Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

# Modelling of recreational boat emissions in Spain

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# Overview & Motivation

- Spanish total boat park: 200.350 recreational boats, around 233 persons per boat (INCOMIA, 2017)
- Emissions occurring near the coast and mostly during the summer season
- EMEP official emissions reported under the NFR category 1A5b (Other Mobile, including military, land based and recreational boats)
- Implementation of a modelling approach in HERMESv3 (Guevara et al., 2020), including spatial and temporal distribution

# Emission estimation approach

EMEP/EEA Tier 3 estimation approach (Chapter 1.A.3.d Navigation)

$$E_i = \sum_b \left( N_{b,e,t} * T_b * P_{b,e} * LF_b * EF_{b,i,e,t} \right)$$

| | |
|---|---|
| $E_i$ | Emissions by pollutant *i* (g/year) |
| $N_{b,e,t}$ | Number of recreational boats of type *b*, engine *e* and technology *t* |
| $T_b$ | Annual hours of use by recreational boats of type *b* (hours) |
| $P_{b,e}$ | Nominal power by recreational boat type *b* and engine *e* (kW) |
| $LF_b$ | Load factor for recreational boats of type *b* [0:1] |
| $EF_{b,i,e,t}$ | Emission factor by recreational boat type *b,* pollutant *i,* type of engine *e* and technology *t* (g/kWh) |

# Boat types

| $N_{b,e,t}$ | Number of recreational boats of type *b*, engine *e* and technology *t* |
|---|---|

| Vessel type | Weight/length | number |
|---|---|---|
| Inflatable boats | <100kg | 5700 |
| | >100kg | 3200 |
| Sailboats | <7.5 | 12500 |
| | 7.6 to 12 | 60000 |
| | 12.1 to 24 | 15000 |
| | >24 | 0 |
| Inboard motor boats | <7.5 | 14500 |
| | 7.6 to 12 | 25000 |
| | 12.1 to 24 | 9500 |
| | >24 | 1600 |
| Other rigid boats (outboard) | <7.5 | 30000 |
| | 7.6 to 12 | 10000 |
| | 12.1 to 24 | 6000 |
| | >24 | 0 |
| Water scooters | | 3000 |

**Source**: INCOMIA (2017)

| Vessel type | Engine type | Fuel type | Technology layer | number |
|---|---|---|---|---|
| Yawls and cabin boats | Outboard-2S | Gasoline | 2003/44 | 6417 |
| Yawls and cabin boats | Outboard-2S | Gasoline | Conv. | 3224 |
| Sailing boats (< 26 ft) | Outboard-2S | Gasoline | 2003/44 | 2588 |
| Sailing boats (< 26 ft) | Outboard-2S | Gasoline | Conv. | 1300 |
| Speed boats | Outboard-2S | Gasoline | 2003/44 | 2337 |
| Speed boats | Outboard-2S | Gasoline | Conv. | 1180 |
| Other boats (< 20 ft) | Outboard-2S | Gasoline | 2003/44 | 8445 |
| Other boats (< 20 ft) | Outboard-2S | Gasoline | Conv. | 4260 |
| Water scooters | Built-In-2S | Gasoline | 2003/44 | 1689 |
| Water scooters | Built-In-2S | Gasoline | Conv. | 852 |
| Yawls and cabin boats | Outboard-4S | Gasoline | 2003/44 | 21359 |
| Sailing boats (< 26 ft) | Outboard-4S | Gasoline | 2003/44 | 8613 |
| Speed boats | Inboard-4S | Gasoline | 2003/44 | 3200 |
| Speed boats | Outboard-4S | Gasoline | 2003/44 | 2183 |
| Other boats (< 20 ft) | Outboard-4S | Gasoline | 2003/44 | 2295 |
| Water scooters | Built-In-4S | Gasoline | 2003/44 | 459 |
| Motor boats (27-34 ft) | Inboard | Diesel | 2003/44 | 14125 |
| Motor boats (27-34 ft) | Inboard | Diesel | Conv. | 10875 |
| Motor boats (> 34 ft) | Inboard | Diesel | 2003/44 | 6272 |
| Motor boats (> 34 ft) | Inboard | Diesel | Conv. | 4829 |
| Motor boats (< 27 ft) | Inboard | Diesel | 2003/44 | 8193 |
| Motor boats (< 27 ft) | Inboard | Diesel | Conv. | 6308 |
| Motor sailors | Inboard | Diesel | 2003/44 | 0 |
| Motor sailors | Inboard | Diesel | Conv. | 0 |
| Sailing boats (< 26 ft) | Inboard | Diesel | 2003/44 | 42375 |
| Sailing boats (< 26 ft) | Inboard | Diesel | Conv. | 32625 |

