Copernicus Atmosphere Monitoring Service

Downscaled source attribution service over the Netherlands

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Introduction

This report provides an overview of the downscaled source attribution service over the Netherlands as provided within the Dutch CAMS NCP project (CAMS2_72NL). The service is based on a downscaling of the European daily source contributions to European cities as provided by TNO within the CAMS policy support service (CAMS2_71) using the LOTOS-EUROS model.
After a description of the applied methodology, details on the set-up and input data are given. In the following sections some results from the updated system are provided and the web interface is presented.

1. Background

Exposure to environmental pollution is associated with 6.7 million premature deaths each year (WHO, 2024). The largest health impacts are associated to air pollutants and particulate matter in particular. In 2019, 99% of the world's population was living in places with concentrations above the WHO air quality guideline values.

Improving air quality in European cities will bring major health benefits. However, air pollution is a complex, multi-faceted problem. Uninformed mitigation efforts can unnecessary impact businesses and may impact society without achieving significant environmental impact. To understand the problem, to inform the public, fulfill reporting obligations and to cost-effectively reduce pollution it is imperative that authorities have accurate information on its origin and effectiveness of potential measures. The quantification of sectoral as well as natural contributions discriminating between local and long rage (trans-boundary) ones is of particular interest. To this end there is a user need for access to consistent, up-to-date source apportionment information.

Chemistry-transport models (CTM) are designed to account for the complexity of the processes impacting air pollution concentrations, solving numerically hundreds or thousands chemical reactions. They can thereby provide the necessary information to support policy makers in the assessment of the main sources contributing to air pollution.

2. Source attribution methodology

2.1 LOTOS-EUROS model

LOTOS-EUROS is an open-source 3D chemistry transport model (Manders et al., 2017). The model is developed at TNO in cooperation with partners from different institutes. The model is one of the 11 models in the Copernicus Regional air quality ensemble since 2008 where it is operated as a joint effort between KNMI and TNO. The model with its source attribution module is one of the 3 models applied in the CAMS policy support service (CAMS2_71).

The LOTOS-EUROS model simulates air pollution concentrations in the lower troposphere on a regular Eulerian grid with variable resolution over Europe. The vertical grid can be adjusted according to the applied meteorological input data. For further details on the LOTOS-EUROS model, the reader is referred to (Manders et al., 2017).

2.2 Source attribution method

Within the LOTOS-EUROS model a source attribution method has been developed based on the tagging approach. For establishing the source contributions to the air pollution concentration at a specific location and time the tagging technique which keeps track of the origin of air pollutants throughout a model simulation is well suited and computationally efficient. The method allows the assessment of many contributions within one model simulation.

After emission different components are followed through the model system, while keeping track of its source sector or region. The routine is implemented for primary, inert aerosol tracers as well as chemically active tracers containing a C, N (reduced and oxidized) or S atom, as these are conserved and traceable. The source attribution is valid for current atmospheric conditions as all chemical conversions occur under the same oxidant levels. For secondary aerosols consisting of two components (e.g. ammonium nitrate (NH_4NO_3)), the contribution is calculated by accounting half of the mass to each component source. For example for ammonium nitrate (NH_4NO_3) half of the mass is attributed to the ammonium source sector or location (mostly ammonia (NH_3) from agricultural sources) and half of the mass to the nitrate source sector or location (a.o. nitrogen dioxide (NO_2) from traffic). Both components are required for formation of the combined aerosol. The contributions are preserved when transported to another region. The chosen method leads to a larger agricultural contribution than the method where the ammonium nitrate mass is allocated to the ammonium and nitrate sources based on the respective molecular masses of these components (NH_4^+ is lighter than NO_3^-). Because the combined aerosol cannot be formed if either of the two components is unavailable, attributing equal contributions seems justified.

For further details on the LOTOS-EUROS tagging source attribution method, the reader is referred to Kranenburg et al. (2013).

