



CAGE - Centre for Arctic Gas Hydrate Environment and Climate Report Series, Volume 8 (2020)

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#### Modifications:

This version of the annual report has been modified from the original published in 2020.

Below is an overview of the changes made.

- The URL links for the PhD dissertations have been changed to a permanent handle in page 23.
- Impact factor values have been removed from page 34-35 (Publications list)



Annual Report 2020  
CAGE - Centre for Arctic Gas Hydrate,  
Environment and Climate





## Words from the Director

CAGE investigates methane release, a greenhouse gas far stronger than CO<sub>2</sub>, 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 ocean warming makes these shallow greenhouse gas reservoirs particularly vulnerable to thawing. CAGE investigates the processes involved and implications for the Arctic climate and environment.

### Challenges

Naturfagsbygget/Science Building is being renovated, so CAGE scientists have, since the end of February 2020, been located at Modulbygget on the UiT Tromsø Campus, together with the rest of the Department of Geosciences. This has led to more cramped working conditions, in particular for PhDs and post-docs. Furthermore laboratory facilities have also had to be moved, leading to considerable disruption and delays to planned laboratory work. Since mid March 2020, CAGE staff have mainly been working from home due to Covid-19 pandemic regulations.

### Scientific recognition

Despite the challenges, 2020 was a productive year for CAGE. Since its start in 2013, the centre has published over 370 peer-reviewed scientific publications that have been cited over 5700 times, 40 of these have been in Nature- or Science-journals. The centre has now an H-index of 39.

### Some scientific highlights

In 2020, CAGE contributed exciting new knowledge on the sources of gas hydrate and methane leakage in the Arctic. New seismic data from Svyatogor Ridge, west of Svalbard, indicate widespread gas hydrate and fluid flow systems sustained by abiotic, crustal processes (Waghorn et al. 2020 Scientific Reports). Whilst results from the Barents Sea revealed that the distribution and shape of gigantic seafloor craters and active gas hotspots are steered by faults, fractures and zones of damaged bedrock (Waage et al. 2020 Scientific Reports).

New results document large variations in gas emissions over time. The first continuous pore-pressure

and temperature measurements from west of Svalbard show that tides significantly affect the intensity and periodicity of gas emissions (Sultan et al. 2020 Nature Communications). Results from long-term monitoring demonstrate that methane seeps are almost halved during cold seasons. This has consequences for greenhouse gas budget estimates, which are mainly based on measurements from the warm seasons cruises (Ferré et al., 2020 Nature Geoscience).

Methane leaking from the seafloor provide energy for microbial communities. We provided new insights into the microbial community structure of gas hydrate-bearing domes called gas hydrate pingos. Key environmental factors that influence these structures and their spatial distribution were addressed, and key taxa characteristics were identified for these Arctic CH<sub>4</sub>-rich environments, demonstrating the uniqueness of this ecosystem (Carrier et al. 2020 Frontiers in Microbiology). CAGE 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.

### CAGE cruises

CAGE carried out 9 scientific cruises in 2020. Joint efforts with the Norwegian Petroleum Directorate resulted in the discoveries of new, extensive oil and gas seepage from shallow petroleum reservoirs, and previously unknown gas hydrate pingos in the Barents Sea. We also conducted our first scientific cruise to investigate the influence of ice sheets on past, present and future methane storage and release on the NE Greenland shelf.

Technologically intensive exploration over the past couple of years payed off during 2020 when unique material from the deep-water gas hydrate system on Vestnesa Ridge, offshore NW Svalbard, was collected using ROV ÆGIR.

### New projects and awards

Bénédicte Ferré was awarded the NFR project EMAN7 where 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, and how this affects the climate and environment. We are proud of our early career scientists; Mohamed Ezat who was awarded the Tromsø Forskningsstiftelse Starting Grant 2020 and Andrea Plaza-Faverola who received the UiT Young Scientist Award 2020.

Despite the difficult situation with Covid-19 regulations and cramped working conditions in Modulbygget, 2020 has still been a successful year for CAGE, mainly fuelled by the enthusiasm, patience and creativity of my good colleagues. We have had 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 questions. Thank you so much to you all!

Prof. Karin Andreassen  
Centre Director

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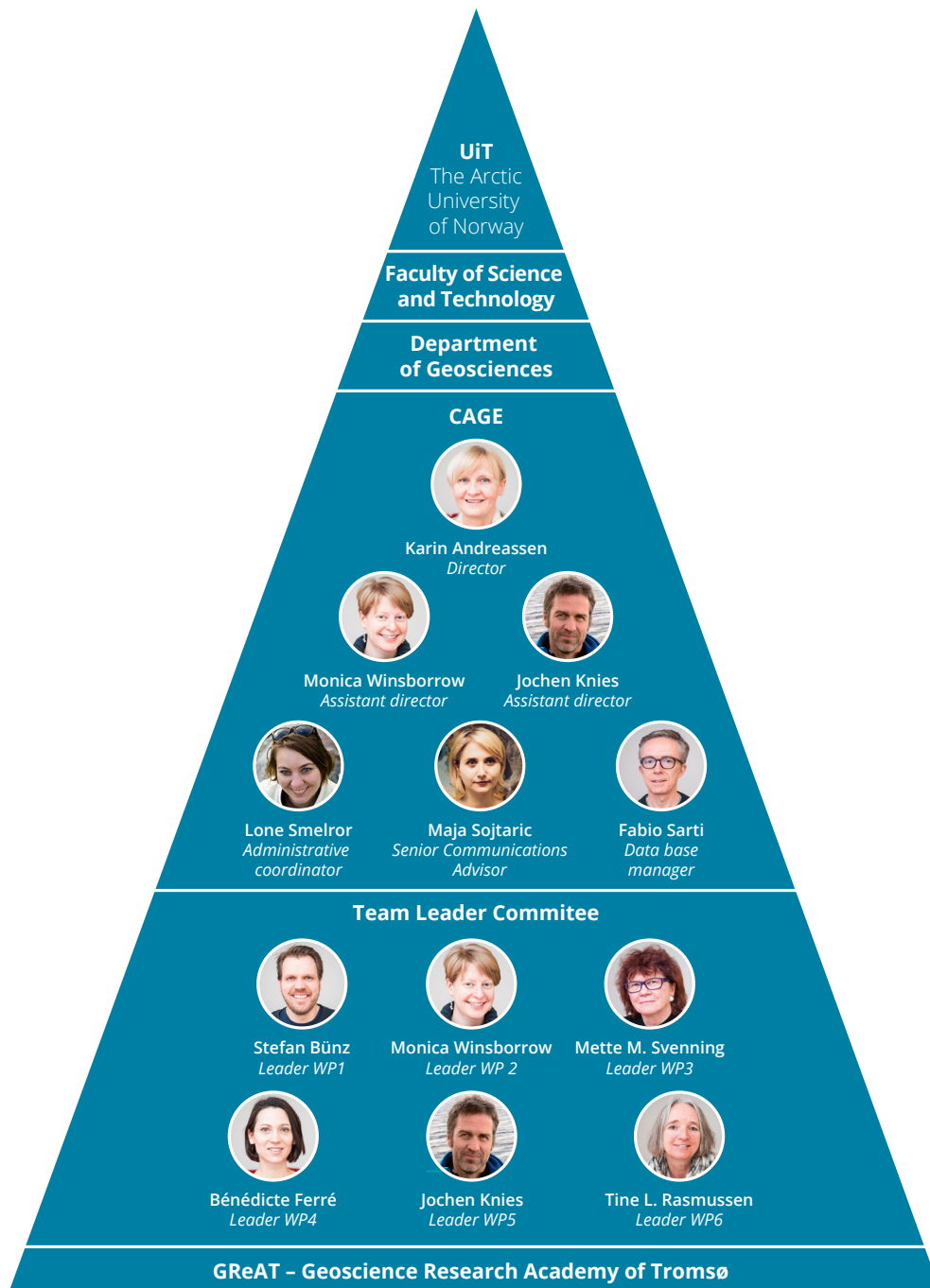
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Cover photo: Scanning electron micrograph of coccolithopharid *Emiliana huxleyi* filtered water samples. Photo by Griselda Anglada-Ortiz.  
Photo page 2: Karin Andreassen; Photo page 3: Polar light in the Arctic, from CAGE cruise 20-8. Photo by Mauro Pau.

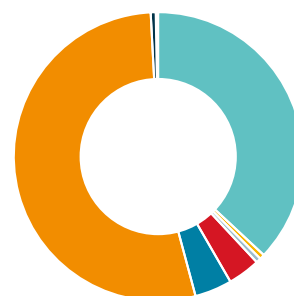
Editorial team: Maja Sojtaric, Lone Abrahamsen Smelror & Karin Andreassen.  
Design and layout by Torger Grytå & Julian P. Høgset.

# Organisation chart of the centre



## Funding 2020

Funding (1000NOK)	Amount	Percentage
The Research Council	24 340	37 %
Industry	377	0,6 %
EU	317	0,5 %
Other external funding (TFS, VISTA)	2 399	3,7 %
Norwegian Petroleum Directorate	2 836	4,3 %
UiT The Arctic University of Norway	34 986	53,3 %
Geological Survey of Norway	444	0,7 %
<b>Total</b>	<b>65 700</b>	<b>100 %</b>



- 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.



**Kenneth Ruud**  
*Chairman*  
*Prof., Prorector for Research and Development, UiT*



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



**May Britt Myhr**  
*Director of the Norwegian Geological Survey (NGU) Trondheim*



**Nalan Koc**  
*Research Director of the Norwegian Polar Institute Tromsø*



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



**Kristina Helland-Hansen**  
*Vice president (VP) Assets Northsea; VP EXP Regional International Offshore*

## 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*

# Gas hydrate and free gas reservoirs



## Stefan Bünz, Team Leader

Professor Stefan Bünz has 20 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<sub>2</sub>-storage in sedimentary basins, seafloor ecosystems, ultra-slow spreading ridges, and tectonic and non-tectonic faulting.

### Members:

**Jürgen Mienert**  
*Professor Emeritus*

**Sunil Vadakkepuliambatta**  
*Researcher*

**Shyam Chand**  
*Researcher*

**Andreia Plaza-Faverola**  
*Researcher, Leader*  
*SEAMSTRESS project*

**Sunny Singhroha**  
*PhD Candidate*

**Malin Waage**  
*PhD Candidate*

**Kate Waghorn**  
*PhD Candidate*

**Frances Cooke**  
*PhD Candidate*

**Przemyslaw Domel**  
*PhD Candidate*

**Rémi Vachon**  
*Postdoctoral Researcher*

**Hariharan Ramachandran**  
*Postdoctoral Researcher*

**Stefan Beaussier**  
*Researcher*

**Jean-Baptiste Koehl**  
*Researcher*

**Cornelia Mentzoni-Binde**  
*PhD Candidate*

**Claudio Argentino**  
*Postdoctoral Researcher*

### 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 seabed, 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.



Recovery of ocean-bottom seismometers in calm waters offshore western Svalbard using the working boat of RV Helmer Hanssen. Preparation of ocean-bottom seismometers for deployment offshore western Svalbard on board of RV Helmer Hanssen. Photos: Vera Schindwein from AWI, Germany.

In 2020, three of the articles published by team members of WP1 were in Nature journals attesting to the high impact science the group has been working on as of late. All articles focus on new insights into geological process governing fluid flow at different geological settings in the Arctic.

In a busy summer and fall, WP1 led four scientific expeditions; to the Møre and Vøring Basin, the SW Barents Sea and the west Svalbard margin, three with the RV *Helmer Hanssen*, and one with RV *Kronprins Haakon*. Two of those expeditions were dedicated to Plaza-Faverola's SEAMSTRESS project, where we continued a large-scale, long-term ocean-bottom seismic experiment. We also acquired a significant amount of site survey seismic data for two IODP initiative (Expedition 396 and Proposal 985-Full).

