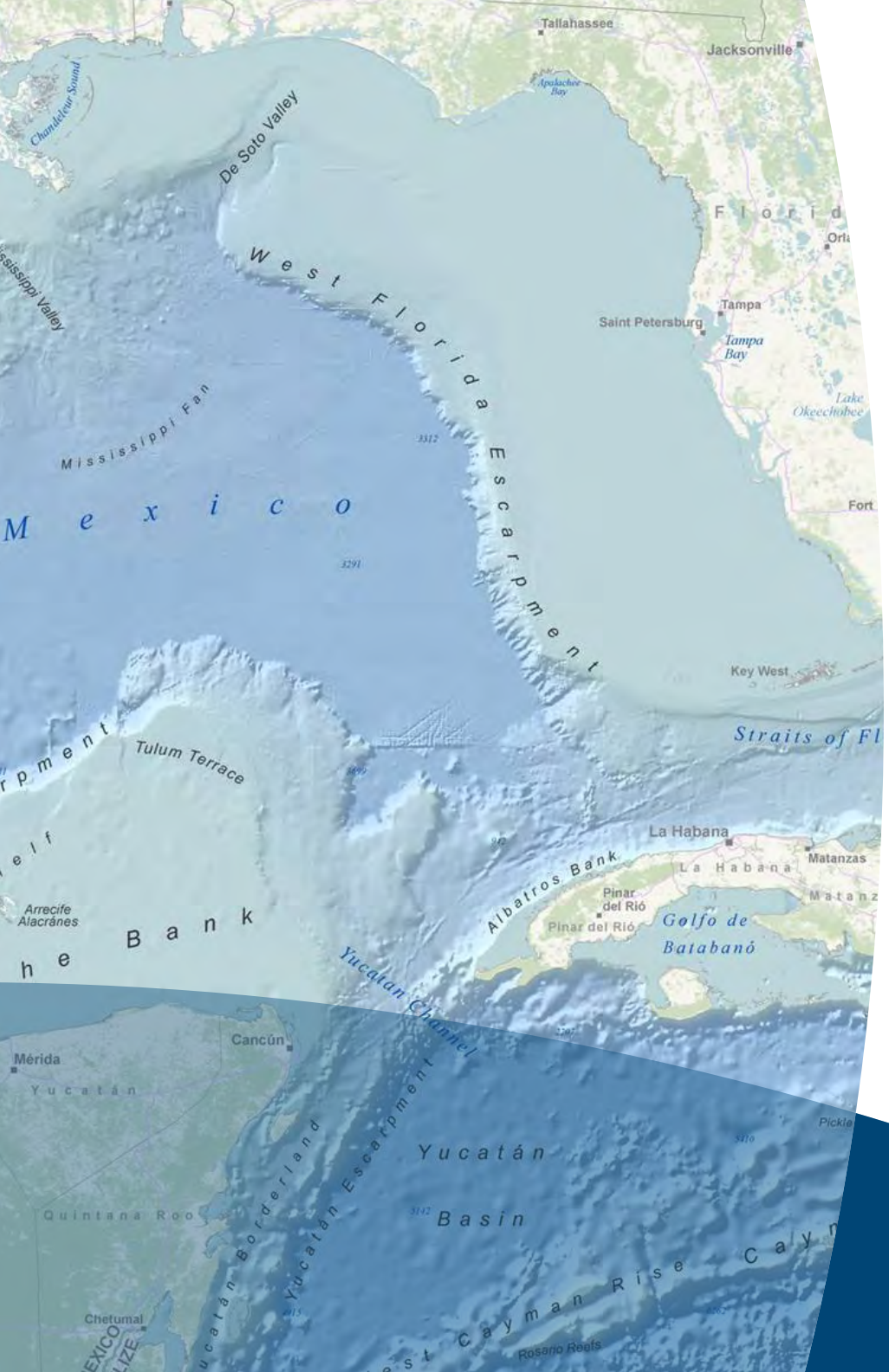

July 2013, Second Edition

The Ocean GIS Initiative

Esri's Commitment to Understanding Our Oceans

By Dr. Dawn J. Wright, Esri Chief Scientist

esri®

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Introduction

On a planet where 71 percent of the surface is covered by water, the oceans are critical for life itself. They feed us, regulate our weather patterns, provide over half the oxygen that we breathe, and contribute to our energy and economy.

An estimated 350 million jobs globally are linked to the oceans. One billion people living in developing countries depend on fish as their primary source of protein. The oceans are also critical to national defense and military security.

There is five times more carbon stored by coastal habitats than by tropical forests. But there is also five times more pollution in the oceans now due to agricultural runoff than there was in 1960.

Eighty-five percent of the world's fisheries are categorized as either "fully exploited," "overexploited," or "depleted." Ninety percent of the big fish in the oceans are gone.

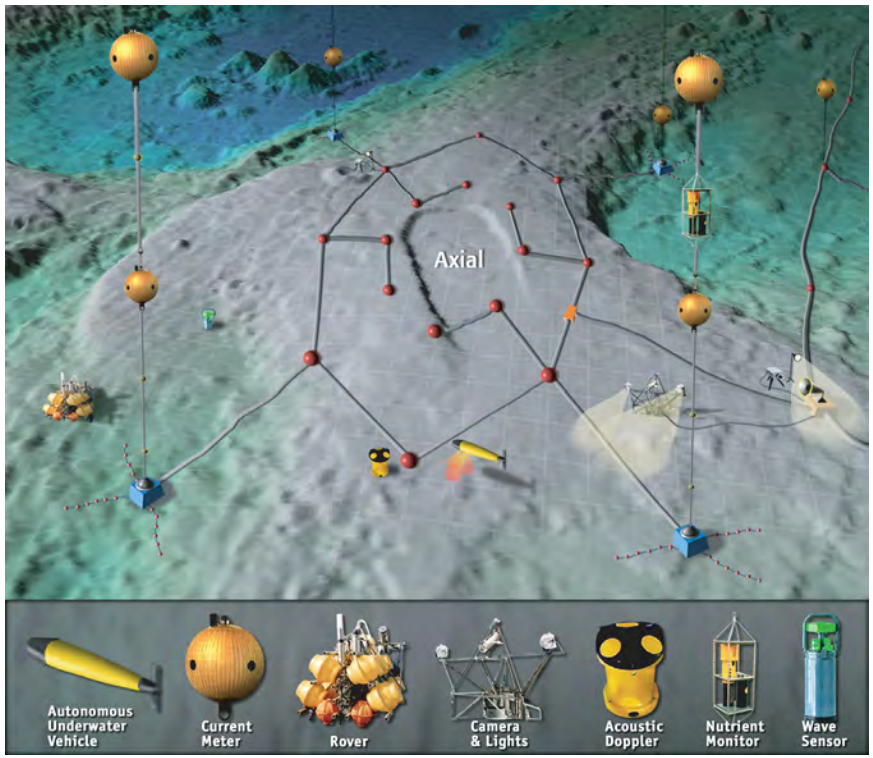
Climate change threatens coastal communities worldwide.

Less than 2 percent of the oceans is legally protected in parks and reserves, compared to 12 percent of land areas globally.

Only 5 to 10 percent of the ocean floor and the waters beneath the surface have been explored and mapped in a level of detail similar to what already exists for the dark side of the moon, for Mars, and for Venus.

Understanding Our Oceans

Geographic information system (GIS) technology, which has long provided effective solutions to the integration, visualization, and analysis of information about land, is now being similarly applied to oceans. In recent years, our ability to measure change in the oceans (including open ocean, nearshore, and coast) is increasing, not only because of improved measuring devices and scientific techniques but also because new GIS technology is aiding us in better understanding this dynamic environment. This domain has progressed from applications that merely collect and display data to complex simulation, modeling, and the development of new research methods and concepts.

