Specific requirements of GEO orbit ocean color observation for China coastal sea

He Xianqiang

State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, SOA, China
Outline

- Introduction
- Specific requirements of GEO OCRS in China coastal sea
- GEO remote sensing satellite plan of China
- Conclusion
Introduction

- Length of China coastal line is more than 38,000Km.
- Every year, more than 20,000 hours of ship measurement (more than 200 ships, 200000 miles cruise), and 800 hours airplane measurement (more than 300 sorties, 300000 miles cruise) must be used to monitor the coastal water environment.
Every year, more than 100 red tides around China coastal sea, especially in the coastal of East China Sea.
SIO Operational System of LEO OCRS Application

Data Processing System → Data Receiving Ground Station

Data Distribution through internet

NOAA
FY-1D
SeaWiFS
HY-1B
MODIS

Products Generation

Data Distribution through internet

Application

Water quality
Red Tide
Fishery
Carbon Cycle
Coastal engineering

……..
The challenges of LEO OCRS in China coastal sea

- The heavy cloud cover around the China coastal sea

Day percents of the cloud coverage less than 40% in one year

- Yellow Sea
- East China Sea
- South China Sea

- Yellow Sea
- East China Sea
- South China Sea
The diurnal variation by tide mixing /storm tide mixing
The incompletely covered by LEO OC satellite for the daily variation of the orbit and sun-glint contaminated.
GEO OC satellite for China coastal sea

- GEO OCRS has high temporal coverage, which could catch the diurnal variation phenomena. So, it is very useful for China coastal sea environment monitoring.

- Already seeing significant activities:
  1. ESA
  2. Korea (COMS/GOCI, 2009)
  3. NOAA (GOES-R/HES-CW, Cancel)
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● Specific requirements of GEO OCRS in China coastal sea

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● Conclusion
The specific requirement of bands

- A minimum band set should include two channels (such as 490nm/555nm or 443nm/555nm) in the visible and two channels (such as 750nm, 865nm) in the near infrared with narrow bandwidth and high SNR.

- For coastal water, there should be more bands (like 412nm for CDOM, 670nm for TSM/atmospheric correction, even chlorophyll fluorescence band 685nm) to separate different ocean color components.

- For China coastal sea, because of the extreme turbidity, the atmospheric correction needs some additional bands.
The bands requirement of atmospheric correction

- China coastal sea is one of the most turbidity water around the global ocean, with the maximum concentration of total suspend matter more than 1000mg/L.
The non-neglect water-leaving radiance in China coastal sea

- Standard algorithm often fail to produce valid values in very turbid waters, e.g., Hangzhou Bay, Yangtze Estuary.
Wang using MODIS SWIR bands (1240 and 1640 nm) data

Results from SWIR Atmospheric Correction for turbid ocean waters


Validation Results (1)

Reflectance $[\rho_w(\lambda)]_N$

(a) March 22, 2003
(120.5°E, 36.0°N)
Time Diff: 4.2 hrs
$\theta_0 = 36.7^\circ$, $\theta = 35.5^\circ$

(b) April 5, 2003
(123.0°E, 33.0°N)
Time Diff: 2.5 hrs
$\theta_0 = 31.2^\circ$, $\theta = 1.7^\circ$

China East Coast

Reflectance vs. Wavelength (nm)
Validation Results (2)

September 25, 2003  (c)  
(122.3°E, 31.5°N)  
Time Diff: 2.2 hrs  
θ₀ = 33.8°, θ = 54.7°

September 23, 2003  (d)  
(122.2°E, 30.5°N)  
Time Diff: -0.4 hrs  
θ₀ = 33.1°, θ = 43.8°

Reflectance \( [\rho_w(\lambda)]_N \)

Wavelength (nm)
Validation Results (3)

China East Coast
March 22-April 6 & Sep. 19-26, 2003

Slope   Int       R

<table>
<thead>
<tr>
<th>λ (nm)</th>
<th>MODIS $[ρ_w(λ)]_N$</th>
<th>In Situ $[ρ_w(λ)]_N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>412 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>443 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>488 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>531 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>551 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>645 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>748 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>859 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALL</td>
<td>0.896</td>
<td>0.005</td>
</tr>
</tbody>
</table>

$ρ_w(λ)$

$[ρ_w(λ)]_N$
He & Pan (2004) developed a practical algorithm of atmospheric correction for turbid coastal and inland water.

