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Utilization of Satellite image and Field sensor for Environmental Study

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GEO Grid Research Group/ITRI/AIST

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Introduction

- Environmental Study
  - Natural environments
  - Urbanization
  - Global Warming / Climate Change
- Monitoring spatial-temporal dynamic changes
  - Sustainable development
- Geo-environmental quality and management
  - Complex chain process
  - Diverse distributed data source
  - Huge of data for time-series data
- Implementation of database and IT solutions

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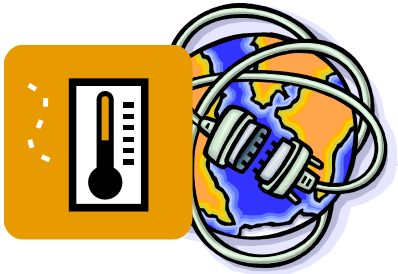
Geospatial Data Gathering

Satellite

Field Survey with Laboratory

Data Center

Data Logger



Smart Sensor

Internet

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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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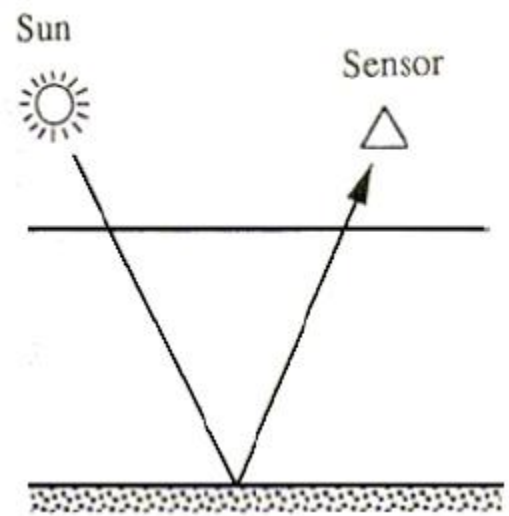
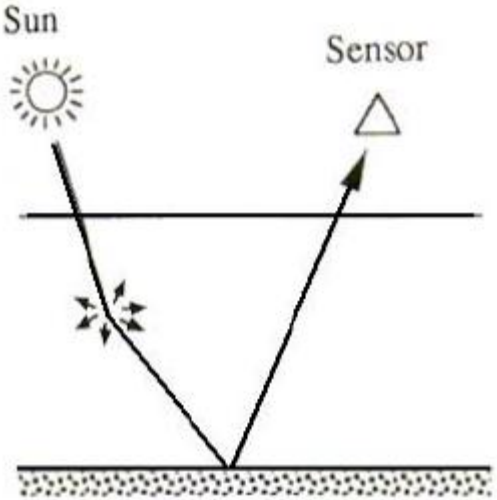
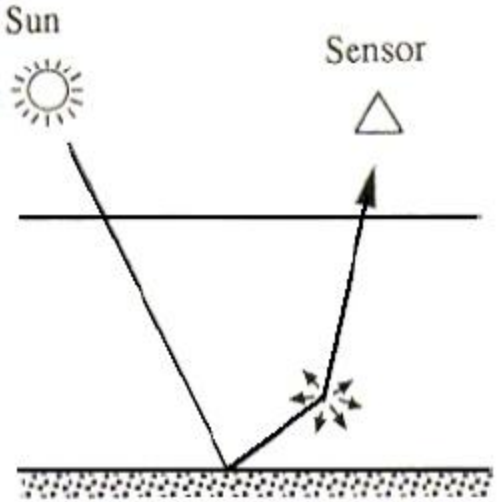
Surface reflectance and Top of the atmosphere







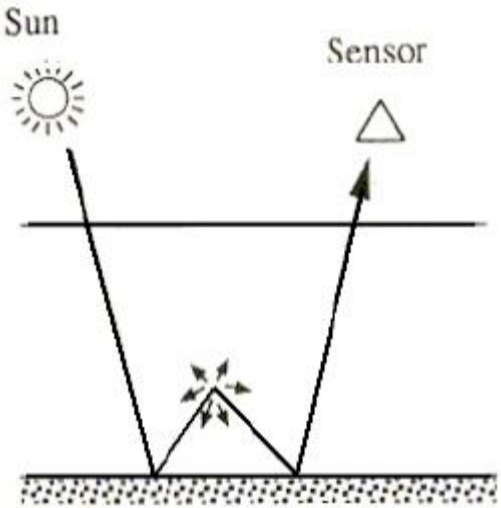


Image from: http://www.profc.udec.cl/~gabriel/tutoriales/rsnote/cp9/cp9-2.htm

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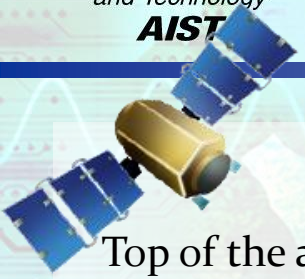
Validation satellite products



Basic Product

Top of the atmosphere

Surface Reflectance

- 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”.
  - Use Radiative Transfer Model (6S, MODTRAN, etc …)
  - Need atmospheric parameters (satellite-based and/or ground-based)
  - Need to calibrate/validate for **surface reflectance** and **atmospheric parameters**
- Focused on aerosol parameters in this research

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MOD04 and MOD08

- The algorithm retrieves daily Aerosol Optical Depth (AOD) as known as MOD04 in Level two product
  - Using seven bands of MODIS.
  - Resolution at 1 x 1, 5 x 5 and 10 x 10 km.
- The MOD08 is a Level three product as global dataset from MOD04
  - Daily Global, Eight-day Global and Monthly Global (Resolution 1º x 1º)
- Validation with ground observation is necessary to improve uncertainly estimate.

Band	Wavelength (μm)	Resolution (m)	Primary Use
1	0.620-0.670	250	Land/Cloud/Aerosols Boundaries
2	0.841-0.876	250	
3	0.459-0.479	500	
4	0.545-0.565	500	Land/Cloud/Aerosols Properties
5	1.230-1.250	500	
6	1.628-1.652	500	
7	2.105-2.155	500	

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PEN

- Phenological Eyes Network
  - Monitoring dynamics of the ecosystem
  - Validate satellite information with reliable information on ground level
- Measurement equipments:
  - Sunphoto meter (SP)
    - 11 spectral bands with FOV 1 degree at 10 minutes interval
    - Optical thickness, aerosol size and aerosol reflective index etc.
    - Main purpose for atmospheric correction and monitoring pollutants
  - Automatic-capturing Digital Fisheye Camera (ADFC)
    - High quality images of the sky, canopy, branch and ground
    - 2 – 180 minutes interval
    - Sky condition at satellite overpass time.
  - Hemi-Spherical Spectral Radiometer (HSSR)

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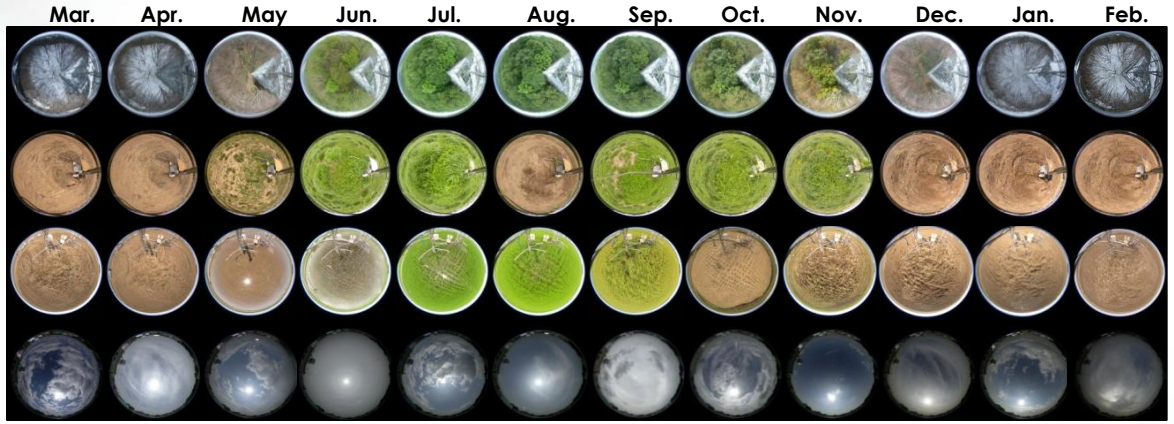
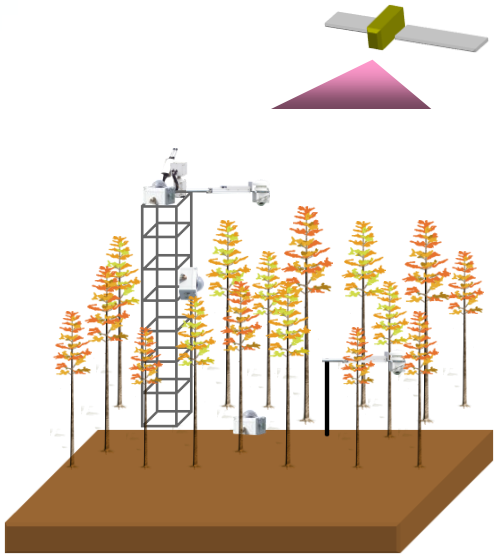
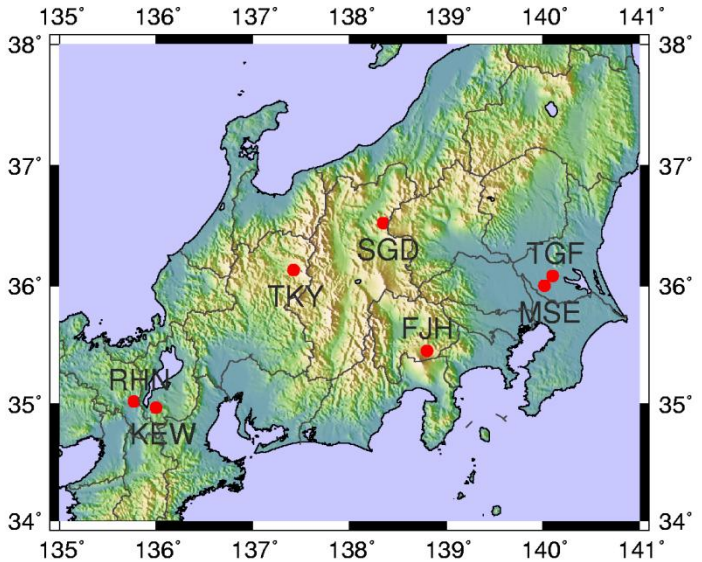
PEN Equipments







