text in draft minutes from the EMEP TFMM meeting express:

CCC prepares a condensed booklet with the summary of parameters measured in EMEP, their environmental relevance and synergy/applicability to addressed Directive. The booklet to be prepared for support of the EMEP observations in front of policy makers (so, should be in easily digestible language). Booklet must be prepared in consultation with countries to reflect possible national issues

By Kjetil Tørseth, EMEP-CCC, 24 Aug 2011

EMEP monitoring – a backbone of the Convention on Long Range Transboundary Air Pollution

The main objective of EMEP is to provide Governments with information of the deposition and concentration of air pollutants, as well as on the quantity and significance of the long-range transmission of air pollutants and fluxes across boundaries.

Monitoring of air concentrations and deposition fluxes was initiated in the 1970ies, and the efforts have gradually expanded to cover variables relevant to address acidification, eutrophication, photochemical oxidants, heavy metals, persistent organic pollutants, and particulate matter/aerosols. A large fraction of the monitoring programme has direct relevance for, and is actively used by other international frameworks addressing Air Quality (i.e. the EU Air Quality Directives), Climate change (WMO), Persistent Organic Pollutants (UNEP), Biodiversity and Biogeochemical Cycles (INI, UNEP, IGBP), Marine environment (HELCOM, OSPAR), Arctic pollution (AMAP) and others. EMEP is a contributing programme to the WMO Global Atmosphere Watch (GAW).

EMEP monitoring obligations are developed through discussions with the scientific community, with national representatives of the EMEP Task Force on Measurements and Modelling (TFMM) and with the EMEP Steering Body before endorsement by the CLRTAP Executive Body (EB). ***The monitoring strategy for 2010-2019*** was adopted by the EB in December 2010 and can be found at http://www.unece.org/env/documents/2009/EB/ge1/ece.eb.air.ge.1.2009.15.e.pdf

This note outlines the fundamentals of EMEP monitoring strategy and serves the purpose to highlight some of the essential elements demonstrating the importance of the programme:

- The **location of EMEP sites** is to the extent possible chosen to avoid significant local influences such as emission sources, local sinks, topographic features etc.), which could result in data not being representative for a larger region**.** The ***siting critera*** is defined in the EMEP manual for sampling and chemical analysis, and includes sites according to the siting criteria rural, background or global sites).

- To determine regional ***spatial trends***, it is fundamental that measurements are made in a comparable way amongst the Parties to the programme. Further, measurements data need to be consistent with time to allow the assessment of ***temporal trends***. The Chemical Coordinating Centre (EMEP-CCC) was established already in 1977 to harmonize these efforts. Capacity building, quality assurance and quality control as well as data dissemination and assessments are key activities which links the EMEP-CCC and Parties through the operational work. Documentation of some of these efforts are available at

http://tarantula.nilu.no/projects/ccc/reports.html. It is also fundamental that EMEP monitoring is continued at decadal time scales to allow future assessment of temporal trends.

- The ***spatial density of sites*** is aiming at resolving regional scale gradients in air concentrations and deposition fluxes. There is a particular need to further develop the site density in areas such as the Mediterranean region, and the ECCAA region. Improvements in the spatial resolution of models used to estimate transboundary fluxes and the importance of assessing the import and export of pollutants with regions outside the EMEP domain will further enhance this need. EMEP has established links with regional monitoring programmes in North America, Central- and East Asia and in Africa.

- To allow assessment of atmospheric composition and deposition in relation to air mass transport, EMEP monitoring requires high ***time resolution of measurements*** (hourly to daily resolution). Some variables are however expensive to measure and a longer sampling time may be acceptable. The specifics of time resolution are subject to revisions as adequate methodology becomes available offering more highly time resolved data. EMEP is also aiming to provide access to data in near-real time to support instant assessments of episodes, for input to chemical weather forecasting and to support calibration and validation of satellite remote sensing data. EMEP is member to GEOSS[1], and has close collaboration with the European Environment Agency. The EMEP database is likely to serve as an appointed node for data dissemination in GMES (GISC) [2]ensuring an efficient use of resources

- ***Monitoring methods*** are generally chosen based on criteria such as appropriate detection limits at low concentration levels, robustness and simple operations in field. Where adequate international standards are available from CEN or WMO, EMEP seeks to apply the same criteria. Where such methods are not available, EMEP develops methodologies in a process which include national experts and relevant scientific groups upon approval by the appropriate bodies.

