GOCI Status and GOCI-II Plan

Joo-Hyung Ryu
On behalf of Korea Ocean Satellite Center

- KIOST/KOSC
- GOCI status
- GOCI applications
- GOCI-II plan
• “Geostationary ocean colour will not be available for at least another decade”...IOCCG Report1, 1998.

• NOAA or Eumetsat require approximately 10 years, from design to launch, to complete a geostationary platform. Little or no chance exists of adding ocean-colour bands on GOES-P, which is planned for launch in 2007 (launch readiness: 2006). Time is available, however, to justify and incorporate Other operational aspects 30 an ocean-colour requirement on the next GOES platform, Q, which is planned for launch in 2010 (launch readiness: 2008)

• 12 years later, GOCI has been successfully launched in 2010 and ...1st IOCS in 2103.
KORDI has set sail to the broader world of marine sciences and technology as KIOST.

Vision: A global leadership in advanced marine sciences and technology

KIOST Goals: Providing solutions to global agendas and pursues technology R&D to develop the national competency in marine sciences and technology

- Researches on basic marine sciences
- Researches on application and commercialization of marine technologies
- Researches for responses to national issues
- Researches on ocean and polar region policies
Introduction of KOSC

GOCI Operation Agency

MISSION

- Ocean remote sensing satellite development/operation
- Ocean/Coastal remote sensing technique development
- Satellite data calibration and validation
- Data distribution service and research support
- Application research
- Operational use (?)
Introduction of COMS

- COMS: Communication, Ocean & Meteorological Satellite
  - Developments of COMS(H/W) and GDPS(S/W): 2003
  - Establishment of KOSC (Ground System): 2005
  - The first Korean Geostationary multipurpose Satellite
  - Launch date: June 27, 2010
  - Lifetime: 7 years
  - Payloads (3 Missions)
    - Geostationary Ocean Color Imager (GOCI)
    - Meteorological Imager
    - Ka-band Communication
Geostationary Ocean Color Imager
- GSD (Ground Sampling Distance) : 500m * 500m
- Target Area : 2,500km * 2,500km (Center : 130°E 36°N)
- Included Nations : Korea, China, Taiwan, Japan, Russia, etc.
- Temporal Resolution : 1小时 (8 times at 1 day)

Spectral Bands Characteristic and Requirements of GOCI

<table>
<thead>
<tr>
<th>Band</th>
<th>Central wavelengths</th>
<th>Band Width</th>
<th>SNR</th>
<th>Type</th>
<th>Primary Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>412 nm</td>
<td>20 nm</td>
<td>1,000</td>
<td>Visible</td>
<td>Yellow substance and turbidity</td>
</tr>
<tr>
<td>B2</td>
<td>443 nm</td>
<td>20 nm</td>
<td>1,090</td>
<td>Visible</td>
<td>Chlorophyll absorption maximum</td>
</tr>
<tr>
<td>B3</td>
<td>490 nm</td>
<td>20 nm</td>
<td>1,170</td>
<td>Visible</td>
<td>Chlorophyll and other pigments</td>
</tr>
<tr>
<td>B4</td>
<td>555 nm</td>
<td>20 nm</td>
<td>1,070</td>
<td>Visible</td>
<td>Turbidity, suspended sediment</td>
</tr>
<tr>
<td>B5</td>
<td>660 nm</td>
<td>20 nm</td>
<td>1,010</td>
<td>Visible</td>
<td>Baseline of fluorescence signal, Chlorophyll, suspended sediment</td>
</tr>
<tr>
<td>B6</td>
<td>680 nm</td>
<td>10 nm</td>
<td>870</td>
<td>Visible</td>
<td>Atmospheric correction and fluorescence signal</td>
</tr>
<tr>
<td>B7</td>
<td>745 nm</td>
<td>20 nm</td>
<td>860</td>
<td>NIR</td>
<td>Atmospheric correction and baseline of fluorescence signal</td>
</tr>
<tr>
<td>B8</td>
<td>865 nm</td>
<td>40 nm</td>
<td>750</td>
<td>NIR</td>
<td>Aerosol optical thickness, vegetation, water vapor reference over the ocean</td>
</tr>
</tbody>
</table>
Progress of GOCI Operation

