California Coastal Environmental Quality Initiative – Final Project Report:

The University of California Marine Laboratories Coastal Environmental Observation Network

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1. Summary

Through support of this project, the Coastal Environmental Quality Initiative (CEQI) has led to establishment of NEOCO (Network for Environmental Observations of the Coastal Ocean) – a permanent network of 7 sites, each monitoring 5 environmental parameters. This is a statewide, spatially distributed observatory. The data have been and will increasingly be used in many different ways in both local and statewide environmental research and management. Further, these data are readily available to the public through a dedicated website that presents graphics and allows data download.

At present, NEOCO is making the transition from a stand-alone network to being an integral part of the developing regional observing associations, notably the Southern California Coastal Ocean Observing System (SCCOOS) and the Central and Northern California Coastal Ocean Observing System (CeNCOOS). The NEOCO sites will form the core of an array of shoreline observations in the envisaged Californian integrated ocean observing systems.

In addition to establishing the network and kick-starting real-time ocean observing activities statewide, this project has been productive in terms of developing collaboration across UC campuses, recruiting and supporting graduate students in environmental science, continuing the pre-existing 88 year-long daily ocean record, and providing key data to management agencies and ocean users.

2. The Concept and Need for NEOCO.

The aim of this project was to establish a permanent network of automated sensors that will provide a simple but high-quality record of coastal ocean conditions for the next century. It has been designed in a way that minimizes operating costs. Each site is associated with a UC campus to advance local research and education, and, through that, to ensure an ongoing interest in the operation and in the quality of the data.

NEOCO was established and designed in recognition of the following needs:

- The need for long-term, high-resolution data;
- The need for ongoing records at UC marine stations;
- The need for concurrent measurement of physical, chemical, and biological parameters;
- The need for a network of sites;
- The need to link coastal time-series data with oceanic, atmospheric, and terrestrial time-series data.
- The need for real-time access to the data.

The ultimate value of this project will be realized long after the final report, as additional sites are added through SCCOOS or CeNCOOS, as additional parameters are added with the advent of new technology, as long-term data records develop over the next years and decades, and as these coastal records are linked to atmospheric, oceanic, terrestrial, and socio-economic drivers.

In recognition of the importance of long-term records, these high-frequency multi-parameter NEOCO sites were co-located with ongoing or previous long-term records of water temperature (and, in some locations, salinity). In so doing, this project has allowed these historical records to be continued – most notably the unique 88-year record at Scripps Pier.

3. NEOCO Activities

The following are the primary activities completed en-route from project approval to established network.

Instrumentation selection, testing, and deployment.

Initial activity was directed at selecting the most appropriate instrumentation for monitoring nearshore temperature, salinity and water level – and, later, selection of instruments for monitoring nearshore chlorophyll fluorescence and light transmission. Ultimate selections were to use the Sea Bird SBE16 (with pump) for temperature, conductivity (salinity), and pressure and also as a base station for the peripheral fluorometer and transmissometer. Pier mounting, data transmission hardware, power supply, sampling strategy, and fouling control options were tested and improved on Scripps Pier (starting in January 2002). This approach was adopted in the interests of adopting common protocols at all sites. Ultimately, the differences between sites require some difference in sampling protocols (most notably the Bodega site, where there is no pier or comparable mounting structure). Data transmission options include wireless and wire connections.

As in prior tests of optical measurements, like fluorescence and transmissivity (or optical back-scatter), fouling resulted in rapid degradation of the data quality. We

tested a variety of instruments without any notable success in extending the interval between diver servicing of instruments. Ultimate selections were to use standard instruments, i.e., SeaPoint fluorometer and a WetLabs 25cm-pathlength transmissometer. This sequence of frustrating tests of fluorometer, transmissometer, and optical backscatter sensor options took well over a year.

Raw data streams are logged to the memory in a local iPAQ pocket PC, and then transmitted to a stream server at Scripps. Power is supplied via the pier. Backup data logging and power supply are provided by the SeaBird unit.Initial 1-minute sampling was changed to 4-minute sampling as fouling rates and data quality were much improved by sampling less frequently; this allowed for improved anti-fouling action in the pumped system. Mounting designs were altered to allow for simpler diver servicing. Water samples for checks on data quality are conducted independently at each site.

