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Ozone exposure indices in Slovakia

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Abstract Currently surface ozone is the most serious regional problem of air pollution over Europe. Exposure indices are applied to evaluate the harmful effects of tropospheric ozone on vegetation (AOT 40f – forests, AOT 40c – agricultural crops) and human health (AOT 60). World Health Organization (WHO) recommends new indicator for health impact assessment - SOMO 35 (the Sum of Ozone Means Over 35 ppb).

The paper presents values these exposure indices at Slovak ozone monitoring stations for the period 2001 - 2005. The lowest ozone exposures are at typical urban stations, higher at suburban and rural stations. Maximal ozone loads are at mountain peak stations. In the environment of the geographical informational system maps of exposure indices were created. The critical levels of ozone are significantly exceeded at the territory of Slovakia.

Key words: *surface ozone, AOT 40$_f$, AOT 40$_c$, SOMO 35*

Introduction

Ozone is a harmful air pollutant. The high concentrations of surface ozone have injurious effects on the health of humans, animals and vegetation. This pollutant is one of the most significant stress factors for the vegetation. Its long-term effects on agricultural crops are expressed by reduction in crop yields. Ozone also harms and reduces the lifetime of various materials.

Therefore the tropospheric ozone is an internationally important pollutant. For these reasons national governments of Europe, taking into account obligations resulting from UN ECE Convention on long-range transboundary air pollution, support surface ozone monitoring programmes as well as are implementing measures to control the emissions of ozone precursors. Among first measures was, for example, restriction of the automobile transport in cities affected by photochemical smog and implementing of three-way catalytic converters in vehicles. Primary (for protection of human health) and secondary (environmental limits) imission limits were implemented as well.

An index AOT 40 (Accumulated amount of Ozone over the Threshold value of 40 ppb) is imission limit for protection of vegetation. The AOT 40$_f$ (for forests) is calculated as a sum of mean 1-hour ozone concentrations above 40 ppb during the period from April to September. Only the concentrations from daytime hours are taken into account. The critical level is 10 000 ppb.hours. The AOT 40$_c$ (for agricultural crops) is calculated in similar way from the daytime hours, but the period is shorter (May – July) and the critical level is 3 000 ppb.h.

Exposure index AOT 60 was used to evaluate the long-term effect of the surface ozone on human health. At present World Health Organization recommends new indicator for health impact assessment - SOMO 35 (the Sum of Ozone Means Over 35 ppb). It is defined as the yearly sum of the daily maximum of 8-hour running average over 35 ppb. For each day the maximum of the running 8-hours average for O_3 is selected and the values over 35 ppb are summed over the whole year. The corresponding unit is ppb.days.

Exposure indices AOT 40 and AOT 60 in Slovakia were mapped in several phases (Závodská et al., 1998, Kremler, 1999, Kremler, 2000). In the paper results of mapping AOT 40 and the new indicator SOMO 35 for the period 2001-2005 are presented.

Tab. 1 The exposure index AOT 40 for forests in ppb.h at the Slovak ozone monitoring stations for the period 2001-2005.

Station	Altitude	2001	2002	2003	2004	2005	Average
BA Koliba	287	13948	15212	31742	15998	18585	19097
BA Petržalka	136	8871	13820	22727	12667	16518	14920
BB Nám. Slobody	343	16882	13404	21697	12276	15892	16030
Hnúšťa	315	16096	19482	26281	12667	12460	17397
Hukavský Grúň	850				22520	22807	22663
Humenné	160	5344	15819	25034	13649	16914	15352
Chopok	2008		33302	31778	22857	25353	28322
Jelšava	255	16959	17412	25796	14126	12527	17364
KE Podhradová	248	5674	25100	25035	15871	14023	17141
Kojšovská hoľa	1248	21601	26955	28822	21181	19311	23574
Liesek	692				9958	16525	13242
Lomnický štít	2635			40875	22799	20126	27933
Poprad Gánovce	694	7074	17860	24586	11308	16066	15379
Predná Poľana	1360				12586	15013	13799
Prešov Solivar	255	12795	12686	22476	7646	11023	13325
Prievidza	269	10283	6751	18013	10744	9108	10980
Ružomberok Riadok	476	8652	9325	4990	6907	12577	8490
Skalnaté Pleso	1770		27209				27209
Smokovec	1000				10197	11697	10947
Solisko	1840				23943	20216	22080
Stará Lesná	808	16357	12279	19173	13045	16006	15372
Starina	345	11054	14951	26084	16478	12731	16259
Štart	1200				21330	11580	16455
Štrbské Pleso	1354	16853	20982	29727	12721	15756	19208
Topoľníky	113	5289	9426	32677	16880	16153	16085
Žiar nad Hronom	263		12756	25272	16922	14286	17309
Žilina Vlčince	368	10341	15375	21535	10084	11051	13677

Data

The continuous surface ozone monitoring in Slovakia started in 1992 when the Slovak Hydrometeorological Institute (SHMI) established a real time air pollution monitoring system of the Slovak Republic. The national secondary ozone calibration standard was installed in Slovakia in 1994. Intercomparisons with the Czech primary ozone standard are regularly organized.

