

UV index forecast, UV indexer and the daily dose vitamin-D

Jos van Geffen^a, Michiel van Weele^a, Jos de Laat^a, Arjan van Dijk^b

In spring and summer, the UV index forecast is a recurring element in the weather forecast. When long hours of sunshine are expected, warnings are issued about the potential harmful effects of exposure to sunlight. This is especially true when the skin is exposed between 12 and 3 in the afternoon. In this article, we explain how the UV index forecast is calculated and introduce the UV indexer, hosted by the RIVM since the summer of 2025. Finally, we also discuss the daily UV exposure, which is important for vitamin-D production.

UV index forecast

Exposure to solar radiation is unavoidable for humans, and it carries both risks and benefits. That is why an internationally agreed-upon standard has been established that expresses how quickly you turn red from that radiation. In Dutch, this measure is commonly called "zonkracht", while internationally and within science it is referred to as the "UV index".

It has been internationally agreed that communications should include the expected maximum UV index without the effects of cloud cover or air pollution. This maximum UV index is calculated by the KNMI based on the expected thickness of the ozone layer and the maximum height of the Sun above the horizon, and therefore it varies with the seasons. The UV index is a measure of the effectiveness of UV radiation from the Sun at the Earth's surface, in the absence of cloud cover, when the Sun is at its highest point. The UV index is based on the sensitivity of Caucasian skin to sunburn ("erythema"), according to the official description by the CIE (= International Commission on Illumination) and as established by the World Health Organization (WHO) in 2002.

The KNMI calculates the UV index worldwide and publishes the calculations for (professional) users via the TEMIS UV website¹. The UV index is calculated based on the globally assimilated ozone distribution. This ozone distribution is calculated using the latest forecasts from ECMWF weather models and satellite observations of ozone distribution. Because ECMWF forecasts are available for several days ahead, a multi-day forecast of the global ozone distribution can also be generated, and thus a multi-day forecast of the global UV index for today and the next eight days. In communications with the Dutch public, the UV index is referred to as the zonkracht, and the index is rounded to the nearest whole number. The UV index forecast for today (in De Bilt) appears daily in the KNMI app and also for today and the next 8 days on the KNMI website². The global UV index is made available via data files with multiple decimal places for further use. The accuracy of the UV index forecast for today is 3–5%, and 4 days ahead up to about 10%; the uncertainty in the UV index calculation is 7% (summer) to 10% (winter) in De Bilt.

An example of the forecast made on 13 July 2022, for that day and the following day for the Netherlands can be seen in Figure 1. The panels show (1) that there can be differences between the north and south, but also between the east and west of the Netherlands, and (2) that the differences from day to day can sometimes be quite large. These differences are determined by variations in the distribution of ozone in the stratosphere and, in the north-south direction, by the position of the Sun.

Calculation of the UV-index

The wavelength dependence of a particular biological effect on radiation is described by an action spectrum: the action spectrum translates radiation intensity into biological effectiveness. The UV index is based on the erythema action spectrum: this action spectrum is relevant for sunburn, visible, for example, as reddening of the skin. Exposure of your skin to UV radiation also leads to the production of

^a Royal Netherlands Meteorological Institute (KNMI), The Netherlands

^b National Institute for Public Health and the Environment (RIVM), The Netherlands

¹ <https://www.temis.nl/uvradiation/>

² <https://www.knmi.nl/nederland-nu/weer/waarschuwingen-en-verwachtingen/zonkracht/>

