SESS REPORT 2018
SUMMARY FOR STAKEHOLDERS

The State of Environmental Science
in Svalbard – an annual report

SIOS
SVALBARD INTEGRATED ARCTIC
EARTH OBSERVING SYSTEM

SESS report 2018 – Summary for Stakeholders
The State of Environmental Science in Svalbard – an annual report

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Foreword

The Svalbard Integrated Arctic Earth Observing System (SIOS) is a Norwegian initiated international collaborative effort to develop and maintain a regional observational system for long-term observations in and around Svalbard. SIOS is interdisciplinary and focuses on processes and their interactions between the different spheres, i.e. biosphere, geosphere, atmosphere, cryosphere and hydrosphere. The core observational programme of SIOS provides systematic long-term observations of key variables to address Earth System Science questions related to global and environmental change. SIOS envisions a significant contribution to the systematic development of new methods and observational design in Svalbard. The programme is dynamic and can adopt new techniques and methods as they appear or society poses new questions. The annual SESS report is the fundamental catalyst to enhance interdisciplinary research and dynamic development of the observing system and our understanding of change in Svalbard. The SESS report has several goals:

- **i.** to summarize the latest developments in the Svalbard environment and provide users with the core data underpinning our knowledge of the changes
- **ii.** point out knowledge gaps for Earth System Science issues in the Svalbard region that are important for society
- **iii.** provide recommendations regarding how to develop the observation system thus forming the basis for the work programmes of SIOS for the coming year

In the Strategy for research and higher education in Svalbard by Norwegian Ministries 2018, it is stated that the Government will work to ensure that research and higher education in Svalbard develop in a forward-looking, sustainable manner. One of the objectives mentioned in the strategy is that research communities active in Svalbard shall take the lead in moving towards shared research data and infrastructures. The aim is that SIOS by developing and building the multidomain research infrastructure further enhances Svalbard as an attractive location for world leading Arctic research. This means among other things sharing of data, infrastructure and findings. The gained knowledge can advance other observational networks and research infrastructures in the Arctic.

SIOS entered into its operational phase in January 2018, after ten years of preparation and implementation. One of the main products of the operational SIOS is this first SESS report. It takes us through all the spheres from the deep permafrost through the surface interfaces, into the ocean and into the upper atmosphere approaching space. It illustrates the breadth of Earth System Science questions as well as the breadth of Svalbard research. As the first report it contains more emphasis on knowledge gaps and recommendations on the future than providing comprehensive summaries of environmental developments. Now it is our, the SIOS consortiums', task to optimize the observing system according to results and recommendations from this report and indeed provide the data that society needs in order to make knowledge based judgements of climate and environmental change in Svalbard. During the coming year the consortium must also deliver on compiling all the diverse data that already exists such that we can address issues regarding how the changes observed influence each other to make more profound system statements rather than just discussing isolated observations of parameters.

We would like to thank the editorial board and anonymous reviewers for their invaluable contributions to this report. Thanks goes also to Janet Holmén who helped to translate the scientific language, which we scientist tend to be blind to, into a more understandable form. Thanks goes of course to all the authors for their time and efforts to improve the observational system of SIOS. We would also like to acknowledge the Norwegian Research Council and the Norwegian Space Centre for their financial support.

Longyearbyen, December 2018

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CHAPTER 1

Permafrost drilling near Barentsburg by the Russian team led by Dr. Nikita Demidov.

Permafrost thermal snapshot and active-layer thickness in Svalbard 2016-2017

Permafrost plays an important role in the Earth System underlying 25% of the terrestrial parts of Planet Earth. It is a thermal condition occurring in the ground in cold regions, and is defined as ground (soil, sediment, or rock) that remains at or below 0°C for two or more consecutive years.

We have for the first time gathered information from all existing permafrost observation infrastructure in Svalbard. We report on the two essential climate variables (ECVs) for permafrost, the permafrost thermal state and the active layer thickness based on the existing permafrost monitoring sites in Svalbard. Several new boreholes were established in different parts of western Svalbard during the last years, thanks to efforts from Italy, Russia, Germany, Poland and Norway. These boreholes have allowed us to compare the permafrost ECVs from sites in Ny-Ålesund, Kapp Linne, Barentsburg, Adventdalen and Hornsund through the hydrological year 2016-2017. We have studied ground temperatures and interpolated active-layer thickness in 11 boreholes, and two active-layer monitoring grids. Svalbard has the warmest permafrost this far north.

