
Building Virtual Earth Observatories Using Semantic Web Technologies

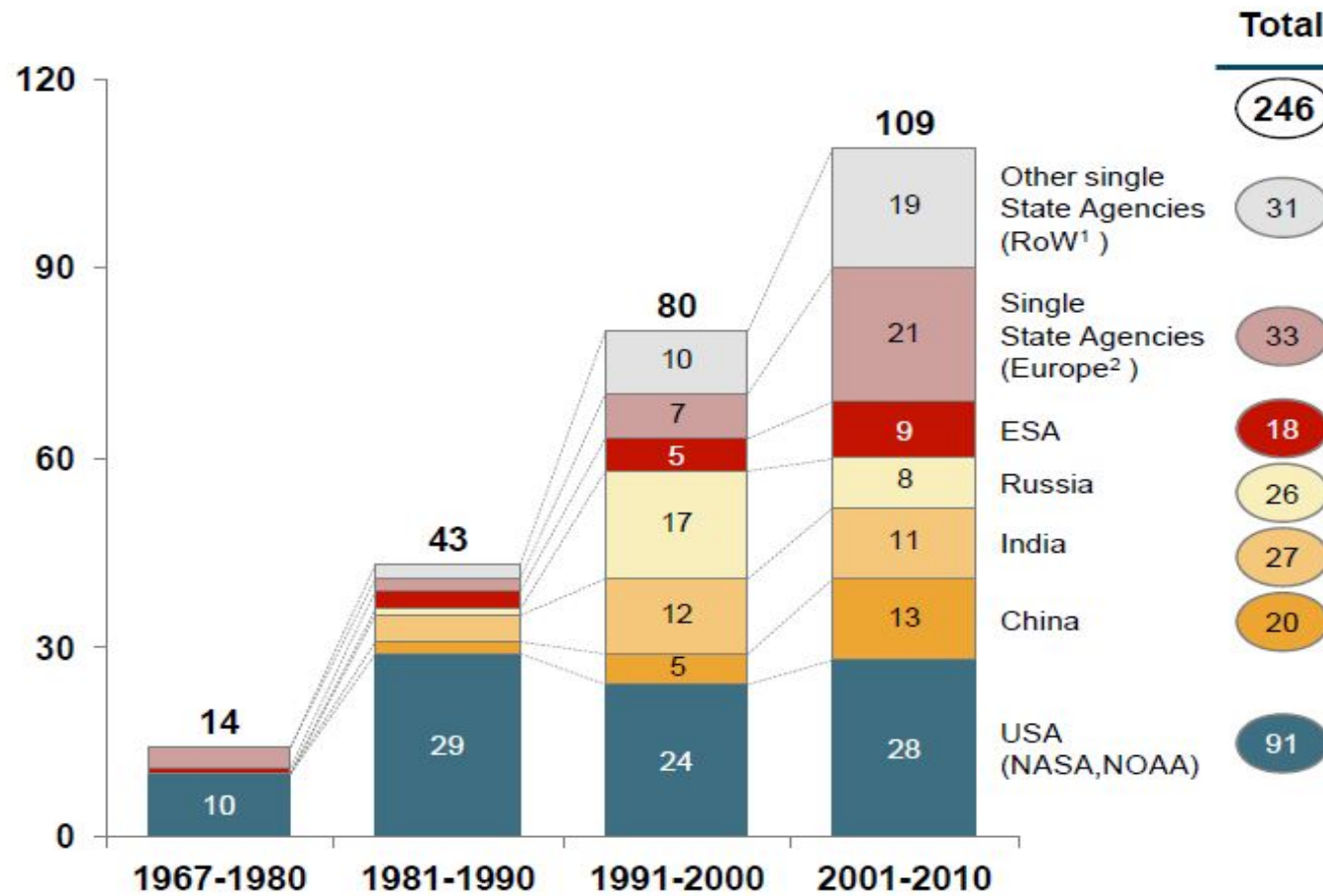
Manolis Koubarakis
Dept. of Informatics and Telecommunications
National and Kapodistrian University of Athens