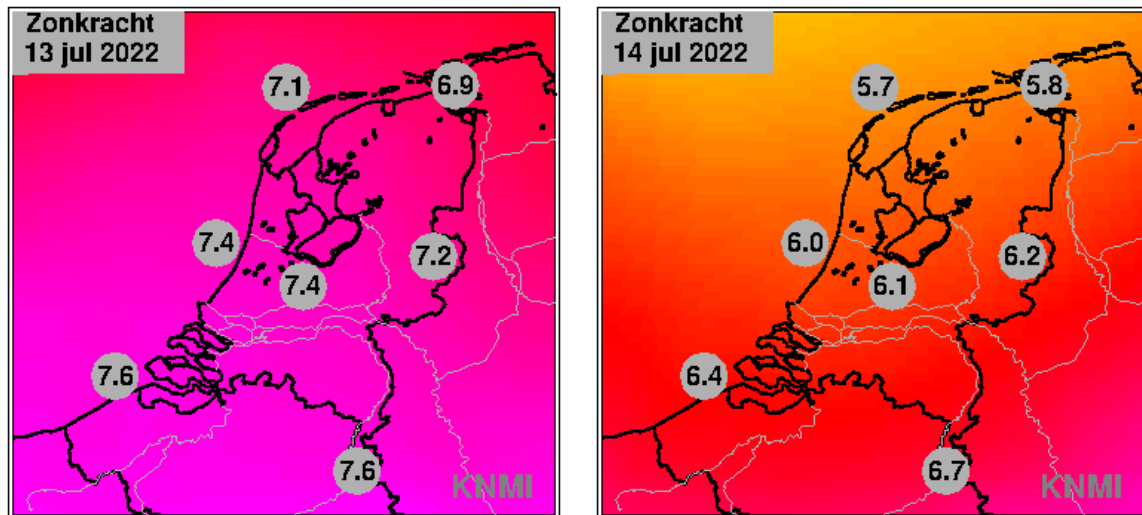


Figure 1: UV index forecast for the Netherlands. determined on July 13, 2022, for that day (*left*) and the following day (*right*), indicated with 1 decimal place to show regional and day-to-day differences.

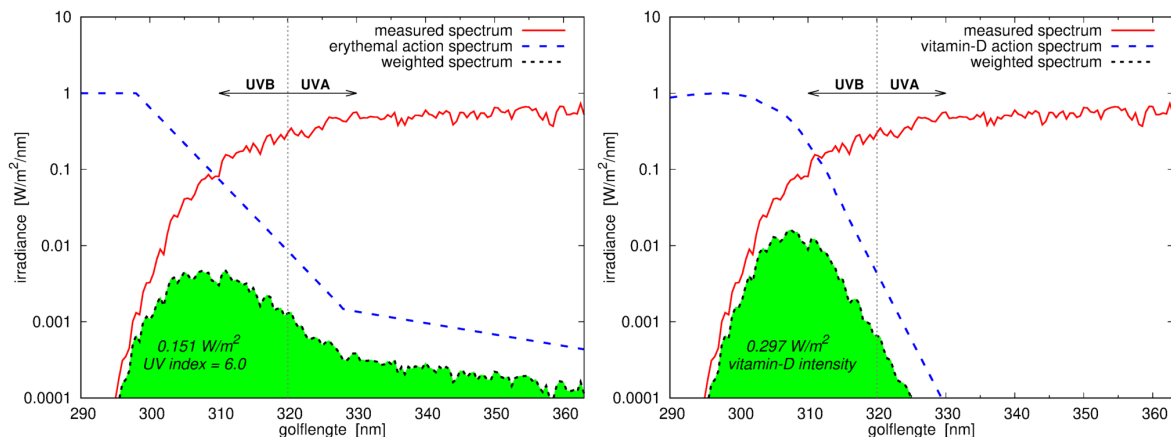


Figure 2: Determination of the UV index (the coloured area under the black dotted line) for the action spectra for erythema (*left*) and vitamin-D production (*right*) based on the spectral UV radiation measured at the KNMI in De Bilt on June 15, 2015, at 11:41 UTC.

vitamin-D; this production has a different spectrum of action. The blue dashed line in the two panels of Figure 2 shows the action spectra of erythema (left) and of vitamin-D synthesis in the skin (right). Multiplying the measured solar spectrum (red solid line) by the action spectrum yields the weighted solar spectrum (black dotted line) relevant for the biological effect in question. The integral of this weighted spectrum – the green area under the black dotted line – is the weighted intensity associated with that measurement in W/m^2 . In public communications, the intensity of erythema-weighted UV radiation is converted into a dimensionless UV index. The figures show that the UVB portion of the radiation has the greatest impact on both biological effects, but that the UVA portion of the solar spectrum also makes a significant contribution to erythema, while the UVA contribution to vitamin-D is much smaller.

The sharp decrease in sunlight intensity at short wavelengths is due to the absorption of UV radiation by ozone in the atmosphere. The average UVA radiation level under clear skies is primarily determined by the position of the Sun above the horizon. In addition, the Earth-Sun distance, the height above sea level, and the albedo of the Earth's surface also play a role. These parameters depend on the time of day, the day of the year, and the location on Earth.

