United Nations ECE/EB.AIR/GE.1/2021/4–ECE/EB.AIR/WG.1/2021/15

Economic and Social Council

Distr.: General
1 July 2021

Original: English

Economic Commission for Europe

Executive Body for the Convention on Long-range Transboundary Air Pollution

Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe

Working Group on Effects

Seventh joint session
Geneva, 13–17 September 2021
Item 2 (b) of the provisional agenda
Progress in activities of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe in 2021 and future work: measurements and modelling

Measurements and modelling

Report of the Task Force on Measurements and Modelling on its twenty-second meeting

Summary

The present document contains the annual report of the Task Force on Measurements and Modelling under the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe, in accordance with the 2020–2021 workplan for the implementation of the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/144/Add.2), and in line with the revised mandate of the Task Force (Executive Body decision 2019/8).[a] The present report summarizes the discussion at and the outcomes of the Task Force's twenty-second meeting (online, 10–12 May 2021).

[a] All Executive Body decisions referred to in the present document are available at www.unece.org/env/lrtap/executivebody/eb_decision.html.

I. Introduction

1. The present report contains the outcomes of the twenty-second meeting of the Task Force on Measurements and Modelling (online, 10–12 May 2021), including the presentation of activities undertaken since its previous meeting (online, 11–13 May 2020). It describes progress in implementation of the monitoring strategy of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) for the period 2020–2029 (Executive Body decision 2019/1) and in the development of modelling tools and specific ongoing assessments, as well as current and potential collaborative activities with other bodies of the Convention on Long-range Transboundary Air Pollution.

2. In all, 103 experts from the following Parties to the Convention attended the meeting: Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Netherlands, Norway, Poland, Russian Federation, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom of Great Britain and Northern Ireland and United States of America. Also present were representatives of: the Chemical Coordinating Centre; the Centre on Emission Inventories and Projections; the Meteorological Synthesizing Centre-East (MSC-East); the Meteorological Synthesizing Centre-West (MSC-West); the Centre for Integrated Assessment Modelling; the EMEP Steering Body; the European Environment Agency; the European Commission; the Task Force on Integrated Assessment Modelling; the Task Force on Hemispheric Transport of Air Pollution; the Task Force on Emission Inventories and Projections; and the World Meteorological Organization (WMO).

3. Mr. Augustin Colette (France) and Ms. Oksana Tarasova (WMO) co-chaired the meeting. They presented the agenda,[1] highlighted the progress on the 2020–2021 workplan for the implementation of the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/144/Add.2), outlined the provided input and further expectations from the Task Force toward the review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol), as amended in 2012 (Executive Body decision 2019/4) and preparations for the 2022–2023 workplan, which was subsequently discussed during the meeting.

4. The Chair of the EMEP Steering Body provided an update on the Convention and EMEP activities. She presented the timeline for the review of the Gothenburg Protocol. She stressed the importance of work on condensables that had been mandated to EMEP and discussed at a technical workshop organized with the support of the Nordic Council of Ministers in 2020 (see footnote 8.). She described the road map proposed at that workshop as a way forward for implementation of the comprehensive accounting of condensables in policy modelling work. She stressed the importance of communication towards national experts and the policy bodies for the implementation of such a road map. She further presented the progress of revision of the Convention long-term strategy[2] for the period 2020–2029. She stressed that the revised strategy would cover both EMEP and the Working Group on Effects to: increase consistencies and linkages between the strategies of those two bodies; set up clear common goals; and focus on the gaps that needed to be filled regarding implementation. The review and subsequent revision of the Gothenburg Protocol would be taken into account while developing the long-term strategy of the Convention. The Convention would pursue efforts to build the global forum for international cooperation on air pollution, which would serve as an outreach tool for the Convention to share good practices.

[1] Available at https://projects.nilu.no/ccc/tfmm/.

[2] Available at www.unece.org/fileadmin/DAM/env/documents/2012/EB/Informal_document_no_18_Revised_Long-term_Strategy_of_the_effects-oriented_activities_clean_text.pdf.

