Analysis of erythemal solar irradiance measured simultaneously at two stations in Czechia

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- joint grant project (1996-98) solved by SOO and IAP
  (i) monitoring of UV-B radiation
  (ii) operational information service
  (iii) short range forecasting of UV-B

This contribution =
analysis of UV-ery measured simultaneously at two locations
  a) comparison of the two sites → altitude effect
  b) Radiation Amplification Factor ( ~ dependence of UVB on O₃)
  c) statistical model relating UVB with solar zenith angle and O₃
    - potential for UVB forecasting
    - reconstruction of the UVB climatology based O₃ climatology.

References (both available on web):


acknowledgments: Grant Agency of CR SOO Hradec Králové
Hradec Králové (278 m a.s.l., lowlands; SOO):

![Fig.1](image1)

Milešovka (827 m a.s.l., top of the mountain; IAP):

![Fig.2](image2)

![Fig.3](image3)
2. DATABASE

$UVB_{obs}$ 10-min sums of UV-ery, RB-biometer [HK + MIL]

G        global solar irradiance  [HK]

$TO$      total ozone, Dobson spectrophotometer  [HK]

$SUN$     hourly sunshine (to identify “clear-sky” terms)  
            [HK + MIL]

$SZA$     solar zenith angle (the angle bound by observer-sun 
            join and local vertical) [HK + MIL]

- **August 28, 1998 - June 25, 1997**
  - 4986 clear-sky observations made in Hradec Králové
  - 3240 clear-sky observations made in Milešovka
    (the difference between the two numbers is mainly
due to the drop-outs in Milešovka observatory)

- both RB-meters were calibrated against each other
**Hradec Králové vs Milešovka**

Time series of daily sums of UV-B irradiances:

- the fit between the 2 stations improves if sunshine
- the fit characteristic $2(\text{MIL-HK})/(\text{MIL+HK})$ exhibits no trend

**Daily cycle of UV-ery on sunny day:**

![Graph showing daily cycle of UV-ery on sunny day]
**altitude effect**

ratio of UV-ery (hourly sums) measured at both stations:
(based on 417 terms with 100% sunshine at both stations)

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**Fig. 6**

- **adjusted**: UV-B irradiances in Milešovka were adjusted for the different latitude ($\Delta \varphi = 23'$) (using the statistical model)

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**Result:**

- attributing the difference between the two stations to the altitude effect $\rightarrow$ UVB by about 4–8 % per 1km
Radiation Amplification Factor (RAF)

~ the dependence of irradiance on total ozone ($TO$):

$$d(\ln UVB) = -RAF \cdot d(\ln TO)$$

$RAF$ determined by bi-linear regression from 100% sunshine observations separately for five 10-degree intervals of $SZA$:

$$\ln UVB^* = -RAF \cdot \ln TO + b \cdot SZA$$

where $UVB^*$ ($\equiv UVB / CD$) is UVB irradiance adjusted for mean Sun-Earth distance.

- the standard error of $RAF$ is lower in Hradec Králové than in Milešovka (higher quality of measurements made in HK?)

weighted average of $RAF$ (over all $SZAs$):

$$RAF \ (HK) \sim 1.06$$
$$RAF \ (Mil) \sim 1.11$$
**statistical model**

\[
\text{model: } UVB(SZA, TO) = UVB^*(SZA) \times C_D \times (TO / TO_0)^{-RAF}
\]

\[
UVB^*(SZA) = \cos(SZA)^a \times \exp \{b + c.m + d.m^2\}
\]

where:

\[
UVB^*(SZA) = \text{UVB for mean Sun-Earth dist. and mean total ozone (TO_0)}
\]

\[
m = 1 / \cos(SZA) \text{ is an airmass}
\]

\[
a, b, c, d = \text{coefficients to be determined from data by regr. analysis}
\]

Fig. 8

HK(data) = running (n = 50) means of UVB* measured in HK
HK(model)/CHMI = ratio of present model and CHMI's model

