Annual report 2019

NILU
50 ÅR
1969-2019

Contents

Editor Christine Forsetlund Solbakken. Layout by Ingunn Trones
Front page photos: An old monitoring station in Kirkegata, Oslo in 1975. Photo: NILU. A new monitoring station at Tiller, Trondheim in 2014. Photo: Claudia Hak, NILU.

MILJØMERKET 241 013 TRYKKSAK

2019 – a year for celebration

In 2019, NILU celebrated 50 years at the service of climate and environment research. We have also celebrated the 25th anniversary of our office at the Fram Centre in Tromsø, and 30 years on Zeppelin mountain in Ny-Ålesund. There, NILU runs Zeppelin Observatory, an important part of a worldwide network to monitor the atmosphere.

We are proud of our 50 years of dedicated effort to create a better environment on Earth. We also have many successes to show for it – research makes a difference. Society urgently needs good advice in a challenging situation for our planet, and together with strong partners, NILU will continue doing research that contributes to a more sustainable society. This will in turn help reverse negative environmental and climate developments.

Locally, NILU plays an important role in both measuring and analysing data on both current and developing status of the air quality where people live. We combine this with in-depth expertise on interpreting the data, thus contributing to good, long-term, knowledge-based solutions.

We are conscious of our responsibility to disseminate science-based and applicable knowledge of the highest quality to government and politicians. Examples of this include our research on fluorinated compounds in air, animals, and ski wax, as well as our work on siloxanes in soap, shampoo, and other consumer products. On this basis and more, Norway's opinions command respect in international negotiations, and its proposals for prohibitions and regulations weigh heavily.

For decades, Norwegian authorities have contributed both their dedication and financial support to long-term environmental and climate research. This is crucial for a country "at the receiving end" of air pollution from many of the most densely populated areas on the planet.

At NILU, our research has a strong focus on innovation. Our greatest contribution is in social innovation, but we also work to find solutions for specific problems. An example is our research on recycling of valuable rare-earth metals from smartphones. In 2020 we are launching a project that will try to figure out how to recycle plastics more efficiently, while avoiding recycling of the pollutants they contain.

Our 50 years in the environment's service is the result of massive effort on the part of more than 700 employees over the decades. Many have been with NILU for most of their working lives, and it is both an honour and a privilege to lead an organisation with such a steady, dedicated and motivated workforce.

Kari Nygaard
Managing director

Managing director Kari Nygaard. Photo: StudioF2, Photographer Ingar Næss

NILU 50 years

Photo: Christine Forsetlund Solbakken, NILU

The launch of ETC / ATNI 17 March

We kicked off the anniversary year 2019 at Kulturhuset in Oslo, with the launch of the new Topic Centre for Air Pollution, Transport, Noise and Industrial Pollution (ETC / ATNI). NILU has the honour of leading the Topic Centre on behalf of the European Environment Agency (EEA). The programme included contributions from the Norwegian Parliament's Standing Committee on Energy and the Environment, EEA, the Norwegian Environment Agency, the Norwegian Institute of Public Health, the Federation of Norwegian Industries, and of course NILU's own scientists.

Photo: Are Bäcklund, NILU

Visit to the Zeppelin Observatory 1-3 April

In April, we invited a number of prominent guests to Ny-Ålesund and the Zeppelin Observatory, to celebrate both NILU's 50th anniversary and the observatory's 30 years. Among the guests were Atle Hamar, second in command at the Ministry of Climate and Environment, as well as collaborators from the Norwegian Polar Institute, the Norwegian Institute of Water Research (NIVA), the Norwegian Meteorological Institute, the Norwegian Academy of Science and Letters, the Research Council of Norway, the University Centre on Svalbard (UNIS), Stockholm University, Svalbard Integrated Arctic Earth Observing System (SIOS), Kings Bay – and a reporter from the Norwegian Broadcasting Corporation (NRK).

Photo: Ingunn Trones, NILU

The Anniversary Day 12 September

On the 12th of September, it was time for the grand celebration! We decided to split the day in two and started with an academic symposium. We were presented with brief lectures emphasising collaboration and joint projects from 1969 to the present, by the Research Council of Norway, the Ministry of Climate and Environment, the European Environment Agency, the European Monitoring and Evaluation Programme, the Norwegian Institute of Water Research (NIVA), the Norwegian Meteorological Institute and the Urban Environment Agency. Then, our own scientists took the stage and presented exciting research from NILU's first days to the present – and gave a tiny glimpse into the future.

The anniversary day then continued with aperitifs, speeches and gifts, before we went back into the hall. It was now filled with beautifully decorated tables – the highlights being the lanterns decorated with pictures from NILU's history. The delicious dinner was only interrupted by an entertaining lecture on the importance of air for all the world's animals and insects, splendidly delivered by zoologist Petter Bøckman of the Natural History Museum.

Photo: Faith Ørnes, NILU

Solution Beer Bash in Tromsø 17 October

NILU in The Fram Centre inTromsø celebrated its 25th year in 2019 welcoming all comers to Tromsø's very first "Løsningspils" ("Solution Beer Bash") at the venue DRIV, run by the local student organisation. The concept is that scientists offer short and solution-focused lectures based on current – and preferably local – research. The audience had a chance to learn about everything from plastic in the sea and fluoride ski wax, to e-waste, studded tires and how your lawn can contribute to slowing down climate change.

Photo: Eldbjørg Heimstad, NILU

Family Day 17 November

No celebration is complete without a proper family gathering, and this was the last happening in a year of celebration from beginning to end. On 17 November, we opened NILU's doors to family and friends of all ages. The youngest could enjoy a science fair with a microscope, a heat camera and someone reading aloud, plus a drawing nook in the canteen. Those who were a bit older could take part in guided tours of the laboratories, or enjoy a popular science lecture or three. But the biggest hit of the day for visitors of all ages was being able to join engineer Are Bäcklund for a visit to Zeppelin and Trollhaugen via VR headsets.

Photo: Kristin Butveit, NILU

About NILU

NILU – Norwegian Institute for Air Research was established as a foundation in 1969. Our research aims to increase the understanding of processes and effects related to our core business areas: atmospheric composition, climate change, air quality and hazardous substances.

The institute holds a strong position both nationally and internationally, provides services closely linked to our research, and have extensive experience in coordinating national and international research projects. Our key clients include the EU, the Research Council of Norway, industry, and both central and local authorities

NILU's departments

NILU's research has a wide range, and explores most aspects of what affects the atmosphere, environment and climate. The institute's composition, represented by our various departments, reflects this:

Atmosphere and Climate Department
does research on air pollution at regional (European) and global levels, greenhouse gases and climate drivers, volcanic ash transport and dispersion, ozone and UV. The department also conducts extensive international cooperation and serves as a data centre for a variety of measurement and research programmes.

Urban Environment and Industry Department
conducts research on issues regarding local and regional air pollution. Their research ranges from development of air quality management systems in large cities, to developing systems that include greenhouse gas emission and local air pollution. In addition, the department plays a leading role in Norwegian environmental monitoring and research on industrial emissions.

The Dept. of Environmental Impacts and Sustainability
works mainly on the development of sustainable solutions in a circular economy, as well as quantifying the effects of systems and products on health and the environment in a lifecycle perspective. The department also works with advising and evaluating policy instruments and measures for sustainable development.

Environmental Chemistry Department
does research on new and established pollutants, and has expertise in all types of environmental samples from air, water and sediment to biological material. The department has a particular focus on contaminants in the Arctic, and has two laboratories at its disposal, one at the main office at Kjeller, and one at the Fram Centre in Tromsø.

Monitoring and Instrumentation Technology Department
is responsible for operational management of NILU's field measurements, sampling equipment and instrumentation. The department is also responsible for data collection and quality assurance, in addition to the operation of NILU's observatories in Ny-Ålesund at Svalbard, Queen Maud Land in Antarctica, Birkenes in Southern Norway and Andøya in Northern Norway.

Software and Hardware Development Department
is responsible for development and maintenance of NILU's software and hardware products, project web sites and adaptation of modules and databases.

The Innovation Department
is working to ensure the highest possible utility value of the institute's research.

The department's primary goal is to make the results from NILU's research available to the public and policy makers, and whenever possible create commercial development from this

More nano projects for the Health Effects Laboratory

The Health Effects Laboratory at NILU has received funding for several new projects during 2019, and they are constantly strengthening their expertise in nanomaterials and toxicity testing.

Christine Forsetlund Solbakken
Head of communications

Elise Rundén Pran, head of the section for the Health Effects Laboratory, says that two of their new projects are EuroNanoMed projects starting in 2020. The projects are funded by the Research Council of Norway through the EU, and the section reports to both agencies.

"The projects are aimed at developing new nanomedicines for the treatment of various diseases", says Rundén Pran. "Nanomaterials have highly unique properties, and one particular advantage is that they can be targeted at a specific cell type that is involved in the disease in question."

From cancer to stroke and eye disease

The Health Effects Laboratory has already been involved in two EuroNanoMed projects, one about lung cancer, which ended in 2019, and one about breast cancer, which will end in 2020. The two new projects starting in 2020 are slightly different – one deals with the treatment of stroke, and the other an eye disease called macular degeneration. Those affected by this disease lose visual acuity and colour vision, because an area of the retina is destroyed.

"Carrying out toxicity testing is important during the development of all types of new drugs", Rundén Pran explains. "We have to check that the medicine does not have any unwanted effects, and within the nano field we often talk about 'safe by design'. This process is about testing toxicity while the medicine is being developed, and making minor alterations that may not change the desired function, but will still prevent harmful side effects."

She goes on to say that by simply changing the surface finish, or the charge, or the size of the nanomaterial you are using, you can change its properties. The goal is to consistently design nanomaterials that have the desired effect, and simultaneously have as few side effects as possible.

"This is a more efficient development process, in terms of both time and money", says Rundén Pran. "In these projects we are responsible for the toxicity testing, and sometimes we also check that the material is only taken up by the cell types it is intended for."

Coveted project partners

The projects are usually carried out in collaboration with partners from various disciplines. The Health Effects Laboratory's special field is genotoxicity, with focus on DNA damage. They offer a sought-after selection of tests and models and are a popular project partner with wide experience in the nano- and toxicology field.

Elise Rundén Pran's colleague, senior scientist Maria Dusinska, heads the third project the Health Effects Laboratory will start in 2020. There, they will contribute with risk assessment of nanomaterials, which Dusinska also works with as a representative in the EU Scientific Committee for Consumer Safety (SCCS).

"SaByDoMa (Safety By Design Of nanoMaterials - From Lab Manufacture to Governance and Communication: Progressing Up the TRL Ladder), is a Horizon 2020 project", says Rundén Pran. "It is a continuation of a previous project, HISENT, where the goal was to develop modules for nanotoxicity screening, so-called 'organ-on-a-chip'."

"Organ-on-a-chip" is, in brief, a technology that tries to mimic various organs on small chips with electrodes and micro-fluid flow. The chips can be linked together and used to test the effect of various nanomaterials on the kidneys, lungs, blood and so on. The Health Effects Laboratory's task in the continuation of this project is to do quality assurance and risk assessments. In addition, they will contribute to establishing risk management tools so that the development of the nanomaterials can be done according to the "safe by design" principle.

"We are looking forward to getting started with these projects, which will further expand our nanotoxicology expertise", concludes Rundén Pran.

