Remote oil spill detection and monitoring beneath sea ice

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The spillage of oil in Polar Regions is particularly serious due to the threat to the environment and the difficulties in detecting and tracking the full extent of the oil seepage beneath sea ice.

Content

- Introduction of the technology
- Introduction of the equipment
- Tests with passive system
- Tests with active system
- Conclusions and Future work

Introduction of the technology

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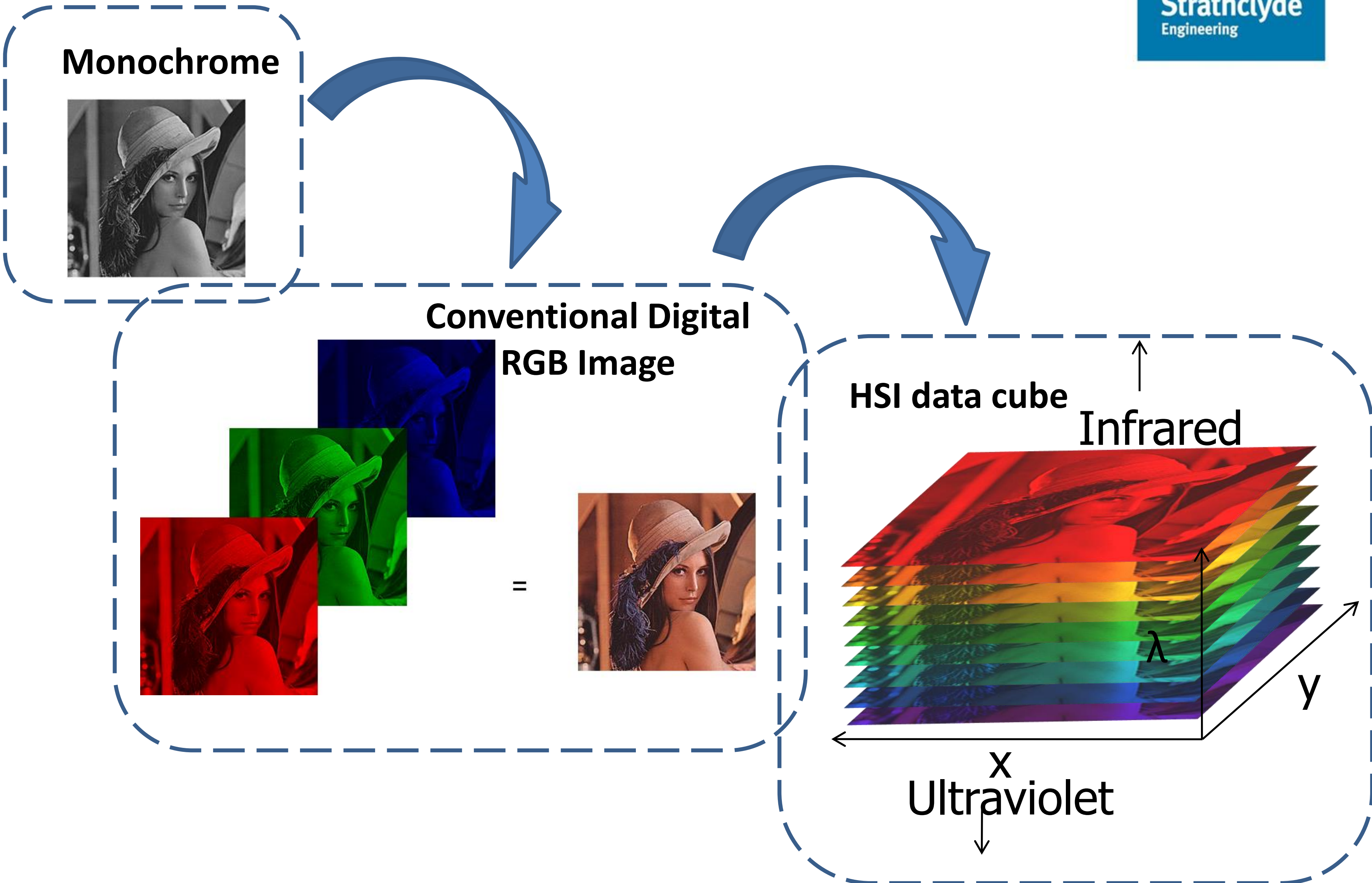
- In this work Hyperspectral Imaging (HSI) is proposed as a technique for detection and monitoring of oil spill beneath the ice.

- Hyperspectral imaging is an emerging technology which uses a new type of camera to capture the spectral signature of a scene. It is the next stage in the logical extrapolation of the technology development which took us from monochrome (black and white) imaging to colour imaging. However, whereas these two image types can be viewed by the human eye, hyperspectral images contain detail beyond human vision.

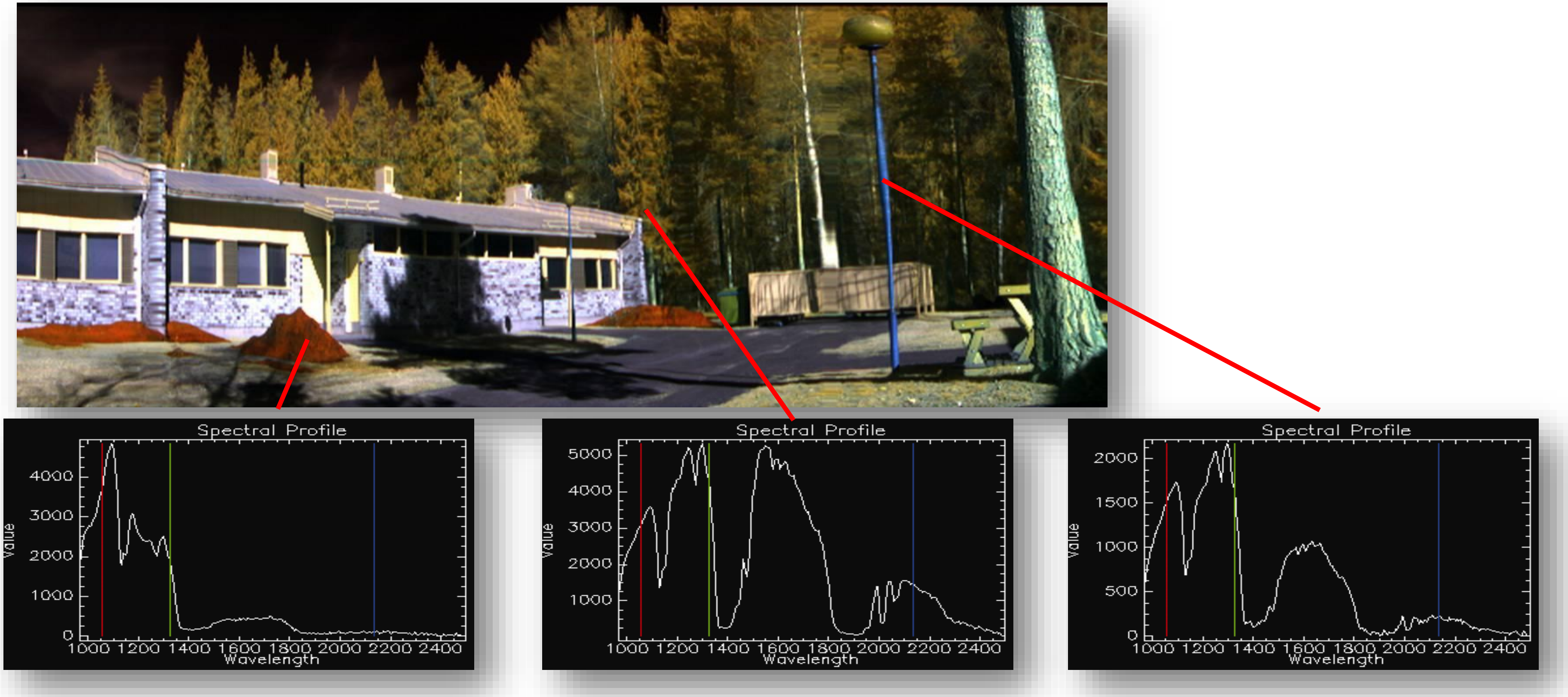
- In monochrome imaging each pixel has a single brightness value, in colour imaging each pixel has three values (red, green, blue) associated with it, but in hyperspectral imaging each pixel has a whole spectrum of values.

