The Equi7Grid – V14

Grid and Tiling Definition Document – Issue 0.7

Bernhard Bauer-Marschallinger

April 6, 2021

Contents

Document History

Issue	Date	Author	Changes
0.1	2015-03-16	Bernhard Bauer-M.	adopted for Equi7 V13
0.2	2015-04-07	Bernhard Bauer-M.	included Pixel Locating
0.3	2015-09-01	Bernhard Bauer-M.	prepared for GitHub
0.4	2015-09-01	Bernhard Bauer-M.	revision for GitHub
0.5	2018-02-12	Bernhard Bauer-M.	updated GitHub reference
0.6	2019-05-03	Bernhard Bauer-M.	updated software references
0.7	2021-04-06	Bernhard Bauer-M.	adopted for Equi7 V14

0 Preamble

Content of Document

This document describes the design, realisation and software of the Equi7Grid. This grid was developed at the Department of Geodesy and Geoinformation at the TU Wien is aimed to use for high resolution remote sensing data.

Scientific Basis

Detailed information on the scientific background is published under:
*B. Bauer-Marschallinger, D. Sabel, W. Wagner: **Optimisation of global grids for high-resolution remote sensing data.** Computers & Geosciences, 72 (2014), 84 - 93, DOI: 10.1016/j.cageo.2014.07.005*

`http://www.sciencedirect.com/science/article/pii/S0098300414001629`

Implementation

A python implementation of the Equi7Grid, and the source geometric files, are freely available via GitHub:

`https://github.com/TUW-GEO/Equi7Grid`

This python package is also on pypi available:

`https://pypi.org/project/Equi7Grid/`

To install it as python package, you can also just use pip via command line:

```
pip install equi7grid
```

License

Acknowledgements

This work is the result from efforts spent during ongoing developments carried out at TU Wien across a number of projects and by various staff members. In the coarse of these developments of data processing and handling capacities, profound expertise on spatial referencing of remote sensing data was built up at the TU Wien group. Thanks to FFG, time was found to craft this design document. The major work on the scientific background was carried out in the *Soil Moisture Data Cubes* project. Rendering the grid operational was done in the *Prepare4EODC-Water* project.

Changes in Version 14

The update from Equi7Grid v13 to V14 comprise two changes:

1. Refinement of ”Land” polygons and shapefiles, and of the corresponding entries in the ”COVERSLAND” attribute of the tiles.
2. Change of License to the (more permissive) CC BY 4.0.

1 Overview

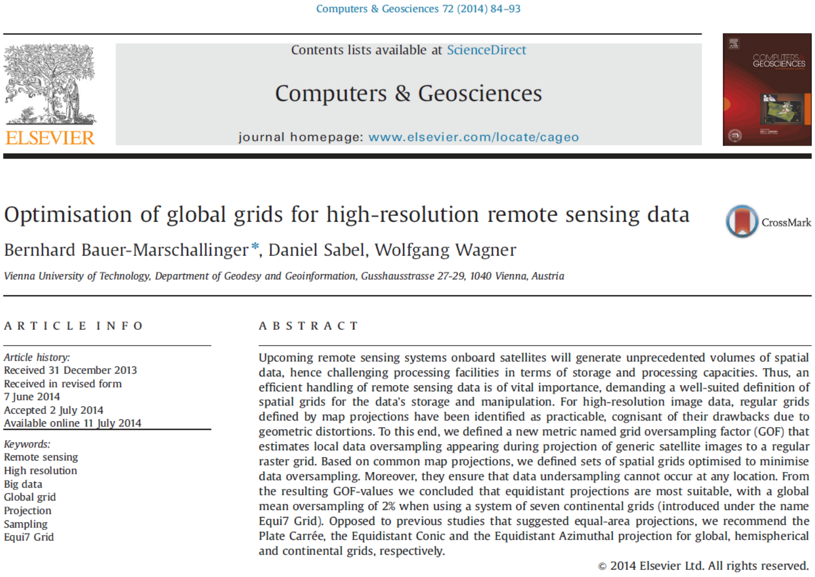
1.1 Rationale

Modern remote sensing systems onboard satellites (e.g. Sentinel-1 or Sentinel-2) generate unprecedented volumes of spatial data, hence challenging processing facilities in terms of storage and processing capacities. Thus, an efficient handling of remote sensing data is of vital importance, demanding a well-suited definition of spatial grids for the data's storage and manipulation. With a suitable grid definition, one can cut down substantially processing time, hard disk volumes, and signal distortions stemming from geometric manipulations.

For high-resolution image data, regular grids defined by map projections have been identified as practicable, cognisant of their drawbacks due to geometric distortions. The Equi7Grid uses the Azimuthal Equidistant Projection that minimises those distortions in the sense of remote sensing and raster imagery.

On a global overage, the Equi7Grid causes only 2% of additional data amount when to projecting satellite images to a regular raster grid, while the commonly used geographic lat/lon projection, as the best performing one-grid solution, causes 32%. Distortions of shapes and directions show the same behaviour.

Further information on the scientific aspect of grid definitions and their suitability to high resolution remote sensing can be found in Bauer-Marschallinger et al. (2014) (Figure 1).



