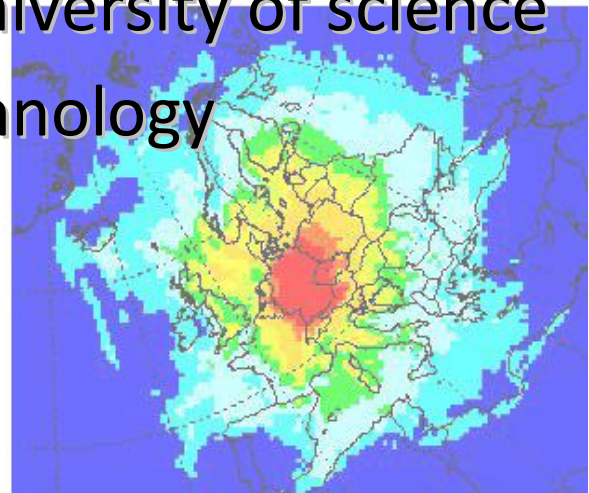




Work placement as assistant engineer

EDF Polska/AGH University of science
and technology



Christophe Letrouvé

Promotion 2010



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Subject and objectives of the internship

Transboundary air pollution: built a model of dispersion linking emissions of countries and concentration of neighborhood.

Critical loads for acidification: proceed to calculation of exceedance of critical loads for acidification in Poland.

Abstract

This sixteen weeks engineer assistant internship was focused on air pollution in Europe and consequences on human health and Poland environment. The work has been divided in two parts: transboundary air pollution and acidification in Poland.

First a short study on air pollution in Europe and especially on The Convention on Long-range Transboundary Air Pollution (LRTAP) has been done. Then a calculation of a dispersion matrix for SO_2 , based on deposition, has been carried out. Then, this matrix has been used to simulate decreases of emissions in some places of Europe and their consequences. It has also been used to optimize invest in SO_2 emission decrease. This part of the work has been performed on GAMS an algebraic modeling system used in the lab. In this part, the impact of one country emission on border countries has been showed, especially in Scandinavia and Poland areas.

After this work, a calculation of exceedance of critical loads for acidification in Poland has been achieved. For this work the main point was to get familiar with the process of critical loads for acidification and to manage to fit databases together. Using EMEP deposition data for sulphur and nitrogen for the year 2006 the calculation revealed a 54 percent of Poland ground in exceedance of critical loads. The database is administrated with oracle software; exploitation and manipulation of data were made with TOAD for oracle sql software.

Finally different calculations were made in order to show the relationship between high emitters and some sensitive areas.

Introduction

Air pollution does not know borders. As some species can be carried many hundreds of kilometres by winds, pollutants emitted in one country may be deposited in other countries. Consequently, air pollution is an issue not only for the country where pollutants are emitted but also for downwind countries. In some cases, domestically produced air pollution can be far exceeded by the pollution arriving from abroad. In order to act efficiently against this kind of transboundary air pollution, international policies have to be conducted. In this process, governments and subsidiary bodies have to be provided with qualified scientific information to support the development and further evaluation of these international protocols.

The AGH University of Krakow is taking part in this European will to solve transboundary air pollution problems. Indeed, its Department of Energy and Fuels led by Artur Wyrwa, is carrying out some researches on atmospheric dispersal. These researches are led to determine how pollutants travel from one place to another in Europe. From the 11th of May to the 28th of August, **Christophe Letrouvé** and I made an internship in this Department of Energy and Fuels.

Sulphur dioxide SO₂ is a common outdoor air pollutant and its main source is from combustion of sulphur-containing fossil fuels, principally heavy oils and coal. Dioxide sulphur has harmful effects on the human health including upper respiratory tract irritation and reduced lung function. Dioxide sulphur can also damage the environment by causing acid rains and acidification.

As coal power plants constitute a large part of the energy production in Poland, this country has high sulphurs emissions. Thus, the effects of these sulphurs emissions on downwind near countries and on Polish environment itself, should be estimated. This explains why transboundary sulphur air pollution and critical loads of acidification in Poland were the subjects of this 16 week internship in Poland.

Presentation of the company

1-AGH University of science and technology

The initiative to establish the Academy of Mining in Krakow has been led by a group of mining engineers and activists in 1912. The Academy had to wait until the end of the First World War to begin its activities and was inaugurated on the 20th of October 1919 by the Head of State Józef Piłsudski. Since the beginning, it was characteristic of the Academy that it collaborated closely with the industry and maintained contact with the Polish economy.

As it was the only technical school in Poland able to operate at the end of World War Two, it also played a major role in the post-war development of other Polish technical universities (the Silesian Polytechnic, the Technical Universities of Częstochowa, Warsaw, Wrocław and Gdańsk). The academy was given its final structure, name, standard and colors in the year of the Jubilee, in 1969.

Currently, AGH is composed of 15 faculties and 2 inter-faculty schools :

- Faculty of Mining and Geo-engineering
- Faculty of Engineering and Industrial Computer Science
- Faculty of Electrical Engineering, Automatics, Computer Science and Electronics
- Faculty of Mechanical Engineering and Robotics
- Faculty of Geology, Geophysics and Environmental Protection
- Faculty of Mining Surveying and Environmental Engineering
- Faculty of Materials Science and Ceramics
- Faculty of Foundry Engineering
- Faculty of Non-Ferrous Metals
- Faculty of Drilling, Oil and Gas
- Faculty of Management
- Faculty of Fuels and Energy
- Faculty of Physics and Applied Computer Science
- Faculty of Applied Mathematics
- Faculty of Humanities
- Inter-Faculty School of Power Engineering
- Inter-Faculty School of Biomedical Engineering

The Faculty of Fuels and Energy is one of youngest faculties at the University of Science and Technology. The Faculty has extended its educational and research offer taking into account new trends and technologies focused on meeting the growing demand for fuels and energy of the highest quality and requirements of sustainable development based on effective implementation of clean, green renewable energy.

In these 17 faculties and Interfaculties, there are over 34000 full-time and part-time students, and over half a thousand of doctoral students. Students can gain qualifications in 30 branches of studies and over 170 specializations. The diversity of branches of science is also worth mentioning.

The University also runs doctoral studies (555 doctoral students at 11 faculties), and postgraduate studies (over 1900 students).

2-EDF Polska

EDF has been present in Poland for over 10 years. It has total generation capacity of over 3000 MWe, and 5000 MWt. The Group provides a full range of energy and environmental services.

The activities of EDF Group in Poland are co-ordinated by the EDF Polska, a ten-person team seated in Warsaw, which is responsible for representing the EDF Group in Poland. Its task is also to guide and co-ordinate activities of service and production companies belonging to the EDF Group in Poland. Its president is Philippe Castanet.



Figure 1 – EDF plants in Poland(4)

Everen Sp. z o.o. is the trading company of the EDF Group in Poland. It was established on 1st of January 2004 in order to render complex trading services for the EDF Group in Poland. Key areas of its activity are energy trade on wholesale market as well as supply of energy to end consumers.

The EDF Group in Poland consists also of several heat generating plants: Elektrociepłownia Kraków S.A, Zespół Elektrociepłowni Wrocławskich Kogeneracja S.A, Elektrociepłownie Wybrzeże S.A, Cergia S.A, Elektrociepłownia Zielona Góra S.A.

Energokrak is the coal purchasing company of the EDF Group in Poland. Total volume of purchased coal reaches 7Mt per year.

As a world-wide energy group, EDF plays a significant part in economic and social development and is responsible to future generations for environment protection. All Polish EDF companies act upon the rules of sustainable development. An outstanding example of this engagement is the project of "Coal Recovery Plant from waste coal piles". We have to notice that all the companies have obtained 14001 certificates.

The example of Krakow: EC Krakow SA

The generated heat covers 47% of the residential heating demand of the 800,000 inhabitants in Krakow city, and is also supplied to several industrial sites and hospitals. The plant has an electrical capacity of 460 MW and a thermal capacity of 1376 MW.

Work completed

1-Background

Acidification

Soils can be polluted by many species, one of the consequences of this pollution can be the acidification of the ground. The decrease of pH can have disastrous impact on vegetation and can have different causes. Sulphur and nitrogen are important sources of Hydrogen cations in the environment, and will contribute to the ground acidification. There is also other species as calcium, magnesium, potassium and sodium which can be responsible of acidification, while absorbing by plants, will be replaced by a proton.

Parameter to control acidification of soils depend a lot of the area studied. Indeed, the ground type can increase the phenomenon of acidification, for example granites, as it contained quartz which can produce salicylic acid, can increase acidification. Plants will be too an important parameter because, even if it can produce some acid while absorbing metallic bases, some can also absorb acids and so decrease the risk of acidification.