Introduction of the technology



Introduction of the technology

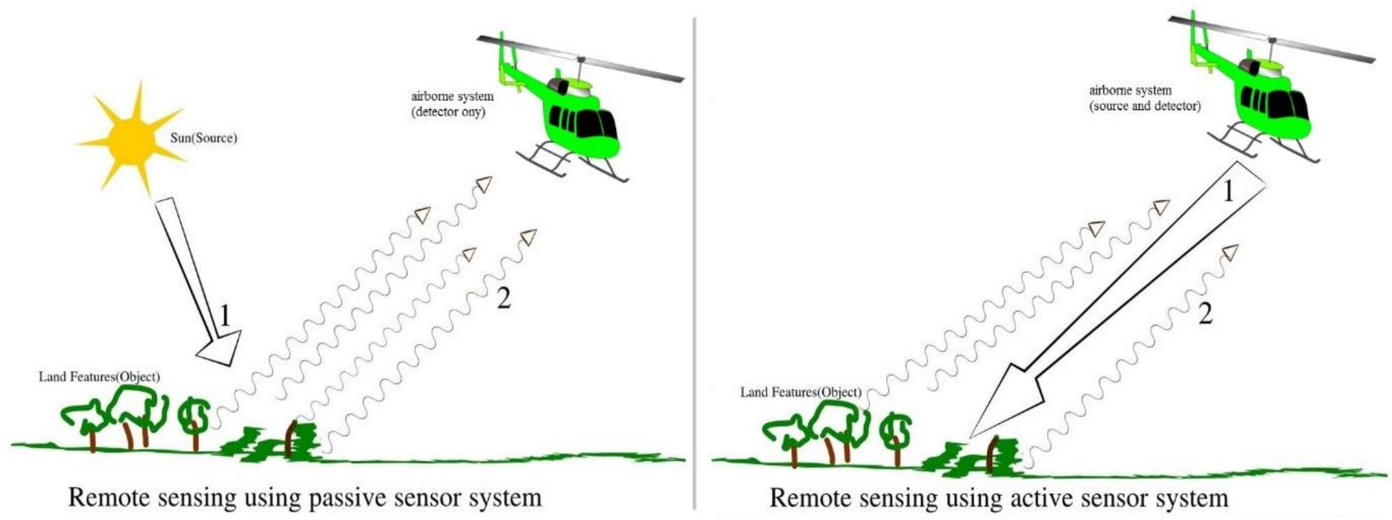
- Hyperspectral data cube is a stack of images, captured at hundreds of wavelength bands, in which each pixel (vector) is represented by a spectral signature that characterizes the underlying objects
- Set of signal processing techniques is able to classify captured objects based on their spectral signatures



Introduction of the technology

- Depending on the type of underlying technology, the cameras can 'see' a different depth into the ice and determine different properties of objects. Within our study we focus on quantifying the limits of detection of oil beneath ice with two technologically and spectrally different hyperspectral imagers.

- Two hyperspectral imagers are considered in this study – active, laser-based, mid-IR imager, and passive, near-IR hyperspectral camera.



Introduction of the equipment

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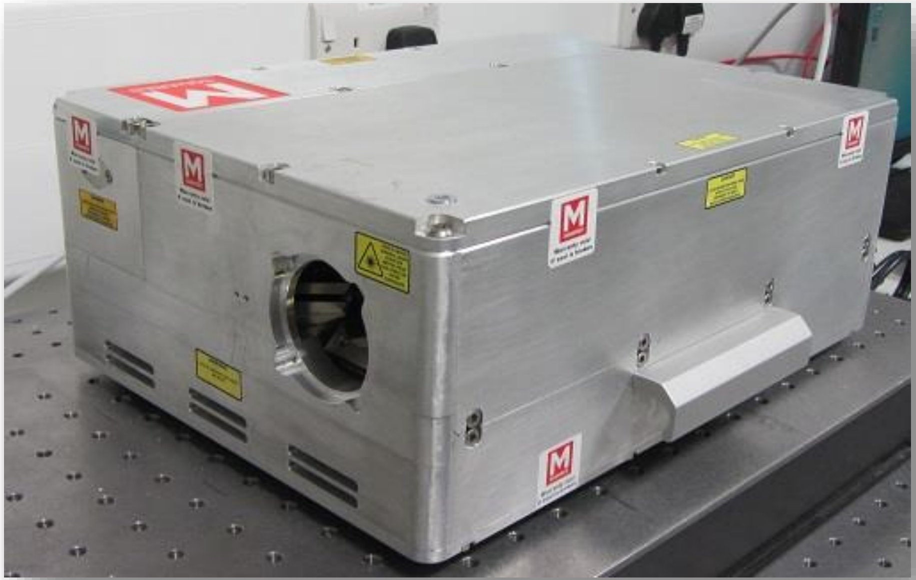
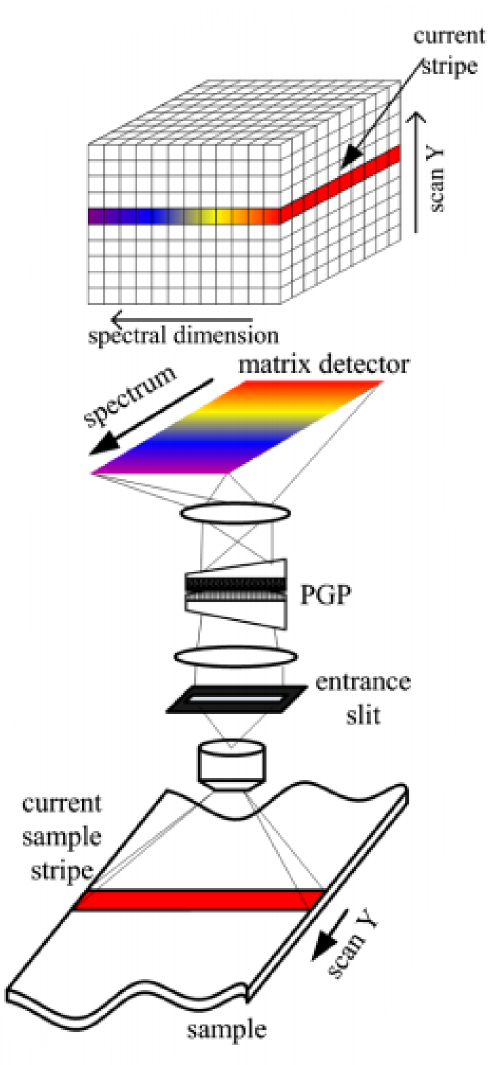
- Two hyperspectral imaging systems were employed during this study: an active, laser based, mid-infrared (1490 - 1850nm & 2500 - 3750nm) hyperspectral imager (Firefly IR Imager©, M Squared Lasers – (a)) and a passive hyperspectral camera operating in the near-infrared (900 - 1700nm) wavelength range (Red Eye 1.7, inno-spec – (b)).

