Land surface albedos from Land SAF (MSG), CYCLOPES (VEGETATION/AVHRR) and POLDER/ADEOS projects: an accuracy assessment based on product inter-comparison and validation with in situ measurements

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On-going projects …

**CYCLOPES**
*(funded by European Union)*

Fusion of data/products (albedo, LAI, fraction of vegetation, fPAR) of several wide FOV optical sensors (period 1997 → 2003).


**SAF (Satellite Application Facilities) on Land Surface Analysis**
June 1999 – December 2004 (Research & Development)
January 2005 – February 2007 (Initial Operational Phase)
*(funded by EUMETSAT & National Meteorological Services)*

Implementation of an operational ground segment for near-real time dissemination of land surface parameters in combining Meteosat Second Generation (MSG) and EUMETSAT Polar System (EPS)

Version 1.0 (started on October 12, 2004)
To exploit complementarity between observing systems

<table>
<thead>
<tr>
<th>Observing System</th>
<th>Spatial Resolution</th>
<th>Temporal Resolution</th>
<th>Spectral Channels</th>
<th>Observation Angles</th>
<th>Illumination Angle</th>
<th>Data Availability</th>
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</thead>
<tbody>
<tr>
<td>POLDER</td>
<td>6km</td>
<td>~1 day</td>
<td>5</td>
<td>variable</td>
<td>~constant</td>
<td>1997, 2003</td>
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<tr>
<td>VGT</td>
<td>1km</td>
<td>~1 day</td>
<td>4</td>
<td>variable</td>
<td>~constant</td>
<td>1998-</td>
</tr>
<tr>
<td>AVHRR</td>
<td>4km</td>
<td>~1 day</td>
<td>4</td>
<td>variable</td>
<td>~constant</td>
<td>1982-</td>
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<tr>
<td>SEVIRI</td>
<td>3km</td>
<td>15 min</td>
<td>3</td>
<td>constant</td>
<td>variable</td>
<td>2003-2018+</td>
</tr>
<tr>
<td>MERIS</td>
<td>1km</td>
<td>~2 days</td>
<td>15</td>
<td>variable</td>
<td>~constant</td>
<td>2002-</td>
</tr>
</tbody>
</table>
**Version 2**

- **POLDER / ADEOS-1 & 2**  
  Nov 1996 - June 1997, April - Oct 2003: 8 km global, 10-days

- **AVHRR / NOAA**  
  1999/2000/2002/2003: 8 km global, 10-days

- **MERIS / ENVISAT**  
  2003: 8 km / 1 km over Europe and Africa, 10-days

- **VEGETATION / SPOT-4 & 5**  
  2002 / Jan - Sep 2003: 8 km global / 1 km over Europe and Africa, 10-days  
  1999: 8 km global North Hemisphere, 10-days
The 4 dimensions of the product fusion

- Observations are available at different sun-view geometries
  - Angular fusion (use of BRDF model of Roujean et al.)

- Sensors observe in different spectral bands
  - Spectral fusion (use of SAIL code + Xs libraries)

- Data are not concomitant
  - Temporal fusion (10-days composite period)

- Projection grid and spatial resolutions are different
  - Spatial fusion (finest resolution to be kept)
Couverture angulaire

BRDF sampling

\[ r = \text{Angle zenithal de visee (0-60)} ; \theta = \text{Azimut relatif} \]

Arc orange = Angle zenithal solaire

VGT

AVHRR

MSG

MERIS
Spectral Normalization

5 spectral albedo products (use MERIS bands as reference)

- 445 nm (blue)
- 560 nm (green)
- 665 nm (red)
- 855 nm (NIR)
- 1644 nm (MIR)

