# GeoTIFF File Format

## Status of this Memo

This RFC provides information to the NASA Earth Science community. This RFC describes an Earth Science Data Systems (ESDS) standard. Distribution of this memo is unlimited.

## Change Explanation

V1.1 Updated to reflect final publication of *OGC GeoTIFF Standard*, Version 1.1 by the Open Geospatial Consortium.

## Copyright Notice



## Abstract

This document designates the GeoTIFF file format as a standard for NASA Earth science data systems. GeoTIFF is a mature, well-established and heavily used file format, initially developed in the early 1990's. The use of GeoTIFF within NASA is widespread. Until recently, there has been no up-to-date specification for the GeoTIFF file format. The Open Geospatial Consortium (OGC) approved version 1.1 of the *OGC GeoTIFF Standard* in September 2019. Version 1.1 is backwards-compatible with the original GeoTIFF 1.0 specification of 1995. There are other scientific file formats that are well established within the NASA community, e.g., HDF5, and netCDF. However, there is continued interest and demand for the GeoTIFF file format, mostly as a distribution format for satellite or aerial photography imagery but also for other kinds of data such as Digital Elevation Model (DEM) data, Digital Ortho Quadrangle data, and satellite-derived data products pertaining to human interactions in the environment.

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## 1 Introduction

The Tagged Image File Format (TIFF) was developed in 1996 by Microsoft and Aldus. Aldus later merged with Adobe, the current copyright holder of the TIFF specification [2]. GeoTIFF builds on the TIFF format by using the TIFF extension mechanism to add tags that embed geographic information, hence the name Geographic Tagged Image File Format (GeoTIFF).

### 1.1 Background

The GeoTIFF format has been in use since the early 1990's, where independent efforts by Ed Grissom of Intergraph Corp. and the Jet Propulsion Laboratory (JPL) Cartographic Applications Group were developing a way to encode geographic data in the TIFF format (see N. Ritter & Ruth, 1997 [7]). The idea was to leverage a mature interoperable file format and embed geographic information in it. TIFF met the requirements as it was lossless and was extensible. In September 1994 SPOT Image Corp. proposed a GeoTIFF structure that was limited to Universal Transverse Mercator (see N. Ritter & Ruth, 1997 [7]). The proposed GeoTIFF specification over

the year was augmented and formalized by Ritter and Ruth as Revision 1.0, specification version 1.8.2 in November 1995 (N. Ritter & Ruth, 1995 [6]). Dr. Roger Lott of the European Petroleum Survey Group (EPSG) provided input that led to bringing the GeoTIFF projection parameterization in line with the Petrotechnical Open Software Corporation (POSC) Epicenter model, and the Federal Geographic Data Committee (FGDC) metadata model [5]. This specification remained the official GeoTIFF specification until 2019.

By 2002, the open source library, libgeotiff, was already at version 1.1.4 [9]. This library remains under active development and has had a role in shaping people's understanding of the original GeoTIFF specification. The GeoTIFF FAQ alluded to this in 2002 [8]:

> *However, the quality of GeoTIFF implementations varies greatly, there are no means to do conformance testing on produced GeoTIFF files. Attempts to flesh out parameter lists for complex projections, and to clarify issues of unit types and other problems has fallen by the wayside. EPSG has released many improvements to the underlying projection and datum tables, but it isn't clear whether these apply to GeoTIFF. Hopes of a GeoTIFF 2.0 specification have not been realized.*

There were many attempts within and outside of NASA to develop a "GeoTIFF 2.0" specification. None were successful until the formation of the OGC GeoTIFF Standards Working Group (SWG) in 2014. In 2019, the GeoTIFF SWG produced a new document, *OGC GeoTIFF Standard,* Version 1.1 which was approved and released as a standard by the OGC in September 2019 [1]. The version number 1.1 was chosen to reflect the new version's backwards compatibility with the original specification.

