Application of the Regional Ocean Modeling System (ROMS) to Water and Sediment Quality Issues in the Southern California Bight

prepared by

The Coastal Center of the UCLA Institute of the Environment

in collaboration with

The Coastal and Marine Geology Program

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Introduction

The purpose of this document is to present in a compact form the capabilities of the UCLA version of the Regional Ocean Modeling System (ROMS), incorporating sediment transport algorithms developed in collaboration with the U.S. Geological Survey, to address water and sediment quality issues in the coastal ocean with particular reference to the Southern California Bight and the coastal region near Los Angeles and Orange County. In the following sections the components of the ROMS model are discussed, including examples of applications. The document concludes with a summary of needs for future model development and potential new applications.

The Regional Ocean Modeling System

Origins of ROMS

The present form of ROMS is an evolution of the S-coordinate Rutgers University Model (SCRUM) described by Song and Haidvogel (1994). ROMS was completely rewritten to improve both its numerics and efficiency in single and multi-threaded computer architectures. It also was expanded to include a variety of new features including high-order advection schemes; accurate pressure gradient algorithms; several subgrid-scale parameterizations; atmospheric, oceanic, and benthic boundary layers; biological modules; radiation boundary conditions; and data assimilation. Currently ROMS does not designate a single model, but a variety of versions developed in an open mode by different institutions. Information on ROMS is available at the official web site for ROMS developers or users (http://marine.rutgers.edu/po/index.php?model=roms&page).

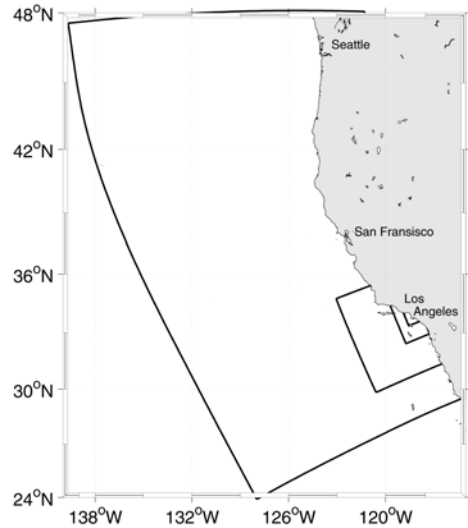

Figure 1: Overview of the US West Coast model grid and the three embedded grids used for the studies in the Southern California Bight.

The version of ROMS described here was developed at UCLA starting in 1997 under support of Sea Grant, EPA, and NSF. Key aspects of the UCLA version related to the fundamental computation of physical variables in the water column have become default features of the ROMS model used by the wider modeling community. Of particular interest in this document are the application of ROMS to the US West Coast (USWC) and including new algorithms for time stepping, tides, trajectory diagnostic calculations, biogeochemical nitrogen, carbon, and oxygen cycles, water quality, and sediment transport. The discussion below discusses the capability of the UCLA ROMS model, but omits the most technical details of the ROMS system, which are presented fully in Shchepetkin and McWilliams (1998, 2003a, 2003b) and Marchesiello et al. (2001, 2003).

The U.S. West Coast Implementation of ROMS

In the United States West Coast configuration of ROMS the domain extends in latitude from the middle of Baja California (28N) to the Canadian Border (see Figure 1). This is about 2000 km alongshore and 1000 km offshore, and it encompasses the California Current System and its most energetic eddy regions. The equations are formulated in three-dimensional curvilinear coordinates that follow horizontally the broad sweep of the coastline and vertically the water depth between the bottom topography and upper free surface (i.e., a so-called sigma coordinate) with a variable sea surface height. The topography of the model is obtained by bi-linear interpolation of the ETOPO2 analysis (NGDC, 1988) and high-resolution USGS data for local subdomains. The local, small-scale dynamics in the Southern California Bight (SCB) are studied using embedded domains (Figure 1).

ROMS Regional Physical Circulation

ROMS solutions have been obtained for the regional physical circulation in the USWC configuration at horizontal resolutions from 20 km to 3.5 km. For the 3.5 km-resolution, a full report of the results, including observational comparisons, is in Marchesiello et al. (2003). Our research has first focused on the structure and dynamical mechanisms of regional and mesoscale physical variability in the California Current System (CCS) in the absence of forced synoptic variability. The surface forcing is by mean-seasonal wind-stress, heat, and freshwater flux derived from COADS (da Silva et al., 1994) **.** The conditions used on the western, northern, and southern open boundaries are a combination of outward advection and radiation and flow-adaptive nudging toward prescribed external conditions (Marchesiello et al., 2001). These external conditions are estimated using climatological data (Levitus et al., 1994) also used for initialization.