2.3 European service

The service presented in this document is based on a downscaling of the European daily source contributions to European cities as provided by TNO within the CAMS policy support service (website[1]) using the LOTOS-EUROS model at a resolution of 0.2°x0.1°. Within this CAMS policy support service LOTOS-EUROS provides country contributions to PM concentrations in 80 large cities in Europe. The information is provided per city both as 4-day forecasts and for previous episodes via an interactive website.

More extended output of the source attribution by LOTOS-EUROS and its source attribution module can be found on the TNO TOPAS-EU website[2]. On this website both source sector as well as country contributions are provided for European cities and measurement sites for the past six weeks. Recently also the annual average as well as downloads of daily average contributions for the previous year are provided.

3. Downscaled source attribution over the Netherlands

3.1 Rationale

For local policy making at city scales there is a need for identification of main sources of pollution with a higher level of spatial detail than provided in the European service. To this end we have developed a downscaled source attribution over the Netherlands at 1 km horizontal resolution. Having such a national service also allows the service to be tailored to national needs.

[1] https://policy.atmosphere.copernicus.eu

[2] https://airqualitymodeling.tno.nl/topas/topas-eu/

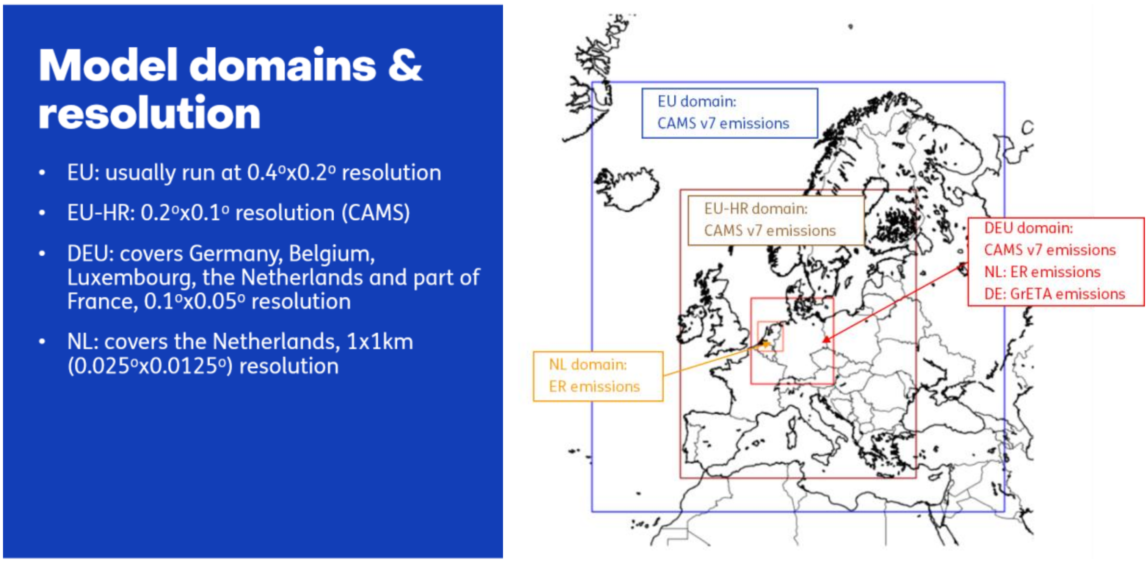
The service is mainly aimed at local policy makers at city/province level, scientific users, and the general public. An example is the use by DCMR to understand their observed PM concentrations as presented during the WP72NL_60 workshop (see the slides in M72.6.3.1).
The service provides valuable information (such as the contributions from national versus foreign sources) in the context of the AAQD.

3.2 Downscaling

The high resolution service for the Netherlands provides sector and country contributions at 1x1km^2 spatial resolution following a nesting approach into the European service.

Figure 1 provides an overview of the nesting approach with the four domains and their resolutions.

