IV.4 Groud-level ozone

IV.4.1 Air pollution by ground-level ozone in 2019

Air pollution by ground-level ozone in 2019 in relation to the limit values for protection of human health

The ground-level ozone limit value (O_3) was exceeded at 56% of stations in the three-year period 2017–2019[1], i.e. in 36 out of 64 stations where the O_3 concentrations were measured (Tab. XI.10; Fig. IV.4.1 and IV.4.2). For the previous three-year periods 2016–2018 and 2015–2017, the ground-level O_3 limit value was exceeded at 33 out of 65 (51%) and at 21 of 71 (30%) stations respectively.

The O_3 limit value was exceeded in the three-year period 2017–2019 over 70.5% of the territory of the Czech Republic with approximately 56.9% of the population (Fig. IV.4.3). Compared to the previous five three-year periods, it is the second largest extent of the area exceeding the limit value for O_3 (80% of the territory in the period 2016–2018, 31.2% of the territory in the period 2015–2017, 18.1% of the territory in the period 2014–2016 and 26.8% of the territory in the period 2013–2015). The reason is the persistently favourable meteorological conditions for the formation of ground-level ozone (for more see Chapter III) that led to increased concentrations and more frequent cases exceeding the O_3 limit value in 2019 (Fig. IV.4.4).

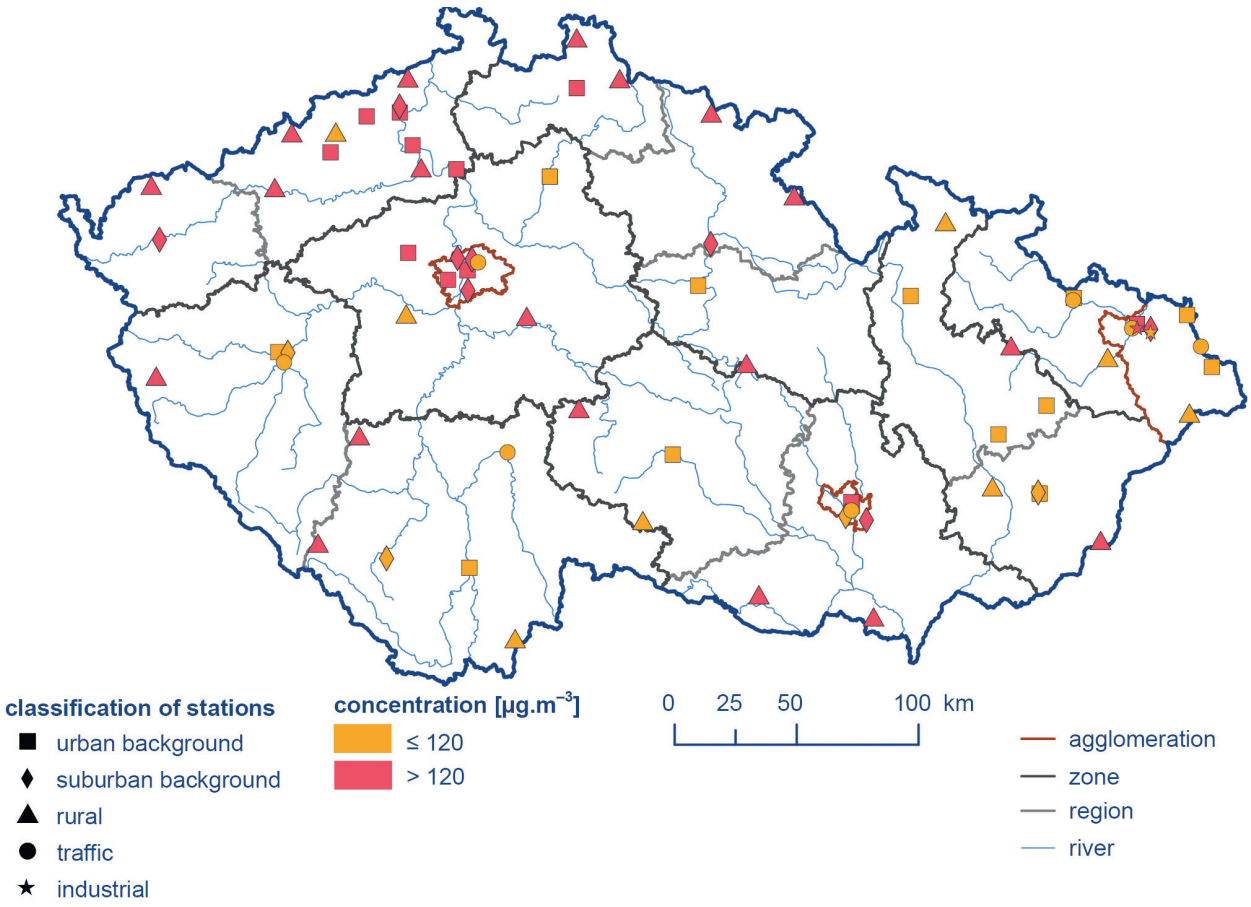

Fig. IV.4.1 26th highest values of maximum daily 8-hour running average of ground-level ozone concentrations (three-year average) in the ambient air quality network, 2017–2019

1 The limit value is exceeded if the O_3 maximum daily 8-hour running average was higher than 120 µg.m^{-3} at least 26 times in three-year average.

