Maintenance and refinement of the Land Surface Reflectance Code (LaSRC) for Landsat’s and Sentinel 2’s

E. Vermote

¹NASA Goddard Space Flight Center Code 619
²Department of Geographical Sciences, University of Maryland

Eric.f.vermote@nasa.gov

USGS-NASA Landsat Science Team Meeting, USGS EROS Center, Sioux Falls, SD, Feb 21-22 2018

The MODIS **Collection 6 AC algorithm** relies on:

- the use of very accurate (better than 1%) vector radiative transfer modeling of the coupled atmosphere-surface system (6S)
- the inversion of key atmospheric parameters
  - Aerosols are processed from Landsat8/Sentinel 2 images
  - Water vapor and ozone from daily MODIS product.

**Home page:** [http://modis-sr.ltdri.org](http://modis-sr.ltdri.org)
Landsat 8/OLI and Sentinel 2/MSI Surface Reflectance is largely based on MODIS C6

Flowchart of the Landsat 8 (and Sentinel 2) atmospheric correction scheme


USGS-NASA Landsat Science Team Meeting, USGS EROS Center, Sioux Falls, SD, Feb 21-22 2018
Landsat8/OLI and Sentinel 2 atmospheric correction

Using the relationship between the blue surface reflectance (490 nm) and the red surface reflectance (665 nm) known from MODIS, we are able to retrieve the AOT.

\[
\frac{\rho_{\text{surf blue}}}{\rho_{\text{surf red}}}_{\text{MSI}} = \frac{\rho_{\text{surf blue}}}{\rho_{\text{surf red}}}_{\text{MODIS}}
\]

We loop the AOT until \(\frac{\rho_{\text{surf blue}}}{\rho_{\text{surf red}}}_{\text{MSI}} = \frac{\rho_{\text{surf blue}}}{\rho_{\text{surf red}}}_{\text{MODIS}}\).

The retrieved AOT is used to compute the surface reflectance at 443 and 2190 nm. The aerosol model is then derived by minimizing the residual:

\[
\text{residual} = \frac{1}{2} \sum (\rho_{\text{surf}}^{l} - \text{Ratio}_{665}^{l} \times \rho_{\text{surf}}^{665})^2
\]

Computation of surface reflectances for all channels

\[
(*)\quad \rho_{\text{surf}} = \frac{Y}{1 + S_{\text{atm}} Y} \quad \text{with} \quad Y = \frac{1}{T_{\text{atm}} \cdot t_{\text{atm}} \cdot t_{\text{water vapor}} \cdot t_{\text{ozone}}} \left( \frac{\rho_{\text{TOA}}}{t_{\text{ozone}} \cdot t_{\text{others}}} - \left( \rho_{\text{atm}} - \rho_{\text{ray}} \right) \cdot t_{\text{water vapor}} \cdot t_{\text{ice}} - \rho_{\text{ray}} \right)
\]

\(\rho_{\text{surf}}\) determined (*) using \(\rho_{\text{atm}}, T_{\text{atm}}\) and \(S_{\text{atm}}\) from LUT knowing AOT, Aerosol model, pressure, altitude, water vapor, ozone...
CURRENT STATUS
Atmospheric correction algorithm

- L8 surface reflectance product (V3) available and validated satisfactorily
- Sentinel 2 atmospheric correction algorithm (V3) developed and implemented (validation through ACIX)
Methodology for evaluating the performance of Landsat8/Sentinel2

Subsets of Level 1B data processed using the standard surface reflectance algorithm

Reference data set

Atmospherically corrected TOA reflectances derived from Level 1B subsets

Vector 6S

AERONET measurements

\( I_{\text{aer}}, \text{H}_2\text{O}, \text{particle distribution} \)

\( \text{Refractive indices, sphericity} \)
quantitative assessment of performances (APU) for MODIS

*Collection 5*: accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (top left), band 2 in the Near Infrared (top right also shown is the uncertainty specification (the line in magenta), that was derived from the theoretical error budget. Data collected from Terra over 200 AERONET sites from 2000 to 2009.
Improving the aerosol retrieval in collection 6 reflected in APU metrics