II. Updates on the activities of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe Centres and research infrastructures and international organizations

5. A representative of the Chemical Coordinating Centre presented an update on the Centre's work, with focus on implementation of data licencing in the EBAS database.[3] He stressed that it was important to maintain open access to EMEP observational data, which had been distributed openly since 1977. Permanent identifiers of the individual data sets would allow for better tracking of the actual use of data sets. EBAS data was licensed under the Creative Commons Attribution 4.0 International licence (CC BY 4.0) and the data were associated with free sharing and adaptation for any purpose. Appropriate credit must be given to EBAS at the Norwegian Institute for Air Research and the individual frameworks defined as the project, programme or organization to which a given data set was affiliated or belonged. It was considered impractical to provide attribution to individual data originators. The wording to describe data policy was proposed for further discussion. The speaker further described the work done at the Centre in relation to coronavirus disease (COVID-19). He noted that several scientific studies (partly based on EMEP data) related to COVID-19 were available or in progress, but that they were largely focused on the immediate impacts. EMEP was specially designed to monitor long-term trends and the linkages between emissions and exposure for the development of emission reduction protocols, hence there was a need to assess the impacts of the COVID-19 pandemic on the achievements with respect to the Convention Protocols on a more systematic basis. The 2020 EMEP data would become available in summer 2021. An EMEP COVID-19 assessment could be initiated in 2021 but would not be finalized before the EMEP status report in autumn 2022.

6. A representative of the Aerosols, Clouds and Trace gases Research InfraStructure (ACTRIS) presented a report on progress with the establishment of ACTRIS. In March 2021, the ACTRIS Interim Council had unanimously approved a 5-year financial plan, membership contributions and the technical and scientific description, and given Finland a mandate to start the signatory process. A legal entity called the ACTRIS European Research Infrastructure Consortium would likely be established in late 2021. ACTRIS included national facilities for data production and physical access, topical centres for measurement procedures and quality control and data centres for curation of and access to data and data products. He explained the mutual benefits of sharing those processes between ACTRIS and EMEP. Further discussions had to be held on the conditions for the ACTRIS quality stamp to be given to ACTRIS-compliant observations for measurement sites not included in ACTRIS national facilities. He also highlighted that users would benefit from that collaboration through: seamless access to data in a find, access, interoperate and reuse (FAIR) environment; wider harmonization of procedures and measurements across Europe and internationally; improved data access quality; availability of added-value services (level 3); and access to a significant quantity of information and to campaign-based data.

7. A representative of MSC-West described the preparation of country reports, including utilization of the condensable emissions for the year 2019 and modelled trend runs for 2000–2019 (no condensables) with new gridding (Centre on Emission Inventories and Projections). MSC-West had developed a new EMEP trend and source apportionment interface[4] that combined observations with modelling results from the EMEP model and that was intended to replace the model evaluation reports. The EMEP model was designed to provide relevant background air pollution information to the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model that provided emission control options and associated costs. Reaching out to local scale was currently based on a redistribution of concentrations from a 28 km grid to a 7 km grid and even urban polygons

[3] See http://ebas.nilu.no/.
[4] See https://aerocom-trends.met.no/EMEP/.

(using population distribution), as well as estimating concentrations at monitoring sites using observations and considering road site increment and regional background level. One new development consisted of introducing "local fraction" in the EMEP model to provide detailed sources map for any point. By early 2022, that approach would serve as a basis for downscaling from 0.3° x 0.2° longitude/latitude to 0.1° x 0.1° longitude/latitude by tracking the relative contribution of local and long-range air pollution. It could even provide subgrid exposure correction factors up to 250 m resolution for primary air pollutants. In addition, in the next version of GAINS, the spatial extent of source receptor calculations would extend further east to better cover the countries of Eastern Europe, the Caucasus and Central Asia.

8. A representative of MSC-East presented updates on the work of the Centre. Those included: the preparation of the assessment of long-term changes in polycyclic aromatic hydrocarbon (PAH) pollution in the EMEP countries (1990–2018); estimates of contributions of residential combustion and other sectors to PAH pollution; research activities to improve PAH pollution assessment (national case studies, EuroDelta-Carb European multi-model intercomparison); and contribution to the assessment of human exposure to particulate matter and toxic PAHs. Trend analysis demonstrated that reduction of mercury (Hg) levels in Europe was 30 per cent on average, while in the Arctic it was only 7 per cent. The decreased emissions from European sources were partly balanced by emissions increase in East Asia and slowly changing legacy emissions. Analysis of different factors had been conducted to improve emission source attribution. Two dedicated workshops on Hg and on persistent organic pollutants (POPs) had been organized by the Task Force on Hemispheric Transport of Air Pollution (online, 13 April and 15 April 2021, respectively), with the aim of initiating research activities to support the expected review of the Protocols on Heavy Metals and on Persistent Organic Pollutants. Eleven modelling groups planned to participate in that exercise. An ad-hoc group on marine pollution had been created by a decision of the EMEP Bureau meeting (online, 1-4 March 2021) to support regional marine conventions with the model assessment of long-term trends of heavy metal deposition to the North Sea and the North Atlantic and sources attribution. The source-receptor matrices of heavy metal deposition to those regions would be calculated for lead, cadmium and Hg. Similar assessment including POPs would be conducted for the Baltic Sea. The Centre – on behalf of EMEP – had provided a contribution to the 2021 Arctic Monitoring and Assessment Programme Mercury Assessment. The MSC-East modelling system had also been updated, with better representation of Hg chemistry and improved parameterization of air-surface exchange. MSC-East had started to look at the problem of microplastics.

