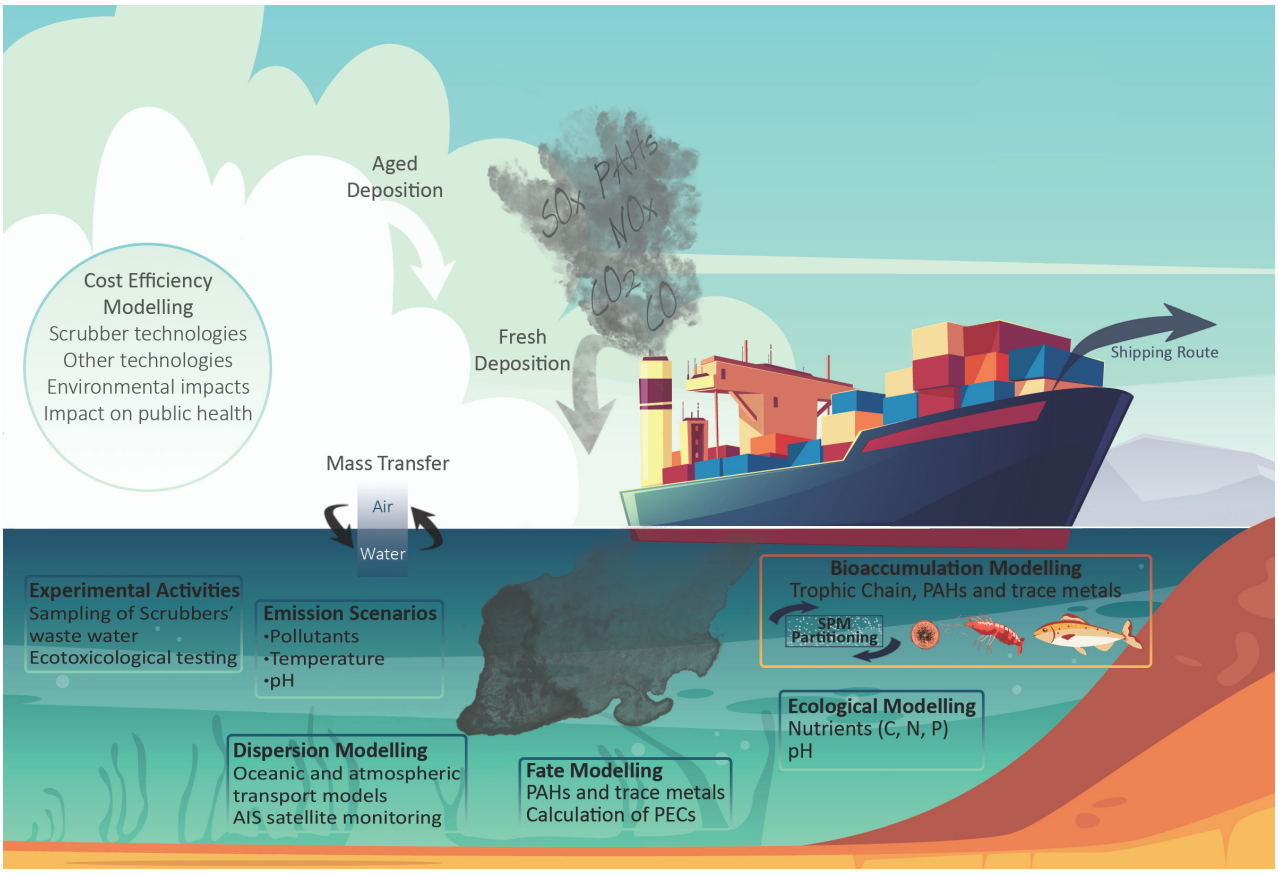
EMERGE

Evaluation, control and Mitigation of the EnviRonmental impacts of shippinG Emissions

