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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

Fourth joint session
Geneva, 10-14 September 2018
Item 4 of the provisional agenda
Progress in activities in 2018 and further development of effects-oriented activities

2018 joint progress report on policy-relevant scientific findings*

Note prepared by the Chairs of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe and the Working Group on Effects, in cooperation with the secretariat

Summary

The present report was drafted by the Extended Bureau of the Working Group on Effects[1] and the Extended Bureau of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)[2] in cooperation with the secretariat to the Convention on

* The present document is being issued without formal editing.

[1] Comprising the Bureau of the Working Group; the Chairs of the international cooperative programme task forces, the Joint Task Force on the Health Effects of Air Pollution and the Joint Expert Group on Dynamic Modelling; and representatives of the programme centres of the international cooperative programmes.

[2] Comprising the Bureau of the Steering Body, the Chairs of the EMEP task forces and representatives

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Long-range Transboundary Air Pollution. The review of recent scientific findings is based on the information provided by the lead countries and the programme centres of the international cooperative programmes, and is submitted in accordance with the 2018-2019 workplan for the implementation of the Convention (ECE/EB.AIR/140/Add.1).

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of EMEP centres.

I. Introduction

1. The present report was compiled by the Chairs of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) and the Working Group on Effects in accordance with the 2018-2019 workplan for the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/140/Add.1). The report reflects achievements during 2017 and 2018 and was prepared with support from the scientific subsidiary bodies. The report is the third common report of the work under EMEP and the Working Group on Effects, reflecting the new organization of the two bodies with joint, integrated sessions based on a common agenda. These joint reports represent a further integration of the scientific work under the Convention and should be seen as a strengthening of the scientific basis for the Convention's policy development.

Critical loads for acidification, eutrophication and biodiversity

2. The workplan for 2015-2017 of the Coordination Centre for Effects (CCE) under the International Cooperative Programme on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping) focused on the call for critical loads on acidification, eutrophication and biodiversity. This call enabled Parties to update their data in the European critical loads database, which can be used to support European air pollution abatement policies. New in this call was the agreed manner for compiling the critical loads for eutrophication, i.e., as the minimum of the empirical and nutrient-nitrogen critical load. The novel aspect of this call was the requirement to compute critical loads of biodiversity.

3. Fourteen Parties to the Convention, all European Union member States, submitted updated critical loads for acidification and eutrophication, while seven Parties embarked on the compilation and submission of critical loads of biodiversity. National focal centres provided most of the data for "Woodlands and Forests" (European Nature Information System class G) followed by "Grasslands, Forbs, Mosses and Lichens" (European Nature Information System class E). Using submitted critical loads and the European background database, a tentative analysis was conducted of exceedances in 2005 for the baseline emission scenario compiled to support the European Union Thematic Strategy on Air Pollution and deposition patterns of sulphur and nitrogen computed by EMEP. Results reveal that critical loads for acidification, eutrophication and biodiversity are exceeded in 11 per cent, 68 per cent and 27 per cent, respectively, of the ecosystem area within the EMEP domain. For the 28 European Union member States the percentages of the ecosystem area at risk are 13 per cent, 81 per cent and 28 per cent, respectively.

4. At the thirty-third meeting of the ICP Modelling and Mapping Task Force (Wallingford, United Kingdom of Great Britain and Northern Ireland, 4-6 April 2017), representatives of national focal centres emphasized that further work on biodiversity critical loads, in particular, was required. While the Task Force recommended that CCE and the Centre for Integrated Assessment Modelling should proceed with the implementation of the updated critical loads for acidification and eutrophication in the Greenhouse Gas Air Pollution Interactions and Synergies (GAINS) model for integrated assessment applications, it was noted that the use of critical loads of biodiversity should, for the time being, be restricted to scientific applications only.

II. Air pollution effects on health

5. The Task Force on Health Aspects of Air Pollution is a joint body of the Executive Body and the World Health Organization (WHO), led by the WHO European Centre for Environment and Health (Bonn, Germany), responsible for evaluating and assessing the health effects of long-range transboundary air pollution and providing necessary information in the field.

6. In 2018, WHO updated its air quality database and estimates of the disease burden attributable to air pollution, using the data for 2016. In the WHO European Region alone, 509,000 premature deaths were attributable to ambient air pollution; 304,000 of these deaths occurred in low-and middle-income (LMI) countries and 205,000 deaths occurred in high-income (HI) countries. The burden of disease attributable to air pollution is not evenly distributed across the Region: 84 premature deaths per 100 000 population occur in LMI countries, while 42 premature deaths per 100 000 population occur in HI countries. However, both in HI countries and LMI countries, the particulate matter fractions with a diameter less than 10 and 2.5 micrometres (PM_{10} and $PM_{2.5}$, respectively) annual means increased in more than 10 per cent of cities.

7. The health impacts of air pollution in the WHO European Region continue to be high on the regional policy agenda. At the Sixth Ministerial Conference on Environment and Health, which was held in Ostrava, Czechia on 13-15 June 2017, improvement of indoor and outdoor air quality was one of the seven priority areas for action. The Ostrava Declaration on Environment and Health adopted at the Conference, includes a compendium of possible actions to enable Member States of the WHO European Region to meet the WHO air quality guidelines and other existing commitments.

8. Initiated in 2016, the process of the update of WHO global air quality guidelines continues. It aims to provide updated numerical concentration values and, where possible, an indication of the shape of the concentration-response function, for a number of ambient air pollutants, for relevant averaging times and in relation to critical health outcomes. The air pollutants included are: $PM_{2.5}$, PM_{10}; nitrogen dioxide, ozone, sulphur dioxide and carbon monoxide. By the end of 2017, the WHO Steering Group, the Guideline Development Group (GDG), the Systematic Review Team (SRT) and the External Review Group (ERG) were established. Commissioned in 2017, five systematic reviews of evidence on health effects from air pollution are ongoing, focusing on:

(a) Long-term exposure to PM, O_3 and NO_2 and all-cause and cause-specific mortality;

(b) Short-term exposure to O_3, NO_2 and SO_2 and emergency department and hospital admissions due to asthma;

(c) Short-term exposure to PM, NO_2 and O_3 and all-cause and cause-specific mortality;

(d) Short-term exposure to CO and emergency department and hospital admissions due to ischaemic heart disease.