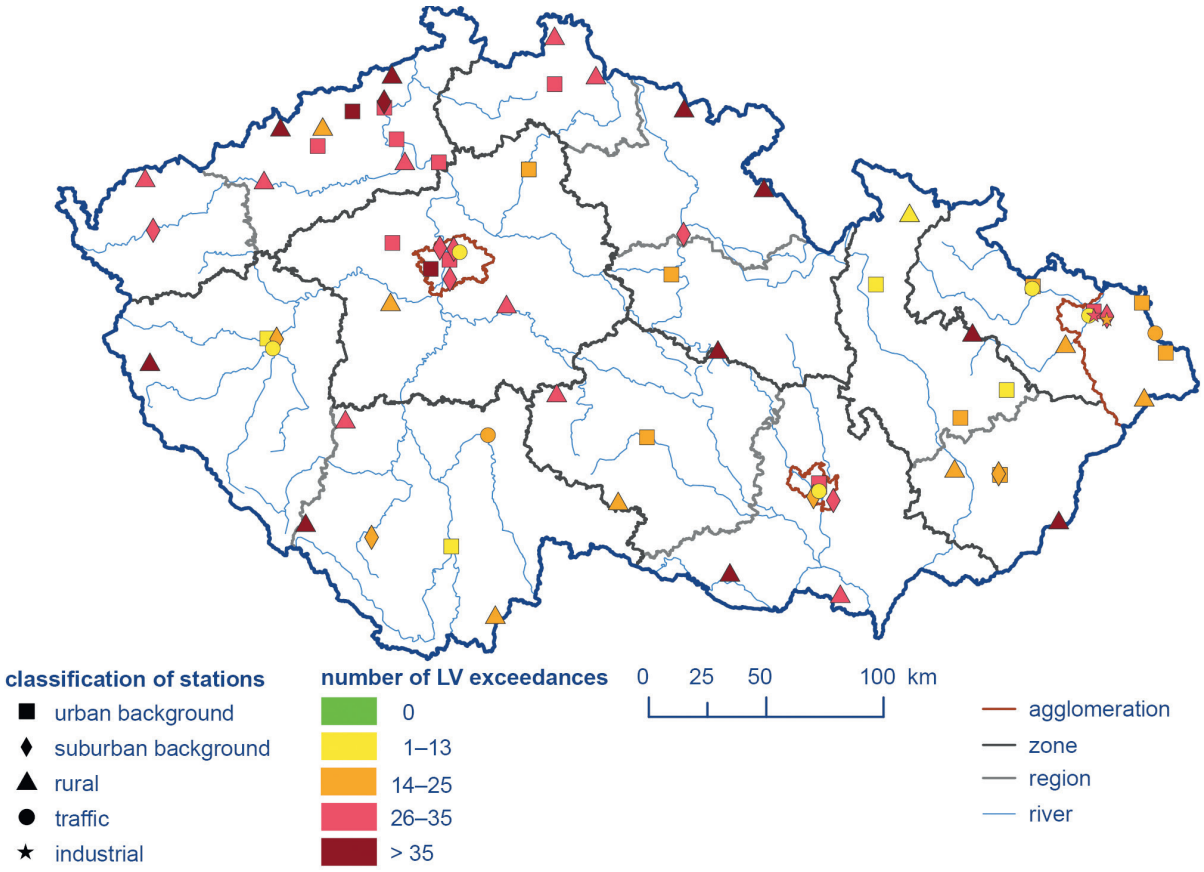

Fig. IV.4.2 Numbers of exceedances of the limit value for the maximum daily 8-hour running average of ground-level ozone concentrations in three-year average, 2017–2019

