4. Atmospheric Supply of Lead to the Baltic Sea in 2006

In this chapter the results of model evaluation of lead atmospheric input to the Baltic Sea and its sub-basins for 2006 is presented. Modelling of lead atmospheric transport and depositions was carried out using MSC-E Eulerian Heavy Metal transport model MSCE-HM (*Travnikov and Ilyin*, 2005). Latest available official information on lead emission from HELCOM countries and other European countries for 2006 was used in computations. Based on these data levels of annual and monthly lead depositions to the Baltic Sea region have been obtained and contributions of HELCOM countries emission sources to the depositions over the Baltic Sea are estimated. Model results were compared with observed levels of lead concentrations in air and precipitation measured at monitoring sites around the Baltic Sea in 2006.

4.1 Lead emissions

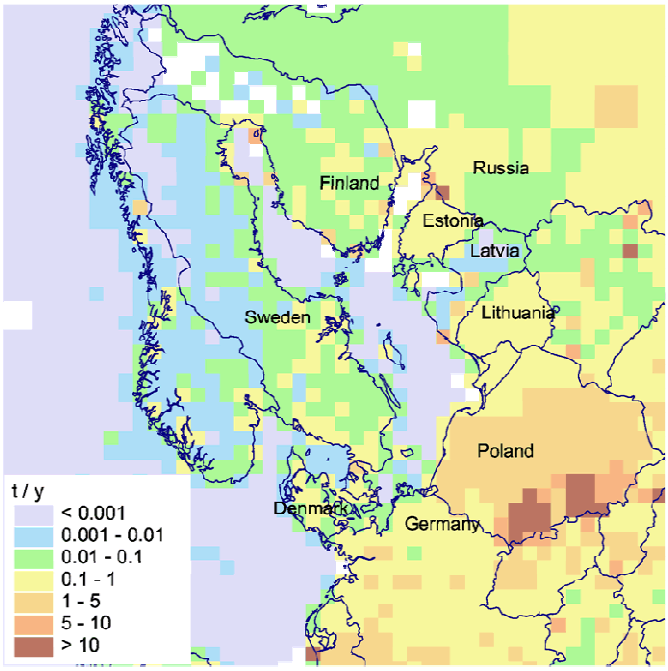


Figure 4.1. Annual total anthropogenic emissions of lead in the Baltic Sea region for 2006, t/y.

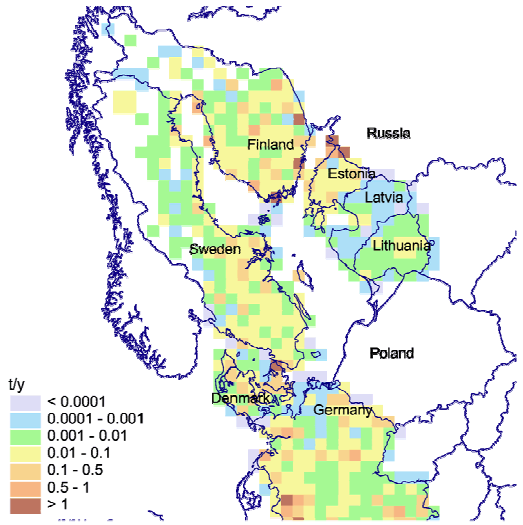


Figure 4.2. Annual lead emission from Combustion in Power Plants and Industry sector for 2006, t/y.

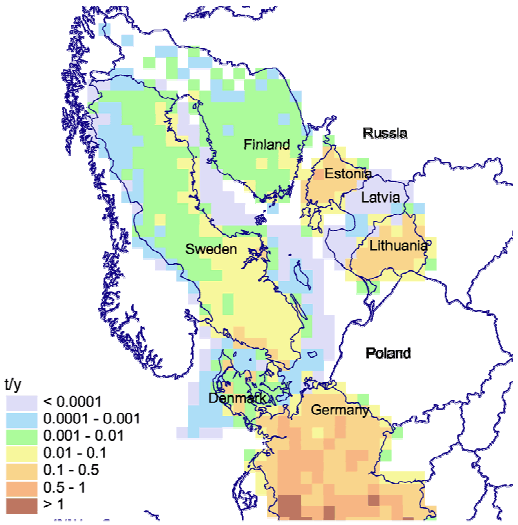


Figure 4.3. Annual lead emission from Transport sector for 2006, t/y.

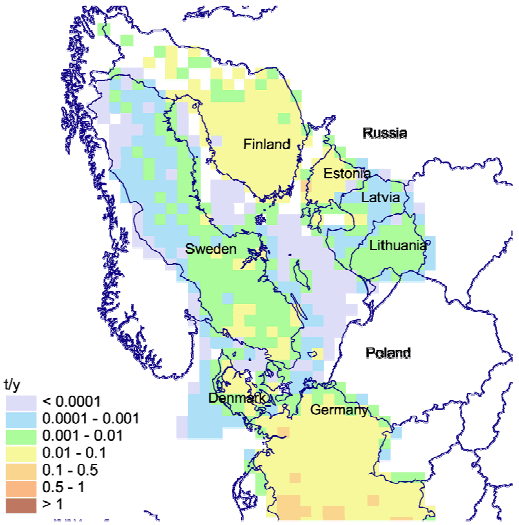


Figure 4.4. Annual lead emission from Commercial, Residential and Other Stationary Combustion sector for 2006, t/y.

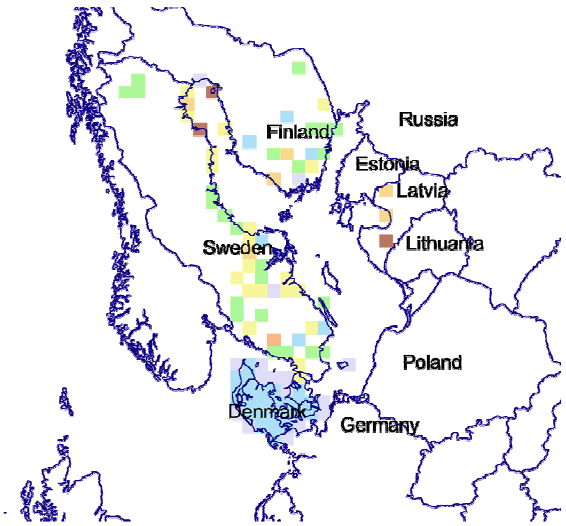


Figure 4.5. Annual lead emission from Industrial processes sector for 2006, t/y.

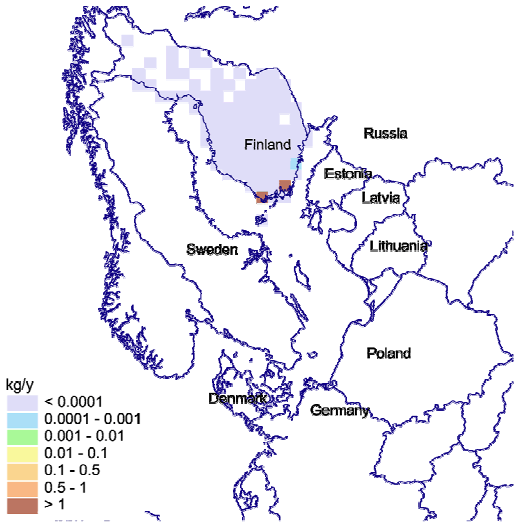


Figure 4.6. Annual lead emission from Solvent and Other Product Use sector in Finland for 2006, kg/y.

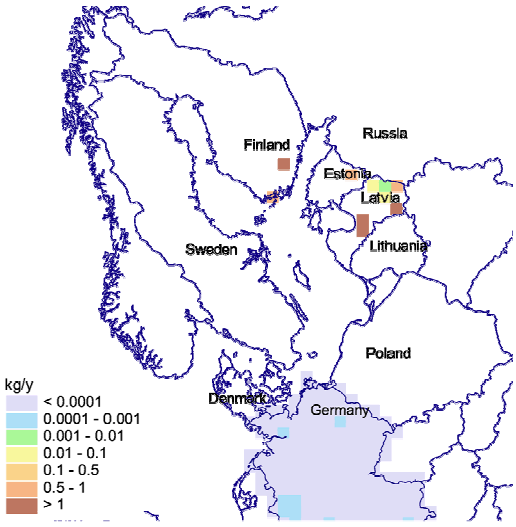


Figure 4.7. Annual lead emission from Waste sector for 2006, kg/y.