9. Moreover, intense work continues to adapt the methods for systematic review and guideline development to the field of air quality and health. The second meeting of the GDG and SRT, which took place in March 2018, provided an opportunity to assess the progress of the systematic reviews and to discuss outstanding methodological issues, as well as the draft table of contents of the guidelines. After the completion of the systematic reviews of evidence (expected in early 2019), the second phase of the update of WHO

global air quality guideline process will follow, to derive numerical guideline exposure levels, set interim targets and formulate recommendations.

10. Following the launch in 2016, a WHO software tool (AirQ+) that quantifies the health impacts of exposure to air pollution, including estimates of the reduction in life expectancy received much interest, with more than 14 thousand visits to the WHO webpage. In May 2018, at the annual meeting of the Joint Task Force on the Health Aspects of Air Pollution, WHO launched an updated version of AirQ+, translated also into the Russian language. Training workshops have been carried out through webinars, for example one for the European Region in June 2018 and one in May for the Italian Environmental Epidemiology Network. A capacity building training, in collaboration with United Nations Environment Programme, is planned for West Balkans countries later in 2018. WHO is currently working on including new functionalities to the AirQ+ tool, which will also be translated in French.

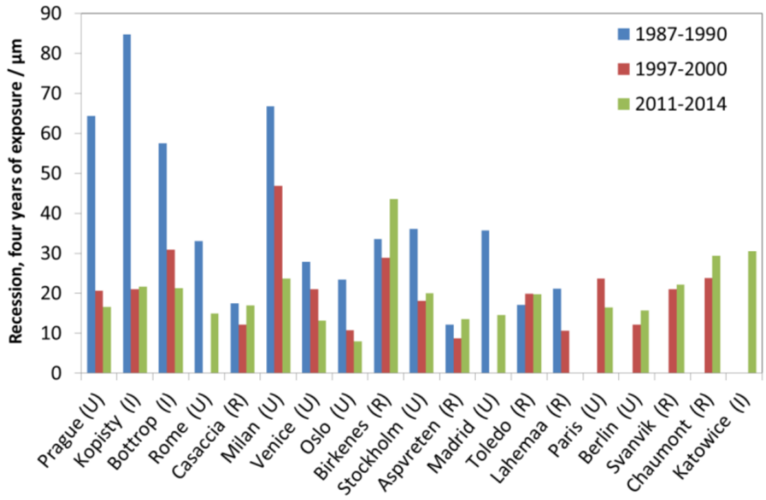
III. Air pollution effects on materials

11. The International Cooperative Programme on Effects of Air Pollution on Materials, including Historic and Cultural Monuments (ICP Materials) conduct repeated exposures for trend analysis each third year and the latest exposure concluded in 2015. All data on environment, corrosion and soiling produced so far is given in the corresponding ICP Materials reports, which are available as PDFs for download at the home page of ICP Materials[3]. The last open access publication includes results from the recently concluded exposure for trend analysis and also includes all data used in the publication as supplementary data (excel format).[4]

12. New, compared to previous reports on trends, is that trends in long term exposures (4 years) are available for several materials. As shown by one year data, corrosion and pollution have decreased significantly and a shift in the magnitude is generally observed around 1997: from a sharp decrease to a more modest decrease or to a constant level without any decrease. The four year data confirm this but allows for more accurate estimation of trends.

[3] URL: http://www.corr-institute.se/icp-materials/.
[4] Tidblad et al (2017), ICP Materials Trends in Corrosion, Soiling and Air Pollution (1987–2014), Materials 2017, 10(8), 969. URL: https://doi.org/10.3390/ma10080969.

Figure I.
Limestone surface recession: four-year exposures at individual sites for three exposure periods, 1987-1990, 1997-2000 and 2011-2014



IV. Air pollution effects on terrestrial ecosystems

A. Forests: Air pollution still a threat for sensitive elements

13. The International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) is contacting long-term monitoring on forest ecosystems focusing at air pollution impacts and other anthropogenic and natural diving factors. Within a total of 13 surveys relevant parameters describing conditions and dynamics of forest ecosystems or its compartments are assessed and evaluated. Due to co-operations within and beyond the convention at national or international levels the research and monitoring infrastructure of ICP Forests as well as monitoring data are used as a basis of or contribution to more advanced studies. One long-lasting co-operation combining both data on of mycorrhizal fungi gained by advanced DNA sequencing techniques on one side and long-term monitoring data of ICP Forests on the other side has now led to a Nature publication showing that there is a distinct influence of nitrogen deposition on the composition of those fungi. Already a throughfall deposition rate of 5.8 kilogram of nitrogen per hectare per year (kg N ha^{-1} a^{-1}) a series of sensitive species leads to a distinct statistical response. Besides N deposition, soil pH, mean air temperature, potassium (P) deposition and foliar N:P ratio are the most influential drivers. The results call with respect for nitrogen deposition for a downward adaptation of empirical critical loads for forests since mycorrhizal fungi play a major role in the nutrition and the water household of forests trees.

14. Nitrogen saturation of forest ecosystems might provoke undesired effects not only for forests and forestry itself, but for societal beneficiaries like the provision of drinking waters from forested areas as well. Therefore, indicators for the nitrogen saturation status of forests are of high political relevance. Decreasing deposition rates for inorganic nitrogen (and sulphur) over the last decades in large parts of Europe probably followed by enhanced leaching of dissolved organic carbon and nitrogen (DOC, DON) may affect total dissolved

nitrogen (TDN) levels. With datasets from soil solution and foliage of ICP Forests Level II plots in areas with formerly high N deposition in the northern part of Belgium the hypothesis was tested, whether these processes are responding to reduced N deposition. Since the molar DON:TDN ratio in the soil solution from the organic and in the mineral horizons of all five monitored plots increased between 2005 and 2014 as well as the molar DOC:nitrate ion(NO3-) ratio between 2002 and 2014 in organic and mineral soil horizons of three respectively four plots, generally a reduction of reactive N in soil solution can be supposed. Over the same time period the N:P ratio and the ratio of base cations:N in foliage remained stable. While the results from the soil solution confirmed an improvement of the nitrogen status of these forests, the biotic response seems to lag behind. These results underline the necessity for continued intensive monitoring of forest ecosystems as single parameters or ratios seem not to reflect sufficiently the tendency of forest ecosystems to recover from high N deposition loads in the past.

