Operational oil spill detection and monitoring on fairways using FerryBox and SmartBuoy technologies

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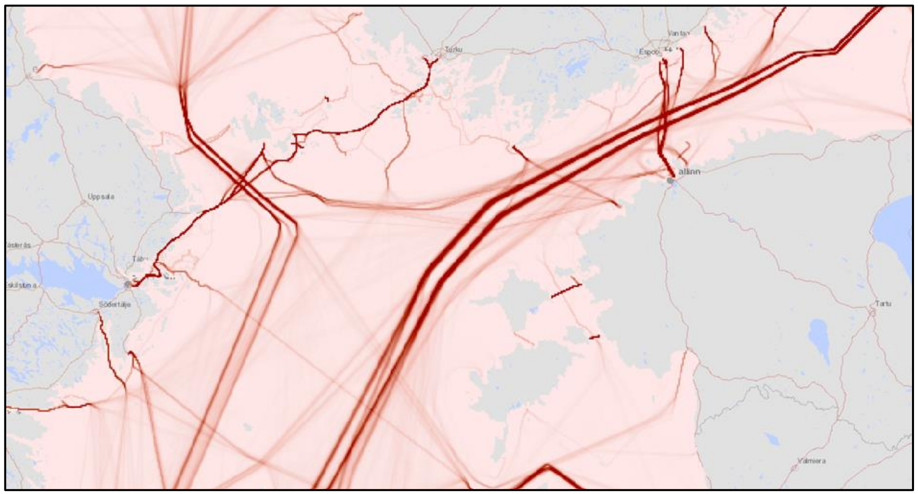
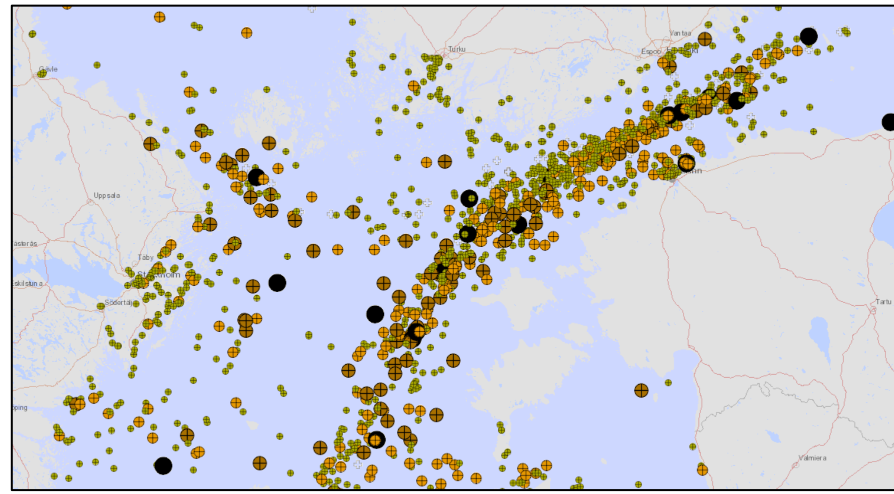
Density of ships operating in the Baltic Sea (2016) and location of illegal oil discharges (1998-2015)





- The Baltic Sea, with its high maritime traffic has high probability for oil pollution occurrence.
- Spatial distribution of detected oil spills show that these are most likely located on major ship routes, which lead to the idea to detect oil spills with a FerryBox and SmartBuoys equipped with an hydrocarbon sensor

Detecting oil contamination in terms of Polycyclic Aromatic Hydrocarbons (PAHs) using UV-fluorometers

- Crude oil and other fossil fuels contain polycyclic aromatic hydrocarbons (PAHs)
- The **fluorescent technique** detects the intensity of fluorescence emission from both dissolved and emulsified PAHs present in oils, when irradiated with UV light
- The method is based on the similarities between the fluorescence excitation and emission spectra
- Low viscosity physically dispersed crude oils typically have two broad UV peaks with excitation between 240 and 300 nm and emission centered at ~350 nm (low molecular weight polycyclic aromatic hydro-carbons, LMW PAH, <3 benzene rings) and ~450 nm (higher MW PAH, >3 benzene rings)

There are issues with relating the signals generated by the fluorometer to the actual concentration of the oil in the water:

- Oil is a mixture of hundreds of different chemical compounds however only a portion of these, specifically some of the aromatic compounds do fluoresce
- The relative proportion of aromatic compounds differs between oils and changes with weathering
- In marine environment, other fluorophores (besides PAHs) could also react, with different magnitudes, to the fluorometers spectral domains
- Calibration of the fluorometers are generally carried out using a specific oil or other compounds, thus, the concentration results obtained in the field are relative to the specific oil or compound and the procedure used to calibrate the instrument

Because of the aforementioned issues, in this study, the UV-fluorometers were used to estimate variability patterns and to detect sudden concentration rises of hydrocarbon concentrations which would directly indicate oil pollution

UV-fluorometers used

- UviLux UV-fluorometer measures oil compounds polycyclic aromatic hydrocarbons (PAH) concentrations

  Sensitivity of the sensor is 0,005 µg/L or 5ppt (**Carbazole**), calibrated range 0,005 – 2000 µg/L, excitation light 255nm and emission light 360nm

