REPORT

Minutes from workshop held at Dragør, November 21-22, 2012

Base cation deposition to forest in Europe

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Report Summary

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Base cation deposition represents a major input to forest nutrient pools and is an essential parameter for quantifying critical loads and its exceedances as well as predictions for the recovery of ecosystems from acidification. Lately, concern about removal of base cations from the forest in connection with intensive forest biomass harvesting has become a discussed issue.

It is essential to be able to measure or estimate the base cation deposition to forests with a reasonable accuracy. During the 1980s and 90s a great deal of work was performed in order to determine the input of base cations to forests whereas there has not been much new literature since the 1990s.

A workshop was arranged November 21-22, 2012 in order to explore the latest developments and advancements within the area. In this report we summarize the workshop outcomes.

The importance of combined methods for measuring or estimating base cation deposition was emphasized. European-wide base cation modelled maps seems feasible and was considered desirable. A division between different sources (ocean sea-salt spray, Saharan dust, European land born dust and anthropogenic emissions) was suggested. Continued cooperation on a European level should be promoted and different ways for this was discussed.

Keywords
Base cation, deposition, forests, emission, base cation mapping and modelling

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Abbreviations and explanations

ANC	acid neutralising capacity, defined as equivalent sum of base cations less equivalent sum of strong acid anions
BC	base cations, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}
C	carbon
Ca	calcium
CCE	Coordination Centre for Effects, part of ICP M&M
Cl	chloride
CLRTAP	Convention on Long-Range Transboundary Air Pollution
DDF	Dry deposition filter factor
EMEP	European Monitoring and Evaluation Programme, part of UN-ECE LRTAP convention
EMEP WSC-W	European Monitoring and Evaluation Programme, Meteorological Synthesizing Centre - West
ICP Forests	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests, part of UN-ECE LRTAP convention
ICP IM	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems
ICP M&M	International Cooperative Programme for Modelling and Mapping, part of UN-ECE LRTAP convention
IPCC	United Nations Intergovernmental Panel on Climate Change
IVL	IVL Swedish Environmental Research Institute
LRTAP	Long-Range Transboundary Air Pollution, convention under the UN-ECE
K	potassium
MAGIC	Model of Acidification of Groundwater In Catchments
Mg	magnesium
Na	sodium
PM	Particulate matter - a mixture of small particles and liquid droplets. PM is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.
SMHI	Swedish Meteorological and Hydrological Institute
Swedish EPA	Swedish Environmental Protection Agency (Naturvårdsverket)
UN-ECE	United Nations Economic Council for Europe
WGE	Working Group of Effects under the Convention on Long-Range Transboundary Air Pollution; includes six International Cooperative Programmes (ICPs)
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Sammanfattning

Deposition av baskatjoner utgör en betydande källa till baskatjonförrådet i skogsmark och är en viktig parameter för att kvantifiera kritisk belastning och överskridande, liksom för att prediktera återhämtning från försurning. På senare tid har baskatjonbalansen i skogsmark diskuterats allt mer, på grund av de ökade förlusterna av baskatjoner till följd av ökat uttag av avverkningsrester (grenar, toppar och stubbar) för att producera förnybar energi.

Det är viktigt att kunna mäta eller beräkna baskatjondepositionen till skog med någorlunda hög noggrannhet. Under 1980- och 90-talen pågick mycket arbete för att förbättra uppskattningarna av baskatjondeposition till skogen. Därefter har insatserna på området varit mer begränsade.

En workshop anordnades 21-22 november 2012, för att få en överblick över den senaste utvecklingen och framstegen inom området. I denna rapport summeras resultaten från workshopen.

Vikten av att kombinera olika metoder för att mäta eller beräkna baskatjondepositionen betonades. Modellering av baskatjondeposition på Europanivå sågs som önskvärt och möjligt att genomföra, och en uppdelning mellan olika källor för att underlätta arbetet (antropogena källor, havssalt och andra naturliga källor) föreslogs. Fortsatt samarbete på Europanivå skulle vara fördelaktigt och bör främjas, och olika sätt för att få det till stånd diskuterades.

Summary

Base cation deposition represents a major input to forest nutrient pools and is an essential parameter for quantifying critical loads and its exceedances as well as predictions for the recovery of ecosystems from acidification. Lately, concern about removal of base cations from the forest in connection with intensive forest biomass harvesting has become a much discussed issue.

It is essential to be able to measure or estimate the base cation deposition to forests with a reasonable accuracy. During the 1980s and 90s a great deal of work was performed in order to determine the input of base cation to forests whereas there has not been much new literature since the 1990s.

A workshop was arranged November 21-22, 2012 in order to explore the latest developments and advancements within the area. In this report we summarize the workshop outcomes.

The importance of combined methods for measuring or estimating BC deposition was emphasized. European-wide BC modelled maps seems feasible and was considered desirable. A division between different sources (ocean sea-salt spray, Saharan dust, European land born dust and anthropogenic emissions) was suggested. Continued cooperation on a European level should be promoted and different ways for this was discussed.

1. Introduction

November 21-22, 2012 a workshop on the emission and deposition of base cations (BC) was arranged in Dragør, Denmark. The workshop was financed by the Swedish Environmental Protection Agency. This short report holds the minutes from this workshop.

The work is part of investigating one of Sweden's environmental objectives: Natural Acidification Only. The goal of this objective is that "the acidifying effects of deposition and land use must not exceed the limits that can be tolerated by soil and water. In addition, deposition of acidifying substances must not increase the rate of corrosion of technical materials located in the ground, water main systems, archaeological objects and rock carvings".

2. Background

Base cation deposition represents a major input to forest nutrient pools and is an essential parameter for quantifying critical loads and their exceedances as well as predictions for the recovery of ecosystems from acidification. Lately, concern about removal of BC from the forest in connection with intensive forest biomass harvesting has become a much discussed issue.

It is thus essential to be able to measure or estimate the BC deposition to forests with a reasonable accuracy. During the 1980s and 90s a great deal of work was performed in order to determine the input of BC to forests, which can be divided into three major lines of work:

- establish knowledge on both natural and anthropogenic emissions of BC, particle size of BC and ways of transport from the free atmosphere to the receptor surface;
- develop and use measurement techniques for determining the deposition to forest including forest uptake of BC;
- develop mathematical models.

The workshop examined the possibilities for combining measurement and modelling techniques and the need to examine methods both nationally and internationally to improve estimates of BC deposition to forests as well as possible estimates of uncertainties in the results.

Since the 1990s there has not been much new literature nonetheless there have been developments in this area. In November 2003 a workshop was arranged in Gothenburg, Sweden. The workshop was organized by IVL Swedish Environmental Research Institute and financed by the Swedish Environmental Protection Agency. The title was 'Emission, transport, deposition and effects of base cations in relation to acidification' – Report from the UN-ECE/CLRTAP workshop in Gothenburg November 2003. This earlier workshop and its results was the starting point for this 2012 workshop.

3. Aims of workshop

The aims of the workshop "Base cation deposition to forest in Europe" were:

- to investigate the status of European work on determination of the deposition of BC to forests;
- to examine methods to improve estimates of BC deposition to forests;
- to bring together and interact with European researchers in the area of deposition of BC;
- to suggest future work in order to estimate the BC deposition to forests with an improved accuracy.

4. Participants

Sixteen experts attended the meeting, representing eight countries (Sweden, Norway, Finland, the Netherlands, United Kingdom, Ireland, Canada and Switzerland). The participants were:

Name	Surname	Title	Institution/Company	Country	E-mail
Wenche	Aas	Dr., Senior Scientist	NILU-Norwegian Institute for Air Research	Norway	w aa@nilu.no
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Roy	Wichink Kruit	Dr.	TNO, Utrecht, the Netherlands	Netherlands	Roy.Wichinkkruit@tno.nl

5. Program

The program for the meeting was as follows:

Date	Time	Name of speaker	Title of talk
2012-11-21	12:00-13:00	*Lunch*	
	13:00-14:25	**Introduction - why do we need good estimates of base cations?**	***Chairman: Joakim Langner***
	13:00-13:15	Karin Hansen	*Welcome and aim of workshop. Practical announcements*
	13:15-13:45	Ron Smith	*Base cation emission and deposition; Status for measuring and modeling in Europe today*
	13:45-14:05	Cecilia Akselsson	*Significance of base cation deposition? Implications for critical load calculations - example from Sweden*
	14:05-14:25	Filip Moldan	*Significance of base cation deposition? Implications for lake acidification calculations - example from Sweden*
	14:25-14:45	*Coffee*	
		Discussion session	
	14:45-18:00	**Emission and deposition of base cations to forests**	***Chairman: Cecilia Akselsson***
	14:45-15:05	Karin Hansen	*Base cation deposition to forests - different methods of estimation*
	15:05-15:30	Peter Waldner	*Time trends in base cation deposition to forests based on ICP Forests data*
	15:30-16:00	Wenche Aas	*Measurements of base cations in EMEP, including trends and new measurements from the EMEP intensive periods*
	16:00-16:30	Ulla Makkonen	*Trends in base cation deposition in Finland*
	16:30-16:50	Gunilla Pihl Karlsson	*Wet deposition of base cations over Sweden*
	16:50-17:30	Discussion session	
	19:00	Dinner	
2012-11-22	07:00-08:30	Breakfast	
	08:30-10:00	**Emission and deposition of base cations to forests**	***Chairman: Cecilia Akselsson***
	08:30-09:00	Per Erik Karlsson	*Estimates of the dry deposition of base cations to Swedish forests based on measurements with Teflon string samplers*
	09:00-09:30	Beat Rihm	*BC related activities in Switzerland including new base cation deposition maps in Switzerland*
	09:30-10:00	Julian Aherne	*Estimating total base cation deposition to Irish forest: A biomass harvesting perspective.*
	10:00-10:30	Discussion session	
	10:30-11:00	*Coffee*	
	11:00-12:00	**Mathematical models for simulation of base cation emission, transport, deposition and geographical mapping**	***Chairman: Max Posch***
	11:00-11:30	Svetlana Tsyro	*EMEP experience in base cations modelling*
	11:30-11:50	Joakim Langner	*The MATCH model - the inclusion of calculation of dry deposition*
	12:00-13:00	*Lunch*	
	13:00-15:00	**Mathematical models for simulation of base cation emission, transport, deposition and geographical mapping (continued)**	***Chairman: Max Posch***
	13:00-13:30	Ron Smith	*Modelling marine base cation emissions, concentrations and depositions in the UK*
	13:30-14:00	Roy Wichink Kruit	*Modeling base cation concentrations and deposition with LOTOS-EUROS*
	14:00-14:30	Julian Aherne	*Estimating total base cation deposition for Canada using measurement-modelling fusion: A critical load perspective.*
	14:30-15:00	*Coffee*	
	15:00-16:00	**Overall discussion**	***Chairman: Filip Moldan***

