

## **Standards based access to EUMETSATs Image Gallery**

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### **ABSTRACT**

The present EUMETSAT Image Gallery provides access to a selection of near real-time imagery from Meteosat and Metop Satellites, but only for pre-defined regions on earth with fixed image size. OGC services such as Web Map Services (WMS) and Web Coverage Services (WCS) allow a more flexible approach for the visualisation and provision of image data. In the context of the EO Portal developments, EUMETSAT offers near real-time satellite products as geo referenced image data via OGC WMS 1.3 (supporting the temporal dimension) and WCS 1.1 interfaces. The "EO Portal Image Gallery Server" is continuously updated with the latest satellite products. The "EO Portal Image Gallery Client" uses the standard OGC services for data access and visualization. It offers browsing per selected collection the temporal extent following by the visualisation on an interactive map. Apart from viewing, users can download the products in a variety of formats, including KML. The EO Portal Image Gallery Server and Client are currently deployed during the beta testing phase into Amazon Elastic Compute Cloud (EC2).

Keywords: EUMETSAT Image Gallery, EO Portal, Cloud, OGC WMS/WCS, Geoserver, OpenLayers, GWT

### **INTRODUCTION**

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) has the mandate to deliver weather, climate and environment-related satellite data, images and products to its member and cooperating states 24 hours a day, 365 days a year. The EUMETSAT Image Gallery provides access to a selection of near-real-time imagery from Meteosat-9 and Meteosat-7 in geostationary orbits, as well as from Metop, polar orbiting the Earth. The previous image gallery allows only to view pre-defined regions on earth with fixed image size.

OGC services such as Web Map Services (WMS) and Web Coverage Services (WCS) provide a much more flexible approach for the visualisation and working with image data. Further, those standards offer the possibility to combine layers of image data from different WMS/WCS servers by means of interoperable interfaces.

In the context of EUMETSAT's EO Portal developments, the Image Gallery Server was implemented to provide near real-time satellite products as geo referenced image data via OGC WMS 1.3 (supporting the temporal dimension) and WCS 1.1 interfaces. A client application, the "EO Portal Image Gallery Client", makes use of those services for visualisation and provides direct access to the data.

### **VISUAL INSPECTION OF EO DATA AND PRODUCTS - OVERVIEW**

Once operational, the EUMETSAT EO Portal Product Navigator (<http://navigator.eumetsat.int>) will offer a link to the new EO Portal Image Gallery.

The EO Portal Image Gallery Client (see Figure 1) shows some common base data covering a global extent from a WMS server (in Figure 1 from the external WMS demis.nl) and a list of available products.

When the user selects a collection from the list, the most recent image of that collection is overlaid on the base map. The user can change the temporal extent and interact with the map by zooming, panning and changing the map to the full extent.