HIGHLIGHTS

Svalbard permafrost temperatures ranged during 2016-2017 from -1.1 to -5.2°C at 10-20 m depth. The thickness of the active layer ranged from 49 to 300 cm. Active-layer freeze-back durations varied from 18 to 140 days, reflecting the particularly warm, wet and long-lasting autumn 2016.

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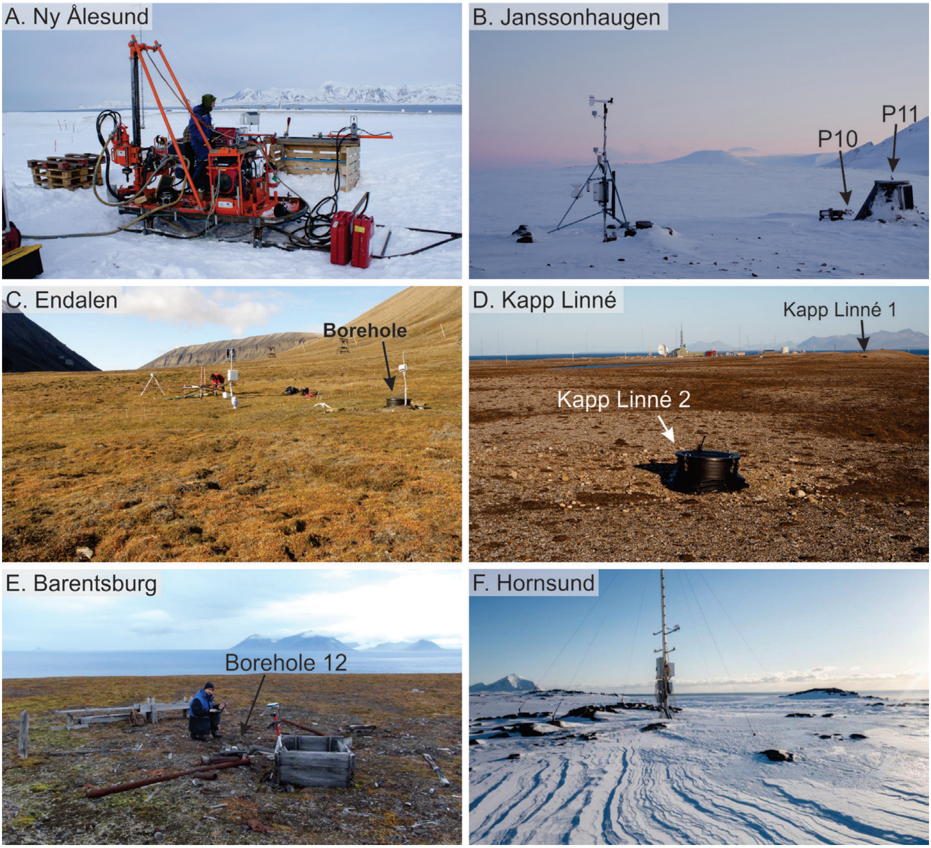

The permafrost borehole sites in Svalbard. Image A was taken during the drilling of the DBNyÅlesund borehole.

RECOMMENDATIONS

Previous and present observations focus on understanding permafrost conditions near to settlements and research stations in western and central Svalbard. However, ground thermal conditions there are likely not representative for the northern and eastern reaches of the archipelago, where the climate is considerably cooler and climate development might be different. Future observations efforts will therefore focus on characterising permafrost environments in northern and eastern parts of Svalbard. Including such areas will most likely allow observations of the full diversity of permafrost conditions throughout the entire Svalbard landscape.

In addition to the presented ECVs for permafrost, ground-ice content is a key parameter for assessing the response of permafrost landscape to changes in climate. Where permafrost contains an abundance of ice, warming and thawing will lead to marked geomorphic change. In flat areas, ground-ice degradation can result in thermokarst (the process by which characteristic landforms result from the thawing of ice-rich permafrost or the melting of massive ice). On slopes, excess water released during ground ice melting, particularly of the top permafrost, can initiate landslides.

CHAPTER 2

Measuring gas emissions

Microbial activity monitoring by the Integrated Arctic Earth Observing System (MamSIOS)

HIGHLIGHTS

Microorganisms play important roles in the generation and decomposition of climate-active gases, yet current climate models do not take account of microbial activity.

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1. Existing monitoring data

Fluxes of climate-active gases are currently being measured at specific field locations in Svalbard. These data are being used to represent the Arctic in the world-wide flux data sets that are incorporated into global climate change models. *To the best of our knowledge, none of the fluxes currently being measured derive from contemporary microbial metabolism.*

2. How can the data be used in a SIOS context?

SIOS offers a unique opportunity to use this information to develop a comprehensive picture of the manner and extent to which microorganisms in the Arctic influence climate processes and how they change over time.

