Academic and research collaboration between the IVT departments

nICE and CoARIce Projects

Presented by
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Funded by
The Research
Council of Norway

Multi-disciplinary Study of Atmospheric Ice Accretion Physics & Developing Optimal Technological Solutions to Minimize Ice Accretion Effects

- UiT Link: https://en.uit.no/project/nice
- RCN Link: https://prosjektbanken.forskningsradet.no/project/FORISS/324156

Multi-disciplinary Study of Atmospheric Ice Accretion Physics & Developing Optimal Technological Solutions to Minimize Ice Accretion Effects

Alternative title: Tverrfaglig studie av isdannelses fysikk og utvikling av optimale teknologiske løsninger for å minimere effekter av ising.

Awarded: **NOK 12.5 mill.**

Source:	Research council of Norway
Project Manager:	Professor Muhammad Shakeel Virk
Project Number:	324156
Application Type:	Forskerprosjekt / Stort, tverrfaglig forskerprosjekt
Project Period:	2022 - 2026
Funding received from:	FRINATEK-Fri prosj.st. mat.,naturv.,tek
Organisation:	UoH-sektor / Universiteter / UNIVERSITETET I TROMSØ - NORGES ARKTISKE UNIVERSITET / FAKULTET FOR INGENIØRVITENSKAP OG TEKNOLOGI / Institutt for industriell teknologi
Location:	Troms - Romsa - Tromssa / Tromsø
Subject Fields:	Matematikk og naturvitenskap / Informasjons- og kommunikasjonsvitenskap / Simulering, visualisering, signalbehandling, bildeanalyse

nICE

Development of Collaborative Academic and Research Program to Study Ice Accretion on Structures in Cold Region

- UiT Link: https://en.uit.no/project/coarice
- RCN Link: https://prosjektbanken.forskningsradet.no/project/FORISS/309241

Development of Collaborative Academic and Research Program to Study Ice Accretion on Structures in Cold Regions

Alternativ tittel: Utvikling av faglig samarbeids- og forskningsprogram for å studere isdannelse på strukturer i kalde regioner

Tildelt: kr 3,6 mill.

Kilde:	Forskningsrådet
Prosjektleder:	Professor Muhammad Shakeel Virk
Prosjektnummer:	309241
Søknadstype:	Koordinerings- og støtteaktivitet / Nettverksstøtte
Prosjektperiode:	2020 - 2024
Midlene er mottatt fra:	INTPART-International Partnerships for Excellent Education and Research
Organisasjon:	UoH-sektor / Universiteter / UNIVERSITETET I TROMSØ - NORGES ARKTISKE UNIVERSITET
Geografi:	Troms - Romsa - Tromssa / Tromsø
Fagområder:	Teknologi / Bygningsfag / Bygg-, anleggs- og transportteknologi
Samarbeidsland:	USA Canada Kina Japan

Case Study on Ice Nucleation

What is ice nucleation?

Why nucleation is important?

