Building Remote Sensing Applications Using Semantic Web Technologies

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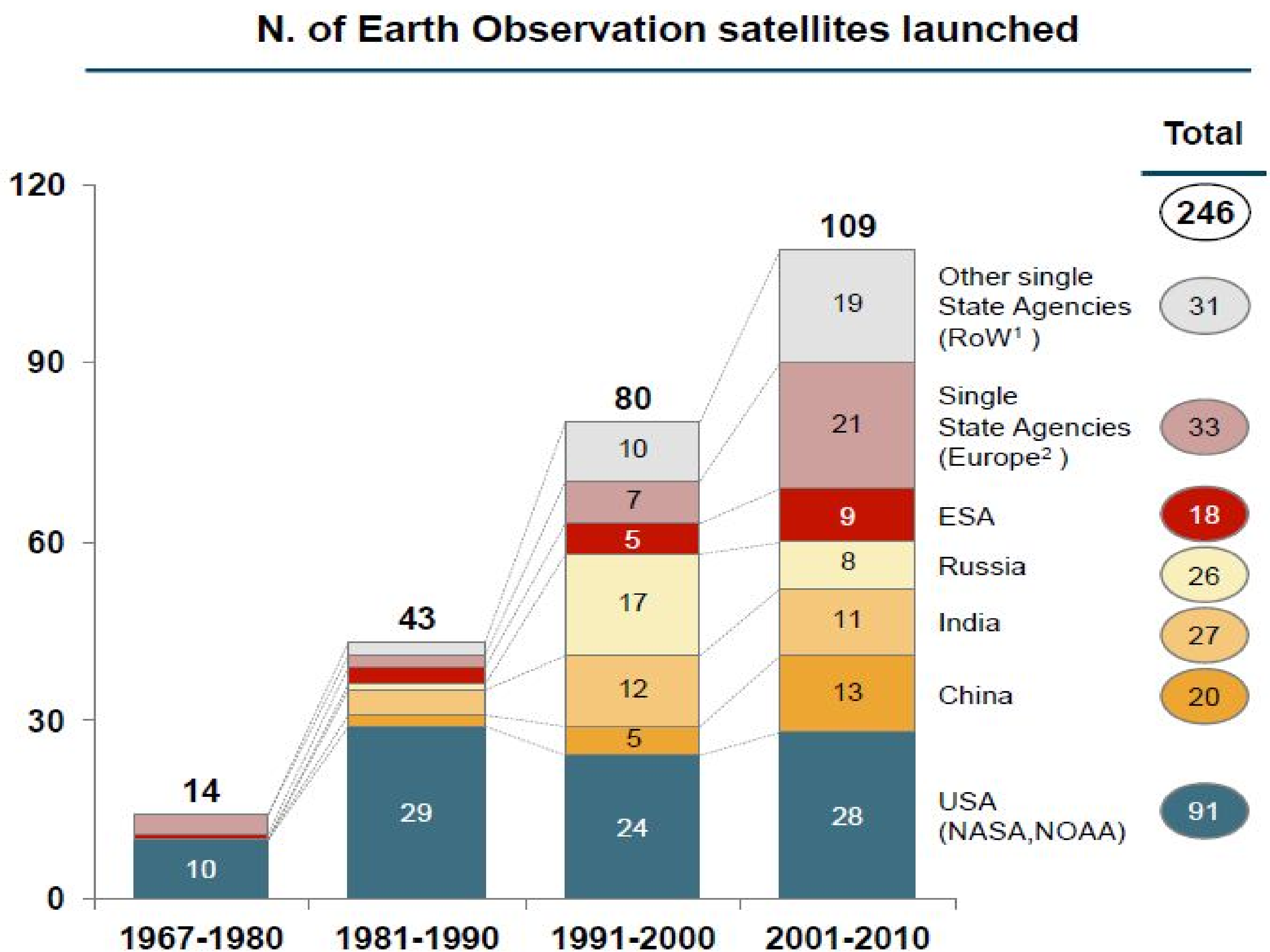
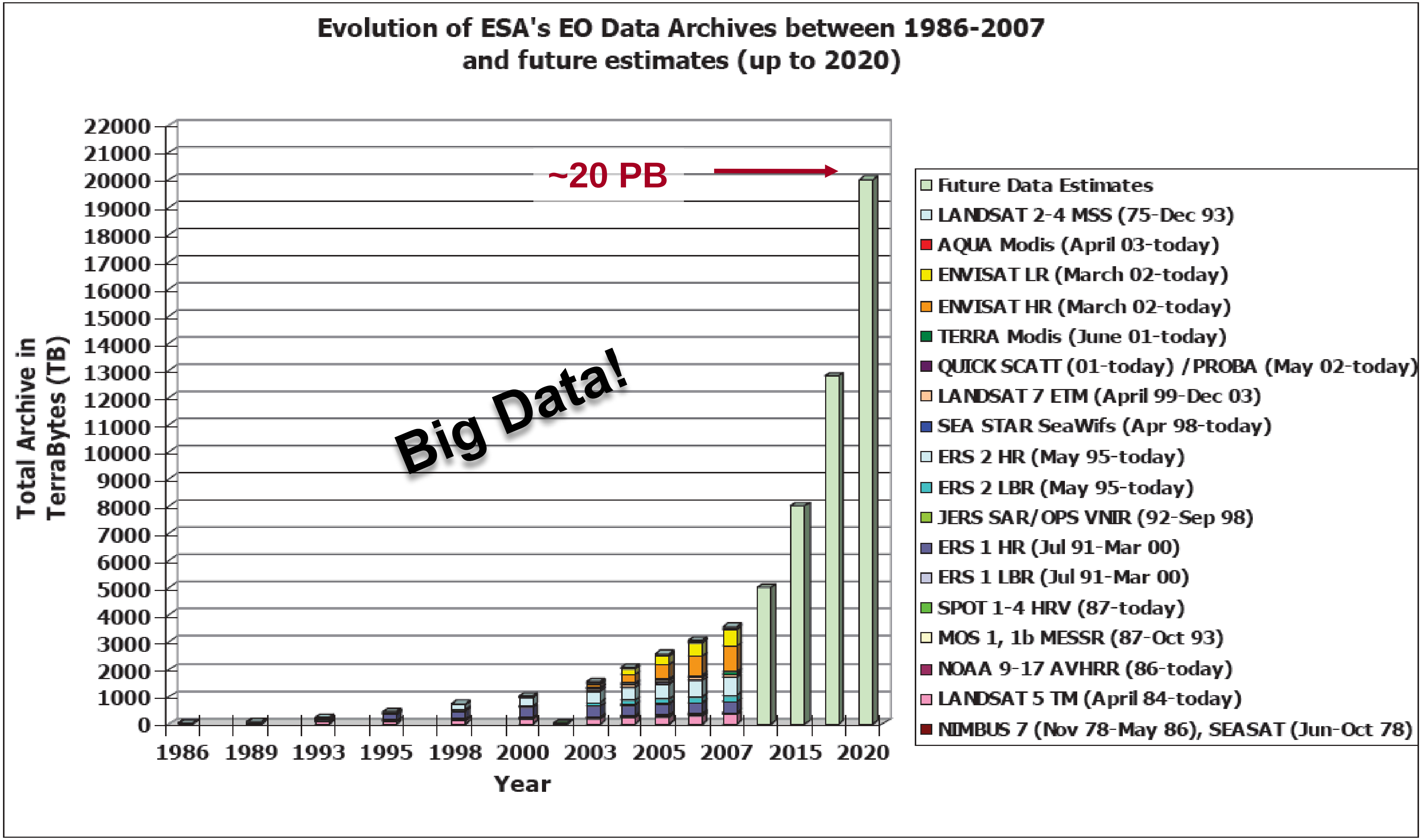
Outline

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

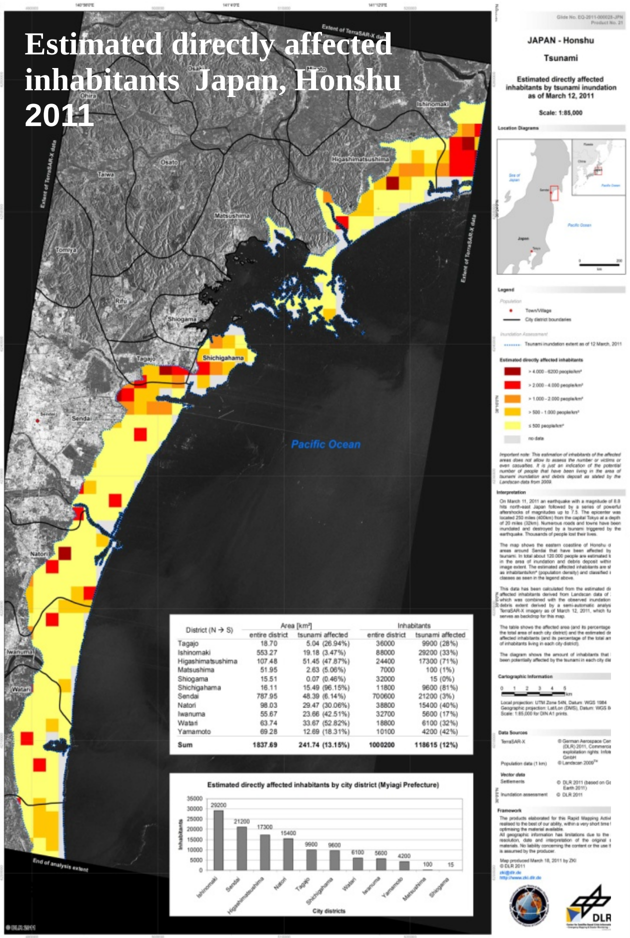
Motivation

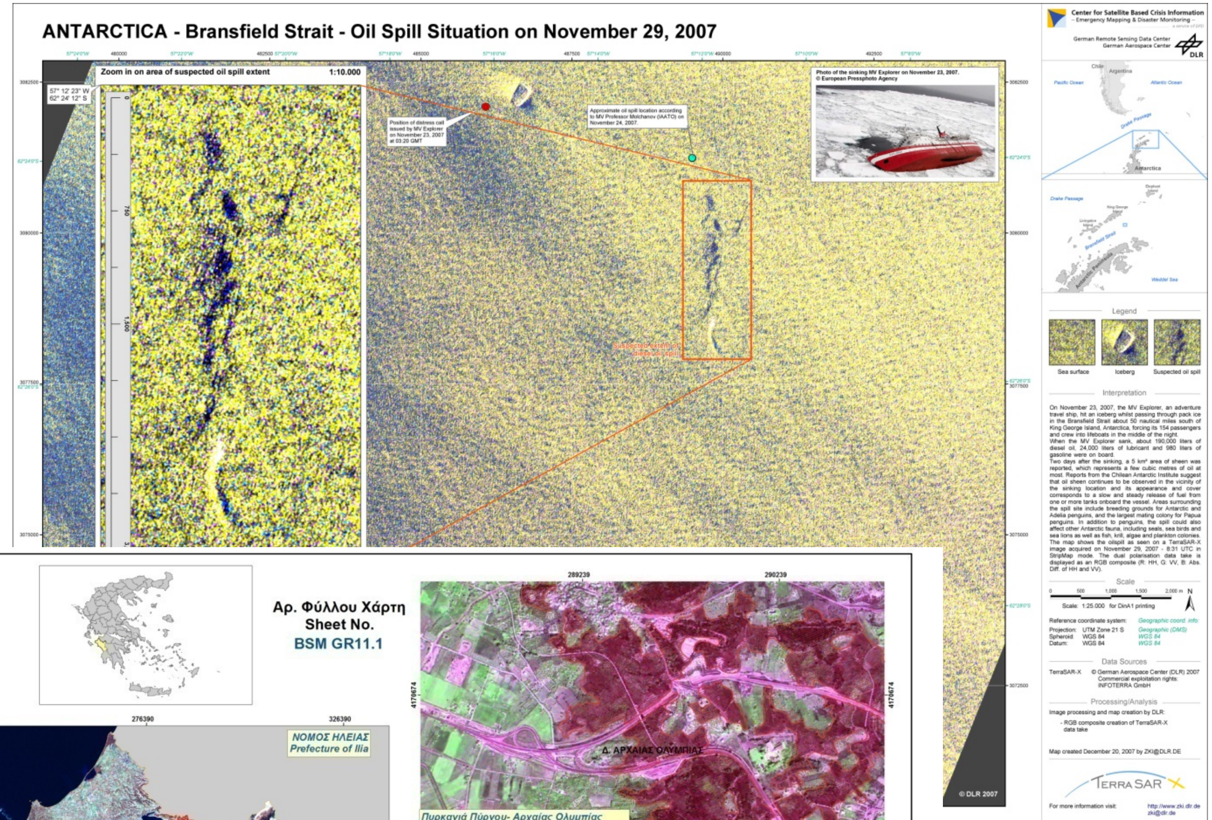

N. of Earth Observation satellites launched
Total
120
90
60
30
0
14
43
80
109
10
29
24
28
5
13
12
11
17
8
5
9
7
21
10
19
1967-1980
1981-1990
1991-2000
2001-2010
Other single State Agencies (RoW¹)
Single State Agencies (Europe²)
ESA
Russia
India
China
USA (NASA,NOAA)
246
31
33
18
26
27
20
91

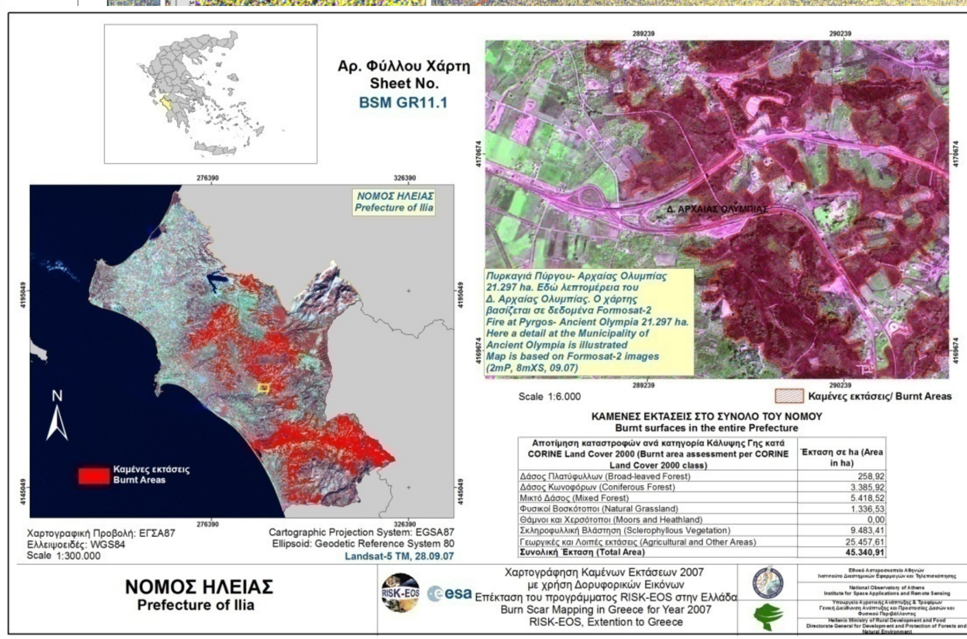
Motivation (cont'd)



