Implementation of a modelling system for the investigation of the Saronikos Gulf marine ecosystem (Eastern Mediterranean)

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Supplementary material

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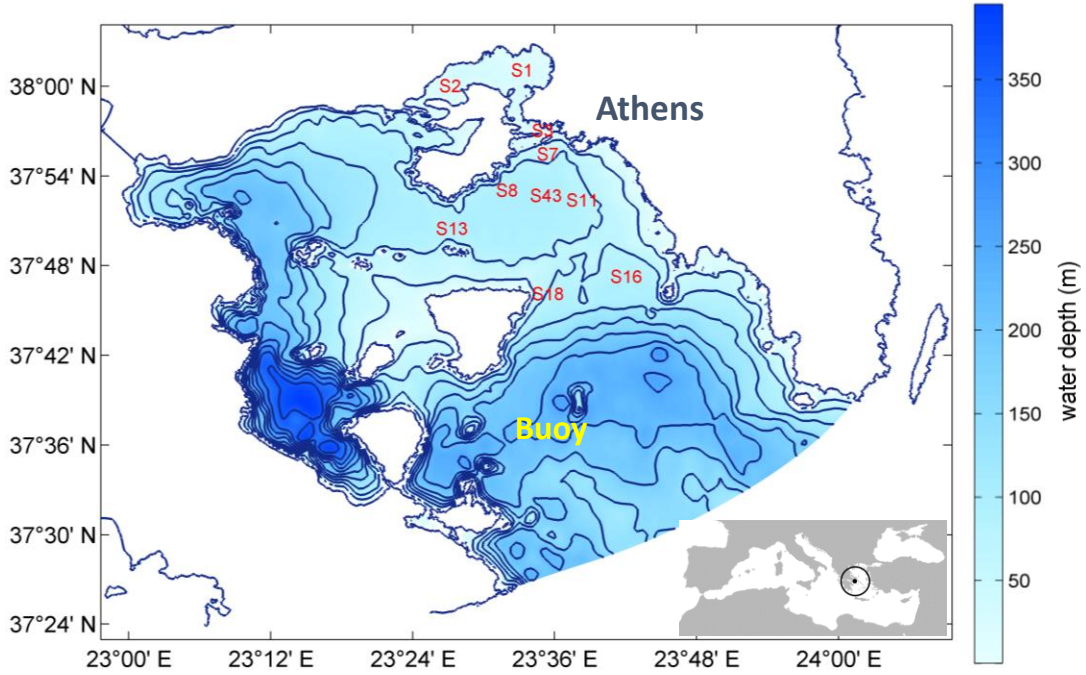
Modelling components and validation data

- ✓ The coastal marine ecosystem of Saronikos Gulf, is examined through a series of state-of-the-art numerical models that address
  - the **hydrodynamics** (**Delft3D-FLOW**)
  - the **wave** regime (**SWAN**)
  - the **biogeochemistry**: chlorophyll-a, nutrients, dissolved and particulate matter (**Delft3D-WAQ**)
  - **pollution** related to species of **trace metals** and **polycyclic aromatic hydrocarbons** (**Delft3D-WAQ**)
- ✓ Simulation **periods**
  - annual cycle Nov 2009 – Oct 2010 (mainly for validation)
  - 2018 (project's reference year)
- ✓ **Validation** data
  - 2009-2010 dataset collected monthly from a network of 10 stations (physics-biogeochemistry by HCMR*, heavy metals by NKUA-LEC**)
  - HCMR buoy (multiyear time series of temperature, salinity, current speed-direction, wave height-direction, WMO platform number 6101001)
  - satellite SST and chl-a data (Copernicus Marine Service)