Figure 1 – Modelling domains for LOTOS-EUROS operational source apportionment



3.3 Emissions

Anthropogenic emissions for Europe are taken from the CAMS-REG emission inventories (Kuenen et al., 2021). In the first quarter of 2025 a development to update these emissions to the CAMS-REG version 8 that has been released in 2024 has taken place. This will ensure alignment with the models applied within the CAMS regional air quality service that will likewise updated their emissions to CAMS-REG version 8 as of November 2025.
For the downscaled source attribution in the Netherlands the national emissions inventory for the Netherlands from the Emission Registration (ER) is applied. These emissions are available at a 1x1 km spatial resolution. Together with the update on the European emissions CAMS-REG v8, in the first quarter of 2025, these emissions have been updated to the newest emission data available for the year 2022 that were released in 2024.

3.4 Sector contributions

In the operational service the main economic sectors as well as natural sources are tracked to provide their source contributions (see Table 1).

Table 1 – Description of source sectors labelled in the operational LOTOS-EUROS source attribution

Energy	Power plants, Refineries and Other combustion in energy industry
Residential combustion	Heating and cooking
Industry	Iron and steel industry, Chemical industry, Paper and pulp industry, Cement production, Storage and handling, etc
Fuel production and distribution	Coal, oil and gas production; gas distribution and flaring
Solvent use	Industrial, domestic and constructional solvent use
Road transport exhaust	Passenger cars, motorcycles, mopeds, and heavy duty transport vehicles exhaust
Road traffic non-exhaust	Tyre and break wear
Shipping	Inland and international shipping
Aviation	Air craft exhaust emissions
Mobile machinery	Non-road mobile machinery
Waste	Waste incineration, Landfills, BBQ and tobacco
Manure and storage	Manure and fertilizer application and storage
Livestock	Animal husbandry
Wildfire	Forest fires
Biogenic	Natural origin, e.g. NOx emissions from soils
Sea-salt	Natural sea-salt aerosols
Saharan dust	Fine desert dust originating from strong winds in the Sahara
Boundary	Origin outside the model domain (i.e. other continents)
Other sources	Source categories with less than 10% relative contribution to the total modelled mass are combined under this label.

3.5 Regional contributions

In the operational service regional source attribution results are provided allocating contributions from the different European countries (see Table 2) in combination with contributions from non-country labels as provided in Table 3.

Table 2 - Countries labelled in the operational LOTOS-EUROS source attribution

Austria	Belgium	Bulgaria	Switzerland	Czech Republic
Germany	Denmark	Estonia	Greece	Spain
Finland	France	Croatia	Hungary	Ireland
Iceland	Italy	Lithuania	Latvia	Netherlands
Norway	Poland	Portugal	Romania	Sweden
Slovenia	Slovakia	Great Britain	Turkey	Ukraine
Belarus	Luxemburg	Cyprus	Malta	Montenegro
Yugoslavia	FYR Macedonia	Bosnia and Herzegovina	Kosovo	Albania
Russia	Greenland			

Table 3 – non-country labels in the operational LOTOS-EUROS source attribution

Sea	International shipping on seas

Other sources	Contribution from countries that did not get their own land code, including e.g. Kazachstan, Georgie, etc.
Sea-salt	Natural sea-salt aerosols
Saharan dust	Fine desert dust originating from strong winds in the Sahara
Boundary	Origin outside the model domain (i.e. other continents), includes a large contribution of desert dust for southern Europe
Rest	Source categories with less than 10% relative contribution to the total modelled mass are combined under this label.

3.6 Developments

Based on feedback collected through the WP72NL_60 workshop we have investigated possible alterations or required developments for increased usability by the national stakeholders.

Within the current project we have updated the model system for the Netherlands to be more consistent with the system applied within the CAMS regional AQ service and the CAMS Policy support service. We have also implemented the update of the emissions to newest inventories to take into account changes in emissions, which is now running pre-operationally alongside the current service (after thorough evaluation it will be updated on the website as well). The previous emissions were dated from 2018.

Another request was to provide the woodsmoke contributions as a separate contribution. However since the Dutch emission inventory does not explicitly specify this source, further developments are needed to allow the uptake of this user requirement. This could be put in as a request to the emission inventory production team in the Netherlands, another option would be to apply the fuel split distribution from CAMS-REG to the national emissions.

