2.5 Aquatic Observing Systems (AQU)

The overarching theme of the Center's Aquatic application area continues to be the creation and application of a new genre of wireless sensing systems that will provide real-time monitoring capabilities of chemical, physical and biological parameters in freshwater and coastal ecosystems. Temporal and spatial measurements at high-resolution are essential for understanding the highly dynamic nature of aquatic ecosystems and the rapid response of microbial communities to environmental driving forces. Our unique approach to aquatic sensing and sampling, Networked Aquatic Microbial Observing Systems (NAMOS), employs coordinated measurements between stationary sensing nodes and robotic vehicles (surface robotic boats and autonomous underwater vehicles) to provide in-situ, real-time presence for observing plankton dynamics (e.g. chlorophyll concentration, dissolved oxygen), and linking them to pertinent environmental variables (e.g. temperature, light, nutrients, etc.). Sensing and sampling capabilities of the autonomous vehicles are carried out through the development of adaptive protocols, directed through the network. These systems enable the generation and testing of novel hypotheses regarding the processes that control the distribution, growth and demise of aquatic microbial populations.

The primary research foci (Figure 4) within the Aquatic Application during the past year have been: (1) participation in two major collaborative field expeditions to characterize and study harmful algal blooms within the southern California Bight region (Bight '08 Study; with the Southern California Coastal Water Research Project) and Monterey Bay off the central California coast (CANON: Controlled, Agile, and Novel Observing Network, with Monterey Bay Aquarium Research Institute); (2) characterization and analysis of fine- to micro-scale temporal and spatial distributions of chemical and physical parameters in protected embayments of southern California for the purpose of defining the factors controlling the appearance and distribution of algal blooms; (3) establishment of a collaborative regional-scale program for monitoring the occurrence of harmful algal species in coastal waters off southern California; (4) the development of a portable algae µflow cytometer to expedite research in algal studies using microfluid-based and state-of-the-art detection technology, and (5) a risk analysis-based approach to the design of safe paths for Autonomous Underwater Vehicles (AUVs).

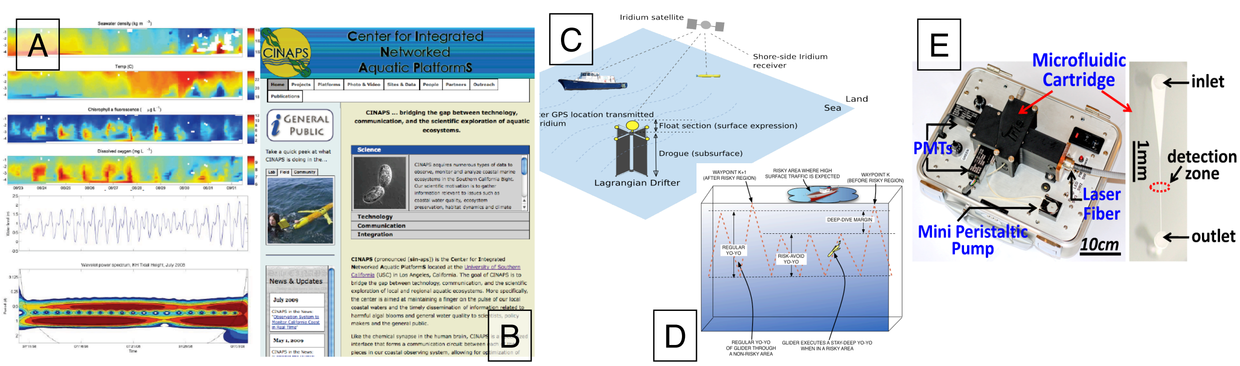

Figure 4: A. Time series of depth-resolved chemical parameters along the coast. Wavelet power spectrum analysis of a tidal record (lower panels) reveals a strong daily and semi-daily periodicity (red bands; bottom panel). B. CINAPS (right panel) is the web portal for the observing systems used for the Aquatic Microbial Observing Systems application. C. Illustration of a Lagrangian drifter being tracked on shore and at sea. D. Glider dive adaptation in risky and non-risky areas. E. The prototype portable algae µflow cytometer.

Research to examine the fine- to micro-scale forcing factors affecting microalgal bloom development in protected embayments have focused on the deployment of sensor networks in marinas within the cities of Redondo Beach and Marina Del Rey. These coastal municipalities struggle to maintain high levels of coastal water quality in the face of an increasing chemical and biological contaminants originating from the activities within their own communities, or via the transport of contaminants from inland sources. Responsible environmental stewardship by these municipalities requires an understanding of the factors affecting local water quality data. Our research efforts in these harbors have involved the deployment of sensing capabilities to support observational and experimental studies of the harmful algal blooms in the harbors, and to examine the complex interactions between physical forcing (e.g. tidal movement, light availability) and microalgal physiology, ecology, and behavior (e.g. photoadaptation, vertical migratory behavior) within these harbors.

