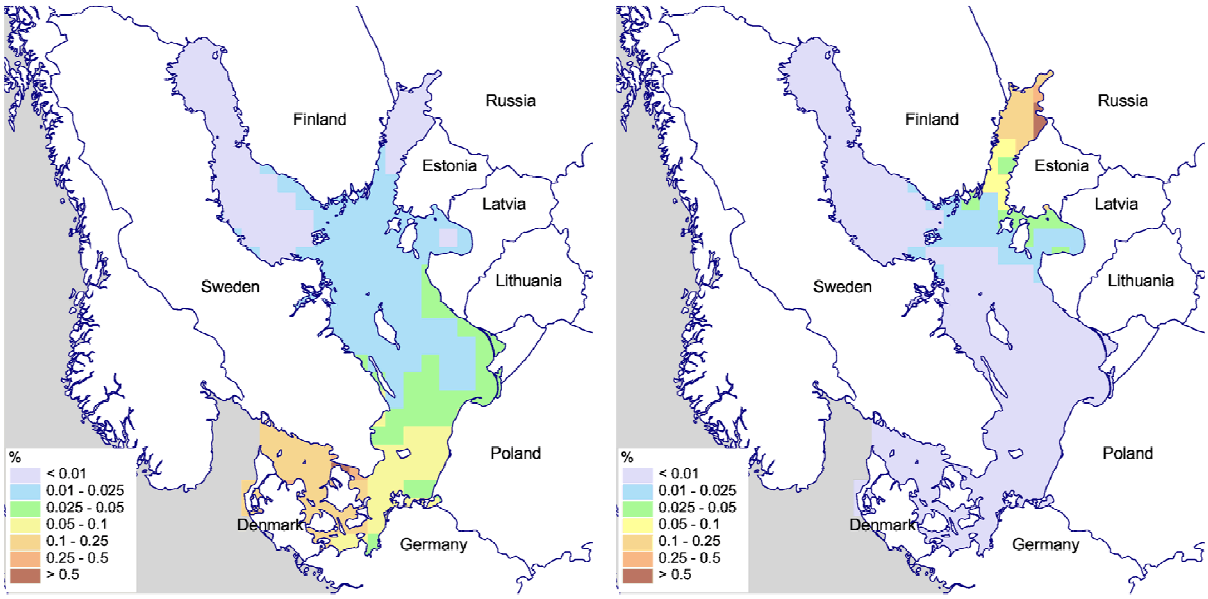
5. Atmospheric Supply of Cadmium to the Baltic Sea in 2005

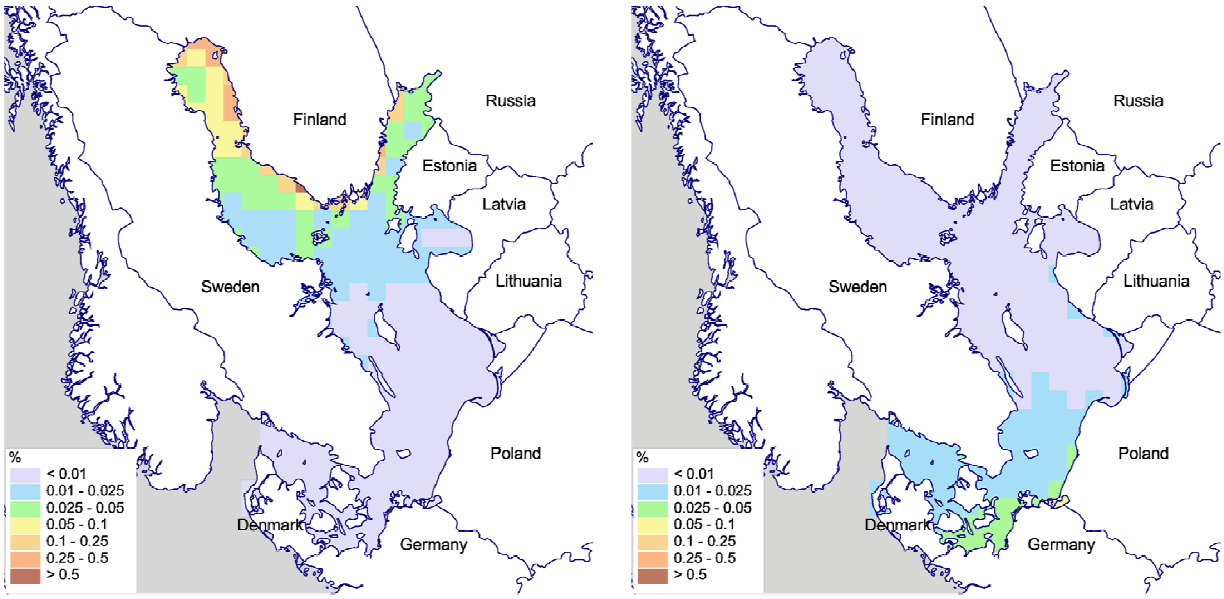
In this chapter the results of model evaluation of cadmium atmospheric input to the Baltic Sea and its sub-basins for 2005 is presented. Modelling of cadmium atmospheric transport and depositions was carried out using MSC-E Eulerian Heavy Metal transport model MSCE-HM (Travnikov and Ilyin, 2005). Latest available official information on cadmium emission from HELCOM countries and other European countries was used in computations. Based on these data levels of annual and monthly cadmium 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 cadmium concentrations in air and precipitation measured at monitoring sites around the Baltic Sea in 2005.

5.1 Cadmium emissions

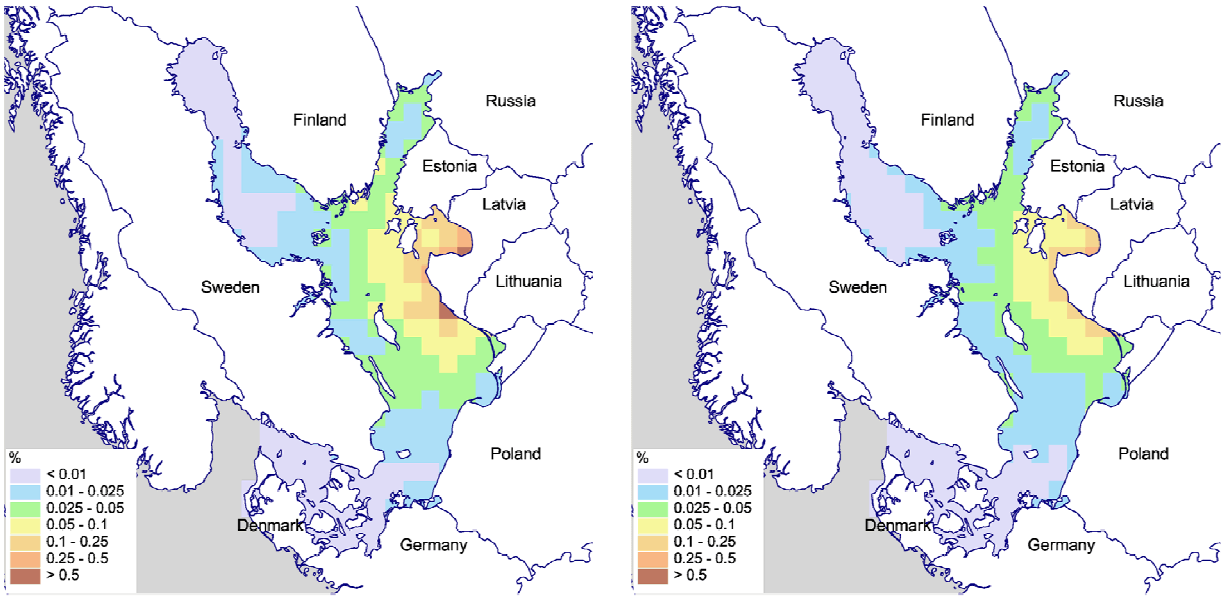


Denmark Estonia

Figure 5.1. Maps with the fractions (in %) of annual total anthropogenic cadmium emissions from HELCOM Parties deposited into the Baltic Sea in 2005.

