GEOTECHNOLOGY IN THE MARINE SCIENCES

GEOSPATIAL TECHNOLOGY MEETS THE GRAND CHALLENGES IN MARINE SCIENCE – AN INTERVIEW WITH PROFESSOR DAWN WRIGHT.

Dawn Wright is professor of geography and oceanography at Oregon State University and a fellow of the American Association for the Advancement of Science. Her research interests include geographic information science, marine geography, benthic terrain and habitat characterization, and the processing and interpretation of high-resolution bathymetry, video, and underwater photographic images. Wright received her Ph.D. in Physical Geography and Marine Geology from the University of California, Santa Barbara.

GEO:connexion International: *You are one of the world's experts in the application of geospatial technologies in marine science. From your perspective, have these technologies helped to make important advances in marine science?*

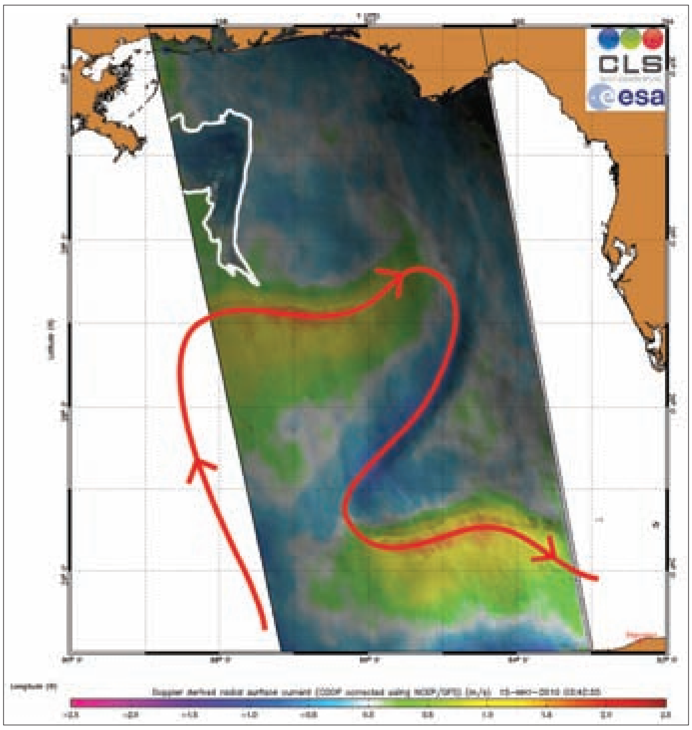
Dawn Wright: "Geospatial technologies" is a very broad term that could now include not just geographic information systems (GIS), but interactive maps both on the web and the desktop, mashups of web mapping services and associated data, location based services that exist on your phone or PDA, other types of mobile mapping apps where you are connected to the Internet but not necessarily to the web, geobrowsers for the masses, high-end scientific geovisualization systems for the scientists, and more. For brevity I'll focus mainly on GIS and remote sensing, including waterborne sensors.

Sensors on satellites and aircraft are great at seeing the surface of the ocean but generally cannot look deeply into the water column. What can be perceived of the water column and ocean floor must be done mostly with the aid of sound (acoustic remote sensing). In order to "see" the ocean floor, sound is essential not only for determining depth to the bottom, but for detecting varying properties of the bottom. As the speed of sound in seawater varies linearly with temperature, pressure, and salinity, the conversion of travel time to depth must take this into account. The intensity of this reflection, or backscatter, can be used to resolve the shapes of objects or the character of the bottom.

