# APPLYING THE FAIRMODE TOOLS TO SUPPORT AIR QUALITY DIRECTIVE: THE EXPERIENCES OF ARPAE

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**Abstract**: The study shows an application of "DELTA Tool" procedure for the benchmarking of the Air Quality Directive (AQD) modelling applications to an Italian region test case.
The Tool, proposed and discussed in the framework of FAIRMODE, is founded on two main components. The first concerns assessment and forecast and it has the main objective to offer a common standardized template for the screening and comparison of model results. The second examines the emission inventories, especially in order to compare bottom-up and top-down evaluations.
The Tool was applied to the analysis of the regional emissions inventory for Emilia-Romagna and of the simulation performed by NINFA, the model suite used in ARPAE
The strengths and weaknesses in the methodology that have been observed in the case tested are presented and discussed.

***Key words: e****missions inventories,air quality modelling; model evaluation; DELTA Tool; benchmarking.*

## INTRODUCTION

The evaluation of air quality models is a complex procedure involving different steps (scientific evaluation, code verification, model validation, sensitivity analysis etc.). Moreover, emissions inventories are recognized as key inputs to atmospheric modelling and one of the main sources of uncertainty in the air quality modelling simulations. FAIRMODE is the Forum for Air Quality Modelling in Europe (http://fairmode.ew.eea.europa.eu/), created for exchanging experience and results from air quality modelling in the context of the Air Quality Directive (AQD).
In that framework a procedure for the benchmarking of air quality models was proposed and discussed (P. Thunis et al., 2012) in order to harmonise the diagnostics and the reporting of air quality model performances, focusing on the pollutants mentioned in the EU Air Quality Directive (AQD) (2008) and addressing all relevant spatial scales (from local to regional).
More recently (M. Guevara et al., 2016) a user-friendly tool has been developed to compare top-down versus bottom-up emission estimates, often not consistent with each other, in order to better understand the differences between these two approaches and reduce the uncertainties in the emissions evaluation.
"DELTA Tool" was applied to the analysis of the Emilia-Romagna emissions inventory and of the operational simulations performed by the NINFA air quality model used in ARPAE.

## BENCHMARKING METHODOLOGY FOR EMISSIONS INVENTORIES

Our regional emission inventory was updated to the reference year 2013 and we compared this with the TNO-MACC3 inventory for 2011 the most recent European inventory available in Delta Emission Tool (.Guevara, M. et al (2016).
The assessment is supported by different comparison methods representing different complementary aspects. The so called "diamond diagram" is designed to identify discrepancies between inventories; it allows to assess whether the differences can be mostly related to different emission factors or in the choice of activity data. The "bar-plot" represents the comparison of pollutant emissions in macro-sectors through ratios between bottom-up and top-down for each pollutant. The "ratio diagram" represents the comparison between ratios of various pollutants for each inventory and for GAINS.
We analyzed the macro-sectors 2 (domestic heating-DOM), 3 and 4 together (industrial combustion and production- IND34) and 7 (road transport-TRAF).
In the diagrams the quantities of pollutants have been normalized respect to NOx, which is the proper pollutant for the analyzed sectors.

The "diamond diagram" (Figure 1) shows that the two compared inventories for the road transport sector are consistent both in terms of activity, slightly lower in the bottom-up, and in terms of emission factors. The markers are close to the unit; the emission factors of NOx and of PM10 are proportional and the emission factors of VOC are fairly proportional. This fact is also shown, in a complementary way, by the "ratio diagram" (Figure 2) that presents a ratio near to one for NOx and PM10 and a lower ratio for VOC.

About the pollutants ratios the two compared inventories present a good agreement (Figure 3), while the NOx/PM10 ratio deviate from the GAINS national average.

The consistency between the two inventories also results in the domestic heating sector: the "diamond diagram" shows that for this sector the compared inventories are consistent both in terms of activity indicators, slightly higher in the bottom-up, and in terms of emission factors (Figure 1). The markers are all close to the unit; there is good proportionality between emission factors of NOx and PM10 and a fairly good in emission factors of VOC.

