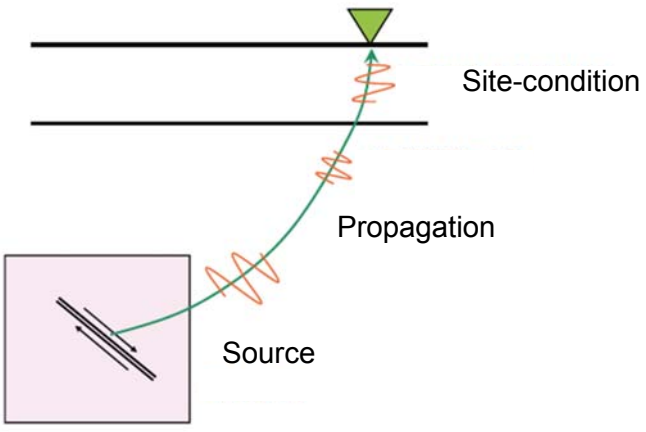
Strong Ground Motion Map (Shake map) Generation System

Masashi Matsuoka
Tokyo Institute of Technology

Strong Ground Motion Estimation

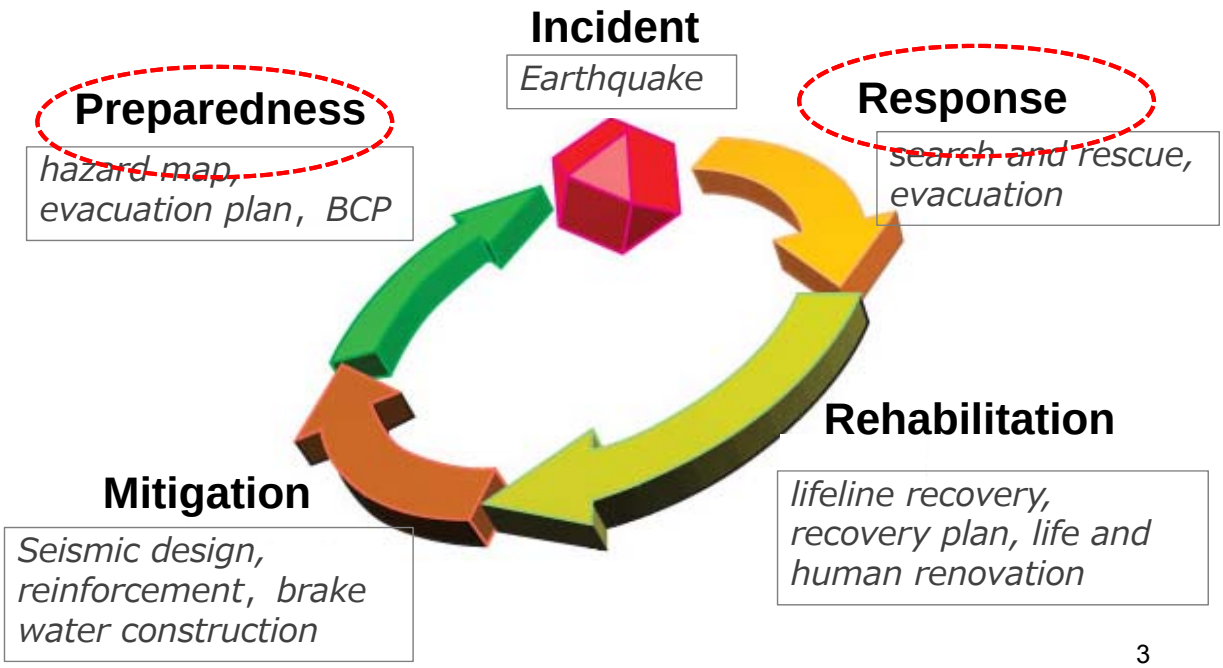
Ground motion = Source x Propagation x Site-condition

(theoretically, empirically, observationally)



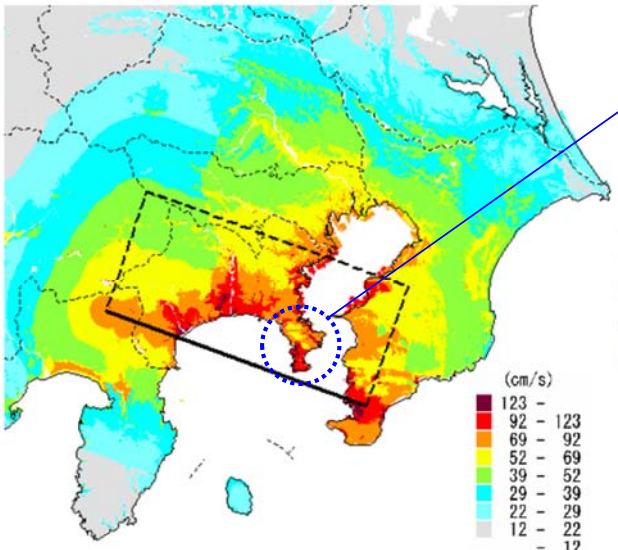
Disaster Management Cycle

Ground Motion Map: Quick mapping → Response Phase
Archived maps → Preparedness



Empirical Estimation

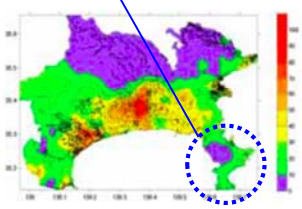
- Source & propagation: Attenuation relation (M, type, distance,…)
- Site-condition: Amplification capability (geology, geomorphology, Vs30,…)



Distribution of computed PGV for the 1923 Kanto earthquake

Some discrepancies in the Miura peninsula, may suggest smaller energy release beneath the peninsula.

