Design Project – SIE 2022

Influence of environmental conditions on individual exposure to solar ultraviolet radiation (UV)

Introduction and objectives

Skin cancer is a very important health concern, induced primarily by **UV radiation** (100-380 nm). To **reduce the negative effects** of UV radiation, it is desirable to be able to **predict and quantify UV exposure**. This is particularly relevant in densely populated areas. While there is a UV climatology in Switzerland which provides risk estimates at population level [1], it does not take into account important **urban factors** (see below). These can largely influence the potential UV exposure within a built environment.

The objective of this project is to develop a method for determining UV exposure changes depending on location and time of the day in an urban environment. Other **goals** of the project include:

- Comparing the performance / accuracy of commercial dosimeters and high-precision UV radiometers.
- Determining which factors of an urban environment can reduce UV exposure.
- Upscaling the obtained results in order to predict UV exposure at the scale of a city.

Method

Instruments

For the measurement campaigns, **three UV radiometers** were used: one reference sensor at MeteoSwiss in Payerne and two mobile onsite (multiple sites in Payerne). Four **dosimeters**, provided by "Sun-a-wear", were used for UV measurement. Two of these were associated with each onsite radiometer, the other two were clipped on the collar of the two operators.

Measurement locations

Measurements were taken in **Payerne** and compared with the recorded UV intensities at the MeteoSwiss station by calculating the **reduction factor** (RF).

$$RF = \frac{\text{UV intensity measured onsite}}{\text{UV intensity measured at MeteoSwiss reference site}}$$

The following **parameters** (urban factors) should influence the UV exposure and were measured or calculated, for each site:

Figure 1: UV radiometer on tripod

- Street width
- Building height
- Street orientation
- Solar zenith angle (SZA)
- Instrument's exposition to direct sunlight
- Sky view factor (SVF): fraction of sky visible at a given location (calculated from a 180° fisheye lens picture and a MATLAB code [2])

UV intensity was measured simultaneously at two sites. At each pair of locations, only one of these parameters varied. Measurements took place on the 13th and 14th of April 2022. The order in which the locations were measured varied from one day to another (different SZA). A few sites were located outside Payerne with trees nearby to asses the influence of vegetation on UV exposure.

Figure 2: Dosimeter and App.

Results and discussion

Identification of relevant predictors using linear regressions

Fig. 3 shows **correlations** between different parameters. As expected, **RF** correlates most with the "**shade**" parameter (direct solar radiation vs. shade). Correlations show that the UV intensity was larger when instruments were exposed to direct sunlight. To better identify the relevant parameters within an urban environment, the dataset should be split into two parts:

1. measurements in direct sunlight
2. measurement taken in the shade

Linear regressions were performed on both datasets and the statistically relevant parameters were selected if their **p-values** were lower than 0.05 (confidence level of 95%). All of the parameters have been standardized.

Figure 3: Correlation matrix of all parameters

Figures 4 and 5 are interpreted as follows:
When the mean value is taken for all the predictors, the increase of one predictor by one standard deviation leads, on average, to an increase of the reduction factor RF by the value shown on the x-axis.

Direct sunlight

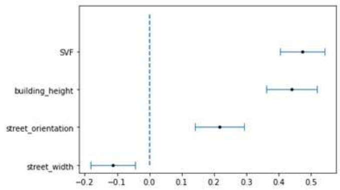

Figure 4: Measurements in direct sunlight (N = 88)

- Results may be partially misleading (e.g. taller buildings, larger UV exposition).
- Measurements in direct sunlight were all taken around noon → **SZA very similar**. Then, building height and street width do not have a high impact on UV intensity.
- A similar effect is seen in Figure 3 → strong biased correlation between street orientation and SVF due to the chosen locations.

In the shade

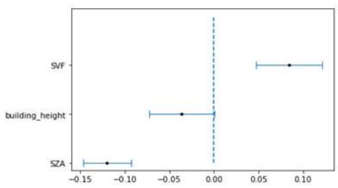

Figure 5: Measurements in the shade (N = 118)

- Results are much **more coherent**.
- Measurements were taken throughout the entire day → larger variability and better **representation of conditions.**
- Basis for the upscaling (see below).

Comparison between UV radiometers and dosimeters

Table 1 shows the various **measured UV intensities** and their respective **index** at two pairs of sites.

- Dosimeters associated with UV radiometers measure either the **same or 1 index difference**.
- Dosimeters worn on collars usually measure indices of 0-2 due to **shade-seeking** of operators.
- 75% of measurements done with UV radiometers have a **standard deviation under** 3.12 mW/m².
- 75% of measurements done with the immobile dosimeters have a **standard deviation under** 7 mW/m².
- Standard deviation of dosimeters worn on collars are large due to constant motion of operator (in and out of shade).

Table 1 : Comparison between instruments [mW/m²]

Site -	Meteoswiss UV/ index	Measured UV / index	RF	Dosimeter on tripod	Dosimeter on collar
4.2-Wide street	44.55 / 2	25.98 / 1	0.58	23.92 / 1	26.64 / 1
4.1-Narrow street	44.55 / 2	14.88 / 1	0.33	12.5 / 1	8.3 / 0
3.1-Low-rise building	115.01 / 5	67.34 / 3	0.59	93.03 / 4	38.3 / 2
3.2-High-rise building	115.85 / 5	59.83 / 2	0.52	70.43 / 3	10.46 / 0

Upscaling

Exploring possibilities to determine spatially distributed **RF** (accuracy currently not quantified).

- Map of **predicted RF** using linear regression based on a
- Digital elevation model (DEM), digital surface model (DSM), street map, and map of the SZA
- Several operations on QGIS
- The spatial distribution of the reduction factor makes sense and is coherent with expectations
- Methodology seems suitable and more robust for applications based on larger data sets
- Resulting map is interesting for population health care and urban planning

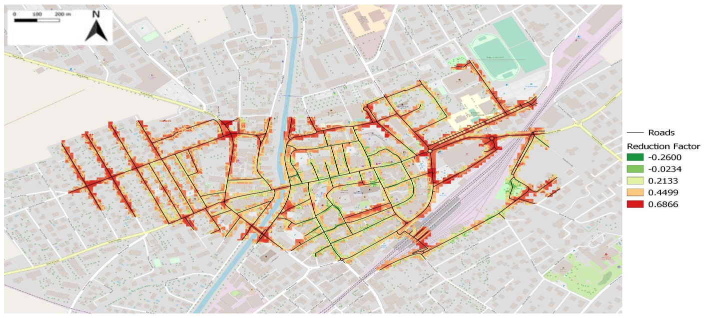

Figure 6: Predicted RF map

Conclusion

- The UV-index derived using dosimeters is in good agreement with values measured by radiometers
- Development of methodology successful → good base for further investigations and optimization of method. Accuracy and confidence in results needs to be assessed systematically.
- Limited amount of data available → less representative of reality → careful with interpretation
- Outlook: Need more measurements → adjust linear regression → produce the map with the same approach → compare values of map with measurements (accuracy) → create similar maps for other cities

References

[1] Laurent Vuilleumier, Todd Harris, Athanasios Nenes, Claudine Backes, and David Vernez. Developing a uv climatology for public health purposes using satellite data. Environment International, 146:106177, 2021.
[2] Fredrik Lindberg and Björn Holmer. Sky view factor calculator, 08 2012.

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