

**NATIONAL IMPLEMENTATION PLAN 2014+ FOR THE AMAP TRENDS AND EFFECTS PROGRAMME**

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## **PREFACE**

The monitoring work within AMAP is based, as far as possible, on existing national and international monitoring and research programmes. The Finnish National Implementation Plan (NIP) has been prepared in accordance with the principle that individual environmental research institutes and other relevant bodies include AMAP issues in their field of work. The monitoring programmes are directed to better meet the needs of AMAP.

The NIP is a comprehensive tentative list of the research, long-term monitoring programmes and other supporting studies that produce data relevant to the AMAP objectives. The environmental research and monitoring programmes are carried out by national research institutes, local authorities and universities, under the auspices of five different ministries. The Finnish NIP is prepared by the Finnish National AMAP Working Group, which is composed of representatives from the following relevant national bodies:

- Ministry of the Environment
- Finnish Environment Institute (SYKE)
- Centre for Economic Development, Transport and the Environment for Lapland
- Finnish Meteorological Institute (FMI)
- Finnish Forest Research Institute (Metla)
- Geological Survey of Finland (GTK)
- Finnish Food Safety Authority (Evira)
- Radiation and Nuclear Safety Authority (STUK)
- Finnish Game and Fisheries Research Institute (RKTL)
- Thule Institute, University of Oulu
- Sami Parliament of Finland

The NIP includes seven sub-programmes. The sub-programmes are defined in terms of parameters and media to be monitored. Climate change effects are included as an entity, monitoring of which targets a wide variety of media and variables. Contaminants with high relevance to AMAP, such as persistent organic contaminants (POPs), heavy metals and radioactivity, are considered in detail. Effects of pollution on human health in the Arctic, including the possible effects of increased UV radiation and climate change, are also priorities. Part of the data (e.g. atmospheric data and freshwater contaminants) will be submitted regularly to the thematic data centres (TDCs). Other data, such as terrestrial data and hydrological data, will be available for the assessment procedure on request.

The strategy for further development of the monitoring activities in Finland is to promote the integration of the sub-programmes. This will enable the sub-programmes to utilise data from other media in their work. Finland has established Long-Term Socio-Ecological Research Network (FinLTSER) that consists of nine sites. Each site consists of several participating organizations that are engaged in multi- and interdisciplinary research and monitoring. The main research themes within the FinLTSER are climate change, biodiversity, ecosystem services, land use and sustainable development. LTER sites and LTSER platforms cover terrestrial, freshwater, brackish water, agricultural and urban ecosystems. The FinLTSER aims to be an integrated, multi-functional network of infrastructures for ecological and socio-ecological research and monitoring. Two of the sites are highly relevant for AMAP: Pallas-Sodankylä LTER observatory and Northern LTSER Platform. These will provide an integral contribution to the monitoring of the Northern Fennoscandian Key area.

## 1. ATMOSPHERIC SUB-PROGRAMME

### 1.1 Objective and structure

The atmospheric monitoring provides data for the future assessment of the state of the Arctic environment, especially for temporal and spatial trends in concentrations of heavy metals, POPs and acidifying substances in air and precipitation.

The Finnish monitoring programme consists of measurements performed within the framework of international and national programmes, supplemented by a number of parameter measurements established for the AMAP programme at Pallas.

The international programmes are:

- EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Pollutants in Europe) coordinated by UN/ECE.
- WMO/GAW (Global Atmosphere Watch of the World Meteorological Organisation). The purpose and long-term goal is to provide data, scientific assessments and other information on changes in the chemical composition and related physical characteristics of background atmosphere from all parts of the Globe.
- Integrated Monitoring, also coordinated by ECE, for estimation of the long-term effects of air pollutants on a complete ecosystem in a restricted catchment area.
- Integrated Carbon Observation System (ICOS) is a European Research Infrastructure for quantifying and understanding of the greenhouse gas balance of the European continent and adjacent regions.

### 1.2 Monitoring and effects studies

Target media	Parameters	Frequency	Location of sampling/ Examination	Programme and/or responsible institute
Air/aerosol	PAH, HCH, PCB, DDE, DDD, DDT, chlordane, trans-nonachlor	Weekly	Pallas	FMI, IVL
	PM10, Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V, Zn	Weekly	Pallas	FMI
	Hg; particulate	Weekly	Pallas	FMI, IVL
	Hg; gaseous	Continuous weekly	Pallas	FMI IVL
	SO <sub>2</sub> , SO <sub>4</sub> <sup>2-</sup> , sum NO <sub>3</sub> <sup>-</sup> + HNO <sub>3</sub> , sum NH <sub>3</sub> + NH <sub>4</sub> <sup>+</sup>	Daily	Pallas	GAW/FMI/IM
	NO, NO <sub>2</sub> , SO <sub>2</sub> , O <sub>3</sub> , CO <sub>2</sub> , CO, N <sub>2</sub> O, CH <sub>4</sub> , SF <sub>6</sub> , condensation nuclei, black carbon, <sup>222</sup> Rn, light scattering, light absorption, aerosol size distribution, aerosol hygroscopicity, insitu cloud microphysical properties	Continuous	Pallas	GAW/FMI
	CO <sub>2</sub> and CH <sub>4</sub> fluxes, sensible and latent heat flux, solar radiation; spruce forest and aapa mire	Continuous	Pallas	ICOS/FMI
	VOCs	Continuous	Pallas	GAW/FMI
	SO <sub>2</sub> , SO <sub>4</sub> <sup>2-</sup> , sum NO <sub>3</sub> <sup>-</sup> + HNO <sub>3</sub> , sum NH <sub>3</sub> + NH <sub>4</sub> <sup>+</sup>	Weekly	Oulanka	EMEP/IM/FMI