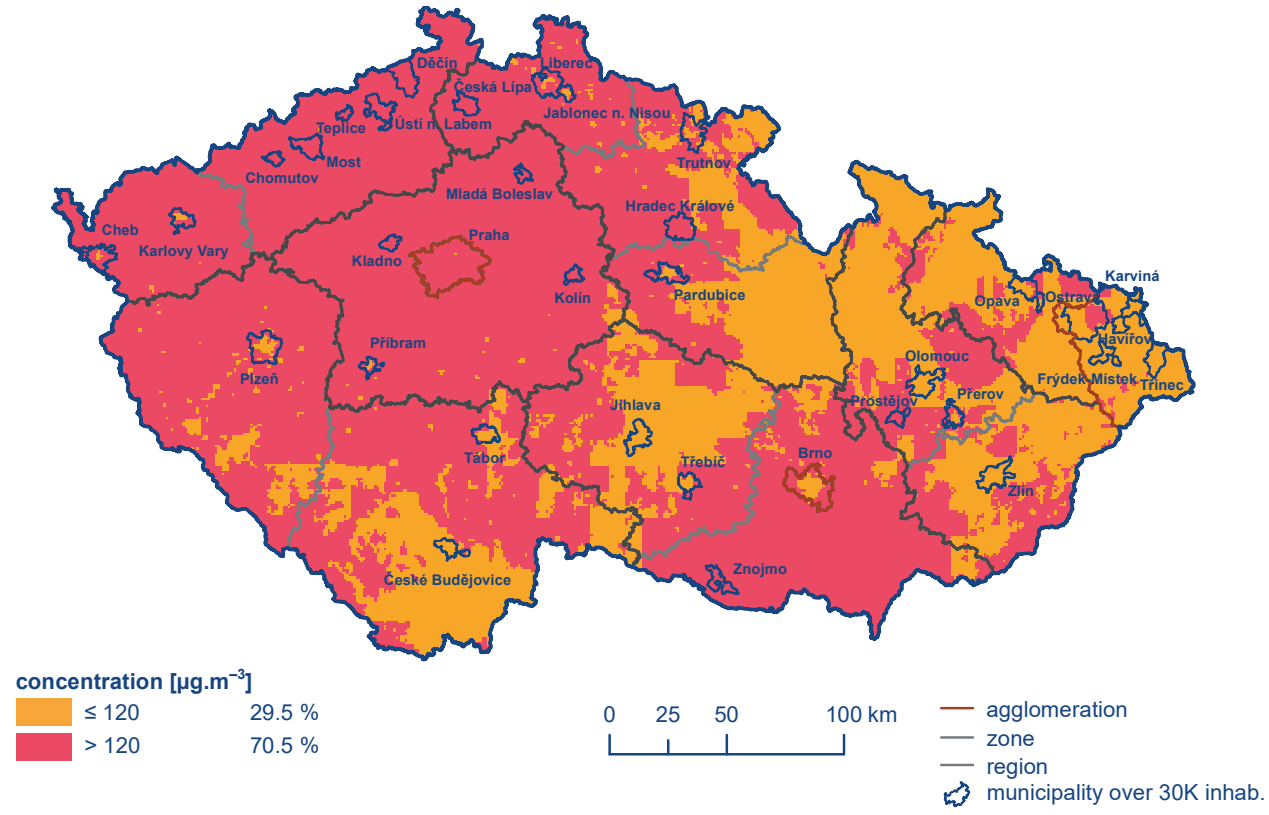

Fig. IV.4.3 Field of the 26th highest maximum daily 8-hour running average of ground-level ozone concentration in three-year average, 2017–2019

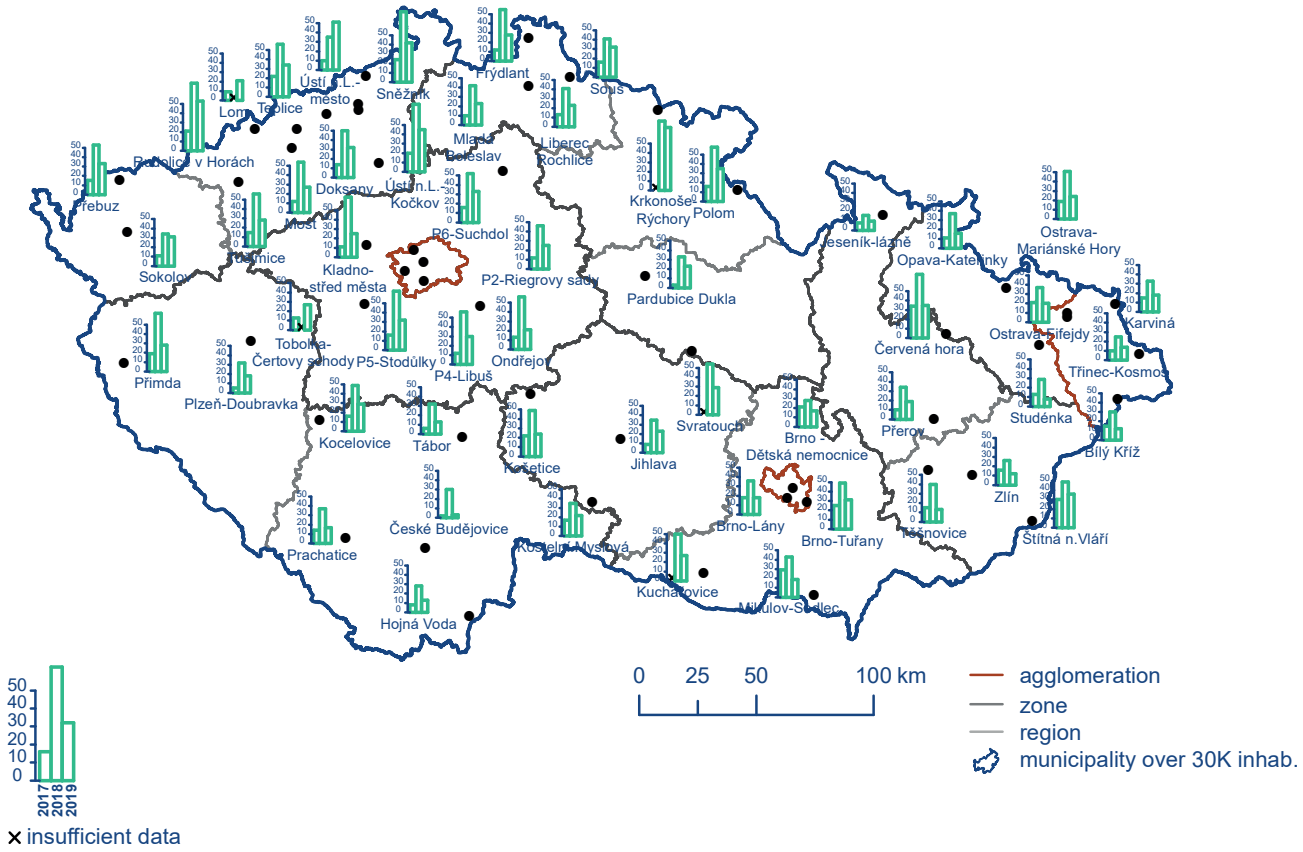

Fig. IV.4.4 Number of exceedances of 8-hour limit value of ground-level ozone per year for selected stations, 2017–2019

