PRODUCT USER MANUAL

Global 1-day UV Index Forecast

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DOCUMENT STATUS SHEET

Issue	**Date**	**Modified Items / Reason for Change**
1.0	02.05.2007	1st version
1.1	10.10.2007	Revised according to ORRA RID
1.2	27.03.2008	Minor changes.
1.3	21.11.2008	Updated sections 1 and 4. NUV version number added to section
1.4	02.06.2010	Introduction to EUM SAF page included Section 3 updated
1.5	17.02.2012	Version for ORR of NUV/CLOUD
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1.7	27.05.2013	Version for Metop-B ORR Minor changes in Sect. 2 and 3
1.8	31.03.2020	1st version for Metop-C ORR GOME-2 ATO from Metop_C included along with Metop-A and Metop-B
1.9	30.05.2020	Final version for Metop-C ORR
1.10	31.01.2022	The three layer, 1h, cloud correction algorithm.
1.11	22.08.2023	Revised according to RR
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Internal product ID's for project control

Global UV index	MxG-NUV	O3M-410.1

Introduction to EUMETSAT Satellite Application Facility on Atmospheric Composition monitoring (AC SAF)

Background

The monitoring of atmospheric chemistry is essential due to several human caused changes in the atmosphere, like global warming, loss of stratospheric ozone, increasing UV radiation, and pollution. Furthermore, the monitoring is used to react to the threats caused by the natural hazards as well as follow the effects of the international protocols.

Therefore, monitoring the chemical composition and radiation of the atmosphere is a very important duty for EUMETSAT and the target is to provide information for policy makers, scientists and general public.

Objectives

The main objectives of the AC SAF is to process, archive, validate and disseminate atmospheric composition products (O_3, NO_2, SO_2, BrO, HCHO, H_2O, OClO, CO, NH3), aerosol products and surface ultraviolet radiation products utilising the satellites of EUMETSAT. The majority of the AC SAF products are based on data from the GOME-2 and IASI instruments onboard Metop satellites.

Another important task besides the near real-time (NRT) and offline data dissemination is the provision of long-term, high-quality atmospheric composition products resulting from reprocessing activities.

Product catsegories, timeliness and dissemination

NRT products are available in less than three hours after measurement. These products are disseminated via EUMETCast, WMO GTS or internet.

- Near real-time trace gas columns (total and tropospheric O_3 and NO_2, total SO_2, total HCHO, CO) and high-resolution ozone profiles
- Near real-time absorbing aerosol height and absorbing aerosol index from polarization measurement detectors
- Near real-time UV indexes, clear-sky and cloud-corrected

Offline products are available within two weeks after measurement and disseminated via dedicated AC SAF web services.

- Offline trace gas columns (total and tropospheric O_3 and NO_2, total SO_2, total BrO, total HCHO, total H_2O) and high-resolution ozone profiles
- Offline absorbing aerosol height and absorbing aerosol index from polarization measurement detectors
- Offline surface UV, daily doses and daily maximum values with several weighting functions

Data records are available after reprocessing activities from the AC SAF archives.

- Data records generated in reprocessing
- Lambertian-equivalent reflectivity
- Total OClO

Users can access the AC SAF offline products and data records (free of charge) by registering at the AC SAF web site.

More information about the AC SAF project, products and services: https://acsaf.org/

AC SAF Helpdesk: helpdesk@acsaf.org

Twitter: https://twitter.com/Atmospheric_SAF

1 INTRODUCTION

1.1 Purpose and scope

This document is the user manual of the Global UV index (NUV) products. It includes the product format description while the algorithm is described in a separate Algorithm Theoretical Basis Document.

1.2 References

1.2.1 Applicable documents

AC SAF Algorithm Theoretical Basis Document for NUV, SAF/ACSAF /DMI/ATBD/001, Issue 1.13 07.02.2025

AC SAF Validation Report NUV, SAF/AC/DMI/V&V/RP/001, Issue 6.3, 07.02.2025

1.2.2 References documents

WMO, Report of the meeting of experts on UV-B measurements, data quality and standardization of UV-indices. Global Atmospheric Watch report no. 95, 1994

CIE (International Commission on illumination): RATIONALIZING NOMENCLATURE FOR UV DOSES AND EFFECTS ON HUMANS, Technical Report, Joint publication of CIE and WMO, CIE 209:2014, WMO/GAW Report No. 211, 2014.

