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METEOR: A Mobile (Portable) ocEan roboTic ObsErvatORy

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ABSTRACT

The oceans make this planet habitable and provide a variety of essential ecosystem services ranging from climate regulation through control of greenhouse gases to provisioning about 17% of protein consumed by humans. The oceans are changing as a consequence of human activity but this system is severely under sampled. Traditional methods of studying the oceans, sailing in straight lines, extrapolating a few point measurements have not changed much in 200 years. Despite the tremendous advances in sampling technologies, we often use our autonomous assets the same way. We propose to use the advances in multiplatform, multidisciplinary, and integrated ocean observation, artificial intelligence, marine robotics, new high-resolution coastal ocean data assimilation techniques and computer models to observe and predict the oceans "intelligently"—by deploying self-propelled autonomous sensors and Smallsats guided by data assimilating models to provide observations to reduce model uncertainty in the coastal ocean. This system will be portable and capable of being deployed rapidly in any ocean.

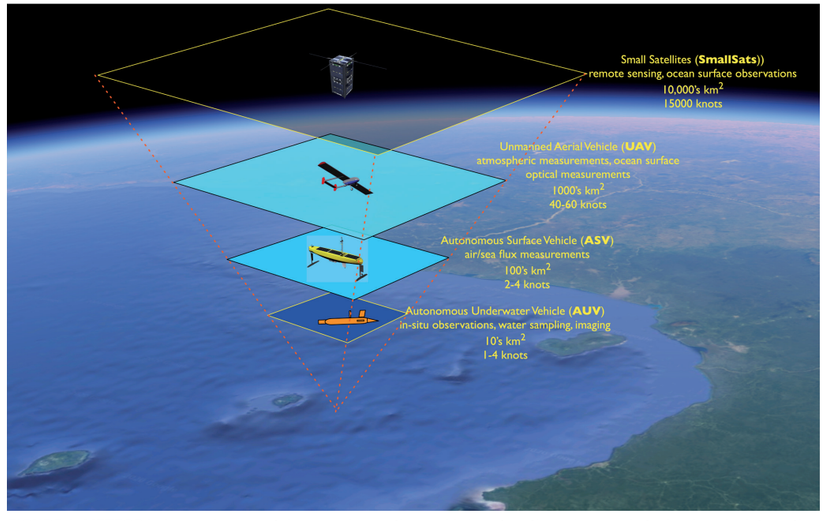

FIGURE 1. METEOR is focused on coastal ocean observation and brings together advances in technology by integrating command and control software that uses Artificial Intelligence (AI) to drive ocean data gathering by networked autonomous platforms, small satellites with data assimilating models, complemented by more traditional shipboard sampling. The end result will be a mobile, portable coastal ocean observatory that can provide information to stakeholders and communities.

Vision and Potential Transformative Impact

Our vision for METEOR (A Mobile [portable] ocEan roboTic ObsErvatORy) is about a paradigm change in coastal ocean observation and response with the development of actionable knowledge about the ocean. We propose to advance ocean observation modalities by integrating command and control software that uses artificial intelligence to drive ocean data gathering by autonomous platforms, small satellites with data assimilating models, complemented by more traditional shipboard sampling. The self-propelled robotic platforms will be directed to regions of the model field with maximum uncertainty to provide data that can be assimilated into the model to reduce that uncertainty.

