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THE FMI EMISSION INVENTORY AND SOURCE-RECEPTOR CALCULATIONS AT THE FINNISH EASTERN BORDER

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Abstract: The source-receptor calculations of EMEP between Finland and Russia have been discussed in the Finnish public media in autumn 2013 after the Russian environmental organization Green Patrol has abused western countries for pollution of the Kola Peninsula. The air pollution fluxes between Russia and Nordic countries calculated with the EMEP western center are based on emission data, which at the Russian side are significantly lower than other European emission estimates. In the paper, the FMI North-western Russian emission inventory is presented and the variation of the pollution fluxes between Finland, Russia and Baltic Sea are discussed.
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Key words: *emission inventory, deposition, sulphur, nitrogen, source-receptor matrixes*

INTRODUCTION

Concern on air pollutant effects on environment lead construction of common measurements programs since the 1950's and the OECD coordinated research program on long-range transport in the 1970's. The European Monitoring and Evaluation Programme (EMEP) was established in 1977 to observe by measurements the air quality trends at background stations. The international convention on long-range transboundary air pollution was signed in Geneve 1979 with Russia one of the participants. The estimates of intercontinental transport and pollution exchange between the neighbouring countries are based on the annual model simulations at the EMEP eastern and western center. The air pollution fluxes between adjacent countries are very sensitive to emission data used, thus the quality of emission inventories should be high and annually evaluated.

MATERIALS AND METHODS

Model

The contribution of the Kola Peninsula, Karelia, Leningrad-Oblast (KoKaLO) and Finland sulphur and nitrogen emissions to Finland, Kola Peninsula and Baltic Sea (BS) deposition was calculated with the regional grid model Hilatar of Finnish Meteorological Institute (FMI). The model, documented in Hongisto (2003) uses the FMI operative HIRLAM hydrostatic weather prediction model (HIgh Resolution Limited Area Model) meteorology and grid. The model has 0.068^o horizontal resolution and 21 vertical layers and it is off-line nested with the European Hilatar model with 0.15^o resolution. The chemistry module includes acid compounds of oxidized and reduced nitrogen (N) and sulphur (S).

The model use the MACC (2011) European emission inventory completed with the EMEP WebDab natural and missing country emissions, the FMI inventory for Finnish and north-western Russian sources, the specific Baltic Sea ship emission inventory (Jalkanen et al. 2009, 2012) and Finnish national stack and areal emissions. The time variation for other than ship emissions is based on the GENEMIS project 1990 country-specific emissions and on the diurnal and weekly traffic indices. The initial vertical mixing was estimated by using for gridded emissions for each S-emission class specific emission height profiles and for stack sources a plume rise algorithm.

The Finnish emissions inventory for North Western Russia

According to Mylona (1996) and Aardenne e.a. (2001) the European (Turkey and USSR included) SO_2 emissions increased by 8 to 12 times from 5 Mt to 40-58 Mt SO_2 between1880-1975 and started to decrease afterwards. The Kola Peninsula S emissions exceeded 700 kt SO_2 in 1984, decreased to 600 kt in 1990, 464 kt in 1997 and stayed at around the same level in the beginning of the 2000's (Tikkanen 1995, EMEP emission data base (DB) before 2004). The SO_2 emissions from Pensanga- and SeveroNikel plants decreased from 490 kt in 1990 to 196 kt in 2000 and 136 kt SO_2 in 2009 (Norilsk Nikel, 2013).

In 2004 the EMEP emission DB SO_2 emissions of Kola Peninsula were reduced from 450-480 kt SO_2 to 32.4 kt SO_2 and further to 18.7 kt in the year 2010 inventory. At the same time also the emission estimates before 2004 were reduced to the same low level. There have also been unexpected stepwise changes in the Russian oxidized nitrogen (NO_x) emissions in Leningrad Oblast and St. Petersburg between the adjacent inventories. Comparison of EMEP and MACC inventories confirms that the emissions used in official calculations of country to country transport budgets should be verified. In 2007 the SO_2 emission sum over the Murmansk region was 21 204 t SO_2 in the EMEP inventory, 289 319 t SO_2 in the MACC inventory, while the MACC NO_x emissions (19 kt NO_2) were lower than the corresponding EMEP emissions (35 kt NO_2). Evidence of existing emission sources at Kola Peninsula can be detected from border area measurements. Nikel, Zapoljarnyi, Monchegorsk, Kirovsk, Apatity and Kovdor are among the highest pollution targets of the environmental hot-spot list of Barentsinfo (2013), and Norilsk Nikel environmental reports show the real, high emissions of Nikel and Zapoljarnyi on the internet.