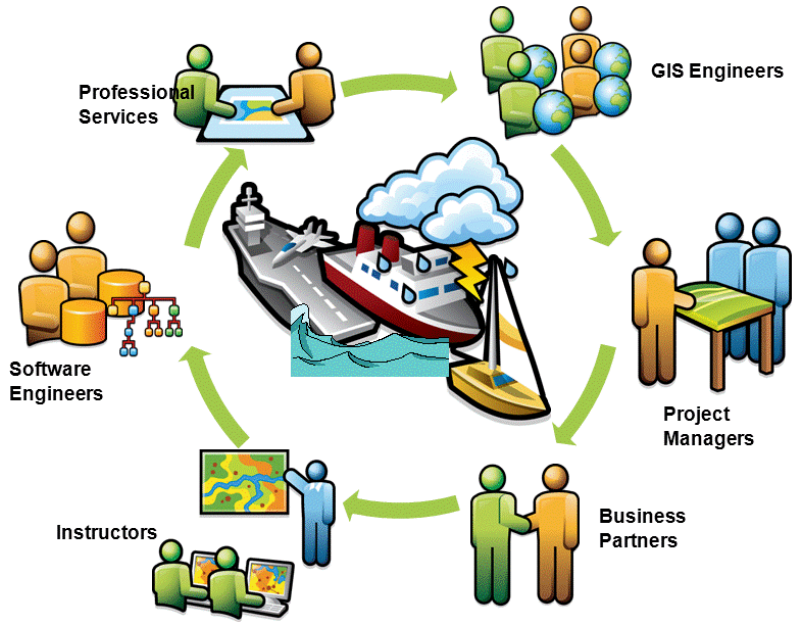


The amount of data being collected about the oceans presents a grand challenge.

The Ocean GIS Initiative

The news is replete with stories of the hazards of hurricanes, tsunamis, sea-level rise and coastal flooding, shark attacks, toxic spills, oxygen-poor "dead zones," and even modern-day pirates. The oceans can be a dangerous place, and mitigating these dangers requires a commitment to science-based understanding.

As an organization with the mission to inspire and enable people to positively impact their future through a deeper, geographic understanding of the changing world around them, Esri recognizes that this understanding must involve a strong **commitment to the oceans**. In 2012, Esri launched an **Ocean GIS initiative** across the entire organization to enhance our capabilities to support GIS in both coastal and open ocean applications. The team supporting this initiative is composed of project managers, GIS software engineers, product engineers, account managers, industry solutions (marketing) managers, distributors, and our federal science team.



The Esri ocean GIS team.

The Ocean GIS initiative has also been motivated in great part by the need to provide effective mapping tools and techniques to respond to recent disasters such as the Deepwater Horizon oil spill in the Gulf of Mexico and the Tohoku-Oki earthquake and tsunami in Japan. Further, it is motivated by a sincere desire to assist in the implementation of the US National Ocean Policy, particularly in the area of coastal and marine spatial planning (CMSP), for which GIS provides a crucial decision support engine.

As part of this initiative, Esri is expanding from an initial emphasis on nautical chart production and applications for commercial shipping, maritime defense/intelligence, and offshore energy (e.g., oil and gas, wind energy) to ocean science and resource management. Esri is pursuing a greater engagement with the ocean science community, as complex ocean data is increasingly used to inform the responsible use and governance of the oceans, as well as effective management and conservation.

Although Esri's engagement with coastal and ocean resource managers and conservationists is deep and will continue, inconsistencies in ocean data models, formats, standards, tools, services, and terminology exist and will be addressed by the initiative. In addition, a paradigm shift is driving an evolution from desktop and server enterprise solutions into a Software as a Service (SaaS) model in the cloud, and the Ocean GIS initiative builds on this important shift.

Areas of Focus

Esri's Ocean GIS initiative is developing mapping and spatial analysis tools, geospatial data, associated resources, and engagement with the oceans community in five main areas:

- Research and Exploration
    - Seafloor mapping and sampling, geomorphological studies, and tectonophysics
    - Benthic habitat mapping for estimating species abundance, identifying essential fish habitat, and ultimately conserving sensitive or endangered areas
    - Shoreline analysis, including calculation of rate-of-change statistics from multiple shoreline positions to analyze historical shoreline change
    - Climate change, including measuring or simulating the potential impacts of sea-level rise on shorelines and wetlands, impacts of storms due to increasing ocean temperatures, impacts to ecosystems due to increasing ocean acidification, and global energy transfer
    - Hazards, including the analysis of risk and potential loss of buildings and infrastructure due to hurricane winds, coastal floods, tsunamis, and nearshore or onshore earthquakes

- Ecosystems and Environment
    - Coral reef health and structure, mangrove assessment, estuary restoration, interaction of coastal ecosystem services, and management of seascape to optimize services
    - Coastal and pelagic animal tracking and marine mammal genomics
    - Marine debris mapping and tracking, especially in situ, as small plastics are not detectable with satellite imagery
- Coastal Protection and Marine Spatial Planning
    - National Ocean Policy Regional Ocean Partnership mandates
    - Marine protected area design and designation
    - Offshore wind, wave, and tidal energy development
    - Beach and recreational fisheries access
- Fisheries and Aquaculture Management
    - Mapping of US fishery management plans and boundaries of groundfish essential fish habitat
    - Analysis of trends in nearshore and estuarine capture of fisheries globally
    - Aquaculture optimization and permitting
    - Fish habitat and distribution for quote-based management systems
    - Aquaculture-related disease and value tracking
    - Analysis of fishery closure areas, protected resources, Gulf Coast Environmental Sensitivity indexes, at-risk species, and federal status to illustrate some of the environmental impact of the 2010 Deepwater Horizon oil spill
- Recreation and Adventure
    - Professional and amateur boat racing, voyages for various causes, and ocean-based sporting events that can benefit from live, map-based tracking of assets and participants
    - Crowdsourced data from recreational vessels

Projects

Esri is already engaged in a wide variety of projects supporting the Ocean GIS initiative. Some of these are highlighted below.

The Ocean Basemap

On World Hydrography Day 2011, Esri officially released the world's first ocean basemap on ArcGIS Online. The focus of the basemap is to provide the best possible cartographic representation of authoritative bathymetric data, as well as ocean floor feature names; water body names; and, in certain regions, derived depth values in meters. Release of the Ocean Basemap represents a crucial first step in the establishment of an ocean GIS.

A variety of authoritative data providers have already contributed several thousand datasets to the Ocean Basemap project, with grids ranging in resolution from 1 km all the way down to 50–100 m in limited areas. Chief among the contributors is the General Bathymetric Chart of the Oceans (GEBCO), an international consortium operating under the auspices of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization (UNESCO).

GEBCO provides the world's most trusted publicly available 1-km-resolution bathymetry data, as well as a complete gazetteer of global ocean floor feature names. Other authoritative providers include the National Oceanic and Atmospheric

The Esri Ocean Basemap, initially released in 2011, is now comprised of thousands of bathymetric datasets from the ocean community, with new data being continually added.

Administration (NOAA); the Canadian Hydrographic Service; the Seafloor Mapping Lab of California State University, Monterey Bay; the University of New Hampshire Center for Coastal and Ocean Mapping (UNH-CCOM); Oregon State University; the National Geographic Society; the Khaled bin Sultan Living Oceans Foundation; the National Institute of Water and Atmospheric Research (NIWA) of New Zealand; the Government of Ireland (Marine Institute and Geological Survey of Ireland); DeLorme; NAVTEQ; and Esri.