To prevent this risk of acidification we need to know which quantity of sulphur and nitrogen, for example, environment can accept, we will see later how this limit is calculated.

Sulphur health impact

It is established that SO₂ have an important role in atmospheric chemistry, it is know too that it has an impact on human health being a precursor of sulphates, a common component of PM_{2.5} particles.

But some studies showed that SO₂ can have a direct impact on human health. On a short term it can increase death by cardiac or respiratory diseases (Katsouyanni *et al.*, 1997; Anderson *et al.*, 1997; Rommer *et al.*, 1998; Schwartz *et al.*, 2001; Wong *et al.*, 2002; Hedley *et al.*, 2002; Sunyer *et al.*, 2003) and on a long term it highly increase the risk of mortality (the smog of London in 1952 analyzed by Bell and Davis, 2001).

That imply that SO₂ air concentration as to be monitored on sensible areas and that damage on population can be calculated and opposed to the cost of reduction.

GAINS/RAINS Model

The International Institute for Applied Systems Analysis (IIASA) developed the Regional Air Pollution INformation and Simulation (RAINS) model as a tool for the integrated assessment of emission control strategies for reducing the impacts of air pollution. The present version RAINS considers health impacts of fine particulate matter and ozone, vegetation damage from ground-level ozone, as well as acidification and eutrophication. To explore links between these environmental effects, RAINS includes emission controls for sulphur dioxide (SO₂), nitrogen oxides (NO_x), volatile organic compounds (VOC), ammonia (NH₃) and fine particulate matter (PM).

Considering the new insights into the linkages between air pollution and greenhouse gases, work has begun to extend the multi-pollutant/multi-effect approach that RAINS presently uses for the analysis of air pollution to include emissions of greenhouse gases (GHG). The emphasis of the envisaged tool is on identifying synergistic effects between the control of air pollution and the emissions of greenhouse gases. The new tool is termed “GAINS”: **GHG-Air pollution INteractions and Synergies**.

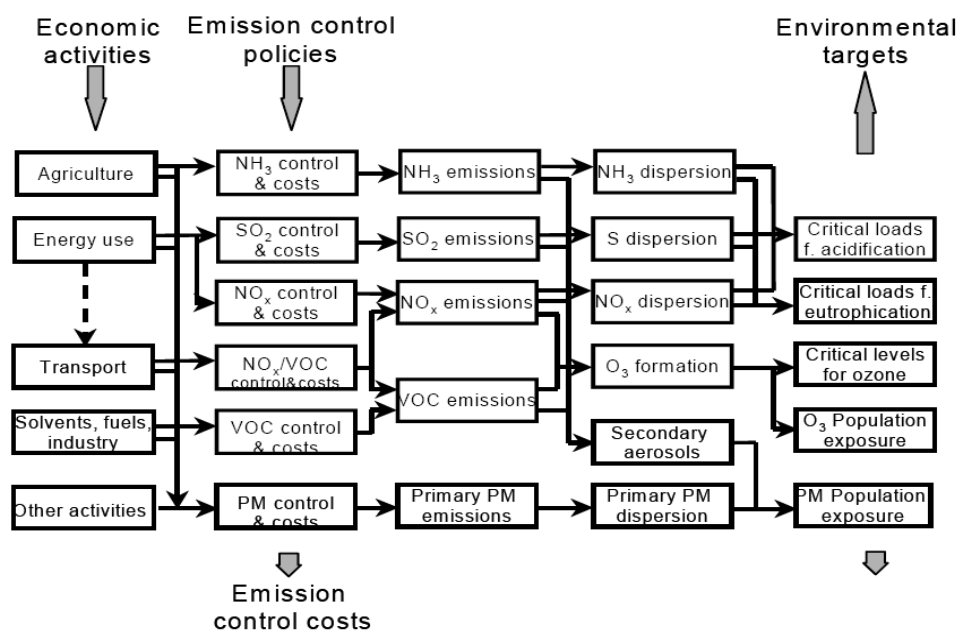


Figure 2 - Information flow in the RAINS model(3)

GAINS model will be used as a reference for pollution reducing methods in this study.

Emep database/LRTAP convention

The Convention on Long-range Transboundary Air Pollution (LRTAP), signed in 1979, is one of the central means for environmental protection. It establishes a broad framework for co-operative action on reducing the impact of air pollution and sets up a process for measures to control emissions of air pollutants. In this process, the main objective of the EMEP program (Co-operative Program for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe) is to regularly provide governments and subsidiary bodies under the LRTAP Convention with qualified scientific information to support the development and further evaluation of the international protocols on emission reductions negotiated within the Convention.

Initially, the EMEP program focused on assessing the transboundary transport of acidification and eutrophication. Later, the program extended to address the formation of ground level ozone and, more recently, of persistent organic pollutants (POPs), heavy metals and particulate matter.

The EMEP program consists in three tasks: collection of emission data, measurements of air and precipitation quality and modeling of atmospheric transport and deposition of air pollutions. Through the combination of these three elements, EMEP fulfils its required assessment and regularly reports on emissions, concentrations and depositions of air pollutants, the quantity and significance of transboundary fluxes and related exceedances to critical loads and threshold levels.

The EMEP program is carried out in collaboration with a broad network of scientists and national experts that contribute to the systematic collection, analysis and reporting of emission data, measurement data and integrated assessment results.

- Four different Task Forces within EMEP provide for discussion and scientific exchange: the Task Force on Measurements and Modeling (TFMM), the Task Force on Emission Inventories and Projections (TFEIP), the Task Force on Integrated Assessment Modeling (TFIAM) and Task Force on Hemispheric Transport of Air Pollutants (TFHTAP).
- CCC, Chemical Coordinating Centre: co-ordinate and carry out inter-calibration of chemical air quality and precipitation measurements.
- MSC-W, Meteorological Synthesizing Centre -West : storage and distribution of reliable information on emissions and emissions projections, modeling assessment of sulphur, nitrogen photo-oxidant pollutants and atmospheric particles.
- MSC-E, Meteorological Synthesizing Centre -East: modeling development for heavy metals and POPs.
- CIAM, Center for Integrated Assessment Modeling: developed integrated assessment (created in 1999, development built on past modeling work, in particular the RAINS model).
- CEIP, Centre on Emission Inventories and Projections: collect emissions and projections data of acidifying air pollutants, heavy metals, particulate matter and photochemical oxidants.

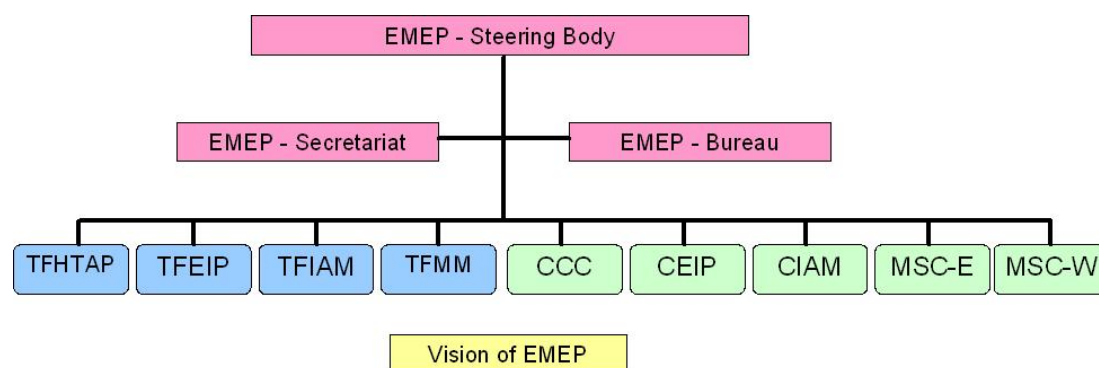


Figure 3 – Emep basic organization chart(1)

2-Concentration matrix

The matrix from EMEP

On the EMEP database we found a SO₂ depositions contribution matrix on which we based our work. This matrix represents the deposition of SO₂ in tons per country due to others countries. This matrix is obtained using an air transportation model taking into account characteristics of several pollutants.

i\j	Country 1	Country 2	Country 3
Country 1	d(1,1)	d(1,2)	d(1,3)
Country 2	d(2,1)	d(2,2)	d(2,3)
Country 3	d(3,1)	d(3,2)	d(3,3)

Table 1 – Simplification of the EMEP matrix

In this table, d(i,j) represent the depositions, in tons of SO₂, in country I due to country j emissions. These matrixes are available for years 2003, 2004, 2005 and 2006, with an extrapolation for the year 2010.

The concentration matrix

In order to determinate the impact on environment and health we needed the concentration contribution per country matrix. To obtain this matrix we assumed that the deposition in SO₂ in one country due to another one was a linear function of the total pollution that the emitter country sent to the receiver. This approximation seems to be accurate as the sulphur deposition is almost a linear function of its air concentration, and so, with the EMEP deposition matrix, we can obtain the desired matrix.

