EARTH SYSTEM MONITOR

A guide to NOAA's data and information services

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Providing Scientific Stewardship of NOAA's Geophysical Data

Christopher G. Fox, Ph.D., Director, NOAA National Geophysical Data Center

Although there is no "G" in NOAA, the term "Geophysics" is used to capture the many mission areas of NOAA that do not fall readily into the category of "Oceanic" or "Atmospheric". From the 1807 founding of its ancestor agency, the United States Survey of the Coast, NOAA has been responsible for nautical charting, tidal prediction, geodesy, and navigation for the Nation. Each of these original mission areas has evolved over the succeeding 205 years, and other geophysical phenomena have also found their way into NOAA's mission. The recognition that solar activity and its impact on the Earth's space environment affected radio communications, led to the establishment of the Central Radio Propagation Laboratory in Boulder, CO in 1946. In our modern "connected" society, the impact of space weather on communications, navigation, transportation, and the electrical grid has led to a global land-based and space-based observing system to forecast disruptions in the space environment. In 1948, the threat of tsunamis led to the establishment of the Pacific Tsunami Warning System, based in large part on earthquake detection and tide gauge confirmation. Today, the global tsunami warning system includes the addition of deep-sea warning buoys and sophisticated forecast models.

The National Geophysical Data Center (NGDC) was formed in 1965 in Boulder, CO from existing data management programs of the Coast and Geodetic Survey and the Central Radio Propagation Laboratory. Today, NGDC stewards over 800 geophysical data sets ranging from the sun to the seafloor. The data are maintained in searchable, relational data bases and delivered to the user via the latest web-based interfaces. Value-added products are also created from these data holdings and provided to users. NGDC maintains a staff of about one hundred employees, composed of both information technology specialists and scientist/data managers who provide stewardship to the wide range of data holdings, and a direct connection to the various scientific communities requiring the information and products.

NGDC's data holdings and expertise provide the capability to rapidly respond to a variety of national needs. After the 2004 Sumatran earthquake and tsunami, NOAA upgraded our national capabilities with an improved warning system, evaluated tsunami hazard/risk, and developed community level tsunami response plans. NGDC was able to provide archive services for the expanded tsunami warning system, and construct Digital Elevation Models of the coasts that formed the foundation of tsunami inundation models and forecasts.

When the Department of Defense (DoD) required a new team to develop and distribute the World Magnetic Model, equally critical to NOAA's navigation mission, NGDC stood up a team that drew on its magnetic field holdings from land observatories and

(continued on page 3)

From the NODC Director

Margarita Conkright Gregg, Ph.D.

It is a great pleasure to introduce this volume of the Earth System Monitor which focuses on the National Geophysical Data Center (NGDC). NGDC is one of three National Data Centers which reside in NOAA's Satellite and Information Service: NGDC stewards geophysical data ranging from the sun to the seafloor; the National Oceanographic Data Center (NODC) stewards ocean and coastal data; the National Climatic Data Center (NCDC) stewards atmospheric and climate data.

The three NOAA National Data Centers together are the curators of the Nation's environmental data. Although we share the mission of scientific data stewardship, each Center is unique in the data we steward, and therefore in the expertise that resides at each of our geographical locations. Data stewardship has evolved over the years as our users demand preservation of the highest quality data and integration of that data to meet multidisciplinary purposes. To meet this demand, our Data Centers are staffed by "science data stewards" who acquire, quality control, assemble, preserve, disseminate, and use the data in applications and analyses. Through these activities, our data stewards describe the current state and historical baselines of the environment; "the what" that enable academia, resource managers, and other users to investigate "the how" and "the why". What makes the three NOAA Data Centers unique is the attention we place on long-term preservation of, access to, and understandability of both the original observations and the aggregated, assembled products and information.

The NOAA Data Centers actively collaborate with each other and share internationally accepted standard tools and services that enable greater transparency across data holdings. This also ensures easy access of data by users regardless of where the data sets reside. The Data Centers also collaborate closely on the implementation of ISO metadata standards, and share a common IT system for handling large array data. The Comprehensive Large Array Stewardship System, known as CLASS, is operated by all three Data Centers and will provide the long-term storage for data holdings. These are just a few examples of shared resources across the NOAA Data Centers that enable us to leverage our expertise across disciplines in the most efficient and effective manner.

In this issue, Dr. Chris Fox, Director of NGDC, introduces the complexity and wide range of data his Center stewards. Starting from the sun, through the Earth's surface, and penetrating into its interior, NGDC provides space weather data and information, a tsunami archive and data services, archive services to the U.S. Extended Continental Shelf effort, coastal digital elevation maps, and geomagnetic modeling. This wide range of data supports safe navigation both in space, and on our oceans and coasts, as well as providing the information needed in tsunami forecasting, sea level rise prediction, and storm surge inundation from hurricanes. ■

Margarita

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(continued from page 1)
satellites to provide the model to DoD and other users. If you use the compass function of your iPhone or Android phone, NGDC's model is integrated into the phone's firmware to provide accurate direction.

The World Bank's Global Gas Flaring Initiative is an international effort to reduce the wasteful and environmentally unfriendly practice of burning off the natural gas associated with petroleum production. The program had depended on accurate accounting from the oil producing nations. Applying its nighttime lights imaging capability, NGDC was able to estimate gas flaring worldwide and identify nations not in compliance. Those nations were confronted by the World Bank and have since begun reducing their emissions.

The ever decreasing extent of sea ice in the Arctic Ocean has accelerated the need for operational forecast products. With continuing funds from NGDC, the University of Colorado's National Snow and Ice Data Center partnered with the National Ice Center to produce a forecast system now used operationally. These organizations provide continuous monitoring of the fluctuation of the Arctic sea ice extent and its implications to global climate change.

The increased societal dependence on wireless and space-based systems, such as cell phones and GPS, has increased our vulnerability to solar events and space weather disturbances. NGDC provides archive services and products for solar imagery and space environment observations, and much more as described in this issue.

