Special Bureau for the Core

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1 Introduction

The Special Bureau for the Core (SBC) is one of the eight Special Bureaus (SB's) of the Global Geophysical Fluids Center (GGFC), established by the International Earth Rotation Service (IERS) on January 1, 1998 to facilitate the link between the space geodetic and the geodynamic communities. Within the GGFC, the SBC is responsible for the research and data service activities related to the core and plays a role in stimulating and coordinating research on this topic. In particular, the SBC focuses on theoretical modeling and observations related to core structure and dynamics (including the geodynamo), and on inner core - outer core - mantle interactions.

Flow in the fluid outer core, and also motion of the inner core with respect to the outer core, can result in various geodetic phenomena observable from the Earth's surface or space. These phenomena include variations in the Earth's rotation and orientation, surface gravity changes, geocenter variations, and surface deformations. Although small, these variations can or could be observed by very precise space geodetic techniques. Observation of these effects then yields unique insight into the core, which can not be observed directly.

Since its creation in 1998, the SBC has set up a web site (www.astro.oma.be/SBC/main.html) as the central mechanism for providing services to the geophysical community. The web site contains documented model data on core flow and core angular momentum, and an extensive bibliography to support and facilitate core research. In addition, to provide some guidance into the vast literature in core dynamics, a description is given of the relevant theories and of the dynamical assumptions used for constructing the flow.

This position paper gives a brief overview of the various scientific issues and covers past and future activities of the SBC. We first describe in Sect. 2 the length-of-day (LOD) variations, the main subject in this field, and treat the other effects in Sect. 3. Section 4, by W. Kuang, contains a critical overview of core-mantle coupling, and the importance of numerical models of core dynamics in this respect is shown. SBC activities are described in Sect. 5, and future plans in Sect. 6.

