CAGE - Centre for Arctic Gas Hydrate Environment and Climate Report Series, Volume 9 (2021)

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Modifications:
This version of the annual report has been modified from the original published in 2021. Below is an overview of the changes made.

- The URL links for the PhD dissertations have been changed to permanent handles in page 20-21.
- Impact factor values have been removed from page 34-35 (Publications list).

Annual Report 2021

CAGE – Centre for Arctic Gas Hydrate, Environment and Climate

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CAGE

Norwegian Centre of Excellence

THE ARCTIC UNIVERSITY OF NORWAY · UIT ·

Words from the Director

CAGE investigates the natural release of the greenhouse gas methane from the Arctic seafloor. Vast amounts of methane are trapped at shallow depths below the seafloor as gas hydrates, ice-like mixtures of gas and water. Current warming makes these shallow Arctic greenhouse gas reservoirs particularly vulnerable to thawing. CAGE investigates the processes involved, how these affect the ecosystem, the ocean and the atmosphere, and implications for future climate and environment.

The importance and uncertainties of rising methane

Methane is a greenhouse gas that has received increased worldwide attention the last years because of its rapid rise in the atmosphere. In the short-term, methane has a warming potential that is up to 87 times higher than CO_2, and may therefore play an increasingly important role in controlling how fast warming on Earth happens. The rapid rise in methane may signal a feedback effect where warming is feeding warming, but the causes of this rise are still not well known.

Scientific excellence

2021 has been another productive year for CAGE. The quality, quantity and the variety of aspects of our activities and output reflect the excellence and drive of our research teams, and how these are effectively combined to provide a transdisciplinary resource to address challenging scientific questions of global relevance.

Since its start in 2013, the centre has published over 430 peer-reviewed scientific publications that have been cited over 7694 times, 54 of these have been in Nature or Science journals. The centre has now an H-index of 44.

Some scientific highlights

In 2021, CAGE scientists carried out 6 scientific cruises. Norway's ice-going research vessel Kronprins Haakon (KPH) has opened new areas in the ice-covered Arctic, and makes it possible to use larger, more advanced equipment for targeted sampling and imaging of the seafloor, such as the underwater remotely-operated vehicle (ROV) ÆGIR 6000. New, exciting results include:

– The first-ever ROV dive on Arctic Hydrothermal vents under permanent sea ice was conducted during the HACON21 cruise led by CAGE scientists.

– Documentation of extensive hydrocarbon seepage from glacially eroded shallow Barents Sea petroleum reservoirs that produce large oil slicks on the sea surface. State-of-the-art data were acquired from the (sub)seafloor, water column, sea surface and atmosphere in this location using an ROV.

New projects and initiatives

In 2021, three new projects began: 1) The NFR project EMAN7 (Environmental impact of Methane seepage and sub-seabed characterization at LoVe-Node 7), which will investigate methane emission dynamics and past evolution offshore Lofoten; 2) ARCLIM (Arctic Ocean under warm climates), which has built a culturing cold lab to run experiments on marine microfossils to test how they are affected by environmental changes; and 3) METHANICE (Methanotrophic communities in ice), which received a NFR Starting Grant to identify the role of methane consuming microorganisms associated with terrestrial seasonal ice. METHANICE is presented on page 18.

CAGE scientists led the application to NFR for a new Centre of Excellence, "iC3: Centre for Ice, Cryosphere, Carbon and Climate" that has now successfully passed to step 2.

Reaching out

Key Arctic messages were delivered by CAGE scientists at COP26 Climate Summit, through several keynote talks and interviews. CAGE scientists also led the Polar Chapter for RECCAP2: Regional Carbon Cycling Assessment Project 2.

Students and researchers on-board the KPH for the AKMA (Advancing Knowledge of Methane in the Arctic) research cruise developed a 'Virtual Research Cruise' - an educational tool for teaching and outreach.

The outreach project "Let's talk about methane", initiated in early 2021, is a short animation aimed at people of all ages. It walks you through the link between ice sheets and gas hydrates, and the significance of methane to the global climate.

A challenging, but successful year

Despite the continued difficult situation with Covid-19 regulations and cramped working conditions, 2021 has still been a successful year for CAGE, mainly fuelled by the enthusiasm, patience and creativity of my good colleagues. We have continued our weekly meeting place on Zoom, sharing work information and results, informing each other on stimulating papers, listening to interesting invited presentations and having fun with Kahoot quizzes. However, our scientific work and results would not have been possible without the generous funding from RCN and the support from UiT, our NT Faculty and the Department of Geoscience. Thank you so much to all of you!

Prof. Karin Andreassen
Centre Director

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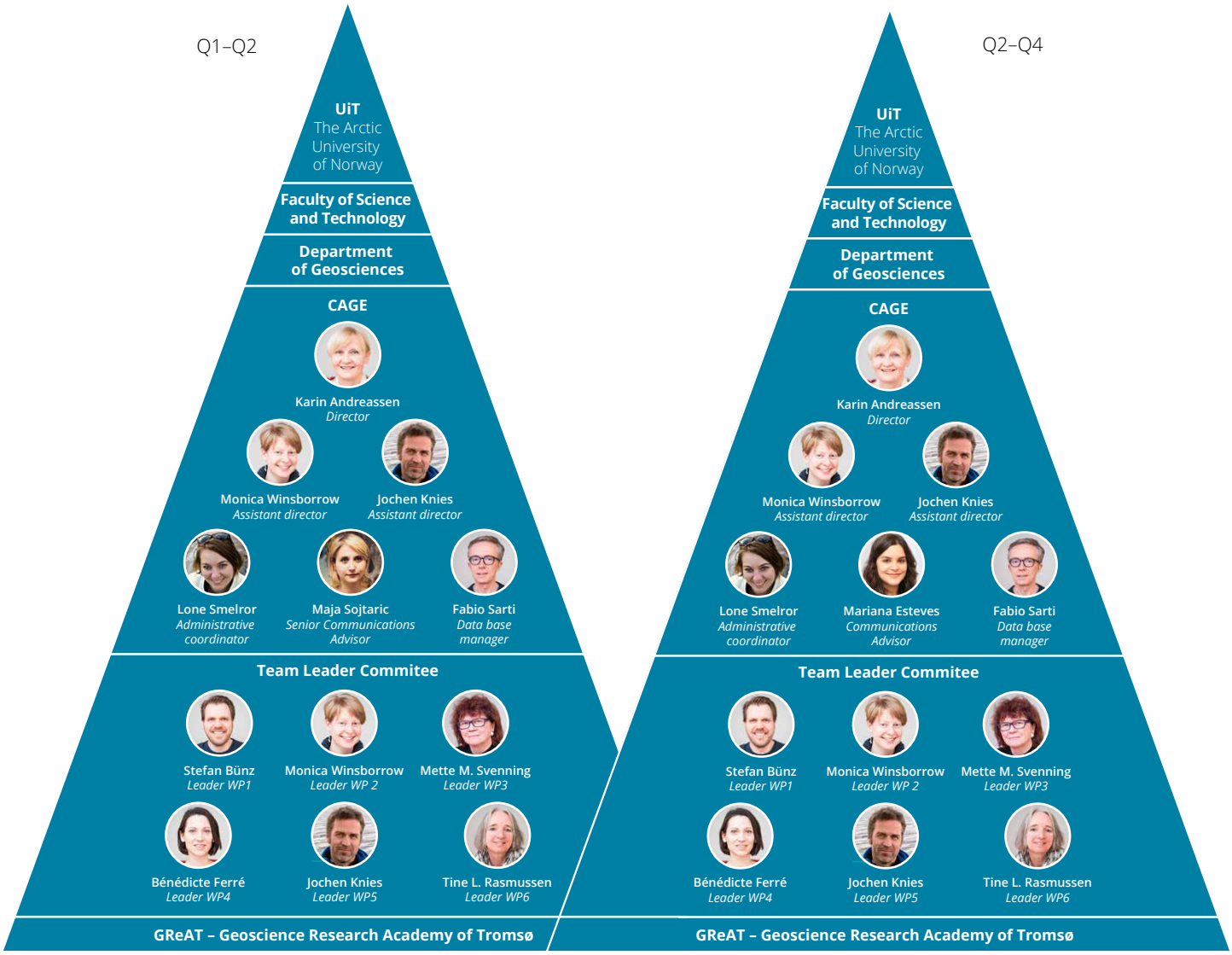
Cover photo: Sunrise at 82N on Monday 4th October, 11:00 in the morning. RV Kronprins Håkon moves through newly formed sea ice on its way to the Aurora Seamount at the western end of the Gakkel Ridge in the Arctic Ocean. Photo: Stefan Bünz; Photo page 2: Karin Andreasesen; Photo page 3: Crushing ice on the way to the Aurora hydrothermal vent field during the HACON21 expedition. Photo: Marie Stetzler.

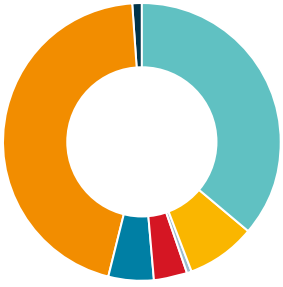
Editorial team: Mariana Esteves, Lone A. Smelror & Karin Andreassen.
Design and layout by Torger Grytå & Elisabeth J. Nilesen, UiT

Organisation chart of the centre



Funding 2021

Funding (1000NOK)	Amount	Percentage
The Research Council	19 350	36,2 %
Industry	4 353	8,1 %
EU	275	0,5 %
Other external funding (TFS, VISTA)	2 131	4,0 %
Norwegian Petroleum Directorate	2 850	5,3 %
UiT The Arctic University of Norway	24 003	44,9 %
Geological Survey of Norway	503	0,9 %
Total	**53 464**	**100 %**



The Research Council of Norway
Industry
EU
Other external funding (TFS, VISTA)
Norwegian Petroleum Directorate
UiT – The Arctic University of Norway
Geological Survey of Norway

Centre Board

The centre board is responsible for overseeing the strategy for research, training, economy, and patent developments at the centre of excellence. The board also oversees operational aspects including the relationships to the university, institutes, and industry. Director of CAGE, Professor Karin Andreassen, reports to the centre board.

Arne Smalås
Chairman
Prof., Dean NT-faculty, UiT

Elina Halttunen
Head of Department, Arctic and Marine Biology, BFE-faculty, UiT

Kjersti Løvseth Ruud
Department Director, Norwegian Geological Survey (NGU)

Nalan Koc
Research Director Norwegian Polar Institute

Ingrid Schjølberg
Prof., Director NTNU Ocean Science and Technology (NTNU Oceans)

Geir Richardsen
Vice president Exploration Assets Norwegian Sea, Equinor

The Scientific Advisory Committee

CAGE has an international scientific advisory committee that gives advice on strategic scientific issues and consists of distinguished experts in their fields.

Prof. Doug Connelly
National Oceanography Centre, Southampton, UK

Prof. Georgy Cherkashov
Institute of Mineral resources of the Ocean, RUS

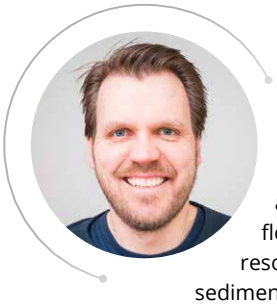
Dr. Carolyn Ruppel
United States Geological Survey, USA

Prof. Mads Huuse
University of Manchester, UK

Prof. Alexander Loy
University of Vienna, Austria

WORK PACKAGE 1

Gas hydrate and free gas reservoirs



Stefan Bünz, *Team Leader*

Professor Stefan Bünz has 25 years of experience in marine geology and geophysics with specific research expertise in: gas hydrates, fluid flow systems, shallow gas accumulations and geohazards, high-resolution 3D/4D and multi-component seismics, CO_2-storage in sedimentary basins, seafloor ecosystems, ultra-slow spreading ridges, and tectonic and non-tectonic faulting.

Members:

Jürgen Mienert
Professor Emeritus

Sunil Vadakkepuliyambatta
Researcher

Shyam Chand
Researcher

Andreia Plaza-Faverola
Associate Professor, Leader SEAMSTRESS project

Sunny Singhroha
Postdoctoral Researcher

Malin Waage
Postdoctoral Researcher

Kate Waghorn
Postdoctoral Researcher

Frances Cooke
PhD Candidate

Przemyslaw Domel
PhD Candidate

Rémi Vachon
Postdoctoral Researcher

Hariharan Ramachandran
Postdoctoral Researcher

Cornelia Mentzoni-Binde
PhD Candidate

Claudio Argentino
Postdocotoral Researcher

Henrik H. Stokke
Business PhD Candidate

About:

One of the greatest uncertainties regarding the Arctic marine methane supply is the amount of frozen methane that lays hidden beneath the seabed. Equally important are the quantities of methane that have been, or will be, released - potentially impacting ocean life and our global climate. In order to shed light on these mysteries, we rely heavily upon UiT's research infrastructure Geosystem 3D Seismic Imaging (G3), a national facility for the acquisition of high-resolution 3D seismic data based on the P-Cable 3D seismic system. It allows for imaging in unprecedented detail when investigating complex and dynamic geosystems of gas hydrates, geofluids and geohazards in marine environments from the shelf to the deep sea. This data enables us to perform excellent reservoir mapping while estimating the amounts of frozen methane and free gas beneath the sea-bed, as well as identifying any leakage from within.

Main questions:

- How much carbon is stored in today's methane hydrate and free gas reservoirs in the Arctic and how much is susceptible to climate change?
- At what rates, by which means, and under which circumstances is methane expelled from sub-seabed reservoirs to the seabed?

Major aims:

- Identify and quantify gas hydrate and free gas reservoirs in the Arctic.
- Develop technologies for direct detection of gas hydrate in marine sediments.
- Understand the spatial and temporal dynamics of gas hydrate reservoirs under changing environmental conditions using high-resolution 3D seismic imaging, sediment drilling and sampling, as well as heat-flow measurements and modelling.
- Understand the genesis, mechanisms and governing geological processes of fluid flow.
- Acquire high-resolution 4D time-lapse data to quantify fluid flow through fractured systems.

Assoc. Prof Andreia Plaza-Faverola and PhD student Przemyslaw Domel on look out onboard RV Helmer Hanssen during cruise CAGE21-3 trying to locate an ocean-bottom seismometer for recovery after a one-year long deployment on the western Svalbard margin. Photo: Frances Cooke. Deployment of the heat flow probe during cruise CAGE21-1 on board RV Kronprins Håkon. Photo: Stefan Bünz.

In another busy year with offshore acticities, WP1 led four scientific expeditions three with *RV Kronprins Haakon* and one with *RV Helmer Hanssen* for a total offshore time of almost 11 weeks. Two of those cruises utilized a remotely operated vehicle (ROV) to investigate fluid and hydrothermal systems from the very shallow shelf (90m) to the deep Arctic basin (4000m). Two other expeditions were dedicated to Plaza-Faverola's SEAMSTRESS project, where we continued a large-scale, long-term ocean-bottom seismic experiment offshore Svalbard.

Main Achievements 2021

1. The Leirdjupet Fault complex (LFC) in the SW Barents Sea has been a focus site for WP1 since it discovered an active gas seepage field in 2017. Sediment and carbonate geochemistry reveal a long history of methane emissions that started during Late Weichselian deglaciation after 14.5 cal ka BP. Methane-derived authigenic carbonates precipitated due to local gas hydrate destabilization. This study published in Nature Scientific Reports is the first of several in line for the LFC seepage system.

2. Together with WP5, WP1 led an expedition on RV Kronprins Håkon investigating several cold vent systems on the Svalbard margin and the Barents Sea using an ROV, heat flow lance, oceanographic and sediment sampling tools. The expedition also acted as teaching cruise for the PhD school GREAT at the Department of Geoscience. The expedition made several unique, first-time visual discoveries, highlighted by (1) active oil seepage from the shelf in 90 m water on the western Svalbard margin, (2) vent ecosystems and heat flow anomalies above basement structures on the western flank of the mid-ocean Knipovich Ridge, or (3) active mud expulsion at the Håkon Mosby mud volcano.

3. A WP1-led expedition on RV Kronprins Håkon within the framework of the *Hot vents in an Ice-Covered Ocean* (HACON) project conducted the first-ever ROV dives on Arctic hydrothermal vents under permanent ice. During the HACON21 cruise, we comprehensibly surveyed and sampled for the first time these remote hydrothermal systems. CAGE team members from WP2, WP4 and WP5 joined the expedition.