9. A representative of WMO gave an update on recent developments within WMO and its Global Atmosphere Watch (GAW) Programme. She described the updated terms of reference for the structures under the GAW Programme to align the Programme with the reform of the constituent bodies. She informed the participants of the publication of the updated statement on the use of low-cost sensors for atmospheric composition measurements.[5] She described the process and outcomes of the development of the WMO Unified Data Policy. She presented the priorities and workplans of the research board that oversaw the GAW Programme for 2021. One of the activities was advances through the work of the COVID-19 Task Team that had produced the *First Report of the WMO COVID-19 Task Team: Review on Meteorological and Air Quality Factors Affecting the COVID-19 Pandemic*[6] in 2021. Several activities related to COVID-19 studies had been initiated under the GAW Programme to address the impact of lockdown measures on atmospheric composition. She further updated the meeting on the activities of the three science-for-services initiatives of the Programme. She invited members of the Task Force on Measurements and Modelling to attend the planned GAW Symposium 2021 (online, 28 June–2 July 2021).

[5] See Richard E. Peltier, ed., *An update on low-cost sensors for the measurement of atmospheric composition: December 2020*, World Meteorological Organization (WMO)-No. 1215 (Geneva, WMO, 2021). Available at https://library.wmo.int/index.php?lvl=notice_display&id=21508.

[6] See WMO-No. 1262 (Geneva, GMO, 2021). Available at https://library.wmo.int/index.php?lvl=notice_display&id=21857.

III. Studies related to residential emissions

10. A representative of MSC-West presented the outputs of the expert workshop[7] on condensable organics organized by MSC-West with the support of the Nordic Council of Ministers (online, 17–19 March 2020). The workshop had concluded that, in the short term, the Netherlands Organization for Applied Scientific Research REF2 emission inventory was a good first no-regret step for describing condensable emissions from residential wood combustion in emission dispersion modelling. The Netherlands Organization for Applied Scientific Research, the Centre for Integrated Assessment Modelling, the Centre on Emission Inventories and Projections, the Task Force on Emission Inventories and Projections and the Task Force on Measurements and Modelling were working towards improved estimates of emission to be used in modelling by MSC-W. A transparent methodology was presented to identify the countries where it was clear that condensables were excluded in the reporting of residential emissions and should be substituted by the REF2 inventory. That approach needed to be further communicated to Parties, documented and evaluated against national emissions and International Institute for Applied Systems Analysis emission estimates. That could, for example, entail requests for types of wood stoves, or exhaust standards on road transport. Such exchange of information had already started, for instance, with the International Institute for Applied Systems Analysis, France and Finland, but further dialogue with Parties was encouraged. In the long term, priority needed to be given to improving the information contained in the EMEP/European Environment Agency air pollutant emission inventory guidebook (the Guidebook)[8] to ensure a sustainable and robust reporting process. Suggestions for improvement would feed into the Gothenburg Protocol review process.

11. A Co-Chair of the Task Force on Measurements and Modelling presented the conclusions of the particulate matter (PM) modelling phase of the Eurodelta-Carb multi-model intercomparison organized jointly with the Copernicus Atmosphere Monitoring Service. The aim of that exercise had been to take stock of the available data from the joint EMEP/ACTRIS/Chemical On-Line cOmpoSition and Source Apportionment of fine aerosol winter 2017/18 intensive measurement period. Thirteen models had participated in the comparison and performed the simulations using different treatment of condensable. Ten models had delivered results with EMEP (Ref1) and science-based emissions (Ref2). The average particles with an aerodynamic diameter equal to or less than 10 micrometres (PM_{10}) bias in the ensemble of Ref2 in comparison to Ref1 had been reduced by 22 per cent on average in Europe, and between 1 per cent and 88 per cent depending on the country. Inclusion of condensable brought the modelling results closer to observations. The follow-up steps would have to address semi-volatile organic compounds (SVOCs)/intermediate-volatility organic compounds modelling. The benzo[a]pyrene experiments had been launched, while model evaluation focusing on black carbon modelling had been put on hold.