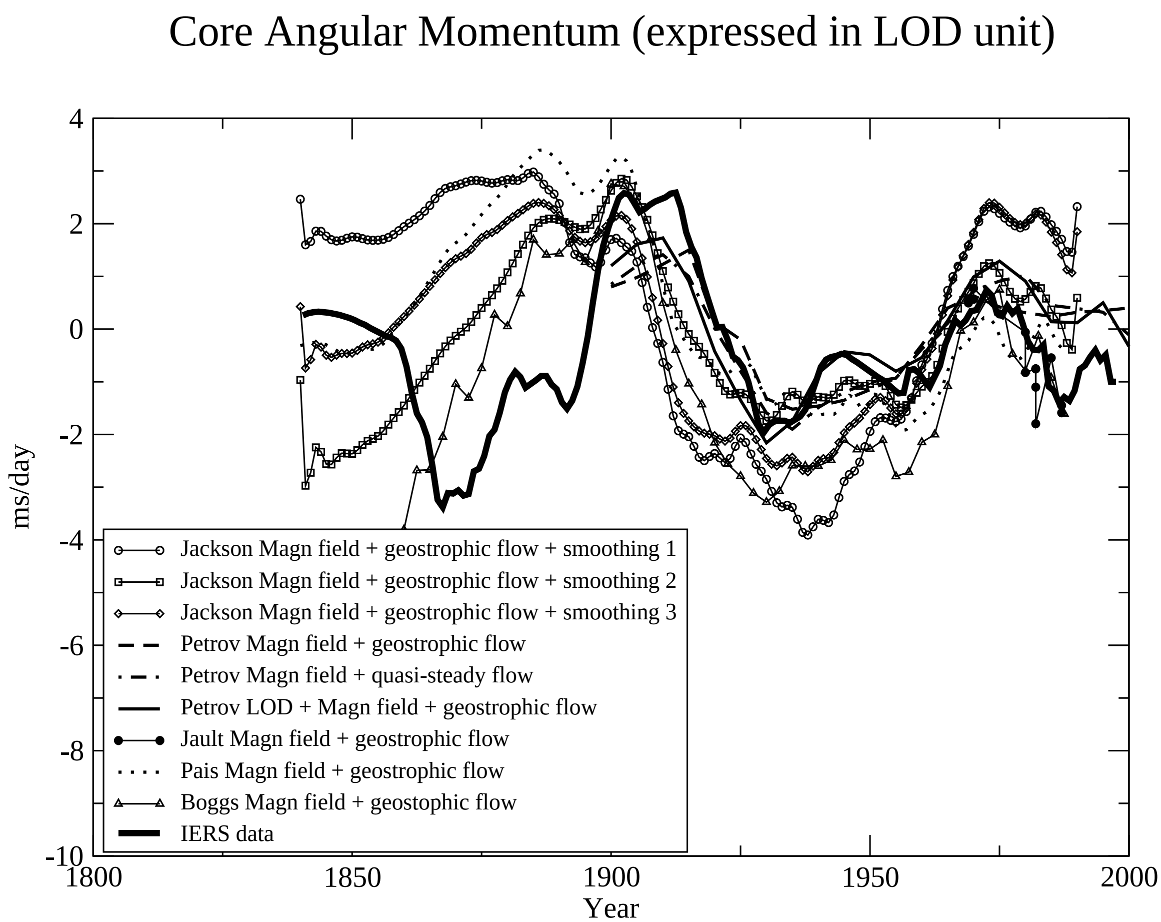

Figure 1: Length-of-day variations for various models and IERS observational LOD data. The data can be found on the SBC website.

2 Length-of-day variations

2.1 Core angular momentum variations

The fluid outer core is in constant motion, and changes in core angular momentum (CAM) are known to be related to length-of-day (LOD) variations of a few milliseconds at decadal time scales (see Fig. 1). These variations can very accurately be measured (uncertainty of about 0.02ms for daily LOD values) and were the main scientific reason behind the creation of the Special Bureau for the Core to stimulate, promote and aid in scientific investigations into the dynamics of the Earth's core by using Earth rotation variations.

The core has been recognized as the major component in explaining the lod variations at decadal scale since it was shown that the time-variations of parameters describing the geomagnetic field (such as the magnetic declination) are correlated with the variations of the LOD at these time scales. Furthermore, no other suitable reservoirs of angular momentum could be found. The core is considered to be able to exchange sufficient angular momentum with the mantle. By using $\vec{H}_m = C_m\vec{\Omega}$, where $\vec{H}_m$ is the angular momentum of the mantle, and C_m is the moment of inertia of the mantle, the change in mantle angular momentum can be estimated to be about 1.3 $\times 10^{26}$kg m s^{-1}. Because of the conservation of angular momentum of the core-mantle system, this also gives an order of magnitude for the core angular momentum change. Given the total core angular momentum of about 6.5×10^{32} kg m s^{-1}, the core therefore changes its relative angular momentum by less then about 10^{-5}.

No direct observations of the core flow exist as do for the atmosphere (and to a lesser extent for the oceans), and core flows are derived from variations in the poloidal magnetic field observed at the Earth's surface. These caculations, however, invoke several simplifying assumptions and hypotheses related, on the one hand, to the downward continuation of the surface geomagnetic field to the core-mantle boundary (CMB), and, on the other hand, to the determination of the horizontal flow in the superficial layer of the outer core from the magnetic induction equation. According to Holme (2002), the implicit assumption, in resolving the non-uniqueness in the core flow determination, that the flow is large scale may be the cause of the fact that all calculated flows are very similar. One may wonder then, whether these flows, although they very well model the geomagnetic secular variations, give a good representation of the true core flow. In this respect, the decadal LOD variations play an important role. Since te pioneering work of Jault et al. (1988), it has been shown that the core flows derived from the geomagnetic observation agree remakably well with the observed decadal LOD variations, adding to our confidence in the obtained core flows (see Fig. 1). To model the LOD variations, core angular momentum (CAM) is calculated from the the top core flow. This can be done since torsional oscillations govern the flow in the outer fluid core on decadal timescales (Braginsky 1970). These oscillations describe differential rigid rotations around the rotation axis of coaxial cylinders, for which magnetism provides the restoring force. Since core flow is then supposed to be constant on cylinders parallel to the rotation axis, velocities everywhere in the core can directly be derived from the velocities at the CMB, and thus the CAM can be derived.