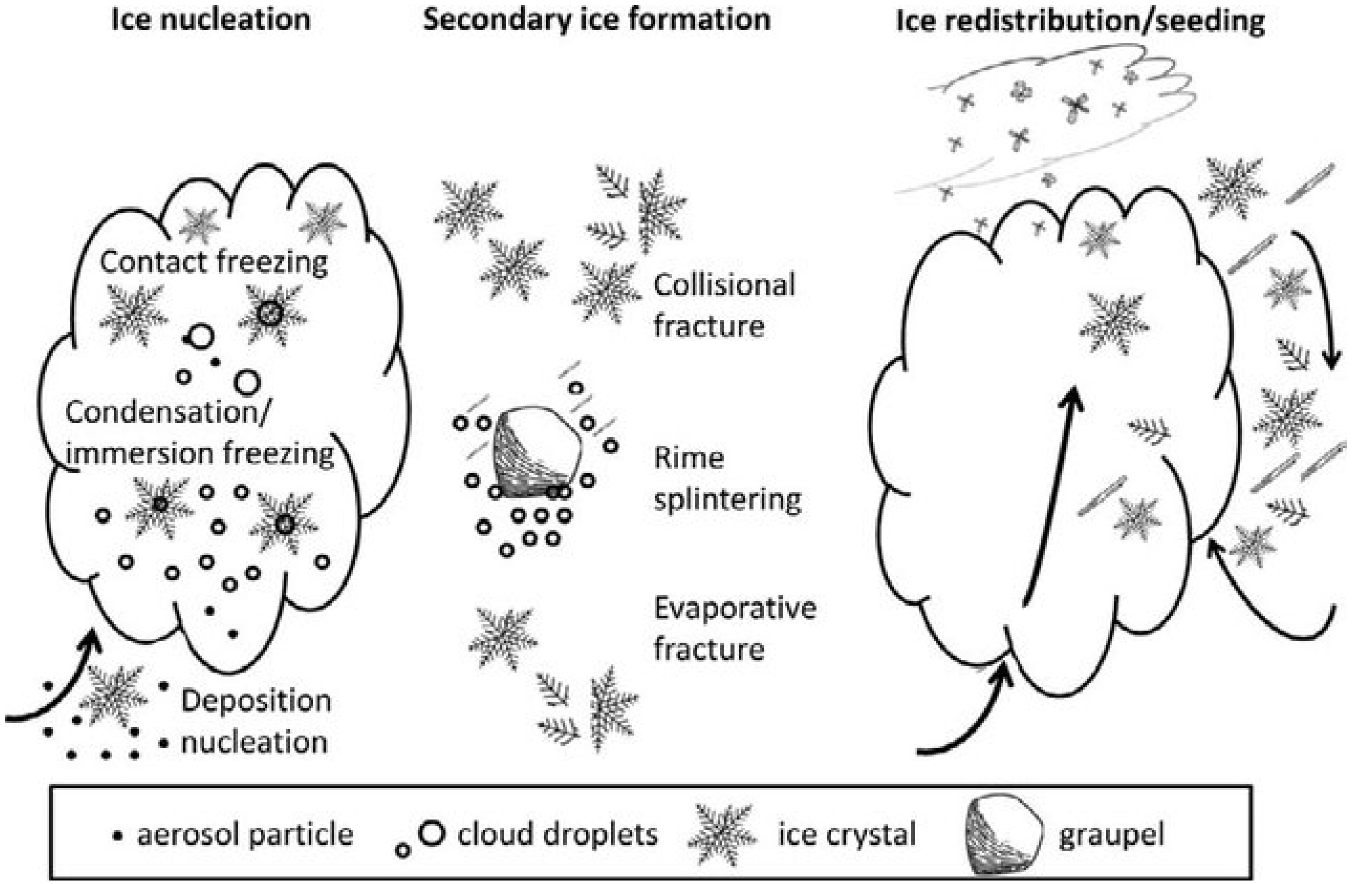
Ice nucleation thermodynamics

Methodology - Experiment Settings

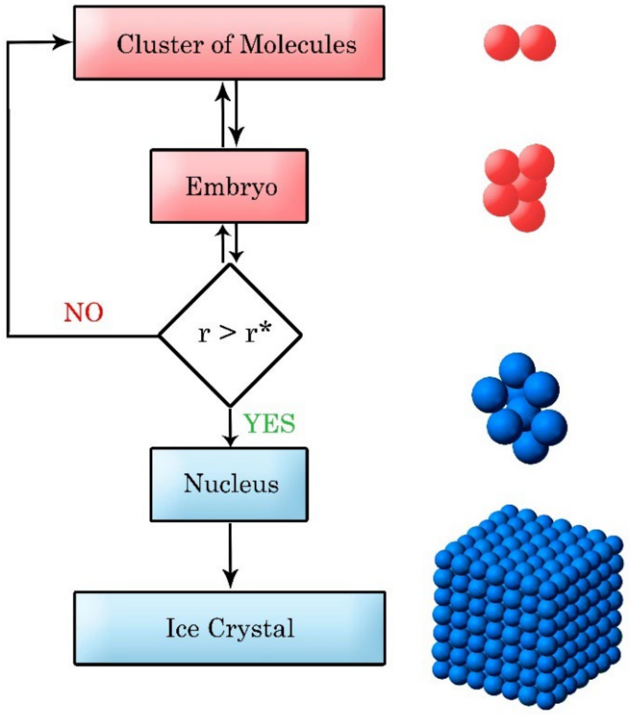
Results & Discussion

- High speed imaging
- High speed thermography
- Temperature with time plot

Conclusion



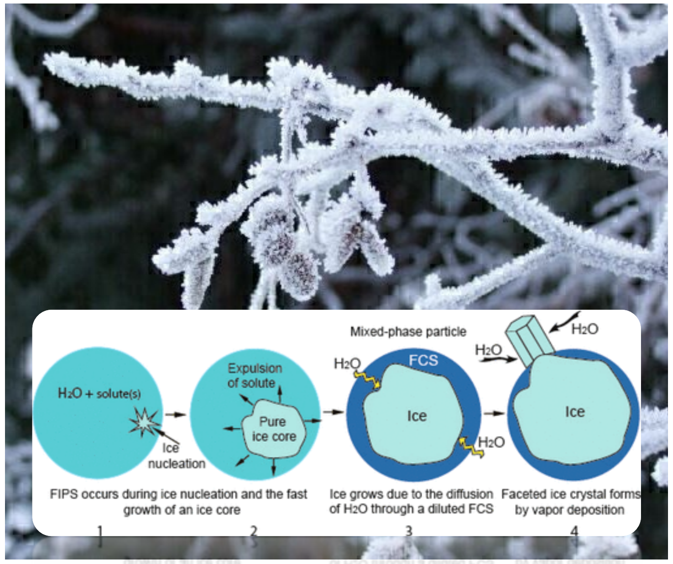
What is ice nucleation?



