Chapter 10

The role of the EMEP monitoring network and EMEP results

Authors: Peringe Grennfelt Jan Willem Erisman, Kjetil Tørseth, Gun Lövblad, Anton Eliassen

10.1 What have we learnt from the EMEP measurements during 25 years?

The EMEP network was one of the first international environmental measurement networks set up in Europe. It was formed with the experience from the OECD-project, in which a number of measurements were done over 11 countries in Europe. The OECD project was however limited in time while the EMEP network was infinite in its nature. It was also directed towards all European countries – *i.e.* the area of concern for the transboundary air pollution. The scientific understanding and skill varied over Europe and one of the main objectives of the network was to establish measurement stations with equipment that was easy to manage and affordable for all countries in Europe, but giving reliable and robust results. The simple devices for sampling of gaseous and particulate sulphate as well as for the determination of the chemical composition in precipitation on a daily basis formed an appropriate task that in principle all European countries could and should establish.

Already from the beginning it was however evident that these measurements, which for many countries were considered as a simple and trivial task, were quite difficult for other countries. In many countries there was no formal organisation or scientific research department that naturally could be responsible for the measurements. While the network had a fast development in those countries taking part in the OECD-project, its pentration into e.g. East Europe was slow and needed help in terms of training and suitable equipment. Training, field tests, checks of the accuracy at the various laboratories have since then been a central task for EMEP and through this quality assurance work the reliability and accuracy of the measurements and measurement data have in general been kept at a satisfactory level throughout the programme. The quality assurance work made it also possible to trace samling and analytical problems as well as problems in data handling and storage.

The long term nature of EMEP has also been important. Many stations have today unbroken timeseries of measurements approaching 30 years and these measurements are of crucial importance for our understanding of the atmospheric responses to the emission control performed in Europe during the last two decades, as discussed throughout the entire report.

The network has slowly evolved over the 25 years along with the widening and changing of interests in relation to regional and transboundary air pollution. The importance of nitrogen was highlighted early and nitrogen species were introduced in the program. Ozone and its precursors became another task for measurements and during the last 10 years measurements have been widened to include heavy metals and persistent organic compounds and in particular the regional distribution of particles threatening human health. Some measurements were introduced in the mandatory list of measurements, with the intention that they should be made at all EMEP stations, while others, in particular those of a complicated measurement nature, already from the beginning were directed towards a limited number of stations. This has resulted in a more diversified network, in which there are a large number of stations with particular objectives.

The EMEP network has also been a basis for short term experimental studies, where the long term series have served as a calibration and a confirmation of the general atmospheric pollution situation during the measurements.

In the recent years, the network has been a model for the setup of networks in other parts of the world, in particular in Asia. The European model and experience have been transferred to this area of the world, where the air pollution problem has large similarities with the European situation.

For the future monitoring and modelling within EMEP, the experiences and lessons learned during the past 25 years and during this assessment should be incorporated into the process. The long time series available should be kept as far as possible and relevant. The measurements started with focus on sulphur, for which the interest and needs today are limited. Other pollutants, such as nitrogen compounds, ozone, mercury and some POPs, are today and for the future more important. Furthermore, the data quality issues should be kept on a high priority level. Extended use should be made of evaluating the data with statistical techniques such as the procedure developed by Giannitrapani and co-workers, see Appendix A. The technique involves a smoothing procedure which enables discontinuities caused by abrupt emission reductions, data quality gaps, weather variations and other factors of importance for evaluating the progress of improvement for the pollution situation over Europe.

10.2 EMEP results as a basis for environmental assessments and policy processes

As shown by the assessment of pollution levels in the previous sections, there have been important improvements in the European air pollution environment during the past 25 years. The view on regional air pollution and the needs for abatement measures have changed dramatically since the start of EMEP in 1977. At that time, there was a widespread scepticism about regional air pollution as a real threat to the European environment and many governments and stakeholders were questioning the needs for control. EMEP has through its work and through its convincing results been a main contributor to the change in view that has occurred over the years.

In the beginning a main task for EMEP was to form a forum for scientific discussions and exploration of results in order to understand the behaviour of the main pollutants over Europe. The advantage of EMEP was that it included both scientists and policymakers and without the large participation and commitment from the European countries to the EMEP programme, it had certainly been much more difficult to reach a common understanding of the problems and its solutions. The yearly calculated blame matrices, from which the overall export/import budgets for all countries in Europe could be considered, focused the discussions and formed a platform for negotiations on emission reductions as expressed in the first sulphur protocol signed in 1985.

