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Federating Satellite RS data and Ground Sensor data based on OGC Web Service Standards

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GEO Grid Research Group/ITRI/AIST

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Standards in real world Electrical Plugs (and voltage!)

- Electronic devices need standardized access to electrical power.

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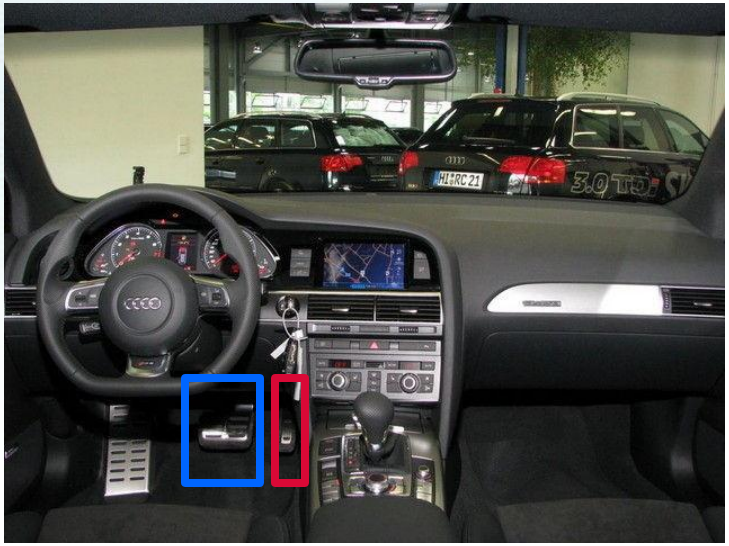
Standards in real world

- Left hand drive



- Right hand drive

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Standards in real – Bottle Caps

- You get the point...

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What makes a standard “Open”?

- **Available –** Anyone is allowed to read and implement the standard.
- **No Royalties –** Free to implement without paying hefty licensing fees or royalties.
- **Not controlled by a single vendor -** Maximizes end-user choice and makes the market more competitive with no lock-in to a single vendor's implementation.

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Open GIS Consortium (OGC)

- Open GIS Consortium (OGC)
  - Non-profit, international voluntary consensus standards organization
  - Industry, government, and university members

- Over 350 members worldwide – over 30 countries & 5 continents
  - 173 European members
  - 44 Asia-Pacific members - Japan, Republic of Korea, Australia, China, and Thailand

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Open GIS Specification

Title	Rev
OpenGIS Coordinate Transformation Service Implementation Specification	1.0
OpenGIS Filter Encoding Implementation Specification	1.1
OpenGIS Geography Markup Language (GML) Encoding Standard	3.2.1
OpenGIS Sensor Observation Service (SOS)	1.0.0
OpenGIS Web Feature Service (WFS) Implementation Specification	1.1.0
OpenGIS Web Map Service (WMS) Implementation Specification	1.3.0
OpenGIS Web Map Context Implementation Specification	1.1
Web Coverage Service (WCS) Implementation Standard	1.1.2
Web Processing Service (WPS)	1.0.0
OGC KML	2.2.0

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Web Map Service (WMS)

- Provide **images of map** data defined by a geographic/spatial component
- HTTP based (GET or POST)
- Currently version 1.3.0
- Operations
  - GetCapabilities
  - GetMap
  - GetFeatureInfo
    - Operation **keywords** are CaSe-InSeNsItIvE
    - Operation **values** are case-sensitive

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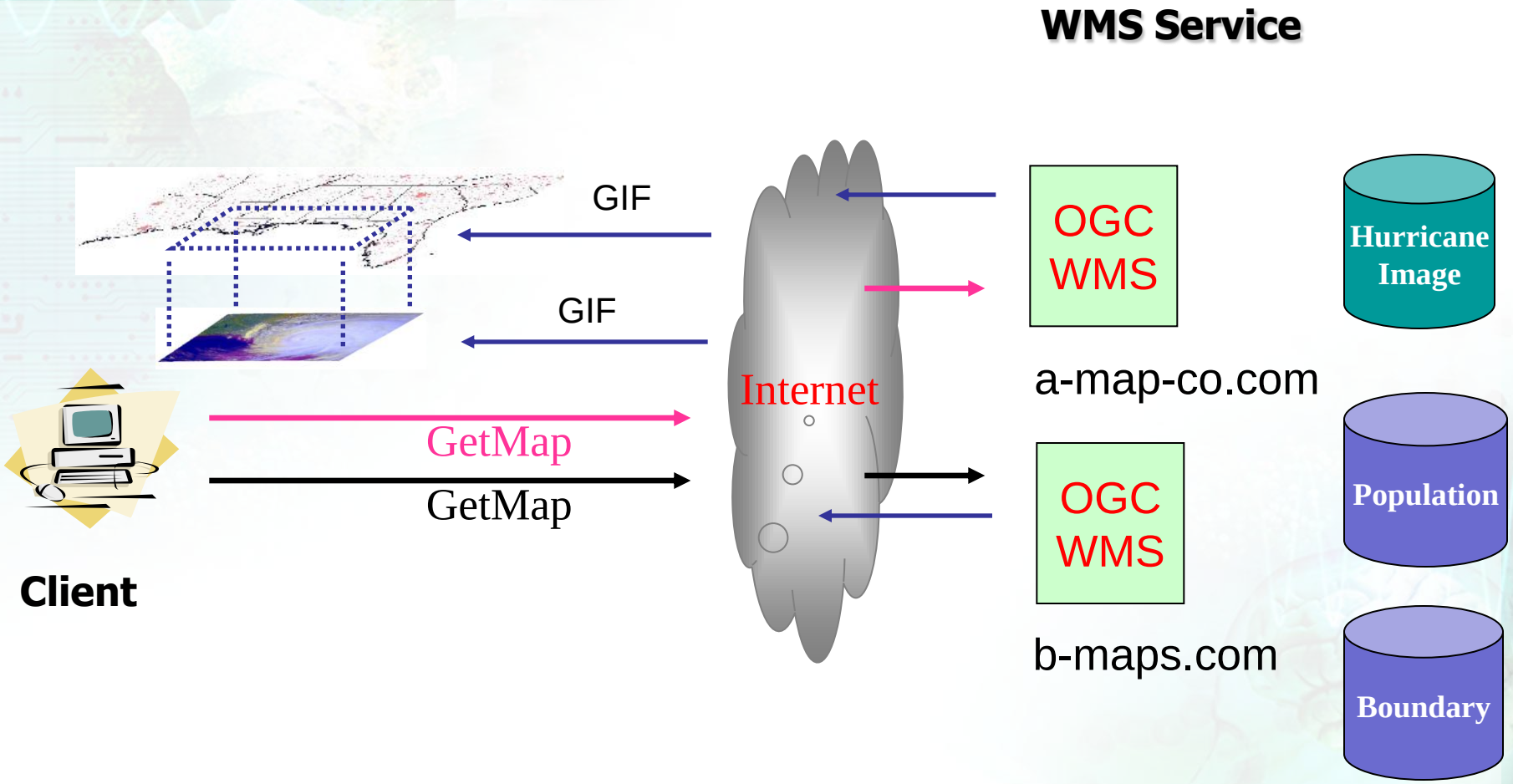
Web Map Service (WMS)