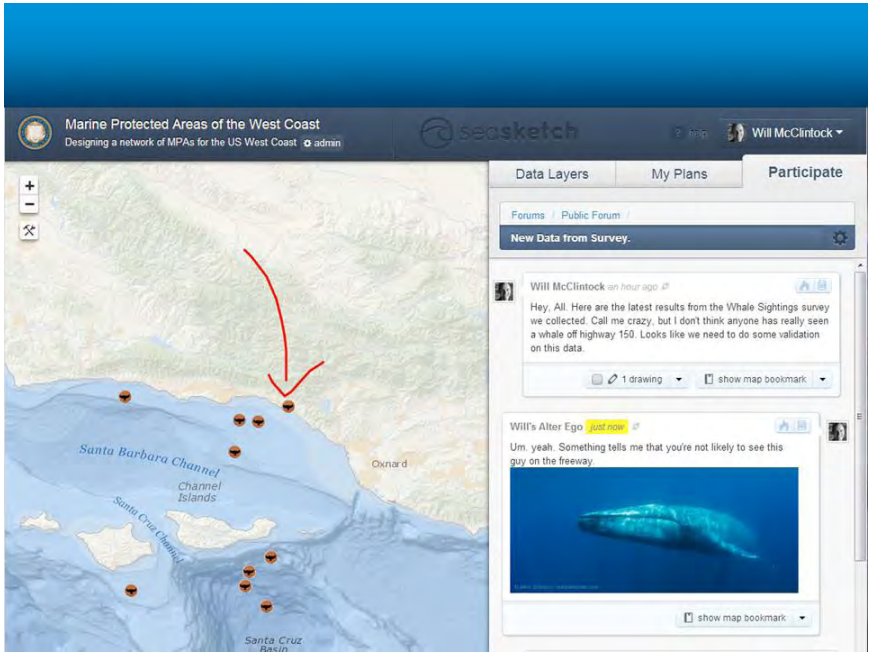
The Ocean Basemap is the clear foundation for an ocean GIS, as any individual or organization involved in maritime operations, ocean science, ocean conservation, or ocean management can deploy feature overlays or web services, such as maritime boundaries, energy infrastructure, shipping activity, subsurface geology, ocean surface and water-column observations, and nautical charts, to dynamically mash up with the bathymetry. GIS specialists focused on land problems are also expressing great interest in the Ocean Basemap as an important step toward an integrated terrain model for the entire planet. New contributions to the Ocean Basemap are always welcome (contact bathymetry@esri.com for more information).

SeaSketch

Esri has been working in close collaboration with Dr. Will McClintock of the University of California, Santa Barbara (UCSB), Center for Marine Assessment and Planning to deliver a cutting-edge decision support tool for effective ocean planning for a range of end users, including government, industries, and regional institutions. In November 2012, UCSB publicly released the initial version of SeaSketch, a web-based ocean geodesign platform that will be accessible via ArcGIS Online.

SeaSketch greatly extends the capabilities of the well-known MarineMap used in support of science-based and stakeholder-driven marine protected area network planning throughout California. Regardless of technical or scientific ability, users of SeaSketch are able to view map data from authoritative sources from all over the world (e.g., distributions of habitats, energy resources, infrastructure, maritime boundaries). Using these maps as a reference, users are then able to sketch, save, and share management plans and discuss them with other users via a facilitated chat forum tied directly to their maps. Survey tools enable users to capture local knowledge, including via crowdsourcing or volunteered geographic information, and create new map data of their own. SeaSketch is always adding to its current suite of spatial analytics, which in the future will **include spatial dimensions of trade-offs** in which users submit the spatial features of their plans to a biological-economic model of trade-offs between ecosystem services (tourism, conservation, energy development, lobster fishing, whale migration corridors, etc.) in relation to potential management strategies.

Opening page of SeaSketch.



SeaSketch map interface with interactive forum to discuss validity of user observation data collected with the survey tool for use in the current project.

Ocean Health Index

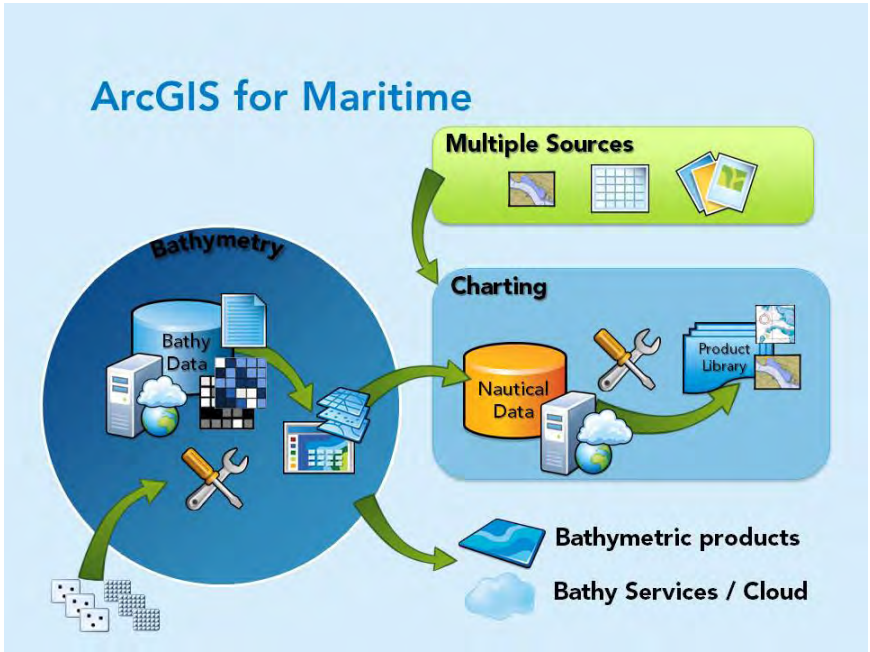
The Ocean Health Index (OHI) is a project cofounded by Conservation International, the National Geographic Society, and the New England Aquarium with the ambitious goal of establishing a new world standard for measuring ocean health by representing that health as a single number. The index is designed to take the pulse of the oceans to provide a quick set of vital signs (i.e., indicators that measure the intensity of the most urgent ocean stressors, including climate change, ocean

acidification, overfishing, habitat degradation, invasive species, loss of biodiversity, pollution, and eutrophication). This will aid managers, policy makers, and the public in quickly diagnosing where problems lie and identifying possible solutions. The project therefore seeks to bridge that important science/policy maker divide and is thus featured prominently in a series of informative articles within the society, policy, and economy journal Pacific Standard. A scientific overview of the project was published in 2012 by Dr. Ben Halpern et al. in the journal Nature.

Esri has been working with Halpern and colleagues at UCSB, Conservation International, and Radical Media on the best methods for "spatializing" this information and presenting it in an web interface that literally maps out the OHI for each country of the world. With these maps, people in every country of the world will soon have detailed information about how they benefit from and impact the environmental and economic health of the oceans around them. A second phase will involve recalculating the OHI globally or regionally using alternative weights, equations, and data layers, especially where there is the richest and most reliable data. Esri will assist with web-enabling certain geoprocessing functions from a new GIS toolbox for OHI and cumulative impacts in development at UCSB.

