IX. ATMOSPHERIC DEPOSITION IN THE TERRITORY OF THE CZECH REPUBLIC

Atmospheric deposition refers to the flux of substances from the atmosphere to the surface of the Earth (Braniš, Hůnová 2009). This is an important process contributing to self-purification of the air; on the other hand, however, it is responsible for input of pollutants into other components of the environment. Atmospheric deposition has both wet and dry components. The wet component is connected with the occurrence of atmospheric precipitation (vertical deposition: rain and snow, and horizontal deposition: fog and rime) and is thus episodic in character. The dry component corresponds to the deposition of gases and particles by various mechanisms and occurs continuously.

The atmospheric deposition of most monitored substances in Europe has decreased substantially over the past twenty years but still remains a problem in a number of regions (EEA 2011). In the Czech Republic, the chemical composition of atmospheric precipitation and atmospheric deposition has been monitored for a long time at a relatively large number of localities.

In 2019, data on the chemical composition of atmospheric precipitation were provided to the Air Quality Information System (AQIS) from 38 locations in the Czech Republic (Fig. IX.1, Tab. IX.4). In the Czech Republic, measurements are provided by CHMI (14 localities), CGS (10 localities), VÚLHM (9 localities), HBÚ AV ČR (2 localities), and ÚH AV ČR, ÚVGZ AV ČR and GLÚ AV ČR (1 locality each).

The substances presented in the atmospheric deposition chapter have no limit values set by legislation as in the case of pollution. Therefore, another colour scale has been chosen to improve clarity of the depositions maps. More detailed information on atmospheric deposition, sampling, measurement and quantification of its components and specifications for preparation of maps are available at CHMI (2020d).

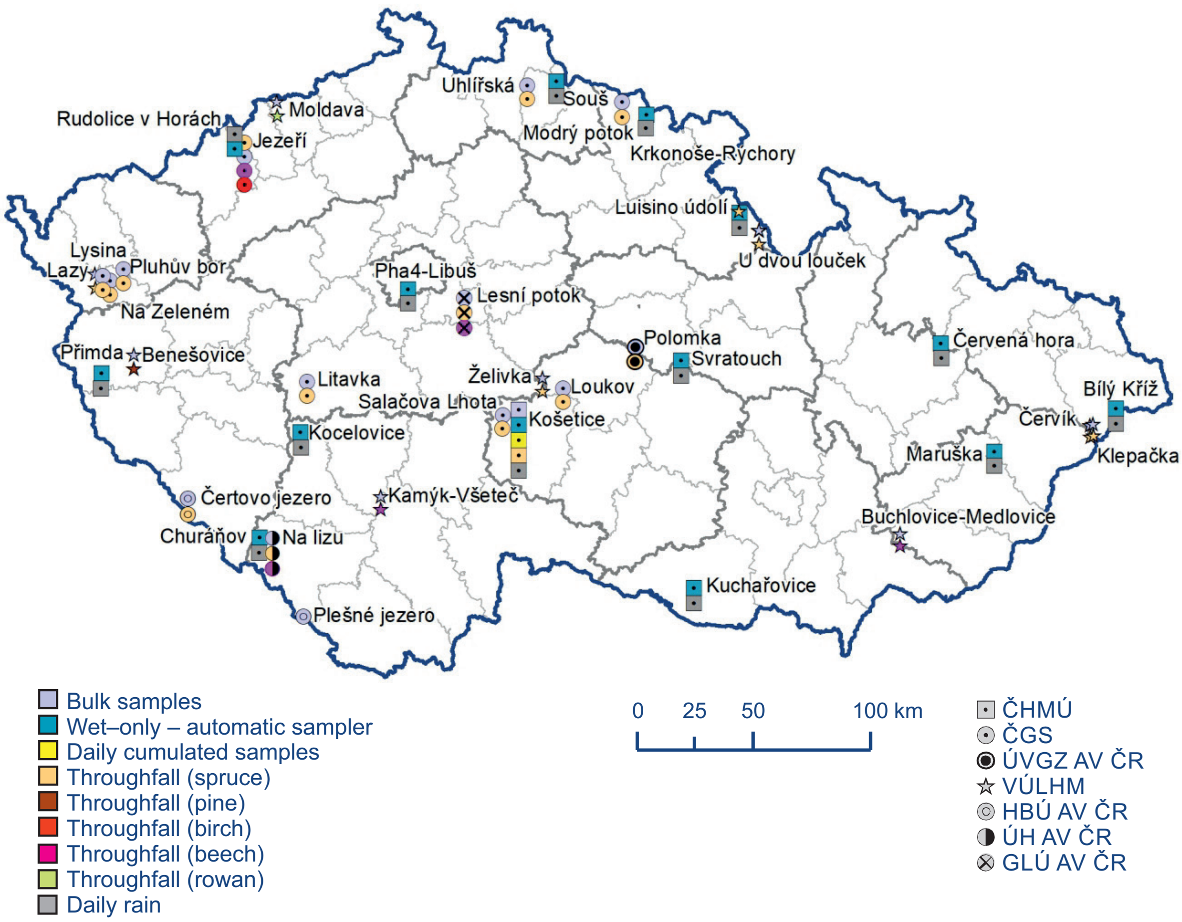


Fig. IX.1 Station networks monitoring atmospheric precipitation quality and atmospheric deposition, 2019

Results

The year 2019 was normal in terms of precipitation. The average annual precipitation of 634 mm represents 92% of the long-term normal 1981–2010 (for more see Chapter III). Higher precipitation totals compared to 2018 (518 mm) resulted in an increase in wet deposition of reduced forms of nitrogen ($N\_NH_4^+$), total wet deposition of nitrogen and wet deposition of cadmium.

Deposition of sulphur

The field of total sulphur deposition represents the total level of sulphur deposition on the area of the Czech Republic. Its quantification is based on concentrations of SO_4^{2-} measured in atmospheric precipitation and SO_2 air pollution concentrations. In 2019, this value was 33,032 t (Table IX.2), compared to 2018, when the value of total sulphur deposition was 34,581 t. Total sulphur deposition exhibits maxima in the Krušné hory and Ostrava areas (Fig. IX.4).

The partial components of sulphur deposition also reached lower values. Wet deposition of sulphur ($S\_SO_4^{2-}$) reached the value of 13,657 t in 2019, while in 2018 the value was 14,682 t. The highest values of the wet component were then reached in the mountain areas, namely in the Moravian-Silesian Beskydy, Jeseníky, Krkonoše and in the Bohemian-Moravian Highlands (Fig. IX.2). In 2019, the dry deposition of sulphur (S_SO_2) amounted to 19,365 t, while in 2018 it was 19,899 t. The highest values of the dry component were reached in the Krušné hory and the Moravian-Silesian Beskydy (Fig. IX.3).

In 2019, throughfall deposition of sulphur ($S\_SO_4^{2-}$) in forested areas of the Czech Republic attained a value of 10,707 t with maximum values occurring in the mountain areas (Fig. IX.5). Map view of the throughfall sulphur deposition was prepared for forested areas on the basis of the sulphur concentration fields for throughfall precipitation and from the verified precipitation field, modified by the percentage amount of precipitation measured under vegetation at the individual stations in the range of 55% (Košetice) to 102% (U dvou louček) of the total precipitation in open areas in 2019. Throughfall deposition generally includes wet vertical and horizontal deposition (from fogs, low clouds and rime) and dry deposition of particles and gases in forests.