http://www.pheno-eye.org

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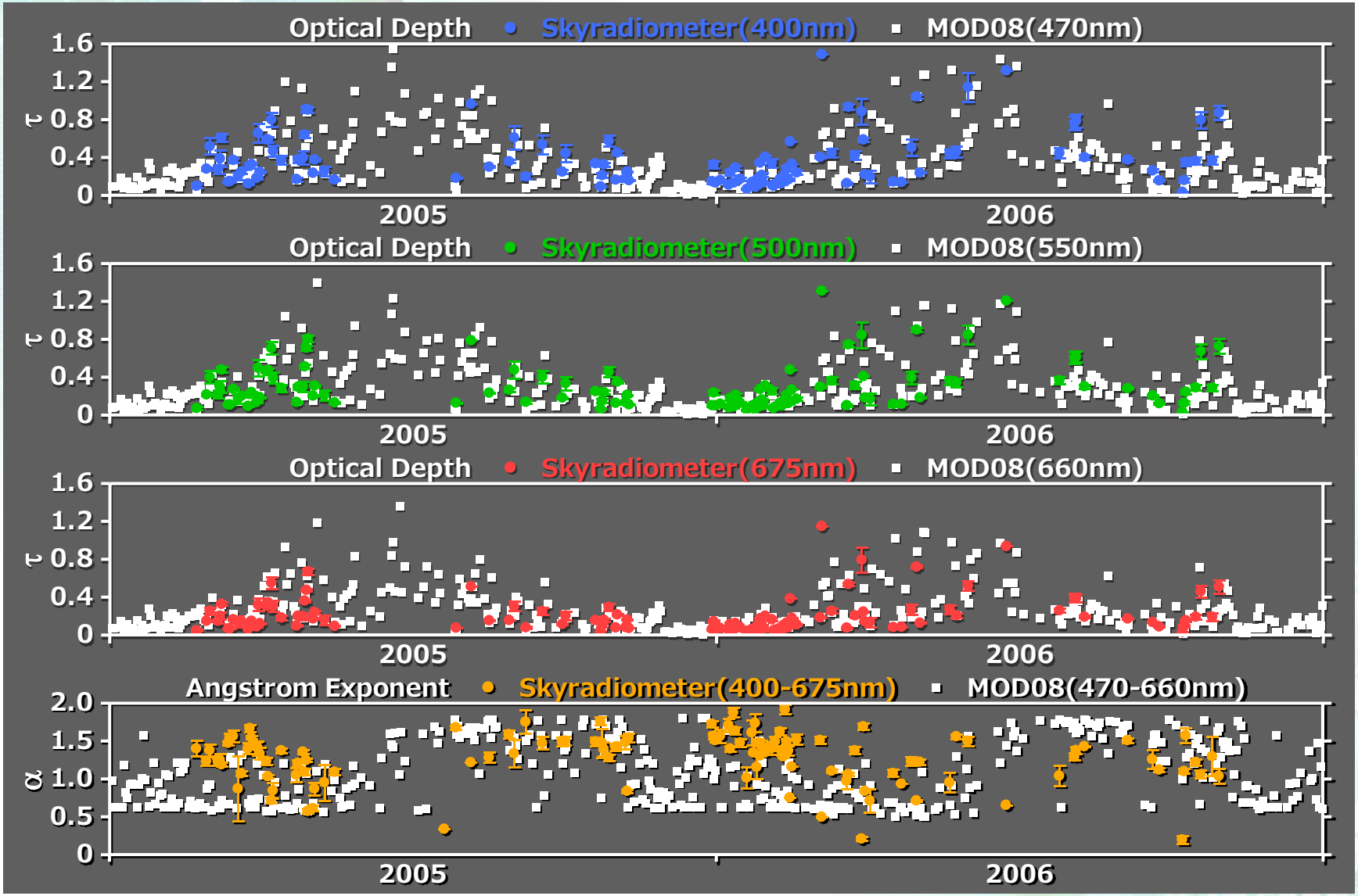
Validation (SP & MOD08)



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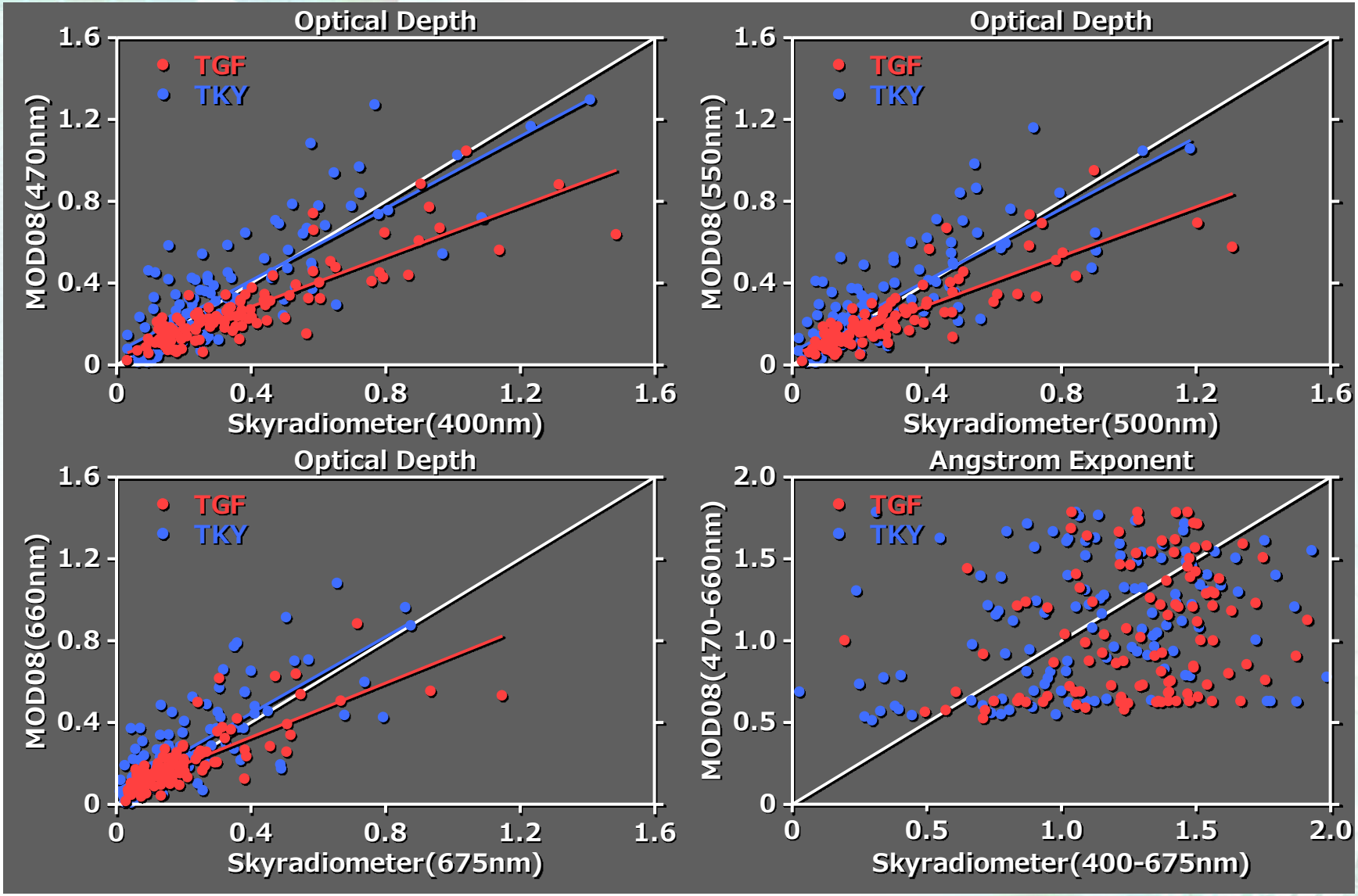
Validation (SP & MOD08)