ArcGIS for Maritime

ArcGIS for Maritime is a comprehensive geospatial platform for chart production and nautical and bathymetric data management. The package enables professional-grade product and service support for the management of ocean GIS. As a result, it can be used to efficiently generate a variety of navigational and nonnavigational products in compliance with industry and organizational standards and requirements. This package supports a wide variety of users in port management, maritime transport, ocean science, coastal resource management, nautical chart production, and maritime defense. Some of the tasks supported include building, maintaining, and creating standard nautical charts; managing, visualizing, and sharing bathymetric



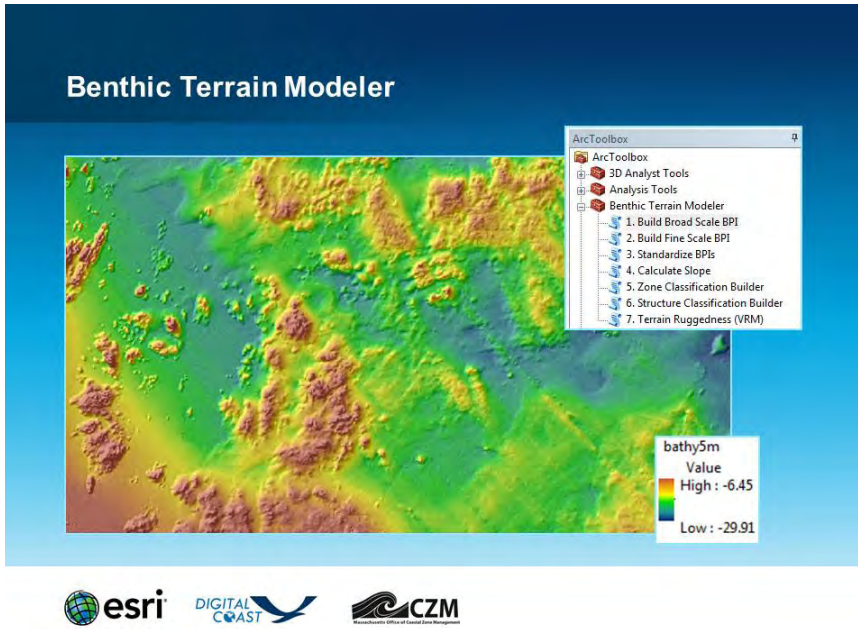
ArcGIS for Maritime concept. Both the bathymetry and the charting products can work either independently or together as needed.

data; and managing multiuser discovery and access to massive collections of ocean and coastal information.

ArcGIS for Maritime includes workflows for nautical chart viewing and converting among International Hydrographic Organization data transfer standards; quality control/quality assurance; for management of bathymetric data (load into a Bathymetric Information System [BIS]; interact with grids, collections, and metadata; create surfaces, features, and queries; share in various modes); and for integration with data models such as Arc Marine, various map services such as the Ocean Basemap, and new tools as they are developed by the community. An excellent overview video shows an example as implemented by the Swedish marine survey company MMT.

Benthic Terrain Modeler

Benthic Terrain Modeler (BTM) is an application originally developed in 2005 at Oregon State University under a cooperative agreement with the NOAA Coastal Services Center (CSC) GIS Integration and Development program. BTM provides a set of geoprocessing tools to analyze benthic terrain for classifying seafloor for benthic fish species distribution and habitat, geomorphology, marine protected area design, and more. From an input grid of multibeam bathymetry, the user may create additional grids of slope, bathymetric position index, and seafloor rugosity. An integrated XML-based terrain classification dictionary gave users the freedom to create their



The Benthic Terrain Modeler is an open-source set of geoprocessing tools to analyze benthic terrain for the purposes of classifying the ocean floor, particularly for benthic habitat studies.

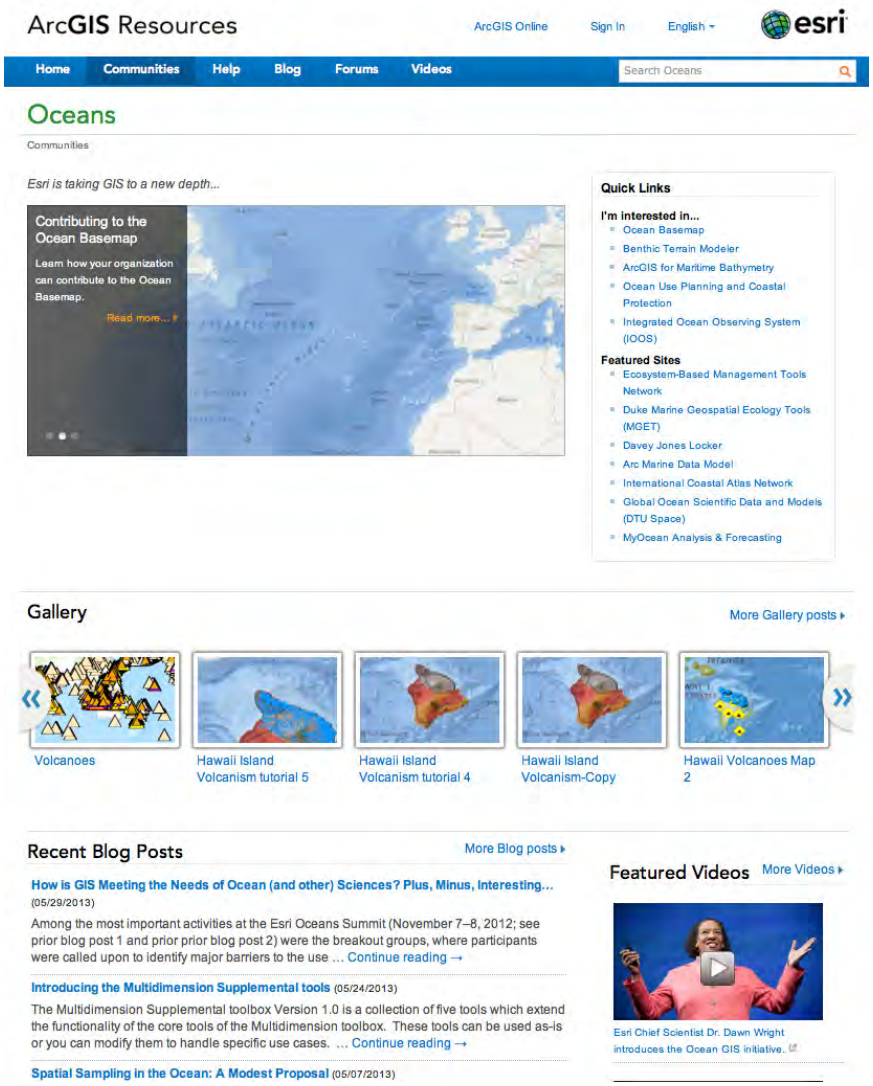
own classifications and define the relationships characterizing them. Thanks to a collaboration of Esri with NOAA and the Massachusetts Office of Coastal Management, the tool has undergone a major revision to make it compatible with ArcGIS 10.x, including the provision of Arc toolboxes for specific functions, a Python add-in so that all code (including model parameters and settings) is easier to edit and manage, a simple interface, and a much improved Excel-based classification dictionary reader. The rugosity function has been updated to a

new vector ruggedness measure of terrain. Certain functions are also being ported to web geoprocessing services deployed as REST endpoints.

A tutorial that accompanies BTM takes users through a ModelBuilder run of all its major functions including broad- and fine-scale bathymetric position index calculations, zone and structure classification builds, depth statistics, curvature (slope of slope), and vector ruggedness measures of terrain. A new Python toolbox with all code (including model parameters and settings) stored in plain-text Python files enables easier editing and managing of the code, removing the need for .tbx files. A simple graphical user interface wraps around all BTM tools and re-creates the full "wizard" experience available in the previous release. And a much improved classification dictionary reader works with .CSV files, as well as XML data from the prior release. Download BTM for free at esriurl.com/btm.

Oceans and Maritime Resource Centers

The ArcGIS Resources site is organized by various communities to provide a prefiltered set of information specifically for a particular community. As such, both the Oceans and Maritime resource centers provide blog posts, Twitter feeds, discussion forums, videos, case studies, maps, apps, data, code snippets, documentation, and associated Esri events and news items, preselected to help you complete your work. The idea is to save



The ArcGIS Oceans resource center.

you from having to search through large volumes of content in an effort to find what applies to you. The Oceans resource center is focused on the general ocean science and resource management community. The ArcGIS for Maritime and ArcGIS for the Military: Maritime Operations resource centers provide resources specific to those software products. These resource centers, where updates are posted all the time, are among the very best ways to stay abreast of ocean developments at Esri. Please feel free to bookmark them or subscribe to their RSS feeds.