Enjoy the following articles providing more details on these efforts and visit our website at www.ngdc.noaa.gov to learn more about the National Geophysical Data Center and its capabilities to serve NOAA and the Nation. ■

Space Weather-Ready

Dr. Janet Green, Solar Terrestrial Physics Division

NOAA's National Geophysical Data Center (NGDC) is the Nation's provider of space environmental data and information, which can be used to contribute to our understanding of how space particle radiation can harm and disrupt the service of satellites and equipment in near earth orbit. Geospace is surrounded by highly energetic ions and electrons that can be problematic for space electronic systems in a number of ways. Charged particles collecting on exposed satellite surfaces may ultimately lead to electrical discharges or sparks that can permanently damage or degrade space electronics and satellite power systems. Very energetic charges can even burrow into satellites causing internal charge build-up or release damaging ionization as they transit within spacecraft structures.

The intensity of space radiation is highly dynamic and varies depending on conditions connecting the earth to the sun, and to outer space. Major satellite outages due to the space environment have become an infrequent occurrence as satellite manufactures use techniques to minimize risk. Such techniques include adding layers of aluminum to shield sensitive parts and adding redundant components should one be compromised. However, the impact of a radiation event that exceeds typical design limits can be potentially severe, particularly given our Nation's critical dependence on its satellite infrastructure for communications, global positioning and weather forecasting.

NGDC continues to assist government and commercial satellite operators and designers to cope with the harmful effects of space radiation. The first line of defense is a well-built satellite, able to withstand the harsh environment of space. To aid in this effort, NGDC provides a long-term archive of data from the NOAA Polar Operational Environmental Satellites and Geostationary Operational Environmental Satellites, which are continuously monitoring the space radiation environment. These data have been incorporated into climatological models used by satellite builders to ensure robust designs. At a recent meeting hosted by NGDC, knowledgeable scientists and engineers recommended that a worst-case radiation environment be included in future satellite design standards. The next line of defense is to monitor the real-time radiation environment and limit risky satellite launches, maneuvers, or maintenance during intervals of high environmental radiation. NGDC is working closely with the National Weather Service's Space Weather Prediction Center to provide satellite operators with a "one-stop" shop for real-time radiation assessments and other pertinent information. Lastly, if an anomaly occurs, it is imperative to quickly identify the root cause so that appropriate actions can be taken to maintain service and improve satellite sub-system design. To this end, NGDC is developing a Satellite Anomaly Mitigation Data Portal to provide data and information along with decision trees for quickly assessing whether an anomaly might be related to the space environment. For large events, NGDC provides detailed space weather event summaries to assist satellite companies in understanding the complex and dynamic space environment. NGDC's goal is a Nation prepared to meet the challenges of our technological society; that is, a truly *space* Weather-Ready Nation. ■

NGDC - NOAA's Tsunami Archive and Data Services Center

Paula Dunbar, Physical Scientist and Heather MCullough, Physical Scientist

Tsunamis are high-impact natural hazards that, if not prepared for, can have devastating effects on U.S. coastal communities. NGDC is NOAA's global tsunami data and information service (http://ngdc.noaa.gov/hazard), providing foundational retrospective data and products, as well as scientific and technical expertise, which helps deliver reliable tsunami forecasts and warnings and promotes community resiliency. NGDC coordinates requirements for and development of digital elevation models (DEMs) for NOAA and the National Tsunami Hazard Mitigation Program – a federal-state collaboration to mitigate the impact of tsunamis on coastal communities.

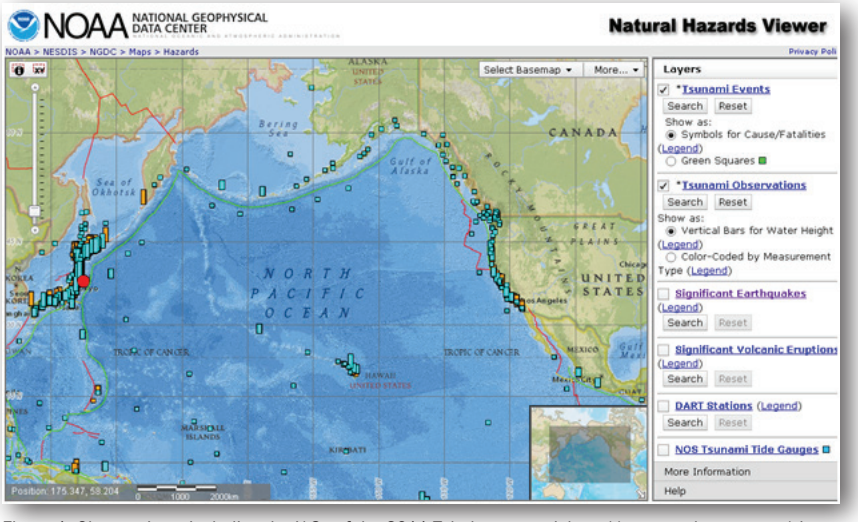


Figure 1. Observations, including the U.S., of the 2011 Tohoku tsunami. http://maps.ngdc.noaa.gov/viewers/hazards

Over 50% of the U.S. population lives in coastal communities. At the heart of NOAA's tsunami mission is the capability to forecast tsunamis using advanced measurement and modeling technologies in order to minimize the loss of life and disruption to communities along our coasts. This capability relies on rapid access to data for real-time evaluation and reliable access to quality post-event data for common operations, forecast validation, research, and hazard assessment.

NGDC provides tsunami data to the public through a variety of maps, interfaces and web services. Searchable databases and map viewers provide integrated access to significant events and impacts, observational data, natural hazards photographs, digital elevation models, posters, and educational materials. NGDC stewards the following tsunami data:

- Global historical tsunami source, impact and socio-economic data since 2000 B.C.
- Tsunami post-event field survey data and damage photographs
- Integrated seamless coastal and regional digital elevation models
- Underlying bathymetry, lidar, and topography source data for DEMs
- High resolution coastal tide gauge raw and event-specific processed data
- Deep-ocean Assessment and Reporting of Tsunamis (DART®) raw and processed data

Figure 2. 1964 Tsunami damage, Resurrection Bay, Alaska: http://ngdc.noaa.gov/hazardimages

While damaging tsunamis don't occur very often, their impacts are severe, frequently leading to fatalities, structural damage and significant economic loss to U.S. coasts. Since 1690, more than 200 events have affected the United States and its territories, causing more than 700 deaths and $300 million in economic loss. As evidenced by tsunamis in Sumatra in 2004, American Samoa in 2009, Chile in 2010, and Japan in 2011, the impacts can be devastating. Hazard mitigation requires knowing the likelihood of an event and the type of damage potential. NGDC is partnering with the U.S. Geological Survey and the National Tsunami Hazard Mitigation Program (NTHMP) to update the *U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves,* NOAA

Tsunami Program Special Report, August, 2008, (ISBN 1234068796). The updated analysis will be based on NOAA's global historical tsunami database and the USGS seismic recurrence analyses. The historical database contains information on tsunami events and the impacts at the coast, including deaths, damage, and economic losses.