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WMS Multi-dimensional data

- WMS for Multi-dimensional data
  - Time : WMS providing daily satellite images
  - Elevation
- WMS-T support to temporal requests
  - Time parameter
  - Based on the ISO 8601:1988(E) “extended” format
  - Examples : 2004-10-12T13:55:20Z, 2004-10-12, 20041012
- WMS-T Time expression:
  - Single value (2004-10-12)
  - Multiple values (2004-10-12, 2004-10-13)
  - Single range : 2004-10-12/2004-10-13
  - Multiple ranges (2004-10-12/2004-10-13, 2004-10-15/2004-10-16)

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Web Map Service (WMS)

- GetFeatureInfo
  - Asks for information about features display in the map by point-based queries on map data
  - No ability for complex, expression-like queries

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Web Map Service (WMS)

- GetFeatureInfo
  - Parameters
  - <all GetMap parameters>
    - **Use** request=GetFeatureInfo instead of GetMap
    - Pass on ALL GetMap keyword-value pairs as if performing a GetMap request
    - x (pixel value in X image coordinates)
    - y (pixel value in Y image coordinates)
    - query_layers (layers to be queried)
      - Can be one or multiple layers
      - This does not substitute passing the layers parameter

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Web Coverage Service (WCS)

- Spatial Data Infrastructure (SDI) of **raster data** defined by a range of properties or values.
  - Share raster data
- Data returned using common formats such as GeoTIFF
- GetCapabilities ,DescribeCoverage ,**GetCoverage**
- Open Source MapServer:
  - WCS server, GML2 & GML3
  - Raster **re-projection** and **re-sampling**

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WCS - GetCoverage

Request Mandatory

http://siteURL/wcs**?version**=1.0.0**&service**=WCS**&request**=GetCoverage

Request Parameters

&coverage=aster

&crs=EPSG:4326

&resx=0.00016391**&resy**=0.00013521
or **&width**=2500**&height**=2600
&format=GEOTIFF

&BBOX=135.863650,34.709941,
135.875779,34.711158

Result

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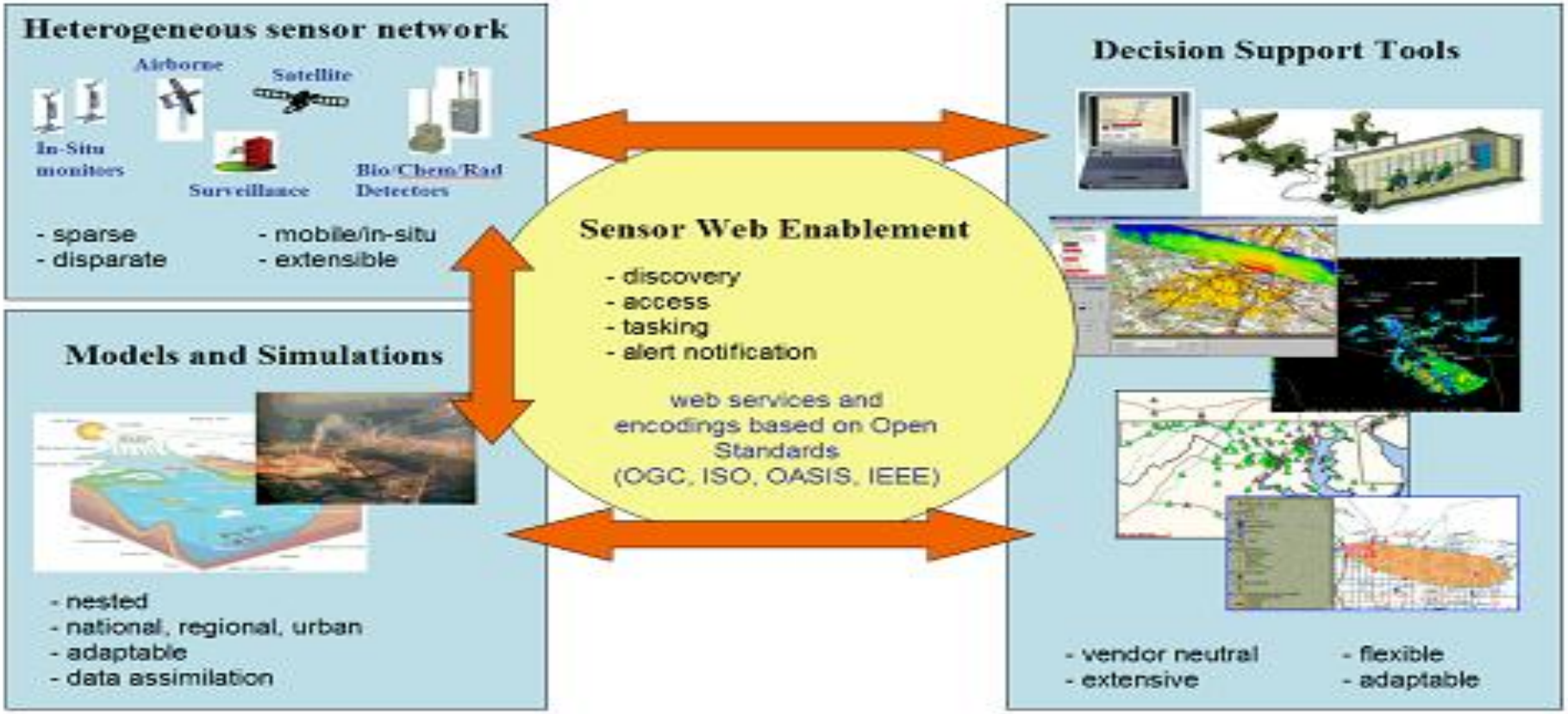
Sensor Web Enablement (SWE)



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Sensor Web Enablement (SWE)

- O&M [Observations & Measurements Schema]
- SensorML [Sensor Model Language]
- TML [Transducer Markup Language]
- **SOS [Sensor Observation Service]**
  - Provides the framework of the sensing resources to service users.
- SPA [Sensor Planning Service]
- SAS [Sensor Alert Service]
- WNS [Web Notification Service]

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Sensor Web Enablement (SWE)

- Different real-time acquisition system
  - Different makers , Different architecture
  - No standards
- Sensor Observation Service (SOS)
  - Accessing observation from various type sensor system in a common manner
  - Compliance testing of standard web service with heterogeneous system [PEN, Live E! and Field Server]
  - Spatial, Temporal and observed value query

