5. Atmospheric Supply of Cadmium to the Baltic Sea in 2006

In this chapter the results of model evaluation of cadmium atmospheric input to the Baltic Sea and its sub-basins for 2006 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 2006.

5.1 Cadmium emissions

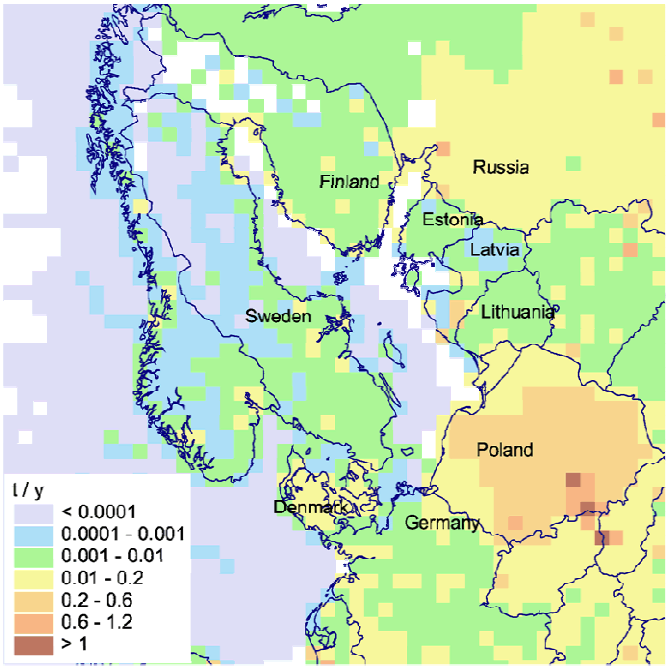


Figure 5.1. Annual total anthropogenic emissions of cadmium in the Baltic Sea region for 2006, t/y.

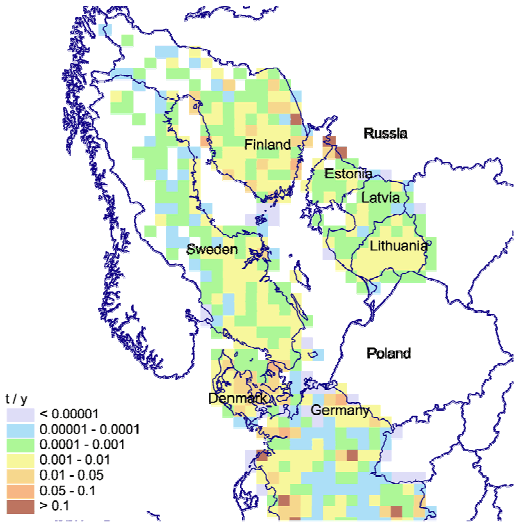


Figure 5.2. Annual cadmium emission from Combustion in Power Plants and Industry sector for 2006, t/y.

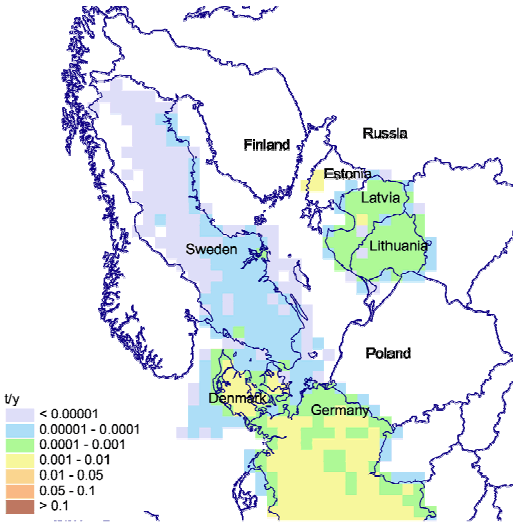


Figure 5.3. Annual cadmium emission from Transport sources below 1000 m sector for 2006, t/y.

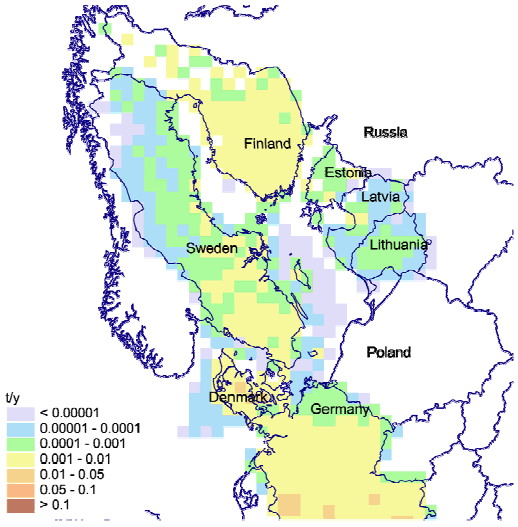


Figure 5.4. Annual cadmium emission from Commercial, Residential and Other Stationary Combustion sector for 2006, t/y.

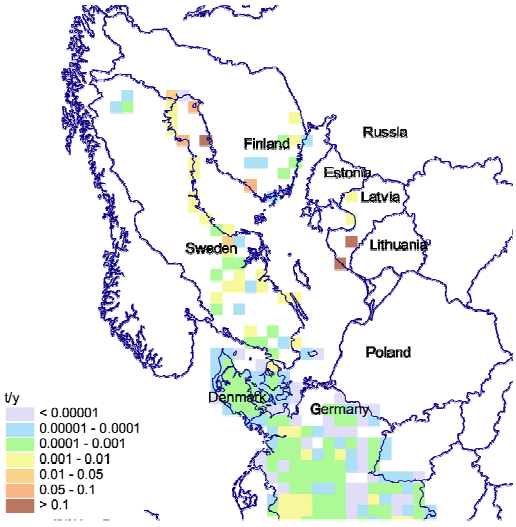


Figure 5.5. Annual cadmium emission from Industrial Processes sector for 2006, t/y.

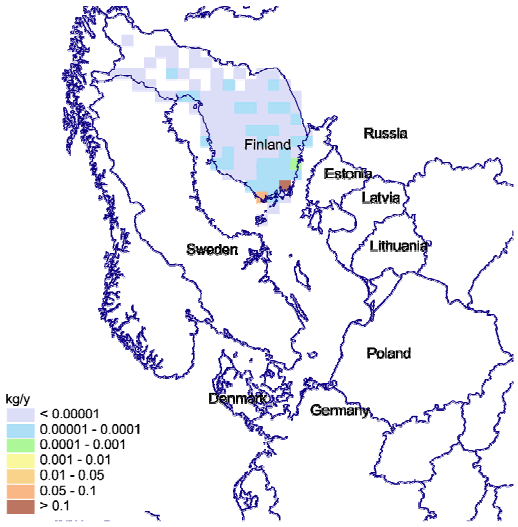


Figure 5.6. Annual cadmium emission from Solvent and Other Product Use sector for 2006, kg/y.

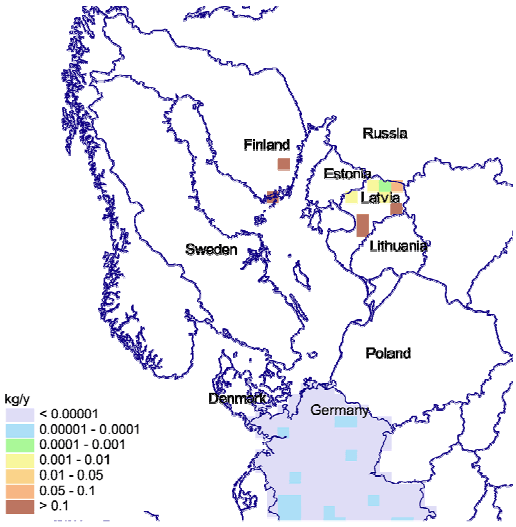


Figure 5.7. Annual cadmium emission from Waste sector for 2006, kg/y.

