Modelling and Evaluation of Concentration, Deposition and Loadings Patterns Resulted from Continuous Emissions of the Severonickel Smelters (Kola Peninsula)

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Abstract

In this study, evaluation of potential impact on population and environment due to continuous anthropogenic emissions (on example of sulfates, mild scenario of sulfates emissions) of the Cu-Ni smelters of the Russian North is presented. To estimate such impact, the Danish Emergency Response Model for Atmosphere was employed to perform long-term simulations of air concentration, time integrated air concentration, dry and wet deposition patterns resulting from continuous emissions of the Severonickel smelters located on the Kola Peninsula (Murmansk region, Russia) using the European Center for Medium-Range Weather Forecasts (ECMWF) three-dimensional meteorological fields for the year 2000 as input. Detailed analyses of simulated concentration and deposition fields allowed evaluating the spatial and temporal variability of resulted patterns on different scales including estimates for surrounding regions and the most populated cities of the North-West Russia.

Pollution from Cu-Ni Smelters

There are several major locations in the Russian Arctic associated with large amounts of SO_2 and heavy metals emissions and known as Cu-Ni smelters having a largest environmental impact. These are 3 Russian enterprises: Norilsk Nickel (Krasnoyarsk Krai); Pechenganickel (cities of Zapolayrnyy and Nickel) and Severonickel (city of Monchegorsk, Murmansk region) (see Fig. 1).

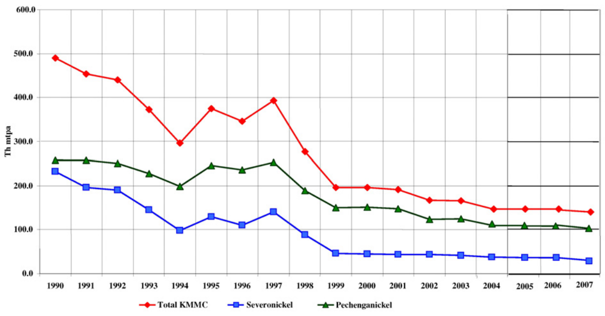


Figure 1 *: Inter-annual variability of SO_2 emissions from the Pechenganickel and Severonickel enterprises /source — presentation of the Open Joint Stock Company KMMC, Norilsk Nickel Mining & Metallurgical Company; Apr 2008)*

Long-Term Modelling of Continuous Emissions

To estimate potential impact on population and environment due to continuous anthropogenic emissions (on example of sulfates) of the Cu-Ni smelters of the Russian North, the Danish Emergency Response Model for Atmosphere (DERMA) was employed (following approach in *Baklanov et al., 2006; Mahura et al., 2005*) to perform long-term simulations of air concentration, time integrated air concentration (TIAC), dry (DD) and wet (WD) deposition patterns (Fig. 2) resulting from continuous emissions of the Severonickel smelters located on the Kola Peninsula (Murmansk region, Russia). To perform such simulations the European Center for Medium-Range Weather Forecasts (ECMWF) three-dimensional meteorological fields for the year 2000 were used as input. For simplicity, it has been assumed that the daily unit releases of sulfates from smelters location occurred at a constant rate of 10^9 μg/sec (i.e. 86.4 ton per day). Then, for each daily release the followed atmospheric transport, dispersion, and deposition on the underlying surface due to dry and wet removal processes were estimated on intervals ranging from 0.5 to 10 days.
Moreover, it should be noted that output from such long-term simulations is an essential input for evaluation of impact, doses, risks, and short- and long-term consequences, etc.