- Start of Project
  - Developments of COMS(H/W) and GDPS(S/W) : 2003
  - Establishment of KOSC (Ground System) : 2005
- Launch : June 27, 2010
- First image acquisition : July 13, 2010
- In-Orbit Test : ~ Apr. 2011
- GOCI data(Level 1B) and GDPS viewer service : Apr. 20, 2011
- GOCI data(Level 2) and GDPS Ver.1.0 service : Sep. 2, 2011
- GDPS Ver.1.1 service : Jul. 2012
- Ocean Science Journal GOCI Special Issues : 13 papers included
- GOCI-II project started : Oct. 2012
- GDPS Ver.1.2 release : Apr. 2013
<table>
<thead>
<tr>
<th>PRODUCTS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-leaving radiance</td>
<td>The radiance assumed to be measured at the very surface of the water under the atmosphere</td>
</tr>
<tr>
<td>Normalized water leaving radiance</td>
<td>The water leaving radiance assumed to be measured at nadir, as if there was no atmosphere with the Sun at zenith</td>
</tr>
<tr>
<td>Optical properties of water</td>
<td>K-coefficient Absorption coefficient Backscattering coefficient</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>Concentration of phytoplankton chlorophyll in ocean water</td>
</tr>
<tr>
<td>TSS</td>
<td>Total suspended sediment concentration in ocean water</td>
</tr>
<tr>
<td>CDOM</td>
<td>Colored dissolved organic matter concentration in ocean water</td>
</tr>
<tr>
<td>Red tide</td>
<td>Red tide index information</td>
</tr>
<tr>
<td>Fishing ground information</td>
<td>Fishing ground probability index, fishing ground prediction</td>
</tr>
<tr>
<td>Underwater visibility</td>
<td>Degree of clarity of the ocean observed by the naked eye</td>
</tr>
<tr>
<td>Sea surface current vector</td>
<td>Sea surface current direction/speed</td>
</tr>
<tr>
<td>Atm. &amp; earth environment</td>
<td>Yellow dust, Vegetation Index</td>
</tr>
<tr>
<td>Water quality level</td>
<td>Coastal water quality level estimation</td>
</tr>
<tr>
<td>Primary productivity</td>
<td>The production of Organic compounds from carbon dioxide, principally through the process of photosynthesis</td>
</tr>
</tbody>
</table>

- **GOCI Data Processing System**
- **Ver1.1 distributed July 2012**
  - More accurate atmospheric correction
  - Improvement of User Interface
- **Ver1.2 (April 2013)**
  - Including more products
  - 64bit Windows OS supported
### 64 bit GDPS

1. Because of extending memory available  
   - Improvement of processing speed  
   - Improvement of program stability  
   - Increasing number of window in GDPS

### New Products

1. Rayleigh Corrected Reflectance for land user  
2. Water current vector  
3. Fish ground index  
4. Yellow dust in ocean

### Batch processing

1. When changed product algorism  
   - processing maximum 1000 image  
2. Applied batch processing in variety function  
   - Subset image, L2 processing, L3 processing, Exporting image, Extracting pixel value of filed measurement point

### User Interface

1. Developing user-friendly GUI in Combine Area, Combine Time-series/Animation, Divide Area
GOCI APPLICATIONS : Aerosol Optical Depth
GOCI APPLICATIONS: Red Tide Detection

5 August 2012
GOCI L2 Chlorophyll

Lw Composite image (6,4,2 bands)

