Scientific Challenges of UV-B Forecasting

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- International activities and the UV Index
- UV Index definition and forecasting requirements
- Challenges in calculation of the radiation transfer
  - effects of aerosols (relation to GEMS), of altitude, and of albedo
  - cloud modification factor
- Example, products, verification
- Conclusion

UNCED 1992, Agenda 21, and INTERSUN

Agenda 21: Undertake as a matter of urgency

- research on the effects on human health of increasing UV reaching the ground due to ozone depletion
- efforts to mitigate the effects on human beings

In response to Agenda 21, WHO and further organisations established **INTERSUN** the Global UV Project:

UV Index

Objective: Primary prevention; Priority Activities:

- Filling gaps in scientific knowledge
- Assessing and quantifying health risks
- Promoting sun protection
- Promoting the UV Index

UV Index

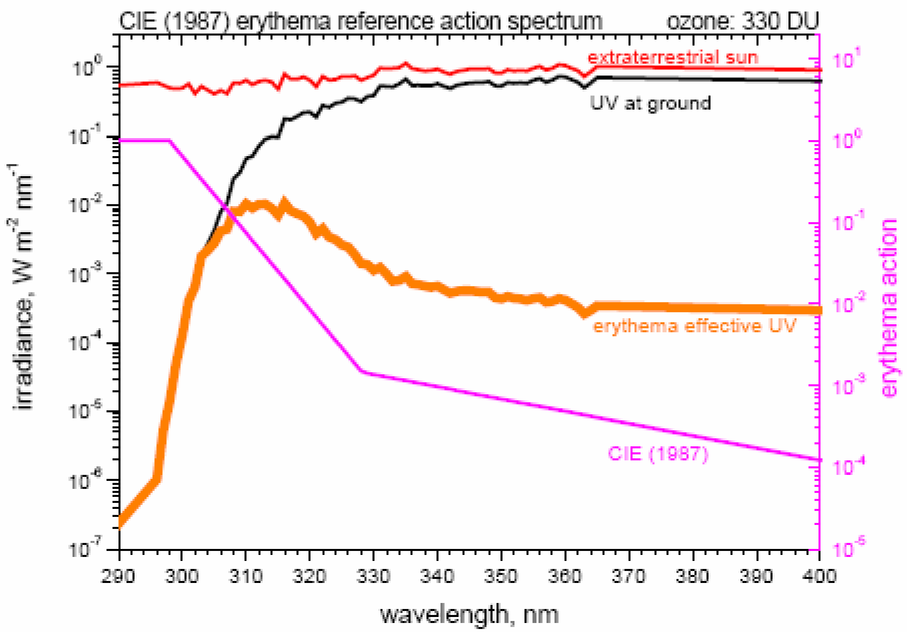
In 1994 introduced by WMO, WHO , ICNIRP, UNEP to

- describe the level of solar UV radiation reaching the ground by means of a simple physical quantity

Objective:

- raise public awareness of the risk of excessive exposure to UV and the need to adopt protective measures
- serve as an educational tool to promote sun protection

UV Index: Biologically weighted physical quantity



UV Index Definition

UV Index	=	$k_{er}\cdot\int_{280\,nm}^{400\,nm} E(\lambda)\cdot s_{er}(\lambda)\cdot d\lambda$
$E(\lambda)$ [$W\,m^{-2}\,nm^{-1}$]	=	spectral solar irradiance at the earth surface
λ, $d\lambda$ [nm]	=	wavelength and wavelength interval
k_{er}	=	40 [$m^2\,W^{-1}$]
$s_{er}(\lambda)$	=	CIE (1987) erythema reference action spectrum

The UV Index is defined in reference to a horizontal surface

Requirements in UV Index forecasting and reporting

WMO

- to take into account cloud cover and other relevant environmental variables (surface albedo, aerosols)
- to report to the public the daily maximum value, *whenever it occurs*

COST-713 on “UV-B forecasting” recommends additionally:

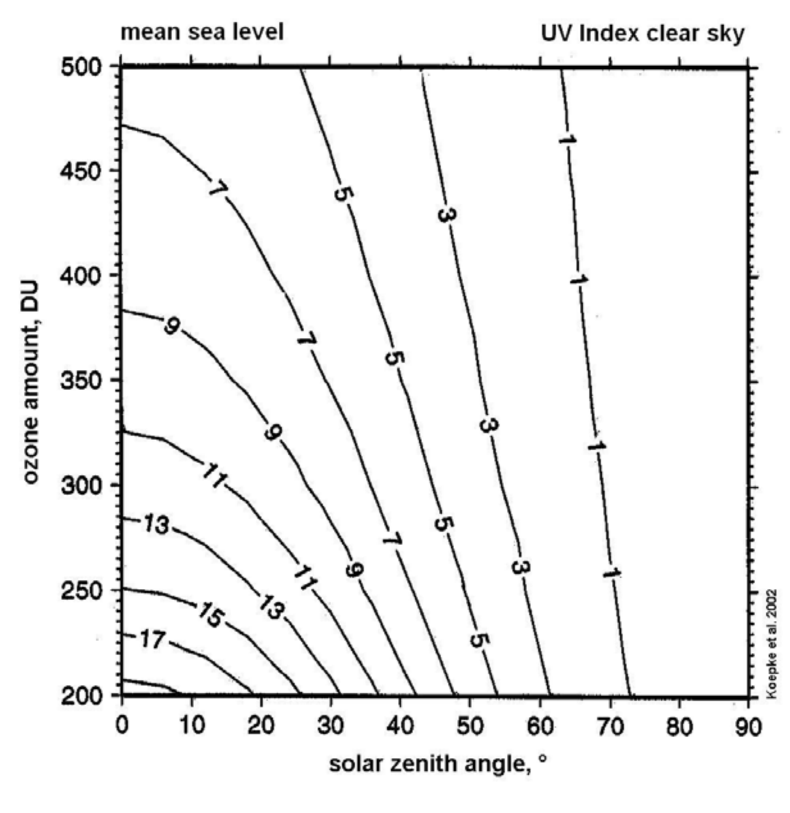
- to forecast total ozone by global dynamical models, including chemistry effects and data assimilation techniques.
- to include aerosol optical depth variable in space and season.
- to model the UV Index by a multiple scattering algorithm.