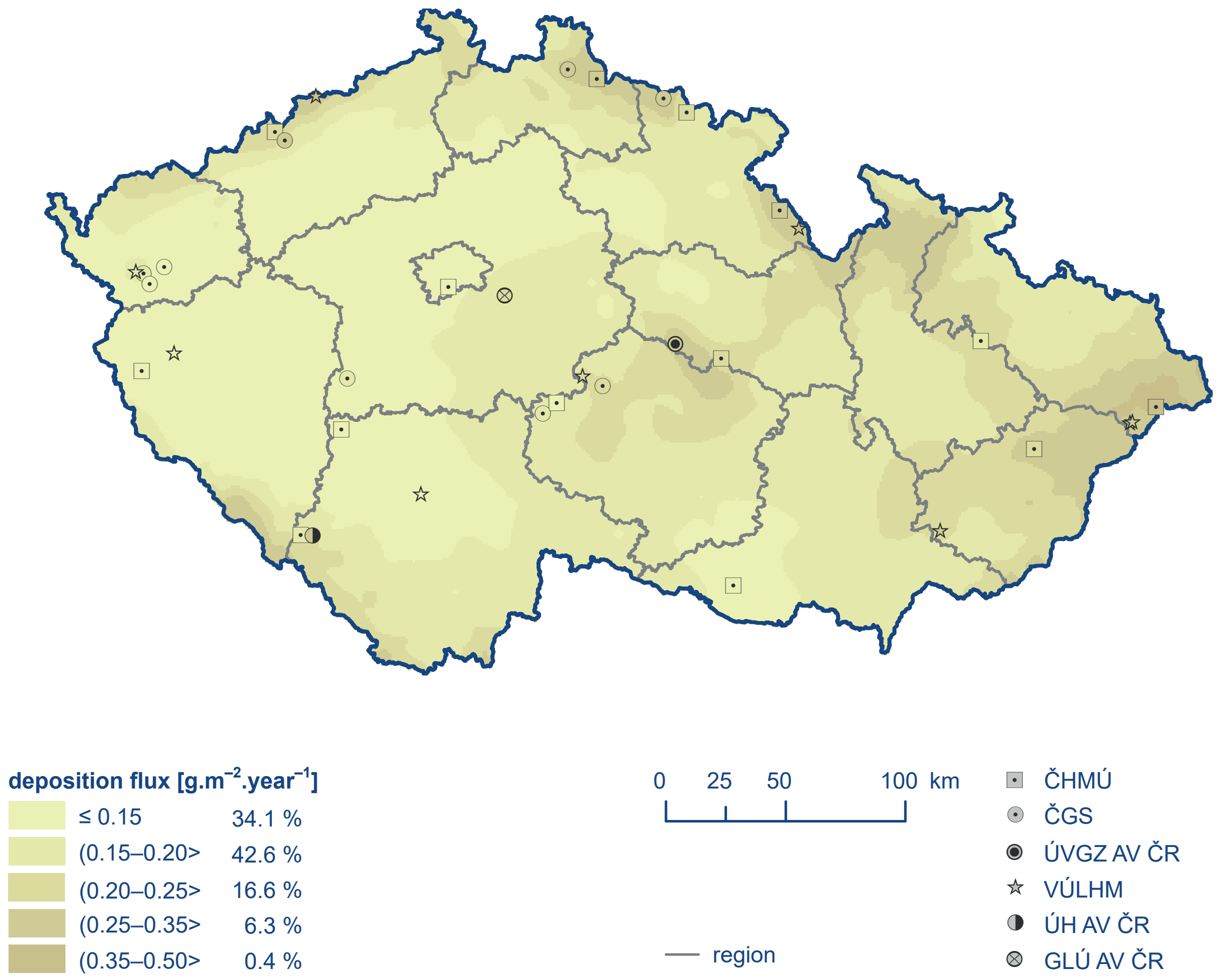


Fig. IX.2 Field of annual wet deposition of sulphur ($S\_SO_4^{2-}$), 2019

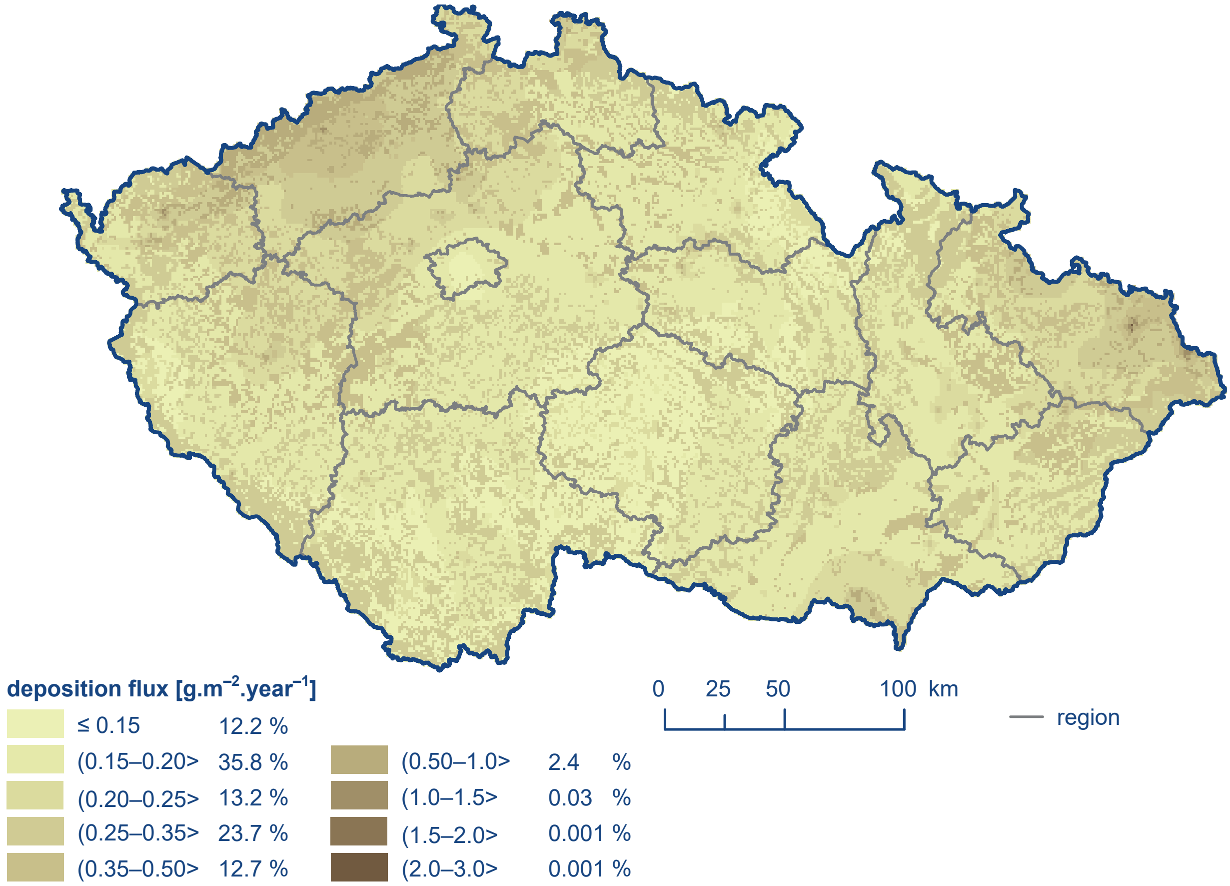


Fig. IX.3 Field of annual dry deposition of sulphur (S_SO_2), 2019

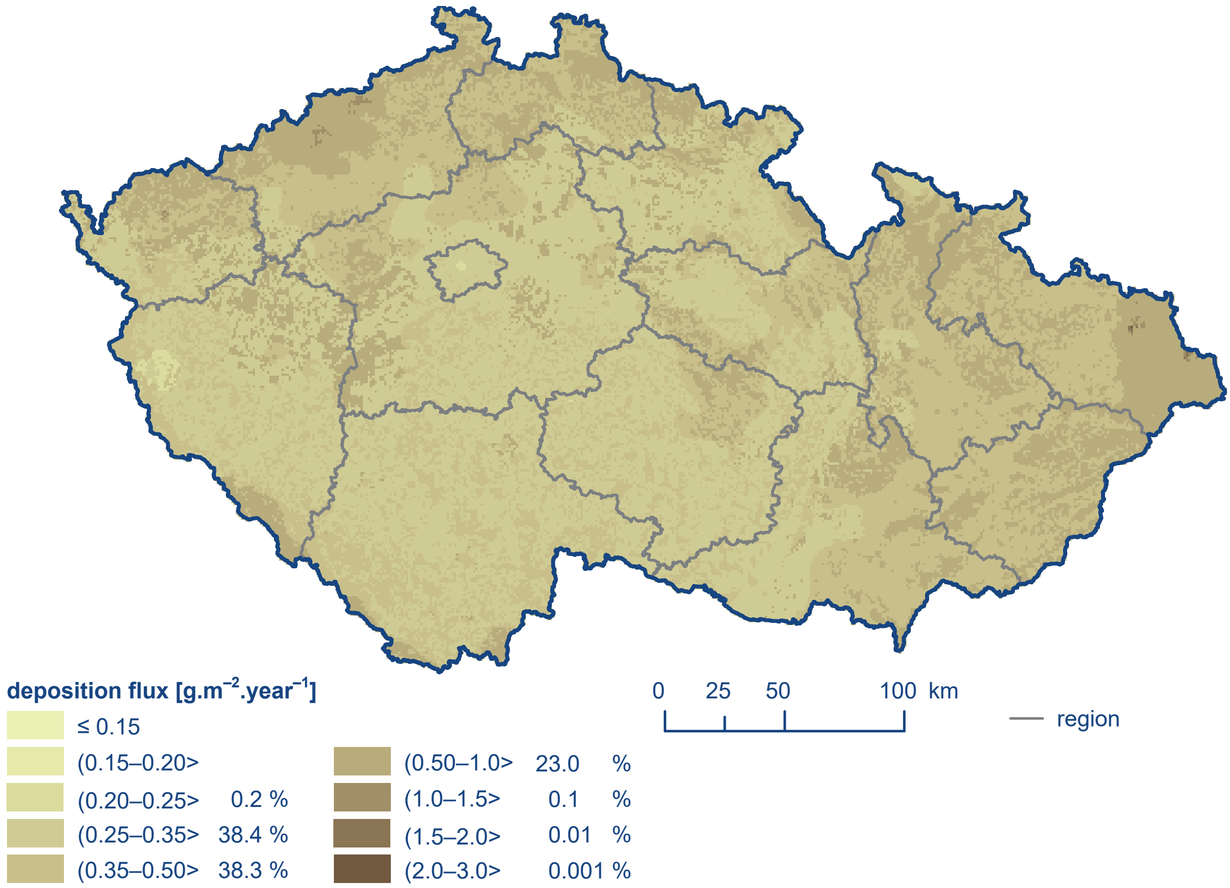


Fig. IX.4 Field of annual total deposition of sulphur, 2019

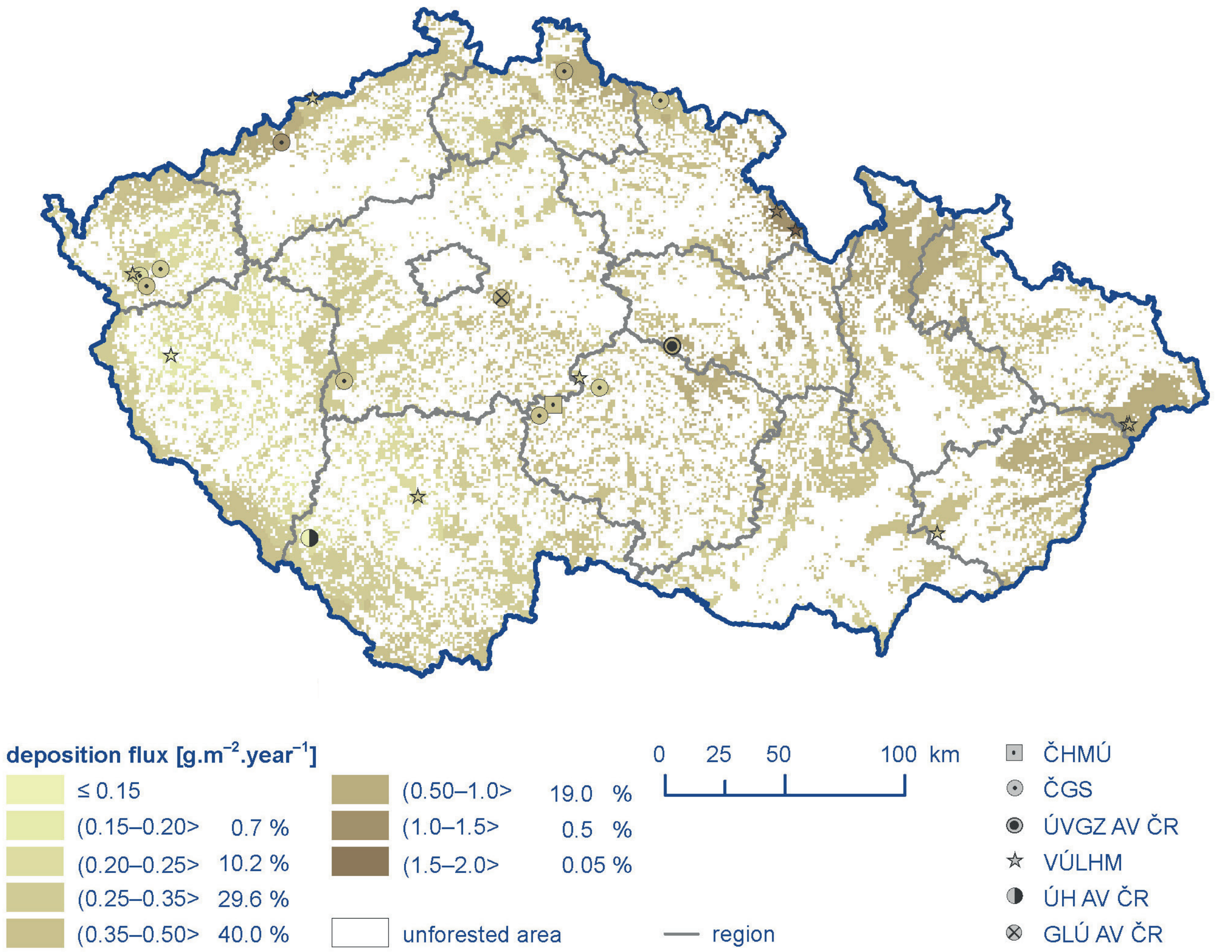


Fig. IX.5 Field of annual throughfall deposition of sulphur, 2019

Tab. IX.1 Average deposition fluxes of S, N and H in the Czech Republic, 2019

Element	Deposition	$g.m^{-2}.year^{-1}$	$keq.ha^{-1}.year^{-1}$
S (SO_4^{2-})	wet	0.173	0.108
S (SO_2)	dry	0.246	0.153
S	total	0.419	0.261
N (NO_3^-)	wet	0.201	0.143
N (NH_4^+)	wet	0.310	0.221
N (NO_x)	dry	0.184	0.131
N	total	0.694	0.496
H (pH)	wet	0.004	0.036
H (SO_2, NO_x)	dry	0.028	0.282
H	total	0.032	0.319

Tab. IX.2 Estimate of the wet, dry and total annual deposition of the given elements on the area of the Czech Republic (78,841 sq. km) in tonnes, 2019

	Deposition [t]		
	wet	dry	total
S	13,657	19,365	33,032
N (ox)	15,815	14,497	30,312
N (red)	24,437		
N (ox + red)	40,252		54,749
H+	290	2,245	2,535
Pb	31	18	
Cd	1.6	1.1	

Tab. IX.3 Estimate of the total and throughfall annual deposition of sulphur on the forested area of the Czech Republic (26,428 sq. km) in tonnes, 2001–2019

	Deposition [t]	
	total	throughfall
2001	27,894	36,899
2002	25,984	31,011
2003	21,306	26,818
2004	23,247	32,835
2005	22,855	26,461
2006	21,975	25,660
2007	17,445	29,279
2008	15,528	30,197
2009	16,590	26,193
2010	17,621	27,944
2011	15,118	18,691
2012	15,311	19,079
2013	16,530	19,723
2014	16,810	12,836
2015	13,294	16,044
2016	12,625	19,724
2017	14,621	12,608
2018	14,870	14,002
2019	13,133	10,707

Deposition of nitrogen

The total nitrogen deposition on the area of the Czech Republic in 2019 equalled 54,749 t (Tab. IX.2). As with sulphur deposition, there was a decrease compared to 2018 when the value was 57,674 t. The highest values of total nitrogen deposition were reached in the Jeseníky, Moravian-Silesian Beskydy, Orlické Mountains, Šumava and Novohradské Mountains (Fig. IX.10).