Site identification and permitting.

The general location of sites is determined by the location of UC facilities and nearby piers or comparable structures. While alternatives were considered, ultimately sites were chosen to match up with long-term historical daily data: SIO Pier at La Jolla, Newport Pier in Orange County, Santa Monica Pier off Los Angeles, Stearns Wharf (instead of Goleta site near UCSB), Santa Cruz wharf, and Bodega Marine Lab seawater intake. The intended deployment on the Farallon Islands was not permitted and an alternative historical site was chosen (Fort Point at the mouth of San Francisco Bay). At all sites, permit and liability issues stalled deployments so that many sites were only deployed in 2003. As one example, permitting took well over a year for Santa Monica Pier. The final site (Fort Point) was permitted and deployed only in 2004.

Data transmission and storage.

Data were transmitted from distributed sites to a stream server at Scripps. Here raw data was loaded into an archive database (backup database). Then, following quality assurance checks, voltages were converted into engineering units using appropriate instrument calibrations. Finally, the Scripps stream server autonomously loaded the processed data into the primary production Oracle database at UCSC. Following termination of direct funding for NEOCO, and as part of the transition of this network to developing SCCOOS and CeNCOOS regional associations, the production database has been moved to a machine at Scripps. This entire data system is now under the purview of the systems manager for the Integrative Oceanography Division at Scripps, ensuring regular maintenance and backup.

Website development.

A website, developed at UCSC (http://es.ucsc.edu/~neoco/) allowed review of real-time data and quick plots of recent data, in addition to queries and data download. This web interface is also being moved to a machine at Scripps and should soon be live again at a different address, either as a stand-alone site or as websites within SCCOOS and CeNCOOS. In the interim, the data are available directly from individual investigators at specific sites.

Historical "shore station" sites.

Building on the almost-century-long record of daily data was a significant motivation in developing this project. These data have been collected by volunteers at a score of west coast sites, but the records are threatened by being discontinued, the data quality is unknown, the data frequency is problematic, and the parameter suite is limited. The NEOCO inherited this legacy and worked to sustain it until such time that the NEOCO electronic data sampling could be shown to yield an unbiased continuation of these records. Six of the seven NEOCO sites are at historical sites and the seventh is at the site of a recently

discontinued USGS historical record (Fort Point). In the absence of other funding, the supervision of this volunteer program has been conducted through NEOCO. Recently obtained state funding is now being used to enter these data and to conduct quality checks in anticipation of inclusion of these long-term records in the new NEOCO website(s).

Transition to regional associations.

NEOCO was developed within the context of uncertainty associated with potential national initiatives in ocean observing systems. Amidst too much talk, it made sense to "just do it". The one question was how NEOCO would be operationalized when the time came and whether federal funding would consider a small but existing system as a priority for support. In the end, federal funding was not available for small existing projects and the focus was placed on developing "regional associations". NEOCO investigators have been primary participants in the development of these regional associations and the existing collaborations developed through NEOCO have promoted collaborations between institutions. As the SCCOOS and CeNCOOS associations obtain some modest funding they have been able to plan for inclusion of NEOCO. Thus, at present, the NEOCO database and website are in transition. The individual sites continue under the supervision of individual investigators and through a variety of interim or ongoing arrangements (e.g., the UCSB site is being managed as part of the SBC-LTER program).

Once the transition is complete, NEOCO investigators can return to giving attention to the benefits of a statewide system (even if it becomes administratively separated). In the interim, a number of other NEOCO-like sites have been deployed in consultation with NEOCO (most notably the CICORE sites) and it is expected that these regional associations will advance the integration of all shoreline sites within California. And so, the NEOCO contribution can be expected to grow, albeit under a different acronym.

4. The NEOCO Dividend

Long-term data records.

By definition, it will be a long time before this outcome is realized. However, it is reasonable to suggest that NEOCO has saved the continuity of the pre-existing long-term daily data (88 years at La Jolla, 79 years at Newport, 49 years at Santa Monica, 49 years at Santa Barbara, 34 years at Santa Cruz, and 47 years at Bodega Bay). Further, the concurrent high-frequency sampling is proving invaluable in removing alias effects from historical data due to internal tides in the southern California Bight.

