Validation of Satellite Image with Ground Sensor Network based on OGC Web Services Framework

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Introduction

• The utilization of satellite remote sensing image
  – Widely applied and been recognized as powerful and effective tool
  – Monitoring state of the environments

• 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$_2$O, O$_3$ etc.) and Scattering (aerosol particles such as dust, ash and smoke)
Surface reflectance and Top of the atmosphere

Atmospheric Correction

- 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
  - Radioactive transfer model
- \textbf{6S} = \textbf{Second Simulation of the Satellite Signal in the Solar Spectrum}
  - Work in cloud free condition
- \textbf{Necessary Input parameters:}
  - Geometrical condition
  - Atmospheric model for gaseous components
  - \textbf{Aerosol mode} (Type and concentration)
  - Spectral condition
  - Ground reflectance (type and spectral variation)
• Capable of viewing the entire globe daily at moderate resolutions
  – Ranging from 250 meters to 1 kilometer pixels.
  – 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm
  – Land, Cloud, Aerosol properties, Atmosphere, Ocean color etc.
• Various products generated for earth observation purpose
  • Vegetation indices, leaf area index, sea surface temperature.
• 6S is a basic code for MODIS atmospheric correction algorithm.
  – Gaseous condition -> MOD05 and MOD07
  – Cloud mask -> MOD35
  – Aerosol concentration -> MOD04
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 1° x 1°)
- Validation with ground observation is necessary to improve uncertainly estimate.

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (µm)</th>
<th>Resolution (m)</th>
<th>Primary Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.620-0.670</td>
<td>250</td>
<td>Land/Cloud/Aerosols Boundaries</td>
</tr>
<tr>
<td>2</td>
<td>0.841-0.876</td>
<td>250</td>
<td>Land/Cloud/Aerosols Properties</td>
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<tr>
<td>3</td>
<td>0.459-0.479</td>
<td>500</td>
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<tr>
<td>4</td>
<td>0.545-0.565</td>
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<tr>
<td>5</td>
<td>1.230-1.250</td>
<td>500</td>
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</tr>
<tr>
<td>6</td>
<td>1.628-1.652</td>
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<td></td>
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<tr>
<td>7</td>
<td>2.105-2.155</td>
<td>500</td>
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</table>
• 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)
PEN Equipments

http://www.pheno-eye.org
Validation (SP & MOD08)

Optical Depth
- Sky radiometer (400nm) • MOD08 (470nm)
- Sky radiometer (500nm) • MOD08 (550nm)
- Sky radiometer (675nm) • MOD08 (660nm)

Angstrom Exponent
- Sky radiometer (400-675nm) • MOD08 (470-660nm)
Validation (SP & MOD08)

Optical Depth

- MOD08 (470nm)
- MOD08 (550nm)
- MOD08 (660nm)

Angstrom Exponent

- Skyradiometer (400nm-675nm)

Data points and trend lines for TGF and TKY are shown across different wavelength ranges and measurement types.
Validation (SP & MOD04)

- **Optical Depth**
  - MOD04(470nm) vs. Skyradiometer(400nm)
  - MOD04(550nm) vs. Skyradiometer(500nm)
  - MOD04(660nm) vs. Skyradiometer(675nm)

- **Angstrom Exponent**
  - MOD04(470-660nm) vs. Skyradiometer(400-675nm)
Validation (MOD08 & MOD04)

Optical Depth

MOD04 (470nm)

MOD08 (470nm)

MOD04 (550nm)

MOD08 (550nm)

MOD04 (660nm)

MOD08 (660nm)

Angstrom Exponent

MOD04 (470-660nm)

MOD08 (470-660nm)
Previous System Framework

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

MODIS MOD08 Daily image
• GEO (Global Earth Observation) GRID
  – An E-Infrastructure to accelerate GEO science based on the concept that whole data related to earth observation are *virtually integrated* with a *certain access management* and *easy to handle* by the end-users those are enabled by a set of Grid and Web Service technologies.
• ASTER and PRISM DEM 3D Generation
• Simulation of Pyroclastic flows on volcano
OGC System Framework

PEN Observation System
- SP
- ADFC
- HSSR

52NorthSOS

Mapserver
- Overpass time scene
- MODIS MOD08 Daily image

WMS, WMS-T

WPS

GetObservation
- [During MODIS overpass time from start to end]

GetFeatureInfo
- [MODIS value from start to end]

PyWPS
- Validation process
- Least Square Fitting process

Client

Execute
- [station, start, end, product]

JSON

ADFC

GetObservation

R
- rpy2
- simplejson
- Etc..
**WMS Time Tiling**

- **WMS-T support for time request**
  - Time instance (etc. 2002-01-01)
  - Time period (etc 2002-01-01/2002-10-01)
- **Currently, Mapserver do not support for WMS Time Tiling for “GetFeatureInfo” request with raster layer**
  - “errors that look like this msShapefileOpen(): Unable to access file. (f:/msapps/gmap-ms40/htdocs/my_layer_idx” Ticket #2796
  - Solution: WxS mapscript

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</table>
Prototype Application
Prototype Application

Time Series Chart
From: 2005/01/01 To: 2006/01/01, [AOD400] of TGF

2005/06/24
MOD08_D3 (470) = 1.2330
Chart Zooming
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

• Validation of aerosol properties from Satellite estimation with ground based sites
  – Improve the following product which relied on satellite image “surface reflectance”
Future Development

• Increase atmospheric observation network
  – Skynet

• Improving performance
  – Distributing ground site data source
    • More than two million records for two station and four years
  – WMS-T full supported with Mapserver
  – MOD03 overpass time to MOD08 Global dataset
    • Possible to error 5 minutes observation

• Satellite image product validation
  – GLEON (Global Lake Ecological Observatory Network)
    • Lake monitoring : SST, Chl. A : MODIS Ocean product
  – CO Flux monitoring : Asiaflux / Japanflux

• Water Column Correction
  – CREON (Coral Reef Environmental Observatory Network)

• Validation with higher satellite image resolution
  – ASTER, FORMOSAT-2