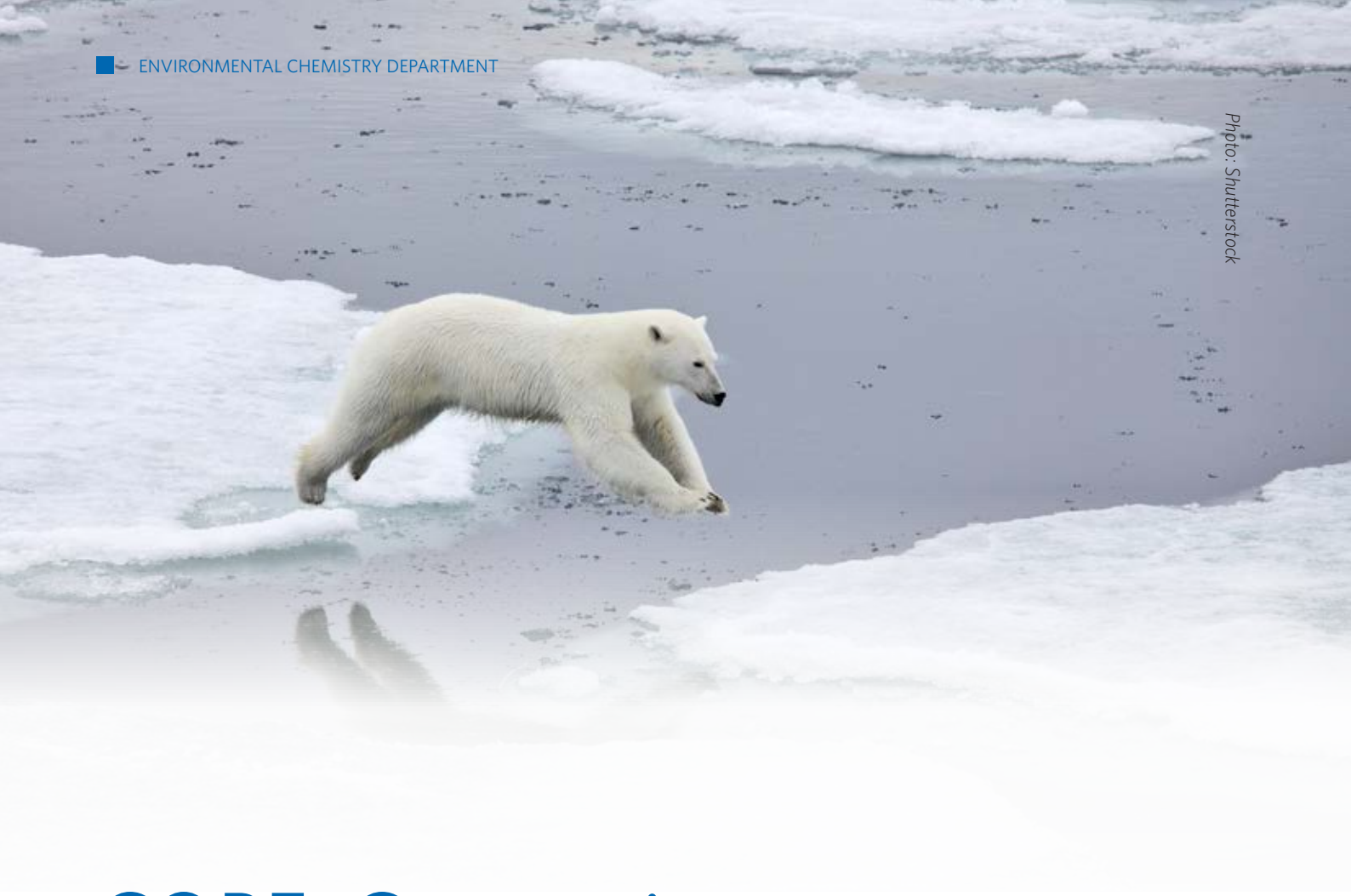


Photo: Shutterstock

COPE: Contaminant climate change interactions on Arctic ecosystems

Changes in climate. Loss of biodiversity. Toxic contaminants. The vulnerable Arctic is subject to multiple pressures induced by human activities. Will it be able to cope in the long run?

Ingjerd Sunde Krogseth
Senior scientist

The Arctic appear to be a harbinger of environmental change, with climate change and exposure to long-range transported, persistent, bioaccumulative, and toxic contaminants being two of the major challenges. How do the Arctic ecosystems cope with this? And how do we cope with it as scientists? This is the key focus in COPE, a new cross-disciplinary project based on long-term collaborations within the Fram Centre Flagship "Hazardous substances – effects on ecosystems and human health".

Persistent organic pollutants (POPs) and chemicals with similar properties are transported to the Arctic from source regions further south. In the Arctic, POPs are taken up in the ecosystems and accumulate through the food web, resulting in high concentrations in top-predators. In parallel with this, the Arctic experiences strong and rapid changes in temperature and climate, with effects such as loss of sea ice and inflow of Atlantic water. This also impacts Arctic ecosystems, including top-predators such as polar bears and Arctic-breeding seabirds.

In COPE, we aim to address this knowledge gap in a comprehensive cross-disciplinary research initiative. We will combine empirical data, time-trends, and statistical methods with mechanistic and novel modelling techniques. To enable development and evaluation of this cross-disciplinary approach, we will focus on data-rich ecosystems and species, including seabirds and polar bears. These animals are vulnerable

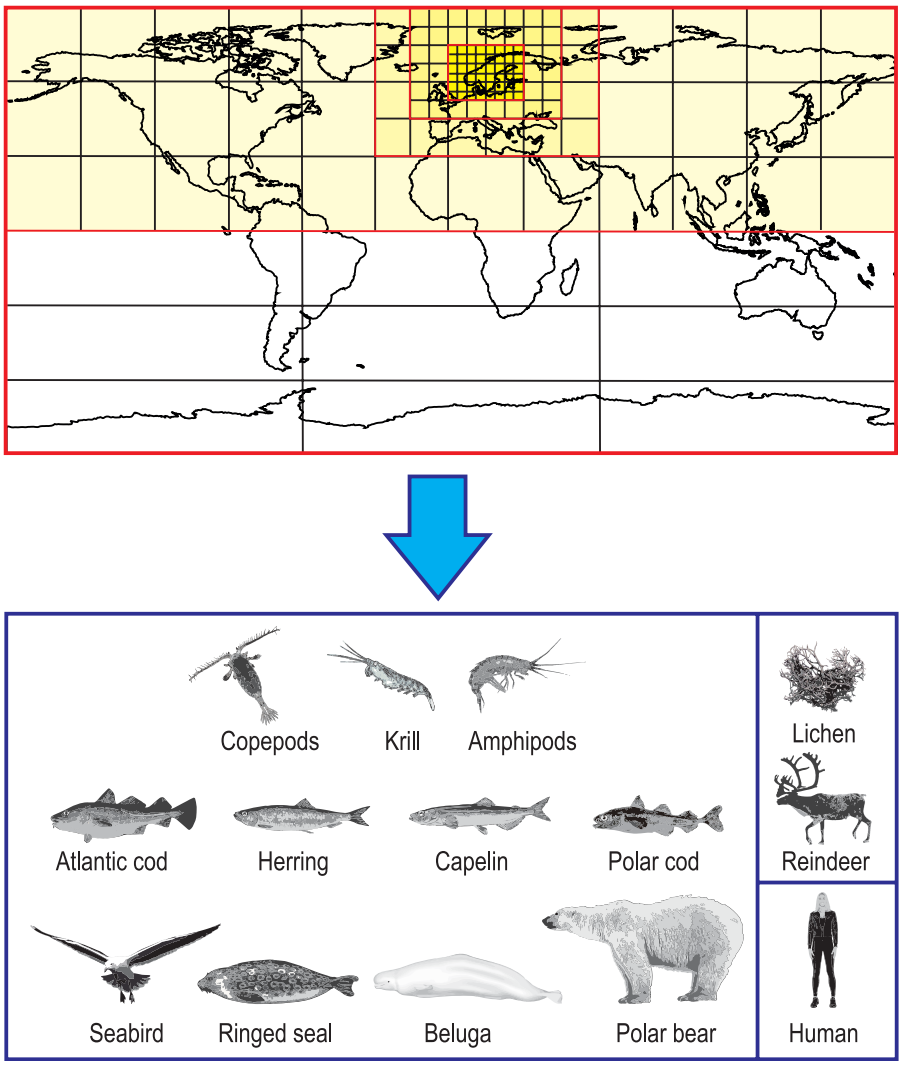
Senior scientist Ingjerd Sunde Krogseth, NILU
Photo: Christine F. Solbakken, NILU

to contaminants and climate change and can serve as indicator species for changes in ecosystem health.

At the core of COPE is the Nested Exposure Model (NEM), currently under development at NILU. NEM is a unique spatially and temporally resolved integrated multimedia model for environmental fate and bioaccumulation of organic contaminants. Its aim is to increase our understanding of the complete link between emissions of contaminants on a global scale and resultant contaminant exposure in Arctic ecosystems and species.

We believe that the combination of the NEM model, the Fram Centre expertise and vast amount of empirical data, and complementary modelling tools at the Norwegian Polar Institute, will be a powerful approach to increase our understanding of the complex interactions of contaminants and climate change in Arctic ecosystems. Such knowledge is vital to support scientifically sound management strategies to ensure the future health of Arctic ecosystems.

The original (and longer) version of this article was first published in Fram Forum 2020.



The Nested Exposure Model (NEM) integrates environmental transport and fate of organic contaminants in the physical environment (top) with bioaccumulation in Arctic food webs (bottom). Copyright: NILU

COPE – "Integrated risk assessment framework for evaluating the combined impacts of multiple pressures on Arctic ecosystems" (2019-2023) is funded by the Research Council of Norway (#287114).

The project is led by NILU – Norwegian Institute of Air Research, in close cooperation with the Norwegian Polar Institute (NPI), Norwegian Institute of Nature Research (NINA), Akvaplan-niva AS, and international collaborators from Canada, France, and Australia.

The Norwegian Environment Agency will act as project advisor to ensure a good communication with regulatory authorities both in the planning of the project and for dissemination of project results.

Silje Eltvik Thomassen from NILUs organic analysis lab starts a purifying process on the new robot from the PC. Photo: Ingunn Trones, NILU

NILU is robotising the laboratory

NILU's laboratories can analyse most samples for a wide range of constituents, but there will be no analysis without prior preparation in the laboratory. This process is often done manually and can be very time-consuming. From now on, a new robot will streamline the work.

Ingunn Trones
Communications advisor

NILU's organic analysis lab recently acquired a robot – a Freestyle from LC Tech. The robot is an advanced computerised instrument with moveable components that can be programmed to perform many different actions depending on which modules it is equipped with.

The Freestyle in NILU's laboratory is equipped with three sample purification modules: GPC (Gel Permeation Chromatography), SPE (Solid Phase Extraction) and EVA (EVAporation).

A beneficial addition

Silje Eltvik Thomassen works as an engineer in the laboratory. She is excited about how this new instrument will affect her everyday life.

"The robot is a relatively new addition. We have not used it systematically yet, but we can see that it can potentially save us a lot of work", she says. "In our laboratory, it will mainly prepare samples to be passed on for analysis."

An example of NILU's commissions is the annual analyses it carries out for the Norwegian Environment Agency as part of the monitoring of environmental pollutants. The laboratory receives many different types of samples, such as liver from rat, fox and other animal species. Each sample is analysed, thus making it possible to follow how the environmental pollutant content in the various animals evolves from year to year.

Replaces manual processes

"The samples come to us first, so we can prepare them", says Thomassen. "The goal is that only the relevant environmental toxins will be left in the samples. Then they are ready for instrumental analysis."

Some trays with extracted samples are inserted into the robot. The arm has moved and is ready to collect the sample. Photo: Ingunn Trones, NILU

"We start with extraction", she explains. "That's a manual process in which fat-soluble substances are isolated by column elution. We add a solvent that exclusively dissolves the fats in the sample, and since the environmental pollutants we are looking for are fat-soluble, they come out of the column together with the solvent."

This solution is then loaded into the Freestyle robot, where it can be processed by selected methods in the various modules. The Freestyle automates time-consuming tasks that the engineers in the laboratory have so far had to perform manually.

Another advantage of the Freestyle, according to Thomassen, is that it can process many samples using different techniques simultaneously.

"In our example from the Environment Agency, which involves a huge number of samples, the Freestyle is ideal", she states.

To illustrate, she inserts a tray filled with extracted samples into the instrument. She chooses the desired purification method from the computer, presses start, and then she can leave the room.

The Freestyle retrieves the correct amount of each sample and runs it through the selected rinse process. The result is a precisely measured amount extract, tapped into a clean glass vial and ready for analysis.

"It sounds simple, but complex processes are being performed, so it's not something you can just waltz through", says Thomassen.

Contributes to a more efficient working day

Although the processes are automated, they still take a long time. Performing just one of the many methods Thomassen can choose from takes the robot anywhere from one to two and a half hours per sample.

"The gain can't necessarily be measured in time saved per sample", says Thomassen. "Rather, it's in the fact that we run the process overnight or on the weekend, without anyone having to be physically present. In addition, we can get other tasks done during the day while the robot is working."

When the Freestyle has processed the samples, they are delivered to the instrument section for analysis, for example in a mass spectrometer. With this instrument and suitable software, environmental pollutants in the samples can be detected and quantified.

In connection with the Norwegian Environment Agency's monitoring programme, they want to determine the levels of pollutants such as brominated flame retardants, chlorinated paraffins, dechloranes and chlorinated pesticides in the samples.

"At NILU, we can perform many kinds of analyses, and we are very proud of our laboratories. We have the capacity to analyse for an unknown number of components, in several different sample types. And with the new robot, the preparatory work becomes much easier", she concludes.

On the red carpet in Cannes:

NILU scientist Cathrine Lund Myhre is in the Leonardo DiCaprio climate documentary "Ice on Fire"

The documentary Ice on Fire premiered at the Cannes Film Festival 22 May 2019. The documentary deals with ongoing climate change and focuses on the research behind modern climate science – as well as the innovative solutions that also exist.

Christine Forsetlund Solbakken
Head of communications

The climate documentary "Ice on Fire" is directed by Leila Conners and produced and narrated by Oscar® winner Leonardo DiCaprio. During the premiere at the Film Festival in Cannes, senior scientist Cathrine Lund Myhre from NILU's Department of Atmosphere and Climate was among those present.