2.2 Torques between core and mantle

Physically, the cause of angular momentum exchange between core and mantle is through coupling torques between core and mantle. These torques can excite torsional oscillations in the core. To explain the observed decadal LOD changes, the torque $\vec{\Gamma}$ can be estimated from the change in angular momentum to be about $\Gamma = C_m d\Omega/dt \approx 10^{18}$Nm. Four mechanisms have been suggested, but due to uncertainties in the flow and torque calculations, it has not been possible to definitely settle the relative importance of the different mechanisms.

1. The topographic torque is related to the effects of the fluid pressure on the boundary topography. The presence of bumps at the CMB has been suggested by both seismological studies in which refracted and internally reflected seismic waves at the CMB are used and convection studies in which the CMB topography deformations are computed from the buoyancy fluxes associated with density lateral heterogeneities in the mantle (seismic tomography). The efficiency of this mecha-

nism is rather controversial, partly because of differences in the assumptions made in the calculation method (does the topography significantly affect the pattern of the flow?) and partly because of the uncertainties in the CMB topography (see Ponsar et al. 2002). The topography is thought to be less than 2 km according to Garcia and Souriau (2000), but about 3 km according to Sze and van der Hilst (2002). For these topographies, the torques are either somewhat too small (e.g. Kuang and Chao 2001, Wu and Wahr 1997) or too large (e.g. Jault and Le Mouël 1989). Considering that the pressure at the CMB derives, in a first approximation, from a tangentially geostrophic balance, the last authors obtain a torque proportional to the ratio of topography to core radius, δ. The other authors, working on diurnal time scales (Wu and Wahr 1997) and decadal time scales (Kuang and Chao 2001), consider the perturbation of the topography on the the flow. An analytical approach is used for the calculation of the effect of topographic torques on nutation, and results of geodynamo simulations are used for the effect on LOD variations. Both studies give a torque proportional to δ^2. According to Wu and Wahr (1997), a topography of 6-7 km can explain the observed retrograde annual nutation, and Kuang and Chao (2001) obain an effect at the level of 20% of the observed LOD variations for a topography of 2-3 km.

2. The electromagnetic torque is generated by the Lorentz force on an electrically conducting layer at the base of the mantle and is associated with the magnetic field (and its variations). The magnetic torque is usually decomposed into poloidal and toroidal parts. The poloidal torque is connected to the poloidal part of the longitudinal component of the CMB magnetic field and its secular variation, which can be deduced from the observation of the magnetic field at the Earth's surface. The toroidal torque is connected to the toroidal part of the longitudinal component of the CMB magnetic field and its secular variation and can further be divided into the advective torque and the leakage torque. The advective torque is related to advection of the radial magnetic field and can in principle be calculated from models of core surface flow derived from measurements of geomagnetic secular variation. The leakage torque is associated with the diffusion of the core toroidal magnetic field at the top of the core into the mantle and is unknown. Holme (1998) has shown that electromagnetic coupling can be large enough to explain the observed LOD variations, if the conductance of the deep mantle layer is high enough (conductance of 10^8 S). Support for this hypothesis comes from nutation (see below). Such a layer could arise as a result of the cooling of the Earth. Cooling is associated with inner core growth and an increase in light element concentration, such as FeO, in the fluid outer core. These elements could be removed from the core and deposited as metallic solids at the base of the mantle (it is interesting to note here that an Fe-FeO system has a high melting temperature). Buffett et al. (2000) proposed that chemical reactions with mantle silicates can lead to silicate mineral deposits with interstitial liquid iron when excess light elements are created as a result of inner core growth.

3. The viscous torque is related to the viscosity of the fluid core at the core-mantle

boundary and is generally believed to be small. However, if the top flow is turbulent, turbulent mixing could increase the coupling by orders of magnitude (Kuang and Chao 2002a)

4. The gravitational torque is related to the gravitational interaction between lateral variations in density within the fluid core and mantle and is generally thought to be small because the density of the fluid can adjust when moving slowly through lateral vartiations in the gravitational potential. The gravitational interaction between the *inner* core and the mantle is thought to be more important for decadal LOD variations, and couples the inner core tightly to the mantle (Buffett 1996). LOD variations can then result from electromagnetic coupling of torsional oscillations inside the fluid core with the inner core that changes the rotation of the inner core, which itself is effectively gravitationally locked to the mantle. Recently, Mound and Buffett (2002) developed a similar inner core–outer core–mantle coupling scheme to explain observed LOD variations with periods of about six to seven years and an amplitude of about 0.12 ms.

