DGIWG 116-3-2

Elevation Surface Model (ESM)
Encoding rules - Part 2: GeoTIFF

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Audience:	This document is approved for public release and is available on the DGIWG website, http://www.dgiwg.org/
Abstract:	This document defines the ESM Encoding Rules on the basis of the DGIWG GeoTIFF profile and the ESM UML model and metadata (DGIWG 116-1). It is to be used in conjunction with ESM Encoding Rules – Core (DGIWG 116-3-1).
Copyright:	

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i. Submitting organizations

Nation	Parent organization
France (Lead Nation)	Institut Géographique National (IGN)
Czech Republic	Military Geographic and Hydrometeorologic Office (MGHM)
Denmark	Danish Geospatial Agency (SDFE)
Sweden	Military Geographic Service
Turkey	General Command of Mapping
United States	National Geospatial-Intelligence Agency (NGA)

ii. Revision history

Date	Release	Primary clauses modified	Description
18/10/2016	1.1	All	Creation DGIWG TP Review October 2016
16/05/2017	1.1		Resolution of comments from DE and FRA, in DGIWG TP May 2017
2/10/2020	1.1.1		Update of normative references (Section 3) and throughout the document + addition of GMLCOV abbreviated term in 4.2

iii. Future work

None identified

Introduction

This document specifies how the Elevation Surface Model (ESM) shall use the Tagged Image File Format (TIFF) and GeoTIFF tags to convey the elevation values assigned to regularly spaced grid points (under the Rectified Grid coverage model) or irregularly spaced grid points (under the Point coverage model) on the basis of the DGIWG standardized GeoTIFF profile for Georeferenced Imagery (DGIWG 108). It also includes the additional rules that apply to the ESM Coverage on the basis of the GMLCOV GeoTIFF extension.

It is to be used in conjunction with ESM Encoding rules – Part 1: Core (DGIWG 116-3-1) for the general encoding rules for ESM data and associated metadata, as well as associated ESM GML document (if applicable).

1 Scope

This document specifies how the Elevation Surface Model (ESM) shall use the Tagged Image File Format (TIFF) and GeoTIFF tags to convey the elevation values assigned to regularly spaced grid points (under the Rectified Grid coverage model) or irregularly spaced grid points (under the Point coverage model) on the basis of the DGIWG standardized GeoTIFF profile for Georeferenced Imagery (DGIWG 108). It also includes the additional rules that apply to the ESM Coverage on the basis of the GMLCOV GeoTIFF extension.

It is to be used in conjunction with ESM Encoding rules – Part 1: Core (DGIWG 116-3-1) for the general encoding rules for ESM data and associated metadata, as well as associated ESM GML document (if applicable).

2 Conformance

Conformance to ESM Encoding Rules for GeoTIFF apply to, as detailed in Annex A, ESM Encoding Rules for GeoTIFF:

- ESM Coverage schema based on GMLCOV for RectifiedGridCoverage or MultiPointCoverage with 2 options for the conformance class:
    - in case of a message based encoding for a web service, with the GMLCOV *gml-coverage* and *multipart* conformance classes incorporating the supported format. This is the multipart data delivery conformance test for ESM Coverage data.
    - in other cases (e.g. a physical media based encoding), with the *gml-coverage* and the *gml* conformance classes, with the exception of Clause A.1.1.17 - GML special format for the GML encoding of the RectifiedGridCoverage. In this case, the ESM GML Coverage document and the ESM data (corresponding to the rangeSet of GMLCOV), encoded in a dedicated format, are 2 distinct files. This is the multifile data encoding conformance test for ESM Coverage data.

Any ESM data claiming conformance to the DGIWG ESM Encoding Rules shall pass the applicable test specified in Annex A, ESM Encoding Rules.

Any software implementation claiming conformance to the DGIWG ESM Encoding Rules for GeoTIFF shall document its ability to import and/or export ESM compliant data in GeoTIFF encoding.