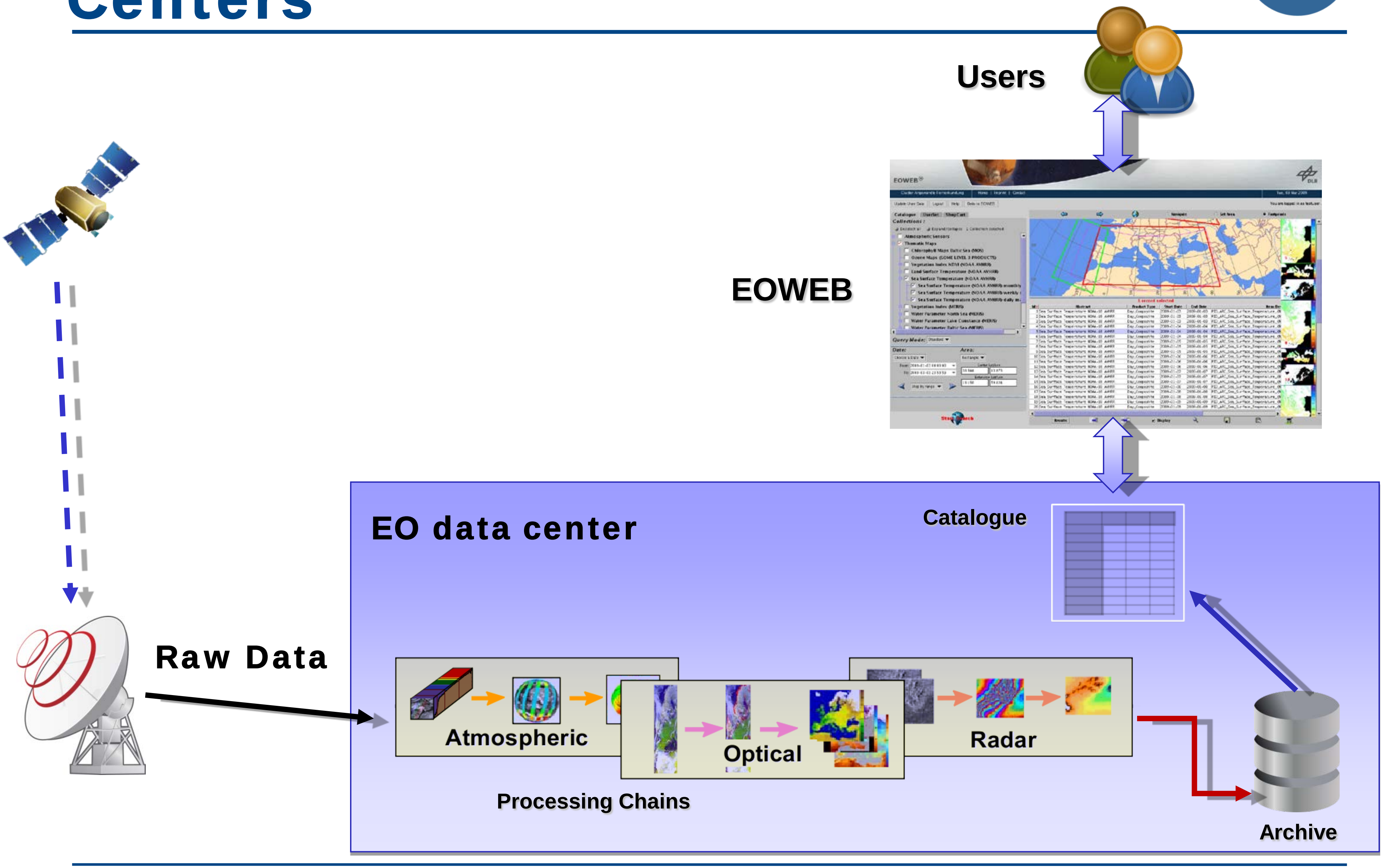
Motivation (cont'd)







State of the Art in EO Data Centers

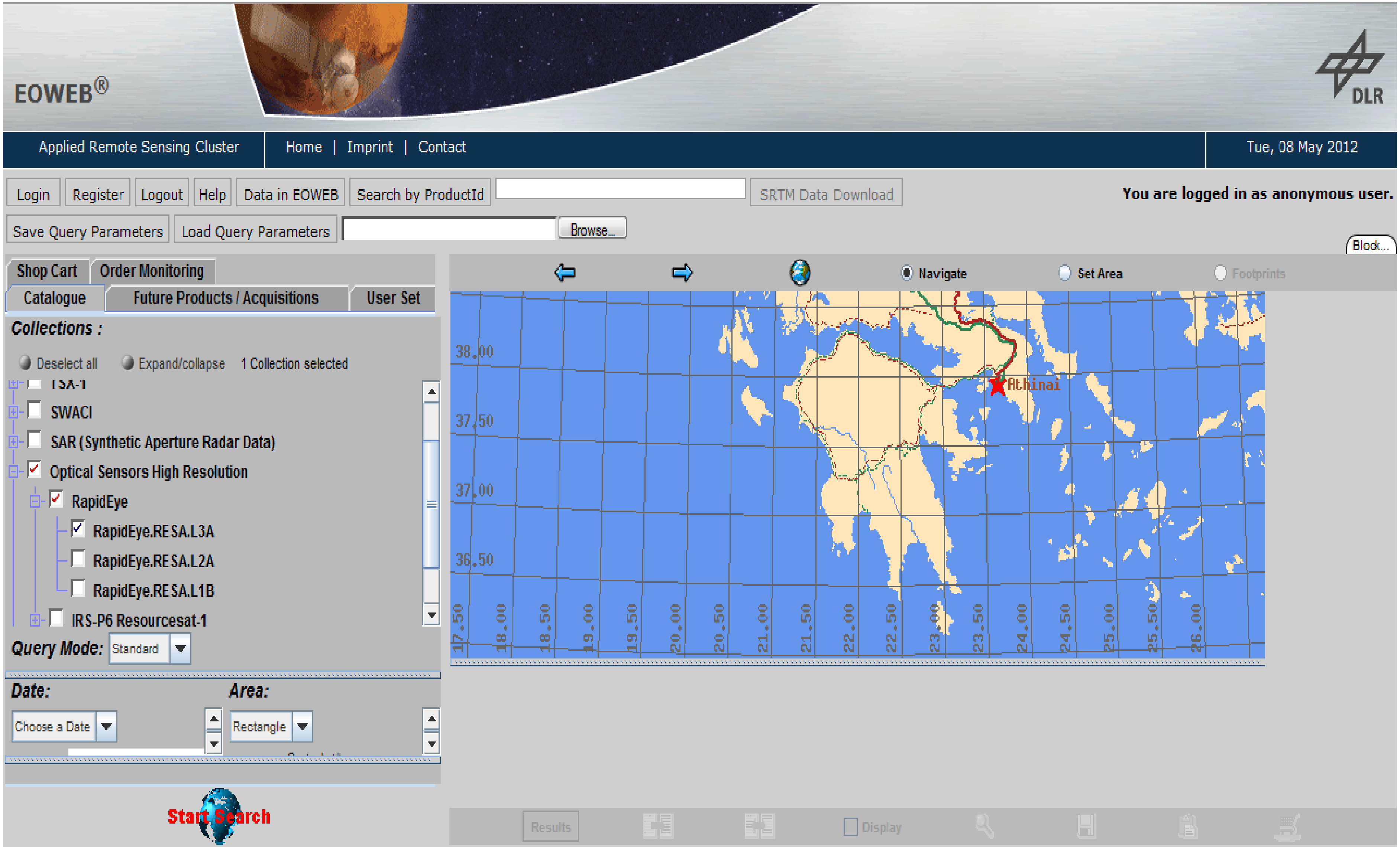


Example

- 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)



Example (cont'd)

- 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.**

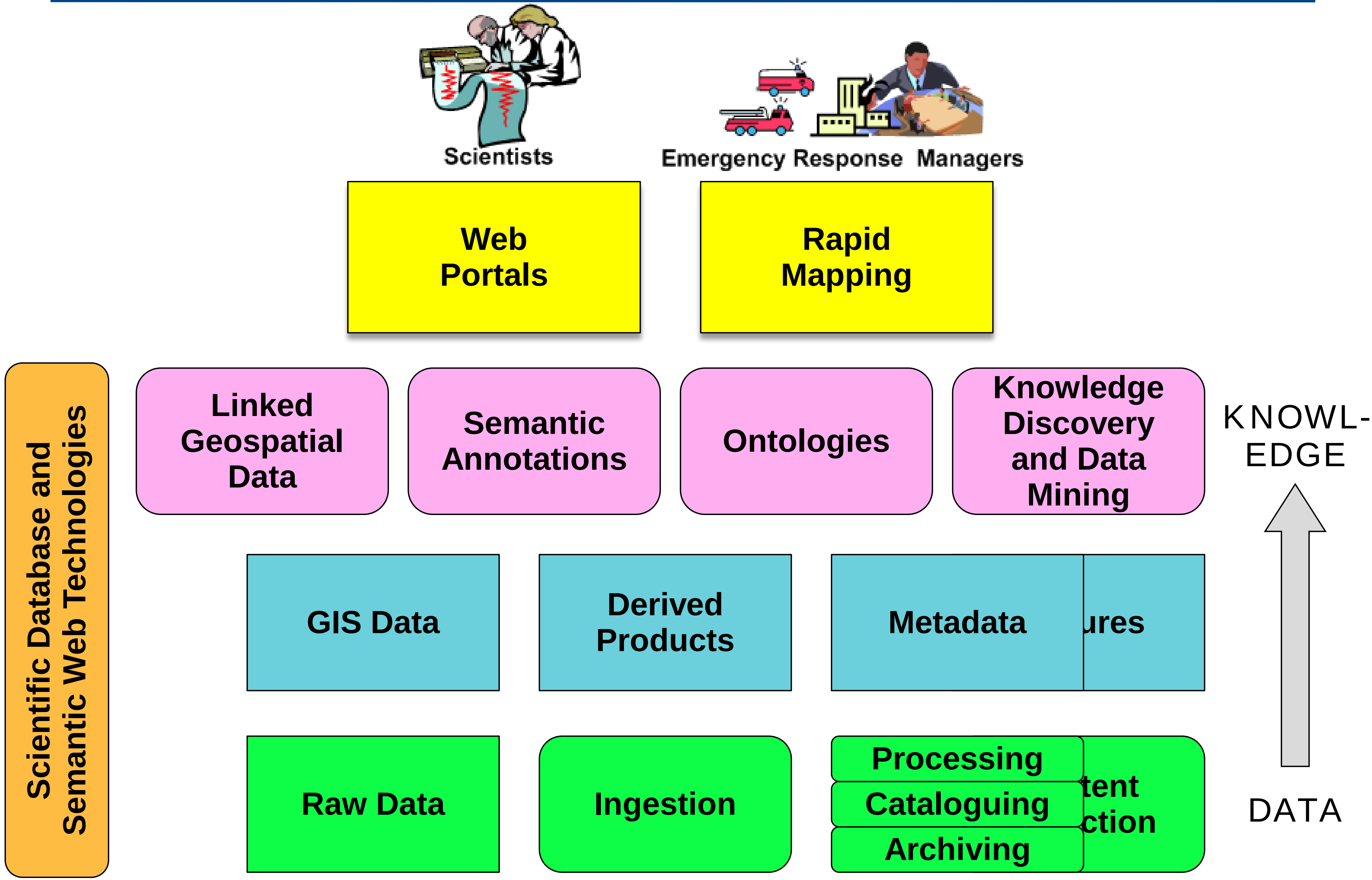
Example (cont'd)

- But why?

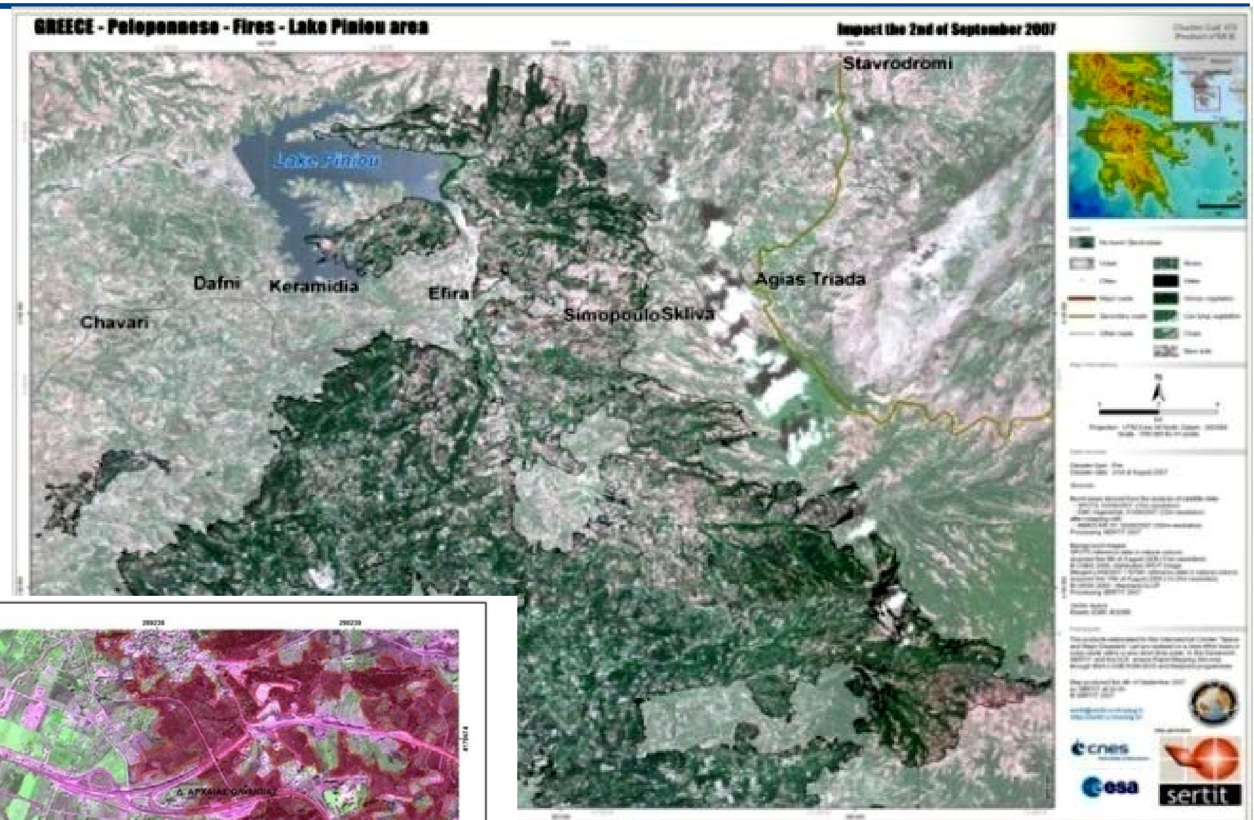
- All this information is available in the **satellite images** and other **auxiliary data sources** of EO data centers or **on the Web.**

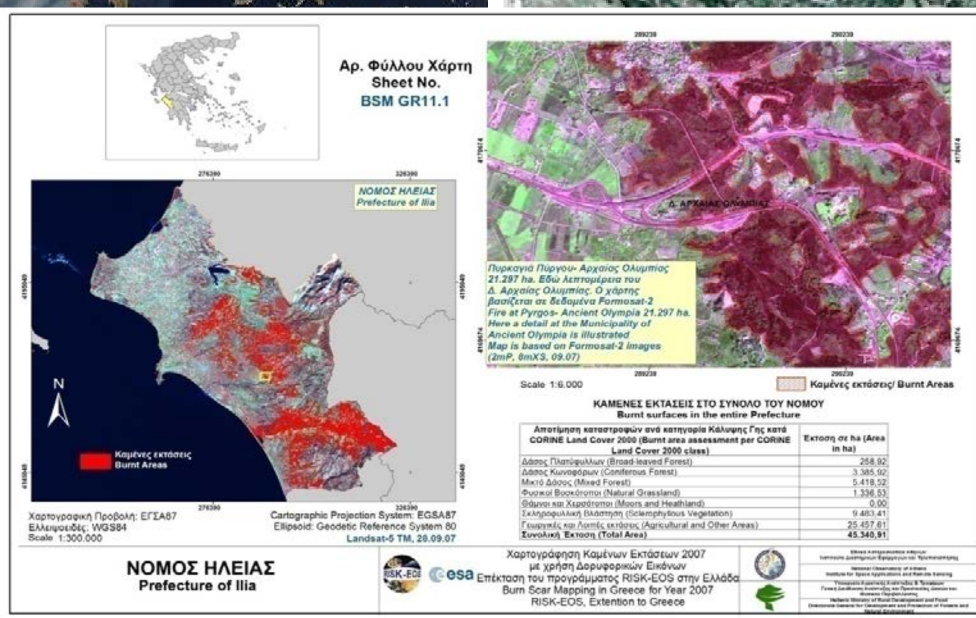
- However, EO data centers today do not allow:
  - **the mining of satellite image content** and
  - **its integration with other relevant data sources** so the previous query can be answered.

