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Evaluation of the Swedish national air monitoring programme “Programområde Luft”

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Preface

This reports presents an evaluation of the Swedish national air monitoring programme, "Programområde Luft", conducted by NILU – Norwegian Institute for Air Research, on contract by the Swedish Environmental Protection Agency (Naturvårdsverket).

Contents

Preface **2**

1 Introduction **4**

1.1 Disclaimer 4
1.2 Introductory comments on air pollution monitoring efforts 5
1.3 The legal aspects of monitoring obligations 7
1.4 Environmental quality objectives 8
1.5 Individual evaluation of the 12 programmes 9
1. Acidifying and Eutrophying components in air and precipitation 10
2. Ground-level ozone 16
3. Particles in air 18
4. Climate forcers (Svalbard) 21
5. Metals in air and precipitation 23
6. Metals in moss 25
7. Organic pollutants in air and precipitation 26
8. Pesticides in air and precipitation 29
9. SWETHRO-NV 31
10. Match Sweden 35
11. Ozone layer 37
12. STRÅNG 38
1.6 Special project 1 – Acidifying and Eutrophying substances 40
1.6.1 Introduction 40
1.6.2 Discussion 40
1.6.3 Evaluation 42
1.7 Special project 2 – Modelling 45
1.7.1 Introduction 45
1.7.2 Discussion 45
1.7.3 Evaluation: 46
1.8 Additional remarks and major conclusions 48
1.8.1 Institutional aspects 48
1.8.2 Strategic aspects 49
1.8.3 Future directions 50

Appendix A Revisjon programområde luft, notat av Helena Sabelstrøm, 12.03.2015 .... **54**

Evaluation of the Swedish national air monitoring programme "Programområde Luft"

1 Introduction

The Swedish Environment Protection Agency (Naturvårdsverket, NV) have tasked NILU – Norwegian Institute for Air Research, to undertake an evaluation of their national air monitoring programme as a basis for a current revision. In this respect, the programme is evaluated with respect to compliance with monitoring obligations defined by national and international agreements, preservation of important long-term data series and consideration of emerging needs/new priorities. The aim is to provide an independent guide to support national discussions regarding priorities of the activities for the coming years.

The national air monitoring programme consists of 12 individual sub-programs, all tendered on contracts by NV, and undertaken by national institutions being responsible for the daily operations (sites, analysis, assessment of data/model calculations, reporting). This evaluation is based on programme descriptions provided by NV, references provided by the national institutions/contractors as well as a set of consultations with the contractors.

A main focus of the evaluation is to assess the individual programs with respect to whether the current activities satisfy the demands and requirements of various agreements. Considerations have also been made in relation to potential new requirements to come, the identification of important activities which are not legally required, and if activities would benefit from being organized in another way than at present (**"Main project – high priority"**).

The evaluation have assessed activities being particularly important with respect to user needs, their importance for environmental quality objectives and also how Swedish activities relate to what is being done in other countries. Further, considerations have been made as to whether there is a potential for Nordic collaboration (**"Main project – lower priority"**).

Two special projects have also been conducted, one related to **"Acidifying and Eutrophying substances"** discussing the current efforts related to the National air and precipitation programme, the Throughfall programme and Integrated monitoring, and a second related to **"Modelling"**. The latter focus on whether chemical transport models provides good estimates on ambient levels and the deposition of pollutants, how they can be combined with measurements and the associated data needs from observations (number of sites, dry deposition measurements) and if modelling activities can be undertaken in collaboration with other international groups.

Attachment 1 lists the detailed specifications of the evaluation criteria (in Swedish).

1.1 Disclaimer

NILU – Norwegian Institute for Air Research is a non-profit research foundation with speciality in coordinating national and international programmes addressing air pollution issues. In this capacity, NILU undertakes nearly all corresponding activities within Norway to those covered under the Programområde Luft Portfolio. Further, NILU is involved in many international programmes to which Swedish monitoring efforts also are contributing. These include EMEP, where NILU is the Chemical Coordinating Centre responsible for developing the monitoring strategies, and WMO Global Atmosphere Watch where NILU acts in several Scientific Advisory groups, and hosts the World Data

Centres for Aerosols and the World Data Centre for Reactive Gases. NILU is also responsible for the data management of the international databases of OSPARCOM, HELCOM and AMAP, as well as all near surface data from the research infrastructure ACTRIS. The mandate of the evaluation call for an assessment related to Nordic collaboration and where NILU may be a potential partner. Considering these aspects, it has been seen advantageous to establish an independent reference group whom will investigate if any of the conclusions and recommendations made may potentially have been given in the favour of NILUs own interest. The reference group has not contributed to the review and it has no responsibility for any of the conclusions or recommendations given. The recommendations and conclusions are thus fully the views of NILU. The reference group consists of Yrjo Viisanen (Finnish Meteorological Institute) and Thomas Ellermann (Danish Centre for Environment and Energy, Aarhus University). Some minor comments and suggestions were received from the reference group in the finalization of the report (all taken into account), and statements confirming that no conflicts of interest have been found has been communicated to Naturvårdsverket.

1.2 Introductory comments on air pollution monitoring efforts

A review like this will to a significant degree deal with subjective matters where no definite answer exists. We have based our review largely on our own experience and views of which matters are essential in relation to providing information supporting atmospheric research and air pollution policies.

Below are a few remarks on the essence of air pollution monitoring, which have served as a general background to the recommendations and conclusions given:

The activities, which are here evaluated, all represents the continuation of long-term efforts to describe ambient levels and fluxes of atmospheric properties and constituents. Some activities originate back to the 1960ies, and have all gradually developed through an iterative processes involving academia, authorities/funding agencies, policymakers and other users of data. The current approach may thus be considered as a compromise and best practise considering the interests and the funding capabilities of the stakeholders mentioned above, but there may also be cases where efforts may be in need of revisions and improvements.

Typically, the underlying concept/approach has been to ensure that efforts are coordinated to allow the use of data on a regional/European level. These recommendations have often led to international agreements and collaborative programmes, defining the data needs in terms of the number of sites, variables to be measured, time resolution of data, quality requirements, timeliness in reporting etc. Most of these foundations have a multi-decadal scope, and atmospheric science commonly considers time scales of 30-years as appropriate to assess the long-term variability of meteorology alone. Meteorology is clearly having a very strong impact also on inter-annual variability in atmospheric composition and related physical properties, while changes in emission levels typically change less from year to year. It is thus fundamental that there is an overarching goal to develop and preserve long-time series of sufficient temporal resolution and quality to assess physical/chemical properties in relation to air mass origin. Emission levels have changed significantly during the last 4 decades, and particularly those time series that extend long back in time should have priority in the future provided they are still adequate and relevant. It is further likely that future trends will be lower than what we have seen in the past. This sets higher requirements on data quality and intercomparability in the years to come.

Another important consideration is the tendency of funding agencies to gradually shift priorities and interests pending on the public interest and debate. While this relevance in relation to current societal needs, it may also impede the long-term perspective needed to detect atmospheric trends.

Acidification was the major concern in the 1970ies, while in the 1980ies concerns related to Forest damage, Eutrophication, photo oxidants and stratospheric ozone layer depletion came on as major concerns motivating monitoring efforts. During the 1990ies, heavy metals and persistent organic pollutants entered the scene, while in later years, focus has growingly been on particulate matter (health) and climate forcers. It should be noted however, that the observation data often have broad applications and may serve many applications across these environmental topics. A prime example is atmospheric sulphur, which initially was measured to understand acid rain and haze (visibility degradation), but later have been recognized to have fundamental impact on vegetation (forest damage), human health through aerosol mass concentration or high ambient SO_2 concentrations. Further, sulphur components affects cloud formation and yield aerosol climate forcing (SLCP), it's a tracer for volcanic ash (affecting aviation) and potentially the future may bring geo-engineering climate measures to which the historic sulphur time series may prove very relevant. This illustrates the maintaining long-term time series of key variables are essential albeit the specific policy questions posed along may have been answered (e.g. agreements on sulphur reductions to abate acidification). Tailoring the monitoring activities to addressing a specific topic of concern may also result in data series that are not particularly well suited to support other questions. We argue thus that general data on atmospheric properties and composition have broader applications, and should be undertaken in a manner which allows future and potential detection of new changes and challenges. In some cases one will however need to address site-specific or thematic specific information, and have an experimental setup accordingly. As an illustration: ambient concentrations measured at regionally representative sites offer a wider understanding than a traffic influenced urban measurement, as the latter is mainly reflecting very local features.

Another complicating matter in terms of long-term monitoring efforts originates in the somewhat different scope with respect to monitoring undertaken in support of conventions and legislation versus data needs for research. While all long-term data series provide an important basis for assessments and peer reviewed publications, many of the emerging research questions rely on process oriented studies and campaigns, but which ultimately would be useful to continue in a long-term perspective (most ongoing monitoring efforts are actually continuation of past research driven activities). Research funding is normally only available for establishment and development of the infrastructure, and interpretation efforts, and does not cover daily operations and support to sites. Relying on research funding is thus not a good way of securing long-term financing of monitoring data series. Important time series should thus be funded through national monitoring programmes and/or institutional commitments. Existing time series result from a mixed financial sharing between governmental agencies, research-funding agencies and the individual institutions themselves. Any major shifts in funding or other matters related the specific activities should thus be thoroughly discussed with all these stakeholders to find consent on future directions.

Monitoring efforts does also play a role in building national competence and ensuring involvement in international efforts to protect the environment. This is the main reason why monitoring programmes are conducted in a way where national institutions operate the sites and do the analysis, as opposed to a set-up with one centralized international agency (which probably would produce better data and be more cost efficient). The strategic direction of the monitoring efforts will thus enable national competence being available if there are scientific questions to guide policymaking. Observations also play a central role for validation of model-based simulations, normally suffering from significant uncertainties. Our experience is that monitoring should have "research ambitions", and not as just serve to comply with legislation.

1.3 The legal aspects of monitoring obligations

One of the essential questions in the evaluation is whether the obligations to various agreements are met or not. It is important to consider that, in a legal sense, it is only those defined by the European Commission Directives which precisely defines monitoring obligations, as well as having legal penalties in case of non-compliance. The EU legislation defining specific monitoring obligations of relevance for "Programområde luft" are the Directive 2008/50/EC (Air Quality Framework Directive) and the Directive 2004/107/EC (4th daughter Directive), while other Directives and regulations provide more general guidance on required activities.

Public international law, which governs the relationship between states and international entities, relies heavily on conventions based on consent. These have rather weak rules related to compliance and implementation, but are still considered as an efficient way to address international challenges. The major conventions relevant for Air Pollution are (monitoring guidelines in sub-bullets):

- Geneva Convention on Long Range Transmission of Air Pollutants (CLRTAP),
  - EMEP monitoring strategy
  - ICP Forest manual
  - ICP Integrated Monitoring manual
  - ICP Vegetation manual
- Helsinki Convention on Protection of the Baltic Environment (HELCOM),
  - HELCOM monitoring manual
- OSPAR Convention on Protection of the North East Atlantic Environment (OSPAR),
  - Comprehensive Atmospheric Monitoring Programme (CAMP)
- Arctic Monitoring and Assessment Programme (a working group under Arctic Council)
  - (no specific requirements, and implemented through EMEP activities and other efforts)
- World Meteorological Organisation, Global Atmosphere Watch (GAW)
  - Strategic implementation plan (2008-2015)(new plan in development for 2016-2018)
- Framework Convention on Climate Change (UNFCCC),
  - No monitoring requirements, but relates to WMO-GAW
- Stockholm Convention on POPs,
  - (no specific requirements, and implemented through EMEP activities)
- Minamata Convention on Mercury,
  - (no specific requirements, and implemented through EMEP activities)
- Vienna Convention on the protection of the Ozone layer
  - WMO Global Atmosphere Watch

To add to the complexity, several agencies are involved in formulating the specific requirements of these international agreements. Examples of UN agencies (all autonomous) include WMO, UNEP, ICAO and IMO, while the European Union have established the European Environment Agency. These agencies do often establish expert groups where scientist and experts may give strategic directions of new activities. The EU Directives on Air is governed by the European Commission through its Directorate General Environment (DG-ENV)(supranational law). Within individual nations there is also national legislation (often based on international demands, but with specific adjustments to serve national needs), and finally there may be contractual obligations for involved institutes to deliver data based on terms given in contracts e.g. for research projects.

We mainly focus on obligations and demands as defined by international law. We add that in cases where there is divergence between formal obligations from different international frameworks, we have given weight to the “scientifically most sound” position, taking into account recent research findings and discussions in the scientific community.

In the evaluation, we have taken the position that any international agreement to which Sweden is a signatory, the associated monitoring requirements/recommendations should be implemented. In general, these specifications are however vaguely defined, so no exact assessment of compliance vs non-compliance can easily be given. We have tried to add some discussions to these matters under each sub-program evaluation. The evaluation mainly focus on the major focus of the activities, and not minor specifics of the activities related to individual sites or variables measured (although some comments have been included in the discussions below).

1.4 Environmental quality objectives

Sweden has defined a number of Environmental quality objectives (miljökvalitetsmål). These objectives are broad and constitutes some easily identifiable goals for national environmental efforts. In annual reports published by NV, one can find listed specific efforts which contribute to the different objectives, and many of the sub-programmes have as their main objective to provide a basis for describing the situation in relation to these matters, and have in their programme descriptions a clear reference to these. It is however more difficult to quantitatively and qualitatively define the specific levels of ambitions which will be required to actually reach these objectives. Further, the activities included in Programområde Luft will also provide useful and relevant information beyond the objectives to which they are specifically addressing. In the table below we have tried to illustrate how the various programmes are positioned to give specific information related to the various Environmental quality objectives (a comprehensive table listing individual variables at geographical locations cannot easily be given).

	1 EMEP/LNKN	2 PM	3 O3	4 Svalbard	5 HM in air/precip	6 HM in moss	7 POPs/VOC	8 pesticides	9 SWETHRO-NV	10 MATCH	11 ozone layer	12 STRÅNG
1. Reduced Climate Impact	Important	Important	Important	Important	not directly relevant	not directly relevant	Important	not directly relevant	not directly relevant	not directly relevant	Important	Important
2. Clean Air	Essential	Essential	Essential	Important	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Important	Essential	not directly relevant	not directly relevant
3. Natural Acidification Only	Essential	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Essential	Essential	not directly relevant	not directly relevant
4. A Non-Toxic Environment	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Essential	Essential	Essential	Essential	not directly relevant	not directly relevant	not directly relevant	not directly relevant
5. A Protective Ozone Layer	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Essential	Essential
6. A Safe Radiation Environment	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant
7. Zero Eutrophication	Essential	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Essential	Essential	not directly relevant	not directly relevant
8. Flourishing Lakes and Streams	Relevant	not directly relevant	not directly relevant	not directly relevant	Important	not directly relevant	Important	Important	Important	not directly relevant	not directly relevant	not directly relevant
9. Good-Quality Groundwater	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Important	not directly relevant	not directly relevant	not directly relevant	not directly relevant
10. A Balanced Marine Environ-ment, Flourishing Coastal Areas and Archipelagos	Important	not directly relevant	not directly relevant	not directly relevant	Important	not directly relevant	Important	Important	Important	not directly relevant	not directly relevant	not directly relevant
11. Thriving Wetlands	Important	not directly relevant	not directly relevant	not directly relevant	Important	Important	Important	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant
12. Sustainable Forests	Important	not directly relevant	Important	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Essential	Important	not directly relevant	Important
13. A Varied Agricultural Landscape	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Important	not directly relevant	not directly relevant	not directly relevant	not directly relevant
14. A Magnificent Mountain Landscape	Essential	not directly relevant	Essential	not directly relevant	Essential	not directly relevant	Essential	not directly relevant	Important	not directly relevant	not directly relevant	not directly relevant
15. A Good Built Environment	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant
16. A Rich Diversity of Plant and Animal Life	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	not directly relevant	Important	not directly relevant	not directly relevant	not directly relevant

Essential
Important
Relevant
not directly relevant

Table 1: Simplified overview of the relation between individual programs and the Swedish environmental quality objectives (as considered by the evaluator).

1.5 Individual evaluation of the 12 programmes

In this chapter, we review individually the 12 programs in respect to the questions raised as part of the “main project” evaluation. Each programme is only superficially described, and we refer to the programme descriptions provided by NV and the responsible institutions. We have tried to list the guiding monitoring obligations of relevance for each programme, and based our evaluation based on these. Considerations are made with respect to the usage of information, not only by the involvement of the participating institutions and scientist, but also on the impact (as we experience it) on the international level, e.g. for international agreements on air pollution reduction policies, public awareness, research use etc. Further, we have considered national use and needs in relation to the Swedish environmental quality objectives. It should be noted that a thorough mapping of the use and impacts of the various activities across all programmes have not been undertaken. The comments as such reflects thus partly what has been informed by the responsible institution in their introductions and program descriptions. In addition we have made some attempts to assess data usage through looking at published reports, questions during consultations and impressions we have from participation at relevant international meetings.

