

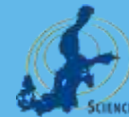


Modelling of pleasure boat activities and emissions at the Baltic Sea

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Motivation

- **Emissions and activities for the registered marine traffic are fairly well known**

At the Baltic Sea some 8200 IMO-registered vessels are responsible for more than 95% of registered shipping emissions

- **In the Baltic Sea there are hundreds of thousands of private pleasure boats**

Concentrated near populated areas

Activities and emissions from this fleet are largely unknown

=> For the first time, pleasure boat activities and emissions are modelled across the Baltic Sea

- Temporal & spatial distribution included
- Gain perspective: results compared against the registered fleet modelling results



Outline

AIS: Automatic Identification System, a messaging system used by the marine vessels for position, identification & status updates

• **Setting up the model**

- Fleet characteristics study
- Utilization of AIS-data – temporal distribution of activities
- Marina locations & boat counts – scanning the coastline (literally)

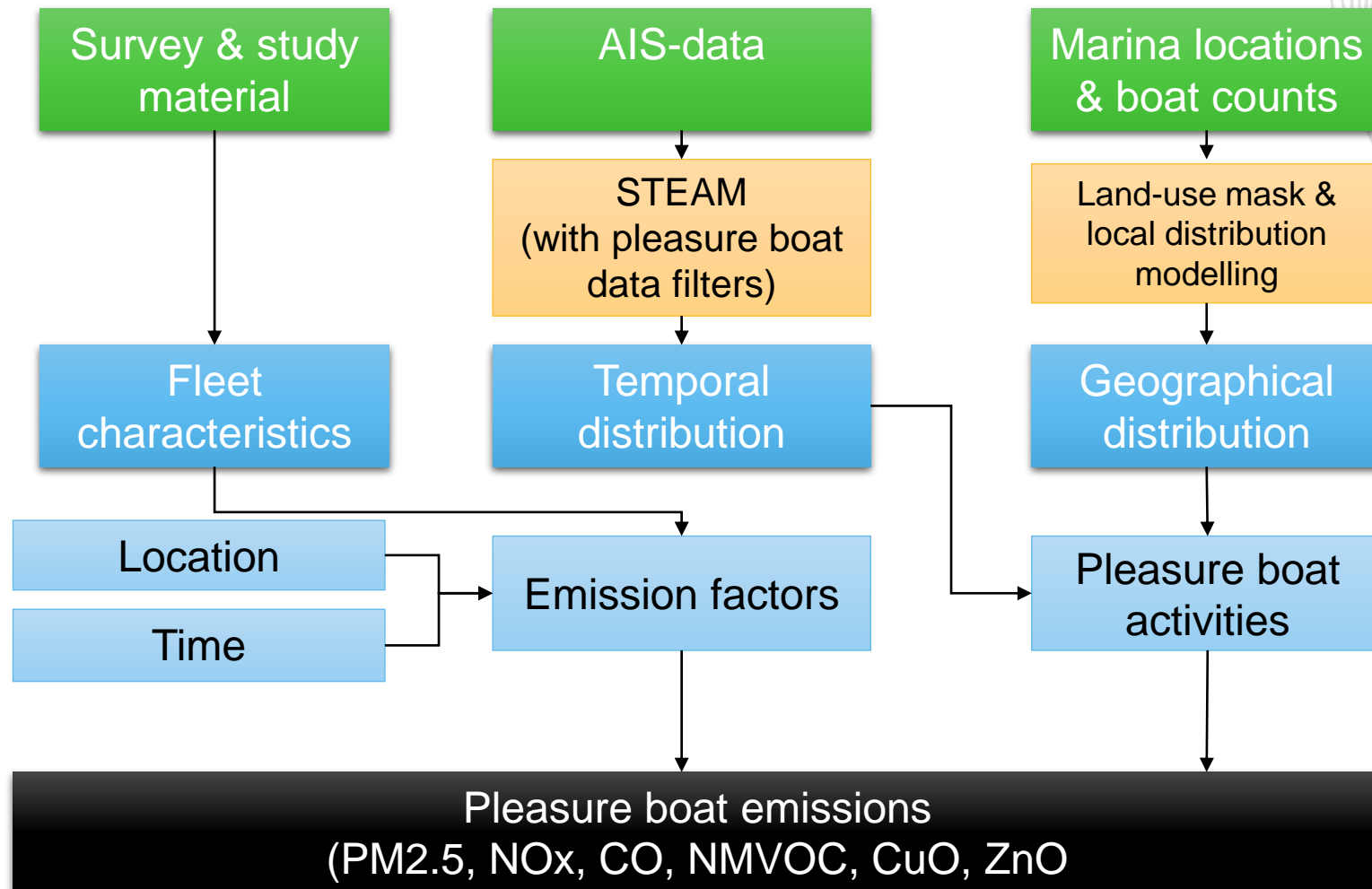
• **Preliminary results**

- Exhaust emissions, anti-fouling paint leech
- Comparison against STEAM model results for 2014 (commercial fleet at the Baltic)