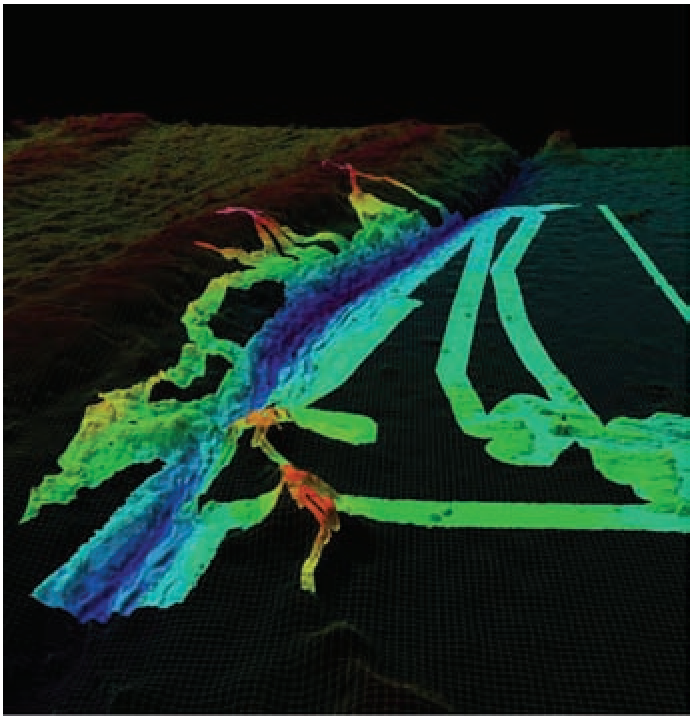
In short, remote sensing has made it possible to collect data on features and processes in the ocean over very broad scales, and GIS has made it possible to organize and integrate the data, make maps from the data, and do analysis. The initial impetus for developing a marine specialty in GIS was the need to automate the production of nautical charts and to more efficiently manage the prodigious amounts of data that are now being collected at sea. GIS to synergize different types of data (biological, chemical, physical, geological) collected in multiple ways from multiple instruments and platforms (ships, moorings, floats, gliders, remotely-operated vehicles, aircraft and satellites) has provided the oceanographic community and policy decision-makers with more information and insight than could obtained by considering each type of data separately. GIS now offers multidimensional visualization, simulation and modeling, and decision support.

GEO:connexion: *What do you see as the big challenges in marine science today?*

Wright: There are many challenges facing marine science in the coming decades. A U.S. National Academy of Sciences report coming out soon will discuss many challenges and the infrastructure needed to meet them, including geospatial technologies. For the first time in American history, we have a comprehensive US National Ocean Policy and a Na-



Monitoring the BP oil spill in the Gulf of Mexico has taxed the technology. Surface slicks can be monitored from space, but what about the underwater plumes? Credit ESA.



Only 5% to 10% of the global seafloor has been charted with ships. In the Tonga Trench region, for the bathymetry simulated from satellite altimetry, resolution is still too coarse for tectonic studies. Overlay is of multibeam bathymetry that is needed for tectonic studies (gathered from ships). Credit: Geologial Data Center, Scripps Institution of Oceanography, CA, USA.

tional Ocean Council. It received very little media attention amidst the horror of the Gulf oil spill and other issues, but on July 19, 2010, President Obama issued an Executive Order establishing this policy, which is meant to meet many of these challenges. Implementation is a long way off, but we have the policy! For the sake of our discussion, I see four challenges - climate change, energy, ecosystems, and exploration.

GEO:connexion: *What does the ocean have to do with climate change?*
Wright: Remember that 71% of the planet is covered by the ocean, which is in constant interaction with the atmosphere providing the "heat engine" that drives changes in climate. Marine scientists are still trying to understand exactly how the ocean modulates Earth's climate, and conversely how climate change affects ocean circulation, the distribution of heat, marine ecosystems, sea level rise, how changes in ocean temperature and CO2 concentration will affect the rate ocean acidification, etc. A huge question is how do we predict the outcomes and impact of climate change, and then adapt and mitigate accordingly?

GEO:connexion: *How can geospatial technologies make a contribution in meeting this challenge?*
Wright: GIS can be used to show sea level rise scenarios and potential impacts, and to calculate how sea level rise may increase the frequency of tidal floods. Three great examples are the tools featured in NOAA's Digital Coast initiative: the Sea Level Affecting Marshes Model (SLAMM), the Sea Level Rise and Coastal Flood Frequency Viewer, and the myriad resources at the NOAA Coastal Services Center (CSC) Coastal Climate Adaptation web site.