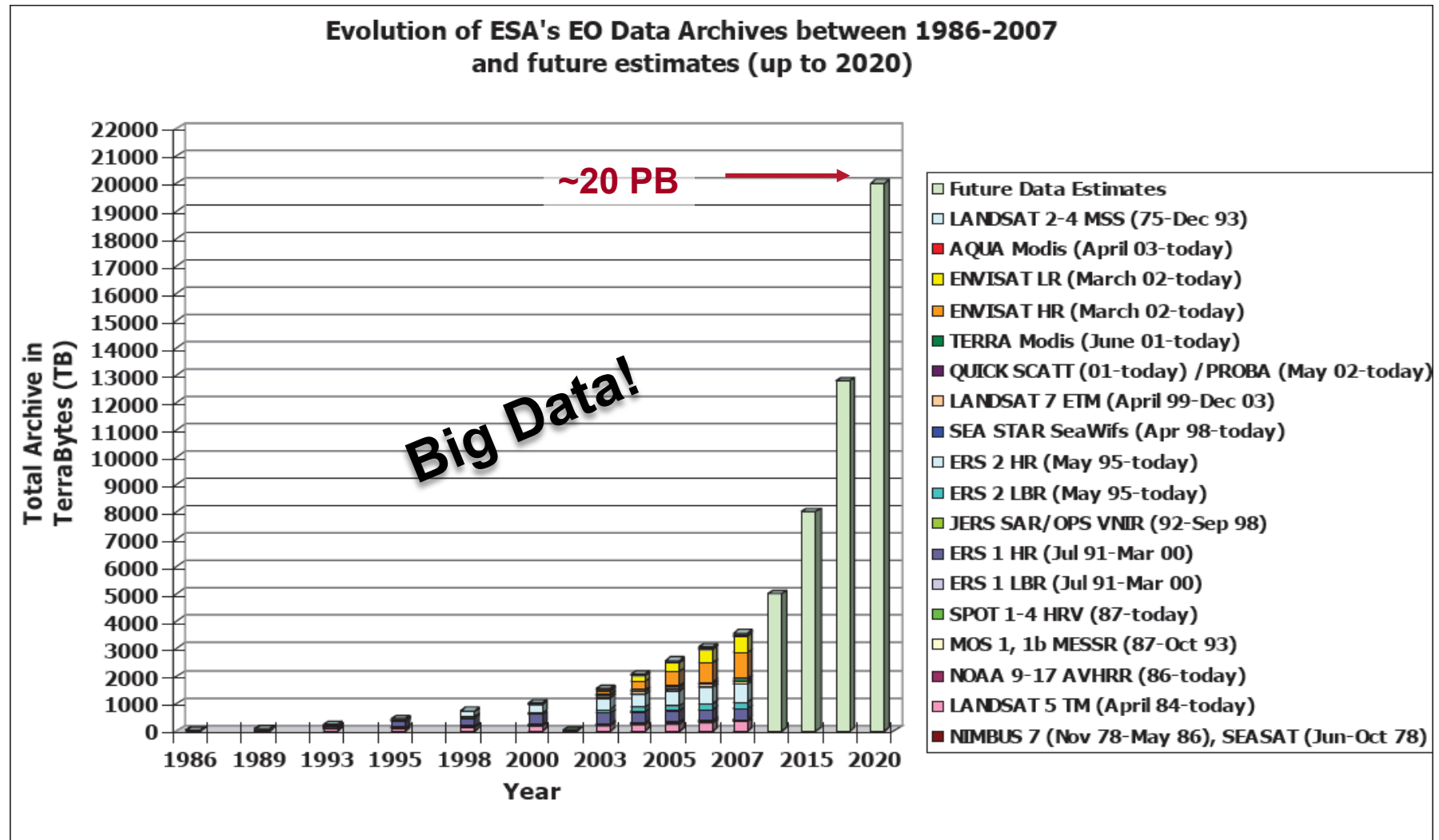
Inria visit May 2012 2012

- Motivation for project TELEIOS
- State of the art in Earth Observation data centers
- Developing Virtual Earth Observatories using Semantic Web technologies
- Technical highlights of the work of my group in this area.

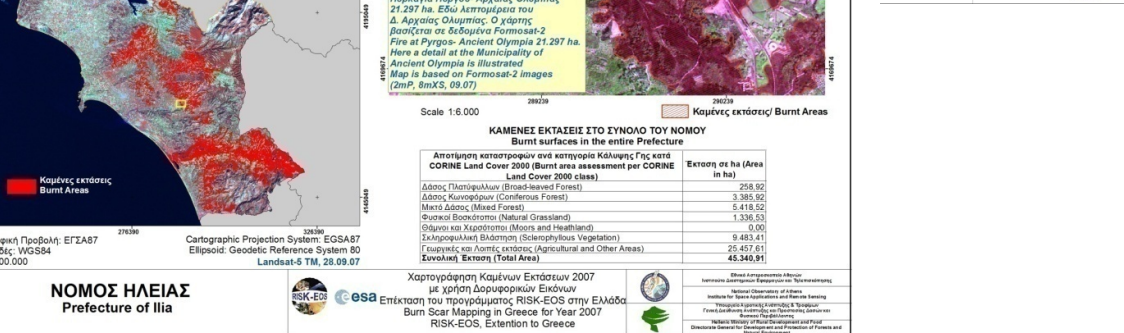
N. of Earth Observation satellites launched



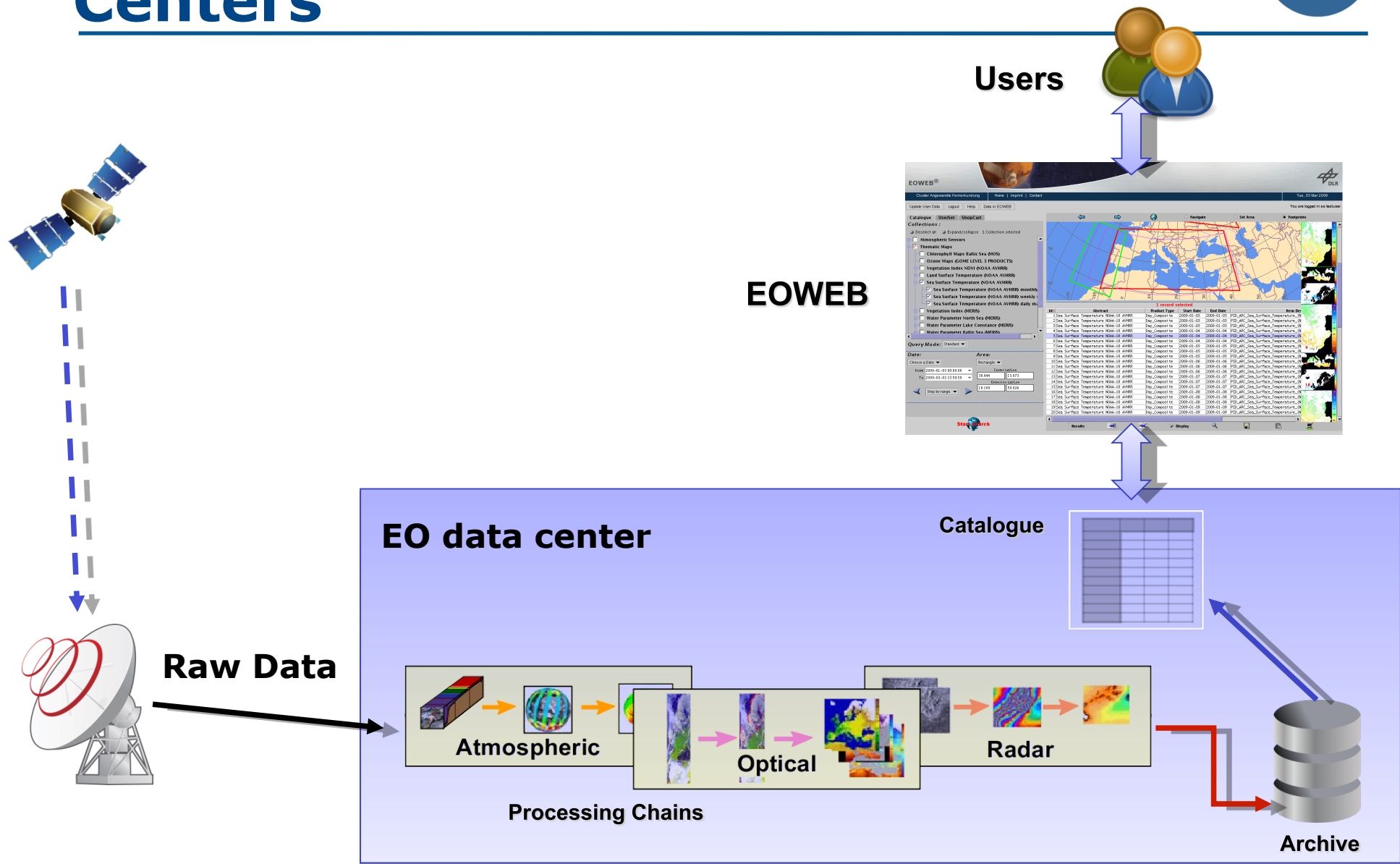
Motivation (cont'd)



TELEIOS



State of the Art in EO Data Centers



- Can I pose the following query using EOWEB?

Find images taken by the MSG2 satellite on August 25, 2007 which contain fire hotspots in areas which have been classified as forests according to Corine Land Cover, and are located within 2km from an archaeological site in the Peloponnese.