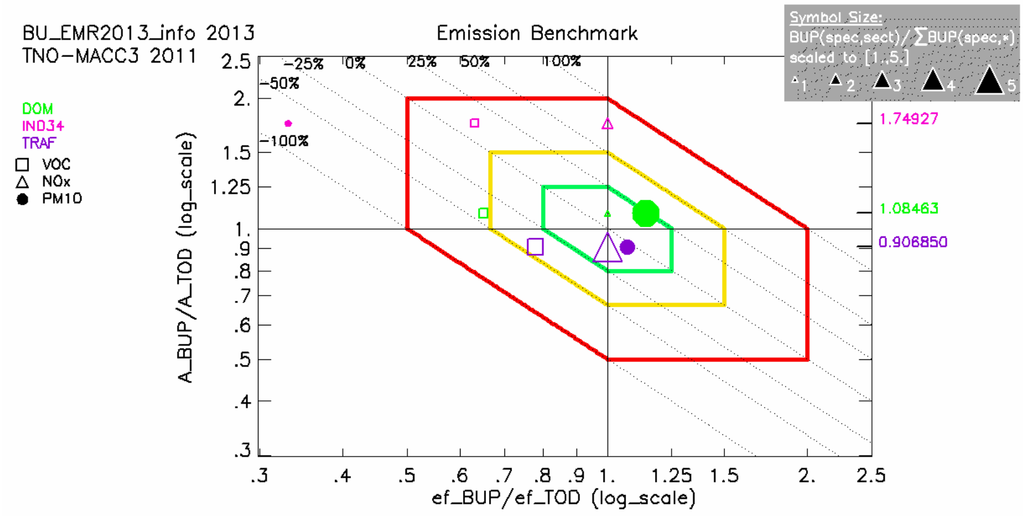


**Figure 1:** Diamond diagram for NOx, PM10, VOC in domestic heating, traffic, industrial sectors.

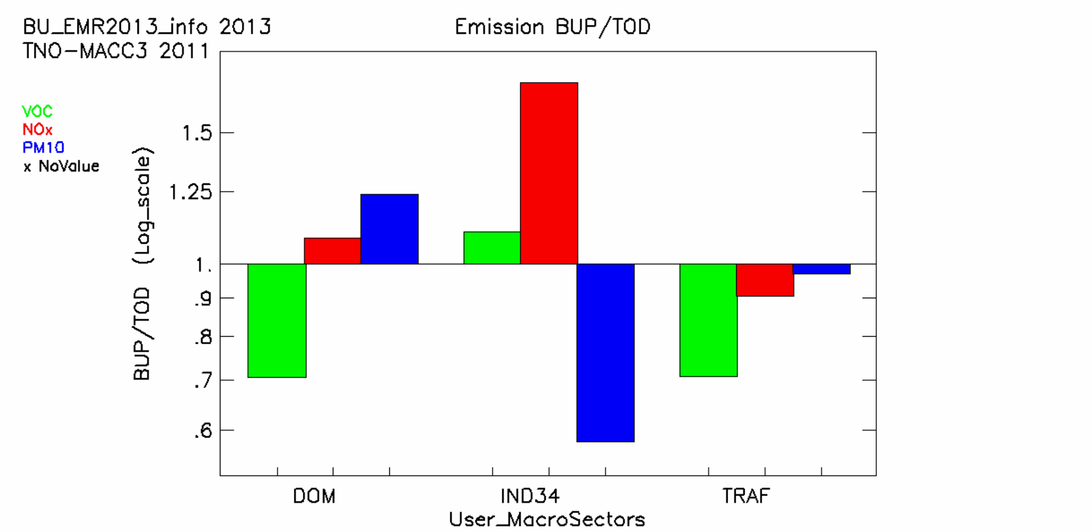


**Figure 2.** Bar-plot diagram with ratios of bottom-up/top-down emissions.

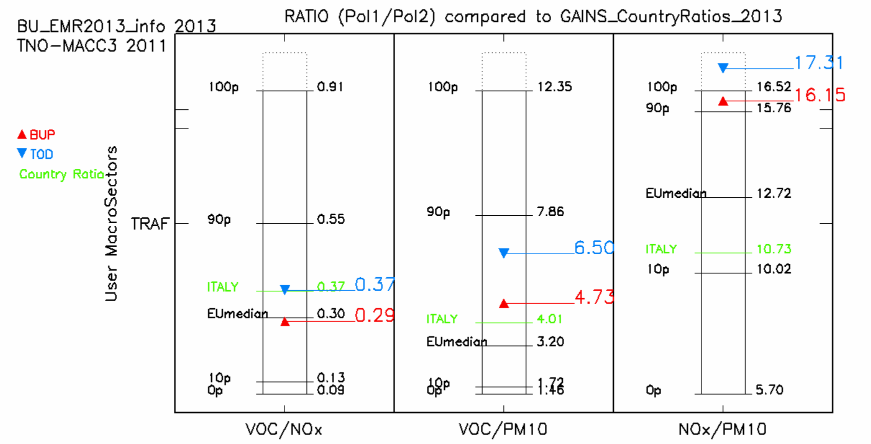


**Figure 3:** Pollutants ratios for traffic sector.

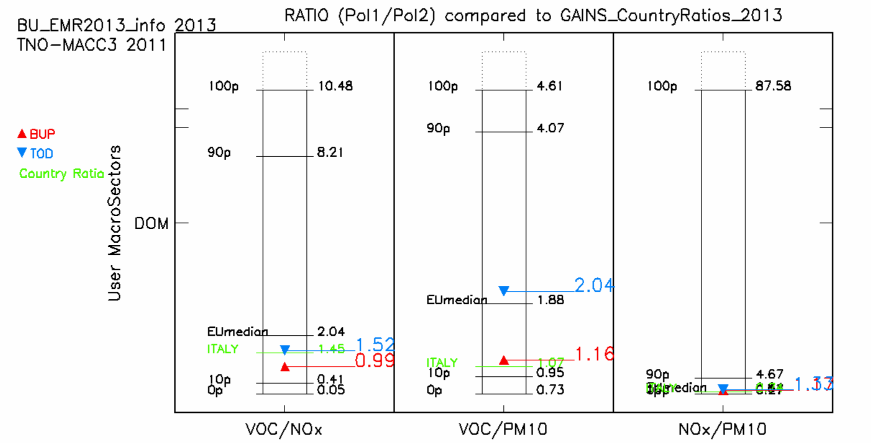


**Figure 4.** Pollutants ratios for domestic heating sector.

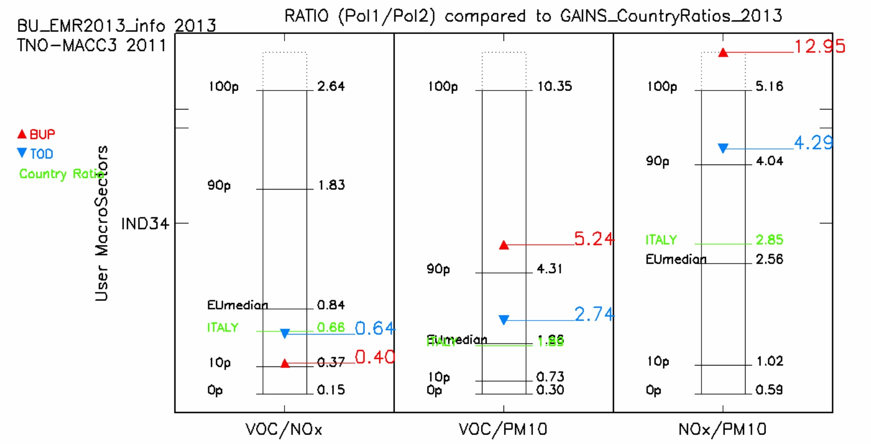


**Figure 5.** Pollutants ratios for industrial production sector.

The "ratio diagram" also presents for NOx and PM10 low ratios and in agreement between them, and a low ratio for VOC although of the opposite sign (Figure 2): we think that this fact is due to overestimated emission factors for VOC in the case of top-down, in accord with the fact that the ratios VOC/PM10 and VOC/NOx for top-down are higher than the European average and GAINS Italy.
In addition there is a good agreement on the ratios between pollutants that are also close to the national average from GAINS about all pollutants (Figure 3). Significant differences are instead observed in productive activities sector with higher activity indicators and lower emission factors in bottom-up, with effects which partially cancel each others.