4. The SEAMSTRESS project successfully recovered all 10 OBS systems that were deployed in August 2020 on the western Svalbard margin. Initial data analysis showed that all OBS contain a full seismological record.

5. IODP proposal 985 passed the science evaluation panel (SEP) and was forwarded to the JOIDES Resolution Facility Board (JRFB). A site-by-site review with the Environmental Protection and Safety Panel (EPSP) is scheduled for February 2022. If all sites pass the site evaluation, the drilling proposal is eligible for scheduling.

WORK PACKAGE 2

The role of ice ages

Monica Winsborrow, *Team Leader*

Monica Winsborrow is an Associate Professor at CAGE. Her research focuses on the reconstruction of past ice sheets, working to understand the processes and mechanisms that control their evolution and dynamics, and examining their environmental impacts. She holds a PhD in Physical Geography from the University of Sheffield, UK, and worked in both academia and industry before joining CAGE in 2014. She became team leader and assistant director of CAGE in August 2017.

Members:

Karin Andreassen
Professor, Centre Director

Alun Hubbard
Professor (50%)

Jemma Wadham
Professor (100 % from September 2021), previously 20% Adjunct Professor

Henry Patton
Researcher

Pavel Serov
Postdoctoral Researcher

Mauro Pau
Postdoctoral Researcher

Nikolitsa Alexandropoulou
PhD Candidate

Frank Jakobsen
PhD Candidate (from August 2021)

Mariana Esteves
Researcher (50 %)

Renata Lucchi
Adjunct Professor (20%) until June 2021

Craig Hammock
PhD Candidate (University of Swansea/CAGE)

About:

Today, vast quantities of methane are sequestered as shallow gas hydrates across the Arctic, fed continuously by gas from deep thermogenic sources. We propose that these hydrate reservoirs were much thicker and more extensive under the extreme conditions of past ice ages, whereby high pressure and low temperature conditions beneath former ice sheets created an environment conducive for stable hydrate formation. We combine state-of-the-art marine geophysical data with high-resolution modelling to provide extraordinary insights into the long-term variability of methane storage and release forced by repeated glacial advance and retreat over the past 2.7 Ma. Our new understanding is crucial to improve the prediction of present and future greenhouse gas release from contemporary Greenland and Antarctic ice sheets.

Main questions:

- How do ice sheets affect fluid flow and gas hydrate systems, and vice versa?
- How does the thickness, extent and volume of gas hydrates change through the ice ages?
- What impact did glaciations have on the Arctic environment?

Major aims:

- Determine, through modelling and empirical observations, the key processes and feedbacks between gas hydrates, fluid flow and ice sheet glaciation.
- Model the long-term impact of past glacial cycles on the Eurasian Arctic, both within and beyond formerly ice-covered regions.
- Isolate critical subglacial controls on past ice sheet and ice stream behaviour and dynamics.
- Develop stratigraphic and environmental frameworks for key CAGE study areas.

Marine life on methane derived carbonate crusts in the Barents Sea. Photo: Jochen Knies. Anticipation as cruise participants inspect a sediment core during cruise CAGE21-4. Abidemi Akinselure (UiT), Frank Jakobsen, Henry Patton and Monica Winsborrow (CAGE, UiT). Photo: Mauro Pau.

Our work package is in a world-leading position to integrate high resolution empirical datasets and numerical models of past glacial cycles and processes to assess their concomitant impact on subglacial gas hydrate dynamics in unprecedented accuracy and detail.

Main achievements 2021

1. Led SFF-V application "iC3: Centre for Ice, Cryosphere, Carbon and Climate" that has now successfully passed to step 2, representing an important collaborative effort between multiple scientists within CAGE, UiT, the Norwegian Polar Institute and numerous national and international institutions.

2. Contributed to COP26 Climate Summit in Glasgow through several keynote talks and multiple interviews on the state of the Arctic with a specific focus on ice sheets.

3. Polar Chapter lead for RECCAP2: Regional Carbon Cycling Assessment Project 2

4. Two successful research cruises to the central Barents Sea (one in collaboration with NPD when an ROV was deployed in the area) to continue investigation of the exceptional hydrocarbon seepage from glacially eroded shallow petroleum reservoirs. These cruises involved a multidisciplinary team of scientists from multiple CAGE work packages, as well as collaborators from NPD, NGU, NILU and UNIS, studying the (sub)seafloor, water column, sea surface and atmosphere.

5. Published the first, high-resolution, continuous seismostratigraphic framework for the entire western Svalbard-Barents Sea margin over the last 2.7 Ma.

6. Integration of ice-sheet and basin modelling reveals "pumping" effect of glacial cycles on fluid migration and release in central Barents Sea over the past 2.7 Ma. The work is done in collaboration with Alexey Kishenkov, Moscow State University, Russia.

7. Completed a high-resolution, quantitative framework defining spatiotemporal patterns of glacial erosion of the Eurasian landscape over the last 2.7 Ma.

8. Participation in the HACON/CAGE cruise with a focus on investigation of the influence of ice sheets on methane storage and release on the NE Greenland shelf.

9. Identified key subglacial controls on marine-based ice sheet retreat and flow dynamics through the compilation of a unique global database of glacial landforms from glaciated continental margins.

10. Start-up of NFR-funded project "Stability of the Arctic climate" led from the Department of Mathematics and Statistics, UiT where WP2 researchers are project partners and will contribute numerical ice sheet modelling expertise.

11. Contributed 6 book chapters on the glacial landscapes of the Eurasian Ice Sheet Complex to the edited book European Glacial Landscapes: Volume 1 Maximum Extent of Glaciations.

Cold loving microbes in a warming Arctic

Mette Marianne Svenning, *Team Leader*

Professor Mette Marianne Svenning is an internationally recognized expert on methods for isolation and cultivation of methane oxidizing bacteria (MOB), and the laboratory has a culture collection of representative MOB from Arctic and sub-Arctic regions. Svenning has extensive fieldwork experience from Arctic (Svalbard) and sub-Arctic regions. This includes leadership, management and coordination of fieldwork, methane emission measurements, vegetation analyses and sampling for microbial and molecular studies in the laboratory.

Members:

Dimitri Kalenitchenko
Postdoctoral Researcher (until Autumn 2021)
Researcher (50% from Autumn 2021)
Project Leader for METHANICE (from December 2021)

Vincent Carrier
PhD Candidate (Dissertation 29 November 2021)
Researcher (from December 2021)

Helge Niemann
Adjunct Professor (20%)

About:

It is uncertain how, and to what extent, methane release from gas hydrates affects arctic marine ecosystems components, such as benthic organisms, communities, microorganisms and food web structures. This research group has been established in order to dig further into this mystery. Our studies are linked to, and coordinated with, geochemical, sedimentological and water column studies of other CAGE teams. In the coming years, WP3 aims to reveal the climate change sensitivity of the cold adapted microbial sub-seabed ecosystem and how it can affect methane emissions through comparative studies in marine and terrestrial pingo systems. This goal will be supported by a future new and unique infrastructure, the Ice-Cold Microorganisms Laboratory (ICOM), to address biodiversity, activity and evolution of cold loving microbes.

Main questions:

- How is microbial community structure and activity in marine seabed pingos as compared to terrestrial pingos?
- What is the role of the seafloor biological communities in mediating the exchange of methane from seafloor sediments into the water column?
- How does the sub-seabed microbial communities and networks respond to changes in temperature and substrate availability?
- How active is the methane oxidising filter in the water column?

Major aims:

- Understand habitat characteristics and locations of seep communities.
- Document the characteristics of microbial communities in sediments and the water column, including methanotrophic activity and community composition.
- Decipher life cycles of macrobenthic and microbial communities, along with the ecological structure and function of communities and food webs associated with seafloor methane emissions.
- Understand responses and evolution of cold seep biological communities.

Vincent Carrier (CAGE, UiT), Karina Weiler (UiT), André Jensen (NPD). Photo: Mauro Pau. Oil slick sample acquisition from the working boat of R/V G.O. Sars during cruise CAGE21-6. Extraction of amplified DNA segments belonging to tubeworms found at Arctic cold seeps for genetic identification. Photo: Anne Grethe Hestnes.

Marine gas hydrate pingos are characterized by unique microbial structures influenced by a complex distribution of methane. A terrestrial active pingo revealed a hotspot hosting a microbial community structured like their marine counterpart.

The platform is built upon Prof. Svenning regarding methane oxidizing bacteria; biodiversity, and the activity of microbial communities; and their involvement in organic carbon degradation and CH_4 emission in Arctic and sub-Arctic regions. The strengthened cross disciplinary collaboration with Svenning's home Faculty of Biosciences, Fisheries and Economics at UiT continues to be of great importance for WP 3..

Main achievements 2021

1. Described prokaryotic and eukaryotic community structure and composition at Arctic gas hydrates formed pingos.

2. Described the bacterial community composition in the water column at the shallow continental shelf west of Svalbard. Structural community changes of methane oxidizing bacteria are marginal, but the methane oxidation capacity are influenced by seasonal shifts and varies according to site-specific geographical features.

3. Organised four terrestrial fieldworks on the active terrestrial pingos in Advantalen In collaboration with Dr A. T. Tveit (UiT) and Andrew Hodson (UNIS) to explore the diversity and function of the sediment and water microbiome of terrestrial open system pingos in different seasons. The CAGE's drone was used to map the site and 3D orthomosaic map was created using WP3 informatic resources allocation on the Norwegian e-infrastructure for research and education (SIGMA2/UNINETT).

4. Enriched a methane oxidising community from ice cores sampled during the HACON cruise in 2019. Set up a sequencing platform, based on the oxford nanopore technology.

5. Participated in the cruise CAGE 20-7 to study the bentho pelagic microbial link that might exist above methane flares in collaboration with Tim de Groot (NIOZ) and to provide chemical microprofiles to other CAGE WPs.

6. Two Master students and one Bachelor student graduated last summer on studies of Arctic methane seeps.

7. Continued the collaboration with The Faculty of Biosciences, Fisheries and Economics to strengthen the research and infrastructure platform of UiT The Arctic University of Norway.

8. Established parts of the Ice-Cold Microorganisms Laboratory (ICOM) in collaboration with Dr. Alexander T. Tveit, for conducting experiments and gaining new insights into how microbial communities work in ice-cold environments.

Gas in the water column

Bénédicte Ferré, *Team Leader*

Bénédicte Ferré is a physical oceanographer whose research activities span from sediment resuspension and transport to oceanographic data associated with methane release. She holds a PhD degree in Marine Science from the University of Perpignan, France. Ferré was a post-doctoral researcher at the United States Geological Survey in Woods Hole, USA, before joining the Department of Geosciences at UiT - The Arctic University of Norway as a researcher in 2008 and CAGE as a team leader in 2013. She is involved in many projects related to ocean observatories and is, among other tasks, responsible for the development, acquisition and analysis of data related to the seafloor observatory K-lander. She is leader of the PETROMAKS 2 project EMAN7 and co-leader of the INFRASTRUKTUR project NorEMSO.

Members:

Anna Silyakova
Researcher

Helge Niemann
Adjunct Professor (20%)

Knut Ola Dølven
PhD Candidate

Manuel Moser
PhD Candidate

Muhammed Fatih Sert
PhD Candidate

Marie Stetzler
PhD Candidate

About:

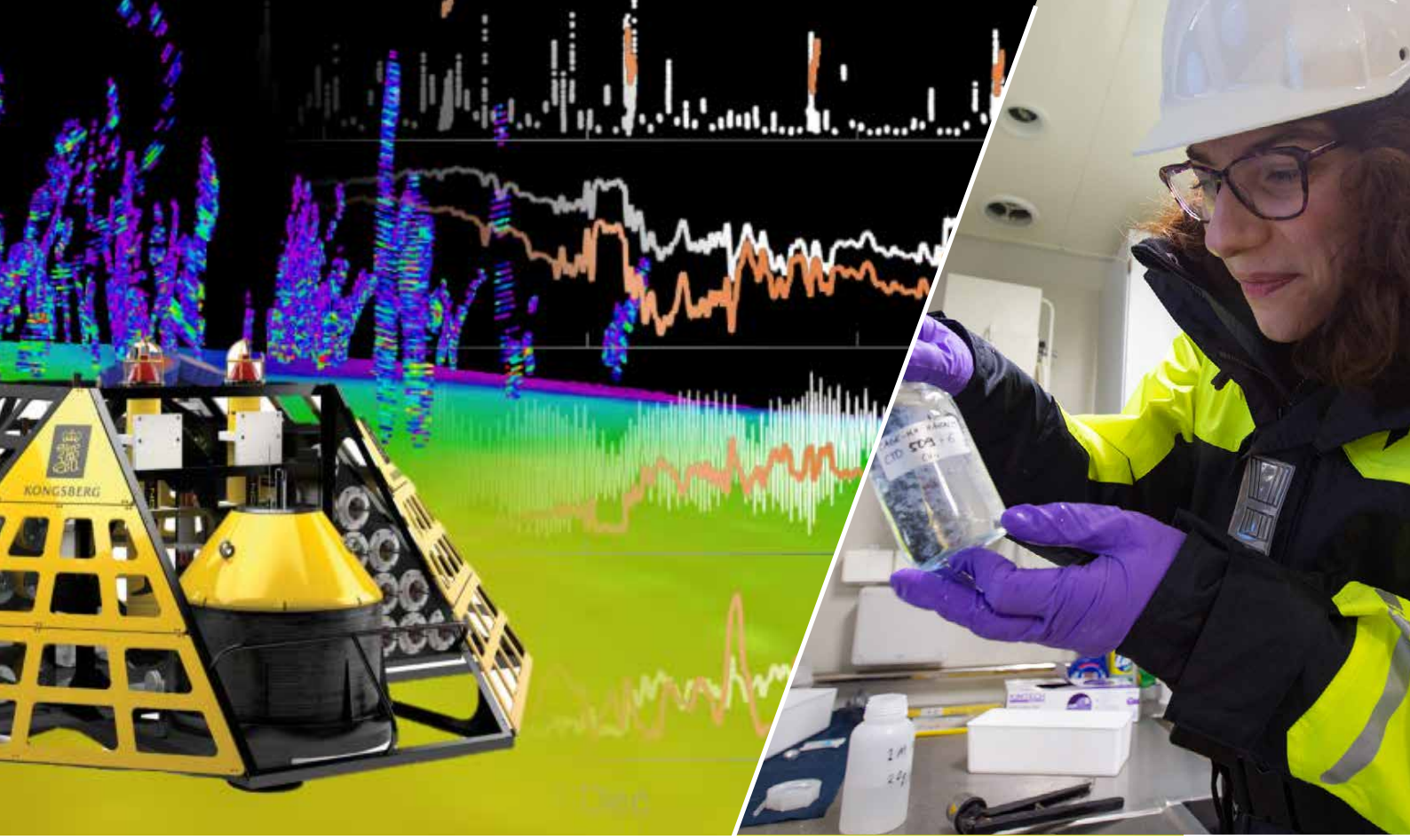
The effects of methane release on underwater ecosystems and our global climate are still unclear. Methane transport in Arctic oceans takes place via bubbles or in dissolved form beneath the seabed and travels vertically towards the ocean surface. However, continuously shifting water dynamics due to changing seasons and other factors can limit vertical methane migration. By understanding the constant evolution of the ocean and the related variability of methane release on a time scale that ranges from hours to years, we can quantify local and regional methane leakages as well as methane transport in the water column over time. This ultimately helps us to determine what effect, if any, this methane has on underwater ecosystems and climate change.

Main questions:

- How much of the methane released from the seafloor reaches the upper water column and the atmosphere?
- Over what horizontal and vertical distances do ocean currents transport methane plumes?
- What is the variability of the methane release and what are the processes involved?
- What are the interactions between the physical, chemical and biological processes that affect methane transport?
- What is the effect of methane seeps on the Arctic Ocean biogeochemistry?

Major aims:

- Observe and model the transport of methane plumes.
- Determine and model methane fluxes from the seafloor to the sea surface.
- Determine physical and chemical boundary conditions of the bottom water that modify methane seep activities.
- Investigate and compare water column biogeochemistry at and around active methane flares



Observatories location (yellow dot) and flow rates from flares mapped in their vicinity. Background color illustrate seafloor bathymetry. Compass diagram shows the relationship between ocean current direction and methane concentration (distance from center, blue shows raw data and black shows response time corrected data). Graphics: Knut Ola Dølven. Marie Stetzler sampling water during the HACON cruise. Photo: Cera McTavish, RevOcean.

