Research overview 2010

http://geo.mff.cuni.cz/documents/research_10.pdf
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Department of Geophysics, belonging to the Faculty of Mathematics and Physics, Charles University in Prague, has its roots seated as deep as in the 20's of the last century. Its structure and priorities have evolved from nearly pure seismology and geomagnetism to the present-day broad scope covering nearly all main branches of the physics of the Earth and, most recently, comprising also planetary aspects. Research is tightly coupled with education at the bachelor, master and doctoral levels. In 2009, there were 20 staff members at the department (counting permanent, temporary and part-time positions), and 21 PhD students (15 of them supervised by the staff members).

In 2010 the Department participated in the EC project C2C (2007-2011): *Crust to Core: the Fate of Subducted Material*, is a pan-European Marie Curie Research Training Network specialized in the fate of subducting material. Research project SW3D, *Seismic Waves in Complex 3-D Structures*, coordinated at the Department of Geophysics since 1993, has continued successfully in 2010. The project has been supported by 5 companies or research institutes (BP America Inc., U.S.A.; Chevron U.S.A. Inc., U.S.A.; NORSAR, Norway; Petrobras, Brazil; Schlumberger Cambridge Research Limited, U.K.) in the framework of the international SW3D consortium. The project commisioned by ESA which aims to develop and test the Swarm Level 2 processing facility started in October 2010. The Charles University, as a member of the SMART consortium, is providing support in development of the time-domain chain for inversion of Swarm data in terms of 3-D mantle conductivity.

Seismic station PRA (created in Prague in 1924), equipped with CMG-3T, is linked with the international data center ORFEUS to provide on-line data transfer to Utrecht. Joint project of the Charles University in Prague and the University in Patras, initiated in 1997, has successfully continued. Current configuration of the jointly operated seismic stations is as follows: SERG (Sergoula), LTK (Loutraki), PYL (Pylos), PDO (Prodromos), ZKS (Zakynthos), ANX (Ano Chora). For details, see http://seismo.geology.upatras.gr/heliplots/ One station EXG (Ithaki) is under reconstruction. Each site is equipped with a pair of the broad-band and strong-motion instruments. All instruments are of Guralp manufacturer, except ZKS (Nanometrics). Main achievement of the year 2010 has been the continuous real-time data transmission of the all broad-band channels to the Patras hub. As such, the stations became a part of the Hellenic Unified Seismic Network (HUSN), with data sharing by three universities (Athens, Thessaloniki and Patras) and the National Observatory of Athens. The participating institutions in Greece make everyday use of the stations in their earthquake locations. Moreover, the broadband waveforms are used to routinely invert moment tensors at the University of Patras and report them to EMSC. Software ISOLA, continually upgraded (http://seismo.geology.upatras.gr/isola/), is used for this purpose. Consultations to many external users of the software are provided, too. The department also participated in operation of the borehole (60 m deep) broadband CMG-3TD station GOPC located at the Geodetic observatory Pecny (GOPE).

Operation of all these stations is partly supported by the project CzechGeo/EPOS, see http://czechgeo.cz . Within this project the department operates also the CzechGeo/EPOS Seismological Software Centre, see http://epos-eu.cz/ssc.

The Department co-organized the Second International Workshop on Rotational Seismology and Engineering Applications, Oct 10-13, 2010, in Prague. This workshop was one of the activities of the International Working Group on Rotational Seismology (IWGoRS, http://www.rotational-seismology.org/), inaugurated during the 2006 Fall Meeting of the American Geophysical Union in San Francisco. The purpose of the International Working Group on Rotational Seismology (IWGoRS) is to promote investigations of all aspects of rotational motions in seismology and their implications for related fields such as, earthquake engineering, geodesy, strong-motion seismology, tectonics, etc. The workshop was co-ordinated by Johana Brokešová (Charles University, Prague), and Heiner Igel (Ludwig-Maximilian University Muenchen) and attended by 50 participants form Europe, United States, Russia, China, Taiwan, etc. The Procceedings of the Workshop will be published as a special issue of the Journal of Seismology.