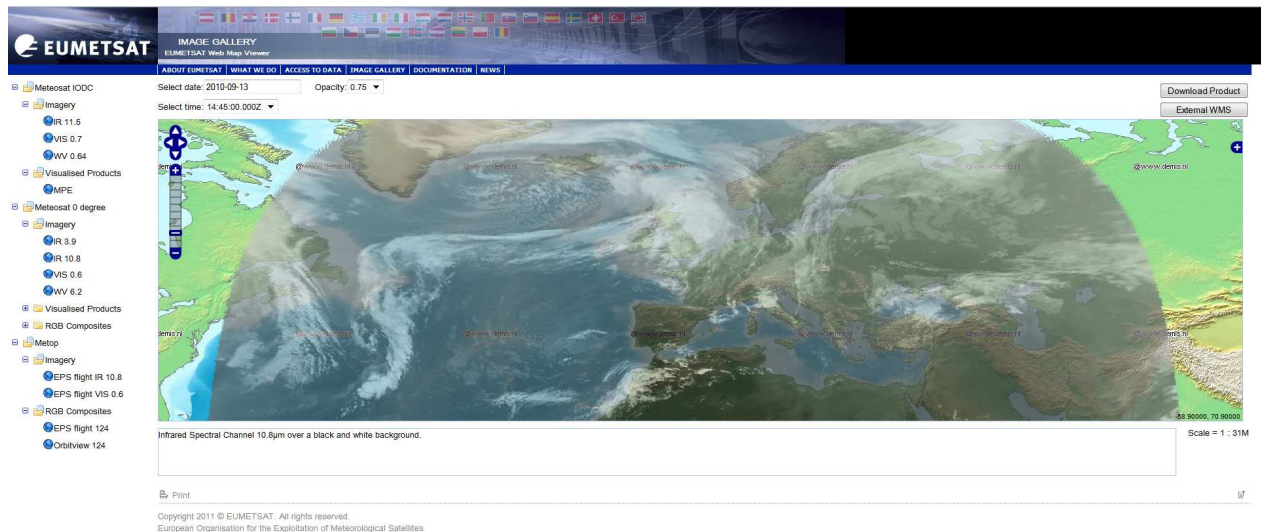


Figure 1: Visual inspection of Meteosat 0 degree product (Infrared Spectral Channel 10.8 $\mu$ m)

## FORMATS AND ORGANISATION OF EO DATA AND PRODUCTS

### Primary storage formats

The earth observation (EO) data and products provided by EUMETSAT are delivered from satellites having different orbit types. The orbit type affects the spatial coverage and spatial/ temporal resolution of the produced products. There are two orbit types:

- **GEOstationary orbit (GEO):** satellites (e.g. Meteosat Second Generation (MSG)) are positioned at a fixed point over the equator and rotate in sync with the earth. Because of the high altitude an image produced covers the whole visible Earth disc. The resolution is  $\geq 1$ km.
- **Low Earth Orbit (LEO):** these satellites (e.g. Metop) circle the Earth in a polar orbit, passing the poles as they circle the Earth. The lower altitude compared to GEO satellites produces images that cover only part of the Earth (swath based).

The exact spatial and temporal resolution of the EO products (datasets) depends on the instrument/product type.

The meteorological products (derived from the satellites described above) relevant for the Image Gallery are mainly stored in the following two formats:

- **BUFR (Binary Universal Form for the Representation of meteorological data):** a binary data format, current edition is 4 (<http://en.wikipedia.org/wiki/BUFR>).
- **GRIB (GRIdded Binary):** a format commonly used in meteorology for the transport and storage of historical or forecast data. The version in use is GRIB second edition (<http://en.wikipedia.org/wiki/GRIB>).
- **NATIVE:** EUMETSAT proprietary format in which the satellite data is stored. The NATIVE format is different between Meteosat First Generation, Meteosat Second Generation and Metop-A.

Only few products are today available in NetCDF 4 (Network common data form - <http://www.unidata.ucar.edu/software/netcdf/>) format, but a harmonisation towards the delivery in NetCDF 4 format is presently anticipated.

## Serving Data

For the data provision using a WMS compliant server, we first used ncWMS (<http://www.resc.rdg.ac.uk/trac/ncWMS/>) a WMS (1.1.1, 1.3.0) for geospatial data stored in GRIB and netCDF formats. ncWMS is also integrated in the **THREDDS (Thematic Realtime Environmental Distributed Data Services)**, which is able to read and serve datasets in GRIB-, BUFR- and netCDF-Format (<http://www.unidata.ucar.edu/projects/THREDDS>) and offers a WCS (1.0.0) implementation. The advantage of setting a WMS/ WCS directly on top of the primary storage formats is that no additional processing steps are required with no information loss (see case B in Figure 2). Disadvantages are lower performance for our kind of datasets e.g. resulting from the large size of the original files (> 100MB). Further ncWMS and TDS (although version 4.1) are still listed experimental on the Unidata Web Site. We performed benchmark tests of ncWMS against other freely available server such as GeoServer and MapServer.