- EnviroFlu-HC Trios UV fluorometer measures PAH concentrations

  Sensitivity of the sensor is 0,3ppt (**Phenantrene**), calibrated range 0-500 ppb, excitation light 254nm and emission light 360nm

- Turner Design C3 fluorometer- measures crude oil

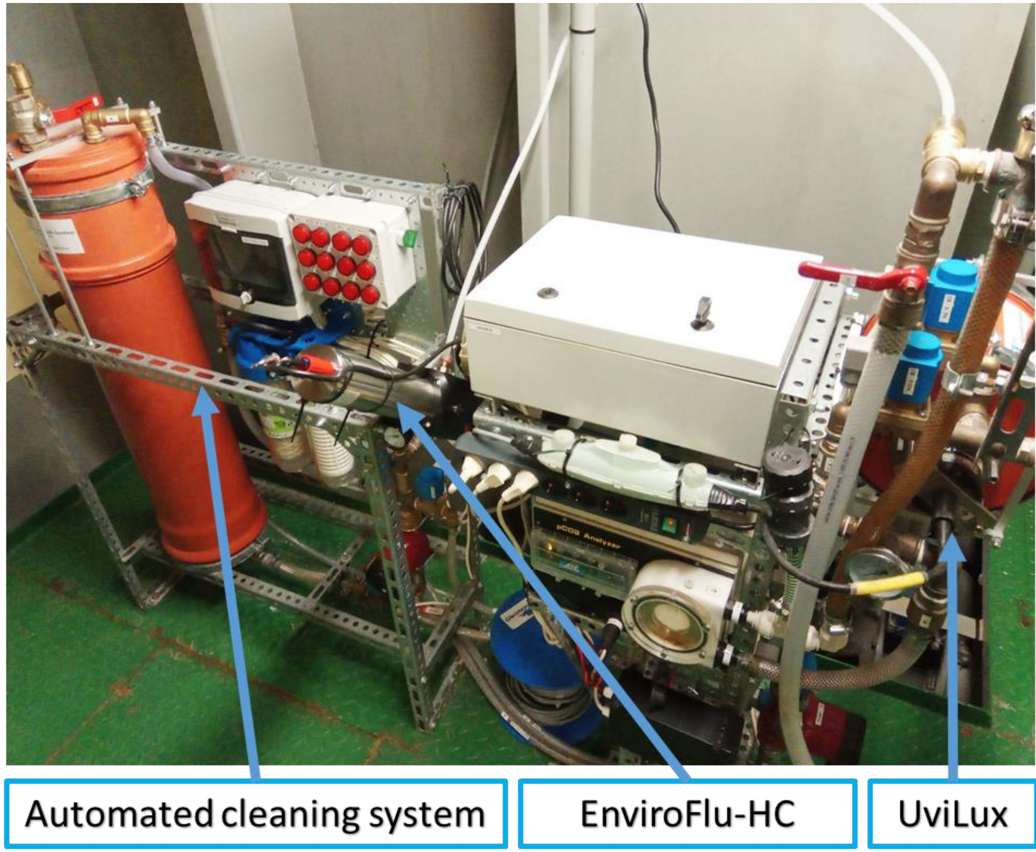
  Sensitivity of the sensor is 0,2 ppb (**PTSA** - Pyrenetetrasulfonic Acid Tetrasodium Salt) with range 0 - 1500 ppb