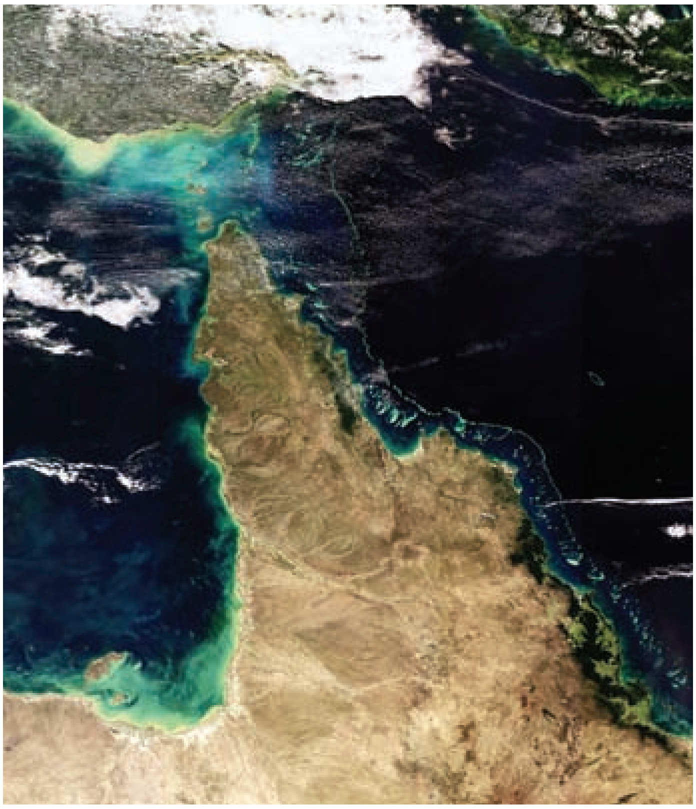
New geo portals can help meet these challenges, such as a coastal web atlas, which organizes and coordinates interactive web mapping, pre-made digital maps, GIS datasets, and remotely-sensed imagery, with supplementary GIS decision-support tools, tables, photography, and other information, through a single web portal. Such atlases play an important role in informing regional decision- and policy-making across several themes, including climate change impacts, but also marine spatial planning, coastal conservation and protected areas management, resource availability and extraction, and more.

GEO:connexion: *You mentioned energy as another big challenge…*
Wright: The nightmare of BP's Deepwater Horizon oil spill in the Gulf of Mexico and the scare of the recent fire on Mariner Energy's Vermillion rig, also in the Gulf, have many thinking again about the urgent need to find alternative forms of energy. Is it possible to develop viable sources of alternative energy from the ocean that could meet, say, 10% of U.S. energy needs? So an exciting marine engineering challenge is the development of ways to produce electricity from ocean wave energy, offshore wind-on-water energy, and tidal energy. A related challenge is the development of ways to power the many devices in the ocean that are used for scientific and military purposes (such as wave or solar energy for underwater gliders, autonomous underwater vehicles, and other kinds of "robots"). What are the ocean space use conflicts that will arise? Ocean space is a human dimensions research problem, examining people's perceptions, biases, and prejudices, where economics come into play, and politics are non-trivial.

GEO:connexion: *And you see the potential for geospatial technologies playing an important role in the future of energy in the ocean space?*
Wright: GIS in general, and coastal web atlases in particular, provide the "engine" to implement Marine Spatial Planning (MSP), a big part of the U.S. National Ocean Policy,. e.g. integrating the necessary data and interactive, collaborative environment in which to map out the potential use conflicts. MSP needs to be guided by specific policies and regulations governing usage of the ocean, the conditions that apply, with an eye toward possible conflicts that arise. MSP experts may not always be GIS experts and will need help from the mapping community.

When there is a crisis involving offshore energy extraction such as the recent Gulf oil spill, satellite/aircraft remote sensing and GIS are key for tracking the spill on the surface and mapping out areas of risk and where response efforts are located. The Gulf oil spill has been diabolical because it emanated from the well on the ocean floor, not at the surface. It's not just a matter of dealing with the slick, but with the underwater plume which isextremely difficult to track.

GEO:connexion: *What are the current and future questions we must answer relative to ocean ecosystems?*
Wright: A continuing challenge will be understanding how various ecosystems function and inter-relate – from microscopic primary producers



Monitoring Australia's Great Barrier Reef – one of the largest living organisms on Earth – from space. Credit ESA.

at the base of the food chain to coral reefs to large marine ecosystems (e.g. the California Current) - and their biodiversity. How will these ecosystems respond to factors such as human uses and waste input, coastal development, coastal storms and flooding fueled by climate change, and invasive species? What is the resilience of coastal ecosystems (plant and animal species) and coastal communities of humans? The marine science community appears to have coalesced now on the efficacy of an ecosystem-based approach where biological elements are not studied in isolation, but with physical factors and human presence/ human impacts as well. This has led to the establishment of ecosystem-based management (EBM) as a core principle guiding marine resource management decisions.