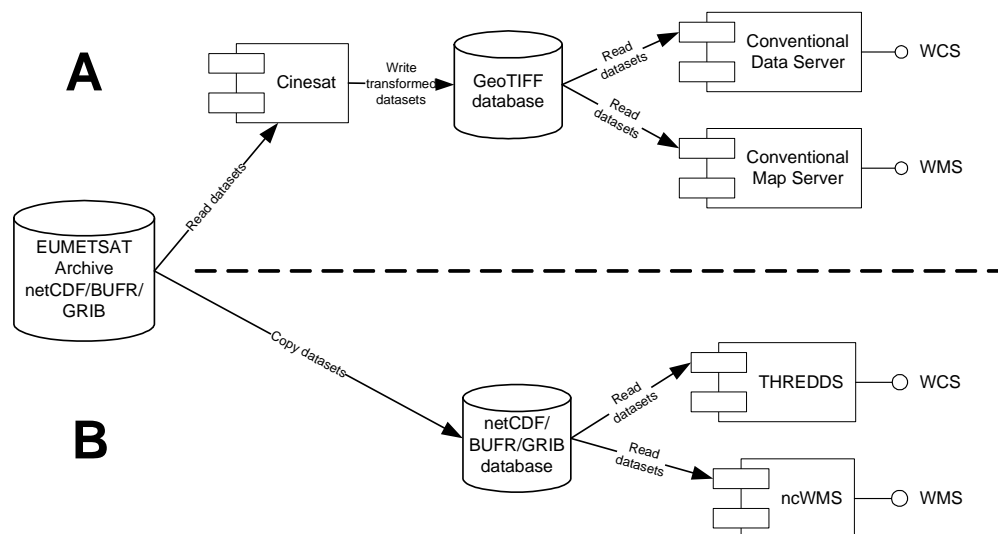


Figure 2: Alternatives for EO data provision with the new Image Gallery

Because of the lack of performance using dataset with larger sizes and the existence of proprietary data formats, we decided to convert the products in general to **GeoTIFF** (<http://trac.osgeo.org/geotiff/>). This reduced the product sizes in general to be below 10 MB. CineSat ([www.cinesat.com](http://www.cinesat.com)) software is used for the conversion to GeoTIFF. The resulting GeoTIFF files can then be served by geoservers via standardised WMS/WCS interfaces (see case A in Figure 2). The information loss due to the GeoTIFF conversion are acceptable for the WMS interface.

## Organizing EO Products related to the temporal dimension

To account for the temporal dimension of the EO products two views have to be considered for the data organization: a physical and a logical view.

### Physical Organization

The organization form we selected is to have one physical dataset for each timestamp. An advantage is that every image format can be used. Disadvantages are that one has to find a (proprietary) mechanism to assign the time values to the individual datasets and that this might result in a large amount of datasets.

Another form of organization would be to have only one physical dataset that covers all points of time in the respective period. There must be distinct data values for each point of time, and the grids all have the same spatial coverage. This results in a simpler file structure and a potentially less overall space requirement, as the data value arrays for each time point share the same metadata and grid. The main problems with this approach are that a single dataset can become large (resulting in long loading time and higher memory requirement) if there are lots of time stamps and that there exists only a limited set of formats that allows such datasets and a limited set of software that can handle the formats.

## Logical Organization

For the mapping functionality, (parts of) EO products are advertised as layers. A layer is the basic unit that may be requested from a mapserver. Layers can be organized hierarchically, such as enclosing parent (or group) layers in an aggregation of a set of other layers. A mapserver offers the list of provided layers in its capabilities.

Using this layer model, image data (same type and location) at different points of time can be represented in two ways. One approach is that a single layer represents the whole period. Time is a special parameter that can be used to parameterize a map-request. This can be a single value, a list of values, or an interval. It is also possible to define any other dimension of the layer as a parameter to the map. With this layer organization, the responsibility to request and return data for a specific timeframe could be on the server as well as on the client side. The layer appears as one concise unit to the client. A problem is that this requires a mapping service supporting dimension parameters, thus limits the choice of server software components and client applications that are able to interpret the dimension.

Another approach is that each point in time is represented as a separate layer. With this organization, the responsibility to request and return data for a specific timeframe would be on the client side as this has to query the layers of interest. In this case no special dimension capabilities are required by client and server. But this approach has different disadvantages:

- The client has to “guess” that individual layers represent different time points
- The layers have no inherent order that is usually imposed by the interval scale of the temporal dimension. The order has to be detected by user interpretation or a proprietary convention.
- The capabilities from which the end user has to select layers, can become extremely large. This problem could be decreased by using parent layers to aggregate the related layers.

## SERVICE INTERFACES

This chapter describes the service interfaces that are relevant for accessing the Image Gallery provided by the Image Gallery Server. Primarily these are the standardized WMS and WCS interfaces of the OGC.

### Web Coverage Service (WCS)

A WCS [3] provides access to geospatial information, in forms that are useful for client-side rendering and input into scientific models and other clients. Like a WMS [1] or a Web Feature Service (WFS) [4] it allows clients to choose portions of the data based on spatial and other constraints. Unlike a WMS, the WCS provides data with its original semantics (instead of pictures). Unlike WFS, which returns discrete geospatial features, the WCS returns coverages, representing space-varying phenomena that relate to a spatial (mandatory) and a temporal (optional) domain to a (possibly multidimensional) range of properties. A range specifies the available coverage values (as list of scalar- or vector-valued fields). A WCS has the following operations (all mandatory):

- **GetCapabilities:** Retrieves a list of the server’s data, the valid WCS operations and its parameters.
- **DescribeCoverage:** Retrieves descriptions of the coverages (including spatio/temporal domain)
- **GetCoverage:** Returns a coverage in a well known format and invokes some of the operations: domain subsetting, range subsetting, resampling, data format encoding and result file delivery.