Using ground-based observations of UV radiation in De Bilt and Paramaribo (to include the highest solar positions and UV indices that are not achieved in De Bilt), an empirical relationship has been established between the weighted UV intensity as a function of the total ozone column and the position of the Sun – see box. This parametrisation is used by TEMIS to determine the UV index and the daily UV dose from the global ozone distribution. The UV index is calculated on a latitude-longitude grid of

Calculation of the UV-index and daily UV dose

The intensity of UV radiation weighted by an action spectrum [in W/m²] at total ozone column T [in Dobson units, DU] and solar angle relative to zenith θ_0 [in degrees] is given by the following parametrisation (Allaart et al., 2004):

$$I_{\text{UVR}}(T, \theta_0) = I_{\text{UVA}} \cdot \left\{ F \cdot \left(\frac{1000 \cdot \mu_0}{T} \right)^G + \frac{H}{T} + J \right\} \quad \text{with:} \quad \mu_0 = \cos \theta_0$$

in which the UVA part of the UV radiation is merely a function of θ_0 :

$$I_{\text{UVA}}(\theta_0) = S \cdot \mu_x \cdot \exp(-\tau/\mu_x) \quad \text{with:} \quad \mu_x = \mu_0 \cdot (1 - \epsilon) + \epsilon$$

This UV intensity (I_{UVR}) is corrected for the Earth-Sun distance, the Earth's surface albedo, the height above sea level, and the presence of clouds (not for the UV index forecast). No explicit correction is made for the presence of aerosols; a radiative transport model has been used to derive that the implicit aerosol optical thickness (AOD) at 368 nm is approximately 0.30, with a UV single-scattering albedo of approximately 0.9.

The UV index is I_{UVR} at the moment the Sun is highest in the sky under a cloudless sky, according to international agreements, converted to a dimensionless index by dividing by 0.025 W/m².

The daily UV dose [in kJ/m²] is $I_{\text{UVR}}(t)$ integrated over the day, taking into account the variation in cloud cover as measured by the Meteosat Second Generation (MSG) cloud imagers.

The equations contain a number of fit parameters (S , τ , ϵ , F , G , H , and J) determined based on the chosen action spectrum and ground-based observations of UV radiation in De Bilt and Paramaribo. In April 2017, the parametrisation was repeated, using more observations than originally included in Allaart et al., 2004.

For further details and references, see <https://www.temis.nl/uvradiation/product/uvi-uvd.html>.

0.25° × 0.25°. For public communications, the erythema-weighted UV index is used at the time the Sun is at its highest point during the day.

UV indexer

The value for De Bilt under a cloudless sky as a forecast for the UV index at noon is a reasonable assumption for the whole of the Netherlands, because the Sun's position is more or less the same across the country and because the ozone distribution is usually quite smooth (see Figure 1). The current UV index is measured at the RIVM national measuring point in Bilthoven³ and that also shows the influence of cloud cover for that location. Cloud cover can vary considerably across the country and throughout the day, meaning that a single point is not representative of the entire country.

To give people in the Netherlands better insight into the current UV index at their own location, the RIVM public website features since the summer of 2025 the UV indexer ("zonkrachtwijzer" in Dutch)⁴, which shows the current and expected maximum UV index for a selected location every day; see Figure 3. For this service, the expected maximum UV index for the whole of the Netherlands is determined every 15 minutes at a higher resolution than the standard TEMIS resolution, namely 0.05° × 0.05°, and combined with current cloud information from observations by the Meteosat Second Generation (MSG) satellites (see below). Because retrieving and processing satellite observations takes some time, the current solar intensity is available in the UV indexer with an average 45-minute delay.

Daily UV dose for vitamin-D production

The position of the Sun varies throughout the day and determines the UV intensity (see box). The blue curve in the left panel of Figure 4 shows the daily variation of UV intensity weighted by the action spectrum for vitamin-D production for 5 June 2022. The green area under the curve represents the UV dose for that day, which is the dose available to someone who is outside all day and has a clear view of the