6. Discussion and conclusions

IVL Swedish Environmental Research Institute arranged a workshop November 2003 in Gothenburg, Sweden. This workshop and its results were the starting point for this current workshop (2012) in evaluating efforts made in the line of emission and deposition of BC to forests.

The topics dealt with at the 2003 workshop are still valid and of great interest now ten years later. The conclusions from 2003 are stated below in headlines and beneath the headlines discussions and conclusions from the 2012 workshop are presented as today's point of view in line with what has been done the latest ten years along with suggestions to proceed with these matters.

One commonly agreed European default map of BC deposition
One commonly agreed European BC deposition map would be nice. We need it. A promising effort was made in 2005 by Van Loon et al. but it needs updating and refinement to fit local conditions. Unfortunately, the model version which Van Loon et al. used for BC calculations has never been updated in line with general developments of the EMEP model, thus it is a different model unlike the one EMEP uses now. Therefore, BC have to be re-implemented in the EMEP model to be able to apply it again. This would require making/obtaining emission estimates for BC from anthropogenic sources and also information about BC content in different soils. At present, the EMEP model includes sea salt and anthropogenic and natural dust without chemical speciation, given that the model can be run for multiple years (e.g. 10 years) to produce average background fields for marine BC already now. WGE urges EMEP to get it into the work plan of EMEP and work further on the mapping. This has to be moved up on the agenda; however, financing has to be solved. TNO can provide a map with wet and dry deposition of BC, but it needs validation. The estimates can be used as default values. A critical look at the maps will supply means to make them better. New material to improve and refine the models is needed.

The resulting modelled BC depositions should be compared with monitoring data such as the EMEP precipitation and air concentration data, ICP Forests, ICP IM and ICP M&M data
Mostly, EMEP data has been used in the estimations of BC deposition. However, one attempt to compare ICP Forests (bulk) data with EMEP data (wet-only) (statistical krieging) was made. Much lower concentrations were observed for EMEP as compared to the ICP Forests data. The frequency of the sampling of bulk precipitation in the two networks is important for the results we get on BC deposition. It seems that there is too much dust in long-term precipitation samples. Further attempts to compare modelled and observed data are welcomed. Using bulk instead of wet-only collectors can therefore make a big difference in wet deposition estimates. If both bulk and wet-only data are available, the differences may be related to the dry deposition of BC to forest canopies. An attempt to formulate an empirical model based on these data would be valuable.

Further compilation and evaluation of dry deposition velocity data
Correct dry deposition velocities are of big importance for the results but difficult to evaluate. The participants were not aware of any newer research in this area. We have nothing better than old data available. For the dry deposition velocity there is a need to distinguish between coarse and fine particles. Information is also needed on the size distribution of BC, so that the appropriate deposition velocities can be used. A follow up on what is done in the particle research related to climate change issues ought to be done through a connection to groups working on PM.

Historic and future BC deposition (1860-2100) should be estimated.
The historic and future BC deposition is still needed. We need to get a better hold of the emission/deposition relationship, and apply that back in time. Base load seems to be more of natural than anthropogenic origin today, but different thoughts about the relative importance of each exist. A division of the BC sources is helpful e.g. in sea salt, dust (from soils and Sahara) and anthropogenic sources. Though model calculation of all BC components is not feasible at present, background (marine) Na deposition from EMEP would be helpful in the historic deposition. A map of ten years average of sea salt Na deposition would be useful and it can be done already with the EMEP model.

Development of additional methods for validation – including the use of artificial surrogate surfaces
The use of surrogate surfaces as an analogue to real trees in order to quantify dry deposition has been explored in a few projects since 10-15 years back. Development of additional methods for validation, including further use of artificial surrogate surfaces, is important and appropriate and may bring more knowledge forward. Surrogate surfaces are not normally used in deposition monitoring. It is however interesting to compare the dry deposition derived from surrogate samplers to other mapping and modelling exercises.

Some further questions were posed at this workshop (2012) and discussed. The questions were: How do we proceed to obtain better methods for measuring and estimating BC deposition? Future recommendations and future work? The following points were discussed:

- Air concentrations are important for validation of mapping and modelling. Only few stations measure it but more measurements have been started during the last 10 years in EMEP. Now 20-30 EMEP stations around Europe are equipped with filter packs but likely national networks have more such measurements. It is important that these measurements are continued in the future, and a wish would be that even more measurements of air concentrations of BC will be performed in the future. These measurements are of water soluble BC and may be an underestimation compared to model estimates of mineral dust. There are on-going measurement campaigns in EMEP for mineral dust in aerosols and these will be valuable data for model evaluation.
- We should not focus on just one method in our efforts to gain more knowledge on deposition of BC. Comparison of methods is important and it has the possibility of teaching us more. A combination of all techniques and an assessment of how they fit each other are needed. It will be a possibility to test different approaches. Sites with

many types of methods are important. Combining methods adds quality. We should also test other methods (e.g. the mass balance method) to set realistic limits within which the "real" BC deposition would fall.

- Wet only to bulk deposition ratios mostly rely on an old studies from the nineties. A new compilation study is needed to bring forward new ratios between bulk and wet-only deposition of BC. A Swedish study with samplers under roof was performed in order to derive correction factors for dry deposition to bulk deposition samplers (different correction for different sites, different seasons and high/low deposition rates). Such new methods need to be explored in order to provide estimates of the total (wet+dry) base cation deposition to forests.
- ICP Forests monitoring network will probably rely solely on national funding in the coming years since no additional EU funding is available. This most certainly leads to fewer precipitation and throughfall measurements (and reduced sampling periods, i.e., biweekly versus weekly, etc.) in forest sites in Europe in the future and this will be a problem for validation data for models.
- Acidification caused by air pollution is not the sole driver for the work of BC deposition estimates. Deposition of BC is urgent for other reasons, e.g. forest management in the form of intensive biomass extraction which will be a large driver in the future. We need to remember that BC deposition estimation efforts can be used in more places and to "rebrand" our work, e.g. use current terminology such as ecosystem services and highlight links to climate change.
- In the past, the influence of anthropogenic inputs on deposition of BC was large. The relative importance of natural BC (from sea salt, windblown dust) has been increasing, and the generation of natural BC is very meteorology driven. Thus, BC deposition shows considerable inter-annual variation and is likely to change due to future climate changes. What will happen under new climate conditions? E.g. the Baltic Sea will not freeze so often and one may expect more Na and Mg input.
- Future wood combustion is uncertain and may be important (e.g. increasing in Switzerland, often small installations). Wood burning emits PM which affects human health. The magnitude of this BC source is a major gap in knowledge. Wood pellets have furthermore become popular. How much BC do they emit?
- UK emission inventory show high decreases of BC. It is surprising that we do not see it in deposition. Maybe long-range transport from Sahara disturbs the picture. Large storms could have a large effect on Na and Cl. Several studies showed that the deposition trend in BC was slowly decreasing or not decreasing at all whereas prior to 1990 larger trends than now were apparent.
- Chemical methods have developed and become better, but since concentrations have decreased, it's harder to measure. There are significant problems with measuring Ca and Mg by ion chromatography, particularly in organic-rich throughfall solutions. This problem is not always recognised, but can be eliminated by acidifying samples before analysis.
- An idea with a common paper was proposed instead of a report. From there the idea developed into a special issue in a journal. The participants were therefore invited to send abstracts outlining ideas to Karin (half a page) as possible contributions to a special issue. Karin will approach the Swedish EPA and present the idea.

