Spatial distribution of UVI

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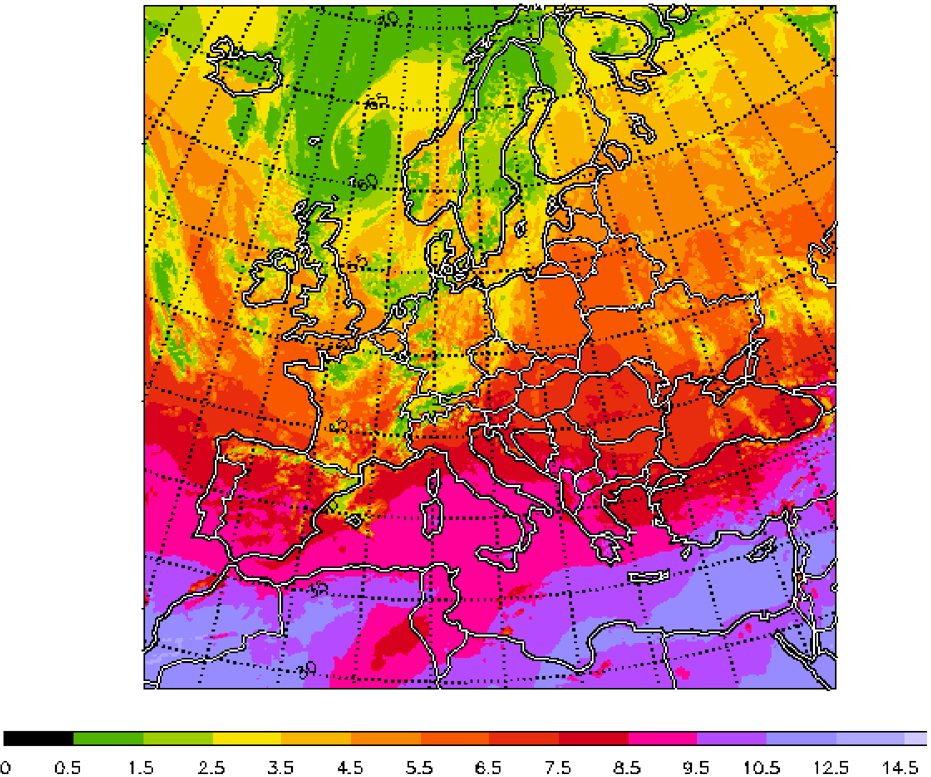
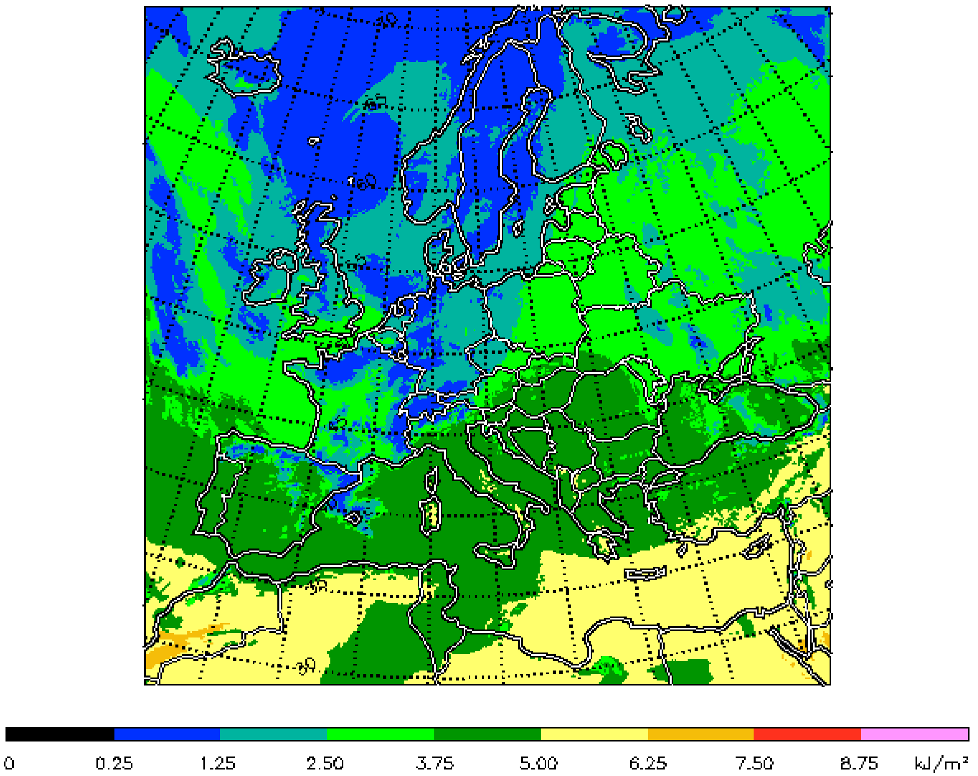
UVery on the basis of dwd forcasted ozone, cloudiness and snow, daily values



Daily maximum of UV Index cloudy, 16.08.07 00:00 UTC period= +12 h

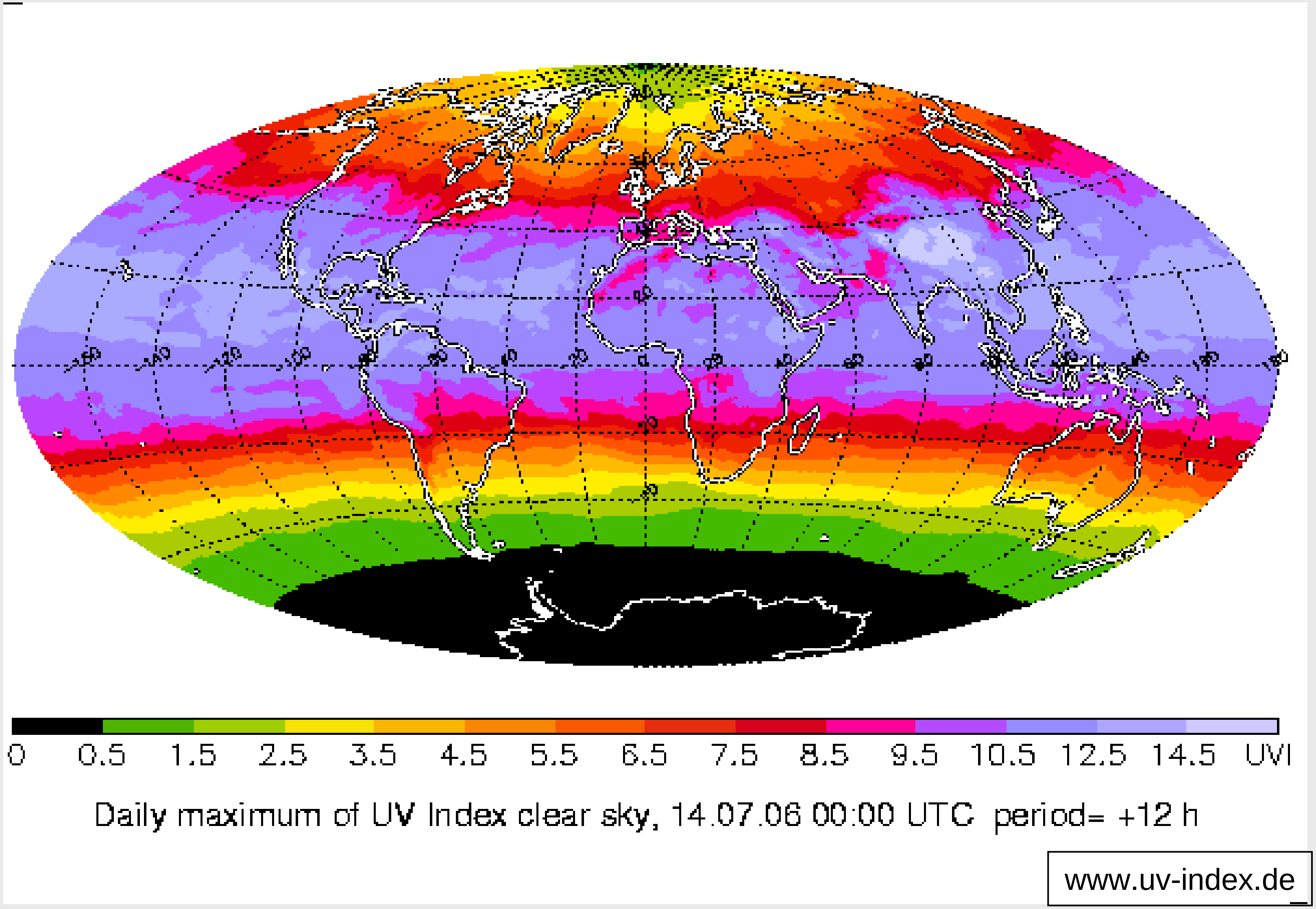


Erythemal effective UV dose cloudy, 16.08.07 00:00 UTC period= +12 h

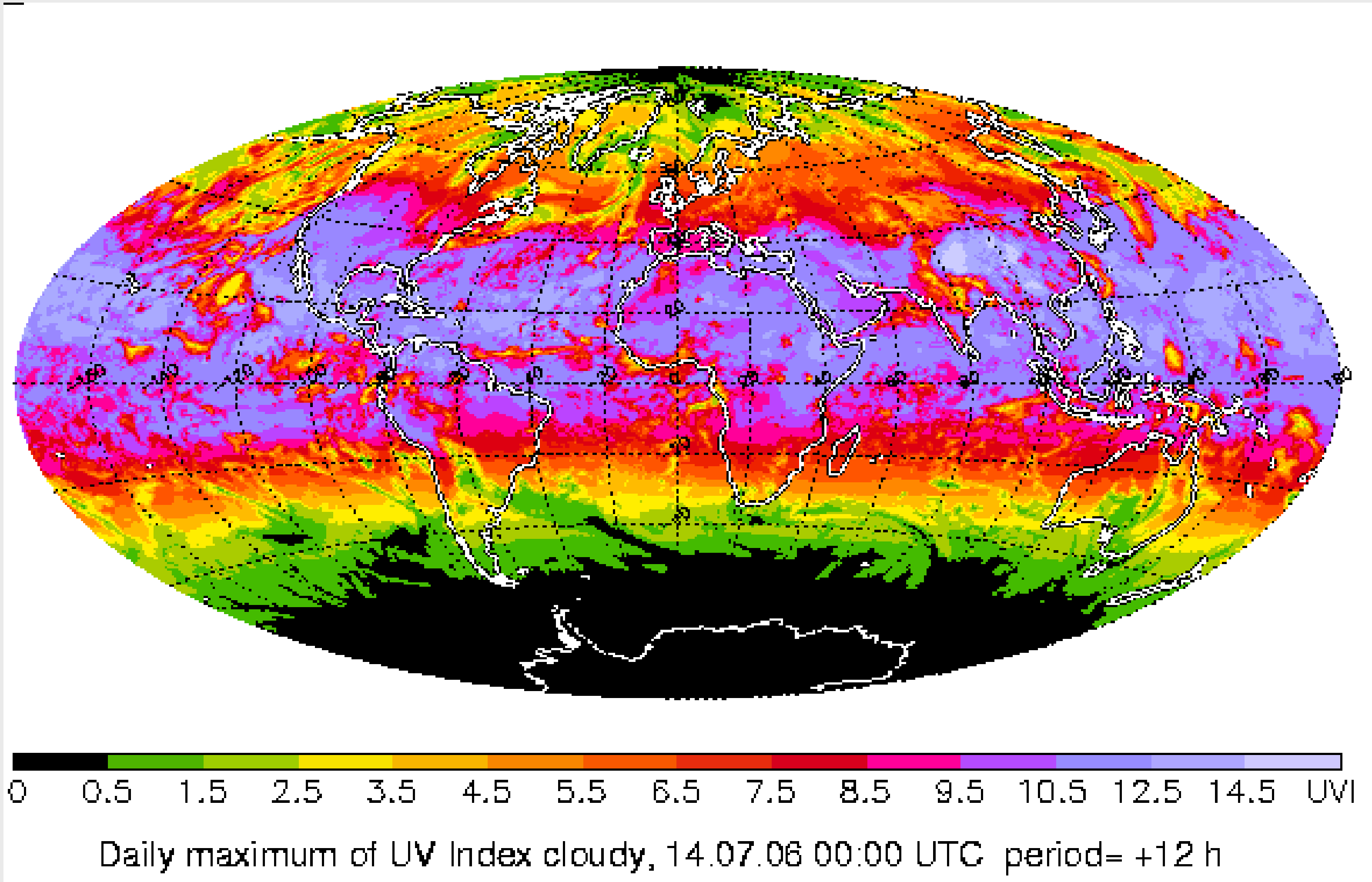
Staiger a. Koepke, 2005, Meteorol. Z.

http:// orias.dwd.de/promote/index.jsp

Example UVI. North summer, cloudfree



Example UVI north summer, with clouds



Staiger a. Koepke, 2005, Meteorol. Z.