For each programme we have commented according the following structure:

a. Short introduction to the activities involved
b. Requirements as defined by legislation and recommendations
c. Relevance of data, and are some of special importance?
d. Level of implementation
e. Aspects related to the responsible institution
f. Financial issues and organization
g. Strengths
h. Critical remarks
i. Conclusions and Recommendations

The order of programmes (official names in brackets):

1. Acidifying and Europhying components in air and precipitation (Försurande och övergödande ämnen i luft och nederbörd)
2. Ground-level ozone (Marknära ozon)
3. Particles in air (Partiklar i luft)
4. Climate forcers (Partiklar och klimatpåverkande ämnen på Svalbard)
5. Metals in air and precipitation (Metaller i luft och nederbörd)
6. Metals in moss (Metaller i mossa)
7. Organic pollutants in air and precipitation (Organiska miljögifter i luft och nederbörd)
8. Pesticides in air and precipitation (Pesticider i luft och nederbörd)
9. SWETHRO-NV (Krondroppsnätet-NV)
10. MATCH Sweden (Spridningsmodellering med MATCH-modellen),
11. Ozone layer (Ozonskiktets tjocklek)
12. STRÅNG (STRÅNG – UV-indikator)

1. Acidifying and Eutrophying components in air and precipitation

a. Short introduction to the activities involved:

Includes both EMEP measurements and the national air and precipitation chemistry network (LNKN)(previously two different programmes). This activity provides the basic information to assess temporal and spatial trends in relation to long-range transboundary fluxes of inorganic major components (mainly targeting the CLRTAP Gothenburg Protocol). At the EMEP sites, both time resolution of observations, as well as data quality and intercomparability needs to satisfy the specific data quality objectives as defined by the EMEP monitoring strategy. The LNKN activities have as a main objective to provide regional scale data related to deposition/exposure assessments to ecosystems.

b. Requirements as defined by legislation and recommendations:

The specifics of the EMEP monitoring strategies can be found here: http://www.unece.org/fileadmin/DAM/env/documents/2009/EB/ge1/ece.eb.air.ge.1.2009.15.e.pdf. The strategy lists three levels of ambition (level 1, 2, and 3), and the activities of Programme 1 is addressing several of the EMEP level 1 requirements (i.e requirements for major inorganic ions in air and precipitation (the other level 1 variables are funded through Programmes 2 (O_3), 3 (PM) and 5 (Heavy metals). Level 2 (super site) requirements are funded through programmes 4 (climate forcers) and 9 (POPs). Beyond EMEP, Programme 1 also supports regional scale monitoring of the same substances, but at lover level of ambition concerning temporal resolution and data quality. These data are essential for monitoring regional spatial and temporal trends. They are essential for the Swedish Environmental quality objectives: “Clean Air” and “Natural Acidification Only” and important or relevant to a number of other quality objectives (see table 1). The air concentrations measured are also relevant for the objectives of Directive 2008/50/EC. Concerning particulate matter chemical composition, Annex IV of the Directive specifies that measurements should be done in the $PM_{2,5}$ fraction. It should be noted however that this requirement have been highly debated within the European Air Quality scientific communities, concluding that measurements would, for the objectives specified by the Directive, preferably be done to include also the coarse fraction (i.e PM10 or even TSP). This because omitting the coarse fraction would make it impossible to assess the complete atmospheric budgets of air pollutants. It would also jeopardize the continuation of existing long-term time series, as a shift to PM2,5 chemical composition measurements would probably make it impossible to continue the efforts started in the 1970ies. The nitrogen measurements are also required for the monitoring obligations of OSPAR (http://www.ospar.org/documents?d=33045) and HELCOM (http://www.helcom.fi/action-areas/monitoring-and-assessment/monitoring-manual/inputs/nutrient-inputs-from-atmosphere).

c. Relevance of data, and are some of special importance?

Major inorganic ions in air and precipitation are essential data in relation to air pollution issues. Data are used to assess trends in emissions (to evaluate emission reduction protocols and to provide exposure data to assessments of effect on ecosystems, health, materials and climate). The Swedish data actually gave rise to the discovery and awareness of long-range fluxes of pollutants and effect in the 1960ies and 1970ies. Strikingly, the same variables represents also today essential information to quantify impacts on ecosystems and health, as well as climate forcing and visibility. Some of the Swedish data series are amongst the longest existing in Europe, and should have high priority concerning continuation into the future. Relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation.

Sweden has historically had a very satisfactory implementation of the EMEP monitoring requirements. However, during a number of years, there was a tendency to extend sampling of inorganic components using integration times exceeding 24 hours, and the number of sites were reduced from 8 to 4. The EMEP monitoring strategy indicates a site density of one to two level 1 sites per 100.000 km2 (~4-8 sites for Sweden in total). With 4 sites, this yields a rather poor performance as assessed by the “EMEP implementation index” as this use 2 sites per 100.000 when comparing monitoring efforts (see also explanation in the fact box below).

We present below specifically the implementation for the two activities which are covered by this sub-programme, namely a) inorganic ions in precipitation and b) inorganic gases and particles in air, while ozone, particulate matter and heavy metals is discussed in subsequent chapters. The complete EMEP level 1 index is presented in part II, special project on Acidification and eutrophication.

For year 2013, the latest year for which reporting to EMEP has been completed, the implementation with regards to precipitation chemistry was 33% of the requirements. The corresponding numbers for NO, FI and DK where 38, 36 and 100% respectively. For gases and inorganic particles in air, the implementation was 31%. The corresponding numbers for NO, FI and DK where 62, 53 and 100% respectively.

<u>Comments regarding the EMEP implementation index:</u> The EMEP implementation index provides a simple way to assess intensity and changes in monitoring activities on the European scale. It is based on the actual submission of data to the EMEP database. It should not be seen as a formal verification of the monitoring strategy implementation however, but allow to illustrate activities between countries, as well as changes over time. For a more elaborate description of how the index is calculated, we refer to the following presentation: [http://www.nilu.no/projects/ccc/tfmm/zagreb_2013/tues_morning/08tfmm2013_torseth_Introductionofasimpleindex.pptx.](http://www.nilu.no/projects/ccc/tfmm/zagreb_2013/tues_morning/08tfmm2013_torseth_Introductionofasimpleindex.pptx) In all figures where "EMEP implementation index" has been presented, the numbers have been calculated using the most strict interpretation of site densities for level 1 sites, namely minimum 1 site per 50.000 km2. The strategy actually states that "For the compounds of interest for EMEP, a target site density of at least one to two sites per 100,000 km2 is recommended". As some countries have more activities than what can be seen as required by EMEP, we have used the annotation "100%limit" to specify that numbers may be even higher than presented (this is not valid for any of the Swedish EMEP activities however).

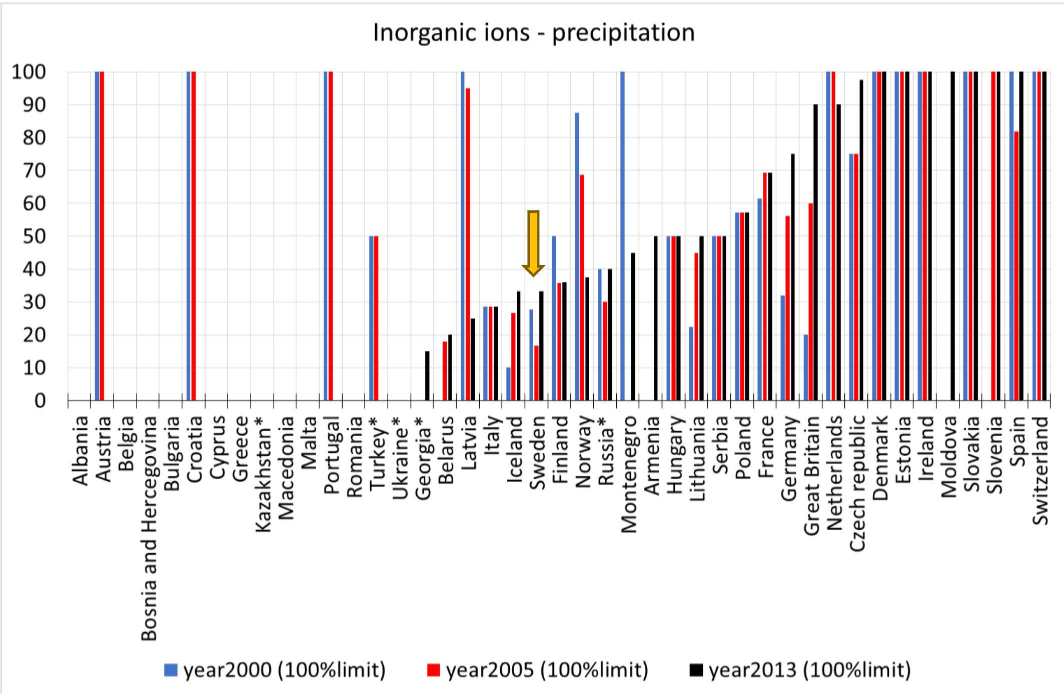

Figure 1: EMEP implementation index – inorganic ions in precipitation

Figure 1 shows the relative implementation of EMEP monitoring efforts addressing precipitation chemistry major inorganic ions across Europe. As can be seen, Sweden, has a relative low degree of implementation as compared to most other western European countries. There is however, an improvement with time compared with years 2000 and 2005 respectively.

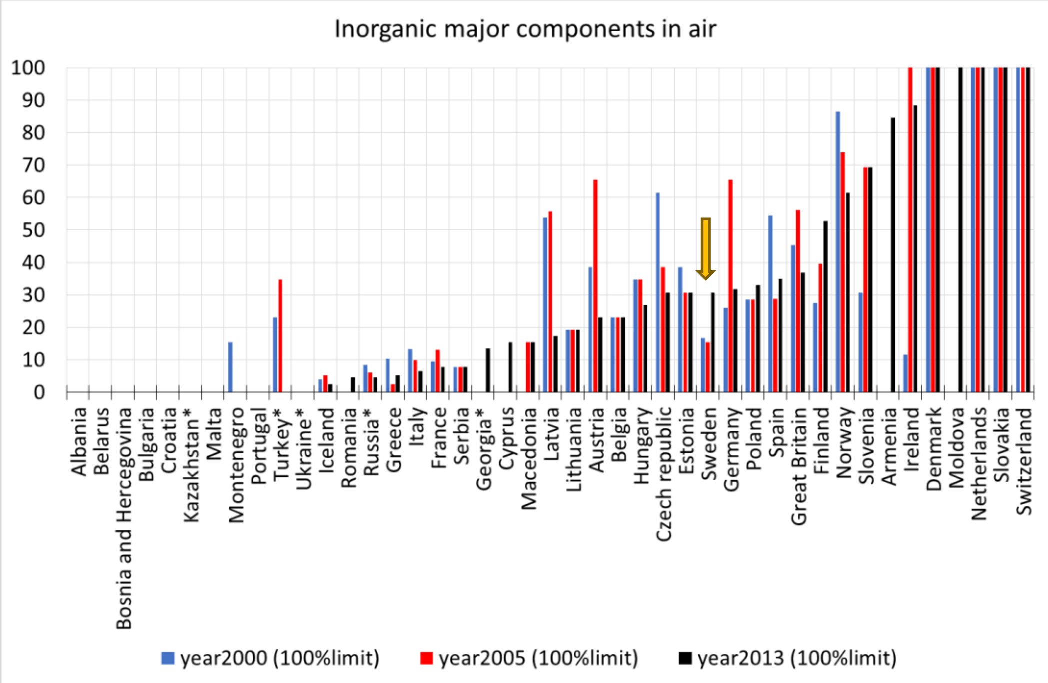

Figure 2: EMEP implementation index - inorganic compounds in air

Figure 2 shows the relative implementation of EMEP monitoring efforts addressing air chemistry inorganic ions across Europe. As can be seen, Sweden, also here has a relative low degree of implementation as compared to most other western European countries. Also here is there an improvement with time compared with years 2000 and 2005 respectively.

The monitoring obligations in OSPAR and HELCOM are less stringent than for EMEP (bi-weekly sampling is accepted in CAMP), but to large extent, they refer to the EMEP and the need for harmonisation and compliance with this programme. Most countries thus use their EMEP programme to satisfy the requirements to HELCOM and CAMP, and when reporting data to the database, this is handled by adding CAMP (Comprehensive Atmospheric Monitoring Program) or HELCOM to the metadata (see also http://ebas.nilu.no). The implementation of OSPAR and HELCOM requirements is thus satisfactory.

e. Aspects related to the responsible institution

IVL is responsible for the program, regarding both EMEP and LNKN activities. IVL is well recognized and have played an essential role in this area since the early days of air pollution monitoring. IVL have accreditation for the methods applied in sampling and analysis, and also participate with satisfactory results in international laboratory intercomparisons. Results from the 32 EMEP intercomparison demonstrate performance well within the data quality objectives for inorganic ions in precipitation and sulphur and nitrogen compounds in air (with the exception of NH_4 for which a deviation from expected value in the order of 100% occurred. This was due to an erroneous calculation in the intercomparison result and the measurement data were thus not affected).

For details, see laboratory number 20 in the tables:
Major ions in air:
http://www.nilu.no/projects/ccc/intercomparison/DQO-luft-32.pdf
Major ions precipitation: http://www.nilu.no/projects/ccc/intercomparison/DQO-G-32.pdf

f. Financial issues and organization

The total costs for the programme is about 3 million SEK. This is in the same order of magnitude as those for similar activities in Norway (exact numbers are difficult to derive due to differences in approach, time resolutions etc.). In general, there are many similarities with how this activity is structured compared with other Nordic countries.

g. Strengths

This is a very mature activity which have provided long and important time series. Data are used to evaluate models describing European scale transport and deposition of pollutants. As emission targets related to Gothenburg Protocol substances is related to the exceedance of critical loads in Scandinavia, the Nordic data are heavily used as fundament for developing efficient abatement policies (CLRTAP and EU). Data are also used to support MATCH-Sweden modelling, and various applications related to deposition and air quality assessments, and many of the components included have high importance also for understanding of climate change over time

h. Critical remarks

The EMEP precipitation measurements is done on a daily basis only at two sites, while another two sites use monthly wet-only sampling. This is very low compared to the recommended site density, and has impact on the EMEP implementation index (see figure 2 above). At LNKN sites, precipitation chemistry is measured using bulk samplers and monthly analysis. International guidelines on precipitation measurements recommends (GAW, EMEP) sampling to not exceed 24 hours, but also weekly sampling may provide data of sufficient data quality to relate observations to emission trends. Monthly sampling is not recommended other than for indicative measurements, and the use of data have more limitations both related to data quality and time resolution to allow assessment of results. There have in the past been problems associated with the Swedish wet-only samplers at EMEP sites, but these have now been replaced.

We note that base cation measurements in air was according to the programme description initiated in 2009 (Sweden was one of the countries which first implemented this change), but only data from 2011 onwards have been reported to EMEP. It would be good if the previous data also could be made available (reporting of these data have later been initiated).

At present, there are no sites in mountain areas. In the past, Sweden operated several sites to quantify levels in high elevation areas. These are ecosystems which may be particularly sensitive, and which now also experience significant shifts in climate. Re-establishing an EMEP-type mountain site would be a good addition to the activities.

The activities include the use of passive sampling for SO2, NO2 and O3, providing monthly data at 9 sites. These data are used for MATCH Sweden model validation/input, and also frequently used for regional/local air quality evaluation of special events (forest fires, volcanic events etc.). The use of these data in the international air quality work is however more limited, due to the preference to high time-resolution data.

Sweden do evidently have low-cost measurements of HNO3/NO3 and NH3/NH4 in air, which is recommended in combination with daily filter-pack measurements at EMEP sites. These data seem however not to have been reported to EMEP (reporting of these data have later been initiated).

i. Conclusions and recommendations

We find it very important to sustain and even strengthen EMEP monitoring. We question if the passive sampling of SO2, NO2 and O3 at LNKN-sites provides essential information and has many applications. It should be considered to evaluate in more detail whether the direction of the monitoring efforts should altered towards fewer sites and more high time-resolution measurements, and reduce “low intensity monitoring” at many sites. Monthly time resolution of precipitation is associated with large uncertainties, and there are several limitations in the application of results. We generally recommend thus to rather reduce sites and increase the number of samples at fewer locations.

2. *Ground-level ozone*

a. Short introduction to the activities involved:

Activities include ozone measurements using continuous monitors at 14 locations (10 rural background and 4 suburban), and in addition is ozone measured using passive samplers at 9 stations (monthly mean values). NO2 is measured using passive samplers at 10 sites. There is additionally 9 passive NO2 sites within LNKN in parallel with passive ozone measurements. Data series of continuous measurements extend back in time to 1984.

b. Requirements as defined by legislation and recommendations:

Ground-level ozone is an essential variable to measure according to the EMEP monitoring strategy (see above for links). Also the Directive 2008/50/EC have a strong emphasis on ozone measurements. This Directive has recently been revised regarding assessment of ozone (Commission Directive (EU) 2015/1480), and these revised monitoring requirements were considered here. The general requirement for rural background is to operate at least one station per 50.000 km2 as an average over all zones per country. Further, the directive recommends 1 station per 25.000 km2 for complex terrain, but we argue that the topography and regional gradients in Sweden is not of a character that this is required. In addition to rural background, there are also requirements for monitoring in agglomerations and other zones in urban background, suburban or rural locations. The level of requirements is dependent upon a zone’s population and whether supplementary assessment techniques are used (e.g. modelling).

c. **Relevance of data, and are some of special importance?**

Ground-level ozone trends are poorly understood by the scientific community, but there is a tendency of increasing levels in background areas, while peak levels in the form of ozone episodes have declined due to European emission reduction measures. Ozone is considered to remain one of the most adverse pollutants affecting population health and damage to vegetation and crops. In addition, ozone is an important short-lived climate forcer. As monitoring of ozone was very sparse before the early 1990ies, it is very important to continue the longest time series. Swedish scientist actually played a central role in compiling the first set of European ozone measurements in the 1980ies.

