INDUSTRIALES
ETSII | UPM

FAIRMODE Technical Meeting

Working Group 2 - Emissions

Session 2 - Main differences on Emission Sectors

The issue of spatial scale in comparing national and local BU v. TD emissions inventories. A case study for Spain and the UK.

Michel Vedrenne[1,2], Julio Lumbreras[1], Rafael Borge[1], Juan Manuel de Andrés[1]

[1]Environmental Modelling Laboratory, Technical University of Madrid (UPM), Madrid, Spain
[2]Air & Environment Quality, Ricardo Energy & Environment, London, United Kingdom

27-29 June 2016
Zagreb, Croatia

FAIRMODE
Forum for air quality modelling in Europe

Outline

1. The spatial scale issue in emissions inventories
2. Analysing the effect of the spatial scale issue
3. Comparison results – UK NAEI v. TNO-MACCIII
4. Comparison results – Spain NEI v. TNO-MACCIII
5. Comparison results – GLA Emissions Inventory v. TNO-MACCIII
6. Comparison results – Madrid Emissions Inventory v. TNO-MACCIII
7. Conclusions
8. Next steps and gaps
9. References

The spatial scale issue in emissions inventories

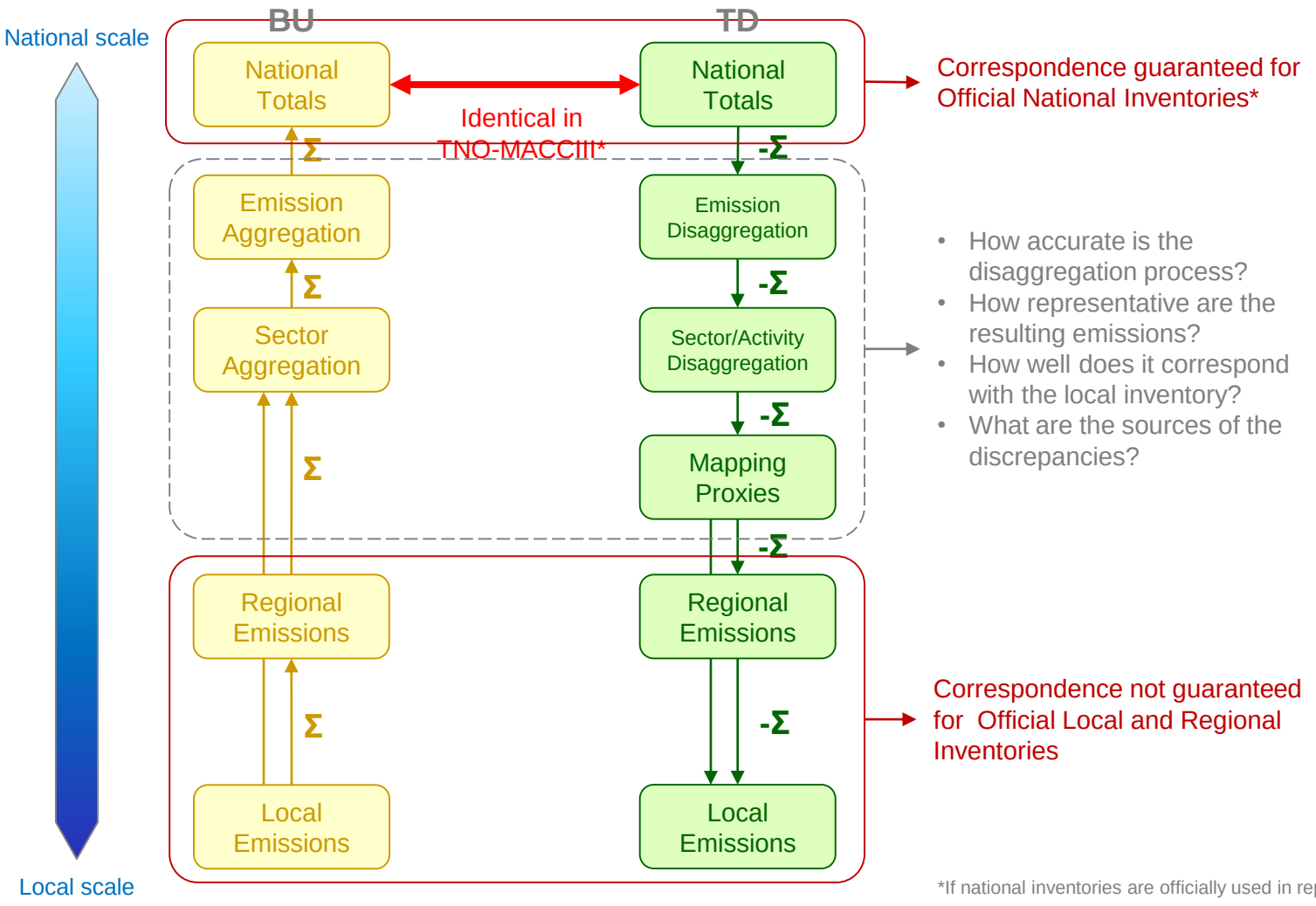
- Emission data should normally be taken from the most reliable, representative and detailed database available at the desired scale. Ideally, this database should provide information about every single source in the studied region → "perfect bottom-up (BD) inventory".

- In many cases, this database does not exist or is unreliable and incomplete so top-down (TD) or mixed-approach inventories are preferred. TD inventories have the advantage of usually relying on institutionalised data collection systems for national/international reporting obligations (Alcorn and Lloyd, 2009).