"I wouldn't call it an ordinary day for a climate scientist", Cathrine said about her adventure in Cannes.

"It was probably the first and last time in my life I rode in a limousine with a police escort! And when we got to where the movie was being screened, we were surrounded by paparazzi and screaming teenage girls. It was quite a change from research conferences, I'll tell you that!"

The road from Kjeller to Cannes

So how does a scientist who usually works at Kjeller outside Lillestrøm in Norway, studying the composition of the atmosphere and how it changes, end up in Cannes?

"Well, it was quite unexpected", Cathrine says, "but it all started with the film team from DiCaprio's production company Tree Media contacting CAGE, the Centre for Arctic Gas Hydrate, Environment and Climate at UiT The Arctic University of Norway in 2016. They wanted to interview scientists from CAGE about the potentially very important greenhouse gas methane."

Then CAGE contacted Cathrine and asked if she was interested in contributing. They had previously collaborated in the project MOCA – Methane Emissions from the Arctic Ocean to the Atmosphere: Present and Future Climate Effects.

"I said yes, and a few months later, director Leila Conners and the Tree Media team came to Tromsø to film. I was standing outside in the middle of winter, talking about how important methane is to the climate system, and had to repeat myself with small variations probably 30 times. The whole interview took about 6 hours, and in the end, I barely remembered what I had said", Cathrine laughs.

We need to know more about methane

Methane is a greenhouse gas far stronger than CO_2, with a life span in the atmosphere of around 10 years. Vast amounts of methane are trapped at shallow depths below the seafloor as gas hydrates, ice-like mixtures of gas and water. The potential abrupt release of even a small fraction of these Arctic methane stores would profoundly change the Earth's atmospheric composition, and accelerate global warming and sea level rise.

Cathrine explains that methane can be released both from natural sources and from human activity.

"A large fraction of the methane is from natural sources that are vulnerable to climate change", she

says. "These include wetlands, seas, and ruminant wild animals."

"To control or mitigate these emissions is beyond our control, so the only thing we can do regarding these sources is to learn more about them and strive to avoid increasing the average global temperature. At the same time, most of the current methane emissions, about 60%, stem from human activities, and we can do something about that."

Ice on Fire gives climate scientists a voice

At the Cannes premiere, both director Leila Conners and producer Leonardo DiCaprio gave brief speeches about their movie.

In her speech, Leila Conners said that we stand at the crossroads:

"We are hearing two different narratives: one where dramatic climate change is the focus, and another where groundbreaking innovation plays the leading role. The question is, which of these two narratives will win in the end? Of course, we hope the latter wins, which is why we made this movie."

Leonardo DiCaprio, for his part, took the opportunity to thank all the scientists and innovators who had contributed to the film, and asked them to stand up and accept the applause of other spectators in the theatre.

He then said that their reason for wanting to make "Ice on Fire" was to give a voice to the scientists and researchers who work tirelessly every day on the front lines of climate change.

"The opposition to the scientific community is often strong, but the scientists still forge ahead. 'Ice on Fire' was filmed so that they could make their voices heard, without interruption."

Senior scientist Cathrine Lund Myhre by the red carpet in Cannes. Photo: Synne Myhre

A hopeful film

Attending the film, and being at the Cannes Film Festival, was quite an adventure. Still, Cathrine Lund Myhre is more concerned about what "Ice on Fire" can mean for people's understanding of the climate, the challenges and the possible solutions associated with it.

"It's a film that I think as many people as possible should watch", she says. "It shows the harsh reality, it explains the challenges we face and what we scientists are struggling with – but it also offers hope. It's a beautiful film, and a film that I think can inspire anyone who watches it. By telling the stories of those who use science to find solutions, it shows that we can do this. But we must do it now."

"Ice on Fire" is available through HBO Nordic.

Measuring instrument mounted above Pilestredet Photo: Anne-Cathrine Nilsen, NILU

Research on air currents and pollution in Pilestredet

On a scaffold high above the heads of the pedestrians at Pilestredet 47c and 48 in Oslo, sophisticated measuring instruments spent a few weeks characterising air currents and measuring various types of air pollution. The instruments were part of a project run by NILU – Norwegian Institute for Air Research, to obtain data on air flow patterns and how air pollution is distributed vertically.

Christine Forsetlund Solbakken
Head of communications

"Most of the pollution in the city streets is from vehicle traffic, and is emitted at street level", says project manager and scientist Gabriela Sousa Santos. "Here, we want to analyse air flow patterns and find out how this air pollution moves and is diluted from ground level up to the rooftops of the buildings along a street."

Streets that "capture" air pollution

Pilestredet, near Frydenlund tram stop, is an example of what scientists call an "urban canyon", a stretch of road with relatively tall buildings on both sides. These tall buildings are part of what makes spreading conditions worse, because they prevent the wind from diluting the air pollution as efficiently as in more open urban landscapes.

The measuring instruments were in place for two weeks in early November 2019 and removed shortly after.

Instruments to measure wind speed and direction, temperature and relative humidity were placed on the roof of Pilestredet 48. The same kinds of measuring instruments were also mounted on different "floors" of the scaffold, along with instruments to measure components such as nitrogen dioxide (NO_2), ground-level ozone (O_3) and CO_2.

In addition, the scientists inventoried traffic on Pilestredet, to obtain up-to-date information on how many

different types of vehicles pass through on an hourly and 24-hour basis.

Models do not account for tall buildings

The objective of this campaign was to provide data for further development of different models for air flow and air quality.

Sousa Santos explains that air quality dispersion models usually disregard buildings, and thus also streets. Furthermore, the rendering of topography is quite simplified and homogeneous, and the flow and dispersion around buildings is based on averages. For example, the models consider air flows above the height of the buildings as representative of the average wind in a city context.

Street-level concentrations of pollution are calculated using a Gaussian model developed by NILU, called EPISODE. It takes into consideration concentrations and distribution of various substances in the air, based on emission data, meteorological data and other factors. In addition, it defines how much of the pollution is emitted from each source and moves to a specific point, and then uses the average city-scale wind described above – without regard to buildings.

Data from Pilestredet will contribute to better modelling

The NILU scientists know, however, that the buildings in a city represent physical obstacles that play a crucial role in raising the level of pollution in the urban environment. This is especially true in urban canyons. There, air currents and eddies may develop, and provide very poor opportunities for diluting air pollution at street level.

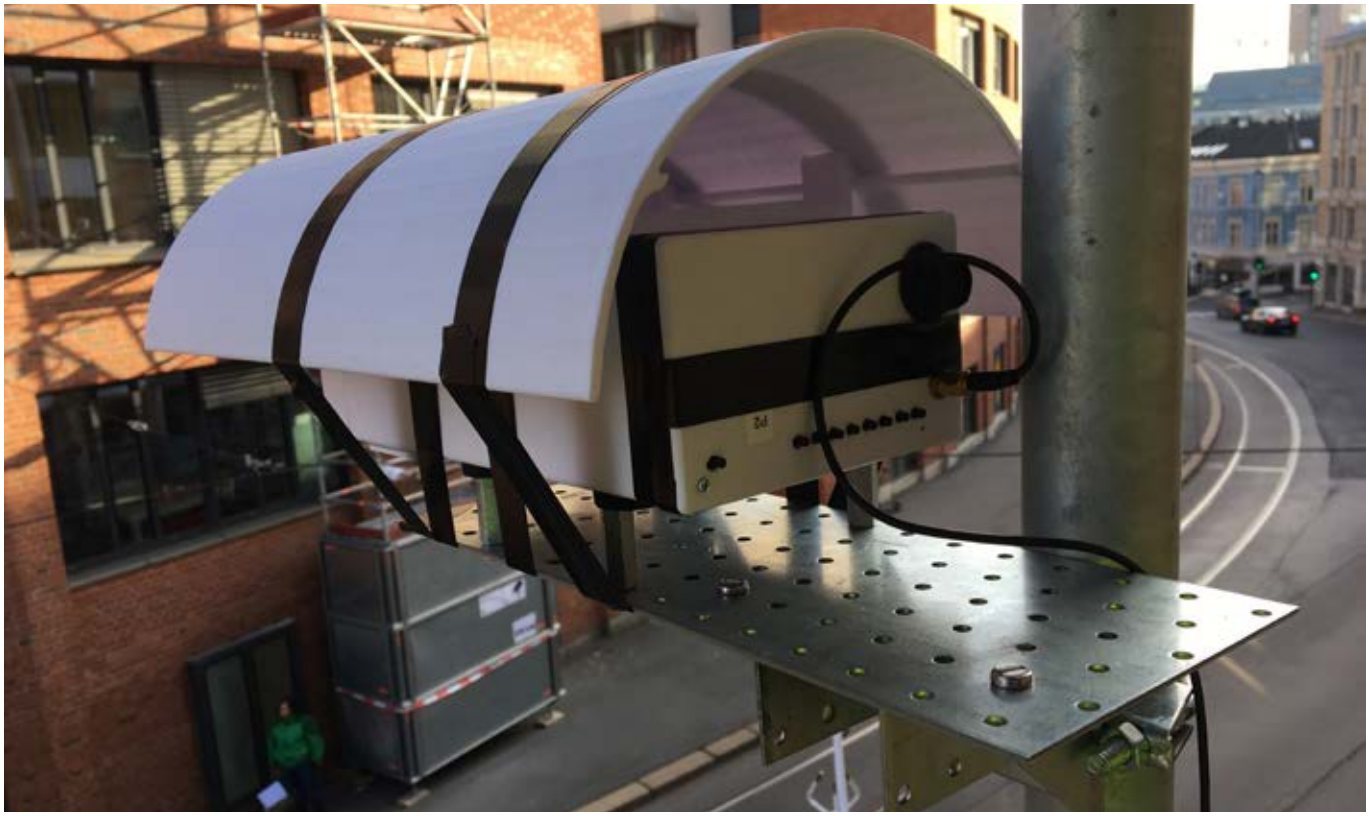
"With these measurements, we hope to capture and characterise these episodes in terms of both flow patterns and pollution levels", explains Sousa Santos. "Ultimately, we want to use the measurements to develop and validate models that include buildings."

One of the models to be further developed using data from this campaign is the EPISODE-3D model. It is based on the EPISODE model described earlier, but it also includes buildings when it parameterises the air flow patterns.

Besides EPISODE and EPISODE-3D, NILU scientists use a computational fluid dynamics model (CFD) that explicitly includes buildings. The PALM model is a so-called large-eddy simulation model, which calculates the properties of turbulence and wind with very high spatial and temporal resolution. The PALM model is open source, and mainly developed at Leibniz University Hannover.

Now that the instruments have been dismantled, the task of analysing the collected data remains. In addition, the intention is to share the most relevant information with the people who live in the buildings where the measuring instruments were situated.

"We will complete the analysis of the observations and start using them to validate our models during 2020", concludes Gabriela Sousa Santos.



This microsensor was loaned to NILU by the municipality of Oslo. It measures nitrogen monoxide (NO), nitrogen dioxide (NO_2), ozone and carbon monoxide (CO). Photo: Anne-Cathrine Nilsen, NILU

The UN Environment Programme's GEO-6 report:

It is time to act!

In March 2019, the United Nations Environment Programme launched its sixth Global Environment Outlook report, "GEO-6: Healthy Planet, Healthy People" (UNEP, 2019). It presents what is known about the current state of the environment, and extrapolates and sketches scenarios for how the environment can and should develop in the future.

Christine Forsetlund Solbakken
Head of communications

"These GEO reports are the main publications of the UN Environment Programme, and the one being published now is the most comprehensive summary of the current and projected future state of the Earth's environment since 2012", says research director Cristina Guerreiro from NILU – Norwegian Institute for Air Research. She coordinated the work on chapter 5 about air, and co-authored chapter 12 about air policy and emission standards.

Experts in various disciplines from around the world are invited to participate producing the report, and Guerreiro sees precisely this interdisciplinary focus on the UN's development goals as one of the report's strengths.

Requires global cooperation

The main message in "GEO-6: Healthy Planet, Healthy People" is that it is time to act. Unsustainable human activities over many years have degraded the earth's ecosystems, and now threaten the ecological foundations of the world community. Measures to halt and reverse this development must be implemented without delay.

