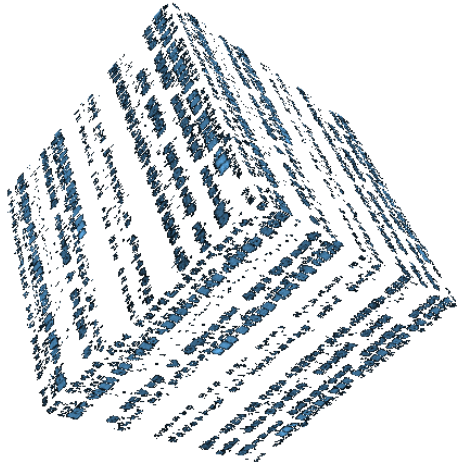


Spatio-Temporal Datacubes: How OGC/ISO Coverages Accomplish Modeling, Accessing, and Processing

2024 Joint OGC – OSGeo – ASF Code Sprint

Peter Baumann

Constructor University | rasdaman GmbH

Agenda

- Services Available for the Code Sprint
- OGC/ISO Coverages
- Dealing with Space & Time
- Serving Coverages
- Discussion

Summary:
Services Available for the Code Sprint

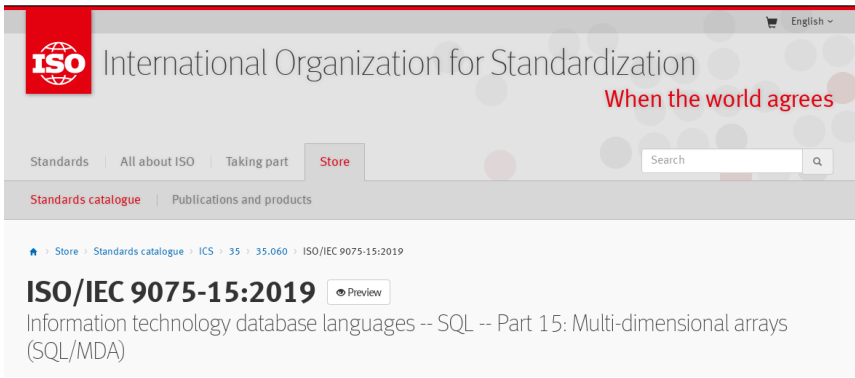
- Earth Datacube Playground: https://standards.rasdaman.com
  - Several 1D..4D datacubes
  - Several clients
- Endpoints:
  - WCS: https://standards.rasdaman.com/demo_wcs.html
  - WCPS: https://standards.rasdaman.com/demo_wcps.html
- Help:
  - https://earthserver.eu/wcs
  - https://ai-cu.be/chatcube
- Powered by rasdaman

rasdaman

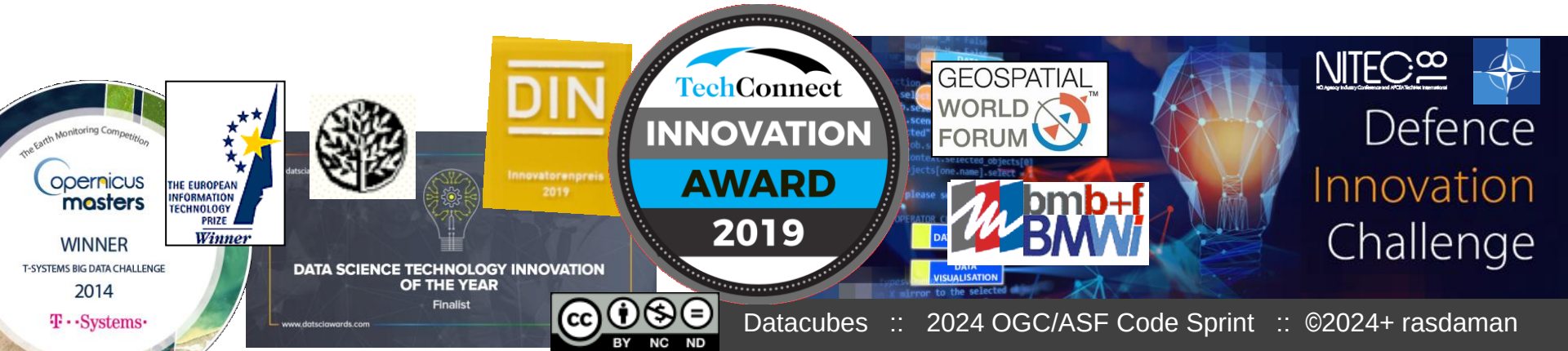
= „raster data manager“: n-D actionable datacubes

- pioneered datacubes, cf. publications & patents

- massively scalable
  Big Datacube Management & Analytics
  - full-stack implementation
  - Multi-PB; 1000x parallelization; federation; security; GreenCubes®

