

Product Specification Document

Semi-Analytical CloUd Retrieval Algorithm for **SCIAMACHY/ENVISAT**

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DOCUMENT STATUS SHEET

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|-------|------------|----------------------------------|
| 1.0 | 01.04.2006 | First version |

1. Product description

SACURA(http://www.iup.physik.unibremen.de/~sciapro/SACURA/SACURA_2006.html) is the semi-analytical cloud retrieval algorithm devoted to the determination of a number of cloud parameters. They are

- ❖ (1) cloud top height (1.2-16.8km);
- ❖ (2) cloud bottom height;
- ❖ (3) cloud geometrical thickness(0.8-9km);
- ❖ (4) cloud optical thickness(5-100);
- ❖ (5) droplet effective radius(4-20);
- ❖ (6) liquid water path;
- ❖ (7) cloud phase index(0.5-1.1);
- ❖ (8) reflection function at the wavelength $\lambda = 443\text{nm}$;
- ❖ (9) cloud fraction(0-1).

Retrievals are based on semi-analytical radiative transfer theory. They are valid for clouds having optical thickness larger 5.0 (see Kokhanovsky et al., 2006). No attempt is made to account for thinner clouds. The presence of snow, ice, and sun glint is not treated by SACURA. This is a matter of ongoing research.

The cloud top height, the cloud bottom height, and the cloud optical thickness are retrieved fitting SCIAMACHY spectrum in the spectral range 758-775 nm using approximate analytical radiative transfer theory results valid for optically thick clouds. The independent pixel approximation is used to determine the cloud reflectance for a broken cloud field. The cloud fraction is determined using OCRA algorithm based on PMD measurements. The phase index is determined as the ratio of reflectances R_{1550}/R_{1670} for wavelengths 1550 and 1670nm. The droplet radius and liquid water path are determined from the reflectances at 1550nm and 443nm.

2. Product format specification

Numerical data can be found at the link “raw data” on the main SACURA webpage (www.iup.physik.uni-bremen.de/scia-arc). In particular, one can find the file (please, follow links: 2005->11) 20051101_NG_L01_S00_SACURA.tgz, which contains the following information:

```

SCI_NL__1PNPDK20051101_095128_000060162042_00108_19200_5713.N1.SCIA
_cloud.out
0000600 0001754 0000144 00004607737 10332530201 024036 0
ustar sciaproc          users          0000000 0000000
# Orbit : 19200
# Product:
SCI_NL__1PNPDK20051101_095128_000060162042_00108_19200_5713.N1
# SolarId: D0
# StaSens: 01-NOV-2005 09:51:28.874036
# StaWavL: 758.20
# EndWavL: 772.60
# Channel: 4
# NumWavL: 70
# NumGPix: 6103
# NumStat: 24
# StatNPx: 84 416 416 416 208 208 208 208 208 208 208 208 208 208 208
208 208 208 416 416 416 390 13
# VarList:
# seq lac loc sza zen azi la0 lo0 la1 lo1 la2 lo2 la3 lo3 tau era lwp cpi ref ghi alb
tau cbh cth cfr rms sts all
1200 64.94 31.46 79.83 34.72 121.24 64.97 31.97 64.74 31.62 65.13 31.30 64.91
30.97 0.71117643E+02 0.1312893E+02 0.6027399E+03 0.8768120E+00
0.6642378E+00 0.14 0.41 23.07 0.20 4.49 1.00 0.2066E-01 2 1

1201 65.11 30.79 79.96 32.58 120.71 65.13 31.30 64.91 30.97 65.30 30.61 65.08
30.29 0.0000000E+00 0.4000000E+01 -0.1986677E+04 0.7961832E+00
0.7331682E+00 0.17 0.41 100.00 0.20 3.69 1.00 0.1909E-01 2 1

1240 64.68 31.08 79.56 34.72 120.92 64.71 31.58 64.49 31.25 64.88 30.92 64.65
30.60 0.2700863E+02 0.2000000E+02 0.4060848E+03 0.7687006E+00
0.5870433E+00 0.17 0.41 8.18 0.51 9.26 0.86 0.8958E-02 5 1

1241 64.85 30.41 79.69 32.58 120.39 64.88 30.92 64.65 30.60 65.05 30.23 64.82
29.92 0.6154241E+02 0.2000000E+02 0.9253129E+03 0.8057140E+00
0.6459238E+00 0.20 0.41 20.90 0.20 4.35 0.93
and so on

```

- several comment lines (starting with #) are preceding the effective data sets
- seq: Sequence number
- lac: Latitude of Ground Pixel (GP) center
- loc: Longitude of GP center
- sza: Solar Zenith Angle of GP center
- zen: Line-of-sight zenith of GP center
- azi: Azimuth of GP center
- laX/loX: Latitude of GP (lat0/lon0, 1,2,3: ne, se, nw, sw)
- tau: Optical depth from Sacura-A (SA) at $\lambda = 443nm$

