BE-106

Umweltbundesamt

BERICHTE

AN ASSESSMENT OF AUSTRIAN OZONE DATA BASED ON DIFFERENT INDICATORS

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An Assessment of Austrian Ozone Data Based on Differrent Indicators

BE-106

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Bundesministerium für Umwelt, Jugend und Familie

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Abstract

Within this report an comprehensive analysis of Austrian ozone measurement data was carried out. The assessment includes calculations of the correlation between AOT[1] values and the number of exceedances of the WHO Air Quality Guideline for ozone.

It could be shown that there is a close relationship between AOT60 values and the days of exceedances of the WHO Air Quality Guideline for ozone. Anyhow, there is almost no correlation between the days of exceedances of the WHO AQG and AOT90 values or maximum eight hour mean values of the year.

Additionally it was shown that the average maximum ozone peak concentrations show a distinct weekly pattern with lowest levels on Sundays.

Zusammenfassung

Innerhalb der vorliegenden Arbeit wurden aufbauend auf Daten des österreichischen Ozonmeßnetzes diverse Auswertungen durchgeführt, welche insbesondere für einschlägige EU-Arbeitsgruppen von Interesse waren.

Unter anderem wurden die Korrelationen von humanhygienisch relevanten Ozonparametern wie die Anzahl der Tage mit Überschreitung des Richtwerts zum Schutz der menschlichen Gesundheit vor Ozon mit integralen Indizes zur Beschreibung der Ozonbelastung (etwa AOT-Werte) berechnet und bewertet.

Dabei konnte gezeigt werden, daß AOT60-Werte sehr gut mit der Anzahl der Tage mit Überschreitung des WHO-Richtwertes zum Schutz der Gesundheit korrelieren, nicht hingegen AOT90-Werte. Darüber hinaus konnte ein Wochengang der Ozonspitzenbelastung nachgewiesen werden, mit einem Minimum jeweils an Sonntagen.

[1] AOT: **A**ccumulated **o**ver **T**hreshold

Table of Contents

1. Einleitung

Derzeit wird von der Europäischen Kommission eine neue Tochterrichtlinie (TRL) über die Luftbelastung durch Ozon vorbereitet. Basis dieser TRL, die die derzeit geltende RL 92/72/EWG ersetzen soll, sind

(a) die Rahmenrichtlinie 96/62/EG über die Beurteilung und Kontrolle der Luftqualität. Diese RL sieht vor, daß für diverse Schadstoffe, unter ihnen auch Ozon, Grenz- oder Zielwerte festgesetzt werden. Von Seiten der EU ist vorgesehen, daß die Basis dieser Werte die Air Quality Guidelines der WHO sein sollten.

(b) Ein Positionspapier, welches von der Kommission in Zusammenarbeit mit den Mitgliedstaaten, der Europäischen Umweltagentur (EEA), Industrievertretern, NGOs und dem Umweltinstitut der EU in Ispra/Italien erstellt wird.

Wie oben angeführt, sollen etwaige Grenz- oder Zielwerte in der neuen Ozonrichtlinie auf den Richtlinien der WHO basieren. Sowohl der Richtwert zum Schutz der menschlichen Gesundheit als auch der Vegetation werden derzeit in weiten Teilen Europas oft und z.T. sehr stark überschritten. Diverse Analysen haben gezeigt, daß dies auch nach europaweiter Durchführung der derzeit geplanten Emissionsreduktionen der Ozonvorläufersubstanzen bis zum Jahr 2010 der Fall sein wird. Deshalb wird von Seiten der Europäischen Kommission eine Strategie ausgearbeitet, die eine weitergehende Reduktion der Ozonbelastung zum Ziel hat. Innerhalb der Strategie sollen jene Kosten-optimierten Emissionsreduktionsmaßnahmen identifiziert werden, welche eine möglichst weitgehende Reduktion der Ozonbelastung bewirken.

Um einerseits die Eignung bestimmter Parameter, welche für die oben beschriebenen Optimierungen verwendet werden, zu überprüfen und andererseits spezifische Fragestellungen, welche in den Arbeitsgruppen zur Erstellung des Positionspapiers bearbeitet wurden, anhand von realen Meßdaten diskutieren zu können, wurden vom Umweltbundesamt österreichische Ozonmeßdaten der letzten Jahren ausgewertet. Die Ergebnisse und die wichtigsten Schlußfolgerungen werden im vorliegenden Bericht, der in Englisch abgefaßt ist, vorgestellt.

2. Introduction and Objectives

The European Commission has established a Working Group on the Ozone Daughter Directive. Within this working group a position paper on ozone is currently being prepared which will be the basis for a daughter directive on ozone.

Within the discussions of the working group it was pointed out that the WHO Air Quality Guideline (WHO AQG) of 120 µg/m^3 (60 ppb) as an eight hour mean value would be a reasonable Long Term Objective. Anyhow, for the development of an abatement strategy it was considered to use AOT60[2] values within the integrated assessment modelling, since AOT values are well suited for calculations using the EMEP model or models derived from it.

Within this paper information is provided on the relationship of different ozone exposure indices which can readily be used within integrated assessment models like AOT60, AOT40 for crops (AOT40c), AOT40 for forest ecosystems (AOT40f) and the days of exceedances of the WHO Air Quality Guideline of 120 µg/m^3.

Additionally, other potentially relevant indicators for the ozone exposure like AOT90 values and maximum eight hour mean values were calculated and compared to other parameters.

Last but not least the weekly variations of maximum ozone levels were determined for selected stations to identify any 'weekend effect'.

For this assessment data from 1990 - 1996 from 13 different Austrian measurement sites were used.

[2] Accumulated Exposure Over Threshold of 60 ppb; a definition is given later in the text.

3. Selection and description of sites

Different types of stations were selected which give a representative overview about ozone levels in Austria. Altogether about 110 ozone monitoring sites are run in Austria from which 13 were selected for this assessment. These include sites from the three largest cities in Austria which are particularly relevant for the assessment of human health effects, but also sites in Alpine areas.

The following tables gives for these sites

⇒ altitude in m (a.s.l)

⇒ a topographic characterisation of the location

⇒ a characterisation of land use and emissions in the surrounding of the site

Site	***Altitude***	***Topography***	***Land use***
Vienna Stephansplatz	183 m	Plain	Central urban; residential, commercial
Vienna Hermannskogel	520 m	Hilltop	Suburban; forest
Graz West (St[3])	370 m	Basin	Suburban, residential
Graz Schloßberg (St)	450 m	Hilltop	Park in city centre, surrounded by central urban residential area
Linz Berufsschule (OOE[4])	274 m	Plain	Urban industrial, residential
Klagenfurt Koschatstr. (K[5])	440 m	Basin	Suburban, residential, traffic
Illmitz (Bgld.[6])	117 m	Plain	Rural, agriculture
Dunkelsteinerwald (NOE[7])	305 m	Hilly terrain	Rural, agriculture, forest
Grundlsee (St)	954 m	Hilly terrain	Rural, forest, pasture
St. Koloman (Sbg.[8])	1020 m	Hilly terrain	Rural, forest, pasture
Vorhegg (K)	1010 m	Slope, hilly terrain	Rural, forest, pasture
Sulzberg (Vbg.[9])	1020 m	Hilly terrain	Rural, agriculture, pasture, forest
Rennfeld (St)	1618 m	Mountain top	Forest

Vienna has about 1.533.000 inhabitants. Stephansplatz is in the centre of Vienna. Hermannskogel is a suburban site in a forest in the north-western part of Vienna, which is occasionally influenced by the plume of the city.

[3] St: Steiermark
[4] OOE: Oberösterreich (Upper Austria)
[5] K: Kärnten (Carinthia)
[6] Bgld: Burgenland
[7] NOE: Niederösterreich (Lower Austria)
[8] Sbg: Salzburg
[9] Vbg.: Vorarlberg

Graz is the second largest town in Austria with 236.000 inhabitants. Two stations were selected from Graz, one in the centre in a park, the second is an urban background site. Though both stations can be classified as *urban background* sites, they can display large differences in their ozone levels.

Linz has about 203.000 inhabitants. It is the third biggest town in Austria and has considerable amount of (heavy) industry.

Klagenfurt (monitoring site: Koschatstraße) has around 90.000 inhabitants.

Illmitz is located in the Pannonian area in the far east of Austria in flat terrain.

Dunkelsteinerwald is a background site approx. 50 km west of Vienna.

Grundlsee and St. Koloman both lie at similar altitudes with similar land-use within a distance of 50 km. Anyhow, St. Koloman is located on a top of a hill, whereas Grundlsee is surrounded by higher mountains, which results in highly divergent ozone levels at those two sites. Vorhegg is located in the south of Austria, Sulzberg in the west. These 4 stations are located in rural areas outside of villages and are representative for ozone pollution at a scale of several tens of km.

Rennfeld is located in high alpine, uninhabited terrain and representative for forested mountainous regions in eastern Austria.

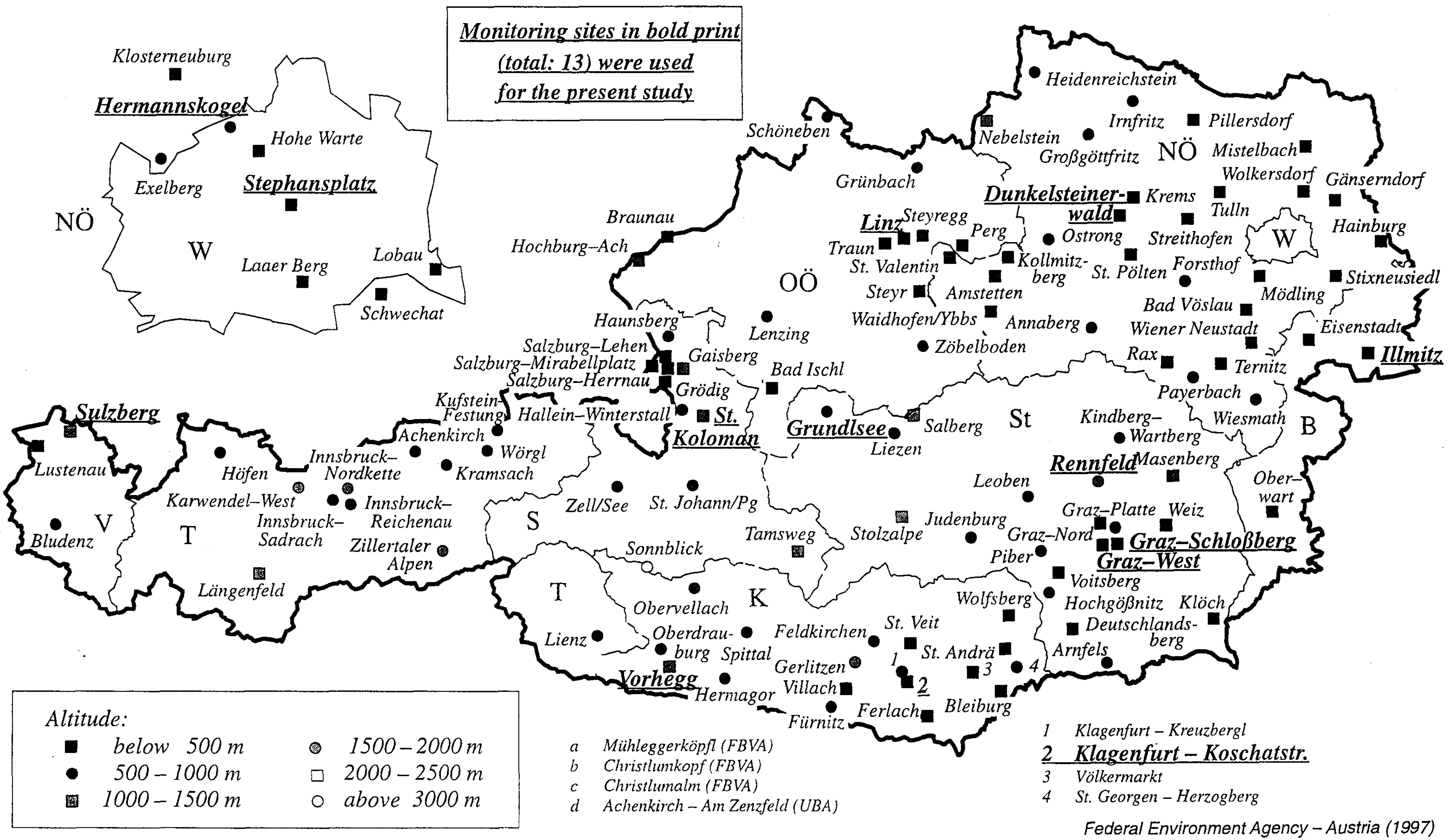
Illmitz, Vorhegg and St. Koloman are Austrian EMEP-sites.

As additional criteria for the characterisation of the stations the following table shows the annual average NO_2 levels in µg/m^3 at stations equipped with a NOx monitor.

	µg NO_2 /m^3 as annual mean				
site	1993	1994	1995	1996	mean 93-96
Wien Stephansplatz	47	37	34		39
Wien Hermannskogel	22	10	11	13	14
Graz West	41	34	37	37	37
Linz Berufsschule	37	30	29	24	30
Klagenfurt Koschatstraße	39	29	26	27	30
Dunkelsteinerwald	17	13	16	16	15
Vorhegg	5	7	5		6

The following figure shows the ozone monitoring stations in Austria. Sites in bold print were used for the present study.

Ozone monitoring sites in Austria



Federal Environment Agency – Austria (1997)

4. Correlation between AOT60, AOT40 and the days of exceedances of the WHO Air Quality Guideline

4.1 Calculation of AOT40 and AOT60 values

AOT40 values were calculated as agreed in a workshop in Kuopio in 1996 using only daylight hours with solar radiation > 50 W/m^2.

For crops a growing season from May till July was taken; the corresponding Critical Level is 3.000 ppb*h.