Currently there are different versions of the WCS specification in use: Version 1.0, 1.1.2 and 2.0 (<http://www.opengeospatial.org/standards/wcs>). Differences are for example that V1.0 requires at minimum one predefined format to be supported per coverage (e.g. GeoTIFF), while the newer versions do not mandate any particular output format (instead advocate the definition of WCS encoding extensions). Further newer versions support multiple fields (variables) per coverage.

## Web Map Service (WMS)

A WMS [1] produces maps as portrayal of geographic information in a digital file (e.g. in a pictorial format such as PNG or GIF or vector-based like in SVG). A map is not the data itself. A basic WMS classifies its geographic information into layers. The WMS specification defines three operations:

- **GetCapabilities** (mandatory): Returns the service metadata, including the (possibly hierarchically nested) layers, coordinate reference systems and response formats for the GetMap request.
- **GetMap** (mandatory): returns a map image reflecting spatial and other constraints. Two or more maps produced with the same geographic parameters and output size can be accurately overlaid
- **GetFeatureInfo** (optional): provides details about features in previously returned maps

The current version 1.3.0 of the WMS specification [1] is no longer restricted to the horizontal spatial dimension defined by the layer's CRS, but also supports the vertical coordinate system and the temporal reference system. Clients can specify the time of interest within an additional request parameter: e.g. a single moment (TIME=2000-08-03) or an interval (e.g. with an extent of 1 month and a resolution of 1 day: TIME=2000-07-01/2000-07-31/P1D). Other dimensions (not predefined in the specification) can also be supported, e.g. different wavelength bands.

The actual rendering of a layer's data on a map image is defined by a style. In a request a client can choose for each layer from a list of predefined styles. The WMS specification supports only predefined ("named") layers and styles, and does not include a mechanism for user-defined symbolization. The SLD profile of WMS [5] allows user-defined symbolization.

## WMS EO Profile

The WMS EO Profile [2] was developed within the Heterogeneous Mission Accessibility (HMA) project initiated by European Agency (<http://wiki.services.eoportal.org>). The specifications included in this profile mainly concern the service metadata in the capabilities (regarding the naming of layers, how to create layers for geophysical parameters, the nesting of layers etc) and the WMS responses (regarding default response behavior, outline view of available EO products, type of rendering of band datasets, spatial metadata set (bitmask) stacks).

## ARCHITECTURE AND IMPLEMENTATION

### Evaluation of software base for server implementation

For the EUMETSAT Image Gallery Server implementation we evaluated the following COTS products:

- **UMN MapServer** (V 5.4.2), an open source platform for web mapping and providing spatial data (<http://mapserver.org>) running on platforms like Windows, Solaris and Linux. Mapserver implements WCS 1.0.0/1.1.x and WMS 1.0.0, 1.1.x and 1.3.0. Lots of input formats and output formats (including GeoTIFF) are supported. The WCS supports filter for temporal and spatial subsetting. The WMS has support for the time dimension, for layer hierarchies and for SLD (except user-defined layers). On-the-fly update of datasets is possible as well. Disadvantages for EUMETSAT are its C++ based implementation and the creation of a new process for every request.
- **Geoserver** (V 2.0.2) is an open source software server written in Java and built on Geotools, an Open Source GIS toolkit (<http://geoserver.org>). It is the reference implementation of the WFS 1.0 and WCS 1.0 (supports 1.1), as well as WMS 1.1.1. GeoServer is configured by means of a Data Directory containing files for global settings, data sources, available service interfaces, styling information etc. As input formats it supports GeoTIFF and lots of other formats. Output formats can be GeoTIFF for WCS and formats like PNG and JPEG for WMS. The WCS allows subsetting of domains and ranges in filters. The WMS does not support dimensions, but layer hierarchies and SLD (except user-defined layers). For automated updates, an extension provides a RESTful interface.
- **Esri's ArcGIS Server 9.3 / Image Server** provides OGC WCS (1.0.0, 1.1.0, 1.1.1) and WMS 1.1.1, 1.3.0. The WCS allows sub-setting of domains and ranges as filter option. The WMS has support for dimensions, layer hierarchies and SLD. The ArcGIS Image Server extension provides