- era: Effective radius (SA)
- lwp: Liquid water path (SA) (gm^{-2})
- cpi: Cloud phase index (SA)
- ref: Reflectance at 443 nm (SA)
- ghi: Ground height from Sacura-B (SB) (km)
- alb: Ground albedo (SB)
- tau: Optical depth (SB) at $\lambda = 758\text{nm}$
- cbh: Cloud bottom height (SB) (km)
- cth: Cloud top height (SB) (km)
- cfr: Cloud fraction from OCRA-IUP
- rms: Root mean square of the oxygen A- band reflectance fit error (SB)
- sts: Status/quality flag: for our processing we reject all sts values ≥ 3
- all: availability: 1: all data; 2: only sac-a products available; 4: only sac-b products available.

The meaning of flags is as follows:

0: no retrieval;

1: cloud top height constrains are not fulfilled (it is assumed in the retrieval procedure that CTH is in the range 1.2-16.8km);

2: cloud bottom height constraints are not fulfilled (it is assumed in the retrieval procedure that the cloud bottom height is equal to 200m above the surface);

3: cloud geometrical thickness constraints are not fulfilled (it is assumed in the retrieval procedure that the cloud geometrical thickness is in the range 0.8-9.0 km);

4: no convergence (the number of iterations is larger than 20);

5: retrieval has been performed without problems.

The extreme values are chosen, if the thresholds are reached.

This is the way the coordinates are arranged. Please do not mix this up with the internal Scia-data order.

```
(lat/lon 2)x ----- x(lat/lon 0)
           |           |
           |           |
(lat/lon 3)x ----- x(lat/lon 1)
```

3. Software release history

| Instrument | Version | Short description | Availability |
|------------|----------|-------------------|-------------------------------------|
| SCIAMACHY | SACURA-3 | Fast version | SACURA online from 01.01.2006 |

4. Implementation details

Back scans are not considered in the retrieval. Only data with the solar zenith angle smaller than 75 degrees are taken into account. For further details, please, see the SACURA ATBD (Kokhanovsky et al., 2006).

We have used the SCIAMACHY Processor 5.01 data (June 1st, 2004). The following calibration coefficients ζ have been applied to the measured reflectances (Kokhanovsky et al., 2006): 1.07 for the wavelength $\lambda_1=443\text{nm}$ and 1.15 for the wavelength $\lambda_2=1550\text{nm}$. So the retrievals were performed using not raw sun-normalized reflectances R but rather calibrated (by us) sun-normalized reflectances $\mathfrak{R} = \zeta R$. No additional calibration (e.g., $\zeta = 1.2$ (Acarreta and Stammes, 2005)) was applied in the oxygen A-band.

The effective radius and the liquid water path are retrieved from measurements at the wavelengths 443 and 1550nm. The cloud top and bottom heights are retrieved from measurements in the spectral range 758-775nm. All wavelengths in this range are used. The phase index is defined as the ratio of reflectances at 1550 and 1670nm.

5. List of known issues and data quality assessment

The comprehensive error analysis of SACURA products has been performed by Kokhanovsky et al. (2003) and Rozanov and Kokhanovsky (2004). The following issues must be resolved for the improvement of SACURA:

- The retrieval of cloud fraction over snow/ice must be improved.
- Clear sky pixels must be screened out for the phase index product.
- All products must be validated or inter-compared with those from MERIS and AATSR.

The estimated error of cloud top height using SACURA is +0.5km. The conclusive answer on errors for all other parameters has not been reached at the moment.

We refer to ATBD for the further description of errors and studies of the possible accuracy of the algorithm. Further validation efforts (e.g., using airborne measurements) are needed.

References

- Acarreta, J. R., and P. Stammes, 2005: Calibration comparison between SCIAMACHY and MERIS onboard ENVISAT, *IEEE Trans. Rem. Sens. Letters*, 2, 31-35.
- Kokhanovsky, A. A. et al., 2003: A semianalytical cloud retrieval algorithm using backscattered radiation in 0.4-2.4 μm spectral region, *J. Geophys. Res.*, D108, 4008, doi: 10.1029/2001JD001543.
- Kokhanovsky, A. A., V. V. Rozanov, M. Vountas, W. Lotz, H. Bovensmann, J. P. Burrows, 2006: *Semi-Analytical Cloud Retrieval Algorithm for SCIAMACHY/ENVISAT*, Algorithm Theoretical Basis Document, Bremen: Institute of Environmental Physics, 38p.
- Rozanov, V. V., and A. A. Kokhanovsky (2004): Semi-analytical cloud retrieval algorithm as applied to the cloud top altitude and the cloud geometrical thickness determination from top of atmosphere reflectance measurements in the oxygen absorption bands, *JGR*, 109, D05202, doi: 10.1029/2003JD004104.