Mapping process to the EMEP/EEA classification

Challenging depending on how the original information is provided

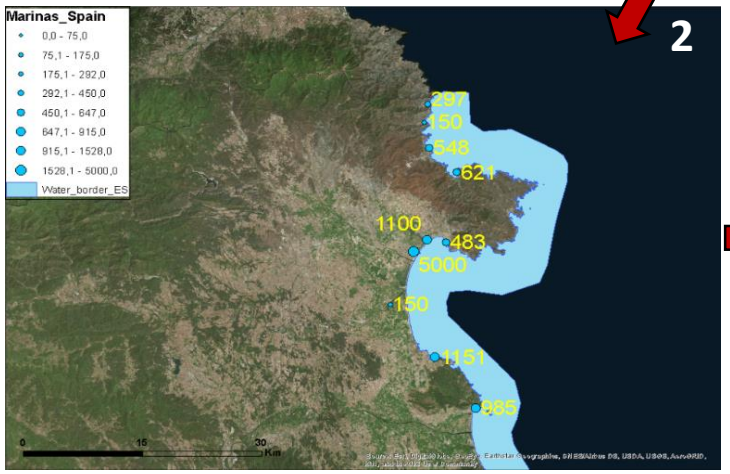
# Boat characteristics

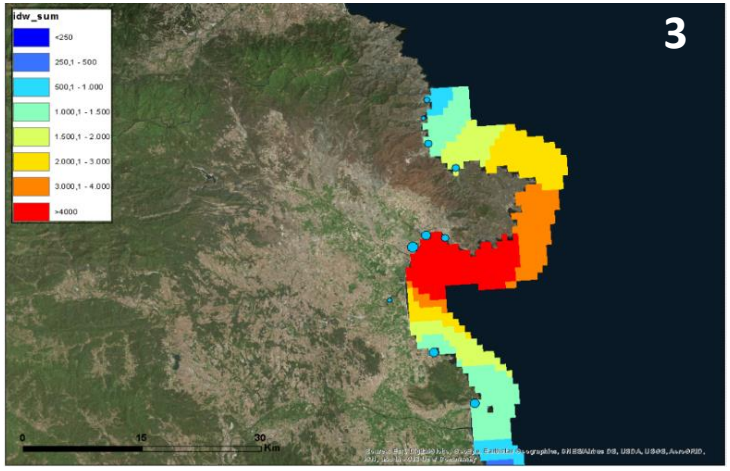
No access to local information, relying on the values provided by EMEP/EEA guidelines
Large uncertainty → All factors are equally multiplying in the equation, so same ”weight”

| Fuel type | Engine type | Vessel type | Engine | Engine size (kW) | Ann, Hours (hours) | Load factor |
|---|---|---|---|---|---|---|
| Gasoline | 2-stroke | Yawls and cabin boats | Out-board | 20 | 50 | 0.5 |
| | | Sailing boats (< 26 ft) | Out-board | 10 | 5 | 0.5 |
| | | Speed boats | Out-board | 50 | 50 | 0.5 |
| | | Other boats (< 20 ft) | Out-board | 8 | 30 | 0.5 |
| | | Water scooters | Built-in | 45 | 10 | 0.5 |
| | 4-stroke | Yawls and cabin boats | Out-board | 20 | 50 | 0.5 |
| | | Sailing boats (< 26 ft) | Out-board | 10 | 5 | 0.5 |
| | | Speed boats | In-board | 90 | 75 | 0.5 |
| | | Speed boats | Out-board | 50 | 50 | 0.5 |
| | | Other boats (< 20 ft) | Out-board | 8 | 30 | 0.5 |
| | | Water scooters | Built in | 45 | 10 | 0.5 |
| Diesel | | Motor boats (27–34 ft) | In-board | 150 | 150 | 0.5 |
| | | Motor boats (> 34 ft) | In-board | 250 | 100 | 0.5 |
| | | Motor boats (< 27 ft) | In-board | 40 | 75 | 0.5 |
| | | Motor sailors | In-board | 30 | 75 | 0.5 |
| | | Sailing boats (< 26 ft) | In-board | 30 | 25 | 0.5 |

**Source**: EMEP/EEA 2019

# Spatial distribution


1. Location of marinas and associated number of docks
2. Assume activity is happening within 5km of the coastline
3. Spatial proxy created considering inverse distance weighted interpolation and number of docks (5km influence)

# Temporal distribution

No temporal disaggregation criteria proposed for recreational boats in the EMEP/EEA guidelines