³ <https://www.rivm.nl/zonkracht/landelijk-meetpunt-zonkracht-bilthoven>

⁴ <https://www.rivm.nl/zonkracht/zonkrachtwijzer>

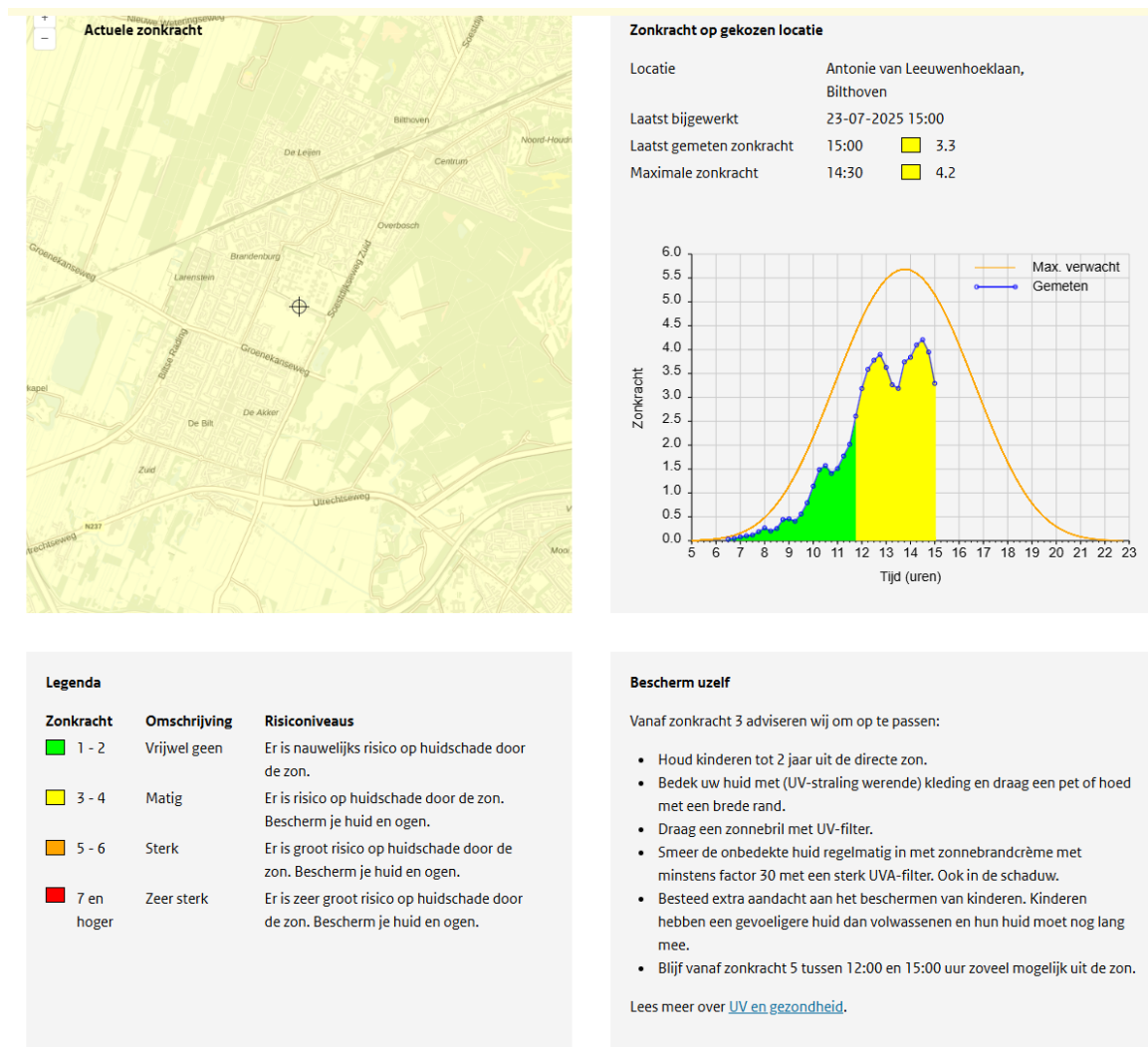


Figure 3: Image of the UV indexer ("zonkrachtwijzer" in Dutch) on the RIVM website. Entering an address or clicking on a map displays a graph showing the maximum expected UV index (solid line) and the measured UV index (line with dots) throughout the day for that address. The box at the bottom left shows the colour legend for the different risk levels, while general advice regarding the UV index is provided at the bottom right.

horizon, still assuming there are no clouds. In reality, there was cloud cover in De Bilt on 5 June 2022, only around 8:00 UTC it was virtually cloudless for a short time. Cloud cover reduces UV radiation at the ground. The red curve in the left panel of Figure 4 shows the cloud-corrected UV intensity throughout the day, and the grey area shows the cloud-corrected UV dose for that day; on this day, cloud cover more than halves the daily UV dose.

