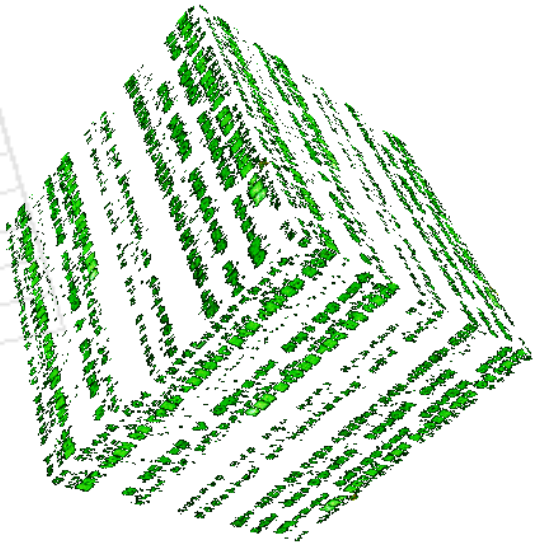
Research supported by EU EarthServer, PublicaMundi

rasdaman raster data management

JACOBS UNIVERSITY



Science SQL

OGC TC Barcelona, 2015-Mar 10

Peter Baumann

Jacobs University | rasdaman GmbH

baumann@rasdaman.com

[gamingfeeds.com]

rasdaman raster data management

JACOBS UNIVERSITY

EarthServer

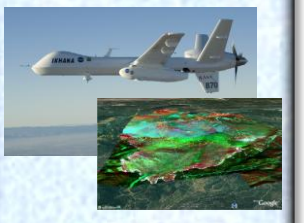
www.earthserver.eu

- Agile Big Data Analytics for Earth & Planetary Sciences
- 20 … 132 TB spatio-temporal databases
  - running rasdaman

Cryospheric Science
landcover mapping

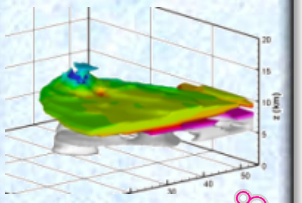
EOX

Airborne Science



NASA

Atmospheric Science
climate variables

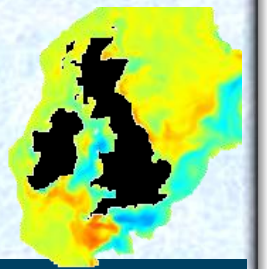


MEEO
Meteorological Environmental Earth Observation

Geology
geological models

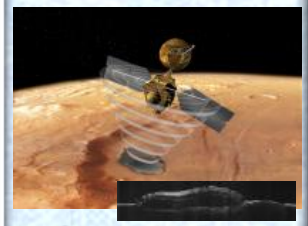
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Oceanography
marine model runs + in-situ data



PML PLYMOUTH MARINE LABORATORY

Planetary Science
Mars geology



JACOBS UNIVERSITY

- EarthServer-2 starting May 2015

What Users Really Want

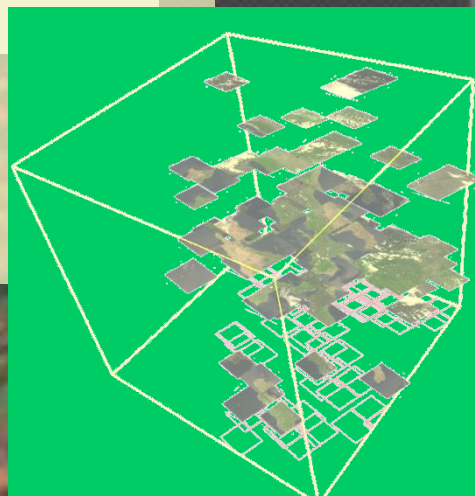
- "Given me all of the images in this geographic area in this this time span that are at least 80% cloud free have been radiometrically corrected and are from these satellites and then pass those images into a workflow to perform functions x,y,z"
  - Carl Reed

complexity + flexibility
...aka „Variety“

- “Find images t , 2007 which contain fire ho as forests according to CORINE Land Cover, and are located within 2km from an archaeological site in the Peloponnese.”
  - INSPIRE related
- „propability that the combined wave and swell height in area X, for a daylight time window of 12 hous, will be less than 1.5m, is 90%“
  - WMS BP draft

