Open Geospatial Consortium

OGC® OWS-9 Engineering Report - OWS Innovations - Map Tiling Methods Harmonization

Warning

Abstract

This document describes the results of OWS-9 IP on Map Tiling methods harmonization. This engineering report proposes a profile for WMTS that limits the flexibility or the standard and mimics what some other tile initiatives are doing. It also proposes some improvements in WMTS to accommodate the need for requesting several tiles of a region at different scales that has been identified by the GeoPackage team. These recommendations help to better harmonize OSGeo tile standards and mass-market technologies.

Keywords

ogcdoc, ogc document, ows9, ows 9, tiling, wmts, osm

What is OGC Web Services 9 (OWS-9)?

OWS-9 builds on the outcomes of prior OGC interoperability initiatives and is organized around the following threads:

- **Aviation**: Develop and demonstrate the use of the Aeronautical Information Exchange Model (AIXM) and the Weather Exchange Model (WXXM) in an OGC Web Services environment, focusing on support for several Single European Sky ATM Research (SESAR) project requirements as well as FAA (US Federal Aviation Administration) Aeronautical Information Management (AIM) and Aircraft Access to SWIM (System Wide Information Management) (AAtS) requirements.

- **Cross-Community Interoperability (CCI)**: Build on the CCI work accomplished in OWS–8 by increasing interoperability within communities sharing geospatial data, focusing on semantic mediation, query results delivery, data provenance and quality and Single Point of Entry Global Gazetteer.

- **Security and Services Interoperability (SSI)**: Investigate 5 main activities: Security Management, OGC Geography Markup Language (GML) Encoding Standard Application Schema UGAS (UML to GML Application Schema) Updates, Web Services Façade, Reference Architecture Profiling, and Bulk Data Transfer.

- **OWS Innovations**: Explore topics that represent either new areas of work for the Consortium (such as GPS and Mobile Applications), a desire for new approaches to existing technologies to solve new challenges (such as the OGC Web Coverage Service (WCS) work), or some combination of the two.

- **Compliance & Interoperability Testing & Evaluation (CITE)**: Develop a suite of compliance test scripts for testing and validation of products with interfaces implementing the following OGC standards: Web Map Service (WMS) 1.3 Interface Standard, Web Feature Service (WFS) 2.0 Interface Standard, Geography Markup Language (GML) 3.2.1 Encoding Standard, OWS Context 1.0 (candidate encoding standard), Sensor Web Enablement (SWE) standards, Web Coverage Service for Earth Observation (WCS-EO) 1.0 Interface Standard, and TEAM (Test, Evaluation, And Measurement) Engine Capabilities.

The OWS-9 sponsors are: AGC (Army Geospatial Center, US Army Corps of Engineers), CREAF-GeoViQua-EC, EUROCONTROL, FAA (US Federal Aviation Administration), GeoConnections - Natural Resources Canada, Lockheed Martin Corporation, NASA (US National Aeronautics and Space Administration), NGA (US National Geospatial-Intelligence Agency), USGS (US Geological Survey), UK DSTL (UK MoD Defence Science and Technology Laboratory).

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OGC® OWS-9 Engineering Report - OWS Innovations - Map Tiling Methods Harmonization

1   Introduction

1.1   Scope

This OGC® document proposes a profile for WMTS that limits the flexibility of the standard and mimics other tile initiatives that are currently being used. It also proposes some other improvements as Change Requests to the current version of WMTS. E.g. accommodate the need for a single request that allows recovering multiple tiles of a region at different scales. These recommendations help to better harmonize OSGeo tile standards and Mass-Market technologies.

This OGC® document is applicable to WMTS clients and servers and the propose profile is brought before the WMS Standards working group to be considered in future revisions of the standard.

1.2   Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

Name	Organization
Joan Masó	CREAF

1.3   Revision history

Date	Release	Editor	Primary clauses modified	Description
2013-01-07	1	Joan Masó	All	First completed version for OWS-9

1.4   Future work

Future work is expected to be done in WMS SWG, and thus some of these recommendations are to be considered as Change Requests for the next version of WMTS.

1.5   Forward

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

2   References

The following documents are referenced in this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

OGC 06-121r3, *OGC® Web Services Common Standard*

OGC 07-057r7 *OpenGIS® Web Map Tile Service Implementation Standard*

In addition to this document, this report includes several XML Schema Document files as specified in Annex A.

3   Terms and definitions

For the purposes of this report, the definitions specified in Clause 4 of the OWS Common Implementation Standard [OGC 06-121r3] and in OpenGIS® Web Map Tile Service Implementation Standard [OGC 07-057r7] shall apply. In addition, the following terms and definitions apply.

4   Conventions

4.1   Abbreviated terms

Most of the abbreviated terms listed in subclause 5.1 of the OWS Common Implementation Specification [OGC 06-121r3] and in subclause Web Map Tile Service

(WMTS) Implementation Standard, version 1.0.0 OGC [OGC 07-057r7] apply to this document, in addition to the following abbreviated terms:

Some more frequently used abbreviated terms are:

TMS   Tile Map Service (OSGeo)

OSM   Open Street Map

4.2   Used parts of other documents

This document uses significant parts of document [OGC 06-121r3]. To reduce the need to refer to that document, this document copies some of those parts with small modifications. To indicate those parts to readers of this document, the largely copied parts are shown with a light grey background (15%).

4.3   Data dictionary tables

The UML model data dictionary is specified herein in a series of tables. The contents of the columns in these tables are described in Table 1.

Table 1 — Contents of data dictionary tables

Column title	Column contents
Names (left column)	Two names for each, including parameter or association (or data structure). The first name is the UML model attribute or association role name. The second name uses the XML encoding capitalization specified in Subclause 11.6.2 of [OGC 06-121r3]. The name capitalization rules used are specified in Subclause 11.6.2 of [OGC 06-121r3]. Some names in the tables may appear to contain spaces, but no names contain spaces.
Definition (second column)	Specifies the definition of this parameter (omitting un-necessary words such as "a", "the", and "is"). If the parameter value is the identifier of something, not a description or a definition, the definition of this parameter should read something like "Identifier of TBD".
Data type and value (third column) or Data type (if there are no second items, they are included in rows of table)	Normally contains two items: The mandatory first item is often the data type used for this parameter, using data types appropriate in a UML model, in which this parameter is a named attribute of a UML class. Alternately, the first item can identify the data structure (or class) referenced by this association, it then references a separate table used to specify the contents of that class (or data structure). The optional second item in the third column of each table should indicate the source of the values for this parameter, the alternative values, or other value information; unless the values are clear enough from other listed information.
Multiplicity and use (right or fourth column) or	Normally contains two items: The mandatory first item specifies the multiplicity and optionality of this parameter in this data structure, either "One (mandatory)", "One or more (mandatory)", "Zero or one (optional)", or "Zero or more (optional)".

Column title	Column contents
Multiplicity (if there are no second items, they are included in rows of table)	The second item in the right column of each table should specify how any multiplicity other than "One (mandatory)" shall be used. If that parameter is optional, under what condition(s) shall that parameter be included or not included? If that parameter can be repeated, for what cases is that parameter repeated?

When the data type used for this parameter, in the third column of such a table, is an enumeration or code list, all the values specified shall be listed along with its. When this information is extensive, these values and meanings should be specified in a separate table that is referenced in the third column of this table row.

The data type of many parameters, in the third table column, is specified as "Character String type, not empty". In the XML Schema Documents specified herein, these parameters are encoded with the xsd:string type, which does NOT require these strings not be empty.

The contents of these data dictionary tables are normative, including any table footnotes.

5   WMTS Harmonization ER overview

In OWS-6, WMTS standard draft was tested and the lessons learned where incorporated in WMTS 1.0 (OGC 07-057r7). Several implementations of different tile services based on other standards or not based on any standard that are still in competition with WMTS. There are 2 different problems. On one hand there are some standards that are similar but cannot be directly supported by WMTS (such as TileCache that orders the J axes in the opposite direction; in fact TileCache can be configured to invert the J axe and generate compatible WMTS tile indices), also there are new approaches to store tiles directly in databases such as MBTiles and there are the mass market providers such Google and Bing tiles that are influencing OpenStreetMap to adopt the same tile pattern that actually is a WMTS RESTful pattern but they don't recognize it (e.g. they just lack a ServiceMetadata document). A set of suggestions to harmonize the panorama has to be collected in an ER and some modification on WMTS can be requested to better support other implementations (such as supporting direct and reversed J ordering) in the change request form. Some of these changes can also be tested in a WMTS service and client.

