Open Geospatial Consortium

Date: 2011-12-19

Reference number of this document: OGC 11-116

http://www.opengis.net/doc/ows8-geoprocessing-eo

Category: Public Engineering Report

Editor: Peter Baumann

OGC® OWS-8 Geoprocessing for Earth Observations Engineering Report

Warning

This document is not an OGC Standard. This document is an OGC Public Engineering Report created as a deliverable in an OGC Interoperability Initiative and is not an official position of the OGC membership. It is distributed for review and comment. It is subject to change without notice and may not be referred to as an OGC Standard. Further, any OGC Engineering Report should not be referenced as required or mandatory technology in procurements.

Document type: OpenGIS® Engineering Report
Document subtype: NA
Document stage: Approved for public release
Document language: English

This document is a deliverable for the OGC Web Services 8 (OWS-8) testbed activity. OWS testbeds are part of OGC's Interoperability Program, a global, hands-on and collaborative prototyping program designed to rapidly develop, test and deliver proven candidate standards or revisions to existing standards into OGC's Standards Program, where they are formalized for public release. In OGC's Interoperability Initiatives, international teams of technology providers work together to solve specific geoprocessing interoperability problems posed by the Initiative's sponsoring organizations. OGC Interoperability Initiatives include test beds, pilot projects, interoperability experiments and interoperability support services - all designed to encourage rapid development, testing, validation and adoption of OGC standards.

The OWS-8 sponsors are organizations seeking open standards for their interoperability requirements. After analyzing their requirements, the OGC Interoperability Team recommend to the sponsors that the content of the OWS-8 initiative be organized around the following threads:

* Observation Fusion
* Geosynchronization (Gsync)
* Cross-Community Interoperability (CCI)
* Aviation

More information about the OWS-8 testbed can be found at:

http://www.opengeospatial.org/standards/requests/74

OGC Document [11-139] “OWS-8 Summary Report” provides a summary of the OWS-8 testbed and is available for download:

https://portal.opengeospatial.org/files/?artifact_id=46176

License Agreement

Contents

Page

OGC® Geo-Processing of Earth Observations Report

1 Introduction

Document contributor contact points

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

Name	Organization
Stephan Meissl	EOX IT Services GmbH
Peter Baumann	Jacobs University Bremen, rasdaman GmbH
Bastian Schaeffer	Münster University / 52north

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 Geo-Processing of Earth Observations

2.1 Introduction

Ad-hoc processing of Earth Observation (EO) data available through online resources is gaining more and more attention. Expected benefits include

- More versatile EO data access
- More convenient EO data access
- Consequently, broadened use and exploitation of EO data
- An important step towards integration of EO data into automatic chaining and orchestration
- More efficient EO data access: indicating the exact desired result and evaluating processing code close to the coverage data source (i.e., on the server) minimizes network traffic, one of today's critical performance limiting factors.

EO data belong to the class of coverages, i.e., "space/time varying phenomena" as defined in ISO 19123 [5] (see below for a more detailed discussion). Therefore, in OGC the coverage standards apply to EO discovery, access, processing, and exchange. In OWS-8, the following standards have been investigated and put in relation:

- Web Coverage Service (WCS)
- Web Coverage Service EO Application Profile (EO-WCS)
- Web Coverage Processing Service (WCPS)
- Web Processing Service (WPS)

In the subsections below these standards are briefly introduced.

2.2 Coverage Model

EO data form a subclass of *coverages*. The term coverage is defined in ISO 19123 [5], which is identical to OGC Abstract Topic 6 [6], as, roughly speaking, a representation of a space/time varying phenomenon. This generic, abstract coverage definition does not yet allow for interoperable implementations – there can be – and are, in fact – many different implementations of the abstract ISO coverage definition which, however, do not allow interchange of coverage documents among each other.

While ISO 19123 defines a generic, abstract coverage model, the OGC GML Application Schema for Coverages[3] establishes a concrete coverage model which implements ISO 19123 and allows for interoperable implementations, including concise conformance testing. This Application Schema for Coverages is based on GML 3.2.1 [1]; by defining coverage data structures through XML (with XML Schema and Schematron) a clear, unambiguous semantics is established which also allows a concise mapping to representations in other data format encodings, such as GeoTIFF.

