Intelligent Observing and Multiscale Modeling for Ocean Exploration and Sustainable Utilization

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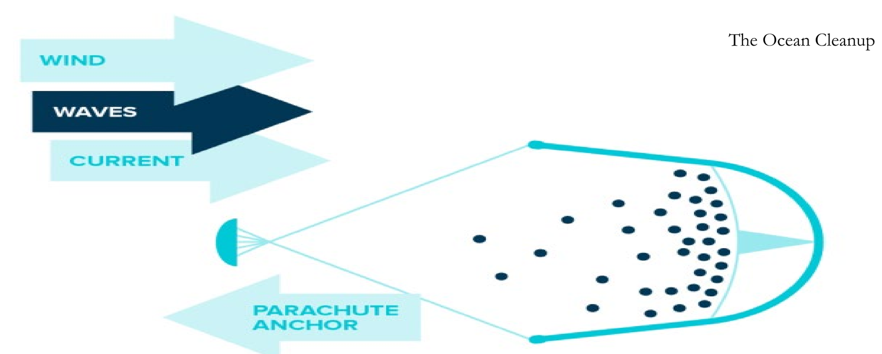
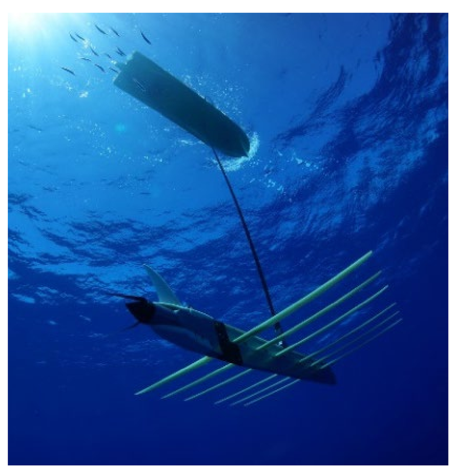
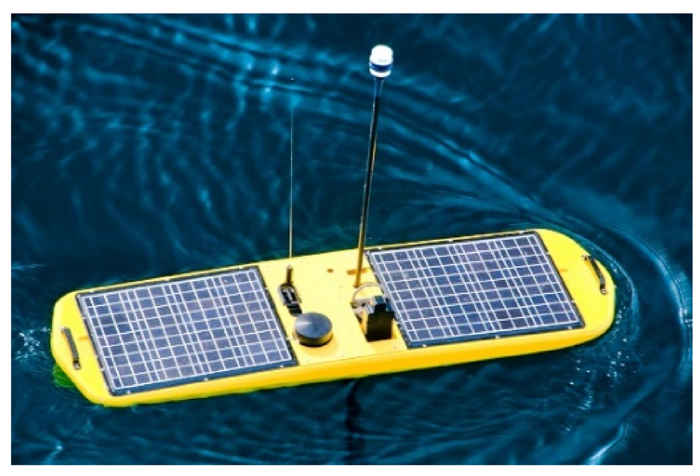
mseas
multidisciplinary simulation, estimation, and assimilation systems
MIT Portugal

Background

For intelligent ocean exploration and sustainable ocean utilization, the need for smart autonomous underwater vehicles, surface craft, and small aircrafts is rapidly increasing. Applications include scientific studies, solar-wind-wave energy harvesting, transport and distribution of goods, naval operations, security, acoustic surveillance, communication, search and rescue, marine pollution, ocean cleanup, conservation, fisheries, aquaculture, mining, and monitoring and forecasting. Designing optimal paths leads to cost savings, longer operational time, and environmental protection.







MIT Portugal Project Goals

Further develop and apply our exact PDE-based planning theory and data-driven ocean modeling methodology to optimize the efficiency and endurance of ocean vehicles:

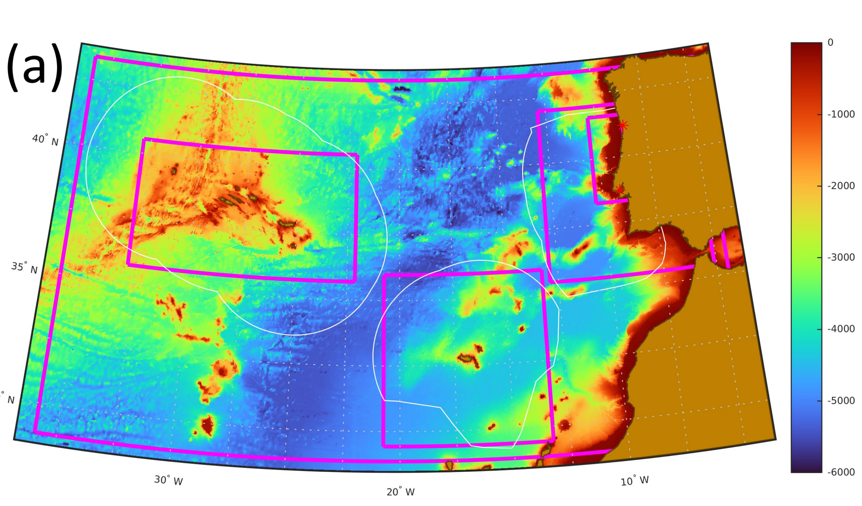
- Develop and apply our optimal planning theory and methodology to increase the efficiency of surface craft and underwater vehicles operating in uncertain dynamic ocean conditions.
- Implement and apply our rigorous theory and schemes for energy-optimal path planning and risk minimization under realistic ocean conditions
- Develop and evaluate mission planning for optimal environmental energy harvesting and optimal dynamic ocean cleanup
- Develop information-optimal theory for efficient scientific exploration and Bayesian machine learning of ocean model parameterizations and turbulence closures.

For the first time, we combine environmental forecasting with stochastic control and risk theory, and employ fundamental partial differential equations (PDEs) and efficient level-set solutions for exact reachability and path planning.

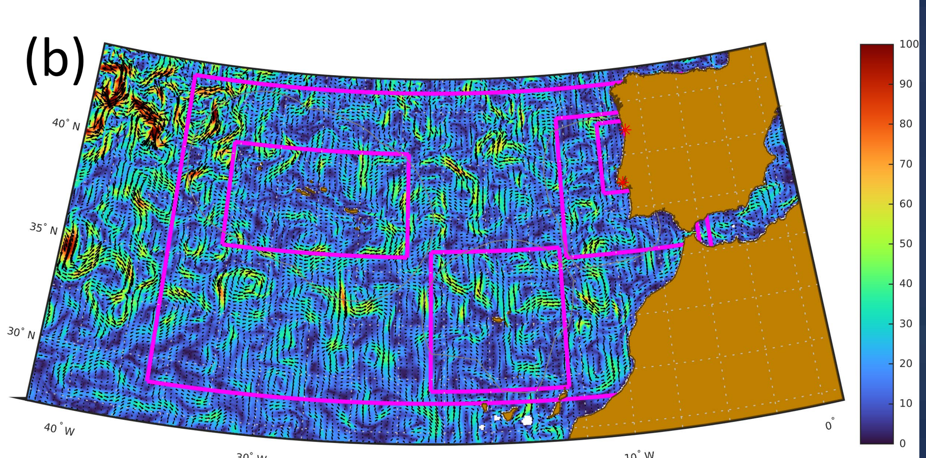
Progress-to-date: Multi-Resolution Modeling & PDE-based Planning

- High-resolution bathymetry
- 100 optimized vertical levels
- TPXO9-Atlas tidal forcing
- Atm. forcing: NCEP CFS (1/5°)
- 1/12° HYCOM initial and open boundary conditions

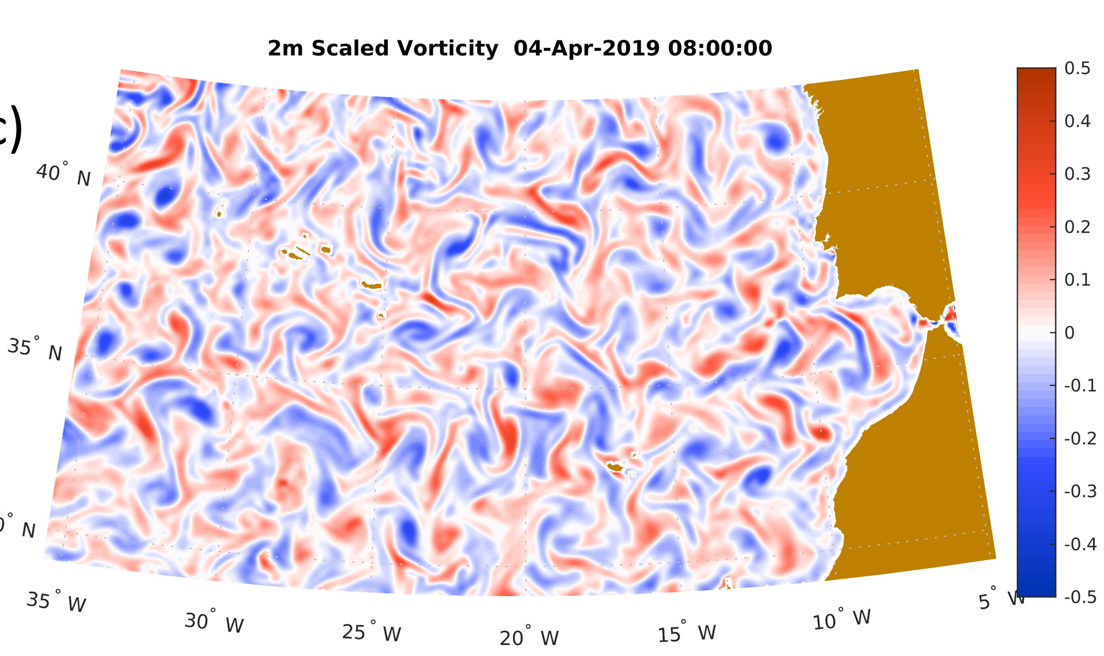
(a)