The team focuses on physical and chemical data collected in the water column and near the seafloor, to understand the link between oceanic settings and methane release and transport. We therefore rely on data collected during experiments at sea, from long-term observatories as well as modeling.

States of the art seafloor observatories make it possible to continuously measure environmental changes associated with methane release at remarkable resolutions and acquire data to tune and force models. This year has been focused on activities related to the seafloor observatories in the frame of CAGE but also *NorEMSO* (Norwegian node for the European Multidisciplinary Seafloor and water column Observatory) as well as starting up the new project *EMAN7* (Environmental impact of Methane seepage and sub-seabed characterization at LoVe-Node 7).

Main achievements 2021

1. The project EMAN7 (Environmental impact of Methane seepage and sub-seabed characterization at LoVe-Node 7) started officially from June 2021 with the Kick-off meeting. During this project we will use node 7 from the LoVe cabled observatory network to investigate methane emission dynamics and past evolution, the causality between methane seepage and oceanic parameters as well as climate change, and how it affects biology and in particular coral reefs that leave around the seepage. WP5 from CAGE is also involved in this project.

2. Collaboration in the newly awarded project REGAME (Reliable global methane emissions estimates in a changing world) led by Stephen Platt at NILU. This project is a follow-up of the MOCA project which represented WP7 in the first phase of CAGE. It will investigate the balance of sources and sinks of methane in and from the atmosphere. In this project, CAGE is WP leader for Ocean observations to identify the possible ocean sources and understand water column processes.

3. Participation to the HACON cruise in September 2021 in order to characterize the water column in and near a hydrothermal vent in the Gakkel Ridge. HACON is a FRINATECH initiative funded by NFR and led by NIVA.

4. Development of a predicable and reliable method for correcting slow sensor response signal inherent to equilibrium extraction technique that suffers from limited response time, from minutes up to over one hour. This article is currently in discussion in Geoscientific Instrumentation, Methods and Data Systems (https://doi.org/10.5194/gi-2021-28).

5. Presentation of the two long time series collected by the K-landers deployed from 2015 to 2016 offshore Prins Karls Foreland on intense seepage areas, showing high short term (100-1000 nmol/L within hours) and seasonal variation as well as higher (2-7 times) methane concentrations compared to previous measurements. A negative correlation with temperature fits with hypothesized seasonal blocking of lateral methane pathways in the sediments. The article is currently in discussion in ocean science (https://doi.org/10.5194/os-2021-85).

Methane seepage history

Jochen Knies, *Team Leader*

Jochen Knies is a senior researcher at the Geological Survey of Norway. He holds a 20% position at CAGE, where he is currently Vice-Director. His research expertise integrates marine geochemical and environmental investigations along formerly glaciated continental margins in the Arctic. Knies holds a PhD degree in Marine Geology from the University of Bremen. His broad professional experience includes, among others, a position as postdoctoral fellow at the Alfred Wegener Institute for Polar and Marine Research (AWI), Germany, and a visiting professor position at the University of Hawaii, USA.

Members:

Aivo Lepland
Researcher

Giuliana Panieri
Professor

Claudio Argentino
Postdoctoral Researcher

About:

To understand the environmental factors that drive methane seepage we need to better constrain the timing of methane release throughout the geological past. To do this we use authigenic carbonates and microfossils to develop records of palaeo-methane seepage for sites around the Arctic. We then assess the influence of various environmental conditions, for example sea ice extent and glacial isostatic adjustment, on methane seepage history.

Main question:

- What caused the evolution of submarine Arctic gas hydrate systems and methane leakage events in the geological past?

Major aims:

- Establish geochemical markers and time constraints for "abnormal" methane release from seabed to ocean.
- Determine paleo conditions of ocean life and links to climate change during the geological past

ROV Ægir 6000 launched from RV "G.O. Sars" in the central Barents Sea, December 2021. Retrieval of a push core from a seep site in the central Barents Sea, December 2021. Photos: Mauro Pau.

Technology intensive explorations over the past couple of years, payed off for work package 5 also during 2021: Unique material from various gas leakage sites in the Norwegian and Barents Seas was collected using ROV Ægir and RV G.O. Sars and Kronprins Haakon.

The alliance with world-class laboratories, and academic and industry partners, allowed the application of cutting-edge technologies that resulted in a deeper understanding of methane dynamics and interrelated processes in the Arctic.

Main achievements 2021

1. Through 3D petroleum system modelling, we show that gaseous hydrocarbons, originating from Miocene age terrigenous organic matter, accumulates largely in ~2 million-year-old (Ma) sedimentary sequences underneath the pockmark system on the Vestnesa ridge's crest, NW Svalbard. These traps are constantly charged until present day and most likely the reason for the continuous leakage of thermogenic gas at the seafloor. Indeed, modelling results show that repeating tapping of hydrocarbon reservoirs are due to (a) fracture formation promoted by glacial isostatic adjustments (GIA) and (b) fracture re-activation that explain recent observations of multiple seepage events on Vestnesa Ridge during episodes of intense cooling and warming over the past 160.000 years.

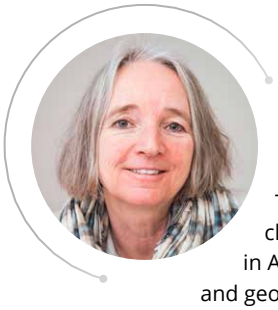
2. We continued the research on Vestnesa Ridge with ROV controlled sampling of various gas leakage sites and show that hydrocarbons at this cold seep site are supplied both by deep thermogenic sources from below the gas hydrate stability zone but also to a significant degree by microbial methanogenesis which dominates the signature in our shallow sediment cores with $\delta^{13}C–CH_4$ values as low as -77‰. Pore water analyses show very shallow sulphate methane transition zones and transport-reaction modelling suggests a considerable amount of dissolved methane passing through the sediment water interface due to upwards advection of an aqueous fluid not previously reported from Vestnesa Ridge.

3. We have developed a multi-proxy approach for paleo seepage reconstruction from sediment records, starting from geochemistry applied on foraminifera shells, expanding to sedimentary proxies, lipid biomarkers and novel isotopes from pore water (eg. strontium). The approach has been applied in shallow water sites in the Barents Sea which are susceptible to climate change with the aim of identifying trigger mechanisms that can be the key to predict methane emission scenarios in a future Arctic impacted by temperature increase.

4. There is still some debate on the possibility of using benthic foraminifera to investigate methane emission, both in the present environment and in the fossil record. To elucidate the last doubts, we have been working on both alive and dead foraminifera. We have expanded the investigation toward hydrothermal vents and naturally oil seepage sites, adding to the well-established isotopic analyses (Carbon and Oxygen isotopes performed in the in-house lab SIL) other isotopes and Single-cell DNA barcoding.

WORK PACKAGE 6

Methane, CO_2 and ocean acidification



Tine Lander Rasmussen, *Team Leader*

Tine Rasmussen is a professor at the Department of Geosciences, UiT The Arctic University of Norway since 2003. She focuese on abrupt climate and oceanographic changes and changes in greenhouse gases in Arctic to sub-Arctic areas. She is educated in the fields of marine biology and geology and stratigraphy. She holds a PhD degree in marine science from Aarhus University in Denmark, and has professional experience most notably from Copenhagen University (Denmark), Lund University (Sweden) and Woods Hole Oceanographic Institution (USA).

Members:

Mohamed Ezat
Researcher, Leader ARCLIM project

Naima El Bani Altuna
PhD Candidate (Dissertation 17 September 2021)

Katarzyna Melanuik
PhD Candidate (Dissertation 4 November 2021)

Siri Ofstad
PhD Candidate (Dissertation 16 December 2021)

Griselda Anglada-Ortiz
PhD Candidate (Nansen Legacy project)

Christine Lockwood-Ireland
PhD Candidate

Thomas Ben Chalk
Postdoctoral Researcher ARCLIM

Freya Sykes
PhD Candidate ARCLIM

Adele Westgård
PhD Candidate ARCLIM

About:

WP6 samples living planktic and benthic foraminiferal faunas and pteropods and past environments by examining the fossilized remains of once-living foraminiferal faunas and macrofaunas, mostly from around Svalbard, both from seep sites and off seep areas. To better understand the Arctic carbon cycle and changes seen at methane release areas, WP6 reconstructs the general paleoceanography by the study of records from the Barents Sea, the Nordic seas and Arctic Ocean not influenced by methane. Here, we also focus on past changes in bottom water temperature and its possible effect on change in degree of methane seepage. In addition, WP6 document changes in planktic and benthic faunas in relation to methane seepage, productivity and ocean chemistry changes over time. In addition, WP6 monitors the response of planktic foraminifera, coccospheres and pteropods to ocean acidification and productivity changes by studying physical properties of their shells in the past and present, and their contribution to the organic and inorganic carbon pump.

Main questions:

- What is the impact of increased methane release on marine micro- and macrofaunas?
- Is there a relationship between this release and climate (ocean bottom water temperature) variability?
- Does methane release contribute to ocean acidification/productivity change?

Major aims:

- Investigate methane release and its impact in relation to past climate and ocean circulation and temperature changes
- Investigate methane release and the isotopic signals in living benthic foraminiferal shells and distribution patterns of species in relation to successive stages of seepage
- Apply multi-proxy techniques to reconstruct high-resolution climate and greenhouse gas records
- Quantify planktic foraminiferal and pteropod responses to changes in ocean chemistry and productivity due to methane release, increasing atmospheric CO_2 and ocean warming.
- Provide robust quantitative records useful for modelling of the carbon cycle and forecasting future changes as a result of ongoing changes in the polar ocean

Newly retrieved core section on November cruise CAGE20-8 to the Northeast Greenland margin coring for glacial history and seepage of methane. Photo: Mauro Pau. Pteropod ('sea butterfly'), a pelagic snail caught in plankton tows east of Svalbard. Photo: Griselda Anglada-Ortiz.

We work to improve existing standards and intergrate established methods with groundbreaking technologies to estimate CO_2 concentrations, productivity patterns, ocean acidification, bottom water temperatures, and ventilation rates of the ocean, sea-ice cover and climate, past and present.

Our work package studies general climate and ocean circulation patterns of the past in relation to ice sheet advances/retreats and meltwater flows. With this information at hand, variations in methane release from the seafloor, and its impact on the environment and micro- and macrofaunas over time can be compared to palaeoceanographic and -climatic developments in order to obtain a better understanding of controlling factors.

Main achievements 2021

1. Mohamed Ezat received the prestigious TFS grant in autumn 2020. The grant covers 2 PhD and 2 Post doc positions and a mass spectrometer for elemental analyses. In 2021, a culturing cold-lab for planktic foraminifera in incubators with photoperiodic and temperature control has been established.

2. Reconstruction of bottom water temperature (BWT) for the last glacial period (13–63 ka) shows that BWT increased up to 5±1°C during the coldest phases and that a vast heat reservoir occupied the intermediate water beneath a strong halocline in the North Atlantic and the Arctic Ocean.

3. Reconstruction of BWT by Mg/Ca for the last 18,500 years in Storfjorden Trough showed a close linkage between BWT, ice movements and strength of methane release.

4. Deep ocean 14C ventilation ages show that ventilation was reduced due to intermittent to no convection taking place in the Nordic Seas. However, a persistent exchange between the Arctic Ocean, the Nordic Seas and the North Atlantic Ocean occurred.

5. The study of planktonic foraminiferal and pteropod shell densities measured by X-ray microcomputed tomography (XMCT) reveal clear inter-species differences in shell density and thickness with water depth and ontogenic stages.

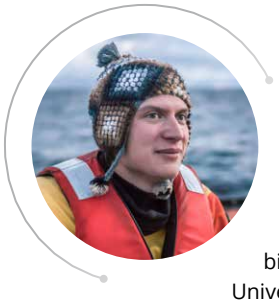
6. Vertical distribution and contribution of living planktic foraminifera and pteropods to the inorganic and organic carbon standing stocks and productivity in the Arctic Ocean north of Svalbard have been investigated.

7. In 2021, the seasonal cruises in March, May, July and August-September covering the northern Barents Sea and towards the Arctic Basin were completed. Living planktic foraminifera, pteropods and coccolithophores were collected.

8. The foraminiferal plankton community in the Arctic gateway in the Fram Strait based on new and published data for the last 50 years shows a decadal trend of changes in fauna compositions and shoaling of the living depth habitat recorded by the species.

9. The Svalbard-Barents Sea Ice Sheet reacted rapidly to the abrupt warmings of the last deglaciation 20–10 ka BP. The break-up was similar to the recent break-ups of the Larsen Ice Shelf in Antartica between 1995 and 2017. Deglacial retreat rates thus matched modern retreat rates in Antarctica and Greenland (>2 km/year).

METHANICE – Methanotropic communities in Ice



Dimitri Kalenitchenko, *Project leader*

Dimitri Kalenitchenko is a 50% researcher within WP3 Cold-Loving Microbes in a warming arctic at CAGE and an associate Professor at La Rochelle University, France. He holds a PhD degree (2015) in microbial ecology from the Benthic Ecogeochemistry Laboratory, Sorbonne University, France. He combined in situ and ex-situ approaches to reveal the core ecosystem services rendered by overlooked microbes that play key roles in the global carbon cycle. In 2021 Dimitri received a 4-year Researcher Project for Young Talent from the Research Council of Norway to identify the role of methane consuming microorganisms associated with arctic terrestrial seasonal ice.

Members:

Postdoctoral Researcher
- to be hired

PhD Candidate
- to be hired

About the project:

The Methanotrophic communities in ice (METHANICE) is a multidisciplinary project that will study methane consuming microorganisms (methanotrophs) associated with terrestrial seasonal ice covering sub permafrost methane springs. Seasonal ice forms on top the springs during winter, trapping methane and carbon dioxide in a thick ice layer surrounding massive, pressurised aquifers oversaturated with greenhouse gases. While the aquifers are full of methanotrophs, it is still unknown whether they are present and active as biological methane filter within the ice during winter. Deep-sea engineer and astromicrobiologist will work together to detect and monitor the activity of these microbes. After this first step, we will combine in-situ and laboratory experiment to understand if the ice-associated microbes can use the greenhouse gases trapped in the reservoir and therefore decrease their release toward the atmosphere. Finaaly, we will isolate these microbes to know their physiology and which mechanisms allow them to survive in this cold and oligotrophic environment.

New infrastructure:

METHANICE, will contribute to the development of two new infrastructures.

A new laboratory in Naturfagbygget, designed for cold-loving microbes studies (ICOM) that will be ready by the end of 2022. It will be equipped with an anaerobic chamber and standard molecular biology equipment all kept at low temperature to process the samples as close as possible to the environment they are belonging to.

A new in situ experimental platform supported by METHANICE and the Svalbard Integrated Arctic Earth Observing System consortium (SIOS). It will be equipped with in situ sensors that will monitor the chemical and physical properties of the terrestrial cold seep and make the data available in real time. The experimental platform will be tested in 2022 and fully operational in 2023.

METHANICE's framework and collaboration:

The METHANICE team will consist of Dimitri (PI), one PhD-student and one postdoc. The project will be performed in a close collaboration with several national and international institutions including The University Center in Svalbard, Norway; Woods Hole Oceanographic Institution, USA; Jet Propulsion Lab, USA; La Rochelle University, France.

METHANICE · The Research Council of Norway · The Arctic University of Norway – UiT · La Rochelle Université · UNIS The University Centre in Svalbard · Woods Hole Oceanographic Institution · JPL Jet Propulsion Laboratory California Institute of Technology

Specimens of benthic foraminifera an gastropod from surface sediment samples collected during the AKMA cruise in May - June 2021. Photo: Griselda Anglada-Ortiz.

GReAT Geoscience Research Academy of Tromsø: activities under the corona debacle

GReAT (Geoscience Research Academy of Tromsø) is a new research school launched at the end of 2019. The school is a continuation of the Trainee School in Arctic Marine Geology and Geophysics (AMGG) established in 2005 at the University of Tromsø.

The training in GREAT focuses on methods related to studies of Arctic continental shelves and margins, including topics such as glacial processes and products, geo-hazards, fluid emissions and gas hydrates, paleoclimate, oceanography, terrestrial and marine Quaternary geology, lithosphere dynamics, bedrock geology, energy and environment. The PhD trainee school offers marine and terrestrial scientific expeditions and excursions to the Arctic and to geologically interesting localities all around the globe, as well as relevant seminars about various aspects of terrestrial and marine geology, climate and environmental change.