http:// orias.dwd.de/promote/index.jsp

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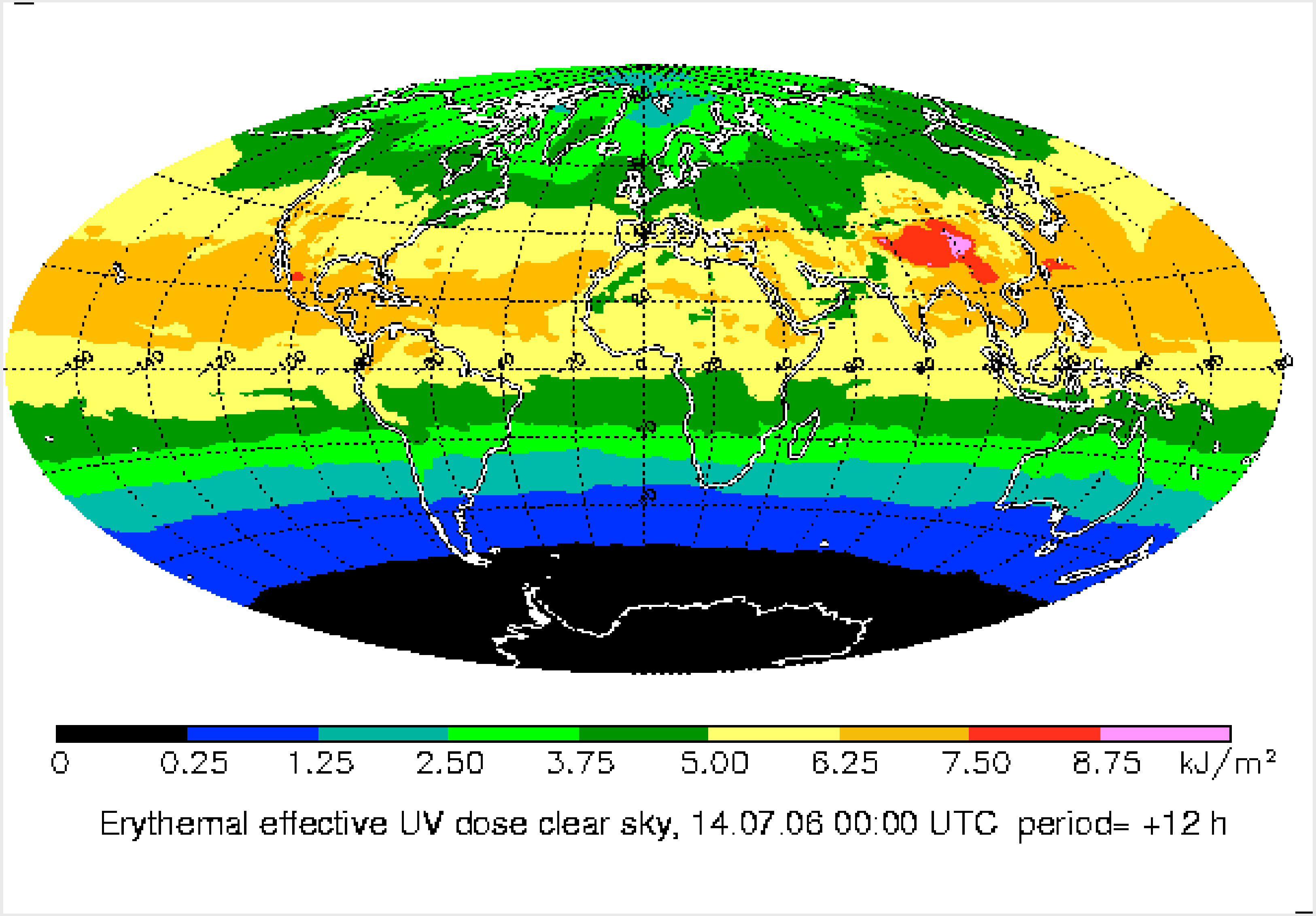
Daily dose UVery , without clouds



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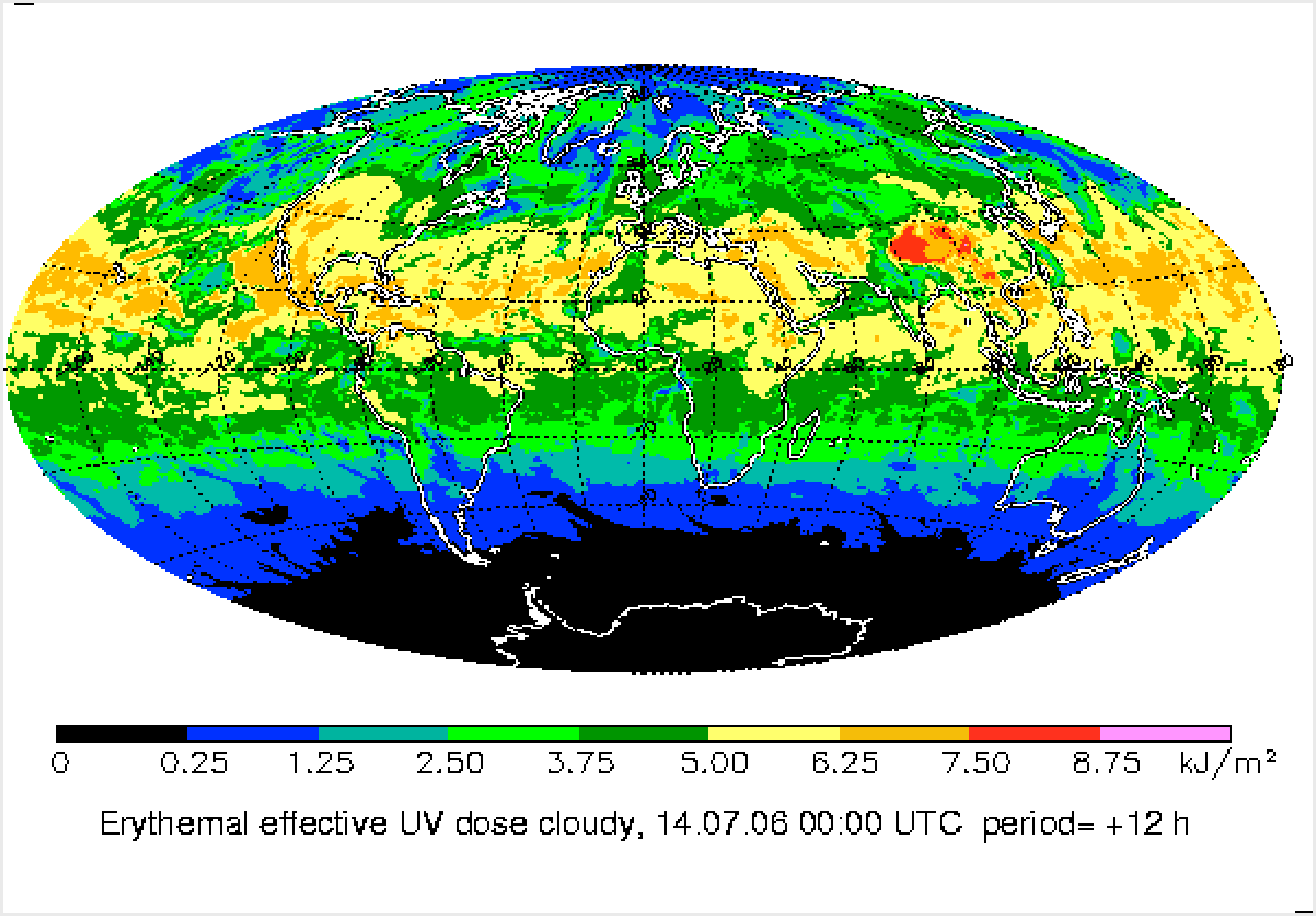
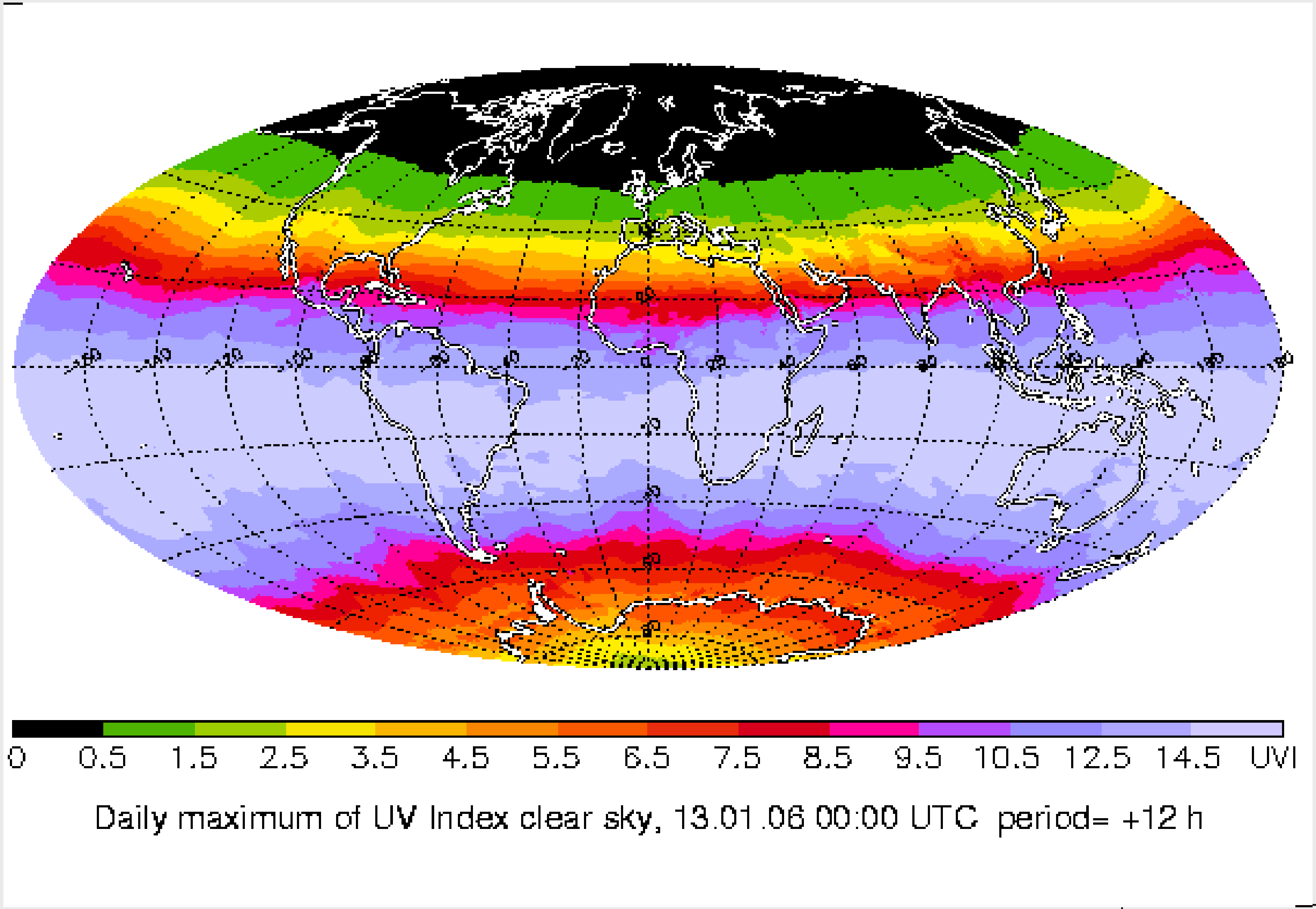
Daily dose UVery , with clouds

