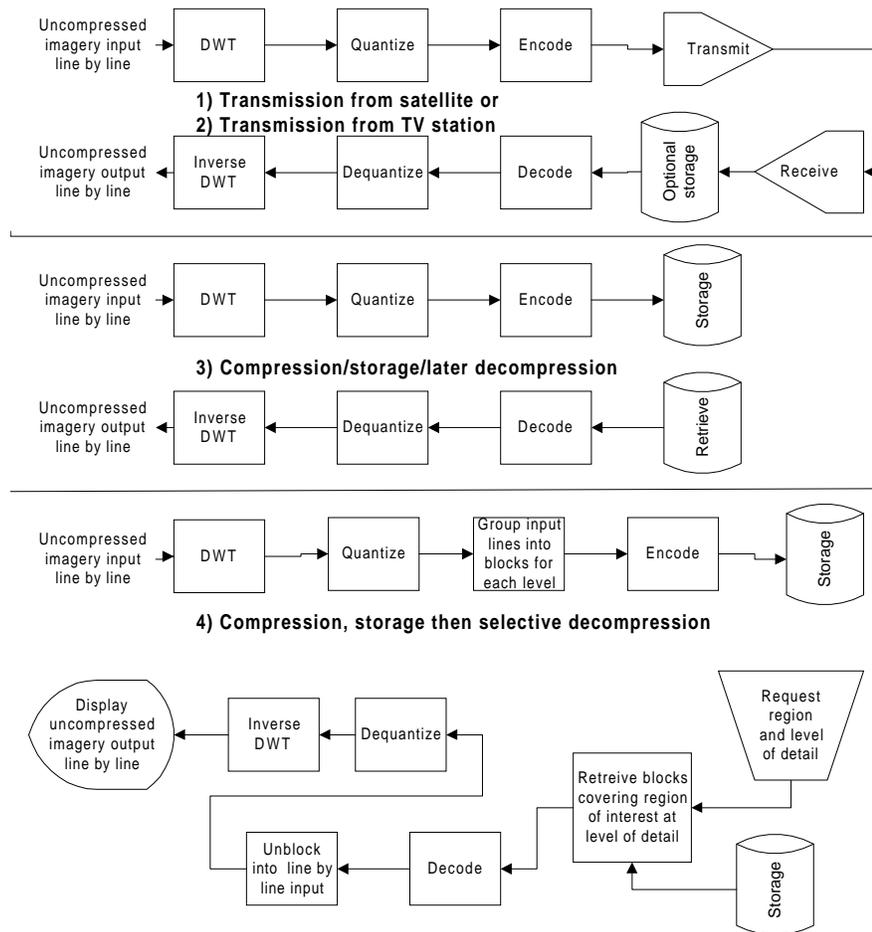
Because wavelet compression inherently results in a set of multi-resolution images, it is well suited to working with large imagery which needs to be selectively viewed at different resolutions, as only the levels containing the required level of detail need to be decompressed.

Wavelet mathematics embraces an entire range of methods each offering different properties and advantages. For example, it is possible to compress 3 or more dimensional imagery using wavelets.

Wavelet compression has not been widely used because the DWT operation takes a lot of compute power, and because historical techniques perform the DWT operation in memory or by storing intermediate results on hard disk. This limits either the size of the image that can be compressed, or the speed at which it can be compressed.

The ER Mapper 6.0 ECW V2.0 wavelet compression uses a breakthrough new technique for performing the DWT and inverse-DWT operations (patent pending), which makes the use of wavelet based compression a practical reality.

The following diagram shows different applications for ER Mapper Compressed Wavelet imagery:



Different applications using the recursive DWT generation technology

ER Mapper Compressed Wavelet (ECW) versus other wavelet compression techniques

The ER Mapper ECW compression by Earth Resource Mapping uses advanced wavelet compression techniques.

Historically, the methods for doing Discrete Wavelet Transformations (DWT), which is an essential part of wavelet compression, have been memory based. This has limited the size of a file that can be compressed using wavelet compression.

Older existing compression techniques involve storing intermediate tile results on hard disk during compression and then later retrieving them to compute results for other tiles.

The ER Mapper ECW compression technique uses a patent pending recursive algorithm pipeline technique which does not require the use of disk storage while performing the DWT.

Most existing wavelet techniques enable compression of very large images - there is no inherent limitation to image size in the compression technology.

The primary advantages inherent in the ER Mapper ECW technique are that it is much faster, for several reasons:

- The ECW technique does not require intermediate tiles to be stored to disk and then recalled during the DWT transformation and
- The ECW technique takes advantage of CPU, L1 and L2 levels of cache to do its linear and unidirectional data flow through the DWT process.