For forest ecosystems a growing season from April till September was taken. The Critical Level is 10.000 ppb*h.

The calculation of the AOT60 values is based on eight hour mean values (MW8). Two different sets of MW8 were used:

MW8fix:	Eight hour mean value from 12.00 till 20:00 (8:00 p.m.); the same period is used in the current ozone directive 92/72/EC, though with a different threshold value (110 $\mu g/m^3$).
MW8max:	Daily maximum eight hour mean value, calculated from moving one hour averages

The AOT60 values were calculated using the following formula:

$$AOT60 = \sum (MW8 - 60) \quad \text{for } MW8 > 60 \text{ ppb.}$$

The results were not adjusted to one hour values. This means that for an eight hour mean value of e.g. 64 ppb, 4 ppb were taken for the eight hour period (i.e. per day). Therefore, results of the AOT60 calculations are, in contrast to the AOT40, not given in ppb*h but rather in 'ppb*8h'.

The periods for which the AOT60 were calculated were

- for the whole year
- from April till September (summer half year)
- from May - July.

Results are given only for stations with a percentage of valid data > 75%. Generally, values were extrapolated to 100 %.

The following tables provide information on the

1. number of days with exceedances of the WHO AQG value
2. number of valid data over the period of interest
3. calculated AOT60 values; for each year from 1990 - 1996 for three different periods
4. calculated AOT40c and AOT40f values

Table 1:	Values for 1990
Table 2:	Values for 1991
Table 3:	Values for 1992
Table 4:	Values for 1993
Table 5:	Values for 1994
Table 6:	Values for 1995
Table 7:	Values for 1996

Percentage of valid data

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz						
Hermannskogel	96	97	98	97	97	97
Graz West	84	86	90	84	86	91
Graz Schloßberg						
Linz Berufsschule	98	96	97	99	99	99
Klagenfurt Koschatstr						
Illmitz	99	99	100	99	100	100
Dunkelsteinerwald	99	99	98	99	99	98
Grundlsee	49	98	99	49	97	97
St. Koloman	49	50	35	50	49	35
Vorhegg	5	0	0	5	0	0
Sulzberg	50	99	100	50	99	100
Rennfeld	98	96	93	98	96	92

AOT60

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz						
Hermannskogel	560	549	282	745	731	387
Graz West	102	102	73	219	219	139
Graz Schloßberg						
Linz Berufsschule	96	96	70	129	129	87
Klagenfurt Koschatstr						
Illmitz	574	557	374	748	727	480
Dunkelsteinerwald	519	519	273	692	692	375
Grundlsee		625	447		855	569
St. Koloman						
Vorhegg						
Sulzberg		1153	738		1523	958
Rennfeld	1106	851	474	1677	1327	710

AOT40

	AOT40c	AOT40f
Wien Stephansplatz		
Hermannskogel	14155	21957
Graz West	9325	14796
Graz Schloßberg		
Linz Berufsschule	5588	8898
Klagenfurt Koschatstr		
Illmitz	16095	25472
Dunkelsteinerwald	12169	20216
Grundlsee	18835	29242
St. Koloman		
Vorhegg		
Sulzberg	24369	39254
Rennfeld	24179	41333

Number of days with Exceedance of WHO Air Quality Guideline of 120 µg/m^3 as eight hour mean value

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz						
Hermannskogel	46	43	26	59	56	34
Graz West	17	17	11	28	28	20
Graz Schloßberg						
Linz Berufsschule	13	13	8	16	16	8
Klagenfurt Koschatstr						
Illmitz	57	55	36	68	64	41
Dunkelsteinerwald	35	35	19	45	45	25
Grundlsee		61	39		73	43
St. Koloman						
Vorhegg						
Sulzberg		88	55		105	65
Rennfeld	81	64	38	112	91	52

Table 1: Values for 1990

1990

Percentage of valid data

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	42	45	24	41	44	23
Hermannskogel	99	100	100	99	100	100
Graz West	95	99	100	96	99	100
Graz Schloßberg	39	37	50	40	38	50
Linz Berufsschule	99	100	100	99	100	100
Klagenfurt Koschatstr	93	92	88	95	95	90
Illmitz	98	98	99	98	97	97
Dunkelsteinerwald	95	91	89	95	91	90
Grundlsee	50	99	100	50	99	100
St. Koloman	98	99	100	98	99	100
Vorhegg	95	91	88	96	92	88
Sulzberg		99	100		99	100
Rennfeld	95	98	99	96	100	100

AOT60

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz						
Hermannskogel	1091	1064	371	1493	1419	506
Graz West	32	32	31	94	94	76
Graz Schloßberg						
Linz Berufsschule	53	53	40	68	68	44
Klagenfurt Koschatstr	103	99	71	190	185	115
Illmitz	111	111	94	180	180	147
Dunkelsteinerwald	205	199	163	286	275	201
Grundlsee		97	15		204	30
St. Koloman	211	211	95	413	413	187
Vorhegg	92	83	18	269	254	95
Sulzberg		745	311		1117	503
Rennfeld	129	118	82	322	294	175

AOT40

	AOT40c	AOT40f
Wien Stephansplatz		
Hermannskogel	15449	34123
Graz West	7658	12363
Graz Schloßberg		
Linz Berufsschule	4396	7667
Klagenfurt Koschatstr	8728	14668
Illmitz	8240	13466
Dunkelsteinerwald	11310	19089
Grundlsee	3378	11972
St. Koloman	9860	18929
Vorhegg	7755	15999
Sulzberg	15542	31786
Rennfeld	14235	24985

Number of days with Exceedance of WHO Air Quality Guideline of 120 µg/m^3 as eight hour mean value

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz						
Hermannskogel	80	75	31	103	92	41
Graz West	9	9	8	19	19	15
Graz Schloßberg						
Linz Berufsschule	6	6	3	8	8	4
Klagenfurt Koschatstr	25	24	14	30	29	16
Illmitz	15	15	12	20	20	13
Dunkelsteinerwald	29	28	16	38	35	19
Grundlsee		17	2		26	3
St. Koloman	31	31	13	50	49	22
Vorhegg	21	17	5	42	36	16
Sulzberg		73	32		98	45
Rennfeld	26	23	16	55	50	29

Table 2: Values for 1991

1991

Percentage of valid data

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	90	98	96	90	98	96
Hermannskogel	93	100	100	93	100	100
Graz West	76	59	65	76	59	65
Graz Schloßberg	99	99	99	99	100	100
Linz Berufsschule	43	86	77	43	85	76
Klagenfurt Koschatstr	98	96	95	99	98	97
Illmitz	98	99	100	99	99	100
Dunkelsteinerwald	92	97	93	91	96	92
Grundlsee	49	97	100	49	98	100
St. Koloman	96	96	99	95	93	97
Vorhegg	96	99	100	99	99	100
Sulzberg	49	98	98	50	98	99
Rennfeld	94	92	90	96	93	90

AOT60

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	192	192	98	287	287	118
Hermannskogel	602	602	253	786	786	355
Graz West						
Graz Schloßberg	208	208	55	272	272	75
Linz Berufsschule						
Klagenfurt Koschatstr	84	84	37	177	176	79
Illmitz	540	540	286	650	650	346
Dunkelsteinerwald	452	452	192	532	532	225
Grundlsee		64	56		109	98
St. Koloman	304	304	154	413	413	217
Vorhegg	296	270	142	588	530	292
Sulzberg		417	260		658	442
Rennfeld	390	389	167	717	701	313

AOT40

	AOT40c	AOT40f
Wien Stephansplatz	9332	16033
Hermannskogel	14112	26116
Graz West		13393
Graz Schloßberg	7640	15787
Linz Berufsschule		
Klagenfurt Koschatstr	9392	16546
Illmitz	16047	28051
Dunkelsteinerwald	13202	23350
Grundlsee	9198	12991
St. Koloman	12977	21566
Vorhegg	12622	22696
Sulzberg	15796	23857
Rennfeld	19036	33771

Number of days with Exceedance of WHO Air Quality Guideline of 120 μg/m^3 as eight hour mean value

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	28	28	16	32	32	18
Hermannskogel	58	58	28	72	72	38
Graz West						
Graz Schloßberg	28	28	8	39	39	14
Linz Berufsschule						
Klagenfurt Koschatstr	17	17	8	37	36	17
Illmitz	57	57	31	67	67	37
Dunkelsteinerwald	41	41	24	47	47	28
Grundlsee		13	10		21	17
St. Koloman	37	37	21	49	49	27
Vorhegg	39	36	16	64	59	30
Sulzberg		47	30		71	47
Rennfeld	46	45	18	80	77	37

Table 3: Values for 1992

1992

Percentage of valid data

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	99	98	97	99	98	97
Hermannskogel	98	98	96	97	97	95
Graz West	94	89	83	97	95	93
Graz Schloßberg	83	98	100	83	97	100
Linz Berufsschule	92	97	98	93	98	100
Klagenfurt Koschatstr	100	100	100	100	100	100
Illmitz	96	97	96	96	99	99
Dunkelsteinerwald	96	99	98	96	98	98
Grundlsee	99	99	99	100	100	100
St. Koloman	95	96	92	96	97	95
Vorhegg	90	85	78	90	82	74
Sulzberg	99	98	100	98	97	100
Rennfeld	96	95	91	98	97	93

AOT60

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	51	51	42	88	88	64
Hermannskogel	442	429	223	584	549	295
Graz West	109	109	95	172	172	150
Graz Schloßberg	206	206	123	252	252	160
Linz Berufsschule	132	132	95	205	198	138
Klagenfurt Koschatstr	62	62	41	138	138	92
Illmitz	298	298	219	417	413	309
Dunkelsteinerwald	341	335	198	450	437	244
Grundlsee	36	20	11	85	59	26
St. Koloman	261	208	119	394	312	172
Vorhegg	219			363		
Sulzberg	535	417	242	812	664	414
Rennfeld	312	275	150	622	558	304

AOT40

	AOT40c	AOT40f
Wien Stephansplatz	5775	9304
Hermannskogel	11775	20387
Graz West	8885	12822
Graz Schloßberg	8995	14733
Linz Berufsschule	7762	12453
Klagenfurt Koschatstr	9205	14378
Illmitz	12741	19660
Dunkelsteinerwald	11113	19059
Grundlsee	5500	9362
St. Koloman	12106	19825
Vorhegg	11748	17308
Sulzberg	14557	23148
Rennfeld	16270	26613

Number of days with Exceedance of WHO Air Quality Guideline of 120 $\mu g/m^3$ as eight hour mean value

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	9	9	6	15	15	8
Hermannskogel	52	50	28	63	58	32
Graz West	20	20	15	30	30	24
Graz Schloßberg	37	37	23	43	43	28
Linz Berufsschule	23	22	13	30	27	16
Klagenfurt Koschatstr	18	18	13	32	32	23
Illmitz	38	38	28	47	45	33
Dunkelsteinerwald	45	44	22	52	49	25
Grundlsee	12	9	4	22	18	8
St. Koloman	37	31	18	52	43	23
Vorhegg	29			40		
Sulzberg	53	43	24	74	63	40
Rennfeld	47	41	22	71	62	34

Table 4: Values for 1993

1993

Percentage of valid data

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	99	100	100	99	100	100
Hermannskogel	99	99	100	98	98	100
Graz West	94	94	88	95	95	89
Graz Schloßberg	93	93	90	91	92	89
Linz Berufsschule	97	96	92	97	97	96
Klagenfurt Koschatstr	49	50	34	49	50	34
Illmitz	92	95	95	91	94	92
Dunkelsteinerwald	99	98	97	99	99	98
Grundlsee	99	99	100	100	100	100
St. Koloman	94	96	96	95	97	97
Vorhegg	96	97	96	98	96	95
Sulzberg	95	98	99	96	99	100
Rennfeld	97	97	99	98	98	100

AOT60

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	225	225	149	314	314	210
Hermannskogel	784	784	502	968	968	616
Graz West	334	334	194	382	382	219
Graz Schloßberg	295	295	165	343	343	190
Linz Berufsschule	353	353	219	414	414	259
Klagenfurt Koschatstr						
Illmitz	369	369	229	490	490	311
Dunkelsteinerwald	614	614	400	765	765	481
Grundlsee	59	59	18	174	174	63
St. Koloman	390	390	230	625	625	382
Vorhegg	353	344	218	565	553	348
Sulzberg	782	781	582	1064	1062	802
Rennfeld	287	287	155	503	503	311

AOT40

	AOT40c	AOT40f
Wien Stephansplatz	8654	13223
Hermannskogel	18045	28691
Graz West	10183	15246
Graz Schloßberg	9994	15712
Linz Berufsschule	10578	15489
Klagenfurt Koschatstr		
Illmitz	14697	24573
Dunkelsteinerwald	17137	27132
Grundlsee	7205	11039
St. Koloman	15813	24802
Vorhegg	14291	22467
Sulzberg	22550	32303
Rennfeld	17354	27739

Number of days with Exceedance of WHO Air Quality Guideline of 120 μg/m^3 as eight hour mean value

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	27	27	17	31	31	20
Hermannskogel	56	56	36	67	67	41
Graz West	29	29	18	32	32	21
Graz Schloßberg	37	37	22	39	39	24
Linz Berufsschule	31	31	22	33	33	24
Klagenfurt Koschatstr						
Illmitz	44	44	29	55	55	36
Dunkelsteinerwald	50	50	33	63	63	40
Grundlsee	15	15	9	28	28	18
St. Koloman	44	44	29	61	61	41
Vorhegg	49	47	31	63	61	42
Sulzberg	65	64	44	83	82	58
Rennfeld	38	38	23	58	58	38