UviLux

enivroFlu-HC

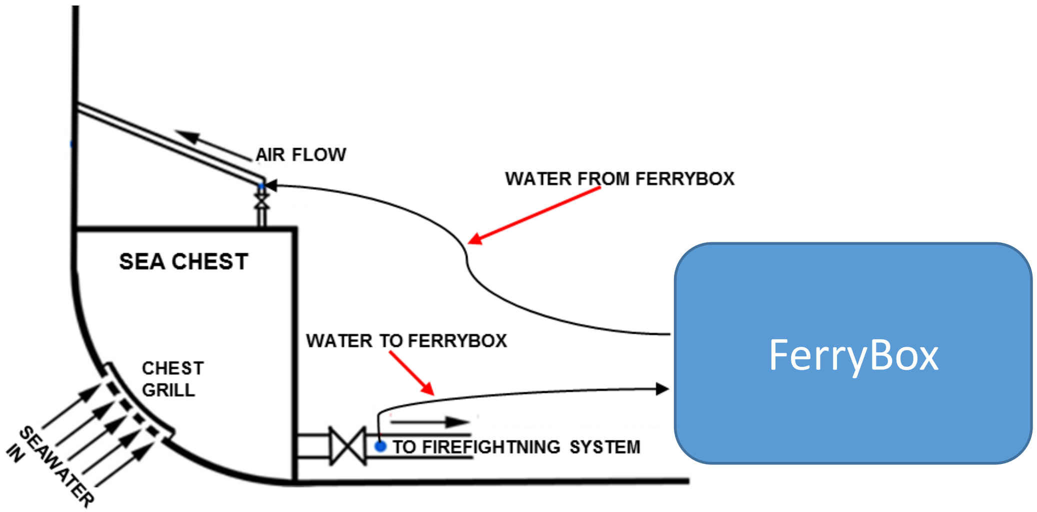
Turner Design C3 fluorometer

FerryBox on M/S BALTIC QUEEN



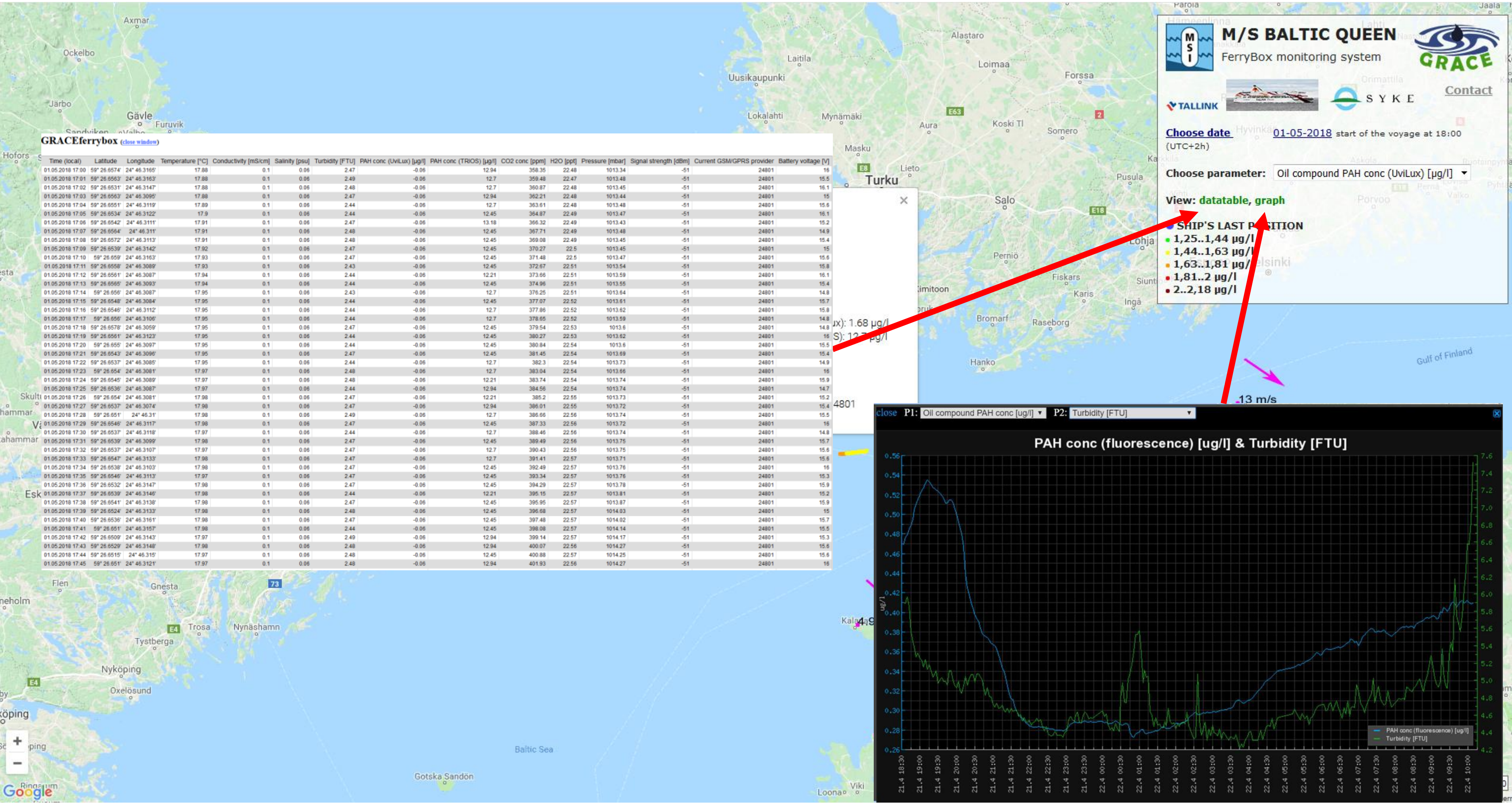
FerryBox on M/S BALTIC QUEEN

- Water intake about 4 m below the waterline
- Other parameters measured – temperature, salinity, turbidity, pCO2 concentration
- Parameters are measured in one minute intervals, which give a 100-150m spatial resolution along the fairway
- Main fluorometer for oil detection - UviLux