(a)

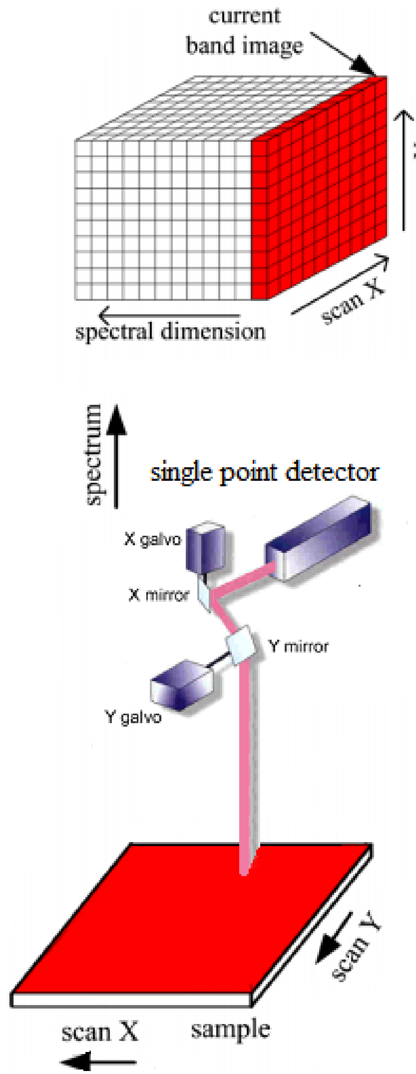


(b)

Introduction of the equipment



(a)

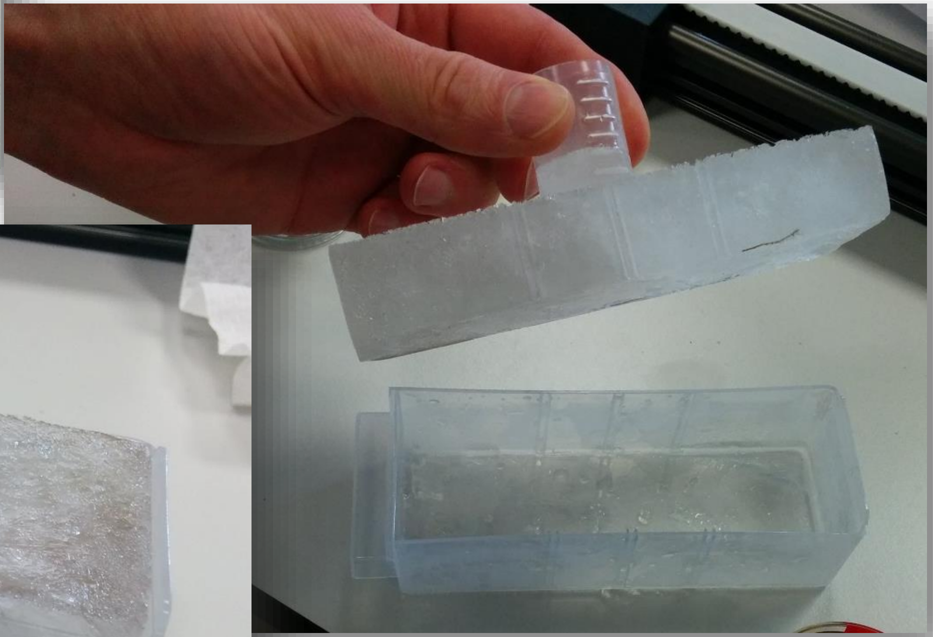


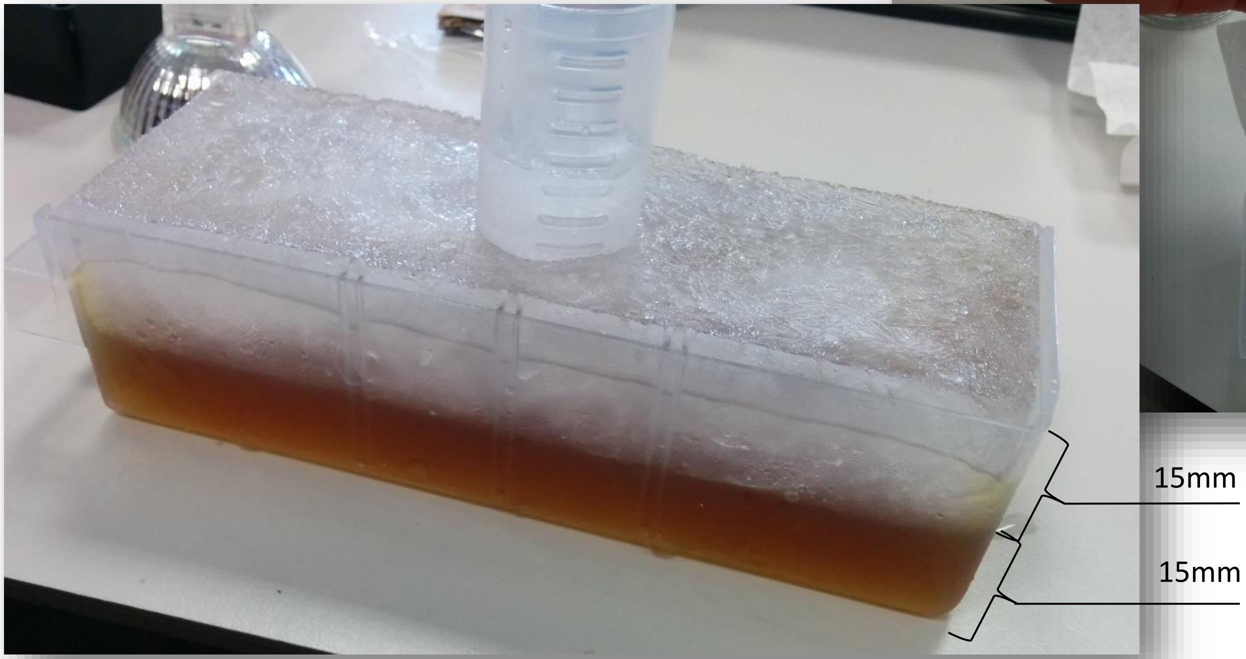
(b)

Apart of illumination technology and wavelength range, these systems also differ in scanning technique. Passive system employs a 'pushbroom' technique (a), while active system a 'whiskbroom' technique (b).