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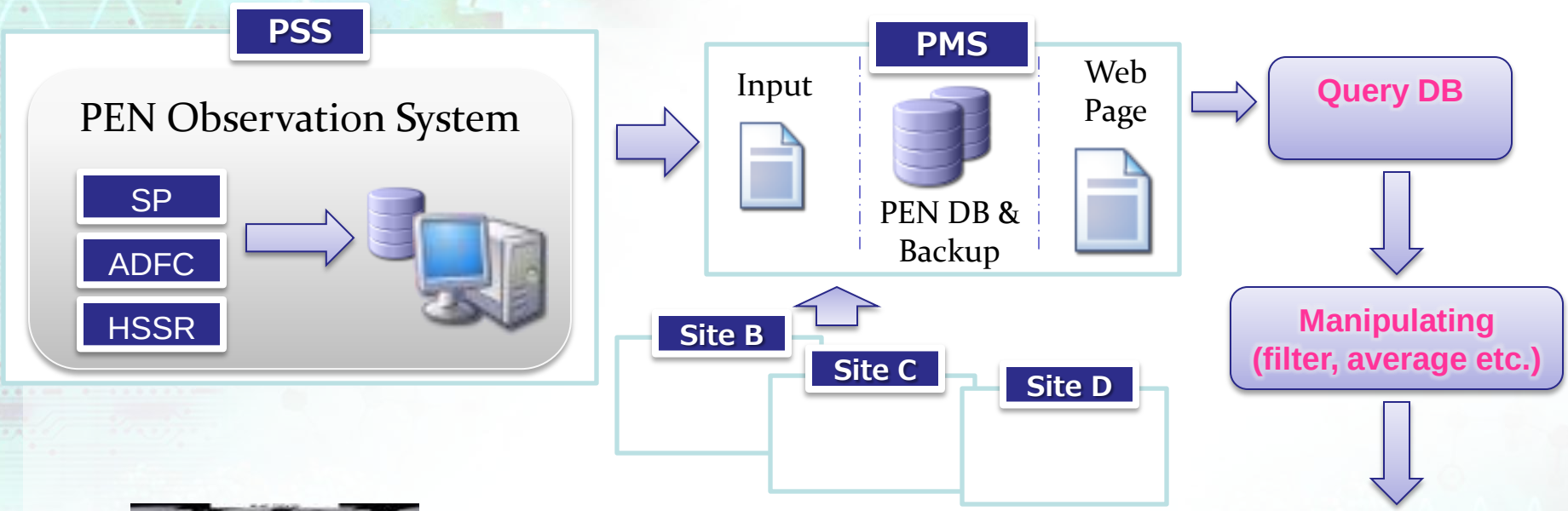
Previous System Framework



MODIS MOD08
Daily image

- Time consuming and need high level user experience.
- Lack of Robustness and scalable
- Not convenience for sharing among communities

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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

- OGC collaborates and works closely with:
  - International Organization for Standardization (ISO)
  - World Wide Web Consortium (W3C)
  - OASIS (Organization for the Advancement of Structured Information Standards)
  - And others…

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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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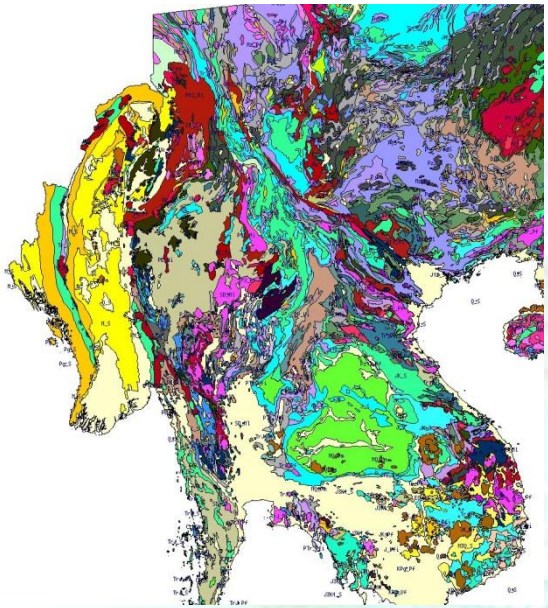
WMS – GetMap

http://geodata1.geogrid.org/mapserv/g2000k/g2000ke?service=WMS&VERSION=1.1.1&REQUEST=GetMap&**layers**=g2000ke&**srs**=EPSG:4326&**width**=1000&**height**=1000&**bbox**=90,10,110,30&**format**=image/jpeg



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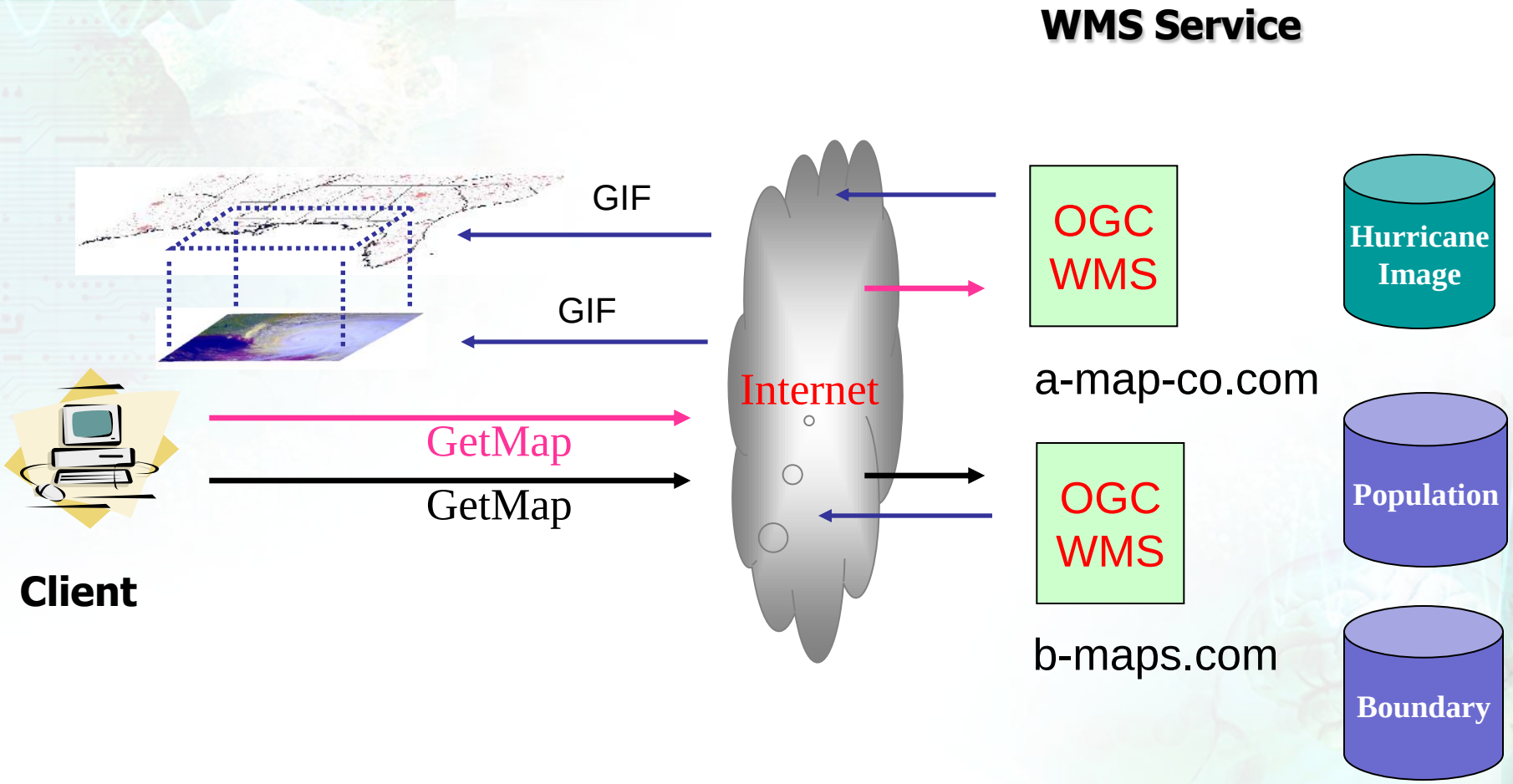
Web Map Service (WMS)