The C2C geodynamic workshop was organised in Marianske Lazne in mid-November. It was attended by scientists from Trondheim, Bayreuth, London and Prague nodes, involved in this Marie-Curie Research Training Network, and several invited scientists outside the C2C network. The focus of the meeting was the numerical modeling of convection applied to subduction process, seismic imaging of the subducted lithosphere, transport properties of the lower mantle material and gravitational signature of the subducted material. The C2C project further supported the lectures of Prof. Shun-Ichiro Karato from the Yale University, Prof. Tomo Katsura from BGI Bayreuth and Dr. Javier Quinteros from GFZ Berlin within the seminar of the geodynamic group.

International conference *Seismic waves in laterally inhomogeneous media 7* was organized by Ivan Pšenčík (Geophysical Institute of the Czech Academy of Sciences and SW3D consortium) and Petr Bulant, June 21-26, in Teplá Premonstratensian Monastery, see http://sw3d.cz/swlim/index.htm.

The Editors or Associated Editors of international journals have been Vlastislav Červený (*Russian Geology and Geophysics*), Luděk Klimeš (*Journal of Seismic Exploration*), Ctirad Matyska (*Journal of Geophysical Research – Solid Earth; Studia Geophysica et Geodaetica*) and Jiří Zahradník (*Journal of Seismology*). Ctirad Matyska has been the member of the editorial board of the journal *Pokroky matematiky, fyziky a astronomie*, which is devoted to popularization of mathematics, physics, astronomy and education in these fields.

The theses defended at the Department in 2010 included the following:
B.C.: David Einšpigel, Jakub Hromádka, Vojtěch Patočka, Jiří Vackář
M.S.: Adela Androvičová, Klára Kalousová
Ph.D.: Petr Kolínský, Ondřej Souček

The department was happy to host the long-term visitors Alexandra Guy and Nicola Tosi within the framework of the C2C project and Mohan D. Sharma as the guest of the SW3D project.

As in previous years, research at the Department was carried out in three directions: Theory of Seismic Waves, Earthquake and Structural Studies, and Geodynamics.

Theory of seismic waves (reported by L. Klimeš)

Ray theory perturbations

In 2002, L. Klimeš proposed the equations for calculating the third-order and higher-order spatial derivatives of travel time and all perturbation derivatives of travel time in smooth heterogeneous media without interfaces in his paper *Second-order and higher-order perturbations of travel time in isotropic and anisotropic media*. The missing equations for the transformation of the third-order and higher-order spatial derivatives of travel time and all perturbation derivatives of travel time at curved interfaces, promised since 2002, are derived in the new paper (Klimeš, 2010c). The transformation equations are expressed in terms of a general Hamiltonian function and are thus applicable to any Hamilton-Jacobi equation.

Paraxial ray methods and Gaussian beams in anisotropic media

Paraxial matrices are required in calculating the second-order and higher-order spatial and perturbation derivatives of travel time, and have found many other applications in the theory of wave propagation. Klimeš (2010d) presents his derivation of the already known explicit equations for transforming paraxial matrices at a general smooth curved interface between two arbitrary media. The transformation equations are expressed in terms of a general Hamiltonian function and are thus applicable to any Hamilton-Jacobi equation.

The paper by Červený and Klimeš (2010) is devoted to the second-order derivatives of travel time in heterogeneous anisotropic media. Simple transformation relations between the second derivatives of travel time in global Cartesian coordinates and in ray-centred coordinates are derived.

Two papers are devoted to the theory of Gaussian beams propagating in inhomogeneous anisotropic layered structures. In the first paper (Červený and Pšenčík, 2010), Gaussian beams are expressed in terms of the 2x2 complex-valued matrix of second derivatives of travel time in ray-centred coordinates calculated along the reference ray. In the second paper (Červený and Pšenčík 2010b), the computation of Gaussian beams in Cartesian coordinates is described. Two types of Cartesian coordinates are considered: a) the global Cartesian coordinates, b) the local Cartesian coordinates (called wavefront orthonormal coordinates).

