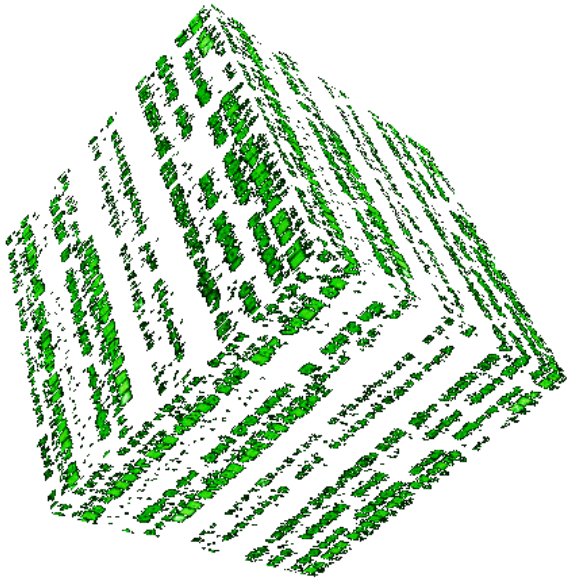

Datacubes
as an Enabling „Big Data“ Paradigm

Prof. Dr. Peter Baumann
Jacobs University Bremen

[gamingfeeds.com]

Helmholtz Open Science Webinars
Webinar 41 – 12 / 16 June 2017

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Why Datacubes?

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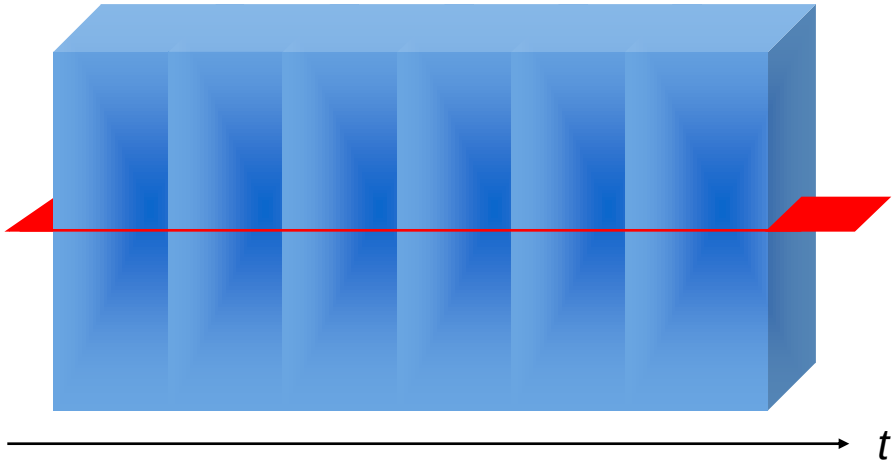
Archives Are Not Analysis-Ready



- Divergent access patterns for ingest and retrieval
- Server must mediate between access patterns

Structural Variety in Big Data

- Stock trading: 1-D sequences (i.e., arrays)
- Social networks: large, homogeneous graphs
- Ontologies: small, heterogeneous graphs
- Climate modelling: 4D/5D arrays
- Satellite imagery: 2D/3D arrays (+irregularity)
- Genome: long string arrays
- Particle physics: sets of events
- Bio taxonomies: hierarchies (such as XML)
- Documents: key/value stores = sets of unique identifiers + whatever
- etc.

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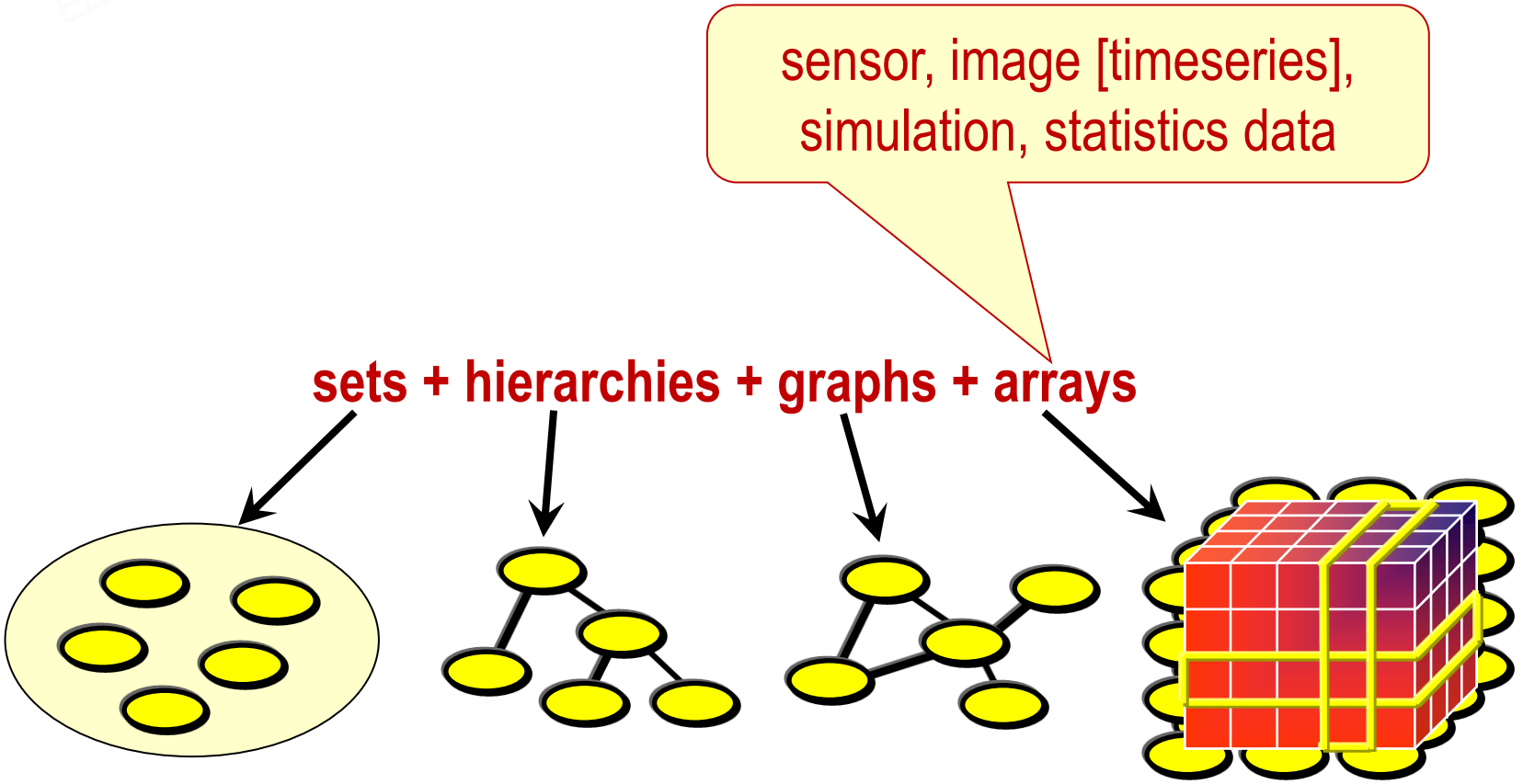
Structural Variety in Big Data



