Major Recent Achievements

Mantle convection (O. Cadek, H. Cizkova and C. Matyska)
In the 1990s, finite-difference and spectral codes to model the thermal convection in Cartesian and spherical geometry were developed. The codes were used to study (i) effects of phase transitions on the style of mantle convection, (ii) stability of density interfaces in the mantle and (iii) to analyse the distribution of the Bullen parameter. The results of numerical simulations of mantle convection were interpreted with the aid of wavelet and fractal analyses. The geodynamical group in Prague has benefited from a close cooperation with the Minnesota Supercomputer Institute (prof. D. A. Yuen) and the Department of Theoretical Geophysics in Utrecht (Dr. A.P. van den Berg) which invited H. Cizkova to participate in the study of lithospheric subduction by using a finite element code developed at the Technical University in Delft, Netherlands.

Viscoelastic relaxation of the Earth (O. Cadek, L. Hanyk, Z. Martinec and C. Matyska)
A new method to model the viscoelasic relaxation of the Earth was developed and tested in co-operation with Prof. D. A. Yuen from the Minnesota Supercomputer Institute. In contrast to the previous methods which were based on application of the Laplace transform, the new technique solves the appropriate equations directly in the time domain and allows the complex viscosity profiles with continuous depth variations in viscosity to be investigated. The new method provides a deep insight into the physics of the problem (determination of unstable modes in a compressible Earth) and simplifies the analysis of numerical error. The method, originally designed for 1D viscosity structures, was generalised to a fully 3D viscosity case by Prof. Martinec in co-operation with Prof. Wolf and his team at the GFZ in Potsdam, Germany. The general code was used to test the effects of lateral variations of the lithospheric thickness on prediction of the sea-level changes. This study was carried out in the framework of the Czech-French project "Barrande" co-ordinated in France by Dr. Fleitout (ENS, Paris). During the minisymposium on postglacial rebound organised in Prague in October 2001, an international working group was established with the aim to study the effects of realistic mantle rheologies. The group includes the researchers from the GFZ in Potsdam, Germany (Prof. Wolf and co-workers), the Italian researchers around Prof. Spada (University of Urbino), and Dr. Fleitout from the ENS in Paris. Informal contacts are also maintained with Dr. Kaufmann from the University of Göttingen, Germany. At present, a benchmark is organised with the aim to compare the software for 3D viscosity calculations used by individual members of the working group.

Dynamical geoid modelling (O. Cadek, H. Cizkova)
The research has been carried out in a close cooperation with the French group (L. Fleitout and C. Froidevaux, ENS Paris, and Y. Ricard, ENS Lyon) which pioneered this type of modelling in the 1980s. In co-operation with Dr. Ricard a method to predict the dynamical response of a non-Newtonian mantle was developed at the beginning of the 1990s. In recent years, attention has been focused on the following problems: (i) incorporating a semipermeable behaviour of the interface between the upper and lower mantles, (ii) testing the effects of lateral variations of the lithospheric thickness on the geoid prediction, and (iii) testing various boundary conditions at the surface (free slip vs. plate velocity boundary condition) and at the core-mantle boundary (free slip vs. no slip). The research was carried out in the framework of the Czech-French programme "Barrande" and its scientific aspects were co-ordinated by Dr. L. Fleitout (ENS Paris). The main output of the project was a model of lateral viscosity variations in the asthenosphere and the core-mantle boundary region which explained 70 % of the observed long-wavelength free-air gravity and 95 % of the geoid. Besides this activity, H. Cizkova participated in the project of interpreting the gravity field observed over the subduction zones, organised by the Department of Theoretical Geophysics at the University of Utrecht, Netherlands, and O. Cadek co-operated with Dr. A. van den Berg from the same institution on inverting the dynamical geoid for determining the activation parameters of mantle creep.

Temporal changes of the Earth's gravity field (Z. Martinec)
The geodetic boundary-value problems were solved. We particularly discussed the effect of planar and spherical terrain models, the ellipsoidal model of the geoid, and the precise geoid determination. The satellite gradiometric mission GOCE (to be launched in 2004) motivated us to solve the spherical gradiometric boundary-value problems to find the external Earth's gravitational potential.

Theory of seismic wave propagation (J. Brokesova, P. Bulant, V. Cerveny and L. Klimes; external collaborators I. Psencik and V. Vavrycuk)
The research focuses on high-frequency asymptotic methods for seismic waves in 3D heterogeneous, dissipative, anisotropic media (ray method, paraxial ray method, method of Gaussian beams and packets, and their combinations with other methods). Attention has been devoted also to involving shear waves, converted waves, thin layers and sources close to discontinuities. Many new algorithms for two-point ray tracing in 3D media have been developed. Lyapunov exponents, describing the ray chaos due to complex heterogeneities in the velocity model, have been applied. The resolution of seismic inversion techniques has been theoretically studied. The linear paraxial approximation of the polarisation vectors has been derived. Fermat's variational principle for anisotropic inhomogeneous media and its relation to the Finslerian metric and Hamiltonian have been studied. Explicit equations for approximate linearised reflection/transmission coefficients at interfaces separating anisotropic media have been derived. Various kinds of the coupling ray theory for weakly anisotropic models have been developed. A new algorithm to optimise the shape of Gaussian beams and packets for prestack migrations in complex models have been designed. Major oil companies, centres and universities have sponsored every year this research within an international consortium on "Seismic Waves in Complex 3D Structures (SW3D)", since 1993 till present. For example: Shell, Amerada Hess, Chevron, Landmark, Petrobras, NORSAR.