Table 4.1. Annual total lead anthropogenic emissions of HELCOM countries from different sectors for 2006, in tonnes per year

NFR emission sector	Sector name	Denmark	Estonia	Finland	Germany	Latvia	Lithuania	Poland	Russia	Sweden
1	Combustion in Power Plants and Industry	4.4	29.0	16.1	13.2	0.058	0.7	267.3	355.0	4.3
2a	Transport above 1000m	0	NA	0.1	NE	NA	NA	NA	NA	NE
2b	Transport below 1000m	1.4	4.0	0.4	83.2	0.002	5.2	17.8		4.4
3	Commercial, Residential and Other Stationary Combustion	0.4	0.8	2.6	9.6	0.057	0.1	147.6		0.7
4	Fugitive Emissions From Fuels		NA	0.02				2.1		NA
5	Industrial Processes	0.1	0	5.4	1.6	17.3		88.0		4.5
6	Solvent and Other Product Use	NA	NA	0.01				NA		
7	Agriculture							NA		
8	Waste		0.2	0.004	6.24E-06	0.037		1.4		
9	Other									
Total		**6.2**	**34.0**	**24.7**	**107.7**	**17.5**	**6.0**	**524.2**	**355.0**	**14.0**

NA – not available
NE – not estimated

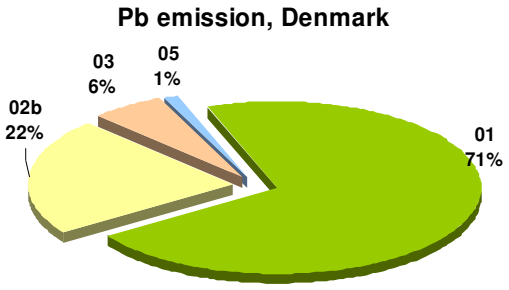


Figure 4.8. Percentage of annual total lead emission from different sectors in Denmark for 2006.

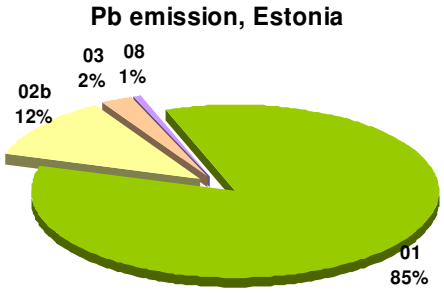


Figure 4.9. Percentage of annual total lead emission from different sectors in Estonia for 2006.

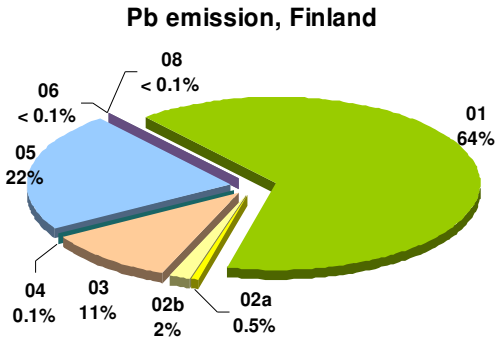


Figure 4.10. Percentage of annual total lead emission from different sectors in Finland for 2006.

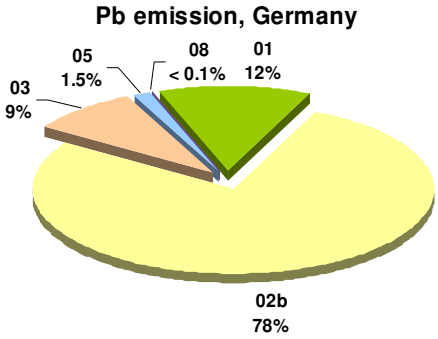


Figure 4.11. Percentage of annual total lead emission from different sectors in Germany for 2006.

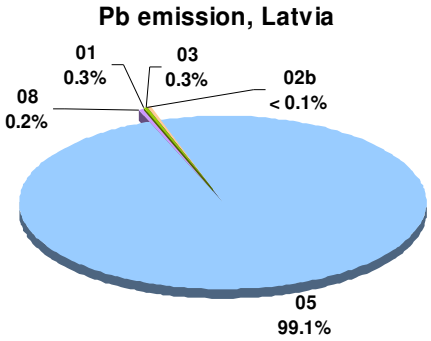


Figure 4.12. Percentage of annual total lead emission from different sectors in Latvia for 2006.

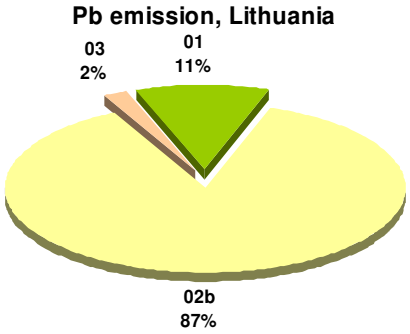


Figure 4.13. Percentage of annual total lead emission from different sectors in Lithuania for 2006.

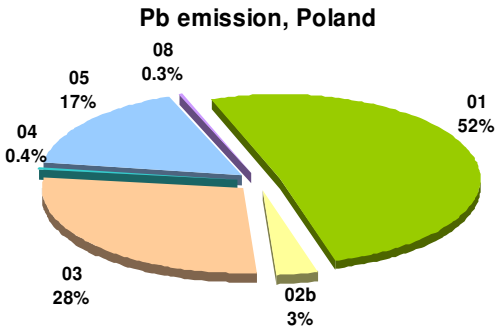


Figure 4.14. Percentage of annual total lead emission from different sectors in Poland for 2006.

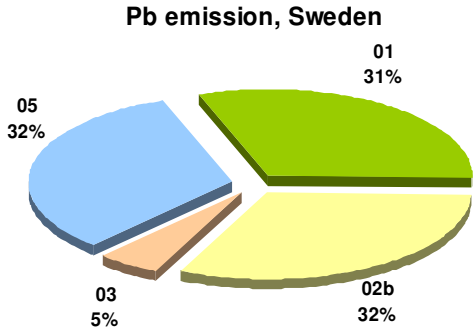
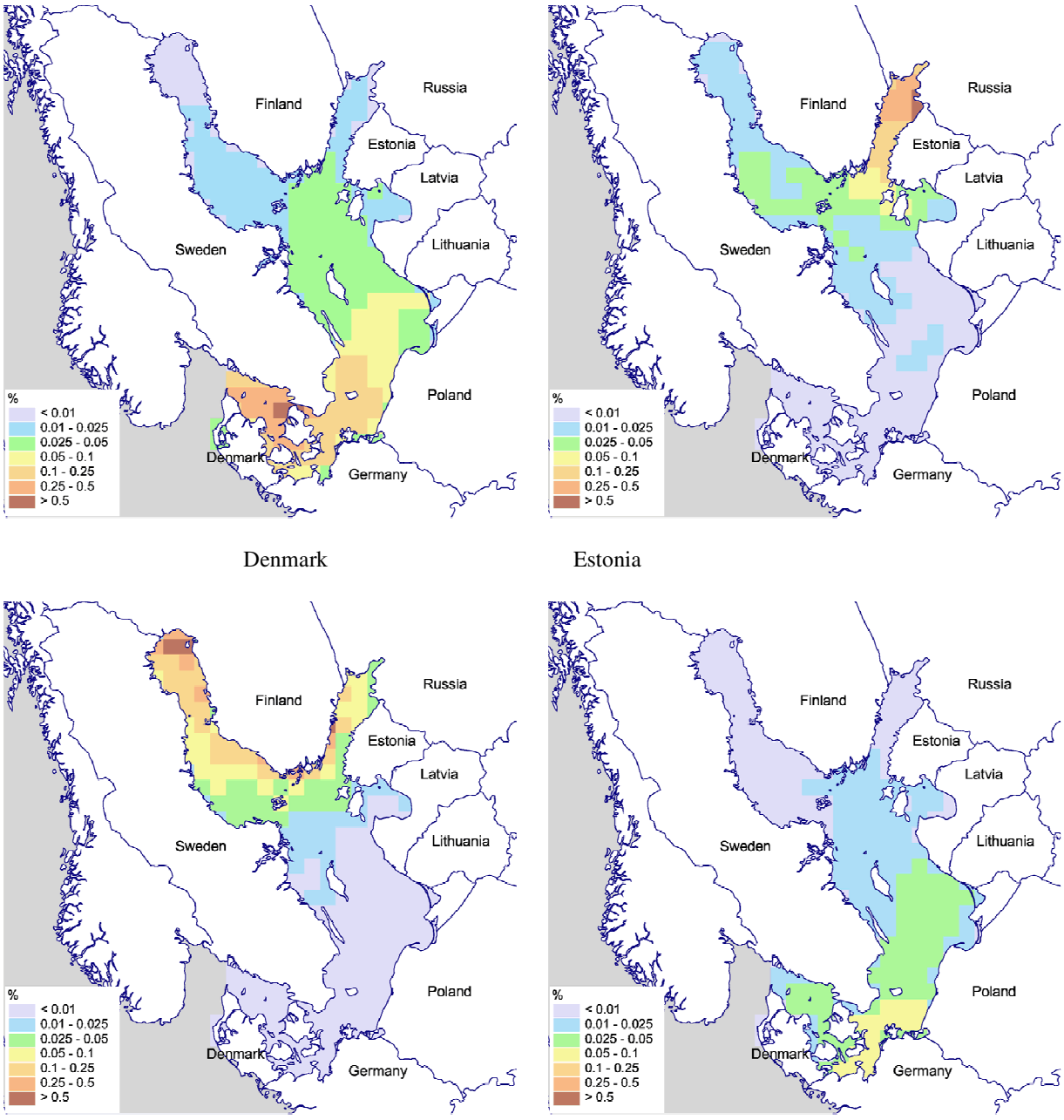