### Main Achievements 2020

1. New seismic data from the Svyatogor Ridge and surrounding areas shows widespread BSR over basement highs with relatively thin sedimentary cover, indicating that large, crustal-scale, tectonic features are intrinsically involved in supplying methane into the system at this study location, most likely through serpentinization of ultra-mafic rock.
2. Within the SEAMSTRESS project, we conducted the first continuous pore-pressure and temperature measurements at a supposed leakage feature on the west-Svalbard margin. Our data from sites where gas emissions have not been previously identified in hydro-acoustic profiles show that tides significantly affect the intensity and periodicity of gas emissions. These observations imply that the quantification of present-day gas emissions in the Arctic may be underestimated. High tides, however, seem to influence gas emissions by reducing their height and volume.
3. Analysis of high-resolution 4D time-lapse seismic data integrated with rock physics and seismic modelling documented the feasibility of the P-Cable system for detecting and monitoring gas leakages in shallow sediments. This technology may hence be particularly useful for its potential to monitor CO<sub>2</sub> storage. Analysis of detection limits of CO<sub>2</sub> models from a CO<sub>2</sub> storage site show the ability to detect very small amounts of CO<sub>2</sub> (1.3-10.6 tonnes; 3.3-27.4% gas saturation) in the shallow subsurface. These detection limits are ~30-300 times smaller than detection limits of conventional seismic data at similar depths.
4. A 6-m-long heat flow probe was procured in 2019 and delivered in early 2020. The probe was tested successfully during a test cruise with RV *Kronprins Haakon* in June. During CAGE20-6 expedition in October 2020, we acquired a dense network of heat flow measurements on the Vestnesa Ridge and adjacent west-Svalbard margin adding a new and much needed physical constraint that will allow us to improve gas hydrate models and understanding of fluid flow in this region.



# The role of ice ages



## Monica Winsborrow, Team Leader

Monica Winsborrow is a Researcher 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%)*

**Renata Lucchi**  
*Adjunct Professor (20%)*

**Jemma Wadham**  
*Adjunct Professor (20%)*

**Henry Patton**  
*Researcher*

**Pavel Serov**  
*Postdoctoral Researcher*

**Mauro Pau**  
*Postdoctoral Researcher*

**Nikolitsa Alexandropoulou**  
*PhD Candidate*

**Mariana de Silveira  
Ramos Esteves**  
*Researcher*

**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.



*Burning ice: gas hydrate retrieved in a core from the central Barents Sea. PhD student Nikolitsa Alexandropoulou holding burning gas hydrate sampled in the central Barents Sea. Photos: Henry Patton*

Numerical models require accurate constraints provided by high quality empirical data. We continue to acquire state-of-the-art geophysical datasets from strategic field sites across the Arctic.

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 2020

1. Developed the first, high-resolution, continuous seismostratigraphic framework for the entire western Svalbard-Barents Sea margin over the last 2.7 Ma.
2. Integration of ice-sheet and basin modelling reveals “pumping” effect of glacial cycles on fluid migration and release in central Barents Sea. The work is done in collaboration with Alexey Kishenkov, Moscow State University, Russia.
3. Developed a high-resolution, quantitative framework defining spatiotemporal patterns of glacial erosion of the Eurasian landscape over the last 123 ka.
4. Joint efforts of CAGE and NPD result in discovery of oil seepage and extensive gas seepage from shallow petroleum reservoirs in the NE Barents Sea.
5. First CAGE cruise to investigate the influence of ice sheets on past, present and future methane storage and release on the NE Greenland shelf.
6. Start-up of a modelling collaboration, JointClimate, between the Department of Physics and Technology (IFT), the Department of Mathematics and Statistics (IMS), UiT’s Aurora Centre for Nonlinear Dynamics and Complex Systems Modelling (DYNAMO) and CAGE. Post-doctoral researcher Mauro Pau is focussing on modelling palaeo ice-ocean interactions in the Arctic using ROMS (Regional Ocean Modelling System).
7. Project partners on NFR-funded project “Stability of the Arctic climate” led from the Department of Mathematics and Statistics, UiT.
8. Impacts of Icelandic glaciation on the periglacial/permafrost realm and the rate of volcanism identified.
9. Ongoing collaboration with IODP exp. 379 ‘Amundsen Sea West Antarctic Ice Sheet History’ scientists to investigate the early-Pleistocene to present bottom current strength variations at Resolution drift, West Antarctica.

# 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 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*

**Vincent Carrier**  
*PhD Candidate*

**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 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.



View of a terrestrial pingo field Adventdalen, Svalbard. Device with sensor instruments installed in a pingo field Adventdalen, Svalbard. Photos: Dimitri Kalenitchenko, CAGE.

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<sub>4</sub> 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 WP3.

### Main achievements 2020

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 benthic 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 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:

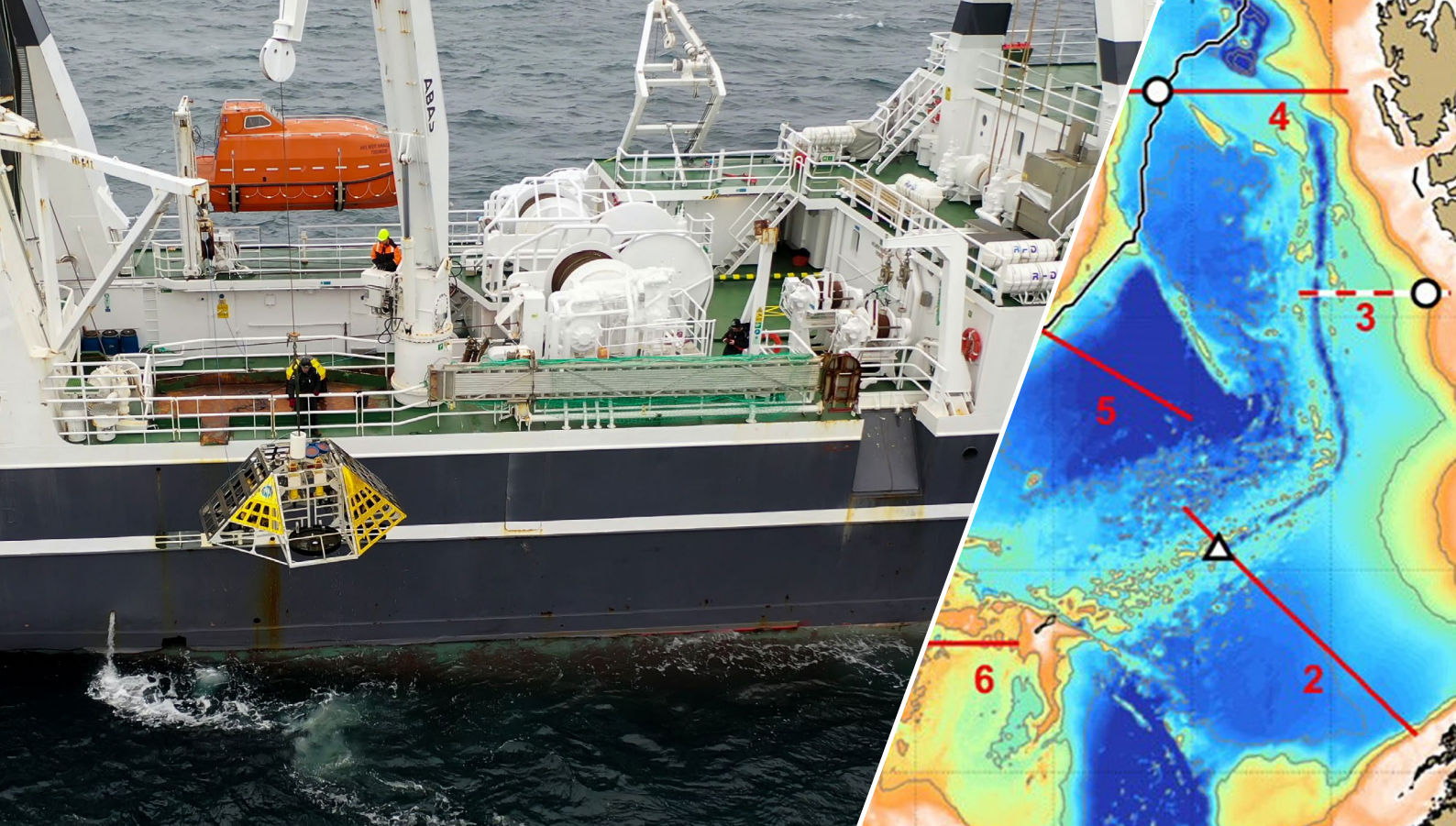
The effects of methane release on underwater ecosystems and our global climate are still unclear. Methane transport in Arctic oceans takes place via bubbles or in dissolved form beneath the seabed and travels vertically towards the ocean surface. However, continuously shifting water dynamics due to changing 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.



*K-lander recovery from RV Helmer Hanssen during CAGE 20-1 (June 2020). Photo: Dimitri Kalenitchenko (drone). NorEMSO component (red lines: glider sections, circles: moored observation systems and triangle: seafloor observatory platform over Mohn Ridge).*

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, as well as from long-term observatories. This advanced equipment makes it possible to continuously measure environmental changes associated with methane release at remarkable resolutions and acquire data to tune and force models. Modeling is also one of the main focuses in order to understand the fate of methane and other gases in the ocean.

The main activities of WP4 during 2020 consisted in ongoing (Lofoten Vesterålen - LoVe; Svalbard Integrated Arctic Earth Observing System - sios and Norwegian node for the European Multidisciplinary Seafloor and water column Observatory - NOREMSO) as well as new projects (Environmental impact of Methane seepage and sub-seabed characterization at LoVe-Node 7 - EMAN7).

### Main achievements 2020

1. We recovered one K-lander offshore Svalbard, which deployment was financed by sios. Along with the data from previous recoveries, one article is currently under review and another one is expected in 2021.
2. We demonstrated that methane content in highly active methane seepage areas is controlled by current rather than by vertical methane transport, limiting the escape to the atmosphere (Silyakova et al., 2020)

3. We showed how chemical diversity of dissolved organic matter at marine methane seeps is higher than non-seep areas (Sert et al., 2020)
4. We questioned climate gas budget by demonstrating that the methane seeps are almost halved during cold seasons (Ferré et al., 2020)
5. We started a collaboration with the Department of Automation and Process Engineering at UiT to build the NOREMSO mooring at Sørkapp, through a bachelor project involving two students. The mooring will be equipped with physical and chemical sensors for oceanographic parameters, CO<sub>2</sub> and CH<sub>4</sub> monitoring, and the mooring is planned to be deployed in August 2021.
6. We performed and participated to three research cruises onboard rvs *Helmer Hanssen* and *Kronprins Haakon* to explore methane

- seepage areas Eastern Greenland as well as Northern, Western and South Svalbard in addition to the Barents Sea. The cruise Eastern Greenland allowed to test a new ice sampling method (Anna Silyakova). The exploration Northern Svalbard was performed with the ROV ÆGIR6000 onboard, allowing a complete picture of the water column and the seafloor with microbathymetry, visual observation and sampling.
7. We were awarded the project EMAN7 where 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 affect biology and in particular coral reefs that leave around the seepage. WP5 from CAGE is also involved in this project.

# 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*

**Shyam Chand**  
*Researcher*

**Wei Li Hong**  
*Postdoctoral Researcher*

**Tobias Himmler**  
*Postdoctoral Researcher*

**Pierre Antoine Dessandier**  
*Postdoctoral Researcher*

**Haoyi Yao**  
*PhD Candidate – completed  
March 2020*

**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



Sediment coring of seep sites on the Mid-Norwegian shelf onboard RV "G.O. Sars". Launching of ROV ÆGIR 6000 from RV "G.O. Sars". Photos: Jochen Knies

Technology intensive explorations over the past couple of years, paid off for work package 5 during 2020: Unique material from the deep-water gas hydrate system on Vestnesa Ridge offshore NW Svalbard, was collected using ROV ÆGIR and RV G.O Sars. In addition, major discoveries on the Arctic sea evolution during extreme climate warm periods analogous to today were made.

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 addition, the NFR funded Norwegian-Indian collaborative project "PACT – Pliocene Arctic Climate Teleconnections" provided breakthrough results on the Arctic sea ice evolution during extreme warm climates.