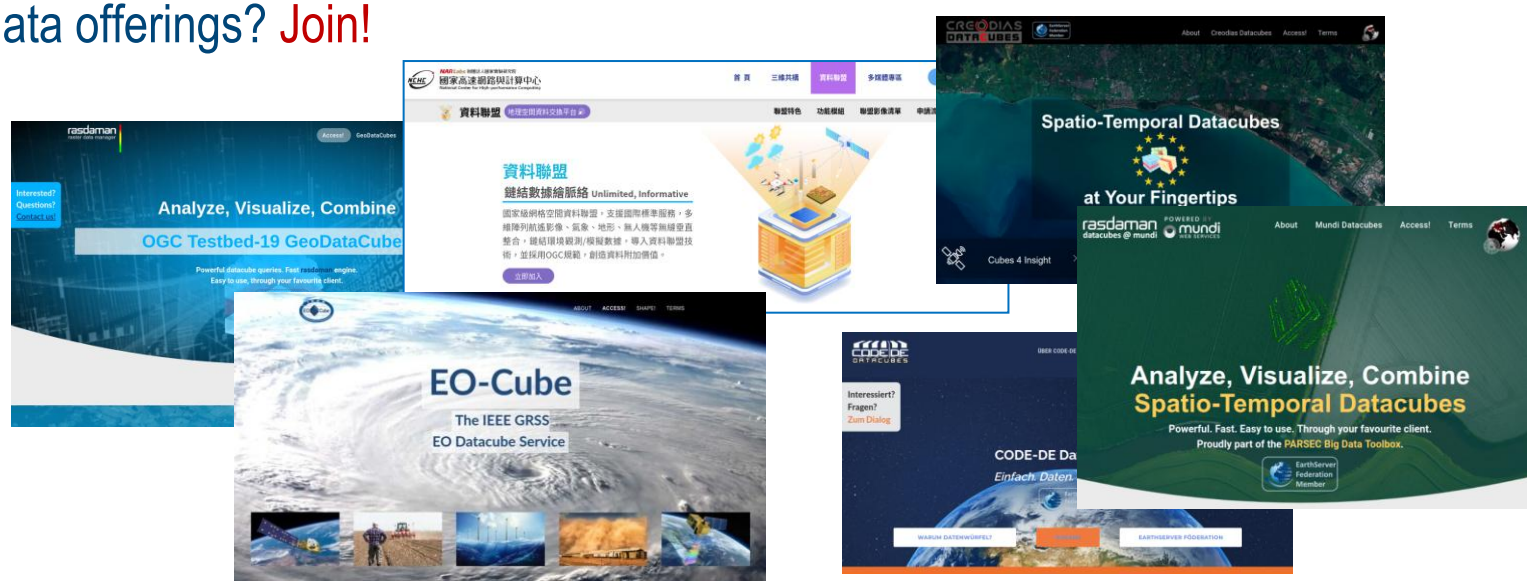


- Interoperable: Reference Implementation, blueprint for standards



EarthServer

- datacube provider federation
  - Multi-PB location-transparent data space
  - Open standards, zero-coding
- Open, free, transparent, democratic
  - Open & private; free & commercial
  - Have data offerings? Join!