Table 5: Values for 1994

1994

Percentage of valid data

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	98	98	100	98	99	100
Hermannskogel	96	97	95	95	97	93
Graz West	93	95	95	93	96	93
Graz Schloßberg	87	87	97	87	86	95
Linz Berufsschule	96	96	93	98	97	93
Klagenfurt Koschatstr	97	98	97	97	99	98
Illmitz	98	99	99	99	100	100
Dunkelsteinerwald	96	93	92	98	96	92
Grundlsee	94	92	88	95	93	88
St. Koloman	97	98	99	96	97	98
Vorhegg	96	95	98	96	95	100
Sulzberg	99	99	98	100	100	100
Rennfeld	99	98	99	99	99	100

AOT60

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	19	19	19	26	26	26
Hermannskogel	463	463	362	611	608	471
Graz West	55	55	49	114	114	91
Graz Schloßberg	225	225	187	283	283	233
Linz Berufsschule	144	144	142	202	202	187
Klagenfurt Koschatstr	16	16	13	37	37	28
Illmitz	278	278	178	432	432	263
Dunkelsteinerwald	396	396	344	510	510	430
Grundlsee	124	124	94	178	178	130
St. Koloman	282	281	216	394	393	318
Vorhegg	242	232	155	389	372	278
Sulzberg	508	508	369	712	709	538
Rennfeld	261	261	228	507	507	387

AOT40

	AOT40c	AOT40f
Wien Stephansplatz	2848	3517
Hermannskogel	16196	22491
Graz West	7743	11145
Graz Schloßberg	11254	16664
Linz Berufsschule	8386	11249
Klagenfurt Koschatstr	5957	9384
Illmitz	13938	22072
Dunkelsteinerwald	16419	22436
Grundlsee	9111	12166
St. Koloman	13225	20107
Vorhegg	10899	18311
Sulzberg	17696	24979
Rennfeld	18941	25341

Number of days with Exceedance of WHO Air Quality Guideline of 120 µg/m^3 as eight hour mean value

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	3	3	3	5	5	5
Hermannskogel	45	45	32	60	59	39
Graz West	12	12	10	19	19	15
Graz Schloßberg	31	31	25	37	37	29
Linz Berufsschule	17	17	15	23	23	17
Klagenfurt Koschatstr	9	9	5	12	12	8
Illmitz	44	44	27	52	52	30
Dunkelsteinerwald	43	43	30	52	52	38
Grundlsee	20	20	14	24	24	14
St. Koloman	37	36	24	50	49	34
Vorhegg	31	29	19	45	41	28
Sulzberg	45	45	33	58	57	41
Rennfeld	36	36	29	60	60	43

Table 6: Values for 1995

1995

Percentage of valid data

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	100	100	100	100	100	100
Hermannskogel	100	100	100	100	100	100
Graz West	92	93	91	91	90	89
Graz Schloßberg	99	98	100	99	98	100
Linz Berufsschule	93	95	93	98	100	100
Klagenfurt Koschatstr	99	99	99	99	99	100
Illmitz	99	100	100	100	100	100
Dunkelsteinerwald	99	99	100	99	98	100
Grundlsee	98	99	99	98	99	100
St. Koloman	98	99	100	99	99	99
Vorhegg	96	94	89	98	96	92
Sulzberg	100	100	100	100	100	100
Rennfeld	99	98	99	99	98	100

AOT60

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	51	51	9	109	109	39
Hermannskogel	358	345	120	471	440	177
Graz West	144	144	78	201	201	101
Graz Schloßberg	284	275	141	363	340	188
Linz Berufsschule	103	103	64	140	140	82
Klagenfurt Koschatstr	142	142	97	214	214	158
Illmitz	233	212	74	335	306	131
Dunkelsteinerwald	161	155	37	209	200	52
Grundlsee	158	158	106	219	218	154
St. Koloman	190	190	131	274	274	174
Vorhegg	481	463	266	715	692	456
Sulzberg	295	240	169	423	338	233
Rennfeld	370	359	222	571	525	322

AOT40

	AOT40c	AOT40f
Wien Stephansplatz	5193	9242
Hermannskogel	9963	17500
Graz West	8683	13745
Graz Schloßberg	10083	16360
Linz Berufsschule	6536	9827
Klagenfurt Koschatstr	9117	12648
Illmitz	10366	18045
Dunkelsteinerwald	6937	12760
Grundlsee	9719	15609
St. Koloman	10954	16823
Vorhegg	14553	21719
Sulzberg	12026	18850
Rennfeld	16567	26772

Number of days with Exceedance of WHO Air Quality Guideline of 120 µg/m^3 as eight hour mean value

	MW8fix			MW8max		
	year	Apr.-Sep.	May-July	year	Apr.-Sep.	May-July
Wien Stephansplatz	9	9	3	14	14	4
Hermannskogel	38	36	18	50	48	25
Graz West	20	20	14	22	22	14
Graz Schloßberg	35	32	19	43	38	24
Linz Berufsschule	15	15	9	17	17	10
Klagenfurt Koschatstr	18	18	15	26	26	20
Illmitz	35	28	11	44	a	17
Dunkelsteinerwald	18	17	7	28	25	11
Grundlsee	20	20	12	27	25	17
St. Koloman	19	19	13	27	27	18
Vorhegg	44	38	26	56	48	33
Sulzberg	42	32	23	58	45	31
Rennfeld	40	36	24	66	53	34

Table 7: Values for 1996

1996

4.2 Calculated Correlations[10]

The following figures give information on the correlation of AOT60, AOT40 and days of exceedances of WHO AQG. If not stated separately, AOT60 is calculated for the period from April - September from daily maximum eight hour mean values (MW8max).

In the figures, data from stations situated in cities are classified as 'urban'. This class comprises central urban and suburban sites. The remaining stations are summarised as 'non urban sites'.

Figure 1 shows the correlation between the AOT60 values and the number of days with exceedances of WHO AQG for the period of 1990-1996.

Figure 2 shows the correlation between the AOT40c values and the number of days with exceedances of WHO AQG for the period of 1990-1996.

Figure 3 shows the correlation between the AOT40f values and the number of days with exceedances of WHO AQG for the period of 1990-1996.

Figure 4 shows the correlation between the AOT60 values and the AOT40f for the period of 1990-1996.

Figure 5 shows the correlation between the AOT60 values and the AOT40c for the period of 1990-1996.

Figure 6 shows the correlation between the AOT40c and the AOT40f values.

Figure 7 shows the correlation between the number of days with exceedances of WHO AQG calculated from daily maximum eight hour mean values versus eight hour mean values from a fixed period.

Figure 8 shows the correlation between AOT60 values calculated from MW8max and MW8fix.

[10] R^2 is the square Pearson correlation coefficient

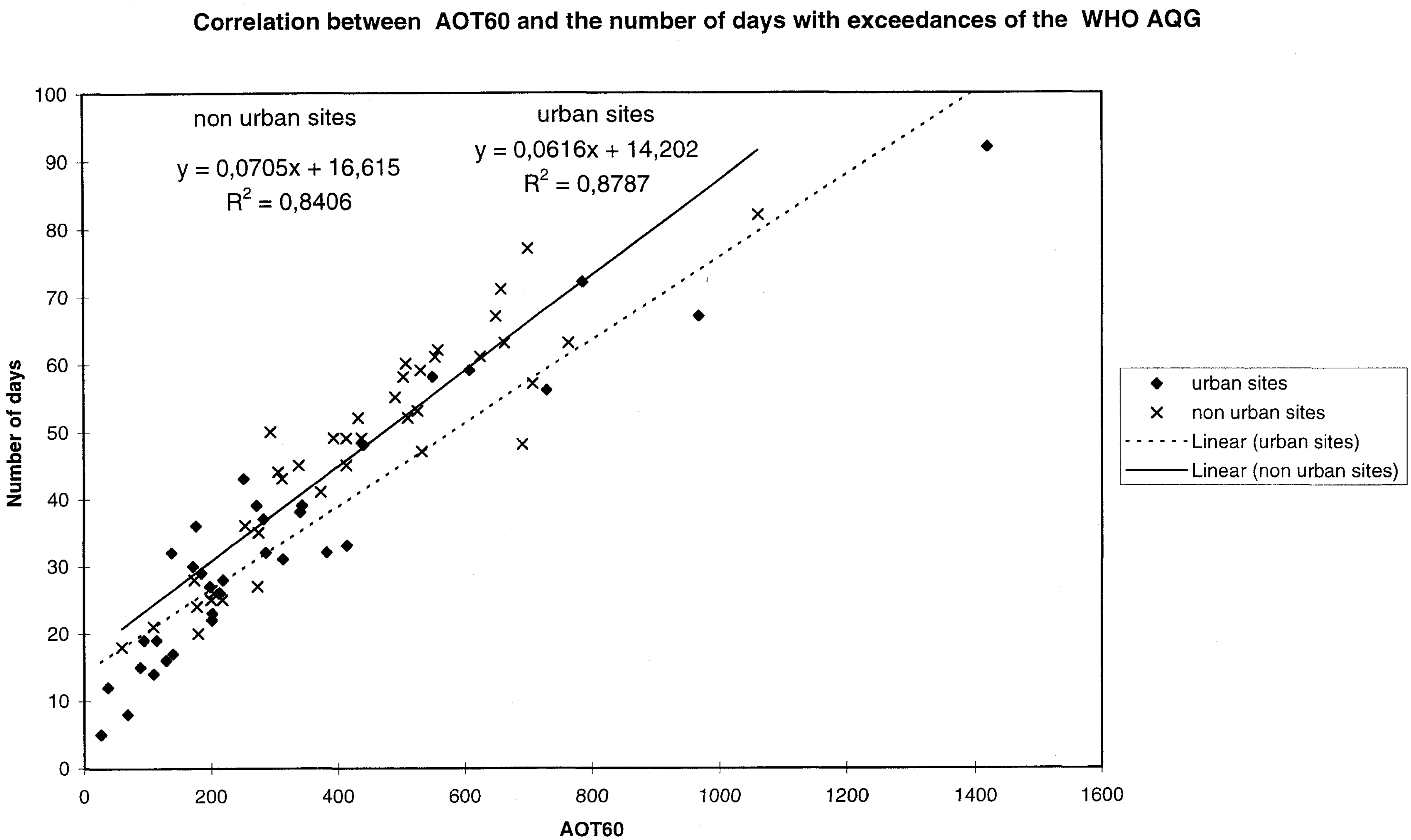
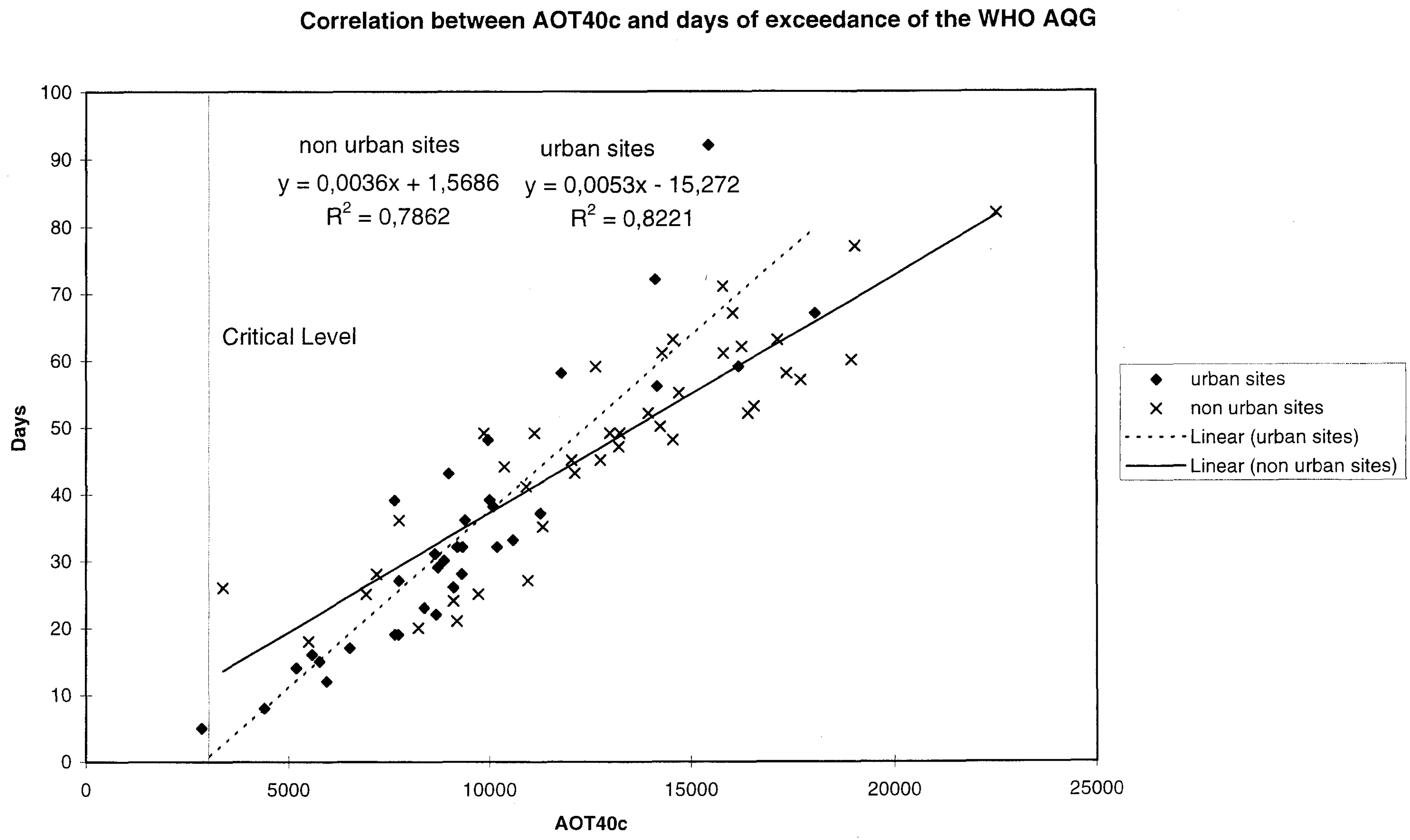