Because the ER Mapper ECW method of DWT is much faster, this speed is used to provide more efficient compression in several ways:

Multiple encoding techniques are used. Once an image has gone through DWT and quantization, it must be encoded. The ER Mapper ECW technique applies multiple, different, encoding techniques, and automatically chooses the best encoding method over each area of an image. Where multiple techniques are equally good, the method that is fastest to decode is chosen.

Asymmetrical wavelet filters are used. Because of its speed, the ER Mapper ECW compression engine can use a larger and, therefore, slower DWT filter bank for DWT encoding. This enables the use of a smaller, faster inverse DWT filter for decoding. This means that decoding of imagery is much faster. A 15 tap floating point filter bank is used for DWT (compression), and a 3 tap integer based filter bank is used for the inverse DWT (decompression).

Even with the additional processing carried out as detailed above, the ER Mapper ECW Compression Wizard is still at least 50% faster at compressing images than other compression techniques, when measured on the same file on the same computer.

The decompression (which with most techniques can be for selective areas at selective levels of detail) is much faster for the ER Mapper ECW compressed image format than for other image formats, resulting in faster and more interactive use of compressed imagery.

Because the ER Mapper ECW technique does not require intermediate DWT tiles to disk while performing the DWT step of image compression, it has other advantages that offer future benefits as well. These include:

Multiprocessor optimizations. The ER Mapper ECW DWT technique is inherently well suited for multi-CPU compression. The ER Mapper ECW V2.0 compression (and decompression) engine takes advantage of multi-CPU hardware to make compression/decompression up to 95% faster on dual CPU machines.

Guaranteed latency. Because the ER Mapper ECW technique is a recursive algorithm pipeline technique, it has guaranteed latency (no disk IO is required) and guaranteed compression time with defined CPU performance. Although the ER Mapper ECW Compression Wizard reads uncompressed imagery from disk and writes compressed imagery to disk, this is simply an implementation and not an architecture requirement. The ECW technique could just as easily take a line by line stream of input uncompressed imagery, compress it, and emit a compressed stream of imagery. This means that the ER Mapper ECW compression/decompression technique can be applied to a range of applications which may have no local disk storage. These applications include transmission of HDTV signals, real time compression of imagery on satellites for reduced down-link data rate requirements, and compression of imagery on digital cameras.

Another significant difference between the ER Mapper ECW and other compression techniques is that the ER Mapper Compression Wizard is tightly integrated with other ER Mapper 6.0 functionality. It can, therefore, compress input from smart data algorithms as well as directly from uncompressed imagery.

This means that the other ER Mapper tools, such as the Ortho Wizard, the Mosaic Wizard, and the Balance Wizard, can be used to prepare seamless mosaics which can then be compressed using the Compression Wizard.

You do not need ER Mapper 6.0 installed to enjoy the benefits of ECW compression. A free standalone utility is available for download at the ER Mapper web site. This free program offers a GUI-only compression interface to compress single files (no batch compression) up to 500MB in size.

ER Mapper 6.0 includes a full suite of free plugins for GIS, CAD and Office applications, that enable those products to directly access compressed ECW image files. These free plugins may be freely distributed with your compressed data. There are no royalty fees for the free plugins, and there are no data royalty fees when compressing with the ER Mapper ECW format. These plugins have been enhanced to support the ECW V2.0 format.

A New ActiveX/ATL control enables full interactive roaming and zooming over compressed imagery from with your own custom applications built using VBA or other ATL and ActiveX compatible products.

Software developers can download the free ECW Compression and Decompression SDKs, and use the Open Standard ECW V2.0 libraries within any application. The code is C based, and has a simple interface enabling it to be easily integrated into a range of products. The ECW Decompression and Compression SDK's are the only libraries on the market that enable you to both compress and decompress, and furthermore they are provided on an open basis, rather than just offering the decompression library as other companies do.

The ECW V2.0 compression and decompression now outperforms all other wavelet based products in both speed and image quality. Independent blind tests comparing ECW V2.0 with MrSID 1.3 have revealed the following:

- ECW V2.0 is faster to compress
- ECW V2.0 produces better quality compressed images
- Images compressed with ECW V2.0 are smaller
- ECW has both viewing/decompression and **compression** SDKs

How to accurately compare ER Mapper compressed images

If you are comparing the compressed image with the original uncompressed image or with the image compressed using another technology, you must ensure that you are compressing the original image, and not a modified version of it. The ER Mapper Compression Wizard is designed for production operation (large files and automatic mosaicing and clipping of imagery) rather than for direct image comparison purposes. The following information describes how you can reconstruct the original image:

Output transforms

To accurately compare the compressed image and uncompressed images you should ensure that:

- Output transforms are removed before the image is compressed.
- Output transforms are removed from the uncompressed image before comparing it with the compressed image.

