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NATIONAL ITALIAN INTEGRATED ATMOSPHERIC MODEL ON AIR POLLUTION: SENSITIVITY TO EMISSION INVENTORY

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Abstract: Sensitivity of MINNI's Atmospheric Modeling System has been tested over year 2005 using two different emission datasets, the National Emission Inventory (top-down approach) and the GAINS-Italy emission estimates (bottom-up approach). Detailed analysis has been carried over the Po Valley region for NO_x and PM_{10} concentrations, since their EU limit values are often exceeded. NO_x and PM_{10} results have been compared to available measurements showing that emission input variation has a detectable influence on simulated concentrations. The variations in model performance in relation to the variation of emission inventory have been analyzed at background urban, suburban and rural monitoring stations.

Key words: *air quality, emission inventory, MINNI, model performance, sensitivity, FAIRMODE*

INTRODUCTION

The MINNI (Integrated National Model in support to the International Negotiation on Air Pollution) Project has been supporting Italian Ministry of Environment for the last ten years, in international negotiation process on Air Pollution and assessing Air Quality policies at national/local level (Zanini et al., 2005). The Project include two models: the Atmospheric Modelling System (AMS–Italy) (Zanini et al., 2010) and the Greenhouse Gas and Air Pollution Interaction and Synergies (GAINS–Italy) (D'Elia et al., 2009). AMS simulates meteorology and air quality fields for all of Italy, on a national domain at 20 km resolution and on 5 nested regional domains at 4 km resolution (see figure 1), either on one reference year or on specific periods. Prognostic meteorology is calculated by RAMS (Cotton et al., 2003), while for chemical and transport modeling, FARM (Silibello et al., 2008; Gariazzo et al., 2007) is used, with initial and boundary condition from EMEP Model. Emission inventory data are processed by Emission Manager (ARIA/ARIANET, 2008), performing grid disaggregation based on CORINE land cover, time modulation, PM and VOC speciation.

Emissions represent one of the principal driving forces (Dennis et al., 2010) and one of the major uncertainty sources (Russel and Dennis, 2000) in modeling air quality. Two main uncertainties are associated to an emission inventory: the amount of pollutants emitted and their spatial and temporal distribution. Moreover, emission inventories are elaborated by either top-down or bottom-up approach. The aim of the present work is to evaluate the sensitivity of the AMS-Italy to two different emission dataset, the National Emission Inventory (NEI) and the GAINS-Italy emission estimates (GIE) while keeping the same meteorological input and chemical EMEP boundary conditions as well the same temporal and spatial distribution on the 4x4 km^2 grid cells. Detailed analysis has been carried out in Northern Italy since the Po Valley region (ca. 45000 km^2) often shows high pollutant concentrations exceeding the EU limit values. The simulations of gas and aerosol concentrations with the NEI and GIE for the year 2005 have been compared to available measurements.

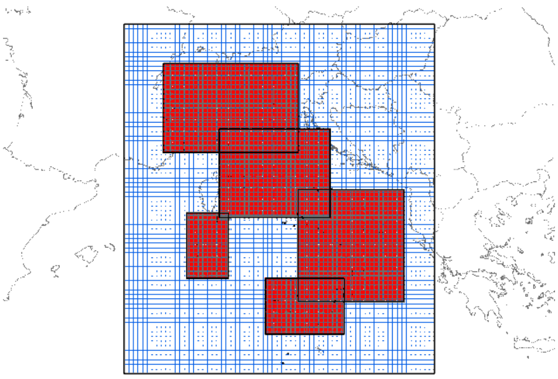

Figure 1. AMS modelling domains and calculation grids.

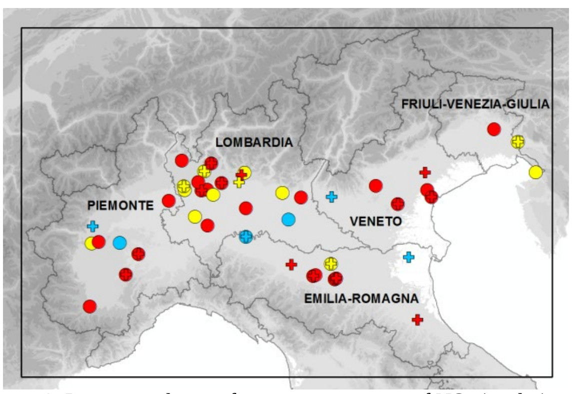

Figure 2. Position and type of monitoring stations of NO_x (circles) and PM_{10} (crosses) in Northern Italy modelling domain. Red=urban, yellow=suburban, blue=rural.