Clause 6 proposes a profile of WMTS called WMTS Simple as a collection of requirements that are complemented by the Annex B. This profile will be submitted to the WMS.SWG for adoption. Clauses 7 to 11 propose other modifications that can be considered Change Requests to the current version of WMTS. Particularly, Clause 7 describes a new GetTiles operation (schemas for this operation are described in Annex A), Clause 8 calls for a definition of a TIME parameter, Clause 9 describes how the tile origin can be extended to support other corner origins, Clause 10 exposes how current standard supports multiple endpoints and Clause 11 discuses the steps needed to adapt WMTS to the new OGC policies and IEFT URL template standard.
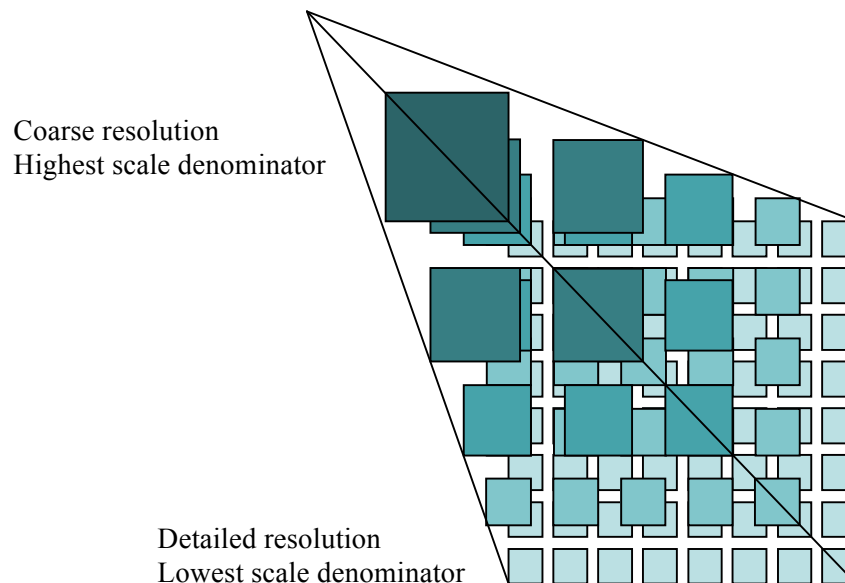
Figure 1 — Tile Matrix Set representation of WMTS

6   WMTS Simple

WMTS Simple profile restricts the flexibility of the WMTS OGC 07-057r7 by adding a new set of requirements. With the aim to make the creation of services and clients simpler, it combines data coming from different services, including some WMTS and some tile implementations that do not claim to be WMTS (e.g some current distributions of OSM), even if they follow most of the current WMTS requirements. At the same time, any client compatible with WMTS 1.0 will be immediately compatible with this profile, even though many current services will have to undergo some changes on how tiles are exposed if they are to follow this particular profile. The aim is to align the WMTS standard to other popular tile initiatives which are less flexible but widely adopted.

The naming conventions used in OSM are shown here:
http://wiki.openstreetmap.org/wiki/Slippy_map_tilenames

6.1   Motivation for this profile

This profile has a double objective: to facilitate the combination of layers coming from different services and to make tile clients applications easier to implement.

One of the main difficulties of WMTS client implementations is to position the tiles in the right place on the screen. The URL of the tile does not include any direct reference to the georeference of the tile (no bounding box). This is due to the original design of the WMTS, which makes the maximum effort to avoid a situation where a single tile has a variety of requests and thus making cache mechanism more inefficient. This has been

addressed by avoiding the use of floating point numbers that could have several text translations as well as floating point inaccuracies.

In a general WMTS, the only way of knowing the georeference of a tile in CRS coordinates is to extract the TileMatrixSet and the TileMatrix identifier from the request, retrieve the ServiceMetadata document and read the TileMatrix definition (xpath: /Capabilities/Contents/TileMatrixSet[ows:Identifier={TileMatrixSet}]/ TileMatrix[ows:Identifier={TileMatrix}]) in order to know the TopLeftCorner, ScaleDenominator, TileWidth and TileHeight values. Then, by extracting the TileRow and TileCol from the request it is possible to apply the math explained in subclause H.2 of the WMTS core standard (of the 07-057r7) and finally, get the bounding box of the tile which will enable to place the tile in the right place of the client screen.

Note that if the client is combining layers coming from the same or different services, the procedure described above should be performed on each layer. In some cases, it could be impossible that two layers share the same ScaleDenominator and under these circumstances the interpolation of tile images is the only solution for layer overlay, even if raster interpolation can degrade the image quality, particularly if text information or textures were used to produce the tile. The WellKnownScaleSet concept was introduced to mitigate these effects. By recommending a set of WellKnownScaleSet, the WMTS standard tries to guarantee that a wide number of layers and servers share the same sets of ScaleDenominators. Nevertheless, even if they have the same ScaleDenominator, tiles with the same TileRow and TileCol values can have different bounding boxes depending on the TopLeftCorner value and the TileWidth and TileHeight.

This specification imposes a common tile framework that clients can hardcode in its implementation as a constant pattern. By doing so, clients know that all layers share the same set of scales (which can be used to present a common zoom dropdown list from a zoom bar) and then just by knowing TileMatrixSet, the TileMatrix identifier, the TileCol and the TileRow values of a tile, the client can immediately know the bounding box of it, without having to read the ServicesMetadata document nor having to maintain a different dynamic tile pattern for each layer.

6.1.1 Indirect benefits

By specifying the use of the REST binding, the caching mechanisms can be more efficient than in a situation where the three bindings can be used to access the same tile. Additionally, changing the extent of a layer to cover more territory will not end up in changing the tile indices and invalidating the tile cache.

6.2 WMTS Simple requirement class

Requirements class *simple-profile* establishes how WMTS services can follow the WMTS Simple Profile. Its identifying URL is given by http://www.opengis.net/spec/wmts_simple/1.0/req/simple-profile.

6.2.1 General

A service that declares conformance to this document also adheres to the Web Map Tile Service (WMTS) Implementation Standard, version 1.0.0 [OGC 07-057r7] standard.

Req 1   req/simple-profile/wmts-1-0:
A WMTS service implementing this profile SHALL conform with WMTS 1.0
Dependency: http://www.opengis.net/spec/wmts/1.0/req

6.2.2 Profile declaration

Req 2   req/simple-profile/wmts-profile-uri:
If a ServiceMetadata document exists, a WMTS service implementing this profile SHALL include one of the following URIs in the ows:Profile element of the ServiceIdentification within a ServiceMetadata document:
http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile
http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile/CRS84

A client that reads this ServiceIdentification document will then be able to know that all the other profile requirements are honoured, assuming a constant relation between TileCol and TileRow and the Bounding Box of the tile.

Note that the existence of a ServiceMetadata document is not mandatory in this profile. Clients may know the URL of a service, the names of the layers and other relevant information by other means rather than the ServiceMetadata document.

6.2.3 REST service bindings

Req 3   req/simple-profile/wmts-profile-rest
A WMTS service implementing this profile SHALL support WMTS 1.0 REST binding.

This does not exclude the server to support other bindings but these can be ignored by WMTS Simple clients.

Req 4   req/simple-profile/wmts-profile-rest-servicemetadata
If a ServiceMetadata document exists, the URL of the service SHALL follow the pattern [http://www.server.bob/path]/1.0.0/WMTSCapabilities.xml (where [http://www.server.bob/path] is a fixed path that will be used in next requirements)

This support is advertised in the ServiceMetadata document using:

```
<ServiceMetadataURL
xlink:href="[http://www.server.bob/path]/1.0.0/WMTSCapabilities.x
ml"/>
```

Clients can ignore the `<ows:OperationsMetadata>` section and the `<WSDL>` element if they exist.

That is perfectly supported by OWS Common 1.1 (the one used in WMTS 1.0).

6.2.4 Mandatory default style

Req 5   req/simple-profile/wmts-profile-default-style
Each layer in a WMTS service implementing this profile SHALL have a style with the identifier "default" that is set as the default style.

If a ServiceMetadata document exists, each layer advertises this style as follows:

```
<Style isDefault="true">
    <ows:Title>default</ows:Title>
    <ows:Identifier>default</ows:Identifier>
</Style>
```

It is recommended that the server uses only one style per layer. If you need to provide the same layer in two different styles, then there is still the possibility to advertise 2 layers connected to the same metadata description in `<ows:Metadata>`.

It would be preferable to remove all references to any style, but style is mandatory in WMTS.

6.2.5 Fixed URL template

Req 6   req/simple-profile/wmts-profile-tile-url-template
A WMTS service implementing this profile SHALL support at least one tile URL template for getting tiles resource back in PNG or JPEG format, furthermore one of those tile URLs SHALL follow exactly this pattern:
`[http://www.server.bob/path]{/layer}{/TileMatrixSet}/{TileMatrix}/{TileCol}/{TileRow}{.file_extension}`
where `file_extension` can be `png`, `jpg`, `jpeg` or blank, where
`[http://www.server.bob/path]` is the same than that used for the ServiceMetadata document and finally, where `{/layer}` is the identifier of the layer or black if the layer identifier is empty).

If a ServiceMetadata document exists, each layer advertises these URL templates as follows:

```
<ResourceURL format="image/png" resourceType="tile"
template="[http://www.server.bob/path]{/layer}{/TileMatrixSet}/{T
ileMatrix}/{TileCol}/{TileRow}.png"/>
<ResourceURL format="image/jpeg" resourceType="tile"
template="[http://www.server.bob/path]{/layer}{/TileMatrixSet}/{T
ileMatrix}/{TileCol}/{TileRow}.jpg"/>
...
```

In practice, this means that a client who knows the URL of the ServiceMetadata document can immediately assume the pattern of the tiles. The only additional thing that needs to know is if the tile format is png, jpeg or both.

If the there is a ServiceMetadata document, the format also has to be advertised in the format element `wmts:layer/ows:Format`.

`{/layer}` shall be interpreted as a `"/"` + the identifier of the layer, or blank if the layer identifier is blank. The same happens with `{/TileMatrixSet}` of the TileMatrixSet identifier. This is in line with the new URI template RFC6570 (http://tools.ietf.org/html/rfc6570) that supersedes the http://tools.ietf.org/html/draft-gregorio-uritemplate-03 mentioned in the WMTS 1.0 document.

When no extension is provided in the URL template, the service is free to provide the tile layers with the optimum format for each case, that is either image/jpeg (for maximum tile compressions) or image/png (for tiles that require some transparency). When this occurs, the ServiceMetadata `wmts:layer/ows:Format` will advertise a "composite" format by using the following string: `image/jpeg, image/png`.