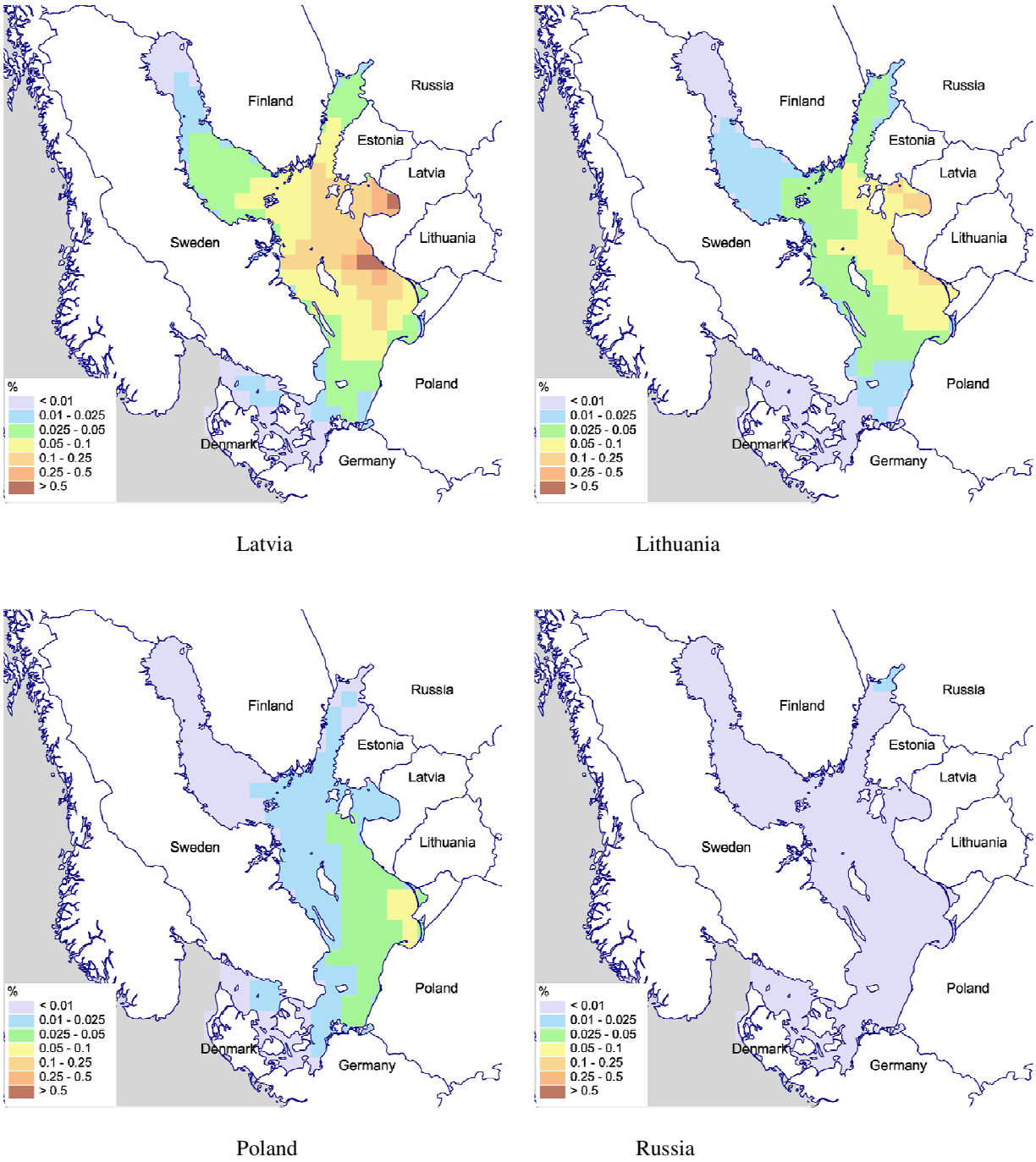
Figure 4.15. Percentage of annual total lead emission from different sectors in Sweden for 2006.



Denmark Estonia

Finland Germany

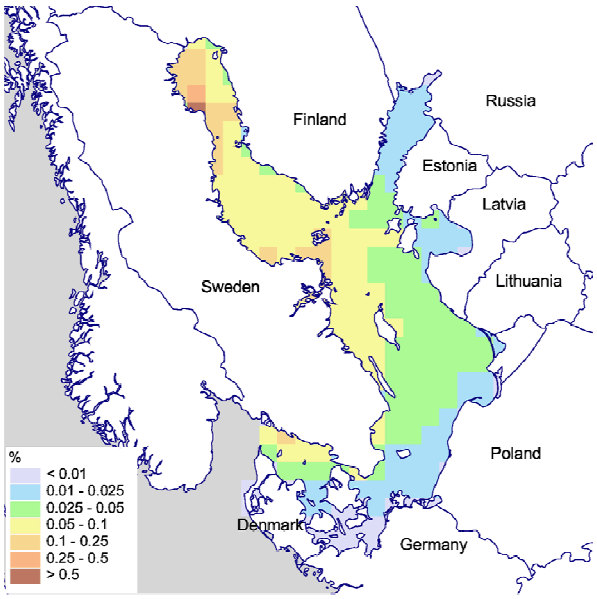
Figure 4.16. Maps with the fractions (in %) of annual total anthropogenic lead emissions from HELCOM Parties deposited into the Baltic Sea in 2006 (percent per deposition over the 50x50 km grid cell).



Latvia Lithuania

Poland Russia

Figure 4.16. **(cont.)** Maps with the fractions (in %) of annual total anthropogenic lead emissions from HELCOM Parties deposited into the Baltic Sea in 2006 (percent per deposition over the 50x50 km grid cell).



Sweden

Figure 4.16. **(cont.)** Maps with the fractions (in %) of annual total anthropogenic lead emissions from HELCOM Parties deposited into the Baltic Sea in 2006 (percent per deposition over the 50x50 km grid cell).