Challenges in UV Index forecasting

The challenges to accept in UV forecasting are of operational nature:

- forecasting not only for local noon
- fast calculation of radiation transfer accounting for
    - aerosol optical depth
    - aerosol absorption (single scattering albedo)
    - altitude effects
    - surface albedo
    - clouds

Radiation Transfer for clear sky conditions



Large Scale UV Index (ls_UVI)

Realised by Lookup Tables (LUT) for
- 12 months
- 5 zonal belts per hemisphere

Resolution 1° in solar zenith angle (SZA), 10 DU in total ozone (TOZ)

Range: 0 - 14 (mean sea level)

Vertical distribution of ozone and temperature: **effects < 3 %**

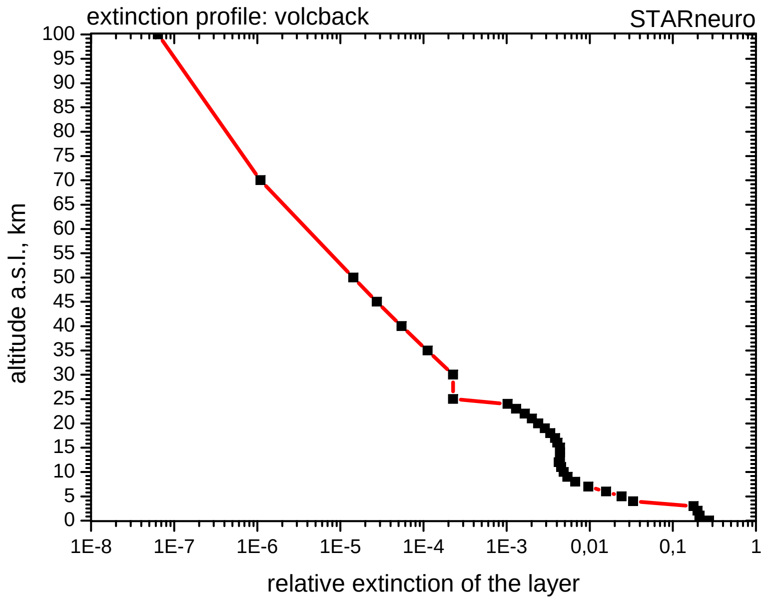
Adjusting for variable atmospheric conditions and altitude

$$\mathbf{UVI} = \mathrm{ls\_UVI}(SZA, TOZ)$$
$$* f_{aerosol}(AOD, SSA, SZA)$$
$$* f_{altitude}(AOD, SSA, SZA, z)$$
$$* f_{albedo}(ALB, SZA, z)$$

[UV Index clear sky]

$$* f_{clouds}(cloud\_cover, cloud\_type[, sw\text{-}rad])$$

Aerosol effects: $f_{aerosol}$(AOD, SSA, SZA)



Aerosol effects modelled by

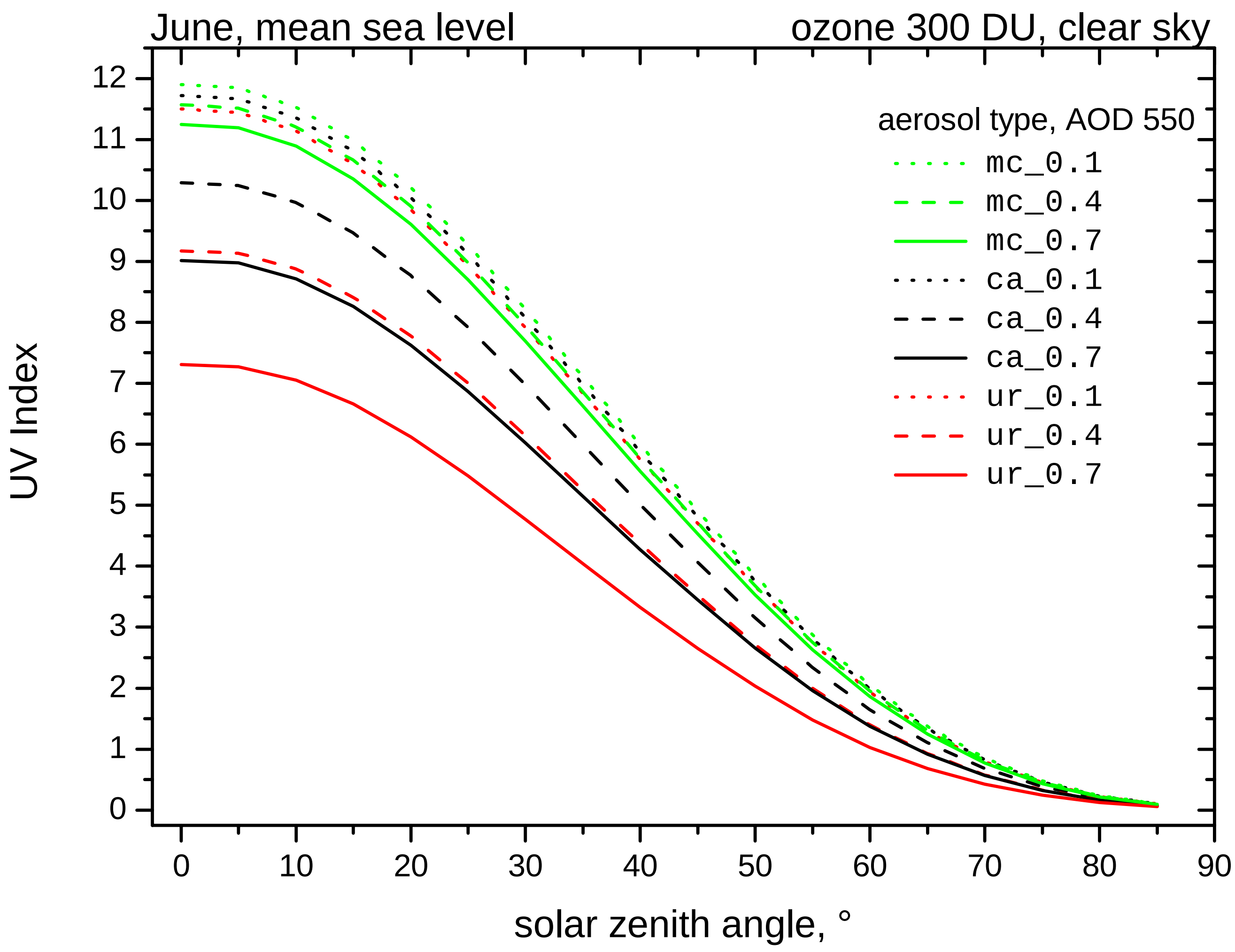
- set type: stratosphere (>12 km)
- set type: free troposphere (<12 km)
- variable types: (0-3 km)

Type of relative aerosol profile:

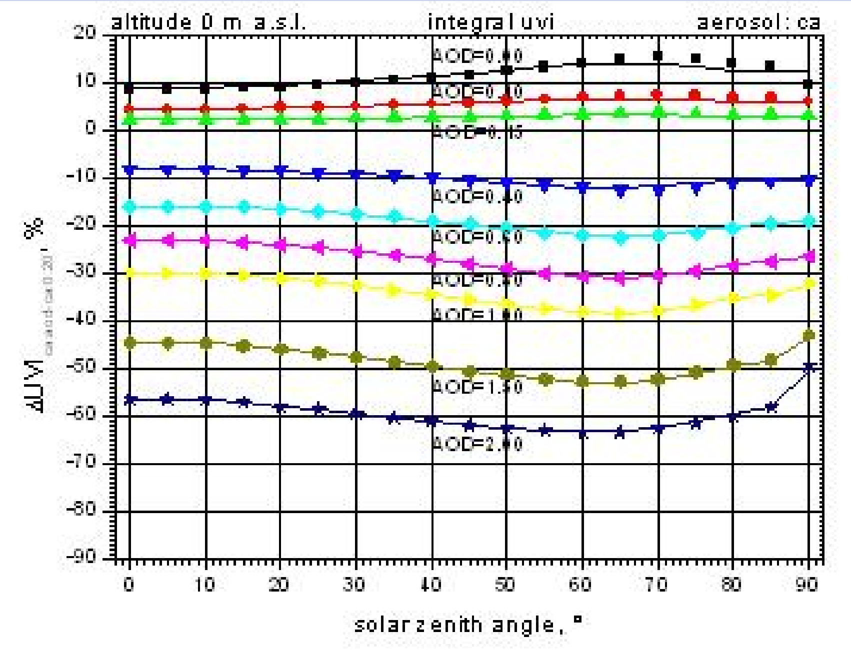
- volcanic background conditions

Phase function, asymmetry factor, and SSA are defined via the aerosol types. Effects of varying profiles <3%

