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EARTH SYSTEM MONITOR

A guide to NOAA's data and information services

INSIDE

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

ERS satellite gravity and airborne gravity over the Arctic Ocean: a comparison

Gravity surveying techniques produce accurate, high spatial resolution results

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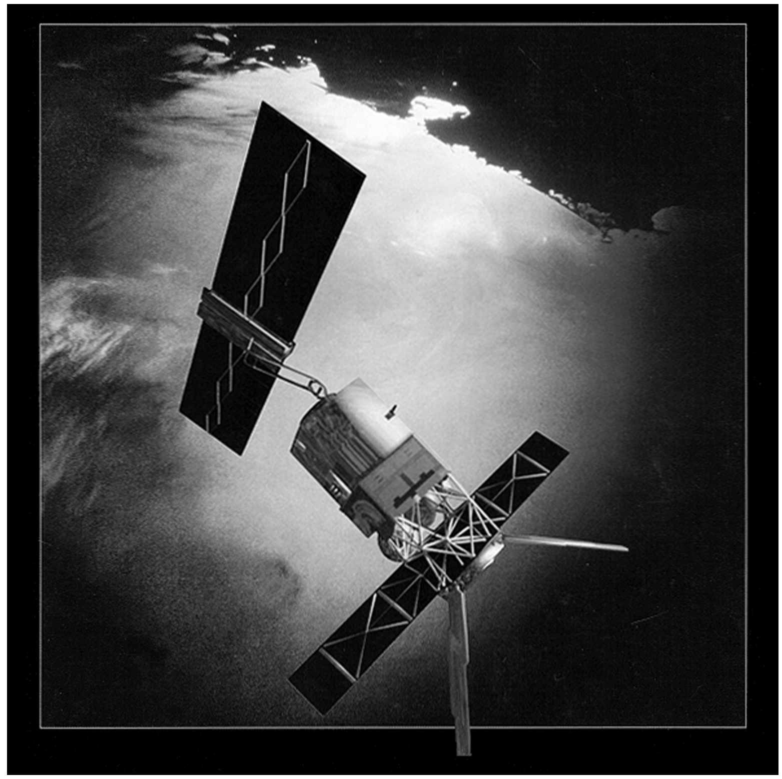

▲ **Figure 1.** Artist's rendition of the European Space Agency's ERS-1 satellite, which operated from 1991 to 1996. Data collected via the satellite was used to extend existing altimetric gravity fields of the global ocean (Laxon and Mcadoo, 1994, Sandwell and Smith, 1997). Figure reproduced from *The Data Book of ERS-1: The European Remote Sensing Satellite*, European Space Agency, esa BR-75, April 1991.

Year-round ice cover in the Arctic Ocean has made geophysical and oceanographic surveying with traditional shipboard techniques difficult or impossible. Until recently, the sparse surveys of opportunity from ice islands and icebreakers yielded virtually all of the available geophysical data for the bulk of the marine Arctic - aside from airborne magnetic surveys. As a result, the Arctic is the least understood of all the world's ocean basins, and the geologic history of the Arctic remains quite uncertain.

Moreover, it is important for global climate research to understand the Arctic Ocean and, in particular, the variations—with time and place—in its sea ice thickness. A new effort is now underway to redress this gap in our scientific knowledge of the Arctic. This article focuses on two relatively new methods for observing and mapping gravity that are major contributors to these new studies in Arctic science. These techniques are: retracked Earth Remote Sensing (ERS) satellite altimetry and Naval Research Laboratory (NRL) airborne gravimetry. Other contributors to this endeavor include the ongoing Scientific Ice Experiment (SCICEX) program to collect unclassified marine geophysical data from U.S. Navy nuclear powered submarines (Pyle *et al.*, 1997) as well release of previously classified U.S. Navy bathymetric data (Johnson and Brass, 1998).

Arctic marine gravity field determinations using each of these two new techniques will continue to improve in accuracy and resolution as more data are collected and further refinements are realized. However, both techniques are now reaching a level of maturity where it is important to compare them in accuracy and spatial resolution. As part of this comparison, an assessment of the horizontal spatial resolution is critical. Seafloor tectonic structures of horizontal scales 10 km to roughly 300 km, such as seamounts, mid-ocean ridge, and fracture zones are associated with significant seafloor topography crustal structure and hence with significant anomalies in the marine, free-air gravity field. Consequently, if one can accurately map marine gravity to scales as short as 10 or 20 km then one is able to map, often rather well, the tectonic fabric of the seafloor (e.g., Smith, 1998).

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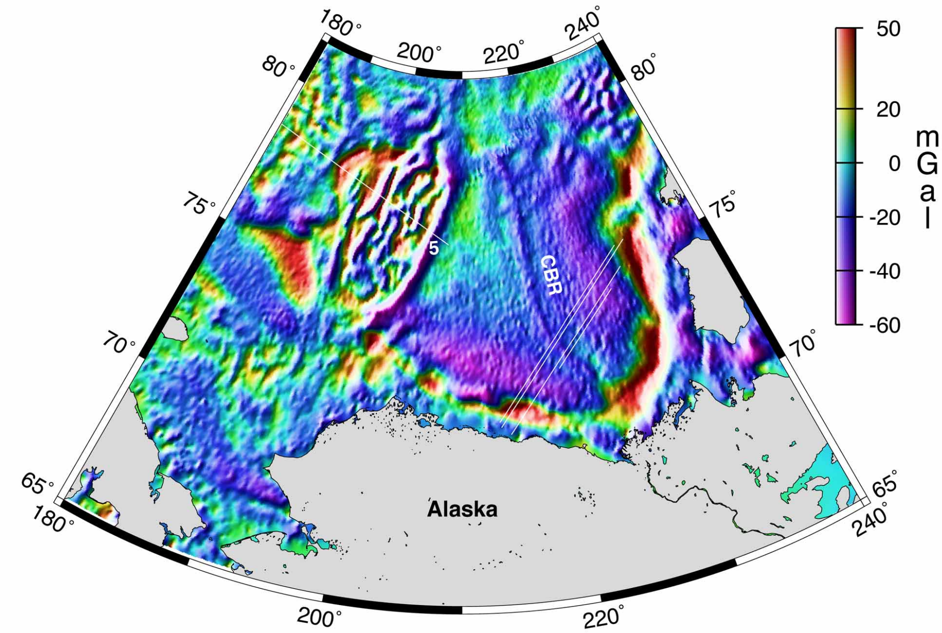

▲ **Figure 2.** ERS-1/ERS-2 satellite marine gravity in the Canada Basin and five NRL aerogeo-physical groundtracks (in white). Line '5' crosses the Chukchi Borderland. Note the gravity low labelled CBR (Canadian Basin Ridge) indicating an apparent extinct spreading axis of the Canada Basin.

Satellite & airborne gravity, *from page 1*

Indeed, the results of the gravity comparisons which are reported below indicate that both techniques do a good job of resolving short spatial wavelengths and hence can be used in mapping the tectonic fabric of the Arctic seafloor. Many of these results were also reported at the 1998 meeting of the European Geophysical Society (McAdoo *et al.*, 1998).

ERS-1 and -2 altimetry

ERS-1 (Figure 1) is the European Space Agency's remote sensing satellite which operated from 1991 to 1996 in a high-inclination (81.6°) orbit. Laxon and McAdoo (1994) showed that 35 days' worth of radar altimeter data from ERS-1 could be used to derive a moderate-resolution gravity field of the largely ice-covered circum-Arctic Ocean, thereby extending existing altimetric gravity fields of the global ocean (Sandwell and Smith, 1997) north to 81.5° N.

However, standard ERS data ocean products (OPRs from the tracker on board ERS-1) of sea surface height could not be used because the highly specular, radar echoes from sea ice confuse the onboard data processor. A careful and laborious analysis of the full ERS waveform (WAP) data set (much larger than the OPR data set) is necessary prior to estimating Arctic Ocean sea surface topography and gravity. Suitable waveforms (WAPs) are reprocessed using a simple threshold-retracking algorithm to recover acceptable estimates of sea surface height and thence along-track slope. The slopes are then used to compute the gravity field, i.e., free-air gravity anomalies at sea level, using established methods (Sandwell and Smith, 1997; Laxon and McAdoo, 1994; McAdoo and Marks, 1992). Although this first ERS-1 circum-Arctic Ocean

—*continued on page 4*

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Kurt J. Schnebele named Deputy Director of NODC

Kurt J. Schnebele, an oceanographer with extensive experience in field work, data processing and analysis, and technical program management, has been named Deputy Director of the National Oceanographic Data Center (NODC) in Silver Spring, MD. The Center is part of the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). The facility is the nation's repository and dissemination center for global oceanographic data. It manages and distributes physical, chemical, and biological oceanographic data collected by organizations in the United States and dozens of other countries around the world.

