## Design and Implementation of Sensor Networks for the Observation and Research of Harmful Algal Blooms in Southern California Coastal Waters

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Harmful Algal Blooms (HABs) have become an important environmental concern along the western coast of the United States. Toxic and noxious blooms adversely impact the economies of coastal communities in the region, pose risks to human health, and cause mortality events that have resulted in the deaths of thousands of fish, marine mammals and seabirds. One goal of field-based research efforts on this topic is the development of predictive models of HABs that would enable rapid response, mitigation and ultimately prevention of these events. In turn, these objectives are predicated on understanding the environmental conditions that stimulate these transient phenomena. An embedded sensor network (Fig. 1), under development in the San Pedro Shelf region off the Southern California coast, is providing tools for acquiring chemical, physical and biological data at high temporal and spatial resolution to help document the emergence and persistence of HAB events, supporting the design and testing of predictive models, and providing contextual information for experimental studies designed to reveal the environmental conditions promoting HABs. The sensor platforms contained within this network include pier-based sensor arrays, ocean moorings, HF radar stations, along with mobile sensor nodes in the form of surface and subsurface autonomous vehicles. Freewave<sup>TM</sup> radio modems facilitate network communication and form a minimally-intrusive, wireless communication infrastructure throughout the Southern California coastal region, allowing rapid and cost-effective data transfer.

An emerging focus of this project is the incorporation of a predictive ocean model that assimilates near-real time, *in situ* data from deployed Autonomous Underwater Vehicles (AUVs). The model then assimilates the data to increase the skill of both nowcasts and forecasts, thus providing insight into bloom initiation as well as the movement of blooms or other oceanic features of interest (*e.g.*, thermoclines, fronts, river discharge, etc.). From these predictions, deployed mobile sensors can be tasked to track a designated feature. This focus has led to the creation of a technology chain in which algorithms are being implemented for the innovative trajectory design for AUVs. Such intelligent mission planning is required to maneuver a vehicle to precise depths and locations that are the sites of active blooms, or physical/chemical features that might be sources of bloom initiation or persistence.

The embedded network yields high-resolution, temporal and spatial measurements of pertinent environmental parameters and resulting biology (see Fig. 1). Supplementing this with ocean current information and remotely sensed imagery and meteorological data, we obtain a comprehensive foundation for developing a fundamental understanding of HAB events. This then directs laborintensive and costly sampling efforts and analyses. Additionally, we provide coastal municipalities, managers and state agencies with detailed information to aid their efforts in providing responsible environmental stewardship of their coastal waters.

## References

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**Figure 1** Data and sensors of the embedded coastal sensor network. Components include (bottom row from the left) an autonomous surface vessel, traditional sampling platforms (Niskin bottle rosette and sensors), custom buoys for quiescent environments, a Webb Slocum glider (center photo) and ocean moorings (middle right). Data outputs include 2-D and 3-D spatial reconstructions (middle and upper left, resp.) and temporal patterns (upper right) of physical, chemical and biological features.