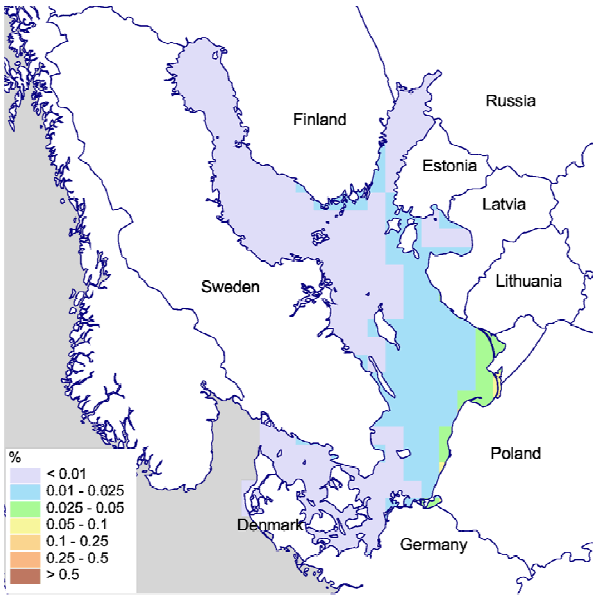


Finland Germany

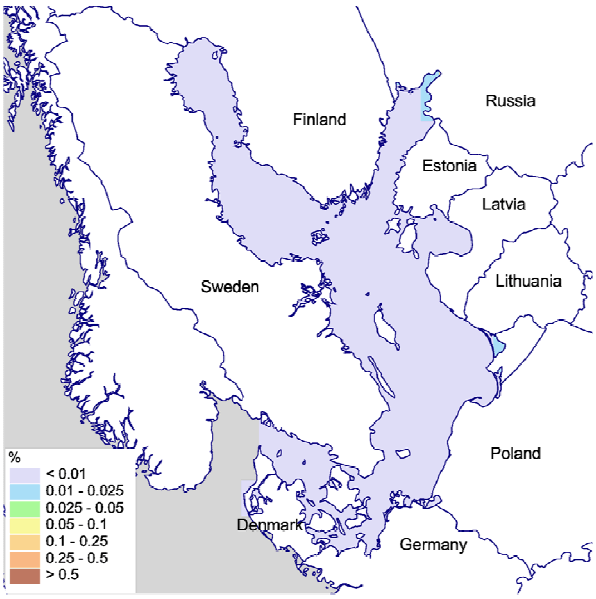


Latvia Lithuania

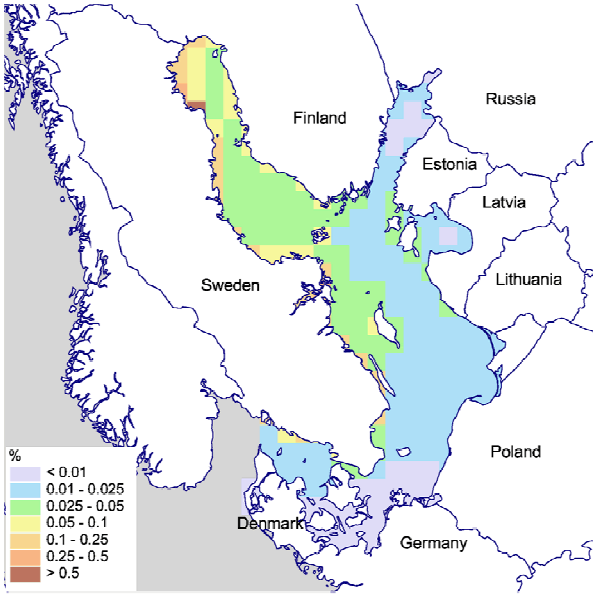
Figure 5.1 (cont.). Maps with the fractions (in %) of annual total anthropogenic cadmium emissions from HELCOM Parties deposited into the Baltic Sea in 2005.



Poland



Russia



Sweden

Figure 5.1 (cont.). Maps with the fractions (in %) of annual total anthropogenic cadmium emissions from HELCOM Parties deposited into the Baltic Sea in 2005.

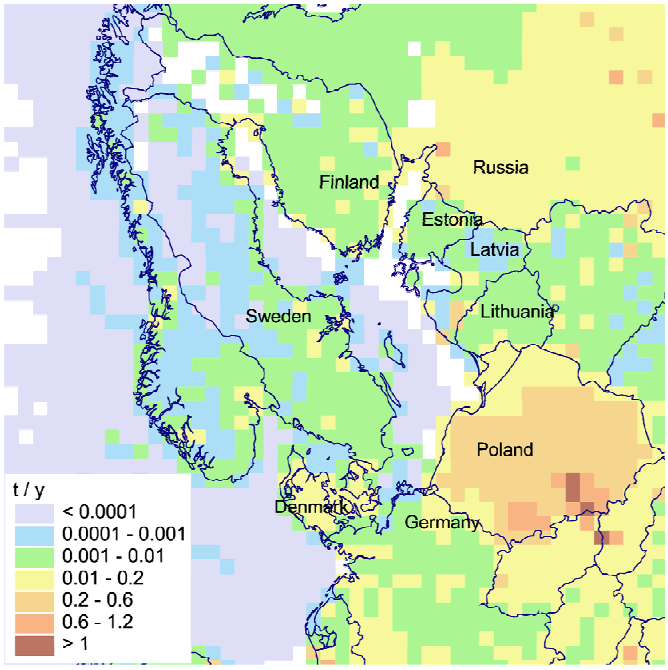


Figure 5.2. Annual total anthropogenic emissions of cadmium in the Baltic Sea region for 2005, t/y.

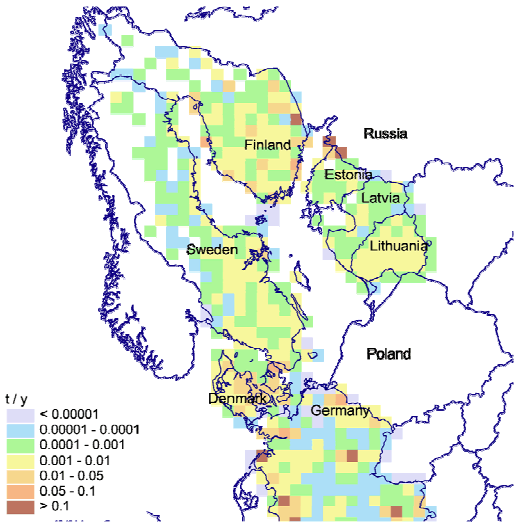


Figure 5.3. Annual cadmium emission from Combustion in Power Plants and Industry sector for 2005.

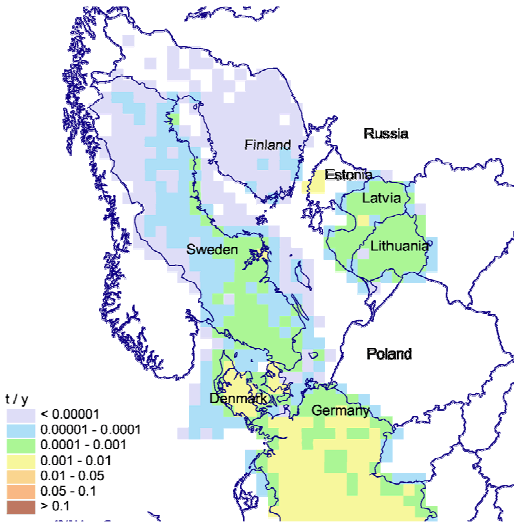


Figure 5.4. Annual cadmium emission from Transport sources below 1000 m sector for 2005.

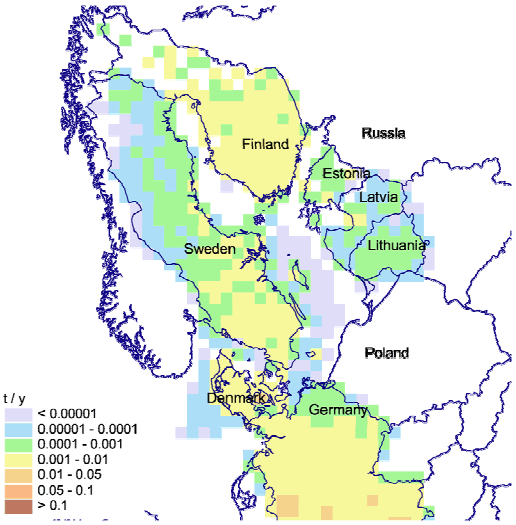


Figure 5.5. Annual cadmium emission from Commercial, Residential and Other Stationary Combustion sector for 2005.