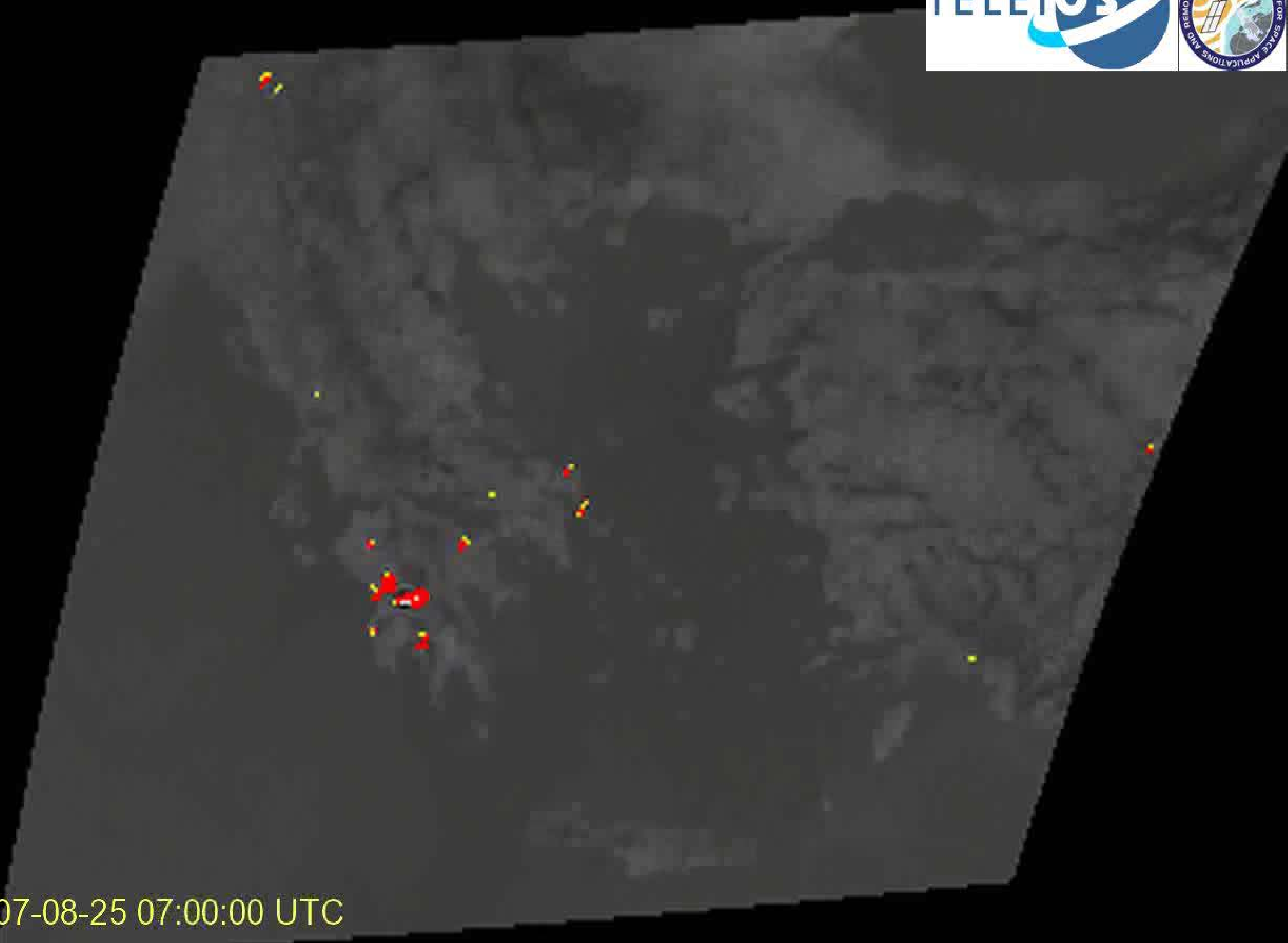
The TELEIOS Earth Observatory: Concept View



Wildfire Monitoring and Burnt Area Mapping (NOA)



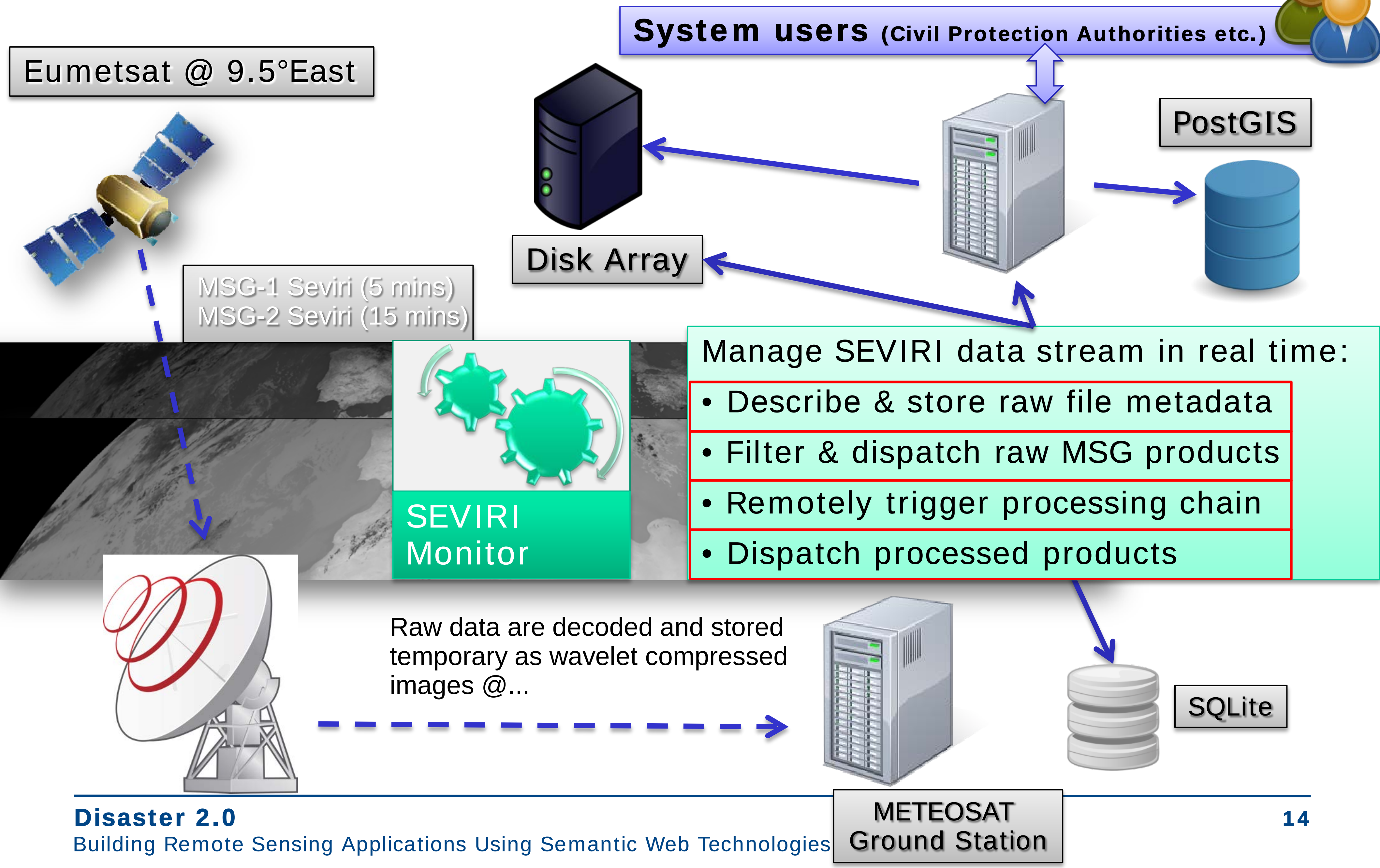




2007-08-25 07:00:00 UTC

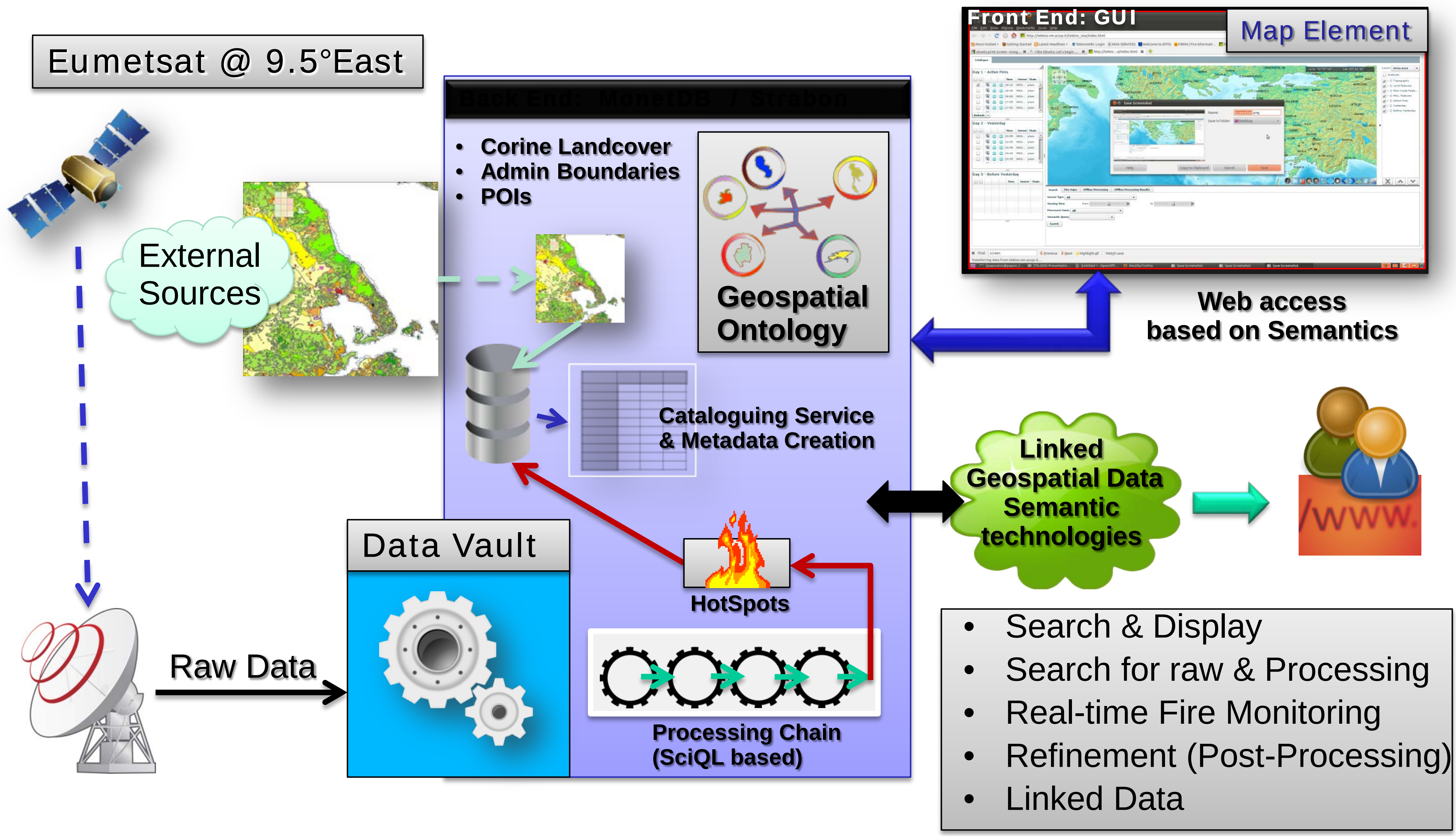
Fire monitoring application

Pre-TELEIOS practice



Fire monitoring application

Advancements - Integration of the TELEIOS technologies



High Level Data Modeling

- 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**

The Data Model stRDF

[ESWC 2010, ISWC 2012]

- **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)

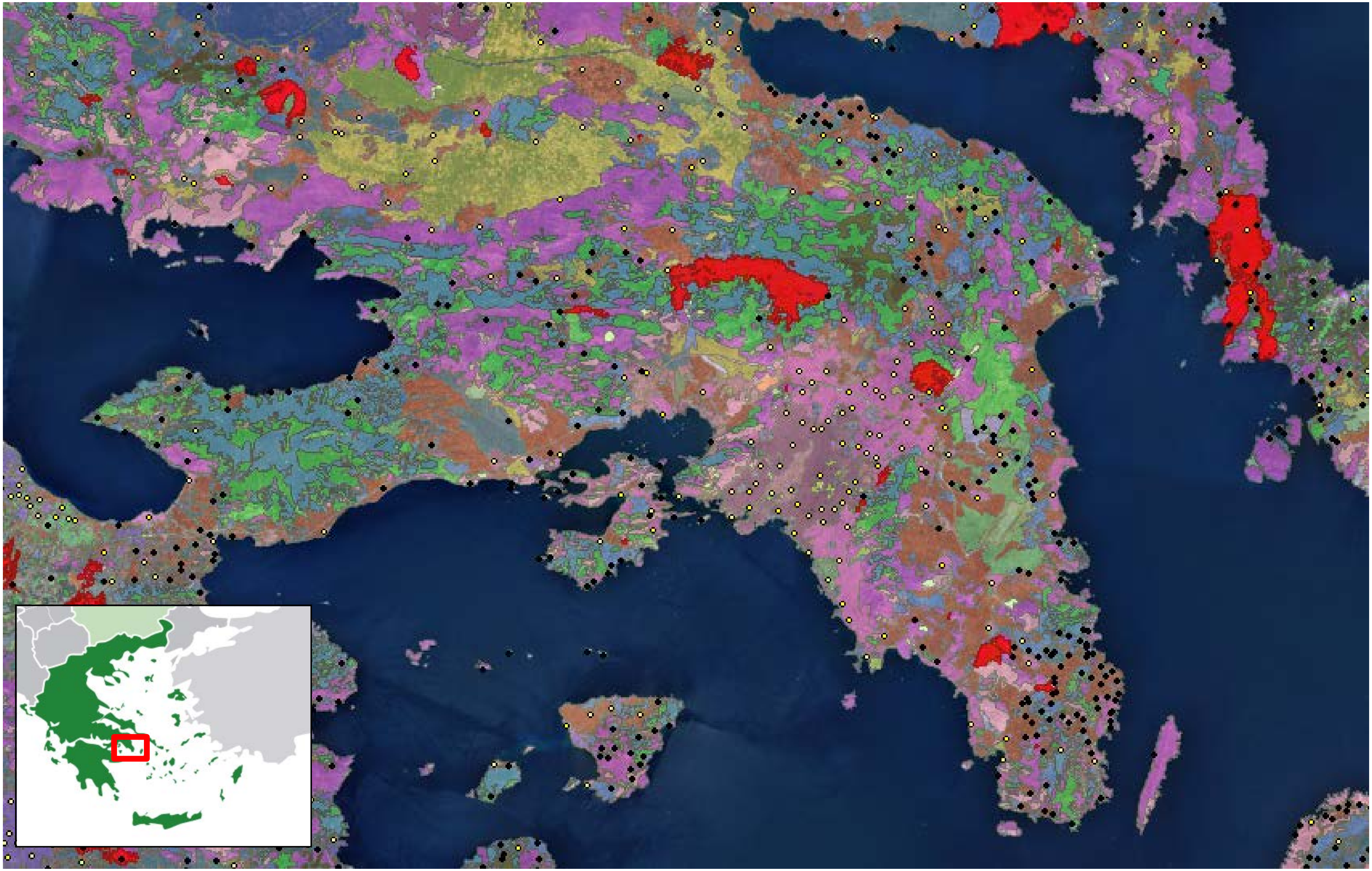
RDF: Resource Description Framework

W3C recommendation

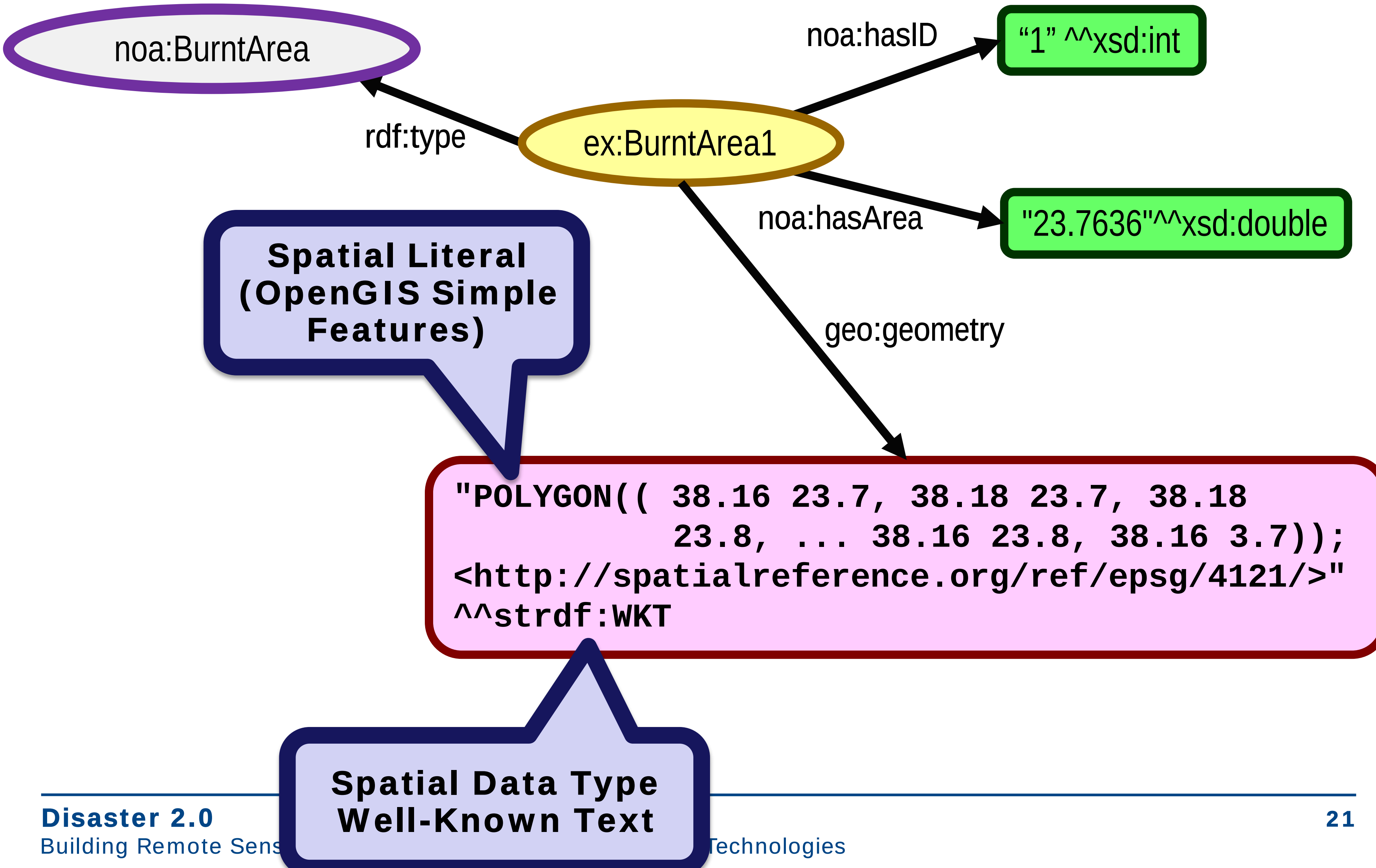
RDF is a **graph data model** (+ XML syntax + semantics)

