Marin Byggteknikkdagen NTNU/PIANC , 19. april, 2018

Arctic Coastal Engineering

A/Prof. Raed Lubbad, NTNU

Sustainable Arctic Marine and Coastal Technology (SAMCoT)

KVÆRNER · SINTEF · POLARFORSKNINGS SEKRETARIATET (SWEDISH POLAR RESEARCH SECRETARIAT) · AkerBP · Lundin Norway · KYSTVERKET · VTT · KONGSBERG · ExxonMobil · HSVA · sfi · NTNU · UNIS · DTU · DNV·GL · Multiconsult · TOTAL · Aalto University School of Science and Technology · TU Delft · Statoil · UCL

12 Industry Partners
9 Research Partners
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Research strategy

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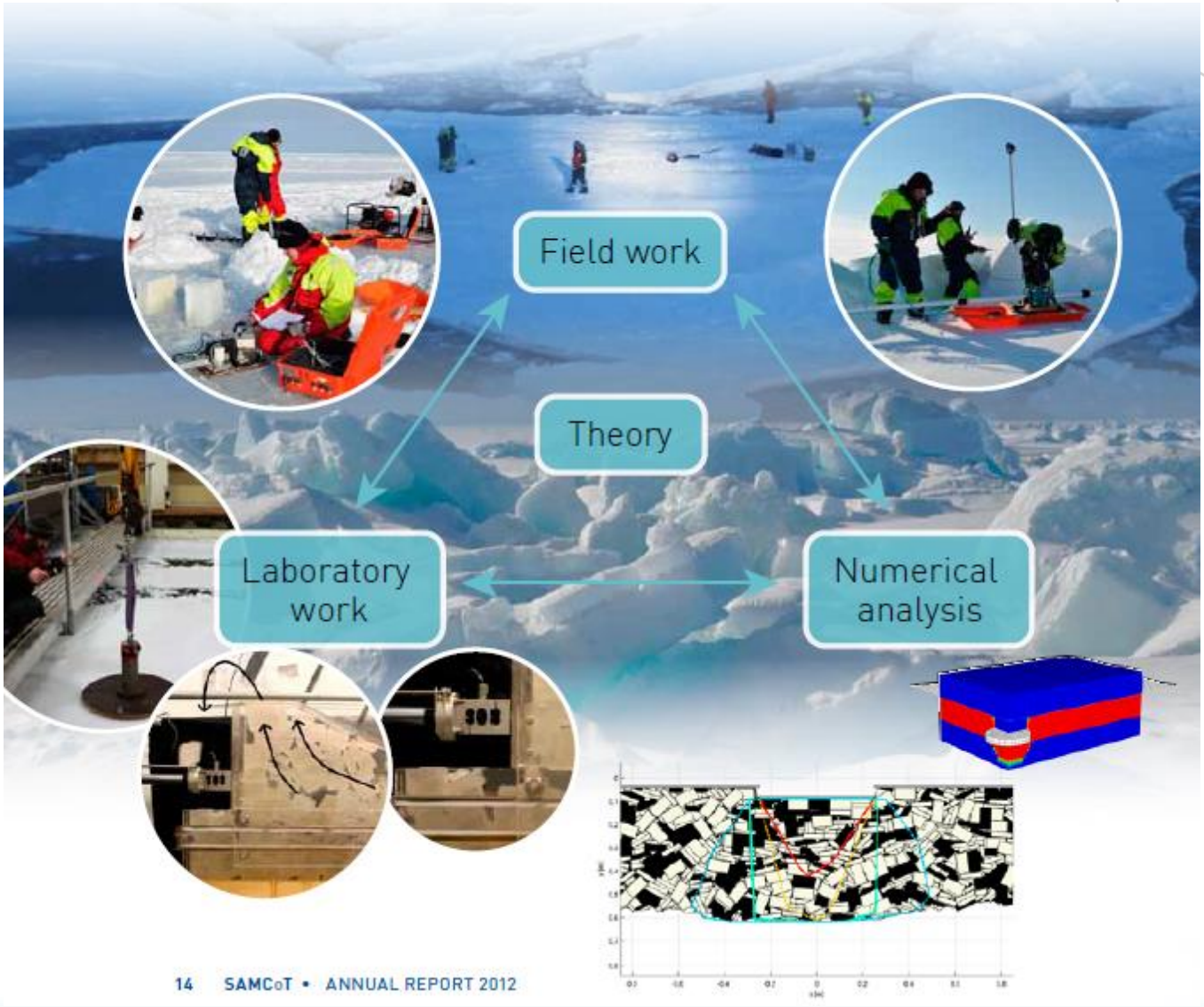

Mantra: Full-scale data - Research Cruises

2012

2013

2015

Arctic Ocean 2016

Oden Arctic Technology Research Cruises: 2012, 2013 and 2015

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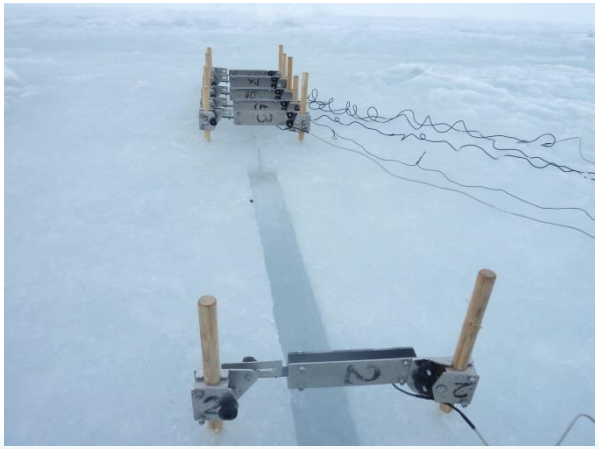
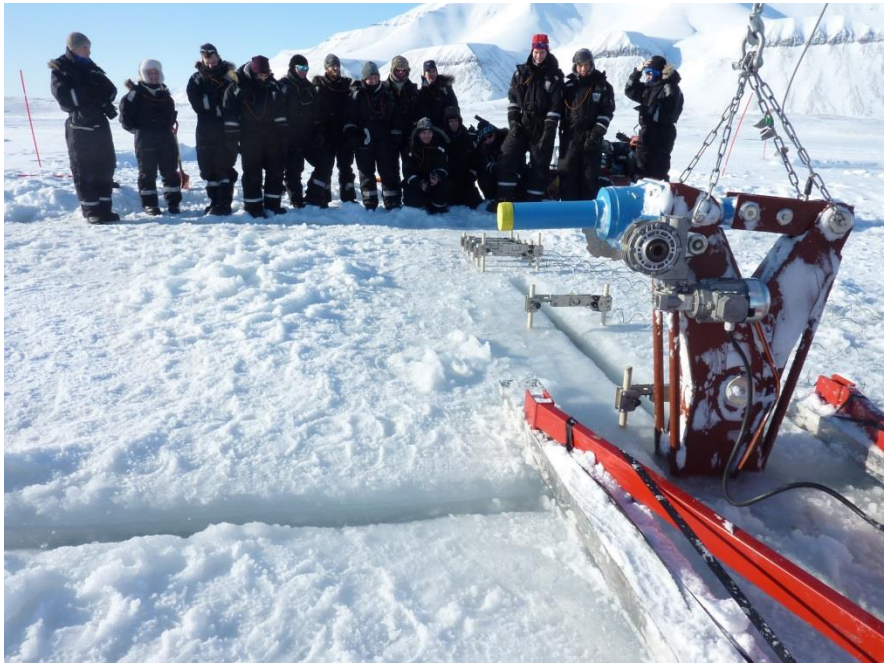
Mantra: Full-scale data – Field work at Svea, Spitsbergen

Data Set	Period	Place / Platform	Description
Large Scale Field Sea Ice Fracture Experiment (Part I: Size Effect)	06.03.2016 – 18.03.2016	Svea, Svalbard	In total 17 ice floes, with 15 useful results, were splitted Floe size ranges from 3 m to 10 m (in length wise)
Large Scale Field Sea Ice Fracture Experiment (Part II: Loading Rate Effects)	09.03.2017 – 19.03.2017 & 02.04.2017 – 07.04.2017	Svea, Svalbard	In total 13ice floes, with 17 useful results, were splitted Loading rate ranges from 1.5 mm/s, 0.6 mm/s to 0.015 mm/s
Large Scale Field Ice Ridge Splitting Experiment	19.02.2017 – 26.02.2017 & 02.04.2017 – 07.04.2017	Svea, Svalbard	One ice ridge was made in Feb. 2017 The Ice ridge is splitted after one month of consolidation





Example of laboratory work at the ice tank HSVA, Germany

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Data Set	Period	Place / Platform	Description
Loads on structures- Waves propagating in ice LS-WICE	24.10.2016- 11.11.2016	HSVA- Germany	Three groups of experiments were performed: ice fracture under wave actions, wave attenuation/dispersion in broken ice covers, and ice-structure interaction under wave

Overview

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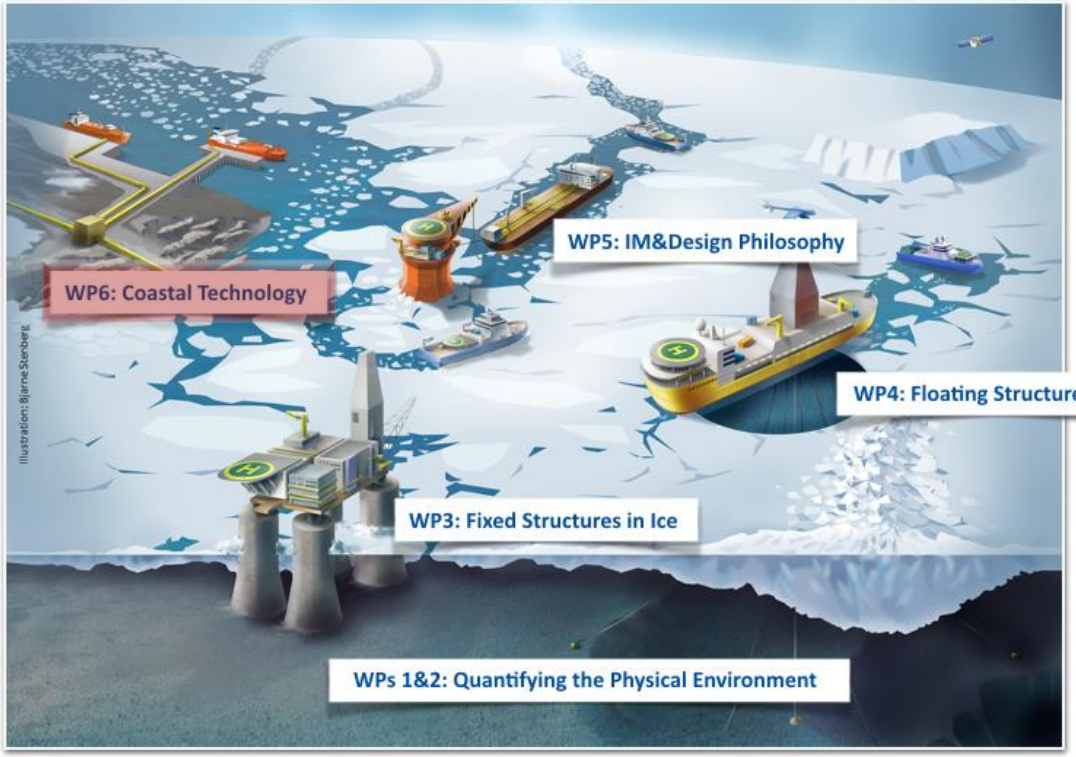

