Reference3D Product Description

Version 5.2 - May 30th, 2005

This edition supersedes previous versions

Acronyms

ANDORRE	Atelier Numérique D'Ortho Rectification
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CC	Confidence (or Correlation) Coefficient
CNES	Centre National d'Études Spatiales
DIMAP	Digital Image MAP (encapsulation format supporting data display with an Internet browser)
DTED	Digital Terrain Elevation Data
DXF	Drawing eXchange Format (AutoCAD)
GeoView	IGN image processing software
HRG	High Resolution Geometric (SPOT 5 sensor)
HRS	High Resolution Stereoscopic (SPOT 5 sensor)
IGN	Institut Géographique National (France's survey and mapping agency)
JPEG, JPG	Joint Photographic Expert Group
Mb, Tb	Megabytes, Terabytes
DTM **DEM**	Digital Terrain Model Digital Elevation Model
CE90	Circular Error (90% confidence level)
LE90	Linear Error (90% confidence level)
SD	Serveur de Déspatialisation (Spot Image's data acquisition & processing server)
STANAG	STANdardisation AGreement (OTAN)
SRTM	Shuttle Radar Topographic Mission
SVG	Scalable Vector Graphics
TIFF - GeoTIFF	Tag Image File Format – GeoTIFF is the geocoded version of TIFF
XML	eXtensible Markup Language – Format of certain files in DIMAP

Contents

1 Introduction

This document describes the specifications and format for the Reference3D database, which chiefly comprises SPOT 5 HRS data covering pre-defined regions of interest. This database is planned to cover at least 30 million square kilometres within the first five years. Reference3D is co-produced by Spot Image and IGN, France's national survey and mapping agency.

Reference3D comprises three registerable layers of data:

- a DTED level 2 DEM
- an HRS orthoimage with a resolution of near five metres
- a full layer of quality and traceability data

These three layers are encapsulated within a DIMAP profile for display using an Internet browser.

Reference3D is designed for a broad range of applications:

- the DEM layer provides a ready-to-use solution for thematic applications
- the orthoimage layer can be used to generate vector databases or interpreted for map updating at scales around 1 :50 000 to 1:100 000
- Reference3D is a sophisticated product that supports low-cost production of highly accurate application-specific DEMs
- Reference3D will be used as an accurate source for producing orthoimages automatically: for example, the ANDORRE system currently under development will allow Spot Image and every SPOT terminal owner to automatically produce SPOT orthoimages. Reference3D is also well suited to generating orthoimages from other satellite data.

2 Product features

2.1 Reference3D contents

Reference3D comprises three layers of information:
- a DTED level 2 DEM
- an HRS orthoimage
- a layer of quality and traceability information

2.1.1 Data structure

Reference3D stores data as tiles of one square degree (about 100 km x 100 km) covering the Earth's landmasses and aligned along parallels and meridians. HRS DEMs and orthoimages are expressed in geographic coordinates. DEMs have a post spacing of one arc second (about 30 metres at the equator) and orthoimages a post spacing of one-sixth of an arc second (about 5 metres). The longitude spacing increases with latitude above 50 degrees, in accordance with the DTED level 2 standard, to maintain nearly constant post spacing.

2.1.2 Coverage

The HRS instrument cannot guarantee complete coverage of some zones due to weather conditions, stereopair correlation limits due to the landscape, and the inherent limits of the sensor when imaging very mountainous terrain (B/H ratio of 0.8). Gaps in DEMs therefore will be filled locally by interpolation or with other source data.

Unless specified, the standard ratio of HRS data within one Reference3D tile is 90% or more.

2.1.3 Quality layer

The quality layer provides:
- general information about each tile, DEM and orthoimage layer
- statistical data derived during the block triangulation process
- references of source image or DEM data, including footprints in polygon form
- binary masks containing georeferenced data for DEM quality control

2.1.4 Product format

Reference3D products are in DIMAP format. Each product is a set of XML files referencing the DEM and orthoimage layers, as well as the metadata.

The advantage of DIMAP is that it allows users to read Reference3D data with off-the-shelf software. For example, they can read the DTED level 2 DEM and the GeoTIFF orthoimage with any software supporting these formats.

