Strategic View on Oil Spill Response Support using In-Situ and Remote Sensing Data Tools

GRACE Final Seminar

23.05.2019, Tallinn, Estonia


Jorma Rytkönen, Finnish Environment Institute (SYKE)

Tarmo Kõuts and Siim Pärt, Tallinn University of Technology

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TAL TECH

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- Deployment platforms:
  - ice surface/vessel,
  - AUV; ROV,
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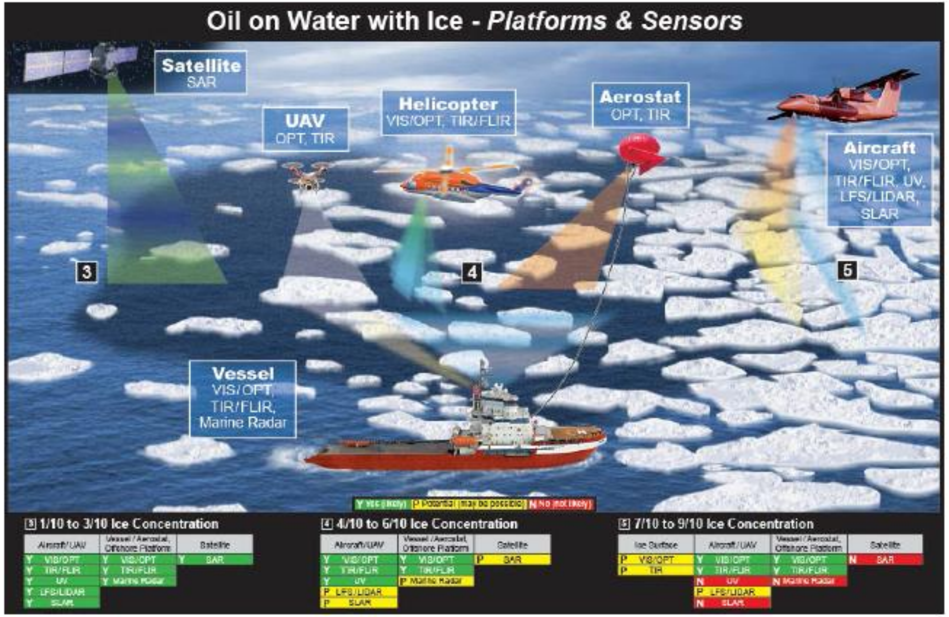
  - Satellites
- Satellites – pros & cons
- Sensor developments
- Some conclusions



Source: Watkins, R. et al. 2016/ JIP

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Arctic Preparedness Requirements

Successful countermeasures against oil spill require an adequate preparedness with

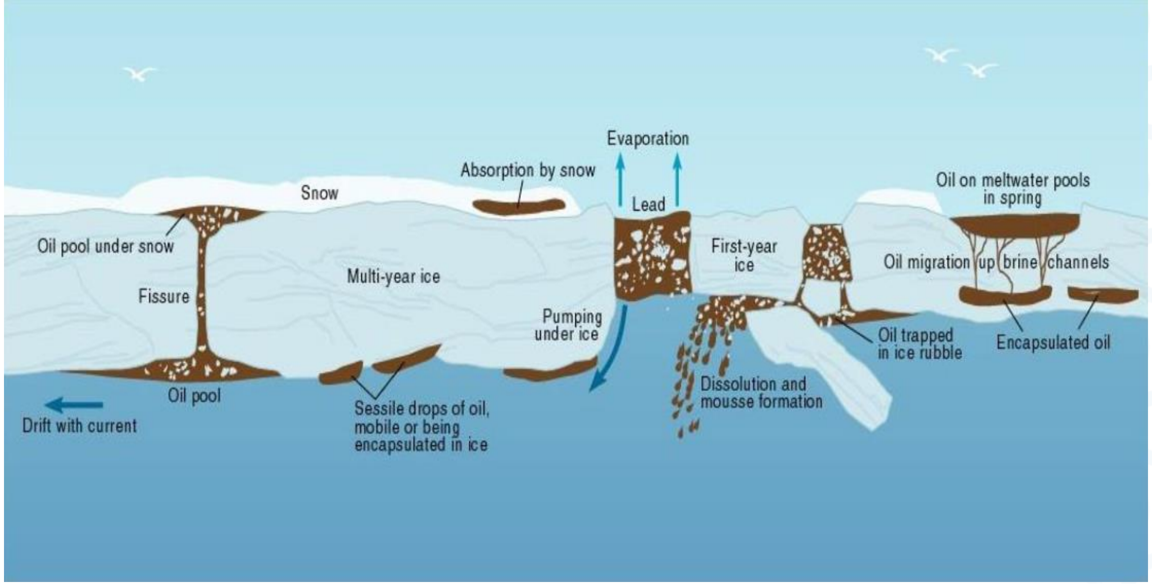
- a large toolbox of oil recovery methods and
- trained personnel and
- excellent communication and surveillance means.