enhanced support for serving satellite data based on image services. Image services support a list of raster formats including GeoTIFF. For automated updates a RESTful interface is available. A main advantage of ArcGIS Server are the client development tools, e.g. ArcGIS Server Web APIs based on JavaScript, Flex or Silverlight, providing access to the Web Services via REST Interfaces. ArcGIS Server is available on Windows, Linux and Solaris. However, ArcGIS 10 will be the last version that is available on Solaris<sup>1</sup> preventing us from using it for the Image Gallery.

## Architecture and Implementation Overview

The final choice was to base the EO Portal Image Gallery Server on Geoserver 2.0.2. To support WMS 1.3.0 with time dimension and to implement automatic updates of the Images, two Geoserver-Extensions (WMS 1.3.0 Façade and Publisher) had been developed. The WMS EO Profile is currently not fully supported by the EO Portal Image Gallery Server.

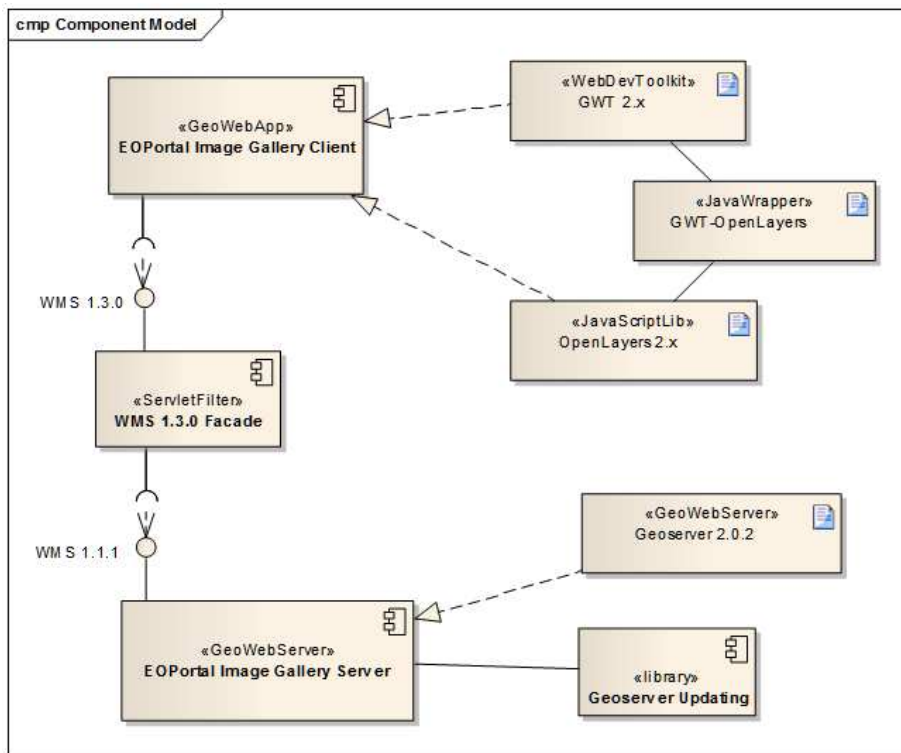


Figure 3: Architecture of the new EUMETSAT Image Gallery

The EO Portal Image Gallery Client is a web application which accesses products available as WMS 1.3.0 layers with time dimension. It is implemented with Google Web Toolkit (GWT 2.x). The map component of the application uses the JavaScript API OpenLayers 2.8 for display. GWT-OpenLayers, a Java wrapper for the OpenLayers JavaScript API is used to integrate OpenLayers with the GWT project.

OpenLayers is a pure JavaScript library for displaying map data in a Web browser (a client-side map composition approach). The library communicates directly with the WMS (or other services type). Therefore, it also has to assemble the different results received from those services in a single map by drawing the data on top of each other. The map uses client-side tiling to speed up reloads.

Server and Client of the new EO Portal Image Gallery had been deployed for testing purposes into Amazon Elastic Compute Cloud (EC2). The Amazon Machine Image (AMI) used is a “large” 64-bit platform with 7,5 GB Memory, 4 EC2 Compute Units (2 cores) and 160 GB of local instance storage. It

<sup>1</sup> [http://resources.esri.nl/downloads/ArcGIS\\_10\\_Deprecation\\_Plan.pdf](http://resources.esri.nl/downloads/ArcGIS_10_Deprecation_Plan.pdf)

runs under RedHat Linux (CentOS). Access for administration is possible using SFTP and SSH (e.g. for data actualization purposes).

