TITLE:

Product Specification Document

FRESCO

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DOCUMENT STATUS SHEET

Issue	Date	Modified Items / Reason for Change
0.9	19.01.06	First Version
1.0	22.01.06	Update after review by A.Piters
1.1	10.08.06	Update for new versions GO-v4 and SC-v4
2.0	12.04.07	Addition of FRESCO+ by P. Wang
2.1	25.06.07	Correction of the format description
3.0	24.05.11	Description of the HDF5 output in FRESCO v6

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1.1 Product description

Clouds influence the depth of absorption lines of a trace gas in the spectrum, in particular if the trace gas concentration is high in the troposphere. For the retrieval of tropospheric trace gas columns it is therefore essential to have information on the cloud cover conditions. Both the cloud fraction and the cloud top pressure are needed as input for the trace gas retrieval algorithms. For the TEMIS project, the (effective) cloud fraction and cloud top pressure are derived with the Fast Retrieval Scheme for Cloud Observables (FRESCO) method.

The cloud top pressures and effective cloud fractions are derived from calibrated level-1 reflectivity data of the GOME or SCIAMACHY spectrum of the oxygen A-band (between 758-775 nm). Three one-nanometer wide parts of the oxygen A-band spectrum are used in the FRESCO near-real time retrieval, both inside and outside the oxygen A-band, namely at 758 nm (no absorption), 761 nm (strong absorption), and 765 nm (moderate absorption).

The reflectivity outside the oxygen A-band is almost independent of cloud top pressure, but depends mainly on cloud fraction, cloud optical thickness, and surface albedo. The reflectivities inside the band depend on cloud top pressure as well, and are used to derive cloud pressure. An effective cloud fraction and cloud pressure are derived for each GOME or SCIAMACHY pixel using non-linear least-squares fitting of a measured spectrum to a simulated spectrum.

The effective cloud fractions are derived by assuming that the clouds have an albedo of 0.8, and must therefore be interpreted as effective cloud fractions. Note that the derived cloud top pressures are rather insensitive to the assumed cloud albedo.

FRESCO+ is an improved version of FRESCO, which includes single Rayleigh scattering in the forward model. The FRESCO+ cloud pressure for the pixels with small cloud fraction (say less than 0.15) is more reliable than the FRESCO cloud pressure.

Details on the algorithm can be found in the algorithm document TEM/AD2/001

1.2 Product format specification

The FRESCO and FRESCO+ data files are in ASCII format, where the data for each groundpixel is given on a single line. The file start with a header line containing the algorithm version and the version of the level 1 data. On each following line the following output parameters can be found :

FRESCO

date,time,pixid,lat1,lat2,lat3,lat4,clat,lon1,lon2,lon3,lon4,clon,esm,th0,cc,zc,ac,asavg,zs,chisq,flag,pc,ps

(with FORTRAN format: 'a8,a11,i2,4f8.3,f9.4,4f9.3,f10.4,2f8.3,5f8.4,e10.3,i2,2f9.3')

The meaning of the parameters can be found in Table 1A.

Table 1A: FRESCO OUTPUT PARAMETERS

PARAMETER	TYPE	RANGE	DESCRIPTION
date	char*8		year/month/day (yyyymmdd) e.g. 19980831 for 31 Aug. 1998
time	char*10		hour/minutes/seconds (HHMMSS.SSS)
pixid	integer	[0,1,2,3]	pixel type
lat1	real	[-90 - 90]	latitude of corner 1 [degree]
lat2	real	[-90 - 90]	latitude of corner 2 [degree]
lat3	real	[-90 - 90]	latitude of corner 3 [degree]
lat4	real	[-90 - 90]	latitude of corner 4 [degree]
clat	real	[-90 - 90]	latitude of pixel center [degree]
lon1	real	[0 - 360]	longitude of corner 1 [degree]
lon2	real	[0 - 360]	longitude of corner 2 [degree]
lon3	real	[0 - 360]	longitude of corner 3 [degree]
lon4	real	[0 - 360]	longitude of corner 4 [degree]
clon	real	[0 - 360]	Longitude of pixel center [degree]
esm	real	[-90,90]	viewing zenith angle relative to zero mirror position [degree]
xth0	real	[0,180]	solar zenith angle at top-of-atmosphere [degree]
cc	real	[0 – 1]	effective cloud fraction
zc	real	[0 – 15]	cloud height [km]
ac	real	[0 – 1]	cloud albedo
asavg	real	[0 – 1]	wavelength averaged assumed albedo
zs	real	[0 – 8]	surface height [km]
chisq	real		chi square fit error
flag	integer	0/1/2/3/4/5	error flag (see Table 2)
pc	real	[0 - 1050]	cloud pressure [hPa]
ps	real	[0 - 1050]	assumed surface pressure [hPa] within FRESCO