Proper oil early warning system and situational awareness tools are elementary tools of the on scene commander of the response units

Oil recovery brush for ice conditions – prototype testing, photo SYKE

Oil detection in Arctic conditions – location of oil in situ !!

- Open water oil detection
- Oil-in Ice:
- Freezing conditions
- Ice formation
- Ice coverage versus open water ratio
- Land fast stable ice



Source: AMAP 1998

Remote sensing sensors for oil spill detection

- Visible range sensors (passive sensors operating in the visible region of the light)
- Infrared sensors
- Ultraviolet sensors
- Radars
- Microwave radiometers
- Laser fluorosensors
- Laser-acoustic oil thickness sensors

Example of a FLIR image, Puestow, 2013

Table 1 Remote sensing bands and related instruments used for oil spill detection (Adapted from Goodman, 1994).

Band	**Wavelength**	**Type of Instruments**
Radar	1-30 cm	SLAR/SAR
Passive microwave	2-8 mm	Radiometers
Thermal infrared (TIR)	8-14 µm	Video cameras and line scanners
Mid-band infrared (MIR)	3-5 µm	Video cameras and line scanners
Near infrared	1-3 µm	Film and video cameras
Visual	350-750 nm	Film, video cameras and spectrometers
Ultraviolet	250-350 nm	Film, Video cameras and line scanners

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Deployment Platforms

- Remotes sensing technology can be deployed to different platforms
- land fast ice,
- satellite systems,
- aircraft systems,
- unmanned aerial vehicles/systems (UAV/UAS),
- tethered balloon systems,
- surface vessels (ship based systems) and
- Autonomous Underwater Vehicles (AUVs) & Remote Operated Vehicles (ROVs)

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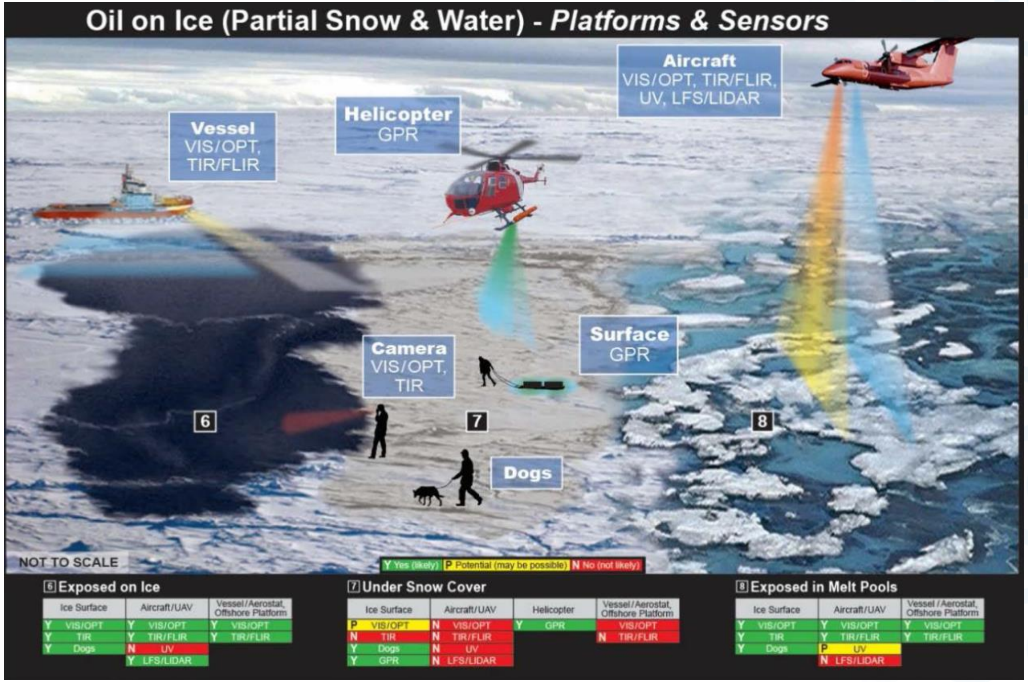
Remote Sensing Platforms

- **Stable Ice Surface (?)**

- Visual observations
- TIR/Thermal Infrared
- FLIR/Forward looking infrared
- Ground Penetrating Radar/GPR operations
- (dogs)
- Remotely Piloted Aircraft Systems/RPAS's