Final conclusions

- Improving accuracy and reducing uncertainties in estimates of BC deposition (present, past and scenarios for the future) is important in order to assess ecosystem recovery from acidification, to increase the robustness in estimations of critical loads and nutrient sustainability at different levels of biomass harvesting.
- There are several approaches for measuring and modelling BC deposition, all with their own strengths and weaknesses. The combination of methods with different strengths is a way to increase robustness in the deposition estimates.
- There are current gaps in knowledge with respect to European-wide BC maps. Base cation modelling on a European level seems feasible, and the work should be continued. Division between different sources (Ocean sea-salt spray, Saharan dust, European land born dust and anthropogenic emissions of burning exhaust and mechanical processes) can simplify the work. Such a division can also be helpful when trying to reproduce historic BC deposition.
- The long-term trends in BC deposition need to be established. Continuous long-term measurements of BC deposition are important to detect changes. An analysis of trends in precipitation and air would facilitate further understanding. The future trends in BC deposition are uncertain; they depend on e.g. wood burning and other indirect and direct effects of climate change.
- Continued cooperation on a European level should be promoted. Publication of a special issue in a journal is one possibility. Another possibility is to form a consortium to quantify past, present and future BC deposition through a research grant application.

7. Some reflections

…from Karin Hansen

While the acidification research is still a very important issue, especially in the Scandinavian countries, the scope of BC deposition work has in some countries somewhat changed the last ten years to more concern about removal of BC from the forest in connection with intensive forest biomass harvesting and issues related to climate change.

The current workshop gave a good overview of the work performed in Europe on deposition of BC to forests for the last ten years. Although we had the feeling that not much work has been performed the last 10-15 years, the workshop showed us that indeed quite some work on BC deposition had been performed in Europe. However, most work has not been published scientifically which makes the newest findings hard to find. The most expressed developments through the latest 10-15 years are connected to the BC deposition mapping performed by EMEP and some single countries, the start of more air concentration measurements throughout Europe (although more are needed) and the extended use of surrogate surfaces to estimate dry deposition. The participants, however, expressed the importance of a continuation of the work.

…from Cecilia Akselsson

The meeting emphasized the importance of BC deposition mappings. It is as important as weathering mappings. There are several promising methods combining measurements and calculations to estimate total BC deposition. There are also mass balance approaches with which limits can be set. There seems to be ways forward for European BC deposition modelling. The first EMEP attempt was good, but the work has to continue and that needs financing. All approaches should be used together, to get as robust estimates as possible.

The division between different sources (sea-salt, dust and anthropogenic) can simplify the work. When it comes to trends back in time and also into the future, it seems like the anthropogenic part was substantial before, and has led to decreasing trends. The change from sulphate to nitrate as being the dominant acidifying anion has also changed the prerequisites for BC deposition. At present, there are no clear trends, and it is likely that the natural part is dominant. This could be an argument for using long-term averages (if available). The inter-annual variation will disappear. The future trends are uncertain; they depend on e.g. wood burning and other indirect and direct effects of climate change.

…from Joakim Langner

From a modelling point of view the workshop provided an update on current modelling and mapping practices used in Europe and Canada.

The group from TNO in the Netherlands seems to be the only group currently in Europe which tries to simulate BC deposition on the regional scale over Europe from BC emissions using a 3D transport deposition model. EMEP had a similar system running ten years ago but this was discontinued. There seems to be substantial differences between

TNO and EMEP results for southern Europe probably due to different assumptions about BC content in soil dust emissions.

Different kinds of mapping techniques are applied in several countries. For example TNO continues to provide mapping for Germany using the methodology of Draaijers. UK use an approach based on modelling dry deposition from air concentrations and mapping of wet deposition using corrected precipitation maps. In Sweden SMHI has initiated work to resume mapping of dry deposition using newly started BC air concentration monitoring in Sweden.

For the different mapping techniques a comparison of methods at a few well characterized sites spread across Europe would probably be a useful exercise to get a handle on the range of uncertainty. Comparison should also be made to independent dry deposition estimates such as surrogate surface sampling.

Given that observational data coverage of air concentrations of BC is limited and that uncertainties in emissions are large (also for sea salt) and will continue to be large, a well-balanced synthesis of observation based deposition estimates and emission model based estimates should be aimed for.

…from Filip Moldan

It is usual for scientists to focus on problems, remaining unknowns, gaps of knowledge, uncertainties etc. It is, however, equally important to make use of knowledge we have and to put the gaps of knowledge into perspective of the already existing knowledge. The anthropogenic emissions of BC appear to be the least well quantified BC source. However, the anthropogenically emitted BC are likely to contribute to deposition of BC much less than both wind-blown BC and BC from sea salt. The uncertainty in overall BC emissions is thus not heavily affected by uncertainty in anthropogenic BC. There has been consensus at the meeting, that there is a wealth of material on deposition of sea-salt and that fairly reliable maps could be constructed by EMEP over the whole Europe with relatively modest additional work needed. Such effort should be supported and encouraged since sea-salt deposition maps would be useful to many.

There are typically four components in a catchment BC mass balance: deposition, weathering (sources), harvest and leaching (sinks). It is useful to consider the relative magnitude of these four BC fluxes when considering BC deposition. Considering the whole mass balance could help to constrain uncertainties in BC deposition estimates and it also helps to assess the importance of these uncertainties.

From the catchment point of view it is also important to separate sources and sinks according to whether or not these are within or across catchment (or other considered land unit) boundaries. E.g. the windblown emissions of BC from within catchment which are re-suspended in the catchment should not be considered as a net deposition on the catchment level.

Presentations and discussions at the workshop opened for many interesting co-operation possibilities among the people and the research teams represented. In some cases several approaches to essentially same task (such as e.g. detection of significant trends in data)

were presented and discussed. In other cases concrete problems were illustrated from different points of view. Teams involved in measurements and monitoring, in data interpretation, modelling and mapping and more were represented. It will be a future challenge to make use of the possibilities which the workshop opened. Publication of a special issue in a journal is one possibility discussed at the meeting. It is an ambitious task which would require substantial commitments from both scientists and a funding agency (ies). Another possibility is to form a consortium to quantify past, present and future BC deposition and to write a research grant application to a suitable research call or funding agency.

…from Gun Löfblad

My participation at the workshop was based on my previous work (before 2004) on BC deposition. Before I left working with the issue I had co-operation with colleagues (mainly Christer Persson SMHI, Olle Westling IVL, Kjetil Tørseth NILU, Leonor Tarrason met-no, Tuija Ruoho-Airola and several others) summarized the knowledge on BC deposition in Sweden and Europe in publications and a workshop:

- Naturvårdsverket/Swedish Environmental Agency report 5119, 2000
- http://www.naturvardsverket.se/Documents/publikationer/620-6145-3.pdf
- IVL Report B 1585, 2004 http://ivl.se/webdav/files/B-rapporter/B1585.pdf
- http://staging.unece.org/fileadmin/DAM/env/documents/2004/eb/ge1/eb.air.ge.1.2004.11.e.pdf
- http://emep.int/publ/reports/2004/assessment/Part1_083-086_05-Basecation.pdf

The presentations at the workshop showed the progress since 2004. Deposition data is still needed when it comes to ecosystem modelling. The need has not become less in view of declining acid deposition and in perspective that BC deposition now is in the same magnitude as BC weathering.

However, the conclusions and recommendations as stated by the participants at the workshop in Gothenburg 2003 are to a large extent fulfilled. The EMEP modelling and mapping work on sea salt deposition is now available and was offered to the countries in the form of ten-year maps over Europe. The EMEP modelling approach is not an on-going activity. The progress is promising not only for sea salt, but also for wind-blown dust. For anthropogenic sources, which in most studies are concluded to be of less importance, there is still a lack of emission data in most countries to make estimates possible.

At the workshop, activities on BC depositions estimates in many countries were presented. National analyses of data have shown useful results, which can be used to further refine data:

- mapping activities based on measurements, models and a combination of techniques;
- data quality assurance;
- trend studies;
- additional measurements.

One important aspect is to assess the results provided by different techniques to find out how well the estimates agree, or disagree, in order to find out the uncertainties of modelling output.

At the workshop I also realized changes since 2003. The environmental conditions have to some extent altered, and will most likely change even more, as regards deposition amounts and climate. The purpose of ecosystem modelling is now both to follow the effects on ecosystems of acid deposition and the effects of forestry management procedures such as intensive harvesting of biomass. Changing climatic conditions, including increasing or decreasing precipitation amounts, increased storm frequencies etc., are likely to influence the BC deposition amounts and must be taken into account in estimates for the future situation.

…from Max Posch

A European wide BC map would greatly facilitate both the calculation of critical loads and the application of dynamic models. Earlier work, as well as on-going work in the context of particulate matter, by EMEP MSC-W makes it the ideal institution to carry out such modelling, and this effort should be prioritized in its work program. This could be facilitated if national representatives to the EMEP Steering Body would be better informed about the importance of BCs and support any efforts by EMEP MSC-W.

8. Highlights and short outline of talks

Ron Smith

Base cation emission and deposition:

- Over the last 20 years there have been changes in the pollution climate, sampling protocols and chemical analyses which should be considered when assessing trends in BC concentrations and deposition.
- Most analysts would filter samples to protect the analytic column. In the EMEP protocols it is however not recommended to filter samples since you will get lower readings of BC.
- When the atmospheric concentrations of acidifying compounds have decreased, we have gone from mainly $CaSO_4$ to $Ca(NO_3)_2$ salts in the atmosphere, which has caused changes in the solubility of BC in cloud and rain, and therefore changes in transport distances.
- 2008 there was a large sea salt event in the early part of the year. It was pointed out that sea salt events are often reflected in the non-sea salt data.
- Concentration maps of aerosols are derived both from rain ion concentrations by a fixed scavenging ratio and from aerosol concentration measurements in the Delta.
- Wet deposition provides typically 80% of the total deposition.
- The total deposition of BC has declined by approximately 30% between 1986 and 2008, though further work is required to confirm this overall decrease and the spatial patterns.