Example (cont'd)

The screenshot displays the EOWEB (Earth Observation Web) interface. At the top, the EOWEB logo is on the left, and the DLR logo is on the right. Below the header, a navigation bar includes links for Home, Imprint, and Contact. A status bar indicates the date as Tuesday, 08 May 2012. The main interface is divided into several sections. On the left, there is a 'Collections' panel with a tree view showing various data sources: ISA-1, SWACI, SAR (Synthetic Aperture Radar Data), Optical Sensors High Resolution (which is expanded to show RapidEye, RapidEye.RESA.L3A, RapidEye.RESA.L2A, and RapidEye.RESA.L1B), and IRS-P6 Resourcesat-1. Below this, there are 'Query Mode' and 'Date' selection options. The central part of the interface features a map of Greece with a grid overlay. A red star marks the location of Athens. The map is surrounded by a coordinate grid with latitude and longitude values. On the right side of the map, there are controls for 'Navigate', 'Set Area', and 'Footprints'. At the bottom of the interface, there is a 'Start Search' button and a 'Results' section with icons for displaying and saving data.

EOWEB®

Applied Remote Sensing Cluster | Home | Imprint | Contact

Tue, 08 May 2012

Login Register Logout Help Data in EOWEB Search by ProductId SRTM Data Download

Save Query Parameters Load Query Parameters Browse...

You are logged in as anonymous user.

Block...

Shop Cart Order Monitoring

Catalogue Future Products / Acquisitions User Set

Collections :

☐ Deselect all ☐ Expand/collapse 1 Collection selected

- ☐ ISA-1
- ☐ SWACI
- ☐ SAR (Synthetic Aperture Radar Data)
- ☒ Optical Sensors High Resolution
 - ☒ RapidEye
 - ☒ RapidEye.RESA.L3A
 - ☐ RapidEye.RESA.L2A
 - ☐ RapidEye.RESA.L1B
 - ☐ IRS-P6 Resourcesat-1

Query Mode: Standard

Date: Choose a Date **Area:** Rectangle

Start Search

Results Display

- Well, only partially.

Find images taken by the MSG2 satellite on August 25, 2007 which contain fire hotspots in areas which have been classified as forests according to Corine Land Cover, **and are located within 2km** from an archaeological site in the **Peloponnese**.

- But why?
- All this information is available in the **satellite images** and other **auxiliary data sources** of EO data centers or **on the Web**.
- However, EO data centers today do not allow:
 - **the mining of satellite image content** and
 - **its integration with other relevant data sources** so the previous query can be answered.

The TELEIOS Earth Observatory: Concept View



Scientists



Emergency Response Managers

**Web
Portals**

**Rapid
Mapping**

**Scientific Database and
Semantic Web Technologies**

**Linked
Geospatial
Data**

**Semantic
Annotations**

Ontologies

**Knowledge
Discovery
and Data
Mining**

**KNOWL-
EDGE**

GIS Data

**Derived
Products**

Meta

Features

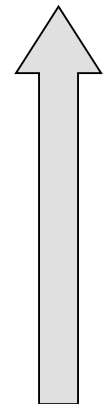
Raw Data

Ingestion

**Proce
Catalo
Arch**

**Content
Extraction**

DATA



Data Modeling Requirements in EO Data Centers



- Need for modeling
 - Standard product **metadata**
 - Standard product **content**
 - **Geospatial information**
 - **Temporal information**
- Need to link to other data sources
 - **GIS data**
 - Other information on the **Web**

- # strabon.di.uoa.gr

[Home](#)
[Demo](#)
[Getting Started](#)
[Download](#)
[Publications](#)
[Contributors](#)

Strabon

Strabon is a fully implemented semantic geospatial database system that can be used to store linked geospatial data expressed in RDF and query them using an extension of SPARQL. Strabon supports spatial selections, spatial joins, a rich set of spatial functions similar to those offered by geospatial relational database systems, support for multiple Coordinate Reference Systems and widely used serializations for geometric objects such as WKT and GML. Strabon is built on top of the well-known RDF store Sesame and extends

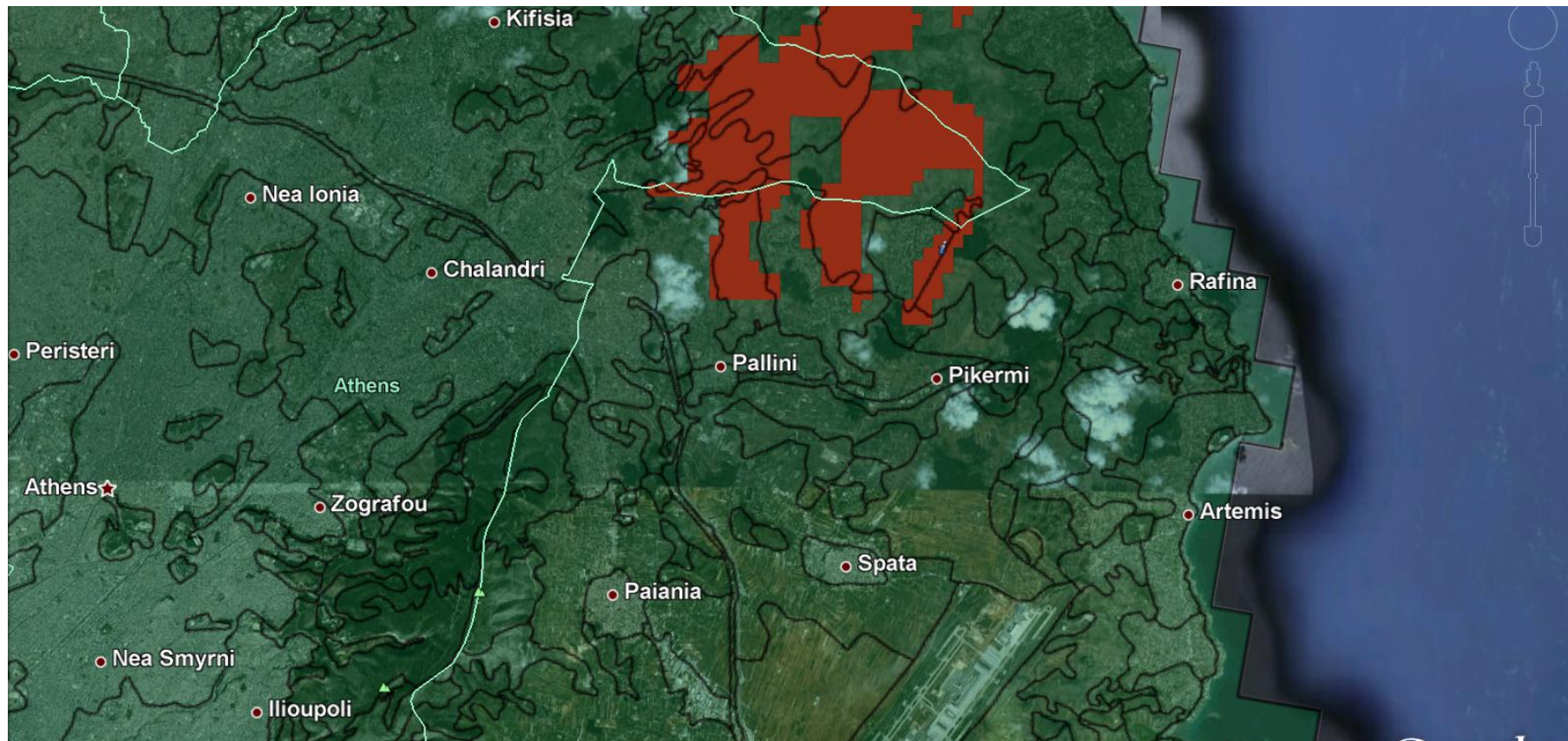
User login

Username *

Password *

- **stRDF** stands for **spatiotemporal RDF**.
- It is an extension of the W3C standard RDF for the representation of **geospatial data that may change over time**.
- stRDF extends RDF with:
 - **Spatial literals** encoded in OGC standards Well-Known Text or GML
 - **New datatypes** for spatial literals (`strdf:WKT`, `strdf:GML` and `strdf:geometry`)
 - **Valid time of triples** (ignored in this talk)

stRDF: An example



stRDF: An example (WKT)



```
ex:BurntArea1 rdf:type noa:BurntArea.
```

```
ex:BurntArea1 noa:hasID "1"^^xsd:decimal.
```

```
ex:BurntArea1 noa:hasArea "23.7636"^^xsd:double.
```

