ESTIMATE OF THE EFFECTS OF NATIONAL AND INTERNATIONAL SOURCES ON AIR POLLUTION

To calculate the effect of Czech air pollution sources on the air quality outside the Czech Republic territory, or the effect of foreign air pollution sources on the air quality of the Czech Republic, the chemical transport model CAMx (Ramboll Environ, 2018) was used. The methodology chosen was based on altering the emission values from the examined sources which lead to changes in the modelled concentration of air pollutants. This methodology offers two calculation options: partial or complete reduction of emission values from the investigated sources. The partial reduction of emission values eliminates the problem of the nonlinearity of atmospheric chemistry, on the other hand, it does not provide information about the overall impact of the investigated air pollution sources. Reducing the emissions from selected sources to zero leads to changes in the atmospheric chemistry, and e.g. the conversion of gaseous precursors to particles then takes place at a different speed than if all sources are included in the model. The results of both calculation options that can be used to determine the impact of foreign sources on the Czech territory are compared in the analytical part of the update to the air quality improvement programme. Based on the comparison, the impact of foreign and Czech air pollution sources to the air quality was assessed in this document and in air quality improvement programme via zeroing the emissions.

In this paper, we present the results obtained by reducing the emissions of Czech or foreign air pollution sources to zero. Along with emissions from anthropogenic sources, biogenic emissions were also set to zero on the corresponding territory. When examining the impact of foreign sources on the Czech territory, the boundary values were also set to zero.

If C_{REF} denotes the concentration obtained from the reference run (i.e. including all emission sources), C_{Z0} denotes the concentration obtained when zeroing the foreign emissions and C_{C0} denotes the concentration obtained in zeroing Czech emissions, then the percentage of contribution of foreign sources on the air quality was calculated using the following formula:

$$P_{ZAHR} = \frac{C_{REF} - C_{Z0}}{C_{REF}} \cdot 100 \quad (1)$$

and the share of Czech sources was calculated using the formula below:

$$P_{CZ} = \frac{C_{REF} - C_{C0}}{C_{REF}} \cdot 100 \quad (2)$$

If we add up the resulting contribution of Czech and foreign sources on the air quality and divide it by the concentration from the reference run, we get an estimate of the error that we make due to the nonlinearity of chemical reactions in the atmosphere. While for the passively dispersed substances (such as primary PM_{10} and $PM_{2.5}$) the ERROR equation (3) is equal to exactly one, for the other substances we can obtain either a higher or a lower concentration than would correspond to the reference run. In this way it is possible to make a first estimate of the error in determining the share of Czech or foreign sources on the quality, calculated as described above.

$$ERROR = \frac{(2 \cdot C_{REF} - C_{C0} - C_{Z0})}{C_{REF}} \quad (3)$$

For completeness it should be added that the following assessment, unlike the assessment carried out in the air quality improvement programme, divides the secondary pollution to a part of foreign origin and a part of Czech origin. Air quality improvement programmes assess secondary pollution collectively regardless of its place of origin. The CAMx model results in the air quality improvement programmes were also rescaled using a detailed Symos'97 model that has a resolution of 0.5x0.5 km (CAMx uses a calculation grid of 4.7x4.7 km). The results of the National Emission Reduction Programme and the air quality improvement programmes are therefore mutually comparable only to a limited extent due to the use of a different approach to secondary pollution and different scaling.

The total contribution of Czech and foreign air pollution sources to the average annual concentration of PM_{10} and $PM_{2.5}$ is shown in Figure 1, or Figure 2. The estimation error caused by nonlinearity of atmospheric chemistry is manifested mainly in the Czech territory, where the sum of contributions from Czech and foreign air pollution sources ranges between 1.1 and 1.3 times the average annual concentration of the reference run. Outside the Czech territory, this ratio ranges between 0.9 and 1.1. In areas outside CZ situated close to the CZ borders (especially in the north and southeast), Czech air pollution sources can contribute around 20-30% to the annual average concentration of PM_{10} and $PM_{2.5}$. In the wider area, the contribution varies between 10 and 20%. Due to the above mentioned estimation error it can be expected that the contribution of foreign air pollution sources to the air pollution in the Czech Republic will be somewhat lower than shown in Figure 2 and will in most regions range between 30-50% of the annual average for PM_{10} and 40-60% of the annual average for $PM_{2.5}$.

The contribution of primary particles from Czech air pollution sources is shown in Figure 3. This estimate is not burdened by the estimation error, because the primary particles in the chemical mechanism of the CAMx model do not undergo chemical reactions. In border areas outside the Czech Republic (i.e. up to 40 km from CZ border), the Czech air pollution sources contribution to the air pollution within those areas ranges between 10-20% (the contribution to the PM_{10} concentrations is more significant than to the $PM_{2,5}$ concentration). The impact of primary particles from foreign sources to the Czech air quality is particularly important in the northeast of Moravia where it ranges between 10-20% of the annual average for PM_{10}, or for $PM_{2.5}$. In the immediate vicinity of the border with Poland, the foreign air pollution sources can contribute up to 20-30% of the Czech annual average of PM.

