Juhan Ross Legacy Symposium

Ispra, Italy
Using the EPIC/DSCOVR O2 B-band for monitoring vegetation

Alexander Marshak (NASA GSFC) and Yuri Knyazikhin (Boston University)

Many thanks to the DSCOVR Project and the DSCOVR Science Team
Feb 11, 2015 at 6:03 pm EST
Cape Canaveral

Courtesy of Space X
At L1, the neutral gravity point between the Sun and the Earth, DSCOVR will remain near the same position relative to the Earth and Sun.
Lissajous Orbit

August 25; 11 GMT:
968.46 day since 01/01/2015
dist. from Earth = 1.577 $10^6$ km
SEV = 7.94°
Velocity = 0.241 km/sec
Earth Polychromatic Imaging Camera (EPIC)

- 2048 x 2048 pixel CCD;
- 8 km pixel size;
- One full set of images
13/day in winter
22/day in summer

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Full width (nm)</th>
<th>Primary Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>317.5 ± 0.1</td>
<td>1 ± 0.2</td>
<td>Ozone, SO₂</td>
</tr>
<tr>
<td>325 ± 0.1</td>
<td>2 ± 0.2</td>
<td>Ozone</td>
</tr>
<tr>
<td>340 ± 0.3</td>
<td>3 ± 0.6</td>
<td>Ozone, Aerosols</td>
</tr>
<tr>
<td>388 ± 0.3</td>
<td>3 ± 0.6</td>
<td>Aerosols, Clouds</td>
</tr>
<tr>
<td>443 ± 1</td>
<td>3 ± 0.6</td>
<td>Aerosols</td>
</tr>
<tr>
<td>551 ± 1</td>
<td>3 ± 0.6</td>
<td>Aerosols, Vegetation</td>
</tr>
<tr>
<td>680 ± 0.2</td>
<td>2 ± 0.4</td>
<td>Aerosol, Vegetation, Clouds</td>
</tr>
<tr>
<td>687.75 ± 0.2</td>
<td>0.8 ± 0.2</td>
<td>Cloud Height</td>
</tr>
<tr>
<td>764.0 ± 0.2</td>
<td>1 ± 0.2</td>
<td>Cloud Height</td>
</tr>
<tr>
<td>779.5 ± 0.3</td>
<td>2 ± 0.4</td>
<td>Clouds, Vegetation</td>
</tr>
</tbody>
</table>
Lunar calibration of the O2 abs. channels

Assumptions:

- Lunar reflection is constant relative to the adjacent pairs: 680 and 688; 764 and 780;

- The ratio between two neighboring channels doesn’t depend on Solar and Viewing geometry;
Lunar calibration of the O2 abs. channels

Assumptions:

- Lunar reflection is constant relative to the adjacent pairs: 680 and 688; 764 and 780 nm

Using GOME Lunar Albedo:
10 nm difference ~ 0.5% increase
Lunar calibration of the O2 abs. channels

from Matt Kowalewski & Alexander Cede
Lunar calibration of the O2 abs. channels

779 nm

- ~ 10%
- < 1%
Using the EPIC/DSCOVR O2 B-band for monitoring vegetation
EPIC reflectance at six bands measured on March 22, 2016 at 10:52 GMT

$SZA=6.4\pm0.5$, $|\mu_0|=0.994\pm0.001$; $VZA=12.7\pm0.5$, $\mu=0.976\pm0.002$; scattering angle is $171.5^\circ$. 
Two EPIC NDVIs from March 22, 2016

$SZA = 6.4 \pm 0.5, \ |\mu_0| = 0.994 \pm 0.001; \ VZA = 12.7 \pm 0.5, \mu = 0.976 \pm 0.002; \text{ scattering angle is } 171.5^\circ.$
Some technical justification

\[ R_\lambda(\Omega, \Omega_0) = \exp\left(-\frac{\tau_\lambda}{|\mu_0|}\right) \rho_\lambda(\Omega, \Omega_0) \exp\left(-\frac{\tau_\lambda}{\mu}\right) + D_\lambda \]

\[ D_\lambda \approx 0 \]

(\(\lambda=688\) nm; O2 B-band)

\[ \Omega_0 \approx -\Omega \]

(back scattering direction)
Spectral Invariant Approximation

\[ R_\lambda(\Omega, \Omega_0) = \exp\left(-\frac{\tau_\lambda}{|\mu_0|}\right) \rho_\lambda(\Omega, \Omega_0) \exp\left(-\frac{\tau_\lambda}{\mu}\right) + D_\lambda \]

\[ \rho_\lambda(\Omega, \Omega_0) = K(\Omega, \Omega_0) W_\lambda \]

\[ W_\lambda = \omega_{0\lambda} \frac{1 - p}{1 - p \omega_{0\lambda}} \]

\[ \omega_{0\lambda} = \exp(-A_\lambda) = \exp\left[-(\alpha k_{Ch,\lambda} + \beta)\right] \]

\[ \frac{W_\lambda}{\omega_{0\lambda}} = p W_\lambda + (1 - p) \]

\[ \frac{\rho_\lambda}{\omega_{0\lambda}} = p \rho_\lambda + K(1 - p) \]

\[ R_\lambda(\Omega, \Omega_0) \bigg|_{\omega_{0\lambda}} = p R_\lambda(\Omega, \Omega_0) + b(\Omega, \Omega_0) \exp\left(-\frac{2\tau_\lambda}{\mu}\right) + D_{A\lambda} \]

\[ K \text{ is determined entirely by canopy geometrical properties while } W_\lambda \text{ by leaves optical properties} \]

Levis&Disney, 2007

Huang et al., 2007; Knyazikhin et al., 2011

\[ k_{Ch,\lambda} \text{ is the chlorophyll absorption spectrum, } \alpha \text{ is its concentration and } \beta \text{ represents the total absorption coefficient of dry matter.} \]
Spectrally variable scattering coefficient $W_\lambda$ obtained from EPIC observations.

The approximated values of $W_\lambda$ mimic the shape of the spectral scattering coefficient over dense vegetation although its magnitudes are overestimated.

It always fits the scattering coefficient at $\lambda = 551, 688$ and $780$ nm independently of atmospheric conditions while its value at $\lambda = 680$ nm fails to be fitted.
Summary

If the EPIC O2 B-band (688 nm) is used instead of the red band, the effect of atmosphere (the diffuse radiation) on surface reflectance will be reduced and the residual uncertainties in atmospheric correction can be better tolerated.

This is due to two factors:
(i) vegetated surface is yet sufficiently dark at 688 nm and
(ii) the O2 absorbing atmosphere substantially reduces multiple scattering.

The spectral invariant approximation supports this statement.
MODIS/Terra&Aqua and EPIC/DSCOVR

MODIS Terra
10:30 equatorial crossing time

EPIC
10:56 UTC

MODIS Aqua
13:30 equatorial crossing time
Using the EPIC/DSCOVR O2 B-band for monitoring vegetation

Alexander Marshak (NASA GSFC) and Yuri Knyazikhin (Boston University)
Example with MISR and EPIC

To summarize, the scattering coefficient $W_\lambda$ at $\lambda = 551, 688$ and $780$ nm (but not at $\lambda = 680$ nm) can be well approximated by the chlorophyll absorption spectrum.