Sentinel 3 Science Products: A US Contribution

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Land Product Validation and Evolution Workshop, Frascati, Italy, January 28-30, 2014
A Land Climate Data Record

Multi instrument/Multi sensor Science Quality Data Records used to quantify trends and changes

Emphasis on data consistency – characterization rather than degrading/smoothing the data

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Land Climate Data Record (Approach)

Needs to address geolocation, calibration, atmospheric/BRDF correction issues.

### CALIBRATION

Degradation in channel 1
(from Ocean observations)

### ATMOSPHERIC CORRECTION

Channel 1/Channel 2 ratio
(from Clouds observations)

### BRDF CORRECTION

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MODIS used as a reference for past and future land data record (example NDVI)

Evaluation over AERONET (2003)
0.007 < Precision < 0.017

Independent evaluation of the precision
Over 2000-2004 CMG daily time series

Precision = 0.016

Precision = 0.013

Precision = 0.01
MODIS product and validation methodology used to evaluate other surface reflectance product: example LANDSAT TM/ETM+

- **WELD (D. Roy)** 120 acquisitions over 23 AERONET sites (CONUS)

- **GFCC: Comparison with MODIS SR products**
  - GLS 2000 demonstration
  - GLS 2005 (TM and ETM+)
WELD/LEDAPS results (Red-band3)

LEDAPS

WELD uses MODIS aerosol

Top of the atmosphere

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MODIS Reflectance time series

- Reflectance time series show high-frequency variability
- The “noise” is partly due to directional effects.
- Selection of specific geometries decreases temporal coverage
- Can we correct for the directional effect and retain the original temporal resolution?

Françoise-Marie Bréon, LSCE
Analytical model and correction

Linear models:

\[
\rho (\theta_s, \theta_v, \phi) = k_0 + k_1 F_1(\theta_s, \theta_v, \phi) + k_2 F_2(\theta_s, \theta_v, \phi)
\]

Several choices for \( F_1 \) and \( F_2 \):

- \( F_1 \): Model surface effects (soil roughness)
- \( F_2 \): Model volume effects (R.T. within canopy)

\[
\rho (\theta_s, \theta_v, \phi) = k_0(t) \left[ 1 + \frac{k_1}{k_0} F_1(\theta_s, \theta_v, \phi) + \frac{k_2}{k_0} F_2(\theta_s, \theta_v, \phi) \right] = k_0(t) \left[ 1 + R F_1(\theta_s, \theta_v, \phi) + V F_2(\theta_s, \theta_v, \phi) \right]
\]

Correction:

\[
\rho^{\text{cor}} = \rho(\theta_s, \theta_v, \phi) \left[ 1 + R F_1(45,0,0) + V F_2(45,0,0) \right] \left[ 1 + R F_1(\theta_s, \theta_v, \phi) + V F_2(\theta_s, \theta_v, \phi) \right]
\]

Maignan et al., Rem. Sens. Env., 2004
Which is the “best” model?

- Look for the parameters for a best fit (invert the model)
- Compute error of fit
- Among the 6 tested models, RossLiHS allows the best fit
- Clear improvement when using Hot Spot correction

Maignan et al., Rem. Sens. Env., 2004
**BRDF model inversion**

\[ R = \alpha_R + \lambda_R n_i \]

\[ \Delta \rho_i = \frac{\rho_{i+1} - \rho_i}{\sqrt{t_{i+1} - t_i}} \]

\[ \Delta F_1^i = \frac{\Delta F_{1}^{i+1} \rho_i - \Delta F_{1}^{i} \rho_{i+1}}{\sqrt{t_{i+1} - t_i}} \]

\[ \Delta F_2^i = \frac{\Delta F_{2}^{i+1} \rho_i - \Delta F_{2}^{i} \rho_{i+1}}{\sqrt{t_{i+1} - t_i}} \]

- \( R \) and \( V \) are linear function of the NDVI
- We look at the difference between successive measurements
- Notations used here for an easy inversion of the model parameters

- Matrix writing:

\[
\begin{bmatrix}
\sum(n_i \Delta F_1^i)^2 & \sum n_i (\Delta F_1^i)^2 & \sum \Delta F_1^i \Delta F_2^i & \sum n_i \Delta F_1^i \Delta F_2^i \\
\sum n_i (\Delta F_1^i)^2 & \sum(n_i \Delta F_1^i)^2 & \sum n_i \Delta F_1^i \Delta F_2^i & \sum n_i^2 \Delta F_1^i \Delta F_2^i \\
\sum \Delta F_1^i \Delta F_2^i & \sum n_i \Delta F_1^i \Delta F_2^i & \sum (\Delta F_2^i)^2 & \sum n_i (\Delta F_2^i)^2 \\
\sum n_i \Delta F_1^i \Delta F_2^i & \sum n_i^2 \Delta F_1^i \Delta F_2^i & \sum n_i (\Delta F_2^i)^2 & \sum(n_i \Delta F_2^i)^2 \\
\end{bmatrix}
\begin{bmatrix}
\alpha_v \\
\lambda_v \\
\alpha_R \\
\lambda_R \\
\end{bmatrix}
= \begin{bmatrix}
\sum \Delta \rho_i \Delta F_1^i \\
\sum n_i \Delta \rho_i \Delta F_1^i \\
\sum \Delta \rho_i \Delta F_1^i \\
\sum n_i \Delta \rho_i \Delta F_1^i \\
\end{bmatrix}
\]
Data location