Correlation between AOT60 and the number of days with exceedances of the WHO AQG
non urban sites
y = 0,0705x + 16,615
R2 = 0,8406
urban sites
y = 0,0616x + 14,202
R2 = 0,8787
Number of days
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
AOT60
urban sites
non urban sites
Linear (urban sites)
Linear (non urban sites)

Figure 1



Correlation between AOT40c and days of exceedance of the WHO AQG
non urban sites
y = 0,0036x + 1,5686
R2 = 0,7862
urban sites
y = 0,0053x - 15,272
R2 = 0,8221
Critical Level
Days
AOT40c
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
15000
20000
25000
urban sites
non urban sites
Linear (urban sites)
Linear (non urban sites)

Figure 2

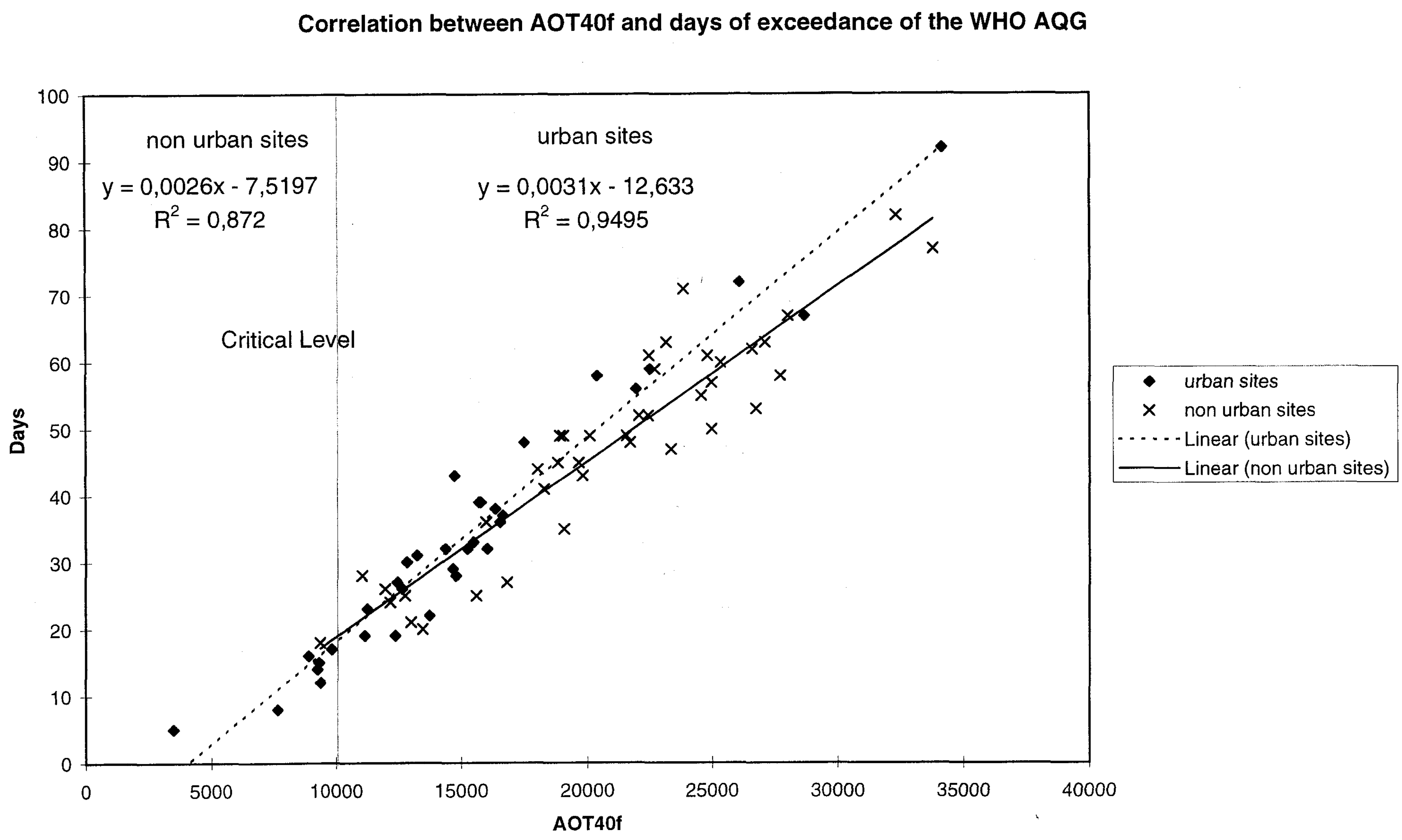

Correlation between AOT40f and days of exceedance of the WHO AQG
non urban sites
y = 0,0026x - 7,5197
R2 = 0,872
urban sites
y = 0,0031x - 12,633
R2 = 0,9495
Critical Level
Days
AOT40f
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
15000
20000
25000
30000
35000
40000
urban sites
non urban sites
Linear (urban sites)
Linear (non urban sites)

Figure 3

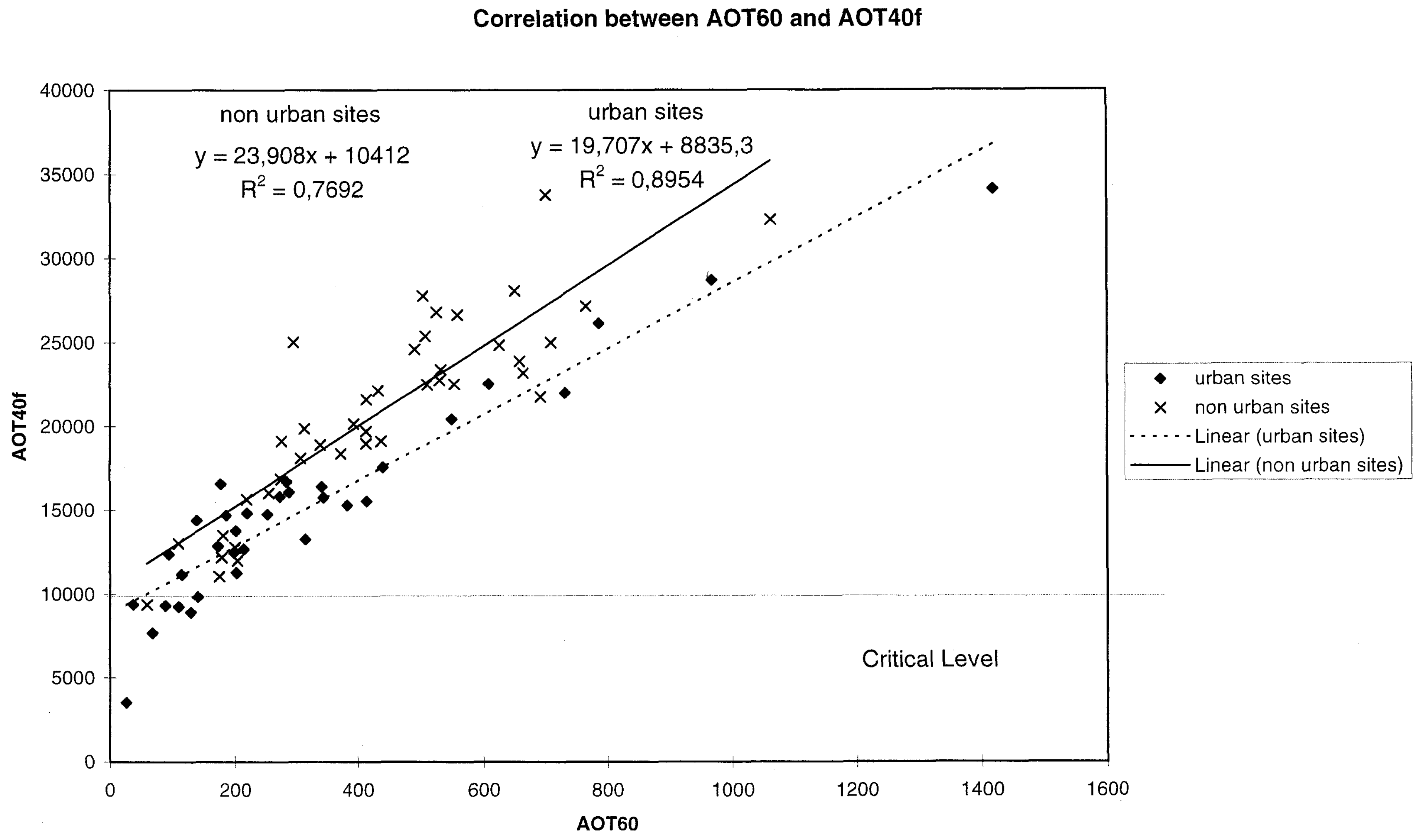

Correlation between AOT60 and AOT40f
non urban sites
y = 23,908x + 10412
R2 = 0,7692
urban sites
y = 19,707x + 8835,3
R2 = 0,8954
Critical Level
AOT40f
AOT60
0
5000
10000
15000
20000
25000
30000
35000
40000
0
200
400
600
800
1000
1200
1400
1600
urban sites
non urban sites
Linear (urban sites)
Linear (non urban sites)

Figure 4

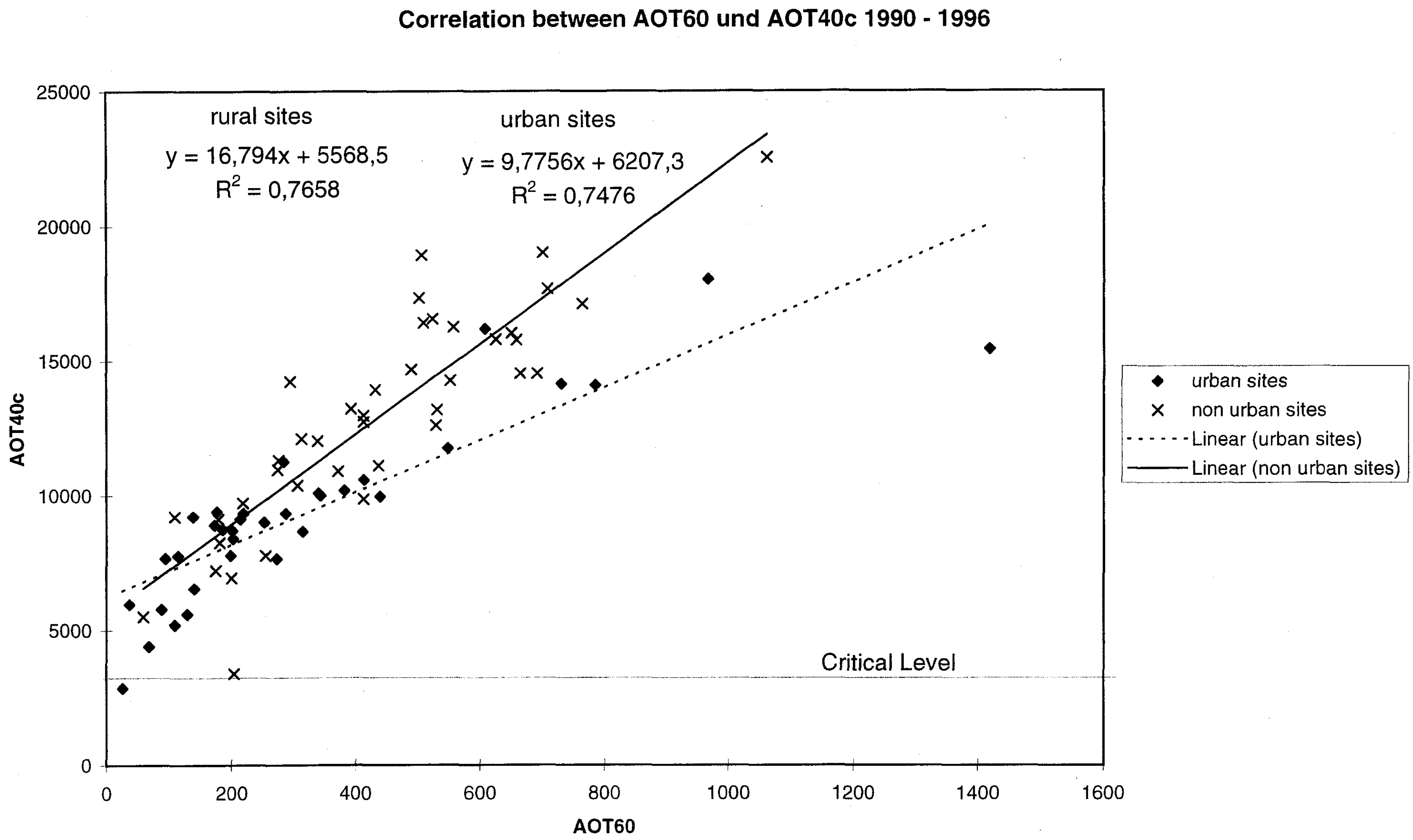

Correlation between AOT60 und AOT40c 1990 - 1996
rural sites
y = 16,794x + 5568,5
R2 = 0,7658
urban sites
y = 9,7756x + 6207,3
R2 = 0,7476
Critical Level
AOT40c
AOT60
0
5000
10000
15000
20000
25000
0
200
400
600
800
1000
1200
1400
1600
urban sites
non urban sites
Linear (urban sites)
Linear (non urban sites)