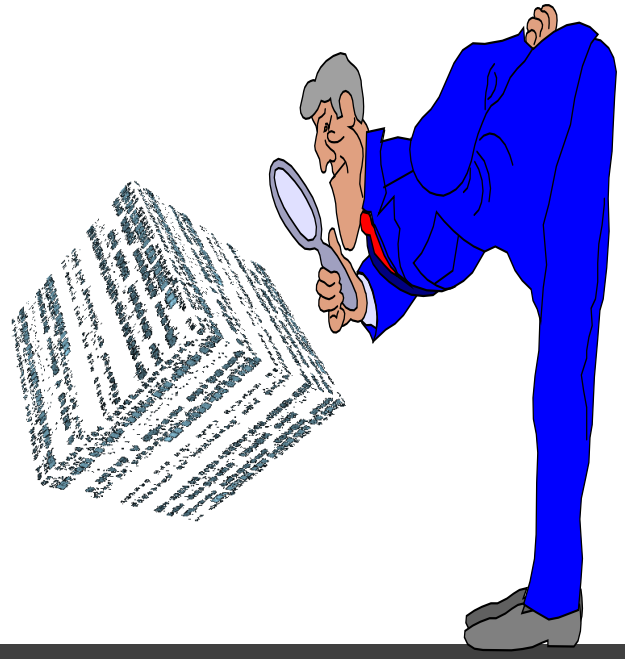


OGC/ISO Coverage Implementation Schema

the rasdaman team

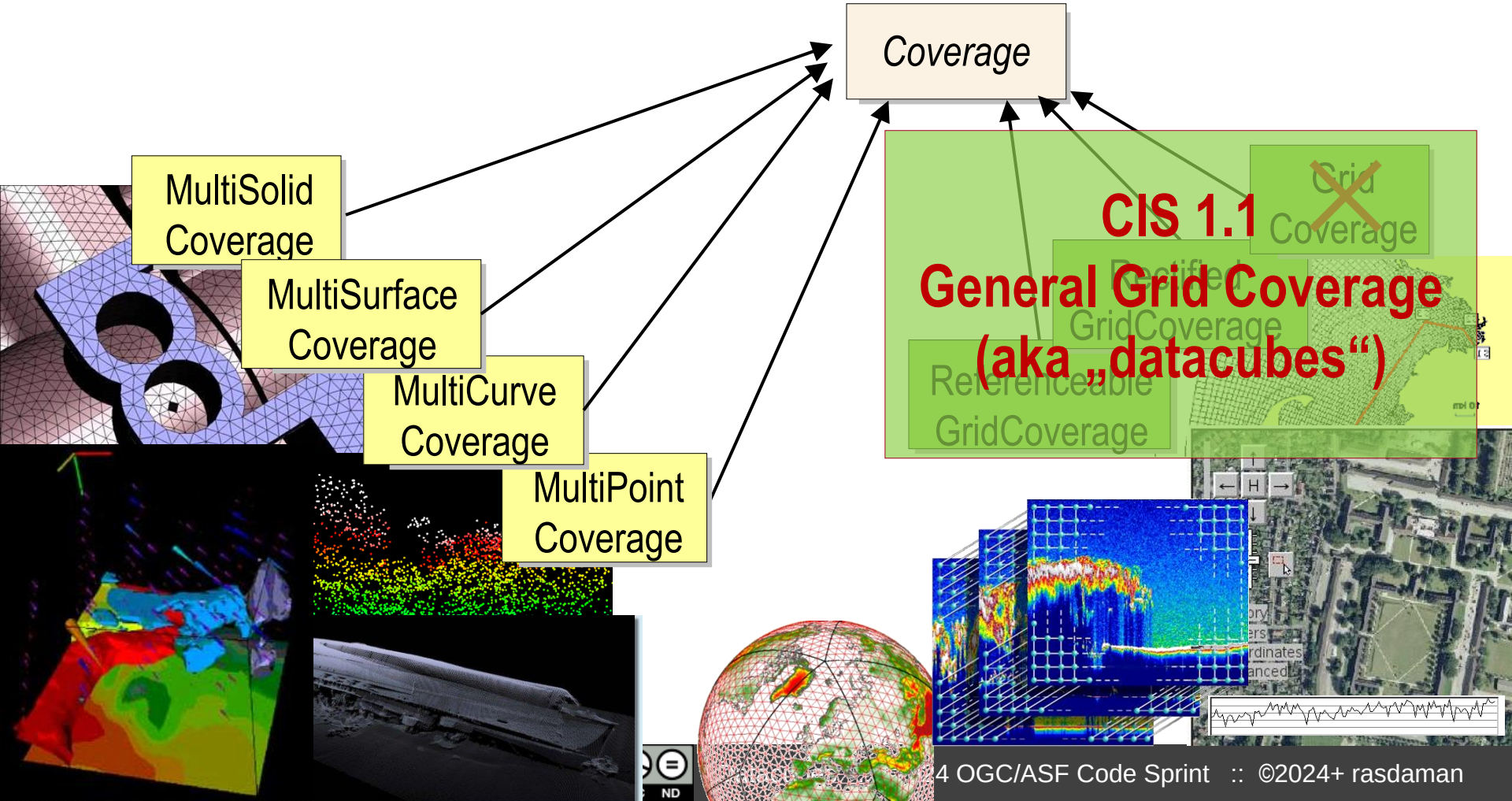
Constructor University | rasdaman GmbH

www.jacobs-university.de/lsis | www.rasdaman.com

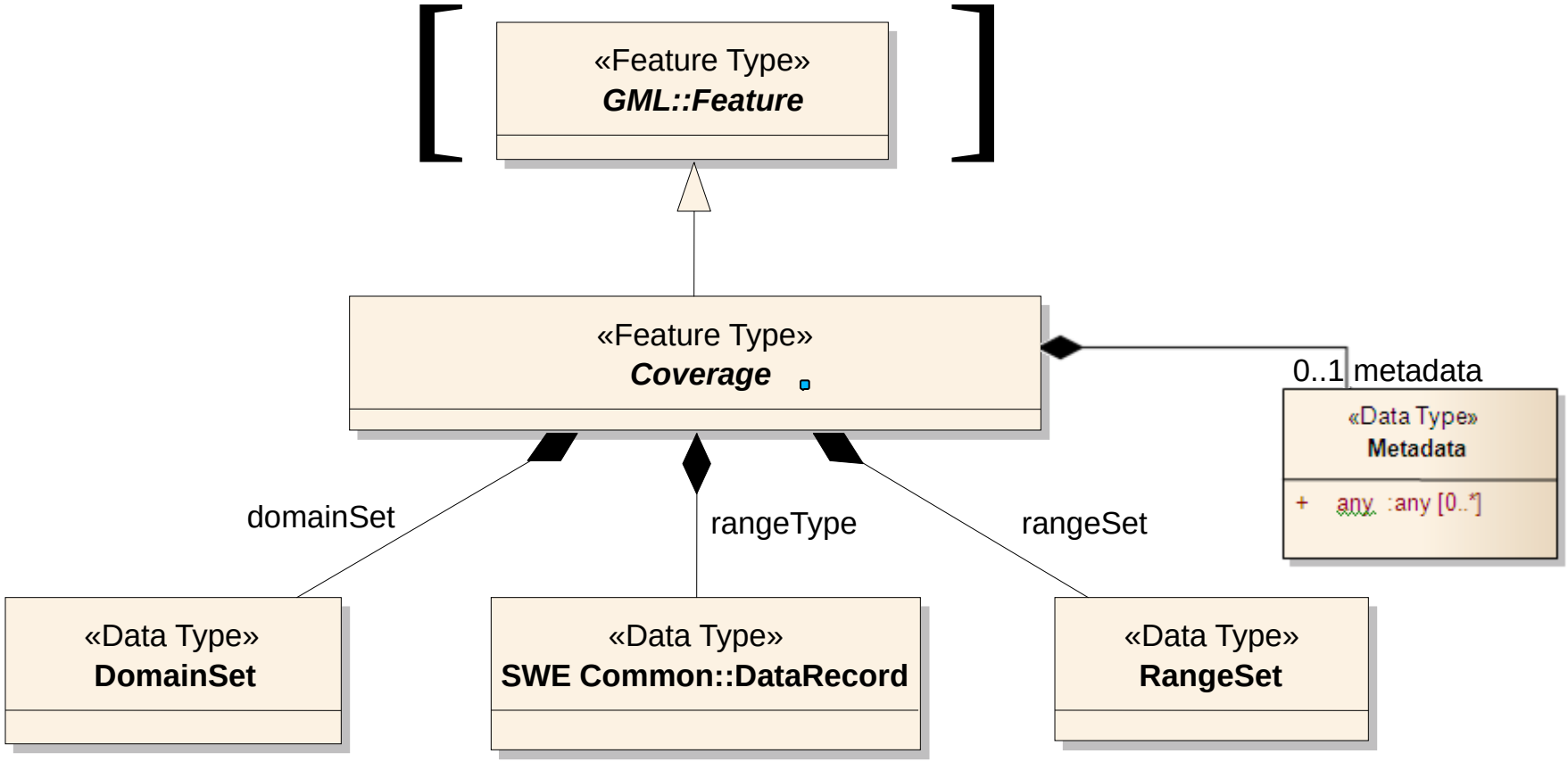


Coverages= Grids + Point Clouds + Meshes

- abstract: OGC Abstract Topic 6, ISO 19123-1
- concrete, interoperable: ISO/OGC Coverage Implementation Schema (CIS, aka GMLCOV)