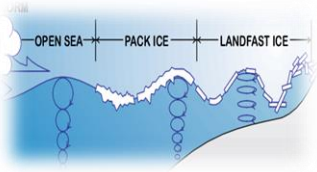

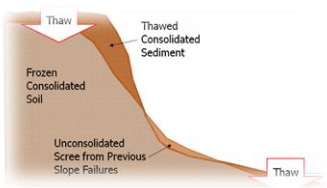

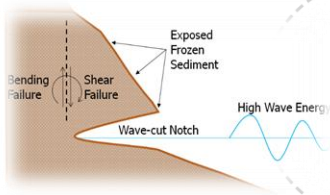

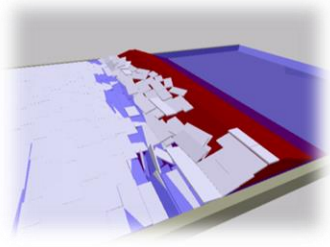

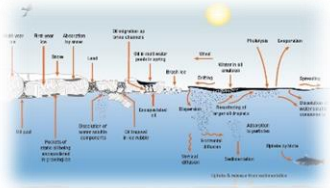

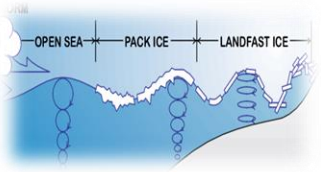

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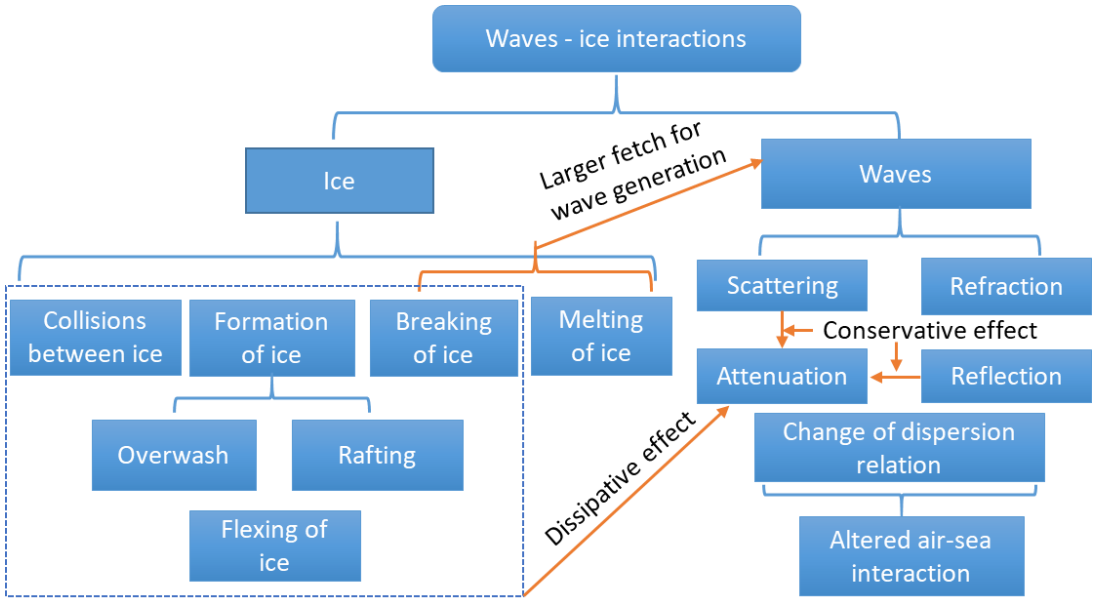
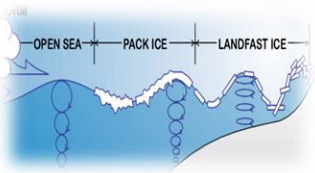
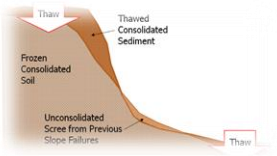
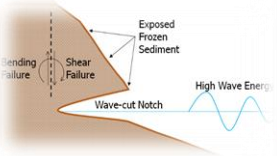
$$\frac{\partial E(f,\vec{x},\theta)}{\partial t}+\nabla_x \cdot c_g E(f,\vec{x},\theta)=(1-C)S_{in}+S_{ds}+S_{nl}+CS_{ice}$$









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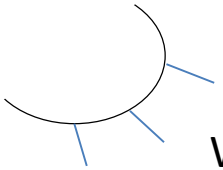
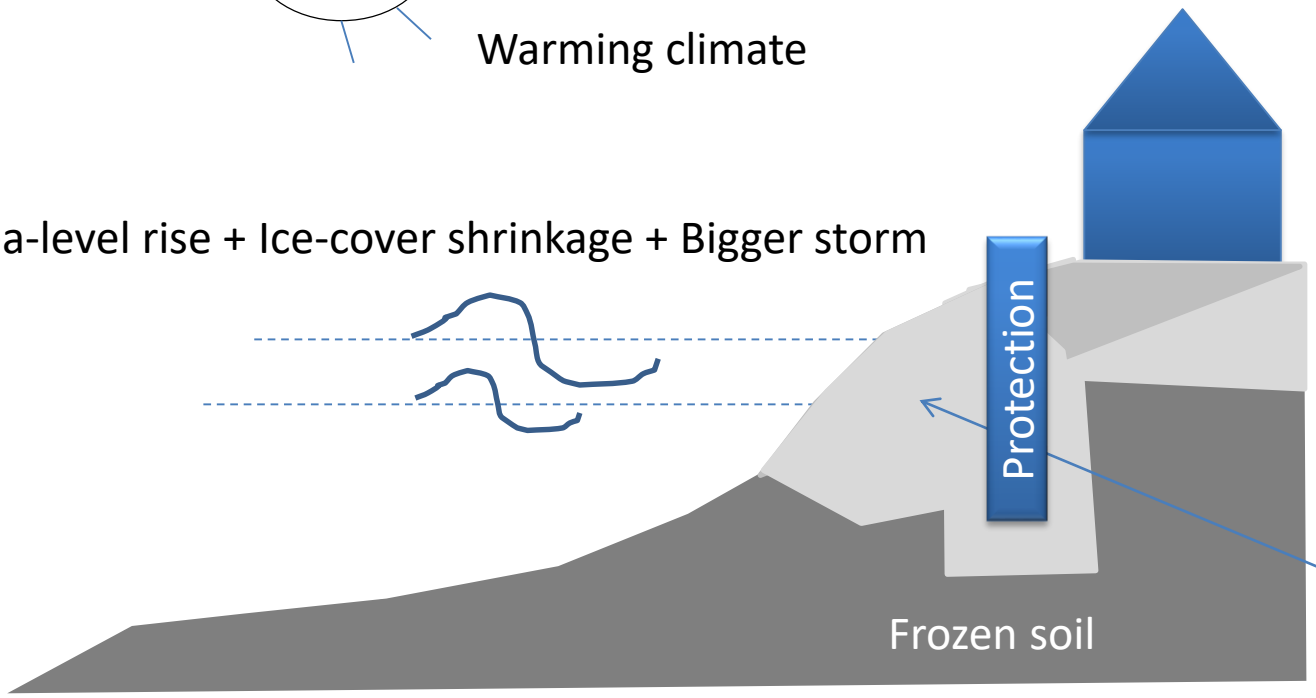
Soil Stability (e.g. slope stability, bearing capacity, settlement, etc.) must be assured during the lifetime of our coastal structures

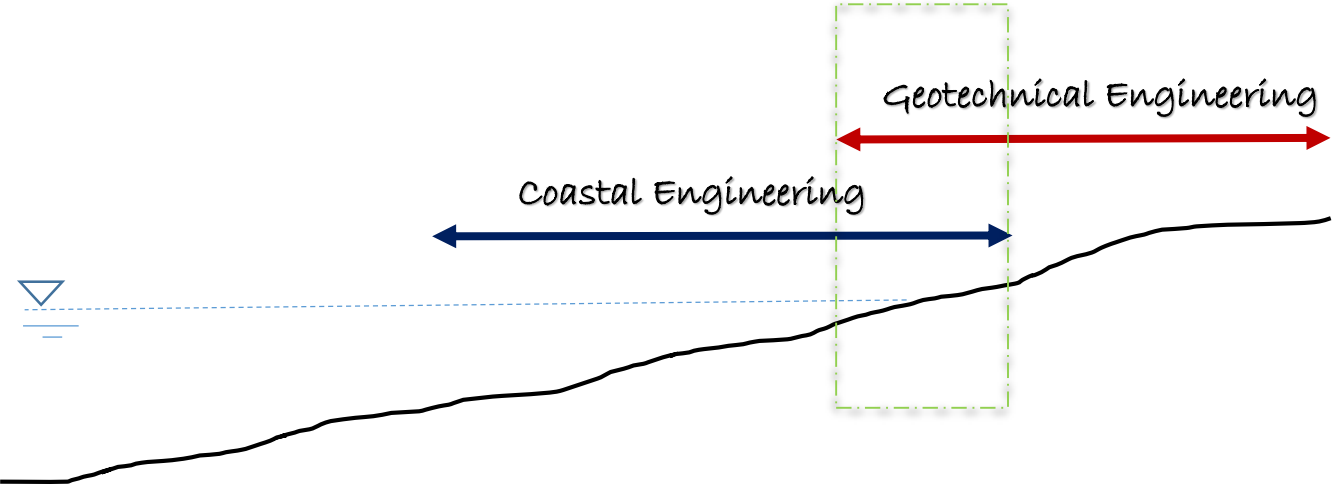


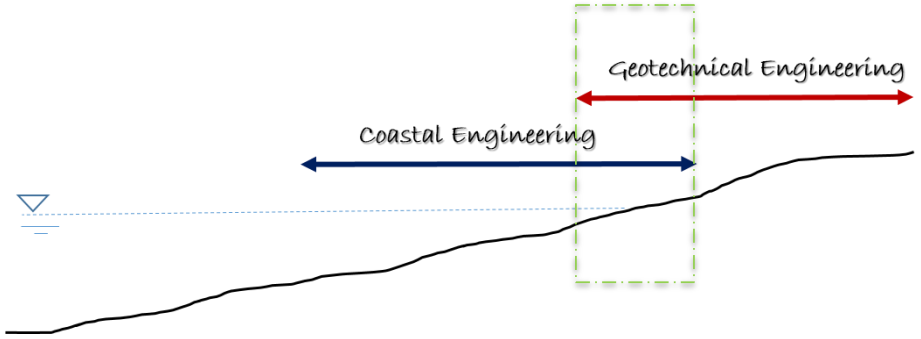
Warming climate

Sea-level rise + Ice-cover shrinkage + Bigger storm



Here in addition to the thermal interaction, we also have mechanical interaction(abrasion)