NOAA and its NTHMP partners are required to strengthen tsunami detection, warning, education and preparedness efforts. NOAA's operational, research, and mitigation activities are efficiently matrixed across the agency.

- *National Weather Service* - operates the Tsunami Warning Centers responsible for issuing tsunami forecasts and warnings; the GTS for providing real-time data flow; the National Data Buoy Center for managing the Deep-ocean Assessment and Reporting of Tsunamis DART ® network and operational data distribution; and the International Tsunami Information Center, a NOAA/UNESCO partnership, for assisting Member States to establish warning systems and a clearinghouse for educational and preparedness materials
- *National Ocean Service-Center for Operational Oceanographic Products and Services* manages the high-resolution coastal tide-gauge network and operational data distribution
- *Office of Oceanic and Atmospheric Research-Pacific Marine Environmental Laboratory* – conducts tsunami research, network and observation enhancements, advanced measurement and modeling technologies
- *National Environmental Satellite Data and Information Service -National Geophysical Data Center*– supports algorithms for operational modeling; maintains the global tsunami archive; provides quality assurance, processing, and integration of deep-ocean and coastal water level data; develops DEMs to support forecast and mitigation, provides integrated access to all tsunami data

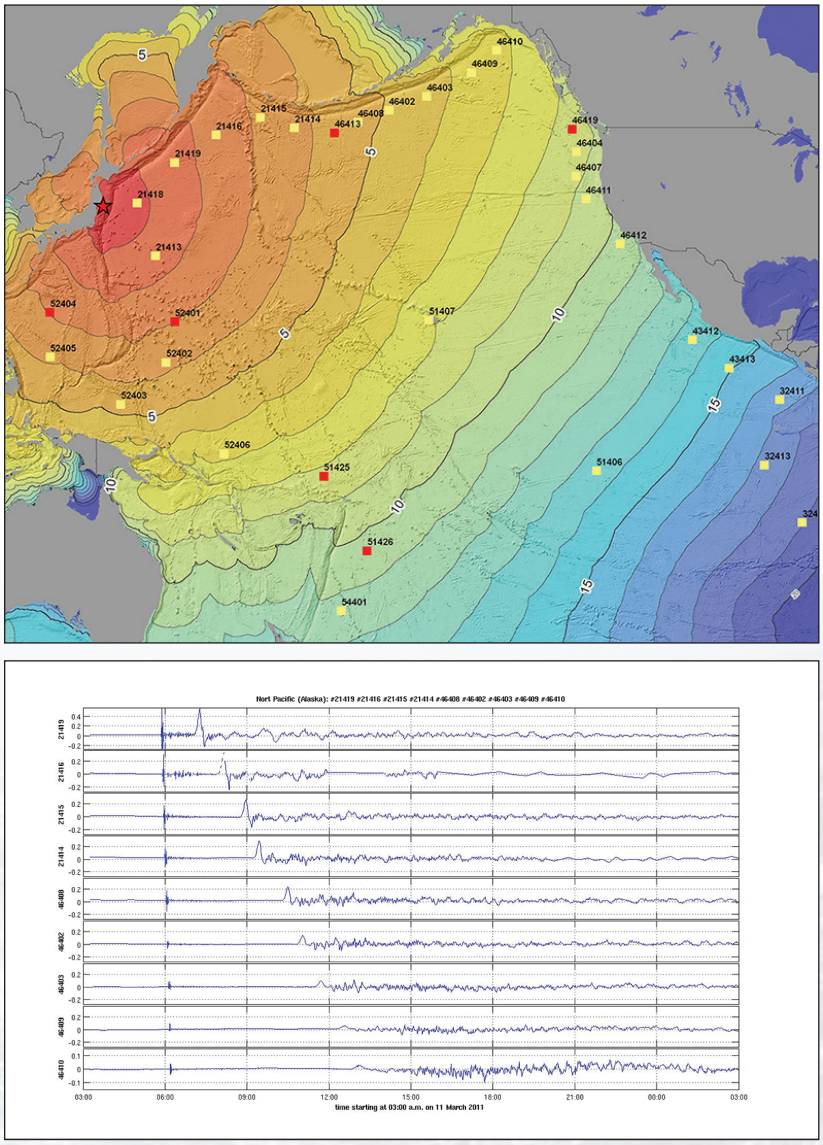


Figure 3. 2011 Tohoku Tsunami Travel Time (TTT) map with DART® locations and processed observations

As coastal populations and economies continue to expand, more lives and infrastructure will be at risk. Through this ongoing coordination, NOAA can efficiently and effectively meet our mission responsibilities. By providing a foundation of resources and a means for collaboration among federal, state and local levels, NOAA helps coastal communities prepare for potential future events and anticipate the imminent tsunami arrival. Partnership is the key to preparedness. ■