Measured concentrations of NO_x and PM_{10} for 2005 have been extracted from BRACE database (Caricchia, 2003; ISPRA, 2010), collecting air quality information at national level and providing it to AIRBASE European database. Given the spatial resolution of the AMS, background monitoring sites inside Po Valley have been selected for the comparison resulting in an observation dataset (figure 2) of 37 stations for NO_x (23 urban, 11 suburban, 3 rural) and 23 stations for PM_{10} (14 urban, 5 suburban 4 rural).

Po Valley monitoring stations have long time series data, from 10 to 20 years, and exceedances of limit values (both daily and yearly) of NO_x, PM_{10} and O_3 established by European Community Directive 2008/50/EC are often registered. In order to manage air quality, the five Po Valley administrative Regions (Piemonte, Lombardia, Veneto, Friuli Venezia Giulia, Emilia-Romagna) developed high quality bottom-up emission inventories, allowing comparison and harmonization with top-down approaches within GAINS-Italy model.

TESTING TWO EMISSION INVENTORIES: NEI AND GIE

In this modeling study on Italy and year 2005, two different emission inventories have been used: the National Emission Inventory (NEI) and the GAINS-Italy Emission estimates (GIE). NEI is computed every year by Institute for Environmental Protection and Research (ISPRA) but it is scaled down at NUTS3 level every 5 years by applying a top-down approach. It is compiled according to international agreements on air pollution and contains pollutant and greenhouse gases emission data for each of the 103 Italian administrative Provinces (NUTS3). Emission sources are classified following the EMEP-CORINAIR Nomenclature (SNAP-Selective Nomenclature for Air Pollution), with division in 11 main classes. The downscaling of emissions from a national to a provincial scale requires the collection of many indicators as economic and demographic data, land use, industrial production data, and possibly information about point source emissions from national registers (Emission Trading, LCP and Italian EPER). All this work results in a database of more than 640,000 records (De Lauretis et al., 2009). This top-down emission inventory allows an homogenous view of emission apportionment in the Italian territory but on the other hand does not take into account the information from local inventories that could provide a better estimate at NUTS 2-3-4 basis.

GIE is compiled according to GAINS-Europe scenario analysis methodology (Klaasen et al., 2004; GAINS, 2011) for each of the 20 Italian administrative Region (NUTS2). GAINS-Italy model calculates anthropogenic emission estimates for SO_2, NO_x, PM_{10}, $PM_{2.5}$, VOC, NH_3 and the 6 GHGs on an annual base from 1990 to 2030 at a 5-year interval. GAINS-Italy model purpose is to provide emission scenarios and, through AMS, alternative air quality and health impact scenarios, consequently its emission classification scheme and its underlying methodology significantly differ from an emission inventory. First of all, emission sources are generally more aggregated than SNAP, and one of the main uncertainties is the way SNAP-GAINS codes are matched. Secondly, respect to an emission inventory, all sources in GAINS can be seen as "diffuse" and their assessment requires the definition of an energy and non energy scenario and of a control strategy. Energy and non-energy scenarios are the drivers of the emission amount while spatio-temporal patterns feed the top-down scaling process at NUTS2 level (20 Italian Regions). In order to produce reliable emission, air quality and health impact scenarios, GIE estimates have been harmonized, at a base year, with both national and regional emission inventories preserving the total levels of energy and non-energy activities. Due to the harmonization process, emissions computed by GAINS-Italy follow the bottom-up methodology. In this study, the harmonization process has been completed at the reference year 2005 for the Lombardia, Piemonte and Emilia-Romagna Regions.