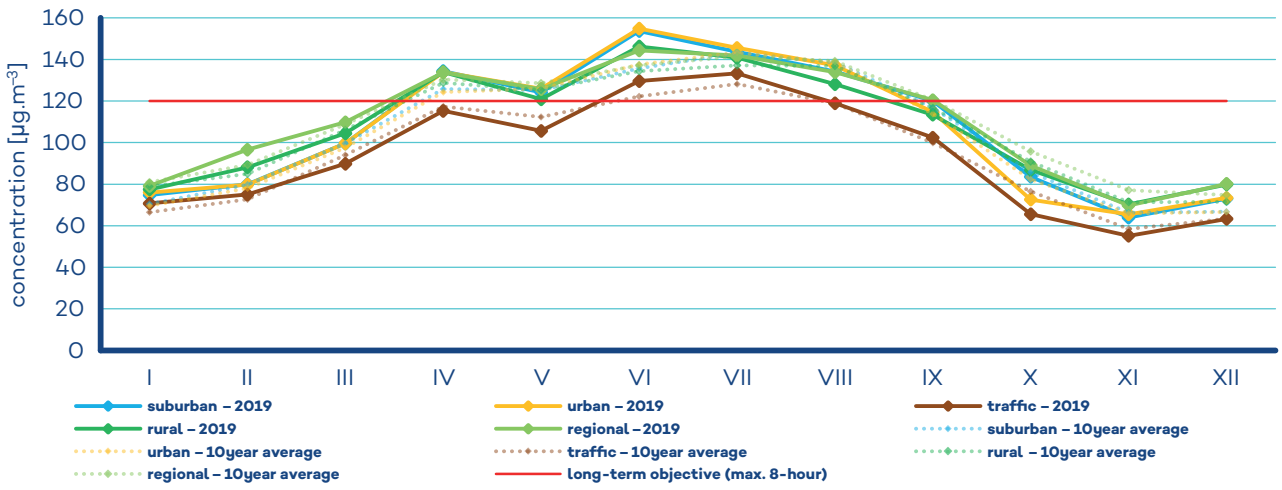

Fig. IV.4.5 Annual course of average monthly concentrations of max. 8-hour running average of O_3 (averages for the given type of station), 2019

The annual course of average monthly and daily concentrations of O_3 (maximum 8-hour average for a given month and day) is characterized by an increase in concentrations in spring and summer months (Fig. IV.4.5) due to favourable meteorological conditions for formation of O_3. In 2019, the average monthly concentrations were above the O_3 pollution limit value from April until August (until September at background and regional stations).

The highest concentrations of O_3 were measured from June to August, which corresponds to the usual occurrence of conditions favourable for the formation of ground-level ozone (for more see subchapter IV.4.3).

Based on a comparison of monthly averages of O_3 concentrations with ten-year average (2009–2019), it can be stated that average monthly

concentrations at monitoring stations in the period April – September, when O_3 concentrations reach elevated to above-limit levels, were similar or higher (by approximately 6% to 13%). The increase of concentrations in June is probably related to the occurrence of extremely above-normal temperatures and below-normal precipitation in June 2019. In the opposite, a slight drop in ground-level ozone concentrations in May 2019 corresponds to the occurrence of lower temperatures and higher precipitation (May is characterized as strongly below normal in temperature and above normal in precipitation).

From this evaluation it is evident that the lowest concentrations are measured at localities subject to traffic load (Fig. IV.4.5 and IV.4.9) where O_3 is decomposed by chemical reactions with NO. It can be assumed that the O_3 concentrations are also lower or below the limit in other areas with heavy traffic where, however, because of the lack of measurements, this probable reduction cannot be documented using current methods of map preparation. The values of concentrations at rural, suburban and urban stations are higher compared to concentrations at traffic stations and reach similar levels (Fig. IV.4.5). This is also confirmed by the study by Paoletti et al. (2014) when, between 1990 and 2010, a decreased difference was observed between the concentrations measured at rural and urban stations in Europe and the USA (Paoletti et al. 2014). Simultaneously, the maximum values measured at these stations also decreased. The mentioned decrease in the concentrations of ground-level ozone is attributed, amongst other things, to a reduction in emissions of precursors, especially of NO_x, in developed countries where there is no as strong decomposition of O_3 in cities due to the reaction with NO. The reduction in concentrations in relatively clean areas is attributed to the reduction of both NO_x and VOC emissions on a wider (European to global) scale (Sicard et al. 2013). An increase in O_3 concentrations due to a decrease in NO_x emissions (modernization and denitrification of large emission sources) is also observed in north-western Bohemia (Hůnová, Bäumelt 2018).

Six smog situations with a total duration of 90 hours were announced for the ground-level ozone in 2019. Smog situations were announced mainly in the third ten-day period of June 2019 and in the Ústí nad Labem region also at the end of July (for more see Chapter VI). The warning threshold value was not exceeded at any representative SWRS station in 2019.