A list of all the feedback on the current downscaled source attribution service over the Netherlands is provided in the deliverable CAMS2_72_NL_ 202407_ D72.6.3.1_Workshop_report. Based on this feedback priorities have been set for future developments which are taking into account for the next phase of the proposal of the CAMS2_72NL project.

3.7 Positioning with respect to other national source attribution tools

One of the main points that came up in the workshop which may hamper increased use of the CAMS downscaled source apportionment tool, was the positioning and consistency of the tool in relation to other existing source attribution tools developed by RIVM in the Netherlands[3,4]

While the RIVM tools focus on yearly averages and use a simplified model which a.o. does not take into account full chemistry and interactions between different sources, the source attribution tool developed by TNO provides hourly contributions taking into account full chemistry and non-linear interactions between sources.

In the next phase of the CAMS2_72NL project, discussions between RIVM and TNO will be organised to assess differences between available source attribution tools in the Netherlands, analyse their application domains and the complementarity of the tools. The results will be used to provide guidance on applicability and complementarity of source attribution tools in the Netherlands and to enhance and clarify the positioning of the CAMS downscaled source attribution service.

[3] https://gcn-app.rivm.nl/

[4] https://rivm.shinyapps.io/BLG-tool/

4. Results/evaluation

In Figure 2 we show the comparison of the source attribution results for Europe before and after the update of emissions. It can be seen that the reductions in NO_2 emissions that have been realized in the last years and that are reflected in the used emission datasets are particularly visible in the contribution from Energy sector but also in the road transport sector.