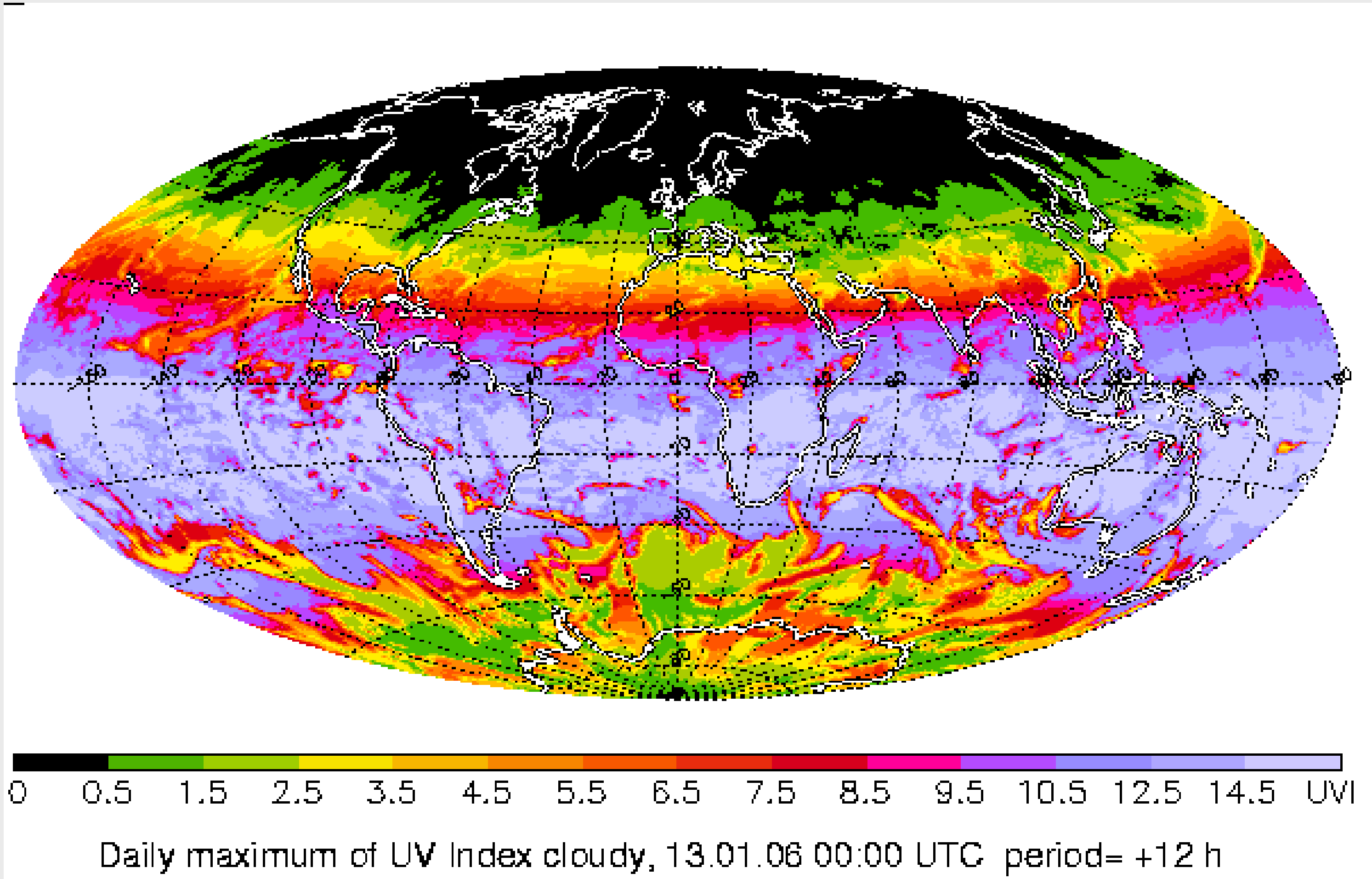


Example UVI. North winter, cloudfree



www.uv-index.de

Example UVI north winter, with clouds



orias.dwd.de/promote/index.jsp

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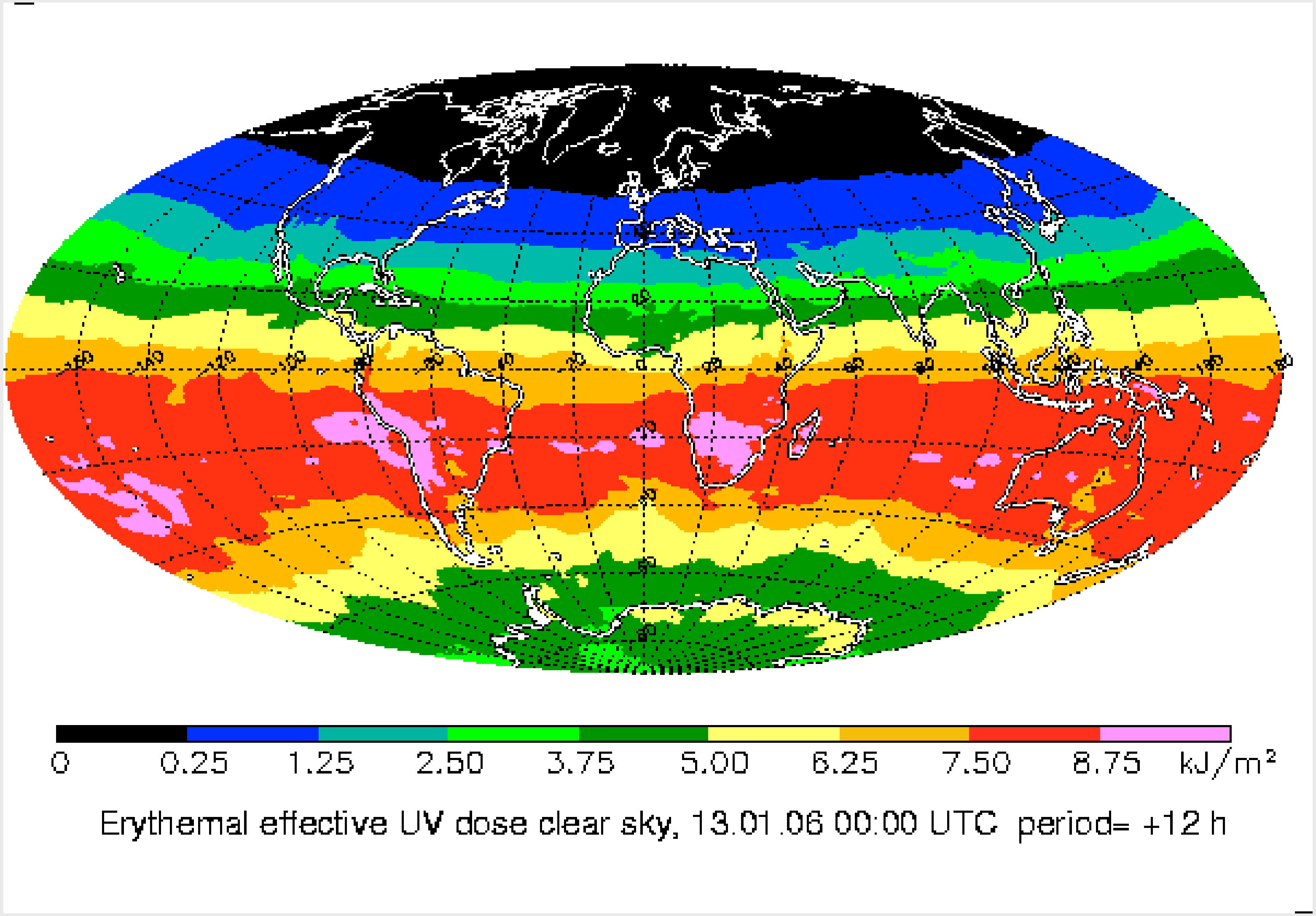
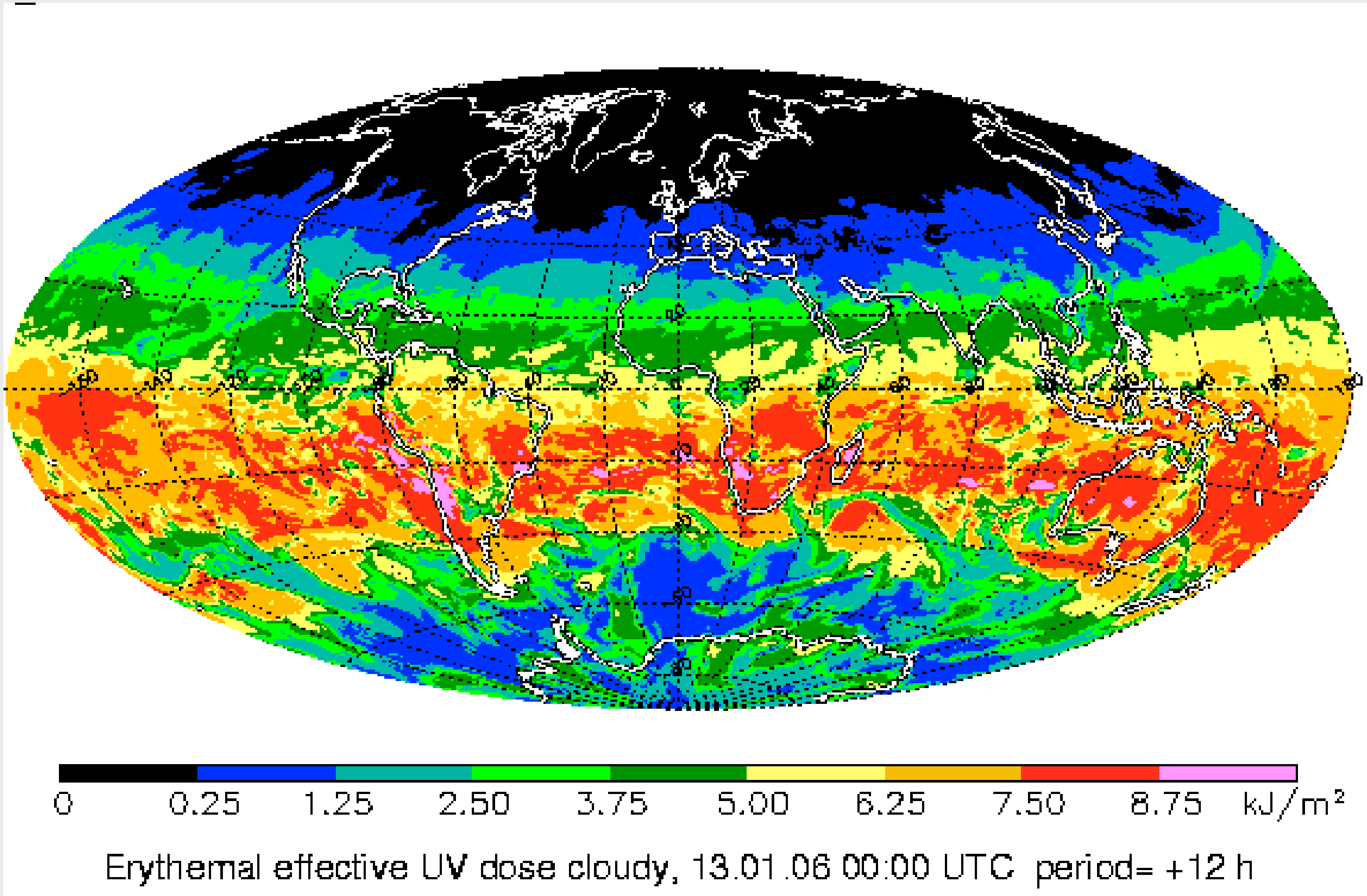
Daily dose UVery , without clouds



Daily dose UVery , with clouds



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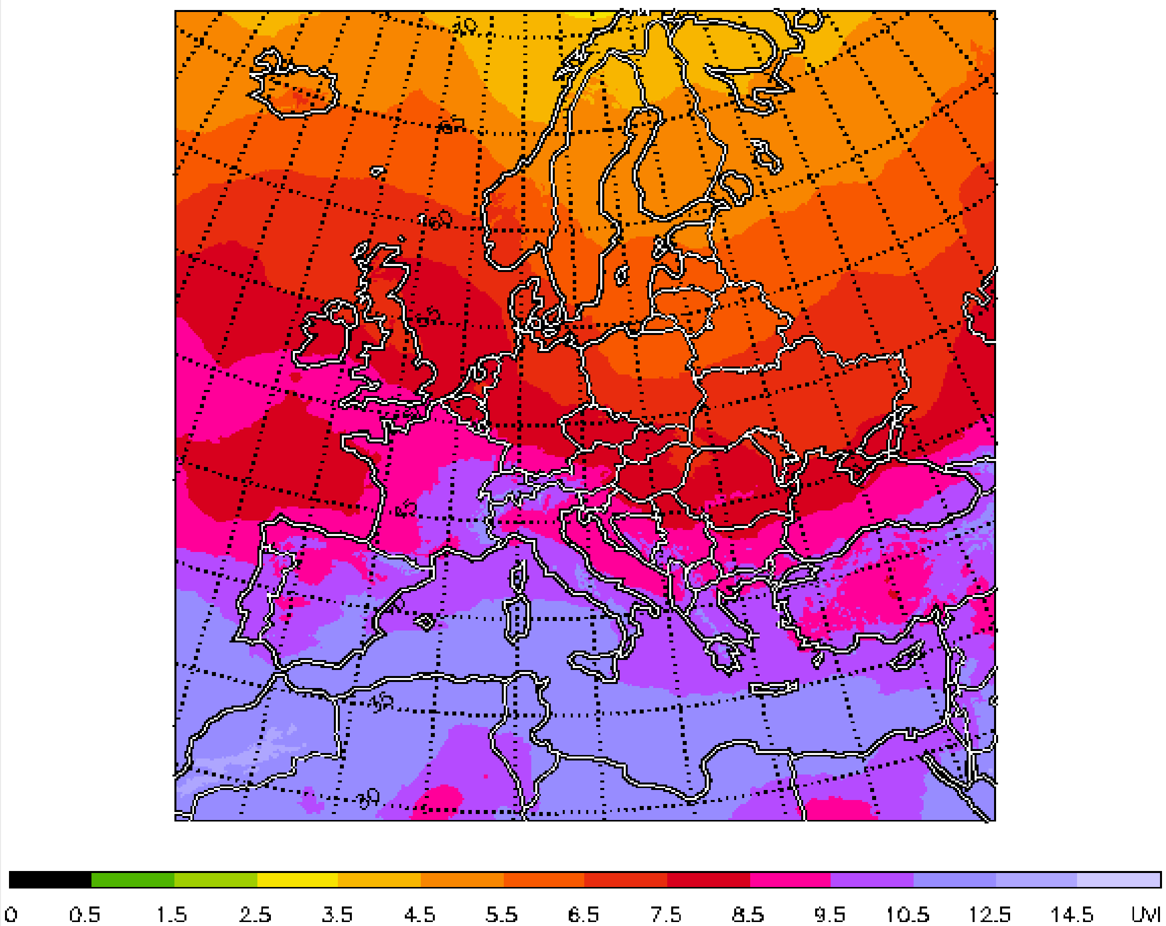
Example for UVI Europe, cloudfree