3 Earth orientation, geocenter, and gravity variations

In the previous section on length-of-day variations, only variations in the component of core angular momentum in the direction of the rotation axis have been considered. Variations in this direction are expected since torsional oscillations are considered to dominate the core flow at decadal time scales. However, this does not rule out the possibility that equatorial components of core angular momentum also vary (say at different time scales or through motion linked with the inner core), and that, through angular momentum exchanges between core and mantle, the core can lead to variations in all three components of Earth rotation. Both nutation and polar motion show features that are thought to be linked with the core, and therefore these variations hold the potential to put additional constraints on the core.

The very accurately observed nutations have proven to be very useful to determine values of several parameters of the Earth's interior. By considering electromagnetic coupling between mantle and core as the dissipative mechanism for the observed out-of-phase nutations, Mathews et al. (2002) showed that, to explain the observed nutation amplitudes, especially the annual retrograde nutation, the semi-annual prograde nutation, and the 18.6 retrograde nutation, a high conductance layer of about 10^8 S at the base of the mantle is needed. This supports the idea that electromagnetic coupling is the main element in explaining the decadal LOD variations and moreover gives the same order of magnitude for the conductance as the LOD studies. The radial magnetic field is estimated to be 0.69 mT at the CMB and 7.17 mT at the ICB. The value at the CMB slightly exceeds the extrapolated value of the geomagnetic field of 0.44 mT (Langel and Estes 1982). At the ICB, geodynamo simulations give radial magnetic fields of between 2 and 3.5 mT (Kuang an Bloxham 1999).

Polar motion shows decadal variations of several tens of milliarcseconds (present daily estimates of polar motion are accurate to ±0.1 mas, McCarthy 2000) that are difficult to explain by atmosphere or surface processes. These variations have first been claimed by Markowitz (1960), and the variations with period of about 30yr are called the Markowitz wobble. Schuh et al. (2000) found several additional decadal periods going from 7yr to 86yr. The effects of oceans are not well known, and several authors have considered torques of the core on the mantle as the main origin of these observed polar motion variations. The main difficulties are that the needed torque is one order of magnitude larger than the torque necessary to explain the decadal LOD variations (which is difficult to reconcile given the same model for conductance and CMB topography to explain the LOD variations), and that at these time scales the torsional oscillations are dominant and only lead to core angular momentum variations in the polar direction. Greiner-Mai et al. (2000) used an angular momentum approach to study whether motions of the inner core can lead to similar polar motion variations as those observed. In particular, they assumed that the figure axis of the inner core is aligned with the geomagnetic dipole axis and follows the observed decadal variations of that dipole axis. They found that the mass redistributions, caused by the relative rotation of the denser flattened inner core with respect to the less dense outer core, give about the correct polar motion magnitude. However, no reason for this large inner core tilt is known, instead, strong pressure and gravitational forces tend to align the inner core axis with that of the Earth. In a follow-up study, Greiner-Mai and Barthelmes (2001) did not use the hypotheses on the inner core tilt anymore, and determined, from the excitation functions, the variations in the figure axis of the inner core necessary to explain the observed decadal polar motion. The angle between the figure axis of the inner core and the mantle is found by Greiner-Mai and Barthelmes (2001) to vary between 0.4° and 1.5°, and the figure axis rotates eastwards with a mean velocity of $0.7° \text{ yr}^{-1}$ but showing large variations of several degrees. In a recent paper, Dumberry and Bloxham (2002) addressed the same problem, but from another point of view. These authors showed that an equatorial torque at the inner core boundary of about 10^{20} Nm is needed to explain the decadal polar motion, and that this torque tilts the inner core out of alignment with the mantle by 0.07deg, the latter value being much smaller than the result of Greiner-Mai and Barthelmes (2001). Such a torque could be obtained by electromagnetic coupling between the inner core and the torsional oscillations in the outer core for a radial magnetic field at the inner core boundary of 3 to 4 mT, corresponding to the geodynamo simulations estimate.