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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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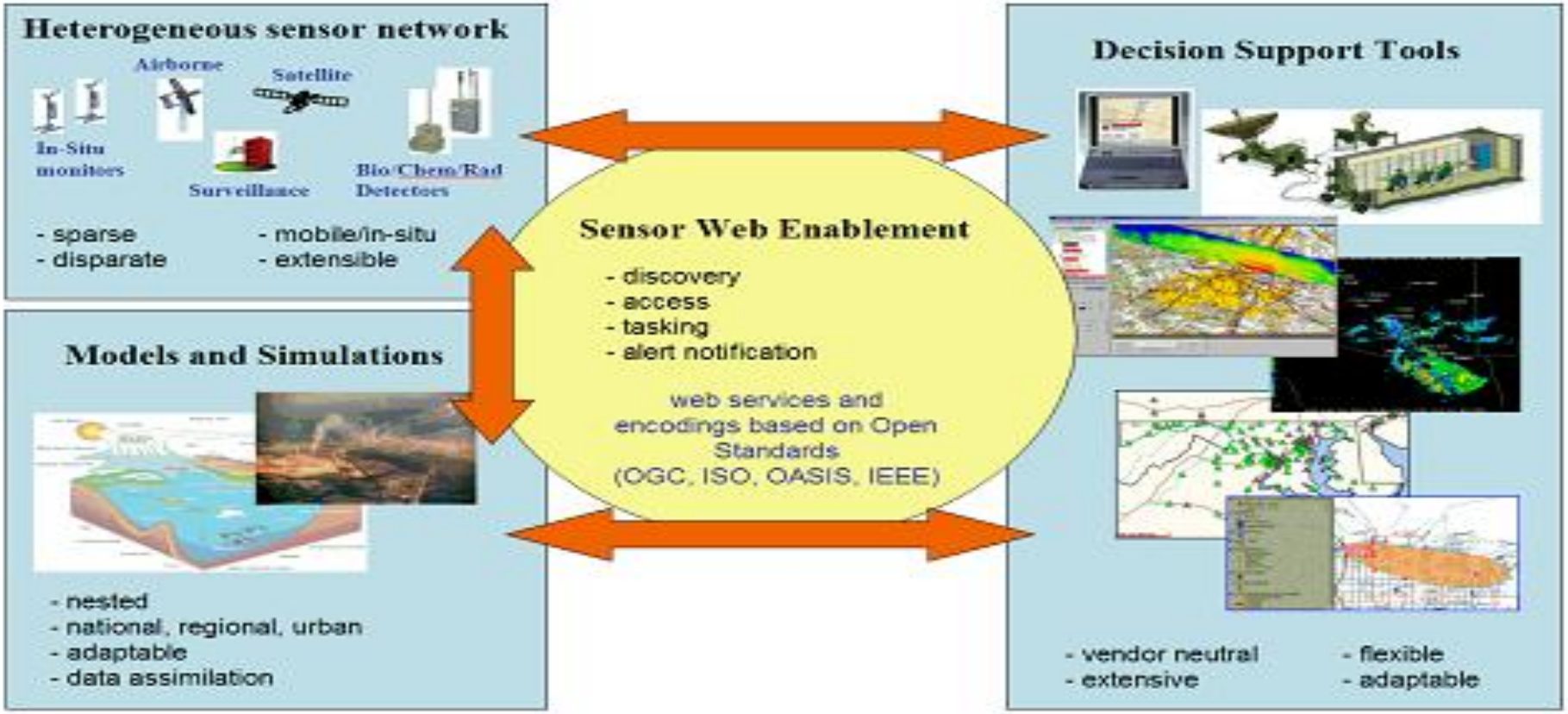
Sensor Web Enablement (SWE)



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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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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 : 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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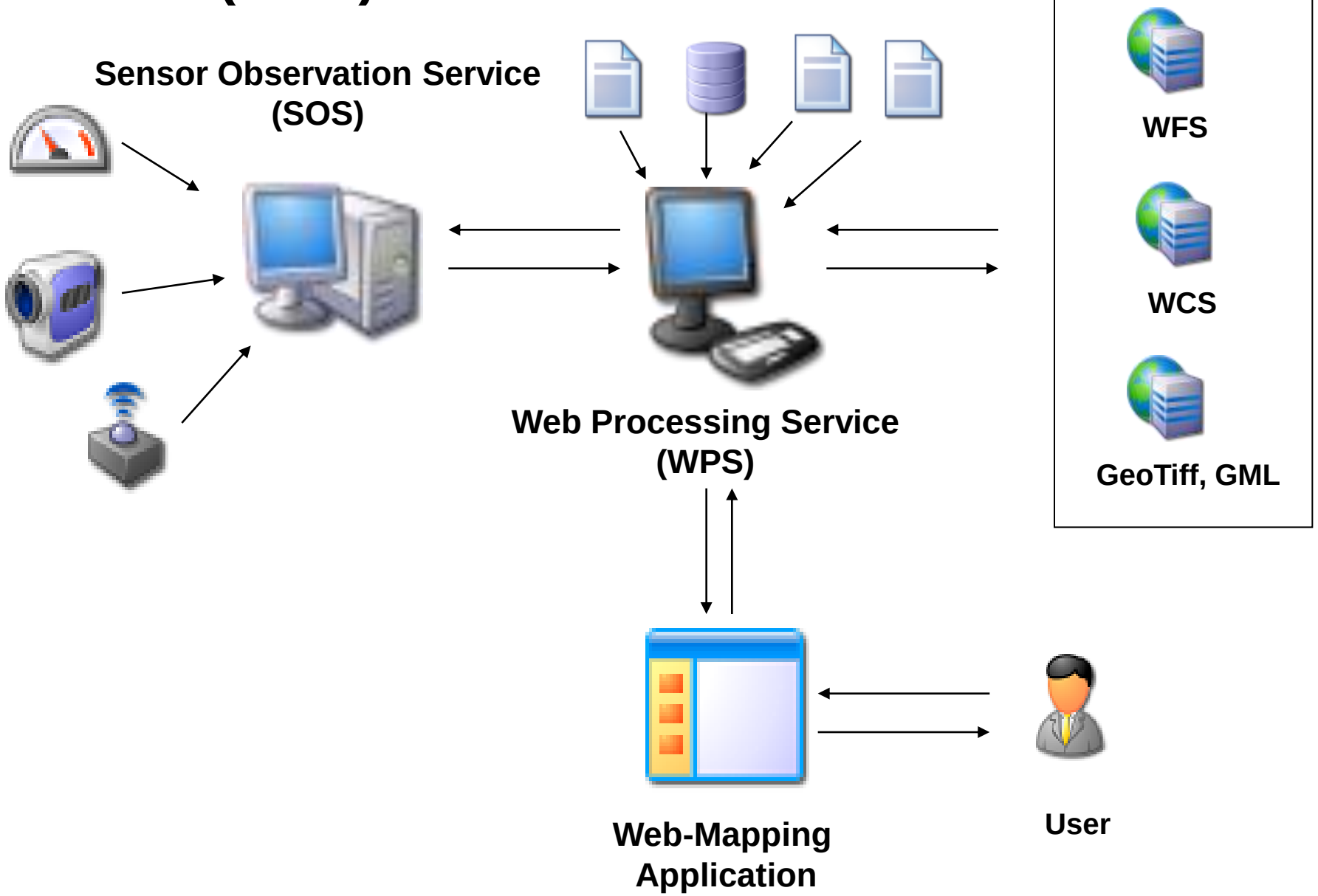
WPS : Result [GML]


```
- <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
```

Implementation of Spatial Analysis using (Near) Real-time data



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Demo site : WQI

Interpolated Water Quality map WPS test

Layers

- [ ] Lake
- [x] Aster image

Model

- [x] Sensor file
- [ ] Turdity Index
- [ ] SST Calculation
- [x] Interpolated Image file