Geotechnical Engineering
Coastal Engineering



	Dr. Seyed A. G. Amiri	NTNU	Postdoc: Thermo-Hydro-Mechanical (THM) modelling of frozen soils
	Dr. Mohammad Saud Afzal	NTNU	Postdoc: Development of an integrated system model for Arctic coastal erosion (MA)
	Mr. Nadeem Ahmad	NTNU	PhD student: High resolution CFD modelling of Arctic coastal erosion
	Mr. Hongtao Li	NTNU/DTU	PhD student: Modelling the propagation of sea-waves in the presence of sea-ice
	Mr. Dennis Monteban	DTU/ NTNU	PhD student:Measurements and modelling of Arctic coastal environments
	Ms. Julie Malenfant Lepage	NTNU/ Laval	PhD student: Erodibility characteristics of frozen/thawing soils
		NTNU	PhD: Numerical Modelling of Short- and Long-term Erosion of Permafrost Coastal Bluffs
		NTNU	PhD: Modelling Oil Spill and Response in the marginal ice zone

Arctic coastal erosion investigations

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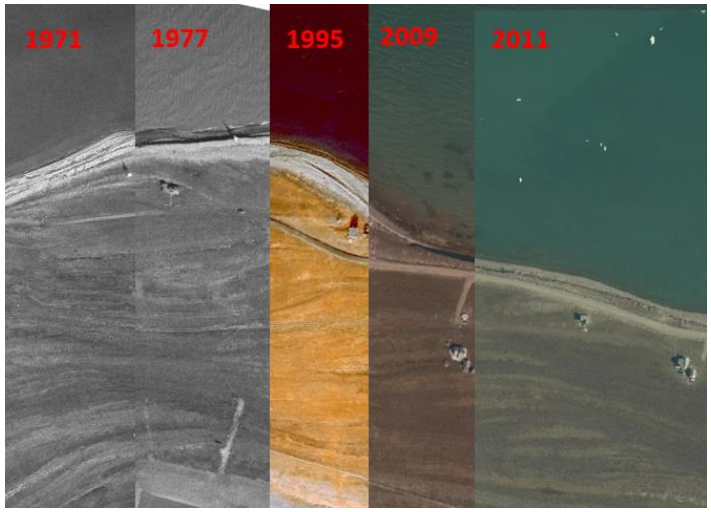
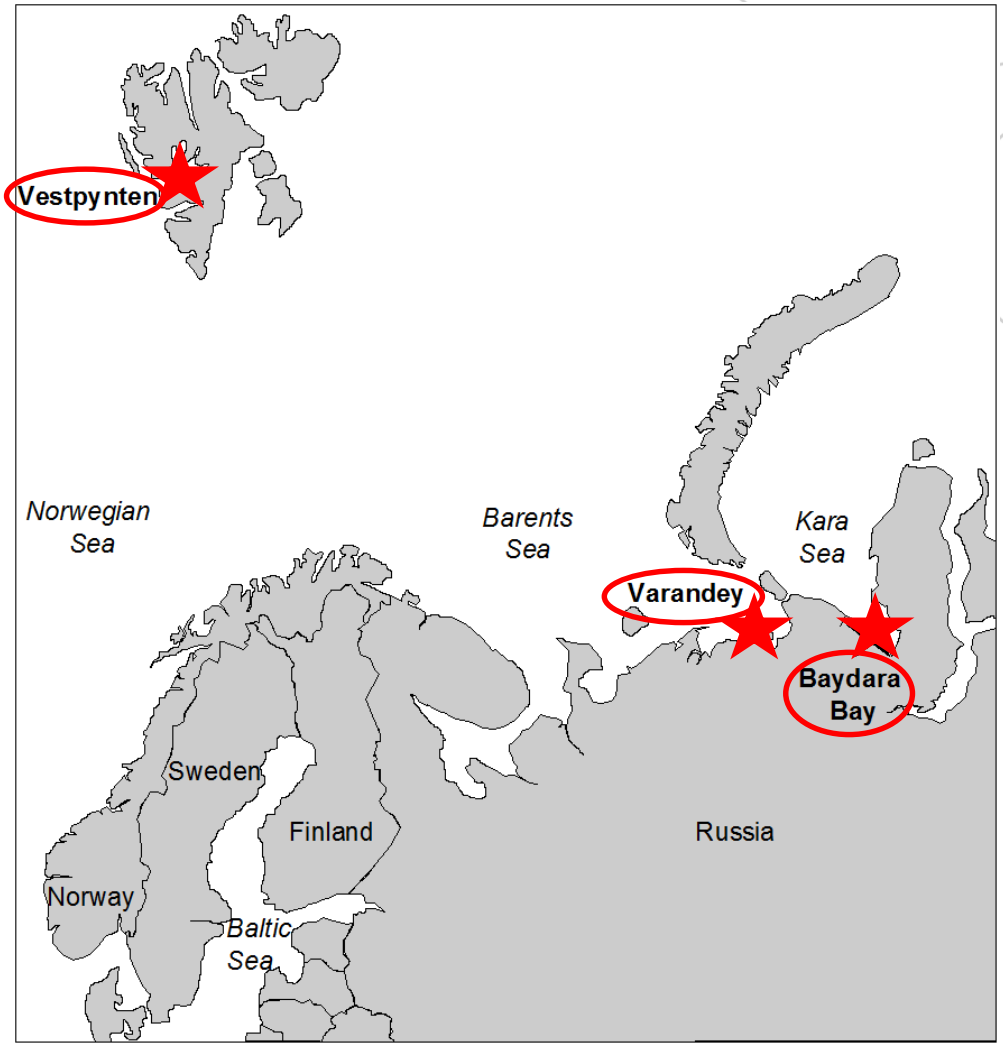
sfi Centre for Research-based Innovation

Sites investigations/monitoring (Since 2012)

- **Evaluated historical erosion rates** (aerial photographs/satellite images)



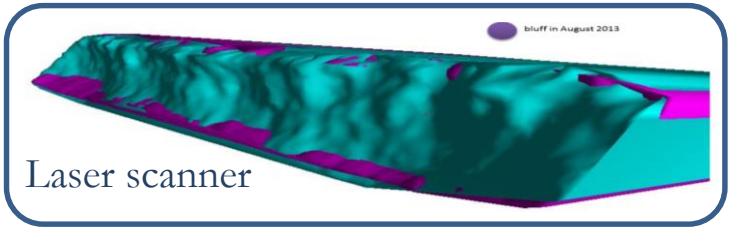


Arctic coastal erosion investigations

SAMCoT

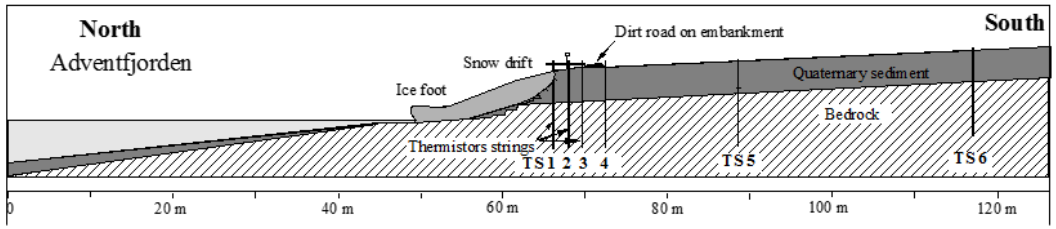
Sites investigations/monitoring (Since 2012)

- Evaluated historical erosion rates (aerial photographs/satellite images)
- **Instrumentation**
- Field survey



Laser scanner

Time-lapse camera



Thermistor-strings

Arctic coastal erosion investigations

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Sites investigations/monitoring (Since 2012)

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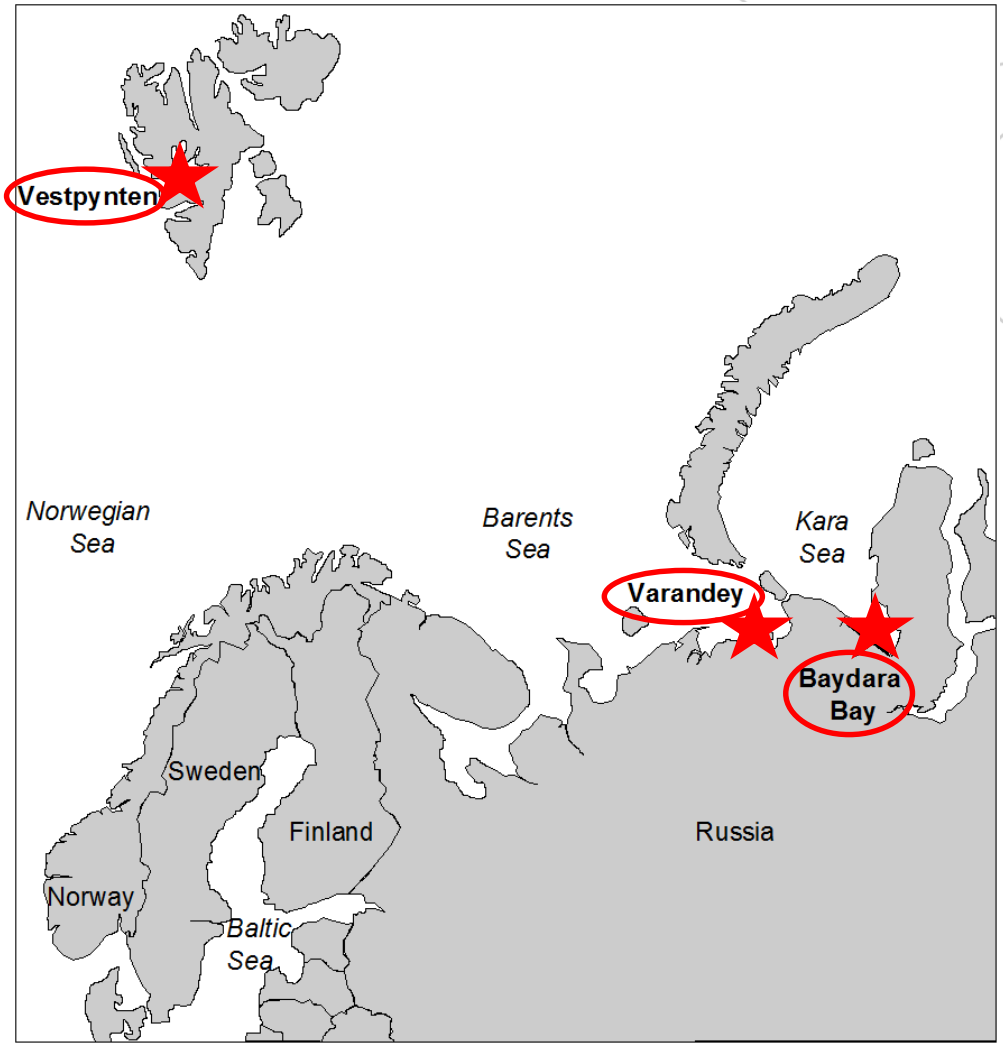
- Instrumentation
- **Field survey**