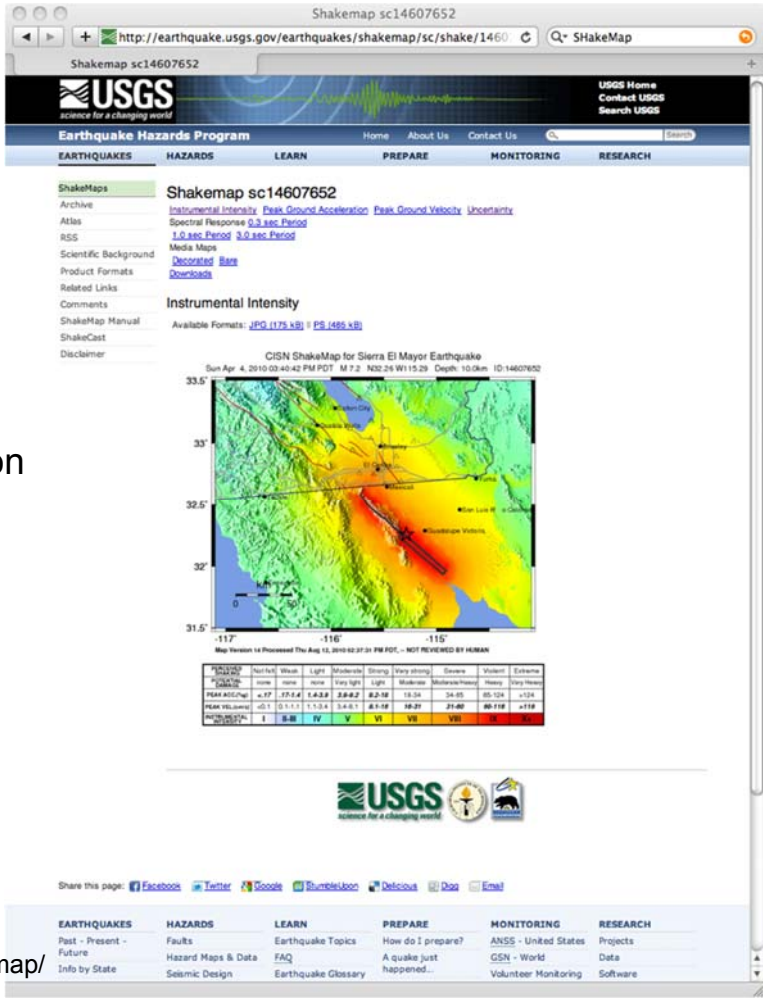
Limitation of the usage of simple attenuation relation



Distribution of collapsed ratio of wooden house due to the 1923 Kanto earthquake

USGS ShakeMaps

- Empirically,
  and observationally if instrumental observation station available



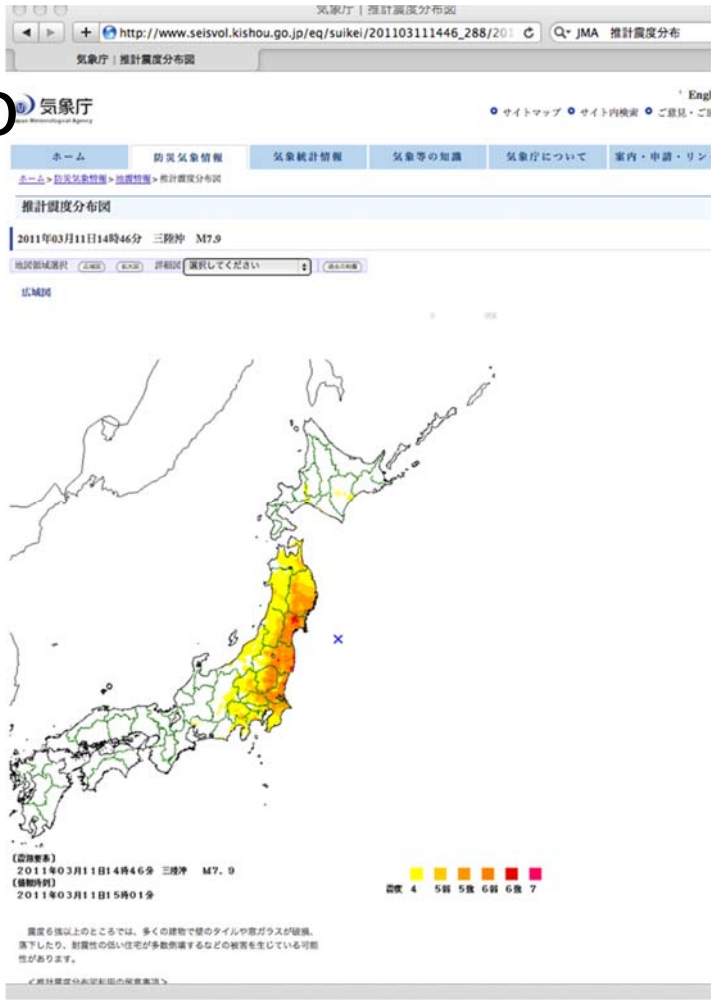
http://earthquake.usgs.gov/earthquakes/shakemap/