Table 4.2. Annual total anthropogenic emissions of lead of HELCOM countries and other EMEP countries in period 1990-2006, tonnes (Expert estimates of emissions are shaded)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Denmark	120	97	88	47	12	12	10	7.7	7.0	7.1	6.8	6.1	5.3	5.0	5.3	5.7	6.2
Estonia	201	185	121	101	124	84	65	52	46	44	37	34	34	39	38	37	34
Finland	327	248	174	99	58	56	35	18	21	15	36	38	40	34	28	24	25
Germany	1801	1055	761	606	405	331	222	95	94	95	102	105	106	105	106	107	108
Latvia	21	17	9.8	7.6	9.6	8.1	9.9	12	13	12	12	12	12	13	13	14	18
Lithuania	47	49	32	28	33	30	18	20	22	19	16	15	15	15	5.2	5.7	6.0
Poland	1372	1336	986	997	966	937	960	896	736	745	647	610	588	596	600	536	524
Russia	3591	3553	3095	3276	2643	2426	2304	2247	2262	2339	2352	2235	2118	2207	330	355	355
Sweden	361	317	296	144	51	37	33	33	32	29	26	23	20	19	18	15	14
HELCOM	**7840**	**6856**	**5563**	**5304**	**4301**	**3920**	**3656**	**3380**	**3233**	**3306**	**3235**	**3079**	**2939**	**3034**	**1143**	**1099**	**1089**
Albania	33	34	35	36	37	38	39	40	41	42	43	39	35	32	28	24	20
Armenia	11	0.820	0.610	0.790	0.340	0.334	0.009	0.009	0.010	0.005	0.005	0.503	1.0	2.5	2.6	2.7	2.7
Austria	207	172	120	86	60	16	15	14	13	12	12	12	12	13	13	14	14
Azerbaijan	12	12	12	12	12	12	12	12	12	12	12	13	13	13	13	14	14
Belarus	794	519	450	377	348	147	46	42	41	38	46	41	44	43	45	50	57
Belgium	442	418	397	320	259	247	251	267	189	155	118	102	72	68	81	77	76
Bosnia and Herzegovina	97	97	97	97	97	97	97	97	97	97	97	91	85	79	72	66	60
Bulgaria	436	408	381	353	325	297	279	231	251	224	213	177	105	148	143	115	124
Croatia	466	426	385	345	304	264	268	190	183	178	147	107	60	23	16	12	9.1
Cyprus	31	31	33	33	33	33	33	32	30	29	27	26	24	23	9.8	3.8	4.0
Czech Republic	269	240	247	232	202	180	165	180	169	157	108	47	47	39	37	47	43
France	4272	2866	2084	1830	1627	1450	1280	1132	1013	778	252	214	208	156	142	138	128
Georgia	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	7.0	7.2	7.3	7.5	7.6	7.8
Greece	505	499	493	488	482	476	470	470	470	470	470	470	470	470	470	470	470
Hungary	663	488	208	187	155	130	100	90	82	39	42	51	34	34	34	38	37
Iceland	6.4	5.8	5.1	4.5	3.9	3.3	2.7	2.1	1.4	0.816	0.197	0.197	0.197	0.197	0.197	0.197	0.197
Ireland	127	114	120	103	91	79	65	68	45	41	30	18	17	16	16	17	16
Italy	4378	3318	2440	2240	2049	1928	1804	1610	1449	1263	935	702	237	242	256	266	274
Kazakhstan	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Luxembourg	77	71	65	59	53	30	26	18	6.8	2.3	1.8	2.0	1.9	1.9	1.9	1.9	1.9
Malta	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.769	0.756	0.816	0.790	0.816	0.826
Monaco	3.9	4.0	4.1	3.7	2.1	0.780	0.673	0.564	0.486	0.427	0.059	0.063	0.056	0.046	0.041	0.041	0.030
Netherlands	338	294	250	225	191	162	111	63	52	44	37	41	45	41	43	39	39
Norway	187	144	129	89	25	23	12	11	11	10	9.0	8.2	9.3	9.0	10	7.6	7.6
Portugal	593	611	656	636	608	586	569	544	531	358	165	185	184	187	188	177	177
Republic of Moldova	249	220	103	71	23	34	28	22	7.9	11	2.8	3.4	3.3	11	2.3	5.1	5.0
Romania	585	573	561	550	538	526	514	502	491	420	402	476	398	319	241	162	118
Serbia and Montenegro	597	567	538	508	478	448	419	389	359	329	300	275	250	225	200	176	151
Slovakia	150	149	148	116	84	71	73	73	70	58	67	68	69	64	70	71	73
Slovenia	329	292	289	307	307	197	81	69	54	47	44	27	18	19	17	17	18
Spain	2681	1809	1220	1115	1104	932	902	839	779	709	589	389	268	265	261	267	270
Switzerland	429	387	342	288	254	192	163	144	124	59	36	33	29	26	25	24	24
The FYR of Macedonia	210	198	185	173	161	148	136	124	112	99	87	83	79	74	70	66	62
Turkey	765	765	765	765	765	765	765	765	765	765	765	717	669	620	572	524	476
Ukraine	3878	3586	3293	3001	2709	2417	2124	1832	1540	1248	955	663	145	123	195	304	297
United Kingdom	2913	2657	2435	2160	1859	1549	1316	1153	849	493	163	155	142	129	134	117	106
EMEP	**34603**	**28859**	**24080**	**22141**	**19576**	**17426**	**15851**	**14429**	**13097**	**11522**	**9438**	**8337**	**6737**	**6576**	**4579**	**4438**	**4290**

Expert estimates:

§ *Denier van der Gon, H.A.C., M. van het Bolscher A.J.H. Visschedijk P.Y.J. Zandveld [2006]*

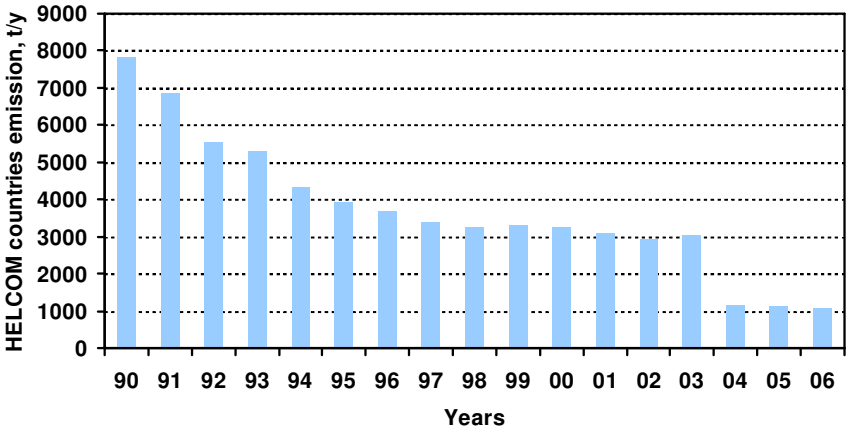


Figure 4.17. Time-series of total annual lead emissions of HELCOM countries in 1990-2006, tonnes/y.

4.2 Annual total depositions of lead

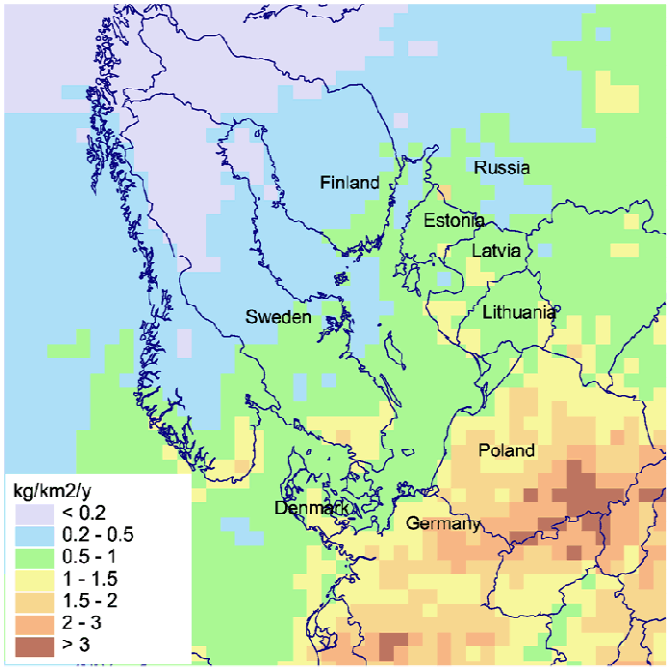


Figure 4.18. Annual total deposition fluxes of lead over the Baltic Sea region for 2006, kg/km^2/year.