15. Heavy metal deposition has been a concern for environmental policy as those elements can accumulate in ecosystem compartments, become a thread for sensitive organisms, and accumulate in food webs. Due to its oil shale industries Estonian forest ecosystems have been exposed to considerable amounts of chromium, nickel, lead and zinc especially during the 1980s. Even the emission has ssbeen strongly reduced during the last two decades, storage and probably mobilisation within ecosystems have to be monitored. cadmium (Cd), copper (Cu), chromium (Cr), nickel (Ni), lead (Pb) and zinc (Zn) were studied in living needles, litterfall, fine roots and forest soil organic horizon (partly also in mycelia) in Scots pine and Norway spruce stands at Estonian ICP Forests and the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP Integrated Monitoring) sites. High element- and compartment-specific concentrations were found. Highest concentrations of Cd, Pb, Cr (the contaminant heavy metals) and Ni were found in soil organic horizons, while highest Zn and Cu concentrations (biogenic heavy metals) occurred in fine roots. Soil type seems to modify distribution of heavy metals as well as translocation pattern within trees, while distinct geographic patterns could not be corroborated. The purely documented role of mycorrhiza seems especially important for Ni, Cr, Cu and Zn, as their concentrations in mycorrhizas are several times higher than in other compartments including fine roots.

B. Forested catchments

16. Long-term trends (1990-2015) for bulk deposition, throughfall and runoff water chemistry and fluxes, and climatic variables were evaluated in 25 forested catchments in Europe belonging to ICP Integrated Monitoring (Vuorenmaa et al. 2018[5]). Most of the sites are also part of the LTER-Europe network. Trends were evaluated for monthly

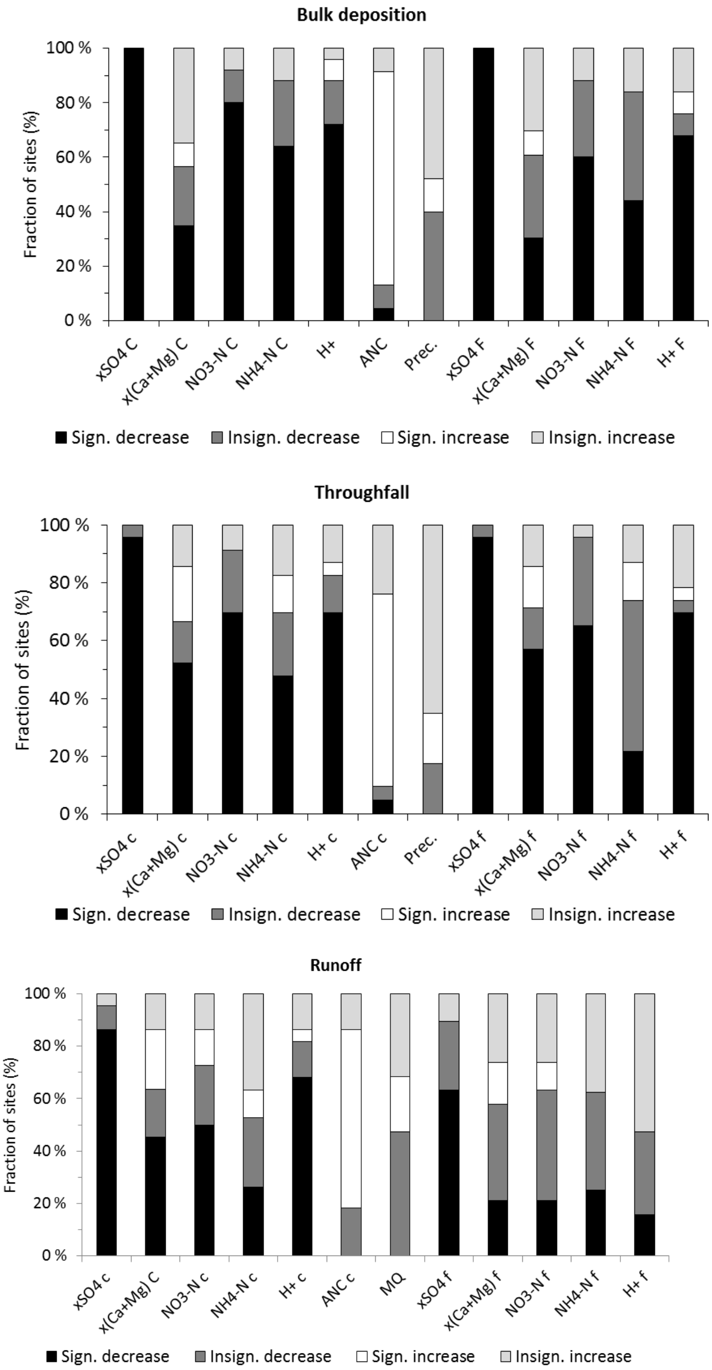
[5] Vuorenmaa, J., Augustaitis, A., Beudert, B., Bochenek, W., Clarke, N., de Wit, H., Dirnböck, T., Frey, J., Hakola, H.., Indriksone, I., Kleemola, S., Kobler, J., Krám, P., Lindroos, A.-J., Lundin, L., Löfgren, S., Marchetto, A., Pecka, T., Schulte-Bisping, H., Skotak, K., Srybny, A., Szpikowski, J., Ukonmaanaho, L., Váˇna, M., Åkerblom, S. and Forsius, M. (2018). Long-term changes (1990–2015) in the atmospheric deposition and runoff water chemistry of sulphate, inorganic nitrogen and acidity for forested catchments in Europe in relation to changes in emissions and hydrometeorological conditions. *Science of the Total Environment* 625: 1129–1145. DOI: https://doi.org/10.1016/j.scitotenv.2017.12.245.