12. An expert from the Netherlands presented the results of source attribution of elemental carbon with the LOTOS-EUROS model compared with fossil fuel and wood burning utilizing the Eurodelta-Carb modelling results and a closer focus with equivalent black carbon source apportionment provided by the Chemical Coordinating Centre. The results demonstrated improved wood burning emission estimates if condensable were taken into consideration. For further analysis, more careful site selection must be conducted.

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7 See David Simpson and others, "How should condensables be included in PM emission inventories reported to EMEP/CLRTAP? Report of the expert workshop on condensable organics organized by MSC-W, Gothenburg 17–19 March 2020", Technical Report No. MSC-W 4/2020 (Oslo, Meteorological Synthesizing Centre-West (MSC-West)/Nordic Council of Ministers, December 2020). Available at https://emep.int/publ/reports/2020/emep_mscw_technical_report_4_2020.pdf.

8 See Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)/European Environment Agency (EEA), "EMEP/EEA air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories", EEA Report No. 13/2019 (Luxembourg: Publications Office of the European Union, 2019). Available at www.eea.europa.eu/publications/emep-eea-guidebook-2019.

13. A representative of MSC-East presented the assessment of PAH pollution in Poland, with a focus on benzo(a)pyrene. The national study for Poland included simulations of benzo(a)pyrene, benzo(b)fluoranthene, benzo[k]fluoranthene and Indeno[cd]pyrene levels in the country involving detailed national data, model assessment using previous and updated national PAH emissions inventory, experimental model simulations using scenario emissions and estimation of exceedances of European Union and World Health Organization (WHO) air quality guidelines for PAHs. The Global EMEP Multi-media Modelling System (GLEMOS) model with 0.1^{o} x 0.1^{o} resolution had been used. Higher resolution modelling with inputs from the national experts had led to a decrease of model bias from -55 per cent to -20 per cent, and an increased correlation between model and observational data from 0.4 to 0.6. The long-term trend simulation runs for B(a)P had demonstrated a lack of decrease of observed and modelled B(a)P pollution levels and presence of exceedances of air quality guidelines in some EMEP countries. It was noted that it was important to consider population exposure to a mixture of toxic PAHs (for example, 16 PAHs) as they had different individual toxicity. A multi-model study of B(a)P pollution in 2017/2018 using data of the intensive winter monitoring campaign (EuroDelta-Carb) was planned, with the presentation of results expected at the next Task Force on Measurements and Modelling meeting.

14. An expert from Switzerland presented an analysis of organic aerosol components across Europe using Aerosol Chemical Speciation Monitor (ACSM)/Aerosol Mass Spectrometer (AMS) measurements. He described a standardized protocol that had been developed to analyse long-term ACSM data using special software (SoFi Pro). The analysis results demonstrated that oxygenated organic aerosols (OOA) remained the largest contributor in Europe. Biomass burning was a considerable source in most of the stations, especially during the cold period, while biomass burning organic aerosol (BBOA), coal combustion organic aerosol (CCOA) and peat organic aerosol all showed distinct seasonal variations. Hydrocarbon-like organic aerosol (HOA) and less-oxidized oxygenated organic aerosol (LO-OOA) contributions to the aerosol load were consistent in different seasons in whole Europe. Urban sites showed larger contributions of primary sources than rural sites. With the overlap of several observational data sets from 2016 to 2017, the origin of long-range transport aerosols could be determined.

15. Another expert from Switzerland presented a highly time-resolved characterization and source apportionment of particulate elemental composition in Zurich (Switzerland). He noted that emissions that occurred inside urban agglomerations had similar chemical fingerprints and emission patterns. That made it challenging for the source apportionment models to identify and distinguish them, thus limiting utilization of novel observational techniques in support of successful mitigation measures and applications. A detailed analysis using emission ratios had been performed for Zurich. Adjustments had been made for the inlet switching system and the source apportionment approach that had improved positive matrix factorization results for Zurich. A clear advantage of that approach was that the model, additionally to the diurnal and temporal variation of the data set, also utilized the variation from the size segregated data. The methodology needed to be tested using long-term data from other areas with more frequent pollution events, which might create complications to the interpolation procedure. Combining data from different instruments was expected to improve the results. Sites with multiple aerosol instruments that operated on a continuous basis had already been established in Europe.