Some partial components of nitrogen deposition also reached somewhat lower values. Wet deposition of oxidized forms of nitrogen ($N\_NO_3^-$) reached the value of 15,815 t in 2019 (Fig. IX.6), while in 2018 the value was 16,073 t. On the contrary, wet deposition of reduced forms ($N\_NH_4^+$) increased in 2019 to value of 24,437 t (Fig. IX.7) compared to 2018, when the value was 23,892 t. The total wet deposition of nitrogen (sum of wet deposition of $N\_NO_3^-$ and $N\_NH_4^+$) in 2019 was equal to 40,252 t, while in 2018 to only 39,965 t. The highest values of total wet nitrogen deposition were recorded in the Šumava, Krkonoše, Jizerské Mountains, Orlické Mountains, Bohemian-Moravian Highlands, Jeseníky and Moravian-Silesian Beskydy (Fig. IX.8).

The value of dry deposition of oxidized forms of nitrogen (N_NO_X) reached the value of 14,497 t in 2019, while in 2018 it was up to 17,709 t. The highest values were reached in the territory of larger cities and along important roads (Fig. IX.9).

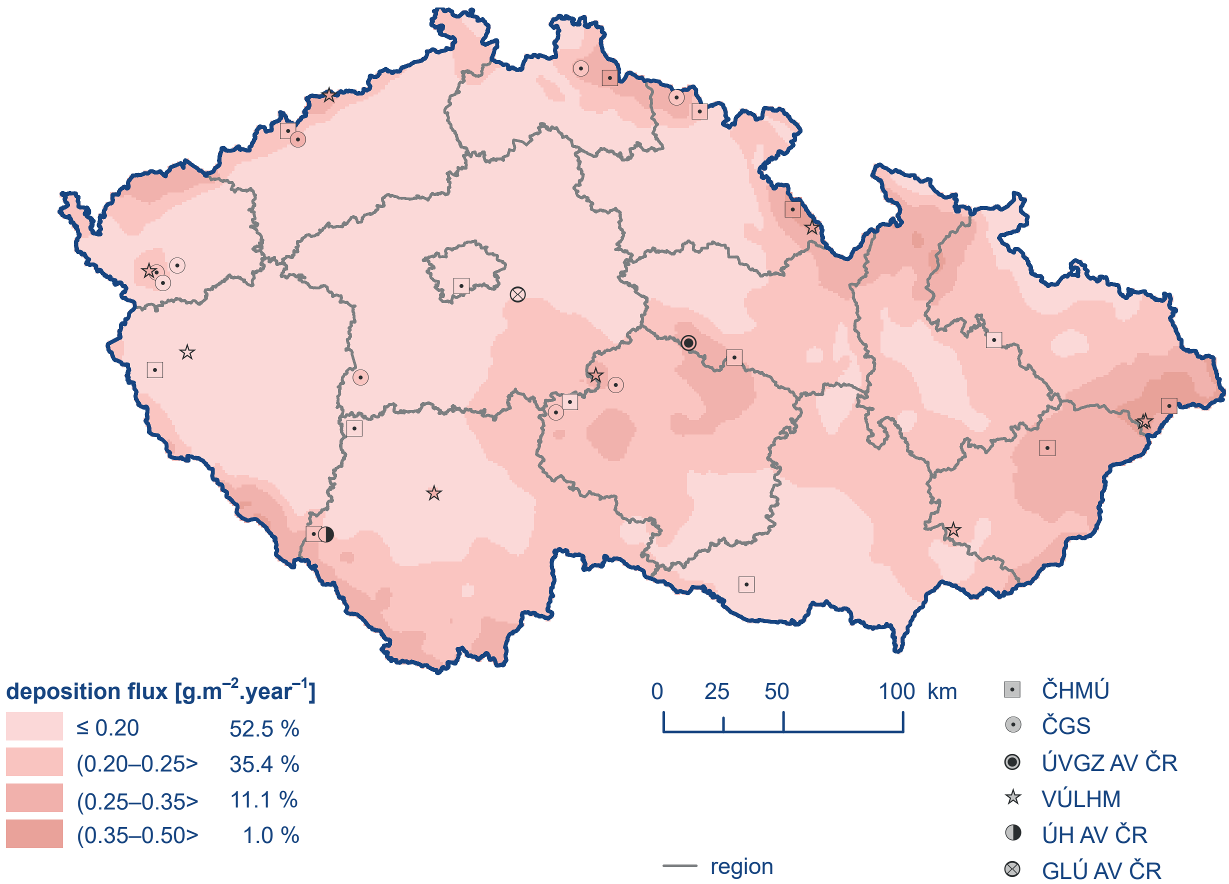


Fig. IX.6 Field of annual wet deposition of nitrogen ($N\_NO_3^-$), 2019

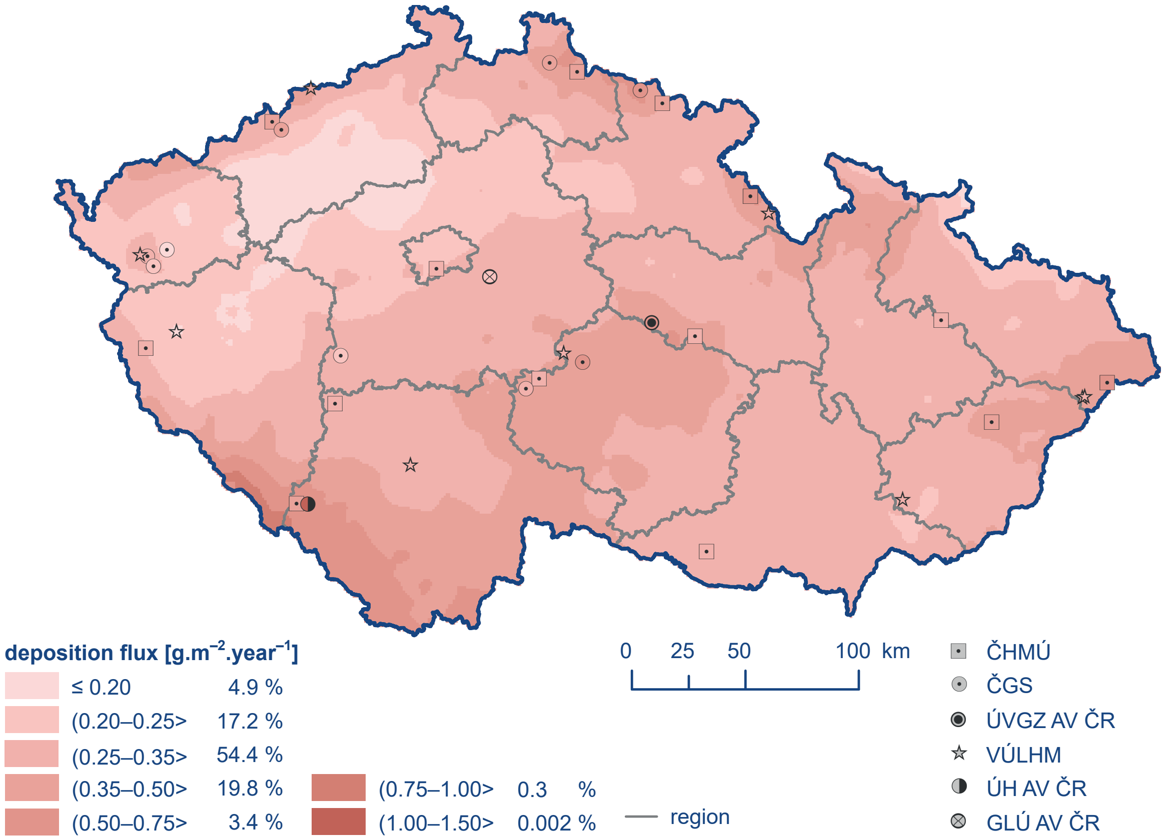


Fig. IX.7 Field of annual wet deposition of nitrogen (N_NH_4^+), 2019

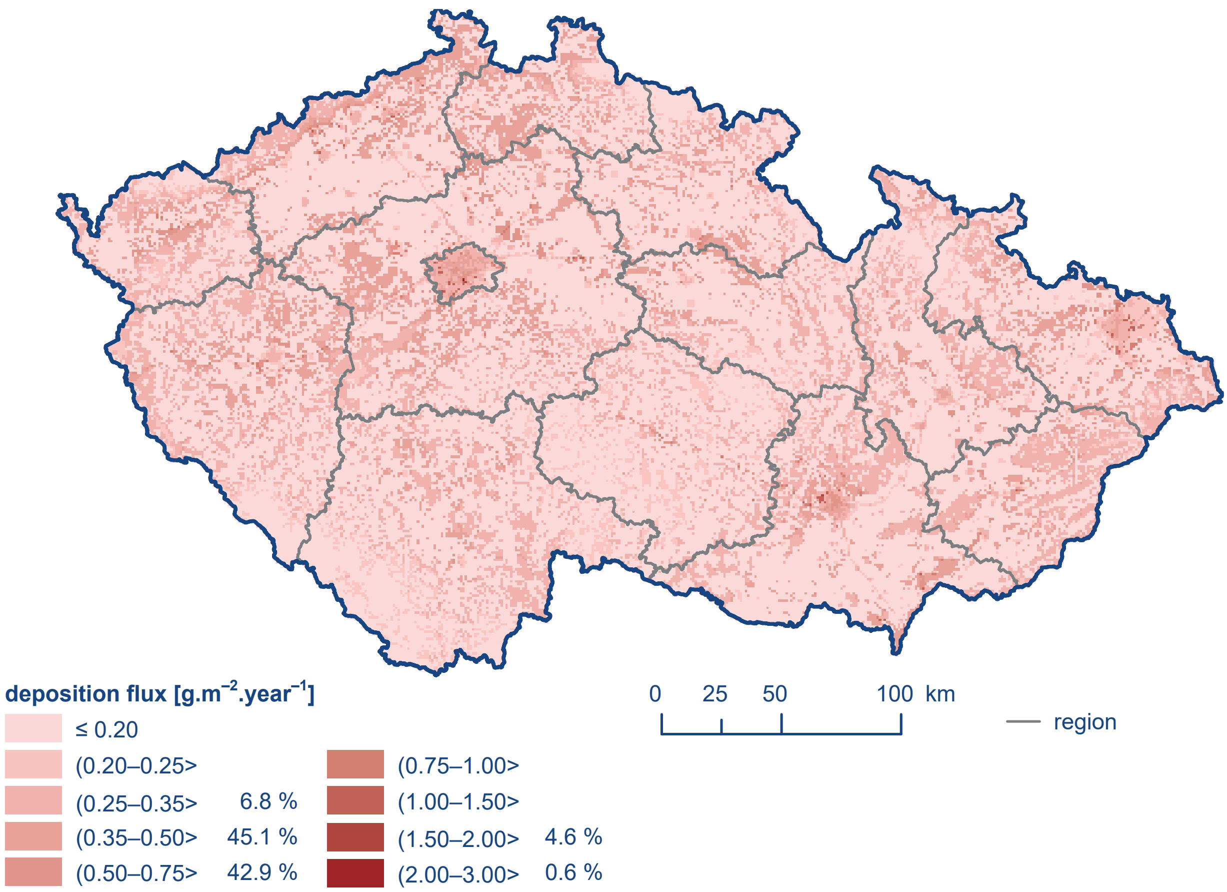


Fig. IX.8 Field of annual total wet deposition of nitrogen, 2019

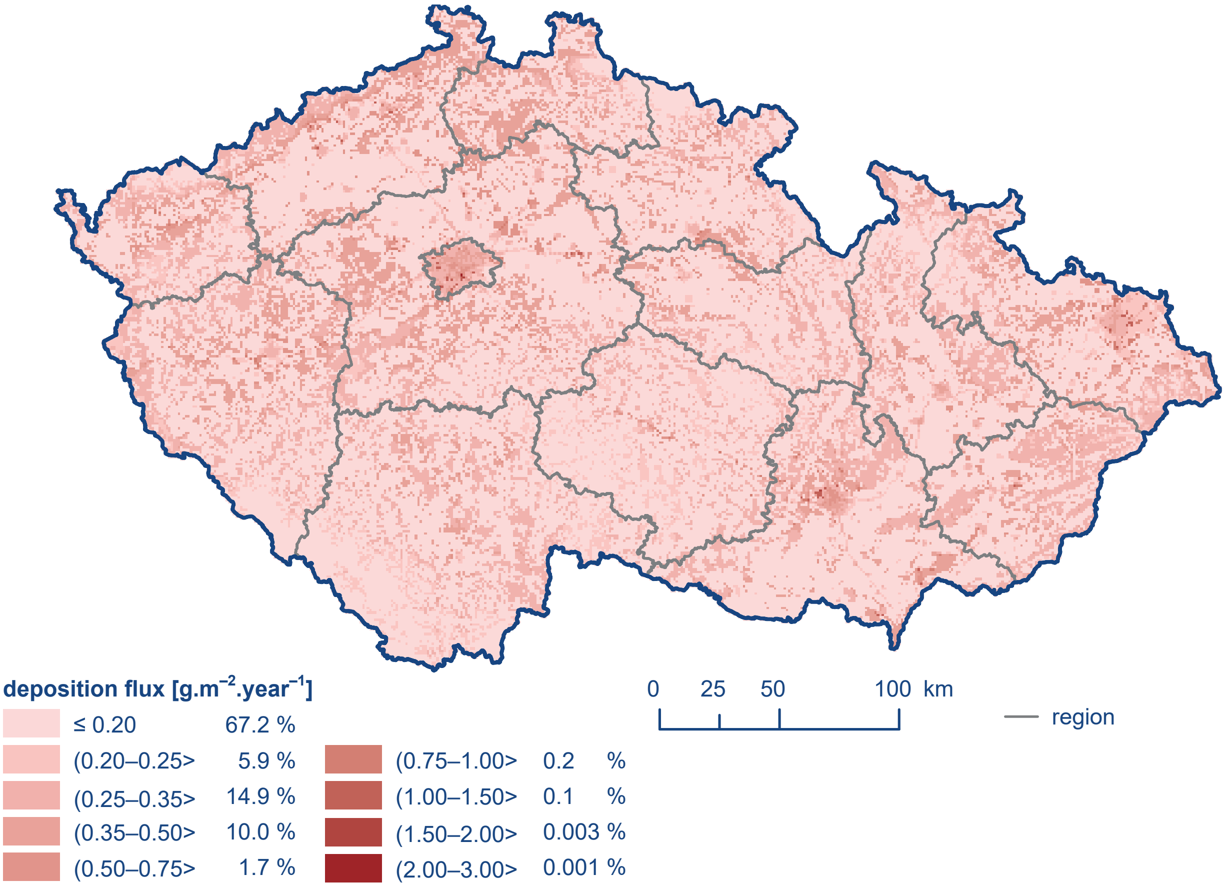


Fig. IX.9 Field of annual dry deposition of nitrogen (N_NO$_x$), 2019

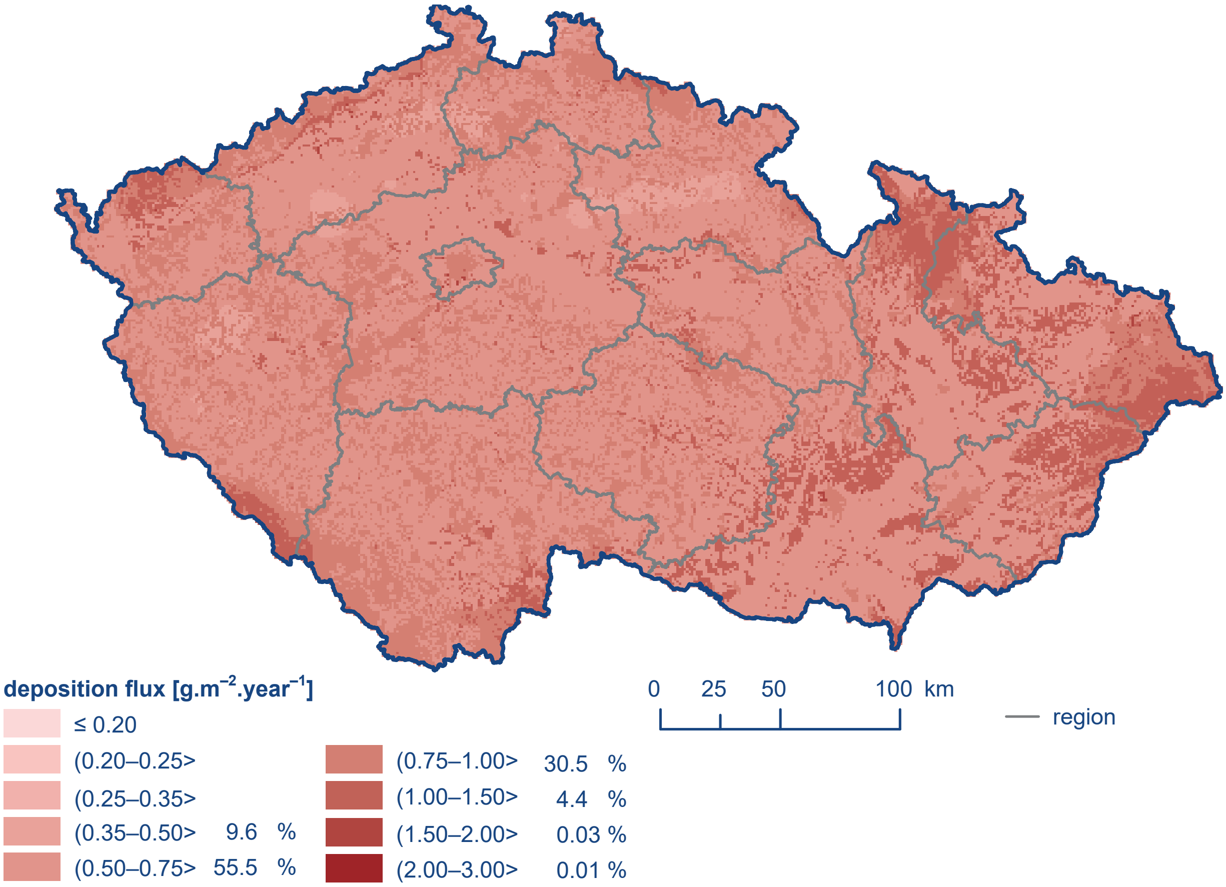


Fig. IX.10 Field of annual total deposition of nitrogen, 2019

Deposition of hydrogen, lead, cadmium, nickel and chloride ions