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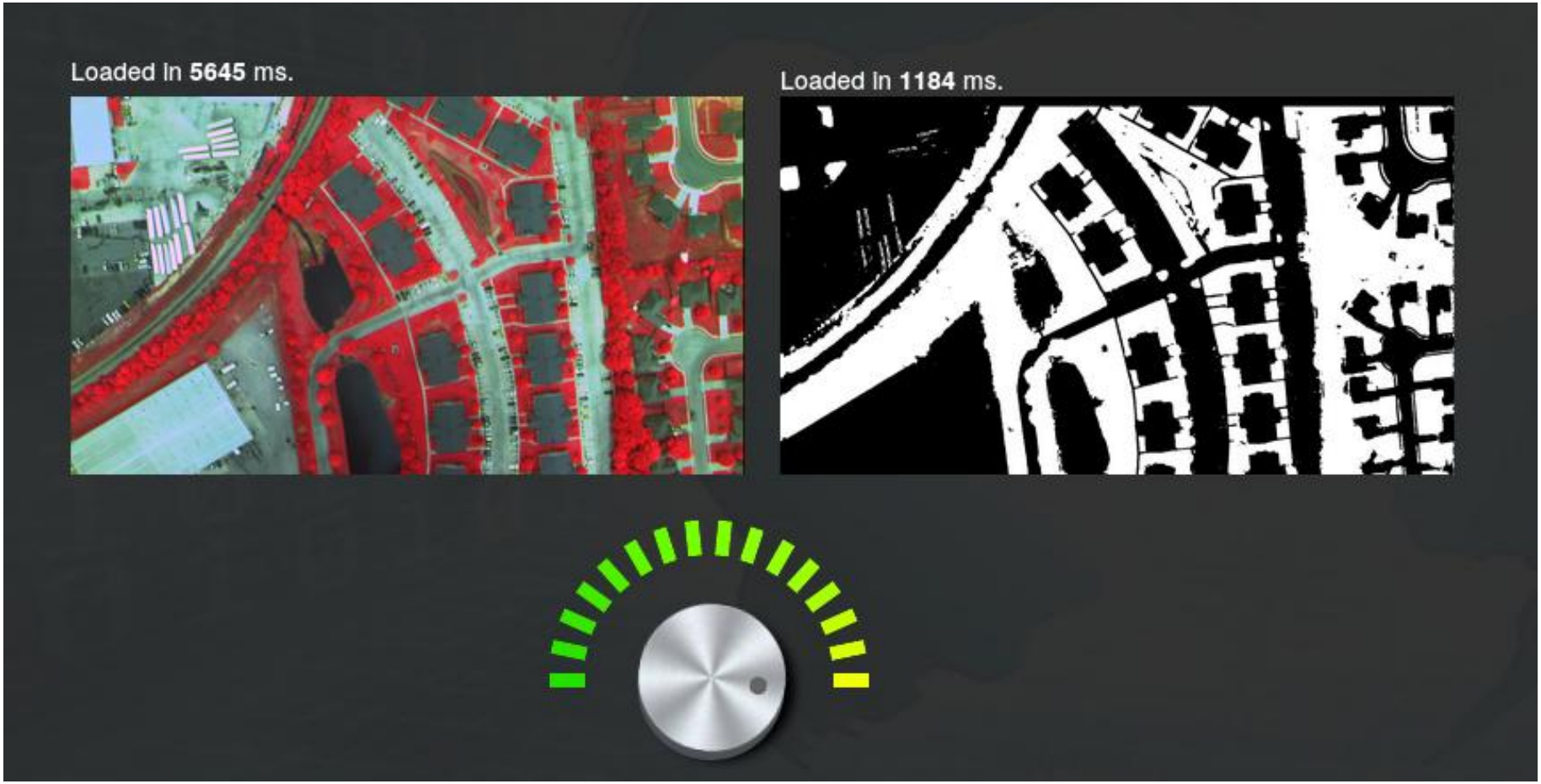
SERVICE QUALITY

„What You Get is What You Need“



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rasdaman

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rasdaman: Agile Datacube Analytics

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

- Mature, in operational use, open source
  - blueprint for ISO Array SQL, OGC WCPS, ...

