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Extending Hydrologic Information Systems to accommodate Arctic marine observations data

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ABSTRACT

The Chukchi Sea Offshore Monitoring in Drilling Area – Chemical and Benthos (COMIDA CAB) project characterizes the biota and chemistry of the continental shelf ecosystem of a region of the Chukchi Sea to form a baseline survey of environmental conditions before drilling for oil commences. This paper describes the COMIDA CAB project data and processing methods, which provide a novel approach to data tracking and archiving from marine sampling cruises. This approach features an adaptation of the Consortium of Universities for the Advancement of Hydrologic Science. Observations Data Model for application with physical, chemical, and biological oceanographic data – a new extension of the CUAHSI Hydrologic Information System – thus bringing hydroinformatics into the oceanographic realm. Environmental sampling has been carried out by five separate scientific teams who characterize particular classes of physical, chemical and biological variables, and who each have their own methods of processing samples in their laboratories following the two sampling cruises made to the Chukchi Sea in the summers of 2009 and 2010. The results of their observations and analyses are stored in data files, mostly in Excel format, whose structure is defined differently by each scientific team. In all, the 2009 and 2010 COMIDA CAB field efforts yielded a database of 510,405 data values. Of these, 474,129 were derived from continuous in-situ data sonde profiles and 36,276 were derived from non-sonde extracted samples of the sediment, epibenthos, and water column. These data values represent 301 variables measured at 65 sites and originated from 26 different source files. The biological observations represented 519 distinct taxa. The data from these files are transformed and synthesized into a comprehensive project database in which a set of standardized descriptors of each observed data value are specified and each data value is linked to the data file from which it was created to establish a chain-of-custody back to the original investigators. The project database is itself further transformed into a file template format specified by the National Oceanographic Data Center.

1. Introduction

The Arctic Ocean is changing. Temperatures are warming and the minimum sea ice extent is retreating (Pachauri and Reisinger, 2007). Changes in the presence and condition of sea ice are stressing some ice-dependent species such as polar bears (Code of Federal Regulations, 2010). On shore, the yield of the Prudhoe Bay oil field has diminished and the Trans-Alaska Pipeline is operating below capacity (American Petroleum Institute, 2009). America's continued thirst for oil and gas has led to an increased desire to explore new offshore sources, including the outer continental shelf regions of the Chukchi and Beaufort Seas off the northwest and north coasts of Alaska. In 2008, the Minerals Management Service (now the Bureau of Ocean Energy Management) generated $2.6 billion in high bids for 488 blocks under Lease Sale 193 (Minerals Management Service, 2008, 2008b). The Chukchi Sea Offshore Monitoring in Drilling Area: Chemical and Benthos (COMIDA CAB) project was initiated in 2008 to be a robust, comprehensive effort to characterize the lease area biota and chemistry, to conduct a baseline assessment of the continental shelf ecosystem via ship-based physical, chemical, and biological sampling of the benthos, and to develop a workable food web model.

The COMIDA CAB effort involves seven Principal Investigators hailing from five universities and one Contracting Office Representative. Over two field seasons aboard the R/V Alpha Helix (summer 2009) and the R/V Moana Wave (summer 2010) in the northeastern Chukchi Sea, the project team collected diverse observational data from multiple instruments and sensors, in varying sample media, across varying spatial and temporal scales, in the broad disciplines of physical, chemical, and biological oceanography. In all, a total of 48 stations were occupied in 2009 and 44 in 2010 including 27 stations which were reoccupied

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for quality control and time series comparative purposes (Fig. 1). One operational goal for this project is to establish an environmental baseline so that "undisturbed" conditions can be described prior to the commencement of oil drilling activities. This necessitates the compilation of information from the project into a database synthesized in a uniform way across the study area rather than having just the original investigator files.

As can be expected from such a multi-disciplinary effort, data management is an important and challenging task. The COMIDA CAB project includes a dedicated, ship-board data manager to provide real-time, field-based data services and Geographic Information System (GIS) support. Project data management is accomplished via the SQL/Server relational database and the Observations Data Model (ODM) relational database schema (Fig. 2). The ODM originates from the Consortium of Universities for the Advancement of Hydrologic Science – Hydrologic Information System (CUAHSI HIS), a National Science Foundation-supported cyberinfrastructure project for the hydrologic sciences, used extensively for storing observations of the physical, chemical, and biological components of the water environment (Horsburgh et al., 2008; Maidment, 2009).

Actively managing data during the project is not enough, as an interdisciplinary project of this magnitude and scope produces a wealth of information and represents a significant research investment. Effective project data management must include public outreach, data sharing, and data archiving both during and after the life of the project. As such, a secure, web-based system was developed for observational data storage (via the Integrated Rule-Oriented Data System (iRODS) (Rajasekar et al., 2006)), geographic data storage (via the ArcGIS Online community), document sharing, and public outreach.

