ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

UTVALAMB Technical Unit for Models, Methods and Technologies for Environmental Assessments

GAINS-Italy : Italian I.A.M for Air Quality

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Opera
www.operatool.eu

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Building blocks of GAINS

MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

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Energy/agricultural projections

Emission control options

Emissions

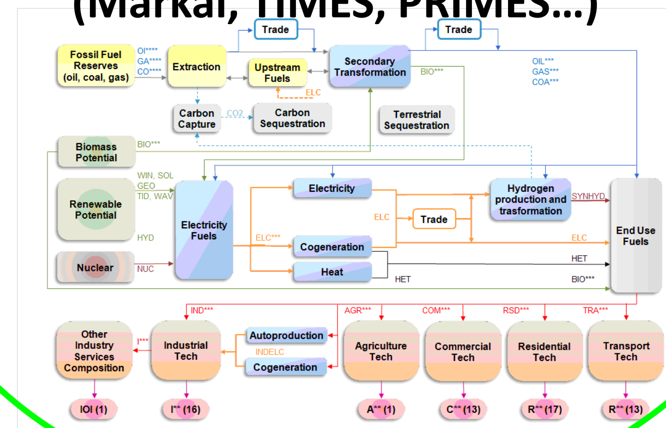
Costs

Atmospheric dispersion

Air pollution impacts,
Basket of GHG emissions

Energy Models

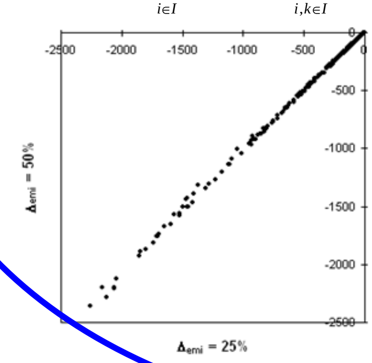
(Markal, TIMES, PRIMES…)

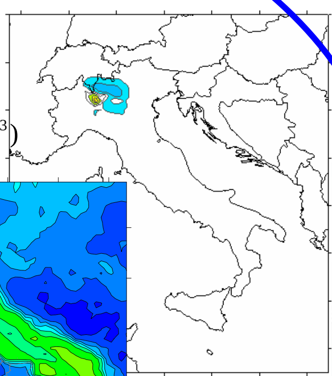


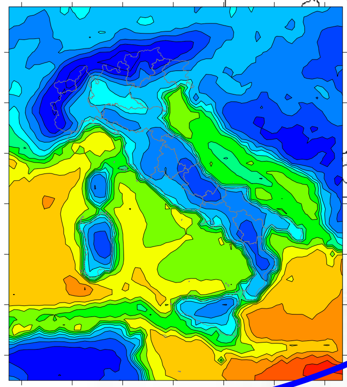
AIR QUALITY MODELS by ATM (EMEP, AMS-MINNI)

$$t_{i\alpha} = \left.\frac{\partial D_\alpha}{\partial E_i}\right|_{S0} \qquad t_{i\alpha} \cong \frac{\Delta D_\alpha}{\Delta E_i} = \frac{D_\alpha^0 - D_\alpha}{E_i^0\ x}$$

$$\Delta D_\alpha = \sum_{i \in I} t_{i\alpha}\Delta E_i + \sum_{i,k \in I} \frac{\partial^2 D_\alpha}{\partial E_i \partial E_k}\Delta E_i \Delta E_k + O(\Delta E^3)$$

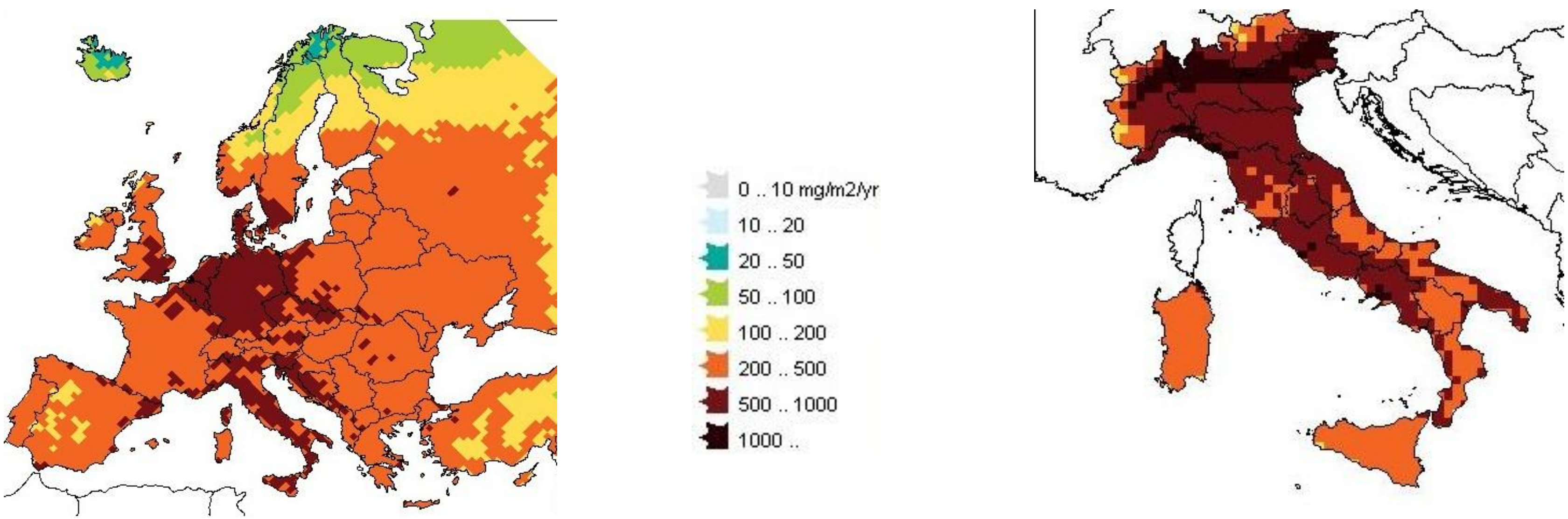






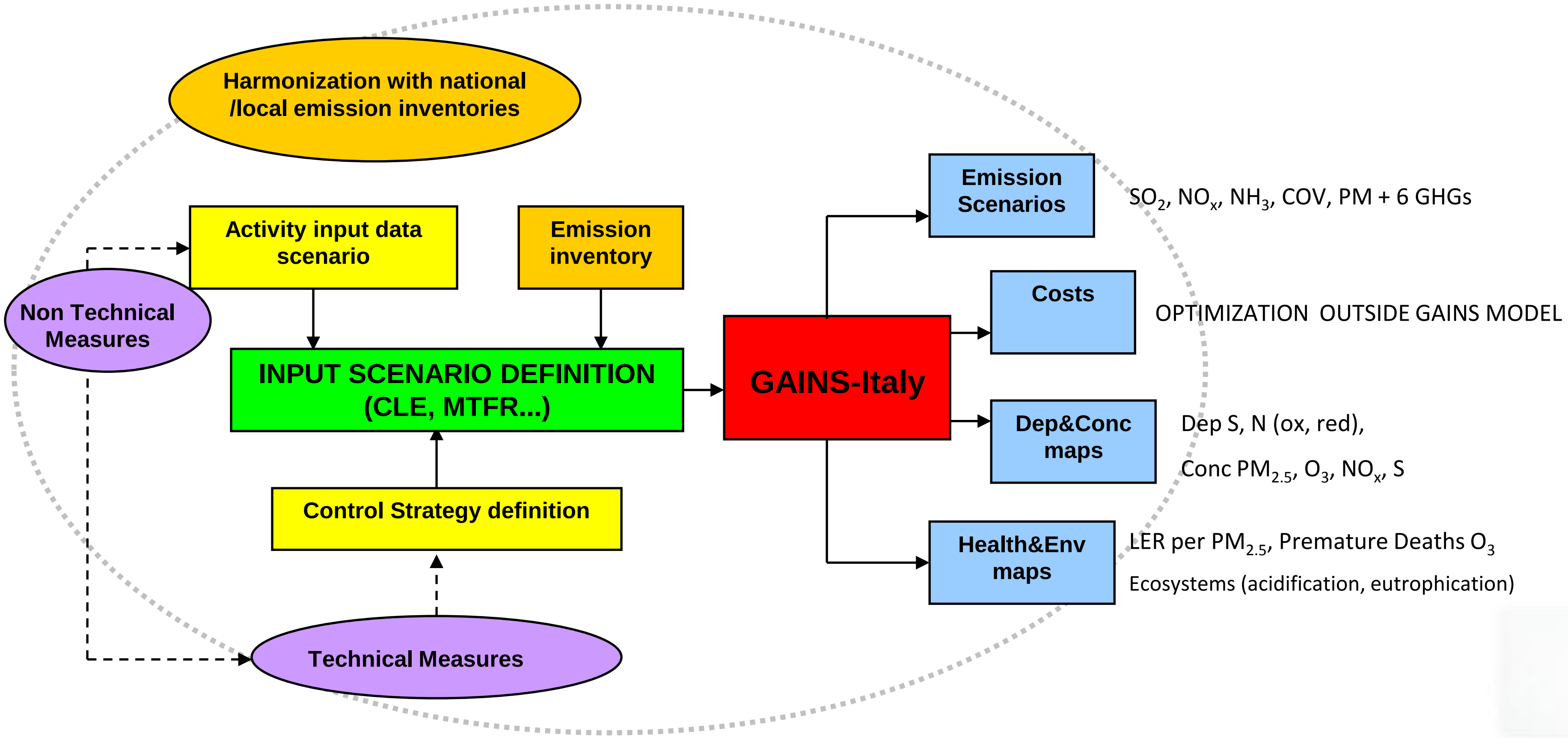
GAINS_IT vs GAINS_EU

from Member States | to | Regions



from 50 km spatial resolution | to | 20 km spatial resolution

GAINS-Italy MODEL



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    2.1 the revision of the Gotebörg protocol
    2.2 the revision of the Thematic Strategy on Air Pollution

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MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

GAINS_IT NEWS

- A NEW ENERGY SCENARIO HAS BEEN DEVELOPED BY ISPRA (Institute for Environmental Protection and Research) based on Interministerial Committee for Economic Planning Resolution which updates the National Action Plan for GHGs emission reduction to comply with Kyoto Protocol

- A NEW MODEL STRUCTURE

- A NEW EMISSION VECTOR

- NEW ATMs

- OPTIMIZATION TOOL FOR ITALY

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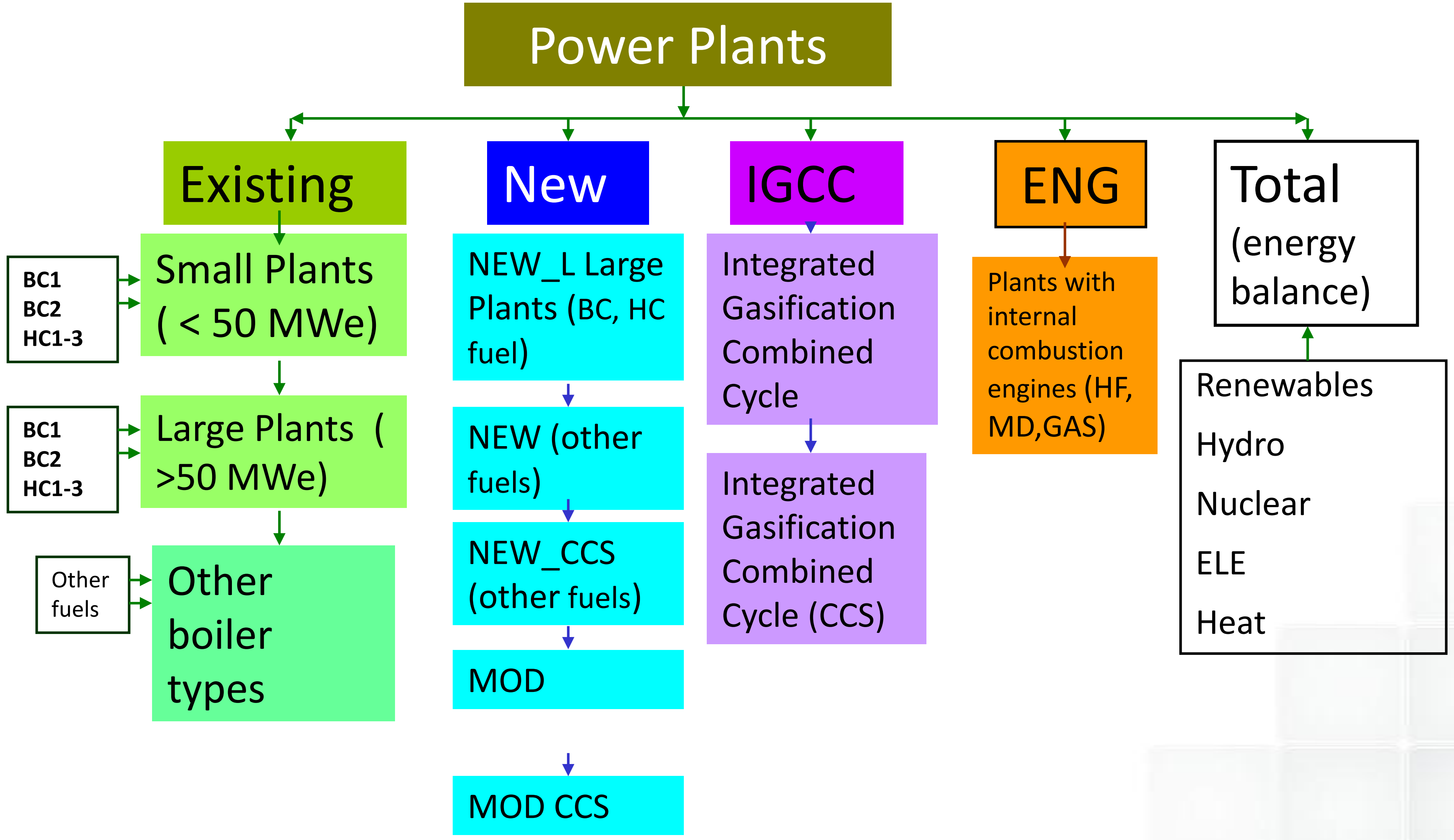
GAINS_IT NEWS

The structure of the Power Plant (PP) and Industrial sector (IN) in the GAINS model has been updated.