Water leaving radiance at UV increases little with increasing of turbidity. Thus, radiance at UV can be used to estimate aerosol scattering radiance.

The performance of the algorithm is validated, and the error of the retrieved remote sensing reflectance less than 10% for the visible bands.

20 May, 2007. HY-1B/COCTS
Chlorophyll concentration
Requirement of AC bands for China coastal sea

- One UV band (<400nm)
- Two shortwave IR bands
- Additional absorption aerosol detection band
The specific requirement of sensitivity

- We use the RT model PCOART to simulate the TOA radiance with different chlorophyll concentration.


- PCOART was an exact numerical model to deal with the vector radiative transfer problems of the coupled ocean-atmosphere system with rough sea-surface.

- The simulated cases:
  (1) Sun zenith angles were 60° and 80°, respectively;
  (2) Sensor viewing zenith angle was 0°;
  (3) Chlorophyll concentrations were 0.01, 0.05, 0.1, 0.5, 1.0, 5.0, 10.0, respectively;
  (4) Wind speed was 7.23 m/s;
  (5) 550 nm aerosol optical thickness was 0.2;
The difference of $L_t$ with variation of chlorophyll concentration
(Sun zenith angle is 60°)

![Graph showing the difference $L_{T(0.05)} - L_{T(0.01)}$, $L_{T(0.1)} - L_{T(0.05)}$, $L_{T(0.5)} - L_{T(0.1)}$, $L_{T(1.0)} - L_{T(0.5)}$, $L_{T(5.0)} - L_{T(1.0)}$, $L_{T(10.0)} - L_{T(5.0)}$ vs. wavelength (nm).]
The difference of $L_t$ with variation of chlorophyll concentration
(Sun zenith angle is 80°)
The requirement of the sensitivity (Radiance per-DC)

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Sun_zen=60°</th>
<th>Sun_zen=80°</th>
<th>CZCS</th>
<th>SeaWiFS</th>
<th>MODIS/AQUA</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>0.005</td>
<td>0.001</td>
<td>412</td>
<td>0.0109</td>
<td>412</td>
</tr>
<tr>
<td>420</td>
<td>0.008</td>
<td>0.002</td>
<td>443</td>
<td>0.021</td>
<td>443</td>
</tr>
<tr>
<td>440</td>
<td>0.004</td>
<td>0.001</td>
<td>490</td>
<td>0.0082</td>
<td>488</td>
</tr>
<tr>
<td>460</td>
<td>0.003</td>
<td>0.001</td>
<td>520</td>
<td>0.015</td>
<td>510</td>
</tr>
<tr>
<td>480</td>
<td>0.03</td>
<td>0.006</td>
<td>550</td>
<td>0.012</td>
<td>555</td>
</tr>
<tr>
<td>500</td>
<td>0.02</td>
<td>0.005</td>
<td>670</td>
<td>0.005</td>
<td>670</td>
</tr>
<tr>
<td>520</td>
<td>0.04</td>
<td>0.008</td>
<td>765</td>
<td>0.0023</td>
<td>748</td>
</tr>
<tr>
<td>540</td>
<td>0.03</td>
<td>0.008</td>
<td>865</td>
<td>0.0016</td>
<td>869</td>
</tr>
<tr>
<td>560</td>
<td>0.03</td>
<td>0.007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>580</td>
<td>0.02</td>
<td>0.004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>0.007</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>620</td>
<td>0.006</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>640</td>
<td>0.005</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>660</td>
<td>0.004</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>680</td>
<td>0.003</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>700</td>
<td>0.002</td>
<td>0.0005</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Specific requirement of radiance dynamic range

- For the fixed bit number per-pixel, the dynamic range and sensitivity is conflict. High sensitivity causes low dynamic range.