Modelling approach

FMI-BEAM (FMI's Pleasure Boat Emission and Activity siMulator)





Boat categories

The ones presented in swedish pleasure boat survey study
(**Båtlivsundersökningen 2010, 2015**)

OSB	MB	LMB	LMSB
Open Small Boat, with (or without) an engine smaller than 7kW	Motor Boat, with no possibilities for over-night stays	Large Motor Boat, with over-night stay capabilities	Large Motor Sail Boat





Fleet characteristics

- Detailed characteristics exist for the Swedish fleet
 - Based on Swedish survey study (**Båtlivsundersökningen, 2010 & 2015**) and other research material

	Share of total fleet	Diesel fraction	wSurf [m2]	aveTravel/a [km]	unitTravel [km/h]	If Gasoline			If Diesel	
						2-stroke	2-stroke(2003)	4-stroke	DSL	DSL(2003)
OSB	0.106	0	7	57	12	0.284	0.563	0.153	0.435	0.565
MB	0.531	0.2	11	228	28	0.207	0.411	0.383	0.435	0.565
LMB	0.216	0.48	16	323	29	0.104	0.207	0.689	0.435	0.565
LMSB	0.147	0.91	26	695	35	0.155	0.309	0.536	0.435	0.565

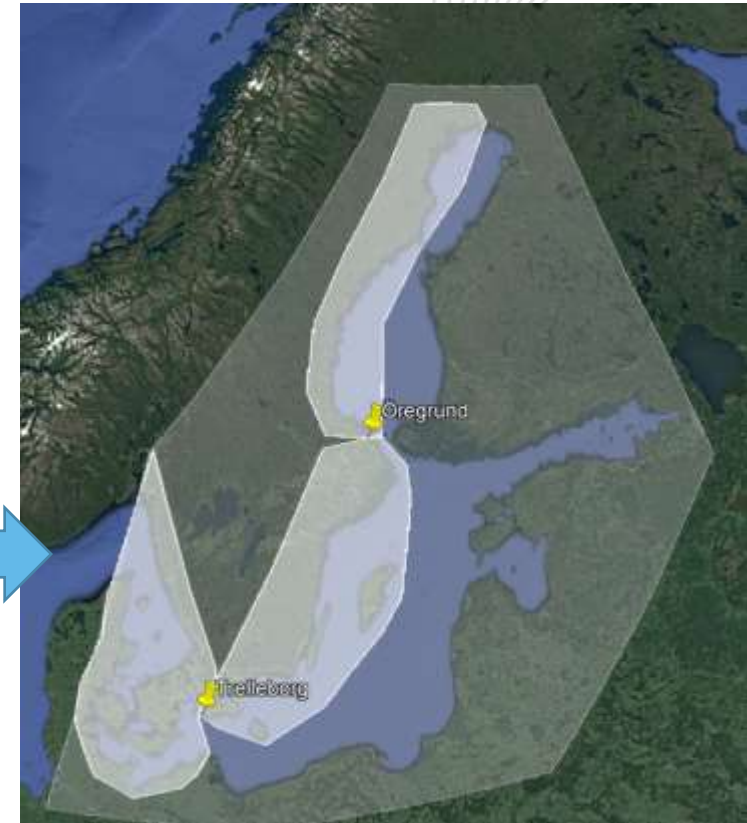
ENGINE	SFC (g/kW)	PM (g/kg)	NOx (g/kg)	NM VOC (g/kg)	CO (g/kg)	Installed kW	EngineLoad_avg
2-stroke	791	12.6	2.5	322.0	539.8	50	0.5
2-stroke(2003)	791	12.6	2.5	57.5	232.6	50	0.5
4-stroke	426	0.2	16.4	50.7	431.9	50	0.5
DSL	281	5.0	64.1	7.7	19.8	40	0.5
DSL(2003)	281	3.6	34.9	6.3	18.6	40	0.5