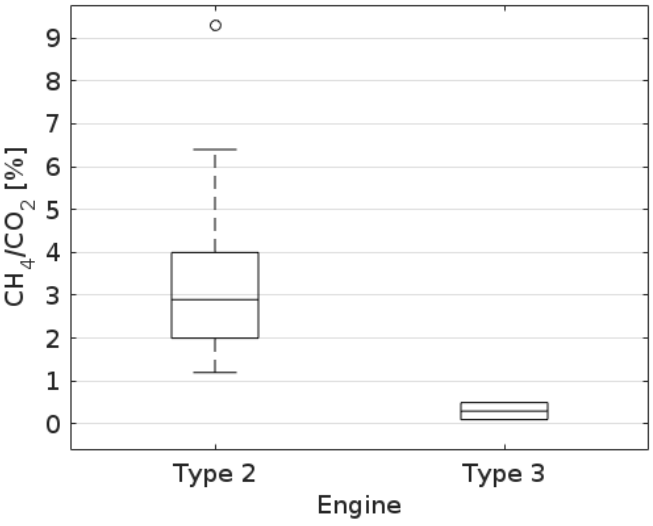


IMPLEMENTATION

The project will include measurements and modelling on actual vessels. Those will focus on abatement techniques and will include emissions to, and concentrations in water, air and marine biota.
A wide spectrum of models will be used, including those for ocean circulation, biogeochemical processes, atmospheric dispersion and the bioaccumulation of pollutants.

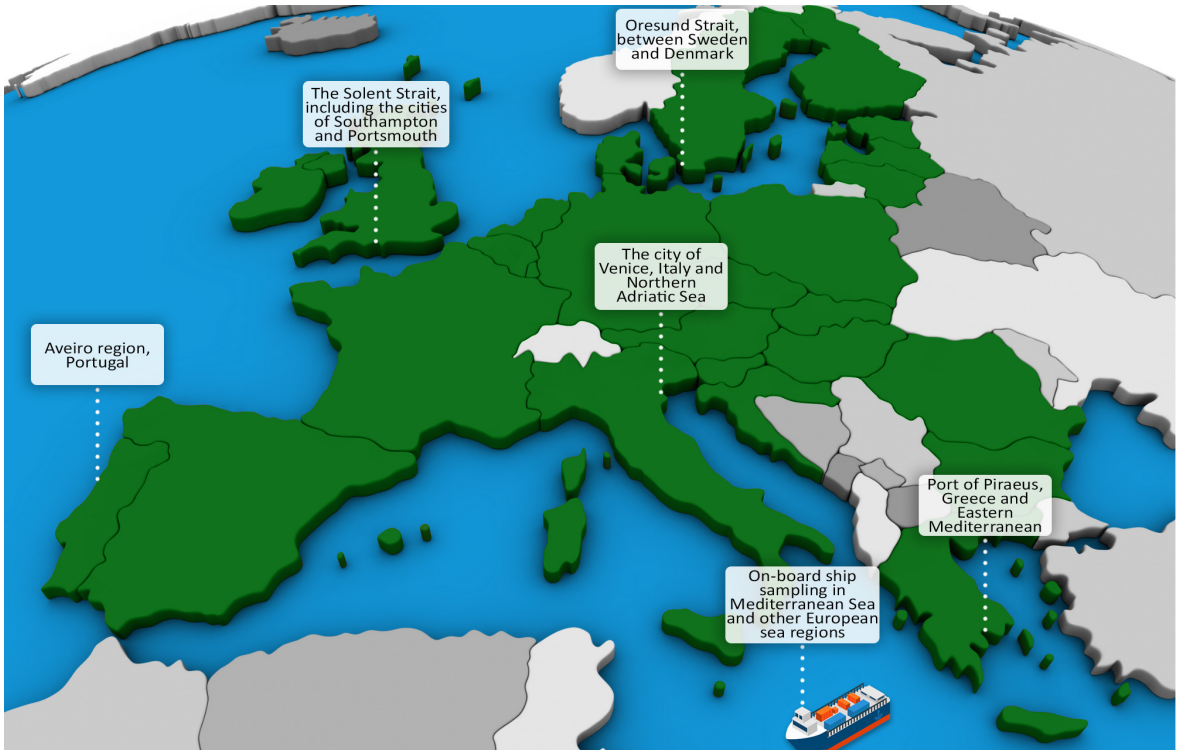
Evaluation of Methane Emissions Originating from LNG Ships

Grönholm et al. (2021) presented for the first time a quantitative assessment of the climatic impacts of various liquid natural gas (LNG) -fuelled ships in real-life marine conditions. The ratio of the measured concentration ΔCH4/ΔCO2 ranged from 1% to 9% for low pressure dual fuel engines (type 2) and from 0.1% to 0.5% for high pressure dual fuel engines (type 3). In case of the highest CH4 emissions from the type 2 engine, the climatic impacts of such an LNG-fuelled ship would be larger than those for the same ship using traditional marine fuels.



