The GGFC Special Bureau for the Oceans: Past Progress and Future Plans

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Abstract: The oceans have a major impact on global geophysical processes of the Earth. Nontidal changes in oceanic currents and bottom pressure have been shown to be a major source of polar motion excitation and also measurably change the length-of-day. The changing mass distribution of the oceans causes the Earth's gravitational field to change and causes the center-of-mass of the oceans to change which in turn causes the center-of-mass of the solid Earth to change. The changing mass distribution of the oceans also changes the load on the oceanic crust, thereby affecting both the vertical and horizontal position of observing stations located near the oceans. Recognizing the important role that nontidal oceanic processes play in Earth rotation dynamics and terrestrial reference frame definition, the International Earth Rotation and Reference Systems Service (IERS) has created a Special Bureau for the Oceans (SBO) as a component of its Global Geophysical Fluids Center (GGFC) in order to facilitate research into these and other solid Earth geophysical processes affected by the oceans. Through the IERS SBO web site, data relating to nontidal changes in oceanic processes affecting the Earth's rotation, deformation, gravitational field, and geocenter can be obtained along with a bibliography of over 200 relevant publications

1 Introduction

The Earth's rotation, encompassing both the rate of rotation as well as the terrestrial location of the rotation pole, is not constant but changes on all observable time scales from subdaily to secular. This rich spectrum of observed Earth rotation changes reflects the rich variety of astronomical and geophysical phenomena that are causing the Earth's rotation to change, including, but not limited to, ocean and solid body tides, atmospheric wind and pressure changes, oceanic current and bottom pressure changes, torques acting at the core-mantle boundary, and post-glacial rebound.

Recognizing the rich variety of processes affecting the Earth's rotation, the International Earth Rotation Service (IERS) created a Center for Global Geophysical Fluids on January 1, 1998 in order to help relate dynamical properties of the atmosphere, oceans, and core to motions of the Earth, including its rotation (Dehant et al., 1997; Chao et al., 2000). The IERS Global Geophysical Fluids Center consists of a Central Bureau and eight Special Bureaus including the Special Bureau for the Oceans (SBO). As part of the IERS Global Geophysical Fluids Center, the Special Bureau for the Oceans is responsible for collecting, calculating, analyzing, validating, archiving, and distributing data relating to nontidal changes in oceanic processes affecting the Earth's rotation, deformation, gravitational field, and geocenter. The oceanic data sets available through the IERS SBO are produced primarily by general circulation models of the oceans that are operated by participating modeling groups and include oceanic angular momentum, center-of-mass, bottom pressure, and torques. Brief descriptions of the computation of these data sets from the products of oceanic general circulation models and their relevance to solid Earth science is given below.

2 Oceanic Angular Momentum and Earth Rotation

In the absence of external torques, the angular momentum of the entire Earth does not change. However, if the angular momentum of one component of the Earth, such as the oceans, changes, then the angular momentum of the other components of the Earth must change in order for the angular momentum of the entire Earth to remain constant.

Since observing stations are located on the Earth's crust, observations of the Earth's rotation determine the rotation of the solid Earth. As the angular momentum of the solid Earth is exchanged with that of the other components of the Earth, the rotation of the solid Earth will change. Interpreting the observed changes in the rotation of the solid Earth, which encompasses changes in both the length-of-day and in the location of the Earth's rotation axis with respect to the crust (polar motion), therefore requires knowledge of the changes of the angular momentum of the other components of the Earth, such as the oceans.

Two different series of oceanic angular momentum (OAM) are currently available from the IERS Special Bureau for the Oceans: (1) a series computed by Ponte et al. (1998) and Ponte and Stammer (1999, 2000) from the products of a simulation run of the MIT ocean general circulation model (OGCM) which spans January 1985 to April 1996 at 5-day intervals, and (2) a series computed by Johnson et al. (1999) from the products of version 4B of the Parallel Ocean Climate Model (POCM) which spans January 1988 to December 1999 at 3-day intervals. Since these OAM series were produced, ocean modeling groups have extended the duration of their model runs and have developed data assimilative models. We plan, through collaborative efforts with the modeling groups, to compute, analyze, and validate the oceanic angular momentum from the products of these current generation ocean models, making the results available to the solid Earth science community through the IERS SBO web site.