4.3 Monthly total depositions of lead

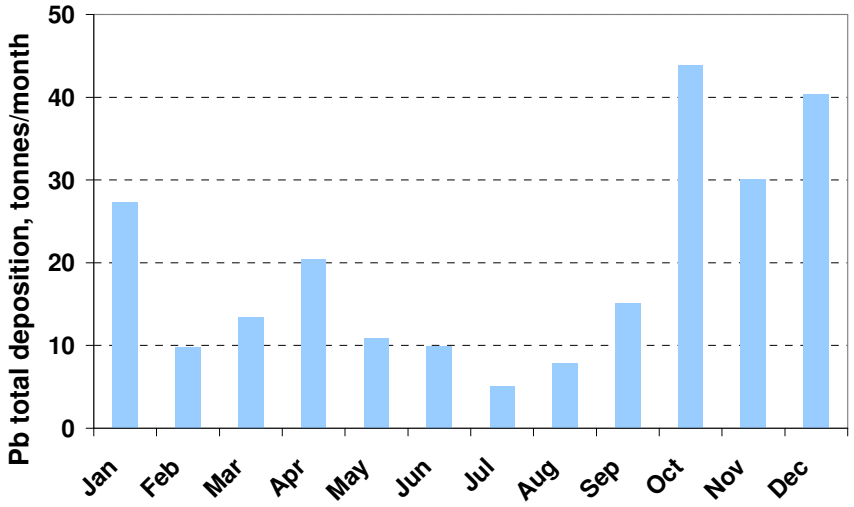


Figure 4.19. Monthly total depositions of lead to the Baltic Sea for 2006, tonnes/month.

Table 4.3. Monthly total depositions of lead to the Baltic Sea for 2006, tonnes/month.

Month	Deposition
Jan	27
Feb	10
Mar	13
Apr	20
May	11
Jun	10
Jul	5
Aug	8
Sep	15
Oct	44
Nov	30
Dec	40

4.4 Source allocation of lead deposition

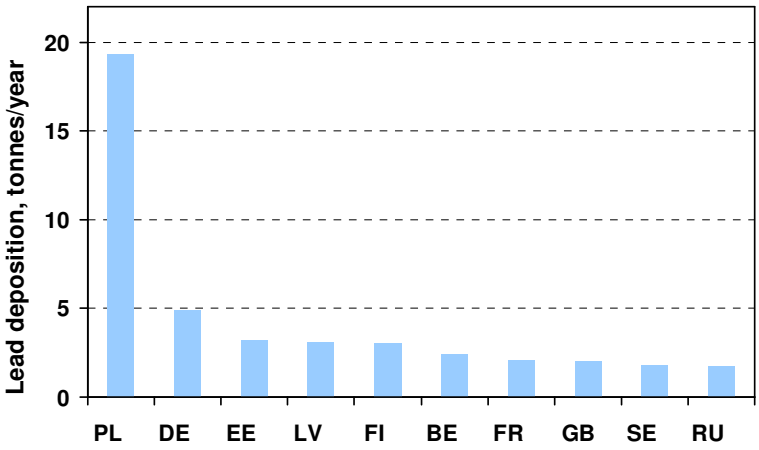


Figure 4.20. Top ten countries with the highest contribution to annual total deposition of lead into the Baltic Sea for 2006, tonnes/year.

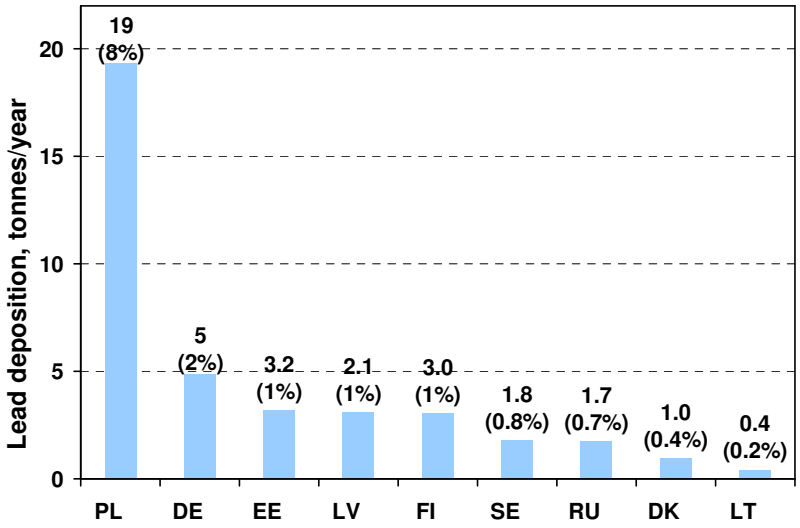


Figure 4.21. Sorted contributions (in %) of HELCOM countries to total depositions to the Baltic Sea for 2006. HELCOM countries emissions of lead contributed about 16% to the total annual lead depositions over the Baltic Sea in 2006. Contribution of other EMEP countries accounted for 7%. Significant contribution was made by other emission sources, in particular, remote emissions sources, natural emissions and re-emission of lead (76%).

Table 4.4. Two most significant contributors to the annual total depositions of lead to the six Baltic Sea sub-basins for 2006.

Sub-basin	Country	%	Country	%	*, %
GUB	Finland	7	Poland	6	73
GUF	Estonia	13	Poland	6	67
GUR	Poland	9	Latvia	4	75
BAP	Poland	10	Germany	2	76
BES	Germany	4	Poland	3	82
KAT	Poland	3	Germany	2	83
BAS	Poland	8	Germany	2	76

* - contribution of re-emission, natural and remote sources.

4.5 Comparison of model results with measurements

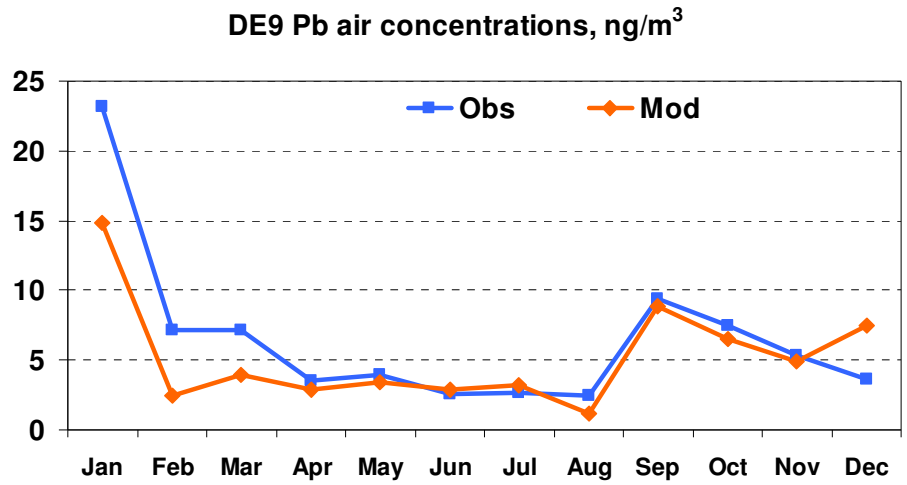


Figure 4.22. Comparison of calculated mean monthly lead concentrations in air for 2006 with measurements of the station Zingst (DE9). Units: ng / m^3.