One of the main characteristics of EMEP is its openness. Data, which during the Cold War often were considered as of strategic importance, were made available to the EMEP Centres and used for modelling and evaluations. The openness with respect to measurements and availability of data also made it possible to examine and assure the quality of the data at an early stage, which then could be used in an ongoing process of improvement in measurements, model calculations and emission inventories. Even if later studies have indicated that the EMEP concept not always worked well, the system with centralised data collection and quality assurance processes formed a basis from which it has been possible to return to the original data and retrieve questionable data.

The experience obtained within EMEP has been of outstanding importance both for the use of the data and air quality assessments in the countries as well as for the general standard of environmental laboratories in Europe. There is probably no environmental monitoring network containing such a large number of countries and so many stations with such a well-developed system for data handling and quality management.

Due to the openness and quality, EMEP data has not only been used within the EMEP community but also in many other scientific and policy connections. These include the support to the marine commissions (e.g. OSPAR[1] and HELCOM[2]), with data for the estimation of atmospheric input to the marine ecosystems. EMEP data has formed the basis for scientific studies of atmospheric processes, in particular chemistry and transport of air pollution, and they have been used for the assessment of environmental and health effects.

Within EMEP, the use of measured data has been focused on validation of models. This was an important task at the early stage of the EMEP network, due to a lack of a good scientific understanding of the processes and mechanisms for the turnover of sulphur and nitrogen compounds in the atmosphere. Even if the understanding today is at much higher level, the use of data for model development and validation is still fundamental. In connection with the development of the critical loads concept, the use of EMEP data for the assessment of environmental effects and exceedances of critical loads and levels became another main task.

The use of EMEP data for general assessments of the air quality and its changes over Europe has been less common. This is in contrary to the use of data within other conventions, e.g. the marine conventions, where the prime use of monitored data has been for assessment reports. The use of monitored and collected data under for example the Convention for the Baltic Sea, HELCOM, is through Assessment Reports published every five years.

10.3 How can EMEP data help us understand the outcome of reductions done and the need for further abatement?

The emission decreases have been the result of many factors, both direct measures and as a result of socio-economic development. The introduction of cost-efficiency as a tool for setting priorities in the 1994 and 1999 UN ECE protocols as well as in the 2001 NEC Directive gave an estimate of the total cost for achievements of the environmental goals.

The cost estimates were to a large extent based on the application of end-of-pipe technologies, e.g. installation of fuel gas desulphurisation and NO_x reduction equipment on large combustion plants and catalytic reduction units on gasoline cars. In reality, a large part of the emission reductions were achieved via other measures, especially fuel switching and increased energy efficiency in houses and

[1] The OSPAR (www.ospar.org) convention is set up for the protection of the marine environment of the North-East Atlantic.
[2] HELCOM (www.helcom.fi) or Helsinki Convention is set up to protect the marine environment of the Baltic Sea.

within the industry. This progress started as a consequence of the mid-1970 energy crisis, when many countries took actions to decrease their dependence on fuel oil.

The progress of environmental improvement has also been influenced by factors enhancing or counteracting the emission reduction. Important factors are identified in the assessment as short-term weather changes such as milder winters and changing pollution climate and connected non-linearities.

As shown by Wuester (2001), the emission control of sulphur could only to a limited extent be explained by those environmental measures on which the Protocols and the NEC Directive were based. Strategic issues such as limiting the dependence on oil have also played a role. Fuel switching has been important for the decreases, mainly switching from coal and oil to gas but also to nuclear and biomass. Also a large number of other measures have contributed to reduced emissions. Industrial emissions were reduced due to economically initiated process changes and energy savings. The costs for these measures, which only to a very limited extent were made in order to reduce the emissions of transboundary air pollutants, could not be attributed to air pollution control. They were instead mainly done for economic reasons or during recent years for the reduction of greenhouse gas emissions. The most obvious breaking point of the European emission trend curve is seen around 1990 and is connected to the economic set-back in Eastern Europe. A thorough analysis of the causes is still lacking.

Nitrogen oxides emissions have decreased during the last ten to fifteen years, even if the decrease is not as large as for sulphur. For the nitrogen oxides reduction, environmental control requirements have played a much more important role and other reasons have been of less importance.