- Emission inventories should provide representative estimates across all the considered scales following a coherent, comparable and transparent approach → harmonisation. For BU inventories, this requires the adequate aggregation of emissions from the sources at the highest available resolution. For TD inventories, this requires relying on consistent downscaling process that correctly maps emissions across scales (Maes et al., 2009).

- Two main questions need to be answered regarding the spatial scale issue (Alonso et al., 2010):
  - *Is the contribution of specific sources to the total emissions of a particular area different?*
  - *Is that result connected to the specific features of the area or to the way the inventory has been produced?*

The spatial scale issue in emissions inventories



*If national inventories are officially used in reporting

Analysing the effect of the spatial scale issue

- TNO-MACCIII is based on officially-reported national emissions to CEIP/EMEP. A comparison of any national official inventory against TNO-MACCIII should deliver a good correspondence with Δ-Emissions Tool for the same year.

- Two national emissions inventories were selected for comparison: the UK National Atmospheric Emissions Inventory (NAEI) and the National Emissions Inventory of Spain (NEI). Both were referred to 2011.

- As TNO-MACCIII is a European-scale emissions inventory, its estimates for urban agglomerations are the result of the spatial disaggregation of the national emissions through selected proxies (Kuenen et al., 2014). Correspondence is not guaranteed and whenever it is observed, it endorses the TD downscaling process in terms of its representativeness.

- Two local emissions inventories were selected for comparison: the official inventory of the City Council of Madrid and the official inventory of the Greater London Authority. Both were referred to 2011.

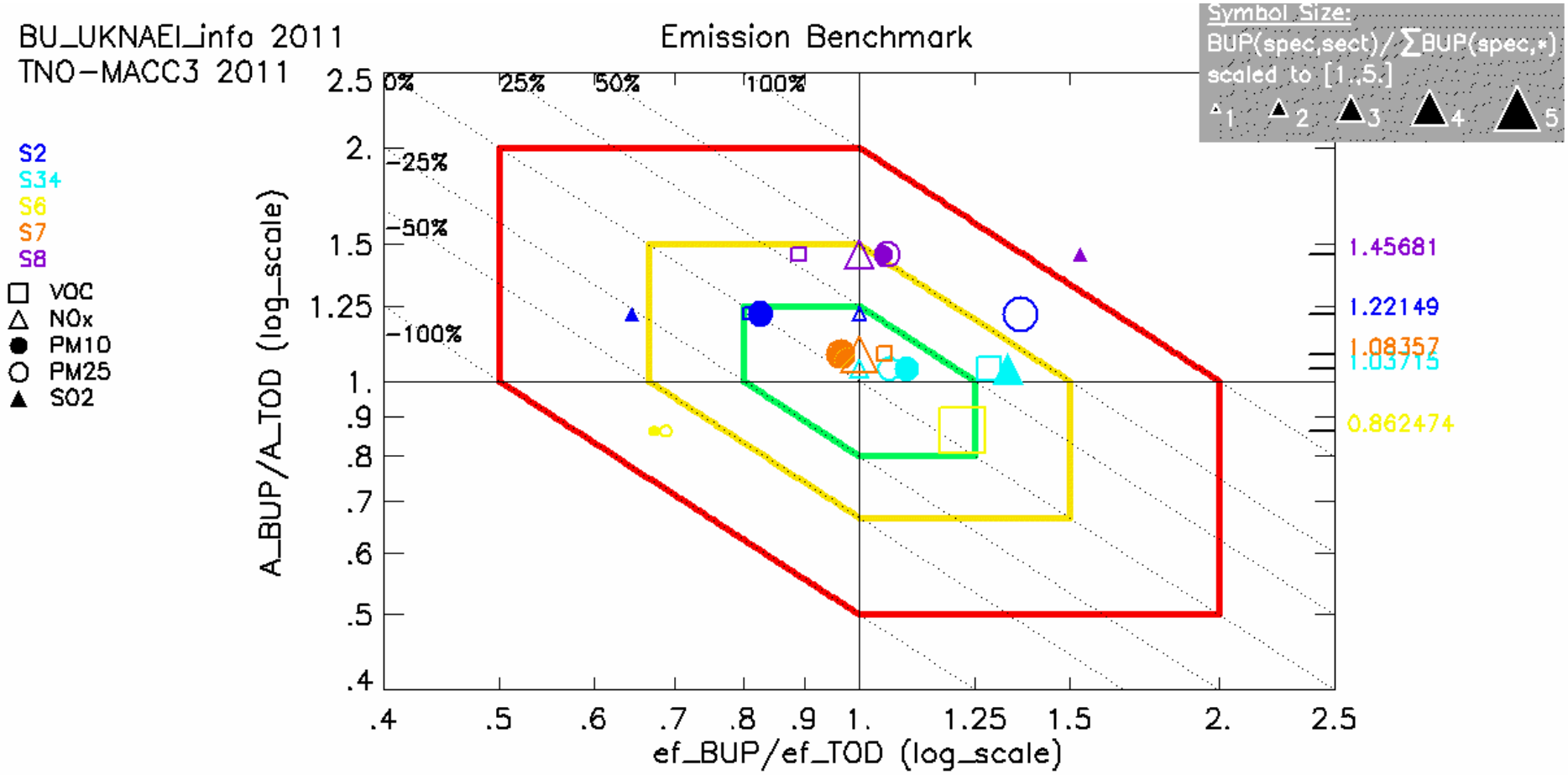
- The main hypothesis of this work is that the difference in performance shown between the national and local inventories against TNO-MACIII will provide useful hints on the scale issue and the potential loss of representativeness when scale is reduced.