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SOS Results

```
<om:CommonObservation xsi:type="om:CommonObservationType">
  <om:time/>
  <om:location/>
  <om:procedure xlink:href="urn:ogc:object:feature:Sensor:WJPWaterQStation1004"/>
- <om:observedProperty>
  - <swe:CompositePhenomenon gml:id="USER_DEFINED" dimension="8" xsi:type
      <swe:component xlink:href="urn:ogc:data:time:iso8601"/>
      <swe:component xlink:href="urn:ogc:def:phenomenon:OGC:1.0.30:BOD"/>
      <swe:component xlink:href="urn:ogc:def:phenomenon:OGC:1.0.30:DO"/>
      <swe:component xlink:href="urn:ogc:def:phenomenon:OGC:1.0.30:Nitrate"/>
      <swe:component xlink:href="urn:ogc:def:phenomenon:OGC:1.0.30:pH"/>
      <swe:component xlink:href="urn:ogc:def:phenomenon:OGC:1.0.30:Phosphate"/>
      <swe:component xlink:href="urn:ogc:def:phenomenon:OGC:1.0.30:TDS"/>
      <swe:component xlink:href="urn:ogc:def:phenomenon:OGC:1.0.30:Temperature"
      <swe:component xlink:href="urn:ogc:def:phenomenon:OGC:1.0.30:Turbidity"/>
    </swe:CompositePhenomenon>
  </om:observedProperty>
- <om:featureOfInterest>
  - <sos:GeoReferenceableFeature gml:id="1004">
      <gml:name>Biwako4</gml:name>
    - <gml:location>
      - <gml:Point srsName="EPSG:4326">
          <gml:coordinates>136.10965216065 35.246504961638</gml:coordinate
        </gml:Point>
      </gml:location>
    </sos:GeoReferenceableFeature>
  </om:featureOfInterest>
```

```
<swe:DataGroup>
- <swe:component name="dateTime">
    <swe:Time definition="urn:ogc:data:time:iso8601"/>
  </swe:component>
- <swe:component name="BOD">
    <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.
  </swe:component>
- <swe:component name="DO">
    <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.
  </swe:component>
- <swe:component name="Nitrate">
    <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.
  </swe:component>
- <swe:component name="pH">
    <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.
  </swe:component>
- <swe:component name="Phosphate">
    <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.
  </swe:component>
- <swe:component name="TDS">
    <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.
  </swe:component>
- <swe:component name="Temperature">
    <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.
  </swe:component>
- <swe:component name="Turbidity">
    <swe:Quantity definition="urn:ogc:def:phenomenon:OGC:1.
  </swe:component>
</swe:DataGroup>
<om:result>
  2007-09-16T16:26:00Z,4,7.1,0.8,9.3,0.03,15,23.7,6@@
</om:result>
```

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Web Processing Service (WPS)

- **Web Processing Service** (WPS)
  - OGC launches a specification as Version 1.0.0
  - Provides client access to **pre-programmed calculations** and/or **computation models** that operate on spatially referenced data
  - The result of request process are available to download for further analysis at user's machine.
  - PyWPS interface
  - GRASS GIS, GDAL etc.

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WPS Interface

- GetCapabilities – This operation allows a client to describe the abilities of specific server implementation.

- DescribeProcess – This operation allows a client to request detailed information about one or more process that can be executed, including the necessary input parameters and formats, and the outputs.

- Execute – This operation allows a client to run a specified process implemented by the WPS, using provided input parameter values and returning the output produced.

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WPS : GetCapabilities Interface

```
- <Capabilities version="0.4.0" xsi:schemaLocation="http://www.opengeospatial.r
  - <ows:ServiceIdentification>
      <ows:Title> PyWPS 0.1 </ows:Title>
      <!--Element Abstract not set-->
    - <ows:Keywords>
        <ows:Keyword> GRASS </ows:Keyword>
        <ows:Keyword> GIS </ows:Keyword>
        <ows:Keyword> WPS </ows:Keyword>
      </ows:Keywords>
      <ows:ServiceType> WPS </ows:ServiceType>
      <ows:ServiceTypeVersion> 0.1.0 </ows:ServiceTypeVersion>
      <!--Element Fees not set-->
      <!--Element AccessConstraints not set-->
    </ows:ServiceIdentification>
  - <ows:ServiceProvider>
      <ows:ProviderName> Help-Service </ows:ProviderName>
    - <ows:ServiceContact>
        <ows:IndividualName> Jachym Cepicky </ows:IndividualName>
        <ows:PositionName> Student </ows:PositionName>
      - <ows:ContactInfo>
        - <ows:Address>
            <ows:DeliveryPoint> Mengendamm 16d </ows:DeliveryPoint>
            <ows:City> Hannover </ows:City>
            <ows:PostalCode> 30177 </ows:PostalCode>
```

```
          </ows:HTTP>
        </ows:DCP>
      </ows:Operation>
    </ows:OperationsMetadata>
  - <ProcessOfferings>
    - <Process processVersion="0.1">
        <ows:Identifier> addvalue </ows:Identifier>
        <ows:Title> Add some value to raster map </ows:Title>
        <!--Element Abstract not set-->
        <!--Element Metadata not set-->
      </Process>
    - <Process processVersion="0.1">
        <ows:Identifier> classify </ows:Identifier>
        <ows:Title> Image classification </ows:Title>
      - <ows:Abstract>
          GRASS processed imagery classification. Only unsupervised is
        </ows:Abstract>
        <!--Element Metadata not set-->
      </Process>
    - <Process processVersion="0.1">
        <ows:Identifier> flow </ows:Identifier>
        <ows:Title> Flow analysis </ows:Title>
        <ows:Abstract> GRASS processed r.flow analysis. </ows:Abst
        <!--Element Metadata not set-->
```

http://mizu.info.gscc.osaka-cu.ac.jp/cgi-bin/wps.py?service=wps&version=0.4.0&request=getcapabilities

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WPS : DescribeProcess Interface

```
- <ProcessDescriptions xsi:schemaLocation="http://www.opengeospatial.net/wps http:/
  - <ProcessDescription processVersion="0.1" statusSupported="false" storeSuppor
      <ows:Identifier> shortestpath </ows:Identifier>
      <ows:Title> Shortest path </ows:Title>
    - <ows:Abstract>
        Find the shortes path on the roads map on Czech republic road network
      </ows:Abstract>
    - <DataInputs>
      - <Input>
          <ows:Identifier> x1 </ows:Identifier>
          <ows:Title> Start x coordinate </ows:Title>
          <!--Element Abstract not set-->
        - <LiteralData>
            <!--Element DataType not set-->
            <SupportedUOMs defaultUOM="meters"/>
            <ows:AnyValue/>
          </LiteralData>
          <MinimumOccurs> 1 </MinimumOccurs>
        </Input>
      - <Input>
          <ows:Identifier> y1 </ows:Identifier>
          <ows:Title> Start y coordinate </ows:Title>
          <!--Element Abstract not set-->
        - <LiteralData>
            <ows:AnyValue/>
          </LiteralData>
          <MinimumOccurs> 1 </MinimumOccurs>
        </Input>
      - <Input>
          <ows:Identifier> cost </ows:Identifier>
          <ows:Title> Calculation parameter </ows:Title>
          <ows:Abstract> time or length (default) </ows:Abstract
        - <LiteralData>
            <!--Element DataType not set-->
            <SupportedUOMs defaultUOM="meters"/>
            <ows:AnyValue/>
          </LiteralData>
          <MinimumOccurs> 1 </MinimumOccurs>
        </Input>
      </DataInputs>
    - <ProcessOutputs>
      - <Output>
          <ows:Identifier> output </ows:Identifier>
          <ows:Title> Resulting output map </ows:Title>
          <!--Element Abstract not set-->
        - <ComplexOutput defaultFormat="text/xml">
          - <SupportedComplexData>
              <Format> text/xml </Format>
```

http://mizu.info.gscc.osaka-cu.ac.jp/cgi-bin/wps.py?service=wps&version=0.4.0&request=describeprocess&Identifier=shortestpath

