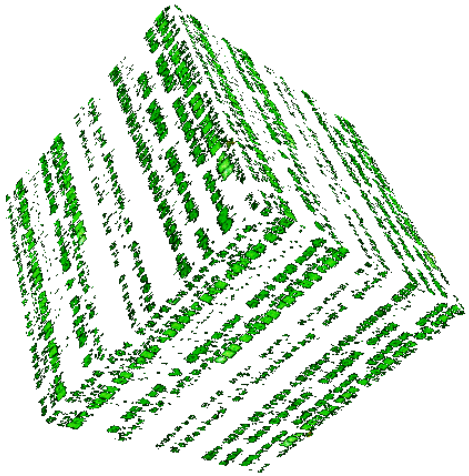


Doing Datacubes in Open-Source: the *rasdaman* Scalable Array Engine

Workshop on Open Source Geospatial Technologies, Albuquerque, USA, 2016-sep-14

Peter Baumann

Jacobs University | rasdaman GmbH

baumann@rasdaman.com

[gamingfeeds.com]

[co-funded through EU EarthServer 1/2, PublicaMundi]

BIG EARTH DATA

The Digitized Planet

Array DB Research @ Jacobs U

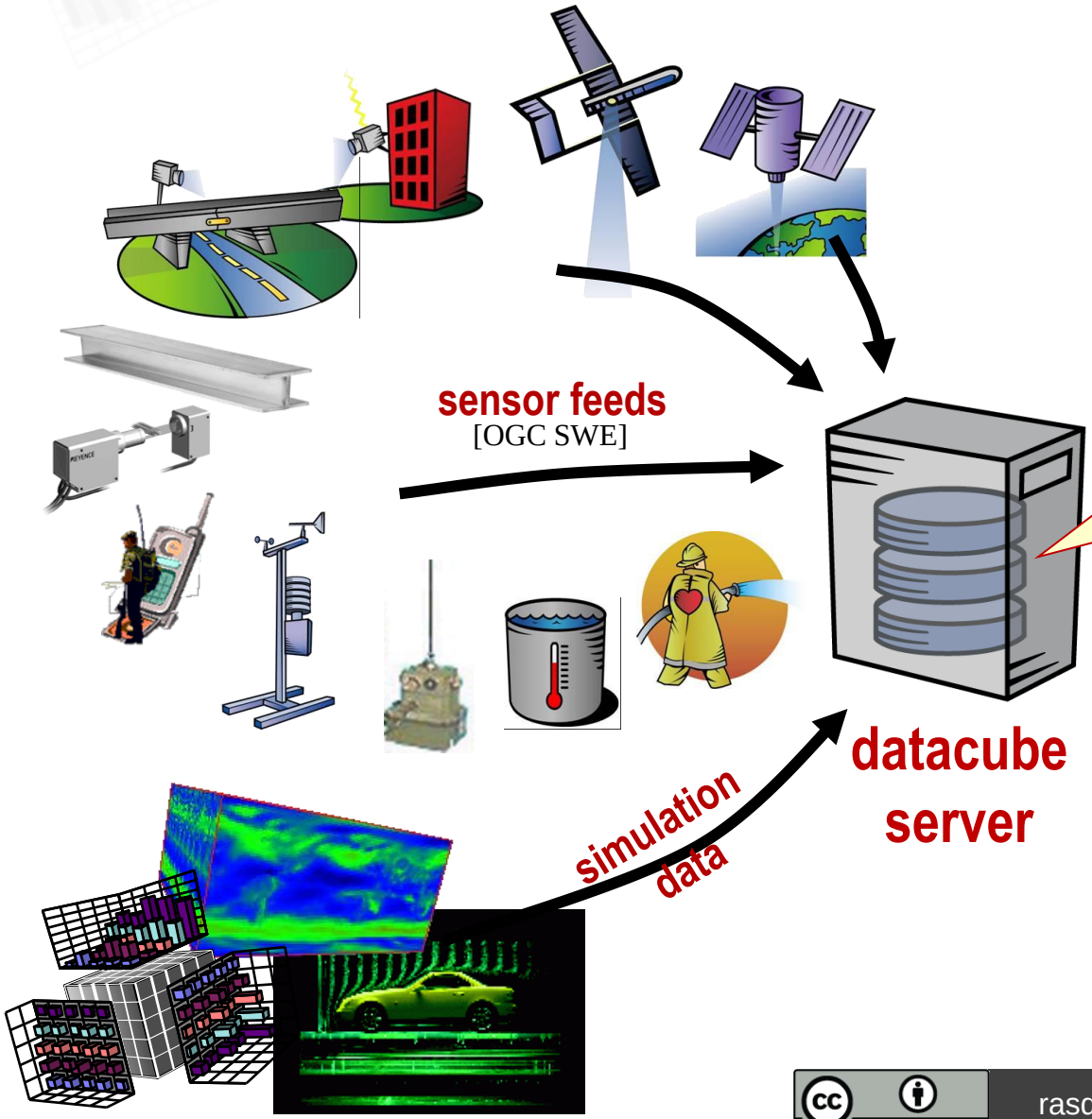
- Large-Scale Scientific Information Systems research group
  - focus: large-scale n-D raster services & beyond
  - www.jacobs-university.de/lsis
- Spin-off company: rasdaman GmbH
- Main results:
  - Array DBMS, rasdaman
  - Big Data standards
    - *OGC, ISO, INSPIRE: spatiotemporal geo datacubes*
    - *ISO Array SQL*
    - *Research Data Alliance: BigData, Geospatial, Array Database Assessment*