concentrations of non-marine (anthropogenic fraction, denoted as x) sulphate (xSO4) and base cations x(Ca+Mg), hydrogen ion (H+), inorganic N (NO3 and NH4) and ANC (Acid Neutralising Capacity) and their respective fluxes into and out of the catchments and for monthly precipitation, runoff and air temperature. A significant decrease of xSO4 deposition resulted in decreases in concentrations and fluxes of xSO4 in runoff, being significant at 90 per cent and 60 per cent of the sites, respectively. Bulk deposition of nitrate (NO3) and ammonium (NH4) decreased significantly at 60-80 per cent (concentrations) and 40-60 per cent (fluxes) of the sites. Concentrations and fluxes of NO3 in runoff decreased at 73 per cent and 63 per cent of the sites, respectively, and NO3 concentrations decreased significantly at 50 per cent of the sites (Figure II).

17. It can thus be concluded that concentrations and deposition fluxes of xSO4, and consequently acidity in precipitation, have substantially decreased in ICP Integrated Monitoring areas. Total inorganic nitrogen (TIN) deposition has decreased in most of the ICP Integrated Monitoring areas, but to a lesser extent than that of xSO4. Substantially decreased xSO4 deposition has resulted in decreased concentrations and output fluxes of xSO4 in runoff, and decreasing trends of TIN concentrations in runoff – particularly for NO3 – are more prominent than increasing trends. In addition, decreasing trends appeared to strengthen over the course of emission reductions during the last 25 years. TIN concentrations in runoff were mainly decreasing, while trends in output fluxes were more variable, but trend slopes were decreasing rather than increasing. The ICP Integrated Monitoring network covers important deposition gradients in Europe, and these results confirm that emission abatement actions are having their intended effects on precipitation and runoff water chemistry in the course of successful emission reductions in different regions in Europe, even though decreasing trends for S and N emissions and deposition reduction responses in runoff water chemistry tended to be more gradual since the early 2000s.

Figure II.

Percentage of ICP Integrated Monitoring sites where significant trends were detected for bulk/wet deposition (top), throughfall deposition (middle) chemistry concentrations (c) and fluxes (f) and runoff water (bottom) chemistry concentrations (c) and fluxes (f) in 1990-2015 (from Vuorenmaa et al. 2018). Legend: significant decreasing (black), insignificant decreasing (dark grey), significant increasing (white) and insignificant increasing (light grey)



18. The effects of climatic drivers on trends of SO4 losses in catchment soils, together with internal SO4 sources, are anticipated to become increasingly important as atmospheric SO4 deposition has declined. The combined effect of climate variability/change and N deposition is also a potential concern, as many of the retention and release processes of TIN are sensitive to changes in climatic variables.

V. Air pollution effects on aquatic ecosystems

19. Monitoring data from water bodies in acid-sensitive regions, presented in the 2018 Regional Assessment Report, indicate that a significant proportion of acid-sensitive water bodies remains acidified (i.e., has an ANC below the critical limit) in North America and in European countries, despite considerable reductions in sulphur deposition. However, there is considerable variation between countries. In some countries where no water chemical monitoring data were available, a potential risk of acidified surface waters was indicated but could not be substantiated because of the lack of monitoring data and/or relevant literature.

20. National reports of acidification and chemical recovery from the Task Force meeting presented national data on acidification status and recovery. In Poland, some areas, monitoring of acid-sensitive water bodies is ongoing but the national monitoring system is not representative with regard to acid-sensitive surface waters. In Sweden, an extensive monitoring dataset was presented that documented reduced sulphate concentrations and increases in acid neutralizing capacity (ANC). Climate is presently a strong control of water chemistry in Sweden, in addition to deposition. In the Italian Alps, evidence of chemical recovery was shown from a recent survey, and ANC is now close to, or over the critical limit. Nitrate is now the main acidifier rather than sulphate in these sites, and climate variability is an important control of surface water acidification status. The lakes remain vulnerable to acidification. In Western Siberia in the Russian Federation, oil and gas extraction lead to emissions of sulphur, chloride and nitrogen to the atmosphere, and low pH in precipitation. However, only part of the area is acid-sensitive. In Eastern Russian Federation there are also some large emissions of acidifying components to the atmosphere. In both regions, there are areas where critical loads for acidification are exceeded. In the United Kingdom, long-term monitoring data show strong decreases in sulphate concentrations in acid-sensitive lakes and streams. Even in recent years, the decline continues. Increases in DOC can be explained by changes in ionic-strength which are a consequence of changes in atmospheric chemistry.

21. Thus, in some countries current monitoring programs are supplying sufficient information for a reliable assessment of temporal changes in acidification, while other countries appear to lack suitable monitoring programs for surface water acidification status. Spatially extensive water chemistry datasets for the regional assessment of acidification are scarce. Monitoring and reporting under the European Union Water Framework Directive is currently not a reliable source of information on air pollution effects on surface waters.

22. In Western Siberia in the Russian Federation, oil and gas extraction lead to emissions of sulphur, chloride and nitrogen to the atmosphere, and low pH in precipitation. However, only part of the region is acid-sensitive. In the European part of the Russian Federation, there are also some large emissions of acidifying components to the atmosphere. In both regions, there are areas where critical loads for acidification are exceeded and there is evidence of acidified lakes. In addition, there is evidence of enhanced concentrations of nickel and copper in lakes located in close proximity to smelters on the Kola Peninsula.