- Analysis made for SNAP 02, 03-04, 06, 07 and 08. Pollutants: VOC, NO_x, PM_{10}, $PM_{2.5}$, SO_2.

National Scale Emissions Inventories

United Kingdom & Spain

Comparison results – UK NAEI v. TNO-MACCIII



Normalisation made for NO_x according to Thunis et al., (2016).

Comparison results – UK NAEI v. TNO-MACCIII

- All the sectors with the exception of SO_2 SNAP 08 lie within the red diamond shape (factor of 2). In general, all pollutants are very close to each other within a given sector, which suggests a consistent treatment of emissions for the same activity (consistent pollutant ratios). In general, BU>TD for all pollutants except VOC.

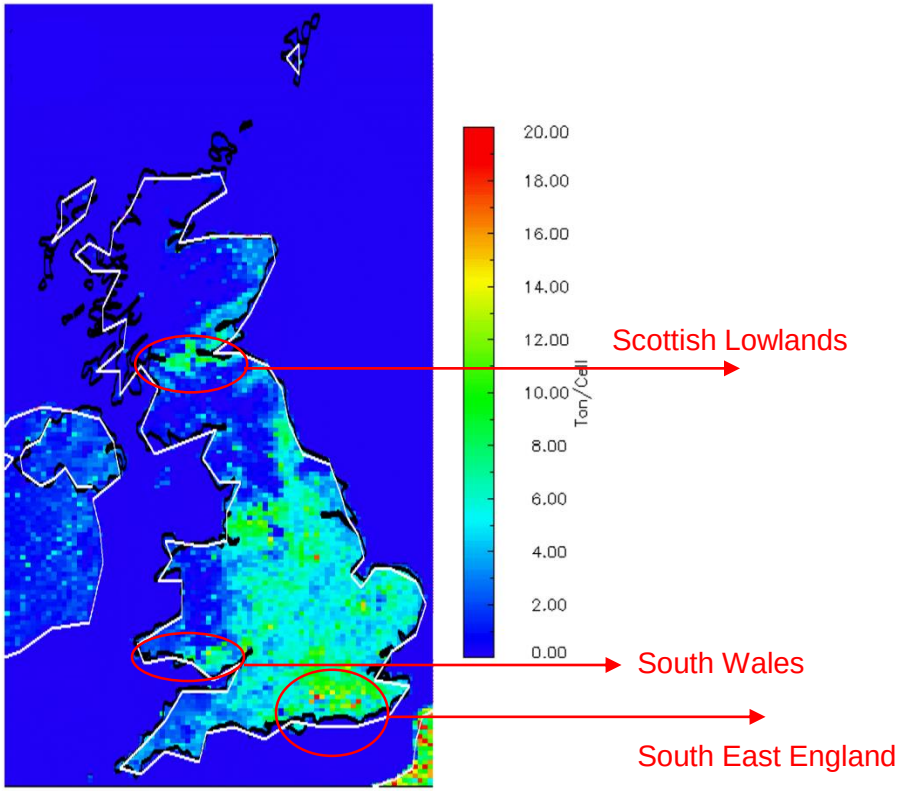
- The emissions of all pollutants for SNAP 07 are between 1.00 and 1.25 times higher in NAEI, as well as the emissions of NO_x, PM_{10}, and $PM_{2.5}$ for SNAP 03-04. Slighter divergences are observed for SNAP 02 (all pollutants except $PM_{2.5}$ and SO_2) and VOC for SNAP 06, all of which are within the factor of 1.25 diamond.

- The activity ratio BU/TD for SNAP 07 is 1.08 and the emission-factor ratios range between 0.96 and 1.05 which indicate an overall good correspondence. The activity ratio for SNAP 03-04 for NO_x, PM_{10} and $PM_{2.5}$ is 1.03 and the emission-factor ratios are 1.00-1.33.

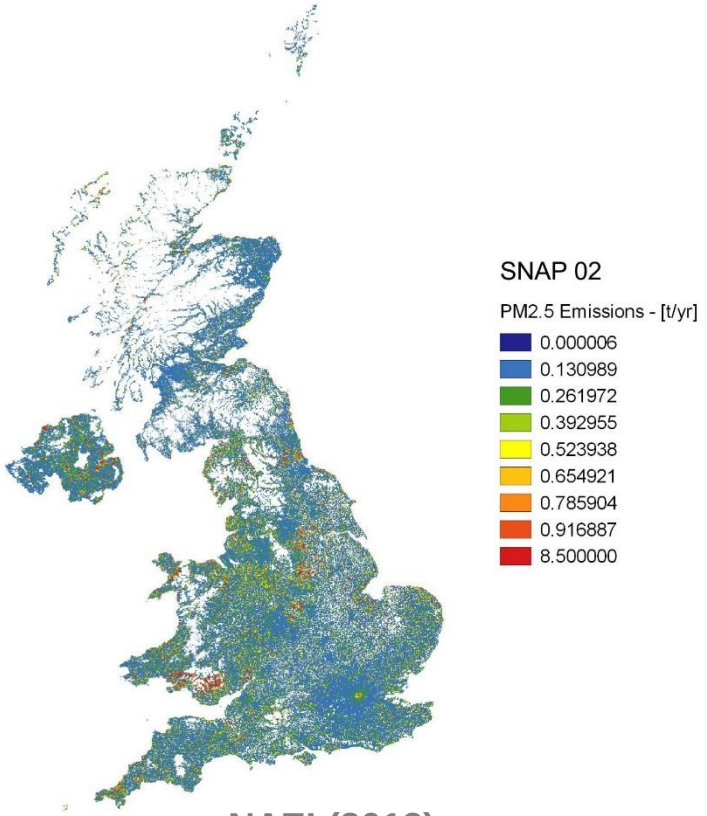
- The emissions from all pollutants from SNAP 08 (except SO_2) and VOC and SO_2 from SNAP 03-04 are between 1.25 and 1.50 higher than in TNO-MACCIII. In most cases this is due to overall higher activity variables and emission factors.