2.1.5 Tile naming

The identifier of each Reference3D one-degree-square tile is built from the geographic coordinates of its South-West corner using a **<N/S>XX<E/W>YYY** model, where XX is the corner latitude and YYY the corner longitude in degrees.

2.2 Data acquisition

The SPOT 5 satellite's HRS instrument acquires stereopairs for Reference3D according to assigned priorities in programming requests. The satellite tasking schedule is revised periodically to include new programming requests.

2.3 Production process

2.3.1 Block triangulation of HRS data strips

This phase determines Reference3D location accuracy.

- A mean orbit is calculated from the forward and aft data strips
- Intra-strip tie points are selected in HRS images
- Tie points in HRG images are selected wherever tri-stereo production is planned
- HRS stereopairs are grouped into triangulation blocks
- Each block is modelled and tie points are selected
- Where possible, Z points near coastlines are selected

Note: no ground control points are used.

2.3.2 Generation of DEMs per HRS data strip

DEMs are extracted by automatic correlation.

- Epipolar resampling of both HRS images to be correlated
- Epipolar resampling of HRG images wherever tri-stereo production is planned
- Three-pass correlation at different sampling steps (120, 60 and 30 meters)
- Recording of confidence coefficients (CCs)
- Calculation of parallaxes
- Filling of gaps not correlated by interpolation and filtering

2.3.3 Assembly into survey areas of 12 to 20 HRS data strips

- Bias correction of strip DEMs where elevation difference is more than 3 m
- Assembly and merging of DEMs and CCs of adjoining data strips
- Generation of dxf and svg assembly files
- “Elastic surface” smoothing (inversely proportional to CCs)
- Histogram equalization of images (for global display only)
- Mosaïc of HRS or HRG images
- Delineation of water and clouds bodies along tiles edges
- DEMs and CCs divided into 1° x 1° tiles

2.3.4 Processing of large water bodies in each tile

This step is run for water bodies more than 600 metres across.

- Interactive delineation and generation of the water mask MWa
- Interactive flattening of DEM to constant elevation, calculated automatically

2.3.5 Processing of DEM artefacts in each tile

- Interpolation of small holes (< 3 km²)
- Interpolation of artificial peaks and valleys in even terrain
- Raising of negative Z areas near coastlines
- Filling of large gaps (> 3 km²) by SPOT, ASTER or SRTM data, or GTOPO30 data in very flat areas with generation of the exogenous mask MEx
- In external DEMS : elevation bias correction according to elevation differences observed in overlapping areas
- Interactive generation of the control mask MQu

2.3.6 Orthoimage production and packaging

- Calculation of final orthoimage from aft HRS images

- Orthoimage divided into tiles
- Generation of the clouds / snow mask MCl
- Generation of final Reference3D product in DIMAP format
- Format and content checking

3 Reference3D layer specifications

3.1 DEM layer

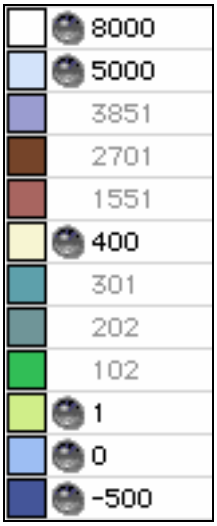
3.1.1 Data format and encoding

The DEM layer of Reference3D is compliant with the DTED level 2 standard.

The DEM contains elevation values in metres, encoded as 16-bit signed integers with the most significant bit first.

The –32767 value in the DTED format that indicates a null value is not used. Instead, the most likely value is given with a reliability indicator in the quality masks.

For the symbolisation of quicklook and thumbnail files, the following radiometric scale is used :



Les radiometric values are interpolated between 2 altitude levels.

3.1.2 Datum

DEM values are given in geographic coordinates with respect to WGS84.
The vertical datum is EGM 96.

3.1.3 DEM post spacing – Number of nodes per tile

The DEM post spacing is in accordance with the DTED level 2 standard, as shown in the table below:

Tile latitude	Latitude post spacing	Longitude post spacing	Nodes
0° to 50° North or South	1 arc second	1 arc second	3601 * 3601
50° to 70° North or South	1 arc second	2 arc seconds	3601 * 1801
70° to 75° North or South	1 arc second	3 arc seconds	3601 * 1201
75° to 80° North or South	1 arc second	4 arc seconds	3601 * 901
80° to 90° North or South	1 arc second	6 arc seconds	3601 * 601

There is an overlap of one post between neighbouring tiles.