3 Oceanic Center-of-Mass and Earth Geocenter

In the absence of external forces, the location of the center-of-mass of the entire Earth does not change. However, if the center-of-mass of one component of the Earth, such as the oceans, changes, then the center-of-mass of the other components of the Earth must change in order for the center-of-mass of the entire Earth to remain constant.

Artificial satellites of the Earth, which orbit about the center-of-mass of the entire Earth, or geocenter, are tracked by a global network of stations located on the surface of the Earth's crust. From these tracking measurements, the offset of the entire Earth's center-of-mass from the center-of-figure of the network of tracking stations can be deduced. Since the tracking stations are located on the Earth's solid surface, changes in the location of the center-of-figure of the network of tracking stations reflect changes in the location of the center-of-mass of the solid Earth. Interpreting the observed offset of the geocenter from the center-of-figure of the network of tracking stations therefore requires knowledge of the changing locations of the center-of-mass of the other components of the Earth, such as the oceans.

Two different oceanic center-of-mass series are currently available from the IERS Special Bureau for the Oceans, both computed by Dong et al. (1997) and both spanning February 1992 to December 1994 at 3-day intervals: (1) a series computed from the results of a version of the Modular Ocean Model (MOM) run at JPL, and (2) a series computed from the results of running the Miami Isopycnal Coordinate Ocean Model (MICOM) at JPL. These series are quite short, spanning only 3 years. Observations of the Earth's changing geocenter are much longer, spanning the last decade. We plan, through collaborative efforts with ocean modeling groups, to compute, analyze, and validate longer ocean center-of-mass series from the products of current generation ocean models, making the results available to the solid Earth science community through the IERS SBO web site.

4 Ocean-Bottom Pressure and Crustal Deformation

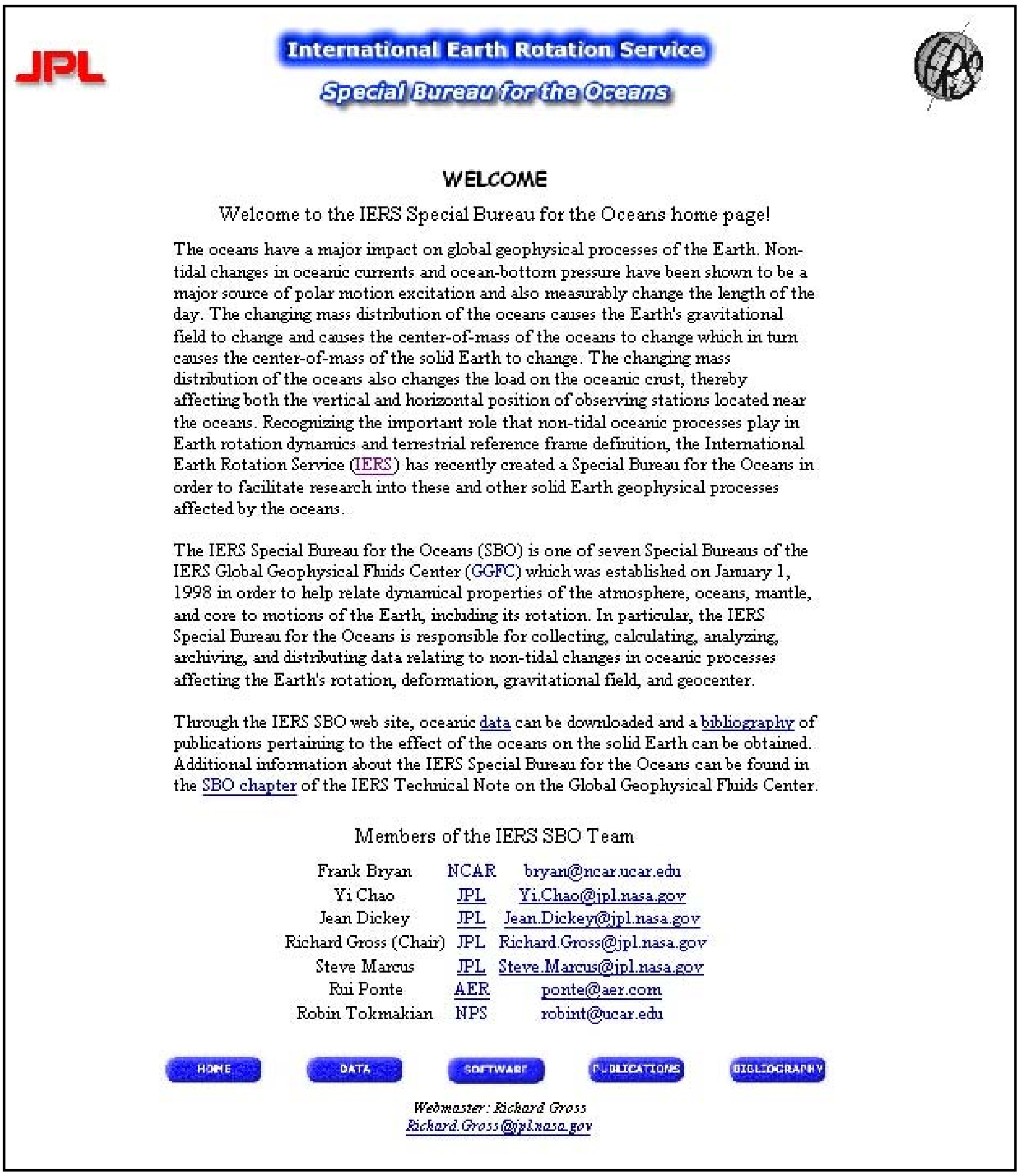
The changing mass distribution of the oceans causes the load on the ocean floor to change. As the oceanic crust and mantle yields to this changing load, the position of stations located on the crust near the oceans will change, and the geoid will deform. Computing station displacements and perturbations to the geoid caused by ocean loading requires knowledge of the pressure at the bottom of the oceans caused by the weight of the overlying oceanic mass.