3. What are the gaps in our knowledge?

The role of microorganisms in the production and destruction of climate active gases is not entirely clear. There is currently a pressing need to understand and monitor changes in the abundance, diversity and – particularly – the ecological function of microbial communities in the polar regions in order to produce more accurate greenhouse gas release models.

RECOMMENDATIONS

We propose following actions:
1. Conduct a comprehensive census of both biodiversity and functional diversity of microbial communities in Svalbard
2. Look at the distribution of this diversity in terms of habitat type
3. Determine the stability of the communities in which this biodiversity exists
4. Link this biodiversity and active gene composition to climate-active gas flux (as measured currently)
5. Use this raw data to construct preliminary models in order to open a broader debate with the climate change community about the relative significance and potential of microbially-mediated processes to bring about a paradigm shift, thus substantially advancing our understanding of climate processes.

Capacity building – Much of this work could potentially be conducted at current research stations in Svalbard. To enable this, further development of microbiology facilities and infrastructure (such as class II microbiological safety cabinets, autoclaves, clean rooms and molecular biology facilities) is an essential and pressing need.


Glacier surface albedo


Nutrient leaching

CHAPTER 3

HIGHLIGHTS

Snow covers all of Svalbard for up to 9 months a year and is very sensitive to warming. Snow is therefore ideal for studying the rate of climate change and predicting its impact on ecosystem functioning. Currently we lack a holistic picture of snow processes and ways of monitoring their effects.

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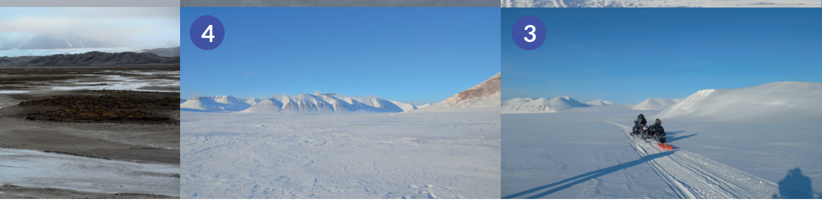
Snow research in Svalbard: current status and knowledge gaps

Snow cover affects all environments in Svalbard: glaciers, ocean (sea-ice) and land. Due to its high reflectivity, snow also impacts the atmosphere and the Earth's energy budget (less snow results in higher temperatures). Snow on the ground insulates the soil against cold air temperatures, and is considered one of the main factors influencing plants and microorganisms, as it determines water and nutrient availability and the length of the growing season. Snow is also very sensitive to climate and its changes; even a brief warm spell can turn a dry snowpack into an icy snowpack, or melt it away completely. A snow pack with icy layers has completely different properties than a homogeneous snow pack: it conducts more energy and can change the thermal profiles of glaciers or ground on which it rests. Reduced snow cover directly affects the health of a glacier, prolonging the melting season and increasing the annual melt rate.

Over the millennia, Arctic life forms have become well adapted to cold and harsh conditions. An altered climate with changed snow cover properties will make it harder for some species to survive. Reindeer will need to dig through ice layers to find food, and ptarmigans will be unable to burrow into the snow for protection against the cold. Ice that forms on the ground below the snow (basal ice), also affects plant growth and survival rates.



Snow and ice in Svalbard. Photos: JC Gallet.

RECOMMENDATIONS

During the last decades our understanding of snow processes has increased substantially. However, due to the specialisation within different research topics, a holistic picture of snow processes and their climate interactions is lacking. Improved knowledge and cross-disciplinary actions are needed to better understand:

1. The deposition processes of rain and snow, and transport of aerosols to the region
2. The chemical, biological and physical composition of precipitation events
3. The spatial-temporal variation of snow in the landscape, and how this can be captured in models
4. The altitudinal, latitudinal and glacier size dependence on snow deposition and snow redistribution by wind
5. The impact of snowpack characteristics on energy balance and how this can be captured by remote sensing
6. The interactions with solar radiation in terms of energy balance and chemical reactions
7. The influence of ice formation within the snow pack as well as on ground
8. The importance of a snow cover for ecosystems and the effects of basal ice formation
9. The rate, timing and release of fresh water during snow melt

CHAPTER 4

Recovery of the Indian arctic multi-sensor mooring (IndARC) from Kongsfjorden. Photo: K Kumar

Temperature time-series in Svalbard fjords. A contribution from the "Integrated Marine Observatory Partnership"

HIGHLIGHTS

West-facing fjords in Svalbard show water temperatures increasing by up to 2°C per decade. In the coldest months temperatures are increasing at around 1°C per decade, with the fjords rarely experiencing freezing temperatures. There have been no changes in the temperature of north-facing fjords.