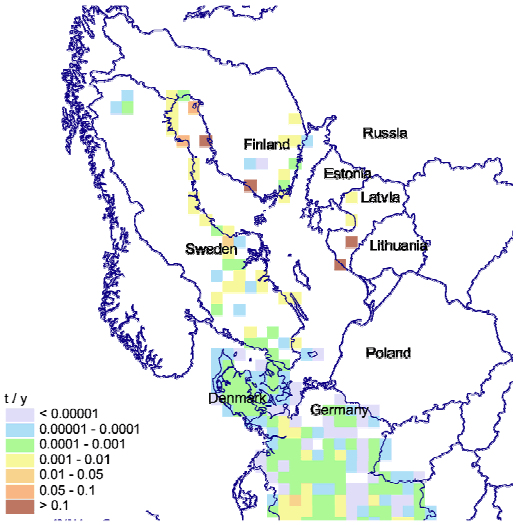


Figure 5.6. Annual cadmium emission from Industrial Processes sector for 2005.

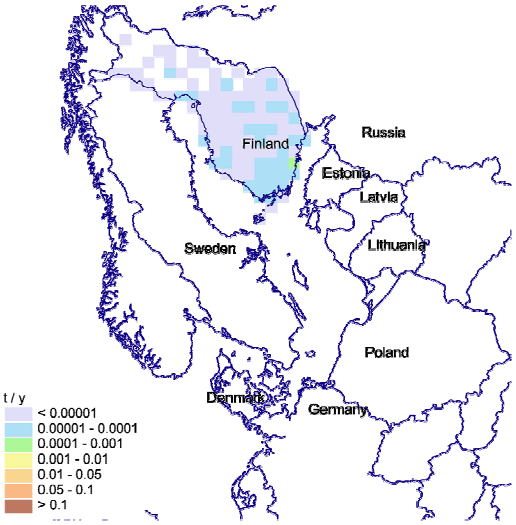


Figure 5.7. Annual cadmium emission from Solvent and Other Product Use sector for 2005.

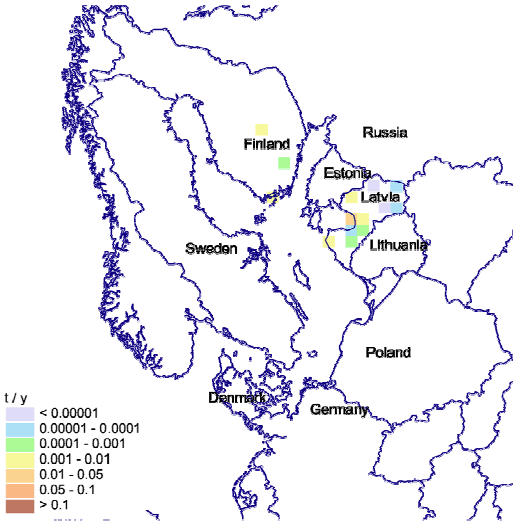


Figure 5.8. Annual cadmium emission from Waste sector for 2005.

Table 5.1. Annual total anthropogenic emissions of cadmium of HELCOM countries from different sectors for 2005, 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	0.37	0.55	0.71	1.6	0.04	0.35	11.76	59.4	0.22
2a	Transport above 1000m	0.0003	NA		NA		0			NA
2b	Transport below 1000m	0.04	0.006	0	0.3	0.009	0.014	0.35		0.02
3	Commercial, Residential and Other Stationary Combustion	0.21	0.02	0.25	0.64	0.008	0.004	25.82		0.14
4	Fugitive Emissions From Fuels	0	0	0	NA		0	0.43		0
5	Industrial Processes	0.005	0	0.33	0.1	0.44	0	1.86		0.15
6	Solvent and Other Product Use	0	0	0.002	NA		0			NE
7	Agriculture	0	NA		NA	0	0	5.55		NA
8	Waste	0	0	0.0005	1.24E-6	0.04		0.26		0.004
9	Other									
Total		**0.62**	**0.58**	**1.30**	**2.66**	**0.54**	**0.37**	**46.02**	**59.40**	**0.53**

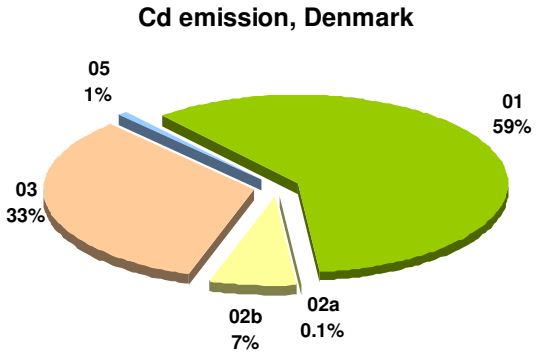


Figure 5.9. Percentage of annual total cadmium emission from different sectors in Denmark for 2005.

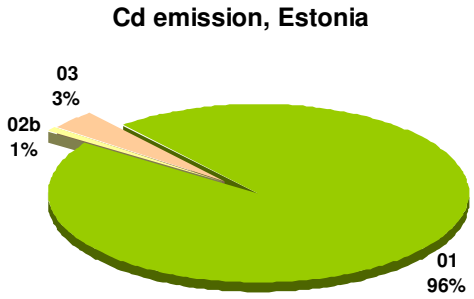


Figure 5.10. Percentage of annual total cadmium emission from different sectors in Estonia for 2005.

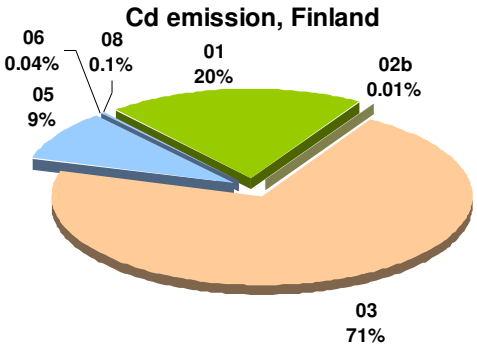


Figure 5.11. Percentage of annual total cadmium emission from different sectors in Finland for 2005.

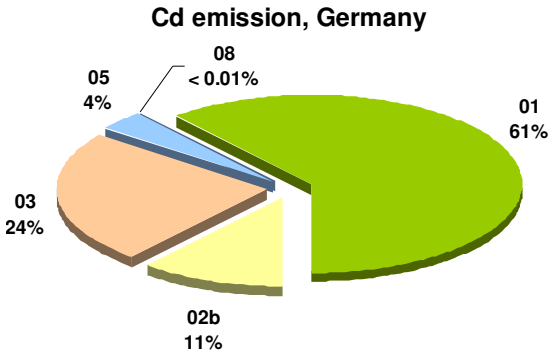


Figure 5.12. Percentage of annual total cadmium emission from different sectors in Germany for 2005.

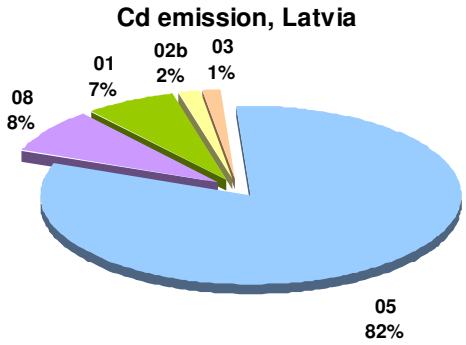


Figure 5.13. Percentage of annual total cadmium emission from different sectors in Latvia for 2005.

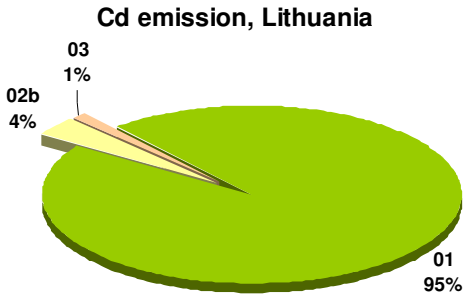


Figure 5.14. Percentage of annual total cadmium emission from different sectors in Lithuania for 2005.