Links are provided through the IERS SBO web site to the GLObal Undersea Pressure (GLOUP) data bank of ocean-bottom pressure measurements and to the Estimating the Circulation and Climate of the Oceans (ECCO) web site from which modeled ocean-bottom pressure fields produced by the ECCO project can be obtained. However, the ocean-bottom pressure fields archived by the ECCO project are not immediately useful to the solid Earth science community because of artificial changes in the ECCO-modeled bottom pressure fields due to the use of the Boussinesq approximation by the MIT OGCM used by ECCO to produce the bottom-pressure fields. General circulation models of the oceans that are formulated using the Boussinesq approximation conserve volume. Artificial mass variations in such models can be introduced if there are density changes due to internal mixing or imposed surface heat fluxes. Since volume is conserved, the changing density will artificially change the mass of the ocean model. Mass conservation can be imposed on Boussinesq ocean models by adding a uniform layer to the surface that has the appropriate time-dependent thickness (Greatbatch, 1994; Greatbatch et al., 2001). The effects of this mass conserving layer have been computed and is included in the oceanic angular momentum and ocean center-of-mass series available through the IERS SBO. We plan to provide through the IERS SBO corrections to the ECCO ocean-bottom pressure fields by computing the effect of this mass conserving layer on the bottom pressure. In addition, we plan, through collaborative efforts with ocean modeling groups, to compute, analyze, and validate ocean-bottom pressure fields from the products of other current generation ocean models, making the results available to the solid Earth science community through the IERS SBO web site.

5 Gravitational Field Coefficients

The changing mass distribution of the oceans causes the Earth's gravitational field to change, an effect that is being measured by the CHAMP and GRACE satellite missions. Interpreting the observed gravitational field changes over the oceans requires knowledge of the ocean-bottom pressure. Expanding the time-dependent ocean-bottom pressure field in spherical harmonics (using appropriate spatial averaging functions, if desired) yields time-dependent gravitational field coefficients that can be compared to those observed by CHAMP and GRACE.

