FROM WIND TO WHALES: USING AN INTEGRATED OCEAN OBSERVATION SYSTEM TO UNDERSTAND CALIFORNIA'S UPWELLING ECOSYSTEM

A 54-month progress report submitted by the Center for Integrated Marine Technologies University of California, Santa Cruz February 2007

Award No. NA160C2936

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Monterey Bay Aquarium Research Institute
Naval Postgraduate School
Moss Landing Marine Laboratories
NOAA National Marine Fisheries Service Southwest Fisheries Science Center
Cornell University
Jet Propulsion Laboratory
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PART 1

BACKGROUND
With increasing human populations, demands on coastal resources are increasing, leading to dramatic changes in coastal ecosystems. Because we rely on the ocean for food, commerce, mineral, and energy resources, as well as for recreation, it is critical that we develop conservation and management strategies that facilitate the sustainable use of marine resources while minimizing impacts on natural systems. A major impediment to achieving this has been a lack of an integrated understanding of the basic processes governing coastal ocean ecosystems.

In an effort to develop this understanding, the U.S. Commission on Ocean Policy recommended that the National Ocean Council make the development and implementation of a sustained, national Integrated Ocean Observing System (IOOS) a key element of its leadership and coordination role (recommendation 26-1). This system should be developed such that it is able to rapidly and systematically acquire and disseminate data and data products to serve the critical and expanding needs of environmental protection, public health, industry, education, research, and recreation.

The IOOS is a system that: 1) is based on sound science and modern technologies, 2) provides timely access to data, and 3) makes effective use of existing resources, knowledge, and expertise (Malone 2001). Malone (2001) proposed that an ICOOS initially develop through the establishment of regional proof-of-concept pilot projects that incorporate existing programs and new initiatives into a coordinated and integrated system. Starting in 2002, the Coastal Observation Technology System (COTS) project funded the Center for Integrated Marine Technologies (CIMT) to develop one of several model demonstrations of regional coastal ocean observing systems based on combined knowledge, expertise, and efforts. In 2003, a regional component of IOOS was initiated (Central and Northern California Ocean Observing System – CeNCOOS) and CIMT joined as a partner in this regional effort.

| Table 1. Proposed core variables for the IOOS (U.S. Commission on Ocean Policy). |
|---------------------------------|-----------------|-----------------|
| **Physical**                    | **Chemical**    | **Biological**  |
| Salinity                        | Contaminants:   | Fish species    |
|                                 | water           |                 |
| Water temperature               | Dissolved      | Fish abundance/biomass |
|                                 | nutrients       |                 |
| Bathymetry                      | Dissolved      | Zooplankton species |
|                                 | oxygen          |                 |
| Sea level                       | Carbon:         | Optical properties |
|                                 | total           |                 |
|                                 | organic         |                 |
| Directional wave spectra        | Contaminants:   |                 |
|                                 | sediments       | Pathogens: water |
| Vector currents                 | Suspended      | Phytoplankton species |
|                                 | sediments       |                 |
| Ice concentration               | pCO₂            |                 |
| Bottom characteristics          | Carbon:         | Benthic abundance |
|                                 | total           |                 |
|                                 | inorganic       |                 |
|                                | Total           | Benthic species  |
|                                | nitrogen:       |                 |
|                                | water           |                 |
| Ice thickness                   |                 | Mammals: abundance |
|                                |                 | Mammals: mortality events |
| Sea-surface height              |                 | Bacterial biomass |
|                                |                 | Chlorophyll-a    |
|                                |                 | Non-native species |
|                                |                 | Phytoplankton abundance |
|                                |                 | Phytoplankton productivity |
|                                |                 | Wetlands: spatial extent |
|                                |                 | Bioacoustics     |

*Core variables measured by CIMT shown in italicized blue.*
A well-integrated interdisciplinary approach offers the best prospect of providing predictions regarding present and future effects of human activities on marine ecosystems. We have assembled a group of physical, biological, and geochemical oceanographers, ecologists, resources managers, and remote sensing experts, together with instrumentation and networking engineers who are working synergistically to develop an integrated Regional Coastal Ocean Observation System (RCOOS). Our unified goal is to create a well-integrated pilot system that will provide novel insights and critical data about the functioning of the California coastal upwelling ecosystem.

In its final report, the U.S. Commission on Ocean Policy proposed a list of core variables to be measured by the national IOOS (Table 1). CIMT currently measures 23 of 36 relevant variables (excluding variables concerning ice). In addition, CIMT measures 13 of 19 provisional IOOS core variables that should be measured by the national backbone for detection or prediction of phenomena of interest. From its inception, the CIMT has sought to develop the resources and technologies needed to: 1) develop an integrated, sustainable system to measure core IOOS environmental variables over the long-term, 2) archive and access these data products using IOOS Data Management and Communication (DMAC) subcommittee data management guidelines, 3) use data products in the development of predictive models to facilitate prognostication of change in the coastal environment with time, 4) identify a broad community of users for measured data products, and 5) create integrated data products that are accessible and understandable to community users. CIMT seeks to explicitly link new technologies across disciplines of marine science to address key questions for environmental protection, public health, industry, education, research, and recreation. CIMT combines emerging technological and data integration approaches to determine the processes underlying the dynamics of coastal upwelling ecosystems, and to investigate the critical linkages between:

- Physical oceanographic measurements of upwelling and surface currents with
- Assessment of the availability of critical nutrients, to determine the extent to which these may be used to predict
- The distribution, abundance and species composition of phytoplankton zooplankton, harmful algal species, and
- The distribution, abundance and species composition of top-level, commercially-important consumers including fish, sea lions, seabirds, sea turtles, and whales.