Esri Oceans Summit and Ocean GIS Conference

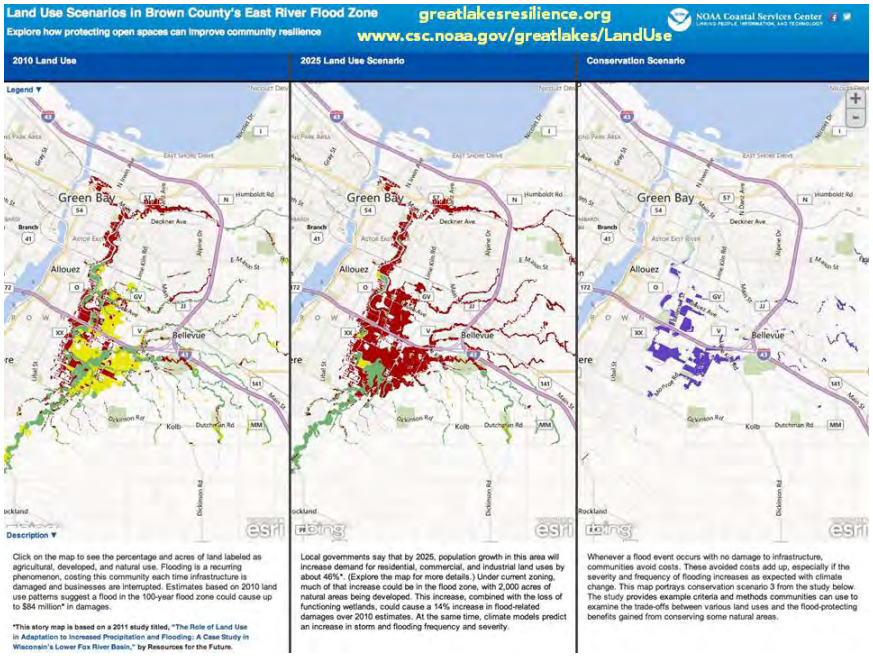
On November 7–8, 2012, Esri held a historic, one-time-only Oceans Summit. This was a high-level, strategic workshop with an eye toward helping Esri to move forward in its approaches to software, associated data formats, tools, workflows, and computing platforms where the oceans are concerned. Day one identified barriers to the use of GIS in ocean science and management, along with associated functional requirements and additional implications for atmospheric and climate science. Day two focused on removal of barriers; bridging of gaps via technical solutions in multidimensional and sensor data formats; and tools, workflows, computing platforms, and issues of accuracy and uncertainty. The summit has paved the way for the first open, all-comers Esri Ocean GIS Conference, scheduled for November 5–7, 2013, at our headquarters in Redlands, California. Results of the 2012 Oceans Summit and information on the 2013 Esri Ocean GIS Conference are available at the ArcGIS Oceans resource center.

On November 7–8, 2012, Esri held the first and only Oceans Summit attended by 50 power users from the ocean science community and 40 Esri staffers.

NOAA Projects

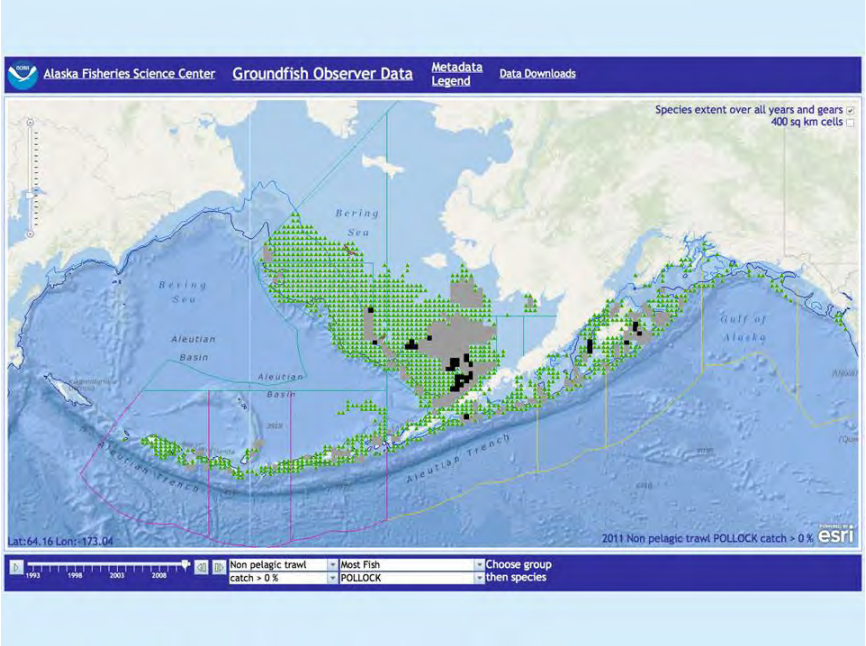
Esri is supporting a wide variety of demonstration projects and service-based contracts with NOAA line offices, including the National Ocean Service (NOS); the National Marine Fisheries Service (NMFS); the National Weather Service (NWS); the

National Environmental Satellite, Data & Information Service (NESDIS); and the Office of Oceanic and Atmospheric Research (OAR). Representative projects include the following:



The NOAA Coastal Services Center worked with Esri to develop several story maps tailored to Great Lakes communities and designed to help coastal planners communicate the benefits of coastal habitats. The story maps are a part of an online Great Lakes Resilience Planning Guide funded by the Environmental Protection Agency's Great Lakes Restoration Initiative.

- NOAA Coastal Services Center and Bureau of Ocean Energy Management: Multipurpose Marine Cadastre
- NOAA CSC: Development of story maps for coastal county planners
- NMFS Northeast Regional Office: Development of a groundfish observation web map application



The NOAA Alaska Fisheries Science Center Groundfish Observer Data site [http://www.afsc.noaa.gov/maps/fma/datamap/obsmap.html] aids users in better understanding where fish and invertebrates have been caught in the Bering Sea, the Aleutian Islands, and the Gulf of Alaska.

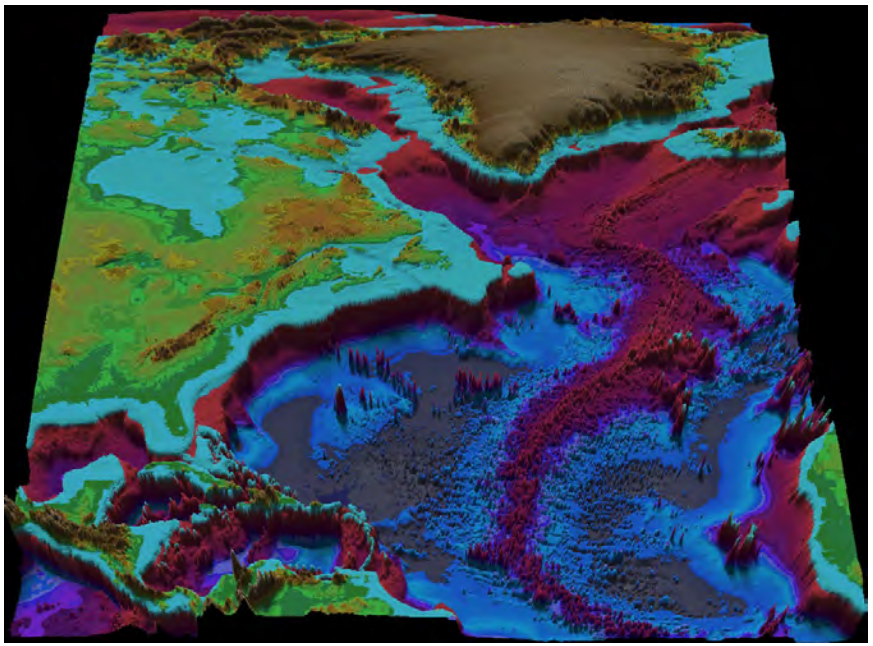
- NOAA NOS Office of Coast Survey Marine Chart Division: Ongoing implementation and production conversion of the NOAA Nautical Chart System II to ArcGIS for Maritime
- NOAA Coast Survey Development Laboratory: Development of a new ArcGIS for Server software-based version of NOAA's ENC Direct to GIS
- NOAA NMFS Pacific Islands Fisheries Science Center: Support for the development and implementation of various desktop applications and web-based viewers, including the various programs within the Coral Reef Ecosystem Division
- National Ice Center: Continued development of the Sea Ice Prediction and Analysis System (SIPAS) based on ArcGIS for Server

Partnerships

Esri is leveraging a number of important partner relationships to advance the Ocean GIS initiative. A small sample of these relationships is presented below.