Spatial Literal
(OpenGIS
Simple
Features)

```
ex:BurntArea1 strdf:hasGeometry "POLYGON(( 38.16 23.7, 38.18  
23.7, 38.18 23.8, 38.16 23.8, 38.16 23.7)); <http://  
spatialreference.org/ref/epsg/4121/>"^^strdf:WKT .
```

Spatial Data Type
Well-Known Text

stRDF: An example (GML)



```
ex:BurntArea1 rdf:type noa:BurntArea.  
ex:BurntArea1 noa:hasID "1"^^xsd:decimal.  
ex:BurntArea1 noa:hasArea "23.7636"^^xsd:double.
```

```
ex:BurntArea1 strdf:hasGeometry
```

```
"<gml:Polygon
```

```
  srsName='http://www.opengis.net/def/crs/EPSG/0/4121'>
```

```
<gml:outerBoundaryIs>
```

```
<gml:LinearRing>
```

```
<gml:coordinates>38.16,23.70 38.18,23.70 38.18,  
                23.80 38.16,23.80,38.16 23.70
```

```
</gml:coordinates>
```

```
</gml:LinearRing>
```

```
</gml:outerBoundaryIs>
```

```
</gml:Polygon>"^^strdf:GML .
```

Spatial Literal
(GML Simple
Features
Profile)

Spatial Data Type
GML

stSPARQL: An example

- Find all burnt forests close to a city

```
SELECT ?BA ?BAGEO
```

```
WHERE {
```

```
?R rdf:type noa:Region .
```

```
?R strdf:hasGeometry ?RGeo .
```

```
?R noa:hasCorineLandCoverUse ?F .
```

```
?F rdfs:subClassOf clc:Forests .
```

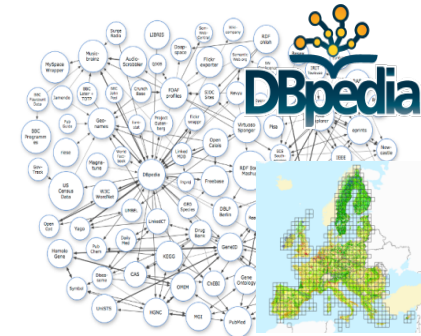
```
?CITY rdf:type dbpedia:City .
```

```
?CITY strdf:hasGeometry ?CGEO .
```

```
?BA rdf:type noa:BurntArea .
```

```
?BA strdf:hasGeometry ?BAGEO .
```

```
    FILTER(strdf:anyInteract(?RGeo,?BAGEO) &&  
           strdf:distance(?BAGEO,?CGEO) < 0.02) }
```



Spatial
Functions

- We start from **SPARQL 1.1**.
- We add the property `strdf:hasGeometry` for **connecting RDF resources to spatial literals**.
- We add a **SPARQL extension function** for each function defined in the OGC standard **OpenGIS Simple Feature Access – Part 2: SQL option (ISO 19125)** for adding geospatial data to relational DBMSs and SQL.

- **Basic functions**

- Get a property of a geometry (e.g., `strdf:srid`)

- Get the desired representation of a geometry (e.g., `strdf:AsText`)

- Test whether a certain condition holds (e.g., `strdf:IsEmpty`, `strdf:IsSimple`)

- Functions for **testing topological spatial relationships**
(e.g., `strdf:equals`, `strdf:intersects`)

- **Spatial analysis functions**

- Construct new geometric objects from existing geometric objects (e.g.,
`strdf:buffer`, `strdf:intersection`, `strdf:convexHull`)

- Spatial metric functions (e.g., `strdf:distance`, `strdf:area`)

- **Spatial aggregate functions** (e.g., `strdf:union`, `strdf:extent`)

- **Spatial terms**

Constants (e.g., "POLYGON((38.16 23.7, ...))" ^^strdf:WKT)

Variables (e.g., ?GEO)

Results of set operations (e.g., strdf:intersection, strdf:union)

Results of geometric operations (e.g., strdf:boundary, strdf:buffer)

- **SELECT clause**

Construction of new geometries (e.g., strdf:buffer(?geo, 0.1))

Spatial aggregate functions (e.g., strdf:extent(?geo))

Metric functions (e.g., strdf:area(?geo))

- **FILTER clause**

Functions for testing topological spatial relationships between spatial terms (e.g.,
strdf:contains(?G1, strdf:union(?G2, ?G3)))