Aerosol effects



Aerosol effects: $f_{aerosol}$(AOD, SSA, SZA)



UVI, maximum abs. error: 0.05

Accounting for aerosol effects:

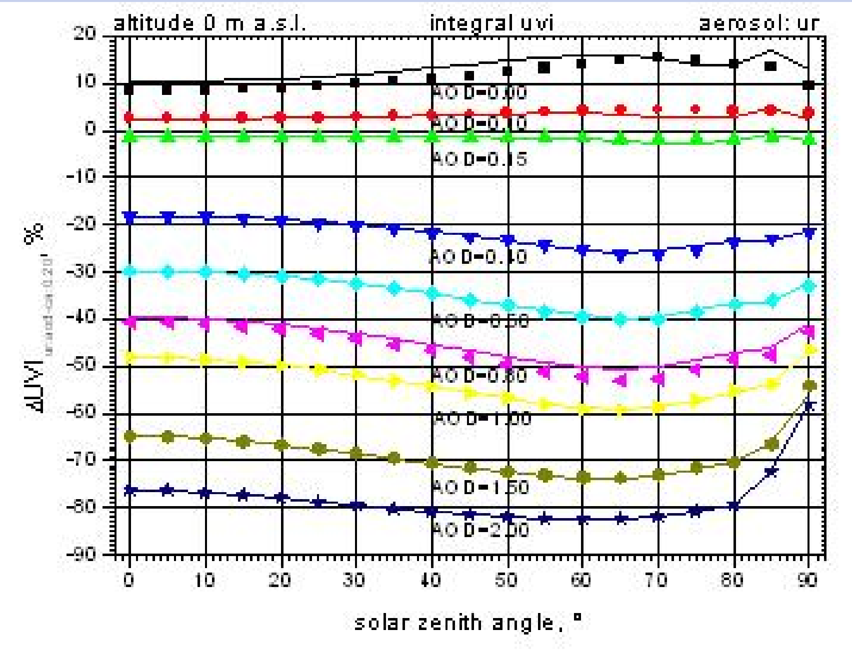
- influence of AOD increases with decreasing SSA
- dependence on SZA is low, strongest at ~60°

<u>Large-scale UV Index</u>

Adjusted to variable aerosol by a factor dependent on

- AOD, SSA, SZA

Aerosol effects: $f_{aerosol}$(AOD, SSA, SZA)



UVI, maximum abs. error: 0.21

Accounting for aerosol effects:

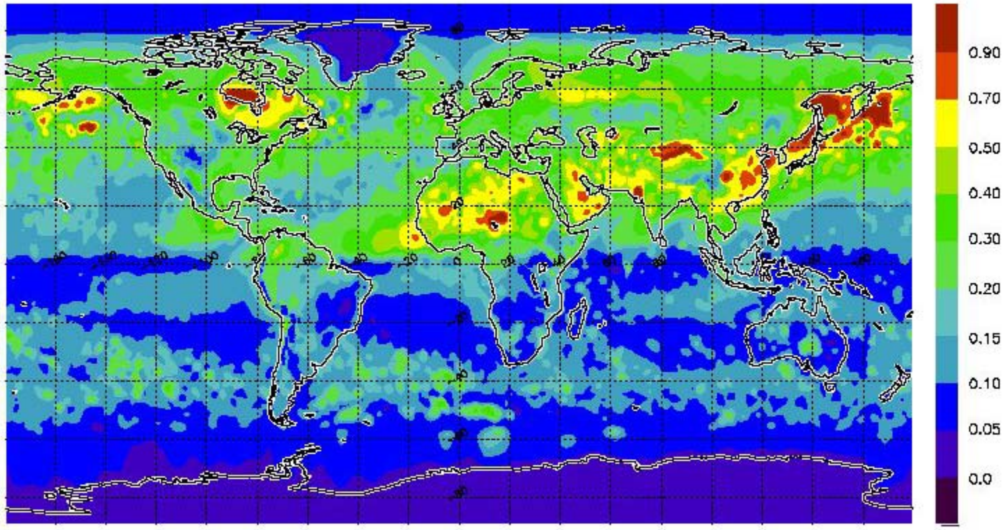
- influence of AOD increases with decreasing SSA
- dependence on SZA is low, strongest at ~60°

<u>Large-scale UV Index</u>

Adjusted to variable aerosol by a factor dependent on

- AOD, SSA, SZA

Seasonal and Regional Variations of AOD and SSA

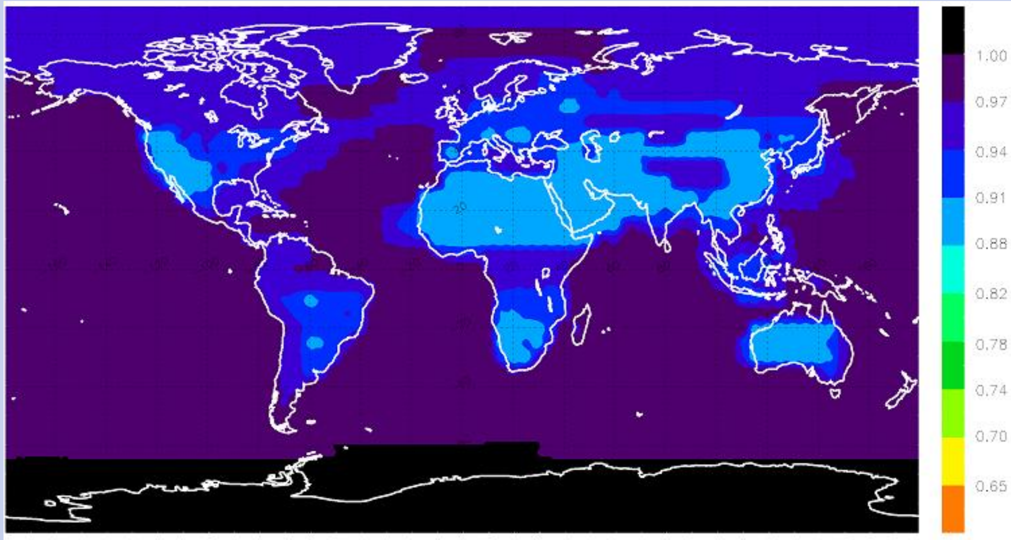


“Climatology”: Average of same months and slight smoothing, April

Accounting for seasonal changes in AOD at 550 nm:

- NASA MOD08_M3, original
- Reduction of pixel mean with increased standard deviation
- Polar regions: set background from GADS and further reading
- Fill data gaps by NASA TOMS AOD, 1979 - 2001
- Average of same months

Seasonal and Regional Variations of AOD and SSA

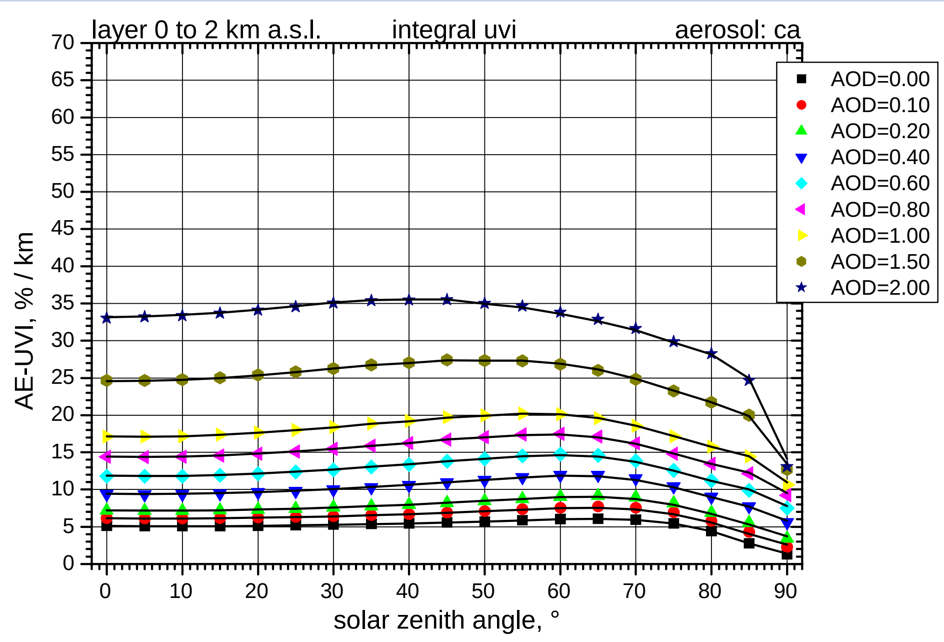


SSA 300 nm (relative Humidity 70%):
GADS limited to SSA > 0.887: Summer

Accounting for semi-annual changes in single scattering albedo (SSA) at 300 nm:

- Global Aerosol Data Set (GADS), University Munich
- spatial resolution: 5° ∗ 5°

Adjusting for Altitude: $f_{altitude}$(AOD, SSA, SZA, z)



UVI, maximum abs. error: 0.04

Altitude Effect = relative difference in the irradiance between two altitudes, scaled to 1 km.

Parameterisation formula:

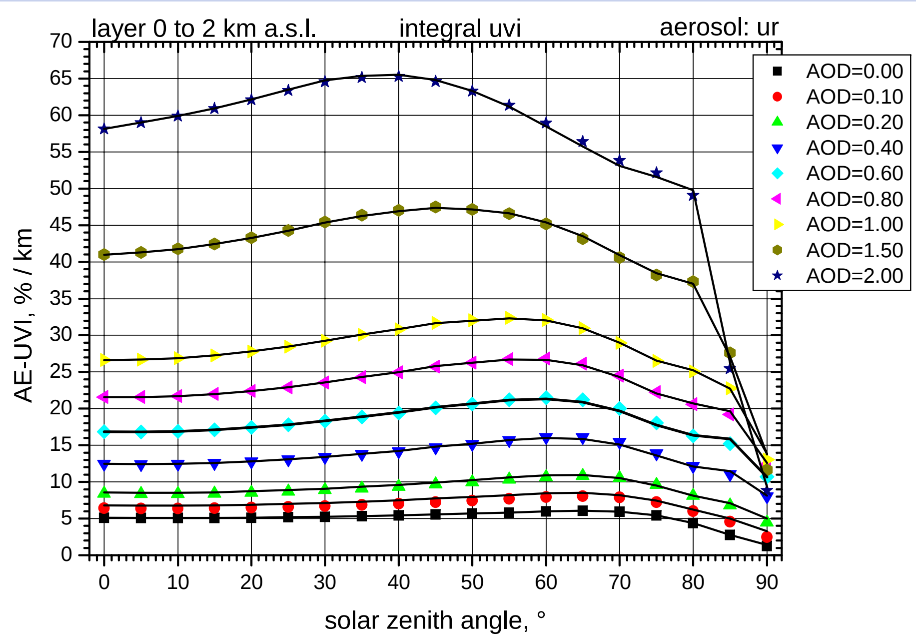
$\ln(UVI_z / UVI_{msl})$ =

+ Ray(SZA, z)

+ Aer(SZA, z, AOD, SSA)

Ray(SZA, z) ~ air pressure special case for AOD = 0.0

Adjusting for Altitude: $f_{altitude}$(AOD, SSA, SZA, z)

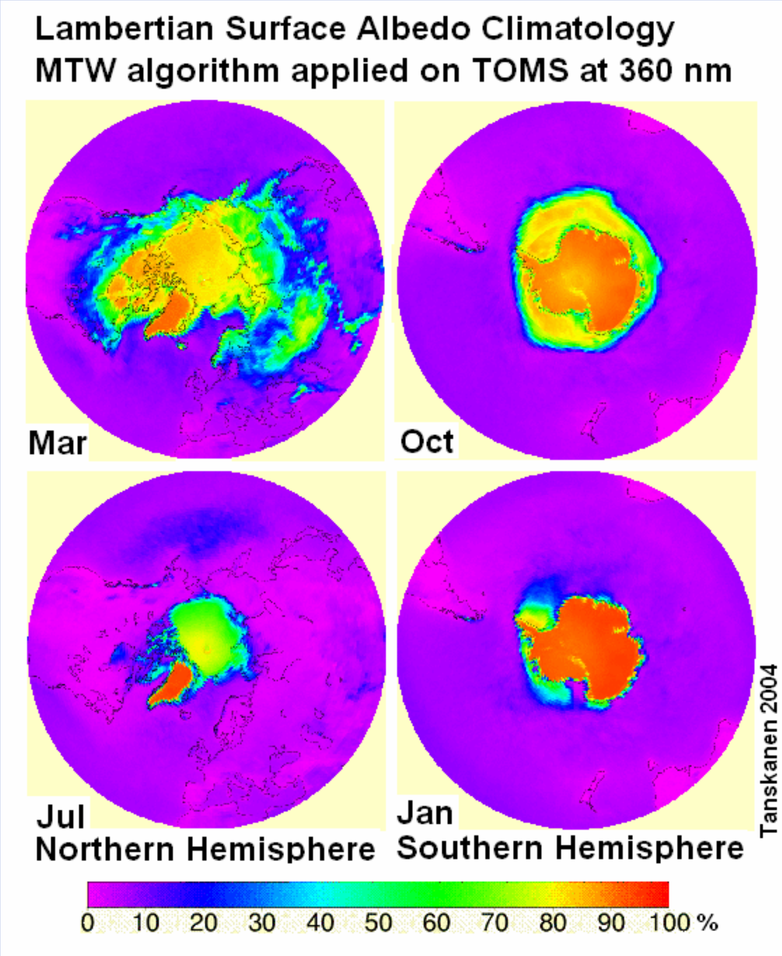


UVI, maximum abs. error: 0.21

Altitude effects of aerosol:

- increasing with increasing AOD
- strongly increasing with decreasing SSA
- slightly dependent on SZA with a maximum at about 50 to 70°

Effect: UVI increase, % per 1 km
aerosol “ca”, AOD=0.20: 7 - 8%
aerosol “ca”, AOD=0.40: 10 -11%
aerosol “ur”, AOD=0.40: 14 -16%



Effects on UVI: 0 - 40 %

Adjusting for Surface Albedo

$f_{albedo}(ALB, SZA, z)$

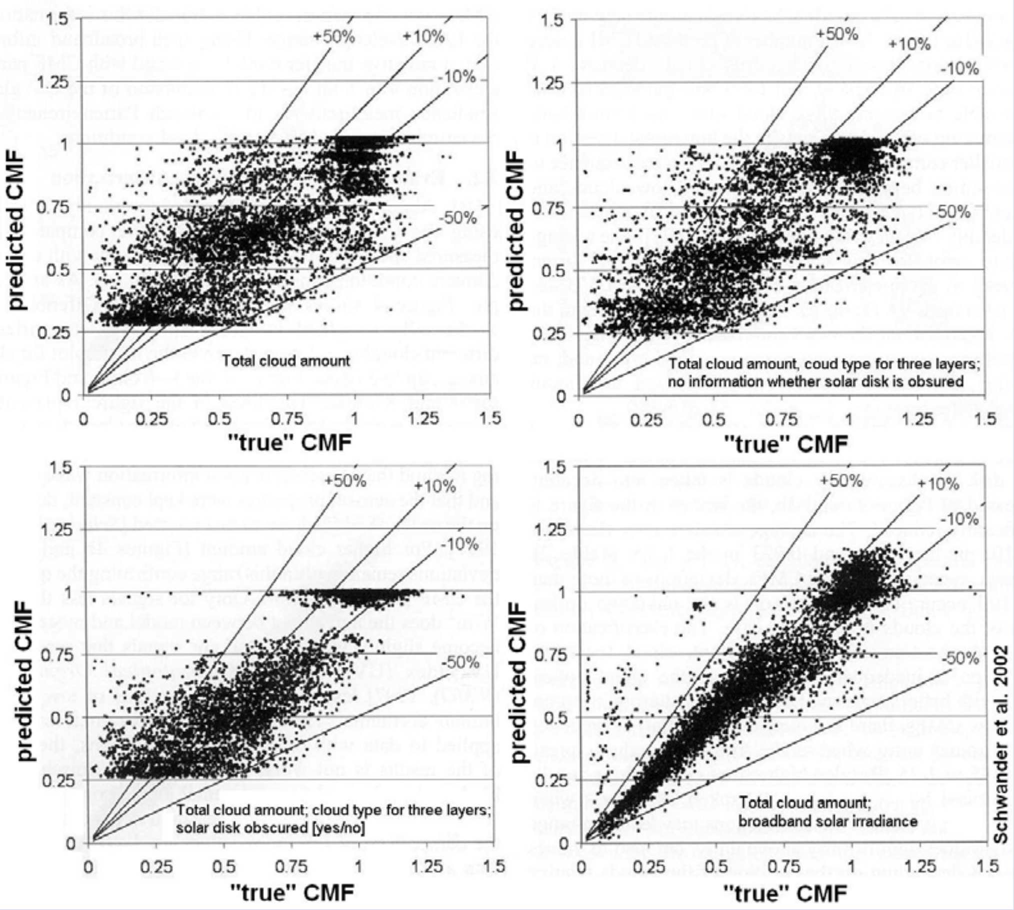
Local surface albedo defined by

alb [%] = 100. ∗ (irr ⇑ / irr⇓)

UV surface albedo generally is low, exception:

- snow/ice, fresh : ~95 %
- old/wet : ~70 %

The irradiance at a receiver is determined by the albedo of an area of up to 30 km^2.



Cloud Modification Factor (CMF)

$CMF = UVI_{cloudy} / UVI_{clear\_sky}$

Function of

- cloud cover
- cloud type
- short-wave irradiance

Challenging is the high micro- and macro-physical variability in space and in time

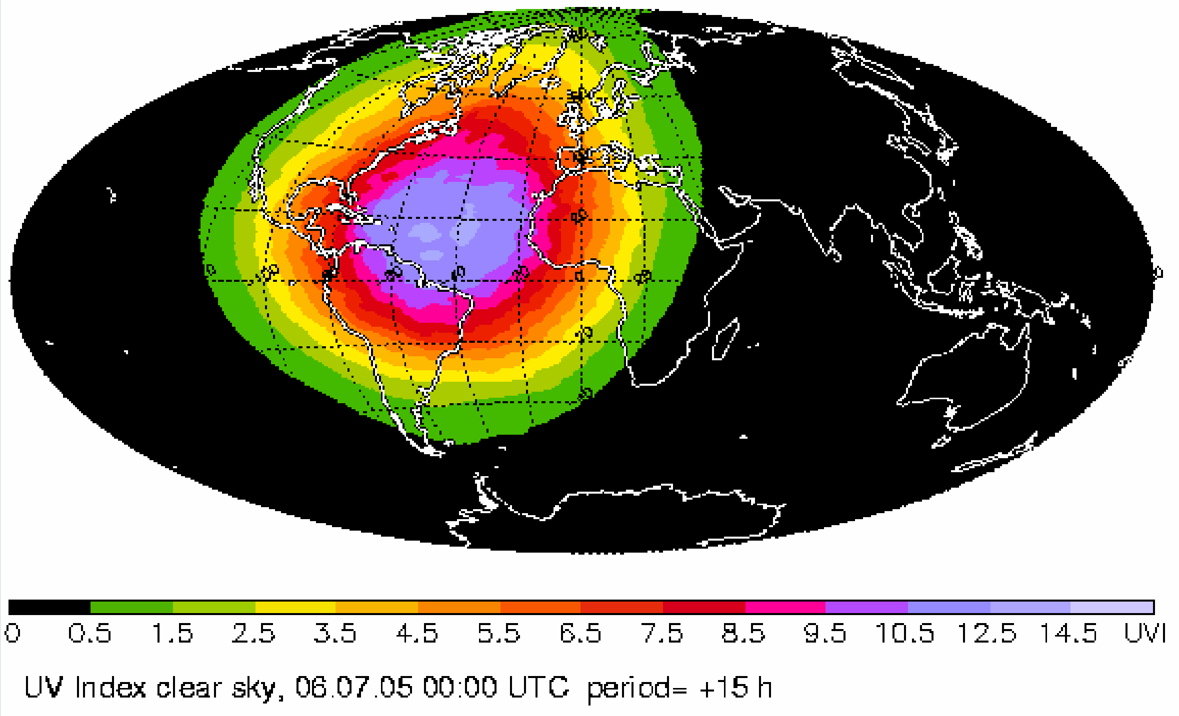
Range of CMF: 1.00 - 0.20

Deutscher Wetterdienst

PROMOTE

DWD

Examples of UV Index Calculation and Derived Products



Radiation transfer:

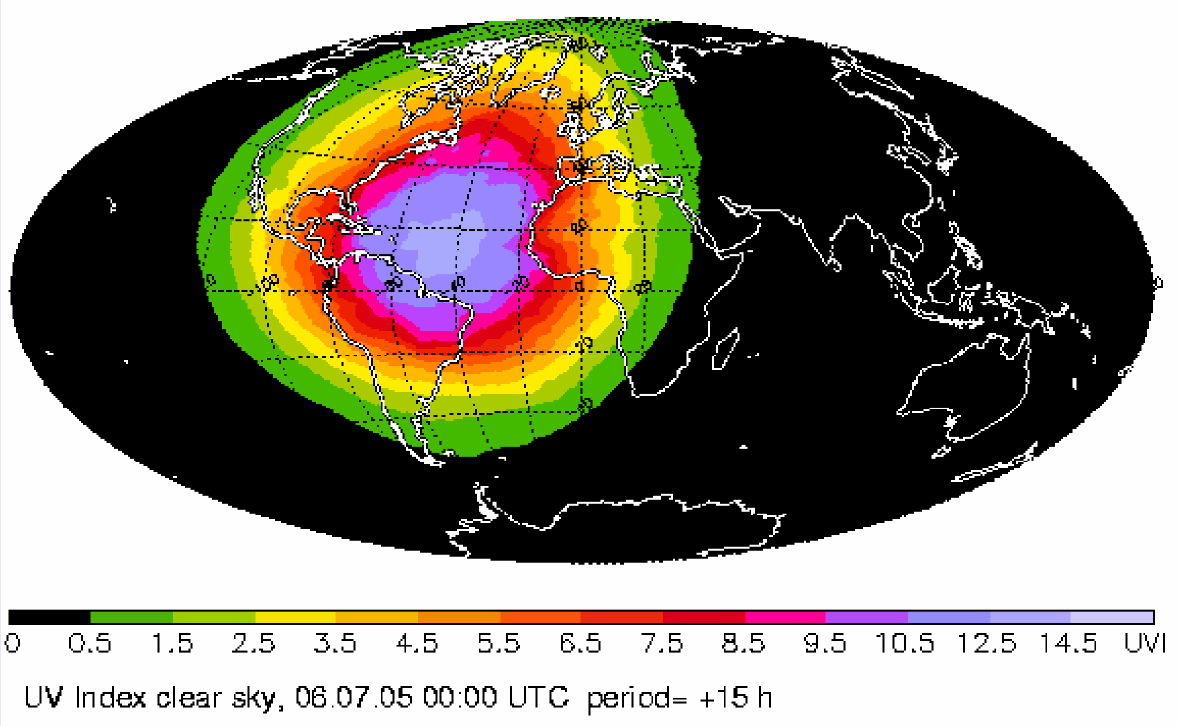
- lookup tables

depending on
- solar zenith angle
- total column ozone

Resolution:
- 12 month
- 10 zonal belts

Set : clear sky , albedo, mean sea level , AOD/SSA
Variable : total column ozone, solar zenith angle

Examples of UV Index Calculation and Derived Products



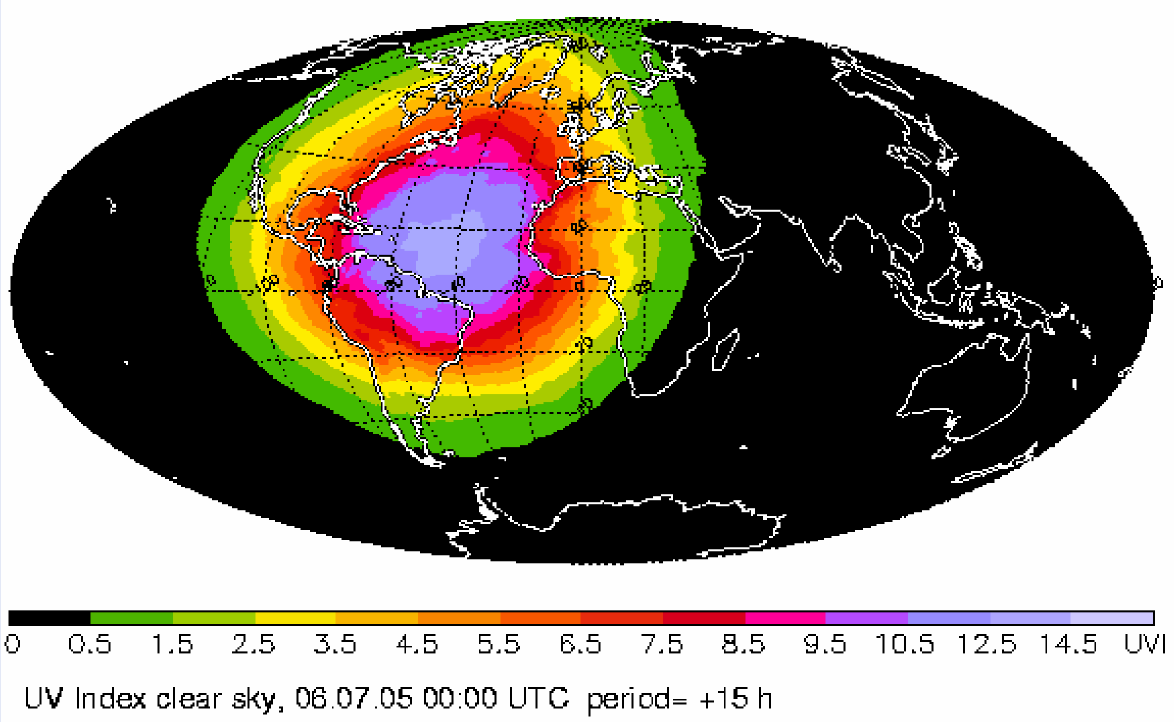
Set : clear sky, albedo, mean sea level
Variable : AOD/SSA

Radiation transfer:

- lookup tables

Adjustment for
- aerosol optical depth (AOD)
- single scattering albedo (SSA)