Web-based user interface

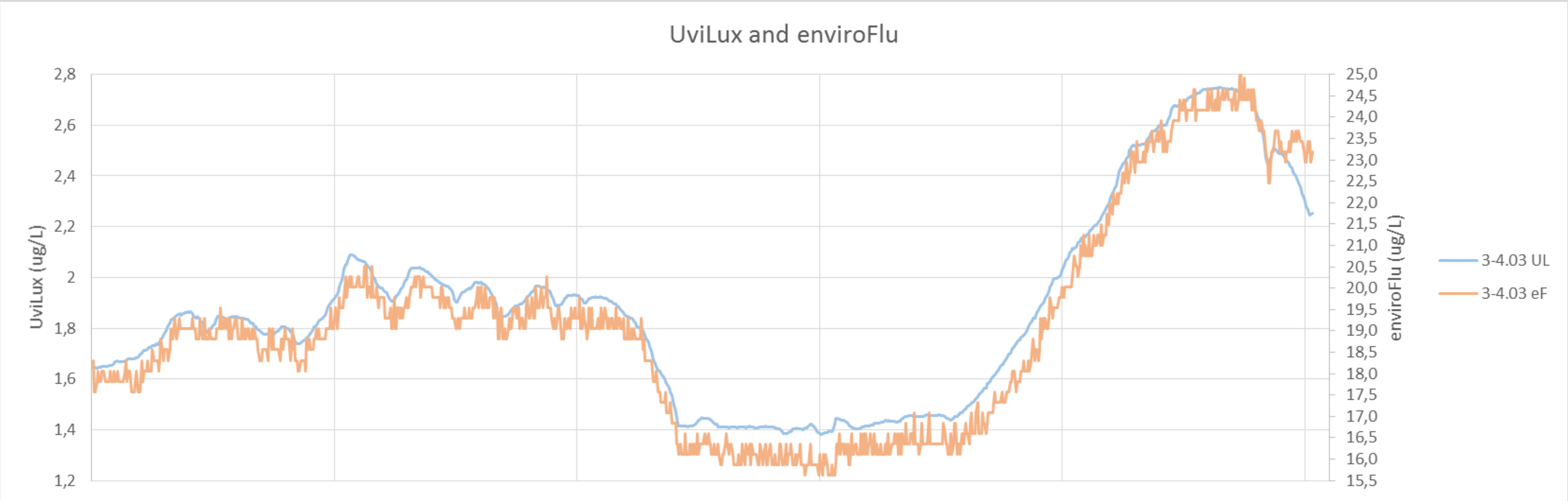
http://on-line.msi.ttu.ee/GRACEferry/



Time (local)	Latitude	Longitude	Temperature [°C]	Conductivity [mS/cm]	Salinity [psu]	Turbidity [FTU]	PAH conc (UviLux) [µg/l]	PAH conc (TRIOS) [µg/l]	CO2 conc [ppm]	H2O [ppt]	Pressure [mbar]	Signal strength [dBm]	Current GSM/GPRS provider	Battery voltage [V]
01.05.2018 17:00	59° 26.6574'	24° 46.3165'	17.88	0.1	0.06	2.47	-0.06	12.94	358.35	22.48	1013.34	-51	24801	16
01.05.2018 17:01	59° 26.6563'	24° 46.3163'	17.88	0.1	0.06	2.49	-0.06	12.7	359.48	22.47	1013.48	-51	24801	15.5
01.05.2018 17:02	59° 26.6531'	24° 46.3147'	17.88	0.1	0.06	2.48	-0.06	12.7	360.87	22.48	1013.45	-51	24801	16.1
01.05.2018 17:03	59° 26.6563'	24° 46.3095'	17.88	0.1	0.06	2.47	-0.06	12.94	362.21	22.48	1013.44	-51	24801	15
01.05.2018 17:04	59° 26.6551'	24° 46.3119'	17.89	0.1	0.06	2.44	-0.06	12.7	363.61	22.48	1013.48	-51	24801	15.6
01.05.2018 17:05	59° 26.6534'	24° 46.3122'	17.9	0.1	0.06	2.44	-0.06	12.45	364.87	22.49	1013.47	-51	24801	16.1
01.05.2018 17:06	59° 26.6542'	24° 46.3111'	17.91	0.1	0.06	2.47	-0.06	13.18	366.32	22.49	1013.43	-51	24801	15.2
01.05.2018 17:07	59° 26.6564'	24° 46.311'	17.91	0.1	0.06	2.48	-0.06	12.45	367.71	22.49	1013.48	-51	24801	14.9
01.05.2018 17:08	59° 26.6572'	24° 46.3113'	17.91	0.1	0.06	2.48	-0.06	12.45	369.08	22.49	1013.45	-51	24801	15.4
01.05.2018 17:09	59° 26.6539'	24° 46.3142'	17.92	0.1	0.06	2.47	-0.06	12.45	370.27	22.5	1013.45	-51	24801	15
01.05.2018 17:10	59° 26.659'	24° 46.3163'	17.93	0.1	0.06	2.47	-0.06	12.45	371.48	22.5	1013.47	-51	24801	15.6
01.05.2018 17:11	59° 26.6558'	24° 46.3089'	17.93	0.1	0.06	2.43	-0.06	12.45	372.67	22.51	1013.54	-51	24801	15.8
01.05.2018 17:12	59° 26.6561'	24° 46.3087'	17.94	0.1	0.06	2.44	-0.06	12.21	373.66	22.51	1013.59	-51	24801	16.1
01.05.2018 17:13	59° 26.6565'	24° 46.3093'	17.94	0.1	0.06	2.44	-0.06	12.45	374.96	22.51	1013.55	-51	24801	15.4
01.05.2018 17:14	59° 26.656'	24° 46.3087'	17.95	0.1	0.06	2.43	-0.06	12.7	376.25	22.51	1013.64	-51	24801	14.8
01.05.2018 17:15	59° 26.6548'	24° 46.3084'	17.95	0.1	0.06	2.44	-0.06	12.45	377.07	22.52	1013.61	-51	24801	15.7
01.05.2018 17:16	59° 26.6546'	24° 46.3112'	17.95	0.1	0.06	2.44	-0.06	12.7	377.86	22.52	1013.62	-51	24801	15.8
01.05.2018 17:17	59° 26.656'	24° 46.3106'	17.95	0.1	0.06	2.44	-0.06	12.7	378.65	22.52	1013.59	-51	24801	14.8
01.05.2018 17:18	59° 26.6578'	24° 46.3059'	17.95	0.1	0.06	2.47	-0.06	12.45	379.54	22.53	1013.6	-51	24801	14.8
01.05.2018 17:19	59° 26.6561'	24° 46.3123'	17.95	0.1	0.06	2.44	-0.06	12.45	380.27	22.53	1013.62	-51	24801	16
01.05.2018 17:20	59° 26.655'	24° 46.3097'	17.95	0.1	0.06	2.44	-0.06	12.45	380.84	22.54	1013.6	-51	24801	15.5