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WPS : Execute Interface [ProcessAccepted]

```
<?xml version="1.0" ?>
- <ExecuteResponse statusLocation="http://mizu.info.gscc.osaka-cu.ac.jp/wpsoutputs/executeresponse-2007-6-18-15-9-3.xml" version="0.4.0"
  xmlns="http://www.opengeospatial.net/wps" xmlns:ows="http://www.opengeospatial.net/ows"
  xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.opengeospatial.net/wps
  http://www.bnhelp.cz/schema/wps/0.4.0/wpsExecute.xsd">
  <ows:Identifier>shortestpath3</ows:Identifier>
- <Status>
    <ProcessAccepted />
  </Status>
</ExecuteResponse>
```

http://mizu.info.gscc.osaka-cu.ac.jp/cgi-bin/wps.py?service=wps&version=0.4.0&request=execute&Identifier=shortestpath&Datainputs=cost,0,x1,596527,y1,4921298,x2,598173,y2,4923383&store=true&status=true

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WPS : Execute Interface [ProcessStarted]

```
<?xml version="1.0" ?>
<ExecuteResponse statusLocation="http://mizu.info.gscc.osaka-cu.ac.jp/wpsoutputs/executeresponse-2007-6-18-15-9-3.xml" version="0.4.0"
  xmlns="http://www.opengeospatial.net/wps" xmlns:ows="http://www.opengeospatia
  xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XM
  instance" xsi:schemaLocation="http://www.opengeospatial.net/wps
  http://www.bnhelp.cz/schema/wps/0.4.0/wpsExecute.xsd">
  <ows:Identifier>shortestpath3</ows:Identifier>
- <Status>
    <ProcessStarted message="Calculate shortest path" percentCompleted="30">Calculate
      path</ProcessStarted>
  </Status>
</ExecuteResponse>
```

http://mizu.info.gscc.osaka-cu.ac.jp/wpsoutputs/executereponse-2007-6-18-15-9-3.xml

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WPS : Execute Interface [ProcessSucceeded]

```
<?xml version="1.0" ?>
- <ExecuteResponse statusLocation="http://mizu.info.gscc.osaka-cu.ac.jp/wpsoutputs/executeresponse-2007-6-18-15-9-3.xml" version="0.4.0" xmlns="http://www.opengeospatial.net/wps" xmlns:ows="http://www.opengeospatial.net/ows" xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.opengeospatial.net/wps http://www.bnhelp.cz/schema/wps/0.4.0/wpsExecute.xsd">
    <ows:Identifier>shortestpath3</ows:Identifier>
  - <Status>
      <ProcessSucceeded />
    </Status>
  - <ProcessOutputs>
    - <Output>
        <ows:Identifier>output</ows:Identifier>
        <ows:Title>Resulting output map</ows:Title>
        <!-- Element Abstract not set  -->
        <ComplexValueReference encoding="utf-8" format="text/xml"
          ows:reference="http://mizu.info.gscc.osaka-cu.ac.jp/wpsoutputs/out-2007-6-18-15-9-3.xml" schema="" />
      </Output>
    </ProcessOutputs>
  </ExecuteResponse>
```

http://mizu.info.gscc.osaka-cu.ac.jp/wpsoutputs/executereponse-2007-6-18-15-9-3.xml

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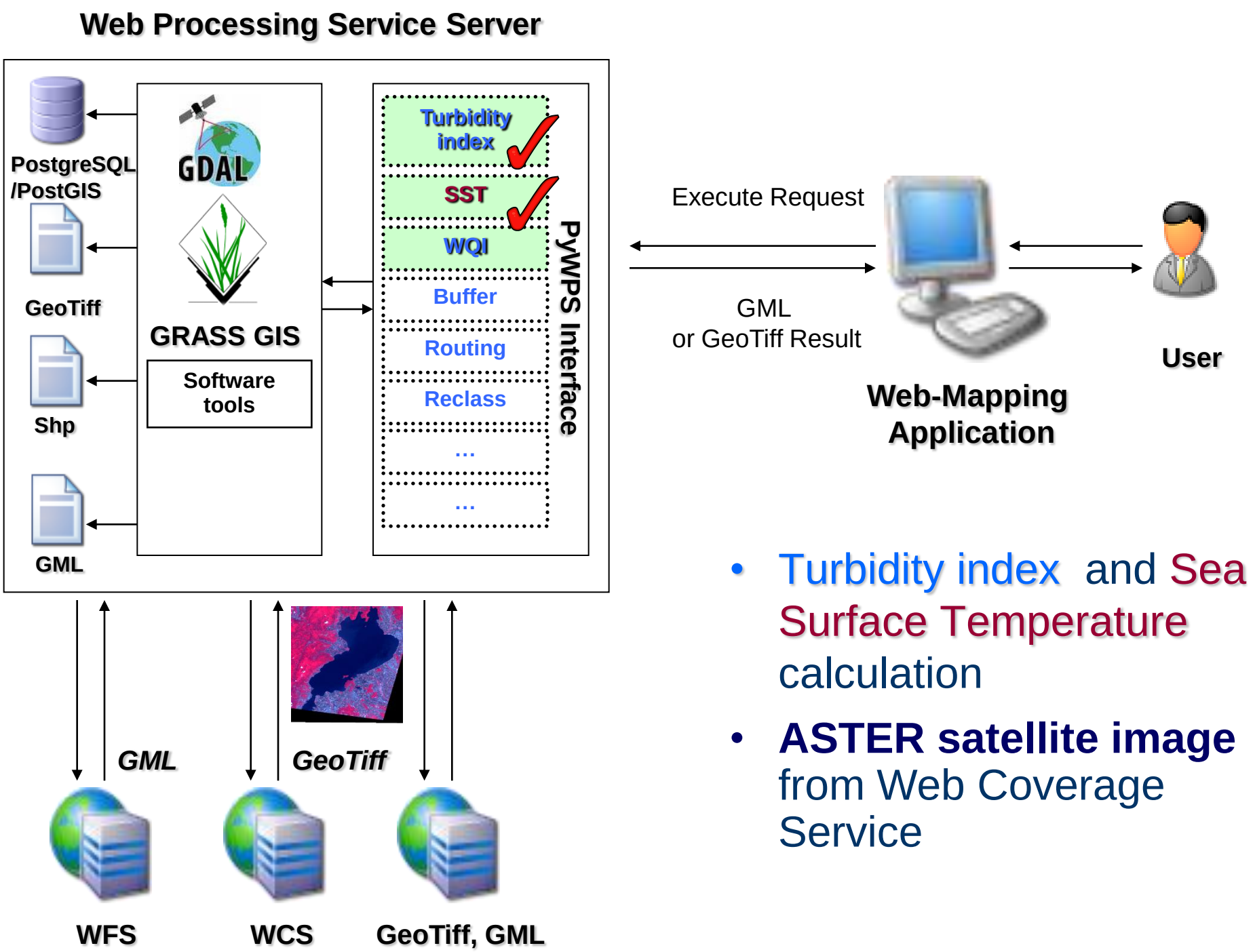
WPS : Result [GML]


```
- <ogr:FeatureCollection xsi:schemaLocation="http://ogr.maptools.org/ out.xsd">
  - <gml:boundedBy>
    - <gml:Box>
      - <gml:coord>
          <gml:X>592843.2968289739</gml:X>
          <gml:Y>4914589.50731653</gml:Y>
        </gml:coord>
      - <gml:coord>
          <gml:X>609094.18166981</gml:X>
          <gml:Y>4926388.634690436</gml:Y>
        </gml:coord>
      </gml:Box>
    </gml:boundedBy>
  - <gml:featureMember>
    - <ogr:path.xml fid="F0">
      - <ogr:geometryProperty>
        - <gml:LineString>
          - <gml:coordinates>
              592846,4915161,0 592843.296828973921947,4915178.570760559290648,0 592922.746579780010507,4915190.793695569969714
              592939.740226919995621,4915203.635474259965122,0 593029.565211800043471,4915270.903554679825902,0
              593067.848180119995959,4915279.518624009564519,0 593120.103363889968023,4915293.04078967962414,0
              593163.858170529943891,4915301.666797780431807,0 593210.70405852003023,4915288.342745279893279,0
              593266.065959259984083,4915273.206030479632318,0 593332.935454610036686,4915276.999082759954035,0
              593332.935454610036686,4915276.999082759954035,0 593343.336534579982981,4915248.964680040255189,0
              593360.451002530055121,4915209.965578059665859,0 593387.294604460010305,4915170.376030060462654,0
              593395.957023610011674,4915105.744418240152299,0 593404.53131463995669,4915078.926154689863324,0
```