No series of gravitational field coefficients are currently available from the IERS SBO. We plan to remedy this major deficiency of the IERS SBO by computing, analyzing, and validating series of gravitational field coefficients from the products of current generation ocean models, making the results



WELCOME

Welcome to the IERS Special Bureau for the Oceans home page!

The oceans have a major impact on global geophysical processes of the Earth. Non-tidal changes in oceanic currents and ocean-bottom pressure have been shown to be a major source of polar motion excitation and also measurably change the length of the day. The changing mass distribution of the oceans causes the Earth's gravitational field to change and causes the center-of-mass of the oceans to change which in turn causes the center-of-mass of the solid Earth to change. The changing mass distribution of the oceans also changes the load on the oceanic crust, thereby affecting both the vertical and horizontal position of observing stations located near the oceans. Recognizing the important role that non-tidal oceanic processes play in Earth rotation dynamics and terrestrial reference frame definition, the International Earth Rotation Service (IERS) has recently created a Special Bureau for the Oceans in order to facilitate research into these and other solid Earth geophysical processes affected by the oceans.

The IERS Special Bureau for the Oceans (SBO) is one of seven Special Bureaus of the IERS Global Geophysical Fluids Center (GGFC) which was established on January 1, 1998 in order to help relate dynamical properties of the atmosphere, oceans, mantle, and core to motions of the Earth, including its rotation. In particular, the IERS Special Bureau for the Oceans is responsible for collecting, calculating, analyzing, archiving, and distributing data relating to non-tidal changes in oceanic processes affecting the Earth's rotation, deformation, gravitational field, and geocenter.

Through the IERS SBO web site, oceanic data can be downloaded and a bibliography of publications pertaining to the effect of the oceans on the solid Earth can be obtained. Additional information about the IERS Special Bureau for the Oceans can be found in the SBO chapter of the IERS Technical Note on the Global Geophysical Fluids Center.

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HOME DATA SOFTWARE PUBLICATIONS BIBLIOGRAPHY

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Fig. 1 The home page of the IERS Special Bureau for the Oceans web site

available to the solid Earth science community through the IERS SBO web site.