“world leading environment”, “standard working horse for OGC standardisation on these innovative data access interfaces“
- G. Landgraf, ESA, 2017

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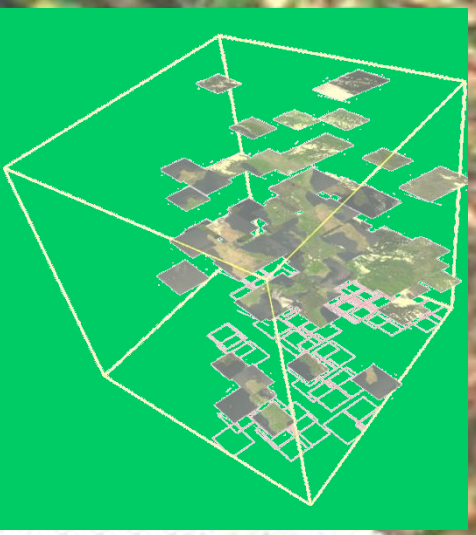
Direct Data Visualization



```
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, 20 )
    },
    "image/png"
  )
from SatImage as s, DEM as d
```

[JacobsU, Fraunhofer; data courtesy BGS, ESA]

Linear Algebra Ops

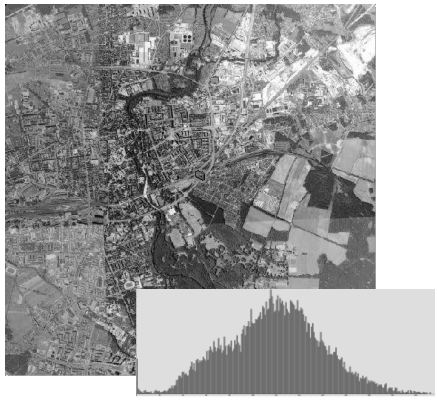
- Matrix multiplication

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

```
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

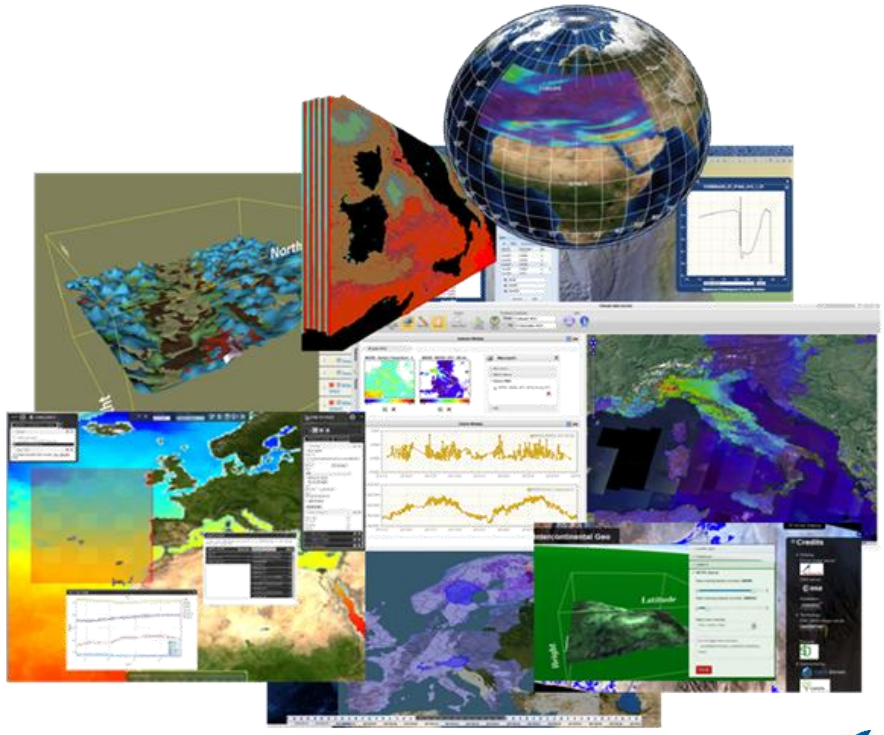
```
select marray bucket in [0:255]
       values count_cells( img = bucket )
from   img
```



- All ops defined through Array Algebra
  - marray, condense

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

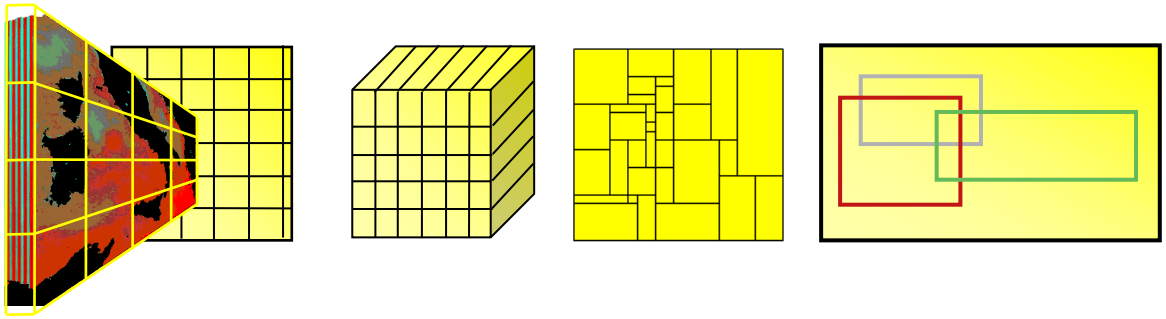
- Users should stay in their comfort zone
  - navigation: Web client; ...; analytics:python, R, ...