- The emissions of $PM_{2.5}$ from SNAP 02 from NAEI are between 1.5 and 2.0 times higher than in TNO-MACCIII. PM_{10} indicates compensation between activity and emission factors (0% diagonal).

Comparison results – UK NAEI v. TNO-MACCIII



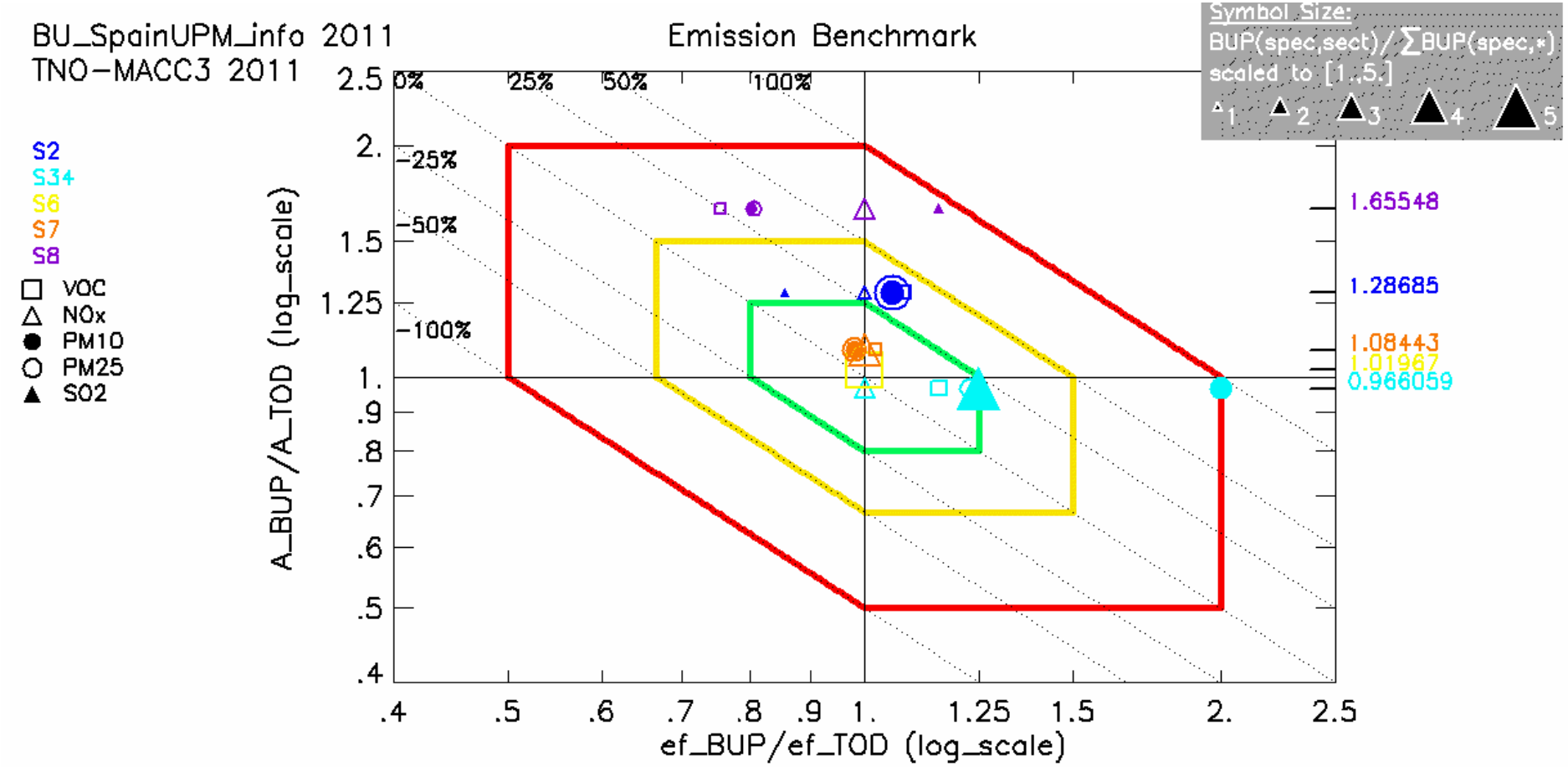
TNO-MACCIII (2011)



NAEI (2013)

The comparison of $PM_{2.5}$ for SNAP 02 indicates similarities in terms of the spatial distribution of emissions and in general, its order of magnitude (two different years).

Comparison results – Spain NEI v. TNO-MACCIII



Normalisation made for NO_x according to Thunis et al., (2016).