Tests with passive system sample preparation

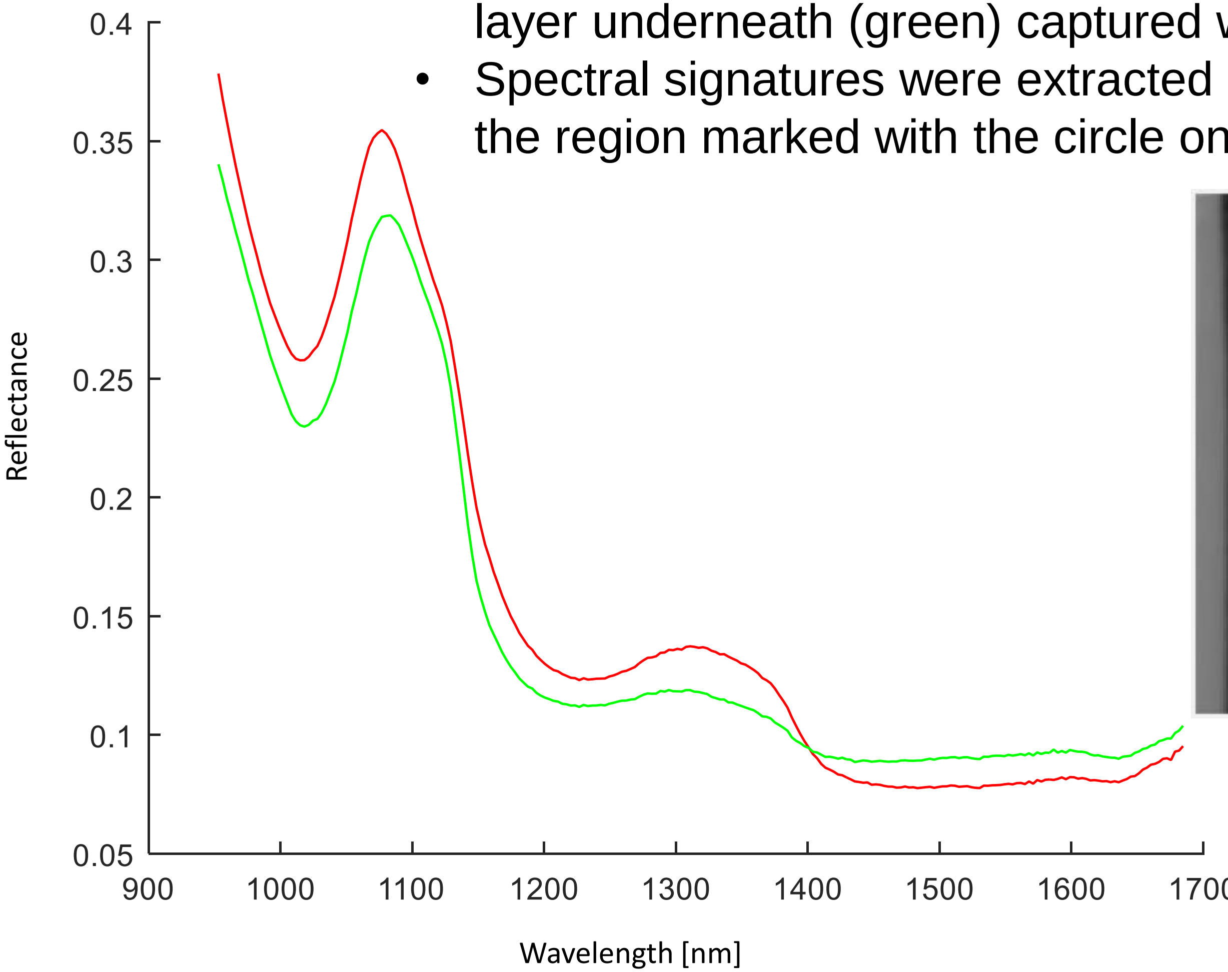
- Water sample was frozen in a freezer (about - 30°C), spectrum was tested and oil sample was introduced under the ice
- Both oil and ice layers had thickness of about 15mm

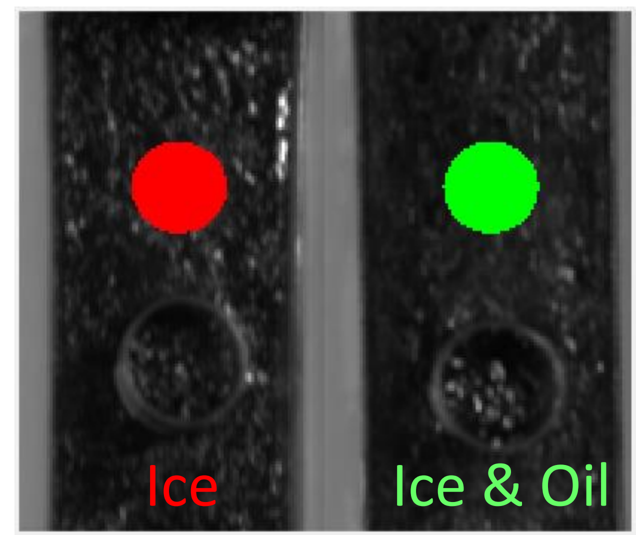




Tests with passive system – spectral response

- Plot of spectral signatures of pure ice (red) and ice with oil layer underneath (green) captured with passive NIR system
- Spectral signatures were extracted as an average value from the region marked with the circle on the intensity image.





