GEO-CAPE Requirements on Measurement Sensitivity, Saturation, and Solar Angles

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GEO-CAPE Requirements
on Measurement Sensitivity, Saturation, and Solar Angles

Objectives

Help define sensor constraints
Help implement measurement plans
Problem with “Low” Sensitivity

From Hu et al. (2001, RSE)
Problem with “Low” Sensitivity

From Hu et al. (2001, RSE)
## MODIS versus SeaWiFS

<table>
<thead>
<tr>
<th>Band</th>
<th>$\lambda$ (nm)</th>
<th>Res.</th>
<th>$L$ (1 DN)</th>
<th>NE$\Delta L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>620-670</td>
<td>250 m</td>
<td>0.0217</td>
<td>0.0170</td>
</tr>
<tr>
<td>2</td>
<td>841-876</td>
<td>250 m</td>
<td>0.0083</td>
<td>0.0123</td>
</tr>
<tr>
<td>3</td>
<td>459-479</td>
<td>500 m</td>
<td>0.0167</td>
<td>0.0145</td>
</tr>
<tr>
<td>4</td>
<td>545-565</td>
<td>500 m</td>
<td>0.0145</td>
<td>0.0127</td>
</tr>
<tr>
<td></td>
<td>438-448</td>
<td>1 km</td>
<td>0.0039 (0.0136)</td>
<td>0.0050 (0.0130)</td>
</tr>
<tr>
<td></td>
<td>546-556</td>
<td>1 km</td>
<td>0.0018 (0.0076)</td>
<td>0.0028 (0.0080)</td>
</tr>
<tr>
<td></td>
<td>673-683</td>
<td>1 km</td>
<td>0.0007 (0.0042)</td>
<td>0.0008 (0.0056)</td>
</tr>
</tbody>
</table>

Radiance ($L$) units: mW·cm$^{-2}$·μm$^{-1}$·sr$^{-1}$. Numbers in () are for SeaWiFS.

1 DN of MODIS 678 band is corresponding to 0.1 – 0.2 mg m$^{-3}$ Chl.
## MODIS versus Others

### Band Center (Bandwidth)

<table>
<thead>
<tr>
<th></th>
<th>Band Center</th>
<th>Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS</td>
<td>665.1 (10)</td>
<td>676.7 (10)</td>
</tr>
<tr>
<td>MERIS</td>
<td>665.0 (10)</td>
<td>681.3 (7.5)</td>
</tr>
<tr>
<td>GLI</td>
<td>666.7 (10)</td>
<td>679.9 (10)</td>
</tr>
<tr>
<td>GOCI</td>
<td>660.0 (20)</td>
<td>680.0 (10)</td>
</tr>
</tbody>
</table>

### $\text{NE} \Delta L$ (mW·cm$^{-2}$·μm$^{-1}$·sr$^{-1}$)

<table>
<thead>
<tr>
<th></th>
<th>0.0008</th>
<th>0.0007</th>
<th>0.0009</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS</td>
<td>0.0013</td>
<td>0.0014</td>
<td>0.0011</td>
</tr>
<tr>
<td>MERIS</td>
<td>0.0015</td>
<td>0.0014</td>
<td>0.0012</td>
</tr>
<tr>
<td>GLI</td>
<td>0.0032</td>
<td>0.0031</td>
<td>0.0020</td>
</tr>
<tr>
<td>GOCI</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*From Xing et al. (2007, Ocean Science Journal)*
MODIS versus SeaWiFS

SeaWiFS
Florida Strait

MODIS/Aqua
Florida Strait
Problem with Low Saturation

MODIS RGB (land bands)

MODIS FLH (ocean bands)
Problem with Low Saturation
SeaWiFS Solution

SeaWiFS Bi-linear Gains

Knee Values
### MODIS versus SeaWiFS

<table>
<thead>
<tr>
<th></th>
<th>551 (555)</th>
<th>667 (670)</th>
<th>748 (765)</th>
<th>869 (865)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS Saturation</td>
<td>6.96</td>
<td>3.50</td>
<td>2.23</td>
<td>1.30</td>
</tr>
<tr>
<td>SeaWiFS Knee</td>
<td>6.00</td>
<td>3.35</td>
<td>2.46</td>
<td>2.03</td>
</tr>
</tbody>
</table>