Table 5.1. Annual total anthropogenic emissions of cadmium 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	0.43	0.52	0.75	1.62	0.03	0.35	12.16	59.40	0.23
2a	Transport above 1000m	0.0003	NA	NA	NE	NA	NA	NA	NA	NE
2b	Transport below 1000m	0.04	0.01	4.9E-07	0.30	0.01	0.01	0.41		0.004
3	Commercial, Residential and Other Stationary Combustion	0.24	0.02	0.25	0.65	0.01	0.003	26.91		0.13
4	Fugitive Emissions From Fuels		NA	NA				0.48		NA
5	Industrial Processes	0.005	0	0.29	0.08	0.55		2.11		0.16
6	Solvent and Other Product Use	NA	NA	0.0004				NA		
7	Agriculture							NA		
8	Waste		0	0.001	1.0E-06	0.003		0.12		
9	Other									
Total		**0.71**	**0.55**	**1.29**	**2.66**	**0.59**	**0.37**	**42.18**	**59.40**	**0.53**

NA – not available
NE – not estimated

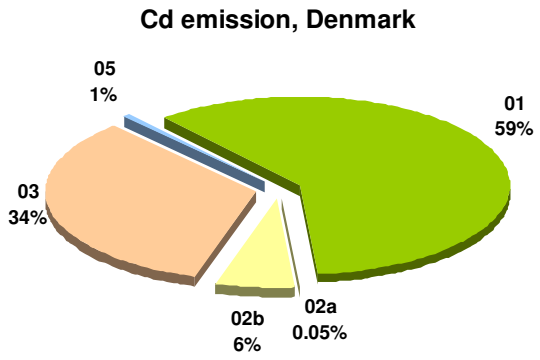


Figure 5.8. Percentage of annual total cadmium emission from different sectors in Denmark for 2006.

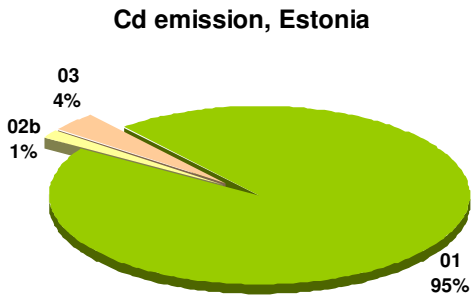


Figure 5.9. Percentage of annual total cadmium emission from different sectors in Estonia for 2006.

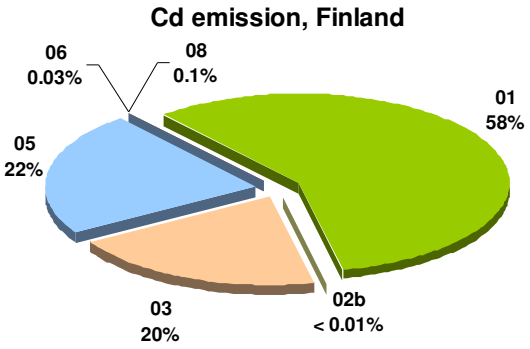


Figure 5.10. Percentage of annual total cadmium emission from different sectors in Finland for 2006.

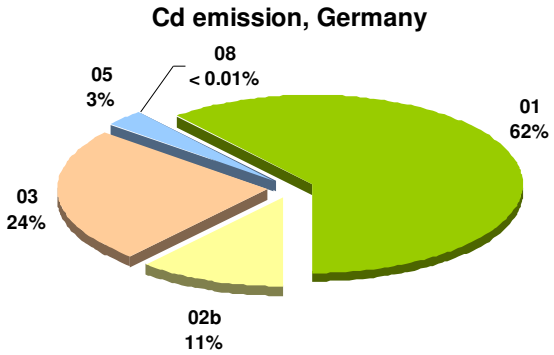


Figure 5.11. Percentage of annual total cadmium emission from different sectors in Germany for 2006.

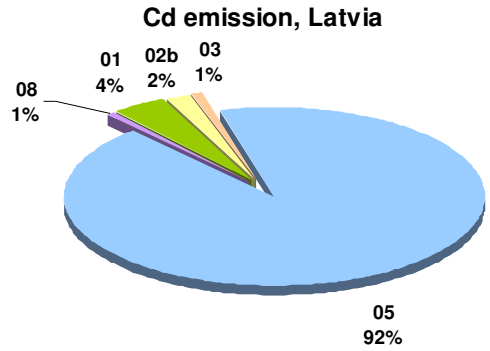


Figure 5.12. Percentage of annual total cadmium emission from different sectors in Latvia for 2006.

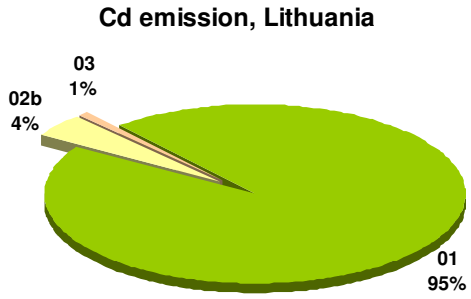


Figure 5.13. Percentage of annual total cadmium emission from different sectors in Lithuania for 2006.

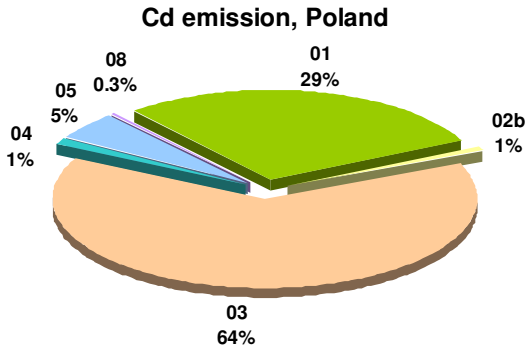


Figure 5.14. Percentage of annual total cadmium emission from different sectors in Poland for 2006.

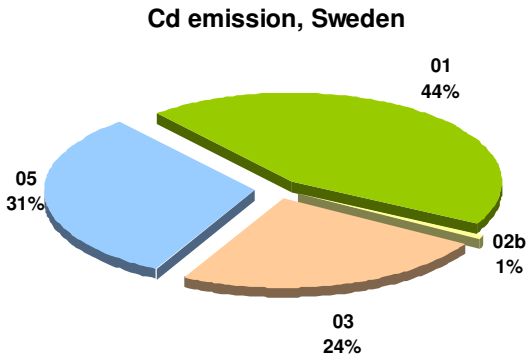
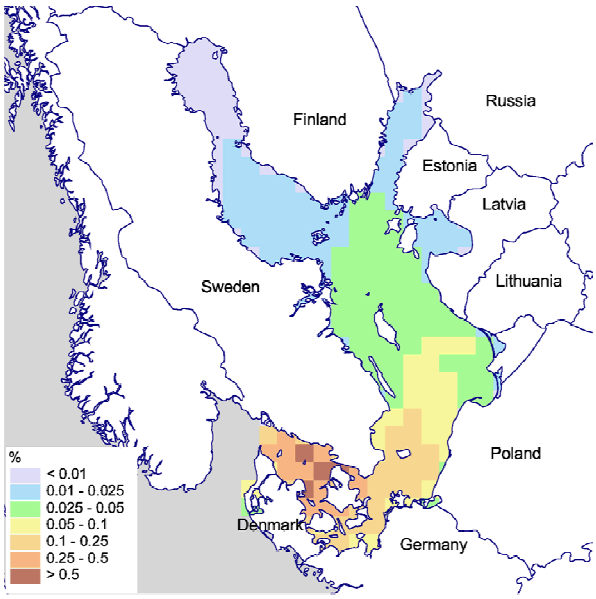
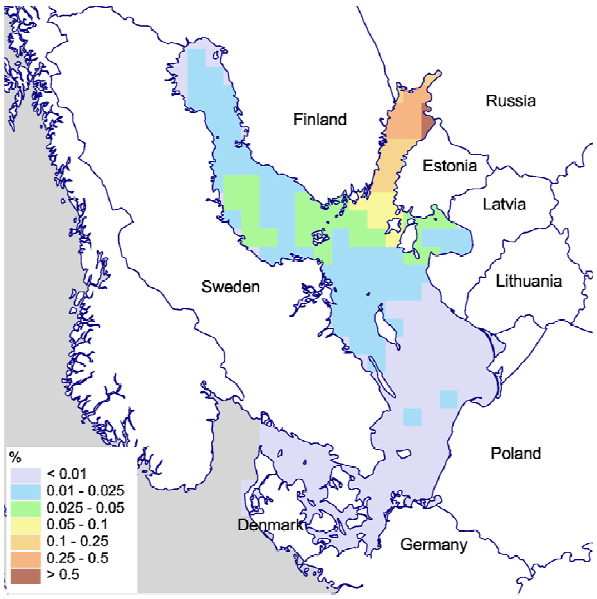