Figure 5

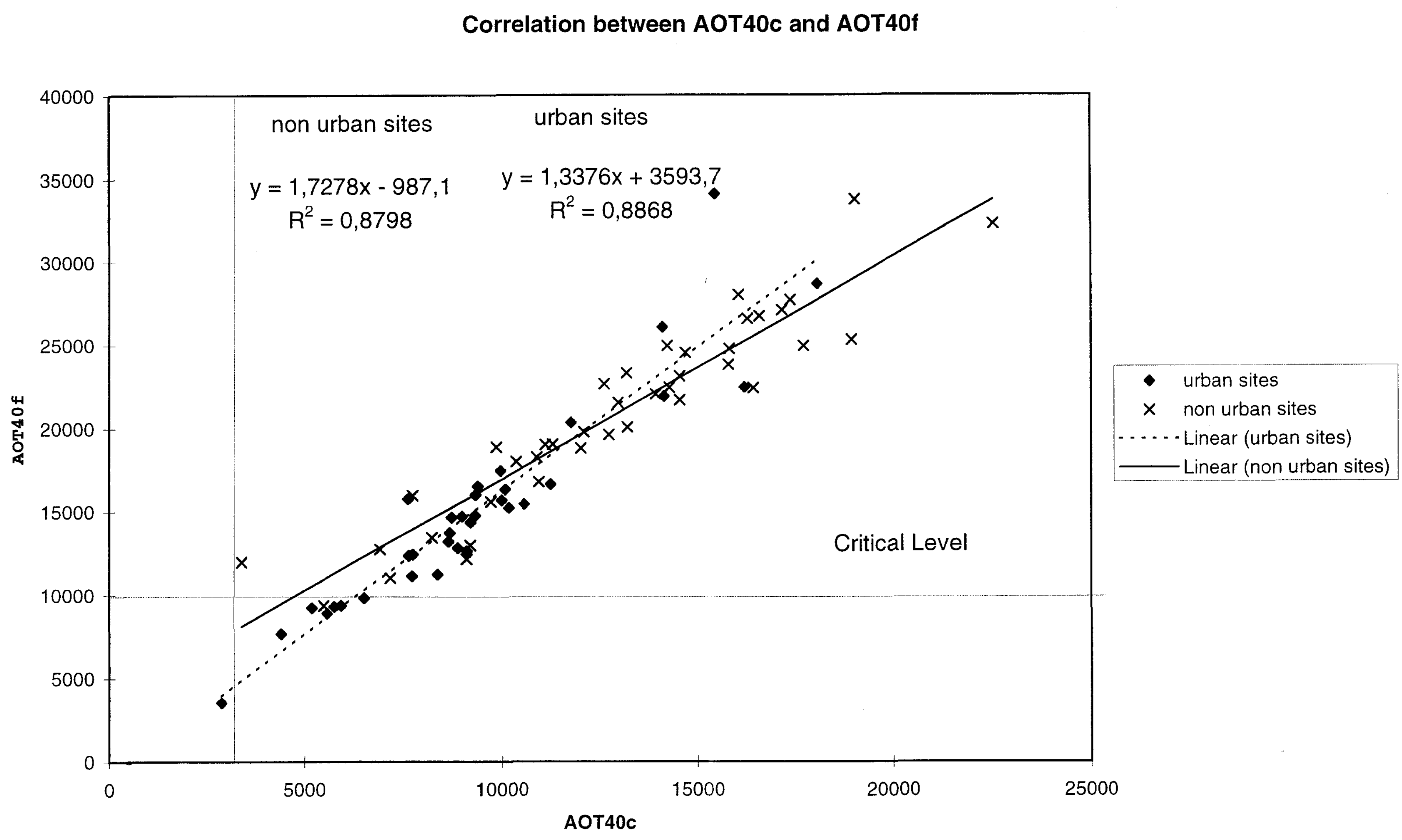

Correlation between AOT40c and AOT40f
non urban sites
y = 1,7278x - 987,1
R2 = 0,8798
urban sites
y = 1,3376x + 3593,7
R2 = 0,8868
Critical Level
urban sites
non urban sites
Linear (urban sites)
Linear (non urban sites)
AOT40f
AOT40c
0
5000
10000
15000
20000
25000
30000
35000
40000

Figure 6

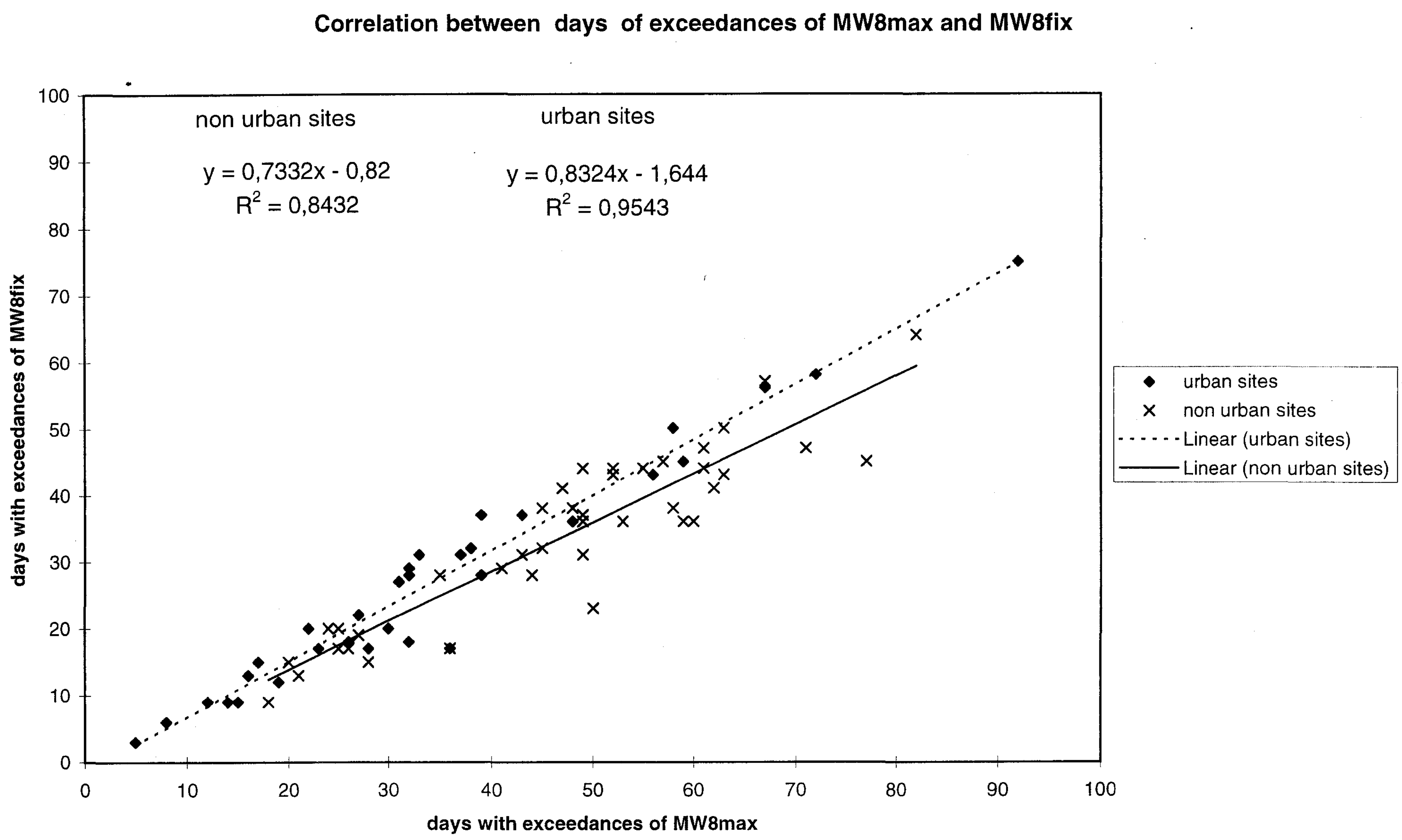
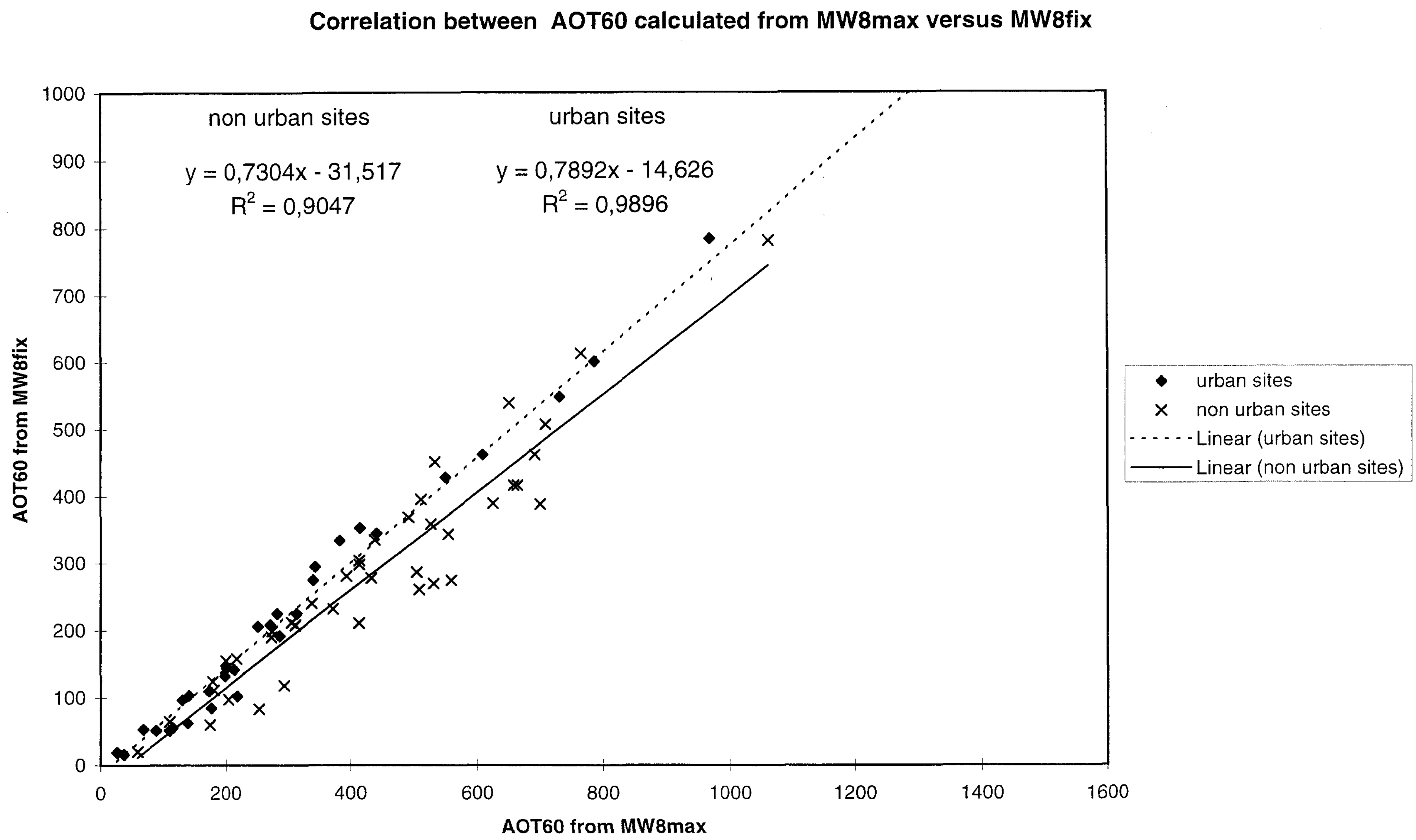

Correlation between days of exceedances of MW8max and MW8fix
non urban sites
y = 0,7332x - 0,82
R2 = 0,8432
urban sites
y = 0,8324x - 1,644
R2 = 0,9543
days with exceedances of MW8fix
days with exceedances of MW8max
0
10
20
30
40
50
60
70
80
90
100
urban sites
non urban sites
Linear (urban sites)
Linear (non urban sites)

Figure 7



Correlation between AOT60 calculated from MW8max versus MW8fix
non urban sites
y = 0,7304x - 31,517
R^2 = 0,9047
urban sites
y = 0,7892x - 14,626
R^2 = 0,9896
AOT60 from MW8fix
AOT60 from MW8max
0
100
200
300
400
500
600
700
800
900
1000
0
200
400
600
800
1000
1200
1400
1600
urban sites
non urban sites
Linear (urban sites)
Linear (non urban sites)

Figure 8

Table 8 summarises the interannual variations of different ozone values for the period of 1990 - 1996. The range of the variation is given for each of the parameters for each measurement site.

Table 8

	Days of exceedance of WHO AQG		AOT60 for summer half year		AOT40c		AOT40f	
Measurement site	min	max	min	max	min	max	min	max
Vienna Stephansplatz*	**5**	**31**	**26**	**314**	*2848*	*9332*	*3517*	*16033*
Hermannskogel	**56**	**92**	**440**	**1419**	**9963**	**18045**	**17500**	**34123**
Graz West*	**19**	**32**	**94**	**382**	7658	10183	11145	15246
Graz Schloßberg	**37**	**43**	**252**	**343**	**7640**	**11467**	**14733**	**19446**
Linz Berufsschule*	**8**	**33**	**68**	**414**	4396	10578	7667	15489
Klagenfurt Koschatstraße*	**12**	**36**	**37**	**214**	5957	13774	9384	17743
Illmitz	**20**	**67**	**180**	**727**	**8240**	**16095**	**13466**	**28051**
Dunkelsteinerwald	**25**	**63**	**200**	**765**	**6937**	**17137**	**12760**	**27132**
Grundlsee	**18**	**73**	**59**	**855**	**3378**	**18835**	**9362**	**29242**
St. Koloman	**27**	**61**	**274**	**625**	**9860**	**15813**	**16823**	**24802**
Vorhegg	**36**	**61**	**254**	**692**	**7755**	**14553**	**15999**	**22696**
Sulzberg	**45**	**105**	**338**	**1523**	**12026**	**24369**	**18850**	**39254**
Rennfeld	**50**	**91**	**294**	**1327**	**14235**	**24179**	**24985**	**41333**

*: these sites are not relevant for vegetation.

4.3 Discussion and Conclusions

Period for AOT60 calculations

From table 1 - 7 it can be seen that there is almost no difference in AOT60 values calculated for the whole year and the summer half year. The values get considerably smaller if a period from May - July is taken. Therefore, for the Austrian case it is reasonable to calculate AOT60 values for half year periods from April to September.

