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The New IERS Special Bureau for Loading (SBL)

The SBL Team

For affiliation of team members, see Table 1.
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Abstract

Currently, the establishment of the International Earth Rotation Service (IERS) Special Bureau for Loading (SBL) is in progress as part of the IERS Global Geophysical Fluids Center (GGFC). The main purpose of the SBL is to provide reliable, consistent model predictions of loading signals that have been thoroughly tested and validated. The products will describe at least the surface deformation, gravity signal and geo-centre variations due to the various surface loading processes in reference frames relevant for direct comparison with existing geodetic observing techniques. To achieve these goals, major scientific advances are required with respect to the Earth model, the theory and algorithms used to model deformations of the Earth as well as improvements in the observational data related to surface loading.

1. Introduction

On 1 January 1998, the International Earth Rotation Service (IERS) established the Global Geophysical Fluids Center (GGFC) in an effort to expand IERS's services to the scientific community. Under the GGFC, seven Special Bureaus (SB) were established [1]. Each of these is responsible for research activities relating to a specific Earth component or aspect of the geophysical fluids of the Earth system. However, until recently, there was no specific focus on the interaction of the different components through gravitational and surface forces on the boundaries. In particular, consistent models of the deformation of the solid Earth due to loading of the atmosphere, ocean and terrestrial hydrosphere are presently not available. This is also reflected in the IERS Conventions [5], where standard models for solid Earth tides and ocean loading are discussed while no standard procedure is given for taking into account other surface loading effects.

In order to foster the development of consistent models for signals due to surface loading, the IERS on 31 October 2001 issued a Call for Proposals for a Special Bureau for Loading (SBL) with the task to promote, stimulate and coordinate the work and progress towards a service providing products related to surface mass loading. Eventually, the SBL is expected to provide in near real-time (NRT) a consistent global solution data set describing at least the surface deformation, gravity signal and geo-centre variations due to the various surface loading processes in reference frames relevant for direct comparison with existing geodetic observing techniques.

On 1 February 2002, the SBL[2] was formally established with a team of 10 members (see Table 1). These ten members represent expertise from all fields relevant for accurately modeling surface deformations, namely, theory of Earth deformation and Earth models, observations of surface loads, computation of tidal and non-tidal loading, space-geodetic and gravimetric observations. The team also includes the seven chairs of the already existing SBs. The chairs of the existing SBs

[1] see http://bowie.gsfc.nasa.gov/ggfc/
[2] see http://www.gdiv.statkart.no/sbl/

Table 1. Current Membership of the SBL
Note that the chairs of the existing SBs are members ex-officio. Currently, these are Ben Chao (Mantle), Veronique Dehant (Core), Richard Gross (Oceans), Richard Ray (Tides), David Salstein (Atmospheres), Michael Watkins (Geocenter), Clark Wilson (Hydrology).

Name	**Affiliation or Function**
Tonie van Dam	European Center for Geodynamics and Seismology (ECGS), Luxembourg (chair)
Hans-Peter Plag	Norwegian Mapping Authority (NMA), Norway (co-chair)
Geoffrey Blewitt	University of Nevada, Reno, U.S.A.
Jean-Paul Boy	Goddard Space Flight Center, U.S.A.
Olivier Francis	European Center for Geodynamics and Seismology, Luxembourg
Pascal Gegout	Ecole et Observatoire des Sciences de la Terre, Strasbourg, France
Halfdan Pascal Kierulf	Norwegian Mapping Authority, Norway
Tadahiro Sato	National Astronomical Observatory, Mizusawa, Japan
Hans-Georg Scherneck	Onsala Space Observatory, Sweden
John Wahr	University of Colorado, Boulder, U.S.A.

are ex-officio members of the SBL and participate in the SBL to insure close cooperation between their SBs and the SBL. Moreover, the combined membership provide the necessary links to other geodetic services and relevant projects, such as the IGS, IVS, ILRS, and the GGP.