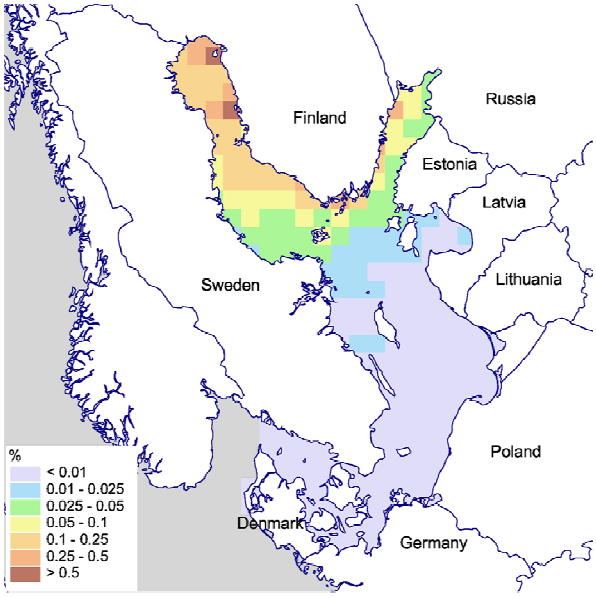
Figure 5.15. Percentage of annual total cadmium emission from different sectors in Sweden for 2006.