The CLRTAP and its Protocols have had a major effect on emission trends in Europe, particularly for SO_2. European emissions are reduced with the clear objective that environmental loads, exposures and effects should be decreased. So far very few studies have been undertaken to investigate the outcomes of various scenarios and reduction plans. The first scenario study on emission reductions and their outcome was presented as a Swedish case study for the UN Environmental Conference in Stockholm 1972. In this study three scenarios were developed for the European as well as the Swedish emissions. These scenarios varied from an emission reduction of 60% by 1982 to a 2,5-fold increase during the same time. When these scenarios for Europe are compared with the actual emissions, there was a continued increase until around 1980 when they started to decrease and reached the most optimistic scenario by 1995.

The emissions have, however, continued to decrease also after that. For Sweden the emissions started to decrease already shortly after the UN Conference and the emissions followed the most optimistic emission reduction scenario until 1982 and they have continued to decrease after that reaching an about 90% reduction at the end of 1990'ies. Figure 10.1 shows the temporal variation in SO_2 emissions in Europe west from the Ural between 1965 and 2000. It shows the time the three protocols were agreed upon and shows the effect the first two protocols had on the European emission. Furthermore, the predicted emissions are displayed.

Another study, in which scenarios for SO_2 and NO_x emissions were elaborated for the period between 1980 and 2000, gave similar results. Three scenarios were assessed in 1985 (Hordijk 1991) to predict the emissions in 2000 based on 1980 data: "Best available technique" (BAT), "Current reduction plans" (CRP) and "No control" (NC). The CRP scenarios were the most realistic. Figure MO-2 shows the trend in emissions between 1980 and 2000 for SO_2, NO_x and NH_3 in Europe, together with the three scenarios and the Gothenburg protocol emission targets for 2010 (Vestreng 2001). SO_2 emissions in 1999 were far below CRP and almost reached the level of BAT. NO_x was also well below CRP, but the BAT level was much lower than the 1999 level. For NH_3 no predictions were given at that time. The

2010 levels for the three components were expected to decrease somewhat, by 8, 5 and 1% for SO_2, NO_x and NH_3, respectivel relative to 1999. The implementation of the Gothenburg Protocol has been an important incentive for the control measures.

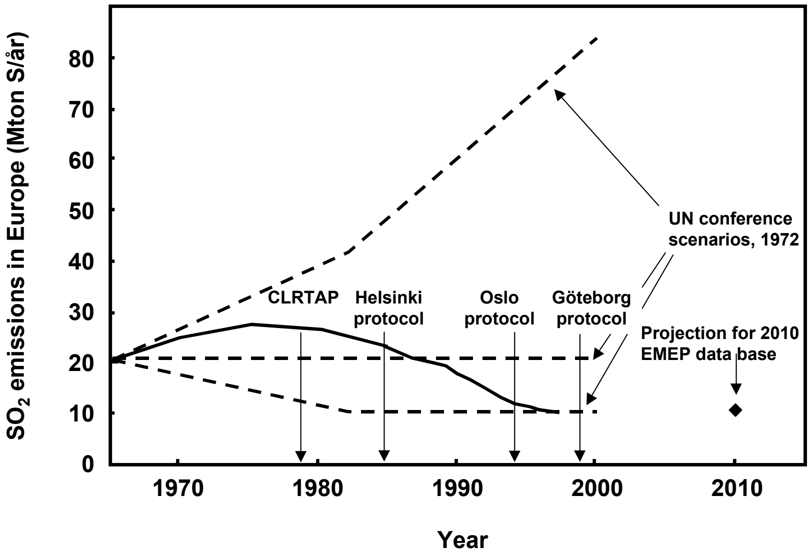

Figure 10.1 SO_2 emissions in Europe west of the Urals between 1965 and 2000 together with the predicted emissions at the UN conference in 1972. (NEGTAP 2002).