(b)

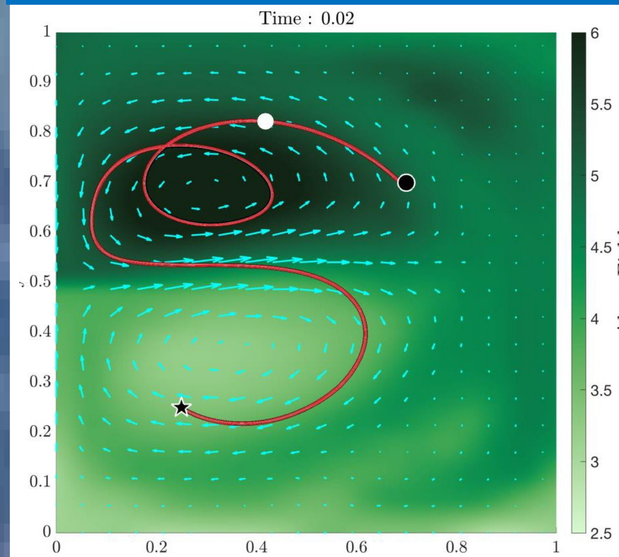


(c)



(a) Bathymetry (m) of Portugal-Azores-Madeira modeling domain
(b) Upper 20m avg. velocity (cm/s)
(c) MIT-MSEAS Primitive-Equation simulation: 5-day hindcast of 2m relative vorticity

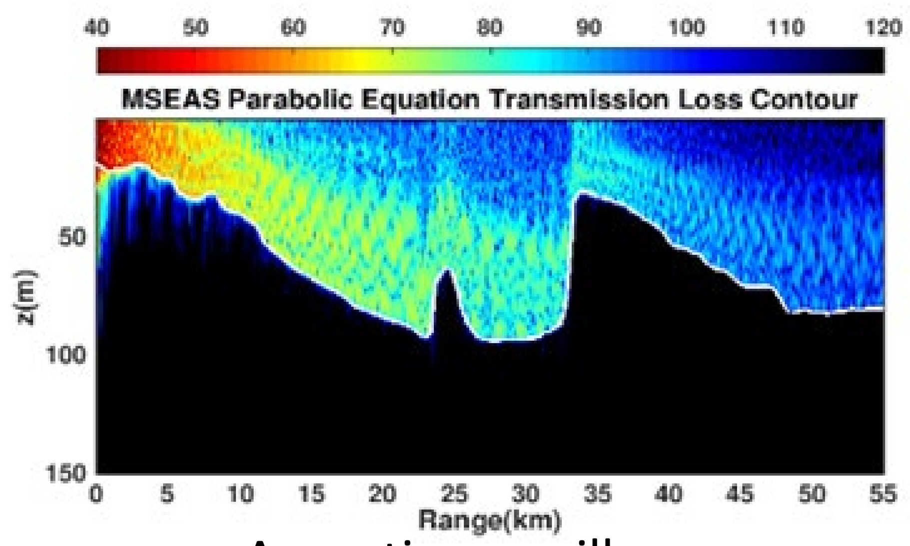
Applications of our Modeling and PDE-based Planning



Optimal Algae Harvesting
[Bhabra et al., 2020]

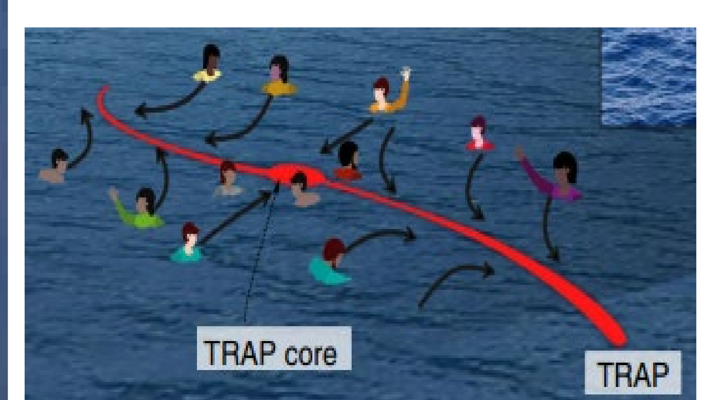
Transport & distribution
(Image credit: Wikipedia)