Under the influences of mean-seasonal atmospheric forcing and subtropical-gyre open boundary conditions, a robust equilibrium state is established for the CCS on a time scale of a few years. It has mean alongshore, cross-shore, and boundary upwelling currents similar to those estimated from hydrographic climatologies, and it also has vigorous, deep, standing-eddy patterns associated with capes and subsurface ridges along the coast. The annual- and seasonal-mean circulations exhibit strong intrinsic variability, generated mainly by baroclinic instability of the persistent currents except very near the coastline where lateral-shear instability is also important. The variability is primarily mesoscale, geostrophic currents, although there is a non-negligible ageostrophic component in the surface boundary layer and near the coast. The mesoscale synoptic structure is a combination of upwelling fronts, offshore squirts and filaments, and eddies, many of which occur as dipoles with vertically displaced centers (surface cyclones; subsurface anticyclones). At the finest available resolution, the instantaneous pattern of sea surface temperature, SST (Figure 2) shows cold upwelled water near the shore off central California being pulled off-shore in thin filaments and otherwise stirred by the mesoscale eddies to a distance of about 500 km away from the coast.

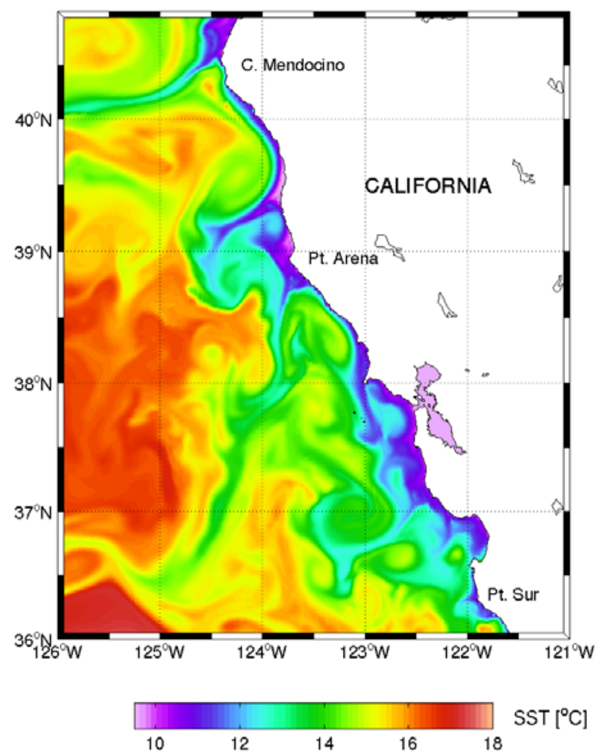

Figure 2: Upwelling filaments in SST (deg. C) in late summer off Northern and Central California from the model with 2.5-km resolution.

Focusing on the Southern California Bight and Santa Monica Bay regions in particular, the model simulations of the equilibrium seasonal cycle show a cyclonic large-scale circulation, which is strongest in summer and fall and centered broadly around San Nicholas. This is also a feature in climatological analyses of hydrological measurements (Lynn and Simpson, 1987). The California Current flows primarily to the east in this region, lying well to the south of the Bight.

Research on the regional physical circulation is now being extended to include forced synoptic and interannual variability. Given that the coastal winds are highly variable, difficult to measure remotely, and important in driving ocean variability, we adopted the optimally blended wind product derived at JPL (Chao et al., 2003) from high-resolution atmospheric models (COAMPS) and from satellite scatterometers (QuikSCAT). To introduce remotely forced, inter-annual oceanic variability, we are using ROMS Pacific basin-scale configuration (at 50km-resolution), which propagates ENSO-like signals through our hierarchy of embedded subdomains.

Nesting Approach in the Southern California Bight

ROMS is discretized on a structured grid, so local refinement can be performed via nested grids (i.e., fixed high-resolution local models embedded in larger coarse-grid models). The interactions between the two components are twofold: the lateral boundary conditions for the