Daily maximum of UV Index clear sky, 28.06.05 00:00 UTC period= +12 h

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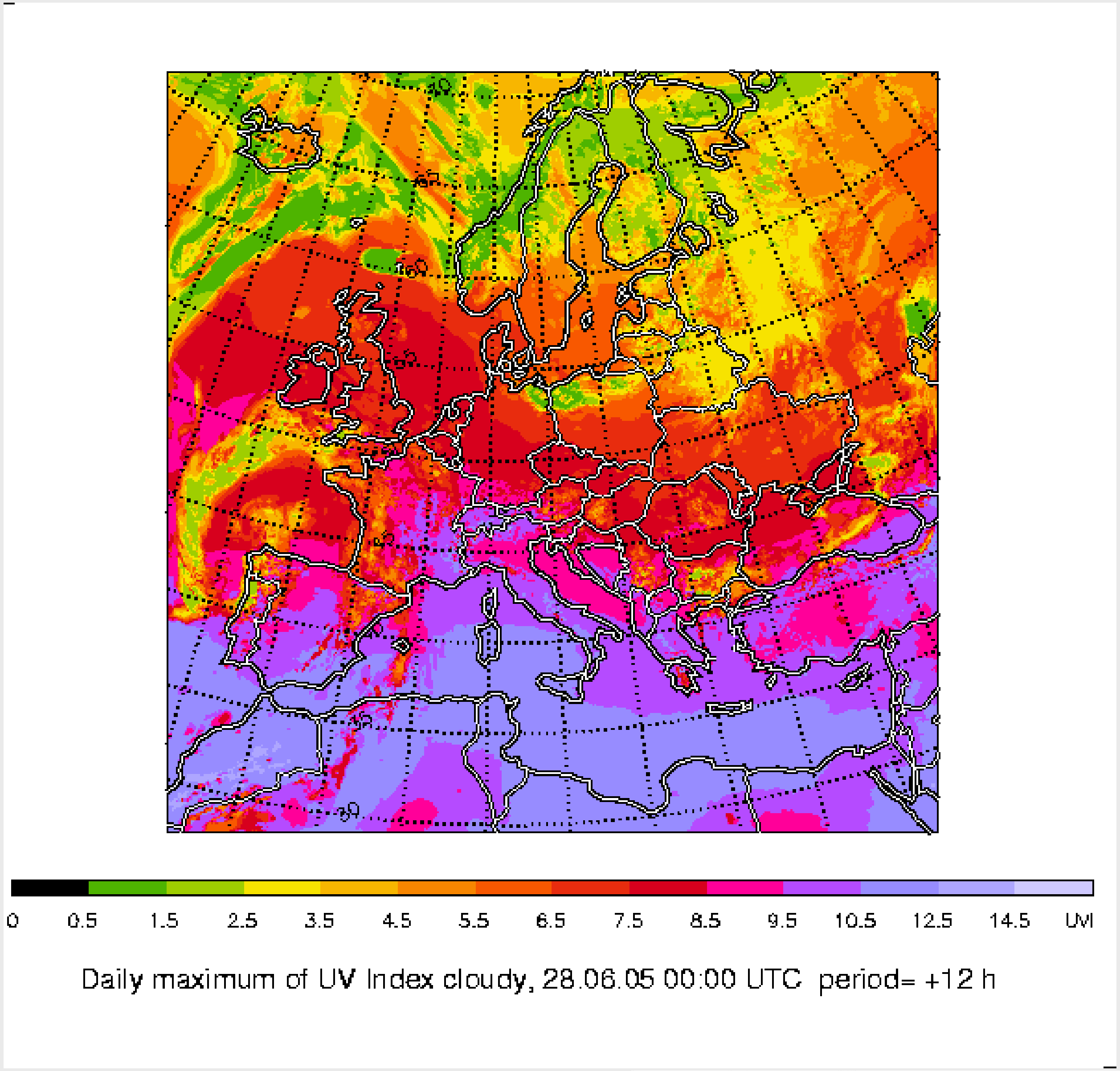
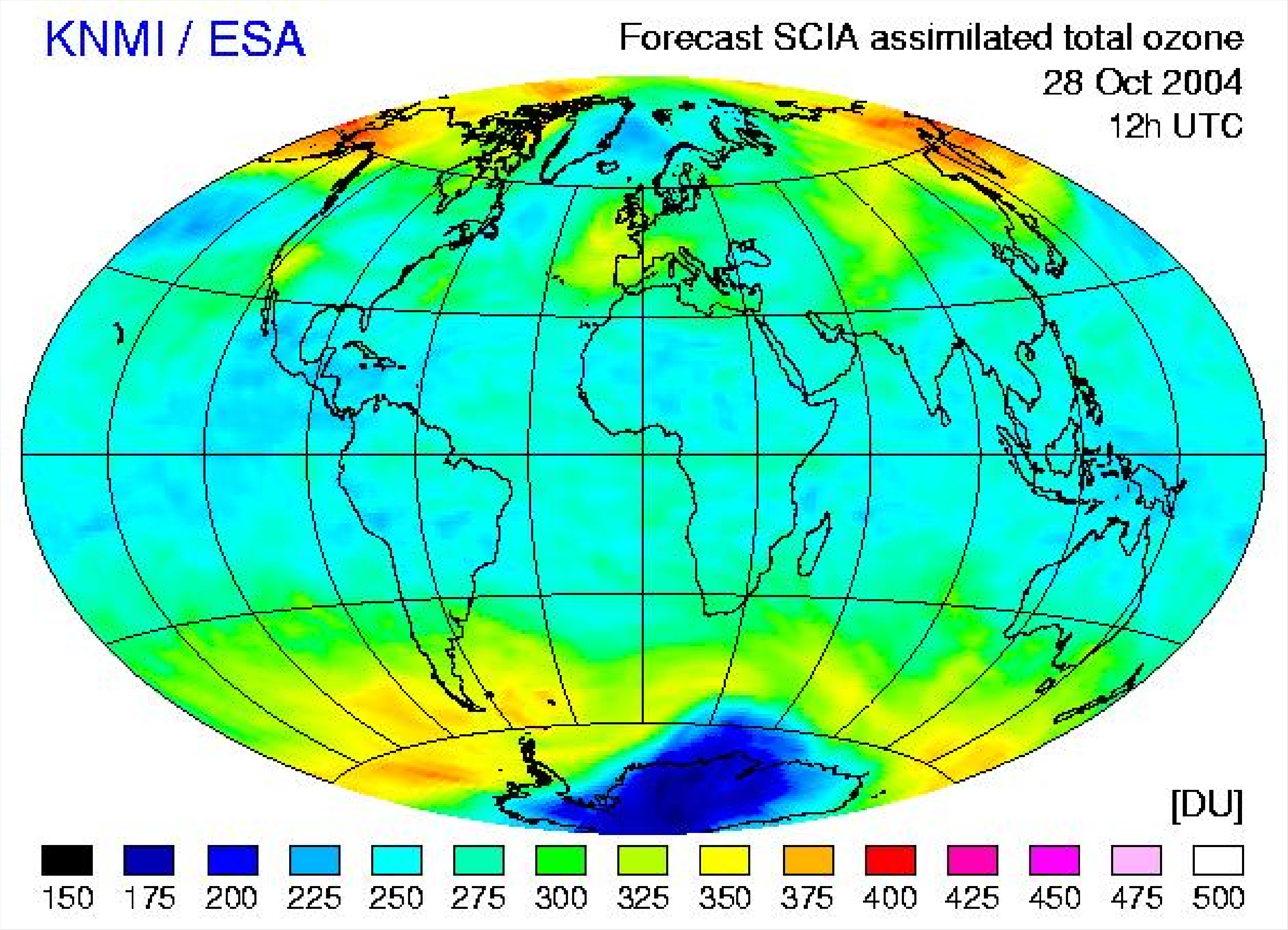
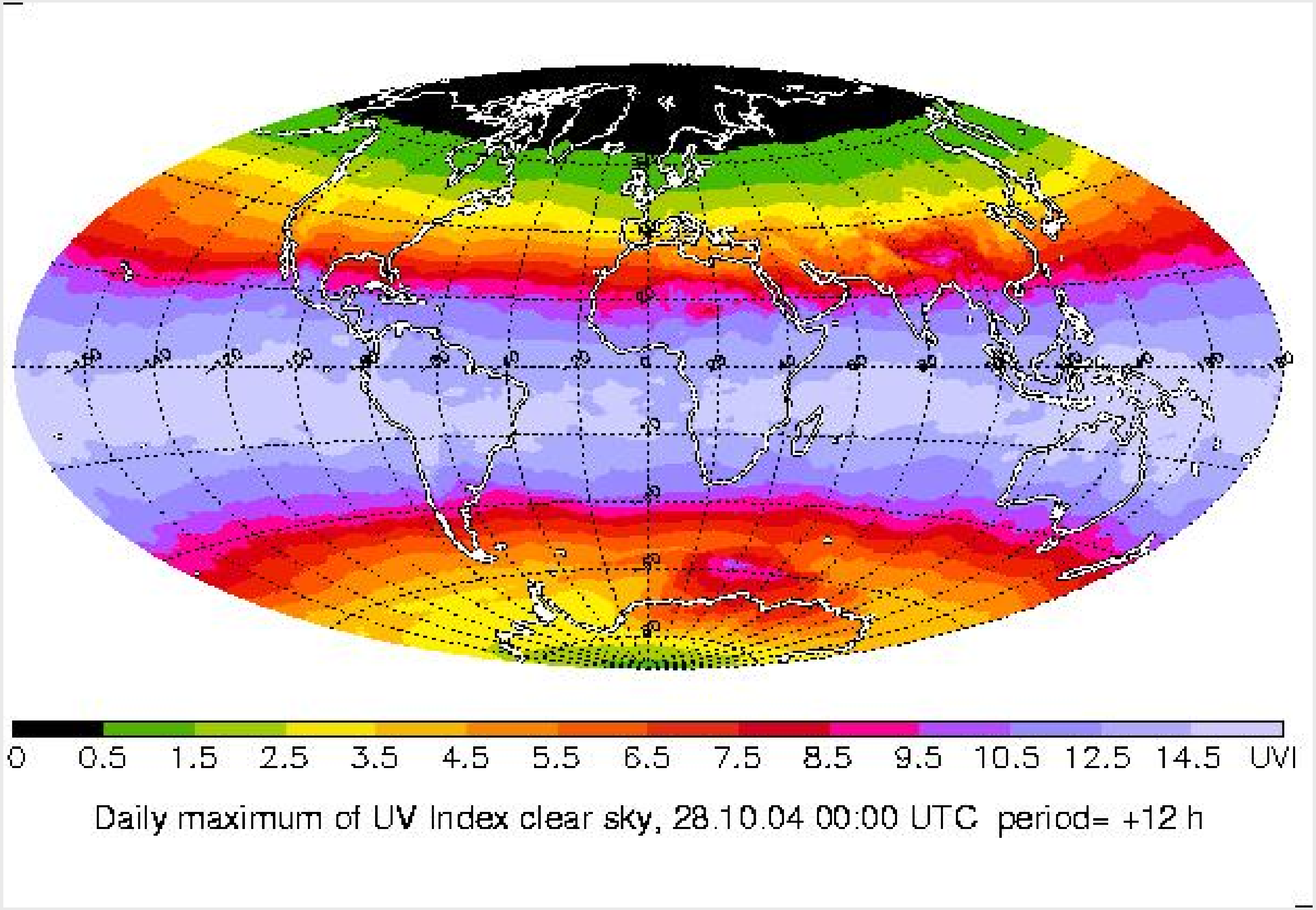
Example for UVI Europe, with clouds