Source: Watkins, R. et al. 2016/ JIP

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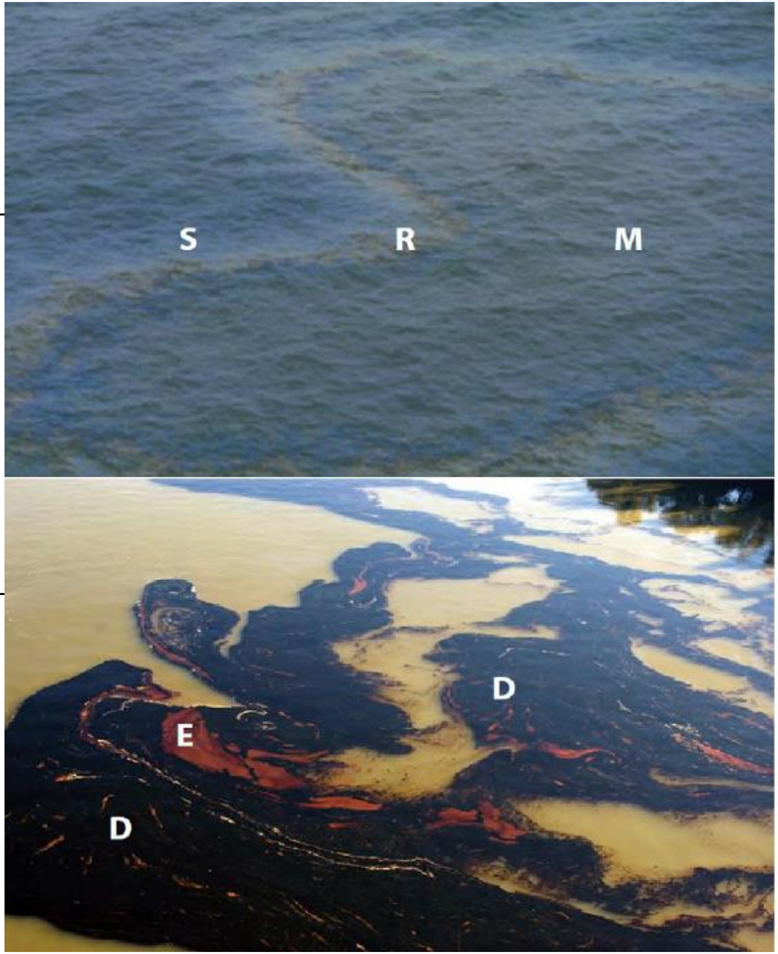
Visual Observations – Aerial Surveillance Code (Bonn Agreement)

Code	Appearance	Layer Thickness (□m)
1	Silvery/gray sheen	0.04 to 0.30
2	Rainbow	0.30 to 5.0
3	Metallic	5.0 to 50
4	Discontinuous true oil colour	50 to 200
5	Continuous true oil colour	200 to >200



Source: NOAA 2012

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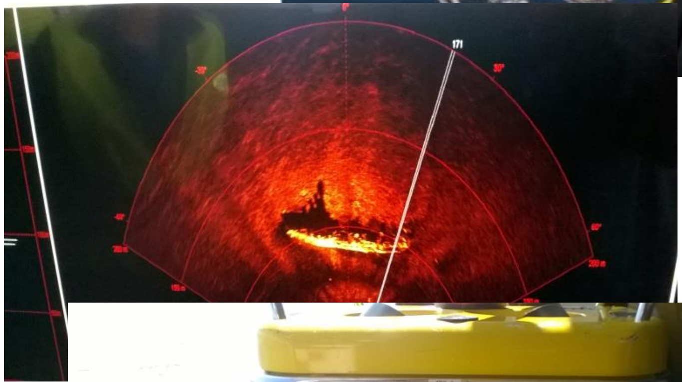
Remote Sensing Platforms

- **Autonomous underwater vehicles/AUV/ and ROVs**

- AUV/Optical cameras/underwater lightning
- Hydrocarbon detectors (laser fluorosensors), sonar
- Data transmission ?
- ROV – distance limitation due to tether – advantage on-line data transmission



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- **Gliders**

- Autonomous
- Surveys for longer durations than conventional AUVs
- Long-range
- No tether

Finnish and Estonian Gliders

Both Finnish Meteorological Institute and the Marine Systems Institute (MSI) of the Tallinn University of Technology are using Gliders for temperature, salinity, chlorophyll a fluorescence, dissolved oxygen, and turbidity measurements. The new sensor set up for hydrocarbon measurements is under development with a preliminary plan to make hydrocarbon measurements around preselected wrecks. The glider can dive down to 200 m and the continuous operation time in the Baltic Sea environment is up to two months