Jacobs MSc in Data Engineering

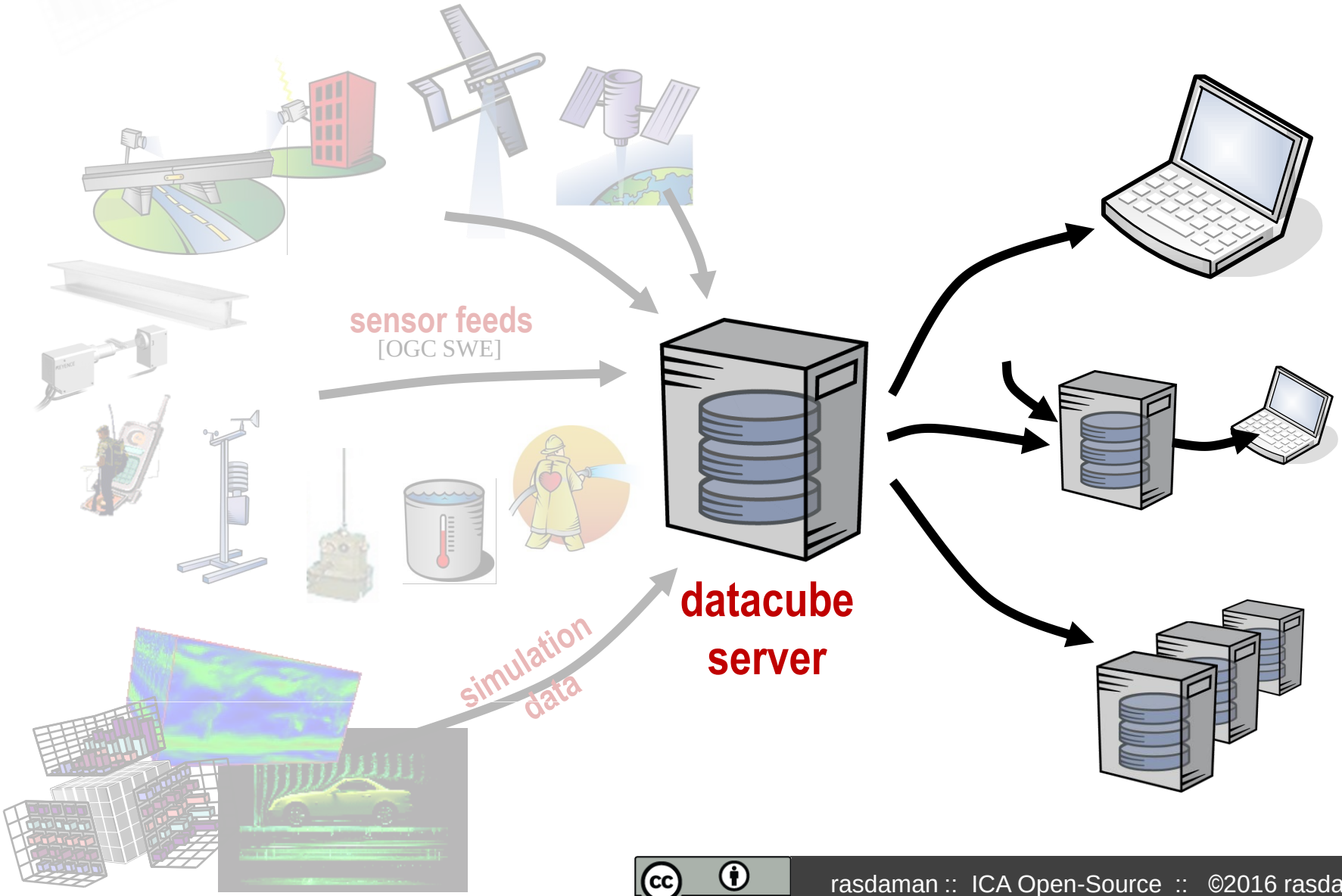
Machine Learning – Big Data – Cloud Computing – Visualization – and more...

all-English, international campus – research involvement – strong industry connections

Homogenizing Data Services



Homogenizing Data Services



rasdaman
raster data management

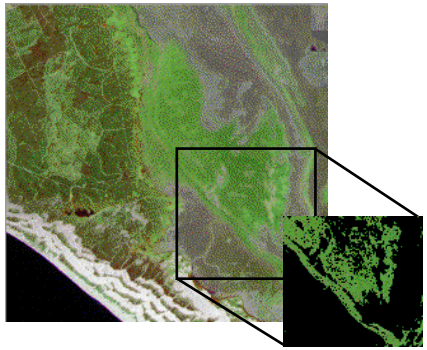
JACOBS
UNIVERSITY

rasdaman

rasdaman

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

- pioneer Array Database System
- Scalable parallel “tile streaming” architecture
- www.rasdaman.org



- Mature, in operational use
  - Ex: www.planetserver.eu
  - OSGeo Live

- OGC WCPS, ISO SQL/MDA blueprint

CIO 100 MOST PROMISING BIG DATA Review SOLUTION PROVIDERS 2016

GEOSPATIAL WORLD FORUM

The Earth Monitoring Competition

Copernicus masters

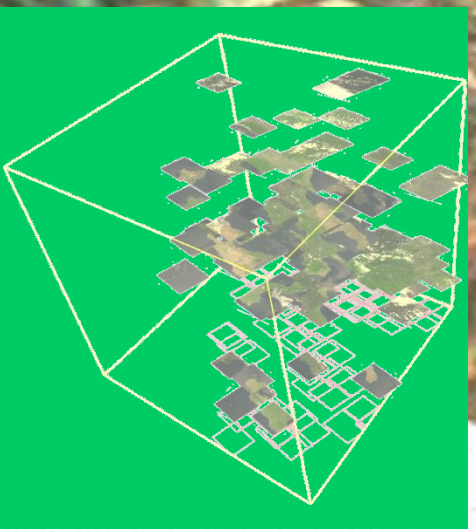
WINNER

T-SYSTEMS BIG DATA CHALLENGE

2014

T · · Systems ·

Direct Data Visualization



```
select
  encode(
    struct {
      red:   (char) s.b7[x0:x1,x0:x1],
      green: (char) s.b5[x0:x1,x0:x1],
      blue:  (char) s.b0[x0:x1,x0:x1],
      alpha: (char) scale(d.elev,20)
    },
    "image/png"
  )
from SatImage as s, DEM as d
```