- the statistical model perfectly fits data
- the models hold for \( TO = 339 \text{ DU} \) and mean Sun-Earth distance
- the models are valid only for \( 25 < SZA < 75 \)
- the model for Milešovka gives higher values (by 2.5-6.5%) compared to Hradec Králové ⇒ altitude effect ~ 5-11% per 1km
Accuracy of the statistical model

- the relative RMSE of the statistical model increases with increasing solar zenith angle (≈10% for SZA ≤ 60°)

- the statistical model better performs for HK data may be again explained by:
  - higher quality of HK data
  - different climatic conditions in the two locations

the knowledge of total ozone only slightly contributes to the quality of the statistical model at low solar zenith angles !!!

unexplained variability ~ cloudiness, turbidity (!), snow cover
effect of cloudiness:

![Graph showing the effect of cloudiness on UV-ery with lines for May 17, May 18, and May 19.](Fig. 10)

effect of snow cover:

![Graph showing the effect of snow cover on UV-ery with lines for Milešovka and various percentage levels.](Fig. 11)
Reconstruction of UVB climatology
(based on total ozone climatology)

assumption:
other factors affecting UVB (especially turbidity) do not change

Annual cycle of midday clear-sky UV-ery irradiance

Legend:
A±xs: total ozone = avg ± x.std  (x =1, 2, 3)
a(62-90): total ozone = average from 1962-1990
a(91-97): total ozone = average from 1991-1997
- **the UVB maximum** occurs at the break of June and July [the delay behind the summer solstice is due to the annual cycle of O3]

- **during low O3 episodes** (O3 < avg-2*std), the expected UVB may exceed the mean annual maximum within relatively long period (MAY-20 to AUG-06). However, even during extremely low total ozone episodes (O3 < avg-3*std) in late winter and early spring (FEB−APR), UVB cannot exceed "normal" summer values

- **1991-1997) vs. (1962-1990):** O3 decreased in 90's with respect to 1962-90. The mean annual maximum based on 1962-90 period is thus exceeded in 1991-97 by about 5%, and the mean annual cycle based on 1991-97 period is about 1½ months (June-07 to July-22) above the 1962-90 maximum
the mean annual cycle of total ozone
based on Dobson data measured in Hradec Kralove
annual cycles smoothed by RoLoWeR

Fig. 14

| a, a ± x.s: avg(TO), avg(TO) ± x.std(TO) (1962-90) |
| avg(91-97): mean total ozone in 1991-97 |
| min(62-97): the minima of daily total ozone in 1962-97 |
| TO(96-97): daily total ozone during the experiment |

note:
68 % of values of normally distributed variable fall within a ± s
95 % .................................................. a ± 2.s
99.7% .................................................. a ± 3.s

• model probability that min(62-97) falls below a-2s: 56% \(=1-[1-F(a-2s)]^{36}\)
  (assuming normal distribution of O3)

• observed frequency: 48%
Time series of monthly and annual means of total ozone
(locally weighted moving average, window = $t \pm 3$ years)

Fig. 10

Trend in total ozone, Hradec Králové

Fig. 11
Conclusions

1. results are comparable with results of other authors:
   - altitude effect $\sim 4 - 8\%$ per km
   - Radiation Amplification Factor $\sim 1.1$

2. statistical model $\text{UVB} = f(SZA, O3, DS-E)$
   - similar for both station
   - comparable with present CHMI's model

3. potential of statistical model for UVB forecasting
   - overall quality: $RV \sim 0.97$
   - $\text{RMSE [ \text{UVB ( SZA )} ]} \sim 10 - 20\%$
   - knowledge of total ozone reduces RMSE by $10 - 40\%$
     (by $10 - 15\%$ for lowest SZAs !!)$\rightarrow$ remaining variability
     is assumed to be mainly due to turbidity and cloudiness

    the statistical model is of only limited use for UV-B
    forecasting (effect of clouds and turbidity
    /unfortunately not easy to be forecast/ is greater)

    moreover, in terrain with great elevation variability,
    the altitude effect may be of significant importance

4. statistical model may be used for estimating UVB climatology
   (using the ozone climatology)