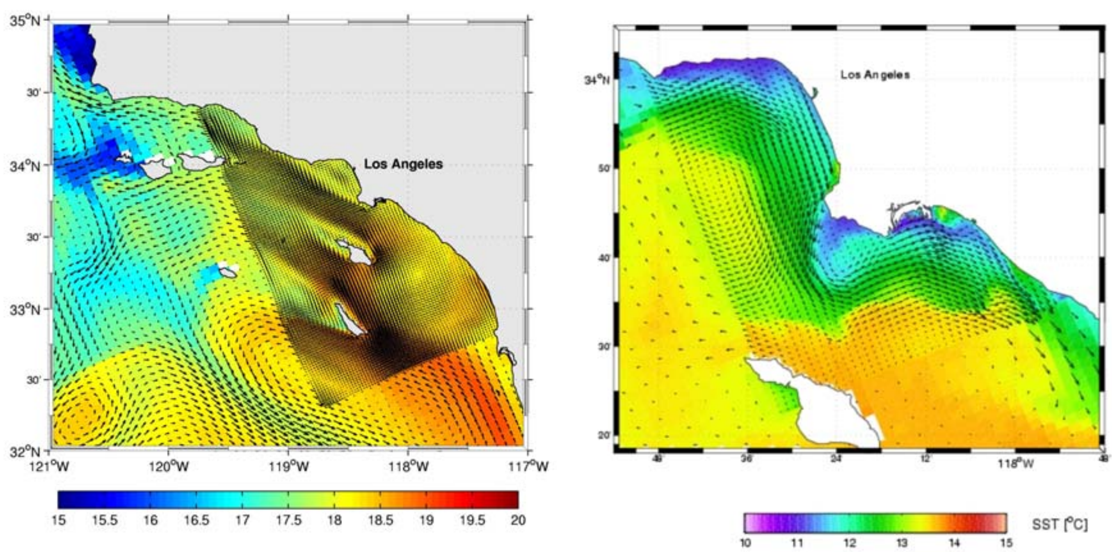

Figure 3: Left: Snapshot of surface temperature and currents on the second and third level grids of the embedded domains for the Southern California Bight; right: ROMS real-time simulation (March 17 2002) of SST (deg. C) and currents (max. vec. = 70 cm/s) on the fine grids of the 4-level embedded domains in Santa Monica Bay. The figure shows a very strong upwelling event observed during 10-18 March 2002 and held responsible for the toxic algal bloom that killed many marine mammals in the area during this period.

fine grid are supplied by the coarse-grid solution, while the latter is updated from the fine grid solution in the area covered by both grids. The method for embedded gridding takes advantage of the AGRIF package (Adaptive Grid Refinement in Fortran; Blayo and Debreu, 1999), which has the ability to manage an arbitrary number of embedding levels as well as to do solution-adaptive grid-refinement.

The local, small-scale dynamics in the Southern California Bight (SCB) are studied using embedded domains. Up to four levels of resolution have been defined: the first level is the 20km-grid USWC domain described above, parent of a second level which is a 6km-grid subdomain of the whole SCB, which in turn is the parent of the third level, a 2km-grid subdomain of the Santa Monica and San Pedro basins, a 600 m-grid subdomain of the Santa Monica Bay (SMB) and the adjacent Santa Monica-San Pedro channels and San Pedro Shelf (see Figure 1). Similar embedded domains have been or are being implemented in Monterey Bay and Imperial Beach near San Diego.

In simulations of the Bight and the Santa Monica Bay region using the embedded-grid hierarchy the instantaneous near-shore currents are dominated by a coastal upwelling, mesoscale eddies, and island wakes in the Santa Monica and San Pedro basins (Figure 3). Note in particular that Santa Monica Bay is not always filled with a single eddy whose direction reverses in time. Rather the region is full of eddies about the same horizontal size as the bay, which move in sequence through the neighborhood.

ROMS Tidal Modeling

For tidal forcing we use data from the OSU TOPEX/Poseidon Global Inverse Solution version 5.0 (TPXO.5). TPXO.5 is a global model of ocean tides, which best-fits, in a least-squares sense, the Laplace Tidal Equations and along track averaged data from TOPEX/Poseidon orbit cycles (Egbert, et al., 1994). The tides are provided as complex amplitudes of earth-relative sea-surface elevation and tidal currents for eight primary harmonic constituents (M2, S2, N2, K2, K1, O1, P1, Q1), on a 1/2 degree resolution grid (Figure 4). These harmonics are introduced in ROMS through the open boundaries using the Flather condition (see Marchesiello et al., 2001). The volume is automatically conserved in the domain and variations due to physical forcing such as tides (but also the other subtidal components) are introduced through the external data.

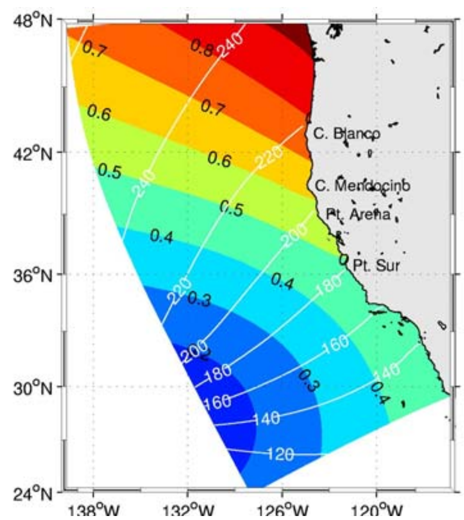

Figure 4: The M2 tidal amplitude and phase used to force the model in the USWC domain.

ROMS solutions with tidal forcing on the USWC domain are directly comparable to TPXO.5. The tidal signal for the region is a well-known mixed (M2+S2/K1+O1), predominantly semi-diurnal tide. Differences between model and data never reach more than a few percent for both amplitude and phase of each components (with maximum errors in the semi-diurnal M2 component), that is on the order of the differences given for TPXO.5 between TOPEX data and the solution for the Laplace Tidal Equations.

ROMS Computation of Biological and Biogeochemical Dynamics

The biological model that we have coupled currently to ROMS consists of a so called Nutrient-Phytoplankton-Detritus-Zooplankton (NPDZ) type model, with a single limiting nutrient (nitrogen) and a single phytoplankton functional type. The model consists of a system of seven coupled partial differential equations that include: nitrate, ammonium, small and large detritus, phytoplankton, zooplankton, and a dynamic phytoplankton carbon to chlorophyll ratio.