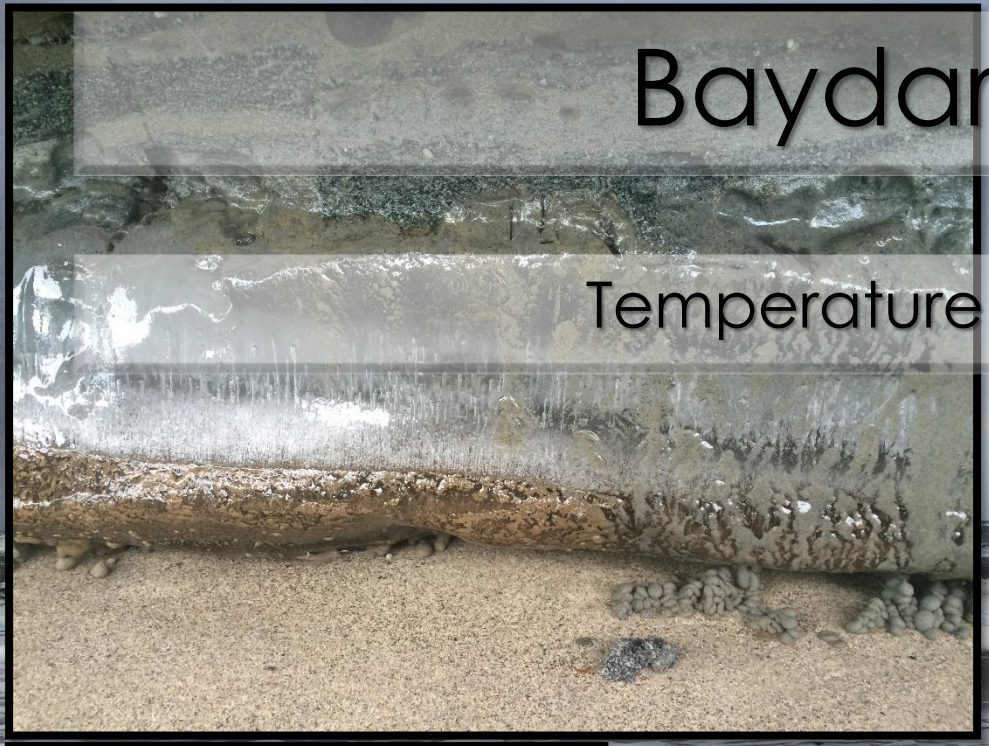
Baydara Bay

Sampling from differ part of coastal sediments for laboratory research on grain content and mechanical properties

Baydara Bay

Baydara Bay

Temperature monitoring

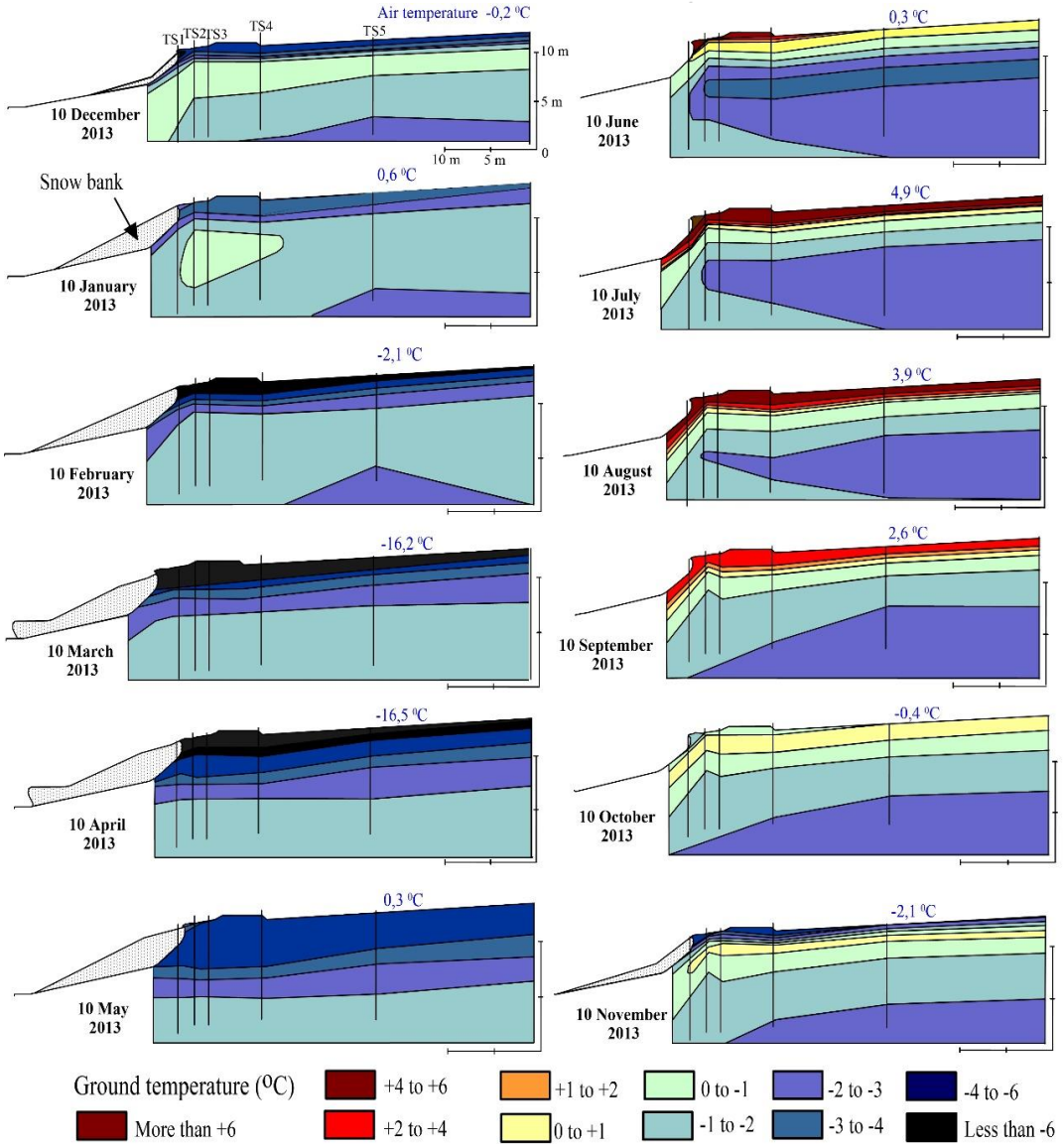


Baydara Bay

Time-laps photo shooting of thermal abrasion process

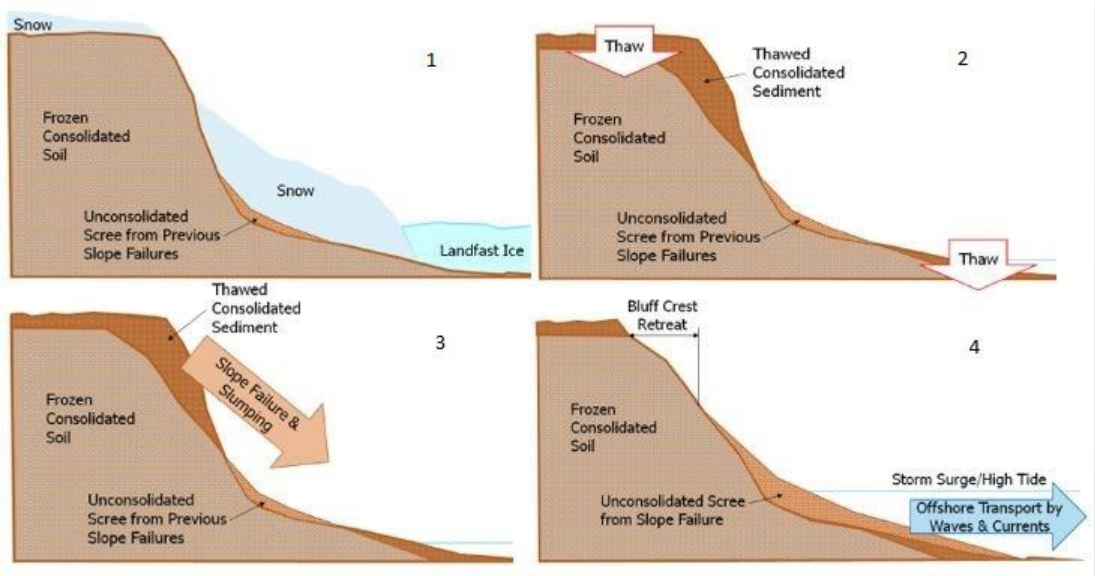
Vestpynten (Svalbard)

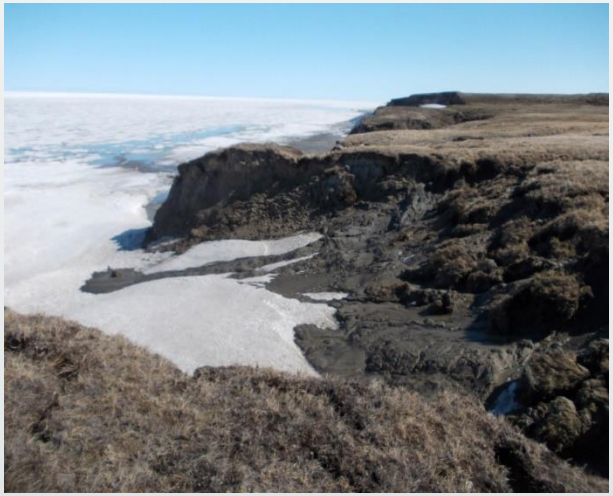
27 May to 1 July
2013
(1 month)



Identification of environmental forces and processes responsible for coastal recession on sites