Červený and Pšenčík (2010a) summarized the main principles of seismic ray theory for heterogeneous isotropic and anisotropic media with curved interfaces, together with paraxial ray methods and some extensions and modifications of seismic ray theory in the invited review paper *Seismic ray theory* for the *Encyclopedia of Geophysics*.

Seismic waves in anisotropic attenuating media

A very suitable approximate method for calculating the complex-valued travel time in attenuating media is the perturbation from the reference travel time calculated along real-valued reference rays to the complex-valued travel time defined by the complex-valued Hamilton-Jacobi equation. The accuracy of this approach strongly depends on the choice of the reference and perturbation Hamiltonian functions. Klimeš and Klimeš (2010) proposed a novel general method for constructing the reference and perturbation Hamiltonian functions for any given complex-valued Hamiltonian function.

Paper by Červený and Pšenčík (2010c) is devoted to the computation of attenuation angles of inhomogeneous plane waves propagating in isotropic or anisotropic viscoelastic media and to the computation of their boundary values.

Electromagnetic waves in bianisotropic media

Ray theory has been generalized to electromagnetic waves propagating in heterogeneous bianisotropic media with a real-valued symmetric constitutive tensor. The theory describing the sensitivity of waves to the structure, originally proposed for seismic waves, have then been extended to electromagnetic waves in the invited paper for the URSI 2010 International Symposium on Electromagnetic Theory in Berlin, Germany, August 16-19, 2010 (Klimeš, 2010e; 2010a).

Structural seismology

Velocity models suitable for ray tracing are usually obtained by minimizing the second-order velocity derivatives to a reasonable extent. Problems with application of this otherwise successful method to a velocity model composed of an upper part with strong velocity gradient continuously matching a nearly homogeneous bedrock are described in (Bulant, 2010).

The theory describing the sensitivity of seismic waves to the geological structure has been demonstrated in the expanded abstract (Klimeš, 2010b, 2010f) presented at the 80th Annual Meeting of Society of Exploration Geophysicists in Denver.

In the paper (Bucha, 2010a), the Kirchhoff prestack depth migration is tested in several simple anisotropic velocity models. Each velocity model consists of two homogeneous layers separated by a curved interface. The velocity models differ by the anisotropy in the upper layer.

CD-ROM with SW3D software, data and papers

Compact disk SW3D-CD-14 (Bucha and Bulant, 2010) contains the revised and updated versions of the software developed within the consortium research project *Seismic Waves in Complex 3-D Structures* (SW3D), together with input data used in various calculations. Compact disk SW3D-CD-14 also contains over 390 complete papers from journals and from the SW3D consortium research reports.

Earthquake and structural studies (reported by J. Zahradník)

Earthquake studies were focused onto source processes (including slip inversions), strong ground motion simulations and instrumental problems. Structural studies were devoted to inverting seismic surface waves for the shear-velocity profiles and revealing a possible fault zone. Operation of seismic stations in Greece has further developed.

Earthquake studies

Simultaneous inversion of hypocenters and a 1D model of the medium has been studied by Janský et al. (2010). Synthetic P- and S-wave onsets from sources that mimic microearthquakes induced by hydrofracture treatment of oil and gas reservoirs were considered. The neighborhood algorithm was used to infer the velocity model, while the grid search was employed to locate the events. The results show that the velocity model can be obtained in the case of two monitoring wells of a suitable relative position. The use of one monitoring well fails due to trade-off between the velocity model and the event locations.

