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# Building Remote Sensing Applications Using Semantic Web Technologies

Kostis Kyzirakos

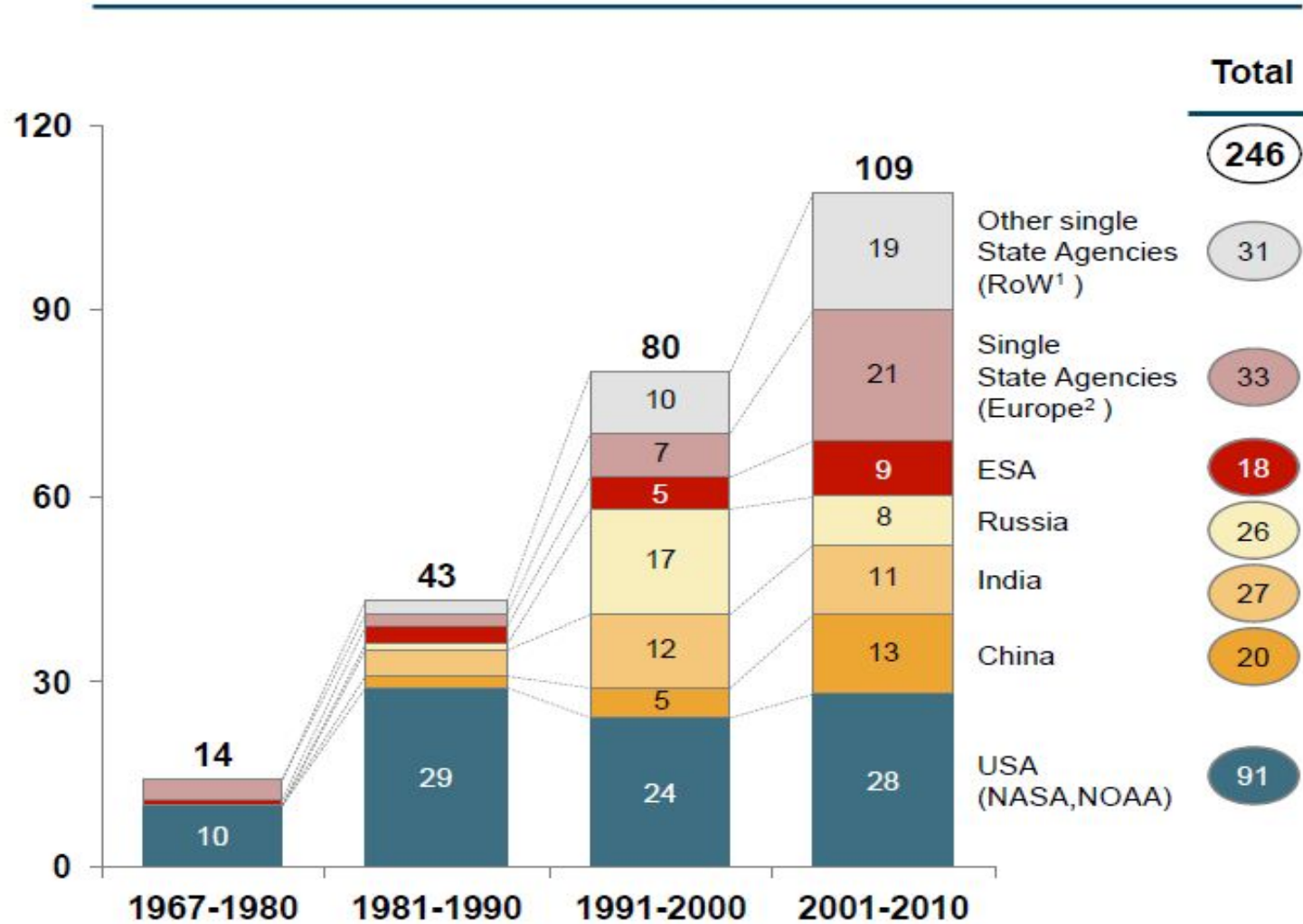
Dept. of Informatics and Telecommunications  
National and Kapodistrian University of Athens

***SWeFS***

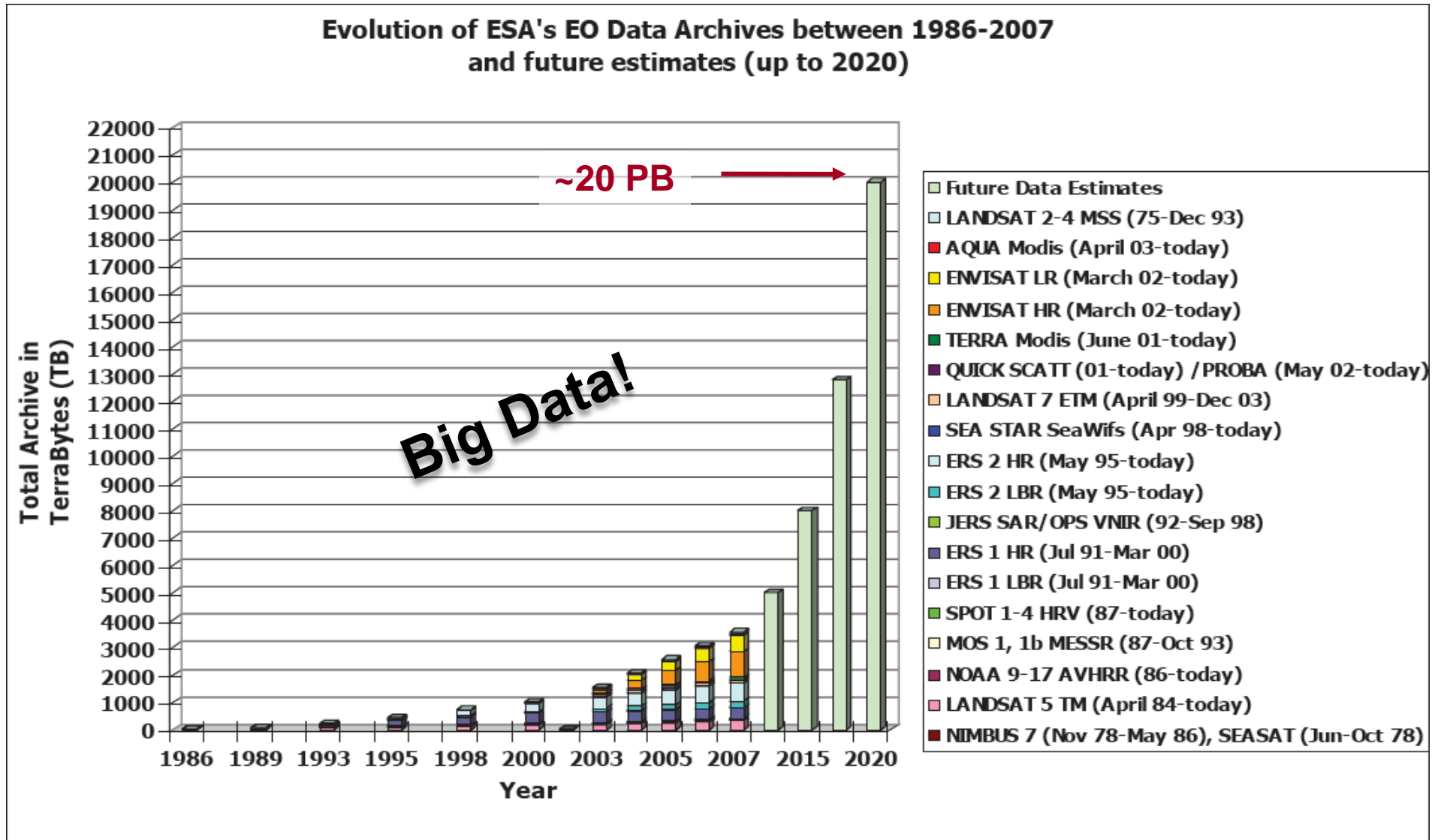


- Motivation
- State of the art in Earth Observation data centers
- The Fire Monitoring Service of the National Observatory of Athens
- Demo
- Evaluation
- Conclusions

N. of Earth Observation satellites launched

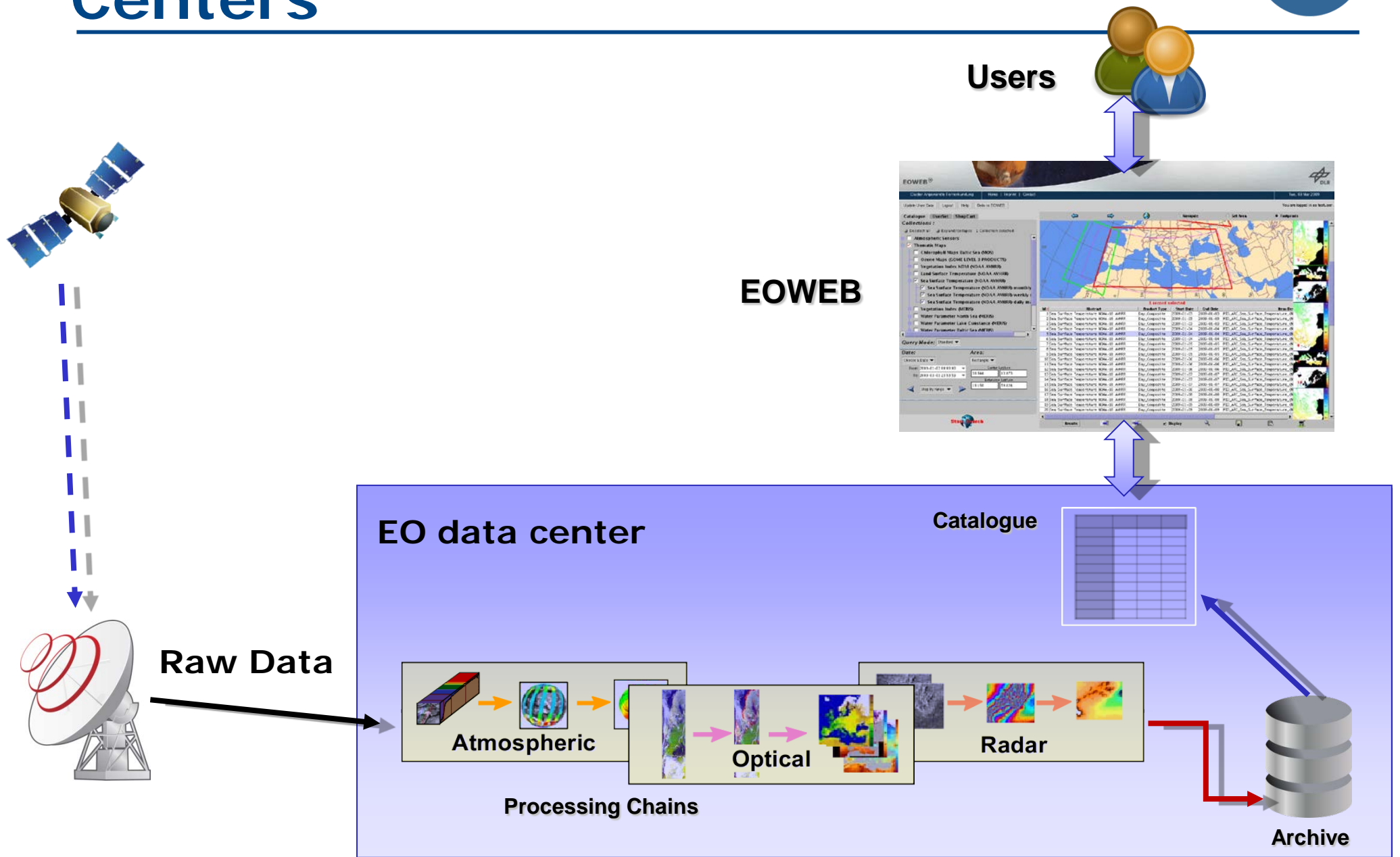


# Motivation (cont'd)





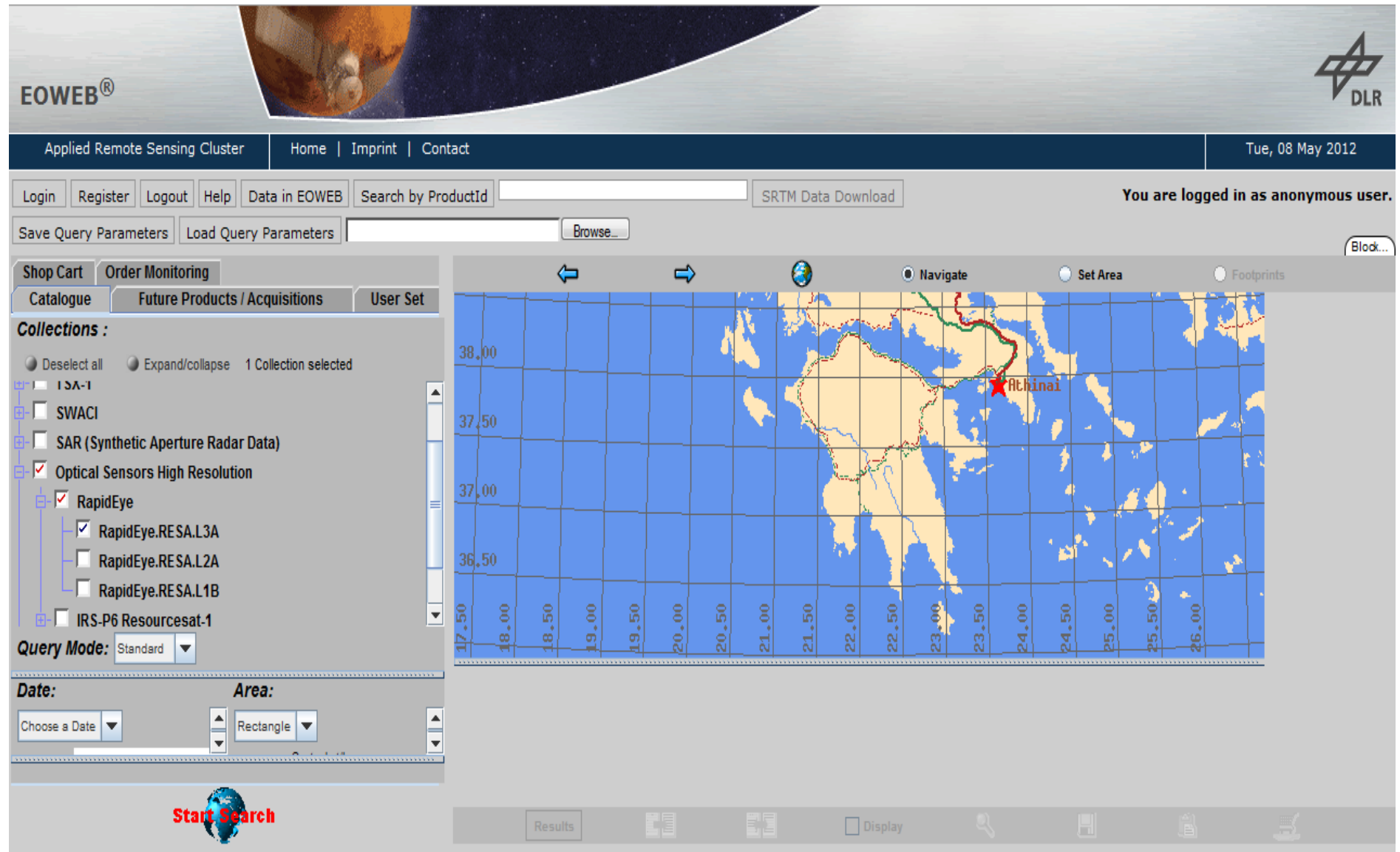
# State of the Art in EO Data Centers



- Can I pose the following query using EOWEB?