Please note that the ordering of `{TileCol}/{TileRow}` in the URL template is the opposite ordering used in the OGC 07-057r7 WMTS 1.0 examples, but it has been introduced here because it is becoming popular in other tile implementations such as current common distributions of OSM.

NOTE 1   Here I'm assuming that the layer name and the TileMatrixSet identifiers can be blank. This is conformal with the WMTS XSD and does not contradict OWS Common 1.0, which relies on ISO19115 and defines it as a CharacterString that can always be empty.

By forcing this URL template pattern in the RESTful binding, a WMTS Simple interaction does not support any extra dimension (e.g. time, elevation, etc.) values in the request. It is still possible that the service supports extra dimensions in other bindings (i.e. KVP or SOAP) or in other URL templates that are not WMTS Simple conformant. In this case, a WMTS Simple server that has layers with extra dimensions will respond a WMTS Simple RESTful request with the 'default' value of the extra dimensions.

Please note that we deliberately do not require any `"WMTS"` word in the URL template. This is done because in this profile we want to include some other implementations, such as OSM, which already follows this requirement as it is currently stated.

6.2.6   Fixed TileMatrixSet definition.

Req 7   req/simple-profile/wmts-profile-world-spherical-mercator
A WMTS service implementing this profile SHALL support a TileMatrixSet which identifier will be blank for all its layers. This is a TileMatrixSet where all TileMatrix using a topLeftCorner coordenate of `-20037508.3427892 20037508.3427892`, with tiles values of TileWidth and TileHeight set as `256` and with WellKnownScaleSet iqual to `urn:ogc:def:wkss:OGC:1.0:GoogleMapsCompatible`. If the server offers a ServiceMetadata document, the TileMatrixSet shall be defined only once for each server.

Following req/simple-profile/wmts-profile-tile-url-template, if the name of the TileMatrixSet is empty, the URL template will have no reference to the TileMatrixSet (that implies a CRS). This means that clients can assume that if no TileMatrixSet is specify, then it is assumed that tiles are in the Spherical Mercator CRS with URN `urn:ogc:def:crs:EPSG:6.18:3:3857`.

If a ServiceMetadata document exists, the exact definition of the TileMatrixSet in the ServiceMetadata document will be exactly as listed in Annex 0.

If needed, you can define more that 19 zoom levels to support layers with better resolution. Currently, resolutions up to 24 are normal.

Even if you declare an origin for the whole world, you can still advertise in the ServiceMetadata some TileMatrix limits by using the element `<TileMatrixLimits>` to declare the tiles that are actually available. Nevertheless, the client can decide to ignore this.

Even if this TileMatrixSet is designed for representing the whole world, the Mercator projection cannot represent the poles correctly. If the server needs to represent the poles correctly, it needs to declare support to the profile http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile/CRS84 and follow the next requirement.

Req 8   req/simple-profile/wmts-profile-world-crs84
If the profile declared is http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile/CRS84, a WMTS service implementing this profile SHALL additionally support another TileMatrixSet with identifier `WorldCRS84Quad` for all layers. This is a TileMatrixSet with all TileMatrix using a topLeftCorner coordinate of -180.0,90.0, with tiles values for `TileWidth` and `TileHeight` set as 256 and with `WellKnownScaleSet` iqual to `urn:ogc:def:wkss:OGC:1.0:WorldCRS84Quad`. If the server offers a ServiceMetadata document, this TileMatrixSet SHALL be defined only once for each server.

If a ServiceMetadata document exists, the exact definition of the `TileMatrixSet` in the ServiceMetadata document will be exactly as listed in Annex 0.

Again, even if you declare an origin for the whole world, you can still advertise some TileMatrix limits using the element to declare the tiles that are actually available. Nevertheless, the client can decide to ignore this.

6.3   Polar stereographic projection discussion

In OWS-9 it has been discussed the possibility to include a Polar Stereographic projection, it was suggested as a way to better represent Polar Regions, since Mercator projection is not able to represent Polar Regions and these are dramatically distorted in CRS84. In fact, it has become clear that there is a need to find an independent solution for the Antarctic and Arctic. Currently, for Arctic regions EPSG:3413 (or EPSG:3995) and for Antarctic EPSG:3031 were suggested.

In fact, currently NASA was tiled WMSs services are available at this endpoints:

http://map1.vis.earthdata.nasa.gov/arctic/wms.cgi (Tiled WMS, Arctic Polar Stereographic/EPSG:3995)

http://map1.vis.earthdata.nasa.gov/antarctic/wms.cgi (Tiled WMS, Antarctic Polar Stereographic/EPSG:3031)

During OWS-9 a WMTS server in Polar Stereographic projection was deployed containing near-real-time imagery for the Antarctica taken by the NASA MODIS instruments:

http://map1.vis.earthdata.nasa.gov/wmts-antarctic/wmts.cgi?SERVICE=WMTS&request=GetCapabilities

Here is an example GetTile request:

http://map1c.vis.earthdata.nasa.gov/wmts-antarctic/wmts.cgi?TIME=2012-11-20&SERVICE=WMTS&REQUEST=GetTile&VERSION=1.0.0&LAYER=MODIS_Terra_CorrectedReflectance_TrueColor&STYLE=&TILEMATRIXSET=EPSG3031_250m&TILEMATRIX=0&TILEROW=0&TILECOL=0&FORMAT=image%2Fjpeg

(If the TIME=parameter is omitted, it will return the current day's tile (when available))
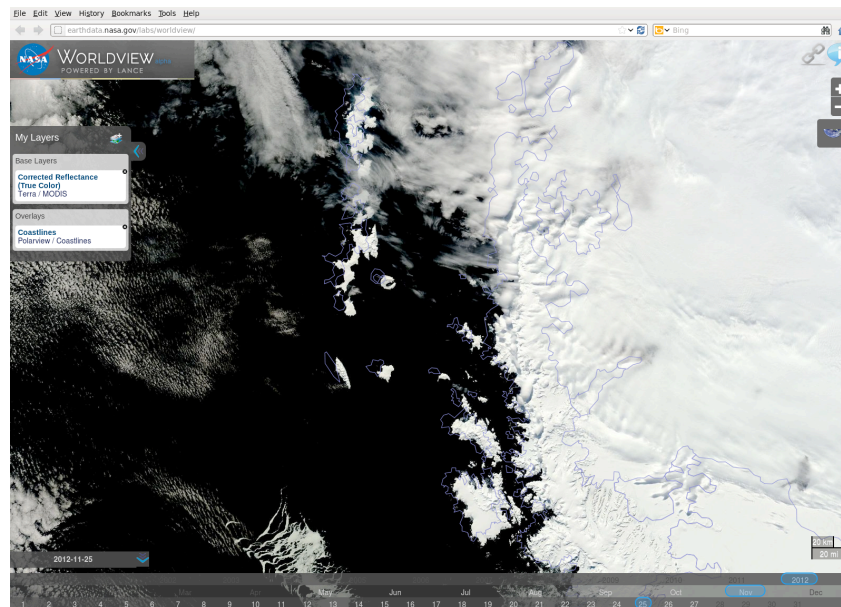
Figure 2 — WorldView WMTS client implementation supporting Polar Stereographic projection

It seems clear that nowadays it is not easy to find a consensus on a CRS based on the Polar Stereographic projection, nor a TileMatrixSet. Furthermore.there is no Mass

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Market implementation considering it. It is also clear that we would need at least 2 TileMatrixSets, one for the North Pole and another one for the Antarctica. We have finally decided that Polar Stereoscopic projections is going to be left out of the WMTS Simple.