## Geoserver Extension - WMS 1.3 Façade

The WMS 1.3.0 façade developed is deployed in front of a standard GeoServer (2.0.2). The purpose of this is to aggregate the images that represent the different time points into a single (virtual) layer with time dimension. It is implemented as a servlet filter that transforms WMS version 1.3.0 requests with time dimension to WMS 1.1.1 requests that reference the image(s) corresponding to the requested time. The single layers to be aggregated must be organized in a specific way and be tagged with special GeoServer configuration information.

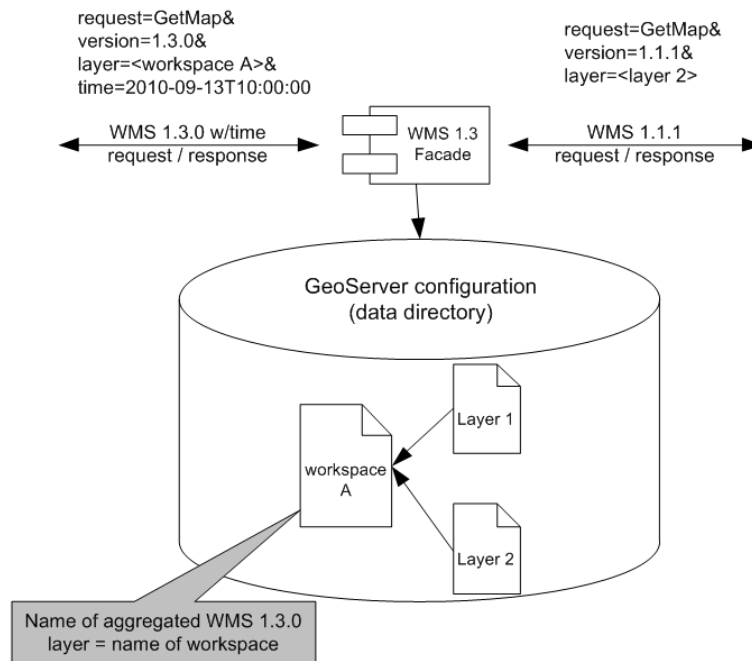


Figure 4: Organization of aggregated layers and request mapping in the WMS 1.3.0 Façade

For the WMS 1.3.0 façade, such an aggregated layer is represented by a single GeoServer workspace. This workspace contains the individual GeoServer layers that represent the available time points for that aggregated layer. The time for each GeoServer layer can be extracted from the file name of the underlying image. Each of the aggregated layers generated by the façade corresponds to a EUMETSAT product type.

The Façade maps in two directions, request and response:

**GetCapabilities:** the Façade transforms the response of a WMS 1.1.1 GetCapabilities request. For this it constructs an XML style sheet. The style sheet creates a response that is compliant with the WMS 1.3.0 schema, with the modifications that each layer that is part of a time series aggregation is removed from the capabilities and for each set of layers that are aggregated, one new layer is generated with the same name as the workspace of its parts. This new layer has a time dimension element. The time values are extracted from the filenames of the underlying GeoTIFFs.

**GetMap:** GetMap requests with version 1.3.0 (and other parameters, s. Fig 4) are transformed to WMS 1.1.1 requests understood by GeoServer. The Façade checks if the requested layer name is an aggregated layer. If this is the case, then the time parameter is processed. If no time parameter is present, the most current layer of the aggregation is selected. With time parameter, the servlet Façade searches the layer with the time that matches the requested time referenced by the aggregate layer name. This layer is then used in the WMS 1.1.1 request to GeoServer. If no matching time is found, the layer with the time that is closest to the requested time is used.

## Geoserver Extension - Updating

To automatically update the images published by GeoServer, a “Publisher” (Geoserver Updating) was implemented. This application publishes GeoTIFFs to GeoServer and creates the GeoServer configuration entries required by the WMS 1.3.0 Façade. The Publisher processes a synchronization source directory with input files. This directory contains configuration settings, together with new images that have to be published. The images are copied to a target directory that can be accessed from GeoServer. Entries in GeoServer that reference these images are then created via the GeoServer REST API. The Publisher also deletes old expired images and their configuration entries in GeoServer.