If you load and display an image using the ER Mapper **File / Open** menu option or the Image Display and Mosaic Wizard, ER Mapper automatically applies a 99% clip to the image. If you then use the Compression Wizard "Use the current algorithm window" default option to compress the image, ER Mapper will compress the image with the 99% clip applied. This is what you would normally want it to do. If, however, you want to do an exact comparison with the original, you should remove the output (99% clip) transforms before compressing the image. Do this by calling up the "Edit Transform Limits" window and either setting the transform to each layer to "Histogram Only" or deleting the transform altogether.

If you use the Compression Wizard "Select input images to compress" option instead of opening and displaying the image before compressing it, the Compression Wizard does not automatically apply a 99% clip to the image. However, once again, for exact comparison, you should also remove any output transforms before compression. To do this you have open and display the image, remove or delete the transforms as described above, and use the Compression Wizard "Use the current algorithm window" option.

View the compressed image

To directly compare the compressed and original images, you must delete the final transforms from the image algorithm after using the File/ Open menu option or Image Display and Mosaic Wizard to display them.

The following paragraphs describe two ways of comparing the original versus compressed images.

Red/Green display

Open the Algorithm window and an image window. Change the display mode to RGB, and create a RED and a GREEN layer.

Load the original image into the RED layer, and the compressed image into the GREEN layer. Make sure that you have either deleted the final transforms in the two layers or that they are identical for both layers. Also make sure that you select the same band (e.g. RED band) from both images to display.

You should now see a yellow image. Any variations between the original and compressed images will show up as red or green.

Virtual Dataset

Create a Virtual Dataset with two bands; one being a band from the original image and the other the same band from the compressed image.

Load this virtual dataset image into a new image window as a single layer (greyscale) display.

Set the formula to "INPUT1 - INPUT2". The result will be the differences between the two images.

Note: When you do these comparisons, be sure to zoom down to the pixel level so that you are not comparing higher level views of the imagery. To create higher level overviews, ER Mapper sub-samples the uncompressed image and uses an advanced wavelet view for the compressed image. This difference in the higher level handling of the compressed and uncompressed images could cause variations.

Performing compression benchmarks

When you perform compression benchmarks you should always use large images. This is because the ER Mapper ECW compression uses recursive pipeline based technology, which does not store and recall partially compressed tiles to and from disk. This means that ECW compression is significantly faster than other technology with larger (over 10GB) file sizes.

Using ECW compression on small files will not result in much better performance than with other compression techniques. Smaller files are more likely to be influenced by other factors like disk caching.

Benefits of the ER Mapper Compressed Wavelet imagery

The ER Mapper Compression Wizard was designed as part of a complete end to end solution to prepare, compress, and distribute imagery.

There are a number of benefits that result from using the ER Mapper Compressed Wavelet (ECW) imagery format:

- **No data royalties.** There are no data royalties when using the ER Mapper Compression Wizard to produce compressed imagery.
- **Full geocoded map projection information stored.** The ECW compressed image format uses the standard ER Mapper ".ERS" image header file to record map projection information. This means that when an image is compressed, full image map projection information is retained.

The ".ERS" header file is optional for ECW V2.0 compressed imagery. Georeference information is contained in the .ECW compressed image file as well as in the .ERS file. This is useful when emailing .ECW files, because the recipient only has to be concerned with one file.

Note that the .ERS file contains a more detailed superset of the header information present in the .ECW files. ER Mapper will automatically recreate the .ERS file for you if you perform statistics or add vector polygon regions, and no .ERS file is present for the .ECW file.

- **Evaluate using your own data.** The free ER Mapper 6.0 (with Compression Enhancement Pack) evaluation CD-ROM contains the complete ER Mapper 6.0 software (including the ECW V2.0 Compression Wizard and the free plugins for GIS and office software). You can trial run the full software, against your own data, for 14

days, at no charge. This enables you to run the Ortho Wizard or Geocoding Wizard to geocode your imagery, the Mosaic Wizard to produce mosaics, the Balance Wizard to create seamless mosaics, and the Compression Wizard to produce compressed image files. Once images have been compressed, you can write them on to a CD-R, with the free GIS and office plugins, to see how the data would work in the real world with your user community. Thus, you can easily evaluate the effectiveness of using the ER Mapper ECW imagery format for your application.

