Deutscher Wetterdienst
Wetter und Klima aus einer Hand

UV Index Forecasting

The German Meteorological Service (DWD) predicts the UV Index on a global scale for up to 3 days in post-processing to DWD's "Global Numerical Weather Prediction System" (ICON, pixel distance 13 km). The effective ozone values are forecasted by the Royal Dutch Meteorological Institute (KNMI) in an hourly resolution and interpolated to the ICON grid.

The forecast has a module structure. In a first step a "large-scale UV Index" is calculated as proposed by COST-Action 713 "UV-B forecasting". It allows for interpolation to other grids and is calculated for clear sky conditions, for a surface UV albedo of 3 % (summer grass), for an aerosol optical depth (AOD) at 550 nm of 0.20 of the aerosol type "continental average" (Hess et al. 1998), that is a single scattering albedo (SSA) at 280 nm of 0.8879. It depends from solar zenith angle (SZA), and forecasted ozone column. In the subsequent steps the "large-scale UV Index" is adjusted to variable AOD and SSA, to the topography, to the albedo of predicted snow cover. The result is the UV Index clear sky. From that the UV Index cloudy is calculated applying cloud modification factors based on predicted solar global radiation.

The calculations include aerosol optical depth forecasts of the ECMWF, provided as part of the Copernicus Atmosphere Monitoring Service (CAMS).

The required single scattering albedo (SSA) at 300 nm is taken from the "Global Aerosol Data Set (GADS)" (Koepke et al. 1997) for a relative humidity of 70 %. Available are global fields for the summer and the winter season with a resolution of 5° in longitude and in latitude. Values lower than the SSA of the aerosol type "continental average" are limited to the SSA of that aerosol type. In the Atlantic area off the North-African west coast it is additionally accounted for westward driven Saharan dust. The data from the 5°*5° GADS grid have been interpolated to the ICON grid.

Algorithms

Lookup Tables to calculate the "large-scale UV Index"

Radiation transfer calculations by the model STAR, System for Transfer of Atmospheric Radiation (Ruggaber et al. 1994), in the neuronal version STARneuro (Schwander et al. 2001) has been applied for determining of the LUT. STAR is a high quality multiple scattering model, tested against models and measurements (Koepke et al. 1998; DeBacker et al. 2001, Mech and Koepke 2004). The LUT are calculated for the 15th of each month, in each hemisphere for the climate zones tropic, sub-tropic, moderate, sub-arctic, arctic using monthly mean profiles of ozone taken from the UGAMP climatology (Li and Shine 1995), temperature and pressure profiles taken from COSPAR International Reference Atmosphere" (Labitzke et al. 1985, Rees et al. 1990, http://nssdc.gsfc. nasa.gov/space/model/atmos/ cospar1.html), humidity profiles taken from the AFCLR data (McClatchey et al. 1972). The LUT have a resolution of 10 DU in total column ozone between 90 and 700 DU, and of 1° in solar zenith angle (SZA) between 0° and 90°. Interpolation between basic values is linear in ozone and linear in the cosine of SZA. The uncertainties of LUT against modelled values for current profiles are <3 %.

Effects of variable aerosol optical depth (AOD) and single scattering albedo (SSA)

The algorithm for effects of aerosol optical depth returns a factor to adjust a "large-scale UV Index" to current values of AOD and SSA at sea level (Staiger and Koepke 2005). The factor depends from AOD, SSA and solar zenith angle (SZA). It is calculated using a parameterisation in AOD by a second degree polynomial in the logarithms of factors depending from SZA and SSA. The parameterisation is derived from modelled values with a resolution in SZA of 5° between 0° and 90°, and in AOD of 0.05 between 0.00 and 2.00. SSA basic values are derived based on a relative humidity of 70 % for the aerosol types “continental average” (SSA at 280 nm of 0.8879), “urban” (0.7787), and “maritime clean” (0.9840). Absolute uncertainties of the parameterisation against modelled values are < 0.27 UV Index for the whole range of SZA.