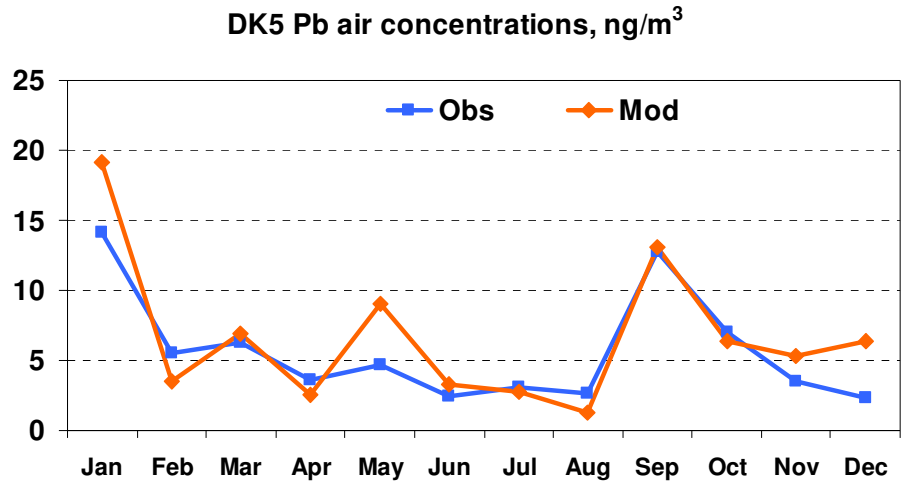


Figure 4.23. Comparison of calculated mean monthly lead concentrations in air for 2006 with measurements of the station Keldsnor (DK5). Units: ng / m^3.

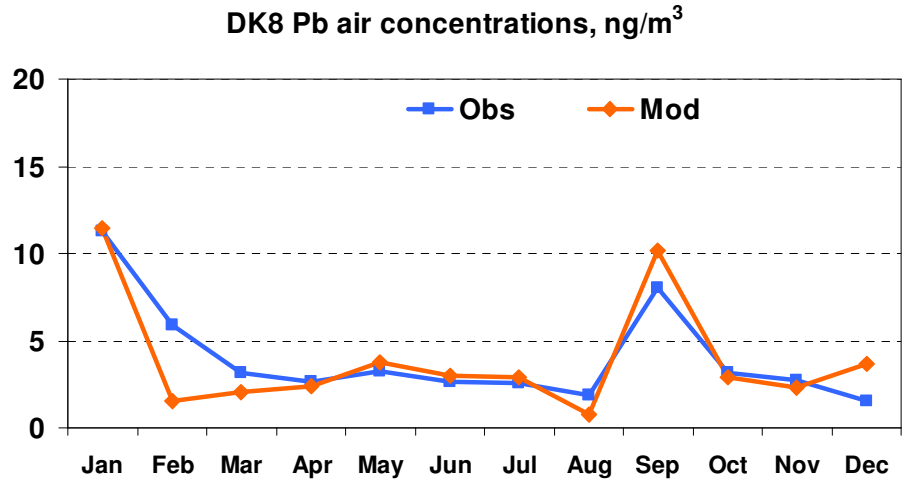


Figure 4.24. Comparison of calculated mean monthly lead concentrations in air for 2006 with measurements of the station Anholt (DK8). Units: ng / m^3.

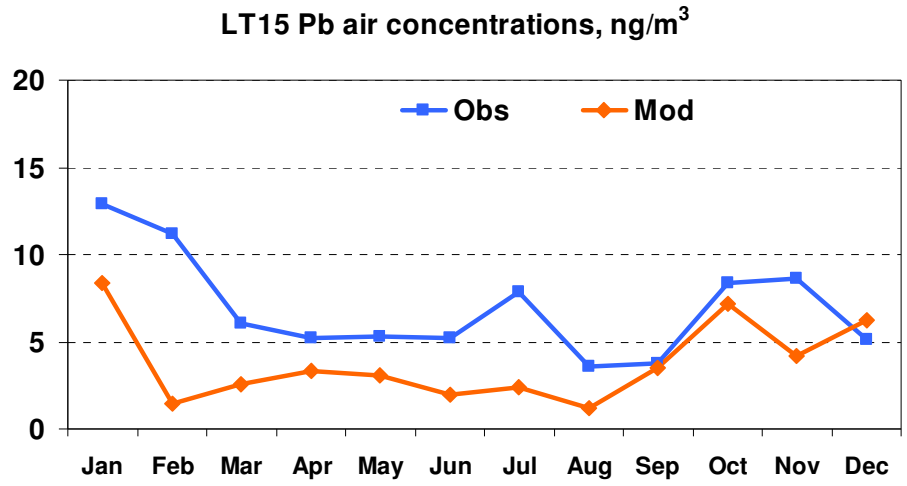


Figure 4.25. Comparison of calculated mean monthly lead concentrations in air for 2006 with measurements of the station Preila (LT15). Units: ng / m^3.

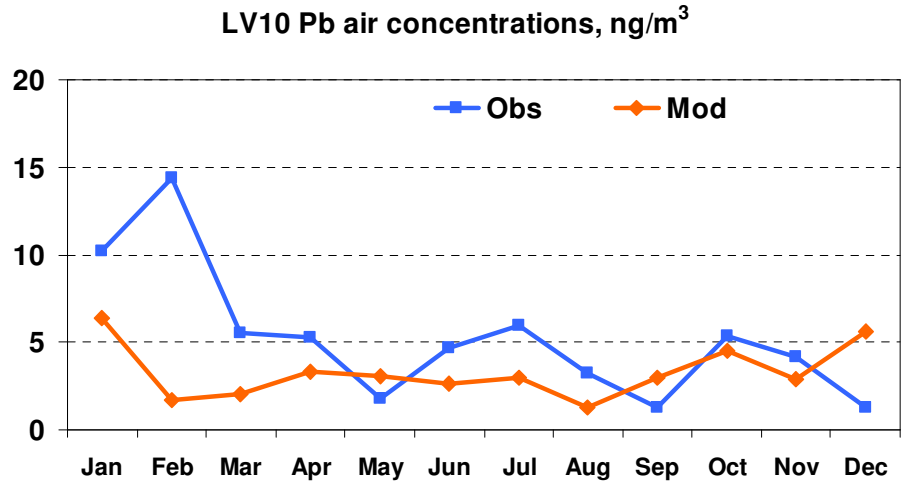


Figure 4.26. Comparison of calculated mean monthly lead concentrations in air for 2006 with measurements of the station Rucava (LV10). Units: ng / m^3.

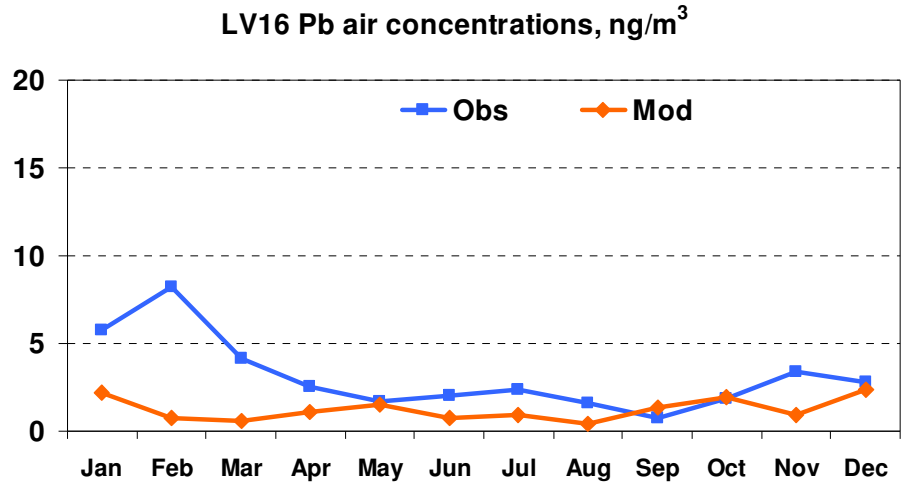


Figure 4.27. Comparison of calculated mean monthly lead concentrations in air for 2006 with measurements of the station Zoseni (LV16). Units: ng / m^3.