- **Batch compression.** You can use the command line version of ECW V2.0 to carry out compression in a batch operation. This allows you to compress a large number of images by entering a single command line.
- **Free plugins.** The free GIS and Office plugins can be distributed with your imagery to enable MS Office, ArcView, MapInfo, AutoCAD MAP, ER Viewer other users to directly access and use your imagery. These plugins have been enhanced to support ECW V2.0 compressed imagery. There is also a new plugin which enables you to both **decompress and compress ECW v2.0 images from within Photoshop**. This is the only large image-format compression plugin for Photoshop that allows you to compress (as well as decompress) large images. The compressor is limited to compressing files of a maximum of 500MB in size. There is no cost for this plugin to Photoshop.
- **New ActiveX/ATL control.** This small (70K) control enables full interactive roaming and zooming over compressed imagery, from within your own custom applications built using VBA or other ATL and ActiveX compatible products. Transparent control support means that you can easily drop this image control under your other controls that manage other geolocated data for merged views.
- **Faster compression.** Due to use of the patent pending Discrete Wavelet Transformation (DWT) technique, the ER Mapper ECW V1.0 compression engine was 50% faster than other products when compressing imagery. ECW V2.0 is now 20% faster than ECW V1.0 on single-CPU PC, and up to 95% faster on a dual-CPU PC.
- **Faster decompression / viewing.** Due to use of the patent pending inverse-DWT technique, the ER Mapper ECW compression engine is up to 300% faster than other products when viewing and/or decompressing imagery. With ECW V2.0, interactive zooming and decompression is up to 400% faster than it was with ECW V1.0.
- **Tightly integrated.** As the Compression Wizard is tightly integrated with ER Mapper 6.0, you can use the Ortho Wizard, Mosaic Wizard and Balance Wizard to prepare mosaics prior to compression.
- **Low cost.** The entire ER Mapper 6.0 product, including Ortho rectification, mosaicing, balancing, compression and a wide range of other tightly integrated functionality, is about the same price as other companies charge for just the compression engines.

A standalone compressor is also available for download free of charge. **This means that you do not need to have ER Mapper 6.0 installed to benefit from ECW compression.** This free program offers a GUI-only interface that will compress single images up to 500 MB in size.

- **Compress smart data algorithms.** Compress from smart data algorithms that can pre-process your data (for example generating a colordraped shaded view of a DEM to be compressed).
- **Free Decompression library.** As part of ER Mapper open-standard commitments, the SDK to read ECW files is available free of fees or royalty payments. The ECW Decompression library enables your applications to directly read ECW compressed images. The library can be linked to C and C++ code, and is quite small (less than 50K in size). You do not need to have ER Mapper installed to use the decompression library, and it may be used by any company (including competitors to ER Mapper) to support reading ECW format. The library features a very clean interface with only 5 function calls, and automatically handles sub-sampling and selective viewing of imagery. You can use the library with a simple read-region call, or a progressive-update call (which is advantageous for imagery being served from an Image Web Server).
- **Free Compression library**> The ECW V2.0 Compression SDK is an open and freely available standard to compress imagery using wavelet technology. The ECW compression library is based on a breakthrough patent-pending wavelet mathematics technique developed by ER Mapper, which enables the compression of very large images, very quickly, with high quality results

Any companies (including competitors to ER Mapper) who wish to compress large images can now do so using the ECW Compression SDK free of costs and royalty fees. Link the library to your application to enable it to directly perform wavelet compression to the ECW v2.0 file format.

The library is provided in binary form, and can be linked to C and C++ code, and is small (less than 100K in size). It features a very clean library interface. It makes no assumptions as to the input data - you simply feed it lines of imagery to compress, and it does the rest.

The library enables wavelet images of up to 500MB in size to be compressed. You still need to use ER Mapper for images beyond this size, (or to contact ER Mapper to discuss access to an unlimited size compression library).

The ECW Decompression and Compression SDK's are the only libraries on the market that enable you to both compress and decompress, and, furthermore, they are provided on an open basis.

Creating wavelet compressed images

Creating compressed images

Creating compressed imagery is easy to do with the ECW V2.0 Compression wizard. This wizard will compress any source, including mosaics of imagery, into a single output compressed image file.

You can then use or distribute the compressed image file.

To compress images using ER Mapper 6.0, select the Compression Wizard from the “File->Save as Compressed Image” menu, or from the “Wizards” toolbar.

The Compression Wizard will ask you for several things:

1. The name of the source image or algorithm (mosaic of input images) to compress.
2. How you want the image compressed: as a grayscale file, or as a color (RGB) file.
3. The desired compression ratio to use; typically between 20:1 to 50:1 for color compression, and 10:1 to 20:1 for grayscale compression.
4. The name of the output compressed file to create.

You will be shown the anticipated output file size based on your target compression ratio, and you can adjust the compression ratio to select a different output file size. A larger compression ratio results in a smaller output file.