3 Normative References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of these profiles.

1. DGIWG 116-1: Elevation Surface Model, Edition 1.1, 17 September 2020 [ESM]
2. DGIWG 114: DGIWG Metadata Foundation, 2.0.0, 12 July 2017 [DMF]
3. DGIWG 116-2: DGIWG ESM GML Application Schema, Edition 1.0.2, 2 October 2020 [ESM_GML_AS]
4. DGIWG 116-3-1: DGIWG ESM Encoding Rules – Part 1: Core, Edition 1.1.1, 2 October 2020 [ESM_ER_Core]
5. DGIWG 108: GeoTIFF Profile for Georeferenced Imagery – July 2020, Edition 2.3.1 [DGIWG_GTIFF]
6. ISO 639-2:1998 Codes for the representation of names and languages
7. ISO 19136-1:2020 — Geographic information – Geography Markup Language (GML) – Part 1: Fundamentals
8. ISO 19136-2:2015 — Geographic information – Geography Markup Language (GML) – Part 2: Extended schemas and encoding rules
9. OGC® GML Application Schema – Coverages, Version: 1.0.1 (OGC 09-146r2), 11 May 2012
10. OGC® GML Application Schema – Coverages - GeoTIFF Coverage Encoding Profile, Version: 1.0.1, 28 May 2014 (OGC 12-100r1)

4 Terms and definitions, and abbreviated terms

4.1 Terms and definitions

Generally, the terms and definitions of the base standard ISO 19106:2004, ISO 19107, ISO 19123, ISO 19136-1 and ISO 19136-2 as well as DGIWG 116-1 (ESM) and DGIWG 116-3-1 (ESM Encoding Rules – Part 1: Core) apply to this profile. Some abbreviated terms are repeated in this document, for the sake of readability

4.2 Abbreviated terms

ASCII	American Standard Code for Information Interchange
CRS	Coordinate Reference System
DMF	DGIWG Metadata Foundation
ESM	Elevation Surface Model
GeoTIFF	Geographic TIFF
GML	Geography Markup Language
GMLCOV	GML Coverage schema (associated to OGC 09-146r2)
IEEE	Institute of Electrical & Electronic Engineers
ISO	International Organization for Standardization
OGC	Open Geospatial Consortium
TIFF	Tagged Image File Format
XML	eXtensible Markup Language

5 Applicability and use

This ESM Encoding Rules for GeoTIFF is applicable to any ESM data encoded in GeoTIFF, claiming compliance to ESM. The following GML instances are optional. A web coverage service must provide this information, but these GML instances are optional depending on implementation choice:

- A single ESM GML Coverage document, together with its associated metadata, including or associated to the corresponding ESM Coverage Data (rangeSet of GMLCOV) encoded in GeoTIFF. Depending on the use case, this ESM Coverage data is either a separate file or included in a multipart message.
- A collection of ESM Coverage or collection of ESM PointSet document, together with its associated metadata which if tiling is used, this metadata is required to include the TilingScheme resource description, and associated TilingScheme geometry, according to the RectifiedGrid or MultiSurface Coverage model.
- Any elevation data file encoded in GeoTIFF.

6 GeoTIFF ESM Coverage encoding for GeoTIFF

The OGC specification GMLCOV GeoTIFF extension (OGC 12-100r1) provides additional requirements to the domain and range of a GMLCOV for GeoTIFF encoded Coverages.

Requirement GTF1: An ESM coverage encoded in GeoTIFF shall conform to the tests A.1.2 to A.1.11 of GMLCOV GeoTIFF extension (OGC 12-100r1):

- TIFF and GeoTIFF conformance,
- Coverage type (gmlcov:RectifiedGridCoverage),
- URI to GMLCOV_geotiff-coverages/1.0/conf/geotiff-coverage,
- MIME type (image/tiff),
- 2 dimensions coverage,
- CRS (specified by the srsName attribute of the gml:Envelope element of the gml:boundedBy element of the ESM coverage instance, which shall be the same as the CRS used in the GeoTIFF elevation data file),
- axis order (in adherence with the axis order defined by the CRS),
- raster space (PixelIsPoint),
- range order (if more than 1 elevation component).

Requirement GTF2: The description of the coverage grid function must reflect the baseline ordering used by TIFF format to store the range values within a file. The following mapping must be applied:

coverageFunction.gridFunction.sequenceRule.type = “linear” AND coverageFunction.gridFunction.sequenceRule.scanDirection = “+2 +1

7 TIFF and GeoTIFF rules for ESM elevation data

In general, the elevation value records for ESM data delivered in GeoTIFF format will conform to the specifications in DGIWG TIFF/GeoTIFF profile. The following clauses constrain the implementation of TIFF and GeoTIFF for use with the ESM.