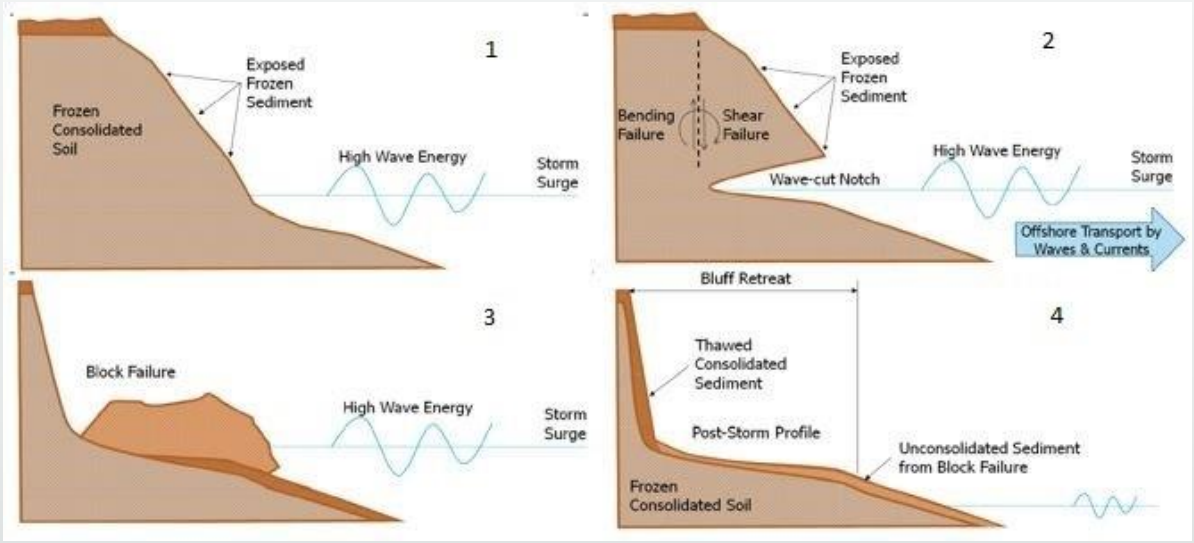
- Thermodenudation

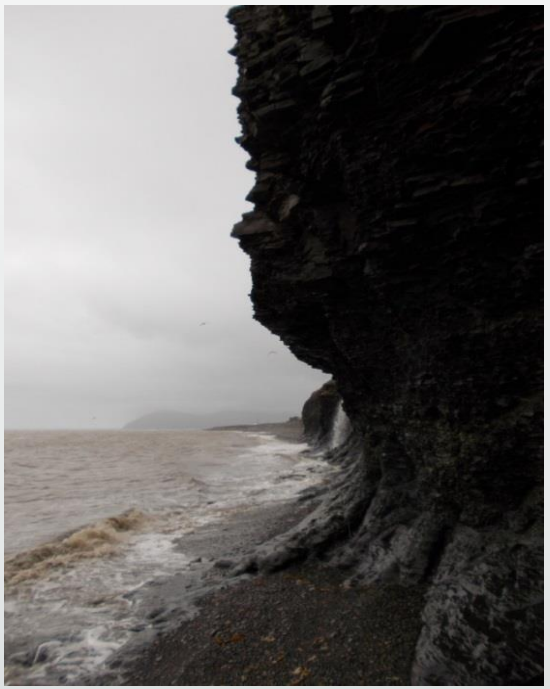




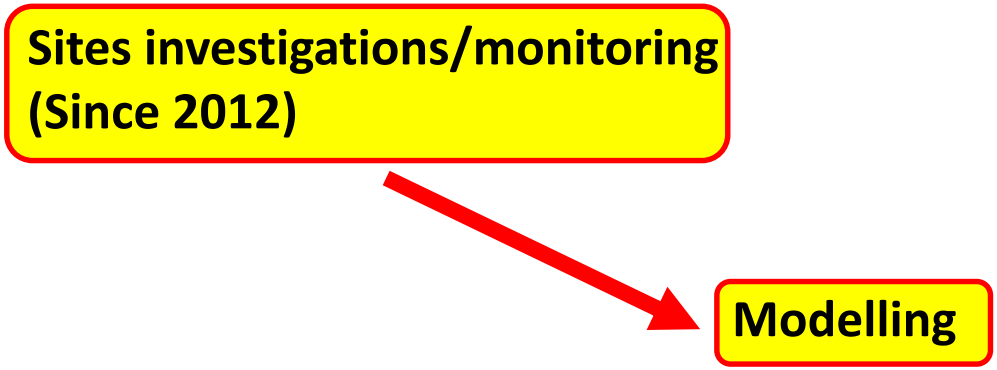
Identification of environmental forces and processes responsible for coastal recession on sites

- Thermoabrasion





Arctic coastal erosion investigations



The Thermodenudation Model

MSc., Agnes Schneider (2017)

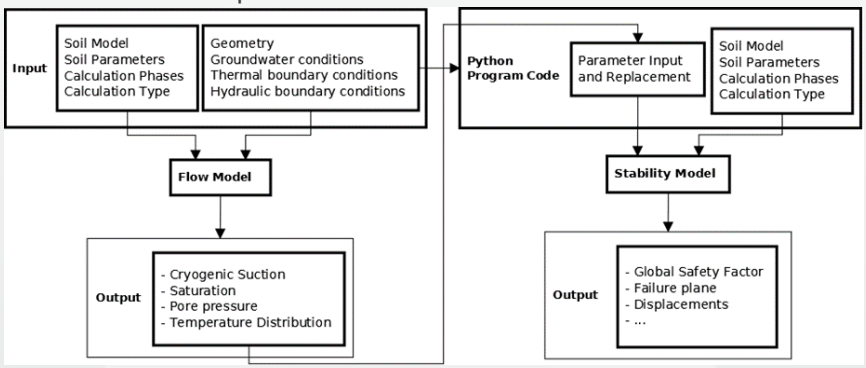
Flow Model

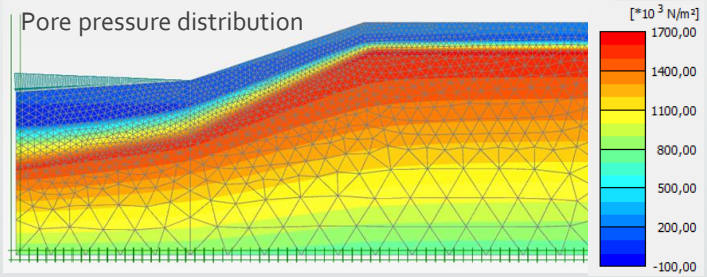
- Combination of the Mohr Coulomb soil model and cryogenic suction
  - Coupled thermal hydro analysis
  - Cryogenic suction according to the Clausius-Clapeyron equation

Stability Model

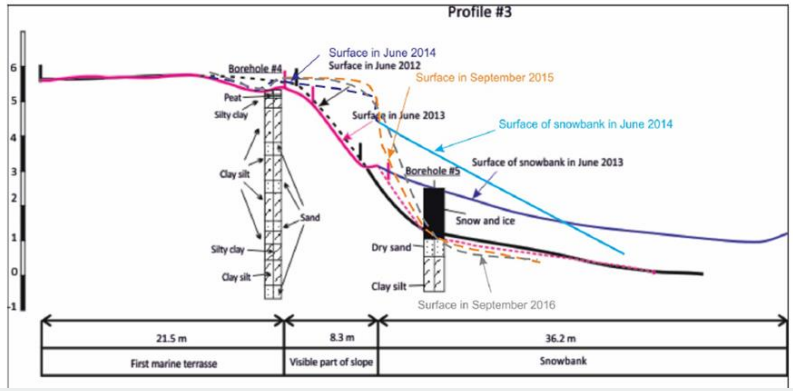
- Mohr-Coulomb soil Model
  - Mechanical part of THM coupling
  - Receives outputs from Flow model via Python program codes

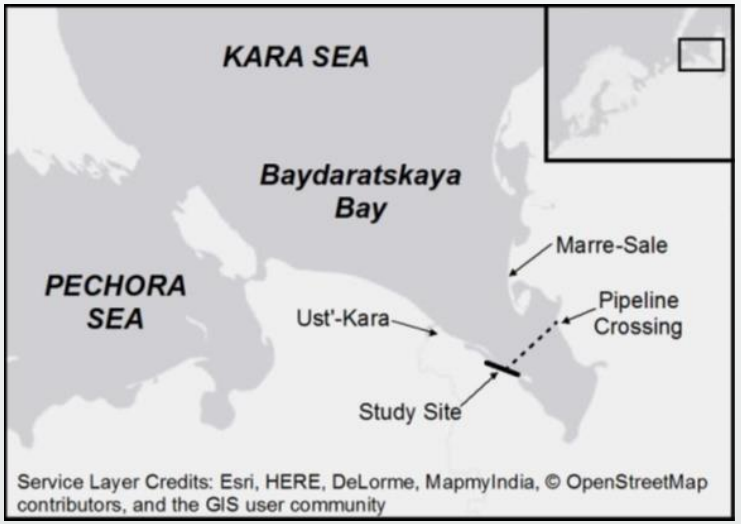
Principle of the Thermodenudation Model





Case Study: Baydara Bay

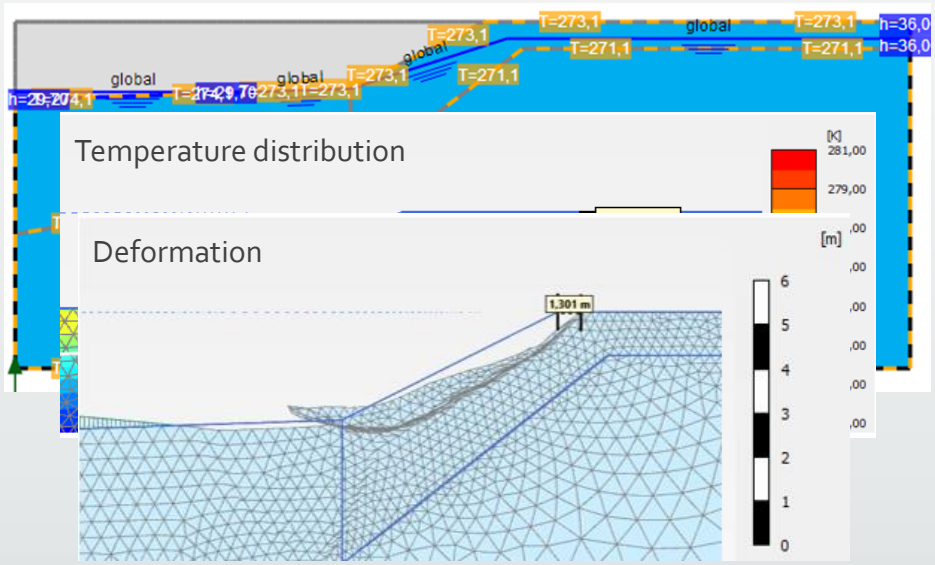




Location of the study site

Calibration of the Thermodenudation Model to Baydara Bay

Thermodenudation Model Baydara Bay



Comparison between measured and calculated data

	Measured	Calculated
ALT [m]	0.86 – 1.0	0.88
Coastal retreat [m]	1.25	1.301
Volume of eroded soil [m³]	21.09	20.4