Quality of the ozone data was not adequate especially in first years of measurements. On some stations the various gaps in the ozone data as to duration occurred due to breakdowns of the analysers, pumps and problems with air-conditioning. This disadvantageous state was caused by budgetary troubles of the Slovak Hydrometeorological Institute.

Besides SHMI stations in this study was used data from stations operated by Forest Research Institute and Research Centre of the Tatra National Park.

Measured ozone data in the electronic database of SHMI are in $\mu g.m^{-3}$. At first all mean 1-hour ozone concentrations had to be converted into ppb. Then the AOT 40 for forests and crops were calculated. The SOMO 35 was computed on the base of running 8-hour means. The special elevation dependence functions were evaluated from 5-year averages of these indices. The maps of AOT 40_f, AOT 40_c and SOMO 35 were created using these functions in the environment of GIS.

Tab. 2 The exposure index AOT 40 for agricultural crops in ppb.h at the Slovak ozone monitoring stations for the period 2001-2005.

Station	Altitude	2001	2002	2003	2004	2005	Average
BA Koliba	287	8489	9220	15305	7750	12300	10613
BA Petržalka	136	4559	9359	10339	6319	10344	8184
BB Nám. Slobody	343	10452	8172	12020	6537	10465	9529
Hnúšťa	315	9207	11393	13567	6130	6811	9422
Hukavský Grúň	850				8711	12978	10845
Humenné	160	2963	8590	12863	7323	9687	8285
Chopok	2008		15888	18228	12396	14204	15179
Jelšava	255	10338	9742	13362	6829	7994	9653
KE Podhradová	248	3556	15283	12869	7949	7626	9457
Kojšovská hoľa	1248	10404	15268	15381	10678	10624	12471
Liesek	692				6196	9802	7999
Lomnický štít	2635			20882	14203	9648	14911
Poprad Gánovce	694	4526	11609	12151	5207	9417	8582
Predná Poľana	1360				7668	9901	8785
Prešov Solivar	255	7017	6992	14400	4512	6831	7950
Prievidza	269	5590	4224	9756	5068	7280	6383
Ružomberok Riadok	476	5362	6022	3606	3613	8183	5357
Skalnaté Pleso	1770		16872				16872
Smokovec	1000				5182	6332	5757
Solisko	1840			10525	12658	10385	11189
Stará Lesná	808	10847	6188	8351	6130	8712	8045
Starina	345	6767	6904	13152	8354	6338	8303
Štart	1200				11292	6103	8698
Štrbské Pleso	1354	11812	12682	15907	5934	9666	11200
Topoľníky	113	4044	1599	17712	8670	10551	8515
Žiar nad Hronom	263		7885	13381	8272	10037	9894
Žilina Vlčince	368	6476	9231	11769	4740	6925	7828

Results

In Tab. 1 and 2 there are calculated AOT 40 for forests and agricultural crops at the Slovak ozone monitoring stations for the period 2001-2005. The yearly exposure indices range considerably at individual stations. The highest ozone exposures appeared in the year 2003 at the most of the stations. The maximal AOT 40 values were reached at the peak station Lomnický štít (40 875 ppb.h for forests and 20 882 for crops).

The mean exposures in the period 2001-2005 for forests range between 8 490 and 28 322 ppb.h and between 5 357 to 16 872 ppb.h for crops. The lowest values are at the typical urban stations (Ružomberok, Prievidza), higher at the suburban stations and the rural stations (for example: Bratislava Koliba, Topoľníky). The highest ozone loads are at the mountain peak stations (Chopok and Lomnický štít).

Calculated values of SOMO 35 at the Slovak ozone monitoring stations are introduced in Tab. 3. They range considerably from 876 to 9 536 ppb.days. The minimum occurred in the year 2003 at Ružomberok. On the other hand, the maximal SOMO 35 was reached at Lomnický štít in 2003. At the most stations the whole period maximum of SOMO 35 occurred in this year. 5-year SOMO 35 averages range between 1 687 (Ružomberok) and 7 222 ppb. d (Lomnický štít).

AOT 40 and SOMO 35 values have considerable interannual variability. It is caused by meteorological conditions in particular.

Tab. 3 The exposure index SOMO 35 in ppb.d at the Slovak ozone monitoring stations for the period 2001-2005.