Ground-level ozone in 2019 in relation to the limit value for protection of ecosystems and vegetation

The O_3 limit value for protection of vegetation of 18,000 $\mu g.m^{-3}.h$ was exceeded at 25 stations (64.1%) of the total number of 39 rural and suburban stations (Fig. IV.4.6) for which calculation of the exposure index AOT40 is relevant according to the legislation (it concerns the 2015–2019 average). The highest AOT40 values were measured at the Rudolice v Horách, Kuchařovice, Krkonoše-Rýchory, Sněžník with Brno-Tuřany stations (for a comprehensive overview, see Table XI.11). Based on the same set of 32 rural and regional stations, it can be stated that the AOT40 index was exceeded at 20 stations in 2019 (average 2015–2019) compared

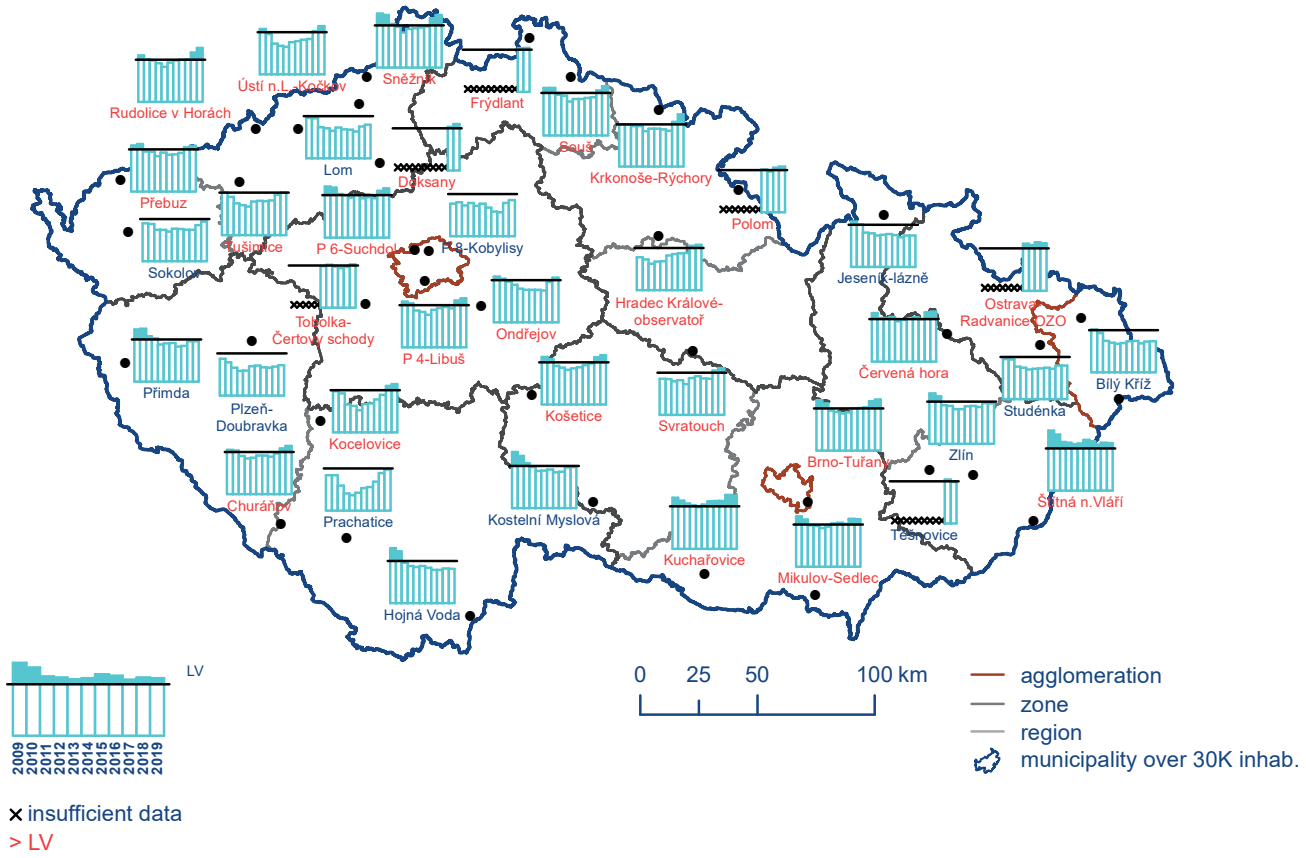

Fig. IV.4.6 Exposure index AOT40 values at selected stations, average of 5 years, 2009–2019