In a first time we divided each country coefficient per the total emission of the emitter country to know the part, in percent, of total pollution going from the emitter (j) to the receiver (i).

$$x(i,j) = \frac{d(i,j)}{\sum_i d(i,j)}$$

i\j	Country 1	Country 2	Country 3
Country 1	x(1,1)	x(1,2)	x(1,3)
Country 2	x(2,1)	x(2,2)	x(2,3)
Country 3	x(3,1)	x(3,2)	x(3,3)

Table 2 – Percentage of j pollution going to i country

The EMEP database provides us the average SO₂ concentration per country and the SO₂ emission of countries. In order to link the emission received by a country and the average concentration we divided the average concentration by the total reception of each country, in tons.

$$total\ reception(i) = \sum_j emission(j) * x(i, j)$$

$$\alpha(i) = \frac{average\ concentration(i)}{total\ reception(i)}$$

Here, $\alpha(i)$ represent the part of concentration due to the reception of 1 ton of SO₂, it is a kind of country effective volume approximation.

Thanks to that coefficient we are now able to link emissions and average concentration in each country. So we multiplied each coefficient of the previous percentage matrix by the suitable $\alpha(i)$.

$$c(i, j) = \alpha(i) * x(i, j)$$

i\j	Country 1	Country 2	Country 3
Country 1	c(1,1)	c(1,2)	c(1,3)
Country 2	c(2,1)	c(2,2)	c(2,3)
Country 3	c(3,1)	c(3,2)	c(3,3)

Table 3 – Concentration contribution matrix

This matrix represents the contribution of each country emissions in the average concentration of others. We can obtain the concentration in each country by adding the coefficient on the same line, multiplied by the emission of the countries, that allow us to simulate a decrease of emissions in a given country and to observe the concentration decreased around (appendicesp.26).

$$concentration(i) = \sum_j c(i, j) * emission(j)$$

Validation of an average matrix

We wondered if the transportation matrix obtained was a general behavior of atmospheric moves in Europe or if it was changing for each year. In order to check this hypothesis we proceeded to obtain the transportation matrix for different years (2003 à 2006) and we made an average matrix of these four matrixes. Then we calculated the total concentration for each country with the original matrix and with the average one.

We plotted the concentration obtained in function of the values given by the EMEP, the following table shows the result of linearization (equation as $y=ax+b$) of graphics which can be found in appendices p. 27:

Year	2003	2004	2005	2006
a	0,929	1,0113	0,9927	0,9854
b	0,0129	0,0225	0,0084	0,0072
R ²	0,9915	0,9934	0,9963	0,9953

Table 4 – Linearization for average matrix validation

So we can see that the concentration obtained with the average matrix and the original one are almost the same as the linearization coefficient is around 1 with a very good correlation level.

We can assume now that the atmospheric transportation in Europe is a general behavior available from one year to another. We will use the average matrix into following solve.

GAMS solve

GAMS (General Algebraic Modelling System) is a high-level modeling system for mathematical programming and optimization. GAMS was the first algebraic modeling language and is formally similar to commonly used programming languages. GAMS is specifically designed for modeling linear, non-linear and mixed integer optimization problems. The system is especially useful with large, complex problems.

The basic components of the structure of a GAMS model are :

Input
<ul style="list-style-type: none"> • Sets • Data • Variables • Equations • Model and Solve statements • Display statements
Output
<ul style="list-style-type: none"> • Echo Print • Reference Maps • Equation Listings • Status Reports • Results

Table 5 - Basis component of a GAMS model

Sets are the basic building blocks of a GAMS model, corresponding exactly to the indices in the algebraic representations of models. In our model we used three sets : the emitters countries set, the receiver countries set, and the technology number set.

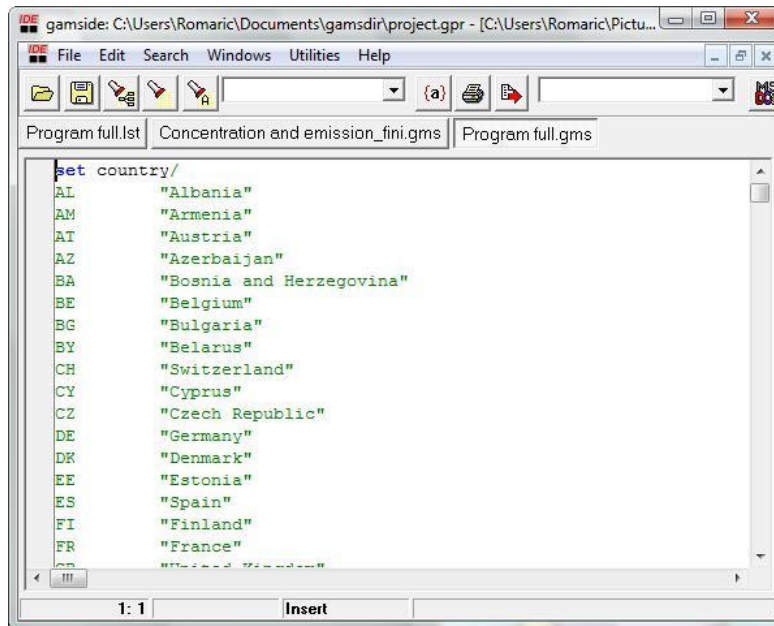


Figure 4- Set statement in the GAMS software

The data which are needed to run the program can be entered either by direct assignment, either in a list or matrix form. We used only list and matrix forms, using the set that we had just defined. Data used in our model are :

- the list of sulphur emission in tons in each emitter country, taken from the CEIP (Centre on Emission Inventories and Projections) web site.
- the list of desired concentration reduction in each receiver country, that should be fixed by the user of the model.
- the matrix of marginal cost to deplete one ton of emitted sulphur in each country by using one technology available in that country according to the GAINS online
- the matrix of maximal reduction that can be reached in each country by using one technology available in that country.
- the matrix of average concentration contribution in each receiver country for one tone emission in each emitter country.

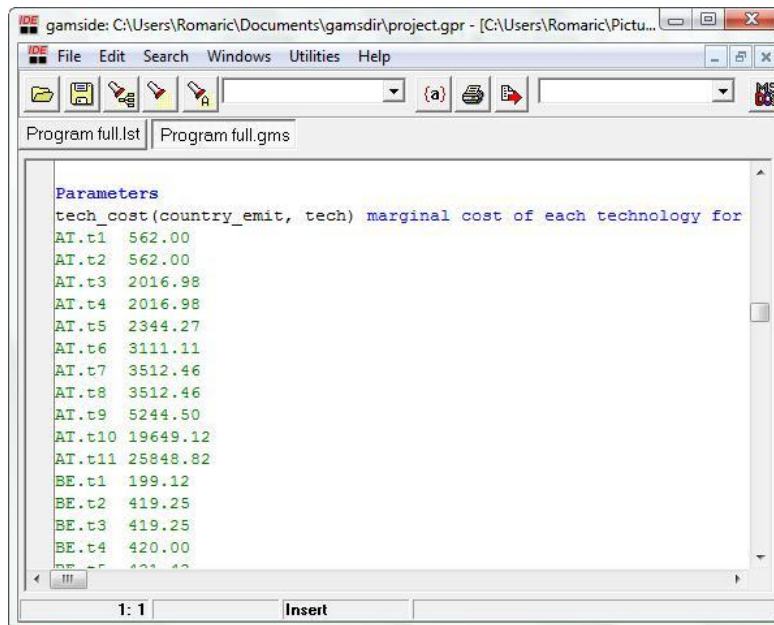


Figure 5 - Parameters statement in the GAMS software

The variable statement of GAMS-expressed model only serve to declare the variables used in the rest of the program. Each variable is given a name, a domain if appropriate, and (optionally) text. Our model contains the following example of a Variable statement :

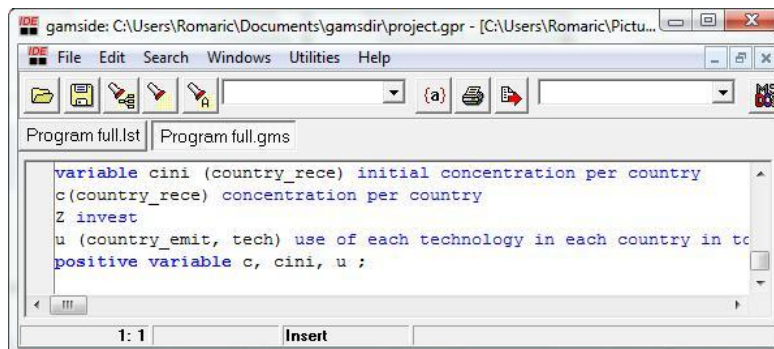


Figure 6 - Variable statement in the GAMS software

Equation statements are more complicated : they encompasses both equality and inequality relationships, and they are used both to declare and define these relationships. These equations can be used to defined values or limits for the variables declared in the previous variable statements. In our model, equations are used in order to :

- calculate initial concentration and concentration after reduction in emission, in each country.
- make sure that the reduction of emission in each emitter country due to the use of a single technology does not exceed the maximal reduction possible.
- impose the desired final concentration in one or several country.
- calculate the total investment needed to achieve this goal.