* HCMR: Hellenic Centre for Marine Research

**NKUA-LEC: Laboratory of Environmental Chemistry, National Kapodistrian University of Athens

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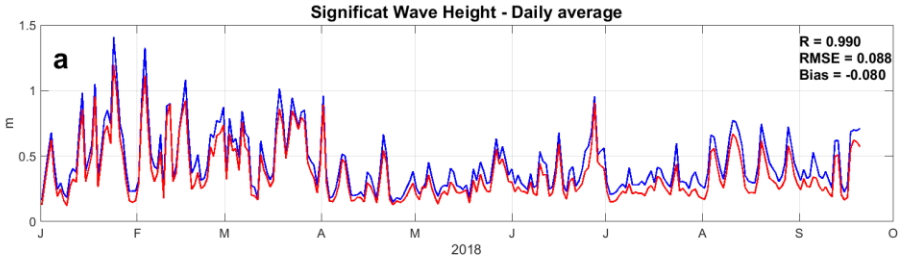
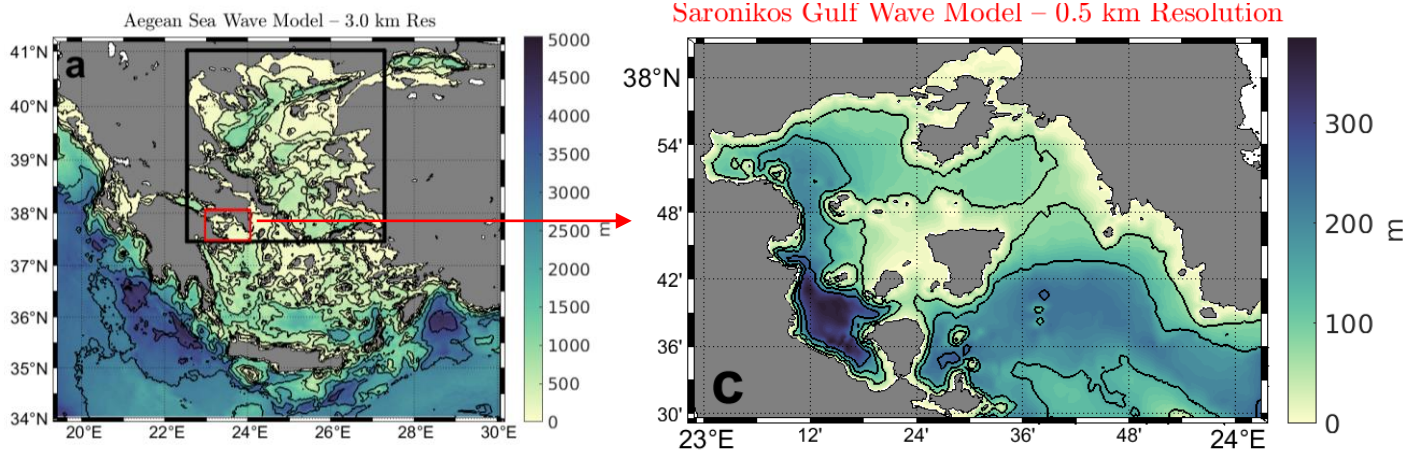
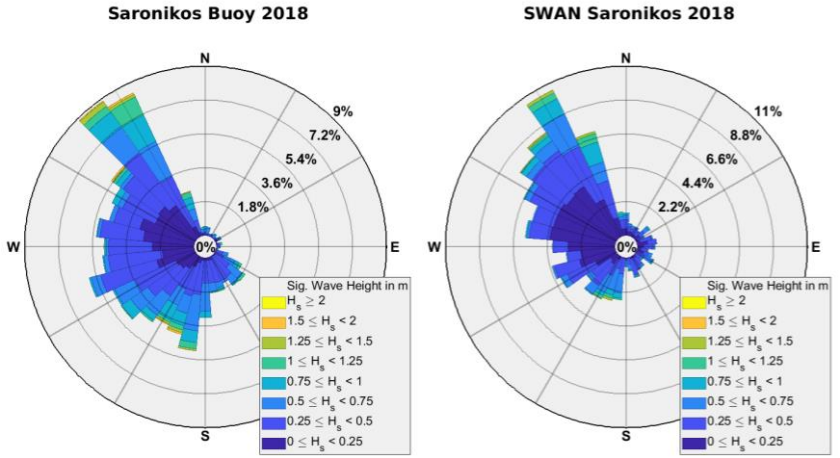
Wave modelling, SWAN

- ✓ **S**imulating **WA**ves **N**earshore (Booij *et al*., 1999) solves the wave action density equation (*N*, energy density divided by relative frequency). Accounts for shoaling, refraction, diffraction, reflection.
- ✓ An orthogonal rectangular **grid** with ~3.0 km resolution covering the Aegean-Ionian-Levantine seas. A 1-way **offline nesting** to downscale the Aegean wave solution in the Saronikos domain (450m resolution).