Air/aerosol	NO <sub>2</sub> , O <sub>3</sub> , SO <sub>2</sub>	Continuous	Oulanka	EMEP/FMI
	O <sub>3</sub>	Continuous	Sodankylä	GAW/FMI
	CO <sub>2</sub> , CO and CH <sub>4</sub> concentrations	Continuous	Sodankylä	FMI
	CO <sub>2</sub> and CH <sub>4</sub> fluxes, pine forest, mire	Continuous	Sodankylä	ICOS/FMI
	<sup>210</sup> Pb, <sup>7</sup> Be	Daily	Sodankylä	GAW/FMI
	<sup>222</sup> Rn	Continuous	Sodankylä	GAW/FMI
	Aerosol Optical Depth, Aerosol vertical distribution	Continuous	Sodankylä	GAW/FMI
Bulk precipitation	PAH, HCH, PCB, DDE, DDD, DDT, chlordane, trans-nonachlor	2-week samples	Pallas	FMI, IVL
	SO <sub>4</sub> <sup>2-</sup> , NO <sub>3</sub> <sup>-</sup> , NH <sub>4</sub> <sup>+</sup> , Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , Cl <sup>-</sup> , K <sup>+</sup> , pH, conductivity	Weekly	Pallas	EMEP/IM/FMI
	PAH, PCB, OCP, PCDD/F, cPCB	Monthly, May-September	Pallas	SYKE
	Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V, Zn	Monthly	Pallas	FMI/IM
	Hg	Monthly	Pallas	FMI, IVL
	SO <sub>4</sub> <sup>2-</sup> , NO <sub>3</sub> <sup>-</sup> , NH <sub>4</sub> <sup>+</sup> , Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , Cl <sup>-</sup> , K <sup>+</sup> , pH, conductivity	Weekly	Oulanka	EMEP/IM/FMI
	Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V, Zn	Monthly	Kevo, Oulanka	IM/FMI
	SO <sub>4</sub> <sup>2-</sup> , NO <sub>3</sub> <sup>-</sup> , NH <sub>4</sub> <sup>+</sup> , Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , Cl <sup>-</sup> , K <sup>+</sup> , pH, conductivity	Monthly	Kevo, Sodankylä	IM/FMI (IM only in Kevo)
Ozone/UV-B	Upper air soundings	Every 2 days	Sodankylä	GAW/FMI
	Ozone soundings	Weekly	Sodankylä	GAW/FMI
	Backscatter soundings	5 / winter	Sodankylä	FMI
	Total column ozone (Brewer #037, Saoz)	Continuous	Sodankylä	GAW/FMI
	NO <sub>2</sub> (Saoz)	Continuous	Sodankylä	GAW/FMI
	UV-B (290 - 325 nm); spectral Brewer	Continuous	Sodankylä	GAW/FMI
	CIE-weighted total UV-dose	Continuous	Sodankylä	GAW/FMI
	Solar radiation: global, diffuse, reflected	Continuous	Sodankylä	FMI
	Radiation balance, sunshine hours	Continuous	Sodankylä	FMI
	Reflected CIE-weighted total UV-dose	Continuous	Sodankylä	FMI
	Meteorology	Continuous	Sodankylä	FMI
	Meteorology, at three sites, 300-760 m a. s. l.	Continuous	Pallas	FMI

AMAP  
EMEP

Arctic Monitoring and Assessment Programme  
Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe

FMI  
GAW  
IM

Finnish Meteorological Institute  
Global Atmosphere Watch of the World Meteorological Organization  
Integrated Monitoring

### 1.3 Supporting studies

Within Integrated Carbon Observing System project, greenhouse gas fluxes between the atmosphere and forest and wetland ecosystems are extensively studied using micrometeorological methods. We measure carbon balances in forest and mire sites to study how terrestrial biosphere in Lapland affects greenhouse gas concentrations observed in Pallas, what are the annual carbon balances in cold climate, and how the biospheric carbon sink is affected by climate changes.

Ozone research is based on measurements and models. FMI is collaborating with NCAR in the field of 3-D stratospheric chemistry and dynamics modelling. The ROSE model has been developed further for Arctic and Antarctic ozone simulation purposes. FMI is also collaborating with MPI (Hamburg) in the field of (stratospheric) climate modelling based on ECHAM4 Middle Atmosphere GCM model. The following topics are currently of interest:

- \* The roles of chemistry and dynamics in the observed ozone depletion at high latitudes
- \* Interactions between (stratospheric) climate change and ozone chemistry
- \* Ozone scenarios
- \* Observed changes in polar vortex behaviour

In addition to carrying out its own UV measurements, FMI is also hosting a European UV database containing spectral UV data from about 30 European stations and ancillary data. The database consists of single files and an Oracle relational database accessible through Internet. Methodology on space-born retrieval of UV radiation at the Earth's surface is also being developed as a part of FMI, NASA and IASB collaboration. The following items are being studied:

- The impacts of ozone depletion, snow cover and cloudiness on UV radiation
- UV trends based on different techniques
- Space-born UV retrieval and its validation
- UV scenarios
- UV measurement methodologies and their errors

Satellite activities related to Arctic regions:

- EUMETSAT Satellite Application Facility on Ozone Monitoring (Ozone SAF)
- Terra (EOS AM) and Aqua (EOS PM) MODIS (Moderate Resolution Imaging Spectroradiometer) reception
- Aura/OMI Very Fast Delivery data reception, processing and dissemination of Northern Europe and Arctic regions (<http://omivfd.fmi.fi/>). OMI VFD provides O<sub>3</sub>, UV, cloud cover, SO<sub>2</sub> and Aerosol information in near real time (within 15 minutes from the satellite overpass). OMI VFD products were used for example to monitor the Arctic ozone hole in March 2011 and the Grimsvötn volcanic eruption in May 2012.
- Under development NASA's Suomi-NPP/OMPS Very Fast Delivery data reception and processing in Sodankylä (TEKES funding).
- TROPOMI, UV algorithm development and processing development as part of the Sentinel Collaborative Ground-segment in Sodankylä (Tekes project)
- Air quality studies at high latitudes. OMI NO<sub>2</sub> data for ship emission monitoring in Baltic Sea and air quality in Northern Europe (urban sites).
- Studies on improved UV forecast after Arctic ozone loss in 2011 (*Karpechko, A. Yu., et al. (2013), The link between springtime total ozone and summer UV radiation in Northern Hemisphere extratropics, J. Geophys. Res. Atmos.*)

- Algorithm improvement for Envisat/GOMOS measurements of ozone, NO<sub>2</sub>, NO<sub>3</sub>, aerosols, H<sub>2</sub>O, temperature (ESA funding)
- Research on-going on polar ozone monitoring – (total ozone from OMI, ozone profiles from Envisat/GOMOS, Odin/OSIRIS, long term time series) (Funding ESA, Finnish Academy)
- Effect of energetic particles on polar middle atmosphere composition and links to climate (Funding from Finnish Academy)
- Research ongoing to analyse and improve the interpretation of satellite observations of atmospheric composition at high latitudes (funding from ESA, Finnish Academy, Tekes)

A UV research centre, Finland's Ultraviolet International Research Centre (FUVIRC), was established at Sodankylä earlier. The centre serves ecosystem research, human health research and atmospheric chemistry research by providing UV monitoring data and guidance, research facilities, instruments and equipment.

#### National projects:

- Aerosols in the atmosphere and cloud formation (University of Oulu, University of Helsinki, University of Kuopio, FMI).
- Environmental effects of the Kola air pollution sources in Kola area and in Finnish Lapland
- Atmospheric hydrogen, methane and ozone – new challenges to air pollution control in changing society
- Nordic Centre of Excellence “Cryosphere-atmosphere interactions in a changing Arctic climate (CRAICC)”, Stability and Variations of Arctic Land Ice (SVALI), Cryosphere-atmosphere interactions in a changing Arctic climate (CRAICC)
- Academy of Finland projects: Arctic Absorbing Aerosols and Albedo of Snow (A4), Aerosol technologies for cooling the climate: Costs, benefits, side effects, and governance (COOL), Greenhouse gas, aerosol and albedo variations in the changing Arctic, Centre of Excellence in Atmospheric Science – From Molecular and Biological Processes to the Global Climate
- Mitigation of Arctic warming by controlling European black carbon emissions, EU LIFE+ ([www.maceb.fi](http://www.maceb.fi))

#### Other programmes:

- TCCON: Total Carbon Column Observing Network
- GRUAN: GCOS Reference Upper Air Network
- ACTRIS: Aerosols, Clouds, and Trace gases Research InfraStructure Network

## 2. MARINE SUB-PROGRAMME

The Arctic Circle marks the southern limit for AMAP area, and therefore Baltic Sea is not included in the Arctic co-operative programmes. Actual monitoring in the arctic area is not conducted by Finland. However, Finland has participated in Arctic marine research and can contribute to the AMAP marine sub-programme with selected supporting studies.

Finnish Institute of Marine Research (FIMR) was in charge of marine monitoring and research until 2009, after which its functions were divided between Finnish Meteorological Institute and Finnish Environmental Institute (SYKE).

The former Finnish Institute of Marine Research (FIMR) participated in several studies in Russia:

- Ecological studies in the Pechora Sea area in cooperation with Murmansk Marine Biological Institute (MMBI), 1991-1885
- Project: Sustainable management of the Marine ecosystem and living resources and living resources of the White Sea, 2000-2002, in cooperation with Nansen International Environmental Centre and Remote Sensing Centre in St. Petersburg and Bergen, MMBI and Northern Water Problem Institute in Petrozavodsk, Russia
- A follow-up project in 2005: The current state of the Russian Marine Ecosystem Monitoring for the White Sea and its relevance to the EU Directive on Water Policy and UN Agenda 21, with the same partners.

Finnish Meteorological Institute conducts physical oceanography in the Baltic Sea and also participates in research work on marine dynamics and modelling in the arctic. For publications, see <http://en.ilmatiiteenlaitos.fi/marine-dynamics-and-modelling>.

In addition, the following studies are considered relevant for the AMAP Programme:

- Arctic snow, sea-ice and glaciers in a changing climate (University of Helsinki, Arctic Centre)
- Sedimentary and geochemical indicators of climatic and environmental change in polar margins (University of Oulu)

### 3. FRESHWATER ECOSYSTEMS SUB-PROGRAMME

#### 3.1 Objective and structure

The main objective of the freshwater programme is to provide both spatial and temporal monitoring data for the assessment of ecological and chemical state.

Monitoring programme is established for national needs and for implementation of legislative objectives, e.g. the water framework directive (2000/60/EY) and international protocols, such as AMAP and international cooperative programmes.

In lakes and rivers water quality monitoring covers a range of chemical and biological parameters. In groundwater monitoring includes chemical quality and quantitative status. Monitoring programme for bioaccumulating compounds in freshwaters follows the concentration of mercury and POPs, among others, in fish tissue.

Monitoring is mainly conducted by Finnish Environment Institute (SYKE) together with regional Centre for Economic Development, Transport and the Environment (LAPELY).