The contribution of secondary inorganic particles is shown in Figure 4. The nonlinearity of atmospheric chemistry is manifested more strongly in particular in the Czech territory, where the sum of contributions from Czech and foreign sources ranges between 1.1 and 1.5 times the average annual concentration of the reference run. It can therefore be expected that the calculated shares of secondary particles from Czech and/ or foreign sources in the annual average will be overstated in the Czech territory. The contribution of secondary particles from Czech air pollution sources to the air pollution outside the Czech Republic is 10-20% of the average annual concentration of PM_{10}, or $PM_{2.5}$; the effect of Czech air pollution sources can be locally detectable up to130 km from the Czech border. Taking into account the expected overestimation of the contribution of secondary particles to the average annual concentration of PM in the Czech Republic, their share can be expected at 20-40% of the annual average of PM_{10} and 30-50% of the annual average of $PM_{2.5}$.

Separate contributions of sulphates, nitrates and ammonium ions to the air pollution are shown in Figures 5 to 7. While for the ammonium ions, the sum of the contribution of Czech and foreign sources varies between 1.1 and 1.5 times the average annual concentration of the reference run and this overestimation is tied mainly to the Czech territory, for nitrates the overestimation is higher (about 1.3-1.8 times the reference run) and even in foreign territory, mainly to the northeast of the Czech Republic, it is about 1.1 to 1.3 times the reference run. Conversely, for sulphates, the sum of Czech and foreign contribution is smaller than would correspond to the reference run (about 0.7-0.9 and 0.5-0.7 in the Northwest zone) and this undervaluation is tied mainly to the Czech territory.

Figure 1: The total contribution of Czech and foreign air pollution sources to the average annual concentration of PM_{10}, incl. an error of the estimate