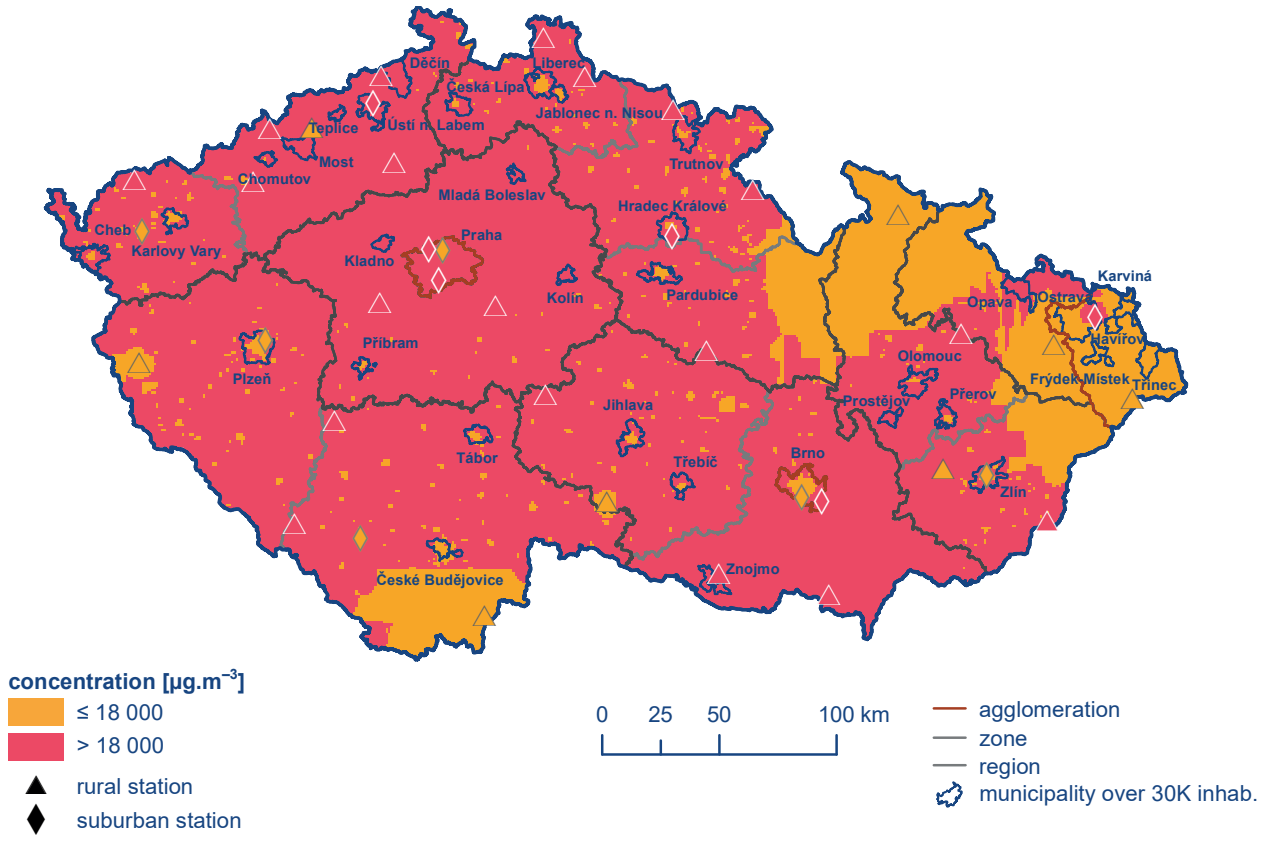

Fig. IV.4.7 Field of AOT40 exposure index values, average of 5 years, 2015–2019

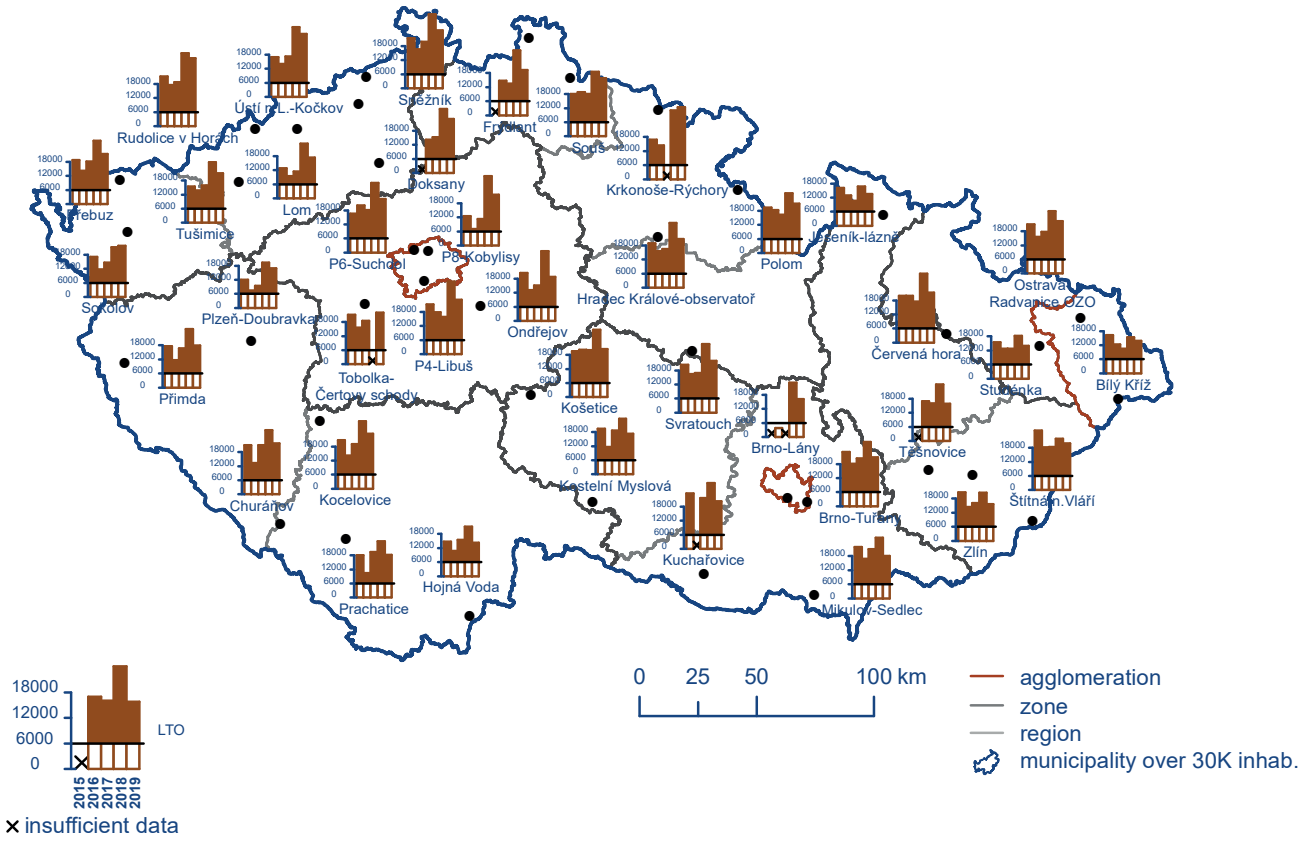

Fig. IV.4.8 Annual exposure index AOT40 values at selected stations in comparison with the long-term objective (LTO), 2015–2019

to 18 stations in 2018 (average 2014–2018). At the same time, the area of the territory with the occurrence of above-limit AOT40 values also increased (Fig. IV.4.7). The increase in the AOT40 exposure index value for 2019 compared to 2018 occurred at most of 32 stations evaluated in both periods, by up to 3,183 $\mu g.m^{-3}$.h.

The annual values of the exposure index AOT40 have long exceeded the value of the long-term pollution limit value (6,000 $\mu g.m^{-3}$.h, Tab. I.2) at all rural and regional stations (same set of stations for the last five years, Fig. IV.4.8). Within the evaluated five-year period, the values of the AOT40 index in 2019 were the second highest after 2018 at most stations.

IV.4.2 Trends in ground-level ozone concentration

The development of ground-level ozone concentrations, unlike previous assessments based mainly on three-year periods, is based on air pollution characteristics in one year, specifically, on average maximum daily 8-hour concentration for a given type of station and for all stations. This air pollution characteristic can be compared with the long-term air pollution target for ground-level ozone (120 $\mu g.m^{-3}$, Tab. I.2). Maximum daily 8-hour concentration (average for all stations for which the measurement is available for the whole evaluated period) ranged from approx. 140 $\mu g.m^{-3}$ to 170 $\mu g.m^{-3}$ in the 2009–2019 period.

Ozone concentrations have not shown a significant course since 2009; the highest concentrations (average for all stations) were measured in 2013, 2015 and 2018 (Fig. IV.4.9). All these years are characterized by the occurrence of favourable meteorological conditions for the formation of ozone – in 2013 high concentrations of O_3 occurred especially at the turn of July and August during a number of tropical days. The years of 2015 and 2018 were exceptionally above average in terms of temperature and strong below average in terms of precipitation. The value of the concentration in 2019 (150.7 $\mu g.m^{-3}$) ranks fifth in the eleven-year period 2009–2019 and is very close to the value of the concentration of the ten-year average.