FRESCO+

date,time,pixid,lat1,lat2,lat3,lat4,clat,lon1,lon2,lon3,lon4,clon,esm,th0,xdphi,cc,dcc,zc,ac,dac,asavg, zs,chisq,flag,pc,dpc,ps

(with FORTRAN format: ' (a8,a11,i2,4f8.3,f9.4,4f9.3,f10.4,3f8.3,7f8.4,e10.3,i2,3f9.3)')

The meaning of the parameters can be found in Table 1B.

Table 1B: FRESCO+ OUTPUT PARAMETERS

PARAMETER	TYPE	RANGE	DESCRIPTION
date	char*8		year/month/day (yyyymmdd) e.g. 19980831 for 31 Aug. 1998
time	char*10		hour/minutes/seconds (HHMMSS.SSS)
pixid	integer	[0,1,2,3]	pixel type
lat1	real	[-90 - 90]	latitude of corner 1 [degree]
lat2	real	[-90 - 90]	latitude of corner 2 [degree]
lat3	real	[-90 - 90]	latitude of corner 3 [degree]
lat4	real	[-90 - 90]	latitude of corner 4 [degree]
clat	real	[-90 - 90]	latitude of pixel center [degree]
lon1	real	[0 - 360]	longitude of corner 1 [degree]
lon2	real	[0 - 360]	longitude of corner 2 [degree]
lon3	real	[0 - 360]	longitude of corner 3 [degree]
lon4	real	[0 - 360]	longitude of corner 4 [degree]
clon	real	[0 - 360]	longitude of pixel center [degree]
esm	real	[-90,90]	viewing zenith angle relative to zero mirror position [degree]
xth0	real	[0,180]	solar zenith angle at the surface [degree]
xdphi	real	[0,180]	relative azimuth angle between the sun and line of sight [deg.]
cc	real	[0 – 1]	effective cloud fraction
dcc	real	[0 – 1]	error of effective cloud fraction (absolute error)
zc	real	[0 – 15]	cloud height [km]
ac	real	[0 – 1]	cloud albedo
dac	real	[0 – 1]	error on the cloud albedo
asavg	real	[0 – 1]	wavelength averaged surface albedo
zs	real	[0 – 8]	surface height [km]
chisq	real	[0 – 15]	chi square fit error
flag	integer	0/1/2/3/4/5	error flag (see Table 2)
pc	real	[0 - 1050]	cloud pressure [hPa]
dpc	real	[0 - 1050]	error of cloud pressure (absolute error) [hPa]
ps	real	[0 - 1050]	assumed surface pressure [hPa] within FRESCO

Table 2: FRESCO ERROR-FLAGS

flag	description
0	default mode, fitting of cloud cover fraction and cloud-top pressure
1	snow/ice mode, fitting of surface albedo and surface-top pressure
2	FRESCO failure, input reflectivity out of range (>1.5)
3	FRESCO warning, viewing angle out of range (>30.º)
4	FRESCO failure, solar zenith angle out of range (>89.5º)
5	FRESCO failure, missing data
10-15	Flag 0 - 5 with the possibility of sun glint contamination according to the geometry