From the set of coverages defined by ISO 19123 and GML, two coverage subtypes are relevant for EO: *RectifiedGridCoverages* consist of values assigned to points which are aligned to a grid with equidistant spacing and with a clear positioning in space and time. L1 and higher-level EO products fall into this category. *ReferenceableGridCoverages*, on the other hand, have an underlying grid which is not bound to this restriction of equidistance; random distances between grid lines, as well as curvilinear grid lines, are possible. Typical use cases include L0 EO data.

2.3 WCS

Based on the coverage model outlined, OGC offers service standards for finding, accessing, and processing of coverages. At the heart is the Web Coverage Service (WCS). WCS actually is not a single standard, but a modular suite of standards. WCS Core [2] establishes the basic service together with functionality for accessing and subsettingcoverages; all WCS implementations must conform to this Core. Several extensions add bespoke extra functionality which implementations optionally may offer. Among these extensions are several protocol bindings (currently: GET, POX, and SOAP), service extensions like scaling & interpolation, CRS transformation, a coverage query language, and upload of coverages to a server. Format encoding extensions allow to send and receivecoverages in a number of formats, such as GML, GeoTIFF, JPEG200, NetCDF, and HDF. (Note that, at the time of this writing, not all extensions are already available.)

2.4 WCPS

The OGC Web Coverage Processing Service (WCPS) language standard [8]defines a raster query language in the style of SQL and XQuery. This query language allows processing and filtering on multi-dimensional raster coverages[1]. Figure 1 illustrates some representative use cases. As a concrete example, let us look at the query "*From MODIS scenes M1, M2, and M3, the absolute of the difference between red and nir, in HDF-EOS - but only those where nir exceeds 127 somewhere inside region R*". In WCPS syntax this is expressed as

```
for $c in ( M1, M2, M3 ),
    $r in ( R )
where
```

[1]In the EarthServer project (www.earthserver.eu) starting Fall 2011, the WCPS language will be extended to address all coverage types defined in the GML Application Schema for Coverages[3].

```
        some( $c.nir> 127 and $r )
    return
        encode(
            abs( $c.red - $c.nir ),
            "nitf"
        )
```

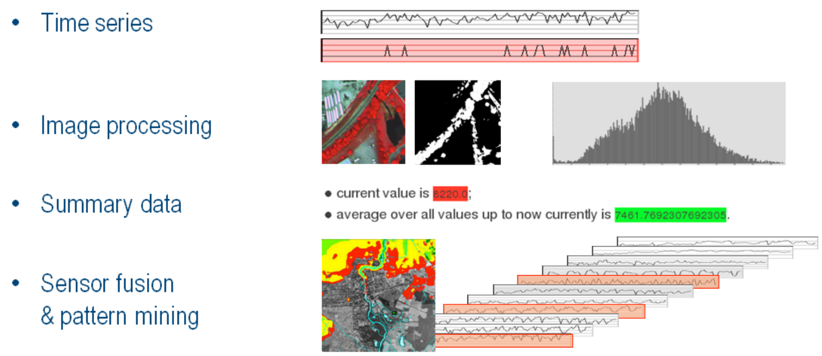

Figure 1: Representative WCPS use cases.

WCPS is a standalone language specification which, however, is tied into the WCS suite as a "Coverage Processing Extension". On WPS side, it is linked in as a "Coverage Processing Application Profile".

2.5 EO-WCS

The OGC *Web Coverage Service (WCS) Application Profile – Earth Observation* (EO-WCS), defines a profile of WCS 2.0 [OGC 09-110r3] for use on Earth Observation data. An Application Profile bundles several specifications and possibly adds additional requirements on an implementation. Extra requirements can be additions (for example, Dataset Series are introduced by this specification) or constraints (for example, coverages offered are restricted to 2-D rasters).

In terms of EO processing, EO-WCS offers several specific relevant functionalities:

- A data model extending 2-D EO scenes with a time dimension and EO metadata
- hierarchical grouping of coverage sets
- spatio-temporal EO coverage discovery

2.6 WPS

The OGC Web Processing Service (WPS) standard [10] defines a generic method of remotely invoking geoprocessing performed in a server. WPS as such describes processes in terms of their function signature (i.e., input and output parameter types), but does not have any concrete domain semantics associated in a machine readable format like any other OGC Web Service (e.g. Semantics of WMS Layer are also not included in a WMS response) ; Syntactic interoperability is thereby achieved. This behavior keeps it open for any kind of processing. This lack of machine-readable semantics is illustrated in Figure 2: the semantics of function "buffer" is only described by freetext elements *title* and *abstract*.