Observational Estimation

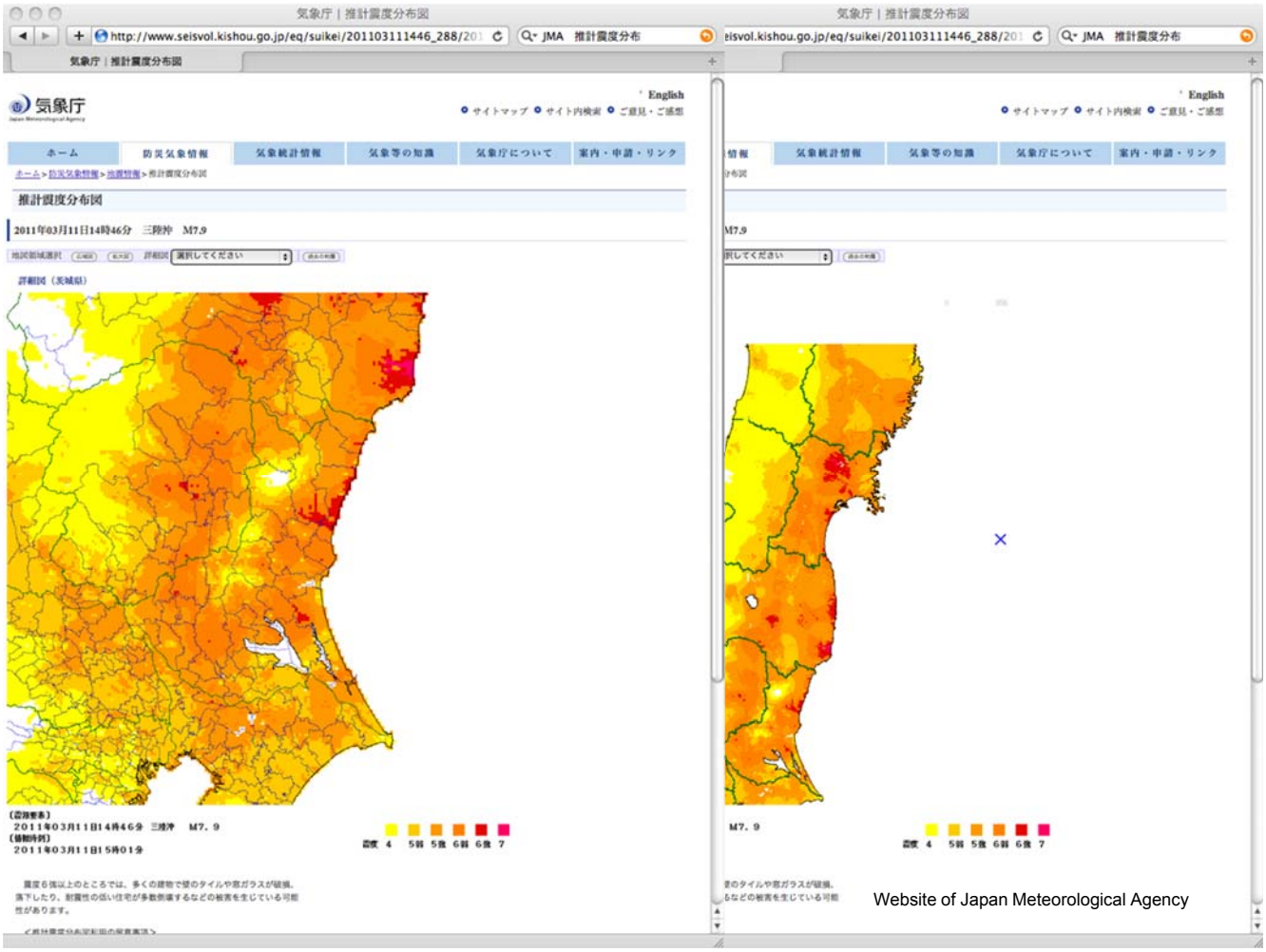
- Global
  - USGS ShakeMaps
- Throughout Japan
  - JMA (Japan Meteorological Agency)
  - AIST (National Institute of Advanced Industrial Science and Technology)
- Local
  - Yokohama City
  - Tokyo Gas

JMA Shake Map

- Grid-cell: 1km
- Obs. Point: approx. 4,200
- Target: earthq. $I_{JMA} \geq 5-$
- Result: report, GIF image
- Delivery: approx. 30-min after an earthq.



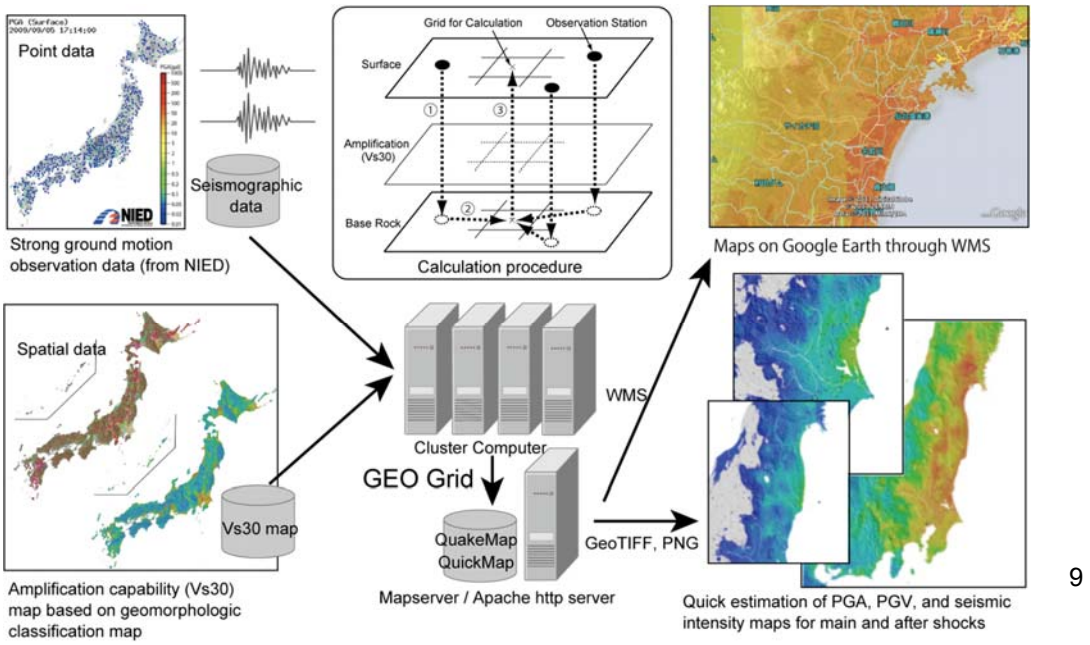
Website of Japan Meteorological Agency
http://www.seisvol.kishou.go.jp/eq/suikei/index.html



Website of Japan Meteorological Agency

QuiQuake by AIST

QuiQuake (Quick estimation system for earthquake maps triggered by observation records) is a system on Grid computer which provides wide-ranging and detailed (250m-grid) strong ground motion maps for quick disaster response soon after the occurrence of an earthquake.