6.4   Validation of the capabilities document supporting this profile.

WMTS Simple does not define its own namespace but relays on the http://schemas.opengis.net/wmts/1.0. Experience with XML schema validation demonstrates that generating a new XSD document (different from the core one) in the same namespace can easily generate validation issues. Also, some of the current WMTS simple requirements cannot be translated to XML validation. For that reason, we used Schematron validation for WMTS Simple. This document is validating all requirements except req. 1 (that is validated by the WMTS core schema) and req. 6. This is how our Schematron for Atom looks like:

```
<?xml version="1.0" encoding="UTF-8"?>
<iso:schema
    xmlns:iso="http://purl.oclc.org/dsdl/schematron"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    schemaVersion="ISO19757-3"
    xsi:schemaLocation="http://purl.oclc.org/dsdl/schematron
../../../../sch/2006/schematron.xsd">
    <iso:title>Schematron validation for OWS context</iso:title>
    <iso:ns prefix="wmts" uri="http://www.opengis.net/wmts/1.0"/>
    <iso:ns prefix="ows" uri="http://www.opengis.net/ows/1.1"/>
    <iso:ns prefix="xlink" uri="http://www.w3.org/1999/xlink"/>

    <iso:pattern name="WMTS Simple validation" id="wmts_simple">
        <iso:rule context="/wmts:Capabilities/ows:ServiceIdentification">
            <iso:assert test="ows:Profile='http://www.opengis.net/spec/wmts-
simple/1.0/conf/simple-profile' or
ows:Profile='http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-
profile/CRS84'">A WMTS Simple shall declare support for one of the following
profiles: "http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile" or
"http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-
profile/CRS84".</iso:assert>
        </iso:rule>
        <iso:rule context="/wmts:Capabilities">
            <iso:assert
test="ows:ServiceIdentification/ows:Profile!='http://www.opengis.net/spec/wmts-
simple/1.0/conf/simple-profile' or
wmts:Contents/wmts:TileMatrixSet[ows:Identifier='']/ows:Identifier">A WMTS
Simple following the "http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-
profile" profiles shall declare a TileMatrixSet with blank
identifier.</iso:assert>
```

```
              <iso:assert
test="ows:ServiceIdentification/ows:Profile!='http://www.opengis.net/spec/wmts-
simple/1.0/conf/simple-profile/CRS84' or
wmts:Contents/wmts:TileMatrixSet[ows:Identifier='WorldCRS84Quad']/ows:Identifie
r">A WMTS Simple following the "http://www.opengis.net/spec/wmts-
simple/1.0/conf/simple-profile/CRS84" profile shall declare a TileMatrixSet
with identifier="WorldCRS84Quad".</iso:assert>
              <iso:assert test="wmts:ServiceMetadataURL/@xlink:href">A WMTS
Simple shall advertise a URL template to get the ServiceMetadata
document.</iso:assert>
        </iso:rule>
        <iso:rule context="/wmts:Capabilities/wmts:Contents/wmts:Layer">
              <iso:assert
test="/wmts:Capabilities/ows:ServiceIdentification/ows:Profile!='http://www.ope
ngis.net/spec/wmts-simple/1.0/conf/simple-profile' or
wmts:TileMatrixSetLink/wmts:TileMatrixSet=''">A WMTS Simple following the
"http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile" profiles
shall declare support to a TileMatrixSet with blank identifier for all layers.
Error in layer "<iso:value-of select="ows:Identifier" />"</iso:assert>
              <iso:assert
test="/wmts:Capabilities/ows:ServiceIdentification/ows:Profile!='http://www.ope
ngis.net/spec/wmts-simple/1.0/conf/simple-profile/CRS84' or
wmts:TileMatrixSetLink/wmts:TileMatrixSet='WorldCRS84Quad'">A WMTS Simple
following the "http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-
profile/CRS84" profile shall declare a TileMatrixSet with
identifier="WorldCRS84Quad" for all layers. Error in layer "<iso:value-of
select="ows:Identifier" />".</iso:assert>
              <iso:assert
test="wmts:ResourceURL[@resourceType='tile']/@template">A WMTS Simple shall
advertise a URL template for all layers. Error in layer "<iso:value-of
select="ows:Identifier" />".</iso:assert>
              <iso:assert
test="wmts:Style[@isDefault='true']/ows:Identifier='default'">A WMTS Simple
shall advertise a default style for all layers. Error in layer "<iso:value-of
select="ows:Identifier" />".</iso:assert>
         </iso:rule>
        <iso:rule
context="/wmts:Capabilities/wmts:Contents/wmts:TileMatrixSet[ows:Identifier='']
">
             <iso:assert
test="ows:BoundingBox/@crs='urn:ogc:def:crs:EPSG::3785' and
ows:BoundingBox/ows:LowerCorner='-20037508.3427892 -20037508.3427892' and
ows:BoundingBox/ows:UpperCorner='20037508.3427892 20037508.3427892'">A WMTS
Simple shall declare support for "http://www.opengis.net/spec/wmts-
simple/1.0/conf/simple-profile" shall have a TileMatrixSet with blank
identifier and BoundingBox in urn:ogc:def:crs:EPSG::3785 (-20037508.3427892 -
20037508.3427892) x (20037508.3427892 20037508.3427892)</iso:assert>
```

```
            <iso:assert
test="wmts:WellKnownScaleSet='urn:ogc:def:wkss:OGC:1.0:GoogleMapsCompatible'">A
WMTS Simple shall declare support for "http://www.opengis.net/spec/wmts-
simple/1.0/conf/simple-profile" shall have a TileMatrixSet with blank
identifier and
WellKnownScaleSet='urn:ogc:def:wkss:OGC:1.0:GoogleMapsCompatible'</iso:assert>
            <iso:assert test="count(wmts:TileMatrix[ows:Identifier='0'])=1 and
wmts:TileMatrix[ows:Identifier='0']/wmts:ScaleDenominator='559082264.0287178'
and wmts:TileMatrix[ows:Identifier='0']/wmts:TopLeftCorner='-20037508.3427892
20037508.3427892' and wmts:TileMatrix[ows:Identifier='0']/wmts:TileWidth='256'
and wmts:TileMatrix[ows:Identifier='0']/wmts:TileHeight='256' and
wmts:TileMatrix[ows:Identifier='0']/wmts:MatrixWidth='1' and
wmts:TileMatrix[ows:Identifier='0']/wmts:MatrixHeight='1'">Wrong definition of
the TileMatrix '0' for WMTS Simple in 'http://www.opengis.net/spec/wmts-
simple/1.0/conf/simple-profile' profile..</iso:assert>
            <iso:assert test="count(wmts:TileMatrix[ows:Identifier='1'])=1 and
wmts:TileMatrix[ows:Identifier='1']/wmts:ScaleDenominator='279541132.0143589'
and wmts:TileMatrix[ows:Identifier='1']/wmts:TopLeftCorner='-20037508.3427892
20037508.3427892' and wmts:TileMatrix[ows:Identifier='1']/wmts:TileWidth='256'
and wmts:TileMatrix[ows:Identifier='1']/wmts:TileHeight='256' and
wmts:TileMatrix[ows:Identifier='1']/wmts:MatrixWidth='2' and
wmts:TileMatrix[ows:Identifier='1']/wmts:MatrixHeight='2'">Wrong definition of
the TileMatrix '1' for WMTS Simple in 'http://www.opengis.net/spec/wmts-
simple/1.0/conf/simple-profile' profile..</iso:assert>
[...]
            <iso:assert test="count(wmts:TileMatrix[ows:Identifier='18'])=1
and
wmts:TileMatrix[ows:Identifier='18']/wmts:ScaleDenominator='2132.729583849784'
and wmts:TileMatrix[ows:Identifier='18']/wmts:TopLeftCorner='-20037508.3427892
20037508.3427892' and wmts:TileMatrix[ows:Identifier='18']/wmts:TileWidth='256'
and wmts:TileMatrix[ows:Identifier='18']/wmts:TileHeight='256' and
wmts:TileMatrix[ows:Identifier='18']/wmts:MatrixWidth='262272' and
wmts:TileMatrix[ows:Identifier='18']/wmts:MatrixHeight='262272'">Wrong
definition of the TileMatrix '18' for WMTS Simple in
'http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile'
profile..</iso:assert>
        </iso:rule>
        <iso:rule
context="/wmts:Capabilities/wmts:Contents/wmts:TileMatrixSet[ows:Identifier='Wo
rldCRS84Quad']">
            <iso:assert
test="ows:BoundingBox/@crs='urn:ogc:def:crs:OGC:1.3:CRS84' and
ows:BoundingBox/ows:LowerCorner='-180 -90' and
ows:BoundingBox/ows:UpperCorner='180 90'">A WMTS Simple supporting
"http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile/CRS84" shall
have a TileMatrixSet with identifier 'WorldCRS84Quad' and BoundingBox in
urn:ogc:def:crs:OGC:1.3:CRS84 (-180 -90) x (-180 -90)</iso:assert>
```

```
[...]
            <iso:assert test="count(wmts:TileMatrix[ows:Identifier='19'])=1
and
wmts:TileMatrix[ows:Identifier='19']/wmts:ScaleDenominator='1066.364791924892'
and wmts:TileMatrix[ows:Identifier='19']/wmts:TopLeftCorner='-180 90' and
wmts:TileMatrix[ows:Identifier='19']/wmts:TileWidth='256' and
wmts:TileMatrix[ows:Identifier='19']/wmts:TileHeight='256' and
wmts:TileMatrix[ows:Identifier='19']/wmts:MatrixWidth='524544' and
wmts:TileMatrix[ows:Identifier='19']/wmts:MatrixHeight='262272'">Wrong
definition of the TileMatrix '19' for WMTS Simple in
'http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile/CRS84'
profile..</iso:assert>
        </iso:rule>
    </iso:pattern>
</iso:schema>
```

Complete Schematron document is referenced in Annex A.

6.5   WMTS Simple implementations in OWS-9

During OWS-9, an implementation of a WMTS Simple was developed showing Satellite images courtesy of GeoEye.
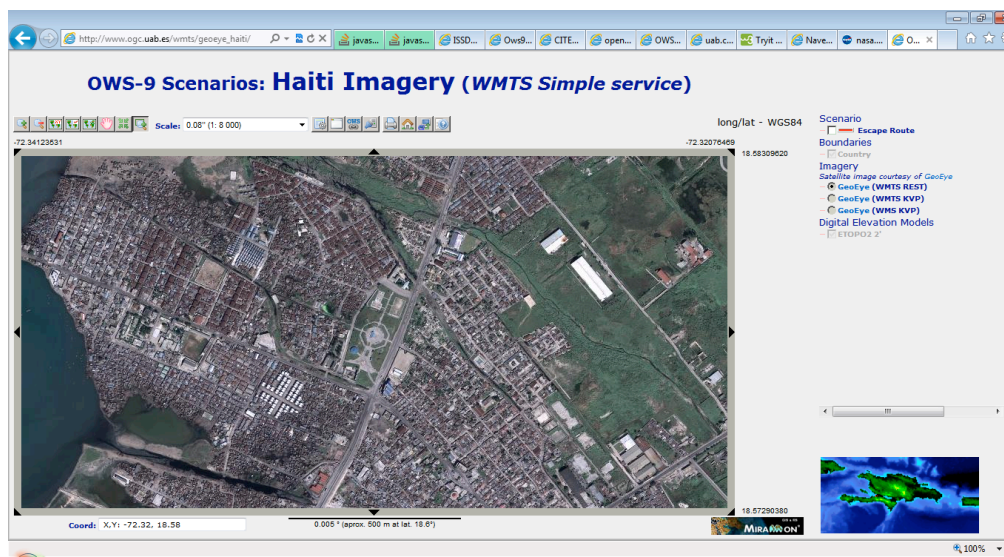
Figure 3 — Haiti Imagery (Satellite image courtesy of GeoEye)

The service uses the following URL template:

http://www.ogc.uab.cat/SITiled/GeoEye_Haiti/GeoEye/{TileMatrixSet}/{TileMatrix}/{TileCol}/{TileRow}.jpg

Supporting req/simple-profile/wmts-profile-world-crs84 and the TileMatrixSet defined in Annex C.2.