Each of these scalar quantities is advected and diffused at rates determined by the physical model. Sinking is allowed for phytoplankton (0.5 m day^{-1}), and the small (1 m day^{-1}) and large (10 m day^{-1}) detritus pools, with most of the vertical transport of particulate mass being associated with the sinking of the larger particles. A unique aspect of the model is that large detritus is created by coagulation of small detritus and phytoplankton, with the expectation that the large detritus sinking velocity is sufficiently high that the effective rate of mass removal from the productive upper layers is determined by the coagulation rate. The sinking particles are remineralized with a first order reaction with rate constants of 0.03 day^{-1} (small detritus) and 0.01 day^{-1} (large detritus), respectively. As we currently don't have an explicit biogeochemical model of the sediments, we remineralize all organic matter that reaches the sea-floor with a first order reaction with a reaction rate of 0.003 day^{-1}.

The expressions relating the flow of nitrogen between the different biological pools are described by equations adapted from the Fasham et al. (1990) plankton dynamics model. The parameters for the model have been set, with minimal adjustment, to represent typical plankton communities in upwelling coastal regions. The model includes explicit treatment of the subsurface light field; it particularly includes the additional attenuation of the downward penetrating light by phytoplankton absorption. The boundary values of all biological state variables are set to zero except for nitrate, for which a climatalogical distribution is used.

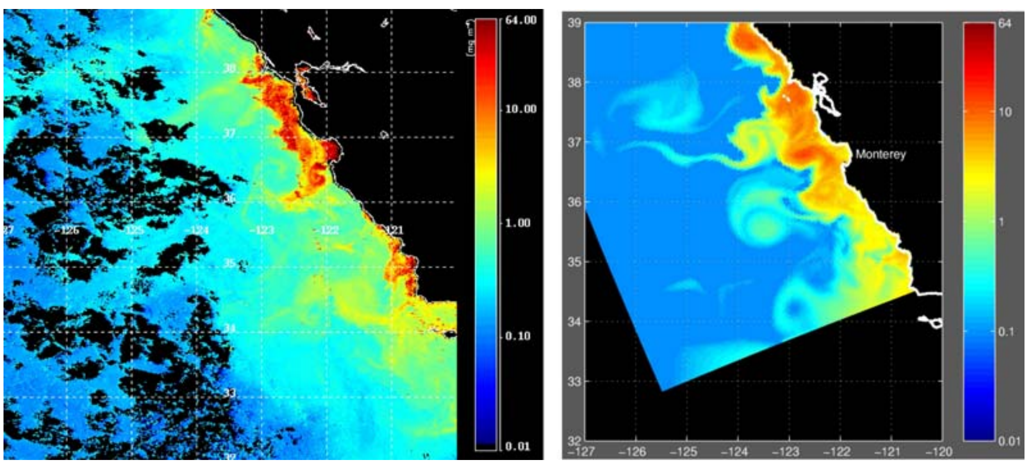

Figure 5: Comparison of remotely sensed (left) and ROMS (right) simulated surface layer chlorophyll in Central California during the spring/summer bloom period (detailed feature correspondence is not to be expected because of the intrinsic variability of upwelling currents. The black regions in the offshore portions of the left figure are regions covered by clouds.

Model runs for a given choice of parameters consist typically of a simulation of ten years of which an average of the last two years are used for comparison with several data sets sea surface temperature and chlorophyll measured by AVHRR and SeaWIFS satellite sensors, respectively, and temperature, salinity, nitrate, and chlorophyll measured by the CALCOFI hydrographic program. Each of these data sets contains multiple years of data used to generate monthly, seasonal, and annual mean values representing the climatology of the upwelling region of the US West Coast.

Comparison of model and data indicates that the combination of the physical and biogeochemical models is capable of replicating many of the essential large-scale time averaged features of the coastal upwelling system. As discussed also in Marchesiello et al. (2001, 2003), the predicted temperature and salinity fields agree quite closely with both horizontal and vertical observed distributions throughout the year. In particular, the offshore scale of the upwelling zone is correctly reproduced. The accuracy with which the physical fields are predicted provides the foundation for generally good agreement between the model and observed averages of biological state variables. The model correctly reproduces the offshore scale of the chlorophyll distribution in surface waters in the upwelling zone (Figure 5).

We have also added recently a full biogeochemical model to this biological model, focusing on the cycling of oxygen and carbon. We coupled these two cycles to that of nitrogen using fixed stoichiometric ratios during photosynthesis, respiration, and remineralization. As the cycling of these two elements include a gas phase, we also added formulations for the exchange with the atmosphere, using a standard bulk parameterization (Wanninkhof, 1992). For carbon, we also consider the formation and dissolution of mineral $CaCO_3$. We thereby assumed that a fixed fraction (0.07) of photosynthesis is associated with the formation of $CaCO_3$, a fraction that is typical for the low-latitude ocean (Sarmiento et al., 2002). The $CaCO_3$ mineral is falling with a sinking speed of 20 m day^{-1}, and being dissolved with a first order reaction using a rate of 0.0057 day^{-1}.