Table 2. Annual NO_x Emission (kt) 2005. National Emission Inventory (NEI) vs GAINS Emission Estimates (GIE) in Northern Italy

REGIONS	SNAP 01+09		SNAP 02		SNAP 03+04		SNAP 07		SNAP 08		Other		Total	
	GIE	NEI	GIE	NEI	GIE	NEI	GIE	NEI	GIE	NEI	GIE	NEI	GIE Total	NEI Total
EMILIA ROMAGNA	1,47	4,01	10,31	12,36	17,53	16,30	63,56	46,54	17,16	13,14		0,05	110,03	92,39
FRIULI VENEZIA GIULIA	6,69	5,25	2,81	2,52	6,75	7,73	32,89	15,86	5,67	4,80		0,00	54,82	36,18
LIGURIA	6,98	11,26	3,06	2,39	1,76	1,15	13,33	23,06	10,08	9,56		0,00	35,21	47,42
LOMBARDIA	8,79	11,17	18,60	24,83	30,63	25,61	84,70	84,62	21,53	12,42		0,10	164,25	158,74
PIEMONTE	0,95	5,04	9,47	9,47	15,58	12,29	39,97	56,77	8,48	10,40		0,13	74,44	94,11
TRENTINO ALTO ADIGE	8,47	0,21	2,33	2,71	3,00	1,24	13,46	13,83	1,43	3,84		0,00	28,68	21,83
VALLE D`AOSTA	3,36	0,00	0,78	0,49	0,24	0,04	2,90	3,82	0,48	0,84		0,00	7,77	5,19
VENETO	13,60	14,66	10,44	10,45	16,82	13,33	46,45	49,74	13,35	14,16		0,01	100,66	102,35
Total	50,32	51,59	57,81	65,23	92,31	77,70	297,26	294,23	78,16	69,16		0,30	575,85	558,21

Table 3. Annual PM_{10} Emission (t) 2005. National Emission Inventory (NEI) vs GAINS Emission Estimates (GIE) in Northern Italy

REGIONS	SNAP 01+09		SNAP 02		SNAP 03+04+06		SNAP 07		SNAP 08		Other*		Total	
	GIE	NEI	GIE	NEI	GIE	NEI	GIE	NEI	GIE	NEI	GIE	NEI	GIE Total	NEI Total
EMILIA ROMAGNA	275,43	886,74	2049,43	1150,62	2415,19	3515,08	4336,06	3149,35	1850,03	1561,09	3208,07	2833,34	14134,21	13096,21
FRIULI VENEZIA GIULIA	281,09	249,37	896,88	635,10	827,41	1537,35	1636,46	1033,67	434,68	461,27	1490,87	576,57	5567,37	4493,31
LIGURIA	362,12	574,87	741,77	646,14	619,73	617,67	1127,13	1468,35	574,81	696,46	681,19	136,01	4106,75	4139,50
LOMBARDIA	1226,64	929,44	6651,42	2555,37	2267,07	7350,61	6737,14	6104,18	2362,70	1325,99	6686,42	4920,58	25931,38	23186,18
PIEMONTE	966,63	926,03	2017,16	1647,18	4246,90	3650,75	3128,16	3695,94	985,17	1277,44	3372,14	1681,16	14716,15	12878,50
TRENTINO ALTO ADIGE	42,65	262,70	800,80	539,56	113,73	418,38	942,79	888,40	177,17	459,95	689,01	215,19	2766,15	2784,17
VALLE D`AOSTA	4,29	1,37	442,57	74,75	70,42	44,07	210,88	216,17	51,88	97,62	110,24	18,87	890,27	452,85
VENETO	846,19	816,56	2712,41	2165,58	1320,82	4779,93	3639,99	3426,80	1249,59	1550,91	6172,29	3131,65	15941,29	15871,44
Total	4005,0	4647,1	16312,4	9414,3	11881,3	21913,8	21758,6	19982,9	7686,0	7430,7	22410,2	13513,4	84053,6	76902,17

* This heading contains PM_{10} emissions estimated in GAINS but not considered in National Emission Inventory for additional 29 kt at national level

In Tables 1 and 2, NO_x and PM_{10} emissions from NEI and GIE are reported showing the different regional distribution arising from the alternative methodology. Particularly significant are some differences in the SNAP Class 07 "Road Transport", where the activity levels for different vehicle types are mileages in NEI and fuel consumption in GIE. Purchases of fuel out of national borders are often accounted in different ways in the inventories of frontier Regions and this could explain sectoral NO_x differences in Piemonte and Friuli Venezia Giulia Regions. The relevant increase of PM_{10} emissions in GIE SNAP Class 02 "Combustion in residential-commercial sector" is related to a better assessment of biomass combustion.