7   GetTiles operation

This clause is going to define a new operation for WMTS. The objective of this new operation is for the client to get all tiles that cover a particular region in a single request.

Use cases supporting it:

- ☐ A client that is designed for WMS that want a simple way to receive the tiles that fits in a WMS BBOX.

- ☐ A client so simple that is not able to calculate the tile positions in the screen, and needs to tell the server how to arrange the tiles.

- ☐ Get an XML document that can be transformed into an XHTML visualization of the required tiles (applying XSLT).

- ☐ A client that wants to harvest some/all tiles of a server layer and store them locally for viewing them offline latter.

- ☐ A GeoPackage Manifest needs to link to a tile service tiles with a single URL and mimic what is currently possible with WCS or WFS.

7.1   GetTiles operation

7.1.1   GetTiles operation request

A request to perform the GetTile operation SHALL use the data structure specified in Table 2. This table also specifies the UML model data type, source of values, and multiplicity of each listed parameter, plus the default server behavior when an optional parameter is not included in the operation request.

Table 2 — Parameters in GetTile operation request

Names	Definition	Data type and values	Multiplicity and use
service Service	Service type identifier	Character String type, not empty SHALL be "WMTS"	One (mandatory)
request Request	Operation name	Character String type, not empty SHALL be "GetTile"	One (mandatory)
version Version	Standard version for operation	Character String type, not empty SHALL contain "1.0.0"	One (mandatory)
layer Layer	Layer identifier	Character String type, not empty identifier that is defined in the ServiceMetadata document	One (mandatory)
style Style	Style identifier	Character String type, not empty identifier that is defined in the ServiceMetadata document	One (mandatory)
format Format	Output format of the tiles	Character String type, not empty value that is defined in the ServiceMetadata document	One (mandatory)
Other sample dimensions [a]	Value allowed for this dimension	Character String type, not empty a single value from a list or a range defined in the ServiceMetadata document	Zero or one (optional)
tileMatrix Set TileMatrix Set	TileMatrixSet identifier	Character String type, not empty identifier that is defined in the ServiceMetadata document	One (mandatory)
tileMatrices Tile Matrices	TileMatrix identifiers [b]	Character String type, not empty a list of values for tile matrices identifiers that are defined in the ServiceMetadata document	zero or many [c]
bBox BBox	Bounding box	Four Doubles type. a Bounding Box that defines the area to be recovered [d]	zero or one [e]
width Width	Display width	Positive Integer type The horizontal size of the visual display in pixels	zero or one [g]
height Height	Display height	Positive Integer type The vertical size of the visual display in pixels	zero or one [g]
CollectionF ormat Collection Format	Output format of the tile collection	Character String type, not empty value that is defined in the ServiceMetadata document	One (mandatory)
inclusion Inclusion	Tile inclusion	Enumeration type "embedded" or "linked" [h]	zero or one default value is "embedded

a   The name of this parameter is, in fact, the identifier of the dimension specified in the ServiceMetadata. See WMS 1.3.0 Annex C for reference. This parameter appears once for each dimension specified for this Layer in the ServiceMetadata document.

b   This will be the identifier for the TileMatrix of the desired scale denominator for the TileMatrixSet requested.

c   If the parameter is not provided, all TileMatrices of the TileMatrixSet will be returned.

d   all tiles that are entirely or partially contained in this boundingBox will be returned.

e   If not provided, all tiles of the TileMatrices will be returned.

f   If Included is "embedded", MIME multipart document or GeoPackage are recommended as an output format. If Included is "linked", application/text" is recommended.

g   If provided, the server will return information on where to render the tiles in the screen.

h   "linked" means the client request tiles URLs (in KVP/GetTile or RESTful/tile notation) that will be requested later. "embedded" means that tiles will be embedded in the document format.

7.1.2   GetTiles operation response

The response of a GetTile operation is a text document describing the returned tiles and the binary tiles linked or embedded in a multipart format.

The text format will enumerate a TileCollection or a TileCollection data type elements (see table 3)

Table 3 — Parts of Tile data structure

Names	Definition	Data type and values	Multiplicity and use
identifier Identifier	tile identifier within the document	ows:CodeType, as adaptation of MD Identifier class ISO 19115	Zero or one (optional) [a]
tileURL TileURL	A URL of the tile	AnyURI, not empty.	One (mandatory) [b]
tileMatrix TileMatrix	TileMatrix identifier	Character String type, not empty a value for tile matrices identifiers that are defined in the ServiceMetadata document	One (mandatory)
tileRow TileRow	Row index in the tile matrix	Non negative integer type value between 0 and MatrixHeight -1 of this tile matrix defined in the ServiceMetadata document	One (mandatory)
tileCol TileCol	Column index of tile matrix	Non negative integer type a value between 0 and MatrixWidth -1 of this tile matrix defined in the ServiceMetadata document	One (mandatory)
width Width	Width of the tile	Positive Integer type width of the tile in pixels	Zero or one (optional)

Names	Definition	Data type and values	Multiplicity and use
height `Height`	Height of the tile	Positive Integer type height of the tile in pixels	Zero or one (optional)
top `Top`	Vertical position	Positive Integer type it is the vertical position from the visual display in pixels. A negative value means that the left side of the tile is outside the top-left corner of the display and should be cut when displayed	Zero or one (optional)
left `Left`	Horizontal position	Positive Integer type. it is the horizontal position from the visual display in pixels. A negative value means that the left side of the tile is outside the top-left corner of the display and should be cut	Zero or one (optional)
a If the format does not support file identification or name, the order in the file will be considered.		
b If tiles are linked, it will be an external link. If the tiles are embedded, it will be a link to the internal data (e.g. in a MIME multipart file).		

This format can be encoded in an XML file, a JSON file or even an HTML page.

7.1.3   GetTiles exceptions

When a WMTS Server encounters an error while performing a GetTiles operation, it SHALL return an exception report message as specified in subclause 7.4.1 of OWS Common [OGC 06-121r3]. The allowed standard exception codes SHALL include those listed in Table 4. For each listed exceptionCode, the contents of the "locator" parameter value SHALL be as specified in the right column of Table 4.

NOTE 1   To reduce the need for readers to refer to other documents, four values listed below are copied from Table 8 in subclause 7.4.1 of OWS Common [OGC 06-121r3].

Table 4 — Exception codes for GetTile operation

exceptionCode value	Meaning of code	"locator" value
OperationNotSupported	Request for an operation that is not supported by this server.	Name of operation not supported
MissingParameterValue	Operation request does not include a parameter value, and this server did not declare a default value for that parameter.	Name of missing parameter
InvalidParameterValue	Operation request contains an invalid parameter value.	Name of parameter with invalid value
NoApplicableCode	No other exceptionCode specified by this service and server applies to this exception.	None, omit "locator" parameter

If the client sends a GetTile request using unknown parameters (for example time, elevation or any other dimension that are not advertised in the ServiceMetadata document) these unknown parameters SHALL be ignored by the server and will not cause an exception to be generated.

A Bounding Box completely out of the area covered by the tiles will not be considered an exception, thus it will return an empty tile collection.

When a WMTS server responds with an ExceptionReport and the report is transmitted via HTTP, the WMTS server should set the status code of the HTTP response to the corresponding value for the given exceptionCode values, as shown in Table 5. When the ExceptionReport contains more than one Exception, then the HTTP status code value should be based upon the exceptionCode of the first Exception in the ExceptionReport.

Table 5 — HTTP exception codes and meanings on GetTile operation

	HTTP Status Code	
exceptionCode value	**Code**	**Message**
OperationNotSupported	501	Not implemented
MissingParameterValue	400	Bad request
InvalidParameterValue	400	Bad request
NoApplicableCode	500	Internal server error

7.1.4   GetTiles KVP linked request Example

This example wants to cover a Bounding Box (355000,4619000) x (475000,4539000) (EPSG:23031) and a width of 600 and a height at 200m of pixel size.