NGDC Data Management Supporting the Extended Continental Shelf Project

Robin Warnken, Oceanographer and Jennifer Henderson, Marine Scientist

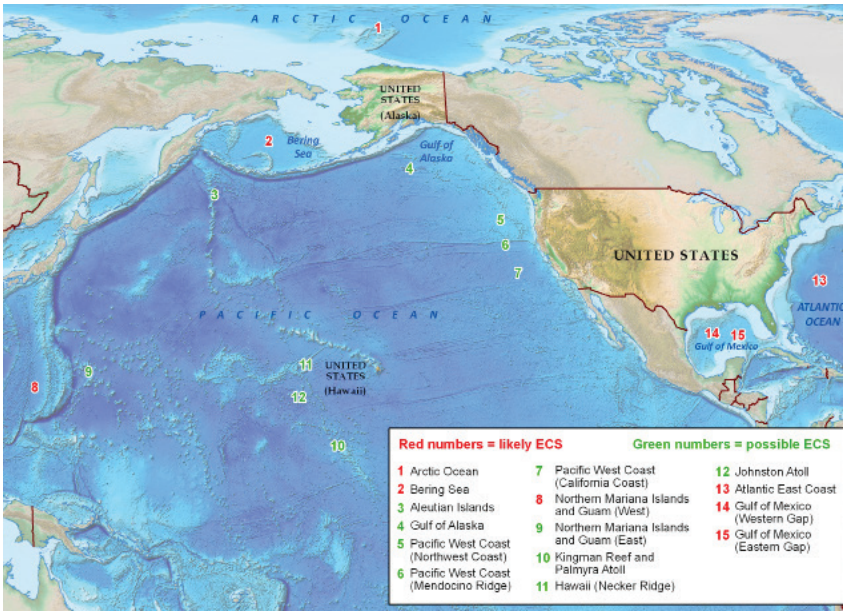
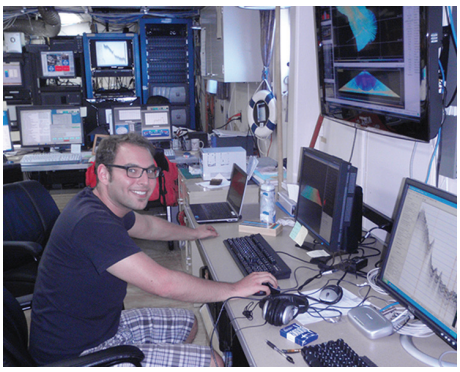


Figure 1. The numbered areas illustrate where the U.S. is considering collecting and analyzing data and does not represent the official U.S. Government position on where it has extended continental shelf. This map is without prejudice to boundary depictions and future negotiations. Credit: continentalshelf.gov

The Extended Continental Shelf (ECS) Project is a multi-agency collaboration led by the Department of State (continentalshelf.gov), whose mission is to establish the full extent of the continental shelf of the United States consistent with international law, thus ensuring management of the resources on and below the seabed. NOAA is involved in the ECS, leading working groups, collecting and processing bathymetry data, participating in the analysis, science and policy decisions, and managing the data and derived products.

As reflected in the United Nations Convention on the Law of the Sea (UNCLOS), every coastal country has a continental shelf out to 200 nautical miles (nm). A coastal country may define a continental shelf beyond 200 nm, known as the extended continental shelf, if it meets the formula and limit lines defined in UNCLOS. In this maritime zone, a country may exercise sovereign rights over the natural resources of the seafloor and sub-seafloor. Determining the outer limits of the ECS requires the collection and analysis of data that describe the depth, shape, and geophysical characteristics of the seafloor and sub-seafloor. Preliminary studies indicate that the U.S. ECS likely totals at least two million square kilometers – an area potentially worth billions of dollars in resources and rich in research opportunities.

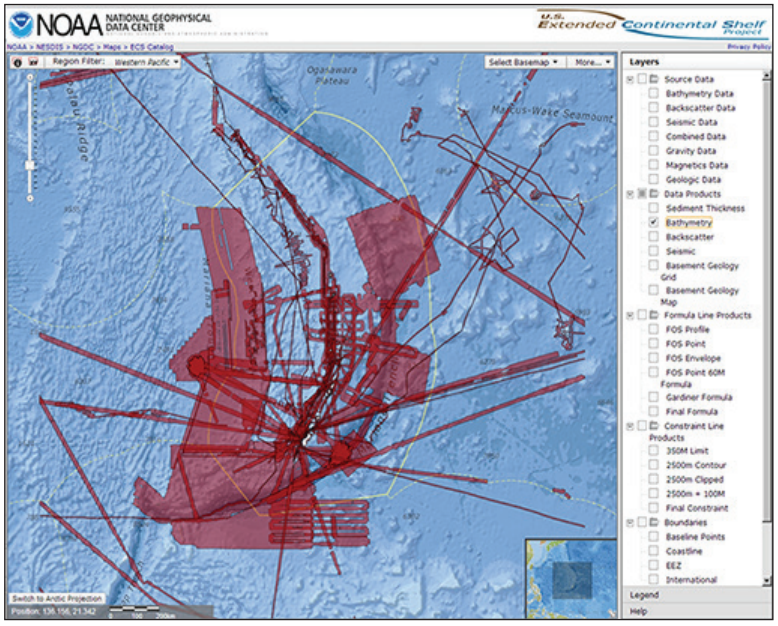


Computer lab aboard ship Ronald Brown

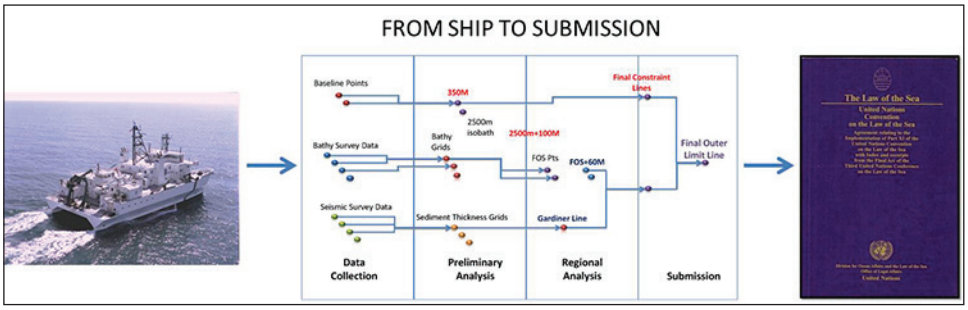
Kilo Moana ported in Pago Pago

Washing dredge samples on U.S. Coast Guard icebreaker, Healy

NGDC's role as the Data Management and Integration Lead of the ECS Project is to steward, integrate, document and maintain the long-term archive for all ECS-related data and derived products. This includes geophysical surveys from a variety of sources and products from analyses conducted by ECS Project scientists. NGDC hosts the ECS Analysis Lab, and ensures that ECS data and information are well documented, archived and readily accessible for the ECS project and the public (http://www.ngdc.noaa.gov/mgg/ecs/). To date, over 30 ECS funded cruises have collected seismic reflection, seafloor samples, gravity, magnetic and multibeam bathymetry data, mapping more than 2 million km^2. NGDC staff participated in seven ECS cruises, collecting data in the Atlantic, Arctic, Bering Sea, Gulf of Alaska, and Pacific Ocean.