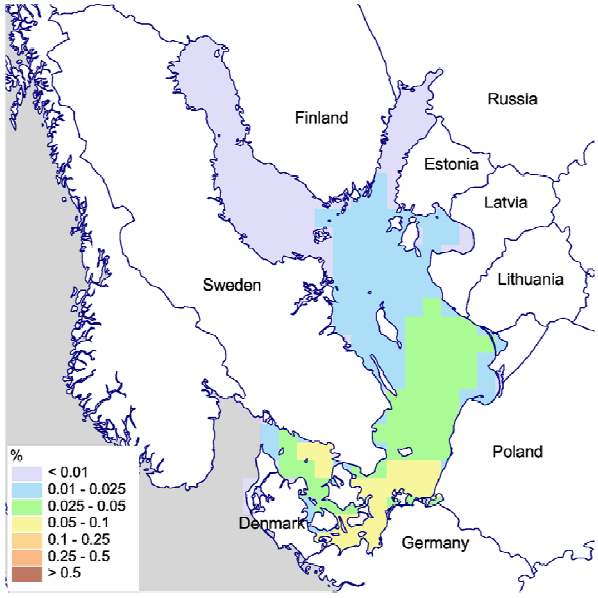
Denmark



Estonia

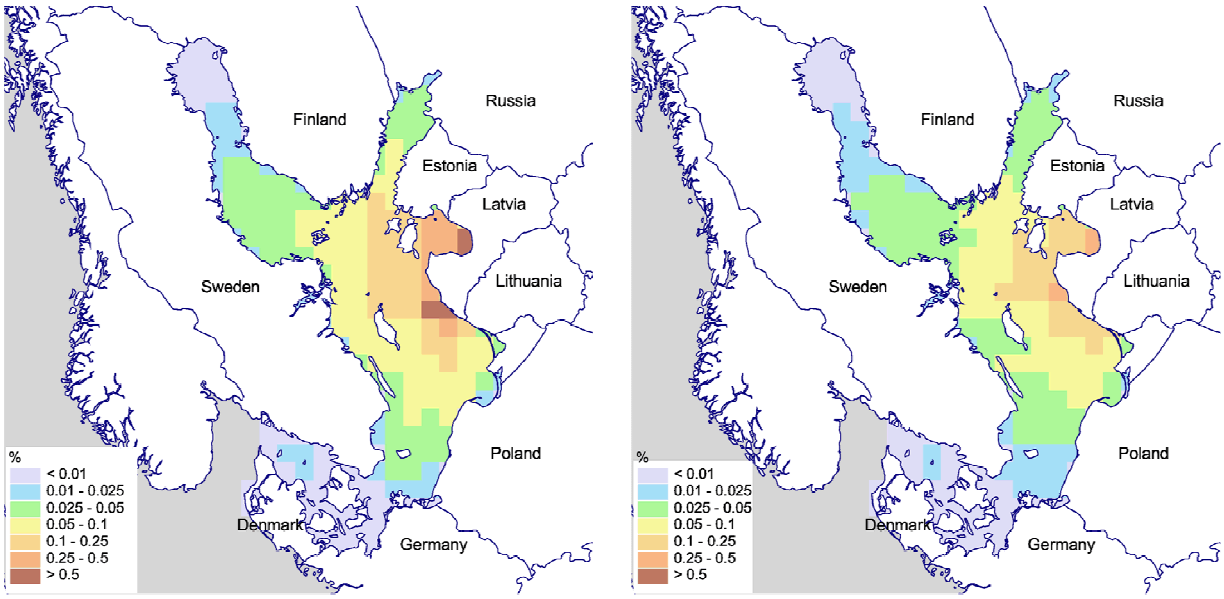


Finland

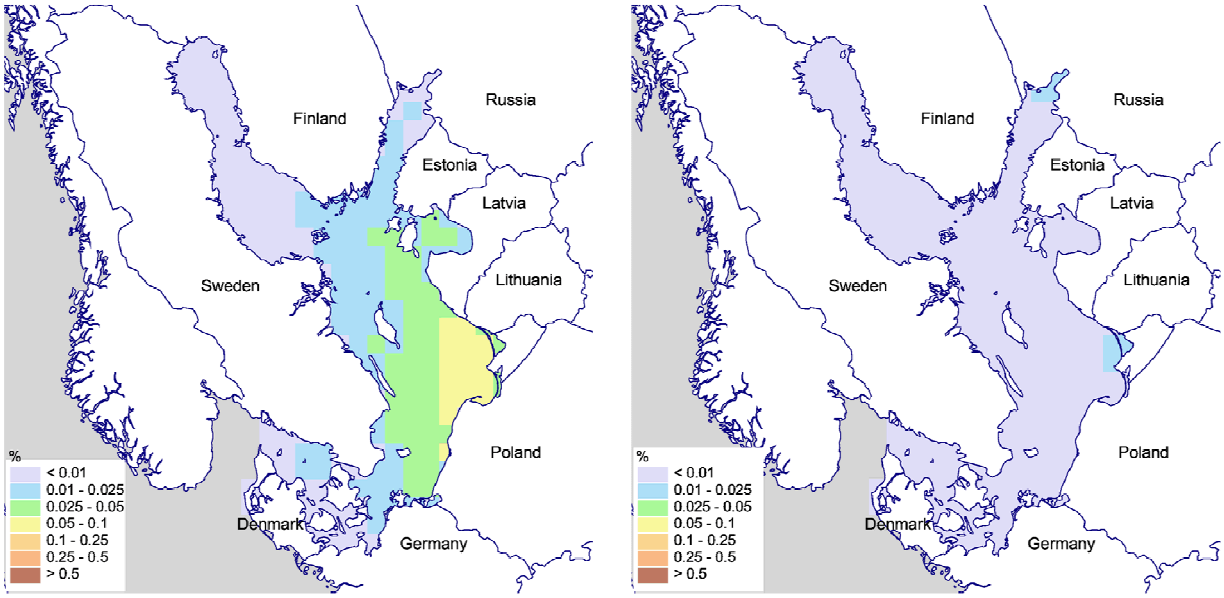


Germany

Figure 5.16. Maps with the fractions (in %) of annual total anthropogenic cadmium emissions from HELCOM Parties deposited into the Baltic Sea in 2006 (percent per deposition over the 50x50 km grid cell).

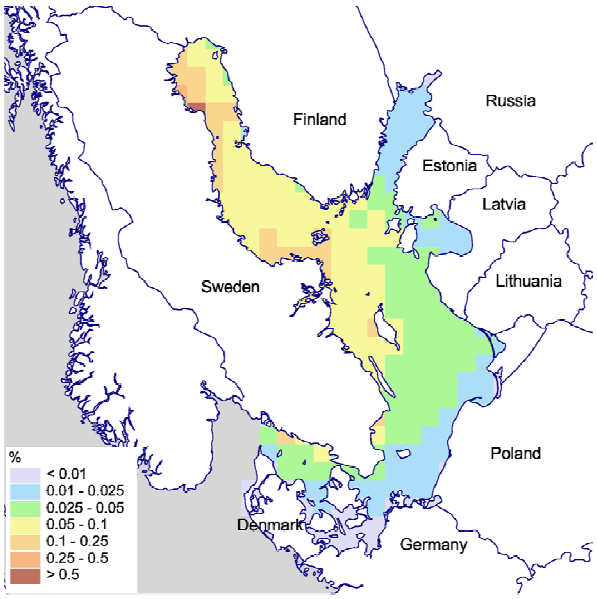


Latvia Lithuania



Poland Russia

Figure 5.16. **(cont.)** Maps with the fractions (in %) of annual total anthropogenic cadmium emissions from HELCOM Parties deposited into the Baltic Sea in 2006 (percent per deposition over the 50x50 km grid cell).



Sweden

Figure 5.16. **(cont.)** Maps with the fractions (in %) of annual total anthropogenic cadmium emissions from HELCOM Parties deposited into the Baltic Sea in 2006 (percent per deposition over the 50x50 km grid cell).

Table 5.2. Annual total anthropogenic emissions of cadmium 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	1.1	1.2	1.2	1.1	1.0	0.831	0.811	0.734	0.721	0.704	0.625	0.676	0.640	0.623	0.625	0.651	0.711
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	0.548
Finland	6.3	3.5	3.0	2.8	2.2	1.6	1.5	0.860	1.3	0.562	1.3	1.6	1.3	1.2	1.5	1.3	1.3
Germany	12	8.0	5.1	3.6	2.5	2.3	2.2	2.4	2.2	2.7	2.4	2.5	2.7	2.7	2.7	2.7	2.7
Latvia	1.5	1.3	0.895	0.758	0.957	0.743	0.921	0.775	0.827	0.724	0.516	0.471	0.463	0.475	0.457	0.499	0.594
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	0.367
Poland	92	85	84	92	86	83	91	86	55	62	50	53	49	48	46	46	42
Russia	79	68	69	59	57	57	51	50.4	49.0	50.9	51	51	52	57	55	59	59
Sweden	2.3	1.7	1.4	1.1	0.753	0.730	0.699	0.694	0.613	0.528	0.511	0.592	0.517	0.501	0.516	0.514	0.527
HELCOM	**202**	**176**	**170**	**165**	**155**	**150**	**152**	**145**	**114**	**121**	**108**	**111**	**107**	**113**	**108**	**112**	**108**
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	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	0.146
Austria	1.6	1.5	1.2	1.2	1.1	0.974	0.995	0.971	0.900	0.975	0.946	0.979	0.998	1.0	1.0	1.1	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	2.6
Belarus	2.1	2.2	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	2.5
Belgium	7.4	7.3	7.9	6.7	5.3	5.5	4.6	4.8	3.3	2.9	2.5	2.4	2.1	1.7	2.3	1.7	1.7
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	1.6
Bulgaria	28	25	22	19	16	13	14	14	15	14	11	10	12	15	15	12	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	0.826	0.838
Cyprus	0.550	0.570	0.650	0.700	0.740	0.670	0.720	0.750	0.820	0.870	0.920	0.900	1.0	0.890	1.1	1.1	1.2
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	3.2
France	20	20	19	18	18	17	17	16	15	14	14	13	12	9.1	6.7	6.6	4.6
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	0.243
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	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	1.7
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	0.083
Ireland	0.828	0.831	0.858	0.847	0.923	0.914	0.897	0.929	0.970	0.963	0.962	0.800	0.626	0.547	0.580	0.582	0.500
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	7.9	8.2	8.4
Kazakhstan	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
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	0.047
Malta	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.480	0.536	0.526	0.573	0.573	0.593	0.601
Monaco	0.056	0.058	0.063	0.069	0.006	0.006	0.007	0.008	0.007	0.007	0.008	0.008	0.007	0.006	0.005	0.005	0.004
Netherlands	2.1	2.4	2.1	1.7	1.4	1.1	1.1	1.2	1.2	1.1	1.0	1.6	2.2	2.4	1.8	1.7	1.7
Norway	1.1	1.0	1.0	1.1	1.2	0.985	1.1	1.0	1.1	1.0	0.690	0.685	0.682	0.660	0.602	0.542	0.542
Portugal	5.3	5.8	5.9	5.2	5.5	5.6	4.8	5.3	6.0	6.0	5.4	5.3	6.1	5.3	5.3	5.9	5.4
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	0.158
Romania	22	20	19	18	17	15	14	13	12	12	8.7	7.4	8.1	8.7	9.4	10	6.5
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	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	6.0
Slovenia	1.3	1.0	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2
Spain	24	23	22	20	21	21	19	19	19	19	18	18	19	17	17	17	16
Switzerland	3.7	3.5	3.3	3.0	2.8	2.5	2.4	2.2	2.2	1.7	1.6	1.5	1.3	1.1	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	9.7
Turkey	17	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	6.8	5
United Kingdom	24	24	24	15	14	12	10	9.2	6.8	6.4	6.2	4.9	4.7	3.4	3.6	3.7	4.0
EMEP	**482**	**447**	**427**	**396**	**373**	**358**	**348**	**335**	**292**	**290**	**266**	**261**	**249**	**277**	**244**	**252**	**241**

Expert estimates:

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

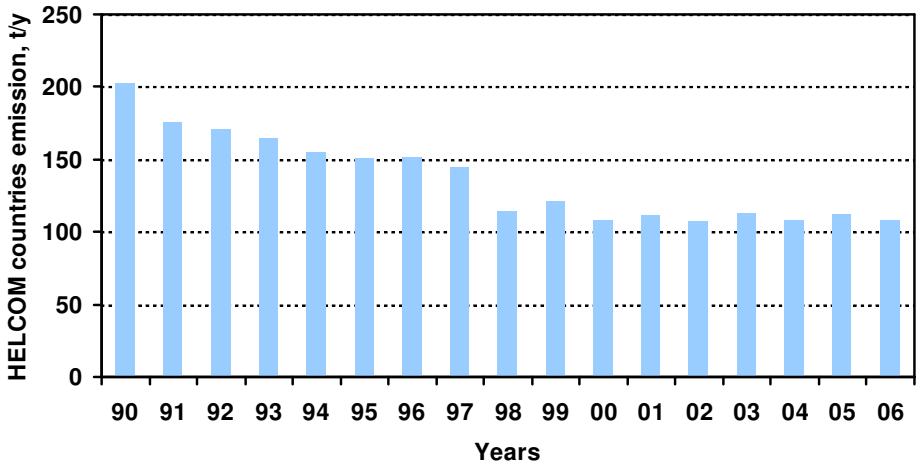


Figure 5.17. Time-series of annual cadmium emissions of HELCOM countries in 1990-2006, tonnes/y.

5.2 Annual total deposition of cadmium

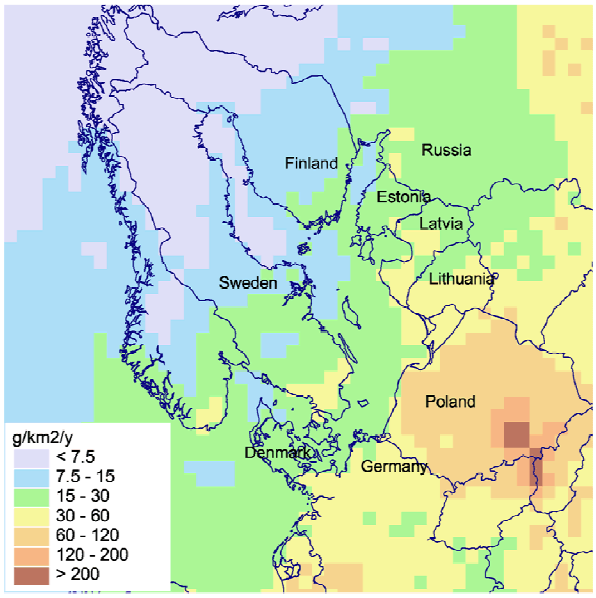


Figure 5.18. Annual total deposition fluxes of cadmium over the Baltic Sea region for 2006, g/km^2/year.

5.3 Monthly total depositions of cadmium

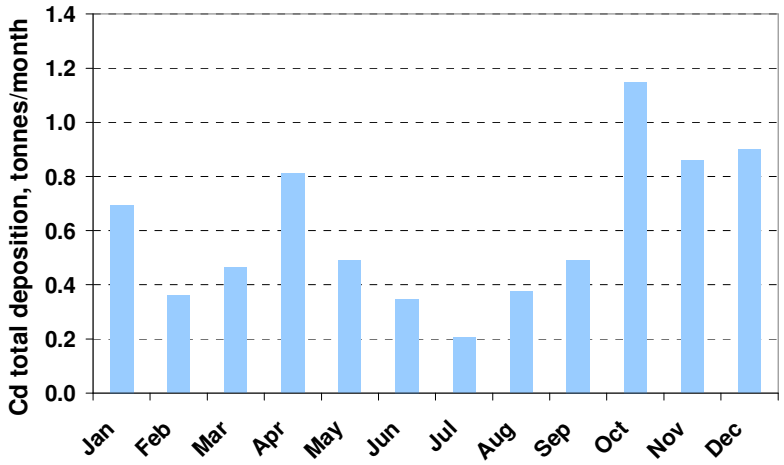


Figure 5.19. Monthly total depositions of cadmium to the Baltic Sea for 2006, tonnes/month.

Table 5.2. Monthly total depositions of cadmium to the Baltic Sea for 2006, tonnes/month.

Month	Cd
Jan	0.70
Feb	0.36
Mar	0.46
Apr	0.81
May	0.49
Jun	0.35
Jul	0.21
Aug	0.38
Sep	0.49
Oct	1.15
Nov	0.86
Dec	0.90

5.4 Source allocation of cadmium deposition

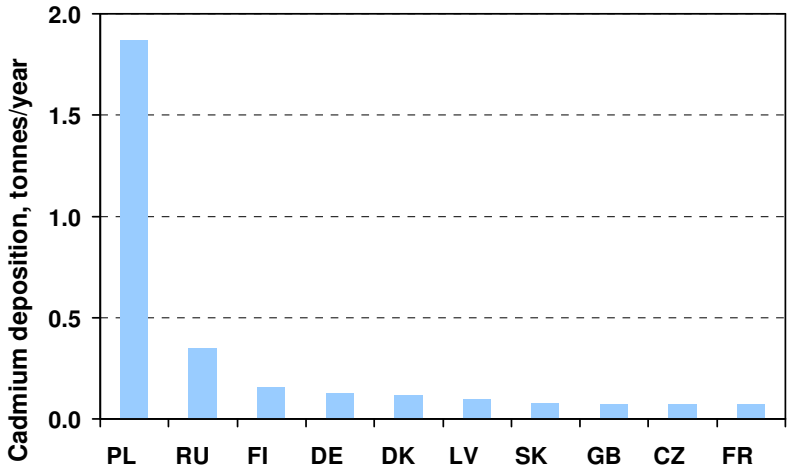


Figure 5.20. Top ten countries with the highest contribution to annual total deposition of cadmium over the Baltic Sea for 2006, tonnes/year.

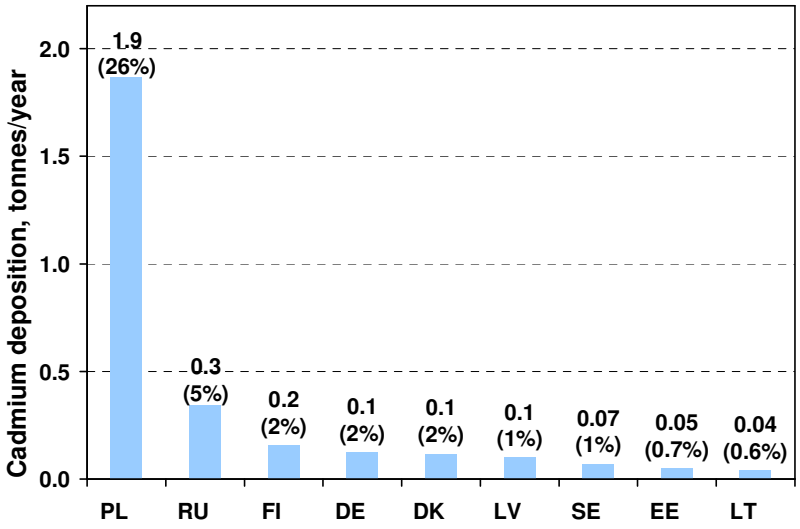


Figure 5.21. Sorted contributions (in %) of HELCOM countries to total depositions over the Baltic Sea for 2006. HELCOM countries emissions of cadmium contributed about 40% to the total annual cadmium depositions over the Baltic Sea in 2006. Contribution of other EMEP countries accounted for 10%. Significant contribution was made by other emission sources, in particular, remote emissions sources, natural emissions and re-emission of cadmium (50%).

Table 5.3. Two most significant contributors to the annual total depositions of cadmium to the six Baltic Sea sub-basins for 2006.