- 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

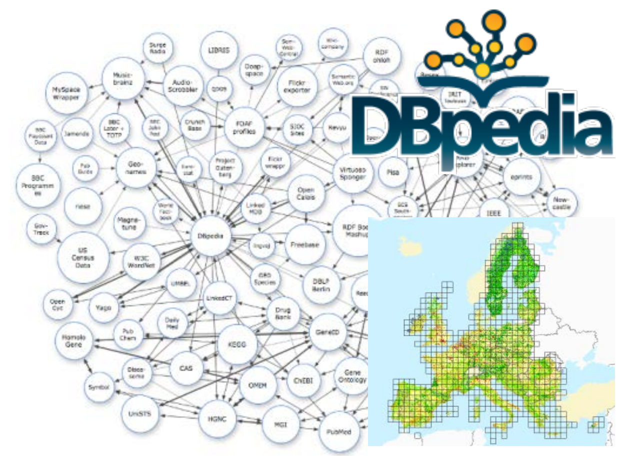


stRDF: An example



stSPARQL: An example

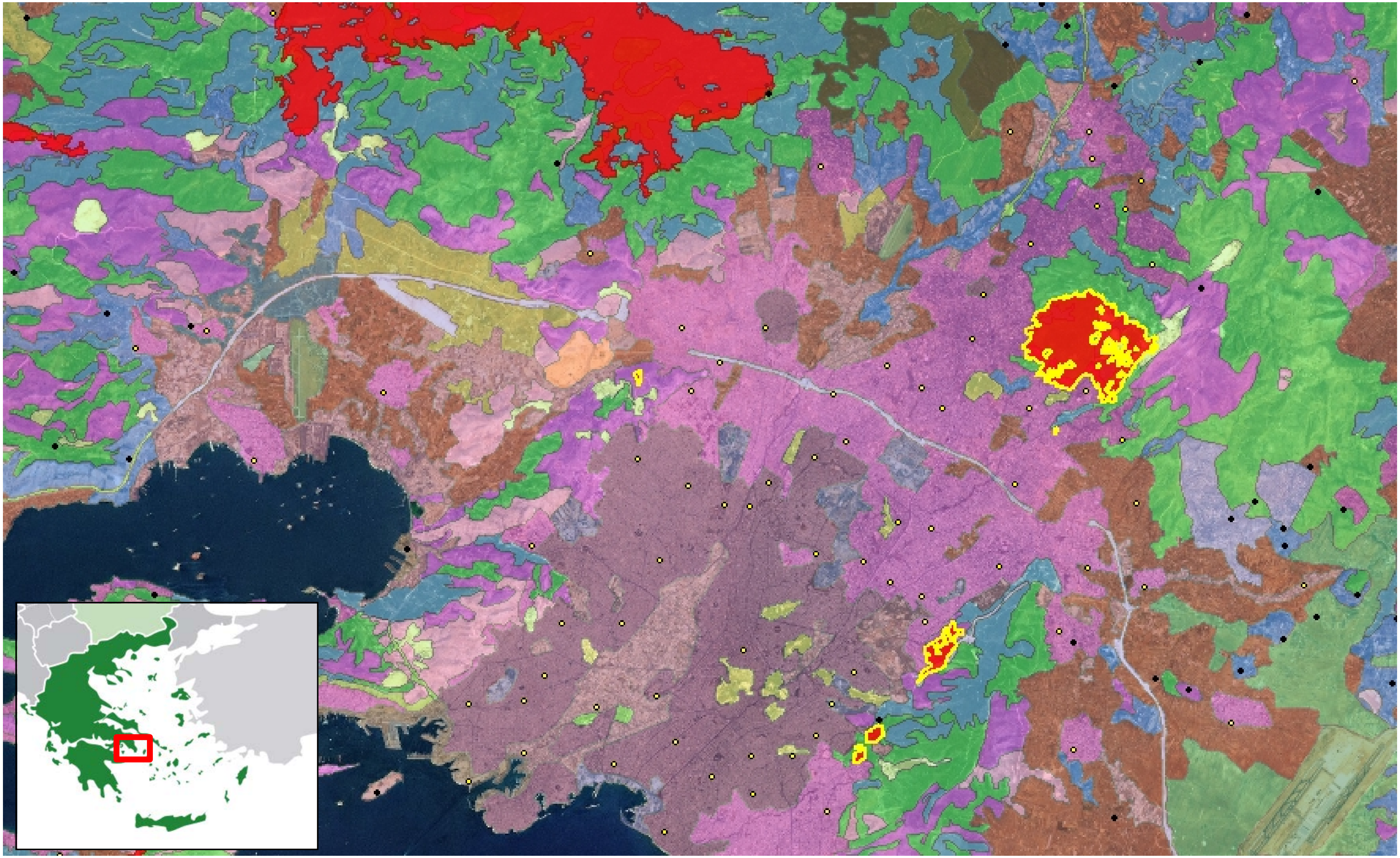
- Find all burned forests within 10kms of a city



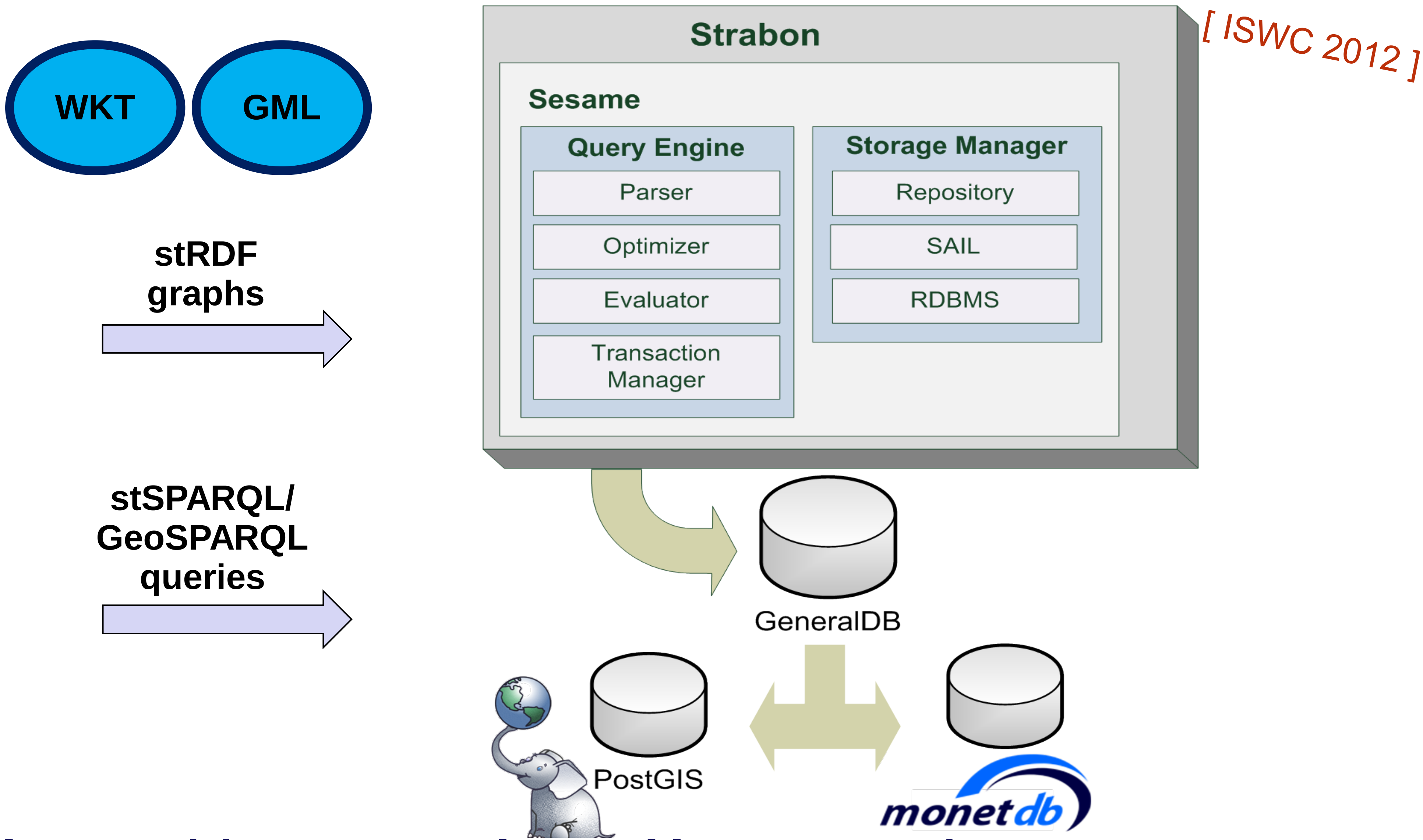

```
select ?BA ?BAGEO
where { ?R    rdf:type noa:Region ;
              geo:geometry ?RGEO ;
              noa:hasCorineLandCoverUse ?F .
        ?F    rdfs:subClassOf clc:Forests .
        ?CITY    rdf:type dbpedia:City ;
                 geo:geometry ?CGEO .
        ?BA      rdf:type noa:BurntArea
                 geo:geometry ?BAGEO .
        filter(  strdf:Intersect(?RGEO,?BAGEO) &&
                 strdf:Distance(?BAGEO,?CGEO) < 10000) }
```

Spatial Functions (OGC Simple Feature Access)

stSPARQL: An example



Strabon: A Scalable Geospatial RDF Store



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

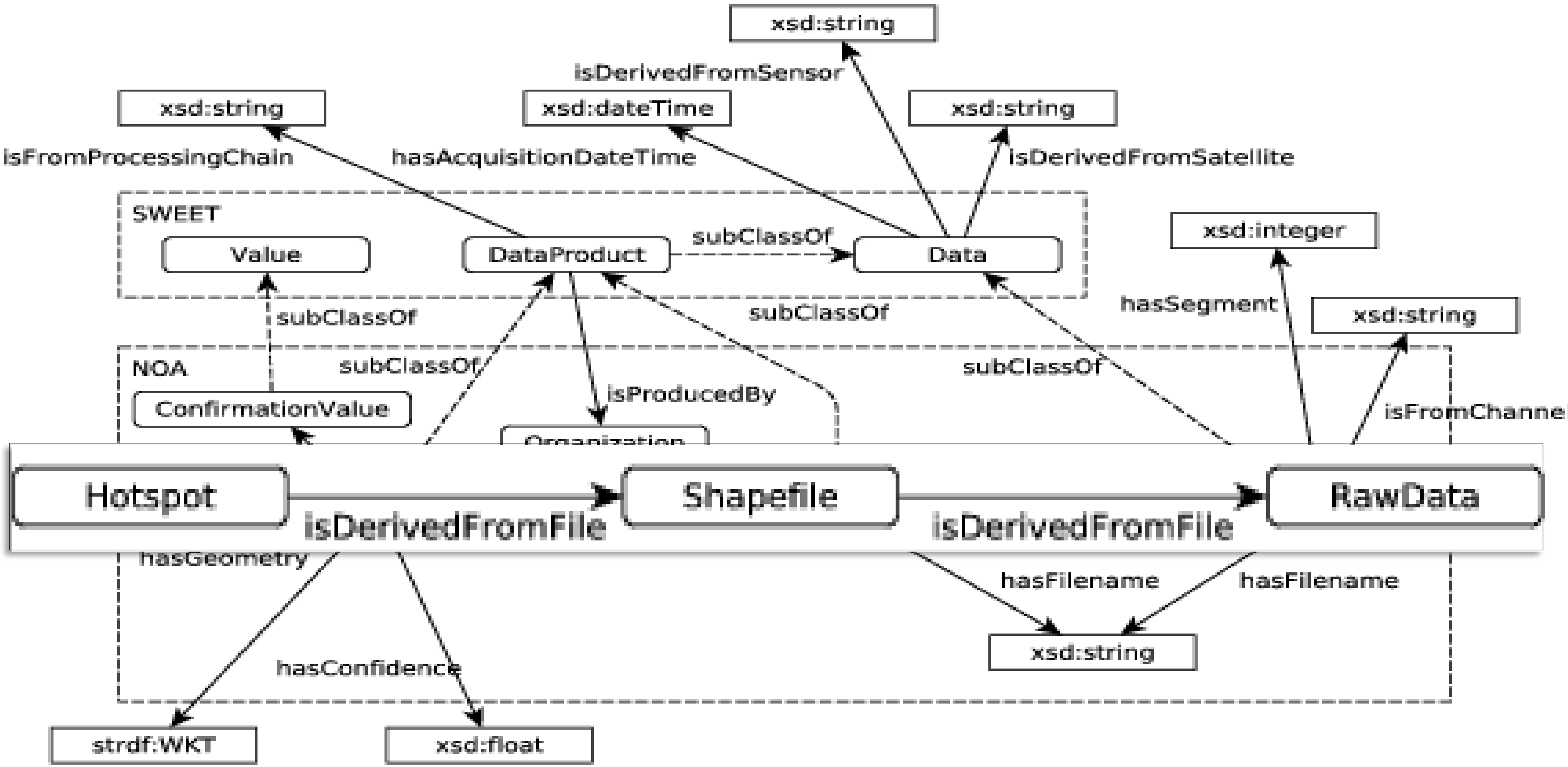
Fire monitoring application

- 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 Semantic Web Challenge 3'rd place winner]

