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GMES SERVICE ELEMENT
PROMOTE 2

C6 Validation Report

Chapter 4
LONG-TERM MULTISENSORAL UV RECORD

Version 3

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Version 3		
2.1	14.05.2009	Editorial changes
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2.3	3.9.2009	Document edited and distributed for final review
3	5.9.2009	Header and chapter number updated

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LIST OF ACRONYMS

EUVDB	European UV Database
WOUDC	World Ozone and Ultraviolet Radiation Data Centre
NSF	National Science Foundation
UVI	UV Index
FMI	Finnish Meteorological Institute
UV	Ultraviolet
CIE	Commission International de l'Eclairage, International Commission on Illumination
PNG	Portable Network Graphics
OMI	Ozone Monitoring Instrument
TOMS	Total Ozone Mapping Spectrometer
GOME	Global Ozone Monitoring Experiment
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric ChartographY
ISCCP	International Satellite Cloud Climatology Project
GADS	Global Aerosol Data Set

N/A	Not Available
n.a.	not applicable
n.s.	not specified

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4 LONG-TERM MULTISENSORAL UV RECORDS SERVICE

4.1 Product Characterization

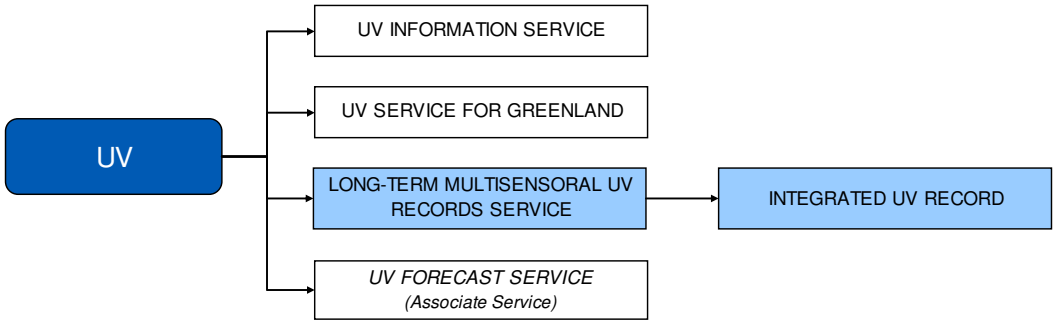

Figure 4.1-1 Position of Long-term Multisensoral UV Records service within PROMOTE 2 UV Services.

This is an integrated service that provides global and homogeneous surface time-series of Vitamin-D and erythemally weighted daily UV doses, and daily maximum UV index. The service provides complete time series covering 1983-2007 available from a web interface which includes documentation of the method, maps, station data, enhanced animation tools, and validation results.

In Phase 1 of PROMOTE2, the primary goal was to ensure continuation of the UV time series with surface UV data based on the OMI instrument. This service included both erythemally weighted daily UV dose and clear-sky UV index at local noon. In Phase 2, the UV algorithm uses assimilated total ozone column (from the Ozone Record Service) and ISCCP cloud data, available every three hours, and the focus was put on long time series of daily erythemal UV doses. In Phase 3 the Vitamin-D weighted daily doses are included in the service, and the daily maximum UV index is adopted instead of local noon UV index.

Service is operational since: June 2008

Research partners: NASA, NILU, etc (not funded by PROMOTE)

Provider(s): FMI (Finland)

Validation contact: Jussi Kaurola (jussi.kaurola@fmi.fi)

Table 4.1-1 Product Characterisation

PRODUCT CHARACTERISATION	
UV-Index (Phase 1 & Phase 3)	
Parameter	1 UVI unit equals 25 mW/m^2