Small variations in the Earth's gravity field can be induced by changing density structures in the core. Degree one variations describe the variations in the geocenter. Gravity field variations caused by the convective motions have recently been calculated from the output of geodynamo models by Kuang and Chao (2002b). They find gravity field variations of the order of 10^{-10} relative to the mean gravity field of the Earth. Their study was motivated by the observation, from satellite laser ranging (SLR), that the Earth's dynamic oblateness J_2 has suddenly, around 1998, changed its decreasing trend, mainly attributed to postglacial rebound, to an almost equally large increasing trend (Cox and Chao 2002). Changes in core flow around that same period are expected from geomagnetic observations, notably the occurrence of a major geomagnetic jerk, or sudden change in the trend of the geomagnetic secular variation, in 1999 (Mandea et al. 2000). The results of the geodynamo models, however, indicate that these core flow changes can, depending on model assumptions, only account for about one tenth of the observed J_2 change. Greiner-Mai and Barthelmes (2001) estimated degree two gravity field variations for their model of relative inner core rotation to be of the order of 10^{-10} to 10^{-12}, with variations of the order of 10^{-12} yr^{-1}. These variations could possibly be measured by the GRACE mission and can then give information on core dynamics.

4 Modeling core-mantle interaction and interpretation of decadal length-of-day variations

Jault et al. (1988) first provided geomagnetic observational evidences for explaining LOD variations on decadal time scales with changes of the core axial angular momentum and concluded that the LOD variation on decadal time scales arise from the exchange of the axial angular momentum between the Earth's core and the solid mantle. Their conclusion is further supported by the following results from Jackson et al. (1993), and Holme and Whaler (2001). These observational evidences therefore demand a fundamental physical interpretation: what is (are) the mechanism(s) responsible for the core-mantle angular momentum exchange? Considering that the observed decadal LOD variation $\Delta\text{LOD} \approx 2$ ms/decade, the required net torque $\Gamma_{\text{net}} \approx 5 \times 10^{17}$ Nm. Therefore the fundamental question is then what core-mantle coupling mechanism(s) can produce the required net torque.

Understanding the physics is very important in several accounts: first of all, it could provide a reasonable explanation for the geodetic observations, thus helping identifying contributions of various solid Earth physics processes on observed LOD variation. In return, the observational results could provide insight and constraints on dynamical processes in the core that can only be partially and indirectly detected. More significantly, this can lead to multi-disciplinary collaboration among geodesy, geomagnetism and geodynamo fields on the Earth's deep interior.

In general, there are four core-mantle coupling mechanisms: electromagnetic, topographic, gravitational and viscous core-mantle interactions. While the molecular kinematic core fluid viscosity ν is in general very small ($\nu \approx 10^{-6}$ m^2/s), and therefore the estimated viscous torque is more than an order of magnitude smaller than the required torque, the three other coupling mechanisms have been proposed separately to be the dominant core-mantle coupling for the core-mantle angular momentum exchange (e.g. Kuang and Chao, 2002a). Regardless, they depend on dynamical processes in the outer core, and on the mechanical and electrical properties in the mantle. For example, electrical conductivity of the lower mantle (e.g. D"-layer) is critical for the "traditional" electromagnetic core-mantle coupling that depends on the current density in the electrically conducting mantle (e.g. Bullard et al., 1950). On the other hand, topographic coupling arises from nonhydrostatic pressure in the core on heterogeneous core-mantle boundary (CMB) topography (Hide, 1969). Gravitational couplings arise from interaction between heterogeneous gravity fields of the mantle and the outer core (Jault et al., 1988), or of the mantle and the inner core (Buffett, 1996).