"I'm very proud to be at NODC. It's a great institution with a vital role to serve both nationally and internationally," Schnebele said.

Schnebele retired from the NOAA Corps in 1997 after serving for 26 years. He served aboard several NOAA ships, including *Oceanographer*, *Peirce*, and was commanding officer of the *Ferrel* and *R/V Vickers*. On shore, he served with the National Ocean Service and NOAA's Atlantic Marine Center. He also was an assistant professor at the Naval Postgraduate School and, most recently, the executive director of NOAA's Office of Oceanic and Atmospheric Research.

Schnebele holds a B.S. and M.S. in oceanography from the University of Washington and the Naval Postgraduate School, respectively. His awards include the Navy Commendation Medal, two NOAA Commendation Medals, NOAA Special Achievement Awards, and unit citations.

NWS releases service assessment for 1998 ice storm and flood

A National Weather Service (NWS) assessment of services provided during the ice storm and flood of January 1998 in northern New England and northern New York has been completed and is available on the Web at: *http://www.nws.noaa.gov / om/omdis.htm*.

The extent and magnitude of this storm was unprecedented in New England history, according to John T. Forsing, director, Eastern Region, NWS. The team that documented NWS performance in fulfilling its mission of providing accurate forecasts and timely warnings prior to, during and after the ice storm and flood

News briefs

of January 1998 found that warning coordination and communications by the NWS field offices and the NWS Hydrometeorological Prediction Center were excellent. The NWS issued the first alert of the impending ice storm up to three days in advance of the event. As the storm unfolded, warnings provided 12 to 39 hours of lead time before the severe icing developed.

Flood potential statements were issued up to two and a half days before the flooding materialized. A survey of NWS customers found that the early forecasts helped utility companies and emergency management officials deploy staffs early and take appropriate preparedness actions. In many instances, states of emergency were declared based on the forecasts to ensure a rapid response once the storm developed. The NWS offices providing services during the storm were: Gray, Maine; Albany, N.Y.; Taunton, Mass.; Burlington, Vt.; Buffalo, N.Y.; Northeast River Forecast Center, Taunton, Mass.; and NWS Hydrometeorological Prediction Center, Camp Springs, Md.

Fire monitoring in South America

The 1998 fire season in the southern Amazon region is expected to be worse than normal. An Interagency Working Group has been formed to address the concerns of the Brazilians as relayed through the U.S. Embassy in Brasilia. NOAA's National Environmental Satellite, Data, and Information Service was asked by the State Department and U.S. Aid to International Development to monitor fires and vegetation stress as determined from imagery recorded on POES, GOES, and DMSP satellites.

Increased radiation hazards to the international space station

The Committee on Solar and Space Physics (CSSP) is reviewing the International Space Station (ISS) for NASA in light of its change in orbital inclination from about 20 to 51 degrees. At 51 degrees, ISS astronauts will encounter significantly increased doses of radiation from the outer radiation belts of the near-Earth space environment, especially during extra-vehicular activity needed to construct the ISS. The National Geophysical Data Center was asked to study the outer radiation belts using POES Space Environment Monitor and DMSP auroral particle measurements and to report back to CSSP/CSTR.

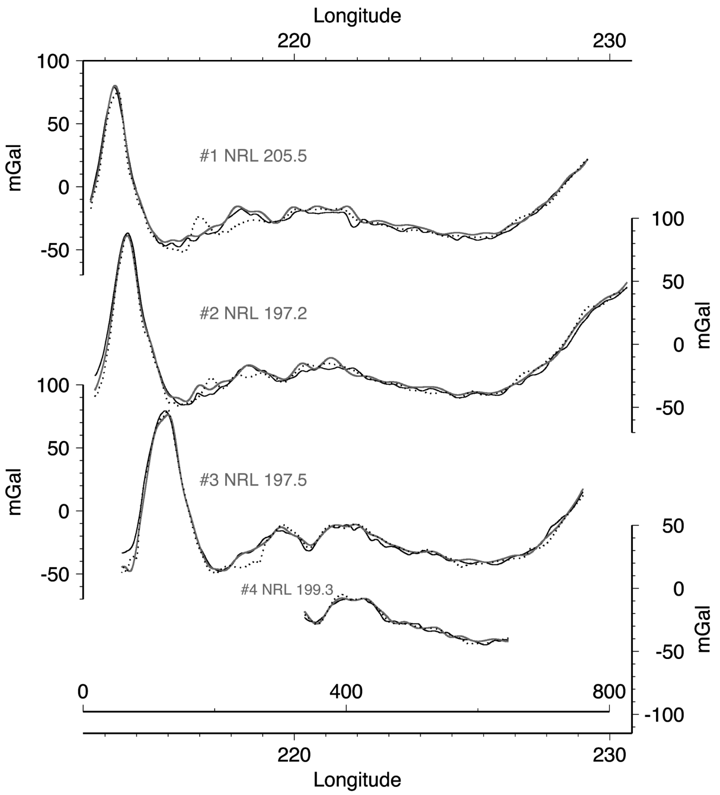
GCIP Mississippi River Climate Conference

Drs. Tingjun Zhang and Richard Armstrong, National Snow and Ice Data Center (NSIDC), attended the recent Global Energy and Water Cycle Experiment (GEWEX) Continental-Scale International Project (GCIP) Mississippi River Climate Conference, in St. Louis, MO. Their presented paper "Detection of frozen soil extent in the Upper Mississippi River during winter of 1997-1998 over snow-free land surface using passive microwave remote sensing data" could provide a regional scale frozen soil extent for global circulation model and hydrological model validation. Also, *in situ* data gathered by the GCIP community can be used for further validation of the remote sensed frozen soil extent in the region. Additionally, Tingjun Zhang presented NSIDC's data products at the GCIP Summer School on Data Sets (also at the University of St. Louis).

Coral reefs to get protection

At the National Ocean Conference in Monterey, Calif., President Clinton and Vice President Gore launched a series of major initiatives to explore, protect and restore America's vital ocean resources. One of these efforts is dedicated to protecting coral reefs. To strengthen protection of natural coral reefs in U.S. waters, President Clinton signed an executive order directing Federal agencies to expand research, preservation and restoration activities. The President is proposing an additional $6 million through 2002 to speed these efforts and complete restoration of 18 damaged reefs in the Atlantic, Caribbean and Pacific.

The Year of the Ocean falls on the heels of last year's International Year of the Coral Reef. This initiative builds on the efforts that began last year. For more online information on Year of the Ocean, please see : *www.yoto98.noaa.gov*. For more online information on the Year of the Coral Reef (97) see: *www.noaa.gov/ public-affairs/coral-reef.html*. For more information on this initiative, please contact Matt Stout at 202-482-6090.



▲ **Figure 3.** Profiles of NRL airborne gravity (gray line) compared with ERS satellite marine gravity (black line) along tracks 1-4 (see Figures 2 and 5). Profiles of gravity predicted from surface observations, e.g. GSC data (dotted line) are also shown.

Satellite & airborne gravity, *from page 2*

gravity field was based on a small amount (35-days) of data and hence had limited accuracy and resolution, it represented a leap forward in Arctic science.

With the shutdown of ERS-1 in 1996, an improved Arctic Ocean gravity field (Laxon and McAdoo, 1998) was derived using all available ERS-1 data including the geodetic phase data. This ERS-1-only field is available on the WWW at *http://ibis.grdl.noaa.gov/SAT* or at *http://msslsp.mssl.ucl.ac.uk:80/people/swl/*. Laxon and McAdoo have continued to significantly improve the ERS Arctic Ocean gravity field by incorporating the many new repeat cycles of altimeter (WAP) data from the ERS-2 satellite.

ERS-2 was launched in 1995 and continues to observe along the same 35-day groundtrack begun by ERS-1. By incorporating these ERS-2 WAP data into the gravity estimation, one continues to reduce measurement noise from sea ice and other sources. Further improvements have been realized via refinements in waveform processing and gravity estimation techniques. The ERS-1/ERS-2 marine gravity presented (Figure 2) is an interim field computed (on a ~2.5 km x 2.5 km grid) for the Canada Basin region of the Arctic using the ERS-1 data plus 9 cycles (roughly one year's worth) of ERS-2 data. Note the linear, north-south trending gravity low that is labelled CBR in Figure 2.

This low was clearly expressed even in the earliest ERS-1 Arctic gravity field of Laxon and McAdoo (1994) and attributed to an apparent, long sought after, extinct spreading ridge buried beneath the thick sediments of the Canada Basin. An improved ERS-1/ERS-2 gravity field for the entire circum-Arctic (south of 81.5° N) will be completed soon using many more ERS-2 data.