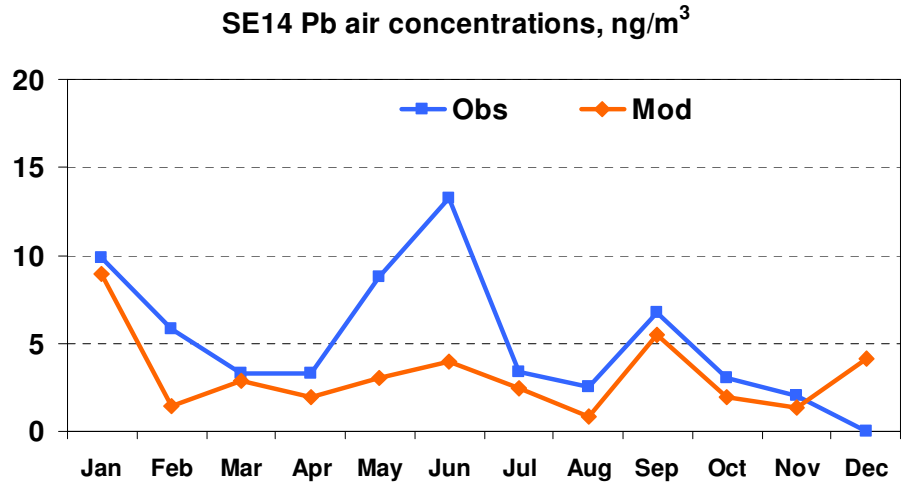


Figure 4.28. Comparison of calculated mean monthly lead concentrations in air for 2006 with measurements of the station Räo (SE14). Units: ng / m^3.

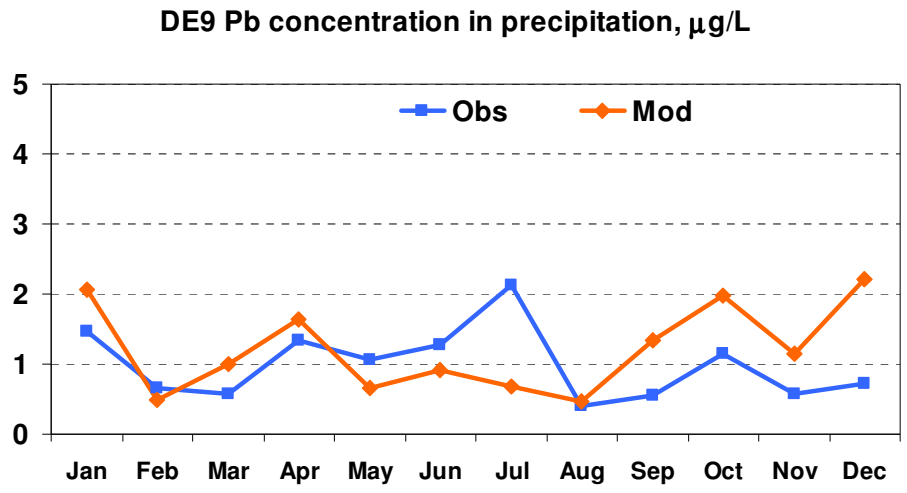


Figure 4.29. Comparison of calculated mean monthly lead concentrations in precipitation for 2006 with measurements of the station Zingst (DE09). Units: µg / L.

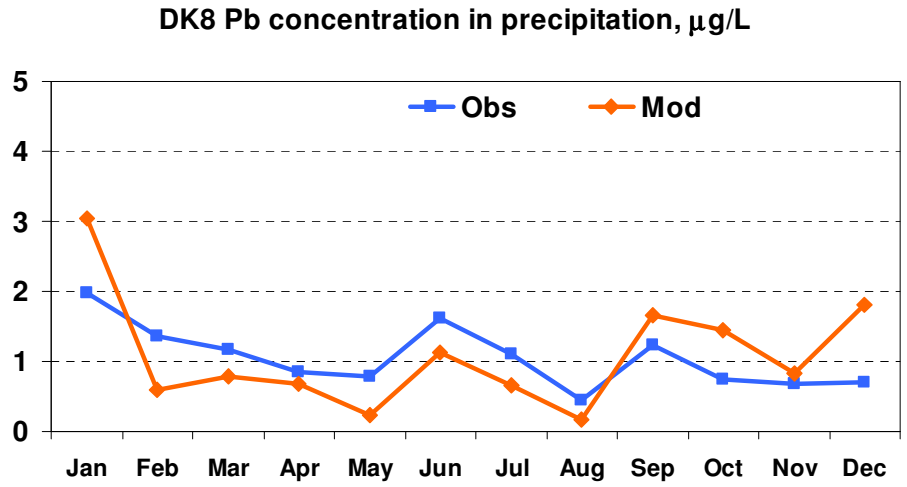


Figure 4.30. Comparison of calculated mean monthly lead concentrations in precipitation for 2006 with measurements of the station Anholt (DK08). Units: µg / L.

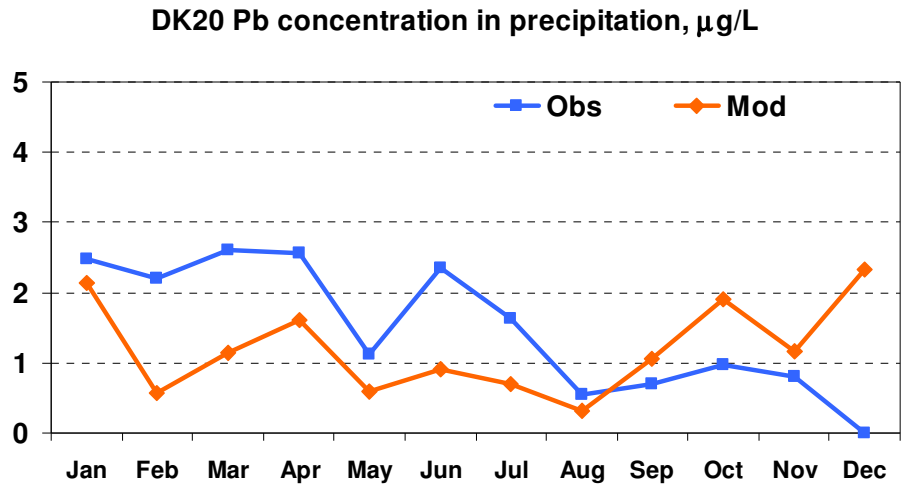


Figure 4.31. Comparison of calculated mean monthly lead concentrations in precipitation for 2006 with measurements of the station Pedersker (DK20). Units: µg / L.

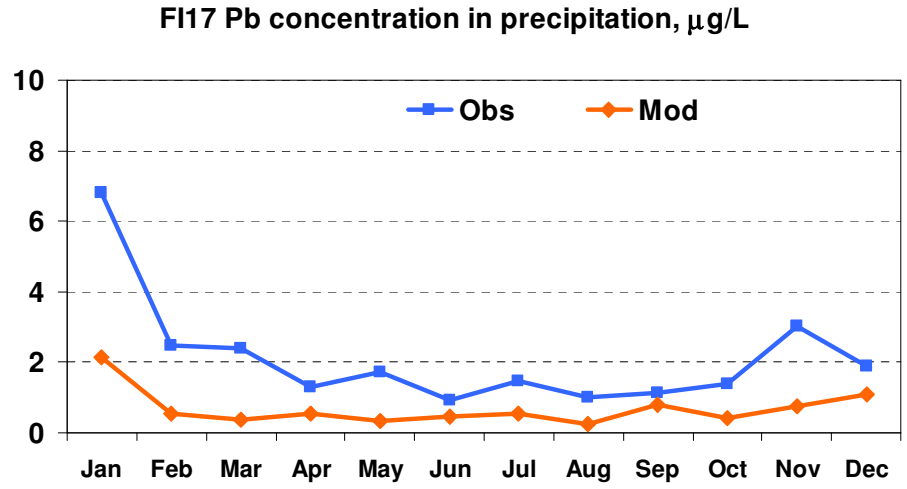


Figure 4.32. Comparison of calculated mean monthly lead concentrations in precipitation for 2006 with measurements of the station Virolahty II (FI17). Units: µg / L.