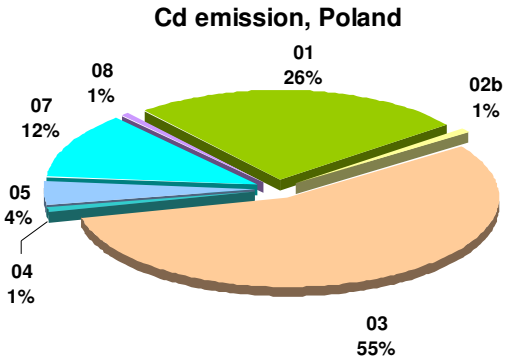


Figure 5.15. Percentage of annual total cadmium emission from different sectors in Poland for 2005.

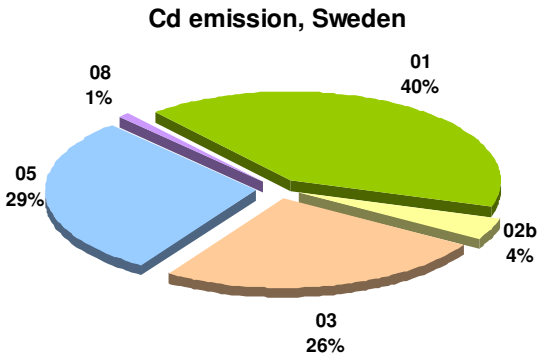


Figure 5.16. Percentage of annual total cadmium emission from different sectors in Sweden for 2005.

Table 5.2. Annual total anthropogenic emissions of cadmium of HELCOM countries and other EMEP countries in period 1990-2005, tonnes (Expert estimates of emissions are shaded).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Denmark	1.1	1.2	1.1	1.1	0.952	0.786	0.808	0.736	0.714	0.695	0.627	0.683	0.638	0.612	0.625	0.623
Estonia	4.4	4.2	3.0	2.2	2.9	2.0	1.0	1.1	1.0	0.945	0.605	0.560	0.560	0.620	0.586	0.576
Finland	6.3	3.4	2.9	2.9	2.4	1.7	1.5	1.1	1.3	0.600	1.4	1.6	1.3	1.2	1.5	1.3
Germany	12	8.0	5.2	3.7	2.6	2.3	2.2	2.4	2.2	2.7	2.4	2.6	2.7	2.7	2.7	2.7
Latvia	1.5	1.2	0.876	0.751	0.950	0.738	0.916	0.771	1.1	0.904	0.811	0.758	0.575	0.538	0.518	0.542
Lithuania	3.8	2.8	2.5	2.3	2.1	2.1	2.2	2.2	2.6	2.0	1.4	1.2	1.0	0.916	0.524	0.371
Poland	92	85	84	92	86	83	91	86	55	62	50	53	49	48	46	46
Russia	79	68	69	59	57	57	51	50	49	51	51	51	52	57	55	59
Sweden	2.3	1.7	1.4	1.1	0.766	0.744	0.713	0.708	0.627	0.543	0.526	0.607	0.533	0.517	0.532	0.530
HELCOM	**202**	**176**	**170**	**165**	**155**	**150**	**152**	**145**	**114**	**121**	**109**	**111**	**107**	**113**	**108**	**112**
Albania	0.647	0.602	0.557	0.513	0.468	0.423	0.378	0.333	0.289	0.244	0.199	0.199	0.198	0.198	0.198	0.197
Armenia	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.132	0.135	0.137	0.140	0.143
Austria	1.6	1.5	1.2	1.2	1.1	0.969	0.991	0.973	0.895	0.980	0.934	0.987	1.0	1.0	1.0	1.1
Azerbaijan	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.5	2.5
Belarus	2.2	2.3	2.0	1.7	1.3	1.1	1.2	1.3	1.5	1.4	1.4	1.8	1.9	1.8	1.8	2.1
Belgium	7.4	7.3	7.9	6.7	5.3	5.5	4.9	4.3	3.7	3.1	2.5	2.4	2.1	1.7	2.3	2.0
Bosnia and Herzegovina	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6
Bulgaria	28	25	22	19	16	13	14	14	15	14	11	10	12	15	15	12
Croatia	1.6	1.5	1.3	1.2	1.1	0.950	1.0	1.0	1.1	1.1	1.0	0.874	0.929	0.948	0.877	0.877
Cyprus	0.550	0.570	0.650	0.710	0.740	0.670	0.710	0.750	0.820	0.870	0.920	0.910	1.0	0.890	1.1	1.1
Czech Republic	4.3	3.9	3.6	3.5	3.5	3.6	2.9	3.0	2.7	2.7	2.9	2.6	2.7	2.2	2.4	3.1
France	19	19	18	17	17	16	16	15	14	13	13	12	11	8.2	6.0	5.9
Georgia	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.215	0.221	0.226	0.232	0.237
Greece	4.5	4.2	4.0	3.7	3.5	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Hungary	5.5	4.7	4.0	4.1	4.1	3.8	3.4	3.3	3.1	3.0	3.0	3.0	2.8	2.9	2.7	1.5
Iceland	0.166	0.158	0.149	0.141	0.132	0.124	0.115	0.107	0.098	0.090	0.081	0.082	0.082	0.082	0.083	0.083
Ireland	0.831	0.835	0.860	0.849	0.928	0.919	0.904	0.937	0.979	0.974	0.973	0.812	0.638	0.559	0.592	0.578
Italy	10	11	10	9.7	9.4	9.4	9.1	8.9	8.6	8.5	8.8	8.7	7.0	7.3	7.8	7.8
Kazakhstan	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.8	5.9	6.0	6.1
Luxembourg	0.600	0.575	0.550	0.525	0.500	0.400	0.400	0.300	0.200	0.054	0.051	0.054	0.047	0.047	0.047	0.047
Malta	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.626
Monaco	0.057	0.058	0.064	0.070	0.006	0.006	0.007	0.008	0.007	0.007	0.008	0.008	0.007	0.006	0.005	0.005
Netherlands	2.1	2.4	2.1	1.7	1.4	1.1	1.9	1.9	1.2	1.1	1.0	1.6	2.2	2.4	1.8	1.7
Norway	1.1	1.0	0.997	1.1	1.1	0.955	1.0	1.0	1.1	0.992	0.660	0.655	0.652	0.630	0.573	0.512
Portugal	5.3	5.8	5.9	5.2	5.5	5.7	4.9	5.3	6.0	6.0	5.5	5.4	6.1	5.4	5.3	5.7
Republic of Moldova	2.4	3.5	1.7	1.4	0.819	0.594	0.659	0.364	0.328	0.148	0.173	0.114	0.226	0.122	0.114	0.145
Romania	22	20	19	18	17	15	14	13	12	12	8.7	7.4	6.3	5.1	3.9	2.7
Serbia and Montenegro	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.7	8.6	8.6	8.6	8.6	8.5
Slovakia	9.4	10	11	8.7	6.6	10	9.0	10	7.8	6.6	7.2	7.2	5.4	5.8	3.6	6.1
Slovenia	1.8	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.7
Spain	24	23	22	20	21	21	19	19	19	19	18	18	19	17	17	17
Switzerland	3.7	3.5	3.3	3.0	2.8	2.5	2.4	2.2	2.2	1.8	1.6	1.5	1.3	1.1	1.1	1.1
The FYR of Macedonia	9.1	9.2	9.3	9.3	9.4	9.4	9.5	9.6	9.6	9.7	9.8	9.8	9.7	9.7	9.7	9.7
Turkey	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Ukraine	54	50	46	42	38	34	30	26	22	18	14	10	2.0	28	3.1	3.1
United Kingdom	24	24	24	15	14	12	10	9.2	6.8	6.5	6.3	5.0	4.8	3.4	3.7	3.8
EMEP	**484**	**449**	**429**	**399**	**375**	**361**	**351**	**338**	**295**	**293**	**269**	**264**	**250**	**276**	**242**	**244**

Expert estimates:

§ *Denier van der Gon, H.A.C., M. van het Bolscher A.J.H. Visschedijk P.Y.J. Zandveld [2005]*

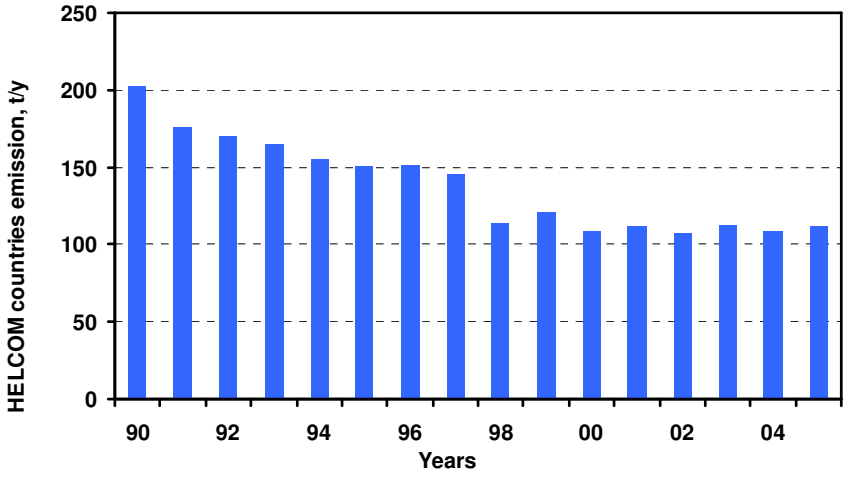


Figure 5.17. Time-series of total annual cadmium emissions of HELCOM countries in 1990-2005, tonnes/y.