Sample Application: Database Visualization

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

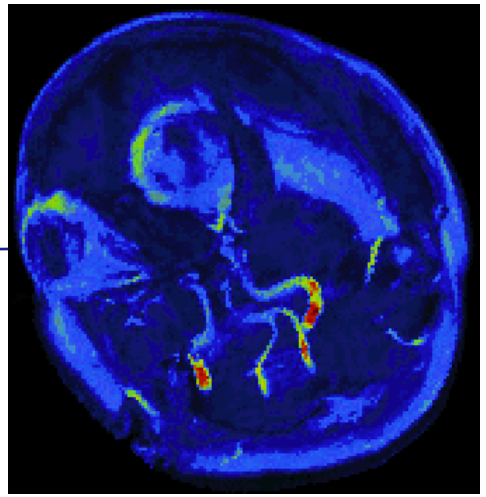


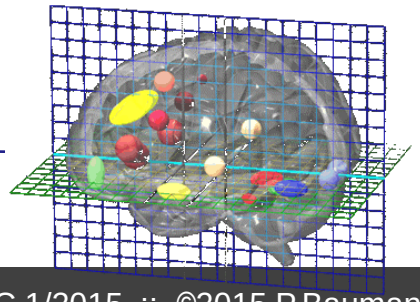
[Jacobs U, Fraunhofer: data courtesy

Human Brain Imaging

- Research goal: to understand structural-functional relations in human brain
- Experiments capture activity patterns (PET, fMRI)
  - Temperature, electrical, oxygen consumption, ...
  - → lots of computations → „activation maps“
- Example: “*a parasagittal view of all scans containing critical Hippocampus activations, TIFF-coded*.“

```
select tiff( ht[ $1, *:*, *:* ] )
  from   HeadTomograms as ht,
         Hippocampus as mask
  where  count_cells( ht > $2 and mask )
         / count_cells( mask )
         > $3
```



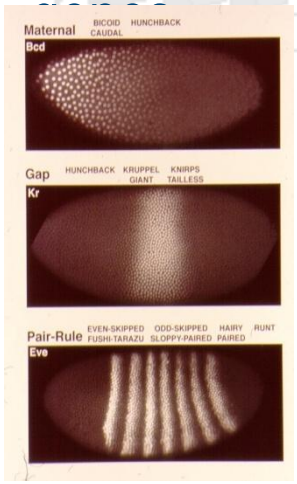


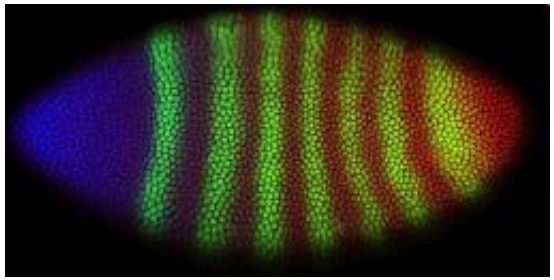
`$1` = slicing position, `$2` = intensity threshold value, `$3` = confidence

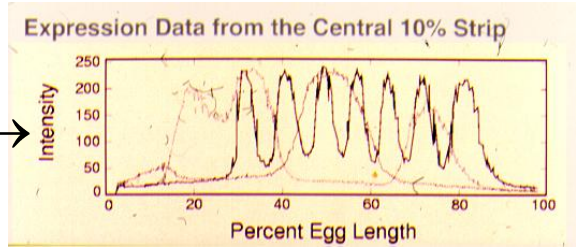
Gene Expression Analysis

http://urchin.spbcas.ru/Mooshka/ [Samsonova et al]

- Gene expression = reading out genes for reproduction
- Research goal: capture spatio-temporal expression patterns in Drosophila








```
select jpeg( scale( {1c,0c,0c}*e[0,*:*,*:*]
                   +{0c,1c,0c}*e[1,*:*,*:*]
                   +{0c,0c,1c}*e[2,*:*,*:*], 0.2 ) )
  from EmbryoImages as e
  where oid(e)=193537
```

„Science SQL“

- ISO 9075 Part 15: SQL/MDA
  - resolved by ISO SQL WG in June 2014

ISO/IEC JTC 1/SC 32

Date: 2014-06-04

WD 9075-15:2014(E)

ISO/IEC JTC 1/SC 32/WG 3

The United States of America (ANSI)

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)

Document type: Technical Report
Document subtype: Technical Report (TR)
Document stage: (3) CD under Consideration
Document language: English

Edited by: Jim Melton (Ed.) and Peter Baumann (Associate Ed.)

- n-D arrays as attributes

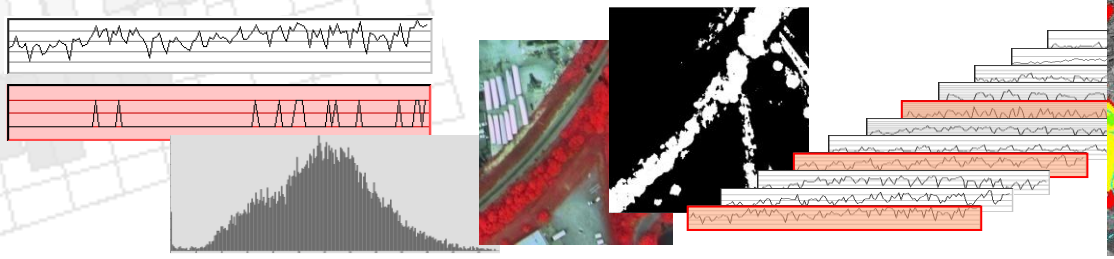
```
create table LandsatScenes(
    id: integer not null, acquired: date,
    scene: row( band1: integer, ..., band7: integer ) array [ 0:4999,0:4999] )
```