Sub-basin	Country	%	Country	%	*, %
GUB	Poland	17	Finland	13	48
GUF	Poland	17	Russia	16	44
GUR	Poland	27	Latvia	6	48
BAP	Poland	32	Russia	4	48
BES	Poland	11	Denmark	6	66
KAT	Poland	9	Denmark	8	65
BAS	Poland	26	Russia	5	50

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

5.5 Comparison of model results with measurements

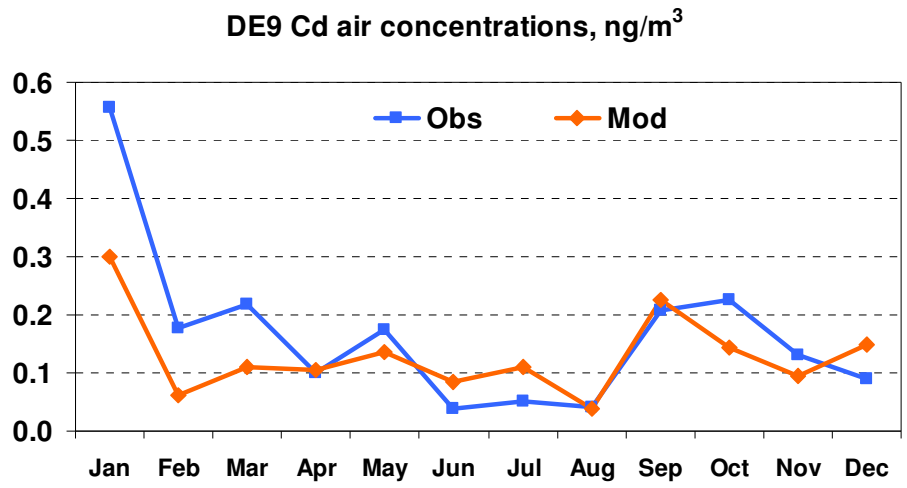


Figure 5.22. Comparison of calculated mean monthly cadmium concentrations in air for 2006 with measurements of the station Zingst (DE9). Units: ng / m^3.

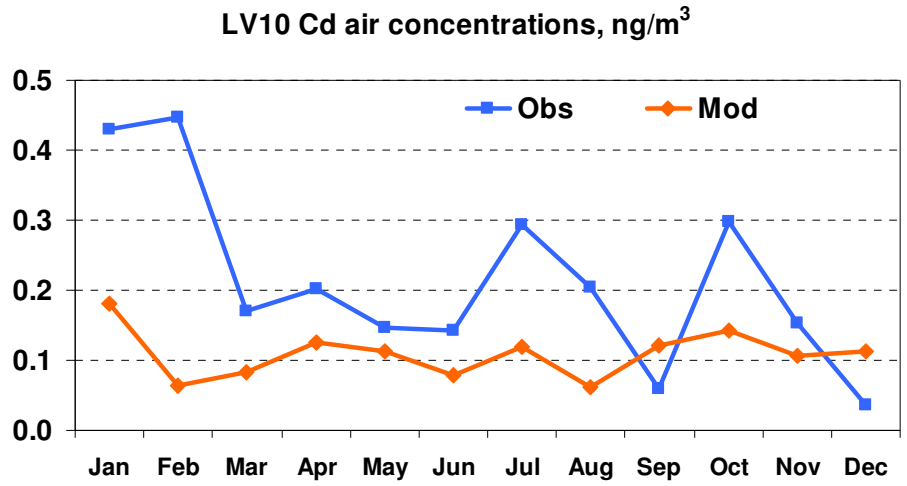


Figure 5.23. Comparison of calculated mean monthly cadmium concentrations in air for 2006 with measurements of the station Rucava (LV10). Units: ng / m^3.

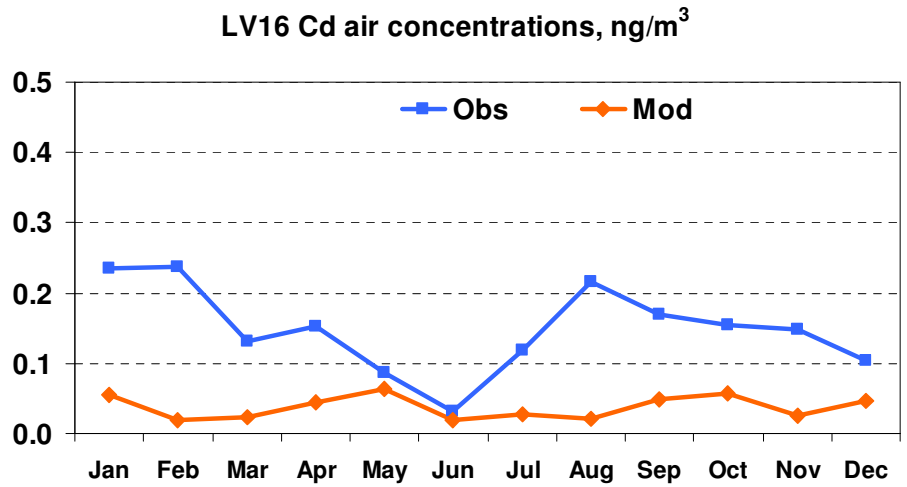


Figure 5.24. Comparison of calculated mean monthly cadmium concentrations in air for 2006 with measurements of the station Zoseni (LV16). Units: ng / m^3.

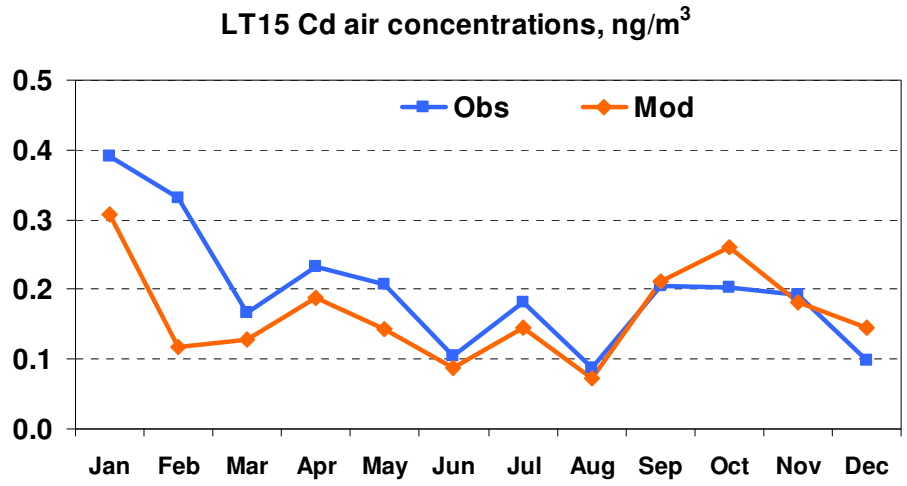


Figure 5.25. Comparison of calculated mean monthly cadmium concentrations in air for 2006 with measurements of the station Preila (LT15). Units: ng / m^3.