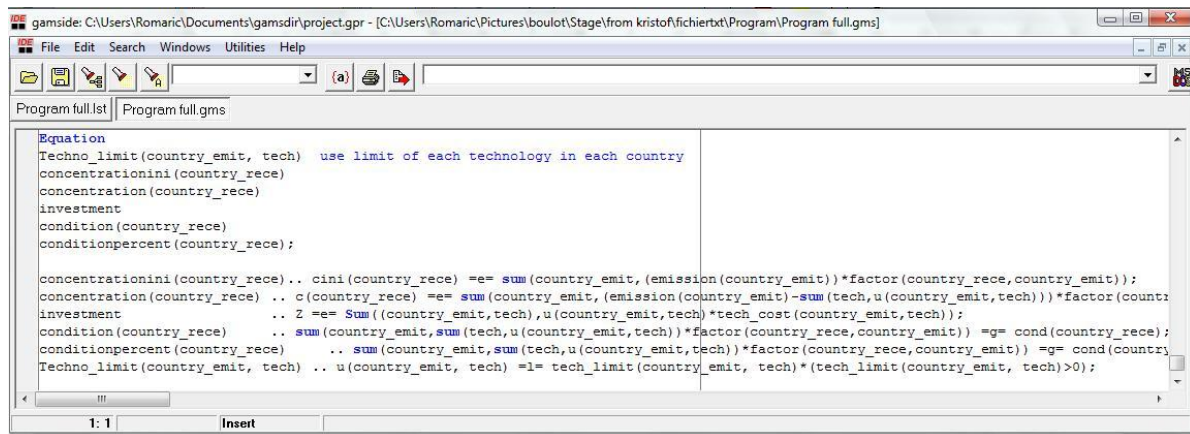


Figure 7 - Equations statement in the GAMS software

These Equation statements are equivalent to those equations put in algebraic form :

$$\begin{aligned}
 C_{ini}(i) &= \sum_j E_j * M(i, j) & C(i) &= \sum_j (E_j - \Delta E_j) * M(i, j) \\
 \Delta E_j &= \sum_k U(j, k) & U(j, k) &\leq U(j, k)_{max} \\
 Z &= \sum_j \sum_k U(j, k) * Cost(U(j, k)) & C(i) &\leq C(i)_{target}
 \end{aligned}$$

Where

- i : receiver country
- j : emitter country
- k : available technology
- $C_{ini}(i)$: initial concentration in the country j
- $C(i)$: concentration in the country j
- E_j : emission of the country i
- $M(i, j)$: coefficient of the country to country blame average matrix
- ΔE_j : variation of emission in the country i
- $U(j, k)$: use of the technology k in the country i
- $U(j, k)_{max}$: maximal use of this technology
- $Cost(U(j, k))$: marginal cost for one ton emission reduction with this technology
- $C(i)_{target}$: the concentration we want to reach in the country j

The model statements precise which equations should be taken into account during the resolution. We do not need to ignore any equation, so we can plainly use the statement :

`model model_name /all/;`

GAMS has no explicit entity called the “objective function”. To specify the function to be optimized, you must create a variable and a solve statement. The solve statement precise which model to solve, the variable which should be optimized, if it should be maximized or minimized, and the solution procedure (linear lp or non linear for example nlp)

`Solve model_name using lp minimalizin Z;`

With this settings, our model will compute the cheapest way, from technologies available in different countries, to decrease the concentration one or several given countries.

3-Critical loads for acidification

In order to protect environment we have to know which quantity of pollutant can be release or deposit without damaging ecosystem. If we know this limit, we can act more efficiently where it needs and protect areas that need to be.

"The highest deposition of acidifying compounds that will not cause chemical changes leading to long-term harmful effects on ecosystem structure and function."(2)

In order to determine which areas are about to suffer of acidification, critical loads have to be calculated: it represents the deposition maximum of sulphur and nitrogen that the soil can accept without being acidified. These constant depend essentially of the nature of the soil, and can be represented with a graphic.

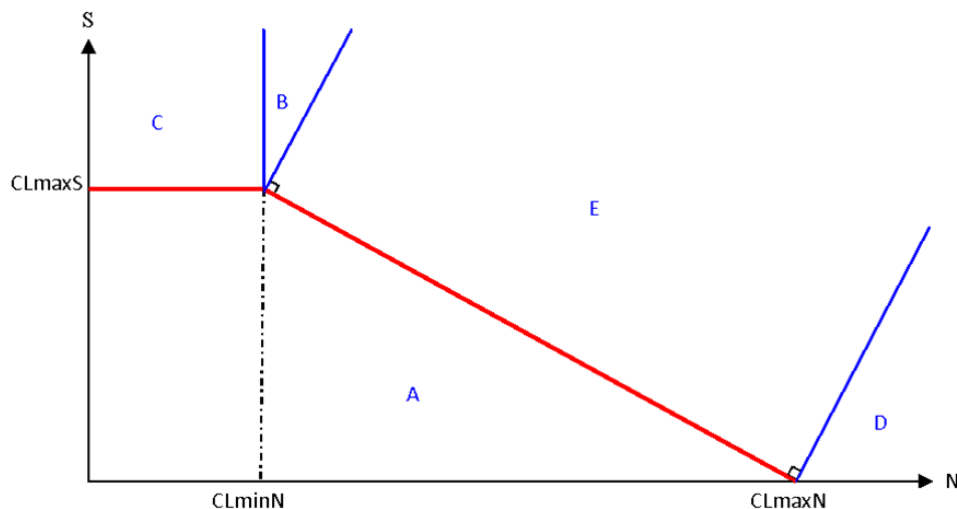


Figure 8 – Critical loads diagram

CLmaxS = quantity of sulphur that can be accepted by soil when there is not nitrogen

CLminN= quantity of nitrogen that can be absorb by vegetation

CLmaxN= quantity of nitrogen that can be accepted by soil when there is not sulphur

Values of CLmaxS, CLminN and CLmaxN will be different for each area and to know if there is risk of acidification you have to check if the point, which abscise is the nitrogen deposition and ordinate the sulphur one, is over or under the critical loads line (red one). In a first time we have to determine limit conditions for each areas of the graphic :

Area	Condition
A	$S - CL_{max}S < 0$ $N * CL_{max}S + S * (CL_{max}N - CL_{min}N) - CL_{max}N * CL_{max}S < 0$
B	$S - CL_{max}S > 0$ $N - CL_{min}N + \frac{(S - CL_{max}S) * CL_{max}S}{CL_{max}S - CL_{min}N} < 0$
C	$S - CL_{max}S > 0$ $N - CL_{min}N < 0$
D	$N - CL_{max}N > 0$ $N - \frac{S * CL_{max}S}{CL_{max}N - CL_{min}N} - CL_{max}N > 0$
E	Other cases

Table 6 – Limit expression for critical loads

Then we determine the exceedance of critical loads, it is divided into two values : the exceedance in nitrogen and the one in sulphur. This represents the “shortest” way to avoid acidification by reducing both of the pollutants.

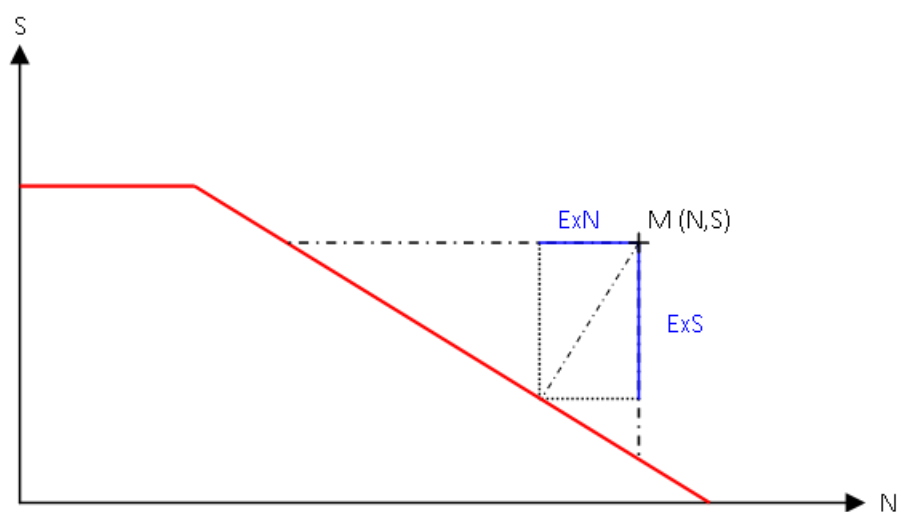


Figure 9 – Exceedant loads representation

The following table gives the expression to calculate exceedances regarding the area where the point is.