01.05.2018 17:21	59° 26.6543'	24° 46.3096'	17.95	0.1	0.06	2.47	-0.06	12.45	381.45	22.54	1013.69	-51	24801	15.4
01.05.2018 17:22	59° 26.6537'	24° 46.3085'	17.95	0.1	0.06	2.44	-0.06	12.7	382.3	22.54	1013.73	-51	24801	14.9
01.05.2018 17:23	59° 26.654'	24° 46.3081'	17.97	0.1	0.06	2.48	-0.06	12.7	383.04	22.54	1013.66	-51	24801	16
01.05.2018 17:24	59° 26.6545'	24° 46.3089'	17.97	0.1	0.06	2.48	-0.06	12.21	383.74	22.54	1013.74	-51	24801	15.9
01.05.2018 17:25	59° 26.6536'	24° 46.3087'	17.97	0.1	0.06	2.44	-0.06	12.94	384.56	22.54	1013.74	-51	24801	14.7
01.05.2018 17:26	59° 26.654'	24° 46.3081'	17.98	0.1	0.06	2.47	-0.06	12.21	385.2	22.55	1013.73	-51	24801	15.2
01.05.2018 17:27	59° 26.6537'	24° 46.3074'	17.98	0.1	0.06	2.47	-0.06	12.94	386.01	22.55	1013.72	-51	24801	15.4
01.05.2018 17:28	59° 26.651'	24° 46.31'	17.98	0.1	0.06	2.49	-0.06	12.7	386.66	22.56	1013.74	-51	24801	15.5
01.05.2018 17:29	59° 26.6546'	24° 46.3117'	17.98	0.1	0.06	2.47	-0.06	12.45	387.33	22.56	1013.72	-51	24801	16
01.05.2018 17:30	59° 26.6537'	24° 46.3118'	17.97	0.1	0.06	2.44	-0.06	12.7	388.46	22.56	1013.74	-51	24801	14.8
01.05.2018 17:31	59° 26.6539'	24° 46.3099'	17.98	0.1	0.06	2.47	-0.06	12.45	389.49	22.56	1013.75	-51	24801	15.7
01.05.2018 17:32	59° 26.6537'	24° 46.3107'	17.97	0.1	0.06	2.47	-0.06	12.7	390.43	22.56	1013.75	-51	24801	15.6
01.05.2018 17:33	59° 26.6547'	24° 46.3133'	17.98	0.1	0.06	2.47	-0.06	12.7	391.41	22.57	1013.71	-51	24801	15.6
01.05.2018 17:34	59° 26.6538'	24° 46.3103'	17.98	0.1	0.06	2.47	-0.06	12.45	392.49	22.57	1013.76	-51	24801	16
01.05.2018 17:35	59° 26.6546'	24° 46.3113'	17.97	0.1	0.06	2.47	-0.06	12.45	393.34	22.57	1013.76	-51	24801	15.3
01.05.2018 17:36	59° 26.6532'	24° 46.3147'	17.98	0.1	0.06	2.47	-0.06	12.45	394.29	22.57	1013.78	-51	24801	15.9
01.05.2018 17:37	59° 26.6539'	24° 46.3146'	17.98	0.1	0.06	2.44	-0.06	12.21	395.15	22.57	1013.81	-51	24801	15.2
01.05.2018 17:38	59° 26.6541'	24° 46.3138'	17.98	0.1	0.06	2.47	-0.06	12.45	395.95	22.57	1013.87	-51	24801	15.9
01.05.2018 17:39	59° 26.6524'	24° 46.3133'	17.98	0.1	0.06	2.48	-0.06	12.45	396.68	22.57	1014.03	-51	24801	15
01.05.2018 17:40	59° 26.6536'	24° 46.3161'	17.98	0.1	0.06	2.47	-0.06	12.45	397.48	22.57	1014.02	-51	24801	15.7
01.05.2018 17:41	59° 26.651'	24° 46.3157'	17.98	0.1	0.06	2.44	-0.06	12.45	398.08	22.57	1014.14	-51	24801	15.5
01.05.2018 17:42	59° 26.6509'	24° 46.3143'	17.97	0.1	0.06	2.49	-0.06	12.94	399.14	22.57	1014.17	-51	24801	15.3
01.05.2018 17:43	59° 26.6529'	24° 46.3148'	17.98	0.1	0.06	2.48	-0.06	12.94	400.07	22.56	1014.27	-51	24801	15.6
01.05.2018 17:44	59° 26.6515'	24° 46.315'	17.97	0.1	0.06	2.48	-0.06	12.45	400.88	22.57	1014.25	-51	24801	15.6
01.05.2018 17:45	59° 26.651'	24° 46.3121'	17.97	0.1	0.06	2.48	-0.06	12.94	401.93	22.56	1014.27	-51	24801	16