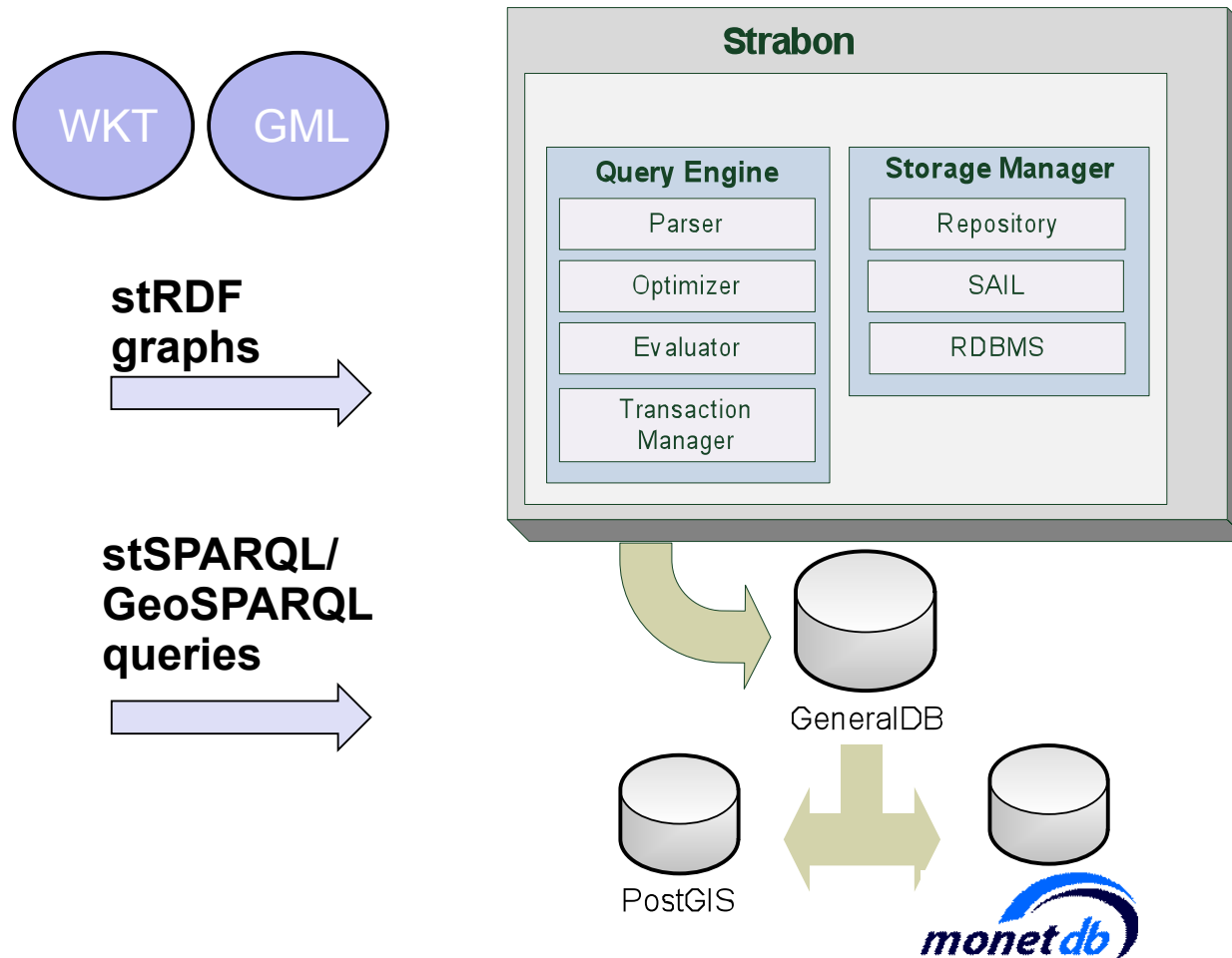
Numeric expressions involving spatial metric functions (e.g., strdf:area(?G1) <= 2 * strdf:area(?G2) + 1)

- **HAVING clause**

Spatial aggregate functions and spatial metric functions or functions testing for topological relationships between spatial terms (e.g., strdf:area(strdf:union(?geo)) > 1)

- stSPARQL geospatial query functionality is essentially a **syntactic alternative to a subset of the recent OGC standard GeoSPARQL (Strabon supports both syntaxes)**
- We add appropriate geospatial extensions to **SPARQL 1.1 Update language**

Strabon: A Scalable Geospatial RDF Store

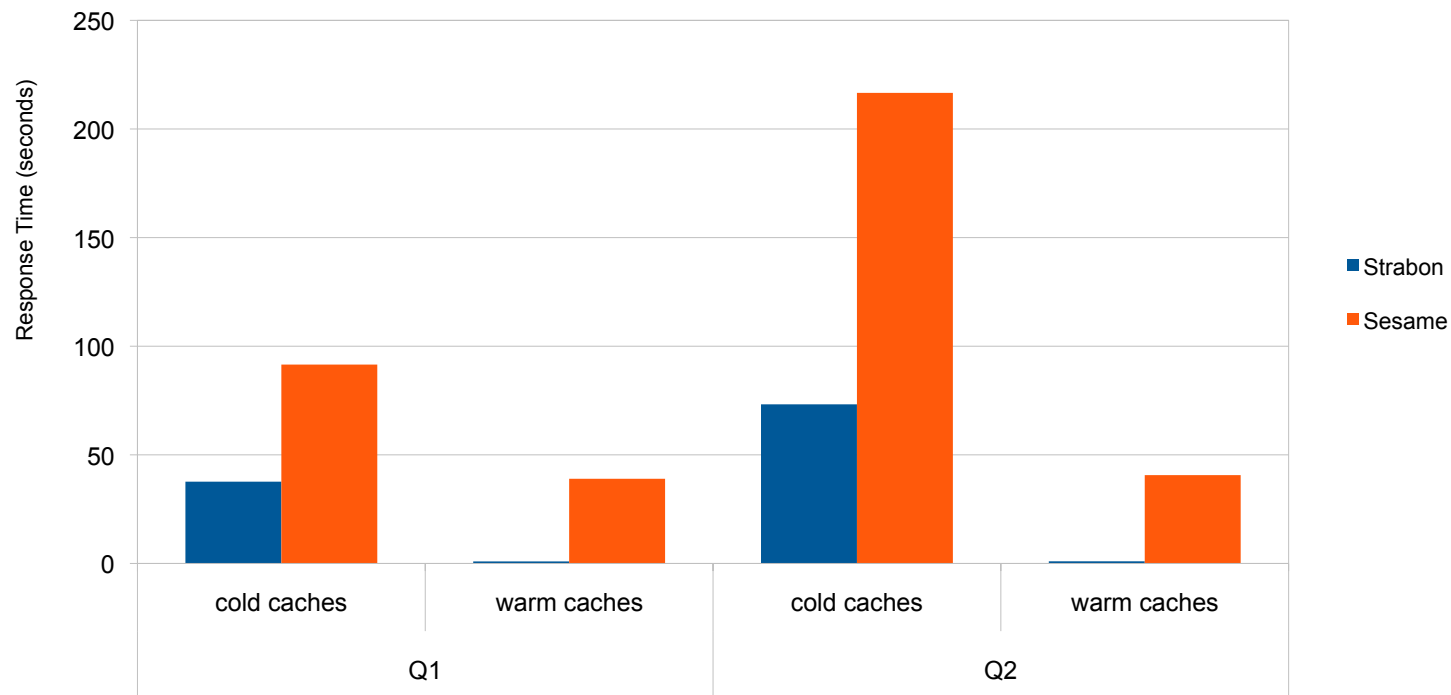


- **Real linked geospatial data sets** available on the Web (DBpedia, Geonames, LGD, Pachube, SwissEx, CLC, GADM).
- **Synthetic data**
- **Geometries of various types** (points, line strings, polygons)
- Up to **1 billion triples**

Experimental Evaluation (cont'd)