The earthquake sequence of April 2006 near Zakynthos Island (Western Greece) was analysed by Serpetisdaki et al. (2010) to identify the activated fault planes. Relocation and the centroid moment tensor solution of three major M5+ events indicated sub-horizontal fault planes. Spatial distribution of 33 aftershocks and moment tensor solutions for 15 events supported the seismotectonic interpretation that the whole sequence activated a single sub-horizontal fault zone. The zone has a depth of about 13 km, and it seems to correspond to the reflector imaged by reflection and refraction measurements in the area. It is dipping slightly to the East, becoming steeper landward. The reflector has been previously interpreted as being the interplate boundary along which the western Hellenides override Africa in the presently active subduction process. Considering that the Ionian Sea is a high seismicity area, the identification of the seismic fault is significant for the seismic hazard investigation of the region.

Possible artifacts of the seismic slip inversion were investigated by Zahradník and Gallovič (2010). The main concept of seismic source tomography, i.e. the projection lines (along which the observed signals are back-projected to the fault) was extended to complete wavefields. The so-called "dynamic projection strips" (DPSs) were defined, and a method to construct the strips from waveforms was described. In this way, each individual station role in the inversion can be better understood. Synthetic models with two asperities (two unilateral and one bilateral rupture scenarios) were used as examples. They were analyzed using two independent slip inversion methods with similar results, both resulting in a biased rupture speed for all scenarios and a strong false asperity in the middle of the bilateral fault. The artifacts can be explained by the DPS analysis as a result of inherent nonuniqueness of the inverse problem due to the joint effect of the two true asperities. Removal of some slip artifacts by imposing various constraints was also discussed. The ideas were applied to the Movri Mountain earthquake in Greece, Mw6.3, June 8, 2008. Few equivalent non-smooth models, all fitting near-regional waveforms equally well, were illustrated.

Contrary to the abovementioned intuitive, physically-based approach, Gallovič and Zahradník (2011) complement the analysis of artifacts by a mathematically-based approach. Seismic slip inversion was studied by means of the singular value decomposition (SVD). As the stable part of the slip-inversion result is given in terms of a linear combination of the leading singular vectors, the performance of the inversion depends simply on how well the real slip model can be expanded into these vectors. The parallel study of the singular vectors from the individual stations and the whole network is suggested to understand how to achieve balance between over-regularized solutions (with possible slip inversion artifacts) and under-regularized solutions (vulnerable to data errors). Application to the Mw 6.3 Movri Mountain earthquake, 2008, Greece, revealed a weak indication of an asymmetric bilateral rupture. It was emphasized that even inversion methods not working explicitly with singular vectors may yield artifacts whose origin can be also often explained by the SVD technique.

The applicability of deterministic strong ground motion simulations at near-fault distances has been studied on the example of the 2004 M6 Parkfield, California, earthquake (Gallovič et al., 2010). Theoretical modeling under the assumption of a planar rupture and 1D medium shows that, as a consequence of the S-wave radiation pattern, the particle motion should be almost linear in the fault-normal (FN) direction, having fault-parallel (FP) and vertical (V) components almost zero valued. However, in practice this is not the case. We numerically investigated this puzzling effect, considering a non-planar fault, a three-dimensional (3D) heterogeneity of the medium, and the non-planar Earth's surface topography. It has been found that just the 3D velocity model is crucial to obtain realistic estimates of ground motions at near-fault distances, i.e., the crustal heterogeneity seems to better explain the observed particle motions than the detailed fault geometry or surface topography.

The scope of seismic investigations of our department has been significantly extended towards the area of development of new seismic instruments. Brokešová and Málek (2010) proposed, constructed, tested and patented a new mechanical sensor system for recording rotational seismic motions (the Rotaphone). The instrument is based on measurements of differential motions between paired sensors mounted along the perimeter of a rigid disk. The elementary sensors creating the pairs are sensitive low-frequency geophones currently used in seismic exploration to record translational motions. The main features of the new rotational seismic sensor system are flat characteristics in the wide frequency range from 1 to 200 Hz and theoretical (noise-free case) sensitivity limit of the order of 10^{-8} rad/s. Such a relatively high rotational sensitivity of the portable instrument, consisting of standard (never identical) geophones, has been obtained by a significant trick: Thanks to the fact that the calculation of the rotation rate is overdetermined, if more than one geophone pair is used for one component, the calibration can be *in situ* performed simultaneously with the measurements. Equations were derived to calculate the relative transfer functions between the paired sensors. Their application ensures that the rotation rate record from each geophone pair is exactly the same. Notable advantages of the new instrument are also small dimensions, portability, easy installation and operation in the field. An important feature of the instrument is that it provides records of translational seismic motions together with rotations, which allows many practical and research applications.