Quality Positioning Services

Esri partner Quality Positioning Services (QPS) is a maritime technology and services provider with headquarters in the Netherlands, with US-based operations in Portsmouth, New Hampshire, and Houston, Texas. It is a highly specialized company well-known in the hydrographic, petroleum, and oceanography communities for its domain knowledge and excellent software. QPS recently acquired Esri partner IVS 3D, maker of the Fledermaus scientific visualization system, and is consolidating product lines. Fledermaus is heavily used at the world-famous Scripps Institution of Oceanography Visualization Center and is a de facto scientific visualization standard throughout the marine geology and geophysics arm of the ocean science community, including the large international National Science Foundation (NSF)-sponsored programs Ridge 2000, Margins, and the Ocean Observatories Initiative. It is also used at many national hydrographic and naval agencies. Esri and QPS are now working together to integrate Fledermaus tools into the geoprocessing framework of the ArcGIS for Maritime solution for 10.1.



Fledermaus 3D visualization of the North Atlantic Ocean.

University of New Hampshire Center for Coastal and Ocean Mapping

Esri is a member of the Industrial Consortium of UNH-CCOM. This is a consortium for collaborating and developing new approaches to ocean and coastal mapping challenges. A recognized global leader in technology, testing, and training in hydrographic tools, UNH-CCOM is a cooperative institute funded via a NOAA line item, as well as by competitive grants, to perform a broad spectrum of work ranging from Law of the Sea surveying (soon to be incorporated into the Ocean Basemap) to multibeam acoustic backscatter analysis.

Duke University Marine Geospatial Ecology Lab

Esri will be working more closely with the Marine Geospatial Ecology Lab of Dr. Pat Halpin and his colleagues at Duke University. A major focus will be deeper integration between the ArcGIS system and MGET (Marine Geospatial Ecology Tools), with its growing suite of over 250 open-source geoprocessing tools for solving a wide variety of problems in ocean science research, conservation, and coastal and marine spatial planning.

Restore America's Estuaries

Restore America's Estuaries (RAE) is a national nonprofit organization that seeks to preserve and restore America's estuaries, marine ecosystems, and wetlands. Esri has been working with RAE on developing support for a national estuary GIS while also fostering an RAE pilot project at People for Puget Sound.

Algalita Marine Research Institute

The Algalita Marine Research Institute (AMRI) is a national nonprofit marine research and education organization seeking to understand the distribution, abundance, and fate of marine plastic pollution and to ultimately eliminate its harmful effects on the ocean. AMRI has been engaged in a project with Esri Professional Services to make multiple years of their marine debris research available for the first time to scientists, scholars, and the general public via the Algalita Marine Research Institute Trip Explorer. This simple, easy-to-use web map provides an interactive view into the marine debris samples taken by AMRI during their expeditions throughout the Pacific Ocean in 1999, 2000, and 2009.

West Coast Governors Alliance on Ocean Health

The West Coast Governors Alliance on Ocean Health (WCGA) is a proactive regional collaboration between the governors of California, Oregon, and Washington and their natural resources policy staff to more effectively manage "human activities and their impact on ocean resources in a way that accounts for the relationships among all ecosystem components, including people and other species and the environment in which we all

live." This is also a key recommendation of the bipartisan Joint Ocean Commission Initiative. WCGA is one of 10 official regional ocean partnerships (ROPs) nationwide that explicitly advance the objectives detailed in the US National Ocean Policy.

Esri has played a key role in helping to establish a new Regional Data Framework action coordination team (ACT). This ACT supports the information needs of the existing WCGA ACTs (Climate Change, Integrated Ecosystem Assessment, Marine Debris, Ocean Awareness and Literacy, Polluted Runoff, Renewable Ocean Energy, Seafloor Mapping, Sediment Management, Spartina Eradication, and Sustainable Coastal Communities). The ACT is coordinating the activities of three technical working groups (Data, Information Technology, and Outreach) and consulting with a broader West Coast network of data experts and users in shaping regional geospatial data coordination activities to inform regional ocean issues.

World Ocean Council

Esri is a member of the World Ocean Council, a global, multisectoral industry leadership alliance for ocean sustainability. Of the five working groups of the council (Policy & Governance, CMSP, Operational and Technical, Regions, and Science), Esri will be most involved in the Science and CMSP groups to "coordinate cross-sectoral ocean industry efforts to call for, and participate in, expanded, improved and better coordinated ocean science [and CMSP], especially in relation to climate change."

Consortium for Ocean Leadership

Esri holds affiliate membership in the Consortium for Ocean Leadership, a nonprofit organization that represents more than 100 of the world's premier oceanographic research and educational institutions, aquaria, and industry partners. With its headquarters in Washington, DC, it is a unified, powerful, and widely respected voice on Capitol Hill for the entire US ocean research and education community. The consortium shapes the future of ocean science, technology, and education by managing and coordinating wide-ranging programs such as the Census of Marine Life, the Ocean Observatories Initiative, the International Ocean Drilling Program, and the National Ocean Sciences Bowl. It is also the program office for the National Oceanographic Partnership Program; the Interagency Working Group on Ocean Observations; and the Ocean Research and Resources Advisory Panel, which provides independent advice and guidance to the US president's National Ocean Council.

Changjiang (Yangtze) Waterway Bureau

The Changjiang (or Yangtze) Waterway Bureau is responsible for waterway planning, construction, management, conservation, and waterway administration on the Yangtze, which is the longest river in Asia and the third longest river in the world. They are collaborating with Esri Professional Services and the Esri China Information Technology Co. Ltd. to modernize their paper nautical chart production system. The bureau has recently

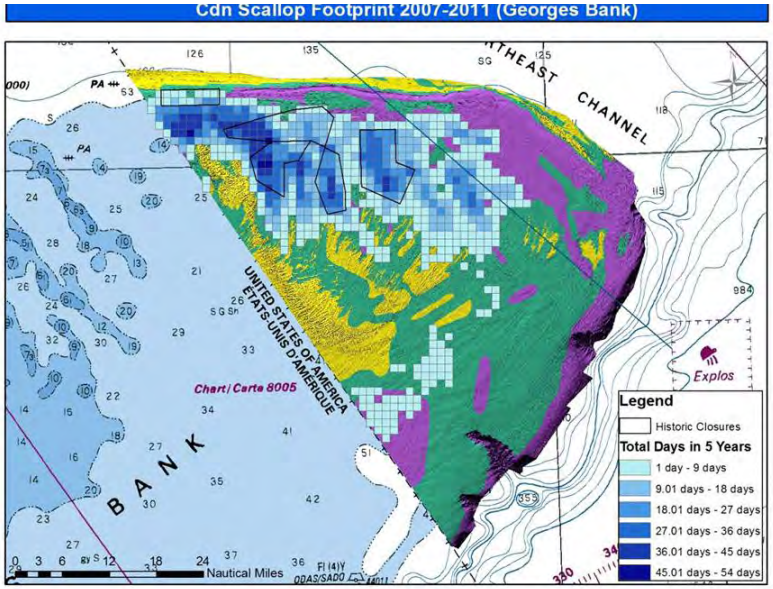
accomplished their first major milestone, with 400 electronic nautical charts now maintained in an enterprise database, with a goal of maintaining an additional 350 in the near future. Recent improvements in ArcGIS for Maritime: Charting are more fully automating and streamlining this workflow, reducing the production time for charts from 3-5 days to a matter of hours. They have also worked closely with Esri China to extend their nautical charting data model to accommodate the national standard, CJ-57.