The Compression Wizard will then compress your input image(s), giving you a GUI graphical progress report while compressing. Once the file has been compressed, you will be informed of the time taken to compress, and the actual compression ratio achieved.

There is also a command line interface to compress images, which is useful where you have many images that you wish to individually compress.

Note: The command line interface is not available with the free standalone ECW V2.0 compressor.

Selecting the best compression ratio to use

When compressing imagery, the “Target Compression Ratio” is specified (see next section).

The following table indicates typical Target Compression Rates:

| Imagery | Application | Target Compression Ratio |
|----------------------------------|--------------------------------|---------------------------------|
| Color airphoto mosaic | High quality printed maps | 25:1 |
| Color airphoto mosaic | Internet or email distribution | 40:1 |
| Grayscale airphoto mosaic | High quality printed maps | 10:1 to 15:1 |
| Grayscale airphoto mosaic | Internet or email distribution | 15:1 to 30:1 |

Depending on the imagery, your final compression ratio may be higher than the target compression rate. Imagery with large areas that are similar (for example desert, forests, golf courses or water) often achieves a much higher actual compression rate.

Scanned topographical maps also often achieve a higher compression rate, as do images with smooth changes, such as colordraped DEMs.

Preserving image quality - the Target Compression Ratio

There are two possible ways to define the final compression:

Output file size: The user specifies the exact output compressed image file size. The compression will vary the compression rate (and hence the quality) to achieve this target file size. This has the advantage of a guaranteed output file size, but the significant disadvantage of a quality variation through the image and between images. ER Mapper ECW compression does not use this technique.

Target quality. The user indicates a desired quality level by setting a target compression ratio. The compression will achieve this specified quality even if the actual output compression ratio is higher or lower than the target ratio. This has the advantage of a guaranteed quality ratio with the disadvantage that the actual compression ratio might be different to the target. ER Mapper ECW compression uses this technique because it is designed for production volume imagery compression, where it is important that:

- **Mosaics of images are seamless.**
- **Archives have a guaranteed quality.**

When you compress an image, you will be asked for the “Target Compression Ratio”. This is the desired compression ratio that you would like to achieve. For example, you might specify a ratio of 20:1 for an input file of 1,000MB to achieve a desired a 50MB compressed image (so the output image is 5% of the size of the input image).

After compressing the image, you may note that the actual compression rate achieved was in fact 40:1, resulting in an output file size of only 25MB in size.

These are the Target compression ratio (what you would like) and the Actual compression ratio (what was achieved). Except when compressing very small files (less than 2MB in size), the Actual compression ratio will generally be equal to or greater than the Target compression; sometimes significantly greater.

The reason for this is as follows:

When you specify a Target Compression ratio, the Compression Wizard uses this as a measure of how much information content to preserve in the image. If, however, your image has areas that are well suited to compression, a greater rate of compression may be achieved while still achieving the desired information content quality. The Compression Wizard uses multiple wavelet encoding techniques at the same time, and adapts and chooses the best technique depending on the area currently being compressed.

It is important to note that these are applied after the image quantization and do not affect the quality, even though the compression ratio is higher than that requested.

One example of this is an image that has large areas of water or desert. These can often be compressed with greater efficiency. Another example is a compressed image that consists of high-resolution airphotos, over lower resolution satellite imagery where there are no airphotos. Because the satellite images are lower spatial resolution, greater compression can be achieved in these areas of the image, while still preserving high quality detail in the airphoto area.

Compressing mosaics of input images to a single compressed image file

The ER Mapper 6.0 Compression Wizard is integrated into ER Mapper. This means that you can use all the other ER Mapper tools, such as the Ortho Wizard, the Mosaic Wizard, and the Balance Wizard, to create a seamless mosaic which can then be compressed out to a single compressed ECW file.

When using the Compression Wizard, you specify the input image(s) to compress. Here, you may specify an ER Mapper *smart data algorithm* as the input to be compressed.

Thus, you can use the ER Mapper Mosaic Wizard and Balance Wizard to create an algorithm that creates a seamless and balanced mosaic of input airphotos, which can then be compressed out to a single compressed image file.

As algorithms perform processing on the fly (without creating intermediate disk files), this means you can go from the collection of input files, to a resultant mosaiced, balanced and compressed image file - without generating any intermediate files.

An easy way to compress imagery is to open an image window, set up the results to your satisfaction, and then select the current image window as input for the Compression Wizard.

In addition to using an algorithm as the source image to be compressed, you can specify any other file format supported by ER Mapper, such as ESRI BIL, TIFF, and JPG as the input.