Changing equilibrium condition and achievement of driving force

Nucleation

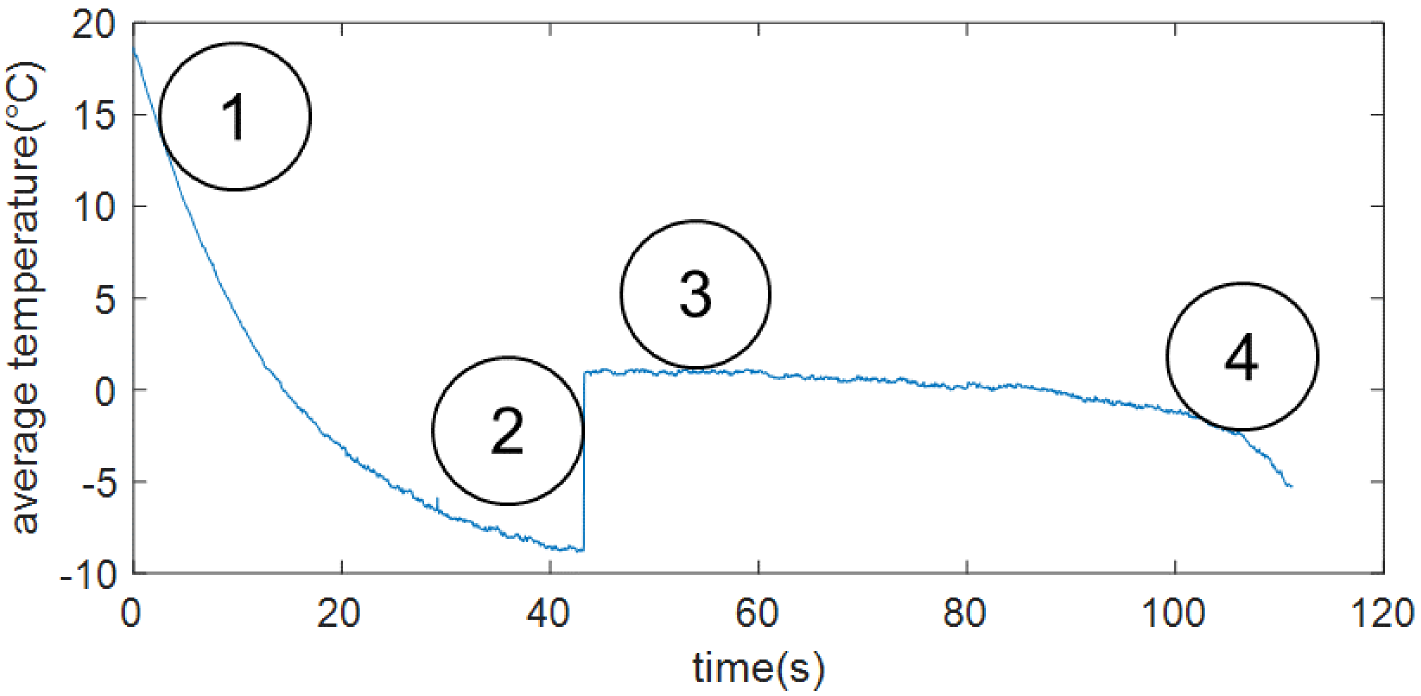
Growth of the nuclei into ice crystals



The process of ice nucleation occurs when small ice crystal embryos form on membrane that act as nucleation sites. These facilitate the aligning of water molecules, which promotes freezing.

Why nucleation is important?

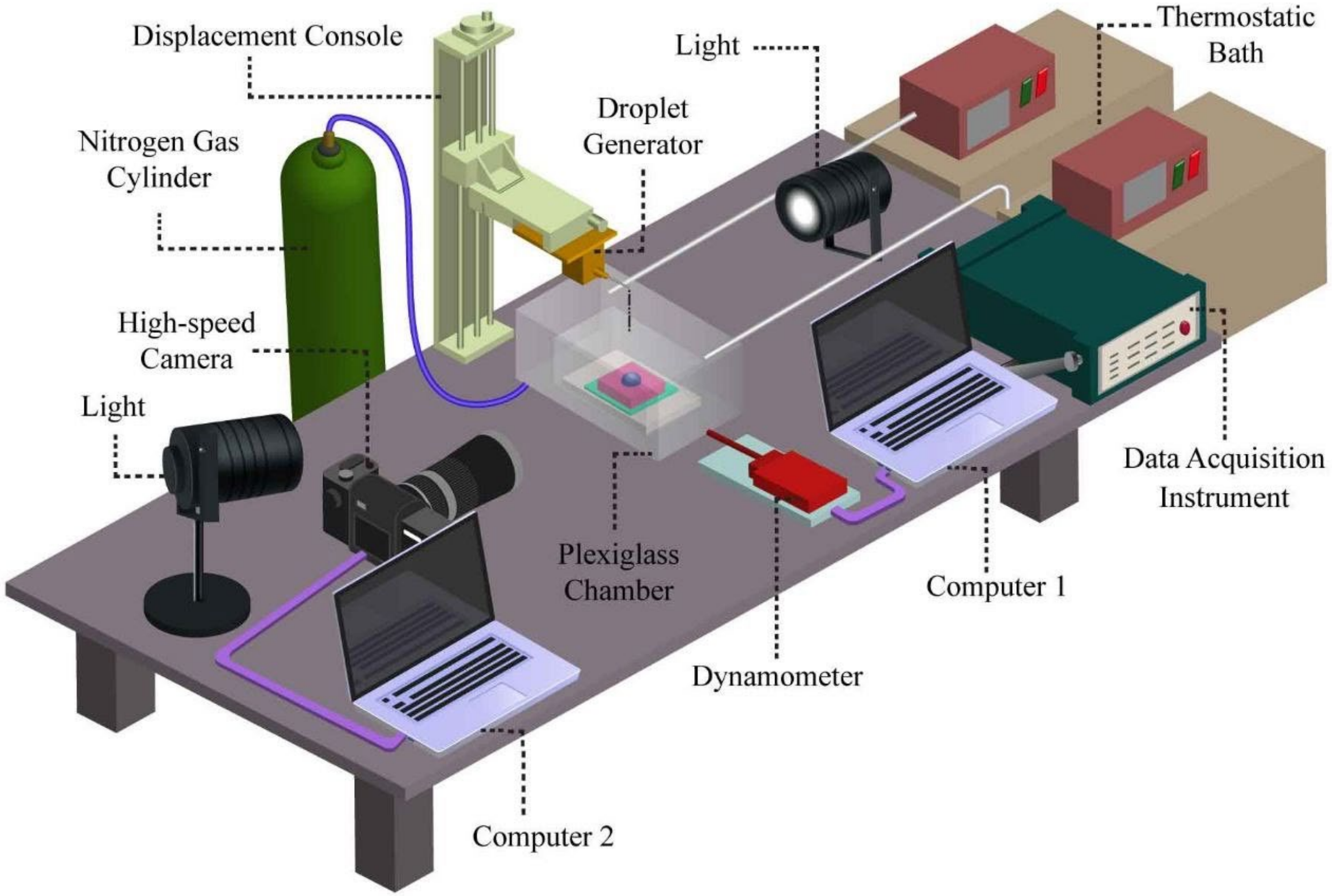
anti-icing strategy: avoid (delay) ice nucleation