Typical range	0 – 15 UVI
Determination of the typical range (Method, criteria)	Ground-based measurements
Units	[W/ m^2], [UVI]
Standards	*http://www.unep.org/PDF/Solar_Index_Guide.pdf*
Daily Erythemal UV Dose (Phase 1 & Phase 2 & Phase 3)	
Parameter	Spectrally and temporally (over the day) integrated erythemally weighted UV irradiance
Typical range	0-10 kJ/m2
Determination of the typical range (Method, criteria)	Ground-based measurements
Units	[kJ/m^2], [J/m^2]
Standards	*ISO/CIE. Erythema reference action spectrum and standard erythema dose. ISO 17166:1999(E) CIE S 007/E-1998.Vienna: CIE Central Bureau; 1999.*
Daily Vitamin-D UV Dose (Phase 3)	
Parameter	Spectrally and temporally (over the day) integrated vitamin-D weighted irradiance
Typical range	0-15 kJ/m2
Determination of the typical range (Method, criteria)	Ground-based measurements
Units	[kJ/m^2], [J/m^2]
Standards	*CIE/Division 6 Photobiology and Photochemistry/TC6-54. Action Spectrum for the Production of Previtamin D3 in Human Skin: CIE 174-2006*

4.2 Validation plan and validation data

The validation of the UV Record Service in Phase 1 was documented in a scientific paper by *Tanskanen et al.* (2007). Here follows a short summary of the results of that paper:

The overpass erythemal daily doses derived from OMI data were compared with the daily doses calculated from the ground-based spectral UV measurements from 18 reference instruments. Although systematic differences exist for sites strongly affected by absorbing aerosols or seasonal snow cover, the OMI-derived daily erythemal UV doses are in general in rough agreement with ground-based measurements. For flat, snow-free regions with modest loadings of absorbing aerosols or trace gases, for instance, the OMI-derived daily erythemal doses have a median overestimation of 0–10%, and some 60 to 80% of the daily doses are within ±20% of the ground reference.

In Phase 2, the surface UV algorithm has been exchanged: in order to have more homogeneous information on the cloudiness, we chose to use the cloud data from the International Cloud Climatology Project (ISCCP; http://isccp.giss.nasa.gov/). This data is available from 1983 onward on a global 280 km equal area grid, and with a temporal resolution of 3 h. In Phase 2, we performed a similar validation as for Phase 1 (see above) based on daily erythemal UV doses by ground-based instruments at seven European stations ranging from Sodankylä in the north to Thessaloniki in the south. It should be mentioned also, that validation against ground-based reference data is considered important by the user. The selected seven high quality stations (see Table 1.2-1) were chosen because their data are conveniently available within the SCOUT-O3 EU funded project, where FMI is also participating. In practice, the aim of the validation in Phase 2 is to determine typical bias and spread of the satellite-retrieved daily UV doses as compared to the ground-based reference. Most reference stations have data starting from the early or mid 1990s. However, the station of Norrköping has data available already since 1983, and will thus make an important contribution to validating the performance of the complete long-term satellite-retrieved UV record. Phase 2 UV Record Service provides only a prototype dataset that covers the period July 2002 to June 2005. Consequently, validation was performed for this period only. The results are documented in a scientific paper by Lindfors et al. (2009) and at project web pages. Typically satellite-derived daily erythemal doses have positive median bias of 3-10%, positive mean bias of about 10-20%, and 56-68% of the daily doses are within ±20% of the ground reference.

In Phase 3, the processing of data was extended to the period of 1983 to 2007 using KNMI-assimilated total ozone and ISCCP D1 cloud data. In addition, two new products were implemented: Vitamin-D weighted daily doses and daily maximum UV index. The processing of data was completed in June 2009 and thereafter maps about the results were generated for Europe and for the whole globe. The validation of the results against ground based data at stations from the SCOUT-O3 project (see Phase 2), has been completed and the results are shown in detail at the project web interface. In the case of daily doses (erythemal and Vitamin D) the satellite-derived data are overestimates when compared against ground-based data. Typically median bias for erythemal daily doses ranges from +8 to +17%, and mean bias ranges from +19 to 27%. For Vitamin D daily doses typical mean bias is 24-29% and median bias 10-18%. For both daily doses roughly 50-60% of the daily doses are within ±20% of the ground reference. The comparison of satellite derived daily maximum UV Index against ground-based measurement is difficult because of the nature of this quantity and because of the different field-of-view of satellite and ground-based instruments. Also differences in temporal resolution of ground-based data affect the results. In general, the satellite maximum UV Index data has positive bias at stations where measurement frequency is low, but bias in negative at stations with high measurement frequency.