- Turbidity index and Sea Surface Temperature calculation
- **ASTER satellite image** from Web Coverage Service

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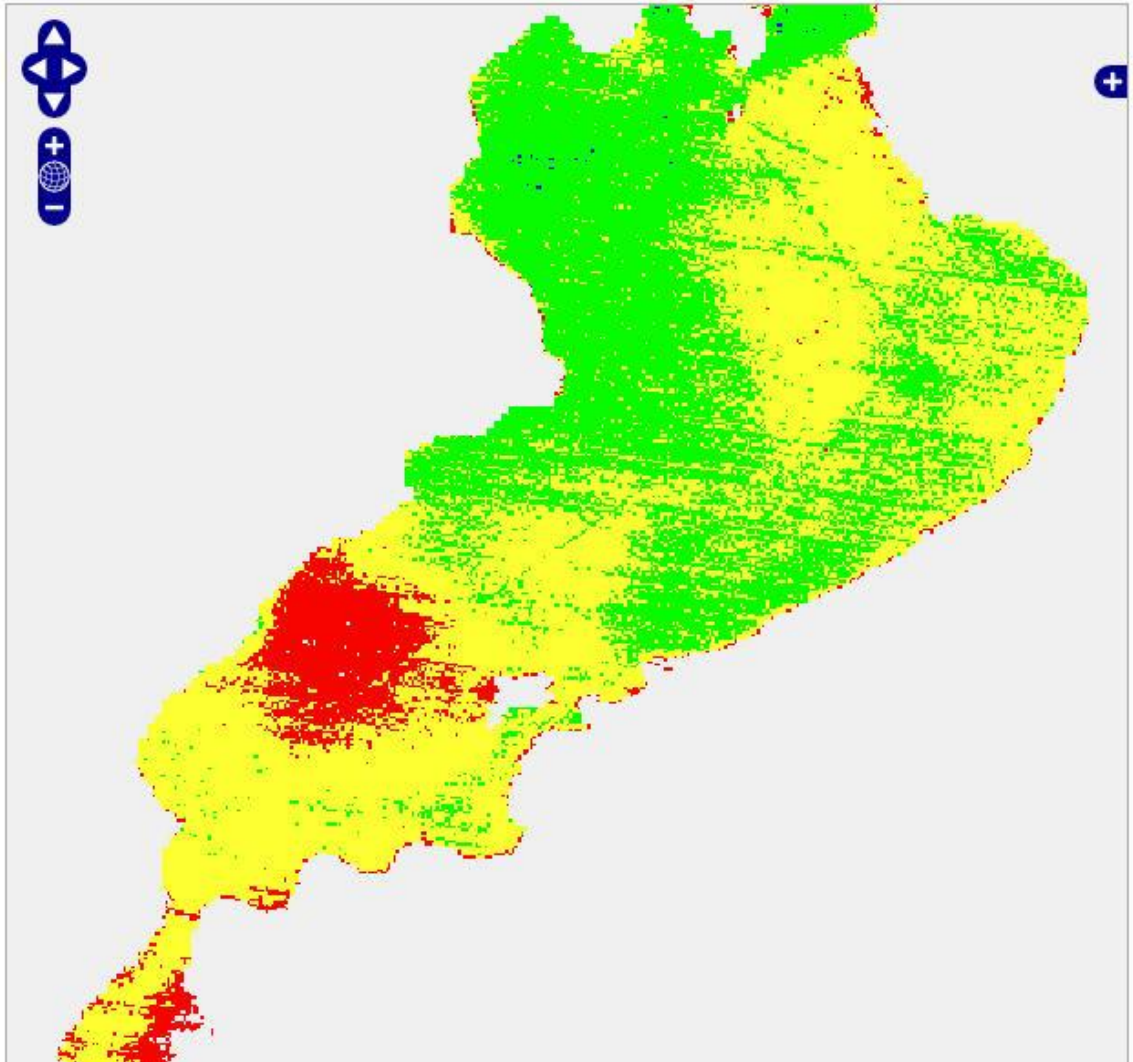
Prototype : SST