http://papos.space.noa.gr/fend_static/

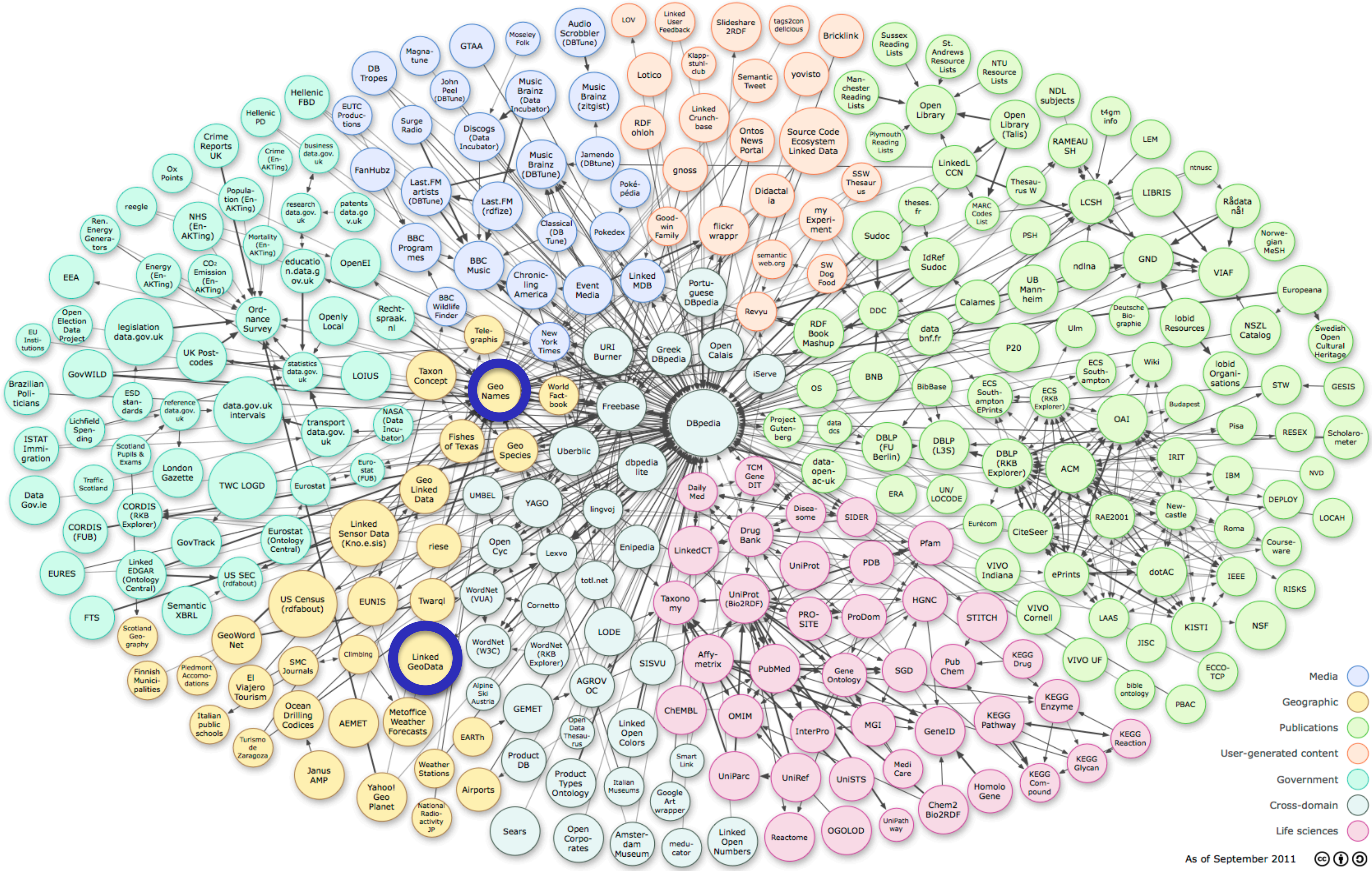
NOA Ontology



Linked Geospatial Data

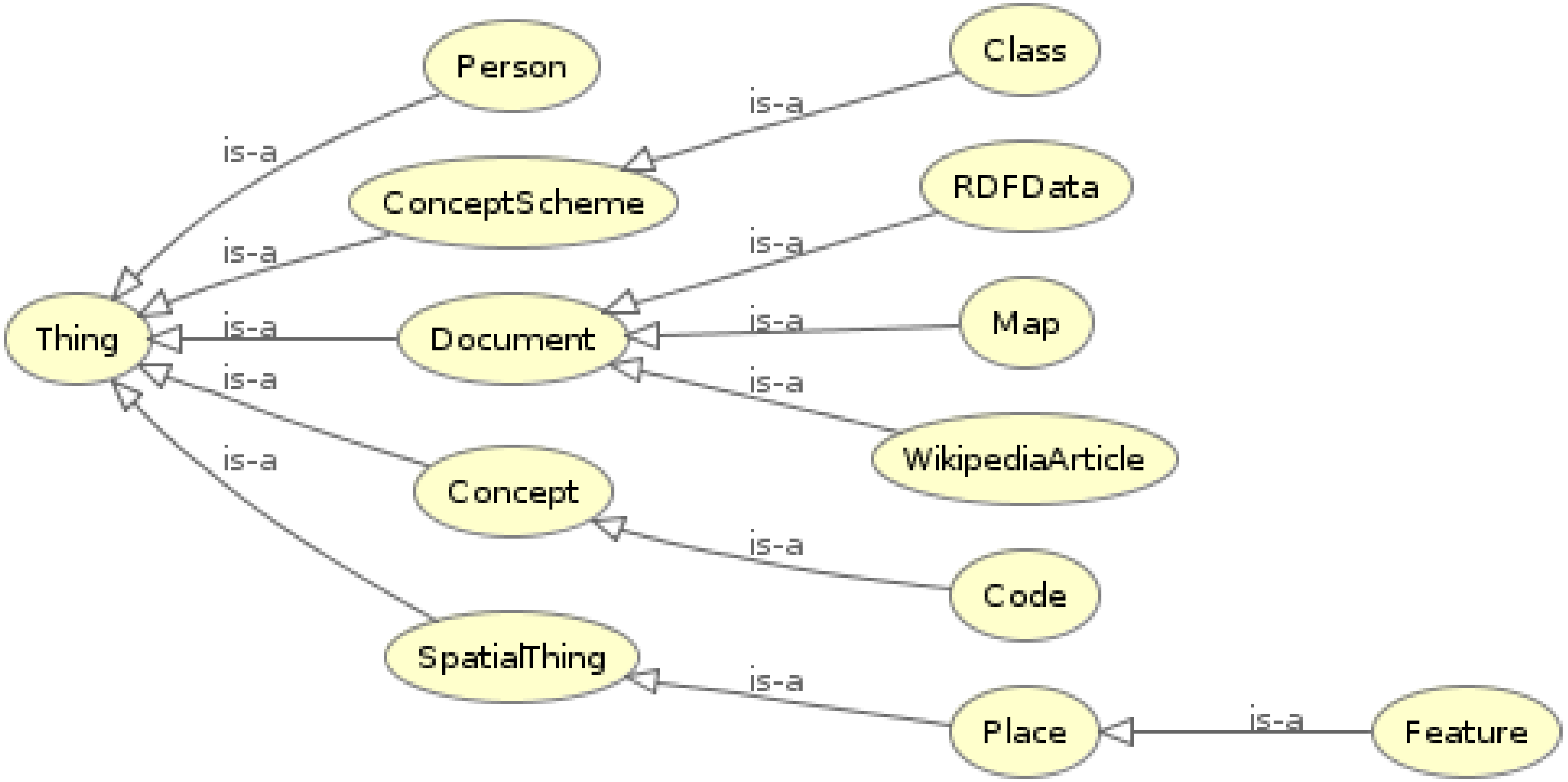
- Datasets that we developed and published as linked data:
  - Corine Land Use / Land Cover
  - Coastline of Greece
  - Greek Administrative Geography
- Portal: **http://www.linkedopendata.gr/**
- Datasets from Linked Open Data Cloud
  - LinkedGeoData
  - GeoNames

Linked Open Data Cloud



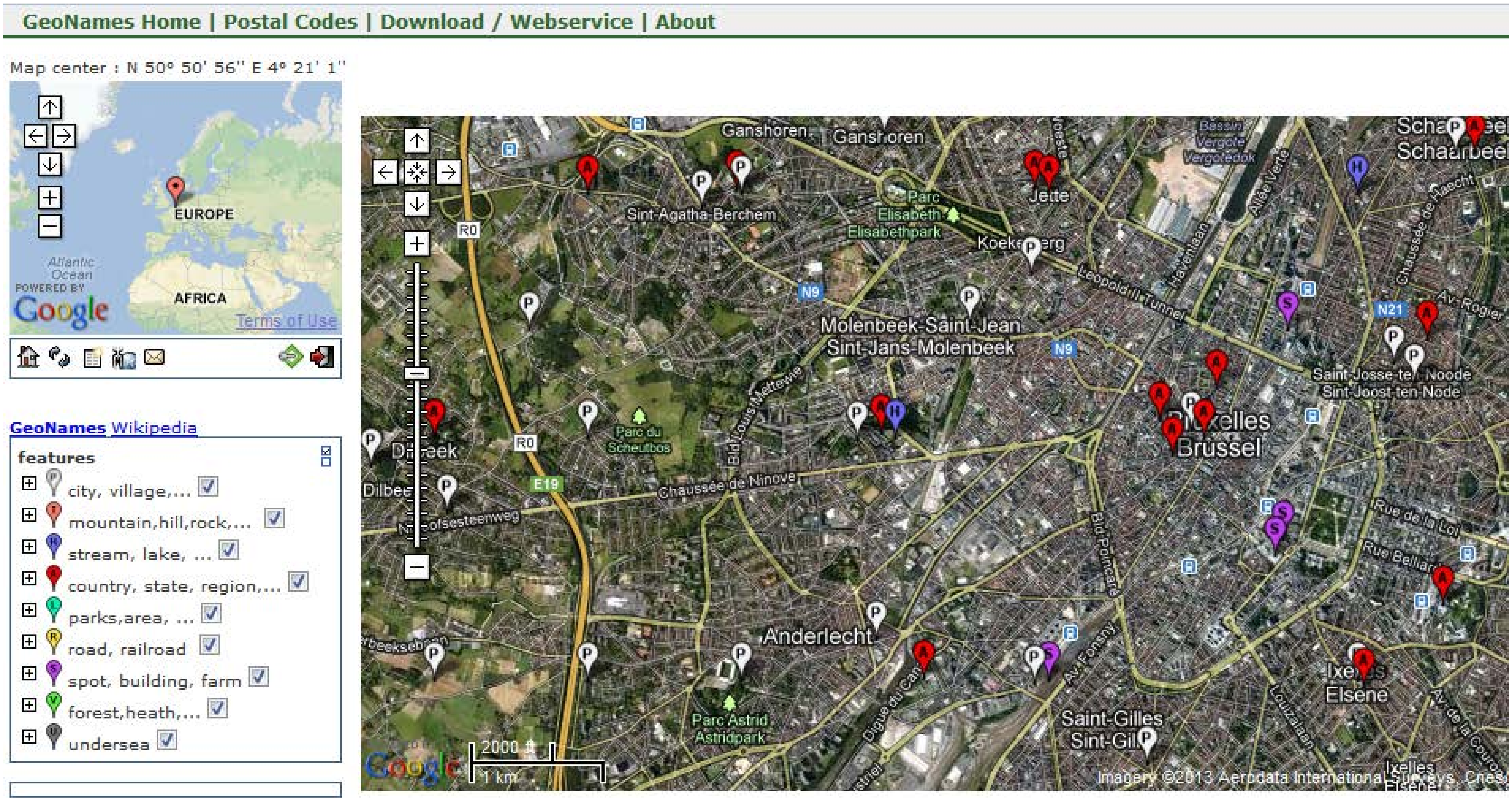
Linked Open Data (1/5)

GeoNames



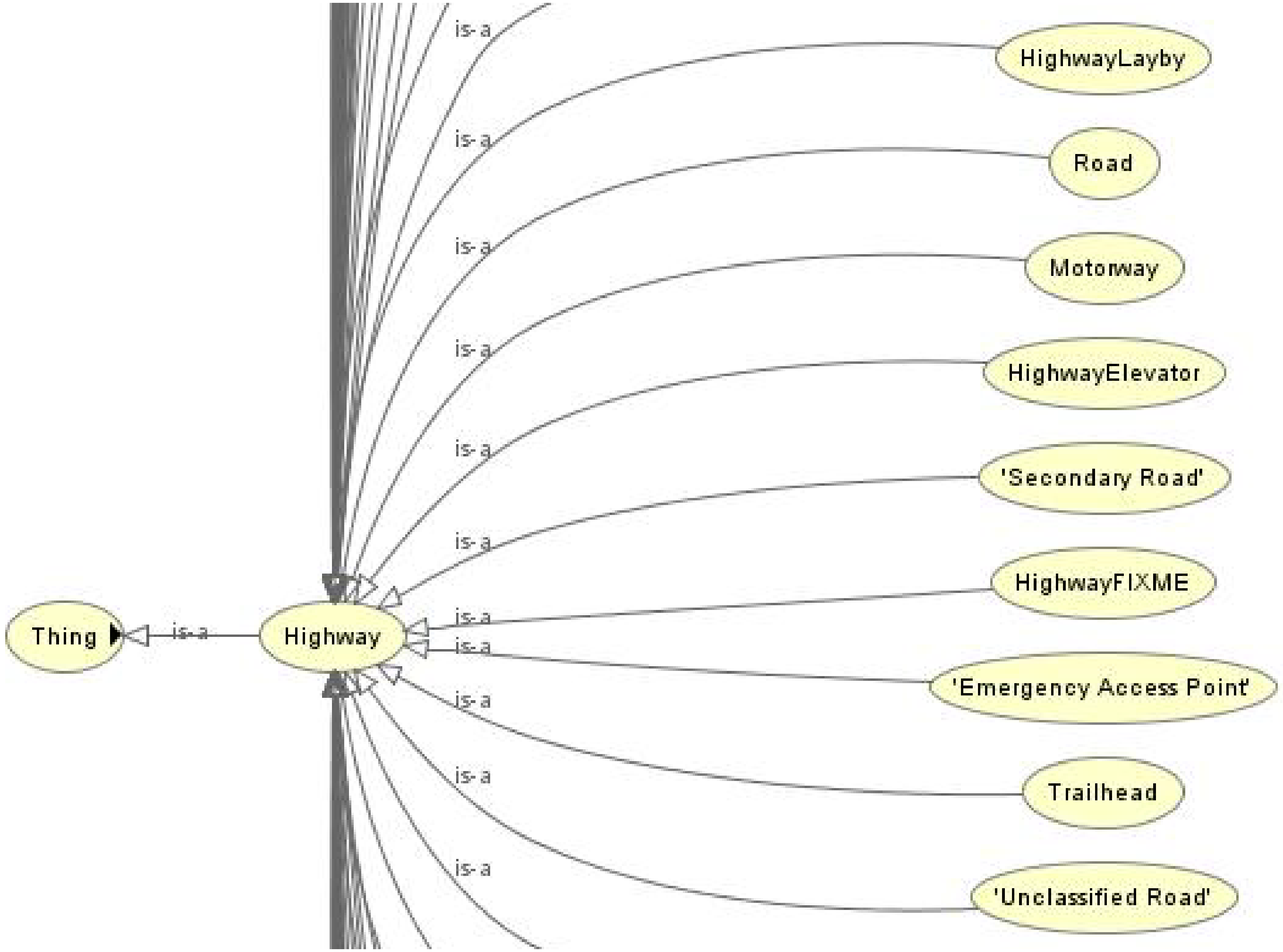
Linked Open Data (1/5)

GeoNames

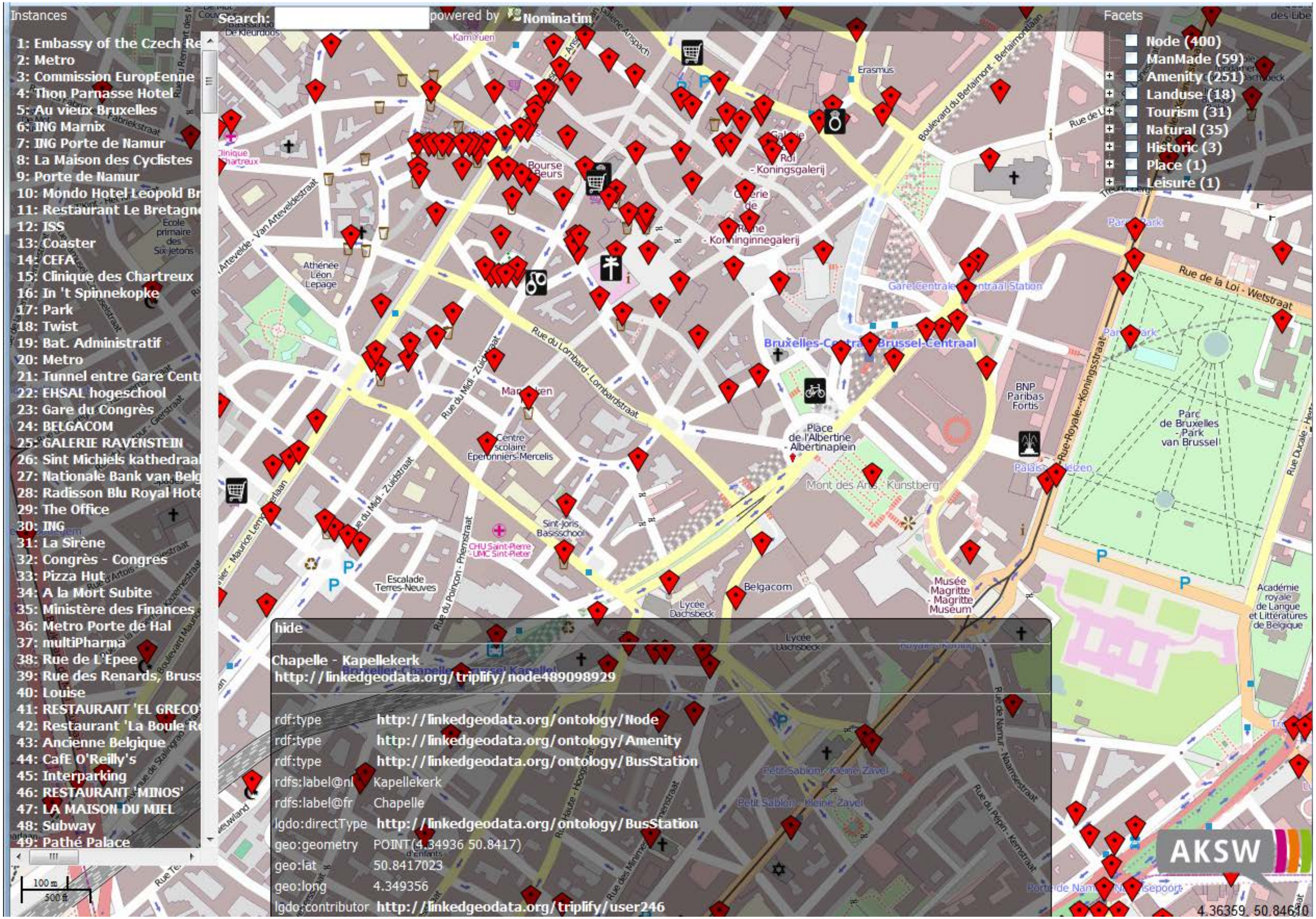


Linked Open Data (2/5)