QuickMap and QuakeMap

- QuickMap for response
  - Near-real time information from K-NET observation site (PGA, PGV, I_{JMA})
  - Interpolation by IDW (Inverse Distance Weighted)

http://qq.ghz.geogrid.org/QuickMap/index.en.html

- QuakeMap for preparedness
  - Published seismic observation data from K-NET and KiK-net
  - Interpolation by simple kriging with a prior trend component derived from attenuation relationship of each event

http://qq.ghz.geogrid.org/index.en.html

Advantage of QuiQuake

based on Grid and GIS technology

- Accurate result
  - reliable and dense strong motion network
  - seamless and high-resolution amplification capability map

(observation data)

- Quick response
  - cluster computer for multi-task computation of a series of earthquakes

(computer resource)

- Geospatial information
  - OGC (Open Geospatial Consortium) compliant

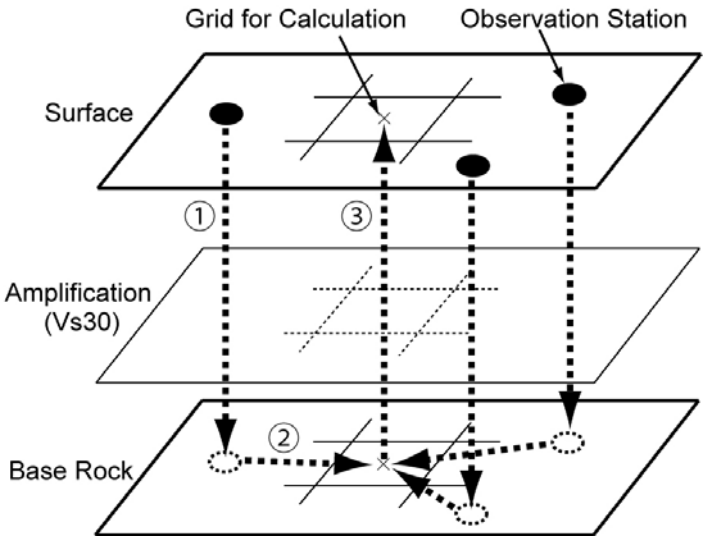
(share and analysis)

Interpolation Algorism

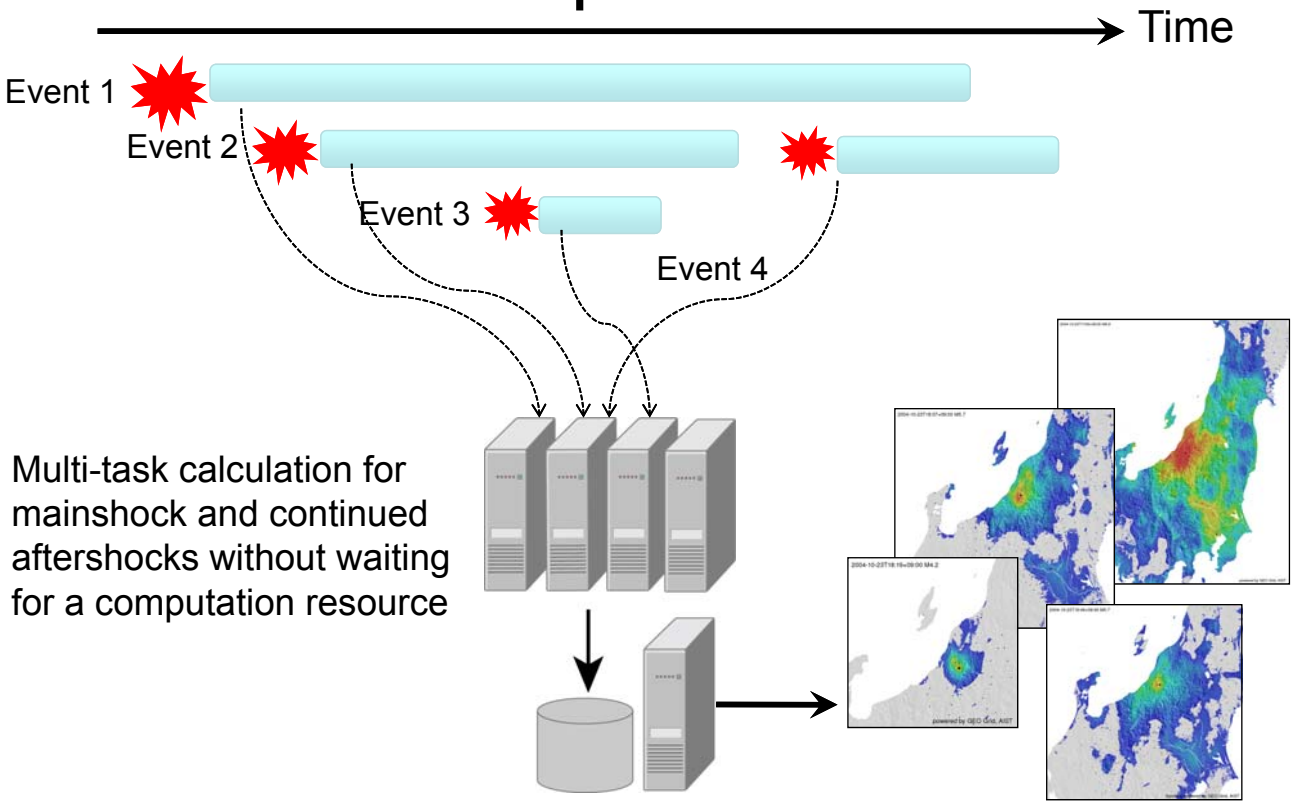
① Estimating strong ground motion intensity value on base rock from the observed record divided by the amplification factor at the seismic station

② Calculating intensity value of the target grid on base rock by interpolating of surrounding values and also attenuation characteristics into consideration