A higher level of details is now provided.



GAINS_IT NEWS

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GAINS_IT NEWS

- The introduction of a new and more detailed structure requires new and verified emission factors

- The use of GAINS-Italy to support the negotiation on the new Thematic Strategy on Air Policy (TSAP) has required a careful revision of all the emission factors considered in the “current_EU” emission vector used in the GAINS-Europe model to elaborate the scenario for the TSAP, especially those considered in the new PP structure

- Italy will propose also emission factors for the pollutants and industrial processes whose emissions are not calculated by GAINS (ie. Bricks and Ceramic furnaces)

- A new emission vector, called “current_IT” harmonized with the national emission inventory, will be provided to IIASA

GAINS_IT NEWS

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THE ATMOSPHERIC MODEL AND GAINS_ITALY

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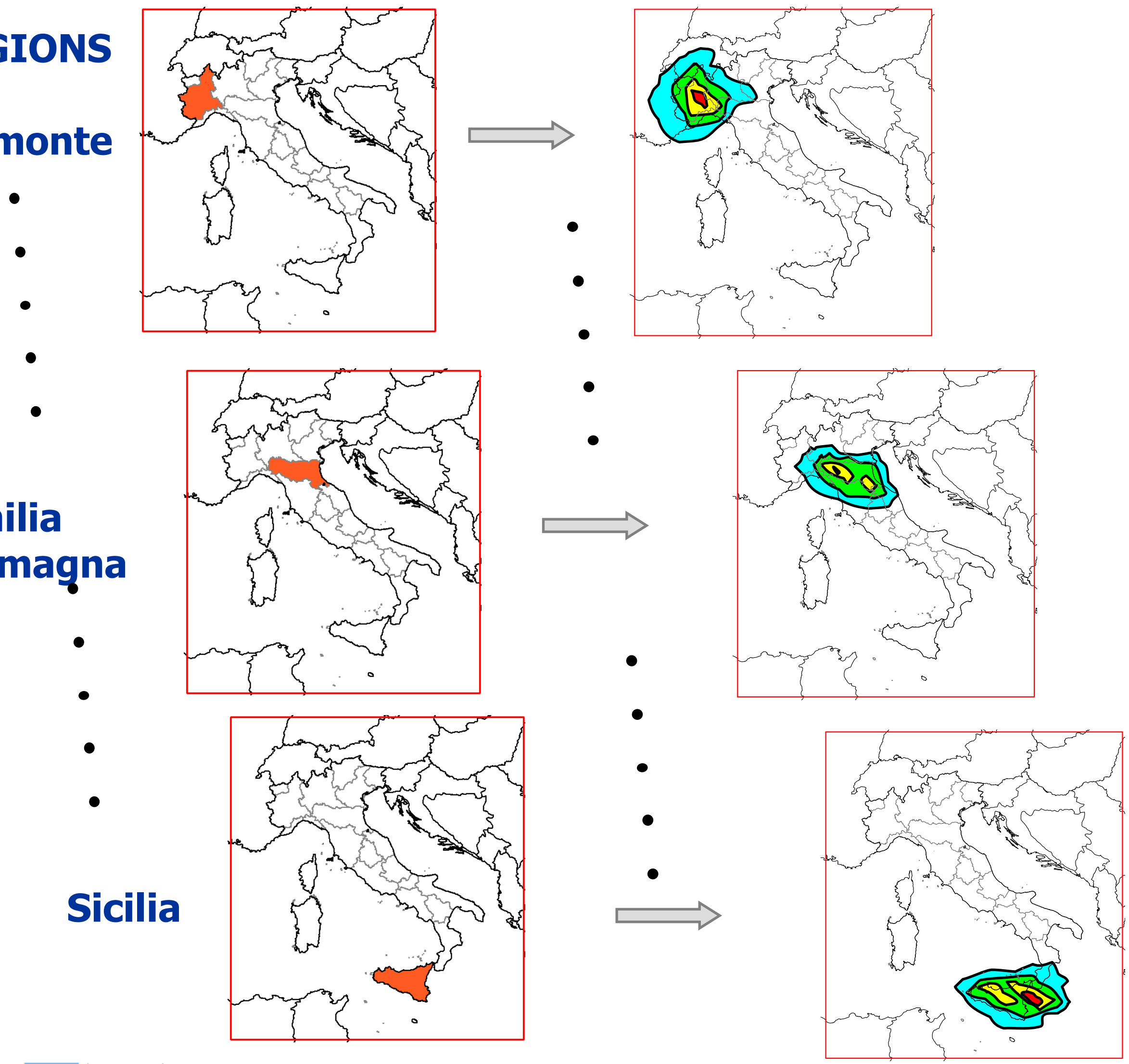
Emissions **Conc. & depositions**

REGIONS

Piemonte

Emilia Romagna

Sicilia



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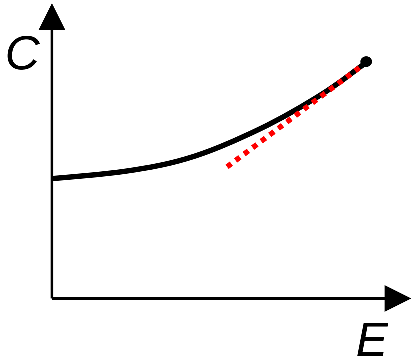
- The **ATM** are the linear approximation of the system behavior when emissions change compared to a reference scenario
- In **GAINS** the emission changes refer to regional administration units (NUTS2)
- The approximate estimates of concentrations and depositions have 20 km spatial resolution

The "new" answers to ATM limits

Approximation of atmospheric system non-linear behavior:

- Contributes to depositions: we can add them only in conditions similar to those of reference scenario
- Emission changes: not beyond the limits tested
- Dependence from the meteorological year



Non-linearity:

- Answer to large changes of a precursor in a given set of emission sources
- Cross-effects (inside a set of pollutants and emission sources)

Meteorological reference year: **AVERAGE OF 4 YEARS 1999, 2003, 2005, 2007**

Emissions reference year : **a scenario year (2015)**

Considered precursors : anthropogenic SO_x, NO_x, NH_3, NMVOC, PM_{10}

Regional : -25%

Methodology/1

- Simulation runs have been developed to test primary dependencies among precursors and GAINS indicators and to test greater or lesser linearity of these dependencies in the considered emission changes range.
- The results led ATMs construction orienting the setup of the simulations needed to elaborate them.

Methodology/2

- Considered Administrative Regions: Lombardia and Lazio, different from the geographic, meteorological and emission point of view.
- Precursors: SO_2, NO_x, NH_3, NMVOC e PM_{10}.
- Emission reduction percentages: -25% e -50%.
- GAINS Indicators :
  - Total annual deposition of S, N, NH;
  - PM_{10};
  - SOMO35 ed AOT40;
  - NO_2 (now included in GAINS-Italy).

Conclusions

		precursors				
		SO_2	NO_X	PM_{10}	NH_3	NMVOC
Calculated species	S	**linear**	negligible	negligible	negligible	negligible
	N	negligible	**linear**	negligible	**Anti correlated Accounts for 30% slightly non linear**	negligible
	NH	negligible	negligible	negligible	**linear**	negligible
	O_3 (SOMO35/AOT40)	no	**semi-linear NO_X limited regime)**	no	no	**linear (VOC limited regime)**
	PM_{10}	linear, secondary In respect to PM_{10}	semi linear, secondary	**linear, dominant**	semi linear, secondary	linear, secondary

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GAINS
source-receptor relationships for PM

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$$PM2.5_j = \sum_{i \in I} \pi_{ij}^{A} \cdot p_i + \sum_{i \in I} \sigma_{ij}^{A} \cdot s_i + 0.5\left(\sum_{i \in I} \alpha_{ij}^{S} \cdot a_i + \sum_{i \in I} \nu_{ij}^{S} \cdot n_i\right) +$$

$$+ 0.5 \min\left(\max\left(0, \sum_{i \in I} \alpha_{ij}^{W} \cdot a_i - \sum_{i \in I} \frac{14}{32} \sigma_{ij}^{W} \cdot s_i + k1_j\right), \sum_{i \in I} \nu_{ij}^{W} \cdot n_i + k2_j\right) + k3_j$$

I	set of emission sources (regions)
J	set of receptors (grid cells)
$PM\,2.5_j$	annual mean concentration of $PM_{2.5}$ at receptor point j
p_i	anthropogenic emissions of primary $PM_{2.5}$ in region i
s_i	SO_2 anthropogenic emissions in region i
n_i	NO_x anthropogenic emissions in region i
a_i	NH_3 anthropogenic emissions in region i
$\alpha^{S,W}_{ij}$, $\nu^{S,W}$, $\sigma^{W,A}_{ij}$, π^{A}_{ij}	linear transfer coefficients for reduced and oxidized nitrogen, sulfur and primary $PM_{2.5}$, winter, summer and annual
$k1_j$, $k2_j$	constants to fit NH_x or NO_3 into reference case
$k3_j$	make sure function fits reference case

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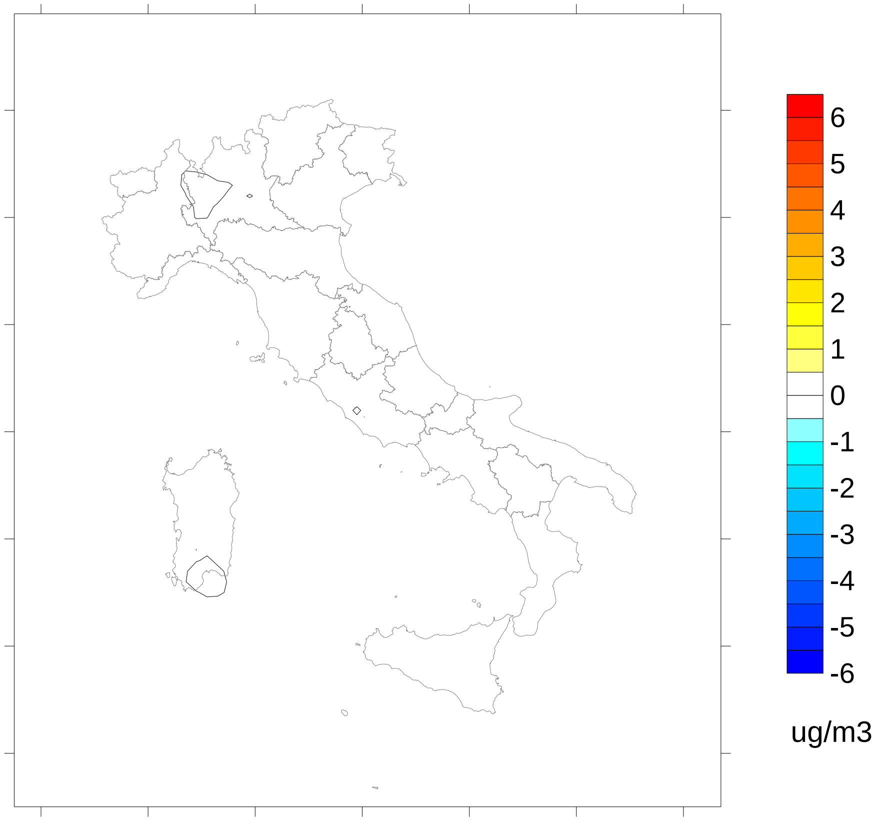
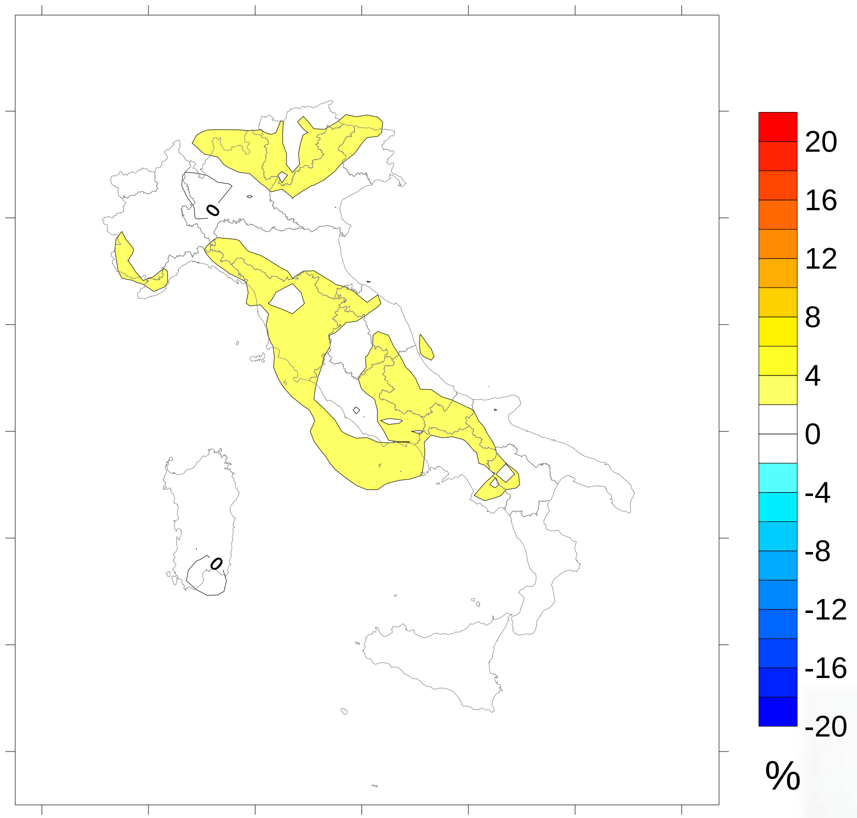
Control run "noCP 2020": model run vs. ATM approximation $PM_{2.5}$