Table 4.2-1 Standard table providing a description of data used for validation

VALIDATION DATA	
Ground based observations	
EUVDB (Phase 1)	Data availability and access: http://uvdb.fmi.fi/uvdb/index.html Spatial coverage and resolution: local time series Temporal coverage and resolution: variable (longest time-series start in early 90's, point measurements) Location(s) (coordinates): 43 sites (Europe) Accuracy: typically ±5%
WOUDC (Phase 1)	Data availability and access: http://www.woudc.org/ Spatial coverage and resolution: local time series Temporal coverage and resolution: variable (longest time-series start in early 90's, point measurements) Location(s) (coordinates): 29 sites (Global) Accuracy: typically ±5%
NSF (Phase 1)	Data availability and access: http://www.biospherical.com/NSF/default.asp Spatial coverage and resolution: local time series Temporal coverage and resolution: variable (longest time-series start in early 90's, point measurements) Location(s) (coordinates): 7 sites (Polar and San Diego) Accuracy: typically ±5%
Reconstructed UV (Phase 2 & 3)	Data availability and access: through SCOUT-O3 EC funded project Spatial coverage and resolution: local times series Temporal coverage and resolution: daily values, mostly starting around 1980 or earlier Locations: 7 sites (Sodankylä, Jokioinen, Norrköping, Bilthoven, Lindenberg, Hradec Kralove, Thessaloniki) Accuracy: n.s.
SCOUT-O3 (Phase 2 & 3)	Data availability and access: through SCOUT-O3 EC funded project Spatial coverage and resolution: local time series Temporal coverage and resolution: Daily values, mostly starting in the early or mid 1990s, one station from 1983 onward. Locations: 7 sites (Sodankylä, Jokioinen, Norrköping, Bilthoven, Lindenberg, Hradec Kralove, Thessaloniki) Accuracy: typically ±5%

4.3 Validation of individual service components

Detailed validation results of Phase 1 are available in the publication by *Tanskanen et al.* (2007), the results of which were summarized above. The paper is also linked to the UV Record Service web page.

The validation results for Phase 2 are presented at project web pages and in the publication by Lindfors et al. (2009), the results of which were summarized above

The central results of the Phase 3 validation are presented in the table beneath. More details, including illustrative figures are available on the UV Record Service web page. Shortly, the results show that the algorithm for satellite-retrieved UV is working more or less as expected. The performance is similar to that of Phase 1 and 2, with quite a clear tendency toward overestimation. The new algorithm shows a median overestimation for erythemal daily doses typically ranging from +8 to +16% and for vitamin D daily doses ranging from +10 to +18%. Roughly 50-60% of the satellite-retrieved daily doses are within plus/minus 20% from the ground-based reference. Validation of daily maximum UV Index is more difficult and results depend e.g. on the characteristics of ground-based data (for further discussion see the project web page). Summer (June, July, August) erythemal doses were compared against reconstructed ground-based data produced in the SCOUT-O3 project. Typically satellite-derived summer doses are overestimates by roughly 15-25%.

Table 4.3-1 Data quality and validation of individual components

VALIDATION OF INDIVIDUAL COMPONENTS	
Uncertainty assessment	
Bias	mean bias (%) = mean value of percentage deviation as compared to reference data, i.e., mean([est-ref]/ref*100%) median bias (%) = median value of percentage deviation as compared to reference data, i.e., median([est-ref]/ref*100%)
Standard deviation	std = standard deviation of ratio of estimated to reference value, i.e., std(est/ref)
W20	W20 = amount (relative frequency in %) of values found within plus/minus 20% from the reference
Quality assessment	
Threshold of 200 J/m2 for daily doses, and 0.5 for	Following *Tanskanen et al.* (2007), a threshold filter of 200 J/m2 was applied, so that only daily doses exceeding that value were included in the validation analysis. The threshold of 0.5 UVI was chosen to mask