#### 3.2 Monitoring and effects studies

Target media	Parameters	Frequency	Location of sampling/examination	Programme and/or responsible institute
Lake water	General water chemistry, including major ions, pH, alkalinity, TOC, conductivity, P, N, Cd, Cu, Pb, Zn, Ni, As, Cr, Co, V, Pt, Pd, Fe, Mn, Al, tot Hg	6 times a year	Vasikkajärvi and Suopalampi	ICP Waters (SYKE+LAPELY)
	General water chemistry, including major ions, pH, alkalinity, TOC, conductivity, P, N, Cd, Cu, Pb, Zn, Ni, As, Cr, Co, V, Pt, Pd, Fe, Mn, Al, tot Hg	7 times a year	Pallasjärvi	ICP IM (SYKE+LAPELY)
	General water chemistry, including major ions, pH, alkalinity, TOC, conductivity, P, N, Cd, Cu, Pb, Zn, Ni, As, Cr, Co, V, Pt, Pd, Fe, Mn, Al, tot Hg	3-6 times a year	8 lakes in Finnish AMAP area	National (SYKE+LAPELY)
	General water chemistry, including major ions, pH, alkalinity, TOC, conductivity, P, N (in some lakes also Cd, Cu, Pb, Zn, Ni, As, Cr, Co, V, Pt, Pd, Fe, Mn, Al, tot Hg)	3-6 year interval	62 lakes in Finnish AMAP area	National (SYKE+LAPELY)
Stream water	General water chemistry, including major ions, pH, alkalinity, TOC, conductivity, P, N	10-15 times a year	Laanioja Vähä-Askanjoki	National (SYKE+LAPELY)
	General water chemistry, including major ions, pH, alkalinity, TOC, conductivity, P, N (in some rivers also As, Cd, Cr, Cu, Ni, Pb, Zn, Fe, Al, K, Ca, Mg, Na, Cl, Mn)	1-6 year interval	62 rivers in Finnish AMAP area	National (SYKE+LAPELY)
Lake sediment	Heavy metals incl. Cd, Cu, Pb, As, Hg, Ni, PAH, , PCBs, DDTs, PCDD/F	ca. 20 year interval	3-5 small lakes in Lapland	SYKE

	Diatom inferred acidification and climate change history from sediment cores	-	3-5 lakes in Northern Lapland	University of Helsinki
Surface temperature	Surface temperature of open waters	Daily	5 lakes north of Arctic circle	SYKE
Ice	Ice freeze-up and break-up dates	Annual	Ca. 10 lakes north of Arctic Circle, River Tornionjoki	SYKE
	Thickness of ice cover in lakes	3 times a month (winter)	Ca. 11 sampling points in Lapland	SYKE
Groundwater	In the field: temperature, pH, conductivity, O and CO <sub>2</sub> . In laboratory: total N, NH <sub>4</sub> <sup>+</sup> , NO <sub>3</sub> , PO <sub>4</sub> <sup>3-</sup> , total P, SO <sub>4</sub> <sup>2-</sup> , alkalinity (HCO <sub>3</sub> ), Cl, TOC, Al, Ba, Fe, Mn, Sr, Ti, Zn, Ca, K, Mg, Na, As, Cd, Co, Cr, Cu, Ni, Pb, Se, V, Z.	2-4 times a year	6 stations in Finnish AMAP area	SYKE
	F-, Hg, SiO <sub>2</sub> , U, NO <sub>2</sub> .	Once a year		
	In the field: temperature, pH, conductivity, O and CO <sub>2</sub> . In laboratory: total N, NH <sub>4</sub> <sup>+</sup> , NO <sub>3</sub> , PO <sub>4</sub> <sup>3-</sup> , total P, SO <sub>4</sub> <sup>2-</sup> , alkalinity (HCO <sub>3</sub> ), Cl, TOC, Al, Ba, Fe, Mn, Sr, Ti, Zn, Ca, K, Mg, Na, As, Cd, Co, Cr, Cu, Ni, Pb, Se, V, Z, Ag, Be, Li, Rb, Tl, B, Mo, Sb, Sn, Pd, Pt, Bi, Th, U	4 times a year	Leppäjärvi, Enontekiö	SYKE
	Ground water level	twice a month	7 stations in Finnish AMAP area	SYKE
Flora and fauna in lakes	Species and community structure of phytoplankton, diatoms, benthic macroinvertebrates, macrophytes, fish*	1-12 year interval	71 lakes in Finnish AMAP area	SYKE, LAPELY, RKTL
Flora and fauna in rivers	Species and community structure of diatoms, benthic macroinvertebrates, fish*	1-12 year interval	62 rivers in Finnish AMAP area	SYKE, LAPELY, RKTL
Fish (muscle)	Hg, chlorine compounds, dioxins, furans, PCBs, PBDE	1-3 year interval	Keimijärvi Lake Inarijärvi	SYKE
	Hg	screening 2010-2013	16 lakes in Finnish AMAP area	SYKE

\* one or more targets depending on location

ICP Waters	International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes
ICP IM	International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems
ECE	Economic Commission for Europe (UN)
SYKE	Finnish Environment Institute
LAPELY	Centre for Economic Development, Transport and the Environment for Lapland
RKTL	Finnish Game and Fisheries Research Institute
EVIRA	Finnish Food Safety Authority

### 3.3 Supporting studies

Geological Survey of Finland has conducted stream water quality and sediment surveys concerning chemical elements and their isotopes. However, these surveys do not continue. Geological Survey of Finland was previously responsible for ground water monitoring until 2006 and it still has ongoing study of groundwater isotopes: sampling four times a year in near vicinity of the Finnish AMAP area. In addition rainwater or snow samples are collected monthly in the same location for isotope analysis.

Following projects are relevant for AMAP programme:

- Interreg IIIA Kolarctic project: Development and implementation of an environmental monitoring and assessment system in the joint Finnish, Norwegian and Russian border area, 2003-2006. The project reports on the state environment and produced implementation guidelines for monitoring in the border area. Participants in Finland include Lapland ELY-centre and Finnish Environment Institute.
- A follow-up project: Trilateral cooperation on Environmental Challenges in the Joint Border Area, 2012-2014. The project is to produce more information on environmental impacts of airborne emissions, regulation of waterways and climate change targeting the surface waters in the border area.