**Table 5-1** **Proposal of the average European temporal disaggregation of emissions. The figures indicate percentages of the disaggregation of total seasonal, weekly, and hourly emissions to seasons, days, and hours**

| | | Seasonal disaggregation (in %) | | | |
|---|---|---|---|---|---|
| **Sector** | **Subsector** | **Winter** | **Spring** | **Summer** | **Fall** |
| Agriculture | All | 10 | 20 | 50 | 20 |
| Forestry | All | 10 | 20 | 50 | 20 |
| Industry | All | 20 | 30 | 30 | 20 |
| Military | | 20 | 30 | 30 | 20 |
| Household and gardening | all but 04<br>04, snowmobiles | 10<br>90 | 40<br>5 | 30<br>0 | 20<br>5 |

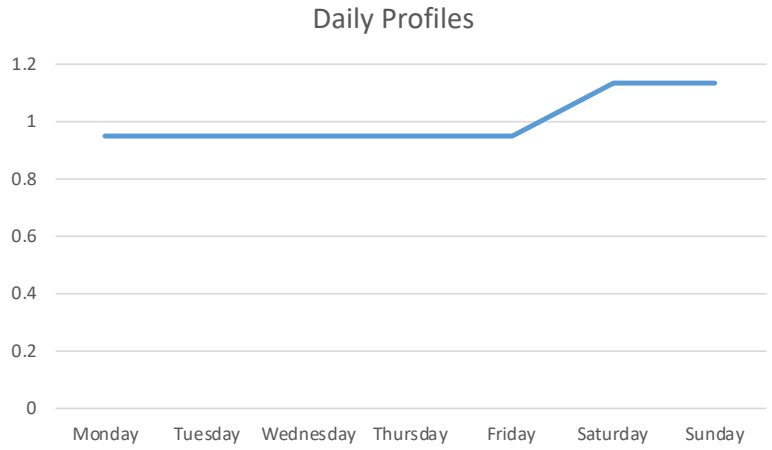
| | | Seasonal disaggregation (in %) | | | | | | | Hourly disaggregation (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sector** | **Subsector** | **M** | **T** | **W** | **T** | **F** | **S** | **S** | **6-12** | **12-18** | **18-24** | **24-6** |
| Agriculture | All | 18 | 18 | 18 | 18 | 18 | 5 | 5 | 45 | 45 | 8 | 2 |
| Forestry | All | 18 | 18 | 18 | 18 | 18 | 5 | 5 | 45 | 45 | 8 | 2 |
| Industry | All | 19 | 19 | 19 | 19 | 19 | 2.5 | 2.5 | 50 | 45 | 4 | 1 |
| Military | | 19 | 19 | 19 | 19 | 19 | 2.5 | 2.5 | 35 | 35 | 15 | 15 |
| Household &<br>Gardening | all but 04<br>04, Snowmobiles | 5<br>10 | 5<br>10 | 5<br>10 | 5<br>10 | 10<br>10 | 35<br>25 | 35<br>25 | 35<br>35 | 35<br>35 | 4<br>4 | 1<br>1 |