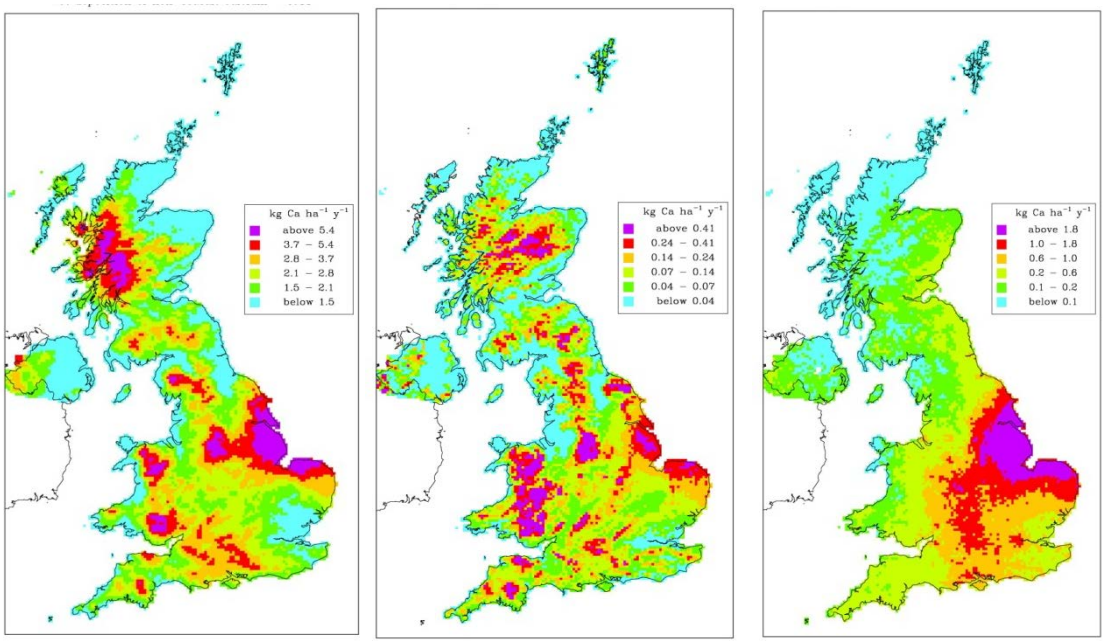

Figure 1. Mapped deposition of wet, cloud droplet and particulate dry deposition of non-sea salt calcium (derived from measured rain ion concentrations using scavenging ratios and a dry deposition velocity) in the UK derived from measurements of rain ion concentrations (kg Ca^{2+} ha^{-1} $year^{-1}$).

Cecilia Akselsson

Base cation deposition in forest ecosystem modelling:

- A wish list was presented: 1) Yearly modelled total BC deposition; 2) A better guess on historical deposition of BC; 3) A prediction of the deposition of BC in the future.
- Long-term averages (10 years) were suggested for steady state calculations in order to reduce the effects of inter-annual variation.
- The high interest on uncertainties in weathering rates as related to BC deposition in Sweden was discussed. It should be highlighted that BC deposition has equal importance like weathering in providing BC to the system.
- The problem with handling uncertainties when close to critical loads was brought up and discussed.

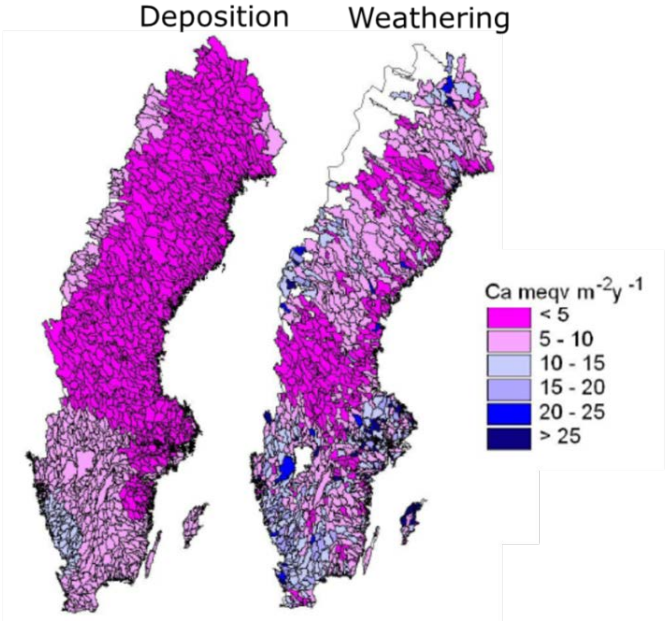

Figure 2. Modelled total Ca deposition and Ca weathering in Swedish forests. The Ca deposition is based on data from the MATCH model, and weathering is modelled using the PROFILE model.

Filip Moldan

Deposition of base cations - the neglected source of uncertainty in assessing surface water acidification in Sweden:

- MAGIC modelling of surface water acidification in Sweden was presented.
- The historical and future deposition of BC in MAGIC is treated as a straight line, i.e. there is no change in BC deposition over the years - Not satisfying. There is now knowledge that the BC deposition is decreasing.
- If we underestimate historical BC input from atmosphere, then we overestimate weathering rate and/or initial pool of exchangeable BC in soil before acidification in 19th and 20th century.

- If we overestimate historical BC input, then we underestimate weathering and/or initial BC pool.

meq/m2/yr	Ca	Mg	Na	K	SBC
deposition marine	2	8	36	1	47
dep non marine + weathering	53	19	14	8	94
uptake (harvest)	14	4	1	5	24
leaching	49	25	47	5	127
balance	-8	-2	2	-1	-10

Figure 3. An average BC mass balance at 1625 acid-sensitive lakes in Sweden modelled with MAGIC model, values for year 2008. According to model calculations, the soils in lake catchments were in average losing 10 meq/m2/yr of BCs as a result of sinks (harvest+leaching) exceeding the sources (deposition+weathering).

Karin Hansen

Assessments of dry and total deposition of BC from field measurements in forests:

- Dry deposition of BC is still largely unknown.
- In order to determine dry and total atmospheric deposition of BC based on precipitation and throughfall measurements, canopy exchange of these elements has to be estimated. For BC, canopy tissue normally acts as a source – leaching from the canopy occur.
- Different approaches available to estimate the total BC deposition to forests were described: Micrometeorological techniques, inferential models and surface wash methods.
- The Ulrich method (canopy budget model) does not always work in Sweden due to higher N deposition in the open field than in throughfall.
- The canopy budget model assumes same size distribution of BC as of Na for all BC. This assumption needs to be improved.
- Both the inferential method and the canopy budget model are uncertain. Comparison of methods is important to allow further developments for validating the dry deposition of BC.

Peter Waldner

Time trends in base cation deposition to forests based on ICP Forests data:

- ICP Forests data is used for trend analyses.
- The Influence of trend analyses techniques (e.g. linear vs. seasonal Mann-Kendall) was studied. More significant trends were found using partial Mann-Kendall instead of linear regression. Good that you get the same slope in both methods – since Mann Kendall is overused. Trends can be detected earlier if monthly data is used in Mann-Kendall.

- Statistical analyses for short time periods can be difficult due to weather events. The longer the time series - the better.
- Trend for Ca in deposition was detectable 1999-2010 – not for the other BC. Data are preliminary. The influence of changes in the determination and transmission limits needs to be studied since often these have changed over years.
- The change in N deposition (ICP Forests data) for 10 years is probably < 3-5% per year. So slow trends cannot be detected. The message was that a trend less than 3% is difficult to detect.
- Figure below: BD = Bulk deposition; TF = Throughfall.

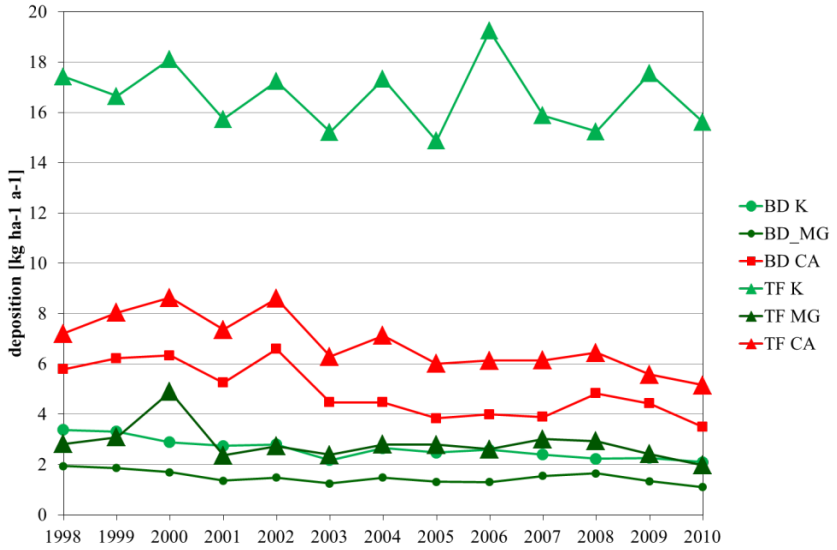

Figure 4. Mean annual bulk (BD) and throughfall (TF) deposition of potassium (K), magnesium (Mg) and calcium (Ca) of ICP Forests plots in Europe with continuous deposition measurements from 1998 to 2010.