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Many observations around Svalbard have tended to be biased towards summer and autumn and we don't always have a full picture of the annual cycles. However, some marine measurements have been sustained over many years; these are exceptionally valuable, as they enable us to quantify the environmental change.

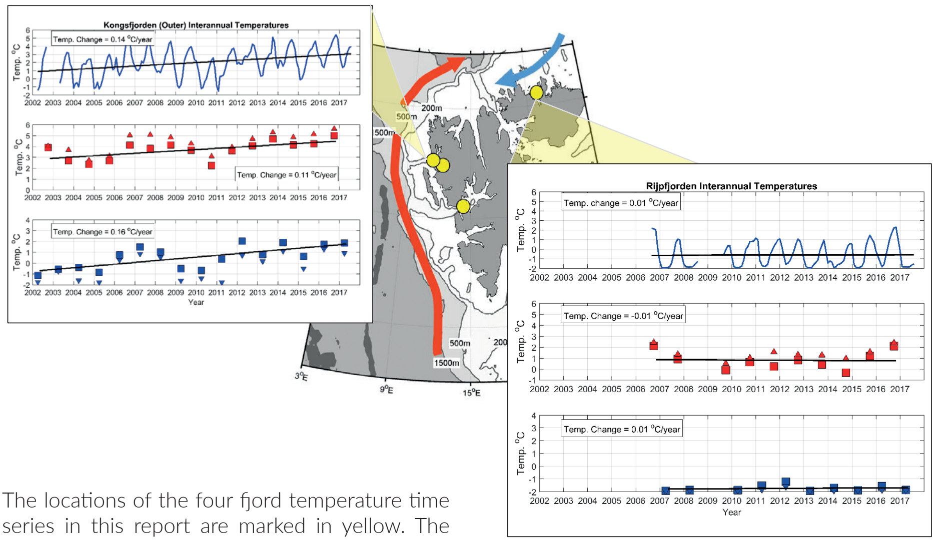
One rich source of data is the network of observatories in the coastal and offshore waters of Svalbard. Some of these observatories have been in operation for more than 15 years with instruments continuously recording data for a variety of parameters. As the data series builds up we reveal both the seasonality of the marine environment and the long term change.

The Integrated Marine Observatory Partnership (iMOP) has studied water temperature records from three fjords. Kongsfjorden and Isfjorden are west-facing and influenced by the West Spitsbergen Current, which carries warm Atlantic Water to the Arctic Ocean. Rijpfjorden is north-facing and is influenced by the colder, fresher Arctic waters. The records come from contrasting locations which experience different oceanographic conditions during their seasonal cycles.

The west-facing, Atlantic fjords are both warming. Water temperatures are increasing in both the warmest months (September, October and November) and the coldest (March, April and May). The rate of change is up to 2°C per decade for the warmest months and around 1°C per decade for the coldest. The impact of warming means that the fjords experience fewer years where the water cools to the freezing point: this limits the formation of sea ice. The warming is related to both the temperature of the West Spitsbergen Current and the pattern of winds that help drive water towards the coast. In contrast, Rijpfjorden does not show any significant warming and sea ice regularly forms in the fjord.

RECOMMENDATIONS

- Develop the network of operators to encourage collaboration, communication and planning of future marine observatories - Analyse temperature records of all long-term inshore moorings and include, where possible, an analysis of water salinity
- Extend the analysis to include offshore moorings
- Identify similar long-term marine records (e.g. zooplankton or fish populations) and for other Earth System processes (e.g. records of meteorology or glaciers) and undertake coupled analyses



The locations of the four fjord temperature time series in this report are marked in yellow. The graphs show the contrasting changes in water temperature at two of those locations: Kongsfjorden (an 'Atlantic' fjord) and Rijpfjorden (an 'Arctic' fjord). Upper panel (blue line) monthly temperature values, middle panel (red markers) temperature of the warmest months (Sept/Oct/Nov), lower panel (blue markers) temperature of the coldest months (March/April/May). The data series are fitted with a simple linear regression.

CHAPTER 5

Calanus finmarchicus copepods

The Continuous Plankton Recorder Survey – Monitoring plankton in the Nordic Sea

HIGHLIGHTS

The Pacific diatom *Neodenticula seminae* (an indicator of trans-Arctic migration) was recorded off Svalbard in 2016, the easternmost observation of this diatom in the Nordic Seas.