1.2.3 Acronyms

FMI	Danish Meteorological Institute
ATO	Assimilate Total Ozone
ECMWF	European Centre for Medium-Range Weather Forecasts
ATBD	Algorithm Theoretical Basis Document

2 PRODUCT OVERVIEW

The AC SAF Global UV product consists of two parts. First the UV index for clear sky conditions (NUV/CLEAR) is calculated and secondly a correction for the expected cloud cover is applied to produce the final all sky product.

The UV clear sky index is derived from the near real time GOME-2 assimilated total ozone (ATO) as the only dynamical input, the ATO is valid for LT 12h globally. Assuming the daily variation of ozone to be modest the 1h NUV/CLEAR values are calculated using the ATO input. Climatological parameters are used for all other atmospheric input data as well as surface albedo. In the case that ATO is either not available at the time of processing (02:00 UT) or the ATO is corrupted, the NUV processor choose to use ECMWF assimilated total ozone instead. If this input data is not available calculations will be based upon a total ozone climatology. The type of input ozone date is clearly marked in the product.

The cloud cover corrected UV fields are produced from the NUV/CLEAR using the ECMWF (most recent IFS version, at time of publication of this document IFS Cyrcle49.1) fractional cloud cover forecast for clouds at three altitude levels, 0-2 km, 2-6 km and above 6 km. The cloud cover fractions are collected on a time step of 1h and NUV all sky is calculated for each hour.

The UV fields are calculated in the same grid size as the input ATO field, with a sub-pixel altitude correction resolution of 0.25° x 0.25°. The output of the processor is thus on a 24x1440x720 (time,long,lat) grid, where the time parameter is the local solar time meaning that 12h corresponds to minimum solar zenith angle and thus maximum clear sky UV index.

The results are updated to the NUV webpage as global and regional maps and the recent data available from the web site as NetCDF4 files. On request the data can be delivered in alternative formats just as regional subset of the full grid can be available and delivered in formats customized for individual users.

At present ATO from GOME-2 instruments on board both the Metop-B and Metop-C satellites are available. NUV is produced operationally for both instruments, the product output will contain information on which instrument has been used

The QA page on the NUV site contains information on the comparison between the two (B and C) NUV products.

The formal accuracy of the derived UV index is calculated using the ATO error field as input and assumed accuracy for all other parameters.

Note on the use of NUV products for the public.

The Global UV index was previously named Near Real Time UV index, thus the acronym NUV. The name was somewhat misleading, since the product is a forecast and the name changed accordingly.

When using the NUV product it must be noticed, that although the cloud cover corrected product is rather accurate, as can be seen in the Validation Report, there will occasionally be situations where the cloud cover forecast is not accurate. One consequence is that there will be days where the actual UV-index at a given location exceeds the UV-index predicted by the NUV all sky product. Thus NUV users, especially those using the product for UV-index warnings to the public, are strongly urged to not only communicate the all sky product but also the NUV/CLEAR product as the maximum available UV-index.

Furthermore, it must be noted that under certain conditions of cloud cover (e.g. scattered white cumulus cloud) the actual UV-index can be higher than even the clear sky index, because of high reflectivity of the clouds. This situation normally only last for a short period, less than 10 minutes.

2.1 Processing and dissemination

ATO is produced at KNMI and delivered to DMI each night and the NUV processor is started at DMI at 03:10. The NUV product is ready for dissemination no later than 04:00 UT and can be distributed to end users via ftp or e-mail, and to the NUV web page (http://nuv.dmi.dk). The ftp and e-mail service can be ordered directly via the NUV web page or the AC SAF page http://acsaf.org

NetCDF-4 files can also be downloaded from the NUV web-page.

At request the output can be customized for special user requirements and individual arrangements for the delivery method can be established. Contact information is found on the NUV web page.