Grönholm, Tiia, Timo Mäkelä, Jukka-Pekka Jalkanen, Joel Kuula, Juha Hatakka, Tuomas Laurila, Lauri Laakso, and Jaakko Kukkonen, 2021. **Evaluation of methane emissions originating from LNG ships based on the measurements at a remote marine station.** Environ. Sci. Technol. 2021, Published by American Chemical Society. 10 pp. Read here.

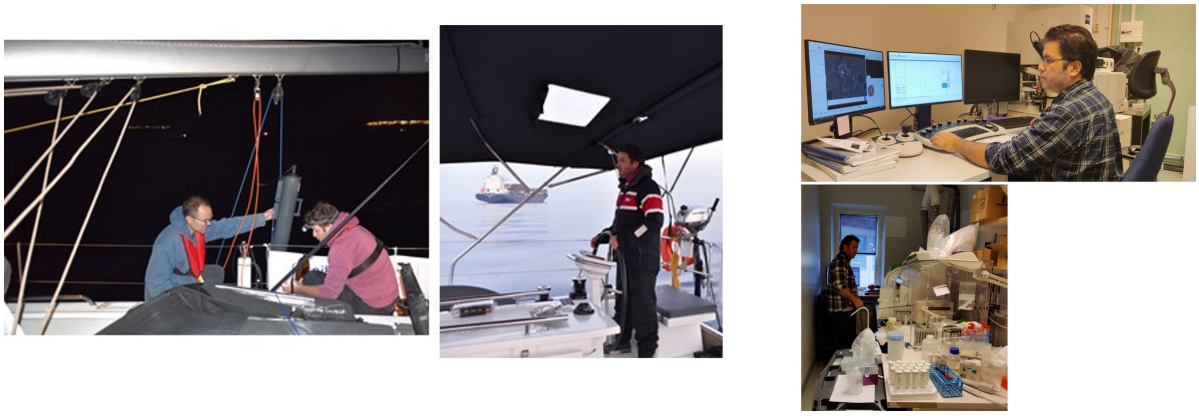
CASE STUDIES, MODELLING AND EXPERIMENTS



Case study map

SELECTED OUTCOMES

In November 2021, Cnano with UGOT and CHALMERS carried out sampling in the Saronic Gulf, collecting experimental traces on waste streams from ships using various emission control technologies. Following the campaign, samples were transported to UGOT for analysis using state-of-the-art techniques. Sampling and analysis aimed at acquiring data on physical chemical characteristics of particles in seawater.



Sampling (Saronic gulf) and analysi work in November – December 2021

On the 13th of November 2021, six excited researchers within the EMERGE project embarked on a 10-day voyage with a commercial container ship, equipped with an open loop scrubber, sailing from Antwerp (Belgium), via Rotterdam (Netherlands) to Gebze (Turkey). The main target was to conduct simultaneous measurements and sampling of atmospheric emissions and scrubber water discharge and to study the potential variances within different regions covered by the journey (see map).

Additional scrubber discharge water samples were collected to be sent and used in ecotoxicological tests within the different case study regions of EMERGE.

While the water sampling onboard was quite straightforward, visiting the engine room on regular (although sometimes unconventional) hours and filling up carefully prepared sampling vials (thank you Andreas et al), the atmospheric part was constantly met with new challenges as many of the online instruments had to be optimized for the onboard reality. The hard work did pay of, and the collected data and samples will continue to keep researchers within the EMERGE project busy in the near, and far, future ahead. Further, the aim is to compile all the collected data and to, for the first time, perform mass-balance calculations to estimate the pathways of contaminants from a 2-stroke combustion engine, running on different fuels and with the scrubber both on and off.
Although there were only a handful of us working onboard, with the help and hospitality of the crew, the campaign could not have been conducted without the work from many more within the consortium. This part of the project really involves most work packages and case studies within EMERGE and will provide important input and knowledge to the ongoing debate regarding the use of scrubbers.