By using a multi-disciplinary approach, CIMT promises to deliver relevant physical, chemical, and biological ocean information to a diverse array of stakeholders.

The CIMT efforts are focused on the Monterey Bay region of the Monterey Bay National Marine Sanctuary (MBNMS) – from Pt. Año Nuevo on the North to Pt. Lobos on the South out to 122°05’ west longitude. This region roughly encompasses the effects of the Davenport/Año Nuevo upwelling region (Rosenfeld et al. 1994). Monterey Bay is an ideal location for the development of a pilot sub-regional OOS. Presently, there are more
than 20 federal, state, and private academic, research, and resource management agencies and institutions actively involved in studying, measuring, and monitoring the waters in and around Monterey Bay and the MBNMS on an ongoing basis. A number of these institutions have been collectively developing, maintaining, and operating a coastal observing system in Monterey Bay and the surrounding region, delivering data in near real-time, for almost 15 years, and these efforts are becoming increasingly interdisciplinary and multi-institutional.

The California Upwelling Ecosystem
California's National Marine Sanctuaries (Cordell Bank, Gulf of the Farallons, Monterey Bay and Channel Islands) are situated in one of four major coastal upwelling regions worldwide. Coastal marine ecosystems are the world’s most productive - producing nearly 95% of the annual global production of marine biomass (Sherman 1991). While they represent only 0.1% of the ocean surface area, upwelling regions account for more than 21% of the world's fisheries landings (Parrish et al. 1983). In 1996, for example, the landings of commercial fisheries in the California upwelling region totaled 208,440 metric tons, with a wholesale value of $183.7 million. Despite the ecological and economic importance of coastal upwelling centers, we have only a rudimentary understanding of how coastal upwelling fuels the engines of productivity associated with them. Progress in understanding the dynamics of upwelling centers and their associated ecological communities has been hindered as workers in disparate disciplines have failed to coordinate their use of new technologies in interdisciplinary studies of upwelling processes. Understanding the strength of these linkages and the factors that contribute to their variability provides us with the foundation of knowledge needed to predict the impacts of climatic change and human activities on coastal productivity. Developing and integrating the new technologies accomplish this and will serve as a model for ocean observing in all U.S. coastal regions. Coastal upwelling occurs along the eastern margins of ocean basins as winds moving from poles toward the equator act in combination with the Coriolis force to move surface waters offshore and draw cold, deep water to the surface (reviewed by Barber and Smith 1981, McGowan et al. 1996). Upwelled water infuses surface waters with essential plant macronutrients such as nitrate, phosphate, and silicic acid, and this often leads to blooms of phytoplankton, forming the foundation of food chains that support coastal fisheries, seabirds and marine mammals. Along the California coastline, upwelling occurs during periods of strong northwesterly winds and is most intense in late spring and early summer, producing a band of cold water along the coast. This band is typically tens of km wide and separated from offshore warmer water by a series of highly variable jets, plumes and eddies (Strub et al. 1991).

The Monterey Bay Upwelling Region
Monterey Bay oceanography is strongly influenced by this persistent upwelling plume (Pennington and Chavez, 2000; Rosenfeld et al., 1994). During the spring and summer upwelling period, satellite imagery indicates cold surface water originates north of Monterey Bay near Davenport and appears to advect southwards across the mouth of the Monterey Bay as an upwelling plume (herein termed the Davenport Upwelling Plume [DUP] [Pennington and Chavez, 2000]). Presence of the DUP is confirmed by shipboard surveys of both temperature and salinity and direction of flow by drifter releases (Chavez
et al., 1997). During active upwelling, drifters move southwards 20 cm/s. Such plumes are common features of upwelling systems, and typically appear ‘anchored’ to capes, headlands, or other features of coastal topography (Strub et al., 1991). During active upwelling, surface temperature is low and nitrate high in the DUP, but chlorophyll and total production values are typically low. Biomass-specific production rates are, however, high under these conditions (Chavez, unpublished). The low production and chlorophyll values found during active upwelling are apparently due to low phytoplankton biomass of water initially upwelled near Davenport (Service et al., 1998; Kudela and Chavez, 2000). In the northeast corner of Monterey Bay, a seasonal front forms between the DUP and older, upwelled water residing in the wind shadow behind the Santa Cruz Mountains (Graham et al. 1992, Graham 1993). In this portion of Monterey Bay, chlorophyll values are often high but productivity/biomass ratios low (Pennington and Chavez, 2000; Chavez, unpublished), suggesting residence times (2-12 d) are sufficient to allow bloom formation in this area. Southeast Monterey Bay, which is not protected from northwest wind, is likely flushed more regularly by recently upwelled water (Pennington and Chavez, 2000), though temperature and phytoplankton biomass are often higher in this area (Waidelich 1976, Schrader 1981). Much of the productivity stimulated by DUP nutrients is probably advected offshore of Monterey Bay and the continental shelves, as has been found in other upwelling areas (Chavez et al., 1991; Hutchings et al., 1995).