Grennfelt, P., and Schjoldager, J. (1984). Photochemical oxidants in the troposphere: A mounting menace. Ambio 13, 61-67.

Grennfelt, P., Saltbones, J. and Schjoldager, J. (1987). Oxidant data collection in OECD-Europe 1985-87 (OXIDATE). April-September 1985. Norwegian Institute for Air Research (NILU) OR 22/87, Lillestrøm, Norway.

Figure 3: Illustration of some historic efforts in relation to ground-level ozone.

d. Level of implementation.

The current activities by large can be considered as fairly good as regards to the obligations listed above. The number of sites was increased in 2013 with the introduction of four new suburban sites. A strict interpretation of the directive obligations would (provided that measurements are adequately supplemented by modelling efforts) however call for a further two sites, one in Northern Sweden and one in Middle Sweden, located in either urban background, suburban or rural locations, in order to reach the required site density in all assessment zones. From scientific perspective however, it is reasonable to assume that the current monitoring is adequate to describe rural ozone in Sweden.

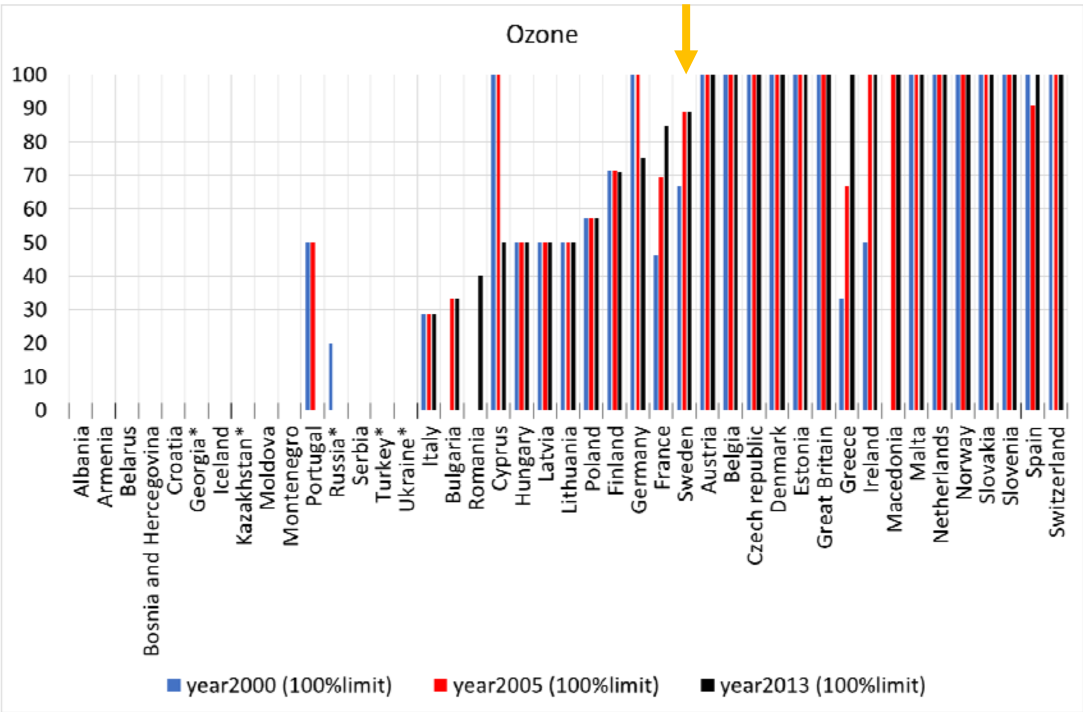

Figure 4: EMEP implementation index – ground level ozone

Figure 4 indicate the implementation of EMEP requirements as regards ozone measurements (note that the number of Swedish sites have increased since 2013, but it not yet reflected in the implementation index as data for 2014 are still being processed at the EMEP Chemical Coordinating Centre (will be ready spring 2016).

e. Aspects related to the responsible institution

IVL is responsible for the program, and in addition is ACES involved with the measurements made at Aspvreten. It's our opinion that the measurements are made according to the required quality standards and is suited for the intended use of data.

f. Financial issues and organization.

The total costs for the programme is about 2 million SEK. This compares well with costs in Norway of similar activities.

g. Strengths:

As mentioned above, the ozone time series represents a very important long-term dataset, of particular importance for the understanding of SLCF over time. The spatial coverage is good. We also find it good that sub-urban measurements of ozone are organized in the same program.

h. Critical remarks:

According to the Directive 2008/50/EC, measurements of NO2 is required at sites where ozone measurements are conducted. To accommodate this, passive sampling with monthly time resolution has been initiated (sufficient according to the Directive requirements at rural sites). While this may be sufficient to be in compliance with the specific requirements, it is unclear if these data provide any essential information. We rather suggest to increase the use of trace level monitors of NO2 at least at one additional rural location.

i. Conclusions and recommendations

The programme has a clear focus on operating the ozone measurements as required by EMEP and Directive 2008/50/EC. Activities mostly satisfy the obligations, but we recommend extending activities to deliver a stronger contribution to ozone precursor evaluations (this is discussed in more detail elsewhere), i.e to extend measurements of continuous NOx and VOC instrumentation in accordance with EMEP level 2 supersite requirements for photooxidants.

3. Particles in air

a. Short introduction to the activities involved:

Activities include measurements of PM2,5 mass, PM10 mass and soot/black smoke concentrations at 4 rural sites, and of PM2,5 mass at 3 urban background sites. At two sites, there is also measurements of aerosol size distribution and concentrations of elemental and organic carbon.

b. Requirements as defined by legislation and recommendations:

Particulate matter measurements is required according to the EMEP monitoring strategy, as well as by Directive 2008/50/EC. Paragraph (8) of the Directive emphasise that measurements at rural background locations should be made in a manner consistent with those of EMEP. While EMEP has its main emphasis on concentrations of individual chemical species, there has been a gradual increase on the efforts on aerosol mass concentration measurements after particulate matter was added to the EMEP programme in the late 1990ies. In the specifics of the monitoring requirements there is however some minor deviations in approach between EMEP and the EU Directive. For a more elaborate description of this, we refer to this page:
www.nilu.no/projects/ccc/emep_monitoring/index.html.

c. Relevance of data, and are some of special importance?

Particulate matter is a major air pollutant and represents the most serious health threat associated with air quality on the global scale. Also in Europe, there are large regions where population is exposed to harmful levels even at the regional scale, distant from local sources. At background locations in Scandinavia, levels are generally quite low, but still PM mass concentration information provides important information related to regional scale transport and effects. Long-range transport may during episodes yield very high concentration levels, and the background contribution to local air pollution may be considerable. Recent research also indicate that health effects may be significant even at ambient concentrations lower than used as current air quality limit values. Further, particulate matter has impact on the atmospheric radiation balance and is important to monitor for understanding the climate system. This calls also for advanced aerosol measurement like aerosol physical and optical properties. Such measurements are partly included here, but also in Programme 4, climate forcers. It is thus key to operate a good particulate monitoring programme. The $PM_{2,5}$ and PM_{10} mass measurements are used assess exceedance of limit values, and to assess the mass closure in aerosol modelling. It is further fundamental to have data on concentrations of the chemical composition of gases and particles in air. There activities of Programme 3 should be seen complementary to programmes 1 and 4. The relevance for Swedish environmental quality objectives is illustrated in Table 1.

d. Level of implementation.

The current implementation is below compared with the requirements given in the EMEP monitoring strategy (based on data reported for 2013).

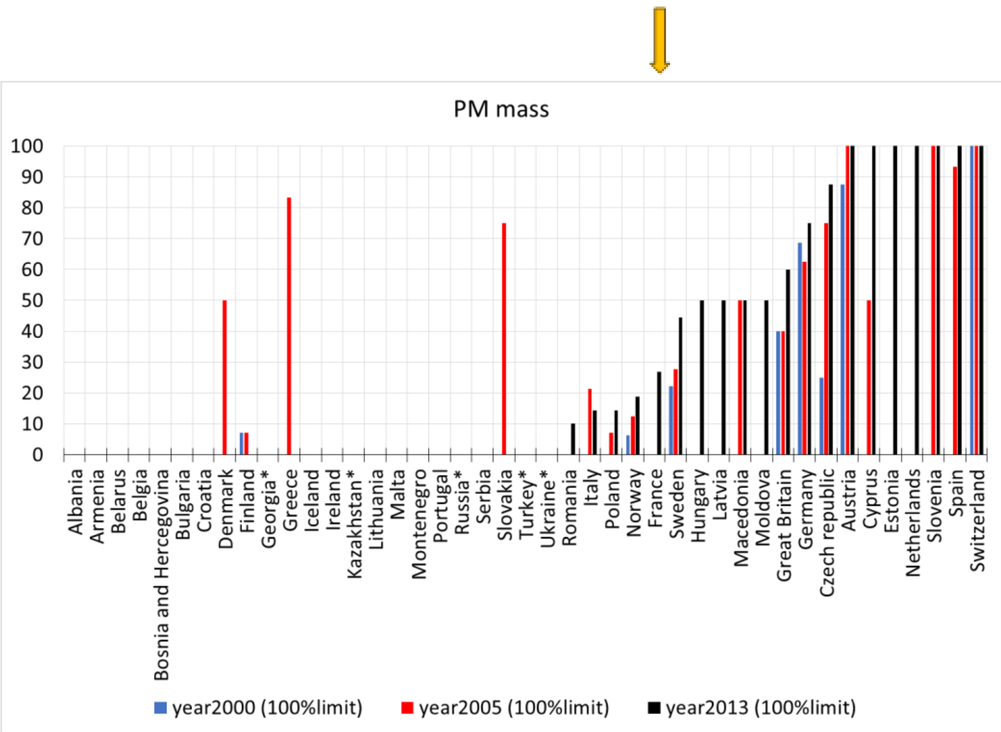

Figure 5: EMEP implementation index – PM mass

Figure 5 indicates the implementation of EMEP requirements as regards PM2,5/PM10 mass measurements. As can be seen, the implementation is generally quite poor on the European scale and that Swedish implementation is about 45%. The other Nordic countries have also very low numbers. This resembles a rather low interest and use of the PM mass concentration data from Nordic background sites, all having quite low concentrations. In the case of Norway, we have also concluded that in a situation with no additional financial resources, there has been no room to extend efforts, as this would ultimately terminate other long and important time series.

e. Aspects related to the responsible institution

Both IVL and ACES have extensive experience with respect to particulate matter measurements. The methods used generally follow international recommendations, and have accreditation. The IVL gravimetric PM method has yet no approval as being equivalent to the reference method, but such an application is currently in review. Both institutions have participated in equivalence testing and CEN working groups, and they are represented in AQUILA, the network of European reference laboratories.

f. Financial issues and organization

The total costs for the programme is about 1,5 mSEK. It is however likely that the actual costs may be significantly higher, and in particular the efforts by ACES (receiving about 0,5 mSEK) has substantial institutional contributions. This is not considered as sustainable funding mechanism, making this activity vulnerable.

g. Strengths:

The particulate mass measurements complements the activities ongoing within the other air programmes, utilizing the same sites. We consider the activities towards physical and optical properties, and of elemental and organic carbon to be very important and should have priority.

h. Critical remarks:

The particulate matter measurements generally extends relatively short back in time as compared to the chemical monitoring. For mass measurements, most activities started after year 2000 when EMEP included particulate matter to its programme (according to Table 1 in the programme description, Aspvreten initiated PM_{10} measurements already back in 1990, and we encourage the reporting of these data to EMEP).

Soot has been measured using the "black smoke" method since the 1980ies. This method is today considered obsolete, and is not used to any significant degree in any air quality monitoring activities elsewhere. A particular challenge is that ambient levels are below the methods level of detection. While sustaining such very long time series for variables which still have significant interest (being relevant both for health and climate research) is commendable, it seems likely that one would benefit from reassessing the current approach. One option is to increase sampling times to ensure that sufficient material is collected on the filters, or to terminate this activity and prioritize other activities instead. We note that the cost for continuing the efforts are rather low however.

i. Conclusions and recommendations

The program includes a comprehensive set of particulate matter measurements. While the "implementation index" may seem somewhat low as regards particulate matter mass concentration measurement, we conclude that the levels of ambition are adequate. As particulate matter is related to VOCs and the formation of organic PM, it could be considered to establish the photooxidant level 2 activities at one of the most comprehensive sites for aerosol measurements, namely Vavihill or Aspvreten. Råö is also a relevant location, but as the Birkenes site in Southern Norway has a similar programme, it could be advantageous consider a site representing a more continental environment.

The black smoke measurements could be re-considered, and maybe be replaced at a few sites by other methods with an overlap period to link to historical data and time series.

4. Climate forcers (Svalbard)

a. Short introduction to the activities involved:

The program includes measurements of aerosol number concentration, aerosol size number concentration, aerosol absorption ("black carbon"), aerosol scattering properties and elemental/organic carbon concentrations at Zeppelin Mountain, Svalbard. Activities complement those undertaken by NILU – Norwegian Institute for Air Research at the same location, and ACES and NILU together provide essential data to describe pollution and climate in the Arctic region.

b. Requirements as defined by legislation and recommendations:

All variables included in the programme can be defined as fulfilling the "supersite" requirements of EMEP and GAW. According to the EMEP monitoring strategy, Sweden should operate at least one aerosol Level 2 site. This is met (Vavihill, recently moved to Hyltemossa). Including, Svalbard, Sweden operates 2 sites with short lived climate forcers. The EMEP and GAW sites in Europe have through a funding opportunity with EU research infrastructures received project based support to improve the methodologies, and operation of atmospheric supersites. The current project supporting this is ACTRIS-2, to which ACES is not a partner, but can participate in joint meetings to discuss data and best practice. It should be noted however that ACTRIS-2 provides no financial support towards any of the site operations or maintenance of measurements, but only to develop improved methods, harmonisation, implementation and usability of data etc. The ACTRIS-2 partners are however expected to provide all essential variables requested by the EMEP/GAW requirements. There is only about 30 sites across Europe which have comparable measurement programmes, and they form a core of research based monitoring activities in relation to EMEP and GAW.

c. Relevance of data, and are some of special importance?

The efforts undertaken provide very important data related to aerosols in the Arctic. As such, the data supports both air pollution and climate research. The Zeppelin site is a very important location, offering excellent facilities and easy access, and at the same time having only little influence from local activities. It is thus considered to be a "global background station" in the WMO-GAW site definitions. Due to its location at 470 meters above sea level it has frequently also fog or cloudy conditions, and the site offers possibilities to study the impacts of particles on cloud properties (relevant for climate system research). The relevance for Swedish environmental quality objectives is illustrated in Table 1.

d. Level of implementation.

The current implementation satisfy the stated needs of EMEP and GAW, and we consider the activities to be in full compliance (taking the complementary activities of NILU into account). Additional variables may be useful to include in the future, however these will then mainly be defined by research needs rather than obligations to the mentioned monitoring frameworks (it is thus not discussed further in this evaluation).

e. Aspects related to the responsible institution

ACES have extensive experience in operating advanced measurements in Arctic conditions since decades. They participate in the international community activities and provide their data to international databases like EMEP and GAW for scientific review. The methods applied represent state-of-the-art.

f. Financial issues and organization

The financial model for this programme is somewhat different compared to the general model applied in most other programs. The total costs are estimated based on actual costs for personnel, travels and consumables etc, but there are no funds related to instrument investment maintenance or replacements. The rent for housing Swedish equipment at Zeppelin is currently being paid by the Norwegian Climate and Environment Department (500 kNOK per annum). ACES contribute using institutional funds to cover about 500 kSEK, while the NV funds about 900 kSEK. This is not considered as sustainable funding mechanism for provision of long time series for atmospheric composition, making these data series and activity vulnerable. We find that the costs are about similar to those in Norway for the same type of measurements (the hourly rates of ACES are low compared to NILU rates, but efforts involved are higher).

It should be taken note that ACES states that it is difficult for them to sustain current level of institutional support.

g. Strengths:

The ACES activities at Zeppelin complement those of NILU and together the site offers a comprehensive monitoring site satisfying the requirements of international programmes like GAW and EMEP. In addition, the data supports climate system research in general, and secures Swedish activities and presence in Ny-Ålesund.

h. Critical remarks:

The funding situation needs attention. Housing costs are currently covered by Norwegian authorities as there is no Swedish funds allocated for this purpose. There is some concerns expressed related to needed replacements and upgrades of instrumentation. EC/OC data have not been finalized and made public yet.

i. Conclusions and recommendations

The financial situation in relation to ACES activities at Svalbard should be discussed with the relevant stakeholders of the activity. As the activities is also related to the SIOS ESFRI-initiative as well as other European scale research initiatives, there needs to be discussions that also include Vetenskapsrådet.

We recommend also that the cost model for the activities takes into account the need for instrument upgrades and replacements in the future, and that operating costs at Svalbard is fully included.