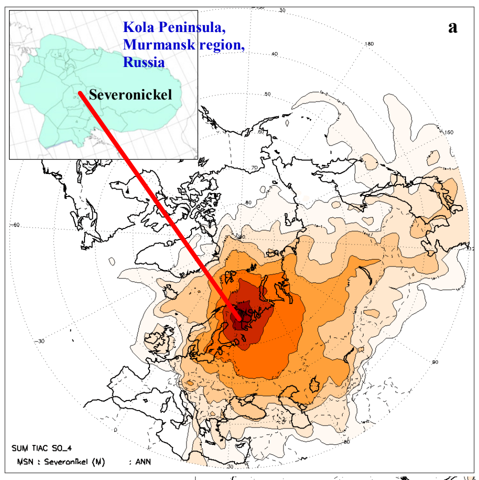
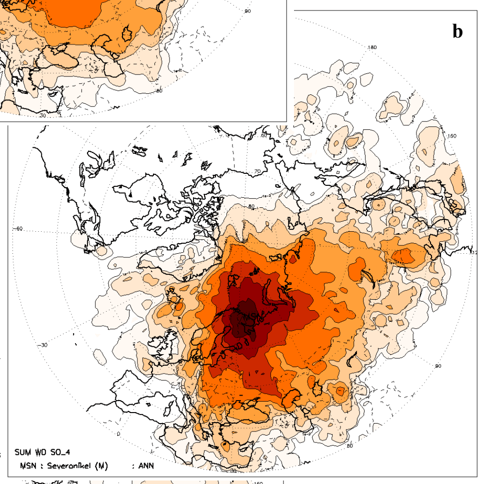
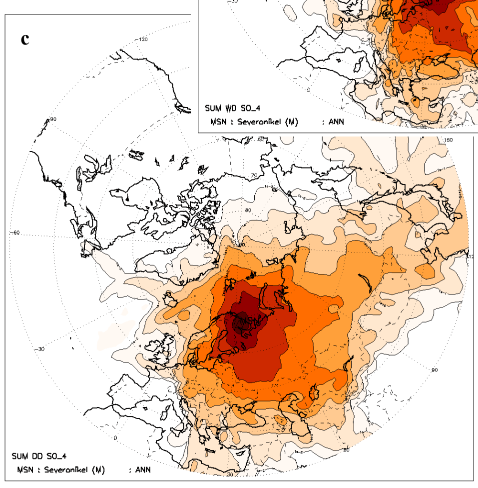


Figure 2 *:*
Spatial patterns of the yearly (2000) summary

(a) time integrated air concentration of sulfates



(b) dry deposition of sulfates



(c) wet deposition of sulfates

due to continuous emissions from the smelters of the Severonickel (isolines are shown starting from 1e-4).

Monthly Variability of Dry and Wet Deposition Patterns

Detailed analyses of simulated concentration and deposition fields allowed evaluating the spatial and temporal variability of resulted patterns on different scales. Temporal variability of both wet and dry deposition as well as their contribution into total deposition have been estimated following approach by *Mahura et al. (2007)*. The concentration and deposition patterns were estimated for the most populated cities of the North-West Federal District of Russia following approach by *Mahura et al. (2006)*.

It has been found (Fig. 3) that for the "mild scenario emissions" (i.e. approx. 31.6 ths. ton), for the Severonickel smelters, the annual average daily dry deposition value is 6 ton. The highest average DD (10 ton) is in September, and the lowest – less than 3 ton – in April. The annual average daily wet deposition is about 23 tons, and a strong month-to-month variability is seen compared with dry deposition. The highest average WD (more than 50 ton) is in February, and the lowest – about 6 ton – in July. There are also differences in amount deposited in total from daily releases. On an annual scale, on average, 33% of emitted amount could be deposited at the surface during the considered duration (i.e. 10 days) of atmospheric transport. The highest deposited amount of 65% is observed in February and the lowest of 14% – in July.