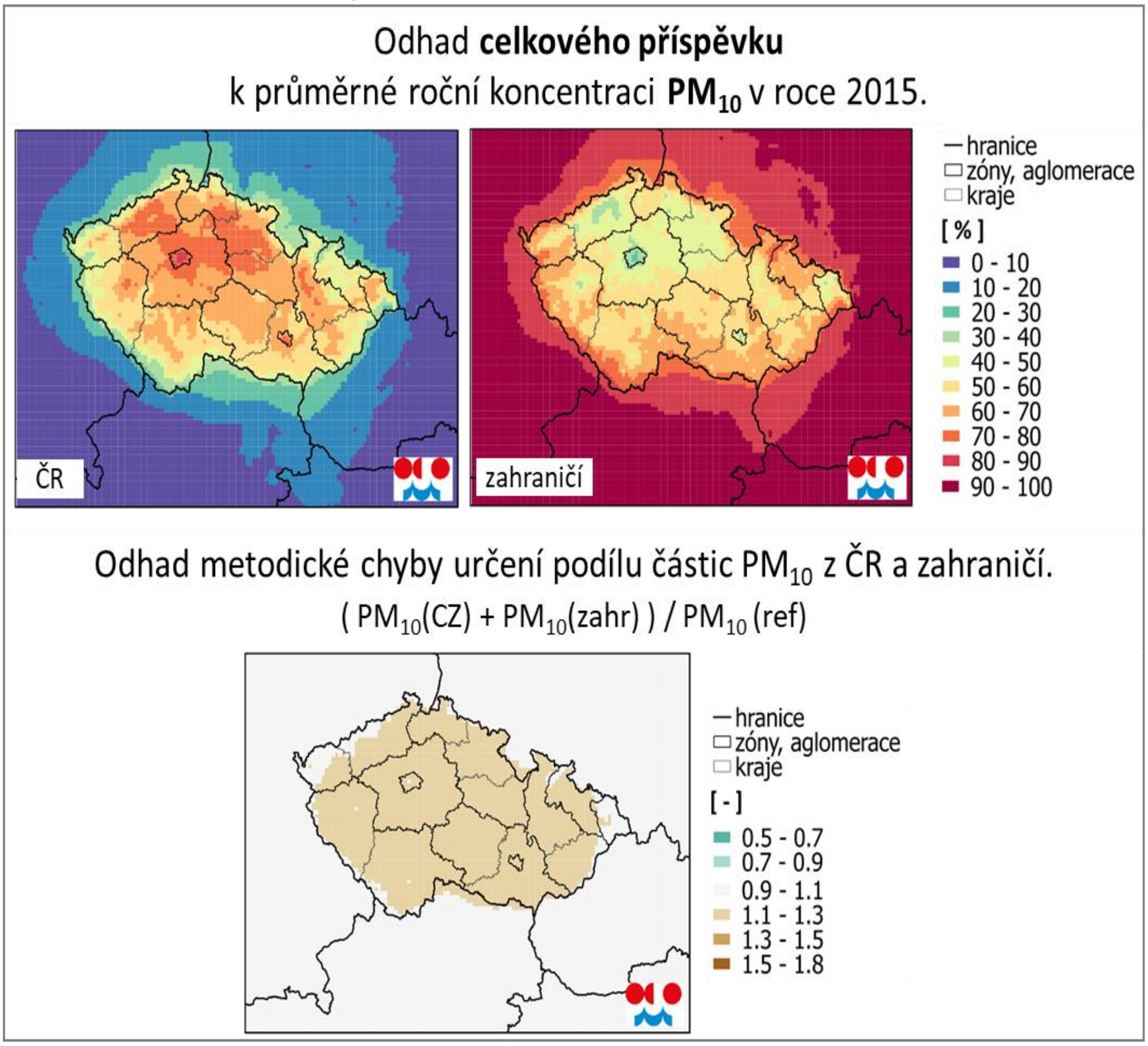


Figure 2 : The total contribution of Czech and foreign air pollution sources to the average annual concentration of $PM_{2.5}$, incl. an error of the estimate

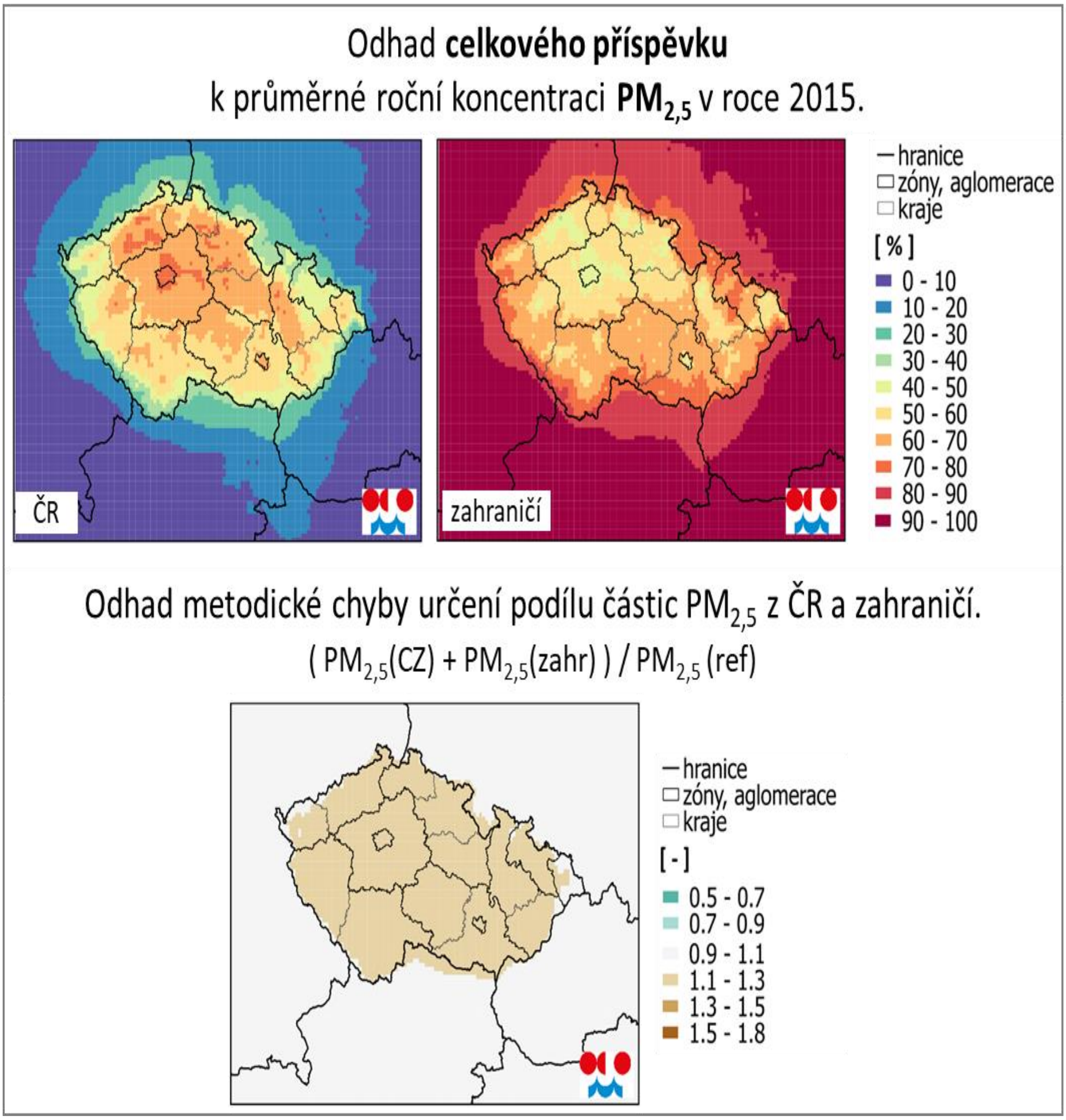


Figure 3 : Contribution of primary particles from Czech and foreign air pollution sources to the average annual concentration of PM_{10} or $PM_{2.5}$