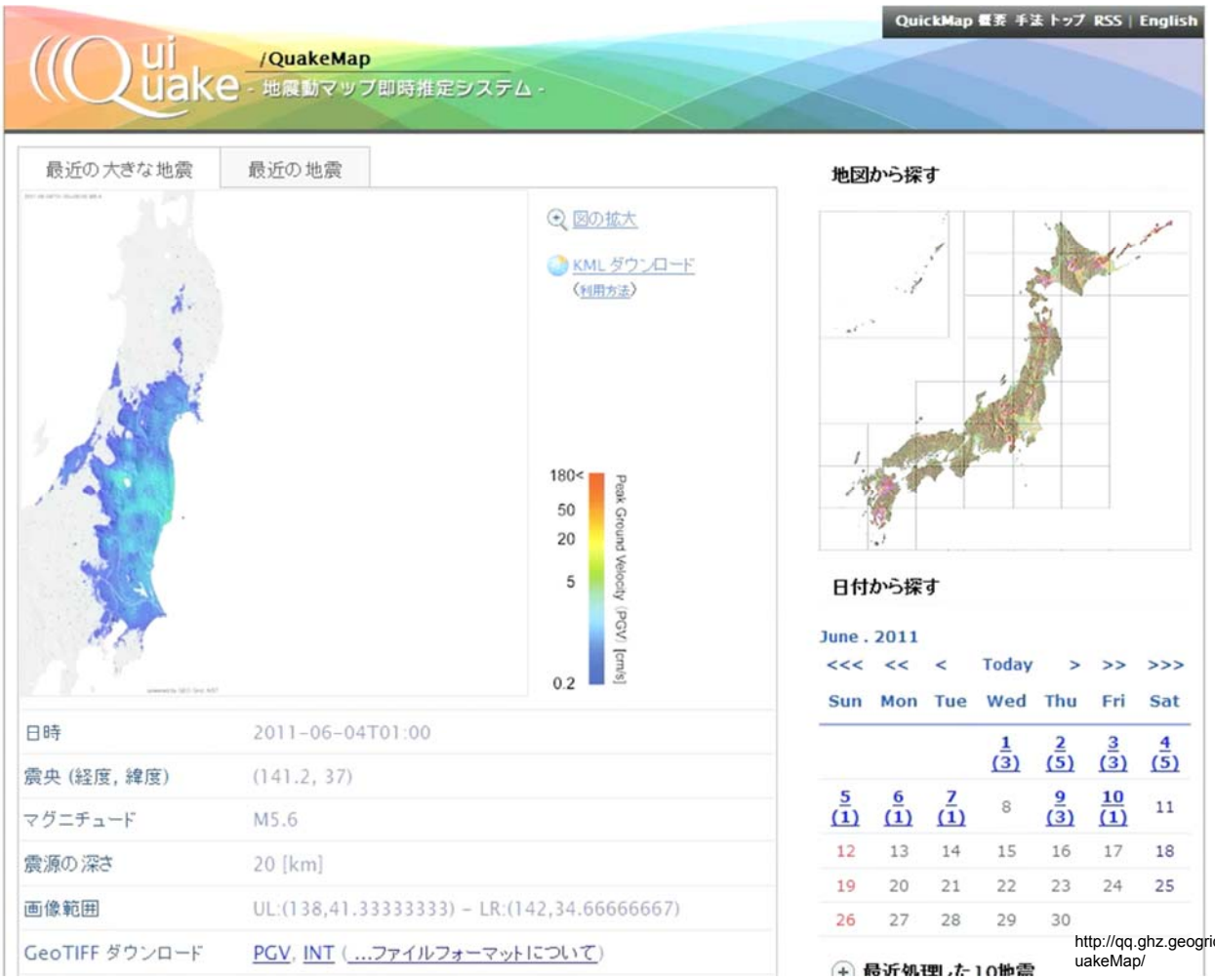
③ Calculating intensity value on surface from multiplying by amplification factor



Automatic and Multi-task Computations



Multi-task calculation for mainshock and continued aftershocks without waiting for a computation resource