## 1.2 Evidence of Implementation

### 1.2.1 GeoTIFF data

GeoTIFF formatted data is available from many different NASA Earth science data providers.

**ORNL DAAC** - https://daac.ornl.gov
Provides 130 published collections containing 25,735 granules in GeoTIFF format in the online archive. Additionally, 188 collections are available in the ORNL Spatial Data Access Tool, and the MODIS/VIIRS subsetting tool suite offers subset output in GeoTIFF file format by user demand.

**SEDAC -** https://sedac.ciesin.columbia.edu/
Provides more than 60 collections containing granules in GeoTIFF format spanning Agriculture, Anthropogenic Biomes, Coastal Zones, Gridded Population of the World (GPW), Gridded Species Distribution, Gridded U.S. Census, High Resolution Urban Data from Landsat, Infant Mortality, Land Use/Land Cover, Satellite-Derived Environmental Indicators, Water Quality, West Africa Coastal Vulnerability, and Wild Areas.

**Visible Earth** - https://visibleearth.nasa.gov
Provides a collection of NASA images and animations of the Earth. Included are bathymetry, topography, lava flow, land use, arctic ice cover, snow cover and many others.

**Earth Observatory** - https://earthobservatory.nasa.gov/features/NightLights/page3.php)
Provides a collection of Earth at Nighttime images.

**NASA Earth Observations** - https://neo.sci.gsfc.nasa.gov
Provides a number of datasets, each available in GeoTIFF format, such as atmospheric, energy, land, life, and ocean.

**NASA Worldview** - https://worldview.earthdata.nasa.gov
Provides a visual browser of data that allows users to snapshot views in the GeoTIFF format.

**Earthdata Search** - https://search.earthdata.nasa.gov/search
Provides a visual search capability that allows users to find NASA datasets, many of which are available in the GeoTIFF format.

**NISAR** - https://nisar.jpl.nasa.gov and **SWOT** - https://swot.jpl.nasa.gov
Provides upcoming Earth observation missions such as NISAR (NASA-ISRO SAR Mission) and SWOT (Surface Water and Ocean Topography) plan to provide data compatible with GeoTIFF 1.1.

### 1.2.2 GeoTIFF software

There are a number of open source implementations of GeoTIFF.

**libgeotiff** - https://github.com/OSGeo/libgeotiff
This library is designed to permit the extraction and parsing of the GeoTIFF Key directories, as well as the definition and installation of GeoTIFF keys in new files. *libgeotiff* serves as the basis for many other software packages that can read or write GeoTIFF files such as GDAL (https://www.gdal.org/), Manifold (http://www.manifold.net), and various Esri products.

**geotiff.js** - https://github.com/geotiffjs/geotiff.js
Read (geospatial) metadata and raw array data from a wide variety of different (Geo) TIFF files types.

**GeotiffParser.js** - https://github.com/xlhomme/GeotiffParser.js
A JavaScript-based parser for the GeoTIFF image format.

Most commercial GIS and spatial data analysis software can read and write the GeoTIFF format, often using the *libgeotiff* library.

### 1.2.3 Related work

The Cloud Optimized GeoTIFF project [3] is working on a specification to define a format that is fully compatible with the GeoTIFF format but which through additional constraints and structure provides easy access of data via the HTTP protocol. In particular, the goal is to have GeoTIFF files that can be accessed as a data stream rather than needing to be downloaded. This should yield efficiency gains when the files are being used in a Cloud computing environment.

## 2 GeoTIFF File Structure

A GeoTIFF file is a TIFF file as specified by the current TIFF specification, version 6.0 [2]. Thus, the files are compatible with existing software and libraries that can handle TIFF format, such as Photoshop and the *libtiff* library. TIFF provides the ability to define tags that can carry information not previously defined in the TIFF format. The information in these tags is ignored by standard TIFF software but can be used by other software.

GeoTIFF uses a small set of these TIFF tags to store georeferencing information. All GeoTIFF tags can be accessed by any other software, nothing is stored in a way that would hide the information.