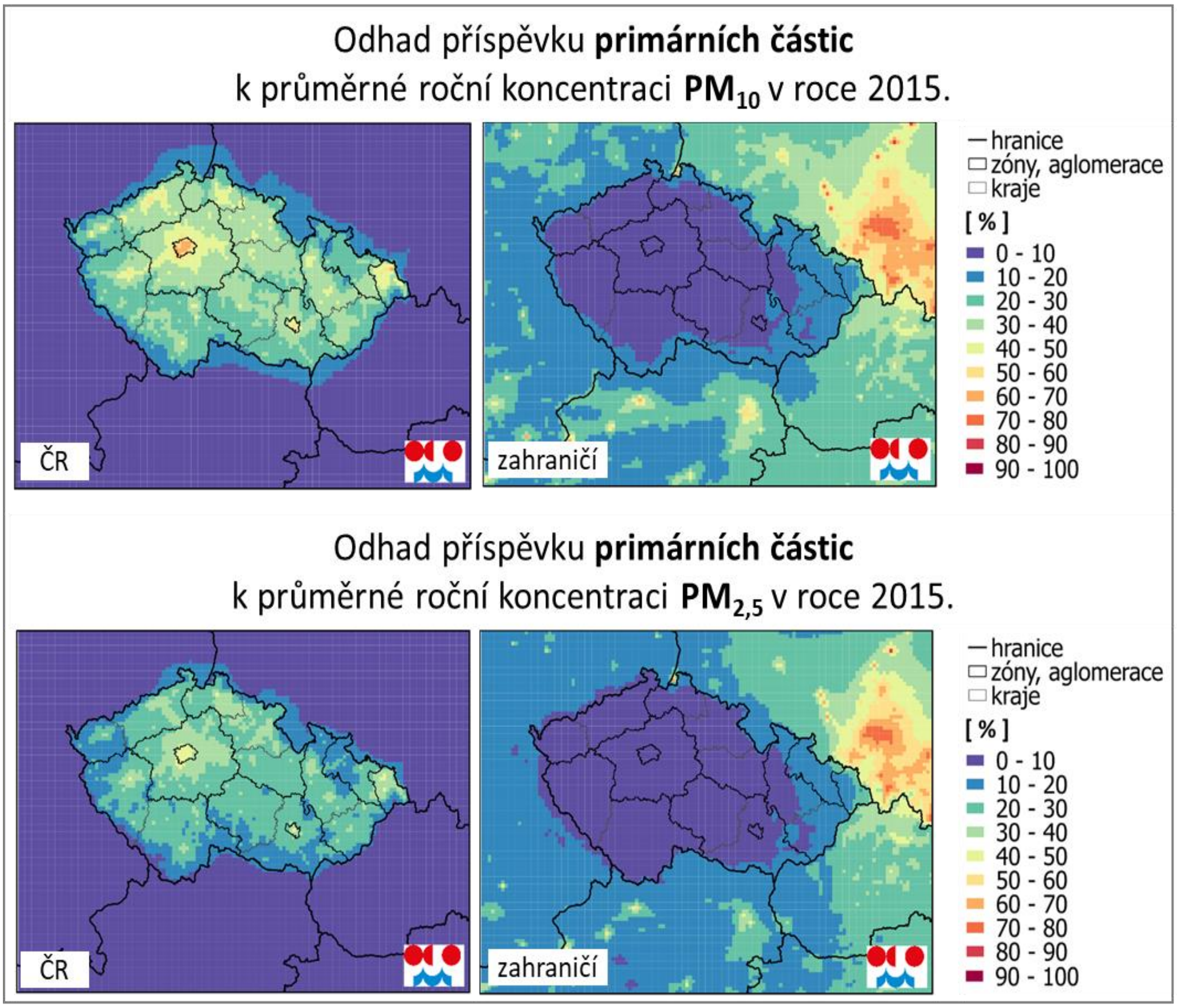


Figure 4: Contribution of secondary inorganic particles from Czech and foreign precursors to the average annual concentrations of PM_{10}, or $PM_{2.5}$, incl. an error of the estimate