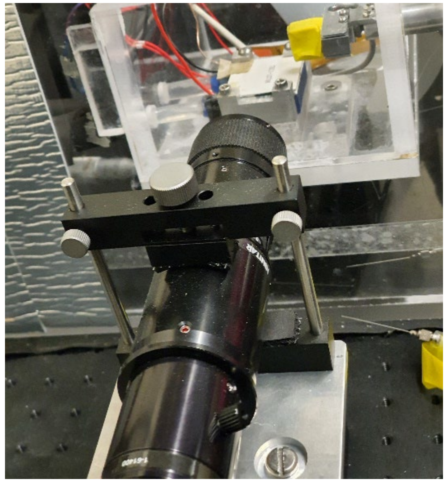
Ice nucleation thermodynamics

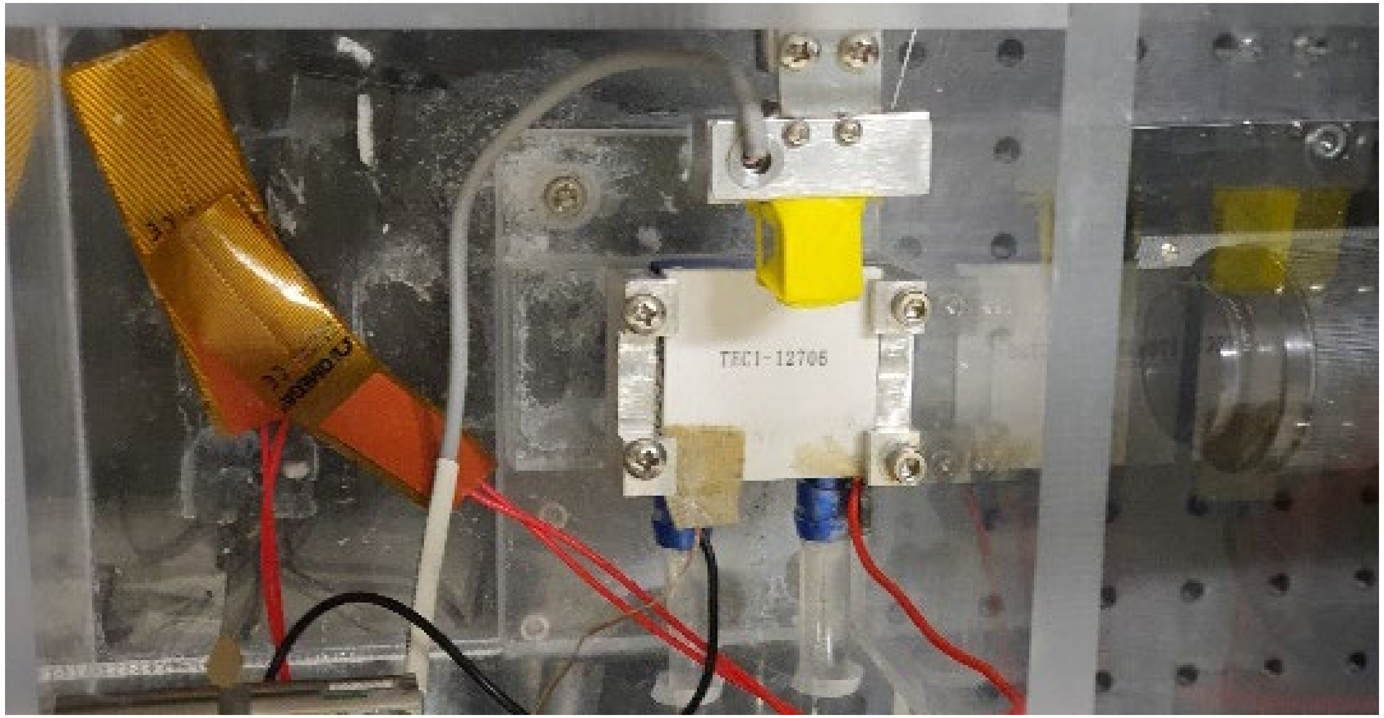
1. Newtonian cooling curve, heat capacity (first order)
2. Nucleation event (sudden release of latent heat of fusion) (Least Understood)
3. Phase change (constant temperature)
4. Newtonian cooling curve, heat capacity (first order)