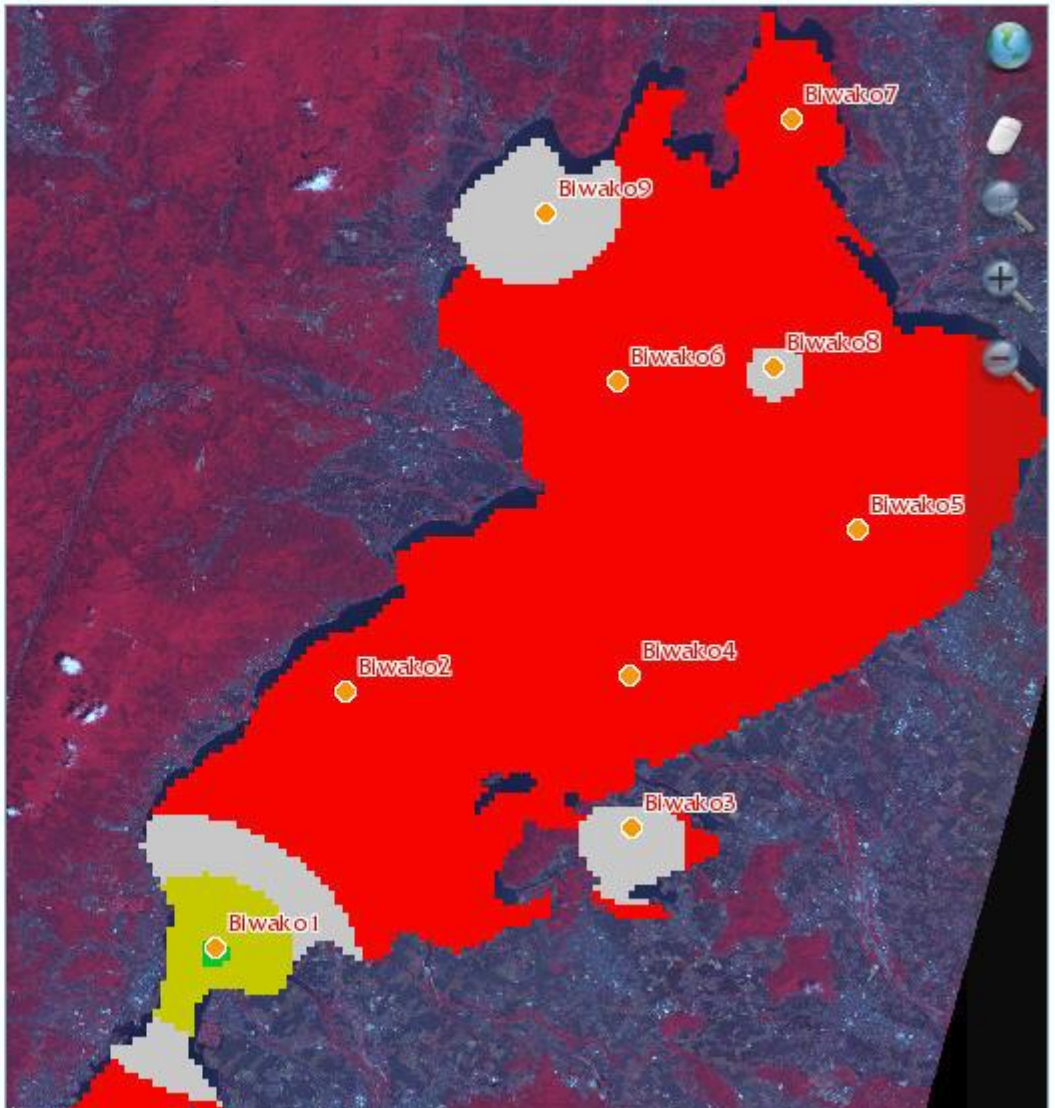
By select Offering,Phenomenon and Date of Sensor data and start to genereate interpolated map by clicking **Create Map** the process will be done and update the result on map screen. This module produce by performance of GRASS module.

Select parameter and Date

Offering	WaterJP
Date	2007-09-13 16:26:00+09
Analysis	WQI Calculation

Create Map

Lake
Sensor
UFD
VeryPoor
Poor



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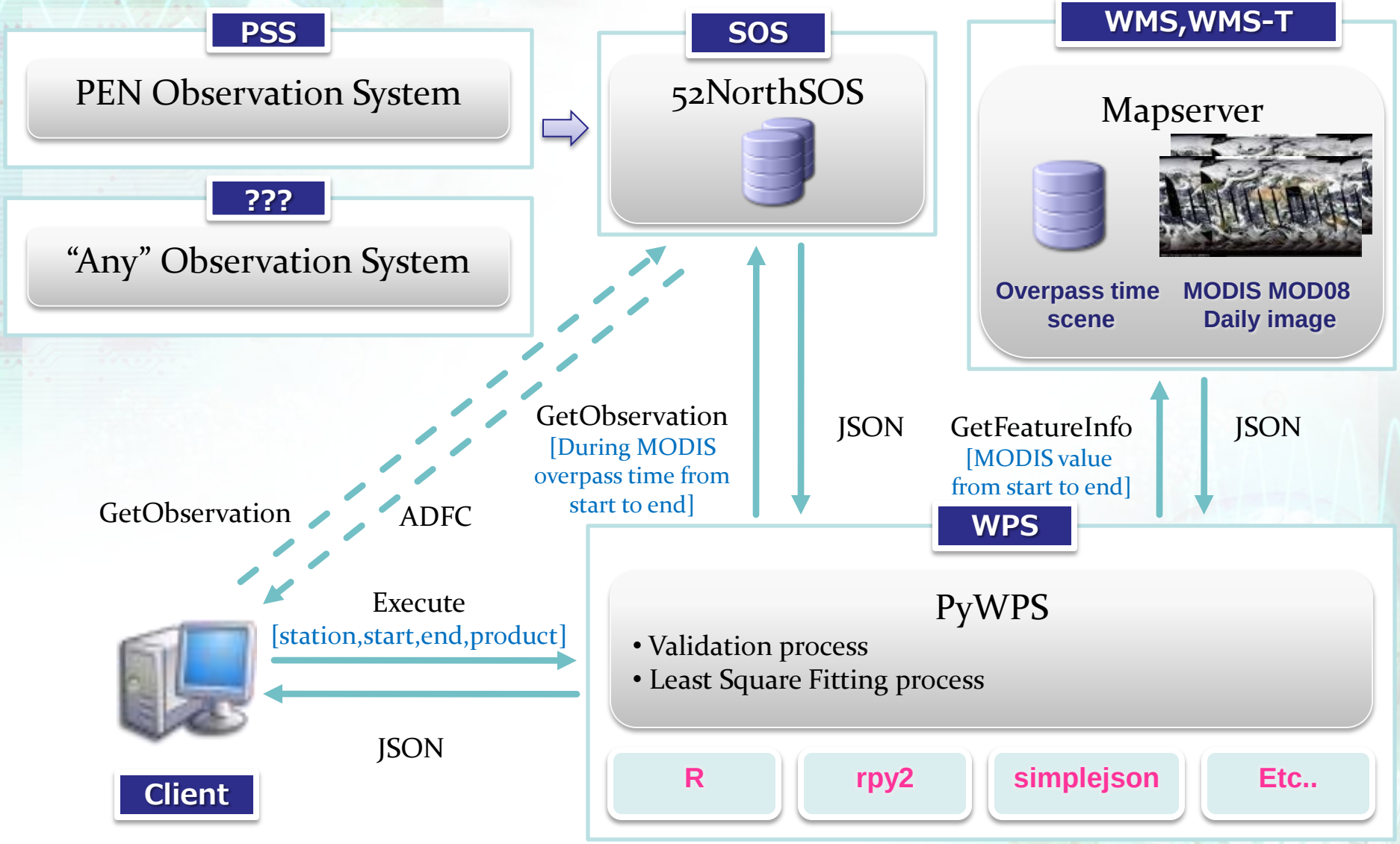
OGC System Framework