During fall and winter, surface currents are northward both within Monterey Bay (Breaker and Broenkow 1994) and across its mouth (Paduan and Rosenfeld 1996). At this time the DUP is absent and the spatial distributions of surface temperature, salinity, primary production and chlorophyll are more uniform relative to the upwelling season. Recent studies have demonstrated that the supply of iron, a key micronutrient necessary for plant growth, plays a critical role in controlling phytoplankton. The major source of iron to the surface waters of California is iron rich coatings on sediments that are discharged from rivers during episodic winter storms. Paradoxically, there is a temporal mismatch between the winter delivery of iron-rich sediment and spring/summer upwelling. However, the continental shelf appears to act as a trap for the sediments delivered by winter floods. When coastal upwelling occurs in the spring, iron from the shelf sediments are entrained in upwelled water along with elevated concentrations of nitrate and silicic acid. Southerly currents result in the enormous productivity of this region being swept into Monterey Bay (Kudela and Dugdale 2000, Kudela and Chavez 2002). Please refer to the 36 month progress report for a summary of findings during 2005.

**Climatic Impacts on Upwelling Centers**

Adding further complexity to coastal productivity are the influences of climatic events occurring interannually (El Niño/La Niña) and interdecadally (climatic regime shifts). Declines in upwelling, potentially linked to human activities, led to changes in productivity along the West Coast of North America beginning in 1977 (McGowan et al. 1998). However, a strong reversal, associated with multidecadal changes, occurred in the late 1990s (Chavez et al., 2003), making it clear that we need to understand the natural system before we can assess human impacts. Unfortunately, our ability to predict the potential impacts of these events is poor. For example, during the 1997/98 El Niño event,
productivity was generally low in the Eastern Pacific. However, weak upwelling very close to the central California coastline fueled moderate levels of primary production (Kudela and Chavez 2000 & 2002, Chavez et al. 2002). Seabirds and marine mammals that normally range far offshore responded to this climate-induced inshore shift in productivity and were concentrated in very nearshore waters (Benson et al. 2002). In contrast, other animals that rely on the productivity of upwelling centers, such as squid, experienced dramatic declines and fishery collapse. Combined, these new insights indicate phytoplankton production and the distribution and abundance of animals from zooplankton to fish, squid, seabirds and whales may be determined by complex interactions among climatic events, riverine input of iron, and wind-driven coastal upwelling of nutrients.

INTEGRATION OF NEW AND EXISTING TECHNOLOGIES

The CIMT has initiated a new approach to interdisciplinary coastal research by simultaneously collecting and integrating data collected via remote sensing, coastal observation moorings, shipboard surveys, and apex predator tagging and tracking. By utilizing technology on these different platforms, we can examine temporal changes in the Monterey Bay coastal environment using (mooring-based measurements) within local (ship-based measurements) and regional (satellite-based measurements). Individually, each component measures physical, biological and chemical components of coastal processes at specific temporal and spatial scales. Integrated together, they provide the data to develop predictive models across multiple spatial and temporal scales of how marine resources respond to variability in coastal dynamics. CIMT is integrating the measurement of a range of key parameters for understanding coastal dynamics.

Program Management Evolution
It isn’t possible to maintain a program of this scope and diversity without program management. In our initial three years of funding we developed a CIMT Governing Board, which consisted of a lead investigator for each of the major research components (refer to CIMT’s 48th month progress report http://cimt.ucsc.edu/documents/CIMT_48mo_Progress_Report.pdf for past structure breakdown). It was the responsibility of these investigators to coordinate the research within each group, including ship time and sampling, data collection and processing, as well as preparing sections for Progress Reports and Proposals to NOAA.

Beginning in FY06 CIMT has an active seven member Steering Committee that meets monthly via conference calls and on an as needed basis. All CIMT Principal Investigators and participants also meet yearly to present results of their work such that all research teams were aware of the progress, data and conclusions being developed by each group. There is collaboration and integration occurring on an on-going basis. Many of the individuals meet regularly as well to integrate their results, plan for data integration and future data collections efforts (for example, HFR/CODAR and ocean current modeling efforts). The Advisory meetings are open (non-CIMT personnel are welcome to attend), and we have made an effort to ensure that regional representation from groups
(such as CICORE, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and CeNCOOS) outside of CIMT attended these meetings. A CIMT workroom has also been built into the CIMT website. This is a password protected resource allows for CIMT business and resources to be streamlined internally and provides a central location for posting and receiving information, creating ease in this collaborative environment.


**In FY06**

*CIMT Steering Committee:*
Program Manager and Board Chair: Gary Griggs, UCSC  
Ship Surveys/Bioacoustics: Don Croll, UCSC  
Mooring: Francisco Chavez, MBARI  
HF Radar: Jeff Paduan, NPS  
Remote Sensing (including Apex Predator Tagging): Raphe Kudela, UCSC  
Database: Raphe Kudela, UCSC  
Modeling and Forecasting: Chris Edwards, UCSC  
Outreach: Rondi Robison, UCSC

This governing board meets monthly via conference calls. Agenda is distributed CIMT wide prior to the meetings and notes are distributed CIMT wide after calls and posted in the CIMT workroom.