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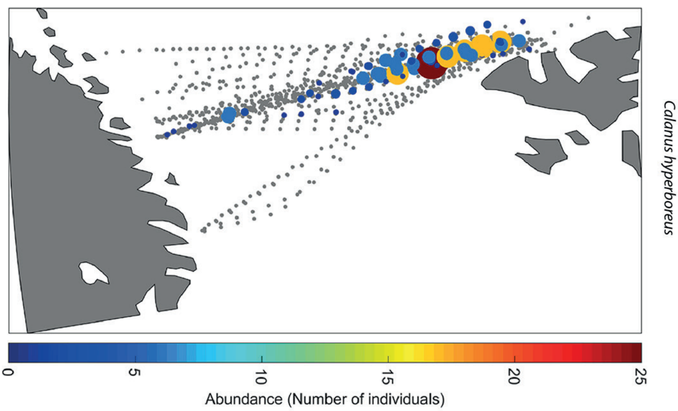
The Continuous Plankton Recorder (CPR) survey monitors plankton in the waters around Svalbard and south to northern Norway. Within this region of the Nordic Seas, the CPR survey adds to and complements other monitoring methods by providing a broader spatial and temporal perspective. Most other surveys are coastal or are sporadically sampled through time. The CPR survey also adds value by providing multi-decadal data at the Atlantic basin scale that can help disentangle and interpret changes observed in the Nordic Seas and help predict changes over the next coming decades. For example, regions that currently support Arctic ecosystems will instead support sub-Arctic systems within the next 10 to 20 years (if not sooner). The biological signals of change we see further south in Atlantic sub-polar systems now can be used to detect the early warning signs of change in the Arctic.

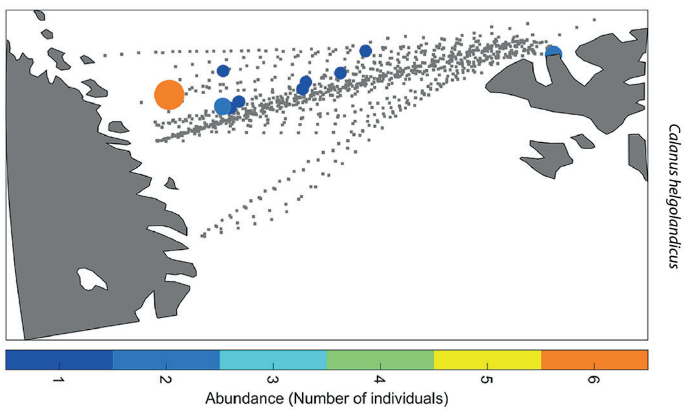
To develop the observation system further, the CPR survey currently works closely with Norwegian scientists to coordinate its sampling on board "ships of opportunity". These are often cargo vessels that regularly ply the same route. They are outfitted with instruments that automatically and routinely collect a range of data on oceanographic parameters.

It is hoped that in the near future, the CPR survey will form part of a more integrated observation system within these waters and enhance its monitoring with an additional suite of biogeochemical and molecular sensors. It is also foreseeable that additional CPR routes could be towed using other ships of opportunity in this region, such as tourist vessels.

RECOMMENDATIONS

The Norwegian FerryBox system is one such ship of opportunity. The CPR survey, by coordinating its sampling programme with the FerryBox system, can obtain valuable complementary information such as pCO_2 in the waters where the sampling was done.





The spatial distribution and abundance of the calanoid species *Calanus hyperboreus* and *Calanus helgolandicus*. Colours represent abundances per sample.

CHAPTER 6

One year after being deployed, the oceanographic buoy and all its instruments returned to the surface with valuable information about deep sea variability
Photo: SOA

Spitsbergen Oceanic and Atmospheric interactions – SOA

HIGHLIGHTS

The deep sea is a little-known environment. How it is responding to recent climate change remains to be discovered. The variability of the bottom currents and thermohaline properties in the deep sea west of Svalbard display an interesting coherence with meteorological processes.

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In the Fram Strait, a remarkable increase in the temperature and salinity of inflowing Atlantic Water has been observed since the 1990s. This is in part a natural trend, but recent temperature anomalies, ~1°C relative to the 1970s are related to anthropogenic causes. Air temperature increased by about 3°C in the 20th century and meteorological stations at Svalbard confirm this positive trend.

At the West Spitsbergen margin, Atlantic and Arctic waters converge, mix and exchange, while air–sea interactions and shelf–slope dynamics trigger vertical mixing and formation of cold and salty water. This water is sufficiently dense to sink to greater depths and contribute to the global thermohaline circulation. The circulation process permits exchange of heat (i.e., energy) between low and high latitudes. Since the formation of dense water and its spreading at greater depths are strongly influenced by the properties of Atlantic Water, which have been changing in the last decades, we cannot exclude the possibility that the global thermohaline circulation may change in the near future.

