The OGC Coverage Standards Suite

WGISS Technology Webinar, 2018-jan-19

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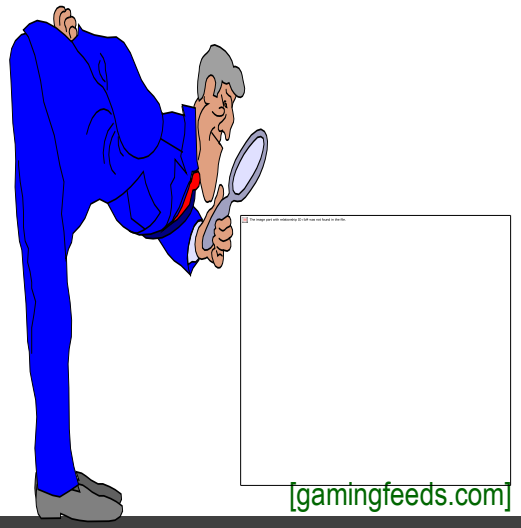
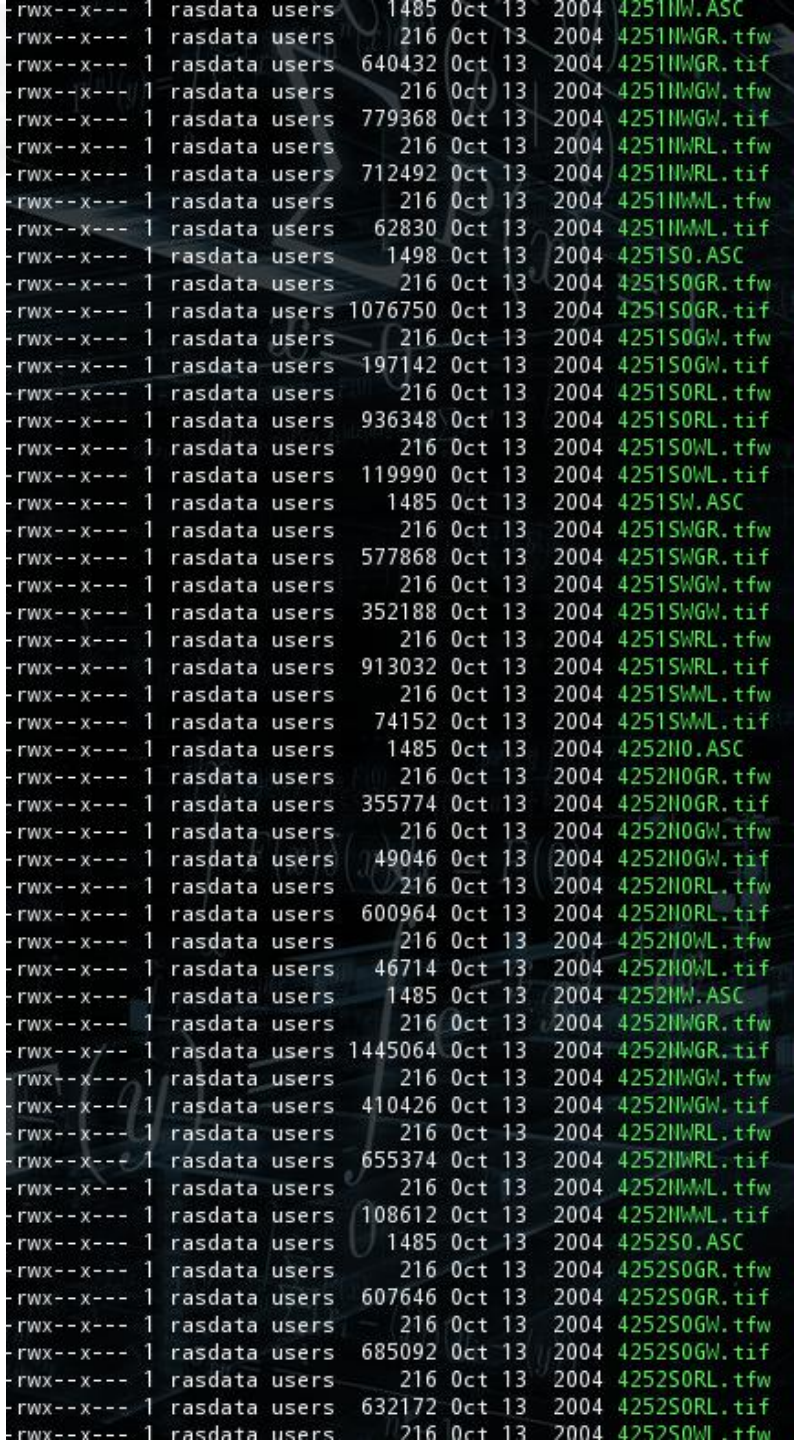
www.jacobs-university.de/lsis





```
-rwx--x--- 1 rasdata users    1485 Oct 13  2004 4251NW.ASC
-rwx--x--- 1 rasdata users     216 Oct 13  2004 4251NWGR.tfw
-rwx--x--- 1 rasdata users  640432 Oct 13  2004 4251NWGR.tif
-rwx--x--- 1 rasdata users     216 Oct 13  2004 4251NWGW.tfw
-rwx--x--- 1 rasdata users  779368 Oct 13  2004 4251NWGW.tif
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-rwx--x--- 1 rasdata users  712492 Oct 13  2004 4251NWRL.tif
-rwx--x--- 1 rasdata users     216 Oct 13  2004 4251NWWL.tfw
-rwx--x--- 1 rasdata users   62830 Oct 13  2004 4251NWWL.tif
-rwx--x--- 1 rasdata users    1498 Oct 13  2004 4251SO.ASC
-rwx--x--- 1 rasdata users     216 Oct 13  2004 4251SOGR.tfw
-rwx--x--- 1 rasdata users 1076750 Oct 13  2004 4251SOGR.tif
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-rwx--x--- 1 rasdata users  936348 Oct 13  2004 4251SORL.tif
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-rwx--x--- 1 rasdata users   49046 Oct 13  2004 4252NOGW.tif
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-rwx--x--- 1 rasdata users  655374 Oct 13  2004 4252NWRL.tif
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-rwx--x--- 1 rasdata users     216 Oct 13  2004 4252SOGR.tfw
-rwx--x--- 1 rasdata users  607646 Oct 13  2004 4252SOGR.tif
-rwx--x--- 1 rasdata users     216 Oct 13  2004 4252SOGW.tfw
-rwx--x--- 1 rasdata users  685092 Oct 13  2004 4252SOGW.tif
-rwx--x--- 1 rasdata users     216 Oct 13  2004 4252SORL.tfw
-rwx--x--- 1 rasdata users  632172 Oct 13  2004 4252SORL.tif
-rwx--x--- 1 rasdata users     216 Oct 13  2004 4252SOWL.tfw
```

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raster data manager

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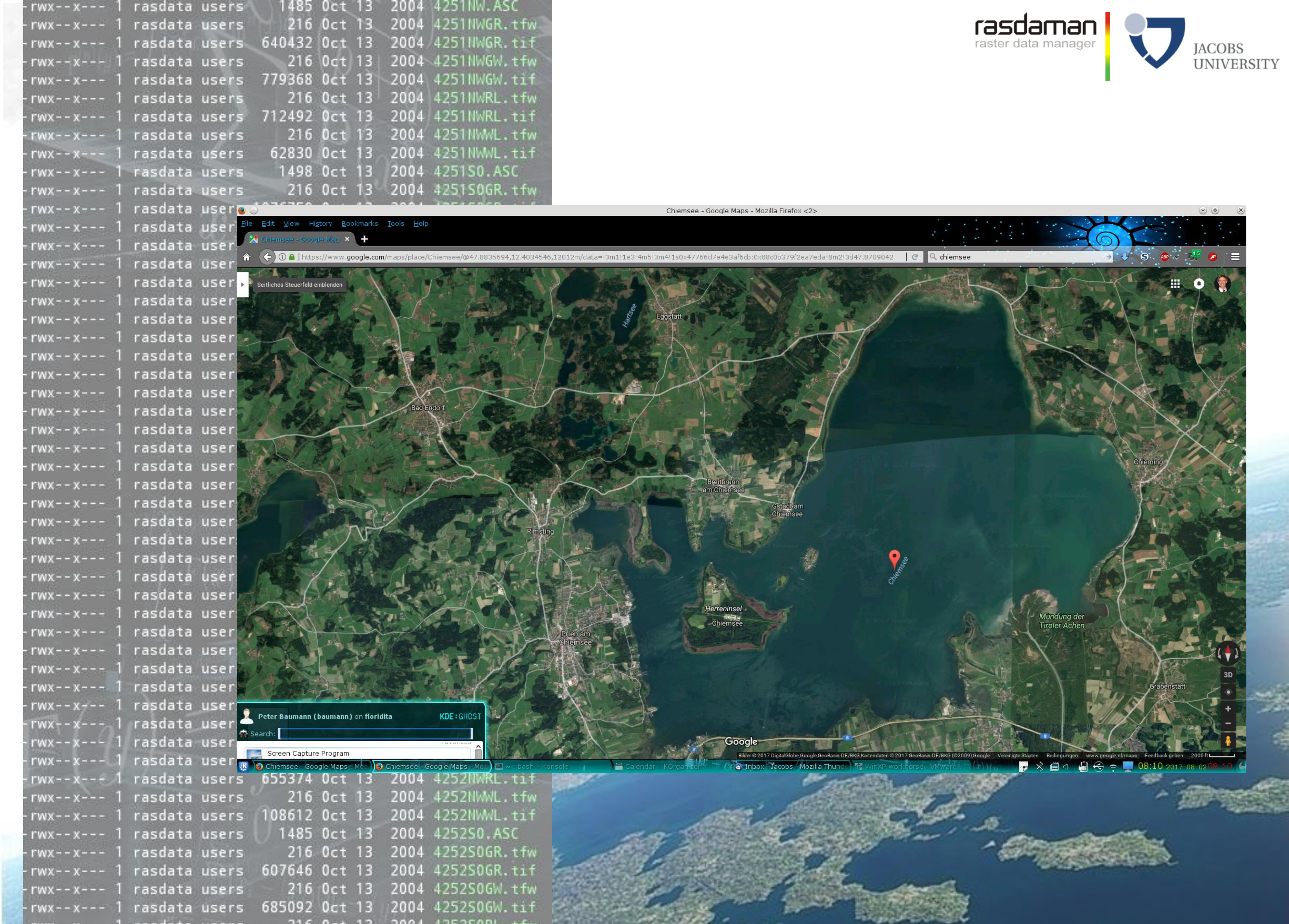
rasdaman
raster data manager
JACOBS UNIVERSITY
-rwx--x--- 1 rasdata users 1485 Oct 13 2004 4251NW.ASC
-rwx--x--- 1 rasdata users 216 Oct 13 2004 4251NWGR.tfw
-rwx--x--- 1 rasdata users 640432 Oct 13 2004 4251NWGR.tif
-rwx--x--- 1 rasdata users 216 Oct 13 2004 4251NWGW.tfw
-rwx--x--- 1 rasdata users 779368 Oct 13 2004 4251NWGW.tif
-rwx--x--- 1 rasdata users 216 Oct 13 2004 4251NWRL.tfw
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-rwx--x--- 1 rasdata users 1498 Oct 13 2004 4251SO.ASC
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-rwx--x--- 1 rasdata users 655374 Oct 13 2004 4252NWRL.tif
-rwx--x--- 1 rasdata users 216 Oct 13 2004 4252NWWL.tfw
-rwx--x--- 1 rasdata users 108612 Oct 13 2004 4252NWWL.tif
-rwx--x--- 1 rasdata users 1485 Oct 13 2004 4252SO.ASC
-rwx--x--- 1 rasdata users 216 Oct 13 2004 4252SOGR.tfw
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-rwx--x--- 1 rasdata users 216 Oct 13 2004 4252SORL.tfw
-rwx--x--- 1 rasdata users 632172 Oct 13 2004 4252SORL.tif
Chiemsee - Google Maps - Mozilla Firefox <2>
File Edit View History Bookmarks Tools Help
Chiemsee - Google Map
chiemsee
Seitliches Steuerfeld einblenden
Hartsee
Eggstatt
Bad Endorf
Breitbrunn am Chiemsee
Gstadt am Chiemsee
Rimsting
Chieming
Chiemsee
Herreninsel
Prien am Chiemsee
Mundung der Tiroler Achen
Grabenstatt
Google
Peter Baumann (baumann) on floridita
KDE:GHOST
Search:
Screen Capture Program