[JacobsU, Fraunhofer; data courtesy BGS, ESA]

Linear Algebra Ops

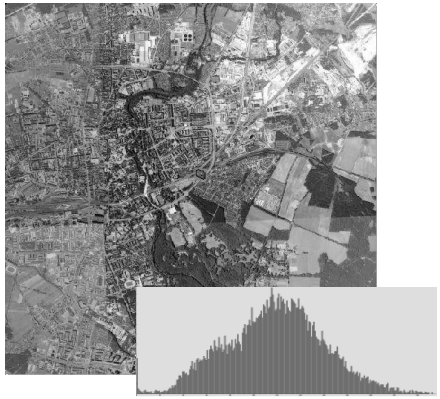
- Matrix multiplication

$$(\mathbf{AB})_{ij} = \sum_{k=1}^{m} A_{ik} B_{kj}$$

```
select marray i in [0:m], j in [0:p]
       values condense +
              over     k in [0:n]
              using    a [ i, k ] * b [ k, j ]
from   matrix as a, matrix as b
```

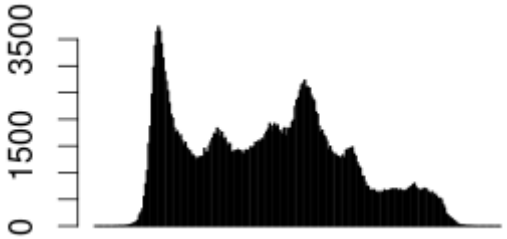
- Histogram

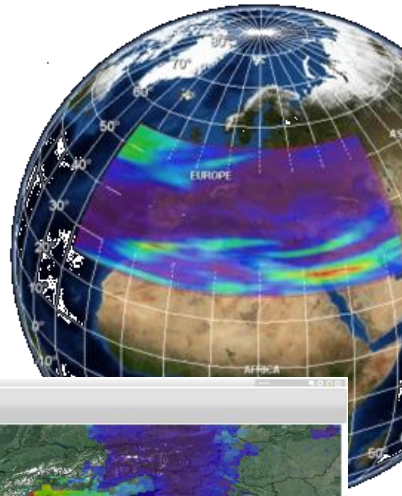
```
select marray bucket in [0:255]
       values count_cells( img = bucket )
from   img
```

