

# ANR–NSERC Autosail

## AI-Driven Optimization for Sustainable Maritime Navigation and Wind-Assisted Propulsion

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<https://autosail-194045.gricad-pages.univ-grenoble-alpes.fr/>

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# Context and Motivation

- Maritime transport:  $\sim 3\%$  ( $\sim 5\%$  by 2050) of global  $\text{CO}_2$  emissions
- Wind-Assisted Propulsion (WAP) as a short-term decarbonization solution
- Current limitation:
  - Passive or weakly adaptive sail control
  - Limited exploitation of physics and onboard data
- **Autosail**: move from assistance to *optimal and adaptive sailing*

Michelin WISAMO : inflatable sails



Yara Marine Tech.: hard sails



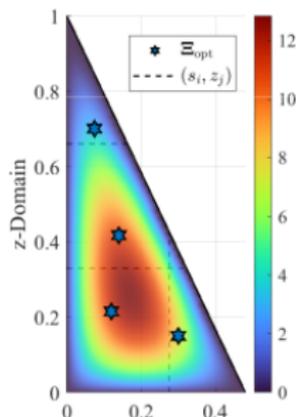
Northpower : rotor sails



## Main Objective

Develop physics-informed, data-driven control architectures to maximize energy efficiency and safety of sail-assisted vessels.

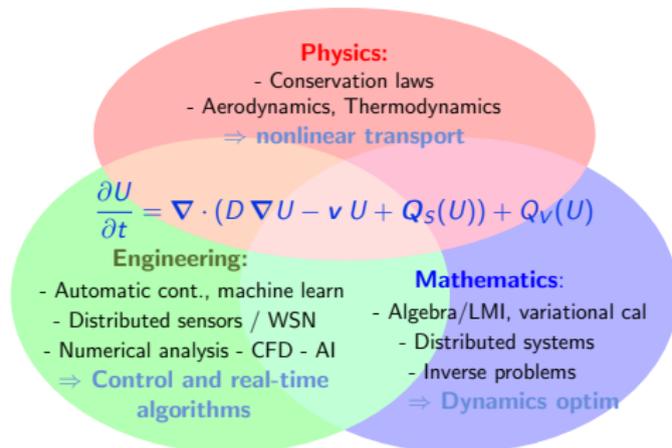
- Model and control fluid–structure interaction (FSI)
- Exploit sparse and noisy onboard measurements
- Design robust and adaptive feedback control laws
- Integrate control with routing and navigation



Optimal Observer-Based Pressure Sensor Placement for Sails

- **Infinite-dimensional dynamics**
  - Navier–Stokes equations on deformable sails
  - Strong coupling with boat dynamics (ODE–PDE)
- **Sparse sensing**
  - Pressure sensors, IMU, GPS, anemometer
  - Need for virtual sensors and observers
- **Hybrid operating regimes**
  - Flow attachment / separation

- Changing wind and sea states



## ● WP1 – Modeling

- From enhanced aerodynamic modeling to physics-informed performance maps
- ML in sensor fusion for real-time sail adjustment
- Integrate first-principles physics with data-driven learning

## ● WP2 – Systems Analysis and Control for FSI

- Boundary control of a

network of nonlinear PDEs

- Hybrid control strategies with safety constraints
  - AI automation with control-theoretic guarantees
- ## ● WP3 – Autonomous sailing and navigation
- Model-based and AI-driven methods for robust decision-making
  - Path planning under wind and current constraints

# Expected Outcomes and Impact

## ● Scientific impact

- Integrating ML with control theory to enhance maritime navigation
- RL and adaptive decision-making handling sensor data with safety and efficiency constraints
- Stabilizing and optimizing propulsion in dynamic, distributed and uncertain environments
- Improve guidance, navigation, and control systems for both crewed and autonomous vessels

## ● Technological impact

- Demonstrated gain in propulsion efficiency
- Transferable control architectures

## ● Societal impact

- Contribution to maritime decarbonization
- Training of 4 PhD and 2 MSc students



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