7.1 Introduction

Requirement GTF3: Elevation Surface Model (ESM) TIFF/GeoTIFF data shall be encoded on the basis of the DGIWG standardized GeoTIFF profile for Georeferenced Imagery (DGIWG 108), according to the Elevation data (ED) conformance class, with support of TIFF extension for elevation values encoding and GeoTIFF vertical parameters extension.

The individual TIFF/GeoTIFF values file population strategy is defined with a means to associate each GeoTIFF file with:

- An ESM Data Set;
- An ESM Elevation Collection / Transmittal, to include tile association, when tiling is used; the TilingScheme may also be encoded in a GeoTIFF file (in case it is provided under a Rectified Grid Coverage);
- The type of data contained within the value file (i.e. rectified grid coverage);
- The surfaces represented by the data in the value file.

The general rules specified in 6.2 - General rules for ESM data (cf. [ESM_ER_Core]) apply to the TIFF/GeoTIFF encoding, as stated in the following paragraphs of this section.

According to Requirement 13 in [ESM_ER_Core], the TIFF/GeoTIFF parameters shall be consistent with metadata provided in ESM Metadata, and, if relevant, in ESM Coverage GML document. Annex B provides the mapping between this various information. In case of discrepancy, the information in TIFF/GeoTIFF elevation data file shall prevail.

7.2 CRS

Requirement GTF4: Horizontal and Vertical datum, CRS

Horizontal datum and Coordinate systems: shall be provided by the following GeoTIFF fields:

GeographicTypeGeoKey / GeogCitationGeoKey, in case of geographic coordinate system;
ProjectedCSTypeGeoKey / PCSCitationGeoKey, in case of projected coordinate system.

Vertical datum: shall be provided by the following GeoTIFF field (*Vertical CS parameter keys*):

VerticalCSTypeGeoKey / VerticalCitationGeoKey

Note: CRS information shall also be documented accordingly in:

- the ESM metadata,
- the ESM Coverage GML instance (if present) based on GMLCOV model.

7.3 Units of Measure

Requirement GTF5: Horizontal and Vertical units

Geographic / Projected units: shall be provided by the following GeoTIFF fields, in accordance with the CRS (according to EPSG register):

- GeogAngularUnitsGeoKey, in case of geographic coordinate system;
- ProjLinearUnitsGeoKey, in case of projected coordinate system.
- Vertical unit: shall be provided by the following GeoTIFF field: VerticalUnitsGeoKey.

Note: Unit of measure information shall also be documented accordingly in the ESM GML instance, based on GMLCOV model.

7.4 Security Classification

Requirement GTF6: When the ESM data is classified, the security marking shall be provided in the TIFF ImageDescription field.

Note: This information must also be duplicated in the additional XML metadata (DMF/Resource Security Constraint).

When the ESM data is not classified, there is no requirement to declare this condition in the encoding format or the additional metadata. This information may also be explicitly set to “Unclassified” in the encoding format and the additional metadata.

7.5 Intellectual property rights information

Requirement GTF7: In case of any copyright to the data or any restriction of usage of ESM data, the TIFF field “Copyright” shall provide the information about copyright notice of the person or organization that claims the Intellectual property rights. The complete copyright statement should be listed in this field including any dates and statements of claims.

Note: This Intellectual property rights information must also be duplicated in the additional XML metadata (DMF/Resource Legal Constraint)

Otherwise, there is no requirement to declare this information in the encoding format or the additional metadata.

7.6 Void Areas

DGIWG GeoTIFF profile provides 2 methods for the encoding of void values / void areas:

- The unofficial private TIFF tag, GDAL_NODATA (#42113) for declaring this void area value (see Table A.1 in DGIWG 108), which should be populated with the most negative value available for the data type selected (or the non-number value designated for the selected data type).
- The use of a transparency mask (refer to § 13.14.2 in DGIWG 108) for identification of void data values treated as transparent.

Requirement GTF8: When an ESM data has void areas, the void area value shall be provided in the TIFF GDAL_NODATA field or in a Transparency Mask according to DGIWG GeoTIFF profile (DGIWG 108).

Note: This void area value shall also be declared in the ESM metadata.

7.7 ESM Data Representation

TIFF image file directory (IFD) allows the definition of the field types.

Depending on encoding format, ESM data may be represented by:

- signed integer, encoded on 2 bytes (signed short) or 4 bytes (signed long). Signed long integers may be used for high resolution elevation values provided in centimetre or millimetre, in conjunction with the corresponding scaling factor (GeoTIFF tag ModelPixelScaleTag)
- floating point values: single precision (4-byte) or double precision (8-byte) IEEE formats.