Comparison results – Spain NEI v. TNO-MACCIII

- All the sectors lie within the red diamond shape (factor of 2). In general, all pollutants are very close to each other within a given sector, which suggests a consistent treatment of emissions for the same activity (consistent pollutant ratios). As in the previous case, BU>TD for all sectors except SNAP 03-04.

- The emissions of all pollutants for SNAP 03-04, 06 and 07 are between 1.00 and 1.25 times higher in SNEI than in TNO-MACCIII. The activity ratio for SNAP 03-04 is 0.96 and the emission-factor ratio ranges between 1.0 and 2.0.

- The emissions of all pollutants from SNAP 02 are between 1.25 and 1.50 times higher in SNEI and pollutants are very close to each other. High presence of PM_{10} and $PM_{2.5}$ which exhibit slightly higher emission factors (activity ratio=1.28, EF ratio=0.85-1.08).

- The emissions from all pollutants from SNAP 08 are between 1.5 and 2.0 higher than in TNO-MACCIII. In the specific case of PM_{10}, $PM_{2.5}$, and VOC there is a compensation effect between activity and emission factors. The emissions of PM_{10} from SNAP 03-04 indicate are over the factor of 2 line, indicating emission factors of double the values than TNO-MACCIII.

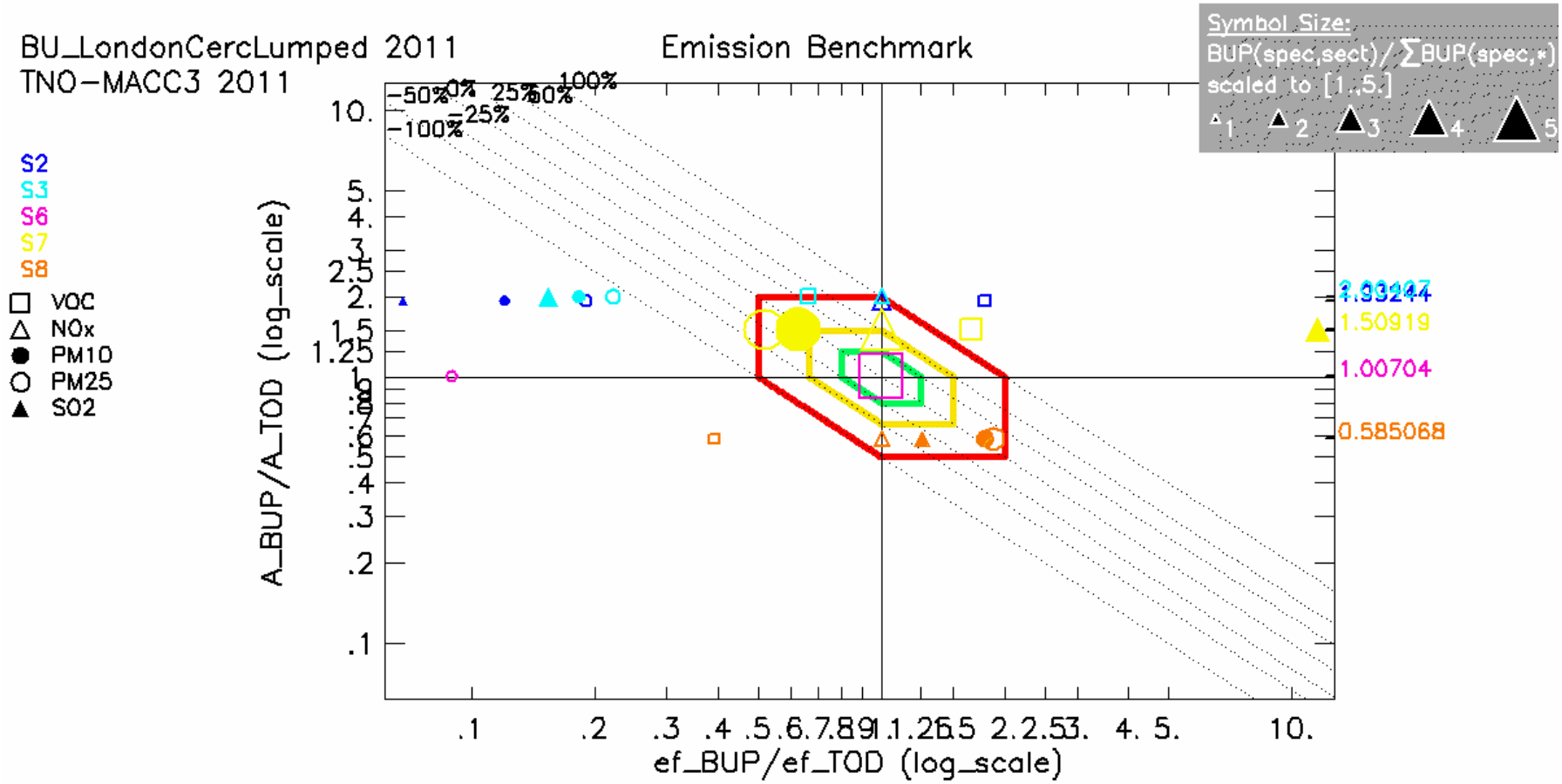
- TNO-MACCIII does not consider the emissions from the Canary Islands and to a much lesser extent, those of the Autonomous Cities of Ceuta and Melilla. Potential differences in SNEI can be due to this absence.