**Advisory Meetings:**
- June 2006  
- TBD

**CIMT Staff:**
- Academic Coordinator: Rondi Robison  
- Graphic Specialist: Laura Beach – half time

**Other collaborations:**
- Surfrider Foundation  
- Central Coastal Long-term Environmental Assessment Network (CCLEAN)  
- Tagging of Pacific Pelagics (TOPP)  
- California Department of Health Services  
- NOAA CoastWatch  
- Monterey Bay National Marine Sanctuary  
- NMFS Southwest Center  
- Naval Research Labs (NRL)  
- California Department of Fish and Game  
- CAL-PREEMPT  
- PISCO

Support provided to Brian Fulfrost of the Environmental Studies Department of UCSC to provide an integrated ArcIMS of CIMT data.
CIMT AND CENCOOS COORDINATION

CIMT is collaborating closely in the development of the CeNCOOS regional IOOS. Since 2003 CIMT has endeavored to provide cogent CeNCOOS committee support. The CIMT Outreach Coordinator was the chair of the End User Committee for CeNCOOS, and at least one CIMT member participated in each of the five CeNCOOS interim committees: Executive (G. Griggs), End Users (R. Robison), Data Management and Communications (J. King), Science (F. Chavez, R. Kudela, J. Paduan, L. Rosenfeld), and Governance and Business Plan Development (L. Rosenfeld, J. Paduan) committees. Many CIMT members participate in quarterly CeNCOOS organizational meetings (June 2004 - present) and provide review of CeNCOOS materials. The following CIMT PIs have or are members of the CeNCOOS Council: Jeff Paduan – served as President of the CeNCOOS Council from December 2005 to January 2007; Francisco Chavez – is acting Vice President of the CeNCOOS Council (December 2005 – present); and Gary Griggs-who has been instrumental in creating CeNCOOS and has been recently elected to the CeNCOOS Council (his one to three-year term begins March 2007).

CIMT has been involved with many aspects of CeNCOOS including attending meetings with Stephanie Watson the former CeNCOOS Coordinator (January 2004 - May 18, 2005) and helping with the transition to the new coordinator Heather Kerkering (August 8, 2005). Robison also provided interim support for CeNCOOS during the two and half months (May 18-August 8, 2005) without a coordinator. Robison acted as the Assistant to the CeNCOOS Coordinator (Heather Kerkering) during the past year (August 2005–August 2006). Robison, working half time for CIMT and half for CeNCOOS, coordinated and/or participated in all CeNCOOS activities and meetings.

CIMT text descriptions and metadata have been provided or entered and updated for several on-going data collection efforts occurring within ocean observing; including COTS, oceanObs (MBNMS/CeNCOOS) www.oceanobs.org, and the SIMoN/MBNMS InfoShare program www.mbnms-simon.org.
PART II

REGIONAL INTEGRATION MECHANISM

During the first six months (August 2006 – January 2007) of FY06, COTS funds provided the opportunity for the continuation of the long-term monitoring of Monterey Bay and the further CIMT support to the Regional Association, CeNCOOS.

CIMT AND CENCOOS COORDINATION

CIMT’s Academic Coordinator, Rondi Robison, continues to collaborate and provide assistance to the CeNCOOS Coordinator (Heather Kerkering).

University of California Santa Cruz (UCSC) collaborators Gary Griggs, Robison, Kerkering, Siri and Lora Lee Martin received a co-award with Communication Partnership for Science and the Sea (COMPASS) to host a Fall 2007 California Current Ecosystem-Based Management (CCEBM) Workshop (funding provided by the David and Lucile Packard and the Gordon and Betty Moore Foundations). Through this workshop, we hope to integrate Ecosystem Based Management (EBM) approaches to our regional ocean observing community and to introduce the EBM community to IOOS.

The Institute of Marine Sciences at the University of California Santa Cruz provides office space and administrative support to Kerkering, and UCSC also hosts the CeNCOOS OceanObs Database Manager, Tom Wadsworth, at the Long Marine Lab facility. OceanObs is a metadata inventory of ocean observing activities in the CeNCOOS region [http://www.oceanobs.org](http://www.oceanobs.org). Wadsworth, Kerkering, Robison and SIMoN/MBNMS Coordinator Josh Pederson meet monthly to maintain and build up and expand OceanObs.

Kerkering and Robison continue to work directly with members of the CeNCOOS Council and the Ocean Sciences Applications Executive Director, Paul Siri, to coordinate with state ocean observing efforts and the state’s Ocean Protection Council. California is unique in that the state has provided $21M in funding for the Coastal Ocean Currents Monitoring Program (COCMP) to install a system of HF Radar instrumentation along the entire coast, using the Regional Associations (both CeNCOOS and SCCOOS) to aid in installation, maintenance, data collection and integration. During the past six months, Kerkering and Robison have met with several IOOS personnel, Paul Siri, SCCOOS staff, the Nature Conservancy, the MBNMS and OceanObs project managers, as well as collaborated with COMPASS on the organization of the CCEBM initiative. Kerkering and Robison continue to work towards meeting the needs of ocean observing outreach in the region. Specifically efforts have been made to develop multi and single page fact sheets that highlight ocean observing activities and other important related issues.