3 PRODUCT FILE FORMAT

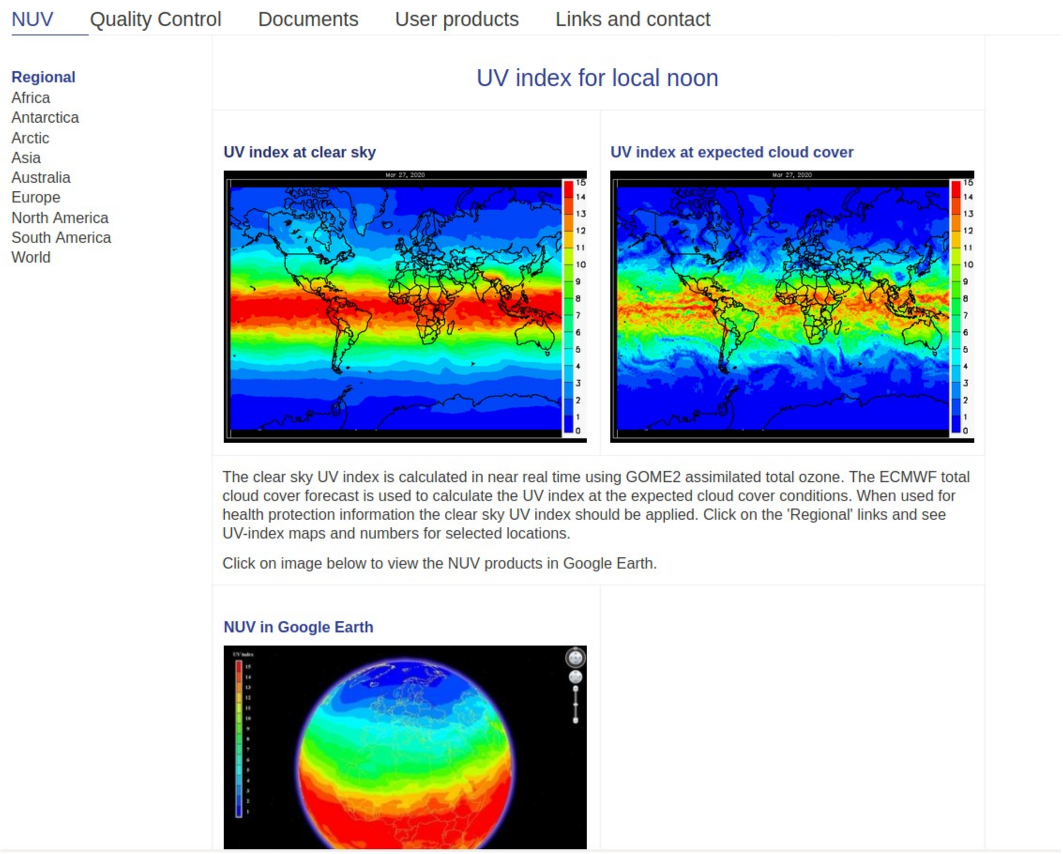
3.1 The NUV web page

The daily output of the NRT UVI processor presented at the NUV web page (http://nuv.dmi.dk) consists of a number of contour maps of UV-index for pre-selected locations, two files containing additional information and a “standard” HTML-page for quick access to the maps and files. On-line quality control data is also presented daily. Furthermore, the NUV can be viewed in Google Earth from the NUV web page.

- The maps are saved as PNG (Portable Network Graphics) files. The maps are named after their centre location and date of production.
- The global UV map is also produced in kml format for access via Google Earth.
- The ASCII file “Errors.txt” contains estimated accuracies of the maps. For each map the average, minimum and maximum error of the UV-index are listed. The input errors/accuracies of the various parameters are listed at the end of the file.
- The HTML file “INFO.html” contains a short general information on UV-index and the NUV processor.
- A link to the NetCDF-4 files

As mentioned in section 2.1 users may request the full daily output, parts of it or customized maps and list of locations etc. These special requests are delivered to end users either directly or via the web page.