ROMS Computation of Water Quality

For water-quality modeling hydrodynamically passive tracer transport by advection and diffusion can be computed straightforwardly in ROMS. Depending on the choice of the boundary and initial conditions for the tracers, residence times, turn-over times and flushing times of designated subdomains can be determined from these model results to obtain additional quantitative information (Belluci et al., 2001).

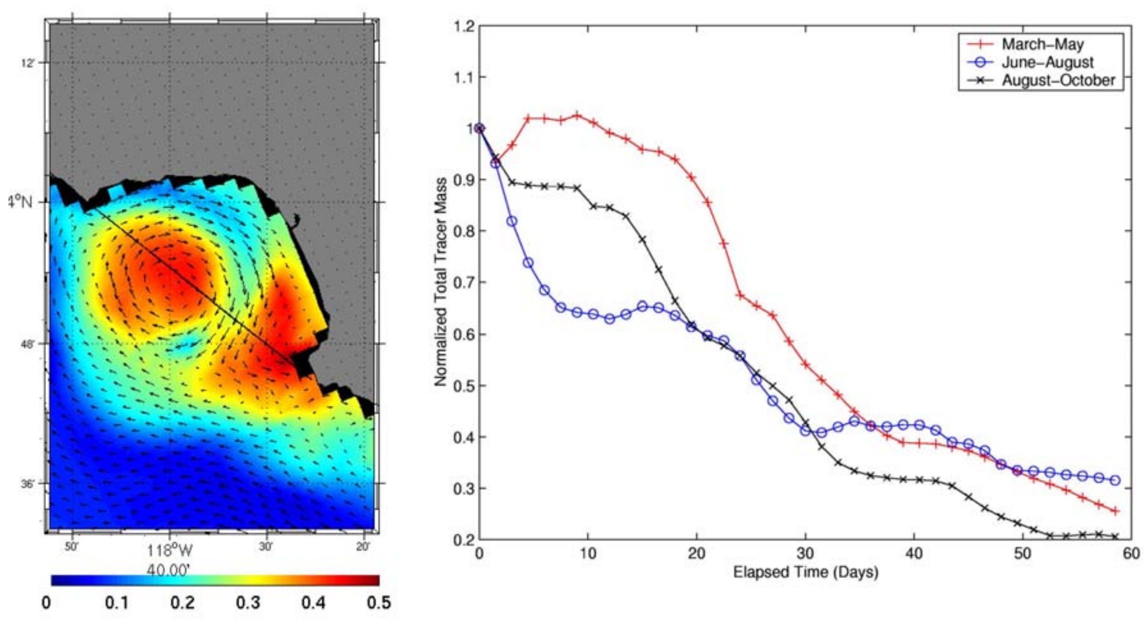

Figure 6: Left - Snapshot of Santa Monica Bay showing the distribution of depth-integrated tracer concentration (arbitrary relative units) following the initial tracer distribution along the coast; Right - Time evolution of volume integrated tracer concentration in the bay (expressed as a fraction of the original tracer mass) for the three tracer release experiments.

We have conducted a set of experiments in which a passive tracer was released on the Santa Monica and San Pedro shelves (all grid points within the 300 m isobath) and its subsequent spreading was tracked. Typical circulation regimes have been selected from the aforementioned multi-year simulations: one in which the flow through San Pedro Channel was equatorward and two in which this flow was opposite (often referred to as equatorward and poleward push (Hickey et al. 2001). During the poleward push a basin-wide anticyclonic circulation cell was present in the SMB, whereas during the equatorward push the flow through the SMB was more laminar. These different flow structures are expected to have a significant effect on the renewal of the shelf waters. To quantify this, the rate at which the total "mass" of tracer is removed from Santa Monica Bay has been calculated as a function of time (see Figure 6) and used to determine an average residence time τ. From this example it becomes clear that the more laminar flow flushed the majority of the SMB relatively efficiently (τ = 12 days) whereas the presence of bay-scale anticyclonic eddies in the other cases cause the renewal to be slower (τ = 22 and 18 days for case 1 and 3 respectively (see Figure 6). Eddies slow down the flushing by retaining the tracer in the domain until they leave the area as whole, then taking the majority of the material with them. The snapshot of the tracer concentration in Figure 6 shows the trapping of material within the eddy at the moment it is about to leave the domain. These results are generally consistent with hydrographic surveys in Santa Monica Bay (City of Los Angeles, 1999) and the study by Hickey et al. (2001). They also point out the importance of both remote forcing enabling the flushing and local eddies that effectively retain material on the shelf. The model allows us to study further the spatial characteristics of the observed disturbances, their generation process and their role in the flushing of the basins.