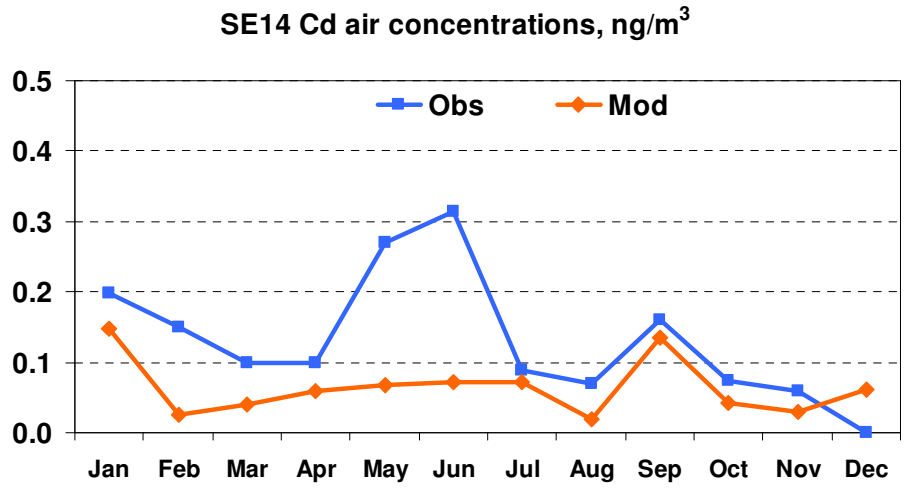


Figure 5.26. Comparison of calculated mean monthly cadmium concentrations in air for 2006 with measurements of the station Räö (SE14). Units: ng / m^3.

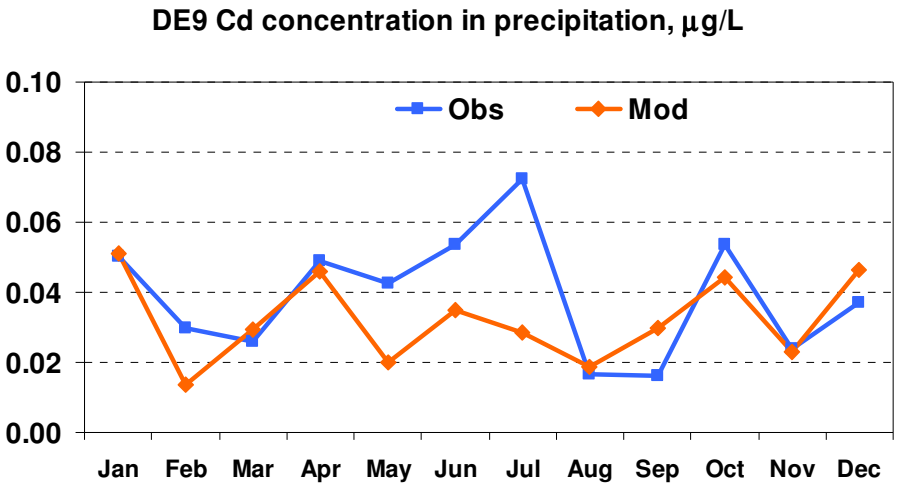


Figure 5.27. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2006 with measurements of the station Zingst (DE09). Units: µg / L.

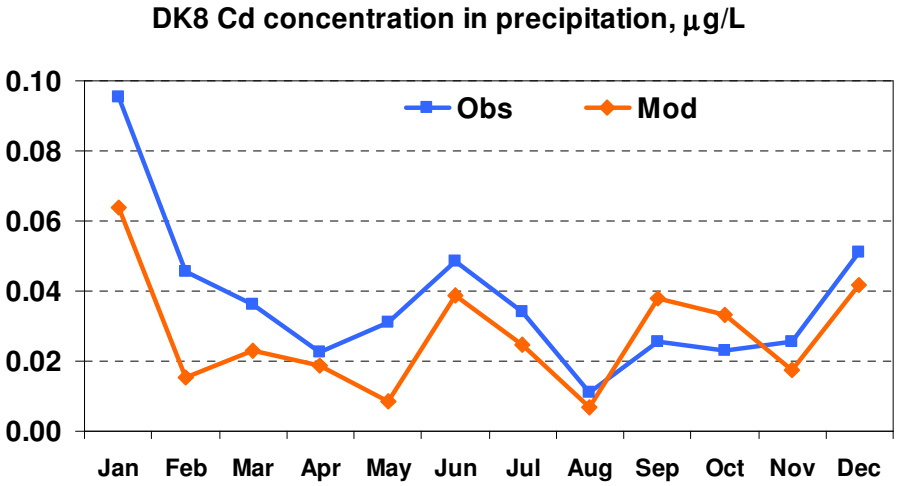


Figure 5.28. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2006 with measurements of the station Anholt (DK8). Units: µg / L.

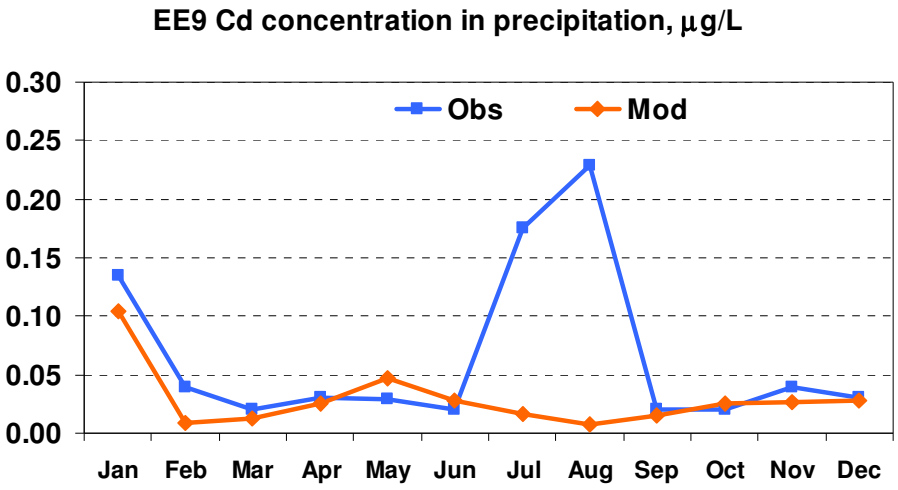


Figure 5.29. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2006 with measurements of the station Lahemaa (EE9). Units: µg / L.

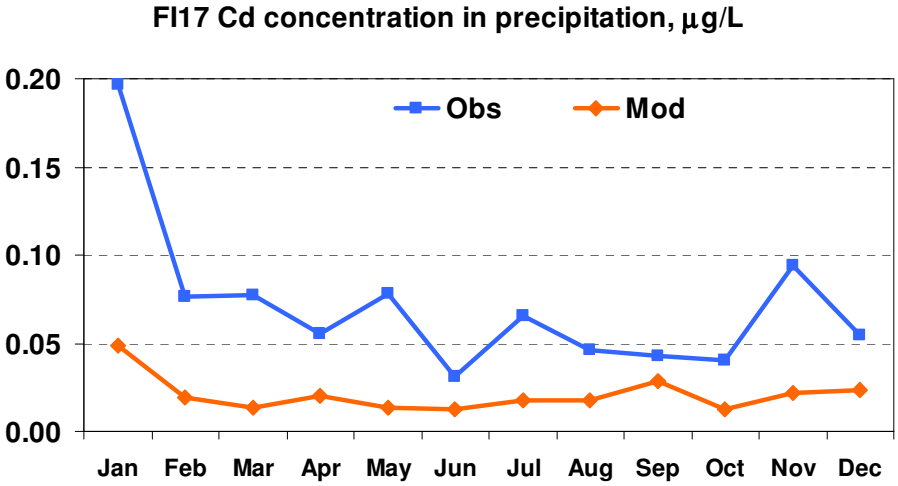


Figure 5.30. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2006 with measurements of the station Virolahty II (FI17). Units: µg / L.