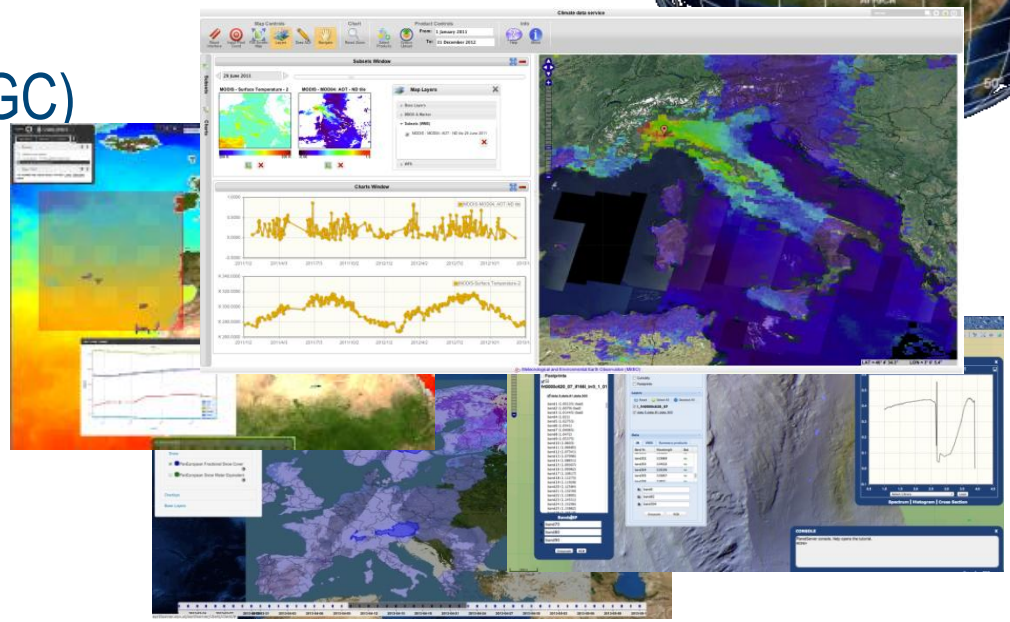


Science & GIS Tool Interfacing

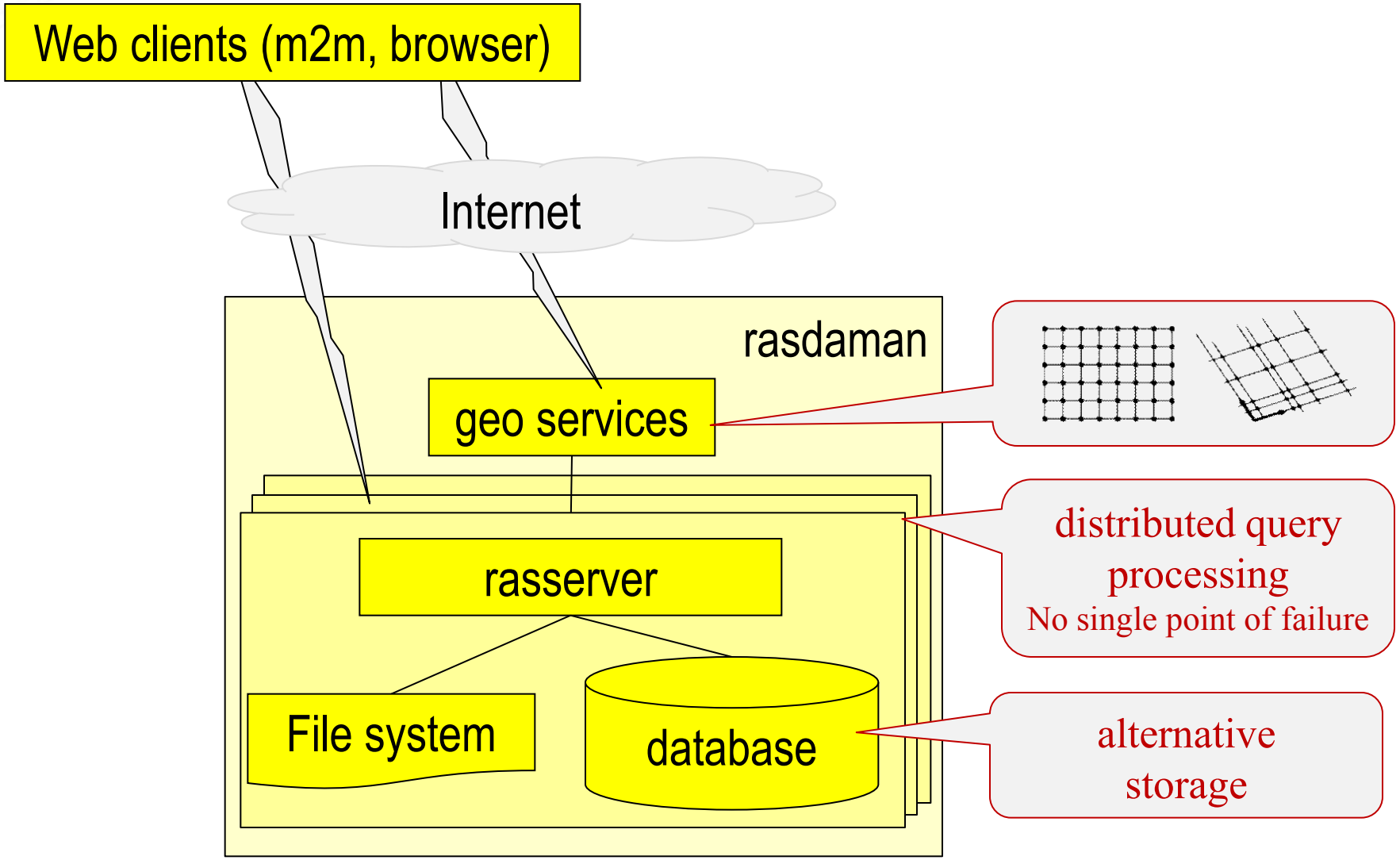
- General-purpose scientist tools:
  - Java, C++
  - python, R (under work)
- Geo tools:
  - MapServer, GDAL, QGIS, OpenLayers, Leaflet, NASA WorldWind, ...
- Open Geospatial Consortium (OGC) Web Coverage Service (WCS) Core Reference Implementation
  - Can interface to all tools supporting OGC's „Big Geo Data" standards suite







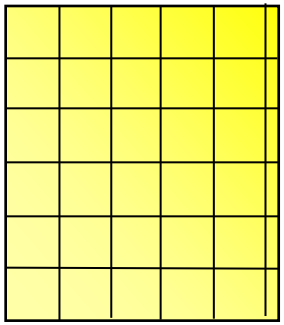
Architecture



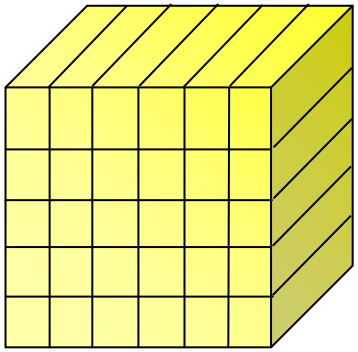
Adaptive Partitioning („Tiling“)

- tiling strategies as service tuning [ICDE 1999]:

regular

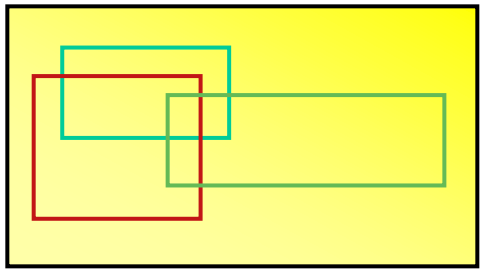


directional



...

area of interest

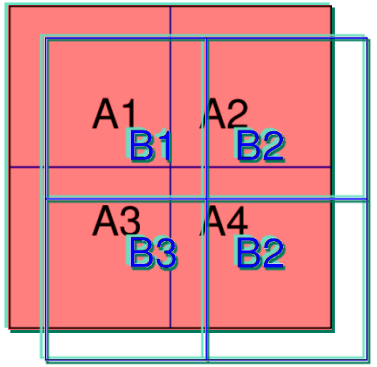


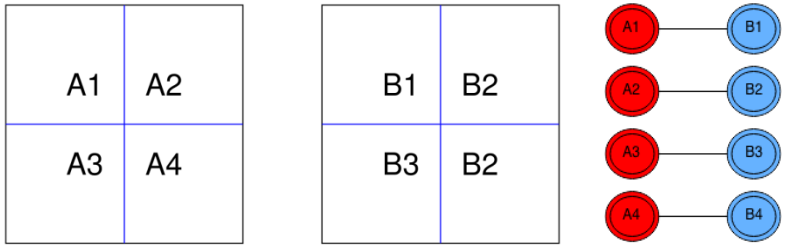
- rasdaman storage layout language

```
insert into MyCollection
  values ...
  tiling area of interest [0:20,0:40], [45:80,80:85]
  tile size 1000000
```

Array Fusion („Join“)

- „A θ B“ in presence of partitioned arrays A, B
  - Challenge: partitions shifted, different size, heterogeneous
  - inefficient multiple reads of sub-arrays
- Goal: optimal partition loading sequence
- Approach: bi-partite graph traversal