- The water-leaving radiance in China coastal sea varied largely, especially at the red/NIR bands.
The black water around East China Sea coastal

- Normalized water-leaving radiances of SeaWiFS, 15/04/2003
In-situ measured Lw distribution (22/03/2003-23/04/2003)

412nm

443nm

490nm

510nm

555nm

670nm
- High water-leaving radiance may cause the saturation of the sensed signal
Specific requirement of polarization sensitivity

- Degree of polarization of the top of atmosphere (TOA) could approach 70%, If sensor polarization sensitivity is 5%, the measured TOA radiance should be corrected by as much as ±3% (5%×70×90%, 90% is the ratio of the atmosphere scattering radiance to the total radiance received by sensor)
Specific requirement of polarization sensitivity

- Gordon (1988) derived a requirement for future ocean color sensor to have polarization sensitivity less than 2.5%.
- According to this requirement, most of the launched ocean color sensors was designed with the polarization sensitivity less than 2.5%, but the actual measured polarization sensitivity may as high as 6%

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Launched date</th>
<th>Country</th>
<th>Designed polarization sensitivity</th>
<th>Measured polarization sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SeaWiFS</td>
<td>Aug.,1997</td>
<td>USA</td>
<td>&lt;2%</td>
<td>&lt;0.3%</td>
</tr>
<tr>
<td>MODIS TERRA</td>
<td>Dec.,1999</td>
<td>USA</td>
<td>&lt;2%</td>
<td>&lt;6%</td>
</tr>
<tr>
<td>MODIS AQUA</td>
<td>May,2002</td>
<td>USA</td>
<td>&lt;2%</td>
<td>&lt;6%</td>
</tr>
<tr>
<td>MERIS</td>
<td>Mar.,2002</td>
<td>Europe</td>
<td>&lt;0.3%</td>
<td></td>
</tr>
<tr>
<td>GLI</td>
<td>Dec.,2003</td>
<td>Japan</td>
<td>&lt;2%</td>
<td>&lt;6%(band 1-2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;2%(other bands)</td>
</tr>
<tr>
<td>OCTS</td>
<td>Aug.,1996</td>
<td>Japan</td>
<td>&lt;5%(412nm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;2% (&gt;412nm)</td>
<td></td>
</tr>
<tr>
<td>COCTS HY-1A</td>
<td>May,2002</td>
<td>China</td>
<td>&lt;5%</td>
<td></td>
</tr>
<tr>
<td>OCM</td>
<td>May,1999</td>
<td>India</td>
<td>&lt;2%</td>
<td></td>
</tr>
</tbody>
</table>
Specific requirement of the spatial resolution

- 100m~300m spatial resolution is preferred

**River plume**

SSC from MERIS
- (2005.8.15)
- 300m Resolution

**Red tide in ECS**

MODIS/Aqua
- (2007.05.02)
- 250m Resolution
The specific requirement of cloud detection

- Traditional, OCRS uses the 865nm bands to detect the cloud, such as SeaWiFS/MODIS/OCTS/POLDER/OSMI process in SeaDAS.
- For China coastal sea, 865nm reflectance of water may larger than thin cloud. Traditional method may mask the coastal water as the cloud which reduces the available data.
- For GEO OCRS, because of the variation of the sun zenith angle as the time, exactly operational cloud detecting method should be developed.
Outline

- Introduction
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- GEO remote sensing satellite plan of China
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The total status of the OCRS in China

- China has drawn out the three series special ocean remote sensing satellite with sun-synchronization orbit, including Ocean Color Satellite (HY-1 Series), Ocean Dynamic Satellite (HY-2 Series) and Ocean Watch & Monitor Satellite (HY-3 Series).

- Up to now, there are no formal plans to launch the special GEO OCRS satellite in China.
HY-1 Satellite Series

- The main use of HY-1 is ocean color satellite and to detect the chlorophyll concentration, suspended sediment concentration, and dissolved organic matter, pollutants, as well as sea surface temperature.

- HY-1A, launched at 15 May, 2002.

- HY-1B, launched at 11 April, 2007.

- HY-1C/D, will be launched 2009/10 on time-stable.

- It will be launched 2(AM/PM) HY-1 satellites every 3-4 years up to 2020.