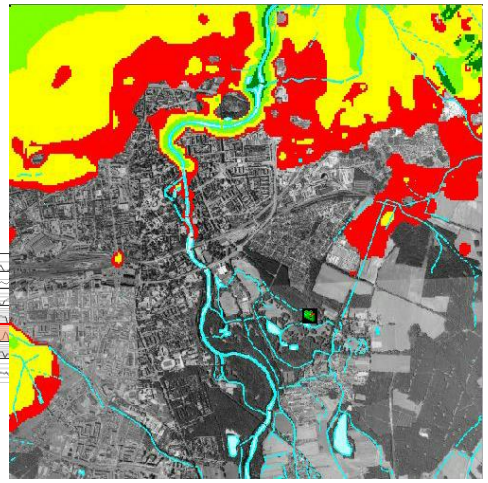
- declarative array operations

```
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
```

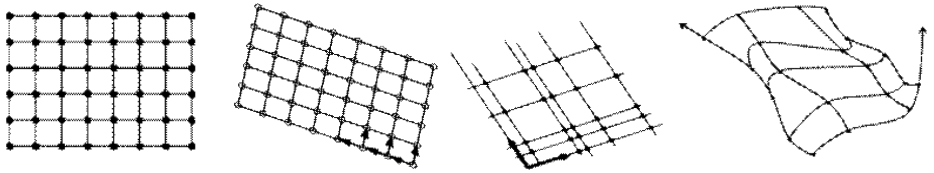
OGC WCPS

- OGC Web Coverage Processing Service (WCPS)
  = high-level geo raster query language; adopted 2008





  - WCPS 2: all grid types:



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

$(tiff_A, tiff_C)$

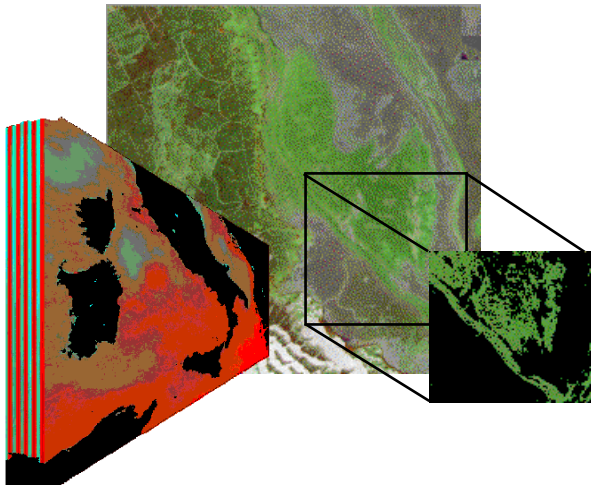
```
for $c in ( M1, M2, M3 )
where some( $c.nir > 127 )
return encode( $c.red - $c.nir, "image/tiff" )
```

rasdaman: Agile Array Analytics

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

```
select img.green[x0:x1,y0:y1] > 130
from   LandsatArchive as img
where  avg_cells( img.nir ) < 17
```

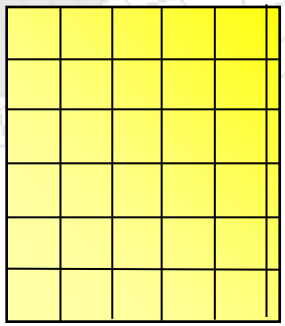
  - Scalable parallel “tile streaming” architecture



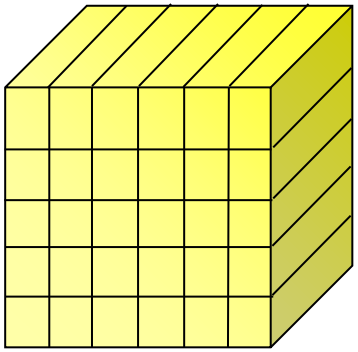
- Implemented & in use: ESA, NASA, PML, DWD, ...
  - OGC WCS Core Reference Implementation
  - Copernicus Masters Big Data Challenge 2014 winner

Adaptive Tiling

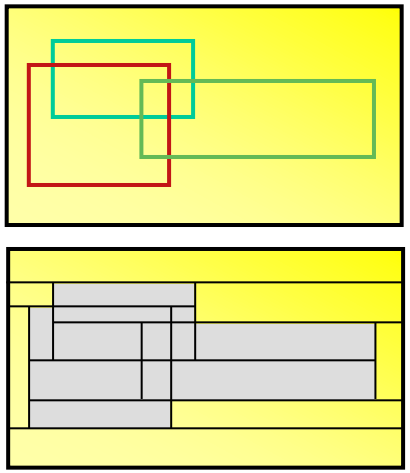
- Sample tiling strategies [Furtado]:
  - regular



