Product Quality README file for GOME
Total Column Water Vapor (TCWV) Climate product

Field	*Content*
Document Title	Product Quality README file for GOME Total Column Water Vapor (TCWV) Climate product
Reference	ESA-EOPG-MOM-TN-16, issue 1.0, 12 April 2018
Abstract	A time-series of the global distribution of Total Column Water Vapor (TCWV) over more than two decades, based on measurements in the red spectral range from the satellite instruments ERS-2 GOME, Envisat SCIAMACHY, and MetOp-A GOME-2 is presented. Particular focus is the data set consistency amongst the different sensors to avoid jumps in the measurement records. This is reached by applying robust and simple retrieval settings consistently. Potentially systematic effects due to differences in ground pixel size are avoided by merging SCIAMACHY and GOME-2 observations to GOME spatial resolution, which also allows for a consistent treatment of cloud effects. In addition, the GOME-2 swath is reduced to that of GOME and SCIAMACHY to have consistent viewing geometries. Remaining systematic differences between the different sensors are investigated during overlap periods and are corrected for in the homogenized time-series. The resulting Climate product version 2.2 allows studying the temporal evolution of water vapor over the last 20 years on global scale.
Applicability	This README file applies to version 2.2 of the GOME Total Column Water Vapor (TCWV) Climate product
Reference Documents	[RD1] Beirle, Steffen; Lampel, Johannes; Wang, Yang; Wagner, Thomas; Grossi, Margherita; Loyola, Diego (2018). The GOME-Evolution total column water vapor "climate" product (Version 2.2). World Data Center for Climate (WDCC) at DKRZ. https://doi.org/10.1594/WDCC/GOME-EVL_water_vapor_clim_v2.2 [RD2] Beirle, S., Lampel, J., Wang, Y., Mies, K., Dörner, S., Grossi, M., Loyola, D., Dehn, A., Danielczok, A., Schröder, M., and Wagner, T.: The ESA GOME-Evolution “Climate” water vapor product: a homogenized time series of H2O columns from GOME, SCIAMACHY, and GOME-2, Earth Syst. Sci. Data, 10, 449-468, https://doi.org/10.5194/essd-10-449-2018, 2018. [RD3] Danielczok, A. and Schröder, M.: GOME Evolution "Climate" product validation report, version 2, 2017. [RD4] Grossi, M., Valks, P., Loyola, D., Aberle, B., Slijkhuis, S., Wagner, T., Beirle, S., and Lang, R.: Total column water vapour measurements from GOME-2 MetOp-A and MetOp-B, Atmos. Meas. Tech., 8, 1111–1133, 2015. [RD5] Wagner, T. and Mies, K.: Support to H2O column retrieval algorithms for GOME-2, O3M-SAF Visiting Scientist Final Report, available at: http://o3msaf.fmi.fi/docs/vs/2011/Wagner_final_report.pdf, 2011.

Change log

The table below records history and status of this Product Quality Readme file.

Issue	Date	Change
1.0	12 April 2018	First release for TCWV version 2.2

Content

Algorithm short summary

Spectral retrieval
Slant column densities (SCDs) of H_2O and O_2 are derived by Differential Optical Absorption Spectroscopy (DOAS) technique in the spectral range between 614 and 683 nm. Details can be found in [RD5].

Spatial downsampling
In order to reach consistent time-series across instruments, the SCDs derived from SCIAMACHY and GOME-2 are downsampled to GOME ground pixel size (320 km x 40 km).
For SCIAMACHY (16 pixels with 60 km across track), 5 Eastern, 6 centre, and 5 Western pixels are merged (or 10/12/10 for 30 km pixels with reduced integration time). For GOME-2 (80 km across track), four pixels are merged into one pixel, matching the GOME ground pixel extent (or eight pixels for 40 km wide pixels in "tandem operation" with MetOp-B). Allocation of the pixels to be merged is done based on scan angles.
By this procedure, also the GOME-2 swath is reduced to that of GOME and SCIAMACHY.
Instead of spectral co-adding of the spectra of the respective satellite ground pixels, the downsampled SCD can be determined as mean of the individual SCDs weighted by the respective radiance averaged within the fit interval.

Processing of TCWV
Vertical column densities (VCDs), i.e. TCWV, are derived by a rather simple, but robust algorithm. The aim is not to derive most accurate TCWV at a given time/place, but to have consistent retrievals (including cloud treatment) across different instruments.