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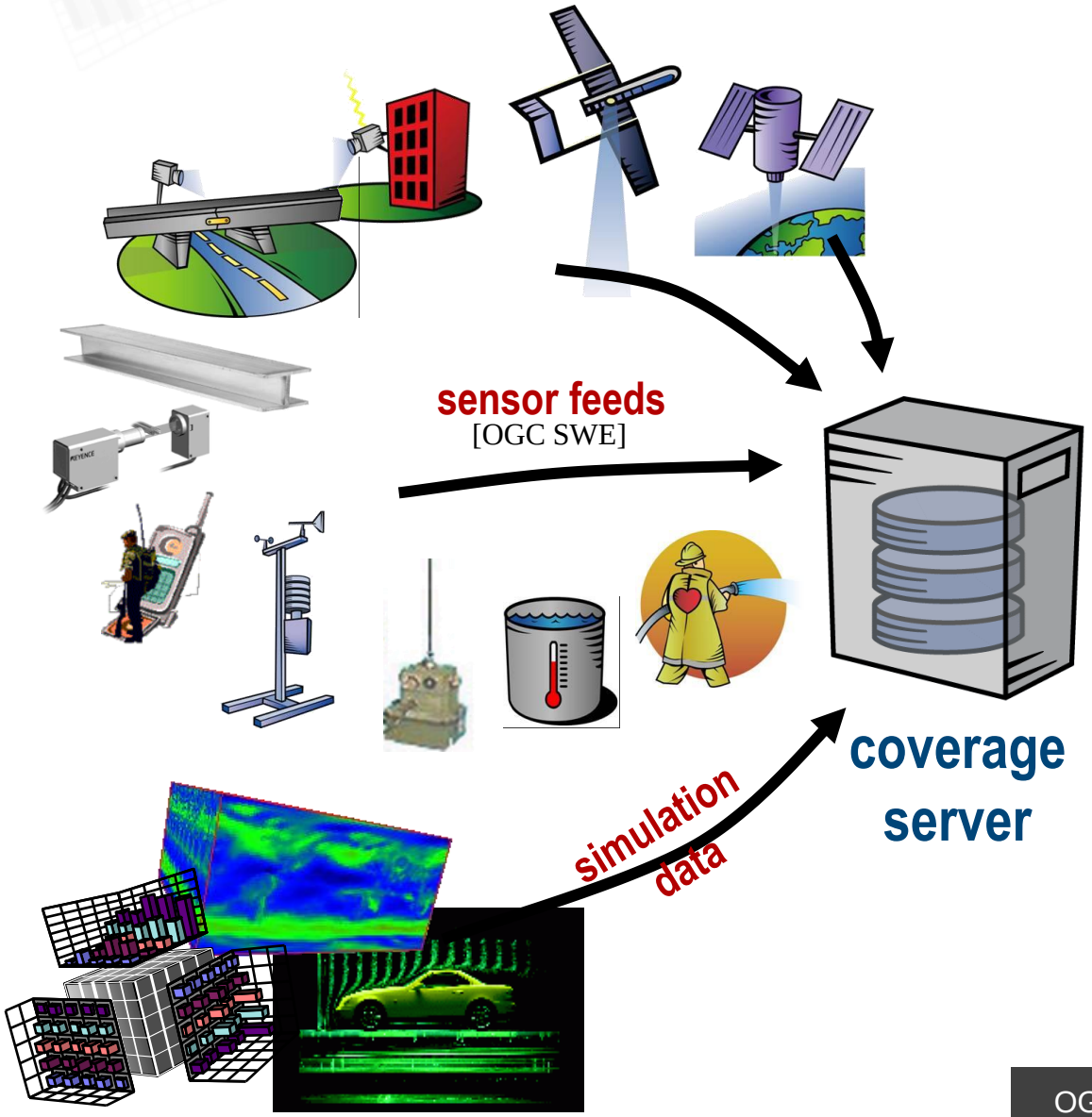
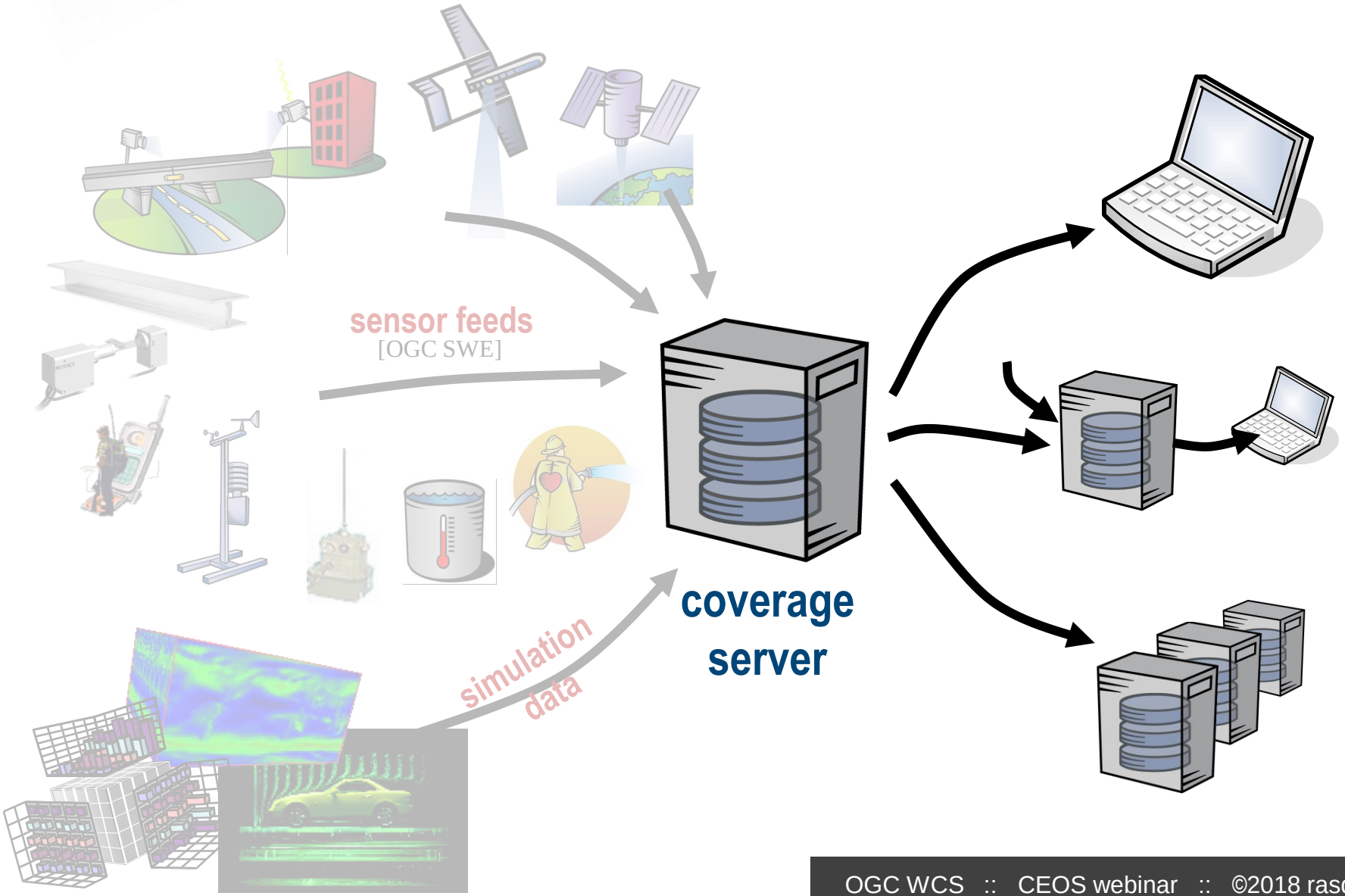
SERVICE QUALITY

OGC Coverages: The Unifying Paradigm



OGC Coverages: The Unifying Paradigm

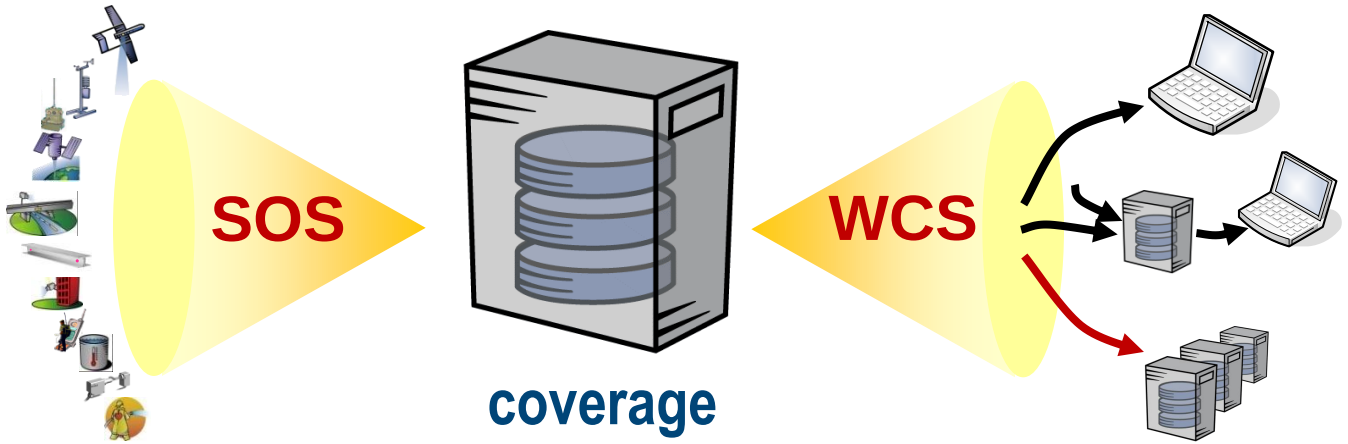


Serving Coverages

„analysis ready data“

WCS:

downstream access & processing services



coverage server

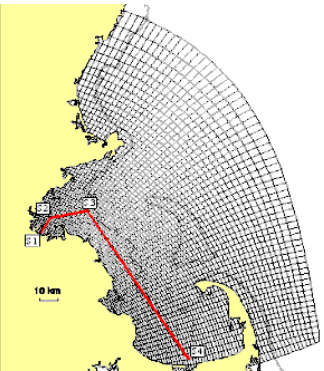
SWE SOS:

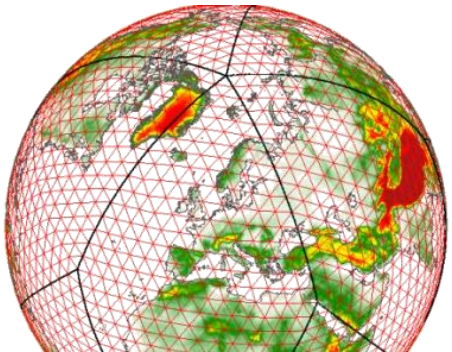
upstream data capturing

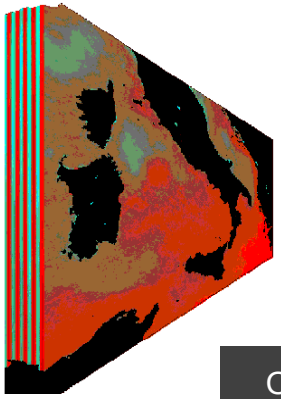
Coverage Data

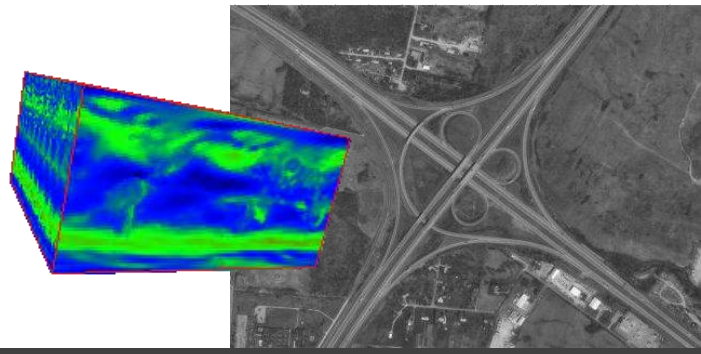
Features & Coverages

- The basis of all: geographic feature
- Feature subtype: coverage
  - aka space-time varying phenomenon
  - Spatio-temporal regular & irregular grids, point clouds, meshes
- Usually, Big Geo Data are coverages



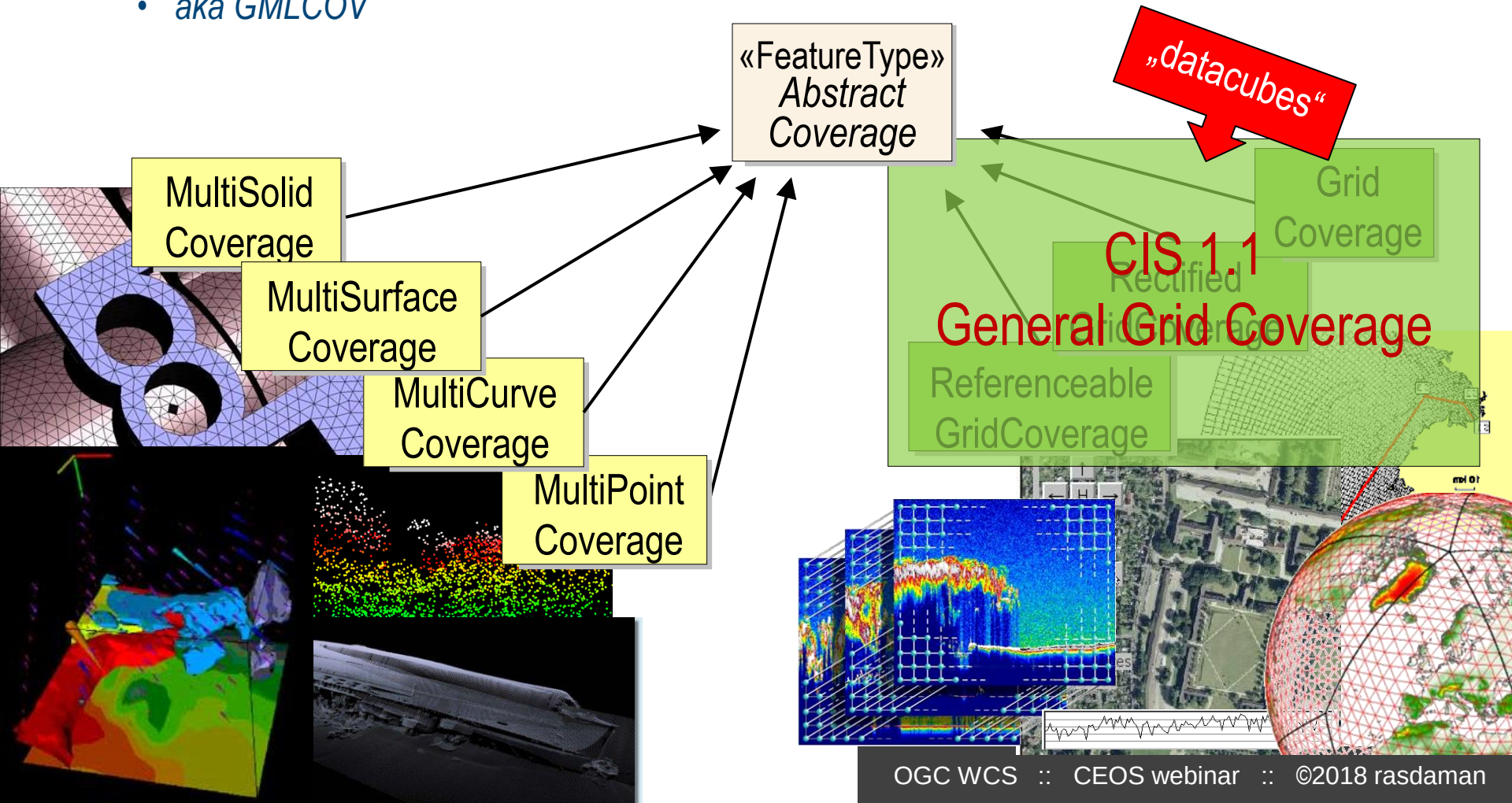




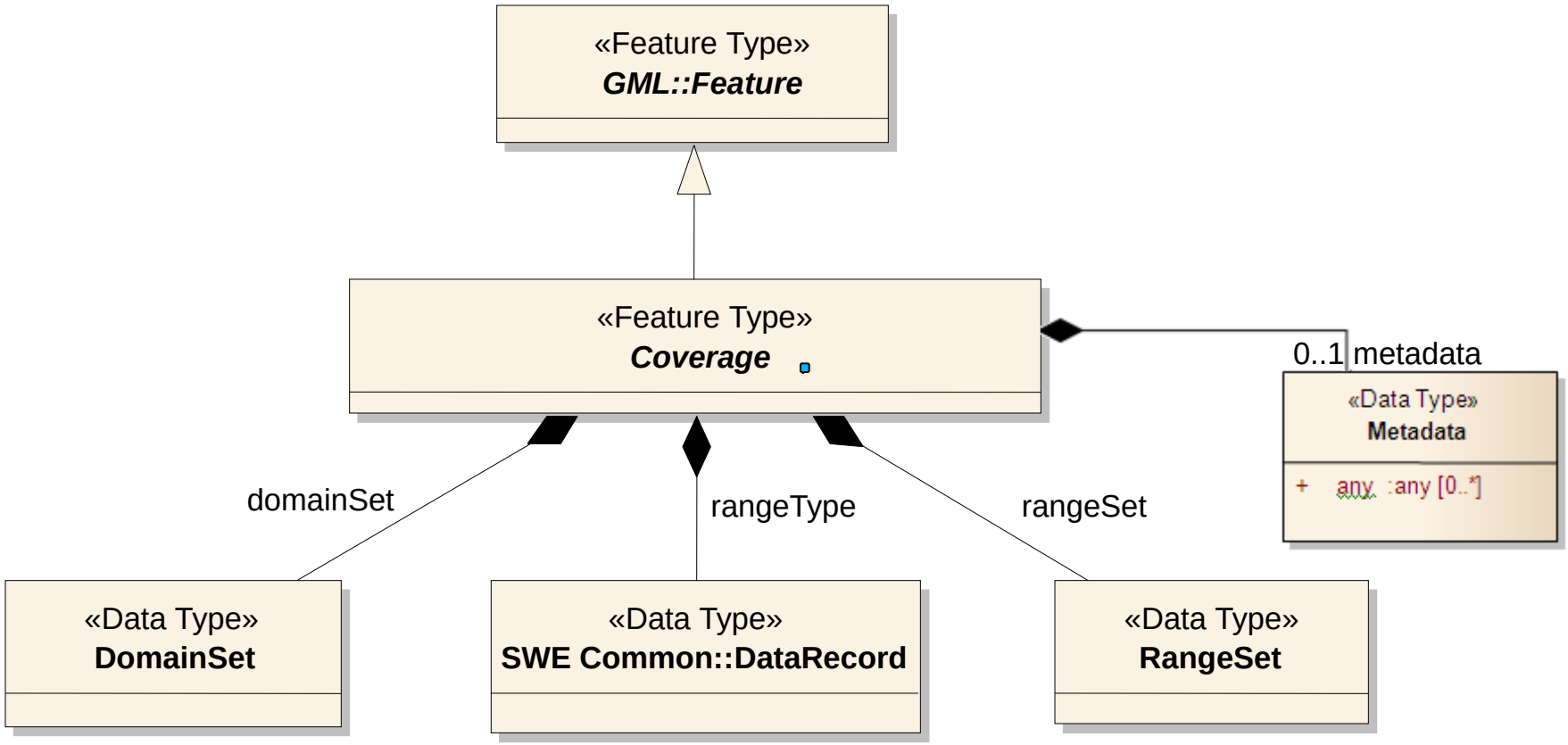


Coverage Types

- abstract: OGC Abstract Topic 6 = ISO 19123 → ISO 19123-1
- concrete, interoperable: Coverage Implementation Schema (CIS) → ISO 19123-2
  - *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

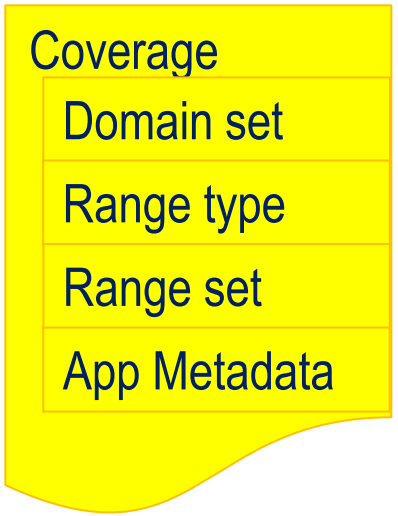
```
{   "type": "CoverageByDomainAndRangeType",
    "domainSet":{
        "type": "DomainSetType",
        "generalGrid":{
            "type":          "GeneralGridCoverageType",
            "srsName":    "http://www.opengis.net/def/crs/OGC/0/Index2D",
            "axisLabels": ["i", "j"],
            "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

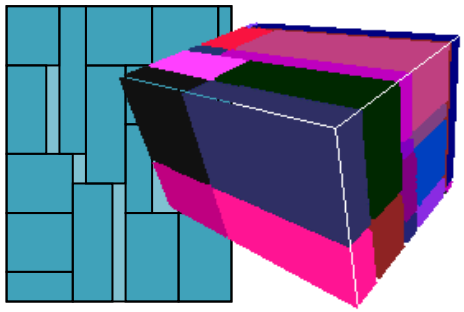
```
<http://www.opengis.net/cis/1.1/examples/CIS_05_2D>
 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
 <http://www.opengis.net/cis/1.1/CoverageByDomainAndRangeType> .