The total deposition of hydrogen ions on the area of the Czech Republic in 2019 was equal to 2,535 t (Table IX.2, Fig. IX.13). Compared to 2018 (2,805 t), this is a slight decrease. The wet component of hydrogen ion deposition reached 290 t in 2019 (Fig. IX.11) which is comparable to 2018 when the value was 296 t. In contrast, the dry component in 2019 was equal to 2,245 t (Fig. IX.12) and compared to 2018 (2,509 t) it is therefore a slight decrease. The deposition of hydrogen ions in the Šumava, Krušné Mountains, Jizerské Mountains, Orlické Mountains, the Hrubý Jeseník and Moravian-Silesian Beskydy reached the highest values.

Lead wet deposition in 2019 (31 t) was lower than in 2018 (37 t). The highest values were reached in the area of the Jizerské Mountains, Orlické Mountains, Jeseníky Mountains and the Moravian-Silesian Beskydy (Fig. IX.15). Dry deposition of lead showed a more significant decrease, reaching 18 t in 2019, while 28 t in 2018. The highest values were reached in the Ostrava, Moravian-Silesian Beskydy and Brdy regions (Fig. IX.16).

Wet deposition of cadmium reached 1.6 t in 2019 which means a year-on-year increase compared to 2018 (1.3 t). On the contrary, dry deposition was lower in 2019 (1.1 t) compared to 2018 (1.3 t). In the long run, cadmium deposition reaches the highest values in the Jablonec nad Nisou district (Fig. IX.17, Fig. IX.18).

Annual wet deposition of nickel ions reaches the highest values in the Uhlířská, Modrý potok, Polomka and U dvou louček localities (Fig. IX.19). Wet deposition of chloride ions attains, similarly to other monitored pollutants, higher values in mountain areas in the Czech Republic (Fig. IX.14).