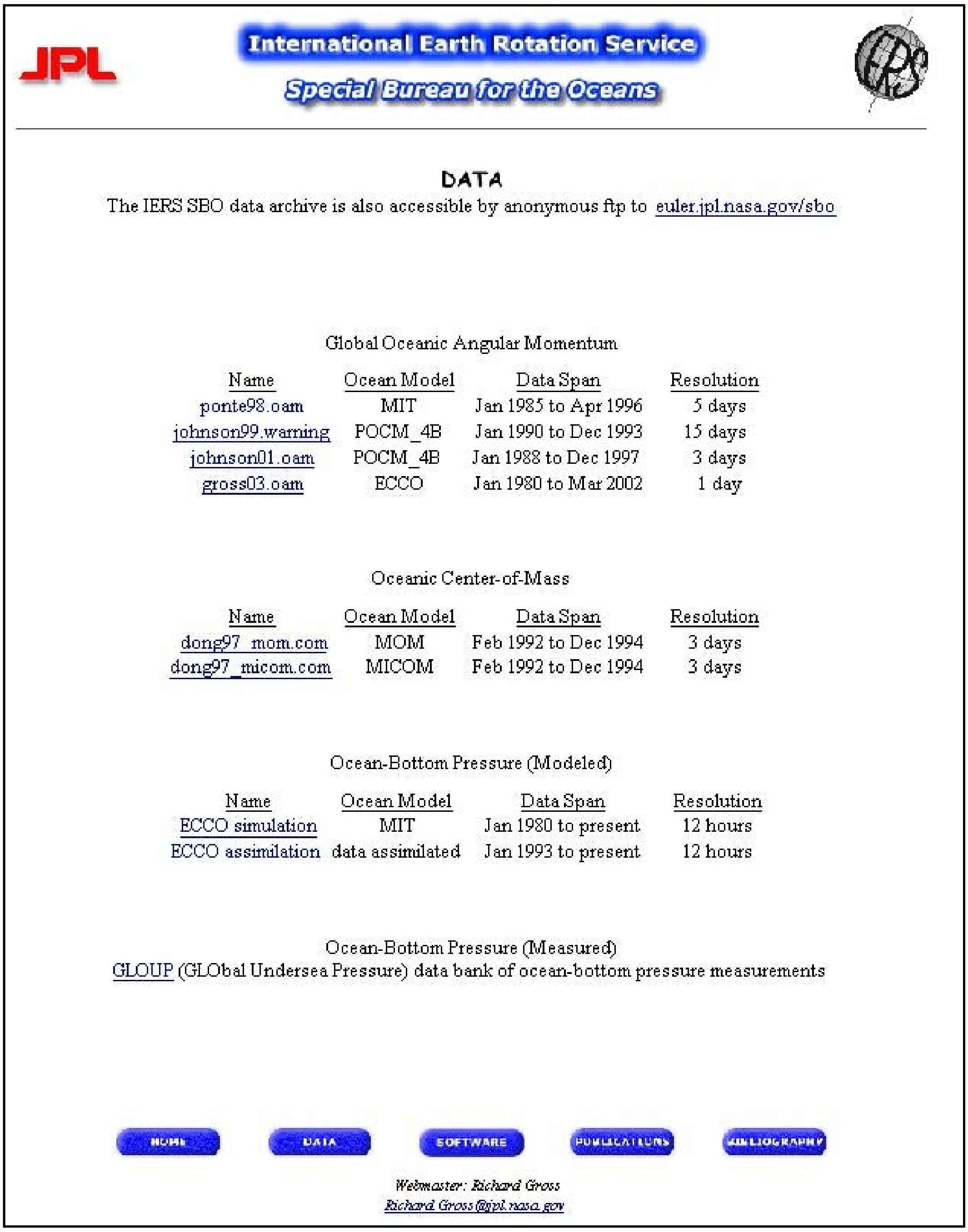
6 Oceanic Torques

Torques exerted by the oceans on the bounding solid Earth effect changes in the rotation of the solid Earth. These torques are due to either frictional stresses acting on the solid boundaries of the ocean basins, or due to pressure gradients acting on topographic features of the ocean basins. Investigating how the oceanic angular momentum is transferred to the solid Earth requires knowledge of these various torques.

No oceanic torque series are currently available from the IERS SBO. We plan, through collaborative efforts with ocean modeling groups, to remedy this major deficiency of the IERS SBO by computing, analyzing, and validating series of oceanic torques from the products of current generation ocean models, making the results available to the solid Earth science community through the IERS SBO web site.

7 The IERS Special Bureau for the Oceans Web Site

Figure 1 shows the home page of the IERS SBO web site located at URL <http://euler.jpl.nasa.gov/sbo/>. After a brief welcoming message describing the importance of oceanic processes to the solid Earth sciences and the mission of the IERS Special Bureau for the Oceans, the members of the IERS SBO team are listed along with their affiliations and email addresses. Through the buttons at the bottom of the home page and hot links within the welcoming message, the user can subsequently navigate to the data, software, and publications pages. The user can also download a bibliography of over



JPL

International Earth Rotation Service
Special Bureau for the Oceans

DATA

The IERS SBO data archive is also accessible by anonymous ftp to euler.jpl.nasa.gov/sbo

Global Oceanic Angular Momentum

Name	Ocean Model	Data Span	Resolution
ponte98.oam	MIT	Jan 1985 to Apr 1996	5 days
johnson99.warning	POCM_4B	Jan 1990 to Dec 1993	15 days
johnson01.oam	POCM_4B	Jan 1988 to Dec 1997	3 days
gross03.oam	ECCO	Jan 1980 to Mar 2002	1 day

Oceanic Center-of-Mass

Name	Ocean Model	Data Span	Resolution
dong97_mom.com	MOM	Feb 1992 to Dec 1994	3 days
dong97_micom.com	MICOM	Feb 1992 to Dec 1994	3 days

Ocean-Bottom Pressure (Modeled)

Name	Ocean Model	Data Span	Resolution
ECCO simulation	MIT	Jan 1980 to present	12 hours
ECCO assimilation	data assimilated	Jan 1993 to present	12 hours

Ocean-Bottom Pressure (Measured)

GLOUP (GLObal Undersea Pressure) data bank of ocean-bottom pressure measurements

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Fig. 2 The data page of the IERS Special Bureau for the Oceans web site

Fig. 3 The software page of the IERS Special Bureau for the Oceans web site

200 relevant publications by clicking on the bibliography button.