Methodology – Experiment Settings

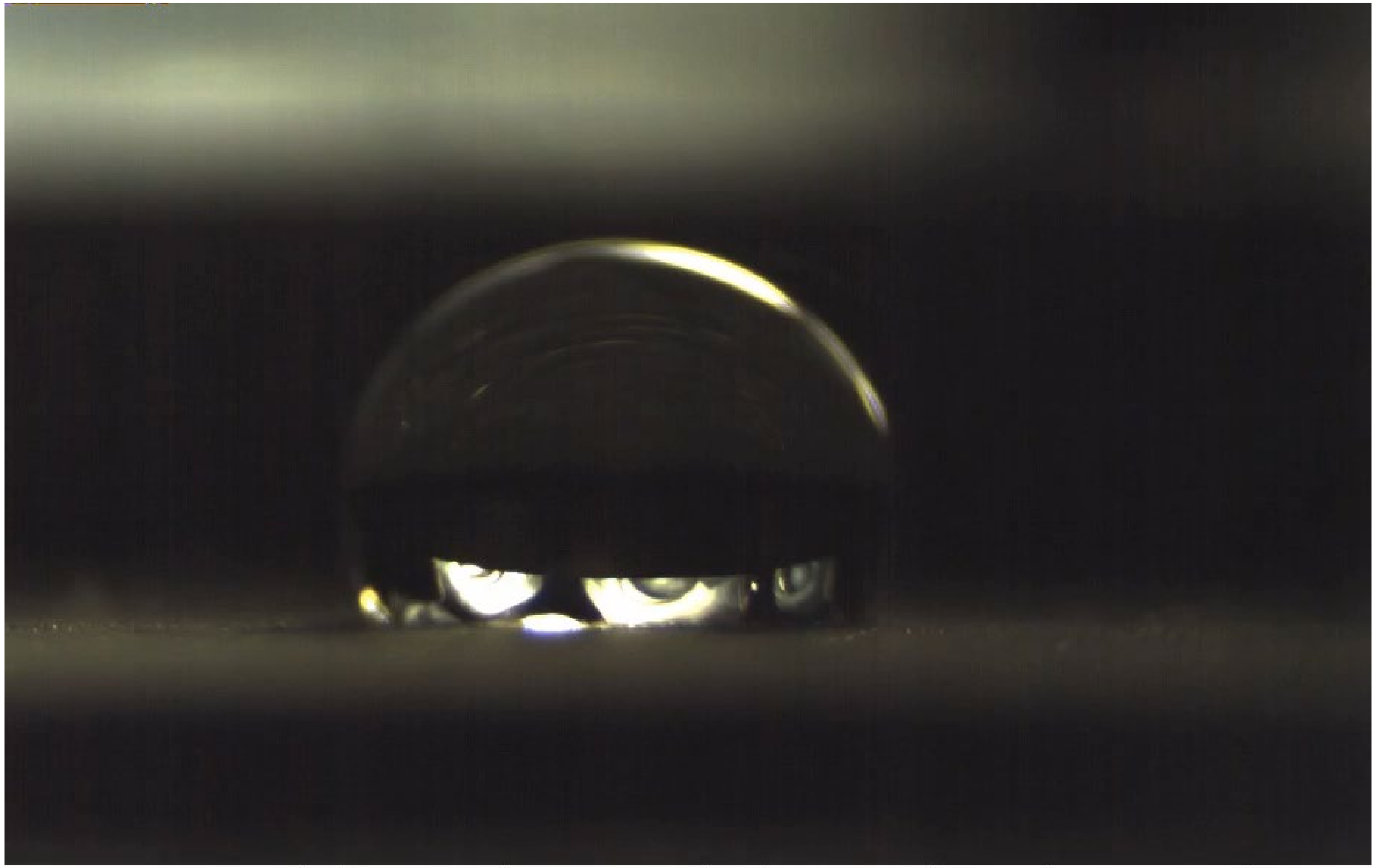


Methodology – Experiment Settings



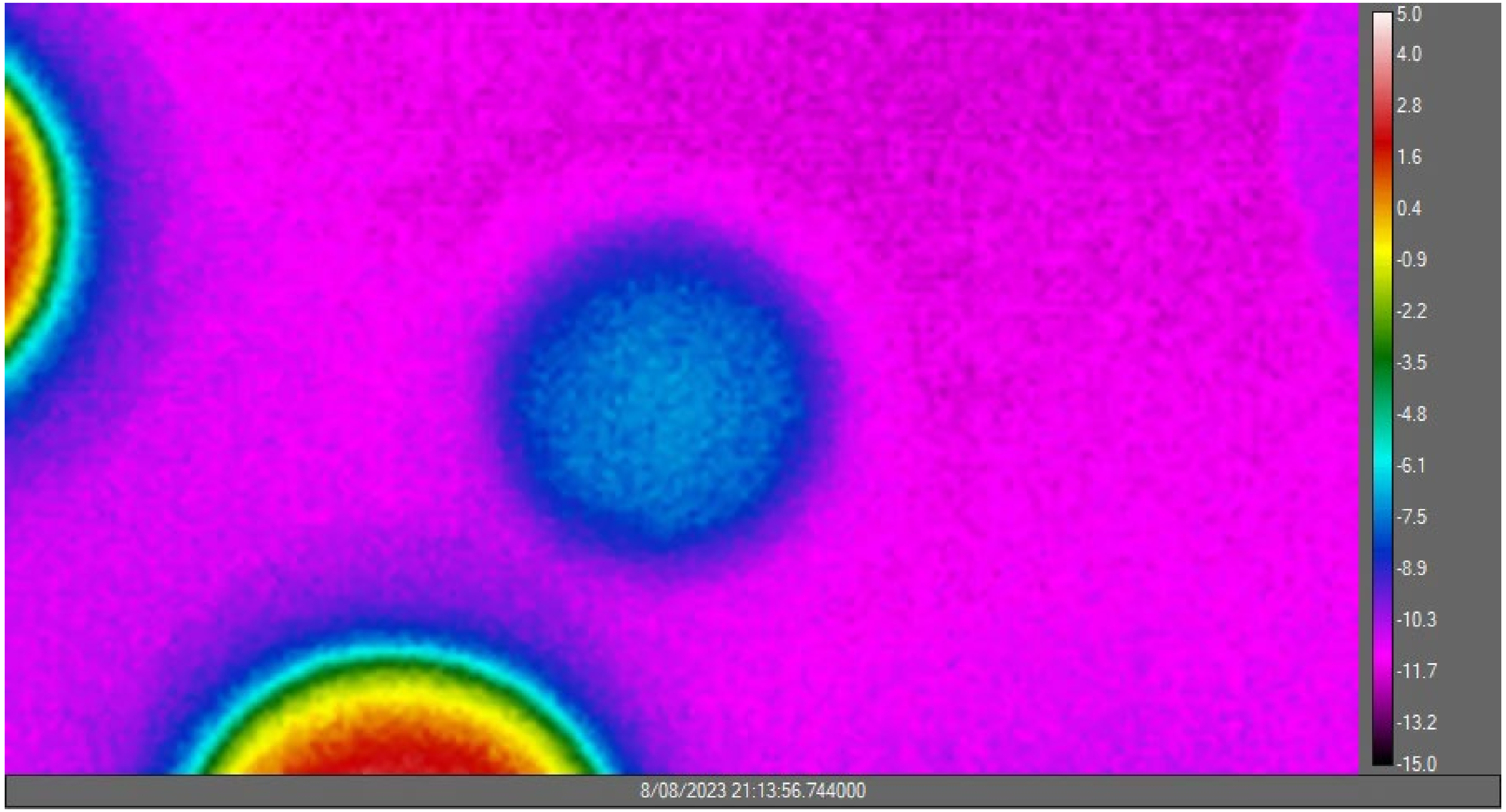


Results & Discussion (high-speed imaging)