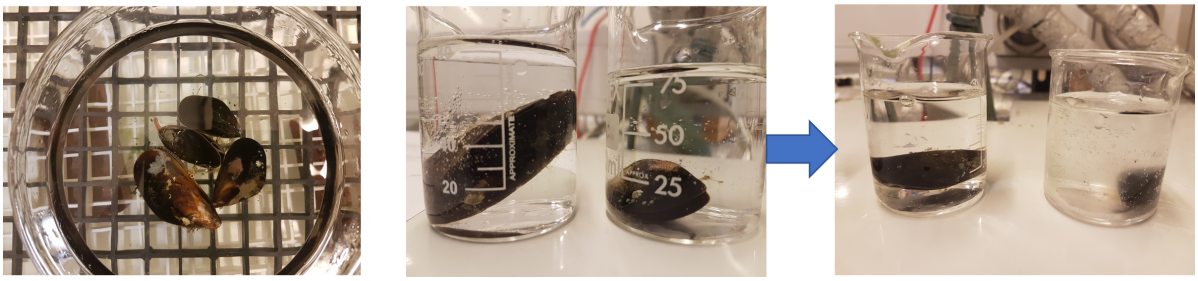
Figure 1: A collage showing: 1) the cruise track from Rotterdam to Gebze with some of the sampling points indicated along the way, 2) the exhaust from the funnel, 3) participating researcher from left Giannis, Nikos, Anna, Håkan and Tasos (missing Jana who took the photo), 4) sunset in the Mediterranean, 5) the on-site built "pump box" for filter samples with Jana, 6) the engine room and 7) Nikos in the heart of the online exhaust measurements at the bridge.

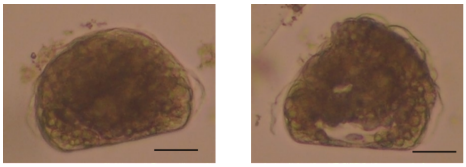
As part of the Solent Case Study, the University of Southampton team has been carrying out ecotoxicological tests on marine organisms. The team, led in the laboratory by Dr Lina Zapata, carried out a multispecies approach toward ecotoxicological testing. This is fundamental for the purposes of risk assessment and securing accurate environmental management and ecological risk assessment procedures.

Two different species reflecting different trophic levels in the marine food web, were investigated. Firstly, they investigated the effects of scrubber water and some of the main polycyclic aromatic hydrocarbons (PAHs) and heavy metals frequently found in scrubber effluents on the growth and mortality of the marine microalgae, Tetraselmis suecica. Secondly, they investigated the toxicity of scrubber water on the early development of the blue mussel (Mytilus edulis).

Blue mussel (*Mytilus edulis*) larvae

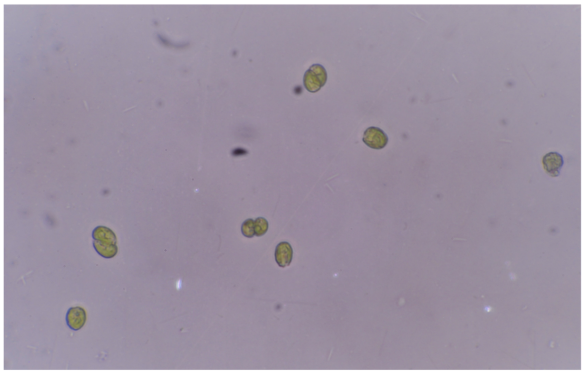
Spawning induction by termal shock





M. edulis normal D-shaped larvae and Abnormal D-shaped larvae with hypertrophy of the mantle. Scale bar: 20µm

Marine unicellular algae (*Tetraselmis suecica*)