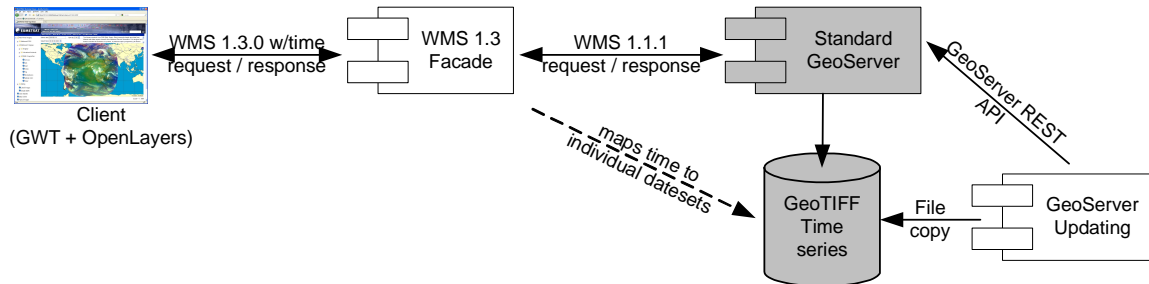


Figure 5: GeoServer extensions

A client application is able to access those actual aggregated layers using the WMS 1.3.0 interface.

## EO Portal Image Gallery Client

The EO Portal Image Gallery Client (see Figure 6) uses a tree structure to access the available products.

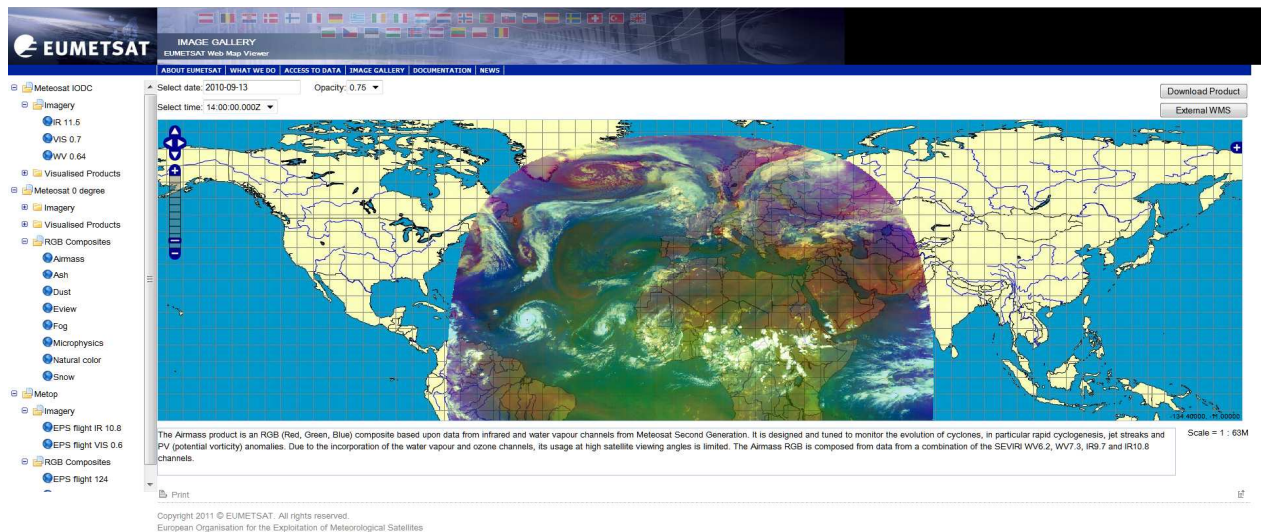


Figure 6: Meteosat Second Generation (MSG): Airmass Product

It further provides the following functionality:

- Map display with zoom and pan (by means of OpenLayers standard functionality)
- Scale display (by means of OpenLayers standard functionality)
- Toggle layer visibility (by means of OpenLayers standard functionality)
- Switching background layers (by means of OpenLayers standard functionality)
- Switch SRS based on background layer (e.g. North Polar Stereographic, s. Figure 7)
- Add a custom WMS 1.1.1 user-defined layer
- Select a date and time for the product
- Set the opacity for the selected product



- Display a description of the product
- Download a product as an image in a customer defined size and in one of the following formats: JPG, GIF, PNG, TIFF, KML (for display in Google Earth)

The portal user can change the base map of the EO Portal Image Gallery Client. The URL of an external WMS can be entered (in Figure 1 from demis.nl).