OpenStreetMap

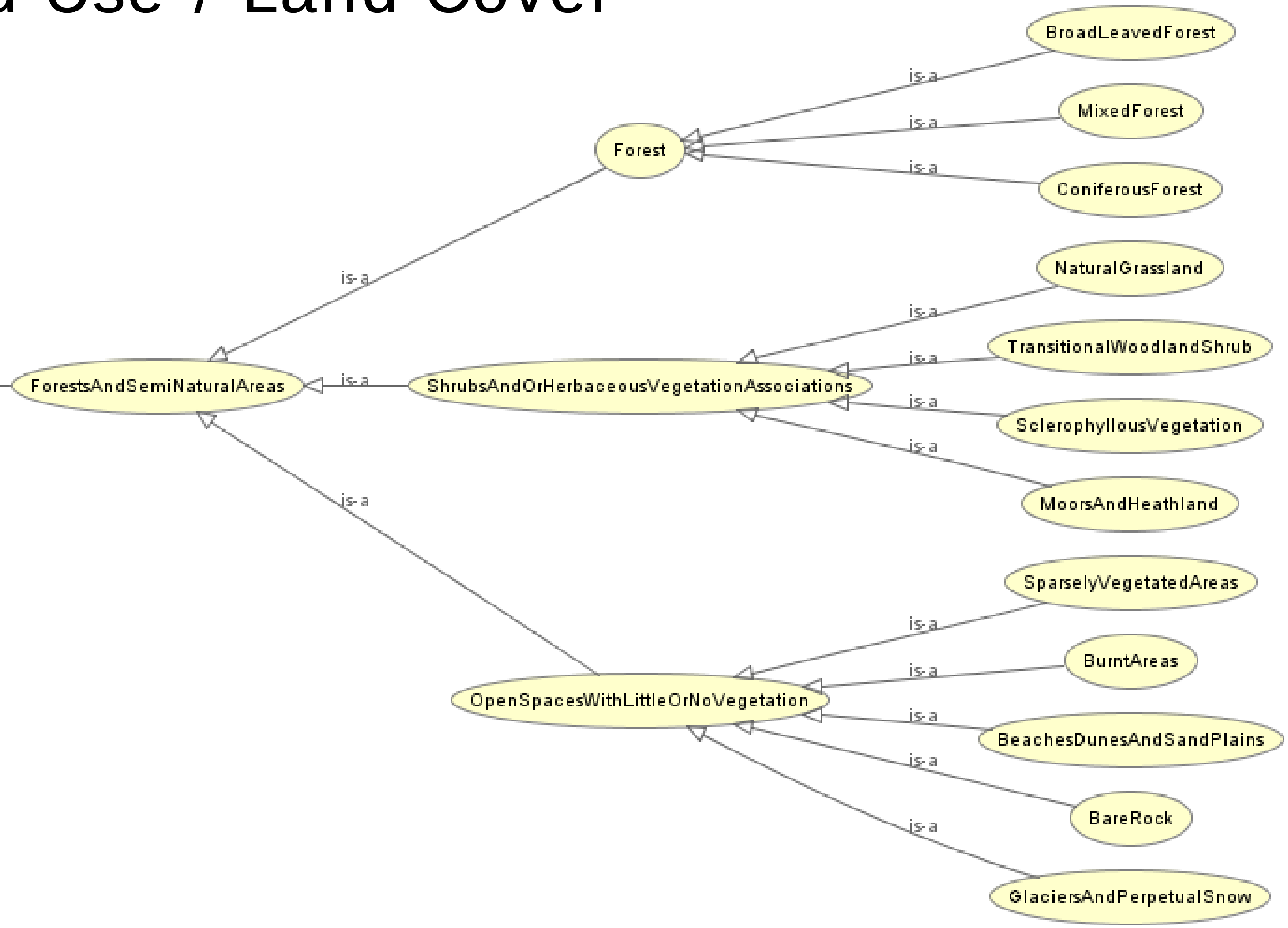


Linked Open Data (2/5)

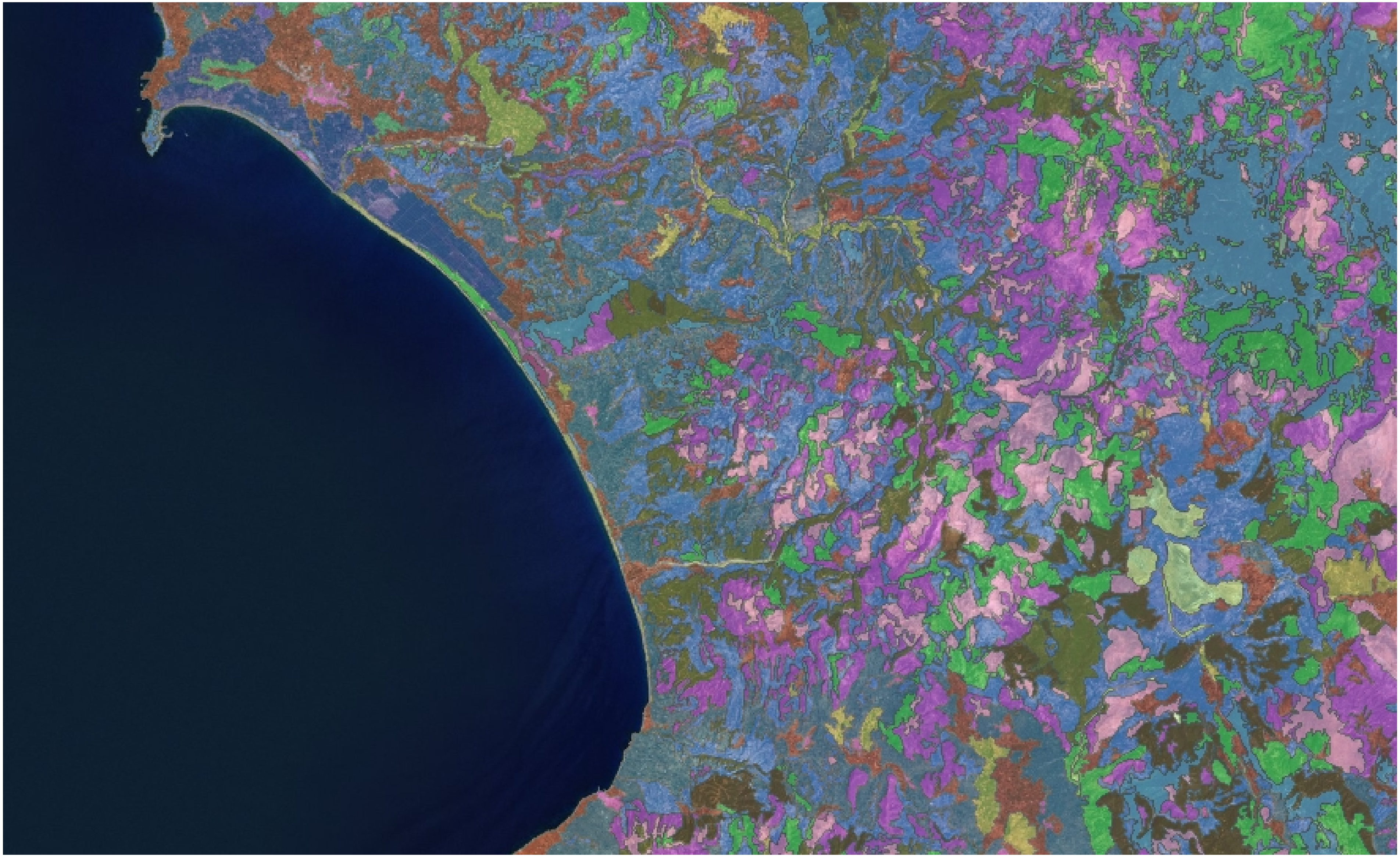


Linked Open Data (3 / 5)

Corine Land Use / Land Cover

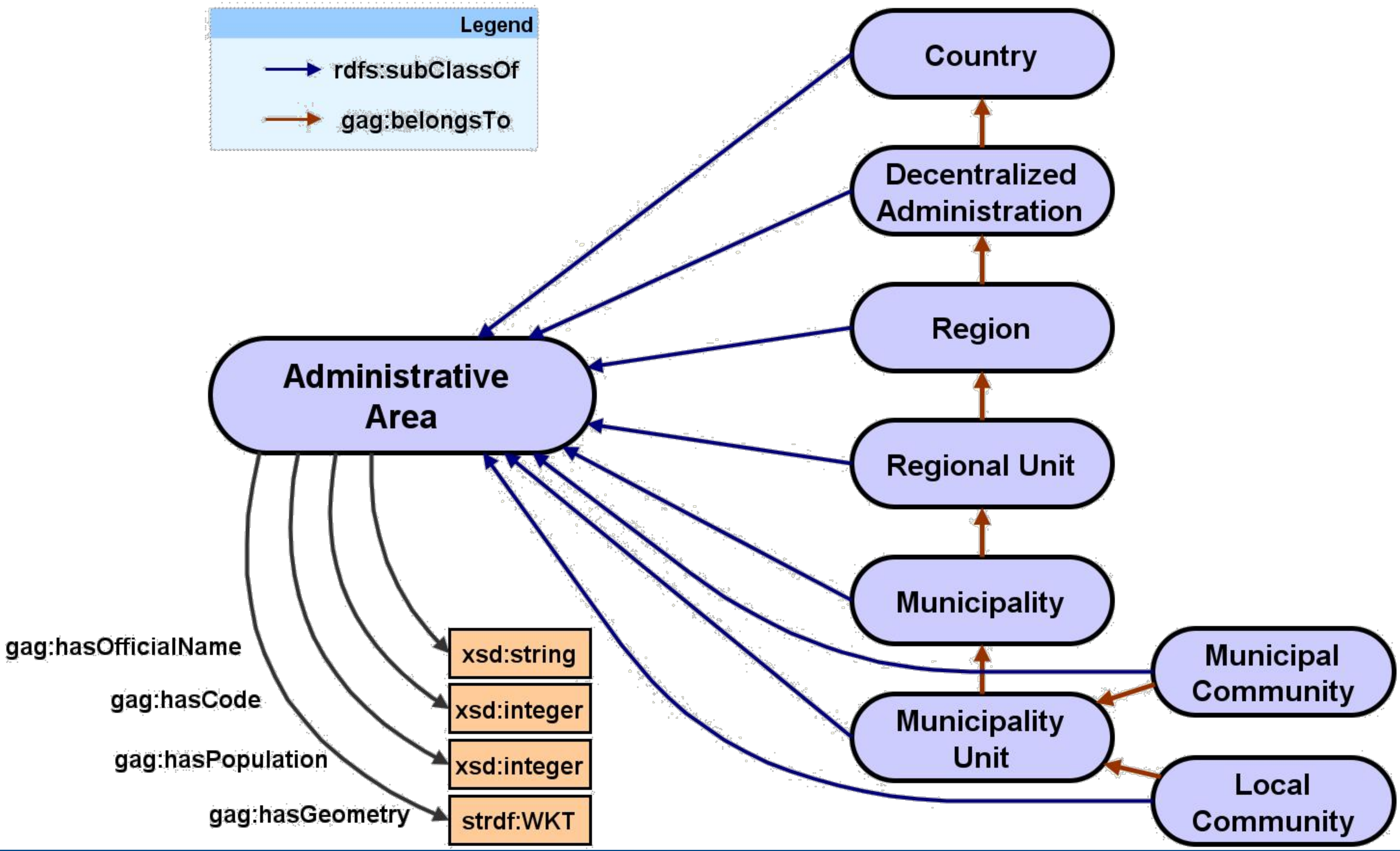


Linked Open Data (3/5)



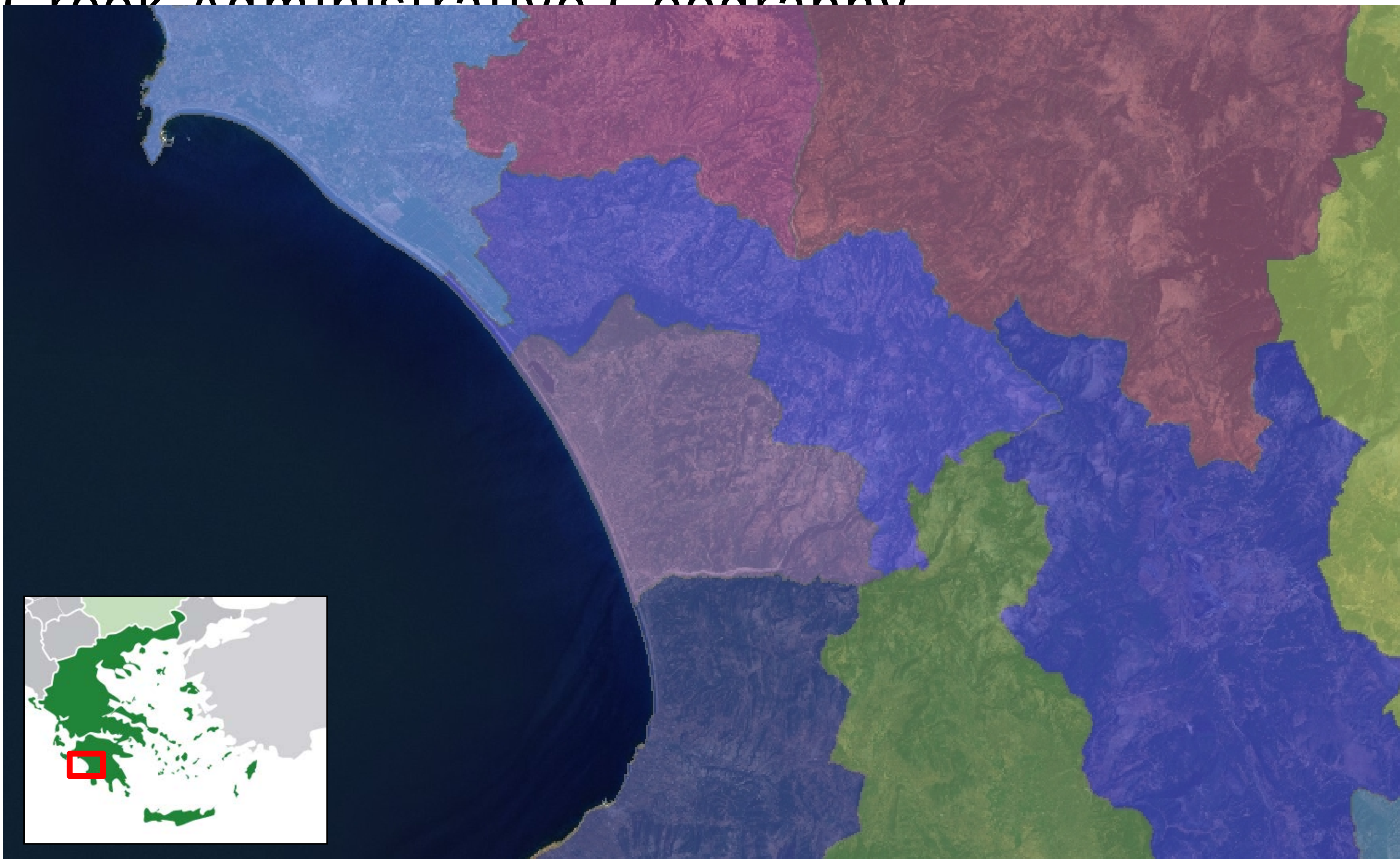
Linked Open Data (4/5)

Greek Administrative Geography

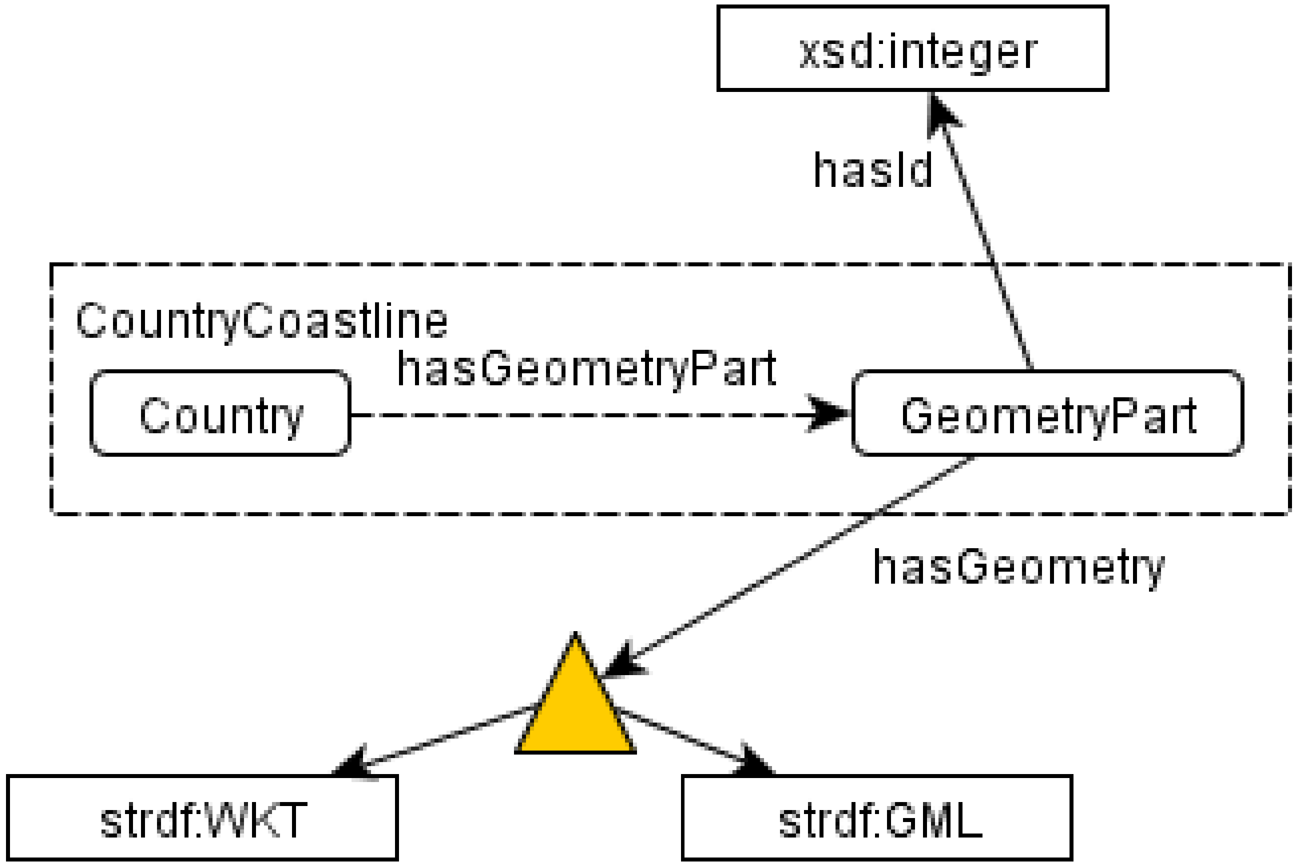


Linked Open Data (4/5)

Greek Administrative Geography



Greek Coastline



Linked Open Data (5/5)

Greek Coastline

Improvements

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

Fire monitoring application

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

DEMO!