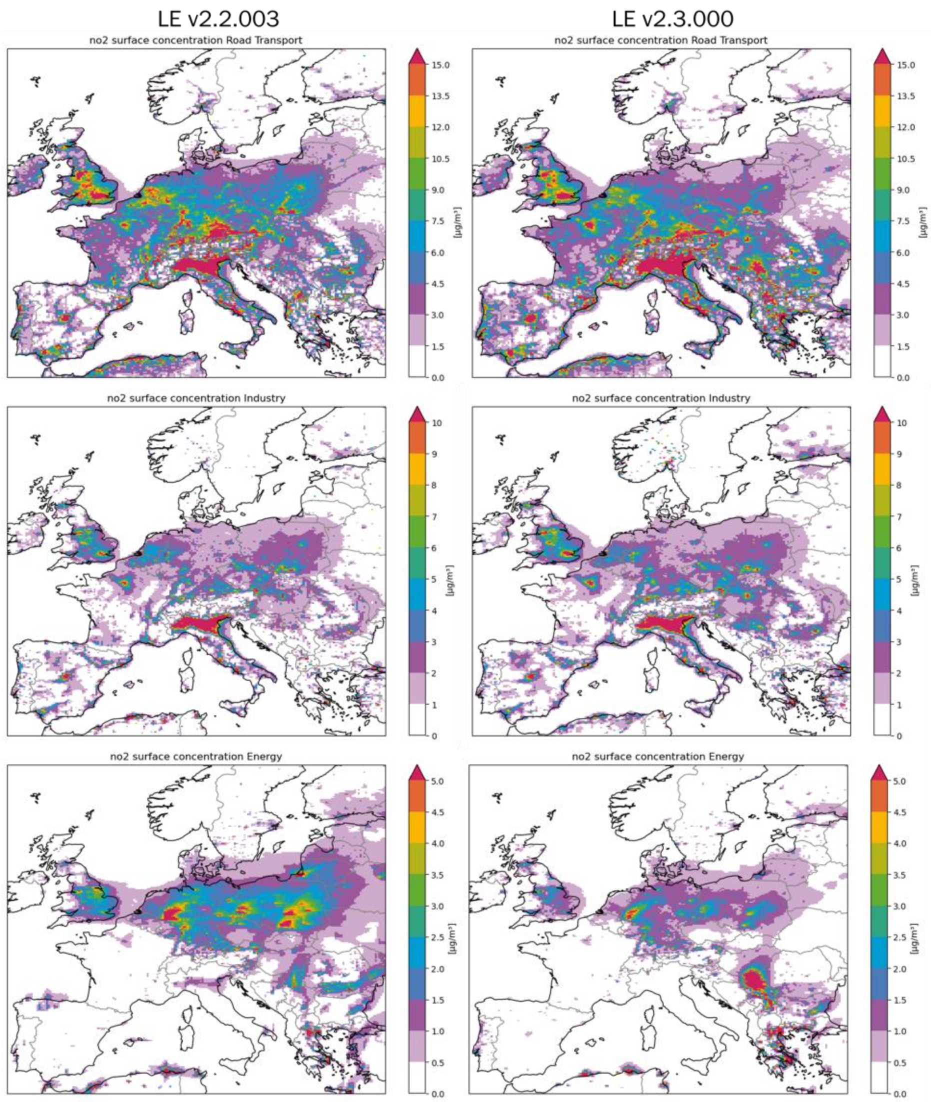


Figure 2 The NO_2 distribution over Europe for the three dominant sectors in current operational (v2.2.003, left panels) and updated version (v2.3.00, right panels).

If we zoom in on a single location (Utrecht) (shown in Figure 3) it is clear that although the general distribution is similar specific contributions to NO_2 (e.g. Residential combustion, Industry and Manure and storage) can differ more than 10% between the two simulations for the first week of January 2025.

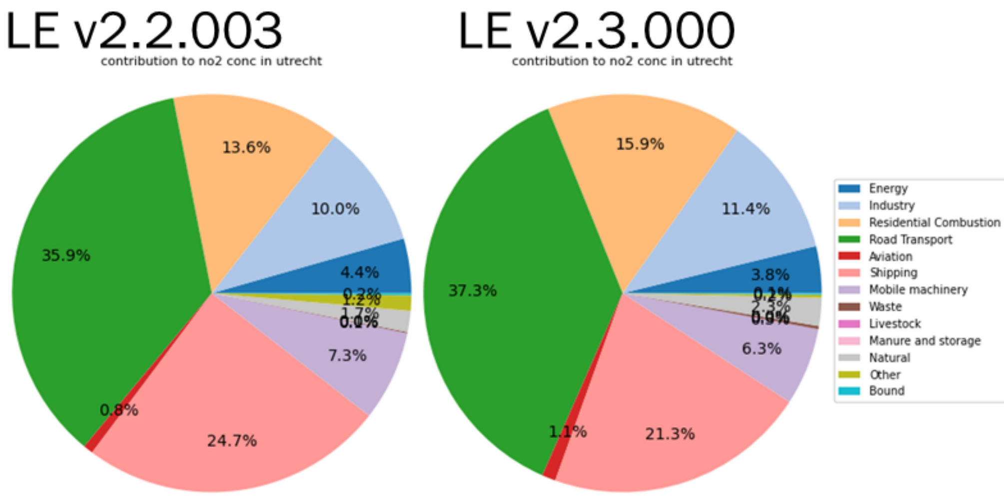


Figure 3. Piecharts showing the contributions to the NO_2 concentration in Utrecht in the first week of Januari in 2025.

In the time series for PM2.5 shown in Figure 4 it can be seen that the contribution is slightly reduced in the updated system. The dotted line in the top panel shows the total concentration in the updated and is generally lower.