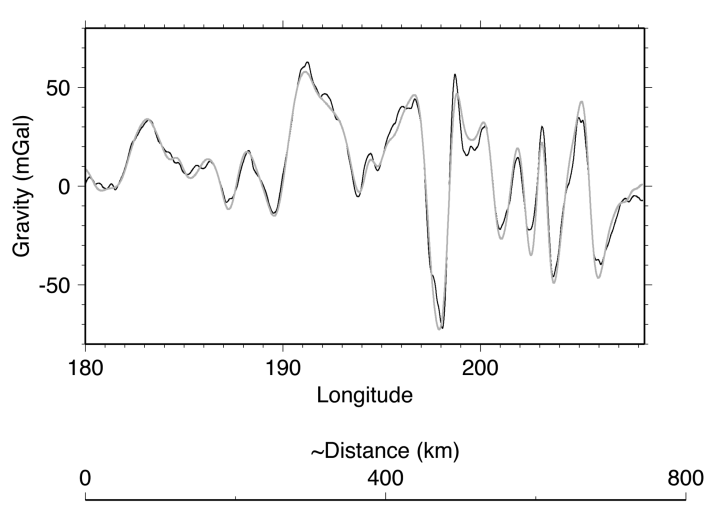
NRL airborne gravimetry

In the 1980s, the Naval Research Laboratory (NRL) pioneered accurate measurement of gravity from fixed-wing gravity. Since 1992, NRL has been using long-range, Navy P-3 aircraft and three-dimensional GPS positioning in an ongoing program to survey gravity (and magnetics) along lines over much of the Arctic Ocean Basin (Brozena *et al.*, 1997). To date, NRL has collected accurate gravity over a 2,000,000 km^2 area of the Arctic that encompasses much of the Canada Basin, Alpha Ridge and Chukchi Borderland. The three-dimensional, interferometric-mode, kinematic GPS positioning also yields good estimates of the vertical component of airplane accelerations. Free-air gravity is then estimated by differencing: (a) the acceleration measured with the gravimetric sensor (e.g., a LaCoste and Romberg Air and Sea meter) aligned to vertical by a gyro-stabilized platform, and (b) the airplane's acceleration estimated from GPS. For details of the data processing and reduction see Brozena *et al.*, 1997, Childers *et al.*, 1998.

Because the NRL flies its Arctic gravity lines at low elevations (typically about 500 m), free-air anomalies at sea level are estimated with a simple, elevation-proportional, additive free-air correction. No "downward continuation" is needed or warranted from these low elevations. All NRL free-air gravity anomaly lines (south of 81.5° N) can therefore be compared directly to ERS marine gravity.

Comparison

Five lines of NRL airborne gravity are compared with ERS gravity (Figure 2): four closely-spaced, NE-SW trending lines which lie in the southern Beaufort Sea and were observed in 1996, plus a nearly E-W striking line over the Chukchi Borderland which was flown in 1997. This fifth line was chosen in an area of year-round ice



▲ **Figure 4.** Profile of NRL airborne gravity (gray line) compared with ERS satellite marine gravity (black line) along track 5.

▲ **Table 1.** ERS-1,2 satellite gravity (NOAA/UCL) vs. airborne gravimetry (NRL)

#	NRL Track	RMS Difference	Coherency/Resolution Limit
1	205.5	3.3 mGal	39 +/-5 km
2	197.2	3.8 mGal	34 +/-4
3	197.5	4.1 mGal	36 +/-5
4	199.3	1.9*mGal	**
5	183.2	4.6 mGal	19 +/-4 km

* RMS Difference between ERS gravity and GSC surface gravity along track 4 is 1.5 mGal
** Track too short to estimate coherency.

cover and represents a more stringent test inasmuch as the southern ends of the other four lines include seas occasionally free of ice, and seasonally ice-free seas are accessible with conventional altimetric methods.

By interpolating (using a bicubic option in GMT) the dense, 2.5 km, ERS-1/ERS-2 field marine gravity field described above (Figure 2) onto NRL flight lines, we constructed the comparison plots shown in Figures 3 and 4. The agreement between ERS altimetric gravity and NRL aerogravity is excellent. Table 1 presents summary statistics. Coherency represents well the short-wavelength, limit of resolution. The coherencies listed in this table are comparable to those observed between high-quality shipboard and conventional altimetric gravity which lie in the range of 23 to 30 km (e.g., Sandwell and Smith, 1997, Marks, 1996) in non-polar, ice-free seas. We describe (paper in preparation) the detailed significance —and techniques for estimation—of these coherencies. Simply put: short-wavelength limits of resolution on order of 20 to 35 km imply that both airborne and retracked ERS gravity do a good job of resolving short spatial wavelengths and hence can be used to effectively map tectonic fabric of the Arctic seafloor. The apparent extinct spreading ridge in the Canada Basin (CBR in Figure 2) is but one example.

Note in Figure 3 that the NRL airborne profiles 1-4 and corresponding ERS gravity estimates are compared with gravity prediction from surface gravity (dotted). Profiles 1-4 were chosen precisely because they overfly a region of extraordinarily dense gravity measurements (Figure 5) taken on ice from the surface of the southeastern Beaufort Sea using primarily helicopter landings. These point measurements, compiled by the Geological Survey of Canada (GSC) were observed for exploration purposes and are spaced approximately 5 km apart in an orthogonal grid.

Much of the Arctic Ocean is devoid of surface gravity observations. Therefore these data provide a unique opportunity in the Arctic to "groundtruth" or assess the quality of these new field determinations, as well as compare the correspondence of the two data sets. Note for example, for line 4 in Table 1 that the RMS difference between any one of the three gravity types—ERS, airborne or surface—and any other, is always 1.9 mGal (1 mGal=10^{-3} gal; 1 gal, named for Galileo, equals 1 cm·s^{-2}) or less. Generally speaking, the ERS and airborne gravity agree with one another approximately as well as each agrees with the gravity from GSC surface observations.

Note, however, that west of 220° E longitude, where the dense GSC surface observations are replaced by sparse shipboard gravity (profiles 1-3 in Figures 3 and 4) causing the "groundtruth" to be slightly discrepant, i.e., less-than-truthful. In Figures 6A and 6B, ERS satellite marine gravity is visually compared in both dimensions with the GSC surface (on sea ice) in the southeastern-most Beaufort Sea. A 2.6 mGal, RMS difference observed (see Figure 6) between the ERS and surface gravity testifies to the precision the ERS gravity and therefore further validates the strong agreement we see between ERS and NRL aerogravity. These comparisons with surface data reveal various strengths and weaknesses of both of the techniques.

In Figure 4 a profile of NRL airborne gravity across the Chukchi Borderland is compared with ERS marine gravity along track 5. The very "rough" or strong gravity signal—due to rifts/grabens in the highly deformed continental crust of this area (Grantz *et al.*, 1998)—is clearly, and similarly, resolved in both NRL airborne and ERS gravity. Note the ~30 km wavelength, 100+ mGal gravity anomalies on this line. Note also that coherency for line 5 (Table 1) is 19 km which is decidedly better than those for profiles 1-3 and slightly better even than coherencies (23-30 km; above) between shipboard

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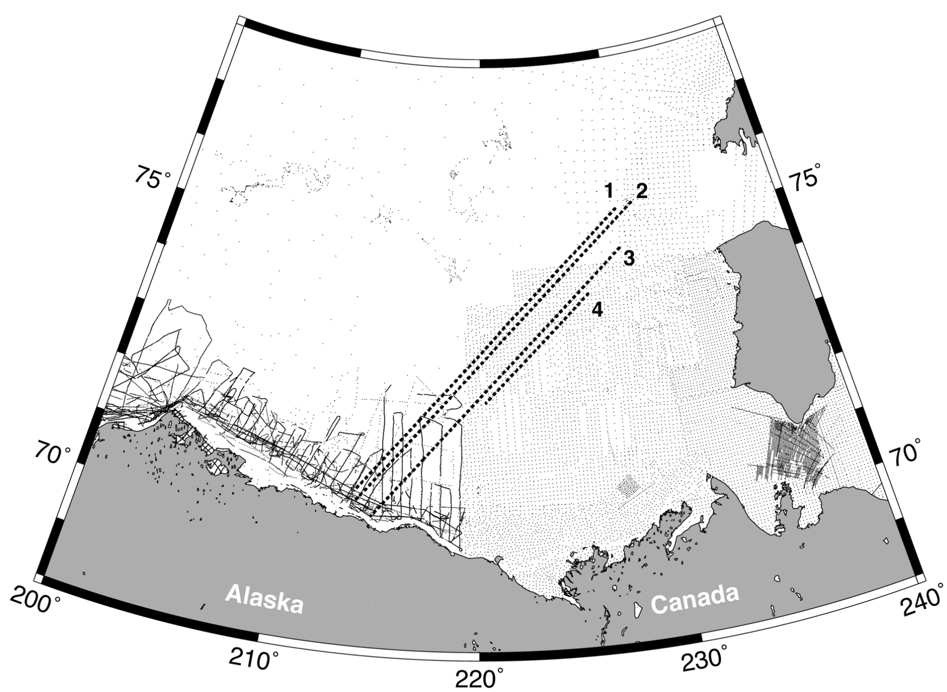