Computers & Geosciences 72 (2014) 84–93

Contents lists available at ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

ELSEVIER
COMPUTERS & GEOSCIENCES
CrossMark

Optimisation of global grids for high-resolution remote sensing data

Bernhard Bauer-Marschallinger*, Daniel Sabel, Wolfgang Wagner

Vienna University of Technology, Department of Geodesy and Geoinformation, Gusshausstrasse 27-29, 1040 Vienna, Austria

ARTICLE INFO

Article history:
Received 31 December 2013
Received in revised form
7 June 2014
Accepted 2 July 2014
Available online 11 July 2014

Keywords:
Remote sensing
High resolution
Big data
Global grid
Projection
Sampling
Equi7 Grid

ABSTRACT

Upcoming remote sensing systems onboard satellites will generate unprecedented volumes of spatial data, hence challenging processing facilities in terms of storage and processing capacities. Thus, an efficient handling of remote sensing data is of vital importance, demanding a well-suited definition of spatial grids for the data's storage and manipulation. For high-resolution image data, regular grids defined by map projections have been identified as practicable, cognisant of their drawbacks due to geometric distortions. To this end, we defined a new metric named grid oversampling factor (GOF) that estimates local data oversampling appearing during projection of generic satellite images to a regular raster grid. Based on common map projections, we defined sets of spatial grids optimised to minimise data oversampling. Moreover, they ensure that data undersampling cannot occur at any location. From the resulting GOF-values we concluded that equidistant projections are most suitable, with a global mean oversampling of 2% when using a system of seven continental grids (introduced under the name Equi7 Grid). Opposed to previous studies that suggested equal-area projections, we recommend the Plate Carrée, the Equidistant Conic and the Equidistant Azimuthal projection for global, hemispherical and continental grids, respectively.

© 2014 Elsevier Ltd. All rights reserved.

Figure 1: The header of the publication on the scientific background of the Equi7Grid in Computer & Geosciences.

1.2 Key Facts

The Equi7Grid is a spatial reference system for the entire Earth and consists of seven planar subgrids for each continent (Figure 2). The coordinates are defined by individual realisations of the Equidistant Azimuthal projection and are referenced to the ellipsoidal WGS84 datum. The Equi7Grid is designed to handle efficiently the archiving, processing and display of high resolution raster data.

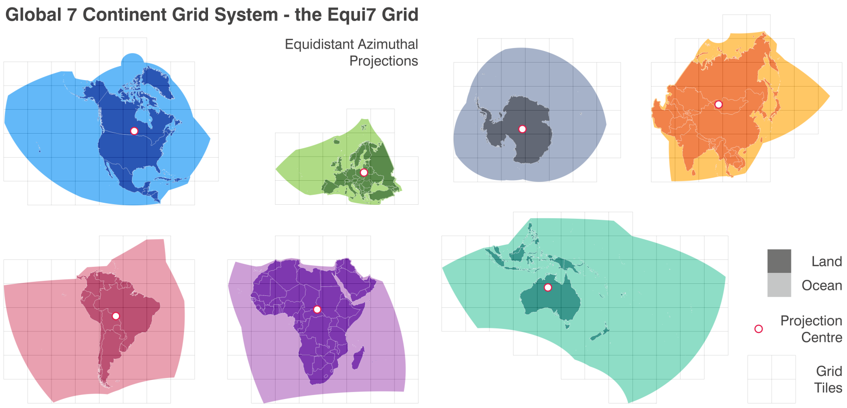

Global 7 Continent Grid System - the Equi7 Grid
Equidistant Azimuthal Projections
Land
Ocean
Projection Centre
Grid Tiles

Figure 2: The Equi7Grid: Schematic images of the (already projected) continental zones with grid tiles and projection centres.

2 Design and Geometry

2.1 Datum

As spatial reference the WGS84-ellipsoid (World Geodetic System 1984) was chosen for the ellipsoidal coordinates on the Earth's surface. These are necessary for the addressing of locations in the global perspective, e.g. during the assignment of satellite scenes to the subgrids. Here the ellipsoid's metrics:

Table 1: The WGS84 Ellipsoid parameters

Major Axis **a**	$6378137m$
Flattening **f**	298.257223563^{-1}
Prime Meridian	$0.0°$
Unit	$0.0174532925199433°$

2.2 Zones

The Equi7Grid is a regular grid which defines each location implicitly with a fixed sampling distance relative to a set of linear axis; here two orthogonal ones. As opposed to a single grid for the whole globe, the Equi7Grid separates the globe into seven subgrids (zones) of identical type of projection. Reducing the extent of a projected grid (in respect to the Earth curvature) reduces negative effects from geometric distortions, like data oversampling or disordered pixel neighbour relationships.

Considering findings of the study of (Bauer-Marschallinger et al., 2014), and with TU-Wien's processor- and user requirements in mind, the zone borders were optimised by following requirements:

1. Landmasses should form compact entities
2. Borders should be preferably over oceans
3. Countries should preferably be not split

The seven grids cover the Earth entirely without gap and with 50km overlap over land borders. A global overview of the delineation is shown in Figure 3.