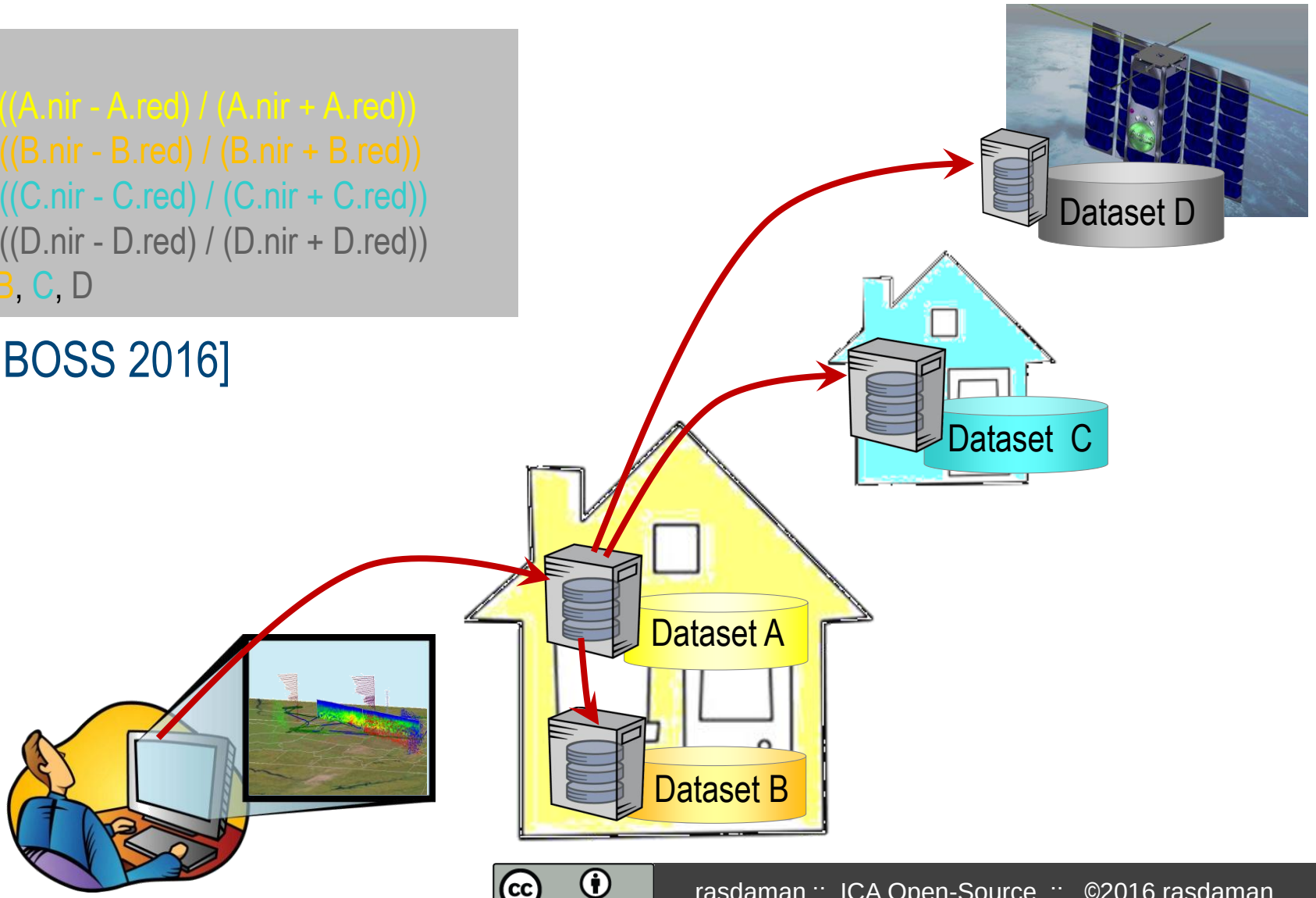


- Also useful for buffer mgmt, parallelization

Parallel / Distributed Query Processing

```
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
```

[VLDB BOSS 2016]