	The procedure follows the steps summarized in [RD4]: - H_2O and O_2 SCDs are saturation corrected. - VCDs are derived applying O_2 Air-Mass-Factors (AMFs). - Correction factors as function of solar zenith angle (SZA) and ground albedo are applied to account for the different vertical profiles of O_2 and H_2O. - For the Climate product, however, no line of sight (LOS) correction is applied, because of the reduced swath of the Climate product and the nontrivial scan angle dependencies of both O_2 (affecting the cloud masking) and H_2O columns. - Pixels with O_2 SCDs less than 80% of the maximum O_2 (at given SZA) are masked as cloudy. The maximum O_2 as function of SZA is determined for each instrument over the Pacific. - Daily and monthly mean maps of TCWV based on observations passing the O_2 threshold are calculated on a 1°x1° grid. **Merged time-series - Offset correction** The spatial down sampling of SCIAMACHY and GOME-2 observations significantly improves the consistency to GOME. Remaining systematic offsets between the instruments, which might be due to instrumental differences (spectral resolution, polarisation sensitivity, remaining pixel size differences) or the different local overpass times, are estimated during overlap periods and corrected for in the Climate product. The Climate product thus provides a single time-series covering the period July 1995 until December 2015. **Data set description** The data is provided as time-series of global maps of monthly mean TCWV in one netCDF-4 file. <u>Dimensions</u>: - time: months since 1995, with 1 meaning January 1995. - lat: center latitude of 1° grid pixels. - lon: center longitude of 1° grid pixels. The period from July 1995 to December 2015 is covered. <u>Data fields</u>: - TCWV(time, lat, lon): For each month, global maps of TCWV are provided with 1° resolution based on the (offset corrected) monthly means from GOME, SCIAMACHY, and GOME-2. - TCWV_smooth_ocean(time, lat, lon): additional spatial smoothing of monthly means is applied over ocean. - std_TCWV(time, lat, lon): monthly standard deviation of TCWV per grid pixel. Unit is kg/m2.

	- cnt(time, lat, lon): the number of daily measurements per pixel per month. Addons (where xy = GOME1/SCIA/GOME2): - contribution_from_xy(time): flag indicating to which months the respective instrument is contributing. - mean_scan_angle_xy(lat, lon): maps providing the mean scan angle. - warning_flag_TCWV(lat, lon): indicates large positive/negative mean scan angles for at least one instrument. These grid pixels should be skipped if TCWV is considered. - warning_flag_TCWV_smooth_ocean(lat, lon): indicates large positive/negative mean scan angles over land for at least one instrument. These grid pixels should be skipped if TCWV_smooth_ocean is considered. - warning_flag_convolution(lat, lon): indicates areas where TCWV_smooth_ocean is probably biased due to convolution. Should be skipped if absolute TCWV is considered, but can be ignored if trends are investigated. ocean_flag(lat, lon): ocean flag on 1° resolution. **Known issues** The Climate product is optimized for consistent time-series across different satellite instruments. It is thus based on a simple retrieval, merged pixels, and reduced swath of GOME-2, at the cost of algorithm accuracy, spatial resolution, and spatial coverage. This is described in more detail below. **Spatial resolution** GOME has a coarse across-track resolution of 320 km. For the Climate product, SCIAMACHY and GOME-2 observations are also merged to the GOME resolution. Thus, gradients in TCWV or in quantities affecting the AMF (like surface albedo, terrain height, or clouds) are not resolved but smeared out in the Climate product. Systematic biases of the Climate product TCWV are thus expected, e.g., for coastal sites, and in particular for mountainous islands. **Spatio-temporal sampling** Satellite measurements from low Earth orbits provide global coverage, but only a limited number of observations at a given location. For the calculation of "monthly means", spatiotemporal sampling is thus an important aspect. The Climate product is based on satellite measurements performed around 10:00 local time. The GOME swath width of 960 km corresponds to global cover within three days, i.e., at low latitudes, about 10 overpasses are available per month. The masking of cloudy

	measurements further reduces the number of days where TCWV measurements are available. Thus, the "monthly mean" within a 1°x1° grid pixel is often determined from less than five snapshots on different days. Note that grid pixels with less than two available days are discarded, resulting in gaps in the Climate product monthly means. This regularly happens, mostly around the Inter Tropical Convergence Zone (ITCZ), in particular for SCIAMACHY due to the poorer spatial coverage resulting from the alternating nadir-limb mode. The simple cloud flagging based on O_2 SCDs also discards observations over high mountains, resulting in persistent gaps in the Climate product over the Himalayas, the Andes, or Antarctica. An additional gap is introduced by GOME calibration measurements, which are regularly performed north of India. The standard deviation and standard error reflect the statistical variability of water vapor and the precision of the monthly mean TCWV product. In addition, systematic effects (like the fixed local time of the measurements or the selection of cloud-free observations) have to be kept in mind when interpreting the Climate data product. **Validation** The validation and verification of the Climate product has been done by DWD Offenbach, see [RD3]. Temporal stability has been found to be about <1 % per decade.
Inputs	MPIC (Max Planck Institute for Chemistry, Mainz) DLR (German Aerospace Center, Oberpfaffenhofen)
Prepared	Steffen Beirle (Steffen.Beirle@mpic.de)
Approved	Diego Loyola (Diego.Loyola@dlr.de)
Released	Angelika Dehn (Angelika.Dehn@esa.int)