Thus, the objectives of this paper are, broadly: to present an approach to making observations of the ocean environment, to put forth a methodology for organizing and storing these observations, and to offer various avenues for communicating scientific results widely via the use of open standards. This paper presents an adaptation of the CUAHSI Observations Data Model for application with physical, chemical, and biological oceanographic data – a new extension of the CUAHSI Hydrologic Information System, and thus brings hydroinformatics into the oceanographic realm.

2. The nature of oceanographic data

Ocean science is multi-disciplinary and conducting ocean research is logistically complex. While remote and satellite-based sensing are common in physical oceanography, chemical oceanography and marine biology largely require in-situ field sampling. Researchers across the globe are connected by a common interest in many of the same questions in many of the same oceanic regions so it is important that data from individual cruises are stored and made permanently accessible. Many parallels exist in collecting, organizing, and storing data for freshwater and marine ecosystems, and though the organisms observed may differ greatly from land to sea, many of the same collections-based principles apply. Some differences exist, however, with respect to biological data management for freshwater versus marine systems.

From a geographic perspective, freshwater systems focus on a waterway (e.g. river, stream, creek, lake, pond, or reservoir) with observations made at point locations, such as at gaging stations, grab sample locations, etc. Marine systems often feature a much broader physical area with sampling performed in a much more

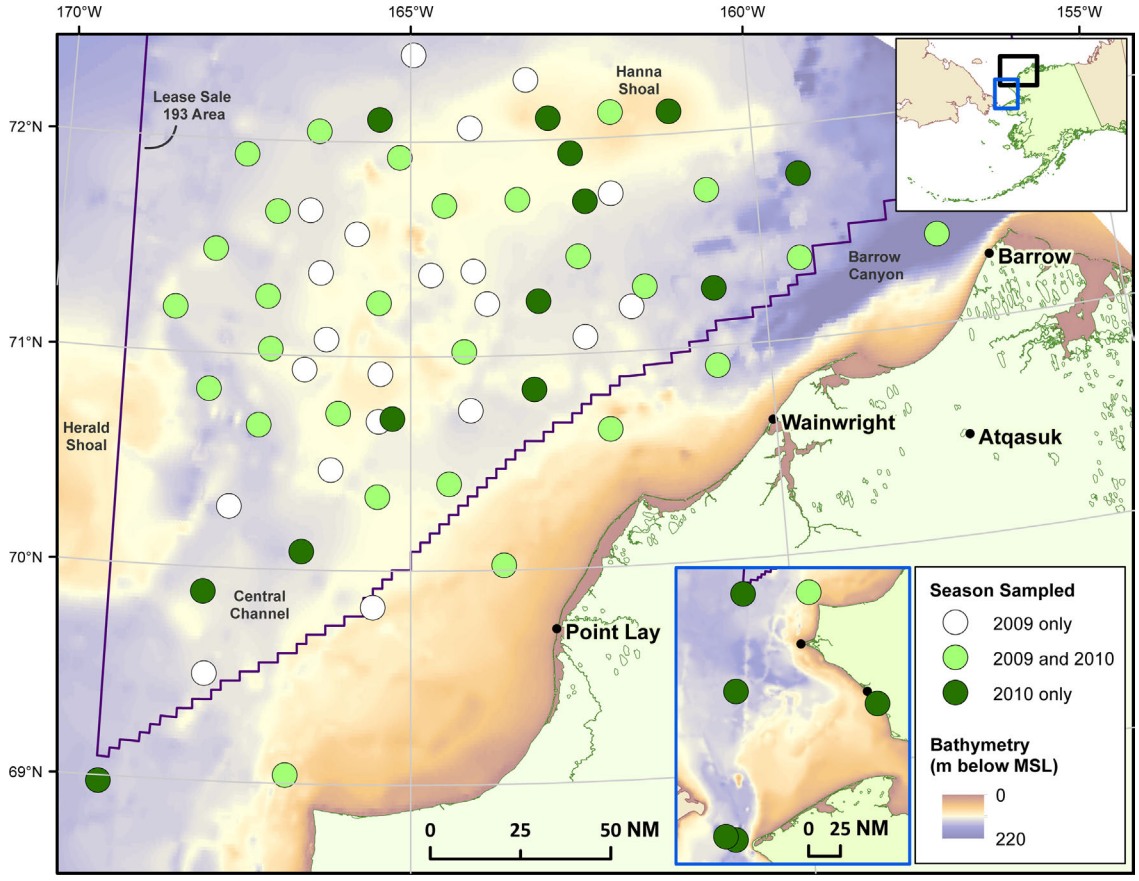

Fig. 1. Stations occupied during the 2009 and 2010 COMIDA CAB field seasons in the Northeastern Chukchi Sea, Alaska.