Find images taken by the SEVIRI 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 left, the EOWEB logo is visible next to a satellite image. The top right features the DLR logo. A navigation bar includes links for 'Applied Remote Sensing Cluster', 'Home', 'Imprint', and 'Contact', along with the date 'Tue, 08 May 2012'. Below this, there are buttons for 'Login', 'Register', 'Logout', 'Help', 'Data in EOWEB', and a search box labeled 'Search by ProductId'. A 'SRTM Data Download' button is also present. A status message indicates 'You are logged in as anonymous user.' The main interface is divided into a left sidebar and a central map area. The sidebar contains a 'Shop Cart' and 'Order Monitoring' section, followed by 'Catalogue', 'Future Products / Acquisitions', and 'User Set'. Under 'Collections', there are checkboxes for 'Deselect all', 'Expand/collapse', and '1 Collection selected'. The collection list includes 'ISA-1', 'SWACI', 'SAR (Synthetic Aperture Radar Data)', 'Optical Sensors High Resolution' (checked), 'RapidEye' (checked), 'RapidEye.RESA.L3A' (checked), 'RapidEye.RESA.L2A', 'RapidEye.RESA.L1B', and 'IRS-P6 Resourcesat-1'. Below the collection list, there is a 'Query Mode' dropdown set to 'Standard'. The 'Date' and 'Area' sections are also visible, with 'Date' set to 'Choose a Date' and 'Area' set to 'Rectangle'. The central map area shows a satellite image of a region with a grid overlay. The grid has latitude labels from 36.50 to 38.00 and longitude labels from 17.50 to 26.00. A red star marks the location 'Athina'. The map area includes navigation controls like 'Navigate', 'Set Area', and 'Footprints'. At the bottom of the map area, there is a 'Start Search' button with a globe icon. The bottom of the interface features a toolbar with icons for 'Results', 'Display', and other functions.



- Well, only partially.

**Find images taken by the SEVIRI 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.

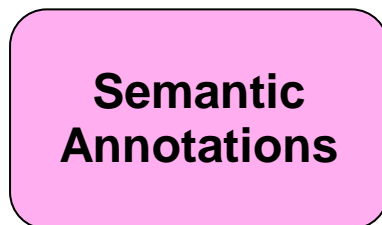
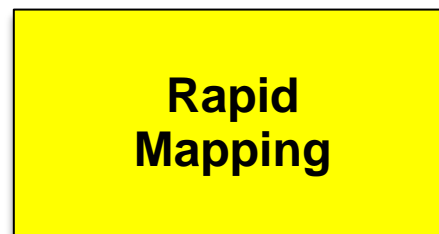
# The TELEIOS Earth Observatory: Concept View



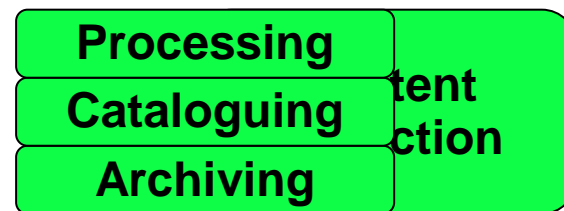
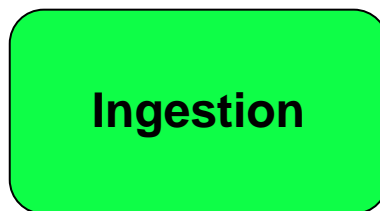
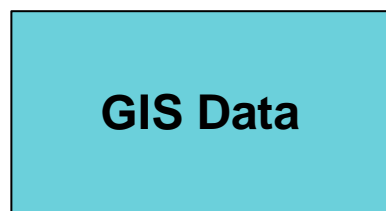
Scientists



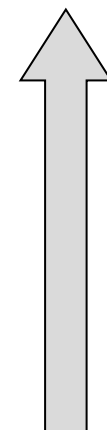
Emergency Response Managers



KNOWL-  
EDGE



DATA

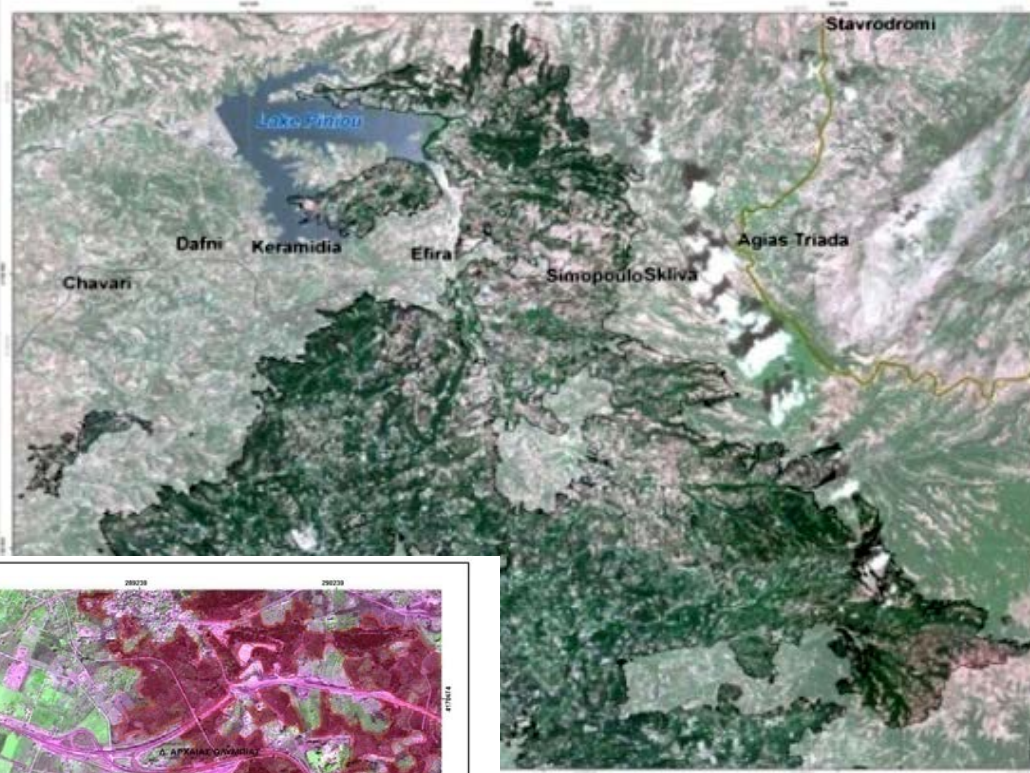


Scientific Database and  
Semantic Web Technologies

# Wildfire Monitoring and Burnt Area Mapping (NOA)



GREECE - Peloponnese - Fires - Lake Pinion area



Αρ. Φύλλου Χάρτη  
Sheet No.  
BSM GR11.1

ΝΟΜΟΣ ΗΛΕΙΑΣ  
Prefecture of Iliia

Χαρτογραφική Προβολή: ΕΓΨΑ87  
Ελλειψοειδής: WGS84  
Scale: 1:300,000

Cartographic Projection System: ΕΓΨΑ87  
Ellipsoid: Geodetic Reference System 80  
Landsat-5 TM, 28.09.07

ΚΑΜΕΝΕΣ ΕΚΤΑΣΕΙΣ ΣΤΟ ΣΥΝΟΛΟ ΤΟΥ ΝΟΜΟΥ  
Burnt surfaces in the entire Prefecture

Αποτίμηση καταστροφών ανά κατηγορία Κάλυψης Γης κατά CORINE Land Cover 2000 classes (Burnt area assessment per CORINE Land Cover 2000 class)	Εκτός σε ha (Area in ha)
Άδασ (Πλάσιφυλλων (Broad-leaved Forest))	258,92
Άδασ (Κωνοφόρων (Coniferous Forest))	3.385,92
Μειοάδασ (Mixed Forest)	2.419,92
Φυσιολά Βοσκήσιον (Natural Grassland)	1.336,93
Φύση και Χλωρίσιον (Moors and Heathland)	0,00
Γεωργικόν και Βοσκήσιον (Cereals/Other Vegetation)	9.483,41
Γεωργικόν και Άλλοις, εκτός (Agricultural and Other Areas)	25.457,61
Συνολικόν (Total Area)	45.545,91

Χαρτογράφηση Καμένων Εκτάσεων 2007 με χρήση δορυφορικών Εικόνων  
Επέκταση του προγράμματος RISK-EOS στην Ελλάδα  
Burn Scar Mapping in Greece for Year 2007  
RISK-EOS, Extension to Greece

Logos: RISK-EOS, GSB, EMERGENCY RESPONSE SERVICE Gmes, INSTITUTE FOR SPACE APPLICATIONS AND REMOTE SENSING



2007-08-25 07:00:00 UTC

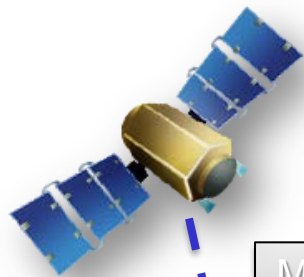
# Fire monitoring application

Pre-TELEIOS practice



System users (Civil Protection Authorities etc.)

Eumetsat @ 9.5°East



MSG-1 Seviri (5 mins)  
MSG-2 Seviri (15 mins)



Disk Array



PostGIS



SEVIRI Monitor

Manage SEVIRI data stream in real time:

- Describe & store raw file metadata
- Filter & dispatch raw MSG products
- Remotely trigger processing chain
- Dispatch processed products

Raw data are decoded and stored temporary as wavelet compressed images @...



SQLite

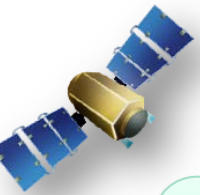
METEOSAT Ground Station

# Fire monitoring application

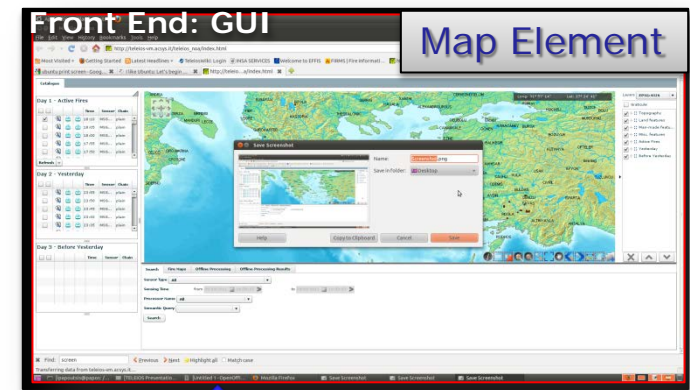
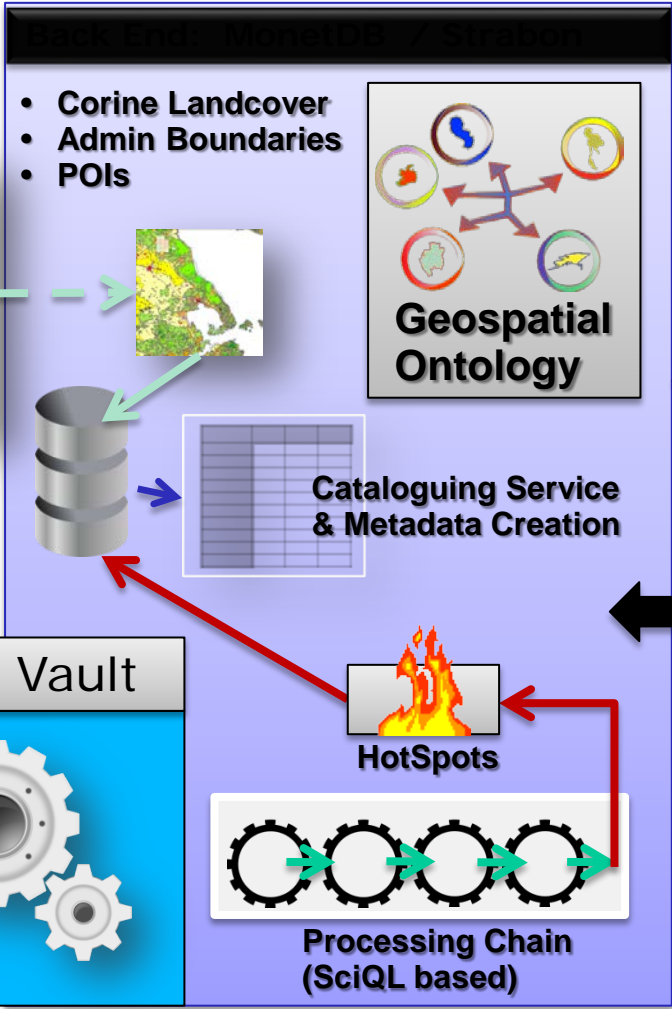
Advancements - Integration of the TELEIOS technologies



Eumetsat @ 9.5°East



External Sources



Web access based on Semantics

Linked Geospatial Data Semantic technologies



- Search & Display
- Search for raw & Processing
- Real-time Fire Monitoring
- Refinement (Post-Processing)
- Linked Data

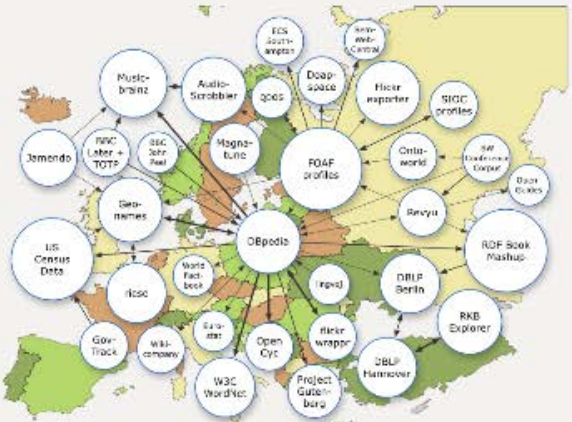
- Need for representing
  - Standard product **metadata**
  - Standard product **semantic annotations**
  - **Geospatial information**
  - **Temporal information**
  
- Need to link to other data sources
  - **GIS data**
  - Other information on the **Web**



# Semantics-Based Representation and Querying of EO Data

- The data model **stRDF** and the query language **stSPARQL**
- The system **Strabon**

strabon.di.uoa.gr



Home Demo Getting Started Download Publications Contributors

- **stRDF** stands for **spatial/temporal 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)