One of the key challenges in the project is the stringent requirement to track the origin of data and derived products. Final regional analyses will result in hundreds of points that define a new maritime boundary, which becomes our extended continental shelf. These points will be developed in a rigorous process of analysis encompassing potentially thousands of raw datasets and derived products. Keeping track of the puzzle pieces, and the ways in which they relate to one another, is the job of NGDC's Information Management System (IMS). The IMS enables scientists performing ECS analyses to contribute data and derived products to NGDC's archive, and to discover and retrieve these data during future stages of the project. The IMS is populated with primary data, derivative data and products, associated metadata, and analyses. The IMS will enable multiple team members to participate in managing ECS data in a consistent way, which is crucial for the success of the ECS Project.



Metadata is part of the overall system for preserving the critical decisions made in the determination of the U.S. ECS. NGDC collaborates with scientists and data experts from several U.S federal agencies and academic science data centers to develop and improve common metadata standards for marine seismic reflection data, multibeam bathymetric data, seafloor bottom geologic samples, gravity and magnetic data, and cruise level data for both the U.S. ECS project and the Integrated Ocean and Coastal Mapping (IOCM) program. Metadata will ensure the utility of data and products at all stages of the ECS project – from "ship to submission". Not only does metadata provide the formal descriptions of data and products, it captures the decision making process and supports the analysis, eventual determination of the limits, and long term archive.

NGDC staff participates on ECS Integrated Regional Teams (IRTs) as team leads, data managers, and GIS experts. As the lead for two of the seven IRTs, NGDC scientists developed preliminary reports that assessed the potential U.S. ECS areas for the Central Pacific and the U.S. West Coast. The reports were the result of year-long, multi-agency studies to apply different possible scenarios to existing data, develop strong legal and geologic arguments to support each scenario, and identify requirements for future survey work. The IRT reports were reviewed by the U.S. ECS Task Force in June, 2012 to determine steps forward.

In summary, NGDC is one of 3 NOAA offices active in the inter-agency U.S. Extended Continental Shelf Project. NGDC has primary responsibility to manage all of the digital data and derived products associated with the ECS: to provide scientific, technical, and data expertise to enable the analysis and final determination of a new maritime boundary for the U.S. This project has long-term international impact, including stewardship of an area potentially worth billions of dollars in resources and rich in research opportunities. Some of the immediate impacts of the ECS include new standards for marine metadata, improved collaboration across federal agencies mapping the seafloor, and over 2 million km^2 of new survey data available to support both the ECS and other research and management projects. ■

NGDC's Integrated Ocean and Coastal Mapping Program

Dr. Chris Fox, Director NGDC and LCDR Daniel Price

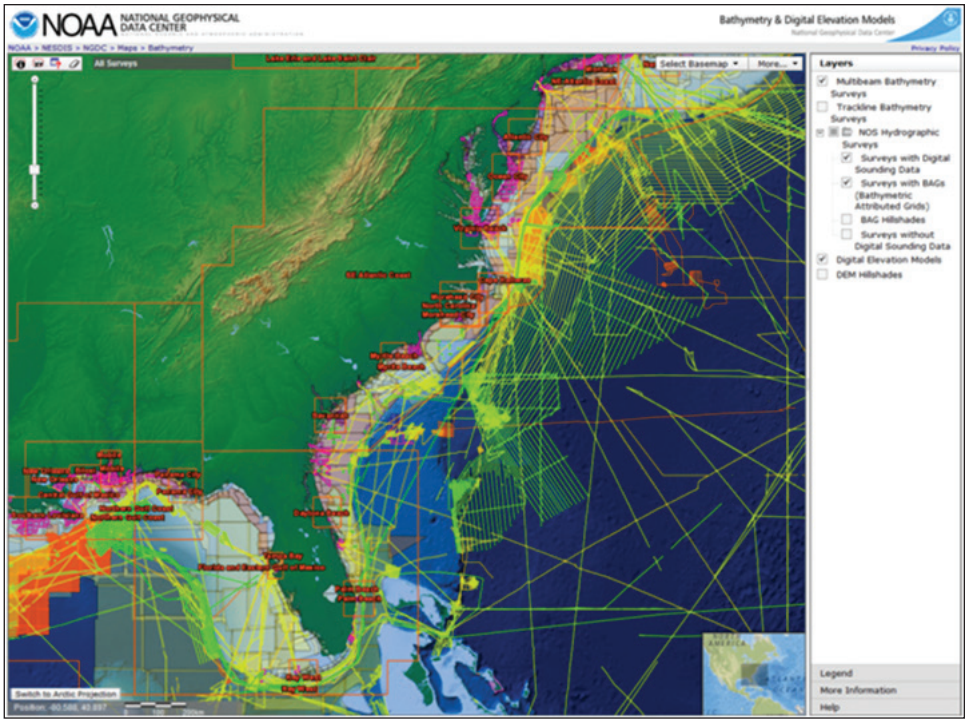
Integrated Ocean and Coastal Mapping (IOCM) is the practice of planning, acquiring, integrating, and disseminating ocean and coastal geospatial data and derivative products in a manner that permits easy access and use by the greatest range of users. Although originally focused on bathymetric mapping data, IOCM data includes all biological, chemical, oceanographic, geological and geophysical data collected from ships, aircraft, or satellites. As the National repository for all geophysical data sets, from the surface of the sun to the center of the Earth, NGDC is a major contributor to many IOCM community efforts.

NGDC is active in all IOCM tasks, but is naturally focused on data discovery and reuse, and end to end data management efforts. NGDC, NOAA's Ocean Explorer Program, and scientists and data experts from several Federal agencies and academic institutions have developed common metadata standards for many IOCM data sets. Clear, standard metadata are essential to the discovery, use and reuse of ocean and coastal mapping data and products. Data standards, along with standard templates for cruise level data, support the U.S. Extended Continental Shelf (ECS) project, the Ocean Explorer Program, the NOAA Fleet, and the broader IOCM community.

Interactive map services have improved discovery and access to data archived at NGDC. These new map services enable integrated access to IOCM data through a variety of common clients such as desktop Geographic Information Systems (GIS) software and interactive Web maps. Integrating map services and metadata based on common standards will both improve discovery of and ease access to the OCM data.