Coverage Definition



[OGC 09-146r2]

A Simple Coverage, in GML

```
<generalGridCoverage ...  gml:id="CIS_001">

    <domainSet>
        <generalGrid srsName="http://www.opengis.net/def/crs-compound?
                              1=http://www.opengis.net/def/crs/EPSG/0/4979
                             &amp;2=http://www.opengis.net/def/crs/OGC/0/AnsiDate"
            axisLabels="Lat Long h date">
            <regularAxis   axisLabel="Lat"  uomLabel="deg" lowerBound="40"  upperBound="60" resolution="10"/>
            <regularAxis   axisLabel="Long" uomLabel="deg" lowerBound="-10" upperBound="10"  resolution="10"/>
            <irregularAxis axisLabel="h"    uomLabel="m">
                <c>  0</c>
                <c>100</c>
            </irregularAxis>
            <irregularAxis axisLabel="date" uomLabel="d">
                <c>2015-12-01</c>
                <c>2015-12-02</c>
            </irregularAxis>
            <gridLimits srsName="http://www.opengis.net/def/crs/OGC/0/Index4D" axisLabels="i j k l">
                <indexAxis axisLabel="i" lowerBound="0" upperBound="2"/>
                <indexAxis axisLabel="j" lowerBound="0" upperBound="2"/>
                <indexAxis axisLabel="k" lowerBound="0" upperBound="1"/>
                <indexAxis axisLabel="l" lowerBound="0" upperBound="1"/>
            </gridLimits>
        </generalGrid>
    </domainSet>

    <rangeSet>
        <dataBlock>
              <v>01</v> <v>02</v> <v>03</v> <v>04</v> <v>05</v> <v>06</v> <v>07</v> <v>08</v> <v>09</v>
              <v>01</v> <v>02</v> <v>03</v> <v>04</v> <v>05</v> <v>06</v> <v>07</v> <v>08</v> <v>09</v>
              <v>01</v> <v>02</v> <v>03</v> <v>04</v> <v>05</v> <v>06</v> <v>07</v> <v>08</v> <v>09</v>
              <v>01</v> <v>02</v> <v>03</v> <v>04</v> <v>05</v> <v>06</v> <v>07</v> <v>08</v> <v>09</v>
        </dataBlock>
    </rangeSet>

    <rangeType>
        <swe:DataRecord>
            <swe:field name="panchromatic">
                <swe:Quantity definition="http://opengis.net/def/property/OGC/0/Radiance">
                    <swe:uom code="W.m-2.sr-1.nm-1"/>
                </swe:Quantity>
            </swe:field>
        </swe:DataRecord>
    </rangeType>

</generalGridCoverage>
```

A Simple Coverage, in JSON

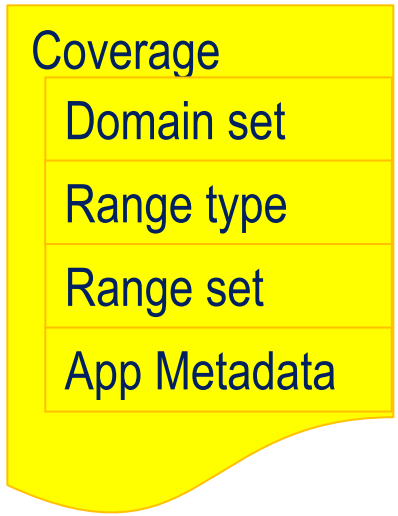
```
{   "type": "CoverageByDomainAndRangeType",
    "domainSet":{
        "type": "DomainSetType",
        "generalGrid":{
            "type":          "GeneralGridCoverageType",
            "srsName":    "http://www.opengis.net/def/crs/OGC/0/Index2D",
            "axisLabels": ["i", "j"],
            "axis": [{      "type": "IndexAxisType“, "axisLabel": "i", "lowerBound": 0, "upperBound": 2
            },{             "type": "IndexAxisType“, "axisLabel": "j", "lowerBound": 0, "upperBound": 2  }]
        }
    },
    "rangeSet": {     "type": "RangeSetType",
                      "dataBlock": { "type": "VDataBlockType",  "values": [1,2,3,4,5,6,7,8,9] }     },
    "rangeType": {   "type": "DataRecordType",
                      "field":[{     "type": "QuantityType",
                                     "definition": "ogcType:unsignedInt",
                                     "uom": { "type": "UnitReference", "code": "10^0“ }     }]
    }
}
```