Mercury

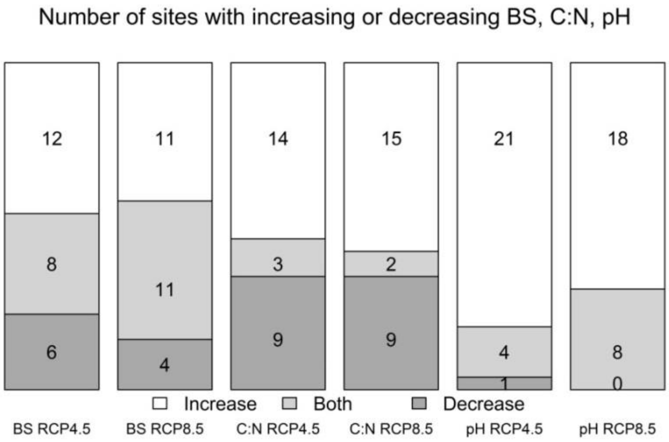
23. The fish mercury (Hg) database is a valuable source of information for continued monitoring of impacts of Hg in the environment. In particular, lakes that are primarily impacted by atmospheric sources of Hg will be relevant for documentation of effects of reduced air pollution on fish Hg. The entire database has a large potential for evaluation of effectiveness of past and future policy to reduce Hg in the environment, including the global Minamata Convention on Mercury (entered into force in August 2017). Results from the report were contributed to Chapter 7 (Mercury concentrations in biota) of the Global Mercury Assessment Draft Report, which was presented at the first Conference of the Parties of the Minamata Convention on Mercury (September 2017). A general recommendation for monitoring of mercury in freshwater fish was to include repeated sampling of the same water body over time.

VI. Critical loads and levels

A. Critical Loads: Dynamic modelling

24. Up to date, European databases and maps of critical loads have been instrumental in the negotiations of effect-based protocols to the Convention. However, the critical load concept is based on steady-state concepts and therefore dynamic models are needed to assess time-scales of impacts and recovery from changes in air pollutant emissions. The interactions with changes in climate variables are also of key importance. Current climate warming is expected to continue in coming decades, whereas high N deposition may stabilize, in contrast to the clear decrease in sulphur (S) deposition. These pressures have distinctive regional patterns and their resulting impact on soil conditions is modified by local site characteristics. A chain of models with VSD+ soil dynamic model in the centre was applied to a combined dataset from ICP Integrated Monitoring, ICP Forests and LTER-Europe sites (Holmberg et al. 2018). The sites are mainly forested, located in the Mediterranean, forested alpine, Atlantic, continental and boreal regions, and provide high quality long-term data on ecosystem response. The single-layer soil model VSD+ accounts for processes of organic carbon (C) and N turnover, as well as charge and mass balances of elements, cation exchange and base cation weathering. VSD+ was calibrated at 26 ecosystem study sites throughout Europe using observed conditions, and simulated key soil properties: soil solution pH (pH), soil base saturation (BS) and soil organic carbon and nitrogen ratio (C:N) under projected N and S deposition and climate change until 2100 (Figure III). Simulated future soil conditions improved under projected decrease in deposition and current climate conditions: higher pH, BS and C:N at 21, 16 and 12 of the 26 sites, respectively. When climate change projections were included pH increased in most cases, while BS and C:N increased in about half of the cases. Hardly any climate warming scenarios led to decrease in pH. Decreasing BS and C:N however, was found in roughly one third of the cases. The study illustrates the value of long-term monitoring sites for applying models that can predict soil, vegetation and species responses to multiple environmental changes. The study will be continued by extending the VSD+ applications to include vegetation impacts using the PROPS model, to study deposition and climate change impacts on biodiversity metrics. This will allow impact assessments at the relevant spatial scales also in support of related policy processes in this field, such as the European Union policies on air pollution, nature and biodiversity.

Figure III.
Simulated change in soil variables from the year 2000 to 2100 at 26 ecosystem study sites throughout Europe. Number of sites with only increase (top), both increase and decrease (middle) or only decrease (bottom) in soil base saturation (BS), soil organic carbon and nitrogen ratio (C:N) or pH. Simulations performed with deposition scenario CLE (current legislation) and twelve climate scenarios: RCP4.5 (largely corresponding to Paris climate change agreement) and RCP8.5 (business-as-usual). The VSD+ model chain was used for the simulations (from Holmberg et al. 2018[6]).



B. Critical Levels: Effects of ozone on vegetation

25. The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) produced the first global flux-based risk map of ozone impacts on crops, reviewed field-based evidence of ozone impacts on crops in developing regions, contributed to the Tropospheric Ozone Assessment Report (TOAR) and monitored air pollutant concentrations in mosses in 2015/16. A global flux-based modelling assessment (in collaboration with EMEP Meteorological Synthesizing Centre-West), shows that ozone (mean of 2010 - 2012) reduced global yield annually by 12.4 per cent, 7.1 per cent, 4.4 per cent and 6.1 per cent for soybean, wheat, rice and maize, respectively, adding up to 227 Tg (million metric tonnes) of lost yield.[7] The highest ozone-induced production losses for soybean are in North and South America whilst for wheat they are in China and India, for rice in parts of Bangladesh, China, India and Indonesia, and for maize in China and the United States of America. Crucially, the same areas are

[6] Holmberg, M., Aherne, J., Austnes, K., Beloica, J., De Marco, A., Dirnböck, T., Fornasier, M.F., Goergen, K., Futter, M., Lindroos, A.-J., Krám, P., Neirynck, J., Nieminen, T.M., Pecka, T., Posch, M., Pröll, G., Rowe, E.C., Scheuschner, T., Schlutow, A., Valinia, S. and Forsius, M. (2018). Modelling study of soil C, N and pH response to air pollution and climate warming using European LTER site observations. (in review, *Science of the Total Environment*).

[7] Mills et al. (2018). Closing the global ozone yield gap: Quantification and co-benefits for multi-stress tolerance. Global Change Biology (under review).

often also at risk of high losses from pests and diseases, heat stress and to a lesser extent aridity and nutrient stress. Tolerance to multiple stresses, including ozone, should be included in crop breeding programmes addressing the yield gap for crops. For wheat, ozone impacts on yield are particularly large in humid rain-fed and irrigated areas of major wheat-producing countries.[8] Ozone could reduce the potential yield benefits of increasing irrigation usage in response to climate change because added irrigation increases the uptake and subsequent negative effects ozone.