Figure 2 shows the data page of the IERS SBO web site. Through this data page, the user can currently obtain two different data sets of oceanic angular momentum and two different data sets of oceanic center-of-mass. These data sets can also be obtained by anonymous ftp to <[1]>. In addition, links are provided to the GLObal Undersea Pressure (GLOUP) data bank of ocean-bottom pressure measurements and to the Estimating the Circulation and Climate of the Oceans (ECCO) web site from which modeled ocean-bottom pressure fields produced by the ECCO consortium can be obtained.

Figure 3 shows the software page of the IERS SBO web site. Through this software page, the user can currently obtain a Fortran subroutine which computes the core products of the IERS SBO (oceanic angular momentum, center-of-mass, and bottom pressure) from the temperature, salinity, and horizontal velocity fields produced by an oceanic general circulation model.

Figure 4 shows the publications page of the IERS SBO web site. Through this publications page, the user can currently obtain, in pdf format, a document describing the IERS Special Bureau for the Oceans and a bibliography of over 200 relevant publications.

As can be seen, these pages of the IERS SBO web site are quite basic and merely serve as an interface to the data sets, software, and publications archived there. We plan to improve this web site by incorporating tools by which the available data sets can be displayed and intercompared, including comparisons with the relevant solid Earth measurements such as those of the Earth's rotation and geocenter. As additional data sets from other OGCMs become available and are archived at the SBO, the ability to intercompare the available series will be invaluable in aiding the user to decide which series is best suited for his purpose.

[1] ftp://euler.jpl.nasa.gov/sbo

Fig. 4 The publications page of the IERS Special Bureau for the Oceans web site

In addition, we plan to improve the bibliography. It is currently only available in the form of a list as a pdf file. We plan to make it browsable online with each entry tagged with searchable keywords such as “torques”, “angular momentum”, etc. As the number of bibliographic entries increases, having a browsable bibliography will enable the user to more quickly locate publications of interest rather than having to visually scan a lengthy list.

8 IERS SBO Data Archive and Formats

The data holdings of the IERS SBO are currently quite sparse, consisting of just two oceanic angular momentum series and two oceanic center-of-mass series. No oceanic torque, gravitational field, or ocean-bottom pressure data sets are archived at the IERS SBO. While a link is provided to the ECCO web site from which the ECCO bottom pressure fields can be obtained, as explained above, these pressure fields must be corrected for the effects of artificial mass variations in them before they should be used in solid Earth science investigations. We plan to provide such corrections through the IERS SBO web site.

We also plan to expand the data sets available through the SBO. For example, the ocean-bottom pressure fields of van Dam et al. (1997) are data sets that could potentially be included in the SBO today.

The oceanic angular momentum and center-of-mass series currently archived at the IERS SBO are available as ASCII text files. This is a convenient format for small data sets such as these series consisting of just a time tag and 3–6 values at that epoch. However, larger data sets such as time-dependent ocean-bottom pressure fields must be archived in a compressed format. For these larger data sets we propose to let the user select from a choice of formats including NetCDF and compressed ASCII text. Decompression routines for a variety of platforms will be provided to the user through the SBO software web page.

9 Summary

The IERS Special Bureau for the Oceans is committed to serving the needs of the solid Earth science community by providing via web and ftp servers relevant oceanic data sets to facilitate investigations into the effect of the oceans on the Earth's rotation, deformation, gravitational field, and geocenter. The Special Bureau for the Oceans was created by the International Earth Rotation Service to foster research by the solid Earth science community. Observations of the Earth's rotation, gravitational field, and geocenter are globally integrated quantities which change in response to natural and human-induced causes. The IERS SBO supports investigations into the observed changes in the Earth's rotation, gravitational field, and geocenter by providing relevant oceanic data such as angular momentum, bottom pressure, and center-of-mass to aid in the interpretation of these observed changes.

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