We analysed oceanographic data (obtained from shelf and deep-sea oceanographic moorings and hydrographic cruises) and meteorological data from the west Svalbard margin, comparing temperature and salinity variability in the deep ocean flow and the wind regime. Time-series revealed occasional intrusions of warm and salty waters at 1000 m depth, mainly during the period October – April, quasi-simultaneously at several locations more than 150 km apart, along the continental slope west of Svalbard. The fact that the most energetic events, both in the deep flow and in the wind speed, occurred with similar periodicities (10-20 days) suggests atmospheric storms as the likely forcing mechanism underlying the observed deep sea variability. Others energetic events with periodicity of 12 and 24 hours, instead, could be related to internal tidal oscillations.

Operations on board the research vessel *Oceania* (IOPAN)
Photo: SOA

RECOMMENDATIONS

The Arctic is changing rapidly. Interaction between atmospheric and oceanic processes is not still completely understood. Effective implementation of in-situ measurements and multidisciplinary numerical modelling is needed to clarify the effects of anthropogenic forcing on the “natural variability” of the Arctic Ocean.

CHAPTER 7

Kongsfjorden seen from the Zeppelin Observatory (Photo: O Hermansen)

The Lower Atmosphere above Svalbard (LAS): Observed long-term trends, small-scale processes and the surface exchange

The lower atmosphere is where clouds and atmospheric particles interact with sunlight and infrared radiation, ultimately driving the heating and cooling of the surface. The surface interacts with the lower atmosphere through transfer of energy, gases and particles between the land, snow, ice or ocean and the atmosphere. With all of these interactions going on, this part of the atmosphere must be well monitored to understand changes in climate and the processes behind them. In addition to measuring long time series of the basic state of the atmosphere (temperature near the surface, frequency of cloud cover, total amount of water vapour, etc.), it is also important to coordinate measurements of different variables to understand complex processes and feedbacks. Clouds cannot be well understood without knowledge about the tiny particles in the atmosphere on which cloud droplets form, where those particles come from and how they are

HIGHLIGHTS

Svalbard has warmed faster than most of the planet over the last decades. Understanding the role of natural versus human-related and global versus regional processes requires detailed observations of many aspects of the lower atmosphere. This work is under way in Ny-Ålesund, but much remains undone.

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exchanged between mid-latitudes and the Arctic. Models to accurately represent the Svalbard region must be developed with an understanding of the peculiarities of the region, such as a complex boundary layer that is strongly influenced by the islands' topography and varied surfaces.

RECOMMENDATIONS

There is a long history of atmospheric observations in Svalbard, especially Ny-Ålesund, where many research groups from different countries work together to understand the whole atmospheric system above and around the Kongsfjord region. It is important that this work continues and becomes even more interconnected, both with different atmospheric fields and with others, such as biology, oceanography and glaciology. However, the climate varies significantly across Svalbard, and most observations are limited to sea level on the west coast. An effort is also needed to expand long-term observations, both in-situ and by remote sensing, to eastern Svalbard and to higher elevation regions away from the coast.

- Better coordinate the observations at existing sites between the different research fields
- Make the information on data (metadata) and data available, exchangeable and accessible
- Establish high-quality, long-term observations at geographically diverse sites around Svalbard
- Improve the modelling to guide, improve and expand observations in the region

The Climate Change Tower in Ny-Ålesund.

CHAPTER 8

Observations of the solar UV irradiance and ozone column at Svalbard

HIGHLIGHTS

Measurements of solar ultraviolet (UV) radiation and the ozone column over Svalbard have been ongoing for many decades. Better understanding of their behaviour requires the integration of our efforts and the creation of a local instrumental network for use in future investigations.