We believe that the cause of the differences highlighted in all type of diagrams (Figures 1, 2, 3.) is partly due to the different reference year, very significant for the industrial sector, and to the different methodology of compilation. For macro-sectors 3 and 4 the bottom-up regional inventory is the result of a systematic analysis of industrial plant documentations and of production cycles, therefore it provides a more accurate result than the inventories employing statistical indicators to describe the industrial production. Furthermore, in some cases, in our compilation we employed emission factors that are different than those of the Guidebook, in order to better describe the production and the abatement systems really implemented, or we have used the results of direct measurement of stack emissions. With this in mind, it is not surprising that the ratios of NOx and PM10 in the industrial sector have opposite sign. Moreover the applied methodology has immediately revealed an important structural difference that surely exists among the two compared inventories.

**SCREENING AND COMPARISON OF MODEL RESULTS**

The NINFA (Stortini M,et al 2007, Stortini M, 2015), air quality model is used since 2003 in ARPAE for operational and assessment purposes. This operational modelling suite is based on the CHIMERE (Menut et al., 2014) chemical transport model, the meteorological input is provided by the COSMO-I7 (Steppeler et al., 2003) non-hydrostatic model, the domain covers northern Italy with a resolution of 5 km. The ”Delta Tool v5.5”, (Thunis, P. at al 2012, Janssen, S. et al 2017), used for evaluate the NINFA (operational results, is based on pairs of measurement and modelled data at given location and it takes into account the measurement uncertainty while calculating model performance indicators related to RMSE, correlation, BIAS and standard deviation.

Several statistical diagram, i.e taylor plot, Q_Q_plot, mean bar plot, are also available.

The main model performance indicator, called modelling quality indicator (MQI), is expected to fulfil the criteria (the model quality objective), easily viewable at the target diagram.

The ”Target diagram” plots for each station the normalized CRMSE against the normalized BIAS. The distance from the origin represents the normalized RMSE. The screen is divided into four areas distinguishing the main source of error type for each station, positive and negative bias (top and lower zones), correlation and standard deviation (left and right areas). Different symbols and colors are used to represent the different stations. For the purpose of this study, urban, suburban, rural background stations from Emilia-Romagna air quality network refer to year 2016 are used.

Figure 6 reports target plot for PM10 NINFA concentrations which provides an immediate overview about the model performance. All stations fulfil the criteria, the bias is always negative, indicating a general underestimation of the PM10 by the model, attributable to the well-known difficulties of air quality model performing over the Po valley.