Distributing and using compressed imagery

CD-ROM/DVD-ROM versus Internet distribution

Internet distribution is likely to increase as Internet access rates increase. Currently, imagery distributed over the Internet is best suited for imagery under 5MB compressed in size, which means that the original image size would be 100MB in size assuming color imagery compressed at 25:1.

CD-ROM and DVD-ROM are ideally suited for distribution of larger amounts of imagery, as 15GB of imagery can be stored on a single CD-ROM when compressed at 25:1, and 250GB of imagery can be stored on a single DVD-ROM when compressed at 25:1.

Reducing storage requirements

The following table demonstrates typical compression rates that can be achieved for imagery. If your imagery contains less detail - for example the imagery covers forested areas, desert or other areas with limited features, the actual compression rate achieved may be higher.

| Type of imagery | Dimensions | Uncompressed size | Compression ratio | Compressed size |
|--------------------|-----------------------|-------------------|-------------------|-----------------|
| Grayscale airphoto | 1 x 8,000 x 8,000 | 64MB | 15:1 | 4MB |
| Color airphoto | 3 x 8,000 x 8,000 | 192MB | 25:1 | 8MB |
| Scanned Topo map | 3 x 40,000 x 60,000 | 7,200MB | 50:1 | 144MB |
| Airphoto mosaic | 3 x 50,000 x 100,000 | 15,000MB | 25:1 | 600MB |
| Statewide mosaic | 3 x 300,000 x 500,000 | 450GB | 25:1 | 18GB |

Compressed sizes of different types of imagery

Fast access on CD-ROM and DVD-ROM

CD-ROM and DVD-ROM media are read using an LED based laser system with a holographic lens system for focussing the returned light from the media being read. The physical weight of this head system limits the speed that it can be moved back and forth over the drive when seeking.

It is this limitation that results in CD-ROM and DVD-ROM media being very slow when being randomly accessed, such as when reading portions of an image from a CD-ROM. The average seek rate for CD-ROM and DVD-ROM drives is about 100ms - which means that only 10 seeks per second can be achieved from the media.

Because of this, it is normally very slow to view large imagery directly from CD-ROM or DVD-ROM media.

Wavelet compressed imagery offer several advantages that enable the effective use of imagery directly from CD-ROM and DVD-ROM media:

- **Reduced size.** Because the images are compressed, less disk IO needs to be carried out in order to view images, resulting in a performance boost.
- **Multi resolution level of detail.** The nature of wavelet compression is such that it processed imagery into multiple levels of detail. This means that when a user is viewing imagery at different resolutions, only information needed to display at that resolution is retrieved. This reduces disk IO and disk seek requirements, resulting in faster image access.

- **Improved disk access.** The ER Mapper Compressed Wavelet (ECW) format uses a technique known as clustering to locate related information in an image closely together. This reduces the number of seeks that need to be carried out - significantly improving performance when imagery is viewed directly from CD-ROM.

CD-ROM and DVD-ROM distribution of imagery

CD-ROM and DVD-ROM offer an attractive distribution method for large imagery, as it is easy to produce master copies, and duplication costs are very low.

One of the biggest problems encountered during data distribution is the measurement of the number of times a single CD-ROM (or DVD-ROM) is ordered. For some satellite companies, who distribute satellite imagery, the average number times that a satellite “scene” (image) is sold is 1.5 times per scene.

Clearly, by increasing the number of images stored in a single media, the production run can be increased, thereby improving efficiency and reducing data distribution costs.

This is a significant benefit of compressing imagery: about 25 times more imagery can be stored on a CD-ROM or DVD-ROM when it is compressed.

The following table shows the approximate cost of creating CD-ROMs and DVD-ROMs in different volumes for data distribution (in this example showing a maximum production run of 1,000 per CD-ROM or DVD-ROM master):

| Volume | Media and size | Production method | Cost per media |
|-------------|----------------|-------------------|-----------------|
| 1 to 50 | CD-ROM, 600MB | Gold CD-R | \$3 |
| 1 to 50 | DVD-ROM, 15GB | Gold DVD-R | \$200 |
| 50 to 1,000 | CD-ROM, 600MB | Stamped | \$1.0 to \$0.50 |
| 50 to 1,000 | DVD-ROM, 15GB | Stamped | \$2.0 to \$1.0 |

Cost of producing media for imagery distribution

Using compressed imagery with GIS/CAD/Office applications

When distributing imagery, an important consideration is the ultimate ability of users to access and effectively use the imagery.

Studies have continually shown that the ability to be able to directly access imagery, without having to import it first, and which geographic information preserved, consistently ranks as the highest requirement by imagery users in the GIS, CAD and office software environments.