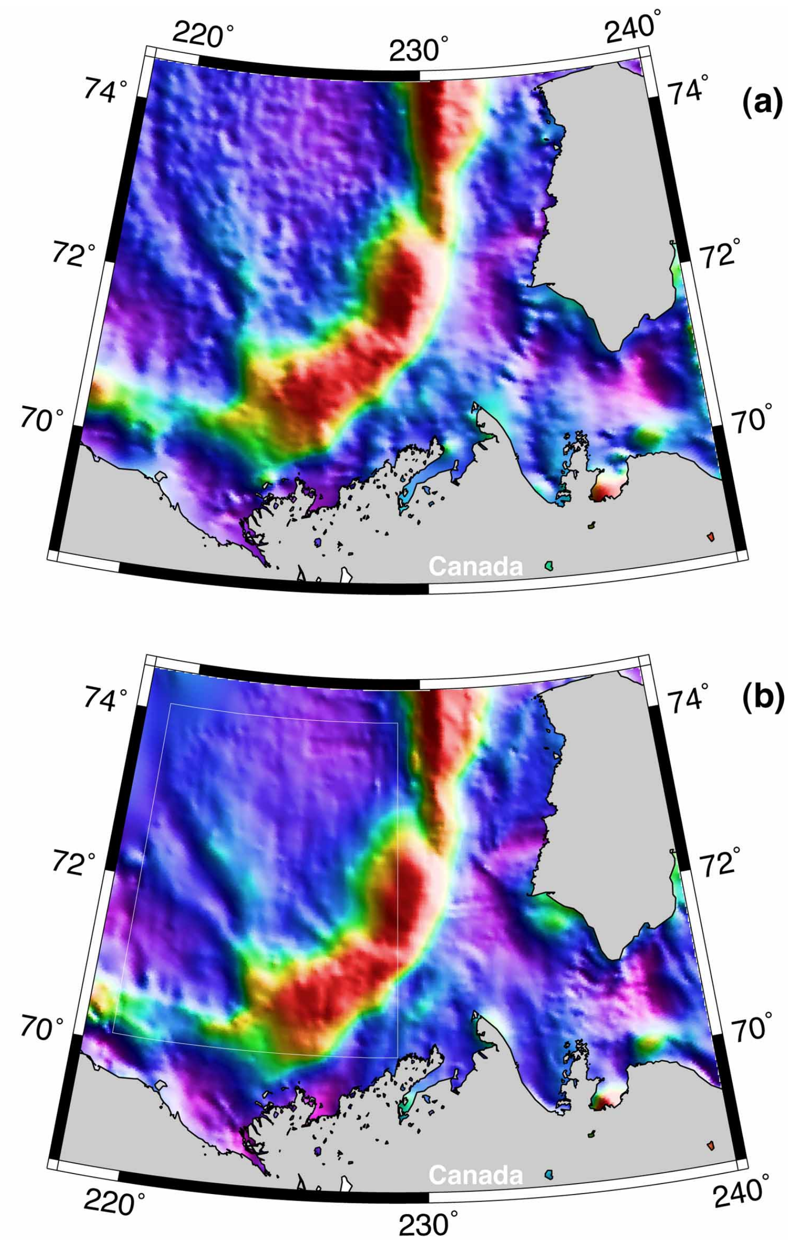
▲ **Figure 5.** Distribution of GSC surface (on sea ice) gravity and shipborne gravity. NRL aerogeophysical groundtracks 1-4 (thick).

Satellite & airborne gravity, *from page 5* and conventional altimetric gravity in non-polar seas. This particularly short-wavelength resolution of 19 km likely owes to the exceptionally strong gravity signal over this area.

Discussion

NRL airborne gravity and ERS altimetric gravity data from the Arctic Ocean are in good agreement. Coherence between the two data types indicates that both types are doing a comparably good job of resolving short spatial wavelengths and hence both—or either—can be used to effectively map tectonic fabric of the Arctic seafloor. Intercomparison of the two can help isolate any systematic errors particular to one or the other.

Moreover, the two methodologies complement each other. In many areas of the Arctic Ocean, NRL's aerogravity program has the advantage that it can be extended north of 81.5° N to 90° N and thus fill in the hole in the ERS' polar coverage. On the other hand, ERS gravity blankets all of the Arctic Ocean south of 81.5° N without geopolitical, logistical or incremental cost limitations. Moreover, NASA is planning to launch a laser altimeter satellite, ICESat (Ice, Cloud, and land Elevation Satellite) in 2001. ICESat is to carry the Geoscience Laser Altimeter System (GLAS), which could extend altimetric gravity north to 86° N. Only a few years ago much of the Arctic Ocean Basin was devoid of gravity data and viewed as virtual *terra incognita*. The future for Arctic science is looking much brighter.



▲ **Figure 6.** (A) ERS-1/ERS-2 satellite marine gravity in the southeastern Beaufort Sea. (B) Corresponding Geological Survey of Canada surface (on sea ice). Note gravity in the box differs (in RMS sense) from ERS-1/ERS-2 gravity in (A) by 2.6 mGal.

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NOAA Fisheries and the state of Louisiana join forces in large wetlands reconstruction project

Successful joint project creates 900 acres of new wetlands

Erik C. Zobrist, PhD and Tim Osborn
NOAA Habitat Restoration Center
NOAA/NMFS

▲ **Figure 1.** Atchafalaya River Delta and site of Big Island and Atchafalaya Sediment Delivery projects (Photo courtesy of NASA Goddard Space Flight Center).

Two large dredging projects are nearing completion in the Atchafalaya River delta (Figure 1), creating new wetland habitats in coastal Louisiana. These projects, sponsored by NOAA's National Marine Fisheries Service (NMFS) and the Louisiana Department of Natural Resources (DNR), are located about 18 miles southwest of Morgan City, Louisiana. When completed, the Big Island and Atchafalaya Sediment Delivery Projects will immediately create over 900 acres of wetlands by strategic placement of dredged material.

The projects will cause another 3,000 acres to be created through natural processes over the next 20 years. Funding for the wetland restoration work is through the Coastal Wetlands Planning, Protection and Restoration Act (Pub. L. No. 101-646, Title III-CWPPRA), also know as the "Breaux Act" after Senator John B. Breaux of Louisiana who led the effort to enact the legislation.

Five Federal agencies and the State of Louisiana are joined in a Task Force to implement the "comprehensive approach to restore and prevent the loss of coastal wetlands in Louisiana" mandated by CWPPRA. The five Federal agencies involved are: the U.S. Department of the Army, the U.S. Department of Commerce (i.e., NMFS), the U.S. Department of Interior, the U.S. Department of Agriculture, and the U.S. Environmental Protection Agency. Approximately $40 million per year in federal funding is available for Louisiana wetlands protection and restoration projects approved by the CWPPRA Task Force.

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Louisiana contains over 40% of the coastal wetlands in the contiguous United States. These wetlands support the ecological, economic, cultural, aesthetic, and recreational needs of both the State and the nation. They are the source of much of the nation's oil and natural gas, they provide habitat for many species of plants and wildlife, and they serve as a vitally important nursery for commercially important fisheries. Louisiana waters alone contributed 75% of the total Gulf of Mexico region fisheries harvest by weight in 1995 and 1996, generating nearly $280 million in dockside value.

The natural processes of accretion and erosion that constantly create and destroy coastal wetlands have historically existed in relative equilibrium. But human activities have disrupted that equilibrium and now jeopardize the future health of the state's wetlands, and hence the resources that they support. Louisiana's marshes are eroding at an estimated rate of 25 square miles per year, which accounts for roughly 80% of total national coastal wetland loss. Without intervention, the losses within the next 50 years could total 800,000 acres.