Another newly developed seismic instrument is the generator of rotational motions which has been submitted for the international patent application (PCT). The generator is anchored with its fixed part in the ground, and the mobile (rotary) part of the generator, after being activated, is stopped instantaneously by the braking mechanism; this instantaneous stopping transmits energy into the rock massif. An advantage of the generator is its relatively small dimensions and weight, which makes it easy to move in the field. The generator is designed to be used for sequentially repeated experiments, so that essentially the same pulse of rotational seismic waves is generated. The signals from repeated measurements may also be combined in the control unit in order to achieve high sensitivity by suppressing noise via stacking. Non-linear combination of signals can be applied for this purpose. The generator is intended for use in a measuring set together with the new mechanical rotational sensor system (the Rotaphone, see above).

The weak earthquakes of the West Bohemia swarm in 2008 were studied from the viewpoint of the near-field source terms. Data of two collocated instruments CMG-40T and STS-2 (Institute of Geophysics, Academy of Sciences of the Czech Republic) were used; in particular, the station Novy Kostel (NKC) was situated at a very small epicentral distance, of about 3 km. The records revealed special long-period disturbances. After removing these artifacts, the records enabled assessment of the small static displacements of the order of 10^{-5} m (Zahradník and Plešinger, 2010).

Structural studies

Shear wave velocity-depth sections were investigated in four geological units in western part of the Bohemian Massif (Kolínský et al., 2010). The seismic models were retrieved by detailed analyses of phase velocities of fundamental Love wave modes, using three earthquakes from Aegean Sea at periods above 12 seconds. New methods of the frequency-time dispersion analysis, developed in the PhD dissertation by Kolínský (2010), were employed. Undulations of the phase velocity dispersion curves were discussed as caused by frequency-varying backazimuths and the surface-wave mode coupling. Corrections for the true backazimuths were performed to partly reduce the undulations. Four sub-profiles crossing three main geological units were studied and compared with previous investigations (Moldanubian, Teplá-Barrandian, and Saxothuringian units). Special attention was devoted to the seismically active area of the Eger Rift (the Teplá-Barrandian and Saxothuringian unit contact), which significantly differs from the other units. Low upper-crust velocities suggest sedimentary and volcanic filling of the rift, while high lower-crust velocities and weak or even missing Moho implies possible upper mantle updoming.

Málek et al. (2010) recognized an active tectonic line (a fault zone) existing beneath the Vltava River valley. The idea is based on detailed analyses of the refraction measurements at the Orlík reservoir, showing that the passage of seismic waves beneath the reservoir leads to their time delays and spectral changes. Similar time delays have been also recognized in earlier data from the nearby international profile CEL09 in the places where the profile crosses the Orlik reservoir. The results are in agreement with earlier repeated levellings, carried out in 1950s and 1960s, that indicated tectonic subsidence of the valley. Existence of the narrow and shallow heterogeneity (of the order of a few hundred meters) beneath the Vltava River is important from the structural and geodynamical points of view. It is a new finding, not yet described in the current geological literature.

Earthquakes in Greece

Significant earthquakes of Greece are investigated for their source effects in a series of joint research papers (http://seis30.karlov.mff.cuni.cz/index.php). For example, new and existing methods of the slip inversion were investigated for the Mw 6.3 Movri Mountain 2008 earthquake by Zahradník and Gallovič (2010) and Gallovič and Zahradník (2011). Results of the study of the Efpalio 2010 earthquake sequence are being prepared for publication.