### Main achievements 2020

1. We discovered that the isotopic signature of sulphur in benthic foraminifera can be used to reconstruct the flux and timing of Arctic methane emissions in fossil records. These findings were made on the species *Cassidulina neoteretis* that were collected at Vestnesa Ridge, a methane cold seep site in the Arctic Ocean. The results show lower benthic foraminiferal  $\delta^{34}\text{S}$  values ( $\sim 20\text{‰}$ ) in the sample characterized by seawater conditions, whereas higher values ( $\sim 25\text{--}27\text{‰}$ ) were measured in deeper samples because of the presence of methane. Past methane history studies indicate that the foraminiferal  $\delta^{18}\text{O}\text{--}\delta^{34}\text{S}$  correla-

tion indicates methane advection on Vestnesa Ridge site during the Early Holocene and the Younger-Dryas – post-Bølling climate intervals.

2. We investigated the uppermost 60 cm of sediment in active pockmarks of a deep-water methane seep site from Vestnesa Ridge offshore NW Svalbard. Using video guided core sampling with a remotely operated vehicle we collected push cores directly from bacterial mats within two active pockmarks, Lunde and Lomvi. Pore water analyses showing very shallow sulphate methane transition zones and transport-reaction modelling suggest 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. In addition, we show that the amount of methane that bypasses the benthic methane filter greatly increases with higher aqueous fluid advection rate. 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.

3. Quantifying the contribution of poleward oceanic heat transport to the Arctic Ocean is important for making future sea ice and climate predictions. To highlight its potential importance in a warmer world, we present a new record of water-mass exchange between the Atlantic and the Arctic Oceans using the authigenic neodymium isotopic composition of marine sediments from the Fram Strait during the mid-Pliocene Warm Period between 3.264–3.025 Ma, the most recent geological analogue for future climate changes. Our estimates of volume transport of warm waters into the Arctic Ocean suggest a near complete "Atlantification" of the Arctic Ocean during the mid-Pliocene Warm Period, with an associated reduction in Arctic spring sea ice concentration of  $\sim 30\text{--}35\%$  compared to today. Our new results of northward volume transport and sea ice extent provide much needed input for validation of current generation models aimed at improving the robustness of future climate modelling in the Arctic.



# Methane, CO<sub>2</sub> 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. Her research interests are focused on abrupt climate and oceanographic changes and changes in greenhouse gases in Arctic to sub-Arctic areas. She is educated in the fields of paleoceanography, paleoclimate, biology/paleobiology, micropaleontology, and ecology/paleoecology. She holds a PhD degree in marine science/paleoecology and micropaleontology from Aarhus University in Denmark, and has professional experience most notably from Woods Hole Oceanographic Institution (USA), Lund University (Sweden) and Copenhagen University (Denmark).

### Members:

**Katarzyna Zamelczyk**  
*Researcher*

**Mohamed Ezat**  
*Researcher,*  
*Leader ARCLIM project*

**Siri Ofstad**  
*PhD Candidate*

**Naima El Bani Altuna**  
*PhD Candidate*

**Griselda Anglada-Ortiz**  
*PhD Candidate*  
*(Nansen Legacy project)*

**Christine Lockwood-Ireland**  
*PhD Candidate*

### About:

To understand the impact of methane release on past and present environments and climate, WP6 studies both modern environments by sampling living planktic and benthic foraminiferal faunas and pteropods and past environments by examining the fossilized remains of once-living faunas, mostly from around Svalbard, both from seep sites and off seep areas. To better understand the processes of the Arctic carbon cycle and changes seen at methane release areas, WP6 also reconstructs the general paleoceanography by the study of cores from sites from the Svalbard margin, 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.

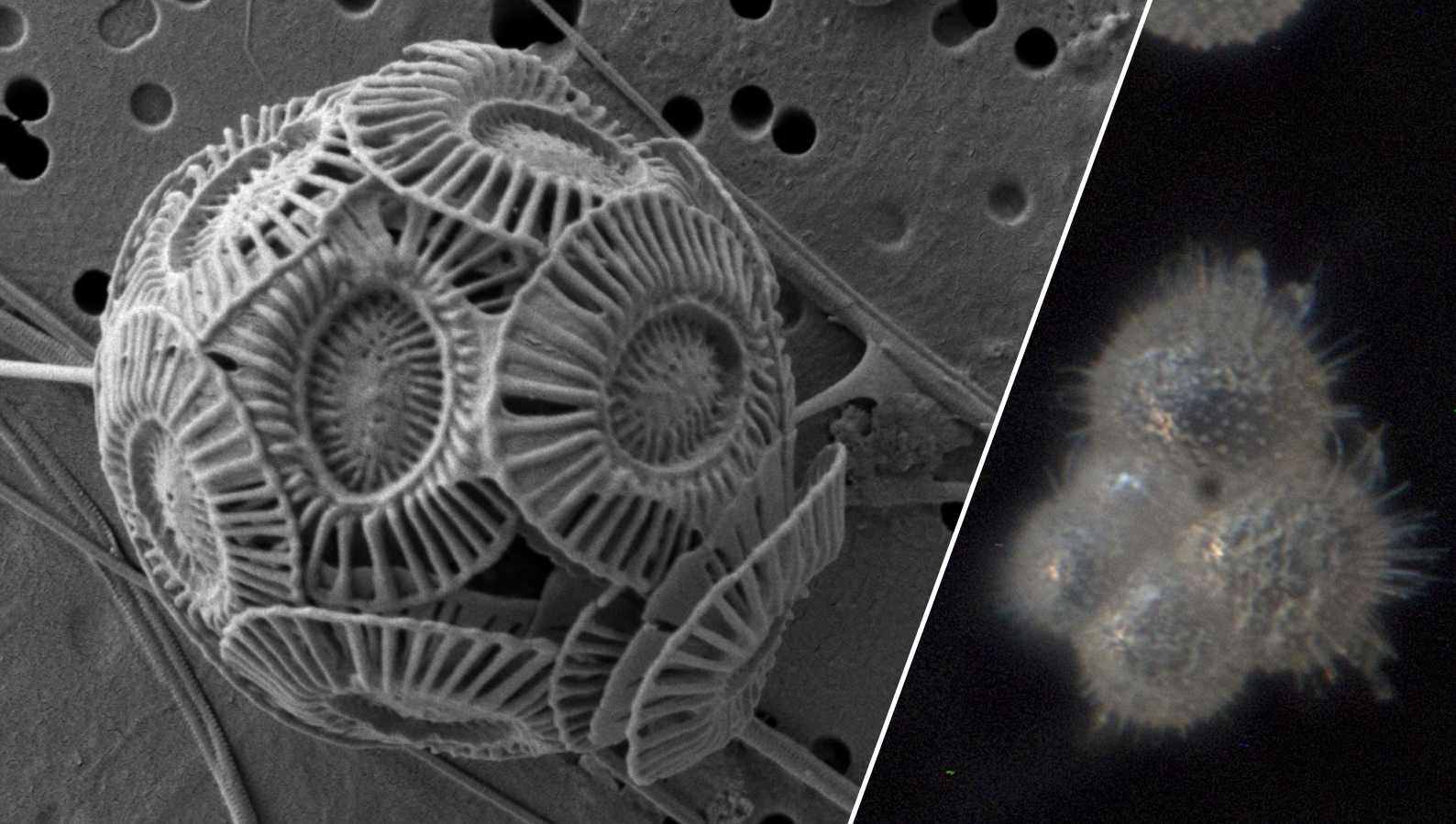
In addition, WP6 investigates methane seep areas by annual and/or seasonal sampling in order to document changes in planktic and benthic faunas in relation to methane seepage, productivity and ocean chemistry changes over time. Methane released from the seabed rapidly oxidizes to CO<sub>2</sub>, which change the carbonate chemistry of the ambient water. This can potentially increase ocean acidification, which can have detrimental effects on the delicate ecosystem of underwater life. In addition, WP6 monitors the response of planktic foraminifera, coccospheres and pteropods to ocean acidification/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
- Apply multi-proxy techniques to reconstruct high-resolution climate and greenhouse gas records
- Detect and quantify planktic foraminiferal and pteropod responses to changes in ocean chemistry and productivity due to methane release, increasing atmospheric CO<sub>2</sub> 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.



Scanning electron micrograph of coccolithophorid *Emiliana huxleyi* from filtered water samples from Nansen Legacy seasonal cruise with RV Kronprins Håkon, 2019. Light microscopy photo of planktic foraminifera *Turbotalita quinqueloba* taken by plankton net on Nansen Legacy seasonal cruise with RV Kronprins Håkon, 2019. Photos: Griselda Anglada-Ortiz.

We work to improve existing standards and intergrate established methods with groundbreaking technologies to estimate CO<sub>2</sub> 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 also identifies 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 2019

1. Dr. Mohamed Ezat received the prestigious TRS (Tromsø Research Foundation) grant in autumn 2020. He has funding to study past periods with climate warmer than today (project ARCLIM: Arctic Ocean under warm climates). The grant covers Dr Ezat's salary, 2 PhD and 2 Post doc positions, mass spectrometer for elemental analyses and in addition, aims to build a culturing cold-lab for planktic foraminifera in incubators with photoperiodic and temperature control.

2. Reconstruction of bottom water temperature (BWT) for the last glacial period (13–63 ka) through the measurement of Mg/Ca of benthic foraminifera at Vestnesa Ridge on millennial-scale shows that BWT increased up to  $5 \pm 1^\circ\text{C}$  during the coldest phases.
3. Deep ocean <sup>14</sup>C ventilation age reconstructions from the Arctic Ocean and <sup>14</sup>C age differences in two species of benthic foraminifera have been critically assessed for the last glacial maximum (LGM).
4. The study of planktonic foraminiferal and pteropod shell densities measured by X-ray microcomputed tomography (X<sub>μ</sub>CT) reveal clear inter-species differences in shell density and thickness with water depth and ontogenic stages.
5. Vertical distribution and contribution of living planktic foraminifera and pteropods to the inorganic carbon standing stocks and

productivity in the Arctic Ocean north of Svalbard are investigated. A reconstruction of climate and changes in water-mass properties southwest of Svalbard correlated closely to the major climate anomalies of the past two millennia correlating with local expressions of the European climatic events known as the Roman Warm Period, the Medieval Climate Anomaly, the Little Ice Age and the Recent Warming.

6. The tolerance to salinity change of the subarctic planktic foraminifera *Neogloboquadrina incompta* was studied in a culturing experiment exposing the foraminifera to a gradient of salinities between 35 and 25 psu.
7. The Svalbard-Barents Sea Ice Sheet reacted rapidly to the abrupt warmings of the last deglaciation 20–10 ka BP. Ice retreat was nearly instantaneous and occurred similar to the recent break-ups of the Larsen Ice Shelf in Antarctica between 1995 and 2017.

# ARCLIM - The Arctic Ocean under warm Climates



## Mohamed Ezat, *Researcher*

Mohamed Ezat is a researcher within WP6 Methane, CO<sub>2</sub> and Ocean Acidification at CAGE. He holds a PhD degree (2015) in paleoclimatology from the Department of Geosciences, UiT The Arctic University of Norway. His research to date has largely been focused around understanding the role of polar ocean-atmosphere exchange of heat and greenhouse gases in past climate change, with potential implications for the accuracy of future climate predictions. He uses a range of geochemical, sedimentological and micropaleontological methods to infer past hydrographic changes, including stable- and radiogenic isotope and trace element analyses. In 2017, Mohamed received a 3-year Marie Curie/Fripro Mobility Fellowship to work at the University of Cambridge for two years and one year at UiT. He has recently received a starting grant from the Tromsø Research Foundation (TFS) for his project 'The Arctic Ocean under warm Climates (ARCLIM)'.