Grid nodes are ordered South to North in data records of constant longitude. Successive records are arranged West to East.

3.1.4 DEM geometric accuracy

The DEM accuracy specifications below apply to DEMs generated from HRS imagery and not to DEMs derived from external sources.

- **Absolute elevation accuracy**
  linear error with respect to EGM96 (confidence level 90%)
  flat or rolling terrain (slope ≤ 20 %)..... **10 m**
  hilly terrain (20 % < slope ≤ 40 %)..... **18 m**
  mountainous terrain (slope > 40 %)..... **30 m**

- **Absolute planimetric accuracy**
  circular error with respect to WGS84 (confidence level 90%) ..... **15 m**

- **Relative elevation accuracy within tile**
  linear error (confidence level 90%)
  flat or rolling terrain (slope ≤ 20 %)..... **5 m**
  hilly terrain (20 % < slope ≤ 40 %)..... **15 m**
  mountainous terrain (slope > 40 %)..... **28 m**

- **Relative planimetric accuracy within tile**
  circular error (confidence level 90%) ..... **8 m**

3.1.5 Landform characteristics

Landform characteristics supplement geometric accuracy specifications, in particular for local features in a DEM. Special attention is paid to the following features, which must be visible in the DEM:

✓ **Critical landforms other than islands** (confidence level 96%)
- features larger than 200 m by 100 m
- and an elevation difference with the surrounding terrain greater than 30 m

✓ **Islands** (confidence level 99%)
- islands larger than 200 m by 100 m
- and an elevation difference with the surrounding water greater than 15 m

OR
- islands larger than 300 m by 300 m

✓ **Watersheds and drains** (confidence level 96%)
- Drains wider than 150 m

✓ **Cliffs** (confidence level 99%)
- longer than 200 m
- higher than 30 m with a local slope greater than 80%

✓ **Artefacts**
- artefacts larger than 300 m by 200 m
- and an elevation error greater than 40 m

must cover less than 1% of the 1° x 1° square

✓ **Water bodies**

Water bodies are:
- oceans and open seas with an elevation of 0 m
- lakes of constant elevation where they are more than 600 m across

Landscapes surrounding water bodies are not artificially raised.

3.1.6 Tile uniformity and continuity

No elevation discontinuities exhibiting a bias greater than 2 m are accepted within a Reference3D tile.

3.2 Orthoimage layer

HRS images—as well as HRG, ASTER and other images, wherever used—are orthorectified using the Reference3D DEM.

3.2.1 Format and datum

The orthoimage is in GeoTIFF 8-bit format.

Values are given in geographic coordinates with respect to WGS84.

3.2.2 Orthoimage post spacing – Number of nodes per tile

The orthoimage post spacing is one-sixth of the DEM spacing, that is, about five metres at the equator. The longitude post spacing increases with latitude as shown in the table below:

Tile latitude	Latitude post spacing	Longitude post spacing	Nodes
0° to 50° North or South	1/6 arc second	1/6 arc second	21606 * 21606
50° to 70° North or South	1/6 arc second	1/3 arc second	21606 * 10806
70° to 75° North or South	1/6 arc second	1/2 arc second	21606 * 7206
75° to 80° North or South	1/6 arc second	2/3 arc second	21606 * 5406
80° to 90° North or South	1/6 arc second	1 arc second	21606 * 3606

The orthoimage footprint registers exactly with the DEM. Orthoimages of two adjoining tiles usually have an overlap of six pixels (see paragraph 5.3 below).

3.2.3 Orthoimage performance specifications

- **Absolute planimetric accuracy**
  Circular error with respect to WGS84 (confidence level 90%)..... **16 m**
- **Residual cloud cover**: 10% or less

3.3 Quality layer

3.3.1 Source data footprint and type

Reference3D contains the references and ground footprints of source data, in polygon form in DXF and SVG formats.