5 August 2012
Red Tide Detection

RCA Algorithm image

Red Tide Warning
◆ **Status of Distribution Service** (20 Apr. 2011~)
◆ **Satellite data DB (for distribution)**: 42,000
◆ **Downloads (~2012)**: 113,400
◆ **Scientific Users by web**: 1006 people (Korea: 649, Others: 357)
◆ **Domestic Gov./Inst. User by ftp**: 24 (near-real-time data service)
◆ **Public User by portal site**
  - Korean portal site (http://map.naver.com; in Korean)
  - Service: L1B RGB, CHL, CDOM, SS Jpeg image (only)
  - Frequency: 8 times/day
  - Maximum daily visitors: 260,000

◆ **Redistribution site** for international scientific users
  - approved by GOCI operation committee (Jan. 2013)
  - discuss with Ministry of Oceans and Fisheries
Raw data

Radiometric / Geometric Calibration

Atmospheric correction CAL/VAL

Algorithm CAL/VAL

Level-0

Level-1

Radiance
($L_w, L_{WN}$)

Level-2

Products
($R_{ref}$, chl, SS, DOM, Red-tide, Fishing ground information, Under water visibility, water current vector, and so on.)

GOCI Data Quality Control (Cal / Val)
Radiometric Calibration
• GOCI Radiance Restitution Process calculated with dark image (offset) and 2D gain matrix correction
• Dark Signal Variation shows very small changes.
• GOCI detector has been operated in stable.

Geometric accuracy (INR) Performance
• Within-Frame, Frame-Frame, Band-Band Registration performances are satisfied with requirement.
• In Winter season, a few date cannot be satisfied with requirement. Because of low intensity or poor circumstance, landmark for INR cannot be found enough.

Inter Slot Radiance Discrepancy (ISRD)
• The issue by sensor type (2D CMOS, frame capture method)
  • It takes 30 min to acquire one set of whole coverage.
  • The zigzag type of capture line brings about non-homogenous time interval.
• Need to clarify the cause of ISRD: straylight/ghost image, sensor calibration or polarization sensitivity, etc.
• A simple ISRD model has been tested and looks promising. Further test and improvement is needed for implementation into processing chain this year.
Atmospheric Correction

- KOSC standard atmospheric correction algorithm for GOCI has been developed.
- The result of comparison of GOCI and in situ data shows good relationship except 412nm.
- nLw comparison result with NOAA algorithm & KOSC algorithm is quite similar.

Level 2 product Validation

- Building Rrs matchup database for validation of CHL, TSS, CDOM.
- Initial validation result of TSS is R2=0.87, Δ=35%. That of CHL is 0.34.
- Results show that the bio-optical algorithms need to be improved. Semi-analytical algorithms should be considered.

GOCI Cal/Val advisory group meeting

- 1st meeting has held at Nagoya Univ. (Japan) in Nov. 2012.
- To discuss for In situ database for GOCI validation/vicarious calibration
• Evolution of GOCI Radiometric Gain
  • Monitoring of Linear Gain(G), Non-linear Gain(b) using SD & DAMD
• Evolution of GOCI Radiometric Gain (2011.~2012.)
  • Sinusoidal Variation of Radiometric Gain : ~ 2.5% (2011.)
  • Gain Evolution with same solar Azimuth/Elevation angle
    • ~0.51% (G_SD, Weekly Obs.) , ~0.14% (G_DAMD, Monthly Obs.)
    • Annual Solar angle variation : 108.4°/10.5° (AZ/EL)
  • Gain Variation(Uniformity) over FPA : ~5% (CV; STDEV/Mean)
In situ measurements
- Research vessel, Ferry box (with KIOST), Glider (with KIOST)
- Buoy, Ocean research station
  - To use Korea Operational Oceanography Network (with KIOST)
  - To cooperate neighboring countries (with Japan, China, Taiwan)
  - To join International Group (with IOCCG, Aeronet-OC)

New System
- Kite, aerostat, airborne (with KARI)
- Argo-type buoy

Uniform land Cal/Val site
- Desert, Ice, Playa

Optical Buoy located at
- An area of the convergence of North Korean Cold Current and East Korean Warm Current
- 10 km off Donghae port at a depth of 130m
- Data collected for April 24-Aug 13, 2012
Rrs Matchup Result / L2 Validation Result