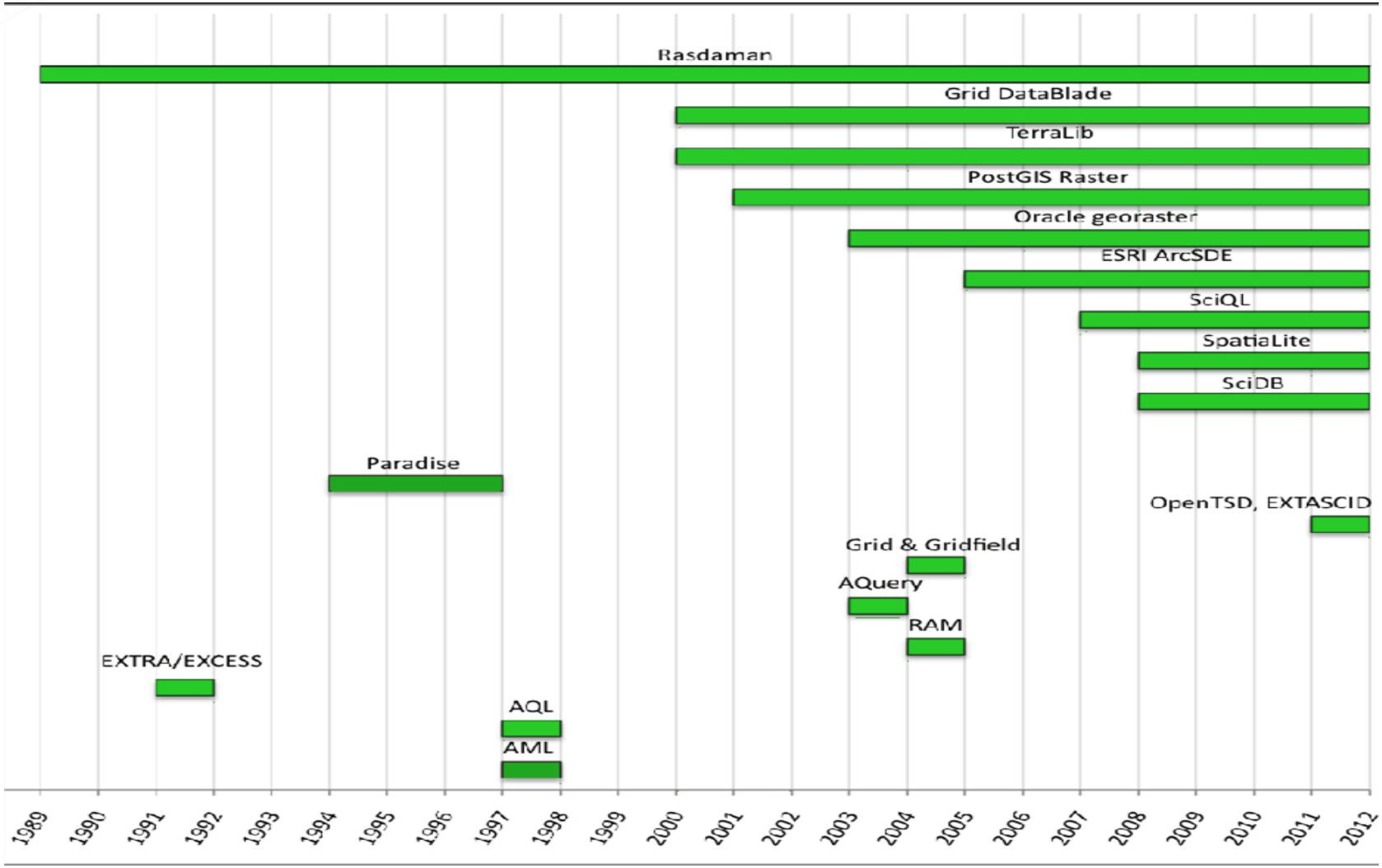


Outlook: Corridor Queries

[D. Dixson, UK MetOffice]