- Aim is to customize these tables for each Riparian state separately
 - For now we have used this Swedish PB characteristics



Anti-fouling paint leach

- **Water pollutants: Cu(I)O, ZnO**
- **Passive leaching rates as a function of water surface exposure [sm²]**
- **Different leaching rates set for different parts of the Baltic Sea**
- **Work in progress:**
 - Higher leaching rates for Spring?
 - Off-season ramp-up/ramp-down?



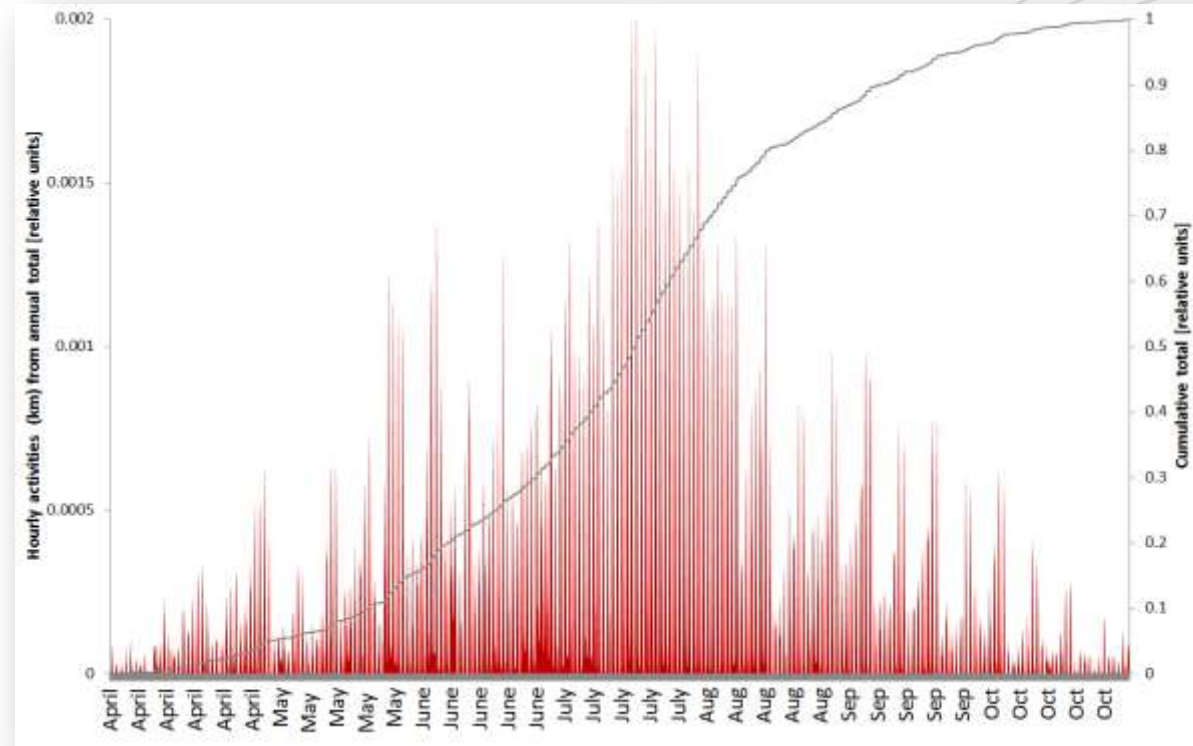


Temporal distribution

- AIS not mandatory for pleasure boats, yet some may still use it
 - "Hidden" among unknown, non-IMO vessels.
- AIS data from Helcom in 2014-2016 and the STEAM model used
- Identification of pleasure boat-like vessels, criteria:
 - No activities during Winter
 - Low annual travel amounts
 - Low (temporal) utilization
 - Size & type limitations (if static AIS data exists)