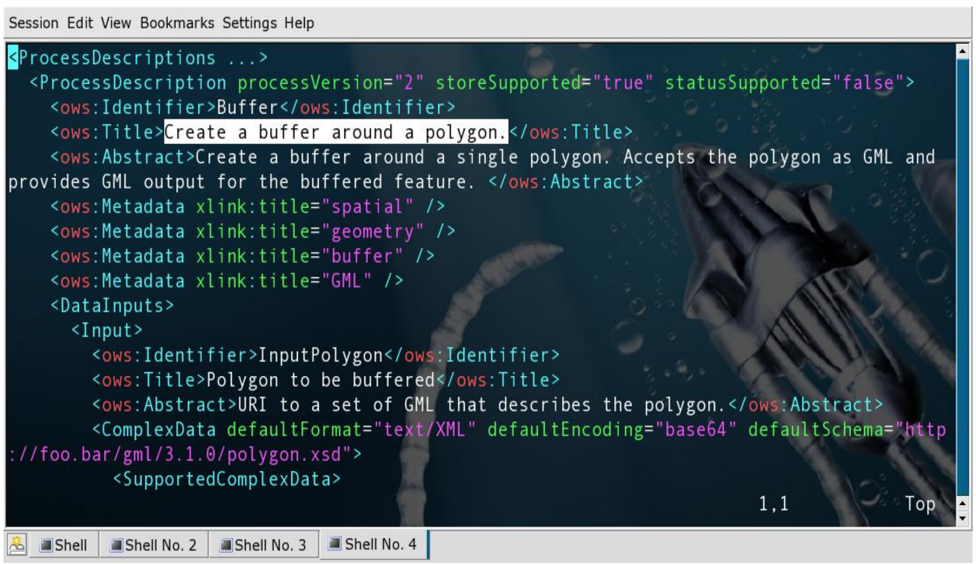

Figure 2: WPS process semantics described by freetext fields.

Therefore, the WPS standard already suggests to establish focused Application Profiles which restrict themselves to particular domains and functionality classes and achieve semantic interoperability. An example of such an application profile is the WCPS Application Profile for WPS, which has been submitted to the OGC WPS Standards Working Group (WPS.SWG) establishing WCPS as a WPS Application Profile [8], thereby enabling interoperable processing services on coverages.

3 OWS-8 Geoprocessing Experiments

3.1 52 North: WPS

The 52°North WPS served as processing and orchestration engine as shown in Figure 3.

The orchestration part was performed as an opaque Geoprocessing workflow. The work-flow was encoded as the 52North Geoprocessing Orchestration Script and contained three WPS Services. The orchestration WPS requests the first WPS in the Geoprocessing workflow and provides all datasets which are send by the client. Since the datasets are sent by reference, the WPS resolves these references from the EOX WCS and aggregates them by using a GRASS function in the backend.

The results are served back to the orchestration WPS, which calls the second WPS in the workflow with the results of the first WPS.