3 broadband albedo products

- Visible
- NIR
- Total
## COMPARISON WITH BSRN NETWORK DATA SETS

**(Baseline Surface Radiation Network)**

### Selected sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Country</th>
<th>Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payerne</td>
<td>Switzerland</td>
<td>BSRN</td>
</tr>
<tr>
<td>Toravere</td>
<td>Estonia</td>
<td>BSRN</td>
</tr>
<tr>
<td>Espirra</td>
<td>Portugal</td>
<td>Fluxnet</td>
</tr>
<tr>
<td>Evora</td>
<td>Portugal</td>
<td>Fluxnet</td>
</tr>
<tr>
<td>Tamanrasset</td>
<td>Algeria</td>
<td>BSRN</td>
</tr>
<tr>
<td>De Aar</td>
<td>South Africa</td>
<td>BSRN</td>
</tr>
<tr>
<td>Solar Village</td>
<td>Saudi Arabia</td>
<td>BSRN</td>
</tr>
</tbody>
</table>

### Characteristics

- High frequency measurements (each 1 or 3 minutes) of down-welling and up-welling solar fluxes (in clear and partially cloudy situations)
- Standard instrumentation in Kipp & Zonen (CM11 & CM21) and Eppley
- only validation of broadband albedo
- Ancillary measurements at sites: diffusion radiation, nebulosity, turbidity
4 BSRN stations in Europe
(Located in various climatic environments)
Validation of broadband albedo
(PAYERNE, Switzerland)

Albedo_1km_V1.0_VGT1_2002
Albedo_1km_V1.0_VGT2_2003 (gras)

BSRN
1998-2003 (yearly average)

\( \Delta : \) BBBHA_VIS
\( \square : \) BBBHA_NIR
\( \bullet : \) BBBHA


- **Desert:**
  - 2002:
    - BBBHA_VIS: △
    - BBBHA_NIR: □
    - BBBHA: X
  - 2003:
    - BBBHA_VIS: △
    - BBBHA_NIR: □
    - BBBHA: X

- **Semi-arid:**
  - 2002:
    - BBBHA_VIS: △
    - BBBHA_NIR: □
    - BBBHA: X
  - 2003:
    - BBBHA_VIS: △
    - BBBHA_NIR: □
    - BBBHA: X

- **Tropical forest:**
  - 2002:
    - BBBHA_VIS: △
    - BBBHA_NIR: □
    - BBBHA: X
  - 2003:
    - BBBHA_VIS: △
    - BBBHA_NIR: □
    - BBBHA: X

**Pixel = 8 km**

**AVHRR (bold) VGT**
Comparing inversion methods (temporal scale)

RED band

Alpilles

Classical Inversion (green)

Kalman filter (yellow)

(from O. Samain)
Comparing inversion method (spatial scale)

Inversion classique - Albedo Rouge (VGT+AVHRR)
1er juillet 2003

Filtre de Kalman - Albedo Rouge (VGT+AVHRR)
1er juillet 2003

'Classical' inversion
Kalman filter

(from O. Samain)
Comparison between MODIS & POLDER (August 15, 2003)

(VISIBLE Black-Sky Albedo at 1 dg resolution)
Satellite Application Facilities (SAF) on Land Surface Analysis

- Institute for Agrometeorology and Environment Analysis Applied to Agriculture
- University of Valencia
- Swedish Meteorological and Hydrological Institute
- Finnish Meteorological Institute
- Universidade de Évora
- Applied Meteorology Foundation
- Meteorological Institute of University of Bonn
- Royal Meteorological Institute
- Institute of Meteorology and Climate Research
OBJECTIVES

The main purpose of the Land SAF is to increase the benefits from MSG/SEVIRI and EPS/AVHRR-3 data related to land, land-atmosphere interactions and biophysical applications, namely by developing techniques, that will allow a more effective use of data from the two planned EUMETSAT satellites (MSG and EPS)
# MSG/SEVIRI CHANNELS