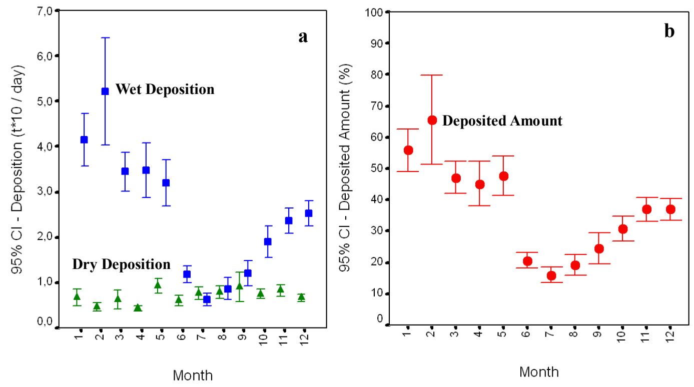


Figure 3 *: Month-to-month variability at 95% confidence interval of daily averaged (a) dry and wet deposition patterns (in ton/ day) and (b) deposited amount (in %) resulted from the Severonickel emissions of sulfates*

Taking into account actual annual (on example of year 2000) emissions of sulfur dioxide as 45.3 ths. ton (Severonickel smelters, city of Monchegorsk), the summary annual time integrated air concentration, dry and wet deposition were re-scaled and these have been estimated for most populated cities (Arkhangelsk, Petrozavodsk, Sankt-Petersburg, Syktyvkar, Pskov, and Vologda) of the North-West Federal District of Russia. It was found that among these cities, the TIAC is the highest – 86 μg/m^3 – for Arkhangelsk and the lowest – 4 μg/m^3 – for Pskov. Both dry and wet depositions were also the highest for Arkhangelsk – 0.5 and 2.2 *m*g/m^2, respectively.

The modeled annual fields were also integrated into GIS environment (Fig. 5) as well as layers with population density (Fig. 6) (from the Center for International Earth Science Information Network, CIESIN) and standard administrative division of the North-West Russia and bordering countries (Fig. 5). The estimation of deposited amounts (loadings) of sulfates for selected regions of Russia and border countries has been performed (Figs. 7-8). Furthermore, the atlas of potential impact from all locations of the Cu-Ni smelters was elaborated (Fig. 4) which included temporal (monthly) variability of both summary and averaged types of the TIAC, DD and WD fields.

Atlas of Potential Impact from Anthropogenic Sources

MSN: Monchegorsk (Severonickel)

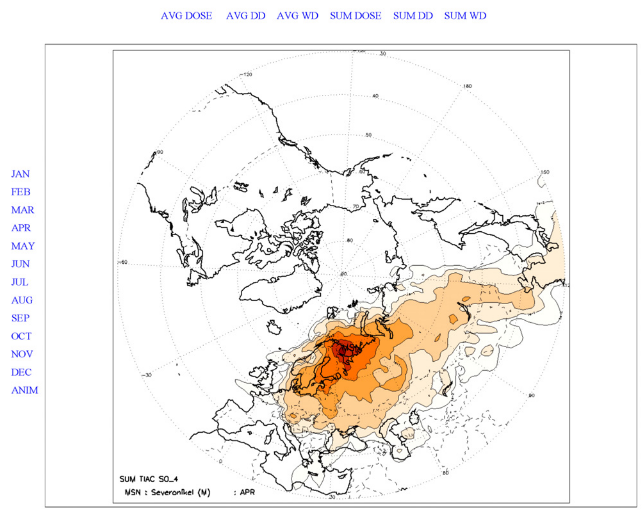


Figure 4*: Snapshot of Atlas showing spatial representation of the summary time integrated air concentration field during April resulted from continuous emissions of sulfates from Severonickel.*

GIS Evaluation of Severonickel Impact on Population

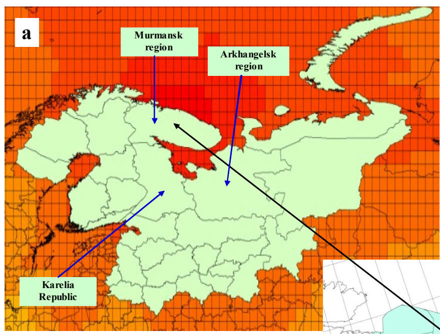
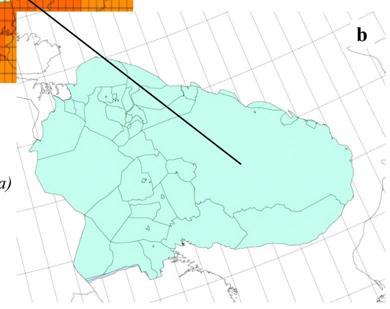


Figure 5 *: Geographical boundaries of territorial units (a) regions, provinces, autonomous republics, etc.; and*



(b) counties of the Murmansk region (Russia) - evaluation loadings from summary deposition.