IV. Advances in monitoring techniques

16. A representative of the United Kingdom of Great Britain and Northern Ireland presented a review of ammonia and other trace gas measurement techniques for background and remote air pollution monitoring. She articulated the importance of ammonia in the context of human and ecosystem health, pollution and atmospheric chemistry. There had been changes in ammonia standards in the United Kingdom of Great Britain and Northern Ireland. It was projected that, under most climate scenarios, ammonia was going to increase. She presented ammonia measurements from two EMEP sites in the country. Though both were considered to be “background” sites, they had a different degree of

agricultural activities around them. Observations demonstrated that diffusive samplers represented a low cost and low maintenance measurement option. They could be quite accurate if done correctly, although the uptake rate needed to be calibrated. There was significant evidence from field comparisons that many automatic instruments on the market had the potential to measure ammonia accurately; however, standard operating procedures for such measurement needed to be established. Those procedures should apply to instrument maintenance (including inlet, cleaning protocols, baseline and span drift). The United Kingdom Centre for Ecology and Hydrology was undertaking laboratory tests with both permeation-based calibration and gas dilution-humidified gas stream calibration systems in order to begin establishing "gold standard" and "field" standard protocols.

17. Another expert from the United Kingdom of Great Britain and Northern Ireland presented a comparison of wet-only samplers at EMEP sites in the country. The objective of the study was to assess Digitel sampler performance against Eigenbrodt. The latter had been in operation since 2016 at Chilbolton station and since June 2006 at Auchencorth Moss station (both locations in the United Kingdom of Great Britain and Northern Ireland). The parallel operation with Digitel covered a couple of years. The bulk rain collectors and rain gauges collocated were compared at both sites. The study concluded that, operationally, the Eigenbrodt wet-only collector was more robust and simpler in design. Digitel had design issues – the instrument could not be used as an EMEP daily wet-only collector without instrument modifications. It also required more care and special training, and it took longer to change weekly samples. Digitel did record additional variables (environmental and operational). Regular comparison to rain gauge data to ensure wet-only operating correctly was very important. The experiment demonstrated the importance of a minimum of a 24-month measurement overlap when changing any instruments at an EMEP site. The presentation also gave the opportunity for follow-up discussions on microplastic sampling in precipitation.

V. General country updates

18. A representative of Latvia presented the plans for the modernization of GAW/EMEP station Rucava (Latvia). The station had been established in 1985 and already covered a broad spectrum of observations of regulated gas pollutants, particulate matter and precipitation chemistry. The planned updates included new online instruments for sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). Beta ray absorption method instruments would be installed for fine particulate matter ($PM_{2.5}$) and PM_{10} laboratory analysis. New instruments would be installed for mercury observations.

19. A representative of Turkey presented observational and modelling activities in the country in relation to air quality. She presented information available at the Air Emissions management portal[9] that contained information on emissions from the point sources and gridded emissions. There was an extended observational network for air pollution in the country that included 162 stations for $PM_{2.5}$ measurements, 302 for SO_2 measurements, 296 for nitrogen oxides (NO_x) measurements, 198 for ozone measurements and 186 for carbon monoxide measurements. "Airface" software was used to produce pollution maps. Future plans included increased data coverage and availability and improved uncertainty of the emission inventory. The number of provinces with city-specific geographic information system and three-dimensional outputs would be increased and the modelling would be implemented on the national scale. Further attention would be paid to engaging with the international air quality community and increased publication of the scientific papers.

20. An expert from Italy presented an update on air quality activities in the country. She presented the collaboration between the Italian National Agency for New Technologies, Energy and Sustainable Economic Development, the Italian National Institute of Health and the National System for Environmental Protection, which comprised the National Institute for Environmental Protection Research and the Regional Agencies for Environmental Protection, on the nationwide investigation (Pulvirus) into: the relationship between air

[9] See https://www.csb.gov.tr/en.

pollution and the spread of the COVID-19 pandemic; physical-chemical-biological interactions between fine particulate matter and viruses; and the effects of the lockdown on air pollution and greenhouse gases. Measurement and modelling activities were combined. The outputs of the analysis were used for the updated 2030 scenarios for the National Air Pollution Control Plan (European Union National Emission Ceilings Directive).[10] Online source apportionment was done using the National Integrated Model supporting International Negotiations on matters of air pollution (MINNI) model. The GAINS model had been updated for Italy utilizing input from 20 Italian regions. She further presented the results of the Aerotrazione con BioCarburanti project. She demonstrated that the use of biofuel doubled the emissions of organic carbon in $PM_{2.5}$.

