DEVELOPMENT OF REAL-TIME DATA MONITORING SYSTEM FOR COASTAL MARGIN RESEARCH AND MANAGEMENT

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ABSTRACT

Coastal margins are of enormous economic, environmental, and societal value. However, coastal margin growth, land-use practices, and deleterious anthropogenic and natural processes impact overall coastal margin health. Events such as storms, accidental oil spills, and harmful algal blooms lead to increased water column particle suspension and ecological degradation. An anthropogenic oil spill stresses the biological species present, as the petroleum contamination can travel as slicks and continue as contaminant sources over time. Several state and federal programs address contaminant effect on estuarine health; however, the data monitoring systems currently available are collecting basic trends on sparse datasets and cannot reflect the overall environmental condition of the coastal margin. The desired support system should incorporate scientific, industrial, and other stakeholder needs by utilizing a network of real-time, synthesized sensor data, as no single parameter can accurately relate the overall conditions.

To better understand conditions in the coastal margin, "smart sampling" should be invoked. This combines remote and continuous monitoring with detailed discrete studies during episodic events, such as oil spills. To measure real-time in situ data from the water column, fixed platforms in Corpus Christi Bay include sensors to measure salinity, temperature, and dissolved oxygen, petroleum concentrations, current and wave profiles, and others. The development of sophisticated cyber infrastructure is needed to provide integrated datasets to end users such as research scientists, policy makers, educators, and the general public. This paper presents details on the needed cyber infrastructure, which includes provisions for in situ real-time data acquisition, the capability of transferring very high frequency of data, desired operation and maintenance with minimal human intervention, and highly-flexible, customizable, modular in-house-built software. Expected results focus on integrated information that can be used by coastal region stake holders with confidence in making public policy decisions. Real time data visualization would make it possible to track chemical and oil spills, to detect harmful algal blooms, to monitor ship channels, water level changes, intra-coastal waterways, freshwater diversion, and other human activities.

INTRODUCTION

Our research program stresses sensor development, deployment, and applications for data collection (geo-referenced and time-series), information synthesis, and analysis for integrative predictive whole coastal ecosystem modeling based on in-situ continuous, periodic, and episodic monitoring. To best accomplish this goal, the most promising pathways for incorporating existing and future coastal margins into a cyberinfrastructure-based network that maximizes the effectiveness of collaboration among scientists must be identified. This process supports proactive coastal management decision-making, as well as navigation, recreation, homeland security, and scientific advancements.

EXISTING INFRASTRUCTURE

We are developing/deploying a comprehensive synergistic monitoring suite of sensors that characterizes the physical (hydrodynamics), chemical (such as nutrients, contaminants, etc), and biological (such as phytoplankton) parameters of shallow Texas embayment. To measure real-time *in situ* data from the water column, sensors deployed from fixed platforms in Corpus Christi Bay include instruments that measure salinity, temperature, and dissolved oxygen (Hydrolab by Hydrolab Corporation), current and waves profiles (acoustic Doppler current profiler (ADCP) by RD Instruments), polycyclic aromatic hydrocarbons (Flash Lamp, Flurometer by WETLabs, Inc), oxygen sensor (Optode by Aanderaa), and meteorological (wind, temperature, barometric pressure using a Wind Monitor System by R. M. Young Company) parameters. In addition to deploying instruments on fixed platforms, we have been adding sensor arrays to a geo-referenced boat. These sensors can provide additional information during/after episodic events such as oil spills, storms, harmful algal blooms, etc.

The schematic diagram shown in Figure 1 provides a description of the components required for the computing and communications technology infrastructure (hereafter referred to as cyberinfrastructure) system. The cyberinfrastructure system is designed for *in situ* real time data acquisition with smart sampling, capability of transferring very high frequency of data (through wireless link), operation and maintenance with minimal human intervention with highly flexible, customizable and modular in-house built software.