directional



area of interest

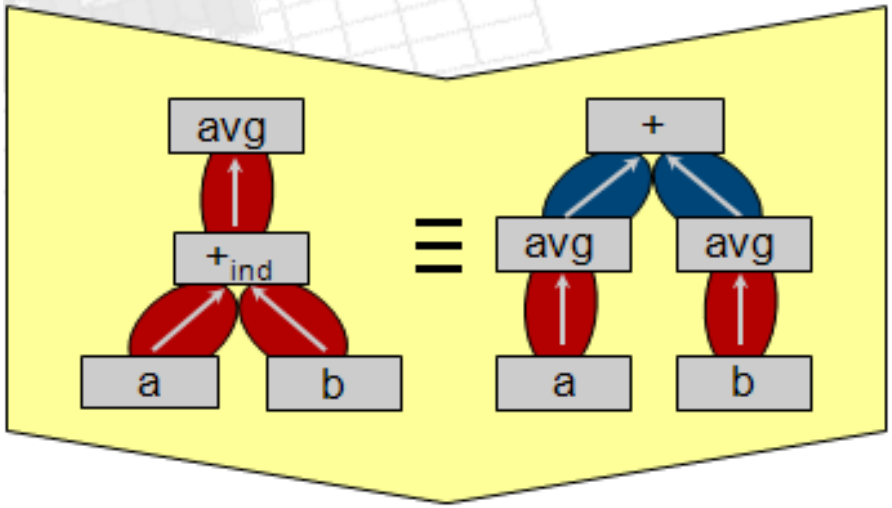


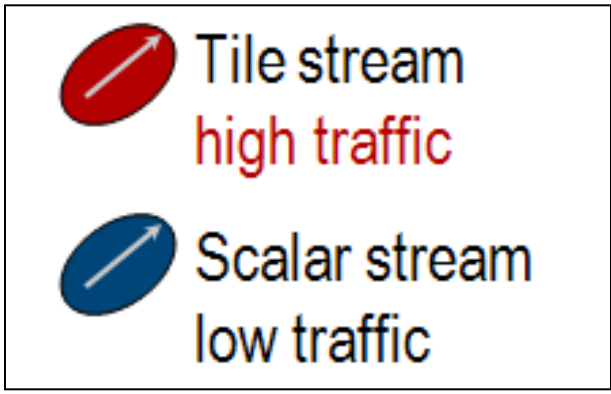
- rasdaman storage layout language

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

Optimization 1: Query Rewriting

```
select avg_cells( a + b )
from   a, b
```






```
select avg_cells( a )
     + avg_cells( b )
from   a, b
```

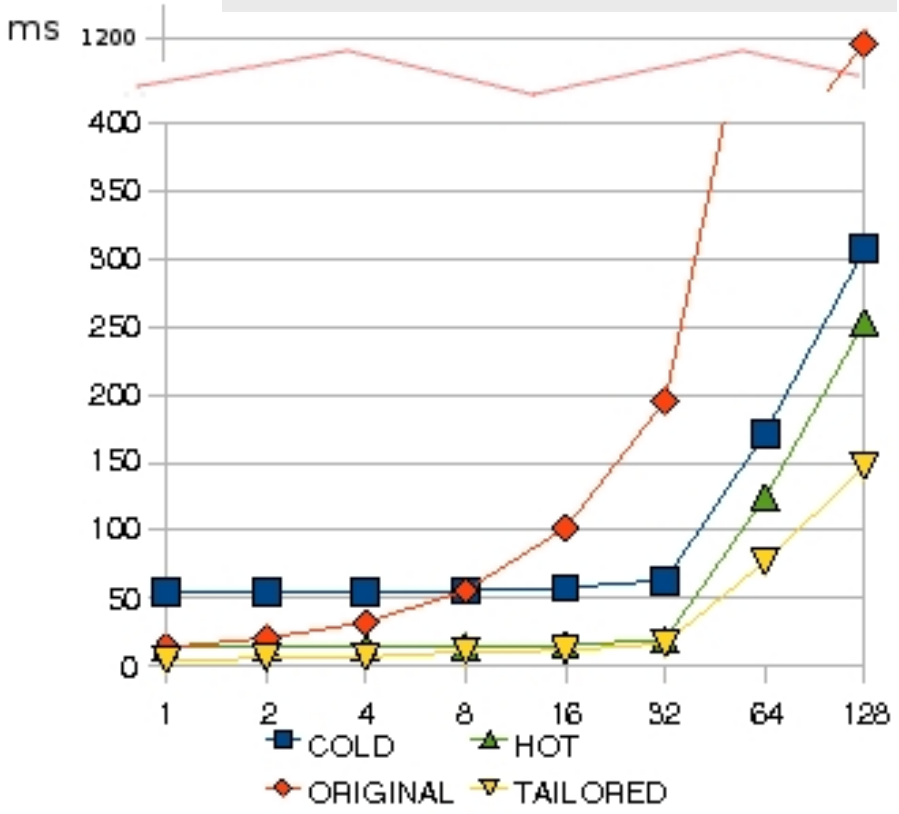
- *understood:*
  heuristic optimization
  – 150 rules in rasdaman [Ritsch 2002]
- *partially understood:*
  cost-based optimization

Optimization 2: Just-In-Time Compilation

[Jucovschi, Stancu-Mara 2008]