## 4. TERRESTRIAL ECOSYSTEMS SUB-PROGRAMME

### 4.1 Objective and structure

The objective is:

- 1) to monitor the effects of anthropogenic air pollutants and contaminants on tundra and forest ecosystems,
- 2) to assess the impact of possible climate change on tundra and forest ecosystems, and
- 3) to determine the effects of UV-B radiation on tundra and forest ecosystems.

Finnish Forest Research Institute (Metla) conducts forest monitoring, which is subdivided into two levels: intensive and regional monitoring.

Intensive monitoring plots include the ICP-Forests (Level II) and ICP-IM plots, which form part of the Pan-European Forest Condition Monitoring Programme, originally instigated under the auspices of the UN/ECE. There are 5 such plots in northern Finland. The purpose of monitoring is to investigate the relationships between anthropogenic and abiotic stress factors and the condition and vitality of forest ecosystems. Monitoring includes physical and chemical parameters in the soil and soil solution, as well as biological parameters related to the functioning of the forests.

Finnish Forest Research Institute (Metla) conducts surveys on forest condition in northern Finland, as part of the ICP-Forests programme, on a network of about 120 plots on Level I. In addition to the annual assessment of parameters relating to forest condition (defoliation, discoloration), needle chemistry surveys are carried out at 2-year intervals. Soil survey was carried out in 1986-89, 1995 and 2006. Heavy-metal survey on moss samples has been carried out in every 5 years since 1985, last time in 2010.

Finnish Food Safety Authority (Evira, formerly EELA) monitors contaminants in reindeer and moose.

### 4.2 Monitoring and effects studies

Target media	Parameters	Frequency	Location of sampling/ examination	Programme and/or responsible institute
Tree stand	Tree growth Defoliation Needle chemistry (N, S, P, B, Ca, Mg, K, Cu, Zn, Mo)	Every 5 years Yearly Every 2 years	Sevettijärvi (pine) Pallas (spruce) Kivalo (pine) Kivalo (spruce) Oulanka (spruce)	ICP Forests (UN/ECE/ LRTAP) Metla
Ground vegetation	Species composition	Every 5 years	Ca. 100 plots	Metla
Mosses, epiphytic lichens, pine bark	As, Cd, Cr, Cu, Fe, Pb, Ni, V, Zn, S	Every 5 years		Metla

Stand throughfall	pH, Ca, Mg, K, Na, Mn, Cu, Zn, DOC, NH <sub>4</sub> , NO <sub>3</sub> , SO <sub>4</sub> , PO <sub>4</sub>	Every 4 weeks	Sevettijärvi (pine) Pallas (spruce) Kivalo (pine) Kivalo (spruce)	ICP Forests (UN/ECE/LRTAP) Metla
Soil solution	pH, Ca, Mg, K, Na, Mn, Cu, Zn, total Al, Al <sup>3+</sup> , Fe, DOC, NH <sub>4</sub> , NO <sub>3</sub> , SO <sub>4</sub> , PO <sub>4</sub>			
Litterfall	Ca, Mg, K, Na, Fe, Cu, Zn			
Phenology	Main tree species	Weekly	Ca. 10 in Lapland	Metla
Forest growth and condition	Tree growth, tree health, amount of deadwood etc.	Yearly	Ca. 1 plot / 10*10 km	Metla: NFI
Stand climate	Above stand Air temperature Wind speed Wind direction Solar radiation PAR  Within stand Relative humidity Air temperature Soil temperature Soil moisture	Continuous (1 h) Continuous (1 h) Continuous (1 h) Continuous (1 h) Continuous (1 h)  Continuous (1 h) Continuous (1 h) Continuous (1 h) Continuous (1 h)	Pallas (spruce) Kivalo (pine) Kivalo (spruce)	ICP Forests (UN/ECE/LRTAP) Metla
Reindeer (muscle, liver and kidney)	DDT, PCBs, HCB, HCHs, PCNB, chlordane, chlorobenzilate, heptachlor, dieldrin, aldrin, endrin, endosulfans, tecnazana, quintozone, azinphos ethyl, chlorpyrifos, diazinon, fenthion (sulfoxide), methidathion, parathion (methyl), paraoxon methyl, pirimiphos methyl, profenofos, pyrazophos, triazophos, Pb, Cd, As, Cr, Cu, Mn, Ni, Se, Zn.	Annual	Lapland	National residue control program, Evira
Elk (muscle)	Cypermethrin, Cyfluthrin, Bifenthrin, DDT, HCHs, HCB, PCBs, chlordane, chlorobenzilate, heptachlor, dieldrin, endrin, endosulfan, tecnazene, quintozone, azinphos ethyl, chlorpyrifos, chlorpyrifos methyl, diazinon, fenthion (sulfoxide), methidathion, parathion (methyl), pirimiphos methyl, profenofos, pyrazophos, triazophos, Pb, Cd, As, Cr, Cu, Mn, Ni, Se, Zn.	Annual	Finland	National residue control Program, Evira

ICP Forests International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests

UN/ ECE United Nations/ Economic Commission for Europe

LRTAP Long-Range Transboundary Air Pollution

NFI National Forest Inventory

Metla Finnish Forest Research Institute

Evira Finnish Food Safety Authority

SYKE Finnish Environment Institute

### 4.3 Supporting studies

A large number of supporting studies have been carried out in north Finland:

- Ecology and management of timberline areas, 1994-1998, 1999-2003, 2004, 2009 (Metla)
- Global Change in Subarctic Environment: Physiological and Ecological Stress Responses and Recovery of Wild Plants (University of Oulu)
- Factors affecting microbial production of nitrous oxide and nitric oxide in agricultural soils (AGROGAS) (University of Kuopio, Agricultural Research Centre of Finland, FMI, University of Joensuu)
- Dynamics and modelling of the functioning and structure of forest ecosystems with implications for sustainability of the forest production and climate change impact (University of Joensuu)
- Climate-biOsphERE interactions (CORE) (University of Helsinki, University of Kuopio, FMI)
- Modelling past global change - forecasting the future (Geological Survey of Finland)
- The impact of increased UV-B on plant ecosystems (University of Oulu)
- Paleoenvironment and Climate in the North (University of Oulu)
- Reindeer husbandry and the changing environment, 2002-2005 (Metla)
- Heavy metal concentrations in berries and edible mushrooms in Eastern Lapland and the Laplandia Biosphere Reserve (Russia) and related areas, 2004-2007 (Metla)
- Discovery of Arctic microorganisms for biotechnical applications, 2001-2005 (Metla, Geological Survey of Finland)
- Interreg IIIA Kolarctic project: Development and implementation of an environmental monitoring and assessment system in the joint Finnish, Norwegian and Russian border area, 2003-2006 (Metla). As part of the project terrestrial monitoring network was established in North-East border area.
- Ecogeochemical Mapping of Eastern Barents Region, 1999-2003 (Geological Survey of Finland). Joint project between Finland, Norway and Russia. Produced data of chemical element concentrations in moss and soil from 1500 sampling points.

## 5. RADIOACTIVITY SUB-PROGRAMME

### 5.1 Objective and structure

The main goal of the surveillance of environmental radioactivity by Radiation and Nuclear Safety Authority (STUK) is to be aware of the radiation levels to which the public is exposed. Another goal is to detect all notable changes in the levels of environmental radiation and radioactivity. Running surveillance programmes on a continuous basis also maintains and develops competence and readiness to respond to radiological emergencies.

The surveillance programme on environmental radioactivity (YSV) includes continuous and automated monitoring of external dose rate, regular monitoring of radioactive substances in outdoor air, in deposition, in surface and drinking water, food and in human body. Since 2002 the surveillance of the Baltic Sea is also included in the programme.

The research programs of STUK's Regional Laboratory in Northern Finland include several environmental research projects in which the transport and accumulation of anthropogenic radionuclides in arctic food chains, and the concentration in locally produced foodstuffs, are studied. The results of these long time series were extensively used in the first and second phase of the AMAP program.

### 5.2 Monitoring and effects studies

Target media	Parameters	Frequency	Location of sampling/examination	Programme and/or responsible institute
External radiation	Dose rate, $\mu\text{Sv/h}$	Continuous	35 stations/Lapland	YSV/STUK
	Gammaspectra, nuclear identification	Continuous	Nuorgam Värriö Rovaniemi	YSV/STUK
Atmospheric: Air/aerosol	Gamma nuclides $\text{Bq/m}^3$	Weekly	Ivalo Sodankylä Rovaniemi	YSV/STUK
Atmospheric: Precipitation/ fallout	Gamma nuclides $\text{Bq/m}^2$ Beta nuclide $^{90}\text{Sr}$ , $\text{Bq/m}^2$	4 times a year	Ivalo Sodankylä Rovaniemi	YSV/STUK
Atmospheric: Precipitation	$^3\text{H}$ , $\text{Bq/m}^2$	4 times a year	Rovaniemi	STUK
Terrestrial: Reindeer meat	Gamma nuclides ( $^{137}\text{Cs}$ ), $\text{Bq/kg}$	Every 5 years	Extensive sampling	STUK
Moose meat		Every 5 years	Extensive sampling	
Terrestrial: Dairy milk	Gamma nuclides ( $^{137}\text{Cs}$ , $^{131}\text{I}$ ), $\text{Bq/kg}$ Beta-nuclide $^{90}\text{Sr}$ , $\text{Bq/kg}$	Annually	Oulu dairy (milk from Lapland)	YSV/STUK
Terrestrial: Mushrooms	Gamma nuclide $^{137}\text{Cs}$ , $\text{Bq/kg}$	Every 5 years	Kivalo Nellim, Inari	STUK/METLA STUK

Terrestrial: wild berries	Gamma nuclide $^{137}\text{Cs}$ , Bq/kg	every 5 years	Kivalo Inari, Nellim	STUK/METLA STUK
Terrestrial: River water	Gamma nuclide, $^{137}\text{Cs}$ , Bq/m <sup>3</sup> Beta nuclide, $^{90}\text{Sr}$ , Bq/m <sup>3</sup>	Annual	River Kemijoki	YSV/STUK
Fresh water: Fish (muscle) - pike - perch -burbot -whitefish -trout -vendace -roach	Gamma nuclide $^{137}\text{Cs}$ , Bq/kg	Every 5 years	Lake Inari	STUK
Brackish water: Salmon (muscle)	Gamma nuclide $^{137}\text{Cs}$	Every 5 years	River Kemijoki River Simojoki	STUK/ RKTL
Marine: Salmon (muscle) (bone)	Gamma nuclide $^{137}\text{Cs}$	Every 5 years	River Tenojoki	STUK/ RKTL

STUK Radiation and Nuclear Safety Authority, Regional Laboratory in Northern Finland  
YSV/STUK The permanent environmental monitoring program of Radiation and Nuclear Safety Authority  
METLA Finnish Forest Research Institute  
RKTL Finnish Game and Fisheries Research Institute

### 5.3 Supporting studies

Whole-body counting of the Finnish Sami reindeer herders in Utsjoki and Ivalo was an important part of the first and second phases of the AMAP program. The long measurement series from 1960 to 2002 together with the food consumption data, illustrated the effects of atomic-weapon testing and the Chernobyl accident on the Sami population. Continuation of these measurements was highly recommended by the AMAP expert groups for Radioactivity and Human Health. STUK has continued the measurements in 5 year intervals. The latest measurement campaign was performed in the spring of 2011.