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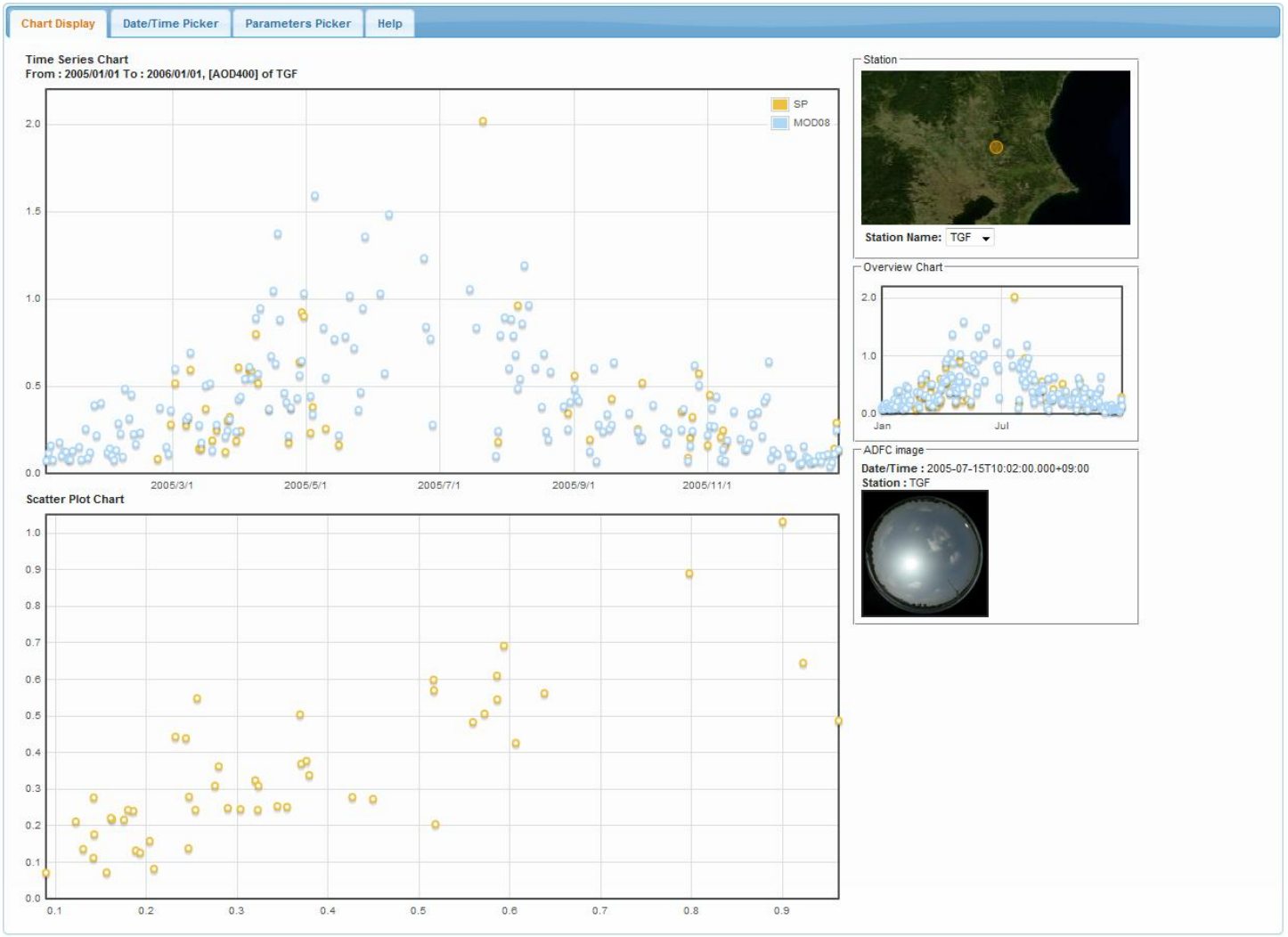
Prototype Application



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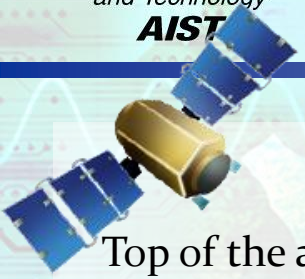
Validation satellite products



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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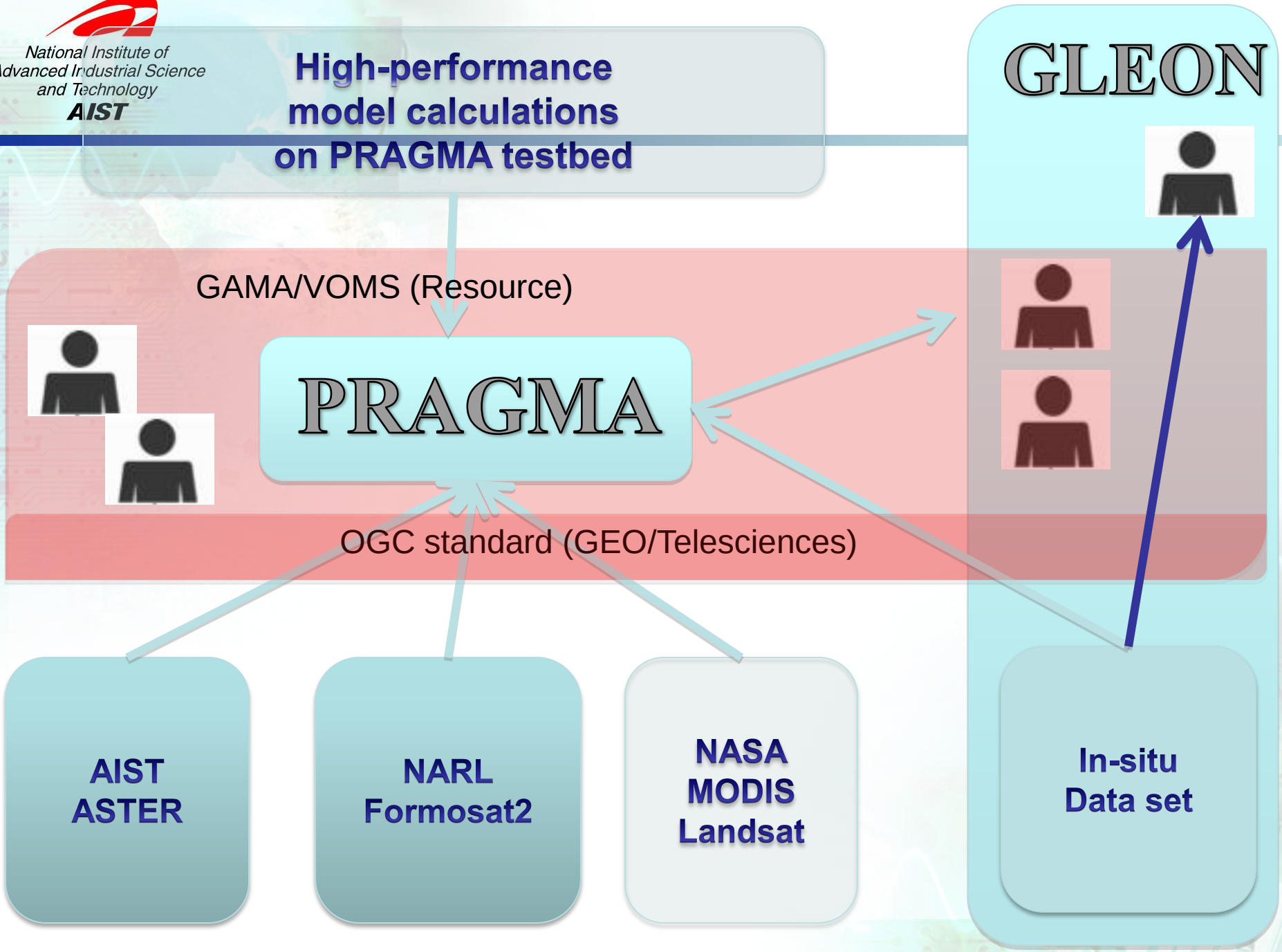
High-performance model calculations on PRAGMA testbed



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Result

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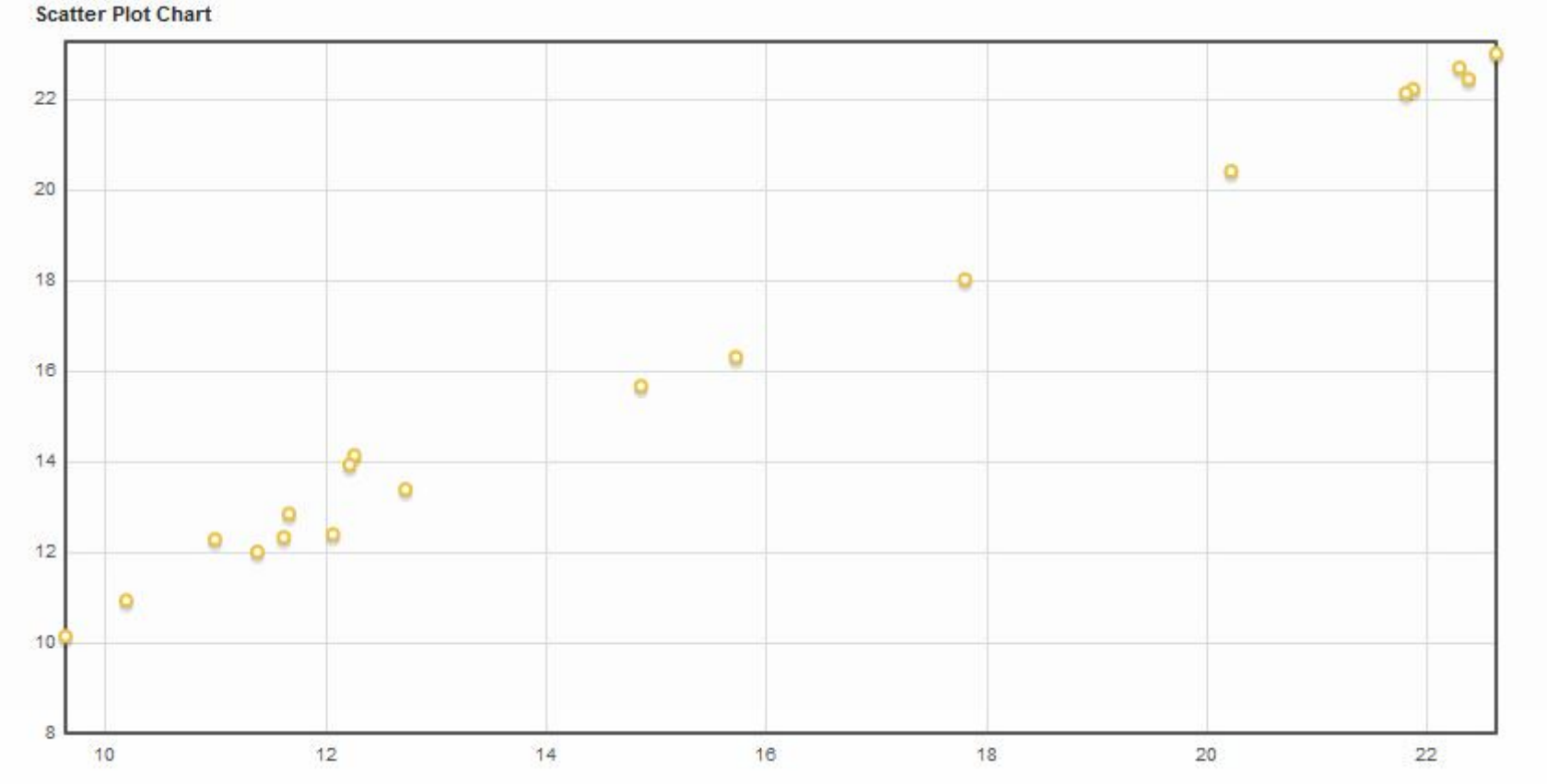
Result