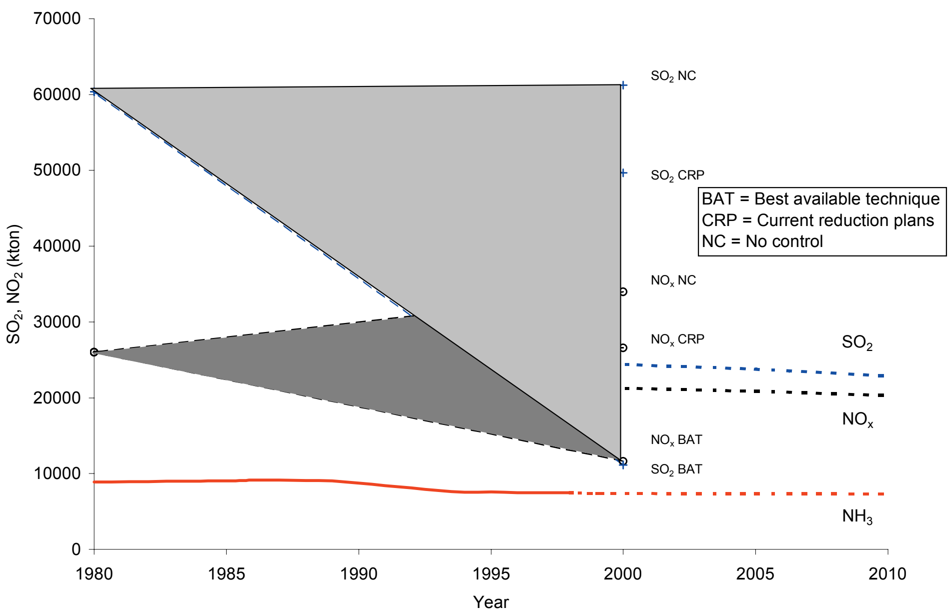

Figure 10.2 Total emissions of SO_2, NO_x and NH_3 in Europe in kton S or N (Vestreng 2001).

The substantial fall in emissions of acidifying gases is due to a reduction of about 67% in SO_2 emissions, mainly from industry and the energy sector since 1980. Nitrogen emissions decreased much less, around 24%. For NO_x the decrease is mainly due to technical measures within the transport and industrial sectors. Within the transport sector, the largest emission reductions are so far achieved through the installation of catalytic converters in gasoline cars and through motor modifications in diesel-fuelled cars. For stationary sources, emission reductions are mainly achieved through selective catalytic reduction (SCR) and through installation of low NOx burners. For NH_3 the reduction - 21% in total over Europe - is mainly due to decreased agricultural activities in Eastern Europe after 1990. The changes in nitrogen emission and deposition in Europe are discussed in Erisman et al. (2001). The change in sulphur emissions in the different European countries is shown in Figure 10.3. Most countries have decreased their emissions between 40 and 95%. All parties that signed the Gothenburg Protocol realised a decrease. Some countries, not part of the Protocol, however increased their emissions, Turkey being the most pronounced with an increase of 78%.