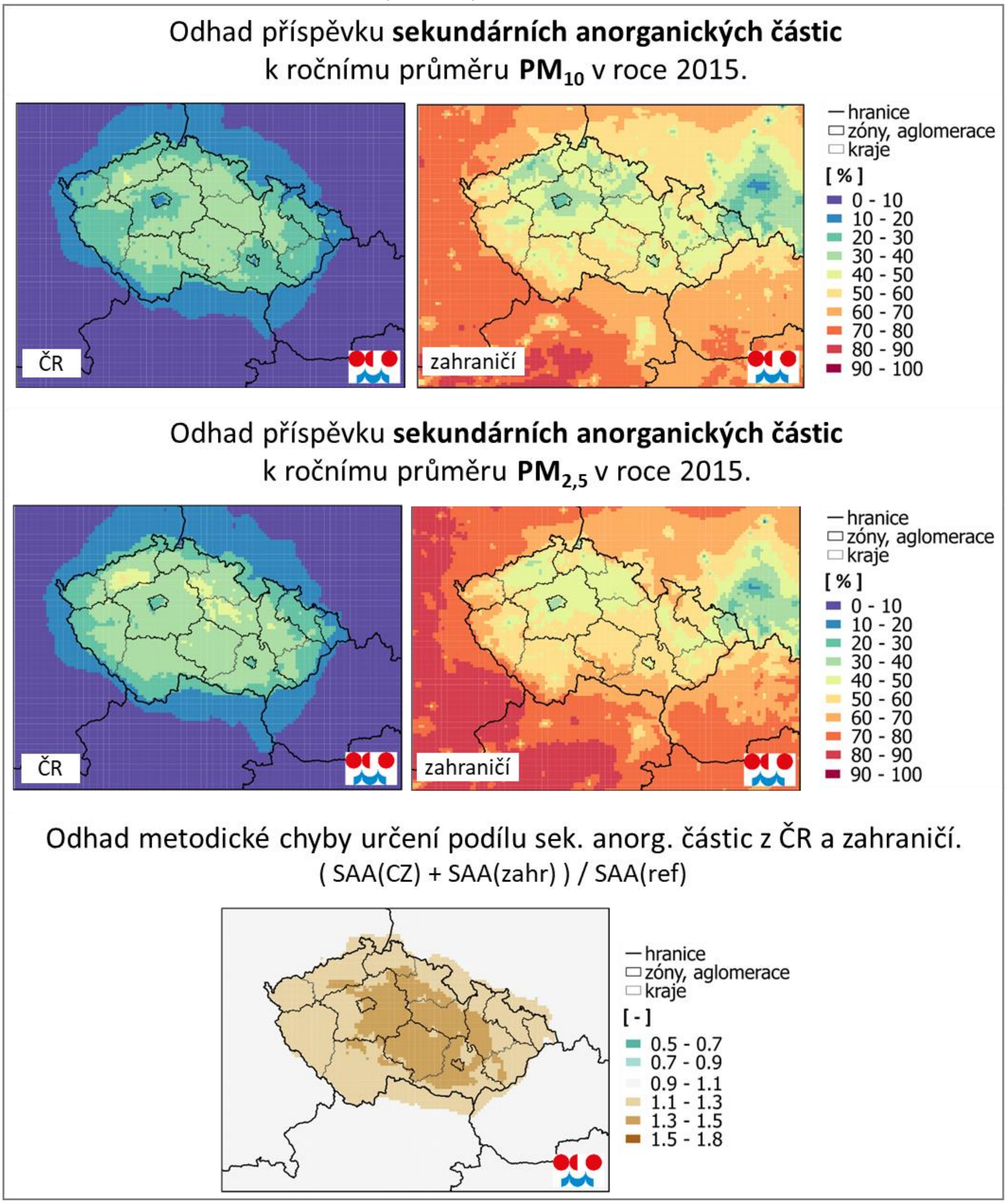


Figure 5 : Contribution of sulphates from Czech and foreign precursors to the average annual concentrations of PM_{10}, or $PM_{2.5}$, incl. an error of the estim