The school also organizes specialized workshops with national and international participants, and soft-skill training courses in collaboration with the Faculty of Science and Technology at UiT. From 2020, following the guidelines from the Faculty, the students enrolled in GREAT will have a mid-way evaluation. All the PhD students will be evaluated by scientists outside the supervisor team, halfway during their PhD program. This is an opportunity to obtain feedback on the PhD work that has been carried out and receive advice for the work ahead.

GREAT has students from 20 different countries. During the organized activities, there are not only scientific and educational exchanges, but also cultural exchange between the participants. This promotes the creation of a new academic culture, similar to the new concept of the 'world-class' university. The students can acquire various transferable skills, create their own professional network, and go "across boundaries" of their own research fields.

2021

GREAT is closely associated with the national research schools CHESS (Research school on changing climates in the coupled Earth system) and DEEP (Norwegian Research School for Dynamics and Evolution of Earth and Planets). Many activities in 2021 were cancelled because of the pandemic, including the CHESS Annual Meeting to have been held on Hurtigruten in March, but GREAT has kept organizing activities. The GREAT Annual Meeting was held on November 17th, and was an opportunity for the students to present their projects and discuss about science. The AKMA educational cruise was held on 22nd of May to the 9th of June followed by an AKMA Workshop 2-5th of November. GREAT early career scientists participate in JEDI Justice Equality Diversity and Inclusivity group at the Department of Geosciences.

Tine L. Rasmussen, *Member of GReAT board*

Professor Tine L. Rasmussen has taken over the membership of GREAT from Bénédicte Ferré (leader of WP4) in Autumn 2021 and is the leader of Work Package 6 (Methane, CO_2 and Ocean Acidification) in CAGE.

JEDI (Justice, Equity, Diversity, Inclusion)

Formed by early career scientists from the Department of Geosciences and CAGE in 2020, JEDI is a group working on spreading awareness of JEDI topics with the following goals:

Goal 1: Educate ourselves on JEDI topics

Goal 2: Open discussion within the department on JEDI topics and help shine light on unconscious biases

Goal 3: Work to inform equality and diversity policies in the department and faculty

Goal 4: Be a gathering place for information on equality, diversity, and inclusion at UiT, and provide access to that information to anyone at the department who needs it

Numerous events have been organized throughout 2021. Together JEDI, CAGE and the Gender Equality and Diversity Committee at UiT, organized a webinar on 'Power relations and lack of gender balance in academia. What are the challenges and how do we react?' to mark the International Women's Day on March 8th 2021. Anna Wahl, a pioneer in the field of gender research in Sweden, gave the presentation, which was followed by a discussion with associate professor Melina Duarte and professor Kenneth Ruud from the PRESTIGE project at UiT.




Naima El bani Altuna (centre) with PhD supervisors and the evaluation committee following a successful PhD defense on 17th September 2021. Photo: Mariana Esteves
Katarzyna Melaniuk (third from right) with PhD supervisors and the evaluation committee following a successful PhD defense on 4th November 2021. Photo: Naima El bani Altuna
Vincent Carrier (right, front row) with PhD supervisors and the evaluation committee following a successful PhD defense on 29th November 2021. Photo: Marie Stetzler
Siri Ofstad (second from right) with PhD supervisors and the evaluation committee following a successful PhD defense on 16th December 2021. Photo: Arunima Sen

PhD dissertations

2013

Safronova, P.
Distribution, depositional environment and post-depositional deformation of Cenozoic gravity-induced deposits along the western Barents Sea continental margin
Supervisor: Andreassen, K.

2014

Faust, J.C.
Environmental response to past and recent climate variability in the Trondheimsfjord region, central Norway - A multiproxy geochemical approach
Supervisor: Knies, J.

Vadakkepuliyambatta, S.
Sub-seabed fluid-flow systems and gas hydrates of the SW Barents Sea and North Sea margins
Supervisor: Bünz, S.

2015

Chauhan, T.
Late Quaternary paleoceanography of the northern continental margin of Svalbard
Supervisor: Rasmussen, T.L., Noormets, R.

Ezat, M.
North Atlantic–Norwegian Sea exchanges during the past 135,000 years: Evidence from foraminiferal $\Delta^{14}C$, $d^{11}B$, $d^{18}O$, $d^{13}C$, Mg/Ca and Cd/Ca
Supervisor: Rasmussen, T.L., Groeneveld, J.

Gudlaugsson, E.
Modelling the subglacial hydrology of the former Barents Sea Ice Sheet
Supervisor: Andreassen, K., Humbert, A.

Jessen, S.P.
Ice rafting, Ocean circulation and Glacial activity on the western Svalbard margin 0–74,000 years BP
Supervisor: Rasmussen, T.L.

Portnov, A.D.
Role of subsea permafrost and gas hydrate in postglacial Arctic methane releases
Supervisor: Mienert, J., Cherckashov, G.

2016

Sauer, S.
Past and present natural methane seepage on the northern Norwegian continental shelf
Supervisor: Knies, J., Mienert, J.

2017

Sztybor, K.
Late glacial and deglacial paleoceanographic and environmental changes at Vestnesa Ridge, Fram Strait: challenges in reading methane-influenced sedimentary records
Supervisor: Rasmussen, T.L.

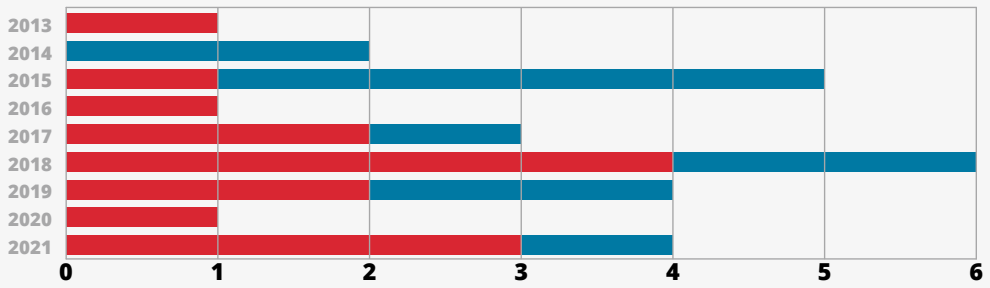
Tasianas, A.
Fluid flow at the Snøhvit field, SW Barents Sea: processes, driving mechanisms and multi-phase modelling
Supervisor: Bünz, S.

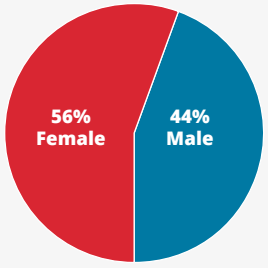
2018

Esteves, M.
Collapse of a marine-based ice sheet
Supervised by: Winsborrow, M.

Jansson, P.
Methane bubbles in the Arctic Ocean - Quantification, variability analysis and modelling of free and dissolved methane from the seafloor to the atmosphere
Supervised by: Ferre, B.

Paiste, K.
Reconstructing the Paleoproterozoic sulfur cycle: Insights from the multiple sulfur isotope record of the Zaonega Formation, Karelia, Russia
Supervised by: Panieri, G., Lepland A.





Schneider, A.
Diagenetically altered benthic foraminifera reveal paleo-methane seepage
Supervised by: Panieri, G., Knies, J., Lepland, A.

Serov, P.
Cryosphere-controlled methane release throughout the last glacial cycle
Supervised by: Andreassen, K.

Åström, E.
Benthic communities at high-Arctic cold seeps: Faunal response to methane seepage in Svalbard.
Supervised by: Carroll, J.

2019

Shackleton, C.
Subglacial hydrology of the Fennoscandian and Barents Sea ice sheets
Supervised by: Winsborrow, M., Andreassen, K., Bjarnadóttir, L. R., Patton, H. 79 pages.
https://hdl.handle.net/10037/15815

Singhroha, S.
Distribution and quantification of gas hydrates and free gas in marine sediments of Vestnesa Ridge, offshore W-Svalbard
Supervised by: Bünz, S.,Plaza-Faverola, A., Chand, S. 127 pages.
https://hdl.handle.net/10037/15824

Waage, M.
3D and 4D seismic investigations of fluid flow and gas hydrate systems - at sites across the Barents Sea and NW Svalbard margin.
Supervised by: Bünz, S., Mienert, J., Andreassen, K. 48 pages.
https://hdl.handle.net/10037/15078

Waghorn, K.A.
Scales of tectonic processes controlling fluid flow systems on the Svyatogor Ridge, Fram Strait
Supervised by: Bünz, S., Plaza-Faverola, A. 90 pages.
https://hdl.handle.net/10037/15813

2020

Yao, H.
Reconstruction of past and present methane emission in the Arctic cold seeps using biogeochemical proxies
Supervised by: Panieri, G.; Niemann, H. 58 pages. https://hdl.handle.net/10037/17821

2021

Carrier, V.
Microbial community structure associated to Arctic cold seeps
Supervised by: Svenning, M.M.; Kalenitchenko, D.; Gründger, F.; Niemann, H. 155 pages.
https://hdl.handle.net/10037/22978

El Bani Altuna, N.
Millennial-scale variability of Atlantic water inflow in the northern Nordic Seas and the northwestern Barents Sea - Relationship to abrupt climate oscillations, cryosphere and methane seepage from the seafloor
Supervised by: Rasmussen, T.; Ezat, M. 146 pages.
https://hdl.handle.net/10037/22253

Melaniuk, K.
Doctoral dissertation. "Assessing the relationship between living benthic foraminifera and methane emission in the Arctic Ocean
Supervised by: Rasmussen, T.; Treude, T.; Zajaczakowski, M. 59 pages
https://hdl. handle.net/10037/22757

Ofstad, S.
Arctic planktonic calcifiers in a changing ocean - A study on recent planktonic foraminifera and shelled pteropods in the Fram Strait-Barents Sea region
Supervised by: Rasmussen T.; Zamelczyk K.; Meilland J. 110 pages
https://hdl.handle.net/10037/23247

Master theses 2021

Mathisen, M. M.
Reconstruction of the paleocenaography west of Lofoten during the Last Glacial Maximum
Supervised by: Rasmussen, T.L.; Ezat, M. 65 pages.

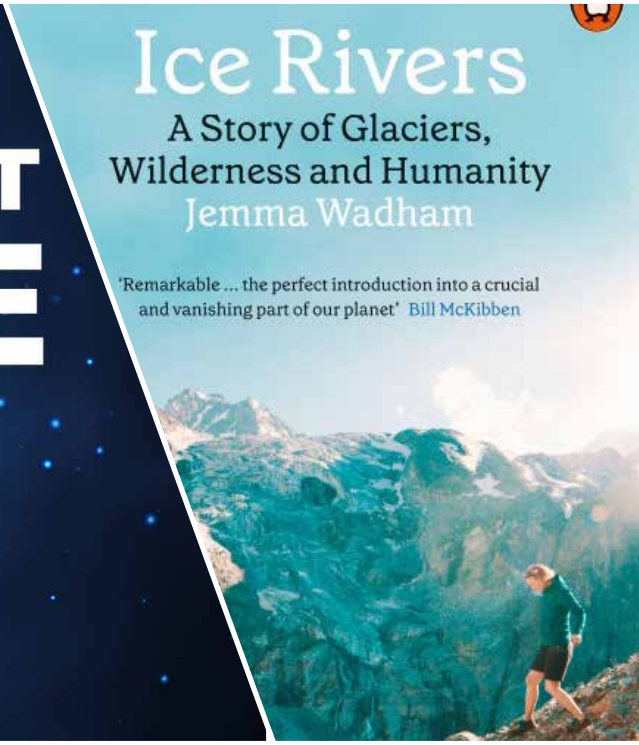
Friedrich, J.
Seasonal variability of methane seep distribution and intensity offshore western Svalbard at the edge and outside the gas hydrate stability zone
Supervised by: Benedicte Ferre, Krastel, S. 68 pages

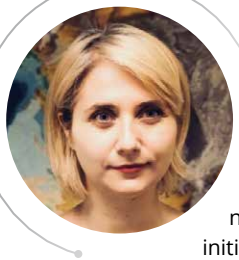
Nguyen, H.
Gas seeps in the Barents Sea – how does the geology influence the natural and well related seeps?
Supervised by: Laberg, JS., Jensen, AF., co-supervisors: Knutsen, S-M., Mattingsdal, R., Serov, P.


ICE ON FIRE


United Nations
Climate Change


LET'S TALK ABOUT
METHANE
CAGE
Norwegian Centre of Excellence
The Research Council of Norway
NORGES ARKTISKE UNIVERSITET
UIT
18 58
GEOLOGICAL SURVEY OF NORWAY
NGU


Ice Rivers
A Story of Glaciers, Wilderness and Humanity
Jemma Wadham
'Remarkable ... the perfect introduction into a crucial and vanishing part of our planet' Bill McKibben



Maja Sojtaric,
Communications Advisor to May

After many impressive years of leading numerous communication and outreach initiatives, Maja left CAGE for new ventures on the 31st May 2021.

Mariana Esteves,
Communications Advisor from April

Mariana began working alongside Maja on 1st April 2021, prior to taking over Maja's position on the 1st October 2021. Mariana writes the press releases, manages CAGE social media, and leads the organisation of workshops and conferences.

Outreach, still in a pandemic

Just as in 2020, Covid-19 related science news remained dominant globally in the first half of 2021. However, as the vaccination numbers increased, corona restrictions eased, and the Intergovernmental Panel on Climate Change (IPCC) 6th assessment report was announced, news quickly returned to climate-related topics on media outlets. Throughout this year, we have managed to increase the level of activity, and the amount of impact has been within CAGE's own targets for achievements. Here are some examples.

CAGE public engagement

Ice Rivers

Professor Jemma Wadham published 'Ice Rivers – A story of glaciers, wilderness and people, histories entwined, at a moment when their relational is about to change forever', a captivating story about the state of the glaciers in a warming climate, and a recollection of her own life and relationship with glaciers. Ice Rivers, released by Penguin on May 6th, has received a lot of attention from international news outlets, including articles written by Professor Wadham in Vogue and New Scientist, and a podcast in The Guardian. Ice Rivers was also profiled in The Independent and Sunday Times.

Dagbladet Interview

Professor Karin Andreassen was interviewed by Dagbladet to comment the impact methane leakage could have on the global climate, following an article published on PNAS by Swedish researchers regarding a large reservoir of methane gas under the seabed in the Laptev Sea. Dagbladet is one of Norway's largest tabloids and have over 1 million daily readers.

Ice on Fire

In the late summer, the Faculty of Science and Technology (UiT) organised a naturvitenskapelig filmkveld (scientific film evening) at a local Tromsø cinema, Verdensteatret, and showed 'Ice on Fire' – an eye-opening documentary that focuses on the cutting-edge research driving today's climate science. This documentary, released in 2019, was produced and narrated by Leonardo DiCaprio, and includes scientists from CAGE/UiT. CAGE Researcher Pavel Serov, one of the scientists interviewed in this documentary, was therefore invited to give a keynote presentation on methane and climate change before the showing of 'Ice on fire' at the naturvitenskapelig filmkveld.

COP26 Summit

The COP26 UN Climate Change Conference in Glasgow united world leaders and chief executives from industry and business. Here, critical policy decisions were discussed to accelerate action towards the goals of the Paris Agreement and the UN Framework Convention on Climate change. Professor Alun Hubbard was invited to the COP26 Climate Summit inner "blue zone" to engage with politicians, industry leaders and policy decision makers, and to present his research. Professor Hubbard gave three keynote talks and multiple interviews. These presentations were live-streamed, televised and his research was further showcased in a documentary "A Seat at the Table", which features key young influencers and Sir David Attenborough.

Both digital and physical events

Gender Awareness Week

To mark the International Women's Day (8th March) during the Gender Awareness Week, communications advisor Maja Sojtaric and CAGE PhD candidate (now researcher) Naima El bani Altuna, organised for Anna Wahl to give lecture on the 'Power relations and lack of gender balance in academic. What are the challenges and how do we react?'. This event was arranged by CAGE in close collaboration with JEDI. The lecture was followed by a panel discussion with Anna Wahl, Associate Professor Meline Duarte and Professor Kenneth Ruud from the PRESTIGE project at UiT.