Area	ExN	ExS
A	0	0
B	$N - CLminN$	$S - CLmaxS$
C	0	$S - CLmaxS$
D	$N - CLmaxN$	S
E	$\alpha * CLmaxS$	$\alpha * (CLmaxN - CLminN)$

Table 7 – Exceedental loads caculation table

$$\alpha = \frac{(N * CLmaxS + S * (CLmaxN - CLminN) - CLmaxS * CLmaxN)}{CLmaxS^2 + (CLmaxN - CLminN)^2}$$

We made calculation for Poland with a resolution of 50 km square grip for deposition data (EMEP database) and total of 88383 values for critical loads data (CLminN, CLmaxN and CLmaxS). The first point was to make the data fit together because coordinate systems were different. So we used formula available on EMEP website to transform the coordinate (longitude and latitude) of our critical loads data into EMEP grid coordinate.

$$x = x_{pol} + M \tan\left(\frac{\pi}{4} - \frac{\phi}{2}\right) \sin(\lambda - \lambda_0) \quad (1)$$

$$y = y_{pol} - M \tan\left(\frac{\pi}{4} - \frac{\phi}{2}\right) \cos(\lambda - \lambda_0) \quad (1)$$

Where $x_{pol} = 8$, x coordinate of the North Pole
 $y_{pol} = 110$, y coordinate of the North Pole
 $M = 237.73$, number of grid distances between North Pole and Equator
 $\lambda_0 = -32$, rotation angle
 λ , the longitude of the point
 ϕ , the latitude of the point
 x, y , coordinates of the point in the EMEP grid

We transform the coordinates of our critical loads data to know which deposition each considered point was receiving, according to EMEP values. So we used the given formula and rounded the values to the nearest unit to know in with cell of the EMEP grip point where located.

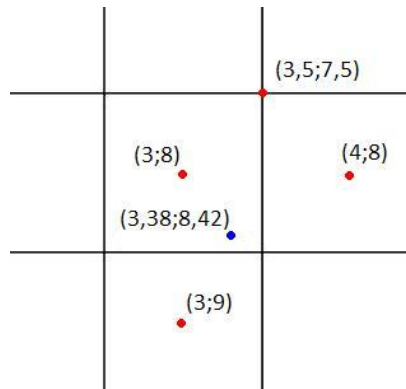


Figure 10 - Exemple of the EMEP grid structure

All the calculation and manipulation of data were carried out using the “TOAD for Oracle” software, which is a database administrator tool allowing SQL programming. Thanks to that software we were able to treat much more data than with a simple table as excel and doing more complex operation faster (joining, sorting out...).

The result obtained with the deposition data of 2006 show an exceedance in 54% of the point (appendices p.29).

4-Results

Scandinavian area

We observed that one of the places where concentration was mostly due to reception than emissions was the Scandinavian area. Besides, this area has an ecosystem very sensitive to acidification, so it was interesting to determine a scenario to decrease concentration in sulphur in this area.

Poland

As it has been showed in the exceedance calculation, Poland territory is highly subject to acidification and so it was interesting to simulate a decrease of sulphur concentration in this place. But our calculation reveals that, for Poland territory, the sulphur concentration is mainly due to Poland emission and that with our simulation, other countries did not enter into account before very high concentration reduction. That is why we decided to simulate a decrease of emissions in Poland in a first time and concentration in a second one, and to observed impacts on Poland and neighborhoods.

Assets and Personal impressions

This engineer assistant internship was first a chance to apply and improve my engineer knowledge on subject as GIS(Geographic Information System) and atmospheric pollution; but it was also an opportunity to continue the discovering of research sector begun during the PDR (Projet de Découverte de la Recherche) this year. Indeed, during this internship I could use reflexes learned during the past year on the way to proceed when you need information and on the way to lead the advance of your project. I particularly liked to have objectives but also to be free regarding the way to reach it with the tool I could use or find.

Engineer always has to deal with a lot of data when working on environment, and thanks this internship I could learn how to administrate and manipulate databases which are a powerful tool in engineer work. Indeed when dealing with ecosystem characteristic or pollution measurement for large areas, database seems to be the best way to work and to exchange your data with collaborators. Since I did not know this method, I learned the use of new software as TOAD or GAMS, and the languages associated, mainly SQL.

It was very interesting to work on a European “project” and became aware of important entities or charts as EMEP, CLRTAP or IASAA. It showed me the real desire in Europe to act efficiently against pollution and that the work of an environment engineer does not limit to the border of one country because nowadays we have to foresee consequences on a more important area, the Europe one in the present case. I was amazed to see how this relationship between high polluter and sensitive areas could have a huge impact on ecosystem, especially regarding the simulation we made on the Scandinavian area. It was rewarding to see that with our approach we could reach such results. Then, I think that if we could obtain more accurate databases we will be able to act more efficiently. It means to act on a dozen factories to preserve one protected natural area. It means that our work could be improved with more funds.

This internship also showed me the limit of the help you can wait for that sort of project, because even if you are working on a cooperation project, you will be confront to concurrences and money issues. I was frustrated to see that we could not proceeded the same calculation we made for Poland in France because the data we needed was not available without convention with France or without paying it. I also was when we looked for giving a more accurate resolution to our matrix, because higher resolution would have mean to succeed in passing agreement with each country we needed or buying each database, thing we could not afford. I was more disappointed when I learned that the database we used for Poland was not the result of an agreement with AGH energy department, but had been buy. So I became aware that, even if the country or entity which possesses the data is supposed to benefit the result of your work, or if it is supposed to work in the same way as you, getting access to these data is always difficult. So, project which are said to be European effort to solve common issue will always face the hindrance of confidentiality.

During these four months I could observe the dynamism of a country in high industrialization living an important renewal. I could also being immersed into a foreign country issues. Indeed Poland is now faced to a need of decreasing its emissions of CO₂, for example, according last Kyoto protocol but as its energy is mainly based on coal plants (more than 80% of the supply) it needs a revaluation of its energy park. According to this idea some programs have been presented during an EDF lecture in AGH energy and fuels department. The main point of this lecture was co-generation plants development by EDF Polska but at the same time we learned that Poland does not used at all nuclear

power plant on its territory because of a blockage due to the last political regime and because, now, of the slow speed the mind change on this subject. As I am going to follow next year classes of nuclear power technology and security, it was very interesting for me to see that abroad this market is not won at all, and that there is still a lot of work to do to make the nuclear a more trustable and safe source of energy in people mind. The other issue for Poland is that until now it has been energetically independent from other country, and opening its energy providing sector to new sources means high invests and new agreements and partnerships with foreign countries. Then it is difficult to make things go faster when the country has to renounce to such an advantage.

It was also very interesting to have this internship in a country with such a rich history. Indeed during my free time, I could discover the past of a country I did not known and learn more about Europe history because of dramatic event which took place in Poland. I could see how deep the country has been bruised because of Second World War which is still commemorated in a lot of places in Warsaw. Indeed I was amazed to learn that all the city has been totally destroyed at the end of the war and that Polish rebuilt it identically as a symbol of their desire to show the strength of hope. I think this desire is now visible with the effort to develop the country after the communism despite the fact that some people seems to be nostalgic of the former regime, as we have been told. The country seems also deeply attached to its Catholics roots, indeed places in memory of former Pope Jean Paul II are numerous in Warsaw or Krakow and it is interesting to see the importance religion can still have in the culture and the economy of a country.

Conclusion

The time Poland was independent on its energy sector will end soon. It may have to choice between paying Kyoto fees for high polluters or invest for changes on its energetic park. If reducing emission in Poland would first rewards Poland ground and habitants, it also shows the importance of European decision regarding transboundary air pollution. The exceedances of emissions in Poland, 65% for sulphur, between 90 and 150% for carbon and between 150 and 200% for nitrogen (according to Environmental Ministry estimation), will have to be reduce and it will impact on the calculation we made. We can hope that the acidification of Poland ground will decrease a lot in the next ten years if huge changes are made and that others areas will gain from these changes.

In a first step, such simulation should be used to know where to replaced former coal plant by nuclear one, for example, in order to decrease at the same time, acidification and pollution concentration on sensitive area. This is applicable for Poland but for other European countries, and at Europe level too.