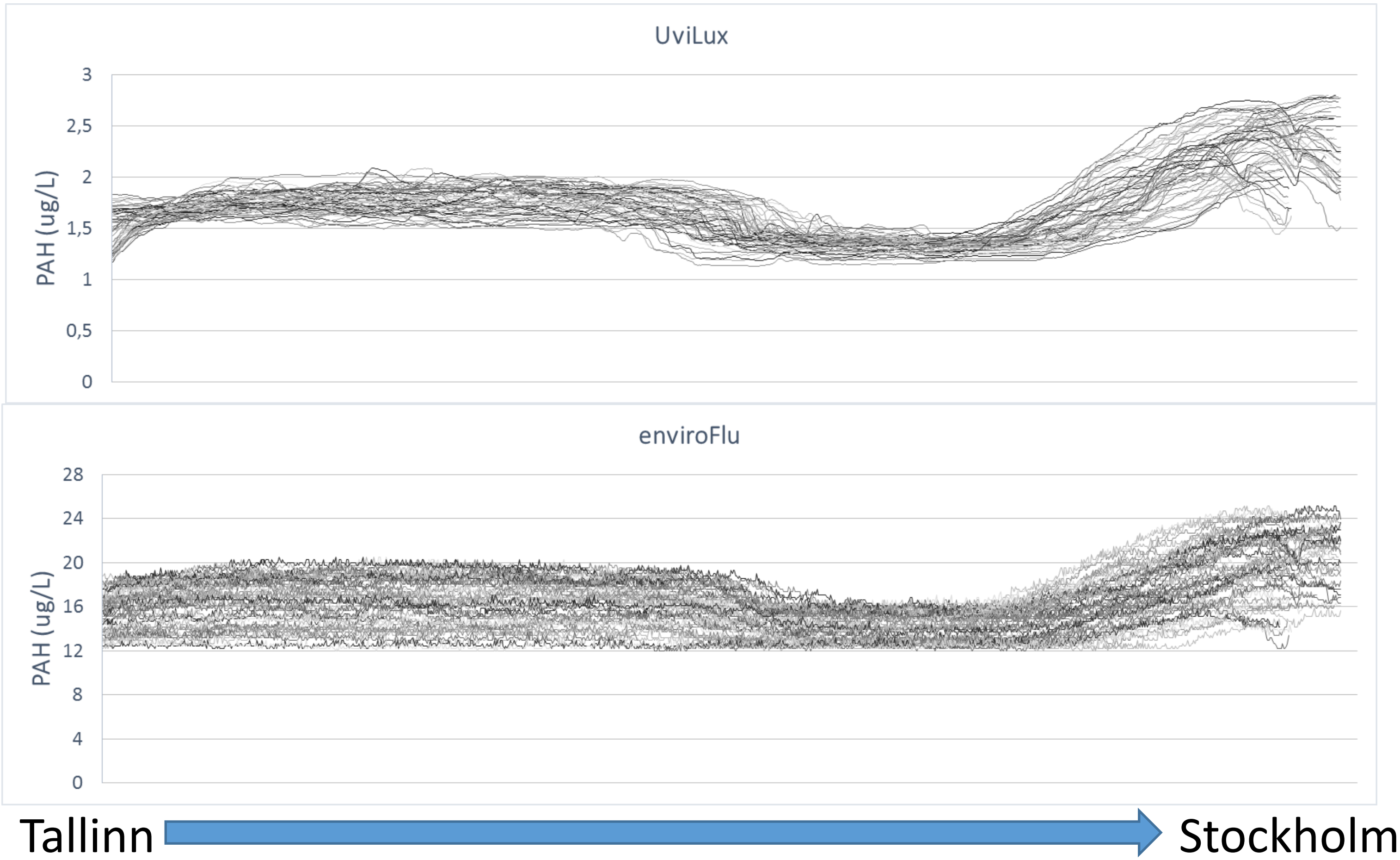
PAH concentration measurements with the UV fluoressence sensors - UviLux and EnviroFlu-HC Trios