```
>>> con = Connection(hostname="127.0.0.1" ,
port=7001)
>>> mr = RasCollection(con, "mr")
>>> mr = mr[100,150] # Array Subsetting
>>> mr += 1
>>> mr = mr ** 2 # Square of all elements
>>> mr = mr. filter (oid=2)
>>> mr.query
<RasQueryObject>
>>> str (mr.query)
"Select exp(mr[100,150]+1,2) from mr where oid(mr) = 2"
>>> arr = mr.eval ()
<RasArrayObject>
>>> arr.to_array () # Default conversion : Numpy Array
[ [ . . . ] , [ . . . ] , [ . . . ] ]
```

Adaptive Partitioning („Tiling“)

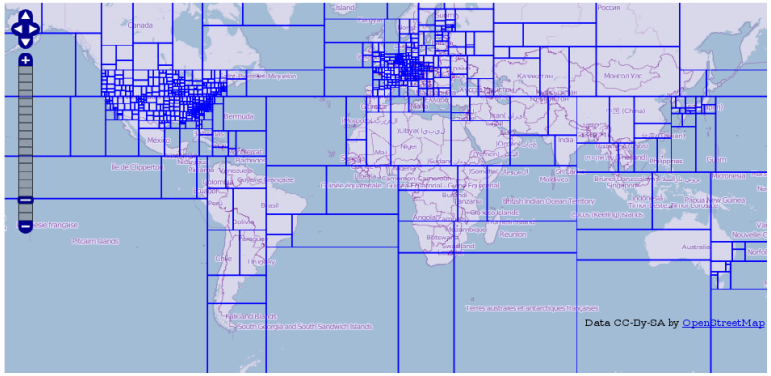
- Any tiling [Furtado 1999]
  - Cast into strategies



  - 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
```

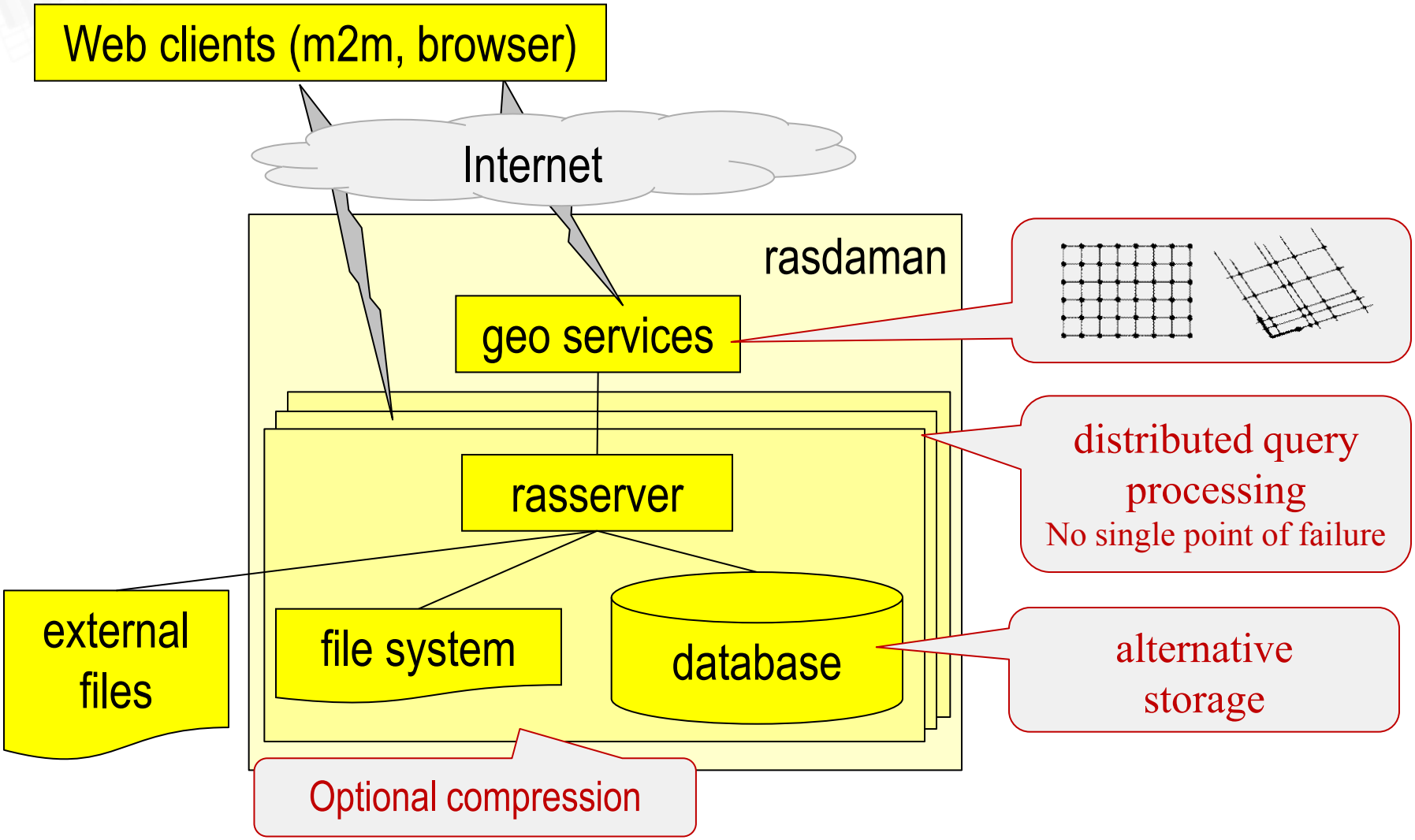
- Why irregular tiling?