◆ initial validation
  - Chla: R²=0.34, Δ=35%
  - SPM: R²=0.87, Δ=35%
  - CDOM: R²=0.18 Δ =330%

◆ Results show that the bio-optical algorithms need to be improved.
  - Semianalytical algorithms should be considered

Flow-through fluorometer for Chl_a
(courtesy of J-H Noh, KIOST)
Continued efforts for ship-based matchup comparison
  - Matchup data in the open ocean
Feedback for algorithm improvement including
  - Vicarious calibration
  - Bio-optical algorithm
Annual GOCI validation cruise
  - Foreign scientist participation encouraged
Autonomous systems
  - Aeronet-OC
  - Validation buoy
  - Flow-through system
Network/collaboration
  - Promote domestic val activities, e.g. HPLC round-robin exercise
  - International validation advisory group
  - International collaboration
GOCI Cal / Val Advisory Group Meeting

Date: Dec, 2012
Location: Nagoya University (Japan)
Attendee
  - Korea, Japan, Russia, Taiwan + China
◆ **1st GOCI PI Workshop (Oct. 29~30, 2008)**
   - 72 peoples from 11 organizations, 7 countries (36 PIs)
   - Discussed the collaboration for *Algorithm development, in-situ data acquisition, and application research*

◆ **2nd GOCI PI Workshop (Jan. 11~12, 2012)**
   - **200 more peoples** including 31 PIs, 62 domestic scientists
   - 16 sessions, 57 presentations
   - Shared the result for GOCI and satellite application research
   - Discussed GOCI application and international cooperation
   - Proposed GOCI-II user requirements

◆ **3rd GOCI PI Workshop (2014 ?)**
   - will be announced...
KOSC has many relationship for GOCI cal/val and research collaboration.
Short-term variability: Tidal Movement

- 642 composite image
- 16 April 2011
areas of relatively high turbidity (in red) gradually decreased over time

- clear water from open sea suppressed turbidity during flood tide

around the time of high tide, turbidity was remarkably lower

- settlement of suspended particulates during the transition from flood to ebb tide and resulting lull in the tidal current
Short-term variability : Sea Ice

2012.02.27 16:15

Sea Ice
Short-term variability : Sea Fog
OCEAN DATA AVERAGE ACQUISITION RATE

DAILY COMPOSITE
8 SCENES / DAY

28%

1 SCENE / DAY

10%
GOCI APPLICATIONS : Ocean Fronts
GeoKompasat-2 Development

COMS : GOCI-I, MI-I, & Ka-band
GeoKompasat-2A : MI-II (ABI)
GeoKompasat-2B : GOCI-II & GEMS

◆ GOCI Development :
  • KARI & KIOST Cooperation Development
  • Payload system - Development Company (TBD) + KARI/KIOST team
  • Bus system - KARI
◆ Supervising : KIOST
GOCI-II is focused on the coastal and global ocean environment monitoring with better spatial resolution and spectral performance for the succession and expansion of the mission of GOCI.

GOCI-II project started the development in 2012, and will be launched in 2018.

The user requirements of GOCI-II will have higher spatial resolution, 300m × 300m, and 13 spectral bands to fulfill GOCI’s user requests, which could not be implemented on GOCI for technical reasons.

GOCI-II will have a new capability, supporting user-definable observation requests such as clear sky area without clouds and special-event areas, etc. This will enable higher applicability of GOCI-II products. GOCI-II will perform observations 8 times daily, the same as GOCI’s.

The main difference between GOCI-II and GOCI is the global-monitoring capability, which will meet the necessity of the monitoring and research on the long-term climate change. Daily global observation once is planned for GOCI-II.