INDUSTRIALES
ETSII | UPM

Local Scale Emissions Inventories

Greater London & Madrid

Comparison results – GLA Emissions Inventory v. TNO-MACCIII



Normalisation made for NO_x according to Thunis et al., (2016).

Comparison results – GLA Emissions Inventory v. TNO-MACCIII

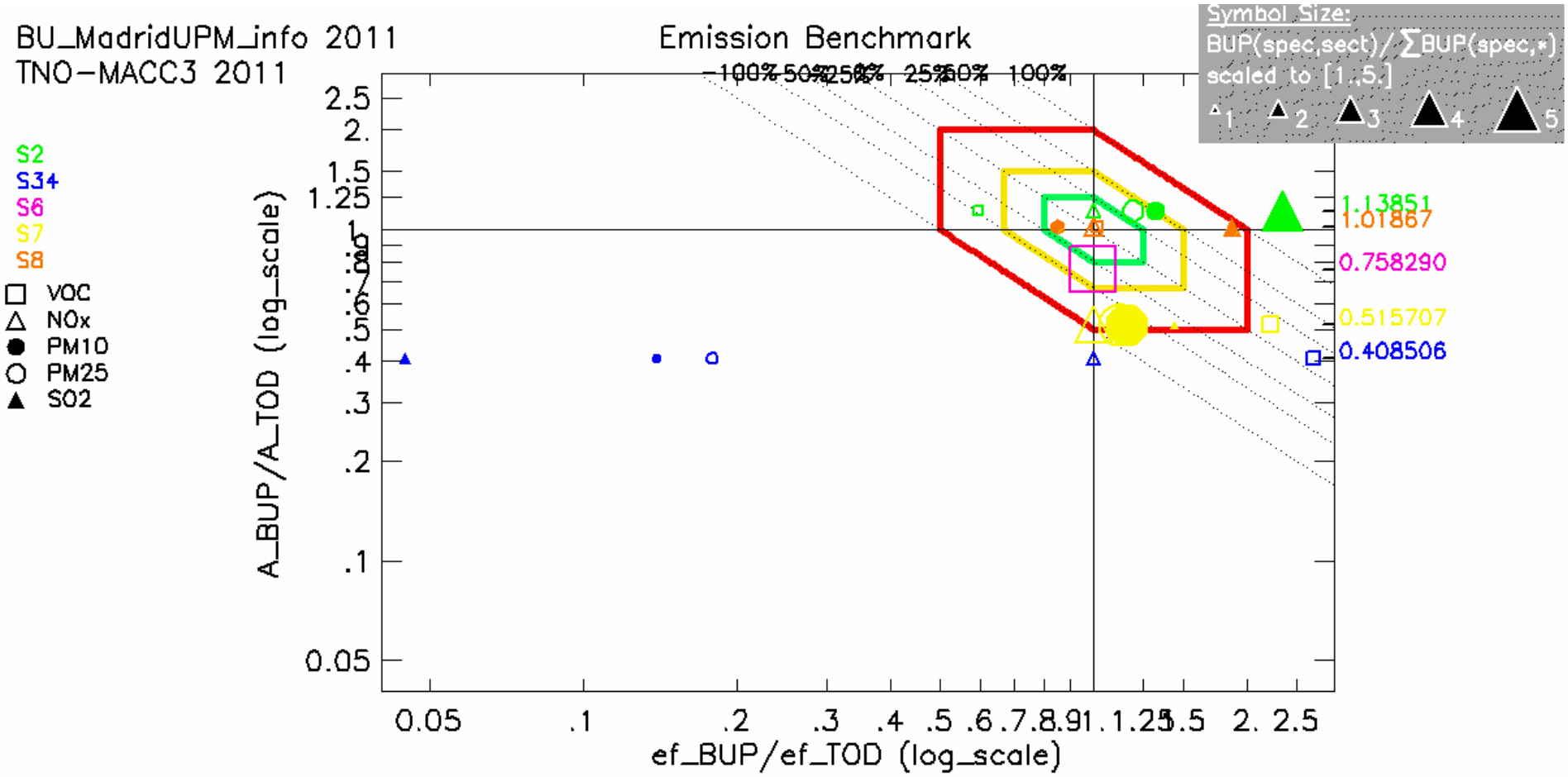
- Most of the pollutants of SNAP 06, 07 and 08 are within the red diamond (factor of 2). Only VOC from SNAP 06 is within the green diamond (factor of 1.25). Mostly all the pollutants for SNAP 02 and 03 lie outside the red diamond indicating discrepancies.

- SNAP 07 shows a mixed behaviour. SO_2 emissions are overestimated basically due to a tenfold emission factor (emission factor ratio = 11.5). This could potentially indicate that the GLA emissions inventory is considering fuels containing sulphur. In the case of PM_{10} and $PM_{2.5}$, it seems that the correspondence in emissions (compensation) is due to an overprediction of activity (ratio = 1.51) and an underprediction of emission factors (ratio = 0.62 and 0.51 respectively).

- The differences between inventories for SNAP 02 mimic the example from Barcelona in Thunis et al., (2016). There is a compensation effect with high activities (ratio = 1.93) and low emission factors (ratio between 0.06 and 0.19). The potential cause of this discrepancy could be related to a much higher consumption of domestic fuels as well as different fuel types (hence higher emissions) considered in TNO-MACCIII. The lower emission factors do not offset emissions to the diagonal lines.