The accuracy of the products provided through the SBL should, as much as model limitations allow, match the accuracy and precision of the space-geodetic and gravimetric observation techniques. Achieving this ambitious goal requires major scientific advances with respect to the Earth model, the theory and algorithms used to model deformations of the Earth and the observational data of surface loading. Consequently, a scientific agenda is required to perform the research necessary for the development of the models and algorithms and an operational agenda is directed towards the provision of validated products to potential users.

2. The Scientific and Operational Agendas

The workplan of the SBL is separated into a total of seven Work Packages. WP1 to WP4, which define the scientific agenda, address the research oriented tasks related to the different components for the computation of deformations due to surface loading, i.e. the Earth model, the theory used to compute the Earth's response to loading, and the observations of surface loads. WP5 to WP7, which define the operational agenda, will provide the product-oriented routines for the operational service and the production of research data sets. These WPs address the development of operational procedures, validation of products, and their distribution to the geodetic community.

Work package 1: Earth model

Up to now, most loading calculations have been carried out for Spherically symmetric, Non-Rotating, Elastic and Isotropic (SNREI) Earth models. The standard model used for these calculations is the Preliminary Reference Earth Model (PREM) [2]. Computation of the Load Love Numbers (LLN) for the PREM is not straight-forward and inconsistencies have to be avoided. Moreover, it may be necessary to take into account rotation and ellipticity, viscoelasticity, the difference between continental and oceanic crusts, and eventually heterogeneous Earth models. The different options for Earth models will be evaluated and the sensitivity of the LLN and Body

Tide Love Numbers (BTLN) on computational algorithms and model differences will be studied. One SNREI and one 3-D model will be selected for the operational processing.

Work package 2: Computation of Green's functions and convolution algorithms

Using the LLNs, Green's functions describing the Earth's response to point loads can be computed in the space domain [3]. For SNREI models, the Green's function depends on the angular distance between load and observer only.

For ocean tidal loading, which is considered as an harmonic process, the loading signal is computed most economically in the frequency domain [3]. The resulting products are space-dependent harmonic loading coefficients, which can be determined for all harmonic tidal constituents, for which a sufficiently accurate ocean tidal model is available.

For non-tidal surface loads, the loading responses are normally computed in one of two ways: (1) Global convolution sum or point loading approach or (2) the spherical harmonic integration. It is expected that the spherical harmonic approach is considerably faster in the computation than the point loading approach. An analysis needs to be performed that weighs the benefits of reduced cpu-time offered by the spherical harmonic approach to the potential loss of accuracy.

In computing the load signals, special attention has to be devoted to the reference frame [1]. One possibility is to provide products in various frames, for example, center of mass of the entire Earth system (common in SLR), center of mass of the solid Earth (Farrell's assumption), center of figure frame (common in GPS).

The theory for rotating and elliptical models is available [11, 12, 6] and a perturbation method can be used to compute LLNs for viscoelastic, laterally heterogeneous and non-hydrostatically prestressed Earth models [6]. For the latter models, the Green's function becomes space-dependent and this complicates the computation of loading signals seriously.

Work package 3: Surface loads

It has been demonstrated that the effects of variations in atmospheric mass [7, 8], non-tidal ocean loading [9] and variations in continental water loading [10] can be observed in geodetic time series. As such, there are currently three global surface loads (atmospheric mass, continental water storage, and ocean bottom pressure) to be considered by the SBL. The accuracy of the available data sets needs to be evaluated before loading products can be generated.

Work package 4: Integrated Earth system models

Matching the accuracy expected for space-geodetic techniques within the next few years may require that we compute surface deformation, gravity changes and other relevant parameters in a consistent, integrated Earth system model. Initial considerations concerning a modular model have been published [4]. Though currently not of high priority, inclusion of WP4 signals that the development of integrated Earth system models may turn out to be unavoidable.

Work package 5: Near-real time product generation

It is likely that during the first year of the SBL, significant changes will take place in the algorithms and routines used for the computations. Moreover, more complete data sets for surface loads are likely to become available.