Wenche Aas

Measurements and trends of base cations in EMEP and new measurements from the EMEP intensive periods:

- Earlier EMEP data as well as recent EMEP data were presented.
- A trend in Ca (mg/l) has been observed from 1990 to 2010 – A decrease by almost 30% in Ca concentrations in precipitation (wet-only) has been found, significant reduction at one third of the sites with long-term measurements. More significant reductions from 1980 (Tørseth et al. 2012, Introduction to EMEP)
- In south Europe large discrepancies in deficit between anions and cations. Large input/output of Ca.
- Fewer sites have measured chemical composition in air samples than in precipitation.
- Bulk gives better measurements for S and N than for BC (due to BC in dust).
- ICP Forests (bulk) data were compared with EMEP data (wet-only) (statistical krieging). Much lower concentrations were observed for EMEP as a result of different

sampling strategies for the networks (sampler type, representativity, sampling frequency). Sampling frequency is important since especially bulk samplers collect more dust if the sampling frequency is long (i.e. a week or more). Using bulk instead of wet-only collectors can make a big difference in wet deposition estimates, especially in dry regions.

- It was pointed out that some EMEP wet-only samplers do not work properly. This has to be handled.

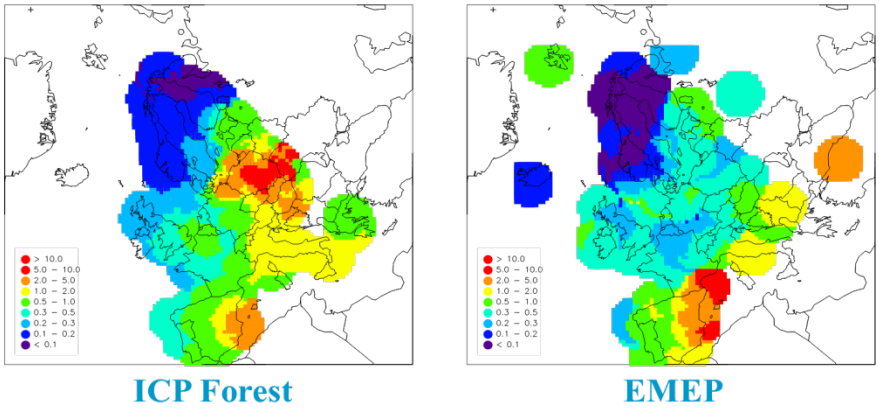

Figure 5. Concentrations of calcium in precipitation (mg/l) in 2000 using measurements from ICP Forests (bulk) and EMEP data (wet-only) and statistical krieging technique.

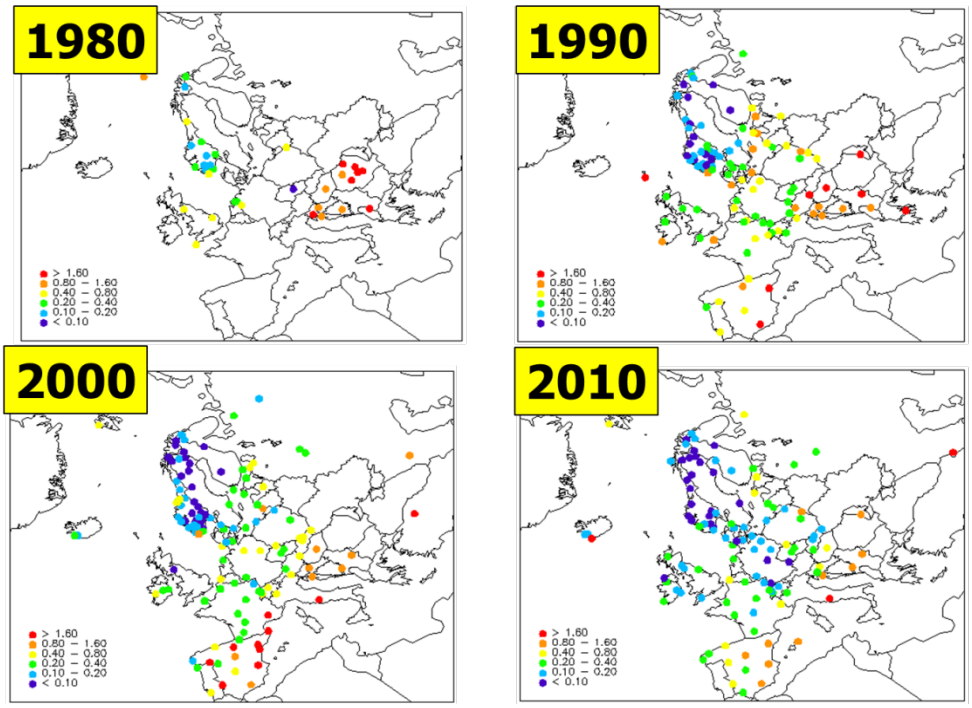

Figure 6. Spatial and temporal trends of calcium concentration in precipitation (mg/l) in EMEP.

Ulla Makkonen

Trends in base cation deposition in Finland:

- Papers: Tuyho et al. 2003; Ruoho-Airola 2012. Boreal Env. Res. 17: 128-138.
- Ruoho-Airola et al 2003: Maps of wet and dry deposition of BC in Finland. Calculated trends for two stations Virolahti and Ähtäri; 1988-2004, daily sampling, thereafter weekly sampling
- Ca time series – decrease in Ca. Influence from Estonian factories diminished.
- For all compounds significant decreasing trends from 1988-1997. For Ca, decrease from 1988-2007.
- Reasons for change: change in emission sources, cleaning systems, changes in precipitation amounts, winter without snow – more Ca, effects of wild fire.
- Why this strong trend in the first period – for Na? The Baltic Sea was covered with ice during the winter.
- K is dependent of pollen.

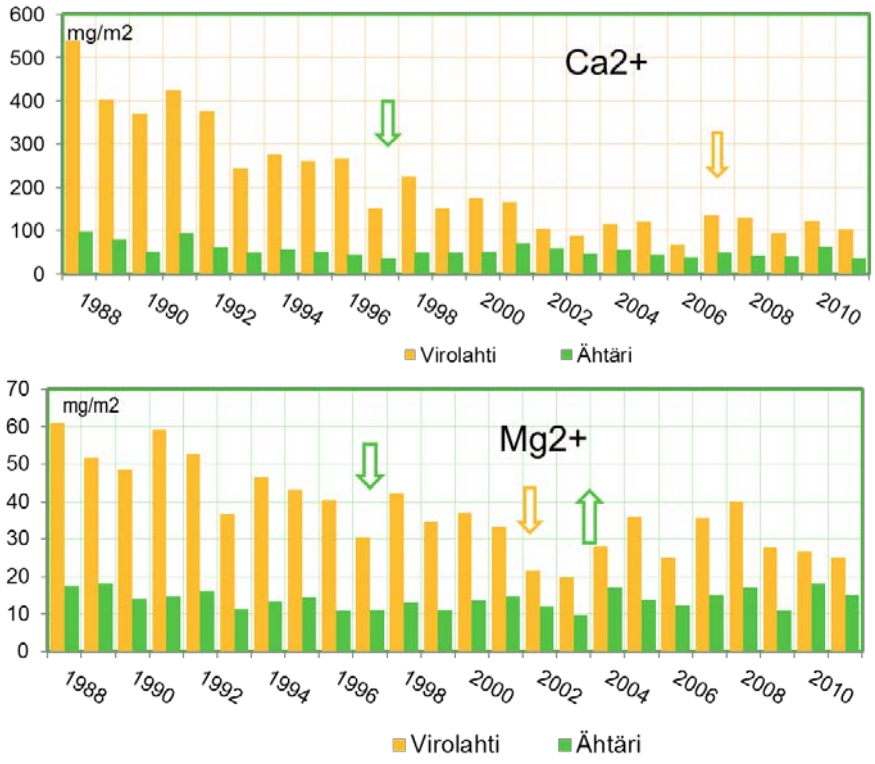

Figure 7. Yearly deposition of Ca and Mg (mg/m^2) at two Finnish EMEP-stations Virolahti and Ähtäri in 1988-2011.

	Na+		Mg2+		K+		Ca2+	
	Ähtäri	Virolahti	Ähtäri	Virolahti	Ähtäri	Virolahti	Ähtäri	Virolahti
1988-1997	-3.5±2.8	-3.0±1.2	-3.8±1.0	-4.1±1.0	-4.6±3.5	-6.9±3.3	-6.0±3.8	-6.7±2.6
1993-2002	no	no	no	-2.9±0.7	no	-4.7±4.4	no	-5.9±0.7
1998-2007	no	no	no	no	no	no	no	-5.8±3.6
2003-2011	no	no	+2.4±1.7	no	no	no	no	no

($p<0.05$), no = no trend at the 5 % level.

Figure 8. Trends (relative annual change in %) calculated from monthly BC deposition data from Ähtäri and Virolahti.

Gunilla Pihl Karlsson

Bulk deposition of base cations over Sweden:

- The Swedish precipitation and throughfall networks were presented.
- Data from all years between 2005 and 2011 were used in an analysis of BC deposition trends but no trends are available during this short period.