A Simple Coverage, in RDF

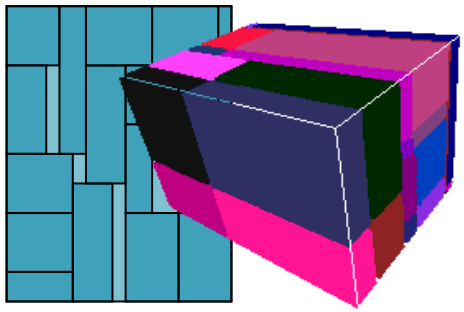
```
<http://www.opengis.net/cis/1.1/examples/CIS_05_2D>
 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
 <http://www.opengis.net/cis/1.1/CoverageByDomainAndRangeType> .

<http://www.opengis.net/cis/1.1/examples/CIS_05_2D>
 <http://www.opengis.net/cis/1.1/domainSet>
 <http://www.opengis.net/cis/1.1/examples/CIS_DS_05_2D> .
<http://www.opengis.net/cis/1.1/examples/CIS_DS_05_2D>
 <http://www.opengis.net/cis/1.1/generalGrid>
 <http://www.opengis.net/cis/1.1/examples/CIS_DS_GG_05_2D> .
<http://www.opengis.net/cis/1.1/examples/CIS_DS_05_2D>
 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
 <http://www.opengis.net/cis/1.1/DomainSetType> .
<http://www.opengis.net/cis/1.1/examples/CIS_DS_GG_05_2D>
 <http://www.opengis.net/cis/1.1/axis>
 <http://www.opengis.net/cis/1.1/examples/CIS_DS_GG_I_05_2D> .
<http://www.opengis.net/cis/1.1/examples/CIS_DS_GG_05_2D>
 <http://www.opengis.net/cis/1.1/axis>
 <http://www.opengis.net/cis/1.1/examples/CIS_DS_GG_J_05_2D> .
<http://www.opengis.net/cis/1.1/examples/CIS_DS_GG_05_2D>
 <http://www.opengis.net/cis/1.1/axisLabels>
 <http://www.opengis.net/cis/1.1/axisLabels0> .
<http://www.opengis.net/cis/1.1/axisLabels0> <http://www.w3.org/1999/02/22-rdf-syntax-ns#first> "i" .
<http://www.opengis.net/cis/1.1/axisLabels0> <http://www.w3.org/1999/02/22-rdf-syntax-ns#rest> <http://www.opengis.net/cis/1.1/axisLa
<http://www.opengis.net/cis/1.1/axisLabels1> <http://www.w3.org/1999/02/22-rdf-syntax-ns#first> "j" .
<http://www.opengis.net/cis/1.1/axisLabels1> <http://www.w3.org/1999/02/22-rdf-syntax-ns#rest> <http://www.w3.org/1999/02/22-rdf-sy
```

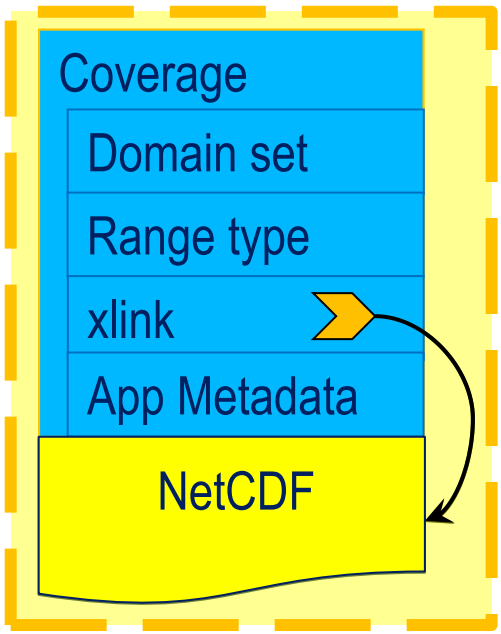
Encoding Coverages

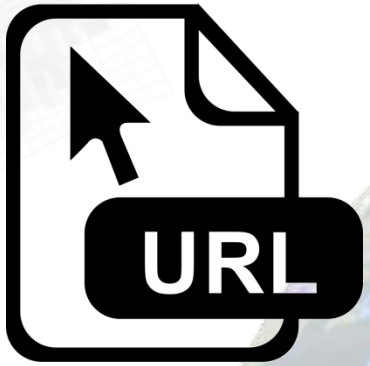
- Single file encoding:
  - Informationally complete: GML, JSON, RDF, …
    - *Caveat: GeoJSON, CovJSON does not work*
  - Further formats: GeoTIFF, NetCDF, JPEG2000, GRIB, …



- Multipart: container(“header” + file1 + file2 + …)
  - Multipart/MIME, zip, GMLJP2, SAFE, GeoPackage, ...
  - Built-in collections / tiling







https://standards.rasdaman.com/rasdaman/ows

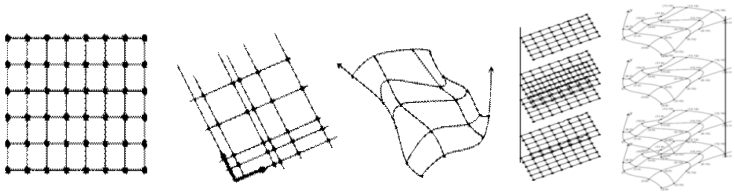
→

BlueMarbleCov,
AvgTemperatureColorScaled

Coverage Data Model: Summary

datacubes

- Coverage = regular & irregular grids, point clouds, meshes
  - See http://schemas.opengis.net/cis/1.1/ for schemas + examples



- Coverage Implementation Schema: OGC CIS = ISO 19123-2
  - 1.0 = RectifiedGridCoverage, ReferenceableGridCoverage
  - 1.1 = GeneraldGridCoverage