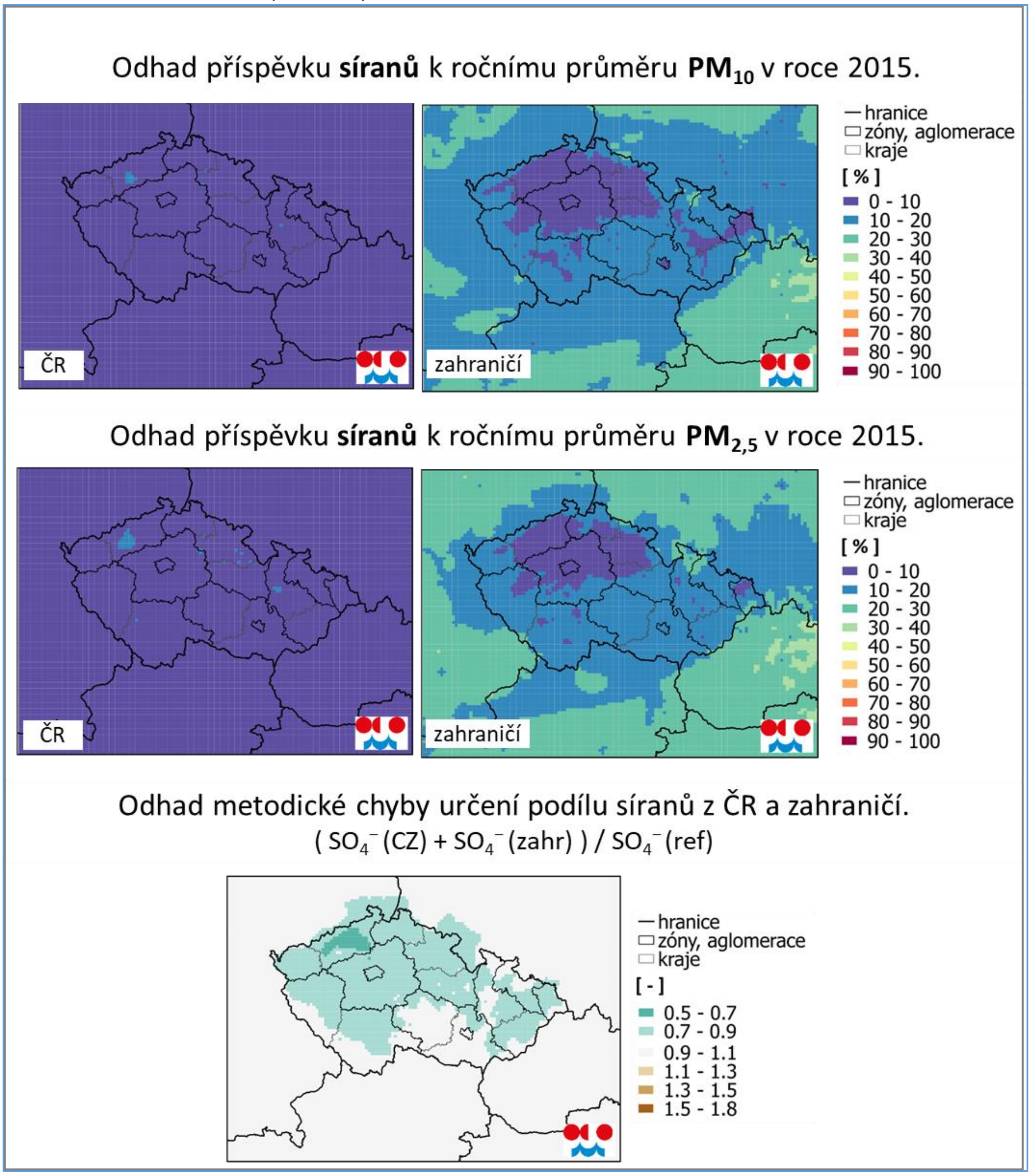


Figure 6: Contribution of nitrates from Czech and foreign precursors to the average annual concentrations of PM_{10}, or $PM_{2.5}$, incl. an error of the estimate