- ✓ **Wind forcing**// ECMWF ERA5 reanalysis dataset
- ✓ **Boundary** conditions// CMEMS Mediterranean Sea Waves Reanalysis (MEDSEA_MYLTIYEAR_WAV_006_012, Korres *et al*., 2021): ~4 km, 1hr time-step fields of significant wave height, peak direction and peak period, combined with a JONSWAP approximation for the ocean wave spectra.





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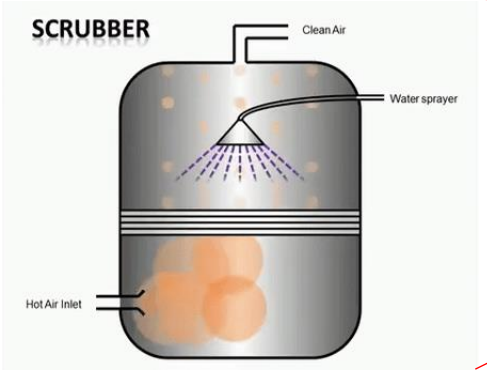
Shipping, marine scrubbers and the STEAM model (EMERGE project)

- ✓ In response to the strict levels of shipping emissions set by the International Maritime Organization (IMO) in Jan 2020, shipping companies are prompted to install marine scrubbers (pollution abatement technology) in their fleet.
- ✓ In scrubbers, the exhaust gases are sprayed with seawater, and pollutants are bounded and removed in liquid or solid phase that is subsequently either released into the aquatic environment or further treated.
- ✓ The direct disposal of the polluted wet stream (metals, hydrocarbons PAHs, nutrients, acidifying substances) at sea can have a significant impact on the marine ecosystem.



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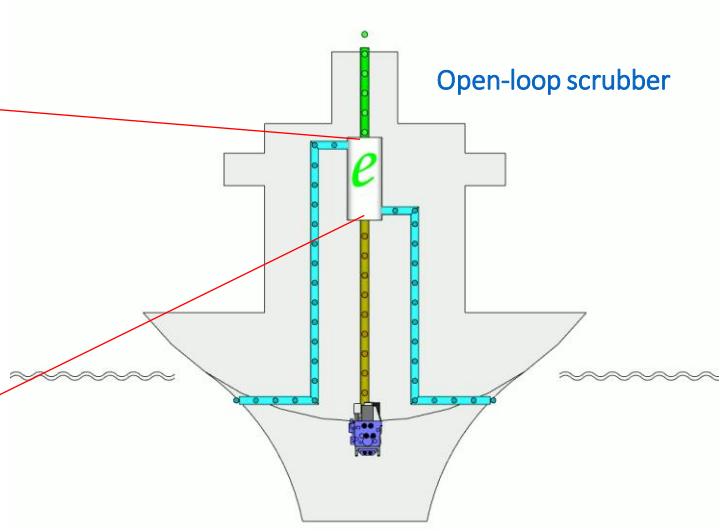
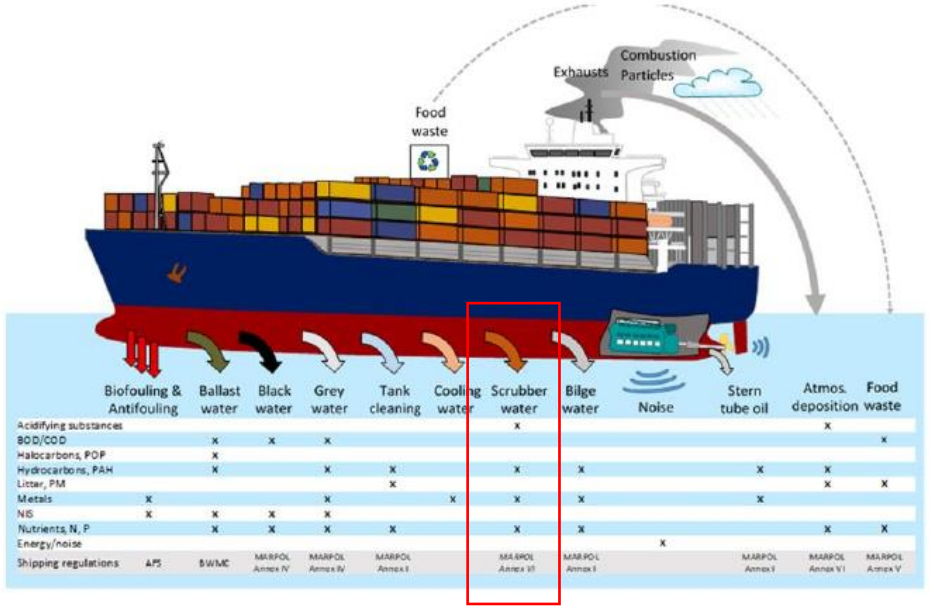