- Caveat: Hijacking Attempts, eg: CoverageJSON – incompatible

rasdaman
raster data manager

Coverage Service APIs

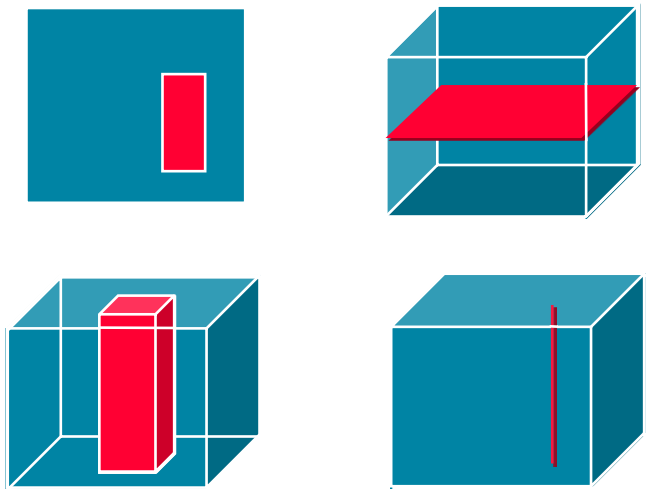
the rasdaman team

Constructor University | rasdaman GmbH

L-sis.org | rasdaman.com

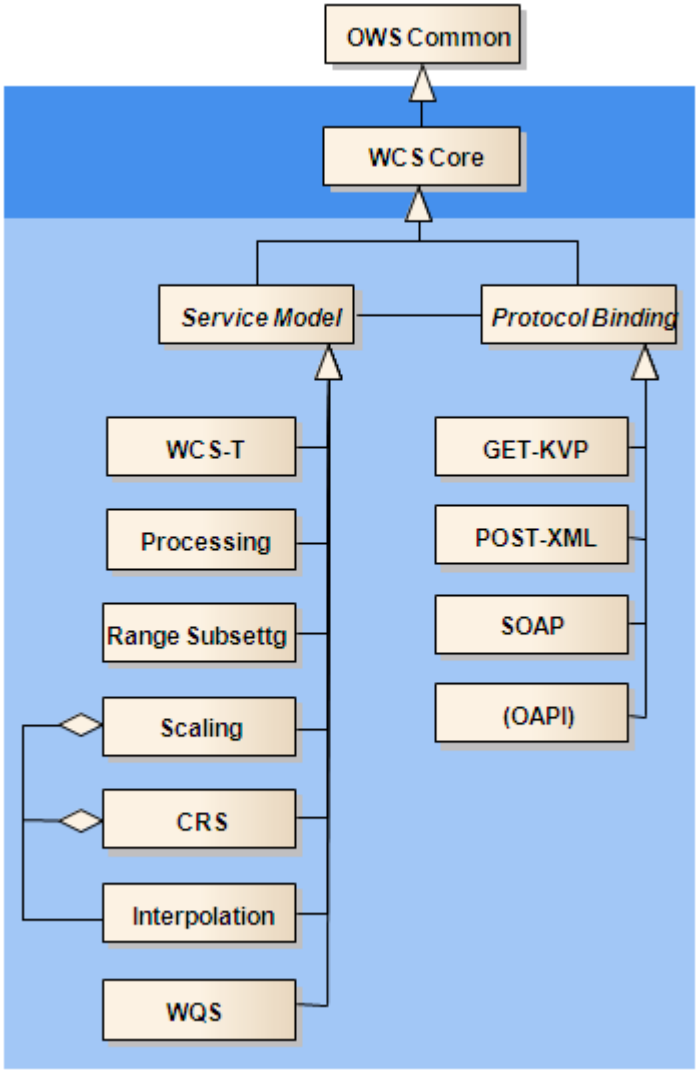
OGC Web Coverage Service (WCS)

- WCS Core: access to spatio-temporal coverages & subsets
  - Encoding on the fly
  - subset = trim | slice

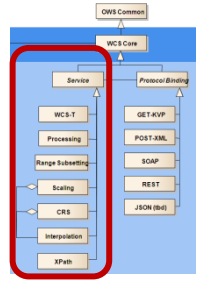


- WCS Extensions: optional functionality facets
- *rasdaman implements WCS Core & all Extensions*
  - *reference implementation*

WCS Extensions (selected)



WCS Range Subsetting



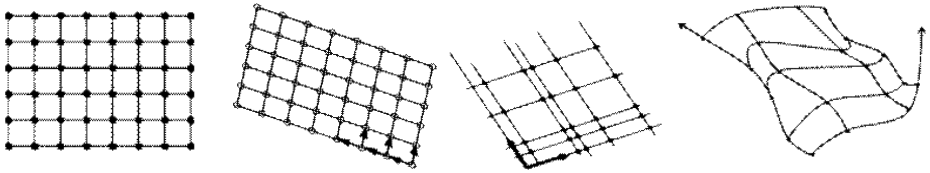
- Extract range components
  - „bands“, „variables“
- Request: http://www.acme.com/wcs ? SERVICE=WCS & VERSION=2.0 & REQUEST=GetCoverage & COVERAGEID=c001 & RANGESUBSET=red
  - or: …& RANGESUBSET=nir,red,green &…
  - or: …& RANGESUBSET=green,red,blue &…
  - or: …& RANGESUBSET=nir:green &…
  - or: …& RANGESUBSET=band01,band03:band05,band19:band21 &…

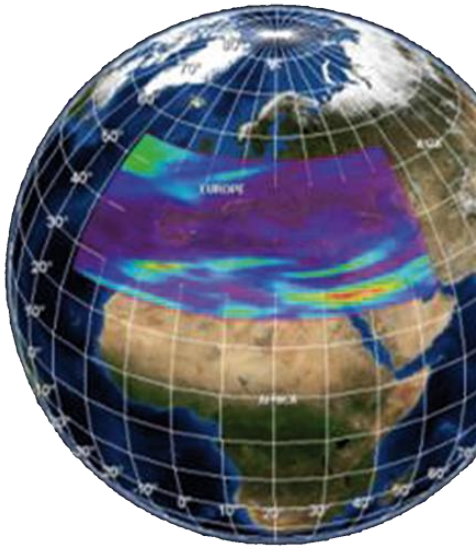
OGC WCPS: Space/Time Datacubes

- Web Coverage Processing Service (WCPS)
  - spatio-temporal datacube analytics language

```
A[ Lat(10.2),Long(8.4),date("2017-12-04")]
```