Station	Altitude	2001	2002	2003	2004	2005	Average
BA Koliba	287	2279	2632	4820	3029	3433	3239
BA Petržalka	136	1503	2285	3594	2228	3241	2570
BB Nám. Slobody	343	2731	2411	3555	2221	2778	2739
Hnúšťa	315	2747	3306	4397	2480	2686	3123
Hukavský Grúň	850				4616	4463	4540
Humenné	160	1219	2785	4556	2997	3438	2999
Chopok	2008	4279	5667	5345	5510	6088	5378
Jelšava	255	2764	2884	4115	2788	2443	2999
KE Podhradová	248	1217	3890	4531	3094	3018	3150
Kojšovská hoľa	1248	5321	4852	5506	4786	4368	4967
Liesek	692				1870	3440	2655
Lomnický štít	2635			9536	6330	5799	7222
Poprad Gánovce	694	1513	2853	4133	2502	3126	2825
Predná Poľana	1360				3064	3859	3462
Prešov Solivar	255	2442	2232	3326	1533	2285	2363
Prievidza	269	1874	1382	3118	2005	1743	2024
Ružomberok Riadok	476	1706	1859	876	1602	2390	1687
Skalnaté pleso	1770		6534				6534
Smokovec	1000				2109	2737	2423
Solisko	1840				5322	4369	4846
Stará Lesná	808	2910	2421	3735	2937	3489	3098
Starina	345	2520	2969	4591	3121	2907	3222
Štart	1200				3595	2799	3197
Štrbské Pleso	1354	3542	3839	5066	3430	3401	3856
Topoľníky	113	927	1690	5274	3166	3290	2869
Žiar nad Hronom	263		2310	4298	3109	2749	3116
Žilina Vlčince	368	1838	2674	3603	2017	2045	2436

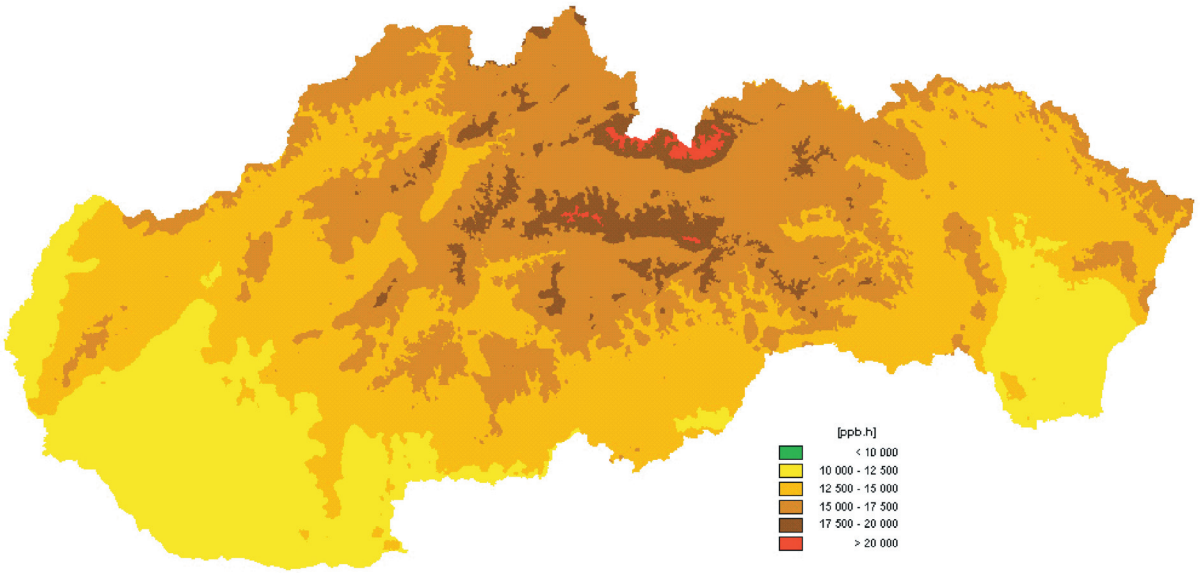

Fig. 1 The exposure index AOT 40 for forests in Slovakia for the period 2001-2005.