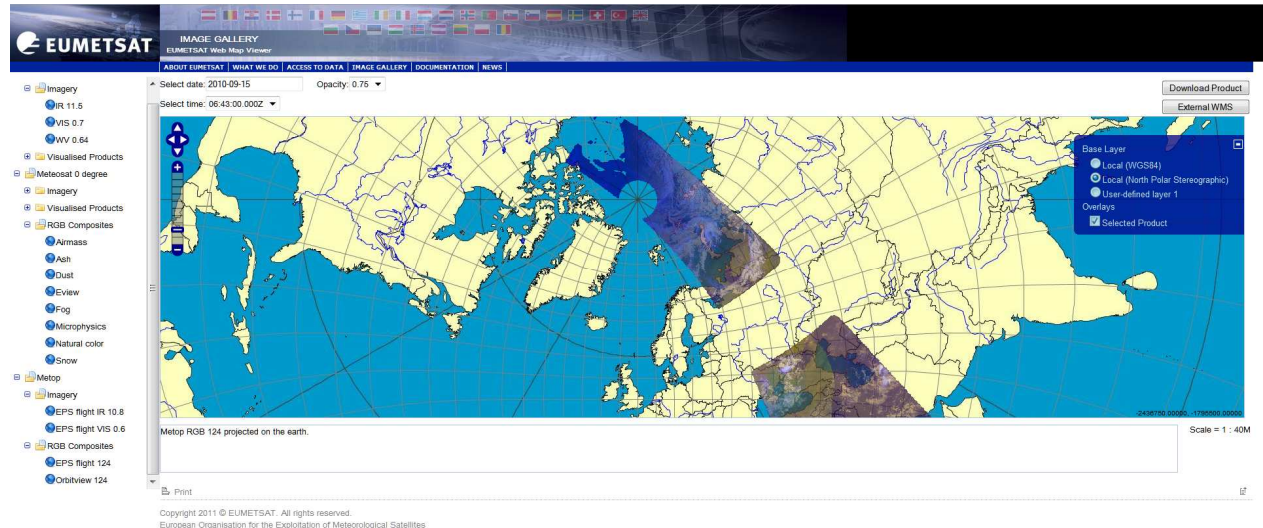


Figure 7: Metop RGB Product projected on North Polar Stereographic

## CONCLUSION

The new EO Portal Image Gallery provides access to a selection of near-real-time imagery from Meteosat-9 and Meteosat-7, in geostationary orbits, as well as from Metop, in low earth orbit. OGC services such as Web Map Services (WMS) and Web Coverage Services (WCS) support the visualisation and provision of EO data and products as geo referenced images in a flexible manner. Geoserver 2.0.2 was selected as software base for the implementation of the WMS and WCS services. For supporting WMS 1.3.0 with time dimension and to support automatic publishing of the images two Geoserver-Extensions - WMS 1.3.0 Façade and Publisher (Updating) - had been developed.

The EO Portal Image Gallery Client is a flexible web client with tree based access to the available products accessible using WMS 1.3.0 layers with time dimension. It provides typical functions of interactive web mapping applications like panning, zooming, scaling, adding and switching visible layers and their opacity, switch CRS etc. Further it provides details of the product and allows downloading. The implementation is based on Google Web Toolkit and OpenLayers.

EO Portal Image Gallery Server and Client are deployed for the beta testing phase into Amazon Elastic Compute Cloud (EC2).

One of the still outstanding requirements to be implemented is the display of continuous changes in the satellite images during the observed time period as a kind of animation. Further it is planned to implement some kind of access control to the WMS/ WCS endpoints.

## REFERENCES

- [1] – OpenGIS Web Map Server Implementation Specification [OGC Doc 06-042], version 1.3.0.
- [2] – OpenGIS Web Map Services – Profile for EO Products [OGC Doc 07-063r1], OGC Best Practice.
- [3] – OpenGIS Web Coverage Service Implementation Standard [OGC Doc 07-067r5], version 1.1.2.
- [4] – OpenGIS Web Feature Service 2.0 Interface Standard [OGC Doc 09-025r1], version 2.0.0.

[5] – OpenGIS Styled Layer Descriptor profile of the Web Map Service Implementation Specification [OGC Doc 05-078r4], version 1.1.0.

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