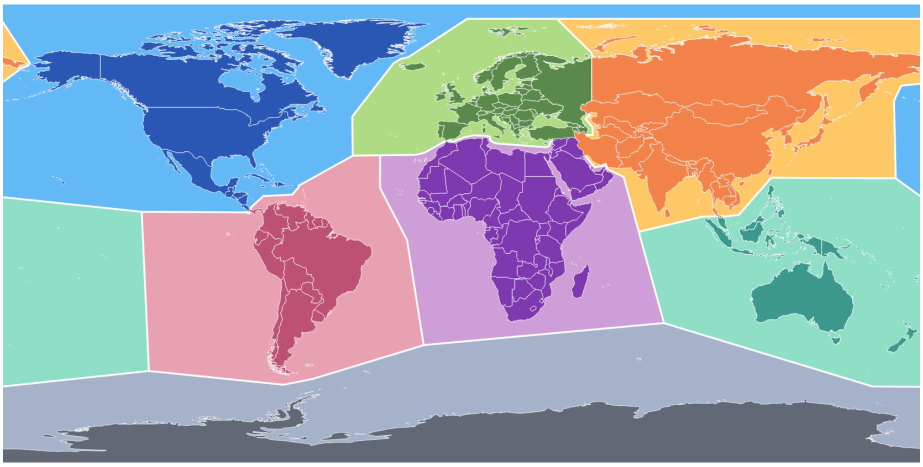


Figure 3: Continental zone partitioning into the seven subgrids, projected for global overview to the Plate Carrée (aka geographic aka Lat-Lon, using WGS84 coordinates).

The zones are defined by manually created shapefiles following above rules 1-3 in the WGS84 space. After transformation to the individual projections (see Section 2.3), zone borders over land are buffered to a 50km extent to allow correct spatial filter operations also on the zone limits. Table 2 lists the zones' basic facts.

Table 2: The Equi7Grid zones.

Zone	**Short Name**	**Colour**	**Covered Land Area**
			[Mio. km^2]
North America	NA	blue	24.2
Europe	EU	green	9.7
Asia	AS	orange	38.6
South America	SA	red	17.9
Africa	AF	purple	33.6
Oceania	OC	turquoise	11.2
Antarctica	AN	gray	12.3

2.3 Projections

All seven zone are projected from ellipsoidal coordinates (lat/lon) in WGS84 to planar grids using the *Equidistant Azimuthal Projection*. Figure 4 exemplifies the projection in oblique aspects.

2.3.1 The Azimuthal Equidistant

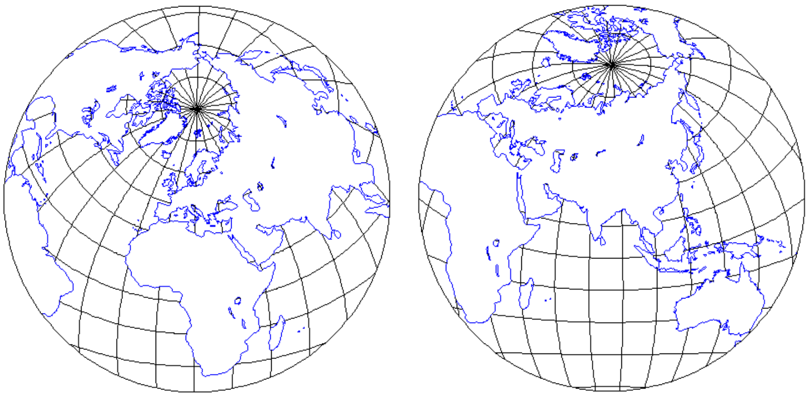


Figure 4: The Azimuthal Equidistant Projection in oblique aspect centred over Austria (left) and Nepal (right). Linear scales emanating from the projection centre are undistorted. Distortion of angles and areas increases with distance to the centre.

The calculation of the planar coordinates x and y (the *forward projection*) implies the solving of the *inverse geodesic problem*, that is

$$dx = c \sin Az \tag{1}$$

$$dy = c \cos Az \tag{2}$$

$$x = dx + FE \tag{3}$$

$$y = dy + FN \tag{4}$$

where x and y the are location's Easting and Northing, c is the length and Az is the azimuth from north of the geodesic line between the location and the projection centre (ϕ_0, λ_0), FE the false Easting, and FN the false Northing. The *inverse projection* from planar to ellipsoidal coordinates (geodetic latitude ϕ and longitude λ) depicts the *direct geodetic problem* and starts with the determination of Az and c:

$$dx = x - FE \tag{5}$$

$$dy = y - FN \tag{6}$$

$$Az = \arctan \frac{dy}{dx} \tag{7}$$

$$c = \sqrt{dx^2 + dy^2} \tag{8}$$

Both, the forward and inverse projection of the ellipsoid involve the solving of elliptic integrals that are favourably computed with numerical methods. Snyder (1987) gives approximating formulae and general information on the projection. However, these formulae lead to significant geometric inaccuracies in areas far from the projection centre. Thus, a more recent approach following findings of (Karney, 2011, 2013) is selected for the transformation between geographical and projected coordinates (degrees and metres; see Section 3.1).

2.3.2 Equi7Grid Projections

The parameters of the Azimuthal Equidistant have been individually optimised in means of minimising data oversampling estimated by the mean *grid oversampling factor* as described in Bauer-Marschallinger et al. (2014). The optimised parameters for each zone are listed in Table 3. For Antarctica, the South Pole is conveniently chosen as origin, since it is almost co-located with the the optimal origin and the additional error is insignificant. False Easting and -Northing are set so that negative coordinates are avoided.