Correlation between different ozone values

⇒ Figure 1 indicates that **there is a close correlation between the AOT60 values and the number of days with exceedances of WHO AQG for the period of 1990-1996. For urban sites this correlation is slightly higher than for non urban sites. Bearing in mind the long period of time (1990 - 1996) and the differences in the types of the stations selected, this correlation is quite high. It can be speculated that a reduction of AOT60 values will almost linearly lead to a reduction of the number of days with exceedances of the WHO AQG**. As stated above the correlation is higher for urban sites. This might be explained by the fact that the group of non urban stations is rather heterogeneous, comprising stations in flat terrain, in valleys and Alpine sites.

⇒ The correlation between the AOT60 values and the number of days with exceedances of WHO AQG (Figure 1) is better (higher R^2) than between AOT40c and days of exceedances of WHO AQG (Figure 2). The difference in R^2 is about 0,05. Therefore it is quite probable that a reduction strategy for AOT40c is not as efficient for a reduction of the exceedances of WHO AQG than for AOT60. This effect might, anyhow, be explained by the fact that for the exceedances of the WHO AQG a period of six months was taken as for the calculation of the AOT60 value, whereas AOT40c is calculated from May - July. Consequently, the correlation between the days of exceedance of WHO AQG and the AOT40f (six months period) was calculated (Figure 3) and turned out to be even higher than the correlation between the days with exceedance of WHO AQG and AOT60, especially at urban sites (R^2 almost 0,95). This result is quite surprising, bearing in mind the different types of measurement sites including central urban sites and suburban sites which are occasionally influenced by urban plumes.

⇒ The correlation between different AOT values was analysed (Fig. 4-6). AOT60 and AOT40c show the smallest correlation. This is not surprising, since they have a different period and a different 'cut-off'. Generally, the correlation between AOT60 and the two AOT40 values is higher for urban sites. Additionally, there is a tendency towards higher AOT60 values in urban areas than in non urban areas (as indicated by a smaller slope of the regression line). This might be explained by higher peak values in suburban areas, whereas average daytime values tend to be higher at non urban sites. The correlation between AOT60 and AOT40f is similar to the correlation of AOT40c and AOT40f, which indicates that the influence of the different period is in the same range as the different cut-off.

⇒ From figure 6 it can be seen that the AOT40c is more stringent than the AOT40f. In the period from 1990 - 1996 only one station in one year was in compliance with the Critical Level for ozone for crops and natural vegetation (at an urban site not relevant for vegetation), whereas in 8 cases the Critical Level for forest was not exceeded (again mostly at urban sites). The mean ratio of AOT40f/AOT40c is around 1,5 (for non urban sites 1,73; for urban sites 1,34). Anyhow, the Critical Level for crops is 3000 ppb*h, for forest 10000 ppb*h.

MW8max versus MW8fix

AOT60 values and the number of days of exceedances of the WHO AQG can be calculated from maximum MW8 values or from MW8 values from a fixed period. For the comparisons presented in this study a fixed period from 12:00 a.m. to 8:00 p.m. was used, since it is known that maximum ozone values usually occur in the afternoon.

⇒ As seen in figure 7 there is a very close correlation between the days of exceedances of the WHO AQG calculated from daily MW8max and the MW8fix. The correlation is again higher for urban sites, the mean ratio is 1:0,83 with a $R^2 > 0,95$. The correlation for non urban sites is smaller with a mean ratio of 1:0,73, which can be explained by the fact that in non urban areas, peak values tend to occur at different times of the day, maybe due to transport phenomena and a smaller influence of local ozone formation.

⇒ Figure 8 shows the close correlation between AOT60 values calculated from MW8max and MW8fix. For urban sites R^2 is almost 0,99. The mean ratio of the two AOT60 values is around 1:0,79 for these sites.

Interannual variations

From table 8 it can be seen that there are quite substantial interannual variations in the ozone levels at each ozone monitoring site.

The number of days of exceedances may vary by a factor of six (Vienna Stephansplatz, which is highly relevant for human health).

AOT60 values may vary more than 1000 % which is mainly due to the fact that actual maximum eight hour mean values are at some sites in the range of 60 ppb. Therefore, relatively small changes in ozone levels may lead to large differences in the AOT60 values.

Variation of ozone levels within cities

From table 8 the large differences of ozone levels within cities can be seen. This is especially true for Vienna Stephansplatz and Hermannskogel. Hermannskogel is occasionally influenced by the plume of Vienna and shows on average higher numbers of days of exceedances of the WHO AGQ than background sites in the same area. In contrast , Stephansplatz in the centre of Vienna is strongly influenced by ozone depletion by NO and displays comparably small AOT values.

5. AOT90 values at selected Austrian sites

5.1 Calculation

The AOT90 value is an indicator for the occurrence and magnitude of ozone peak concentrations. The following formula was used to calculate the values:

$$AOT90 = \sum (MW1 - 90) \quad \text{for } MW1 > 90 \text{ ppb.}$$

Note: The AOT90 was calculated from (running) one hour mean values (as the AOT40). The result is given in ppb*h; in contrast, the AOT60 was calculated from daily eight hour mean values.

5.2 Results

The AOT90 was determined for each station for each of the 7 years.

AOT90 (ppb*h)	1990	1991	1992	1993	1994	1995	1996	mean
Vienna Stephansplatz	+	+	256	1	174	0	59	98
Hermannskogel	291	948	657	44	453	130	34	365
Graz West	1	3	0	0	16	0	19	6
Graz Schloßberg	+	+	0	0	1	0	37	8
Linz Berufsschule	0	0	+	0	124	14	0	23
Klagenfurt Koschatstraße	+	0	0	0	+	0	2	0
Illmitz	322	53	38	33	37	14	78	82
Dunkelsteinerwald	305	59	446	50	261	170	12	186
Grundlsee	+	+	+	0	0	0	0	0
St. Koloman	+	6	33	0	1	30	0	12
Vorhegg	+	0	26	19	77	2	486	102
Sulzberg	+	+	+	17	51	89	0	39
Rennfeld	787	0	0	0	3	0	61	122

+: Percentage of valid data < 75%

shaded: Occasionally influenced by the plume of Vienna

It can be clearly seen that

- the highest AOT90 values in urban or rural locations outside of mountainous regions[11] can be detected at stations near or in Vienna
- there are extremely large inter-annual variations at all stations.

Hermannskogel, which is situated in the territory of Vienna, has the highest mean AOT90 value of all 13 stations. This can be explained by the fact that this station is relatively often influenced by the plume of Vienna. High AOT90 values in 1996 in Vorhegg can be attributed to long range transport of ozone from the Italian Po valley.

5.3 Correlation between AOT90 and other ozone related parameters

The following figures provide information on the correlation of AOT90 with AOT60, AOT40 and days of exceedances of WHO AQG, respectively.

Figure 9 shows the correlation between the AOT90 values and the number of days with exceedances of WHO AQG for the period of 1990-1996.

Figure 10 shows the correlation between the AOT90 values and AOT60 calculated from MW8max

Figure 11 shows the correlation between the AOT90 values AOT40c

[11] The bottom five sites (Grundlsee to Rennfeld) are situated in mountainous regions.

Correlation between AOT90 and the number of days with exceedances of the WHO-AQG

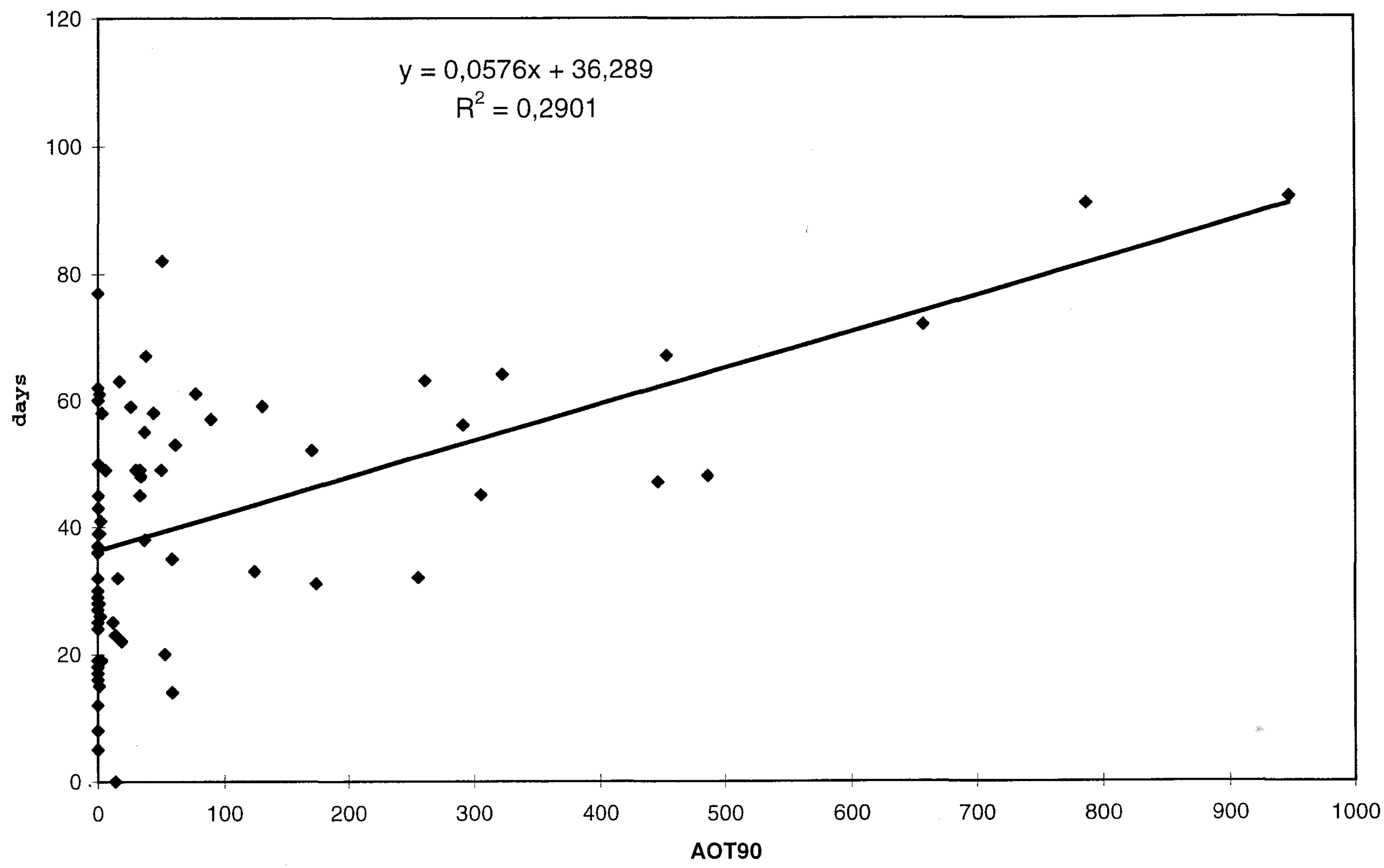


Figure 9

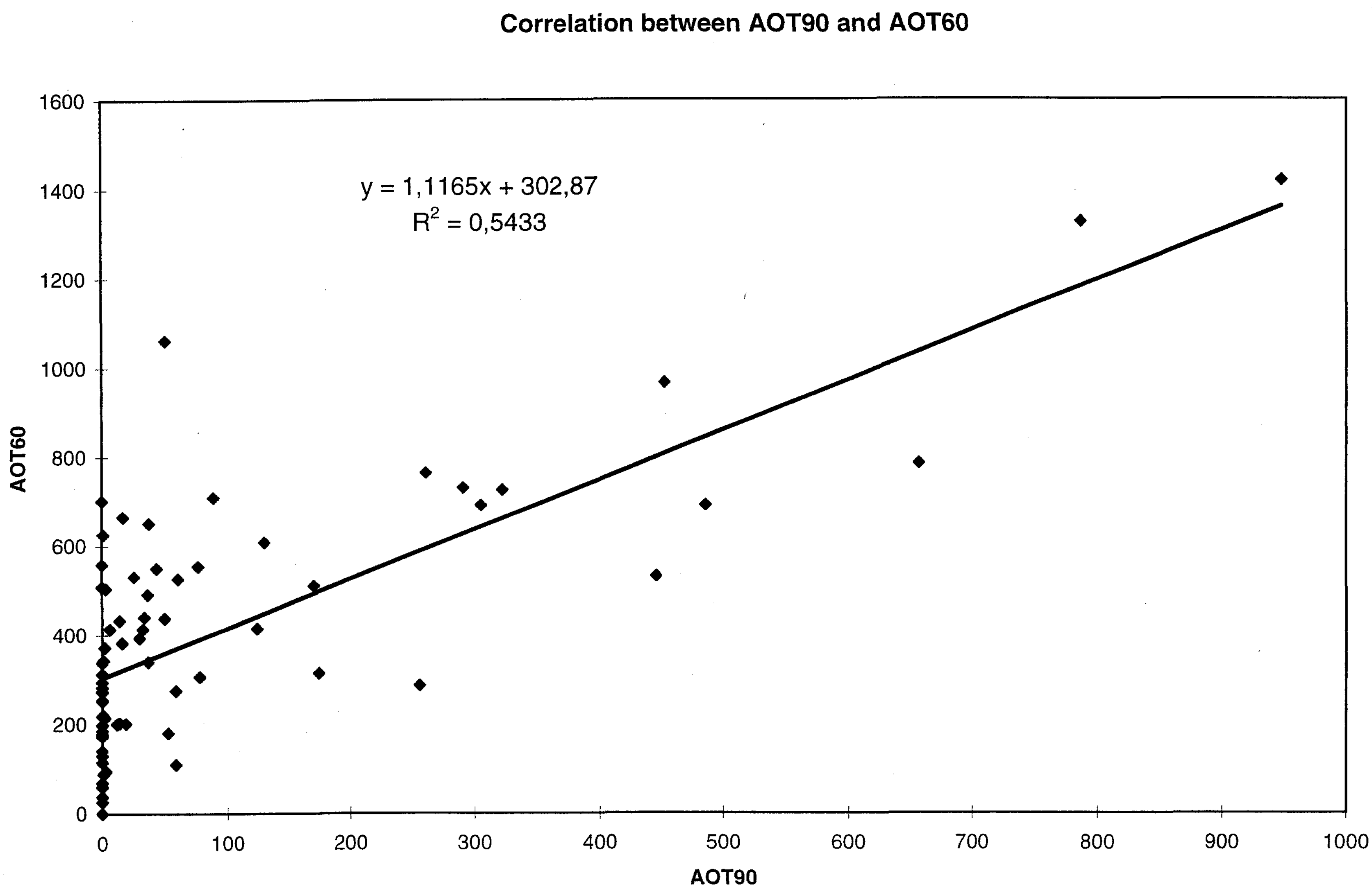

Correlation between AOT90 and AOT60
y = 1,1165x + 302,87
R2 = 0,5433
AOT60
1600
1400
1200
1000
800
600
400
200
0
AOT90
0
100
200
300
400
500
600
700
800
900
1000