3.3.2 Quality control masks

Masks are 1-bit GeoTIFF files containing geographic coordinates, with the same post spacing as the DEM. They all refer to the DEM, except the MCl (cloud/snow) which describes the orthoimage.

✓ **Water mask (MWa)**

Contains flat maritime or inland water bodies visible in Reference3D orthoimages. It is produced by manual delineation with an orthoimage underlay. The water mask is not significant in zones that are zero-rated in the MCl mask (snow or cloud).

0: sea or water body more than 600 m across
1: no water

✓ **DEM merge mask (MMe)**

Contains areas derived from a single DEM and is generated automatically.

0: single source
1: at least two merged sources or no HRS source (e.g. sea)

✓ **Correlation mask (MCo)**

Generated by a 50% thresholding of CCs.

0: confidence coefficient less than 50%
1: confidence coefficient greater than or equal to 50%

✓ **Cloud/snow mask (MCl)**

Describes the cloud- and ice/snow-covered areas which remain in the Reference3D orthoimage. It is delineated manually using the orthoimage and the DEM. MCl only contains "problematic" areas regarding DEM extraction ; therefore, MCl does not systematically register all snowy areas, as DEM extraction is often possible through a light snow coverage.

0: cloud or snow
1: no cloud nor snow

✓ **Exogenous mask (MEx)**

Indicates areas computed using external data. It is delineated manually.

0: exogenous data
1: no exogenous data

✓ **Regulation mask (MRe)**

Contains DEM artefacts corrected without external data. Water bodies in the MWa mask are not included.

0: artefacts detected and corrected
1: no artefacts

✓ **Visual control mask (MQu)**

Generated by a visual examination of the final DEM. This mask identifies areas in the DEM deemed by the operator not to meet specifications.

0: data do not meet Reference3D specifications
1: data meet Reference3D specifications

✓ **Validated area mask (MVa)**

Contains all areas deemed unsatisfactory in the initial stages of production (some may have been corrected). The MVa mask is generated automatically by merging several other masks:

MVa = MQu+MRe+MCl+MEx

3.3.3 Metadata

✓ **HRS data strip**

The following metadata are provided for each HRS data strip used to produce a tile:

SPOT5SEGMENTS5S1S0210150732178

DESCRIPTION	SEGMENT HRS1 S
DATE	2002-10-15
TIME	07:32:32
INSTRUMENT	HRS1
MODE	B_W
INCIDENCE_ANGLE	-22.957857 (DEG)
VIEWING_ANGLE	0.000000 (DEG)
SUN_AZIMUTH	154.089591 (DEG)
SUN_ELEVATION	39.245105 (DEG)

✓ **Block triangulation**

Tie points:
- number of points
- mean of planimetric residuals (in 10-m pixels)
- standard deviation of planimetric residuals (in 10-m pixels)

Z points:
- number of points used
- mean of Z residuals (in metres)
- standard deviation of Z residuals (in metres)

- ✓ **Mosaic seams in orthoimages**
  Value of planimetric discontinuities (in metres)
- ✓ **DEM**
  number of rows/columns
  coordinates of 4 corners
  post spacing
- ✓ **Orthoimage**
  number of rows/columns
  coordinates of 4 corners
  post spacing
- ✓ **DEM derived from HRS data strips merged to produce tile**
  mean of elevation differences in overlap areas
  standard deviation of elevation differences in overlap areas
- ✓ **Exogenous data**
  Source
  Rotation/translation
- ✓ **General information**
  Geodetic reference system
  Producer reference

4 Quality checks

✓ **Block triangulation**

Checks are performed on:
- tie point planimetric residuals
- Z point elevation residuals

✓ **Production**

Checks are performed on:
- bias between adjacent HRS DEMs
- matching of DEM and water mask with adjoining tiles
- flattening of water bodies in the DEM
- artefact removal in the DEM
- final DEM quality: content (for generation of MQu mask), seams, elevation value statistics
- final orthoimage quality: content, mosaic seams
- format (certification report)
- viewing of DEM, orthoimage and metadata layers in Internet browser