Table 3: The Equi7Grid projection parameters for the Azimuthal Equidistant. With λ_0 as central meridian and ϕ_0 as latitude of origin.

Parameter	λ_0	ϕ_0	False Easting	False Northing
Zone / Unit	°E	°N	m	m
North America	−111.0	47.5	8264722.18	4867518.35
Europe	24.0	53.0	5837287.82	2121415.70
Asia	94.0	47.0	4340913.85	4812712.92
South America	−60.5	−14.0	7257179.24	5592024.45
Africa	21.5	8.5	5621452.02	5990638.42
Oceania	131.5	−19.5	6988408.54	7654884.54
Antarctica	0.0	−90.0	3714266.98	3402016.51

The individual *Well-Known-Text*-strings giving the full georeference information are the following:

America

```
PROJCS["Azimuthal_Equidistant",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",
    SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich
    ",0.0],UNIT["Degree",0.017453292519943295]],PROJECTION["
    Azimuthal_Equidistant"],PARAMETER["false_easting",8264722.17686],
    PARAMETER["false_northing",4867518.35323],PARAMETER["
    central_meridian",-97.5],PARAMETER["latitude_of_origin",52.0],UNIT["
    Meter",1.0]]
```

Europe

```
PROJCS["Azimuthal_Equidistant",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",
    SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich
    ",0.0],UNIT["Degree",0.017453292519943295]],PROJECTION["
    Azimuthal_Equidistant"],PARAMETER["false_easting",5837287.81977],
    PARAMETER["false_northing",2121415.69617],PARAMETER["
    central_meridian",24.0],PARAMETER["latitude_of_origin",53.0],UNIT["
    Meter",1.0]]
```

Asia

```
PROJCS["Azimuthal_Equidistant",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",
    SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich
    ",0.0],UNIT["Degree",0.017453292519943295]],PROJECTION["
    Azimuthal_Equidistant"],PARAMETER["false_easting",4340913.84808],
    PARAMETER["false_northing",4812712.92347],PARAMETER["
    central_meridian",94.0],PARAMETER["latitude_of_origin",47.0],UNIT["
    Meter",1.0]]
```

South America

```
PROJCS["Azimuthal_Equidistant",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",
    SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich
    ",0.0],UNIT["Degree",0.017453292519943295]],PROJECTION["
    Azimuthal_Equidistant"],PARAMETER["false_easting",7257179.23559],
    PARAMETER["false_northing",5592024.44605],PARAMETER["
    central_meridian",-60.5],PARAMETER["latitude_of_origin",-14.0],UNIT
    ["Meter",1.0]]
```

Africa

```
PROJCS["Azimuthal_Equidistant",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",
    SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich
    ",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["
    Azimuthal_Equidistant"],PARAMETER["false_easting",5621452.01998],
    PARAMETER["false_northing",5990638.42298],PARAMETER["
    central_meridian",21.5],PARAMETER["latitude_of_origin",8.5],UNIT["
    Meter",1.0]]
```

Oceania

```
PROJCS["Azimuthal_Equidistant",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",
    SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich
    ",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["
    Azimuthal_Equidistant"],PARAMETER["false_easting",6988408.5356],
    PARAMETER["false_northing",7654884.53733],PARAMETER["
    central_meridian",131.5],PARAMETER["latitude_of_origin",-19.5],UNIT
    ["Meter",1.0]]
```

Antarctica

```
PROJCS["Azimuthal_Equidistant",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",
    SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich
    ",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["
    Azimuthal_Equidistant"],PARAMETER["false_easting",3714266.97719],
    PARAMETER["false_northing",3402016.50625],PARAMETER["
    central_meridian",0.0],PARAMETER["latitude_of_origin",-90.0],UNIT["
    Meter",1.0]]
```

2.4 Tiling

The seven planar grid zones are independently divided into square tiles. Point of reference is *LowerLeft* – for the tile numbering as well as for the grid coordinates. Figure 6 explains the principles of the tiling system, whereas Figure 5 illustrates them on the example of the Africa grid. Please note the projection centre that coincide with the centre of land area (indicated as white dot).

Tiles are defined in squares that are (partially) overlapping with the grid zone. Consequently, there are sections of tiles that are not defined by the individual grid zone but are actually covering area that is in realm of the neighbouring continent grid zone (bright orange areas in Fig. 5).

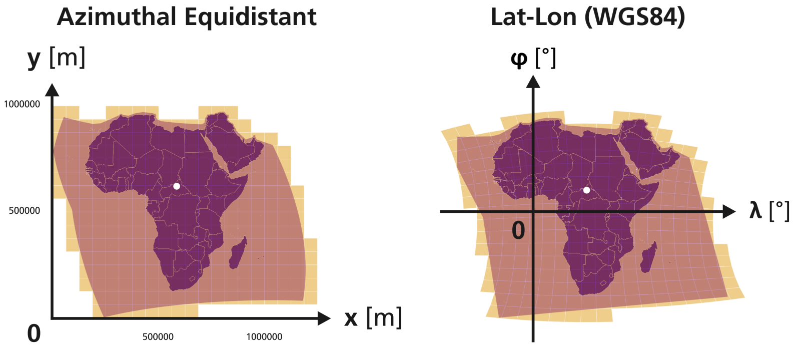


Figure 5: Realisation of the Equi7Grid tiling on the example of the African grid, displayed in the Equi7- and geographic space. Please note the different shapes of the tiles and boundaries. The white dot indicates the centre of origin of the Azimuthal Equidistant projection.