## 6. HUMAN HEALTH SUB-PROGRAMME

### 6.1 Objective and structure

The objective of human health sub-programme in Finnish Lapland is to be a reference area, because people in Lapland do not eat marine mammals or much marine fish, which are on the top of arctic food chains. Also until now the pollution from northwest Russia has not had influence on the population. The food chain of radioactive caesium: lichen-reindeer-human is monitored by the radioactive group of AMAP.

Monitoring was conducted by State Provincial Office of Lapland until 2010. At the moment, in 2014, the maternal blood testing and the related food questionnaires have been conducted by Thule Institute in University of Oulu. Health statistics are collected by National Institute for Health and Welfare (THL) and Statistics Finland (Tilastokeskus).

### 6.2 Monitoring and effects studies

Target media	Parameters	Frequency	Programme and/or responsible institute
Maternal blood	Cd, Hg, Pb, Se, PCB, DDTs, HCH, HCB, chlordane, dieldrin, toxaphene (PCC)	50 mothers in 2013-2014	Thule Institute, University of Oulu
Mothers/ food	Food questionnaire	50 mothers in 2013-2014	Thule Institute, University of Oulu
Drinking water	Acrylamide, antimony, arsenic, benzene, benzo(a)pyrene, boron, bromate, cadmium, chrome, copper, cyanides, selenium, 1,2-dichloroethane, epichlorohydrin, fluoride, lead, mercury, nickel, NO <sub>3</sub> , NO <sub>3</sub> -N, NO <sub>2</sub> , NO <sub>2</sub> -N, PAHs, vinyl chloride, pesticides, tetrachloroethene, trichloroethene, trihalomethanes, chlorophenols	Annual-daily*	Valvira/municipal health authorities
Farmed fish	Bifenthrin, cyfluthrin (-beta), cypermethrin, permethrin, deltamethrin, chlordane, chlorobenzilate, HCHs, lindane, HCB, heptachlor, DDT sum, dieldrin, endrin, endosulfan, PCBs, tecnazene, quintozone, azinphos ethyl, chlorpyrifos (methyl), diazinon, fenthion (sulfoxide), methidathion, parathion (methyl), pirimiphos methyl, profenofos, pyrazophos, triazophos, Hg, Cd, Pb, As, Cr, Cu, Mn, Ni, Se, Zn	Annual	Evira

\*frequency depends on the size of the water distribution facility

Surveys	Parameters	Target Population	Responsible institution
Health statistics	Morbidity/ Mortality data	Lapland, Sami population	THL/Statistics Finland
Statistics	Abortion Gestational age	Population of Lapland	THL
Statistics	Developmental malformations	Population of Finland	THL

Valvira National Supervisory Authority for Welfare and Health  
 Evira Finnish Food Safety Authority  
 THL National Institute for Health and Welfare

## **6.2 Related projects**

- Kolarctic ENPI: Food and health security in the Norwegian, Finnish and Russian border region, 2012-2014 (Thule Institute, Centre for Arctic Medicine)

## 7. CLIMATE CHANGE AND UV-B SUB-PROGRAMME

### 7.1 Objective and structure

Finnish AMAP National Implementation Plan (NIP) for the Climate Change is based on existing national and international monitoring and research programmes. The parameters monitored include climatological data, greenhouse gas concentration and flux measurement data together with hydrological and water quality data north of the Arctic Circle in Finland. Also aerosol particle concentration and size distribution, and their optical properties are measured. The gathered data will be available for the assessment procedure on request. Other users of the produced data include e.g.

- EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Pollutants in Europe) coordinated by UN/ECE
- WMO/GAW (Global Atmosphere Watch of the World Meteorological Organisation).
- UN/ECE Integrated Monitoring Programme
- UN/ECE ICP Waters Programme
- ICOS (Integrated Carbon Observing System)
- UN/ECE ICP Forests Programme

### 7.2 Monitoring and effects studies

#### 7.2.1 Atmosphere and meteorology

Air-related studies (tables 1-3) are conducted by Finnish Meteorological Institute.

Table 1. Ground-level observations.

Parameter	Frequency	Location
Air temperature	Every 10 min	Pallas
	Every 10 min	Kevo
	Every 10 min	Sodankylä
Air humidity	Every 10 min	Pallas
	Every 10 min	Kevo
	1/10 min	Sodankylä
Barometric pressure	Every 10 min	Pallas
	Every 10 min	Kevo
	Every 10 min	Sodankylä
Cloud cover	Every 10 min	Sodankylä
	Every 10 min	Kevo
	Every 10 min	Pallas
Wind direction and speed	Every 10 min	Sodankylä
	Every 10 min	Pallas
Amount of precipitation	Every 10 min	Sodankylä
	Every 10 min	Kevo
	Every 10 min	Sodankylä
Snow cover depth	Daily	Kevo
	Daily	Sodankylä
Snow water equivalent	Every 5 days	Kevo
CO <sub>2</sub> concentration	continuous	Pallas
CH <sub>4</sub> concentration	continuous	Pallas

CO2 flux over spruce forest	continuous	Pallas
CO2 flux over pine forest	continuous	Sodankylä
CO2 flux over bog	continuous	Pallas
	continuous	Kaamanen
CH4 flux over bog	continuous	Pallas
Flux of sensible and latent heat	continuous	Pallas
	continuous	Kaamanen
	continuous	Sodankylä
Solar radiation	continuous	Sodankylä
	continuous	Pallas
UV-B radiation	continuous	Sodankylä
UV-B radiation – reflected	continuous in winter	Sodankylä
Surface ozone	continuous	Pallas
Aerosol particle number concentration	continuous	Pallas
Aerosol particle size distribution	continuous	Pallas
Aerosol scattering coefficient	continuous	Pallas
Aerosol absorption coefficient	continuous	Pallas
PM10 mass concentration	continuous	Pallas
Black carbon	continuous	Pallas

Table 2. Air column observations.