In addition to providing archive and access for geophysical data from every Line Office in NOAA, NGDC is the designated archive for the University-National Oceanographic Laboratory System (UNOLS) Rolling Deck to Repository (R2R) program. R2R aims to ensure that data collected aboard research ships are efficiently documented, preserved, and accessible for the long-term. By coordinating across line offices and programs, the delivery of data to the archive is streamlined. Data are also made more easily available to the stakeholders who depend on it for decision making, habitat management, hazard mitigation, and research. Largely based on the UNOLS R2R program funded by the National Science Foundation, the NOAA R2R project provides coordination, facilitation, and support for the NOAA programs that already have primary responsibility for their ship-based data management activities. With the demand for environmental data increasing and the resources to provide ship time growing scarcer, the efficiency with which we utilize the data collected becomes even more vital. Reuse of data gathered aboard research vessels results in savings of millions of dollars, and more accurate, robust products such as improved tsunami forecast capabilities, sound ECS assessments, and science-based habitat characterizations.

Ocean data discovery and reuse scenarios exemplified by Hurricane Katrina, tsunami preparedness following the Sumatran Earthquake, and the Deep-Water Horizon disaster, underscore the need to produce new and unforeseen products utilizing NOAA data holdings and expertise. Areas such as climate change, ecosystems management, sustainable coastal areas, and coral reef decline are ongoing priorities that will greatly benefit from the efforts of the Ocean and Coastal Mapping Integration program. ■



Space Weather Products for NOAA Satellites

Dr. William F. Denig, Solar Terrestrial Physics Division

The aurora borealis is a particularly beautiful manifestation of space weather that has captivated the imagination of storytellers for countless generations. Ancient peoples of the frozen north evolved various folklores as their way of interpreting and dealing with the aurora. There was a time when the Eskimos of Alaska took their children indoors whenever the aurora appeared for fear that their children would be harmed by the evil spirits of the northern lights. It is interesting to ponder the fact that it is only happenstance that the aurora borealis occurs at high latitudes as a consequence of the near alignment of the geomagnetic field to the earth's spin axis. In the southern hemisphere these ephemeral lights are known as the aurora australis. As a scientist, to experience the dynamic and undulating motions of the aurora is to marvel at the interconnectedness of the earth's magnetic field with interplanetary space and with that of our closest star, the sun. Not unlike our ancient predecessors, modern technologists understand that the aurora, as an indicator of enhanced space weather, remains a "harbinger of evil" which can have serious societal impacts.

Figure 1. NOAA scientist Dr. Rob Redmon in Fairbanks, Alaska, on a recent travel assignment to study the aurora.

In March 1989, a large geomagnetic storm devastated the power grid in Quebec, leaving some 6 million people without electricity for over 9 hours. A recent study by the National Research Council estimated that the extreme costs for a severe geomagnetic event, could have a total economic impact from 1 to 2 trillion dollars. However, in addition to the impacts of geomagnetic storms on the National power grid, there are other consequences of space weather with which NOAA, and other Federal agencies, are deeply concerned. Adverse space weather has led to; 1) the disruption and, in some cases, the total loss of satellites due to spacecraft charging, 2) increased positional accuracy errors associated with Global Positioning System (GPS) receivers and 3) forced commercial airlines to divert away from cost-effective polar routes due of the fear of increased space radiation and loss of communications. For these reasons, space weather has been identified as a Grand Challenge for Disaster Reduction by the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR). For its part, NOAA continuously monitors the space environment by fielding space weather sensors on the Geostationary Operational Environment Satellites (GOES) and the Polar Operational Environmental Satellites (POES).

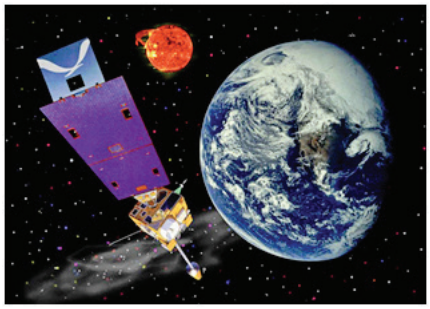


Figure 2. The GOES satellites are NOAA's space weather sentinels

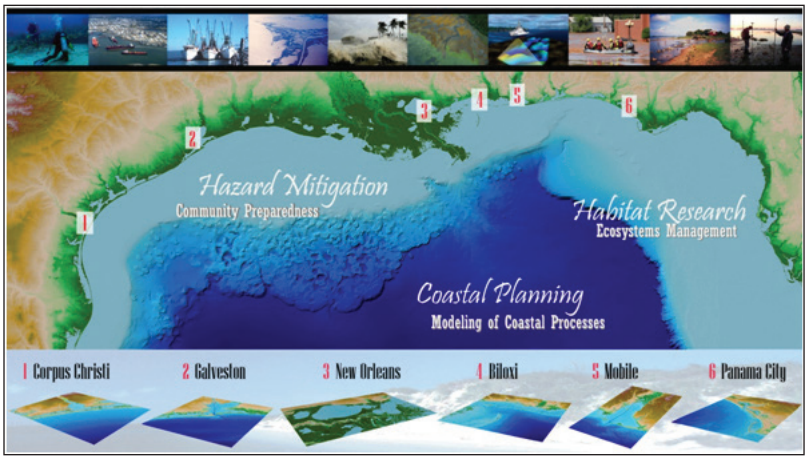
The NOAA National Geophysical Data Center (NGDC) is responsible for development of algorithms used to produce space weather products from the GOES and POES, and for managing the on-orbit performance of the NOAA space environmental sensors. These sensors include instrumentation to measure the "geospace" environment, in terms of local space weather conditions that have a direct effect on earth and satellites in near-earth orbit. Additional GOES sensors continuously monitor the sun for solar flares, and to detect the ejection of massive amounts of solar material that can travel from the sun to earth and cause debilitating geomagnetic storms. A specialized team of dedicated scientists within NGDC are currently developing space weather capabilities for the next generation of NOAA geostationary satellites known as the GOES-R series. ■

Figure 3. NGDC scientists responsible for the developing of next-generation space weather capabilities for GOES-R.

Understanding the Marine Realm Through Coastal Digital Elevation Models (DEMs)

Dr. Barry Eakins, Marine Geophysicist

Coastal digital elevation models (DEMs) integrate ocean bathymetry and land topography in U.S. coastal waters to help visualize the ocean floor. They enable scientists to predict geophysical marine processes such as tsunami inundation, storm surge from hurricanes, sea level rise, and even contaminant dispersal, to name a few. DEMs are a foundational data layer supporting NOAA's mission to understand and predict changes in Earth's environment, and to conserve and manage coastal and marine resources meeting our Nation's economic, social, and environmental needs.