Using the the identified vessels only, STEAM model run again to estimate hourly travel distances.

Resulting profiles for the three years combined and normalized
=> Several temporal patterns visible: **monthly, week days, diurnal.**



Estimated temporal profile of pleasure boat activities at the Baltic Sea based on AIS-data. X-axis: hour of year, y-axis: relative activity weighting (fraction of total)



Spatial distribution (1/2)

- **Approach: identify the number of boats in each marina and simulate their activities near-by**

- Satellite image analysis used
- Available marina data used
- 3000 locations spotted, with 250 000 PB:s

- **Sweden: approx 2000 marina locations**

- 115 000 boats
- **This is only 50% from the expected count!**



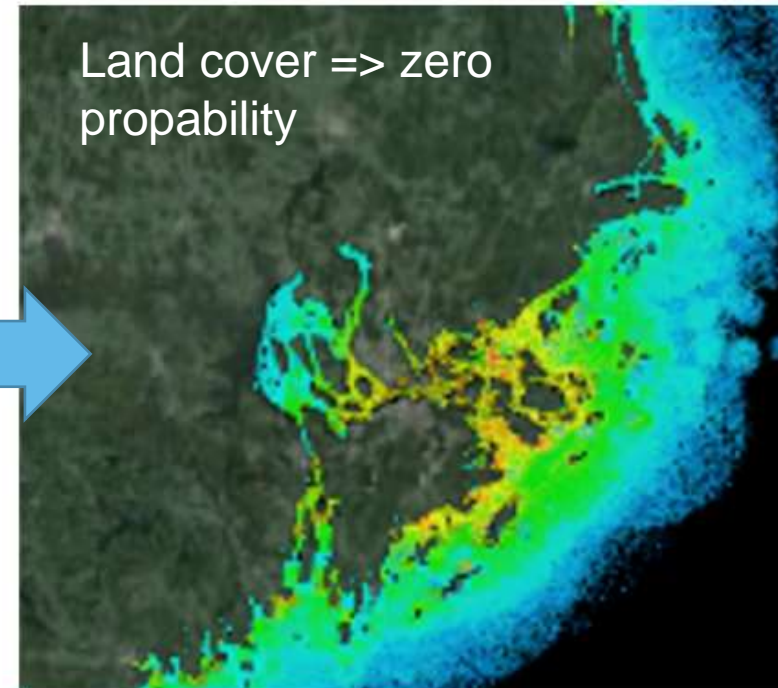
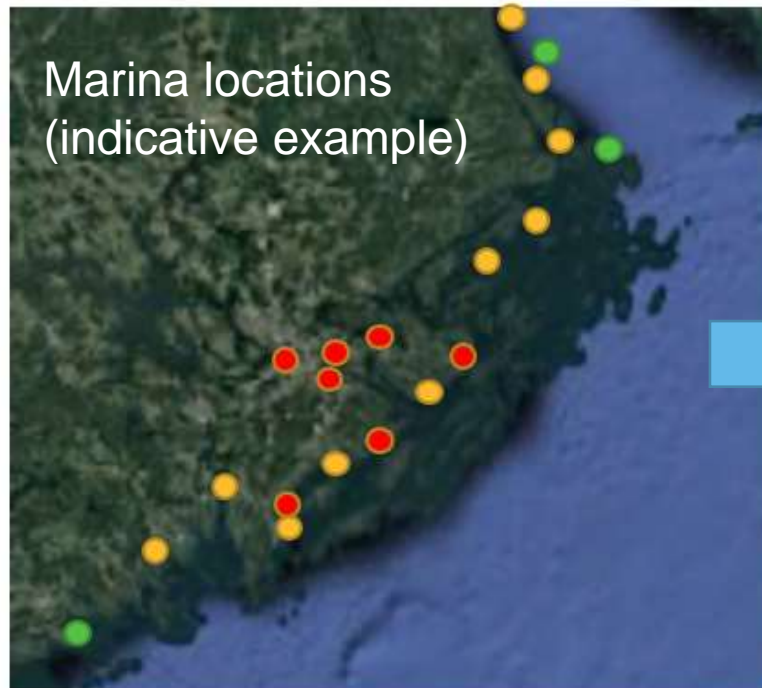
Figure : An example of satellite imagery used to calculate the number of boat places in a small boat marina (Soukka/Espoo, Finland).