Tests with passive system Classification results

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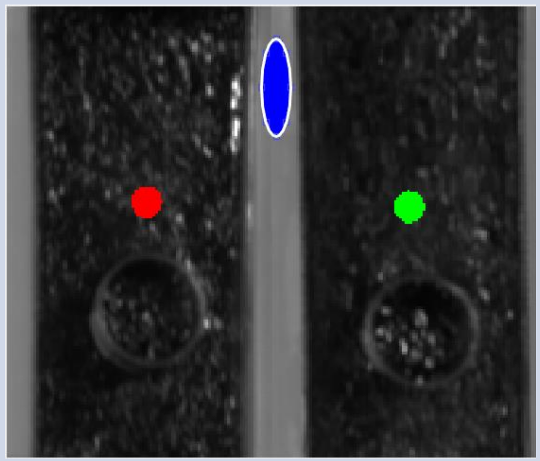
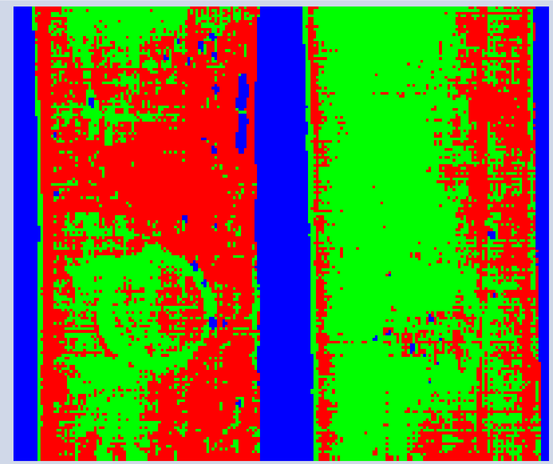
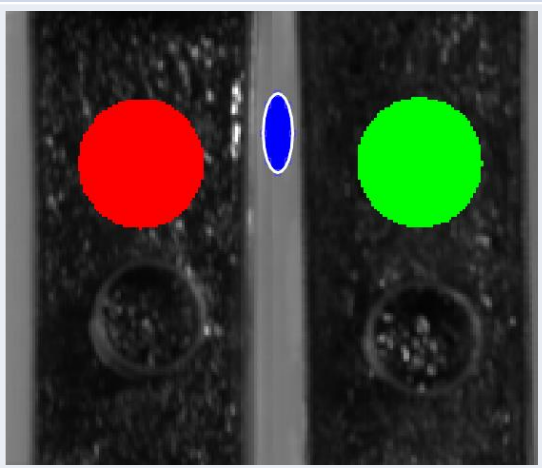
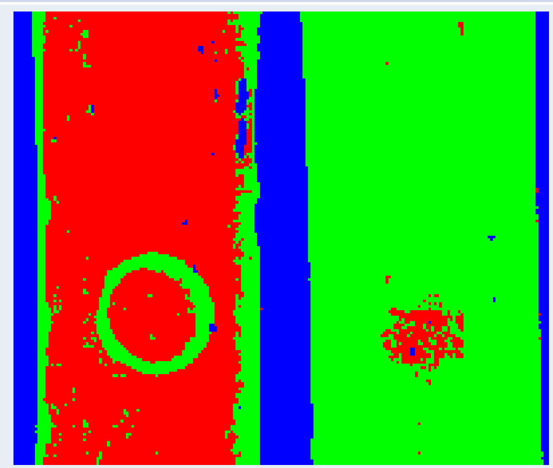
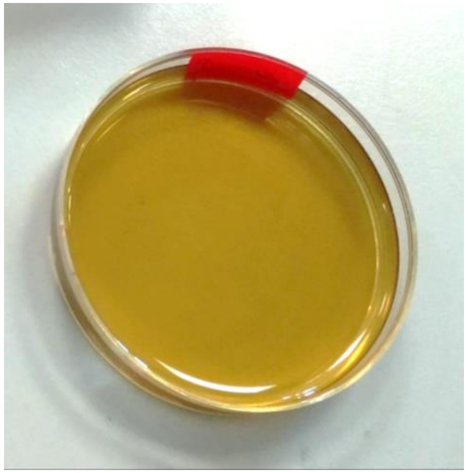
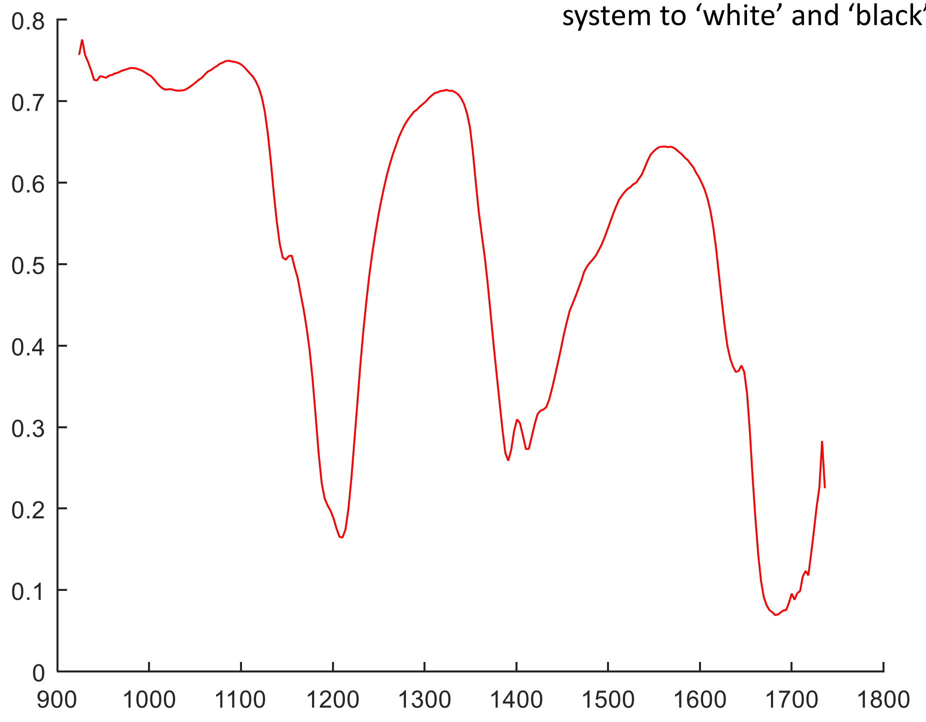
	Training data Ice Ice & Oil	Classification result
Low amount of training data (~5%)		
Medium amount of training data (~25%)		

Tests with passive system
Oil spectrum

- Spectra of oil was also collected with Inno-Spec passive system providing wavelength range 900-1700nm

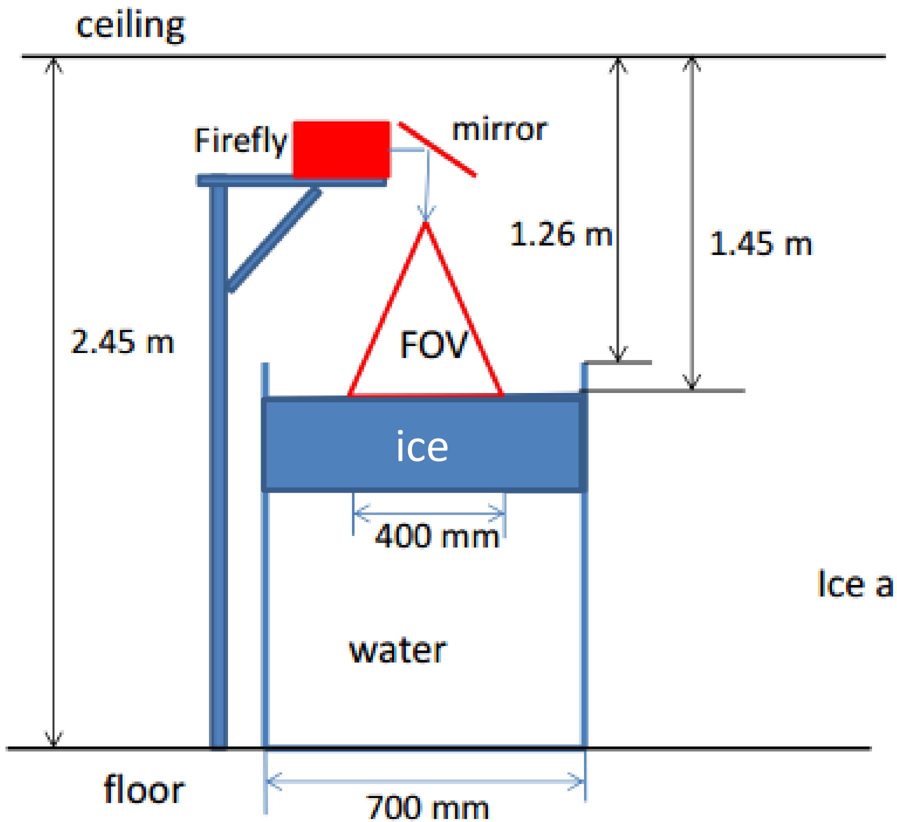


Measurements with passive system are depending on the illumination source and calibration of the system to ‘white’ and ‘black’