Also included in the existing infrastructure for coastal monitoring is a number of High Frequency (HF) Radar systems which map water surface currents and directional waves in real-time (Kelly et al., 2003), and can be utilized in modeling contaminant movement in coastal waters(Ojo and Bonner, in review). This radar system provides an invaluable means for collecting real-time measurements of surface circulation patterns, wave height/direction/period, and wind direction within the targeted water bodies. A unique feature of an HF Radar system is its ability to provide real-time measurements over a large area. For example, surface

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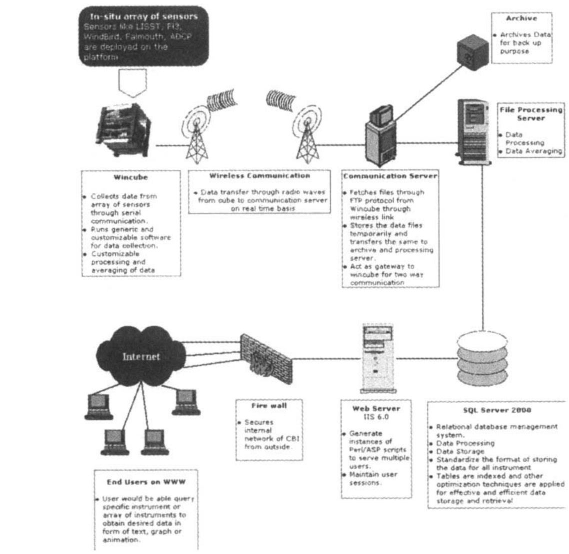

FIGURE 1 SCHEMATIC SYSTEM ARCHITECTURE OF EXISTING CYBER INFRASTRUCTURE AT CONRAD BLUCHER INSTITUTE FOR SURVEYING AND SCIENCE, TEXAS A&M UNIVERSITY-CORPUS CHRIST

currents covering most of Corpus Christi Bay can be measured at nearly 280 locations and on an hourly basis. Figure 2 depicts a snapshot of surface current vectors in Corpus Christi Bay, generated from HF radar data. We are in the processing of extending its radar coverage along the Texas coast. Once an additional site is deployed on/near the Matagorda Peninsula, there will be continuous radar coverage between North Padre Island (Corpus Christi area) and Rollover Pass near Galveston, yielding total radar coverage of approximately 20,000 square kilometers.

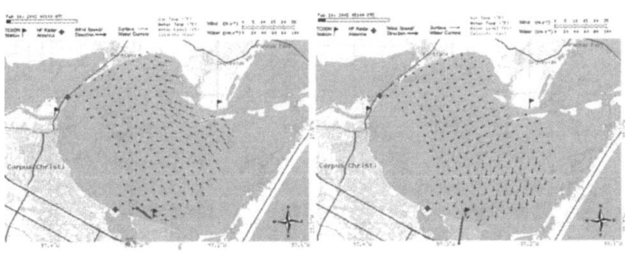

FIGURE 2 OBSERVED SURFACE CURRENTS IN CORPUS CHRISTI BAY. CORPUS CHRISTI BAY OBSERVATIONS SHOWING THE CHANGE IN WIND VELOCITY AND RESULTING SURFACE CURRENTS (SMALL BLUE ARROWS) OVER A TWO-HOUR PERIOD OF TIME. THE LEFT FIGURE OCCURRED AT 3:00PM UTC ON FEBRUARY 10, 2002 AND THE RIGHT FIGURE OCCURRED TWO HOURS LATER.

RESULTS FROM EXISTING INFRASTRUCTURE

This integrated information can be used by coastal region stake holders with confidence in making coastal margin public policy decisions. Real time data visualization would make it possible to track chemical and oil spills, to detect harmful algal blooms, to monitor ship channels, water level changes, intra-coastal waterways, freshwater diversion, and other human activities. For example, HF radar can provide the Texas coastal communities key information for use as a navigation aid for ship traffic, scientific studies of the bays, oil-spill control, and recreational uses. The radar system can report the water currents within ship channels, thereby increasing the available information for marine safety. Data from the radar system is being used further enhance our contaminant transport models (Sterling et al., 2004, Ojo et al., in review) and can improve bay circulation models. The real-time nature of the system will be a major asset in the tracking of oil spills and the determination of the best oil spill countermeasure strategy, such as the location of boom and skimmer deployment, or use of dispersants.