- EMEP monitoring includes an ***extensive range of chemical and physical variables*** important either as a measure of the adverse exposure to protect ecosystems (waters, forests, crops), materials and health. In addition monitoring has a strong focus on variables which are important to understand sources, atmospheric processing, regional scale transport and deposition. Many of the variables are also central for the assessment of climate change. Data for more than 800 different variables have been reported to the EMEP observation database (http://ebas.nilu.no), and the number is continuously growing as new methodologies and resources becomes available, and new environmental challenges are identified.

- ***Sites with different complexity.*** EMEP monitoring has gradually developed to include basic operations using well established methods at the so-called level 1 sites. A more elaborate and advanced programme is implemented at so-called level 2 supersites, ideally one or two per country. These are normally joint EMEP-GAW sites where additional measurements to

[1] http://www.earthobservations.org/geoss.shtml

[2] http://gisc.ew.eea.europa.eu/

the level 1 requirement also may be made by scientific expert groups. Level 3 activities include specific studies which provide observational information required to understand processes related to the transport, transformation and deposition of substances, but which do not necessarily need to be made at sites operating a full level1 or level 2programme.. Level 3 activities also include campaign type data of a nature for which it is unrealistic to operate a continuous monitoring effort.

- The monitoring obligations clearly represent an ambitious activity but there are several **relaxations** which open for Parties not to operate in full compliance.

- ***The involvement of national competence*** is essential to address the policy relevant questions of EMEP. Monitoring activities represents a very efficient way to achieve this goal. National competence contributes through representatives nominated by governmental institutions/stakeholders, as well as by universities and research institutes. Scientific groups increasingly have a need to demonstrate the relevance of their research and this forms an important basis of activity which directly develops competence and infrastructure to be utilized for EMEP objectives. This also expands the resources available for EMEP far beyond the national budgets allocated for EMEP monitoring. One excellent recent example was the EU-FP7 Research Infrastructures project EUSAAR[3] where EMEP-GAW site operators have developed standardized procedures for monitoring of aerosol chemical, physical and optical properties. This activity has recently been extended to include activities which will strengthen the quality of NOx and VOC compounds in the EU funded project ACTRIS[4]. The deliverables of ACTRIS will be made available to serve the full EMEP community, and is to be implemented in the EMEP monitoring manual. A large number of research projects have addressed EMEP relevant questions, and have used EMEP observations in combination with models. Data from EMEP appear in many hundred scientific journal papers each year.

EMEP monitoring obligations is harmonized with and supports a variety of information needs to address air pollution and climate change issues on the European and global scale. An introduction to some important recent areas of stakeholder interest is given in the following:

EMEP monitoring vs the requirements of the Directive 2008/50/EC.

The Directive has several references to the EMEP monitoring strategy in relation to the requirements for monitoring at rural and background sites. On the strategic level, there are also obvious benefits of taking advantage of EMEP monitoring obligations to ensure efficient use of resources. Data from EMEP sites are normally also reported to the EC as part of the national reporting obligations.

As the Directive has its main focus on Air Quality and population exposure in relation to air quality limit values, its development has however differed from the processes established under CLRTAP. As a result, monitoring obligations are not fully harmonized regarding background monitoring. So while the objectives and selection of variables are close to identical, minor differences on the technical level have resulted in requirements where Directive requirements have taken priority and in some cases resulting in the termination of long-term EMEP data series due to cost limitations.

[3] http://www.eusaar.net/
[4] http://www.actris.net/

A brief introduction to some of these items is given below:

The Directive has introduced monitoring obligations on chemical composition of ***fine particulate matter (PM2,5).*** While all the chemical compounds required to be monitored is included in the EMEP requirements (i.e. SO_4^{2-}, NO_3^-, NH_4^+, Ca^{2+}, K^+, Na^+, Mg^{2+}, Cl^-, elemental carbon (EC) and organic carbon (OC), the requirements differs by not considering the fraction of particulate matter having a size exceeding 2,5 micrometers (EMEP require inorganic ions by filter pack without size segregation at its level 1 sites, at level 2 sites EC/OC in PM10 is required, while speciated inorganic composition of PM2,5 and PM10 is part of the level3 recommendations. The introduction of size limitation on filterpack sampling in EMEP has regularly been discussed over the years, but it has always been concluded that this will introduce strong limitations in the applicability of data to support EMEP needs as a) a large fraction of the aerosol mass is present in particles larger than 2,5 micrometer. By not including this fraction to the monitoring programme it is impossible to quantify the long range transport of chemical substances regulated by the EMEP protocols. b) The monitoring and model evaluation of fluxes to ecosystems and to other sensitive receptors will be strongly limited c) introduction of a size cut-off may also introduce additional uncertainty in data from artefacts in the sampling system, d) ongoing time series would be discontinued is such a systematic change was introduced resulting in a reduced possibility to quantify temporal trends. It should further be noticed that other metrics than PM2,5 may be introduced to indicate harmful effects on health in the future, and limiting monitoring to changing size cut-off with time will cause difficulties in assessing temporal trends in time series.