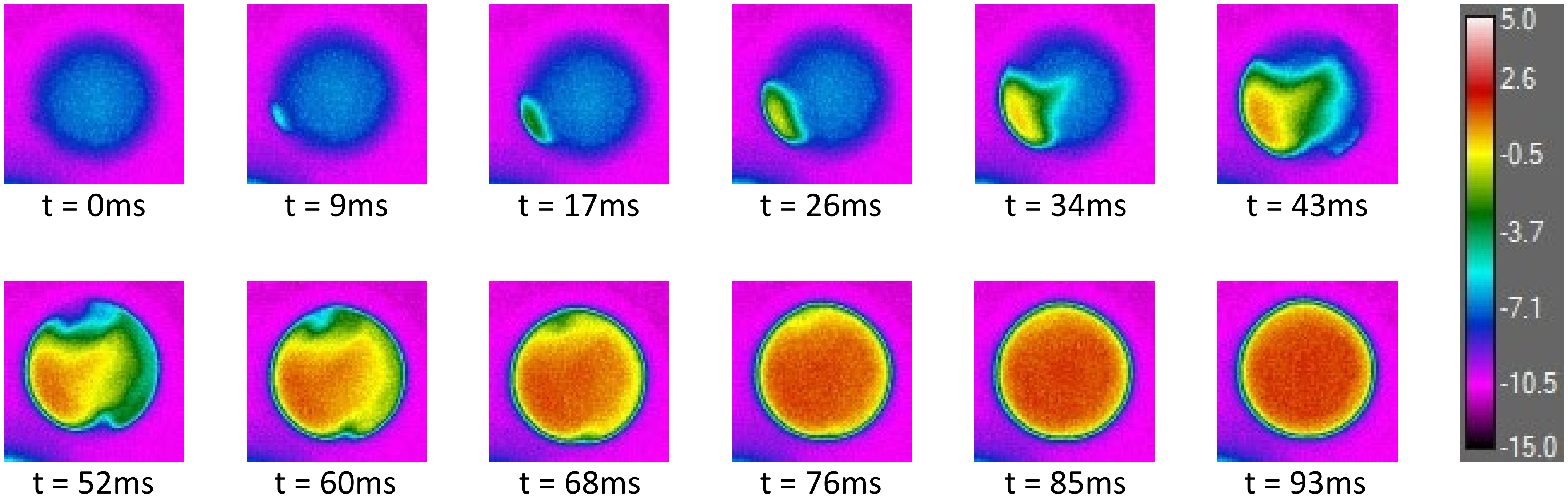


2020-01-31 11:53:18 -2610.9[ms] 000003550 MotionBLITZ EoSens Cube7 color LIMA_AMIL Mikrotron GmbH 928x586 @ 1663fps 153μs

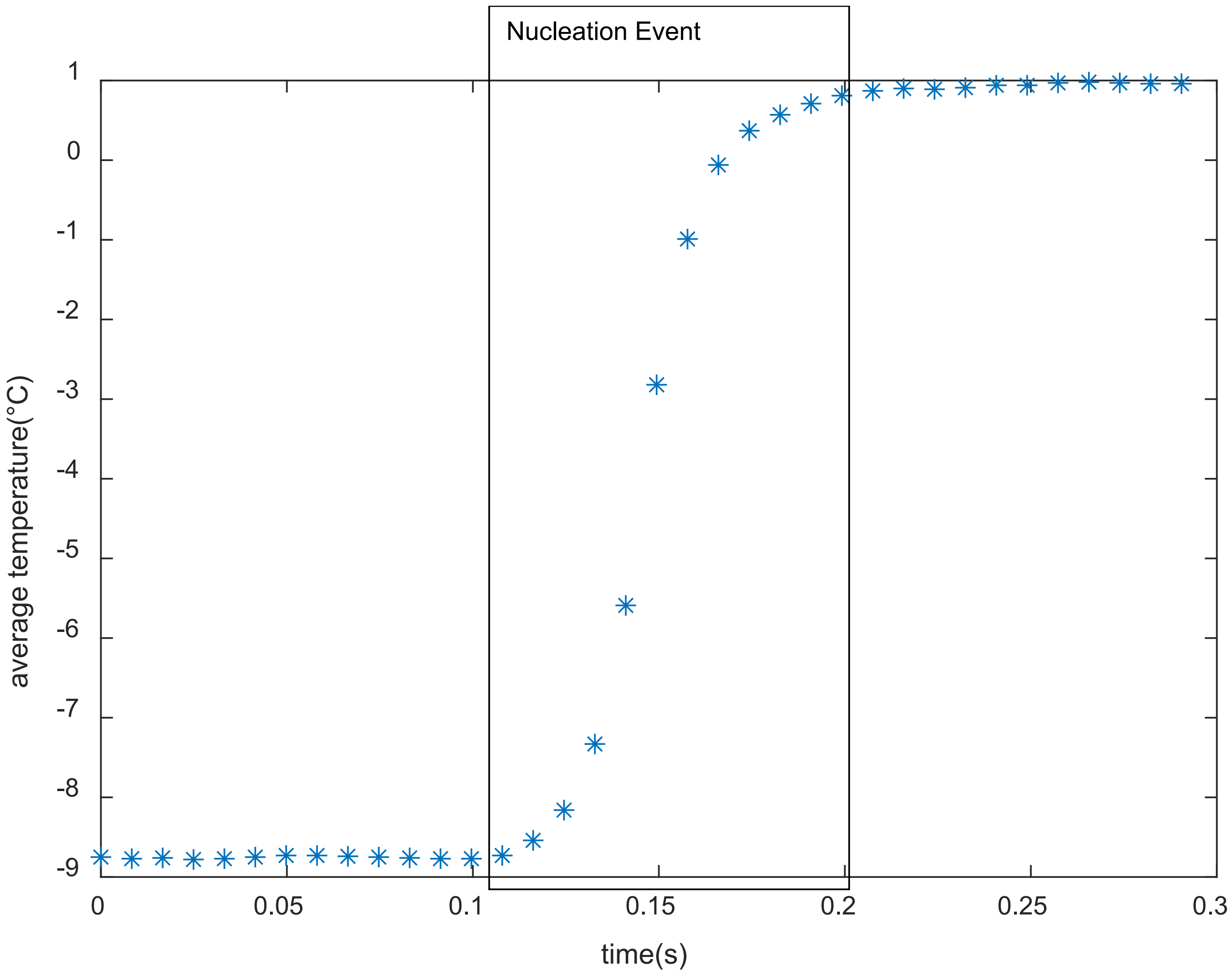
Results & Discussion (high-speed thermography)