5. Metals in air and precipitation

a. Short introduction to the activities involved:

The program includes monthly measurements of heavy metals (10 elements) in precipitation at 4 sites, and at 3 of these sites bi-weekly measurements of mercury are performed. Mercury is also measured on a bi-weekly basis in collaboration with FMI at Pallas in Finland. In addition, heavy metals (10 elements) in air is measured at 4 sites using a PM10 cut-off, with monthly sampling (50% time coverage). Mercury in air (TGM) is further measured at 3 Swedish sites and at Pallas in Finland, but with different approaches with regards to time resolution etc. In addition, TPM (Total Particulate Mercury) is measured at one Swedish site and at Pallas in Finland. Heavy metal activities was initiated in the 1980ies, whereas Hg activities started in the early 1990ies.

b. Requirements as defined by legislation and recommendations:

The main motivation of the measurements are to comply with the EMEP monitoring strategy, and of Directive 2004/107/EC, but data are also used to provide a basis for national assessments and regional assessments (i.e for AMAP, OSPAR and HELCOM). Precipitation measurements are required as part of the EMEP level 1 obligations, while heavy metals in air are variable defined for level 2 sites. Specifically, the requirements at level 2 is as follows: "For heavy metals, the level- 2 programme includes air concentrations of cadmium (Cd) and lead (Pb) (with copper (Cu), zinc (Zn), arsenic (As), chromium (Cr) and nickel (Ni) as a secondary priority) and mercury (Hg) in air and precipitation".

c. Relevance of data, and are some of special importance?

Heavy metal concentrations have generally been declining due to emission reduction efforts in Europe. Level of Hg have however not been significantly reduced during the last two decades, and there are high levels in Scandinavian lakes and rivers of concern for human health. Recently, an international convention on Mercury was established to extend effort on the global scale. The Swedish activities in relation to heavy metals have established some important time-series that preferably should be continued, i.e. Sweden has one of the longest time series of Mercury in both air and precipitation. The relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation

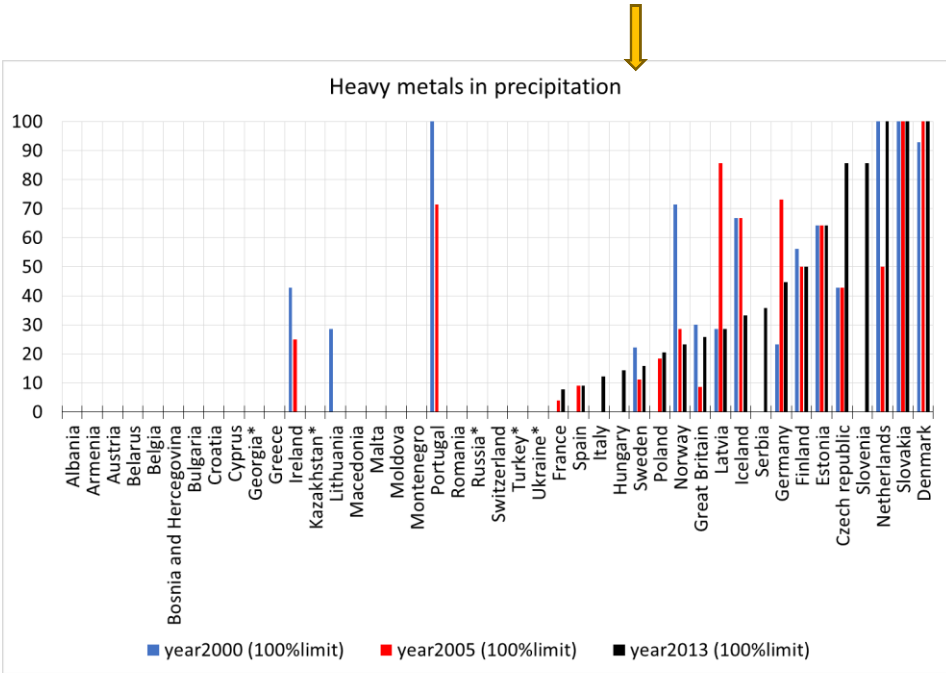

Figure 6: EMEP implementation index – heavy metals in precipitation

Figure 6 compares the implementation of EMEP level 1 heavy metal requirements across Europe. As can be seen, the Swedish (and Norwegian) implementation is low as compared to Finland and Denmark. The numbers do however not take into account the fact that activities are shared at the Pallas station (this is credited Finland in this figure). There exists no European scale comparison regarding the implementation of level 2 activities on heavy metals, but clearly Sweden have important and strong contributions in this respect. The activities are in accordance with the requirements as defined by Directive 2004/107/EC.

e. Aspects related to the responsible institution

The activities are undertaken by IVL, and as for the other programs they have a very well documented quality assurance system. Results from the most recent EMEP laboratory intercomparison shows that IVL had very satisfactory results (see lab 20 at this page: http://www.nilu.no/projects/ccc/intercomparison/DQO-H-32.pdf)

IVL is a leading international institute in respect to Hg research and participate in most relevant international activities on this subject.

f. Financial issues and organization.

The annual cost of the activities is about 1 mSEK. This is accost which seem reasonable considering the range of activities included.

g. Strengths:

A main strength of the program is the long time series using comparable methods. There is also a strong focus on air measurements, and particularly of mercury where few other countries undertake a more comprehensive programme.

h. Critical remarks:

For wet deposition, a scheme of monthly sampling and analysis is employed. This introduce limitations in the possibility to study concentrations in relation to air mass origin. The same is valid for air sampling, but here the quality aspects are less critical, and there are fewer artefacts to be expected than in relation to precipitation sampling. To compensate for the long sampling intervals in precipitation, three parallel samples are collected. The cost associated with operating a weekly scheme is not extremely higher than the current approach (assuming that duplicates can be omitted).

i. Conclusions and recommendations:

Sweden has a comprehensive heavy metal monitoring program, and in particular for Mercury components. A Tekran Hg-monitor has been established at Råö through EU-funding. It would be useful to sustain these measurements also after the project ends, as only very few sites offer Mercury speciation data in Europe. It might be considered to shift from monthly to weekly sampling in precipitation, but this will have cost implications and may have impacts on the existing time series.

6. Metals in moss

a. Short introduction to the activities involved:

Moss is directly exposed to atmospheric deposition of heavy metals and has since decades been used as an indicator of the actual fluxes. There exists a high spatial resolution network from where moss samples are collected and analysed. The number of locations is about 600. The data are used to resolve both temporal and spatial trends for selected elements (As, Pb, Fe, Cd, Cu, Cr, Hg, Ni, V and Zn). Moss surveys are conducted every 5 year (last was in 2015).

b. Requirements as defined by legislation and recommendations:

Moss surveys was initiated by Scandinavian scientists, and have later been included into the work programme of the CLRTAP Working Group on Effects, International Cooperative Programme on Vegetation (ICP-W). ICP-W is one of several ICPs supporting the Convention with information about the efforts of pollution on ecosystems, materials and health. The moss survey data is used by EMEP in the development, improvements and validation of Chemical Transport Models describing source–receptor relationships. They here mainly serve to validate the models capabilities to resolve spatial gradients. The legal obligations enforcing implementation of the monitoring programmes of WGE-ICPs is as described above rather weak. The Moss Monitoring Manual of ICP-W states the following in relation to sampling densities of the surveys: " Similar to previous surveys each country should aim to collect at least 1,5 moss samples per 1000 km2". This corresponds to 616 samples to meet the requirements, and the actual number for 2015 was 613 samples.

c. Relevance of data, and are some of special importance?

As mentioned above, there are several neat aspects related to moss surveys. It is probably the cheapest way to monitor long-term trends in deposition levels, but the method has also some significant limitations (concentrations in moss is not a true measure of atmospheric deposition and time resolution is very low). The relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation.

The approach utilized in Sweden is similar to the others Nordic countries. As describe above, the existing activities represents a full implementation of the requirements.

e. Aspects related to the responsible institution

IVL has participated in moss surveys since 1975, and all applied methods are included in the quality assurance system employed. The performance in laboratory intercomparisons show that the laboratory performs very well.

f. **Financial issues and organization: The overall cost for 2015 is 1,4 mSEK. The corresponding** cost in Norway is about 1,6 mNOK. The Norwegian activity covers moss sampling at 232 locations (reduced from 464 since previous survey), and analysis of heavy metals (POPs are also measured, but through another project).

g. Strengths:

Time series exists back to 1975 and the surveys offer a high spatial resolution dataset on heavy metals. Sampling is done in association with other field work activities, and thus is cost efficient. The data are coordinated and used on a European level.

h. Critical remarks:

There seems to have been no direct studies related to the relationship between deposition as measured using moss surveys and wet deposition at individual sites within Sweden. Nor has there been a thorough assessment of the sampling density required to resolve the key objectives of the studies. Sampling numbers corresponds well to the requirements of the manual. There are suggestions to expand moss surveys to include nitrogen components and POPs. Due to the significant costs associated with such an expansion, we recommend a careful assessment of the applicability of moss surveys for these substances.

i. Conclusions and recommendations:

It is recommended to continue moss surveys at the current level of ambition. If cost reductions are required, we recommend that the 5-year turnover is maintained (both to correspond with what is done in other countries, but also since this will ensure continuity and continuous involvement by the staff members having expertize), and that one re-consider the number of sampling points needed to reflect the trends. A special study using statistical approaches based on existing data should give useful insight on this matter. An advantage of moss surveys is that the collected material can be analysed also at a later stage, should there be specific findings requiring more in-depth information.

7. Organic pollutants in air and precipitation

a. Short introduction to the activities involved:

The program includes measurements of organic pollutants in air and precipitation at four background locations (POPs are measured at three EMEP-sites and PAHs are measured at one site) from southern to northern Sweden. The measured POPs include seven PCBs, HCB, 15 Organochlorine pesticides, eight Brominated flame retardants, two PFAS, 17 Dioxins and Furans, and short and medium-chained Chlorinated paraffins. Not all compounds are measured at all sites. In addition, Volatile Organic Compounds (VOCs) are measured at one urban background station in Gothenburg.

b. **Requirements** as defined by legislation and recommendations:
POP measurements are required according to the EMEP monitoring strategy, OSPAR and HELCOM, as well as by AMAP (Arctic Monitoring and Assessment Programme). The latter follows an ad-hoc rather than operational data reporting approach, i.e. there are no obligations to submit data on an annual basis. Rather, data are collected in relation to special assessments, and data are then in principle restricted and only available for the involved scientists. The Scandinavian sites (including the Swedish Pallas activities) however report their OSPAR, HELCOM and AMAP data as part of the EMEP reporting on an annual basis and is thus public. POPs are also regulated by the global UNEP Stockholm Convention, but no separate monitoring obligations exists here, rather POP data are collected on a global scale for the Global Monitoring Programme and it is expected that the EMEP requirements and reporting will be utilized for EMEP sites. PAH measurements are required by the EU Directive 2004/107/EC, and VOC measurements are done in response to the EU Directive 2008/50/EC. PAHs and VOCs are also required at EMEP level 2 sites on photooxidants.

c. Relevance of data, and are some of special importance?
Monitoring of POPs was established in the early 1990ies, and with time there has been a growing interest and concern about POPs in the environment. While some substances demonstrate declining trends as a consequence of control strategies (regulated/banned), others are still found at high levels (e.g. unintentionally produced substances, like HCB). New substances with POP-like characteristics are continuously being introduced (as replacements for banned POPs or with novel purposes) calling for a system which can detect their presence and potential harmful effects at an early stage. Scandinavian institutes are at the forefront of this research area, and the background monitoring is combined with various screening studies and measurements in other environmental compartments. The relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation.
In general, Sweden complies with the above mentioned monitoring obligations (although the obligations are loosely defined). However, the approach is somewhat different to what is done at most other European sites. The focus of the Swedish monitoring strategy for POPs and PAHs is mainly in long-term (monthly sampling) and there is little data to support studies of concentrations in relation to air mass origin for source-appointment. The PAH and VOC measurements have a low level of ambition, and the main purpose seem to be the formal requirements of the directives rather than scientific use of data.

e. Aspects related to the responsible institution.
IVL has a very well documented experience in the measurements included, and can document adequate quality assurance procedures. They are also active in related research projects and screening studies utilizing data. This contributes to quality assessments and more use of information and results.

f. Financial issues and organization:
The total costs of the activities is approximately 2 mSEK per annum. These costs are low as compared to Norwegian activities (which is based on weekly sampling).

g. Strengths:

The monitoring activities have produced long time series of data which are highly needed to understand POPs in the environment. Data are used in combination with screening studies and other methods to assess atmospheric abundance and transport. As there are relatively few sites elsewhere in Europe (and even globally), the sites of the Nordic countries become even more important.

h. Critical remarks:

The sampling strategy for POPs relies on long sampling integration times and has thus a rather poor time resolution. This limits the usefulness of data for comparisons with atmospheric transport models, which rely on time-resolution of preferably 24 hours or less. Due to the low levels of POPs in air, high time resolution sampling would however result in low sampled air volumes and problems with the levels of detection. The usefulness of the current approach is also evident in relation to screening studies and to provide results to users which do not rely on highly time-resolved information.

The monitoring of VOC have several limitations, and it is questionable if the effort allows to address the broader objectives as outlined by the Directive. The main objectives of the VOC monitoring requirements 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 attribute emission sources to observed pollutions concentrations. It should be noted that these objectives are the same as those of EMEP in relation to ozone precursors. In the EMEP community however, the recommendation is to address this by having VOC measurements at rural sites rather than at and urban background sites or suburban site, as required by the Directive (while such sites also provide information, this will mainly reflect local conditions and cannot be extended to the regional scale ozone precursor concentrations). By having such measurements at EMEP sites however, a much lower number of sites would be required). VOC monitoring should preferably be done with sufficient time resolution throughout the year. Examples of the use of VOCs data in EMEP can be found in
http://emep.int/publ/reports/2015/EMEP_Status_Report_1_2015.pdf

During the review, it was discovered some gaps in the historic time series of POPs being reported to EMEP (Figure 7). We recommend that the submissions to EMEP is reviewed to identify if there are any datasets available that have not been reported.

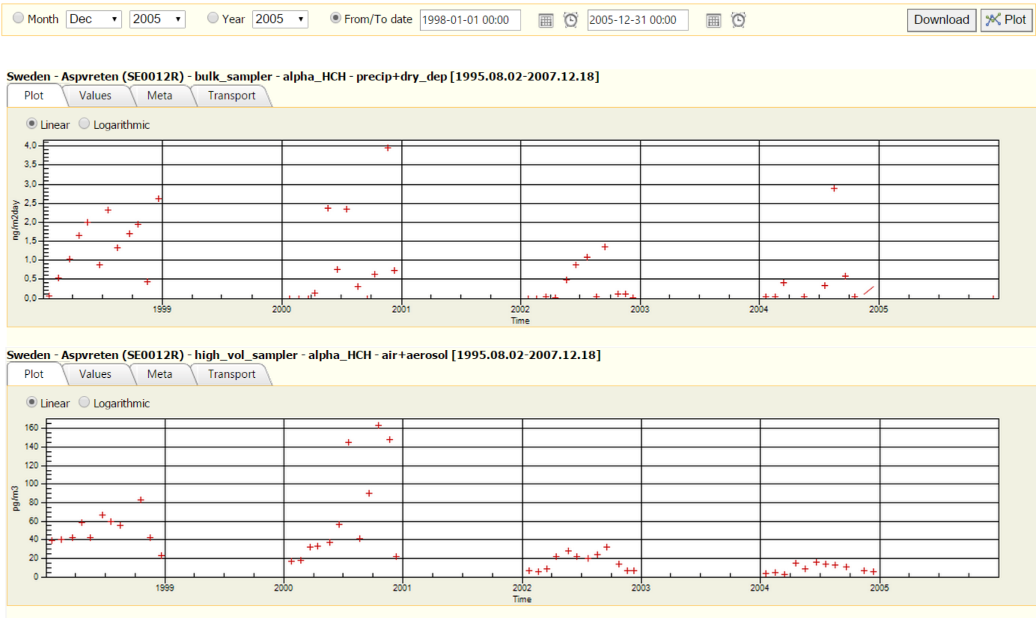

Figure 7: Illustration of gaps in POP time series

While looking at data, we also noted that HCB concentrations in air are very low as compared to what is measured at Norwegian sites (not shown here). We assume this is due to sampling artefacts, and it would be worthwhile to investigate the reasons of this deviation.

i. Conclusions and recommendations:

The list of POPs measured is seen as comprehensive and adequate considering the current monitoring obligations. It could be considered however to expand the list of substances should e.g. screening studies or other information indicate additional needs in the future. As most of the POP monitoring relies on monthly analysis, it should be considered to complement activities with campaigns or even operationalize short-term sampling intervals at one site (in particular for the emerging components, this would be important). One option may be to give this priority in relation to pesticide monitoring for which levels are quite low at sites distant from local sources.

The approach for VOCs monitoring should be reconsidered, and we recommend at establishing a complete level 2 photo-oxidant precursor site as recommended by the EMEP monitoring strategy. The location of this effort should take into account the already existing activities elsewhere in the Nordic countries. We also recommend that the VOCs activities are administratively closer linked to the efforts towards ground-level ozone, and NOx (programs 1 and 2).

