Validation of the MERIS aerosol product over land

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L2 aerosol algorithm over land

- Select Land Aerosol Remote Sensing target (LARS) using a threshold on ARVI (Atmospherically Resistant Vegetation Index (ARVI) built with Rayleigh corrected reflectance at 443, 670 and 865 nm
- Predict LARS reflectance at 412, 443 and 670 nm using a linear relationship between ARVI and surface reflectance. This linear model is given on a monthly basis and 1°x1° spatial resolution
- Invert AOT at 443 and 670 nm using various aerosol models (m=1.44 -0*i, Junge Size Distribution with various Angström α exponent from 0 to 2.5)
- Product AOT is given at 443 nm for α=1
- Angström exponent of the aerosol model that gives the best spectral dependence between AOT at 443 and AOT at 670 nm is the second parameter of the aerosol product.
- Product at the same spatial resolution than level 1
Status of the current L2 product validation

• No validation at the pixel resolution
  – Note that MODIS level 2 aerosol product is given for a 10 km box
  – We validate MERIS for 10x10 boxes (level 2 « macro-pixels »)

• AOT(443), a primary L2 product, is validated when filtered with 2 tests very easy to implement
  – Very similar in fact to what is done during the level 2 processing of MODIS macro pixels.

• Angström coefficient $\alpha$ (computed between 443 and 670 nm), a primary L2 product, is not validated
Level 2 AOT intercomparison (Khokanovsky et al., 2007)

AOT retrievals over central Europe on 13th September 2005
With different instruments and algorithm
Improvement 1: Surface Pressure Filter

\[ \Delta P = (P_{\text{ECMWF}} \times \exp(-z/H)) - P_{\text{O}_2} \]
Improvement 2: Local Variance of AOT filter

**Left**: mean AOT at 550 nm (MEGS v7.4) averaged over 9.28 km grid

**Middle**: local standard deviation of the AOT at 550 nm.

**Right**: RGB composite with cloud flagged pixels in magenta (L2 flag).
 Alta Floresta (2002-2007)

\[\text{regression lineaire}\]

\[a = 1.29996\]
\[b = -0.147517\]
Avignon

\[ a = 1.13167 \]
\[ b = -0.0277818 \]
Ispra

\begin{align*}
a &= 1.33155 \\
b &= -0.109436
\end{align*}
Mongu

Regression lineaire

\[ a = 0.951934 \]
\[ b = -0.0174402 \]
All (39 stations 200-2007)  
$\Delta P < 40 \text{ hPa}, \sigma_{\text{AOT}} < 0.1$
Current L3 Algorithm

• Sinusoidal grid with size of 9.28 km (~L2 macro pixel)

• Mask applied on L2 pixels
  – Filter out pixels in bins with AOT outside mean ± 2σ
  – Filter out pixels close to clouds (morphological dilatation in the along tack of 3 pixels)
  – Filter out pixels with retrieved α outside [0, 2.5]
  – Filter out PCD_19 flag or CLOUD flag raised

• Monthly mean
Current MERIS L3 vs AERONET (global June 2003)

TA443-2h-L3

\[
y = 0.1167 + 0.4292x
\]

\[
R = 0.3557
\]
• Quite bad

• Different L3 algorithms
  – [1] MERIS home made (rejection of clouds for $\Delta P=50\text{hPa}$ and $\sigma(\text{AOT})<0.15$);
  – Top right [2] same as [1] but with an additional spatial filter, rejecting isolated groups of macro-pixels of size $\leq 2$ in daily maps;
  – Bottom left [3] same as [1] but with an additional spatial filter, rejecting isolated groups of macro-pixels of size $\leq 3$ in daily maps;
Simple Accumulation