5.2 Annual deposition of cadmium

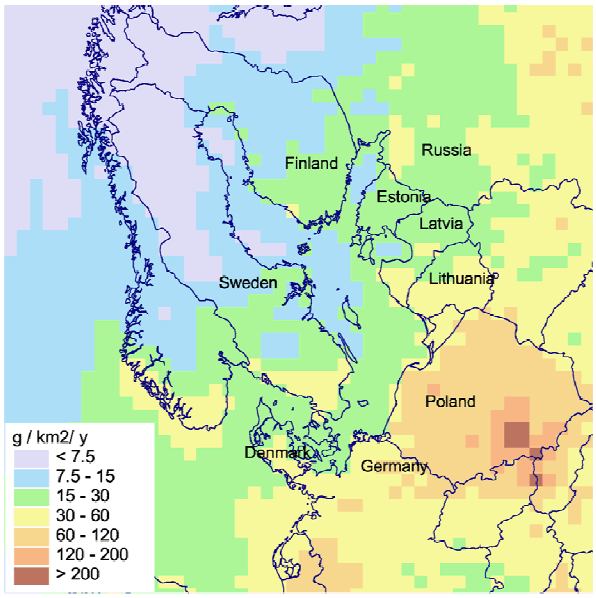


Figure 5.18. Annual deposition fluxes of cadmium over the Baltic Sea region for 2005, g/km^2/year.

5.3 Monthly depositions of cadmium

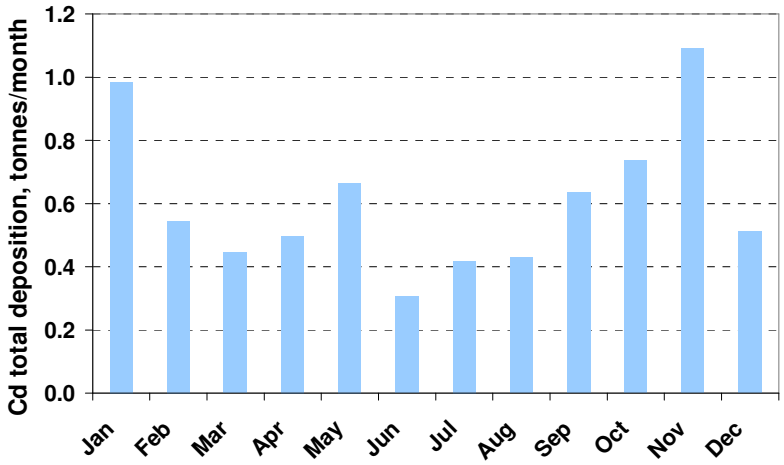


Figure 5.19. Monthly depositions of cadmium to the Baltic Sea for 2005, tonnes/month.

Table 5.2. Monthly depositions of cadmium to the Baltic Sea for 2005, tonnes/month.

Month	**Cd**
Jan	0.98
Feb	0.54
Mar	0.45
Apr	0.50
May	0.67
Jun	0.31
Jul	0.42
Aug	0.43
Sep	0.64
Oct	0.74
Nov	1.09
Dec	0.51

5.4 Source allocation of cadmium deposition

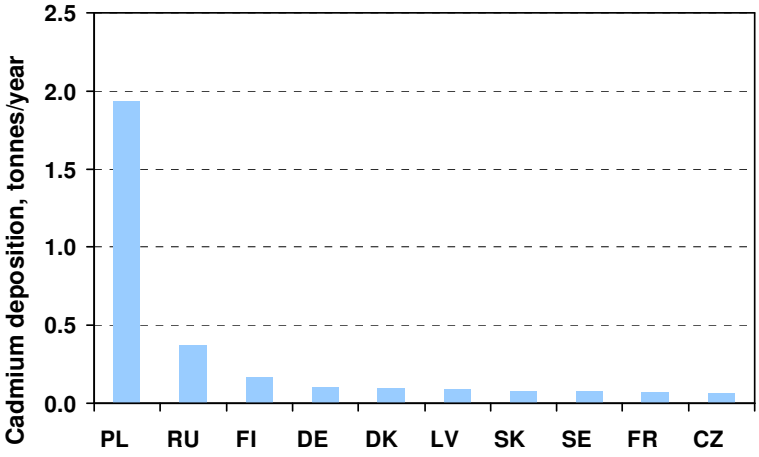


Figure 5.20. Top ten countries with the highest contribution to annual deposition of cadmium over the Baltic Sea for 2005, tonnes/year.

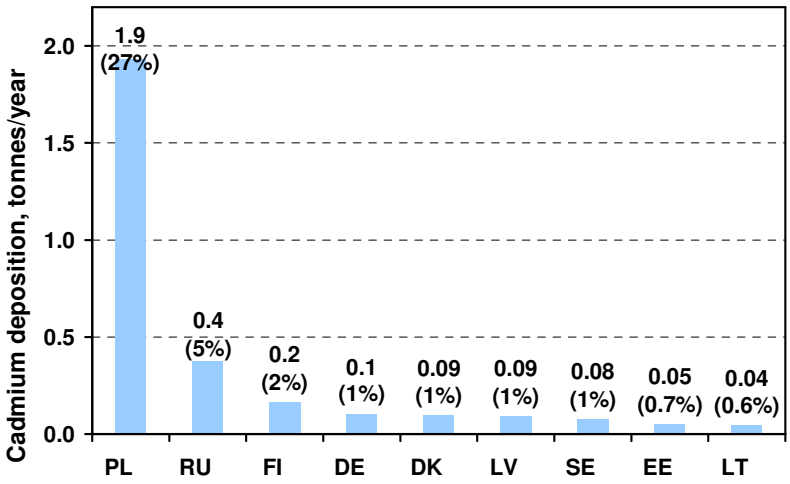


Figure 5.21. Sorted contributions (in %) of HELCOM countries to total depositions over the Baltic Sea for 2005. HELCOM countries emissions of cadmium contributed about 40% to the total annual cadmium depositions over the Baltic Sea in 2005. Contribution of other EMEP countries accounted for 8%. Significant contribution was made by other emission sources, in particular, remote emissions sources, natural emissions and re-emission of cadmium (52%).

Table 5.3. Two most significant contributors to the annual total depositions of cadmium to the six Baltic Sea sub-basins for 2005.

Sub-basin	Country	%	Country	%	*, %
GUB	Poland	21	Finland	10	50
GUF	Poland	19	Russia	18	41
GUR	Poland	27	Russia	8	46
BAP	Poland	33	Russia	4	49
BES	Poland	11	Denmark	4	71
KAT	Poland	13	Denmark	5	69
BAS	Poland	27	Russia	5	51

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

5.5 Comparison of model results with measurements

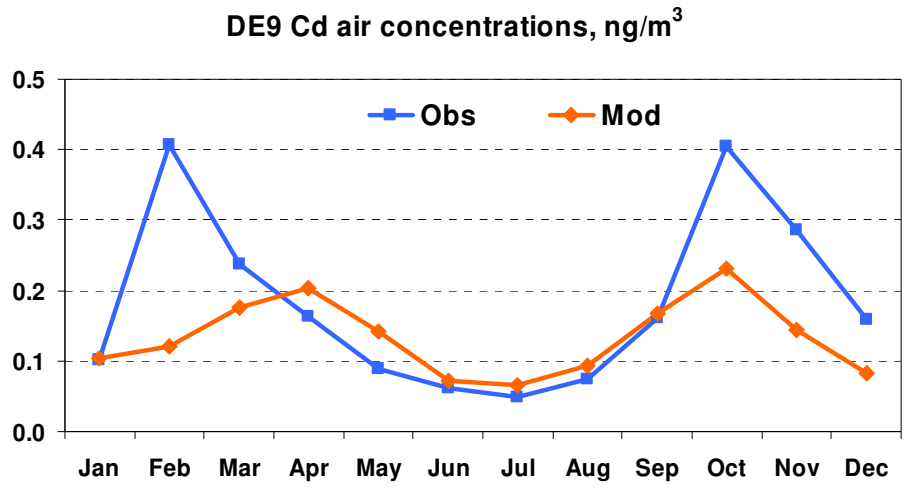


Figure 5.22. Comparison of calculated mean monthly cadmium concentrations in air with measured at

station Zingst (DE9). Units: ng / m^3.