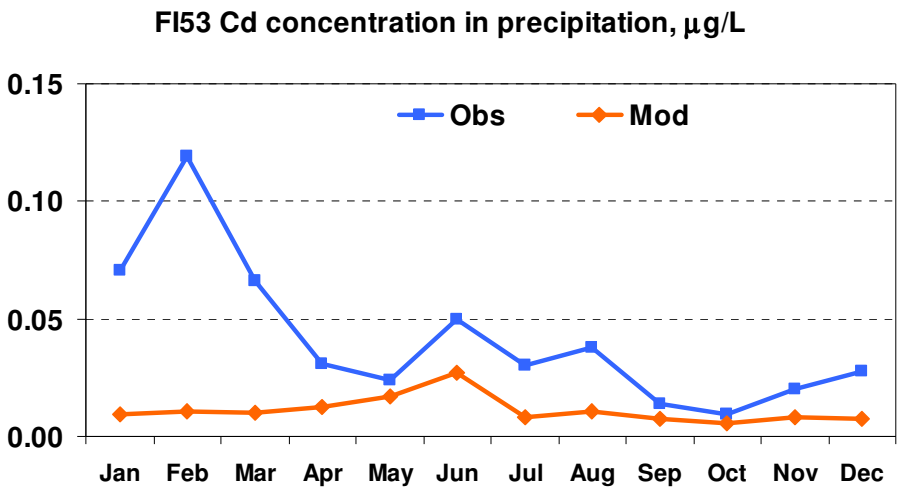


Figure 5.31. Comparison of calculated mean monthly cadmium concentrations in precipitation 2006 with measurements of the station Hailuoto (FI53). Units: µg / L.

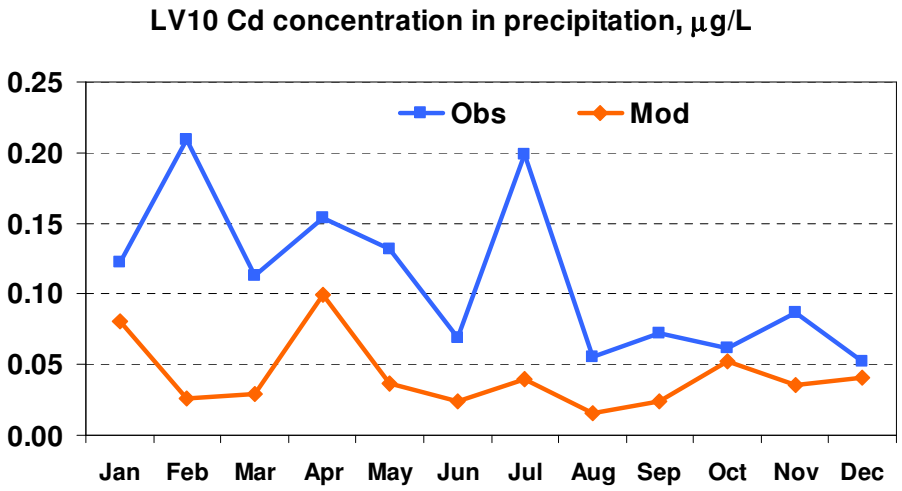


Figure 5.32. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2006 with measurements of the station Rucava (LV10). Units: µg / L.

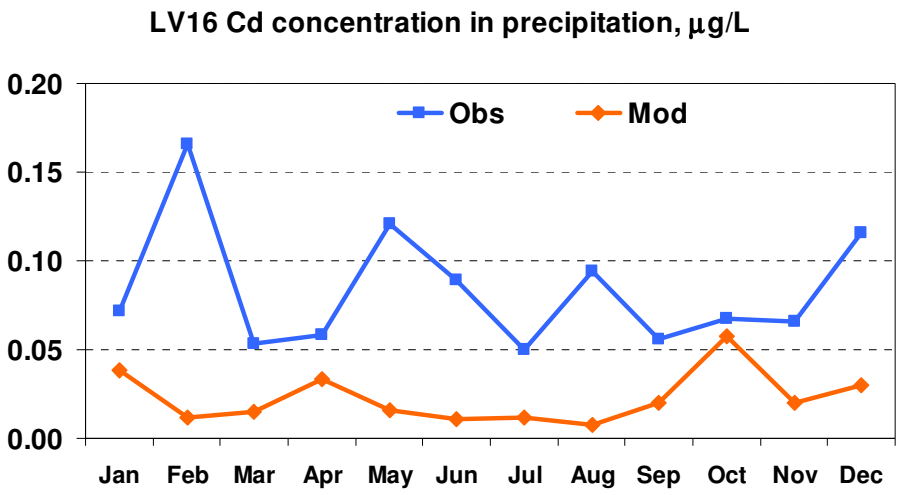


Figure 5.33. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2006 with measurements of the station Zoseni (LV16). Units: µg / L.

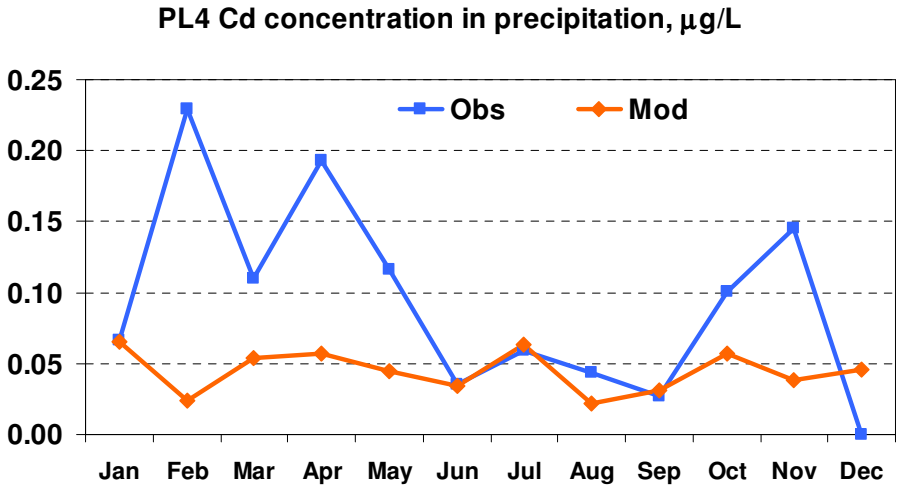


Figure 5.34. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2006 with measurements of the station Leba (PL4). Units: µg / L.

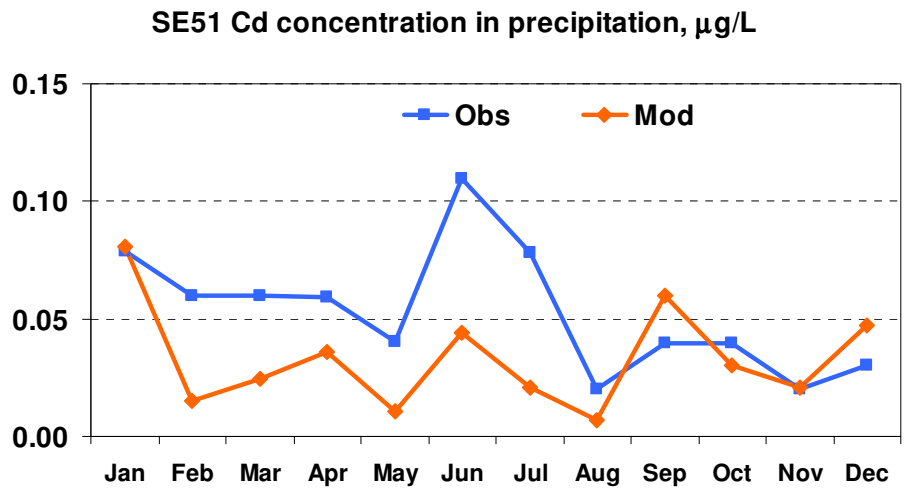


Figure 5.35. Comparison of calculated mean monthly cadmium concentrations in precipitation for 2006 with measurements of the station Arup (SE51). Units: µg / L.

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.