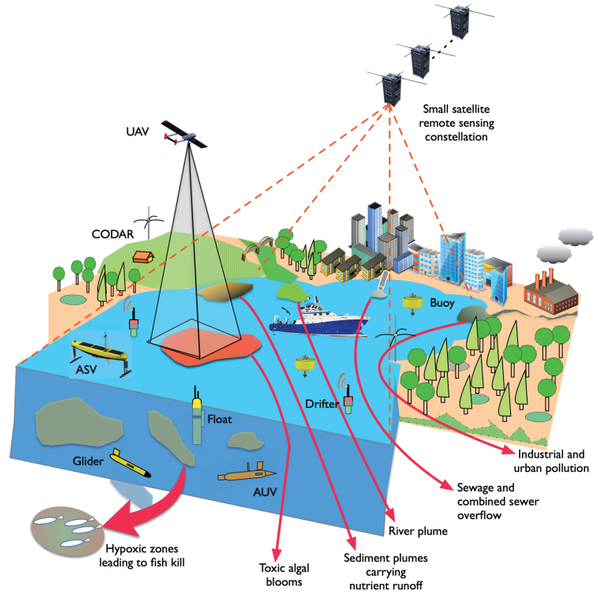

FIGURE 2. In METEOR, self-propelled robotic platforms will be directed to regions of the model field with maximum uncertainty to provide data that can be assimilated into the model to reduce that uncertainty. The platforms will use the model output of flow fields to efficiently relocate to other regions of the model grid to further reduce mode uncertainty. "Intelligent" deployment of in-situ assets in this manner will help produce higher-resolution model output while reducing the time and energy needed for ocean observation. While METEOR will use a substantial amount of robotic hardware, the focus is on the software capabilities, which will provide high-value information coupled with high-revisit times (~ 3–5 hours) of satellite remote sensing products to close the sense-assimilate-predict-sample loop.

The platforms will use the model output of flow fields to efficiently relocate to other regions of the model grid to further reduce uncertainty in the model. "Intelligent" deployment of in-situ assets in this manner will help produce better model output while reducing the time and energy needed for ocean observation. METEOR will be a modular system with bespoke approaches to ocean observation. It will integrate state-of-the-art hardware including a small satellite (SmallSat) constellation, in-situ air, surface and underwater vehicles with software to control and visualize the information gathered.

Realizable, With Connections to Existing U.S. Scientific Infrastructure, Technology Development, and Public–Private Partnerships

The PI of METEOR is from private industry specializing in data science, while two of the co-PIs come from leading academic institutions (Professor Ajit Subramaniam at Columbia University and Professor Pierre Lermusiaux at Massachusetts Institute of Technology). METEOR builds on a legacy of command and control software developed for controlling robotic rovers on Mars as well as long range autonomous underwater vehicles. The PIs have extensive experience in adaptive sampling of oceans and in developing data assimilating models.

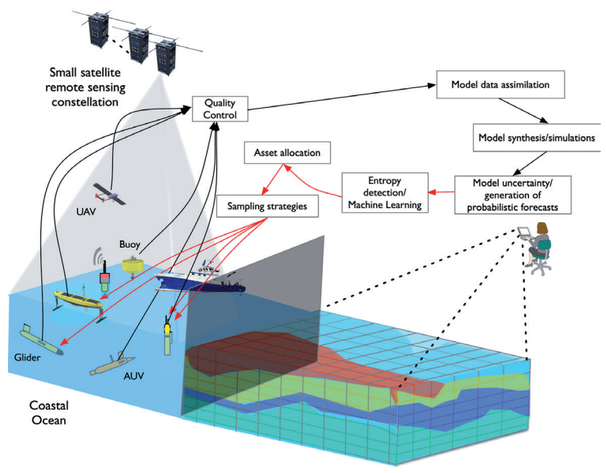

FIGURE 3. METEOR is a collaboration of scientists and technologists across disciplinary and geographic boundaries to envision a new way to observe the coastal ocean, with an emphasis on building a robust software system-of-systems to sense-assimilate-predict-sample with principled methods in engineering of complex systems. The multi-vehicle multi-domain ensemble of robots across space, aerial, surface and underwater domains will observe, collect, assimilate, and learn from data from a range of sensors and platforms to drive and sample in-situ assets to increase model skill over time.

Scientific/Technological Sectors Engaged Outside of Traditional Ocean Sciences

This project involves computer scientists with expertise in artificial intelligence, engineers with expertise in marine robotics, engineers with expertise in small sat technology development, in addition to field-going observational oceanographers and ocean modelers.

Opportunities for International Participation and Collaboration

There are three non-U.S. PIs in METEOR—João Sousa is a Professor at the Faculty of Engineering, University of Porto, Portugal and is the head of the Underwater Systems and Technology Laboratory (LSTS). Fernando Aguado is an Associate Professor at the University of Vigo and PI of several small sat missions. Joaquín Tintoré is Professor of Physical Oceanography from CSIC (Spanish Research Council) and Director of the Spanish Large-Scale Marine Infrastructure SOCIB (Balearic Islands Coastal Ocean Observing and Forecasting System).

Develops Global Capacity and Encourages the Development of the Next Generation of Ocean Scientists, Engineers, and Technologists

We will build a cohort of trans-disciplinary young researchers who will be entrained in using a mix of science and technology from the fields of Integrated multiplatform ocean observation, Artificial Intelligence and Machine Learning, Control Theory, Robotics and Modelling, in the service of understanding coastal ocean processes.