  - space & time, regular & irregular grids





- "From MODIS scenes M1, M2, M3: difference red & nir, as TIFF"
  - "…but only those where nir exceeds 127 somewhere"

```
for $c in ( M1, M2, M3 )
where some( $c.nir > 127 )
return encode( $c.red - $c.nir, "image/tiff" )
```

WCPS in Python

```
from IPython.display import Image
import requests
query = '''
for $c in (S2_L2A_32631_B12_20m),
    $d in (S2_L2A_32631_B08_10m),
    $e in (S2_L2A_32631_B03_10m)
let $cutOut := [ ansi( "2021-04-09" ), E( 670000:730000 ), N( 4990220:5015220 ) ]
return
  encode( { red: $c[ $cutOut ]; green: $d[ $cutOut ]; blue: $e[ $cutOut ] } / 15.0,
          "image/png"
  )'''
response = requests.post( service_endpoint, data = {'query': query}, verify=False )
Image( data=response.content )
```

- More examples: https://standards.rasdaman.com/demo_jupyter.html, https://nbviewer.org/github/earthserver-eu/INSPIRE-notebooks/blob/master/index.ipynb

WCPS via Command Line

- Request type = `ProcessCoverages`, so URL schema is:

```
https://standards.rasdaman.com/rasd
aman/ows?
    SERVICE=WCS&
    VERSION=2.0.1&
    REQUEST=ProcessCoverages&
    query={your-query-here-escaped}
```

- Use any URL resolution tool, such as **`curl`**

- Ex:

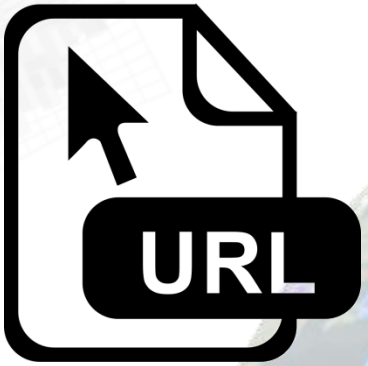
```
$ curl "http://standards.rasdaman.com/rasdaman/ows" \
  --out test.png \
  --data-urlencode \
'service=WCS&version=2.0.1&request=ProcessCoverages&query=
for c in (mean_summer_airtemp) return encode(c, "png")'
```

Sample Sandbox Tasks

- Extract timeslice from AvgLandTemp datacube:
  - for $c in (AvgLandTemp)
    return encode($c[ansi("2014-01")], “png”)
- Extract timeline from AvgLandTemp datacube:
  - for $c in (AvgLandTemp)
    return encode($c[Lat(53.08), Long(8.80)], “csv”)
- Minimum temperature in January 2014:
  - for $c in (AvgLandTemp)
    return min($c[ansi("2014-01")])

Sample Sandbox Tasks

- Pixel-wise operations (all expected unary & binary ops available):
  - ```
    for $c in ( AvgLandTemp )
    return encode( $c[ansi("2014-01" ) ] + 15, “png” )
    ```
- Masking:
  - ```
    for $c in ( AvgLandTemp )
    return encode( $c[ansi("2014-01" ) ] > 100, “png” )
    ```
- Case distinction:
  - ```
    for $c in (AvgLandTemp)
    return encode( switch
                   case $c[ ansi("2014-01" ) ] > 100 return { red:0; green:0; blue:255 }
                   default                          return { red:0; green:0; blue:0 }
                   end ),
                  “png” )
    ```
    ```

Sample Sandbox Tasks

- Mean summer temperature inside polygon:

```
for $c in (mean_summer_airtemp)
return
    encode(
        clip( $c,
                POLYGON( ( -12.3829 132.0117, -33.4314 120.4102, ... ,
                                -36.3151 143.7891 ) )
        ),
        "image/png",
        "{\"nodata\": [0] }"
    )
```

- WKT syntax documentation

Sample Sandbox Tasks

- Query too big? Structure it with variables:
  - ```
    for $c in (mean_summer_airtemp)
    let $polygon := POLYGON( ( -12.3829 132.0117, -33.4314 120.4102, ... ,
                                          -36.3151 143.7891 ) )
    return
        encode( clip( $c, $polygon ), "image/png" )
    ```
- Any number of variables
    ```