Simple Accumulation + Low pass 2x2

Simple Accumulation + Low pass 3x3

Current L3

MODIS

23/09/2008

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Simple Accumulation

Simple Accumulation + Low pass 2x2

Simple Accumulation + Low pass 3x3

Current L3

MODIS

23/09/2008

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Simple Accumulation

Simple Accumulation

Simple Accumulation + Low pass 2x2

Simple Accumulation + Low pass 3x3

Current L3

MODIS

HALIFAX AERONET

AOT(440) = 0.33

23/09/2008

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Simple Accumulation

Simple Accumulation+ Low pass 3x3

Current L3

Alta_Floresta
AERONET 0.2

MODIS
Simple Improved L3 Algorithm

- Decompose binning process between spatial (sinusoidal grid size ~9.28 km) and temporal (daily).
- In the spatial binning process, mask pixels for which difference between barometric pressure corrected from DEM and apparent surface pressure L2 product is greater than 50 hPa.
- In the temporal binning process, mask the macro pixels of the daily composites for which local standard deviation of the AOT greater than 0.15 and filter out AOT spots of size <= 3 macro-pixels.
L3 MODIS vs AERONET
global june 2003

MODIS-2h

AOT(443nm) MODIS
AOT(443nm) CINCEL

y = 0.8793x + 0.6631
r = 0.7577
Improved MERIS L3 vs AERONET global June 2003
Angström Exponent: what to do?

• Improve LARS reflectance Look Up tables
  – Use MERIS data as input (from ESA ALBEDO MAP project)
• Algorithm alternatives
  – Test 2 band algorithm
  – Substitute band B3 to band B7
  – Perform filtering and averages to retrieve Angström exponent at a coarser spatial resolution than AOT
LARS reflectance: Methodology I of current LUT building

• Get MODIS filled white sky albedo maps at 470, 659, 856 nm ($\rho_{\text{modis}}(\lambda_i), i=1,2,3$) for a 16 days period and 1'x1' spatial resolution

• Compute ARVI_{modis}

• Compare with spherical albedo at 443,670 and 865 nm of DDV models ($\rho_{\text{ddv}}(\lambda_i), i=1,2,3$) and derived ARVI_{ddv}
Methodology I

• Perform linear regression of

\[(\rho_{\text{modis}}(\lambda_i) - \rho_{\text{ddv}}(\lambda_i)) = f_i(\text{ARVI}_{\text{modis}} - \text{ARVI}_{\text{ddv}}), \ i=1,2 \]

and for pixels in a 12'x12' box satisfying:

\[\text{ARVI} > \text{ARVI}_{\text{min}} \quad \text{ARVI} < 0.9 \quad \rho_{\text{modis}}(\lambda_3) > 0.15\]

Keep fit if 
\[-0.2 < \text{slope}_{443} < 0 \quad \text{and} \quad -0.25 < \text{slope}_{670} < -0.04\]

• if **no good fit**, then repeat with a higher ARVI_{min}
Methodology I

- $\rho_0(\lambda_i) = f_i(ARVI=ARVI_{ddv})$, $\Delta ARVI_{min}$ and slope($\lambda_i$)
- $C(\lambda_i) = \rho_0(\lambda_i)/\rho_{ddv}(\lambda_i)$
- Average over 1deg x 1deg box
- Timely aggregated in one month period
Methodology II, with MERIS albedo data

• Get MERIS ALBEDOMAP white sky albedo maps at 412, 443, 490, 670 and 865 nm ($\rho_{\text{meris}}(\lambda_i), i=1,2,..5$) for a 30 days period and 3'x3' spatial resolution and for year 2003 and 2005

• Compute $\text{ARVI}_{\text{meris}}$

• Compare with spherical albedo at 443, 670 and 865 nm of DDV models ($\rho_{\text{ddv}}(\lambda_i), i=1,2,..,5$) and derived $\text{ARVI}_{\text{ddv}}$
Methodology II

- Perform linear regression of

\[(\rho_{\text{meris}}(\lambda_i) - \rho_{\text{ddv}}(\lambda_i)) = f_i(\text{ARVI}_{\text{meris}} - \text{ARVI}_{\text{ddv}}), \quad i = 1, 2, 3, 4\]

and for pixels in a 60'x60' box satisfying:

\[\text{ARVI} > \text{ARVI}_{\text{min}}\quad \text{ARVI} < 0.95\quad \rho_{\text{meris}}(\lambda_5) > 0.15\]