8. Pesticides in air and precipitation

a. Short introduction to the activities involved:

The program includes measurements of pesticides in air and precipitation at two locations in Skåne (Vavihill, moved to Hallahus in 2016) and Södermanland (Aspvreten). These two sites offer information of many other variables measured through other programs. The focus is on agricultural areas, and atmospheric measurements are complemented with analysis of run-off water, groundwater and sediments. Deposition sampling is run continuous during the summer-half-year, whereas air sampling is more intermittent but at a fixed schedule during April- October. The measured pesticides include regulated OCPs and current-use pesticides.

b. **Requirements** as defined by legislation and recommendations:
Pesticides are priority substances under a number of international conventions including EMEP, OSPAR, HELCOM, Stockholm Convention on POPs, and there are several EU Directives and Regulations relevant for the control of environmental release of such substances to the Environment (e.g. Water framework Directive and the regulation EC 1107/2009 concerning the placing pesticides on the market). It is however difficult to find a concrete reference to the monitoring requirements associated with these substances beyond the ones for the above mentioned UN Conventions. It is our interpretation that the current activities represents a bottom-up approach, forming a network of research institutions having operated a set of stations since about 2002.

c. Relevance of data, and are some of special importance?
Information on ambient levels of pesticides in air is important to assess the impacts on ecosystems affected by local agricultural practises (use of pesticides). It is also important to obtain monitoring data in advance of regulations. The relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation.
As mentioned above, any precise formal requirements of this activity is not defined, and the efforts are of a rather low level of ambition with respect to sampling strategy. While the number of substances is very good (nearly 140 individual components measured), the sampling only includes about 10 air samples per season at one location. The main usage of information is in relation to national environmental quality objectives and also feedback to the pesticide regulatory authority.

e. Aspects related to the responsible institution:
The activity is led by the Swedish University of agricultural sciences (SLU), and the involved staff can documents substantial experience of relevance for the activities. The laboratory has accreditation for the methods used.

f. Financial issues and organization:
Total costs for 2015 is about 0,5 mSEK, which seem appropriate considering the costs of operating laboratory facilities for pesticides. Potentially this activity could be more closely linked to the “organic pollutants in air and precipitation” programme, but it is not evident that this will add significant benefits.

g. Strengths:
The activity provides a direct measure of ambient levels of pesticides in two areas with local agricultural activities, and supports national assessments and awareness related to regulated and current-used pesticides. The activities is combined with complementary measurements in surface water, groundwater and sediments, and contributes to a complete monitoring effort related to pesticides in the environment at these two locations.

h. Critical remarks:

The usefulness of these data for more broad based atmospheric transport of pesticides is more limited (due to the fact that there are no year-around measurements, and partly also because samples may be affected by local emissions of some of the substances measured). The approach differs from the one applied for monitoring regional scale transport of organic pollutants, and there seem to be no close connection between these two activities.

i. Conclusions and recommendations.

The activities represents a useful contribution to the national monitoring of the environmental fate of pesticides, and supports assessments related to environmental quality objectives as expressed by NV, as well as the agricultural sector.

9. SWETHRO-NV

a. Short introduction to the activities involved:

The program includes NV-funded part (SWETHRO-NV) of a national effort to monitor atmospheric deposition to forests (SWETHRO). Precipitation samples are taken both in open field, and under forest canopies to quantify both wet- and total deposition. The program also include the use of "artificial surfaces" – Strängprov (SP). soil water (markvatten – MV) and air concentrations (gases only). In total, 19 locations are included in SWETHRO-NV, while another 50 locations are operated under a separate programme(s). The NV financial contribution is thus in the order of 14% to the total cost of the Swedish throughfall programme (SWETHRO). Of the 19 sites, 10 sites have also SP measurements funded by this programme, and 1 site have MV and 1 site measure air concentrations of SO2, NO2, NH3 and O3 using passive samplers.

b. **Requirements** as defined by legislation and recommendations:

Deposition measurements to forest ecosystems is on the international level an activity governed by the CLRTAP WGE ICP-Forest programme. ICP-Forest have several (8) sub-programmes, including one on Deposition and another on Ambient air quality. The monitoring efforts are discussed in a process involving national experts, and the resulting programme has been included to the ICP-Forest manual (http://icp-forests.net/page/icp-forests-manual), e,g, part XIV on deposition and part XV on ambient air quality. The ambitions of ICP-Forest is to operate a set of regional so-called level II sites, which are sites where comprehensive measurements of the relevant variables affecting forest ecosystems are made. Quote: *"Deposition monitoring must be representative for the site and it is recommended that measurements should be made, as far as possible, on all Level II sites. If deposition is only measured on a selection of plots, it is recommended to choose them in such a way that they are spatially well distributed over the country."* ICP-Forest deposition measurement are used as a measure of the exposure to each site as such, and there is generally no overall goal to provide deposition or exposure estimates on a regional or national level. ICP Forest have in total about 550 Atmospheric deposition sites in operation, as compared to about 150 EMEP sites.

In addition to the international efforts related to forest deposition monitoring there is a significant national interest and use of such information. This national need/use seem to be the main motivation of the Swedish activities, and there are no funds available to allow strong engagement in ICP forest. The SWETHRO-NV program must thus mainly be evaluated in relation to its relevance in relation to national needs.

c. Relevance of data, and are some of special importance?

Forest ecosystems are very important as they represent an important trade, and is fundamental for biodiversity reasons. Potential effects of pollutants, particularly through altered soil chemistry and species composition occurs on timescales of many decades, or even at centennial scales. Sustaining long time series of forest ecosystem data is thus important, also in relation to more recent concerns like climate change, ecosystem services etc. While the long-term changes in deposition can also be derived from other monitoring networks, it is very useful for forest research activities to sustain the throughfall activities, including deposition measurements at a regional level. The relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation.

The full SWETHRO activities stand out as quite comprehensive compared to the level of ambition in the neighbouring countries. We note also that the programme includes the use of artificial surfaces sampling to study dry deposition processes. It should be noted that this method have some limitations as regards to representing the actual dry deposition of gases and particles to a forest ecosystem, and that it has historically not been broadly applied across the network of ICP Forest level II sites in Europe.

e. Aspects related to the responsible institution.

IVL is responsible for the coordination of the activities, and of the analysis and interpretations of data. There is close collaboration with other agencies related to sampling etc. Methods are quality assured according to the accreditation of IVL. There is evidently a very interested group of scientist working with the results.

f. Financial issues and organization.

The annual budget of SWETHRO-NV is about 0,45mSEK per annum. This constitute only about 14% to the total costs of the full SWETHRO programme. There is thus an additional efforts which is funded by other stakeholders like Luftvårdsförbund (air pollution management associations), Länsstyrelser (county administrative boards) and private companies. In addition, there is also some throughfall related measurements done at 4 sites in Sweden in the framework of WGE ICP Integrated Monitoring.

g. Strengths:

The activity provides information with high spatial resolution of deposition fluxes to forest ecosystems. A recent change in precipitation samplers to become similar to those used in the LNKN programme makes data more comparable. Data are according to the responsible institution used by many national, regional and local authorities, and other stakeholders (a full user survey has not been conducted for any programmes in this evaluation, see comments also elsewhere). Forest deposition data are coordinated on the European level (although it seem that the Swedish engagement in the ICP Forest throughfall collaboration is not very active). Data series extend back to the mid-1980ies.

h. Critical remarks:

The data are mainly used to estimate deposition fluxes and exposure to forest ecosystems. Data are due to data quality and or time resolution reasons not much used for MATCH modelling/assimilation (MATCH modelling is evaluated in a later chapter). Measurements are not made with a time resolution or data quality objectives which satisfy obligations to e.g. EMEP (which is also addressing regional scale deposition to ecosystems). It is difficult to assess if the results of monthly air concentration measurements add much value to assessing regional concentration and ecosystem exposure, as compared with using active sampling data combined with models, but certainly together the information is important to study forest ecosystem effects. In the evaluation criteria, one main focus was to assess the compliance with international monitoring obligations. The figure below is taken from the most recent ICP-Forest data report, illustrating that the information provided on e.g. ozone information is quite crude.

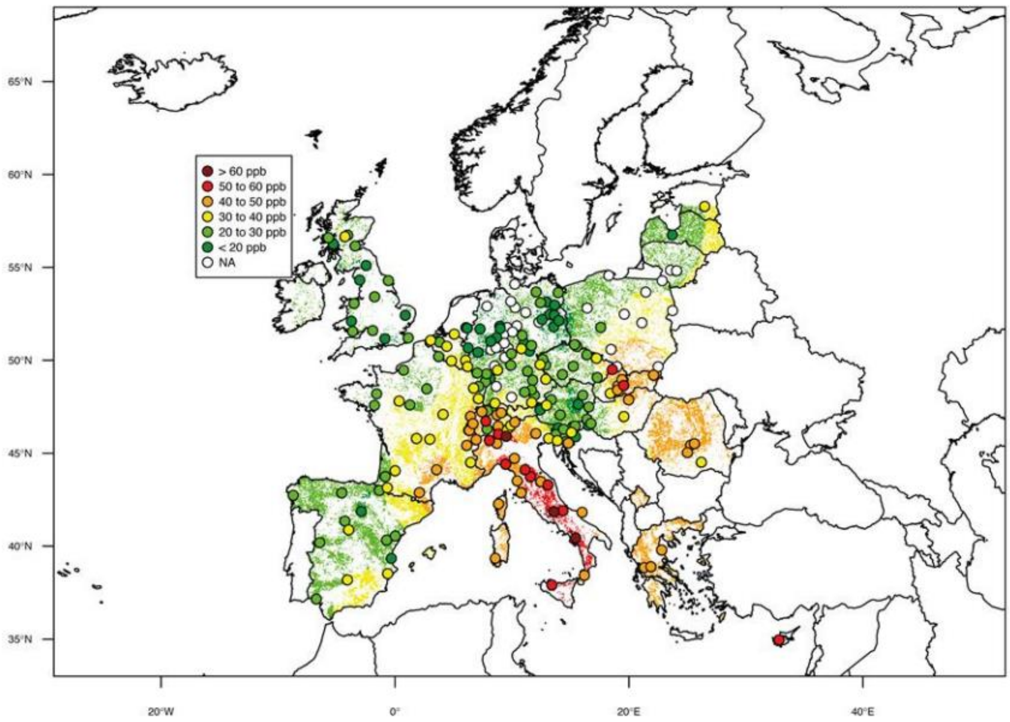

Figure 5-2. Spatial distribution of April–September mean ozone concentrations (ppb) from passive samplers on 203 plots and 20 countries during 2000-2013.

Figure 8: Ozone concentrations in Europe as measured by ICP Forest (from IPC-Forest Technical Report 2015, available at www.icp-forest.org).

We note that Swedish data are not included in all maps presented in recent ICP-Forest technical reports. Below are the charts presenting deposition data in reports TR2015 (data for 2013) and TR2013 (data for 2011) Figure 9. The reasons for data not being presented have later been explained (neither SWETHRO-NV or SWETHRO have any funding for participating in ICP Forest at the moment).

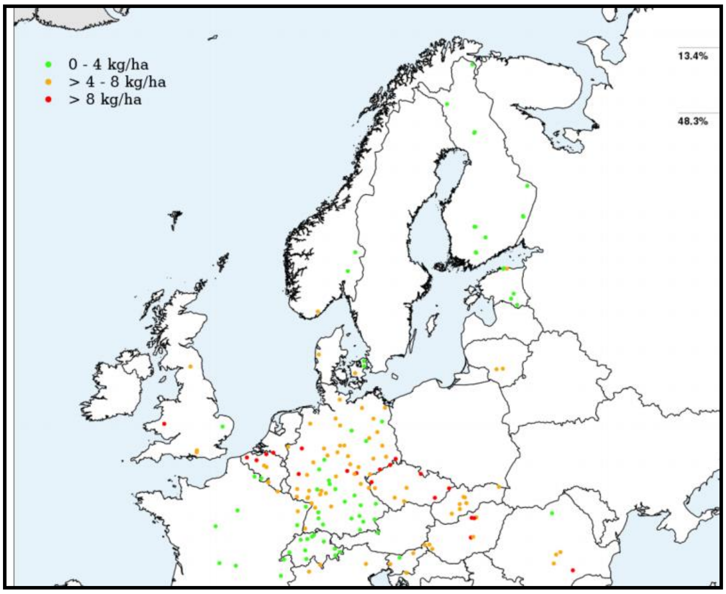

Figure from ICP-Forest TR2015, (throughfall deposition of S).

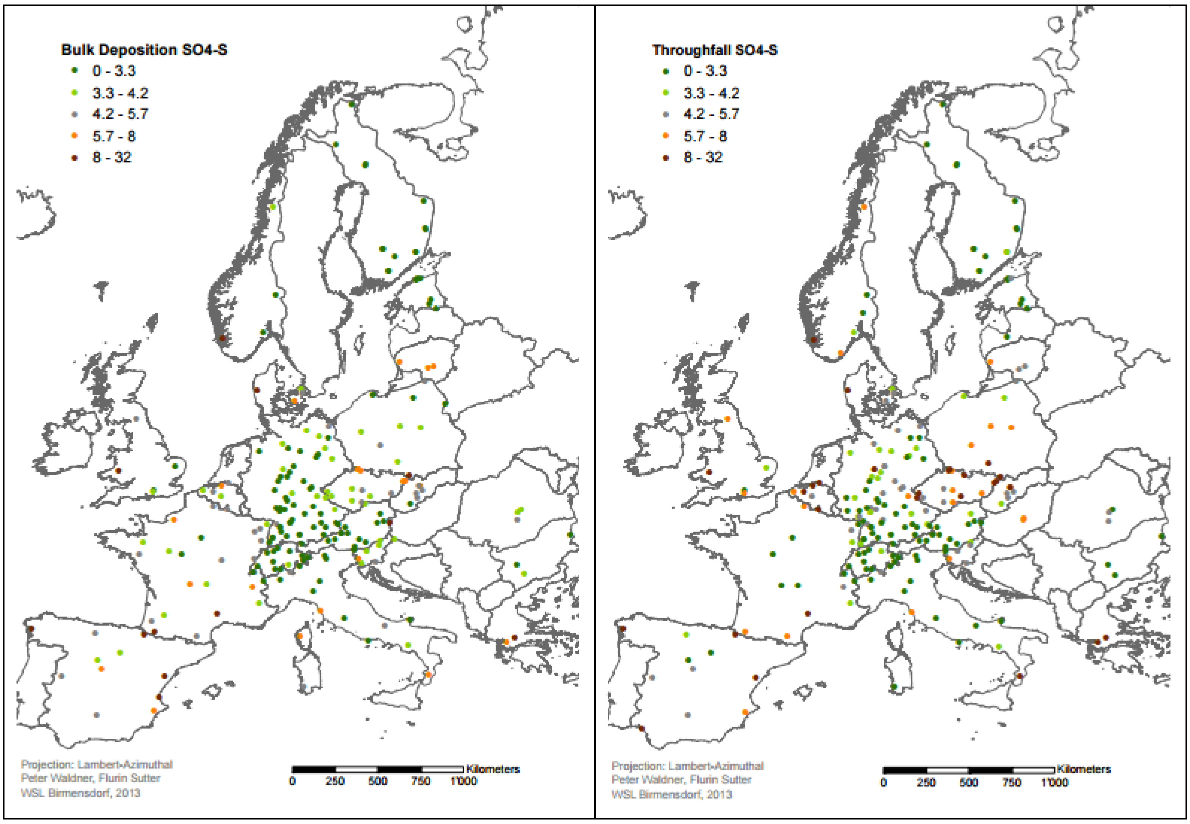

Figure 4.3.1-1 Annual sulphate sulphur (SO_4^--S) bulk and throughfall deposition in 2011 (in kg ha-^{1}).

(Figure from ICP-Forest TR2013)

Figure 9: Illustration of data not presented on ICP Forest maps.

We have through the consultation process and the further evaluation learned that for SWETHRO-NV, the national needs as defined by the Swedish environmental quality objectives, and the interest of the direct national stakeholders is more forming the basis than the international requirements. In such a light, the above critical remarks related to international reporting may be somewhat misplaced. On the national level, the SWETHRO-NV activities seem to complement the other national efforts on forest deposition in a very good way, and clearly the data are actively presented to a variety of users through various reports and publications. It should still be considered if even a more active involvement in the efforts of ICP Forest could be established.

i. Conclusions and recommendations:

The overall activities SWETHRO-NV combined with the remaining SWETHRO efforts can be considered to be well within the demands of ICP Forest obligations, and that the spatial resolution is significantly higher than in e.g. Norway and Finland. This comprehensive activity is motivated by a large interest from local agencies and other users of the information. During the consultations there were comments that the distributed funding causes challenges in priorities and steering of overall Throughfall measurements, and it might be considered to investigate if a common financing and steering arrangement would be beneficial. Further discussions related to "Acidifying and Eutrophying substances" is given in the next chapter.