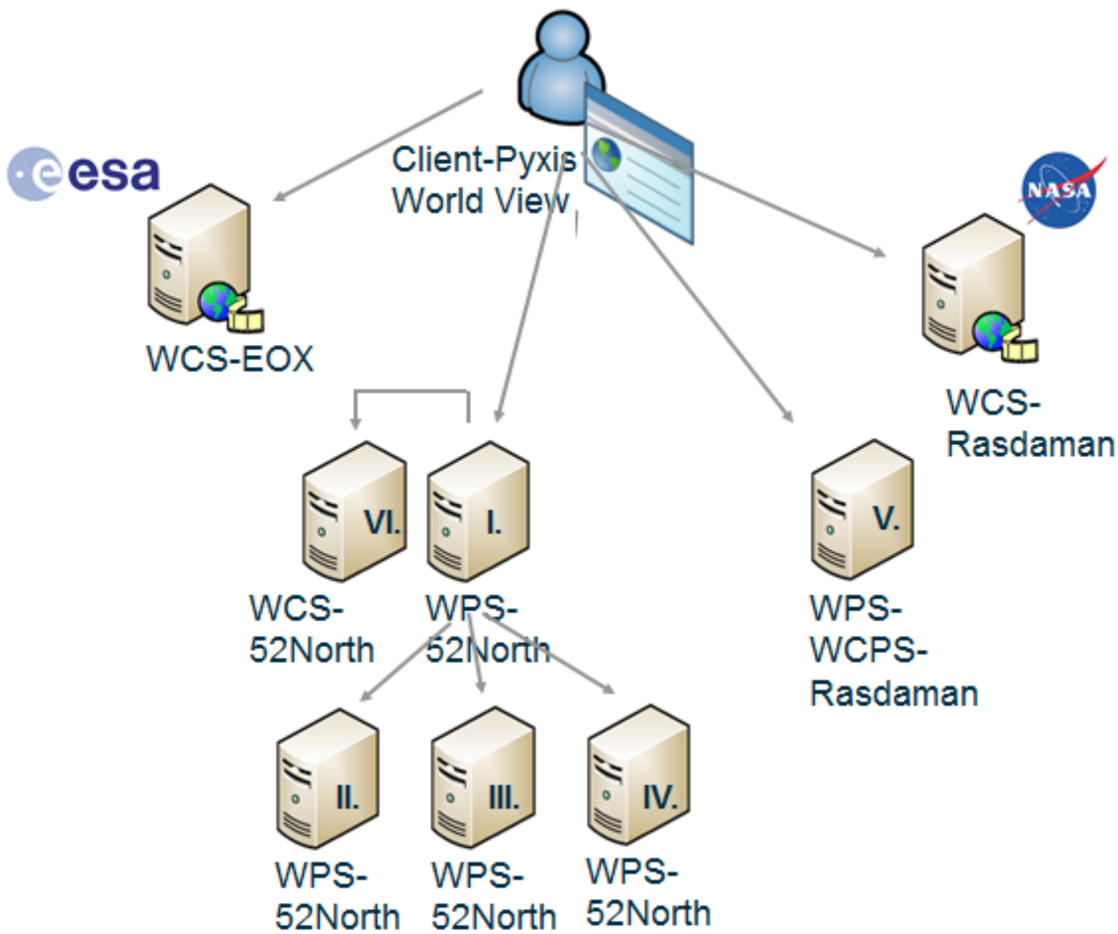

Figure 3: WPS orchestration.

This WPS resolves the references for the input data from the first WPS and normalizes them via a Z-Transformation.

The results are send back by reference to the orchestration WPS. That WPS calls the third WPS in the workflow, which also resolves the input data from the previous WPS and performs a Masking task in the basis of some java algorithm.

3.2 EOxServer: WCS, EO-WCS

A demonstration of the EO-WCS functionality was provided at the two service endpoints http://ows.eox.at/cci/ows? and http://ows.eox.at/ofc/ows?. A summary of the available data and some sample requests can be found at http://ows.eox.at. Note that these demonstration services serve data for the OWS-8 demonstration scenarios namely the "Monterey Earthquake emergency response scenario" in the Cross-Community Interoperability (CCI) thread and the "Amazon Drought analysis" scenario in the Observation Fusion – Coverages (OFC) sub-thread.

For the "Amazon Drought analysis" scenario a selected set of products from the ENVISAT MERIS L1 Full Resolution Full Swath (FRS) collection is offered online and was used in the drought analysis. The selection covers the Amazon area i.e. the spatial bounding box spanning from 10° North to 20° South and 45° West to 80° West with as few clouds as possible. Only images taken in the July, August, September period of 2009 are part of the set. The MERIS data is offered via EO-WCS grouped together into one DatasetSeries.

The second data offered is the FAPAR (Fraction of Absorbed Photosynthetically Active Radiation) band from MERIS Global Vegetation Index (MGVI) L3 products [WR3]. This band is available from the monthly products for July, August, and September in the years from 2006 to 2010 again via EO-WCS grouped together into one DatasetSeries.

Additionally both DatasetSeries are also available via EO-WMS.

The consumption of these datasets both by the WPS services and by the PYXIS client directly was demonstrated successfully in the frame of OWS-8.