The decrease in UV intensity due to cloud cover is determined based on observations from the Meteosat Second Generation (MSG) satellites; specifically, this uses the "surface downwelling shortwave radiation" (SDS) from the MSG Cloud Physical Properties (CPP) data⁵. The correction factor for UV intensity is the ratio of the SDS from MSG observations to the SDS expected in the absence of cloud cover, with a small correction to convert the broadband SDS to values representative of the UV component of solar radiation. A new correction factor is available every 15 minutes. The right panel in Figure 4 shows an example of the cloud-corrected daily UV dose over Europe for 5 June 2022, as found on the TEMIS website. MSG observations have been available since January 2004 for much of Europe, Africa, the Atlantic Ocean, including the Caribbean, and part of South America.

Cloud cover varies from season to season and from year to year – much more than the thickness of the ozone layer – so the variation in the daily UV dose is primarily determined by cloud cover. The left panel of Figure 5 shows the variation in the UV dose for vitamin-D production in De Bilt for the period

⁵ <https://msgcpp.knmi.nl/>

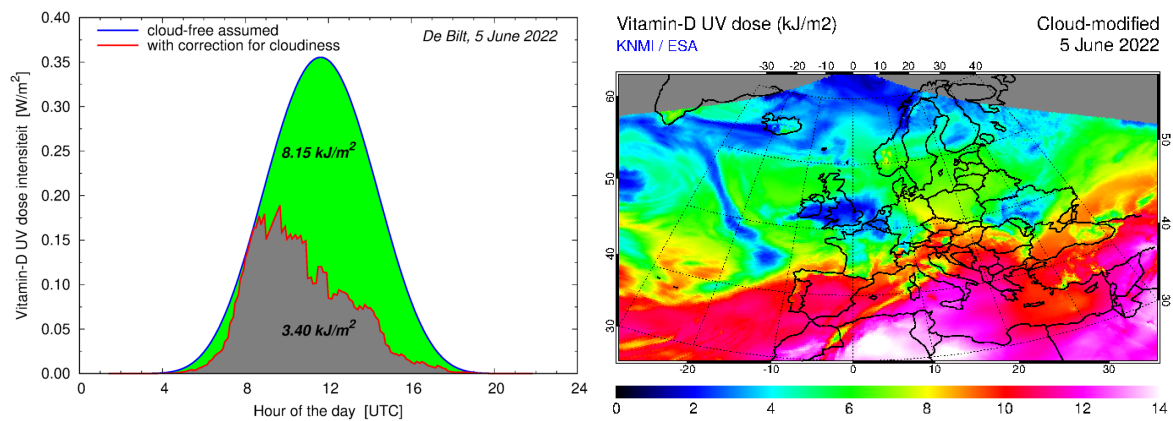


Figure 4: *Left*: The daily variation in UV intensity, assuming clear skies (blue curve) and correcting for cloud cover (red curve), for 5 June 2022 in De Bilt. *Right*: Map of the daily UV dose over Europe for the same day; the grey area is outside the range of the MSG satellites from which the cloud information is obtained. In both cases, this concerns the UV dose weighted by the action spectrum for vitamin-D production.