Geodynamics (reported by O. Čadek and Z. Martinec)

Earth's mantle dynamics

Thanks to the close cooperation between the modellers and mineral physicists involved in the C2C project (Marie-Curie Research Training Network supported by EC), recent findings in the field of rheology and material properties of subducting slabs could be tested through numerical models of the thermal convection in the Earth's mantle. The main attention was paid to the state of slabs in the lower mantle, their deformation due to the phase transition of perovskite to potsperovskite and to consequences of the material properties of the lower mantle materials for the style of mantle flow.

Čížková et al. (2010) published a study investigating the impact of low-viscosity postperovskite domains inside the core-mantle boundary region on the style of thermal convection in the lower mantle. These domains are mostly developed at the very bottom parts of subducting slabs and their positions and size are thus linked to the plate tectonics evolution of the lithosphere. Čížková et al. (2010) clearly demonstrated that the presence of postperovskite can strongly influence the transfer of the heat from the core to the mantle and speculated how much the postperovskite phase could modulate the behaviour of the Earth dynamo and its temporal changes. The role of the changable amount of postperovskite in the core-mantle boundary region in the thermal history was also studied by Benešová and Čížková.

The influence of lower mantle properties on the cooling of the Earth and the thermal state of the mantle upper boundary layer was investigated by Tosi and co-workers (Yuen et al., 2011) in terms of a 2-D Cartesian model of mantle convection. They found that the formation of the asthenosphere in the upper mantle in the vicinity of large upwellings is only possible in models where both depth-dependent thermal expansivity and conductivity are included. The constant thermal expansivity and constant thermal conductivity models fail to deliver a hot low viscous zone, resembling the asthenosphere. These findings argue for the important role played by lower-mantle material properties on the development of a plume-fed asthenosphere in the oceanic upper-mantle.

Tosi et al. (2010) studied the role of postperovskite rheology on the convective planform, heat transport and mean temperature in the Earth's mantle. Assuming a reduction in the viscosity of postperovskite by 1 to 2 orders of magnitude and using realistic values of thermal conductivity and expansivity in perovskite, they obtained strikingly long-lived thermal anomalies in the deep mantle with characteristic wavelengths corresponding to the observed ones.

New developments in mineral physics investigation of the mechanical properties of lower mantle materials motivated the Prague modellers to simulate the deformation of subducting slabs throughout the mantle (until recently, the slab models were mostly restricted to the upper 650-1000 km of the mantle). The numerical modeling of the slab deformation was focused on two main problems: (i) the role of the crust and upper mantle rheology in the decoupling of the subducting and overriding plates and shallow slab deformation and (ii) the effect of postperovskite to the stress distribution within the slabs in the lower mantle. As for the first group of models (i), we have shown that crustal viscosity and initial geometry influence the shallow slab deformation and plate velocities considerably. Also, the parameterization of the low temperature plasticity (Peierl's creep) may play an important role and influence the resulting slab morphology (shallow dip angle, buckling). In the second group of models (ii), we used the recent estimates of the postperovskite rheology and studied the stress distribution within the slabs in the lower mantle. We have shown that the low viscosity postperovskite reduces the stresses developed within the slabs in the mid-lower mantle and enhances the heat flux from the core.

Tectonophysical modeling

The cooperation of the modellers with the geological community, facilitated by the C2C project, enhanced the quality of crustal deformation models developed for convergent plate margins and former subduction zones by the CUP team. Alexandra Guy, a PhD student supported by the C2C project, and co-workers (Guy et al., 2011; Lexa et al., 2011) studied the gravity data from the Bohemian Massif and interpreted them using a broad variety of other geophysical and geological data available for this region. They suggested a structure model of the Bohemian Massif, which is consistent with the tectonic scenario proposed on the basis of plate reconstructions and, in cooperation with Petra Maierová, a PhD student at CUP, simulated the collision process at the contact of the Moldanubian region and Brunia. Alexandra Guy now applies a similar methodology to investigate the Central Asia Collision Belt.