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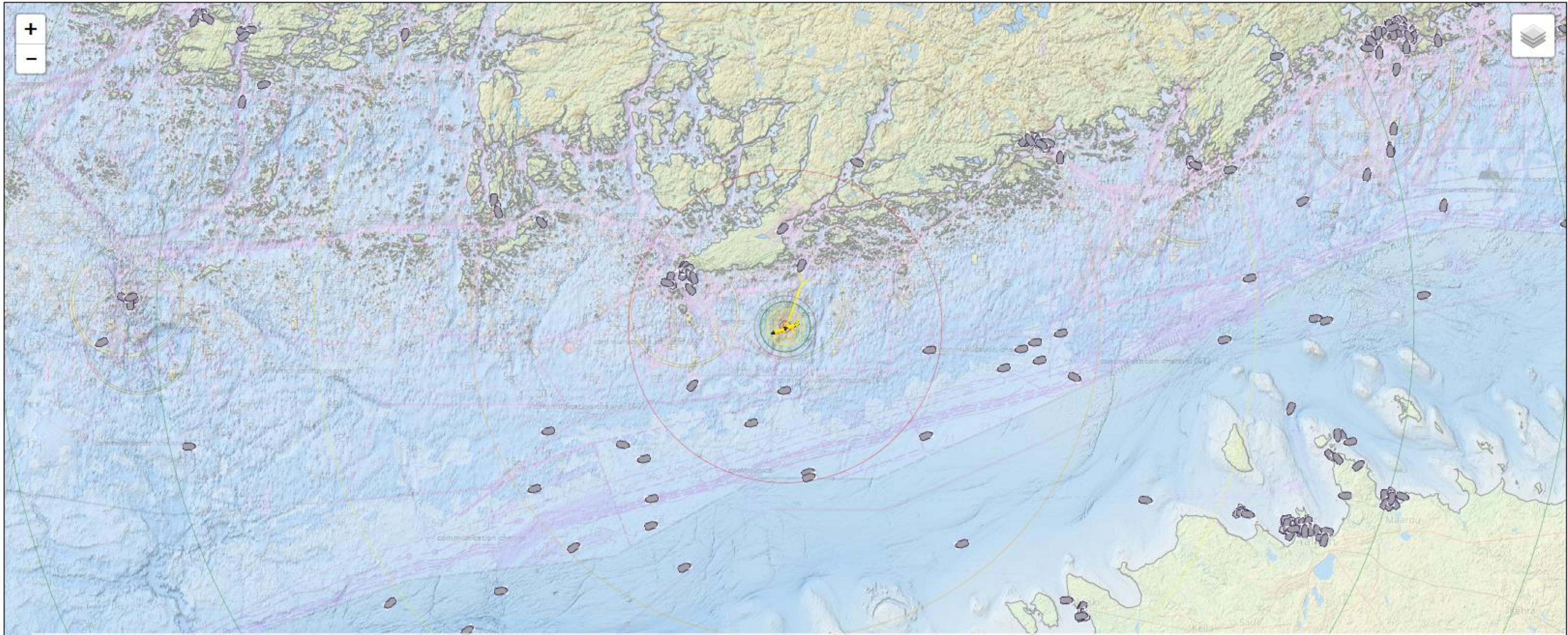
Glider missions in Finland

Current mission: off Tvarminne: *starting 2019-05-13* ending on *2019-05-16*

On this short mission off Tvärminne Zoological Station we will test the new SeaOwl payload bay and run various measurement and thruster strategies.