To illustrate the content of the GeoTIFF information in a TIFF file, here is the output of a program called *gdalinfo* being used to decode the metadata of a GeoTIFF file. *gdalinfo* is part of the open source software tools called GDAL (Geospatial Data Abstraction Library).

```
> gdalinfo example.tif

Driver: GTiff/GeoTIFF
Files: example.tif
Size is 4049, 3770
Coordinate System is:
PROJCS["WGS 84 / UTM zone 52N",
       GEOGCS["WGS 84",
       DATUM["WGS_1984",
              SPHEROID["WGS 84",6378137,298.257223563,
                 AUTHORITY["EPSG","7030"]],
             AUTHORITY["EPSG","6326"]],
       PRIMEM["Greenwich",0],
         UNIT["degree",0.0174532925199433],
         AUTHORITY["EPSG","4326"]],
    PROJECTION["Transverse_Mercator"],
    PARAMETER["latitude_of_origin",0],
    PARAMETER["central_meridian",129],
       PARAMETER["scale_factor",0.9996],
    PARAMETER["false_easting",500000],
       PARAMETER["false_northing",0],
       UNIT["metre",1,
         AUTHORITY["EPSG","9001"]],
    AUTHORITY["EPSG","32652"]]
Origin = (236010.000000000000000,4589730.000000000000000)
Pixel Size = (60.000000000000000,-60.000000000000000)
Metadata:
```

```
  TIFFTAG_XRESOLUTION=72
  TIFFTAG_YRESOLUTION=72
  TIFFTAG_RESOLUTIONUNIT=2 (pixels/inch)
  AREA_OR_POINT=Point
Image Structure Metadata:
  INTERLEAVE=BAND
Corner Coordinates:
Upper Left  (  236010.000, 4589730.000) (125d50'28.77"E, 41d24'56.79"N)
Lower Left  (  236010.000, 4363530.000) (125d56' 6.40"E, 39d22'51.27"N)
Upper Right (  478950.000, 4589730.000) (128d44'52.62"E, 41d27'31.97"N)
Lower Right (  478950.000, 4363530.000) (128d45'19.62"E, 39d25'15.74"N)
Center       (  357480.000, 4476630.000) (127d19'11.49"E, 40d25'41.19"N)
Band 1 Block=4049x1 Type=Byte, ColorInterp=Gray
  Overviews: 1013x943
```

Image content of a GeoTIFF file can be viewed with readily available TIFF-aware software like Windows Photo Viewer, macOS Preview or open source image tools like the GNU Image Manipulation Program (GIMP), with no need to parse the content of the GeoTIFF tags.

## 3 Interoperability and Applicability Considerations

GeoTIFF is not necessarily suitable for every data type. There are other scientific file formats that are well established within the NASA community, e.g., HDF5 and netCDF, that are approved for use in NASA Earth science data systems.

However, there is continued interest and demand for the GeoTIFF file format, primarily as a distribution format for satellite or aerial photography imagery as well as for other kinds of data such as Digital Elevation Model (DEM) data, Digital Ortho Quadrangle data, and satellite-derived data products pertaining to human interactions in the environment.

While the GeoTIFF format provides for a tremendous amount of interoperability as evidenced by its widespread use within NASA and elsewhere, there is room for further discussion about how to increase interoperability. Work on this topic continues in the NASA Dataset Interoperability Working Group (DIWG) as part of the larger Earth Science Data System Working Group effort within NASA ESDIS.

Some areas, such as embedding Rational Polynomial Coefficients (RPC) to provide a compact representation of a ground-to-image geometry by relating (latitude, longitude, height) locations with (row, column) locations in the image, have been identified by the OGC GeoTIFF SWG and are likely to be addressed in future versions of the GeoTIFF format specification.

Other areas are probably best addressed by specific communities. A leading example of community guidelines for dataset interoperability is the two-part series of *Dataset Interoperability Recommendations for Earth Science* [4] produced by the DIWG.