Important measures include reducing land degradation, and preventing loss of biodiversity and pollution of air, land, and water. Water, air and other resources must be managed better, greenhouse gas emissions must be stopped, and resources must be

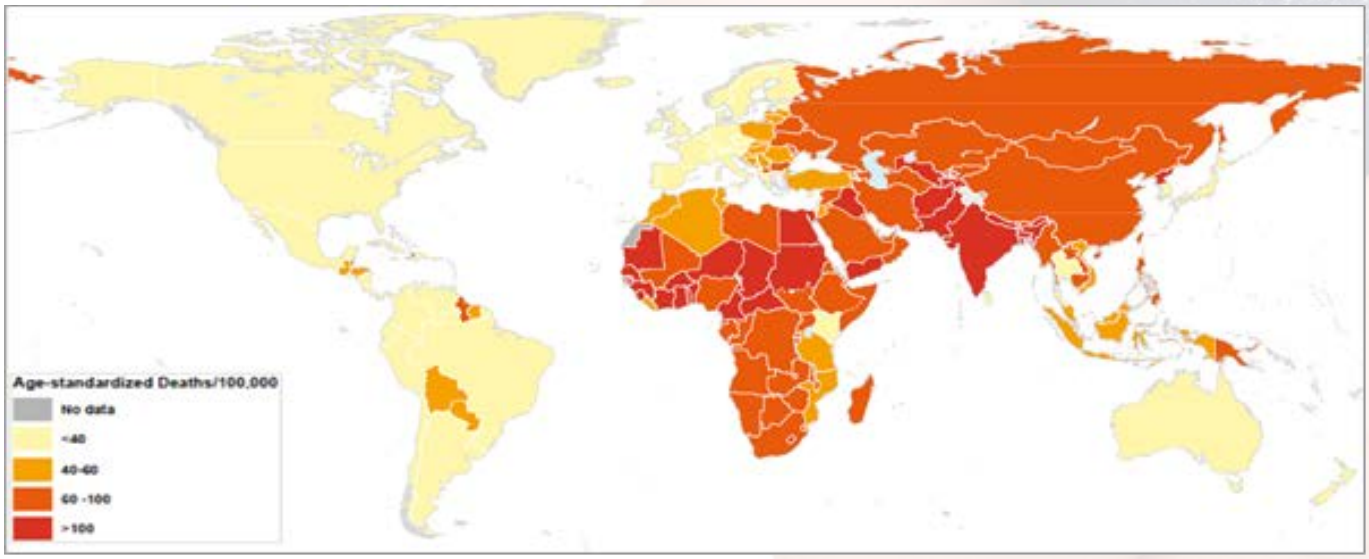


Figure 1: Premature deaths per 100 000 population owing to air pollution outdoors ($PM_{2.5}$) in 2016. Source: UNEP (2019), adapted from HEI (2018)

distributed and used more efficiently. Authorities all around the world must focus on preventing and managing risks and disasters. The goal must be to ensure us all healthy, meaningful lives in a healthy environment, now and in the future.

"All this requires a more ambitious and effective political governance across countries and sectors", says Guerreiro, "and that way of thinking characterises the entire report. These challenges cannot be met by any one country alone; that requires global cooperation."

Viewing air in a broad perspective

We already know that indoor and outdoor air pollution accounts for six to seven million premature deaths each year worldwide (Figure 1). This corresponds to a loss of 5.1 trillion USD annually. It also exacts huge costs associated with treatment of disease and lost working days, as well as poor crop yields owing, for example, to high levels of tropospheric ozone. Crop failures can lead to food shortages in some parts of the world, which in turn lead to starvation, disease, and death. Everything is interconnected, and as the effects of climate change grow stronger, they also affect other parts of the value chain we rely on.

"It is obvious that emissions from human activity continue to change the composition of the atmosphere", Guerreiro explains. "And it's not just air pollution from combustion and traffic. Emissions from human activity also lead to climate change, they break down the ozone in the stratosphere and make holes in the ozone layer, and people are exposed to various environmental toxins."

What do we know now, and what can we do?

The objective of the report is to support authorities and other decision-makers in their efforts to achieve the United Nations Sustainability Goals, to fulfil international obligations such as the Paris Agreement, and hopefully comply with the 1.5-degree target.

To provide a foundation for these efforts, the report contains fact-based assessments of recent scientific information and data on the environment, as well as analyses of current and previous environmental policy. In addition, it looks at our various options for achieving sustainable development by 2050.

"The report takes a relatively practical approach", says Guerreiro, "though it doesn't give definitive answers about what we must do. Instead, it outlines different paths forward based on existing knowledge. It tells which measures have so far proven feasible and which haven't worked, and discusses possibilities for further development. Moreover, the GEO-6 report is not exclusively for politicians: anyone who wants to learn more about the environment and environmental policy can benefit from reading it."

The future often looks bleak in reports like this one, but GEO-6 emphasises that the existence of good, sustainable solutions for most of the challenges we face. The proposed solutions have in common that they will promote social and economic development while reducing the risks associated with climate change, declining biodiversity, and pollution.

"The investments required are small compared to the huge costs of doing nothing", concludes Guerreiro.

Cristina Guerreiro, research director, Environmental Impacts and Sustainability Department, NILU
Photo: StudioF2, photographer Ingar Næss

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NILU on assignment in Chile: Measuring of volatile organic compounds

In 2019, NILU measured the concentrations of volatile organic compounds (VOCs) in the air over a period of four months, in the Chilean municipalities of Quintero-Puchuncaví and Concón in the Valparaíso region. The measurements were carried out on behalf of the Chilean Ministry of the Environment. So far, the results show no sign that VOC emissions from the industrial area affect the air quality in neighbouring residential areas.

Christine Forsetlund Solbakken
Head of communications

"NILU was contacted in the autumn of 2018, after there had been several episodes of malodorous emissions from industrial activities in these areas", says senior scientist Norbert Schmidbauer from NILU's Department of Monitoring and Instrumentation Technology.

"The Chilean Ministry of the Environment wanted help from an independent expert, who could carry out measurement campaigns in the affected areas."

NILU's assignment was to map concentrations of VOCs in the air. In addition, if possible, NILU was to trace the compounds back to the source – which is most likely the industrial activity in the immediate area.

Background for the assignment

In both Quintero-Puchuncaví and Concón, various forms of industrial activity take place close to residential areas and schools. Among the businesses is an oil refinery in Concón, and two coal-fired power plants, a copper smelter and several plants that receive, store, and distribute petrochemical products.

Back in August–September 2018, there was at least one episode when large amounts of pollutants may have been released into the air. Several hundred people went to the hospital with various symptoms they thought were


Photo: Susana Lopez-Aparicio, NILU

related to air emissions, and these events also attracted a lot of media attention.

To investigate the case, the local authorities used a newly purchased measuring instrument. The measurements carried out with this instrument showed very high concentrations of methyl chloroform, nitrobenzene, butane, and toluene for several consecutive weeks throughout the area in question.

Incorrect results from earlier measurements

"The concentrations of methyl chloroform that have been mentioned in the media are so high that they simply have to be wrong", says Schmidbauer.

"We are talking about a factor of several million times higher than is reasonable, so we assume that the instrument used was not properly calibrated."

Schmidbauer further explains that methyl chloroform is a substance that has been phased out in accordance with the Montréal protocol. This means that neither its use nor its production is permitted, and it is measured at monitoring stations and observatories worldwide. Before methyl chloroform was banned, the concentration in air globally was somewhat above 100 ppt (parts per trillion). At present, it is about 2 ppt.

The previous measurements performed in Quintero-Puchuncaví showed results at around 200 ppm (parts per million), which would indicate that the substance must have been used on a large scale. The researchers from NILU regard that as very unlikely, and their later measurements also showed an average methyl chloroform concentration in the air of approximately 1.7 ppt.

"Both media and citizens would like to know which substances were polluting the air last autumn and what the air quality is actually like in the area. Since NILU was not there taking samples in August and September 2018, we are sadly unable to say anything about what happened back then", says Schmidbauer, "but we understand that people are concerned and want answers."

NILU's measurement results

Regarding nitrobenzene, butane, and toluene, the NILU scientists also found very low concentrations in the air. The levels of nitrobenzene never exceeded the detection limit of 0.1 ppb (parts per billion), while butane and toluene also appeared in very low ppb levels.

"We can't say for certain that the concentrations of these substances in the air were never higher at an earlier time", says Susana Lopez-Aparicio from NILU's Department of Urban Environment and Industry.

"For methyl chloroform especially, levels above normal would have been recorded at atmospheric observatories, because this is a prohibited substance that is very closely monitored."

In Quintero-Puchuncaví, NILU's measurements also showed low to moderate levels of hydrocarbons from oil- and gas-related products in the surrounding residential areas.

Within permitted limits

"With the exception of benzene, there is no legal limit for volatile organic compounds in outdoor air", explains Lopez-Aparicio.

"For benzene we found levels between 0.3 and 1 microgram per cubic meter of air (µg/m3), while the legal limit is 5 µg/m3 as an annual average. For all substances, we found levels that are lower than what is permissible for industrial use."

In Concón, there is an oil and gas plant and a refinery. In this area, the researchers from NILU measured higher concentrations of volatile organic compounds, especially at night. During the measurement period, citizens living in residential areas just a few hundred metres from the two industries reported several episodes of very strong odour. But the measurements still did not show values above the limit value for benzene in outdoor air.

What happens next?

The final report for the measurements carried out was sent to the environmental authorities in Chile in May 2019. It has been presented to the authorities, media, at schools, and to residents of Quintero-Puchuncaví and Concón.

"Unfortunately, we were not able to take all the samples we had planned", says Schmidbauer. "But we will present the final results of our analyses in January 2020."

Subsequently, Schmidbauer has also assisted the Chilean authorities in establishing a dedicated laboratory for the measurement and analysis of air pollutants. The premises have been set up, the instruments have been ordered, and Schmidbauer is scheduled to return in March 2020 to be present during the start-up phase.

Schmidbauer and Lopez-Aparicio can also reveal that Chile is considering an air quality measurement station on Easter Island. If they receive funding, the NILU scientists will be involved in this project as well. The aim is to start during 2020.

RAVEN: Sharing air quality data across a growing number of borders

All EU countries must monitor and report air quality data to the European Environment Agency (EEA) in accordance with EU directives and standards. Every year, data on air quality zones, monitoring regimes, monitoring methods and "near real-time data" are reported, as well as environmental goals, plans and measures to comply with the limit values.

Christine Forsetlund Solbakken
Head of communications

In collaboration with the EEA Topic Centre on Air Pollution, Transport, Noise and Industrial Pollution (ETC/ATNI, see also page 24), technical data reporting has been harmonised and standardised to provide targeted and reliable data related to air quality. NILU – Norwegian Institute for Air Research has continuously contributed to this development through our role in the Topic Centre, which we now lead.

Modest beginning in the Western Balkans

Among other things, the EEA is working to support the six countries that make up the Western Balkans (Albania, Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro, and Serbia) in their environmental efforts. In this context, NILU was in 2016 asked to contribute to the development of an open source-based system, supporting the EEA's new mechanism for measuring and reporting air quality data.

Developing such a system requires both air quality expertise and relevant software development expertise. That is expensive, and the Western Balkan countries could not finance it on their

Extraction of measurement data. Screenshot from the RAVEN-system

own. The EEA initiative thus enabled them to report and share their data with the rest of the EU, via a secure and easy-to-use platform.

As the Western Balkan countries are not EU members, they currently only need to report metadata for the stations and the actual measurements to the EEA. Thus, the order NILU initially received from the EEA was to develop a database for storing metadata and air quality measurements, as well as a program that could provide an API for extracting data in the correct XML format. This was the background for the project that was given the development name RAVEN.

Senior system developer Christoffer Stoll at NILU was responsible for the product, and during 2017 it was installed in five of the six Western Balkan countries. Everything worked as planned, and the EEA was very pleased with the result.

"Our success is due to the fact that we have created an application that is both easy to use and easy to install", says development manager Rune Ødegård.

RAVEN flies further

The success in the Western Balkans led to NILU being asked to expand the project in 2018. Now the goal was to find out how the countries of Azerbaijan, Georgia, Ukraine, Moldova, Belarus and Armenia could share their data with the EU. The project had two parts: the first part was about providing up-to-date information on air quality systems and measurements from the countries; part two was about how the countries could share their air quality data with the EU.

"We then proposed to the EEA that RAVEN be introduced there as well, and that we should further develop the user interface for the solution", says Ødegård. "This was agreed upon, and the extended contract with the EEA was signed in 2019."

Ødegård goes on to say that all the countries involved wanted to use the system. Some wanted to use RAVEN in its entirety, while others, such as Georgia, integrated the solution into their existing system. They use RAVEN to report up-to-date (UTD) data to the EEA, making the data available through the EEA's air quality index portal https://airindex.eea.europa.eu/

"NILU has a new project in place now, that includes all Western Balkan countries from the original deployment", says Ødegård. "The plan is to expand the system to contain more data flows, so that the countries can start reporting air quality zones, monitoring regime, monitoring methods, and model data as well. Doing that, they will be in line with other EU countries regarding air quality data reports."

Open source and GitHub

The next step for NILU is to develop an open data logger. One of the current challenges is proprietary data loggers, where users must deal with "closed" systems that are difficult to integrate. Ødegård and his colleagues want to develop an open source solution for this. That will in turn make RAVEN into a complete system that eliminates the need to handle different file formats for each monitoring station.

The RAVEN system is free and open source, but Ødegård says they plan to license it so that anyone can use it, but not sell it. Anyone who wants to can develop solutions based on RAVEN, but what is developed must be returned to the system.