The directive is not specific regarding the temporal resolution of measurements. It should be noted that daily resolution as required by EMEP is associated with significant costs, but represents a very important part of the programme and extend back in time by about 4 decades. The additional cost of establishing new time series with a PM2,5 size segregation puts pressure on national resources. Several examples exist of long-term time series being terminated to satisfy the directive requirements, although the overall objectives for doing such measurements are similar. A stronger link to EMEP monitoring activities could largely satisfy the objectives as set out in the Directive.

The Directive require ***Volatile Organic Compounds (VOCs)*** to be measured "in particular in urban or suburban areas at any monitoring site set up in accordance with the requirements of this Directive and considered appropriate with regard to the monitoring objectives referred to in Section A". Section A states: "The main objectives of such measurements are to analyse any trend in ozone precursors, to check the efficiency of emission reduction strategies, to check the consistency of emission inventories and to help attribute emission sources to observed pollution concentrations. An additional aim is to support the understanding of ozone formation and precursor dispersion processes, as well as the application of photochemical models".

The formation of tropospheric ozone occur however on the regional scale, it has been addressed by the EMEP programme since the 1980ies and protocols regulating precursor emissions have been developed (http://www.unece.org/env/lrtap/status/lrtap_s.htm) The

consensus in EMEP (measurements as well as modeling activities) is that in order to serve the purpose listed above, measurements should preferably be made at rural sites, and not at urban or suburban sites. As documented in EMEP reports, the Parties ability to implement the monitoring requirements regarding VOCs have however been very limited (e.g. http://tarantula.nilu.no/projects/ccc/reports/cccr4-2010.pdf).

It should be noted that Air Quality Monitoring of SO2 and NOx should based on online monitors offering hourly time resolution. While monitors can be operated according to high Data Quality Objectives required for background monitoring with the objectives listed above, EMEP has still its focus on manual methods since it is considered the most reliable and cost efficient approach to ensure consistent long-term trends at trace levels.

For measuring deposition of heavy metals in accordance to the EU directive, the associated CEN standard allows for the EMEP reference method to be used at regional scale to serve the objectives of both programmes.

The monitoring of Short-lived Climate forcers in EMEP

During the last few years, a growing scientific and political interest have been devoted to explore the potential of reducing emissions of substances of short life times which have an impact on radiative forcing (SLCFs). These include particulate matter, methane and tropospheric ozone, and require data on emissions, transport, transformation and deposition of inorganic ions, soot (also called black carbon or elemental carbon), organic carbon, as well as on VOCs and NOxy substances being precursors to ozone formation.

- Note: The term “Black Carbon” (BC) is used to reflect that observations are made using instrumentation which quantifies the absorption of radiation (at one or several wavelengths) by particulate matter, while “Elemental Carbon” (EC) is a measure of the mass concentration of refractory carbon, and is typically analyzed using termo-optical analysis, during which EC and organic carbon evolves at different temperature and oxidation conditions according to the predefined temperature profile. EMEP data originators operate a mixture of such instrumentation at level2 sites. BC is most commonly used in the climate community as it directly refers to the radiative effects of aerosols while EC is most commonly used in the air quality community as it refers to the mass concentration of carbon as a contribution to the total mass.

EMEP did already in the late 1990ies take first steps to include a comprehensive aerosol/particulate matter programme across Europe (see eg. http://tarantula.nilu.no/projects/ccc/reports/cccn1-2000.pdf and http://tarantula.nilu.no/projects/ccc/reports/cccr8-99.pdf). This built on the efforts made under the EUROTRAC2-Aerosol programme. EMEP had a particular focus on chemical mass closure and source apportionment of particular matter and conducted the so-called EMEP ECOC campaign in 2002-2003 (Yttri et al 2007). Since 2004, aerosol/particulate matter monitoring has also included optical and physical variables though the latter measurements became mandatory first in the present monitoring strategy for 2010-2019

An implementation of the EMEP monitoring strategy can thus be seen as an adequate response to secure sufficient data for regional transport of aerosols and associated radiative forcing.