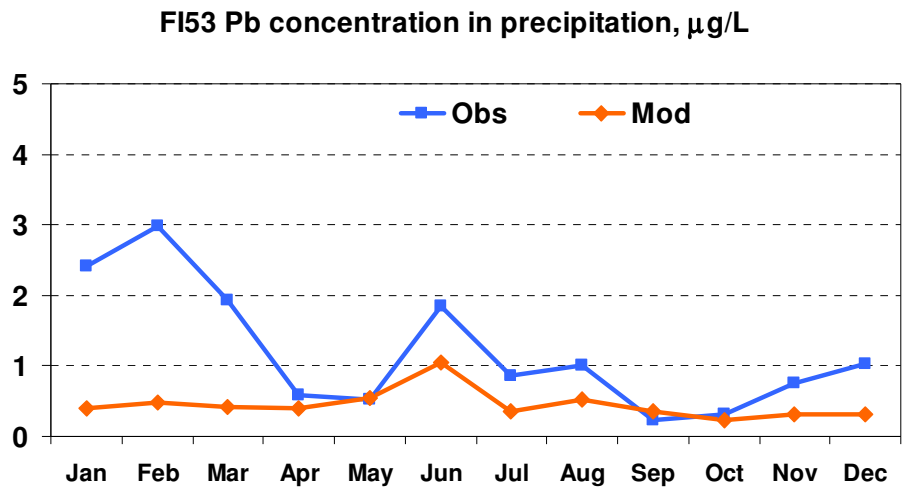


Figure 4.33. Comparison of calculated mean monthly lead concentrations in precipitation for 2006 with measurements of the station Hailuoto (FI53). Units: µg / L.

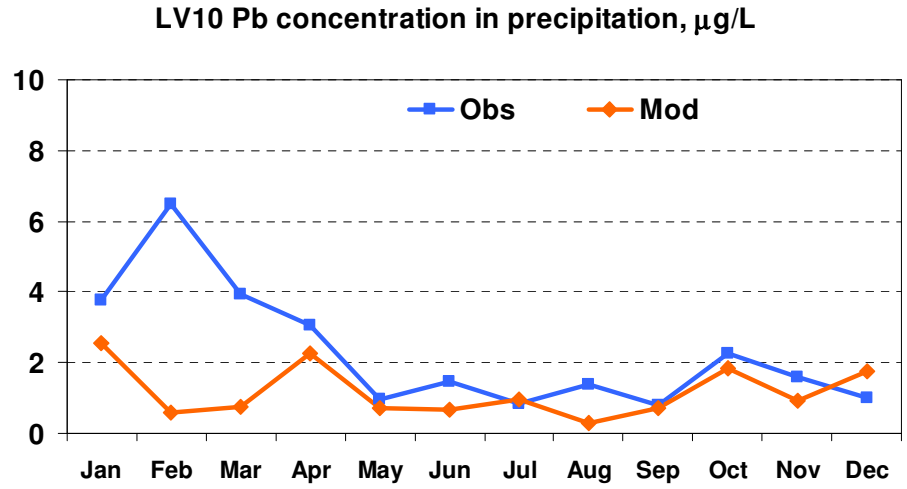


Figure 4.34. Comparison of calculated mean monthly lead concentrations in precipitation for 2006 with measurements of the station Rucava (LV10). Units: µg / L.

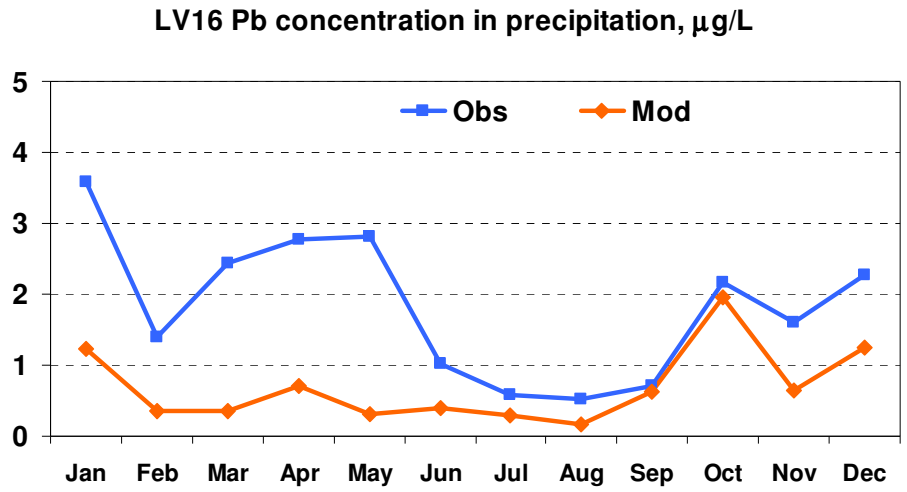


Figure 4.35. Comparison of calculated mean monthly lead concentrations in precipitation for 2006 with measurements of the station Zoseni (LV16). Units: µg / L.

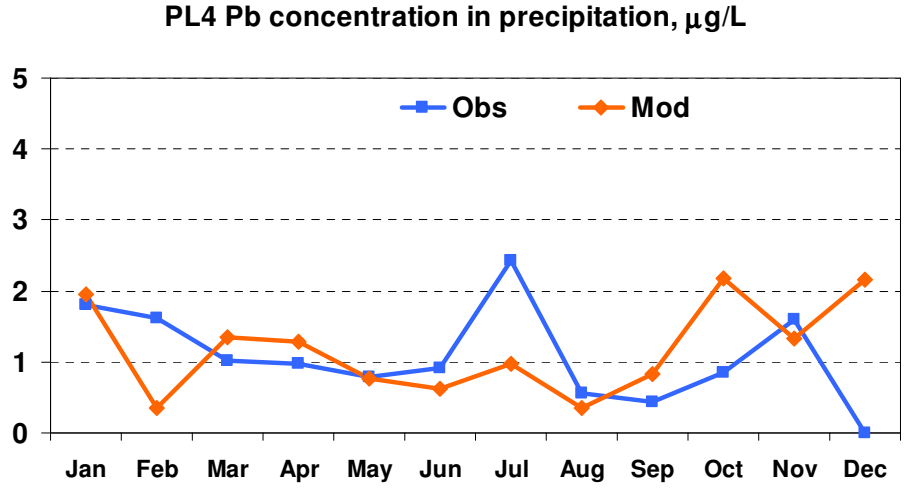


Figure 4.36. Comparison of calculated mean monthly lead concentrations in precipitation for 2006 with measurements of the station Leba (PL04). Units: µg / L.

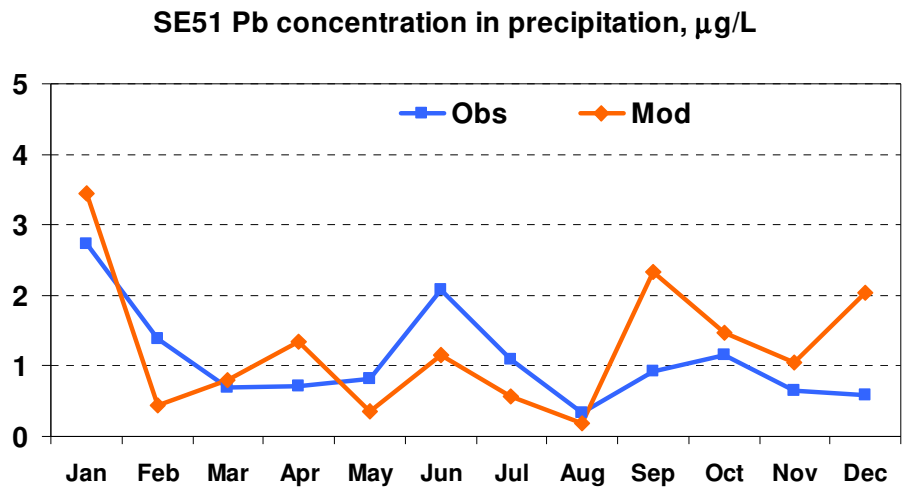


Figure 4.37. Comparison of calculated mean monthly lead concentrations in precipitation with measured at station Arup (SE51). Units: µg / L.

It can be seen that in general, computed concentrations of lead in air and in precipitation obtained for the selected monitoring sites around the Baltic Sea reasonably agree with the measured concentrations. Some deviations between simulated and observed monthly mean concentrations of lead can be connected with the uncertainties in seasonal variation of lead emission used in modeling, differences between measured precipitation amount and the one used in the model, and difficulties in measurements of heavy metals.