A Landsat ortophotographic map of the region can be obtained from this WMS request:

```
http://www.opengis.uab.cat/cgi-
bin/SatCat/MiraMon.cgi?SERVICE=WMS&VERSION=1.1.1&REQUEST=GetMap&S
RS=EPSG:23031&BBOX=355000,4539000,475000,4619000&WIDTH=600&HEIGHT
=400&LAYERS=TotCatalunyaED50&FORMAT=image/jpeg&STYLES=opti_fals&T
IME=2011-03)
```

The region looks like this:

Figure 4 — WMS orthophotographic view of the region

A GetTile request for a single 640x480 tile of a Catalan topographic map is:

```
http://www.opengis.uab.es/cgi-bin/ICCTiled/MiraMon.cgi?
SERVICE=WMTS&VERSION=1.0.0&REQUEST=GetTile&
Layer=Topo250k_Vers5_ICC&Style=&
TileMatrixSet=Cat_topo250k_v5_EPSG23031&TileMatrix=200m&
TileRow=1&TileCol=1&Format=image/jpeg
```

An example of a GetTiles operation request KVP look like a mixture of the previous two ones, but instead of specifying the TileRow and TileCol we have a BBOX and WIDTH and HEIGHT. The example encoded for HTTP GET is:

```
http://www.opengis.uab.es/cgi-
bin/ICCTiled/MiraMon.cgi?SERVICE=WMTS&VERSION=1.0.0&
REQUEST=GetTiles&Layer=Topo250k_Vers5_ICCStyle=&
TileMatrixSet=Cat_topo250k_v5_EPSG23031&TileMatrix=200m&
BBox=355000,4539000,475000,4619000&Width=600&Height=400&
Format=image/jpeg&CollectionFormat=application/xml&
inclusion=linked
```

7.1.5   GetTiles linked response example

A GetTiles operation response for the GetTiles request example in subclause 7.1.4 will be the following XML document.

```
<?xml version="1.0" encoding="UTF-8"?>
<TileCollection
      xmlns="http://www.opengis.net/wmts/1.0/get_tiles"
      xmlns:wmts_gt="http://www.opengis.net/wmts/1.0/get_tiles"
```

```
        xmlns:ows="http://www.opengis.net/ows/1.1"
        xmlns:xlink="http://www.w3.org/1999/xlink"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.opengis.net/wmts/1.0/get_tiles
            ..\wmtsGetTiles_response.xsd
    http://www.opengis.net/ows/1.1
            ../../../ows/1.1.0/owsAll.xsd">">
    <tile>
        <ows:Identifier>200m_1_0</ows:Identifier>
        <fileURL
xlink:href="http://www.opengis.uab.es/SITiled/ICC/Topo250k_Vers5_
ICC/default/Cat_topo250k_v5_EPSG23031/200m/1/0.jpg"/>
        <TileMatrix>200m</TileMatrix>
        <tileRow>1</tileRow>
        <tileCol>0</tileCol>
        <width>640</width>
        <height>480</height>
        <top>-185</top>
        <left>-485</left>
    </tile>
    <tile>
        <ows:Identifier>200m_1_1</ows:Identifier>
        <fileURL
xlink:href="http://www.opengis.uab.es/SITiled/ICC/Topo250k_Vers5_
ICC/default/Cat_topo250k_v5_EPSG23031/200m/1/1.jpg"/>
        <TileMatrix>200m</TileMatrix>
        <tileRow>1</tileRow>
        <tileCol>1</tileCol>
        <width>640</width>
        <height>480</height>
        <top>-185</top>
        <left>155</left>
    </tile>
    <tile>
        <ows:Identifier>200m_2_0</ows:Identifier>
        <fileURL
xlink:href="http://www.opengis.uab.es/SITiled/ICC/Topo250k_Vers5_
ICC/default/Cat_topo250k_v5_EPSG23031/200m/2/0.jpg"/>
        <TileMatrix>200m</TileMatrix>
        <tileRow>2</tileRow>
        <tileCol>0</tileCol>
        <width>640</width>
        <height>480</height>
        <top>295</top>
        <left>-485</left>
    </tile>
    <tile>
        <ows:Identifier>200m_2_1</ows:Identifier>
```

```
    <fileURL
xlink:href="http://www.opengis.uab.es/SITiled/ICC/Topo250k_Vers5_
ICC/default/Cat_topo250k_v5_EPSG23031/200m/2/1.jpg"/>
    <TileMatrix>200m</TileMatrix>
    <tileRow>2</tileRow>
    <tileCol>1</tileCol>
    <width>640</width>
    <height>480</height>
    <top>-295</top>
    <left>-155</left>
  </tile>
</TileCollection>
```

This response is linking to 4 WMTS tiles that are deliberately not square and in a rare tiling size (640x480), with the origin at (258007, 4751992) and 200m of pixel size, which covers the requested Bounding Box (355000,4619000) x (475000,4539000):

(258007, 4655992) x (386007, 4559992)	(386007, 4655992) x (514007, 4559992)
(258007, 4559992) x (386007, 4463992)	(386007, 4559992) x (514007, 4463992)

7.1.6   GetTiles KVP embedded request example

```
http://www.opengis.uab.es/cgi-
bin/ICCTiled/MiraMon.cgi?SERVICE=WMTS&VERSION=1.0.0&
REQUEST=GetTiles&Layer=Topo250k_Vers5_ICCStyle=&
TileMatrixSet=Cat_topo250k_v5_EPSG23031&TileMatrix=200m&
BBox=355000,4539000,475000,4619000&Width=600&Height=400&
Format=image/jpeg&CollectionFormat=Multipart/Related&
inclusion=linked
```

7.1.7   GetTiles embedded response example

A GetTiles operation response for the GetTiles request example in subclause 7.1.6 will be the following MIME Multipart document fragment (contents of the tile parts are omitted):

```
Content-Type: Multipart/Related; boundary=wmts;
        start="TileCollection-Part"
        type="application/xml"

--wmts
Content-Type: application/xml

<?xml version="1.0" encoding="UTF-8"?>
<TileCollection
      xmlns="http://www.opengis.net/wmts/1.0/get_tiles"
      xmlns:wmts_gt="http://www.opengis.net/wmts/1.0/get_tiles"
      xmlns:ows="http://www.opengis.net/ows/1.1"
      xmlns:xlink="http://www.w3.org/1999/xlink"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation="http://www.opengis.net/wmts/1.0/get_tiles
         ..\wmtsGetTiles_response.xsd
   http://www.opengis.net/ows/1.1
         http://www.opengis.net/ows/1.1.0/owsAll.xsd">">
   <tile>
      <ows:Identifier>200m_1_0</ows:Identifier>
      <fileURL xlink:href="cid:200m_1_0.jpg"/>
      <TileMatrix>200m</TileMatrix>
      <tileRow>1</tileRow>
      <tileCol>0</tileCol>
      <width>640</width>
      <height>480</height>
      <top>-185</top>
      <left>-485</left>
   </tile>
   <tile>
      <ows:Identifier>200m_1_1</ows:Identifier>
      <fileURL xlink:href="cid:200m_1_1.jpg"/>
      <TileMatrix>200m</TileMatrix>
      <tileRow>1</tileRow>
```

```
            <tileCol>1</tileCol>
            <width>640</width>
            <height>480</height>
            <top>-185</top>
            <left>155</left>
        </tile>
        <tile>
            <ows:Identifier>200m_2_0</ows:Identifier>
            <fileURL xlink:href="cid:200m_2_0.jpg"/>
            <TileMatrix>200m</TileMatrix>
            <tileRow>2</tileRow>
            <tileCol>0</tileCol>
            <width>640</width>
            <height>480</height>
            <top>295</top>
            <left>-485</left>
        </tile>
        <tile>
            <ows:Identifier>200m_2_1</ows:Identifier>
            <fileURL xlink:href="cid:200m_2_1.jpg"/>
            <TileMatrix>200m</TileMatrix>
            <tileRow>2</tileRow>
            <tileCol>1</tileCol>
            <width>640</width>
            <height>480</height>
            <top>-295</top>
            <left>-155</left>
        </tile>
</TileCollection>
--wmts
Content-Type: image/jpeg
Content-Description: tile imatge
Content-Transfer-Encoding: binary
Content-ID: 200m_1_0.jpg
Content-Disposition: inline

...
--wmts
Content-Type: image/jpeg
Content-Description: tile imatge
Content-Transfer-Encoding: binary
Content-ID: 200m_1_1.jpg
Content-Disposition: inline

...
--wmts
Content-Type: image/jpeg
Content-Description: tile imatge
Content-Transfer-Encoding: binary
Content-ID: 200m_2_0.jpg
Content-Disposition: inline
```
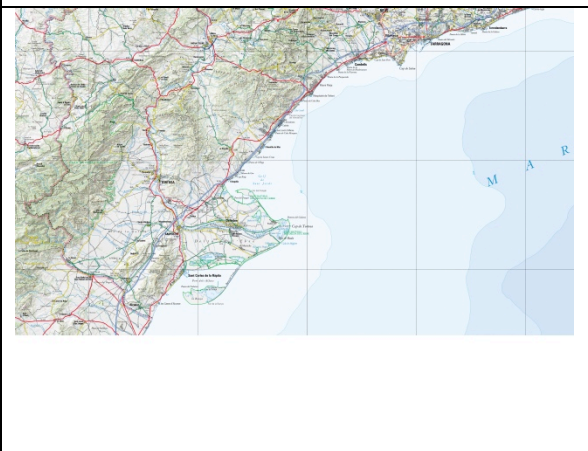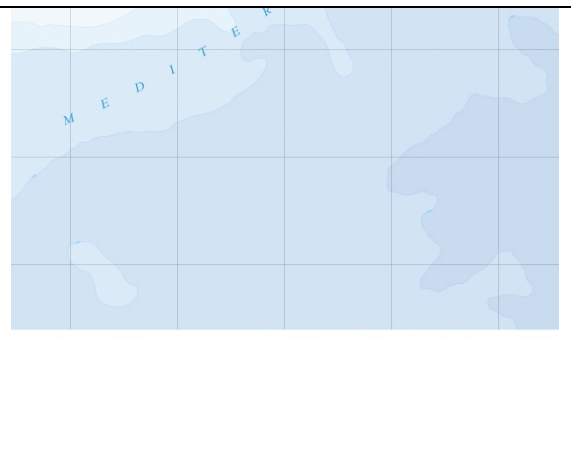
```
...
--wmts
Content-Type: image/jpeg
Content-Description: tile imatge
Content-Transfer-Encoding: binary
Content-ID: 200m_2_1.jpg
Content-Disposition: inline

...
--wmts--
```

8 TIME support

In WMTS there is a way to introduce time using a "sampleDimensions" parameter (different from WMS 1.3 that specifically defines TIME and ELEVATION). The current mechanism allows too much flexibility, since it does not specify the format of the time values leading to lower interoperability.

8.1 TIME parameter name

The name of the time parameter in KVP and SOAP shall be "TIME".