Figure 10

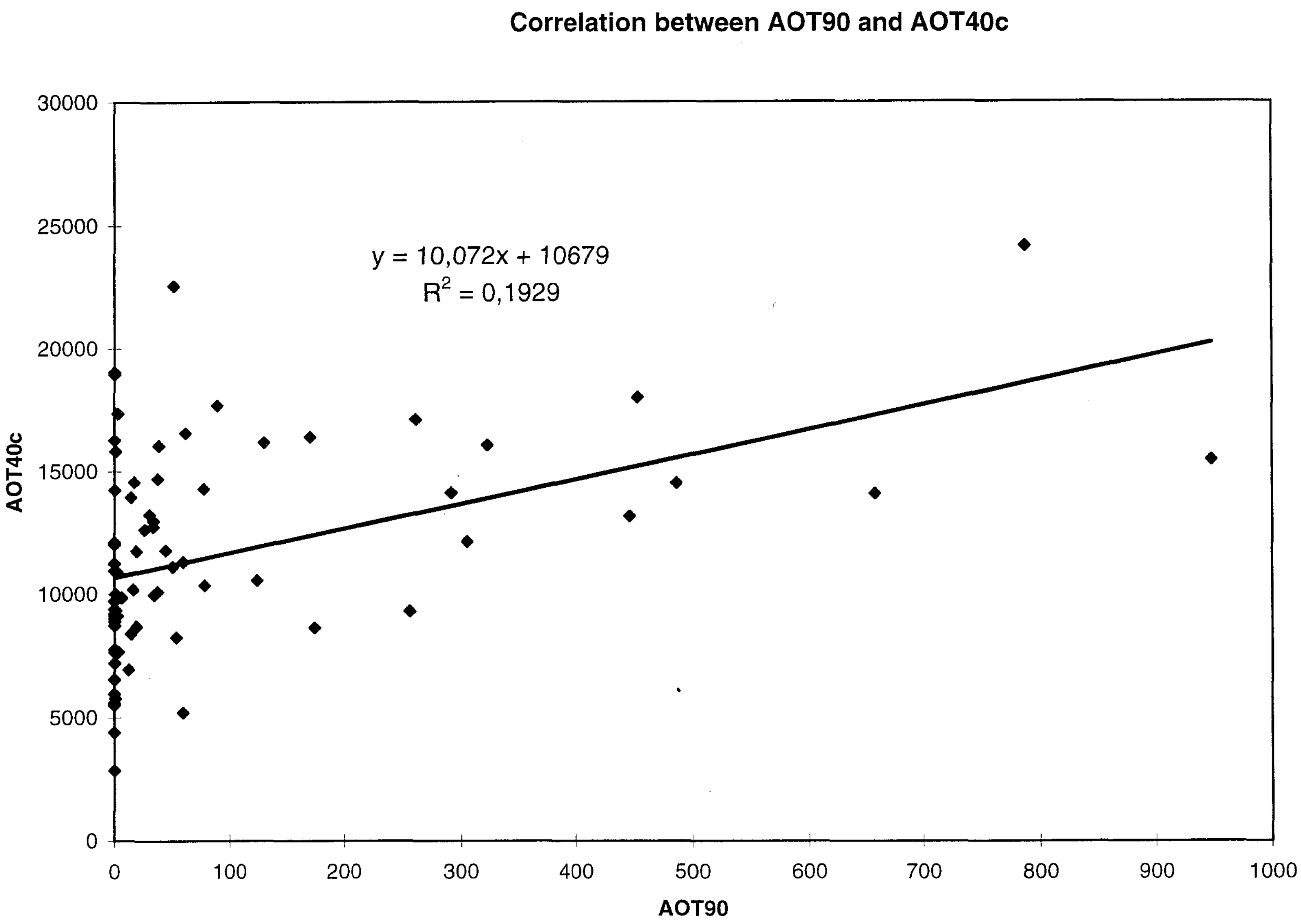

Correlation between AOT90 and AOT40c
y = 10,072x + 10679
R² = 0,1929
AOT40c
30000
25000
20000
15000
10000
5000
0
AOT90
0
100
200
300
400
500
600
700
800
900
1000

Figure 11

It can be clearly seen that the AOT90 is not a suitable surrogate for the number of days with exceedances of WHO-AQG. The correlation (R^2: square Person correlation coefficient) is less than 0,28. Additionally, there are some stations in selected years with quite a considerable number of days with exceedances of WHO-AQG (up to >70) **and** AOT90 values of 0. Such a situation is typical for mountainous sites, where elevated long term average concentrations occur, but seldom high (local) peak values.

At one urban site, no exceedances of WHO-AQG but AOT90 is >0 could be detected, indicating the occurrence of short term peak levels.

6. The weekend effect

Some studies have been carried out on the weekly variations of ozone concentrations in different European countries. Dumont (personal communication) reported on elevated ozone levels at several Belgian sites during the weekend:

The average afternoon peak values on Saturdays and Sundays can be up to 20 % higher than during workdays. This effect can be explained by the complex processes involved in photochemical ozone production. For example, NOx emissions can locally act as a sink for ozone, since the reaction of NO with O_3 results in the formation of NO_2 and O_2 (anyhow, this NO_2 will be available for subsequent new ozone formation). Therefore, the reduction of NO emissions, e.g. at weekends, can lead under certain circumstances to an increase of ozone levels. This effect can especially be expected in regions with high emission densities of NOx, as in parts of Great Britain, the BENELUX countries and north western Germany. In this regions, ozone formation is NMVOC-limited and highly non linear.

To check if this is also true for Austria, ozone measurement data from Austria were analysed.

<u>Selection of stations</u>

For this analysis, only data from stations in or near Vienna were taken, where a weekend effect should be most pronounced (rural background stations are usually in NOx-limited areas). 10 stations were selected, four of them in Vienna, five in Lower Austria, the province surrounding Vienna, and one in Burgenland. The geographical location of the sites can be seen in the map on page 5.

The table displays the stations used for the assessment and gives a description of topography and land use.

Site	Altitude in m	Topography	Land use
Vienna Stephansplatz	183	plain	central urban, residential, commercial
Vienna Lobau	150	plain	suburban, recreational area, forest
Vienna Hohe Warte	195	hilly	suburban, residential
Vienna Hermannskogel	520	hilly	suburban, recreational area, forest
Kollmitzberg	480 m	hilly	pasture
Gänserndorf	161	plain	agriculture
Klosterneuburg	200	hilly	urban small town
Dunkelsteinerwald	215	hilly	agriculture
Illmitz	117	plain	agriculture, lake
Pillersdorf	215	hilly	agriculture

Calculation

Data from 5 years and a period from May - August were used (1992 - 1996). For each station and day, the average maximum three hour mean value was calculated.

Figure 12 Mean maximum three hour mean value for different weekdays for selected stations from 1992 - 1996, period (May - August)

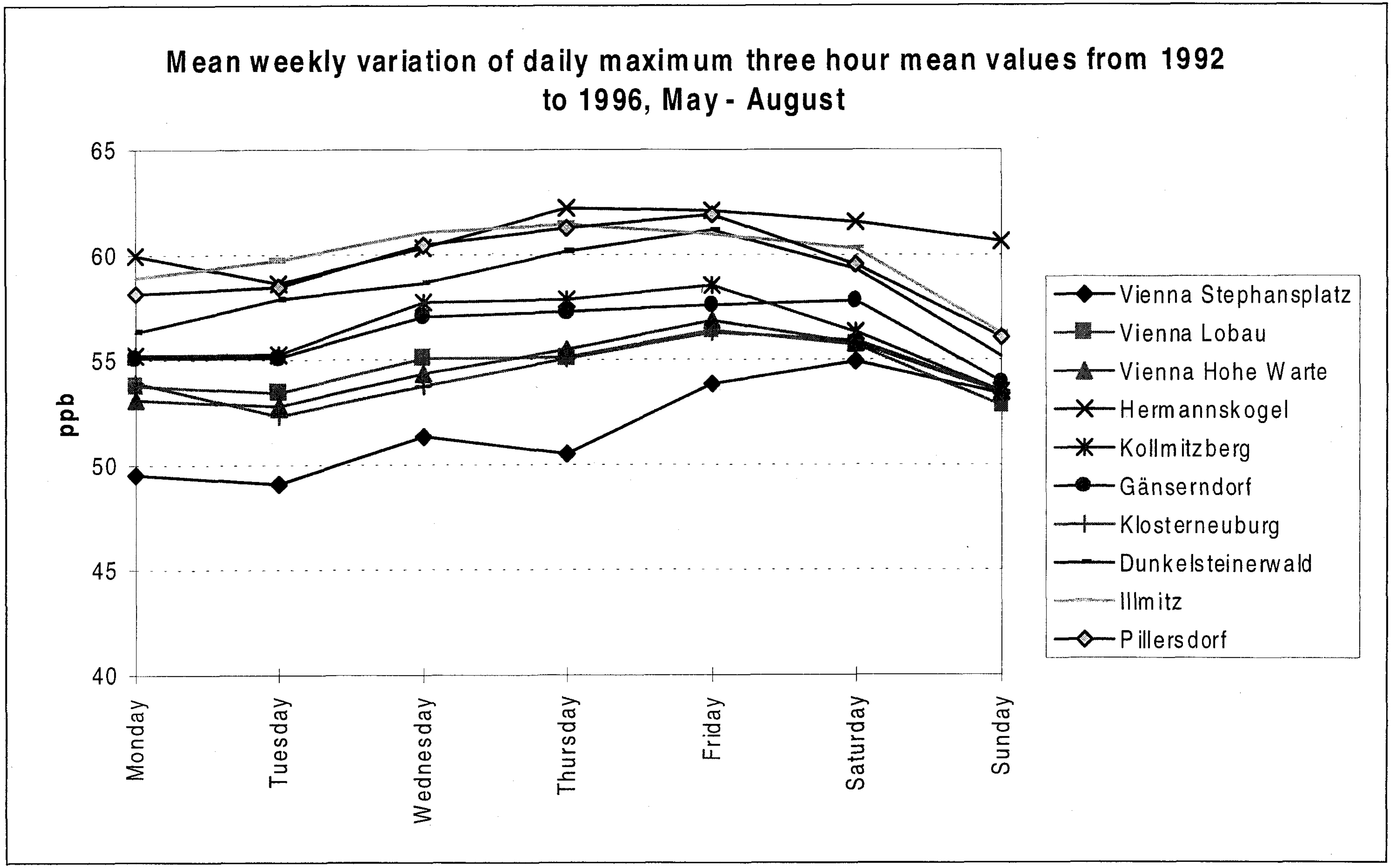

Mean weekly variation of daily maximum three hour mean values from 1992 to 1996, May - August
ppb
65
60
55
50
45
40
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Vienna Stephansplatz
Vienna Lobau
Vienna Hohe Warte
Hermannskogel
Kollmitzberg
Gänserndorf
Klosterneuburg
Dunkelsteinerwald
Illmitz
Pillersdorf

Figure 12

In contrast to the situation in Belgium, no weekend effect can be seen at all in and around the agglomeration of Vienna.

The maximum average three hour mean values vary generally only by about 5 ppb during the week. They show a general increase during the week with maximum concentrations on Thursday to Saturday, a pronounced decline on Sunday and minimum concentrations on Monday or Tuesday. This average weekly variation can be attributed to the variation of large scale precursor emissions, which induce a steady increase in ozone formation during the workdays and a drop in ozone pollution on weekend.

7. Maximum eight hour mean values

The WHO AQG gives a Guideline value of 120 µg/m^3 as an eight hour mean value. The next table provides information on the maximum eight hour mean value for each station and year.

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Wien Stephansplatz			210	158	191	148	177
Hermannskogel	207	224	224	171	194	198	183
Graz West	168	156	136	149	176	150	177
Graz Schloßberg			154	151	168	163	185
Linz Berufsschule	165	159		158	201	174	158
Klagenfurt Koschatstr.		154	152	146		131	165
Illmitz	233	188	174	184	178	165	172
Dunkelsteinerwald	203	192	211	180	198	195	175
Grundlsee		161		141	160	159	155
St. Koloman		175	170	164	175	182	170
Vorhegg		160	175	171	183	170	212
Sulzberg	211	192		179	181	192	158
Rennfeld	223	158	164	159	176	167	185

It can be seen that each station exceeded the WHO AQG in each year. To test if the yearly maximum MW8 could be a surrogate for any other (health)-relevant ozone parameter, the relation to the number of days with exceedances of the WHO AQG was calculated.

Figure 13 displays the relation between the yearly maximum MW8 and the number of days with exceedances of the WHO AQG.