Planetology

Marie Běhounková and co-authors proposed a new method to simulate the thermal convection in mantles of moons and planets driven by tidal dissipation and applied it to Enceladus, a small but geologically active moon of Saturn and a generic exoplanet (Běhounková et al., 2010). In the following paper (Běhounková et al., 2011), the same group of researchers studied Earth-like exoEarths tidally locked on an orbit around its star and demonstrated that, for some parameter ranges, the tidal dissipation can significantly influence the habitability of the planet.

GRACE and present-day ice-mass change

The Gravity Recovery and Climate Experiment (GRACE) provides important constraints on glacial-isostatic adjustment and present-day ice-mass change. Sasgen et al. (2010a) performed a joint inversion of GRACE gravity data from August 2002 to August 2008 and InSAR data (years of outflow measurement 1992, 1996 and 2006) to determine the mass balances of eight West Antarctic drainage basins. Depending on the GRACE errors approximately three to five combined drainage basins can be resolved by GRACE data alone. For the reduced number of four combined drainage basins, values from InSAR and GRACE agree within ±5 Gt/yr for most of the drainage basins. The GRACE total mass loss in West Antarctica is of -91.0 ± 3.5 Gt/yr (years 2002 to 2008), which is, despite being in agreement with previous GRACE estimates, by 26 Gt/yr lower than the values derived from InSAR. There is evidence that this difference arises from anomalously large accumulation within the GRACE time interval (August 2002 to August 2008) in the Amundsen Sea sector and possibly from an overestimation of ice thickness for parts of the Bellinghausen Sea sector underlying the InSAR mass-budget values.

Sasgen et al. (2010b) further used the GRACE gravity data to estimate interannual ice-mass variations along the Antarctic Peninsula (AP) and in the Amundsen Sea Sector (AS) for the years 2002 until 2009. These data correlate well ($r \approx 0.7$) with accumulation variations based on the net precipitation from the European Centre for Medium Range Weather Forecasts. Moreover, mass signals for AP and AS are anti-correlated in time ($r \approx -0.4$) and contain El Niño Southern Oscillation signatures related to the strength of the Amundsen Sea Low pressure system, that has a dominant influence on West Antarctic atmospheric moisture transports. The GRACE interannual mass variations exhibit root-mean squared amplitudes of: 16.4 ± 4.1 Gt (AP) and 28.6 ± 10.5 Gt (AS), which are significant compared to the mean annual mass loss of -110.2 ± 6.7 Gt/a in coastal West Antarctica.

Ice-Sheet dynamics

Roghozina et al. (2010) analyzed the memory of the Greenland Ice Sheet (GIS) with respect to its past states. According to ice core reconstructions, the present-day GIS reflects former climatic conditions dating back to at least 250 thousand years before the present (kyr BP). This fact must be considered when initializing an ice sheet model. The common initialization techniques are paleoclimatic simulations driven by atmospheric forcing inferred from ice-core records and steady state simulations driven by the present−day or past climatic conditions. When paleoclimatic simulations are used, the information about the past climatic conditions is partly reflected in the resulting present−day state of the GIS. However, there are several important questions that need to be clarified. First, for how long does the model remember its initial state? Second, it is generally acknowledged that, prior to 100 kyr BP, the longest Greenland ice core record (GRIP) is distorted by ice−flow irregularities. The question arises: to what extent do the uncertainties inherent in the GRIP−based forcing influence the resulting GIS? Finally, how is the modeled thermodynamic state affected by the choice of initialization technique (paleo- or steady state)? To answer these questions, a series of paleoclimatic and steady state simulations is carried out. We conclude that (i) the choice of an ice−covered initial configuration shortens the initialization simulation time to 100 kyr, (ii) the uncertainties in the GRIP−based forcing affect present−day modeled ice−surface topographies and temperatures only slightly, and (iii) the GIS forced by present−day climatic conditions is overall warmer than that resulting from a paleoclimatic simulation.