However, most of the studies on the core-mantle couplings have been focused on a single dominant coupling mechanism: evaluating the coupling torque from geomagnetic observations and a series of assumptions on force balances in the core (e.g. Stix and Roberts, 1984; Jault and Lemouël, 1989; Hide etal, 1993; Love and Bloxham, 1994; Holme, 1998). There are two potential problems in these studies. The first one is that all calculations are kinematic in nature, which could result in erroneous torque estimation due to dynamical inconsistencies (e.g. Kuang and Chao, 2002a). The other is that it could be misleading to identify one dominant core-mantle coupling mechanism responsible for the decadal LOD variation.

The kinematic studies can be summarized as follows. The poloidal part of the geomagnetic field $\vec{B}_P$ and its time variation can be observed at the surface of the Earth, and can be continued downward to the CMB by assuming the mantle is a good electrical insulator (good for much of the mantle). Assuming further that magnetic dissipation in the core is not important on decadal time scales ("frozen-flux" approximation), and that core flow is tangentially geostrophic, one could obtain the fluid flow $\vec{v}_H$ and the pressure p beneath the CMB. In addition, if the D"-layer is electrically conducting, one could then obtain the portion of the toroidal field $\vec{B}_{TA}$ in the layer advected from the $\vec{B}_P$ in the core via the core flow $\vec{v}_H$. Therefore, one could then evaluate the topographic torque given the CMB topography, or the electromagnetic torque given the electrical conductivity of the D"-layer.

The dynamic inconsistencies of above studies are apparent. For example, the core fluid flow $\vec{v}_H$ should be adjusted to the CMB topography in order to obtain the appropriate topographic coupling torque. The question is then whether such small adjustment is critical for correct torque evaluation. In kinematic studies, it can not be answered because this small adjustment could not be resolved from observations, due to both measurement errors and poor knowledge on the CMB topography.

On the other hand, the toroidal field $\vec{B}_T$ in the core can also be diffused into an electrically conducting D"-layer. This "leakage" toroidal field $\vec{B}_{TD}$ is ignored in the kinematic studies because $\vec{B}_T$ is simply not observable. One is certainly aware that $\vec{B}_{TD}$ depends on the electrical conductivity of the D"-layer. Therefore, its importance on evaluating electromagnetic coupling torque directly affects the assumptions on the properties of the lower mantle. The gravitational coupling torque could not be evaluated from any observations because density anomaly in the fluid core is not detectable [Though recent time-varying gravity observations (Cox and Chao, 2002a) could include some information on the core density anomaly, it still can not be used for the torque evaluation].

To assess the impact of these dynamical inconsistencies on coupling torques, one must find a different approach that could combine core-mantle coupling and core dynamics studies. Currently, the most promising approach is to use numerical models on core dynamics to the core-mantle interactions, as is demonstrated by recent results of Buffett and Glatzmaier (2000) on gravitational coupling via inner core-mantle locking, and of Kuang and Chao (2001) on topographic coupling.

In particular, Kuang and Chao (2001, 2002a) used their dynamo solutions on electromagnetic and topographic couplings. Their solutions, which are dynamically consistent, are very different from those of kinematic results, primarily due to the dynamic inconsistencies in kinematic studies. For example, the consistency of the core flow to the CMB topography is critical for the coupling torque. Though the core flow is only perturbed by a small topography (with typical amplitude of several kilometers, compared to the CMB mean radius of 3500 km), numerical solutions demonstrate that it is this perturbation that contributes to the most of the coupling torque. This is very different from previous suggestions in the kinematic studies that such perturbation is not important in evaluating topographic torque. A direct consequence of these new results is that given the CMB topography, the coupling torque is much smaller than that from kinematic analysis. Therefore Kuang and Chao (2001) concluded that unless the CMB topography amplitude is at least on the order of 3 km, the resulting torque is too small for the decadal core-mantle angular momentum exchange.