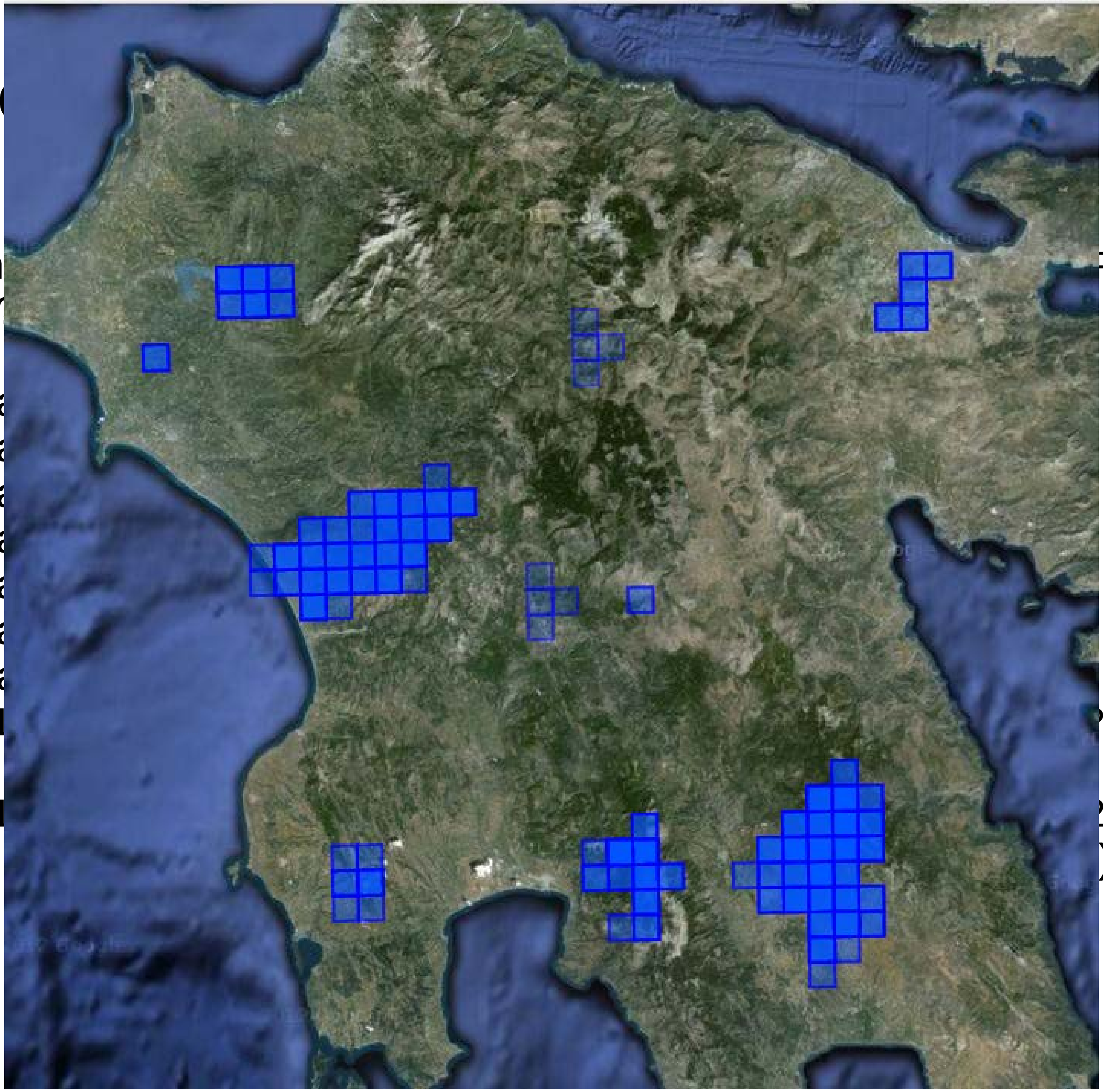
Discovering EO data

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 on
24/08/



```
SELECT ?h ?h                                              Provider
   ?hSensor
WHERE {   ?h
          noa
          noa
          noa
          noa
          noa
          noa
          noa
          FIL                                            ?hAcqTime &&
                                                         :dateTime).
          FIL                                            23.77 38.36,
                                                         ))"
```

Retrieving a map layer (1/3)

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 c

```
SELECT
WHERE{?
                                    pe.
    FIL
                                    .
    FIL                             1.027
                                    '7 36.05,
                                    36))"
                                    ?aGeo)).
}
```

Retrieving a map layer (2/3)

Get all primary roads in Pelloponnese

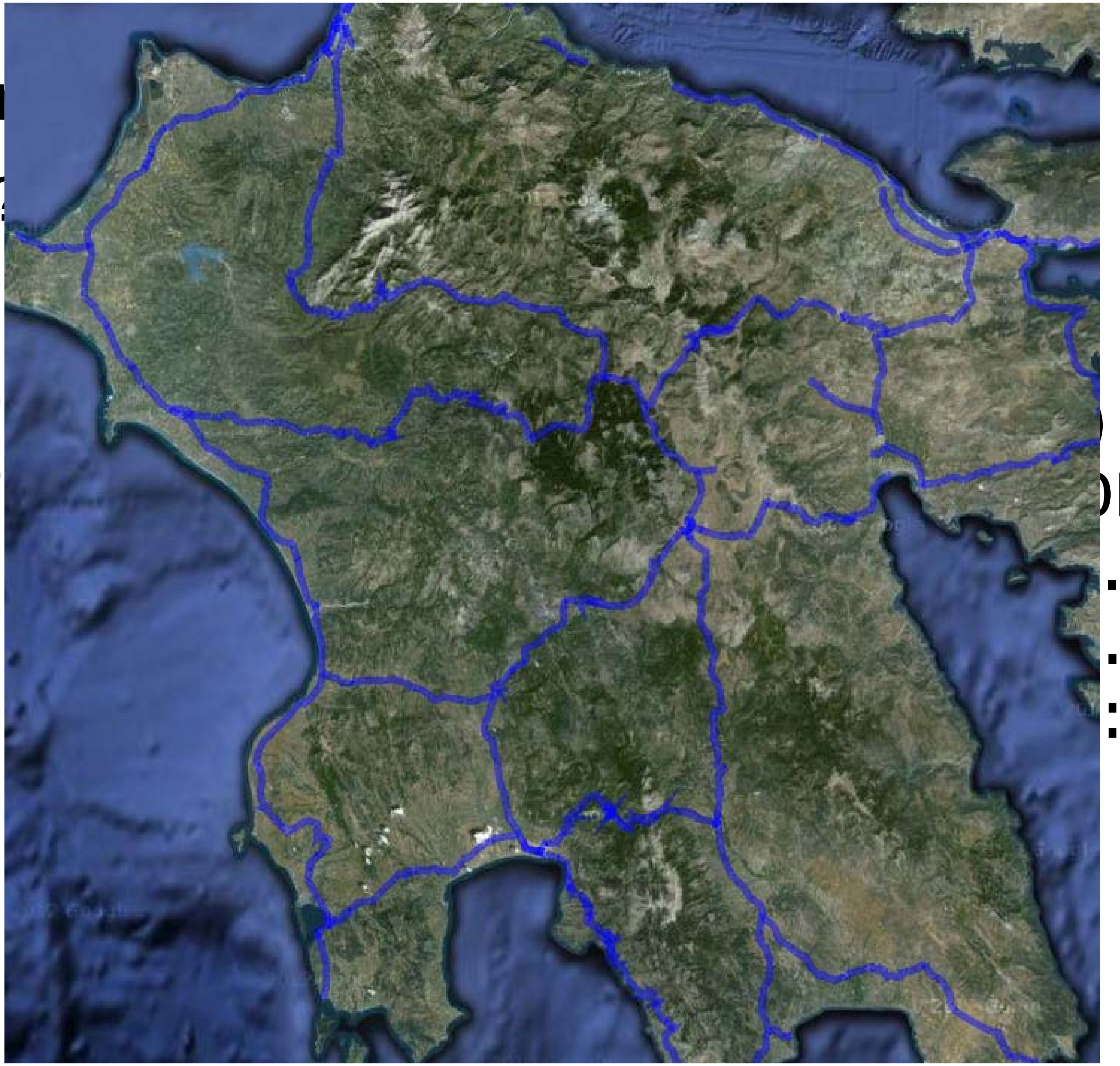
```
SELECT ?r ?rGeo
WHERE{ ?r  a ?rType ;
       noa:hasGeometry ?rGeo .
       FILTER(?rType = lgdo:Primary) .
       FILTER(strdf:contains("POLYGON((
             21.027 38.36, 23.77 38.36,
             23.77 36.05, 21.027 36.05,
             21.027 38.36))"^^strdf:WKT,
             ?rGeo) ).
}
```

Retrieving a map layer (2/3)

Get all pr

```
SELECT ?
WHERE{ ?
       n
       F                          ) .
       F                          ON((
                                  .36,
                                  .05,
                                  :WKT,

}
```



Retrieving a map layer (3/3)

Get all capitals of prefectures of the Peloponnese.

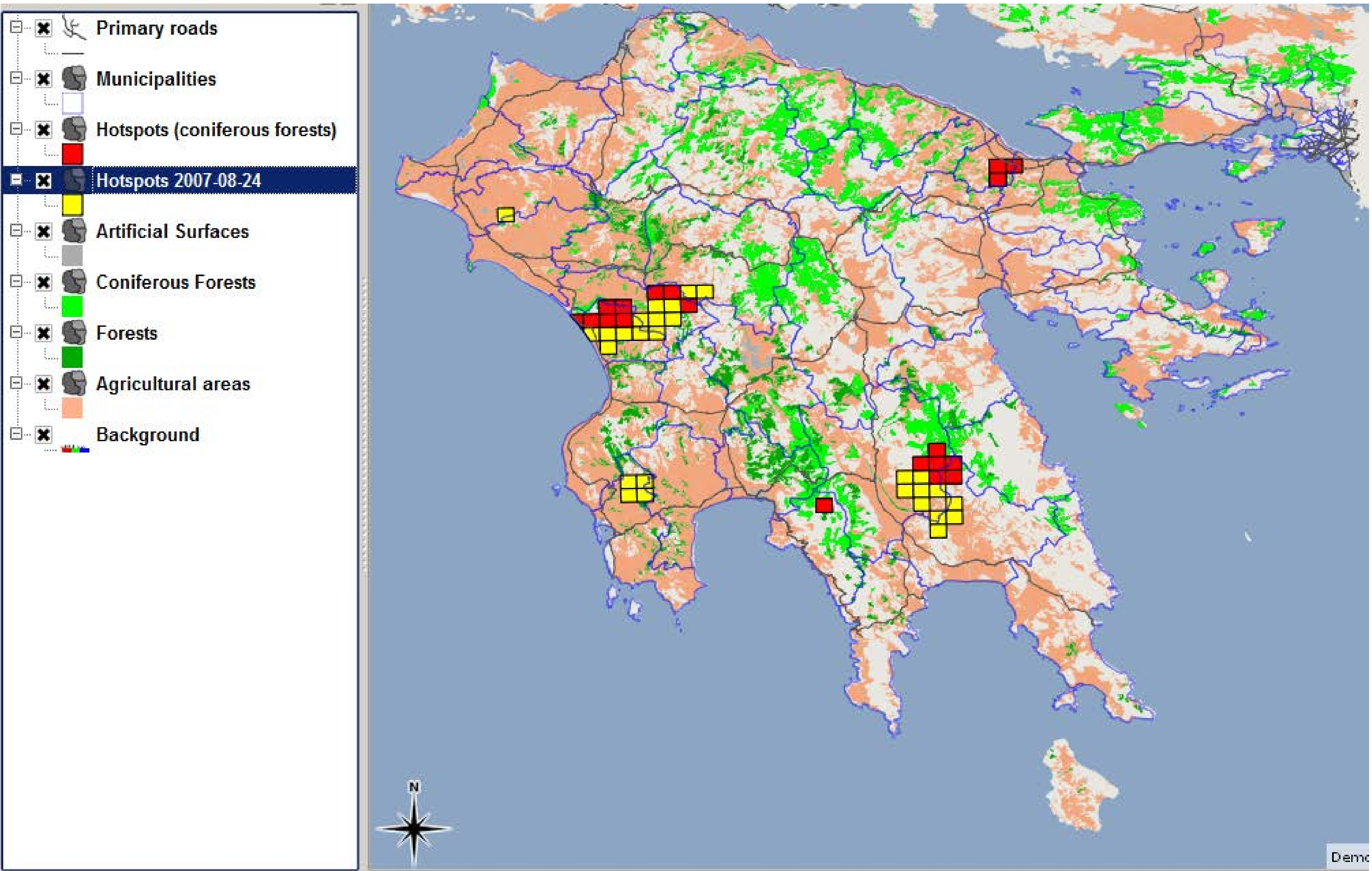
```
SELECT ?feature ?fName ?fGeo
WHERE{ ?feature rdf:type gn:Feature;
                 noa:hasGeography ?fGeo;
                 gn:name ?fName;
                 gn:featureCode ?fCode.
        FILTER(?fCode = gn:P.PPLA
               || ?fCode = gn:P.PPLA2 ) .
      FILTER(strdf:contains("POLYGON((21.51
                 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 … nnese.