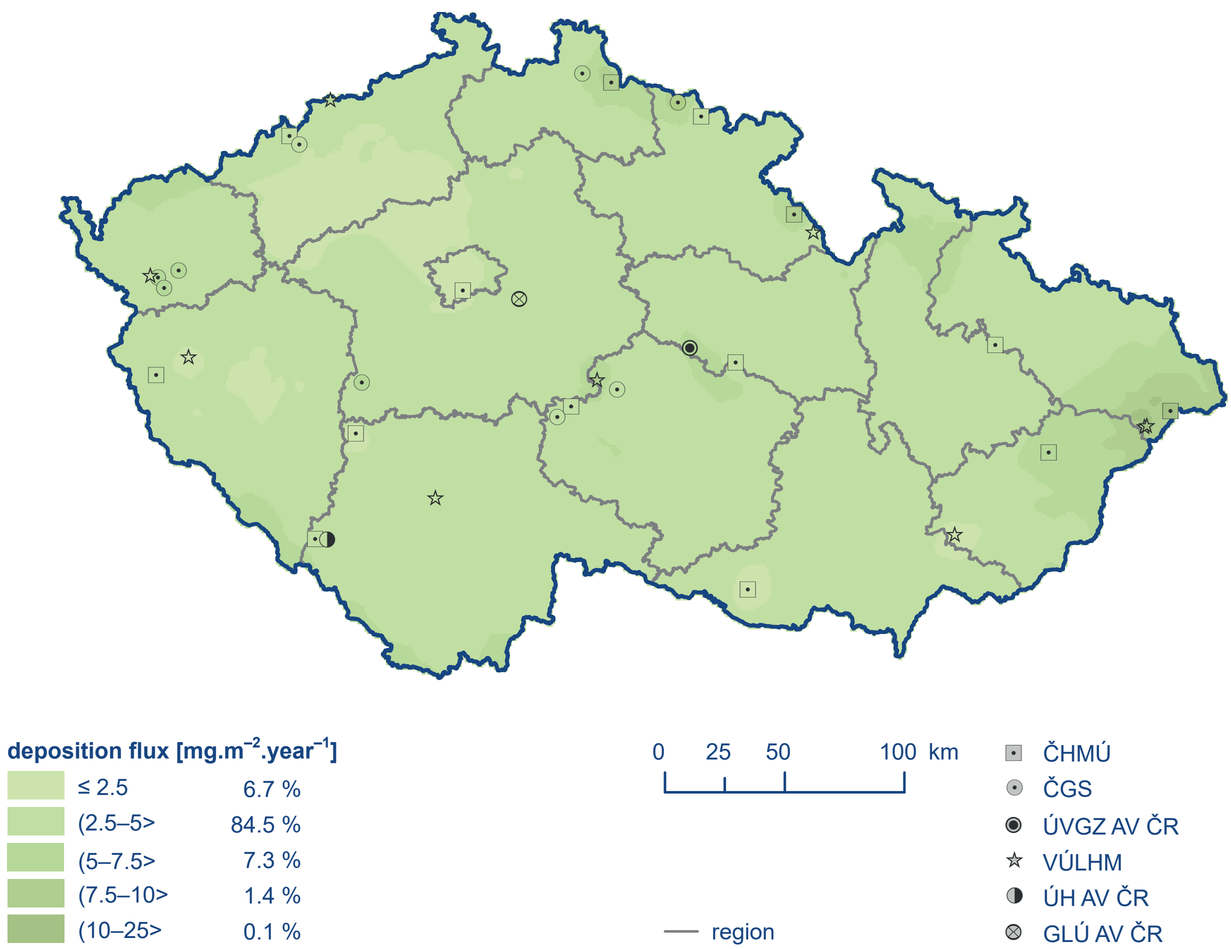


Fig. IX.11 Field of annual wet deposition of hydrogen ions, 2019

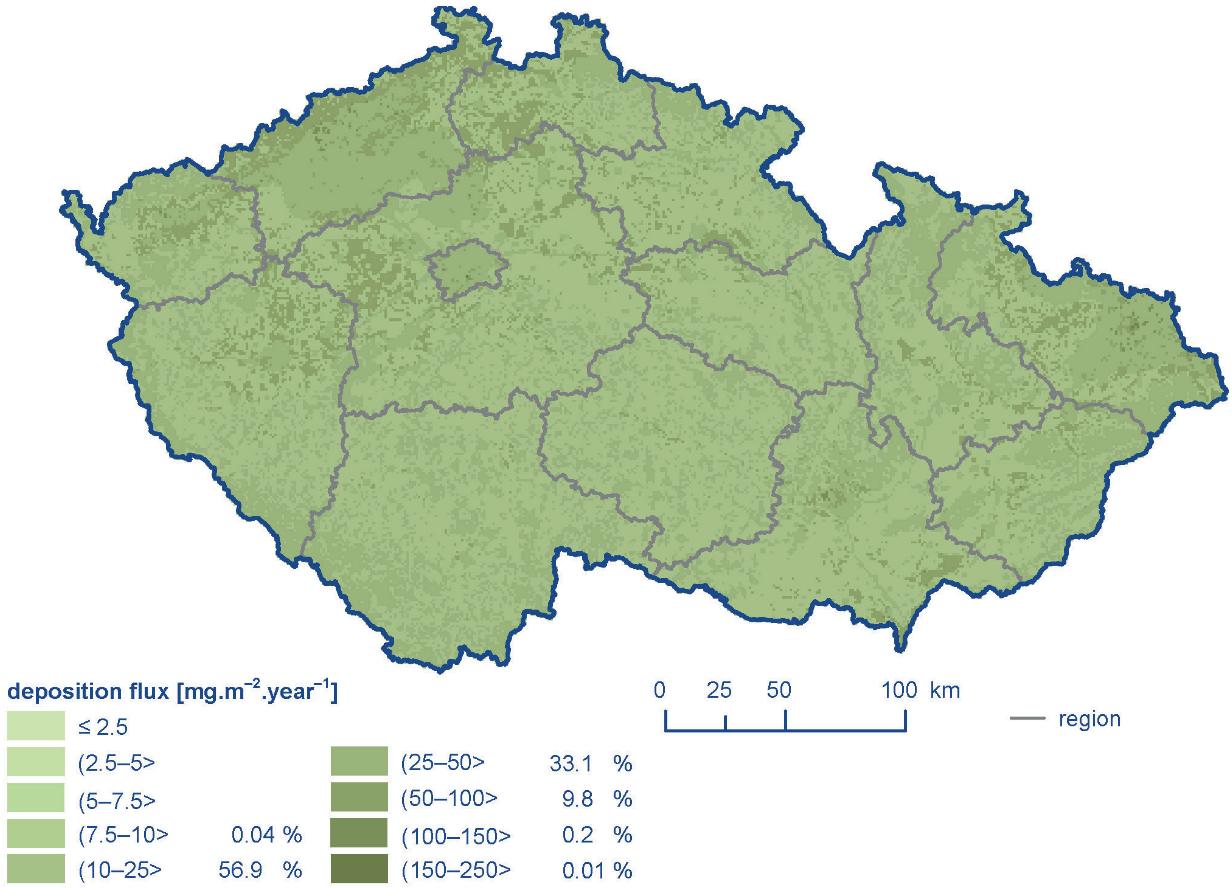


Fig. IX.12 Field of annual dry deposition of hydrogen ions corresponding to SO_2 and NO_x gas deposition, 2019