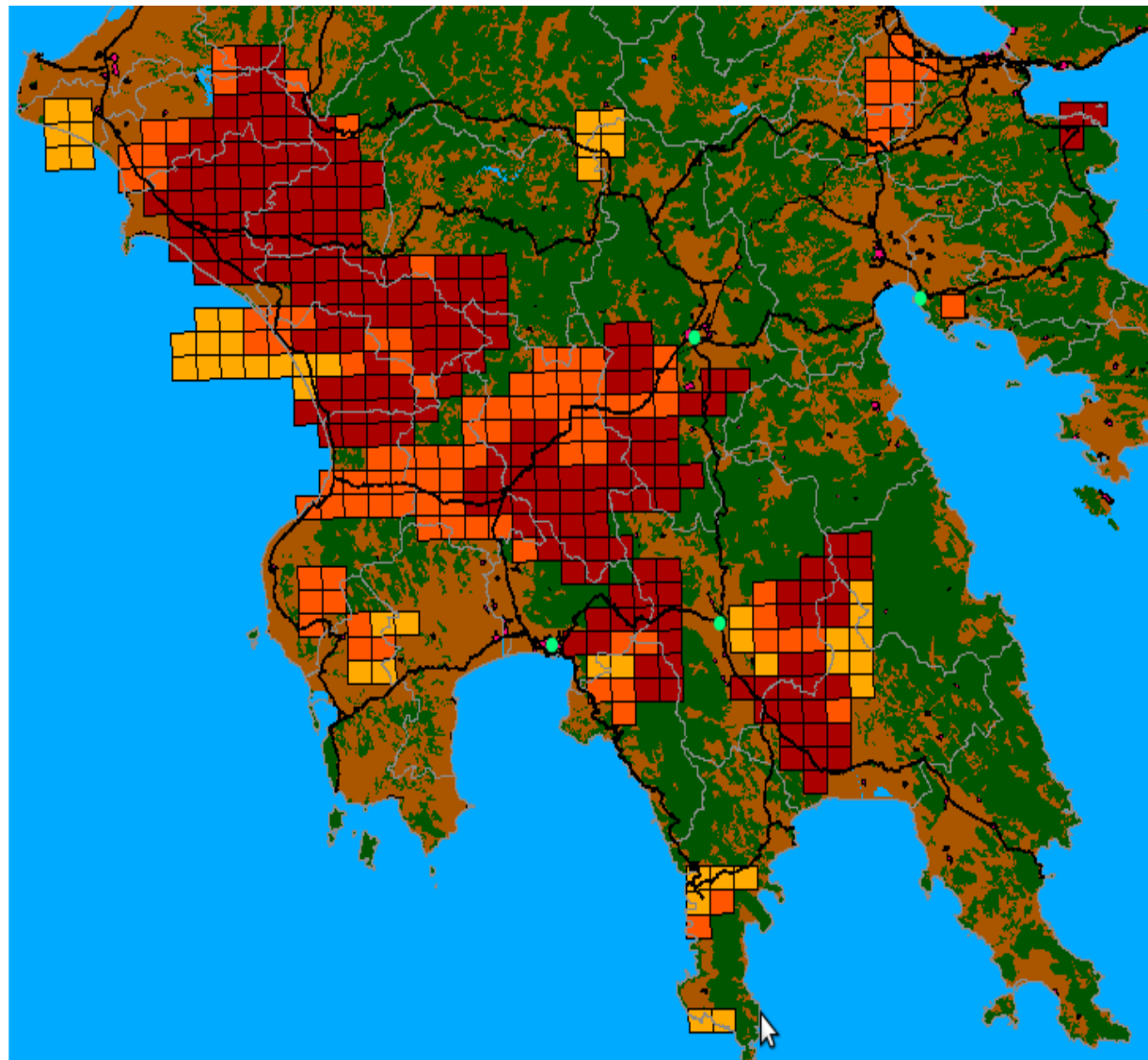
Workload based on real data (143 million triples – 30GB – 9 million spatial literals)



Rapid mapping in the NOA Fire Monitoring Service



- GeoNames
 - Seat of a first-order administrative division
- Hotspots
 - Acquired at 26-8-11
 - Acquired at 25-8-11
 - Acquired at 24-8-11
- Greek Administrative Geography
 - Perfecture boundaries
- LinkedGeoData
 - Primary roads
- Corine Land Cover
 - Land Use: Wet Bodies
 - Land Use: Forests and Seminatural Areas
 - Land Use: Wet Lands
 - Land Use: Artificial Surfaces
 - Land Use: Agricultural Areas



Linked Geospatial Data Currently Used



- Hotspots (MSG/SEVIRI)
- Hotspots (FIRMS/MODIS)
- Administrative regions of Greece
- Corine Land Use / Land Cover data set
- OpenStreetMap
- GeoNames

TELEIOS

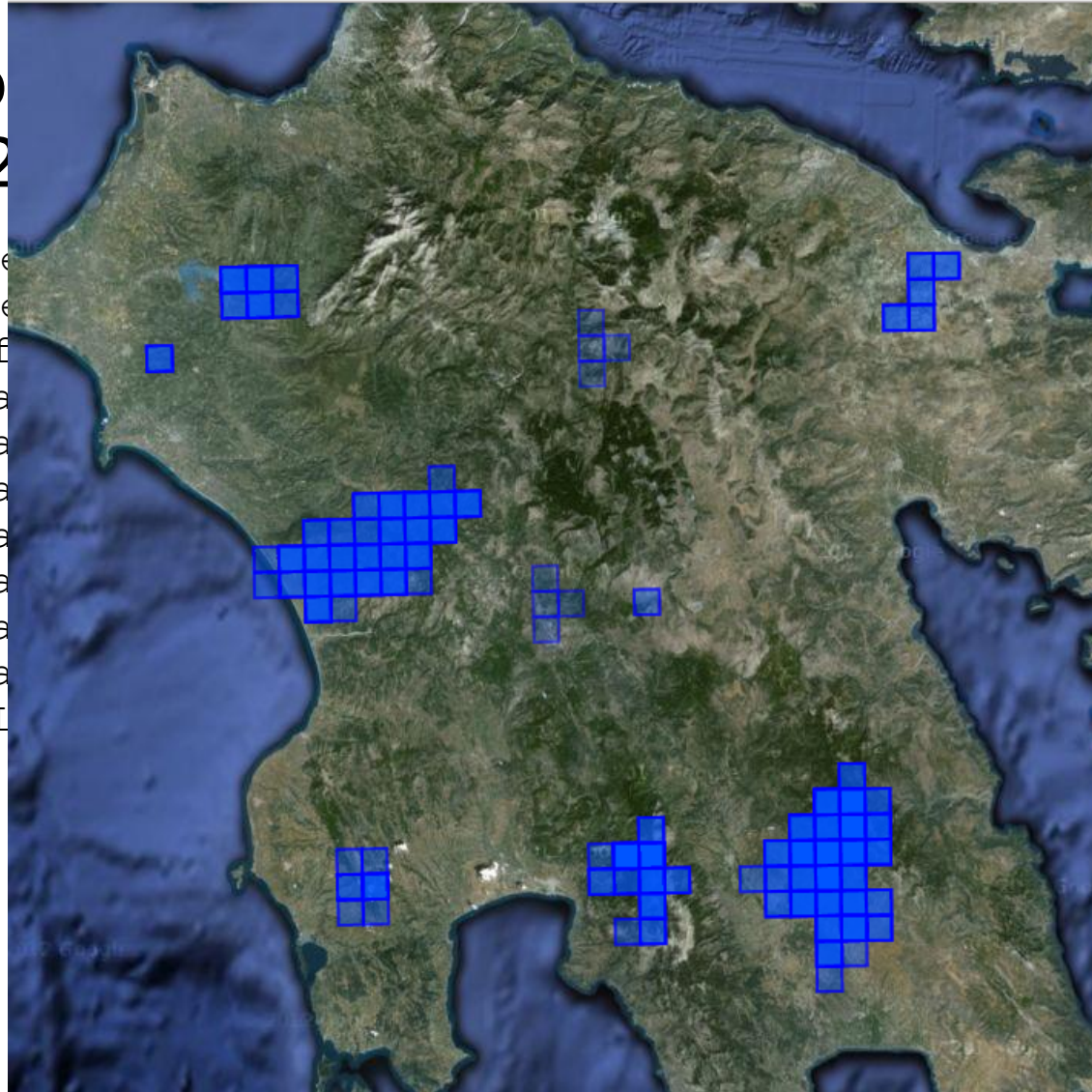
ese on

ovider ?

```

nAcqTime &&
dateTime).
, 23.77
027 38.36))"