<table>
<thead>
<tr>
<th>Items</th>
<th>GOCI Specs</th>
<th>GOCI-II Specs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increased</strong> band number</td>
<td>8 bands</td>
<td>13 bands</td>
</tr>
<tr>
<td><strong>Improved</strong> spatial resolution</td>
<td>500m</td>
<td>300m</td>
</tr>
<tr>
<td><strong>More</strong> observations</td>
<td>8 times/day</td>
<td>10 times/day</td>
</tr>
<tr>
<td><strong>Pointable &amp; Full Disk</strong> coverage</td>
<td>Local Area</td>
<td>Local Area + Full Disk</td>
</tr>
</tbody>
</table>
• Better Quality in GEO
  • Easy to achieve High SNR with longer Integration time and Noise Reduction with averaging of multiple acquisitions.
  • Effective 1-Day coverage of GEO is larger.

• Necessity of Global Area Observation
  • Global Obs. can enable the ocean climate change research.

1-day Composite Image (MERIS)

Ref. http://www.globvapour.info/images/NF_2_fig1_SSMI_MERIS_combined_L3_DC_20070715_TCWV_retrieval.png
◆ Spectral Bands Requirements (TBD)
  • 13 Bands (GOCI : 8 Bands)
  • Phytoplankton type verification, Enhanced Atmospheric Correction Accuracy

<table>
<thead>
<tr>
<th>Band</th>
<th>Band Center</th>
<th>Bandwidth</th>
<th>Nominal Radiance</th>
<th>Maximum Ocean Radiance</th>
<th>Saturation Radiance</th>
<th>Maximum Cloud Radiance</th>
<th>SNR @ Nominal Radiance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>380 nm</td>
<td>20 nm</td>
<td>93</td>
<td>139.5</td>
<td>143.1</td>
<td>634.4</td>
<td>998</td>
</tr>
<tr>
<td>2</td>
<td>412 nm</td>
<td>20 nm</td>
<td>100</td>
<td>150</td>
<td>152</td>
<td>601.6</td>
<td>1050</td>
</tr>
<tr>
<td>3</td>
<td>443 nm</td>
<td>20 nm</td>
<td>92.5</td>
<td>145.8</td>
<td>148</td>
<td>679.1</td>
<td>1145</td>
</tr>
<tr>
<td>4</td>
<td>490 nm</td>
<td>20 nm</td>
<td>72.2</td>
<td>115.5</td>
<td>116</td>
<td>682.1</td>
<td>1228</td>
</tr>
<tr>
<td>5</td>
<td>510 nm</td>
<td>20 nm</td>
<td>55.3</td>
<td>85.2</td>
<td>122</td>
<td>665.3</td>
<td>1124</td>
</tr>
<tr>
<td>6</td>
<td>555 nm</td>
<td>20 nm</td>
<td>55.3</td>
<td>85.2</td>
<td>87</td>
<td>649.7</td>
<td>1124</td>
</tr>
<tr>
<td>7</td>
<td>620 nm</td>
<td>20 nm</td>
<td>40.3</td>
<td>67.8</td>
<td>70.5</td>
<td>616.5</td>
<td>1080</td>
</tr>
<tr>
<td>8</td>
<td>660 nm</td>
<td>20 nm</td>
<td>32</td>
<td>58.3</td>
<td>61</td>
<td>589</td>
<td>1060</td>
</tr>
<tr>
<td>9</td>
<td>680 nm</td>
<td>10 nm</td>
<td>27.1</td>
<td>46.2</td>
<td>47</td>
<td>549.3</td>
<td>914</td>
</tr>
<tr>
<td>10</td>
<td>709 nm</td>
<td>10 nm</td>
<td>27.7</td>
<td>50.6</td>
<td>51.5</td>
<td>450</td>
<td>914</td>
</tr>
<tr>
<td>11</td>
<td>745 nm</td>
<td>20 nm</td>
<td>17.7</td>
<td>33</td>
<td>33</td>
<td>429.8</td>
<td>903</td>
</tr>
<tr>
<td>12</td>
<td>865 nm</td>
<td>40 nm</td>
<td>12</td>
<td>23.4</td>
<td>24</td>
<td>343.8</td>
<td>788</td>
</tr>
<tr>
<td>13</td>
<td>PAN</td>
<td>515 nm</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