High resolution Elevation data are usually stored as 4 bytes signed integers or single precision point values.

Section 19 of the TIFF specification presents a scheme for describing a variety of data sample formats. The BitsPerSample field in the TIFF Image File Directory defines the number of bits per component.

Annex A
ESM TIFF/GeoTIFF encoding rules - Abstract test suites
(normative)

This Annex provides abstract test suites for ESM GeoTIFF Encoding Rules build upon the DGIWG ESM and the DGIWG GeoTIFF profile, for data encoded in conformance with the rules specified in this document.

A.1 ESM GeoTIFF Coverage GML instance conformance test

Purpose: An ESM GeoTIFF coverage instance shall conform to the additional requirements to the domain, range and coverageFunction of a GMLCOV for GeoTIFF encoded Coverages.

Method: Inspect ESM Coverage instance against the 2 requirements referenced below.

Reference: Requirements GTF1 and GTF2.

A.2 Conformance of GeoTIFF elevation data with DGIWG GeoTIFF profile

Purpose: An ESM GeoTIFF data file shall conform to DGIWG GeoTIFF profile, according to Elevation (ED) conformance class.

Method: Inspect ESM GeoTIFF data file against the requirement referenced below.

Reference: Requirement GTF3.

A.3 Correct encoding of CRS and UoM

Purpose: An ESM GeoTIFF data file shall include correct definition of Horizontal and Vertical datum, as well as UoM for elevation data.

Method: Inspect ESM GeoTIFF data file against the 2 requirements referenced below.

Reference: Requirements GTF4 and GTF5.

A.4 Correct encoding of Security classification and Intellectual property rights information

Purpose: An ESM GeoTIFF data file shall provide (when relevant) Security classification and Intellectual property rights information as specified.

Method: Inspect ESM GeoTIFF data file against the 2 requirements referenced below.

Reference: Requirements GTF6 and GTF7.

A.5 Correct encoding of Void areas

Purpose: An ESM GeoTIFF data file shall provide (when relevant) Void areas definition as specified.

Method: Inspect ESM GeoTIFF data file against the requirement referenced below.

Reference: Requirement GTF8.

Annex B
Mapping between ESM GML instance, ESM metadata and TIFF/GeoTIFF data structures
(normative)

The following 3 tables provide the mapping between values in TIFF/GeoTIFF encoding format and the required ESM GML and ESM metadata elements:

- Table 1, mapping with baseline TIFF tags,
- Table 2, mapping with baseline GeoTIFF tags for baseline (horizontal) GeoKeys,
- Table 3, mapping with baseline GeoTIFF tags for Vertical GeoKeys.

Legend for following tables:

- columns Field, Description, Tag, Type refer to corresponding specification items of tag (resp. geokey) according to TIFF (resp. GeoTIFF) specifications
- Card column specifies cardinality of the item
- Obligation column specifies presence of the item:
  - R: required (same as M, Mandatory)
  - O: optional
  - C: conditional (condition must be specified)
  - I: inadequate for profile (not applicable for georeferenced imagery conformant to this profile)
- Restricted values for the profile: indicates (when applicable) required values for tag or geokey for this standard.
- TM: transparency mask

Table 1: Baseline TIFF Fields in DGIWG profile and mapping with GML elements from ESM GML AS and ESM metadata

TIFF Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
Artist	Person who created the image	315	ASCII	1	O	If used, populate with the name of the organization responsible for the file. (This information is redundant with additional metadata)	N/A	Dataset originator RSRPTY:originator
BitsPerSample	Number of bits per component	258	Short	1 Samples per post	R	1 (for Transparency mask) For other ESM data, constrained to 16 and 32 bits per range (sample) value.	For each sample per post i, rangeType.field[i].constraint.interval ="0 *2^BitsPerSample[i]-1*"	N/A
ColorMap	A color map for palette color images	320	Short	3*(2** BitsPerSample)	I	Not used for elevation data	N/A	N/A
Compression	Compression scheme used on the image data.	259	Short	1	R	1 (corresponding to not compressed) 5 LZW compression	N/A	Resource Format.decompression (RSFMT) NB: This information must be populated in order to provide decompression information (if LZW compression)
Copyright	Copyright notice	33432	ASCII	1..*	O I (for TM)	(When restricted) Restrictions for access or usage, complete copyright statement (including person or organization claiming the copyright, dates…)	N/A	Resource Legal Constraint (RSLCST)
DateTime	Date and time of image creation	306	ASCII	20	O	Creation date of image Use of this tag is recommended in order to support discovery of the data. This information should be	N/A NOTE the field DateTime should not be confused with the properties phenomenonTime and beginLifespanVersion that	Resource Reference Date (RSDATE)