Example ozone hole



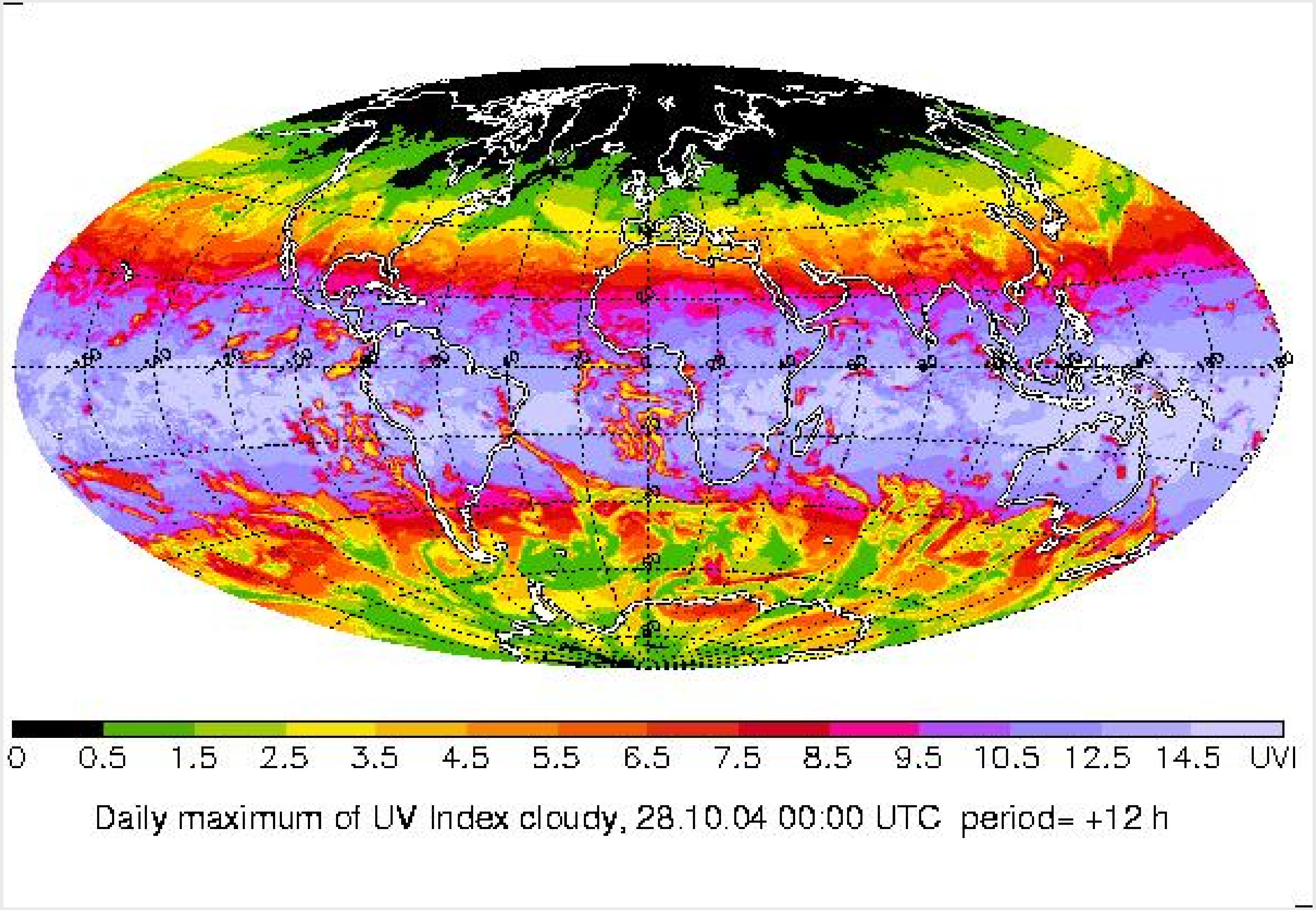
UVI at ozone hole, without clouds



DWD

2004

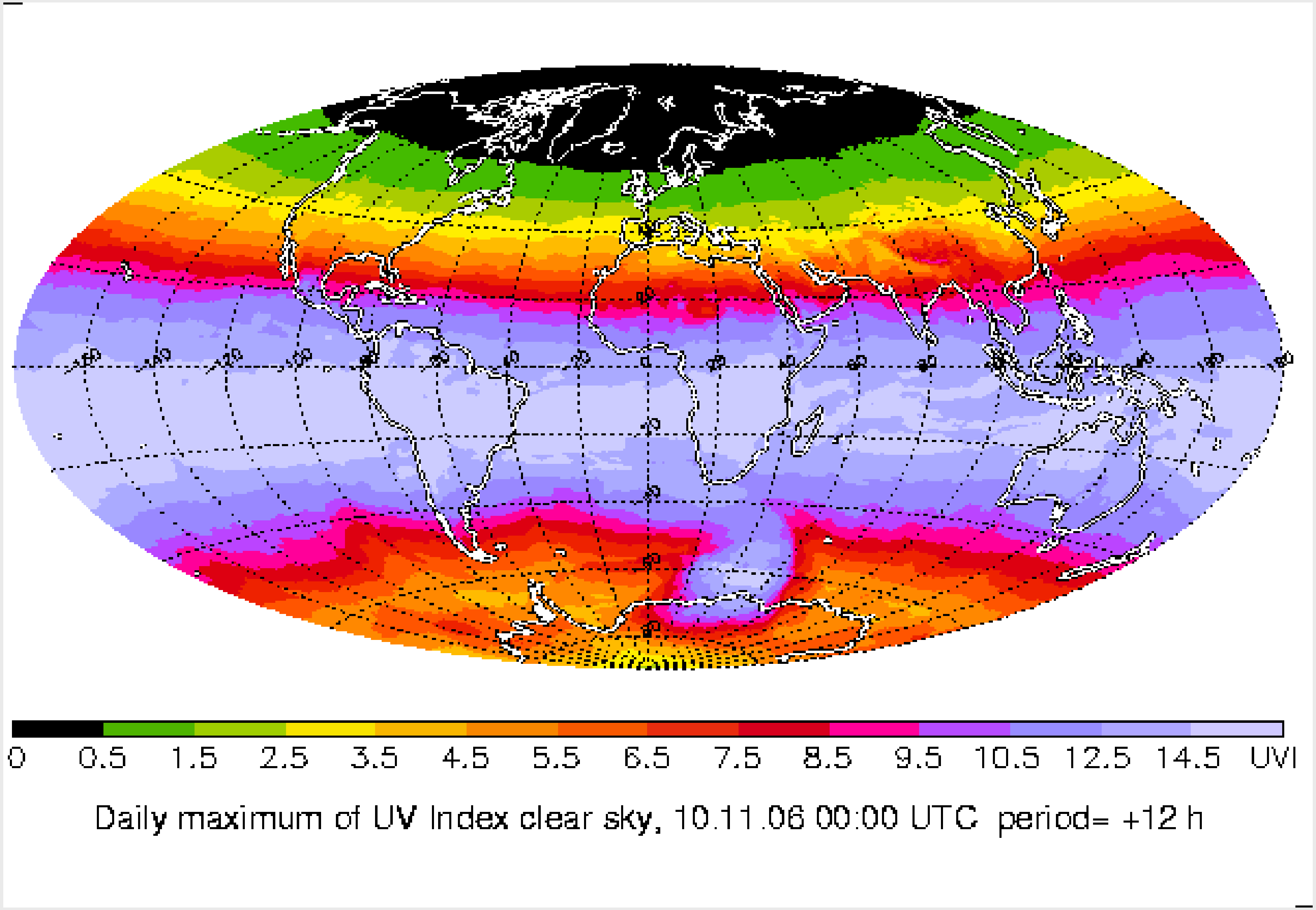
UVI at ozone hole, with clouds



DWD

2004

UVI at ozone hole, without clouds



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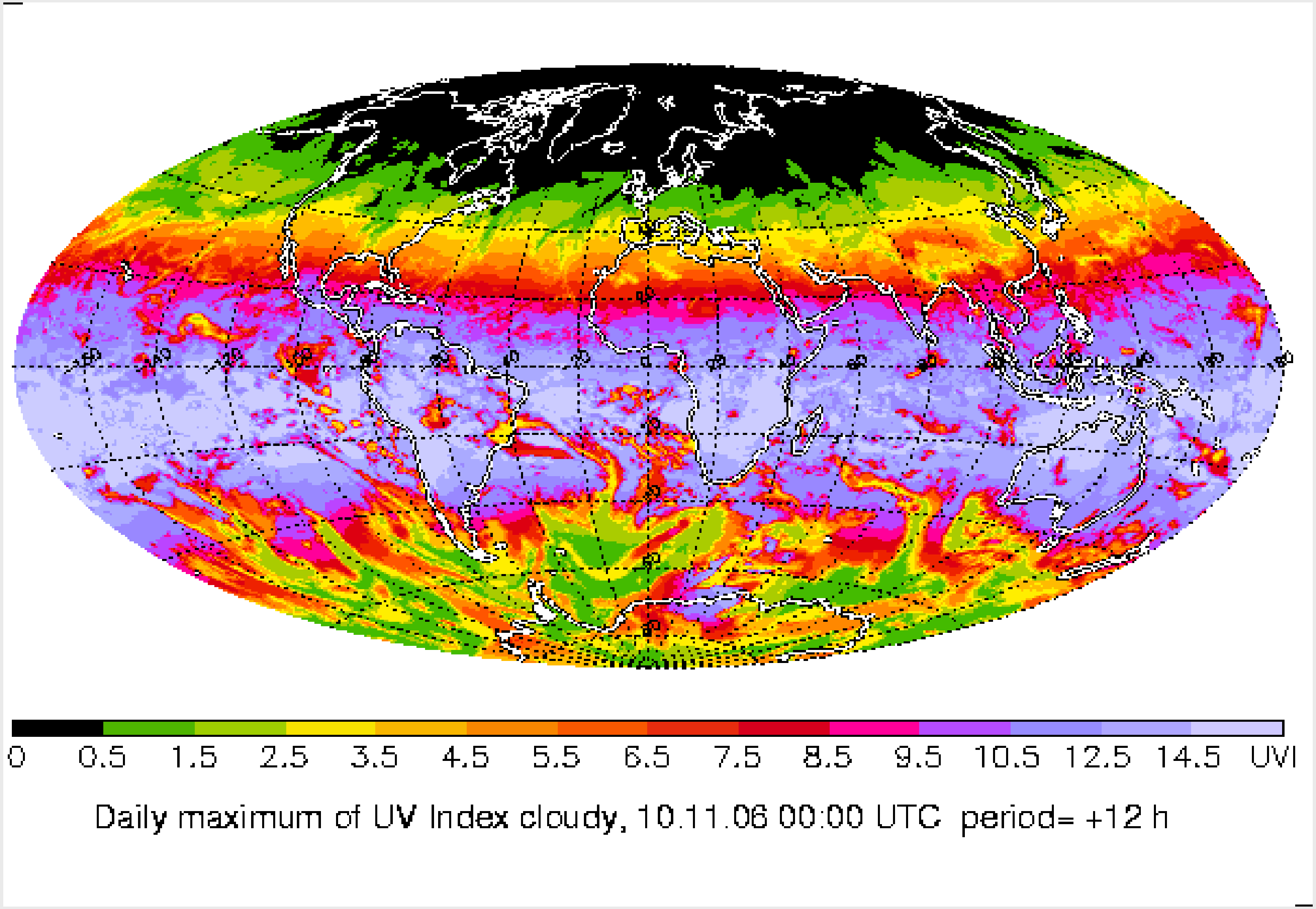
UVI at ozone hole, with clouds



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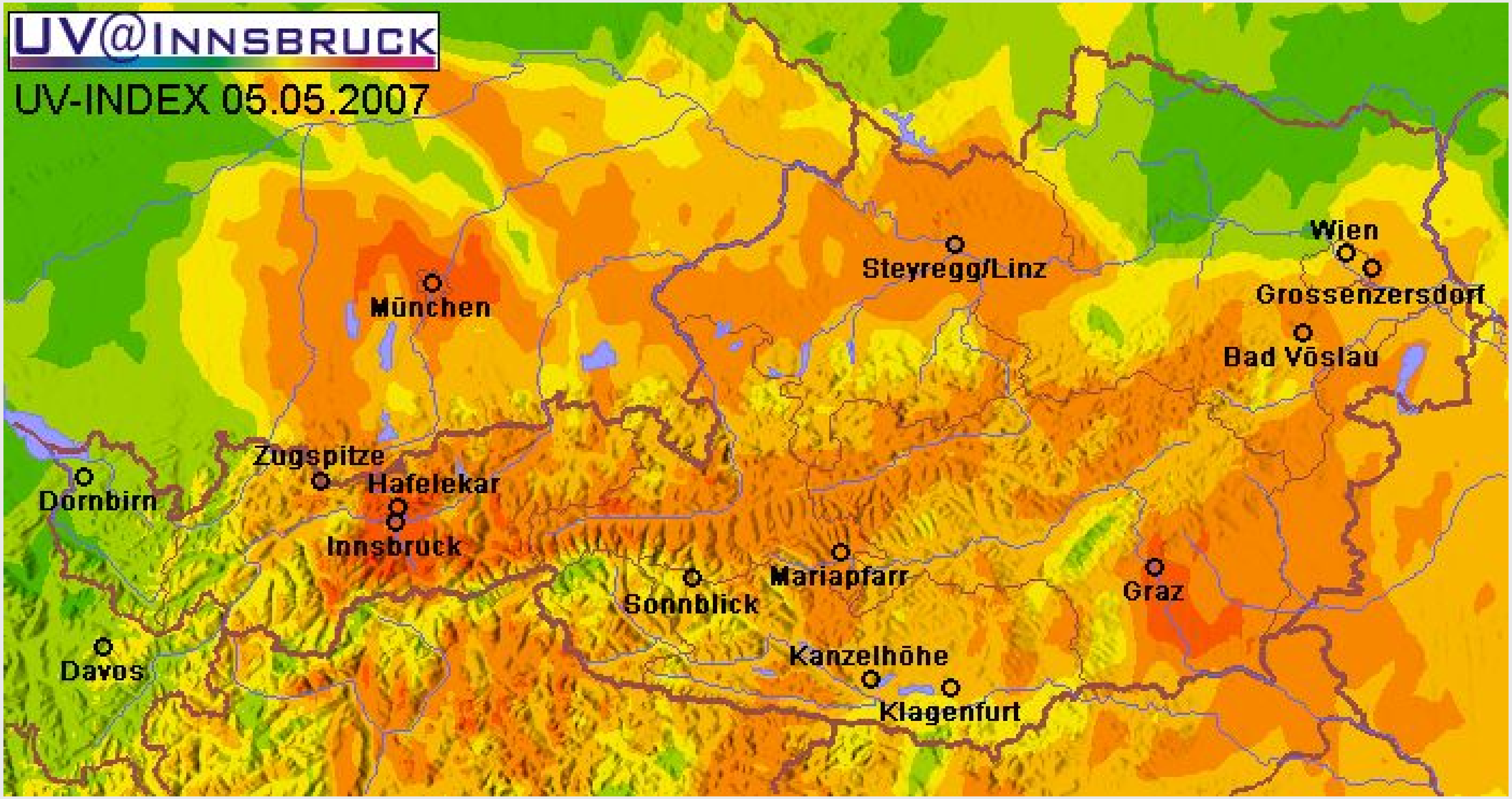
Example for UV-map Austria and southern Bavaria



www.uv-index.au

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Modelling UV radiation

Modelling UV:

- Mathematical procedure to solve radiation transfer equation (RTE)
- Data of extraterrestrial sun
- (Actual) data of relevant atmospheric parameters

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Radiative Transfer:

Description of scattering and absorption (and emission) processes of radiation in the atmosphere

Radiative Transfer Equation

Mathematical description of scattering and absorption processes ; Solution leads to the radiation field:

$$\mu \frac{dI(\tau,\mu,\varphi)}{d\tau} = I(\tau,\mu,\varphi) - \frac{\omega_0}{4\pi} \int_{4\pi} I(\tau,\mu',\varphi')\, P(\mu,\varphi;\mu',\varphi')\, d(\mu',\varphi') - \frac{\omega_0}{4\pi} \pi F_0\, P(\mu,\varphi;\mu_0,\varphi_0)\, e^{\frac{-\tau}{\mu_0}}$$

extinction

multiple scattering

scattering

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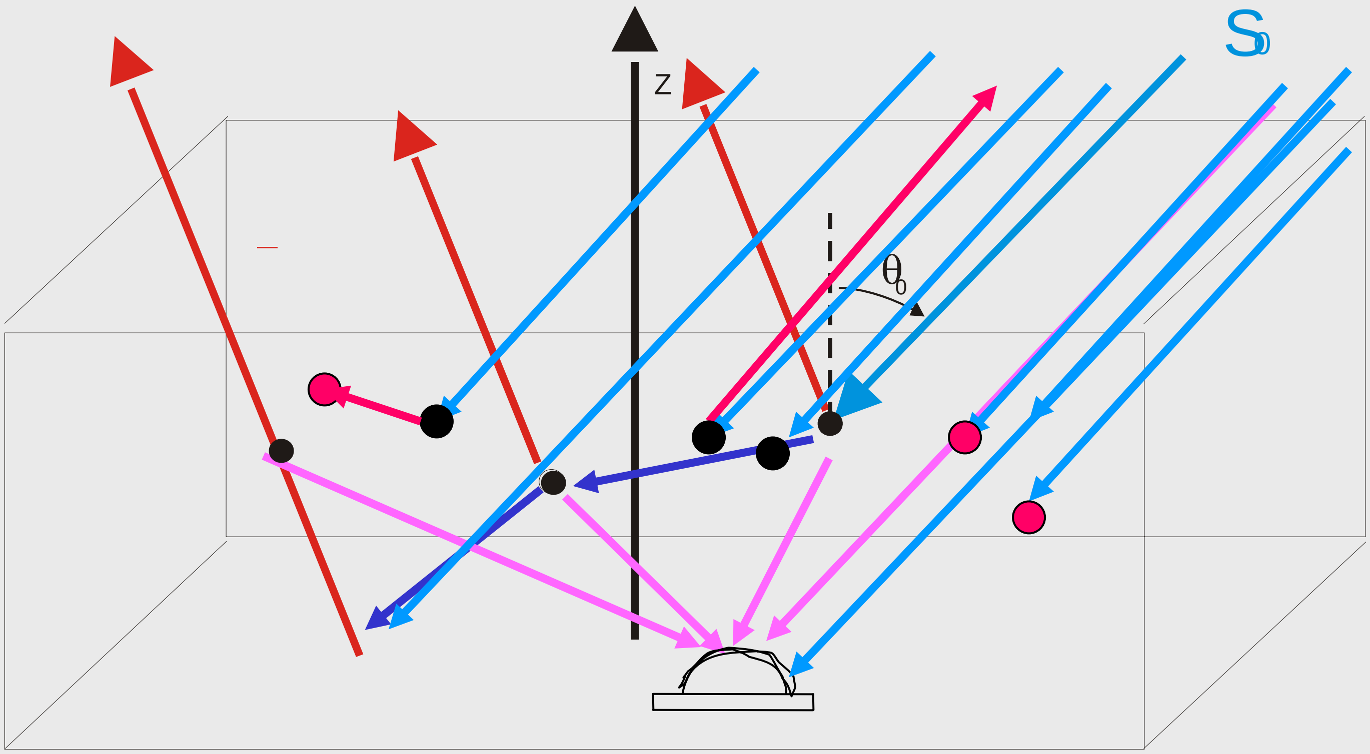
Multiple scattering and absorption