FMI has maintained an own emission inventory for north-west Russia since the 1990's (Hongisto e.a., 1995, Häkkinen e.a., 1995). The year 2009-2011 the St Petersburg emissions were given by the city authorities for FMI commercial projects, for the rest areas the emissions are updated with all information available. For the year 2011 the total sum of SO_2 emissions used in the simulations were 240 462, 63406 and 51553 t SO_2 and 25600, 18700 and 92940 t NO_2, for Kola Peninsula, Karelia and Leningrad Oblast (LO), respectively. They were split among the Si-classes 1-10. A minor share 0.01-0.2 % of the total emissions were divided over the whole respective land areas evenly, know point sources presented partly in Table 1 (41 in Kola peninsula, 34 in Karelia and 15 in LO) were allocated to the respective grids, the traffic emissions (sectors S7 and S8) were distributed along the main roads and city traffic and the rest emissions were divided between the main urban areas (30 in Karelia, 79 in LO, 33 in Kola Peninsula) with population number weighting.

RESULTS

The deposition of sulphur and nitrogen from Kola Penisula, Karelia and Leningrad Oblast (KoKaLO) emissions and separately from Kola Peninsula and from Finnish emissions in 2011 is presented in Figure 1, the monthly variation of KoKaLO emissions in Figure 2 and the deposition sums to the target areas in Table 2. Only grids where the target area share is > 99% were included in the budgets because of the seashore gradients, thus the target areas were 319 000, 372 000, 496 000 and 135 000 km^2 for Finland, BS, KoLaLO and Kola Peninsula, respectively.

The KoLaLO deposition share exceeded 50 % along the whole Finnish-Russian border being higher, >80 % near the Kostamus and Kola Peninsula sources. The iron pellet factory at Kostamus, missing also from the MACC inventory, has three separate production lines with own stack for flue gases; one of them is furnished with a flue gas desulphurization process, but it has never been in operation. The emission of Kostamus was calculated with 4000 h operating hours and design value of the S content in the flue gases for the Lifac equipped line. With full capacity operation the emissions are higher.

According to the simulations the KoKaLO emissions contributed by 15 kt S and 4.6 kt N to the Finnish sulphur and NO_x depositions while the contribution to the BS deposition was 2.6 kt S and 1.6 kt N. The Kola Peninsula contribution to Finland was 6.3 kt S and 1.6 kt N and to BS only 0,3 kt both N and S. The BS ship-emission (95 kt SO_2 in 2011) originated sulphur deposition contributed by 15 kt S and N to the BS deposition. The Kola NOx deposition originated from Finnish emissions was 5.7 kt N, it decreased from 7-10 % at the Finnish border to < 2 % of the total NO_x deposition at the Kola Peninsula.

According to the source-reception tables of EMEP status report 1/2013 total Russian contribution to the Finnish S deposition in 2011 was 8.3 kt S and to the NO_x deposition 14.3 kt N, and to the Baltic Sea (BS)

4.6 kt S and 20.8 kt N. The EMEP-calaulated Finnish contributions to Finland were 10.6 kt S and 7.9 kt N; the Finnish area used here is smaller, but in the Hilatar model the life time of S compounds seems to be longer. Because the Russian source area is much smaller in this study, the budgets between Finland and Russia cannot be directly compared.