Graduate student research.

NEOCO data is being used by numerous graduate students at UC sites. Being readily available, these data are used as contextual information for many local studies at each site. The following specific examples provide an idea of the diversity of studies for which these data are used:

- Youngsul Jeong (UCI) is an environmental engineer working on the fecal contamination of southern California beaches. He is using NEOCO data to develop an ANN (artificial neural network) approach for determination of the water quality at public beaches in California. At present, public beaches in California are posted as unfit for swimming whenever the concentration of fecal indicator bacteria (FIB) in the surf zone exceeds one of seven single-sample and geometric standards – this protocol is not very effective due to the delay in obtaining test results. Youngsul is developing a method of now-casting coastal water quality so that signs can be posted when water quality is poor and not posted when water quality is good.

- Anna Pfeiffer-Hoyt (UCSC) is developing a description of the hydrography of Monterey Bay using data from NEOCO, CIMT (the Center for Integrated Marine Technology) and AOSN II (the Adaptive Ocean Sampling Network II). NEOCO provides a long-term, spatially limited measurement of temperature, salinity and fluorescence, while CIMT and AOSN II provide short-term, spatially extensive measurements of temperature, salinity, fluorescence and larval abundance. Through working with investigators in the PISCO project, she is relating the mesoscale patterns in hydrography and larval distribution to the recruitment of barnacle larvae.
- Andrew Lucas (UCSD/SIO) is exploring the impact of internal waves in nearshore communities and ecosystems. He is using NEOCO data to examine the temporal modulation of internal wave fields due to forcing, stratification, and low-frequency currents. High-resolution NEOCO data from Scripps Pier is used to examine the high-frequency covariation of temperature with turbidity and fluorescence. This will serve as a basis for short-term process experiments.
- Maureen Martin (UCB) is working on the role of the coastal waters of the Farallons and eastern Pacific on the ecology of Central San Francisco Bay. The recently restarted Fort Point site will provide ongoing data to reference this site.
- Jong Ho Ahn (UCI) is studying the patterns of runoff of storm water via the urbanized Santa Ana River watershed and its impact on coastal water quality.
- Amber Mace (UCD) is investigating the settlement of invertebrates off northern California and relating this to local environmental conditions, which are better indexed by direct measurement of water temperature and salinity than by the broad-brush “upwelling index”.

Other research benefits.

In addition to use of these data by graduate students, many other investigators make use of the combination of high-frequency NEOCO data with historical daily

data. These uses include:

- Comparison of La Jolla NEOCO data with high-frequency records along the San Diego shoreline, and comparison of long-term daily La Jolla data with other long-term stations, to determine what alongshore coherence exists in the temperature signal at what time scales. This study also has practical benefit to NEOCO in that it provides an idea of the alongshore scale over which NEOCO data may be a valid index of nearshore temperature variations.
- Use of La Jolla pier data in NMFS fishery management models for sardine populations in the eastern Pacific.
- Relation of high-frequency data to internal wave activity and the possible role of internal waves in controlling shoreline settlement of invertebrates.
- NEOCO data in Santa Barbara is used in a variety of ways in the studies of larval dispersal, environment fluctuations, and kelp ecology – specifically, these data are integrated into the databases and analyses of both the SBC LTER and PISCO programs.
- Fluorometer data at Scripps and other sites are used as a monitor of phytoplankton levels, with specific attention during late summer and fall when harmful algal blooms may develop.
- Recent high-frequency NEOCO data are being used to add significant value to the long-term daily data as an index of climate change. These high-frequency data allow evaluation of the bias introduced by aliased daily sampling in the presence of internal tide activity.

Education & outreach.

As in research, NEOCO data are used in many ways by ocean users, in education, and in outreach. The data are readily available and use of the data is not monitored. Example uses include:

- The “Diving into Science” (DIS) program. Members of the DIS program from Oakland Unity high school participated in a project with NEOCO scientists.

Students collected underwater water samples to help calibrate NEOCO instruments at the Santa Cruz station: temperature, salinity and chlorophyll *a*. The DIS findings served as ground truthing for this site and have thus contributed to the ongoing NEOCO effort. The opportunity to participate in this project allowed DIS students to know how science is done in the real world.