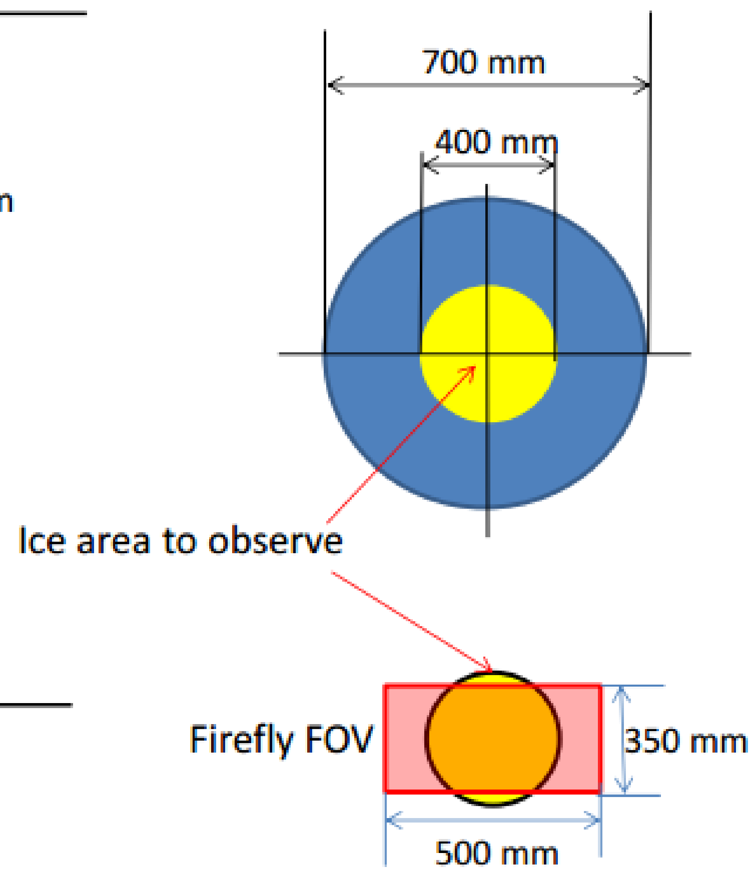


Tests with active system
Setup of the experiment

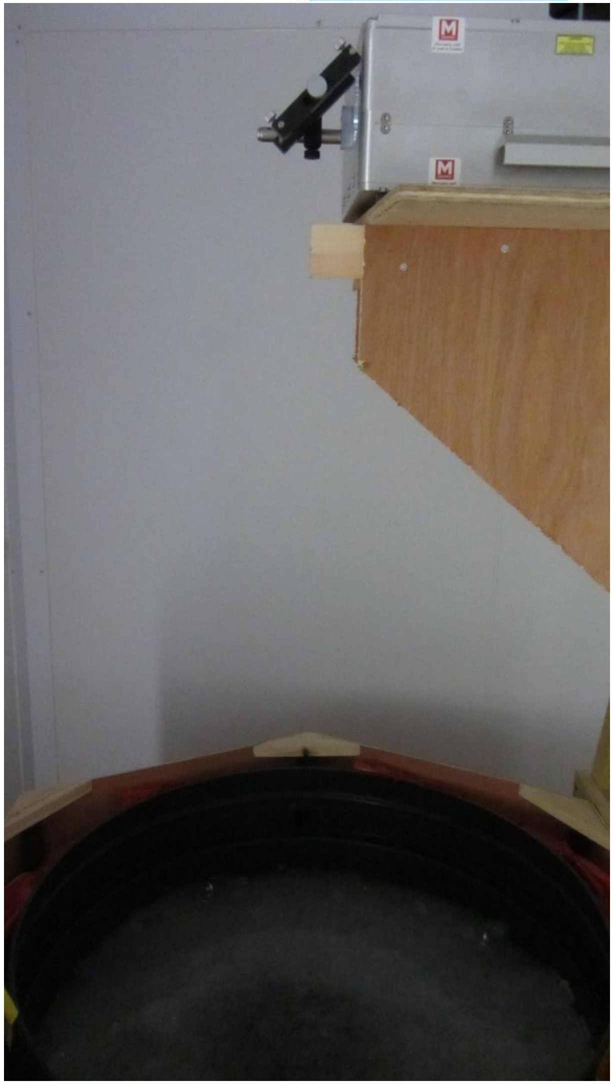
View from side



View from above

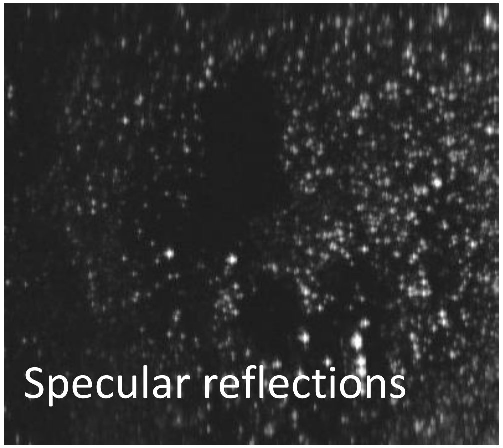


Tests with active system
Setup of the experiment



Tests with active system
Data collection issues

- The surface of ice is highly reflective, strong local specular reflections experienced during the test.
- Significant melting of the ice was observed in the room temperature and some water layer on top of the ice could affect the data.
- In the second part of the test - when oil was injected - the water has sunk under the ice what may have had impact on the repeatability of the test conditions.