The NUV home page on http://nuv.dmi.dk



Example of the content of the 'Error.txt' file

UVI maps produced at Mon Mar 12 04:07:14 2012
Based on assimilated GOME (Metop-B) input for 20120312 at UT=12:00
Internal precisions calculated on the basis of the GOME input error field

```
AVERAGE INTERNAL PRECISION OF THE UVI-FIELDS

MAP      AVERAGE ERROR  ERROR IN %   AVERAGE UVI
------------------------------------------------------
Europe       0.21       6.79       3.11
Africa       0.77       6.57      11.81
Asia       0.46       6.52       6.91
Australia       0.74       6.35      11.71
North-America       0.36       6.73       5.38
South-America       0.75       6.41      11.69
Antarctica       0.05       6.62       0.80
Arctica       0.01       5.94       0.13
World      0.466      6.508      7.102
------------------------------------------------------
Calculated on the basis of the following input errors:
SZA:         0.017 [deg]
Albedo:         0.050
Dayofyear:         0.000 [days]
AOD:         0.100
Altitude:         0.100 [m]
Average Ozone error:         9.121 DU
```

3.2 The NetCDF4 files

The output files uvallsky1h_[yyyymmdd].nc and uvclear1h_[yyyymmdd].nc contains the all sky and clear sky results for the specific date and will be available from the NUV web page. The results are on a global grid and stored in one variable for each hour from 7 to 17 local solar time. The time period is chosen so because the UV index outside this range is zero or close to zero for the vast majority of grid points. The time stamp for each grid point is the local solar time for that grid point.

Global attributes for both output files

Attribute	Possible values	Description
Title	Near Real Time Clear Sky UV index or Near Real Time All Sky UV index	The title of the product

Institute	DMI (AC SAF)	The institute responsible for the product
Processor_version	NUV 3.5	Version of the processor used for the product
Cloud_processor_version	NUV 3.5	Version of the processor handling cloud cover data
Satellite	Metop-C or Metop-B	The name of the satellite from where the ozone data input is retrieved from.
Ozone_data	ATO GOME-2	The input assimilated total ozone
Date	yyyymmdd	The date
creator_email	hjs@dmi.dk	Contact information for the product responsible
product_content	Global clear sky UV index for 7-17h local solar time. Global all sky UV index for 7-17h local solar time.	Short description of the content
geospartial_latitude_min	-89.875	Minimum latitude
geospartial_latitude_max	89.875	Maximum latitude
geospartial_latitude_resolution	0.25	Resolution of the NUV
geospartial_longitude_min	-179.875	Minimum longitude
geospartial_longitude_max	179.875	Maximum longitude
geospartial_longitude_resolution	0.25	Resolution of the NUV

Dimensions in the data file

Dimension name	Unit	Size
Longitude	Degree east	1440
Latitude	Degree north	720

Variables in the clear sky file

Variable name	Unit	Size	Description
Longi	Degree east	1440	Longitude values of the grid points

Variable name	Unit	Size	Description
Lati	Degree north	720	Latitude of the grid points
uvclearHH	1	1440x720	Clear sky UV index for all grid points, HH is the hour from 07 to 17

Variables in the all sky file

Variable name	Unit	Size	Description
Longi	Degree east	1440	Longitude values of the grid points
Lati	Degree north	720	Latitude of the grid points
uvallskyHH	1	1440x720	All sky UV index for all grid points, HH is the hour from 07 to 17

APPENDIX: DESCRIPTION OF ATO

Assimilation of Total ozone

The assimilation of total ozone ATO service will be based on the GOME-2 ozone processing chain that is provided by the KNMI. The system is based on: 1) NTO ozone columns; 2) Medium-range meteorological analyses and forecasts of the ECMWF. Pre-processing of this meteo data is required to match form and resolution for the TM chemistry-transport model; 3) The ozone column data assimilation model TM3DAM. One 9-day assimilation/forecast run will be performed around 2 am, directly after completion of the ECMWF medium-range weather forecast.

