GLOBAL OPERATIONAL OCEANOGRAPHY

The Naval Oceanographic Office

The Naval Oceanographic Office is proud of the role that it plays within the international hydrographic community. It traces its roots to hydrographic origins: the Depot of Charts and Instruments that was founded in 1830. The Depot evolved through time and, in 1962, the Hydrographic Office was renamed the Naval Oceanographic Office. An article by LCDR Brian Connon, USN, earlier this year proclaimed, â€˜U.S. Navy Hydrography is Backâ€™.

A natural question might well be, â€˜What were you doing while you were gone?â€™ Given the nature of this special edition, the present article will describe what we were doing while you think we were gone. The answer, in short, is operational oceanography and we have been taking care of business as always! That is to say, we have been conducting a programme that both was and is important to our sponsor, the United States Navy.
Ever since the end of World War II, the United States Navy has been concerned with deep ocean Anti-Submarine Warfare (ASW). The Office studied and became very expert in acoustic transmission loss and the parameters affecting it, ocean measuring and modelling, and measurements of other fields such as the magnetic field and gravity. It continues this work for ASW and other applications as a part of operational oceanography.

Introduction
Indeed, the scope of work done at the office under the name of oceanography covers a broad range of physical parameters across a wide scale, from millimetre to global, from below the ocean bottom to the atmosphere. With respect to function, the office is a collector of data, the receiving â€˜partnerâ€™ in Research and Development, a production centre for the fleet and others, and a system integrator for the fleet. Few organisations must do so much.
Operational oceanographyâ€¦ What do you mean? Simply put, we are operational because we deliver routine and special ocean-related products to customers who need them anywhere in the world. Frequently, we must deliver a synoptic product (present state of the ocean) or short range forecasts (24 to 48 hours) within hours of the request. To do so, we maintain a large infrastructure that routinely collects data and generates products. We do not do â€˜Research and Developmentâ€™ and would rather leave that activity to the many outstanding research organisations around the world.
Our mission, as described by our Admiral (Commander, Naval Meteorology and Oceanography Command, also titled â€˜The Hydrographer of the Navyâ€™) is to: â€˜Conduct multidisciplinary ocean surveys, analyse all-source oceanographic data, provide global numerical products and generate products to meet safe navigation and weapon/ sensor performance needsâ€™.

Multidisciplinary Ocean Surveys
Our tools in gathering data are ships, satellites, buoys, and other equipment like towed systems or autonomous vehicles. The Office has eight survey ships operating world-wide, manned and operated by a civilian crew. We provide an additional ten to fifteen mission scientists and technicians for each survey. Six ships are T-AGS 60 class ships, which can perform broad spectrum oceanography survey work including physical, chemical and biological oceanography, ocean engineering and marine acoustics, and marine geology and geophysics. The ships have an underway mapping system that measures near-surface temperature, salinity bioluminescence and chlorophyll fluorescence. They also have over-the-side systems to measure vertical distribution of the same parameters, plus acoustical transmission loss, water clarity and optical back-scatter. The resulting flow of data from the ships is enormous and we have to carefully manage data processing to avoid backlogs. To help in this, a 2.4 MB C-Band communications capability between the Office and the survey vessel USNS Pathfinder has been tested (Figure 1).
We use satellites extensively to help us initialise ocean models and analyse ocean features. The most important satellite systems are those that provide high-resolution visual and infrared imagery, and active and passive microwave data. Under a partnership with NOAA and the Air Force, we represent the National Center of Expertise for global satellite Sea Surface Temperature (SST) and satellite altimetry. This data is crucial to the success of oceanographic and marine meteorological modelling and is available to the public.
Drifting and fixed systems are deployed to areas of Navy activity and in data-sparse regions around the globe. We annually deploy about 225 drifting buoys which provide in situ real-time environmental data such as SST, air temperature, barometric pressure, wind speed and direction, and surface layer drift. We also deploy about twenty profiling floats and occasionally utilise moored buoys when we need long-term measurements in an area and more power to run active sensors. Finally, we have systems mounted on the bottom with sensors tailored to the customer.
Other equipment includes four roll-on/roll-off systems that collect site-specific oceanography and hydrography data: TOSS, SEAMAP, SEAHORSE and SAMS. None are manned. All were developed through research activities at various universities with funding from the Navy. Collectively, these systems allow a wide spectrum of exploration from our survey fleet or contract vessels.
Our primary towed system is TOSS, a vehicle with real-time sonar and imaging capabilities and an extensive suite of oceanographic environmental sensors. It was designed and built by Woods Hole Oceanography Institute (WHOI). TOSS can survey in waters as deep as 6,000 metres using sonars and cameras, Acoustic Doppler Current Profiler, a conductivity, temperature and pressure sensor, audio

hydrophones and optical sensors. Data is recorded and transmitted back to the ship along a high bandwidth, two-way, fibre-optic cable. SEAMAP is also a towed vehicle for rapid, large-scale sea floor topographic mapping. It was designed and built by the Hawaii Institute of Geophysics and reengineered by us and operates at a shallow depth.