### Members:

PhD Candidate  
- to be hired

PhD Candidate  
- to be hired

Postdoctoral Researcher  
- to be hired

Postdoctoral Researcher  
- to be hired

### About the project:

ARCLIM is a multidisciplinary project that brings together expertise from marine ecology, micropaleontology, geochemistry and numerical modelling. The primary objective of ARCLIM is to improve knowledge of the poorly-constrained interactive feedback processes between the Arctic Ocean, the carbon cycle, the Atlantic Meridional Overturning Circulation (AMOC) and regional/global climate. To achieve this, ARCLIM will reconstruct and study key components of Arctic climate change (ocean temperature, carbonate chemistry and the freshwater system) in relation to North Atlantic Ocean circulation (deep-water formation and poleward heat transport to the Arctic) during past warm periods that are similar to the ongoing and projected climate change. ARCLIM focuses on warm periods: the last interglacial period (the Eemian, ~129,000–116,000 year ago), and to a lesser extent, on the mid-Pliocene epoch (~3.5–3 million years ago). Specific research objectives are:

- To develop a novel proxy toolbox for sea surface temperature, salinity, freshwater input and sourcing, and carbonate chemistry.
- To reconstruct the Arctic Ocean heat, freshwater and carbon exchanges with the North Atlantic Ocean.
- To map deep water mass sources and mixing in the Arctic Ocean and subpolar North Atlantic as indicators for North Atlantic overturning variability.
- To compare the proxy records with fully coupled Earth system model (iLOVECLIM) simulations to gain understanding of the climate processes that led to the reconstructed climatic and oceanic changes.

Collectively, this will allow the study the reciprocal interactions between the Arctic, North Atlantic Ocean circulation and climate in a warmer-than-present real world. In addition, the study of different periods that represent different boundary conditions and different rates of climate change (in addition to climate simulations) will allow interactive processes within the Arctic-carbon cycle-AMOC-climate system to be diagnosed in multiple ways, which will provide a further understanding of the mechanistic linkages between these interactive components and processes. In addition, the project will provide invaluable datasets that can be used to constrain the reliability of climate models that are being used to project future climate changes e.g., relevant to the Paleoclimate Modelling Intercomparison Project (PMIP4) simulations in the Coupled Model Intercomparison Project (CMIP6). Ultimately, ARCLIM will improve our ability to predict future climate changes in the Arctic and their far-reaching impacts.



Mohamed Ezat recieved the TFS Starting Grant Diploma from the foundation's head of administration Unn Sorem. Photo: Christian Halvorsen.

New infrastructure: During the lifetime of ARCLIM, two new laboratories will be established.

First, a laboratory for culturing foraminifera, and it will be ready by summer 2021. It will be equipped with low temperature incubators with photoperiodic system, fluorescence microscopes and several digital meters. This culturing laboratory will be instrumental for the method development component of the ARCLIM project as well as for fostering new areas of research at CAGE and the Department of Geosciences.

Secondly, a new mass spectrometer for trace elemental analyses will be purchased and installed in year 3 of the project.

#### ARCLIM's framework and collaboration

The ARCLIM team will consist of Mohamed (PI), two PhD-students and two postdocs. The project will be performed in a close collaboration

with several national and international institutions including Bremen University, MARUM, Germany; Southampton University, Cambridge University, UK; Vrije Amsterdam University, Netherlands; Aarhus University, Denmark; NORCE, Norway; Ohio State University, USA.



# EMAN7



**Bénédicte Ferré, Project leader**

Bénédicte Ferré is the leader of WP4 Gas in the water column at CAGE. She holds a PhD degree (2004) in marine science from the University of Perpignan (France) where she compared the natural (storm) and anthropogenic (trawling) sediment resuspension. She joined the Department of Geosciences at UiT The Arctic University of Norway as a researcher in 2008. Prior to this she was a post-doctoral researcher at the United States Geological Survey in Woods Hole (USA) where she worked on applied problems involving numerical models of sediment-transport for evaluation of long-term environmental impacts of contaminated sediments on the Palos Verdes shelf (southern California). Her research activities in CAGE span from sediment resuspension and transport to oceanographic data associated with methane release.

**Members:**

**Anna Silyakova**  
*Researcher*

**Giuliana Panieri**  
*Professor*

**Thibaut Barreyre**  
*Postdoctoral Researcher at UiB*

**Postdoctoral Researcher UiT**  
- to be hired

**Postdoctoral Researcher UiT**  
- to be hired

**Phd Candidate IMR**  
- to be hired

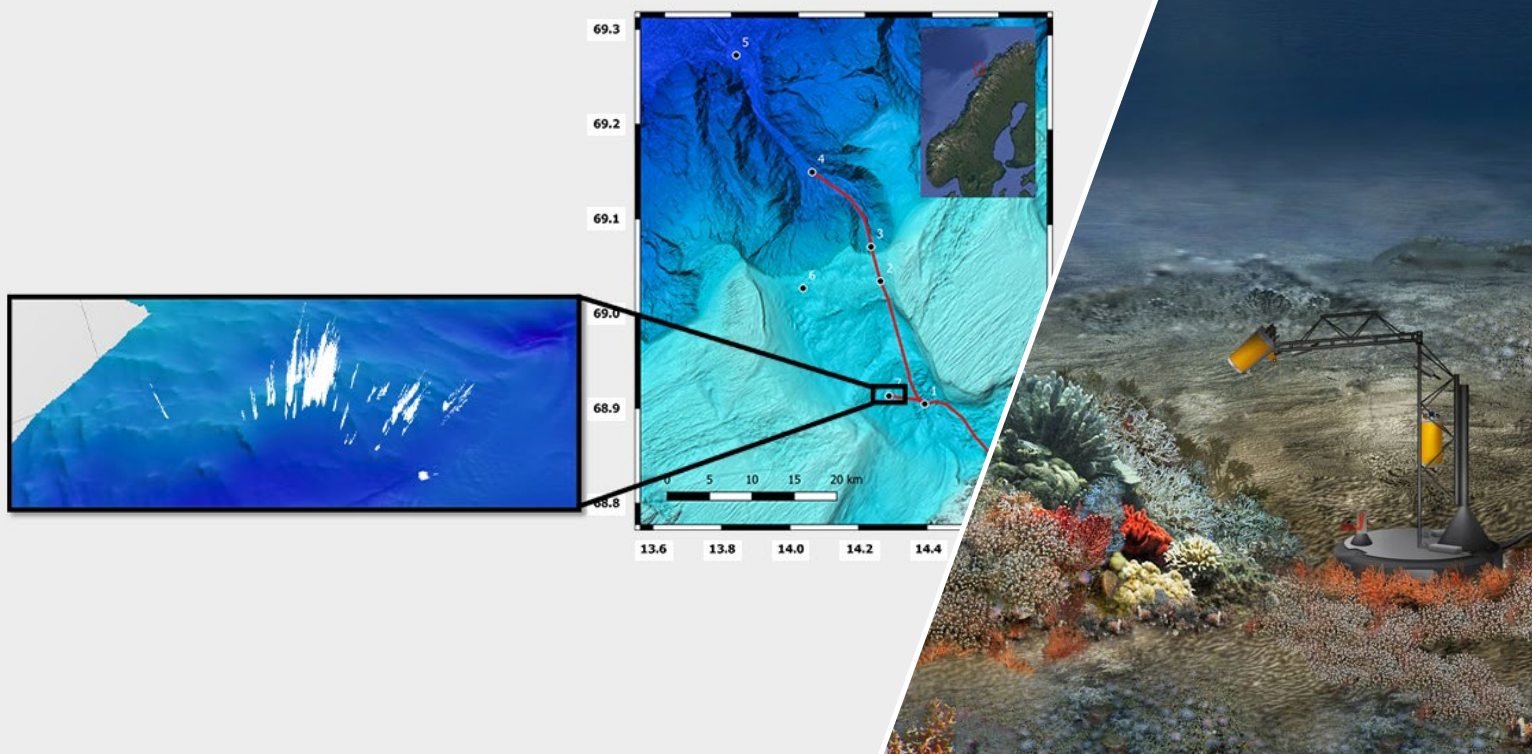
**Tina Kutti**  
*Researcher at IMR*

**Samuel Rastrick**  
*Researcher at IMR*

**About the project:**

EMAN7 (Environmental impact of Methane seepage and sub-seabed characterization at LoVe – Node 7) aims at shedding light on how oceanic parameters and climate change influence methane seepage from the seafloor, and their subsequent impacts on ecosystem health and carbon fluxes. The project has been awarded to Bénédicte Ferré by the Norwegian Research Council (RCN-KSPKOMPETANSE20). EMAN7 is funded for four years and the project partners are the University of Bergen (UiB) and Institute of Marine Research (IMR). In addition, Equinor, ConocoPhillips Norge and Total E&P Norge are funding partners. This project comes with two Postdoctoral position at UiT The Arctic University of Norway and one PhD Candidate at IMR, and we will use the expertise of Ocean Network Canada by sending a postdoctoral researcher for a few months for education and knowledge transfer.





*Bathymetry of the Hola Trough offshore Lofoten Vesterålen (inlet map). Black dots represent the LoVe observatories (nodes) and the red segments represent the cable connected to land. Node 7 is deployed near methane seepages collecting physical and chemical data in addition to hydroacoustic and images.*

At a time when climate change is no longer a debate, much focus has been placed on reducing anthropogenic inputs of greenhouse gases such as carbon dioxide (CO<sub>2</sub>).

However, methane (CH<sub>4</sub>, a more potent greenhouse gas compared to CO<sub>2</sub>) associated with underwater reservoirs of hydrocarbons, can erupt as climate driven changes to the physical environment reduce its stability. In addition, increased anthropogenic activities in hydrocarbon rich areas (i.e., oil and gas exploration) may cause additional release of greenhouse gases (CH<sub>4</sub> and CO<sub>2</sub>) altering several biogeochemical processes and threatening health of the local ecosystem.

EMAN7 will use state of the art observatory facility located in the resource rich area of Lofoten-Vesterålen (LoVe) for monitoring a

wide range of physical, biological and chemical parameters associated with cold-water coral reefs and CH<sub>4</sub> seepage. These parameters will provide cross-disciplinary research with a complete picture of the ecosystem response to CH<sub>4</sub> seepage, as well as temporal and spatial variation of the seepage system itself. Furthermore, as this region serves as a conduit of warm Atlantic water transport to the Arctic, data collected at the LoVe nodes will provide needed insight to predict potential impacts of climate change in Arctic regions. Annual research surveys in the Hola Trough will complement the long-term data with spatial variability in CH<sub>4</sub>

seepage and greenhouse gases exchange across air-sea interface. We also anticipate that the results of our proposed research will improve the understanding of sub-seafloor fluid flow over a wide range of systems that are involved in the transfer of carbon from the sub-seafloor to the ocean. These results will thus provide constraints to estimate fluxes both at the studied sites and globally, while gaining particular insight into the properties, dynamics and fluxes of sediment-hosted systems.



Early career scientists during their shift of work during an expedition on board of the RV Kronprins Haakon. Photo: Marie Stetzler.

## GReAT Geoscience Research Academy of Tromsø: a new journey

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, lithosphere dynamics, bedrock geology, energy and environment.

The PhD trainee school offers 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. From 2020, following the guidelines from the Faculty of Science and Technology at UiT, 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 in the course of 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 new academic culture, similar to the new concept of the 'world-class' university as was done so far by AMGG. The students can

acquire various transferable skills, create their own professional network and go "across boundaries" of their own research fields.

### Giuliana Panieri, Member of GReAT board

Professor Giuliana Panieri is steering member of the trainee school GReAT and project leader of a new educational project, Advancing Knowledge of Methane in the Arctic (AKMA) <https://akma-project.com>



### 2020

Even if in 2020 almost all the activities were cancelled because of the pandemic, in 2020 GReAT has kept organizing activities. The annual meeting, that was held online, was an opportunity for the students to present their project and discuss about science. The AKMA educational project kept planning and organizing an expedition to be held in 2021. In addition, some of the GReAT early career scientists participated in establishing the JEDI Justice Equality Diversity and Inclusivity group at the Department of Geosciences. The JEDI is an open forum for everyone at the department, willing to educate on JEDI topics, encourage discussion on JEDI, improve access and knowledge to current resources to detect inequalities and mistreatment and promote inclusivity and openness.