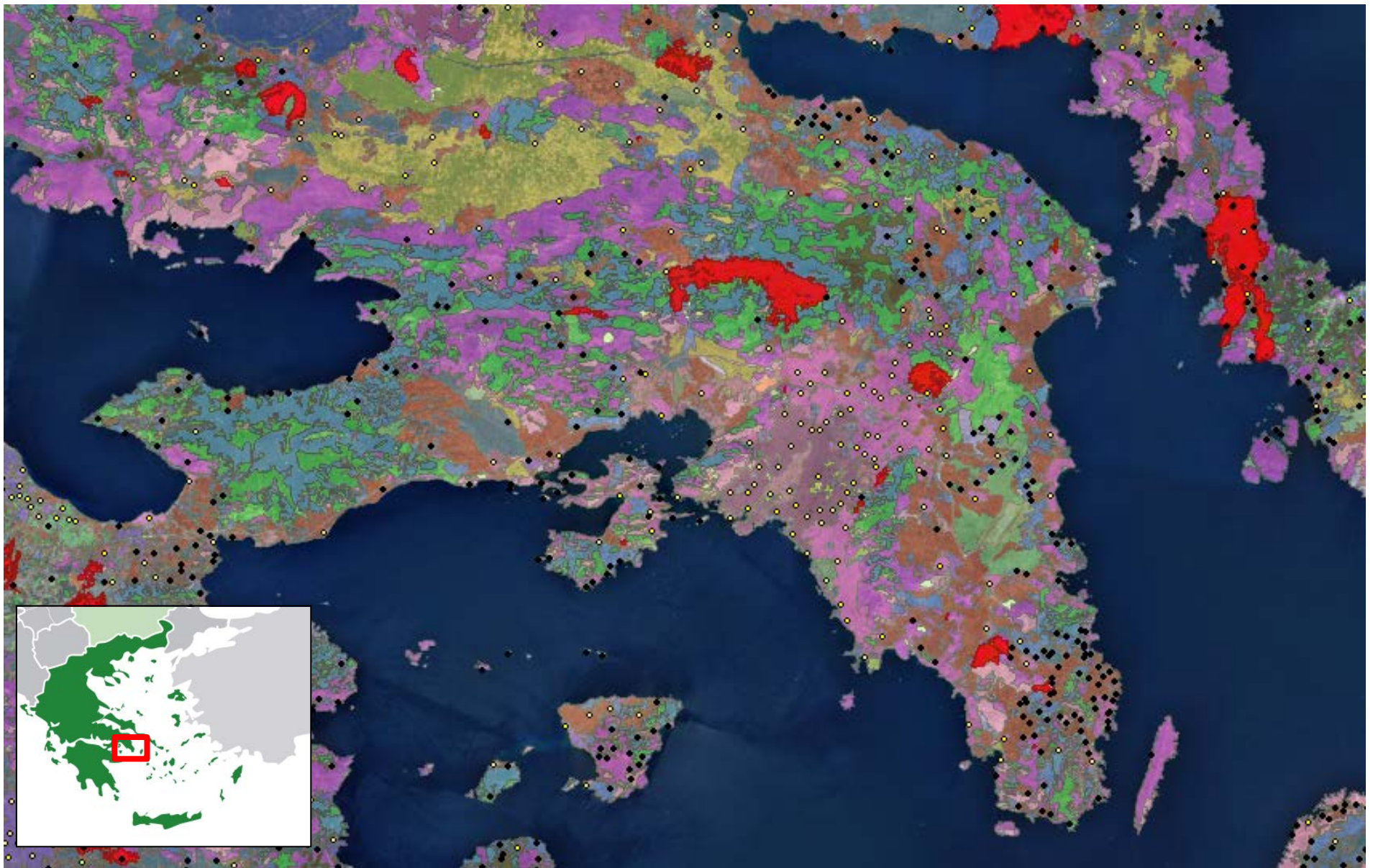
## W3C recommendation

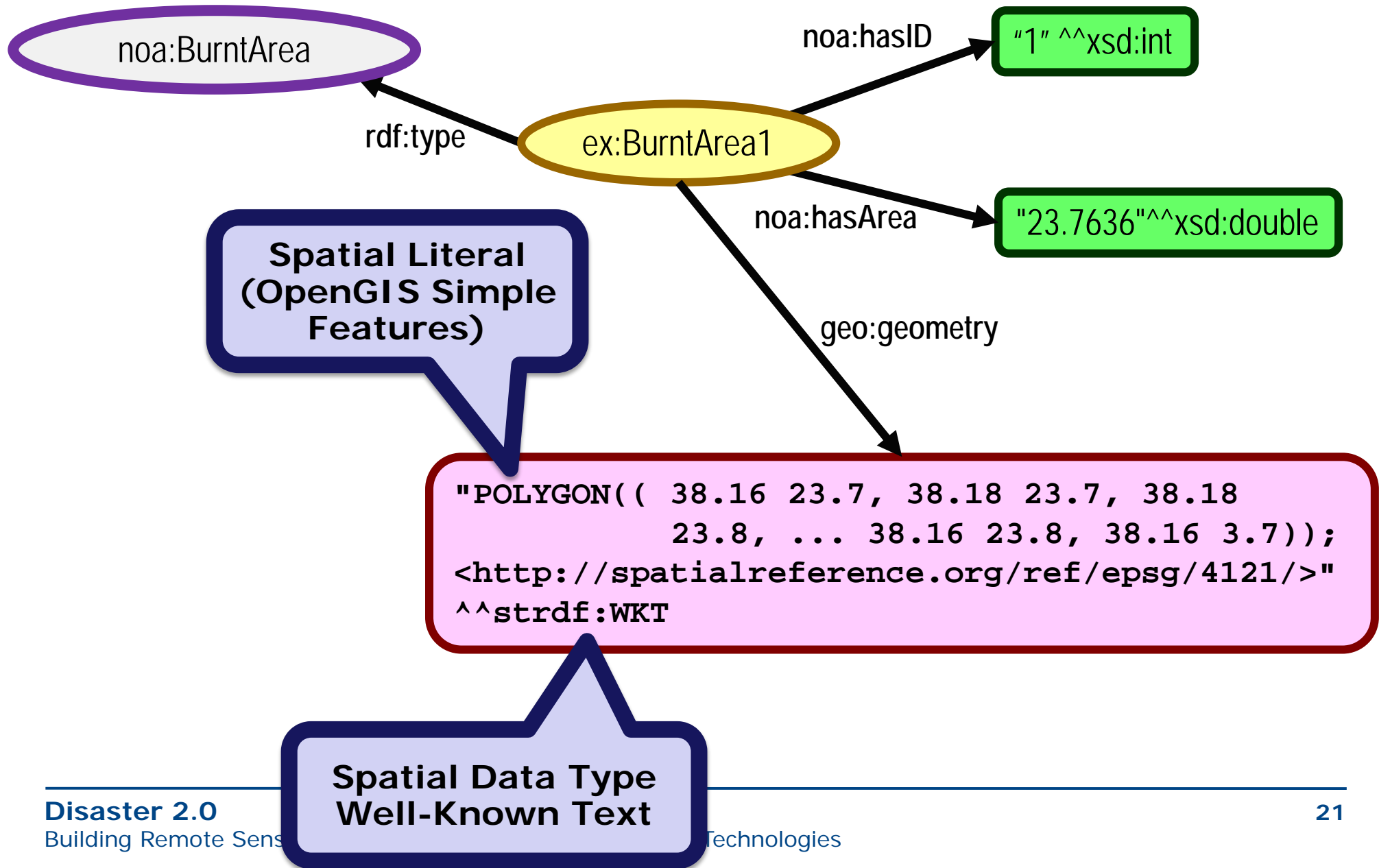
RDF is a **graph data model** ( + XML syntax + semantics)

- For representing metadata
- For describing the semantics of information in a machine- accessible way
- Resources are described in terms of properties and property values using RDF statements
- Statements are represented as triples, consisting of a subject, predicate and object. [S, P, O]



# stRDF: An example





# stSPARQL: An example

- Find all burned forests within 10kms of a city

```
select ?BA ?BAGEO
```

```
where {
```

```
?R    rdf:type    noa:Region ;  
      geo:geometry ?R GEO ;  
      noa:hasCorineLandCoverUse ?F .
```

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

```
?CITY  rdf:type    dbpedia:City ;  
      geo:geometry ?C GEO .
```

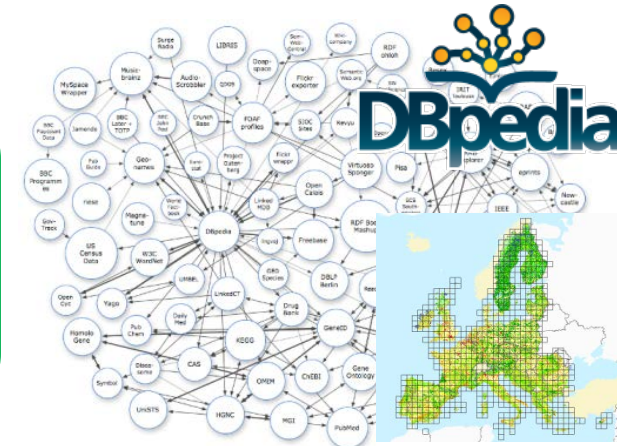
```
?BA    rdf:type    noa:BurntArea  
      geo:geometry ?BAGEO .
```

```
filter(
```

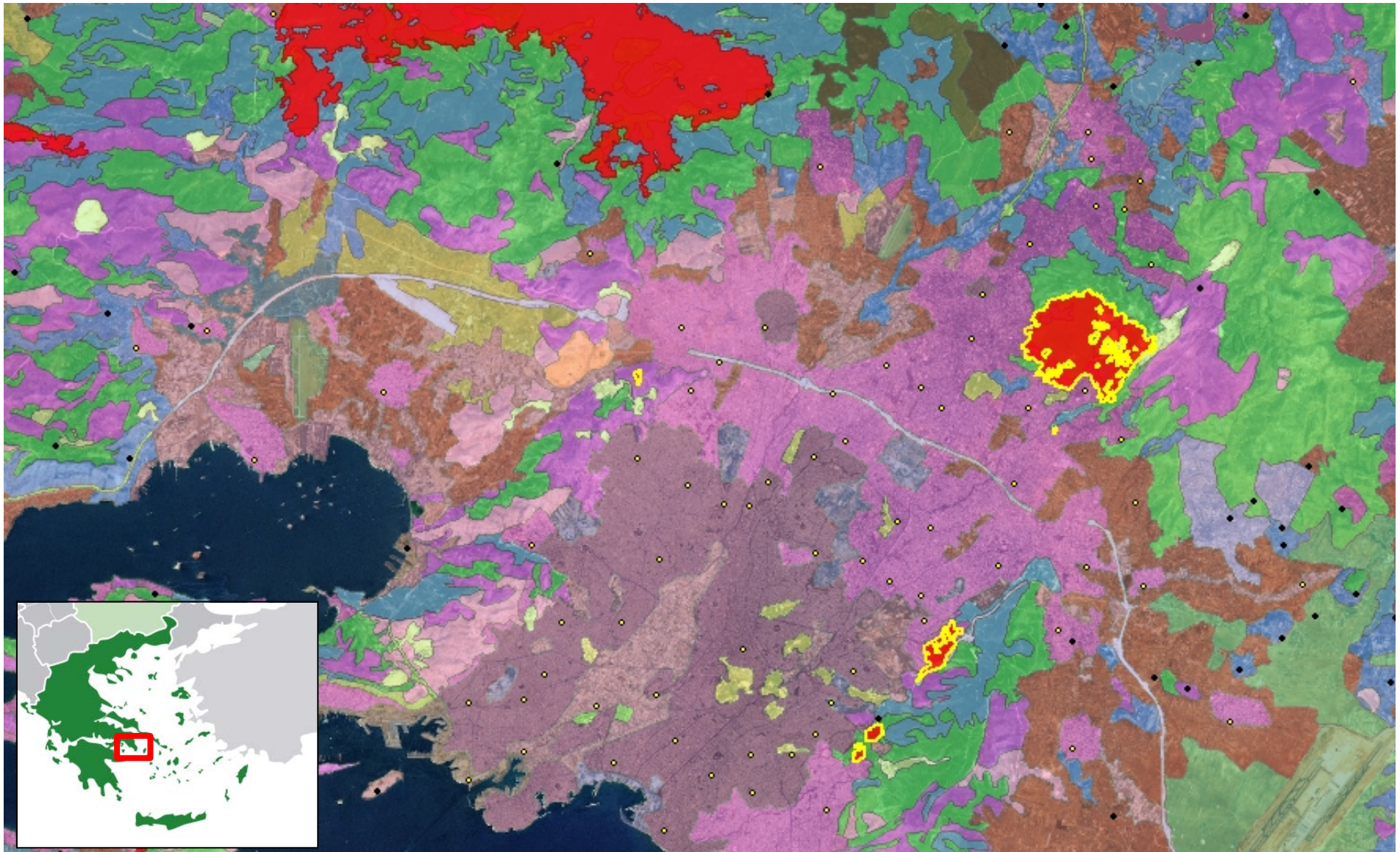
```
  strdf:Intersect(?R GEO, ?BAGEO) &&
```

```
  strdf:Distance(?BAGEO, ?C GEO) < 10000 )
```

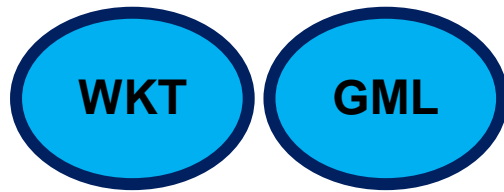
```
}
```



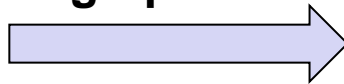
Spatial  
Functions  
(OGC Simple  
Feature  
Access)



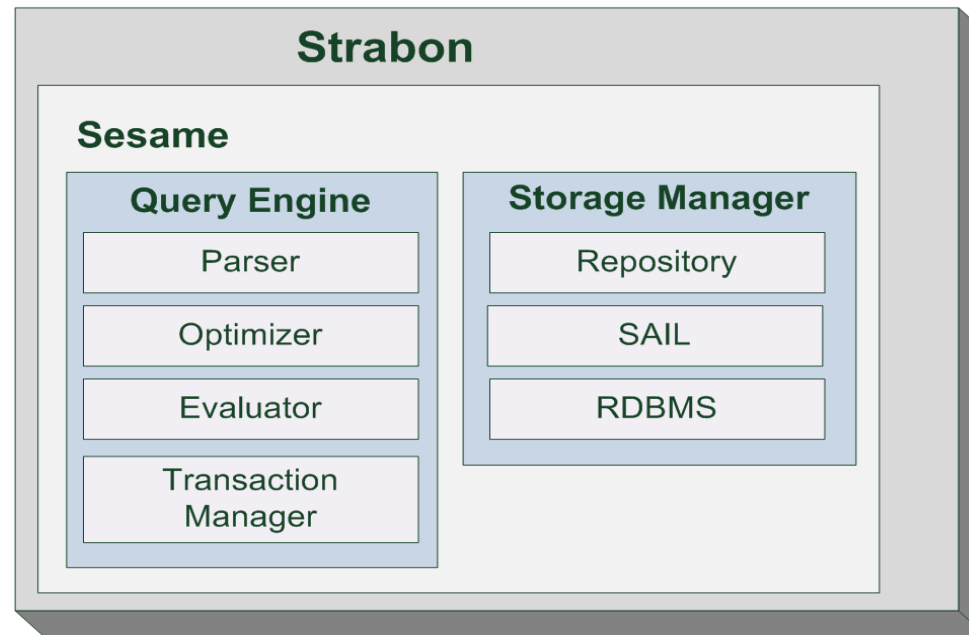
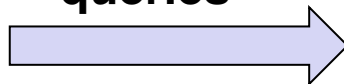
# Strabon: A Scalable Geospatial RDF Store



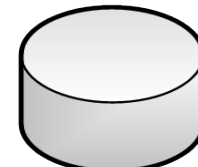
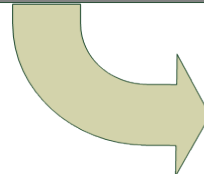
stRDF graphs



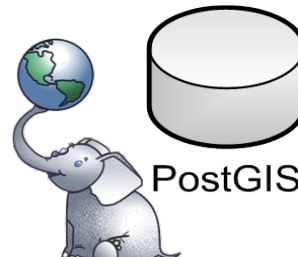
stSPARQL/  
GeoSPARQL  
queries



[ ISWC 2012 ]