Community guideline topics could include

- Maximum file size (a variation of the TIFF format, called BigTIFF allows files larger than 4 GB)
- A list of allowable projections and referencing systems tailored to the community's data
- Band data types could be restricted to a subset of the allowable types
- Use of internal masks to indicate pixels and areas of no data
- Use of internal overviews (see, for example, the Cloud Optimized GeoTIFF specification)
- How to encode file-level metadata in the TIFF and GeoTIFF tags
- Use of color profiles
- Use of No Data values
- Use of compression
- Multi-image files

## 4 Future versions of the specification

Users of this version (1.1) of the GeoTIFF specification should be aware that the specification is under continued development within the OGC. Future versions may introduce changes that could be incompatible with current use. The specification itself contains notes identifying areas that are likely to be revised in future versions.

Careful use of the specification version tags within GeoTIFF files is recommended. Newly created GeoTIFF files conforming to this version should use Key Revision 1 and Minor Revision 1 (c.f. section 7.1.2, Requirements 2.7, 2.8 and 2.9 [1]).

# 5 References

## 5.1 Normative References

[1] **OGC GeoTIFF Standard**, OGC Document 19-008r4, September 14, 2019
https://docs.opengeospatial.org/is/19-008r4/19-008r4.pdf

## 5.2 Informative References

[2] Adobe Systems Incorporated. *TIFF Revision 6.0 Final,* June 3, 1992,
https://www.adobe.io/open/standards/TIFF.html

[3] Cloud Optimized GeoTIFF
http://www.cogeo.org/

[4] Dataset Interoperability Recommendations for Earth Science
https://earthdata.nasa.gov/standards/dataset-interoperability-recommendations-for-earth-science

[5] Di, Liping. *Imagery and Gridded Data Input based on TIFF and GeoTIFF Formats*, discussion paper, 1999, not published.

[6] Ritter, Niles, & Ruth, M. (1995). *GeoTIFF Format Specification, GeoTIFF Revision 1.0, Specification Version 1.8.1*, 31 October, 1995
https://cdn.earthdata.nasa.gov/conduit/upload/6852/geotiff-1.8.1-1995-10-31.pdf

[7] Ritter, N., & Ruth, M. (1997). *The GeoTIFF data interchange standard for raster geographic images.* International Journal of Remote Sensing, *18*(7), 1637–1647. doi:10.1080/014311697218340

[8] WayBack Machine copy of the GeoTIFF FAQ Version 2.1 page on remotesensing.org
http://web.archive.org/web/20020617170128if_/http://www.remotesensing.org/geotiff/faq.html

[9] WayBack Machine copy of the GeoTIFF page on remotesensing.org
http://web.archive.org/web/20020604064339if_/http://www.remotesensing.org/geotiff/geotiff.html

## 6 Authors' Addresses

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## Appendix A Glossary of acronyms

| | |
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| DAAC | Distributed Active Archive Center |
| DEM | Digital Elevation Model |
| EPSG | European Petroleum Survey Group (Now the International Association of Oil & Gas Producers) |
| TIFF | Tagged Image File Format |
| GDAL | Geospatial Data Abstraction Library |
| GeoTIFF | Geographic Tagged Image File Format |
| GIMP | GNU Image Manipulation Program |
| ESDS | Earth Science Data Systems |
| HDF | Hierarchical Data Format |
| HTTP | Hypertext Transport Protocol |
| JPL | Jet Propulsion Laboratory |
| NASA | National Aeronautics and Space Administration |
| NetCDF | Network Common Data Form |
| NISAR | NASA-ISRO SAR Mission |
| POSC | Petrotechnical Open Software Corporation |
| OGC | Open Geospatial Consortium |
| ORNL | Oak Ridge National Laboratory |
| RFC | Request for Comments |
| SEDAC | Socioeconomic Data and Applications Center |
| SWG | Standards Working Group |
| SWOT | Surface Water and Ocean Topography |