The challenge of Poland, and Europe, in the next 20 years is not only to act anymore, because changes are requested, but to act efficiently. That is why such projects, on transboundary air pollution or just on inside atmospheric dispersion, will always be necessary to apply pollution decrease jointly to technologies improvement projects.

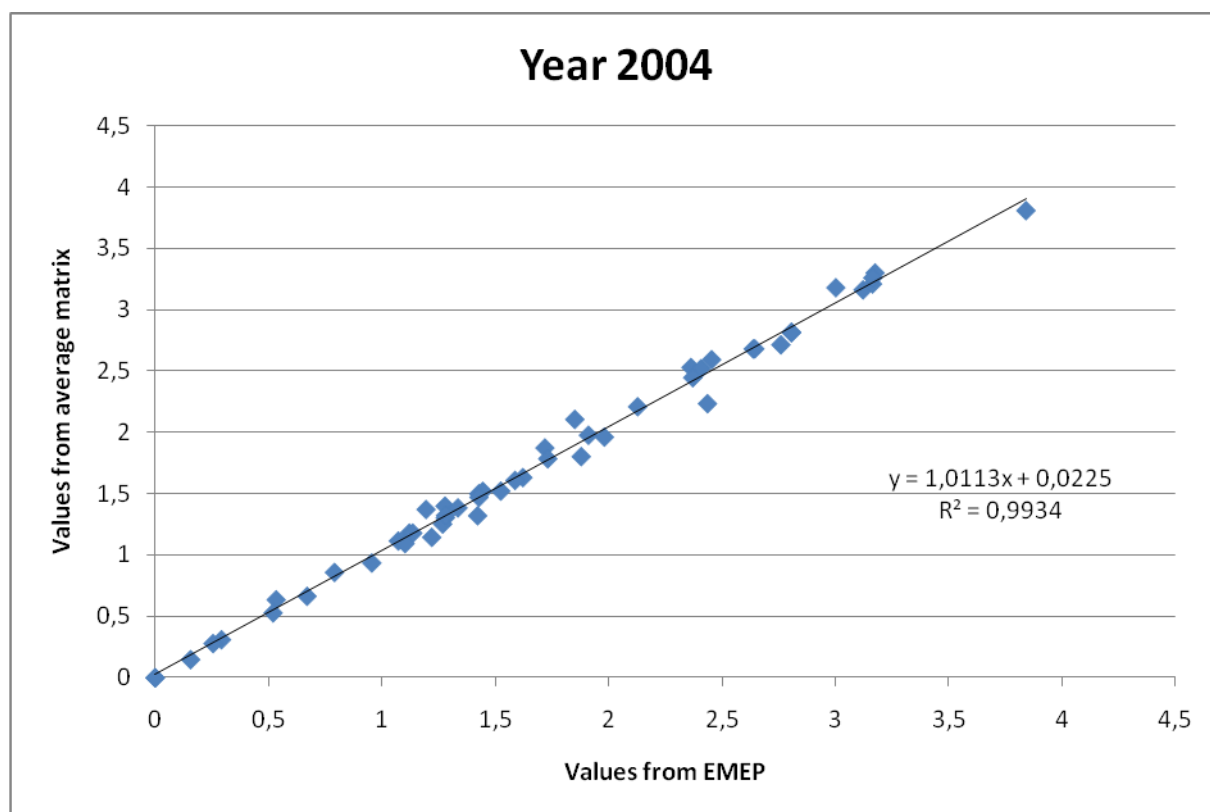
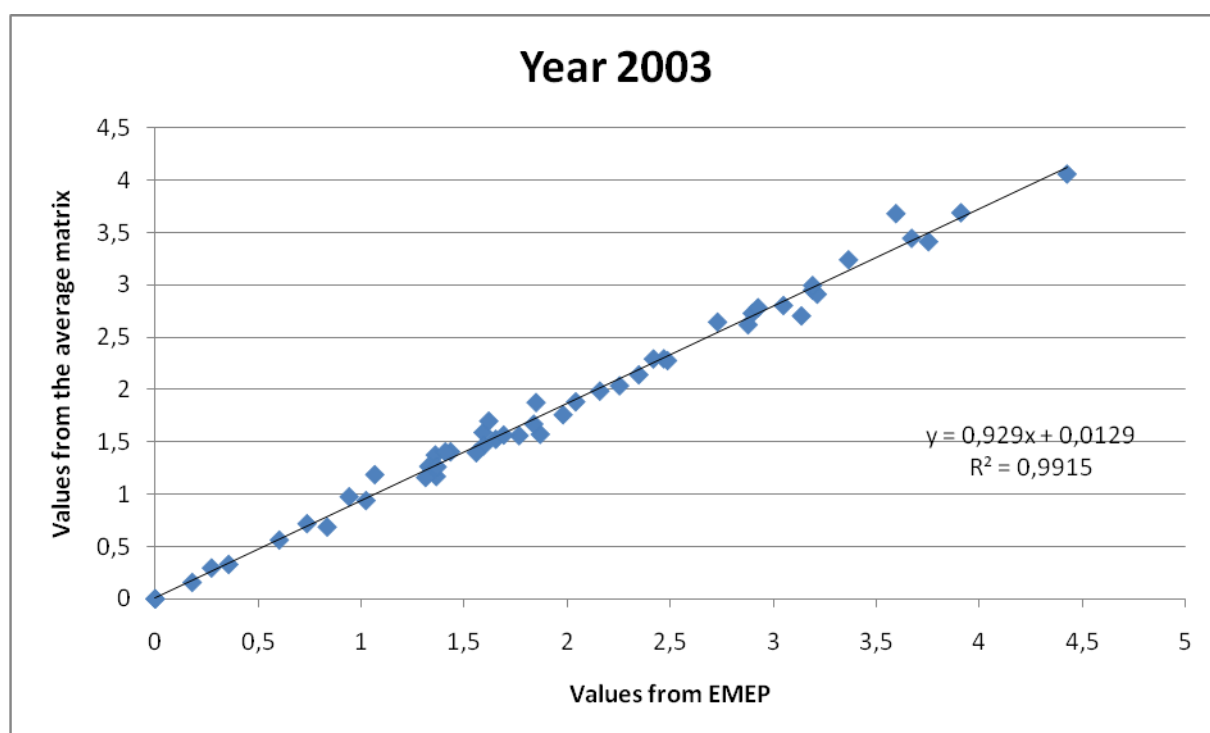
Appendices