These are open issues in pollutant emission accounting, therefore it is important to understand the effect of differences on air quality predictions.

RESULTS AND DISCUSSION

GIE data have been translated in CORINAIR/SNAP classification system using correspondance schemes and procedures. Point sources have been reconstructed for GIE as in NEI simulation and diffuse emissions have been scaled on NUTS3 level (Provinces) and then, through emission pre-processing, on the 4x4 km^2 cell grid and on an hourly base considering the same temporal and spatial distribution used for NEI dataset.

It is worth noting that different emission distributions can result from the different sectoral allocation of emission shares and/or from the inaccurate matching of two differently aggregated emission classes while the spatial layers and temporal profiles used in the two simulations are equal. For a primary pollutant as NO_x it is worthwhile to examine on a qualitative basis how emission differences are translated in concentration differences. Figure 3 shows the map of gridded yearly NO_x emissions differences between NEI and GIE against annual NO_x concentrations differences between the two AMS simulations and the decreasing and increasing trends are actually confirmed.

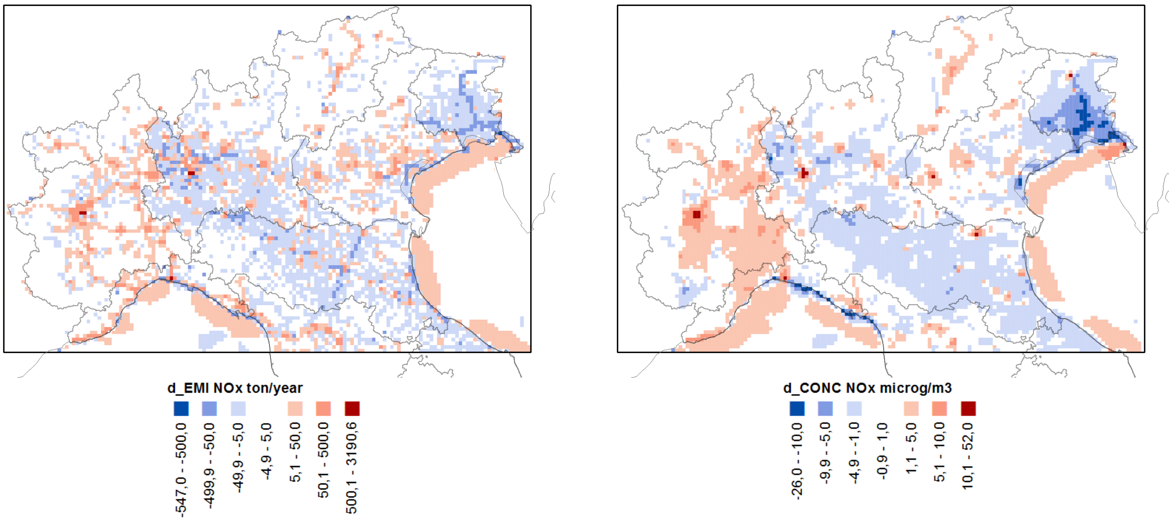

Figure 3. NO_x total 2005 emission (left) and concentration (right) differences between NEI and GIE on NI domain.

In order to assess the effect of the two emission inputs on air quality simulations in Northern Italy, Figure 4 shows a comparison of modeled concentrations against the observations of the BRACE dataset with two ensembles of barplots: the first two graph rows show, for each monitoring station considered in the study, observed NO_x and PM_{10} yearly averages versus corresponding values simulated using NEI and GIE; the last two graph rows present the values of correlation coefficient calculated comparing simulated NEI and GIE with observed data. For clearness, urban stations are separated from suburban and rural stations. Yearly average and correlation coefficient were chosen for model performance evaluation according to the current EU guidance (Denby, 2010).