- SNAP 08 presents a classical example of compensation due to low activities (ratio = 0.58) and higher emission factors (ratio between 1.25 and 1.87). The potential cause of this discrepancy could be related to the lower presence of off-road sources (potentially Heathrow and London City airport or construction machinery) in TNO-MACCIII. The high emission factors offset the high activities.

Comparison results – Madrid Emissions Inventory v. TNO-MACCIII



Normalisation made for NO_x according to Thunis et al., (2016).

Comparison results – Madrid Emissions Inventory v. TNO-MACCIII

- With the exception of SNAP 02 and SNAP 08, the remaining considered sectors exhibit underestimations with respect to TNO-MACCIII. This is the case of SNAP 03-04, 06 and 07. In general, most pollutants can be found inside the factor of 2 line (red diamond), with the exception of SNAP 03-04 (all pollutants), VOC from SNAP 07 and SO_2 from SNAP 02.

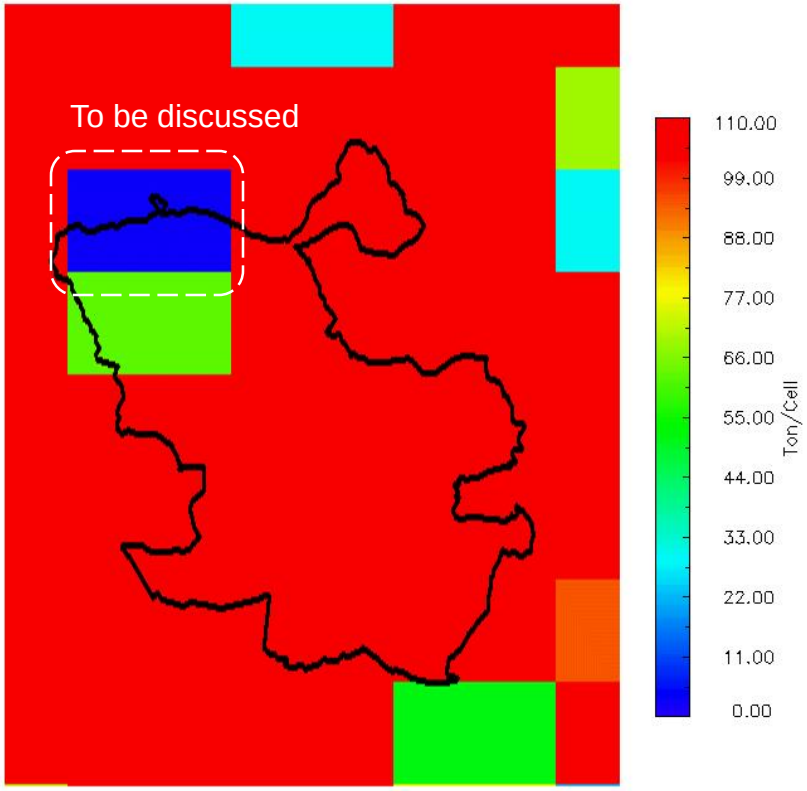
- Most of the pollutants of SNAP 08 with the exception of SO_2 are inside the green diamond (factor of 1.25). In particular, NO_x and VOC show significant correspondence with TNO-MACCIII (activity ratio = 1.01).

- All pollutants from SNAP 02 can be found within the red diamond, with NO_x being within the green diamond and PM_{10}/$PM_{2.5}$ within the yellow one. The majority of the SO_2 emissions in the inventory come from this sector, which is overestimated through a BU emission factor that is more than double the TD (EF ratio = 2.35). The inventory considers coal combustion for residential heating (2.2% of total energy consumption) but higher emission factor.

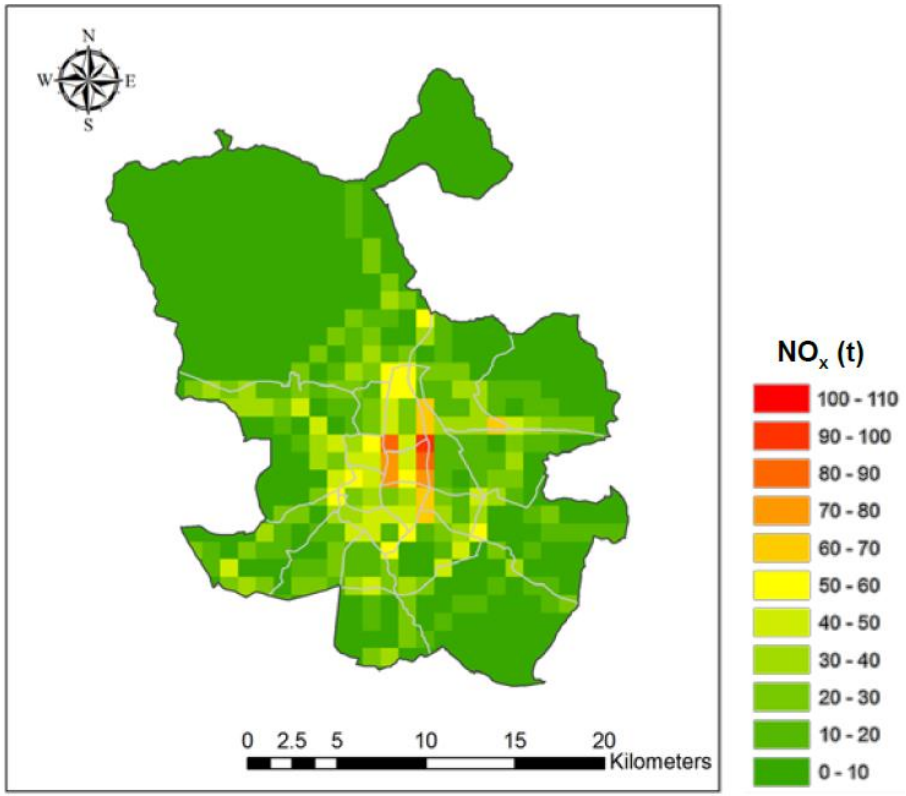
- The emissions of SNAP 07 are underestimated in almost half with respect to TNO-MACCIII (activity ratio = 0.5) for all pollutants. The inventory considers vehicle flows and average speeds for 14,000 road links as opposed to the TRANSTOOLS network and population data (potential overestimation of cars).