```



Improve product accuracy



```
    FILTER( strdf:anyInteract(?hGeo, ?cGeo) }  
  GROUP BY ?h ?hGeo  
HAVING strdf:overlap(?hGeo, strdf:union(?cGeo)) }
```

Creating a map (cont'd)



Get all c

```
SELECT  
WHERE {
```

```
((21.02  
23.77 3  
21.027  
aGeo)) .  
}
```



de .

.

ON

8.36,

05,

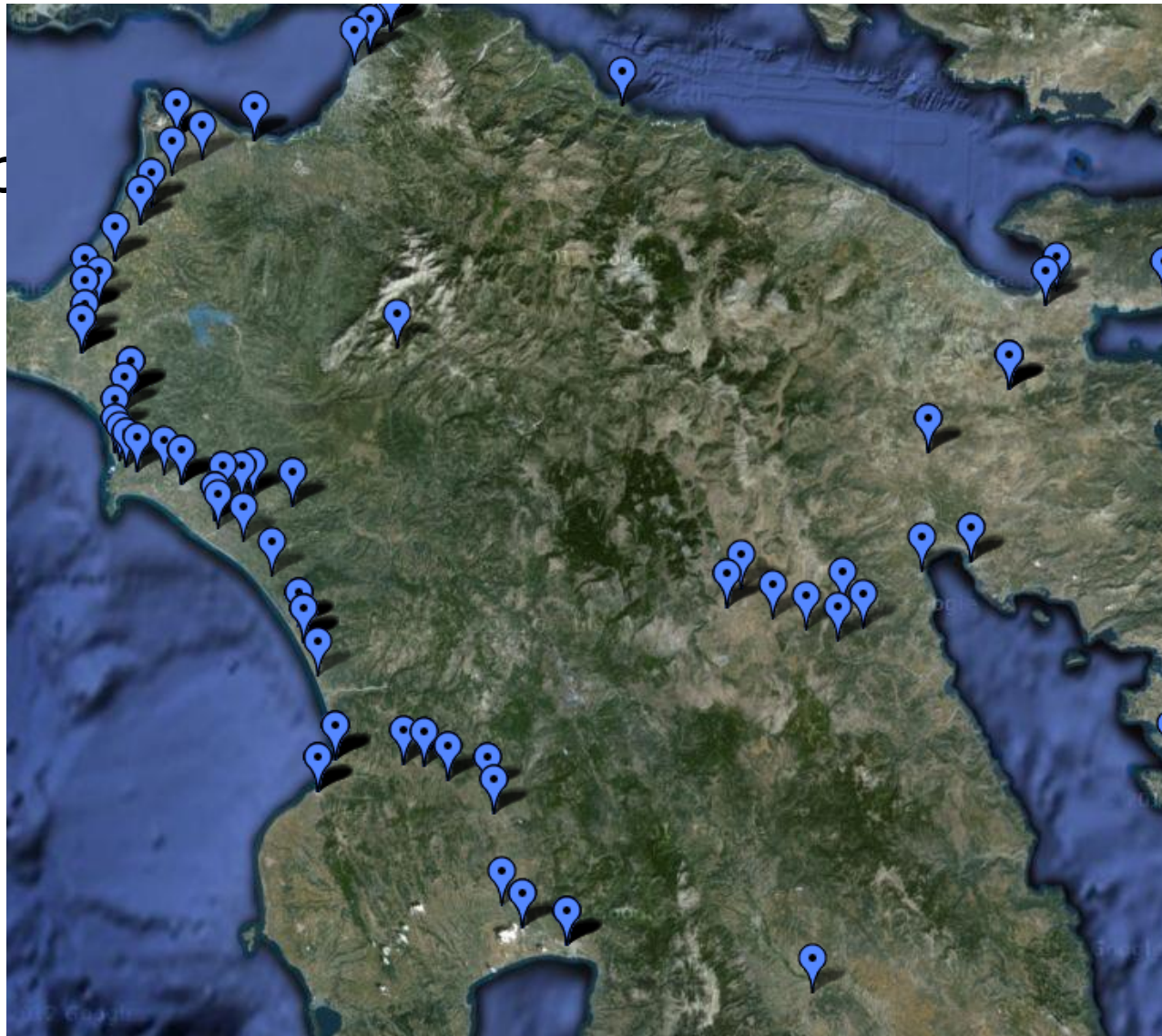
:WKT, ?

Creating a map (cont'd)

Get all
Pelop

SELECT
WHERE {

6.05,
38.36)
}



|
21.027
77
27
eo)).