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Model types

	time [s] for one spectrum (UVI)
▪ Empirical-statistical models	10^{-3}
▪ Simple spectral model (Two stream)	10^{-1}
▪ Multiple scattering models (1-dim, spectral)	$10^{0} – 10^{+1}$
▪ Cloud algorithmus	10^{-2}
▪ Look up tables	10^{-6}
▪ 3-dimensional models	$10^{+3} – 10^{+4}$
▪ Irradiance on tilted surfaces	10^{+1} (10^{-3})

Typical modelling for UV:

1 dimensional, multiple scattering, spectral

1 dimension: Altitude, given as optical depth

horizontally homogenious

Multiple scattering: scattering processes, using scattering functions combinded from all scattering atmospheric parameters

absorption, using absorption coefficients from all absorbing atmospheric parameters

Spectral: scattering coefficient and function and absorption coefficient changes with atmospheric component and wavelength individually

(spectral modelling not as dense as Frauenhofer lines in the Sun)

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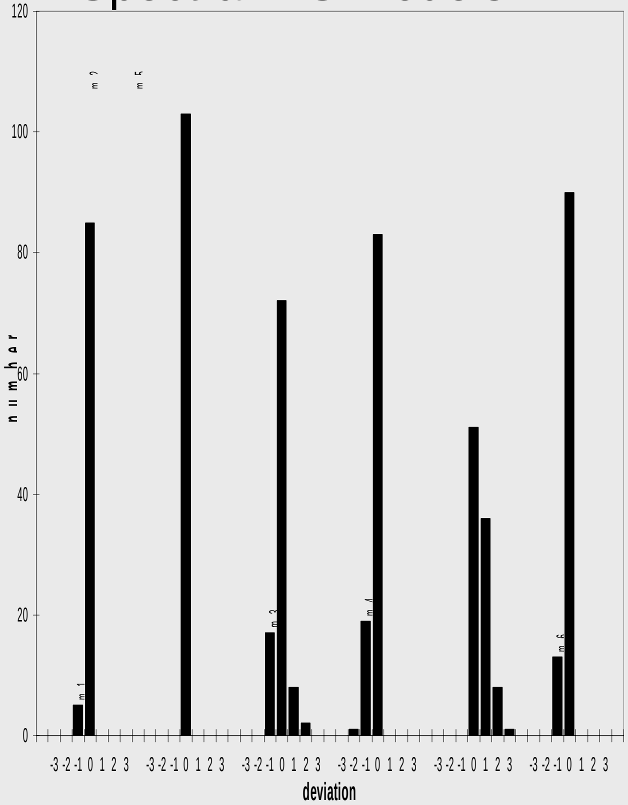
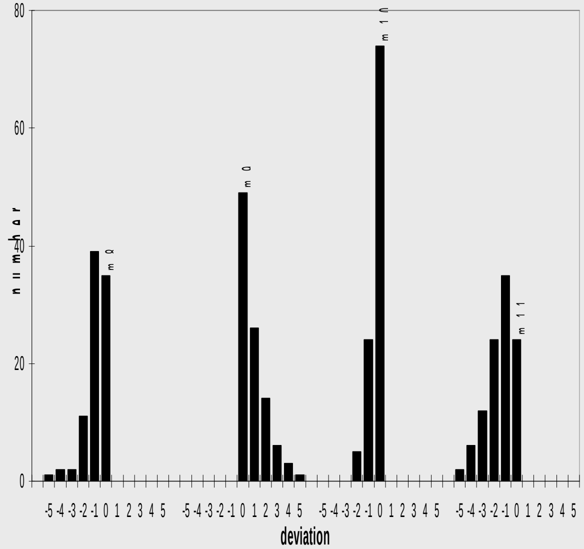
Comparison of UV models with fixed input parameters of 106 atmospheres and SZA

Koepke et al., 1998

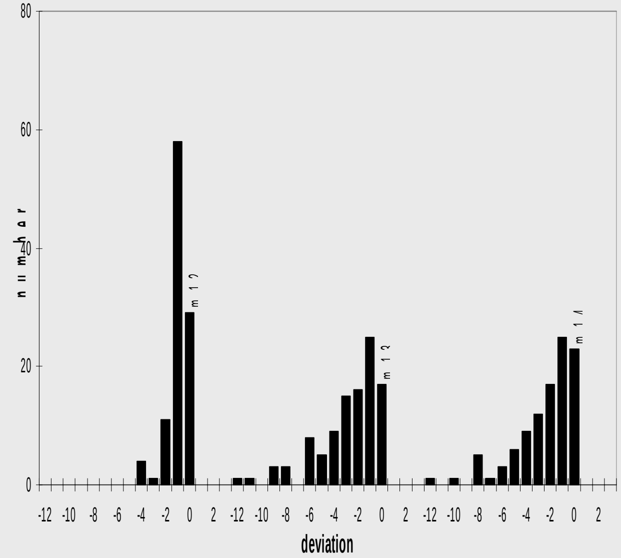
Spectral MS models



Fast spectral models



Empirical models



Deviation in UVI against average result of MS models

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Examples for 1 Dim MS UV- models

DISORT (DIScrate Ordinate Radiative Transfer)

GOMETRAN (Global Ozone Monitoring Experimant TRANsmission model)

SBDART (St Barbara DISORT)

STAR (System of Transfer of Atmospheric Radiation)

UVSPEC (improved DISORT)

TUV (Tropospheric Ultraviolet and Visible radiative transfer code)

Uncertainty of UVI due to quality of input data

adapted from Schwander et al. (1997)

		mean Δ UVI
Modell accuracy		2 %
Sun:	zenith angle ; Sun-Earth distance	0 %
	absolute solar irradiance	2 %
Ozone:	interpolation from station; Satellit: 3% = 9 DU	3 %
Trace gases: no information		3 %
Aerosol:	AOD and Absorption: measured at 330 nm	2 %
	only AOD 370 nm	5 %
	AOD 550 nm and aerosoltype from air mass	10 %
	fom visibility	30 %
	climatic mean	30 %
Albedo	summer	3 %
	variable snow conditions	10 %
clouds		
	CMF from cloudines	50 %
	CMF cloud in front of Sun or not	20 %
	CMF from measured solar irradiance	10 %
	clouds in 3D model: How to describe actual clouds??	??

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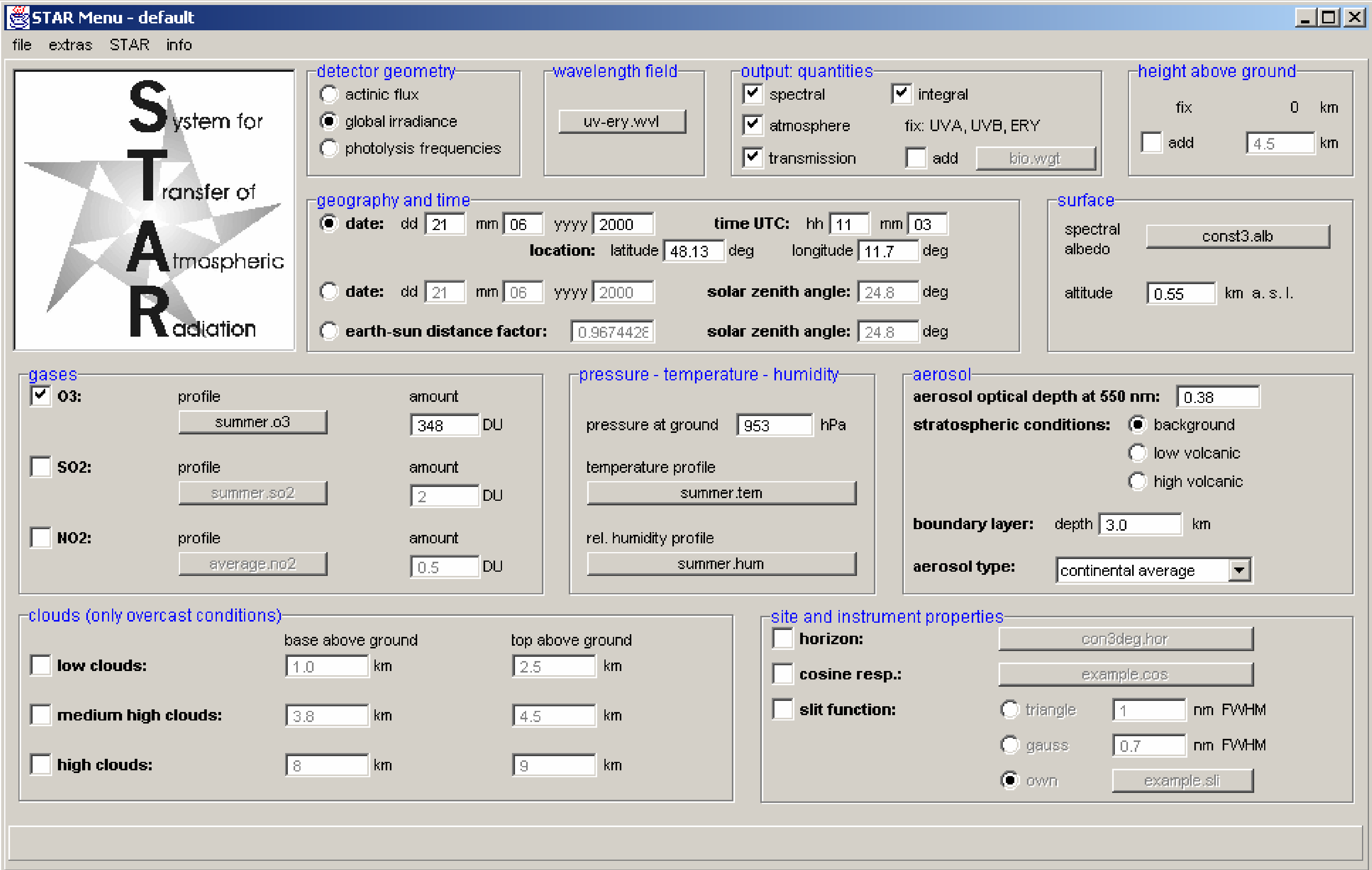
STAR: System for the Transfer of Atmospheric Radiation



References STAR:

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•Mech, M. and P. Koepke, 2004, Model for UV irradiance on arbitrarily oriented surfaces, Theor Appl Climatology, 77(3-4),151-158

•Ruggaber, A., R. Dlugi, and T. Nakajima, 1994, Modelling of Radiation Quantities and Photolysis Frequencies in the Troposphere, J. Atmos. Chem., 18, 171-210

•Schwander, H., A. Kaifel, A. Ruggaber, and P. Koepke, 2001, Spectral radiative transfer modeling with minimized computation time by use of neural-network technique, Appl. Opt., 40(3), 331-335

•Schwander, H., P. Koepke, A. Kaifel and G. Seckmeyer, 2002, Modification of spectral UV irradiance by clouds, J. Geophys. Res., 107 (D16), art. no.-4296

http://www.meteo.physik.uni-muenchen.de/strahlung/uvrad/Star/STARinfo.htm

UVI Forecast

•Staiger. H and H. Claude. 2002. GME Large-Scale UV index Forecasts. In: Quarterly Report of the German NWP system No1. Part1. 12-25

•Staiger, H and P. Koepke, 2005, UV Index forecasting on a global scale, Meteor. Z., 14 (2), 259 – 270

•Reuder, J., P. Koepke, and M. Dameris, 2001, Future UV radiation in Central Europe modelled from ozone scenarios, J. Photochem. Photobiol., B: Biology, 61 (3), 94-105

Cloud modification factor: CMF

$$CMF = \frac{E_{cld}}{E_{clea}}$$

Values from measurements cloudy and clear

or modelled for clear to get the same conditions

Description of clouds for use of CMF:

Cloudiness: x/8 or x/10

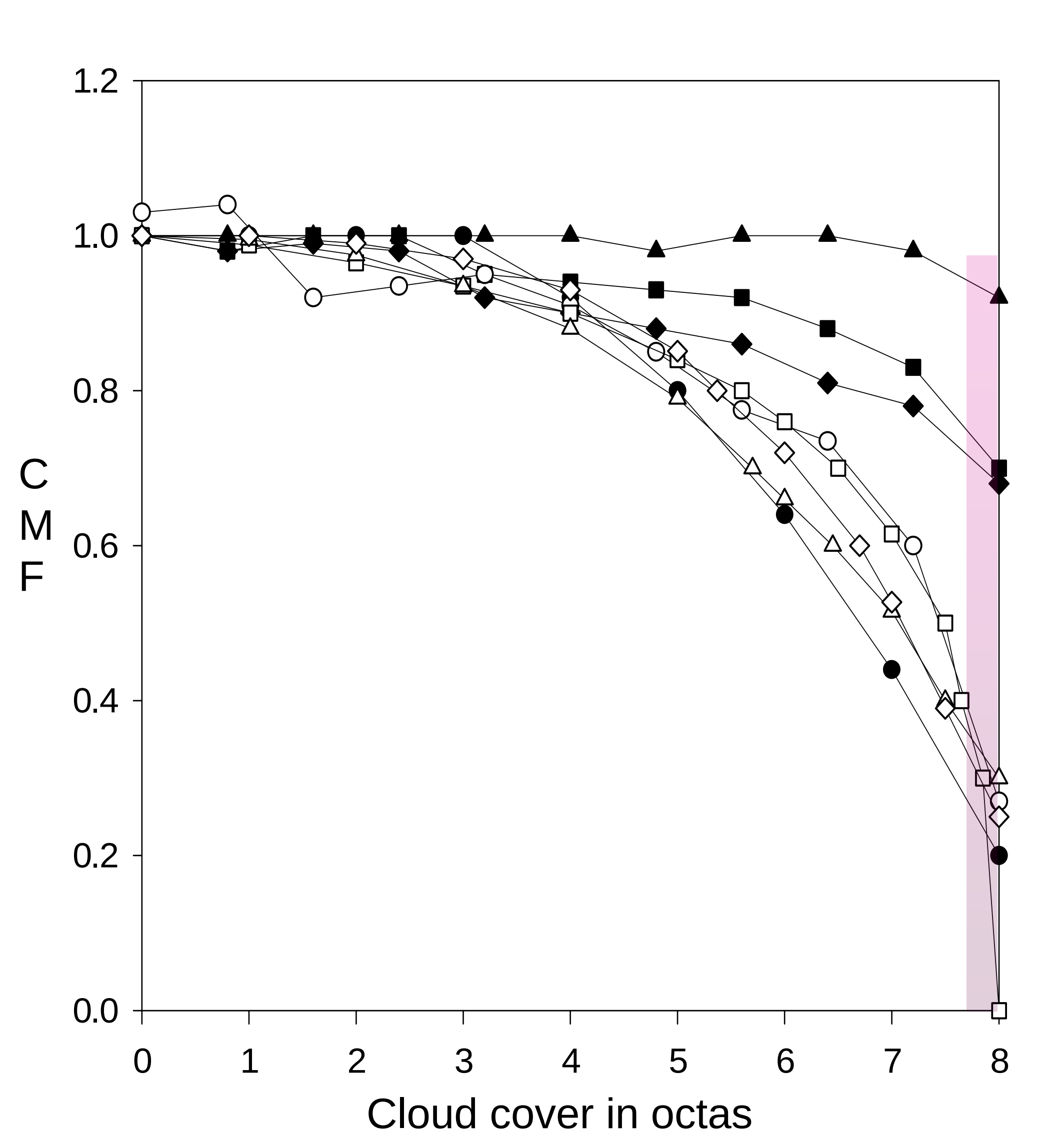
cloudiness for low, medium, high clouds

cloud in front of the Sun

Cloudiness plus solar global irradiance

Schwander et al., 2002

Effects of clouds (reduction against clodfree conditions)

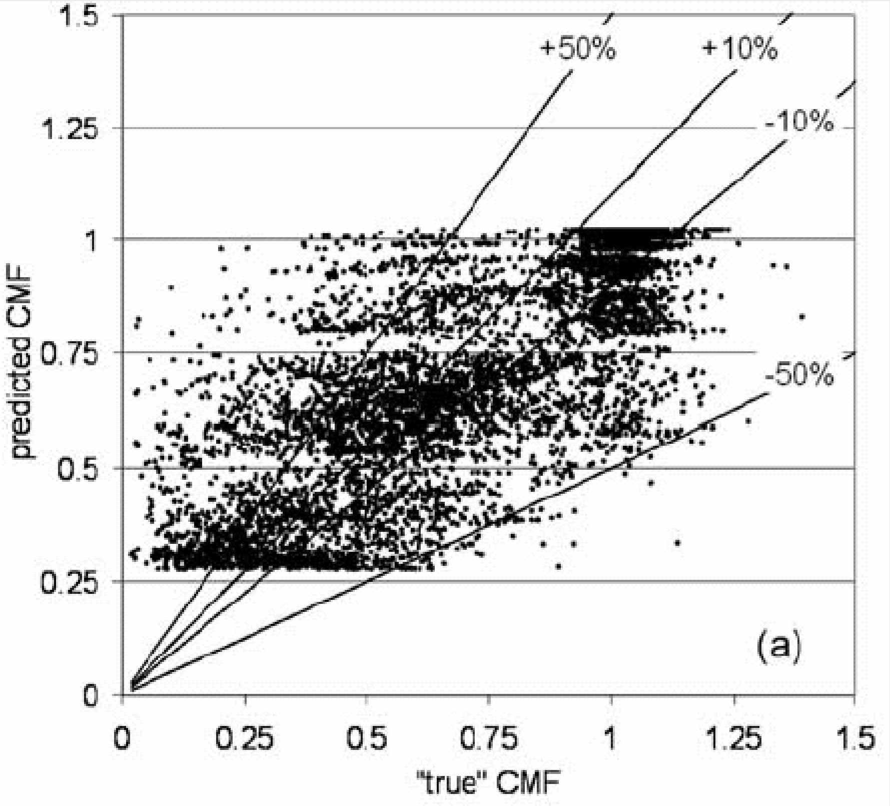


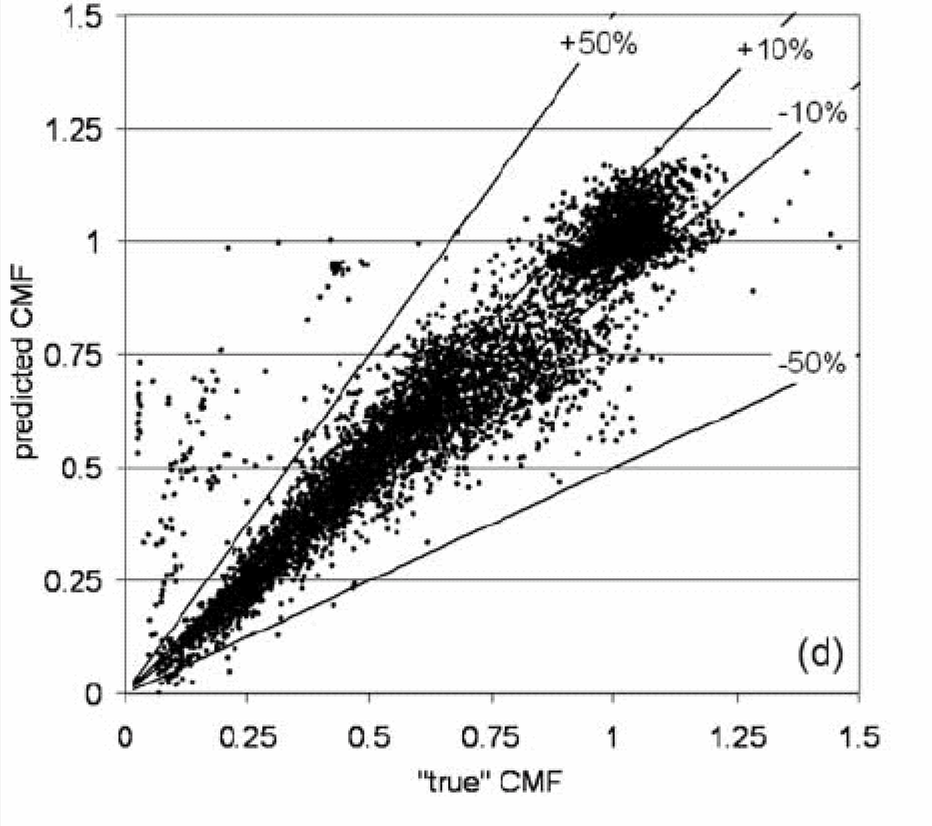
CMF =
Cloud modification factor =

$$\frac{\text{UVirrad cloudy sky}}{\text{UVirrad sky without clouds}}$$

Koepke et al.,
2002,
Rec. Res. Devel. Photochem. Photobiol.
after different authors

Check of quality of CMFs



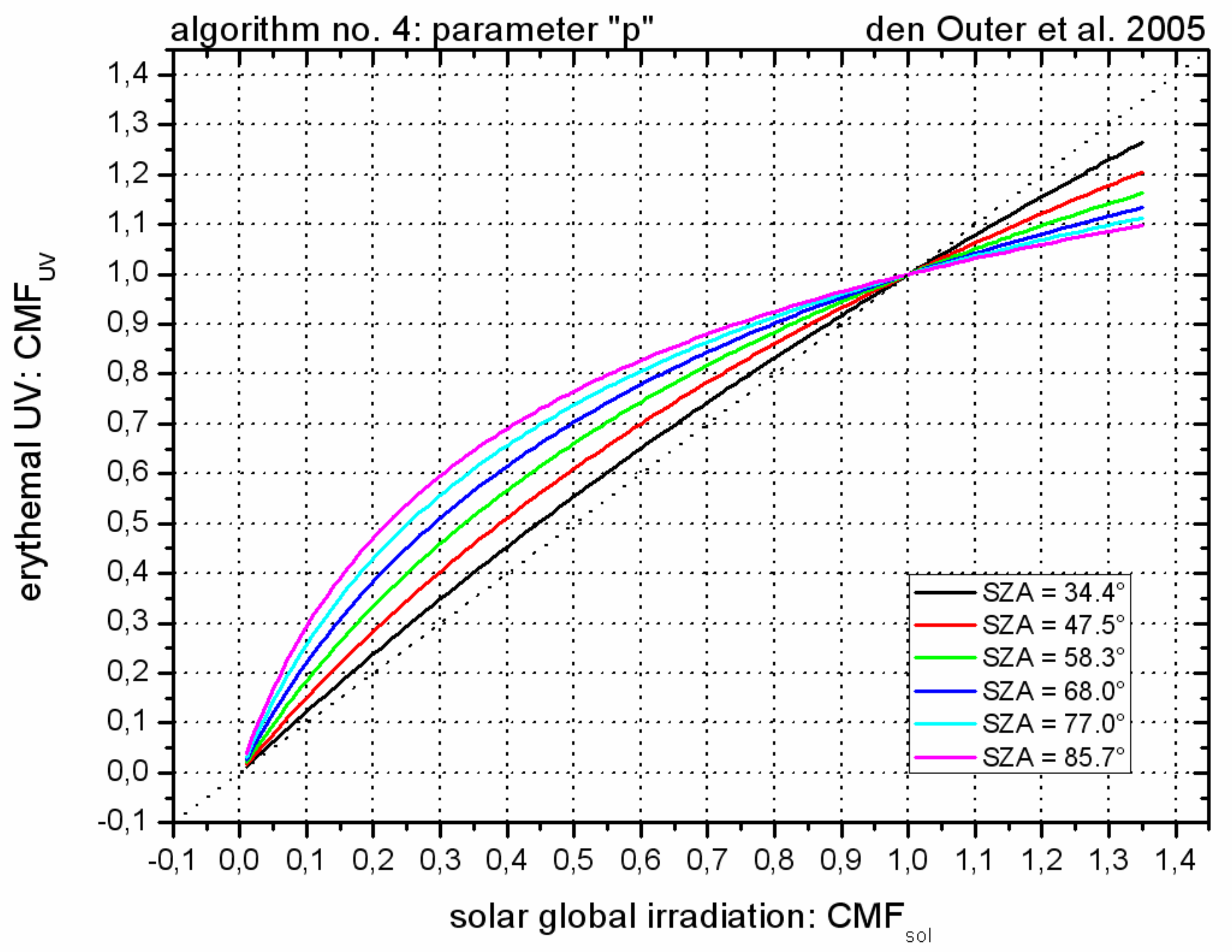


CMF based on cloudines

CMF based on cloudines plus solar irradiance

Schwander et al., 2002

CMFuv as function of CMFsolar



den Outer et al., 2005, J.Geophys.Res.

Effects of all input parameters

parameter	effect on UV	data availability
SZA	high	perfect
Earth-Sun-Distance	low	perfect
Air molecules	moderate	perfect
Geometrical height	moderate	perfect (but: area, shadow)
Albedo no snow	low	good
snow	moderate	by parameterization
Aerosol amount	low / moderate	low (climatic data)
properties	low / moderate	low
Ozone	high	good (parameterization)
Clouds	high	low (parameterization)
Trace gases	low	no (climatic data)
Height profiles	low	no (climatic data)