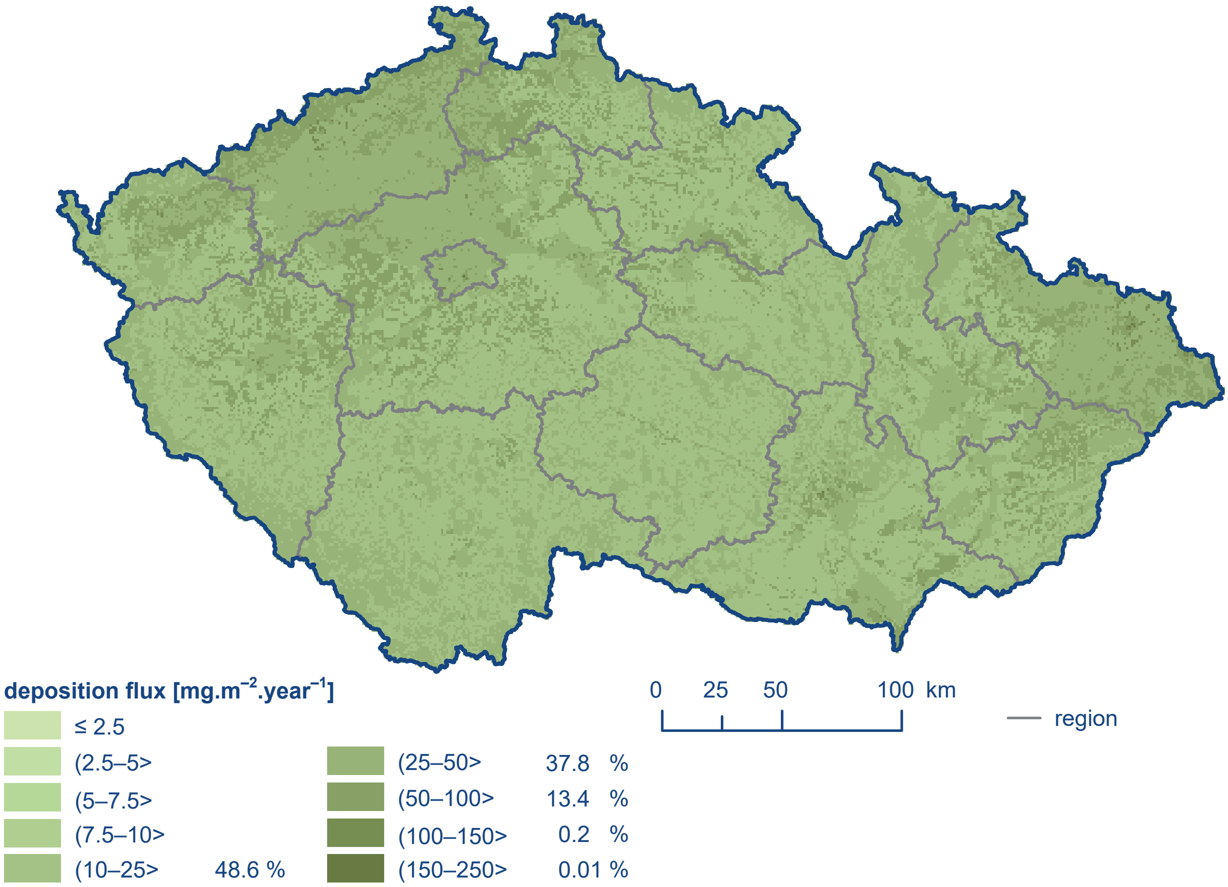


Fig. IX.13 Field of annual total deposition of hydrogen ions, 2019

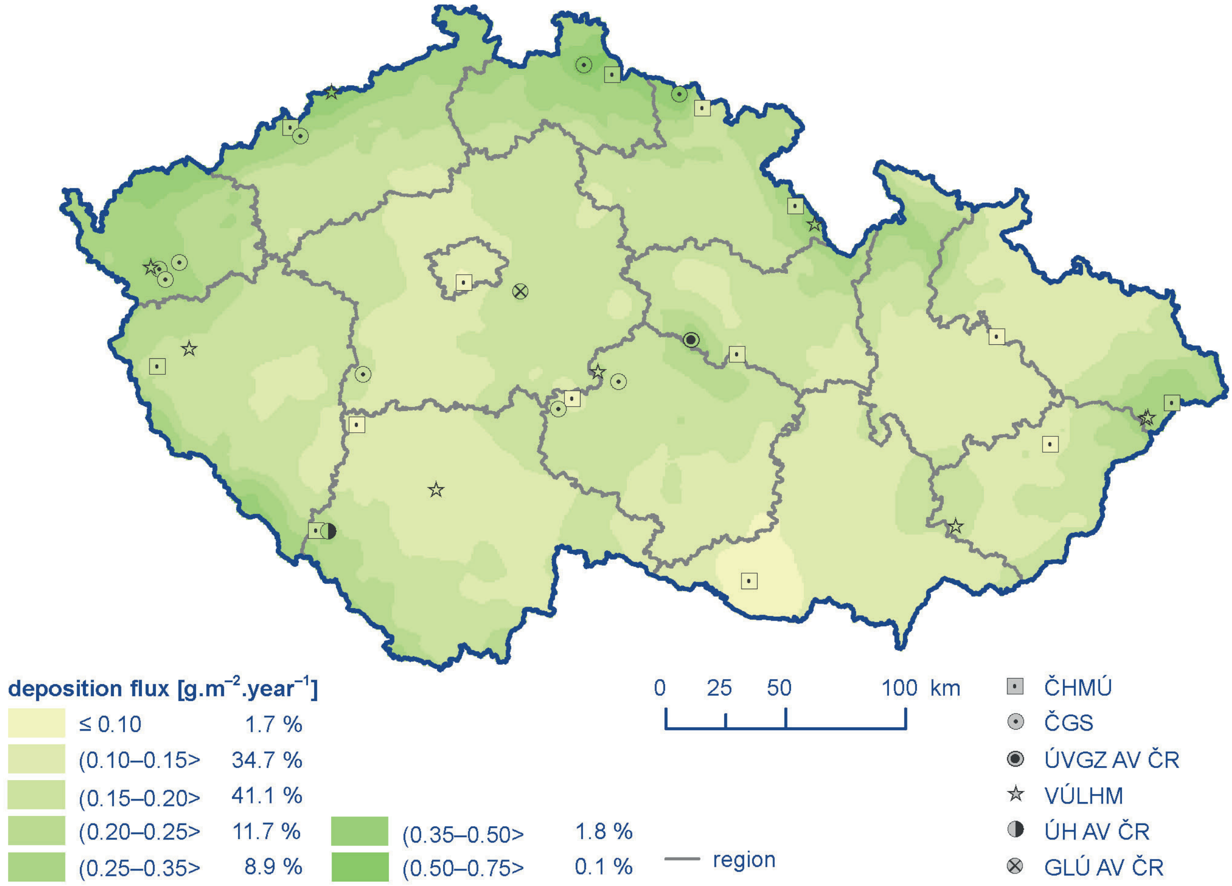


Fig. IX.14 Field of annual wet deposition of chloride ions, 2019

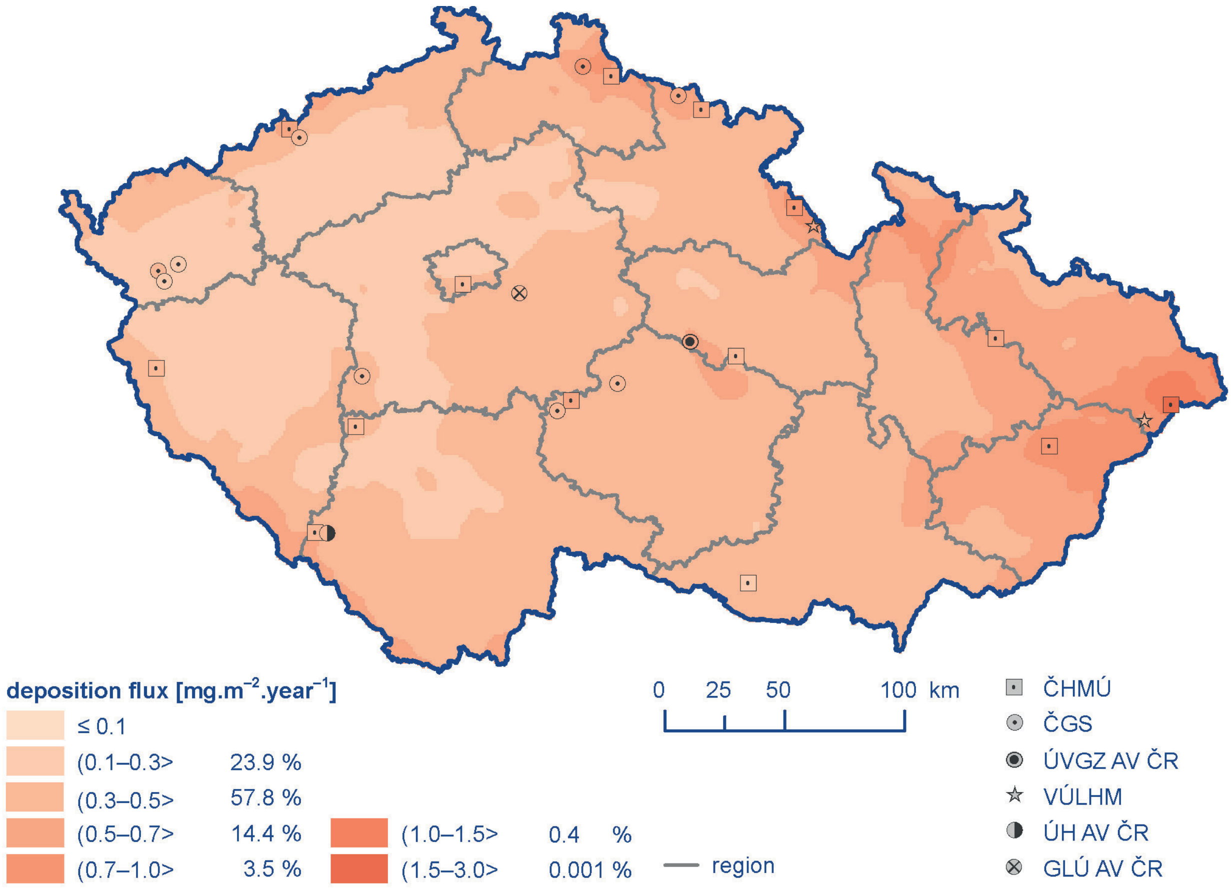
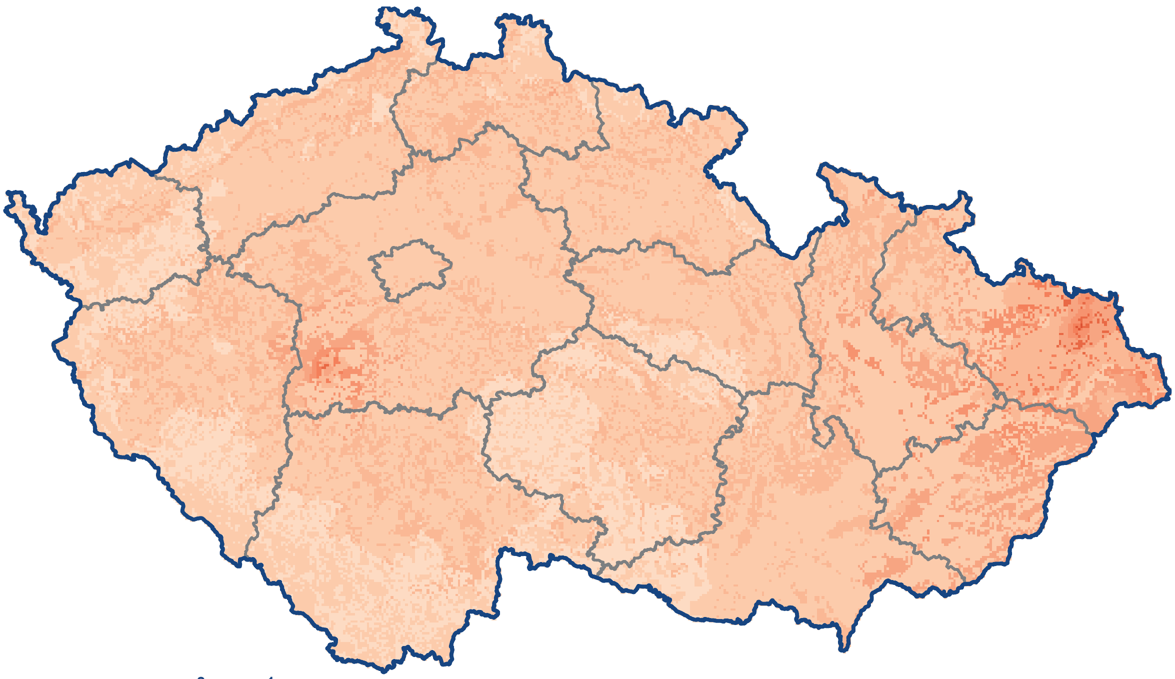


Fig. IX.15 Field of annual wet deposition of lead ions, 2019



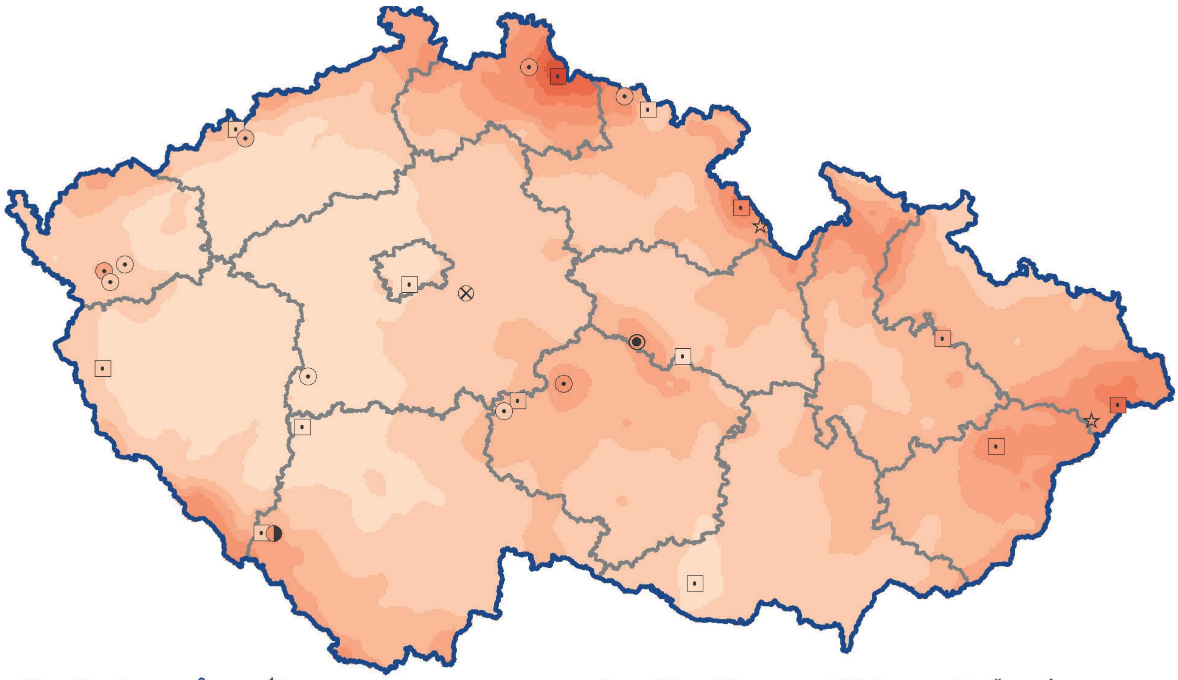
deposition flux [mg.m^{-2}.year^{-1}]

≤ 0.1	14.3 %
(0.1–0.3>	60.1 %
(0.3–0.5>	19.4 %
(0.5–0.7>	4.5 %
(0.7–1.0>	1.3 %
(1.0–1.5>	0.3 %
(1.5–3.0>	0.1 %
(3.0–5.0>	0.01 %

0 25 50 100 km

— region

Fig. IX.16 Field of annual dry deposition of lead, 2019



deposition flux [mg.m^{-2}.year^{-1}]

≤ 0.015	20.1 %
(0.015–0.20>	38.2 %
(0.020–0.025>	27.2 %
(0.025–0.030>	8.6 %
(0.030–0.040>	4.9 %
(0.040–0.050>	0.6 %
(0.050–0.075>	0.3 %
(0.075–0.100>	0.1 %
(0.100–0.150>	0.02 %