Basic + Airmass + Hi Res Vis Missions

<table>
<thead>
<tr>
<th>Basic</th>
<th>Band (µm)</th>
<th>Airmass</th>
<th>Band (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS 0.6</td>
<td>0.56 - 0.71</td>
<td>WV 6.2</td>
<td>5.35 - 7.15</td>
</tr>
<tr>
<td>VIS 0.8</td>
<td>0.74 - 0.88</td>
<td>WV 7.3</td>
<td>6.85 - 7.85</td>
</tr>
<tr>
<td>IR 1.6</td>
<td>1.50 - 1.78</td>
<td>O_3 9.7</td>
<td>9.38 - 9.94</td>
</tr>
<tr>
<td>IR 3.9</td>
<td>3.48 - 4.36</td>
<td>CO_2 13.4</td>
<td>12.40 - 14.40</td>
</tr>
<tr>
<td>IR 10.8</td>
<td>9.80 - 11.80</td>
<td>High Res VIS</td>
<td>1km Sampling</td>
</tr>
<tr>
<td>IR 12.0</td>
<td>11.00 - 13.00</td>
<td>HRV</td>
<td>0.6 - 0.9</td>
</tr>
</tbody>
</table>
Spectral to Broadband Albedo Conversion

Reflectance of woody and herbaceous vegetation (Asner), soil and snow reflectance (ASTER); Solar Irradiance (E/2000, W/m²/nm)
MSG Atmospheric uncertainty

### MSG RED
- AOT 0.1
- H2O 1 g/cm²
- O3 0.1 atm/cm
- 1 km elevation

### MSG NIR
- AOT 0.1
- H2O 1 g/cm²
- O3 0.1 atm/cm
- 1 km elevation

### MSG SWIR
- AOT 0.1
- H2O 1 g/cm²
- O3 0.1 atm/cm
- 1 km elevation

### MSG HRV
- AOT 0.1
- H2O 1 g/cm²
- O3 0.1 atm/cm
- 1 km elevation

Relative error (%)

- MSG RED: 4.6%
- MSG NIR: 5.5%
- MSG SWIR: 1.7%
- MSG HRV: 4.6%
Aerosol type effects (0.1 error in AOT)

- MSG red
- MSG NIR
- MSG SWIR
- MSG HRV

Surface - Apparent reflectance

<table>
<thead>
<tr>
<th>Continental</th>
<th>Desertic</th>
<th>Smoke</th>
<th>Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.4</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- 0.1
- 0.4
- 0.9
### Theoretical accuracy assessment for surface Albedo

#### Uncertainty ($u$)

<table>
<thead>
<tr>
<th>Source</th>
<th>MSG</th>
<th>AVHRR-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Sampling</td>
<td>0-10%</td>
<td>0-10%</td>
</tr>
<tr>
<td>Cloudmask</td>
<td>0-10%</td>
<td>0-10%</td>
</tr>
<tr>
<td>Calibration</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>4.5%</td>
<td>4.9%</td>
</tr>
</tbody>
</table>

#### $u_c(A)$ range

<table>
<thead>
<tr>
<th>Source</th>
<th>MSG</th>
<th>AVHRR-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$u_c(A_{300-4000})$ range</td>
<td>6.8-15.7%</td>
<td>7.0-15.8%</td>
</tr>
<tr>
<td>Broadband Conversion</td>
<td>~1%</td>
<td>~1%</td>
</tr>
</tbody>
</table>

#### $u_c(A_{300-4000})$ range

- **MSG**
  - Broadband Conversion: 4.4 - 9.8%
- **AVHRR-3**
  - Broadband Conversion: 4.6 - 9.9%

The uncertainty ($u_c$) for the broadband conversion of Albedo ($A$) is given by:

$$u_c^2(A_{300-4000}) = w_{\text{red}}^2u^2(A_{\text{red}}) + w_{\text{NIR}}^2u^2(A_{\text{NIR}}) + w_{\text{SWIR}}^2u^2(A_{\text{SWIR}}) + u^2(sbc)$$
Data processing chain

SAF NowCasting

ECMWF

(H2O, O3, aerosols?)
Albédo 0.6µm

**MSG**
(0.56 - 0.71 µm)

**MODIS**
(0.62 - 0.67 µm)

28/07/2003

DAY 209 (16-days average)
Albédo 0.8µm

MSG
(0.74 – 0.88 µm)

MODIS
(0.84 – 0.88 µm)

28/07/2003
DAY 209 (16-days average)
Albédo 1.6µm (prototyping algorithm)

**MSG**
(1.50 – 1.78 µm)

**MODIS**
(1.63 – 1.65 µm)

28/07/2003
DAY 209 (16-days average)
Synopsis of the Land SAF albedo operational product

- Europe, N_Africa, S_Africa, S_America
- Pixel by pixel basis
- MSG full resolution (3km×3km at nadir)
- SEVIRI instrument projection
- Units: Dimensionless
- Range: 0 - 1
- Accuracy: 10%
- Format: 16 bits signed integer
- 8 bits (quality flag)
- Frequency of Generation: daily
Examples of SAF Land (MSG) image products on March 11, 2005.