**Units:** mW·cm⁻²·μm⁻¹·sr⁻¹
EO-1 Hyperion Top of Atmospheric Radiance


TOA radiance (mW cm⁻² μm⁻¹ sr⁻¹)

λ (nm)

- Deep Water
- Shallow Reef
- Turbid Water
- Land Vege.
- Clouds
- Clouds
Summary

- MODIS sensitivity can serve as a good template
- Saturation radiance needs to be better determined
  - Statistics from MODIS/Hyperion measurements
  - Simulations

Next – solar angles?

- Integration time considerations
- Sun glint considerations
- Fluorescence efficiency – phytoplankton physiology
Chlorophyll fluorescence quantum yield

Morrison (2003, L&O)

Quantum Yield

PAR (mole m^{-2} s^{-1})

1                        10                      100                     1000

Decreased Photochemical Quenching

Increased Non-Photochemical Quenching
Surface PAR

GMT: 18:30
Longitude: 95°W

Surface PAR (\( \mu \text{mole m}^{-2} \text{ s}^{-1} \))
Hours from Sunrise and Sunset

- June 22
- Solar zenith = 60°
- Solar zenith = 70°
- Solar zenith = 80°
Hours from Sunrise and Sunset

December 22

Solar zenith = 60°
Solar zenith = 70°
Solar zenith = 80°

Hours from sunrise and sunset vs. Latitude (degrees)

PAR ~ 970
PAR ~ 600
PAR ~ 250
June 22. # of hourly observations with $\theta_o < 80^\circ$

June 22. # of hourly observations with sun glint (wind = 6 m/s)
June 22. # of hourly observations with non-photochemical quenching (100 < PAR < 1000)

June 22. # of hourly observations with photochemical quenching (PAR < 100)
Dec. 22. # of hourly observations with $\theta_o < 80^\circ$

Dec. 22. # of hourly observations with sun glint (wind = 6 m/s)
Dec. 22. # of hourly observations with non-photochemical quenching (100 < PAR < 1000)

Dec. 22. # of hourly observations with photochemical quenching (PAR < 100)
Importance of Glint Measurements
(require higher saturation)
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(require higher saturation)
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Conclusions

- MODIS sensitivity can be followed
- Saturation radiance needs adjustment
- Work with instrument team on sensitivity, saturation, and integration time
- Work with instrument and science teams to implement data acquisition plan
MODIS, MERIS, GLI, etc.

MODIS (9):  412.5  443  488  531  551  667  678  748  869.5
(SNR)    880  838  802  754  750  910  1087  586  516
(all 10-nm bandwidth except 412.5 and 869.5)

MERIS (15):  412.5  442.5  490  510  560  665  681.25  708.75  753.75  760.625  778.75
(SNR) Not available. But 681.25 has SNR > 2000 for typical TOA radiance
(all 10-nm bandwidth except 681.25, 753.75, and 760.625)

GLI (19):  380  400  412  443  460  490  520  545  565  625  666  680  678  710(2)  749  763  865(2)
(SNR) Not available.
(all 10-nm bandwidth except 763 and 865)

For coral reef mapping: 451  482  498  526  556  580  610  647 (Hochberg et al., 2003)
For inter-tidal benthic algae: <500, 540, 565, 580, 610, 790 (Borstad, pers. comm.)
Twice/day versus once/day

Cloud-free percentage from daily MODIS and SeaWiFS data from 1 June to 15 October 2003. Zero value means no data collection.
Area: 22 to 31°N, 91 to 79°W

MODIS Daily Average: 48.88%
SeaWiFS Daily Average: 25.72%
Hyperspectral surface reflectance

Different Minerals