- Observation: interpreted mode slows down
- Approach:
  - cluster suitable operations
  - compile & dynamically bind
- Benefit:
  - Speed up complex, repeated operations
- Variation:
  - compile code for GPU (later)

```
select x*x*...*x
from float_matrix as x
```

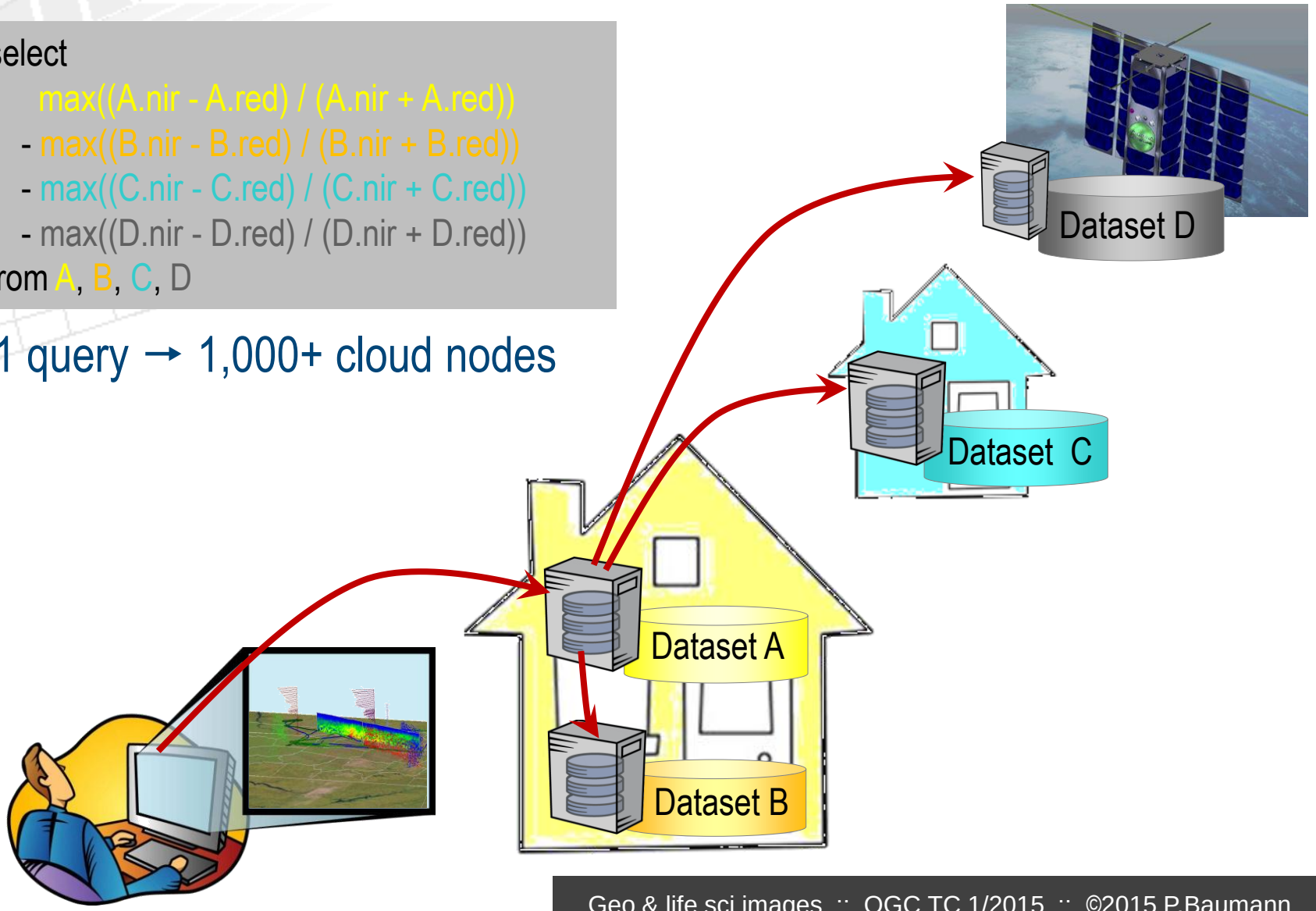


Times [ms] for 512^2 * n ops

Parallel / Distributed Query Processing

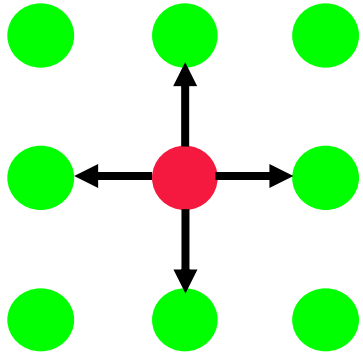
```
select
      max((A.nir - A.red) / (A.nir + A.red))
    - max((B.nir - B.red) / (B.nir + B.red))
    - max((C.nir - C.red) / (C.nir + C.red))
    - max((D.nir - D.red) / (D.nir + D.red))
from A, B, C, D
```