GeneralDB



PostGIS



monetdb

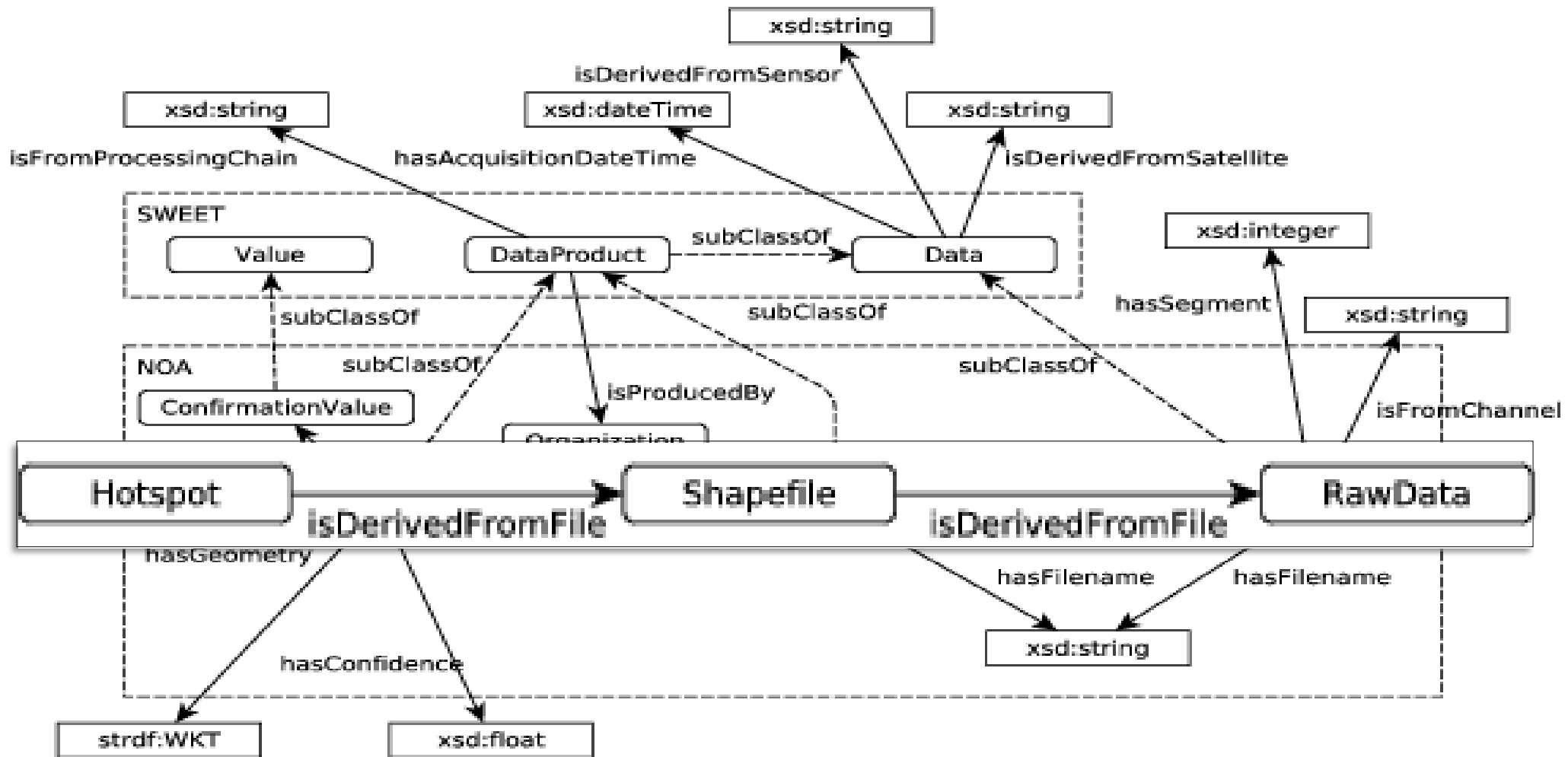
<http://www.strabon.di.uoa.gr/>



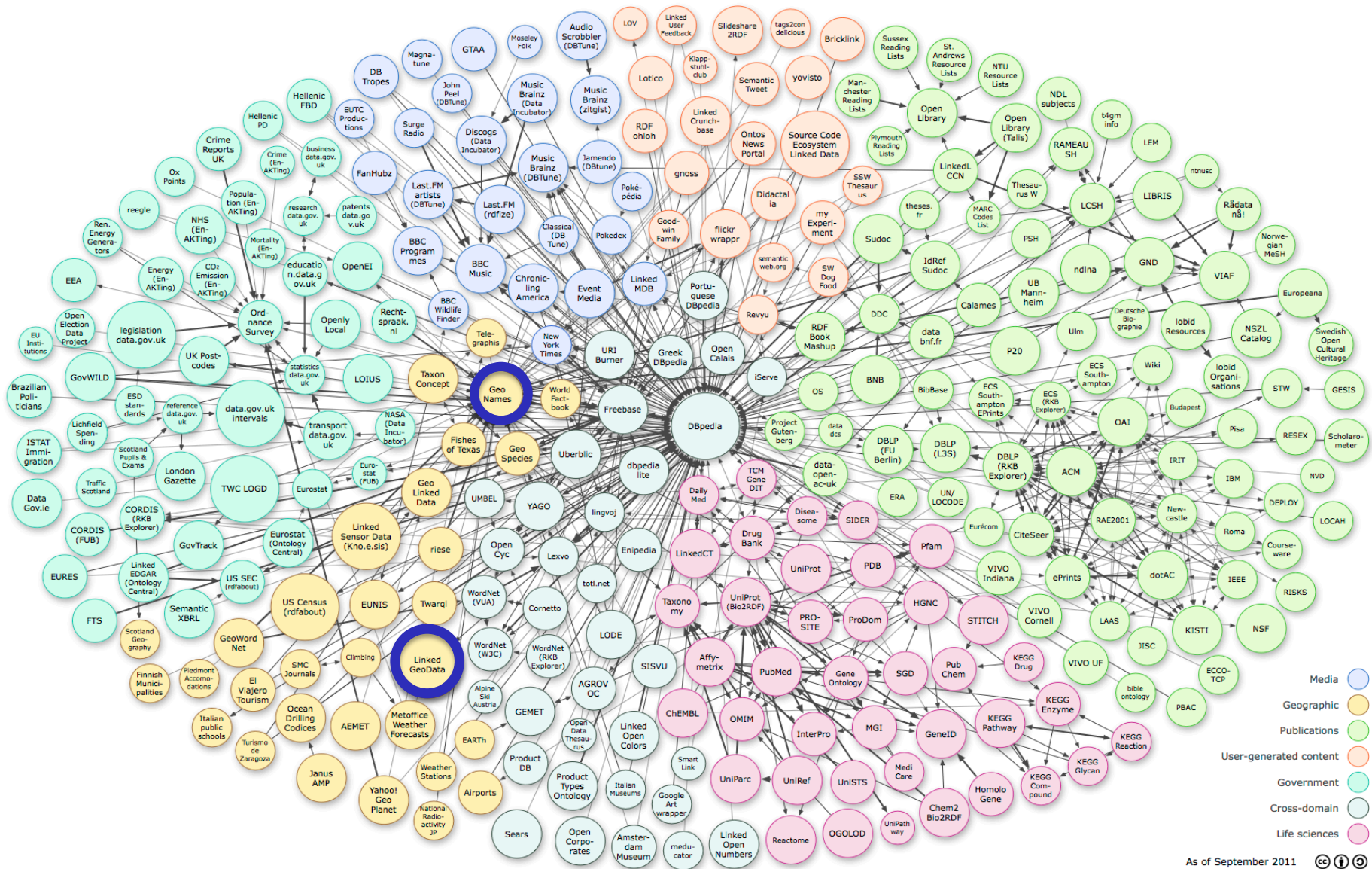
- Improving the fire monitoring service using Semantic Web technologies
  - **Representing** fire related products using ontologies
  - **Enriching products** with linked geospatial data
  - **Improving accuracy** with respect to:
    - Underlying land cover/land use
    - Persistence in time

*[ ISWC 2012 Semanti  
Web Challenge  
3'rd place winner]*

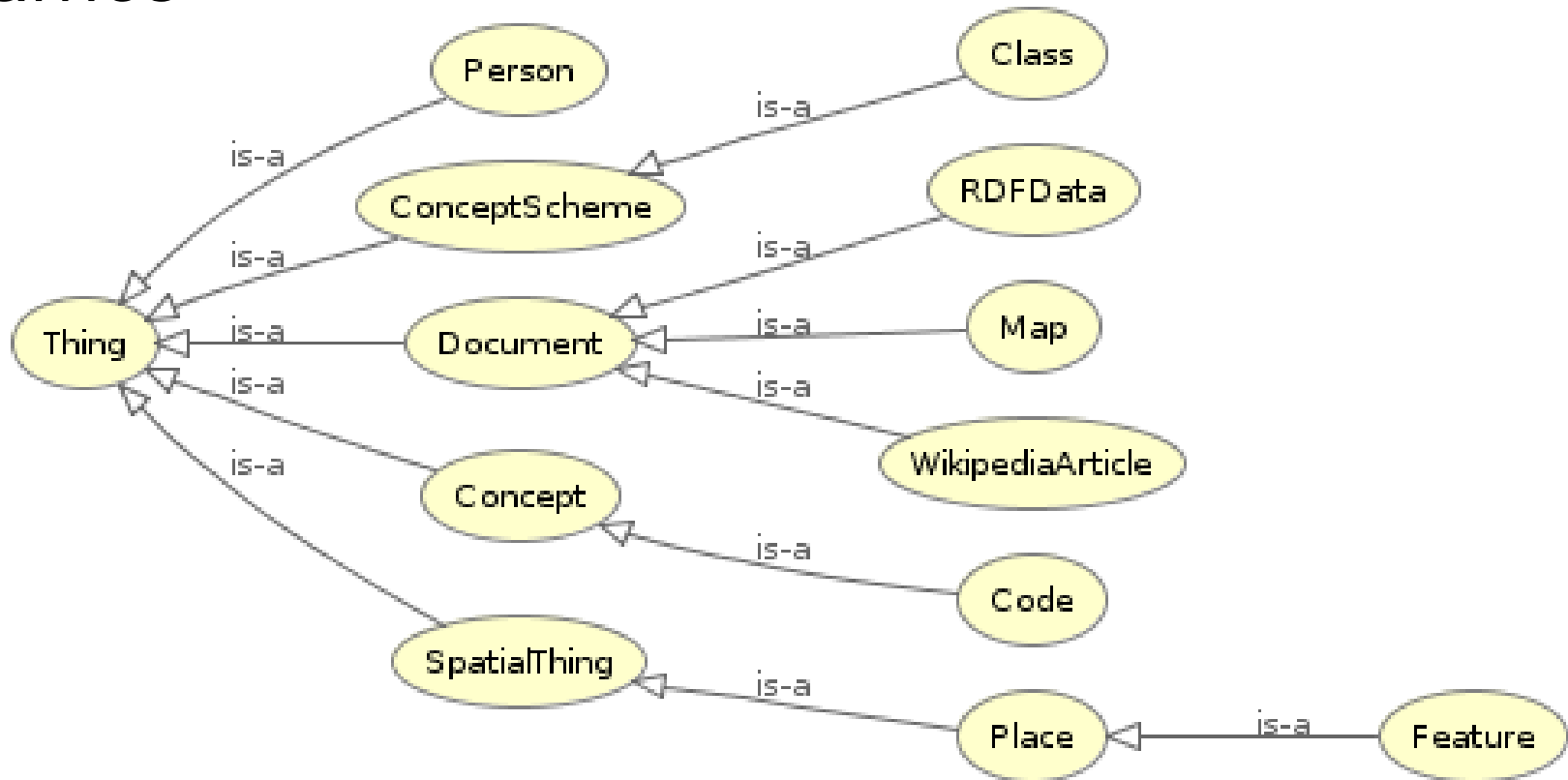
[http://papos.space.noa.gr/fend\\_static/](http://papos.space.noa.gr/fend_static/)



- Datasets that we developed and published as linked data:
  - Corine Land Use / Land Cover
  - Coastline of Greece
  - Greek Administrative Geography
- Portal: <http://www.linkedopendata.gr/>
- Datasets from Linked Open Data Cloud
  - LinkedGeoData
  - GeoNames



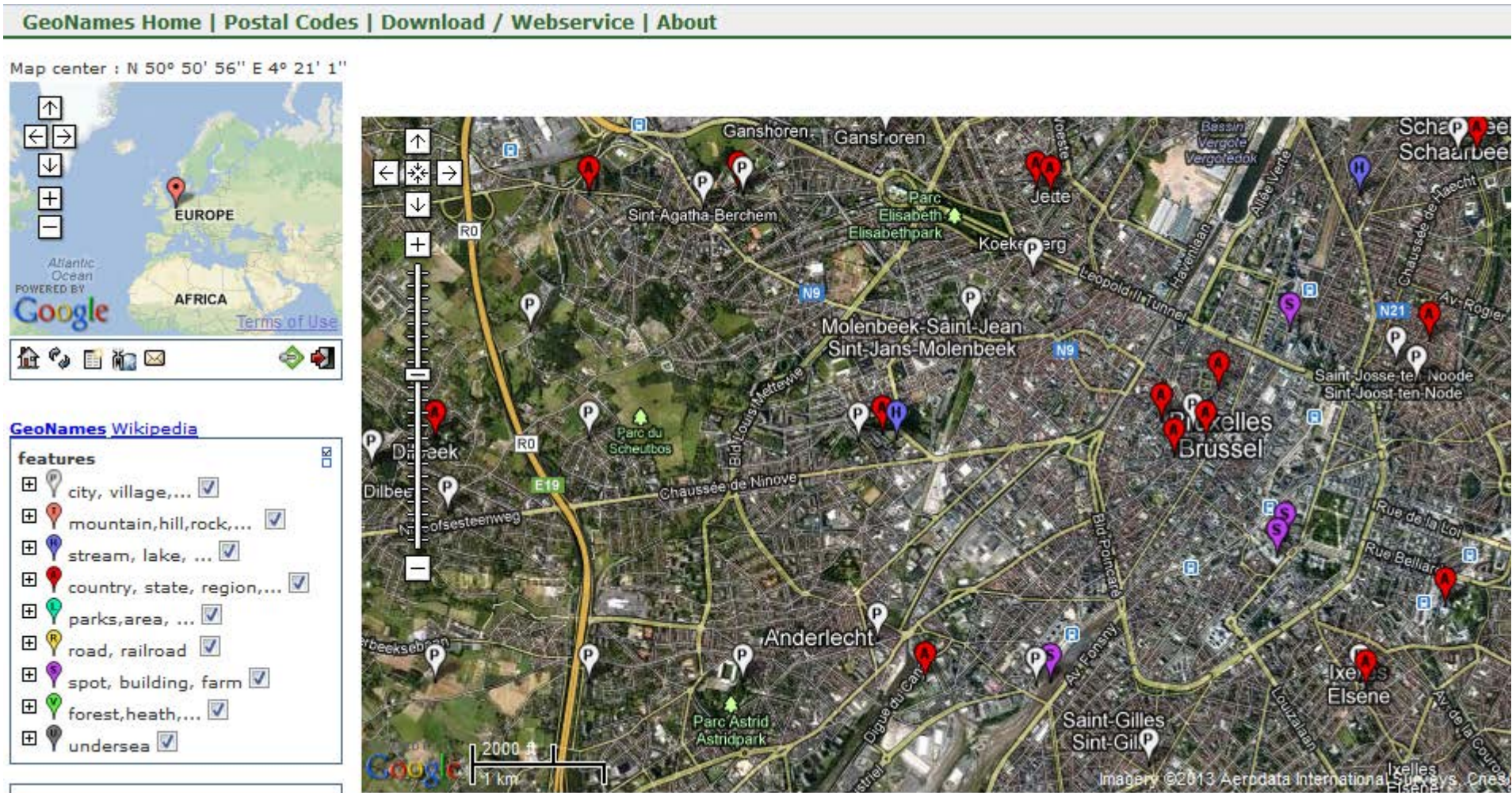
## GeoNames



## GeoNames

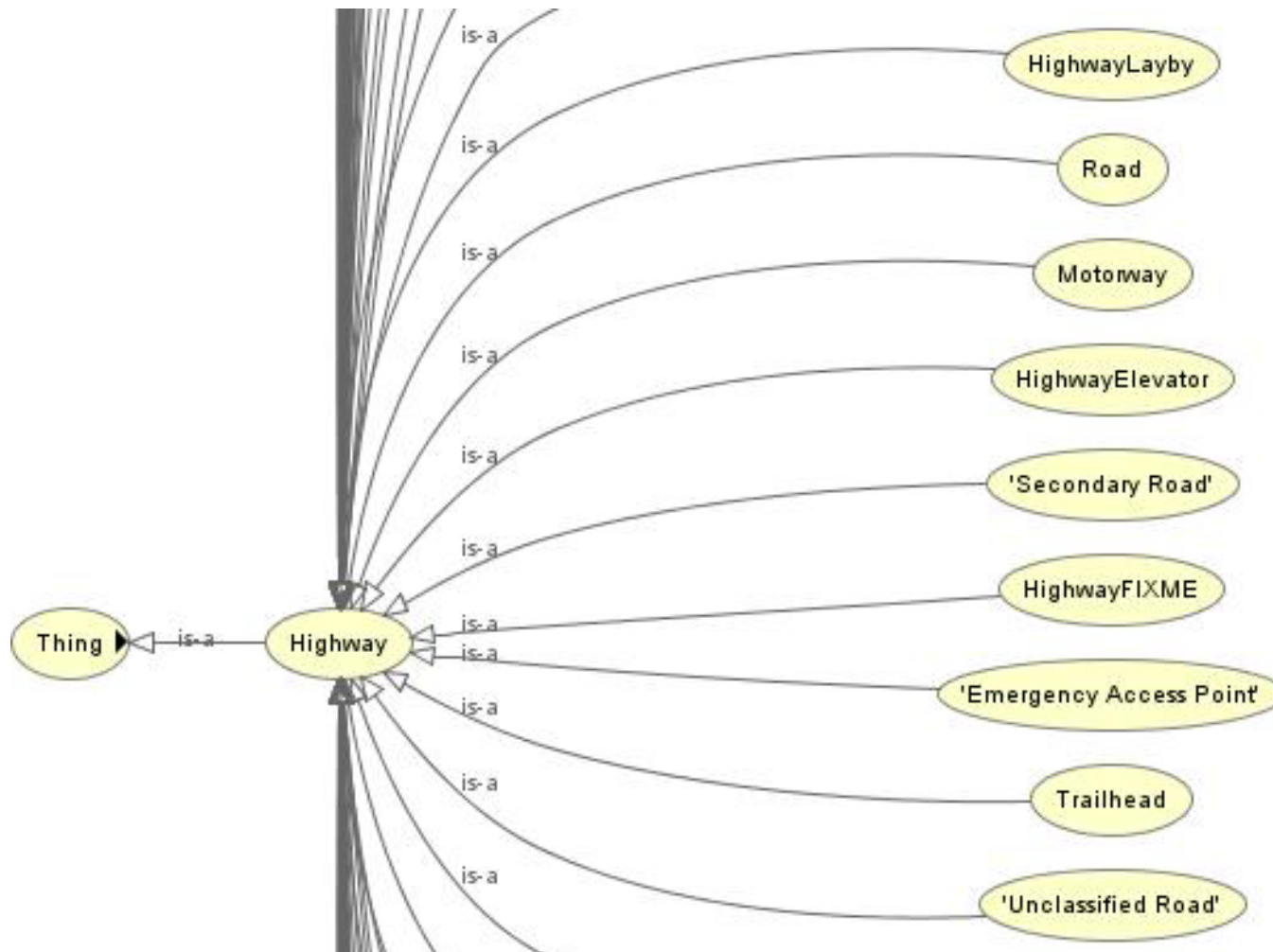
GeoNames Home | Postal Codes | Download / Webservice | About