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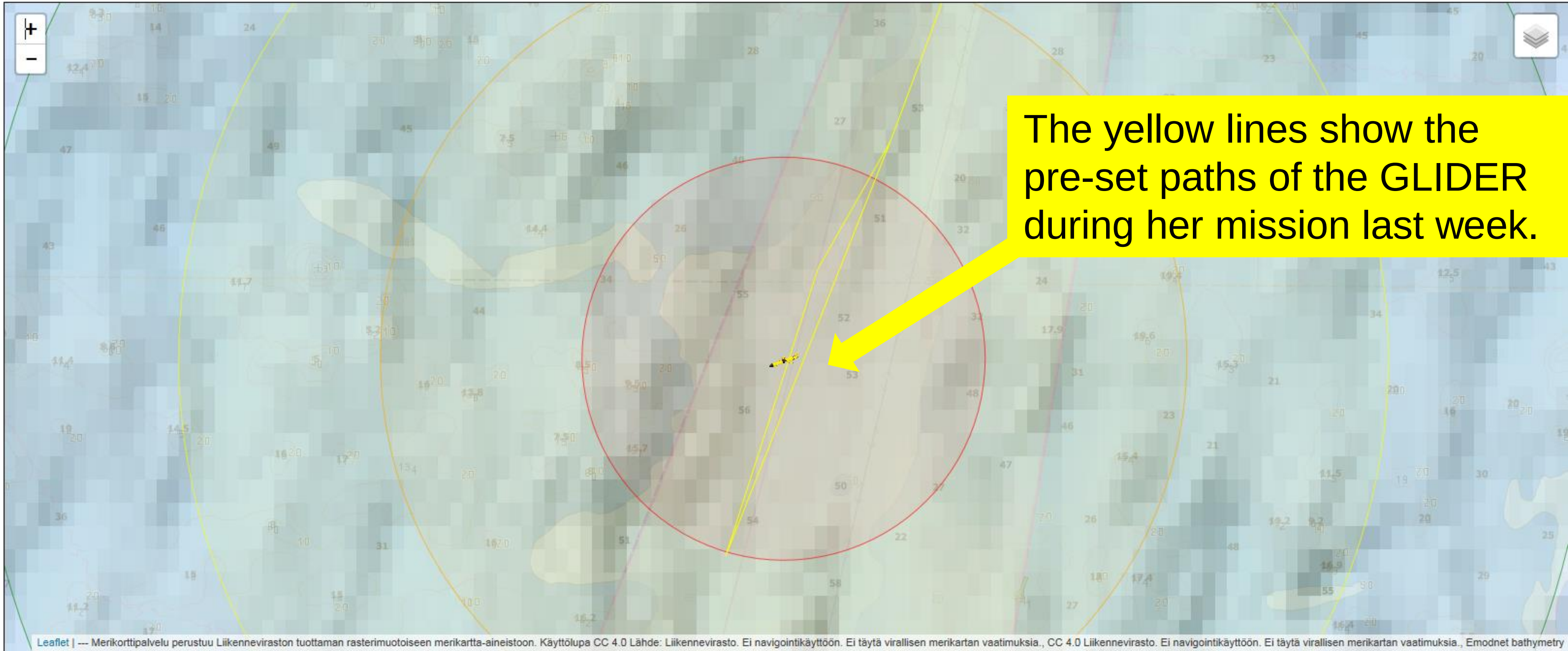
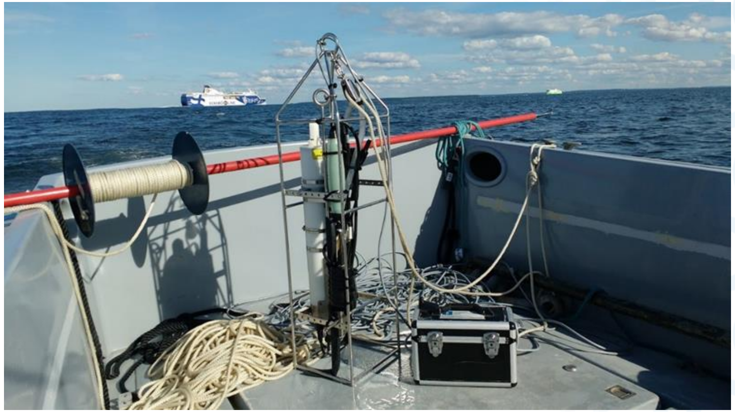
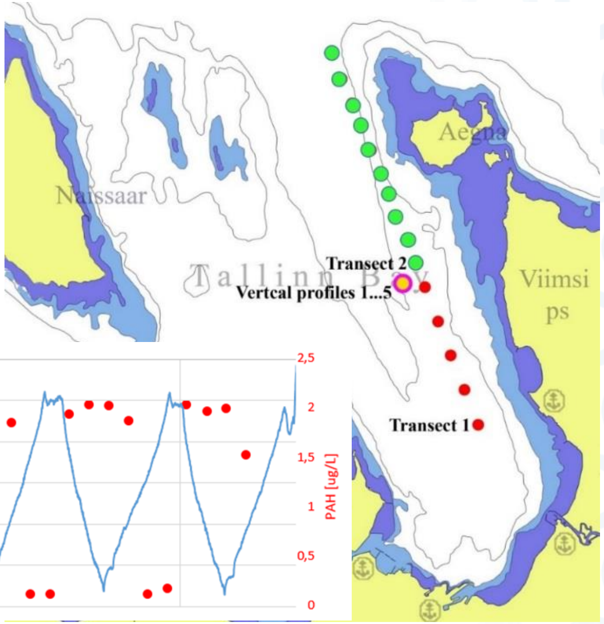
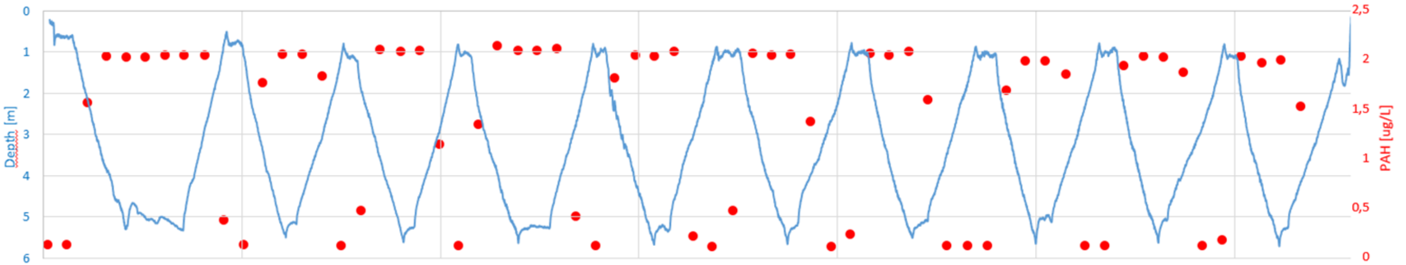