ROMS On-line Lagrangian Model

In ROMS, the Primitive Equations are solved using spatial discretization where model variables are computed at fixed points (Eulerian approach). However, for physical as well as biogeochemical purposes, a description of oceanic processes in terms of particle trajectories can be very useful (Lagrangian approach). Several algorithms have been developed to compute these trajectories off-line at moderate computational cost. In this case, the velocity field is stored periodically and used after completion of a run to estimate the velocities of the tracked particles. To take fully advantage of our high resolution solutions (which exhibit small-scale structures such as localized fronts and submesoscale eddies), we are implementing an on-line (parallelized) model for computing Lagrangian trajectories. Velocities computed on the ROMS grid are interpolated on-line to provide an accurate estimation of the right-hand side terms. In addition, a random turbulent vertical velocity term is computed to parameterize unresolved subgrid-scale phenomena along the vertical axis (in the horizontal directions, the effect of the subgrid scales is less significant and therefore neglected. Note that the computational cost of the Lagrangian model is very low (e.g. adding a single float is less costly than computing ROMS equations on one grid point in usual model configurations). This technique has been used in preliminary calculations of the sewage plume from the Hyperion treatment plant in Santa Monica Bay (see Figure 7).

ROMS Sediment Transport

Both water and sediment quality in the nearshore regions off Southern California depend in part upon the transport of suspended particulate matter. Resuspension of deposits of polluted

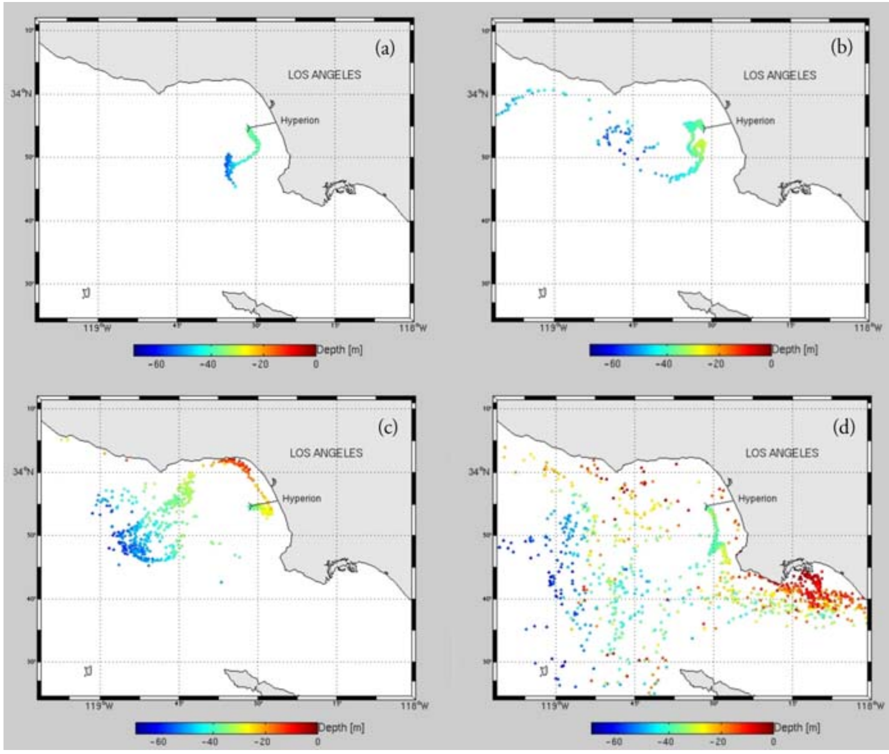

Figure 7: ROMS simulated Lagrangian floats position and depth (color) released from the Hyperion Wastewater Treatment Plant outfall in April 2002. Five floats are released every 10 minutes from the outfall. The locations of all floats remaining in the domain are shown at four times following the start of float releases on April 1: (a) 3 days; (b) 10 days; (c) 17 days; (d) 30 days.

sediments is a potential source of environmental hazard that may extend well beyond the time of initial input.

Various hydrodynamic processes determine sediment resuspension, transport and deposition on the shelf: local swell-waves, tides, internal waves, remote sub-tidal currents etc. Surface waves enhance bottom shear stress and are the dominant factor for resuspension in the Californian waters (e.g., Drake et al., 1985). Near-bottom motion due to tides and internal waves excited by sea-breeze cause initial transport. Sub-tidal currents are most often remotely forced. They are strongly determined by mesoscale eddies and filaments originating from the California Current system. Eddies form coherent flow structures with dimensions similar to the coastal embayments. They propagate through these embayments on a time scale of a few days. Hence, these mesoscale features are potentially effective in redistributing suspended sediments over longer distances.