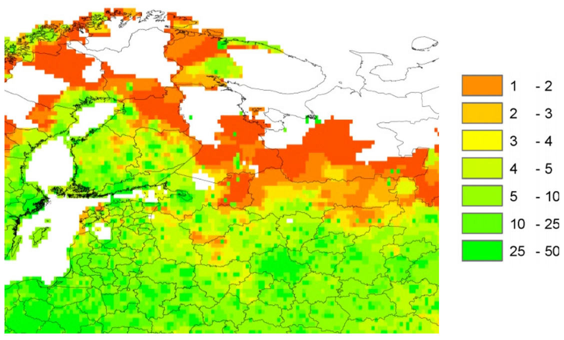


Figure 6 *: GIS integration of population density data into studied regions (only cells with density more than 1 person per sq. km are used)*

Detailed analysis showed that for regions surrounding the Kola Peninsula, on average (maximum), the total (dry plus wet) deposition was 0.6 (3.0), 1.8 (5.1), and 28.3 (122) *m*g/m^2 for the territories of the Arkhangelsk, Karelia, and Murmansk regions of Russia. For border regions with Scandinavian countries, on average (maximum), the total deposition was 2.2 (6.7) *m*g/m^2 in Finnmark (Norway); 0.2 (0.4) in Norrbotten and 0.03 (0.1) *m*g/m^2 in Vesterbotten counties (Sweden); 0.6 (1.2) in Eastern Finland, 2.2 (7.2) in Lapland, and 1.4 (2.9) *m*g/m^2 in Oulu provinces of Finland.
For population residing in the central and northern territories (in urban settlements) of the Kola Peninsula the yearly loading due to deposition of sulfates could be more than 40 kg/person. For bordering territories with the Murmansk region such loadings are less than 5 kg/person for the Eastern Finland, Karelia, and Arkhangelsk regions; and up to 15 kg/person – for the Northern Norway.

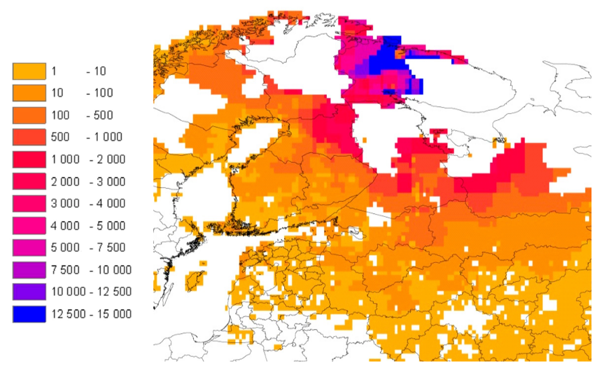


Figure 7: *Yearly loading (mg m^{-2} / person km^{-2}) for population from deposited sulfates from the Severonickel plant as a function of total deposition vs. density of population.*

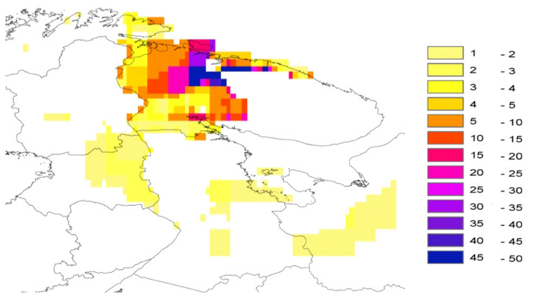


Figure 8: *Yearly loading (kg / person) for population (per 1 person) from deposited sulfates from the Severonickel plant.*

References

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