- Display of NEOCO data at local outreach venues (e.g., aquaria). The UCSB data is due to become part of an exhibit at the Santa Barbara Sea Center when that facility re-opens later this year. Similar plans have been discussed with the Birch Aquarium in La Jolla.
- Use of NEOCO sea temperature data by beach and ocean users. We are aware of wide use of these data in La Jolla and Santa Barbara, but expect that savvy beach/ocean users also use data available from other sites.

Appendix 1. Publications & Presentations.

2002. Wilkinson L., M.M. Dekshenieks, J.L. Largier, L. Washburn, K.D. Stolzenbach, S.G. Morgan, B. Sanders and M. Stacey.
Network for Environmental Observations of the Coastal Ocean (NEOCO).
Presentation at AGU/ASLO Ocean Sciences Meeting, Honolulu, Hawaii.

2002. Largier J.L., M.A. McManus, L. Washburn, S. Morgan, B. Sanders, K. Stolzenbach, M. Stacey, D. Lucas, M. Carter and S. Scott.
Early Results and Historical Data from NEOCO.
Invited presentation at California and the World Ocean Conference. Santa Barbara, California.
Manuscript in press.

2002. McManus M.A., J. Largier, S. Morgan, B. Sanders, M. Stacey, K. Stolzenbach, L. Washburn and L. Wilkinson.
Data Management Techniques for NEOCO, the Network for Environmental Observations of the Coastal Ocean.
Invited presentation at California and the World Ocean Conference. Santa Barbara, California

2002. Palomino E., M.A. McManus, J.L. Largier, L. Washurn, K.D. Stolzenbach, S.G. Morgan, B. Sanders and M. Stacey.
Network for Environmental Observations of the Coastal Ocean (NEOCO).
Eastern Pacific Ocean Conference, Mt. Hood, OR.

2002. Newspaper article in the Orange County Register (16 April 2002).
Sensors will track coastal waters' pulse.
(Journalist: Gary Robbins)

2003. McManus M.A., J. Largier, E. Palomino, L. Wilkinson, L. Washburn, S. Morgan, K. Stolzenbach, B. Sanders, M. Stacey.
Data Management Techniques for NEOCO.
Sea Technology, 44(8), 56-60.

2004. Flick, R.E., L.F. Bargatze, K.Y. Zhang, T. Kacena, M. Carter, J. Largier.
California Shore Station Program and Global Warming.
Headwaters to Oceans (H2O) Conference, Long Beach, CA.

2004. Jeong, Y. and S.B. Grant.
Forecasting beach postings using historical FIB data and real-time measurements of salinity, temperature, transmissivity, water-level, and chlorophyll-a.
Presentation to Orange County Sanitation District.

2005. Pfeiffer-Hoyt A.S. and M.A. McManus.
Modeling the effect of environmental variability on *Balanus glandula* larval development.
Submitted to *Journal of Plankton Research*.

2005. Pfeiffer-Hoyt A.S., M.A. McManus, Y. Chao.
Modeling the Growth, Behavior and Dispersal of *Balanus glandula* larvae within the hydrography of the Central California Coast.
Presentation to be given at American Society of Limnology and Oceanography, Salt Lake City, UT.

2005. Grant, S.B. and Y. Jeong, Y.
Fisher information and analysis of complex environmental signals in coastal water quality monitored at Newport Bay, California.
Presentation to be given at American Society of Limnology and Oceanography, Salt Lake City, UT.

2005. Ahn, J.H., S.B. Grant, C.Q. Surbeck, P.M. DiGiacomo, N.P. Nezlin, and S. Jiang.
Storm water runoff from an urban watershed in southern California: 1. Impact on coastal water quality.
Submitted to *Environmental Science and Technology*.

2005. Largier, J.L., A.J. Lucas, and M.L. Carter.
Long-term observations of ocean temperature along the west coast of the United States, 1916-2001.
In preparation for submission to *Continental Shelf Research*.

Appendix 2. People involved in NEOCO.

Principal Investigators:

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Other Personnel:

Fred Wright, UCSD/SIO

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Vic Chow, UCD/BML

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Jerry Wanetick, UCSD/SIO