Map center : N 50° 50' 56" E 4° 21' 1"

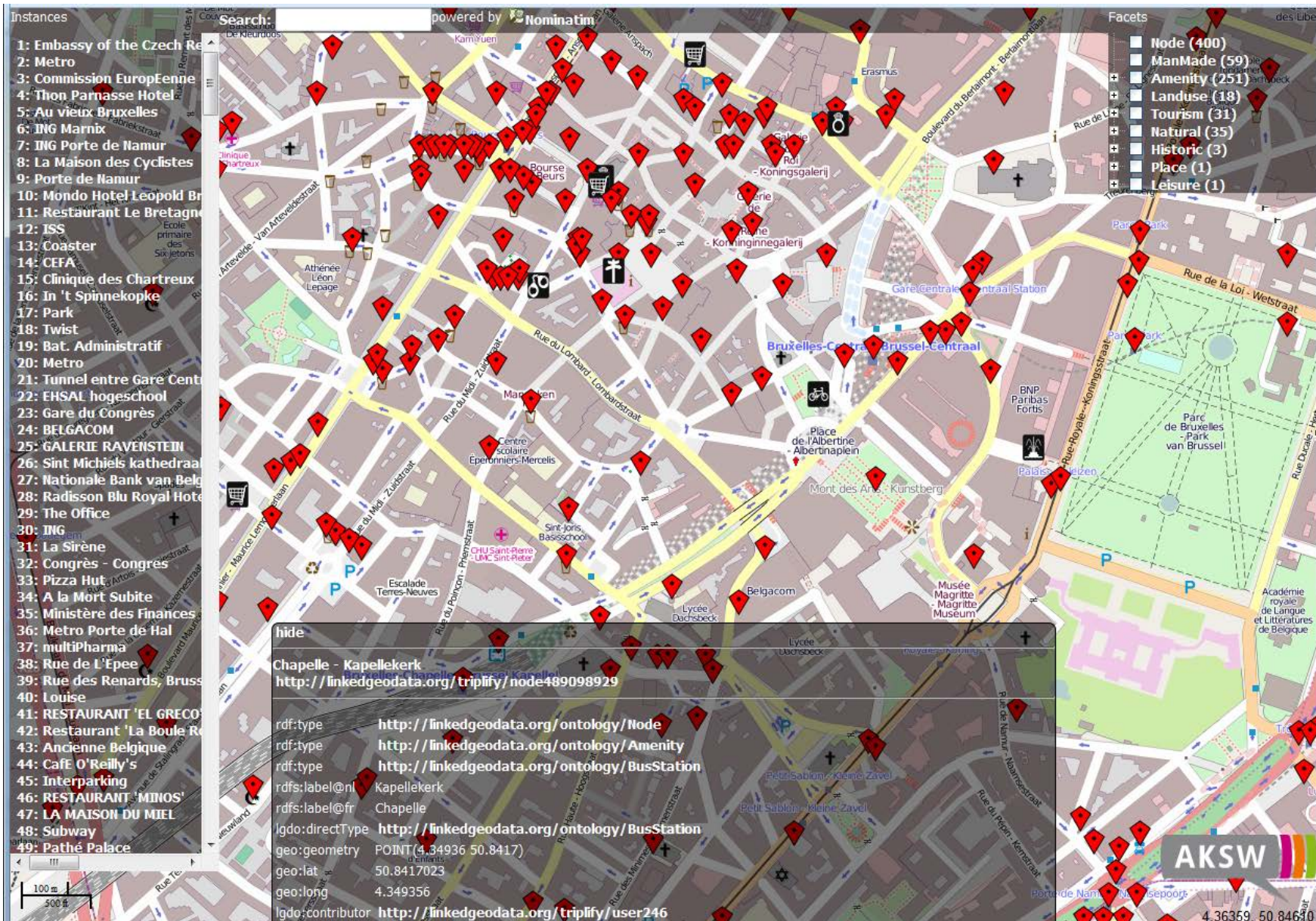


The screenshot displays the GeoNames web interface. At the top, there is a navigation bar with links: "GeoNames Home | Postal Codes | Download / Webservice | About". Below this, the map center coordinates are shown as "Map center : N 50° 50' 56" E 4° 21' 1\". The main map area shows a satellite view of Brussels, Belgium, with numerous red location pins and other colored markers (blue, purple, green) indicating different geographical features. Labels on the map include "Ganshoren", "Sint-Agatha-Berchem", "Jette", "Koekberg", "Molenbeek-Saint-Jean", "Sint-Jans-Molenbeek", "Anderlecht", "Ixelles", "Elsene", and "Brussel". A legend on the left side, titled "GeoNames Wikipedia", lists various features with checkboxes: "city, village, ..." (checked), "mountain, hill, rock, ..." (checked), "stream, lake, ..." (checked), "country, state, region, ..." (checked), "parks, area, ..." (checked), "road, railroad" (checked), "spot, building, farm" (checked), "forest, heath, ..." (checked), and "undersea" (checked). The map also includes a scale bar (0 to 2000 feet and 1 km) and a copyright notice at the bottom right: "Imagery ©2013 Aerodata International, Surveys, Cnes".

## OpenStreetMap



# Linked Open Data (2/5)



Instances

- 1: Embassy of the Czech Republic
- 2: Metro
- 3: Commission Européenne
- 4: Thon Parnasse Hotel
- 5: Au vieux Bruxelles
- 6: ING Marnix
- 7: ING Porte de Namur
- 8: La Maison des Cyclistes
- 9: Porte de Namur
- 10: Mondo Hotel Leopold
- 11: Restaurant Le Bretagne
- 12: ISS
- 13: Coaster
- 14: CEFA
- 15: Clinique des Chartreux
- 16: In 't Spinnekopke
- 17: Park
- 18: Twist
- 19: Bat. Administratif
- 20: Metro
- 21: Tunnel entre Gare Centrale
- 22: EHSAL hogeschool
- 23: Gare du Congrès
- 24: BELGACOM
- 25: GALERIE RAVENSTEIN
- 26: Sint Michiels kathedraal
- 27: Nationale Bank van België
- 28: Radisson Blu Royal Hotel
- 29: The Office
- 30: ING
- 31: La Sirène
- 32: Congrès - Congres
- 33: Pizza Hut
- 34: A la Mort Subite
- 35: Ministère des Finances
- 36: Metro Porte de Hal
- 37: multiPharma
- 38: Rue de L'Epee
- 39: Rue des Renards, Brussels
- 40: Louise
- 41: RESTAURANT 'EL GRECO
- 42: Restaurant 'La Boule Rouge
- 43: Ancienne Belgique
- 44: Cafe O'Reilly's
- 45: Interparking
- 46: RESTAURANT 'MINOS'
- 47: LA MAISON DU MIEL
- 48: Subway
- 49: Pathé Palace

Facets

- Node (400)
- ManMade (59)
- Amenity (251)
- Landuse (18)
- Tourism (31)
- Natural (35)
- Historic (3)
- Place (1)
- Leisure (1)

hide

Chapelle - Kapellekerk  
<http://linkedgeo.com/triplify/node489098929>

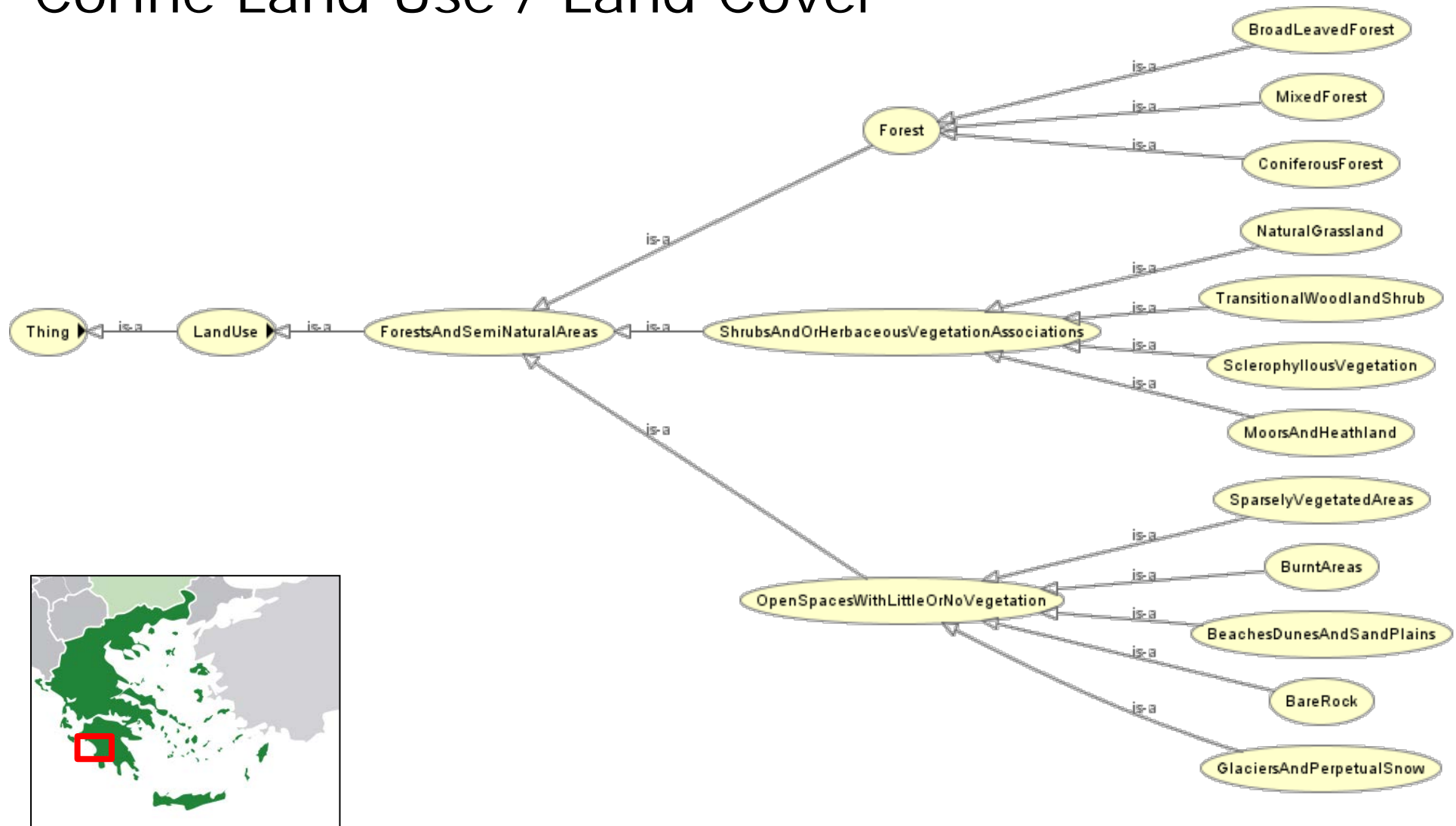
rdf:type	<a href="http://linkedgeo.com/ontology/Node">http://linkedgeo.com/ontology/Node</a>
rdf:type	<a href="http://linkedgeo.com/ontology/Amenity">http://linkedgeo.com/ontology/Amenity</a>
rdf:type	<a href="http://linkedgeo.com/ontology/BusStation">http://linkedgeo.com/ontology/BusStation</a>
rdfs:label@nl	Kapellekerk
rdfs:label@fr	Chapelle
lgdo:directType	<a href="http://linkedgeo.com/ontology/BusStation">http://linkedgeo.com/ontology/BusStation</a>
geo:geometry	POINT(4.34936 50.8417)
geo:lat	50.8417023
geo:long	4.349356
lgdo:contributor	<a href="http://linkedgeo.com/triplify/user246">http://linkedgeo.com/triplify/user246</a>