## COCTS bands and detecting object

*Spatial resolution is 1100m*

<table>
<thead>
<tr>
<th>Band (µm)</th>
<th>Main detecting object</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.402～0.422</td>
<td>CDOM</td>
</tr>
<tr>
<td>0.433～0.453</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td>0.480～0.500</td>
<td>Pigment, diffuse attenuation coefficient</td>
</tr>
<tr>
<td>0.510～0.530</td>
<td>Chlorophyll, suspended sediment</td>
</tr>
<tr>
<td>0.555～0.575</td>
<td>Chlorophyll, suspended sediment</td>
</tr>
<tr>
<td>0.660～0.680</td>
<td>Atmospheric correction, suspended sediment</td>
</tr>
<tr>
<td>0.740～0.760</td>
<td>Atmospheric correction, aerosol</td>
</tr>
<tr>
<td>0.845～0.885</td>
<td>Atmospheric correction, aerosol</td>
</tr>
<tr>
<td>10.30～11.40</td>
<td>Sea surface temperature</td>
</tr>
<tr>
<td>11.40～12.50</td>
<td>Sea surface temperature</td>
</tr>
</tbody>
</table>
## CZI bands and detecting object

- **Spatial resolution is 250m**

<table>
<thead>
<tr>
<th>Band (µm)</th>
<th>Main detecting object</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.433～0.453</td>
<td>Pollutant, ocean color, sea ice, topography</td>
</tr>
<tr>
<td>0.555～0.575</td>
<td>suspended sediment, Pollutant, <em>ice, beach</em></td>
</tr>
<tr>
<td>0.655～0.675</td>
<td>Atmospheric correction, suspended sediment</td>
</tr>
<tr>
<td>0.675～0.695</td>
<td>Atmospheric correction, chlorophyll fluorescence</td>
</tr>
</tbody>
</table>
Geostationary meteorological satellite program of China

- The first generation geostationary meteorological satellite of China (FY-2 Satellite Series)

<table>
<thead>
<tr>
<th>Launch time</th>
<th>Satellite Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997.06.10</td>
<td>FY-2A</td>
<td>Experimentation</td>
</tr>
<tr>
<td>2000.06.25</td>
<td>FY-2B</td>
<td>Experimentation</td>
</tr>
<tr>
<td>2004.09.19</td>
<td>FY-2C</td>
<td>Operation</td>
</tr>
<tr>
<td>2006.12.08</td>
<td>FY-2D</td>
<td>Operation</td>
</tr>
<tr>
<td>2008</td>
<td>FY-2E</td>
<td>Operation,Plan</td>
</tr>
<tr>
<td>2010</td>
<td>FY-2F</td>
<td>Operation,Plan</td>
</tr>
<tr>
<td>2012</td>
<td>FY-2G</td>
<td>Operation,Plan</td>
</tr>
</tbody>
</table>
Two FY-2 operational satellite configuration
(Every 15min)
Image of Multi-channel Scanning Radiometer onboard FY-2D (Five channels)
The next generation geostationary meteorological satellite of China (FY-4 Satellite Series)

- Development:
  - FY-4 Phase A: 2007-2008
  - FY-4 Phase B: 2009-2010
  - FY-4 Phase C: 2011-2012

- R&D/Operation
  - FY-4A/B: 2012-2014 (R&D)
  - FY-4C/D/E/F: 2016 beyond (Operation)
FY-4 Satellite configurations

- Main payload considerations
  - Imaging Radiometer
  - CCD Imager (option)
  - Infrared Sounder
  - Lightning Mapper
  - Solar X-ray Imager
  - Space Environment Monitor Suite

Estimated weight: 3200Kg
Estimated power: 2000W
FY-4 Imaging Radiometer

- Currently 12 channels, reference to MSG and GOES-R
- Imaging channels with higher spatial resolution and frequent observation (China territory: 5 minutes)
- Radiometric channel: higher radiometric performance.
FY-4 CCD Imager

- Broadband visible at
  500Km × 500Km area with spatial resolution between 50 and 100 meters rapid refresh
Conclusion

- GEO OCRS is important for China coastal sea environment monitoring.
- Because of the extreme turbidity in China coastal sea, it needs UV/SWIR bands for the accuracy atmospheric correction.
- In order to derive the ocean color information in the early morning or nightfall, the GEO sensor should have high sensitivity.
- The dynamic range of GEO sensor should be large enough in order to avoid the signal saturation in high turbid water.
- The polarization sensitivity should be considered.
- The 100-300m spatial resolution is prefer.
- China has no formal GEO OCRS plan now, but it has GEO meteorological satellite program which may be used to measure the ocean color.
谢谢
Thanks