Interpretation: for every counted boat there is another one outside of the marina locations
=> Largest source of uncertainty!



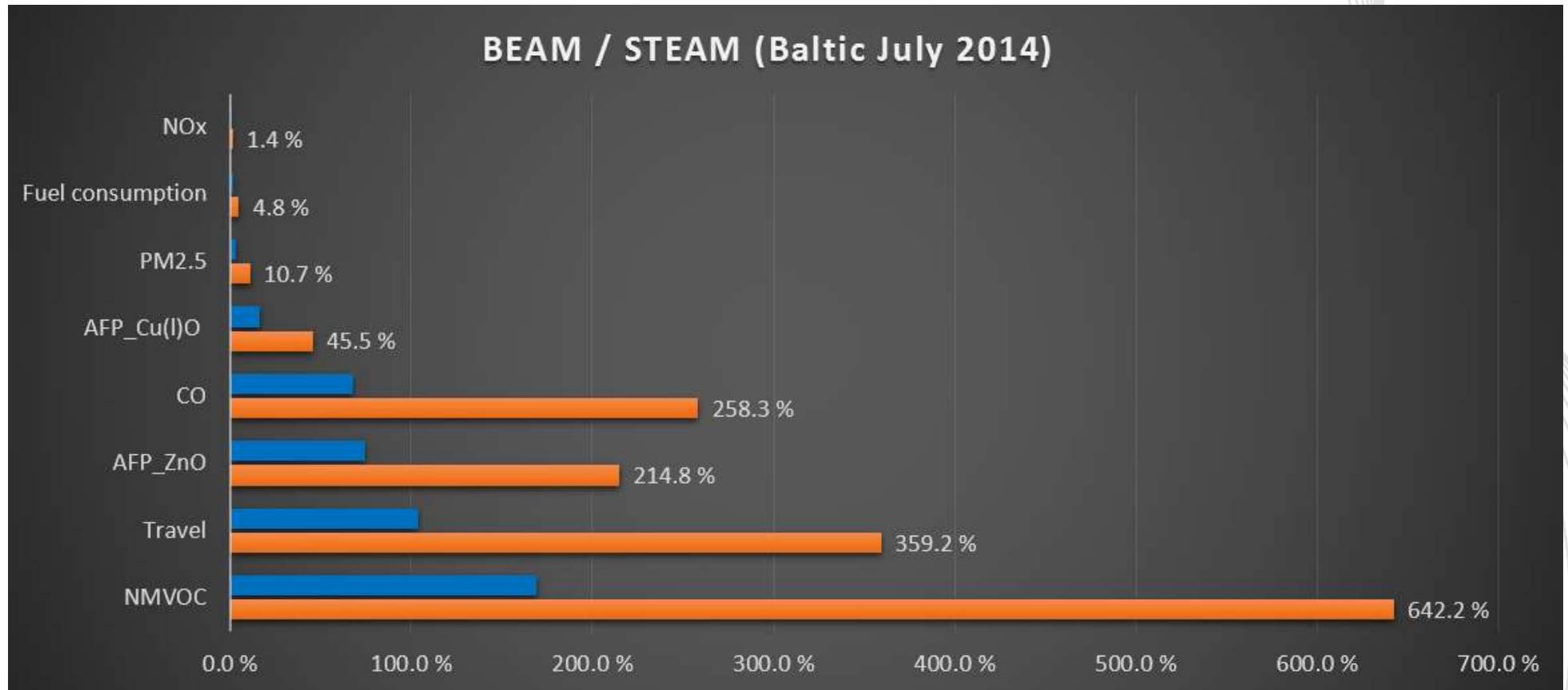
Spatial distribution (2/2)