Recently the scope of ROMS has been extended by the incorporation of suspended sediment transport. Both the sediment transport and water quality modeling use ROMS's reliable tracer transport schemes. Various sediment size classes are modeled by tracers with a specified settling velocity. Within ROMS point sources of tracers such as rivers, outfalls, and dump sites can be defined readily, but the major nonpoint source (or sink) of sediments is the sea floor. The exchange of material between the bed and water column is parameterized according to Smith and McLean (1977) the resuspension flux of noncohesive suspended sediments is proportional to the excess of the bottom shear stress beyond a certain critical threshold value. This is still one of the most widely and successfully applied parameterizations (e.g., see the test of various parameterizations by Garcia and Parker, 1991). A parameterization for cohesive sediments is to be implemented soon. The sediment concentrations are solved using the advection scheme by Shchepetkin and McWilliams (1998) extended with a super-Courant settling routine. The erosion flux depends on the maximum skin frictional stress under combined waves and currents. Bottom-roughness is calculated depending on the local hydrodynamic and sedimentary conditions (cf. Li and Amos, 2001; Harris and Wiberg, 2001). Because of its role in the bottom-sediment flux, accurate determination of the bed shear stress has become even more of an issue. Conditions where currents and waves combine are especially relevant in applications on the Californian Shelves. In addition to the existing wave-current bottom-boundary layer model (Styles and Glenn, 2000) we have implemented a parameterization of lower complexity (Soulsby, 1995), which is computationally less demanding. When using the sediment modules we not only enhance the vertical resolution near the sea surface, but also near the bottom, since the suspended sediment concentration profiles are predominantly confined in the lower part of the water column.

The sediment transport capability is currently being implemented in the Southern California Bight. Two size classes of non-cohesive sediments are considered to represent the fine silt and coarser sand fractions. The sediment-transport calculations are restricted to the innermost model domain to save computational resources. The open boundaries of this fourth domain are located in deep water whenever possible such that vanishing concentrations are a natural open boundary condition. In this region ROMS waves are prescribed using data from an independent swell model that can be initialized by either off-shore wave buoy data or locally observed wave data (http://cdip.ucsd.edu/models/wave.models.html, O'Reilly and Guza 1993). The tidal motion is especially relevant on the shallow shelves and the adjacent canyons. For example, internal tidal motion has been hypothesized as one of the major agents in the resuspension and transport of contaminated suspended matter off Huntington Beach.

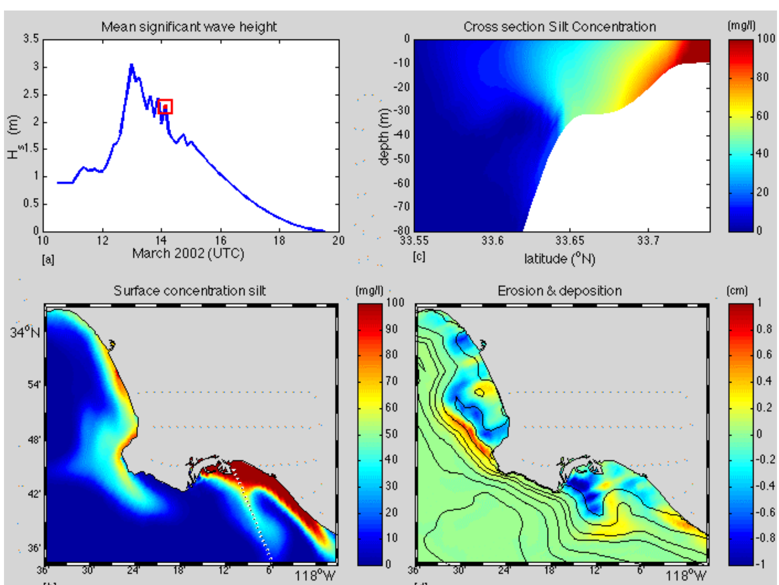

Figure 8. (a) Time evolution of spatial mean of the significant wave height Hs [m] as applied to the innermost model domain in simulation of the upwelling and wave event of March 11-20, 2002; (b) Surface concentration [mg/l] of the fine (silt) fraction of suspended sediment (settling velocity 0.2 mm/s, critical erosion stress 0.1 N/m^2, erosion rate 0.2*10^{-5} kgm^{-2}s^{-1}) on time indicated by red square in Fig. 8a; (c) Vertical transect SE of Palos Verdes peninsula (indicated by the dashed line in 8b) showing silt concentrations at same instance; (d) Change in thickness of the active sediment layer [cm] since the beginning of the wave event.

Figure 8 shows results of a case study in which the sediment transport model has been applied to an event of local upwelling in the central Southern Californian Bight which occurred in March 2002. During the event the significant height (Hs) of swell and locally generated waves in the area increased to values of about twice the average. Because there was no rainfall, this case serves as an ideal example to study redistribution of material already deposited because no significant input of sediment into the shelves is to be expected. Figure 8a shows the time evolution of the significant wave height imposed during the simulation of the event as it has been isolated from preceding and subsequent wave events. The model is spun up from the beginning of March 2002 until the 11th with a constant wave field corresponding to the observed mean. Between March 11 and 15 the actually observed waves have been imposed using the abovementioned model by O'Reilly and Guza (1993). At the end of the event Hs has been tapered to enable study of the eventual settling of suspended matter.