<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-rdfsy
```

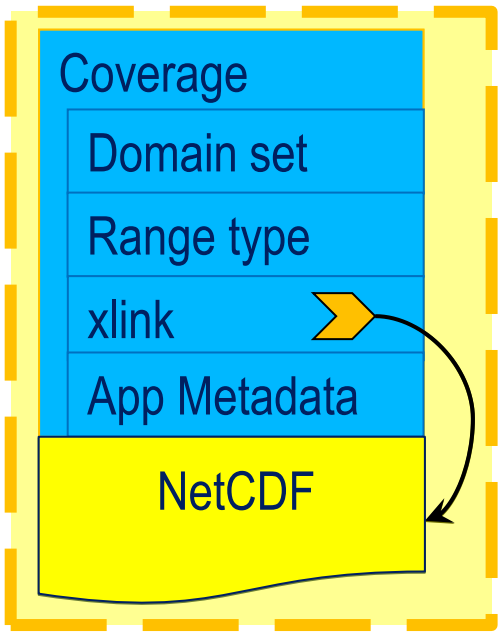
Encoding Coverages

- Single file encoding:
  - Informationally complete: GML, JSON, RDF, …
  - Further formats: GeoTIFF, NetCDF, JPEG2000, GRIB, …



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





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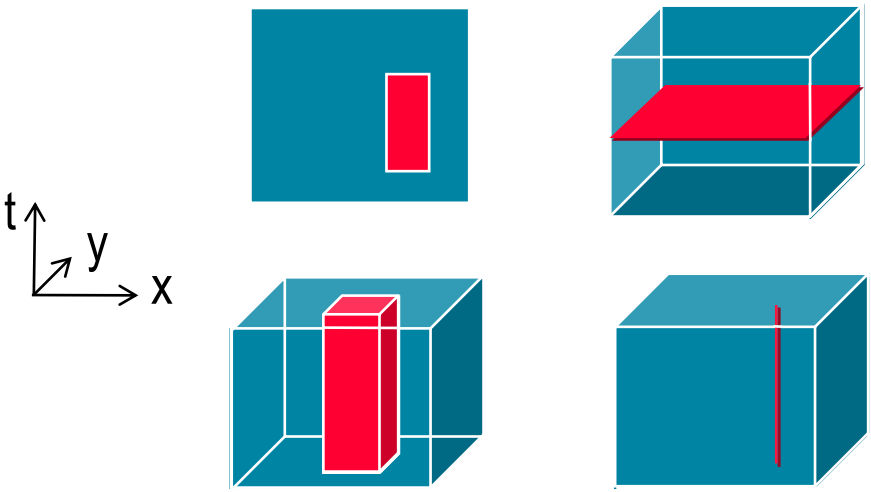
Coverage Services

OGC Web Coverage Service (WCS)

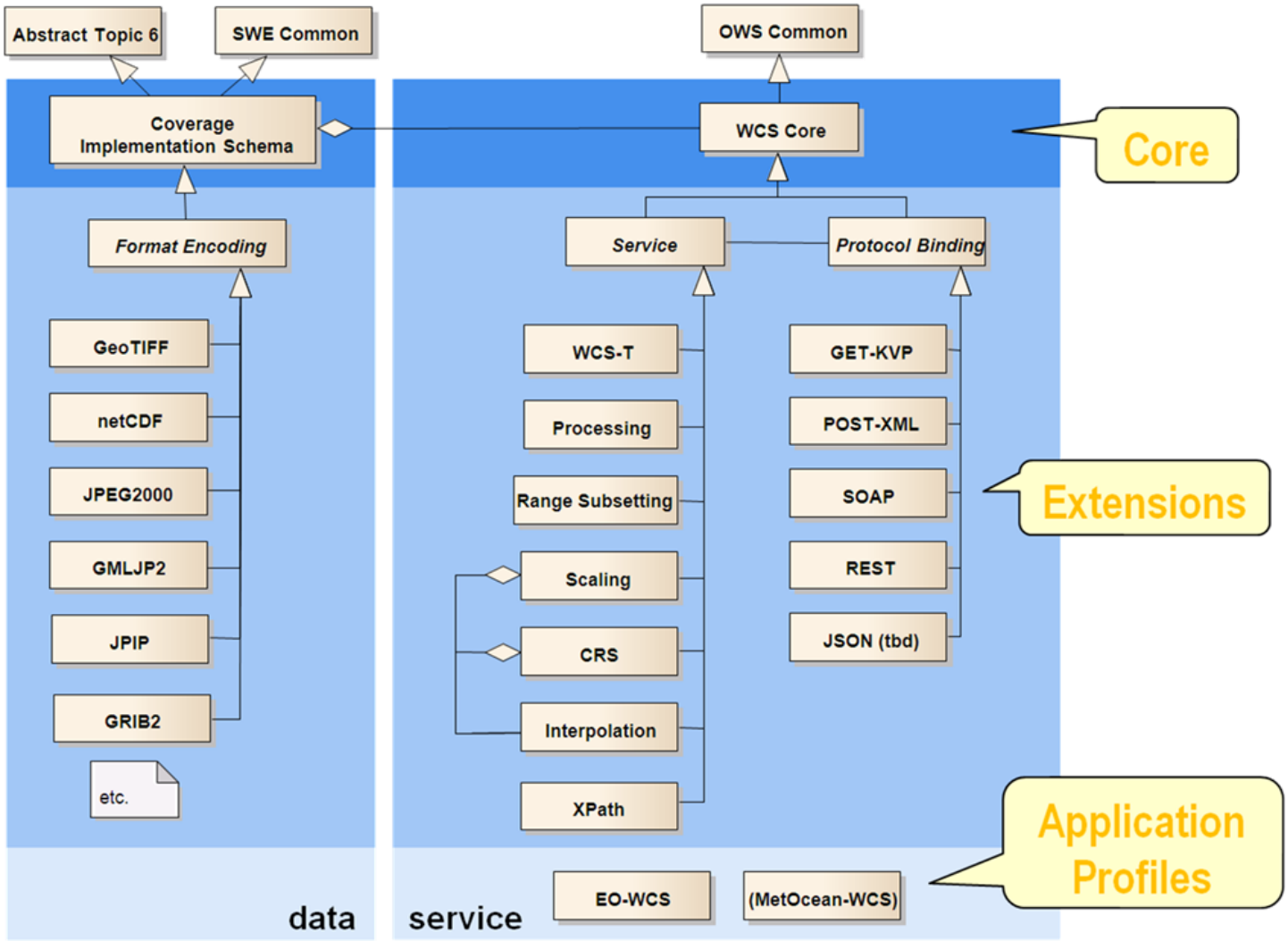
- WCS Core: access to spatio-temporal coverages & subsets
  - Encoding on the fly
  - subset = trim | slice



Large, growing implementation basis: rasdaman, GDAL, QGIS, OpenLayers, Leaflet, OPeNDAP, MapServer, GeoServer, GMU, NASA WorldWind, Cesium, EOx-Server; Pyxis, ERDAS, ArcGIS, ...

- WCS Extensions: optional functionality facets
- WCS Application Profiles: bespoke specializations

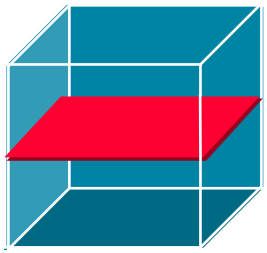
Coverages & WCS: The Big Picture



WCS Core *GetCoverage*

- Download a coverage (or a subset thereof)
  - values guaranteed unchanged
- Ex: „*coverage c001, lat/long cutout, time slice t=2009-11-06T23:20:52*”

```
http://www.acme.com/wcs ? SERVICE=WCS & VERSION=2.0
    & REQUEST=GetCoverage & COVERAGEID=c001
    & SUBSET=Long(100,120) & SUBSET=Lat(50,60)
    & SUBSET=time("2009-11-06T23:20:52")
```



- Ex: “*coverage c001, in GeoTIFF*”

```
http://www.acme.com/wcs ? SERVICE=WCS & VERSION=2.0
    & REQUEST=GetCoverage & COVERAGEID=c001 & FORMAT=“image/tiff“
```

CRSs in Coverages

- Native CRS = CRS of coverage as stored in server
- srsName in GML::DomainSet + further attributes
- Ex:

```
<gml:boundedBy>
   <gml:Envelope srsName=" http://www.opengis.net/def/crs-compound?
      1=http://www.opengis.net/def/crs/EPSG/0/4326 &
      2=http://www.opengis.net/def/crs/OGC/0/AnsiDate“
      axisLabels="Lat Long Time" uomLabels="deg deg day" srsDimension=“3">
      <gml:lowerCorner>1 1 2012-03-10</gml:lowerCorner>
      <gml:upperCorner>3 10 2012-03-10 </gml:upperCorner>
   </gml:Envelope>
</gml:boundedBy>
```

- Capabilities doc contains list of supported CRSs:

```
<wcs:crsSupported> http://www.opengis.net/def/crs/EPSG/0/4326 </wcs:crsSupported>
<wcs:crsSupported> http://www.opengis.net/def/crs/EPSG </wcs:crsSupported>
<wcs:crsSupported> http://www.opengis.net/def/crs?authority=OGC&version=1.3&code=
 AUTO42003&UoM=m&CenterLongitude=-100&CenterLatitude=45 </wcs:crsSupported>
<wcs:crsSupported> http://www.acme.com/def/this-is-EPSG-4326 </wcs:crsSupported>
<wcs:crsSupported> http://www.opengis.net/def/crs/ISO/0/AnsiDate </wcs:crsSupported>
```

WCS Range Subsetting [OGC 12-039]

- 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 &…

WCS Transaction [OGC 13-057]

= WCS-T: Modify coverage offerings on a server via Web

- New request types:
  InsertCoverage + *DeleteCoverage* + *UpdateCoverage* (incl. partial replacement)

- Core design goal: *GetCoverage* → *InsertCoverage*

- Ex:

```
http://www.acme.com/wcs
    ? SERVICE=WCS & VERSION = 2.0
    & REQUEST=InsertCoverage
    & COVERAGEREF=http://bcme.com/archive/hurricane.nc
    & USEID=new
```

OGC WCPS

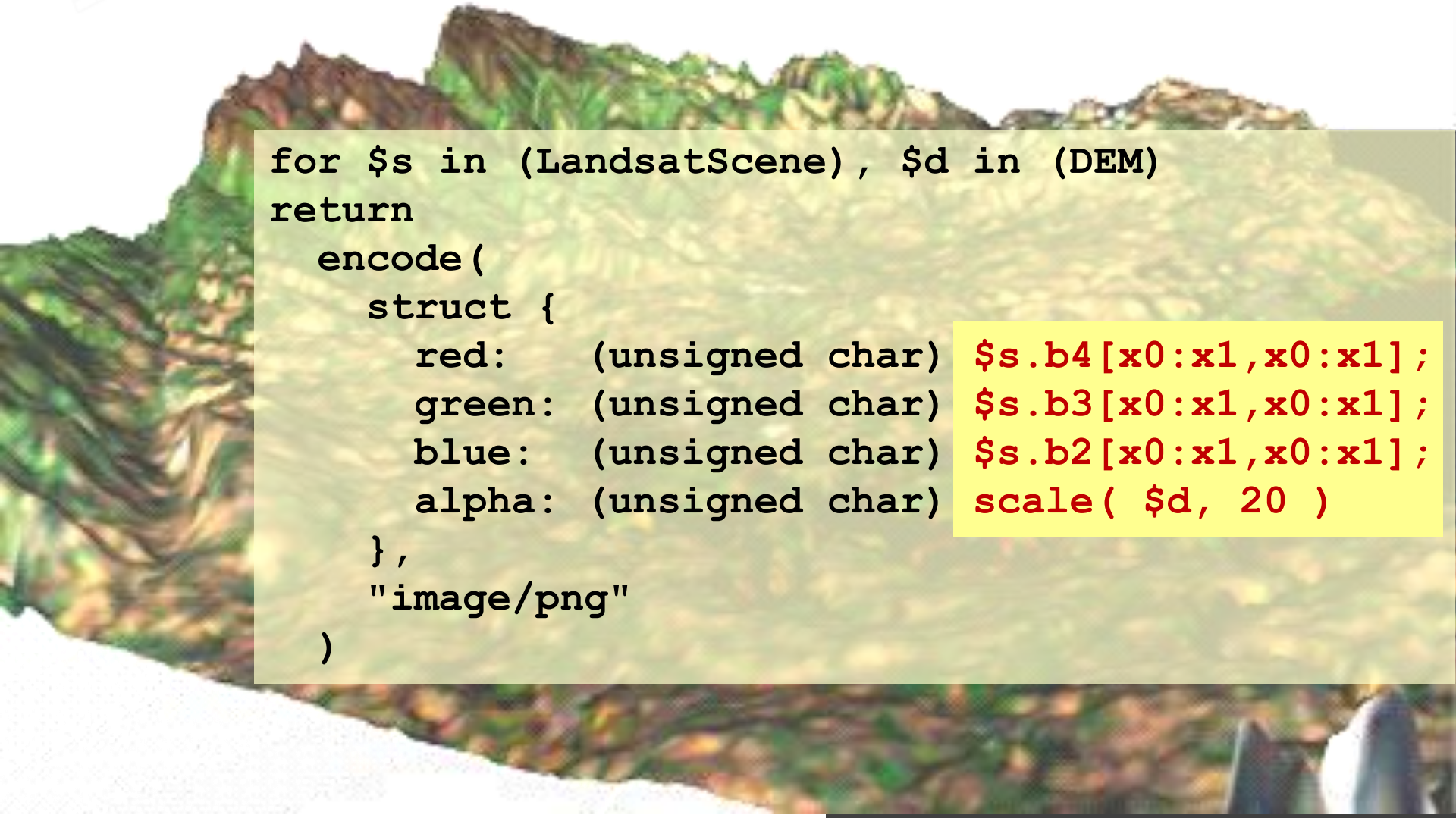
- Web Coverage Processing Service (WCPS) [08-068r2]
  - = spatio-temporal datacube analytics language

- "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" )
```

- s/t regular & irregular grids

3-D Terrain Draping

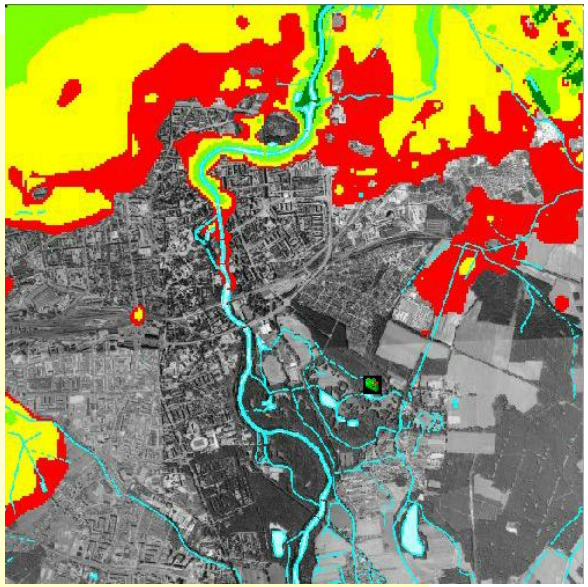


```
for $s in (LandsatScene), $d in (DEM)
return
  encode(
    struct {
      red:   (unsigned char) $s.b4[x0:x1,x0:x1];
      green: (unsigned char) $s.b3[x0:x1,x0:x1];
      blue:  (unsigned char) $s.b2[x0:x1,x0:x1];
      alpha: (unsigned char) scale( $d, 20 )
    },
    "image/png"
  )
```

[JacobsU, Fraunhofer; data courtesy BGS, ESA]

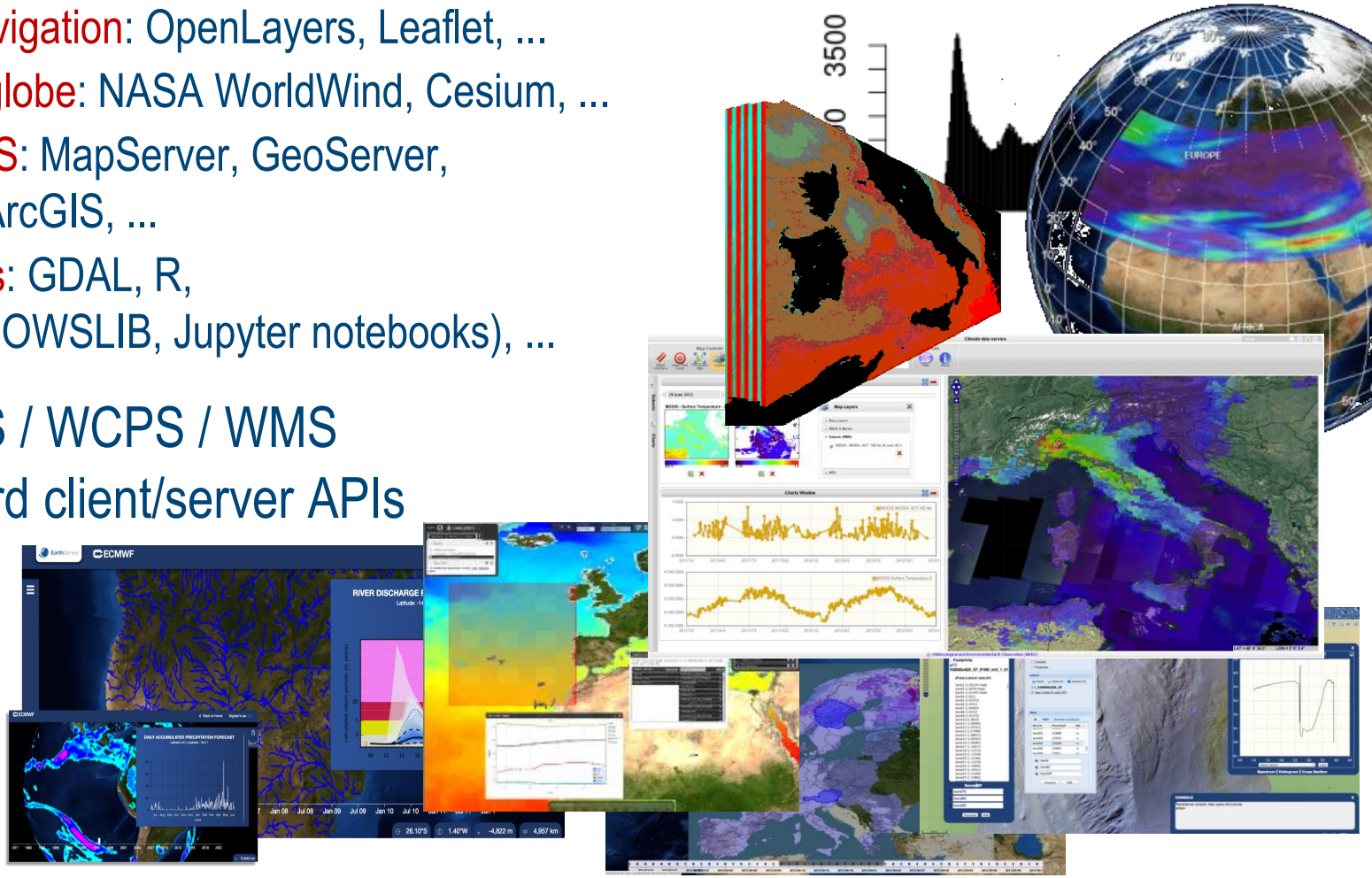
Advanced Examples: WMS

```
for $p in (OrthoPhoto),
    $wl in (WaterLines), $wa in (WaterAreas),
    $d in (DEM)
return
    encode(  (unsigned char) (
          $p * { 1, 1, 1 }
        overlay
          $wl * { 0, 128, 255 }
        overlay
          $wa * { 191, 255, 255 }
        overlay
          switch $d
          case $d > 260 return { red:255, green:0, blue:0 }
          case $d > 262 return { red:0, green:255, blue:0 }
          case $d > 264 return { red:0, green:0,  blue:255 }
          default       return { red:0, green:0, blue:0 }
          end
       ),
      "image/png" )
```



...But That's Not What You Want to See

- Let users remain in comfort zone of well-known tools
  - Map navigation: OpenLayers, Leaflet, ...
  - Virtual globe: NASA WorldWind, Cesium, ...
  - Web GIS: MapServer, GeoServer, QGIS, ArcGIS, ...
  - Analysis: GDAL, R, python (OWSLIB, Jupyter notebooks), ...
- ...via WCS / WCPS / WMS as standard client/server APIs



[screenshots: diverse clients accessing rasdaman]

Sample Services
(WCS Reference Implementation)