There is a range of free plugins for common GIS/CAD/MS Office applications, which directly read compressed ECW image files. Plugins are available than enable products to directly read compressed image files, for products including:

- AutoCAD MAP 3
- ArcView 3.1
- MapInfo 4.0/4.5/50
- Microsoft Office (WORD, EXCEL, etc)
- ER Mapper
- Photoshop
- Stand alone image viewing

When distributing imagery, these plugins can be distributed with your imagery, free of charge. Each plugin is typically 2MB to 3MB in size prior to installation, and is available as a single .EXE file that uses InstallShield to install the plugin.

A common approach is to have a “plugins” directory on the CD-ROM or DVD-ROM, and include all the free plugins in that directory.

Cheaper distribution costs

It can be seen that wavelet compression reduces distribution costs, and improves usage of data, in several ways:

- **Improved production volume.** By storing more on a single media, the number of individual different media can be reduced, significantly reducing production costs.
- **Faster access.** Improves usage and therefore demand for data.

Advanced compression topics

Grayscale versus RGB versus multi-band compression

When you compress an image using the ER Mapper Compression Wizard GUI, you have the option of compressing to a Grayscale image, or to a RGB image.

In the first instance, a grayscale view of your input data is constructed and compressed. This uses the normal formula for Intensity from Red, Green and Blue.

If you compress to RGB format, the compression engine internally converts the RGB color image into YUV color space, specifically the one defined as the “JPEG Digital version of YUV”. YUV is a color space that separates out intensity (Y) from chromatic or color changes (U and V). This enables more efficient compression of color imagery, ensuring that detail is preserved. The RGB to YUV conversion (and back again for decompression) is automatic; the user always sees the file as a RGB file.

However, there may be cases where you wish to compress three-band images where the three separate bands are not directly correlated. An example of this might be the compression of Radiometric values of Potassium, Thorium and Uranium. In this instance, it may not be desirable to do YUV compression.

Although the Compression Wizard offers only RGB and Grayscale compression alternatives, the command line “ecw_compress” version of the compression engine supports compressing imagery that is treated as 3 different bands.

Note that the current version of the compression engine supports only 3 band, 8 bit integer format multi-band images. The compression logic does handle multi-band imagery such as hyperspectral data, and we anticipate releasing support for this and non-integer data in the future. Contact your nearest ER Mapper office and ask to be put on the beta program for the hyperspectral and non-integer compression engine.

Compressing image mosaics that are larger than available disk space

If you wish to create a single 5GB compressed image, which is the result of compressing 100GB of input imagery at 20:1 - but have only 12GB of disk space, here are some hints to assist you:

- Compress the 100GB input image in sets of 10GB input, resulting in 10 output compressed images each about 500MB in size.

You then have several alternatives:

- Distribute the compressed imagery with an ER Mapper algorithm that mosaics the 10 x 500MB images into a mosaic. As ER Mapper algorithms run under the free imagery plugins for GIS products, this also means you could distribute your data on 5 x CD-ROMs, and still enable people to use part of the data, or all of it, depending on their disk space.
- Create an algorithm that is a mosaic of the 10 x 500MB compressed images, and then run the Compression Wizard to generate a single compressed 5GB output file.

Note that in the second example, ER Mapper is actually decompressing the source 10 compressed images, mosaicing them together, and then compressing them together again as a single compressed file.

This means that the files will have gone through two compressions.

Generally speaking, re-compressing a previously compressed image will result in some reduction in quality, although the difference will not be noticeable. If you do decide to decompress and then recompress an image, try and either keep the new target compression rate the same (20:1 in this example). Better still, use a lower compression rate the first time (you could use 10:1 in this example and still fit the 10 compressed 1Gb files on disk), and then use a multiple but larger compression rate the second time (for example 20:1).

Using the above techniques, you can break TB (1,000GB) compression projects down to manageable chunks, for example 100GB per compression, and still result in a single compressed file.

Compressing TB (1,000GB) image files

An input file can be up to 2^{64} bytes in size, so TB (1,000GB) files can be compressed. There is no real limit other than physical disk space needed to hold the input files being compressed.

If your input imagery mosaic is larger than your physical disk storage, and you want to create a single compressed image file, compress the imagery in sections, and then mosaic and compress the compressed sections into a single file.

Note: The free ECW compressor will not allow you to compress images that are larger than 500MB. To compress larger image you will need ER Mapper 6.0 with the Compression Enhancement Pack.

Compression / decompression memory requirements

The Compression Wizard has a very small memory footprint. However, compression of large images often involves using complex algorithms to do the mosaicing and balancing while compressing. For example, compressing a mosaic of 1,000 x 200MB input airphotos (100GB total size) might require 64MB of RAM for efficient operating system and ER Mapper operation.