Single trip, Tallinn-Stockholm



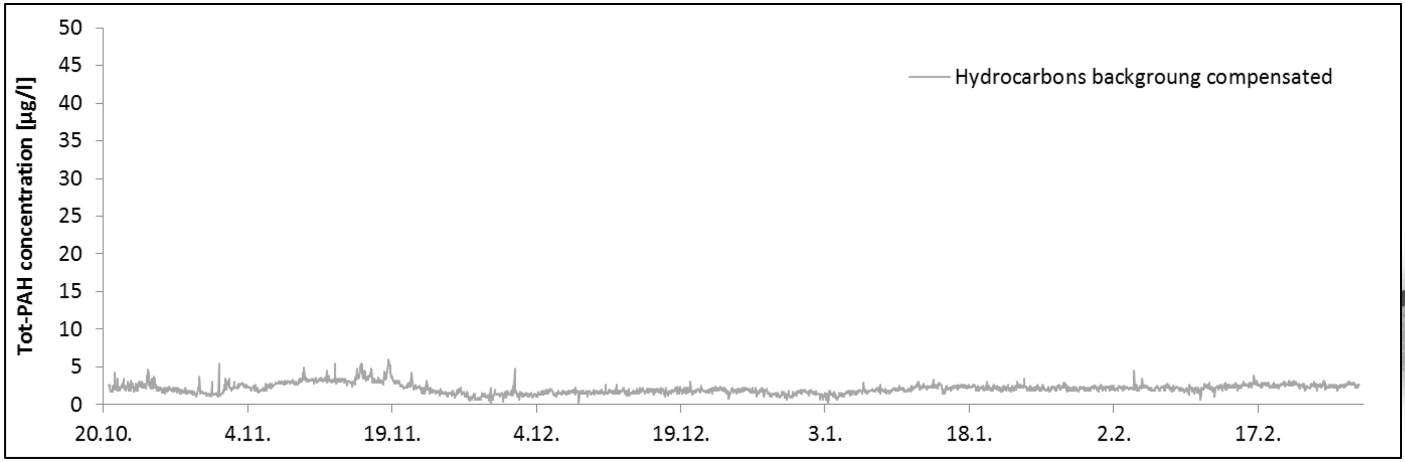
Tallinn → Stockholm

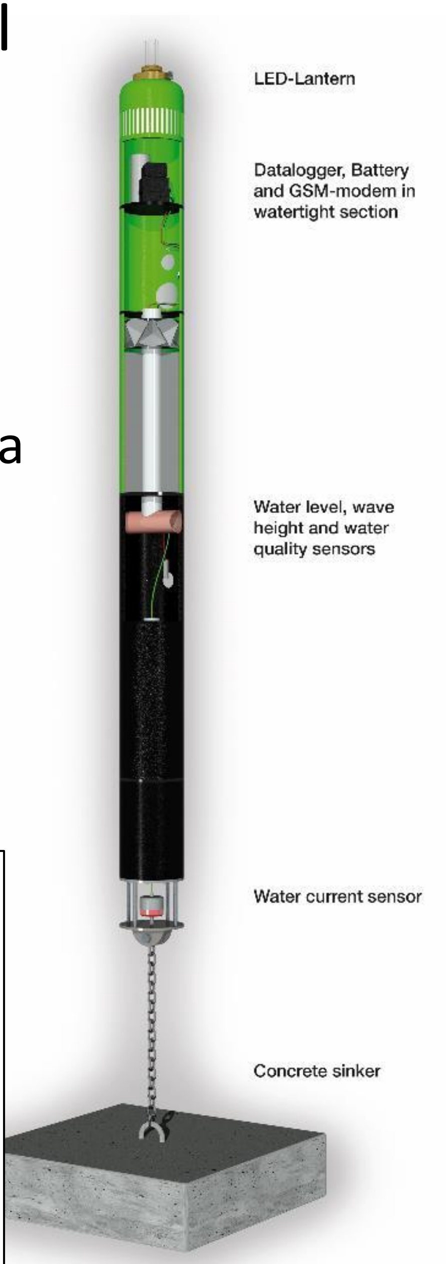
PAH concentration measurements with UviLux and EnviroFlu-HC Trios (19.02 – 19.04.2018)



SmartBuoy technology and integration with oil spill detection

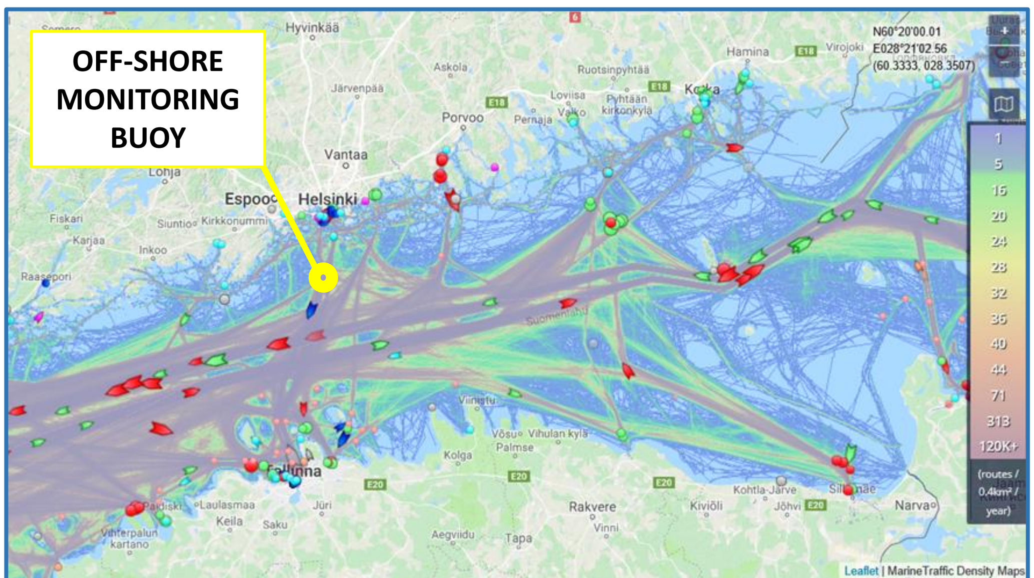
- The first system fo automatic hydrocarbon monitoring (Trios EnrivoFlu hydrocarbon sensor) was laboratory tested and installed inside a SeaHow Smart Buoy and deployed in October 2016 for first wintertime trials.
- Results were visualized on on-line data service as raw data and calibrated readings based on measured turbidity records and laboratory samples.
- Based on the collected hydrocarbon concentration data, values remained more or less constant and no sign of oil contamination was detected.