Keep fit if -0.2 < slope412 < 0 and
-0.2 < slope443 < 0 and
-0.2 < slope490 < 0 and
-0.25 < slope670 < -0.04

- if no good fit, then repeat with a higher \(\text{ARVI}_{\text{min}}\)
$A_0(\lambda)$: Albedo for ARVI=ARVI_{DDV}  
$C(\lambda) = A_0(\lambda)/A_{DDV}(\lambda)$

MODIS June 2002 (12’ x 12’ box)

Central Europe

Amazonia

Slope: $S(\lambda)$

MODIS June 2002 (12’ x 12’ box)
MERIS June 2003 (60’ x 60’ box)

Amazonia

中央Europe

Lat= -5.0; Lon= 50°; Month= 6

ALB_200306

Lat= 46.0; Lon= 5°; Month= 6

ALB_200306
MODIS October 2002 (12’ x 12’ box)

AlbMap.WS.v1.2.2002.289.0.47_v1.4

450: 0.0165(0.0053) +X* -0.0073(0.0070) alb:0.0101 chi:0.0010
645: 0.0891(0.0065) +X* -0.0842(0.0086) alb:0.0154 chi:0.0013

Lat= -5.0 ; Lon= -100.0 ; Month= 10

AlbMap.WS.v1.2.2002.289.0.47_v1.4

450: 0.0443(0.0029) +X* -0.0335(0.0053) alb:0.0183 chi:0.0041
645: 0.1134(0.0039) +X* -0.1090(0.0072) alb:0.0288 chi:0.0055

Lat= 46.0 ; Lon= 8.0 ; Month= 10
MERIS October 2003 (60’ x 60’ box)

Lat = -5.0; Lon = 10; Month = 10

Lat = 46.0; Lon = 10; Month = 10
Time Stability: MERIS June 2005 (60’ x 60’ box)
Meris June 2003 (60' x 60' box)

Amazonia

Central Europe

Lat = -5.0; Lon = 50°; Month = 6

Lat = 46.0; Lon = 5°; Month = 6
10 percentile ARVI, June

ALBEDOMAP (2003)

MODIS filled albedo
LARS Albedo in band 2 for ARVI=0.8, June

ALBEDOMAP (2003)

MODIS filled albedo
LARS Albedo in band 7 for ARVI=0.8, June

ALBEDOMAP (2003)

MODIS filled albedo
LARS Albedo in band 2 for ARVI=0.8, January

ALBEDOMAP (2003)  MODIS filled albedo

Color name list
Magenta Yellow Green Red White
Coral Forest Plum Cyan Turquoise
Blue Sienna Violet Black

Color name list
Magenta Yellow Green Red White
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Algorithm changes

• Heavy coupling Rayleigh-aerosol in B1 Can we use B1?
• B1 does not add lot of spectral information combined to B2 and B7 and slow the algorithm.
• Angström exponent derived from B1 and B3 only is very dependant upon the radiometric calibration.
• Angström exponent derived from B2 and B7 only is very dependant upon the accuracy of B7 LARS reflectance. It is worse with a low aerosol loading.
Conclusions & Recommendations

• Any LUT or algorithm changes need careful validation as AOT 443 is OK now.
• Derivation of LARS reflectance at 412, 443, 490, and 670 nm from MERIS ALBEDOMAP has started recently and needs consolidation as a first analysis exhibits significant differences with MODIS derived values.
• Integrate state of the art cloud screening
Conclusions & Recommendations (II)

• 10 km spatial resolution (level 2 of MODIS)
  – Good performances can be achieved with current L2 macro-pixels AOT at 443 nm over land, when compared to AERONET and MODIS. At least compute 10 km average and standard deviation
  – Angström exponent, more sensitive to instrument and algorithm noise, should be retrieved on a macro pixel basis only

• The basic algorithm should be simplified
  – Threshold on AOT(B2) depending on accuracy on LARS surface reflectance
    • below threshold: use standard aerosol model in B2
    • above threshold: use 2 bands algorithm (B2 – B7)

• Implement the two bands algorithm B2 – B7 (standard) and B1 – B3 (test) and qualify them against substantial amount of in situ data
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