- For each marina a local distribution of activities is simulated
 - Survey data: only 10% of PB owners report to have trips longer than 50km
 - Marina-to-Marina activities are excluded at this stage
- Propability distribution based on distance from a) marina b) coastline





Pleasure boat emissions compared against STEAM vessels



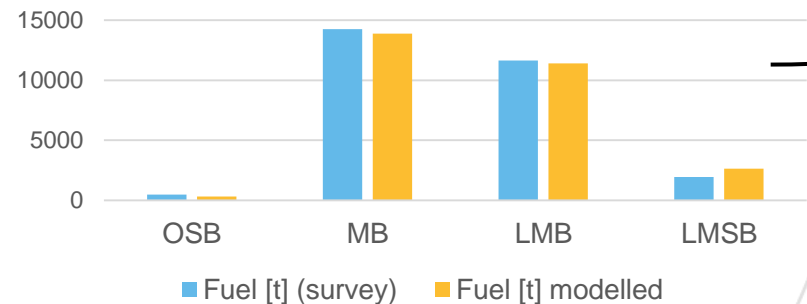


Results – Flagstates & types

	CO [ton]	NMVOC [ton]	NOx [ton]	PM25 [ton]	AFP_Cu [ton]	AFP_Zn [ton]	Fuel [kton]
Sweden	6532	1980	518	194	14.7	17.7	28
Finland	2911	882	232	87	5.9	7.4	12
Denmark	3046	923	243	91	18.0	11.5	13
Germany	1107	335	88	33	6.6	4.4	5
Other	471	143	37	14	1.1	1.4	2