AKSW

4.36359, 50.84650

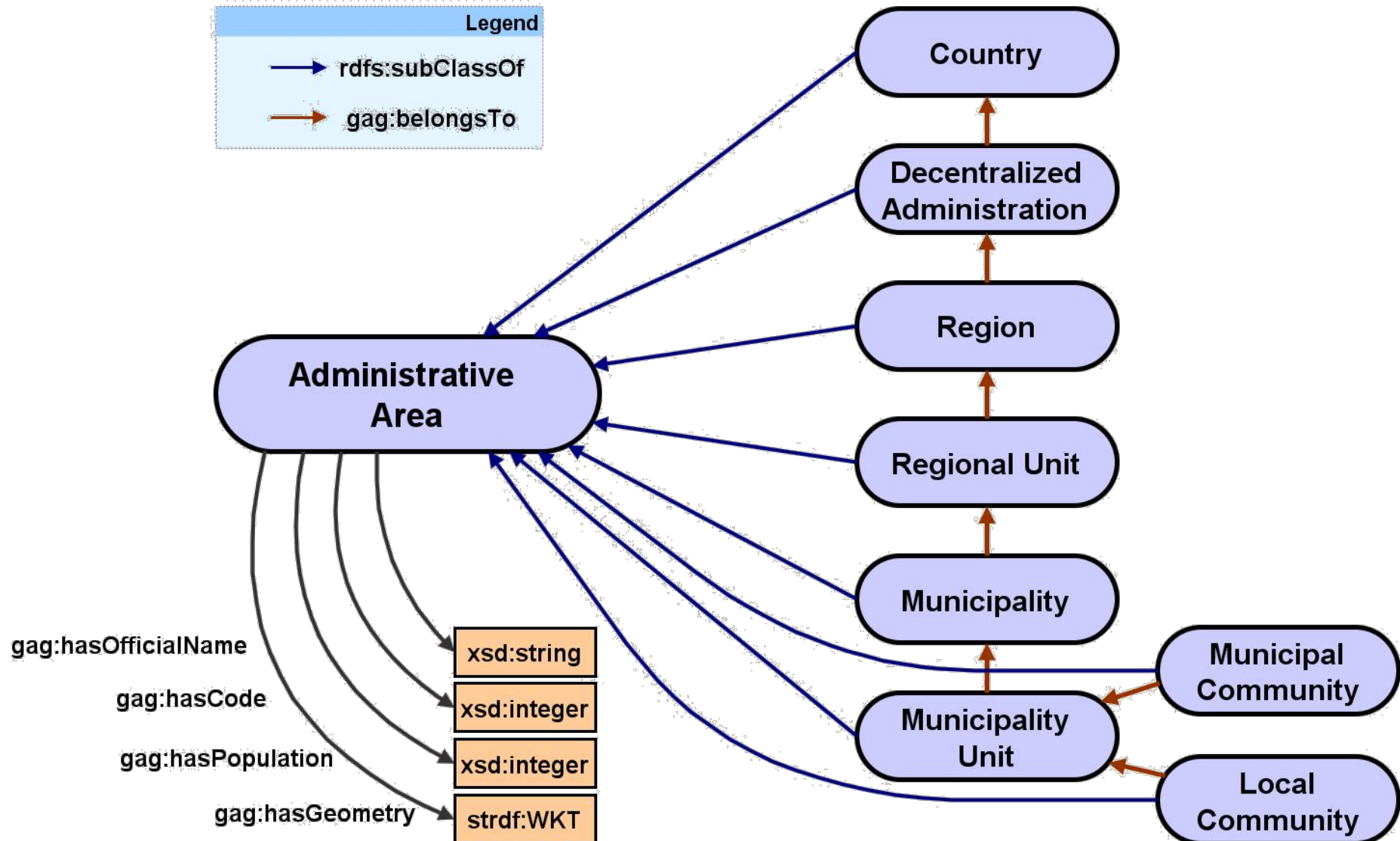


## Corine Land Use / Land Cover

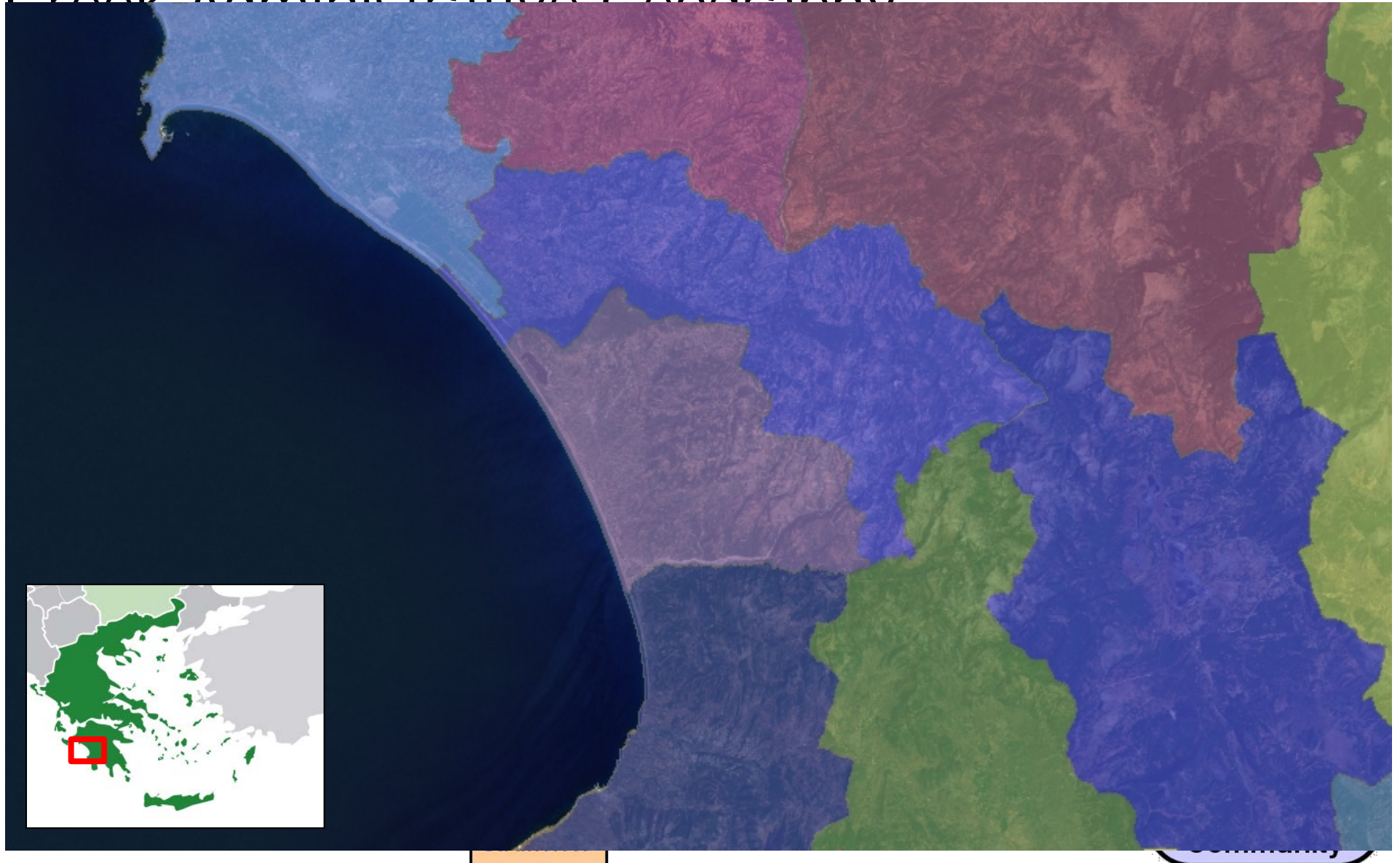




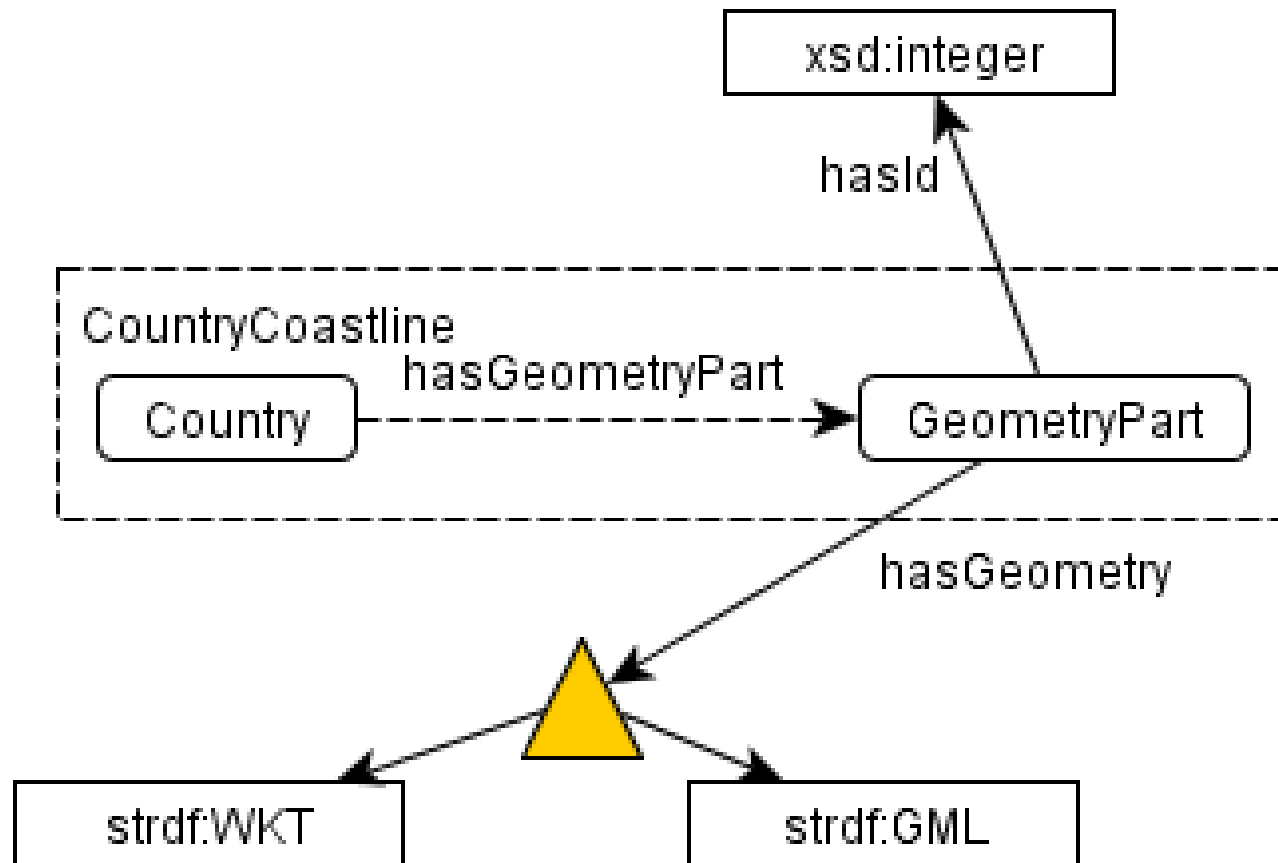
## Greek Administrative Geography



## Creek Administrative Geography



## Greek Coastline



## Greek Coastline



Using ontologies and stRDF to model knowledge extracted from satellite images, metadata of satellite images and auxiliary geospatial data can improve tasks like:

- **Generated maps** combining diverse information sources
- **Increase hotspot accuracy** correlating them with auxiliary data

- **Generating maps** combining diverse information sources
- **Semantic Enrichment** for Hotspots
- **Fire monitoring** application

**DEMO!**



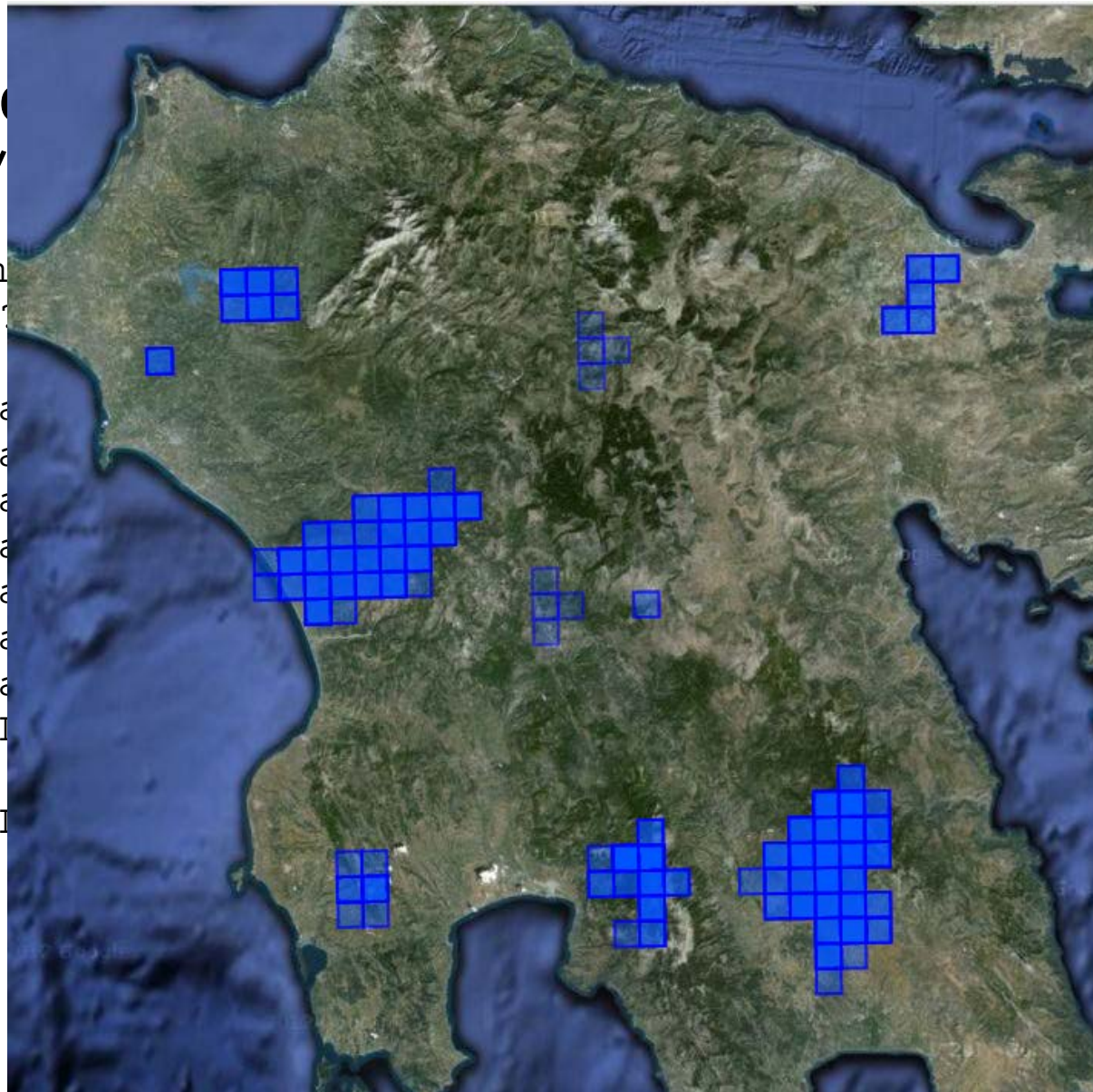
## Get all hotspots detected in Peloponnese on 24/08/2007.

```
SELECT ?h ?hGeo ?hAcqTime ?hConfidence ?hConfirmation ?hProvider
       ?hSensor ?hSatellite
WHERE {
  ?h rdf:type noa:Hotspot ;
  noa:hasGeometry ?hGeo ;
  noa:hasAcquisitionTime ?hAcqTime ;
  noa:hasConfidence ?hConfidence ;
  noa:isProducedBy ?hProvider ;
  noa:hasConfirmation ?hConfirmation ;
  noa:isDerivedFromSensor ?hSensor ;
  noa:isDerivedFromSatellite ?hSatellite .
  FILTER("2007-08-24T00:00:00"^^xsd:dateTime <= ?hAcqTime &&
         ?hAcqTime <= "2007-08-24T23:59:59"^^xsd:dateTime).
  FILTER(strdf:contains("POLYGON((21.027 38.36, 23.77 38.36,
                               23.77 36.05, 21.027 36.05, 21.027 38.36))"
                        ^^strdf:WKT, ?hGeo) ) . }
```

# Discovering EO data

Get all h  
24/08/

```
SELECT ?h ?h  
    ?hSensor  
WHERE {  
    ?h  
    noa  
    noa  
    noa  
    noa  
    noa  
    noa  
    noa  
    noa  
    FII  
    FII
```



on

Provider

```
    ?hAcqTime &&  
    :dateTime).  
    23.77 38.36,  
    ) )"
```

Get all coniferous forests in Peloponnese

```
SELECT  ?a ?aGeo
WHERE { ?a rdf:type clc:Area;
        clc:hasLandUse ?aLandUse;
        noa:hasGeometry ?aGeo.
        ?aLandUse rdf:type ?aLandUseType.
        FILTER(?aLandUseType =
                clc:ConiferousForest) .

        FILTER(strdf:contains("POLYGON((21.027
                38.36, 23.77 38.36, 23.77 36.05,
                21.027 36.05, 21.027 38.36))"
                ^^strdf:WKT,?aGeo)) .
}
```

# Retrieving a map layer (1/3)

Get all o

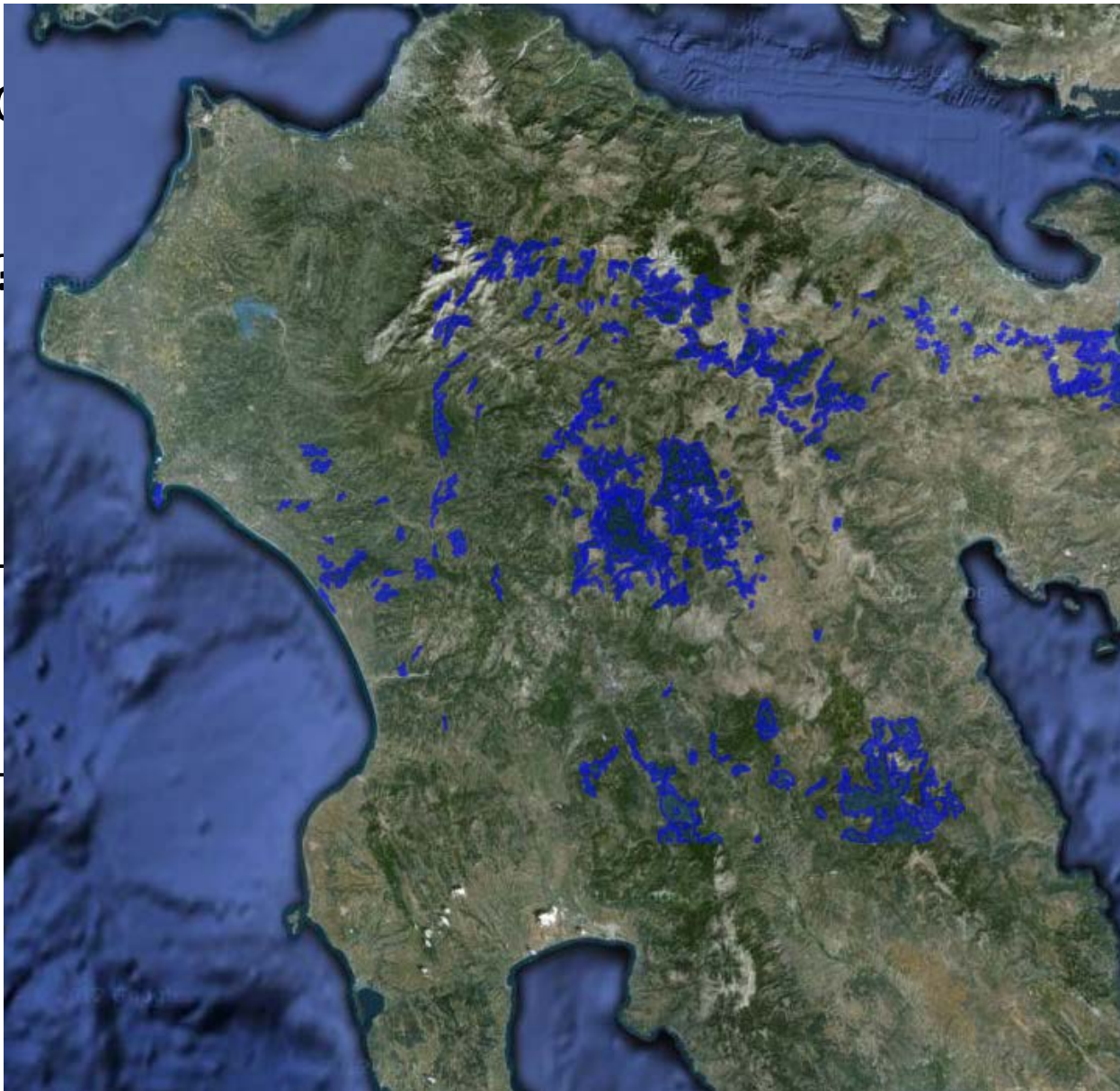
SELECT

WHERE { ?