10. Match Sweden

a. Short introduction to the activities involved:

The MATCH-Sweden project funds model estimates of air concentrations, and wet and dry deposition of major inorganic components to Swedish areas. Ozone concentrations are also modelled. The model is developed and continuously updated by SMHI, and annually a set of calculations are prepared using emission estimates and available observations through an assimilation approach. The results are compared with independent observations, and the produced fields represents a spatially high resolution map on exposure/deposition levels which can be used to study potential effects, to resolve domestic versus foreign sources to pollution levels. The model system can also be used to calculate scenarios of future exposure based on expected emission trends. Finally, model products are useful to assess uncertainties in observations as well as in emission numbers.

b. Requirements as defined by legislation and recommendations:

There are no international requirements regarding the operation of a national modelling systems as represented by MATCH-Sweden. Actually, Sweden do through the EMEP Protocol contribute to the funding of two so-called meteorological synthesizing centres undertaking such efforts on the conventions as a whole. As such, the specific products produced here would likely also be available directly from EMEP on request (but not with the same detail, and including the assimilation of the national measurements).

c. Relevance of data, and are some of special importance?

Even though there are international models which can produce deposition and exposure calculations as provided by MATCH-Sweden, it is very common for countries to operate a national capacity in this respect. This allows much more flexibility in delivering specific information as needed by Swedish stakeholders, and tailored to their specific needs. The activities also demonstrate that alternative, and probably even better, approaches like the data assimilation efforts can be developed. Also the fact that there is national competence related to atmospheric transport and chemical transformations is very valuable also for the international community. Another aspect is that the Directive 2008/50/EC (Article 6) opens for the use of models to assess ambient air quality limit values, and having a strong national model is advantageous also for this purpose (not evaluated in this report). The relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation.
As mentioned above, there are no specific international requirements related to implementing a national modelling system.

e. Aspects related to the responsible institution.
SMHI is the responsible institution for operating the MATCH-Sweden model. They have for years had a strong- capacity in this field, and have contributed significantly with internal funding to develop the model system in previous years. There are probably no other relevant institutions nationally that could replace their activities and serve this role better.

f. Financial issues and organization.
The activity has an annual funding contribution from NV of about 0,6 mSEK per annum. In addition, SHMI contributes with significant resources in developing and sustaining the model system. There seem to be a close collaboration with the relevant data providers (observations and emission data).

g. Strengths:
MATCH-Sweden is a very advanced and mature modelling system. Its linked to other applications and have been utilized also outside Sweden (Europe, Asia…). The model system allow geographical scaling ranging from global to very local resolution (typically provided at 20x20 km2, but can be given at resolutions down to 1x1 km2). Its ability to run data assimilation is interesting, and allows to deliver results of high spatial resolution. Results are easy to access, and presented in a way which is very attractive for users.

h. Critical remarks:
Operating a state-of-the art modelling system is very demanding, and the funding provided by NV can only partly contribute to this. While the model is used in relation to services on the European scale, it would be very useful to compare the high resolution (assimilation) approach with e.g. the EMEP model results specifically for Swedish ecosystems, as well as deposition estimated derived from observations alone ("the NILU inferential method" (as described in Aas et al. 2013):
http://www.nilu.no/DesktopModules/NiluWeb.UserControls/Resources/File.ashx?filename=41-2012-waa.pdf&filetype=file). MATCH-Sweden has not been developed to include particulate matter, and does not provide data on urban scales.

i. Conclusions and recommendations.
Modelling plays an important role in any monitoring system, and allows value adding beyond what observations alone can provide. The efforts undertaken provide very user relevant information, and the activities have resulted in a large number of reports and publications. It should be considered to revisit model performance compared to other models, as well as other approaches to deriving similar estimates (e.g. observation based). We recommend SMHI to engage in the EMEP Task Force on Measurements and Modelling in this respect, and link the work closer to this Further development towards modelling of PM mass

concentration is recommended. Also urban scale modelling of air quality related variables could have more attention in the future.

11. Ozone layer

a. Short introduction to the activities involved:

The program includes measurements of total ozone at two locations, Norrköping (since 1988) and Vindeln (since 1991). Both locations use Brewer instruments, and in addition a Dobson spectrometer is in operation in Vindeln. Both the Brewer and Dobson spectrometers are high quality instruments that have proved good precision and stability for decades.

b. Requirements as defined by legislation and recommendations:

The destruction of stratospheric ozone by CFCs was discovered in the 1970s and led later to the establishment of the Vienna Convention for Protection of the Ozone Layer (1985) and its Montreal Protocol (1987). Stratospheric ozone measurements are coordinated by the World Meteorological Organization through the Global Atmosphere Watch Program, and all nations are encouraged to submit data to the World Data Centre (www.woudc.org). Parties to the Montreal protocol are obliged to provide information supporting the data needs to assess the development of the ozone layer. However, there is no specific list of variables that needs to be monitored, nor is there a defined spatial resolution required.

c. Relevance of data, and are some of special importance?

The ozone layer is anticipated to gradually recover as the emissions of Ozone Depleting Substances (ODS) has been reduced. At present however, ozone concentrations are still at historically low levels. The most recent assessment indicates that the stratospheric ozone decline has stopped and that there are signs that a positive trend is in development. On a global scale there has been a significant reduction in the ozone measurement activities (surface based), while additional space-based capacities have appeared. Sustaining the old stations with total ozone measurements should be a high priority to follow the recovery to be expected, but not least to provide basic information about the stratospheric ozone layer and its characteristics (e.g. in the prospect of large volcanic eruptions, geoengineering etc). Also, satellite observations rely on proper ground-based monitoring as satellites have varying and unpredictable life times, and calibration and validation rely upon high quality ground-based observations. The relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation.

Sweden, with its two locations and measurements of total ozone columns, has a fairly modest level of activities. There are no measurements of ozone vertical distribution (sondes or lidar), while Ozone Depleting Substances measured by Chalmers at Harestua in Norway is funded by NV (not evaluated here).

e. Aspects related to the responsible institution.

SMHI has had a strong involvement in the international ozone research for decades. The institute has representatives in the Nordic Ozone Group (NOG), COST-actions, the European Brewer Network, and the Ozone Research Managers of the Parties to the Vienna Convention (ORM). The operation of instruments follows international guidelines, and the instrument intercomparisons and calibrations recommended by WMO are followed. Total ozone data are regularly submitted to the Word Ozone and Ultraviolet Data Centre (WOUDC)

f. Financial issues and organization.

Annual budget is close to 0,5 mSEK per annum, which seems satisfactory under normal circumstances. However, the budget do not cover the costs related to repair and upgrades of the instruments. The corresponding budget in Norway is around 1,3 mNOK per year. The Norwegian and Swedish programs are however not directly comparable (the Norwegian monitoring program includes both total ozone and UV-measurements at three locations, and specific user fees related to the infrastructure and calibration costs of around 0,5 mNOK is included).

g. Strengths:

The Swedish activities on stratospheric ozone have offered high-quality observations since the early 1990s, and the data series are very important in the international ozone assessments. Data are shared with operational services and are utilized in a number of applications. There is also substantial use of data by a number of stakeholders (researchers, policy makers and not least by the public)

h. Critical remarks:

There are evidently some challenges in relation to sustaining instrument operations. As Brewer and Dobson instruments have high costs, and are sensitive to maintenance, calibration and upgrades of electronics and other parts, the funding available is likely quite limited to support the full needs. We note also that there is an anticipated change of responsible scientist at SMHI (due to retirement), so a transfer of knowledge to the follower would be an important objective.

i. Conclusions and recommendations.

SMHI has offered high-quality observations since the early 1990s, and the data series are very important in the international ozone assessments. Even if we can see signs of ozone recovery today, it is still crucial to follow the development of the ozone layer in order to verify that the Vienna Convention and its amendments work as expected. It is also important to detect possible changes in the ozone layer related to factors other than ODS, like climate change. Thus, it is highly recommended that the Swedish measurements of total ozone continue in the present form.

12. STRÅNG

a. Short introduction to the activities involved:

STRÅNG is a model system used to provide radiation data for any location requested by the user (within Northern Europe). Data are available through a public website with open access. Provided variables are Global irradiation, Direct irradiation, Photosynthetic Active Radiation, CIE weighted UV irradiation and Sunshine duration. As the model is 15 years old, there is a need to implement several technical upgrades and there are some suggestions of other improvements to the model system. The programme provides funds to upgrade the STRÅNG model system.

b. **Requirements** as defined by legislation and recommendations:

There are no formal obligations which needs to be implemented. This is rather an activity which provides useful data for its user community.

c. Relevance of data, and are some of special importance.
The model system provides, at low cost, essential information for a wide range of research applications. Data can be used to support pollution, biological, health, marine and climate research. The relevance for Swedish environmental quality objectives is illustrated in Table 1:

d. Level of implementation.
The model system is already in operation and the NV contribution is supporting a needed upgrade. The upgrades have evidently been discussed by the user community (in another project funded by NV and results are found here:
http://strang.smhi.se/validation/validation.html). Comparisons between STRÅNG and 12 of the stations in the radiation network reveal a bias for some of the stations.

e. Aspects related to the responsible institution.
SMHI has a long track record in relation to radiation measurements and modelling. They offer an operational IT environment and can sustain the operations of STRÅNG in an adequate way.

f. Financial issues and organization.
The NV contribution to the STRÅNG programme is 0,125 mSEK. This cost definitively appears reasonable, and we see no potential for reducing the costs. Also the organization of the programme is straight forward.

g. Strengths:
Model estimates are openly available to its user community without any restrictions. Estimates are compared with ongoing observations, and thus contributes to the quality assurance activities.

h. Critical remarks:
There is no complete statistics on the actual use of the products available. There are however ideas on how this can be logged in the future. It is important that ease of access is not jeopardized by access registrations or other attempts to monitor the use of data. There are clear indices that this is a very useful and highly used service (based on interactions with users, and appearance in reports and publications). More promotion of the product outside Sweden may also be considered.

i. **Conclusions and recommendations**. STRÅNG is a very useful model system, and the data are downloaded by a variety of users for a many different application purposes, ranging from studies of health effects to aging of materials. It's a great benefit that data are available to the user community without any restrictions. Data are free of charge and easy to download. The STRÅNG model can provide spectral radiation, which gives a potential for various dose calculations and new application areas. The model domain covers Northern Europe, and the system might be highly relevant for users outside Sweden. More promotion of the product should be considered.

1.6 Special project 1 – Acidifying and Eutrophying substances

1.6.1 Introduction

This section address the "special project related to acidifying and Eutrophying components", and includes a discussion on the activities funded as part of programmes 1 and 9, and also considering the activities under SWETHRO and ICP Integrated Monitoring (these programmes are not evaluated specifically in the main project). All these programs involve monitoring specifically aiming to quantify deposition fluxes regionally and to specific ecosystems. The activities include precipitation chemistry (open field wet deposition), air concentrations, throughfall wet deposition and surrogate surface measurements. The common major focus is to quantify deposition fluxes of sulphur, nitrogen and base cations. In the specific programme evaluations above, we have commented on the programmes individually. The objective here is to assess if they together offer a complementary effort or if there may be a potential to develop a more appropriate monitoring design. Below is first a general discussion, and toward the end of this section we have tried to conclude on the specific questions raised in the evaluation criteria.

1.6.2 Discussion

The immediate impression when looking at the activities overall, is that there is not strong national coordination and strategy of the activities involved across these programs. There are activities at in total quite many locations, but levels of ambition varies across programmes, and methods/procedures are not always directly comparable. The main reason explaining why not all sites operate according to the highest level of ambitions is naturally the associated costs (e.g. daily sampling instead of monthly has a huge impact on costs). It is also so that the need for high time-resolution data may be less for some applications as compared to others. As an example, any forest damage from soil acidification will occur on very long time scales, as a result of soil chemistry changes occurring over many decades, while emission source attribution requires time resolution to allow to resolve synoptic scale transport processes. It is challenging for users to take advantage of all data, and many of the assessments show that data are often/typically used on a programme basis rather than on a subject basis. As an example, there are many reports showing results of the "Throughfall" programme, but fewer reports assessing regional scale deposition, or ecosystem specific deposition, which includes the use of data also from other programmes.

As commented in the evaluation of program 9 (SWETHRO-NV), the total number of forest sites in Sweden stands out as high as compared to what is common in other countries. At the same time Sweden do have a rather low score regarding implementation of EMEP obligations (see figures below illustrating implementation of EMEP level I obligations). We assume this reflects the stakeholders interests related to these matters. The application of throughfall data in the international air policy work is however perhaps less than the number of sites would indicate. It is also so that that CLRTAP WGE deposition measurement activities (e.g. IPC Forest, ICP Integrated Monitoring, IPC Vegetation….) do not have as their mandate to deliver national or European scale deposition data in support of CLRTAP EMEP work, but rather to offer exposure data for effect related assessments on specific sites/ecosystem types. The Swedish activities thus appears like a high spatial resolution national network, rather than an optimum implementation of international monitoring obligations. Having said that, there are many examples also of international studies taking advantage of the data. Clearly, high spatial resolution maps of deposition are attractive for users, and can support many specific applications.

Norway had until about one decade ago a national forest damage monitoring programme which was co-funded between the Ministry of Climate and Environment and the Ministry of Agriculture (established in 1985). Later, the programme evolved to become a more general forest ecosystem program, now governed by the Ministry of agriculture alone. The Ministry of Climate and Environment operates separately a national monitoring programme of long-range transboundary air pollutants. This kind of disconnect between deposition monitoring done in support of EMEP vs the activities under the CLRTAP WGE is a typical feature seen in many countries, and has been pointed out as a difficult matter to resolve. Stakeholders for ecosystem effects put priority on site specific measurements, but often with relaxed requirements in terms of time resolution and data quality, while the atmospheric transport community request sites with sufficient time resolution and quality to resolve individual transport events.

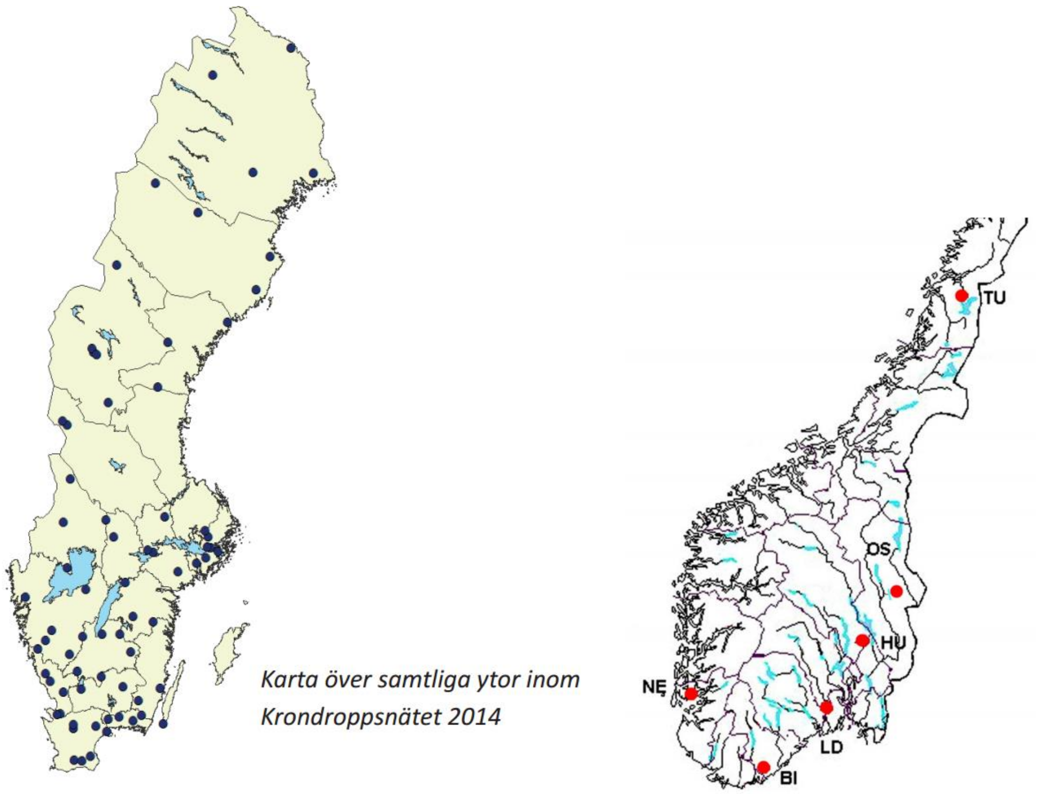

Figure 10: Illustrate the number of ICP-Forest deposition sites (n=70). In comparison, there are 6 sites with throughfall measurements in Norway, and about 12 sites in Finland.