ALT = Active layer thickness

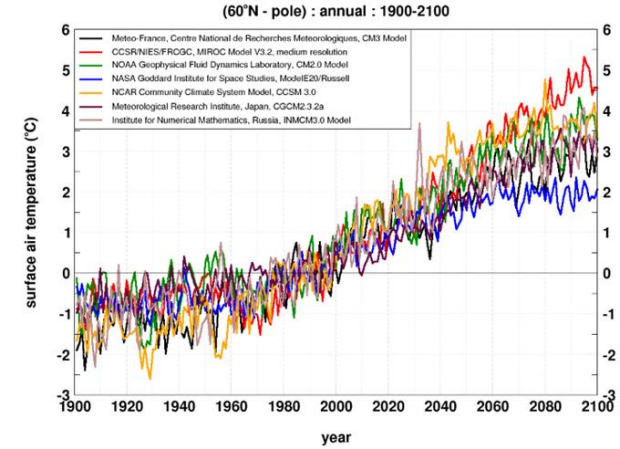
Climate Change in Arctic Regions

Scenario 1: Average scenario, based on B2 emission scenario

Scenario 2: Extreme scenario, based on A2 emission scenario

Baydara Bay 2013 is the reference situation

	2013	2050		2100	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
Surface air Temperature increase	0	+1.5	+2	+2.5	+6
Permafrost temperature increase	0	+1	+1	+2	+3



IPCC projected Arctic surface air temperature development (based on the B2 emission scenario)

Results Climate Change Scenarios

	Baydara 2013	Baydara 2050		Baydara 2100	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
Active layer thickness [m]	0.89	1.24	1.28	1.51	1.90
Coastal retreat rate [m]	1.30	1.79	1.87	2.4	3.2
Eroded soil volume [m³]	20.40	24.06	26.29	39.92	37.65

- Active layer thickness increased by 39 – 44 % until 2050 and by 71 - 116 % until 2100 compared to 2013
- Coastal retreat increased by 38 – 44 % until 2050 and by 85 - 146 % until 2100 compared to 2013

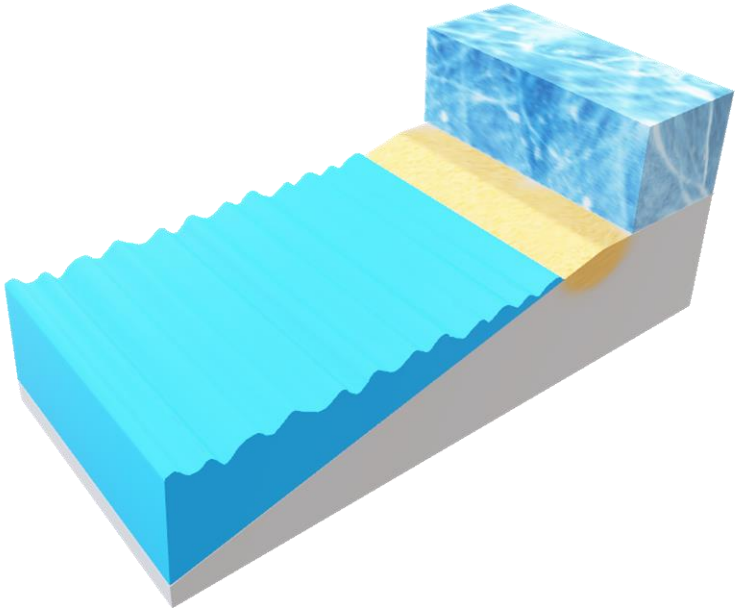
➢ Strong correlation between active layer thickness and coastal retreat rate

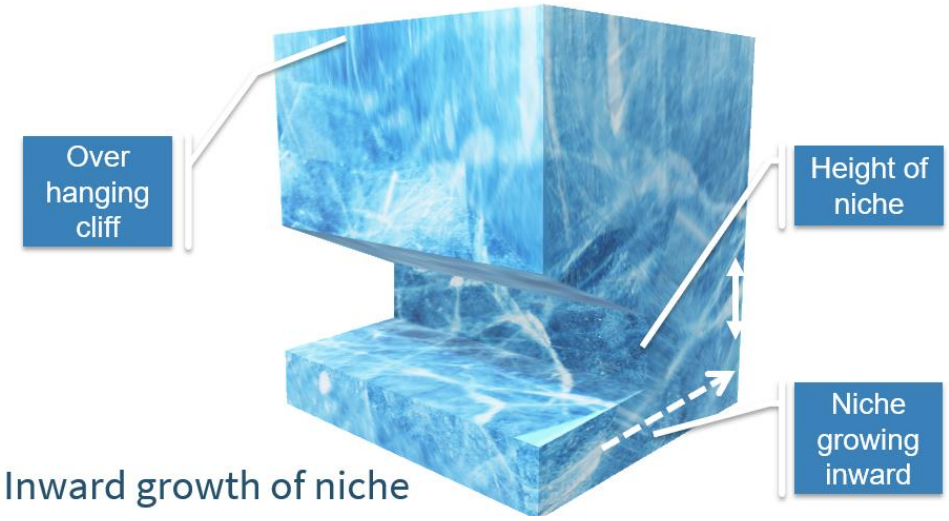
Erosion in Arctic: a thermoabrasion model to predict shoreline change after an extreme event

- Student: Md. Akhsanul Islam, CoMEM2016

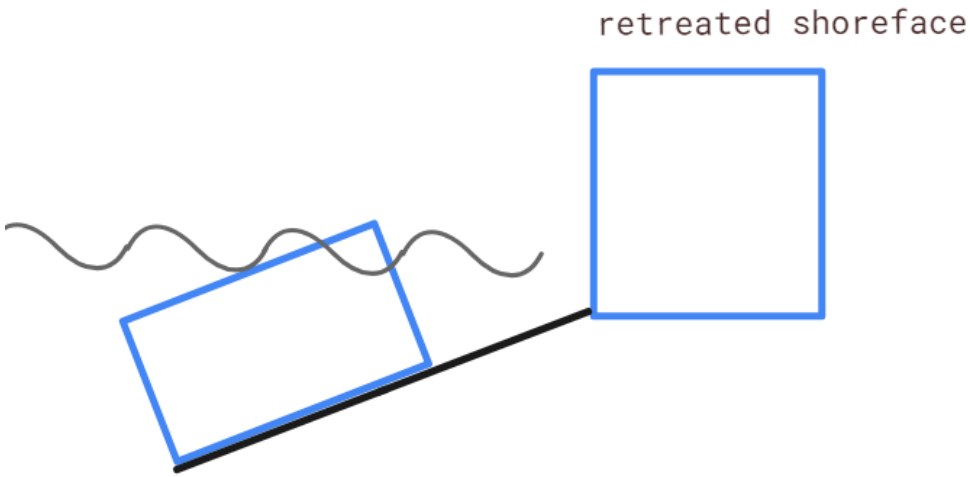
Research Question

- How to assess stability of coastal bluffs and predict shoreline erosion in the Arctic after an extreme event?