OneOcean

Esri is entering into a new partnership with OneOcean Corporation, a new startup that provides a robust cloud-based platform for storage and distribution of big data sets without the need for hardware, software, or specialized services. As the company continues to evolve, the complement of Esri's GIS products, particularly ArcGIS for Maritime and ArcGIS Online, will be an important set of tools that OneOcean is excited about leveraging on behalf of stewards of ocean data in government, industry, and research. In turn, Esri is very interested in the integration of OneOcean's ClipCard technology for providing rich abstracts of data to facilitate management, access and exchange.

Clearwater Seafoods

Clearwater Seafoods Limited is a global leader in the seafood industry and the largest harvester of wild shellfish in Atlantic Canada. Based in Nova Scotia, Canada, the award-winning company has built its business around a core commitment to long-term sustainability and responsible fishing. Always looking to improve operations, Clearwater invests significantly in technologies that enable top-quality seafood to be delivered from ocean to plate. A recent investment in ArcGIS has resulted in significant cost savings, minimized impact on ocean ecosystems, and aided the company in meeting the stringent



This ArcGIS map by Clearwater Seafoods details a five-year activity footprint in the Georges Bank, a prime area for the Canadian scallop fishery. Maps such as these help the company to earn and maintain Marine Stewardship Council certification, thus demonstrating a continuous commitment to resource and ecosystem sustainability.

requirements for Marine Stewardship Council certification of sustainable seafood. Specifically, it uses ArcGIS to study fish resources and population dynamics and overlay spatial and temporal fishing data with sediment types, survey data, harvest areas, and benthic habitat. Clearwater Seafoods is looking to expand the use of GIS, including using it on the bridge of its commercial fishing vessels to manage real-time positioning of the vessels as well as manage dataflow from ship to shore, and the organization has partnered with Esri and Esri Canada Limited toward this end.

Strategic Goals

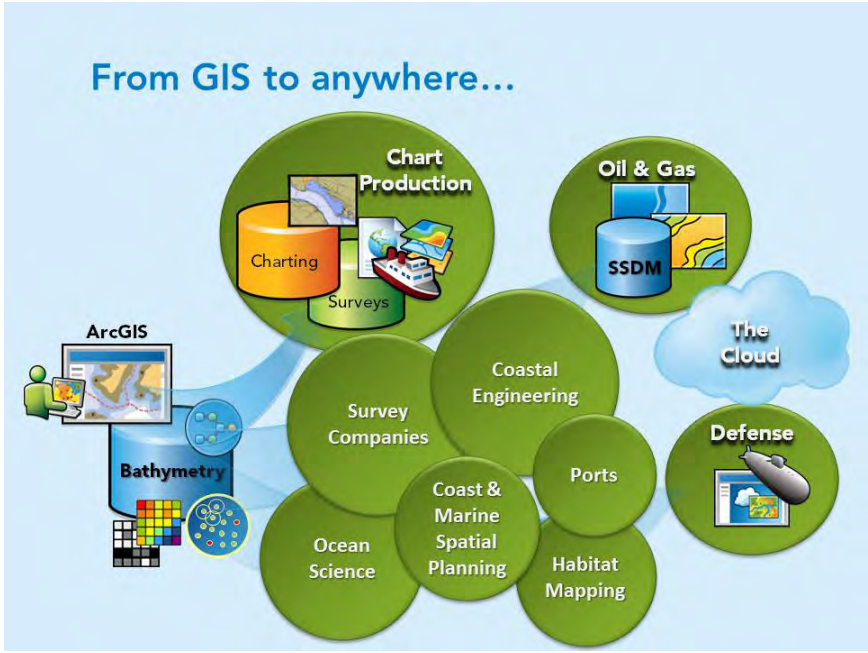
To support a better understanding of our oceans, Esri is focused on improving and expanding its products, tools, services, partnerships, and connections with the broader ocean community. Some of the initiatives being pursued toward this goal are outlined below.

Grow the Ocean Basemap

Esri will continue to build the bathymetry data asset in the Ocean Basemap via crowdsourcing, with a continued strong emphasis on authoritative contributions from international hydrographic offices and scientific institutions. It will also explore and implement the provision of additional public domain content layers, such as existing nautical chart services with IHO S-57 symbology, and global maritime boundaries, offshore energy infrastructure, sea surface temperature, salinity, sediment classifications, and more.

Build a More Integrated Elevation Service

Esri will expose the Ocean Basemap as part of the World Elevation Service, making it a truly integrated "land and ocean" elevation service, including visualization services (e.g., profiling) and data download.



Esri's vision for bathymetry in the cloud for a multitude of applications, expanding capabilities beyond the desktop.

Provide Intelligent Bathymetry in the Cloud

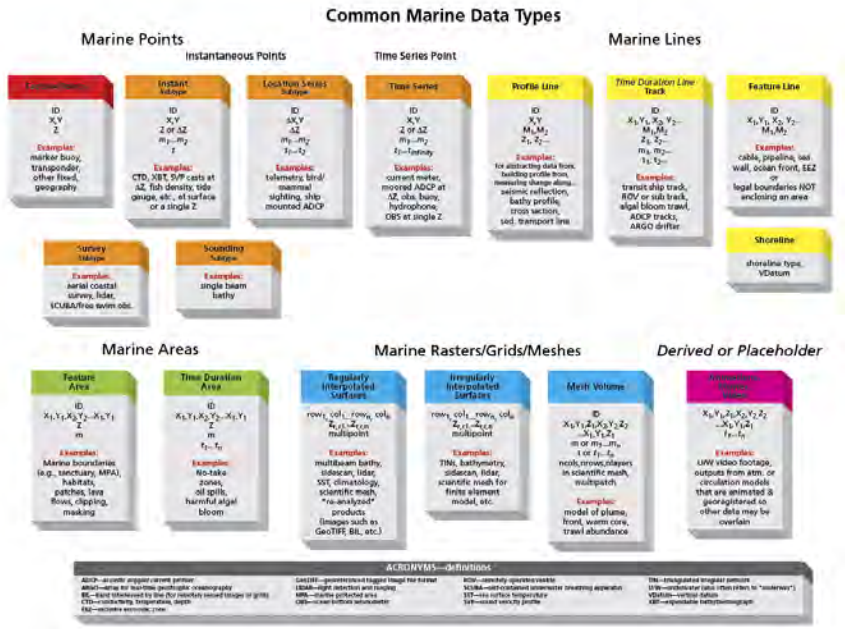
Esri's goal is to provide intelligent bathymetric services in the cloud by underpinning the Ocean Basemap with the power of ArcGIS for Maritime—Bathymetry and the Bathymetric Information System therein. A BIS server would push out additional management functions for bathymetry, such as database rules to sequence and display data by highest resolution, acquisition date, and so forth, as well as have the benefit of faster performance. This capability will allow the Ocean Basemap to deploy in the cloud a truly worldwide model of bathymetry. There are also important implications for expanding ArcGIS for Maritime to other parts of the ArcGIS platform, such as ArcGIS Online or ArcGIS for Server.