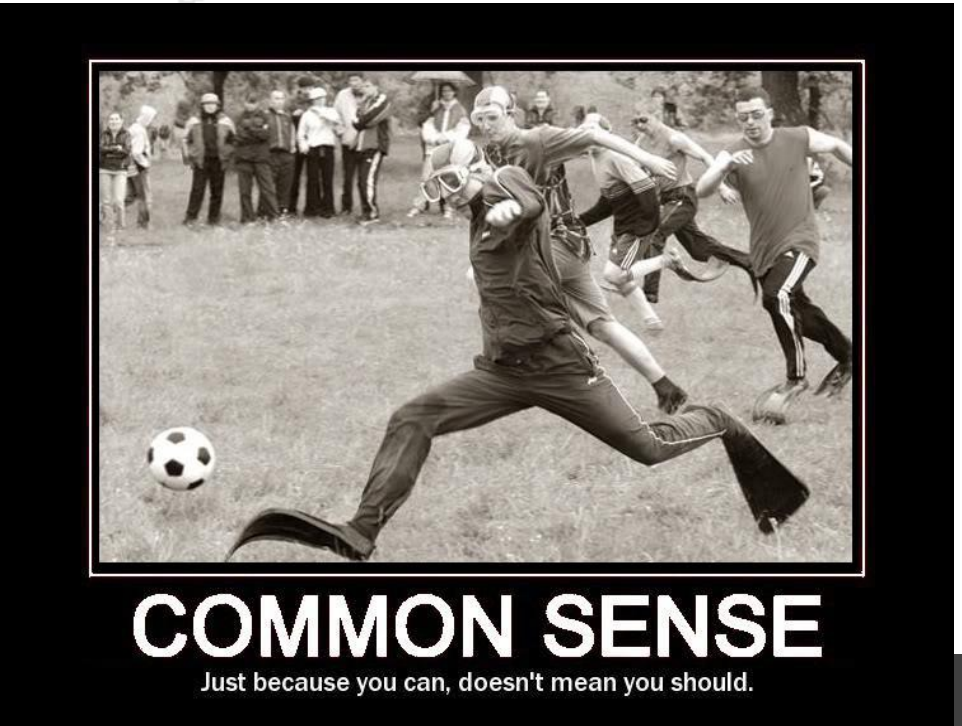
1 query → 1,000+ cloud nodes

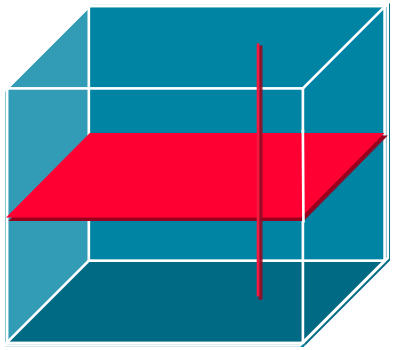


Inset: Hadoop is not the Answer to All

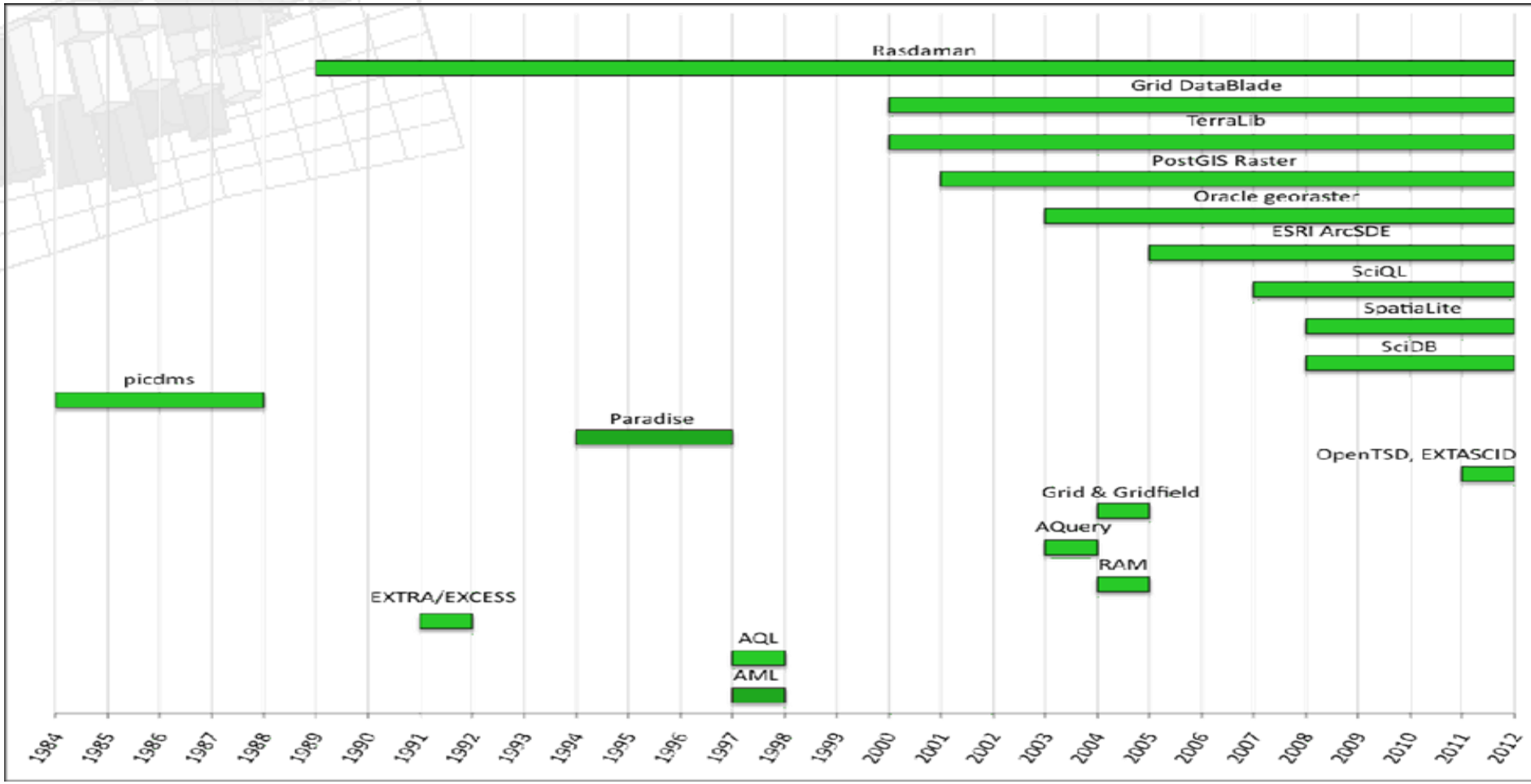
- no builtin knowledge about structured data types
  - "Since it was not originally designed to leverage the structure […] its performance […] is therefore suboptimal" [Daniel Abadi]
  - M. Stonebraker (XLDB 2012): „will hit a scalability wall"