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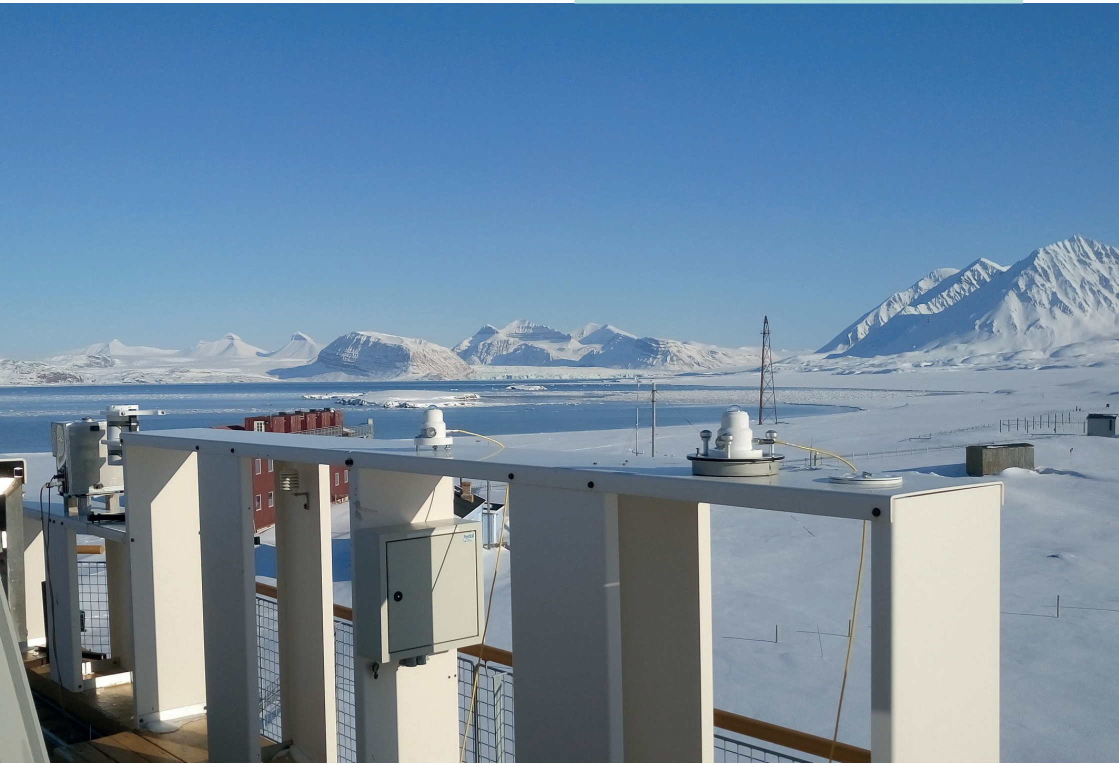
Solar radiation is the earth's main energy source and governs a variety of chemical and biological processes in the atmosphere and biosphere. The amount of solar radiation that enters the atmosphere varies mainly due to two important astronomical parameters. First, Earth's orbit is elliptical rather than perfectly round; second, the planet's spin axis is tilted in relation to the plane of its orbit. These parameters cause seasonal changes at different latitudes and polar nights and days. As it passes through the atmosphere, solar radiation is scattered and absorbed by molecules and aerosols. Scattering and absorption are complex processes that strongly depend on a range atmospheric parameters and conditions, and they induce additional variations in the amount of solar radiation that reaches the earth's surface. Thus, examination of the variability in the irradiance at the surface can contribute significantly to our knowledge about atmosphere and climate.

Solar ultraviolet (UV) radiation reaching Earth's surface is an important factor for various chemical and biological processes. Propagating through the atmosphere, a significant part of UV irradiance is strongly absorbed by atmospheric ozone, which in turn raises the temperature of the middle atmosphere and affects dynamical processes. This makes the study of solar UV radiation and the total amount of ozone an important task.

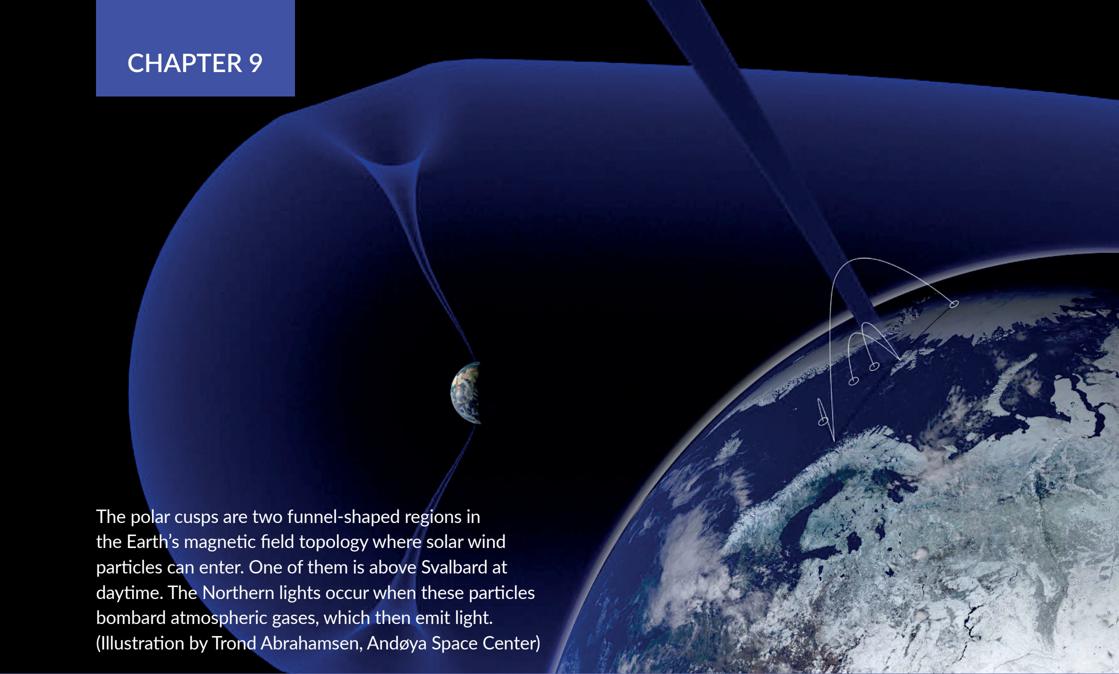
At Svalbard, measurement UV radiation and ozone levels started in 1950 and continue to this day. This long observational series has provided better understanding of the climatic processes in polar regions, and the conclusions reached through these years have been published in scientific journals. However, our picture of the polar environment is still far from complete.