Methane was introduced to the monitoring programme in 2004 on a voluntary basis, and is required at level 2 supersites in the monitoring strategy for 2010-2019.

Precipitation Chemistry

EMEP operates a programme where daily precipitation samples are analysed for major ions. While initially established to address deposition of acidifying and eutrohying compounds, this activity now represents a fundamental tool to study the fluxes of chemical constituents for a range of purposes. Daily sampling allow high quality data on composition and detailed information on the deposition fluxes to ecosystems as well as on the removal rates by scavenging of gases and particles by precipitation. Such scavenging is clearly the most important sink for particulate matter, and any numerical description of long range transport need to be tested and validated against precipitation data. The presence of precipitation and clouds also strongly affect the chemical processing en route during transport.

The Reactive Nitrogen Cycle and links to the Carbon Cycle

Nitrogen compounds were measured in precipitation samples already from the start of the programme in the 1970ies. While the initial rationale was to use ion balance as a tool for quality assurance, it soon became evident that long range transport of nitrogen species was essential to address eutrophication and the production of photooxidants (see also http://tarantula.nilu.no/projects/ccc/reports/cccr1-93.pdf). The EMEP time series represents a unique dataset to assess temporal and spatial trends across Europe. It should be noted however that many Parties have not been able to operate an adequate program for nitrogen monitoring. More recently, activities have been extended to also include more spatially dense sampling using low-cost methods, methods which can separate gas and particulate phase nitrogen compounds as well as to include measurements of ecosystem exchange fluxes. As the nitrogen cycle is strongly coupled with the other biogeological cycles (including the carbon cycle), EMEP monitoring has a strong link to climate change issues. This is one of the argumentations for locating rural and background ambient greenhouse gas monitoring at EMEP sites. CO2 and N2O have thus appeared on the list of voluntary monitoring obligations in the 2010-2019 monitoring strategy, and there is an important overlap with efforts made in support of the WMO-GAW monitoring programme. The EMEP monitoring is thus adding value to topics like biodiversity, water quality etc. For more info about reactive nitrogen see e.g http://www.clrtap-tfrn.org/webfm_send/331

Persistent Organic Pollutants

Persistent organic Pollutants was added to the EMEP monitoring programme in the early 1990ies and some sites have continuous time series of about two decades (http://tarantula.nilu.no/projects/ccc/reports/cccr7-93.pdf). Due to the high cost associated with POPs measurements, the monitoring approach is somewhat different than for the other substances

covered by EMEP. A combination of active high-volume air sampling, typically collected once per week, or sampling made over time periods of weeks to months is utilized. Several POPs are semi-volatile and may undergo reversible atmospheric deposition with environmental surface media. Hence, what is measured in air today could represent a legacy of the past. POPs modeling activities which aim to discriminate between primary and secondary emissions in controlling environmental burdens thus also need to take into account the concentrations in other environmental compartments like water, soil and vegetation. The monitoring activity under EMEP directly support the needs outlined by the UNEP Stockholm Convention on POPs as well as by AMAP. Specifically, the global monitoring plan for POPs is a key component of the effectiveness evaluation under the Stockholm Convention on POPs which targets the core media ambient air and human milk / blood only. http://chm.pops.int/Implementation/GlobalMonitoringPlan/MonitoringActivities/tabid/181/language/en-US/Default.aspx However, the Stockholm Convention on POPs largely relies on existing information from various international or regional monitoring programs like EMEP for their regional and global assessment reports. Thus, the EMEP POPs monitoring program is of key importance for the collection of comparable monitoring data not only under CLRTAP, but also for the effectiveness evaluation of the Stockholm Convention on POPs.

Mercury

EMEP initiated its Mercury monitoring effort in the early 1980ies (http://tarantula.nilu.no/projects/ccc/reports/cccr3-86.pdf). Today monitoring is extended to include concentrations in precipitation as well as total gaseous Mercury in air at level 2 sites. Concentrations of speciated Mercury in air is part of the level 3 monitoring programme. Efforts are currently made to extend the monitoring of Mercury towards the Global Scale, and the European Commision has funded a project named Global Mercury Monitoring System (GMOS), where EMEP sites are contributing, and it supports the objectives of the UNEP Mercury Program. Gaseous Mercury is also required by and harmonized with the requirements given in Directive 2004/107/EC.