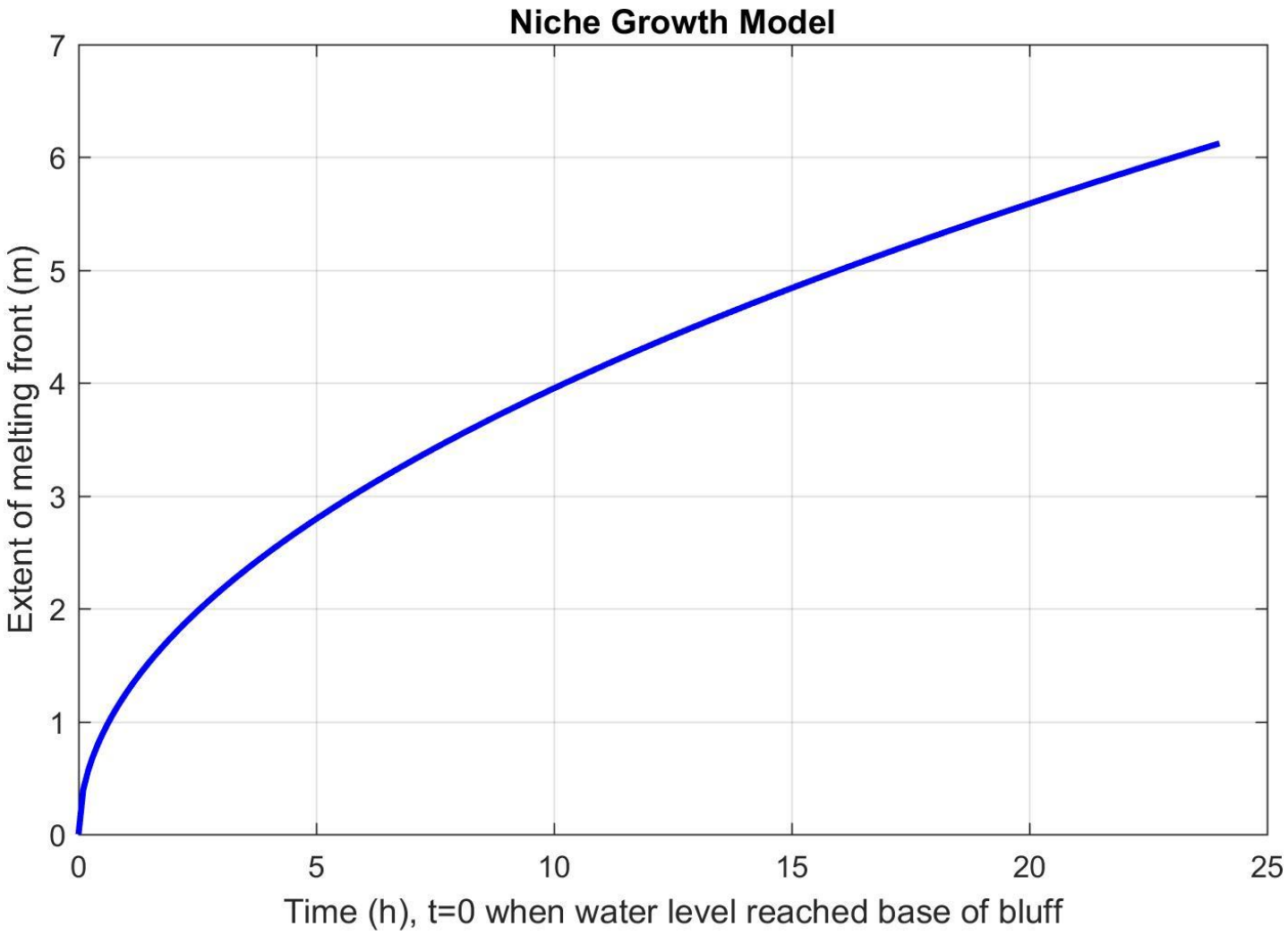


Methodology

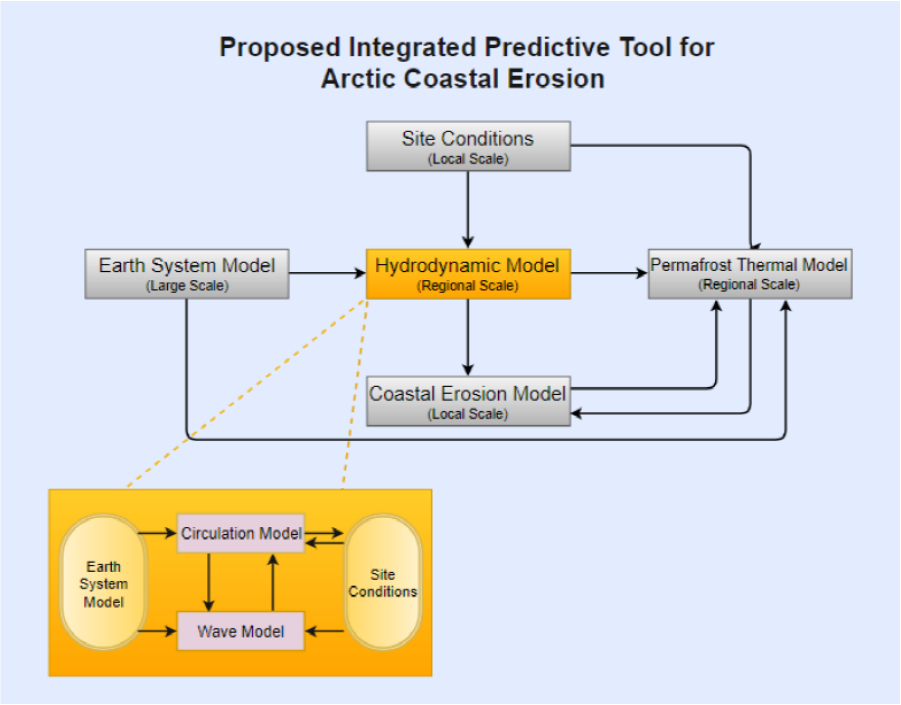


- Model is based on the physical processes.
- Holistic model is divided into four interdepending models:
    - storm surge
    - niche growth
    - bluff erosion
    - shoreline erosion
- A proper dynamics of these processes need to be established
- Verification of the model with field data.

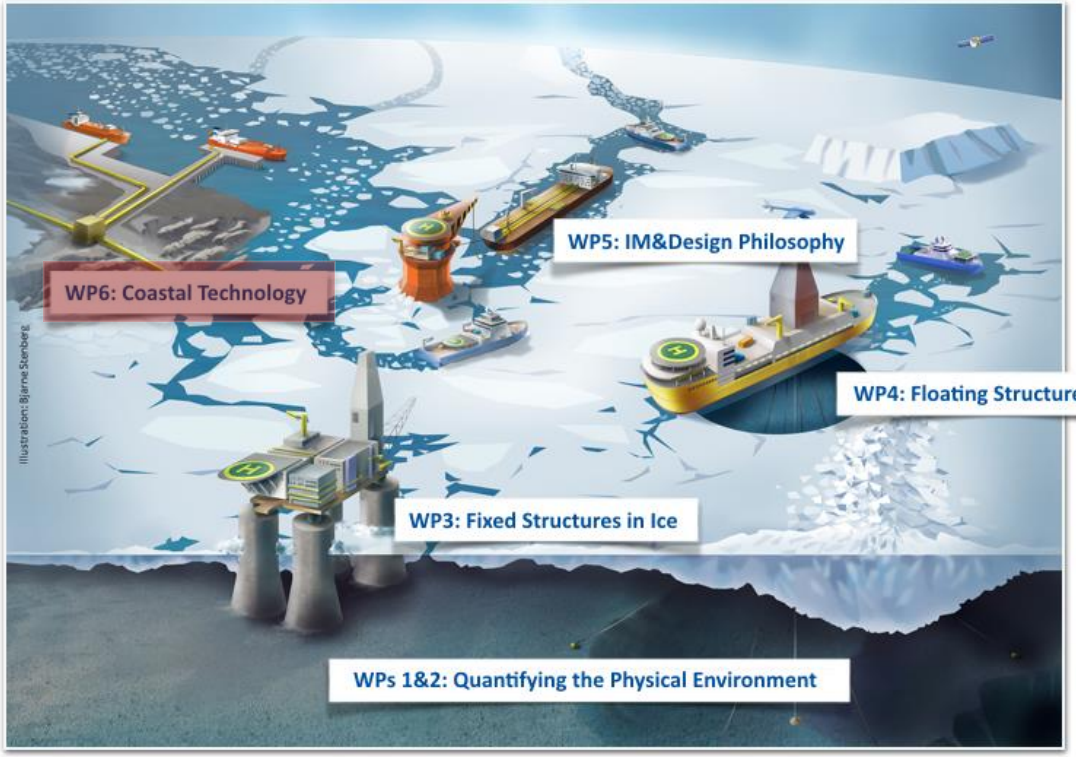
Preliminary Results

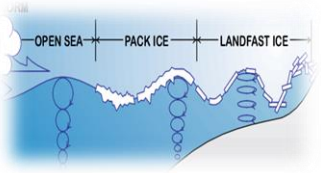


PhD: Numerical Modelling of Short- and Long-term Erosion of Permafrost Coastal Bluffs

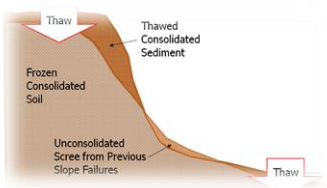


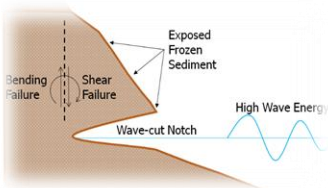
Overview


WP6: Coastal Technology
WP5: IM&Design Philosophy
WP4: Floating Structures in
WP3: Fixed Structures in Ice
WPs 1&2: Quantifying the Physical Environment
Illustration: Bjarne Stenberg


OPEN SEA
PACK ICE
LANDFAST ICE

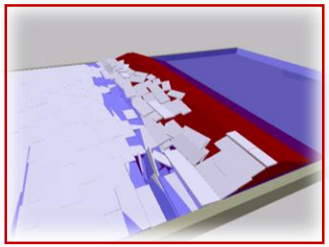

Tsarau (2016)


Thaw
Thawed Consolidated Sediment
Frozen Consolidated Soil
Unconsolidated Scree from Previous Slope Failures
Thaw


Exposed Frozen Sediment
Bending Failure
Shear Failure
Wave-cut Notch
High Wave Energy


Legend
Guegan (2014)


USGS/ Getty

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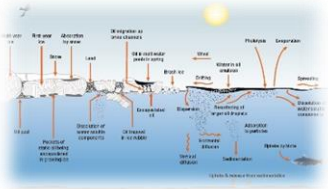
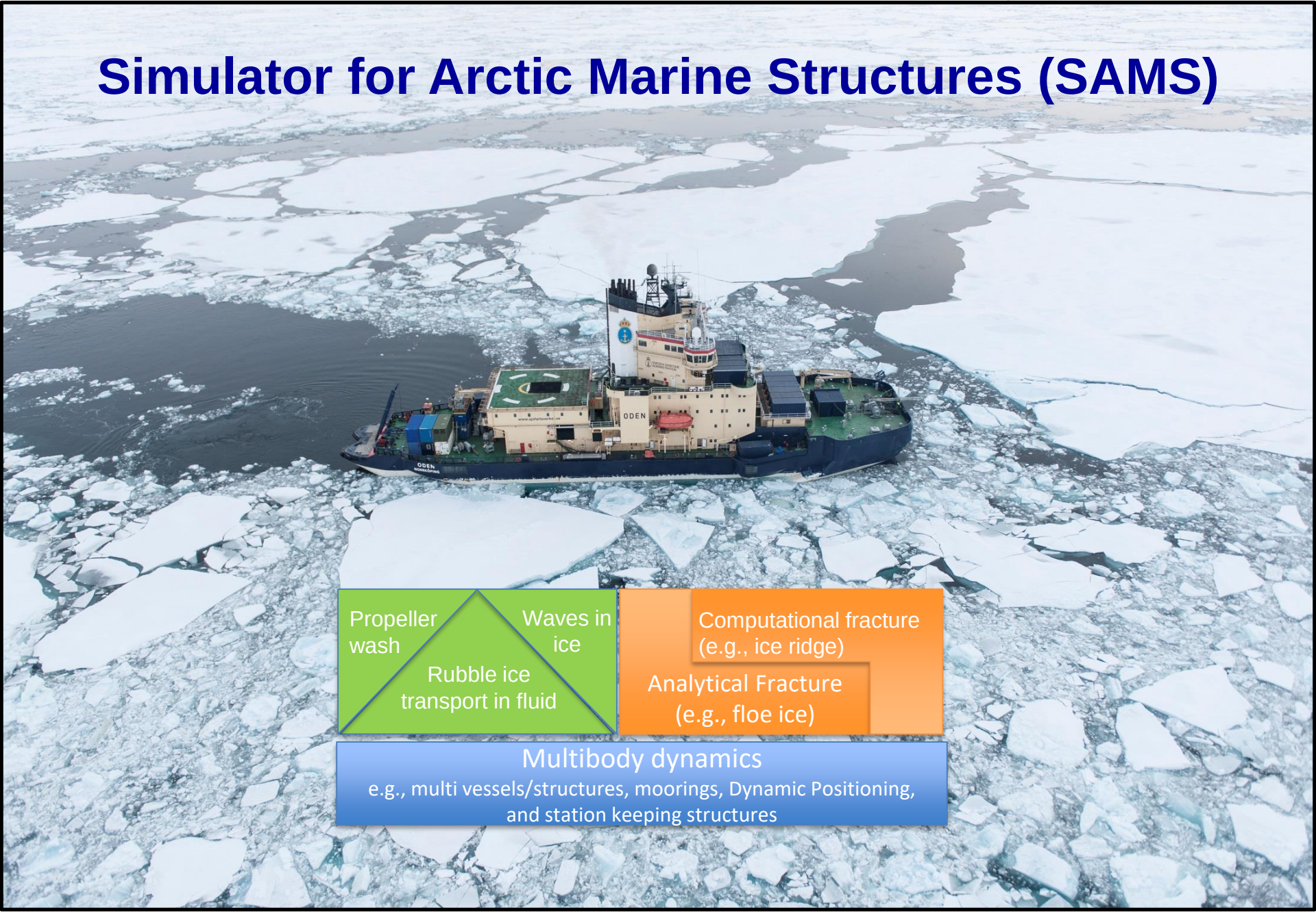


Simulator for Arctic Marine Structures (SAMS)