[OpenStreetMap]

Architecture

[SSTD 2013]



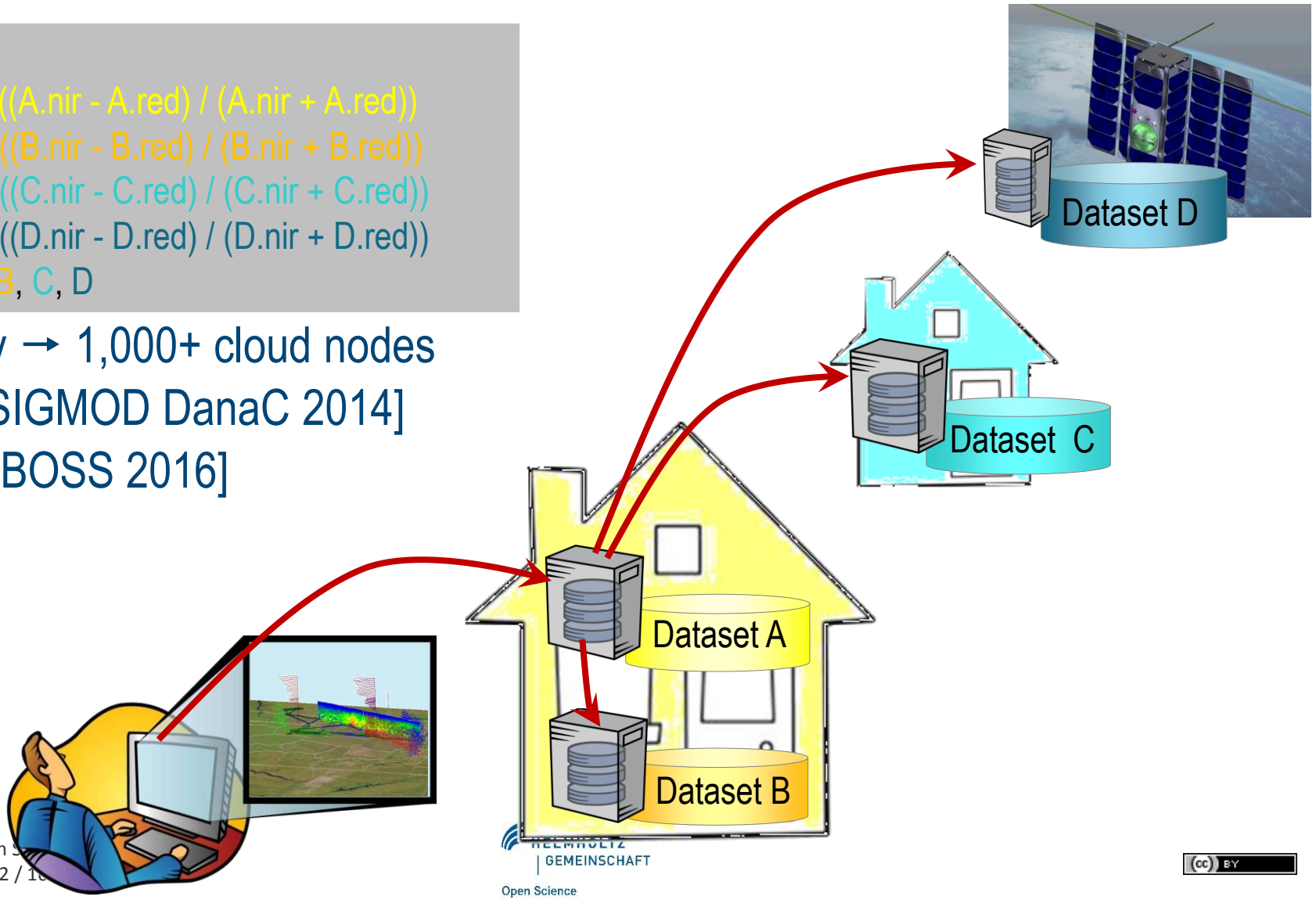
Parallel, Distributed Processing

```
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
```

1 query → 1,000+ cloud nodes

[ACM SIGMOD DanaC 2014]

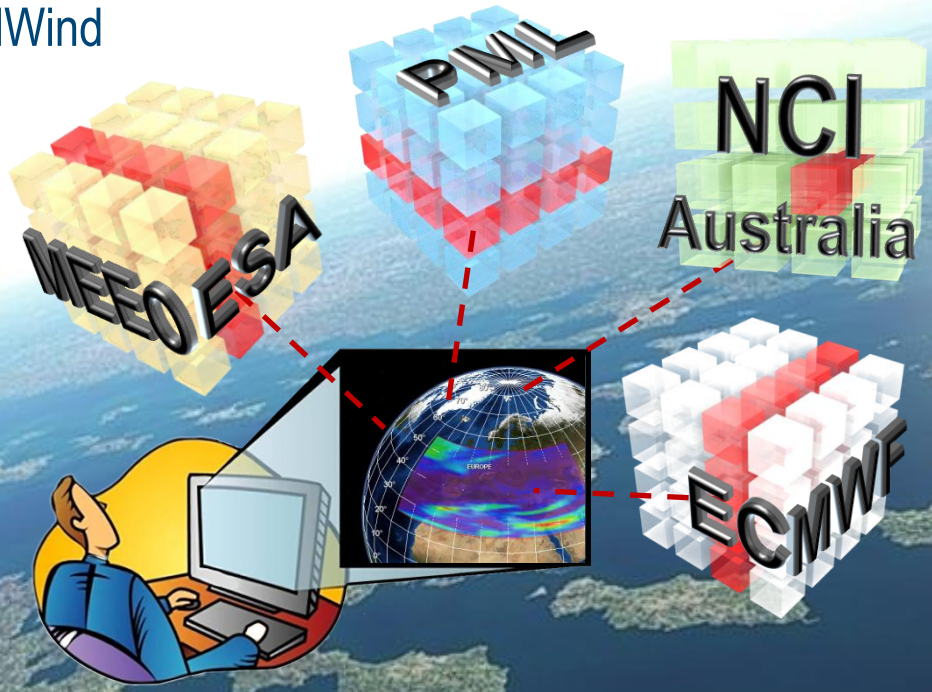
[VLDB BOSS 2016]



The EarthServer Example

EarthServer: Datacubes At Your Fingertips

- Intercontinental initiative: EU + US + AUS, 3+3 years, since 2011
- Agile Analytics on 3D, 4D Earth & Planetary datacubes
  - 500+ TB sites now, next: 1+ PB
  - EU rasdaman + US NASA WebWorldWind
- Towards federation:
  single common information space
- www.earthserver.eu,
  www.planetserver.eu