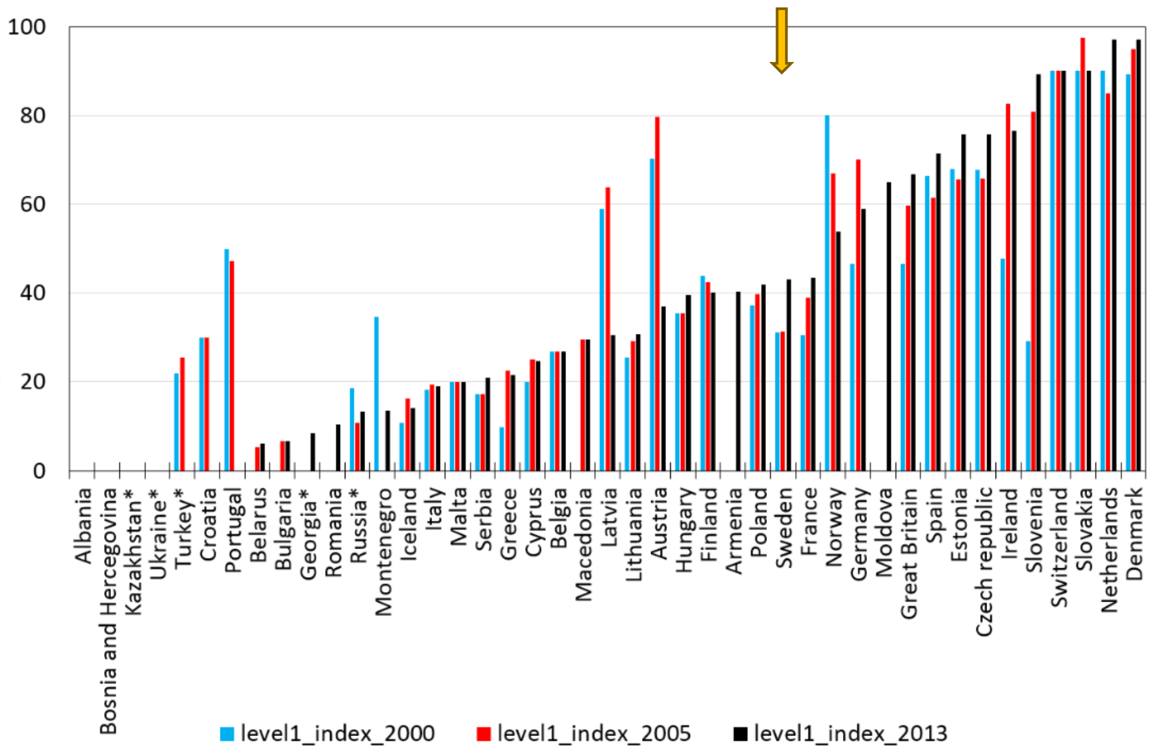

Figure 11: EMEP implementation index – level I

Figure 11 shows the EMEP implementation Index (including variables measured in programmes 1, 2, 3 and 5)(note that the implementation for 2014 will be somewhat higher, due to the increase in the number of ozone sites as described in the evaluation of program 2). As can be seen, Sweden has a rather low implementation in comparing with other western European countries. The implementation for 2013 was about 43% of the requirements (corresponding numbers for Norway, Finland and Denmark were 54, 40 and 97% respectively). A key objective of EMEP monitoring efforts are, as earlier mentioned, to support atmospheric transport models and to allow investigation of ecosystem impacts.

Considering these aspects, we recommend to revisit the strategic direction of the monitoring activities (sites, measurement program, time resolution etc) related to the “Gothenburg protocol” components across EMEP, LNKN, SWETHRO-NV, SWETHRO and ICP Integrated Monitoring. Even the activities related to ICOS – Integrated Carbon Observing System, to which Sweden has a very large contribution, may be relevant in this context. The use of common sites would be one important aspect. In doing so, we recommend that the objectives of the respective activities are more clearly distinguished, and that resources are allocated such that most of the aspirations can be met. Below is an evaluation which outlines some way to reach these goals, by directly discussing the points raised in the evaluation criteria.

1.6.3 Evaluation

a. *Can the monitoring within the relevant sub programmes be made more efficient, without jeopardizing the Programområde Luft objectives?*

   For the objective of mapping national scale deposition of acidifying and Eutrophying substances, we see a potential to reallocate some resources by reducing the number of sites with deposition measurements within SWETHRO. It is unclear however, if this will be problematic for those users of data which have interest in the regional throughfall activities. This could be addressed in discussion with local authorities and other stakeholders to the regional efforts. The reduction in number of sites could free resources to increase time resolution and data quality at remaining sites. Such an approach, combined with the use of MATCH-Sweden can be anticipated to resolve future regional trends and spatial distribution of atmospheric concentrations and fluxes, and with sufficient quality to allow the detection of emissions trends as well as to quantify exposure to ecosystems to allow impact assessments. We see less potential for reducing costs in relation to the way monitoring is organized in terms of laboratory cost etc. It should be remembered that sustaining laboratories facilities do have a significant resource implication both related to sustaining instruments and facilities as well as to man power. Reducing the number of samples can thus not directly be taken out as cost savings, but may result in higher costs per analysed sample.

b. *Where are there overlaps in relations to activities at specific sites?*

As we consider it, there has been focus on making use of existing sites supporting other programmes before establishing new sites, and co-location of efforts is economically and scientifically often very beneficial Hence, several sites do support several programs under Programområde Luft. We have not been able to identify any clear and unnecessary duplication of efforts, but clearly there are also many site locations which are not very distant from their neighbouring sites. As there certainly are local characteristics of deposition patterns, the site density must be considered according to the requested levels of uncertainties in deposition estimates. We would recommend a special study to investigate geospatial trends, auto correlations etc. and total representativity to better guide the site density of deposition monitoring sites.

c. *Can models replace/reduce the need of observations?*

As discussed above, models represent an important component in any monitoring system. Modelling can offer higher spatial resolution information, and may be used to better understand the observations, and expose lack of knowledge. At the same time, they mainly produce information based on the current level of understanding, and is fully dependent on the quality of input data. As such, models cannot replace observations, but an integrated observation-model system should have as its ultimate goal to in combination deliver a cost-efficient basis for research and policymaking. Special project 2 gives additional comments on modelling efforts. As models offer capabilities to resolve spatial and temporal gradients, their use may allow reductions in the number of sites having observations. There exists many studies which address spatial requirements in relation to the needs of modellers, but it is very difficult to generalize and give strict guidance on minimum site densities. For regional scale air pollution issues the general consensus is that sites densities need to be in the order of 1-2 sites per 100.000 km provided that observations have a temporal resolution allowing to investigate synoptic scale transport features. Effect studies however rely on site specific input data (which may be significantly different than the regional scale data), and one may choose different approaches to address this. One being to operate dense observation networks in the long term, or to rely more on models, but with occasional testing and validation activities (experimental campaigns etc.). In practice, most countries applies a combination of these approaches, and Swedish activities points out to be quite typical in this sense. Our assessment is still that there is potential to reduce the total number of sites measuring wet deposition and air concentrations, provided that remaining sites have intensified activities specifically targeting the needs for model development, testing and for assimilation purposes.

d. *What is the importance of the regional monitoring, and how can they complement the national monitoring to provide an efficient system?*

The challenge is to provide a national coordinated effort to derive temporal and spatial trends of the relevant species, and also to provide site specific deposition measurement to Forest ecosystems across Sweden. We recommend that priority is given to establishing a stronger and more coordinated open field precipitation chemistry network. This will improve the basis for regional mapping, and needs to be closely linked to chemical transport model requirements. This could be achieved by organizing all measurements of open field precipitation chemistry in one programme (LNKN, EMEP, SWETHRO-NV, SWETHRO and ICP-IM), using identical methods and have sampling time resolution not exceeding one week. At 6-8 sites, sampling should be done on a daily basis, to meet the needs defined by the EMEP monitoring strategy. As this will have cost implications, other activity areas may need to be reduced accordingly (by reduction in the number of sites with either precipitation chemistry measurements, or reduce the number of sites with canopy throughfall and surrogate surface measurements). As discussed below, this will however require a coordinated funding/steering approach where all stakeholders pool their resources (see also discussion in point d) above. This is the approach which have been chosen in Norway, and in our view we find that this has offered a reasonably good program.

e. *How should the responsibility for monitoring these components be organized within Programområde Luft, and between Programområde Luft and Programområde Skog respectively?*

As described under the evaluation of SWETHRO-NV, the funding situation is special in the sense that NV only funds 14% of the total effort. It is indicated by the involved community that it may be beneficial to reorganize the Throughfall activities as funded by NV, Luftvårdsförbund (air pollution management associations), Länsstyrelser (county administrative boards) and private companies to constitute one national program with centralized funding/steering. This evaluation has not addressed the non-NV funded part of the Throughfall programme to any detail, but we would suggest that NV should, due to its large contribution to the other national activities related to regional deposition, take initiative to discuss ways of organizing deposition related activities supporting the national needs. Objectives would be to explore ways to better secure ownership, steering and funding of the activities across programs, considering the information the activities can provide for each stakeholder to the activity. The discussions should thus both take into account the relationships and steering of the overall throughfall activities (including ICP-IM), as well as the other deposition related subprograms of Programområde Luft. One option would be to organize all canopy throughfall and surrogate surface activities under one program (SWETHRO-NV, SWETHRO and ICP IM), while the open field wet deposition now funded in sub programmes 1 as well as under the various forest/ecosystem programmes are considered together in another program. Such an approach will need to be guided by the different stakeholders to secure pooling of their individual resources. It is certainly important to consider how the large funding made available from the other funders of the throughfall program would be impacted in a revised funding arrangement (i.e. will these funds still be available for deposition related activities or not).

1.7 Special project 2 – Modelling

1.7.1 Introduction

This section address the special project related to modelling, and the overall objective is to discuss regional scale modelling from MATCH-Sweden and its relation to the associated measurement programmes. We will discussed what models provide, how MATCH relates to demands of air quality assessments, and how monitoring capacities must be dimensioned to support model based evaluations. Finally, there is a short comment on a potential collaboration to link Norwegian and Swedish deposition mapping resources.

1.7.2 Discussion

Chemical transport modelling has proven to be an essential tool to evaluate the relationships between emission fluxes and levels at distant scales, and the temporal trends in relation to abatement measures. As observations also have their limitations in terms of quality, representativeness and spatial resolution, it is a common view that modelling complements and constitutes an essential component in a mature monitoring system. It is thus recommended to specifically structure the monitoring systems so that observations have as a primary goal to deliver the information which is required to allow the models to derive the spatial resolution. Taking this to the extreme, focus of observations should be on a few carefully selected sites, offering state-of-the-art comprehensive data of all relevant variables (allowing process understanding and model development), rather than many sites with data having limitations with respect to time resolution etc. This has been the guiding principle of the EMEP monitoring strategy, and experience show that nearly all international agreements heavily rely on the EMEP models and the projections available. Improving this understanding would thus be very important. As monitoring also have significant associated costs, the use of models will reduce costs. It is important to note however that models have significant (and larger) limitations, and unfortunately both policymakers and the public may have too large confidence in the results they provide. Also emission data have large uncertainties, and any projections into the future should be discussed with care. Data assimilation is growingly being applied to derive the “best optimization” of measured and modelled results.

Current models can provide estimates of ambient levels and deposition fluxes of all major inorganic compounds with a fair precision, but there are some major differences in performance depending of the actual compounds (best for sulphur, less good for nitrogen components). Model performance is typically better on aggregated time averages than on the timescales of synoptic transport (i.e. annual regional gradients are better represented than for any given day or hour). As many applications rely on input on hourly or daily scales (i.e. air quality forecasts), the model performance needs assessment against high time-resolution data. Low time-resolution data may however provide higher spatially resolved data for validation of results (e.g. regional deposition fluxes etc.). It is our view that any precise definition of site density and time resolution for observations to optimize models cannot easily be given. At the same time, it is also clear that current practise has led to the formulation of monitoring strategies which have a specific objective to support modelling activities.

Observations can only be made “in real time”, while modelling studies can be undertaken at a later stage in time. It is also possible to test different models and approaches later in time, so it would be most important to secure and prioritize the monitoring activities in the annual budgets.

Directive 2008/50/EC Article 6 opens for the use of models to assess the ambient air quality. This puts specific challenges towards the models capabilities to provide information adequate to address such questions. To harmonize the performance and quality assurance of models for this purpose, a

European initiative was launched to exchange experience and results from air quality modelling in the context of the AQD: http://fairmode.jrc.ec.europa.eu/
SMHI/MATCH have participated in the Fairmode activities, and have also participated to the MACC (EU-project) ensemble modelling. Here, the main European regional scale models have been compared, and results show that the MATCH-Sweden has a performance in the same range as the others. With its possibility to assimilate observation data, we consider its usefulness to resolve spatial trends in Sweden as very good. Criteria for Model Quality Objectives (MQO) and Benchmarking of models have recently been established in Fairmode, and we refer to their website for more detailed information in this respect: http://fairmode.jrc.ec.europa.eu/wg1.html. SMHI is currently participating to the ongoing efforts of Fairmode, and participated in the European Composition mapping exercise in 2015 (NO2 and PM10 in Urban areas).

1.7.3 Evaluation:

a. *What can be modelled?*

As discussed above, current models have reasonable good abilities to resolve ambient levels and fluxes of pollutants. There are still *significant* uncertainties, and typically more than 30-50% deviation from observed values (see also the figure shown below under point f.). Models also depend on the uncertainties of their input data, and often have parametrizations of some involved processes.

To illustrate the difference in results applying different approached for estimating deposition we refer to the maps below calculated for Norway. Here, deposition has been calculated using the "NILU inferential method" (purely based on interpolation of available observation data) and EMEP model calculations (no data assimilation). The differences in estimated deposition fluxes further yield a significant difference in critical load exceedances.

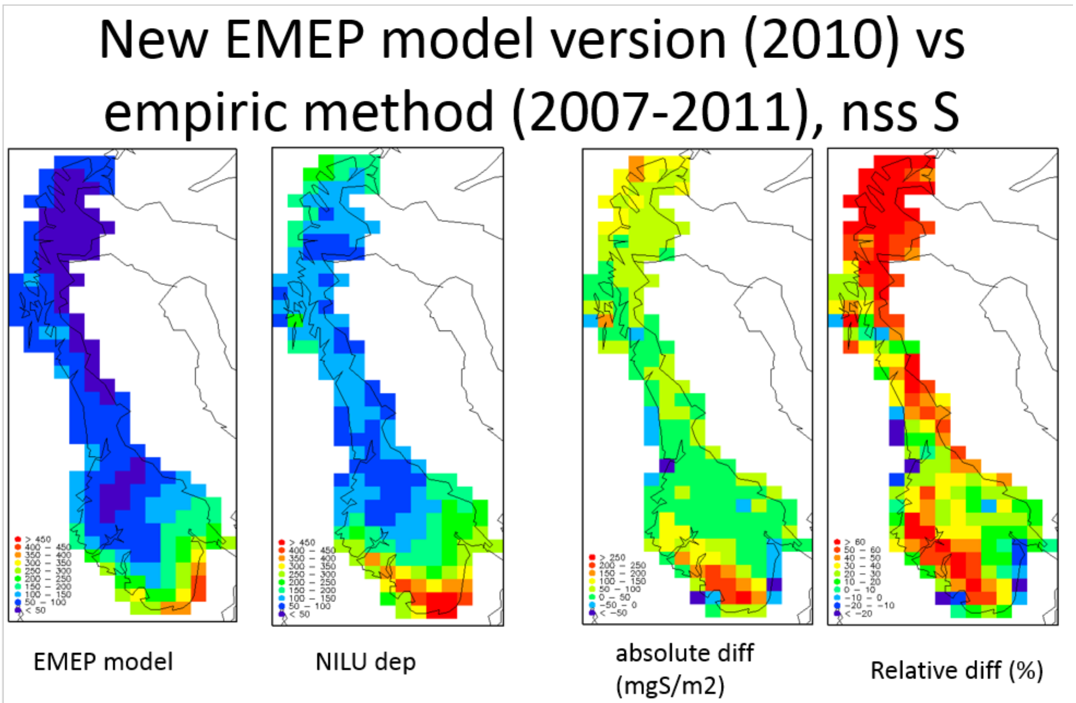

Figure 12: Estimated total sulphur deposition in Norway using the EMEP model and observations (NILU dep) respectively.