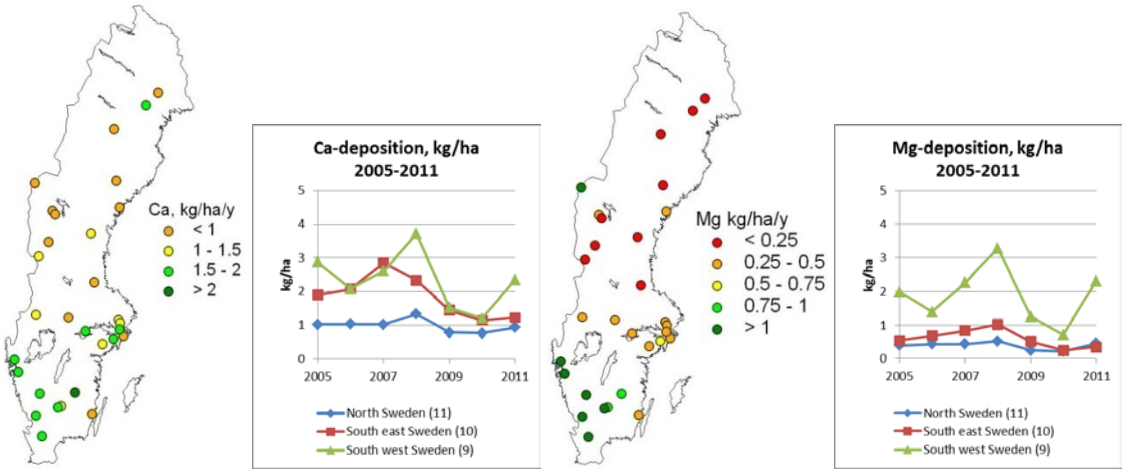

Figure 9. Diagrams: Bulk deposition (kg ha^{-1}) of Ca and Mg in three different parts of Sweden between 2005 and 2011. Maps: Ca and Mg bulk deposition for all sites in SWETHRO, IM and LNKN-networks in Sweden for a three year average (2009-2011).

Per Erik Karlsson

Base cation deposition to Norway spruce forests in Sweden (preliminary results):

- Samplers under roof were used in order to derive correction factors for dry deposition to bulk deposition samplers (different correction for different sites). A correction factor of 0 is all dry deposition, 1 is no dry deposition. Correction for dry deposition onto bulk precipitation samplers was performed by multiplying it with the correction factors.
- Teflon strings placed under a roof was washed with 150 ml clean water and used to estimate the dry deposition of BC. The basic assumption is that Vx/Vna to the strings is the same as Vx/Vna to the canopy. Teflon strings do not have the same structure as the canopy.
- If one use the sum of latitude and longitude it becomes nicely correlated with the deposition.
- The fraction between wet and dry deposition is similar for Ca and Mg but differ from K and Na.
- Low Na in the north→ several years required to be able to use the method there.
- Dry deposition contribution ranged from 70% in coastal southwest to below 10% in the far north.
- The BC deposition estimated corresponded relatively well with that estimated with the "canopy exchange model" by ICP Forests 2001.

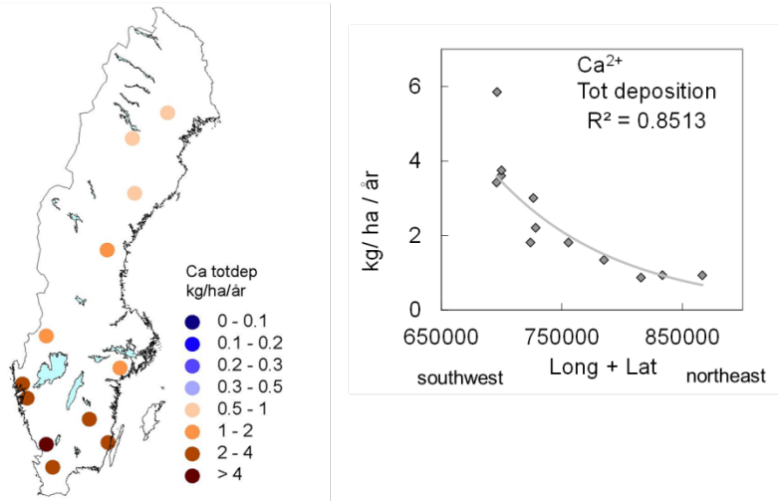

Figure 10. Left: Mapped average annual total deposition (kg ha^{-1} yr^{-1}) of Ca to deciduous forest in Sweden during the years 2001-2008. Right: Connection between the total deposition of Ca (kg ha^{-1} yr^{-1}) and the geographical position (sum of latitude and longitude) for 12 forests.

Beat Rihm

Base cation related activities in Switzerland, including new deposition maps:

- van Loon et al. 2005: Publication on EMEP modelling of base cation deposition in Europe. Those results were compared with monitoring data from Switzerland and Northern Italy.

- 2012 new provisional maps for forests based on Swiss wet and throughfall monitoring data. Dry deposition maps 150 - >350, wet deposition 140 - >350 eq/year/ha
- Throughfall data will be adjusted by canopy exchange models at WSL.
- How do we distinguish between nearby and far away sources? BC emissions from nearby arable land partially explain the pattern of dry deposition.
- The best equations were found for wet deposition of all ions (Ca+Mg+K+Na+Cl) vs. altitude.
- Higher values of dry deposition of BC (Ca+Mg+K) were assessed in the North than in the South, vice versa for wet deposition.

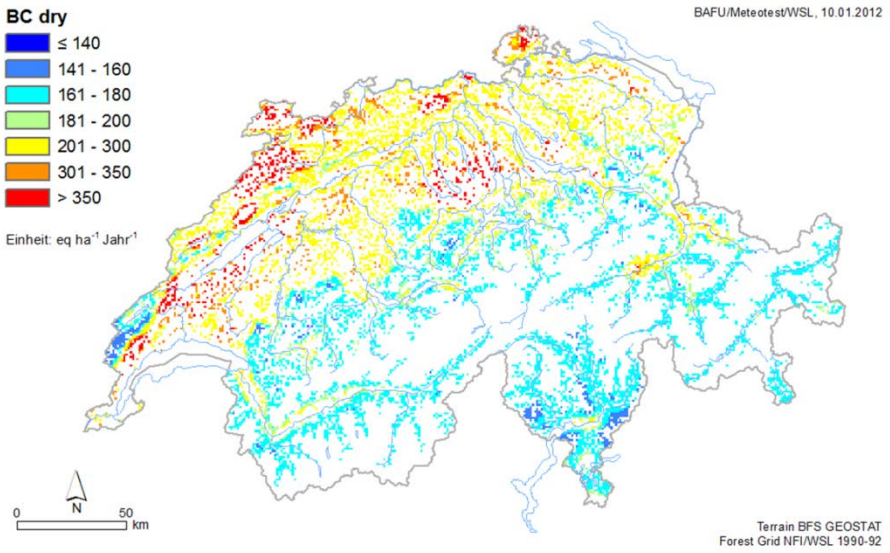

Figure 11. Dry deposition of BC (Ca+Mg+K) in Swiss forests calculated by geo-statistical interpolation, average 2006-2009 (provisional data). Units: eq ha^{-1} year^{-1}."

Julian Aherne

Biomass harvesting: is base cation deposition important in Irish forests?:

- Is biomass removal/nutrient removal sustainable? How important is deposition? Forests in Ireland are on poor mineral soils (low BC weathering), marine inputs dominate deposition.
- The ForFlux project on ICP Forests sites (objective to estimate BC budgets for Irish forests).
- Ion exchange resin columns were used to estimate total BC deposition; the difference between throughfall and open bulk sodium deposition was used as an estimate for dry deposition filter factors (DDF) = 1.2 on average wet to dry deposition.
- Total BC deposition = concentration in rainfall × volume × filter factor.
- BC deposition is the dominant source of calcium input and determinant of sustainable harvest removals (more important than weathering) in Irish forests.
- There is good agreement between EMEP wet and ICP Forests bulk chemistry under Irish climate conditions (owing to the high frequency of rain days).

- The long-term observations at ICP Forest plots do not strongly suggest a monotonic trend in BC deposition (since 1991).

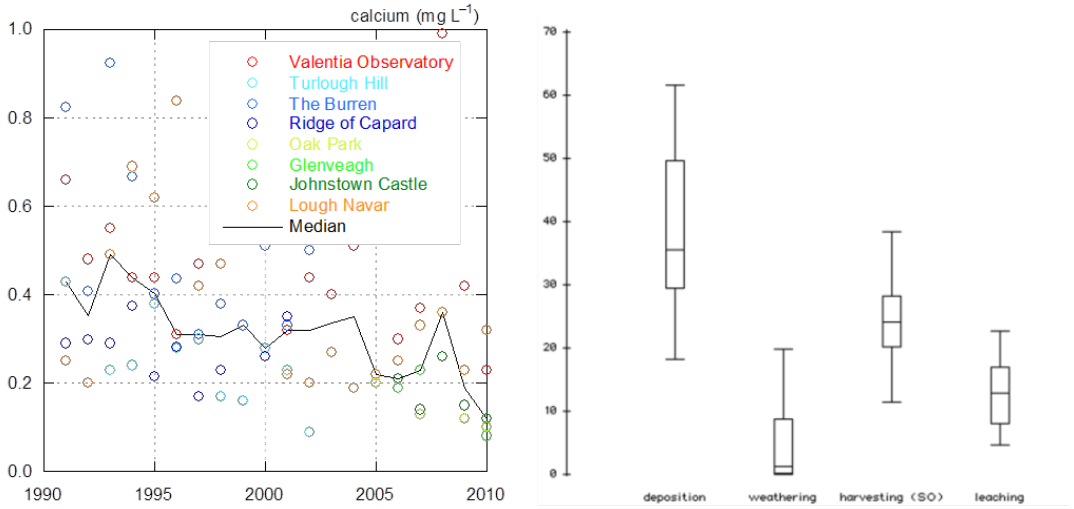

Figure 12. Left: Long-term annual trend (1991–2009) in calcium concentration in precipitation (mg L^{-1} [open circles]) at monitoring stations in Ireland contributing to the co-operative programme for monitoring and evaluation of the long range transmission of air pollutants in Europe (EMEP). Volume-weighted annual average data were derived from daily observations at all monitoring stations except Lough Navar which changed from daily to fortnightly during 1999–2000. The median concentration across all stations is also shown (black line). Data source: Chemical Co-ordinating Centre of EMEP (URL: www.nilu.no/projects/ccc). Right: Box-plot comparison of calcium input (deposition and weathering) and output (stem-only harvesting and leaching) fluxes (meq m^{-2} a^{-1}) in 35 Irish ICP Forest plots.