Absolute error



Relative error



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GAINS
source-receptor relationships for Ozone

$$O_j = \sum_{i \in I} to_{ij}^{n} \cdot n_i + \sum_{i \in I} to_{ij}^{v} \cdot v_i + ko_j$$

I	set of emission sources (regions)
J	set of receptors (grid cells)
O_j	ozone indicator (SOMO35 / $AOT40_f$ / $AOT40_c$) at receptor point j
n_i	NO_x anthropogenic emissions in region i
v_i	NMVOC anthropogenic emissions in region i
$to^n{}_{ij}$, $to^v{}_{ij}$	linear transfer coefficients for nitrogen oxides and NMVOC
ko_j	constant to calibrate the linear approximation

Control run "noCP 2020": model run vs. ATM approximation SOMO35

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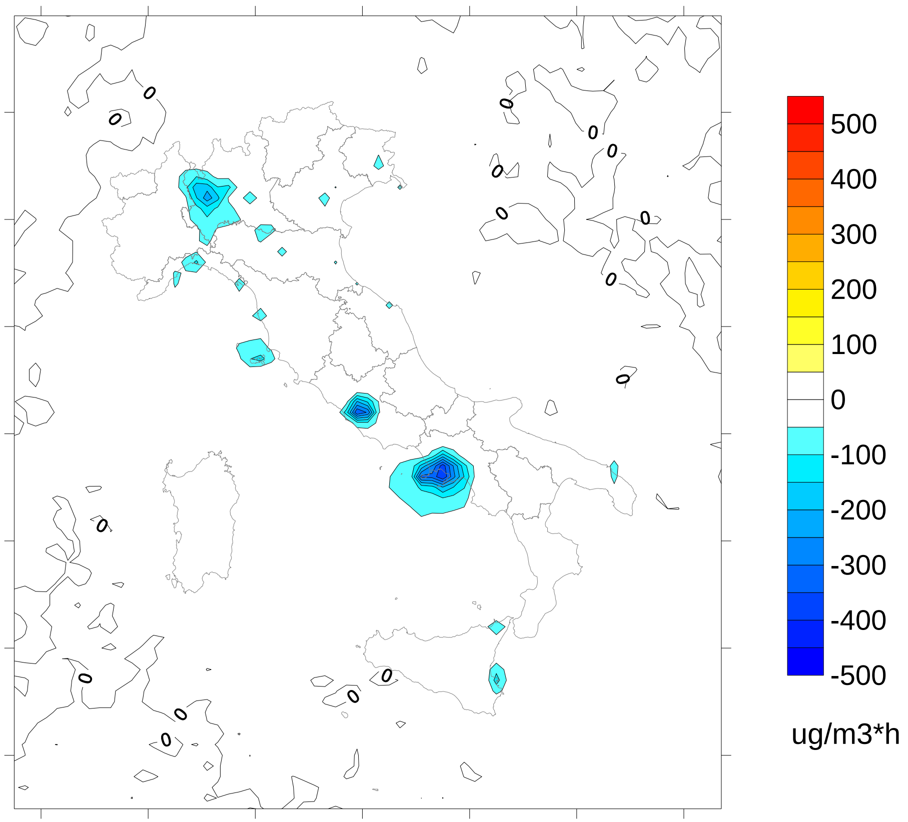
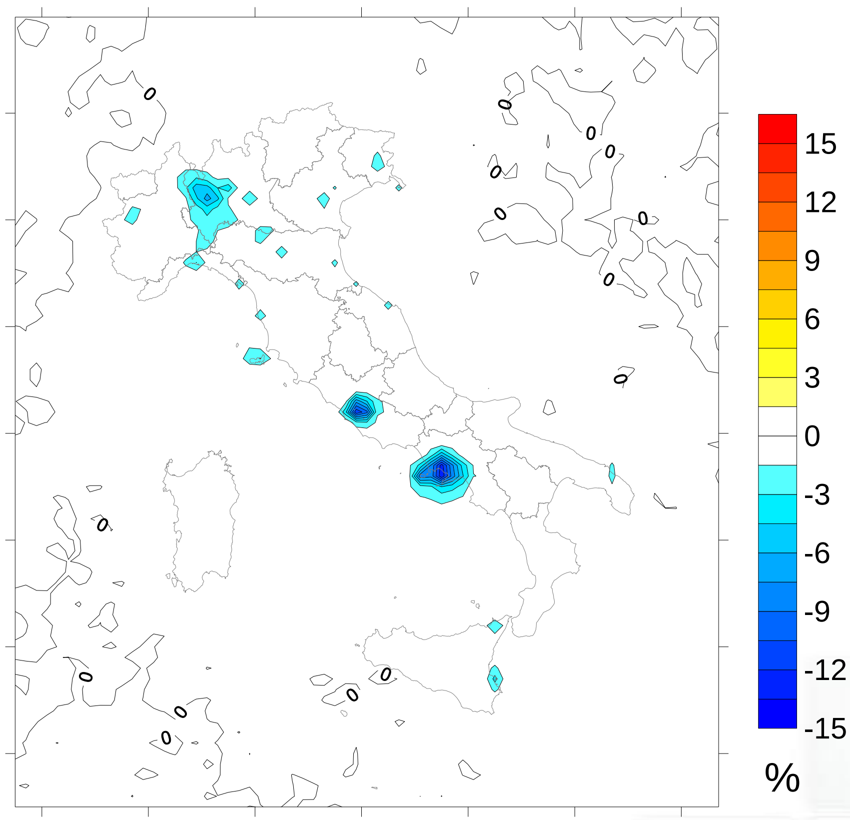
Absolute error



Relative error



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SOMO35
Application of non-linear terms to"noCP 2020" scenario on selected regions (Lombardia, Lazio, Campania)

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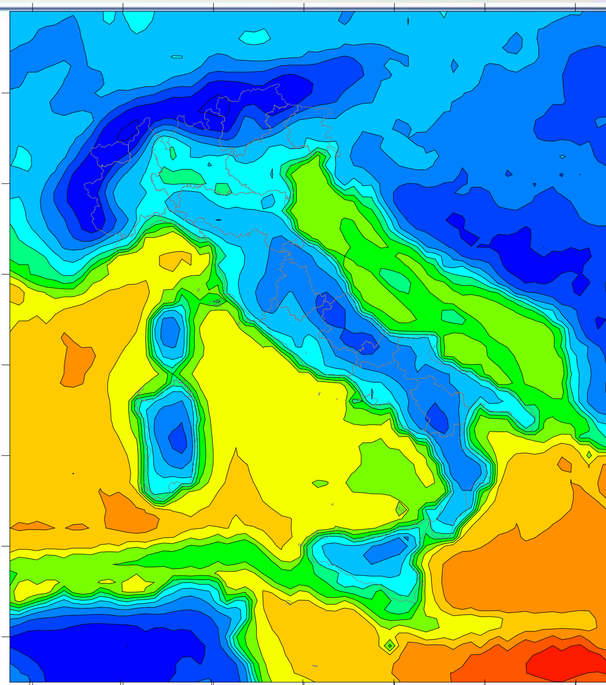
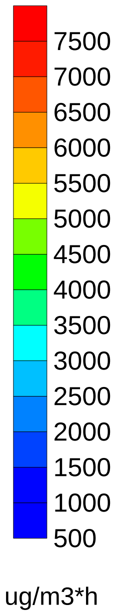
SOMO35 = α n + γ v + δ

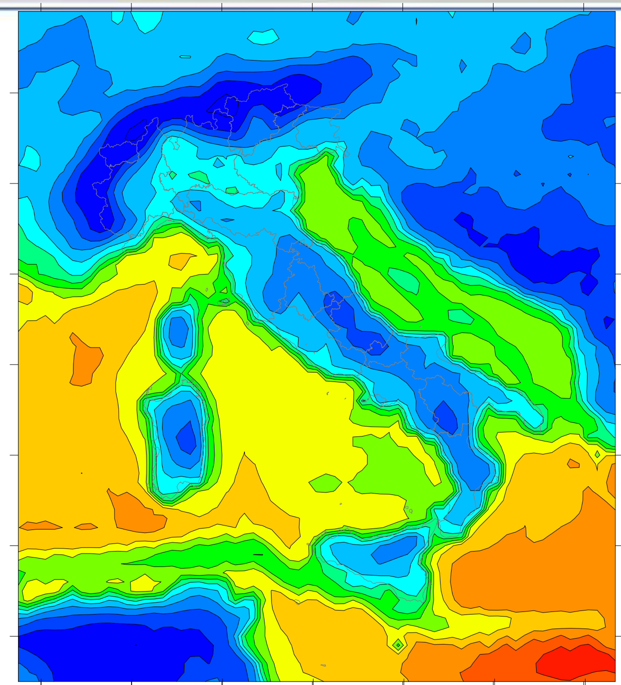
Application to “noCP 2020” scenario

Direct run of the atmospheric model

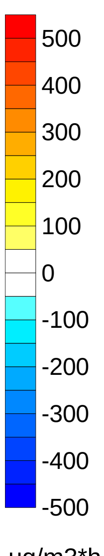


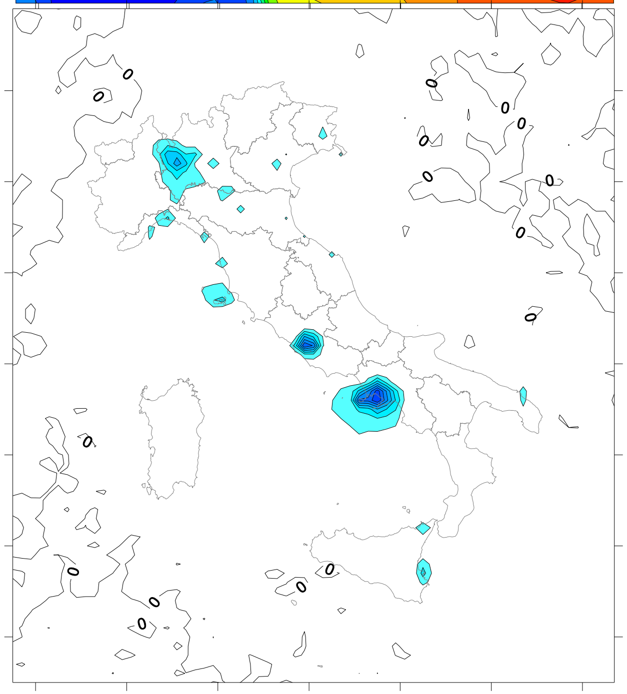


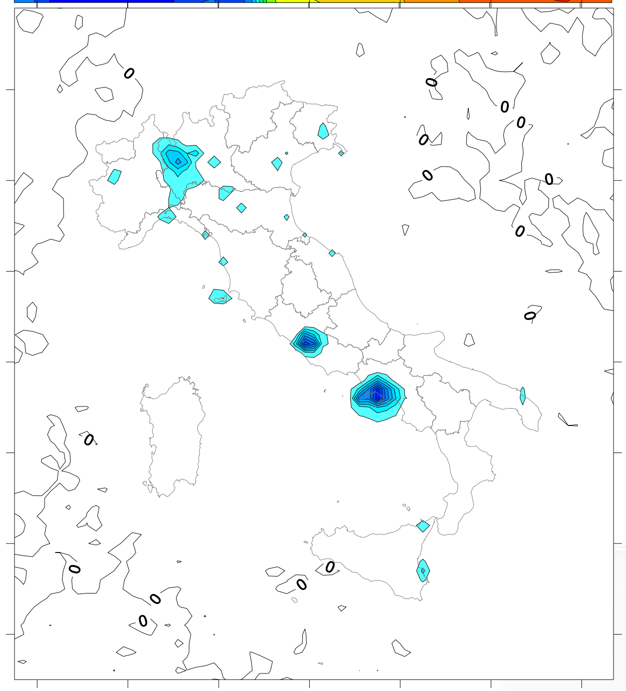
ATM guess



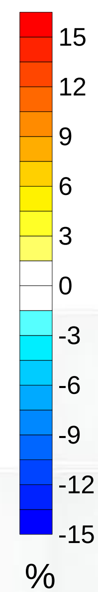
Abs. error (guess – direct run)