RECOMMENDATION

To advance our understanding of the processes governing how UV radiation and ozone amount interact we need to combine our research efforts. Integrating the instrumental infrastructure, and creating a local Svalbard network with common methods for data analysis, will contribute to enhancing our knowledge about polar environment and climate.



CHAPTER 9



The polar cusps are two funnel-shaped regions in the Earth's magnetic field topology where solar wind particles can enter. One of them is above Svalbard at daytime. The Northern lights occur when these particles bombard atmospheric gases, which then emit light. (Illustration by Trond Abrahamsen, Andøya Space Center)

Grand Challenge Initiative – Cusp: rockets to explore solar wind-driven dynamics of the top side polar atmosphere

HIGHLIGHTS

GCI-cusp comprises twelve rockets to study the solar wind forcing of the top side polar atmosphere. Four rockets will be launched over Svalbard in December 2018, two from Andøya and two from Ny-Ålesund. Svalbard is the only place in the world to explore daytime auroras by rockets.

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"The Grand Challenge Initiative – Cusp" (GCI-Cusp), a strategic coordination between the Japanese Aerospace Exploration Agency, NASA, SIOS and UiO, is the largest sounding rocket project ever. Twelve sounding rockets will be launched during the winters of 2018/19 and 2019/20. Each mission has been selected by their respective funding agency as a stand-alone project with the potential to do compelling science. Andøya Space Center can support two simultaneous launches from both Andøya and Ny-Ålesund. Thus, by coordinating missions, we may have up to four rockets in the sky nearly at the same time.

Polar cusps are two funnel-shaped regions in the Earth's magnetic field, where solar wind particles can enter the polar atmosphere, where their collisions produce the Northern lights. Cusp aurora is the technical term for the Northern lights in daytime. In Svalbard, this phenomenon is visible to the naked eye during December and January. Since Svalbard is the only place in the world where cusp aurora can be studied by rockets, cameras and radars, it is a world class laboratory for studying solar wind interactions with the atmosphere. Major research infrastructure such as the EISCAT Svalbard Radar, the Kjell Henriksen Observatory and SVALRAK has been built to capitalise on Svalbard's unique location. These ground instruments will be key in defining the launch condition for each rocket.

GCI-Cusp questions:

The polar atmosphere is strongly forced by the solar wind. The major Grand Challenge questions to be addressed in 2018/19 include how the spatio-temporal behaviour of how the solar wind couples to the Earth's magnetic field (TRICE-2), how solar wind particles are accelerated by waves along the magnetic field lines (CAPER-2), and how these energy inputs into the Earth's atmosphere lead to upwelling and escape of oxygen (VISIONS-2). The Norwegian rocket, ICI-5, to fly in December 2019, will be equipped with 12 ice hockey puck size daughters to obtain a 3D imaging of turbulence within the northern lights. This turbulence sometimes gives rise to severe disturbances/black-out of radio signals. This new instrument will be test flown on the student rocket G-CHASER in January 2019.

Svalbard is the only place in the world where we can explore the daytime northern lights (cusp aurora) with sounding rockets. (Illustration by Trond Abrahamsen, Andøya Space Center)

RECOMMENDATION:

GCI-Cusp will implement the SIOS Data Management System (SDMS). Standardised data formats expressed in SI units will be essential in stimulating efficient collaboration within a broader community including Earth System Science modellers.

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