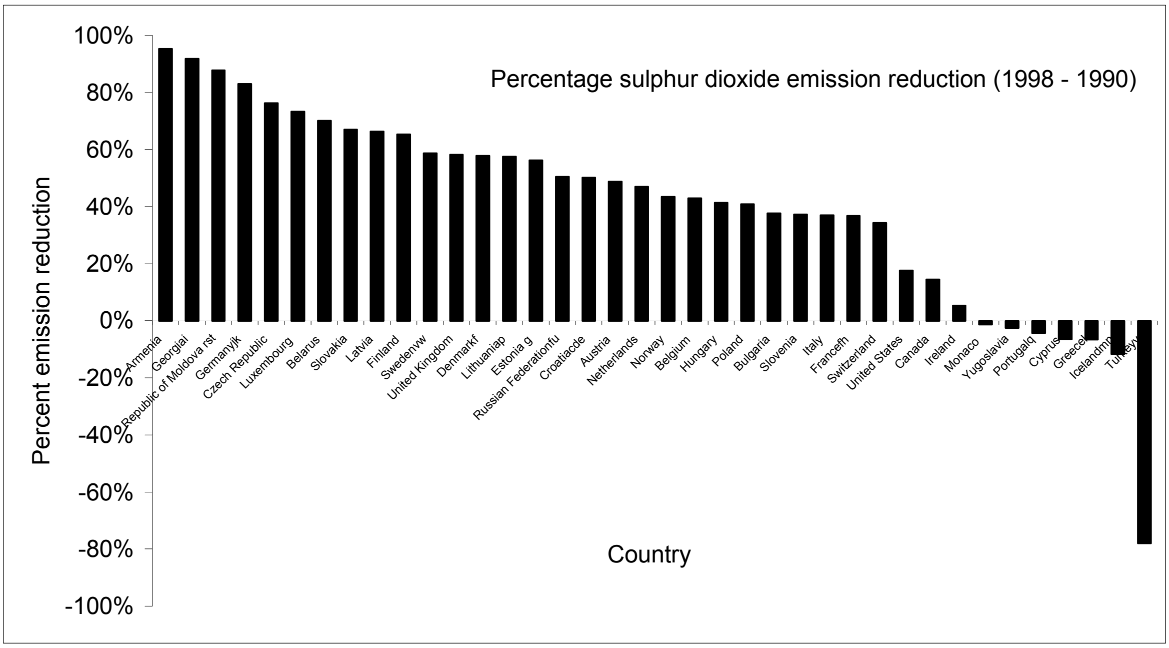

Figure 10.3 Relative changes in sulphur emission in the European countries between 1998 and 1990 (Vestreng 2001).

The driving forces for emission reductions in SO_2 are given for the Netherlands in RIVM (2000) and displayed in Figure 10.4. The changes in emissions due to different measures are compared to the reference case, which would have been the emissions without any measures. The largest decrease in emissions is obtained through a shift in fuel by increasing the use of natural gas and by flue gas desulphurisation.

European data on causes of emission reductions have recently been presented in a report from IIASA (Wuester 2001). This report shows in same way as for the Netherlands (see the national contribution from the Netherlands) that emission reductions were caused by several factors and that pure environmental control is only one.

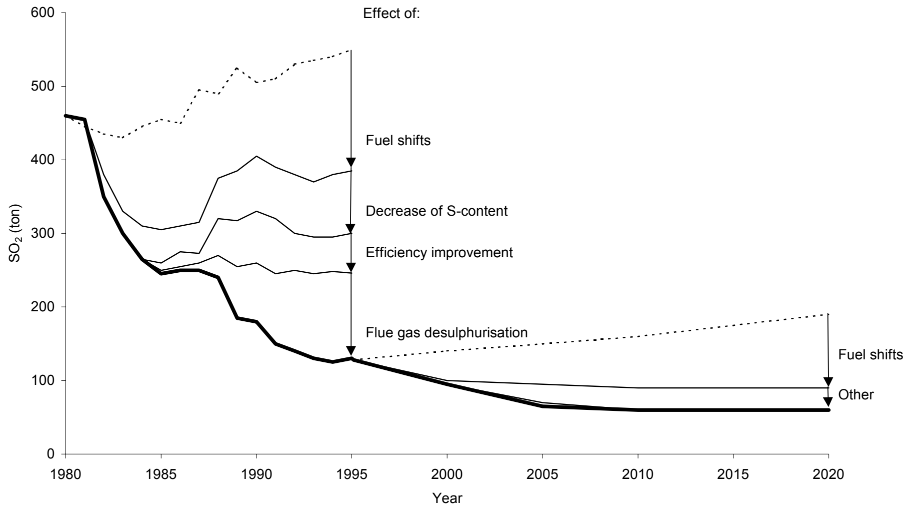

Figure 10.4 Driving forces for emission reductions in the Netherlands for SO_2 (RIVM 2000).

10.4 Future need for emission decreases and potential difficulties

The assessment has shown that a considerable improvement is achieved in European regional air pollution. However, there is a need for further reductions to overcome future risks for health effects and ecosystem damages. Reduction changes necessary to comply with the Kyoto protocol may interact with the reductions necessary for sulphur and nitrogen emissions. Reductions in energy use will lead to improvements for both purposes.

However, there is also a risk that pollution as regards sulphur, nitrogen and hydrocarbon may need more energy. The abatement options directed towards environmental control solely are not free from energy penalties. Energy penalties can be due to the additional energy used to run the abatement system or as the result of lower efficiency. Furthermore, additional energy is used because of the production and use of additives, catalysts or reductants. The energy penalty leads to additional emissions. So far, the energy penalty has not been much discussed because the cost-effective reduction of emissions and effects was the main issue. Currently, with climate change being a main focus of international environmental policy, the energy penalty becomes more and more important. In the discussions of carbon sequestration after capture of CO_2 resulting from fossil fuel combustion e.g. the energy penalty might even become limiting.