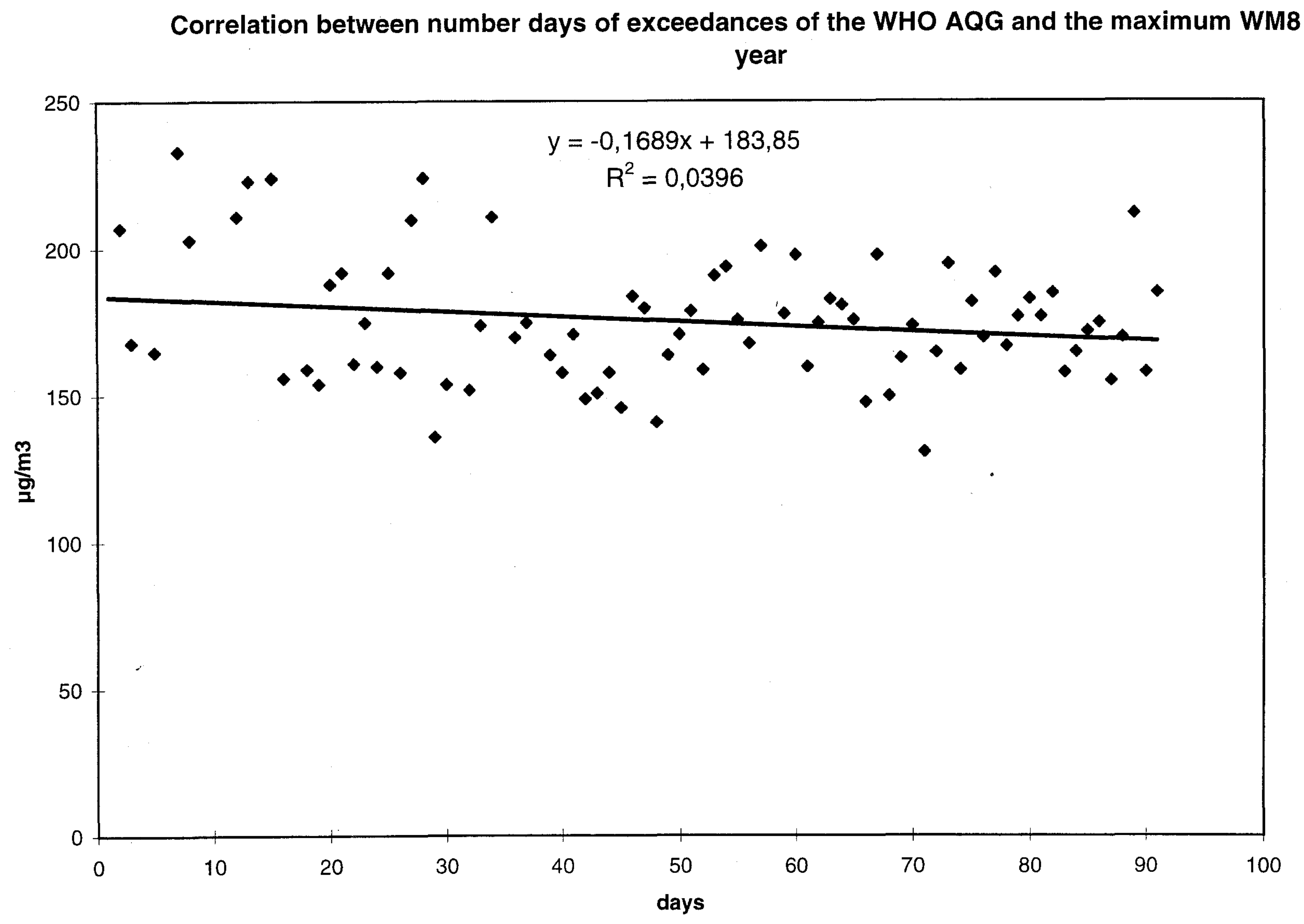

Correlation between number days of exceedances of the WHO AQG and the maximum WM8 of a year
y = -0,1689x + 183,85
R2 = 0,0396
µg/m3
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100
days

Figure 13

There is in fact no correlation between the maximum eight hour mean values and the frequency of exceedance of the WHO AQG.

8. Cumulative distribution function of MW8

For the assessment of health effects, cumulative distributions of eight hour mean values can be utilised.

Method

All daily maximum eight hour mean values were grouped in classes comprising 10 ppb (20 µg/m^3) starting from 1-10 ppb. All values in the classes up to 51-60 ppb comply with the WHO AQG.

Figure 14 shows the cumulative distribution function for eight hour mean values for the period from 1990 - 1996 for selected sites. Urban sites have an uninterrupted line (except the suburban site of Hermannskogel, which is dotted with short lines), rural sites are dotted, Rennfeld (Alpine) has small lines.

Figure 15 focuses on the sector with values above the WHO AQG from figure 14. The values on the y-axis (class from 51 – 60 ppb) show the percentage of values in compliance with the WHO AQG

From figure 14 three types of measurement sites can be distinguished:

⇒ At urban and suburban sites (except Hermannskogel), up to more than 20% of the values lie in the class from 0-10 ppb. Generally, only between 5 and 10 percent of the values exceed the WHO AQG.

⇒ At suburban or non Alpine rural sites, the first class comprises less than 10 % of all values.

⇒ At the Alpine site Rennfeld (1600 m a.s.l) very few eight hour mean values lie below 30 ppb, but 20 % of the values above the WHO AQG.

In figure 15, also three classes can be differentiated:

⇒ urban sites (Wien Stephansplatz, Graz West, Linz Berufsschule and Klagenfurt Koschatstraße) have exceedances on approx. 6 - 8% of the days

⇒ rural sites and the suburban site of Graz Schloßberg (which is in a park) exceed the WHO AQG on 11 - 16 days

⇒ Hermannskogel (suburban in a forest in Vienna) and Rennfeld (Alpine) have ozone levels above the WHO AQG on nearly 20 % of the days. At Hermannskogel, an eight hour mean value of 160 µg/m^3 (80 ppb) is exceeded on more than 3 % of the days.

Cumulative disribution function of daily maximum MW8 for selected stations from 1990-1996

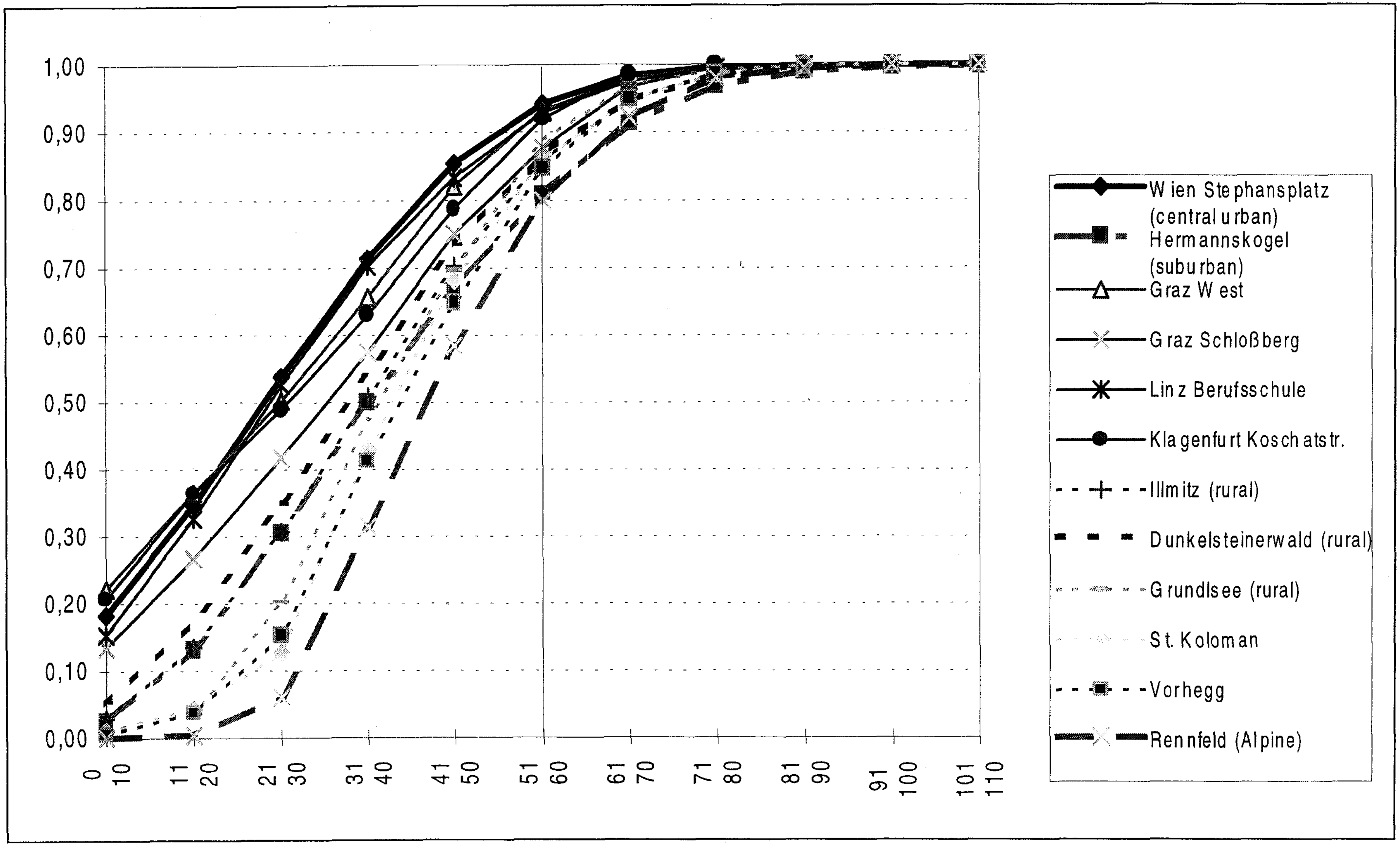


Figure 14

Cumulative distribution function of daily maximum 8-hour mean values exceeding the WHO AQG, from 1990 - 1996

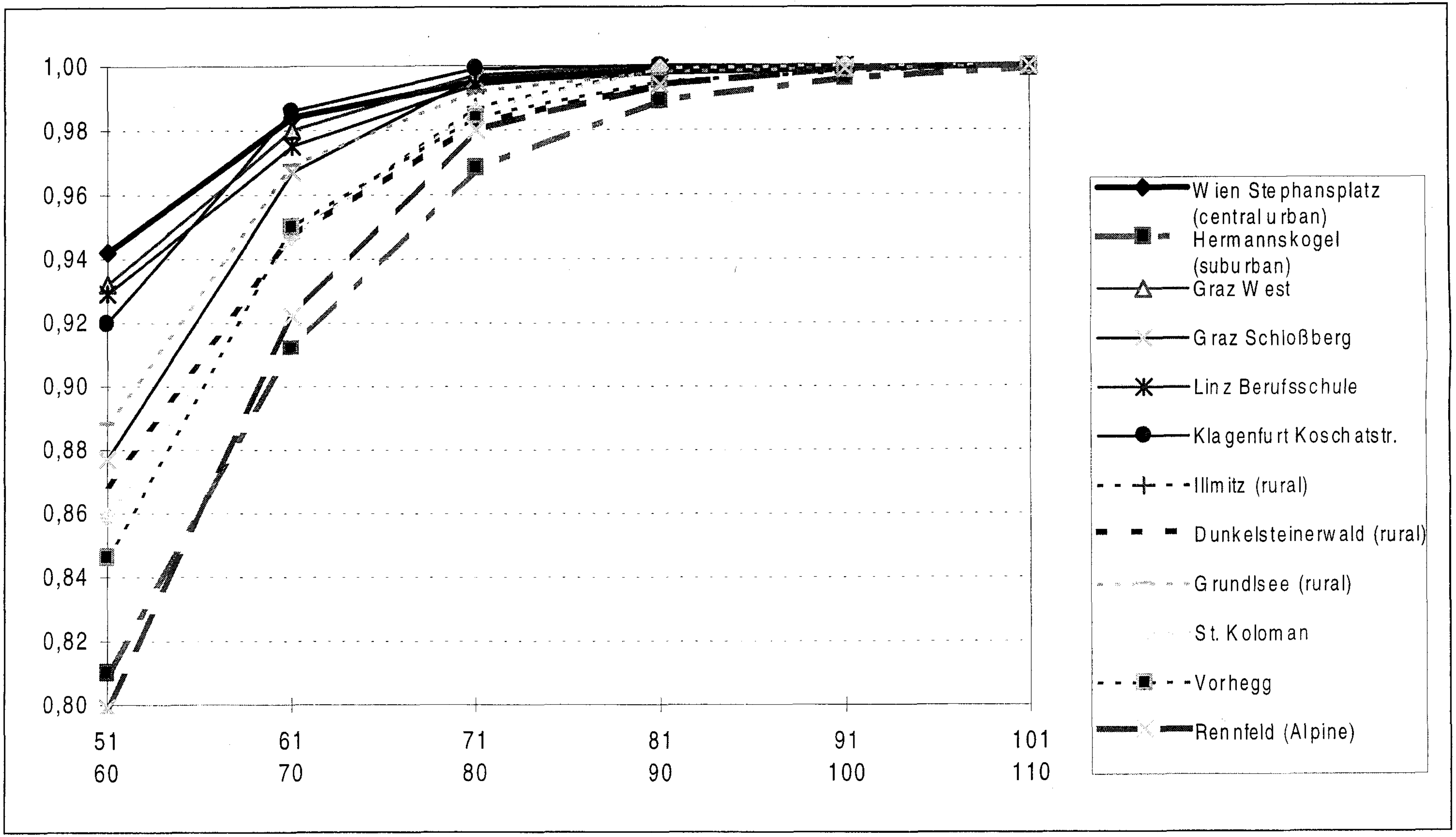


Figure 15