Tiling Levels

The Equi7Grid V14 features multiple levels of tilings, meeting the different requirements during processing images of low and high spatial resolution and data volumes. By reducing the tile extent, the number of pixels per tiled image remains operable even at high resolutions. This setup ensures also that the different levels are mutually aligning and congruent.

In version 14, three levels are available for low, medium and high resolution spatial data. Table 4 lists basic characteristics of these tiling levels **T6**, **T3**, and **T1**:

Shapefile Tile Naming

As evident from Fig. 6, the tiles are not ordinary numbered but named after the coordinates of the lower left corner:

Table 4: The Equi7Grid Tiling Levels for different target samplings.

Tiling Level Code	**T6**	**T3**	**T1**
Tile Extents	600km	300km	100km
Typical Pixel Sampling	500m / 75m	40m	10m / 5m
Samples (1 Axis)	1200 / 8000	7500	10000 / 20000

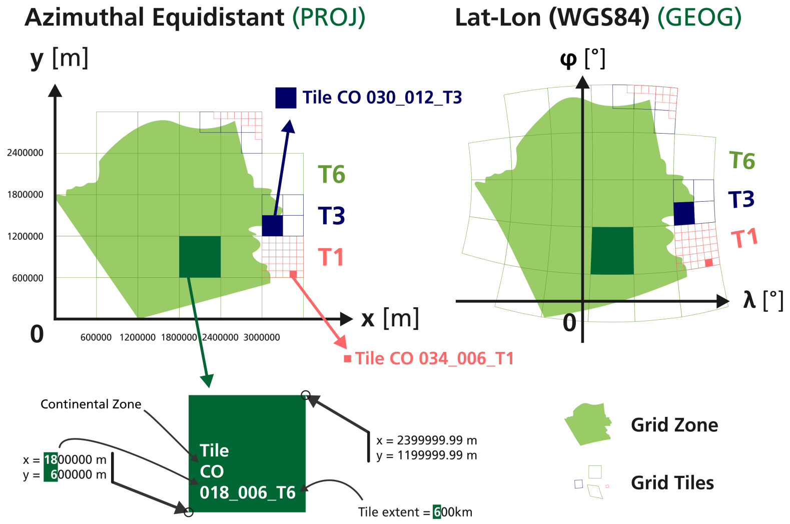


Figure 6: Schematic relationship of the Equi7 subgrids (left, folder name PROJ) and the geographic Lat-Lon coordinate system (right, folder name GEOG). With exemplary tile namings in green, blue and orange for T6, T3, and T1 tile layer, respectively. CO is a placeholder for the grid continent's acronym as in Tab. 2.

```
Unique Tilename = CoSampM_EeeeNnnnTt

Co = continental zone acronym
Samp = the grid's pixel sampling [unit 1m]
eee = Easting lower left corner [unit 100km]
nnn = Northing lower left corner [unit 100km]
Tt = tile extent in 100km
```

And as example:

```
Tilename in longform = AF500M_E018N006T6
Tilename in shortform = E018N006T6
```

Figure 7 displays as example the Europe subgrid with the zone boundary and the T6-tiling.

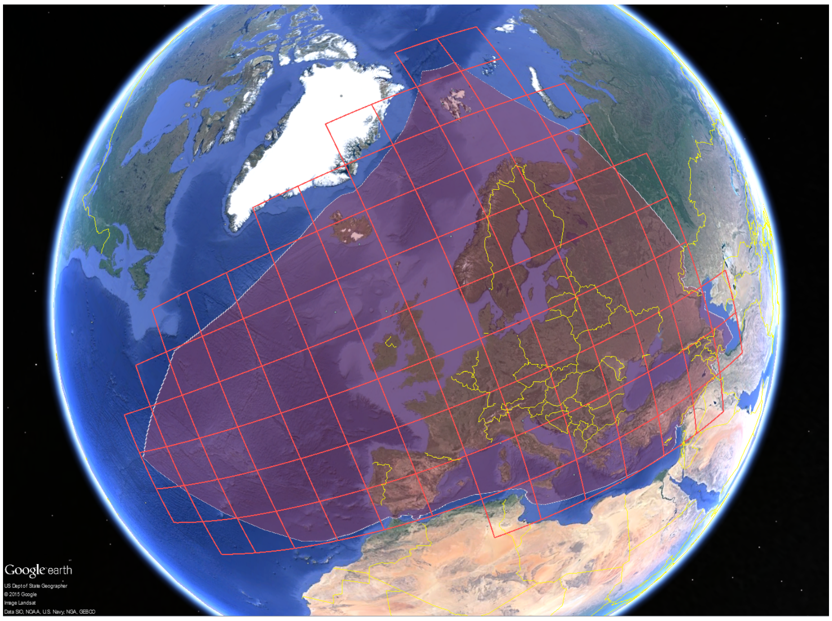

Google earth
US Dept of State Geographer
© 2015 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Figure 7: The subgrid for European displayed as kmz-file in Google Earth.