3.3 Rasdaman: WCS, WCPS, WPS

A rasdaman database was established with multi-dimensional holdings. The PYXIS client accessed this database.

3.3.1 Data sets

3.3.1.1 5D forecast data

The forecast consists of temperature, height, and windspeed variables, with axes modelTime, pressure, t, x, y.

Sample WCPS query: “initial temperature at model time 0 and surface level”:

for c in (Temperature_5D)
*return encode((char)((c[t(0), modelTime(0), pressure(0)] - 240) * 4), "png")*

Same request, embedded in WPS:

http://212.201.49.173:8080/ows8/wps?service=WPS&Version=1.0.0&Request=Execute&identifier=ProcessCoverages&DataInputs=[WcpsAbstractSyntax=for%20c%20in%20(%20Temperature_5D%20)%20return%20encode(%20(char)((c[%20t(0),%20modelTime(0),%20pressure(0)%20]%20-%20240)%20*%204),%20%22png%22%20)]

Sample WCS request:

```
<?xml version="1.0" encoding="UTF-8"?>
<wcs:GetCoverage xmlns:wcs=http://www.opengis.net/wcs/2.0
   xmlns:gml=http://www.opengis.net/gml/3.2
   xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
   xsi:schemaLocation=http://www.opengis.net/wcs/2.0 ../../wcsAll.xsd
   service="WCS" version="2.0.0">
   <wcs:CoverageId>u_wind_5D</wcs:CoverageId>
   <wcs:DimensionTrim>
      <wcs:Dimension>x</wcs:Dimension>
      <wcs:TrimLow>100</wcs:TrimLow>
      <wcs:TrimHigh>109</wcs:TrimHigh>
   </wcs:DimensionTrim>
   <wcs:DimensionTrim>
      <wcs:Dimension>y</wcs:Dimension>
      <wcs:TrimLow>100</wcs:TrimLow>
      <wcs:TrimHigh>109</wcs:TrimHigh>
   </wcs:DimensionTrim>
   <wcs:DimensionSlice>
      <wcs:Dimension>t</wcs:Dimension>
      <wcs:SlicePoint>3</wcs:SlicePoint>
   </wcs:DimensionSlice>
   <wcs:DimensionSlice>
      <wcs:Dimension>pressure</wcs:Dimension>
      <wcs:SlicePoint>3</wcs:SlicePoint>
   </wcs:DimensionSlice>
   <wcs:DimensionSlice>
      <wcs:Dimension>modelTime</wcs:Dimension>
      <wcs:SlicePoint>1</wcs:SlicePoint>
   </wcs:DimensionSlice>
</wcs:GetCoverage>
```

Sample WPS-WCPS PostXML request:

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<wps:Execute service="WPS" version="1.0.0"
xmlns:wps="http://www.opengis.net/wps/1.0.0"
xmlns:ows="http://www.opengis.net/ows/1.1" xmlns:ogc="http://www.opengis.net/ogc"
```



```
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/wps/1.0.0
http://schemas.opengis.net/wps/1.0.0/wpsExecute_request.xsd">
  <ows:Identifier>petascope.wps.n52.ProcessCoverages</ows:Identifier>
  <wps:DataInputs>
    <wps:Input>
      <ows:Identifier>Query</ows:Identifier>
      <wps:Data>
        <wps:ComplexData mimeType="text/plain">
        for c in ( Temperature_5D )
        return encode( (char)((c[ t(0), modelTime(0), pressure(0) ] - 240) * 4), "png" )
        </wps:ComplexData>
      </wps:Data>
    </wps:Input>
  </wps:DataInputs>
  <wps:ResponseForm>
    <wps:RawDataOutput mimeType="image/png">
      <ows:Identifier>CoverageList</ows:Identifier>
    </wps:RawDataOutput>
  </wps:ResponseForm>
</wps:Execute>
```

3.3.1.2 Oil Spill (Gulf of Mexico)

This 3D (x, y, t) cube contains daily (?) observations of the oil carpet emerging from the “Deepwater Horizon” disaster, and shows how pollution reaches the US coast.

3.3.1.3 TRMM Rainfall Data:

This 3D (x, y, t) cube contains monthly rainfall data.

3.3.1.4 NDVI / EVI / VI_Quality over Amazon

3D (x, y, t) data with a 16 days temporal resolution. Data used in Amazon drought use case scenario.

3.3.2 Services offered

On these above datasets (and further ones), interfaces were established for WCS 2.0, WCPS, and WPS. Below some sample request are reproduced.

3.3.2.1 WCS 2.0

GetCapabilities:


```xml
<?xml version="1.0" encoding="UTF-8"?>
<wcs:GetCapabilities  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:ows=http://www.opengis.net/ows/2.0
   xmlns:wcs="http://www.opengis.net/wcs/2.0"
   xsi:schemaLocation=http://www.opengis.net/wcs/2.0 ../../wcsAll.xsd
   service="WCS">
   <ows:AcceptVersions>
      <ows:Version>2.0.0</ows:Version>
   </ows:AcceptVersions>
</wcs:GetCapabilities>
```

DescribeCoverage:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<wcs:DescribeCoverage  xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
   xmlns:wcs="http://www.opengis.net/wcs/2.0"
   xmlns:gml="http://www.opengis.net/gml/3.2"
   xsi:schemaLocation="http://www.opengis.net/wcs/2.0 ../../wcsAll.xsd"
   service="WCS" version="2.0.0">
   <wcs:CoverageId>TRMM</wcs:CoverageId>
</wcs:DescribeCoverage>
```

GetCoverage 2D:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<wcs:GetCoverage xmlns:wcs=http://www.opengis.net/wcs/2.0
   xmlns:gml=http://www.opengis.net/gml/3.2
   xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
   xsi:schemaLocation=http://www.opengis.net/wcs/2.0 ../../wcsAll.xsd
   service="WCS" version="2.0.0">
   <wcs:CoverageId>LAND_USE_AMAZON</wcs:CoverageId>
   <wcs:DimensionTrim>
      <wcs:Dimension>x</wcs:Dimension>
      <wcs:TrimLow>20</wcs:TrimLow>
      <wcs:TrimHigh>29</wcs:TrimHigh>
   </wcs:DimensionTrim>
   <wcs:DimensionSlice>
      <wcs:Dimension>y</wcs:Dimension>
      <wcs:SlicePoint>1</wcs:SlicePoint>
   </wcs:DimensionSlice>
</wcs:GetCoverage>
```

GetCoverage 3D:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<wcs:GetCoverage xmlns:wcs=http://www.opengis.net/wcs/2.0
   xmlns:gml=http://www.opengis.net/gml/3.2
   xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
   xsi:schemaLocation=http://www.opengis.net/wcs/2.0 ../../wcsAll.xsd
   service="WCS" version="2.0.0">
   <wcs:CoverageId>radar_base_reflectivity</wcs:CoverageId>
   <wcs:DimensionTrim>
      <wcs:Dimension>x</wcs:Dimension>
      <wcs:TrimLow>740</wcs:TrimLow>
      <wcs:TrimHigh>749</wcs:TrimHigh>
   </wcs:DimensionTrim>
   <wcs:DimensionTrim>
      <wcs:Dimension>y</wcs:Dimension>
      <wcs:TrimLow>880</wcs:TrimLow>
      <wcs:TrimHigh>889</wcs:TrimHigh>
   </wcs:DimensionTrim>
   <wcs:DimensionSlice>
      <wcs:Dimension>t</wcs:Dimension>
      <wcs:SlicePoint>3</wcs:SlicePoint>
   </wcs:DimensionSlice>
</wcs:GetCoverage>
```

3.3.2.2 WCPS 1.0

ProcessCoverages:

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<ProcessCoveragesRequest xmlns="http://www.opengis.net/wcps/1.0" service="WCPS"
version="1.0.0">
   <query>
      <abstractSyntax>
            for c in ( OIL_SPILL_MONTEREY_BAY )
            return encode( (c[ t(0) ]  ), "png" )
      </abstractSyntax>
   </query>
</ProcessCoveragesRequest>
```

3.3.2.3 WPS 1.0

Execute:

```
http://212.201.49.173:8080/ows8/wps?service=WPS&Version=1.0.0&Request=Execute
&identifier=ProcessCoverages&DataInputs=[WcpsAbstractSyntax=for c in (
NDVI_AMAZON) return encode( c[ t(0) ] , "png" )]
```

4 Findings

Coverage processing spans a wide field, with frequently varying, if not contradicting, requirements:

- From simple access over repeating fixed processing to complex, specialized processes
- From ad-hoc, individual one-off requests over repeating parametrized tasks to standing queries
- From interactive, exploratory access to routinely invoked, automated tasks

In the context of this discussion it is noteworthy that this query language is restricted in expressive power: it cannot perform recursive or iterated function calls. This restriction is necessary to obtain a language which is “safe in evaluation”, i.e.: every possible request is guaranteed to terminate after a finite number of steps. Well known from database languages, this “security belt” safeguards against a class of Denial of Service attacs.

It turns out that the specifications investigated are not competing, but together provide a powerful, versatile Swiss Army Knife to address the complete spectrum of coverage processing. Notably this is not constrained to EO data in the narrower sense, i.e., satellite imagery. According to the participants’ experience, this likewise applies, for example, to atmospheric and ocean data.

As a recommendation, service providers may use Table 1 as a decision aid. It consists of the following categories:

- **Simplicity of use by clients:** Important factor in all applications
- **New Function Effort:** Effort for implementing new functionality on the server side
- **Reusability of existing Functions:** Effort for reusing exiting functionality, e.g. algorithms in other programs/formats
- **Expressive Power:** Measurement of how expressive the service protocol is
- **Functional Flexibility:** How Flexible is the standard to adapt new requirements
- **Data Flexibility:** How Flexible is the standard to use new datasources

Table 1 — Coverage Processing: Services Functionality vs. Requirements

Standard	Simplicity of use by clients	New function effort	Reuseabilitof existing functionality/ data	Expressive power	Functional Flexibility	Data Flexibility

WCS Core	+	-[2]	/	-	-	-
WCS extensions	o	-[3]	/	o	o[4]	-
EO-WCS	+	-	/	o[5]	o	-
WCPS[6]	o … +[7]	+[8]	--[9]	+[10]	+	-
WPS	+	-[11]	++	++	-[12]	+

In summary, this can roughly be simplified to the following recommendation for coverage processes:

- For comparatively narrowly defined tasks, use WCS Core and Extensions;
- For ad-hoc processing and filtering where queries are not known in advance, but can be expressed analytically, and data is known and under control of the same service, use WCPS with a host service such as WCS or WPS;
- For well-defined processing tasks of algorithmic complexity or for proprietary algorithms and where data source shall be held loosely coupled/flexible as well as for orchestration tasks to shield complexity, use WPS.

[2] No changes possible

[3] Adding an extension requires server-side programming

[4] Only choice is to implement a conformance class or not

[5] Functionality is specialized towards satellite image data, but not built, e.g., for 4D/5D atmoslpheric and ocean data

[6] Identical in all aspects to WPS Coverage Processing Application Profile

[7] Query writing effort depends on task complexity

[8] Client phrases new query, no change on server side required

[9] Only querys formulated in WCPS can be used. No existing legacy systems/code

[10] Expressions of unlimited complexity

[11] Changes require server-side programming

[12] Process code implemented cannot be influenced by the client, parameters can be influenced

5 References

[1] OGC 07-036, *Geography Markup Language (GML) Encoding Standard*, version 3.2.1

[2] OGC 10-110r3. *OGC® Web Coverage Service 2.0 Interface Standard*, version 2.0.0

[3] OGC 10-146r1. *OGC® GML 3.2.1 Application Schema for Coverages*, version 1.0.0

[4] OGC 11-140. *OGC® Web Coverage Service (WCS) Application Profile – Earth Observation*, version 1.0.0

[5] ISO: *Geographic Information – coverage geometry and functions*. ISO 2005:19123

[6] OGC 07-011, Ab*stract Specification Topic 6: The Coverage Type and its Subtypes*, version 7.0 (identical to ISO 19123:2005)

[7] OGC 09-146r1.*OGC® WCS 2.0 Core Interface Standard*, version 2.0.0

[8] OGC 08-068r2. *Web Coverage Processing Service (WCPS) Interface Standard*, version 1.0.0

[9] OGC 09-045. *OGC 11-116(WPS) - OWS-8 Geoprocessing for Earth Observations* Engineering Report, version 0.2.0

[10]OGC 05-007r7. *OGC 11-116Web Processing Service Implementation Specification*, version 1.0.0