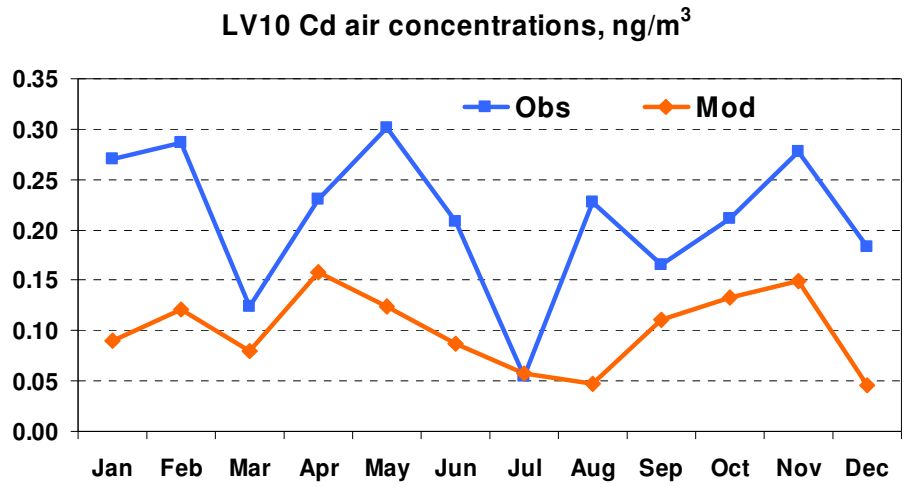


Figure 5.23. Comparison of calculated mean monthly cadmium concentrations in air with measured at station Rucava (LV10). Units: ng / m^3.

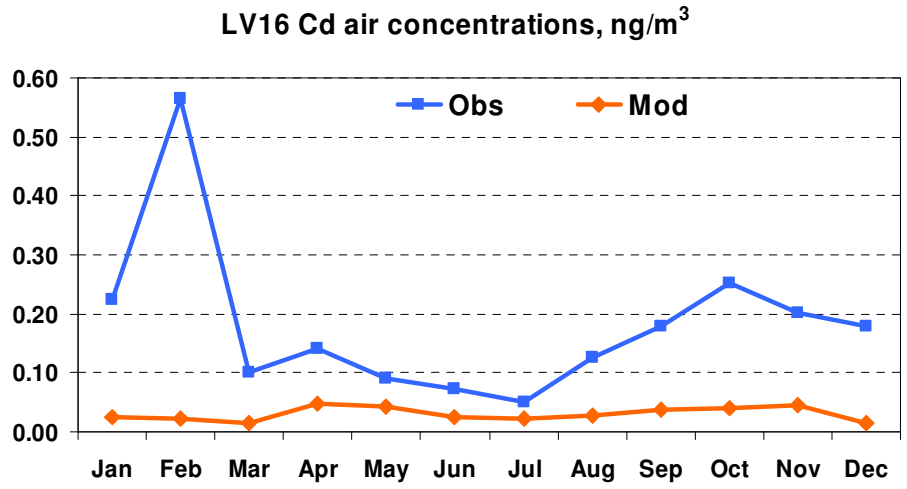


Figure 5.24. Comparison of calculated mean monthly cadmium concentrations in air with measured at station Zoseni (LV16). Units: ng / m^3.

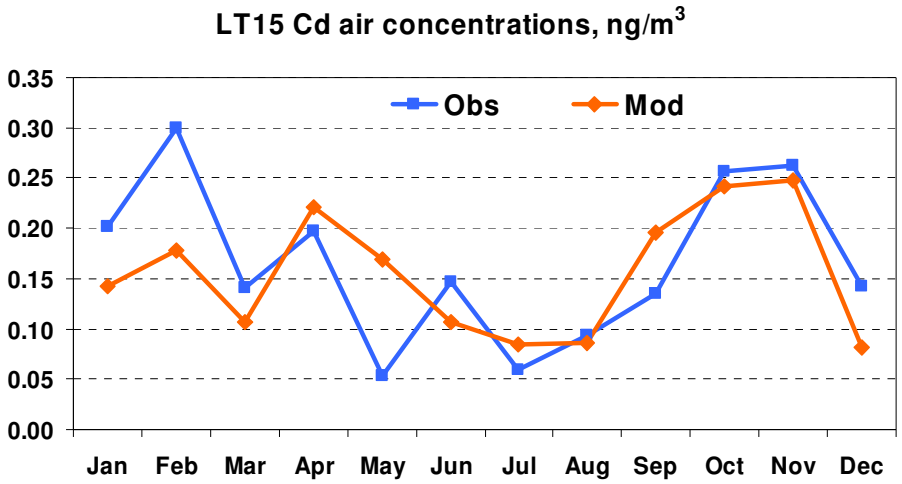


Figure 5.25. Comparison of calculated mean monthly cadmium concentrations in air with measured at station Preila (LT15). Units: ng / m^3.

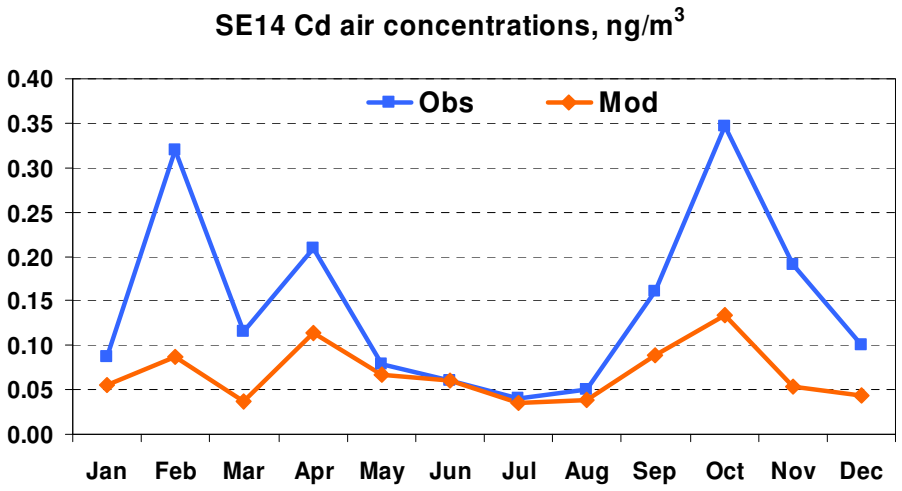


Figure 5.26. Comparison of calculated mean monthly cadmium concentrations in air with measured at station Räö (SE14). Units: ng / m^3.

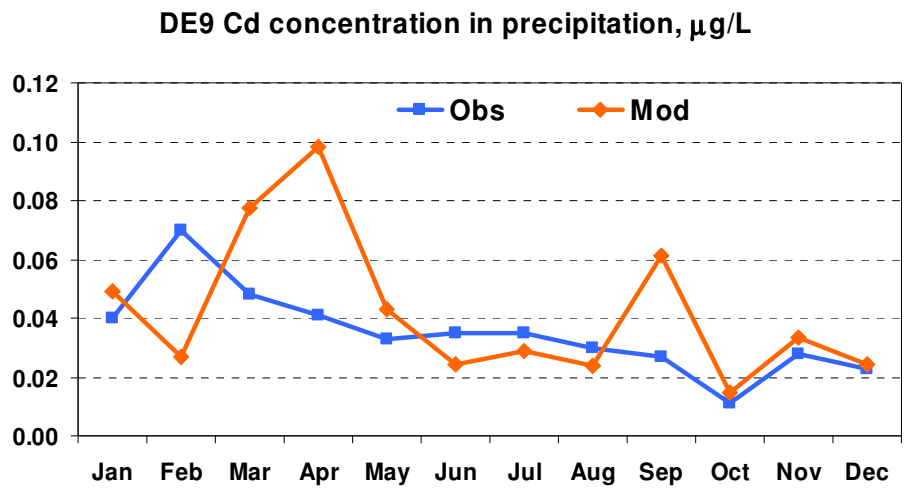


Figure 5.27. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Zingst (DE09). Units: µg / L.