PROPOSED CYBER INFRASTRUCTURE

The need for enhancing our knowledge base on anthropogenically-stressed, large-scale, geographically-distributed systems has never been more evident. Furthermore, the need for interactions and communications among a diverse group of stakeholders, i.e., researchers, educators, policy makers and the affected public, involving such broad and complex systems, provides impetus for a new analytic approach for study and research of theses impacted sites.

In order to achieve the above goals, cyberinfrastructure systems must be fully instrumented for real-time data acquisition, system understanding and information dissemination to all participants. Furthermore, it is important to identify suites of policy decision for problem-driven research at specifically impacted sites via a distributed network which embraces development of tools to capture data, store, distribute and analyze the data.

Schematic system architecture has been depicted in Figure 3. Real-time data is collected through existing cyber infrastructure and stored in a relational database management system. Data mining is one step in the process called knowledge discovery in databases (KDD). The results of the KDD process will provide better data sets to drive predictive modeling, thus providing more valuable information to resource managers, spill responders, and others. Figure 4 provides more details to the steps in the KDD process, which involve data cleaning (where inconsistent data are removed), data integration (where multiple data sources may be combined), data selection (the retrieval of relevant data), data transformation (where data are converted into a form suitable for mining), data mining(the application of statistical methods in order to discover patterns in the data), pattern evaluation (the identification of interesting patterns), and finally, knowledge presentation (the uses of various visualization and knowledge presentation techniques). In a broader sense, however, data mining can be defined as the process of discovering interesting patterns from large amounts of data. After process of data mining, knowledge gaps can be discovered which might require redesigning the experiments and/or modifying existing models, such as predictive oil-spill trajectory models. This process is a continuous process.

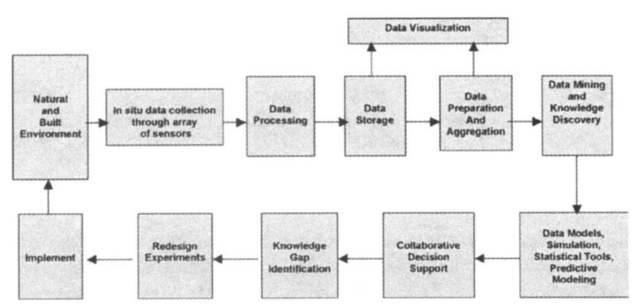

FIGURE 3 COLLABORATIVE CYBER INFRASTRUCTURE FRAME WORK

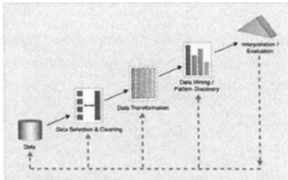

FIGURE 4 STEPS IN KNOWLEDGE DISCOVERY IN DATABASE (KDD) PROCESS (ORIGINALLY PUBLISHED BY ALG, 2003)

VISION

The proposed system is envisioned to be a collaborative engineering analysis network, using high performance tools and infrastructure, to transform our understanding of environmental change in human-dominated systems, and to accelerate development of cyber engineering and the sensor industry. Using a geographically distributed network of sensors and open-access databases, this infrastructure can change forever how researchers collect, model, and interpret information to critically analyze human-impacted environmental systems for sustainability. The primary impediment to analysis of human impacts on the environment, particularly in modeling and forecasting, is the severe lack of appropriately scaled spatial and temporal environmental data, coupled with the lack of accessibility and interoperability of databases for data mining and model testing.

BIOGRAPHY

Kinjal Shah is a Master's student in Industrial Engineering Department at Texas A&M University.

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