Tiling Statistics

When it comes to the design of data processing engines, the number of tiles and furthermore the number of tiles covering land surfaces are of special interest. Table 5 summarises these statistics.

Table 5: Statistics of Equi7Grid V14 Tiling Levels in comparison to Earth's surface area as from Wikipedia. Displaying, per Tiling Level, the number of total tiles, tiles over land and the total area of all tiles and corresponding ratios.

	Area Total	*Area Land*	% Land
Wikipedia - Earth surface area [km^2]	510072000	148940000	***29%***

Zone	*Tiles Total*	*Tiles Land*	*% Land*
Tiling Level T6			
AF	266	150	56%
AN	213	73	34%
AS	228	171	75%
EU	94	60	64%
NA	286	137	48%
OC	429	176	41%
SA	273	87	32%
WORLD	***1789***	***854***	***48%***
Total Tile Area [km^2]	644040000	307440000	
Ratio to Area from Wikipedia	126%	206%	
Tiling Level T3			
AF	1004	498	50%
AN	792	217	27%
AS	829	595	72%
EU	340	198	58%
NA	1065	443	42%
OC	1611	426	26%
SA	1009	276	27%
WORLD	***6650***	***2653***	***40%***
Total Tile Area [km^2]	598500000	238770000	
Ratio to Area from Wikipedia	117%	160%	
Tiling Level T1			
AF	8603	3815	44%
AN	6793	1514	22%
AS	7089	4547	64%
EU	2823	1374	49%
NA	9185	3155	34%
OC	13830	2027	15%
SA	8645	2055	24%
WORLD	***56968***	***18487***	***32%***
Total Tile Area [km^2]	569680000	184870000	
Ratio to Area from Wikipedia	112%	124%	

2.5 Pixel Locating and Indexing

The Equi7Grid relates locations on the Earth with points defined in a set of planar subgrids. As dealing with satellite imagery, the location of image pixels with an areal extent must be efficiently handled.

In Figure 8, the Equi7Grid point location rules are schematically displayed. It shows exemplary how to relate location to the projected subgrids and to the tiles.

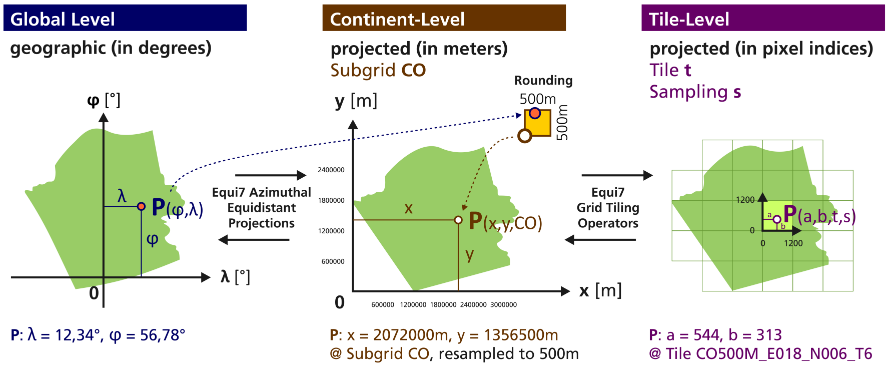


Figure 8: Schematic relationship of locations on the globe, in the Equi7 subgrids and Equi7 tiles. Below, for each level a coordinate example is given.

The following sections describe the transformation from geographic to projected to tiled. The inverse is then trivial and not described.

From Geographic to Projected

All locations on the globe should have a representation in the Equi7Grid. Completeness is given by the Equi7Grid, but not uniqueness in the globe-to-grid projection: Theoretically, every location can be described by all seven continental subgrids. But practically, only locations in the overlapping land areas are described by more than one subgrid. So, for some land areas, on geographic location can have two or three representations in the Equi7Grid.

In the Equi7Grid, the continental zone of a pixel's location is determined. Then, it's projected location in the continental subgrid is calculated. This coordinate transformation from the geographic space in degrees to projected space in meters is done with the Azimuthal Equidistant Projections as defined in Equations 4, 8, and 16. The result is in the unit meters and is geo-referenced at its lower-left corner.

Depending on the pixel sampling s in meters, some coordinate rounding is necessary during coordinate transformation from geographic to projected: After precise coordinate transformation, the closest pixel centre is determined by rounding the yielded *x* and *y*:

$$x_{Equi7\_CO\_subgrid} = (x_{precise} \mod s) + \frac{s}{2} \tag{9}$$

$$y_{Equi7\_CO\_subgrid} = (y_{precise} \mod s) + \frac{s}{2} \tag{10}$$

Since the reference location is the lower left corner, the $\frac{s}{2}$ can be skipped and pixel's coordinate in the Equi7-subgrid is simply then:

$$x_{Equi7\_CO\_subgrid} = x_{precise} - (x_{precise} \mod s) \tag{11}$$

$$y_{Equi7\_CO\_subgrid} = y_{precise} - (y_{precise} \mod s) \tag{12}$$

To sum up, each location in the continental zone is defined individually by its Easting and Northing in integers of meters, rounded down to the closest lower left pixel corner of the grid's target sampling.