Natural expansion of the Atchafalaya River Delta has been hampered by the deposition of material dredged from the Federal navigation channel and is the focus of the Big Island and Atchafalaya Sediment Delivery projects. Big Island was created in 1973 as a designated disposal site for dredged material generated during maintenance dredging of navigation channels within the Atchafalaya River delta. Resulting from frequent disposal of dredged material at this location, Big Island, which is located just west of the navigation channel, presently contains 1,070 acres and has an elevation of +10 to +12 feet National Geodetic Vertical Data (NGVD), the highest point in the Atchafalaya coastal basin. Big Island effectively blocks the flow of water and sediments to the western reaches of Atchafalaya Bay and thus

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▲ **Figure 2.** Hydraulic dredge Katrina pumping material into containment area on Big Island project site. (Photo courtesy of Dr. Erik Zobrist, NOAA Habitat Restoration.)

Wetlands, *from page 5*

impedes the natural delta growth of wetlands.

The Atchafalaya Sediment Delivery project centers on two distributary channels, Natal Channel and Castille/Radcliffe Pass, located to the east of the navigation channel. These two channels represent pathways for suspended sediment to flow into the more eastern regions of the Atchafalaya Bay. These channels became blocked partly as a result of the movement of material dredged from the Atchafalaya River for navigation purposes.

Because coastal wetlands evolve slowly as a result of annual sediment deposition and organic accumulation, a reduction in the volume of sediment and frequency of deposition reduces delta growth and marsh expansion and may even cause a net erosion of newly created wetlands. The goal of these two projects was to enhance sediment delivery throughout the delta, which involved the creation of new distributary channels north and west of Big Island and the reopening of two existing distributary channels, Natal Channel and Castille/Radcliffe Pass to the east.

In addition to creating or reopening channels, knowledge of delta expansion within the Atchafalaya Bay suggested that strategic placement of spoil at the point of channel bifurcation could create elevations which would be conducive to the establishment of wetland vegetation and would enhance long-term delta development. During flood events, water from the channel would flow over this man-made bank and deposit sediment behind the spoil area due to the reduced velocity of the water. Thus, strategic placement of dredged material from the dredging activity to establish east-west distribution channels can also create lobe islands and wetlands, two common characteristics of natural delta development and growth.

The dredge disposal requirements of the project called for placement of created lobe islands to elevation +3.0 NGVD and contiguous wetlands behind the islands at elevation of +1.5 NGVD to mimic the natural delta building process. Through a competitive process, two bids were received by the state with the winning bid submitted by River/Road Construction, Inc. of Mandeville, LA, for the $7.5 million project.

Most of the cutterhead dredging was performed by the 108-foot dredge Katrina (20" discharge, 2150 hp) with support from the 70-foot dredge North Carolina (20" discharge, 1125 hp). River/Road, Inc. has been pumping about 20,000 cubic yards/day depending on sediment quality (Figure 2). Major containment diking (Figure 3) was constructed with the contract bucket dredge, Capt. Bufford Berry (8-yard bucket, 140' boom).

The Big Island project entails construction of several new distributary channels having a combined length of about 36,750 feet, extending from the Atchafalaya River into the shallow waters west of Big Island. About 3.3 million cubic yards of dredged material will be placed in a pattern to mimic

▲ **Figure 3.** Bucket dredge, Capt. Bufford Berry, constructing containment levee in Atchafalaya Sediment Delivery site. (Photo courtesy of Dr. Erik Zobrist, NOAA Habitat Restoration.)

▲ **Figure 4.** Marsh buggy inside containment area moving sediment away from discharge pipe. (Photo courtesy of Dr. Erik Zobrist, NOAA Habitat Restoration.)

natural delta wetlands and create a system of distributary channels which will transport water and sediments throughout the western reaches of the project area. Construction started in March and is expected to be completed by September, 1998.

The Atchafalaya Sediment Delivery project, which was completed in March, 1998, reopened two distributary channels having a combined length of about 12,400 feet, extending from the East Pass channel of the Atchafalaya River, through Natal Channel and Radcliffe Pass, and into the shallow waters east of the existing delta. About 670,000 cubic yards of dredged material was deposited to create delta wetlands as in the Big Island project.

Together, the projects will restore freshwater and sediment delivery processes to the delta. Project construction is creating over 900 acres of deltaic wetlands through careful placement of dredged sediment. Additionally, the projects will re-establish the natural deltaic growth processes by creating new or reopening silted-in channels (Figure 4) throughout the delta and allowing water and sediment to flow through the delta. Natural delta growth, enhanced by the projects, is expected to create more than 3,000 more acres of wetlands habitat over the next 20 years.

Already, marsh grass and other vegetation are growing on the newly created lands. Alligators and numerous species of birds—including ducks, roseate spoonbills, black terns and American egrets—have been observed using the new delta wetlands. Several species of fish also have been seen in waters adjacent to the new islands.

Federal funds provided by CWPPRA were awarded by NOAA to the Louisiana DNR in 1994. Projects are cost-shared (85% federal, 15% state) for engineering and design, construction and monitoring. The DNR awarded contracts for engineering and design, then construction, and will monitor post-construction operations while NMFS was responsible for meeting numerous regulatory requirements such as cultural resources, project permits, and environmental compliance with State and Federal law.

Engineering and design, by Brown, Cunningham & Gannuch, Inc., of Baton Rouge, LA, was challenging due to the proximity of the projects to the federal navigation channel and location within a state wildlife preserve. This required close coordination with the U.S. Army Corps of Engineers and the Louisiana Department of Wildlife and Fisheries.

While the projects utilized standard dredging techniques, they were unique in their exacting dredged material placement requirements. The successful implementation of the projects required the dredging contractor to fully understand the environmental objectives and the stringent design requirements necessary to achieve the beneficial goals of the project. Engineering plans and specifications called for more than simple dredging. For example, containment areas (Figure 5) were designed with exacting elevations and slopes which were necessary to support wetlands vegetation and wildlife. This required the contractor to schedule work to accommodate the

– continued on page 16

▲ **Figure 5.** Aerial view of the Big Island projects area. The three containment areas cover approximately 200 acres of created wetlands. (Photo courtesy of Dr. Erik Zobrist, NOAA Habitat Restoration.)

Oceans and the Earth's climate: the World Ocean Circulation Experiment

CD-ROM set contains data from largest internationally coordinated global ocean program

Douglas R. Hamilton
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Oceanographers from twenty-five countries around the globe are finishing work on what is the largest internationally coordinated global ocean observation program to date. From 1990 to the present, the world's oceans have been observed, measured, sampled and monitored by instrumented ships, moored buoys, satellites, surface and subsurface floats and tide stations. This comprehensive observation program was developed by the World Ocean Circulation Experiment (WOCE) project to gain a better understanding of the world ocean and its relationship to earth's climate. The first release of data from this comprehensive program, "WOCE Global Data, Version 1", is available from the National Oceanographic Data Center.

Climate change

Extremes of heat, storms, floods and drought in different regions of the globe have captured our attention in recent years and added weight to the argument that our climate is changing. For many years, the ocean's role in these changes was unknown and assumed to be minor. As recently as the early 1970s, oceanographers and meteorologists were largely unaware of the tight link between ocean and atmosphere in El Niño/Southern Oscillation (ENSO) events. However, as new tropical Pacific Ocean measurements revealed tantalizing glimpses of large-scale ocean-atmosphere interactions, it became obvious that there was indeed a connection which needed to be researched.

In 1983, the World Climate Research Program established two Scientific Steering Groups (SSG) to develop programs for improving the predictability of ocean-atmosphere climate variations. The Tropical Ocean Global Atmosphere (TOGA) SSG was set up to focus on short term seasonal to interannual variability, and the World Ocean Circulation Experiment (WOCE) SSG was given the task of researching ocean roles in climate variations over periods of several decades to centuries.

The TOGA program was able to limit ocean sampling to upper layers of tropical oceans, because seasonal-to-inter-annual oceanic variability is confined to those depths and latitudes. However, in order to understand and predict decade-scale global climate variations, the WOCE project designed an all-inclusive global ocean observation and modeling program.

WOCE Data

The World Ocean Circulation Experiment Science Steering Group set two goals: (1) to develop models useful for predicting climate change and to collect data necessary to test them, and (2) to determine the representativeness of the specific WOCE data sets for the long-term behavior of the ocean, and to find methods for determining long term changes in the ocean circulation.

The first goal called for large-scale programs to measure global ocean circulation directly and indirectly. Observation and data management plans developed around several ocean measurement systems, listed in Table 1. WOCE observation plans were built primarily on existing measurement systems; but a unique, new instrument which was developed for WOCE will permanently change how some quantities are measured in future research.

The Autonomous Lagrangian Circulation Explorer (ALACE) is a free-floating instrument designed to seek a pre-programmed depth, drift with ocean currents at that depth, and pop

▲ **Table 1.** Measurement systems in the WOCE Observation Program.

Hydrographic - physical and chemical measurements from continuous sampling lowered instruments and bottle samples along 73 one-time sections and 65 repeatedly sampled sections and time series stations.

