Satellite Observations of Atmosphere-Sea Interaction in the Coastal Ocean

Summary

Wind induced surface-wave breaking injects bubble plumes that mediate key air–sea exchanges, yet their subsurface structure is presently sampled only at limited locations by acoustic instruments. Measuring on the large scale is often impractical due to high maintenance costs. Alternatively, satellite Synthetic Aperture Radar (SAR) offers high-resolution spatial overview independently from daylight or cloud coverage. This PhD will develop and benchmark machine-learning models—from classical methods to deep networks—to translate SAR imagery into quantitative bubble-plume properties and establish the spatial and temporal limits of these retrievals. Outcomes will support a broader effort to derive air–sea fluxes from remote sensing observations.

Research field:	Earth sciences
Supervisors:	Sander Rikka Dr. Sven Nõmm
Availability:	This position is available.
Offered by:	School of Science Department of Marine Systems
Application deadline:	Applications are accepted between June 01, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich)

Description

The research

Global observations highlight the pivotal role of surface waves in mediating ocean–atmosphere exchanges. When waves break, they inject subsurface bubbles that organise into vertical plumes, extending from a few metres under moderate conditions to more than 30#m during severe storms. Plume depth and concentration covary with wind and wave parameters. In-situ measurements with Acoustic Doppler Current Profilers (ADCPs) and high-frequency echosounders provide quantitative information on plume geometry and dynamics. At the sea surface, satellite Synthetic Aperture Radar (SAR) offers a synoptic view of sea state—delivering bulk wave parameters and even spectrum—independent of daylight or cloud cover.

The overarching goal of this PhD project is to evaluate a suite of machine-learning approaches—from classical statistical learning to deep neural networks (DNNs)—for mapping SAR imagery to subsurface bubble-plume properties. The project will also define the spatio-temporal bounds within which robust estimation is feasible, and assess whether multi-modal fusion (e.g., integrating measurements, or reanalysis data) can enhance predictive skill. The results will feed into a larger goal that seeks to quantify air–sea exchanges from satellite-derived wave information.

The thesis should address the following questions: 1) How successful have previous or ongoing attempts been at estimating subsurface bubble-plume characteristics via remote sensing? 2) Which processing workflows yield the most accurate subsurface estimates? 3) What capabilities are required to extract reliable subsurface parameters from historical and contemporary SAR missions? 4) Where and when do bubble plume events occur in the Baltic Sea?

Responsibilities and (foreseen) tasks

- Compile datasets for different open-source C and X-band SAR data, in situ and numerical model parameters
- Develop and validate analytical, empirical or machine learning based methodology to derive bubble plume characteristics
- Spatio-temporal analysis of bubble plume depths estimated from SAR data
- Support teaching activities of Dr. Sander Rikka

Applicants should fulfil the following requirements:

- A master’s degree in one of the following subjects: Natural Sciences (Earth Sciences, Oceanography, Physics etc.) or Computer Science.
- A clear interest in the topic of the position

- Good skills in one of the following computer languages – Python, MatLab, R.
- Excellent communication of English
- Strong and demonstrable writing and analytical skills
- Capacity to work both as an independent researcher and as part of an international team

The following experience is beneficial:

- Knowledge about Linux/Unix systems, High Performance Computing (HPC) environments.
- Previous experience with data bases (i.e., Copernicus), data mining, implementation of machine learning methods.
- Previous experience in analyzing geospatial data (remote sensing imagery, structured- and unstructured model fields).
- It is desirable if candidate can share some of their GitHub projects to demonstrate programming skills.

The candidate should submit a research plan for the topic, including the overall research and data collection strategy. The candidate can expand on the listed research questions and tasks, and propose theoretical lenses to be used.

We offer:

- 4-year full time (fully funded) PhD position in an outstanding Baltic Sea research institution with a large portfolio of ongoing pan-European and national public sector applied research projects
- Opportunity to participate in applied research projects funded by European Commission (e.g. LIFE program), European Space Agency (ESA)
- Opportunities for conference visits, research stays and networking with globally leading universities and research centers in the fields of applications of machine learning, satellite data processing and oceanography

About the department

Tallinn University of Technology (TalTech), the only technological university in Estonia, is the flagship of Estonian engineering and natural sciences. Here the synergy between different fields (technological, natural, exact, economic and health sciences) is created and new ideas are born.

The Department of Marine Systems at TalTech is a leading oceanographic and meteorological R&D unit in the Baltic Sea region. We focus (1) on oceanographic process research based on scientific analysis to find cause-and-effect relationships and (2) on developing marine monitoring and forecasting services. The implemented methods include machine learning based algorithms for satellite image processing and for model data analysis as well as development of innovative (operational) methods for monitoring the marine environment and analyzing the changes. We have long-term experience in developing applications and methods for operational oceanography, the outputs of which are information products provided to the public and to various authorities on water level variability, ice conditions and other parameters of marine physics. We are contributing significantly to the pan-European Copernicus program (CMEMS) and Destination Earth (DestinE) initiative.

(Additional information)

For further information, please contact Sander Rikka (sander.rikka@taltech.ee) or Sven Nõmm (sven.nomm@taltech.ee).

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