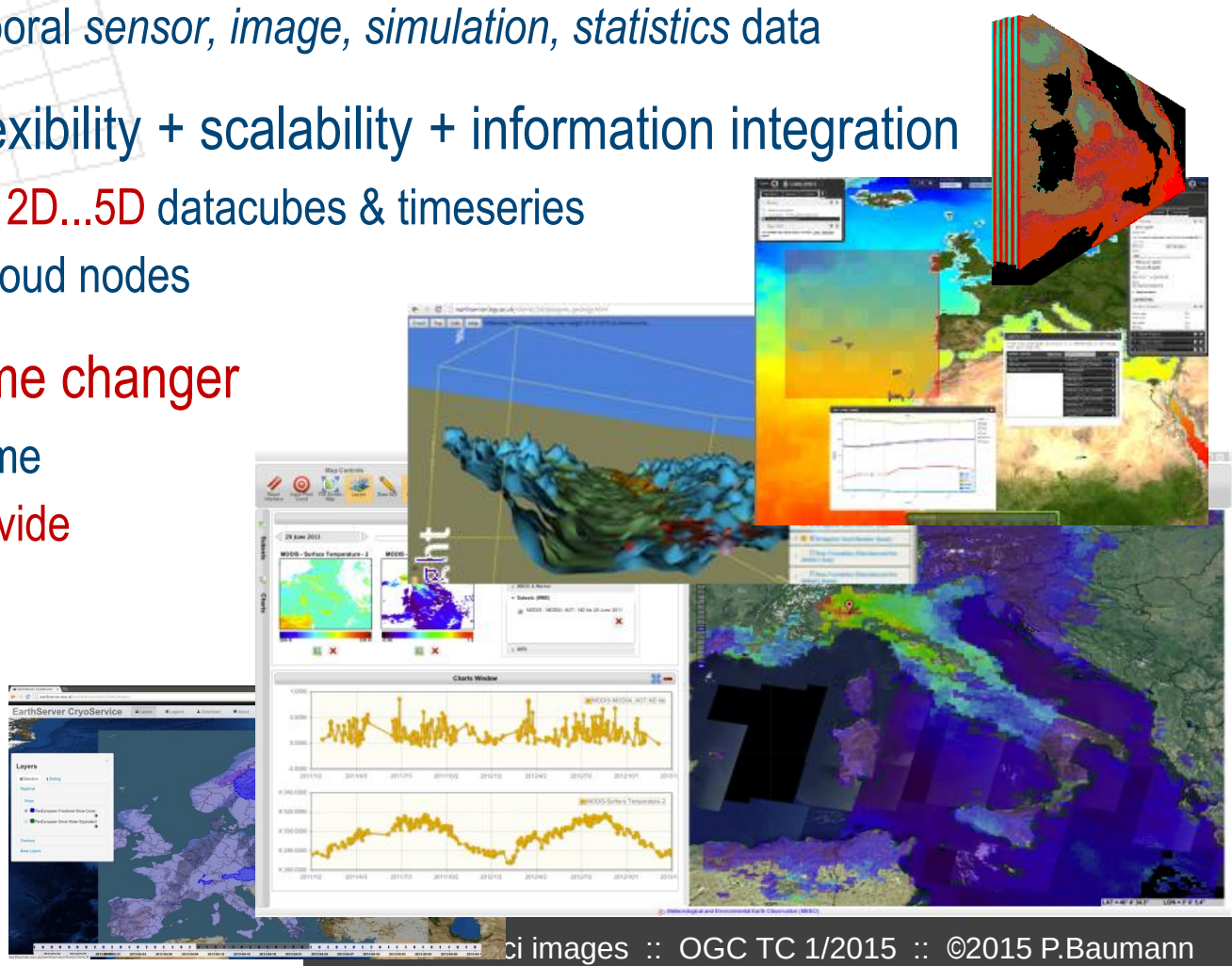


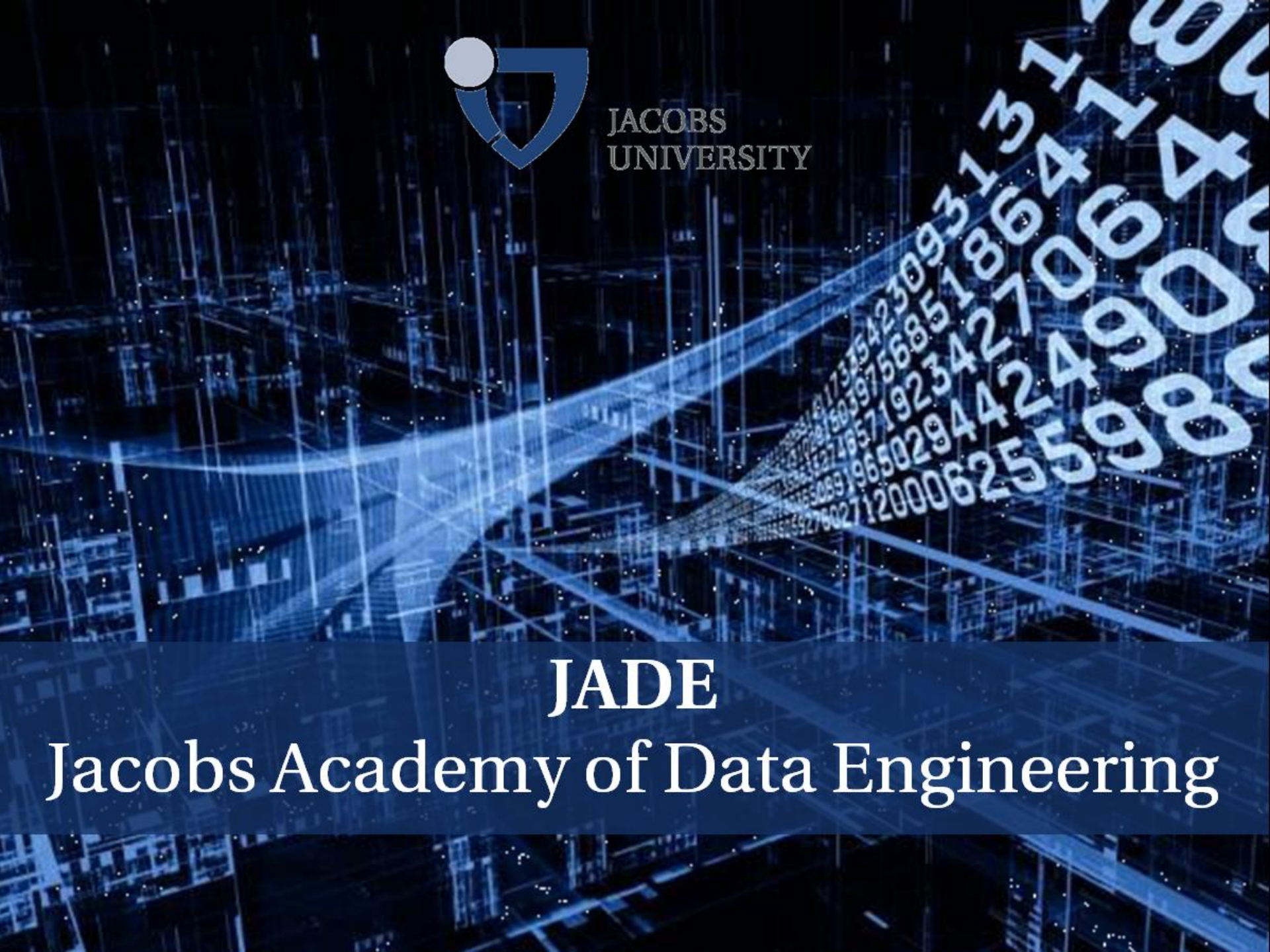
A Brief History of Array Databases



Conclusion

- n-D Arrays a major datatype, central to science, engineering, business
  - Massive spatio-temporal *sensor, image, simulation, statistics* data
- Query language = flexibility + scalability + information integration
  - 130+ TB databases, 2D...5D datacubes & timeseries
  - 1 query → 1,000+ cloud nodes
- ISO SQL/MDA a game changer
  - Any question, any time
  - No data/metadata divide
- Visit us:
  - www.rasdaman.org
  - www.earthserver.eu





JADE

Jacobs Academy of Data Engineering