### Master theses 2020

**Binde, C.M.**

*Master Thesis. "Fluid flow and faulting along the northern margin of the Loppa High". (2020). Supervised by: Bünz, S.; Vadakkepulyambatta, S. 127 pages. <https://hdl.handle.net/10037/18388>*

**Fåne, P.**

*Master Thesis. "Novel methanotrophic community assemblages in a terrestrial methane seep in Svalbard". (2020). Supervised by: Kalenitchenko, D.; Tveit, A.T. 115 pages.*

**Garpestad, T.G.Ø.**

*Master Thesis. "Glacial dynamics and fluid flow processes in Bjørnøyrenna and the Loppa High area, SW Barents Sea". (2020). Supervised by: Winsborrow, M.; Bünz, S.; Andreassen, K. 115 pages. <https://hdl.handle.net/10037/18490>*

**Haldorsen, J.**

*Master Thesis. "The relationship between shallow anomalies and gas-flaring on the flank of the Nordkapp Basin in the SE Barents Sea". (2020). Supervised by: Knutsen, S.-M.; Serov, P.; Jensen, A. F. 99 pages. <https://hdl.handle.net/10037/18468>*

**Moen, J.-E.**

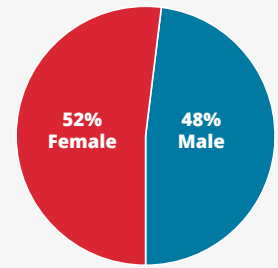
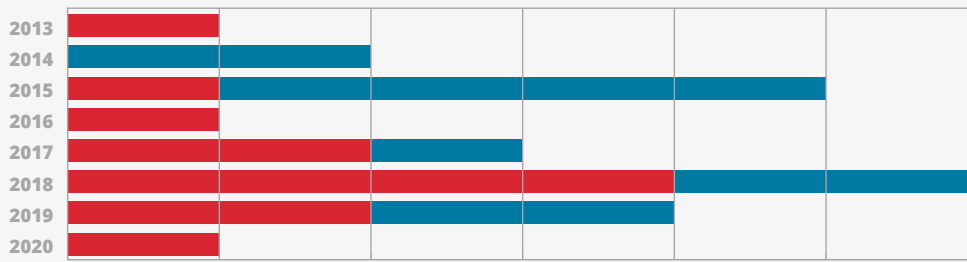
*Master Thesis. "Gas migration and sealing modelling in the Haapet Dome area, Norwegian Barents Sea - analysis of seismic anomalies and water column data". (2020). Supervised by: Knutsen, S.-M.; Serov, P.; Mattingdal, R. In press pages.*

**Mol, A.**

*Master Thesis. "Microbial community of arctic terrestrial cold seeps". (2020). Supervised by: Kalenitchenko, D.; Fåne, P. In press pages.*

**Selsaas, B.**

*Master Thesis. "Stratigraphy, neo-tectonics and mass wasting of deep water drifts in the Fram Strait". (2020). Supervised by: Bünz, S.; Waghorn, K. A. 91 pages. <https://hdl.handle.net/10037/18404>*



## List of 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.

#### | Vadakkepuliambatta, 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., Cherkashov, G.

### 2016

#### | Sauer, S.

*Past and present natural methane seepage on the northern Norwegian continental shelf*

Supervisor: Knies, J., Mienert, J.

### 2017

#### | Szybor, 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.d.S.R.

*Doctoral dissertation. "Collapse of a marine-based ice sheet". (2018).*

Supervised by: Winsborrow, M.

#### | Jansson, P.

*Doctoral dissertation. "Methane bubbles in the Arctic Ocean - Quantification, variability analysis and modelling of free and dissolved methane from the seafloor to the atmosphere". (2018).*

Supervised by: Ferre, B.

#### | Paiste, K.

*Doctoral dissertation. "Reconstructing the Paleoproterozoic sulfur cycle: Insights from the multiple sulfur isotope record of the Zaonega Formation, Karelia, Russia". (2018).*

Supervised by: Panieri, G., Lepland A.

#### | Schneider, A.

*Doctoral dissertation. "Diagenetically altered benthic foraminifera reveal paleo-methane seepage". (2018).*

Supervised by: Panieri, G., Knies, J., Lepland, A.

#### | Serov, P.

*Doctoral dissertation. "Cryosphere-controlled methane release throughout the last glacial cycle". (2018).*

Supervised by: Andreassen, K.

#### | Åström, E.

*Doctoral dissertation. "Benthic communities at high-Arctic cold seeps: Faunal response to methane seepage in Svalbard". (2018).*

Supervised by: Carroll, J.

### 2019

#### | Shackleton, C.

*Doctoral dissertation. "Subglacial hydrology of the Fennoscandian and Barents Sea ice sheets". (2019).*

Supervised by: Winsborrow, M., Andreassen, K., Bjarnadóttir, L. R., Patton, H. 79 pages. <https://hdl.handle.net/10037/15815>

#### | Singhroha, S.

*Doctoral dissertation. "Distribution and quantification of gas hydrates and free gas in marine sediments of Vestnesa Ridge, offshore W-Svalbard". (2019).*

Supervised by: Bünz, S., Plaza-Faverola, A., Chand, S. 127 pages. <https://hdl.handle.net/10037/15824>

#### | Waage, M.

*Doctoral dissertation. "3D and 4D seismic investigations of fluid flow and gas hydrate systems - at sites across the Barents Sea and NW Svalbard margin". (2019).*

Supervised by: Bünz, S., Mienert, J., Andreassen, K. 48 pages. <https://hdl.handle.net/10037/15078>

#### | Waghorn, K.A.

*Doctoral dissertation. "Scales of tectonic processes controlling fluid flow systems on the Svyatogor Ridge, Fram Strait". (2019).*

Supervised by: Bünz, S., Plaza-Faverola, A. 90 pages. <https://hdl.handle.net/10037/15813>

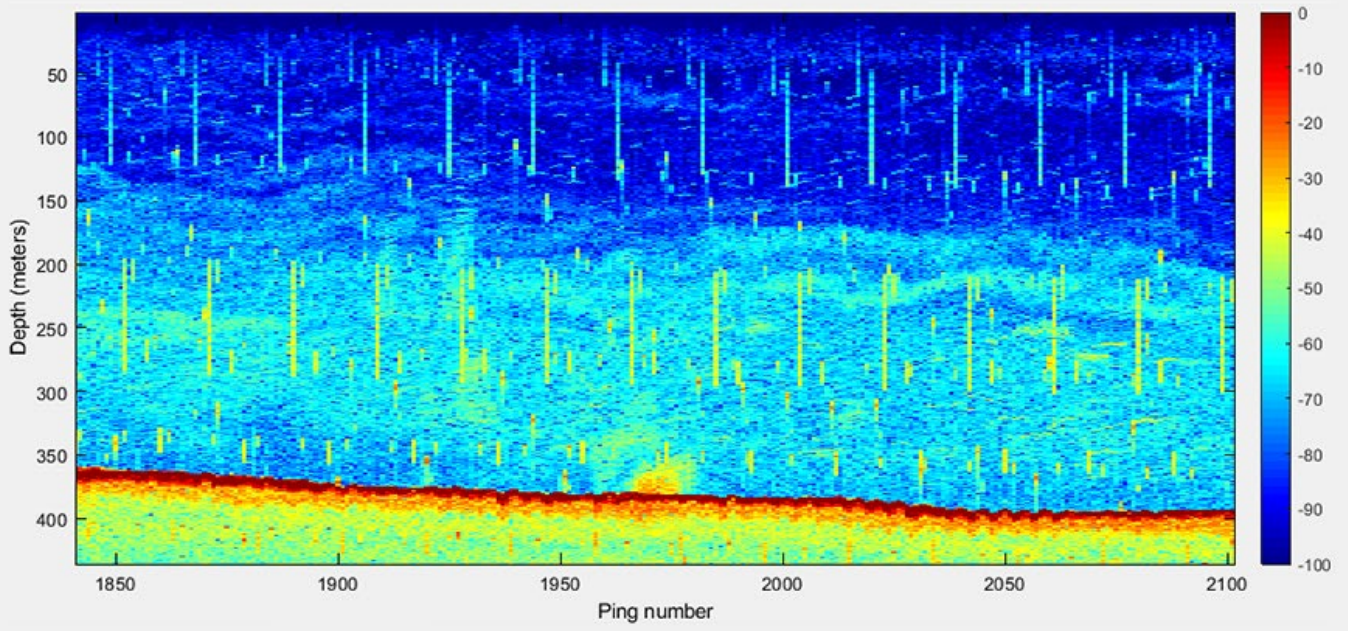
### 2020

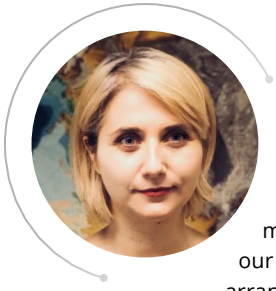
#### | Yao, H.

*Doctoral dissertation. "Reconstruction of past and present methane emission in the Arctic cold seeps using biogeochemical proxies". (2020).*

Supervised by: Panieri, G.; Niemann, H. 58 pages. <https://hdl.handle.net/10037/17821>







**Maja Sojtaric, Senior  
Communications Advisor**

Maja writes our press releases, manages media contact and maintains our social media distribution, as well as arranging workshops in communication.

## Outreach in a pandemic

It is safe to say that in 2020 most of the science news in the world revolved around a virus that kept us all confined to our homes. COVID19 has thus made outreach on climate and environmental sciences less interesting to the media outlets, which have in many ways been our main mode of distribution. We have still managed to keep a reasonable level activity, and an amount of impact has been within our own targets for achievement. Here are some examples.

### TV, radio and global news cycle

Professor Karin Andreassen contributed to a report on a second largest TV broadcaster in Norway. TV2. The CAGE director highlighted the importance of methane release in the Arctic for the global climate budget. TV2 appearance is important for CAGE as we have had a great amount of success in international media but needed to increase our presence closer to home.

Researcher Benedicte Ferré appeared both on Radio Canada and in numerous news articles in international outlets due to a press release on a scientific paper in Nature Geoscience. The press release pointed out that climate gas budgets highly overestimate methane discharge from the Arctic Ocean because they do not take into the account seasonal variability of gas release. “During cold periods the emissions from these seeps are almost halved, as if they are hibernating”, said Benedicte Ferré, who was first author of the paper.

Another press release “The moon controls the release of methane in Arctic Ocean” spread like wildfire from India to Colombia late in the year. It referenced an article in Nature Communications. The moon controls one of the most formidable forces in nature – the tides that shape our coastlines.

Tides, in turn, significantly affect the intensity of methane emissions from the Arctic Ocean seafloor. “We noticed that gas accumulations, which are in the sediments within a meter from the seafloor, are vulnerable to even slight pressure changes in the water column.» said researcher and co-author Andreia Plaza Faverola who was interviewed by several outlets.

### Events and public discussions

Even though many events were cancelled in 2020 we managed to make an appearance on digital platforms and contribute to important societal discussions.

Our communications advisor Maja Sojtaric contributed to EGU digital General Assembly with a presentation “Gender equality in science can be achieved, but it requires ambitious efforts from society, institutions and individual leaders” co-authored by director Karin Andreassen. The presentation was well discussed, especially among the early career scientist in the cyber space. Sojtaric also contributed to the committee for the “Angela Broome Award” at EGU General Assembly. The award promotes excellence in Space, Earth and planetary science journalism and was given to BBC journalist Roland Pease.