Our sensor network research in the open coastal ocean represents a larger-scale implementation of a distributed sensing system to study the environmental factors leading to toxic algal blooms caused by phytoplankton species that produce the powerful neurotoxin domoic acid. This component of the Aquatic Application is being conducted in conjunction with a NOAA-funded Monitoring and Event Response for Harmful Algal Blooms (MERHAB) program entitled Rapid Analysis of Pseudo-nitzschia & Domoic Acid, Locating Events in near-Real Time (RAPDALERT), and involves regional waters districts, ocean observatories, animal rescue and care centers, and other partnerships (see below). Our research applies CENS hardware, software, and overall approaches in the southern California Bight (coastal waters from Santa Barbara to San Diego CA) to characterize these toxic algal events, investigate their causes and establish a causal relationship between toxin outbreaks and mass stranding of marine mammals and sea birds in the region. This project entails a network of coastal sensor buoys and autonomous underwater vehicles. Advancements in vehicle control accomplished through CENS constitute major advancements in our ability to characterize rapidly evolving biological events in the coastal ocean. The work includes the development of algorithms and approaches for transmitting sensed information to shore-based facilities, assimilating the information into predictive models of coastal ocean physics, and using the resulting predictions of feature dynamics to retask the underwater vehicles to optimize their activities (setting new tasks, way points, etc.).

Our web portal (CINAPS: Center for Integrated Networked Aquatic PlatformS) provides an overview of research projects, study site locations, instruments and platforms, partnerships and outreach that encompass our CENS research activities and collaborative programs. Datasets generated by CENS and other research programs are also publicly available for viewing and download.

Knowledge transfer and outreach activities of the Aquatic Application research group have been accomplished through partnerships with local municipalities (Cities of Redondo Beach, Los Angeles and San Diego), regional water districts (West Basin Municipal Water District, Orange County Sanitation District, Los Angeles County Sanitation District), and universities and joint powers agencies concerned with water quality in the southern California Bight. Collaboration with the Southern California Coastal Water Research Project and Southern California Coastal Ocean Observing System (a regional component of the national Ocean Observing System) are being conducted in Spring 2010 as part of an extensive investigation of water quality within the southern California Bight. Our partnership with local municipalities provides these cities with vital information to aid decision making for preventing harmful alga blooms or ameliorating their impact. Finally, we have worked closely with marine animal rescue and care centers (Fort McArthur Marine Mammal Care Center, San Pedro CA; Pacific Marine Mammal Center, Laguna Beach, CA; International Bird Rescue Research Center, San Pedro, CA; Wetlands and Wildlife Care Center, Huntington Beach, CA; Whale Rescue Team, South Bay, CA) to examine linkages between harmful algal blooms in coastal waters and mass stranding events of local marine animal populations. In this role we have provided numerous interviews to newspapers, radio and television, as well as scientific lectures, on the causes and impacts of harmful algal blooms in the southern California region.

We are working on the development of a to portable µflow cytometer that is suitable for in-field monitoring of algal population and reduce test time. Many of today's ocean-observing systems provide only rough proxies for algal biomass (e.g. chlorophyll fluorescence, absorption, or backscattering) and cannot distinguish different species. To solve this problem we build a portable algae µflow cytometer system to provide a precise evaluation of the algal population. The µflow cytometer measures individual algal cells for their size, chlorophyll fluorescence and other biological properties, which is important to distinguish different species, especially to resolve the harmful ones among algal communities. Also, the portable system can be used for constant vigilance in the pre-bloom stage to tie down processes contributing to the increased growth of algae.

The Southern California Bight (SCB) region is home to the ports of Los Angeles and Long Beach which collectively handle approximately 40% of all US container traffic. This large shipping traffic along with a significant presence of smaller crafts in the ocean necessitates careful path-planning to avoid risking collisions with ships while the vehicle is at the surface. All container ships as well as commercial passenger craft are mandated to transmit their locations to VTS terminals nearby to indicate their location, speed and other parameters using the Automatic Information System (AIS). We have analyzed AIS information from 2009 and 2010 for the SCB and use this processed data along with path-planning algorithms to plan missions for the gliders which reduce risk while traveling between way-points chosen for the scientific mission. Finally, we have been working on AUV-based observation in a Lagrangian frame of reference moving with a feature of interest. Often, the only way to understand an ocean process is to acquire measurements at sufficient spatial and temporal resolution within a specific feature while it is evolving. Examples of coastal ocean features whose study requires such techniques include concentrated patches of toxic algal blooms or anoxic patches of low-oxygen that may cause marine life mortality. To study and track such phenomenon, drifters are often used as proxies which are in turn tracked by robotic vehicles such as Autonomous Underwater Vehicles (AUVs). In collaboration with MBARI's CANON initiative we have performed a series of Lagrangian survey experiments carried out with drifter relative AUV surveys.