In Lapland the high emissions from Kola industry are detected as high SO_2 concentration peaks, however wet deposition is low because of low precipitation amounts generally and especially during eastern winds, which are also rare in winter. Scavenging of SO_2 with snow is also weak, and the humidity- and temperature-dependent conversion of SO_2 to SO_4 is slow especially in winter. However, modelled dry deposition is rather high, as it should be: in Sevettijärvi, during the Lapland forest damage project, S deposition was three times higher in forest than in open measurement place indicating high dry deposition (Tikkanen 1995). Although the monthly variation of deposition from a single source area, especially when the target is not located downwind of main wind direction, has high inter-annual variation due to large-scale weather changes and blocking, the role of dry deposition can be detected from the high summertime deposition from Kola presented in Figure 2.

DISCUSSION AND CONCLUSIONS

In the old EMEP reports published in the 1990's the SO_2 emissions in Kola peninsula were > 600 000 t SO_2 in 1990, the sulphur mass exchange budgets between Finland and Russia were realistic and the EMEP model estimated sulphur deposition in parts of Kola Peninsula exceeded 1.5 g(S) m^{-2}. Since 2004 the pollution budgets strongly underestimate the role of Russian emissions. The purpose of the international institutes is to highline the main environmental problems for estimation the pollution reductions needed. Thus it would be recommended to check and correct the emissions used in official budget calculations.

REFERENCES

Aardenne J.A., Dentener F.J., Olivier J.G.J., Klein Goldewijk C.G.M. and Lelieveld J., 2001. A 1°×1° resolution data set of historical trace gas emissions for the period 1890-1990. *Global Biogeochemical cycles* Vol 15, No 4., pp. 909-928.

Barentsinfo, 2013. Barents environmental hotspots. http://www.barentsinfo.fi/beac/hotspots/ (9.12.2013)

Hongisto M., 2003. Modelling of the transport of nitrogen and sulphur contaminants to the Baltic Sea Region. FMI Contributions No. 40, Helsinki 2003, 188 p.

Hongisto M., Kangas L., Nordlund G., Markkanen K., Häkkinen A.,J., Kartastenpää R.,and Kivivasara J., 1995. Model calculations of the influence on Finland of air pollution sources in the areas of St. Petersburg, Leningrad Oblast Karelia and Estonia. Anttila P., Kämäri J., Tolvanen M., (ed´s) in Proc. of the 10th World Clear Air Congress, Espoo, Finland, Vol 2, 306. The Finnish Air Pollution Prevention Society, 1995.

Häkkinen A.J., Markkanen K., Hongisto M., Kartastenpää R., Milayaev V.B., Yasensky A., Kuznetsov V.I., Kopp I.Z. and Kivivasara J., 1995. Emissions in St. Petersburg, the Leningrad area and Karelia. In: Tolvanen M., Anttila P., Kämäri J. (Eds). ibid.

Jalkanen, J-P., Brink A., Kalli, J., Pettersson H., Kukkonen J. and Stipa T., 2009. A modelling system for the exhaust emissions of marine traffic and its application in the Baltic Sea area. Atmospheric Chemistry and Physics 9: 9209–9223. doi: 10.5194/acp-9-9209-2009.

Jalkanen, J-P., Johansson L., Kukkonen J., Brink A., Kalli J., and Stipa T.. 2012. Extension of an assessment model of ship traffic exhaust emissions for particulate matter and carbon monoxide. Atmospheric Chemistry and Physics 12: 2641–2659. doi:10. 5194/acp-12-2641-2012.

Mylona S., 1996. Sulphur dioxide emissions in Europe 1880-1991 and their effect on sulphur concentrations and depositions. *Tellus* 45B, 662-689.