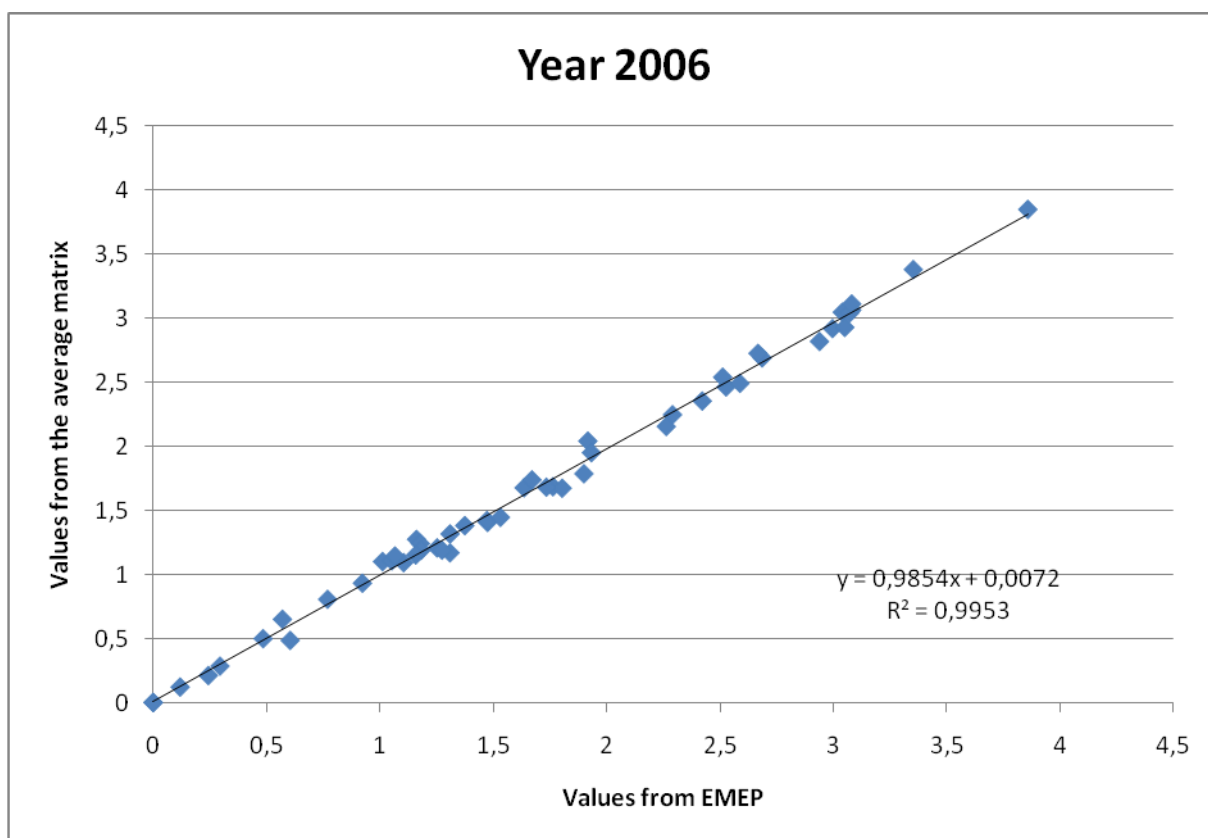
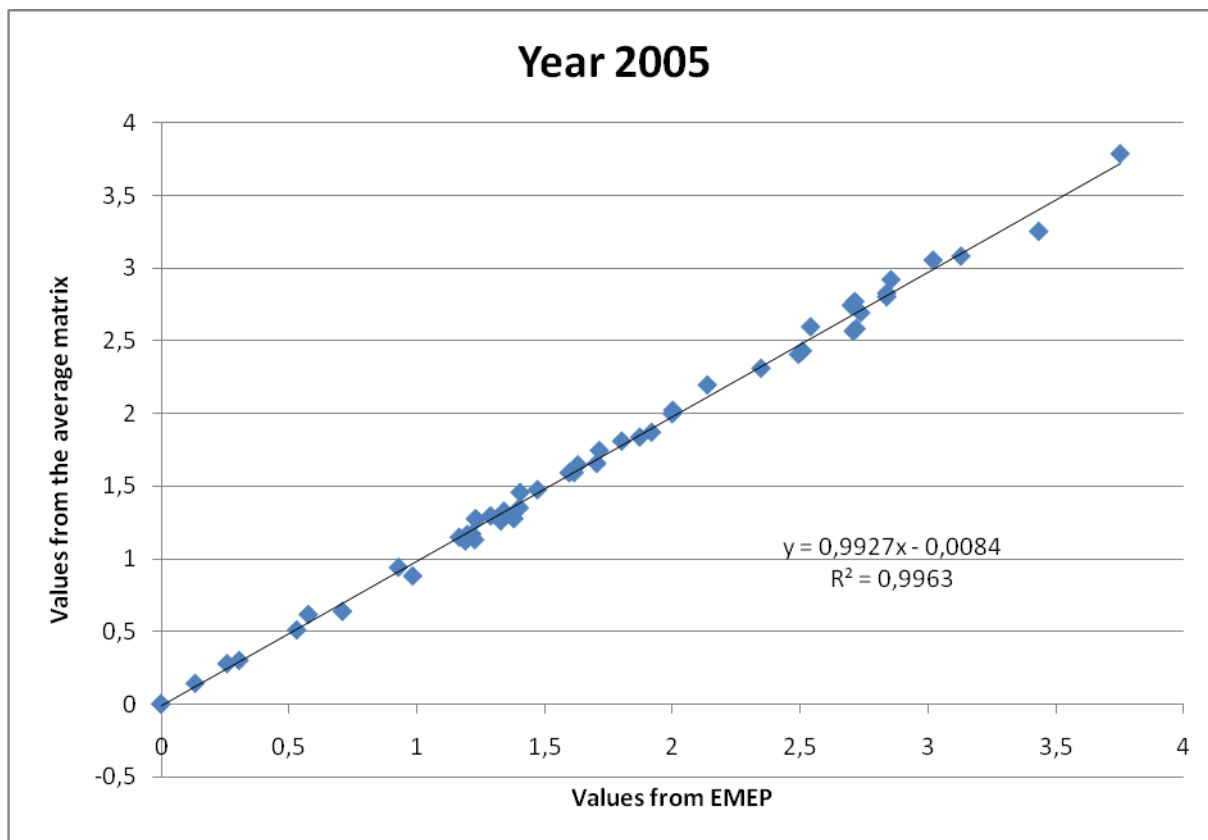
View of a part of the transportation matrix.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	
2	AL	4.42E-06	1.82E-09	3.27E-08	1.29E-09	1.36E-07	3.16E-09	2.89E-07	9.84E-09	2.00E-08	2.43E-08	2.20E-08	8.03E-09	3.81E-09	4.39E-09	2.22E-08	2.73E-09	1.46E-08	2.44E-09
3	AM	2.45E-09	4.41E-06	1.02E-09	1.20E-06	1.65E-09	2.15E-10	5.10E-09	3.55E-09	8.98E-10	1.19E-07	4.96E-10	3.10E-10	5.76E-10	1.77E-09	5.49E-10	9.30E-10	4.48E-10	2.55E-10
4	AT	2.29E-08	3.56E-09	3.64E-06	2.04E-09	1.38E-07	6.85E-08	3.01E-08	2.57E-08	4.82E-07	2.28E-09	4.97E-07	2.46E-07	3.10E-08	1.23E-08	2.83E-08	5.77E-09	8.40E-08	3.12E-08
5	AZ	1.36E-09	7.30E-07	9.52E-10	3.84E-06	1.58E-09	2.47E-10	4.85E-09	7.85E-09	5.97E-10	4.53E-08	9.61E-10	4.82E-10	1.18E-09	2.14E-09	3.88E-10	1.29E-09	3.36E-10	4.21E-10
6	BA	2.94E-07	2.89E-09	1.70E-07	1.97E-09	3.78E-06	1.15E-08	8.91E-08	1.97E-08	6.84E-08	8.79E-09	1.17E-07	3.22E-08	1.75E-08	5.38E-09	2.77E-08	5.47E-09	3.32E-08	7.17E-09
7	BE	5.52E-09	6.01E-10	8.38E-08	5.01E-10	2.26E-08	6.98E-06	3.83E-09	1.51E-08	1.37E-07	1.95E-10	1.13E-07	9.95E-07	6.33E-08	3.30E-08	9.94E-08	1.79E-08	9.54E-07	3.80E-07
8	BG	2.56E-07	1.02E-08	6.12E-08	1.07E-08	1.69E-07	5.39E-09	2.48E-06	4.93E-08	2.71E-08	4.21E-08	4.94E-08	1.54E-08	1.27E-08	1.94E-08	8.78E-09	8.83E-09	1.09E-08	3.90E-09
9	BY	2.57E-08	9.03E-09	8.13E-08	9.53E-09	8.28E-08	2.57E-08	4.88E-08	2.70E-06	3.95E-08	8.04E-10	1.26E-07	4.78E-08	7.68E-08	1.60E-07	1.09E-08	7.46E-08	2.24E-08	2.17E-08
10	CH	7.23E-09	4.65E-10	2.79E-07	2.78E-10	3.79E-08	9.96E-08	5.08E-09	3.65E-09	4.92E-06	9.79E-10	4.02E-08	1.68E-07	1.16E-08	6.27E-09	6.81E-08	4.99E-09	2.33E-07	4.17E-08
11	CY	1.60E-08	2.31E-08	4.43E-09	6.91E-09	1.10E-08	6.57E-10	2.78E-08	2.21E-09	3.53E-09	1.41E-05	2.30E-09	9.89E-10	1.06E-09	1.40E-09	3.13E-09	5.83E-10	1.36E-09	5.57E-10
12	CZ	1.82E-08	6.78E-09	9.92E-07	4.07E-09	8.02E-08	1.33E-07	3.43E-08	4.70E-08	2.87E-07	8.49E-10	3.27E-06	4.14E-07	8.95E-08	1.84E-08	2.69E-08	9.99E-09	1.09E-07	5.74E-08
13	DE	6.15E-09	2.00E-09	3.49E-07	1.30E-09	2.12E-08	5.74E-07	5.44E-09	2.33E-08	5.94E-07	3.14E-10	5.95E-07	1.54E-06	2.09E-07	3.26E-08	4.84E-08	1.61E-08	3.18E-07	1.74E-07
14	DK	2.45E-09	1.94E-09	5.17E-08	1.20E-09	1.14E-08	2.47E-07	1.72E-09	3.11E-08	5.60E-08	1.01E-10	8.90E-08	3.02E-07	3.62E-06	3.98E-08	3.50E-08	3.61E-08	1.20E-07	2.13E-07
15	EE	9.42E-09	2.12E-09	8.10E-08	1.12E-09	3.12E-08	5.37E-08	1.23E-08	2.58E-07	4.03E-08	1.55E-10	1.45E-07	9.28E-08	1.45E-07	3.03E-06	1.33E-08	3.65E-07	3.25E-08	3.81E-08
16	ES	5.08E-09	3.14E-10	1.24E-08	1.35E-10	1.23E-08	1.14E-08	1.74E-09	9.09E-10	2.40E-08	5.04E-11	7.17E-09	8.53E-09	3.08E-09	4.37E-10	8.08E-07	3.36E-10	5.78E-08	8.99E-09
17	FI	3.13E-09	1.34E-09	2.14E-08	9.60E-10	1.59E-08	2.59E-08	6.62E-09	6.60E-08	1.80E-08	1.02E-10	4.77E-08	3.92E-08	8.49E-08	4.69E-07	7.67E-09	1.18E-06	1.65E-08	3.02E-08
18	FR	7.90E-09	4.27E-10	7.02E-08	2.77E-10	3.19E-08	3.22E-07	3.99E-09	3.57E-09	4.88E-07	4.72E-10	4.50E-08	1.37E-07	1.16E-08	7.42E-09	2.33E-07	3.60E-09	7.85E-07	8.94E-08
19	GB	1.27E-09	3.82E-10	1.90E-08	2.78E-10	8.03E-09	1.62E-07	1.08E-09	5.12E-09	1.58E-08	2.51E-11	2.31E-08	6.46E-08	3.72E-08	1.27E-08	6.14E-08	1.05E-08	1.34E-07	1.17E-06
20	GE	2.89E-09	1.67E-06	2.14E-09	1.14E-06	2.98E-09	5.02E-10	8.82E-09	6.75E-09	1.28E-09	8.43E-08	2.22E-09	8.04E-10	1.28E-09	2.78E-09	6.33E-10	1.28E-09	7.10E-10	5.07E-10
21	GR	3.54E-07	5.60E-09	2.68E-08	4.93E-09	8.14E-08	3.66E-09	8.66E-07	2.14E-08	1.69E-08	4.16E-08	2.17E-08	7.68E-09	4.63E-09	1.17E-08	1.28E-08	4.69E-09	1.04E-08	2.19E-09
22	HR	1.54E-07	3.27E-09	3.80E-07	2.13E-09	1.84E-06	2.05E-08	6.23E-08	2.84E-08	1.09E-07	5.79E-09	2.02E-07	5.39E-08	2.48E-08	8.15E-09	4.29E-08	6.76E-09	5.55E-08	1.24E-08
23	HU	1.06E-07	1.07E-08	6.26E-07	8.12E-09	7.16E-07	3.82E-08	1.02E-07	5.55E-08	1.63E-07	5.16E-09	3.48E-07	9.87E-08	4.03E-08	1.25E-08	3.90E-08	1.05E-08	6.37E-08	2.31E-08
24	IE	1.23E-09	2.65E-10	7.60E-09	2.74E-10	9.80E-09	5.66E-08	1.16E-09	3.28E-09	7.23E-09	2.06E-11	1.47E-08	2.89E-08	1.80E-08	9.11E-09	7.57E-08	6.90E-09	4.51E-08	2.35E-07
25	IS	3.19E-10	1.68E-10	2.00E-09	6.36E-11	4.26E-10	1.93E-08	1.51E-10	2.14E-09	4.56E-09	9.98E-12	5.31E-09	1.06E-08	6.09E-09	2.55E-09	1.40E-08	7.86E-09	1.31E-08	3.75E-08
26	IT	1.97E-07	1.24E-09	2.49E-07	9.86E-10	2.88E-07	1.68E-08	7.87E-08	1.12E-08	2.27E-07	6.23E-09	8.01E-08	3.75E-08	1.05E-08	6.43E-09	4.58E-08	3.23E-09	7.59E-08	9.05E-09
27	KZ	4.87E-09	1.33E-07	5.70E-09	1.23E-07	1.10E-08	1.45E-09	1.48E-08	1.96E-08	3.11E-09	1.59E-08	9.23E-09	3.44E-09	5.62E-09	1.66E-08	1.37E-09	8.50E-09	1.76E-09	1.90E-09
28	LT	1.84E-08	1.60E-09	1.34E-07	2.26E-09	5.85E-08	7.00E-08	2.24E-08	8.21E-07	6.84E-08	4.48E-10	2.22E-07	1.19E-07	2.03E-07	2.11E-07	1.92E-08	1.11E-07	4.27E-08	5.39E-08
29	LU	5.23E-09	4.72E-10	9.12E-08	4.58E-10	1.61E-08	1.18E-06	3.40E-09	7.75E-09	1.79E-07	1.45E-10	1.20E-07	1.08E-06	4.02E-08	1.13E-08	7.87E-08	9.85E-09	1.02E-06	1.86E-07
30	LV	1.28E-08	1.16E-09	9.33E-08	9.27E-10	3.36E-08	5.58E-08	1.68E-08	9.58E-07	4.62E-08	2.66E-10	1.73E-07	1.01E-07	1.73E-07	4.36E-07	1.70E-08	1.51E-07	3.37E-08	4.47E-08
31	MD	1.28E-07	2.67E-08	6.39E-08	2.88E-08	1.51E-07	7.52E-09	3.15E-07	1.35E-07	3.71E-08	8.04E-09	5.71E-08	2.00E-08	2.69E-08	4.05E-08	1.07E-08	2.13E-08	1.08E-08	5.74E-09
32	ME	4.10E-06	2.90E-09	1.07E-07	2.41E-09	6.25E-07	8.39E-09	2.36E-07	1.91E-08	5.03E-08	3.49E-08	7.37E-08	2.42E-08	1.26E-08	6.46E-09	3.37E-08	5.72E-09	3.21E-08	6.55E-09