The name in the URL template parameter shall be {time}.

8.2 TIME parameter format

If the sample dimension is a temporal dimension, the format specified in WMS 1.3 OGC-06-042 Annex D "Web Map Service profile of ISO 8601" shall be used. Additionally, the parameter value shall not include time steps or intervals, and it will just specify a simple time. One example of this notation is YYYY-MM-DD.

8.2.1 TIME parameter example

An example GetTile operation request KVP encoded for HTTP GET that included TIME is:

http://map1.vis.earthdata.nasa.gov/wmts-geo/wmts.cgi?TIME=2012-08-15&SERVICE=WMTS&REQUEST=GetTile&VERSION=1.0.0&LAYER=MODIS_Terra_CorrectedReflectance_TrueColor&STYLE=&TILEMATRIXSET=EPSG4326_250m&TILEMATRIX=6&TILEROW=23&TILECOL=70&FORMAT=image/jpeg

9   Extending tile origin

WMTS follows the convention that the tile indexing origin is at the upper left corner of the tiled space. TMS OSGeo standard follows the tile indexing origin lower left convention. Many others such as Google maps, OSM, etc., follow the upper left convention. Having a standard aiming at being as generic as possible, it constraints to the upper left corner preventing to consider TMS services as a WMTS service.
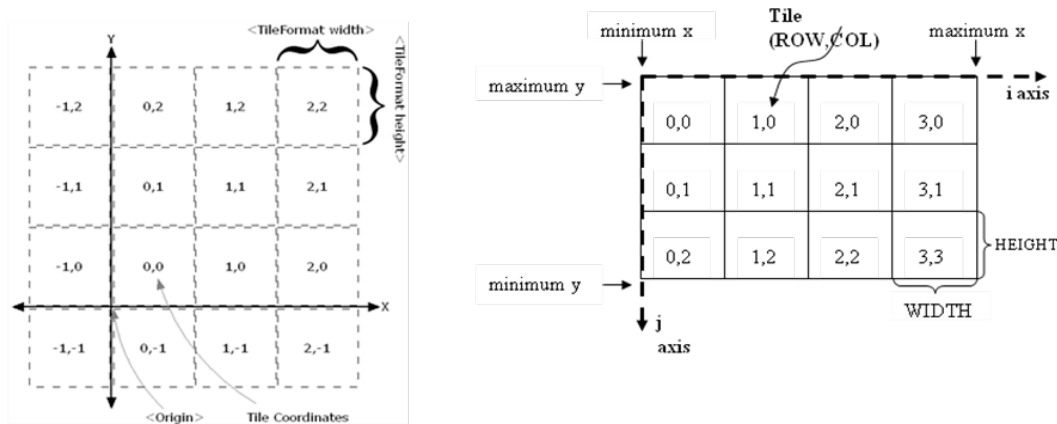
Figure 5 — Tile origins in TMS (left) and WMTS (right)

We suggest adding a new subelement in the TileMatrix data type for specifying tile origin.

In "Table 14 — Parts of TileMatrix data structure" of the WMTS 1.0 OGC 07-057r7 add the following attribute:

Table 6 — Fragment TileMatrix data structure

Names	Definition	Data type and values	Multiplicity and use
originCorner `OriginCorner`	The corner that is the origin for the tile indices TileRow and TileCol [f]	OriginCorner enumeration. See table 7	Zero or one (optional) Default value is "top-left"
a Note that the TopLeftCorner coordinates parameter is independent of the originCorner and always refers to the coordinates of the top-left corner. This means that a TileMatrixSet with bottom-left originCorner and fixed bottom-left coordinate position for all TileMatrices could be forced to have different TopLeftCorner y coordinate values between TileMatrices.			

Add a new table 7

Table 7 — Values of OriginCorner Enumeration

Value	Definition	Multiplicity and use

27

Value	Definition	Multiplicity and use
top-left	The origin for the TileRow and TileCol indices is the top left corner.	Zero or one (mutually exclusive)
bottom-left	The origin for the TileRow and TileCol indices is the bottom left corner.	Zero or one (mutually exclusive)
top-right	The origin for the TileRow and TileCol indices is the top right corner.	Zero or one (mutually exclusive)
bottom-right	The origin for the TileRow and TileCol indices is the bottom right corner.	Zero or one (mutually exclusive)

10 Support for multiple endpoints

For performance, scalability and reliability reasons, some Mass Market tiling implementation use multiple endpoints for the same tiles. For instance, here is an example using MapQuest Open Aerial Tile URLs:

```
http://oatile1.mqcdn.com/tiles/1.0.0/sat/0/0/0.jpg
http://oatile2.mqcdn.com/tiles/1.0.0/sat/0/0/0.jpg
http://oatile3.mqcdn.com/tiles/1.0.0/sat/0/0/0.jpg
http://oatile4.mqcdn.com/tiles/1.0.0/sat/0/0/0.jpg
```

In fact, this is possible in the current specification, but it could be useful to have a white paper or even a clause in a new revision of WMTS, explaining how to do this and thus improve interoperability.

From the client prospective, Openlayers already supports multiple endpoints: http://trac.osgeo.org/openlayers/wiki/OpenLayersOptimization#multipleURLs

10.1 Example on how to support multiple endpoints in the ServiceMetadata document (procedure oriented architectural style)

In the ServiceMetadata document the xpath /ows:Capabilities/ows:OperationsMetadata/ows:Operation/ows:DCP/ows:HTTP/ows:Get has cardinality 0..* so it is already possible to advertise multiple URL endpoints:

```
<ows:OperationsMetadata>
   <ows:Operation name="GetTile">
      <ows:DCP>
```

```
                <ows:HTTP>
                   <ows:Get
                    xlink:href="http://www1.maps.bob/maps.cgi?">
                       <ows:Constraint name="GetEncoding">
                           <ows:AllowedValues>
                               <ows:Value>KVP</ows:Value>
                           </ows:AllowedValues>
                       </ows:Constraint>
                   </ows:Get>
                   <ows:Get
                    xlink:href="http://www2.maps.bob/maps.cgi?">
                       <ows:Constraint name="GetEncoding">
                           <ows:AllowedValues>
                               <ows:Value>KVP</ows:Value>
                           </ows:AllowedValues>
                       </ows:Constraint>
                   </ows:Get>
                </ows:HTTP>
             </ows:DCP>
          </ows:Operation>
      </ows:OperationsMetadata>
```

This is consistent with OWS 2.0 (OGC 06-129r9) Table 16 Parts of HTTP data structure 'Note a' that says: "Normally, one Get and/or one Post is included in this subsection. More than one Get and/or Post is allowed to support including alternative URLs for uses such as load balancing or backup."

10.2   Example on how to support multiple endpoints in the ServiceMetadata document (resource oriented architectural style)

In the ServiceMetadata document the xpath /ows:Capabilities/ows:Contents/ows:Layer/ows:ResourceURL has cardinality 0..*, so it is already possible to advertise multiple URL endpoints:

```
  <Contents>
     <Layer>
        [...]
        <ResourceURL format="image/png" resourceType="tile"
           template="http://www1.maps.bob/
            wmts/BlueMarbleNextGeneration/default/BigWorldPixel/
            {TileMatrix}/{TileRow}/{TileCol}.png"/>
        <ResourceURL format="image/png" resourceType="tile"
           template="http://www2.maps.bob/
            wmts/BlueMarbleNextGeneration/default/BigWorldPixel/
            {TileMatrix}/{TileRow}/{TileCol}.png"/>
     </Layer>
  </Contents>
```

11 Update the standard to new OGC policies and IEFT.

11.1 Core and extension model

WMTS was defined just before the modular specification [1] was adopted in OGC. Adapt WMTS to the modular specification will require two things: To identify what is core and what can be considered extension in WMTS, and to elaborate a clear list of requirements for each one.

After some experience adopting the modular specification in other standards such as WCS 2.0 and OWS Context 1.0, it has become clear that WMTS can be modularized as:

- OGC® Web Map Tile Service Conceptual Model

- OGC® Web Map Tile Service KVP Encoding

- OGC® Web Map Tile Service SOAP Encoding

- OGC® Web Map Tile Service RESTful Encoding

The requirements list will take into consideration the experience that the CITE group collected when developing the WMTS standard test.

11.2 CRS URLs

The WMTS standard was produced in the short period of time that OGC recommended the use of URNs for CRS identifiers [2]. Later a new OGC policy recommended the use of URLs for CRS identifiers [3][4]. This only requires small modifications in the WMTS standard keeping consistency with other standards.

11.3 URL template standard

The WMTS spec references an URL template draft http://tools.ietf.org/html/draft-gregorio-uritemplate-03. It will be good that the new IETF adopted standard is used instead: http://tools.ietf.org/html/rfc6570.

This does not require any modifications on how the RESTful URL templates were defined in OGC 07-057r7, but it will be consistent with WMTS Simple.

Annex A

XML Schema Documents

In addition to this document, this report includes several XML Schema Documents. These XML Schema Documents are bundled in a zip file with the present document.

The WMTS Simple abilities now specified in this document use specified Schematron included in the zip file with this document. These Schematron Document combine the Schematron fragments listed in various subclauses of this document, eliminating duplications. These XML Schematron Documents are named:

wmts\1.0\profiles\WMTSSimple\wmtsSimpleGetCapabilities.sch

Additionally, examples of ServiceMetadata document are provided in the following folder:

wmts\1.0\profiles\WMTSSimple\examples

The WMTS GetTiles abilities now specified in this document use specified XML Schema Documents included in the zip file with this document. These XML Schema Documents combine the XML schema fragments listed in various subclauses of this document, eliminating duplications. These XML Schema Documents are named:

wmtsGetTiles_response.xsd

These XML Schema Documents use and build on the WMTS XML Schema Documents specified [OGC 07-057r7] and OWS common XML Schema Documents specified [OGC 06-121r3].