In addition, Kuang and Chao (2002a) examined the effect of the "leakage" toroidal field $\vec{B}_{TD}$ in electromagnetic core-mantle coupling. They found that when the conductivity of the D"-layer is close to that of the core fluid (e.g. about one order of magnitude smaller), this part of the field is comparable to the "advected" toroidal field $\vec{B}_{TA}$, in both magnitude and time-varying frequency. This suggests that the offset between the full electromagnetic torque and that from the kinematic studies can be significant when a thin and highly conducting D"-layer is assumed. A more detailed analysis of their results indicates that contributions from both parts of the field can either negate or enhance each other during numerical simulation, raising the concern on the true net electromagnetic coupling torque in the Earth's core, and proper assumptions on the D"-layer structures. It should also be pointed out that the magnetic torque is estimated to be 50% of the net torque required for the decadal LOD variation.

All these numerical modeling results indicate that it is unlikely that a single coupling mechanism dominates for the decadal LOD variation. Not only several mechanisms are capable of producing a significant portion of the required torque, they influence each other in very complicated ways. For example, a finite CMB topography shall introduce electromagnetic heterogeneity in the D"-layer, thus affecting electromagnetic core-mantle interaction. On the other hand, the inner core/mantle locking mechanism (Buffett) depends on the electromagnetic coupling across the inner core boundary (ICB), as well as on density anomalies in the outer core (that change the gravitational force on the inner core). Furthermore, density anomalies in the outer core may also contribute significantly to the overall core-mantle coupling. All these suggest that our near future research should include efforts of investigating multiple core-mantle coupling mechanisms simultaneously in numerical core-dynamics modeling.

5 Present status of the SBC

The SBC has about twenty members from the fields of geomagnetism, Earth rotation, geodynamo modeling (numerical and experimental), and gravimetry. In contrast to other geophysical flows such as the atmosphere and the oceans, the geophysical fluid under study for the SBC, the fluid outer core, can not be observed directly. This constitutes a problem, observational data on the core is limited and the calculation of various core effects is necessarily based on modelisations, but also an advantage, a lot is to be learnt about the core from studying observational data that is influenced indirectly by the core. The data on core flow are derived mainly from geomagnetism. This information is only indirect because the mantle and crust, between the observer and the core, influence the magnetic observations and partly hide the core field. One of the tasks of the SBC then is to keep contact with, e.g., the geomagnetism and geodynamo community.

The SBC promotes and stimulates research on core dynamics. As a first step in achieving this goal, the SBC has created a website (www.astro.oma.be/SBC/main.html). Because of the multidisciplinary nature of our activities, we give there a description of the relevant theories and information necessary to understand and use the data. Subjects treated include: core convection, core flow, geomagnetism, CMB torques, inner core differential rotation, Earth's rotation changes due to the core, and core composition. Additionally, we have built a bibliography of articles relevant to the core that presently contains more than a thousand references.

The SBC collects and makes available relevant data for studies of core dynamics. The data we want to provide include (1) the observed magnetic field and its secular variation, (2) CMB topography derived from seismology or from steady-state convection computation, (3) core flows and angular momentum derived from computations constrained by the observed surface magnetic field and its secular variation, (4) angular momentum derived from LOD data, (5) core flows and angular momentum derived from both LOD variations and surface magnetic field data, (6) core flows and angular momentum from geodynamo modeling, (7) data on core-mantle torques, including viscosity, magnetic fields and core topography (8) data on inner core motion and structure.

The data on angular momentum can already be downloaded directly from the SBC website, for the other data, some web links are provided but most data must still be collected. To be able to make full use of the data, they are documented. In particular, the hypotheses used in the computations are described. Further, a special form for scientists wishing to provide data has been prepared and put on the web site.

Nine series of core angular momentum (CAM) data are at present available on the SBC website:

- Jackson's three different CAM series based on torsional oscillations using the hypothesis of fully time-dependent geostrophic flow and the surface magnetic field UFM1 model of Bloxham and Jackson (1992) (for three different smoothings, see Jackson 1997);

- Petrov's three different CAM series based on torsional oscillations using (a) the IGMF surface magnetic field and the geostrophic flow approximation, (b) the surface magnetic field and the quasi-steady flow approximation, and (c) the LOD observation, the surface magnetic field and the geostrophic flow approximation (Petrov and Dehant, EGS 2000 abstract);

- Jault's CAM based on the torsional oscillations using the tangential geostrophic flow and the surface magnetic field (Jault et al. 1988);

- Pais' CAM based on the torsional oscillations using the tangential geostrophic flow and the surface magnetic field UFM1 model of Bloxham and Jackson (1992), see Pais and Hulot (2000);

- Boggs' core angular momentum (CAM) based on the torsional oscillations using the tangential geostrophic flow and the surface magnetic field UFM1 of Bloxham and Jackson (1992), see Hide et al. (2000).