Norilsk Nikel, 2013. http://www.kolagmk.ru/ecology/monitoring: see the link below to ppt presentation Презентация - Мониторинг окружающей среды в зоне влияния ОАО «Кольская ГМК» и рекультивация нарушенных земель 34 p. (9.12.2013)

Tikkanen E. (ed), 1995. The Kola Peninsula pollution stress for forest in Lappland. Final report of the East Lappland Forest damage project, 232 p. (in Finnish)

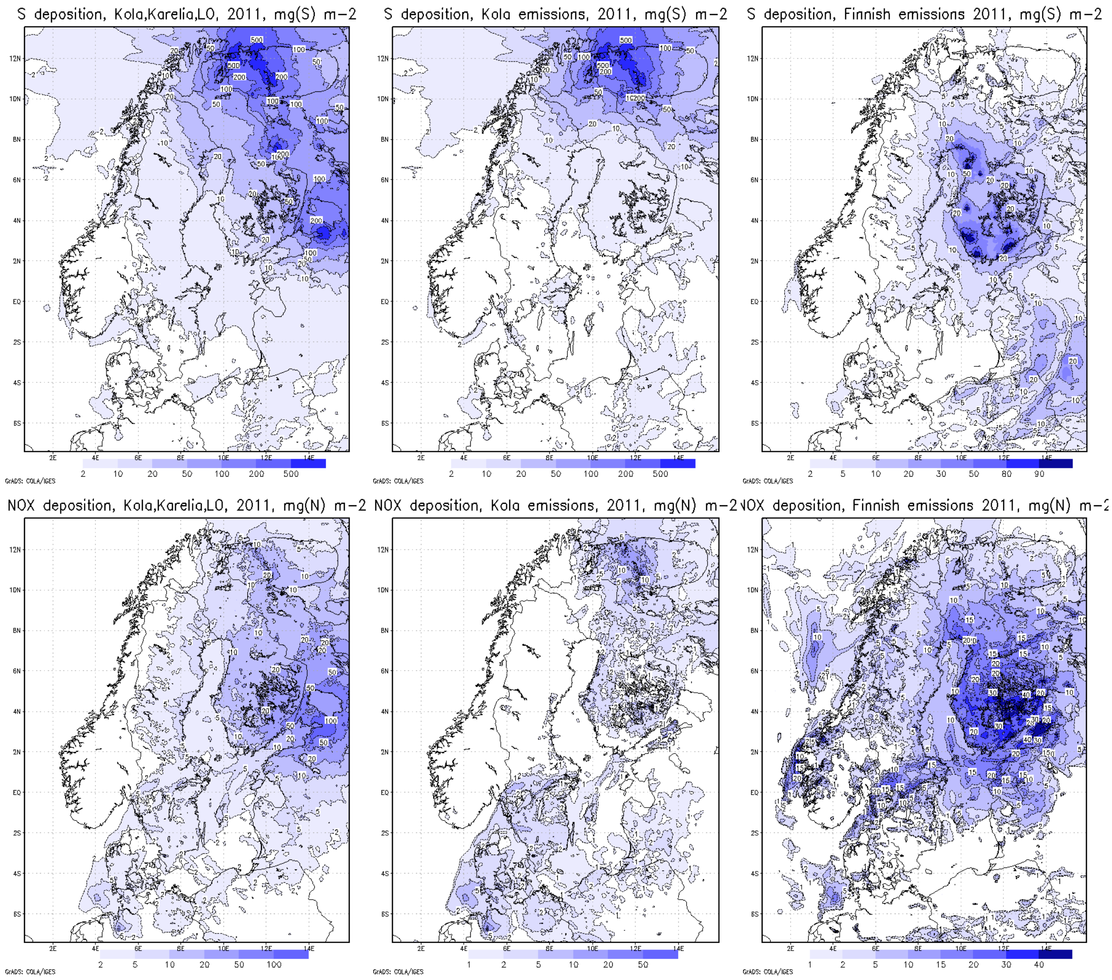

Figure 1. Sulphur and nitrogen deposition from Kola Penisula, Karelia and Leningrad Oblast (LO) emissions