FILE

FILE

}



pe .

1.027  
7 36.05,  
36))"  
(?aGeo)).

Get all primary roads in Pelloponnese

```
SELECT ?r ?rGeo
WHERE { ?r a ?rType ;
        noa:hasGeometry ?rGeo .
        FILTER(?rType = lgdo:Primary) .
        FILTER(strdf:contains("POLYGON( (
            21.027 38.36, 23.77 38.36,
            23.77 36.05, 21.027 36.05,
            21.027 38.36) )"^^strdf:WKT,
            ?rGeo) ) .
}
```

# Retrieving a map layer (2/3)

Get all pr

```
SELECT ?
```

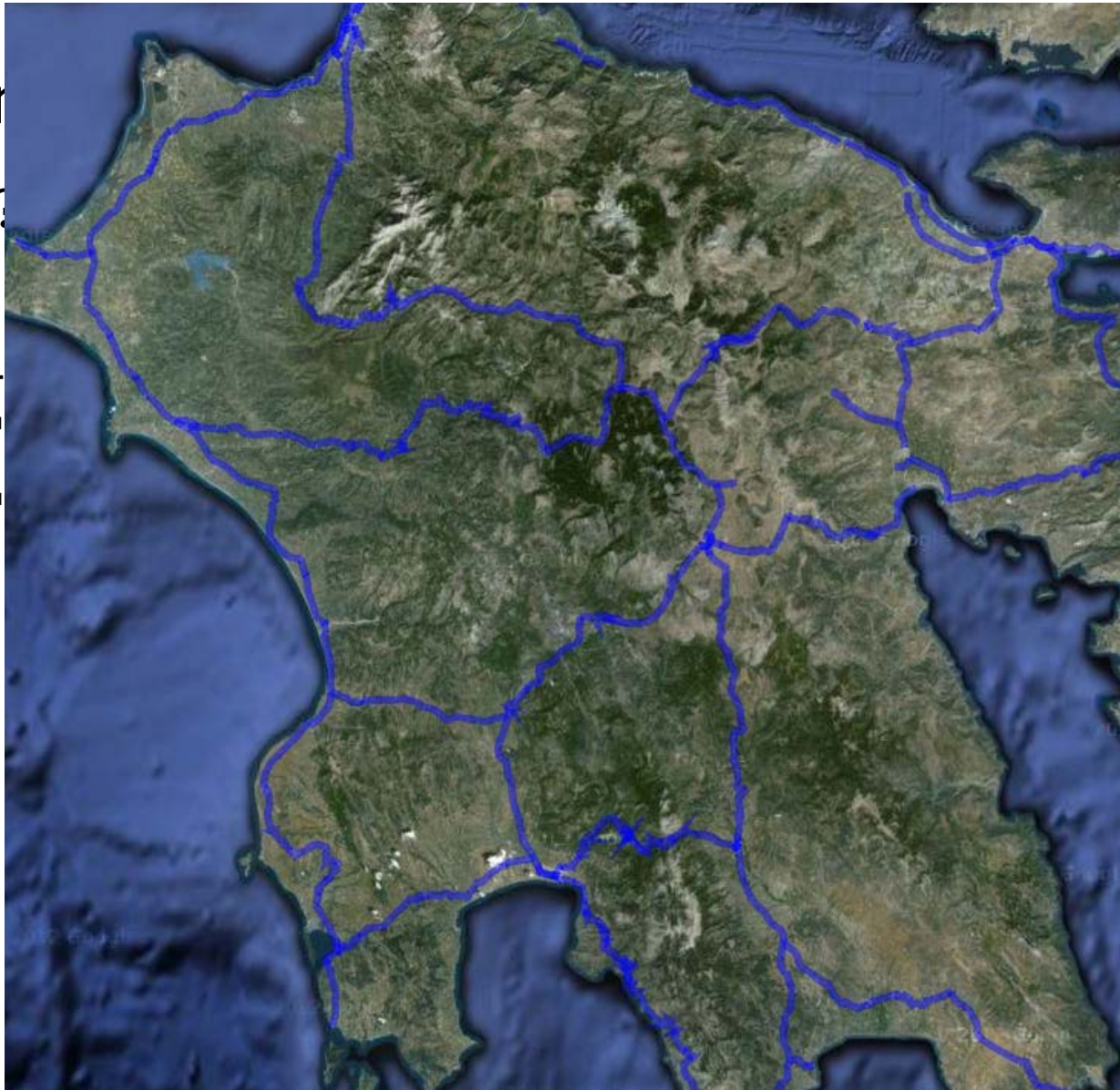
```
WHERE { ?
```

```
n
```

```
F
```

```
F
```

```
}
```



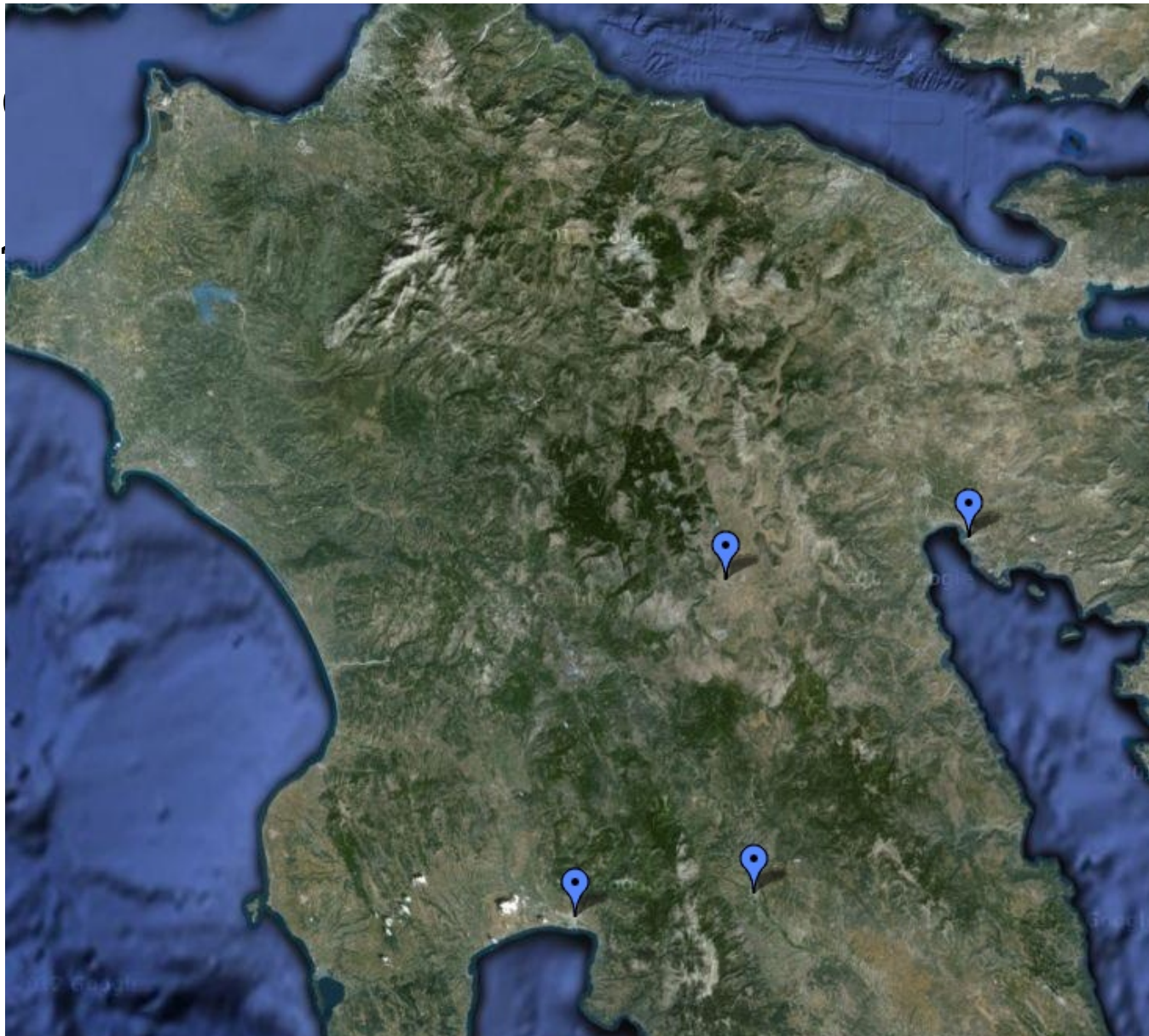
```
.  
ON ( (  
.36,  
.05,  
:WKT,
```

Get all capitals of prefectures of the Peloponnese.

```
SELECT ?feature ?fName ?fGeo
WHERE { ?feature rdf:type gn:Feature;
        noa:hasGeography ?fGeo;
        gn:name ?fName;
        gn:featureCode ?fCode.
        FILTER(?fCode = gn:P.PPLA
                || ?fCode = gn:P.PPLA2 ) .
        FILTER(strdf:contains("POLYGON((21.51
        36.41, 22.83 36.41, 22.83
        37.69, 21.51 37.69,
        21.51 6.41 ))"
                ^^strdf:WKT, ?fGeo)).
}
```

# Retrieving a map layer (3/3)

Get all  
SELECT  
WHERE {

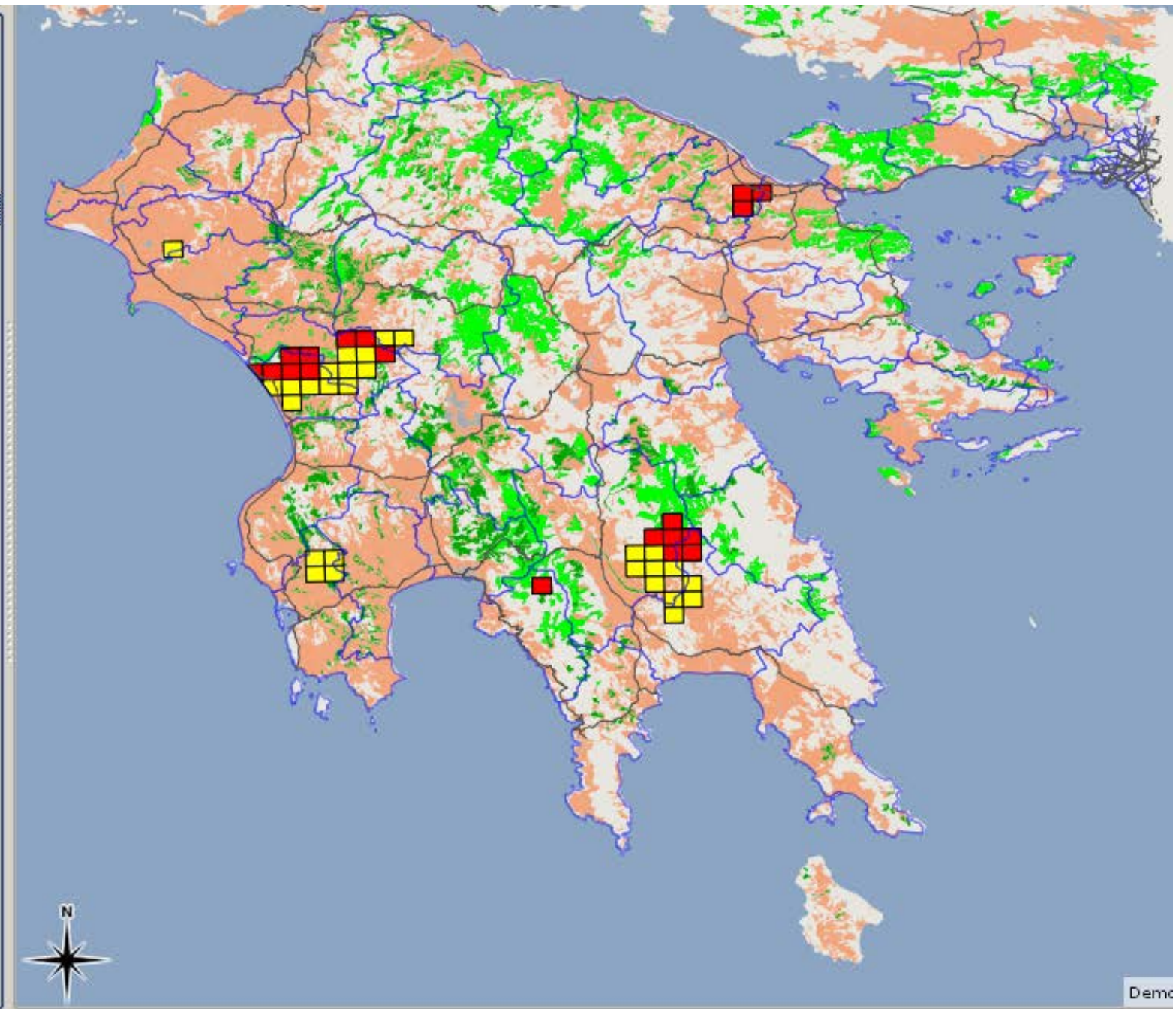
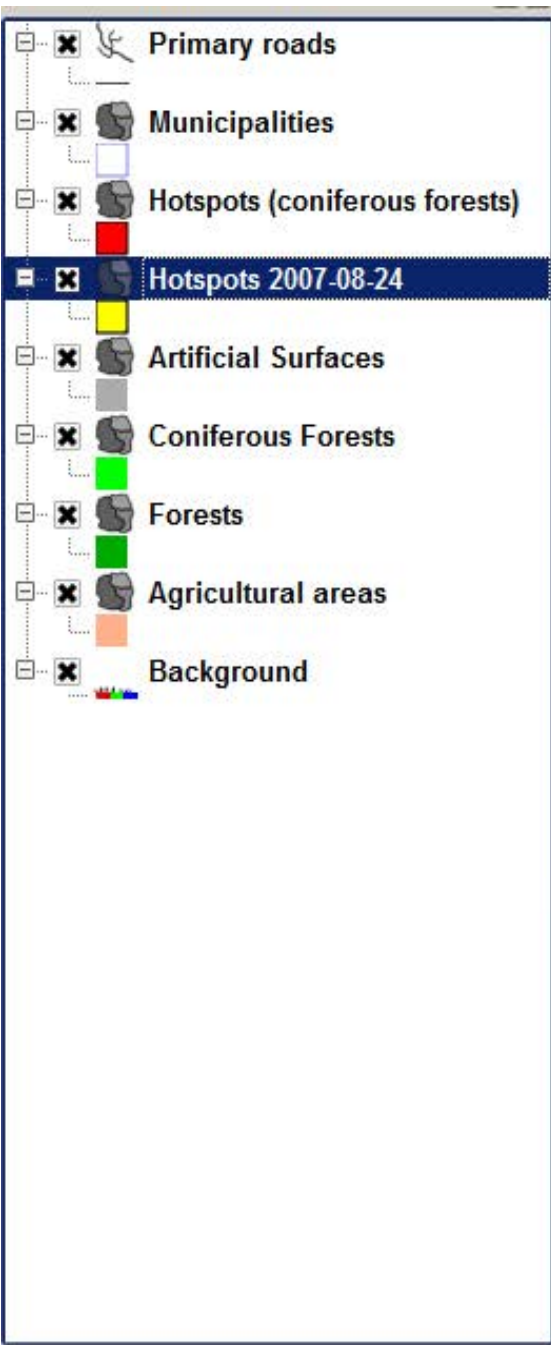


Japanese.  
oi  
.  
) .  
21.51  
2.83  
eo) ) .