Bathymetry - high quality depth measurements along hydrographic survey cruise tracks.

Current meter - upper, mid, and deep ocean multi-instrument current meter moorings, some with additional parameters, from 39 sites.

Subsurface Floats - over 2,140 subsurface drifting floats which were tracked acoustically or by satellite.

Surface drifting buoys - ocean surface velocity measured by over 4,300 surface drifting buoys, some with atmospheric pressure sensors.

Acoustic Doppler Current Profiler (ADCP) - upper ocean currents measured by ship-mounted ADCP instruments while underway on over 200 cruises.

Expendable Bathythermograph (XBT) - upper ocean depth-temperature profiles (over 200 thousand) measured along 80 WOCE XBT track-lines.

Surface meteorology - marine surface meteorological observations collected on over 150 WOCE research cruises.

In situ sea level - sea level data derived from tide station records from 160 global sites.

Satellite - Global sea surface temperature data from the National Oceanic & Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer.

Satellite - Global sea level data from the TOPEX/POSEIDON satellite.

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up periodically to report its position via satellite. It proved to be successful and inexpensive, giving almost instant results and lasting for years. Compared to earlier subsurface floats, which required acoustic tracking from at least three stations, the ALACE could be tracked simply by analyzing reports from satellites.

Later versions of ALACE (termed PALACE for Profiling ALACE) were modified to include temperature and conductivity sensors and memory to store data gathered on its way to the surface. Hundreds of PALACE floats are now reporting on subsurface currents as well as profiles of temperature and salinity. Drifter tracks and subsurface profiles from NOAA's Atlantic Circulation and Climate Experiment can be found online at *http://www.aoml.noaa.gov/phod/acce/index.html*.

WOCE data management

To properly deal with the vast amount of highly varied data, and ensure quality data for ocean models, WOCE developed a data management system of distributed Data Assembly Centers (DACs) and Special Analysis Centers (SACs). DACs were established for most of the measurement systems listed in Table 1, and are responsible for tracking data as it is collected and for gathering data from scientists and distributing it to users.

SACs were established for the Hydrographic Program and for Surface Meteorological Data. As data are made available to SACs, special analyses and products are generated as an additional data quality review step, and to make interim results of WOCE available to researchers and modelers. The WOCE Data Information Unit maintains contact with DACs and SACs and acts as a central information site for up-to-date, online reports of the status and availability of all WOCE data.

The WOCE Archive, located at the U.S. National Oceanographic Data Center (NODC), will be the long-term repository for WOCE data and documentation, and ensures that WOCE data are freely distributed through the system of World Data Centers for Oceanography.

DACs and SACs are located in government and academic research laboratories throughout the world, and meet annually with the WOCE Data Products Committee to review the status of WOCE data collection and processing. Each maintains a web site with the latest information about its data, and provides access to the data as well. The best starting point for access to DAC and SAC sites is the Data Information Unit available online at *http://www.cms.udel.edu/woce*.

WOCE Global Data Version 1.0

Eight years of WOCE program global ocean observations were released by the WOCE Data Products Committee at the WOCE Conference (Halifax, N.S.) in May, 1998. Data, documentation, and products are contained in a set of thirteen compact discs (CD-ROM) which are easily browsed with web-browser software. The discs include all WOCE data that were available in January 1998.

Users are cautioned that many data sets have not yet been released by WOCE principal investigators, and are not included in the Version 1.0 data set. Release of Version 2.0 data is planned for early 2000, and the final version is expected in 2002.

NOAA National Data Center roles in WOCE data management

The National Geophysical Data Center in Boulder, Colorado is the DAC for bathymetry data. The NODC, jointly with other centers, supports work of the Acoustic Doppler Current Profile DAC, the Sea Level DAC, and the Upper Ocean Thermal (UOT) DAC. NODC maintains the Global Temperature Salinity Profile Program database, in which all UOT DAC data and data quality information are stored.

NODC's principal role, as WOCE Archive, is to be a good steward of the data. The WOCE program created what is the largest and most varied global ocean data set ever generated by one project. WOCE data will be used as a standard "snapshot" of the world's oceans for decades to come, so it is imperative that the data be stored in such a way that it is preserved completely and accurately for future uses. As the nation's center with responsibility for storing and distributing oceanographic data, NODC has worked closely with the WOCE Data Products Committee to ensure smooth transfer of data and documentation to the center.

What's next

The WOCE Project's true benefits will come from development of models to predict global climatic conditions and regional climate change. The Analysis, Interpretation, Modeling, and Synthesis (AIMS) phase of WOCE has begun, and is using data collected during, and prior to, the WOCE observation period. One of the challenges of this phase is to merge disparate data types into models which integrate the data in a manner that is scientifically sound. Such work is already underway at several institutes.

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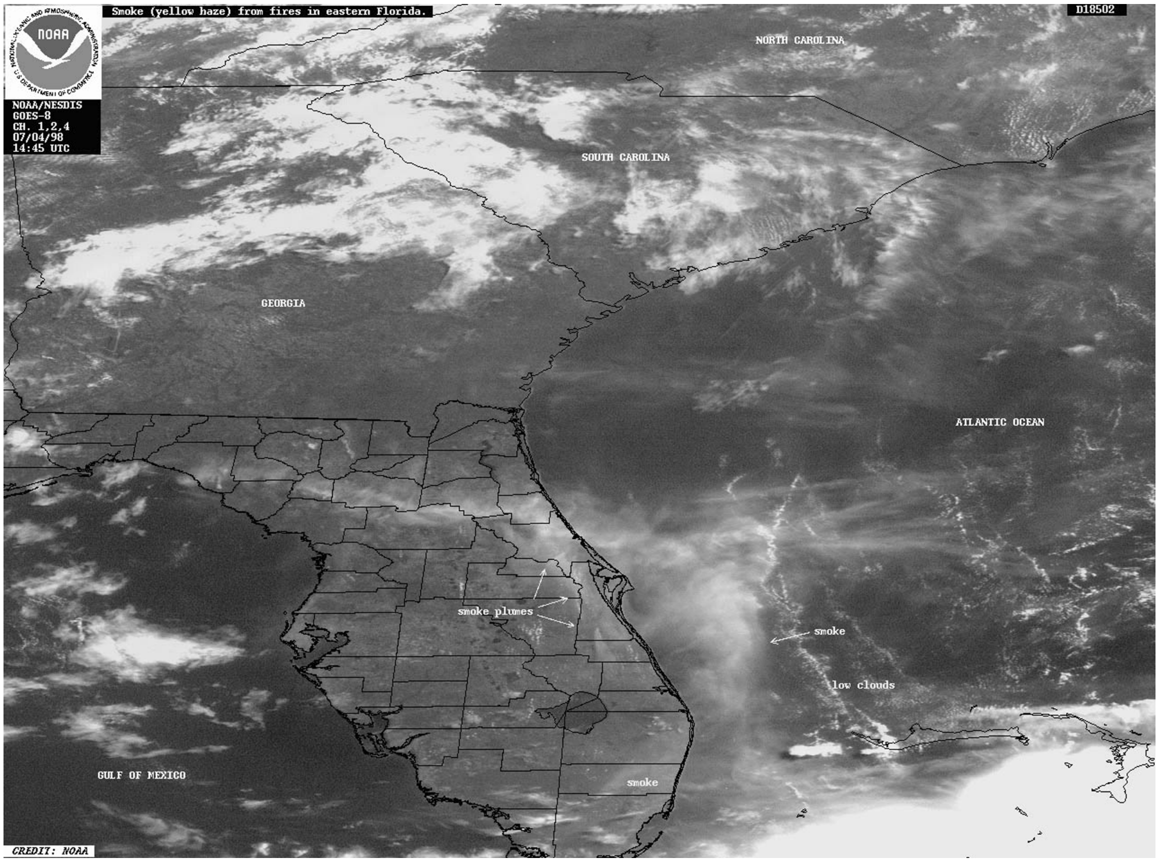

▲ **Figure 1.** GOES-8 image of the 1998 Florida wildfires. Note the large smoke plumes over the east Florida coastline.

NOAA's GOES-10 replaces GOES-9

The Commerce Department's National Oceanic and Atmospheric Administration (NOAA) announced in July that one of NOAA's weather satellites, GOES-9, was failing as it reached the end of its planned life, but that the GOES weather satellite data and imagery seen daily on TV weather forecasts would continue to flow without a break. The smooth transition was due to a decision to store a backup weather satellite on orbit to quickly replace a failing one. NOAA's GOES-10, the nation's newest geostationary weather satellite (which was put into a storage orbit and completed operational testing in June) was activated on July 9 in its position over the central United States (105° W).