Emissions of precursors and meteorological conditions, i.e. intensity and length of sunshine, temperature, wind speed and precipitation or relative air humidity, respectively, play a crucial role in evaluating concentrations (Blanchard et al. 2010; Ooka et al. 2011). However, the relationship between the amount of precursors emitted and ground-level O_3 concentrations is not linear. This non-linearity is caused by complicated atmospheric chemistry of O_3 formation and destruction, long-range transport of O_3 and its precursors and other factors including meteorological conditions (Chap. IV.4.3), and climate change, emissions of non-methane volatile organic compounds (NMVOC) from vegetation and forest fires (EEA 2013b). With regard to the above mentioned factors and also to the dependence of O_3 concentrations not only on absolute quantity but also on the relative share of its precursors in the air, it is difficult to comment on the year-to-year changes.

Based on the results of long-term monitoring in the CR where a 25-year series of O_3 concentrations is available at a number of stations, its long-term trends can be meaningfully evaluated despite the high year-to-year variability of O_3 (Weatherhead et al. 1998). A detailed analysis of spatio-temporal trends of long-term monitoring by 26 stations of varying types (urban, rural, mountain) for the 1994–2015 period indicated that despite substantial decrease of precursors emissions and of O_3 pollution concentrations at a majority of stations, O_3 represents still a considerable problem for the Czech Republic. It has been clearly demonstrated that for the appropriate decrease of O_3 levels the NO/NO_2 ratio is critical and a concurrent substantial decrease of NO_x emissions alone is not therefore sufficient for decrease of O_3 concentrations (Hůnová, Bäumelt 2018). The analysis of changes in the spatial distribution of O_3, specifically the characteristics of the AOT40 exposure index for the 2000–2015 period indicated that the area permanently affected by high exposure is mainly the southern part of the Czech Republic, probably related to the length and intensity of solar ra-