The various model LOD data are given in Fig. 1.

An AGU monograph, entitled "Earth's Core: dynamics, structure, rotation" has been prepared by V. Dehant, K. Creager, S. Karato, and S. Zatman (editors), and published in December 2002.

6 Future steps and recommendations

After the initial phase of setting up the website and gathering data, we plan to revise and update the website and to add some new features. In particular, main and new references will be added to the science overview parts of the website. This will be flexible as new references can easily be introduced without the need to revise the concise explanatory texts. To make new results and methods easily available, we will add a section with recent news and highlights. To be able to do that, it would of course be very much appreciated if people would keep us informed of new papers relevant to the SBC. To aid scientists who work or intend to work in core-related studies, an extensive bibliography will be maintained on the SBC website, which is presently ordered alphabetically by first author, and it will be studied whether it would be useful and possible to additionally make a division by content (e.g. by topics from the science overview).

Providing reliable data and methods is one of the main tasks of the SBC. In particular, we plan to include all kinds of data that are needed to calculate the effects of the core on LOD variations, nutation, polar motion, surface gravity changes, geocenter variations, and surface deformations. At present, only data on polar core angular momentum in the form of LOD variations at one (or more) year interval are available on the SBC website. More extensive data sets are clearly needed. For LOD studies, data on torsional oscillations must be made available. But also data on other components of the core flow, and of core angular momentum in all directions is needed. To better understand the core-mantle coupling, data relevant to the different coupling mechanisms are important, such as data on top core flow with high resolution, data on the CMB topography, data on the lower mantle conductance, and data on magnetic field strengths. In this sense, data from geodynamo modeling seem very interesting. In addition, we plan to add data on the inner core (relative motion, magnetic field strength, ICB topography,...). It is recommended that the members of the SBC make these data available, and actively stimulate others to do so. We plan to test and validate the data by intercomparison and hypothesis testing to be able to provide reliable data sets.

One of the goals of the SBC is to make the geophysical community aware of the various geodetic effects that could be linked with the core and to stimulate research in this field. It is important to bring together different groups with expertise in different aspects of the relevant topics, so that, by sharing expertise and working together, the whole group can achieve more than the sum of their individual contributions. At the joint EGS-AGU-EUG meeting in Nice in April 2003, a session will be organized on "Earth Rotation and Polar Wander: Internal Processes", and we also foresee a business meeting at that occasion with the SBC members to dicuss future activities. The adaptation of our website as described above is foreseen for that period. The following items could be discussed: which data should be made available, which formats should be used, would it be interesting or needed to distribute software, what is the usefulness of the present services, which new activities need te be undertaken,...

Our work and our web site can only be up-to-date if sufficient interactions exist with the scientific community related to the Earth's rotation and to the Earth's core. Any constructive comment or information is welcome. Our web-master, Lydia Van Camp, will receive them with great pleasure (lydia.vancamp@oma.be). You may of course also contact one of the SBC team members.

Current and future projects look very promising. Satellite mission like Oersted and CHAMP provide high-quality vector magnetic field data. We thus obtain a better resolution of the magnetic field, which will in turn lead to improved models of core flow. It is also likely that the secular variation can be obtained at spherical harmonic degrees higher than 13. The lithosperic field dominates at these high degrees, but as this field is believed to vary very slowly in time, the time variations of the high degree geomagnetic field can be used to probe the Earth's core. Several missions, such as CHAMP, GRACE and GOCE, will also (and already do) improve the resolution and precision of the gravity field to an extent that core processes can be detected. In the coming years, we can therefore expect significant new insight in core dynamics and an improved understanding of variations in Earth orientation and gravity field.

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