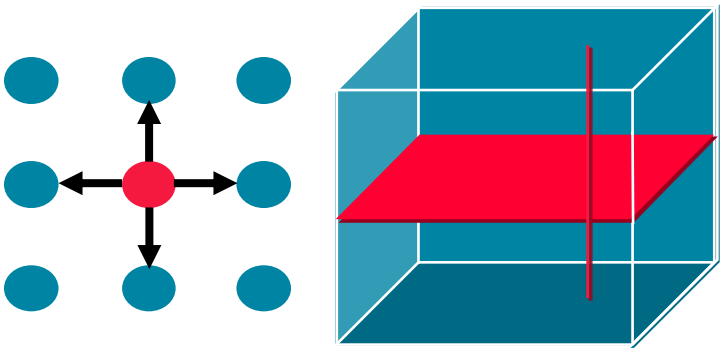
Background

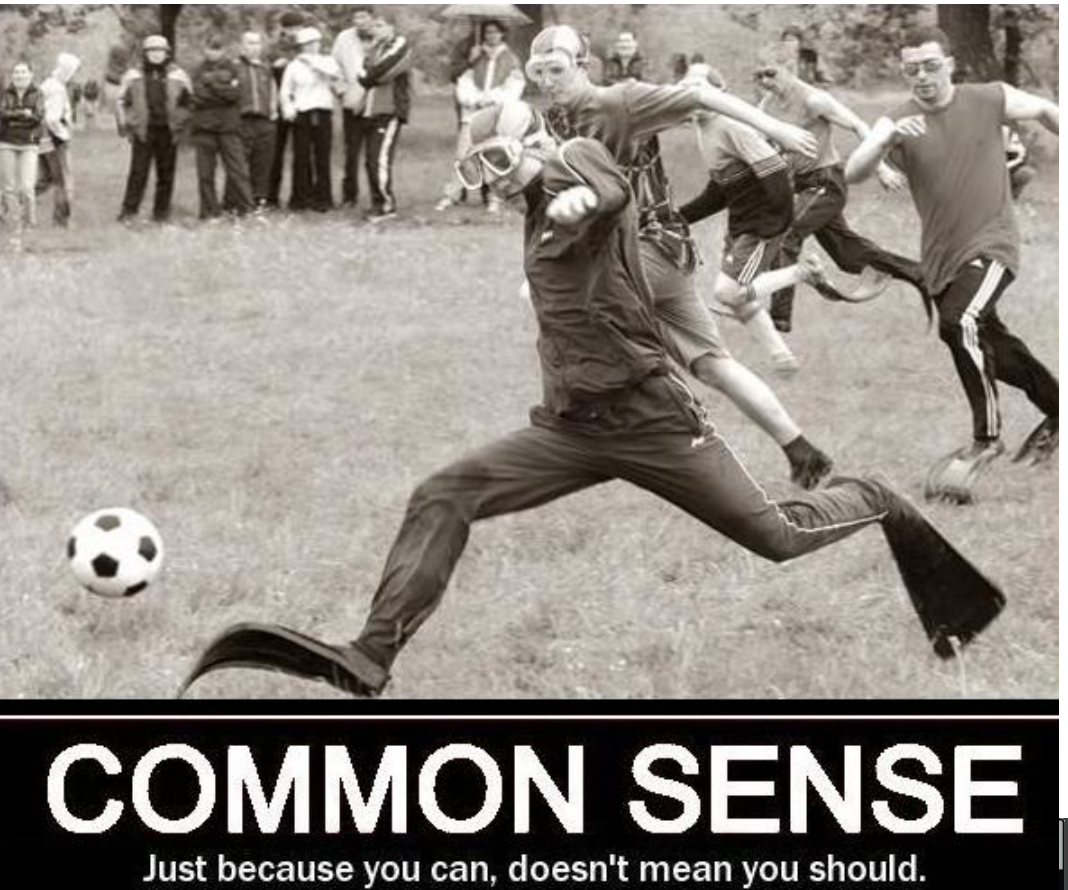
A Brief History of Array Databases

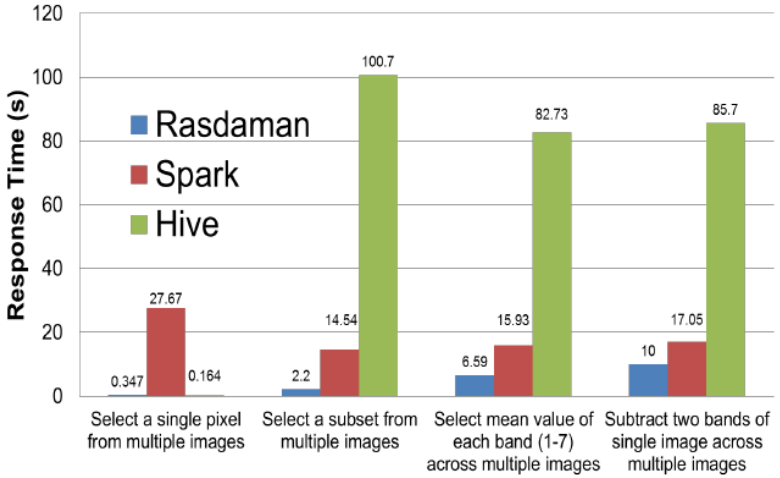


Hadoop/Spark – *one size does not fit all*

- "Since it was not originally designed to leverage the structure its performance is suboptimal" [Daniel Abadi]
- U Madison / GMU benchmark confirms [AGU 2015]



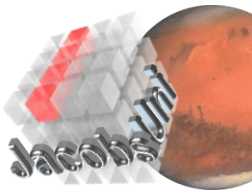


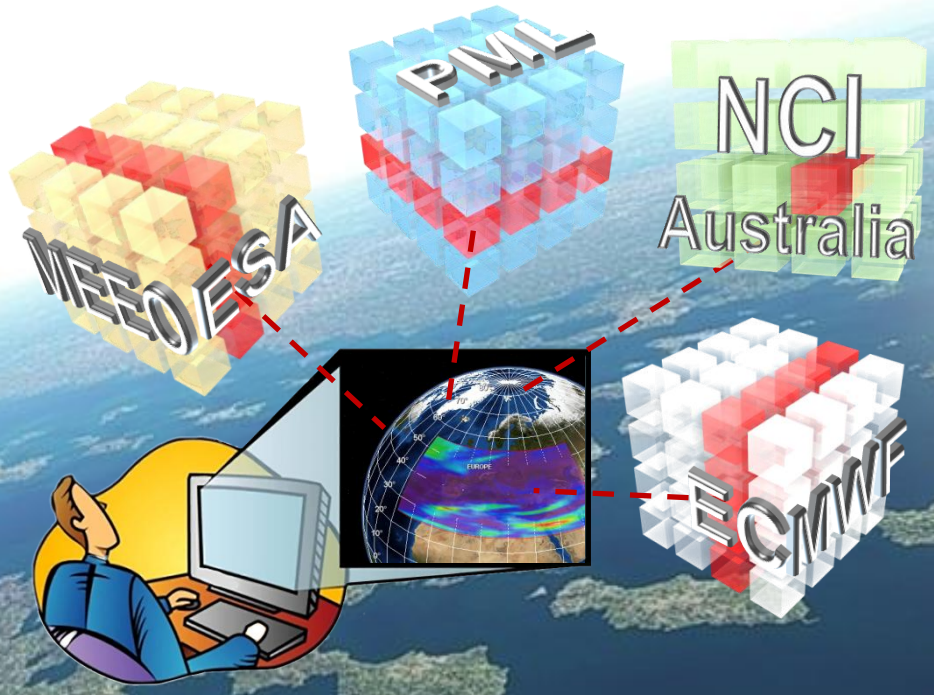


[C. Scheele, F. Hu, M. Yu, M. Xu, K. Liu, Q. Huang, C. Yang 2015]

EarthServer: Datacubes At Your Fingertips

- Agile Analytics on x/y/t + x/y/z/t Earth & Planetary datacubes
  - EU rasdaman + NASA WorldWind
  - 100s of TB sites now, next: 1+ Petabyte per cube
- Intercontinental initiative, 3+3 years:
  EU + US + AUS
- Global data federation
  - Access, extract, aggregate, combine any-size datacubes
  - Common basis: OGC WCS





Co-funded by the European Union

www.earthserver.eu

EarthServer Phase 1 & 2 Partners

JACOBS UNIVERSITY

rasdaman raster data manager

MEEO Meteorological Environmental Earth Observation

NASA

PML Plymouth Marine Laboratory

NCI

CITE

ECMWF

Ερευνητικό Κέντρο Αθηνά
Athena Research Center

BGS 1835 British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Fraunhofer

EOX

CNR-IIA

COMETA

Co-funded by the European Union

www.earthserver.eu

EarthServer Global Federation

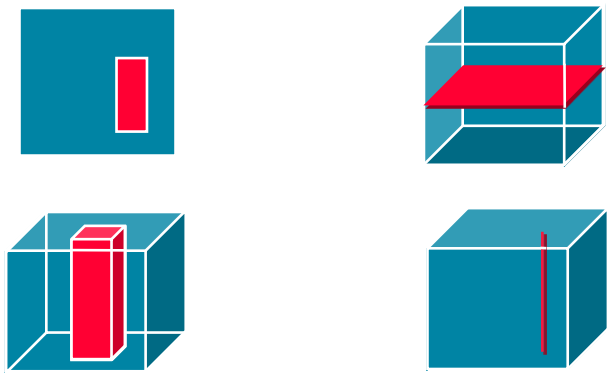
- Access, extract, aggregate, combine any-size datacubes
- User benefits:
  - single common information space, location transparent
  - OGC WCS for unified standardized access
- Data provider benefits:
  - More users, multiplied offering
  - Support in adopting standards
- Goal: 3.5 PB in 2017
  - Receiving requests to join

keeping contributions visible

Standards

OGC Web Coverage Service (WCS)