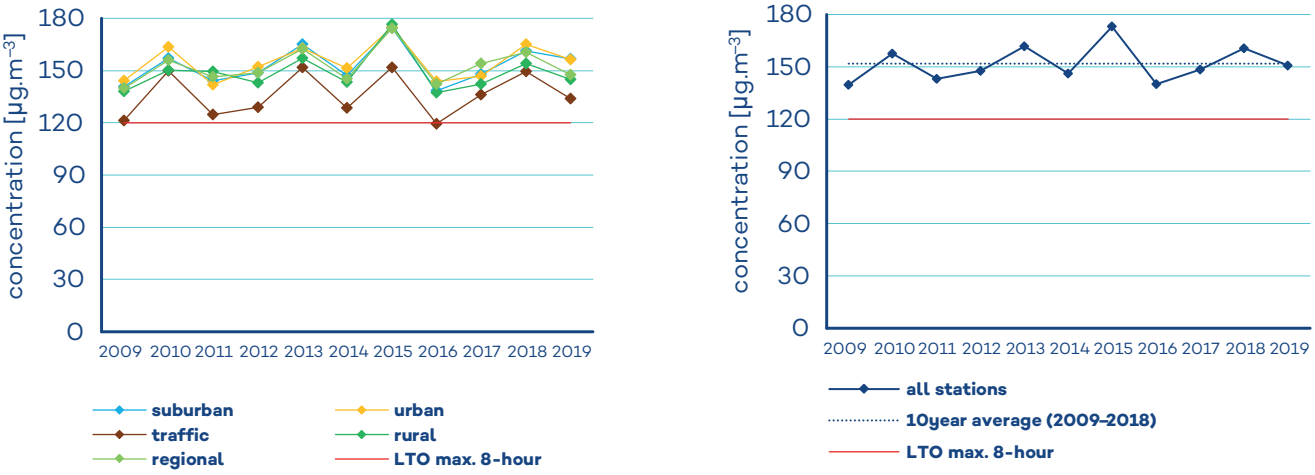

Fig. IV.4.9 Concentrations of ground-level ozone (maximum daily 8-hour running average), at particular types of stations in the Czech Republic, 2009–2019

diation (Hůnová et al. 2019a). The significant influence of meteorological conditions and air pollution on the daily variability of O_3 concentrations was confirmed also through the measured data. In addition to the influence of individual explanatory variables on the daily O_3 concentrations, the interactions between certain meteorological characteristics, such as between temperature and solar radiation, temperature and relative humidity, and solar radiation and relative humidity, have also been statistically significant for daily variability of O_3 (Hůnová et al. 2019b).

IV.4.3 Formation of ground-level ozone

O_3 does not have a significant source of its own in the atmosphere. This is a "secondary" substance formed by a number of complicated non-linear photochemical reactions (e.g. Seinfeld and Pandis 2006). Precursors of O_3 include nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOC), while methane (CH_4) and carbon monoxide (CO) play a role on a global scale. The photolysis of NO_2 by solar radiation with wavelength of 280–430 nm is an important reaction, forming NO and atomic oxygen. O_3 molecules are formed by the reaction of atomic and molecular oxygen in the presence of a catalyst. Simultaneously, O_3 is titrated by nitrogen monoxide, NO, with the formation of NO_2 and O_2. If O_3 is replaced by radicals in this reaction, its concentration increases in the atmosphere. The OH radical plays an especially important role in this reaction (in more detail e.g. Hůnová, Bäumelt 2018). NO_x are formed in all combustion processes. NMVOC are emitted from a number of anthropogenic sources (transport, manipulation with petroleum and its derivatives, refineries, the use of coatings and solvents, etc.), and also natural sources (e.g. biogenic emissions from vegetation).

In the formation of O_3 not only the absolute amount of precursors is important but also their relative share (Sillman et al. 1990; Fiala, Závodský 2003). In areas where the regime is limited by NO_x, characterized by relatively low concentrations of NO_x and high concentrations of VOC, the O_3 concentrations increase with increasing NO_x concentrations, but only minimally with increasing VOC concentrations. On the other hand, in areas with a regime limited by VOC, the O_3 concentrations decrease with increasing NO_x concentrations and the O_3 concentrations increase with increasing VOC concentrations. Areas with a high NO_x/VOC ratio are typically polluted areas around the centres of large cities. The dependence of the formation of O_3 on the initial concentrations of VOC and NO_x is frequently expressed by ozone isopleth diagrams, which depict the maximum attained O_3 concentration as a function of the initial NO_x and VOC concentrations (Moldanová 2009). Not only the concentrations of precursors, but also meteorological conditions, play an important role in the formation of O_3 (Colbeck, Mackenzie 1994). The pollution concentrations of O_3 increase with increasing ultraviolet radiation and temperature but decrease with increasing relative air humidity. These relations were also demonstrated on the results of long-term CHMI measurements (Hůnová et al. 2019a). High concentrations are often related to prolonged anticyclone situations. In addition to the above-described photochemical mechanisms, the concentrations of O_3 can also increase in episodes as a result of penetration of stratospheric O_3 into the troposphere and also during thunderstorms. Recently, there has also been an increase in the importance of long-range of O_3 in the northern hemisphere to Europe and North America from source areas in south-east Asia. O_3 is removed from the atmosphere by reaction with NO, the mechanism of dry or wet deposition and interaction with plants (stomatal uptake).