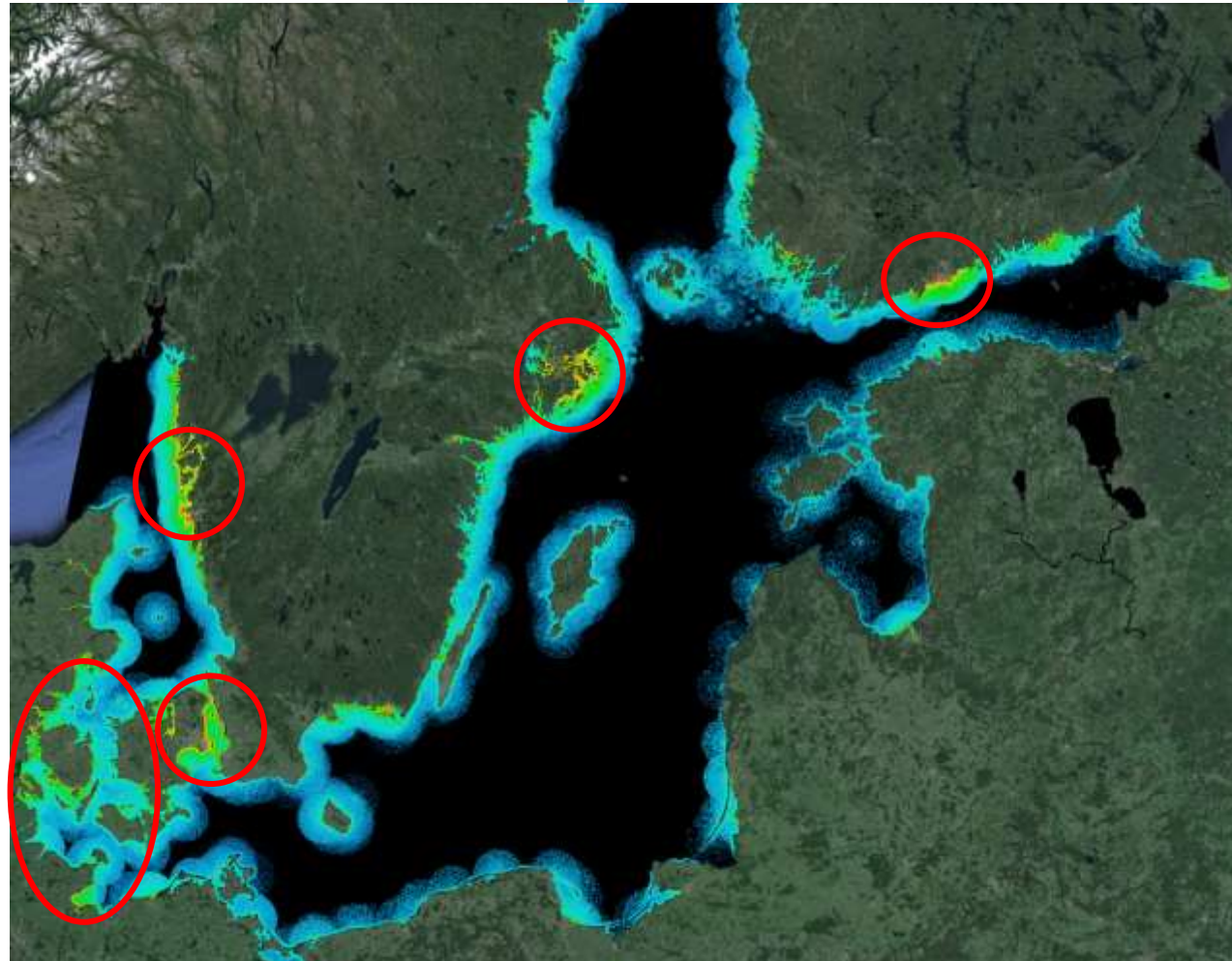
	CO [ton]	NMVOC [ton]	NOx [ton]	PM25 [ton]	AFP_Cu [ton]	AFP_Zn [ton]	Fuel [kton]
OSB	470	102	3	9	2.6	2.4	1
MB	9923	3374	277	271	20.8	19.0	30
LMB	3914	812	583	122	12.2	11.2	25
LMSB	230	79	258	26	13.4	12.3	6

Mostly from: older 2-stroke gasoline engines





Annual fuel consumption



Simulated geographical distribution of pleasure boat fuel consumption based on survey data (national totals) and marina data (location, ship count)



Conclusions

- **A model has been developed for the assessment of pleasure boat activities and emissions**
 - High level of uncertainty at this initial stage
- **Some pleasure boat emission species seem surprisingly relevant with respect to those of registered marine traffic**
 - NMVOC, CO, anti fouling paints
- **More research needed, especially:**
 - Fleet characteristics for non-Swedish fleet
 - Boat count disparity
 - What would be the result if these PB emission datasets were used in ecological/atmospheric models?