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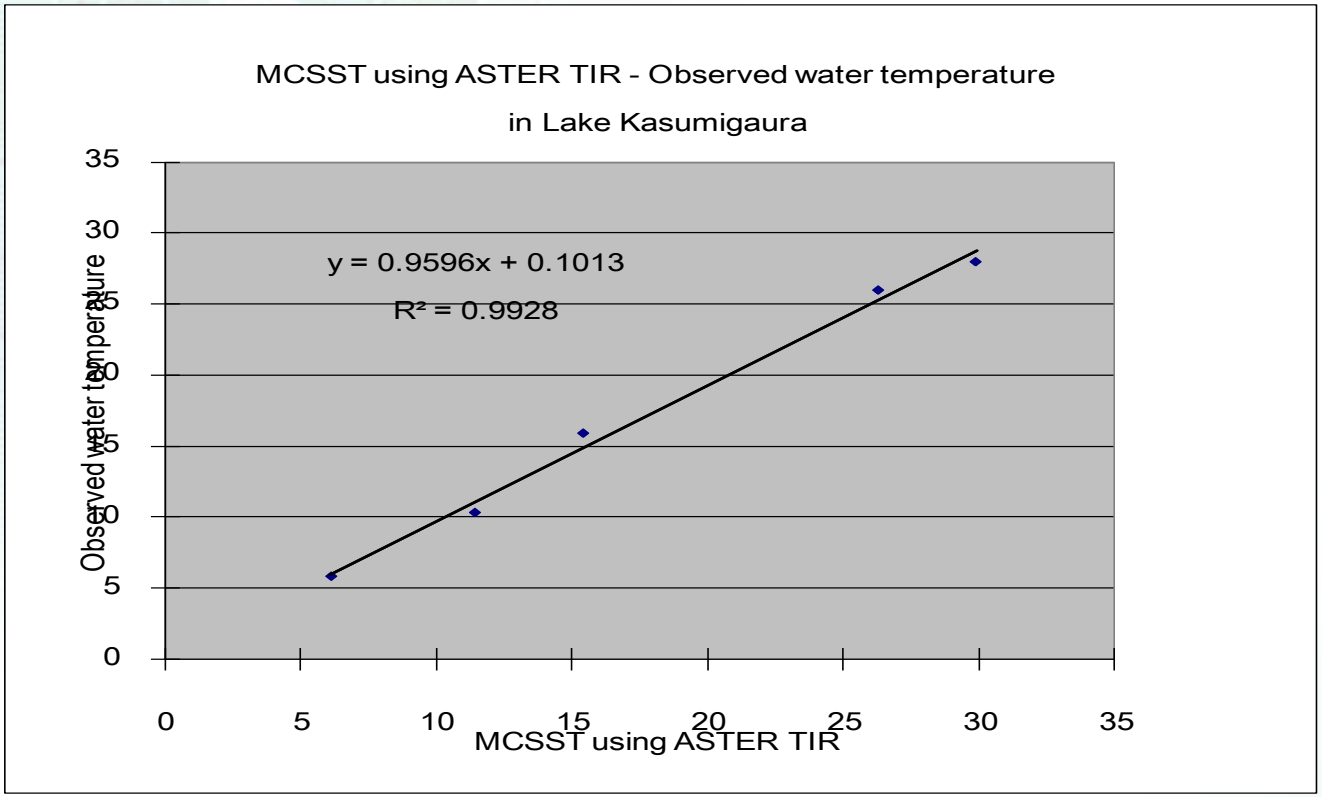
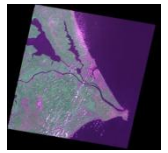
MCSST Equation

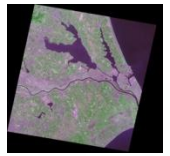


ASTER acquisition date

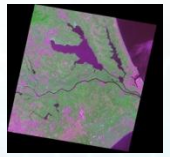
2001.8.16



2002.3.12



2004.7.7



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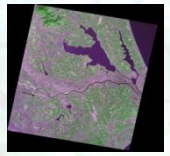
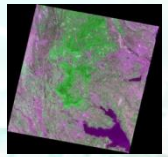


2006.5.1



MCSST: Multi-Channel Sea Surface temperature

MCSST = 1.16 - 1.07*T10 + 0.49*T11 + 1.13*T12 + 0.78*T13 - 0.32*T14

T10-14: ASTER TIR channel (Radiance)

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Conclusion

- Comprehensive web-based GIS system framework enabled
  - Based on various open standards of OGC specifications
  - Using FOSS
    - Mapserver, 52North SOS, PyWPS
    - OpenLayers, jQuery,
- Assimilation of sensor observation data and satellite image
  - Wider area, More accuracy, Reasonable cost
- Data sharing via standard web services
  - Information vs Data Storage available (Peter, *this morning*)
  - On-demand accessing
  - Reduce data redundancy

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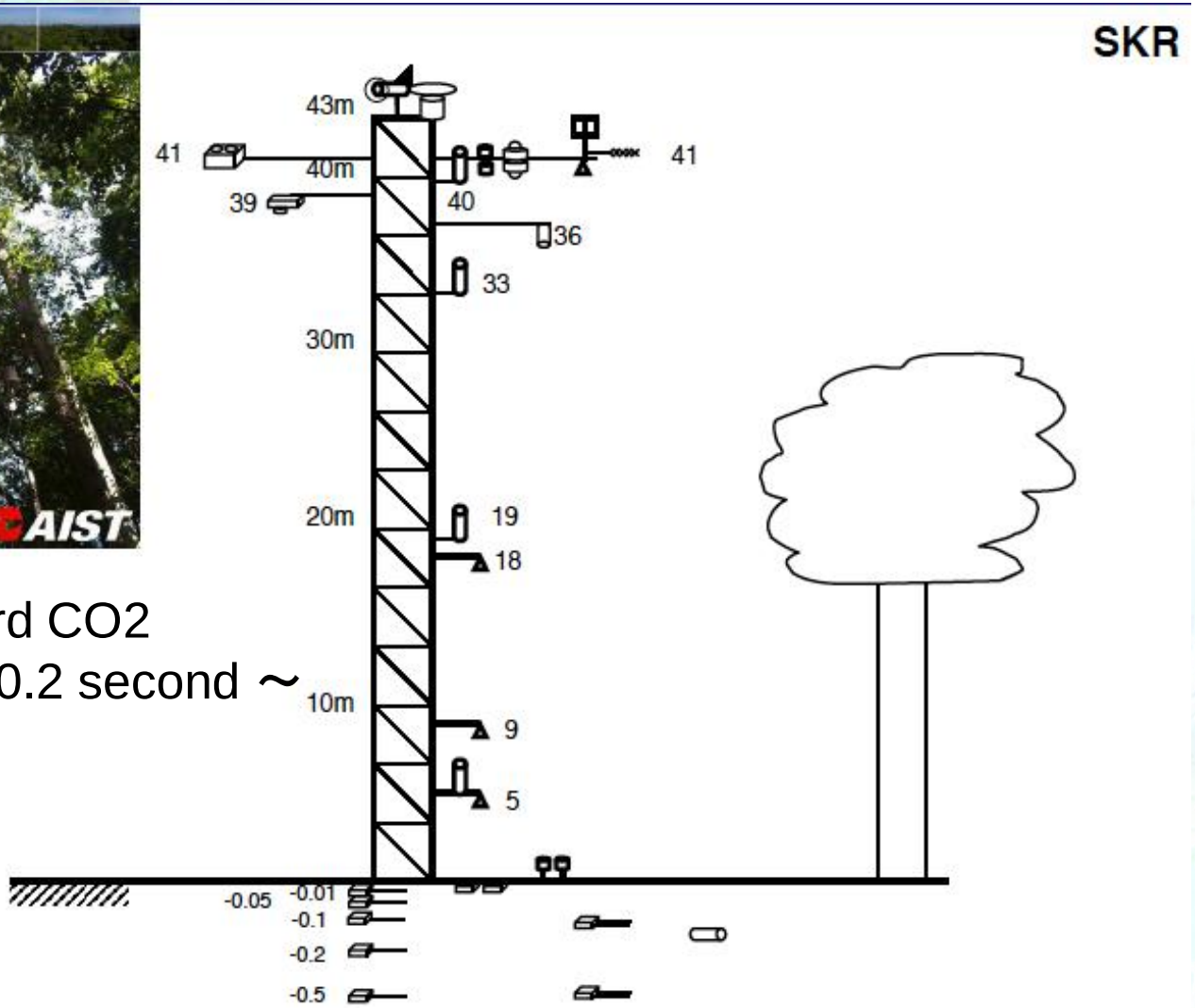
Overview of Sensor at observation SKR tower