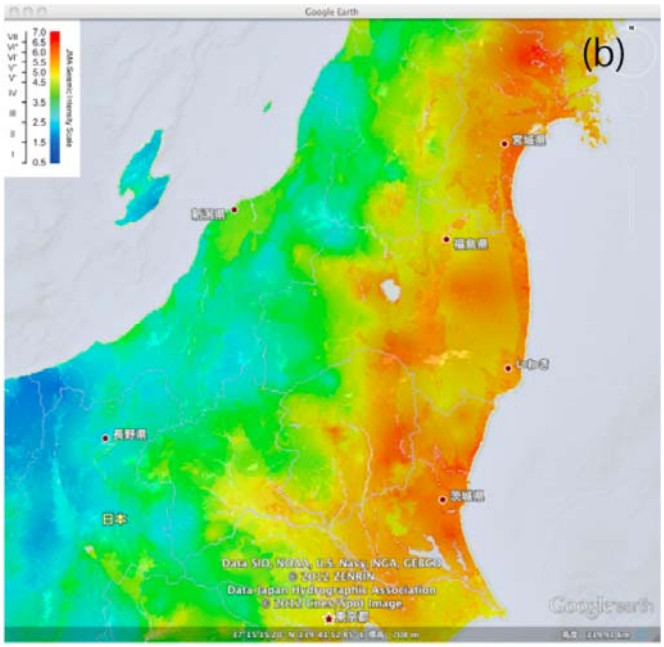
http://qq.ghz.geogrid.org/QuakeMap/

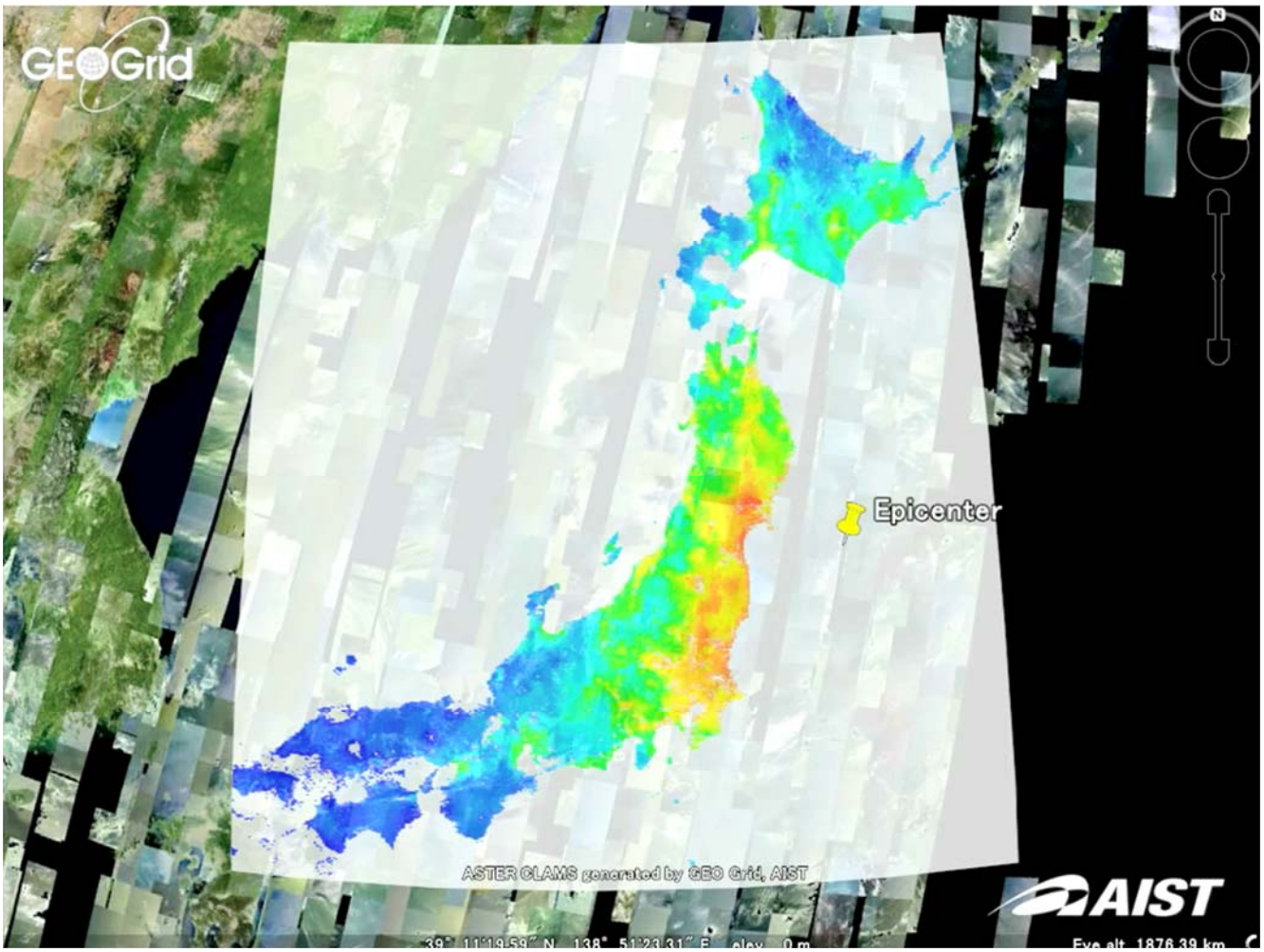
QuiQuake Maps by WMS

More than 7,400 QuakeMaps since 1996 can be accessed by WMS client software (also Google Earth)

(a)

```
<Folder>
<name>Intensity</name>
<GroundOverlay><visibility>1</visibility>
        <name>JMA-scale Seismic Intensity</name>
  <visibility>1</visibility>
        <LookAt>
                <gx:TimeStamp><when>2004-10-23T17:56:00Z</when></gx:TimeStamp>
                <longitude>137.5</longitude>
                <latitude>38.666666665</latitude>
                <altitude>0</altitude>
                <range>1157890.243133473</range>
                <tilt>0</tilt>
                <heading>0.7233993440523578</heading>
                <altitudeMode>relativeToGround</altitudeMode>
        </LookAt>
        <color>b8ffffff</color>
        <Icon>
<href>http://ows.geogrid.org/quake?LAYERS=INT_20110311144600&amp;TRANSPARENT=true&amp;FORMAT
=image%2Fpng%3B%20mode%3D24bit&amp;SRS=EPSG%3A4326&amp;SERVICE=WMS&amp;VERSION=1.1.
1&amp;REQUEST=GetMap&amp;STYLES=&amp;EXCEPTIONS=application%2Fvnd.ogc.se_inimage&amp;WID
TH=1024&amp;HEIGHT=1024&amp;</href>
                <viewRefreshMode>onStop</viewRefreshMode>
                <viewRefreshTime>1</viewRefreshTime>
                <viewBoundScale>1.2</viewBoundScale>
        </Icon>
        <LatLonBox>
                <north>46</north>
                <south>31.33333333</south>
                <east>146</east>
                <west>129</west>
        </LatLonBox>
</GroundOverlay>
</Folder>
```