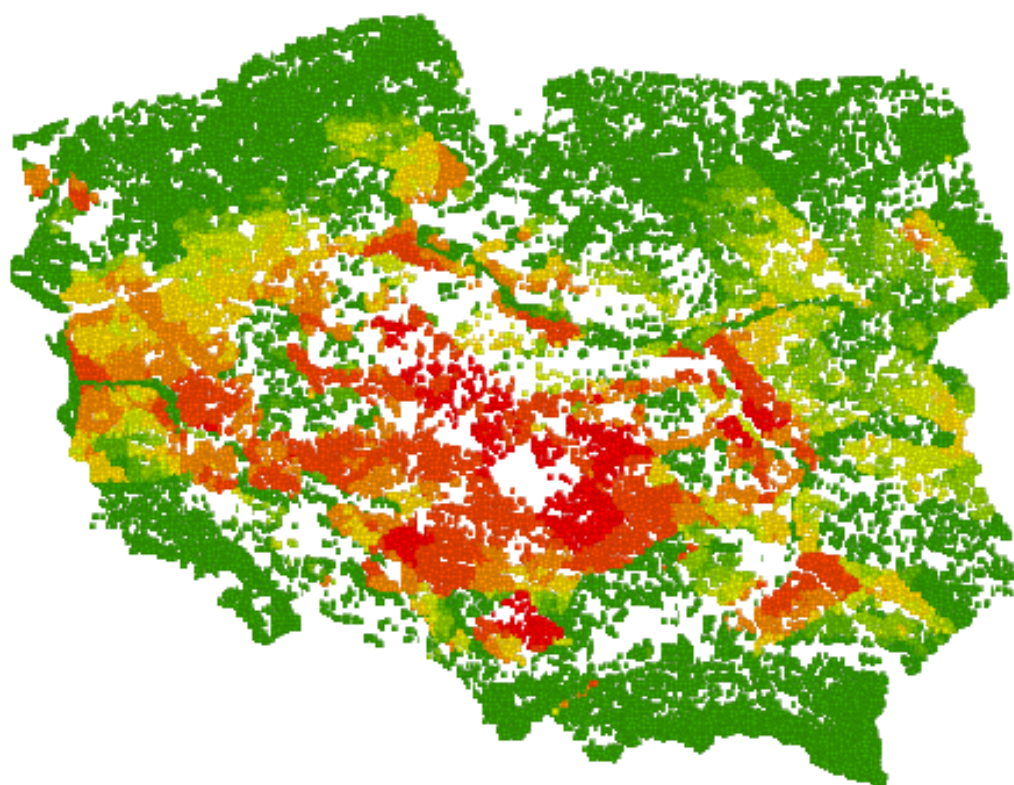
Emitters are ordered in columns and receivers in lines. In each case there is the relationship coefficient between emitter country and receiver one in $\mu\text{g}/\text{cm}^3/\text{ton}$ emitted.

Validation graphics for the average matrix of transportation





Map of critical loads exceedances



SUM_EX

■	0.00 - 25.80
■	25.81 - 79.40
■	79.41 - 136.54
■	136.55 - 205.73
■	205.74 - 290.42
■	290.43 - 409.88
■	409.89 - 660.33
■	660.34 - 1562.31

This map shows the sum of exceedances, sulphur and nitrogen.

The unit is equivalent/ha/year.

Shapes table

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