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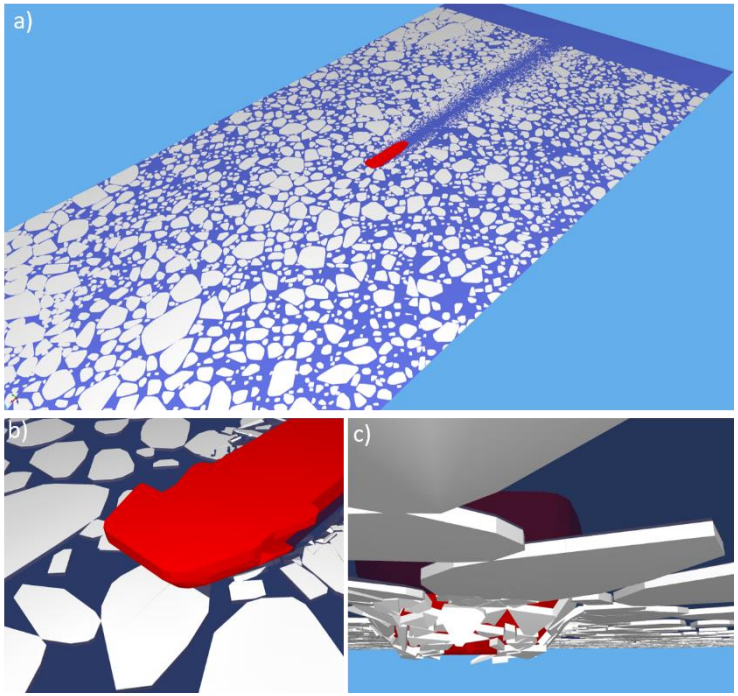
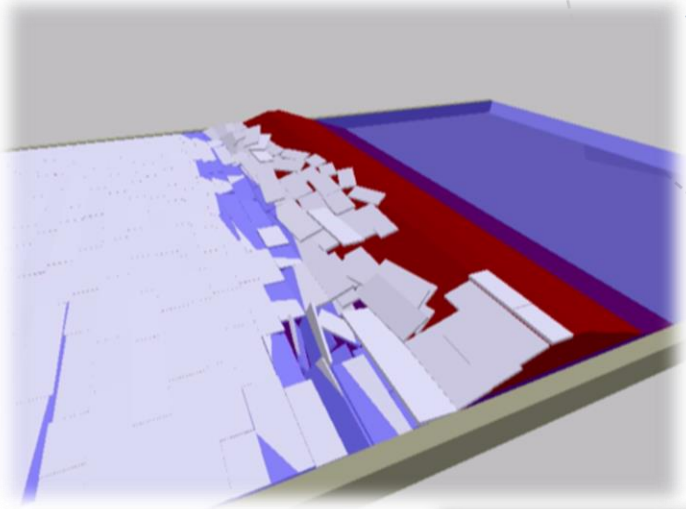
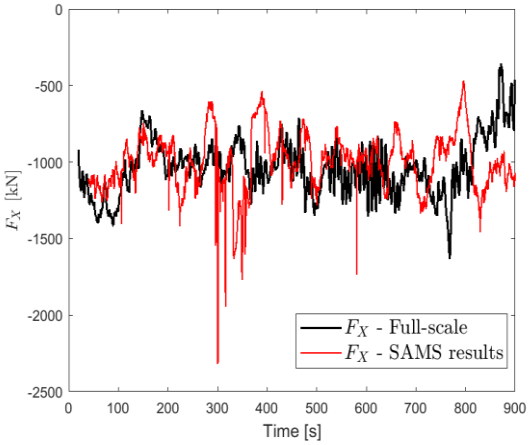
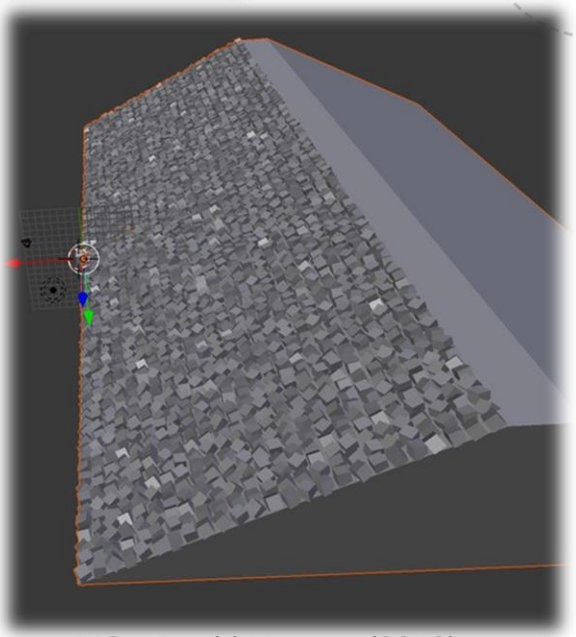
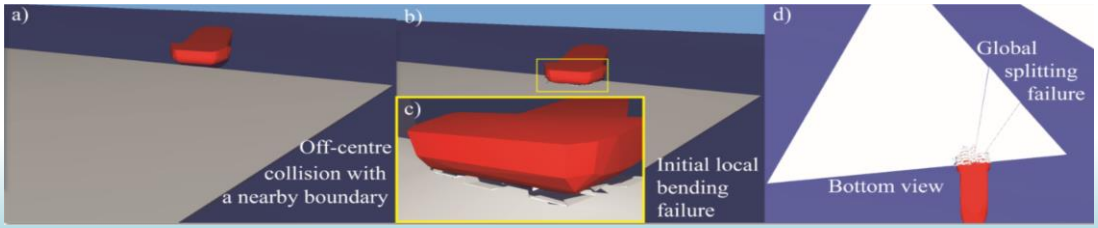








MSc. David Massey (2018)



Overview

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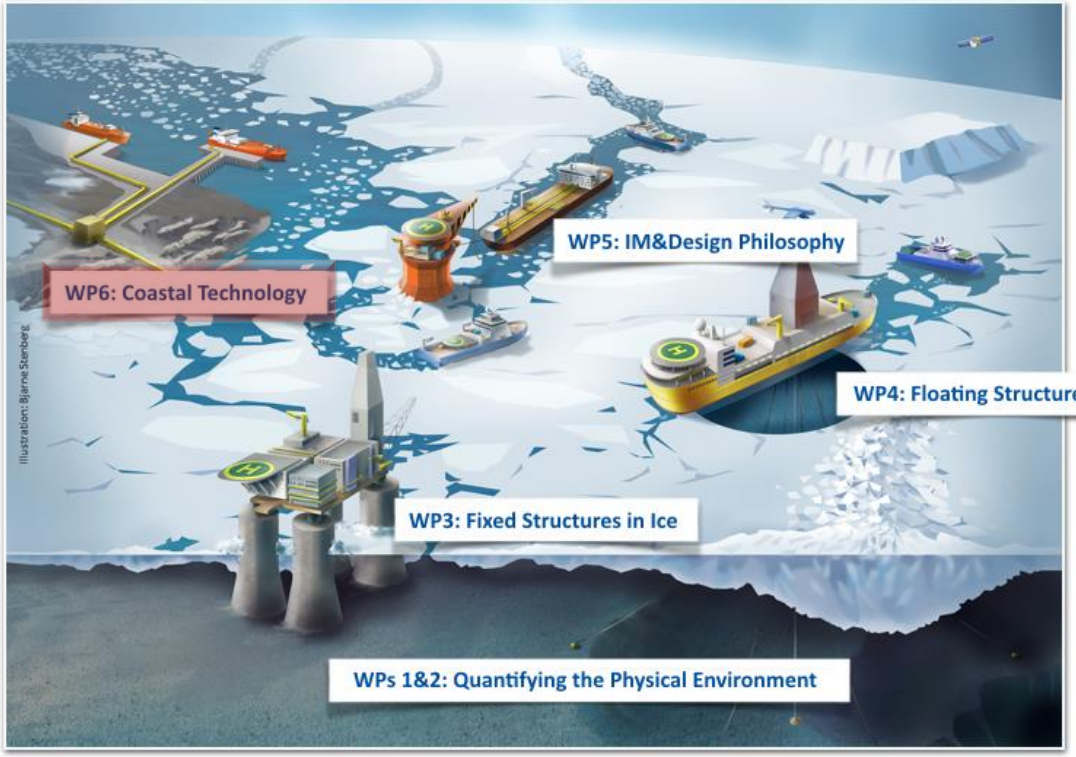

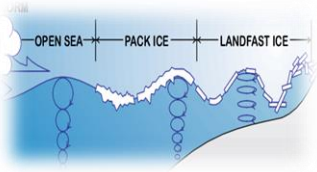

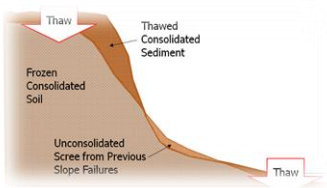

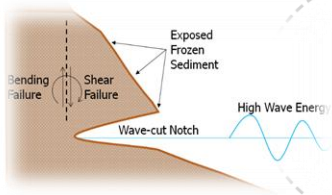

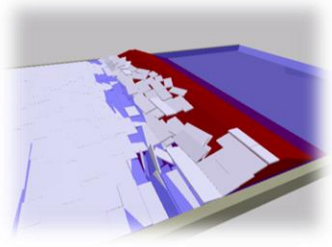

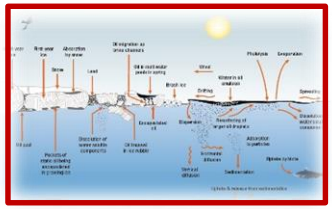

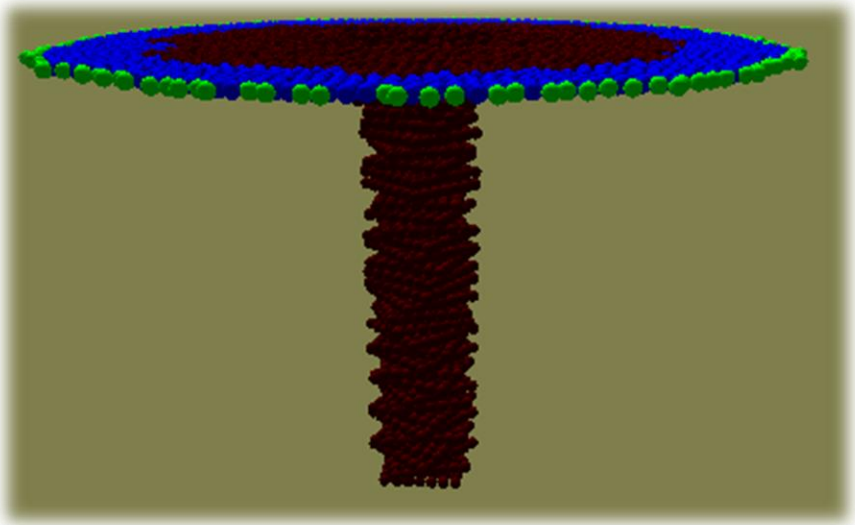


Akihisa Konno (2017)