In Table 10.1 we have made an estimate of the fuel penalty for NO_x and SO_2 abatement options and its effect on energy use in Europe. The fuel penalty is largest for SCR techniques. The energy penalty experienced by plants range between 0.5% and 2.5%, depending on the control technology employed and the facility controlled. In general implementation of techniques to reduce NO_x and SO_2 emissions have resulted in an increase of CO_2 emissions because of the fuel penalties. It is therefore useful to consider the impacts on CO_2 emissions when developing emission reduction techniques for SO_2 and NO_x, and vice versa. For measures to reduce CO_2 emissions there are good possibilities to reduce acidic gases, especially in relation to sequestration options for CO_2.

Table 10.1 Summary of NO_X and SO_2 control strategy fuel penalties.

Control Strategy		Source Description					NOX/SO_2	Capital Cost		Fuel Penalty	Source
Type (5)			Coal	Oil	Gas						
FGT	SNCR	Utility Boiler				600 MW	25 - 38 %			0.2 - 0.5 %	1
PM	Low NOX Burners	Utility Boiler (1)	X	X	X		40 - 60 %	20 -25	$/KW	None	2
PM	Staged Combustion	Utility Boilers	X	X	X		20 - 50 %	5 -10	$/KW		2
PM	Flue Gas Recirculation	Utility Boilers (3)	NA	X	X		20 - 50%				2
PM	Steam Injection	Gas turbines					80%			1%	2
PM	Steam Injection	Utility Boilers	NA	X	X		25 - 35 %				2
PM	Low-Excess-Air Firing (LEA)	Utility Boiler	X	X	X		10 - 30 %				2
FGT	SCR	Utility Boiler	X	X	X		60 - 90 %	40 - 80	$/KW		2
FGT	SNCR	Utility Boiler	NA	X	X		30 - 70 %	10 - 20	$/KW		2
FGT	Dry Adsorption	Utility Boiler (4)				40 MW	70%				2
FGT	SCR	Gas turbines			X	300 MW	Selected SCR as BACT - 2.5 ppmvd @12% O2				3
FGT	Wet Scrubbing - SO2	Utility Boiler	X			700 MW				1.50%	8
FGT	SCR	Utility Boiler	X							1.5 - 2.0 %	9
Fuel	Distillate Fuel Desulfurization	Fuel Oil/Gasoline		X			90%			3.50%	10
FGT	SCR	Cement								9.80%	11

10.5 The future of EMEP monitoring and modelling

The control of some of the traditional compounds causing regional air pollution over Europe can be described as a success story. Emissions of sulphur have gone down substantially, while lower but still significant reductions are seen for nitrogen compounds. Will this mean that emissions now are at levels where there is no need for further reductions? Some arguments have been put forward in this direction, in particular since the Gothenburg protocol indicated such improvements in terms of ecosystem protection for acidification, that one would feel that Europe now is protected from environmental effects.

There are however several reasons for a continued intense work within EMEP on preparation of data on emissions, concentrations, deposition and transboundary fluxes:

- The benefits of the Gothenburg Protocol were seriously overestimated. One reason is a too simple treatment of the deposition in the preparation of the Gothenburg Protocol. For example, the higher depositions to forest ecosystems were not taken into account.

- The interest in health effects from air pollution, in particular from particles, has increased. The Gothenburg protocol did not take into account health effects from particles. Epidemiological research has repeatedly shown that air pollution is causing severe health effects both in terms of mortality and morbidity. Since there is not yet any enough strong evidence that specific particle fractions are essentially more important than others, emission control strategies are directed towards the overall content of fine particles (PM10 or PM 2.5) in Europe. Long range transport of aersols form an important contribution to the overall exposure and any control strategy for the protection of health needs to include control of the regional emissions and transboundary fluxes.

- The dynamic aspects have not yet been included in the critical loads concept. The critical load is defined as "*the maximum load that will not cause any long term harmful effects to ecosystem and function"*. This definition of critical loads did not, however, take into account the problem of already damaged ecosystems. If damaged ecosystems are to be recovered within a reasonable time, the maximum load must be lower than the critical loads. This new concept is expected to be used in further air quality strategies.

- Sources outside Europe are becoming more important. This is especially the case with respect to emissions from marine sources, air traffic and emissions in earlier pristine areas (e.g. the Arctic region).