Glacial isostatic adjustment modelling

Modern modelling approaches to GIA are based on several techniques ranging from purely analytical formulations to fully numerical methods. Various European teams nowadays are independently working on the post-glacial rebound process in order to constrain the rheological profile of the mantle and the extent and chronology of the late-Pleistocene ice sheets which are prerequisites for the determination of the GIA contribution to geodetic observables. Z. Martinec contributed to the benchmark study performed within the Working Group 4 of the ESF COST Action ES0701 *Improved constraints on models of Glacial Isostatic Adjustment*. The results of the benchmark have been submitted for publication (Spada et al., 2011). Klemann and Martinec (2011) dealt with GIA contribution to geocenter motion.

Electromagnetic induction research

The oceans play a specific role in electromagnetic induction due to their relatively high conductivity and the dynamo effect of ocean currents. Observations of the ocean-induced magnetic field by the CHAMP magnetic space mission have the potential to be used as a constraint when examining ocean dynamics. This has initiated theoretical studies on the prediction of the ocean-induced magnetic field. These studies predict the poloidal magnetic field induced by the horizontal ocean-circulation flow by employing a single-layer approximation. Since the toroidal magnetic field cannot be modelled by this approximate model, Martinec and Dostal (GeoForschungsZentrum Potsdam) treated the ocean as a layer of finite thickness and modeled the toroidal magnetic field by a matrix-propagator technique with a source of electrical currents in the ocean layer. Although this primary toroidal magnetic field is not observable outside the oceans, it couples with a strong conductivity contrast between the oceans and continents and generates a secondary poloidal magnetic field. This field is observable by magnetic satellite missions and ground-based magnetic observatories situated close to the shoreline. We found that the toroidal magnetic field induced by ocean tide circulation flow is extremely sensitive to the vertical gradient of the horizontal ocean velocities. This result is promising in the respect that, if the secondary poloidal magnetic field is detected by SWARM satellite after its launch then SWARM satellite data would constrain ocean dynamics. The theory and numerical results are now being written in the form of a paper.

Seven years of CHAMP satellite data were inverted in terms of 1-D conductivity with emphasis on the deepest part of the Earth's mantle, the D'' layer (Velimský, 2010). No significant conductivity increase was observed. This can be explained (as confirmed by 3-D modelling) as a lack of interconnection of the highly conductive post-perovskite phase in the longitudinal direction, i.e., in the dominant direction of polarization of the external currents (follow-on manuscript in preparation).

A decrease of electrical conductivity with depth in the range of 1000-1500 km was observed by inversion of the same dataset, using different parameterizations, and partially confirmed also by inversion of selected observatory data. This could be the first independent geophysical confirmation of the spin transition in iron atoms in the lower mantle, hower further tests are needed to confirm this hypothesis. Preliminary results were presented by Velímský at the EM Induction Workshop, Cairo, Egypt. Velimský and co-workers have also studied the sensitivity of secular geomagnetic variation to the electrical conductivity of the lowermost mantle. The data are much more sensitive to the geometry of magnetic field at the CMB than to the particular value of electrical conductivity (presented at EGU General Assembly, Wien).

Velímský and Finlay studied the effect of highly conductive core on the separation of Dst index into the external and internal (induced) counterparts. They demonstrated that long decay times of magnetic field in the Earth's core can shift the baselines of observed induced field at the Earth's surface by small, but nevertheless observable amount.

Publications (published in 2010-11 or in press):

Běhounková M., Tobie G., Choblet G., Čadek O., 2010. Coupling mantle convection and tidal dissipation: Applications to Enceladus and Earth-like planets, *Journal of Geophysical Research - Planets*, 115 E09011.

Běhounková M., Tobie G., Choblet G., Čadek O., 2011. Tidally induced thermal runaways on extrasolar Earths: Impact on habitability, *Astrophysical Journal*, 728, article id. 89.

Brokešová, J., Málek, J., 2010. New portable sensor system for rotational seismic motion measurements. *Review of Scientific Instruments*, 81, article number 084501.

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