Experiment with the UviLux fluorometer in glider mode

- Slocum glider used in MSI is not compatible with the Uvilux UV flouorometer
- A towable measurement rig was constructed, consisting of a Sea-Bird CTD profiler and the UviLux sensor to simulate glider-like movement





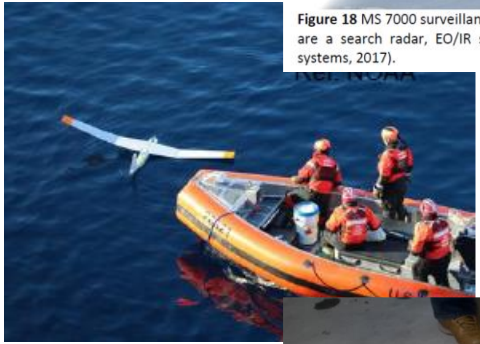


Remote Sensing Platforms

- **Aircraft /UAV /RPAS**

- Aircraft can carry sophistigated means for oil spill detection: FLIR, (SAR), SLAR, Video, cameras, etc…
- UAV's – novel sensors under development – various platform concepts for sensors

Figure 18 MS 7000 surveillance aircraft delivered to Estonian Police and Border guard recently. There are a search radar, EO/IR scanner, IR/UV scanner and SLAR on-board the aircraft (ST airborne systems, 2017).



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Remote Sensing Platforms

- **Satellites**

- CleanSeaNet as a reference
- SAR images – processing – algorithms
- Miniatyre Satellites such as https://www.iceye.com/

Satellite	Band	Resolution (m)	Image Swath (km)	Return Pass Rate (Days)
COSMO SkyMed	X Band	1 – 100	10 – 200	16
PAZ	X Band	1 – 18	5 – 150	11
RADARSAT-2	C Band	3 – 100	20 – 500	24
TerraSAR-X / TanDEM-X	X Band	1 – 18	5 – 150	11

Commercially available satellites providing SAR images

SAR satellites available

Table 2 Satellite borne synthetic aperture radar (SAR) sensors – current and future [3]

Satellite	Launch Date	Owner/Operator	Band	Polarization
ERS-1	1991 (end 2000)	European Space Agency	C	
ERS-2	1995 (end 2011)	European Space Agency	C	VV
RADARSAT-1	1995 (end 2013)	Canadian Space Agency	C	HH
RADARSAT-2	2007	Canadian Space Agency	C	
ENVISAT (ASAR)	2002 (end 2012)	European Space Agency	C	HH, VV, Cross pol
ALOS (PALSAR)	2006 (end 2011)	Japan Aerospace Exploration Agency	L	
TerraSAR-X	2007	German Aerospace Centre	X	
Tandem -X	2010	German Aerospace Centre	X	
Cosmo Skymed-1/2	2007, 2010	Italian Space Agency	X	
TecSAR	2008	Israel Aerospace Industries	X	
Kompsat-5	2013	Korean Space Agency	X	
Sentinel-1	2013	European Space Agency	C	
RADARSAT-Constellation (3-satellites)	2018	Canadian Space Agency	C	

Fingas & Brown, 2017

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Remote Sensing Platforms

- **Vessel/Aerostat**

- Optical cameras, videos, FLIR/TIR systems, marine radar, humans as observers (nose and eyes)
- Limitation of the observation distance
- Tethered balloon - significantly larger range with video, camera, IR and AIS


Ref. Aerophile SAS

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Remote Sensing Platforms

- **Drones /RPAS**

- Useful for mapping of the spread, relative and absolute oil layer thickness, as well as classification of the type of oil.
- Can be used to monitor localized oil pollution such as oil leakage from shipwrecks.