NO_x yearly average results show in 7 cases (IT0741A, IT0902A, IT995A, IT1017A, IT1035A, IT1177A, IT1216A – 19% of total stations) that GIE emissions cause reduction of differences from measured values, while in 4 cases (IT0554A, IT0966A, IT1120A, IT1523A – 11% of total stations), lead to increased differences from measured values. In the remaining 26 cases (70% of total stations) NEI and GIE simulations produce similar results. Improved model performances using GIE appear to be concentrated in Lombardia, while Piemonte results seems to be negatively affected by the remarkable emission reduction in Road Transport Sector. Emilia Romagna and Veneto look less sensitive while Friuli Venezia Giulia has not a clear behaviour; the increase of emission in Road Transport Sector is detectable with an effect specular to Piemonte Region but the distance from the observed concentrations increase in one case (IT0966A) and decrease in the other (IT1216A). The scarcity of the available monitoring stations does not consent a definite statement about that.

Correlation of NO_x show not-negligible variations in Lombardia and Piemonte: IT1174A and IT1522A indicate better performance in GIE not evidenced in yearly average comparison; IT0741A has a better GIE performance both of correlation coefficient and of yearly average; 6 stations (IT0732A, IT0839A, IT1088A, IT1518A, IT1523A, IT1529A) have higher values in NEI. In Friuli Venezia Giulia, IT0966A has a higher value in NEI. Elsewhere, correlation is not sensitive to emission inventory.

Among the 11 stations with yearly average variations, 7 are urban (out of 23 analyzed), 3 are suburban (out of 11 analyzed) and 1 is rural (out of 3 analyzed): there is no evidence of different sensibility to emission inventories between urban and non-urban stations.

For PM_{10} yearly average concentrations, results show that GIE emissions cause reduction of the differences between simulated and measured values at 3 stations (IT0770A, IT1035A, IT1469A – 13% of total stations), while the difference increases in 1 case (IT1018A – 4% of total stations). At the remaining 19 stations (83% of total) NEI and GIE simulations are similar. The best model performances appear to be achieved more in Lombardia and Emilia-Romagna, than in Piemonte, Veneto and Friuli Venezia Giulia, where the measured concentrations remain underestimated. The although significant increases of primary PM_{10} emissions (domestic combustion and other sectors not considered in NEI) do not improve the model simulation of the resulting PM_{10} concentrations. Correlation of PM_{10} show not-negligible variations in Lombardia and Veneto, with IT0770A and IT1035A performing better in GIE both in correlation coefficient and in yearly average; IT1018A and IT1549A indicate better performance in GIE not evidenced in yearly average comparison; IT0448A has a higher value in NEI. Elsewhere, correlation is not sensitive to emission inventory.

Among the 4 stations showing variations on yearly average, 3 are urban (out of 14 analyzed), 1 is suburban (out of 5 analyzed) and no one is rural (out of 4 analyzed): though stations numbers are small to draw definitive conclusions, urban and suburban stations appear to be sensitive to different inventories while this is not the case of rural ones.

CONCLUSIONS AND FUTURE WORK

An analysis of sensitivity to emission inventory input has been carried out using MINNI's Atmospheric Modeling System, focusing on Po valley in Northern Italy. 2005 annual simulations of NO_x and PM_{10} have been compared to observed values, analyzing yearly average concentrations and correlation coefficients produced by NEI and GIE case studies. NEI follows a top-down approach, while GIE is compiled by an harmonization process with local NUTS2 inventories, resulting in a bottom-up inventory. Their differences concern more Regional and SNAP sector distribution than total emitted quantities.
Results show that simulated concentrations change following variations in grid disaggregation of emission input. There is no clear evidence of improvement in using NEI or GIE: model performances are improved at certain stations and worsened at other stations. However, yearly average and correlation coefficient statistical indicators show coherent variations.
Results suggest further work on different classification schemes matching between NEI and GIE, investigating hourly time profiles of simulated and measured concentrations on selected episodes.