Initially, the SBL will concentrate on the computation of atmospheric loading products for the comparison with geodetic time series in the frame of a demonstration project. The initial NRT products will be flagged as a product under development made available for scientific research. Atmospherically driven loading effects will be made available for specific coordinates (e.g. all ITRF sites) and as global grids. The initial products will be computed on a SNREI model for both an oceanless and an inverted barometer ocean model. After a successful demonstration phase, routines for the computation of Version 1 NRT products will be specified and implemented.

Work package 6: Validation and reanalyses

All products provided through the SBL will have to go through a thorough validation. For that, comparison of the modeled loading effects with geodetic time series will be crucial. GPS is the most globally distributed geodetic technique, and will play a central role in the validation. Additional validation through VLBI, SLR and DORIS observations will help to improve the assessment of the loading products. It is hoped that IERS will set up a coordinated validation project.

For a validation of the gravity loading corrections, observations from the approximately 30 globally distributed sites with superconducting gravimeters will be of key importance. Here, co-operation of the SBL with the Global Geodynamics Project (GGP) is a prerequisite.

Comparison of the predicted geocenter motion with those observed using low Earth orbiting satellites and made available by the SB Geocenter will provide validation for these products.

Work package 7: Web-based distribution of products

The main interface between the SBL and users will be through a web site providing access to all loading predictions as well as documentation of the data sets and the underlying algorithms used in the computations. The primary operational computations will be undertaken at and made available through the primary SBL web site maintained by NMA with identical mirror site at the ECGS in Luxembourg and at location to be selected in the United States.

The list of available products will eventually include but is not limited to NRT estimates of the radial and horizontal displacements, and gravity changes derived from the NCEP and ECMWF surface pressure fields; historical estimates of the deformation and gravity changes due to surface pressure, global water storage models, and ocean bottom pressure models.

In the case of the atmospheric loading estimates, results for both the case of no oceans and the inverted barometer ocean will be generated. Historical estimates will be made available as time series for at least all ITRF. Depending on the required cpu time, the historical estimates will also be made available as global grids. These grids will allow taking into account the loading signal at stations not included in one of the global networks (e.g. EUREF sites, GPS sites at tide gauges, or even campaign sites).

3. Outlook

It is planned that the newly established SBL eventually will provide an operational service for all geodetically and geophysically interesting signals due to surface loads. The list of relevant variables includes but is not limited to horizontal and vertical displacements, gravity changes, changes in the geoid, motion of the geocenter, and polar motion. Additionally, surface load induced relative sea level changes and changes in the length of day may become of interest. Global grided data sets with sufficient spatial and temporal resolution and time series for specific locations will be the basic means of providing these variables. All products will be computed consistently using the accepted IERS Conventions. The necessary spatial and temporal resolution of the products will depend on the accuracy requirements defined by the users and may change over time.

After validation, access to ocean tidal loading will be made available through links to existing web pages, which provide loading coefficients in agreement with the IERS Conventions.

Substantial progress is needed to provide the products with an accuracy matching the present accuracy and precision of the geodetic techniques. Moreover, the anticipated developments of these techniques over the next years will pose even higher demands on the models and algorithms used in the computation of loading signals. It is expected that the initial version 1 products will be more of research value than being useful for e.g. corrections of station motion in real time positioning and meteorological applications of GPS.

Initially, we plan to set up a demonstration phase starting on 1 June 2001. The goal of the demonstration phase is to show that loading signals can be computed and made available in NRT. The minimum model for the demonstration phase is based on a SNREI model using the global atmospheric pressure field as input. The minimum product will be a global grid of radial surface displacement for both no ocean and inverse barometer ocean. A main contribution to the validation of the products hopefully will come from a coordinated IERS project involving all IERS techniques. It is planned to end the demonstration project by the end of 2002 and to start operational production of an extended list of products from 1 January 2003 according to standards developed by the different WPs.

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