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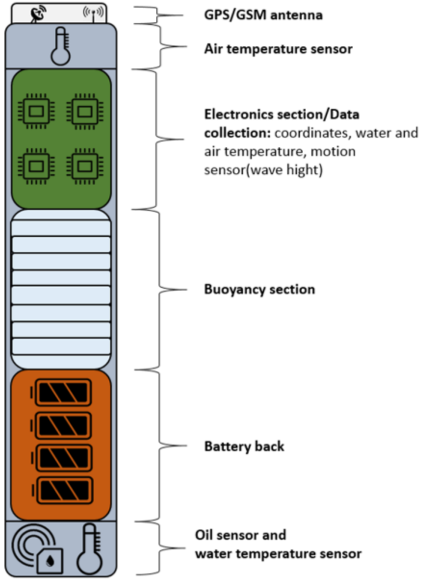
Remote Sensing Platforms

- **Drifter buoys**

- Can be used to track oil spills during response operations providing the response teams with real-time, accurate information related to speed, position, direction and etc. of the pollutant
- Like drones, drifters can be used to monitor localized oil pollution such as oil leakage from shipwrecks, when moored nearby

Oil detecting drifter buoy prototype developed in MSI, Taltech



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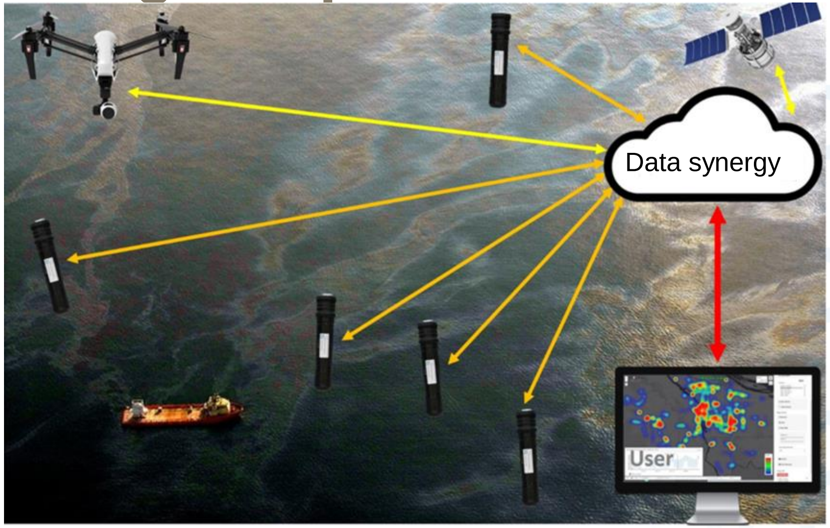
Tactical scale system supporting oil spill response locally



- **Concept for an on-line/real-time system that combines information from UAVs and drifters (and satellites, if possible), in case of an oil spill**

- UAV images give good local scale overview of situation dynamics in high resolution and buoy data contribute with in situ ground truth knowledge. Moreover, aerial image data can be extended to give various other parameters like local wave field, ice conditions in high resolution and concentration of the polluting matter.

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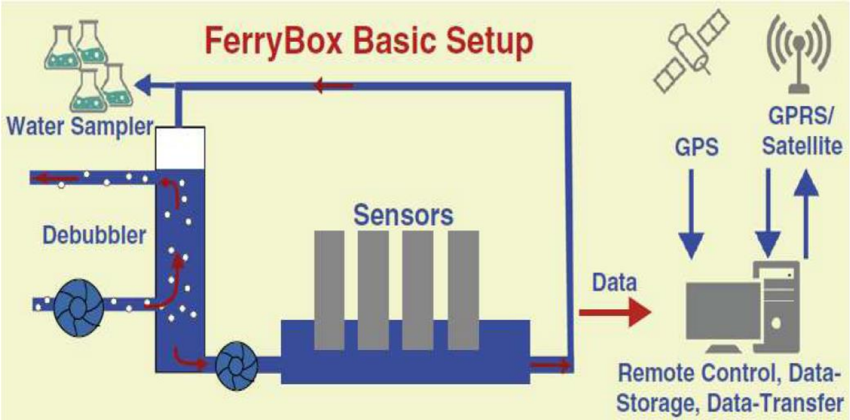
Ship Based Systems - FerryBox