https://www.purenviro.com/2018/09/11/nytt-sox-reglement-pavirker-70-000-skip/



Waste streams from ships and groups of stressors on the marine environment in the output of the STEAM model (Jalkanen et al. 2021)

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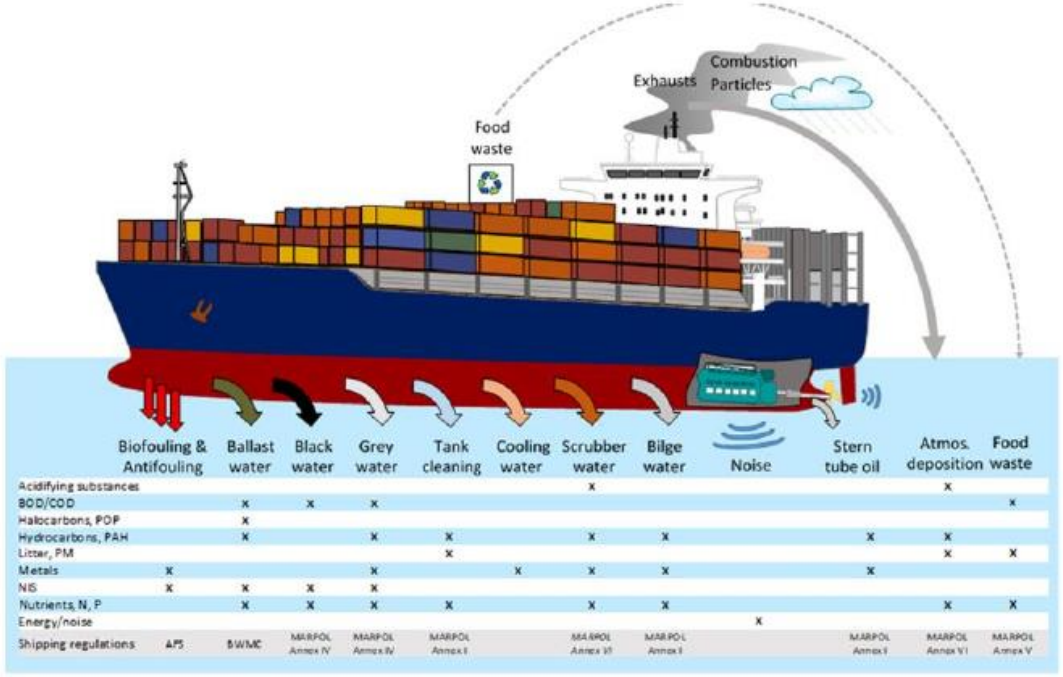
Shipping, marine scrubbers and the STEAM model (EMERGE project)

- ✓ The Ship Traffic Emission Assessment Model (STEAM) provides direct discharge volumes from ships to the sea (Europe and case study areas, Saronikos Gulf being one of them).