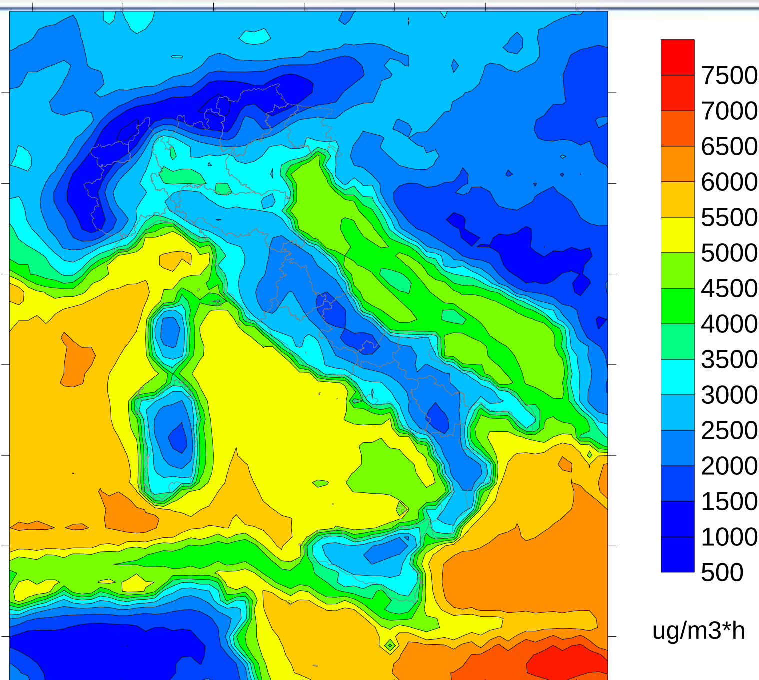
Rel. error (guess – direct run)



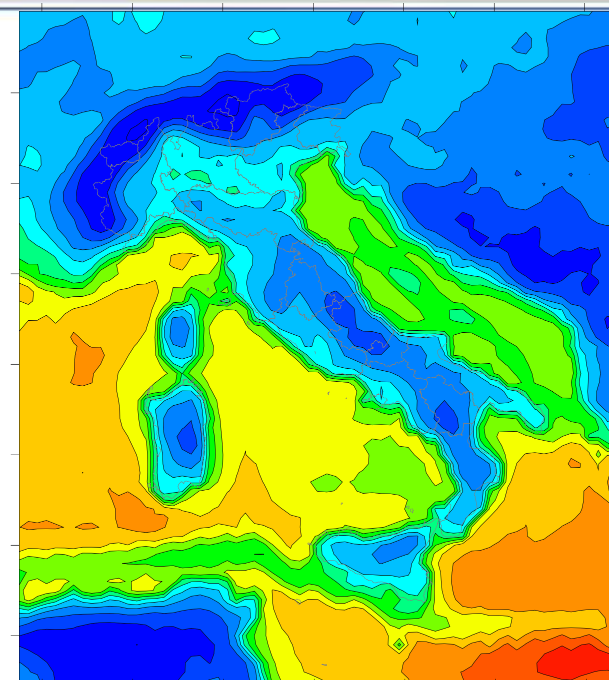
LOM, LAZ, CAM: SOMO35 = α n + β n^2 + γ v + δ; other regions: SOMO35 = α n + γ v + δ

Application to “noCP 2020” scenario

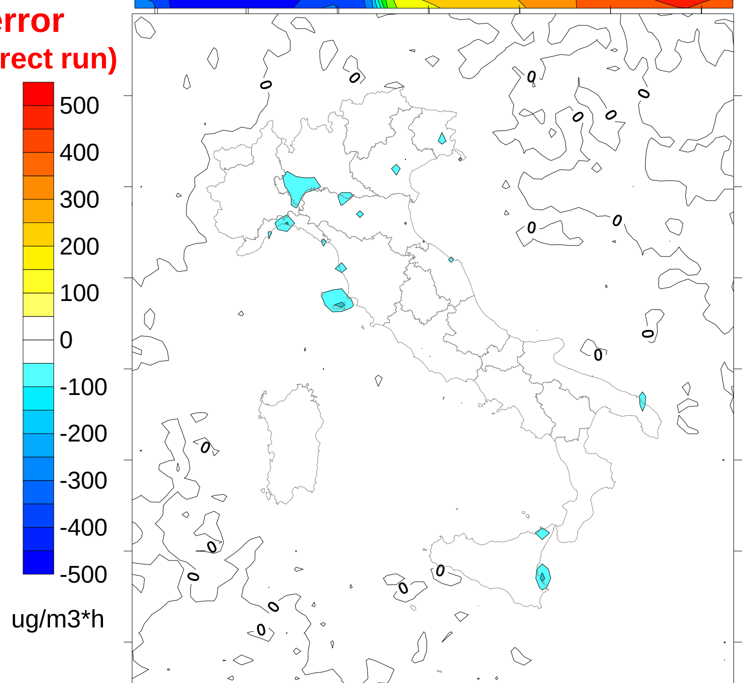
Direct run of the atmospheric model



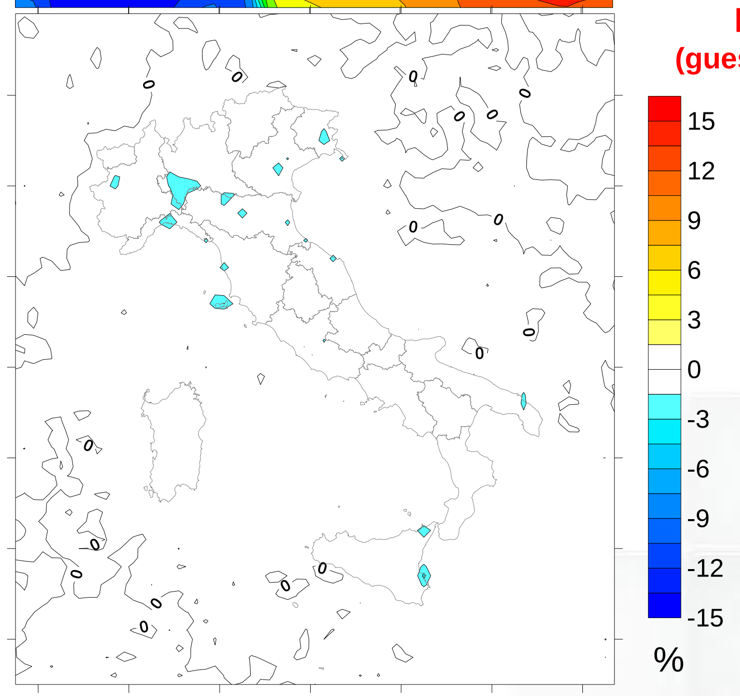
ATM guess



Abs. error (guess – direct run)



Rel. error (guess – direct run)



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The average atmospheric transfer matrices

Comparison of atmospheric transfer matrices for years 2003, 2005, 2007

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In the following slides …

- **Average** indicates average concentrations/depositions values processed through ATMs for the years 2003, 2005, 2007

- **Anomalies** the differences, in absolute values, between the ATMs estimated values in each year and the 3 years averaged values

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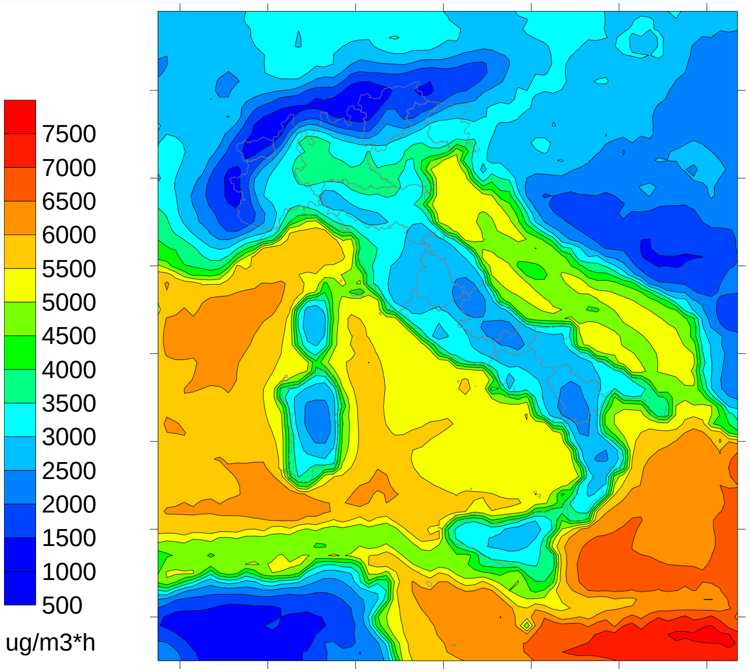
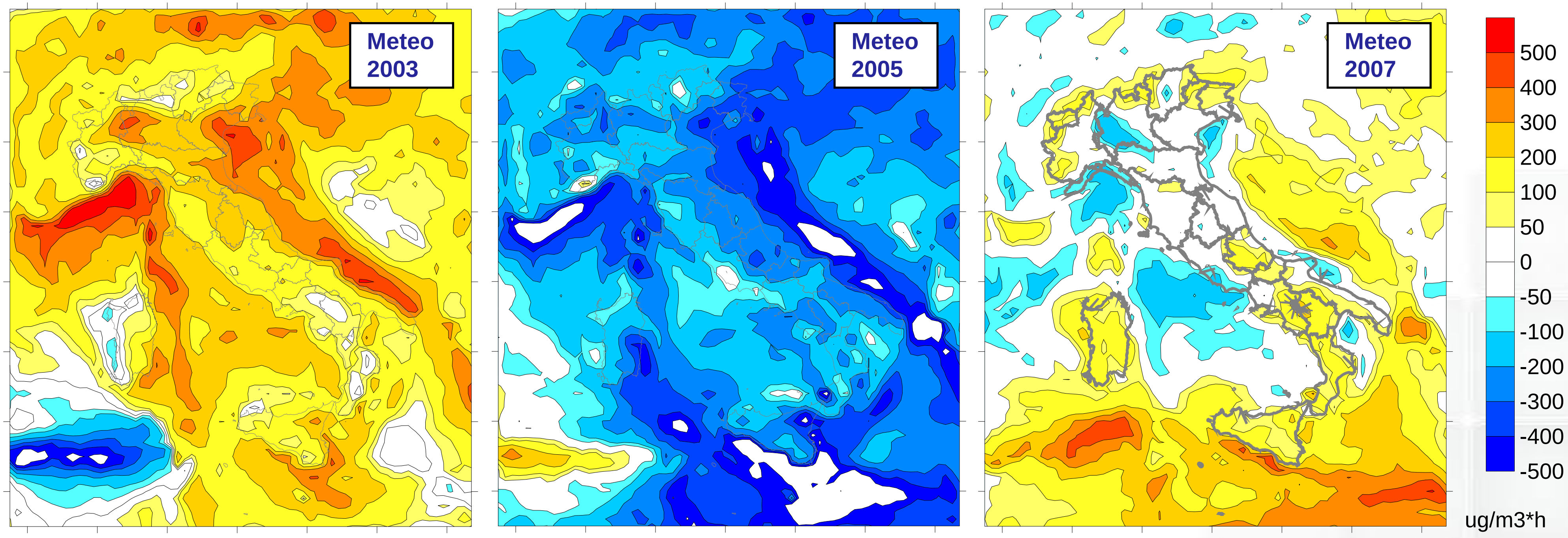
Response with reference emission scenario (noCP-2015)
SOMO35