26. A literature review shows that there is a lack of investigating and reporting field-based evidence of ozone impacts on crops in countries receiving Official Development Assistance (ODA).[9] Data is especially lacking for South Eastern and Eastern Europe, Caucasus and Central Asia, Africa and Central and South America. In the last 15 years, considerable evidence of ozone impacts on crops has emerged from a limited number of locations in China, India and to some extent Pakistan. The reduction of crop yield losses due to ozone in these countries is often in the range of 5 - 20 per cent. Similar losses were reported for a modelling study conducted for the years 2010-2012 (see para. 22). The mean modelled percentage yield losses for four major regions (South Eastern and Eastern Europe, Caucasus and Central Asia; South and Eastern Asia; Central and South America; Africa) ranged from 3.3-5.3 per cent, 4.5-7.6 per cent, 5.3-10.0 per cent and 7.4-15.3 per cent for rice, maize, wheat and soybean respectively.

27. TOAR on the current state of knowledge of ozone metrics of relevance to vegetation (*TOAR-Vegetation*)[10] reports on present-day global distribution of ozone at over 3300 vegetated sites and the long-term trends at nearly 1200 sites for the vegetation-relevant metrics. Although the density of measurement stations is highly variable across regions, in general, the highest ozone metric values (mean, 2010-14) are in mid-latitudes of the northern hemisphere, including southern Unites States, the Mediterranean basin, northern India, north, north-west and east China, the Republic of Korea and Japan. The lowest metric values reported are in Australia, New Zealand, southern parts of South America and some northern parts of Europe, Canada and the United States. In North America, the dominant trend during 1995-2014 was a significant decrease in ozone, whilst in Europe it was no change and in East Asia it was a significant increase. TOAR-Vegetation provides recommendations to facilitate a more complete global assessment of ozone impacts on vegetation in the future, including an increase in monitoring of ozone, an increased coordinated effort to collate field evidence of the damaging effects on vegetation and an innovative integration of observations and modelling including ozone flux.

28. Data on concentrations of heavy metals in mosses have been submitted to the ICP Vegetation in 2015 and 2016 from ca. 5,000 sites in 34 countries, including eight countries in South-Eastern Europe and nine countries in the Eastern Europe, the Caucasus, Central Asia region (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Republic of Moldova, Russian Federation, Tajikistan and Ukraine). Ten countries reported on nitrogen concentrations in mosses and six countries submitted data from selected sites for selected persistent organic pollutants (POPs). Data confirm previously observed spatial patterns for

[8] Mills et al. (2018). Ozone pollution will compromise efforts to increase global wheat production. Global Change Biology 2018: 1-15.
[9] Harmens et al. (2018). Evidence of ozone effects on crops in ODA countries: field data and modelling. Report ICP Vegetation to Defra (contract AQ0846).
[10] Mills et al. (2018). Tropospheric Ozone Assessment Report: Present-day tropospheric ozone distribution and trends relevant to vegetation. Elementa - Science of the Anthropocene (in press).

many metals and nitrogen, i.e. there is an east-west gradient with concentrations being higher in (South) Eastern than Western Europe. The lowest concentrations are generally found in Northern Europe. Although the metal and nitrogen concentrations in mosses have continued to decline for metals and nitrogen in some countries, many countries have reported no change or even a slight rise in concentrations since 2010/2011.

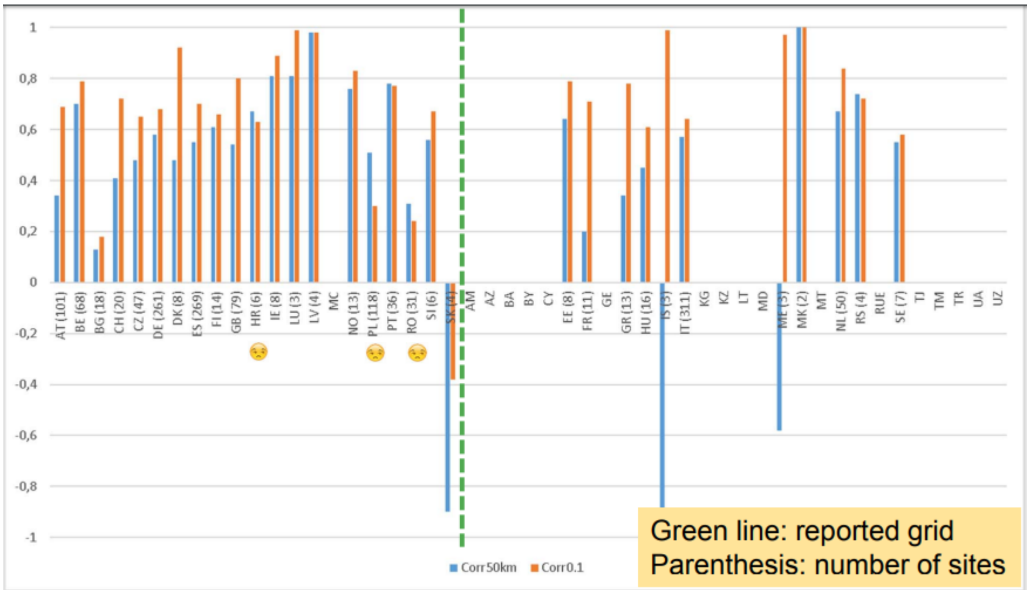
VII. Emissions

A. Improving emission inventories

29. Beyond regular activities dedicated to the management of annual emission data reported each year by the Parties, high resolved (10 x 10 square kilometers (km^2)) gridded emissions have been reported by the Parties in 2017, the second half of the year 2017 has been dedicated to the implementation of analysis, quality checking and gap filling processes for the gridded data. The Centre on Emission Inventories and Projections (CEIP) was helped in this task by the Meteorological Synthesizing Centre-West (MSC-W) and the Meteorological Synthesizing Centre-East (MSC-E) since gridded data is mainly used as input data for chemistry-transport models. In 2017, as part of their quadrennial report, 27 Parties and 8 Parties submitted datasets in 2018, with for two of them updates on historical years. Finally, 2000 to 2016 gap-filled and gridded datasets are available for the main pollutants and particulate matter, and 2016 data is available for heavy metals and persistent organic pollutants. When data is not reported or available, other scientific datasets like those issued from the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model, the Netherlands Organization for Applied Scientific Research Monitoring Atmospheric Composition and Climate - Interim Implementation (TNO-MACC_II) emission inventory, the emission data base for Global Atmospheric Research (EDGAR), the Global Mercury Assessment 2013, the POPCYCLING-Baltic project or the Global atmospheric emission inventory of polycyclic aromatic hydrocarbons (PAHs)) were used for gap-filling.