rasdaman
raster data manager

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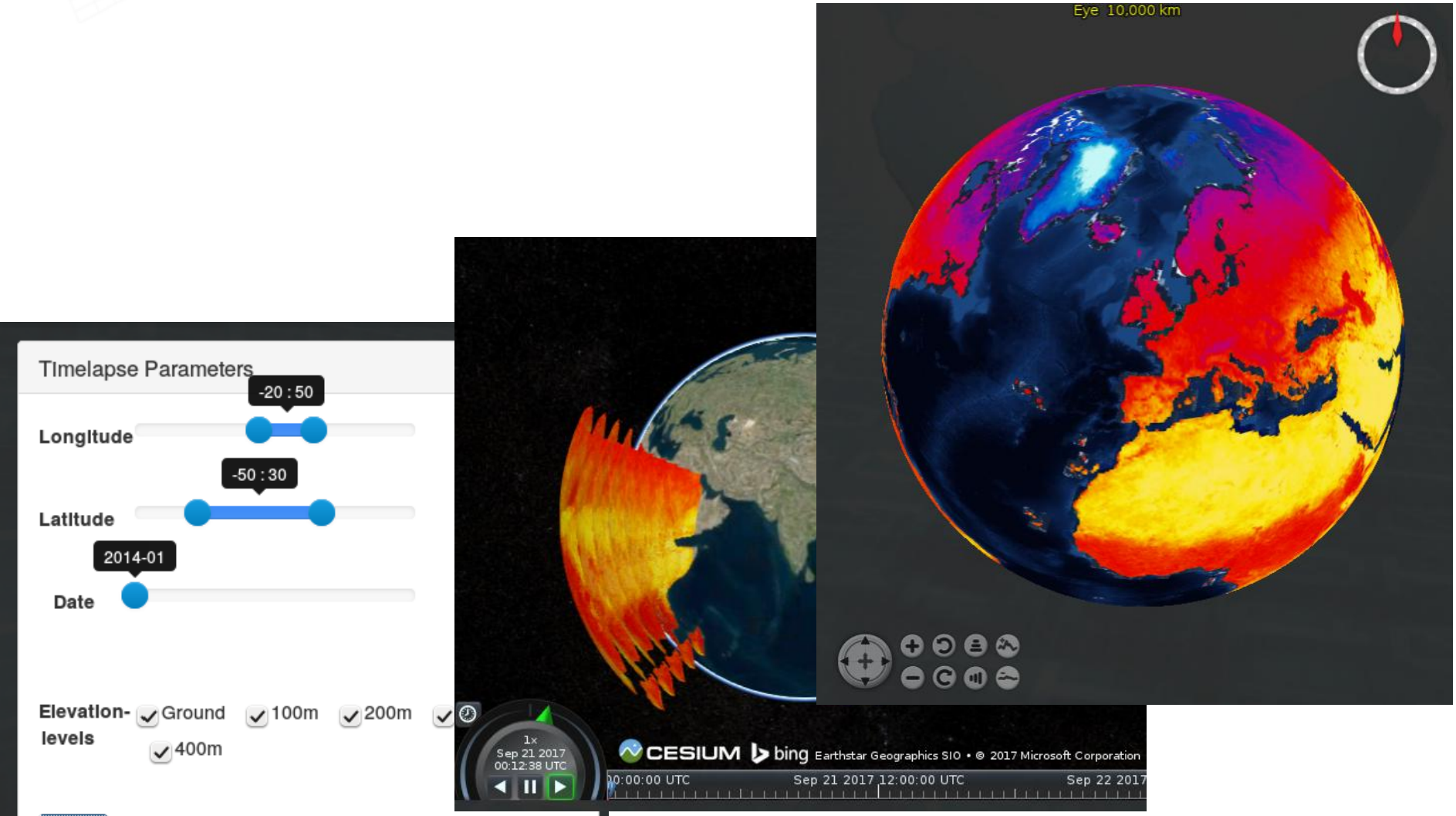
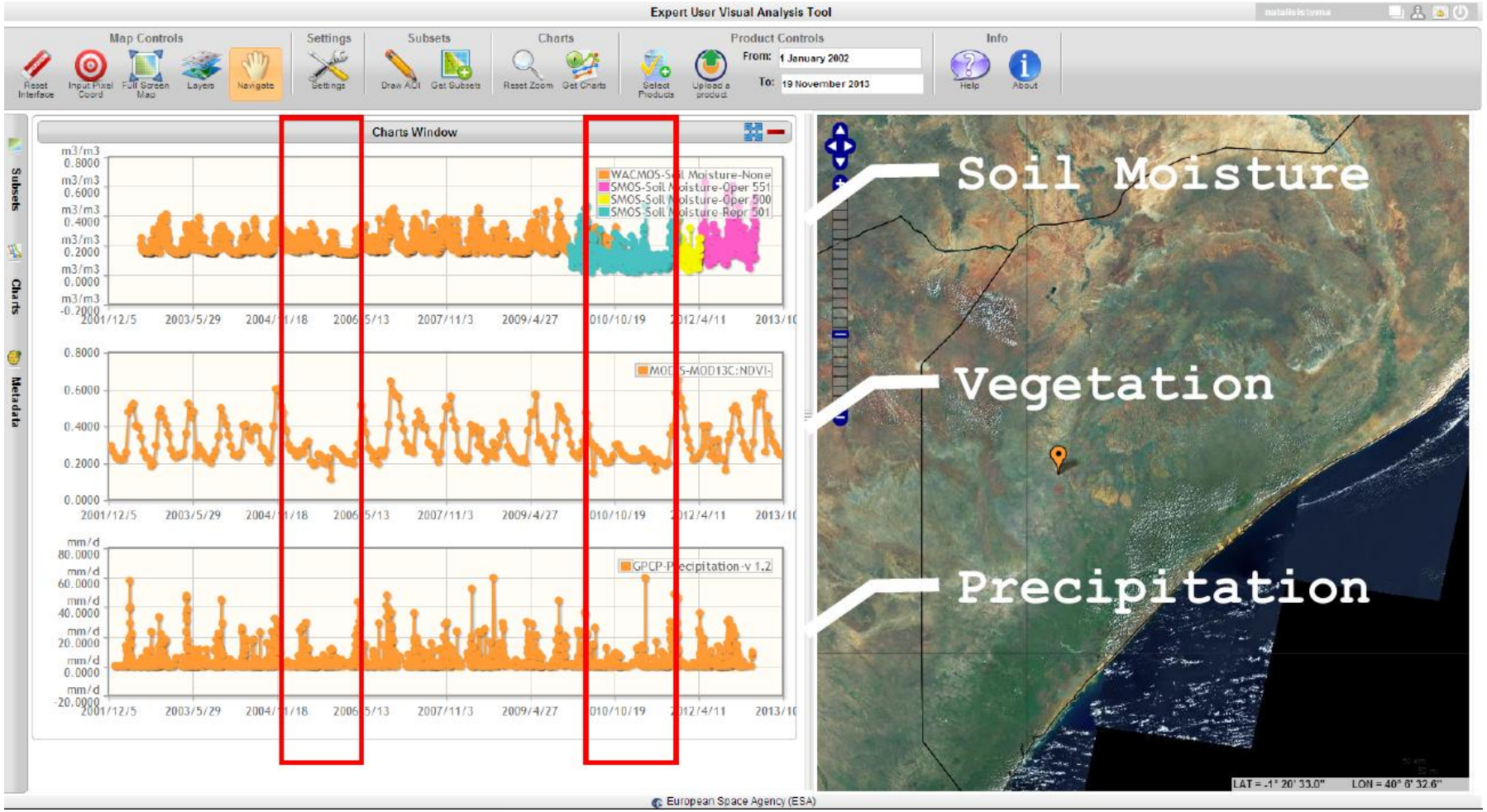
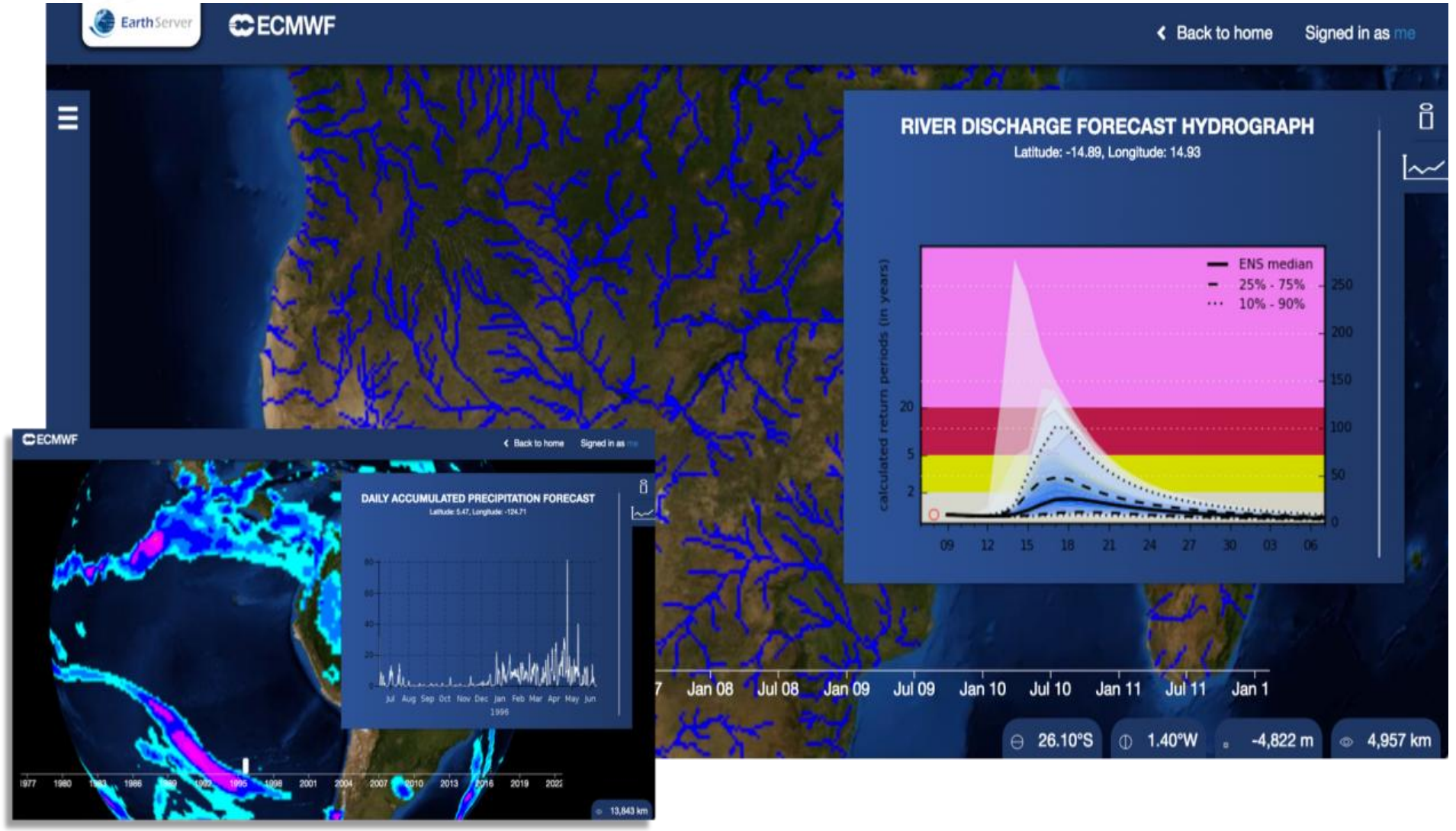
Spatio-Temporal Datacubes on Virtual Globes