The first physical CAGE social in over a year

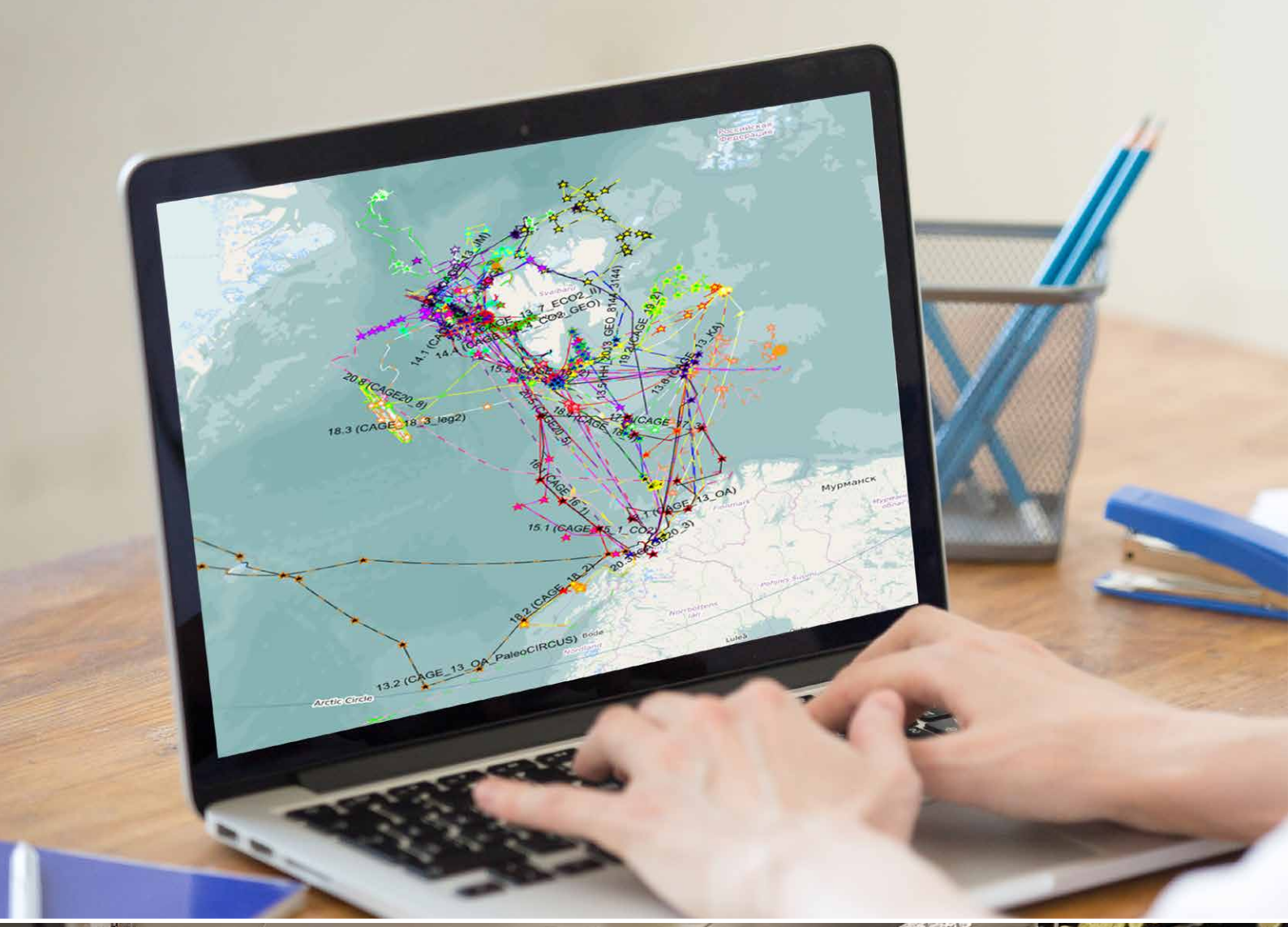
After a year of Covid-19 related restrictions and postponed or cancelled CAGE social events and seminars, CAGE scientists were finally able to gather for a summer social at Charlottenlund when the restrictions eased here in Tromsø. This was a great opportunity to network with our colleagues and play some team building games before a busy summer of research cruises began.

Ongoing outreach project

"Let's talk about methane" Animation

The outreach project, "Let's talk about methane" is a short animation aimed at people of all ages. This animation walks you through the link between ice sheets and gas hydrates, and the significance of methane to the global climate. The concept for this project was initiated in early 2021, by Maja Sojtaric, Karin Andreassen, and Monica Winsborrow. Together with Monte Video – a Tromsø based film and animation agency, and Alice Kvalvik – a Tromsø based graphic designer and illustrator, the design, template and script was put together. In April/May 2021, Mariana Esteves took over this project from Maja Sojtaric, and together with Karin Andreassen and Monica Winsborrow, the animation was completed. The final version of this animation will be available for viewing and use in presentations and outreach events, from Spring 2022. Stay tuned.

CAGE Researcher Pavel Serov during the naturvitenskapelig filmkveld. Photo: Malin Waage | Professor Alun Hubbard gave multiple keynote talks and interviews on glaciers and ice sheets during the COP26 Climate Summit. Photo: Alun Hubbard. | New animation to discuss the link between methane and ice sheets. Photo: Mariana Esteves. | Ice Rivers was published by Penguin on May 6th. Photo: Jemma Wadham | CAGE was finally able to have a social as corona restrictions eased before the summer. Photo: Lone Smelror.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Arctic Circle

Fabio Sarti, *Database manager*

Fabio is the centre's database manager and is responsible for data storage, reporting of scientific results, and statistics.

Ensuring the CAGE legacy

CAGE works continuously to ensure that our data and results are as accessible as possible. Since 2013, our website has acted as a portal to our publications and data repositories. However, as CAGE approaches its final year, it is essential to archive key reports and main results in an open access report series to ensure visibility for many more years to come.

The CAGE Database

The CAGE database plays an important role in our open data strategy. It is the bridge between the scientific community, the public, and CAGE. Using a user-friendly platform with an interactive map, this database is easily navigable and provides access to all information about CAGE cruises and links to publications derived from these data. In addition, the online map shows the ship tracks, sample locations, representative images and photos, and tables with relevant further information regarding, for example, sample analyses and data processing, as well as chief scientist name and contact information, for each cruise. All the raw data from CAGE is archived in the UiT storage facility run by the IT department, ensuring data integrity. The database manager for CAGE, Fabio Sarti, has continued to regularly monitor and record new publications and datasets, to ensure that this database and site is up-to-date and available to all interested users.

Septentrio Academic Publishing

As CAGE approaches its final year, there have been numerous discussions between the UiT library and the database manager and CAGE communication advisor Mariana Esteves, regarding how to archive and establish a report series that can act as an archive for all CAGE reports and main results. The solution: Septentrio Academic Publishing, an Open Access publishing service at the University Library of Tromsø. In this report series there will be a collection of reports and main results from 2013 to 2023, including annual reports, cruise reports, scientific publications, theses, and science communication articles. The Centre for Arctic Gas Hydrate, Environment and Climate Report Series will remain active, citable, and reusable beyond the end of CAGE, safeguarding the CAGE legacy.

Publications and statistics

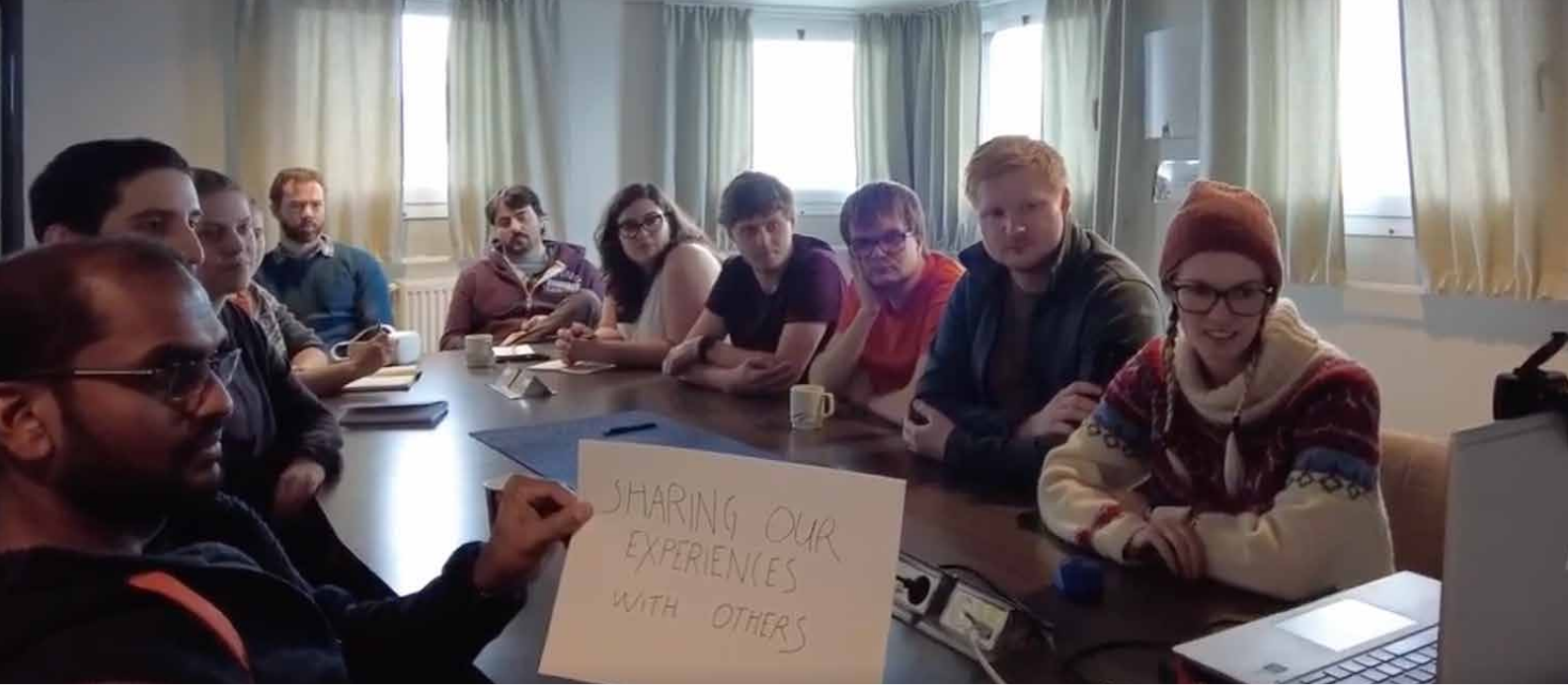
Reports and statistics, often utilized to celebrate achievements or merely to quantify results, have been an important asset for the Centre throughout the years: they are food for thought about compliancy, quality, impact of the Centre's output in terms of publications. This is the reason why key metrics like self-archiving, Open Access, Open Research Data and media attention are continuously monitored, recorded and available, becoming a valuable treasure of information and enriching the ability to describe and improve the Centre's results.

Sediment Core Repository

The sediment core repository for CAGE and the Department of Geosciences (IG) has been managed by Sarti since 2017. Last year the global pandemic did not stop the Centre's scientific expeditions, but it did hinder planned activities to organise the sediment core repository. A backlog of cores was created due to this, as cruise after cruise they were not able to be stored correctly. Sarti has now been able to organise these, and added the new cores to the database, which now stores almost 10,000 items. The core repository is organised in an efficient manner: traceability of specific core and sample is guaranteed, extended set of information describe every item stored, a dedicated online map provide access to those precious data.

The sediment core repository through the different stages of the post-cruise organisation. Photo: Fabio Sarti.

Screen shot of the CAGE database. Photo: Fabio Sarti.



AKMA cruise Participants. Photo: Giuliana Panieri

AKMA cruise blog

Reflections of a project leader and co-chief scientist for the AKMA cruise

I had never really thought about writing a blog before, but as I am on-board of a near-ending cruise and am in the middle of writing a report for summarizing this cruise, I realize how much this cruise has been valuable under many prospects, not only as a scientist and a teacher, but also as a person. So, I decided to write this blog, and explain to you all the many great experiences, emotions and feelings that this cruise brought me.

Text and photos: Giuliana Panieri, AKMA (Advancing Knowledge of Methane in the Arctic) project leader and co-chief scientist of the AKMA cruise.

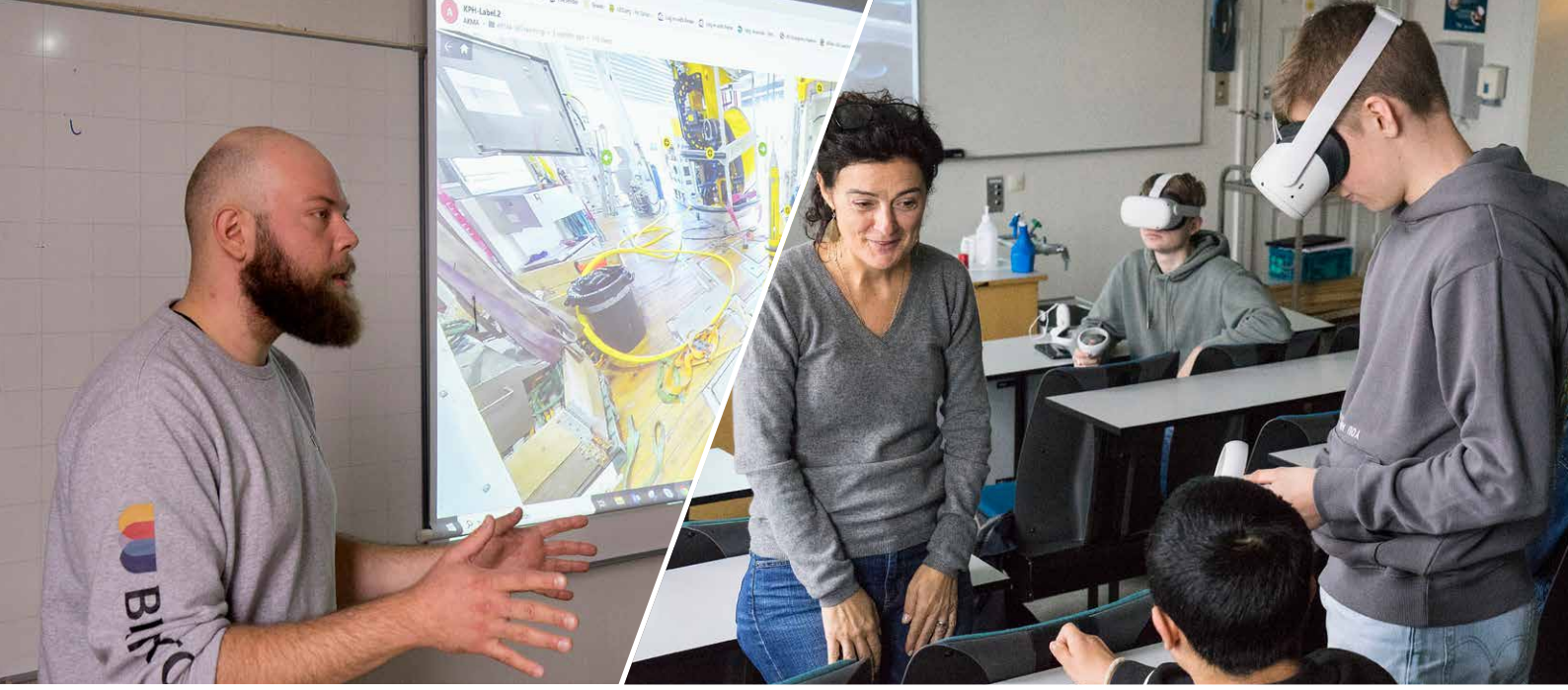
June 2021

The AKMA project had a rough start, it was granted by the Norwegian Research Council at the beginning of 2019, and with the partners (WHOI, Woods Hole Oceanographic Institution) we began discussing and planning the course and the cruise we wanted to develop for the students. Our ultimate goal was to develop a course that would focus on a multitude of aspects related to methane in the Arctic. Little did we know that our newborn project would be completely halted by a global pandemic. We all remember March 2020, and one thing I clearly remember was in fact one of the first meetings we were having to plan this cruise. All of a sudden, all of the participants of the meeting (which were all gathered in an actual physical room with walls at the time, not a virtual room like on Zoom) were basically kicked out of the department because everything was starting to close down.

This is why I say that the project had a rough start, but this rough start gave it tough skin and resilience. Although this pandemic made us distance ourselves from each other, I believe that it also brought people closer. I started thinking about ways in which, with our science, we could touch a broad audience to inspire and share knowledge in these times of darkness and uncertainty. From colleagues and scientists to adolescents. So, me and the team had to think differently than usual, we had to think creatively and diversely because we would not give up and we accepted the challenge. These challenges had to be transformed into solutions and we came up with ideas that were developed through a Polaroid project, a virtual cruise, a short video to inform people about our work and we established social media platforms for our project. And finally, during May and June of 2021 we were given the green flag to have our AKMA expedition in the Arctic Ocean and in the Barents Sea.