Svetlana Tsyro

EMEP/MSC-W experience in Base Cations modelling:

- A quite successful attempt of modelling the BC total deposition for 2000 was performed and reported in van Maarten et al. (2005), Modelling BC in Europe. The model showed reasonable performance, in particular for Ca, for which better input information was available. The work unfortunately stopped. At the meeting, the participants urged EMEP to make a new follow up on BC deposition mapping.
- The relative contribution of the main BC sources to BC deposition was presented, including the importance of dry and wet removal processes in the deposition of individual BC components.
- To improve BC modelling, we need to have better information about the geographical distribution of different soil types and about chemical content of BC in the topsoil. Back in 2005, this knowledge was mostly available for Ca. Soil maps should be looked into.
- There is no good description of the land use types: desert and bare land, agricultural crops, including growth seasons
- The anthropogenic part of BC sources appears rather small – and constant (not shown as the calculations were only made for 2000). It was suggested that maybe the anthropogenic part was larger before. This could explain the trends before 2010.

- BC wet deposition tends to be underestimated by the model and require special attention.
- Better input information on erodible soils (emission potential) and meteorology (u*, soil moisture) is essential to improve the windblown dust parameterization.
- Up-to-date inventory of BC anthropogenic emission would be needed in order to re-implement BC in the EMEP model.

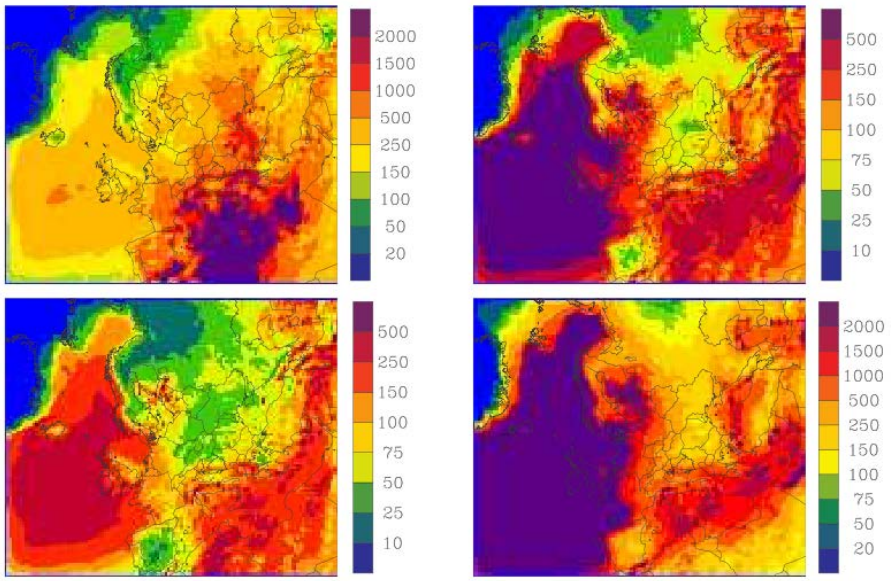

Figure 13. Total deposition of base cations calculated with the EMEP model for the year 2000: Ca^{2+}(upper left), Mg^{2+}(upper right), K^{+}(lower left), and Na^{+}(upper left). Units: mg/m^2.

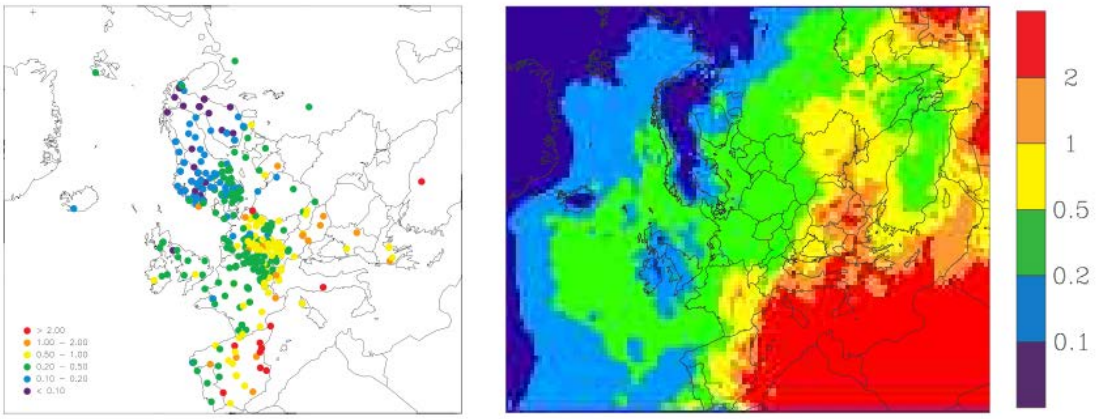

Figure 14. Observed (left) and modelled with the EMEP model (right) average concentrations in precipitation of Ca^{2+} in the year 2000 (mg/l).

Joakim Langner

Revisiting estimation of base cation deposition using MATCH-Sweden – preliminary results:

- MATCH-Sweden is a mapping activity – model calculated sea salt is used as input. Data is available on the SMHI web site. Shifts in the methods complicate the comparison.
- It is currently not possible to use MATCH Sweden for trend analysis on the MATCH-Sweden data – since the methods have changed with time.
- Monitoring air concentrations of BC started again 2009. Observed air concentrations are taken into the dry deposition module. A problem is that BC concentrations are too close to detection limits.
- Dry deposition modelled as described in Klein et al 2004: SMHI report on dry deposition.
- Application of a correction factor with the distance to the coast.
- Cannot do trend analyses with MATCH data for Ca due to changes in methodology.
- Maps below: Wet deposition of Ca from 1998 to 2010.

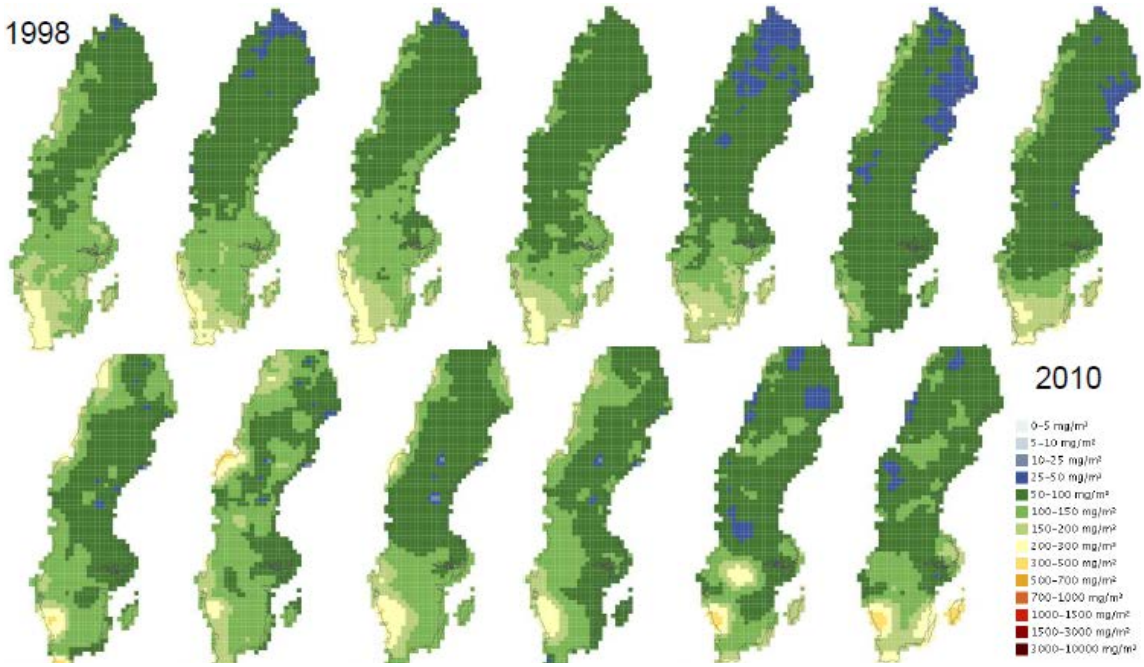

Figure 15. Total wet deposition of Calcium over Sweden for the period 1998-2010 from MATCH-Sweden mapping. Units: mg Ca m^{-2} yr^{-1}.