(from B.Geiger)
Comparison between MODIS & MSG albedo products

List of selected sites amongst available MODIS ASCII subsets

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Site Name</th>
<th>Site Code</th>
<th>Site Name</th>
<th>Site Code</th>
<th>Vegetation Type</th>
<th>DEM Site Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>atneusti</td>
<td>47.112500</td>
<td>11.320317</td>
<td></td>
<td>Evergreen needleleaf forest</td>
<td>1208 970</td>
</tr>
<tr>
<td>2</td>
<td>frpuecha</td>
<td>43.737500</td>
<td>03.592775</td>
<td></td>
<td>Mixed forest</td>
<td>229 250-270</td>
</tr>
<tr>
<td>3</td>
<td>itnonant</td>
<td>44.687500</td>
<td>11.082544</td>
<td></td>
<td>Cropland/Natural vegetation</td>
<td>11 25</td>
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<tr>
<td>4</td>
<td>itnovara</td>
<td>44.795833</td>
<td>08.425848</td>
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<tr>
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<td>19.458831</td>
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<td>Evergreen needleleaf forest</td>
<td>244 226</td>
</tr>
</tbody>
</table>
02 - 17 feb. 2005

**MSG Albedo product quality flag:**

01 No MSG observations (Land)
03 No MSG observations (inland water)
05 MSG observations (Land)
07 MSG observations (inland water)
37 Snow

(from S.Lanjeri)
06 - 21 march 2005

MSG Albedo product quality flag:

- 01 No MSG observations (Land)
- 03 No MSG observations (inland water)
- 05 MSG observations (Land)
- 07 MSG observations (inland water)
- 37 Snow

(from S.Lanjeri)
A kernel for snow (Roujean & Stroeve, JAM, 2005)

AirMISR BRDF over snow targets (Steam Boat, Colorado)

\[ \rho(\theta_s, \theta_v, \phi) = k_0 + k_{\text{snow}} f_{\text{snow}}(\theta_s, \theta_v, \phi) \]

Symbols: AirMISR measurements
(solid line) simulations from BRDF model

\( \theta_s = 48.65 \)
\( k_0 = 0.71 \)
\( k_{\text{snow}} = 0.64 \)
\( g = 0.49 \)
VALIDATION PLAN

WP 1. Intercomparison with similar spatially distributed products

Statistical analysis (error bar, bias, standard deviation) between co-registered MODIS and MSG/CYCLOPES/POLDER images for the 3 broadband albedos (visible, NIR, total) [topography, clouds, aerosols, sub-pixel variability]

WP 2. In situ measurements from sites BSRN

Data processing for selected sites (speed-up communication with site captains, statistical analysis, coordination with MODLAND)
High resolution imagery (Landsat, SPOT, MODIS at 250 m) for 2 or 3 BSRN stations to assess the degree of homogeneity (<clumping indices) → strategy to be defined

WP 3. Field campaigns

SNORTEX: Seasonal variability of snow/vegetation BRDF in Lapland with airborne POLDER (coll. Finnish Meteorological Institute)
Comparison with BRDF from NOAA/AVHRR et other sensors (MODIS, MISR, POLDER, VGT)
Short-term scheduled activities (high priority !)

- Resolve known technical issues plus improve cloud mask (Land SAF)

- Inter-calibrate sensors (VGT & AVHRR), improve cloud mask, aerosol correction (CYCLOPES)

- Broadband Albedos: tuning of theoretical values of conversion coefficients with real data sets (precision < 10 %)

- Filling missing data: use of Kalman filter and/or land cover map

- Snow Albedo: use of snow kernel proposed by Roujean and Stroeve (JAM, 2005)

- Systematic comparison with MODIS albedos (down-link with DAAC)