VI. Impact of COVID-19 2020 lockdown on European air quality

21. A representative of the Chemical Coordinating Centre presented an analysis of the impact of lockdown measures on nitrogen dioxide levels throughout Europe. The analysis was based on the direct observations made at the European monitoring stations reporting to the European Environment Agency Air Quality e-reporting database. Generalized additive statistical models had also been implemented that took into consideration meteorological variables to explain the variability of the levels of the chosen pollutant. Those models demonstrated the best performance for traffic/urban/suburban sites and higher uncertainties in Southern Europe (Spain/Italy/Bulgaria). Errors in measurement data were one of the reasons in that regard and improvements had been made through screened data. The study concluded that variability of meteorology must be considered in order to analyse reductions in concentrations due to lockdown. NO_2 concentrations had been greatly reduced due to reduced traffic during lockdown everywhere in Europe, but the variations were large between countries, cities and stations. The strongest reductions had been observed in Italy, France, the United Kingdom of Great Britain and Northern Ireland and Spain (40–60 per cent in April) and the least reductions in the east (Hungary, Czechia and Poland) with less than 20 per cent change.

22. An expert from Switzerland presented an analysis of impact of lockdowns on air quality in European urban areas. Nine pairs of sites had been compared, and machine learning used for data analysis. The analysis approach had derived models to calculate counterfactuals and Bayesian change point. The results demonstrated that reductions of NO_2 by about a third were accompanied by increases in ozone. That pattern represented the general trend of what had occurred in the past couple of decades, but the lockdowns had exacerbated the trends for a few months in 2020. The near-complete replacement of NO_2 with ozone was somewhat surprising and indicated that urban European atmospheres were VOC-limited with respect to ozone generation. The analysis gave a glimpse of a likely future situation where fewer vehicles powered by internal combustion engines were in use and highlighted future issues with urban ozone management. Further analysis was required to compare responses in urban areas with those in rural locations. Similar analyses were required for individual constituents of PM concentrations, as measured at EMEP sites, which represented a challenge due to a more diverse suite of sources and processes. Many European countries had seen less severe second, or even third, lockdowns in 2020 and 2021; the pollutant responses for those periods had not yet been investigated.

[10] Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, *Official Journal of the European Union*, L 344 (2016), pp. 1–31.

VII. Analyses of long-term trends and spatial scales for the contribution to the review of the amended Gothenburg Protocol

23. A representative of MSC-West presented the results of high-resolution exposure calculations for Europe, the Western Balkans and Eastern Europe, the Caucasus and Central Asia countries using EMEP and uEMEP models. Calculations had been done for 2018 with EMEP 0.1° resolution data. The focus was on $PM_{2.5}$ concentrations. The uEMEP model had been applied at 250 m on annual mean data with downscaling. The portion of the population exposed above threshold had been estimated for each model grid of EMEP and uEMEP models. Including high resolution exposure in uEMEP in the studied regions, increased population weighted concentration between 5 and 24 per cent. The percentage of population exposed to > 15 micrograms per cubic metre ($\mu g/m^3$) $PM_{2.5}$ concentration was in the range of 13–54 per cent with the EMEP model estimate and 6–115 per cent with implementation of uEMEP. The results demonstrated significant variability in bias between the two approaches among countries in Europe. The Western Balkans had higher contributions from residential combustion. Eastern Europe, the Caucasus and Central Asia analysis demonstrated some extremely divergent and unrealistic emissions in some countries.

24. An expert from Sweden presented an analysis of the co-benefits of air quality and climate mitigation. He recalled the diverging cooling/warming climate impact of SO_2 and black carbon. The climate impacts of different pollutants were distributed geographically non-uniformly, for example, the largest impacts of black carbon were observed in the Arctic. Past climate changes in the Arctic (1990–2015) had been driven by increasing carbon dioxide (CO_2) and decreasing SO_2 emissions. Half of the temperature increase of about 2°C–2.5°C could be due to the SO_2 emission decrease. Future emission scenarios demonstrated further strong influence of short-lived climate pollutants on Arctic temperatures. Climate mitigation called for focus on reduction of black carbon and methane emissions, while air quality mitigation called for reduction of $PM_{2.5}$ concentration. Asian emissions dominated climate impact, while regional emissions affected the regional health impact. That demonstrated that air quality and climate policies had to be coordinated.