✓ **Reference3D product checks**

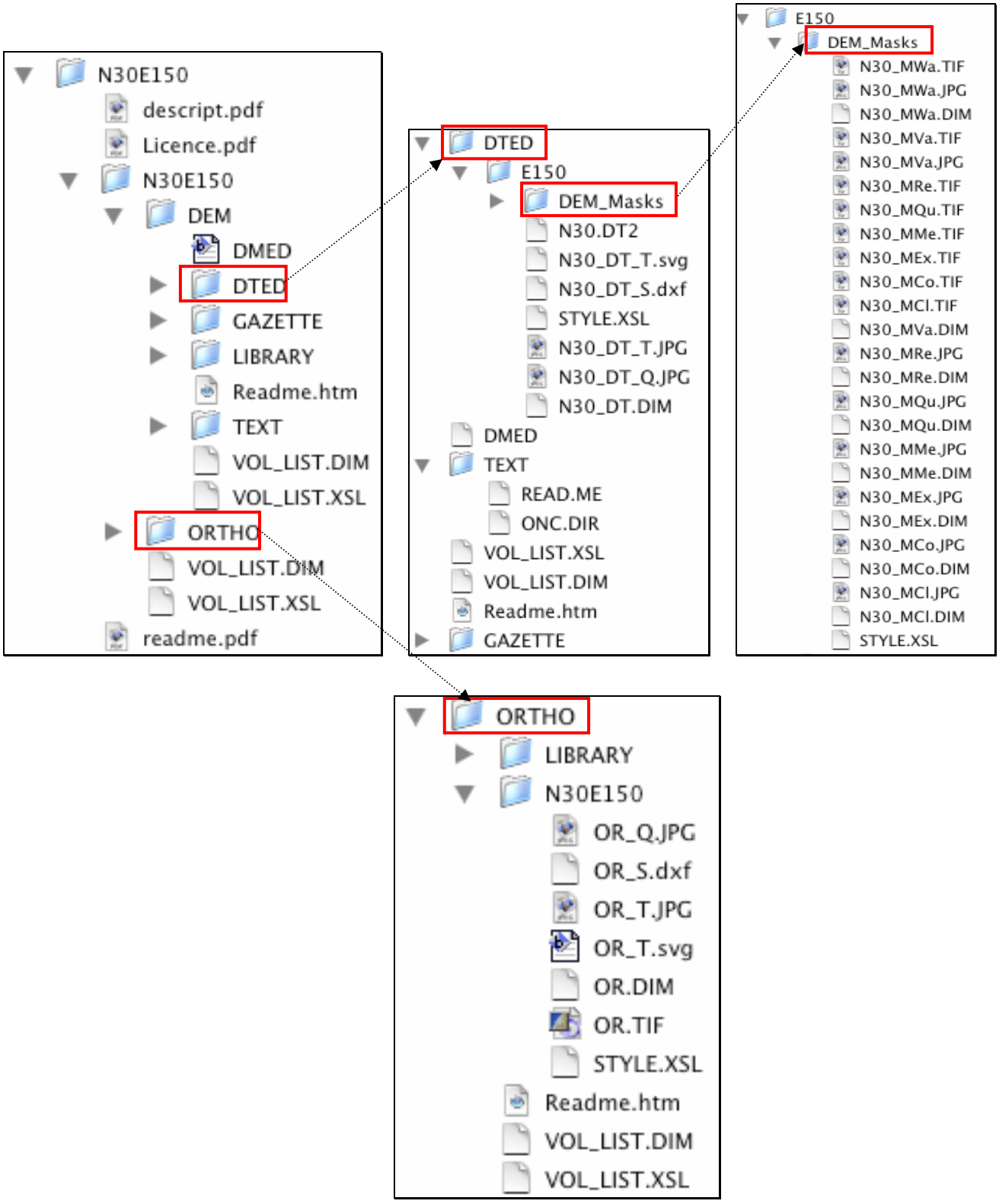
A person outside the production team checks:
- Z min / Z max consistency (against available map or atlas)
- MQu / DEM consistency
- MWa / DEM consistency
- DEM Mme / MEx / svg / dxf consistency
- Orthoimage / MCl / MWa consistency
- orthoimage svg / dxf consistency
- connections between adjacent products : orthoimage, DEM, MCl, MEx and MWa masks
- format