**COLLECTION 6:** accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (top left), band 2 in the Near Infrared (top right also shown is the uncertainty specification (the line in magenta), that was derived from the theoretical error budget. Data collected from Terra over 200 AERONET sites for the whole Terra mission.
The “preliminary” analysis of OLI SR performance in the red band over AERONET is very similar to MODIS Collection 6.
ACIX results for the LaSRC algorithm (L8/S2A) (Land sites only, no cloud)

L8 AOT 550nm
0.017+0.851*x
y=x

AOT 550nm LaSrc-land R2 0.948
Samples 86
RMS 0.100 Bias 0.016

S2A AOT 550nm
0.094+0.880*x
y=x

AOT 550nm LaSrc-land R2 0.870
Samples 63
RMS 0.128 Bias -0.069
ACIX results for the LaSRC algorithm (L8/S2A) (Land sites only, no cloud)
ACIX results for the LaSRC algorithm (L8/S2A) (Land sites only, no cloud)


USGS-NASA Landsat Science Team Meeting, USGS EROS Center, Sioux Falls, SD, Feb 21-22 2018
Use of combined L8/S2A is on-going

The accuracy, precision and uncertainty (APU) values estimated when inter-comparing atmospherically corrected images acquired by Landsat-8/OLI and Sentinel-2A/MSI satellites

Use of combined L8/S2A is on-going

Table 1. Comparison of satellite-derived winter crop areas with official statistics on harvested areas at district level. Estimates of the APU metrics are given in ha.

<table>
<thead>
<tr>
<th>Metric</th>
<th>LC8-S2A</th>
<th>LC8</th>
<th>S2A</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>612</td>
<td>1081</td>
<td>839</td>
</tr>
<tr>
<td>$P$</td>
<td>1719</td>
<td>5061</td>
<td>1962</td>
</tr>
<tr>
<td>$U$</td>
<td>1785</td>
<td>5056</td>
<td>2090</td>
</tr>
<tr>
<td>$rU$,%</td>
<td>11.6</td>
<td>32.7</td>
<td>13.5</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.90</td>
<td>0.64</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Table 2. Comparison of satellite-derived winter wheat yields with official statistics at district level without using GDD and using GDD. Estimates of the APU metrics are given in t/ha.

<table>
<thead>
<tr>
<th>Metric</th>
<th>No GDD</th>
<th>GDD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LC8-S2A</td>
<td>LC8</td>
</tr>
<tr>
<td>$A$</td>
<td>-0.17</td>
<td>-0.48</td>
</tr>
<tr>
<td>$P$</td>
<td>0.26</td>
<td>0.31</td>
</tr>
<tr>
<td>$U$</td>
<td>0.31</td>
<td>0.57</td>
</tr>
<tr>
<td>$rU$,%</td>
<td>7.7</td>
<td>14.3</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.45</td>
<td>0.29</td>
</tr>
</tbody>
</table>


USGS-NASA Landsat Science Team Meeting, USGS EROS Center, Sioux Falls, SD, Feb 21-22 2018
Sentinel 2 has “features” that help improving the SR product (e.g. cloud mask)

L1C cloud mask (red)  Shift between band 4 and 2  Parallax cloud mask (magenta)


USGS-NASA Landsat Science Team Meeting, USGS EROS Center, Sioux Falls, SD, Feb 21-22 2018
Validation is on-going moving into a systematic routine assessment.

USGS-NASA Landsat Science Team Meeting, USGS EROS Center, Sioux Falls, SD, Feb 21-22 2018
Conclusions

• Surface reflectance code (LaSRC) is mature and pathway toward validation and automated QA is clearly identified.
• Algorithm is generic and tied to documented validated radiative transfer code so the accuracy is traceable enabling error budget.
• The use of BRDF correction enables easy cross-comparison of different sensors (MODIS, VIIRS, AVHRR, LDCM, Landsat, Sentinel 2, Sentinel 3…)
• Sentinel 2 surface reflectance validation shows good performances but needs to be extended using the whole record on the full collection of AERONET sites.