Average

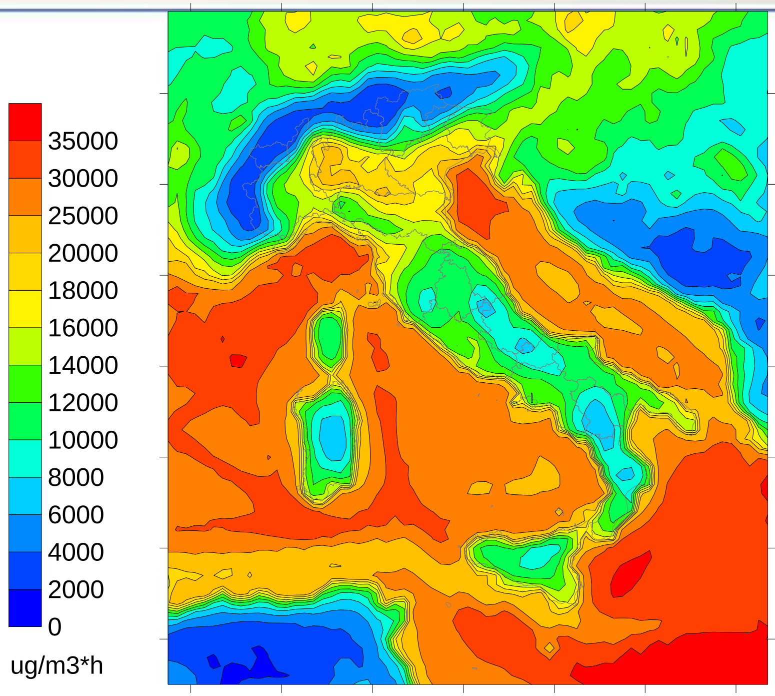


Anomalies



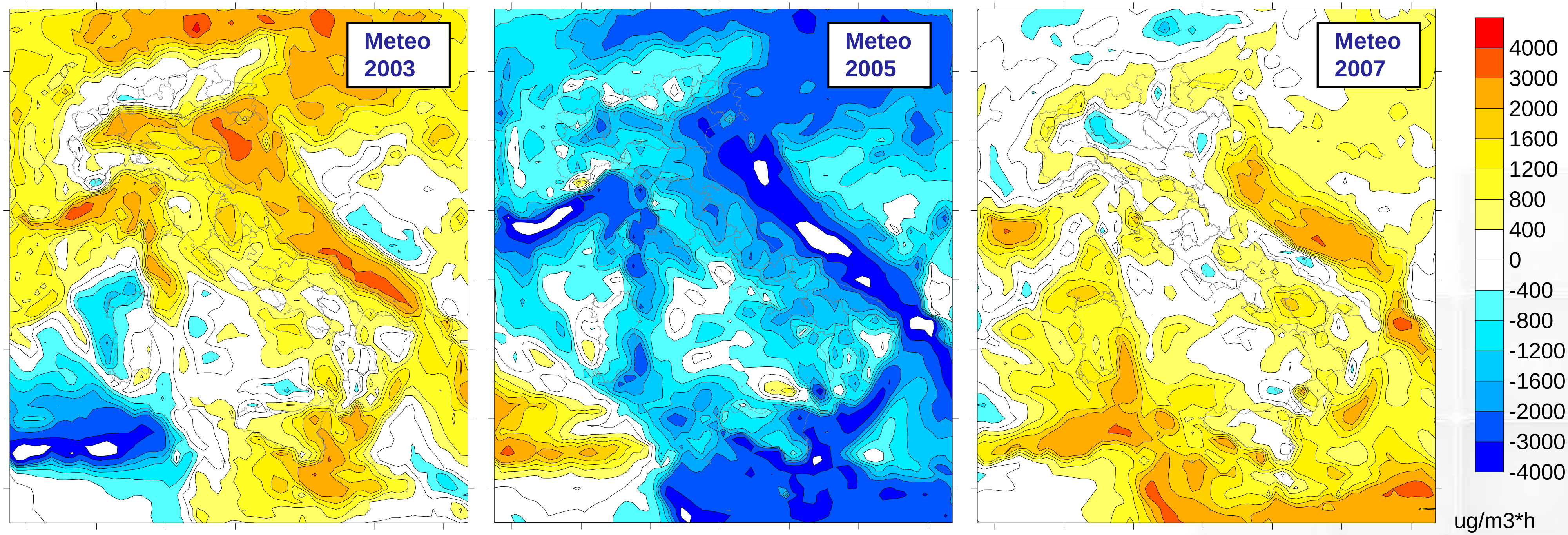
Response with reference emission scenario (noCP-2015)

AOT40$_f$



Average

Anomalies



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Response with reference emission scenario (noCP-2015)
$PM_{2.5}$

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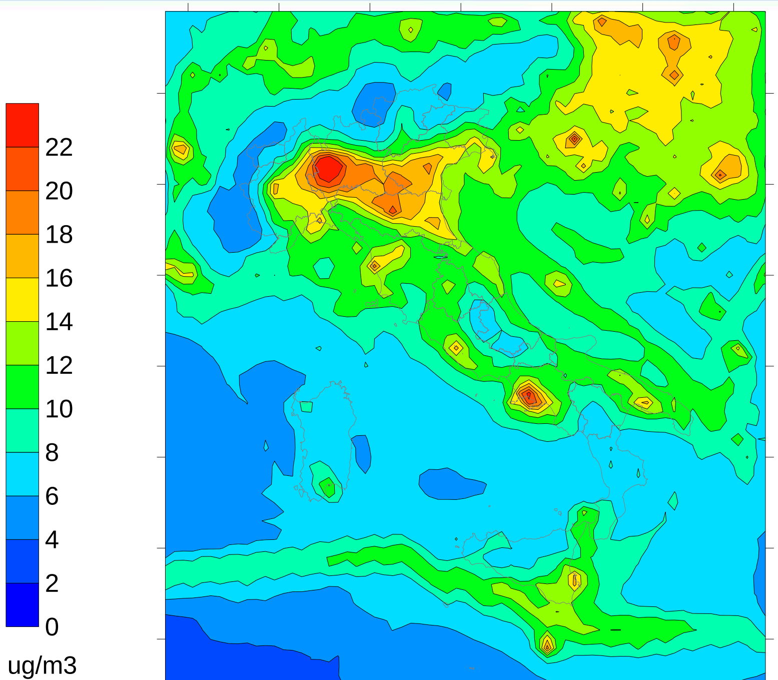

Average

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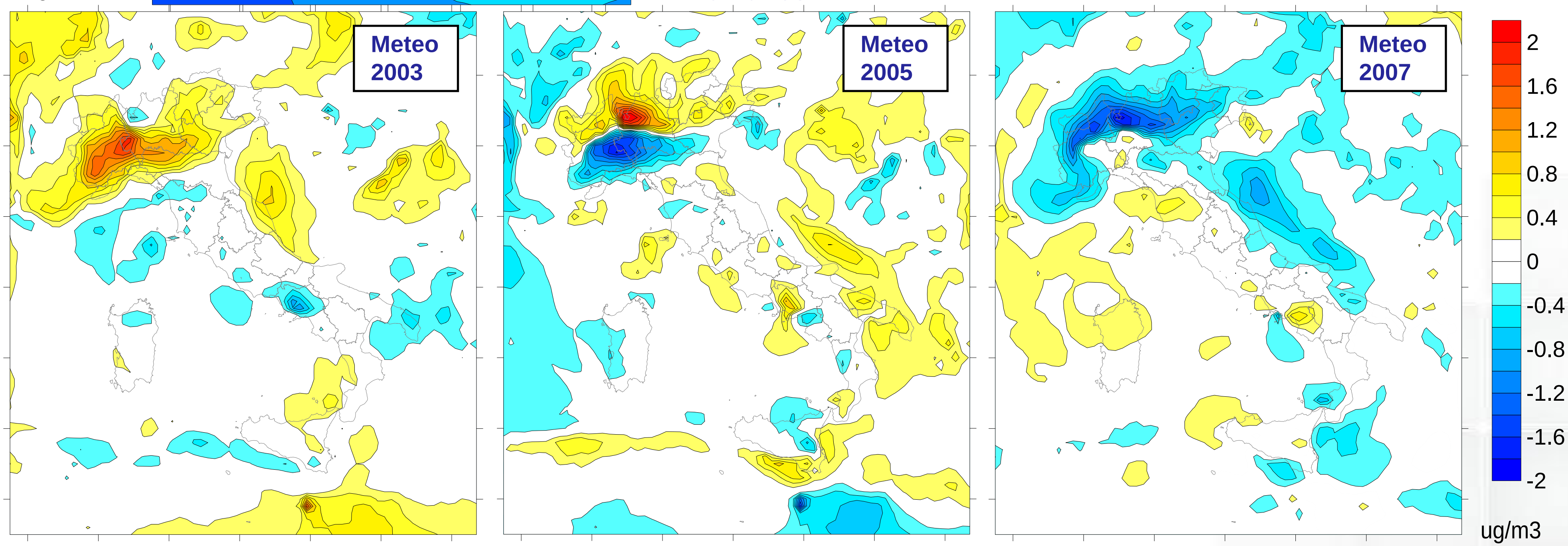
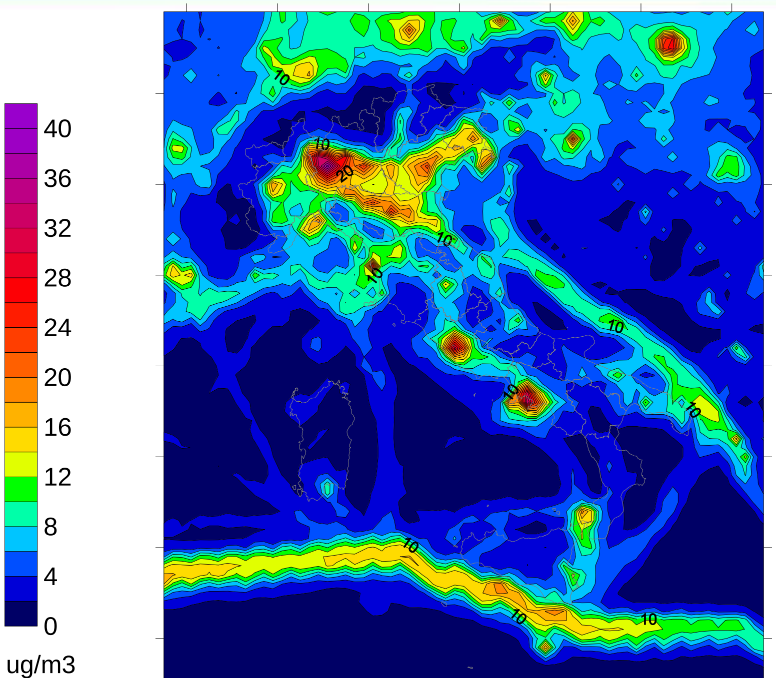
Anomalies



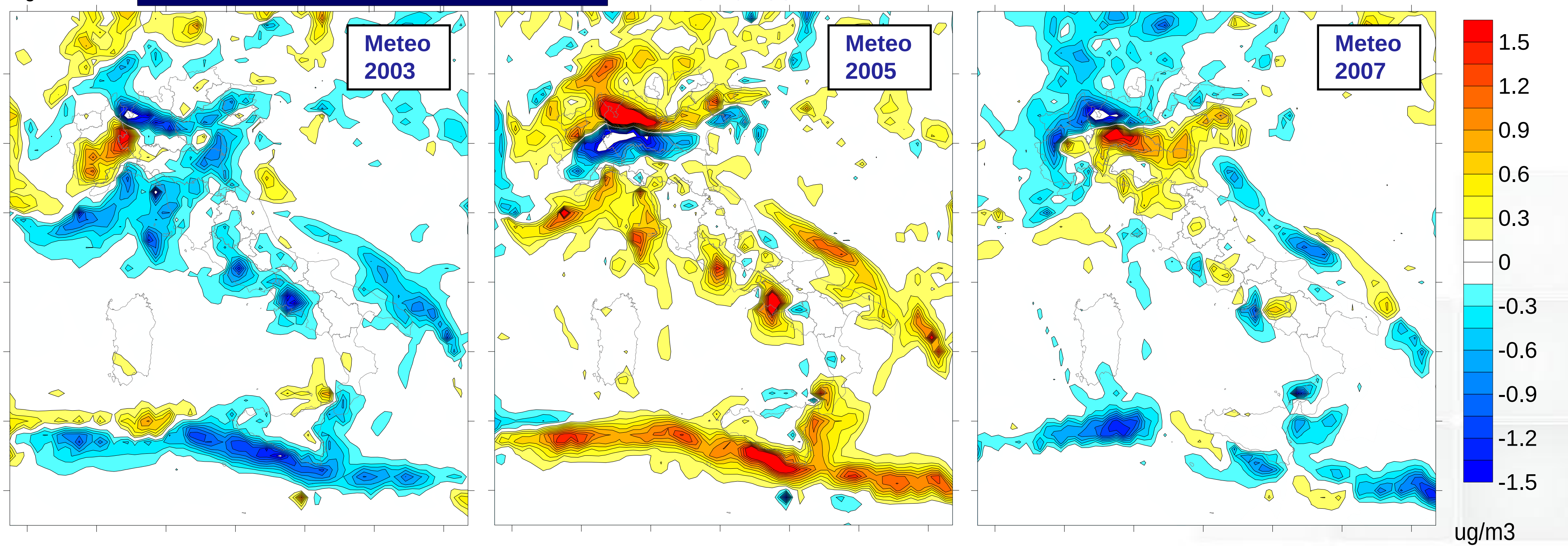
Response with reference emission scenario (noCP-2015)

NO_2



Average

Anomalies



In the following slides …

- **Max / Min anomaly** indicates the maximum and minimum absolute variation (at the top) and percentage variation (at the bottom) of the values calculated with ATMs for each year compared to the average values