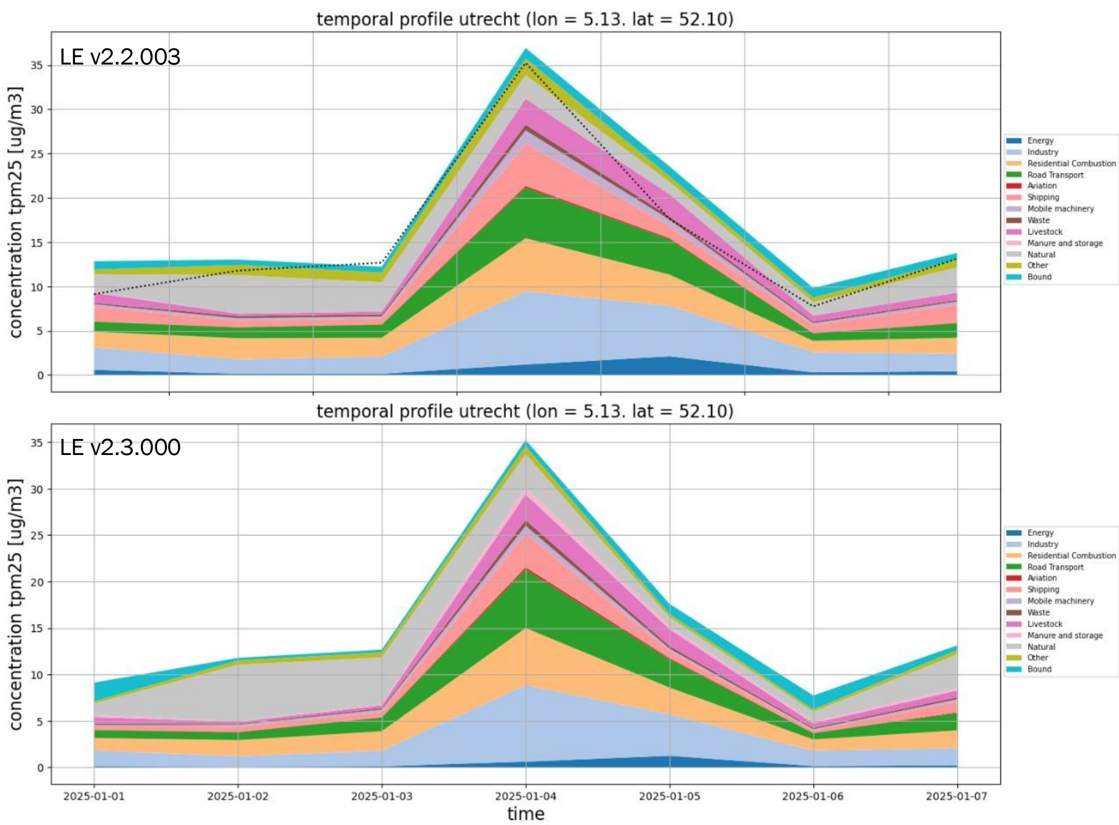


Figure 4 Time series showing the total PM2.5 concentration and its distribution in Utrecht in the first week of January. The dashed line shows the cumulative PM2.5 from updated version 2.3.000

The system with updated emissions will be kept in pre-operational mode alongside the operational version on the website for several weeks before making the switch to the new version.

5. Web interface

The operational source attribution for the Netherlands is visualised through an interface on TNO TOPAS-NL website[5]. A screenshot of the web interface is shown in Figure 5.