```
SELECT
WHERE{
o;
.
) .
21.51
2.83
eo)).
}
```

Final map


Primary roads
Municipalities
Hotspots (coniferous forests)
Hotspots 2007-08-24
Artificial Surfaces
Coniferous Forests
Forests
Agricultural areas
Background
N

Semantic Enrichment for Hotspots

- **Enrich** hotspot products

  1. Connect each hotspot with a municipality that it is located

- **Improve accuracy** with respect to **underlying area**

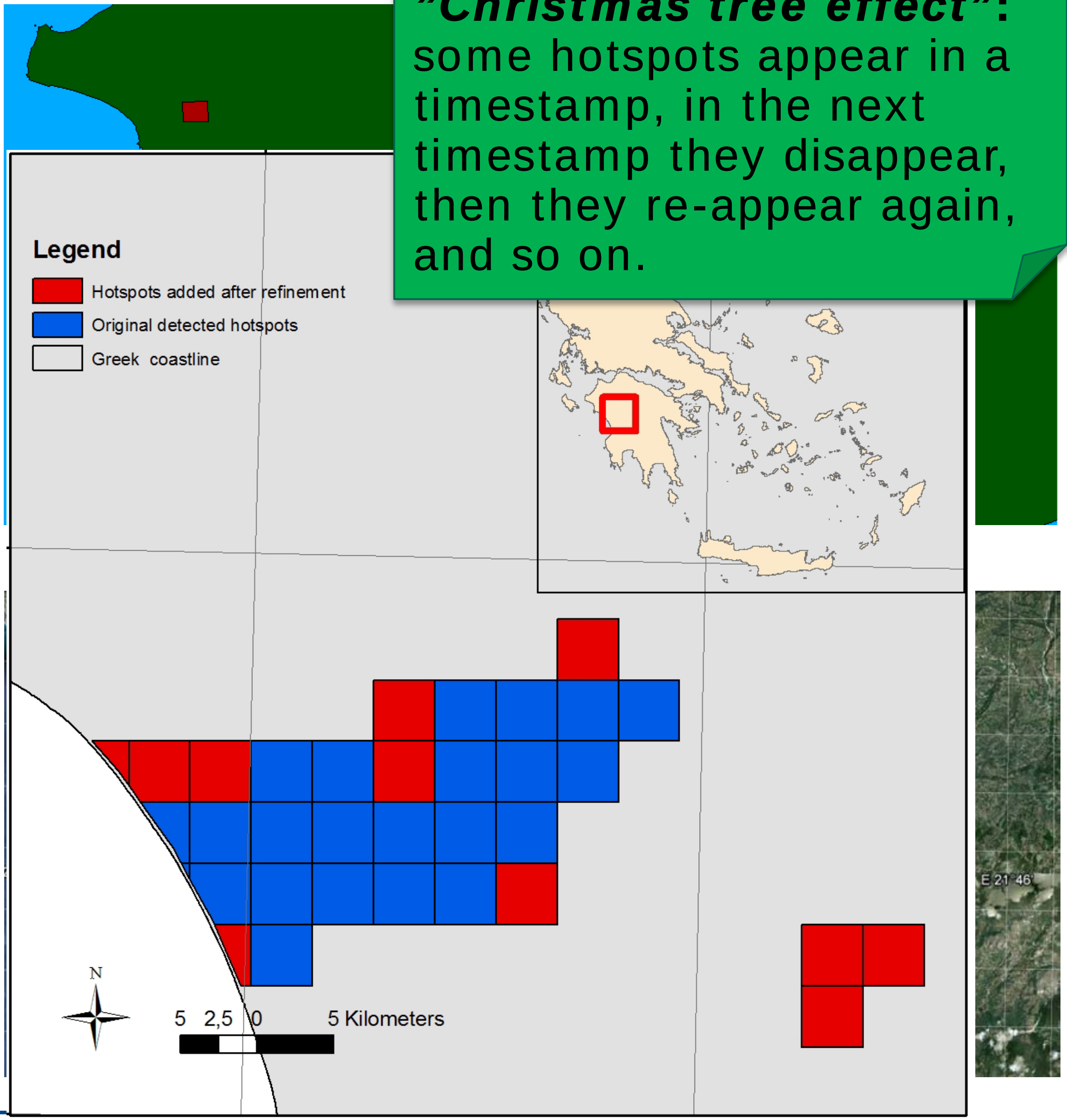
  2. Eliminate false alarms in sea

  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



”Christmas tree effect”: some hotspots appear in a timestamp, in the next timestamp they disappear, then they re-appear again, and so on.

Fire monitoring application

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

DEMO!

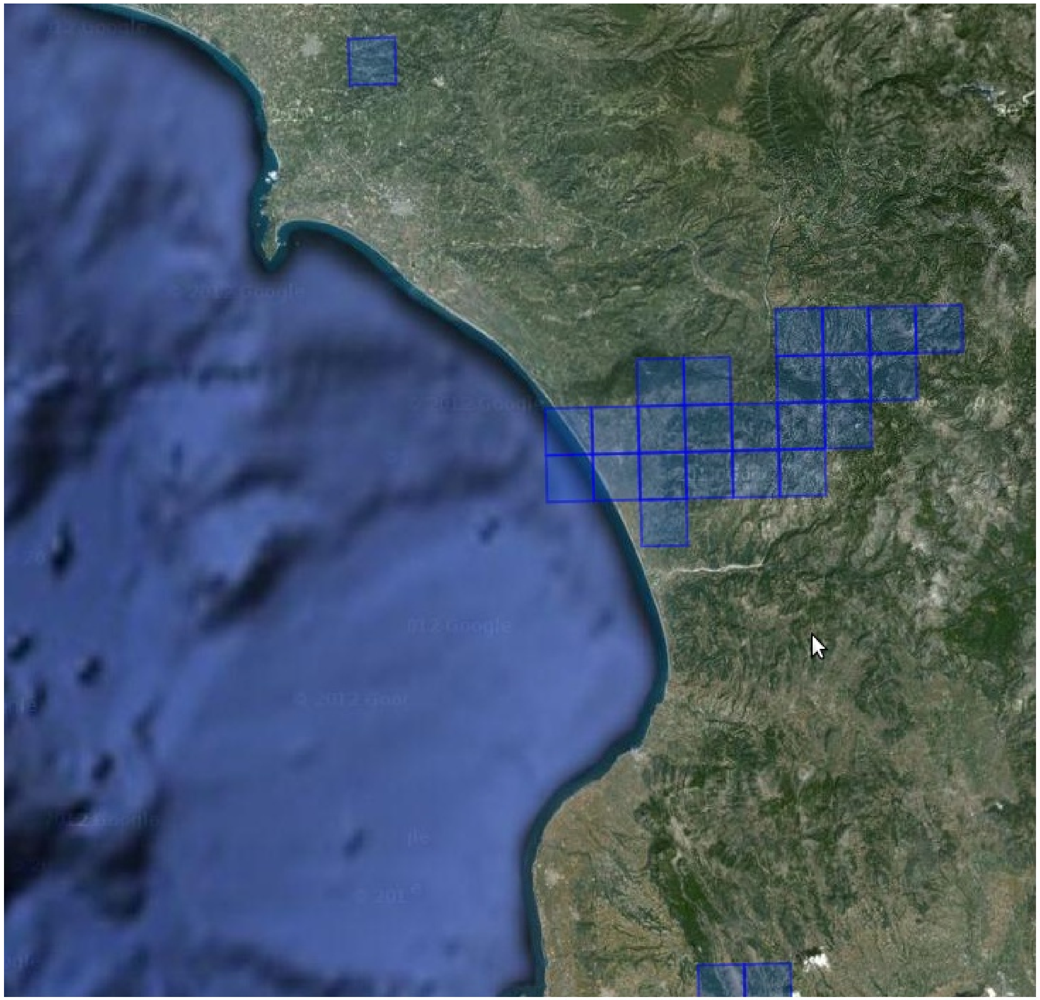
http://test.strabon.di.uoa.gr/NOA

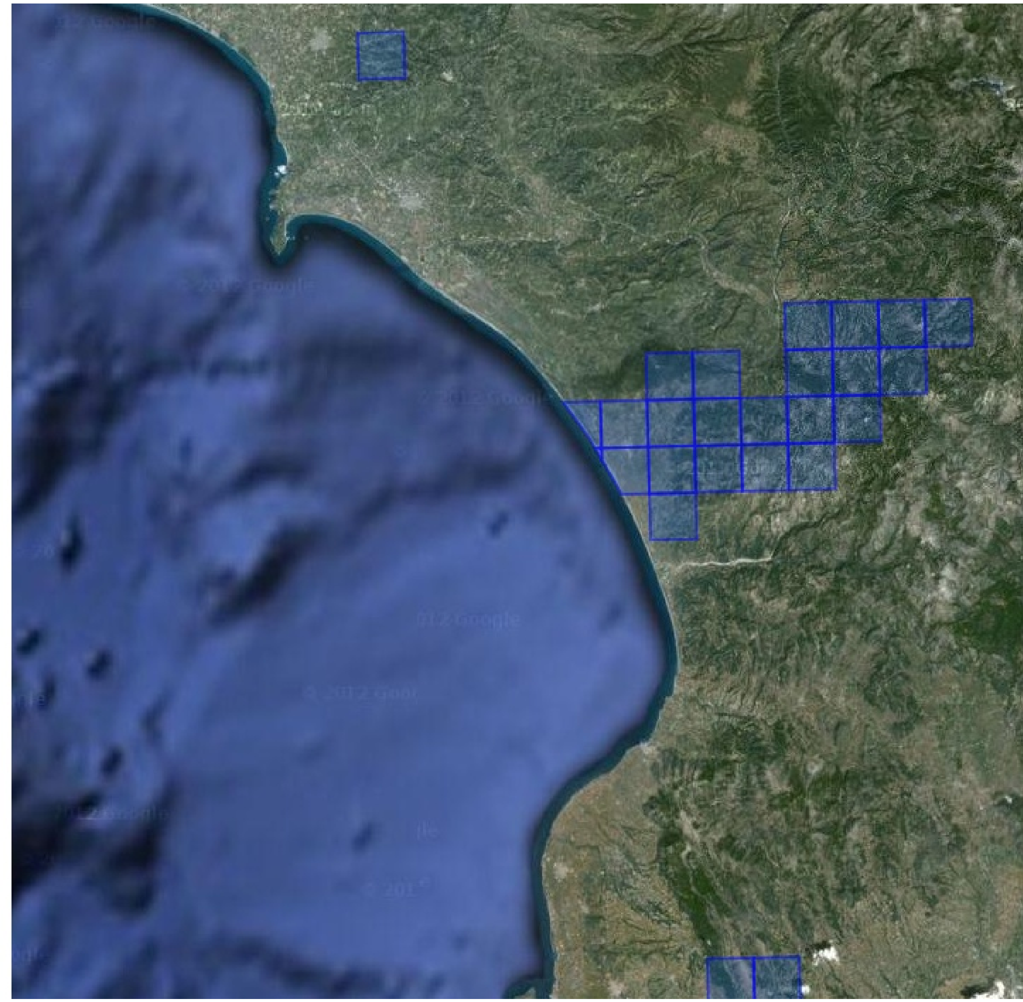
Improve the accuracy of EO data

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))}
```

Fire monitoring application

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

DEMO!

http://papos.space.noa.gr/fend_static

Fire monitoring service
Validation

- 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

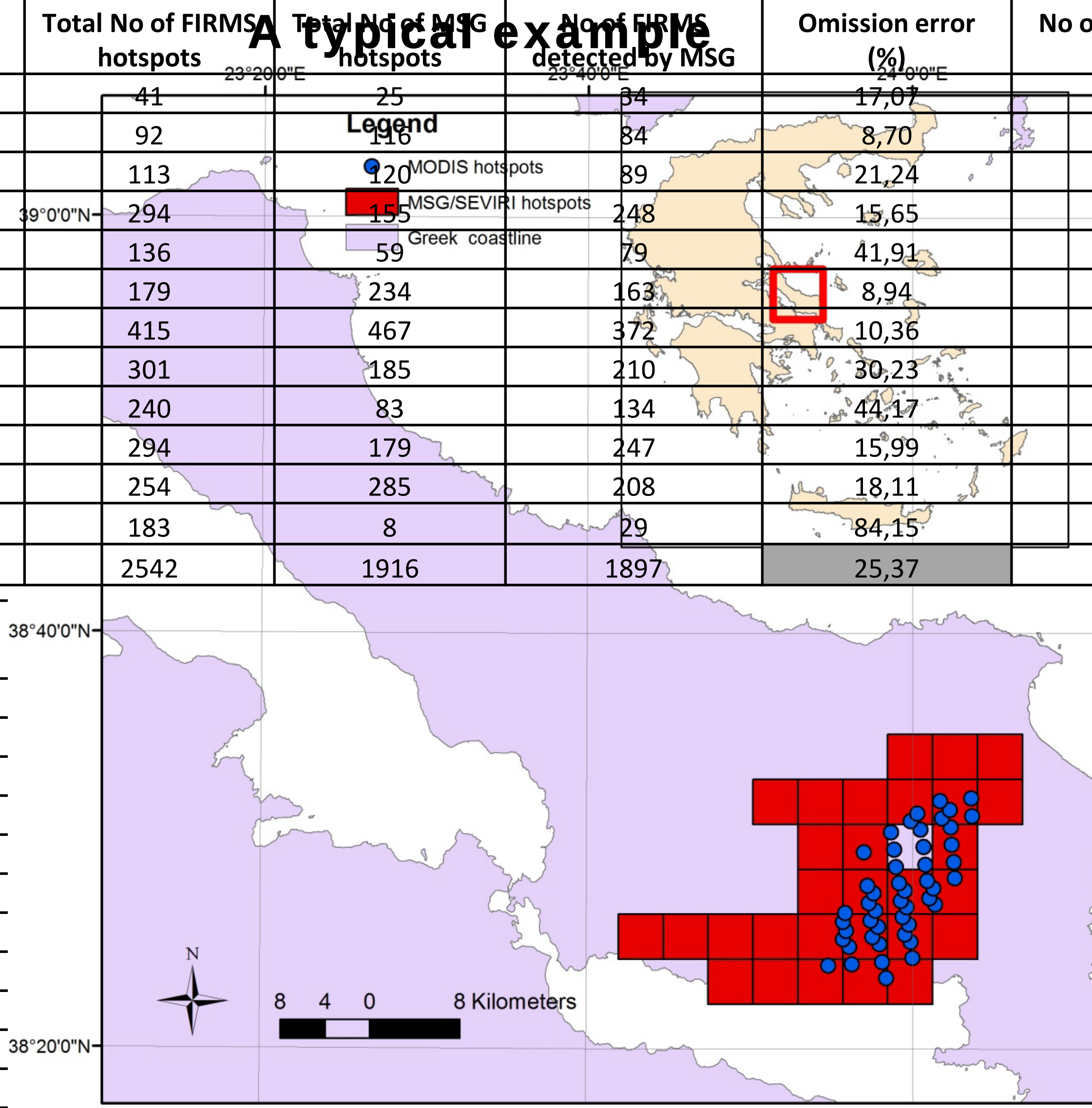
Preliminary evaluation – Thematic accuracy

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

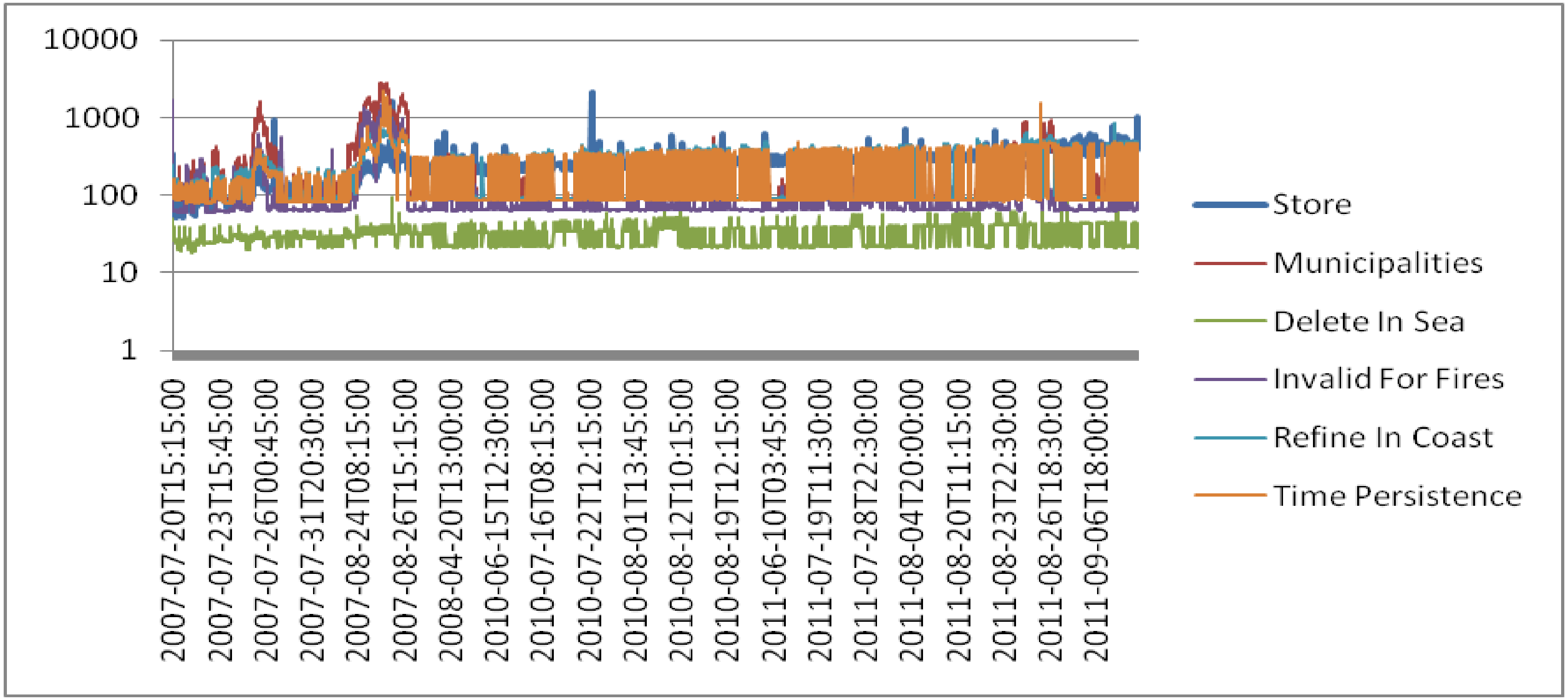
Date	Time					MSG detected by FIRMS	False alarm rate (%)
24/8/2007	0:21					36	40,00
24/8/2007	9:46					83	28,45
24/8/2007	11:25					87	27,50
24/8/2007	20:51					186	35,19
25/8/2007	1:03					153	29,17
25/8/2007	8:51					172	26,50
25/8/2007	12:08					334	28,48
25/8/2007	19:55					320	27,60
26/8/2007	0:09					216	15,95
26/8/2007	9:34					132	26,26
26/8/2007	11:12					214	25,44
26/8/2007	20:39	183	92	150	18,03	68	26,09
Total		2542	2757	2252	11,41	2001	27,42



Fire monitoring service

Preliminary evaluation – Processing times

- 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



Conclusions

- 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

Discussion

- 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/

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/