- **Average** in the left side shows again the average values as a reference

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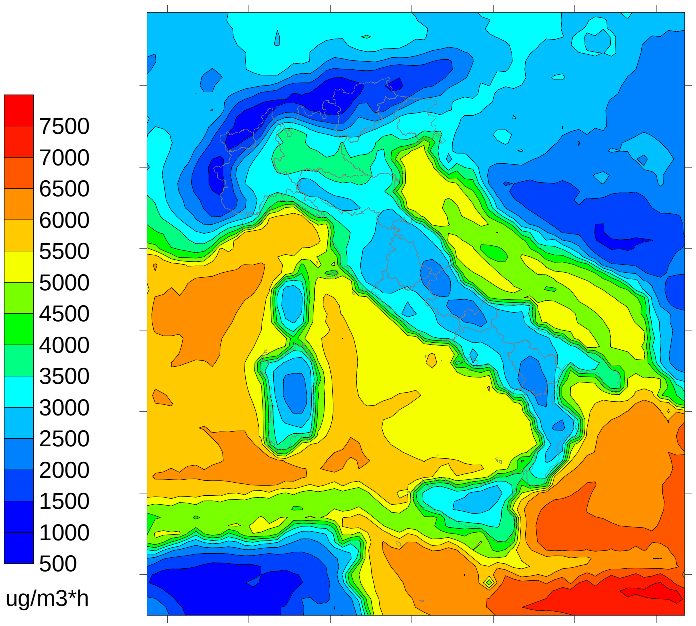
Response with reference emission scenario (noCP-2015)
SOMO35

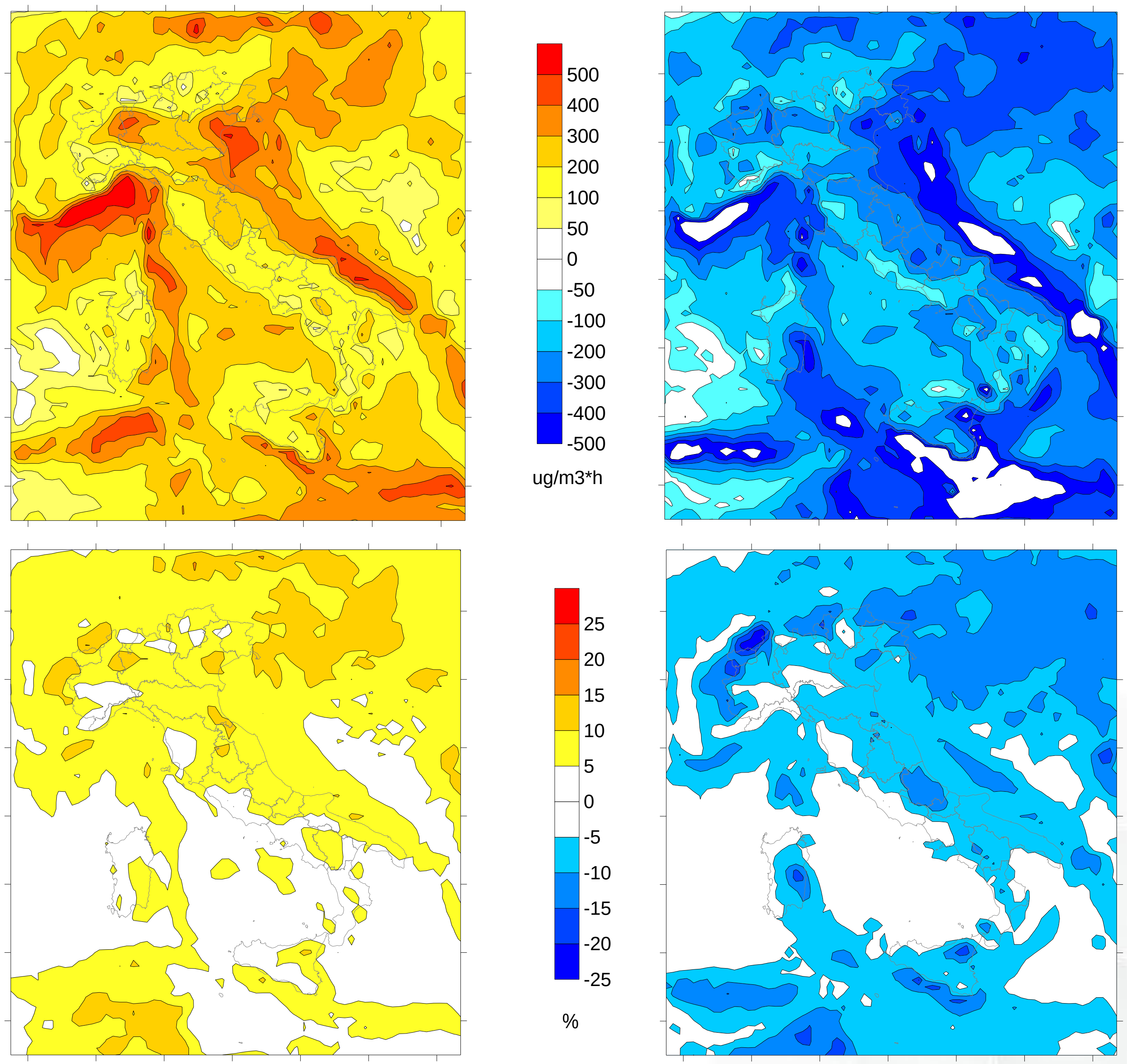
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Average



Max anomaly

Min anomaly



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Response with reference emission scenario (noCP-2015)
$PM_{2.5}$

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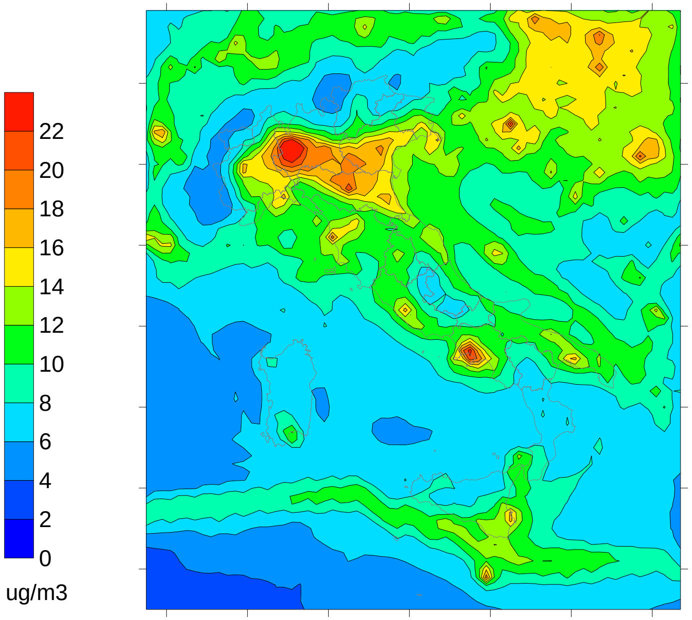
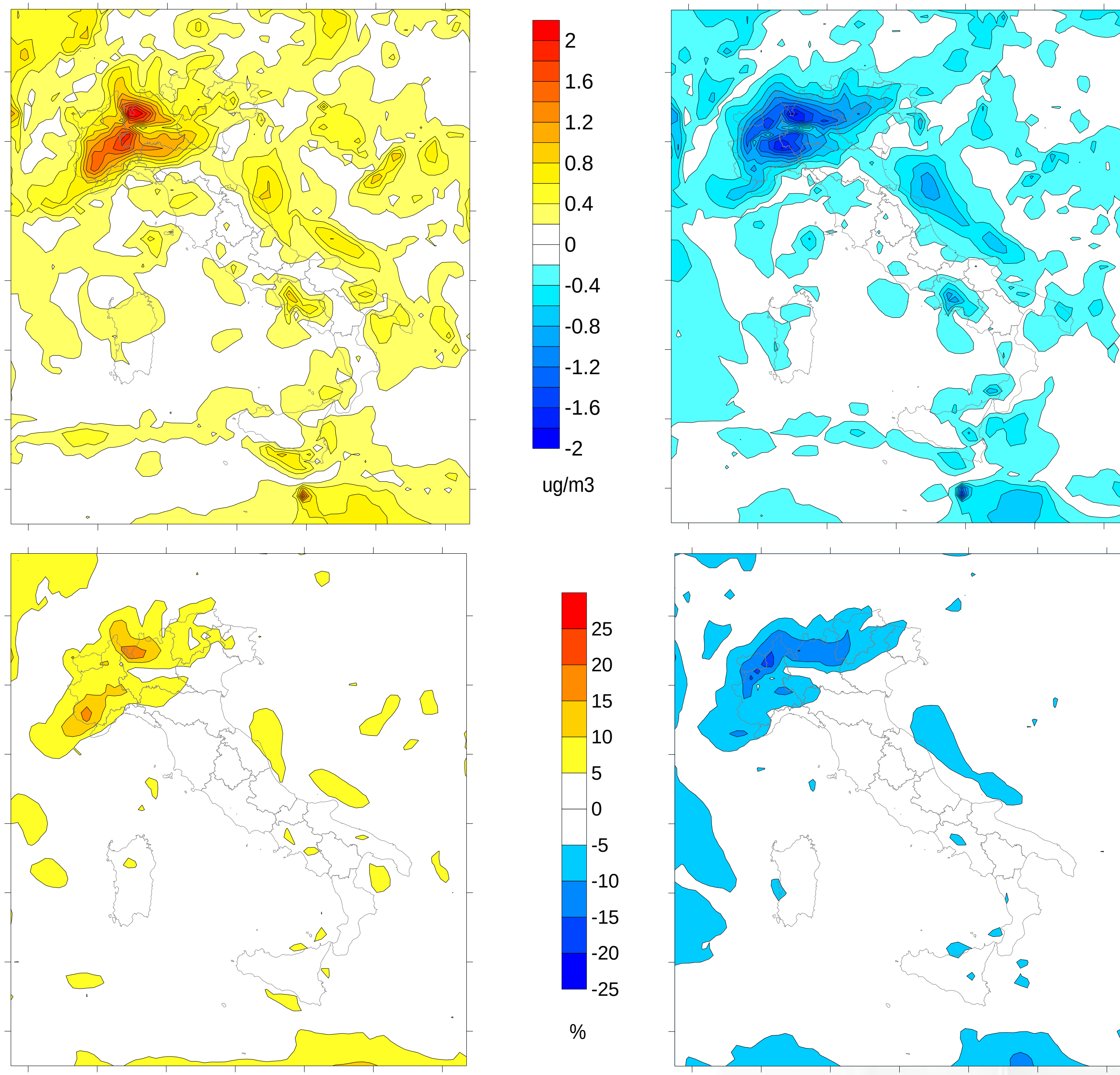
Average