Compressing imagery

As a rule of thumb, we recommend 64MB of RAM to compress images 1GB in size, 128MB to compress images 10GB in size, and 256MB to compress images 100GB or larger in size. This ensures you have sufficient RAM to run the Operating System, the ER Mapper algorithm processing engine, and the compression wizard compression engine, without page swapping (which slows down operation considerably). If your source images are simple imagery files (e.g. not smart data algorithms) you will be able to use less memory than indicated here.

Compression is compute-bound and uses floating point operations, so a CPU with fast FPU capabilities, and a CPU with good L1 or L2 cache, will make compression much faster.

Decompressing imagery

Viewing of compressed files requires much less memory than compression. A system with 32MB of RAM will be able to comfortably roam and zoom around a 100GB compressed image file (more RAM might be required for efficient operation of some software, particularly GIS products).

Where as compression uses floating point operations, the decompression of imagery uses integer based calculations, so fast floating point is not important for decompression.

Compressing hyperspectral and non-byte imagery

The ECW format has been built to support hyperspectral imagery and non-byte based imagery in the future.

The current version of the ECW Compression Wizard does *not* support compression of imagery with more than 3 bands, and automatically rescales non-integer data into a 0..255 data range. If there is sufficient demand, a future release will include the above functionality. Please contact your nearest ER Mapper regional office for more information.

Common questions and answers

Command line usage to batch compress many images

You can use the command line version of the compression engine to carry out compression in a batch operation. To do this, use the command “ecw_compress”. As this is an ER Mapper executable, you need to ensure that the ER Mapper environment variables are correctly set up; the easiest way to do this is to use the “erm_run” command.

An example command line might look like:

```
C:\ermapper60\bin\win32\erm_run ecw_compress input.ers -o output.ers -rgb -c 20
```

The full command line syntax for “ecw_compress” is:

Usage:

```
erw_compress infile [-show] [-o outfile] [-c compression_ratio] [-g | -rgb | -multi]
-show      will report the expected output size only, and not compress
-nowait    after compression, do not report a message dialog and wait for user
-g         will compress to a single band UINT8 grayscale output file.
-rgb       will compress to a RGB file optimized for color imagery compression.
-multi     will compress to a multi-band image (only 3 band, UINT8 format, supported at present)
```

Note that the only way to select multi-band compression, as compared to RGB compression, is to use the command line “-multi” switch.

If you wish to write your own ER Mapper Wizard to interface to the compression engine, use “ecw_compress_gui” as the executable to run, not “ecw_compress”. See the Batch Script “Compression_Wizard.erb” for an example of how to create your own wizard interface into the compression engine.

Command line image decompression utility

You can expand a compressed image file out to an uncompressed image file with the ER Mapper GUI by opening the compressed file, then selecting “File->Save As...” menu, and writing the image out to the desired format.

There is also a command line program that will decompress a compressed image out to an uncompressed .ERS format file.

Usage is:

```
erw_decompress infile.ecw outfile.ers
```

Renaming compressed files

Compressed images are contained in two files: The optional .ERS file which contains map projection and statistics information, and the .ECW file which contains the compressed data.

Note: With ECW V2.0, the .ERS file is optional because georeference information is contained in the .ECW image file as well as in the .ERS file.

If you rename a compressed image file, you must edit the .ERS header file to change the line indicating the name of the compressed .ECW file. Use a normal text editor, and look the line:

```
Datafile = "image.ecw"
```

Where "image" is the name of your file. Change this to the new name of your file.

Using smart data Algorithms as the source image to be compressed

The ER Mapper 6.0 Compression Wizard supports the use of ER Mapper smart data algorithm as input for compression. So you can have an algorithm generating a color draped and sun-shaded version of a DEM, which could be used as the input file to be compressed.

Multi-surface transparency, mosaicing, balancing, and other ER Mapper algorithm capabilities can all be used in the input algorithm to be compressed.

Automatically or manually defining data rescaling

As a convenience, if you select an input file that is not an algorithm, an algorithm will automatically be created. If you want to preserve the full data range, use an algorithm as input that either has no output transforms, or has the transforms set to scale or clip (or not as the case may be) the input image to the desired range.

If you select an algorithm, that has no transforms rescaling data, as the input, the result will exactly match the input imagery.

Cell size when compressing different resolution images as a mosaic

When you select an algorithm as the input file to be compressed, the effective cell size of the algorithm is the cell size of the smallest image in the algorithm. For example, if you have an algorithm that is a mosaic of 5 meter imagery and 1 meter imagery, the effective cell size is 1 meter, and that is the cell size used for compression.

Note that, in this example, your actual compression ration will be much higher than the target compression ratio, as the 5 meter imagery can be compressed more than the 1 meter imagery.