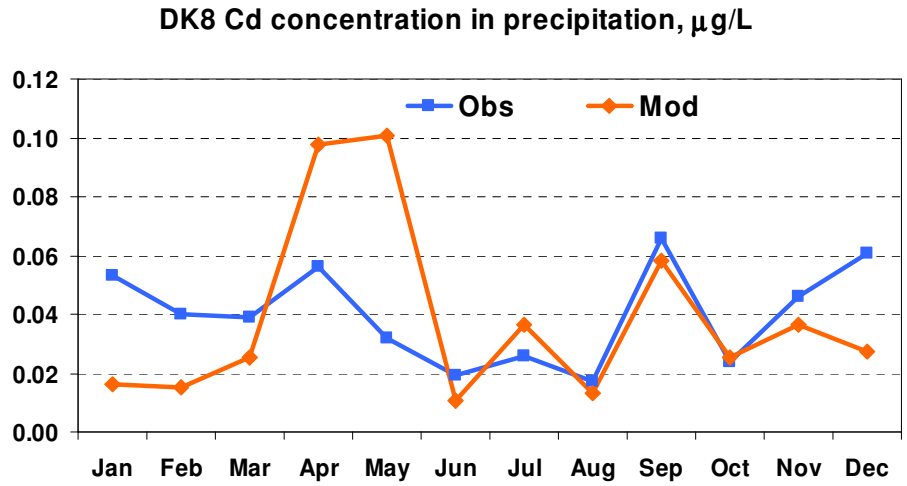


Figure 5.28. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Anholt (DK8). Units: µg / L.

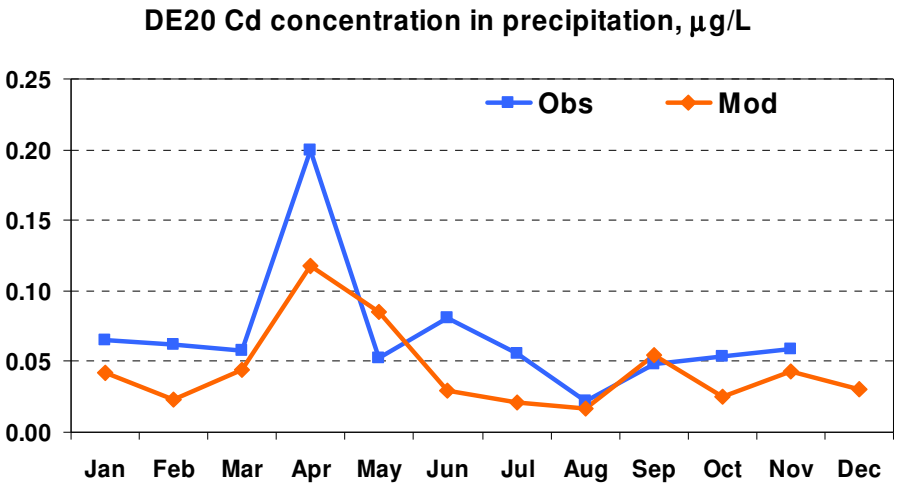


Figure 5.29. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Pedersker (DK20). Units: µg / L.

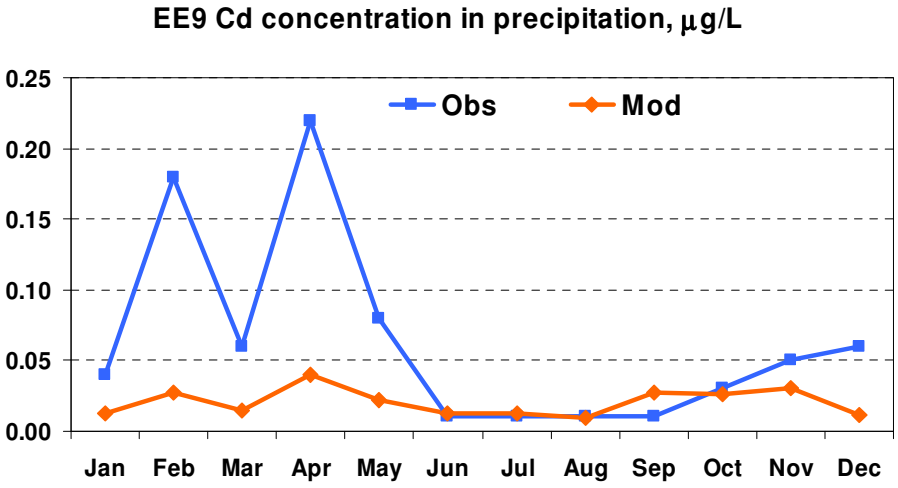


Figure 5.30. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Lahemaa (EE9). Units: µg / L.

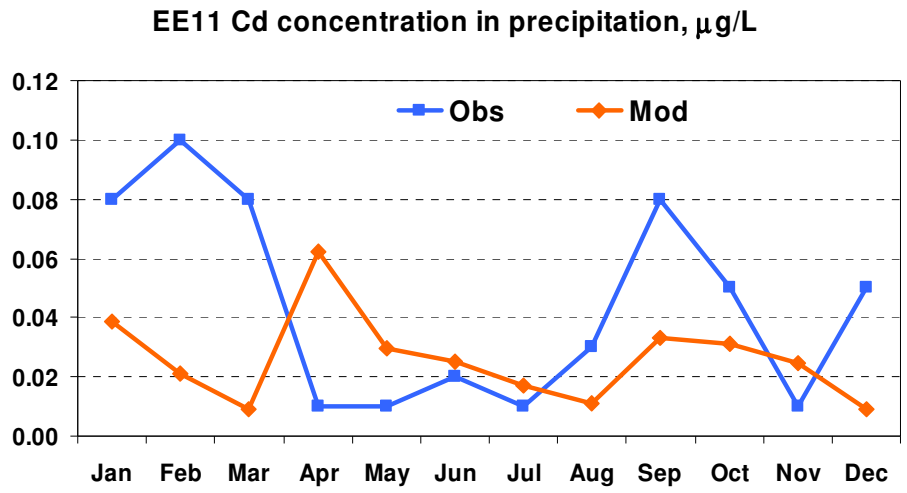


Figure 5.31. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Vilsandy (EE11). Units: µg / L.

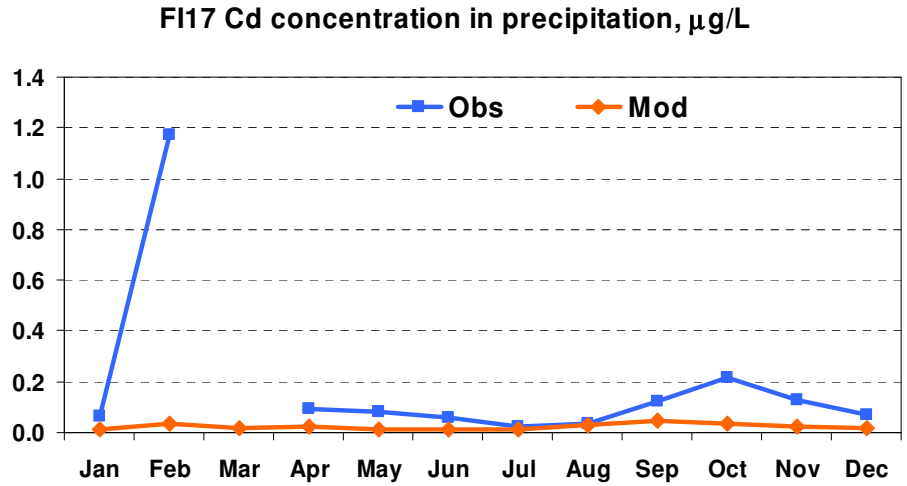


Figure 5.32. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Virolahty II (FI17). Units: µg / L.