✓ **Final checks on CD-ROM before delivery**
- formats
- visual check of DEM and orthoimage files (on a sample of tiles)
- calculation of relative percentages of 0/1 values in MQu and MVa masks (on a sample of tiles)

5 Reference3D product structure

5.1 File tree

Files containing data for tile N30E150 are organized according to the tree below:

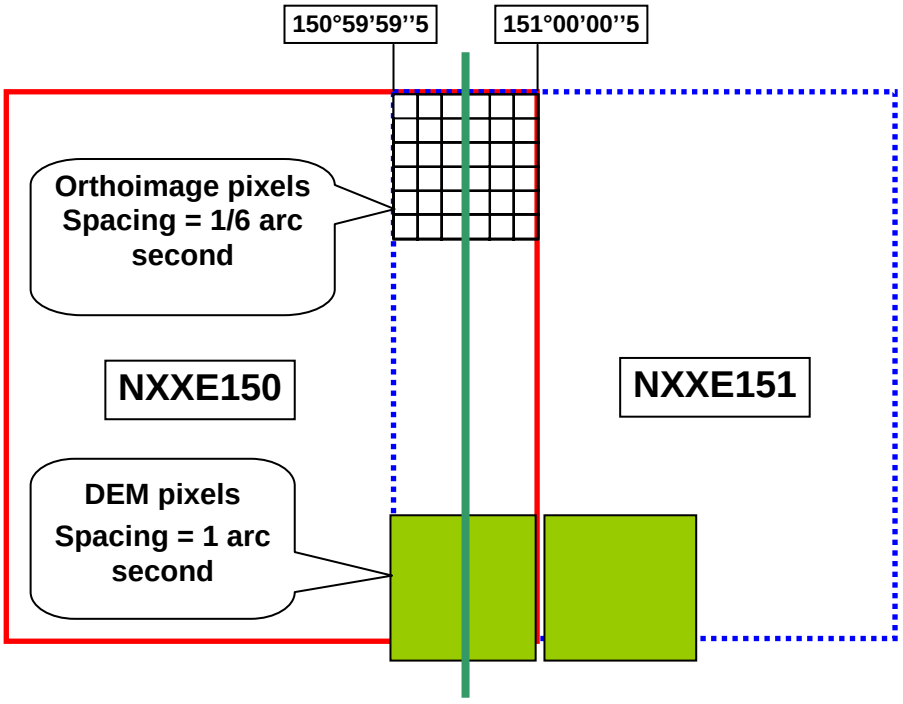


File names are eight characters and file extensions three characters maximum, in accordance with the ISO 9660 standard.

5.2 File formats

File	Format
Tile metadata	XML
Source metadata	XML
DEM metadata	XML
Orthoimage metadata	XML
DEM	DTED 2
Orthoimage	8-bit uncompressed GeoTIFF
DEM quality masks	1-bit uncompressed GeoTIFF
DEM source image footprints	DXF (polygons)
Orthoimage source image footprints	DXF (polygons)
DEM and orthoimage quicklooks	JPEG
DEM and orthoimage thumbnails	JPEG
Quicklooks of DEM and orthoimage source image footprints	SVG