Altitude effects

The algorithm for the altitude effect returns a factor to adjust a large-scale UV Index adapted to current values of AOD and SSA to any altitude between -500 m and +9000 m (Staiger and Koepke 2005). The mixing layer altitude is fixed at 3 km above ground; it begins to shrink when its upper boundary has reached the maximal approved altitude of 5000 m above sea level. The factor depends from altitude, AOD, SSA, and SZA. It is calculated using the logarithms of modelled factors representing the dependency from Rayleigh scattering (AOD= 0) and a parameterisation in AOD by a second degree polynomial in the logarithm of a factor representing the aerosol dependency. The parameterisation is derived from modelled values with a resolution in SZA of 5° between 0° and 90°, in AOD of 0.05 between 0.00 and 2.00, and in altitude of 500m between 0 to 9000 m. SSA basic values for relative humidity of 70 % are derived for the aerosol types “continental average” (SSA at 280 nm of 0.8879), “urban” (0.7787), and “maritime clean” (0.9840). For the whole range of SZA and the whole range of altitudes the maximum absolute uncertainty for the adjustment to altitude against the modelled values is +0.23 UV Index.

Albedo effects of snow cover

In the UV the albedo of the ground is markedly high only for snow and ice. The applied algorithms return a factor to adjust a UV Index to a value accounting for the additional albedo of snow and (sea) ice cover. It is differentiated between a terrain homogeneously covered with snow, that is assumed for Antarctica, the arctic region, and the inland ice on Greenland, and a regional albedo (Schwander et al. 1999, Lapeta et al. 2001).

Homogeneously snow/ice covered terrain: If there is an actual snow cover than the albedo factor varies from snow quality, from SZA, and from altitude above sea level. Applied are four linear regression equations derived from STAR modelled values depending from the albedo of “old” or “fresh fallen” snow (Grenfell et al. 1994), and SZA lower or greater than 65°. Independent variable is the altitude. The albedo of fresh fallen snow is assumed if the water content of snow/ice cover has increased within the last 24 hours or reaches a maximal value of 10 m H2O (ice shield of Antarctica and Greenland). The correlation coefficients of parameterised versus modelled values varies between 0.90 and 0.95.

Regional albedo: The albedo of a site is influenced from the albedo of areas up to more than 20 km in distance. In the regions outside the aforementioned there are always in part snow free surfaces reducing the albedo to a “regional” value; e.g. from trees, rocks, roads, roofs and buildings. A regional albedo due to snow cover is accounted for, if the height of snow cover exceeds 0.02 m. Applied is an algorithm derived from multiple regression of modelled versus observed albedo effects on UV Index (Schwander et al. 1999, Lapeta et al. 2001). It requires as input snow height and snow height variations within the last 4 days. The required snow height is parameterised from snow water content using factors given by Caspar (1962). In the case that there is no increase in snow water content within the last 4 days “old” snow is applied to calculate snow height. In the other case a linear conversion from “fresh fallen” to “old” snow is assumed, depending from the last day with increase in snow water content. The applied multiple regression model was able to explain 78 % of observed variations in albedo values (Schwander et al. 1999). Deviations between measured and modelled UV global irradiances for conditions with snow are not significantly higher than for snow-free conditions. The maximum error by applying snow water content to parameterise the height of snow cover is less than 2.5 % in the resulting UV Index.

Cloud Modification Factors (CMF)

The hourly based forecasts account for the impact of cloudiness by cloud modification factors. They are based on the predicted solar global radiation and comprise important effects for radiative transfer such as cloud optical depth, different cloud layers, multiple reflection and obscuration of the solar disc by clouds (Staiger et al. 2008). The high variability of cloud optical depth and the modification of the irradiance as effect of broken cloudiness (solar disk obscured by clouds or not) accounts for the largest uncertainty within all effective atmospheric conditions.

Comparisons of forecasted UV Index due to all effective atmospheric conditions versus measured daily maximum from 11 European sites, May to September 2003, reveals that 80 % of the forecasts fall in the range of +/-1 UV Index of measured values (Staiger and Koepke 2005).

Products

The production is performed once a day starting with the 00 UTC initialised analysis and with a resolution of one hour for +78 hours. The coverage is global with a spatial resolution of about 20 km iin latitude and ongitude. The hourly forecast are reassembled to daily forecasts of maximum of UV Index cloudy as well as of UV Index clear sky and are additionally accumulated to daily erythemal effective UV doses cloudy and clear sky. The presentation of maps and site specific forecasts is in agreement with the WHO (2002) recommendations.

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