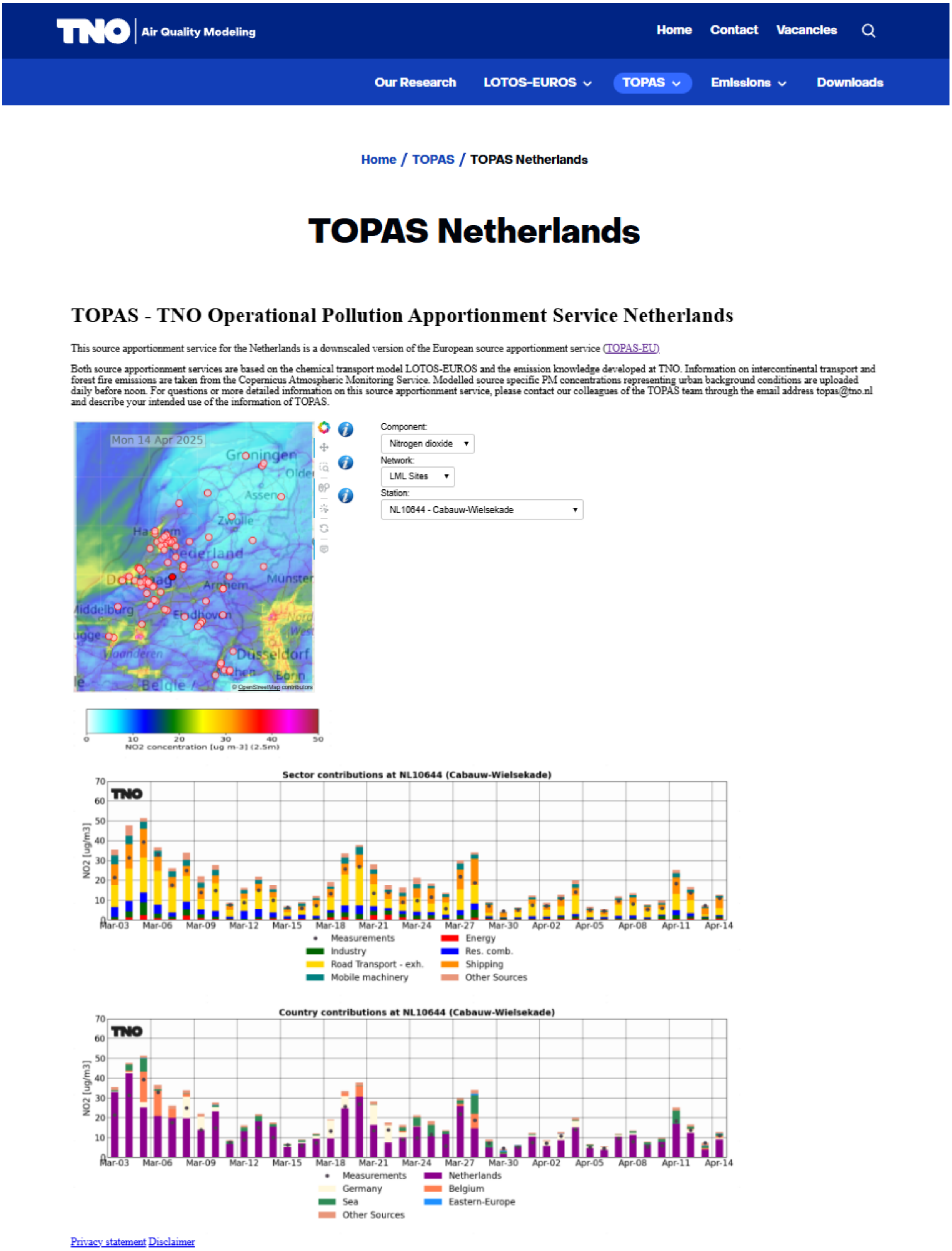
The user can select the air quality component of interest from four options: PM10, PM2.5, NO_2 and SO_2. The source attribution is provided for all official measurement stations (LML) as well as for all locations from a citizen science network (samen meten). The location can be chosen on the map or from a dropdown list.

The service then provides the main source sectors and source countries contributing to the air pollution for the selected component at the selected location over the past six weeks.

The modelled results are accompanied with the observed concentrations at the locations to allow an evaluation of the model performance. The results are updated on a daily basis.

[5] https://airqualitymodeling.tno.nl/topas/topas-netherlands/

Figure 5 - Web interface showing the operational source attribution results for the Netherlands.



6. Conclusion

We have updated the downscaled source attribution service for the Netherlands using more up-to-date model versions and input emissions. First evaluations shows decreased emissions and concentrations which reduce the bias with the observations. An extended evaluation is foreseen in the next phase of the project, alongside collaborations with the RIVM institute on the positioning of this service with respect to other available source attribution tools.

Moreover, we want to improve the use of the tool by focusing on the positioning of this service within the Netherlands with respect to other available source attribution tools produced by RIVM, through intensified collaborations and exchange of knowledge with RIVM.

7. References

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