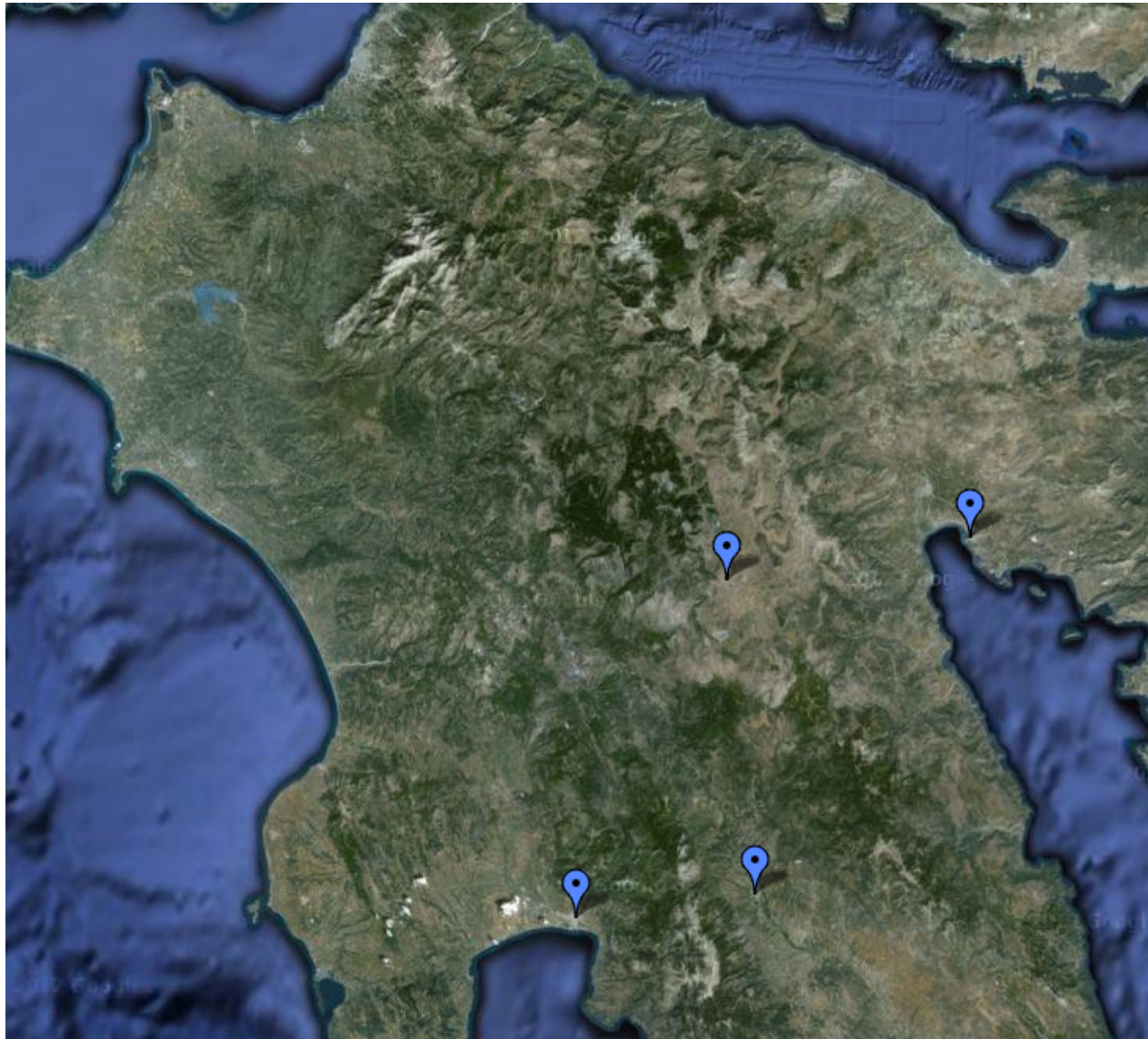
Creating a map (cont'd)



Get all

```
SELECT  
WHERE {
```

```
6.41  
}
```

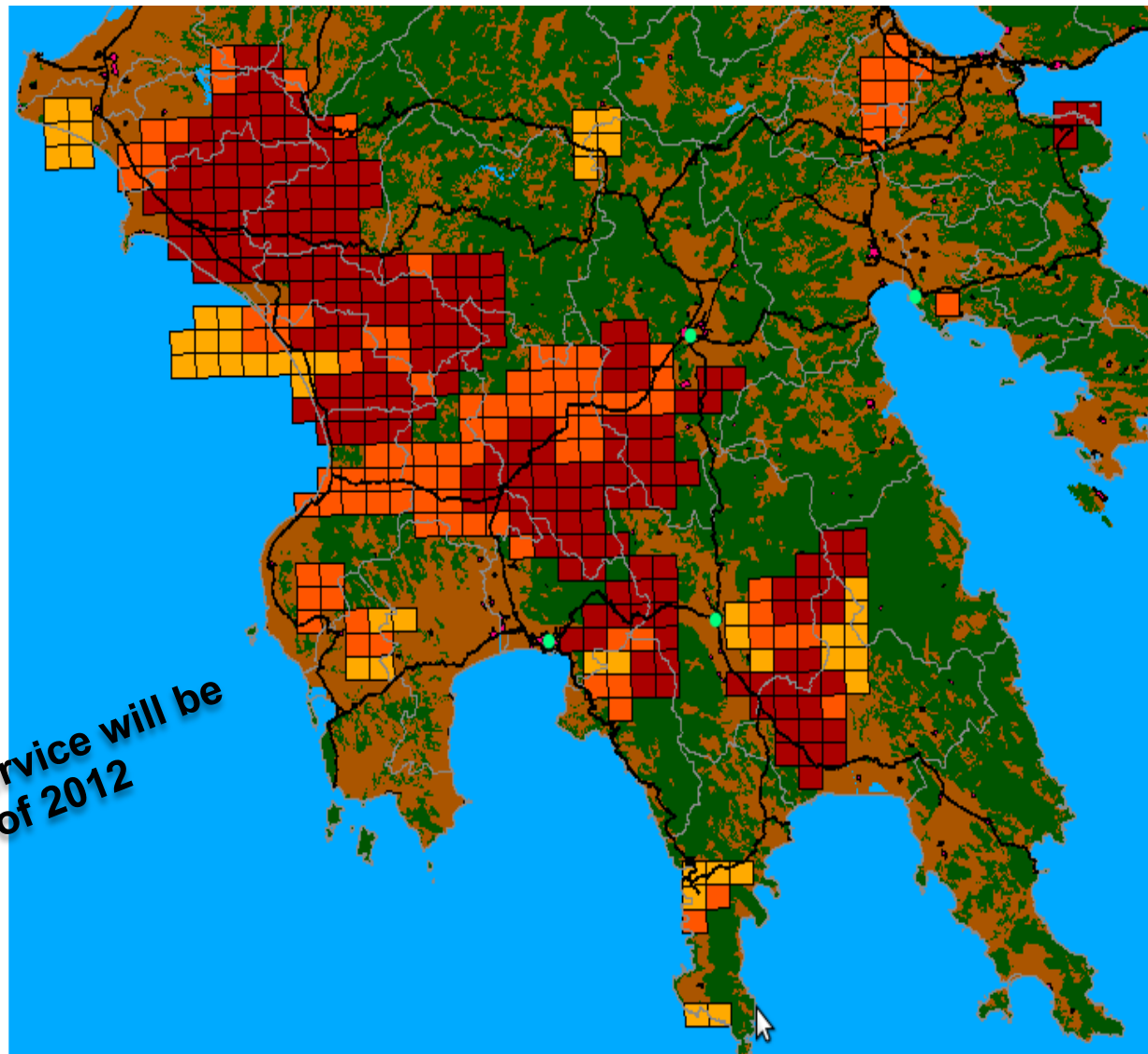


nnese.

```
) .  
21.51  
83  
51  
Geo) ) .
```

Final map

- GeoNames
 - Seat of a first-order administrative division
- Hotspots
 - Acquired at 26-8-11
 - Acquired at 25-8-11
 - Acquired at 24-8-11
- Greek Administrative Geography
 - Perfecture boundaries
- LinkedGeoData
 - Primary roads
- Corine Land Cover
 - Land Use: Wet Bodies
 - Land Use: Forests and Seminatural Areas
 - Land Use: Wet Lands
 - Land Use: Artificial Surfaces
 - Land Use: Agricultural Areas



The NOA Fire Monitoring Service will be operational in the summer of 2012

Thank you for your attention!

More information about TELEIOS can be found on
<http://www.earthobservatory.eu/>

Attend our tutorial on Linked Geospatial Data at