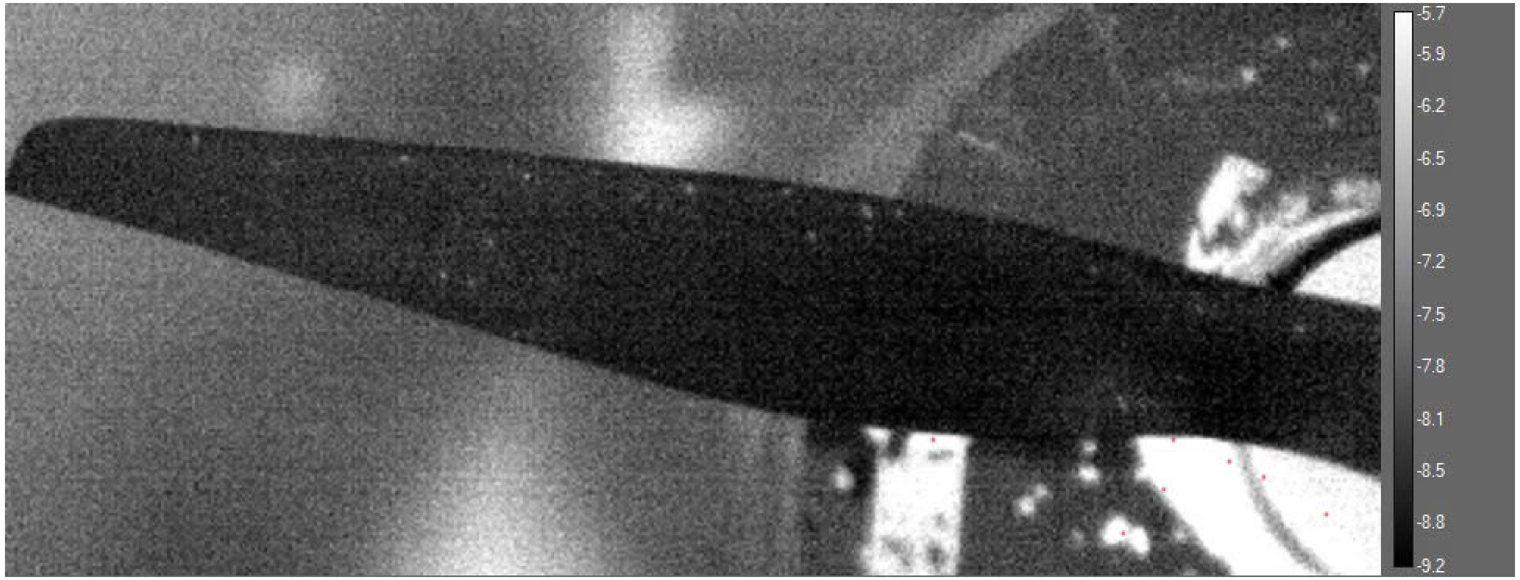
Results & Discussion (high-speed thermography)



Results & Discussion (high-speed thermography)



Results & Discussion (rotor blade)



Conclusion and Future Work

First ever, high-definition (1024 X 768 pixels), at maximum zoom capacity (4x zoom), high-speed (120 Hz), **thermography** of ice nucleation event.

We are working with the development of **multiphysics** based structure/fluid mechanics/heat transfer model of the nucleation event.

TEK-3602 Thermography and Spectroscopy

The course is divided into two main parts:

- **Thermography** - In this part, student will learn to obtain and interpret the data from thermography using infrared thermal imaging devices and associated software.

- **Spectroscopy** - In this part, student will learn the basic theory behind spectroscopy and typical measurement techniques in both laboratory and field environments.

In both, students learn to appreciate the applications of electromagnetic waves in infrared, visual and ultraviolet bands of the electromagnetic spectrum.

UiT Link: https://en.uit.no/education/courses/course?p_document_id=765546

TEK-3604/TEK-8015 Multiphysics Simulation

The course covers **multiphysics modelling techniques for structural mechanics and fluid mechanics/heat transfer**. Students will learn about structures problem and simulation techniques with the use of Finite Element Methods (FEM). Similarly, students will learn about fluid mechanics/heat transfer problems with the use of Finite Volume Methods and Finite Difference Methods (FVM / FDM). In both, students will learn about governing equations, discretization techniques, initial & boundary conditions, and solving techniques. They will also learn ANSYS® Multiphysics and MATLAB® software.

UiT Link: https://uit.no/education/courses/course?p_document_id=822267

Acknowledgment

Exploring knowledge gaps on atmospheric ice accretion

We spoke to **Professor Muhammad Virk** about the work of the nICE project in investigating how atmospheric ice accumulates on ground structures. Researchers are also exploring new technological solutions to detect and mitigate ice on structures and streamlining strategies regarding ice disaster management for safe and cost-effective human industrial operations in the High North and the Arctic.

The accretion of ice on key infrastructure like power transmission lines, wind turbines, communication towers, roads and railway infrastructure can have a significant impact on wider society, disrupting energy transmission, telecommunication, and transport networks for example. Much has been learned over recent years about icing on airborne structures but not much for ground structures. Now Professor Muhammad Virk and his colleagues from UiT- The Arctic University of Norway - are focusing their attention in this nICE project on improving the scientific understanding of atmospheric ice accretion on ground structures. "We're looking at how we can improve scientific knowledge about ice accretion on ground structures," he outlines.

It is essential to know the type, frequency, severity, and duration of icing events. The severity of atmospheric icing varies depending on local weather conditions. Climate change has also started to affect icing cycles. A lot of the existing knowledge on ice accretion relates to high-wind speed conditions, which holds relevance to the aviation sector, but there are clear knowledge gaps in terms of understanding the icing process on ground structures. "One of the core aims of the nICE project is to fill in that knowledge gap," continues Professor Virk.