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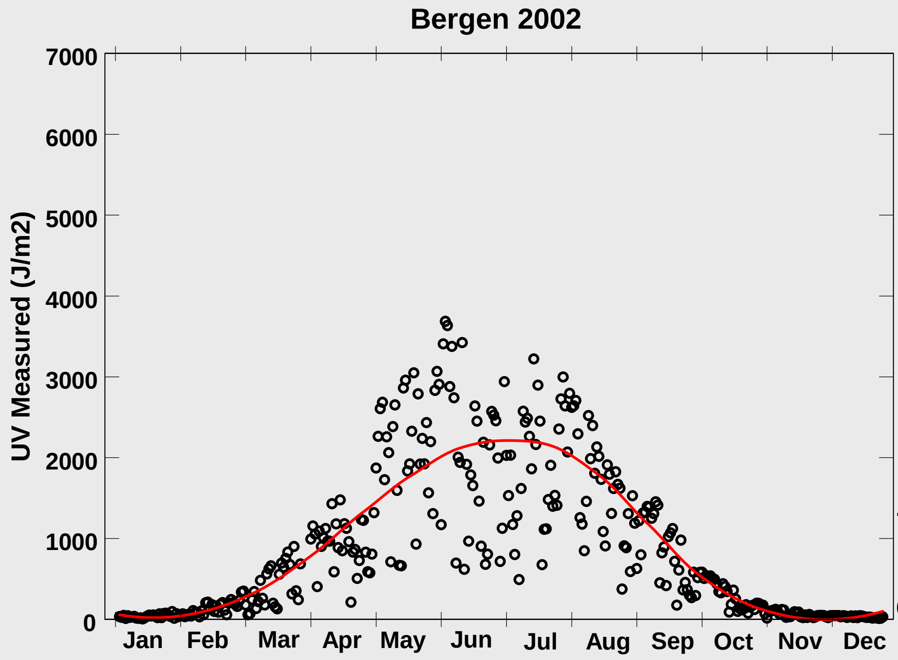
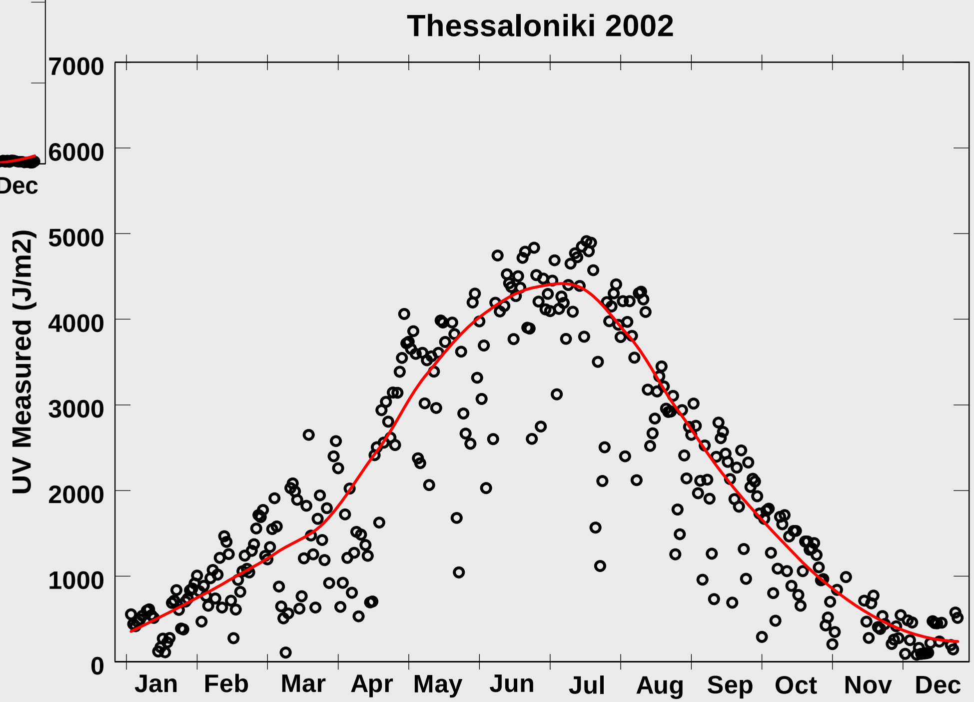
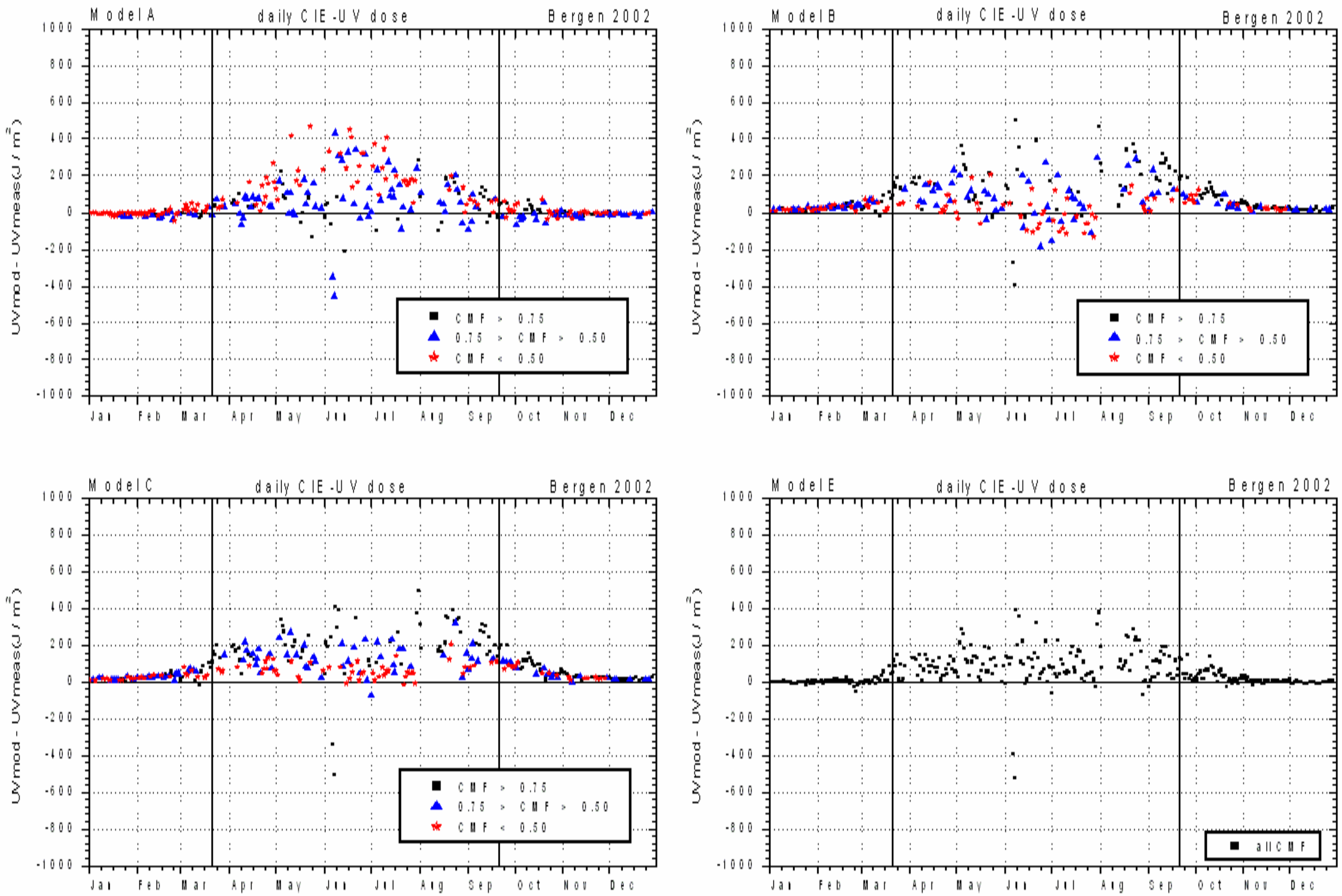
Measured daily UV dose





(daily_dose_mod - daily_dose_meas) in J/m² Bergen 2002



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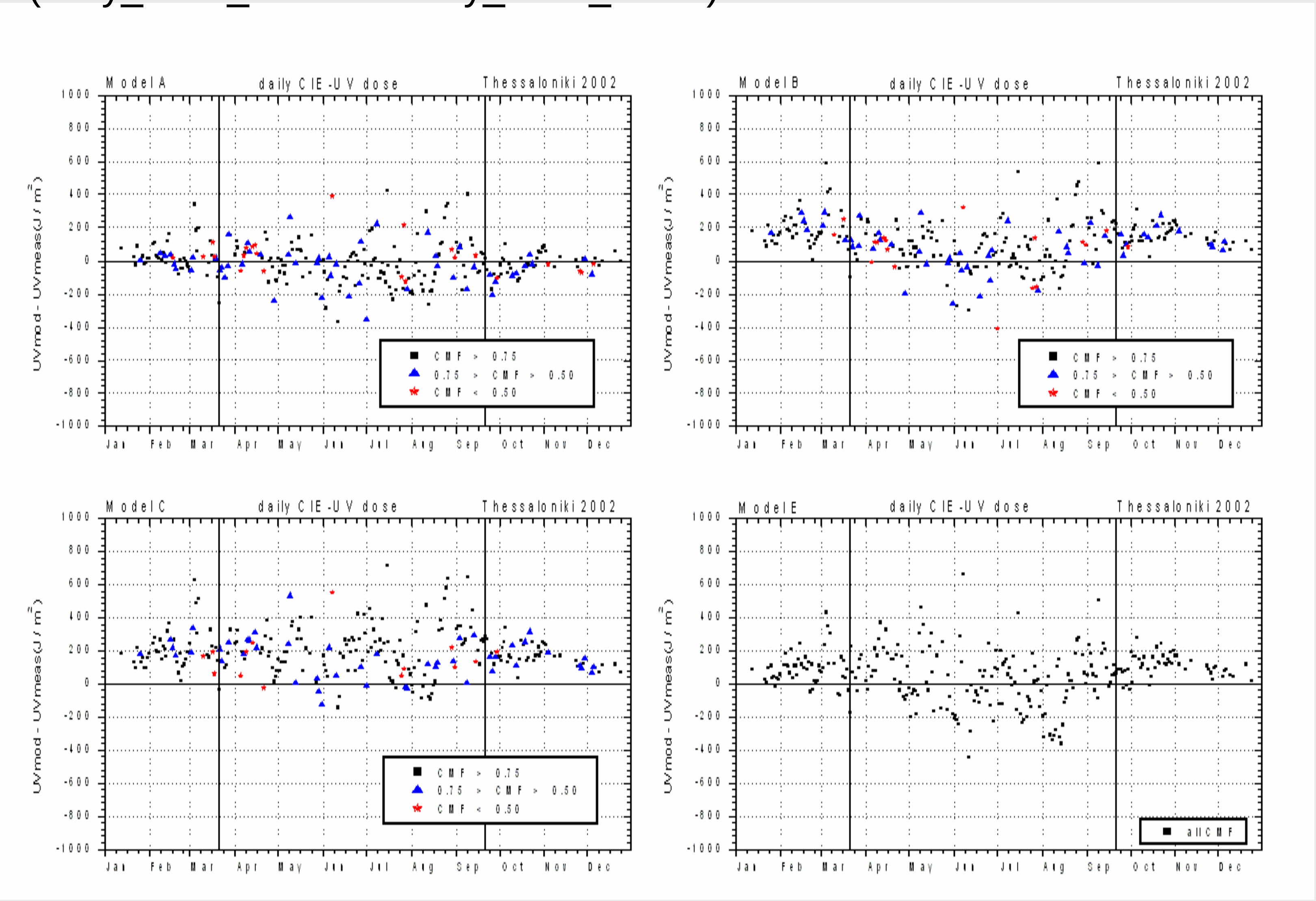
(daily_dose_mod - daily_dose_meas) in J/m² Thessaloniki 2002



Modelling Exercise of COST Action 726

-- results in a huge amount of data ➔ good basis for further UV studies

-- Modelling of UV in the past is possible with good results

(Erythemal daily dose: RMS ~ < 200 J/m²)

-- Cloud effects give largest uncertainty

-- Models that use CMF_{UV} based CMF_{sol} show best agreement with measurements

-- Uncertainty of aerosol effects results from inadequate input data (visibility)

-- Snow effects to be improved (e.g. latitude dep.) ?

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special modelling for UV:

3 dimensional, multiple scattering, spectral

3 dimensions: every point in the model region is given with individual properties

- Individual clouds
- Topography
- Variable albedo

} How to get the data ?

Multiple scattering: as in 1 dimensional

Spectral: as in 1 dimensional

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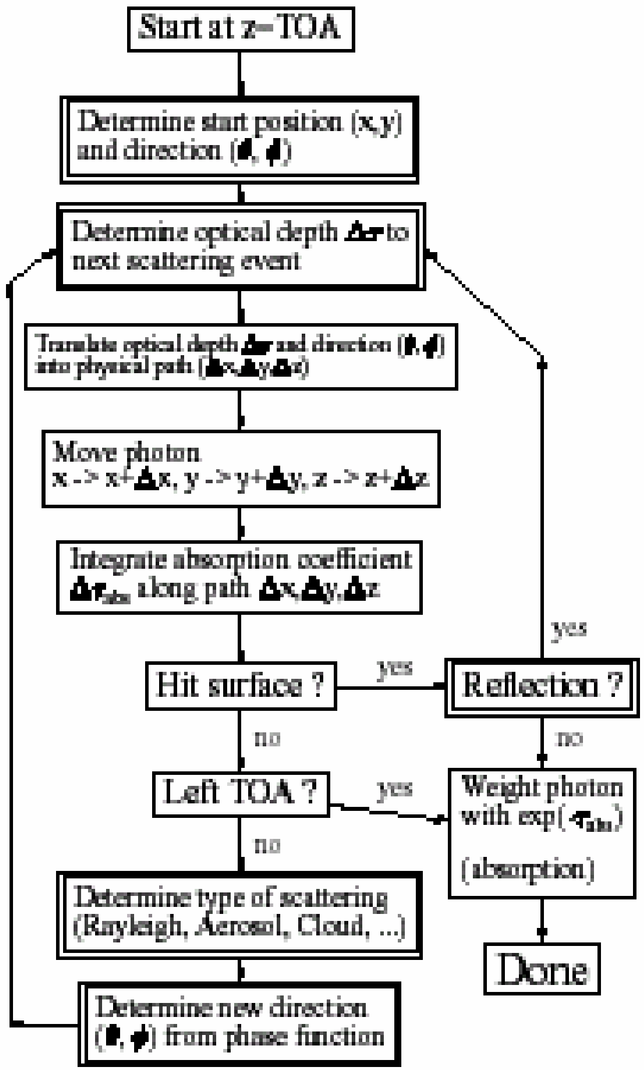

Figure 2. Schematic overview of the MYSTIC model. The double-framed boxes include a random number generation process.

.Monte Carlo Method

What happens with individual photons entering the atmosphere, Random processes with respect to scattering, absorption and reflection, weighted due to the atmospheric properties

B. Mayer(1999) MYSTIC Monte Carlo Model

I3RC Workshop

Summary

Radiative transfer in the UV is well established

Different models are available: STAR, LibRadtran, sbdat

Challenges

Correct input data

reasonable radiation with limited input knowledge

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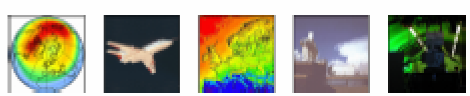
Can we really calculate everything?

Challenges in RT theory:

- Inelastic (Raman) scattering
- UV radiative transfer into water
- Fully spherical RTE solver:
  Radiances at large solar zenith angles
- Polarization
- Tilted surfaces
- Three-dimensional radiative transfer (A4, Tuesday)



Examples for www UV- information

- www.uv-index.de
- www.uv-index.au
- www.cost726.org
- www.epa.gov/ozone/othlinks.html#uvindex
- www.who.int/uv/en