TIFF Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
						consistent with additional XML metadata, where other dates can also be provided. Date and Time in Coordinated Universal Time (UTC)	report other types of temporal information	
ExtraSamples	Description of extra components For the ESM Profile:, this value should not be used	338	Short	1	I	Populate with values of '0' for additional bands and '1' for opacity data	N/A	N/A
FillOrder	The logical order of bits within a byte.	266	Short	1	O	1 (Default) (2 shall never be used)	N/A	N/A
HostComputer	The computer and/or operating system in use at the time of image creation.	316	ASCII	1..*	O	If used, populate with descriptor of the computer system used to process/create the range values from the raw instrument data or other source of sample data.	N/A	N/A
ImageDescription	A string that describes the subject of the image.	270	ASCII	1..*	O	Identify the product type; must content the identification of product. It is recommended to include security constraint info in this field in order to support Security marking of the data, consistently with additional XML metadata. « Transparency Mask » for transparency mask	N§A	Resource Abstract (RSABSTR) for identification of data + Resource Security Constraint (RSSCST) if security constraint

TIFF Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
ImageLength	The number of rows of pixels in the image.	257	Short or Long	1	R		domainSet.extent.high.coordValues[0] - domainSet.extent.low.coordValues[0]	axisDimensionsProperties of Grid Spatial Representation (GRSPREP)
ImageWidth	The number of columns in the image, i.e. the number of pixels per row.	256	Short or Long	1	R		domainSet.extent.high.coordValues[1] - domainSet.extent.low.coordValues[1]	axisDimensionsProperties of Grid Spatial Representation (GRSPREP)
Make	The scanner manufacturer	271	ASCII	1	O	The manufacturer of the instrument used to obtain the range values.	N/A	N/A
Model	The scanner model name or number.	272	ASCII	1	O	The manufacturer's model name or number of the instrument used to obtain the range values.	N/A	Resource Environment description (RSENVD)
MinSampleValue[1]	The minimum component value used.	280	Short	1	O	If used for statistical purposes, applies to Integer case values	N/A	Vertical Extent (WGS84 ellipsoid) (minZ)
MaxSampleValue1	The maximum component value used.	281	Short	1	O	If used for statistical purposes, applies to Integer case values	N/A	Vertical Extent (WGS84 ellipsoid) (maxZ)
NewSubfileType	A general indication of the kind of data contained in this subfile.	254	Long	1	C Present when transparency mask is used as 2nd subfile	All bits equal 0 except bit 2 = 1 (value = 4, e.g. 0...0100 if little-endian) (for transparency mask)	N/A	N/A

[1] This field is not to be used to affect the visual appearance of an image, nor to affect the interpretation of any other field; it is used only for statistical purposes

TIFF Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
Orientation	The orientation of the image with respect to the rows and columns.	274	Short	1	O	1 (Default value) Orientation of the image to the external coordinate reference system is defined by the GeoTIFF tags.	N/A	N/A
PhotometricInterpretation	The color space of the image data.	262	Short	1	R	1 greyscale image file or bi-level qualification layer or elevation file) 4 (for transparency mask).	N/A	Content Information of the Coverage GRCINF
Thresholding	For black and white TIFF files that represent shades of gray, the technique used to convert from gray to black and white pixels.	263	Short	1	I	This field should never be used for ESM data.	N/A	N/A
PlanarConfiguration	How the components of each pixel are stored.	284	Short	1	I	This field should never be used for ESM data.		N/A
ResolutionUnit	The unit of measurement for XResolution and YResolution.	296	Short	1	R	2 (designating dpi (dot per inch)) Used by TIFF readers that do not read GeoTIFF keys.	N/A	N/A[2]
SamplesPerPixel	The number of components per pixel. For Profile: Allowed values are 1, 3 and 4.	277	Short	1	R	1 for monochrome/greyscale data or bi-level TM	rangeType.field.size()=SamplesPerPixel	N/A

[2] This information is relevant for display or printing; no mapping should be established to GRCINF.range.units.