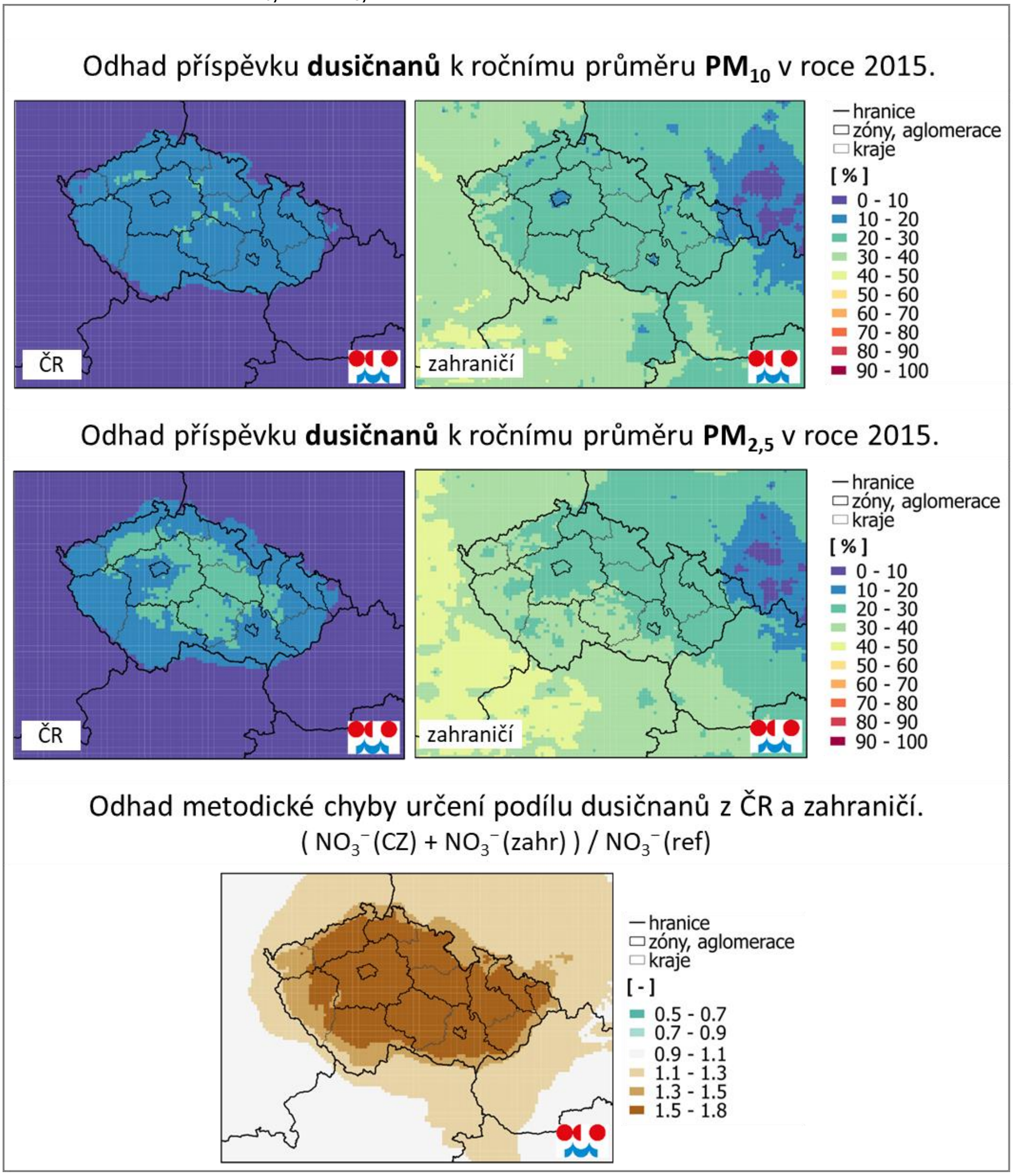
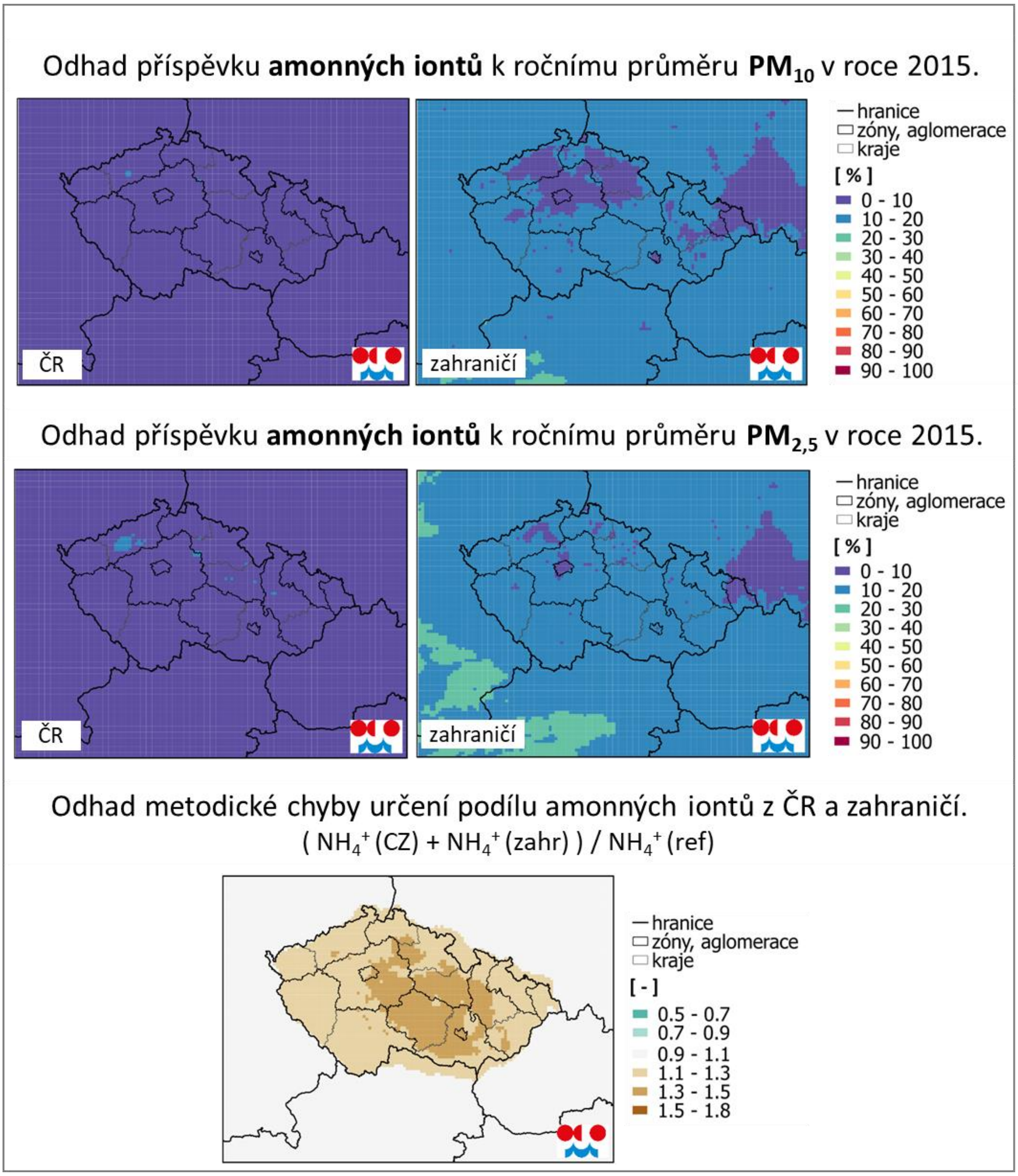