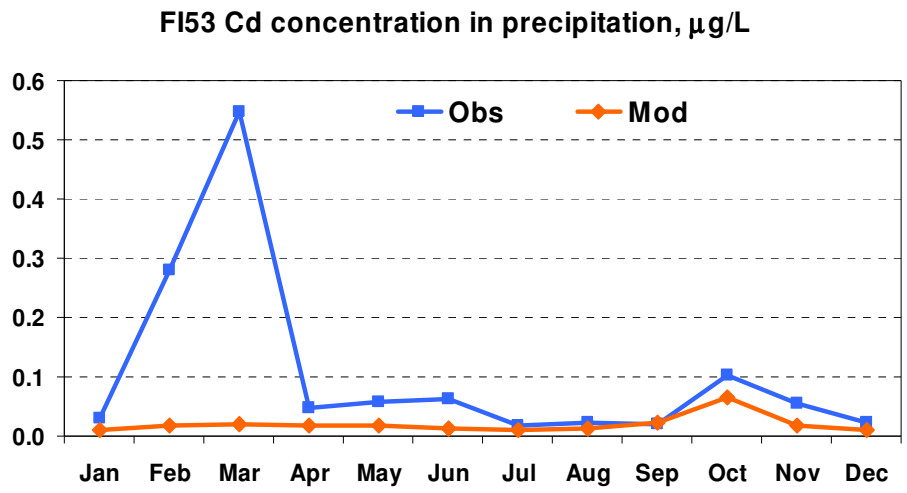


Figure 5.33. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Hailuoto (FI53). Units: µg / L.

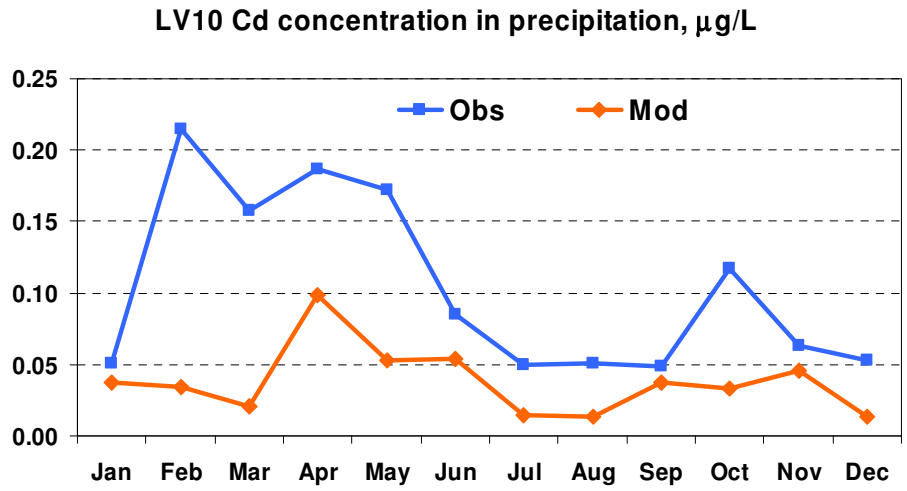


Figure 5.34. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Rucava (LV10). Units: µg / L.

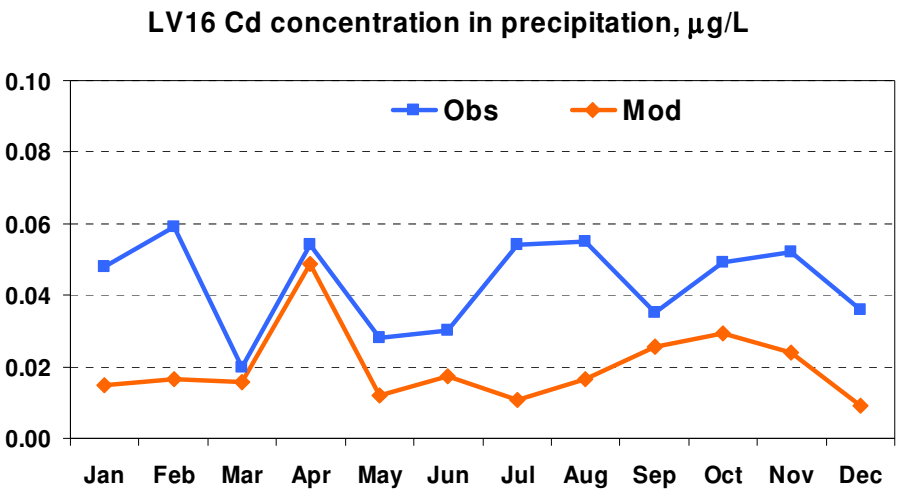


Figure 5.35. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Zoseni (LV16). Units: µg / L.

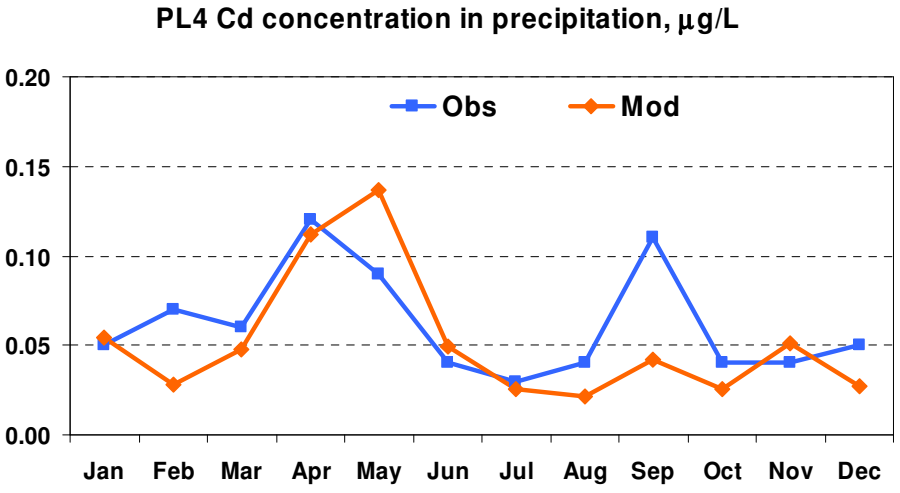


Figure 5.36. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Leba (PL4). Units: µg / L.

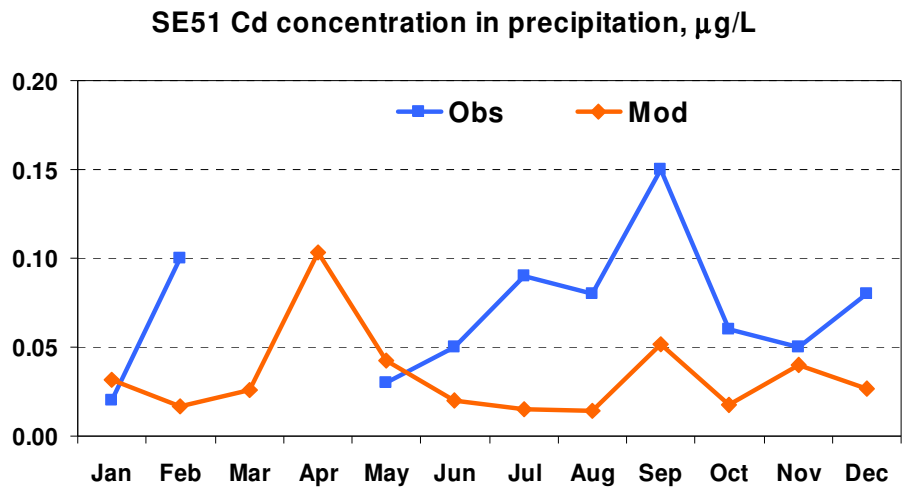


Figure 5.37. Comparison of calculated mean monthly cadmium concentrations in precipitation with measured at station Arup (SE51). Units: µg / L.

In general, reasonable level of agreement between the computed concentrations of cadmium in air and in precipitation is obtained for the selected monitoring sites around the Baltic Sea. Comparing to lead more significant deviations between simulated and observed monthly mean concentrations of cadmium can be mentioned. The reason of deviations is connected with the uncertainties in seasonal variation of cadmium emission, differences between measured precipitation amount and the one used in the model, and difficulties in measurements of heavy metals.