Continuous record CO2 concentration at 0.2 second ~ 30 minute

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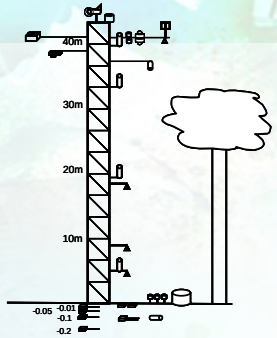
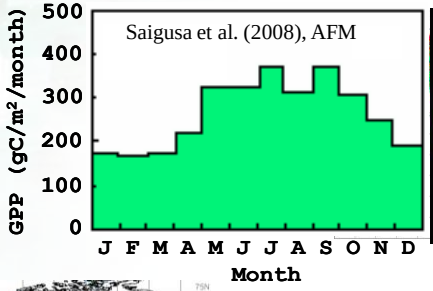
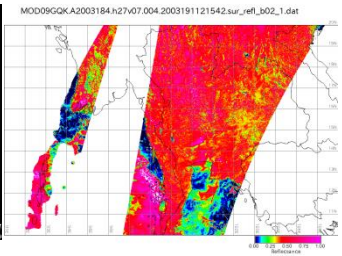
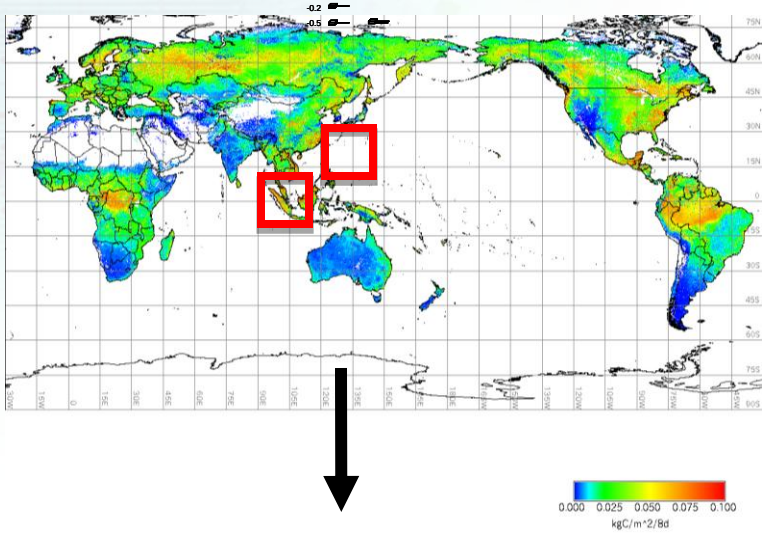
Field Observation data (Primary production, daily)

MOD09 →Vegetation Index (EVI, NDVI)



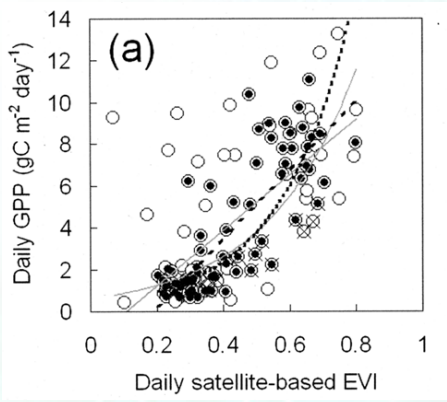






Satellite / Field data study

Applying to same forest type for GPP map.



(Nagai et al., submitted to IJRS)

- The prototype system will done with observation in Japan and Thailand.
- The success of study will extend sensor network to regional and global FLUX group.

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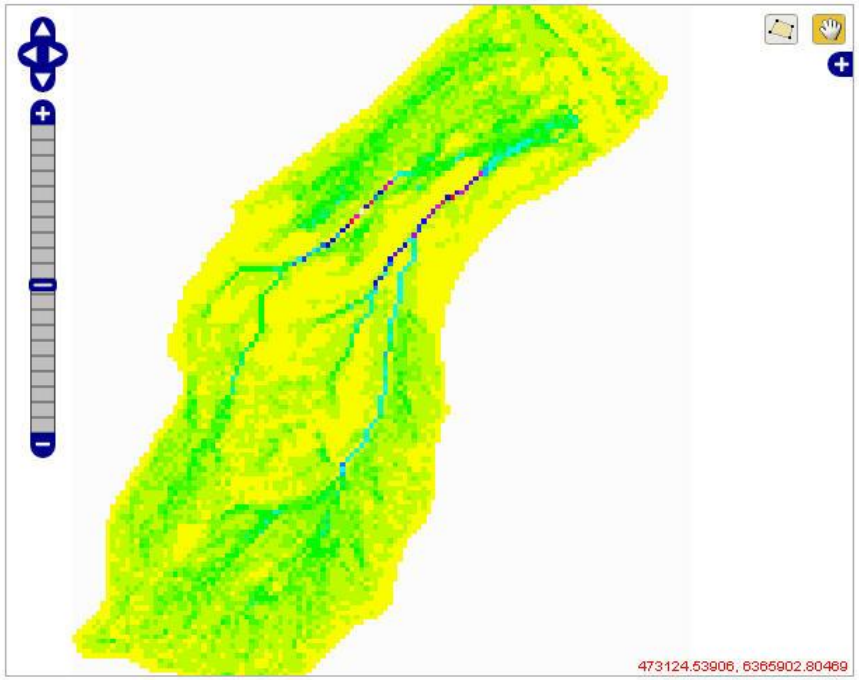
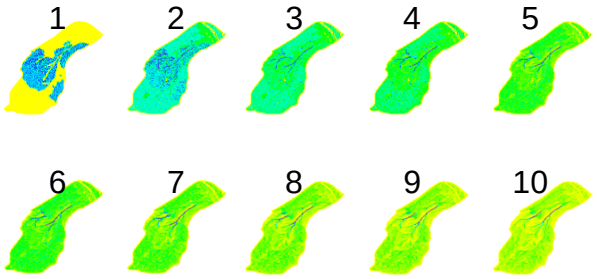
Prototype : Run Off Modeling



Animation



Processing Status

Parameters

Precipitation Data

Please enter Precipitation value (mm) at each time step (1 hr).

time	value	time	value
0	0	5	70
1	10	6	80
2	20	7	40
3	30	8	20
4	60	9	0

Running Model

Near Time Rain Gauge

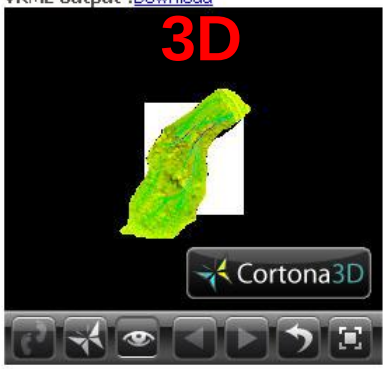
- 10 minutes
- Network accessible
- OGC standard SOS
- Feng Chia University

Current Bouding Box

UL X: 472512.234
UL Y: 6366553.195
LR X: 474281.766
LR Y: 6365152.805

Result for downloading

Animation output: Download AVI file
Max RunOff Image: Download Image file
VRML output :Download



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What Next

- Increase atmospheric observation network
  - SKYNET, AERONET
- Satellite image product validation
  - CO2 Flux monitoring : Asiaflux / Japanflux
  - Rainfall : GSMaP (Global Satellite Mapping of Precipitation)
- 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/debris flow with Rain-Gauge sensor in Taiwan
  - Increase processing speed

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