Product description	
Summary	Daily ozone analyses and 9-day ozone assimilation / forecast of the global total ozone field
Product properties	
Parameter(s)	- Daily ozone analysis based on GOME-2 ozone observations - Ozone forecasts for days 0 to 9
Accuracy	2 dimensional field of accuracy is provided as part of the product (typically 3%)
Geometric resolution	2D, 1 degree latitude by 1.5 degree longitude
Grid / projection	Latitude-longitude grid, various projections possible
Spatial coverage	Global
Temporal coverage	Hourly fields
Data format	HDF4 and ASCII
availability	Operational implementation based on GOME-2 ozone measurements since April 2007.
Production process	
Method/ algorithm	TM3DAM chemistry-transport model driven by ECMWF medium-range forecast wind, pressure and temperature fields.
Model / assimilation	TM3DAM data assimilation approach.

reference	Eskes et al, Q. J. R. Meteorol. Soc., 129, 1663-1681 (2003) Eskes, Atmos. Chem. Phys., 2, 271-278 (2002)
Quality standards	
Production	- Routine monitoring of production chain during working hours; - Monitoring of ozone observations and model forecast quality by means of observation-minus-forecast (OmF) reports. Quality screening to reject bad retrievals and outliers.
Product	- Retrospective analysis of performance - Study of OmF reports, fine tuning of two-dimensional analysis precision distributions that are part of the product.
Validation	- Intercomparison of the TM3DAM analyses (2D, 3D) with ground-based observations (Brewer, Dobson, DOAS, SAOZ, ozone sondes, lidar etc..) - Study of OmF statistics: bias, rms as a function of relevant parameters in the assimilation model and retrieval.
Input data	
EO data	GOME-2 level 2 NTO data in HDF5 format
Other data	Meteorological medium-range forecast data of ECMWF
Optional or other specific properties (if applicable)	
Historical archive	Archive of global ozone analyses and forecasts since April 2007
Offline/NRT	Once per day (Offline for reanalysis runs)
Visualization standards	Images in gif format provided for northern hemisphere, southern hemisphere and globe. Data sets: HDF4
Underlying primary user requirement(s)	
Key requirement	Reliable forecasts for UV forecast processing
Originator(s)	KNMI, DMI

Table -1: Characteristics of the ozone assimilation product

Total Ozone Assimilation/Forecast Service

System overview

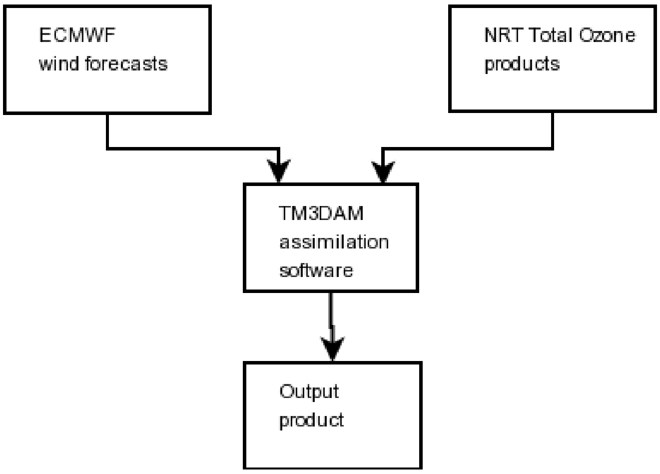


Figure -1: Overview of the Total Ozone assimilation process

The diagram summarizes the ozone assimilation/forecasting process. The different elements are:

Input data: This consists of GOME-2 level-2 data and the 10-day medium-range meteorological forecast of ECMWF.

Processor: The ozone columns are used by the TM3DAM assimilation software to provide an analysis of the present global ozone distribution, and subsequently an ozone forecast run is performed.

Output data: This consists of an analysis of the global ozone distribution (O3AN) and a 9-day ozone forecast (O3FC).

Storage, internet: The data base of ozone products is linked to the TEMIS website (www.temis.nl) ozone internet service. Dynamical web pages provide users with the most recent ozone products.

Technical requirements

External interface(s)

or NRT processing direct transfer of GOME-2 data from EUMETCast is provided. The KNMI has direct access to ECMWF forecast meteo. Pre-processing software is running operationally on the ECMWF hardware. This converts ECMWF forecast fields (temperature, pressure, vorticity, divergence) to a resolution and form suitable for the TM model. These pre-processed meteorological fields are subsequently transferred to the KNMI by ftp.