Viable cells

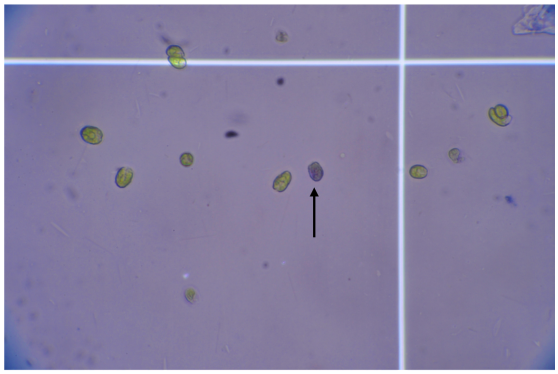
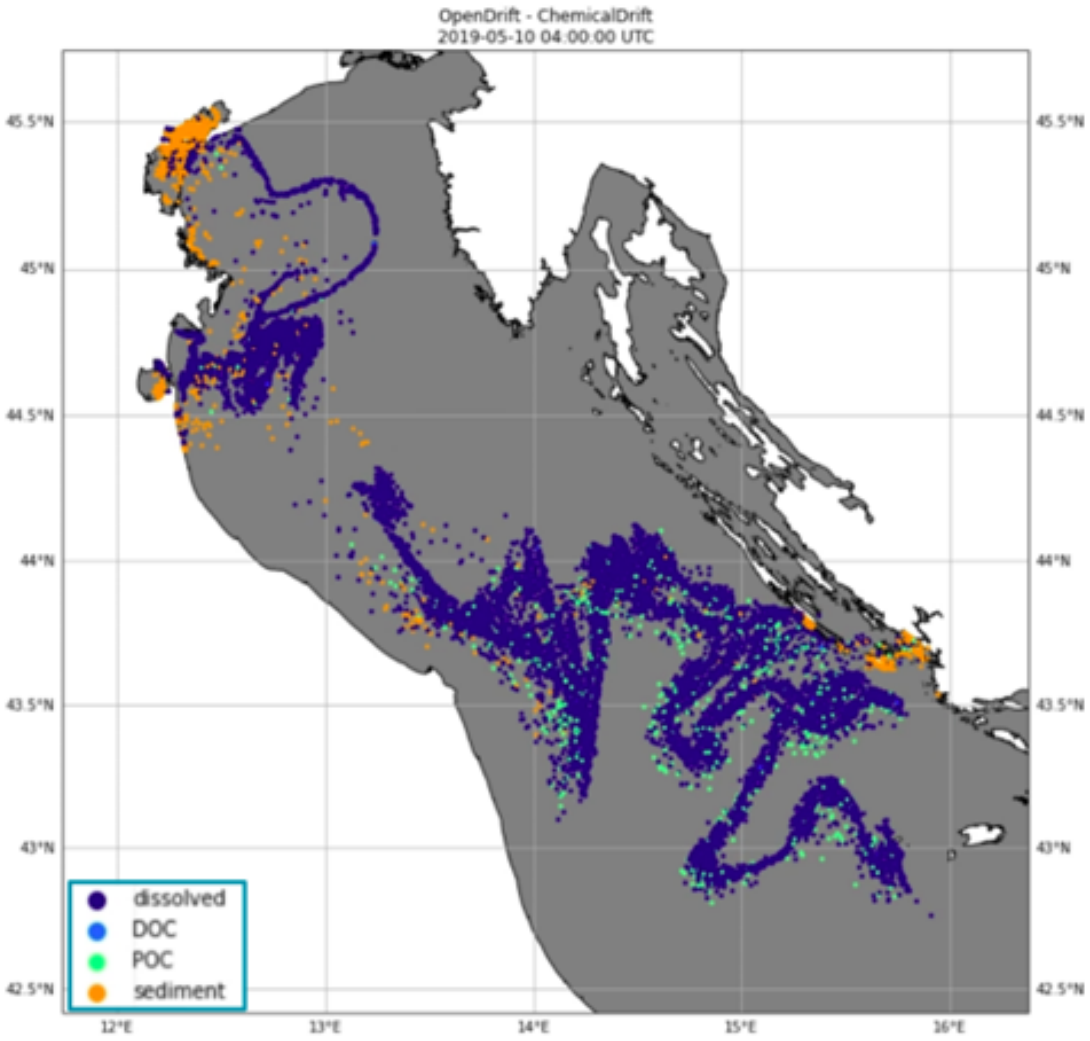


Image represents unicelular algae cells that have been stained with trypan blue and analyzed under microscope. Arrow: dead trypan blue positive cell

Preliminary findings show increased algal mortality rates when exposed to concentrated scrubber water, PAHs in combination (and more so than when exposed to individual PAHs) and heavy metals. In the same manner, blue mussel larvae were shown to be highly sensitive to scrubber water, showing effects on development. After more detailed evaluation, the work will be written up as a formal report and submitted for peer review in due course.

The ChemicalDrift model for the transport and fate of chemicals in aquatic environments has been developed in WP4 by the Norwegian Meteorological Institute in collaboration with Ca' Foscari University of Venice. The model is built on the open source Lagrangian framework OpenDrift. It supports non-ionizable organics such as PAHs and heavy metals that are found in the effluents of exhaust gas cleaning systems. The model considers that chemicals in the water column can be dissolved or sorbed to either colloidal particles (i.e. dissolved organic carbon, DOC) or larger suspended particles (i.e. particulate organic carbon, POC). Large particles might also sink and settle to the seabed sediment layer. Resuspension back to the water column is also modelled. Degradation and volatilization of organic compounds are modelled as first order decay processes with the necessary correction factors for temperature and salinity. ChemicalDrift will be used to model the dispersion of the chemicals originating from shipping activity at the European scale, thus providing also lateral boundary conditions for each case study area, as well as within the Venice-Northern Adriatic and Øresund case studies. Interface to emission data from the STEAM model is included, as well as emission factors for open and close loop scrubbers provided by WP2. A database of chemical parameters for a set of PAHs is integrated. Metocean forcing data from the Copernicus Marine Service or from case study specific models will be used.