— region

0 25 50 100 km

ČHMÚ
ČGS
ÚVGZ AV ČR
VÚLHM
ÚH AV ČR
GLÚ AV ČR

Fig. IX.17 Field of annual wet deposition of cadmium ions, 2019

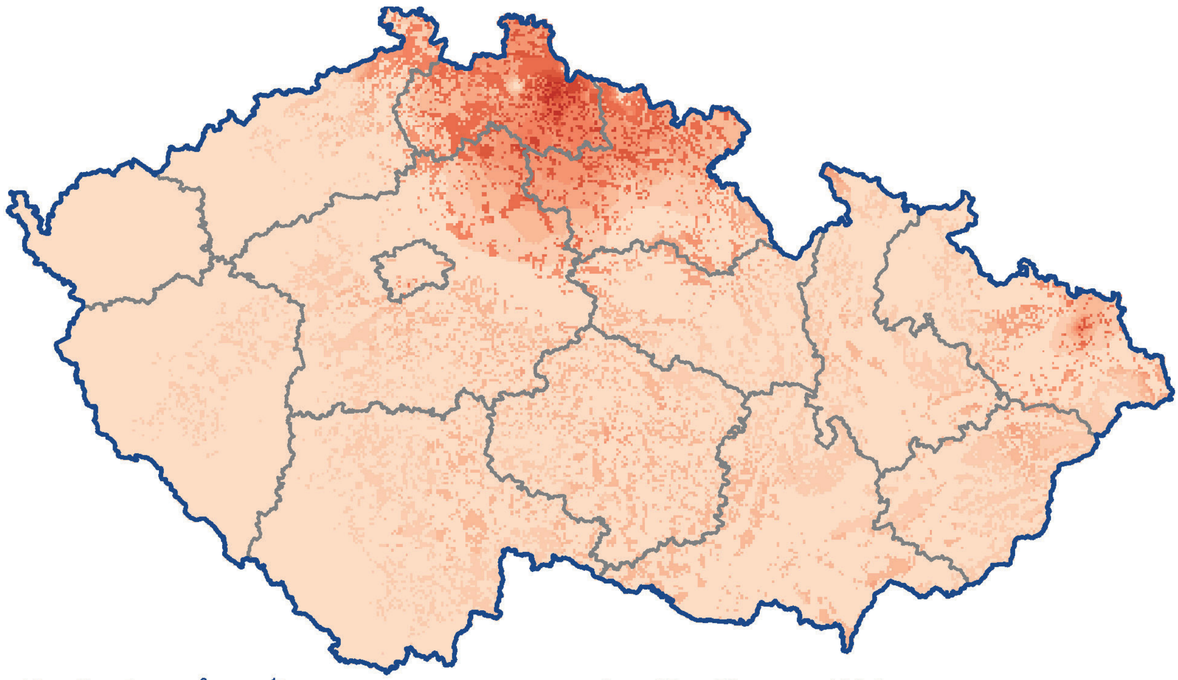


Fig. IX.18 Field of annual dry deposition of cadmium, 2019

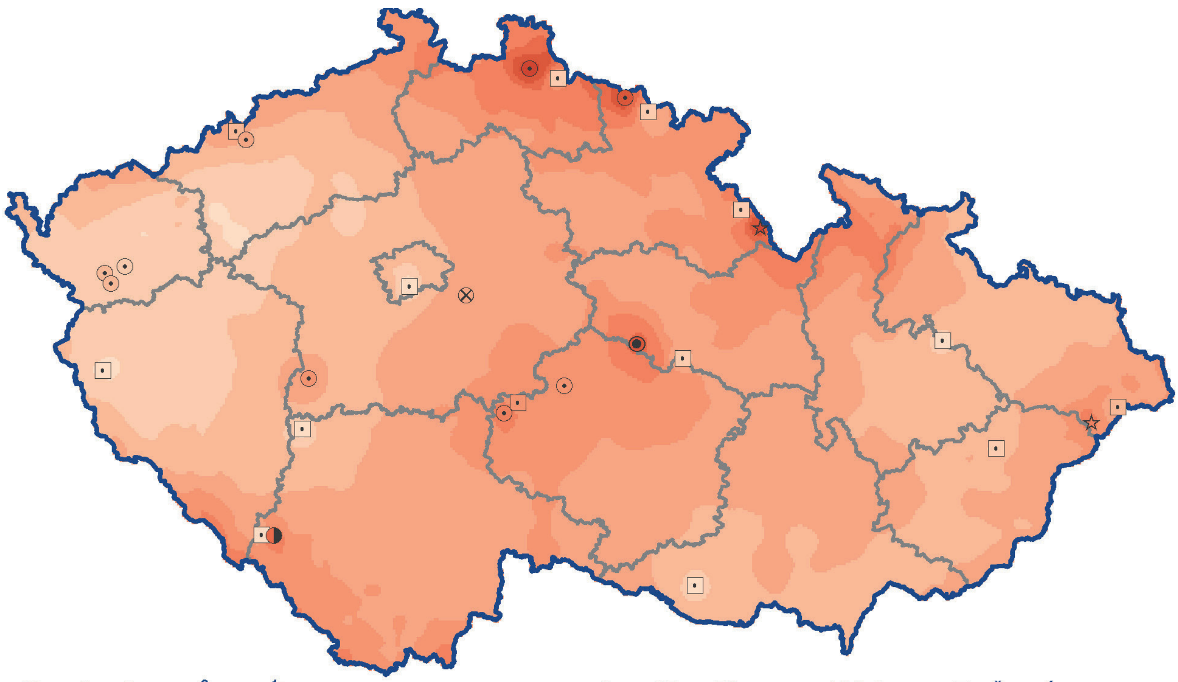


Fig. IX.19 Field of annual wet deposition of nickel ions, 2019

Trends in deposition

In the 1990s, the values of the total annual sulphur deposition were significantly higher than 100,000 t. Since 2000, a declining trend can be observed (Fig. IX.21). In 2000–2006, the value of total deposition remained in the range of approx. 65,000–75,000 t, except for 2003, which was significantly subnormal in terms of precipitation (516 mm, i.e. 77% of the long-term normal). Since 2011, the values of annual sulphur deposition have not reached 50,000 t, since 2015 they have fallen below 40,000 t on the area of the Czech Republic. The values of wet deposition of sulphur in 2000–2007 ranged from 30,000 to 50,000 t, except lower deposition in 2003 (19,128 t). Since 2008, depositions have not exceeded 30,000 t, after 2015 the downward trend below 20,000 t continues. The values of dry deposition are around 30,000 t until 2006, in 2007 and 2008 there was a significant decrease to values below 20,000 t. After an increase in deposition between 2009 and 2014, steady to slightly decreasing values can be observed in the last five years, in accordance with the level of sulphur dioxide concentration in the ground atmosphere.

Since 2001, the annual deposition of sulphur on the forested area of the Czech Republic (26,428 km^2) has shown a rather declining trend (Table IX.3). The value of total deposition in 2019 is the second lowest after 2016; the value of sub-crown deposition is the lowest since 2001. In some mountain areas in the country, the long-term throughfall deposition values are higher than the values of total sulphur deposition determined as the sum of wet (vertical only) and dry deposition from SO_2. This increase can be attributed to the contribution from deposition from fog, low clouds and rime (horizontal deposition) which is not included in the total deposition because of its uncertainty.

Total annual nitrogen deposition has ranged from 40,000 to 50,000 t since 2000. Since 2013, a declining trend can be observed, except for 2017 (Fig. IX.22). No significant trend has been observed since 2000 for wet or dry deposition of oxidized forms of nitrogen. Fluctuations in annual deposition values are related to air pollution concentrations of NO_X in the troposphere.

Together with the variation of deposition of sulphur and nitrogen, a variation can be followed in the mutual ratio of these two elements in atmospheric precipitation related to trends in emissions of particular compounds (Fig. IX.20). A slight, although not steady, increase in the ratio of nitrates to sulphates can be observed at some stations since 2000 (Hůnová et al., 2017).

Since 2000, no trend of hydrogen ion deposition has been observed. The values of total deposition range between 2,500 and 4,500 t per year (Fig. IX.23). Since 2015, the total deposition of hydrogen ions does not exceed 3,000 t.

In the second half of the 1990s, there was a decrease in the wet deposition of some substances at selected stations in the Czech Republic (mainly SO_4^{2-}, H^+ and Pb_2^+). Since 2000, the values have rather stagnated, after 2010 there is a slight decrease in some substances again. These are, for example, H^+ at all stations, NO_3^- especially at the Souš, and slightly also at the Svratouch, Košetice and Přimda localities(Fig. IX.24).

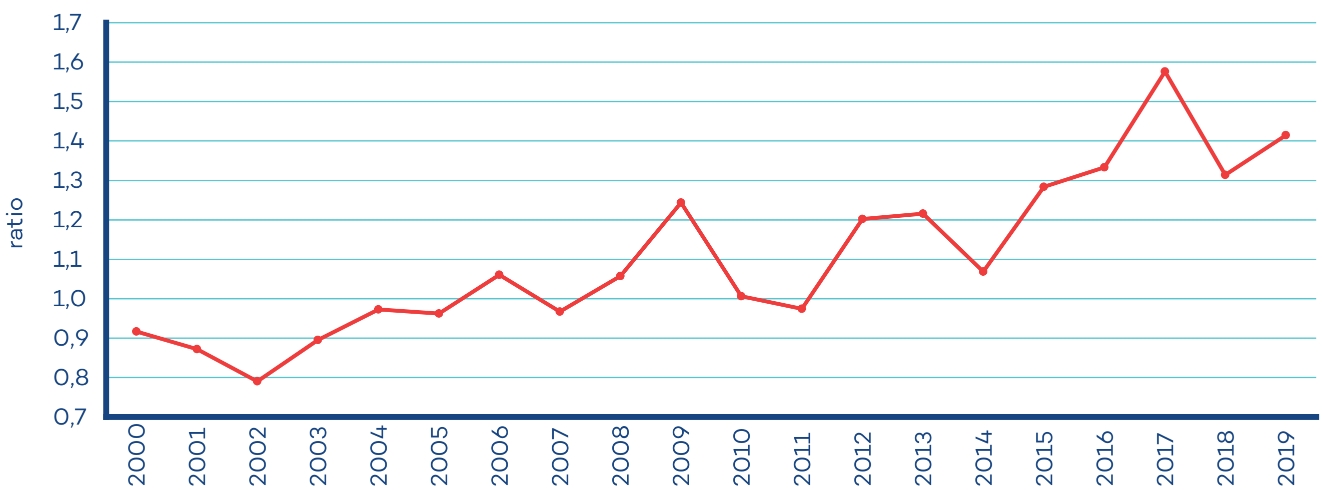


Fig. IX.20 Ratio of nitrate to sulphate concentrations in atmospheric deposition (expressed as μeq.l^{-1}) at the CHMI localities, 2000–2019

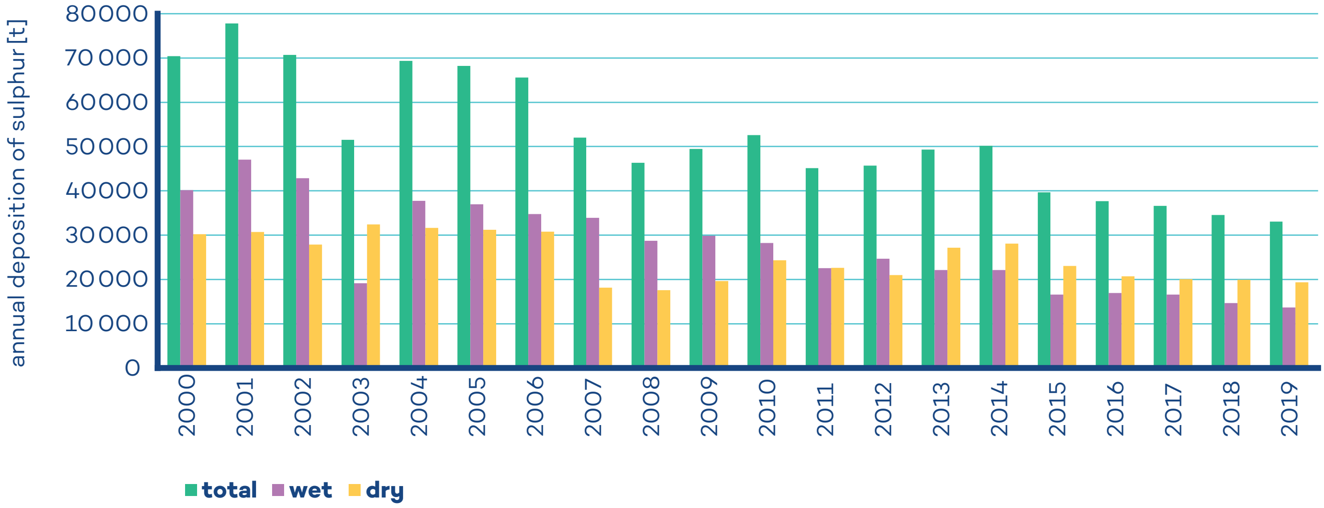


Fig. IX.21 Annual deposition of sulphur (S_SO_4^{2-}, S_SO_2) on the area of the Czech Republic, 2000–2019

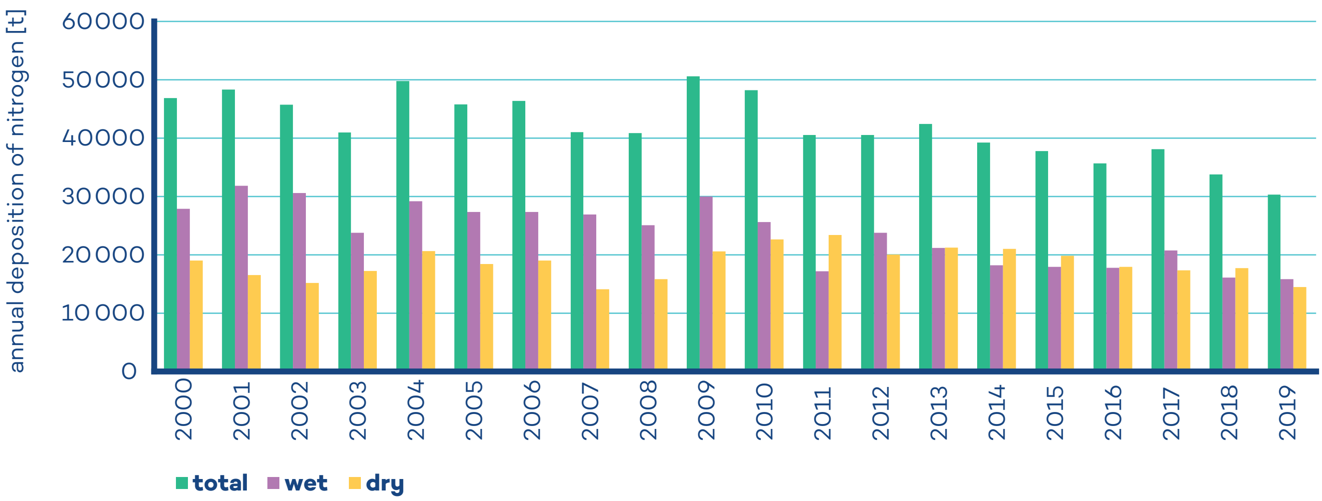


Fig. IX.22 Annual deposition of oxidized forms of nitrogen (N_NO_3^-, N_NO_x) on the area of the Czech Republic, 2000–2019