GEO:connexion: *Geospatial technologies are well known for their tremendous contributions to the study and management of terrestrial ecosystems. Do they offer similar benefits to ocean ecosystems?*
Wright: GIS has made a real impact here, as researchers and developers worldwide have developed scores of GIS tools for the implementation of EBM. A terrific example is the EBM Tools Network, where tools are organized under several categories such as data collection, processing, and management, stakeholder engagement, conceptual modeling, visualization, project management, monitoring and assessment, modeling and spatial analysis, and decision-support.

Remote sensing of ocean color radiance from space (SeaWiFS/ MODIS) will continue to make a huge contribution in this area as this is how marine scientists can assess the amount and type of phytoplankton in the ocean, which also gives indicators of ocean nutrient levels (ocean health) and ocean currents. Future international collaborative efforts are needed to sustain and bring online new satellite sensors, to calibrate and validate data, develop new sensor algorithms, and to integrate with geospatial observations from ships, buoys, and aircraft.

GEO:connexion: *You also mentioned exploration as a challenge. Is there still that much we don't know about the ocean?*
Wright: A recent quote from Luis Valdes and colleagues of the United Nations Intergovernmental Oceanographic Commission (IOC) sums up the issue brilliantly: "Put into a larger context, more than 1,500 people have climbed Mount Everest, more than 300 have journeyed into space, and 12 have walked on the moon, but only 5% of the ocean floor has been investigated and only two people have descended and returned in a single dive to the deepest part of the ocean. On the other hand, no part of the ocean remains unaffected by human activities, such as climate change, eutrophication, fishing, habitat destruction, hypoxia, pollution, and species introductions. Therefore, the scientific study of ocean should be an international priority." [1]

How can we understand and mitigate the impacts of climate change, clean up oil spills, protect species, sustain fisheries, etc. if we have not explored and fully understood the deep water column and the deep ocean floor? The recent Gulf oil spill has shown how much ocean exploration is needed, acknowledging that there was an underwater plume of oil and learning how to track and understand its impacts.

GEO:connexion: *How can geospatial technologies aid in this exploration?*
Wright: Examples of remote sensing in the ocean include towed acoustic sensors, vertical line arrays, omni-directional acoustic sensors that can sense in all directions with one acoustic ping, multibeam sonar on ships, upward-looking sonar towed under ice. In the water column and on the ocean bottom there are small autonomous underwater vehicles (AUVs), larger remotely-operated vehicles (ROVS), and still larger human-occupied vehicles (HOVs, aka submersibles), all with the ability to georeference observations and samples.

For ALL of the aforementioned challenges we'll need interdisciplinary data collection at coastal upwelling regions, seafloor spreading centers, where tropical storms and hurricanes form, where oil spills occur, etc. Data will be collected from various platforms, instruments, at different sites and different scales and resolutions. We need ways to organize, mine, and translate between data to maintain and exchange data and information over large distances and long time scales.

GEO:connexion: *Is there anything else you would like to share about the relationship between marine science and geospatial technologies?*
Wright: GIS and remote sensing are "enabling technologies" for marine science, but marine science can help to improve GIS and remote sensing. The ability to better handle and visualize time has been a long-standing research issue for GIS. In the oceans it is often only by time that we can get location, especially on the deep seafloor or in the deeper parts of the water column that are out of reach of satellites, global positioning or otherwise. Accurate clocks and accurate timing of the travel of acoustic pulses are critical.

We have many research issues endemic to marine science applications of GIS, such as the handling of spatial data structures that must vary their relative positions and values over time (e.g.), geostatistical interpolation of data sparse in one dimension compared to the others, the analysis of volumes, and the input and management of very large spatial databases (e.g. LiDAR). I think these and many more will continue to advance the body of knowledge in GIS design and architecture, as well as the body of knowledge in the broader field of geographic information science.