Thus there is a further need to follow the development of the atmospheric situation in Europe. The needs for measurements and model calculations will however change in the same way as it has changed during the more than 25 years history of EMEP. Some parameters will become less important and the needs for measurements and modelling of these will be less important. New parameters may instead be of larger importance as recently has been the case with particles. One of the main challenges of the EMEP system is therefore to follow the needs appearing from scientific findings and from policy development and adapt to these in an appropriate manner. This does not mean that every new idea should be taken on board, but for the further development of the EMEP programme it is essential to understand where the long-term policy needs are and which scientific findings that are important enough to take on board. It is also important to include new knowledge in the EMEP models. The development of specific modules for particles and the possibility to take non-linear processes into account are examples on important directions for today's and tomorrow's model development.

An important step in this direction is the preparation of a new monitoring strategy for EMEP. The strategy has been discussed in depth for a couple of years, assessing various needs; the establishment of long term trends to verify emission changes, the support to model development, the delivery of input data for the assessment of effects and not the least to support our general understanding of occurrence and causes of transboundary air pollution.

The EMEP observations and model calculations are important elements not only in establishing the regional air pollution situation in Europe, but also through its links to the global as well as the urban scales. The geographical scope of EMEP will have to be extended to take into account the needs of new Parties as well as the impact of intercontinental pollution transport. In addition, the Convention should investigate the consequences of the interactions between global change and air quality issues..

Particulate matter has become a priority under the Convention in relation to the envisaged revision of the Gothenburg Protocol. Although significant progress has been made over the past five years in understanding the sources, transport, transformation, air concentrations, and deposition of particulate matter in the atmosphere, considerable uncertainties still remain. In particular, there is an urgent need for measurements of the chemical composition of particulate matter, and carbonaceous aerosols.

Another main issue for the Convention over the coming years is to support the further work on the Protocols on Persistent Organic Pollutants (POP), on Heavy Metals (HM). Measurements of the chemical composition of hydrocarbons, mercury and different POPs will be necessary.

The monitoring strategy of EMEP is aiming to utilize progress in the scientific understanding represented by, for example, new methods and technologies. The monitoring strategy will evolve, making use of new approaches and methodologies as these become available. The monitoring programme will be organised into stations having measurements at different levels of scope and complexity. Three different levels are proposed, each targeting EMEP objectives in different ways.

The main objective of monitoring at Level 1 sites is to provide long-term basic chemical and physical measurements of the traditional EMEP parameters. Level 1 activities would be the first priority when extending the network into areas not covered by measurements up to now (Mediterranean regions, Eastern Europe and Central Asia). By undertaking a more requiring monitoring programme, a subset of the Level 1 stations should gradually be upgraded to Level 2 sites.

Level 2 sites will provide additional parameters essential for process understanding and further chemical speciation of relevant components, and represents thus an important supplement to the Level 1 sites. The aim is to establish a total of 20-30 Level 2 sites over Europe within 2009. Level 1 and Level 2 sites represent mandatory requirements. Level 2 sites will be defined according to topic and do not have to cover all topics. This means that a Level 1 site extending its programme to include the level 2 activities for any of the specific topics will be identified as a "supersite" for this topic.

Level 3 activities are research oriented. The main objective of Level 3 sites is to develop the scientific understanding of the relevant physical-chemical processes in relation to transboundary pollution and its control. Level 3 activities will typically be undertaken by research groups and may also include campaign data. Level 3 sites are a voluntary component of the new monitoring network. As a level 3 approach other measurements may also be of interest. One such possibility may the use of remote sensing from satellites, which might become an integral part of the network where ground-based stations and remote sensing complement each other.

Level 2 and level 3 sites will be nominated as "EMEP supersites"; this is intended to be an important motivation factor and to provide appropriate recognition of the data providers.

EMEP monitoring will maintain and further improve its quality assurance programme to make sure that observational data are of known quality and adequate for their intended use. Field inter-comparisons and laboratory ring tests are important, as well as the maintenance of good links between national data providers and the EMEP centers.

It is important that the EMEP monitoring network is dynamic and ready to adapt to new needs and requirements identified by EMEP and the Convention. At the same time, consistent long-term time series should be maintained to monitor emission reductions. This requires that the strategy and its implementation is being regularly reviewed and, as appropriate, revised.

10.5 References

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