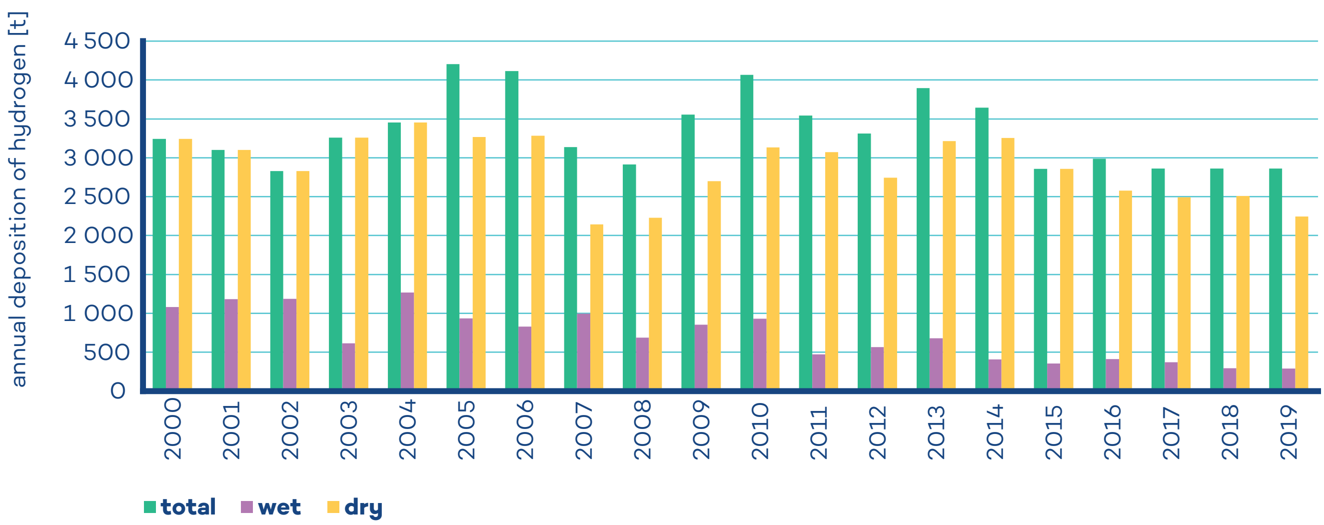


Fig. IX.23 Annual deposition of hydrogen ions on the area of the Czech Republic, 2000–2019

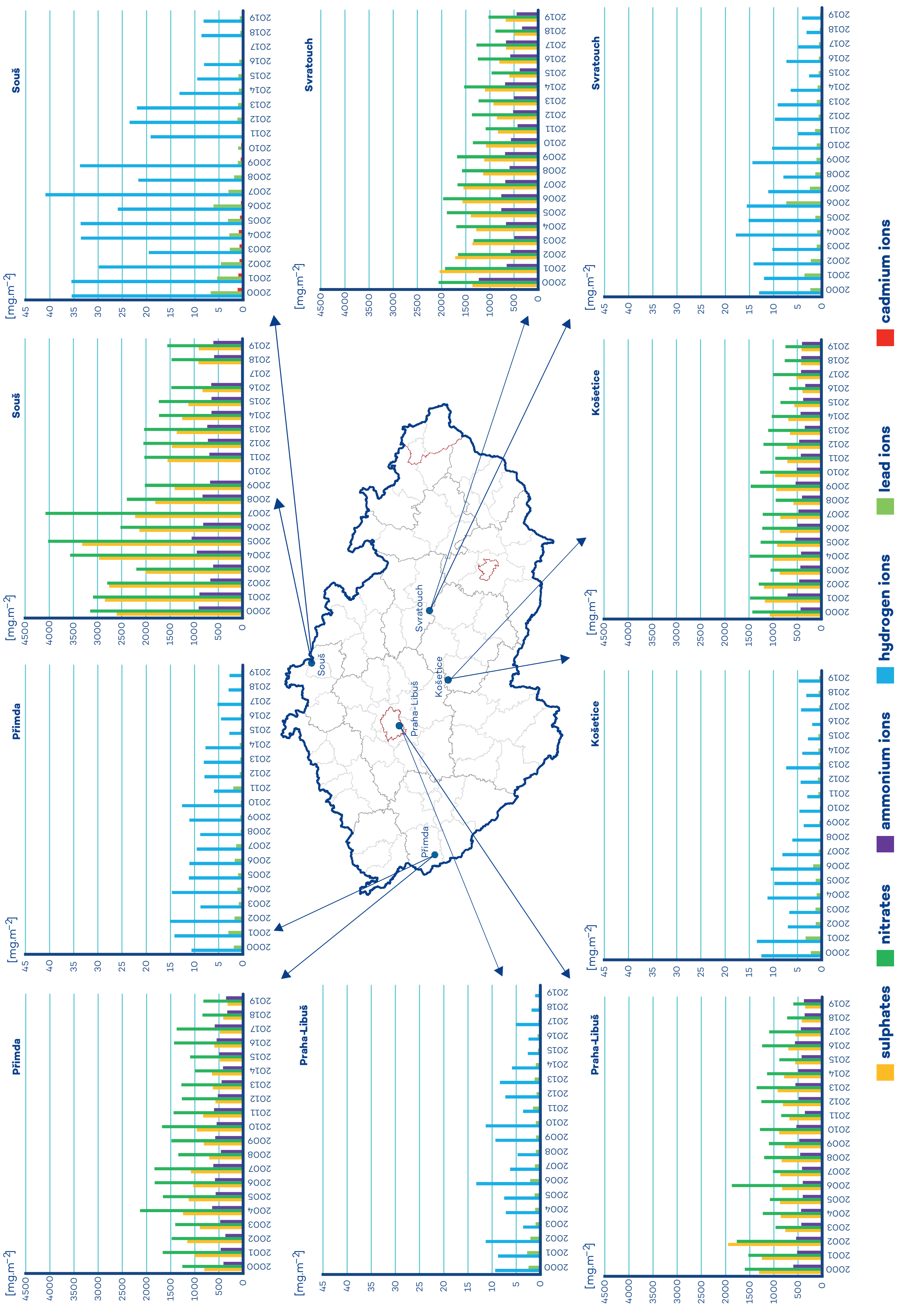


Fig. IX.24 Annual wet deposition at selected stations, 2000–2019

Tab. IX.4 Station networks monitoring atmospheric precipitation quality and atmospheric deposition, 2019

Code	Station	Region/country	District	Owner	Data supplier	Altitude [m]	Sampling
ALIB	Praha 4 - Libuš	Prague	Praha 4	CHMI	CHMI	301	W1(HM)
BKUC	Kuchařovice	South Moravian	Znojmo	CHMI	CHMI	334	W1(HM)
CCHU	Churáňov	South Bohemian	Prachatice	CHMI	CHMI	1 118	W1(HM)
CKAM	Kamýk-Všeteč	South Bohemian	České Budějovice	VÚLHM	VÚLHM	593	M2(HM), M4(HM)_bu
CKOC	Kocelovice	South Bohemian	Strakonice	CHMI	CHMI	519	W1(HM)
CLIZ	Na lizu	South Bohemian	Prachatice	ÚH AV ČR	CGS	828	M2(HM), M4(HM)_sm, M4(HM)_bu
CPL1	Plešné jezero	South Bohemian	Prachatice	HBÚ AV ČR	HBÚ AV ČR	1 087	F2
CPL2						1 122	F2
CPL3						1 334	F2
EPOM	Polomka	Pardubice	Chrudim	ÚVGZ AV ČR	CGS	512	M2(HM), M4(HM)_sm
ESVR	Svratouch	Pardubice	Chrudim	CHMI	CHMI	735	W1(HM)
HKRY	Krkonoše-Rýchory	Hradec Králové	Trutnov	CHMI	CHMI	1 001	W1(HM)
HLUD	Luisino údolí	Hradec Králové	Rychnov n. Kn.	CHMI	CHMI	875	W1(HM)
HLUU	Luisino údolí	Hradec Králové	Rychnov n. Kn.	VÚLHM	VÚLHM	940	M4(HM)_sm
HMOP	Modrý potok	Hradec Králové	Trutnov	CGS	CGS	1 010	M2(HM), M4(HM)_sm
HUDL	U dvou louček	Hradec Králové	Rychnov n. Kn.	VÚLHM	CGS	880	M2(HM), M4(HM)_sm, M4(HM)_bu
JKOS	Košetice	Vysočina	Pelhřimov	CHMI	CHMI CGS	535	D1(HM) (POPS,PAHs), M2(HM), M4(HM)_sm
JLKV	Loukov	Vysočina	Havlíčkův Brod	CGS	CGS	500	M2(HM), M4(HM)_sm
JSAL	Salačova Lhota	Vysočina	Pelhřimov	CGS	CGS	557	M2(HM), M4(HM)_sm
JZEL	Želivka	Vysočina	Havlíčkův Brod	VÚLHM	VÚLHM	440	M2(HM), M4(HM)_sm
KLAZ	Lazy	Karlovy Vary	Cheb	VÚLHM	VÚLHM	875	M2(HM), M4(HM)_sm
KLY1	Lysina	Karlovy Vary	Cheb	CGS	CGS	867	M2(HM)
KLY2						836	M4(HM)_sm
KNZ1	Na Zeleném	Karlovy Vary	Cheb	CGS	CGS	773	M2(HM)
KNZ2						750	M4(HM)_sm
KPB1	Pluhův bor	Karlovy Vary	Cheb	CGS	CGS	753	M2(HM)
KPB2						714	M4(HM)_sm

Code	Station	Region/country	District	Owner	Data supplier	Altitude [m]	Sampling
LSOU	Souš	Liberec	Jablonec n.N.	CHMI	CHMI	771	W1(HM)
LUHL	Uhlířská	Liberec	Liberec	CGS	CGS	780	M2(HM), M4(HM)_sm
PBEN	Benešovice	Plzeň	Tachov	VÚLHM	VÚLHM	385	M2(HM), M4_bo
PCJ1	Čertovo jezero	Plzeň	Klatovy	HBÚ AV ČR	HBÚ AV ČR	1 180	F2
PCJ2						1 057	F4_sm
PPRM	Přimda	Plzeň	Tachov	CHMI	CHMI	740	W1(HM)
SLES	Lesní potok	Central Bohemian	Kolín	GLÚ AV ČR	CGS	400	M2(HM), M4(HM)_sm, M4(HM)_bu
SLI1	Litavka	Central Bohemian	Příbram	CGS	CGS	700	M2(HM)
SLI2						710	M4(HM)_sm
TBKR	Bílý Kříž	Moravian-Silesian	Frýdek-Místek	CHMI	CHMI	890	W1(HM)
TCER	Červená hora	Moravian-Silesian	Opava	CHMI	CHMI	749	W1(HM)
TCRV	Červík	Moravian-Silesian	Frýdek-Místek	CGS	CGS	640	M2(HM), M4(HM)_sm
TKLE	Klepačka	Moravian-Silesian	Frýdek-Místek	VÚLHM	VÚLHM	650	M2(HM), M4(HM)_sm
UJEZ	Jezeří	Ústí nad Labem	Chomutov	CGS	CGS	820	M2(HM), M4(HM)_sm, M4(HM)_bu, M4(HM)_br
UMOD	Moldava	Ústí nad Labem	Teplice	VÚLHM	VÚLHM	805	M2(HM), M4(HM)_je
URVH	Rudolice v Horách	Ústí nad Labem	Chomutov	CHMI	CHMI	840	W1(HM)
ZBUC	Buchlovice-Medlovice	Zlín	Uherské Hradiště	VÚLHM	VÚLHM	350	M2(HM), M4(HM)_du
ZMAR	Maruška	Zlín	Vsetín	CHMI	CHMI	664	W1(HM)

Explanatory notes:

M2 – monthly bulk samples
M4 – monthly throughfall
W1 – tweekly wet-only - autom. sampler
D1 – daily wet-only - autom. sampler
F1 – wet-only- irregular samples
F2 – bulk- irregular samples
F4 – throughfall- irregular samples
(HM) – heavy metals analysis in mentioned sampling (POPs, PAHs) - POPs and PAHs analysis
_sm – spruce
_bu – beech
_bo – pine
_du – oak
_br – birch
_je – rowan