Table 3:. FRESCO v6 HDF5 file OUTPUT PARAMETERS

GROUP	PARAMETER	TYPE	RANGE	DESCRIPTION
GEOLOCATION	DayOfYear	integer	1-366	Day of year
	IndexInScan	integer	[0,1,2,3]	pixel type
	IntegrationTime	real	-	Second
	Time	char*10	-	UTC time hour/minutes/seconds (HHMMSS.SSS)
	StateId	integer	-	State number for SCIAMACHY
	LatitudeCenter	real	[-90 - 90]	latitude of pixel center [degree]
	LatitudeCorner_A	real	[-90 - 90]	latitude of corner 1 [degree]
	LatitudeCorner_B	real	[-90 - 90]	latitude of corner 2 [degree]
	LatitudeCorner_C	real	[-90 - 90]	latitude of corner 3 [degree]
	LatitudeCorner_D	real	[-90 - 90]	latitude of corner 4 [degree]
	LongitudeCenter	real	[0 - 360]	longitude of pixel center [degree]
	LongitudeCorner_A	real	[0 - 360]	longitude of corner 1 [degree]
	LongitudeCorner_B	real	[0 - 360]	longitude of corner 2 [degree]
	LongitudeCorner_C	real	[0 - 360]	longitude of corner 3 [degree]
	LongitudeCorner_D	real	[0 - 360]	longitude of corner 4 [degree]
	LineOfSightAzimuthAngle	real	[0 - 360]	line of sight azimuth angle at the surface [degree]
	LineOfSightZenithAngle	real	[-90 - 90]	viewing zenith angle relative to zero mirror position at the surface [degree]
	SolarAzimuthAngle	real	[0 - 360]	solar azimuth angle at the surface [degree]
	SolarZenithAngle	real	[0 - 180]	solar zenith angle at the surface [degree]
	RelAzimuthAngle	real	[0 - 180]	relative azimuth angle between the sun and line of sight [degree]
	ScatteringAngle	real	[0 - 360]	scattering angle [degree]
	SunglintAngle	real	[0 - 360]	sun glint angle [degree]
	SatelliteAltitude	real	-	satellite altitude [km]
	NElements	integer	-	Not used for SCIAMACHY, is set to 1.
	NrOfPixelsInScan	integer	-	Number of pixels in one scan, is set to 1 for SCIAMACHY.
DATA	CloudFraction	real	[0 – 1]	effective cloud fraction
	CloudFractionErr	real	[0 – 1]	error of effective cloud fraction (absolute error)
	CloudHeight	real	[0 – 15]	cloud height [km]
	CloudAlbedo	real	[0 – 1]	cloud albedo
	CloudAlbedoErr	real	[0 – 1]	error on the cloud albedo
	SurfaceAlbedo	real	[0 – 1]	wavelength averaged surface albedo
	SurfaceHeight	real	[0 – 8]	surface height [km]
	ChiSquared	real	[0 – 15]	chi square fit error
	FRESCOFlag	integer	0/1/2/3/4/5/10/11	error flag (see Table 2)
	CloudPressure	real	[0 - 1050]	cloud pressure [hPa]