daily maximum UV Index	out days with very weak UVI.
Model/algorithms	
Calculation of surface UV	Look-up-table approach for radiative transfer calculations under various atmospheric conditions. Based on libRadtran radiative transfer simulations. Typically: mean bias=0.5%; std=1.5%.
FastRT	Not used. http://nadir.nilu.no/~olaeng/fastrt/README.html
libRadtran	libRadtran is a radiative transfer model, that has been developed during many years, and has been validated against both measurements and other models. This has been described more in detail in a paper by *Mayer and Kylling* (2005). The uncertainty of the radiation quantities produced with libRadtran is almost completely depending on the uncertainties in the input: the calculations themselves are accurate. http://www.libradtran.org/
Consistency	
Validation vs. ground-based UV data	Validation was performed for eight European stations and the period July 1983to June 2007, comparing satellite-retrieved daily erythemal and vitamin D doses, and daily maximum UV Index against ground-based measurements. Not all stations provide Vitamin D weighted daily doses and daily maximum UV Index.
	Erythemal daily doses. Typical range of results (including the middle six stations concerning each parameter): mean bias=+19 to +27%; median bias=+8 to +16%; std=0.38 to 0.48; W20=54 to 62%. Vitamin D daily doses. Typical range of results (including three out of four stations, excluding one outlier): mean bias=+24 to +29%; median bias=+10 to +18%; std=0.48 to 0.51; W20=48 to 59%. Daily maximum UV Index. Typical range of results (including all five stations): mean bias= -15 to +21%; median bias= -19 to +12%; std=0.28 to 0.47; W20=45 to 71%.

Validation vs. reconstructed SCOUT-O3 time series	Validation was performed for seven European stations and the period July 1983to June 2007, comparing satellite-retrieved summer (June, July, August) erythemal doses against reconstructed ground-based data.
	Typically satellite-retrieved summer doses overestimate reconstructed summer doses by 15-25%.

4.4 Validation against specifications and against user requirements

According to the SLA between FMI and University of Manchester, the UV Record Service should provide global UV information time series from 1979 onward and the UV Record should be validated against ground-based data. Data should be made available as ASCII (for time series) and figures in PNG (UV maps).

Table 4.4-1 Validation against specifications and against user requirements.

*Requirements in *italics* were not compulsory for Phase 2.

VALIDATION AGAINST SERVICE SPECIFICATIONS & USER REQUIREMENTS			
SPECIFICATION	**S5**	**REQUIRED***	**ACTUAL**
Product	Clear-sky UV Index (Phase 1) Daily Erythemal UV Dose (Phase 1 & Phase 2) Spectral Surface UV Irradiance (N/A)		
Accuracy			
Uncertainty	Relative accuracy of 3% per decade	n.s.	N/A (expected ~3%)
Uncertainty minimum	n.s.	n.s.	n.s.
Uncertainty target	n.s.	n.s.	n.s.
Spatiotemporal characteristics			
Spatial coverage	Global	Global	Global
Horizontal resolution	1°x1°	*Highest available*	1°x1°
Vertical resolution	n.a.	n.a.	n.a.
Grid/Projection	Grid at 1x1°	*Maximum and optimal resolution*	Grid at 1x1°
Temporal coverage	1979-present	n.s.	Phase 1: 2004-2006 Phase 2: July 2002 to June 2005 Phase 3: 1983-2007 (ISCCP cloud data begins in 1983)
Temporal resolution	Daily, weekly, monthly averages	*Daily, weekly, monthly (averages)*	Daily
User Interfaces			
PROMOTE Web	Complete, operational and up to date	Complete, operational and up to date	Complete, operational and up to date
Other Webs	Yes	n.s.	yes