In addition, NILU, together with Sweden's Meteorological and Hydrological Institute (SMHI), plans to form an open source community for developers working on open air quality systems based on RAVEN.

RAVEN can be downloaded from NILU's code repository: https://git.nilu.no/eea-tools/raven

Western Balkans in blue

Project leader Svein Knudsen with senior system developers Mirjam Fredriksen and Håvard Vika Røen
Photo: Ingunn Trones, NILU

ClairCity: Citizen-led air pollution reduction in cities

The ClairCity project aims to increase awareness about air pollution and carbon emissions in cities by looking at how people's behaviour contributes to the problems. Unlike many other projects, ClairCity focuses on involving citizens in deciding on the best solutions, since citizens are among those ultimately affected by poor air quality and climate change.

Sonja Grossberndt
Scientist

"We got in contact with as many citizens as possible to better understand their motives and the choices they make regarding environmentally friendly behaviour", says Svein Knudsen, senior scientist at NILU. Knudsen works at NILU's Innovation Department and is NILU's project lead for ClairCity.

Co-creating solutions

"We also wanted to know more about citizens' viewpoints about how to solve problems related to air pollution and climate change", Knudsen continues. "This is why we developed engaging resources, such as an app and a game, to facilitate interactions with non-scientists. We have been creative how we engaged with citizens, encouraging them to have their say."

The results have been used in the development of solutions for each

partner city, based on individual air pollution models. The ClairCity scientists also used research on the different policy and governance landscapes to ensure that their solutions would be incorporated into the decision-making processes in each partner city.

An innovative engagement process based on citizen-led scenarios resulted in a range of different political options. NILU was involved in the scenario development and compiling the final report about these activities.

"NILU had several tasks in this project", explains Knudsen. "Our scientists have been working on assessing the health impact of particulate matter (PM) and NO_2 in the participating cities and urban regions. This assessment is a crucial part of the ClairCity generic model and can be applied to any other city."

NILU's second main task was running the innovation process that defines products and services from the project and makes them available to a broad range of potential customers after the project is completed. The third main task was to develop the GreenAnt system. Its scope is to map citizens' travel patterns and changes in these patterns due to measures taken by the municipality.

Learn from the ants - become a smart and green traveller

Ants are constantly on the move, finding the smartest route to reach their goal. That inspired both the name and the concept behind the GreenAnt system. GreenAnt consists of two parts – a web page for creating a user profile and accessing data, and a smartphone application for data collection.

After development and extensive testing at NILU, GreenAnt has also been tested in the different ClairCity partner cities/regions. Receiving user input and engaging users in testing the system's functionality has been very useful.

"GreenAnt offers a wide selection of application options", explains Mirjam Fredriksen. She and Håvard Vika Røen are the senior system developers behind the GreenAnt app.

"The system has been designed to provide insight into people's daily travel habits, and their reaction to changes. It visualises how people's travelling behaviour causes air pollution and contributes to GHG emissions. The system also indicates areas of high air pollution, helping people avoid travelling in zones where exposure can be high. Through this, people can be motivated to not use their car because of high pollution emissions."

GreenAnt can also be used for strategic planning of activities and in campaigns run by governmental entities, NGOs, service providers, and industry. For instance, if a municipality wants to close a road for general traffic, GreenAnt can be used as tool to analyse changes in people's behaviour before and after the road closure.

"We see a lot of potential in the GreenAnt system", Fredriksen concludes. "It can basically be used anywhere to quantify change. This opens up for many options and will keep the system alive beyond the official end of the project."

ClairCity

ClairCity (2016-2020) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 689289. Ten partner organisations have been working closely together with the following 6 cities/urban regions: Amsterdam (The Netherlands), Bristol (UK), Aveiro (Portugal), Liguria (Italy), Ljubljana (Slovenia) and Sosnowiec (Poland). Since each city/region faces different air quality and climate change issues, individual solutions have been developed for each city/region to help local authorities to make the right choices.

GreenAnt

GreenAnt website with user manual:
https://greenant.nilu.no/

Mobile application for Android and iOS: GreenAnt

Photo: Colourbox

A Greener Europe: NILU contributes through topic centres

With its "European Green Deal", the new European Commission has initiated hectic activity to translate political visions into a climate-neutral Europe that ensures good lives for its citizens. This means that pan-European environmental and climate cooperation will play an increasingly important role.

Christine Forsetlund Solbakken
Head of communications

"NILU – Norwegian Institute for Air Research is an important contributor to the European Environment Agency's work, not least through its participation in two "European Topic Centres". In this way, the institute also becomes an important part of both national and international efforts to combat climate change and pollution", says EU coordinator and research director Alena Bartonova from NILU.

Bartonova heads the topic centre on Air Pollution, Transport, Noise and Industrial Pollution (ETC/ATNI) on NILU's behalf. In addition to leading the work of ETC/ATNI, NILU scientists also contribute to the topic centre on Climate Change Mitigation and Energy (ETC/CME).

Joint environmental efforts increasingly important

The efforts for a greener Europe come as no surprise to Norway, which according to Bartonova can be called the "motherland" of sustainability.

At the same time, Norway still needs a push in the right direction when it comes to greenhouse gas emissions and the green shift.

"The European environmental policy we are seeing now is broadly based", says Cristina Guerreiro, research director for NILU's Department of Environmental Impacts and Sustainability. "It is linked to global sustainability ambitions expressed in the UN's Sustainability Goals, and it is to be implemented at a pace that reflects the urgency of the climate and environmental crisis. This makes environmental cooperation across sectors and national borders more important than ever."

Both Norwegian and European legislation make many demands aimed at reducing emissions of pollutants to the environment, and set legal limits on the concentrations of various substances in air. Reliable information and data are essential to follow up on the implementation of environmental policy and measures, as well as to monitor developments in environmental conditions and impacts. Good data enable us to tailor measures that ensure the least possible adverse effects on climate, the environment and health.

"Evidence-based and evidence-oriented politics, firmly grounded on research and knowledge, must play a central role", Bartonova continues. "The topic centres have two primary tasks when it comes to this: The first is to support data collection and assure the quality of those data. The second is to use the data in integrated assessments of environmental status and trends, and to assess the impacts, trade-offs and synergies of environmental policy and measures implemented."

The topic centres as knowledge disseminators

The topic centres are intended to serve as bridges between the countries' environmental data and the European Environment Agency's environmental information systems. Another important task is to disseminate the environmental knowledge they acquire through joint research, development and innovation work in the networks linked to the topic centres. In this way, the topic centres ensure both the continuity of long time series of monitoring data, and that the observations are used in connection with new tasks that emerge as policy develops further.

Alena Bartonova is EU coordinator and research director at NILU, as well as heading ETC/ATNI on NILU's behalf
Photo: StudioF2, photographer Ingar Næss

Cristina Guerreiro is research director for NILU's Department of Environmental Impacts and Sustainability, and involved in ETC/CME.
Photo: StudioF2, photographer Ingar Næss

A practical example of how the work done at the topic centres has already contributed is the European Environment Agency's annual report "Air quality in Europe", which is in part based on data and analyses from ETC/ATNI. Cristina Guerreiro has been the lead author of this report, which provides an annual updated overview and analysis of air quality in Europe – and celebrates its tenth anniversary in 2020. The report also summarises the progress made in reducing the negative effects of air pollution on health and ecosystems in Europe.

"Other new topics we are working on in ETC/ATNI include the use of microsensors and earth observation data for measuring air quality and emissions and urban sustainability. In addition, we monitor developments in industrial emissions, their effects and societal costs", explains Bartonova.

"In ETC/CME, we are working on projections of greenhouse gas emissions, life cycle analyses of energy systems in Europe, as well as life cycle effects of the use of chemicals in the circular economy", Guerreiro concludes.

Read more:
The European Environment Agency's report "Air quality in Europe 2019":
https://www.eea.europa.eu/publications/air-quality-in-europe-2019

Reports from the topic centre on Air Pollution, Transport, Noise and Industrial Pollution (ETC/ATNI)
https://www.eionet.europa.eu/etcs/etc-atni/products/atni-reports

Reports from the topic centre on Climate Action and Energy (ETC/CME):
https://www.eionet.europa.eu/etcs/etc-cme/products/cme-reports

Newly developed particle sensor from Kjeller Innovation and NILU:

New opportunities for NILU: Services for industry

Road dust and wood burning are well-known sources of particulate matter in Norwegian cities, but industry and construction sites are also where workers may at times be exposed to high levels of particulate matter in their daily lives. In a new project, NILU has developed services that can provide more detailed information on real-time pollution levels in industrial workplaces

Sonja Grossberndt
Scientist

It can be harmful to inhale too much particulate matter (PM) – but how do you know when you have reached the limit? To answer that question, Kjeller Innovation initiated the project "Leopard", to which NILU – Norwegian Institute of Air Research contributed significantly. The aim of the project was to develop a small, portable sensor that measures particulate matter of different sizes in real time with high accuracy, and warns of high concentrations of particulate matter in the air.

The creation of a dust sensor

"It has been a very exciting project, which resulted in new products and services that NILU can offer in the future", says senior scientist Matthias Vogt.

"As a first step, we used what's called CAD drawing (computer-assisted design). The drawing was the starting point for a small, lightweight sensor that could measure particulate matter of different sizes and with high accuracy", he elaborates. "At the same time, it had to be able to calibrate itself, automatically and in real time, to adapt to the concentrations of particulate matter in the surrounding air."

To get the best result, NILU hired senior scientist Tuan-Vu Cao, who holds a doctorate in electrical engineering. As key designer and technical coordinator, he worked with developing the sensor in the Leopard project. His knowledge of light scattering, mechanics, air currents and calibration of sensors was crucial in being able to create the suspended dust sensor for the project – but also as part of NILU's products and services in the future.

A complementary approach...

As a complementary approach to the design of the sensor, scientist Islen Vallejo and engineer Torbjørn Heltne from NILU used an iterative methodology between mechanical design and computer experiments to better understand what goes on inside the sensor – before it was put into production.

Computational fluid dynamics (CFD) enables simulation of how the geometry affects the flow of air with different levels of pollution as it moves through the sensor. At the same time, it is possible to observe how the components of the pollution behave on the inside of the sensor. For example, do particles of different sizes move through the sensor at the same speed, or will some particles settle on the sensor wall? CFD can be used for both gas and particle sensors.

...that opens up new opportunities

"This way, we can find out exactly how the sensor will behave in real situations and under different meteorological conditions", Vallejo explains. "It can save us many months of field testing."

The same principle can also be used to test low-cost air quality sensors, which are usually unable to provide measurement data of adequate quality.

"We can use and adapt these algorithms to improve the data quality from the low-cost monitoring instruments", Vallejo continues. "It will also make it possible to install large networks of affordable air quality sensors across an entire city, to measure air quality in real time at various locations in the city. This is an important service, which NILU can

NILU scientist Matthias Vogt is testing the sensor in the production hall. Photo: Francisco Periales

now deliver to municipalities and other stakeholders."

Testing under real conditions

A major metal manufacturer was very interested in the Leopard project and made its production halls available to test the sensor under real-life conditions.

"It turned out that both employer and employees had limited knowledge about particulate matter pollution", says Vogt. "Obviously they conducted indoor air quality surveys in line with the Working Environment Act, and as long as the pollution level was within the legal limit, they assumed everything was fine. But that's not necessarily the case, because even PM levels that are within the limit can lead to health damage if ultra-fine particles are inhaled deep into the lungs", he explains.

As the manufacturing firm involved gained access to more information about the composition of particulate matter and how the various particles can damage people's health despite low levels, they became very interested. Previously, they had been unaware that the levels of pollution that could vary in different parts of the factory, as the levels are linked to the various emission sources, work processes and structure of the building at each individual site. For the employers, this prompted a desire for even more information from the Leopard project.

Creating solutions

"With our method, we were able to map real-time pollution levels in the entire work area", says Vogt. "Thus, we could identify different sources of pollution. The dialogue with scientists made the employer more aware of the issue, and our information gave the employer a greater sense of ownership."

"Based on the results of the project, the metal manufacturer has now initiated construction measures to reduce the level of suspended PM in one of the halls we investigated, to protect workers from PM-related health damage. This is great", says a satisfied Vogt.

Thus the Leopard project has opened up for new services that NILU can offer to industry and other customers.

Photo: Helge Markusson, The Fram Centre

Positive evaluation of the research collaboration at the Fram Centre and the flagship "Hazardous substances"

During the autumn of 2018 and spring of 2019, the research collaboration at the Fram Centre was externally evaluated by an international group of experts, at the behest of the Research Council of Norway. The evaluation was based on interview rounds and documentation from the flagships, members and the secretariat.

Eldbjørg S. Heimstad,
Research director High North

The evaluation report concludes that the Fram Centre has largely achieved the goals set when the centre was established in 2010. The committee was impressed with the productivity and number of projects in the flagships and described the knowledge production as both relevant and of high quality.