Our primary autonomous vehicle is SEAHORSE, designed and built by Pennsylvania State University. It is able to execute a survey mission that can range as far as 500 km. Typical operating depths are from 5 to 300 metres and endurance is 72 hours. SEA-HORSE is of moderate size, nine metres long by one metre in diameter, and it weighs 5,000 kilograms. The Semi-Autonomous Mapping System (SAMS), also developed by WHOI, is lightweight, 3.5 metres long by 0.6 metres wide and it weighs 500 kg. Typical operating depths are 100 to 6,000 metres and endurance is12 hours (Figure 2).

Data Analysis and Numerical Product Provision

Our primary tools in data analysis are models which produce estimates of the state of the ocean or its forecast state by numerically combining data in a statistical and/or physical sense. A wide range of ocean features and parameters such as circulation, thermal structure and waves, are modelled in global, coastal or harbour domains. Physical fields generated by a physical model are used in energy propagation models such as acoustic forecasts or drift models for search and rescue, mine or oil spill drift.

The first operational numerical weather prediction occurred in May 1955 as a joint USAF, Navy and Weather Bureau project. Although ocean circulation modelling is in principle similar to atmospheric modelling, ocean modelling has lagged behind. There are good reasons for this. Primarily, oceanic space and time scales are much different from those of the atmosphere. Ocean eddies are typically 100 km in size, twenty to thirty times smaller than their atmospheric counterparts. As a result, more computer time is required.

The Naval Research Laboratory developed the world's first eddy-resolving global ocean model: the Navy Layered Ocean Model (NLOM), which has been making daily analyses and forecasts at the Office since October 2000. The model covers from 72S to 65N, with a horizontal resolution of 1/16th degree (about eight km) and seven layers in the vertical. It assimilates SST and sea surface height (satellite altimetry data) and is forced by wind and temperature flux obtained from global weather analyses from our sister organisation, the Fleet Numerical Meteorology and Oceanography Center. The global model can be used to provide boundary conditions for smaller, regional and coastal models, which in turn provide the same for estuary and harbour models. Tides, waves and surf are modelled in an analogous sense (Figure 3).

Of interest to the hydrographer, ocean circulation models are inaccurate in coastal areas without a high resolution bottom bathymetry - how high a resolution depends on the application. Surf is totally dependent upon bottom bathymetry and orientation, thus the better these are known, the better the forecast!

Product Generation

Data that has been checked for quality, imagery and model output is integrated into products defined by the customer. For example, the Warfighting Support Center generates products fused from imagery and in situ data to support coastal, harbour, beach and riverine operations world-wide. Frequently, we must deliver products describing an area that is inaccessible to us.

To do so, we thoroughly research data from other sources, model extensively, and use remote sensing to its maximum. Products are provided both digitally (posted on WEB or pushed) and hard copy (Figure 4).

Remote sensing also plays a crucial role in the generation of global ice analyses and forecasts at the National Ice Center, a partnership between NOAA and the US Coast Guard that reports to this Office. Analyses of current ice conditions are produced weekly by near real-time integration of satellite-derived data, aerial ice reconnaissance, ship/shore station observations, drifting buoy reports, meteorological guidance products, ice prediction model output, climatology and sea ice information obtained from international partners. These products are disseminated in both digital and analogue format through a variety of communications paths.

Conclusion

What makes the Naval Oceanographic Office unique is our global operational mission requirements, the broad range of physical parameters that fit within â€˜oceanographyâ€™, and our various functional roles. Every product that we generate represents a process of optimisation - we use tools that are readily available and if more accurate data is needed, we collect it. We cannot do the work without help - help from the research community such as the Naval Research Laboratory located with us at the Stennis Space Center. We cannot do the work easily without partnerships with other national and international agencies that complement our work. We have the greatest tools in the world to do our job - ships, supercomputers, models, satellites - yet these do not represent our greatest asset: well-trained and motivated people who follow sound procedures. People make operational oceanography possible.