30. MSC-W performed a number of runs with the EMEP model to investigate the actual impact of new gridded emission data on air pollutant concentrations. Such an evaluation is essential to qualify the potential added-value of high resolved emission data on the quality and reliability of simulations. The results are very encouraging as illustrated below for nitrogen dioxide ambient concentrations. The Figure IV. shows the correlation coefficient value between simulations and observations in the EMEP countries. The results for the simulations performed with the new high resolved emission inventory are in red while those related to the former one are in blue. The countries on the left of the green line are those that reported gridded emissions, the other did not report but ambient concentrations throughout their territory were influenced by updated datasets. The correlation coefficient generally improves, except for few countries in Eastern Europe which will be more deeply investigated. Nevertheless, such results are very encouraging and demonstrate relevance of improving the resolution of gridded emissions.

Figure IV.
Correlation coefficient values between simulations and observations in EMEP countries



31. Black carbon emission data are gathered on a voluntary basis from the Parties following the reporting process. This is a successful initiative since 37 countries submitted data in 2018 and 20 of them provided historical datasets. Other organizations expressed their interest in sharing data and methodologies developed under the Convention and its database on black carbon emissions. In particular, a cooperation started with the Arctic Monitoring and Assessment Programme in the framework of a scientific project supported by the European Commission to assess impact of black carbon emission on the Arctic region. This 3-year project started at the end of 2017.

32. Regarding the emission review process, the second cycle of in-depth emission review (2013-2017) ended with 44 parties reviewed and a new plan for the period 2018-2020 has been adopted. It is aligned with review activities under the European Union National Emission Ceilings Directive[11] and, in order to minimize duplication of work and inconsistencies between the finding of both review processes. The Convention emission review process will focus in 2018-2020 on non-European Union countries, including those in Eastern Europe, the Caucasus and Central Asia.[12]

33. One of the most sensitive topic in emissions and modelling area relates to the treatment of condensable and semi-volatile organic compounds in emission inventories that could impact the amount of particulate matter emissions and ambient air concentrations. Condensable particulate matter is not systematically included in emission data reported by Parties. However, recent scientific studies proved the major role of semi-volatile organic

[11] 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, 2016 O.J. (L 344), pp. 1–31.

[12] Armenia, Azerbaijan, Belarus, Finland, Montenegro, Republic of Moldova and Ukraine are planned for the year 2018.

species in the formation of secondary aerosols, and possible underestimation of particulate matter concentrations modelled by current chemistry transport models because of lacking emission data (semi-volatile organic compounds), and inappropriate process parameterizations in the model. It is urgent to define common rules in the emission guidelines for reporting or not reporting such emissions to ensure consistency between emission datasets and facilitate their use for modelling. The task Force on Emission Inventories and Projections sent a questionnaire to the Parties to investigate their practices regarding integration of the condensable part in reported particulate matter (PM) emissions. Considering feedback received and scientific knowledge it has been agreed that a sectoral approach should be developed:

(a) Particulate matter emissions from the transport sectors should include condensable contribution;

(b) Particulate matter emissions from industry sectors should not include them.

(c) More work and consultation with the national experts are needed to set how to report particulate matter emissions from residential sectors. If reporting condensable part remains difficult for some parties, a country approach may be developed to set correction emission factors that reflect practices in the countries.

B. Applications for adjustments to emission inventories

34. For the year 2018, two new applications for adjustments to emission inventories have been submitted: Hungary for non-methane volatile organic compounds in the agriculture sector and the United Kingdom for nitrogen oxides emissions in the transport sector. In 2017, Spain made an adjustment application for ammonia emissions in the agriculture sector, and the 2017 review could not conclude without additional information, so that the application has been set with an open status to be reconsidered by the review team in 2018. Furthermore, the reviewers are supposed to check also adjustments approved prior to 2018. Applications from Belgium, Denmark, Finland, France, Germany, Luxemburg and Spain were concerned. To make the procedure more efficient, the Centre on Emission Inventories and Projections developed an online database system that allows online calculation of differences between emission data already approved and the latest reporting in 2018. Moreover, countries are invited to declare in a one-page Word document that there are no significant changes in criteria or methods and respectively explain reasons if there are minor differences in calculated emissions. If all countries provide the requested information the review of adjustments previously approved should be significantly less resource demanding. This process produces successful results since 2016, and Parties are encouraged to adopt it systematically.

VIII. Monitoring strategy

A. Revision of the monitoring strategy

35. The Chemical Coordinating Centre (CCC) together with the experts of the Task Force on Measurements and Modelling started the revision of the EMEP monitoring strategy which should be adopted in 2019. The proposal for revision has been prepared taking into consideration recent developments in other relevant initiatives like the Arctic Monitoring and Assessment Programme, WMO Global Atmosphere Watch, European

Union Directives, Minamata and Stockholm Conventions. It has been discussed with national experts during the annual meeting of the task Force on Measurements and Modelling. Actually, no major change is proposed for the new monitoring strategy compared to the previous one. It will be still organized according to three levels, level 1 being mandatory for Parties and level 3 only voluntary (on the basis of international or national scientific programmes). For example, it is proposed to move elemental carbon and organic carbon in PM_{10} and hourly measurements of nitrogen dioxide from level 2 top level 1. Alignment with the Global Atmosphere Watch and with the European Union ACTRIS research Infrastructure is also suggested. Work for the revision of the EMEP monitoring strategy is still under progress to collect feedbacks and requirements from the Parties to consolidate a text that should be formally adopted by the Executive Body in 2019.