Vice Director of CAGE Monica Winsborrow contributed to furthering the discussion on climate change in the regional newspaper Nordlys with an opinion piece stating that “we believe that ice sheets will play a bigger role for the climate budget in the future, than what is thought today”

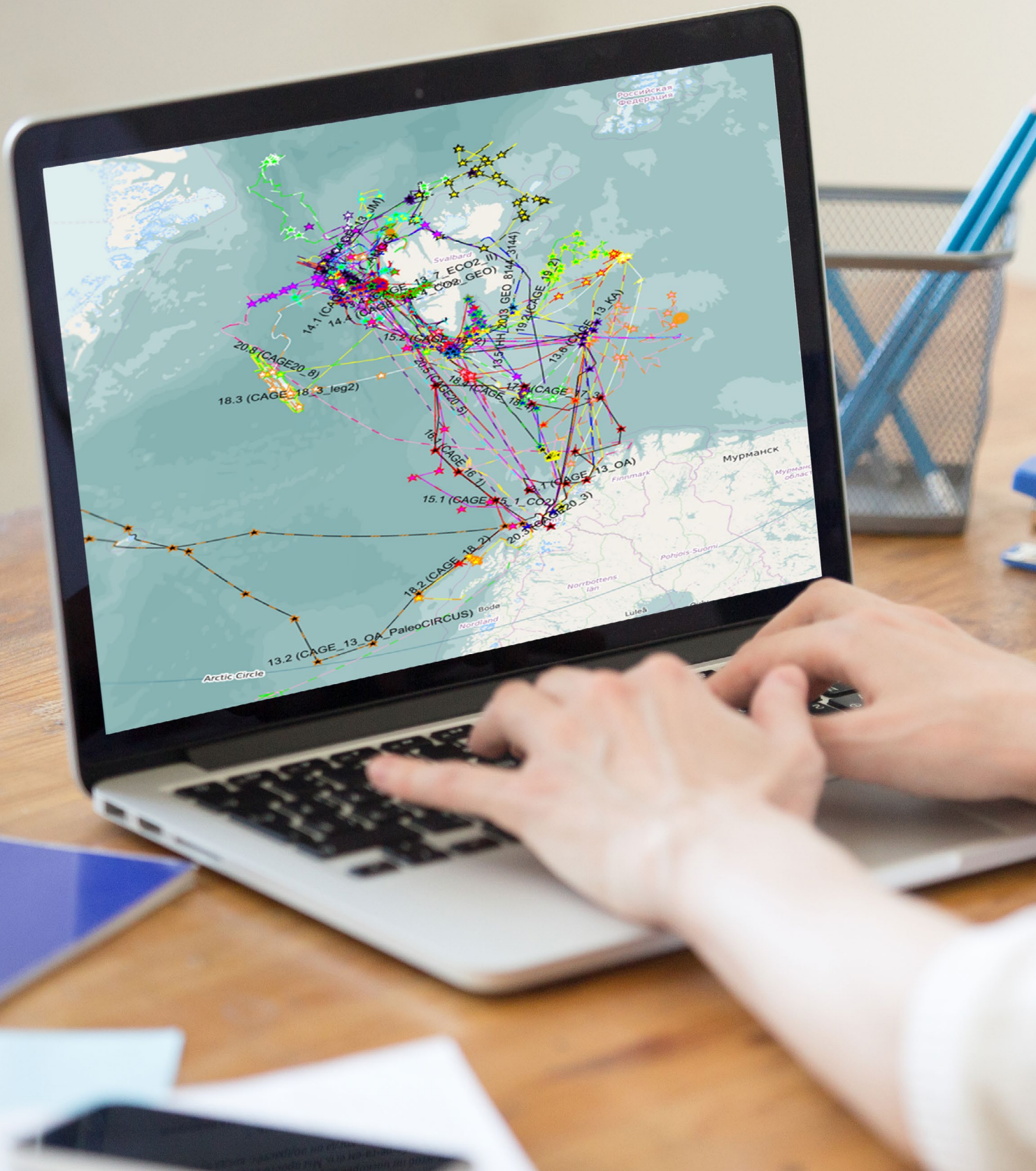
Winsborrow also contributed to an online panel by Anchorage Museum in Alaska, together with CAGE researcher Pavel Serov. North x North was a multi-modal, multi-site, multi-month, multi-discipline creative festiva, and Serov and Winsborrow were a part of the Scientist Spotlight events, which include a presentation of current science research by experts in the field. The backdrop for the event was the 2019 documentary Ice on Fire, which CAGE contributed to.

Those are a few examples of the outreach for 2020. In spite of the difficulties that the COVID 19 pandemic brought about we have managed a fair amount of communication through cyberspace. Also, we did a really good job on our blog! Check out on pages 28-29.

*Flares in Nature Geoscience publication. Photo: Benedicte Ferré.*

*North x North. Screen shot from AnchorageMuseum.org.*

*Moon. Photo: Maja Sojtaric.*





**Fabio Sarti, Data base manager**

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

## The CAGE database plays an important role in our open data strategy

CAGE works continuously to ensure that our data and results are as accessible as possible. Our website acts as a portal to our publications and data repositories.

### Towards more data sharing

Since 2016, CAGE has participated in a pilot project to improve access to our raw research data. This mostly includes data from Arctic scientific cruises, such as samples of the sea-floor sediments and water, seismic survey data, and image/video data. For this project Fabio Sarti, our data base manager, teamed up with the IT department at UiT and Avinet, a consultancy company specializing in map and data base solutions, and the result of this is the CAGE database we have today.

With a desire to create a user-friendly platform, the data base is centered around a map-based interface for data that is embedded in our website.

The site is easily navigable and allows access to all information about CAGE cruises, including ship tracks and sampling locations. There are good, prominent and cross-referenced links to publications from CAGE derived from these data, most of which are self-archived. CAGE is committed to open access, facilitated in part by national policies and deals Norwegian research organizations have with most of the prominent scientific publishers.

### Improving routines for data acquisition, access and storage

Our data base manager has developed templates and guidelines for data acquisition to ensure that data retrieving processes are more organized, efficient and fast. These are continuously up-

dated and refined following feedback from the scientists using them, and our Scientific Advisory Committee.

Preparation of cruise reports following pre-defined templates, allows the data base manager to effectively load these into the CAGE database and make them available from the Centre's website (<https://CAGE.uit.no/cruise-logs/>). In addition an 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.

*Screen shot from the CAGE database showing the ship tracks of the CAGE scientific cruises from 2013-2020.*

*Photo/illustration: Aleksandr Davydov, Julian P. Høgset.*



Text and photos: Mauro Pau, Researcher CAGE.

## Most fabulous experience

The Arctic ice pack is a natural wonder. Observations over the past decades show that is drastically shrinking and in our lifetime it may disappear for parts of the year. We are privileged to have seen it now.

### 23<sup>rd</sup> November

A storm from the south will hit us on our way back to Tromsø. The captain decides therefore to start our way out of the sea ice. Better not be here when the strong southerly winds will blow, compacting the sea-ice cover. As a consequence, the acoustic team has to come up with a new surveying plan suiting the new situation.

The most appealing scientific problem in the vicinity lies at 3000 m water depth on the northern flank of the East Greenland Ridge, a topographic high that originated during the opening of this part of the Atlantic Ocean. The ridge has been deflecting deep ocean currents ever since, and while doing so the currents weakened and lost their sediment load. The resulting contourite deposits, as they are called, could potentially reveal information on the temporal variability of the thermohaline ocean circulation, which redistributes heat around the globe.

### 24<sup>th</sup> November

We carry out our measurement and sampling program at three stations, this time deploying also the heat-flow probe at the deepest of the stations (3100 m). It takes about one hour to lower each piece of equipment to the seabed,

and another hour is needed to bring it back on board. This means that we spend the whole day surveying the area. Once we are done, it is time to start our journey back to mainland Norway.

### 25<sup>th</sup>-26<sup>th</sup> November

Steaming across a moonlit ocean, the captain manages to avoid the storm and brings us safely to the northernmost coast of Finnmark, near North Cape. Life onboard goes on with some work in the labs, cleaning duties, chatting in the day room, and the usual mealtimes. Passing from 78 to 72 degrees of latitude has remarkable effects: now there is light in the sky around mid-noon, and the frozen sea spray on deck is thawing!

### 27<sup>th</sup> November

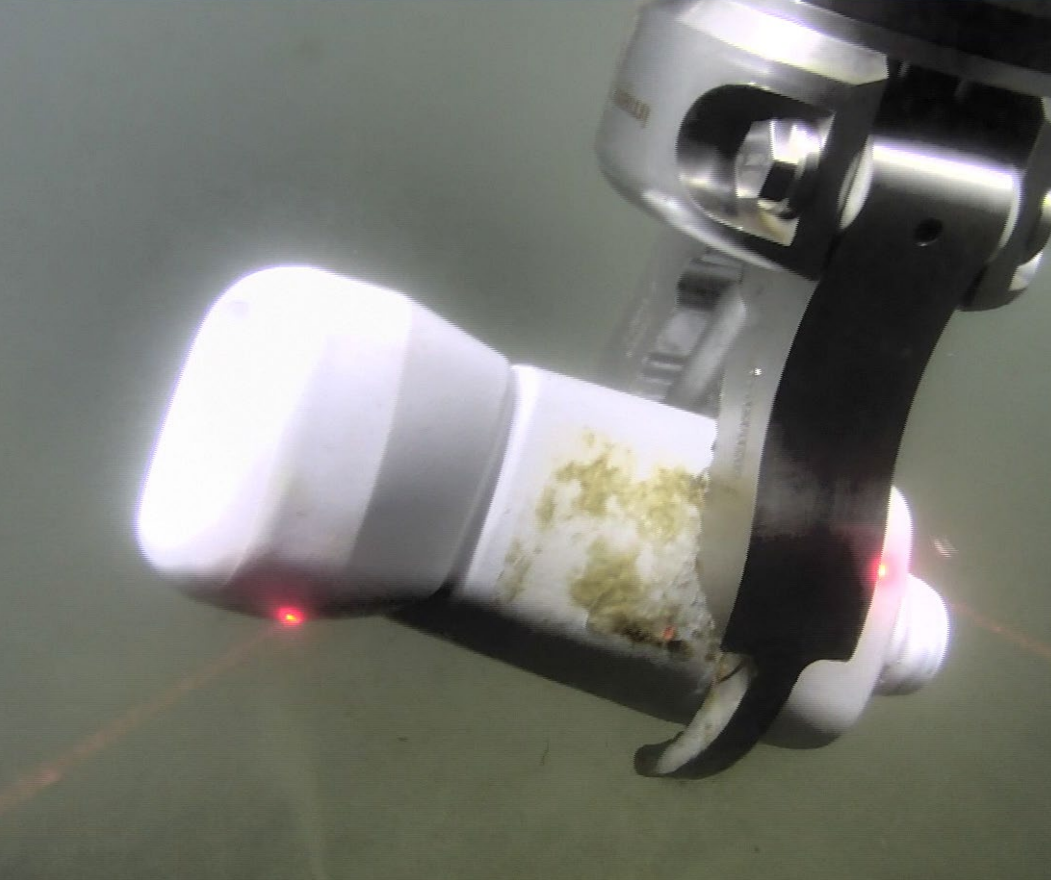
We pass North Cape at 3:00 AM, and just over two hours later we reach the first sampling station. We then proceed to survey and sample the interior of Tanafjorden.

At 10:00 AM we start our journey to Tromsø. The expected storm has arrived, but we are navigating safely through the spectacular fjords of northern Norway. We will arrive in Tromsø tomorrow morning.

### General impressions

Despite the odds, we can be happy with what we have achieved. The quantity of the data is not abundant, but we did collect great quality data in a sea-ice setting in a time of the year polar expeditions are, to say the least, not common. We have pushed the limits of what *rv Kronprins Haakon* can do, we and have acquired fabulous experience.

The Arctic ice pack is a natural wonder. Observations over the past decades show that is drastically shrinking, and in our life time it may disappear for parts of the year. We are privileged to have seen it now. At least some of us got deeply fascinated by that extreme environment, so much so that from the moment we left the sea ice we felt the urge to go back: there where even liquid seawater is below zero degrees Celsius, where an immense table of frozen ocean surrounds you, the night is several months long, and polar bears roam, sometimes under the northern light.



Text and photo: Marie Stetzler.

## Picking up plastic trash

According to a study from 2015, between 4.8 to 12.7 million tons of plastic end up in the ocean per year. Everyone has already heard about the “plastic continent” of macro- but mostly microplastic swirling in the world’s gyres. But, everything is connected.

The ocean currents are a huge two-lane-highway around the globe with the water’s salinity and temperature gradients as the main motor of transport: surface currents hence stream in a different (mostly opposite) direction than deep-sea currents. And like on a proper highway, there are plenty of exits, branching out in complex, always thinner paths, leading the currents to the most remote places. That plastic would also end up in the Arctic, transported by the West Spitsbergen Current, was just a matter of time.