	CloudPressureErr	real	[0 - 1050]	error of cloud pressure (absolute error) [hPa]
	MeasReflectance	real	[0 – 1.5]	measured reflectances at 15 wave-lengths for FRESCO retrievals and 5 wavelengths at 772-773 nm.
	MeasReflectanceErr	real	[0 – 1.5]	error of measured reflectance
	SimuReflectance	real	[0 – 1.5]	FRESCO simulated reflectance
	WavelGrid	real	[758-773]	wavelength grids for the measured the simulated reflectance [nm]
	Niter	real	[0 – 5]	number of iterations for FRESCO retrievals with cloud albedo of 0.8
	WarningFlag	real	0/1	warning flag about convergence for standard FRESCO retrievals, 1: converge, 0: may not converge
	FSI_ChiSquared	real	[0 – 15]	chi square fit error for FSI run
	FSI_CloudAlbedo	real	[0 – 1]	scene (cloud) albedo
	FSI_CloudAlbedoErr	real	[0 – 1]	error on the scene (cloud) albedo for FSI run
	FSI_CloudHeight	real	[0 – 15]	scene (cloud) height for FSI run [km]
	FSI_CloudPressure	real	[0 - 1050]	scene (cloud) pressure for FSI run [hPa]
	FSI_CloudPressureErr	real	[0 - 1050]	error of scene (cloud) pressure (ab-solute error) for FSI run [hPa]
	FSI_Niter	real	[0 – 5]	number of iterations for FSI run
	FSI_WarningFlag	real	0/1	warning flag about convergence for FSI run, 1: converge, 0: may not converge
	SSI_ChiSquared	real	[0 – 15]	chi square fit error for FRESCO SSI run with cloud albedo of 0.95
	SSI_CloudAlbedo	real	[0 – 1]	cloud albedo for SSI run
	SSI_CloudAlbedoErr	real	[0 – 1]	error of the cloud albedo for SSI run
	SSI_CloudFraction	real	[-0.05 – 1.2]	effective cloud fraction for SSI run
	SSI_CloudFractionErr	real	[0 – 1.0]	error of effective cloud fraction (absolute error) for SSI run
	SSI_CloudHeight	real	[0 – 15]	cloud height for SSI run [km]
	SSI_CloudPressure	real	[0 - 1050]	cloud pressure for SSI run [hPa]
	SSI_CloudPressureErr	real	[0 - 1050]	error of cloud pressure for SSI run [hPa]
	SSI_Niter	real	[0 – 5]	number of iterations for SSI run
	SSI_WarningFlag	real	0/1	warning flag about convergence for SSI run, 1: converge, 0: may not converge
	SSI_CloudIndex	real	[0 – 1.2]	cloud index
	SSI_ClearSkyIndex	real	[0 – 1.2]	clear-sky index
	SSI_AerosolOpticalThickness	real	[0 - 100]	aerosol optical thickness used in SSI calculations
	SSI_WaterVaporColumn	real	[0 – 10]	Water vapour column used in SSI calculations [cm]
	SSI_BroadBandSurfaceAlbedo	real	[0 - 1]	broadband surface albedo used in

				SSI calculations
	SSI_FullSkySurfaceSolarIrradBeam	real	[0 - 1500]	Full-sky direct solar irradiance at the surface [W/m^2]
	SSI_FullSkySurfaceSolarIrradGlobal	real	[0 - 1500]	Full-sky global solar irradiance at the surface [W/m^2]
	SSI_ClearSkySurfaceSolarIrradBeam	real	[0 – 1500]	clear-sky direct solar irradiance at the surface [W/m^2]
	SSI_ClearSkySurfaceSolarIrradGlobal	real	[0 – 1500]	clear-sky global solar irradiance at the surface [W/m^2]

FRESCO v6 ASCII file has the same format as FRESCO+, see Table 2.

FRESCO v6 HDF5 file includes 3 FRESCO runs, 1) the standard FRESCO run with fixed cloud albedo of 0.8 for non-snow/ice pixels and fixed cloud fraction of 1 for snow/ice pixels; 2) the forced snow/ice run with fixed cloud fraction of 1 for all pixels; 3) similar to 1) but cloud albedo is assumed to be 0.95, called SSI run. These effective cloud fraction values are used to calculate broadband surface solar irradiances. In Table 3, the outputs for the force snow/ice runs are named as FSI_XXX. The outputs for the SSI run and the data related to SSI calculations are named as SSI_XXX.

1.3 Software release history

Instrument*	Version	Short description	Availability
GOME :	GO-v1	fixed albedo's	NL-SCIA-DC
	GO-v2	LER albedo's	various isolated data sets (not supported by KNMI)
	GO-v3	LER albedo's, GomeCal used for level 1b correction	was available via TEMIS till 23.06.06
	GO-v4	**1. Improved resolution of surface albedo at coastlines:** 0.25°x0.25° (*Fournier et al.*, ACP, 2006) **2. Improvement of surface albedo over deserts:** Correction of GOME surface albedo over deserts, which was too low due to absorbing aerosols, using the GOME AAI (*Fournier et al.*, ACP, 2006) **3. Level 1 version update** For the extraction of the level 1 data the GDP2.4 extractor was used. **4. New RTM calculations** The RTM calculations are based on the HITRAN 2004 database and calculated	TEMIS