Examples of UV Index Calculation and Derived Products



Set : clear sky, albedo
Variable : AOD/SSA, topography

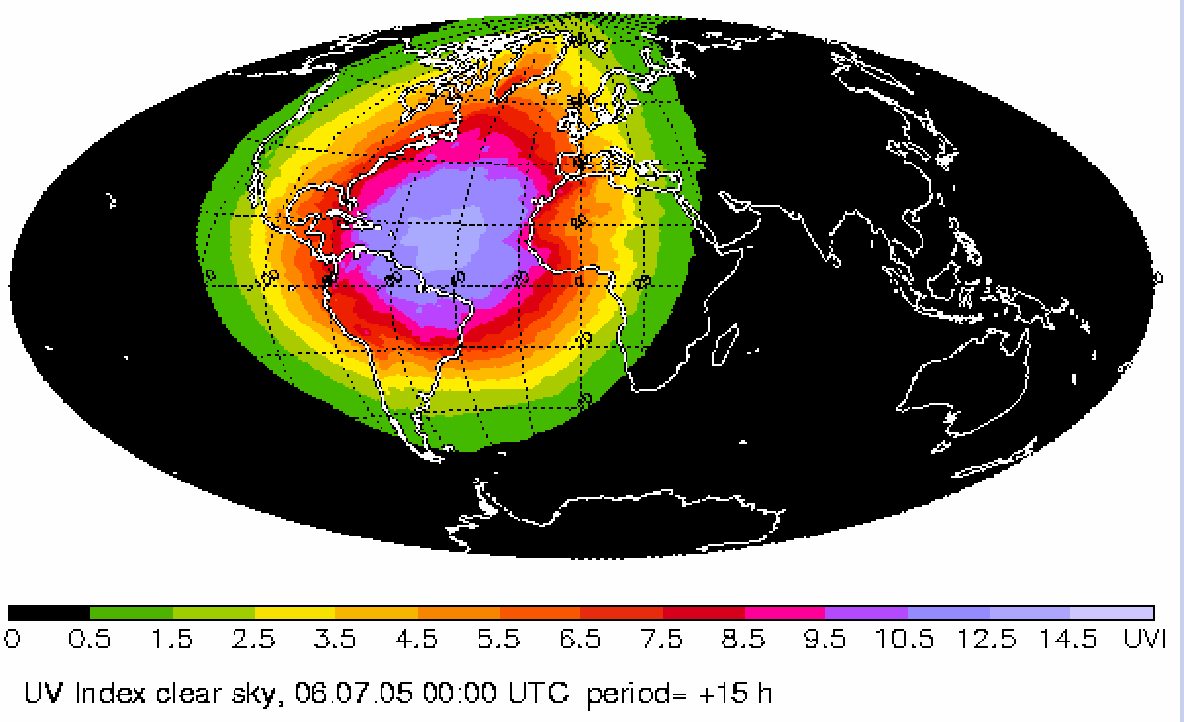
Radiation transfer:

- lookup tables

Adjustment for

- AOD and SSA
- altitude a.m.s.l

Examples of UV Index Calculation and Derived Products



Radiation transfer:

- lookup tables

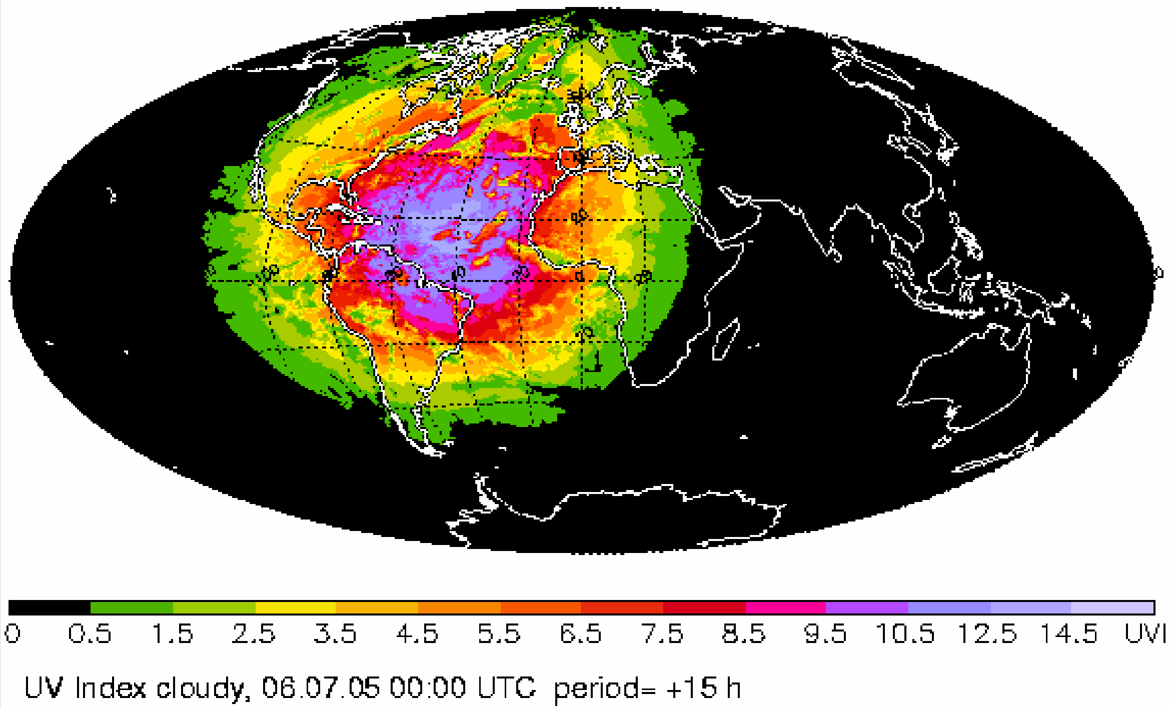
Adjustment for
- AOD and SSA
- altitude a.m.s.l
- albedo

UV Index clear sky

Set : clear sky
Variable : AOD/SSA, topography, albedo

Deutscher Wetterdienst

Examples of UV Index Calculation and Derived Products



Radiation transfer:

- lookup tables

Adjustment for

- AOD and SSA
- altitude a.m.s.l
- albedo

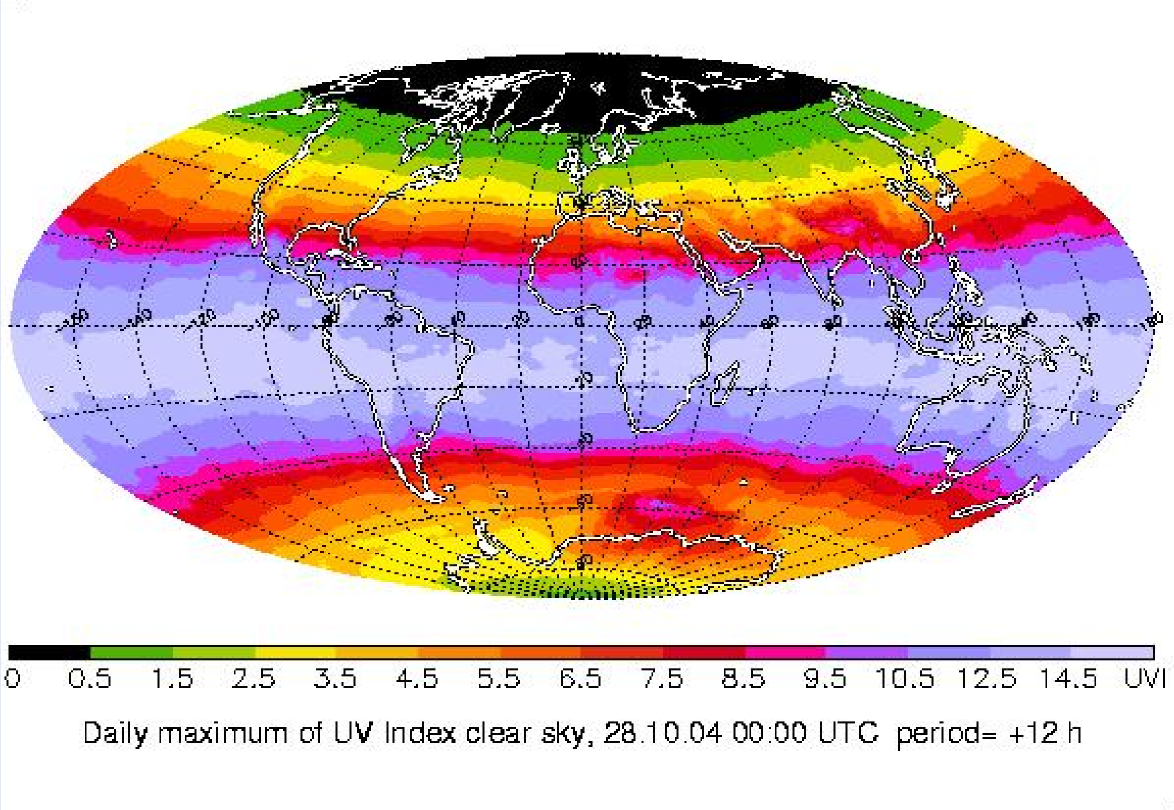
UV Index clear sky

- CMF

UV Index cloudy

Set : ---
Variable : AOD/SSA, topography, albedo, clouds

Examples of UV Index Calculation and Derived Products



Daily Maximum of UV Index clear sky

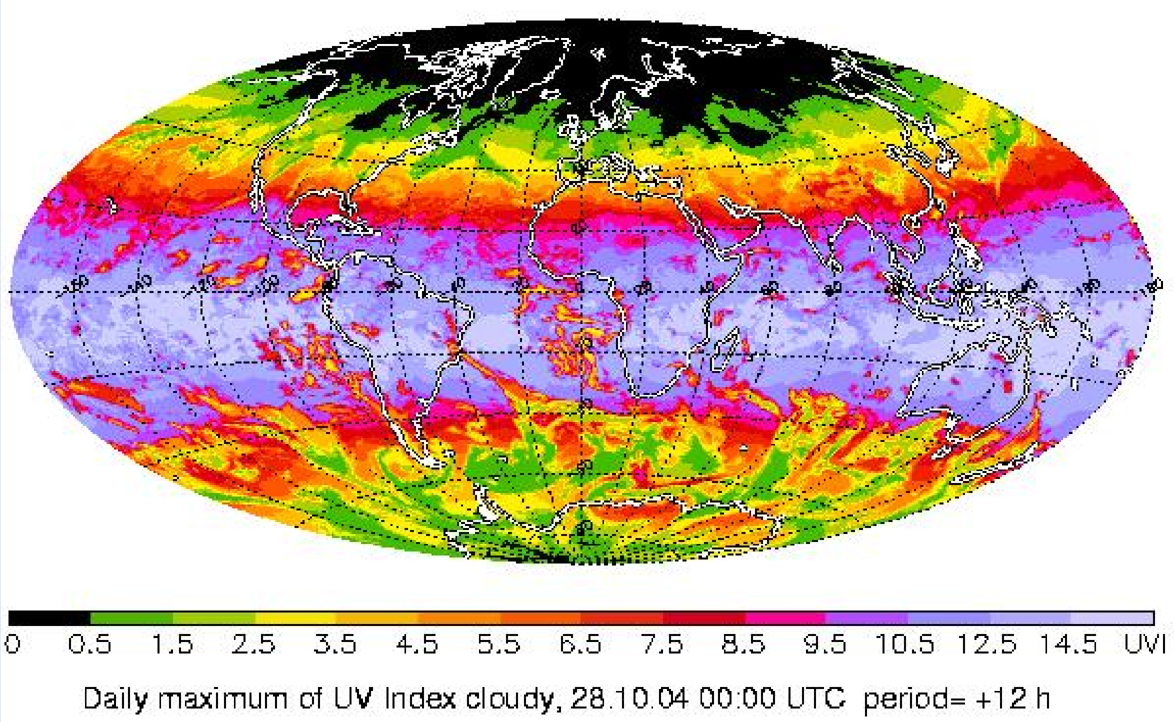
- reassembly of hourly data

Antarctic Ozone Hole:

additional effects:

- sun elevation mid spring
- albedo of snow/ice

Examples of UV Index Calculation and Derived Products



Daily Maximum of UV Index cloudy

- reassembly of hourly data

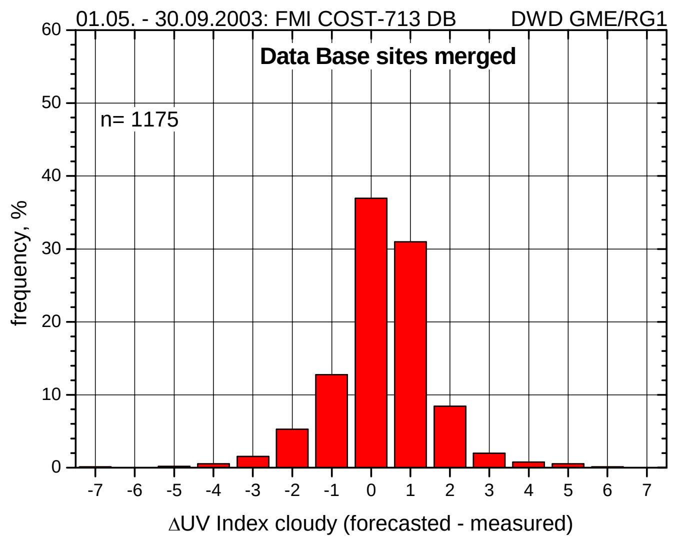
Antarctic Ozone Hole:

additional effects:

- sun elevation mid spring
- albedo of snow/ice
- in essential parts masked by clouds

Verification of forecasted UV Index

Measured UV Index: FMI COST-713 UV Index data base: 21.11.03



sites merged:	11	
co-ordinates:	Europe	
time series:	01.05. - 30.09.2003	
measurements:	1175	
	UVI	ozone, DU
measured mean:	5.23	323.6
forecasted mean:	5.50	331.7
bias:	+0.27	+8.1
rms error:	1.29	18.6
correlation:	0.88	.88

Acknowledgement: Thanks to all contributors and to FMI hosting the data base

Conclusion

- Aerosols can influence the UV Index up to an amount comparable to that of day to day changes in ozone column.
- UV Index forecasting is prepared to account for aerosol effects.
- GEMS could be a source providing operationally:
  - current values of aerosol optical depth and aerosol type as near real time assimilated fields of aerosol properties having a global coverage.
  - future: forecasts.
- The largest uncertainties are due to cloudiness.
  - Improvements for the future will be possible.
  - COST-726 on UV climatology and trends can contribute to more accurate Cloud Modification Factors.

WMO EC-LV (2003) approves a UV Index function for RSMC Offenbach