Still, it is a bitter reality-check when the lights of our underwater robot the roV (Remotely Operated Vehicle) laid down on a white plastic bottle. And this at 353m depths and 80° N, miles away from the next soul, and even hundreds from the closest settlement. Our environmental consciousness forbid-

ding us to leave this piece of trash behind, we pick it up with the roV’s pliers. But even for a piece of plastic scientific interest can be found: the “fouling”, so micro- and macroorganisms which inevitably settle on all submerged surfaces after a while, are worth investigating.

Plastic is a light material, nevertheless, most of it won’t float on the ocean’s surface. It is the weight of the fouling that will drag it down to the bottom of the ocean, as will currents. Around 80% of the plastic in our seas is therefore lying on the ground. In absence of light, oxygen, and weathering, it won’t be degraded and can remain there, preserved for centuries, eventually becoming a new habitat for organisms. Not the nicest trace left behind by humankind, but at least this white bottle won’t go down in the geological records of the Anthropocene.

## Cruise Reports 2020

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# The year in short: 2020

## Haoyi Yao defended thesis online

Haoyi Yao defended her thesis in cyberspace, due to strict social distancing restrictions implemented by the Norwegian government to tackle the spread of the coronavirus. She was the first PhD student at UiT to defend her thesis after the first lockdown was implemented in Norway in March 2020. Both the trial lecture and the defense went ahead as planned March 26, 2020, thanks to digital technology.

The thesis «Reconstruction of past and present methane emission in the Arctic cold seeps using biogeochemical proxies» can be read via the UiT The Arctic University of Norway's open repository Munin.

## Andreia Plaza-Faverola wins Young Researcher Award at UiT

She was given the award for her leadership talents, and for excelling as an early career scientist ever since she joined UiT The Arctic University of Norway as a PhD student.

Plaza-Faverola is a researcher within 'Gas Hydrates and Free Gas Reservoirs' group at CAGE, and leader of the project SEAMSTRESS – Tectonic Stress Effects on Arctic Methane Seepage for which she was awarded two separate starting grants from Research Council of Norway, and Tromsø Research Foundation.

“Her development of innovative geophysical interpretation techniques and her interest in cross-disciplinary research has led to publications in Science and Nature Geoscience, and provide us with new knowledge about methane release from the seafloor in the Arctic”, the award committee states in a press release.

## LoVe Ocean Observatory is officially launched

This tenderly named infrastructure is not very romantic. It is, however, a dreamy addition to a marine scientist's toolbox: a cabled observatory that consistently relays exciting environmental information from the seafloor. Congratulations to Bénédicte Ferré.

LoVe Ocean Observatory, launched on August 25 2020, will make it possible to consistently monitor the ocean off the coast of

the Norwegian archipelago Lofoten and Vesterålen throughout the seasons. Thus, the enamoured acronym – LoVe. Several observatories are placed along 60-kilometre-long fibre optic and electric cables, making it possible for most of them to be operative 24/7, all year round.

CAGE is involved in the development and implementation of node 7 which is placed near an area of substantial methane seepage, close to a coral reef. The observatory will provide a long term, real-time observations of methane seepage from the ocean floor 270 meters below the surface. Methane is bubbling up in this area, potentially affecting the ecosystem.

## Mohamed Ezat awarded Starting Grant, 25 million NOK

Tromsø Research Foundation's Starting Grant is a highly competitive, and attractive funding for early career scientists. Mohamed Ezat is awarded the grant for the project The Arctic Ocean under Warm Climates (ARCLIM). See page 18-19.

Mohamed Ezat received his PhD from UiT The Arctic University of Norway in 2015. After his PhD he has been associated with CAGE Centre for Arctic Gas Hydrate Environment and Climate as postdoc and researcher. Since March 2018, Ezat has been working as a Marie-Curie Fellow at the University of Cambridge (UK). The TFS starting Grand brings him now back to UiT.

Ezat will now establish a group of early-career scientists, two Ph.D.'s and two postdocs, who will contribute to the project.

## Grassroots gender equality group, JEDI, established

Justice, equality, diversity and inclusion (JEDI) group was established at by the early career scientists at the Department of Geosciences and CAGE. The group is a digital meeting space on Microsoft Teams, where all employees at the department can share thoughts, ideas and links to useful resources. Among the topics that the group has contributed to is the new Action plan for gender equality, diversity and inclusion at the Faculty of Science and Technology.

*Andreia Plaza-Faverola wins Young Researcher Award.  
Photo: Maja Sojtaric.*

*Haoyi Yao's digital dissertation. Photo: Aivo Lepland.*

*LoVe launch in August 2020. Photo: Maja Sojtaric.*

*R/V Helmer Hanssen tows a small passenger boat in trouble to a safe place. Photo: Andreia Plaza-Faverola.*

*Mohamed Ezat recieved the TFS Starting Grant Diploma from the foundation's head of administration Unn Søren.  
Photo: Christian Halvorsen.*



# 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* opens up new areas for CAGE in the ice-covered Arctic. Equipped with a moon-pool 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

The 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 carry 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.



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# Publications list 2020

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## Subject area, publications

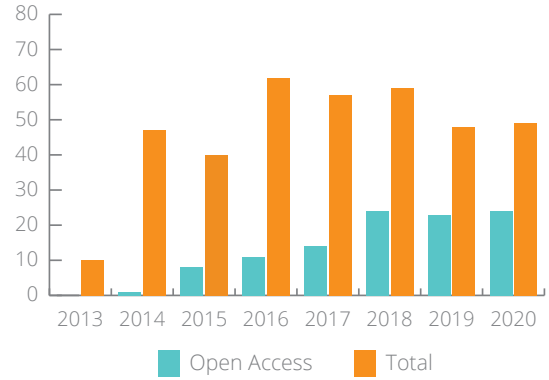
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- 20% Environmental Science
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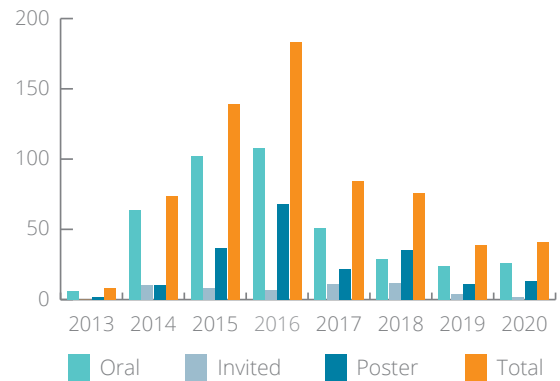
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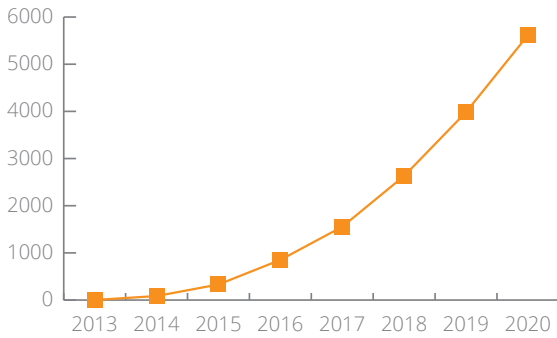
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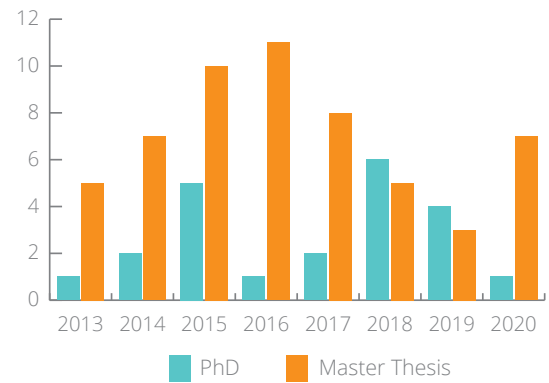
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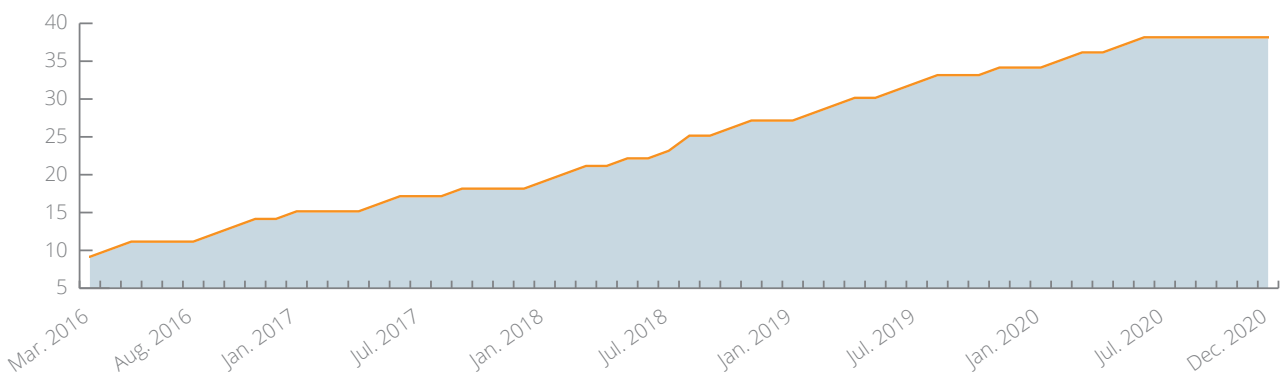
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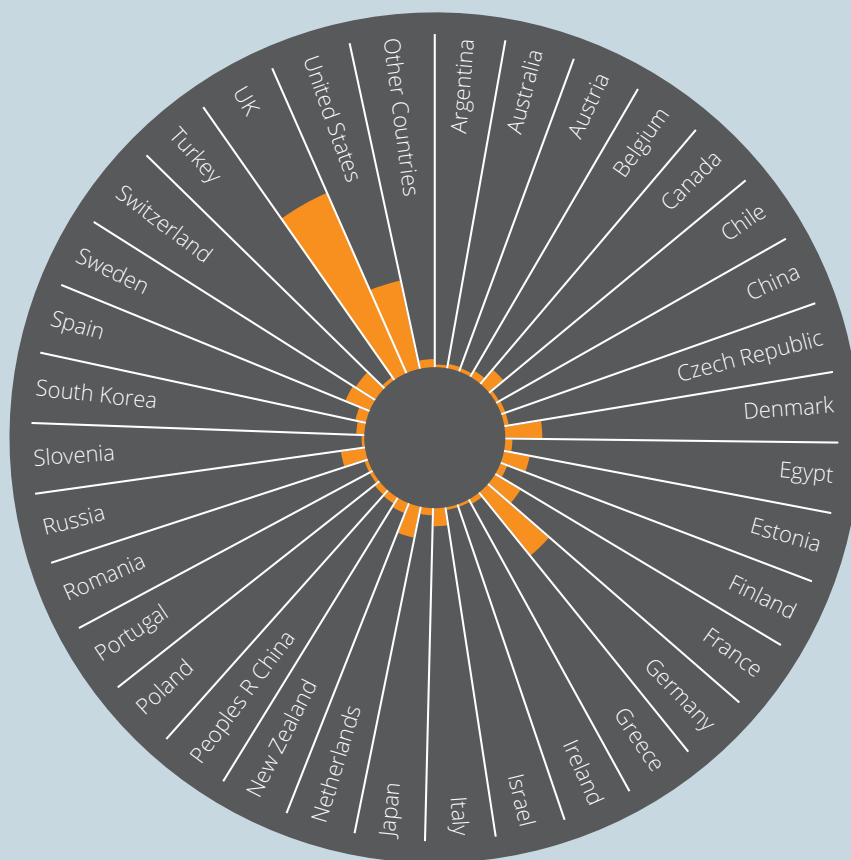


# International collaboration 2013–2020

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.