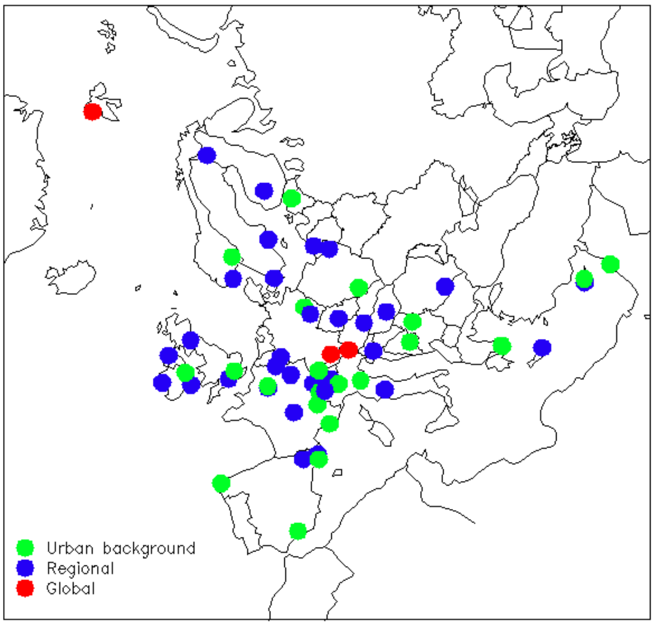
36. According to the Convention workplan and the priorities set by the EMEP Steering Body, the Task Force on Measurements and Modelling supported the elaboration, under WMO coordination, of a statement report on low-cost sensors for the measurement of atmospheric composition. This report is based on peer-reviewed literature that reflects the most recent experience with the performance of low-cost sensors and sensor systems, describes current and potential application areas for such systems and provides expert advice on the measures required in order to improve their performance. Following the Task Force’s recommendation, the EMEP will endorse this document since it gives valuable insight regarding operational use of low-cost sensors for air quality monitoring.

B. New Intensive Observation Period

37. According to the current EMEP monitoring strategy, Intensive Observation Periods (IOP) are set-up by CCC to collect complementary high resolved and high quality data to support scientific understanding of air pollution patterns in the EMEP region. This is also essential for modelling activities with the provision of good data for the evaluation of model processes and results.

38. The last EMEP field campaign was focused on better knowledge of carbonaceous compounds (and black carbon) in particulate matter and their sources with the implementation of high time-resolution and on-line devices such as multi- wavelengths aethalometers. Chemical analysis of relevant tracers like levoglucosan completed the network. Winter period (December 2017-March 2018) was targeted to highlight the contribution of biomass burning in winter particulate episodes. Twenty Two countries participated to the field campaign and 57 sites were monitored (see figure 5.). The data was to be reported to the CCC by the national experts by the beginning of June and first results will be presented during the joint meeting of the EMEP Steering Body and the Working Group on Effects in September 2018.

Figure V.
Location of 57 sites that were monitored during the latest EMEP field campaign.



IX. Linking the scales

A. Need to bridge the scales

39. Considering the recommendations set by the ad hoc policy review group that is mandated for the revision of the long term strategy of the Convention (to be adopted in 2019), and the conclusions of the Saltsjöbaden 6 workshop[13] organized by the Swedish Environmental Research Institute (IVL) and Swedish Environmental Protection Agency in March 2018, it is essential that the work of the Convention, initially focused on the ECE region, could benefit from cooperation’s at the global and local scales. Regional air pollution is influenced by hemispheric transport of some compounds on one hand and on the other hand influences air pollution patterns in the cities. Therefore, conceiving efficient action plans against air pollution requires optimal use of synergies between global, regional and local emission reductions strategies. Modelling and integrated modelling tools developed within EMEP by the Task Force on Integrated Assessment Modelling, the Task Force on Hemispheric Transport of Air Pollution and the Task Force on Measurements and Modelling, can support the development of this collaborative framework.

40. The Task Force on Hemispheric Transport of Air pollution achieved the HTAP2[14] experiment in 2017 which aimed at characterizing global air pollution source-receptor relationships for various parts of the world, thanks to an ambitious model intercomparison

[13] http://saltsjobaden6.ivl.se/.
[14] See http://www.htap.org/.

experiment which involved about 20 models. The synthesis of these results is expected by the end of 2018. All the results are integrated in the FAst Scenario Screening Tool (FASST tool) initially developed by the Joint Research Centre of the European Commission. The tool is no longer maintained by the Joint Research Centre, but the United States of America Environmental Protection Agency proposed to take over this responsibility and results should be published through the new FASST Tool by the end of 2018 as well.

41. Finally, following the Saltsjöbaden 6 recommendations, the Task Force on Integrated Assessment Modelling will establish an ad hoc expert group focused on local air pollution policies to investigate the most cost-efficient ways to tie linkages between urban and regional air pollution control policies. Experts from local authorities will be invited to contribute to the expert group together with experts from the Convention.

B. The twin sites project

42. To establish scientific evidences of the linkages between local and regional air pollution and characterize them, the Task Force on Measurements and Modelling set up in 2017 a new project, called the “twin site” project. This project aims at investigating several approaches based data collected at monitoring stations and modelling experiments.

43. The monitoring approach is coordinated by national experts from Spain and is based on use of triples of urban/suburban/backgrounds monitoring sites in France, Germany, the Netherlands, Spain and Switzerland. A report will be published by the end of 2018.

44. Modelling approaches are based on several tools. The Greenhouse Gas Air Pollution Interactions and Synergies (GAINS) model methodology developed by the Centre on Integrated Assessment Modelling can be used for assessing local/non-local contributions to air pollution. The Joint Research Centre developed the Screening for High Emission Reduction Potential on Air (SHERPA) tool to assess urban increment, and urban impact on regional air pollution. Also, French experts investigated the ability of EMEP model and of the multi-scale chemistry-transport models to capture both observed urban/rural gradients in total PM_{10} and individual chemical species used in the “twin site” analysis.

45. Conclusions of the twin site project are expected in 2019 and should provide science sounding inputs to help in dealing with the strategic question of how to account for patterns and physico-chemical phenomena that develop at various geographical scales when setting air pollution control strategies