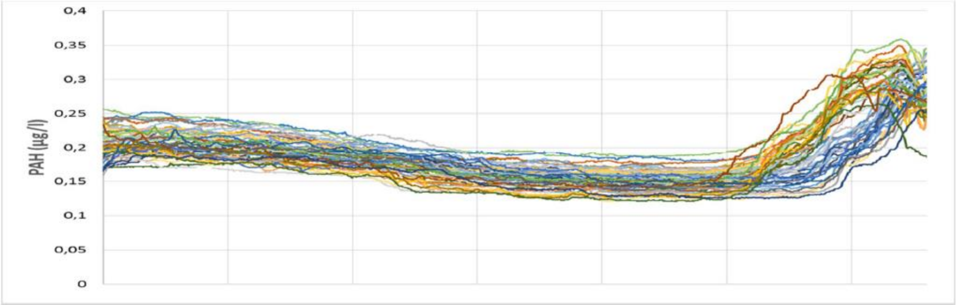


Figure 25 Example of the oil compounds PAH measurement results on Tallinn - Stockholm route (16.02.2017-11.04.2017 route)

Smart Bouy Technology

Photo: S. Virtanen/SeaHow LtD)

Satellite Remote Sensing – pros & cons.

- Can potentially cover a large area in a short period of time
- Data may potentially be transmitted via the internet almost immediately
- Many radar satellites are useful in detecting large offshore spills and spotting anomalies
- Some operational commercial satellites can be tasked to respond to emergencies within a range of 90 minutes to 4 hours

- The timing and frequency of overpasses by satellite systems may not be optimal for the situation
- Clear skies are needed to perform optical work
- The probability of detecting oil may be low
- Developing algorithms to highlight oil slicks is difficult
- Extensive time may be required to convert data into actionable information

Sensor Development(s) for Oil Spill Detection

- Extensive studies conducted by SINTEF in Oil In Ice –JIP and in Arctic Oil Spill Response Technology Joint Industry Programme (JIP) and recent R&D Finland in sensor technology
- •**Passive optical sensors**: cameras and multispectral imaging systems, ultraviolet (UV) and Near-InfraRed(NIR) sensors, hyperspectral sensors
- •**Passive Thermal InfraRedsensors** (TIRs) and **MicroWaveRadiometer** (MWR) systems
- •**Active radar sensors**: Side-Looking Airborne Radar (SLAR) and (Synthetic Aperture radar (SAR) systems, Marine Radar, Ground Penetrating Radar (GPR)
- •**Active Laser and fluorosensors**: fluorosensors, TunableDiode Laser Spectroscopy (TDLS), Laser-Ultrasonic Remote Sensing of Oil Thickness (LURSOT), Light Detection and Ranging LiDAR
- •**Experimental sensors**: Acoustic Sensors, Nuclear Magnetic Resonance (NMR) Spectroscopy, trained dogs
- **Concepts:** biosensors, zebrafish larvae

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Technology	Oil among Pack Ice Ice concentration < 30%	30-60%	>60%	Oil on ice	Oil under ice / snow or encapsulated	Low visibility Blowing snow	Darkness	Rain or fog
VIS, MS, UV, Hyperspectral							Active systems	
TIR								
MWR								
SAR, SLAR Marine radar								
GPR								
LFS								
TDL								
LURSOT								
LIDAR								
Acoustic								
NMR								
Trained dogs								

(Ref. Puestow et al. 2013)

Green box: Proven and validated technology, its performance and limitations under current scenario well understood.

Orange box: Technology potentially applicable, partial validation may have taken place but the technology has not been comprehensively validated for performance under the given scenario.

White box: The likely performance of the technology not known; never been tested under the given scenario.

Red box: The technology is not applicable to the given scenario.

Some Conclusions

- Flexible combination of sensors operating from aircraft, helicopters, vessels, satellites and the ice surface are recommended for future Arctic oil spill emergency preparedness
- Attention need to be carried out for data transmission solutions
- Current generation of all-weather SAR satellites can play a valuable support role in mapping detailed ice conditions and directing marine resources
- New technologies may enhance the ability to detect oil over a broader range of Arctic spill scenarios in the near future. These include NMR (Nuclear Magnetic Resonance), hyperspectral sensors, , UAVs, AUVs and next generation GPR optimized for the oil in ice problem
- The optimum mix of remote sensing technologies depends heavily on the spill characteristic and prevailing weather and ice conditions

More Information

jorma.rytkonen@ymparisto.fi

and

tarmo.kouts@taltech.ee

Oil Recovery vessel
LOUHI in Ice

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TALLINN UNIVERSITY OF TECHNOLOGY