25. A representative of Spain presented 2010–2020 ozone variability and 2019–2020 measurements of VOCs, ozone precursors in Spain. The complex phenomenology of ozone pollution episodes had been known since the 1980s. Specific regions in Madrid, Valencia, Galicia and Asturias tended to have increased ozone for specific parameters and environments. Abatement of emissions due to lockdown had reduced ozone in the summer season, when traffic had been reduced by 20–25 per cent. The WHO air quality guideline for ozone was not attainable, even with best available techniques implemented. To meet the standard, national, European Union and hemisphere-wide measures would be required. Local to regional to national measures should be implemented to abate emissions in four major basins where acute pollution of ozone was recorded. Such measures should be especially implemented from May to July. The situation in Spain was reported to be more complex than that in Eastern or Central Europe.

26. An expert from Sweden presented the historical evolution and future scenarios of atmospheric nitrogen deposition to Northern Europe using measurement model fusion with a focus on the Baltic Sea and Sweden. Current nitrogen deposition to the Baltic Sea and Sweden was at the level of the 1960s, below the highest levels reached in 1970–1990 to Sweden and to the Baltic Sea. That was supported by both pure modelling and measurement-model-fusion of atmospheric deposition results. A continued decrease in oxidized nitrogen deposition was projected, but levels were still expected to exceed the pre-industrial level in 2050. The estimates (trends/levels) compared well with observed (reanalysed) deposition. Increased deposition of reduced nitrogen was projected from the current time to mid-century in parts of Europe, including Sweden and the Baltic Sea, with stronger signal compared to previous estimates using the current legislation emissions projection. There was a need for continued efforts to further decrease nitrogen emissions to the atmosphere for protection of the terrestrial and aquatic environment, not least because

ecosystems were under additional pressure from climate change and more intensive management.

27. Another representative of Spain presented changes in NO_x, ozone, PM_{10} and SO_2. When comparing 2000–2002 to 2016–2018, the following changes in concentration percentiles were observed: for SO_2 and PM_{10} significant reductions of air concentrations had been observed, more pronounced for the highest values. The air concentration of SO_2 decreased less than the emissions, suggesting changes in SO_2 oxidation. An observed higher decrease of air concentrations compared with the emission reduction for PM_{10} might imply that secondary PM_{10} was also reduced. Significant reductions of NO_2 air concentration were shown, more pronounced for the lowest values. NO_x concentration decreases were similar to emission reduction. Ozone concentrations increased, except for the highest values (99 percentile). That trend was more pronounced in urban traffic sites (NO-titration effect). There were slight decreases at rural background sites. A specific study investigating the sensitivity of ozone-modelled response to the chemical mechanism was also presented.

28. An expert from Norway presented relative changes in sulfur oxides, nitrogen oxides and ammonia emissions for 2005–2030 and their effects on secondary inorganic aerosols and nitrogen deposition. Emissions of particulate matter with a diameter of 2.5 or less ($PM_{2.5}$), precursors sulfur oxides (SO_x) and nitrogen oxides (NO_x) were decreasing but at the same time Europe was struggling to meet even the modest reduction targets for ammonia. The ratio of ammonia to sulfate and nitric acid in the European atmosphere had increased in past decades, and with the projected emission trends that ratio would continue to increase. As an annual average, it had been found that the efficiency of mitigating $PM_{2.5}$ concentrations by reducing ammonia emissions by 10 per cent would be reduced by a factor of 2.6, from 0.61 to 0.22 nanograms per cubic metre per gigaton of ammonia emitted between 2005 and 2030. However, ammonia emissions from agriculture differed by season, with a minimum in winter. As a result, the ratio of ammonia to sulfate and nitric acid was much higher in winter, and a much larger portion of the ammonia would form ammonium particles. Emissions of ammonia on the one hand, and SO_x and NO_x on the other hand, differed in space and time. Even if there was a large surplus of ammonia over SO_x and NO_x on a European scale, that might not always be the case locally, in particular in urban areas with little agricultural activity nearby. Advection of ammonia-rich air into urban areas might cause $PM_{2.5}$ episodes. He also explained that deposition of nitrogen was decreasing in Europe. That decrease was mainly a result of reductions in NO_x emission. As a result, the fraction of reduced nitrogen in the total nitrogen deposition was increasing and might reach 70 per cent in large parts of Europe by 2030. Exceedances for critical loads of nitrogen deposition were also projected in large parts of Europe in 2030, and reductions in ammonia emissions were needed in order to minimize damage to ecosystems.