We involved all the colleagues that could not join from the U.S., hosting them every evening on Zoom calls, we shared our discoveries and daily experience on social media and on video calls, which we had with our younger audience from all over Europe. I am not going lie, I was quite skeptical about the social media aspect of the project, until one of my colleagues told me something beautiful: "for the first time my family sees what I am doing at sea looking at the live video feed from the ROV, and they are asking questions... this is the first time they really understand what my work is". Our jobs are not easy, and what we do is not simple to explain. But via social media we were finally able to truly show everyone back home what it is that we really do on our cold days in the middle of the Arctic Ocean miles and miles away from land.

Although this is a big part of my job, I can tell you that being at sea is not always easy… Seasickness and being homesick become your best friends, but this time, my best friends changed. I was thrilled by the enthusiasm and curiosity of the students, their drive to learn and their thousands of questions made it such a remarkable experience! This happiness of mine was not only limited to the students, but equally to the professional and friendly behaviors of my colleagues on-board, the availability from the colleagues ashore, the support from my university and the many EGU friends and volunteers, and lastly the crew: all those women and men that spend their days at sea, navigating in the waters of the unknown, science and knowledge always seeking, imagining and with an open mind, always learning.



Exploring the Kronprins Haakon with virtual reality at Kongsbakken Skole in Tromsø. Photo: Kai Mortensen

AKMA Project: Activities towards education

The AKMA (Advancing Knowledge on Methane in the Arctic) project, led by Professor Giuliana Panieri, received funding in 2019 for three years by The Research Council of Norway.

AKMA aims to advance the collective knowledge surrounding methane activity in the ocean in Arctic Regions, and it is a collaborative project between the Centre for Arctic Gas Hydrate, Environment and Climate in Tromsø Norway and Woods Hole Oceanographic Institution (WHOI) in Massachusetts USA.

Polaroid project

High school students in France, Italy, and Norway, received handwritten letters and polaroid photo albums created by early career scientists in AKMA during the 2021 expedition. The Polaroid project is part of a broader goal to connect students from around the world with scientists in AKMA.

During the first phase of the AKMA project, the team designed teaching materials for the teachers involved in the Polaroid project, and discussed with the teachers and students discussed about the research process and how research ships are used in search of answers to important scientific questions. The students were tasked with writing by hand questions to their dedicated scientist to find out more about them, their science and the AKMA research expedition. Once the scientists received these questions, they set about answering the students with another hand-written letter. This turned out to be long task since the students had written many interesting questions and there was a lot to describe and tell.

Following this, the scientists went on the research expedition in May 2021 on board of RV Kronprins Håkon. Amongst all the scientific equipment, they also had a polaroid camera each and a stack of negatives. They made wonderful photo albums about their experiences onboard and described what was happening. At the end of the expedition, each of the schools involved received the photo album from the scientists that were connected to them.

At the end of this initiative, we asked the students/teachers/scientists to evaluate the Polaroid project to see if these "retro" communications methods helped to create a meaningful and more personal dialogue. The evaluations showed that many of the students clearly enjoyed connecting with scientists using hand-written letters, Polaroid photo albums, and a final face-to-face meeting.

Virtual cruise

The AKMA project believes that access to learning, knowledge and experiences is a critical part of efforts to understand and protect the Arctic environment. A lot of Arctic research is based on research vessels, which can be cost prohibitive and not always accessible for example to impaired students. Therefore, we want to make our expeditions available to everyone who might otherwise not be able to experience being on a research vessel in the Arctic. To this end, AKMA has developed a virtual reality expedition, which enables people to jump aboard and see what we do.

Forskningsdagene

Forksningsdagene, or Research Days, is an annual event in Norway where all types of research-based institutions are invited to present their activities to the public. Forskningsdagene began in 1995, to create enthusiasm for research and to convey what research is and what research results mean in our daily lives. This year, AKMA's Giuliana Panieri, Matteus Lindgren and PhD Candidate Maximillian Weber participated in the 'Order a Researcher' portion of Forskningsdagene - where researchers offer availability to visit a classroom or company to talk about their research. Giuliana Max and Matteus offered a virtual expedition aboard the Research Vessel Kronprins Haakon.

Connection to schools

During the AKMA Expedition, we were able to connect to people onshore and share our experiences while onboard the research vessel Kronprins Haakon. In conjunction with the Polaroid Project, we connected digitally with schools in Italy, France and Norway to share our experiences at sea. The topics that we discussed with the classes ranged from the food onboard, to our scientific fields of research, to broader questions about science and society. After the expedition, AKMA early career researchers were also able to visit the schools in person.

We also connected from the research vessel with the Department of Geoscience at the University of Tromsø, the Centre for Gas Hydrate, Environment and Climate, and we gave a presentation for CHESS - Research School on changing climates in the coupled earth system.

During all the ship-shore connections, we were able to display a live feed of the scientific instrumentation, in particular the camera feed from the ROV Ægir when it was on the seafloor.

HACON21 Cruise participants on the sea ice. Photo: Lawrence Hislop. Department of Geosciences PhD Candidate Christine Tømmervik Kollsgård taking an air sample. Photo: Henry Patton

Using interactive maps for cruise blogs

HACON21

The HACON21 (Hot Vents in an Ice-Covered Ocean) cruise, led by Stefan Bünz (CAGE) and Eva Ramirez-Llodra (Norwegian Institute for Water Research - NIVA), visited the Aurora Hydrothermal Vents and used an ROV (Remotely Operated Vehicle) for the first time. Many CAGE scientists, including Kate Waghorn and Claudio Argentino, Frank Jakobsen, and Marie Stetzler, and Stefan Bünz, contributed to the cruise blog.

Saturday, Oct 23:

One of your finest bottles, please.

Marie Stetzler, PhD candidate

When I filled out paperwork to get my precious samples shipped back from the harbor of Longyearbyen to Tromsø, I had to give an estimate of their value.

"Invaluable!" was my first thought.

I wrote some steep numbers down and thought of the border officer's surprise when they read that the shipment contained merely vials of… seawater.

This water is more special than the finest of Bordeauxs: coming from directly above the Aurora vents, under the ice.

My CAGE (UiT) team aim to understand how nutrients and carbon compounds necessary for microbial life are distributed in the water column and how hydrothermal fluid affects this distribution. For this, we need special sampling bottles, called Niskin bottles, mounted on a frame with a Conductivity (for salinity)-Temperature-Depth sensor. Together, these apparatuses form the CTD rosette, which gives us both the physical properties of the water column and the ability to sample water at various depths.

Special situations, such as ice cover, require special means. In this case, ROV Aurora lent me a hand underwater to sample the dark hydrothermal plume into a Niskin bottle a couple of meters above the vent, at 3800m depth. This bottle turned out to be one of my finest!

Sunday, Oct 24:

A tribute to a team

Stefan Bünz, Professor, Cruise Leader

This expedition started two years ago after the first HACON cruise in 2019. We recognized what we could do on the Aurora Vent site, but technical challenges resulted in unfulfilled sampling needs. What followed were two years of great uncertainty and numerous challenges. Yet here we are, a team bonded by that experience and with great mutual support. A group of intelligent, skilled, passionate and motivated people worked together to achieve something nobody had done before.

When we sailed out on 30th September, everyone was well aware of the challenges that lay ahead. Accessing and sampling an area the size of a few ping pong tables in the vastness of the Arctic Ocean at 4000 m water depth under the ice is no small feat. The ethereal beauty of the ice in the Arctic Ocean is breathtaking, yet it influenced and dictated our every move on an hourly basis. Getting the vessel back in a good position required patience and persistence. The officers on the bridge were tirelessly working the ice. Their endurance and perseverance cannot be understated.

It took great patience, understanding and flexibility from a team of ROV pilots who were of utmost crucial to the success of this expedition. Adept and skilful in collecting samples at the bottom of the Arctic Ocean, they also were calm as the sea ice, in which they were locked in. It appeared like our results were never in doubt.

Every member on board this expedition is excellent on their own; together, they are exceptional. It was truly an honor to lead a team of individuals greater than the sum of their parts

and work well together to accomplish something remarkable.

This voyage is a historic achievement that will last in our memory forever, especially for the outstanding teamwork and fantastic atmosphere. Collaborations and friendships are ongoing or just beginning, and we've learned a lot about ourselves and others while on this journey. Looking at the wonderful photos from our expedition will always put a smile on our faces.

CAGE21-6 Cruise

The CAGE21-6 Cruise, led by Monica Winsborrow and Jochen Knies, visited the Hjopendjupet Seepage area. For the first time, an ROV was used to survey the hydrocarbon leakage in this area. Contributions to the cruise blog include posts from CAGE employees Henry Patton, Vincent Carrier, Marie Stetzler, Mauro Pau, Monica Winsborrow and Mariana Esteves.

Friday 10th December:

Looking for a needle in a haystack

Vincent Carrier, Researcher

Microbes are ubiquitous on Earth: they are inside of you, on you, in your room and every time you swim you touch simultaneously thousands of them at the same time. On the picture above is one of the sediment core the microbiologists onboard has been taken. Only the microbes at the very thin surface of this core likely outnumber largely the entire population of Norway! Yet in seeping areas such as Hopendjupet we are particularly interested in a selection of them. So how do we find so tiny living organisms in a world filled with them?

Microbiologists rely on two key elements:
1) A multi-disciplinary team composed of geologists, oceanographers, and/or geochemists that combine efforts with microbiologists to find clues where these microbes are active: changes in chemical composition, the proximity of hydrocarbon-rich sediments, water mass movements. On this cruise, the microbiology team is recovering several tens samples, and analyzing all of them would be time and financially costly. Thereby, they are working closely with geochemists to determine changes in porewater chemistry, offering clues on which environmental samples to further process.

2) A large diversity of methods where there is one for each different question to be answered. From microscopy to molecular tools, microbiologists are equipped to determine an exhaustive description of environmental microbial community composition, functions, metabolism, trophic relationships, etc. On this cruise, microbiologists are especially interested in identifying microbial community composition (which microbes are there and how many of them?) and which ones are the most active. Therefore, sediment and water column samples have been taken and subsampled, stored onboard in very cold freezers (down to -80°C) to limit damages to DNA and RNA. Onshore, protocols are followed to extract these and will subsequently be sent for genetic analyses.

Microbes are fascinating! Near the surface they help us breath oxygen and down in the sediments they mitigate climate change by oxidizing vast quantities of methane escaping the seafloor. They are our tiny Avengers!

Friday 10th December:

Arctic sources of greenhouse gases

Henry Patton, Researcher

CO_2 emissions often dominate the climate discussion. Yet methane is an even more potent greenhouse gas, with a global warming potential 84 times greater than CO_2 over a 20-year time frame, and could make or break any actions to curb climate change over the coming decades. An important objective of this cruise therefore is to understand just how much of the methane we see naturally leaking from the Barents Sea floor can traverse through the ~340-m thick water column and into the atmosphere.

Through a collaboration with NILU (the Norwegian Institute for Air Research) we have been provided with numerous bulbous cannisters with which to collect air samples during this cruise. The process is quick, and with a quick turn of some screws Monica and Christine (pictured) are able to let the vacuum sealed spheres suck in some air within a matter of seconds. To avoid any possible contamination with fumes coming from the ship, we have been collecting these samples from the ship's bow while its nose points into the wind.

With the screws tightened again these air samples will be analysed later in the lab back onshore, where we hope to find out just how well the ocean can buffer this leakage, and how varied the methane concentrations are across this Arctic setting.

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Plaza-Faverola, A., Schlindwein, V., Domel, P., Schmidt-Aursch, M., Cooke, F. A., Holm, T., Jensen, S. Cruise Report. *Cage21-3 Ocean bottom seismics and acoustic surveys on the West-Svalbard margin – a study of local seismicity and its effect on methane seepage.* (2021). 42 pages. https://cage.uit.no/wp-content/uploads/2021/08/cage21-3-hh-cruisereport-cage.pdf

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Plaza-Faverola, A. Cruise Report. *CAGE21-5 Cruise Report. Test of offshore instrumentation for in-situ sediment pressure measurements, west-Svalbard continental margin.* (2021). 11 pages. https://cage.uit.no/wp-content/uploads/2021/11/cage21-5-cruise-report.pdf

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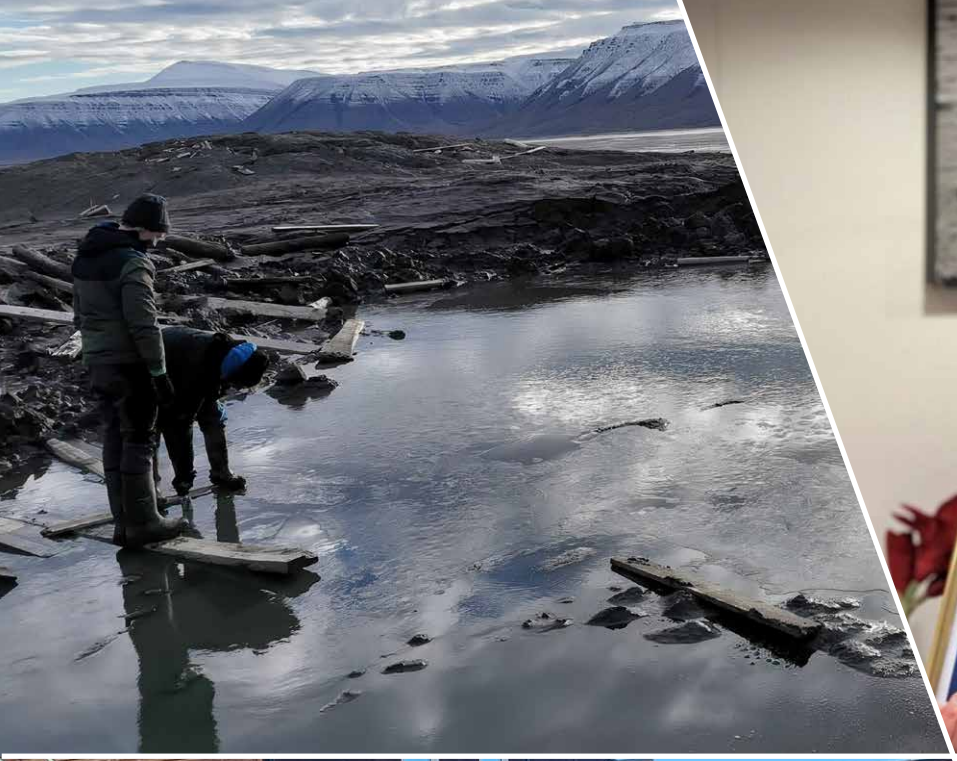
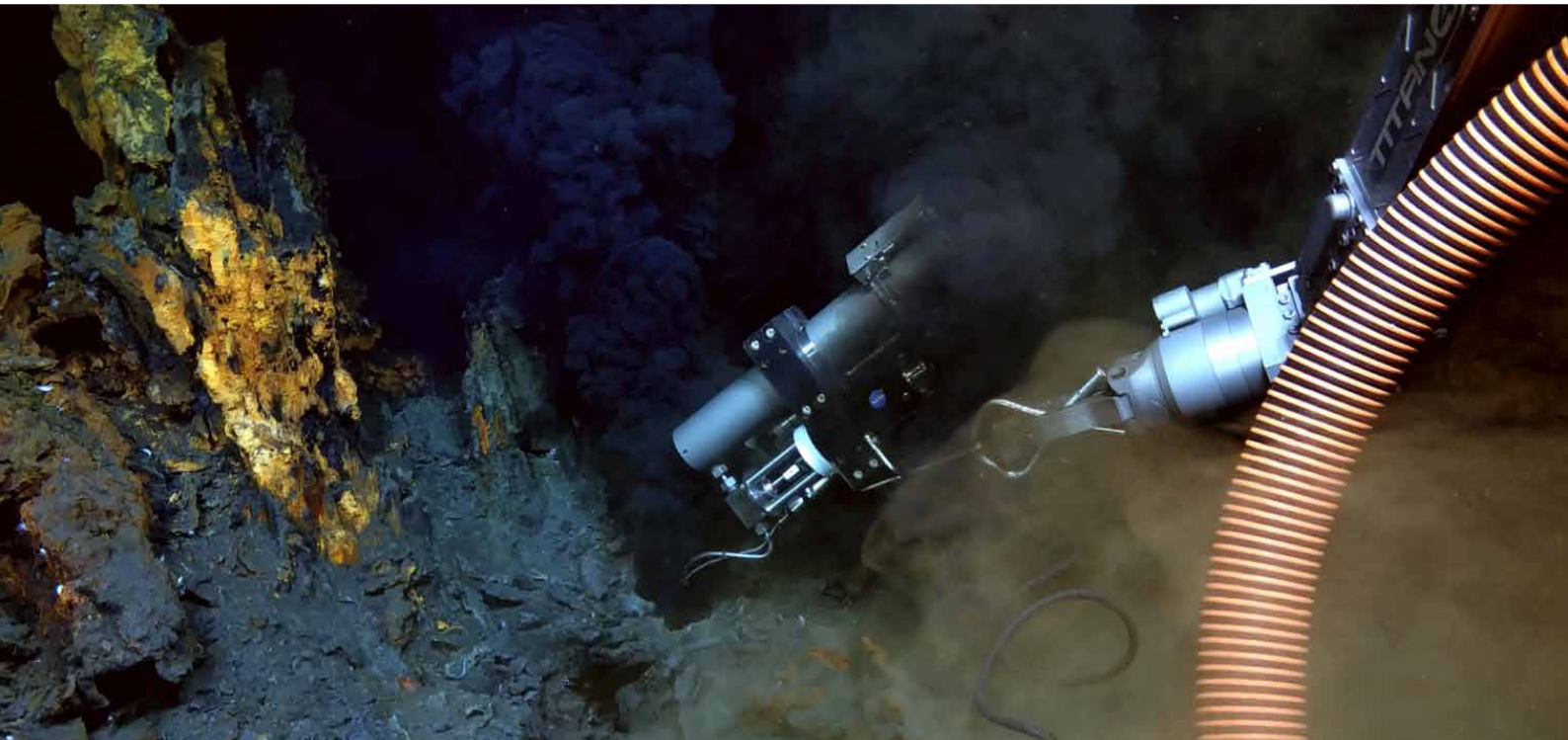