Figure 7 : Contribution of ammonium ions from Czech and foreign precursors to the average annual concentrations of PM_{10}, or $PM_{2.5}$, incl. an error of the estimate



The analyses of causes of pollution show the following conclusions on the share of Czech and foreign sources on the air pollution:

- Close to the borders (especially in the north and southeast areas outside CZ), Czech air pollution sources can contribute around 20-30% to the annual average concentration of PM_{10} and $PM_{2.5}$. In the wider area the contribution varies between 10 and 20% (aggregate evaluation of primary and secondary particles).

- The contribution of foreign sources to the air pollution of the Czech Republic can in most areas range between 30-50% of the annual average of PM_{10} and between 40-60% of the annual average of $PM_{2.5}$ (aggregate evaluation for the primary and secondary particles).
- **The contribution of primary particles** from Czech air pollution sources in border areas outside the Czech Republic (i.e. up to 40 km) is about 10-20% and is more significant for PM_{10}.
- **The impact of primary particles from foreign air pollution sources** is particularly important in northeast Moravia where it ranges between **10-20%** of the annual average of PM_{10}, or $PM_{2.5}$. **In CZ Region in the immediate vicinity of the border with Poland, the impact of primary particles from foreign air pollution sources can contribute up to 20-30% of the annual average of PM.**
- **The contribution of inorganic particles from Czech air pollution sources** outside the Czech Republic is 10-20% of the average annual concentration of PM_{10}, or $PM_{2.10}$ and the contribution can be somewhere detectable up to 130 km from the Czech border.
- **The contribution of secondary inorganic particles from abroad to the annual average concentration of PM in the Czech Republic reaches 20-40% of the annual average of PM_{10} and 30-50% of the annual average of $PM_{2.5}$.**
- **The contribution of sulphates** from Czech air pollution sources to the air pollution level outside of the Czech Republic moves up to 7% of the annual $PM_{2.5}$ average. Conversely, sulphates from foreign air pollution sources contribute to the annual $PM_{2.5}$ average in most regions of the Czech Republic at up to 16%. In 2015 , 60% of sulphur oxides emissions of the Czech Republic originate from the public energy sector and heat production, 14% originated from local home heating and the rest are smaller proportions of other sectors which individually do not exceed 7%.
- **The contribution of nitrates** from Czech air pollution sources outside to the air pollution level outside the Czech Republic moves up to 7% (in the immediate vicinity of the border it reaches 10%) of the annual $PM_{2.5}$ average. Conversely, nitrates from foreign air pollution sources contribute to the annual $PM_{2.5}$ average concentrations in most regions of the Czech Republic at up to 20%. In 2015, 30% of the nitrogen oxides emissions originated from the public energy sector and heat production, 30% originated from road and non-road transport and the rest are smaller proportions of other sectors, which individually do not exceed 5%.
- **The contribution of ammonium ions** from Czech air pollution sources to the air pollution level outside the territory of the Czech Republic moves up to 5% of the annual $PM_{2.5}$ average (in remote areas up to 3%). Conversely, ammonium ions from foreign air pollution sources contribute to the annual $PM_{2.5}$ average in the Czech Republic at max. 10%. The main source of ammonia is agriculture, which in 2015 was responsible for 88% of its anthropogenic emissions in the Czech Republic[1].

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[1] http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emepdatabase/reported_emissiondata/