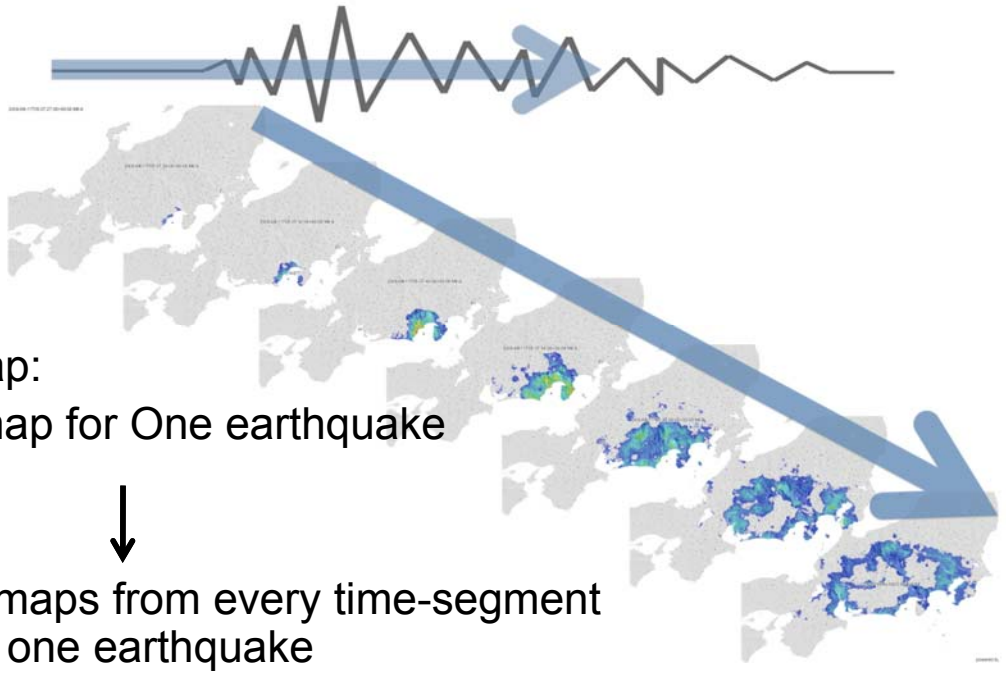
Comparison

JMA Shake Map:
- Grid-cell: 1km
- Obs. Point: approx. 4,200
- Target: earthq. $I_{JMA} \geq 5-$
- Result: report, GIF image
- Delivery: approx. 30-min after an earthq.

AIST QuickMap:
- Grid-cell: 250 m
- Obs. Point: approx. 1,000
- Target: earthq. $I_{JMA} \geq 1$
- Result: raw data, WMS
- Delivery: depends on its Magnitude, approx. few min after receiving the near-real time information

AIST QuakeMap:
- Grid-cell: 250 m
- Obs. Point: approx. 1,700
- Target: earthq. $I_{JMA} \geq 2$
- Result: raw data, WMS
- Delivery: after publishing wave form data

Ground Motion Propagation Animation



- QuakeMap:
  - One map for One earthquake

↓

  - Many maps from every time-segment during one earthquake

Ground Motion Propagation Animation

Shake Map Generation System

- IT Requirements and solutions-

- Redundancy : Migration of data processing and distribution functions of the system to external servers and Cloud system seeking stabilized and redundant operations (Virtual Machine)
- Rapidity : High speed automatic data processing using high-performance computers
- Standardization : Most of the geographic information is open to the public as Web Map Service (WMS) and KML (KMZ), which are international standards for geographic data

OGC (Open Geospatial Consortium)

For sharing GIS data

- “The Open Geospatial Consortium, Inc (OGC) is an international industry consortium of 381 companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications. ”

- OpenGIS® Specifications support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The specifications empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications.

OGC (Open Geospatial Consortium)

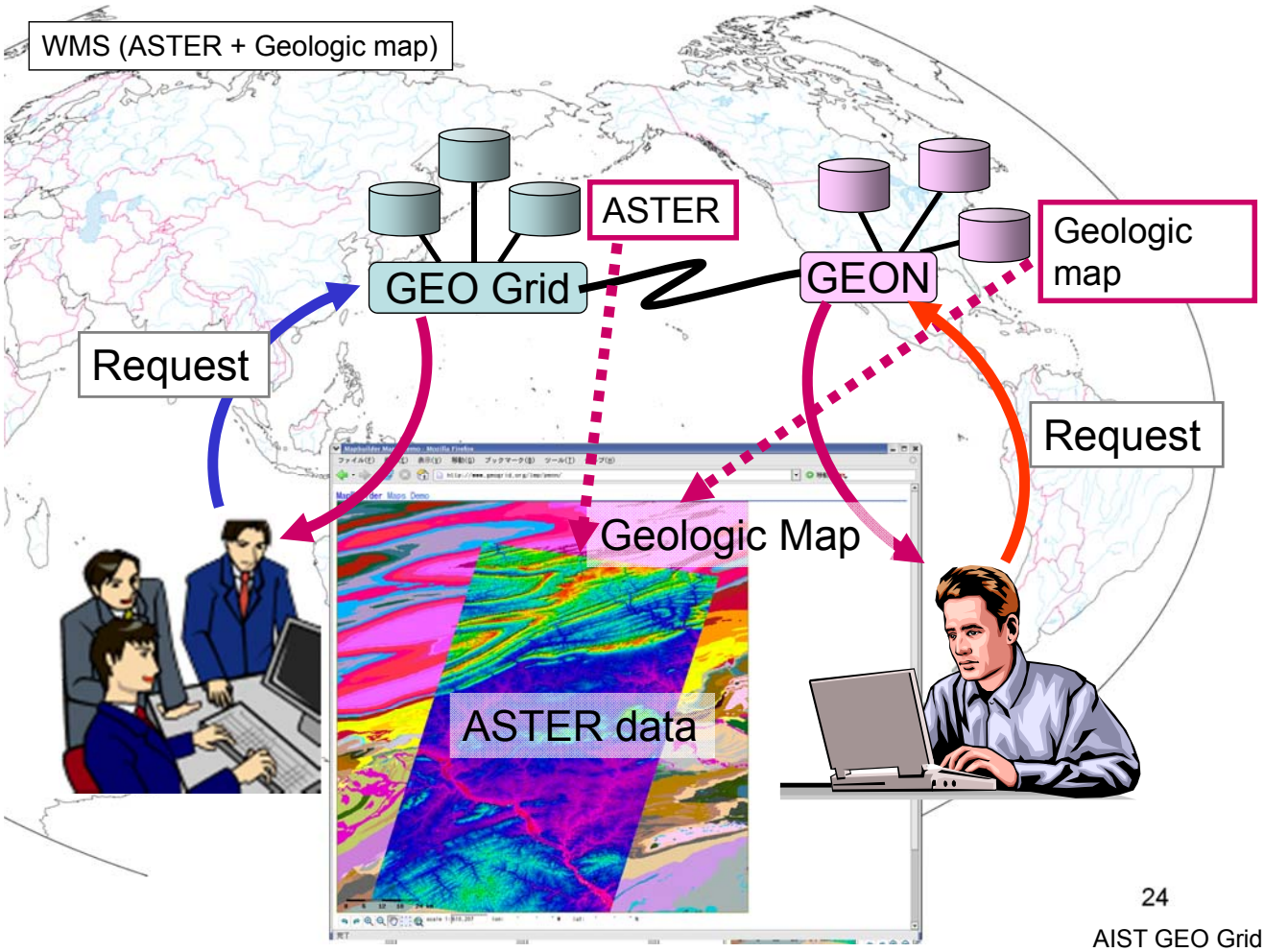
Strategic Goals:

- Provide free and openly available standards to the market, tangible value to Members, and measurable benefits to users.
- Lead worldwide in the creation and establishment of standards that allow geospatial content and services to be seamlessly integrated into business and civic processes, the spatial web and enterprise computing.
- Facilitate the adoption of open, spatially enabled reference architectures in enterprise environments worldwide.
- Advance standards in support of the formation of new and innovative markets and applications for geospatial technologies.
- Accelerate market assimilation of interoperability research through collaborative consortium processes.

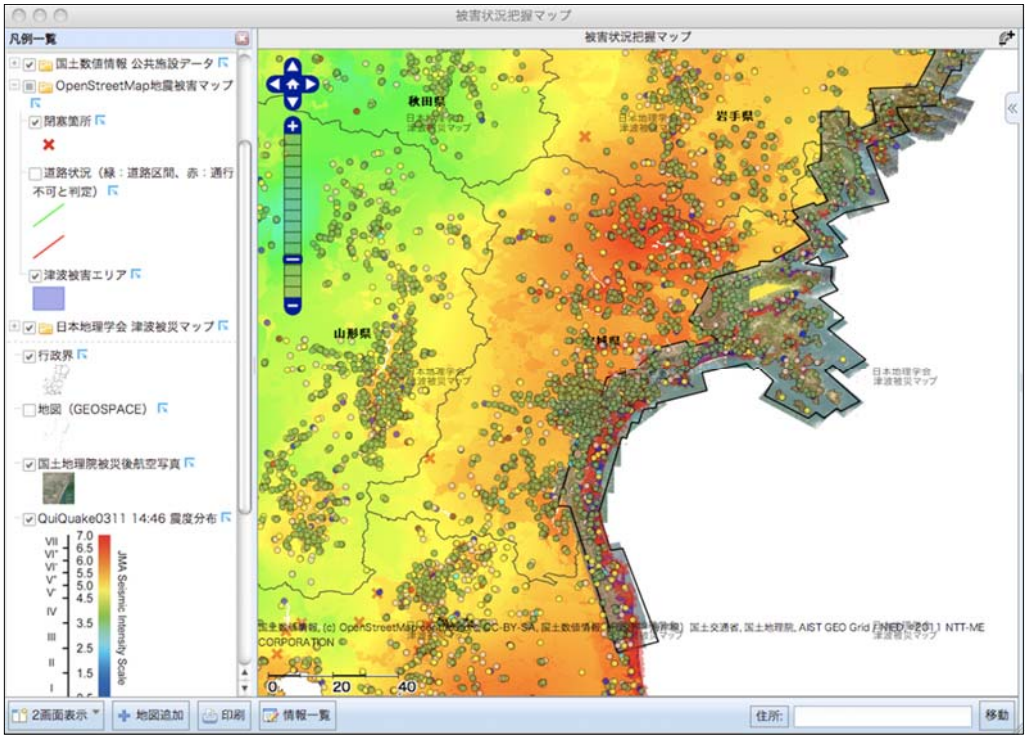
WMS (Web Map Service)

Web Map Service Standard

- provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases.
- WMS-produced maps are generally rendered in a pictorial format such as PNG, GIF or JPEG, or occasionally as vector-based graphical elements in Scalable Vector Graphics (SVG) or Web Computer Graphics Metafile (WebCGM) formats.
- WMS operations
  - GetCapabilities
  - GetMap
  - GetFeatureInfo



Utilization of WMS-based QuakeMap on Other Portal



ALL311 activity operated by NIED (http://all311.ecom-plat.jp/) utilizes GEO Grid and other contents through WMS.

WFS (Web Feature Service)

Web Feature Service Standard

- defines an interface for specifying requests for retrieving geographic features across the Web using platform-independent calls.
  - Get or Query features based on spatial and non-spatial constraints
  - Create a new feature instance
  - Get a description of the properties of features
  - Delete a feature instance
  - Update a feature instance
  - Lock a feature instance

- Operations
  - GetCapabilities
  - DescribeFeatureType
  - GetFeature
  - GetGmlObject
  - Transaction
  - LockFeature

WCS (Web Coverage Service)

Web Coverage Service Standard

- The OpenGIS® Web Coverage Service Interface Standard (WCS) defines a standard interface and operations that enables interoperable access to geospatial "coverage".
- The term "grid coverage" typically refers to content such as satellite images, digital aerial photos, digital elevation data, and other phenomena represented by values at each measurement point
- Operations
  - GetCapabilities
  - DescribeCoverage
  - GetCoverage

WPS (Web Processing Service)

Web Processing Service Standard

- provides rules for standardizing how inputs and outputs (requests and responses) for geospatial processing services, such as polygon overlay.
- The standard also defines how a client can request the execution of a process, and how the output from the process is handled. It defines an interface that facilitates the publishing of geospatial processes and clients' discovery of and binding to those processes. The data required by the WPS can be delivered across a network or they can be available at the server.
- Operations
  - GetCapabilities
  - DescribeProcess
  - Execute

FOSS4G

- Free and Open Source Software for Geospatial -

Open-source and Free?

- Open-source means the code is available to the general public for use, modification and re-distribution. (http://www.osgeo.org)
- User controls: select your favorite OS, vendor independency, access to source code
- Interoperability (OGC compliance)
- Support: forum, email-list, quick response for bug fixes
- How many projects here http://opensourcegis.org/?