The flagship "Hazardous substances – effects on ecosystems and human health", led by NILU, got a very positive evaluation. It was emphasised that the research is of high quality; that it has contributed important knowledge to international organisations; and has had an influence on national and international regulation of environmental pollutants. In addition, the flagship received praise for good scientific and popular scientific dissemination. The Committee concluded that the flagship is a unique platform for Arctic monitoring and research on global pollution and ecosystem changes. Furthermore, the flagship and Norway have great potential to influence environmental pollutant regulation at the international level.

It was emphasised for all the flagships, that social sciences should be more strongly integrated into the projects, in both planning and implementation. This will be followed up as we move forward with strategy meetings and updates of programme plans for a new five-year period.

Link to the report:
https://www.forskningsradet.no/contentassets/8695dd49ad9b46b283ab2760de69136c/fram-evaluation-report.pdf

Head of IT Morten Pedersen in NILU's new server room. Photo: Ingunn Trones, NILU

NILU's new server room

NILU's total volume of data is increasing year by year. This is the bedrock of much of our research, and in order to safeguard and ensure accessibility, the IT department in 2019 made a major improvement in NILU's server infrastructure.

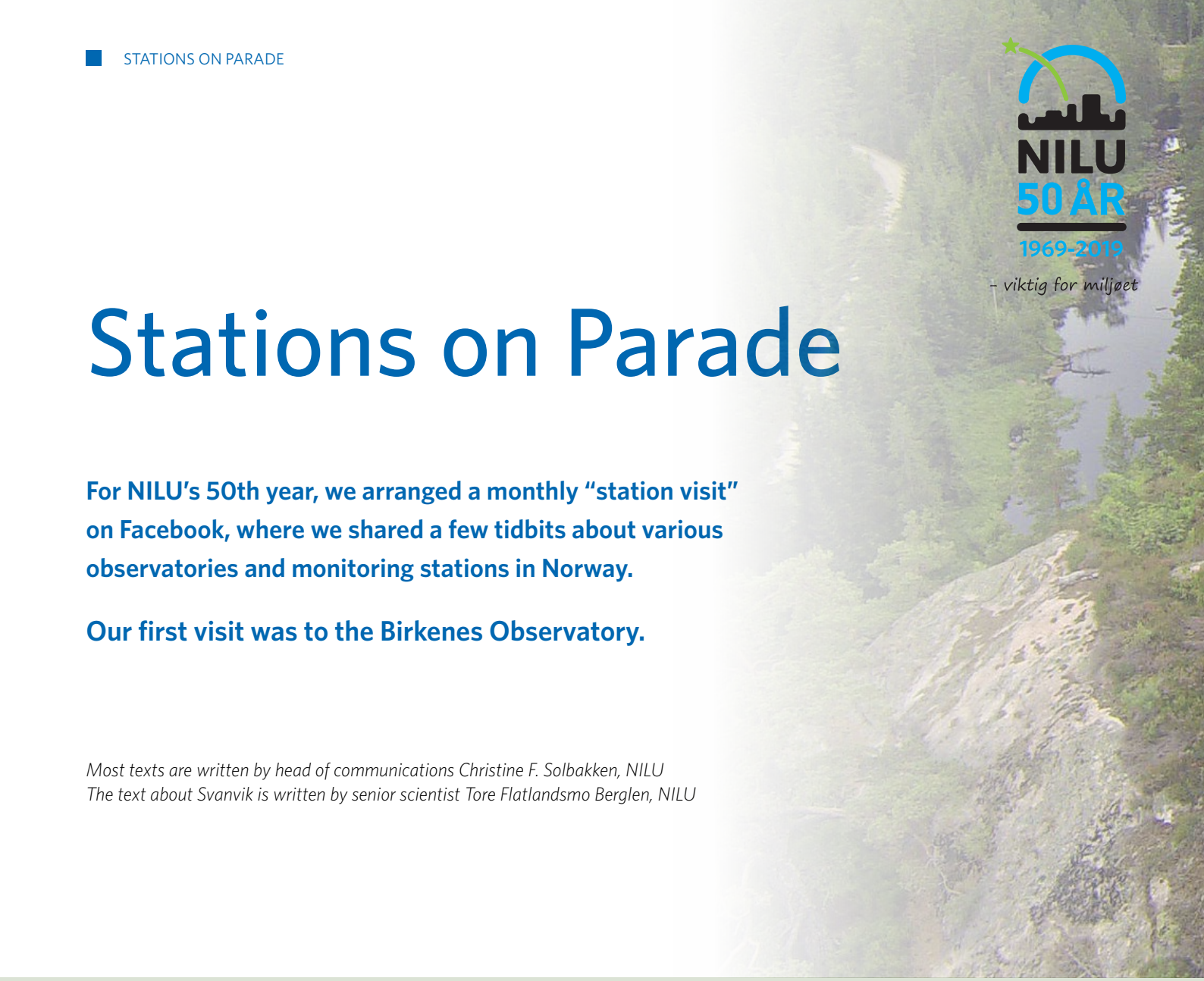
Morten Pedersen,
Head of IT

Our scientists generate large amounts of data that must always be both maintained and accessible. In order to secure these data in case of problems, NILU has for several years relied on one main server room, plus one secondary server room. But we have grown out of this solution, and have therefore built a brand-new server room at NILU.

During planning, the IT department took into consideration the ever-increasing need for storage. In addition, for security reasons, we have duplicated large parts of the server infrastructure over the last ten years. This means that if problems occur in one server room, the other can take over operations.

The planning was mainly done in 2018, whereas the work was carried out in the summer and autumn of 2019. Since the intention was that the new server room would be connected to the same power and cooling system as the main server room, digging was required to lay cables and pipes. In addition, some changes were made to the outdoor platform where the generator and outdoor cooling units are located. An outdoor solution gives the benefit of "free cooling": for much of the year, the temperature is low enough that the outdoor air can be used directly to cool down the server rooms.

With a few exceptions, the IT department at NILU operates all of NILU's IT services. This requires optimal power and cooling systems. The requirements for uptime and availability must be met while still ensuring safety. The IT department offers a wide range of services to both internal and external users, and our new server infrastructure ensures flexibility, good redundancy and high uptime.



Stations on Parade

For NILU's 50th year, we arranged a monthly "station visit" on Facebook, where we shared a few tidbits about various observatories and monitoring stations in Norway.

Our first visit was to the Birkenes Observatory.

Most texts are written by head of communications Christine F. Solbakken, NILU
The text about Svanvik is written by senior scientist Tore Flatlandsmo Berglen, NILU

January: The Birkenes Observatory

Our first visit was to the Birkenes Observatory, NILU's oldest observatory! Birkenes in Aust-Agder was first established in 1971, and is one of Europe's longest-running monitoring stations.

The Birkenes Observatory is located in the part of Norway that is most strongly affected by emissions from the continent. In the 1960s, fish in Scandinavian waters began dying, and researchers suspected that the cause might be sulphur-containing pollutants (often called acid rain) transported from far away.

Basis for the Convention on Long-Range Transboundary Air Pollution

To find out whether acidity could actually be transported with the atmosphere in large enough quantities to cause such damage, it was necessary to start measurements and determine the chemical composition of the pollutants in air and precipitation.

Based on results from Birkenes and other baseline measurement stations, researchers could prove that pollution from other countries was causing the problems. These results also formed the basis for the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the protocols under it.

Photo: Harald Wiloch, NILU

The work with CLRTAP revealed that most European countries receive substantial amounts of air pollution from other countries. As a consequence, the pan-European Monitoring and Evaluation Programme (EMEP) was established.

Data since 1970

From the outset, NILU was assigned responsibility for coordinating the chemical measurements undertaken within EMEP, as well as collecting, compiling and publishing all the results. NILU still performs these tasks, in addition to storing and doing quality control on all data from EMEP's 40 member states, developing measurement strategies, recommending methodology, and contributing training and support.

At present, five of Norway's approximately 20 monitoring stations participate in the EMEPs monitoring programme for chemical compounds in air and precipitation. The Birkenes Observatory still plays a very important role in NILU's documentation of long-term changes in the composition of the atmosphere, with data back to the 1970s.

This provides a unique opportunity to follow historical changes in the type and amount of pollution, and to see how airborne pollution is transported across national boundaries.

Photo: Claudia Hak, NILU

February: Lillehammer barnehage

The monitoring station Lillehammer barnehage is what we call an urban background station. These types of stations should be placed so that they capture total air pollution originating from all possible sources (traffic, heating, industries, natural sources, etc).

Lillehammer barnehage is owned by the Norwegian Public Roads Administration, and is run by chief engineer Gudbrand Skinnerlien for Lillehammer Municipality. It is one of the measuring stations in Norway that was established to conform with the European Air Quality Directive (2008/50/EC).

This directive, together with European Commission Directive 2015/1480 and Section 7 of the Norwegian Pollution Regulation, set forth a highly detailed policy for what is to be measured, how, where, and how often.

Pan-European AQ directives

All European countries measure air quality in accordance with the same directives. This means that they employ the same standardised methods for measuring air quality, and the same routines for operating and calibrating the instruments, to ensure collection of data with high quality and precision.

Here in Norway, NILU is the National Reference Laboratory for Air. This means that the Institute is ultimately responsible for ensuring that the data collected from Norwegian monitoring stations meets high standards of quality. To this end, NILU organises courses in quality assurance, quality control and operation of monitoring stations and instruments for those in charge of stations all over the country.

Location and measurements

Not surprisingly, the measuring station called Lillehammer barnehage is located right next to a kindergarten. The station has had the same location ever since it began operations in early October 2004. It is one of the Norwegian monitoring network stations where the highest levels of PAH are detected. This is related to the fact that many households in the area burn wood. PAH has been measured at the station since 2012. Measurements of NO_2 and PM_{10} started as early as October 2004, and $PM_{2.5}$ has been measured since January 2005. The data can be viewed at http://luftkvalitet.info.

Lillehammer barnehage is representative of Norwegian cities of similar size, and is a prime example of the Norwegian network for the measurement of local air quality.

Measurements at the Lillehammer Olympics

Lillehammer did a thorough job related to air quality at the 1994 Olympics. A highly advanced system was developed specifically to monitor and provide information about environmental parameters, and was used at the 1994 Olympic Games. The system was named ENSIS (Environmental Surveillance and Information System, Lillehammer '94). ENSIS was developed within the framework of Eureka, a European technology collaboration. NILU was in charge of developing the ENSIS components related to air.

NILU measured air quality at six stations during the Winter Olympics in Lillehammer. The results were not always encouraging. Five of the six stations showed heightened hourly averages for NO_2 concentrations, and highest NO_2 value was measured in Lillehammer. Although use of private vehicles was restricted during the Olympics, emissions of nitrogen oxides increased due to bus traffic. Combined with extreme cold and unfavourable dispersal conditions, this resulted in high NO_2 concentrations during the Olympic Games.

Over the same period, levels of particulate matter (PM_{10}), carbon monoxide (CO), sulphur dioxide (SO_2) and ozone (O_3) were also measured. None of these air pollutants exceeded permissible limits during the Games

March: Svanvik

Svanvik monitoring station in Pasvik valley in East Finnmark is located approximately 40 km south of Kirkenes and only a few kilometres from the Russian border. The reason NILU does monitoring at Svanvik is the smelting plant in the Russian city of Nikel, just 8 km away. The plant emits large amounts of sulphur dioxide (SO_2) and heavy metals, and when the wind is from the east, NILU measures high concentrations of SO_2 at Svanvik.

Geologically, the area is rich in metals and minerals (as illustrated by the Sydvaranger mine on the Norwegian side of the border).

East of the Pasvik River, an area of land called Petasmo belonged to Finland from 1920 until World War II, and it was the Finns who first discovered nickel there.

Smelters were established in the 1930s, and when the area became part of the Soviet Union after the war, the smelting plant was put back in commission. In the 1990s the plant was privatised and is now owned by the Kola Mining and Metallurgical Co (Kola MMC), a subsidiary of Norilsk Nickel (Nornickel), the world's largest producer of nickel and palladium.

The ores processed in Nikel are so-called sulphidic ores. This means that they contain sulphur, and when the ore is refined sulphur dioxide (SO_2) is emitted, along with heavy metals such as nickel, copper, cobalt, and arsenic.

Emissions from the briquetting plant in Zapoljarny farther east and the smelter in Nikel affect air quality in the areas along the Norwegian–Russian border.

Measurements since 1974

NILU has been taking measurements in the border areas since 1974, making this one of the Institute's oldest, most long-running monitoring projects. The measurements are funded by Norwegian authorities (the Norwegian Environment Agency and the Ministry of Climate and Environment).

Today, NILU has a monitoring station at Svanvik (8 km west of the smelting plant in Nikel) and a another in Karpdalen in Jarfjord, north of Nikel and Zapoljarny. In addition, NILU has long time-series of SO_2 levels at Viksjøfjell and precipitation at Karpbukt. The measurement data from Svanvik and Karpdalen are posted on the website luftkvalitet.info, and the results are published in annual reports.