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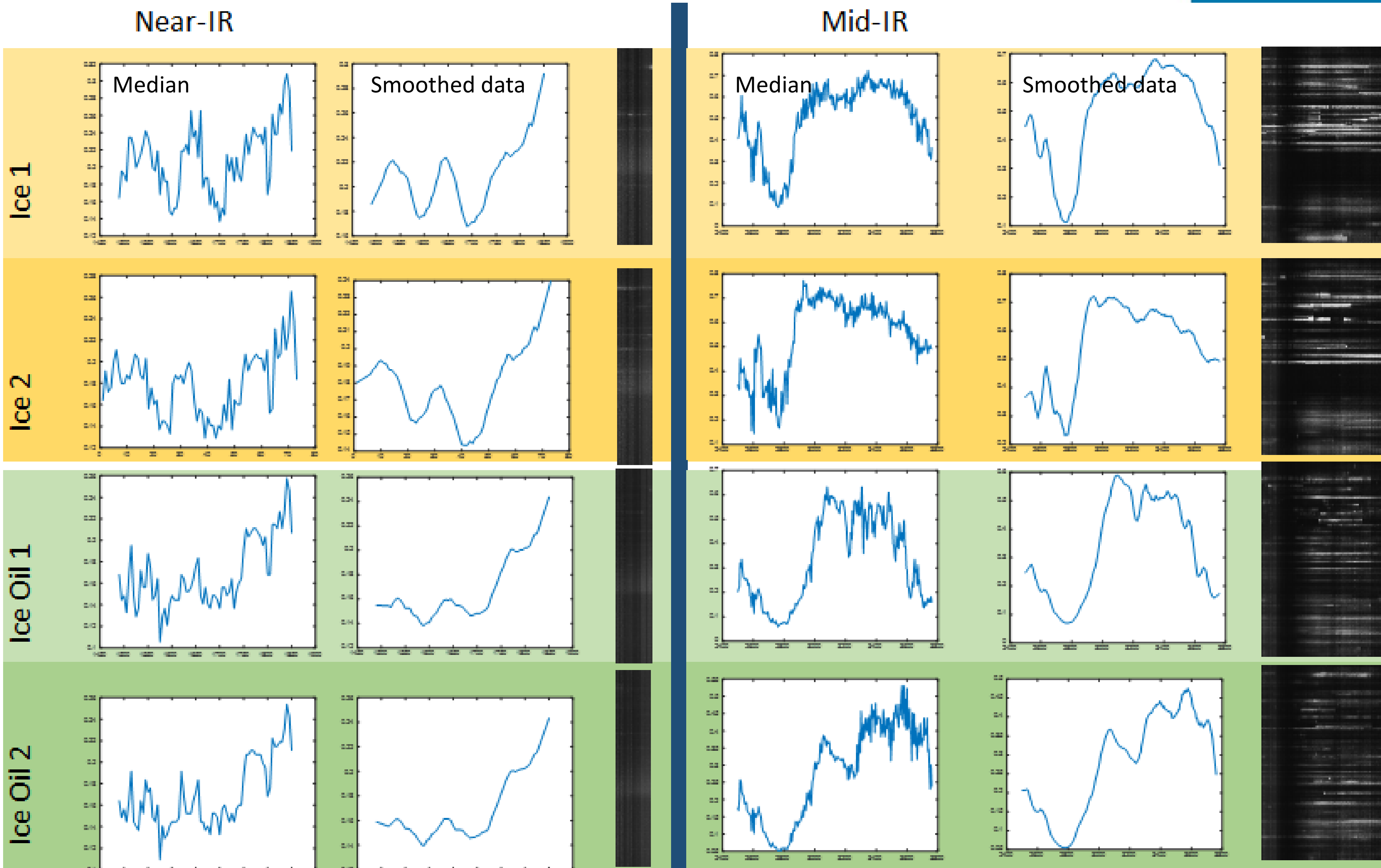
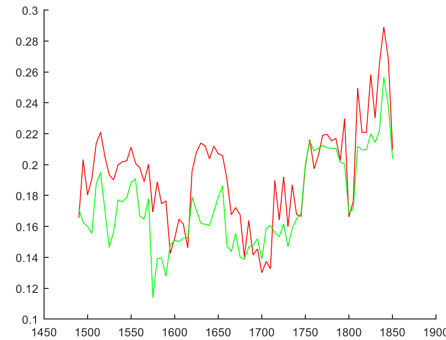
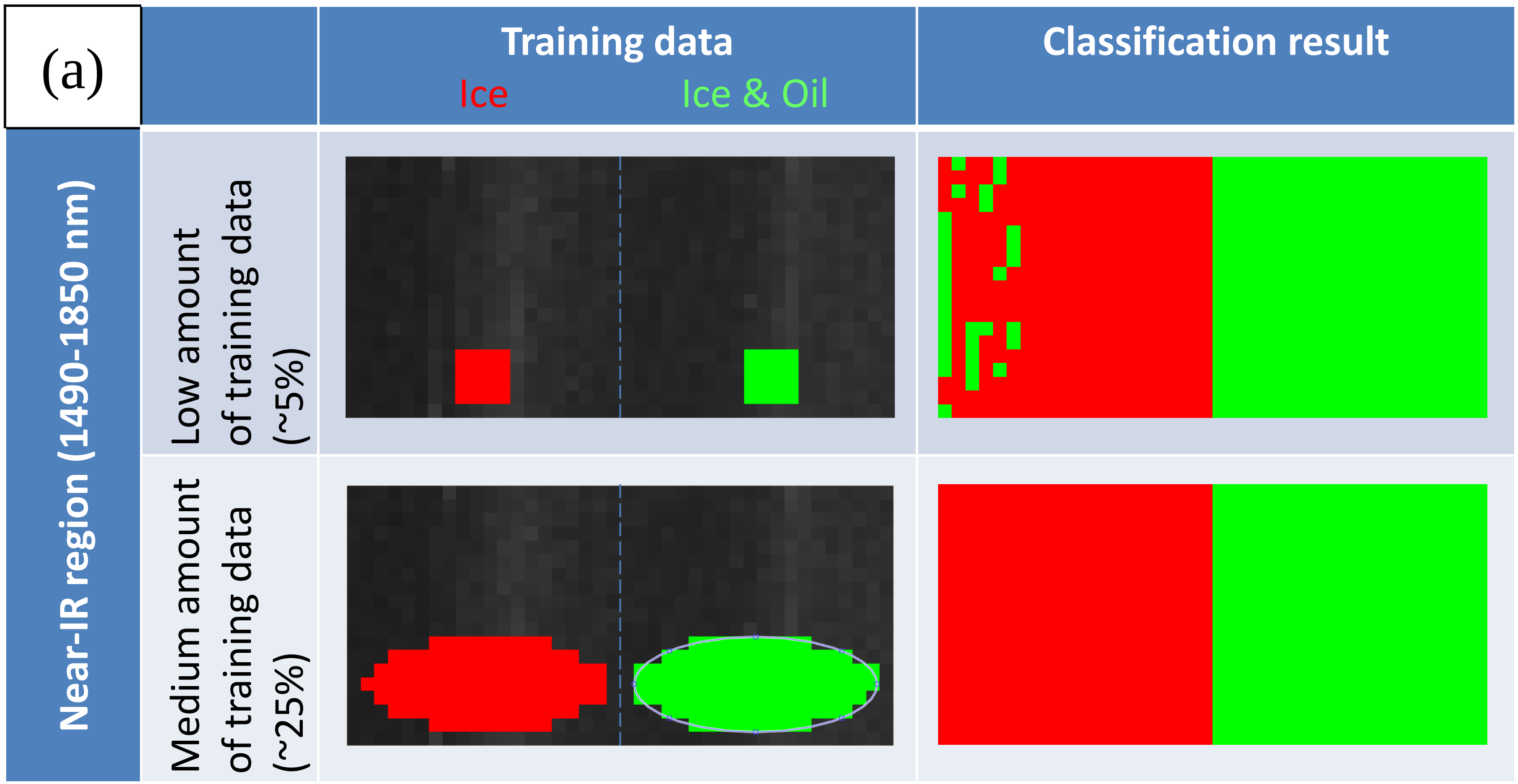
Tests with active system
Spectral response