		on a shifted wavelength grid (by P.Wang)	
	GO-v5	FRESCO+, new RTM (incl. single Rayleigh scattering) calculations (by P.Wang)	TEMIS
	GO-v6	MERIS albedos and hitran2008 used	
SCIAMACHY :	SC-v2	LER albedo's , a calibration correction of 1.25 for the O2 A-band is used.	Formerly on TEMIS
	SC-v3	**1. Reflectance calibration correction** Following *Acarreta et al.* (2005) and *Tilstra et al.* (2005) through a comparison between SCIAMACHY and MERIS/GOME/POLDER, a calibration correction of 1.20 for the O2 A-band is used. **2. Improved resolution of surface albedo at coastlines:** 0.25°x0.25° (*Fournier et al.*, ACP, 2006) **3. Improvement of surface albedo over deserts:** Correction of GOME surface albedo over deserts, which was too low due to absorbing aerosols, using the GOME AAI (*Fournier et al.*, ACP, 2006)	TEMIS till 4-8-2006
	SC-v4	**1. New RTM calculations** The RTM calculations are based on the HITRAN 2004 database and calculated on a shifted wavelength grid (by P.Wang)	TEMIS from 4-8-2006
	SC-v5	FRESCO+, new RTM (incl. single Rayleigh scattering) calculations (by P.Wang)	TEMIS
	SC-v6	MERIS albedos and hitran2008 used In addition to standard FRESCO product in ASCII file, FRESCO output for forced snow/ice mode, FRESCO output with fixed cloud albedo of 0.95 and	

		broadband surface solar irradiances are provided in HDF5 format.	
GOME-2 :	G2-v2	LER albedo's	within L1b-product
		MERIS albedos and hitran2008 used	

* Each version for a different instrument has another transmission database because of differences in slit function.

1.4 Implementation details

See the FRESCO algorithm document TEM/AD2/001

1.5 List of known issues and data quality assessment

List of known issues:

- For areas with effective cloud fractions smaller than 0.15, cloud pressures cannot be derived reliably. In the cloud-top pressure images these pixels are not plotted. This is not a problem for FRESCO+.
- No attempt is made to account for the presence of snow, ice, or sun-glint. Thus if cloud-free land or ocean is covered by snow or ice shelves, or if a pixel is affected by sun-glint, these areas will show up as having low-altitude clouds with high cloud coverage. If snow or ice is suspected a flag is set and an effective surface/cloud-top height is determined.
- The versions of FRESCO not based on the corrected LER albedo's may have too high cloud fractions over the Sahara and other desert regions.

For detailed validation results, see the FRESCO algorithm document TEM/AD2/001. In summary the following is concluded:

- After the correction of FRESCO for desert surfaces (*Fournier et al.*, ACP, 2006), it appears that the accuracy of the effective cloud fraction from FRESCO is now better than 0.05 for all surfaces, excluding snow and ice surfaces.
- FRESCO compares very well with ISCCP regarding global average effective cloud fraction (< 0.02 difference) and well regarding cloud pressure (about +50-80 hPa difference).

Data quality of FRESCO surface solar irradiance (SSI) products

- FRESCO surface solar irradiances are derived from the FRESCO effective cloud fraction retrieved with the assumption of cloud albedo of 0.95. The validation results are given by Wang et al., (2011).

- The SCIAMACHY SSI data set was evaluated against the global irradiances from the Baseline Surface Radiation Network (BSRN) and the ISCCP-FD fluxes data sets. The instantaneous SCIAMACHY SSI data were validated using the BSRN hourly mean global irradiances for one year of data in 2008 at 20 BSRN stations. The mean difference between SCIAMACHY SSI and BSRN global irradiances is -4.1 Wm^{-2} (-0.8%) and the RMSD is 101 Wm^{-2} (20%) for all the stations. The correlation coefficient is 0.93 for 1006 collocated data points.

- For areas above 4000 m the SCIAMACHY SSI can be too low, because the surface height is not included in the SSI algorithm. The water vapour and aerosol data are taken from the monthly climatological data, which can be different from the instantaneous values.