- MODIS data are distributed as “tiles” (10° of lat.)
- To limit data volume, we focus on a single tile
- Select a tile over Eastern Australia for (i) variety of surface cover, (ii) number of clear observations, (iii) low aerosol load
BRDF parameters: R and V

- Analyzed the BRDF parameters distributed in the official MODIS products
- Parameters show very unrealistic temporal variations.
- Our method shows more realistic results
Quantification of time series noise

- For each triplet of observations, one can estimate middle one from the earlier and later:
  \[ \rho_i^* = \frac{(t_i - t_{i-1})\rho_{i+1} + (t_{i+1} - t_i)\rho_{i-1}}{t_{i+1} - t_{i-1}} \]

One can then compute a “noise” from the quadratic sum of the difference between the measurement and their interpolated counterpart:

\[ \sigma^2(\rho) = \frac{\sum_{i=2}^{N-1} \frac{1}{t_{i+1} - t_{i-1}} (\rho_i^* - \rho_i)^2}{\sum_{i=2}^{N-1} \frac{1}{t_{i+1} - t_{i-1}}} \]

We use this definition in the following to quantify the time series quality
Impact of spatial scale

- The noise of the corrected time series is much larger than that we obtained earlier using CMG (Climate Modeling Grid : 5 km) lower resolution data.

- We show here a comparison of the noise obtained at the full resolution against that obtained when aggregating 5x5 pixels.
Noise vs Spatial heterogeneity

- There is a very strong correlation between the spatial heterogeneity (quantified here as the 3x3 standard deviation) and the noise on the corrected time series.

- Clearly, the spatial heterogeneity affects the quality of the time series and there is an easy explanation for that.
Impact of spatial scale

- The “noise” of the time series decreases when the spatial aggregation increases. There seems to be an optimal scale at 2 km (4x4 pixels)
Conclusions (1/2)

- Directional effects on the Earth reflectances are large (factor of 2 to 4 depending on wavelength)

- There are simple analytical models (3 parameters) that reproduce accurately the observed signatures

- The reflectance is modelled as the product of a normalized reflectance, that may vary rapidly, and a BRDF model (2 parameters) that varies more slowly.

- The two model parameters can be parameterized as a linear function of the NDVI.

- We have developed a method to estimate easily these parameters from the reflectance time series

- Corrected time series are much smoother than their original counterpart, and can be used to extract fine signal
Conclusions (2/2)

- The official MODIS BRDF parameters are unreliable
- The time series at the full (500 m) resolution appear noisier than at lower resolution
- Spatial heterogeneity of the reflectance is the driving factor for this additional noise
- We suggest an optimal resolution of 2 km for the use of MODIS data time series
Use of BRDF correction for product cross-comparison

Comparison of aggregated FORMOSAT-2 reflectance and MODIS reflectance. No BRDF correction. Density function from light grey (minimum) to black (maximum); white = no data.

Comparison of aggregated FORMOSAT-2 reflectance and BRDF corrected MODIS reflectance. Corrections were performed with Vermote al. (2009) method using for each day of acquisition, the angular configuration of FORMOSAT-2 data.
Cross-Calibration of NOAA 16 AVHRR

Calibration of NOAA16 AVHRR over a desert site using MODIS data

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The coefficients were consistent within less than 1%
Use of BRDF corrected reflectance for cloud mask evaluation of AVHRR Time Series

CLAVR (Pathfinder II) cloud mask

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Use of BRDF corrected reflectance for cloud mask evaluation of AVHRR Time Series

AVHRR Time series LTDR V3.0 cloud mask

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Using Direct comparison with MODIS Aqua for validation

Comparison of MODIS Aqua and NOAA16 AVHRR data, A (Red), B (NIR), C (NDVI) are observed over AERONET sites for 2003-2004, D (Red), E (NIR), F (NDVI) are simulated using a vegetation model that account for spectral difference between MODIS and AVHRR bands. G shows over the AERONET sites MODIS NDVI versus corrected AVHRR NDVI computed from spectrally adjusted AVHRR surface reflectance.
One of the VIIRS First light images generated by UMD/NOAA

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Use of BRDF correction (VIIRS)

VIIRS SR product  Aqua SR product

A ~50km x 50km site in Australia
VIIRS calibration is being monitored on a continuous basis (selected daily obs)
Conclusions

- Surface reflectance algorithm is mature and pathway toward validation and automated QA is clearly identified.
- Algorithm is generic and tied to documented validated radiative transfer code enabling easier inter-comparison and fusion of products from different sensors (MODIS, VIIRS, AVHRR, LDCM, Landsat, Sentinel 2 …)