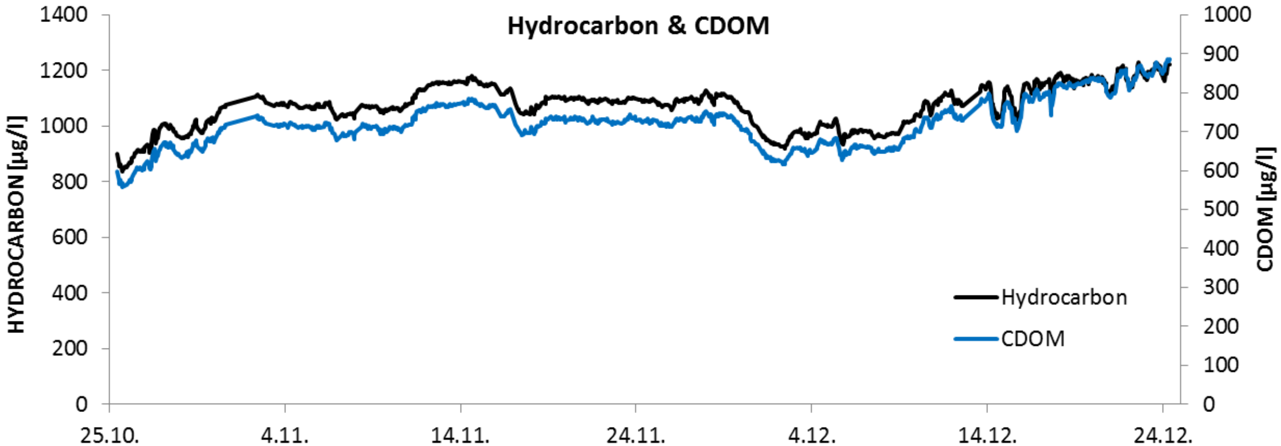


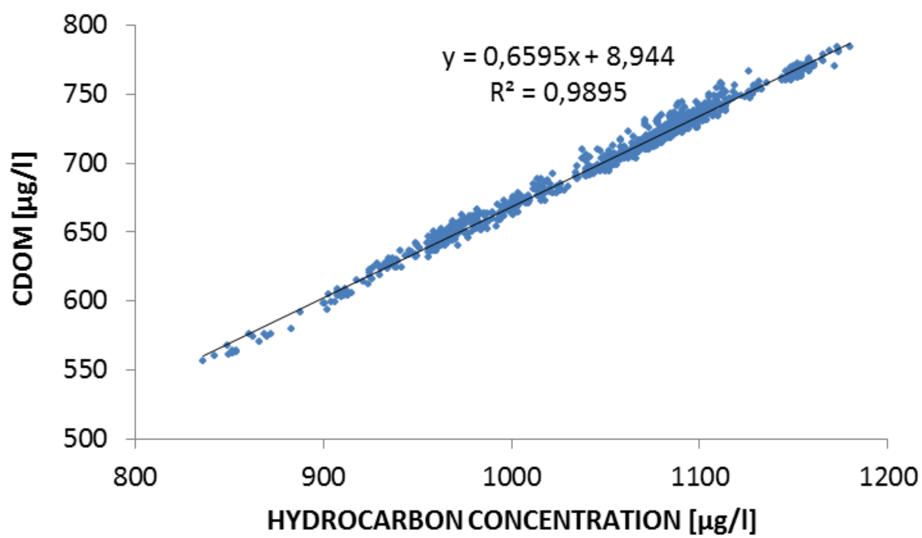
SmartBuoy technology with satellite data transmission in off-shore oil detection in the Baltic Sea

- The SmartBuoy model for oil detection with satellite data transmission was developed, tested and deployed to challenging off-shore conditions of the Baltic Sea for the autumn period in 2018. In addition to test the monitoring technology, goal was to detect potential illegal oil effluents originated from vessel traffic navigating on the merchant shipping lanes of the Gulf of Finland
- The SmartBuoy platform with the integrated sensor technology and satellite data transmission module was successful monitoring method in challenging off-shore conditions.



- No clear sign of oil contamination was detected, variation of the collected hydrocarbon concentration was caused by river water originated organic carbon.





New developements

- The upper part of the SmartBuoy is being revised to be even better to use and maintain
- Solar panel unit is designed to power the system

Conclusions

- Measured hydrocarbon concentrations could not be handled as absolute values, but relative, still main variability pattern of the concentrations in the surface layer of the sea can be seen
- No sudden anomalies in the hydrocarbon concentrations which would indicate an oil spill, were registered on the ferry transect or during SmartBuoy moorings.
- Nevertheless, as the sensor technology was capable to detect oil contamination in the laboratory experiment, true oil contamination can be detected also in field conditions.
- It is crucial to monitor also concentrations of interference compounds in order to distinguish true oil contamination from natural background water quality variation
- The SmartBoy is operational and being developed further
- On-line FerryBox system on board MS BALTIC QUEEN is continiously operational and mesurements can be seen on-line via link http://on-line.msi.ttu.ee/GRACEferry

Thank You!