The monthly outlines below include highlights of CIMT and CeNCOOS coordination over the past six-months (August 1, 2006 – January 31, 2007).
**AUGUST 2006**

August 3: IOOS Raytheon Quality Assurance Workshop held at the Monterey Bay Aquarium Research Institute in Moss Landing

August 9, 14, 24: Wadsworth, Kerkering, Robison, Pederson- OceanObs Coordination

August 16: Paul Siri, Heather Kerkering, Maureen Wilmot – Topic CA State opportunities for ocean observing

August 18: Review of CeNCOOS logo sketches with designer

August 28: Scoping talks with Don Croll, Mark Carr, Paul Siri, Heather Kerkering for CCEBM Workshop

August 29: Kerkering, Griggs, Robison, Siri met at Long Marine Lab in Santa Cruz to develop letter of intent to Packard and Moore for the CCEBM Workshop

**SEPTEMBER 2006**

September 16-21: CeNCOOS/SCCOOS Ocean Observing Exhibit at California World Oceans (CWO) in Long Beach California

September 28: CeNCOOS CWO follow-up; Wadsworth, Robison, Kerkering; lessons learned & next steps

**OCTOBER 2006**

October 11: Wadsworth, Kerkering, Robison, Pederson- OceanObs Coordination

October 13: Kerkering & Robison- Outreach Coordination meeting

October 13: Kerkering and Robison meet with Mike Beck of the Nature Conservancy to discuss EBM efforts and upcoming tools workshops

October 24 & 25: Griggs and Robison participate in The Nature Conservancy Ecosystem Based Management Tool Conference, Seymour Marine Discovery Center, Santa Cruz.

October 26: Baldo Marinovic, Robison, Griggs meet with UCSC Interim Chancellor, George Blumenthal to provide briefing on ocean observing activities (CIMT & CeNCOOS) at UCSC and in the region.

**NOVEMBER 2006**

November 1: Wadsworth, Kerkering, Robison, Pederson OceanObs Coordination

November 6-9: NOAA NFRA & COTS workshop Chicago, IL (Chavez & Robison)

November 13: Water Quality data collaboration efforts (Kerkering, Kudela, Robison & Gary Connelly (NOAA NMFS))

November 16: Year 6 (FY07) proposal submitted to NOAA Coastal Services Center (CSC) COTS

**DECEMBER 2006**

December –January (2007)– CCEBM Project Manager search

December 5: Post-award CCEBM planning meeting at UCSC Long Marine Lab; Participants included UCSC/CeNCOOS: Griggs, Siri, Kerkering, Robison;
CIMT AND CICORE COLLABORATION

At some point, we anticipate CICORE (another COTS funded program) and CIMT being organized under the “umbrella” structure of CeNCOOS. To the extent that we can identify areas of mutual interest, potential conflicts, and overlapping products, the easier it will be to make this transition. Importantly, CICORE provided vital interim funding during our one-year gap (FY05) in funding to ensure the continued success of all regional programs. From a regional perspective it is important to identify how CIMT and CICORE compliment and also duplicate efforts. We have had several meetings to discuss collaborative efforts (October 2005 & February 2006) and the CIMT (Robison) & CICORE (Krista Kamer) coordinators held a workshop (August 2006) to identify areas of collaboration and coordination between the two programs. This workshop was supported by the CeNCOOS Governing Council (March 2006).

August 1: CIMT (Griggs, Kudela, Croll, Paduan, and Robison), and CICORE (Kenneth Coale, Rikk Kvitek, Krista Kamer, Toby Garfield, Erika McPhee-Shaw), and CeNCOOS (Kerkering) met at Moss Landing Marine Laboratories. The overall goal for the meeting was to discuss the ways in which the CICORE and CIMT programs differ yet complement each other and to explore ways in which both programs can be leveraged to provide value-added products under the CeNCOOS label.

Noted differences between CICORE and CIMT

- **CICORE**
  - Geographically dispersed
  - Significant in situ component
  - Baseline data of ocean forcing functions
  - Relatively limited field work
  - Collects fewer samples

- **CIMT**
  - More process oriented
  - Physical forcing functions affecting trophic structure of Monterey Bay (MB) region
  - Massive monthly field efforts
  - Better developed analytical component
  - Collects more samples
  - Collects and forwards samples to Department of Health Services (DHS) for analysis
    - Weekly at 3 locations for HAB species
We agreed to move forward with a collaborative product-centralized online distribution of water quality data (bacteria and HAB).

CIMT COORDINATION

Upon notification of the opportunity for continued COTS funding in FY06, CIMT participants met on February 3, 2006 to create a transition plan from FY05 (with limited extramural support) to expanded support in FY06 to best assure that key aspects of the CIMT program are carried through to the award date of August 1, 2006. While funding uncertainty has affected all aspects of the CIMT program, the group has been eager to move forward with a suite of user-driven end products once FY06 funds became available. Below is a brief description, milestones and a calendar outline highlighting CIMT coordination activities from August 1, 2006 to January 31, 2007 (for CeNCOOS related coordination see previous section on CIMT and CeNCOOS Coordination).