Grow Ocean Content

In terms of business drivers and business partnerships, our current focus is in hydrography, offshore energy, ports, defense, commercial fisheries, ocean science, and ocean regulatory/policy administration (national, regional, and local). Along these lines, we are developing a strategy to provide a wide range of ocean content, leveraging the business needs/solutions process to define the specific content needs of these sectors. Esri ocean content is currently focused on foundational data (e.g., bathymetry/bathymetric elevation services, support for a polar basemap projection, charting services), as well as support of our public (e.g., NOAA) and private partners in making their data available as free or premium content in ArcGIS Online. Over time, we wish to move into geoenrichment and other analytic services.

Update and Support the Arc Marine Data Model

The Arc Marine data model, first published in a research monograph in 2007, has been widely adopted by agencies and organizations responsible for our oceans. It is still recognized as a valuable model, and adoption of it appears to be ongoing, with a number of organizations seeking to standardize on Arc Marine. Esri will be further updating the data model as new versions of



Common marine data types, from the Arc Marine data model.

ArcGIS are released, while noting that there are now a variety of standards efforts ongoing for communities, data formats, metadata, etc., that we could leverage. For more information on the evolution of Arc Marine, see this blog post.

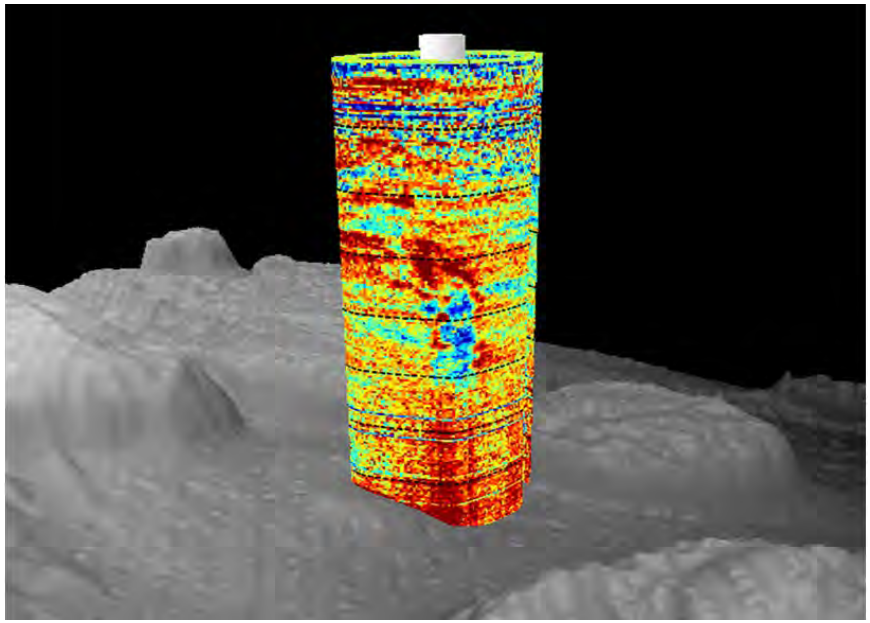
Develop Vertical, Time-Dependent Data Transformations

In collaboration with the USGS and Scripps Institution of Oceanography, Esri is developing a series of vertical, time-dependent datum transformations to help researchers transform data between ellipsoidal, orthometric, and tidally referenced elevation data at the shoreline. This is absolutely critical for coastal surveying, coastal geomorphology, and coastal terrain models that connect nearshore bathymetry for terrestrial digital elevation models (DEM) that are used for storm surge, hurricane, and tsunami inundation modeling.

Improve Support for Multidimensional Data and Analyses

Satellites can clearly map the ocean surface, and acoustic sensors can map the ocean floor, but ocean scientists currently have a limited view of the water column between the ocean surface and the ocean floor. There is a critical need to study the internal structure of features in the water column such as plumes (hydrothermal vent plumes, oil well plumes as in the Gulf of Mexico spill) or schools of fish to obtain fish stock dynamics, spawning grounds, seasonal habitats, and the impact of climate change on these. To exploit water column data, an efficient means of reading, processing, and analyzing the data is required.

Esri is continually improving support for scientific spatial and temporal data formats such as the climate forecast (CF)



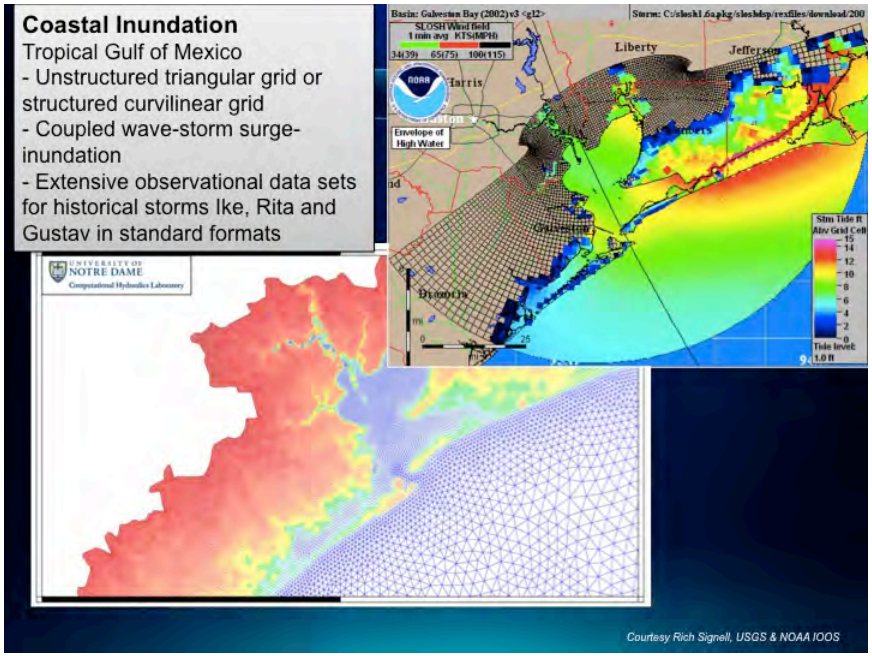
The importance of visualizing the water column (aka "midwater" above the ocean floor), as shown by this screen capture of an output of the Fledermaus midwater mapping tool over the source of the Deepwater Horizon oil spill in the Gulf of Mexico. The visualization was produced by UNH-CCOM, courtesy of http://ccom.unh.edu/project/deepwater-horizon. It shows acoustic backscatter data over the wellhead collected after it was successfully capped in mid-July 2010. Although the wellhead was indeed capped, the visualization suggests a small amount of natural gas was still escaping.

convention of the Network Common Data Form-4 data model (netCDF-4) and the closely related Hierarchical Data Format (HDF). In addition, Esri seeks to better articulate to users the rich palette of 3D representation that ArcGIS already contains, such as features, TINs, vectors, multipatches, arrays, and the like; consideration of the voxel data structure; and continued work on handling point clouds and associated functions on them.

Esri will be adding more 3D analytics in ArcGIS 10.2, enhancing all 3D representations to deal with the visualization and interpretation of scientific data, imagery features, point clouds, and arrays. This is particularly important in Esri's quest to improve software functionality for ocean and atmospheric GIS.

Support Ocean Numerical Models

Building a GIS platform that various kinds of numerical modelers could use to associate their efforts would provide a kind of geospatial fabric to interrelate the models. One of the most widely used models in the oceans space is the Regional Ocean Modeling System (ROMS), yet models such as ROMS pose great challenges for GIS, as they are often not uniformly spaced and may be composed of either unstructured triangles or structured curvilinear grids. There is a great need for tools to handle these grids in a more standardized way, allowing the possibility of standard access to data on the model's native grid. To address this important issue, Esri is investigating the use of netCDF Markup Language (NcML), an XML representation of netCDF metadata, which contains attributes that work effectively with the third dimension.



Example of how ocean models are often not uniformly spaced, as grids may be composed of unstructured triangles (left) or structured curvilinear grids (right).

(Courtesy of Rich Signell, USGS)

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