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

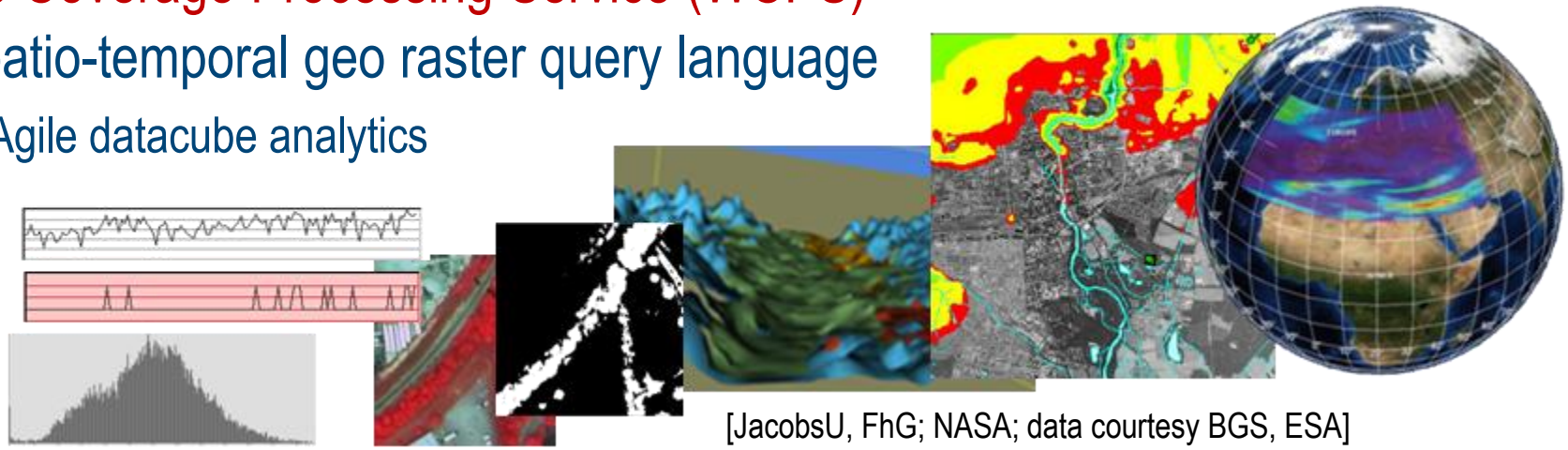


Large, growing implementation basis:
rasdaman, GDAL, QGIS, OpenLayers, OPeNDAP, MapServer, GeoServer, GMU, NASA WorldWind, EOxServer; Pyxis, ERDAS, ArcGIS, ...

- WCS Extensions: optional functionality facets
  - Such as WCPS

OGC WCPS

- Web Coverage Processing Service (WCPS)
  = spatio-temporal geo raster query language
  - Agile datacube analytics



[JacobsU, FhG; NASA; data courtesy BGS, ESA]

- "From MODIS scenes M1, M2, M3: difference between 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" )
```

Semantic Interoperability: WPS vs WCPS

- WCPS: semantics in query → machine understandable, any query anytime

```
for $c in ( M1, M2, M3 )
return encode abs( $c.red - $c.nir ), "hdf" )
```

- WPS: semantics in human-readable text, predefined processes

```
<ProcessDescriptions ...>
  <ProcessDescription processVersion="2" storeSupported="true" statusSupported="false">
    <ows:Identifier>Buffer</ows:Identifier>
    <ows:Title>Create a buffer around a polygon.</ows:Title>
    <ows:Abstract>Create a buffer around a single polygon. Accepts the polygon as GML and
provides GML output for the buffered feature. </ows:Abstract>
    <ows:Metadata xlink:title="spatial" />
    <ows:Metadata xlink:title="geometry" />
    <ows:Metadata xlink:title="buffer" />
    <ows:Metadata xlink:title="GML" />
    <DataInputs>
      <Input>
        <ows:Identifier>InputPolygon</ows:Identifier>
        <ows:Title>Polygon to be buffered</ows:Title>
        <ows:Abstract>URI to a set of GML that describes the polygon.</ows:Abstract>
        <ComplexData defaultFormat="text/XML" defaultEncoding="base64" defaultSchema="http
://foo.bar/gml/3.1.0/polygon.xsd">
          <SupportedComplexData>
                                                                    1,1           Top
```

Array SQL

ISO/IEC JTC 1/SC 32

Date: 2014-06-04

WD 9075-15:2014(E)

Information technology — Database languages — SQL —

Part 15:
Multi-Dimensional Arrays (SQL/MDA)

ISO/IEC JTC 1/SC 32/WG 3

The United States of America (ANSI)

Technologies de l'information — Langages de base de données — SQL —

Partie 15: Tableaux multi-dimensionnels (SQL/MDA)

```
create table LandsatScenes(
    id: integer not null, acquired: date,
    scene: row( band1: integer, ..., band7: integer ) mdarray [ 0:4999,0:4999] )
```

```
select  id, encode(scene.band1-scene.band2)/(scene.nband1+scene.band2)), „image/tiff“ )
from    LandsatScenes
where acquired between „1990-06-01“ and „1990-06-30“ and
          avg( scene.band3-scene.band4)/(scene.band3+scene.band4)) > 0
```

Big Datacube Standards

- Open Geospatial Consortium (OGC):
  - Coverages & WCS suite
  - rasdaman reference implementation

- ISO:
  - OGC coverages → 19123-2
  - 19123 revised → 19123-1
  - OGC WCS → ISO WCS
  - SQL/MDA („Multi-Dimensional Arrays“)

- INSPIRE:
  - coverages & WCS
  - rasdaman reference implementation

Wrap-Up

Conclusion

- OGC Coverages for pixel-level interoperability: CIS & WCS
  - consensus: stds bodies, major tools & vendors
  - From simple access (WCS Core) to agile analytics (WCPS)
  - Many tools support it -> interoperability, freedom of choice
- rasdaman community: scalable array engine for spatio-temporal regular & irregular grids
  - OGC, INSPIRE reference implementation
  - blueprint for datacube standards
- See us:
  - www.earthserver.eu
  - www.rasdaman.org
  - www.jacobs-university.de/lsis

[Dali]