NGDC builds coastal DEMs of select U.S. coastal communities to support NOAA's Tsunami Program. This includes NOAA's real-time tsunami warning system, operated by the National Weather Service (http://www.tsunami.gov/), research at the NOAA Center for Tsunami Research (http://nctr.pmel.noaa.gov/), as well as coastal State partners through the National Tsunami Hazard Mitigation Program (NTHMP) (http://nthmp.tsunami.gov/). The NTHMP focus is to better prepare at-risk communities for future events. DEMs are available for communities along the U.S. East and West Coasts, the Gulf of Mexico, Alaska, Hawaii, Puerto Rico and Pacific Islands, along with lower resolution regional and global DEMs (http://www.ngdc.noaa.gov/mgg/coastal/).

The President's National Ocean Policy (http://www.whitehouse.gov/administration/eop/oceans/) calls for improved mapping products that will better support a range of activities, including models of marine elevation from on-shore coastal areas to the limit of the U.S. Exclusive Economic Zone and extended continental shelf. To meet this goal, NGDC is collaborating with the United States Geological Survey (USGS) to develop integrated bathymetric-topographic DEMs within a consistent, sustainable framework that will enable regular updating of models and public access. When realized, this seamless depiction of elevation will support mission-requirements across NOAA from accurate coastal flood forecasts and improved port facilities and habitat management capabilities.

NGDC also stewards many of the source elevation data sets used in building coastal DEMs, including NOS hydrographic surveys, multibeam swath sonar data, coastal lidar surveys, and data from older single-beam soundings (http://maps.ngdc.noaa.gov/viewers/bathymetry/). NGDC works closely with the University-National Oceanographic Laboratory System Rolling Deck to Repository (UNOLS-R2R) program (http://www.rvdata.us/) and the parallel NOAA R2R program, to effectively and efficiently transfer ship-collected digital data to NGDC for long-term archive and access. NGDC also participates in the NOAA and Inter-agency Ocean and Coastal Mapping program (http://iocm.noaa.gov/) to facilitate the acquisition and re-use of bathymetric data and products. ■

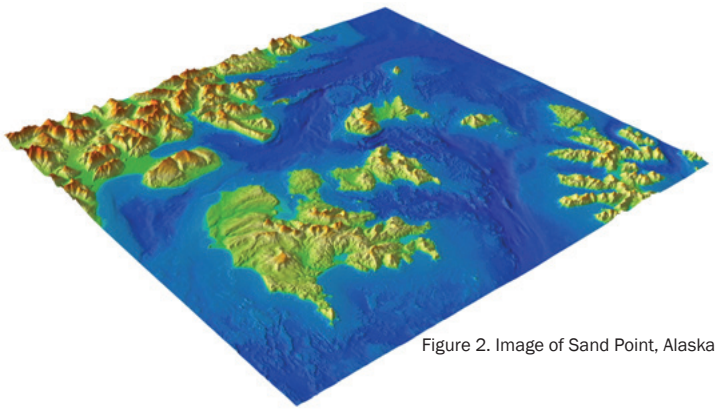


Figure 2. Image of Sand Point, Alaska -DEM

Geomagnetic Modeling and Data Services – Supporting Safe and Efficient Navigation

Susan McLean, Physical Scientist and Manoj Nair, Geophysicist

Do you have a smart phone with compass function, or perhaps a GPS car navigation system? Does your camera record not only the location the picture was taken, but the direction the camera was facing? If so, you are among the millions of people who daily use a product developed by NOAA's Geomagnetic Field Modeling Team at the National Geophysical Data Center (NGDC). NGDC provides users a first stop for understanding and incorporating magnetic field information into research and operations. The team collects and processes geomagnetic data and produces models of the Earth's magnetic field, primarily used to aid military and civilian navigation of ships, aircraft, submarines and satellites. These models are also widely incorporated into many handheld devices.

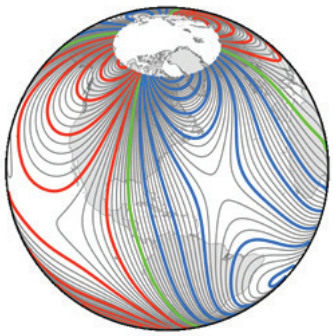


Figure 1. Contour lines of magnetic declination based on the WMM. Red contours are positive (east) declination.

NGDC develops the World Magnetic Model (WMM) for the U.S. Department of Defense (DOD) every five years, for use as the navigation standard model for DOD, North Atlantic Treaty Organization (NATO), NOAA, and the Federal Aviation Administration (FAA). NGDC also participates in the development of the International Geomagnetic Reference Field, a research community model that directly benefits from the WMM. The WMM is incorporated into millions of commercial products from GPS units to cameras, cell phones, and watches for navigational and directional assistance. For example, all the smartphones powered by the Android operating system come with WMM pre-installed. NGDC maintains the largest comprehensive archive of marine and airborne geomagnetic data, supporting research, resource exploration, and marine living resource management. NGDC supports industry use of the models by providing documentation, validation, and consultation. NGDC's online "magnetic field calculator" (http:// http://ngdc.noaa.gov/geomag/) serves several million users annually from defense organizations to the international science community.

NGDC also supports requirements for specialized uses such as directional drilling and "de-magnetizing" ships to make them magnetically invisible. With the availability of nearly 20 years of high quality satellite observations combined with hundreds of marine and airborne observations, the Geomagnetic Field Modeling team has developed unique high-definition models that account for local magnetic anomalies. These models support the growing demand for secure and accurate navigation and military uses by enabling increasingly precise determination of true bearings. In addition to improved nautical and aeronautical charting, these new models support directional drilling.

Solar-wind variations influence electric currents in the Earth's ionosphere and magnetosphere and can change the geomagnetic field in unpredictable ways, especially at high latitudes. Efforts are underway to account for these space-weather effects in real time to improve the accuracy of geomagnetic field models. One of the major challenges is transmitting the output from these real time models with minimal time delay to users, who may be in remote locations.