[1] *Valdes, L., Fonseca, L., and Tedesco, K., 2010. Looking into the future of ocean sciences: An IOC perspective. Oceanography, 23(3): 160-175.*

For more information, visit:
US National Ocean Policy - //bit.ly/dimXi4/
SLAMM - //www.csc.noaa.gov/digitalcoast/tools/slamm/
Sea Level Rise and Coastal Flood Frequency Viewer - //www.csc.noaa.gov/digitalcoast/tools/slrviewer/
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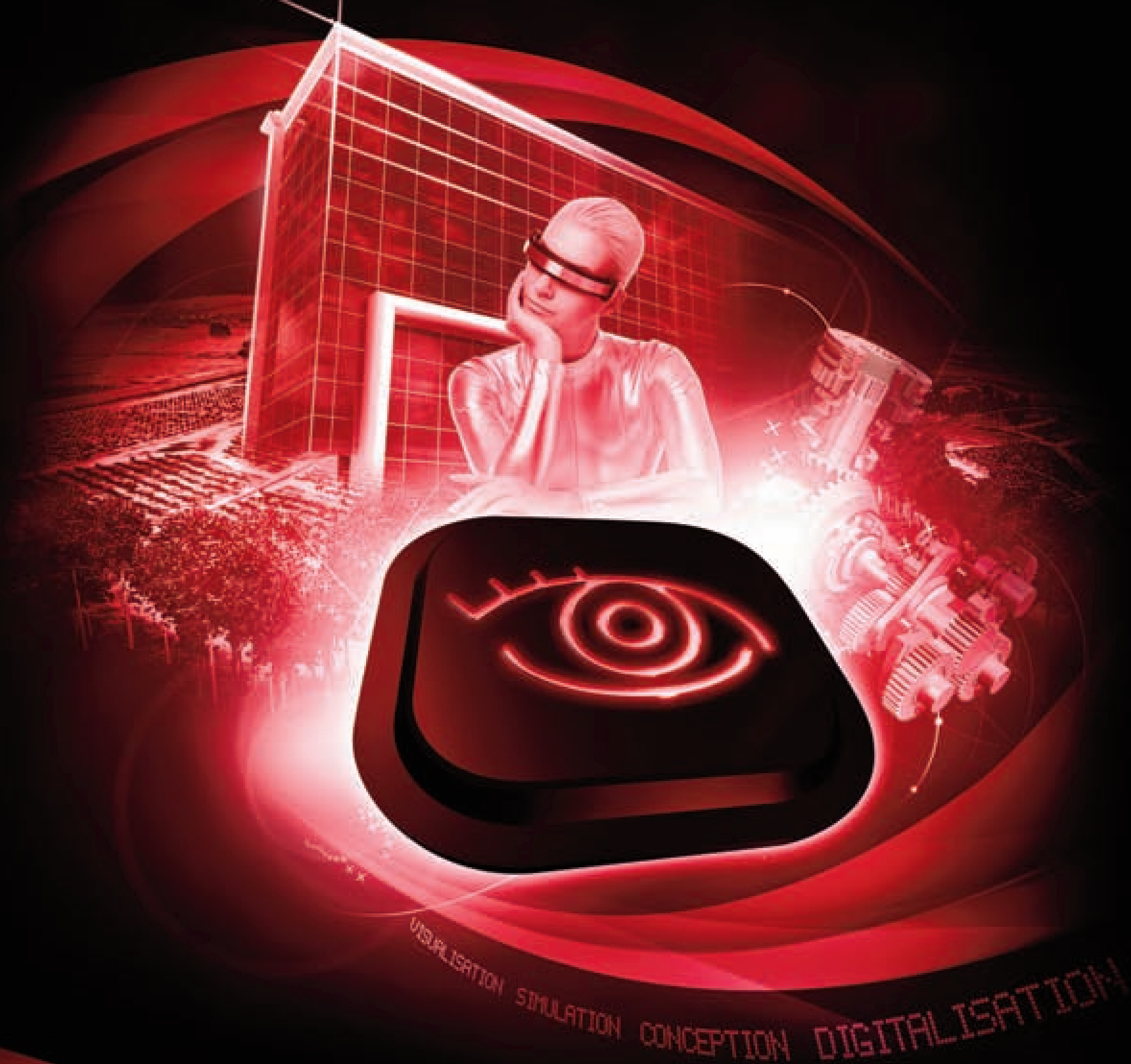

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