◆ User Requirements for GOCI-II Direct Broadcasting
  • Data Rate : 23Mbps
  • Service Coverage : ~ Full Disk Area
  • Data Format : (TBD)
  • Receiving Antenna on Ground Station : < 6.5m (Diameter, TBD)
## GEOKomsat-2 Payloads Requirements

<table>
<thead>
<tr>
<th></th>
<th>MI-II (ABI)</th>
<th>GOCI-II</th>
<th>GEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spectral Range</strong></td>
<td>0.47μm-13.3μm</td>
<td>380-900nm</td>
<td>300-500nm</td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
<td>500m, 1km(VIS), 2km(IR)</td>
<td>300m</td>
<td>7.0 km</td>
</tr>
<tr>
<td><strong>Spectral Resolution</strong></td>
<td>400~1,000nm</td>
<td>10~40nm, 500nm</td>
<td>0.8nm</td>
</tr>
<tr>
<td><strong>Bands</strong></td>
<td>16</td>
<td>13</td>
<td>Hyperspectral</td>
</tr>
<tr>
<td><strong>Coverage</strong></td>
<td>FD, NHFD, North-East Asia, Korea Peninsula (LA)</td>
<td>2,500 x 2,500km(LA), FD</td>
<td>FD, NHFD, North-East Asia, Korea Peninsula (LA)</td>
</tr>
<tr>
<td><strong>Observation Period</strong></td>
<td>FD 4 times/hour</td>
<td>10 times/day</td>
<td>8 times/day</td>
</tr>
<tr>
<td></td>
<td>LA 120 times/hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Observation Time</strong></td>
<td>FD 15 min, NHFD 5 min, LA 30 sec</td>
<td>&lt; 30 min (LA)</td>
<td>30 min</td>
</tr>
</tbody>
</table>
Various Application of Geostationary Orbit Satellites could be constructed with high performance.

Planning

What fields can be fused with Geostationary satellite?
What can we obtain the NEW products from integration & fusion science?

What / How can we do integrate and apply Geostationary satellite?

Cooperation

Ocean + Meteorology + Environment + Communication

NEW Technology & Synergy
High Quality
High Accuracy
High Speed
Low Cost

Conference
Completion
Ocean Application

**Original application**
- Long-term climate change, carbon emissions
- Environmental monitoring for coastal/marine/land
- Real-time marine environmental monitoring (disasters reduction)
- Fishing cost saving for increased production

**MI-II**
- Fisheries using SST
- Marine numerical weather prediction
- Atmospheric correction precision
- Marine meteorological disasters surveillance (hurricanes, torrential rain)

**GEMS**
- DOM distribution research using UV data
- Improving atmospheric correction accuracy using vertical aerosol data
- Marine environment analysis accuracy improvement removal of NO2

In case of Ocean Application, **Ocean product accuracy** will be enhanced with integration of other satellite.
GEO new mission & Synergy

Efficiency
Accuracy
Low cost

Multi-sensors fusion algorithm can be installed to GDPS-II (GOCI-II Data Processing System)
A Constellation of Geostationary Ocean Color Satellites

OCAPI+

GEO-CAPE+Tempo (?)

GOCI-II+MI+GEMS
• GOCI Operation
  – There is no significant technical issue for GOCI operation.
  – To distribute 8 times GOCI images to user this year
  – To make an international mirror site for fast download: under discussing the detail conditions

• GOCI Cal/Val and Research
  – To collaborate the GOCI Cal/Val and application
  – To release the GDPS and ATBD Ver1.2
  – To strengthen the operational algorithm (WCV, FGI etc)

• GOCI-II development
  – To select the manufacturing company for GOCI-II this month
  – To propose the integrated research using 3 payloads of GeoKompasat-II

We need more collaborations for blooming the GEO OC potentials
Structure of Chlorophyll Distribution in the North-East Asian Seas

Thank you