Naval operations

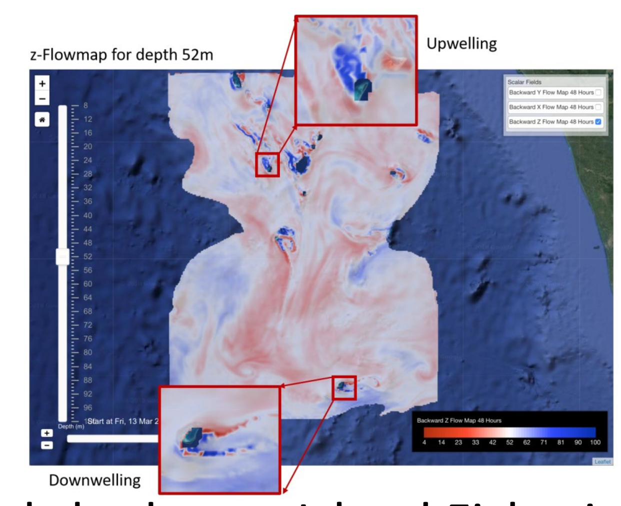


Acoustic surveillance
[Ali et al., 2019]

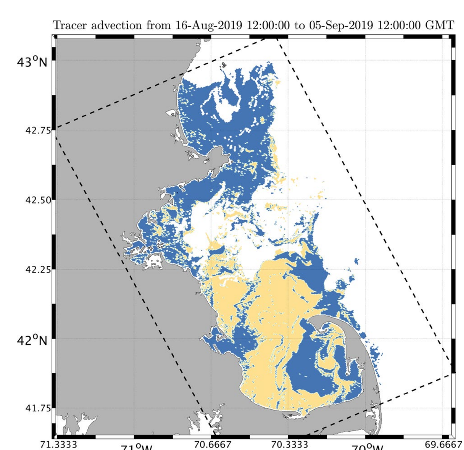
Communications & cables
(Image credit: OpenStreetMaps/Wikipedia)



Search & rescue
[Serra et al., 2020]

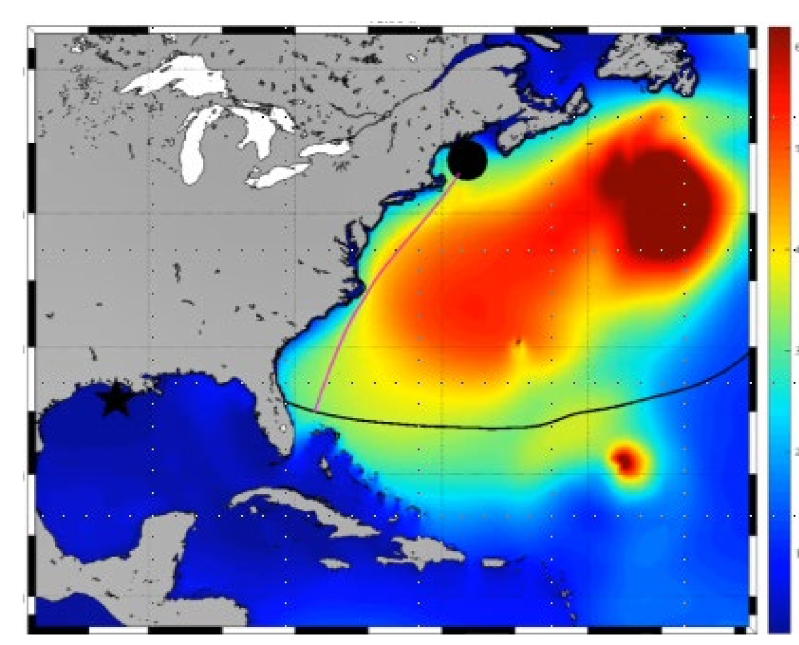


Lakshadweep Island Fisheries
[Gupta et al., 2019]



Plastic pollution
[Lermusiaux et al., 2019]

Planning for Autonomous Undersea Vehicles [Subramani et al., 2017]



Optimal Safe Tanker Path: Boston - Houston [Lermusiaux et al., 2017]

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