CIMT has been monitoring and collecting data in Monterey Bay since its inception in 2002, integrating and extending the existing oceanographic and environmental records for this region. This long-term monitoring is critical to our understanding of the state and health of the marine ecosystem, because it provides a baseline for comparison to more recent data. CIMT's efforts have allowed us to capture an apparent transition in this ecosystem which appears to have shifted in approximately 2005/2006. During Spring 2005, we documented a dramatic delay in the onset of normal, upwelling favorable winds (the spring transition). Because of the delayed wind forcing, there was a subsequent delay in coastal upwelling, primary production and krill recruitment. Because of the interconnected nature of the coastal ocean, this physical perturbation depressed the biological growth of algae (primary production), which resulted in nest failure of seabirds, a depressed abundance in whales, and (potentially) a shift in the oceanic phytoplankton in favor of dinoflagellate blooms. Since 2005, CIMT has documented new/different species of harmful algae blooms in the bay, dominated by dinoflagellates. Thus, our long term goal of connecting wind to whales has provided an important ability to document and evaluate this massive restructuring of the California Current System. See Figure 1.
Figure 1: The ability to monitor the ocean over longer periods helps scientists to document oceanographic shifts because we have been monitoring before and after conditions change. Because of CIMT’s efforts in Monterey Bay over the last five years in addition to data collections preserved through these efforts and the integration of physical, chemical and biological ocean conditions we have been able to begin to describe an oceanographic shift occurring during 2005/2006. The above figure shows (a) temperature, (b)water column stratification, (c)nitrate, (d)chlorophyll, and (e)dinoflagellate concentrations from pre-1990 to 2006. We can see El Nino’s happening in 92-93 and 97-98 with evidence pointing to larger climate shifts from El Viejo (during 98-99) to a La Vieja.
CIMT MILESTONES

CIMT continues to meet milestones (below in bold type from page 31 of FY06 proposal) set out in the FY06 proposal in addition to moving ocean observing system efforts to the next level. Milestones met and additional efforts include:

- **CIMT web site revised** and hired half-time Graphic Specialist to help maintain site – 10/2006
- CIMT representatives Robison, Paduan, Chavez and newly elected Griggs continue to help the governance within CeNCOOS – on-going
- CIMT has developed two fact sheet products toward the education and outreach of ocean observing and ocean issues – on-going
  - HABs [http://cimt.ucsc.edu/factsheets/2HaB_Factsheet.pdf](http://cimt.ucsc.edu/factsheets/2HaB_Factsheet.pdf) -1/2007
- Talks, presentations and posters are listed in the section Recent CIMT publications, Talks & posters. Further outreach and product development
  - EcoReview public TV show – 1/07
  - GIS static images of krill abundance 2003 – 2006
    - 2003 & 2004 expected available on the web in March 2007
    - 2005 & 2006 expected available on the web in June 2007
    - Animation of images expected available on web in June 2007
  - Hindcast animation of sealions as animal platforms (expected mid-2007)
  - State of the Monterey Bay (expected completion mid-late 2007)
    - Report draft complete August 2006
    - Presentation at Sanctuary Currents Symposium March 2007
    - Product output design in process
  - Toxic algal and non-harmful algal species photo library (mid-late 2007)
  - Report to CCLEAN on water quality sampling integration
    - Draft report February 2007
  - Press release on Red Tide events November 2006
- **Continue ship surveys**: 5 of 5 monthly ship surveys have been carried out over the past six-months (8/2006, 9/2006, 10/2006, 11/2006 & 1/2007). In 2007, the ship survey protocols were modified in order to 1) increase efficiency with respect to ship time and 2) allow for opportunist use of the Monterey Bay National Marine Sanctuary’s new oceanographic research vessel. These changes included 1) reducing the survey grid to 5 transect lines and 9 hydrographic stations and 2) conducting the underway transect surveys on either a separate day or a separate vessel than the one used for hydrographic station sampling. The net effect of these changes were a reduction in the overall ship time required to conduct the survey as well as a more efficient use of key personnel involved in the implementation of shipboard surveys. It is important that these changes did not impact the spatial scale of the monthly surveys and improved the synoptic quality of both the underway and fixed observations collected by allowing each component to be collected during one sampling period.
- In addition to the regular zooplankton sampling conducted in the course of scheduled CIMT monitoring, the Marinovic lab has led the engagement in several
collaborative efforts that have taken advantage of archived CIMT samples. These include:

- A contract with the National Marine Fisheries Service – Southwest Fisheries Science Center (NMFS-SWFSC), La Jolla Lab to conduct an analysis of the nearshore zooplankton community structure between 2003 and 2005 in order to characterize the seasonal and interannual prey environment for large scyphomedusa. This project was in support of ongoing NMFS research into the foraging dynamics of leatherback sea turtles within the central California coastal region.
- A cooperative effort with researchers at NMFS-SWFSC, Santa Cruz Lab to examine archived plankton samples collected in the offshore regions of the CIMT survey grid for the presence of humboldt squid (*Dosidicus gigas*) larvae. This is part of an investigation by NMFS to understand the population dynamics of this southern species of squid which has become increasingly more established within the central California coastal region.
- A contract with the Monterey Bay National Marine Sanctuary to characterized the distribution of critical forage (prey) species within the sanctuary’s waters. This includes krill, large scyphomedusae, squid, schooling fishes (anchovies/sardines), and juvenile rockfishes and includes data collected during CIMT sampling activities as well as other cruises conducted within the central California coastal region.