TIFF Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
SampleFormat	This field specifies how to interpret each data sample in a pixel. Possible values are: 1 = unsigned integer data (Default) 2 = two's complement signed integer data 3 = IEEE floating point data [IEEE] NB: This field does not specify the size of data samples; the BitsPerSample field does this.	339*	Short	1	M	2 or 3 for ESM data	N/A	N/A
SminSampleValue	The minimum sample value. This tag is used in lieu of MinSampleValue when the sample type is other than integer.	340*	Field type that best matches the sample data	SamplesPerPixel	I	This field should never be used	N/A	If this field is used, maps to Vertical Extent (WGS84 ellipsoid) (minZ)
SmaxSampleValue	The maximum sample value. This tag is used in lieu of MaxSampleValue when the sample type is other than integer.	341*	Field type that best matches the sample data	SamplesPerPixel	I	This field should never be used.	N/A	If this field is used, maps to Vertical Extent (WGS84 ellipsoid) (maxZ)
Software	Name and version number of the software package(s) used to create the image.	305	ASCII	1..*	O	If used, populate with descriptor of the software package(s) used to process/create the range values from source of gridded data.	N/A	Resource Process Step RSPRST
StripOffsets	For each strip, the byte offset of that strip.	273	Short or Long	Number of bands	C Not used if Tiling	Populate per TIFF specification when opting to use strips (for each strip, byte index to strip within file)	N/A	N/A

TIFF Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
RowsPerStrip	The number of rows per strip[3].	278	Short or Long	1	C Not used if Tiling		N/A	N/A
StripByteCounts	For each strip, the number of bytes in the strip after compression.	279	Short or Long	Number of bands	C Not used if Tiling.	Populate per TIFF specification when opting to use strips (number of bytes of the strip)	N/A	N/A
XResolution	The number of pixels per ResolutionUnit in the ImageWidth direction.	282	Rational	1	R	Populate with resolution for display or prints, e.g. 254/1. Used by TIFF readers that do not read GeoTIFF keys	N/A	N/A[4]
YResolution	The number of pixels per ResolutionUnit in the ImageLength direction.	283	Rational	1	R	Populate with resolution for display or prints, e.g. 254/1	N/A	N/A[4]
TileWidth	The tile width in pixels. This is the number of columns in each tile.	322*	Short or Long	1	C For internal TIFF tiling		N/A	N/A
TileLength	The tile length (height) in pixels. This is the number of rows in each tile.	323*	Short or Long	1	C For internal TIFF tiling		N/A	N/A

[3] TIFF specification recommends selecting the value for RowsPerStrip such that each strip is about 8K bytes; it makes buffering simpler for readers.

[4] Note: As these dimensions are not geographic but related to display or printing dimensions, no mapping should be made for XResolution and YResolution.

TIFF Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
TileOffsets	For each tile, the byte offset of that tile, as (compressed and) stored on disk.	324*	Long	TilesPerImage[5]	C For internal TIFF tiling		N/A	N/A
TileByteCounts	For each tile, the number of (compressed) bytes in that tile.	325*	Short or Long	TilesPerImage	C For internal TIFF tiling		N/A	N/A
GDAL_NODATA	An ASCII value intended to specify what pixel value is being used to represent missing or background data.	42113*	ASCII	1	R for 3D data with void areas (otherwise optional)	If used, populate with the number that represents void areas in the dataset.	N/A	Coverage Content Information. SpecialCell
GEO_METADATA	This tag may be used for embedding XML-encoded instance documents prepared using 19139-based schema	50909*	ASCII	Count: 4-byte (max. size = 4GB)	O For embedded XML metadata	This tag may be used and information populated with embedded additional XML metadata[6].	N/A Note: When this tag is used, the GML instance should not include the metadata set. The metadata attribute of the coverage may reference the metadata set resource.	N/A

[5] TilesPerImage = (ImageWidth + TileWidth - 1) / TileWidth * (ImageLength + TileLength - 1) / TileLength

[6] Also refer to Chapter 8 in DGIWG 108. The “DGIWG metadata profile“ (DMF) is the reference specification for ESM metadata.