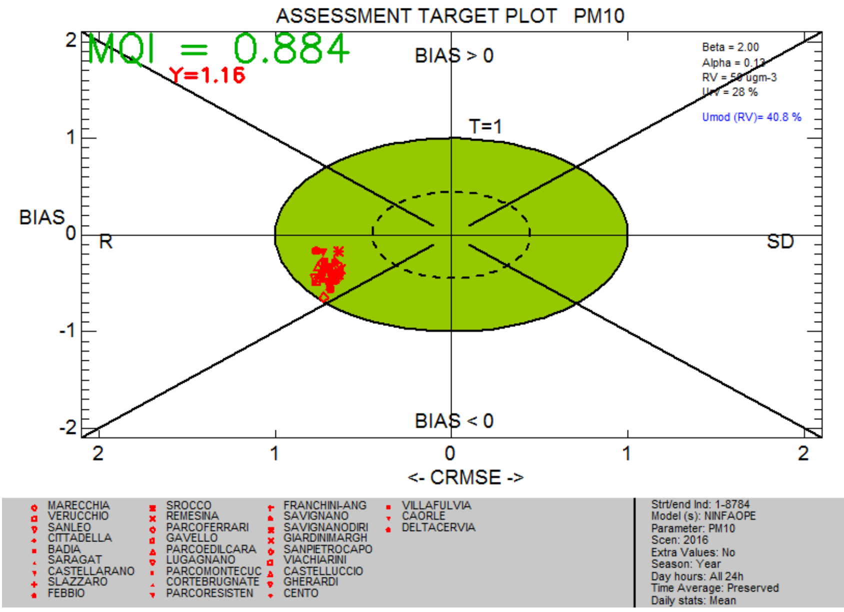


**Figure 6.** Target plot for PM10 NINFA concentrations.

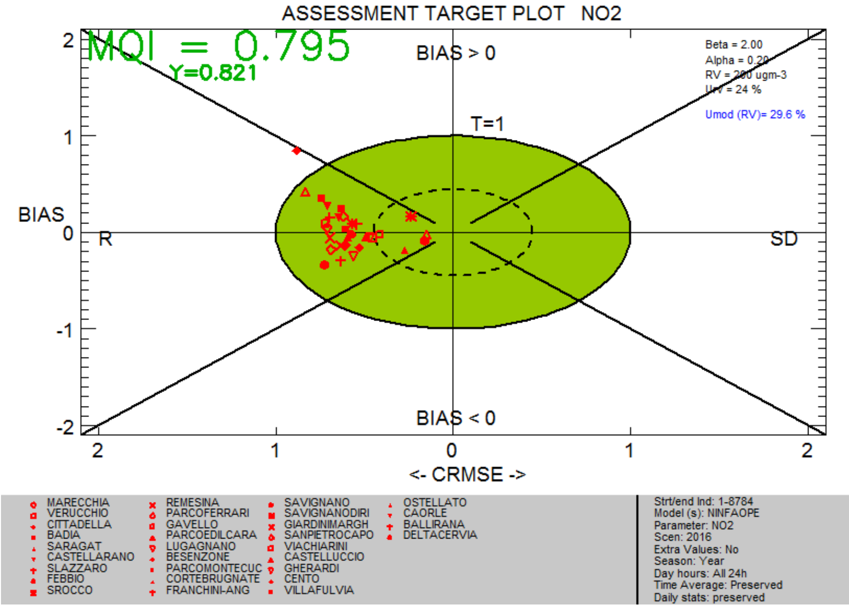


**Figure 7.** Target plot for NO2 NINFA concentrations.

Inside the random error, the source of error is due to the correlation between the modelled and observed data. All dots are also outside the dashed circle which represents the area where the model is within the range of observation uncertainty, this suggests that further improvements to the model can be achieved.
The Figure 7 reports target plot for NO2 NINFA concentrations. Only one station is outside the green circle. The 54% of sites shows negative bias, indicating an underestimation. The 16% of the points lie inside the dashed circle, thus there is no margin for a model improvement at these sites. Also for NO2, the correlations is the source of error inside CRMSE zone.

## CONCLUSIONS

This study presents an application of "Delta Tool" in the regional Environmental Agency of Emilia Romagna. The model results provided by NINFA for PM10 and NO2 have been compared to measured data provided by 34 monitoring background Emilia Romagna air quality stations for year 2016. The target plot analysis shows that NINFA fulfils all criteria for all sites for PM10 and for 97% of sites for NO2.
The application to a real modelling case shows that the Tool can be used to support modellers for evaluation of theirs models in the frame of AQD. The benchmarking methodology allowed an immediate evaluation of the consistency between two inventories and in some cases it was able to highlight the causes of discrepancy. In our analysis, a good agreement was reached between the bottom-up and top-down inventories for domestic heating and traffic: in these cases the tool is been able to provide an indication for the reason of the little differences observed, in particular for VOC emission factor.
For the macro-sectors 3 and 4 the Tool highlighted significant differences but the comparison alone does not explain where this can originate. In our compilation of the macro-sectors 3 and 4 we followed a completely bottom-up approach, therefore there is a low methodological alignment between the two inventories compared. This is one of the cases in which the Tool correctly reveals a difference but not his interpretation. However the Tool was able to providing a quantitative indication, i.e. in the resultant use of emission factor of PM10 significantly lower in bottom-up inventory in accord with experimental findings in our region.

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