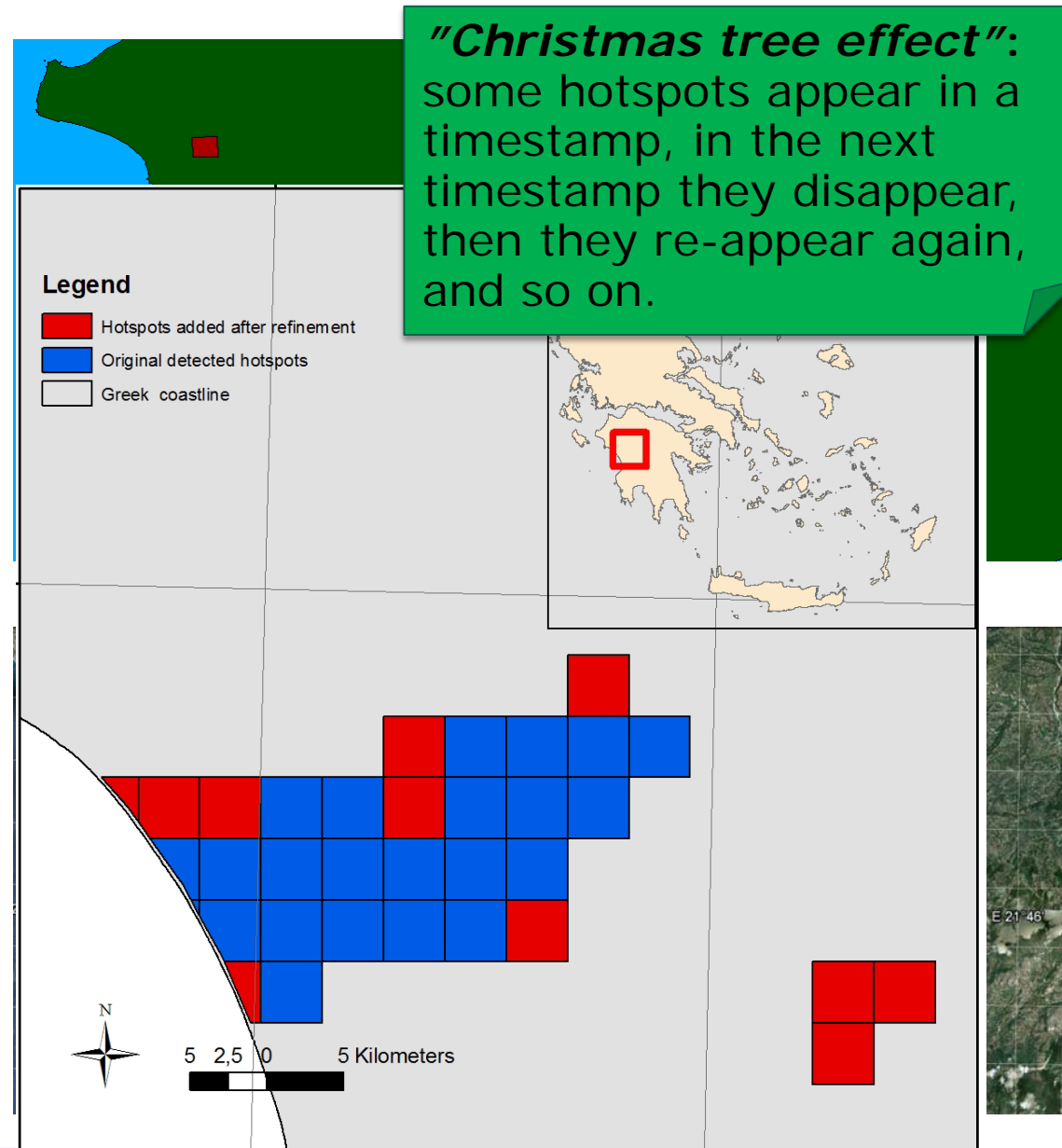
}



# Final map



- **Enrich** hotspot products
  1. Connect each hotspot with a municipality that it is located
- **Improve accuracy** with respect to **underlying area**
  2. Eliminate false alarms in sea
  3. Eliminate false alarms in inconsistent land cover areas
  4. Keep land part of the polygon
- **Improve accuracy** with respect to **temporal persistence** of each hotspots
  5. Remove “Christmas tree” effects



- **Generating maps** combining diverse information sources
- **Semantic Enrichment** for Hotspots
- **Fire monitoring** application

**DEMO!**

**<http://test.strabon.di.uoa.gr/NOA>**

Correlate fire products with auxiliary data to increase their thematic accuracy e.g., delete the parts of the polygons that fall into the sea.

```
DELETE {?h noa:hasGeometry ?hGeo}
INSERT {?h noa:hasGeometry ?dif}
WHERE {
SELECT DISTINCT ?h ?hGeo
    (strdf:intersection(?hGeo, strdf:union(?cGeo)) AS ?dif)
WHERE {
    ?h rdf:type noa:Hotspot.
    ?h strdf:hasGeometry ?hGeo.
    ?c rdf:type coast:Coastline.
    ?c strdf:hasGeometry ?cGeo.
    FILTER( strdf:anyInteract(?hGeo, ?cGeo) }
GROUP BY ?h ?hGeo
HAVING strdf:overlap(?hGeo, strdf:union(?cGeo)) }
```

# Improve the accuracy of EO data



```
HAVING strdf:overlap(?hGeo, strdf:union(?cGeo)) }
```

- **Generating maps** combining diverse information sources
- **Semantic Enrichment** for Hotspots
- **Fire monitoring** application

**DEMO!**

[http://papos.space.noa.gr/fend\\_static](http://papos.space.noa.gr/fend_static)

- The fire monitoring service was used **operationally** during the **fire season** of **2012**
- Used in a **daily basis** by the
  - Greek civil protection agency
  - Greek fire brigade
  - Greek army
- Initial user feedback very encouraging!

# Fire monitoring service

## Preliminary evaluation – Thematic accuracy

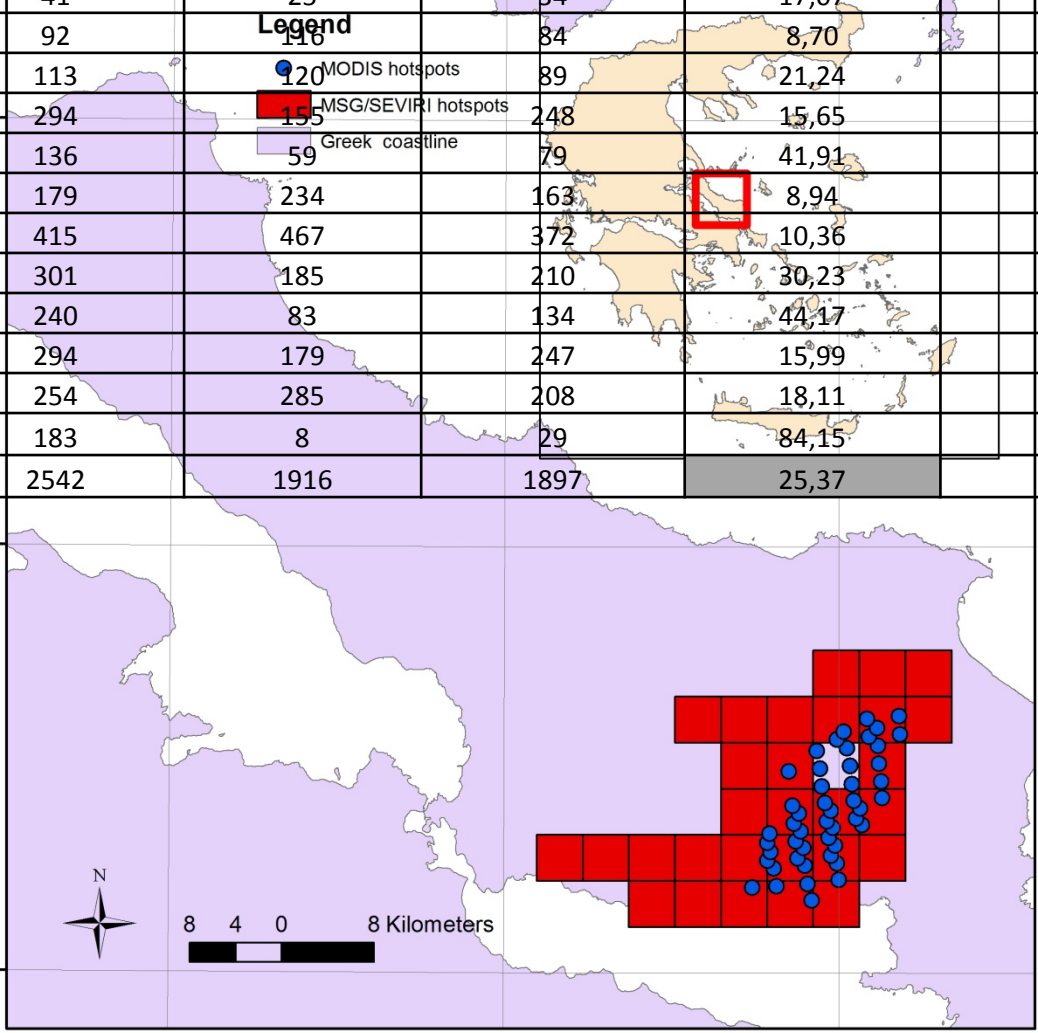


Static thresholds

Date	Time	Total No of FIRMS hotspots	Total No of MSG hotspots	No of FIRMS detected by MSG	Omission error (%)	No of MSG detected by FIRMS	False alarm rate (%)
24/8/2007	0:21	41	25	34	17,07	18	28,00
24/8/2007	9:46	92	116	84	8,70	83	28,45
24/8/2007	11:25	113	120	89	21,24	87	27,50
24/8/2007	20:51	294	155	248	15,65	126	18,71
25/8/2007	1:03	136	59	79	41,91	41	30,51
25/8/2007	8:51	179	234	163	8,94	172	26,50
25/8/2007	12:08	415	467	372	10,36	334	28,48
25/8/2007	19:55	301	185	210	30,23	166	10,27
26/8/2007	0:09	240	83	134	44,17	79	4,82
26/8/2007	9:34	294	179	247	15,99	132	26,26
26/8/2007	11:12	254	285	208	18,11	214	24,91
26/8/2007	20:39	183	8	29	84,15	8	0,00
Total		2542	1916	1897	25,37	1460	23,80

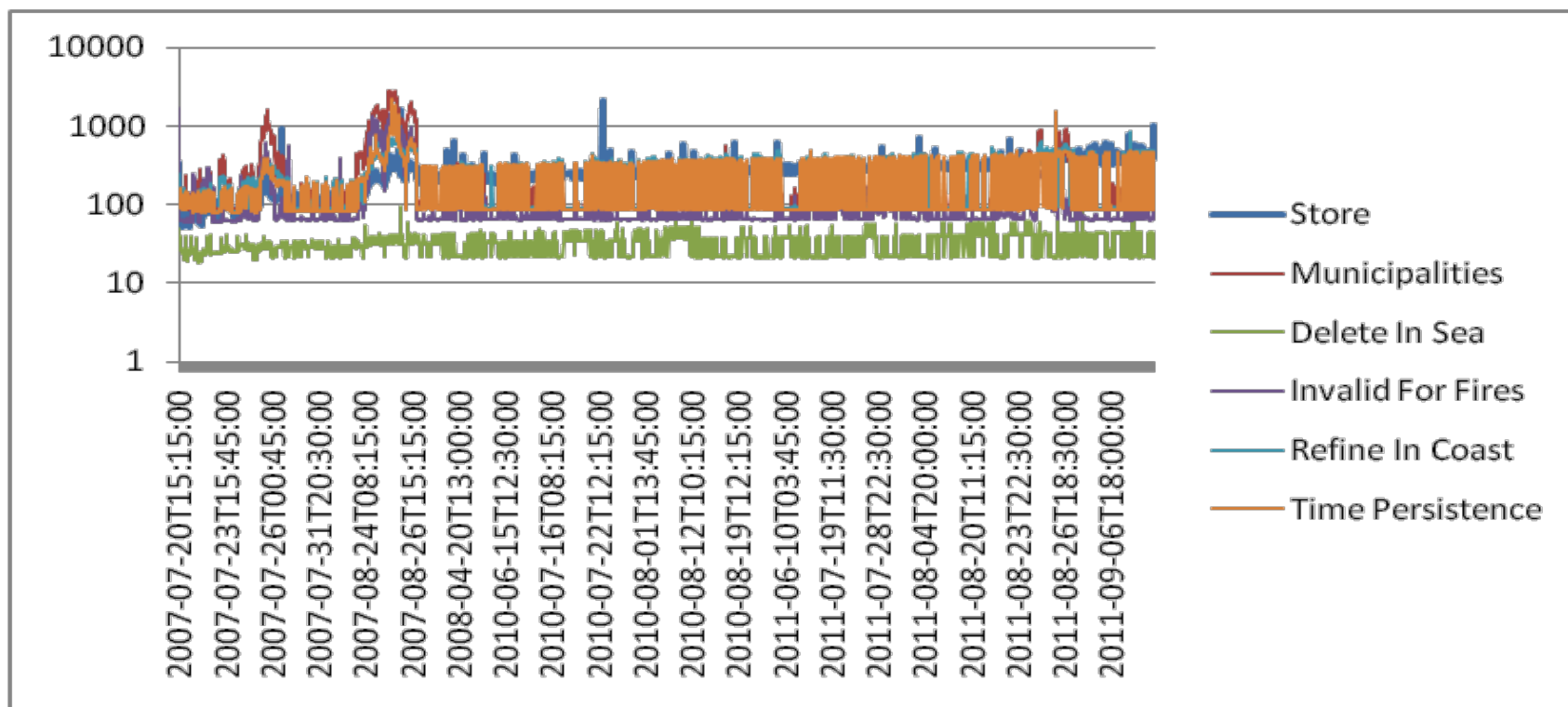
Dynamic thresholds

Date	Time	Total No of FIRMS hotspots	Total No of MSG hotspots	No of FIRMS detected by MSG	Omission error (%)	No of MSG detected by FIRMS	False alarm rate (%)
24/8/2007	0:21	41	25	34	17,07	36	40,00
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24/8/2007	11:25	113	120	89	21,24	87	27,50
24/8/2007	20:51	294	155	248	15,65	186	35,19
25/8/2007	1:03	136	59	79	41,91	153	29,17
25/8/2007	8:51	179	234	163	8,94	172	26,50
25/8/2007	12:08	415	467	372	10,36	334	28,48
25/8/2007	19:55	301	185	210	30,23	320	27,60
26/8/2007	0:09	240	83	134	44,17	216	15,95
26/8/2007	9:34	294	179	247	15,99	132	26,26
26/8/2007	11:12	254	285	208	18,11	214	25,44
26/8/2007	20:39	183	8	29	84,15	68	26,09
Total		2542	2757	2252	11,41	2001	27,42





- Product ingestion, processing and refinement is completed in less than 12 seconds
- More refinement operations to be added later given the five minutes time frame



- General architecture for EO applications enriched with semantic web technologies
- The Fire Monitoring Service of the National Observatory of Athens
  - Architecture
  - Improving the service using semantic technologies

- Use **higher-level languages**, stop worrying about how to store and manage metadata, just **focus** on the actual **processing**
- Express common earth observation operations easily using the **stSPARQL/GeoSPARQL queries** instead of using a lengthy **C** program
- **Rapid prototyping** and new refinement modules without the need to recompile everything

# Thank you for your attention!

Real-time fire monitoring application

[http://papos.space.noa.gr/fend\\_static/](http://papos.space.noa.gr/fend_static/)

Examples of stSPARQL queries:

<http://test.strabon.di.uoa.gr/NOA/>

More information about TELEIOS:

<http://www.earthobservatory.eu/>

Linked Open Geospatial Data Portal

<http://www.linkedopendata.gr/>