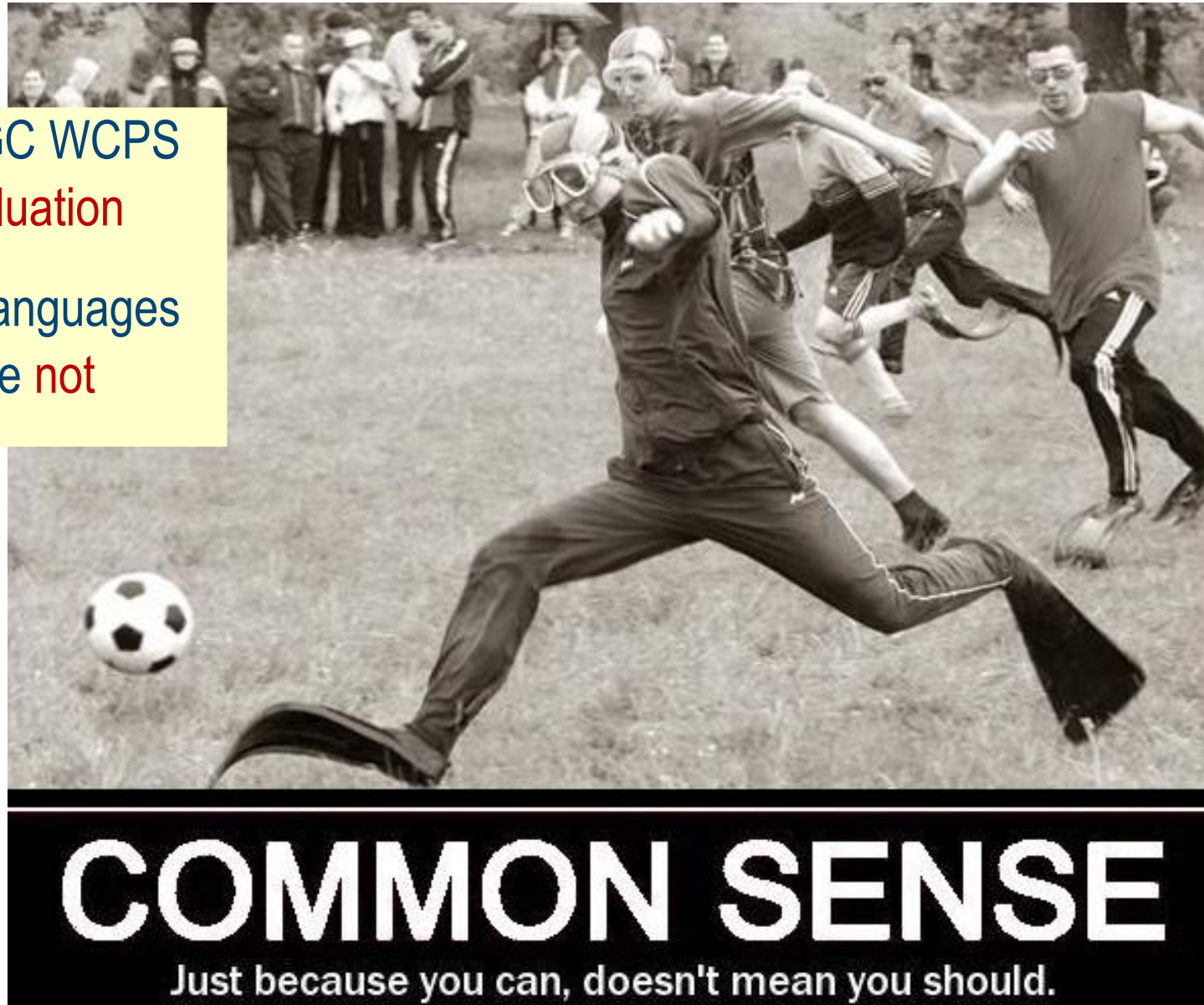
Hands-On: Say Hello

→

https://ai-cu.be/chatcube,
https://earthserver.xyz/wcs

„Ship Code to Data“ -- *What Code to Ship?*

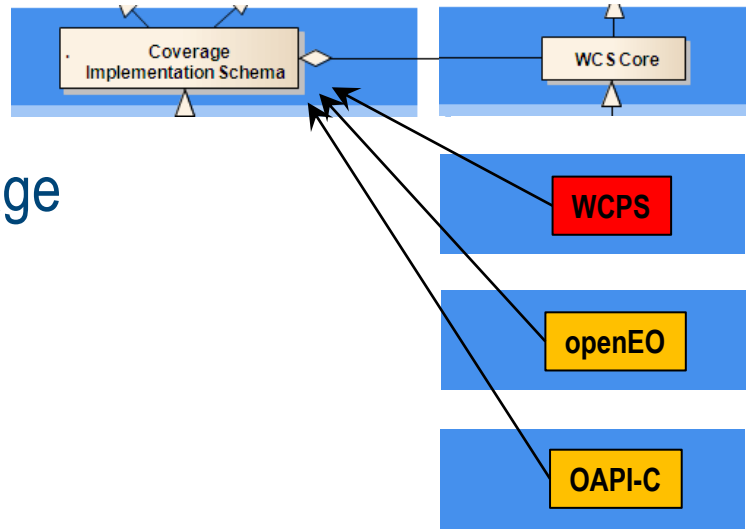
- ISO SQL & OGC WCPS are safe in evaluation
- programming languages (like python) are not



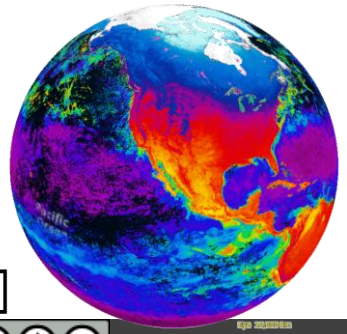
[pinterest]

Summary: Datacube aka Coverage Services

- OGC WCS Core & extensions:
  - Original coverage (aka datacube) API
- OGC WCPS: geo datacube query language
  - robust, scalable, mature:
    proven on multi-Petabytes with EarthServer
- OAPI-Coverages, openEO: new APIs
  - different syntax, in places different behavior



- ...all based on same data structure: Coverage Implementation Schema



[AWI]

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  - Several clients
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  - WCPS: https://standards.rasdaman.com/demo_wcps.html
- Help:
  - https://earthserver.eu/wcs
  - https://ai-cu.be/chatcube
- Powered by rasdaman, pioneer datacube engine