Data request → Data import → SST calculation → Export data



Water Quality Index Map

Select parameter and Date

WaterJP

2009-01-30 00:00:02+09

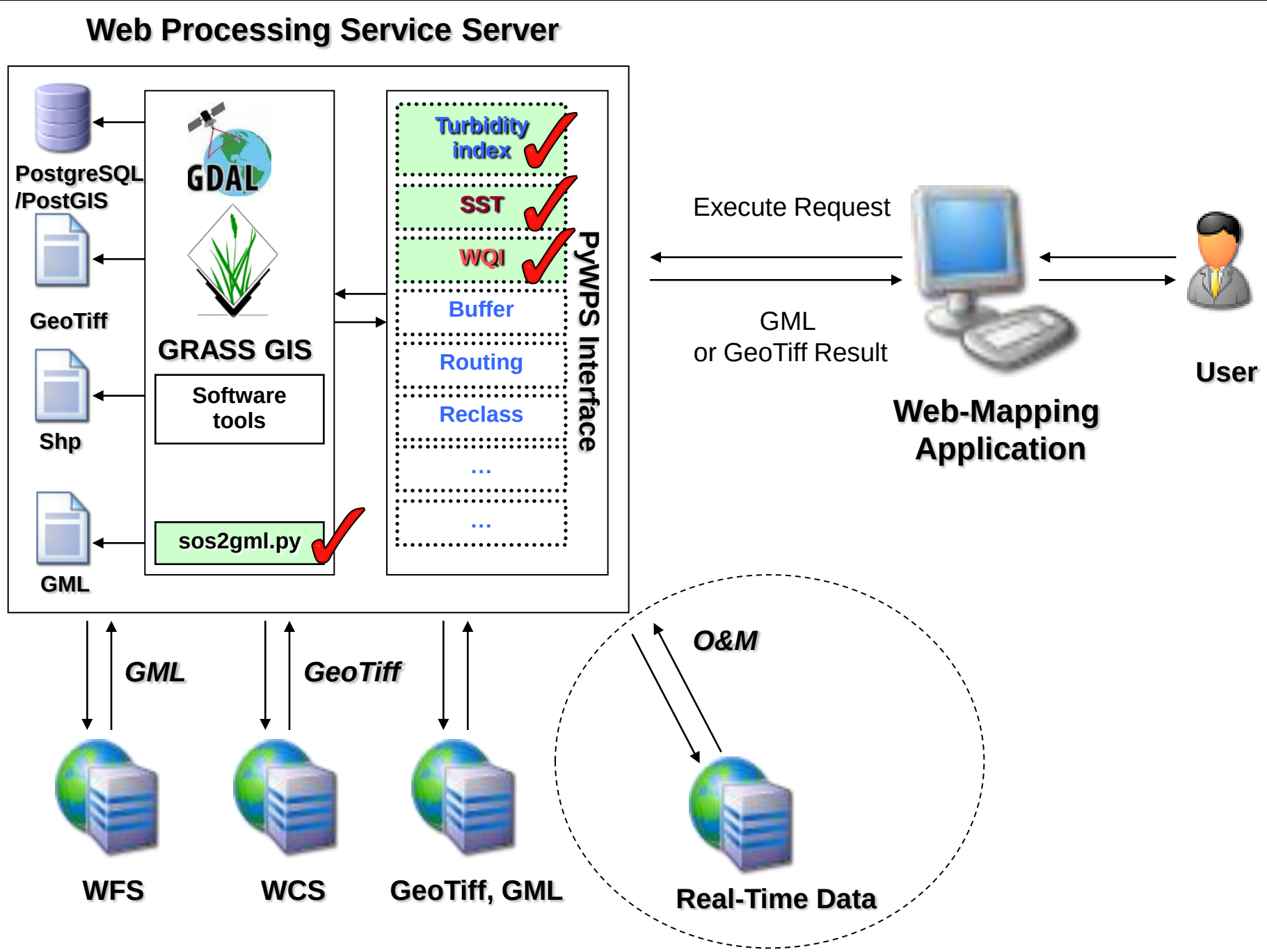
SST Calculation

Create Map

Result for downloading

Modelling Calculation :Download

Sensor
< 14 C
14 - 15 C
15 - 16 C
> 16 C


Web Processing Service Server
PostgreSQL /PostGIS
GeoTiff
Shp
GML
GDAL
GRASS GIS
Software tools
sos2gml.py
Turbidity index
SST
WQI
Buffer
Routing
Reclass
...
...
PyWPS Interface
Execute Request
GML
or GeoTiff Result
Web-Mapping Application
User
GML
GeoTiff
O&M
WFS
WCS
GeoTiff, GML
Real-Time Data

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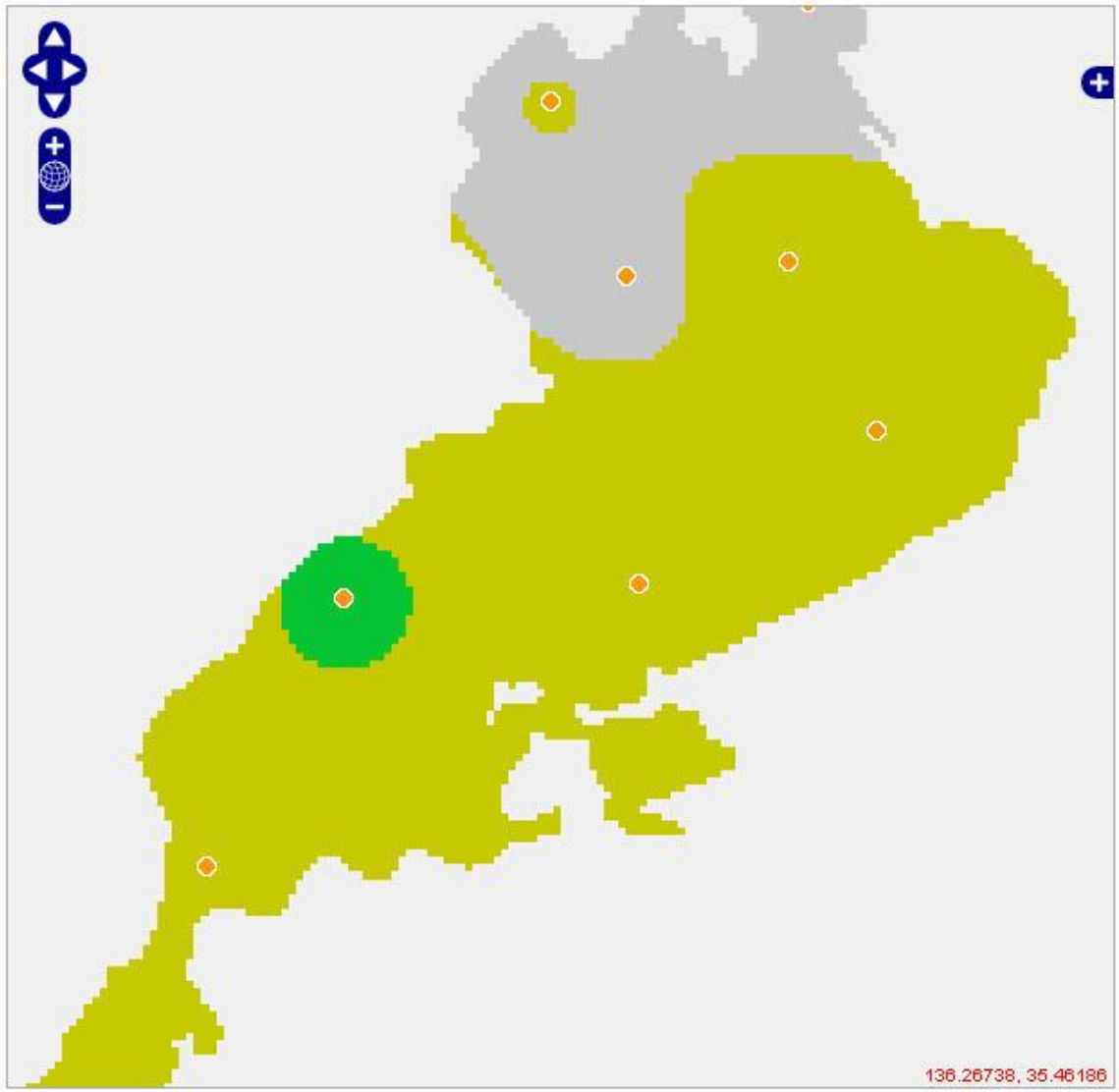
Prototype : Water Quality Index

Data request → SOS2GML → Data import → IDW interpolation → WQI calculation → Export data



Water Quality Index Map

Select parameter and Date

WaterJP

2009-01-15 00:00:01+09

WQI Calculation

Create Map

Result for downloading

Modelling Calculation :Download

Sensor Data :Download

Sensor
UFD
VeryPoor
Poor
Good
Excelllent

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Satellite RS & Ground-based

- Benefit of satellite RS:
  - Cheap and rapid over large geographic area
  - Regional coverage and broadly spectral resolution
  - Continuous acquisition of data
  - Archive of historical data

- Limitation of satellite RS:
  - Not direct sample of the phenomenon.
  - Interference of atmospheric gaseous and particles
    - Absorbing (H_20, O_3 etc.) and Scattering (mainly by aerosol particles such as dust, ash and smoke)

- Ground-based observation:
  - Direct sample of the phenomenon is possible
  - Real-time or Near Real-time observation
  - High temporal resolution
  - Expensive for wide area observation

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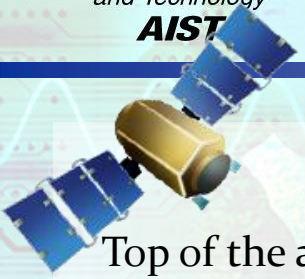
Validation satellite products



Basic Product

Top of the atmosphere

Surface Reflectance

Higher Product

Land Surface Temperature

Sea Surface Temperature

Gross Primary Productivity

Chlorophyll A

Land Cover

Vegetation Indices

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MODIS Ocean Products

- Ocean Temperature
  - **Long-wave SST (11-12 μm),** day and night
  - Short-wave SST (3.9 - 4.0 μm), night only
  - SST quality level (0-4)

- Ocean Color (day only)
  - Normalized water-leaving radiances, nLw(λ)
  - **Chlorophyll, C_a**
  - Diffuse attenuation, $K_d(490)$
  - Aerosol type and concentration
  - Processing flags
    - Cloud, land, glint, atmfail, atmwarn, chlfail, chlwarn, etc.