- ✓ These discharge volumes are combined with results of waste streams effluent analysis (pollutant concentrations determined by project partners) to determine the mass flux of discharged pollutants.



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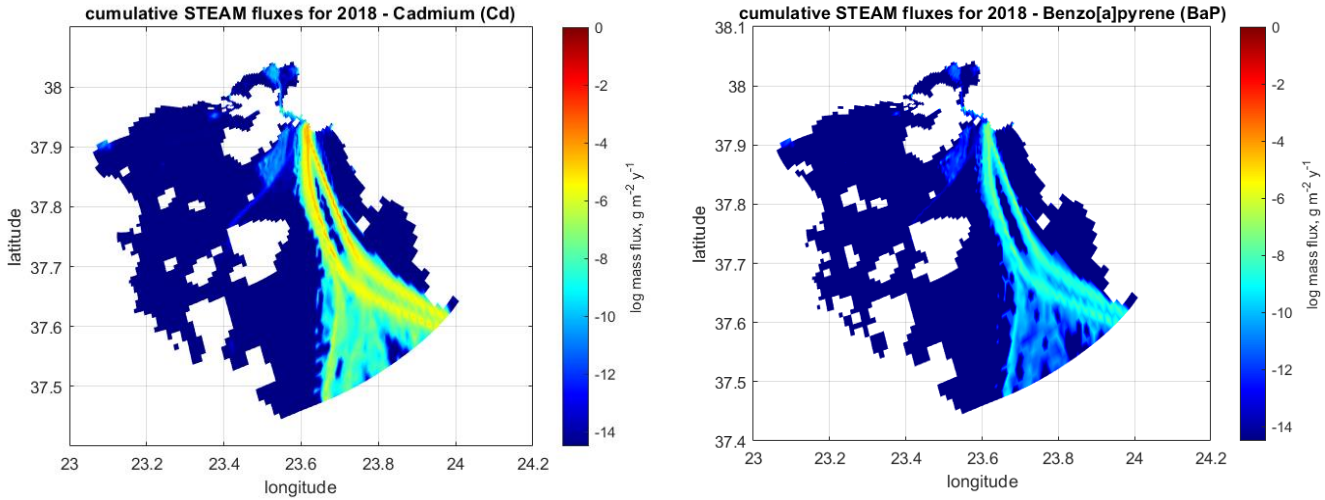

Cumulative pollutant fluxes from shipping (water stream emissions) at the sea surface for 2018 (total mass in g per m^2 for the baseline year 2018, in logarithmic scale) for Cadmium (left) and Benzo(a)pyrene (right) in the Saronikos Gulf.

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… some Findings and Challenges

✓ **Hydrodynamics and Waves**

- The model configuration producing minimum errors employs 20 σ-layers with higher resolution at the near-surface zone.
- Salinity is better reproduced with boundary conditions from the climatological simulation of the Eastern Mediterranean-Black Sea domain (that resolves dynamically the exchanges through the Dardanelles strait), as it manages to convey a clearer Black Sea Water signal in a timely manner.
- the high-resolution wave model reproduces in an adequate way the dominant wave conditions for 2018 having very good statistical scores of correlation coefficient, root mean square error (RMSE) and Bias for the significant wave height and mean wave direction.

✓ **Water quality**

- For heavy metals, the model appears to reproduce reasonably well the *in situ* levels of concentrations.
- *In situ* PAH concentrations are found to be below limit-of-detection, as are modelled concentrations.
- For 2018, loads from shipping (N-nutrients, heavy metals, PAHs) amount to less than 1% of the mass loads introduced from other major land-based polluting sources (for metals involved in antifouling paints -Cu, Zn- this figure is to be calculated).

✓ **Challenges**

- Compiling available information on pollution loading from the numerous human activities.
- Lack of published PAH concentrations representative of the area for model validation.
- Assessment of model performance is ongoing, they **need further tuning, testing and validation**