29. Another expert from Norway presented trends, composition and sources of carbonaceous aerosol at the unique record of Birkenes Observatory (Norway) in northern Europe from 2001 to 2018. Carbonaceous aerosol at Birkenes was among the lowest in Europe. Elemental carbon had a peak in summer and decreased by 4 per cent per year. It was most pronounced in the non-heating season and mainly related to fossil sources. The majority of organic carbon was associated with the fine fraction of particulate matter. The coarse fraction was mostly responsible for the seasonality. No reduction in organic carbon had been observed, natural sources prevailed. Levoglucosan had been analysed to identify the signal of residential wood burning. It was the longest time series in Europe and continuous since 2008. Levoglucosan increased during the heating season, a peak during a particularly cold winter (due to negative North Atlantic Oscillation index) was visible. Levoglucosan decreased by 2.8 per cent per year. Biogenic secondary organic aerosol was found to be 25 per cent from local sources and 75 per cent due to long-range transport. Comprehensive speciation was required to understand carbonaceous aerosol sources and their seasonal, annual and long-term trends.

30. Another expert from Spain presented 2009–2018 trends of particulate matter with a diameter of 2.5 or less ($PM_{2.5}$) related to secondary organic aerosol in north-east Spain as inferred from receptor source apportionment analysis. PM levels in north-east Spain had decreased by 50 per cent since 2005 but had been quite constant since 2010. In north-east

Spain, both ammonia and ozone levels were high; the region could be considered a hotspot. $PM_{2.5}$ was more toxic than previously. That could be related to more secondary organic aerosol, which had a dramatically increased formation rate. That represented a policy challenge, as the origin of secondary organic aerosol was extremely complex.

VIII. Planning of activities within the workplan for 2020–2021

31. Three breakout sessions were organized to discuss future priorities for the next workplan. The focus of the sessions was on ozone, organic aerosols and POPs/heavy metals/chemicals of emerging concern/microplastics. The sessions concluded that there was a need to better understand/predict ozone episodes to ensure support to environmental policy. The current observational network for ozone observations and its precursors did not cover the range of conditions needed for comprehensive understanding of ozone behaviour. The lack of VOC measurements and their speciation was indicated as one of the major limiting factors, in particular in the context of emission verification and modelling ozone chemistry. It was proposed that additional passive sampling for VOC be considered to address the issue. The meeting participants concluded that biogenic VOCs were at least as important for ozone production in Europe as anthropogenic VOCs, but that they were not well characterized and constrained in the models. The contribution of volatile chemical products, in particular in relation to domestic emissions, was an emerging concern for the assessment of overall VOC emissions, in particular highly reactive species. Natural emissions of NO_x from the soils and vegetations were also considered to be poorly documented. The connection between spatial scales needed to be further evaluated, with further possible improvements through linkage with the Task Force on Hemispheric Transport of Air Pollutants (in particular in relation to methane) but also at the local scale. Linking temporal scale would also bring relevant open questions, for instance in relation to the climate penalty bearing upon ozone pollution. It was also noted that ozone and PM policies should be connected as, in many cases, they addressed the same precursor gases, including VOCs, which also contributed to the formation of secondary organic aerosols. The issues of the scale and precursors were raised at the organic aerosol discussions as well. The sophistication of aerosol characterization had increased greatly over the past decade and could be further used to prioritize mitigation measures. With the decrease of anthropogenic sources, natural contributions were becoming more important in relative terms, and those sources were difficult to constrain in the models. It was proposed to combine efforts, for instance through an EMEP Intensive Measurement Period (during the next summer), with the planned large experiment in Paris to improve understanding of the chemical and physical processes that led to ozone and organic aerosol formation. In the area of new contaminants, a workshop was planned for 2022, with a preparatory survey to collect information about compounds and their measurement methods. That workshop would be used to establish connections between measurement and modelling communities and jointly with the Task Force on Hemispheric Transport of Air Pollutants to identify the most important chemicals that were subject to long-range transport. For microplastics, a lot of preparatory work was still required, although some case studies could be initiated based on the data from national surveys with the timeline beyond 2023. A benzo[a]pyrene multi-model exercise was expected as a contribution to the EuroDelta-Carb comparison. Processes that controlled mercury concentration (resuspension, chemistry) needed to be better assessed through the measurement-model case studies. An intensive measurement of gas-aerosol partitioning of PAHs in particular (although other POPs might be included) for those sites with ongoing high-volume observations was proposed. It was stressed that collaboration with the health impact community could be substantially increased in the area of heavy metals and PAH, with some links to the new developments in the monitoring and modelling of the oxidative potential of particulate matter.