GOES-10 replaced GOES-9 on July 28, 1998. GOES-9 showed signs of near-term failure of its attitude control system in early July. "Both momentum wheels on GOES-9 exhibited problems," said Kathleen Kelly, director of NOAA's Satellite Operations Control Center. "Momentum Wheel 2 failed and was turned off in June. A few weeks later, Momentum Wheel 1 began experiencing extremely high current levels. We need at least one wheel in operation to maintain pointing accuracy."

Once activation began, GOES-10 provided useful data within 72 hours. The satellite was repositioned after consultation with the National Weather Service. GOES-10 reached its final operational station of 135° W on August 21, 1998. GOES satellite images are best known to television viewers as the cloud images and movies that are broadcast on TV weather forecasts.

"Having a GOES satellite stored on orbit ready to back up the other two GOES satellites turned out to be an excellent idea," said Gerald Dittberner, NOAA's GOES program manager. "It's the first time we had ever had a backup satellite in place. Without such a satellite, we would have had to wait as much as 12 to 15 months to get a launch time slot. Now we can have GOES-10 transmitting data within 72 hours after activation, meeting our program needs without any loss in data continuity."

Both GOES-8 and GOES-9 were the first in a new series of satellites and had projected planned lifetimes of three years. GOES-8, launched four years and two months ago, continues to function with no significant changes in the past 18 months. GOES-9, launched in May 1995, had reached its projected planned life. The planned mission life for GOES-10 is five years. The next satellite in the series, GOES-L, is scheduled for launch in May 1999 and will be stored on orbit.

NOAA's new GOES series has produced an excellent set of real-time weather data for weather forecasters and researchers. Combined with data from Doppler radars and automated surface observing systems, these satellite data have proved to be crucial in improving weather forecasts and numerical models. Better warnings of thunderstorms, winter storms, flash floods, hurricanes, and other severe weather help to save lives, preserve property, and benefit commercial interests (Figure 1).

NOAA's National Environmental Satellite, Data, and Information Service funds and operates the GOES series of satellites at the Satellite Operations Control Center in Suitland, Md. NASA's Goddard Space Flight Center manages the design, development, and launch of the GOES spacecraft for NOAA.

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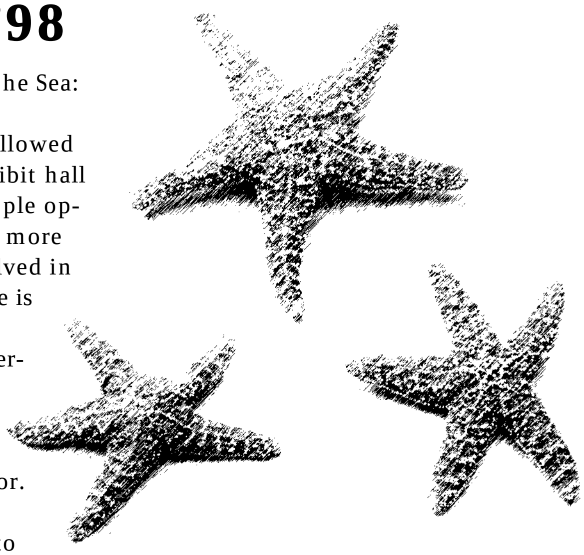
Ocean Community Conference ’98



The Marine Technology Society’s (MTS) annual conference celebrates the 1998 International Year of the Ocean. Called the Ocean Community Conference ’98, it will be held from November 16 to 19 at the Baltimore Convention Center in Baltimore, Maryland. Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere, is this year’s Conference Chair and Dr. W. Stanley Wilson, NOAA’s Deputy Chief Scientist, is the Conference Vice Chair. Captain Fred Klein, USN, is the Executive Assistant. Additionally, 21 organizations, including five government components with an ocean focus, are actively participating in the conference.

In order to focus on 1998 International Year of the Ocean themes, the annual MTS conference format has been changed to include two-hour thematic plenary sessions each morning featuring some of the nation’s senior-most and highly accomplished marine scientists, engineers, educators, attorneys, and managers. The Plenary Session on Tuesday the 16th is “The Global Ocean: Influencing Weather and Climate”; on Wednesday it is “The Coastal Ocean: Balancing Competing Use” (Figure 1); on Thursday it is “Economics: The Ocean and Business”; and on Friday it is “Exploration in the Sea: The Ocean as a Frontier”.

The Plenary Sessions are followed by a two-hour break in the exhibit hall that should allow attendees ample opportunities to have lunch, visit more than 130 exhibits, and be involved in special planned activities. There is an MTS Awards Luncheon on Monday at the Baltimore Conference Center and a dinner on Wednesday at the National Aquarium, the centerpiece of Baltimore’s famous Inner Harbor.

Each afternoon, there are “track” sessions from 1:00 PM to 3:00 PM and from 3:30 to 5:30 PM in nine different meeting rooms. The tracks, or technical topics, include applied ocean sciences; ocean measurements systems, marine resources; ocean and coastal engineering; data processing and management; communications; maritime commerce and charting; vehicles, platforms, and advanced technology; marine policy, and education. The present count is 311 individual 20-minute papers and two 60-minute panel sessions

NOAA plans to have open houses on two of its coastal vessels, the 90’ *Rude* and the 65’ *Bay Hydrographer*; both ships employ the latest hydrographic technologies for nautical charting and surveying. The Coast Guard plans to have an open house on one of its newest buoy tenders, the *James Rankin*, featuring the latest in station keeping and positioning techniques. The Environmental Protection Agency will provide the Peter Anderson, an environmental research platform. The conference planners also expect visits by Army Corps of Engineers and Navy vessels.

The Ocean Community Conference ’98 promises something for everyone and the new format should bring sharper focus and depth to the major marine issues and opportunities. For further information and registration materials, call Ms. Vita Feuerstein at 1 (800) 810-4333 in the U.S. or Canada, (732) 562-6826 outside the U.S. and Canada, Fax at (732) 981-1203, or e-mail at *mts-occ98@ieee.org*.

For those who cannot attend OCC ’98, the proceedings can be purchased from the MTS Headquarters Office in Washington, D.C. Please contact the MTS at (202) 775-5966 or Fax: (202) 429-9417.

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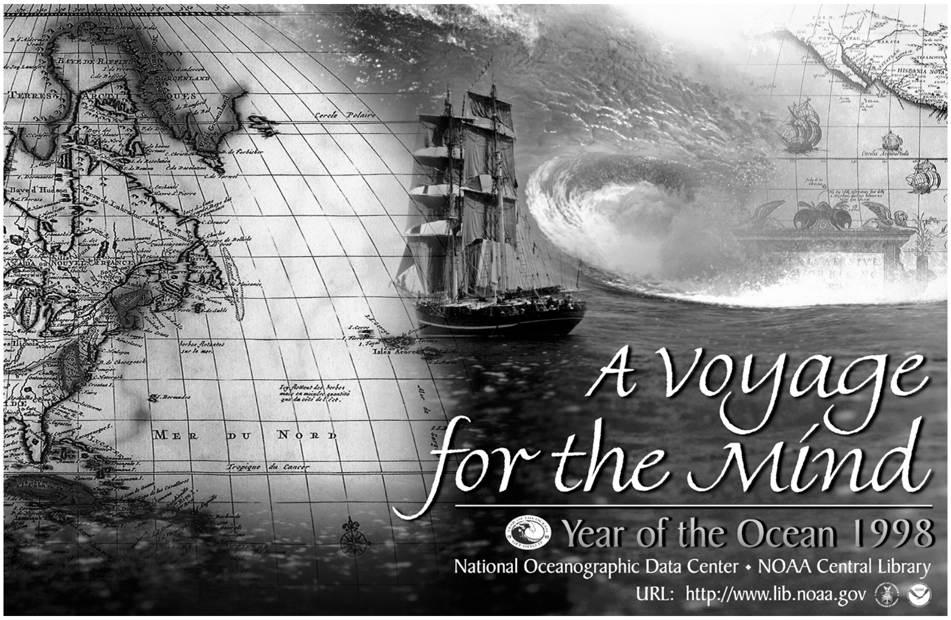
▲ **Figure 1.** Coastal ocean management issues are among the many topics that will be examined during the Marine Technology Society’s Ocean Community Conference ’98. Information about the conference can be obtained through the NOAA home page at: *http://www.publicaffairs.noaa.gov/MTS98.html*.

"Year of the Ocean" poster available from NOAA Library



▲ **Figure 1.** A "montage" of antique marine images is presented by the NOAA Central Library in a colorful 11" by 17" poster celebrating the 1998 Year of the Ocean. A color version may be viewed online at: *http://www.lib.noaa.gov/docs/poster.html*.