A new regional mapping using the NILU inferential method is foreseen for the period 2011 -2015, and it would very interesting to extend this effort to also include Swedish data and the SMHI-MATCH + EMEP models, and produce a set of estimates covering both Norway and Sweden.

b. *Will MATCH Sweden fulfil the coming quality requirements given for the Delta-tools?*

   It is our view that MATCH-Sweden represents state-of-the-art in relation to deposition of sulphur, nitrogen, ozone and base cations, and that it likely will perform at least with same skills as other models which are candidates to fulfil these requirements. It is essential that the model takes part in relevant intercomparisons and is carefully compare with observations. The JRC has developed a specific software (Delta tool) which is to be used for benchmarking AQD modelling applications. Through the use of this software, model performance can directly be compared with observations. The focus of Delta is mainly performance for PM mass, NO2 and Ozone, while the Match-Sweden activities mainly include regional scale deposition. It is thus difficult from the provided information to comment specifically on the model performance in relation to the Delta tool and the Model Quality Objectives of Fairmode. There exists however earlier studies where MATCH has been compared with observations in relation to ground level ozone in Europe, showing very a good performance (e.g. Solberg et al, (2005), Changes in Nordic surface ozone episodes due to European emission reductions in the 1990ies, Atmospheric Environment 39, 179-192).

c. *How can modelling be improved through optimization of monitoring efforts, and sites be relocated to accommodate better use of models?*

   All monitoring systems follow the basics originally derived from synoptic meteorological forecasting, i.e. to have a set of sites, with directly related information being measured (comparable data and representativity). However, due to the complexities, difficulties and costs associated with atmospheric composition variables, the modelling community have grown used to taking advantage of what may exist. In this aspect, there is substantial experience in making use of various data types to document model capabilities in resolving physico-chemical properties of the atmosphere and the fluxes to the surface. Site densities should reflect the actual geospatial gradients (i.e. low density if no small scale trends (i.e. long-lived GHGs), and high density if large trends (i.e. precipitation chemistry). The number of sites currently in operation across Sweden must be considered to be more than adequate to support regional scale atmospheric transport models. The modellers should be invited to discuss the data needs for various applications, and a shift in the monitoring approach to strengthen activities at important sites could hopefully result.

d. *How many sites are required for input data and validation respectively, and which sites are most important?*

   Following the discussion above, one could foresee a consolidated network of about 10 sites with an ambitious monitoring programme (EMEP), supported by a limited number of LNKN sites and a modified Throughfall network. Site density should be highest in South Western Sweden, but still have a significant focus also on the northern areas, mountains etc.

e. *Is there a need to measure dry deposition? Can it be modelled instead?*

   Dry deposition (i.e. the direct deposition of gases and particles to the ecosystem) constitutes a significant part of the total deposition. It is thus important to estimate these fluxes both for assessing impacts, but also to ensure mass consistency in regional scale modelling of fluxes. While the basic micro-meteorological processes involved are fairly well understood, there are many challenges associated with both measuring fluxes and modelling fluxes. It is our view that both measurements as well as model calculated fluxes are associated with large uncertainties. In some cases, there is also reason to believe that models better represents actual fluxes than site specific observations as the latter may be affected by methodological uncertainties. Throughfall and surrogate surfaces are considered to be the most appropriate way to monitor dry deposition. The alternative to this approach is advanced experiments where gases and particles are measured with sufficient time resolution to be used for micrometeorological methods (eddy covariance or similar). Such experiments will offer dry deposition velocities that can be applied in models to calculate fluxes (in addition one will need good characteristics of surface properties and the geophysical conditions, chemical interactions etc.). In any case, it is fundamentally difficult to upscale results from a specific site or experiment to a larger spatial scale. Flux measurements have become an area of high research focus in relation to greenhouse gases however, but also here the community struggles with the upscaling of individual site data to larger scales, and top-down approaches using models are essential. In EMEP, dry deposition measurements are considered a level 3 activity. This means that it constitutes a voluntary reporting of relevant experimental results from campaigns only. Ideally, simple large scale monitoring, as represented by Throughfall/surrogate surface monitoring, should be combined with specific micrometeorological experiments AND the use of canopy exchange models.

1.8 Additional remarks and major conclusions

1.8.1 Institutional aspects

The monitoring programmes are all conducted by experienced institutions all being well positioned to fulfil the tasks. We experiences engaged scientists and a lot of enthusiasm related to the activities in which they are involved. There is also a substantial amount of publications and reports presenting the results.

The activities are conducted by a relatively small number of institutions, and we find this beneficial to sustain focus and facilitate efficient collaboration. This builds critical mass, and there is many synergies related to the use of laboratory infrastructures etc. The institutions are also active in related research activities and thus adds significant value to the monitoring efforts.

There are many examples of data sharing and close collaboration, but also indications that the programmes in some cases could benefit from more interaction (we refer here mainly to the two “special projects” discussed elsewhere). Many sites are used across the different programs.

There is significant contributions by the institutes which add to the NV funding. Together with supporting projects, the efforts builds a broad general knowledge. The activity thus generates national competence beyond the delivery of monitoring data reports.

Several of the programs presents their results in bi-annual monitoring reports. We find these very relevant, and they serve as an important way to quality assure, as well as raise awareness of the activities. In particular, the quality assurance aspects of data are important, and it could be considered to issue more simplified data reports annually to ensure that errors are detected at an early stage This is best practice, and common strategy in monitoring programs.

Some of the programs have limited budgets set aside for long-term replacements of instrumentation, and it is important to ensure that sufficient resources are reserved to support the required data quality of the activities undertaken. Many of the programmes indicate that funding is insufficient to sustain current scientific ambitions.

1.8.2 *Strategic aspects*

The activities clearly constitute a mature monitoring activity. Long-term data series exits, some amongst the longest available in Europe. Sweden should have as a high priority to sustain these into the future. Examples of such datasets of special importance can be found in relation to air and precipitation measurements of sulphur, nitrogen, ground-level ozone, Hg, POPs and total ozone.

There are many similarities with what is done in neighbouring countries. Also costs are fairly similar. The total use of resources seem reasonable, but funding available for the whole program could with benefit be increased. All involved activities should, to our opinion be continued.

Swedish obligations to international agreements are generally met. Many of these obligations are however vaguely defined, and we recommend that priorities should not be based on legal aspects alone, but also take into account the needs for research and other applications of data. There are also examples of monitoring which today is done mainly to satisfy legal needs, and that the data user perspective is less in focus. This can be illustrate by e.g. NO2 measurements with monthly time resolution at ozone sites to satisfy Directive 2008/50/EC requirements and VOC measurements at an urban background site, which represents an effort to which there are relatively few scientific stakeholders.

Table 2: A simplified illustration of the implementation of the various monitoring obligations:

	1	2	3	4	5	6	7	8	9	10	11	12
Monitoring obligations	EMEP/LNKN	O3	PM	Svalbard	HM in air/precip	HM in moss	POPs/VOC	pesticides	SWETHRO-NV	MATCH	ozone layer	STRÅNG
EC Directives	a,c	a,c	a,c		b,c		a,c					
UN conventions	e,i,j,k	e,i	e,i	e,i	j,k,m	h	e,j,k,l		f,h *		n	
National needs												

letters refer to bullet points of table 3

** strong implementation if considering the full SWETHRO*

- strong implementation
- sufficient implementation
- low implementation
- no requirement

Strong implementation is used to term activities which is higher than minimum requirements of the respective conventions and also higher than in neighbouring countries. *Sufficient implementation* is used to term activities more or less in line with the respective obligations (there may still be minor aspects needing attention). *Low implementation* is used to term activities where Swedish ambitions are low as compared to requirements and activities in neighbouring countries (we refer to individual program evaluations above for details).

Table 3: List of international programmes and direct links to their monitoring obligations:

EU legislation:

a) **Directive 2008/50/EC**: http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L0050
b) **Directive 2004/107/EC**: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32004L0107
c) **Annexes to Directive 2008/50/EC and Directive 2004/107/EC:** http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2015_226_R_0002
d) **Regulation (EC) no 2152/2003:** http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:324:0001:0008:EN:PDF

Convention on Long Range Transmission of Air Pollutants

e) **EMEP monitoring strategy:** http://www.unece.org/fileadmin/DAM/env/documents/2009/EB/ge1/ece.eb.air.ge.1.2009.15.e.pdf
f) **ICP Forest:** http://icp-forests.net/page/icp-forests-manual
g) **ICP integrated monitoring:** http://www.syke.fi/en-US/Research__Development/Maintaining_ecosystem_services_and_biodiversity/Monitoring/Integrated_Monitoring/Manual_for_Integrated_Monitoring
h) **ICP Vegetation:** http://icpvegetation.ceh.ac.uk/manuals/mapping_manual.html

World Meteorological Organisation

i) **GAW:** ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw172-26sept07.pdf

Helsinki Commission

j) HELCOM manual: http://www.helcom.fi/action-areas/monitoring-and-assessment/manuals-and-guidelines

OSPAR Commission

k) OSPAR CAMP manual: http://www.ospar.org/documents?d=33045

Stockholm Convention on POPs:

l) SC – Global Monitoring Plan: http://www.pops-gmp.org/

Minamata Convention on Mercury:

m) Minamata Convention: http://www.mercuryconvention.org/Convention/tabid/3426/Default.aspx

Vienna Convention for the protection of the ozone layer:

n) http://ozone.unep.org/pdfs/viennaconvention2002.pdf
ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw172-26sept07.pdf

1.8.3 Future directions

There are high ambitions to cover a wide range of activities within the Programområde Luft, but evidently funds are somewhat sparse to do everything with the required expectations in terms of time resolution and spatial coverage. The immediate advice is that funding for this programme area should be increased.

It is difficult to justify major shifts in activities, and any revised strategy will have impacts on the respective programmes. There are many users to the data, so a revision process needs to involve the relevant stakeholders.

There are several examples of monitoring not being fully compliant to requirements of various programmes, this is mainly due to a general tendency to prioritize low time resolution activities at many locations rather than short time resolution at fewer sites.

It is recommended to discuss the approach related to monitor deposition of major inorganic components (S, N, base cations) across the involved programmes, and also with programs outside Programområde Luft (i.e. Programområde Skog)). There is potential that a more harmonized approached can be developed, through the use of models, without the loss of critical capacities in relation to regional scale deposition estimates.

The activities in relation to ground-level ozone precursors is recommended to be revisited. We recommend that the measurements of VOC (currently part of the "organic pollutants" programme) are strengthened with full-year measurements at a rural station instead of the limited activities now undertaken at a suburban site, and becomes part of the ground-level ozone programme. Even measurements of NOx could be organized here, in order to coordinate better the ground-level ozone precursor activities. Also the PM programme will benefit from a photo-oxidants supersite effort.

Sweden has a very comprehensive and interdisciplinary monitoring program. However, it seems that most involved institutions indicate that the full potential in terms of data interpretation is not met due to a lack of supporting funds etc. We recommend that possibilities for "bottom-up" initiated studies is strengthened, e.g. through the establishment of research calls specifically supporting the use of monitoring data. On the other hand, the involvement of the institutions in the monitoring activities represents a potential for involvement in other supporting projects, so there is partly a win-win situation in the way the activities are organized and funded. It should be noted however that internationally there is probably less opportunities for projects which can support atmospheric monitoring in the future (e.g. EU Horizon2020 has very little focus on experimental projects in this domain).

The involved institutions express that programmes should extend their activities and have good proposals for how their efforts could be strengthened if additional funds becomes available. We recommend that the institutions in dialogue with NV more clearly express their own strategical directions across programmes, and contribute to identifying the least important activities and which can be phased out of the programme (provided that additional funding cannot be made available from the stakeholders).

In the revision of the programmes, we recommend that the time-horizon for prioritizing monitoring efforts is kept long, to avoid too frequent changes in the approach. Main focus must be to have consistent data series at timescales of decades, which is problematic if not also funding strategies is corresponding to this time-scale.

Sweden could with advantage, strengthen its activities at so-called super-sites, i.e. sites where there is a comprehensive programme undertaken corresponding to level 2 and or 3 of the EMEP monitoring strategy. The sites Råö, Vavihill/Hyltemossa/Hallahus, Aspvreten, Pallas and Zeppelin are the most relevant candidates, but also other locations may be considered. These sites serve, or can serve as "research infrastructures" and this can open for other sources of funding to develop the activities. The basic monitoring however, needs to have long-term funding from national sources. There is substantial benefits for the involved institutions and scientist if monitoring can develop further towards "research grade" efforts. This will ultimately also form a better basis for NV in the future by having excellent research groups linked to Programområde Luft.

There is a number of adjustments of the programme which can be suggested both at current level of funding and in a situation with increased budgets. In Table 4 below, we have tried to summarize the various aspects discussed in more detail under the specific programs in chapter 1.4. Some of these suggested changes imply that resources needs to be prioritized across the respective programmes in order to be realistic.

Table 4: Simplified overview of alternative changes and suggested increased efforts in a revised programme (for details and discussions we refer to chapters above)

Sub program	alternative changes at current budget level	Increased efforts if higher budget
EMEP/LNKN	Increase number of sites satisfying EMEP level 1 obligations (better time resolution of data), on the cost of "low time resolution" activities	Increased time-resolution to comply with EMEP monitoring strategy. An additional site in mountains may be considered
O3	Reassess the use of passive samplers, to potentially add an additional site with continuous NO2 measurements	Increase efforts towards VOCs and NO2 monitoring (one supersite for ozone precursors
PM	Reassess the Black Smoke measurements	suggestion above will be relevant also for PM
Svalbard	No changes suggested	Funding situation need attention, for instruments and operating costs
HM in air/precip	No changes suggested	Sustain Tekran Hg monitor at Råö. Increase time resolution will be beneficial
HM in moss	No changes suggested	No changes suggested
POPs/VOC	Consider to transfer VOCs monitoring to programmes related to O3 and PM	Time resolution of POPs is low and could be improved. VOCs could preferably be conducted with higher ambitions (see also O3 and PM above)
Pesticides	Small activity and difficult to see alternative approaches to study local inputs of agricultural emissions	No changes suggested
SWETHRO-NV	For the purpose of national deposition mapping, a closer integration with EMEP/LNKN and MATCH Sweden should be considered	No increased efforts suggested
MATCH	MATCH Sweden should more directly have impact on the observational requirements, and contribute to regional scale national estimates of deposition to ecosystems and health. Further assessments of model vs observations to guide monitoring strategies	Developements towards particulate matter and urban scales
Ozone layer	No changes suggested	No changes suggested
STRÅNG	No changes suggested	No changes suggested

Appendix A

Revisjon programområde luft, notat av Helena Sabelstrøm, 12.03.2015

Helena Sabelström
2015-03-12 1(3)

Revision av Programområde Luft

Mål med revisionen: Att ta fram ett nytt program fr.o.m. 2017 som emotser nya krav, avslutar det som inte längre behöver övervakas samt moderniserar och effektiviserar programområdet.

Leverans
Uppdraget omfattar ett huvudprojekt och två specialprojekt.

Huvudprojekt
En grundläggande genomgång av hela programområdet ska göras (delprogrammen (DP) Försurande/övergödande ämnen i luft och nederbörd, Krondroppsnätet, Partiklar i luft, Marknära ozon, Metaller i luft och nederbörd, Metaller i mossa, MATCH spridningsmodellering, Organiska miljögifter i luft och nederbörd, Pesticider i luft och nederbörd samt i viss mån Ozonskiktets tjocklek, STRÅNG UV-strålning och Svalbard). Även visst hänsynstagande till IM Integrated monitoring och Markinventeringen, som båda ligger i Programområde Skog. Fokus i projektet ska ligga på de delprogram där effektiviseringsvinster finns att hämta, i och med detta ska alltså mindre fokus läggas på Ozonskiktets tjocklek, STRÅNG UV-strålning och Svalbard, som är mer avgränsade verksamheter (punkt 1-5 nedan ska dock utföras).

Hög prioritet
1. Problembeskrivning (nulägesbeskrivning)
2. Vilka krav/åtaganden (direktiv, konventioner etc.) på antal stationer, uppmätta parametrar, mätfrekvens och mätmetoder gäller för Sverige?
3. I vilken utsträckning uppfyller vi kraven? Var finns det luckor?
4. Finns det några kommande parametrar/krav som vi behöver ta hänsyn till i det nya programmet?
5. Vad är önskvärt, men ej krav?
6. Finns det ett värde i att organisera programområdet på ett annat sätt än idag? I så fall, hur?

Lägre prioritet
7. Vilka mätningar i programområdet är särskilt viktiga att slå vakt om ur ett användarperspektiv (miljömålen, modellering), miljöperspektiv (aktuella miljöfrågor) samt ur ett politiskt perspektiv (klimatfrågan)? Vilka frågor är på ingång?
8. Hur gör andra nordiska länder? Finns det något som vi kan inspireras av?
9. Vilka möjligheter finns till nordiskt samarbete?

Helena Sabelström
2015-03-12 2(3)

Specialdel om försurande och övergödande ämnen

1. Hur kan övervakningen inom DP Försurande/övergödande ämnen, Krondroppsnätet samt IM och markinventeringen effektiviseras utan att nyttan går förlorad?
2. Var finns överlappningar i övervakningen (mätstationer)?
3. Finns möjligheter att modellera delar av programmen?
4. Vilken betydelse har de regionala mätningarna? Hur kan de samspela med de nationella så att vi får ett effektivt system?
5. Hur bör ansvaret för övervakningen av dessa parametrar organiseras/fördelas inom PO Luft och mellan PO Luft och PO Skog?

Specialdel om modellering

1. Vad kan modelleras?
2. Förväntas MATCH uppfylla kommande kvalitetskrav för modellering (Deltaverktyget)?
3. Hur kan modellering förbättras med optimal mätning? Hur kan stationerna omfördelas för att optimera modellen bättre?
4. Hur många stationer behövs för indata/validering? Vilka stationer är nödvändigast?
5. Finns det behov av att mäta torrdeposition? Går det att modellera torrdeposition istället?
6. Finns det delar av modelleringsuppdraget som kan vara bra att lägga på SMHI och utföras i samarbete med NILU?

Redovisningsform

Rapport på engelska.

Två ambitionsnivåer ska redovisas:

1. Nationella och internationella krav och åtaganden uppfylls
2. Nationella och internationella krav och åtaganden uppfylls samt ytterligare önskemål/behov tillgodoses (utifrån miljömålsuppföljning, aktuella miljöfrågor etc.)

Delprogram inom Programområde Luft

Samordnare Programområde Luft: Helena Sabelström	
	Delprogramsansvarig
Försurande och övergödande ämnen i luft och nederbörd	Maria Barton
Spridningsberäkningar med MATCH-modellen	Maria Barton
Krondroppsnätet	Maria Barton
Partiklar i luft	Titus Kyrklund
Marknära ozon	Matthew Ross-Jones
Metaller i luft och nederbörd	Lars Klintwall
Ozonskiktets tjocklek	Lars Klintwall

STRÅNG - UV-indikator	Lars Klintwall
Partiklar och klimatpåverkande ämnen på Svalbard	Pelle Boberg
Organiska miljögifter i luft och nederbörd	Linda Linderholm
Pesticider i luft och nederbörd	Anna Hellström
Metaller i mossa	Lars Klintwall

NILU – Norwegian Institute for Air Research

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