Co-funded by
the European Union

Transparent Federation

```
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,0c} + (212) *
{0c,0c,1c,0c} + (255) * {0c,0c,0c,1c})

WHEN (CONDENSE + over i_i in [42364:42368] u
d[0:3600, 0:1800, i_i[0]] / 973) > ((CONDENSE + o
in [42364:42368] using (c) [*:*,*:*,i_k[0]])*(1000))
THEN ((0) * {1c,0c,0c,0c} + (64) * {0c,1c,0c,0c} + (1
{0c,0c,1c,0c} + (255) * {0c,0c,0c,1c})

WHEN (CONDENSE + over i_i in [42364:42368] u
d[0:3600, 0:1800, i_i[0]] / 875) > ((CONDENSE + o
```

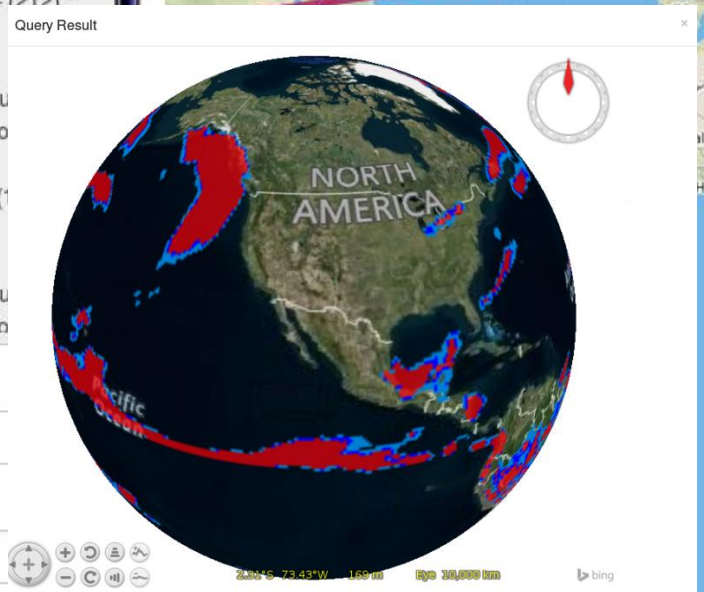
Query:

Heavy rainfall risk areas

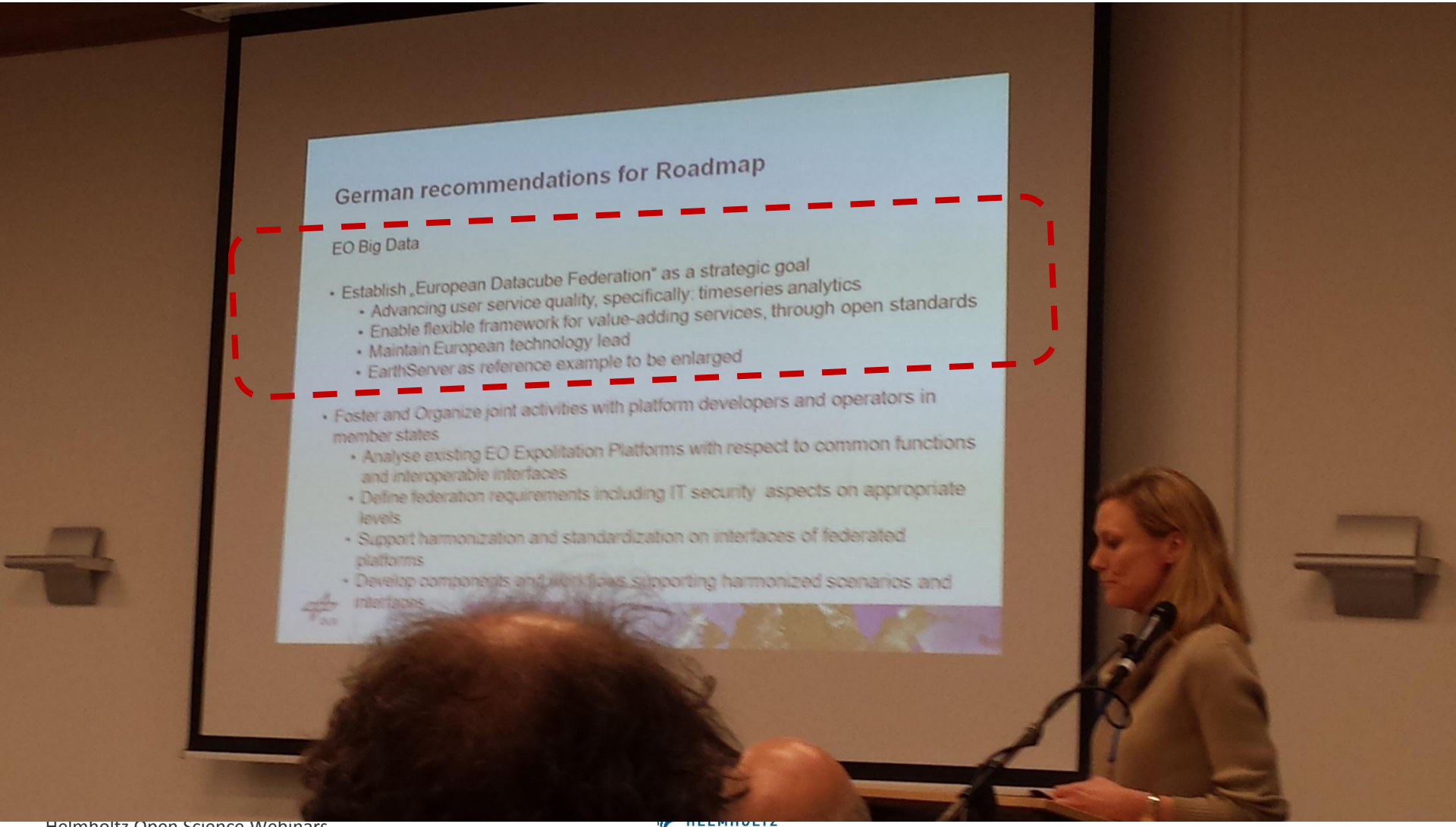
Server:

ECMWF

Run Query



ESA Tech Harm Strat Meetg, 2017-feb-21



Standards & Related

ISO Array SQL

[SSDBM 2014]

Information technology — Database languages — SQL —

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

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

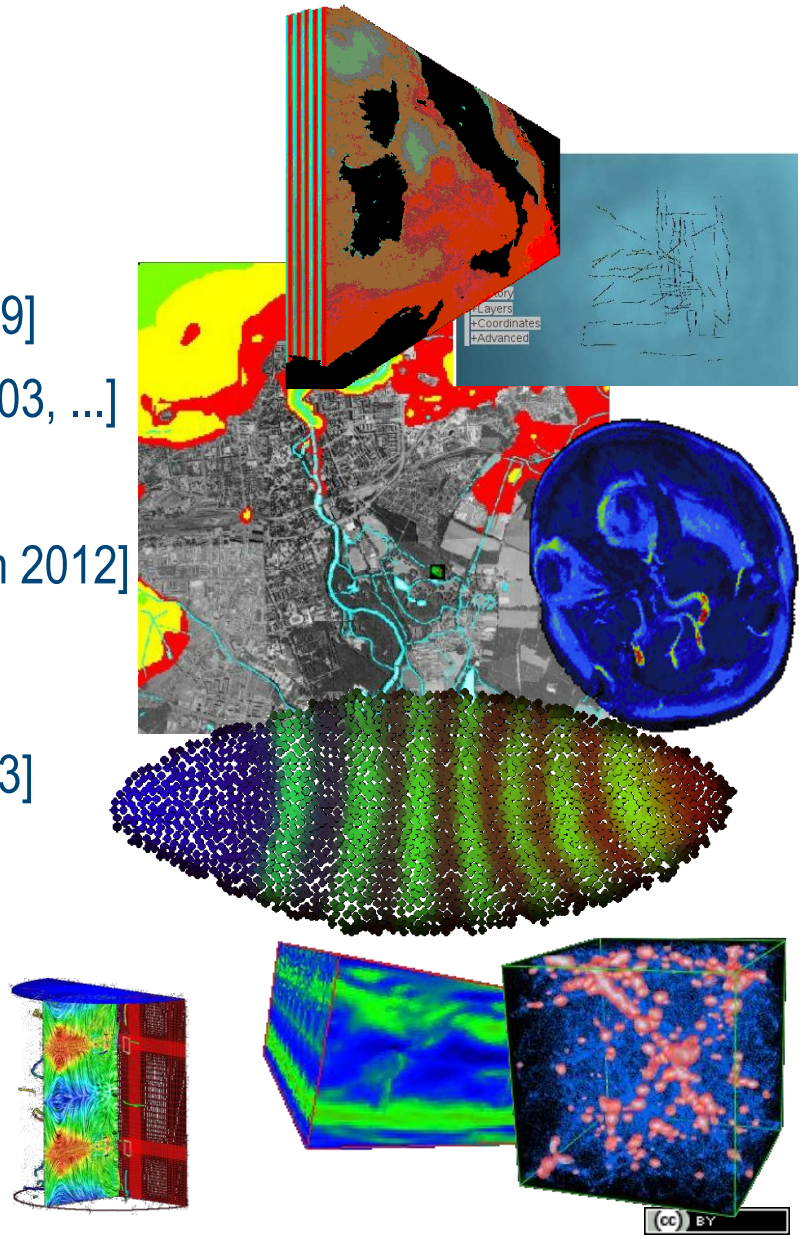
Partie 15: Tableaux multi-dimensionnels (SQL/MDA)

```
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
```