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GLEON

- Global Lake Ecological Observatory Network (GLEON)
  - Network of researchers, educators and community groups
  - Utilizing time series and high frequency observation on/in lakes all over the world
- Participating lakes:
  - Lake Sunapee, New Hampshire, USA
  - Lough Feeagh, County Mayo, Ireland
  - Trout Lake, Wisconsin, USA
  - Lake Rotorua, New Zealand etc.
- Each observation will be send in near-real time to web-accessible database
  - At web portal, various web services are provide user to access and utilizing observed data

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Lake Rotorua monitoring

- Data collected from the buoy will be used to monitor and improve of lake health
  - Due to impact of both urban and rural development
- Since 2007-07-13 every 15 minutes

Sensors	Make/model	Depths
Water temperature	Apprise TempLine	0.5 - 20.5 every 2m
Dissolved oxygen	D-opto	0.5, 20
Chlorophyll	Seapoint/Trios	1
Phycocyanin	Trios	1
Climate	Vaisala WXT510	n/a

Figure from http://www.lernz.co.nz/gallery/lakerotorua.html

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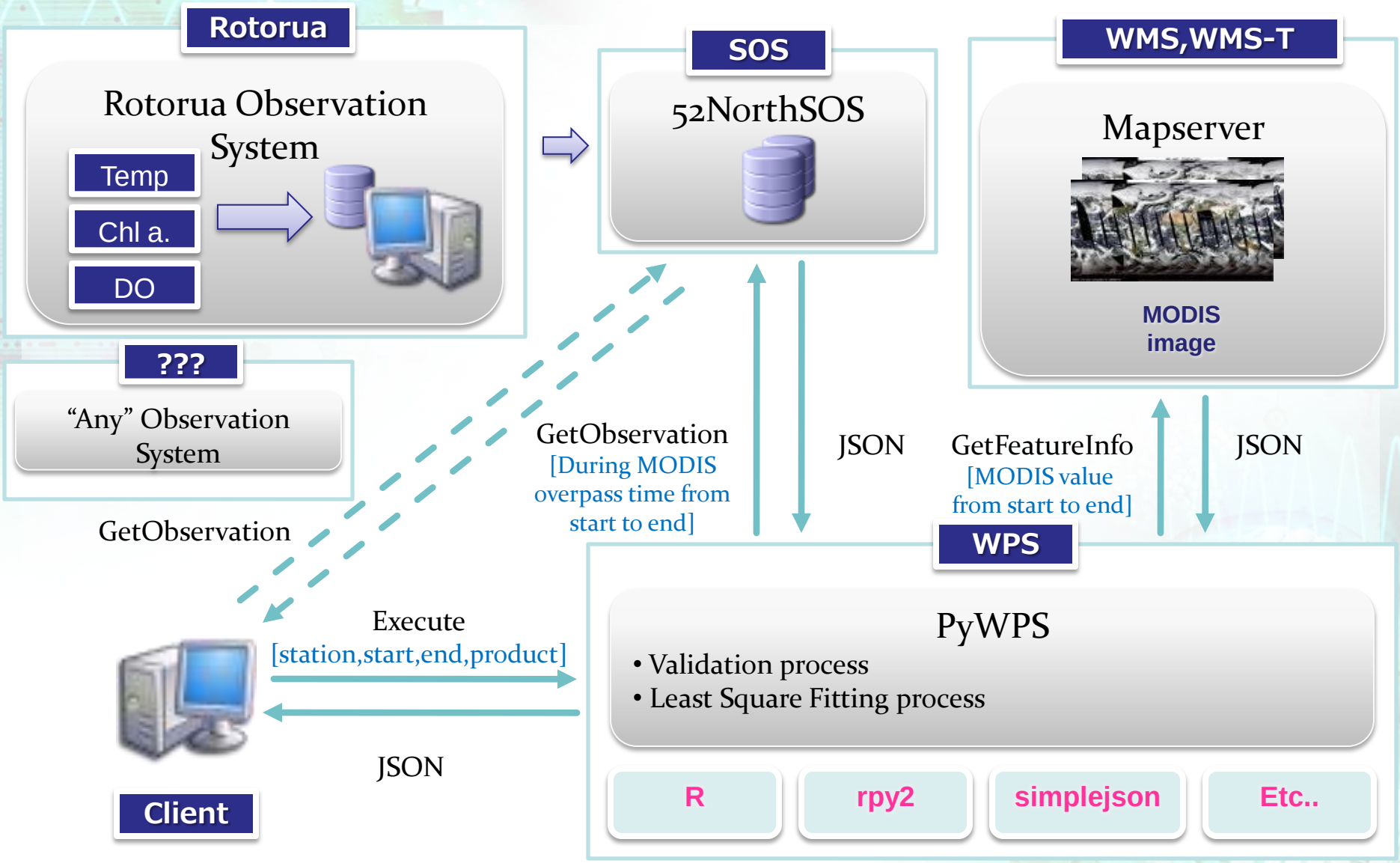
OGC System Framework