Applying these equations to the example in Figure 8 yields the following:

$$\begin{aligned} x_{precise} &= 2072204m \\ y_{precise} &= 1356978m \\ x_{Equi7\_CO\_subgrid} = 2072204 - (2072204 \mod 500) &= 2072000m \\ y_{Equi7\_CO\_subgrid} = 1356978 - (1356978 \mod 500) &= 1356500m \end{aligned}$$

From Projected to Tiled

The Equi7Grid Tiling Operators take care of addressing the location of pixels as segment of the Equi7-tiles.

According to Section 2.4, these operators as follows and yield horizontal *a* and vertical *b* pixel indices in respect to the overlapping tile (lower-left-indexing):

$$a_{tile} = \frac{x_{Equi7\_CO\_subgrid} \mod t_{tile}}{s} \tag{13}$$

$$b_{tile} = \frac{y_{Equi7\_CO\_subgrid} \mod t_{tile}}{s} \tag{14}$$

The Tile Extent t_{tile} is in meters and can take on values as listed in Table 4.

Applying these equations to the example in Figure 8 yields the following:

$$a_{tile} = \frac{2072000 \quad \bmod 600000}{500} = 544$$

$$b_{tile} = \frac{1356500 \quad \bmod 600000}{500} = 313$$

3 Production and Structure

3.1 Projection Implementation

The Equi7Grid uses a precise algorithm including iterations, as described in Karney (2013), yielding effectively following equation for inverse and direct geodetic problem, here in the python-notation of the *GeographicLib* library:

$$[c, Az] = \text{Geodesic.WGS84.Inverse}(\phi_0, \lambda_0, \phi, \lambda) \quad (15)$$

$$[\phi, \lambda] = \text{Geodesic.WGS84.Direct}(\phi_0, \lambda_0, Az, c) \quad (16)$$

The definitions for the Equi7Grid-projections based on above equations are computed with a python software on a Linux system, using *PROJ 6.2.1* via *GDAL/OGR v3.0.2*.

Python Package

All relevant coordinate transformations, from geographic to projected & from projected to tiled, are implemented in the `Equi7Grid` python package. Examples how to use these function can be found in the python tests of this package: `https://github.com/TUW-GEO/Equi7Grid/blob/master/tests/test_equi7grid.py`.

3.2 Grid Defining Files

The Equi7Grid Version 14 constitutes of four main components:

- Shapefiles
  - Geometries
- DEM Geotiffs
  - 7 Zone DEMs
  - DEM Tiles
- Code and Seedfiles
  - Generating code
  - Seed shapefiles for zone and country boundaries in WGS84
  - Projection files
- Documentation

Figure 9 displays the file structure and lists all elements of the Equi7Grid. There are three types of datasets:

Zone Shapefile `EQUI7_V14_co_PROJ_ZONE.shp`

A (vector-) shapefile determining the outline of the continental subgrids. `co` holds place for the continent name. `proj` for the coordinate space.

Tiles Shapefile `EQUI7_V14_co_PROJ_TILE_Tt.shp`

A (vector-) shapefile carrying the outline of the zone's tiles.

Land Shapefile `EQUI7_V14_co_PROJ_LAND.shp`

A (vector-) shapefile describing the land polygons, based on the layer "Land" from Natural Earth Physical Vectors datasets at 1:10 scale, accessed from:

`https://www.naturalearthdata.com/downloads/10m-physical-vectors/.`

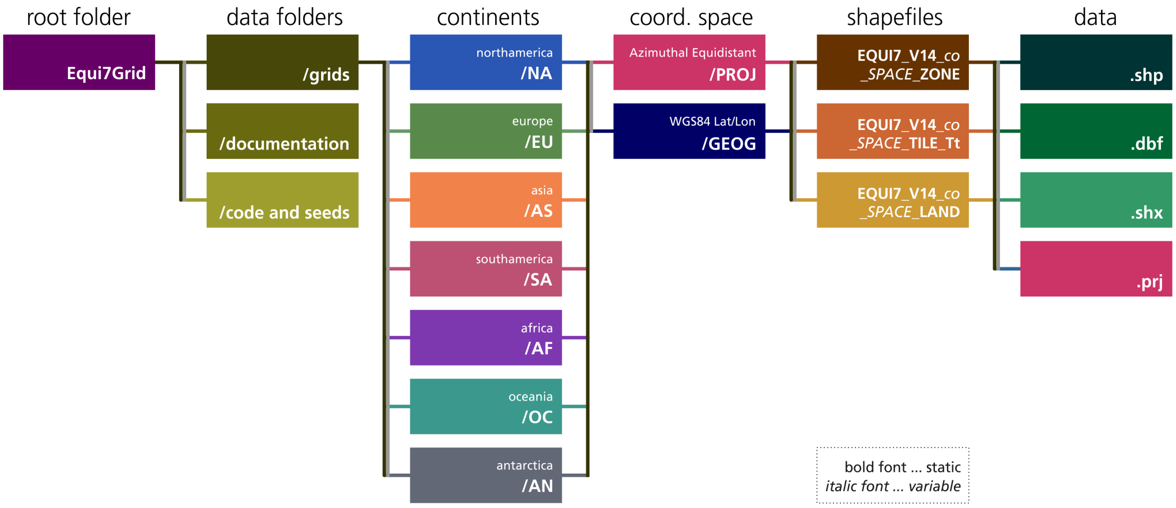


Figure 9: File structure of the Equi7Grid Version 14. Documentation and code- and seed-files are not displayed. co is a placeholder for the continent's name; SPACE for the coordinate space (PROJ = Azimuthal Equidistant; GEOG = geographic/ellipsoidal).