Max anomaly

Min anomaly



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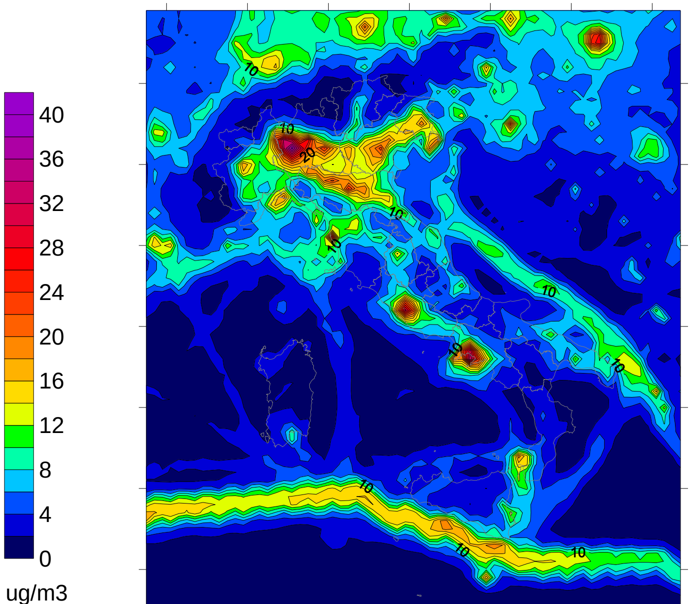
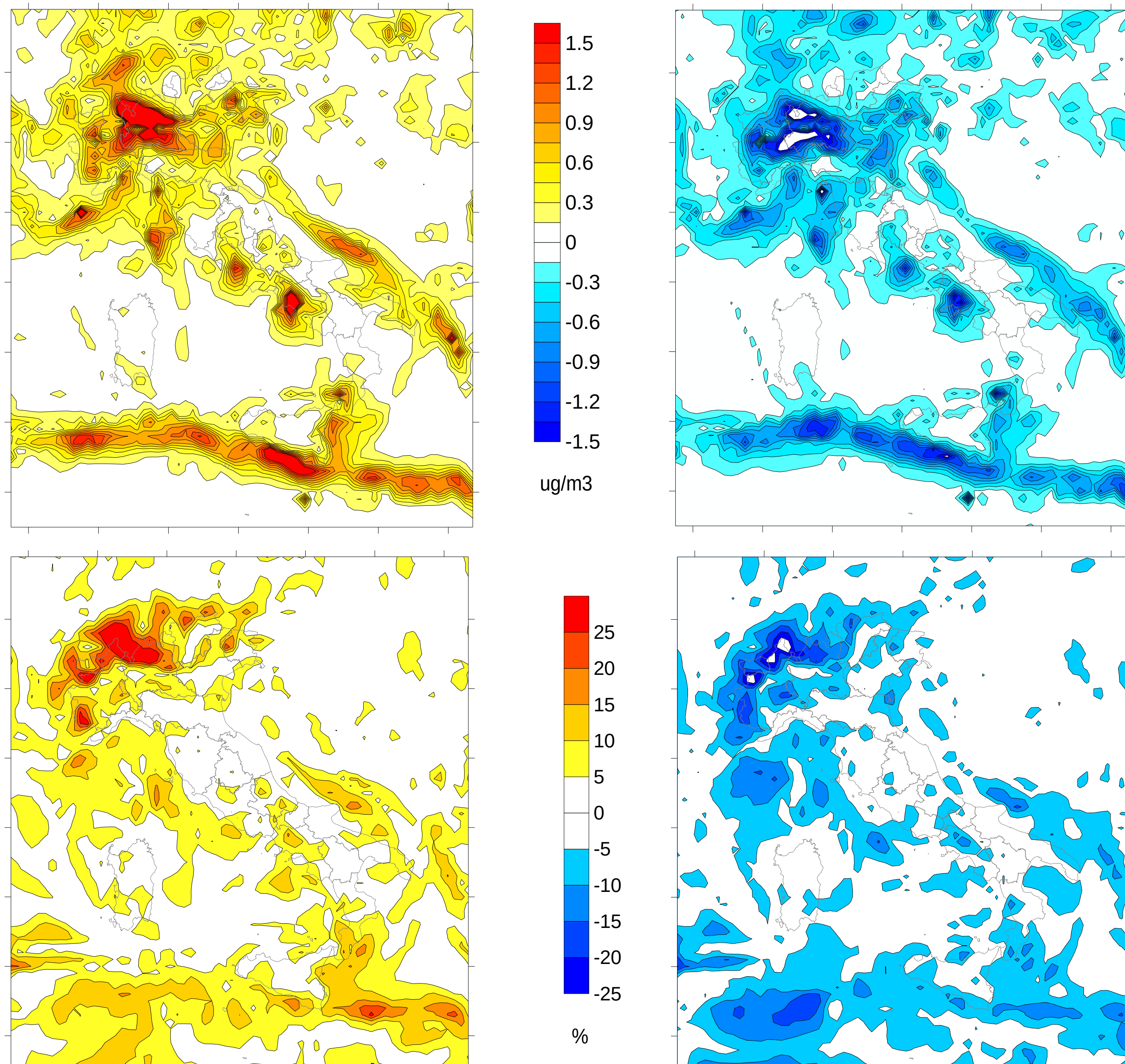
Response with reference emission scenario (noCP-2015)
NO_2

Average



Max anomaly   Min anomaly



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2. GAINS_IT: a tool to support policy makers

    2.1 the revision of the Goteborg protocol
    2.2 the revision of the Thematic Strategy on Air Pollution

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The first results elaborated by the GAINS-Europe model of the emission scenarios for SO_2, NO_x, $PM_{2.5}$, VOC and NH_3 were presented by IIASA in February 2011.
Those emission scenarios were compared with the national emission scenarios available at that time:

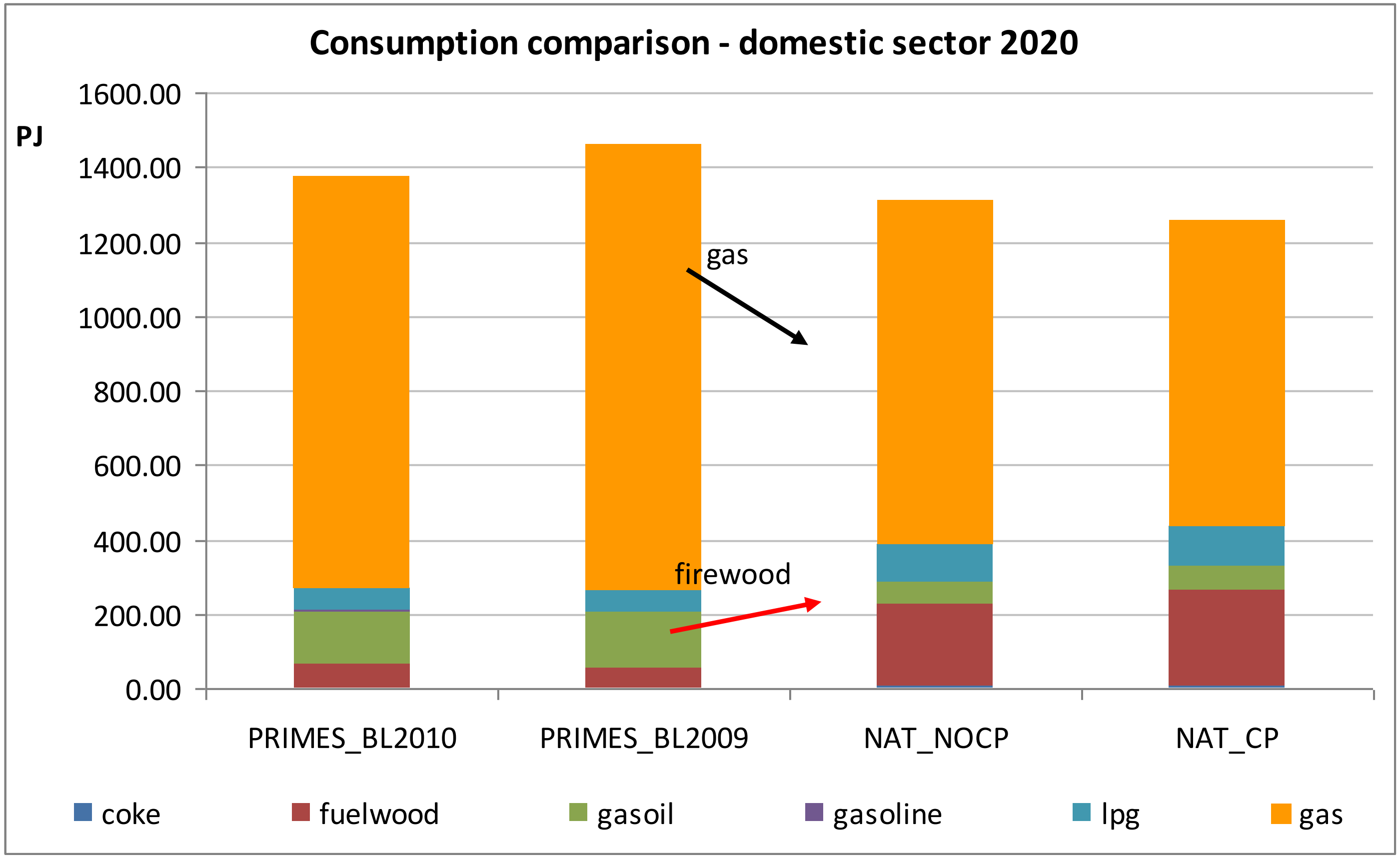
- **the NO-Climate Policy Scenario (NOCP);**
- **the Climate Policy Scenario (CP).**

The comparison between the reduction percentages at the year 2020 respect to 2005 proposed for Italy by the Commission and those calculated by GAINS-IT in the national scenarios show a good agreement for SO_2, NO_X e NH_3.

% Reduction at 2020 from 2005 level			
Pollutant	**COMM** Proposal	**IT - NOCP**	**IT - CP**
SO2	-38%	-38%	-37%
NOx	-43%	-45%	-43%
NH3	-5%	-5%	-5%

The main differences are observed in emission percentage reductions for $PM_{2.5}$ and NMVOC because of huge discrepancies between national and PRIMES energy scenario.
The differences are mainly due to

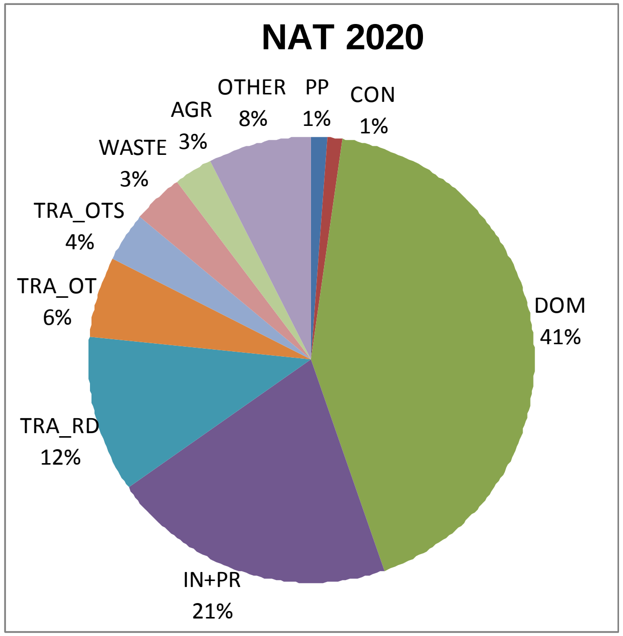
- biomass consumption estimation in the residential sector
- gasoline consumption for mopeds and motorcycles

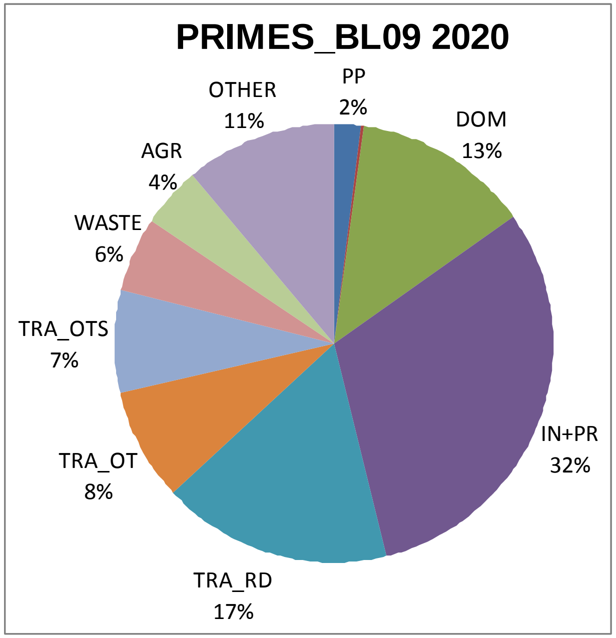


Difference in total consumption at 2020 in the domestic sector around 5-10% but different fuel allocation:

- Gas overestimation
- High firewood underestimation

Differences in consumption have a great influence in PM2.5 emission estimate





In the national scenario at the year 2020, PM2.5 emissions from residential sector represent the main source (41% in NAT and 13% in EU scenario based on PRIMES).

High influences on cost analysis:

In the cost analysis carried out by IIASA the main measures to reduce PM2.5 emissions affect the industrial sector

The use of the GAINS-It model allowed Italy to carefully investigate all emissions sector by sector and to provide the COMM with a reliable national emission scenario.

… the final agreement on the Göteborg Protocol

Pollutant	% Reduction at 2020 from 2005 level		
	Initial COMM proposal (nov 2011)	COMM proposal (feb 2012)	IT Ceilings in the GP (may 2012)
SO_2	-38% / -42%	-35%	-35%
NO_X	-43% / -46%	-40%	-40%
PM2.5	-34% / -45%	-17%	-10%
NH_3	-5%	-9%	-5%
VOC	-48% / -56%	-35%	-35%

The importance of National Integrated Assessment Model (IAM) in the negotiation processes has been underlined at the last Task Force on Integrated Assessment Modelling

What happened during the Goteborg Protocol influenced the following negotiation on the new EU Thematic Strategy on Air Pollution

IIASA planned bilateral meetings with Member States in order to define control strategies, emission factors and to harmonize data with the national emission inventory

The bilateral meeting for Italy happened the 19th – 20th of September 2012 at IIASA where experts from ENEA (Ilaria D'Elia) and ISPRA (Emanuele Peschi) partecipated on behalf of the Ministry of the Environment

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MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