Demonstration of ChemicalDrift showing emissions of Phenanthrene from open loop scrubbers in the Adriatic sea in mai 2019, using forcing data from HYCOM and SHYFEM by ISMAR.

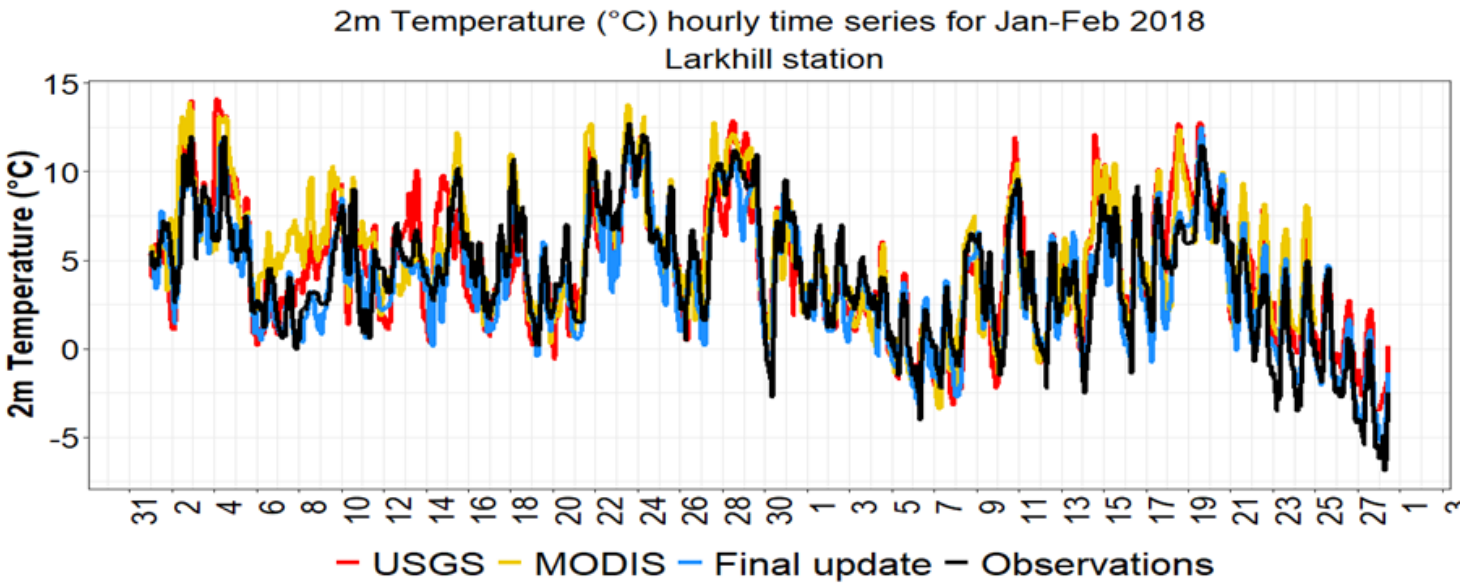
The current situation of CACP for atmospheric modelling and Solent case study area

The WRF model, which is used to drive the chemistry model, was configured for the Europe domain with 5km grid resolution. To improve model performance on the coastal regions, several sensitivity experiments were designed.

First two sensitivity analyses focused on land use land cover misrepresentations on coastal regions based on two different land use datasets: USGS and MODIS. As the further refinement, along with MODIS land use data, multiple WRF options were combined which are including grid nudging, sea surface temperature update and daily initialization. This final refinement improved model performance significantly.

What's coming next?

- CMAQ model runs will be started after completion of the WRF model runs with the final settings for the whole year 2018.
- A street scale model will be used for the Solent case study area to decide locations of the low-cost sensors.
- A journal paper is being prepared for WRF model performance in the coastal regions.
- WRF model results are also being shared with other EMERGE modelling teams with the intention of using common meteorology for all the case study analysis.



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