Tests with active system
Classification results

Classification based on Near IR part of the spectrum

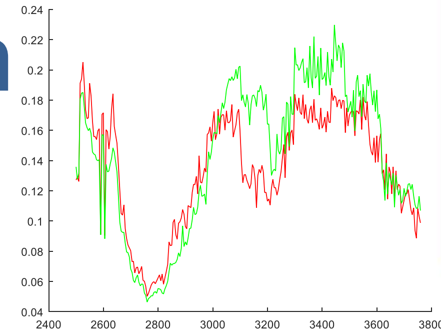


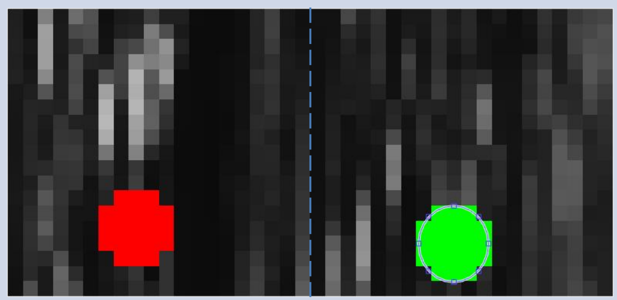
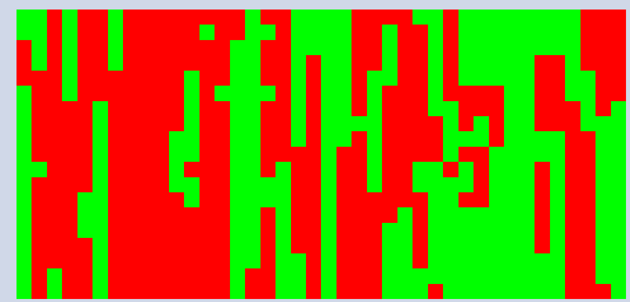
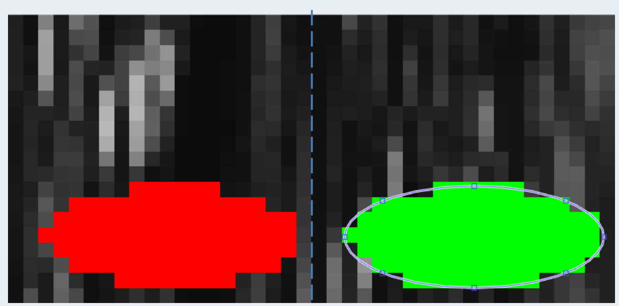
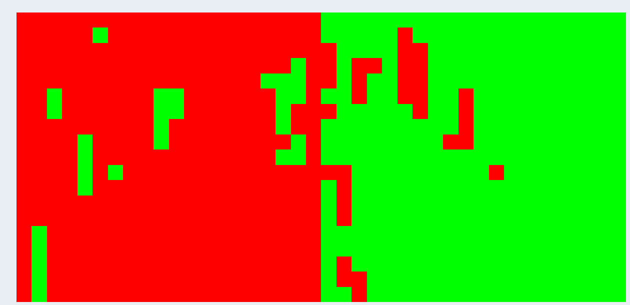


With low amount of data used for training the classifier, the result is highly dependant on what data was used for training.

Tests with active system
Classification results

Classification based on Mid IR part of the spectrum

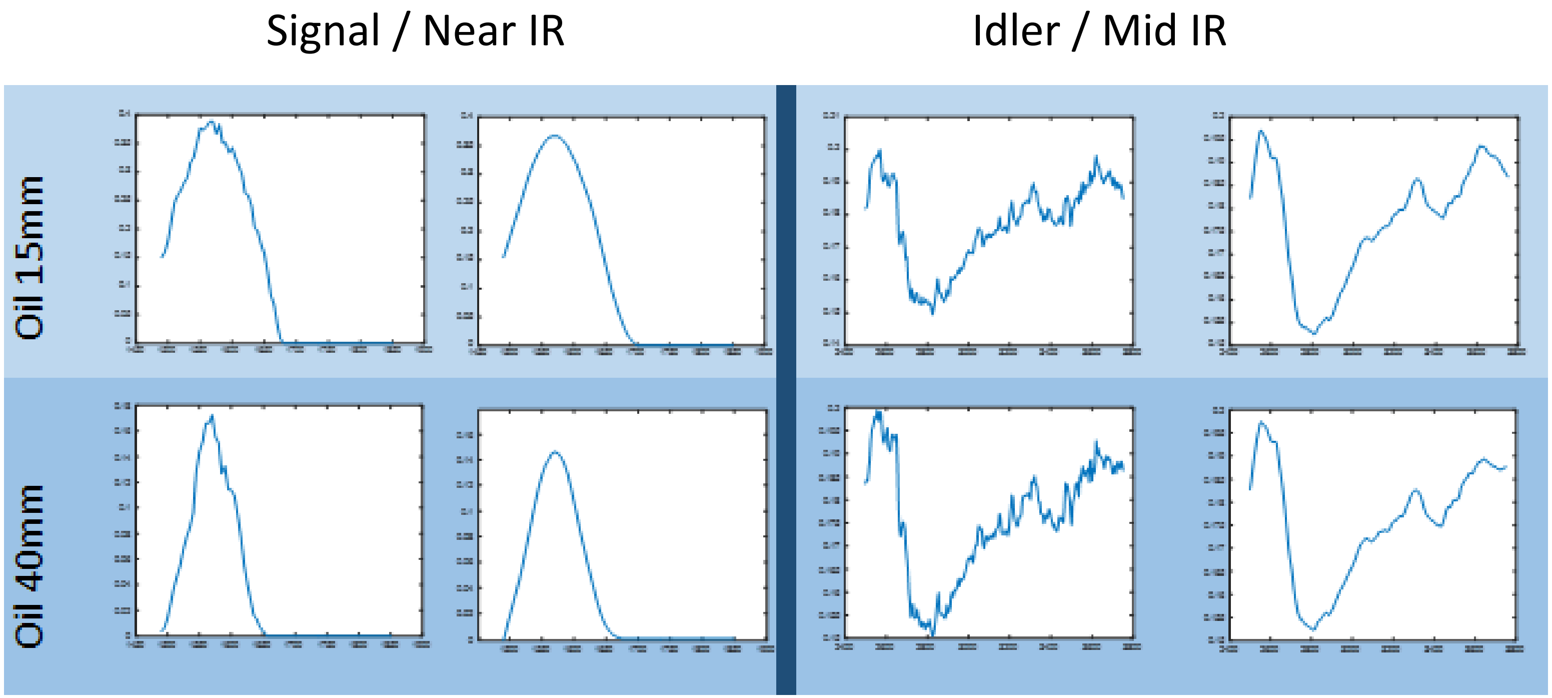


(b)		Training data Ice Ice & Oil	Classification result
Mid-IR region (2500-3750 nm)	Low amount of training data (~5%)		
	Medium amount of training data (~25%)		

With low amount of data used for training the classifier, the result is highly dependant on what data was used for training.

Tests with active system
Oil spectrum

- Spectra of oil used in this experiment were collected.
- Data was collected with Firefly with oil layer of 15mm and 40mm



Conclusions and Observations

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- Presented experimental results demonstrate that hyperspectral imaging empowered by signal processing techniques is able to detect the oil underneath a thin layer of ice.
- The oil under ice scenario could be correctly distinguished from the pure ice case based on the data from both employed HSI cameras.
- Results from presented experiment served as proof of concept for extensive feasibility study, exploring the capabilities of HSI for the oil spill detection underneath the sea ice.
- Two different HSI technologies – passive NIR camera and laser based, active Mid-IR system – will be assessed for this task and their capabilities and limits for oil spill detection beneath sea ice will be explored.
- Funding for this study was granted by The International Tanker Owners Pollution Federation Limited (ITOPF)

ITOPF

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