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Result

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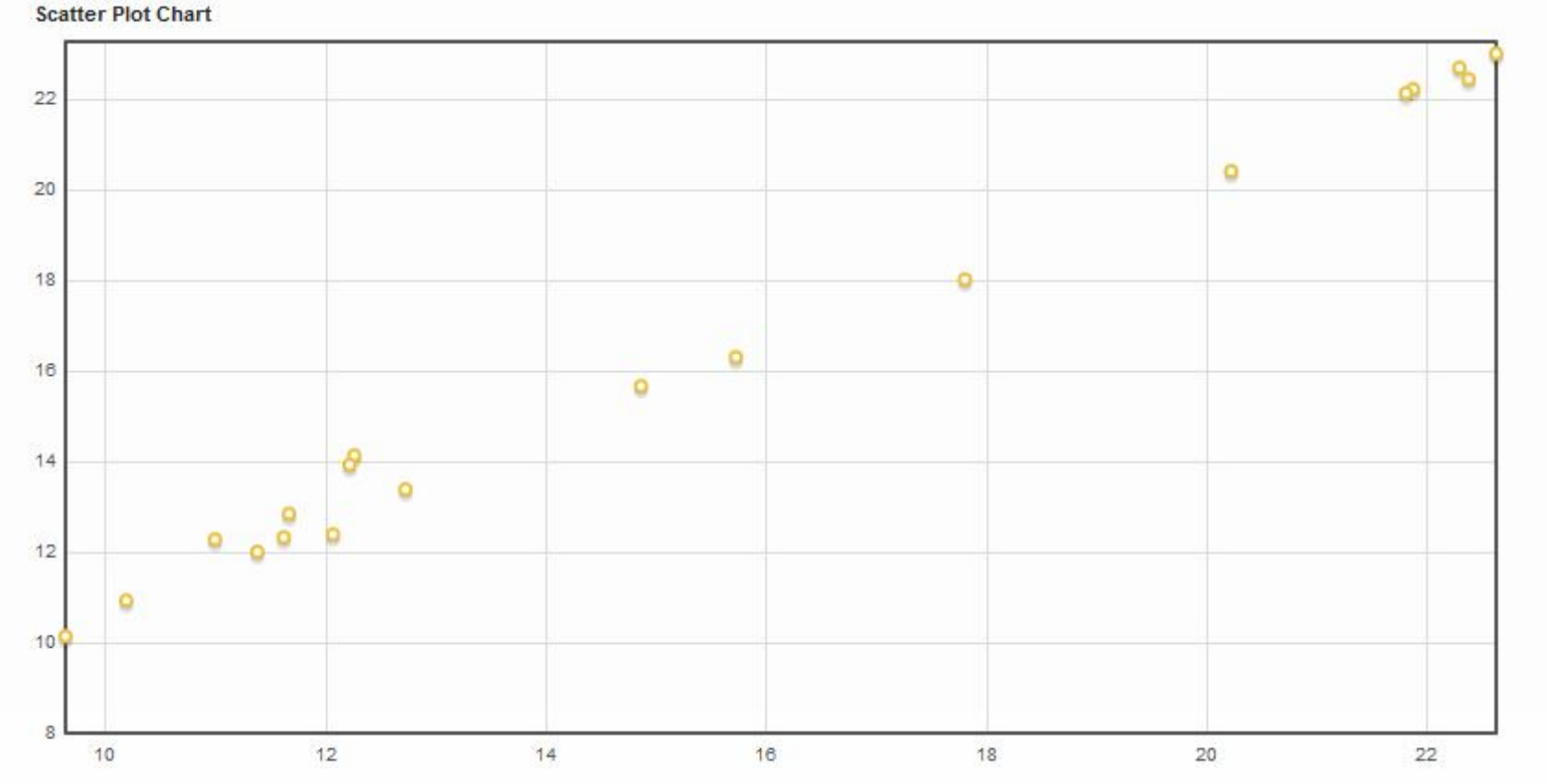
Result



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Cal/Val for satellite products

- Surface reflectance is basic product for higher level products (land use, land cover, biomass, etc …)
  - Need to convert the “top of the atmosphere” signal to the “surface reflectance”.
  - Estimating the surface spectral reflectance as it would have been measured at ground level
  - Use Radiative Transfer Model (6S, MODTRAN, etc …)
  - Need atmospheric parameters (satellite-based and/or ground-based)
  - Especially, aerosol over land is complicated by the higher variability and spatial heterogeneity
  - Need to calibrate/validate for surface reflectance and atmospheric parameters
- Focused on aerosol parameters in this research

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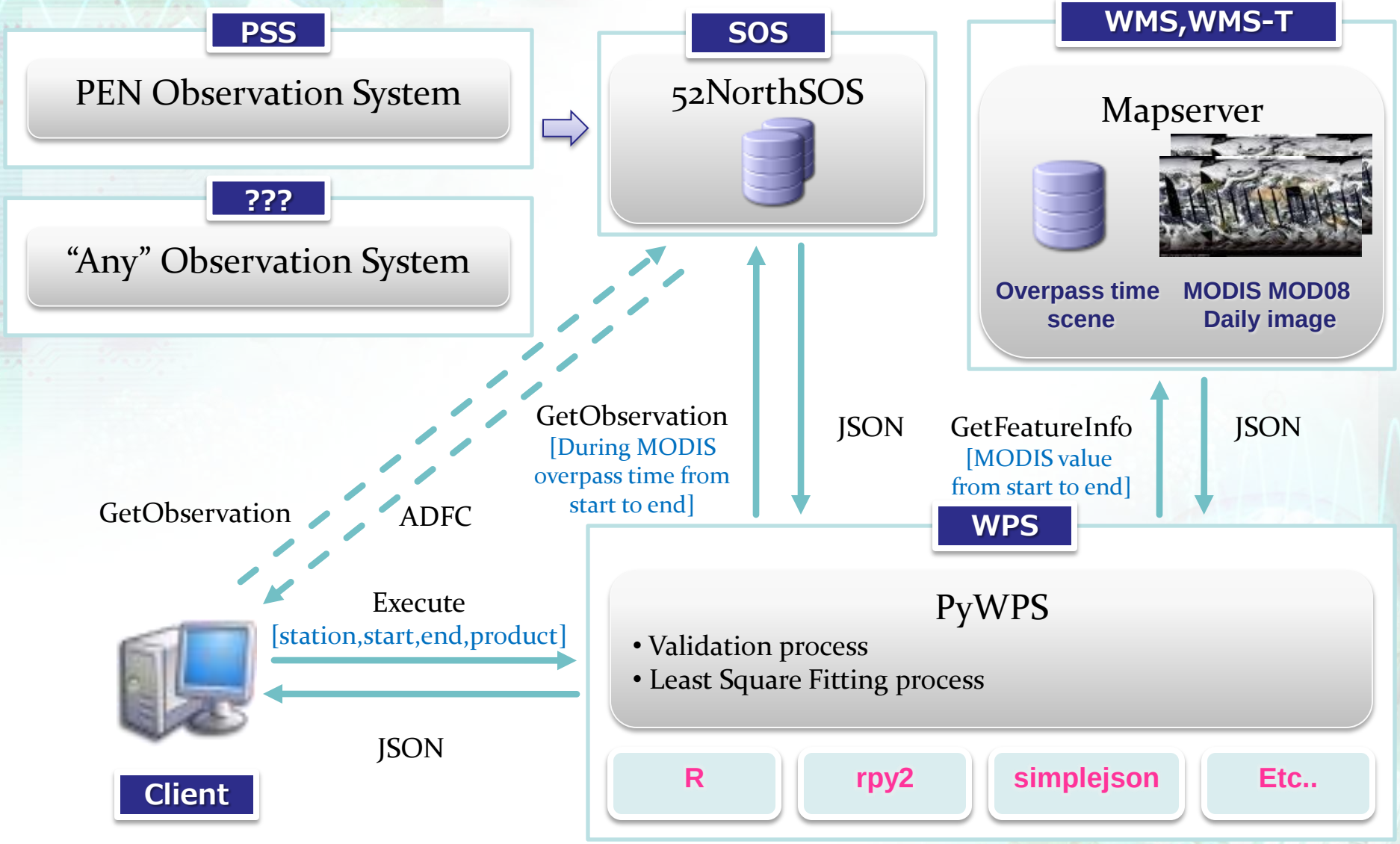
OGC System Framework



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What Next

- Increase atmospheric observation network
  - SKYNET, AERONET
- Satellite image product validation
  - CO2 Flux monitoring : Asiaflux / Japanflux
- Validation with higher satellite image resolution
  - ASTER, FORMOSAT-2
- Enabled-security OGC web service
  - Accessible control for each sensor site
- Real-time modeling application
  - Surface Runoff with Rain-Gauge sensor in Taiwan
- Enabled grid/cloud computing
  - Increase processing speed

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