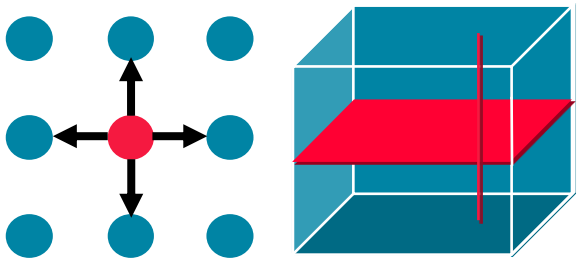
Domains Investigated

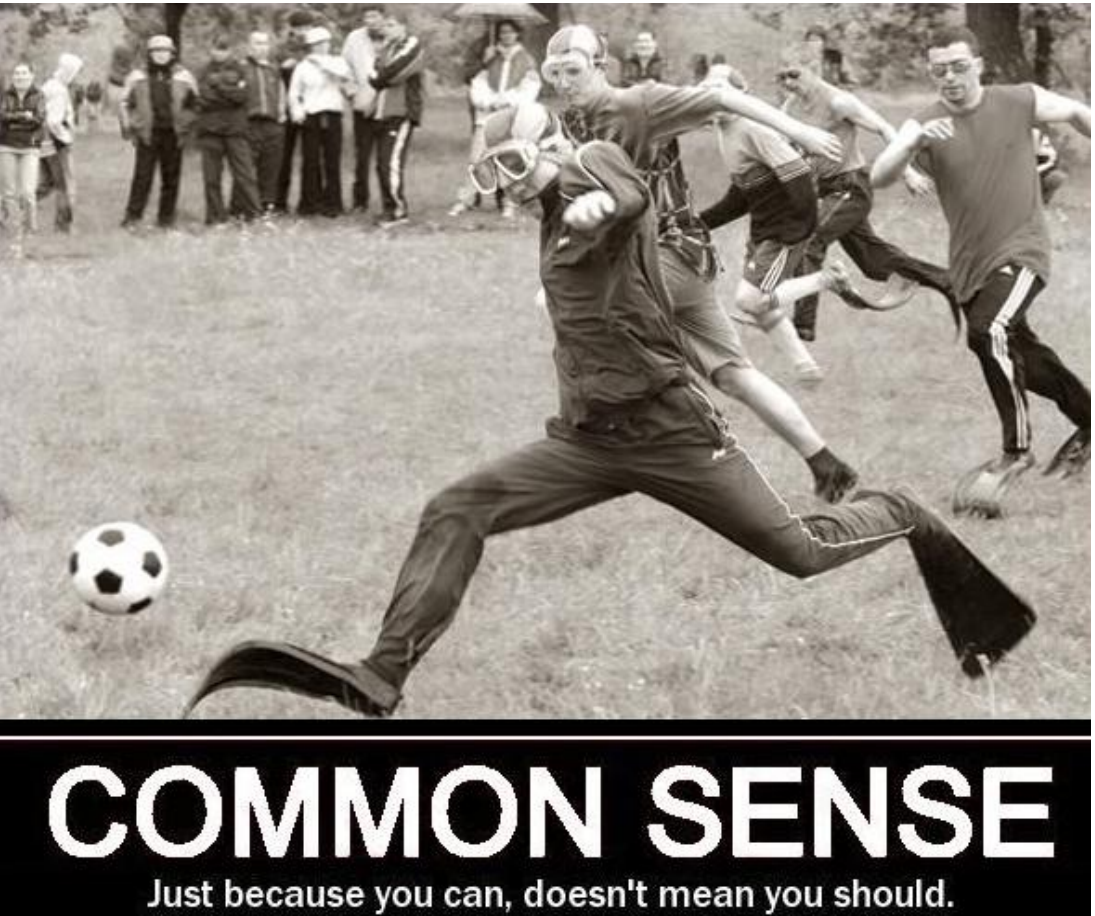
- Geo
  - Environmental sensor data, 1-D [Sensors 2009]
  - Satellite / seafloor maps, 2-D [VLDB 1999, 2003, ...]
  - Geophysics (3-D x/y/z)
  - Climate modelling (4-D, x/y/z/t) [DB Spektrum 2012]
- Life science
  - Gene expression simulation (3-D) [InfSys 2003]
  - Human brain imaging (3-D / 4-D) [TiNS 2001]
- Other
  - Computational Fluid Dynamics (3-D)
  - Astrophysics (4-D)
  - Statistics (n-D)

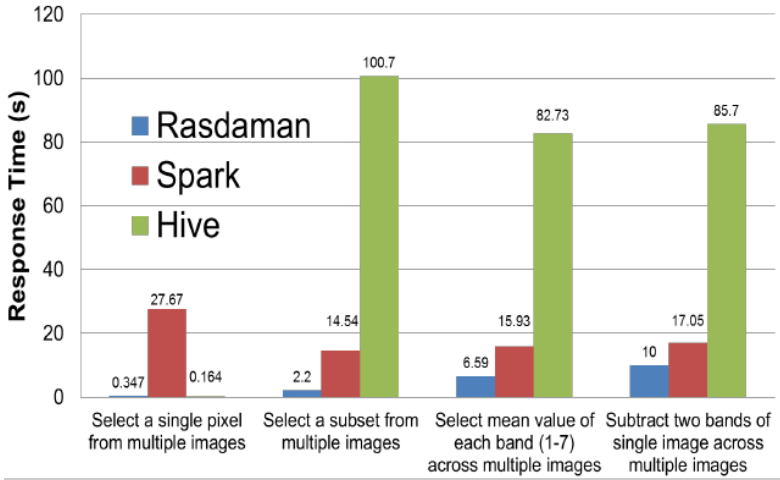


Related Work: Hadoop – *one size does not fit all*

- "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]

RDA Array Database Assessment WG

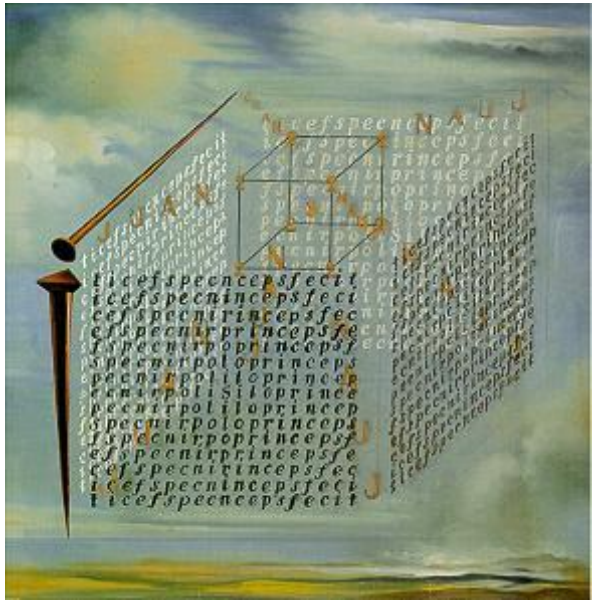
- Spinoff from Big Data IG
  - Chairs: Peter Baumann, Kwo-Sen-Kuo
- **Mission:** to provide support for technologists and decision makers
  - in academic and industrial environments
- **Approach:** neutral, thorough hands-on evaluation
  - Feature comparison, benchmarks, deployments at scale
- **Value proposition:** aid data scientists & engineers in question: [how] can we benefit from Array Database technology?

Conclusion

Conclusion

„A cube says more than a million images“

- Spatio-temporal datacubes major „Big Data“ category in sci & eng
  - = *sensor, image (timeseries), simulation, statistics data*
- rasdaman datacube engine:
  - More user friendly, better performance & scalability
  - Mature, operational on 500+ TB, standards blueprint
- See us: www.rasdaman.org, www.jacobs-university.de/lsis



[Dali]