5.3 Tile overlap

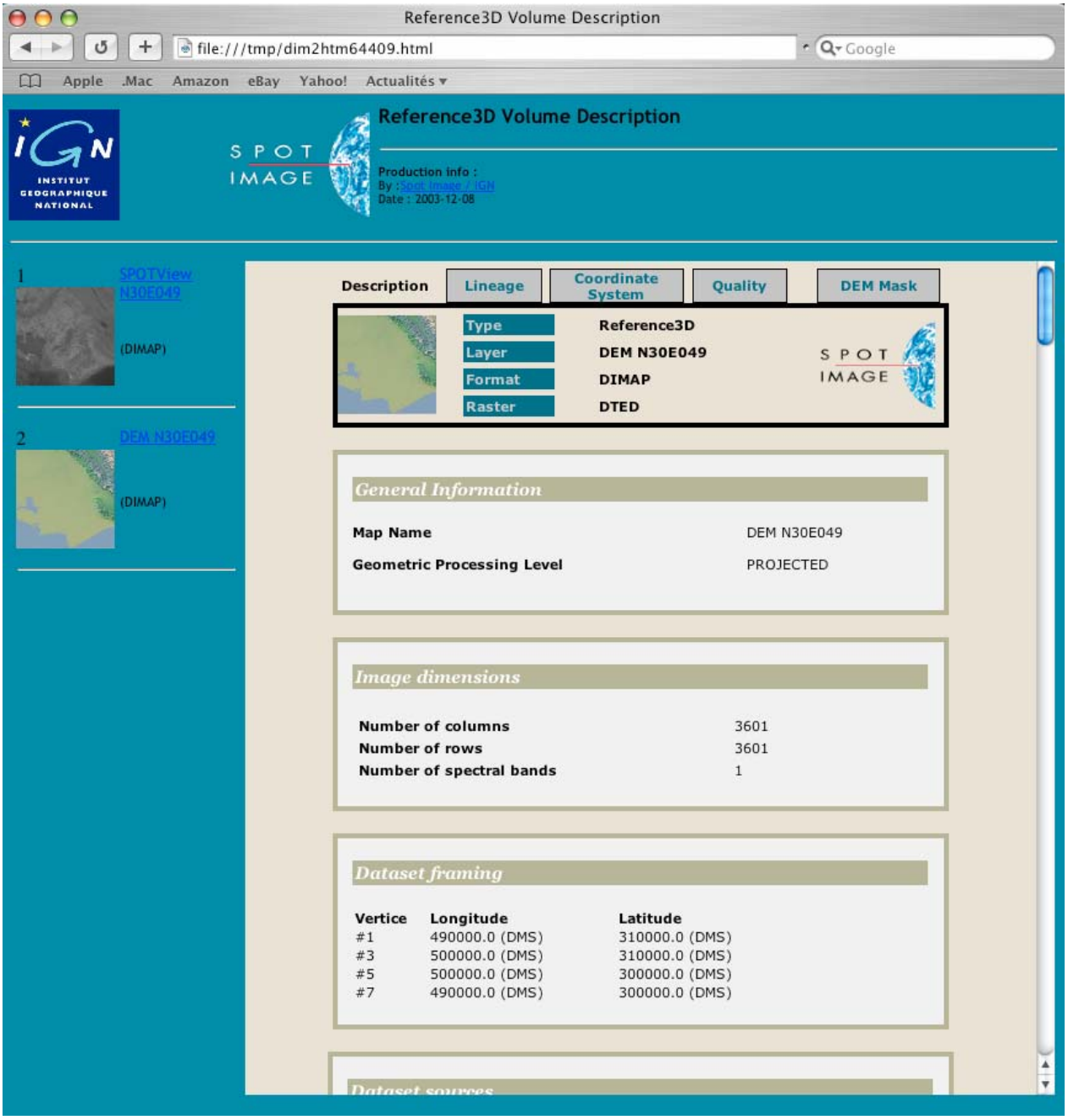


Important : Orthoimage data overlapping the neighbouring tiles (three rows/columns along the four edges of the tile) are only given to ensure that the DEM and orthoimage register exactly. They are provided for information purposes only and Spot Image does not warrant their fitness for any particular use.

5.4 Style sheets

Every Reference3D product in DIMAP format comes with several XSL style sheets that allow its main features to be displayed with an Internet browser.

An example style sheet is shown below:



6 Reference3D file sizes

The appropriate maximum file sizes for each layer of a Reference3D tile can be estimated as shown below. The largest files will be those constituting tiles at latitudes below 50°. File sizes for all other tiles will decrease significantly as latitude increases.

- ✓ **DEM**
  3,600 x 3,600 pixels, two-byte encoded = **25 Mb**
- ✓ **Orthoimage**
  21,606 x 21,606 pixels, one-byte encoded = **445 Mb**
- ✓ **DEM quality control masks**
  3,601 x 3,601 pixels, one-bit encoded = 1.5 Mb per mask, i.e. about **12 Mb** for all 8 masks
- ✓ **Other files**
  Remaining files take up about **3 Mb**.

Giving a total of about 485 Mb per tile.

After 5 years, when Reference3D covers an area of 30 million km² as planned (corresponding to approximately 4,000 tiles), the complete database will take up **2 Tb**.