Brøggerprisen
2021
Karin Andreassen
GEOLOGISK



The year in short: 2021

Karin Andreassen awarded Brøggerprisen by Norsk Geologisk Forening (NGF's Honorary Prize)

The Brøgger Award, established in 2002 by The Norwegian Geological Society and named after the Norwegian Geologist W.C. Brøgger, is given to a scientist who has contributed in a unique way to the understanding of geoscience. During the Society's annual winter conference in January 2021, Professor Karin Andreassen was honoured with this prestigious award. The award committee highlighted that Professor Andreassen has throughout her career distinguished herself at a high professional level in Norwegian Polar Research and made pioneering contributions to our understanding of glacial tectonics, seabed morphology, and rapid fluid migrations along the Norwegian continental shelf.

EMAN7 project kick-off

The EMAN7 (Environmental impact of Methane seepage and sub-seabed characterization at LoVe-Node 7) is a multi-disciplinary project, led by Bénédicte Ferré, that officially started in June with a kick-off meeting. EMAN7 project aims to understand the environmental impact of methane seepage from the sea floor in the Lofoten-Vesterålen area in Norway.

French ambassador visits CAGE to learn about methane hydrates in the Arctic

With the aim to better understand maritime and polar issues, French Ambassador, Olivier Poivre D'Arvor, embarked on a journey through Longyearbyen, Ny Alesund, and Tromsø, to meet and discuss these topics with scientists, politicians, and explorers. Activities at CAGE were of particular interest for the French Ambassadors agenda during the visit in Tromsø. Bénédicte Ferré, team leader for the research group Gas in the Water Column, met with the ambassador and presented CAGE and work package activities, highlighting the importance of improving our understanding of methane hydrates in the Arctic.

ARCLIM project sets up Culturing Lab

The ARCLIM (Arctic Ocean under warm climates) project led by Mohamed Ezat has built a culturing lab for planktic foraminifera using incubators with photoperiodic and temperature control. This lab is designed to establish robust methods for reconstructing past ocean changes in the polar regions as well as to study the response of polar planktic foraminifera growth and calcification to ongoing climate and ocean changes.

Dimitri Kalenitchenko awarded 8 million NOK of funding for METHANICE

The METHANICE (Methanotrophic communities in ice) project, led by Dimitri Kalenitchenko, was funded for four years through the Researcher Project for Young Talent from the Research Council of Norway. This multidisciplinary project will identify the role of methane consuming microorganisms associated with arctic terrestrial seasonal ice.

Opening new frontiers in deep sea exploration and sampling

The first-ever remotely operated vehicle (ROV) dive on Arctic Hydrothermal vents under permanent sea ice was conducted during the HACON21 expedition, which was led by CAGE (UiT) and NIVA (Norsk institutt for vannforskning). The expedition brought together a diverse multi-national and interdisciplinary team of scientists that worked together to comprehensively survey and sample the remote Aurora Hydrothermal Vent systems for the first time.

An Autumn filled with PhD defenses

As corona restrictions began to ease in 2021, four PhD candidates were able to defend their PhD during hybrid public defenses. This year, three of the team members from WP6 and one from WP3 have completed their PhD. This included: 1) Naima El bani Altuna who defended her PhD thesis entitled, 'Millennial-scale variability of Atlantic water inflow in the northern Nordic Seas and the northwestern Barents Sea – Relationship to abrupt climate oscillations, cryosphere and methane seepage from the seafloor' on September 17th 2021; 2) Katarzyna Melaniuk who defended her PhD thesis entitled, 'Assessing the relationship between living benthic foraminifera and methane emission in the Arctic Ocean' on November 4th 2021; 3) Vincent Carrier who defended his PhD thesis entitled, 'Microbial community structure associated to Arctic cold seeps' on November 29th 2021; and 4) Siri Ofstad who defended her PhD thesis entitled, 'Arctic planktonic calcifiers in a changing ocean – A study on recent planktonic foraminifera and shelled pteropods in the Fram Strait-Barents Sea region' on December 16th 2021. All of the PhD theses mentioned here can be read via the UiT The Arctic University of Norway's open repository Munin.

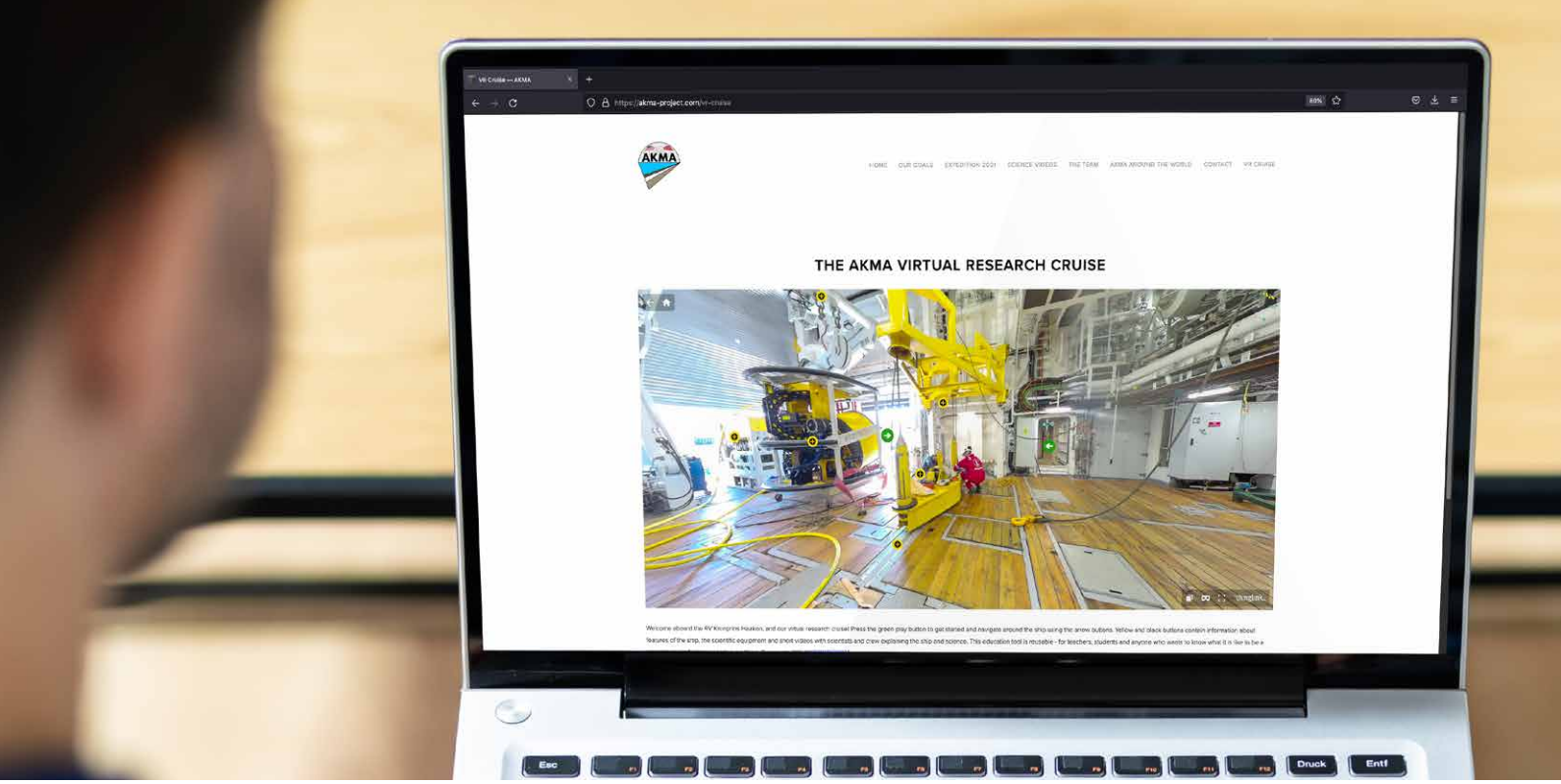
Dimitri Kalenitchenko and a colleague investigating methane seeping activity at a terrestrial pingo on Svalbard. Photo: Vincent Carrier

Professor Karin Andreassen is the second woman to receive this lifetime achievement award. Photo: Maja Sojtaric

Remi Lafaye, Jérôme Chappellaz, Bénédicte Ferré, Olivier Poivre D'Arvor, Laurence Frémion. Photo: Bénédicte Ferré.

A planktic foraminifer collected from the Greenland Sea for culturing. The thinner and more transparent part has been grown under controlled conditions in the ARCLIM culturing lab. Photo: Adele Westgård.

Sampling at the Aurora Hydrothermal Vent field. Photo: HACON21 expedition.



The Virtual Research cruise can be easily accessed through the AKMA Project website. Photo: Andrey Popov, Mostphotos. The CAGE Crucial Cruise Tool Box. Photo: Matteus Lindgren.

The CAGE Toolbox: From birds-eye view to deep sediment imaging

Our success builds upon the integration of world-class empirical and numerical methods. These methods require development and clever implementation of innovative technologies - from drones to ice breakers.

The CAGE toolbox is used to find the controlling mechanisms for build-up and release of Arctic submarine gas hydrate systems, and how methane release from sub-seafloor reservoirs has influenced Arctic and global climate. This toolbox has already been applied in permanently ice-covered regions, and we are steadily approaching new discoveries on potential amplifiers for global change, including methane release from thawing submarine gas hydrates and diminishing sea ice.

Birds-eye view using drones

The Mavic 2 pro DJI drone (RO1 pilot License), equipped with a Sentera near - infrared (NIR) sensor is used to map sea ice and terrestrial methane seeps. One goal is to examine whether the red and NIR band can prove useful for mapping variations in ocean cover: from open water, to grease ice – thin, soupy layer of ice which makes the ocean surface resemble an oil slick; as well as from grey young ice to first and multi-year ice. The drone is also used to examine the terrestrial gas seep sites that we are exploring on Svalbard.

Streamer depth-steering system

CAGE recently expanded its capabilities for seismic acquisition by obtaining a streamer depth-steering system. These so–called streamer birds provide depth control for the 2D seismic streamer and allow us to extend its length resulting in bandwidth stability and higher fold improving S/N-ratio. CAGE seismic expeditions in 2020 used these streamer birds for the first time, allowing tripling the streamer length with significant improvements for seismic imaging quality.

Heat flow probe

Estimation of the thermal state of the lithosphere is one of the most challenging topics in Earth Sciences today. The heat flow probe, acquired in 2020 measures the geothermal gradient and thermal conductivity of the sediments. It will add significant value to our understanding of gas hydrate and fluid flow systems, and provide constraints for the numerical modelling. It was successfully used for the first time on a KPH cruise in 2020 for systematically measuring heat flux cross Vestnesa Ridge west of Svalbard.

Ocean observatories

The ocean observatories (K-Landers) developed in a collaboration between Kongsberg Maritime and CAGE were deployed and recovered five times offshore Svalbard and in the Barents Sea, providing unprecedented multi-sensor data on Arctic methane seepage and the physical and chemical properties of the ocean. These give us insights into the frequency of methane release and how this is influenced by ocean conditions, as well as on ocean acidification processes and trends.

CAGE video-camera system

CAGE developed a towed video-camera system through collaboration with WHOI (Woods Hole Oceanographic Institution). This digital imaging equipment provides real-time HD video and images of the seafloor, real-time digital depth and altitude, and allows visually guided water column (Niskin bottles) and sediment (multicores) sampling. In addition to dedicated digital imaging campaigns, the CAGE video-camera system plays a vital role in planning ROV operations. The system has been deployed at several methane leakage sites in the Barents Sea since 2017.

4D seismic using P-cable

CAGE uses UiT's national infrastructure P-cable high-resolution 3D seismic system, which CAGE scientists have been involved in developing. Studies of gas hydrates, shallow gas and geological structures in sediments near the seafloor are ideal targets for this system. By repeated P-cable data collection of the same study area over multiple years, we can monitor spatial

and temporal variations (4D) of fluid flow in the sediments. The unprecedented resolution of the P-cable seismic provides a unique opportunity to investigate the processes and drivers that regulate past and present gas hydrate, fluid flow systems and methane seepage.

National facility for stable isotope analyses

CAGE has established a stable isotope laboratory, equipped with a MAT 253 Isotope Ratio Mass Spectrometer. The laboratory is an integral part of our palaeoclimatic, oceanographic, geobiological and carbon cycling research, and is a part of the national infrastructure FARLAB (Norway's national facility for advanced isotopic research).

Fully automated palaeomagnetic laboratory

CAGE partner, the Norwegian Geological Survey (NGU), has installed a fully automated 2 G Cryogenic Magnetometer in Trondheim. This provides the ability to analyze changes in the polarity, intensity and direction of the geomagnetic field of the Earth over the past millions of years. It also provides a powerful means to trace variations in methane seepage in the sub-seafloor sediments over timescale of millions of years.

Numerical ice sheet modelling

Numerical modelling is a valuable tool that can be used to explore the role ice sheets have played in shaping and driving changes in the Arctic environment. CAGE developed a high-resolution, 3D reconstruction of the last 120.000 years of glacial cycles to have affected the Eurasian continent, constrained and tested against a variety of up-to-date empirical datasets. Data-rich outputs derived from these modelling experiments inform us how the ice sheet developed and impacted with its surroundings through time, including the evolving pattern of crustal warping, hydrological routing and storage, broad-scale climate distributions, subglacial temperature-pressure conditions and sea-level changes.

Numerical gas-hydrate modeling

CAGE developed an integrated gas hydrate stability model coupled with glacial (subglacial temperature-pressure conditions) and isostatic effects but also accounting for changes in sea-level, sedimentation, erosion and paleo temperatures in order to study the spatial and temporal dynamics, processes and feedbacks of gas hydrate systems and methane release in many of the seepage systems on the Barents-Svalbard Margin.

Research Vessels Kronprins Haakon and Helmer Hanssen

The ice-going research vessel Kronprins Haakon opends up new areas for CAGE in the ice-covered Arctic. Equipped with a moonpool and dynamic positioning, KPH is capable of deploying large equipments like ROV, AUV and seafloor rigs. The vessel is based in Tromsø, officially owned by the Norwegian Polar Institute, run by the Institute of Marine Research, and largely used by UiT. CAGE has already led several cruises using KPH for ROV operations, in-situ petrophysical measurements, and for exploring the ice-covered Arctic Ocean. More expeditions are planned for the coming years. UiT's RV Helmer Hanssen is regularly used to explore areas with less harsh ice conditions or areas where we are not in need of dynamic positioning.