Ron Smith

Modelling of base cation emissions, concentrations and deposition:

- The FRAME model (Lagrangian) and EMEP4UK (Eulerian) are 2 models used in the UK for estimating deposition for future or historic scenarios, and both rely on the availability of good emission inventories.
- Anthropogenic emissions are available on www.naei.org.uk

- For sea salt aerosols, following the paper by Gong et al., 1997, a spatially disaggregated BC emissions inventory has been made available (Werner et al., 2011) and used in FRAME to generate new predicted BC deposition.
- Spatial patterns of air concentrations of BC show the gradient from the coastal regions towards low concentrations over land.
- Wet deposition of BC reaches their highest values on the western coast, and over the high precipitation mountainous regions, where deposition of Na^+, Mg^{2+} and Ca^{2+} exceeds 50 kg ha^{-1} $year^{-1}$, 6 kg ha^{-1} $year^{-1}$ and 2.5 kg ha^{-1} $year^{-1}$, respectively.
- The substantial enhancement in wet deposition with altitude can be partially explained with the seeder-feeder enhancement mechanism.

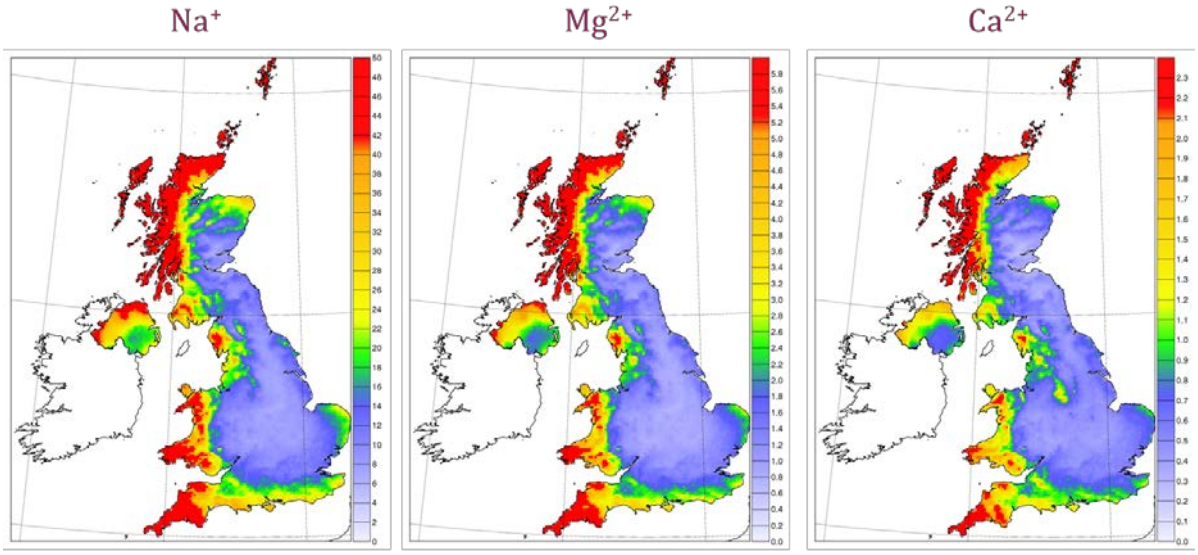

Figure 16. Base cation deposition in 2006 over the UK calculated using the FRAME model (kg ha^{-1} $year^{-1}$). On the western coast and over the high precipitation mountainous regions deposition of Na^+, Mg^{2+} and Ca^{2+} exceeds 50 kg ha^{-1} $year^{-1}$, 6 kg ha^{-1} $year^{-1}$ and 2.5 kg ha^{-1} $year^{-1}$ respectively.

Roy Wichink Kruit

Modelling Base Cation concentrations and deposition with LOTOS-EUROS:

- Data on BC content in topsoil for Europe is used for the modelling – see figure below.
- Sea salt contributes more than 95% in large parts of Europe.
- A fraction of PM is assumed to be BC – a fixed ratio which is not correct.
- It is important to get the emission inventories consistent – review literature.
- Strong indications that wood burning is 50-70% underestimated in the southern countries. In the model, they have put the wood burning to outskirts of the cities and in the countryside.
- Recommend to revise the Draaijers approach to calculate dry deposition.
- Currently working on a module of pollen – pollen will have different amounts of K in it. Local – difficult to calculate the episodes. Pollen prognoses – can be compared to K in wet deposition and throughfall.

- Have done BC mapping for Germany. Put a lot of effort into the emissions since there are large uncertainties in these. Na mainly from natural sources is modelled quite well. Use Na as a tracer – check with Cl. But Cl is more reactive and complex. Non sea salt Mg is not important – only sea salt. For K and Ca a small extra deposition is coming in the north part of Germany next to the sea.
- Agreement between measured and modelled deposition is relatively OK north of the Alps but south of the Alps not very well. Probably likely that they miss the Saharan dust in the model.
- Ca (but also K) mainly from anthropogenic sources is more challenging to model due to timing problems and an uncertain magnitude of the emissions. There are differences in inventory emissions from what has been reported.

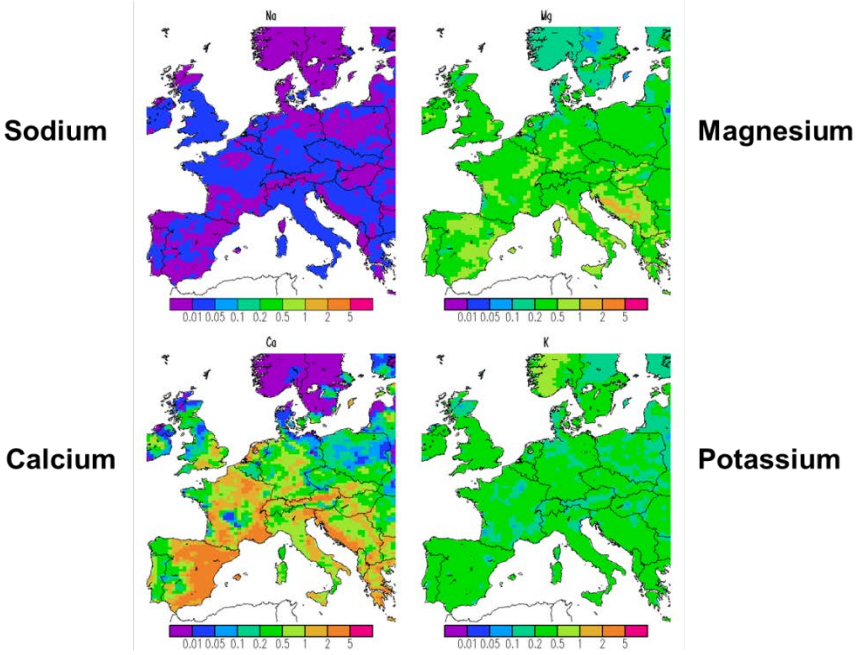

Figure 17. Base cation fractions in European top soils (g/kg soil).

Julian Aherne

Critical loads: estimating Canada-wide base cation deposition:

- Objective to develop a simple approach to map Canada-wide base cation deposition to forest ecosystems (based on fusion of observations and modelled data) for determination of critical loads.
- Used BC deposition observations from the CAPMoN network (Canadian air and Precipitation Monitoring Network): 17 stations in eastern Canada and only 3 in western Canada.
- Environment Canada developed a map of the total BC deposition from 1994–1998 for most Canadian provinces by interpolation of wet deposition, and inferential modelling of dry deposition from air concentrations. A simple approach was used to infill total

deposition for remaining provinces, i.e., linear regression between a global dust model and total BC deposition estimates.

- Increasing trend in long-term (1990–2010) calcium deposition is observed as opposed to many places in Europe.

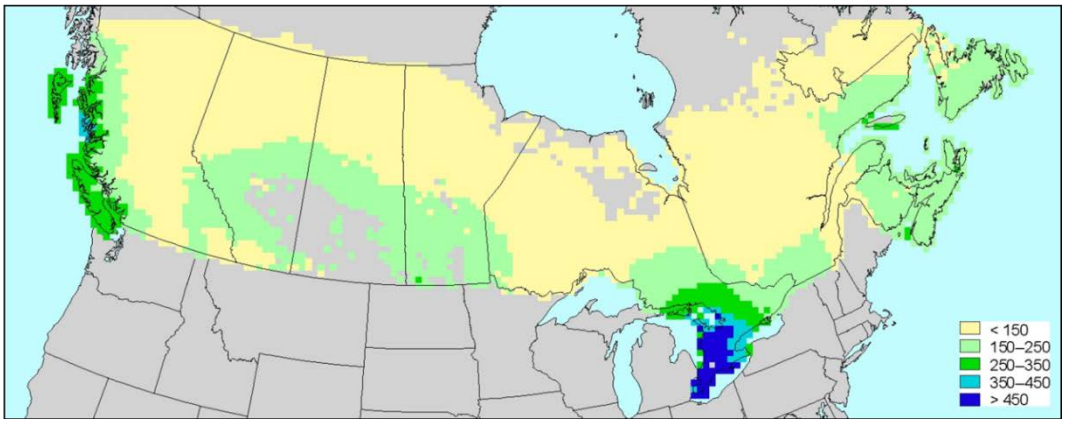

Figure 18. Total (wet and dry) non-marine base cation deposition (eq ha^{-1} a^{-1}) for Canadian provinces.