- The emissions of SNAP 03-04 are underestimated, showing an activity ratio of 0.41. This may be explained by the low presence of industries in Madrid, which are individually characterised in terms of their fuel consumptions as opposed to E-PRTR or TNO PS information.

Comparison results – Madrid Emissions Inventory v. TNO-MACCIII



TNO-MACCIII (2011)



Madrid (2013)

The comparison of NO_x for SNAP 07 indicates noticeable differences between inventories. The city centre of Madrid in TNO-MACCIII is overestimated.

Conclusions

- The comparison between TNO-MACCIII and the national official inventories for Spain and the UK revealed in general, a good correspondence with the great majority of the pollutants for all sectors found within the red diamond (factor of 2). This correspondence is due to the fact that national totals are conservative in both inventories, regardless of the spatial allocation procedures.

- The comparison between TNO-MACCIII and the local official inventories for Greater London and Madrid revealed different correspondence degrees for different sectors. In general, the most representative sectors of urban emissions (e.g. SNAP 02 or 07) show a reasonable degree of correspondence although differences are noticeable.

- Where gridded emissions of problematic sectors were available, these were used to highlight the differences in the allocation criteria in the region of interest.

- Besides the fact that the national (and by extension TNO-MACCIII) and local inventories were compiled with different criteria and differences should be expected, the downscaling process that takes national emissions to the local scale may also affect the value and location of these emissions. The native scale of the inventory may also play a role.

- To what extent is TNO-MACCIII suitable for air quality modelling? For the national scale, emissions are largely comparable but this is not always the case for the local scale.

Next steps and gaps

The current framework is very useful for detecting differences between inventories in a streamlined way. However, there are a number of issues which still require further investigation.

- Direction of improvements. The objective of the tool is to check differences, investigate the causes and apply corrective actions. To which inventory should these be applied? One inventory should be considered as "standard" and this need not be TNO-MACCIII. The possibility of comparing any pair of emissions inventories should be allowed in the tool.

- Granularity of emissions. Some sectors are inherently very heterogeneous (e.g. SNAP 04, SNAP 08). At the local scale, the activities of these sectors might be just a handful but for larger-scale inventories, identifying discrepancies for this sectors may be harder. The possibility of comparing emissions from different detail levels (not only SNAP level 1) would increase the interpretative power of the tool.

- Spatial interactions within the tool. It is our understanding that the tool clips the TD inventory based on the boundaries of the geographic region. Are the resulting emissions those completely within the boundaries or are these considering the overlaid cells?

- Guidance on the suitability of emissions inventories. Modelling requirements v. reporting requirements. Comparing local/regional inventories against an "air quality-validated inventory" could provide useful information on suitable directions of improvements. Potential cross-cutting activity with WG1??

References

- Alcorn, J. and Lloyd, S., 2009. From the trenches: top-down and bottom-up GHG inventory approaches. In: FES-East Conference, Bethesda, MD. United States of America. Available online at: http://www.ndcee.ctc.com/technologies/ESOH/Alcorn_FES-East_GHG_Trends_Final.pdf

- Alonso, M.F., Longo, K.M., Freitas, S.R., Mello da Fonseca, R., Marécal, V., Pirre, M., Gallardo Klenner, L., 2010. An urban emissions inventory for South America and its application in numerical modelling of atmospheric chemical composition at local and regional scales. Atmospheric Environment 44, 5072-5083.

- Kuenen, J.J.P., Visschedijk, A.J.H., Jozwicka, M., Denier van der Gon, H.A.C., 2014. TNO-MACC_II emission inventory; a multi-year (2003-2009) consistent high-resolution European emission inventory for air quality modelling. Atmospheric Chemistry and Physics 14, 10963-10976.

- Maes, J., Vliegen, J., Van de Vel, K., Janssen, S., Deutsch, F., De Ridder, K., Mensink, C., 2009. Spatial surrogates for the disaggregation of CORINAIR emission inventories. Atmospheric Environment 43 (6), 1246-1254.

- Thunis, P., Degraeuwe, B., Cuvelier, K., Guevara, M., Tarrasón, L., Clappier, A., 2016. A novel approach to screen and compare emission inventories. Air Quality, Atmosphere & Health. DOI 10.1007/s11869-016-0402-7

INDUSTRIALES
ETSII | UPM

Thank you for your attention.

Dr. Michel Vedrenne

c/ José Gutiérrez Abascal 2
28006 Madrid
SPAIN
m.vedrenne@upm.es

30 Eastbourne Terrace, 2nd Floor
W2 6LA London
UNITED KINGDOM