Emissions of SO_2 have decreased in recent years and, according to the smelting company, are now approximately 80 000 tonnes per year. This is five times Norway's total emissions. In the 1970s and 1980s, emissions were over 400 000 tonnes SO_2 per year. The high emissions at the time were due to the processing of ore from Siberia with a high sulphur content.

Now the only ore processed is local, from the mines around Zapoljarny. Over the past few years, the briquetting plant in Zapoljarny and the smelter in Nikel have been modernised, the emissions have gone down, and are expected to be reduced further by 2023.

The last two years (2017 and 2018) saw relatively low concentrations of SO_2 at Svanvik. But shortly after the beginning of 2019 there were two episodes with high concentrations, 14 and 25 January.

High air pollution warning

A system to warn local inhabitants about high air pollution has been established. This is a collaboration between NILU, Sør-Varanger municipality and the Norwegian Environment Agency.

On Friday, 25 January 2019, Sør-Varanger municipality issued the first warning about high SO_2 concentrations in Pasvikdalen to 204 subscribers. The event attracted a lot of attention both locally and throughout Norway.

Pollution from the nickel plant on the Russian side of the border is also a political topic in bilateral relations between Russia and Norway. The issue was discussed at the meeting of the Norwegian–Russian Environmental Commission in Moscow on 19 February.

The episodes of high SO_2 concentrations in winter demonstrate the need for continued measurements of air pollution along the border.

As such, NILU has an important task of monitoring air quality and providing up-to-date information on the environmental to local citizens, administrators, governmental authorities and other stakeholders.

April: The Zeppelin Observatory

In April, we welcome you to the Zeppelin Observatory. Perched near the top of Zeppelin mountain outside Ny-Ålesund, Svalbard, the Observatory has been in operation for 30 years. Its location at 79 degrees North makes it an ideal place for monitoring global changes in the atmosphere and long-range transport of pollutants into the Arctic.

The Zeppelin Observatory is one of just a handful of stations in the Arctic, and is located in a particularly important area, where the climate is changing faster than elsewhere on Earth.

Consequently, Zeppelin Observatory provides data that are used by a multitude of international programmes and research infrastructures, including EMEP (The European Monitoring and Evaluation Programme under LRTAP, UNECE), AMAP (Arctic Monitoring and Assessment Programme), ACTRIS (European Research Infrastructure for the Observation of Aerosol, Clouds, and Trace gases), ICOS (Integrated Carbon Observation System) and WMO/GAW (World Meteorological Organization/Global Atmosphere Watch).

Measuring background levels

The Arctic (and Antarctica) are among the planet's most vulnerable places, where climate change will be felt first. That is one of the reasons it is crucial to keep a close watch on the composition of the atmosphere near the poles. In addition, these regions have the cleanest air in the world, which means that atmospheric scientists can measure what they call "background levels".

The background level is the lowest level of various particles and gases found in the atmosphere. Nowadays, background levels can only be measured in places where human activity does not cause local pollution. Based on air samples, researchers can figure out where the pollutants come from and in what quantities they are emitted. Over time, these measurements will constitute what is often called "long time series", which show trends in the levels of various pollutants.

Long time series

Long time series are particularly important for monitoring the climate, and Zeppelin Observatory has some of the longest time series in the world for atmospheric components such as carbon monoxide (CO) and carbon dioxide (CO_2, which has been measured there right from the start by Stockholm University), methane, other greenhouse gases, mercury, organic pollutants and ozone-depleting substances. These Norwegian time series are also valuable in an international research perspective.

Monitoring air quality since 1989

NILU has been monitoring air quality at Zeppelin Observatory since 1989, but NILU's first atmospheric measurements in Svalbard were done as early as 1974, also in Ny-Ålesund. NILU runs the Zeppelin observatory in close cooperation with the Norwegian Polar Institute. The Polar Institute handles daily technical maintenance of the observatory, and NILU is in charge of the scientific programme. In addition, Kings Bay AS provides practical and logistical support for researchers and other guests visiting Ny-Ålesund.

Photo: Ove Hermansen, NILU

Photo: Dorothea Schulze, NILU

May: Kårvatn

Kårvatn monitoring station is located at Kårvatn Farm at the top of Todalen, on the outskirts of Trollheimen in Møre og Romsdal county. At this location, far away from major sources of pollution, Kårvatn also measures some of Europe's lowest levels of airborne pollutants. Thus, the readings from Kårvatn provide a background level against which European measurements done closer to the emission sources can be compared.

Measurements taken at Kårvatn include tropospheric ozone, nitrogen and sulphur compounds in air and precipitation, carbonaceous material in particles, particle mass, and heavy metals in precipitation.

Part of the EMEP programme

Data from Kårvatn and the other background stations are used in the national surveillance programmes that NILU carries out on behalf of the Norwegian Environment Agency.

In addition, these data are used in several international programmes, such as the extensive European Monitoring and Evaluation Programme (EMEP) under the Convention on Long-range Transboundary Air Pollution (CLTRAP).

Kårvatn is one of five similar EMEP stations scattered throughout Norway. The other four are Zeppelin, Tustervatn, Hurdal and Birkenes.

NILU owns and operates these stations, which play an important role in national and international networks for airborne pollution monitoring.

Airborne pollutants can travel with the atmosphere over great distances and across borders, and this transport is called "long range". Data from the network of monitoring stations enable researchers to trace the movements of long range transported contaminants.

Acidification is still an environmental problem

Kårvatn has been operating since 1978. This makes it an important measurement station for documenting changes in emissions and air pollution over time. Major reductions in sulphur emissions in Europe over time have meant that acid rain is a considerably smaller problem in Norway now than in the 1970s to 1990s.

Nevertheless, acidification remains an environmental problem, especially in southern parts of the country. Emissions in Europe are the main cause of acid rain in Norway. 90% of the sulphur deposited in Norway comes from other countries. At Kårvatn, sulphur deposition has fallen by about 60% since 1990.

Operation and maintenance

NILU's Division for Monitoring and Instrumentation Technology is responsible for maintaining the equipment NILU uses in monitoring.

Everyday routines are attended to by the staff at each station. At Kårvatn it is now Gudmund Kårvatn who handles the daily measurements. The samples he takes are sent to NILU at Kjeller for analysis and registration. He and the other station staffers collect air and precipitation samples from "their" background stations every day, all year long. Without their dedication, the comprehensive monitoring programme Norway has today would not have been possible.

June: Prestebakke

The monitoring station Prestebakke is a so-called regional background station that measures tropospheric ozone – ozone near the ground. The station lies 25 km south-southeast of Halden and east of Iddefjorden in Østfold County. The location is particularly well suited for detecting peak ozone episodes caused by long-range transport of air pollution from the continent to south-eastern Norway.

Most of us think of ozone as the stuff up in the stratosphere that protects us from harmful UV radiation from the sun.

Tropospheric ozone

But tropospheric ozone, which is present near the earth's surface, doesn't protect us. It is a poisonous gas formed when carbon monoxide (CO), nitrogen oxides (NO_x) and volatile organic compounds (VOC) react with each other in the presence of sunlight and heat.

This means that tropospheric ozone is essentially a summer problem in Norway.

High levels of tropospheric ozone can harm vegetation, reduce crop yields, and have negative on our health. Ozone harms plant cells after entering through the stomata (openings) in their leaves. Tropospheric ozone can cause breakdown of exposed surfaces, and is considered a short-lived greenhouse gas. Exposure to tropospheric ozone can result in substantial economic losses for agriculture, especially in southern Europe.

Moreover, tropospheric ozone can be detrimental to human health, impairing respiratory function and exacerbating illnesses of the respiratory tract. Fortunately, ozone levels are rarely high enough to threaten life and health here in Norway.

NILU has monitored ozone at Prestebakke since November 1985. The station was originally set up as part of the acid rain surveillance programme, and previously measured several components of air. Ozone data from Prestebakke are also used in the Swedish surveillance programme.

National Reference Laboratory for Ozone and Air

The Norwegian Metrology Service has appointed NILU to be the National Reference Laboratory for Ozone. This means that NILU represents Norway's top competence in the measurement of ozone. In addition, NILU is the National Reference Laboratory for Air (NRL).

Consequently, at Prestebakke – and all other measuring stations in Norway – the instruments are operated, and the data are quality-controlled according to stringent protocols. These ensure that the ozone instruments function well, with minimal downtime.

Photo: Helene L. Halvorsen, NILU

July: Hjortnes

The Hjortnes monitoring station lies just off the E18 motorway at Hjortneskaia in Oslo. It has been there since October 2008. The monitoring station is owned by the Norwegian Public Roads Administration and operated by NILU. The station measures particulate matter (both PM_{10} and $PM_{2.5}$), nitrogen oxides (NO_x) and polyaromatic hydrocarbons (PAH). The PAHs are analysed in NILU's laboratory and reported annually; the other air components are presented continuously online.

Hjortnes is what is called a roadside station. Such monitoring stations mainly measure pollution from vehicle traffic and should therefore be located close to roads. The station is just 5 metres south of the eastbound lanes of the E18 motorway, well situated to measure pollution from the passing traffic.

The station is also near Oslo's busiest bicycle route, where 2100 bicycles come through on an average day. In other words, in 2018, nearly 770 000 cyclists passed Hjortnes! This makes the data from this station highly relevant for this group of commuters, not to mention others who live and spend time in the area.

Good location

Many people wonder why monitoring stations are placed along roads, rather than in parks and public gardens where people spend their time. It's because the location is chosen to keep an eye on threshold limits for pollution. In short, the limit values are rules for how much pollution is allowed over a given period. They are set based on two factors: what levels of a pollutant are known to be hazardous to health, and the distance between the monitoring station and the source of the pollution.

For example, the limit value for the hourly average for NO_2 is max 200 micrograms per cubic metre of air (µg/m^3). To be able to take into account that an entire year may bring a few episodes of severe air pollution, it is permissible to exceed this threshold 18 hours per year. The nineteenth hour the levels exceed 200 µg/m^3, the law is being broken.

The reason the threshold limit value is set as high as 200 micrograms per cubic metre is because roadside monitoring stations are placed so close to the source of pollution – i.e. the traffic. If the directive had stated that the monitoring stations should be farther away from the vehicles, the threshold limit would have been set lower to compensate for the greater distance. Moreover the placement of monitoring stations will always be a compromise between the requirements of the EU directive and practical factors, e.g. availability of relevant monitoring sites, permission to place the station on the site, power supply, vegetation and other obstacles, local sources of pollution, traffic conditions, parking facilities for those who operate the station, etc.

From this perspective, Hjortnes is well placed. It is easily accessible for maintenance staff – but also for passers-by and local graffiti artists. The station's exterior is a constantly changing symphony of colour! A few years ago, the décor caused some embarrassment. One of NILU's scientists was being interviewed by French television about air quality in Oslo. The Hjortnes monitoring station was chosen as the site of the interview, but the filming was quickly interrupted when the French photographer discovered that the side of the station was tagged with the words "I love sluts" and a big heart...

Photo: Claudia Hak, NILU

August: Andøya

At the end of August, our journey takes us to the Observatory at Andøya, which was completed in 2010. The observatory participates in a monitoring programme funded by the Norwegian Environment Agency and is tasked with identifying and quantifying emissions of organic pollutants and trace elements.

Among the substances measured at Andøya are airborne heavy metals, including lead, mercury, copper and nickel, as well as semi-volatile organic pollutants (POPs) such as ionic and volatile PFAS, including PFOA and hexachlorobenzene (HCB).

NILU has overall responsibility for the monitoring, and Andøya Space Center AS is in charge of daily operations on behalf of NILU.

The Andøya Observatory did not open until 2010, though measurements got a head start in 2009. Nevertheless, NILU started monitoring ozone at this site as early as 1994, in cooperation with Andøya Space Center/ALOMAR.

Measures long-range transported pollutants

The island called Andøya is part of Vesterålen archipelago, and Andøya observatory is located 380 metres above sea level, at 69°16′42″ N, 16°00′31″ E. There are few local sources of pollution this far north; instead, it is usually what scientists call "long-range transport" that brings in most of the pollution measured at Andøya. Long-range transport means that the pollutants are carried by wind, weather and oceans from their sources – which can be thousands of miles away.

Air masses that sweep in over Norwegian territory bring with them pollutants that were originally released in other countries. In the south of Norway, most long-range transported air pollution comes from industry, agriculture, and population centres on the European continent.

But at latitudes as far north as Andøya, emissions from North America and Asia contribute a larger proportion of the pollution detected by the measuring equipment at the Observatory.

Many organic pollutants and heavy metals have physical properties that make them more likely to be deposited in cold places, and less likely to be transported onward. At some point the temperature becomes so low that the substances no longer evaporate and blow away with the wind; thus they can accumulate up here in the north.