4 Usage

Apart from directly using the Equi7Grid-projected Zone/Tile shapefiles and DEM geotiffs, a python class object named `Equi7Grid` is created, providing several functionalities for using it in the python processing environment.

4.1 The Equi7Grid Class

Basic examples of usage towards geometric and geographic operations can be found in the test section of the python code:

`https://github.com/TUW-GEO/Equi7Grid/blob/master/tests/test_equi7grid.py`

4.2 Resampling Images to the Equi7Grid

The module

`image2equi7grid.py`

of the `Equi7Grid` package should help to easily bring your raster images to the Equi7Grid spatial reference.

5 Glossary

General Terms

Pixel A pixel is a square segment of a raster image, carrying a value.

Alignment is the property of a pixel point in level n also being a pixel point in level $n+1$

Congruency is the capability of decomposing a tile of level n into smaller cells of level $n+1$.

An **ellipsoid** is a closed surface formed by the rotation of an ellipse about its shorter (minor) axis.

A **coordinate system** (CS) is a set of rules to define how coordinates are assigned to points, usually by means of associated axes.

A **geographic coordinate system** (GCS) is a CS describing the location on the Earth by a set of coordinates, usually geographic latitude and longitude.

An **ellipsoidal coordinate system** (ECS) is a CS specified by geodetic latitude and longitude on an ellipsoid.

Height is the distance to a reference surface along a line perpendicular to that surface.

A **meridian** is the intersection of an ellipsoid by a plane containing the short axis of the ellipsoid.

Geodetic latitude is the angle from the equatorial plane to the perpendicular to the ellipsoid through a given point.

Geodetic longitude is the angle from the prime meridian plane to the meridian plane of a given point.

A **coordinate reference system** (CRS) is a CS that defines position, scale and orientation of its axes defined with respect to an object, which for our purposes is the Earth.

A **datum** is the information that is required to fix a CS to an object. In general terms, a datum positions and orientates a CS to turn it into a CRS.

A **geodetic datum** defines the relationship of a two or three dimensional CS to the Earth. It further defines the position of the origin, the scale, and the orientation of the axes of an ECS with respect to a particular Earth ellipsoid. For global applications, the World Geodetic System (WGS 84) is commonly used.

A **geodetic coordinate reference system** (GCRS) is an ECS defined for a particular geodetic datum.

A **coordinate conversion** is a change of coordinates from one CRS to another, in which the CRSs are either based on the same datum or, if they are based on different datums, no algorithm has been applied to transform the coordinates from one datum to the other.

A **coordinate transformation** is a change of coordinates from one CRS to another in which the CRSs are based on different datums. In this case, a coordinate transformation algorithm is applied to convert the coordinates of one CRS to conform to the datum of the other CRS.

In general, a **map projection** is a set of mathematical functions that transform geographic locations on the sphere or ellipsoid to a plane, the map. All maps distort the surface in some manner during transformation. A map projection depicts a coordinate conversion from an ECS to a plane. It is defined by various projection parameters, including the projection ellipsoid, the ECS coordinates of the projection origin in the plane, the orientation of the projected axes in the plane with respect to the ECS, and other projection-specific parameters.

A **projected coordinate reference system** (PCRS) is a CRS derived from a GCRS by applying a specified map projection. Note that the projection ellipsoid specified in the map projection may or may not match the datum specified in the GCRS.

Northing is the distance in a CS, positive northwards and negative southwards along an east-west reference line.

Easting is the distance in a CS, positive eastwards and negative westwards along an north-south reference line.

Equi7 Nomenclature

The complete definition of the spatial referencing by means of the Equi7 is called the **Equi7Grid**.

A **continental zone** is the part of the Earth assigned to a individual continent.

The Equi7Grid distinguishes between the ellipsoidal **geographic space** in geodetic latitude and longitude and the planar **projected space** in metres defined for each continental zone.

A **subgrid** is orthogonal axis system for each continental zone.

A **tile** is a square part of a subgrid named after 1) the continental zone, 2) the location of its lower left corner, and 3) the tiling level.

The **tiling level** describes the tiles’ extent.

References

Bauer-Marschallinger, B., Sabel, D., and Wagner, W. (2014). Optimisation of global grids for high-resolution remote sensing data. *Computers & Geosciences*, 72(0):84 – 93.

Karney, C. F. F. (2011). Geodesics on an ellipsoid of revolution. Technical report, SRI International.

Karney, C. F. F. (2013). Algorithms for geodesics. *Journal of Geodesy*, 87(1):43–55.

Snyder, J. P. (1987). *Map projections – A working manual*. Number 1395. USGPO.