Annex B

TileMatrixSet definition for WMTS Simple (Normative)

This Annex includes the normative definitions for the two TileMatrixSets that will be included in the ServiceMetadata document when it is required.

C.1 World Spherical Mercator TileMatrixSet definition.

Following requirement **req/simple-profile/wmts-profile-world-spherical-mercator,** when a ServiceMetadata document exists, the exact definition of the TileMatrixSet in the ServiceMetadata document will be included (ows:Title can be presonalized).

```
      <TileMatrixSet>
          <ows:Title>Google Maps Compatible for the
World</ows:Title>
          <ows:Identifier></ows:Identifier>
          <ows:BoundingBox crs="urn:ogc:def:crs:EPSG::3785">
             <ows:LowerCorner>-20037508.3427892 -
20037508.3427892</ows:LowerCorner>
             <ows:UpperCorner>20037508.3427892
20037508.3427892</ows:UpperCorner>
          </ows:BoundingBox>
          <ows:SupportedCRS>
              urn:ogc:def:crs:EPSG::3785
          </ows:SupportedCRS>
          <WellKnownScaleSet>
              urn:ogc:def:wkss:OGC:1.0:GoogleMapsCompatible
          </WellKnownScaleSet>
          <TileMatrix>
             <ows:Identifier>0</ows:Identifier>

<ScaleDenominator>559082264.0287178</ScaleDenominator>
             <TopLeftCorner>
                 -20037508.3427892 20037508.3427892
             </TopLeftCorner>
             <TileWidth>256</TileWidth>
             <TileHeight>256</TileHeight>
             <MatrixWidth>1</MatrixWidth>
             <MatrixHeight>1</MatrixHeight>
          </TileMatrix>
          <TileMatrix>
             <ows:Identifier>1</ows:Identifier>

<ScaleDenominator>279541132.0143589</ScaleDenominator>
             <TopLeftCorner>
```

```
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>2</MatrixWidth>
            <MatrixHeight>2</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>2</ows:Identifier>

<ScaleDenominator>139770566.0071794</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>4</MatrixWidth>
            <MatrixHeight>4</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>3</ows:Identifier>

<ScaleDenominator>69885283.00358972</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>8</MatrixWidth>
            <MatrixHeight>8</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>4</ows:Identifier>

<ScaleDenominator>34942641.50179486</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>16</MatrixWidth>
            <MatrixHeight>16</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>5</ows:Identifier>

<ScaleDenominator>17471320.75089743</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
```

```
            <TileHeight>256</TileHeight>
            <MatrixWidth>32</MatrixWidth>
            <MatrixHeight>32</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>6</ows:Identifier>

<ScaleDenominator>8735660.375448715</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>64</MatrixWidth>
            <MatrixHeight>64</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>7</ows:Identifier>

<ScaleDenominator>4367830.187724357</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>128</MatrixWidth>
            <MatrixHeight>128</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>8</ows:Identifier>

<ScaleDenominator>2183915.093862179</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>256</MatrixWidth>
            <MatrixHeight>256</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>9</ows:Identifier>

<ScaleDenominator>1091957.546931089</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>512</MatrixWidth>
```

```
            <MatrixHeight>512</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>10</ows:Identifier>

<ScaleDenominator>545978.7734655447</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>1024</MatrixWidth>
            <MatrixHeight>1024</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>11</ows:Identifier>

<ScaleDenominator>272989.3867327723</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>2048</MatrixWidth>
            <MatrixHeight>2048</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>12</ows:Identifier>

<ScaleDenominator>136494.6933663862</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>4096</MatrixWidth>
            <MatrixHeight>4096</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>13</ows:Identifier>

<ScaleDenominator>68247.34668319309</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>8196</MatrixWidth>
            <MatrixHeight>8196</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
```

```
            <ows:Identifier>14</ows:Identifier>

<ScaleDenominator>34123.67334159654</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>16392</MatrixWidth>
            <MatrixHeight>16392</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>15</ows:Identifier>

<ScaleDenominator>17061.83667079827</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>32784</MatrixWidth>
            <MatrixHeight>32784</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>16</ows:Identifier>

<ScaleDenominator>8530.918335399136</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>65568</MatrixWidth>
            <MatrixHeight>65568</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>17</ows:Identifier>

<ScaleDenominator>4265.459167699568</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>131136</MatrixWidth>
            <MatrixHeight>131136</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>18</ows:Identifier>
```

```
<ScaleDenominator>2132.729583849784</ScaleDenominator>
            <TopLeftCorner>
                -20037508.3427892 20037508.3427892
            </TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>262272</MatrixWidth>
            <MatrixHeight>262272</MatrixHeight>
        </TileMatrix>
      </TileMatrixSet>
```

If needed, you can define more than 18 zoom levels to support layers with better resolution. Currently, resolutions up to 24 are normal.

C.2 CRS84 TileMatrixSet definition.

Following requirement **req/simple-profile/wmts-profile-world-crs84,** when being conformance to the profile http://www.opengis.net/spec/wmts-simple/1.0/conf/simple-profile/CRS84 and when a ServiceMetadata document exists, the exact definition of the TileMatrixSet in the ServiceMetadata document will be included (ows:Title can be personalized).

```
            <ows:Title>CRS84 for the World</ows:Title>
            <ows:Identifier>WorldCRS84Quad</ows:Identifier>
            <ows:BoundingBox crs="urn:ogc:def:crs:OGC:1.3:CRS84">
                <ows:LowerCorner>-180 -90</ows:LowerCorner>
                <ows:UpperCorner>180 90</ows:UpperCorner>
            </ows:BoundingBox>
            <ows:SupportedCRS>
                urn:ogc:def:crs:OGC:1.3:CRS84
            </ows:SupportedCRS>
            <WellKnownScaleSet>
                urn:ogc:def:wkss:OGC:1.0:WorldCRS84Quad
            </WellKnownScaleSet>
            <TileMatrix>
                <ows:Identifier>0</ows:Identifier>

<ScaleDenominator>559082264.0287178</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>1</MatrixWidth>
            <MatrixHeight>1</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>1</ows:Identifier>
```

```
<ScaleDenominator>279541132.0143589</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>2</MatrixWidth>
            <MatrixHeight>1</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>2</ows:Identifier>

<ScaleDenominator>139770566.0071794</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>4</MatrixWidth>
            <MatrixHeight>2</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>3</ows:Identifier>

<ScaleDenominator>69885283.00358972</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>8</MatrixWidth>
            <MatrixHeight>4</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>4</ows:Identifier>

<ScaleDenominator>34942641.50179486</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>16</MatrixWidth>
            <MatrixHeight>8</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>5</ows:Identifier>

<ScaleDenominator>17471320.75089743</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>32</MatrixWidth>
            <MatrixHeight>16</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>6</ows:Identifier>
```

```
<ScaleDenominator>8735660.375448715</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>64</MatrixWidth>
            <MatrixHeight>32</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>7</ows:Identifier>

<ScaleDenominator>4367830.187724357</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>128</MatrixWidth>
            <MatrixHeight>64</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>8</ows:Identifier>

<ScaleDenominator>2183915.093862179</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>256</MatrixWidth>
            <MatrixHeight>128</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>9</ows:Identifier>

<ScaleDenominator>1091957.546931089</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>512</MatrixWidth>
            <MatrixHeight>256</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>10</ows:Identifier>

<ScaleDenominator>545978.7734655447</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>1024</MatrixWidth>
            <MatrixHeight>512</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>11</ows:Identifier>
```

```
<ScaleDenominator>272989.3867327723</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>2048</MatrixWidth>
            <MatrixHeight>1024</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>12</ows:Identifier>

<ScaleDenominator>136494.6933663862</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>4096</MatrixWidth>
            <MatrixHeight>2048</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>13</ows:Identifier>

<ScaleDenominator>68247.34668319309</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>8196</MatrixWidth>
            <MatrixHeight>4096</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>14</ows:Identifier>

<ScaleDenominator>34123.67334159654</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>16392</MatrixWidth>
            <MatrixHeight>8196</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>15</ows:Identifier>

<ScaleDenominator>17061.83667079827</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
            <TileWidth>256</TileWidth>
            <TileHeight>256</TileHeight>
            <MatrixWidth>32784</MatrixWidth>
            <MatrixHeight>16392</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>16</ows:Identifier>
```

```
<ScaleDenominator>8530.918335399136</ScaleDenominator>
            <TopLeftCorner>-180 90</TopLeftCorner>
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            <TileHeight>256</TileHeight>
            <MatrixWidth>65568</MatrixWidth>
            <MatrixHeight>32784</MatrixHeight>
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<ScaleDenominator>4265.459167699568</ScaleDenominator>
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            <TileHeight>256</TileHeight>
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            <MatrixHeight>65568</MatrixHeight>
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        <TileMatrix>
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<ScaleDenominator>2132.729583849784</ScaleDenominator>
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            <TileHeight>256</TileHeight>
            <MatrixWidth>262272</MatrixWidth>
            <MatrixHeight>131136</MatrixHeight>
        </TileMatrix>
        <TileMatrix>
            <ows:Identifier>19</ows:Identifier>

<ScaleDenominator>1066.364791924892</ScaleDenominator>
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            <MatrixHeight>262272</MatrixHeight>
        </TileMatrix>

    </TileMatrixSet>
```

If needed, you can define more than 19 zoom levels to support layers with better resolution. Currently, resolutions up to 24 are normal.

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