As a result, we now find high levels of poorly biodegradable pollutants in some Arctic animals at the top of the food chain.

Photo: Ingjerd Sunde Krogseth, NILU

The GUV instrument. Photo: Ingunn Tørnes, NILU

September: UV and ozone monitoring – Oslo and Kjeller

The instruments that measure UV and ozone can't be found inside any measuring station. They're placed out in the open air. For the first 42 years they stood atop the Physics Building at the University of Oslo. Since July 2019 they have been on the roof of the NILU building at Kjeller.

The first reliable, quality-assured ozone measurements of ozone started at Blindern in 1977, organised by Søren Larsen.

Dobson, the ozone pioneer

Larsen used a Dobson instrument, named after the ozone pioneer Gordon Dobson, who also lent his name to the unit used to describe the thickness of the ozone layer: Dobson units, DU.

In the 1980s, ozone measurements became increasingly urgent. Researchers discovered the hole in the ozone layer over Antarctica, and found that anthropogenic emissions of chlorofluorocarbon-based greenhouse gases were the cause, such as those used as propellants in spray cans. This discovery prompted a desire for automated measurements.

Around 1990, the Brewer instrument (below) came to Blindern. It could stand outdoors all the time. Professor Arne Dahlback, who worked first at NILU and later at the University of Oslo, has been responsible for these readings at the University in recent decades. In 1995, Brewer was joined by a so-called GUV instrument (over) that measures UV radiation.

The Brewer instrument. Photo: Ingunn Tørnes, NILU

The GUV and the Brewer instrument have been ticking along faithfully since that time, but when Dahlback retired in April 2019, the University found no successor to continue with the UV and ozone readings. Thus, the instruments moved to NILU at Kjeller in late June. Here they have been calibrated and placed on the roof, where we expect them to stand for many years to come.

Ozone data from the measurements conducted here at Kjeller (and the earlier data from the University) are entered into an international database under the WOUDC (World Ozone and Ultraviolet Radiation Data Centre). But they are also reported to the Norwegian Environment Agency, and published in an annual monitoring report.

October: Hurdal

In the forest east of Hurdal Lake stands what we call a regional background station. There, NILU measures tropospheric ozone, particles, carbonaceous compounds, and sulphur- and nitrogen-containing compounds in air, as well as inorganic compounds and heavy metals in the rain on behalf of the Norwegian Environment Agency.

The term "Regional background station" designates a station where long-range transported air pollution is measured. In other words, it measures substances that are transported by weather and wind from afar. The station is part of the European Monitoring and Evaluation Programme (EMEP). The purpose of EMEP is to monitor air pollution that is transported across borders in Europe.

Hurdal station has a close cooperation with the Norwegian Institute for Bioeconomy Research (NIBIO).

Hurdal is one of three Norwegian stations that are engaged in intensive forest surveillance. One of the objectives is to study the effects of air pollution on forests, soil and vegetation.

Location

The monitoring station in Hurdal was originally established at Nordmoen in 1987. It was moved to its current position in 1998 because of the amount of local pollution at Nordmoen became excessive.

The monitoring station itself is fairly inconspicuous. It consists of two small arches and, on the ground, some instruments for collecting precipitation and particles.

Measurement instruments on the mast

What you will notice as you pass by Hurdal is the 25-metre mast. This is the only place where NILU has a mast this tall. The reason for this is that long-range transported air pollution at the site must be measured well above the treetops, the air is more representative of the region than it is in the forest.

The measurement instruments ride up and down from the top of the mast in a specially constructed box, a Rube Goldberg contraption that makes it possible to take samples at several heights. The filters in the instrument are changed every day by the station attendant.

This person is not a NILU employee but is commissioned by the Institute to do these tasks. The filters, precipitation samples and other samples are collected and sent to the NILU lab every week.

Currently, NIBIO is in the process of replacing the mast with a larger version that will reach higher and have room for more measurements. This is part of efforts to establish Hurdal station as part of the European Integrated Carbon Observation System (ICOS).

Data from regional background stations such as Hurdal must be gathered over a long time period if they are to be valuable for research and environmental management. A data series may need to span decades in order to be used to understand and document changes in the composition of the atmosphere. The measurements must also be performed correctly and with adequate frequency. It must be possible both to relate the composition of local air to transport and transformation in the atmosphere, and to compare local measurements with results obtained at other sites and in other countries.

Photo: Dorothea Schulze, NILU

November: Sofienbergparken

In Sofienbergparken in Oslo we find the urban background station which is named after the park. It is placed right next to the recycling station, a playground, and the Environment House allotment gardens.

An urban background station should be located so that it captures the total air pollution from all possible sources (traffic, heating, nearby industries, natural sources, etc). It should provide researchers and the municipality with the best possible summary of the total pollution load in places where lots of people live.

Permanent monitoring since 2004

Oslo Municipality owns the monitoring station in Sofienbergparken.
A permanent station that makes continuous measurements was established there in 2004, after individual pollutants had been measured periodically.

The station "moved in" with as much speed as humanly possible on an ice-cold day in January.

The employees at the recycling station in Sofienbergparken offered hot coffee and a bit of shelter to the hardy souls who were setting up the monitoring station, so they wouldn't freeze to death as they worked.

Since 2012, NILU has operated the measuring station in Sofienbergparken for Oslo municipality. It has been included in many measurement campaigns organised by the municipality and NILU.

Measures particulate matter, PAH, tropospheric ozone and sulphur dioxide

At present, the station in the park monitors coarse and fine particulate matter (PM_{10} and $PM_{2.5}$), PAH, tropospheric ozone and sulphur dioxide.

PAH (which stands for polycyclic aromatic hydrocarbons) is a group of over 100 different substances formed by incomplete combustion of organic matter (oil, coal, firewood, food).

The main sources of PAH emissions are industrial facilities such as aluminium factories, vehicular traffic, wood burning, and other stationary combustion. For example, you can find PAH in the charred residues in your frying pan or grill. They may be carcinogenic if consumed or inhaled in large amounts. If you're going to the park for a barbecue, don't char the sausages too much!

Speaking of barbecuing, the readings from Sofienbergparken reveal if it has been a particularly pleasant summer evening. Then the particulate matter from dozens of barbecues makes the PM_{10}-curve do a little extra jump.

Photo: Jøran Solnes Skaar, NILU

Photo: Chris Lunder, NILU

December: Trollhaugen

The last and by far most remote station we will visit is Trollhaugen Observatory in Dronning Maud Land in Antarctica. Trollhaugen Observatory sits on the slope of the mountain Trollhaugen, 1553 metres above sea level between the Antarctic plateau and the coast. The location is unique and unaffected by the local activity.

The observatory was established in January 2007, with the support of the research programme Norwegian Antarctic Research Expeditions (NARE).

Initially the observatory was placed near the main Norwegian research station, Troll, but an unacceptably strong influence of local pollution prompted moving the observatory to Trollhaugen in February 2014.

At Trollhaugen, the observatory is about 1 km east and 300 metres above the main station at Troll, in the nunatak landscape named Jutulsessen, approximately 235 km from the coast.

Only present during austral summer

NILU's researchers and engineers only visit Trollhaugen during the austral summer season. The rest of the year, technicians from the Norwegian Polar Institute crew that overwinters in Antarctica do maintenance and take measurements. When the last flight leaves Troll in late February, the station is isolated from the outside world for nine months.

Measuring "background levels"

The Zeppelin Observatory near Ny-Ålesund in Svalbard and Trollhaugen Observatory are surrounded by cleanest air in the northern and southern hemisphere, respectively. This means that NILU's atmospheric scientists can measure what they call "background levels".

Background levels are the lowest levels of various particles and gases found in the atmosphere, and they can only be measured in places where human activity does not contribute to local pollution.

The cleanest place on Earth is in Antarctica, and air samples taken there give researchers the best possible opportunity to determine how airborne particles formed prior to the industrial revolution. And when scientists know the "background level", they can also use the air samples to figure out where the pollutants come from, and how much pollution is emitted.

Using various advanced measuring instruments, NILU researchers capture pollutants and particles that come floating with the air from afar. For example, ash from forest fires in Brazil has been recovered at Trollhaugen – about 8500 km away from the source.

Openly available data

All data NILU obtains from measurements polls at Trollhaugen and the other observatories are openly available as soon as they have been checked for quality and delivered to the client. Data from Trollhaugen are used extensively by both Norwegian and international researchers.

Key figures

Extract from the annual statement (all figures in MNOK):

INCOME STATEMENT	2019	2018
Project revenue	154,8	154,0
Basic grant, strategic institute initiatives included	32,2	31,3
National tasks and assignments	12,0	15,8
STIM-EU	5,9	4,6
Other operating income	0,0	0,1
Operating revenue	**204,9**	**205,8**
Wages and social expenses	-143,4	-142,9
Direct project expenses	-23,4	-26,0
Other expenses	-41,3	-39,5
Operating profit	**-3,3**	**-2,6**
Net financial items	-1,7	0,2
Tax	0,6	-0,7
Profit for the year	**-4,4**	**-3,1**

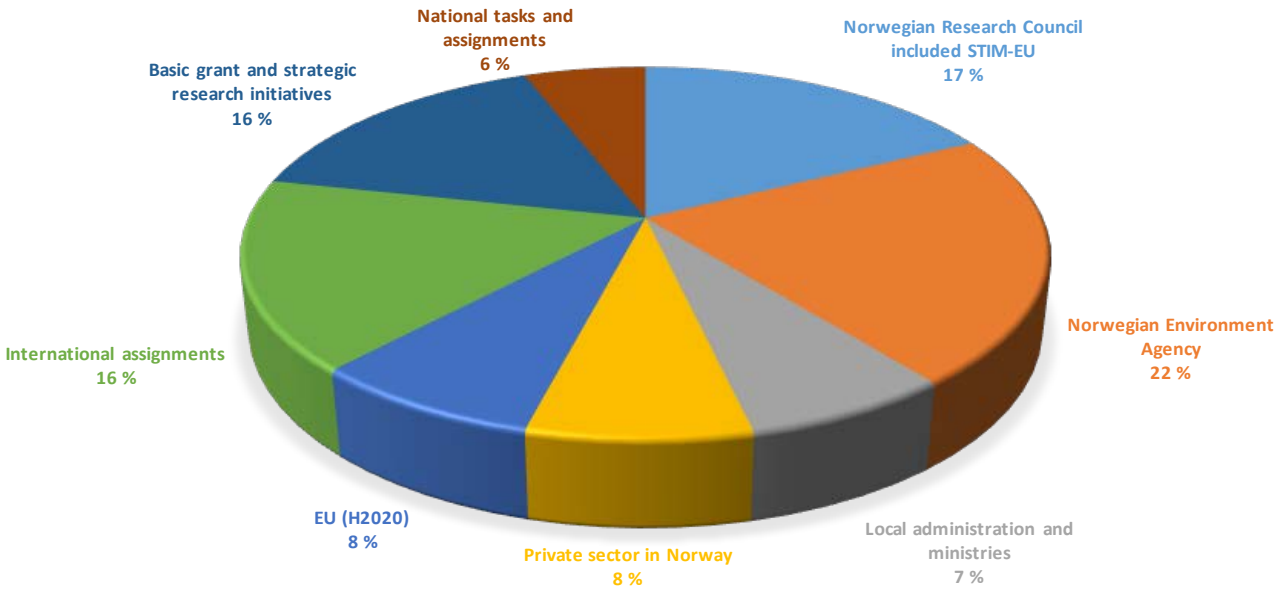
BALANCE SHEET	31.12.19	31.12.18
Fixed assets	97,2	102,1
Current assets	82,9	85,9
Total assets	**180,1**	**188,0**
Total equity	116,3	120,7
Short-term liabilities	63,8	67,3
Total equity and liabilities	**180,1**	**188,0**

NUMBER OF MAN-YEARS	2019	2018
Total	155	160
– whereof research man-year	101	103
– whereof man-years of other personnel	54	57
Turnover per research man-year	**2 038**	**1 998**

NUMBER OF EMPLOYEES	31.12.19	31.12.18
Total from over 20 different nations	161	175
– whereof women	81	92
– whereof men	80	83
Number of employees holding a doctorate	**68**	**69**

PUBLICATIONS AND DISSEMINATION	2019	2018
Scientific articles and chapters	104	122
Lectures and posters	254	194
NILU reports	26	39
EMEP/CCC reports	4	4
External reports	22	14
References in the media	320	371
Followers on Facebook	1217	1080

Project portofolio – percentage 2019



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NILU – Norwegian Institute for Air Research

NILU – Norwegian Institute for Air Research is an independent, nonprofit institution established in 1969. Through its research NILU increases the understanding of climate change, of the composition of the atmosphere, of air quality and of hazardous substances. Based on its research, NILU markets integrated services and products within analyzing, monitoring and consulting. NILU is concerned with increasing public awareness about climate change and environmental pollution.

NILU's values: Integrity - Competence - Benefit to society

NILU's vision: Research for a clean atmosphere

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