In Figure 8b the surface concentration of the fine grained silt fraction is shown after the peak of the wave event has passed. It is clear that resuspension still occurs on the shallow areas of the shelf. By the time represented in the graph, the material that has been brought into suspension during maximum wave height has been advected offshore in distinct plumes by the tidal and subtidal flow.

A vertical section across the plume SE of Palos Verdes is shown in Fig. 8c. Clearly visible is the increase in concentration toward the bottom. Also clear is that the extent of the plume is larger in the near-surface layer due to higher transport velocities up in the water column.

Figure 8d shows the total accumulation (deposition) and depletion (erosion) of the active sediment layer at the same time instance since the beginning of the event. The areas of erosion are localized in the shallow zones where the waves are most effective in stirring the material. Deposition occurs on the nearby deeper shelf and upper slope west of Palos Verdes and in a wider patch forming the footprint of the plume extending SE of Palos Verdes.

Future Work

Modeling Issues

The modeling examples discussed above clearly demonstrate the potential for UCLA ROMS to address issues of water and sediment quality at a scale of interest to environmental managers. However, the implementation of the finer-scale embedded grids is sufficiently recent that only preliminary calculations have yet been made of important phenomena such as sewage plume dynamics and sediment transport. To realize the full potential of ROMS for these applications, a number of crucial model refinements and extensions must first be made:

- Evolution of the physical transport model to include internal tide generation and propagation, surface gravity wave vortex forces and advective effects, refinement of the algorithm for grid embedding to couple circulations on large and small scales;
- Refinement of the Lagrangian tracking capability to simulate the smaller scale features of sediment and river discharge plumes, such as the initial depth and width of the plume;
- Expansion of the coupling of model calculations with hindcasts or forecasts of wave conditions;

- Evolution of the biogeochemical component of the model to include additional nutrients, plankton groups, and chemical species;
- Evolution of the sediment component of the model to include treatment of cohesive sediments, the dynamics of sediment properties within the bed, and benthic biogeochemical cycling;
- Refinement of the capability for simulating specific events through data assimilation of measurements to provide model initial and boundary conditions;
- Testing of model formulations by comparison of model simulations with observations, including satellite sensing of temperature and chlorophyll, ship-based surveys of water movement, hydrography, and water quality, and moored instrument measurements of currents and sediment transport.

Regional Applications

A major goal of the UCLA Coastal Center is to facilitate the application of ROMS technology to water and sediment quality issues in the Southern California Bight in a way that is useful for environmental managers. Potential areas of application include: sediment transport during high wave events (important for transport of contaminated sediments such as the DDT off of Palos Verdes), onshore transport of treated sewage by internal tides and waves (possibly a key process at Huntington Beach), blooms of toxic algae following nutrient inputs by shoreline sources or localized upwelling, and the response of near shore water quality to storm water discharges following major rainfall events. To the extent possible the model can be applied to problems primarily biological in nature, such as larval retention in local areas and dispersal of exotic species from harbor areas following release of ballast water. To accomplish this, a number of region-specific tasks must be performed:

- Extension of embedded model grids to scales on the order of 100 meters or less to permit adequate resolution of bottom topography and, where necessary, complex shoreline topography typical of harbors and embayments;
- Better resolution of the regional wind field using a combination of local measurements and high resolution atmospheric modeling;
- Development of hindcasts and forecasts of near-shore wave conditions in areas of interest;
- Development of hindcasts and forecasts of hydrological inputs (precipitation and runoff);
- Development of the capability for ROMS to be used to hindcast actual environmentally significant events (upwelling, blooms, spills, runoff, etc.) that have already happened, and to forecast the progression of events in process.

UCLA-Agency Cooperation and Collaboration

To accomplish the regional implementation of ROMS by carrying out the tasks outlined above will require cooperation and collaboration between the UCLA Coastal Center and agencies responsible for managing water and sediment quality. This partnership can take a variety of forms:

- UCLA is in the process of implementing a joint agreement with the U.S. Geological Survey (USGS) to implement and test the sediment transport components of ROMS. This joint effort is being done as a component of the Community Model for Coastal Sediment Transport (see http://woodshole.er.usgs.gov/project-pages/sediment-transport/) supported by the USGS and the NOPP program of the Office of Naval Research and the National Science Foundation. This collaboration will focus on evolution of fundamental algorithms for sediment transport and on the comparison of model predictions with observation of sediment deposition, resuspension, and transport.
- The UCLA Coastal Center is seeking support from local water quality agencies to accomplish the key modeling tasks necessary for model application to regional and local issues. This support will complement other funding being sought from federal agencies such as Sea Grant. However, it is important to stress that, as model evolution becomes increasingly focused on localized water and sediment quality issues, it is correspondingly difficult to obtain support from agencies whose resources are directed toward basic research.
- Ultimately, the Coastal Center envisions a transfer of ROMS modeling technology to appropriate agencies that will then use the model for "real-world" applications involving regional and local water and sediment quality. The Coastal Center would continue to serve as a partner in terms of appropriate technical support, training, and evaluation of results.

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