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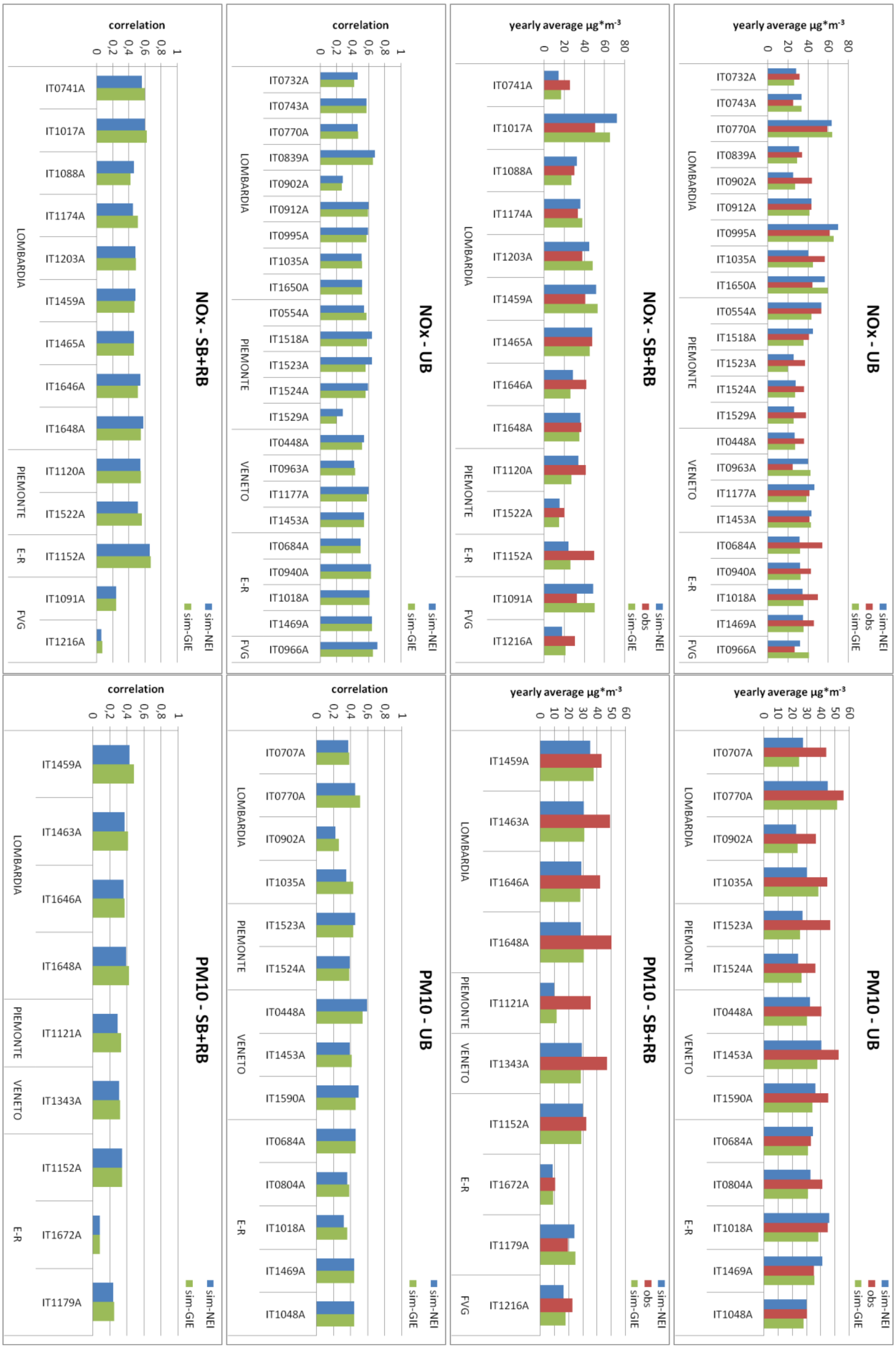

Figure 4. NO_x and PM_{10} observed (red) versus simulated NEI (blue) and GIE (green) yearly averages, and simulated NEI (blue) and GIE (green) values of correlation. UB=urban background, SB=suburban background, RB=rural background.