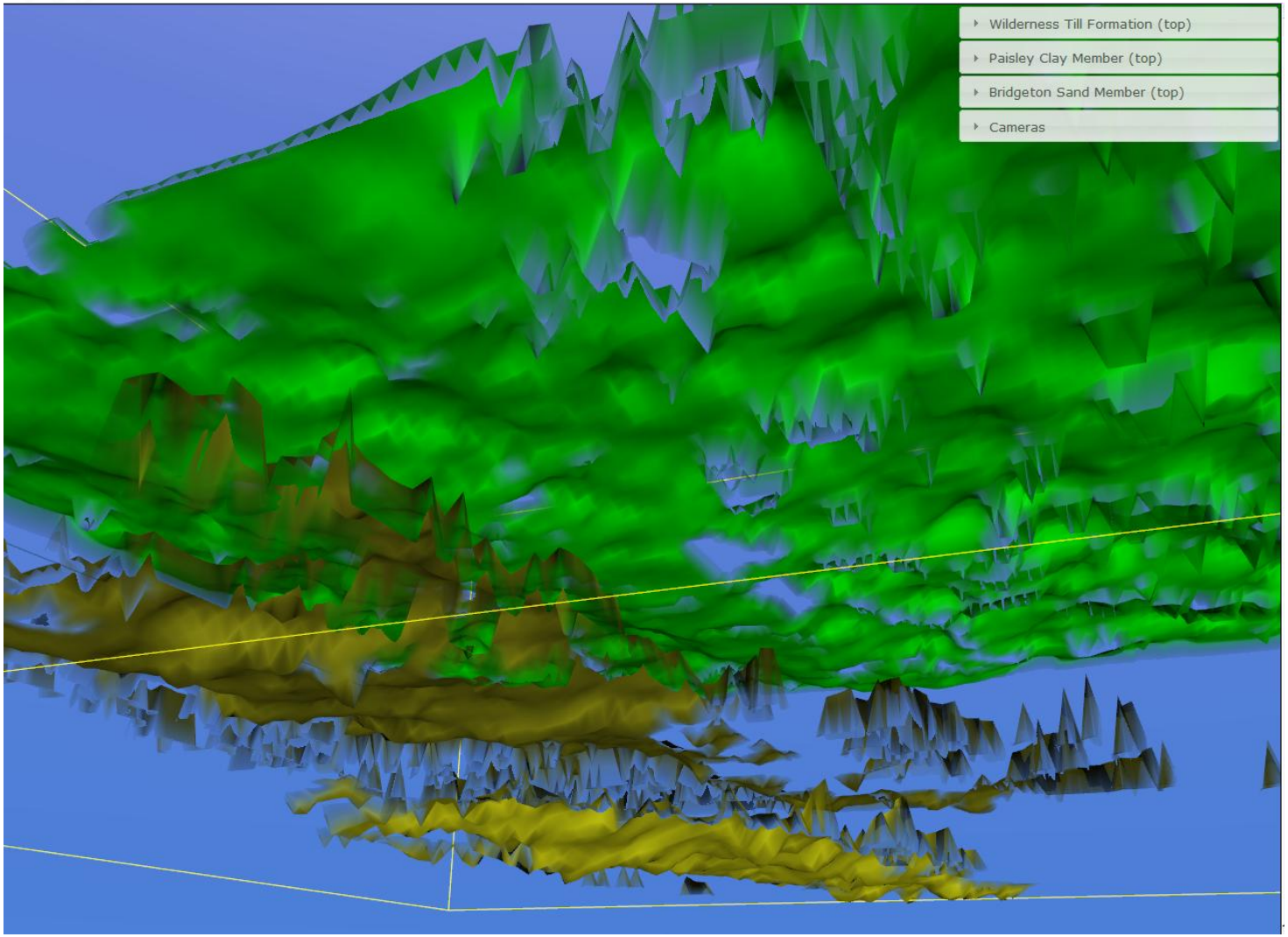
ESA EO Datacube [eodataservice.org]



ECMWF: River Discharge



British Geological Service



[BGS 2013]

Jupyter Notebooks

Jupyter Notebook Viewer

nbviewer.jupyter.org/github/earthserver-eu/INSPIRE-notebooks/blob/master/ps2_inspire_notebook.ipynb

Apps For quick access, place your bookmarks here on the bookmarks bar. Import bookmarks now...

jupyter nbviewer

JUPYTER FAQ

INSPIRE-notebooks / ps2_inspire_notebook.ipynb

Planetserver WCPS ipython notebook for the INSPIRE conference 2016

- Please, run the next cell to see a RBG combination retrieved using WCPS

To run the code below:

1. Click on the cell to select it.
2. Press SHIFT+ENTER on your keyboard.

RGB false color combination

In [7]:

```
%matplotlib inline
import urllib2
import matplotlib.pyplot as plt

# create a file-like object from the url
f=urllib2.urlopen("http://access.planetserver.eu:8080/rasdaman/ows?service=WCS&version=2.0.1&request=ProcessCoverages&query=for%20data%2
# read the image file in a numpy array
a = plt.imread(f)
plt.imshow(a)
plt.show()
```

rasdaman raster data manager

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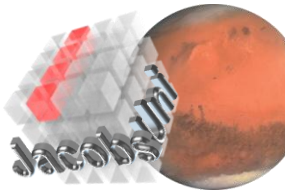
EarthServer: Datacubes At Your Fingertips

- Agile Analytics on x/y/t + x/y/z/t Earth & Planetary datacubes
  - C/S APIs rigorously coverage standards
  - EU rasdaman + US NASA WorldWind
- 1+ PB now; with ECMWF: working on 220 PB archive
- Intercontinental initiative,
  3+3 years: EU + US + AUS
- www.earthserver.eu,
  www.planetserver.eu



Co-funded by the European Union

rasdaman Federation Example

```
SELECT ENCODE(CASE
WHEN (CONDENSE + over i_i in [42364:42368] using
d[0:3600, 0:1800, i_i[0]] / 1423 + 1.47) > ((CONDENSE +
over i_i in [42364:42368] using (c) [*:*,*:*,i_i[0]])*(1000))
THEN ((255) * {1c,0c,0c,0c} + (255) * {0c,1c,0c,0c} + (255)
* {0c,0c,1c,0c} + (0) * {0c,0c,0c,1c})

WHEN (CONDENSE + over i_i in [42364:42368] using
d[0:3600, 0:1800, i_i[0]] / 1423 + 4) > ((CONDENSE + over
i_j in [42364:42368] using (c) [*:*,*:*,i_j[0]])*(1000))
THEN ((0) * {1c,0c,0c,0c} + (128) * {0c,1c,0c,0
```

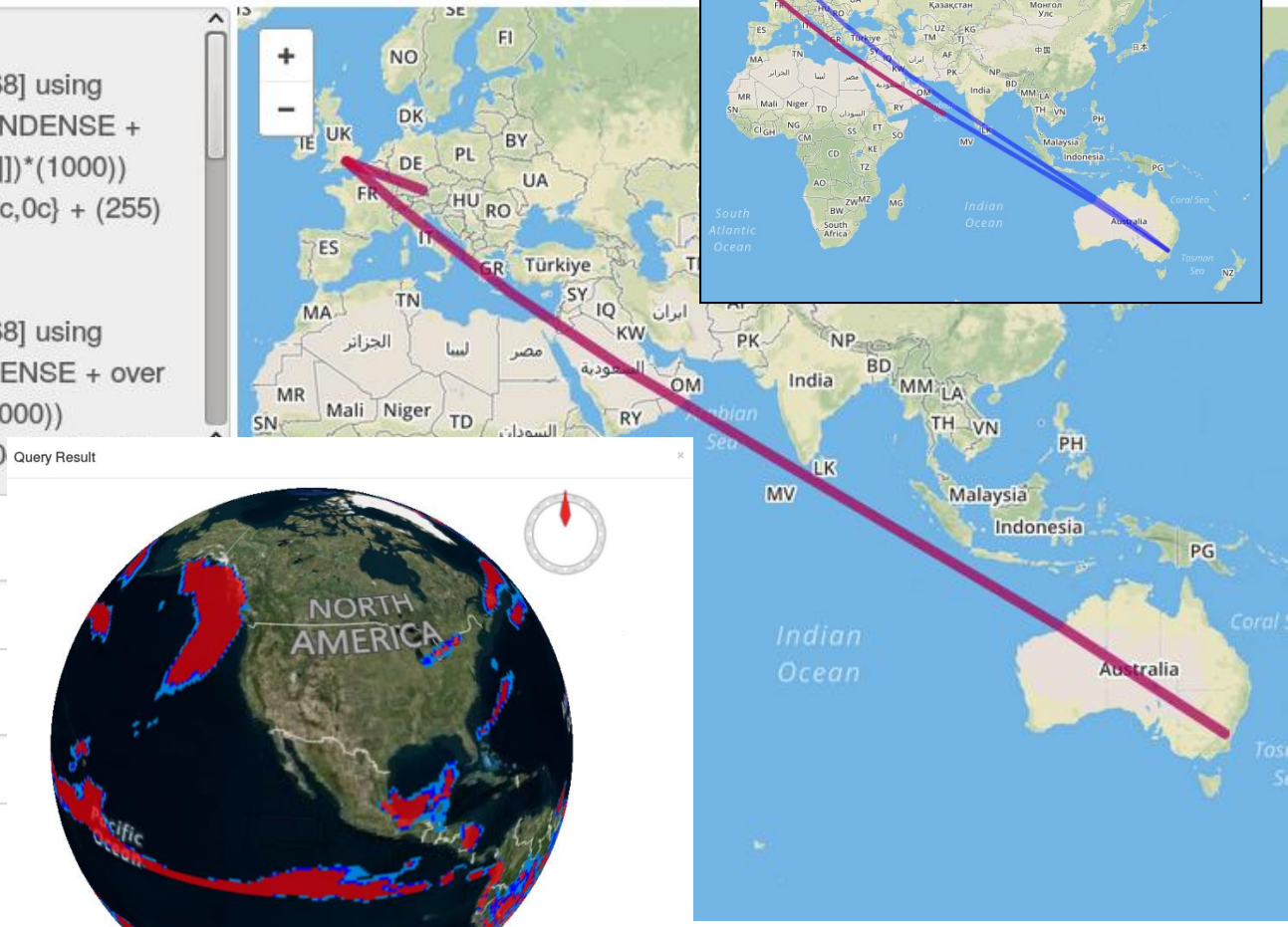
Query:

Heavy rainfall risk areas

Server:

ECMWF

Run Query



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Sample Datacube Engine (WCS Reference Implementation)

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rasdaman: Agile Datacube Analytics

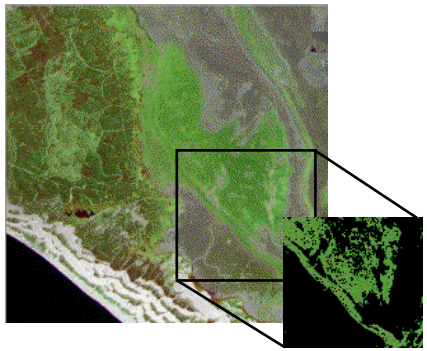
www.rasdaman.org

= „raster data manager“: SQL+ n-D arrays

- Scalable parallel “tile streaming” peer architecture

- Mature, in operational use, on OSGeo Live
  - 1+ PB databases, 1000x parallelization, federation

- ESA 2017: “world leading environment”, “standard working horse for OGC standardisation“
  - Reference Implementation



CIO 100 MOST PROMISING BIG DATA Review SOLUTION PROVIDERS 2016

GEOSPATIAL WORLD FORUM

The Earth Monitoring Competition

Copernicus masters

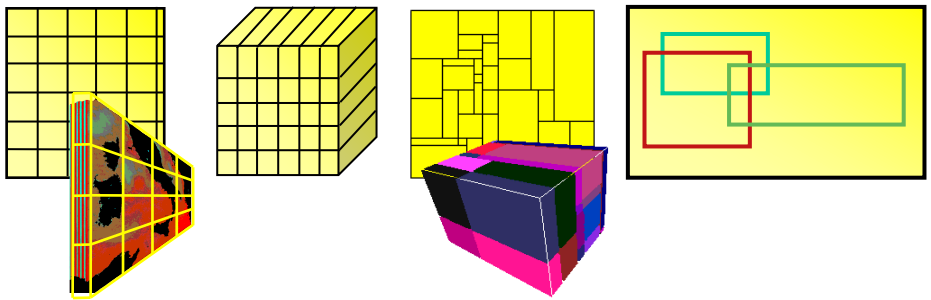
WINNER

T-SYSTEMS BIG DATA CHALLENGE 2014

T · · Systems ·

Adaptive Partitioning („Tiling“)

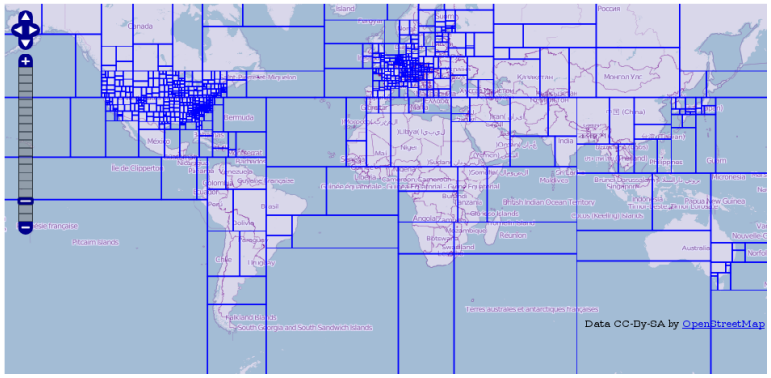
- Tiling analysis [Furtado 1999]
  - strategies



  - rasdaman storage layout language

```
insert into MyCollection
   values ...
   tiling
     area of interest [0:20,0:40], [45:80,80:85]
     tile size 1000000
     index d_index storage array compression zlib
```

- Why irregular tiling?