Table 2: GeoTIFF tags and parameter keys specifications in DGIWG profile and mapping with GML elements from ESM GML AS and ESM metadata

Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
GeoTIFF Tags								
GeoKeyDirectoryTag	Stores GeoKey Directory, which defines and references the GeoKeys specified below. All Keys in GeoTIFF are referenced from the GeoKeyDirectoryTag	34735	Short	4..*	R	Values of header field: KeyDirectoryVersion = **1** KeyRevision = **1** MinorRevision = **0** NumberOfKeys = variable (cf. following GeoKeys)	N/A	N/A
GeoDoubleParamsTag	Used to store all of the Double valued GeoKeys, referenced by the GeoKeyDirectoryTag	34736	Double		I	There is no need to include this tag if no double parameter is required.	N/A	N/A
GeoAsciiParamsTag	Used to store all of the ASCII valued GeoKeys, referenced by the GeoKeyDirectoryTag	34737	ASCII		R	Required for ASCII valued GeoKeys	N/A	N/A
ModelTiePointTag	raster -> model tiepoint pairs in the order ModelTiepointTag = (…,I,J,K, X,Y,Z…) where (I,J,K) is the point at location (I,J) in raster space with pixel-value K, and (X,Y,Z) is a vector in model space[7]	33922	Double	6	R	grid origin, tag value is: **0 0 0 Ox Oy Oz** where Ox, Oy et Oz are coordinates of the grid origin (in the reference system identified by GeoKeyDirectoryTag) Oz only used for elevation data (as offset elevation value at origin)	gml:origin element of the domain of the gmlcov:RectifiedGridCoverage	1st cornerPoint of the gridLocation of the Grid Spatial Representation (GRSPREP)

[7] Note that X is always equal to Easting or Longitude, and Y is always equal to Northing or Latitude.

Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
ModelPixelScaleTag	Used to specify the size of raster pixel spacing in the model space units, consists of the following three values ModelPixelScaleTag = (ScaleX, ScaleY, ScaleZ)	33550	Double	3	R	Value is: **px py pz** where px (resp. py/pz) is pixel spacing along X axis (resp. Y resp. Z axis) (in the reference system identified by GeoKeyDirectoryTag and in its associated unit) Pz= 1 for elevation data provided in meters or Z-scaling factor otherwise (e.g. 0.01 for values provided in cm).	gml:offsetVector of the domain of the gmlcov:RectifiedGridCoverage	N/A
GeoTIFF Configuration GeoKeys								
GTModelTypeGeoKey	Defines general type of model coordinate system used, and to which the raster space will be transformed.	1024	Short	1	R	The applicable codes are: 1 – ModelTypeProjected (UTM / UPS, ...) 2 – ModelTypeGeographic (e.g ARC)	N/A	N/A
GTRasterTypeGeoKey	Establishes the raster space coordinate system: RasterPixelIsPoint RasterPixelIsArea	1025	Short	1	R	The applicable codes are: 1 – RasterPixelIsArea (used by imagery products) 2 – RasterPixelIsPoint (for discrete coverage data including elevation data)	N/A	cellGeom of the Grid Spatial Representation (GRSPREP)
GTCitationGeoKey	Provided to give an ASCII reference to published documentation on the overall configuration of this GeoTIFF file.	1026	ASCII	1..*	0	This tag may identify detailed product specification (e.g this profile), used to define this GeoTIFF file.	N/A	Resource product specification.citation (RSPSPC)

Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
Geographic CS Parameter Keys								
GeographicTypeGeo Key	This key may be used to specify the code for the geographic coordinate system used to map lat-long to a specific ellipsoid over the earth.	2048	Short	1	C Present only for ARC data (or other Geographic type data).	EPSG code for CRS, as specified in DGIWG 108.	srsName of the gml:origin or gml:offsetVector elements of the domain of the gmlcov:RectifiedGridCoverage	Resource Reference System (RSRSYS) (for HOR CRS) Note: URI or URI+ text
GeogCitationGeoKey	This key provides a general citation and reference for all Geographic CS parameters.	2049	ASCII		C When GeographicTypeGeoKey is present	WGS84 + may include Reference document citation (EPSG, DGIWG Registry or [DMA TR 8350.2])	N/A	N/A
GeogAngularUnitsGeo Key	This key Allows the definition of **geocentric** CS Angular units. It is optional in this profile (though no user-defined GCS is allowed) in order to clarify that "decimal degrees" is the angular unit to be used.	2054	Short	1	O When GeographicTypeGeoKey is present	9102 (meaning decimal degrees) (Default) (may be present only if GeographicTypeGeoKey is present)	Implicit Uom attached to CRS in GMLCOV document	N/A
Projected CS Parameter Keys								
ProjectedCSTypeGeo Key	This code is provided to specify the projected coordinate system.	3072	Short	1	C	Value = 326zz – UTM Northern Hemisphere 327zz – UTM Southern Hemisphere (Where zz is the UTM zone number) Other PCS allowed by this standard (in	srsName of the gml:origin or gml:offsetVector elements of the domain of the gmlcov:RectifiedGridCoverage	Resource Reference System (RSRSYS) (for HOR CRS) Note: URI or URI+ text

Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
						conformance with DGIWG Geodetic Codes and Parameters Registry) Present only for cartographic data. In this case, GTModelTypeGeoKey = 1 and GeographicTypeGeoKey is absent		
PCSCitationGeoKey	This key is provided to give an ASCII reference to published documentation on the Projected Coordinate System.	3073	ASCII	1..*	C When ProjectedCSTypeGeoKey is present	Citation of Projected Coordinate System + may include Reference document citation (EPSG, DGIWG Registry or [NIMA TM 8358.2] For example, value may be: « **UTM zzN / WGS84** »	N/A	N/A
ProjLinearUnitsGeoKey	This key defines the linear units used by the projection. It is optional in this profile (though no user-defined GCS is allowed) in order to clarify that "meters" is the linear unit to be used[8].	3076	Short	1	O When ProjectedCSTypeGeoKey is present	9001 (meaning Linear_Meter) (Default) (may be present only if ProjectedCSTypeGeoKey is present)	Implicit Uom attached to CRS in GMLCOV document	N/A

[8] The use of this optional tag for UTM projection adds no information as meters is adequately defined in EPSG codes (for UTM). However, it might prove useful for other PCS.

Table 3: GeoTIFF Vertical CS parameter keys specifications in DGIWG profile and mapping with GML elements from ESM GML AS and ESM metadata

Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
Vertical CS Parameter Keys								
VerticalCSTypeGeoKey	This key may be used to specify the vertical coordinate system.	4096	Short	1	C Only for 3D data	Allowed values are: following EPSG codes: 4979 (WGS84 3D ellipsoid) 5773 (EGM96) 3855 (EGM08) 5798 (EGM84) 5714 (MSL height) 5715 (MSL depth) 32767 for other Sounding datums idenfied in DGIWG Geodetic registry, or user defined Vertical CRS (see §13.5 in DGIWG 108).	referenceFrame for the swe:quantity of the swe:DataRecord of the gmlcov:rangeType	Resource Reference System (RSRSYS) (for Vert. CRS) Note: URI or URI+ text
VerticalCitationGeoKey	This key may be used to document the vertical coordinate system used, and its parameters. For other vertical datum than WGS84, this information must content identification of EPSG code or name for the datum (e.g EGM96, or EPSG code= 5119 for IGN69,NGF in France). It may also include reference of the datum in the DGIWG Geodetic Codes and Parameters registry.	4097	ASCII		C Only for 3D data	Allowed values are (see §13.5 in DGIWG 108): 4979 (WGS84 3D ellipsoid) 5773 (EGM96) 3855 (EGM08) 5798 (EGM84) 5714 (MSL height) 5715 (MSL depth) 32767 for other Sounding datums idenfied in DGIWG Geodetic registry (S-1 to S-40) or other user-defined Vertical CRS.	N/A	N/A

Field	Description	Tag	Datatype	Card	Obligation	Restricted value	ESM GML element / attribute	DMF element / attribute
VerticalUnitsGeoKey	This key may be used to specify the vertical units of measurement used in the geographic coordinate system, in cases where geographic CS's needs to reference the vertical coordinate. This, together with the Citation key, comprises the only fully implemented keys in this section, at present.	4099	Short	1	C Only for 3D data	9001 (meaning Linear_Meter) (Default)	swe:uom quantity of the swe:DataRecord of the gmlcov:rangeType	Unit of Range of Content Information of the Coverage GRCINF

Bibliography

1. D2.8.II.3 Data Specification on Elevation – Technical Guidelines, 2013-12-10 (INSPIRE document D2.8.II.1_v3.0)
2. D2.8.II.1 Data Specification on Orthoimagery – Technical Guidelines, 2013-12-10 (INSPIRE document D2.8.II.3_v3.0)