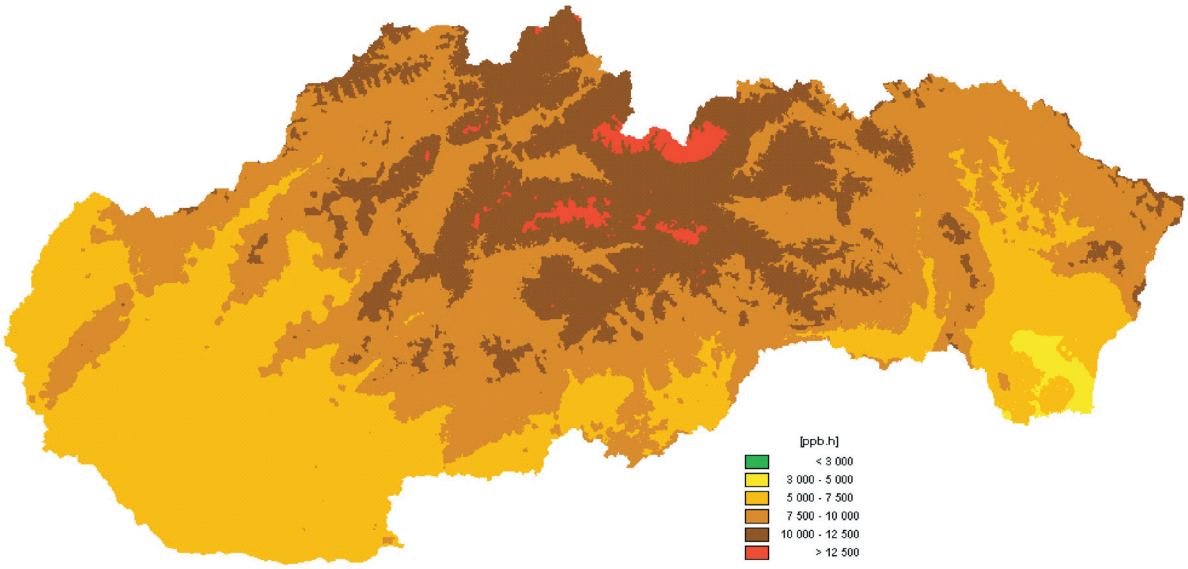

Fig. 2 The exposure index AOT 40 for agricultural crops in Slovakia for the period 2001-2005.

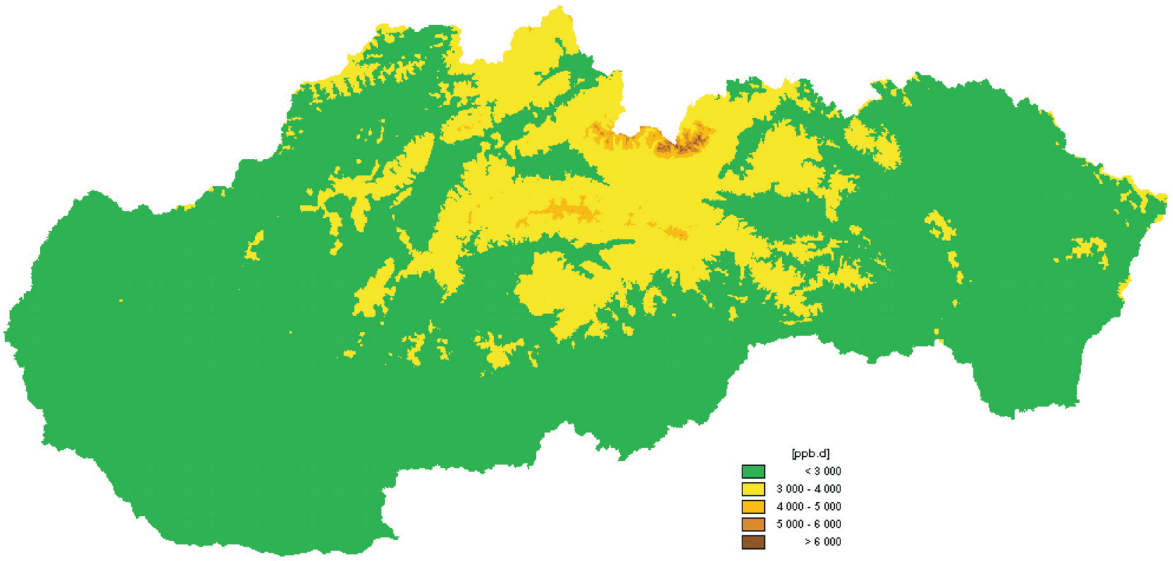

Fig. 3 The exposure index SOMO 35 in Slovakia for the period 2001-2005.

The ozone exposure index maps of Slovakia for forests and agricultural crops in 2001-2005 are presented in Fig. 1 and 2. The maps show that the exceedances of the critical levels are considerable. Both critical levels (for forests and crops) are exceeded at the whole territory of Slovakia. When we compare these maps with AOT 40 maps for the period 1992-1996, we can conclude that present ozone loads are a bit higher than in the nineties.

The SOMO 35 map of Slovakia in 2001-2005 is presented in Fig. 3. The most of the Slovak territory have SOMO 35 values under 3 000 ppb.d, higher values are in the mountains.

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