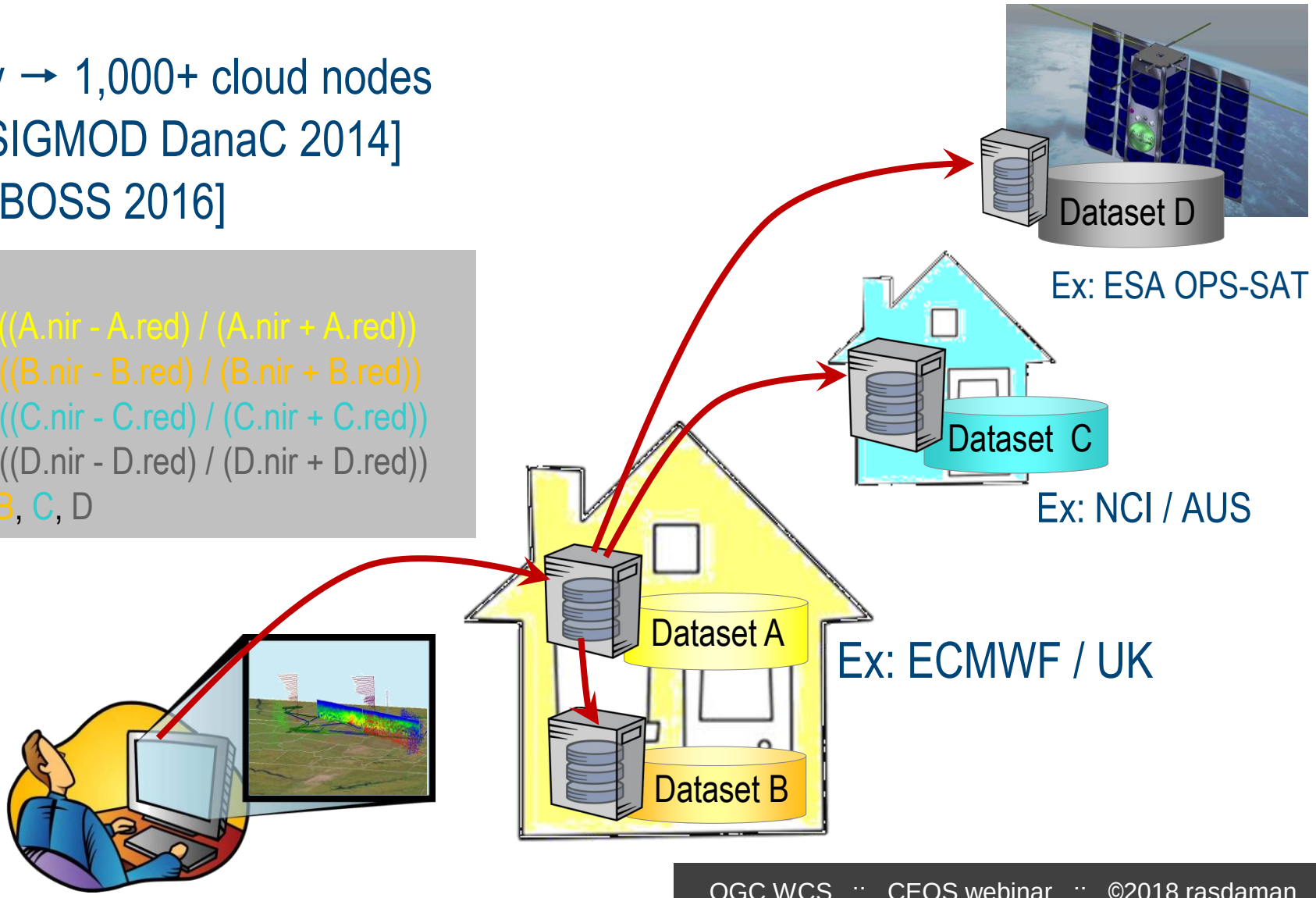


[OpenStreetMap]

Parallel, Distributed Processing

1 query → 1,000+ cloud nodes
[ACM SIGMOD DanaC 2014]
[VLDB BOSS 2016]

```
select
      max((A.nir - A.red) / (A.nir + A.red))
    - max((B.nir - B.red) / (B.nir + B.red))
    - max((C.nir - C.red) / (C.nir + C.red))
    - max((D.nir - D.red) / (D.nir + D.red))
from A, B, C, D
```



Wrap-Up

„Big Datacube“ Standards

- Earth Sciences:
  - Open Geospatial Consortium (OGC):
    - *Coverages & WCS suite*
    - *rasdaman reference implementation*
  - ISO:
    - *OGC CIS → 19123-2*
    - *19123 revised → 19123-1*
    - *OGC WCS → ISO WCS*
  - INSPIRE:
    - *coverages & WCS*
    - *rasdaman reference implementation*
- General Data Analytics:
  - ISO: SQL/MDA („Multi-Dimensional Arrays“)
    - *rasdaman as blueprint*

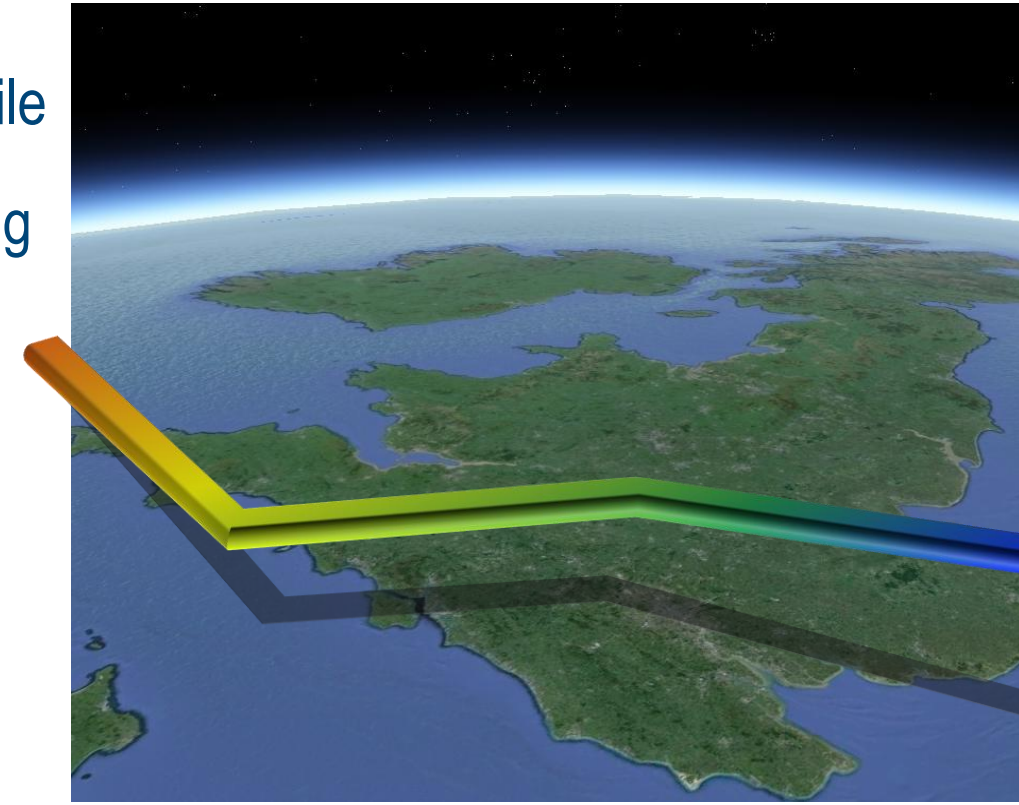
OGC® Making location count.

ISO

INSPIRE · Infrastructure for Spatial Information in Europe

Outlook: Future Work on WCS

- MetOcean-WCS Application Profile
- Space/time polygon/raster clipping
- Data/Metadata query integration
  - Web Query Service (WQS)
- Asynchronous requests
- *...further input welcome*

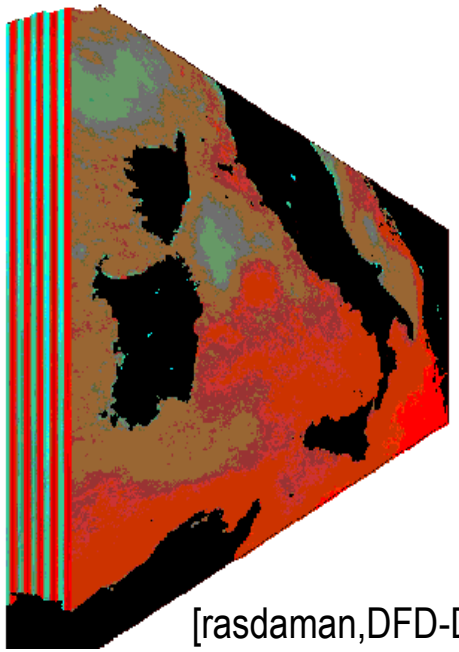


[D. Dixson, UK MetOffice]

Resources

- OGC authoritative standards page
  - http://www.opengeospatial.org/standards/wcs
  - http://www.opengeospatial.org/standards/wcps
  - http://schemas.opengis.net/cis , http://schemas.opengis.net/wcs
- OGC Coverages.DWG wiki (background info, stds pre-releases)
  - http://myogc.org/go/coveragesDWG
- Training material
  - Wikipedia: coverages, WCS, WCPS
  - WCS webinars: www.earthserver.eu/webinars
  - WCS tutorials: http://tutorial.rasdaman.org/rasdaman-and-ogc-ws-tutorial/
  - Online WCS interactive demos & sandbox: http://standards.rasdaman.com/
  - WCS Jupyter notebooks: http://nbviewer.jupyter.org/github/earthserver-eu/
- rasdaman Reference Implementation: www.rasdaman.org

Conclusion



[rasdaman,DFD-DLR]

OGC Coverages for pixel-level interoperability on datacubes & beyond

- consensus: OGC + ISO + INSPIRE stds bodies, major tools & vendors

> "Web developers who have not heard of OGC standards before immediately feel at home with these coverage standards"
> -- Stephan Siemen, ECMWF

- rasdaman: Datacube Analytics Engine
  - robust, scalable, mature: 1+ PB datacube services → working towards 220 PB
  - Datacube stds blueprint, Reference Implementation