ENEA AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

1. GAINS_IT news
2. GAINS_IT: a tool to support policy makers

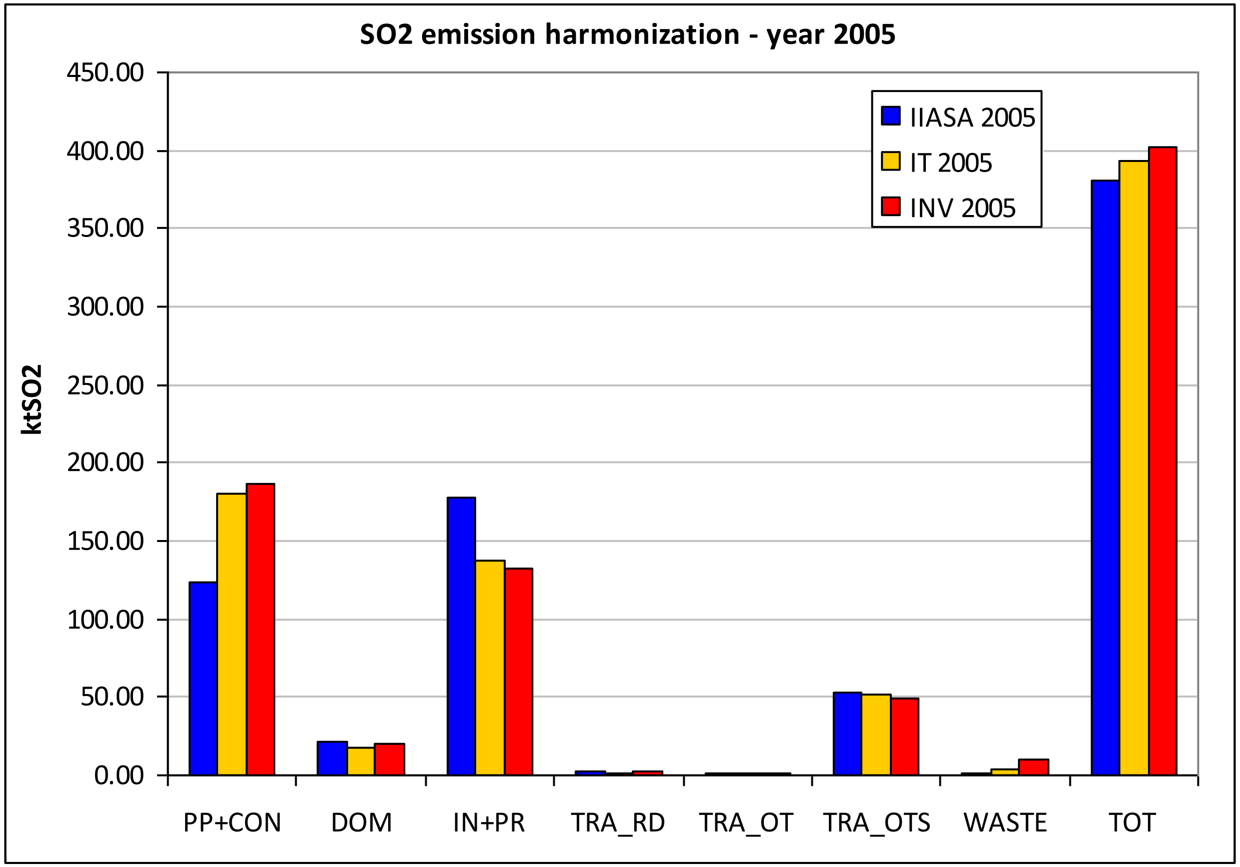
    2.1 the revision of the Gotebörg protocol

    2.2 the revision of the Thematic Strategy on Air Pollution

ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale

During the bilateral meeting, Italy compared GAINS-EU emissions at the year 2005 for all pollutants with values from the national emission inventory.
Many differences were identified for several activity/sector combinations.

SO_2 total emissions at the year 2005



The SO_2 emission comparison for the year 2005 among the 3 different estimates (IIASA, GAINS-IT and the INVENTORY) shows a good agreement in total SO_2 emissions (differences from 2% to 5%) but significant sectorial differences!

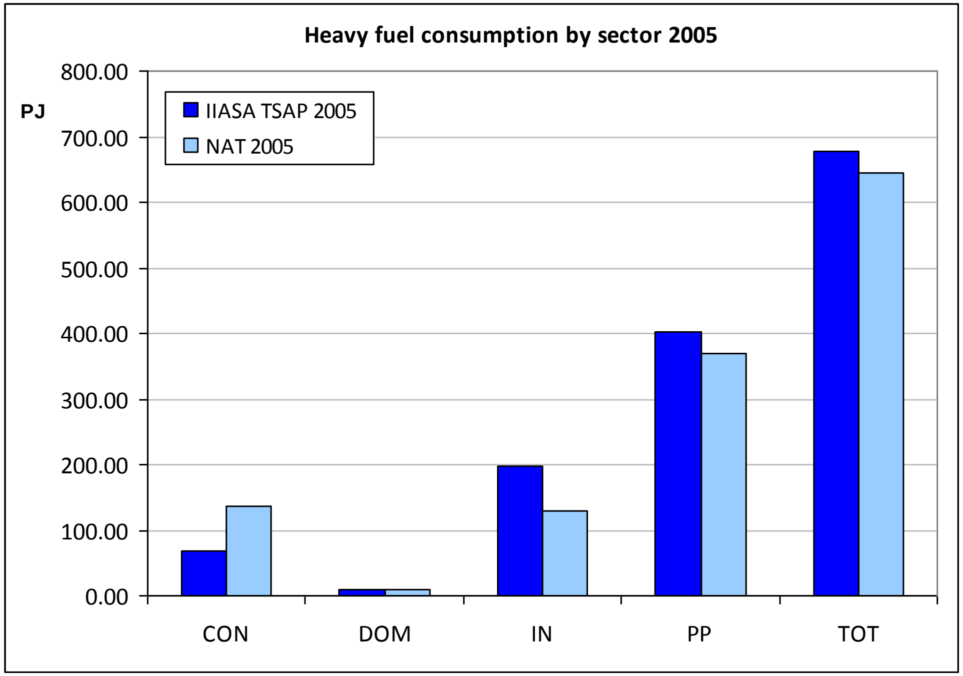
IIASA vs INV

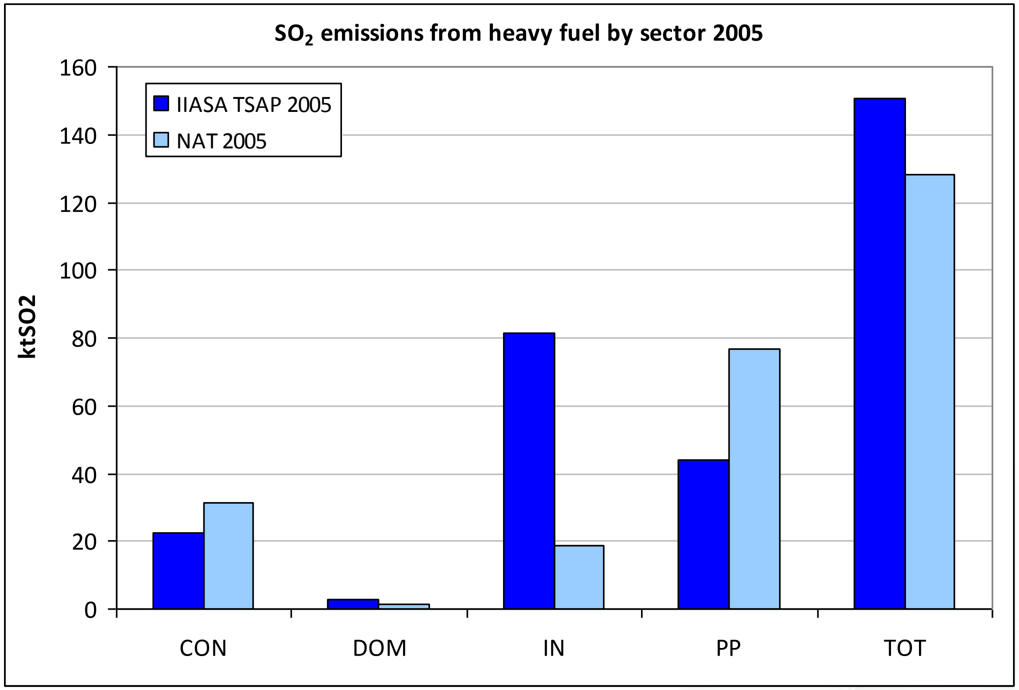
PP = -34%

IN = +35%

These differences are partially explainable as
- different total liquid fuel allocation among sectors and fuels;
- different S content;
- different technologies;
- …

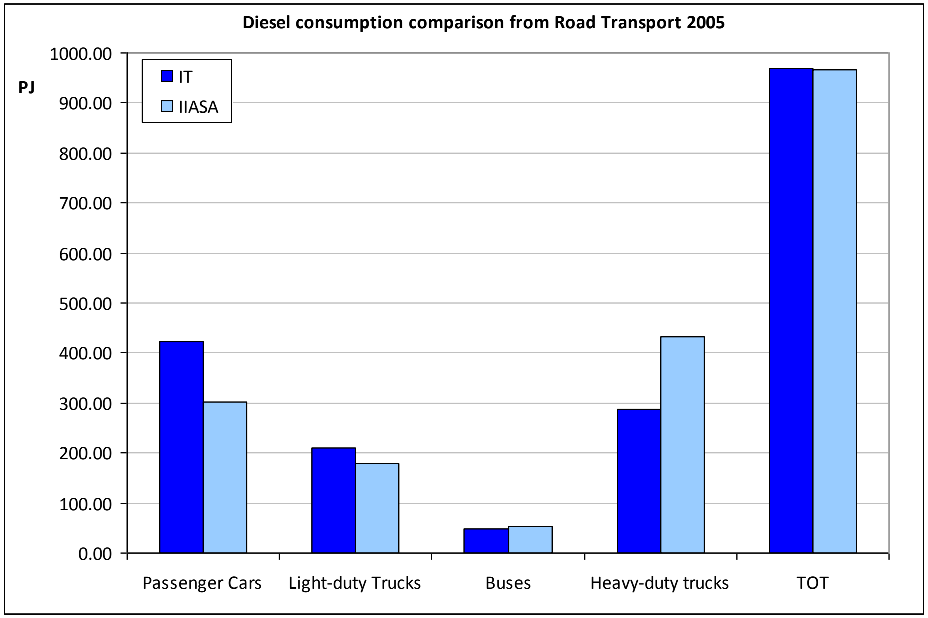
SO_2 emissions at the year 2005 from Heavy Fuel in stationary sources

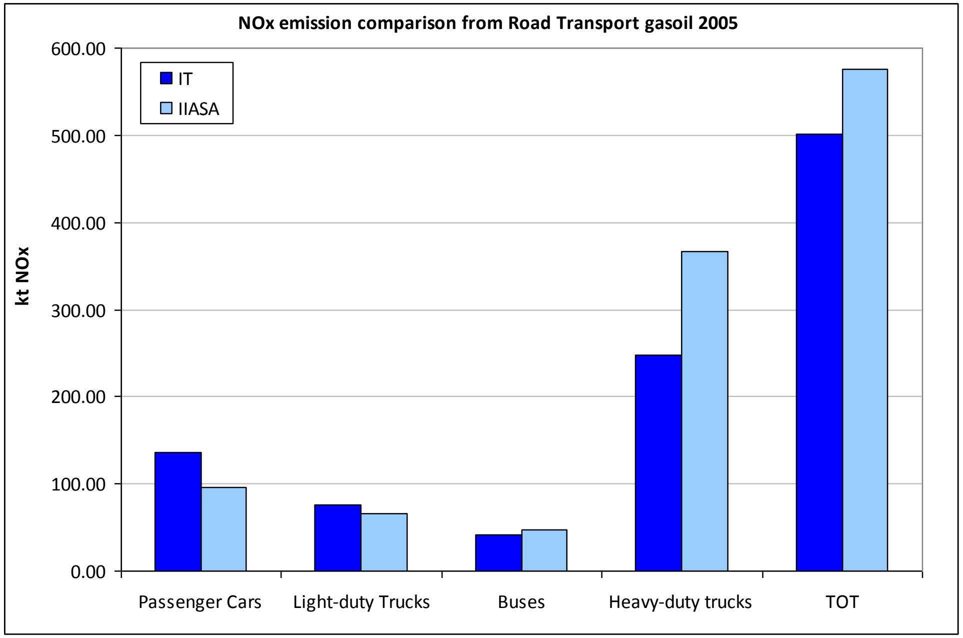




Differences in total HF consumption at the year 2005 are negligible but fuel allocation among stationary sources is completely different. No negligible differences in SO_2 emissions from HF from different sectors.

NO_X emissions at the year 2005 from diesel in road transport sector





Differences in total diesel consumption at the year 2005 are negligible.
Notable different is the diesel allocation among vehicles that heavily reflects on NOx emissions from road transport.

- The bilateral meeting was a good chance to discuss and understand all the data behind the scenario elaborated by IIASA

- Many differences were observed at the year 2005 in emission estimations due to diversities in fuel allocation, emission factors, control strategies, S content, biomass consumption, share of firewood in domestic technologies (stoves, fireplaces….)

- Total fuel consumption is often comparable but the allocation in the PRIMES scenario is not reliable especially in road transport and liquid fuels for industry, power plants and conversion sectors.

- These discrepancies will lead to a different emission starting point at 2020 and will influence the following cost analysis with the risk that in the optimization process the most polluting sectors might not be considered

THE OPTIMIZATION TOOL

The functions of the GAINS-Italy model will be expanded (end of 2013) through the optimization tool based on the GAMS model.

The basic objective is to develop, in collaboration with IIASA, a documented optimization methodology and tools in order to perform national cost-effectiveness analysis and to address questions of compliance with air quality regulations.

In the same context one task is devoted to understand better connections, constraints and results at different spatial scales (national vs regional) and to draw lessons on an improved design for the integrated assessment models.