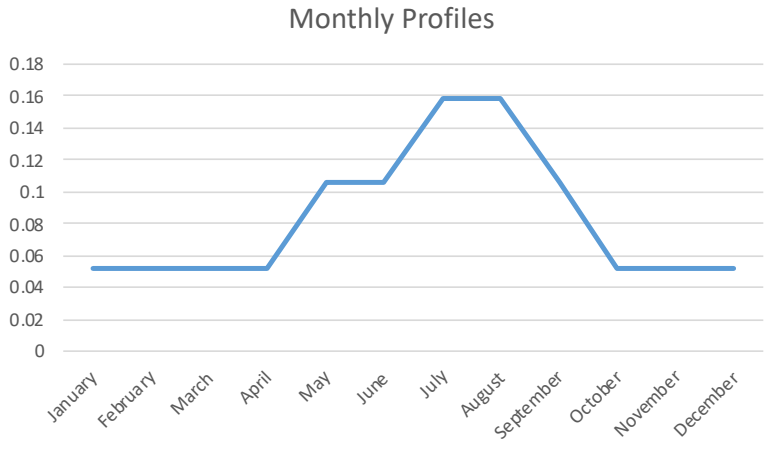
**Source**: EMEP/EEA 2019

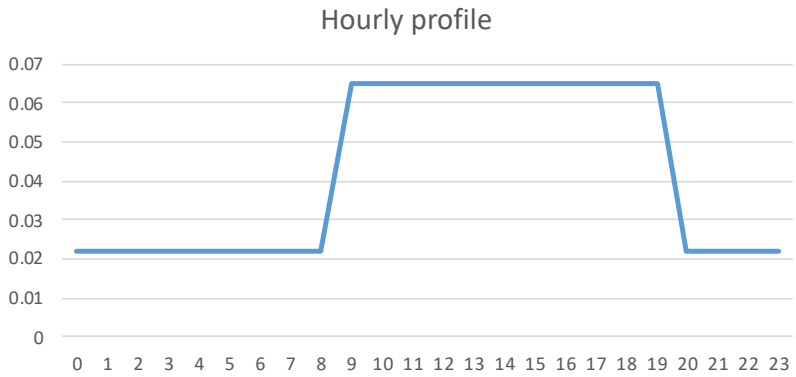
# Temporal distribution

Application of a “common sense criteria” (need to be validated against e.g. AIS data):

- More activity during the summer, weekends and daytime

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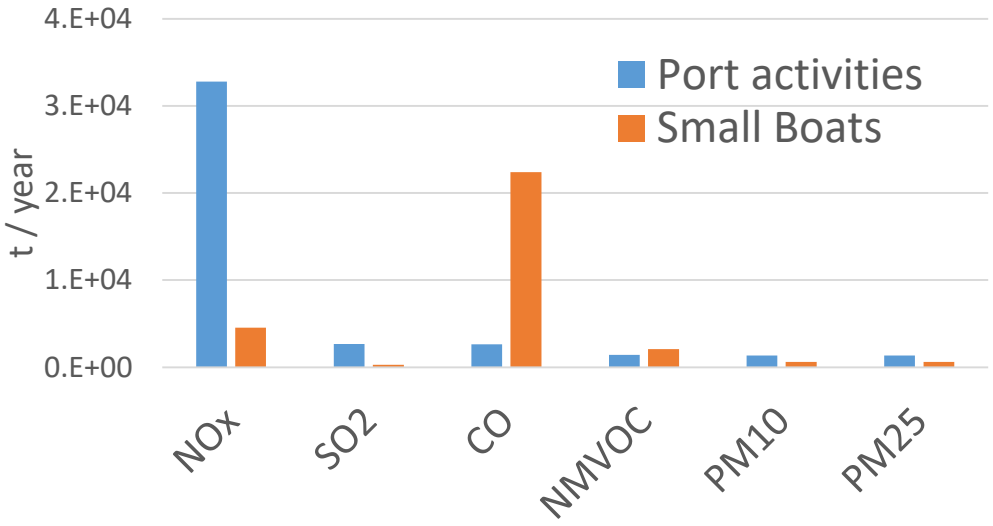
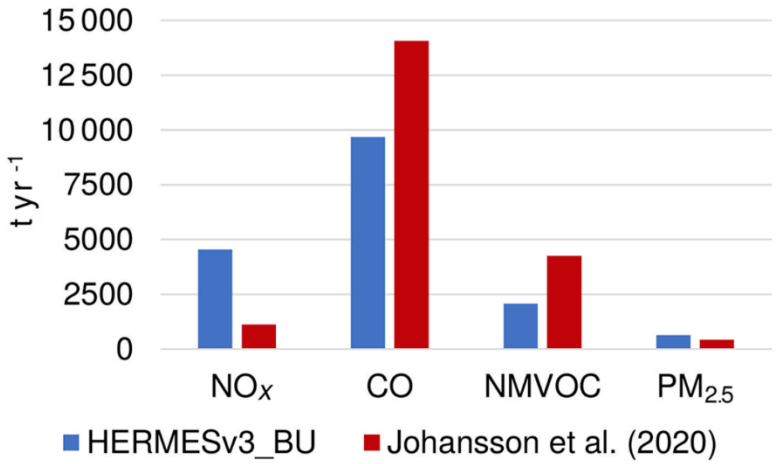
# Intercomparison

## Shipping in ports vs. Recreational boats




## Spain vs. Baltic sea region




**Significant source of CO and NMVOC**

Importance of emissions from old 2-stroke gasoline engines (poor combustion process)

**Influence of the fleet composition**

In Spain more than 40 % of the boats are related to large diesel motor sail boats while in the Baltic Sea this category accounts for less than 15%

# Conclusions

- Large emission estimates for recreational boats…
- But also large uncertainties. Several factors should be investigated in greater detail
  - Fleet composition (official registration databases provide a limited classification)
  - Boat characteristics
  - Spatial/Temporal distribution (use of AIS to improve this aspect, e.g. Johansson et al., 2020)
- Future work: assess the impact/contribution to total pollution in coastal areas (i.e. O3 during summer season)