NOAA's Central Library has produced and is distributing an 11" by 17" full-color poster (Figure 1) in support of the 1998 Year of the Ocean. The brightly colored image is a composite of images of antique globes, an old sailing vessel, and ocean waves, reflecting the NOAA Central Library's unique historical collections of manuscripts and imagery. The overall colors are dominated by rich blues and ambers, and the poster is highly suitable for classroom use.

Complimentary copies of this poster can be obtained by contacting Ms. Doria Grimes at:

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SSMC3, Suite 2000
Silver Spring, MD 20910
Phone: 301-713-2600 x142
Fax: 301-713-4599
E-mail: *dgrimes@nodc.noaa.gov* ■

NASA/NOAA Prototype Long-Term Archive operational

The National Climatic Data Center and NASA/Goddard Space Flight Center (GSFC) have developed a prototype to demonstrate the functionality of the proposed NOAA/NASA long term (permanent) archive for NASA's Earth Observing System (EOS) data. The prototype is designed to demonstrate the processes involved in acquiring the data and products, in limited interoperability with users, in working co-located with NASA, and in providing rapid access to data and products.

The Total Ozone Mapping Spectrometer-Earth Probe (TOMS-EP) data set and the Upper Atmosphere Research Satellite-Micro Limb Sounder (UARS-MLS) data are now available online. The NOAA Prototype Archive Facility at GSFC currently ingests, archives, and provides access to the data and products. NASA and other researchers can access the data and products from the NOAA facility. The entire process demonstrates the functionality of the long term archive to receive and service data and NASA Science Team's products from the Distributed Active Archive Center (DAAC).

This demonstration fits the NOAA Virtual Data System architecture with a NOAA facility at NASA GSFC and the data being serviced from another location. There will be a six-month evaluation phase to ensure suitable access to and servicing of data and products to meet the general user requirements of the U.S. Global Change Research Program (USGRP), NOAA, and EOS.

NOAA will provide online service to NASA as well as to NOAA users. At the end of the demonstration, a report detailing the transfer, archiving, and servicing functions will be prepared by NOAA and NASA. The report will evaluate baseline costs and system needs associated with the archiving of the EOS data by NOAA.

The report will also evaluate the benefits of the co-located archive facility and the rapid availability of the EOS data. The prototype will provide data access to meet initial USGRP requirements. The report will use the prototype experience to reanalyze these USGRP requirements and the success of the prototype to fulfill those requirements.

Additionally, projections for various levels of long term archive effort and associated costs will be refined by NOAA and NASA and presented as additional costs, above baseline, for providing enhanced data management support services for the MTPE. The UARS and TOMS data can be obtained using the prototype at:

http://www.ncdc.noaa.gov

and going to Satellite Resources> and then Get/View Data.

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NOAA places information about Florida wildfires online

Information on Florida's unusual weather that set the stage for its raging forest fires has been placed on the World Wide Web by the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). The Web site, developed by NOAA's National Climatic Data Center, was unveiled by Vice President Al Gore, who visited fire sites.

The Web site, titled "Florida Wild Fires and Climate Extremes," explains how Florida's unusual weather led to the fires. The unusually wet mild winter in Florida promoted abundant growth in the underbrush. This weather was immediately followed by a severe drought during April, May and June, which rapidly dried out the dense underbrush. This combination—wet and mild in the winter, dry and hot in the summer—provided abundant fuel to the wildfires throughout Florida.

Details on recent abnormal weather, including temperature and precipitation as well as drought indices, are available on the Web site. Links to related Web sites, such as NOAA satellite imagery of the fires and the fire forecast, are provided. The Web site can be reached at: *http://www.ncdc.noaa.gov/ol/climate/research/1998/fla/florida.html*.
Contact: NCDC

NCDC provides climate change, extremes, and events WWW site

With the growing interest in climatic and weather extremes, the National Climatic Data Center (NCDC) now has a web system on line which links to all NCDC web pages related to climatic extremes, weather events, climate change, El Niño, natural disasters, and U.S. climatologies for extremes. The recent surge in news media, government, and individual interest in these topics has led to numerous inquiries for data and information, and even the formation of a "Rapid Response" team at NCDC.

Users can go to a single web page (*http://www. ncdc.noaa.gov/ol/climate/severe weather/severeweather.html*) to find what NCDC has to offer online regarding these topics. Within this system, users will find a wealth of data, maps, images (e.g., satellite, radar), and reports for each topic, such as El Niño, 1993-1998 Weather Events, U.S. Tornadoes, Historical Global Extremes, and other events.
Contact: NCDC

Data products and services

Central Asian snow cover data

The National Snow and Ice Data Center (NSIDC) has recently released the Central Asian Snow Cover from Hydrometeorological Surveys data. The data are based upon observations made by personnel throughout three river basins: the Amu Darya, Sir Darya, and Naryn. These observations include end-of-month snow depth, snow density and snow water equivalent for snow points measured from the ground. Only snow depth is included for additional snow points measured from the air.

Temporal coverage varies for each snow point, with the longest station record extending from 1932 through 1990. Data were provided to NSIDC by the State Hydrometeorological Service (Russian acronym SANIGMI) in Tashkent, Uzbekistan.
Contact: NSIDC

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WWW: *http://www.nodc.noaa.gov*

NOAA Environmental Services Data Directory
301-713-0572
(Gerry Barton)
Fax: 301-713-1249
E-mail: barton@esdim.noaa.gov
WWW: *http://www.esdim.noaa.gov/#data-products*

NOAA Central Library
Reference Services:
301-713-2600
Fax: 301-713-4599
E-mail: *reference@nodc.noaa.gov*
WWW: *http://www.lib.noaa.gov/*

NGDC releases WebBook of Natural Hazards Resources

Paula Dunbar and Rich Fozzard of the National Geophysical Data Center (NGDC) released a new and improved Natural Hazards Data Resources Directory with data resources organized by natural hazard topic and lists of hazard-related organizations. The new release uses the NGDC-developed "WebBook" tool for ease of reading and chapter-based searching. The Directory is at *http://www.ngdc.noaa.gov/seg/hazard/resource/*.
Contact: NGDC

GEBCO Grids for coastal regions

The National Geophysical Data Center (NGDC) provided the U.S. Naval Oceanographic Office with a preliminary version of the U.S. West Coast Coastal Relief Model. The data will be used in the beginning versions of the General Bathymetric Chart of the Oceans (GEBCO) grids for coastal regions of the world. GEBCO has long produced bathymetric contours of the world's oceans, but generally has not provided details for the continental shelves. Due to the increased importance of these regions, in terms of climate, commerce, and resources, GEBCO is undertaking the generation of gridded relief models.

Initial grid size will be two arc minutes of latitude and longitude. NGDC is generating a much more detailed three arc-second Coastal Relief Model for the coastal United States. Therefore, the preliminary grids of the West Coast were the ideal starting point for GEBCO gridding in that region.
Contact: NGDC

New snow data added to archives

A new data set of observed snowfall extremes and derived return period statistics for 8718 Cooperative (COOP) stations in the contiguous U.S. and Alaska has been added to the National Climatic Data Center's (NCDC) holdings. Of these, 7464 were identified as "current" stations and were provided to the Federal Emergency Management Agency (FEMA) to aid in Federal snow disaster declarations. The four time frames/parameters are: one-day, two-day, and three-day extreme snowfall, and August-July seasonal total snowfall.
Contact: NCDC

▲ **Figure 6.** (Left to immediate right) Senator John Breaux, Sec. Jack Caldwell (Louisiana DNR) and Mr. Rolland Schmitten (Assistant Administrator for NOAA Fisheries) attending project dedication ceremony in the Atchafalaya Delta, July 1, 1998. (Photo courtesy of Dr. Erik Zobrist, NOAA Habitat Restoration.)

Wetlands, *from page 9*

need for greater handling time and frequent disposal pipe movement, all which was included in the specifications.

Distributary channels were designed at 45 degree angles to mimic features of natural deltas. Through close coordination between the contractor and Louisiana DNR and NOAA Fisheries, the projects are ahead of schedule and within budget.

Projects like these provide a challenge to both the dredging industry and the resource agencies that plan and design projects to benefit wetland systems by replicating and restoring natural processes. Such projects require agencies planning restoration projects to understand constraints and capabilities of the dredging industry, while requiring dredgers to fully understand the criticality of meeting exacting design standards necessary for successful wetland restoration. Ultimately, the success of dredge projects designed to enhance coastal wetlands depends on an open dialogue and educational process between groups designing and constructing restoration projects.

As demonstrated by the Breaux Act projects (Figure 6) in the Atchafalaya River delta, coastal restoration provides an opportunity for the dredging industry not only for significant work, but also in becoming a partner in the efforts to restore and create wetlands along the nation's coast.

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