**Summary multi-year HAB and plankton**: Multi-year HAB and plankton data have been summarized – 1/2007

**Real-time composite images** have been established - 1/2007

**Develop HAB warning algorithms**: Progress is being made on the development of HAB warning algorithms – on-going *See Figure 2*.

**CIMT has evaluated the physical model of 2003**: - 8/2006; Efforts are underway to have this model available on the CIMT web site.

**CIMT is currently running the real-time ocean model** [http://ourocean.jpl.nasa.gov/MB06/](http://ourocean.jpl.nasa.gov/MB06/) – 8/2006 The remainder of this process is on-going and next steps include incorporating HF Radar assimilations. Further work is being done to link this model to the CIMT web site.

**Evaluate biological model**: through collaborations with Christine Peterson and Steve Ralston at NMFS the process studies of fish larval are underway and making progress with successful model runs of calculated larval dispersal statistics which can be used to help identify the export out of the region and the connectivity (average transport) from one region to another. Further work is continuing on the model but summary statistics of what is happening in the region are available upon request. We expect further results and outputs in May 2007.

**CIMT wind model has been developed and displayed on CIMT web site** – 2006 and maintenance on-going; CIMT developers are working with CeNCOOS and CIMT coordinators to identify the best long-term home for the product.

**Complete MySQL CTD database & Establish LAS/OpenDAP access**: Database progress has been slowed due to losing our database manager during FY05. Every effort has been made to hire a replacement for this role. Database efforts have been maintained through CIMT PI (Kudela) including up-to-date data
inventory of CIMT ship board surveys in a MySQL database, these data sets are available for download on-line at http://cimt.ucsc.edu/data_portal.htm. Further efforts have been made to maintain the current LAS at http://cimt.ucsc.edu/data.portal.htm through collaboration with Dave Foley at NOAA Coastwatch. In February 2007 CIMT expects to have hired a database contract to help in the evaluation of our current system and to begin implementation of newer standards leading toward visualization out-put.

- **Maintain CIMT/M0:** CIMT’s M0 mooring continues to be maintained and instruments updated – on-going
- Maintenance continues to the Santa Cruz wharf CTD and fluorometer collecting temperature, depth, salinity and fluorescence. – on-going
- **Install dual-freq. SeaSondes:** Dual-frequency SeaSonde was installed in Moss Landing but software for automated, 2-frequency processing is not complete.
- **Transition velocity mapping to COCMP:** This was done; basic hourly mapping is handled exclusively by COCMP technicians while CIMT programming time is being used to develop and test trajectory forecast models and other products based on the data.
- **Test 3-freq wind mapping & Test real-aperture SeaSonde:** Together with John Vesecky (UCSC) and the MCR radar at Long Marine Lab, we will be testing a 3-frequency version of their HF radar-based wind mapping algorithm after the 2-frequency radar in Moss Landing becomes operable. Hence, there has not been any progress on these items during 2006.
- **Test wave mapping & Convert to SeaSonde:** Extensive testing of the CODAR-based significant wave height, peak direction, and peak period detection algorithms is underway using data from 5 CODAR SeaSonde units in the CIMT region and validation data from offshore NOAA buoy 46042, from two shallow water wave moorings, and from wave refraction modeling based on the buoy 46042 observations. Preliminary multi-month wave time series have been produced and the quantitative assessment of the HF radar-derived wave parameters under various wind conditions is underway as part of the UCSC M.S. thesis of Daniel Atwater.
- **Establish real-time QC and data flows:** this part of the CIMT effort was finished up in FY05 with the no-cost extension funds. No further funds in FY06 were dedicated to this piece. Collaboration is currently being done with TOPP to produce a hindcast animation of efforts over three years of COTS support. This will be available on the CIMT web site, anticipated mid-2007.
Figure 2: Working with Rick Stumpf (NOAA), we have been testing similar remote sensing methods to the HAB event early warning system in the Gulf of Mexico for California. To determine the optimal bloom anomaly product, data from the M1 mooring (situated in central Monterey Bay) was used. These data were chosen (rather than satellite data) to avoid biases due to cloud cover, spatial resolution, etc. Data from Nov 1, 2003 to Nov 1, 2004 (upper panel), collected during an oceanographically “normal” time period which exhibited several types of HAB event in Monterey Bay, was used to develop our anomaly product. Based on the time-series data, an optimal bloom anomaly was determined to consist of a 30-day median average stopping 5 days prior to the anomaly period, which consisted of a 5-day median window. Anomalies were considered to be chlorophyll values greater than 2 standard deviations from the annual average.
August 2006
August: CIMT’s JPL partner is running real-time ocean model accessible at http://ourocean.jpl.nasa.gov/MB06/; further development is needed to include HF Radar assimilation.
August: CIMT completed a hyperspectral over flight to calibrate ship survey instruments
August: Robison (CIMT) and Yann Tremblay (TOPP) discussed new technological advances within and across ocean observing programs during an Industry Day event at the University of California, Santa Cruz.
August 14: CIMT Steering Committee Call – Finalize CIMT decision making structure
  o Outcome: Decision Making Structure document
August 28: Review applications for CIMT Graphic Specialist position