Verification and quality control

The main source of information for quality control is the observation-minus-forecast statistics (OmF) produced by the TM3DAM analysis system. This mechanism allows detection of sudden changes in the data quality and provides error estimates for the total ozone retrieval as well as the model performance. A quality screening is implemented to reject unrealistic ozone retrievals which will not influence the analyses. The forecast continuity is guarded by a routine monitoring of forecast production chain during working hours. The overall performance of the ozone forecasting system is studied by a-posteriori comparison of the forecast with the corresponding verifying analyses. The analyses uncertainty is reported as a two-dimensional field, part of the analysis product.

Hardware

The meteorological preprocessing runs on machines at ECMWF.

The TM3DAM assimilation runs on the AC SAF computer at KNMI.

The TM3DAM ozone assimilation and forecast

The ozone chemistry-transport model

The ozone forecasts are based on a tracer-transport and assimilation model called TM3DAM. The modelling of the transport, chemistry and the aspects of the ozone data assimilation are described in detail in a recent paper [Eskes et al, 2003]. Here we will only provide a brief overview of the model set-up.

The three-dimensional advection of ozone is described by the flux-based second order moments scheme of Prather. The model is driven by 6-hourly meteorological fields (forecasts of wind, surface pressure, and temperature) and follows the latest ECMWF vertical layer definition, operational from the end of 1999 until the present. The 60 ECMWF hybrid layers between 0.1 hPa and the surface have been reduced to 44 in TM3DAM by removing 16 layers in the lower and middle troposphere. The horizontal resolution of the model version used in this study is 2 by 3 degree.

Ozone chemistry in the stratosphere is described by two parametrizations. One consists of a linearization of the gas-phase chemistry with respect to production and loss, the ozone amount, temperature and UV radiation. A second parametrization scheme accounts for heterogeneous ozone loss. This scheme introduces a three-dimensional chlorine activation tracer which is formed when the temperature drops below the critical temperature of polar stratospheric cloud formation. Ozone breakdown occurs in the presence of the activation tracer, depending on the presence of sunlight. The rate of ozone decrease is described by an exponential decay, with a rate proportional to the amount of cold tracer and a minimal decay time of 12 days. The cold tracer is deactivated with a time scale of 10 days in the Southern hemisphere when light is present.

Ozone assimilation and ozone forecasts

The total ozone data are assimilated in TM3DAM by applying a parameterized Kalman filter technique. In this approach the forecast error covariance matrix is written as a product of a time independent correlation matrix and a time-dependent diagonal variance. The various parameters in the approach are fixed and are based on the forecast minus observation statistics accumulated over the period of one year (2000). This approach produces detailed and realistic time- and space-dependent forecast error distributions.

On average the root-mean-square difference between new GOME-1 or SCIAMACHY observations and the short range model forecast (between 1 and 3 days) is small: about 9 Dobson Units (DU), or roughly 3%. The bias between the model and the GOME-1 columns is in general smaller than 1%.

The quantitative performance of the ozone forecasts was reported recently [Eskes et al., 2002]. Medium range stratospheric ozone forecasts can be produced for a forecast period similar to 500 hPa geopotential height anomaly forecasts: the anomaly correlation in the extratropics crosses the value of 0.6 after about 6-7 days with the present set-up. In the tropics the anomaly statistics are worse, and possible reasons for this have been identified. Special events such as ozone mini-holes and the South Pole ozone hole development can be forecasted successfully at least 4-5 days in advance.

Post-processing

Post-processing consists of several aspects:

• Quality checks: The OmF statistics will be inspected in order to quantify errors in either the retrieval of the ozone columns or the TM3DAM model.

• Monitoring: The forecast continuity is guarded by a routine monitoring of forecast production chain during working hours. OmF monitoring is performed to detect changes in the analysis / forecast.

• Image processing: After completion of the forecast run images (and possibly additional data formats) are produced for the TEMIS internet ozone service.

• Dynamical web page generation: The TEMIS ozone service web page is automatically updated directly after completion of the analysis/forecast runs

References

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