ROV ÆGIR 6000 is a remotely operated vehicle (ROV). It is a national facility that is operated by the Norwegian Marine Robotics Laboratory (NORMAR) at the University of Bergen (UiB). An ROV is an unmanned submersible tethered to the ship through the moon pool. ÆGIR 6000 can cary coring devices, a gas sampler to catch gas bubbles, a water sampler to collect water, geochemical and oceanographic sensors or a multibeam system for cm-scale imaging of the ocean floor. CAGE use of Ægir has resulted in many interesting publications.

CAGE Crucial Cruise Tool Box (CAGECCTB) is a tool box with some basic tools often used on cruises, during sampling of sediment, water or gas. It is meant to be shared among all research groups at CAGE, and anyone in CAGE can bring it along for their cruise.

Virtual research cruise

When some of the participants for the first AKMA (Advancing Knowledge of Methane in the Arctic) cruise were unable to join the cruise due Covid-19 restrictions, the idea to develop a virtual research (VR) cruise was born. Students and researchers from AKMA project, CAGE and UiT worked together to film and create an educational tool that can be used by anyone who wants to know what it is like to be a scientist on an Arctic research expedition. The VR cruise on-board the R/V Kronprins Haakon can be explored both online through the web browser or with a virtual reality headset. A total of 10 virtual reality headsets are available for schools to borrow, and they have already ventured around Europe allowing students from several schools in Italy, Norway, and France explore the R/V Kronprins Haakon and virtual cruise. This is a unique experience for people of all ages, from school children to adults, to experience being on a research cruise and feel inspired for polar research.

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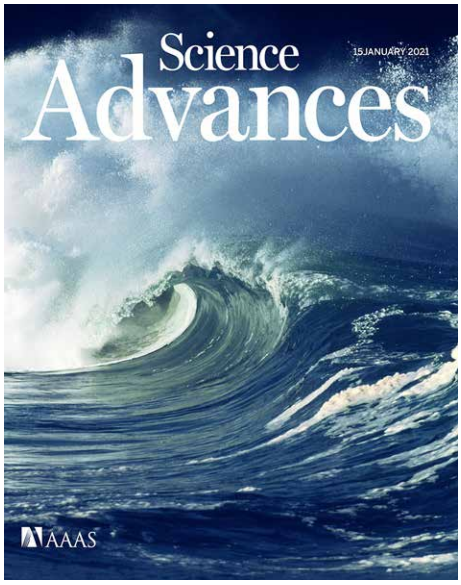

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Subject area, publications

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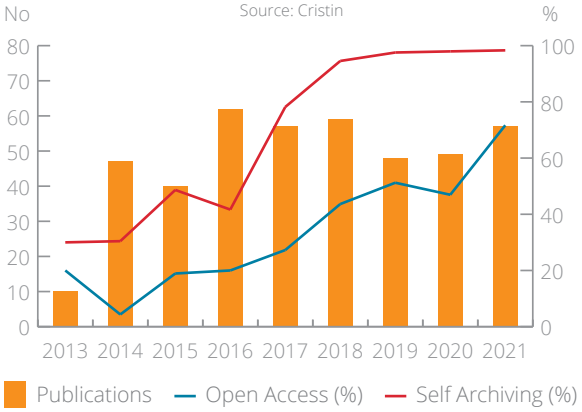
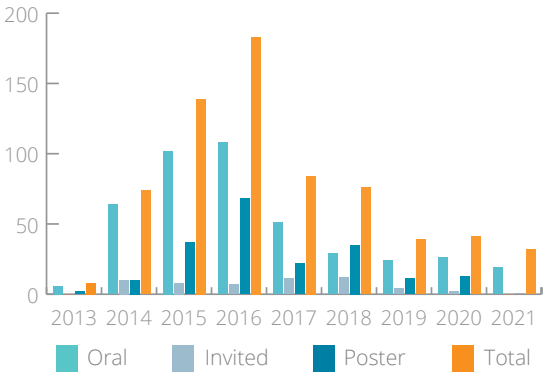


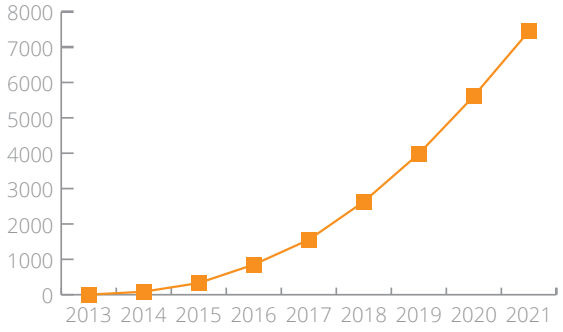
Presentations

Source: Cristin



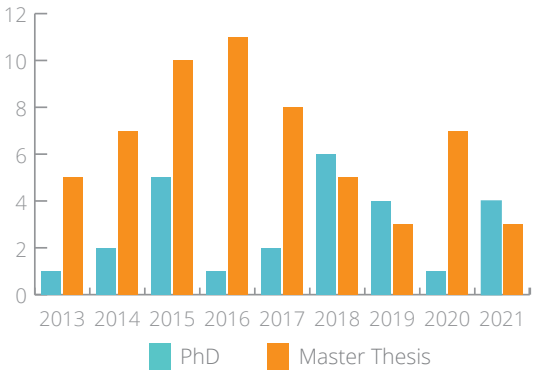
Citations

Source: Web of Science



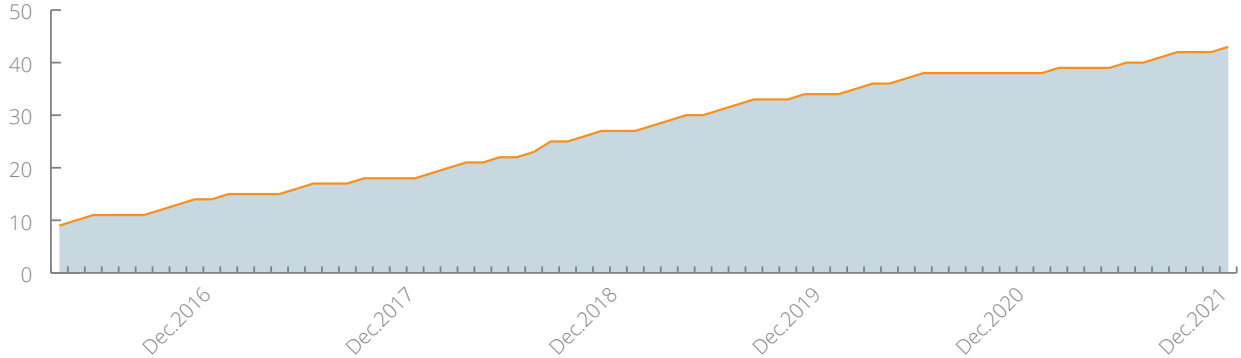
PhD and Master thesis

Source: Munin



H-Index

Source: Scopus

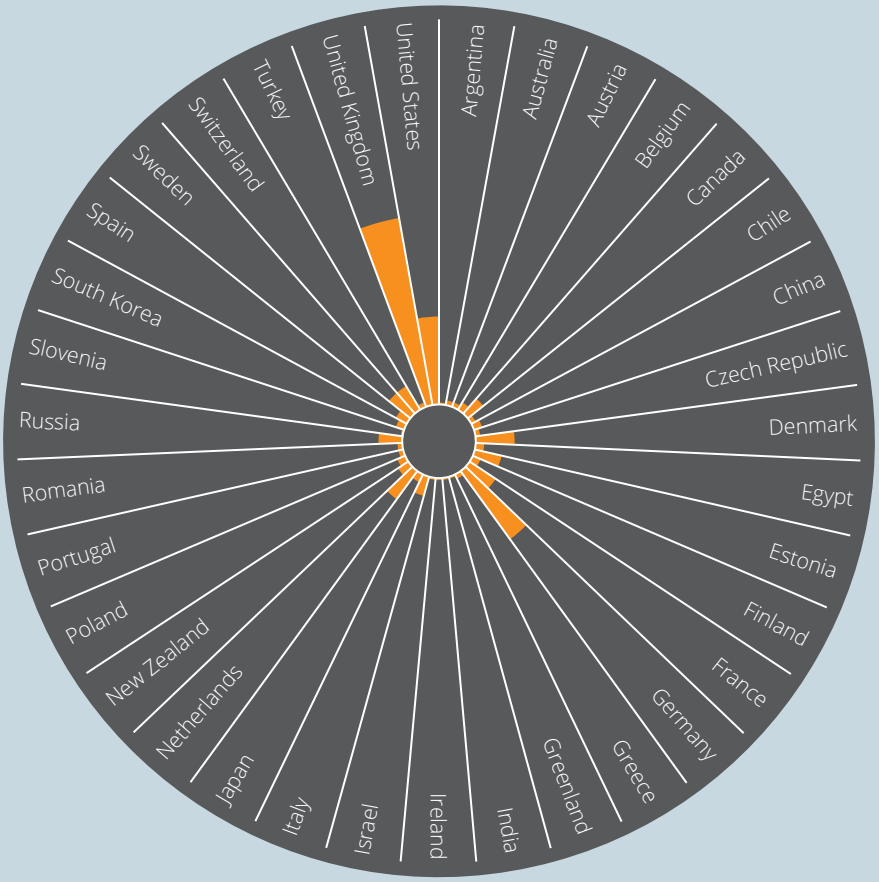


International collaboration 2013–2021

Our projects are connected with international scientific communities that are outlined as important collaborators by RCN and Norwegian Ministry of Foreign Affairs. We participate in EU projects and actions, as well as collaborate with institutions on other continents such as Woods Hole Oceanographic Institution in USA and NCAOR in India. In addition to that we collaborate on papers with relevant colleagues from all over the world.

International collaborations on publications
(2013 to present)

Source: Web of Science | Illustration: Torger Grytå; Julian P. Høgset

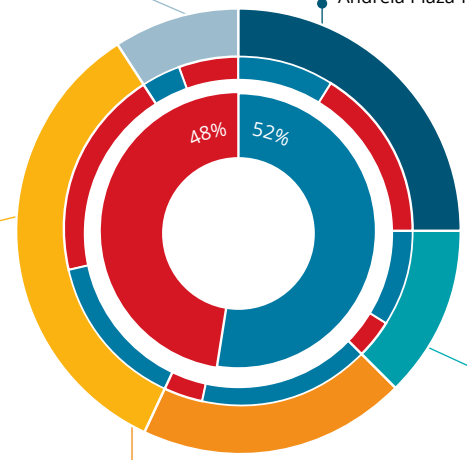


Full list of personnel at the centre

We constantly work towards gender equality within our staff. Not only is the centre director a woman, but 4 of 6 work package leaders are women, and 3 of 5 of the administrative/technical staff members are also women. Our overall staff numbers show that we place importance to the subject, with 52 % men and 48% women working for CAGE in 2021. This is 23 % above the average staff for women in STEM fields in OECD countries, and 20–30 % above the average in Norway. We also support young researchers – almost 50 % of our staff are PhD Candidates and Postdoctoral Researchers, where 43 % of these are women.

Adminstrative and technical staff:
Lone Smelror, Administrative coordinator
Maja Sojtaric, Senior Communications advisor
Mariana Esteves, Communications advisor
Fabio Sarti, Data base manager
Matteus Lindgren, Manager, Mass Spectrometer Laboratory

Senior Scientific staff
Karin Andreassen, Professor, Director CAGE
Stefan Bünz, Professor, Leader WP1
Monica Winsborrow, Associate Professor, Asst Director, & Leader WP2
Mette Mariannne Svenning, Professor, Leader WP3
Bénédicte Ferré, Researcher, Leader WP4
Jochen Knies, Researcher, Asst Director, Leader WP5
Tine Lander Rasmussen, Professor, Leader WP6
Giuliana Panieri, Professor
Alun Hubbard, Professor 50%
Renata Giulia Lucchi, Adjunct Professor
Helge Niemann, Adjunct Professor
Jemma Wadham, Professor
Jürgen Mienert, Professor Emeritus
Andreia Plaza-Faverola, Associate Professor

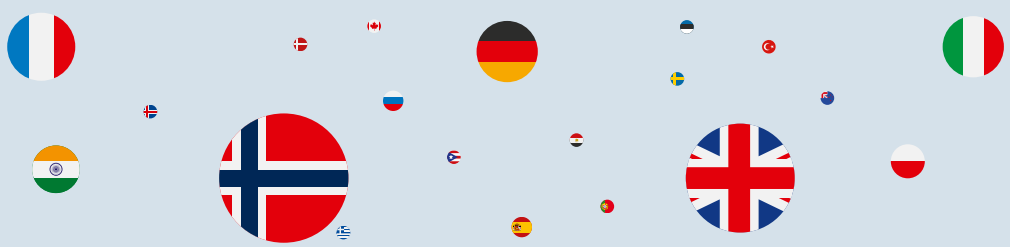


Researchers:
Mariana Esteves
Shyam Chand
Henry Patton
Anna Silyakova
Sunil Vadakkepuliyambatta
Mohamed Ezat
Aivo Lepland

PhD Candidates:
Nikolitsa Alexandropoulou
Vincent Carrier
Frances Ann Cooke
Przemyslaw Domel
Knut Ola Dølven
Naima El Bani Altuna
Craig Hammock
Katarzyna Melaniuk
Manuel Moser
Siri Ofstad
Griselda Anglada-Ortiz
Muhammed Fatih Sert
Cornelia Mentzoni Binde
Christine Lockwood-Ireland
Freya Sykes
Adele Westgård
Henrik H. Stokke
Frank Jakobsen
Marie Stetzler

Postdoctoral Researchers:
Pavel Serov
Claudio Argentino
Pierre-Antoine Dessandier
Dimitri Kalenitchenko
Hariharan Ramachandran
Remi Vachon
Malin Waage
Kate Waghorn
Sunny Singhroha
Thomas Ben Chalk
Mauro Pau

Personnel by country



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Director CAGE

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Thomas B. Chalk
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Shyam Chand
Researcher

Frances A. Cooke
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Pierre-Antoine Dessandier
Postdoctoral Researcher

Knut Ola Dølven
PhD Candidate

Przemyslaw Domel
PhD Candidate

Naima El Bani Altuna
PhD Candidate

Mariana Esteves
Communication advisor/
Researcher

Mohamed Ezat
Researcher

Bénédicte Ferré
Researcher
Leader WP4

Craig Hammock
PhD Candidate

Alun Hubbard
Professor 50%

Frank Jakobsen
PhD Candidate

Dimitri Kalenitchenko
Researcher

Jochen Knies
Researcher
Assistant Director
Leader WP5

Aivo Lepland
Researcher

Matteus Lindgren
Manager, Mass Spectrometer Laboratory

Christine Lockwood-Ireland
PhD Candidate

Renata Giulia Lucchi
Adjunct Professor

Katarzyna Melaniuk
PhD Candidate

Jürgen Mienert
Professor Emeritus

Manuel Moser
PhD Candidate

Helge Niemann
Adjunct Professor

Siri Ofstad
PhD Candidate

Griselda Anglada-Ortiz
PhD Candidate

Giuliana Panieri
Professor

Henry Patton
Researcher

Mauro Pau
Postdoctoral Researcher

Andreia Plaza-Faverola
Assoc. professor

Hariharan Ramachandran
Postdoctoral Researcher

Tine L. Rasmussen
Professor
Leader WP6

Fabio Sarti
Data base manager

Pavel Serov
Postdoctoral Researcher

Muhammed Fatih Sert
PhD Candidate

Anna Silyakova
Researcher

Sunny Singhroha
Postdoctoral Researcher

Lone Smelror
Administrative coordinator

Maja Sojtaric
Senior Communications Advisor

Marie Stetzler
PhD Candidate

Henrik H. Stokke
Business PhD Candidate

Mette Marianne Svenning
Professor
Leader WP3

Freya Sykes
PhD Candidate

Rémi Vachon
Postdoctoral Researcher

Sunil Vadakkepuliyambatta
Researcher

Malin Waage
Postdoctoral Researcher

Jemma Wadham
Professor

Kate Waghorn
Postdoctoral Researcher

Adele Westgård
PhD Candidate

Monica Winsborrow
Assoc. professor,
Assistant director
Leader WP2


CAGE
Norwegian
Centre of
Excellence
GEOLOGICAL
SURVEY OF
NORWAY
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