Field ice monitoring station of UiT located at Fagernesfjellet in Narvik.

nICE project

The nICE project aims to strengthen research activities about atmospheric icing, developing technological solutions and multi-disciplinary research infrastructures to gain new knowledge about atmospheric icing on ground structures. The project is led by Professor Muhammad Virk and the team consists of a multi-disciplinary group of researchers, whose work mainly involves multi-scale numerical modelling of ice accretion, ice detection and mitigation and ice disaster management. The numerical models are being validated with the field measurements data gathered from a field ice monitoring station installed by UiT researchers inside the Arctic Circle in northern Norway. "From this advanced field ice monitoring station, we 'will have a set of meteorological data, including wind speed, atmospheric temperature, pressure, humidity, liquid water content, super cooled water droplet size, icing intensity and accreted ice loads, which are important variables for numerical modelling of ice accretion," says Professor Virk.

The behaviour of super cooled water droplets suspended in air is quite different close to ground to that seen in high wind speed conditions at higher altitudes. In the nICE project researchers are studying this closely, with the objective of improving ice accretion physics models. More detailed information on the micro-scale ice accretion physics can help to develop improved mesoscale weather forecasting models, for the development of ice load maps. "We aim to provide meteorological organisations with more mature forecasting models for icing events by the end of the project," outlines Professor Virk. Professor Yngve Birkelund and his team are working on meso scale modelling of ice accretion in nICE project.

The project's agenda also includes the design of a new, hybrid ice detection and mitigation system, suitable for covering large surface areas. "Currently most ice detection sensors provide information at a single location, but we are interested in seeing ice over a large surface area, and in developing methods which can improve ice detection and mitigation," Professor Virk explains. "In nICE project, Dr Hassan Khawaja and his team are designing a new, infrared-based ice detection and mitigation system."

This new system can provide a greater level of detail about the extent of ice detection, so mitigation can then be proportionate to the severity of the problem, rather than simply turning on a power-hungry heating system. Heating systems prevent super cooled water droplets from freezing on structural surfaces, yet they are expensive. "You have to use a lot of electrical power, which costs money. That may be fine for some applications, but for others we will have to utilise cost effective optimal methods," says Professor Virk.

Another approach involves using hydrophobic surface coatings to prevent water droplets from sticking to a surface, yet Professor Virk says this approach is not fully suitable for all applications either.

Professor Javad Barabady and his team is also working on developing strategies for ice disaster management, which is an important safety consideration for populations in ice-prone regions. Norway experienced one of the heaviest ice loads (305 Kg/m) ever measured on power transmission lines during the early 60's, and it proved almost impossible to de-ice power lines in a short timespan. Under such circumstances, damage to infrastructure is highly likely, as well as loss of power for thousands of inhabitants in affected areas. Furthermore, atmospheric icing on rotor blades can lead to the complete stop of a wind turbine. A reliable method to secure operational safety is needed to avoid damage and loss of production. An ice storm in Quebec & Ontario in Canada in 1998 lasted for five days and affected more than 4 million people. This ice storm was considered as one of the worst natural disasters in Canadian history. Similarly, in 2008, an ice storm struck the south-central region of China and significantly damaged communication, transportation, and power distribution networks.

These incidents highlight the need for better preparation and management in case of such disasters. In the nICE project, researchers aim to create a comprehensive plan for icing safety and ice disaster management, which will benefit from knowledge that has been acquired on ice accretion physics and methods for prediction of icing events. "We are looking at ice disaster management, so that we can put forward some recommendations in future," says Professor Virk. "If such a situation occurs here in Norway, or elsewhere in Scandinavia, how should we deal with it? That's one of the outcomes of the nICE project that will bring benefits to wider society."

System application

The main target in terms of the potential future application of the knowledge gained during the nICE project will be High North and Arctic regions, and Professor Virk hopes to assess the system in future. "We want to see how this knowledge will be useful, and whether it could be used to help reduce infrastructure maintenance costs," he says. The wider aim in the project is to gain new knowledge about ice accretion on ground structures, which could play an important role in the development and maintenance of infrastructure in the Arctic and High North. "If it is decided to build a new power line or communication tower in a remote area of these regions, then we hope that our mathematical models will show what kinds of ice loads can be expected over the next 40-50 years," continues Professor Virk. "We're also considering how industry in Norway, and other ice prone cold climate countries can benefit from this knowledge."

We aim to improve knowledge about **ice accretion physics** and propose new technological solutions for **safe human industrial activities** in Arctic and High North regions.

The nICE: Multi-disciplinary Study of Atmospheric Ice Accretion Physics project team.

nICE

Multi-disciplinary Study of Atmospheric Ice Accretion Physics

Project Objectives
The nICE project aims to gain new knowledge about atmospheric icing and develop innovative technological solutions to related problems. This research holds wider relevance in the context of increased human activities in the high north, and innovative solutions will be required to maintain key infrastructure and keep it running effectively.

Project Funding
nICE is a multidisciplinary joint research project between IVT and NT faculty of UiT. The project is funded by the Norwegian Research Council (FRIPRO/ Large Scale Inter-disciplanary Project) with total funding of 27.5 mNOK.

Project Partners
This 04 years (2022-2026) project is coordinated and managed by Professor Muhammad Virk. The project involves researchers from 06 departments, 03 research centers and 10 research groups of UiT.
Other leading project researchers:
1) Professor Yngve Birkelund
2) Professor Jinmei Lu
3) Dr Hassan Abbas Khawaja
4) Professor Javad Barabady.
In addition, there are 02 post doctoral research fellows and 04 PhD students in this project.
https://en.uit.no/project/nice/prosjektgruppe

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Professor Muhammad Virk

Muhammad Virk is Professor in the Institute for Industrial Technology at the Arctic University of Norway, where he leads the Arctic Technology and Icing Research Group. He works with a range of collaborators on cold climate technology, icing and renewable energy.

nICE

UiT The Arctic University of Norway

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Thank you and Questions