NOAA's magnetic observing and modeling roots are planted in America's oldest scientific agency: the Survey of the Coast, created in 1807 by President Thomas Jefferson to provide nautical charts to the American maritime community. The 80th Congress (1947-1948) reaffirmed this mission authorizing the Director of the Coast and Geodetic Survey to conduct geomagnetic measurements, provide for the orderly collection of geomagnetic data, and establish a "central depository for geomagnetic data", responsible for archive, correlation, and dissemination of geomagnetic data and products. While the responsibility for operating magnetic observing stations was transferred to the U.S. Geological Survey in 1973, data archive, modeling, and data dissemination have remained active within NOAA for over 200 years. NGDC's Geomagnetic Modeling Team offers a mix of scientific expertise and a focus on meeting the needs of users. We develop standard operational models and products to support safe and efficient navigation of our nation's waterways while also undertaking innovative research. ■

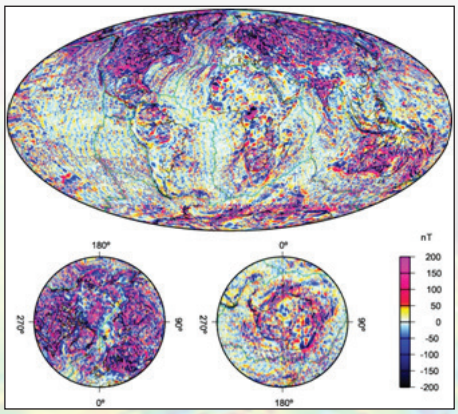


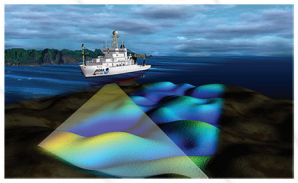
Figure 2. NGDC's high resolution geomagnetic model NGDC-720, compiled from satellite, marine, aeromagnetic and ground magnetic surveys, has a spatial resolution of 56 km.

The NOAA National Geophysical Data Center

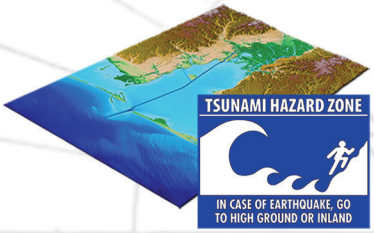
Supporting Informed Decisions with Authoritative Data

Earth Observations from Space

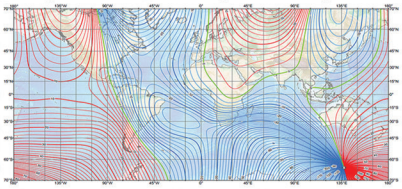
Ocean Mapping & Law of the Sea



Coastal Resiliency & Hazards

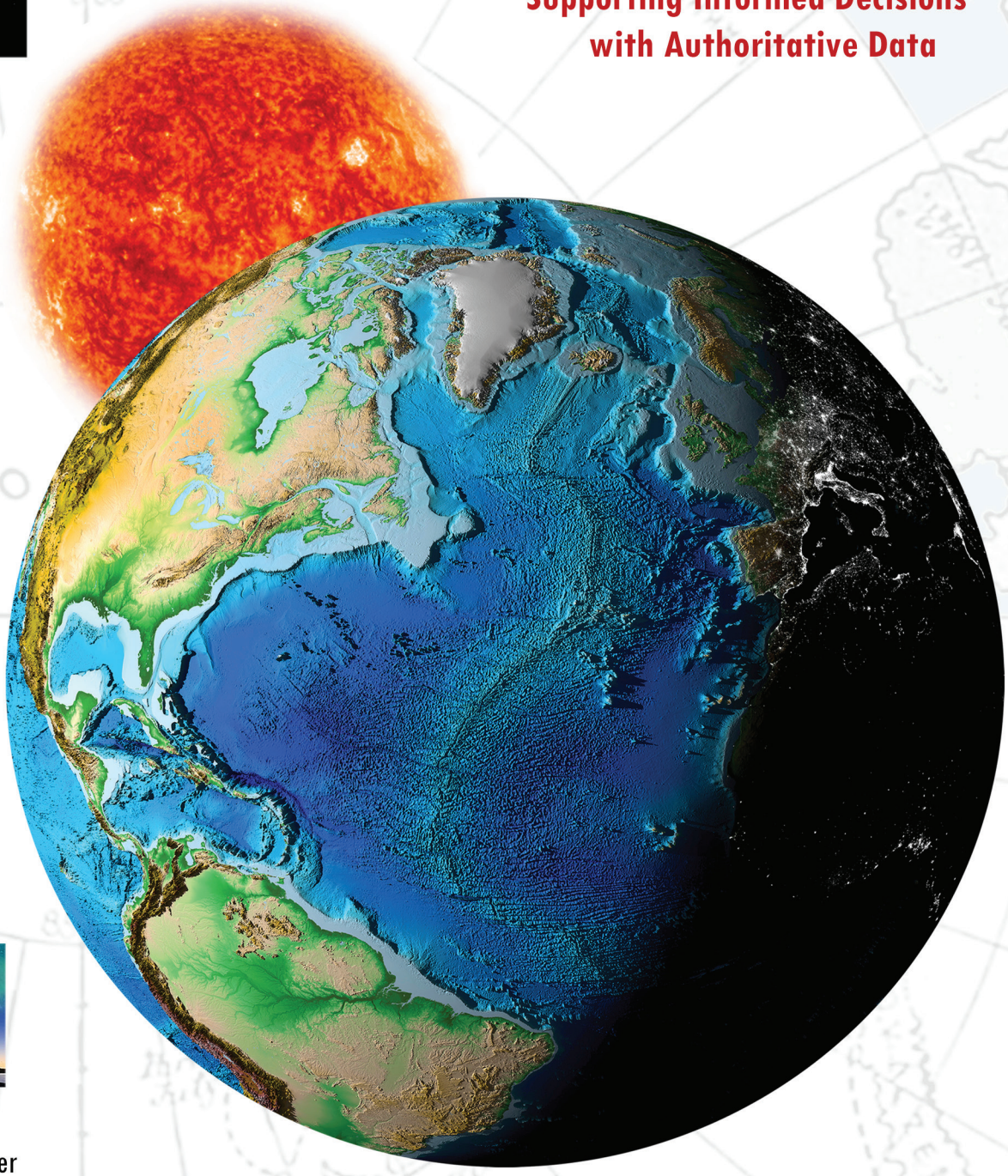


Magnetic Modeling & Navigation



Space Weather & Solar Events

The National Snow & Ice Data Center



Over 600 data types - from the core of the Earth to the surface of the Sun