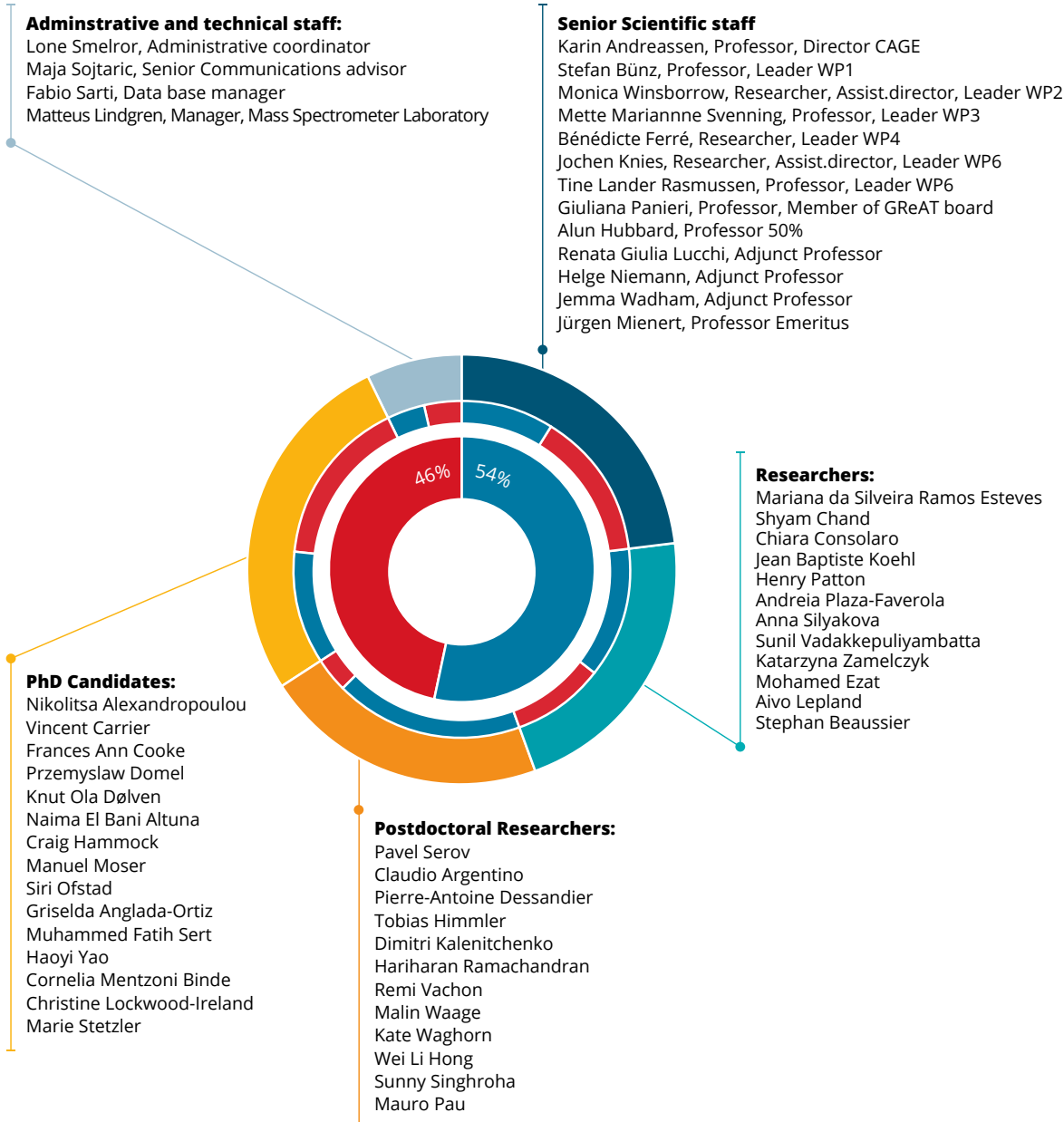
## International collaborations on publications (2013 to present)

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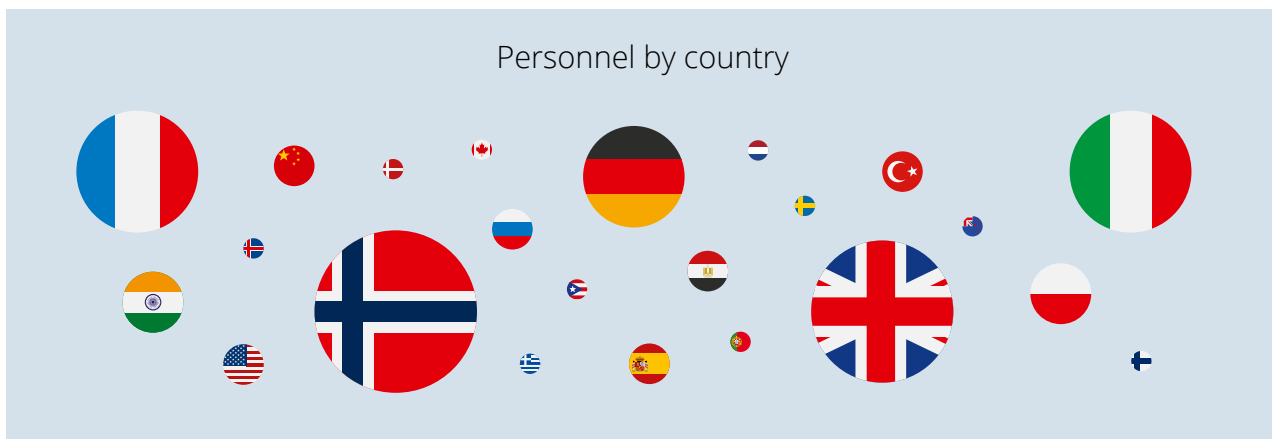


# Full list of personnel at the centre

We constantly work towards gender equality in our staff. Not only is the centre director a woman, 4 of the 6 work package leaders are women, and 2 of the 4 administrative/technical staff members are women. Our overall staff numbers also show that we place importance to the subject, with almost 50% men and women working for CAGE in 2020. This is 20% above the average staff for women in STEM fields in OECD countries, and 15-20% above the average in Norway. We also support young researchers – more than 50% of your staff are PhD Candidates and early career scientists.



## Personnel by country





**Nikolitsa Alexandropoulou**  
PhD Candidate



**Karin Andreassen**  
Professor  
Director CAGE



**Claudio Argentino**  
Postdoctoral Researcher



**Stefan Beaussier**  
Researcher



**Cornelia Mentzoni Binde**  
PhD Candidate



**Stefan Bünz**  
Professor  
Leader WP1



**Vincent Carrier**  
PhD Candidate



**Shyam Chand**  
Researcher



**Chiara Consolaro**  
Researcher



**Frances A. Cooke**  
PhD Candidate



**Mariana da Silveira Ramos Esteves**  
Researcher



**Pierre-Antoine Dessandier**  
Postdoctoral Researcher



**Przemyslaw Domel**  
PhD Candidate



**Knut Ola Dølven**  
PhD Candidate



**Naima El Bani Altuna**  
PhD Candidate



**Mohamed Ezat**  
Researcher



**Bénédicte Ferré**  
Researcher  
Leader WP4



**Craig Hammock**  
PhD Candidate



**Tobias Himmler**  
Postdoctoral Researcher



**Wei Li Hong**  
Postdoctoral Researcher



**Alun Hubbard**  
Professor 50%



**Dimitri Kalenitchenko**  
Postdoctoral Researcher



**Jochen Knies**  
Researcher  
Assistant Director  
Leader WP5



**Jean Baptiste-Koehl**  
Researcher



**Aivo Lepland**  
Researcher



**Matteus Lindgren**  
Manager, Mass Spectrometer Laboratory



**Christine Lockwood-Ireland**  
PhD Candidate



**Renata Giulia Lucchi**  
Adjunct Professor



**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



**Andrea Plaza-Faverola**  
Researcher



**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



**Mette Marianne Svenning**  
Professor  
Leader WP3



**Rémi Vachon**  
Postdoctoral Researcher



**Sunil Vadakkepuliambatta**  
Researcher



**Jemma Wadham**  
Adjunct Professor



**Kate Waghorn**  
Postdoctoral Researcher



**Monica Winsborrow**  
Researcher  
Assistant director  
Leader WP2



**Malin Waage**  
Postdoctoral Researcher

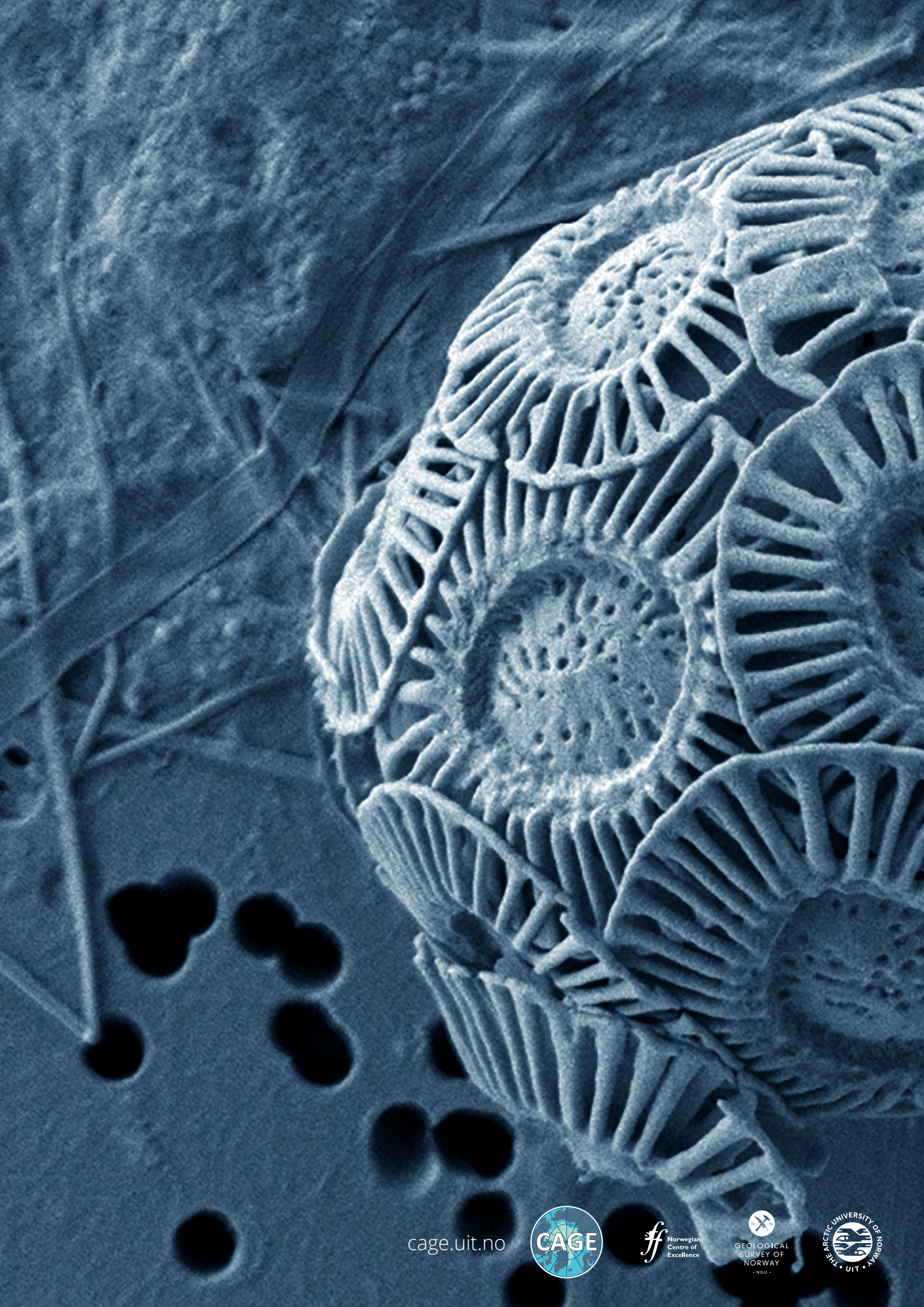


**Haoyi Yao**  
PhD Candidate



**Katarzyna Zamelczyk**  
Researcher





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