September 2006
September 11: CIMT Steering Committee conference call - Updates & upcoming deadlines
September 11-17: Interviews for CIMT Graphic Specialist position
September 16-21: California World Oceans Conference
  o CIMT’s ocean observing activities and collaborations were represented by over seven talks or poster presentation (see recent papers, posters & talks at the end of this section for more information)
September 22: Steering Committee meeting at Long Marine Laboratory, Santa Cruz.
  o CIMT vision exercise for upcoming FY07 proposal
  o Outcome: Summary doc of recommendations made to CIMT

October 2006
October 1: Laura Beach is hired as CIMT Graphic Specialist – half time
  • Responsibilities
    o Product outreach production and design
    o Web site maintenance
October 4: Mike Weise & Robison discuss next steps and collaborations for sea lion animation and product development.
October 9: CIMT Steering Committee conference call – Priorities for FY07 proposal
October: CIMT prepares for upcoming COTS proposal requests
October: Static GIS images showing krill abundance and predicted krill abundance were completed for years 2003 and 2004 in Fall of 2006 and will soon be available on http://cimt.ucsc.edu (March 2006).

November 2006
November: CIMT prepares budget for COTS proposal

December 2006
December 11: CIMT Steering Committee conference call – Updates from IOOS Chicago, IL & Next steps for supporting CIMT/CeNCOOS infrastructure
December 19: Coastal Zone 2007 CIMT Poster Abstract accepted.

**JANUARY 2007**

January 12: Yi Chao, Laura Beach and Robison fact sheet draft on sea level change next steps include coordination with CeNCOOS

January 25 - March: Robison and Beach began CIMT PI meetings
  - Purpose: identify progress, outreach and collaboration next steps
  - Participants through beginning of February: Dan Costa, Mike Weise, Mark Carr, Dan Hoover, Chris Edwards, Raphe Kudela, Baldo Marinovic

January 26: Monterey Bay National Marine Sanctuary Currents Symposium on Ocean Observing Abstract submitted/accepted.

January 30: Public Outreach: The EcoReview live public TV show; Griggs, Kudela, Marinovic, Julie Barrett-Heffington

January: Real-time composite images have been created that prove successful “predicting” capabilities of ID to potential HAB events in Monterey Bay with historical data.

January: Satellite data and seabird observations are being integrated by graduate student Kelly Newton to show mortality patterns of Monterey Bay seabirds.

January: CIMT Harmful Algal Bloom fact sheet released
  http://cimt.ucsc.edu/factsheets/2HaB_Factsheet.pdf

**RECENT CIMT PUBLICATIONS, TALKS & POSTERS:**


Lipphardt, B.L. Jr., A.D. Kirwan, Jr., J.D. Paduan, C.E. Grosch, Variations in surface particle transport in Monterey Bay during summer. 6th International Radiowave Oceanography Workshop (ROW-6), Hotel Lindtner, Hamburg, Germany, 15-18 May, 2006.

Miller, P.E., G.W. Langlois, R.M. Kudela, and M.W. Silver. The California Program for Regional Enhanced Monitoring of Phyco-Toxins (Cal-PReEMPT). 12th International Harmful Algal Bloom Meeting, September 4-8, 2006, Copenhagen, DK.


### BUDGET EXPENDITURES

Table 2: Balance for the University of California, Santa Cruz Center for Integrated Marine Technologies after 01-August-06 to 31-Jan-07

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<th>31-Jul-06</th>
<th>31-Jan-07</th>
<th>Balance</th>
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<td>Staff Salaries</td>
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<td>General Assistance</td>
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<td>Foreign Travel</td>
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<td>Subcontacts</td>
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<td>Participant Support</td>
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<td>$1,497,567.46</td>
<td>$1,338,477.11</td>
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</table>

CIMT’s remaining balance for FY06 is $1,338,477.11. Commentary on expenditures that differ from budget justification submitted with proposal FY06 follow.

- A Simrad EK60 echosounder was purchased at $4896.91 from Simrad Inc. in October 2006 to be swapped out with unit on M0 mooring.
- Graphic Specialist (Staff Research Associate II) has been supported 50% time for four months.
- Coordinator has used travel funds, approximately $1,800 in and around Monterey Bay for CIMT and CeNCOOS related meetings and outreach. Domestic travel was also used by staff and graduate students to attend conferences like California World Oceans (September 2006), EPOC (September 2006) and the NOAA IOOS Coordination workshop in Chicago, IL (November 2006).
- Production of CIMT’s printed outreach materials is approximately $708 as of 1/31/07.
- Foreign funds of $1,167.04 were spent to send a graduate student to Copenhagen to the Harmful Algal Bloom Conference. Retro-active approval is in progress.
- Database manager position was offered as a staff position through the University of California, Santa Cruz. The position was advertised for approximately six months. Only one qualified applicant applied. The position was offered and the position turned down. We have moved forward with contracting out the work needed on the database system. The contractor will begin in February 2007.
- All subcontract have been paid out.
CIMT may request a no-cost extension given uncertain funding conditions for FY07, but we don't anticipate any major changes in goals, outcomes, or personnel.
REFERENCES