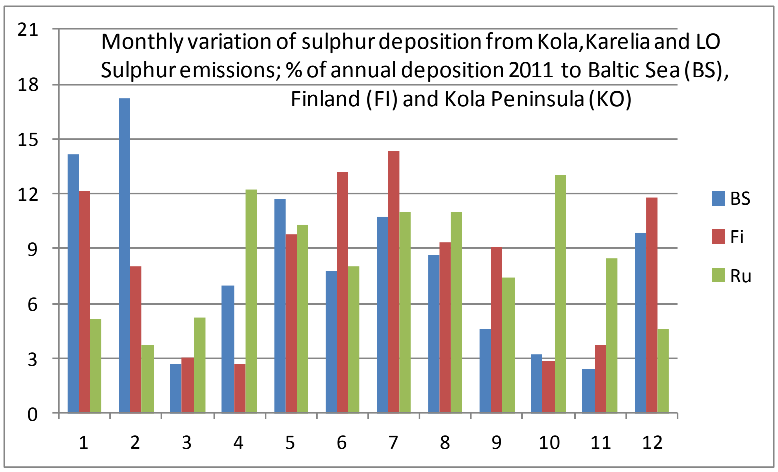

Figure 2. Monthly variation of deposition of Kola. Karelia and Leningrad Oblast emissions to the Baltic Sea, Finland and Kola Peninsula, % of annual value.

Table 1. Main point source locations and emission sums in Karelia, Leningrad Oblast and Kola Peninsula used in simuations

Karelia main point sources (total 34)				
t SO2 and NO2			SO2	NO2
Kostamus	64.60	30.07	40000	2000
Vojatyi.Na	63.90	34.08	1500	100
Nadvoitsy	63.92	34.25	300	50
Segezha	63.75	34.30	2300	650
Pitkaranta	61.57	31.47	1500	500
Sortavala	61.73	30.68	500	150
Petroskoi	61.78	34.05	1450	4900
Kontupoh	62.18	34.12	1700	2500
Karhumak	62.92	34.45	200	50
Suojarvi	62.00	32.40	1000	200
sorakka	64.50	34.75	700	100
Vienan	64.97	34.55	800	170
Leningrad Oblast main point sources (total 15)				
t SO2 and	**lat**	**lon**	**SO2**	**NO2**
Kirishi	59.47	32.03	15100	7110
Sjastroi	60.17	32.57	1000	500
Kingisepp	59.38	28.58	2000	600
Olhava	59.90	32.37	200	400
Svetogors	61.12	28.87	150	1280
Viipuri.	60.72	28.75	933	500
Kamenogo	60.97	29.07	200	100
Lesogorsk	60.97	28.93	200	150
Sovetski,J	60.55	28.72	700	700
Pikalevo	59.53	34.17	200	500

Kola Peninsula main point sources (total 41)				
t SO2 and NO2	lat	lon	SO2	NO2
Murmansk	68.90	33.10	22670	643
Kantalahti	67.17	32.40	4475	274
Olenogorsk	68.14	33.25	3690	296
Poljarnyi	69.20	33.45	4886	580
Severomorsk	69.07	33.35	5256	377
Kola district	68.87	33.00	1298	87
Kovdor district	67.55	30.40	4215	131
Apatit	67.63	33.40	15270	3838
Kirovsk	67.67	33.75	2660	39
Lovozersky district	68.02	35.10	1595	80
Terin district	66.70	34.30	359	18
Montshegorsk	67.90	32.85	33500	1570
Zapoljarnyi	69.40	30.65	52500	500
Petshanganikel	69.42	30.25	50670	235
sum			203044	8668

Table 2. Deposition of oxidized nitrogen (NOx) and sulphur (SOx) from Kola, Karelia and Leningrad Oblast (KoKaLO), Finnish and Kola Peninsula emissions to the Baltic Sea, Finland and Kola Peninsula 2011

revised		Sox deposition, t S				Nox deposition, t N		
	2011	tot	wet	dry		tot	wet	dry
from KoKaLO	to Baltic S	2644	1658	984		1580	962	616
from KoKaLO	to Finland	15061	9715	5346		4559	2298	2259
from KoKaLO	to Kola	73990	37157	36833		6139	3260	2875
from Finland	to Baltic S	1633	887	746		851	442	408
from Finland	to Finland	7258	3838	3420		5221	2666	2555
from Finland	to Kola	335	241	95		711	477	233
from Kola	to Baltic S	267	112	155		271	106	166
from Kola	to Finland	6303	4139	2164		1564	841	722
from Kola	to Kola	6747	4408	2338		511	77	434