On demand	Processed local time-series available	n.s.	Additional local time series of specific sites can be added on request
Data formats and data delivery			
Data availability (online)	November 1978-September 2004	n.s.	see temporal coverage above
Data access	Maps and local time series Online	Online	Online
Delivery Mode	Offline (Online no NRT)	Online no NRT	Offline (Online no NRT)
Delivery frequency	n.a.	Always accessible	Always accessible
Data Format	n.s.	ASCII; PNG	ASCII, images in various but common formats (mostly PNG)
Historical archive	Yes	Monthly averages 1979-present *As long as possible (min 20 years)*	PROMOTE: 1979-1993, 1996-2006 PROMOTE2, Phase1: 2004-2006 PROMOTE2, Phase2: 2002-2005 PROMOTE2, final: 1983-2007
Visualization	n.s.	Figures, maps	Figures, maps
Remarks			
All results including station data, maps, documentation and evaluation for Phases 1, 2 and 3 are available from the project web interface.			

*Requirements in i*talics* were not compulsory for Phase 2.

4.5 Quality assessment and control procedures: Service quality

The UV Record Service provides an archive of past UV radiation quantities. It does not include any near-real-time processing. This means that the service is manually updated and checked when new data/algorithms become available.

Table 4.5-1 Quality Control

QUALITY ASSESSMENT AND CONTROL PROCEDURES				
Service delivery start date: 6 June 2008				
SPECIFICATION	**S5**	**REQUIRED***	**ACTUAL**	**N checks/Delivery period °** **June 2008-**
Quality checks	n.s.	*Required*	n.s.	n.s.
Product confidence interval	n.s.	*n.s.*	n.s.	n.s.
Error bar definition and representation	1σ	*Estimation of error limits: min-max range of expected true value in the ground for each individual day/month/year*	n.s.	n.s.
Representation of missing data	Missing data is indicated	*Clearly indicated*	Missing data is indicated by '-99' in the UV time series. In the UV maps, missing data is indicated by a grey area.	n.s.
Documentation of process failure	Offline service. Manual process failure control	*Clear and complete*	Offline service. Manual process failure control	n.s.

Version control mechanisms and representation	Old versions are still available. Modifications will be shortly documented and introduced to the user	*n.s.*	All versions of the UV Record (Phase 1, 2 and 3) are available at the web page. Versions are clearly indicated.	n.s.

*Requirements in *Italics* are recommended bu not compulsory for Phase 2

4.6 References

[Complete/update section and subsections below]

4.6.1 Electronic references and online data access paths

UV Record archive; http://promote.fmi.fi

EUVDB: http://uvdb.fmi.fi/uvdb/index.html

WOUDC: http://www.woudc.org/

NSF: http://www.biospherical.com/NSF/default.asp

FASTRT: http://nadir.nilu.no/~olaeng/fastrt/README.html

libRadtran: http://www.libradtran.org/

ISCCP: http://isccp.giss.nasa.gov/

GADS: http://www.lrz-muenchen.de/~uh234an/www/radaer/gads.html

4.6.2 Bibliographic references

Lindfors, A., A. Tanskanen, A. Arola, R. van der A, A. Bais, U. Feister, M. Janouch, W. Josefsson, T. Koskela, K. Lakkala, P. N. den Outer, A. R. D. Smedley, H. Slaper, and A. R. Webb (200), The PROMOTE UV Record: toward a global satellite-based climatology of surface ultraviolet irradiance. Accepted for publication in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (IEEE J-STARS).

Tanskanen, A., Lindfors, A., Maatta, A., Krotkov, N., Herman, J., Kaurola, J., Koskela, T., Lakkala, K., Fioletov, V., Bernhard, G., McKenzie, R., Kondo, Y., O'Neill, M.,

Slaper, H., den Outer, P., Bais, A., Tamminen, J. (2007): Validation of Daily Erythemal Doses from OMI with Ground-Based UV Measurement Data, *Journal of Geophysical Research, Vol. 112*, D24S44, doi:10.1029/2007JD008830.

Mayer, B., and A. Kylling (2005): Technical note: The libRadtran software package for radiative transfer calculations—Description and examples of use, *Atmos. Chem. Phys., 5*, 1855 – 1877, doi:1680-7324/acp/2005-5-1855.