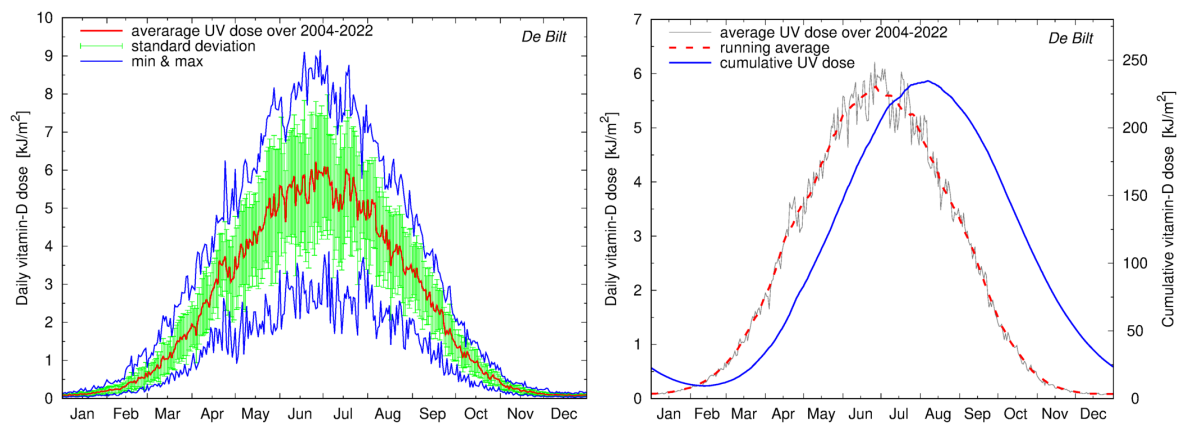


Figure 5: *Left*: Variation of the daily UV dose for De Bilt: the red line in the middle represents the average over the years 2004–2022, with the green lines indicating the standard deviation of this average, and the blue lines indicating the minimum and maximum values. *Rechts*: The average daily UV dose over the years 2004–2022 from the left panel (grey line, units on the left y-axis) with a running average (dashed red line) compared to the daily cumulative-weighted UV dose (blue line, units on the right y-axis). In both cases, this concerns the UV dose weighted by the action spectrum for vitamin-D production.

2004–2022: the red line shows the average UV dose; the minimum and maximum values are indicated by blue lines. The right panel of Figure 5 shows the average UV dose again, now as a grey line. To better illustrate the general trend, a running average has been drawn through it with a red dashed line. This line clearly shows that, as expected, the UV dose has a maximum around midsummer and a minimum around midwinter.

Vitamin-D is produced in human skin by UV radiation. At the same time, vitamin-D is also broken down in the body by biological processes. This breakdown of vitamin-D is described in the literature as an exponential decline with a half-life of approximately 35 days. By weighting the daily UV dose (UVD) over a period of approximately four months prior to a specific date by the exponential decay and summing the product, the cumulative weighted UV dose per day ("cw-UVD") for vitamin-D production is obtained. The cw-UVD is therefore a good measure to compare with the actual presence of vitamin-D in the body throughout the year.

The blue line in the right panel of Figure 5 shows the cw-UVD for De Bilt, based on the long-term average UV dose. It is clear that the cw-UVD has a maximum not around midsummer but around 10 August, and a minimum not around midwinter but around 10 February. This means that 10 February can be seen for De Bilt, and therefore for the Netherlands, as the middle of what is sometimes called the "vitamin-D winter": the period when the body is most likely to have a vitamin-D deficiency. Several studies compare the cw-UVD based on TEMIS UV data with blood values of people as a function of the

city or region where they live (see references). These studies confirm the important role of skin exposure to UV radiation from the Sun in vitamin-D production. The daily exposure of outdoor workers and office workers, for example, will naturally differ, but the seasonal changes in blood values for both groups will be synchronised. So, a little UV radiation is good for your health, but this effect does not negate the importance of warnings about the harmful effects of UV radiation.

Closing remarks

The Netherlands has become sunnier since the beginning of this century, especially in spring and summer. There has been an increase in sunshine hours of approximately 27% over the past 30 years ⁶ as well as from a stronger average irradiation (climate dashboard KNMI ⁷). The increase in sunshine in the Netherlands is partly due to improved air quality (this was likely most effective in the last century), partly due to more frequent high-pressure systems in spring and summer, and partly due to less evaporation over land during these seasons. Relative humidity decreases further because moist air drifting in from the sea warms up over land, suppressing cloud formation. How much these different explanations have contributed to the observed increase in sunshine this century has not yet been properly quantified and requires further research.

The observed increase in sunshine and therefore in the average solar intensity is important for UV exposure. An increase in the number of warm, summery days also means we spend more time outdoors and cover our skin less with clothing. The daily UV index forecasts, supplemented since the summer of 2025 with the UV indexer for your own location, help with publicity campaigns. These campaigns are coordinated by the Dutch Skin Foundation, among others, to warn people repeatedly about the harmful effects of excessive UV radiation on skin and eyes – "Enjoy, but don't turn red!" – and tell them how to minimize these risks: "Slip, slop, slap" (in Dutch converted to "Weren, kleren, smeren").

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Cumulative-weighted vitamin-D UV dose

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⁶ <https://www.knmi.nl/over-het-knmi/nieuws/zonneschijnduur-in-de-lente-is-2-keer-zoveel-toegenomen-als-de-zonnestraling>

⁷ <https://www.knmi.nl/klimaat>