Parameter	Frequency	Location
Aerosol optical depth	continuous February - October	Sodankylä
Aerosol vertical distribution	continuous	Sodankylä
Ozone	continuous	Sodankylä

Table 3. Upper atmosphere observations.

Parameter	Frequency	Location
PTU sounding, temperature	twice a day	Sodankylä
PTU sounding, humidity	twice a day	Sodankylä
PTU sounding, wind	twice a day	Sodankylä
ozone sounding	weekly	Sodankylä

### Satellite remote sensing

The 2010 Update of the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (United Nations Framework Convention on Climate Change)*, GCOS-138, describes observational actions to support understanding, prediction and response management of climate and climate change. In particular, the GCOS-138 report calls for sustained observations of the Essential Climate Variables (ECVs). In response to this, European Space Agency has launched a Climate Change Initiative (CCI) programme that will run from 2009 – 2016. The aim of the programme is to develop satellite based datasets of the most important ECVs. FMI is co-leading the aerosol-CCI and participating also strongly in ozone-CCI. The datasets used in these ECVs are mainly from European satellite instruments (AATSR, GOMOS, SCIAMACHY, MIPAS, OMI, GOME, GOME-2, OSIRIS). The Phase 1 of the programme ended in 2013 and the Phase 2 will run from 2014 – 2016.

### 7.2.2 Hydrology and hydrobiology

Hydrological (table 4.) and hydrobiological monitoring (table 5.) is coordinated by Finnish Environmental Institute and implemented together with Lapland Centre for Economic Development, Transport and the Environment.

Table 4. Hydrological and water quality parameters

Parameter	Stations in Finnish AMAP area	Frequency	Programme
Surface water level	31	continuous/daily	hydrological monitoring
Surface water temperature	5	continuous or daily in summer	hydrological monitoring
River discharge	32	continuous/daily	hydrological monitoring
Runoff	Vähä-Askanjoki, Laanioja	continuously	studies of small hydrological basins
Ice freeze-up and break-up dates	ca. 10 lakes and 1 river	annual	hydrological monitoring
Ice thickness	7	10 <sup>th</sup> , 20 <sup>th</sup> and 30 <sup>th</sup> every month in winter	hydrological monitoring
Groundwater level	5	1 <sup>th</sup> and 16 <sup>th</sup> every month	hydrogeological monitoring
Snow course	27	16 <sup>th</sup> every month in winter	hydrological monitoring
Groundfrost depth	13	3 times a month in winter 6 times a month in spring	hydrogeological monitoring

Table 5. Biological monitoring of community structure in rivers and lakes.

	Target organisms	Locations in Finnish AMAP area	Frequency
Lakes	diatoms, benthic macroinvertebrates, macrophytes, fish*	71 lakes	1-12 year interval
Rivers	diatoms, benthic macroinvertebrates, fish*	62 rivers	1-12 year interval

\*one or more targets depending on location

### 7.2.3. Terrestrial

The following studies (table 6.) are conducted by Finnish Forest Research Institute (Metla).

Table 6. Terrestrial parameters to be monitored for the AMAP climate change studies on four northernmost ICP Forests monitoring plots (in Sevettijärvi, Pallasjärvi, and 2 in Kivalo).

Parameter	Frequency
Crown condition	Annual
Soil condition	Every 10 years
Needle chemistry	Every 2 years
Tree growth	Every 5 years
Stem diameter growth	Continuous
Deposition	Every 2 weeks in snow free period, otherwise every 4 weeks
Soil solution	Every 4 weeks during snow free period
Ground vegetation	Once in 5 years
Litterfall	Once in 2 weeks

Table 7. Meteorological parameters for ICP Forests monitoring plots (Sevettijärvi, Pallasjärvi, Kivalo) managed by Finnish Meteorological Institute.

Parameter	Frequency
Air temperature	Daily
Relative humidity	Daily
Precipitation	Daily
Wind speed and direction	Daily
Solar radiation	Daily

### 7.3 Supporting studies

- National research programmes, e.g. Academy of Finland, Centre of Excellence: Physics, Chemistry, Biology of Atmospheric Composition & Climatic Change, Arctic Absorbing Aerosols and Albedo of Snow (A4), Greenhouse gas, aerosol and albedo variations in the changing Arctic, Centre of Excellence in Atmospheric Science – From Molecular and Biological Processes to the Global Climate
- International research programmes, e.g. EU/InGos, Nordic Council of Ministers, Nordic Centre of Excellence: “Impacts of a changing cryosphere-depicting ecosystem-climate feedbacks from permafrost, snow and ice – DEFROST”, EU/EURO-LIMPACS and EU/ENSEMBLES, EU LIFE + : “Mitigation of Arctic warming by controlling European black carbon emissions”, Nordic Centre of Excellence : “Cryosphere-atmosphere interactions in a changing Arctic climate (CRAICC)”.
- In Pallas integrated monitoring station, there is long-term monitoring on spruce forest and aapa mire sites, in Sodankylä on a Scots pine forest and aapa mire, and in Kaamanen on an aapa mire. The measured carbon balances are used to study how terrestrial biosphere in Lapland affects greenhouse gas concentrations observed at Pallas, what are the annual carbon balances in cold climate and how the biospheric carbon sink is affected by climate changes.