Structural seismic studies (J. Jansky and O. Novotny)
The lithospheric structure in Europe has been studied by using surface waves along the profile Prague-Warsaw in co-operation with the Moscow State University (Prof. T.A. Proskuryakova, Dr. A. Shilov) and along the profile Prague-Uppsala in co-operation with the University of Uppsala (Dr. C.-E. Lund) and the University of Warsaw (Prof. M. Grad). The crustal structure in western parts of the Bohemian Massif, Western Carpathians and Greece has been investigated, too. The Fresnel volumes of PKP waves have been used for estimating resolution power of tomographic images of the Earth's core. For purposes of the improved magnitude estimation, P and PKP waves have been simulated by WKBJ and ray methods in global Earth models (co-operation with Prof. S. Duda, University of Hamburg).

Numerical finite-difference simulations of seismic waves (I. Oprsal and J. Zahradnik)
Cost-efficient codes based on spatially irregular 2D (and recently also 3D) grids were developed, concentrating mainly on non-planar discontinuities, large velocity contrasts, and non-planar free surfaces (NATO Linkage Grant "Improving assessment of Seismic Site Effects at Underground Nuclear Waste Storages" co-ordinated by Prof. F. Hron, University of Alberta, Canada). The finite-difference and ray methods have been applied to special problems of shallow reflection investigation of lignite deposits in Greece within a NATO Science for Stability programme (GR-COAL project co-ordinated by Prof. G-A. Tselentis, University of Patras, Greece). Hybrid methods, combining the discrete wavenumber treatment of the source and path effects, and the finite-difference treatment of the site effects have been developed. Their practical application has comprised the Tiber valley in Rome, and the EUROSEISTEST near Thessaloniki within an Inco-Copernicus EC project (ISMOD project co-ordinated by Prof. P.-Y. Bard, J. Fourier University, France). The Department has actively participated in three IASPEI/IAEE international project aimed at modelling site efftects at Turkey Flat in California, Ashigara Valley in Japan, and Kobe, Japan.

Observation and modelling of earthquakes in Greece (J. Jansky, V. Plicka and J. Zahradnik)
Since 1997, the Department has started operation of the broad-band seismic stations in the Corinth Gulf, Greece, in co-operation with the University of Patras (Prof. G-A. Tselentis). A new method of the focal-mechanism inversion combining the amplitude spectra and polarities has been developed, ASPO. Focal mechanisms of the clustered weak events have been used to calculate the so-called Empirical Green's Tensor Derivatives. The EGTD method represents an innovation of the classical EGF method. New earthquake location algorithms have been tested and applied, such as the differential evolution, and the grid search. The methods have been applied to local events in the Corinth Gulf within an Inco-Copernicus EC project (COME project co-ordinated by Prof. G-A. Tselentis). Our broad-band observations contributed to the understanding of the damaging 1999 Athens earthquake and the 2001 Skyros Island earthquake in Greece. Since 2000 we operate also two strong-motion instruments in Corinth Gulf. A combined deterministic-stochastic method PEXT for synthesising strong motions from finite-extent sources has been developed (the 5th framework project PRESAP co-ordinated by Prof. J. McCloskey, University of Ulster).

Climate change study (T. Halenka, J. Kalvova and A. Raidl; external collaborators M. Borak and A. Farda)

In the beginning of the 1990s the impact of climate change due to green-house gases changes on the agriculture, forests, health and other sectors of economy and environment of the Czech Republic was studied under National Climate Programme of the Czech Republic, in 1993–95 with international co-ordination by US Country Study Programme. Since that, appropriate scenarios of climate change for the Czech Republic have been constructed based on the analysis of progress in results of several GCM's available to improve the estimates of the climate change impacts, resulting in several local projects funded by Ministry of Environment in last years. In one of them our team participates in preparation of regional climate model with aim to downscale results of GCM more precisely by means of dynamic methods rather than complex statistical techniques commonly used previously. In this approach previous experience with regional climate model available from ICTP, Trieste, is used, as well as the experience and co-operation of CHMI, Prague, and MeteoFrance concerning the model Aladin used as a basis for modification for regional climate modelling purposes. Moreover, our team is working in more general problems of climate change modelling as well. In 1994–95 we took part in EC 3rd framework project "Global ice sheets during the last two climatic cycles", co-ordinated by A. Berger, Catholic University of Louvain, Louvain-la-Neuve, Belgium, solving the task "Inclusion of dust into the paleoclimate simulations with 2D climate model". We have also been interested in global circulation analysis by means of PCA or wavelet transform methods, and non-linear modelling of time series.

Air-quality modelling (J. Bednar, J. Brechler, T. Halenka, students)

Since 1980 the department has been involved in the air-pollution and air-quality modelling. At the very beginning the problems of transboundary fluxes of sulphur from industrial and energy sources were computed and compared with the aircraft measurements. In the subsequent step, the ground concentrations and depositions of sulphur compounds (SO_2 and sulphates) were computed for the area of the Czech Republic. The main users of these activities were: the Research Institute of Energetics, the Czech Hydrometeorological Institute, the Czech Ministry of Industry and Trade, the consulting agency SEVEn, together with other environmental and energy institutions. In the framework of this activity our team took part in the EC 3rd Framework Programme – project EASE. Since the mid 1990s the activity has been focused on the problems of photochemical reactions modelling in the troposphere (photochemical smog modelling). The first important results were achieved in the international Czech–Japan project "Air-Pollution in Prague", financed by the ASAHI GLASS Foundation. In the framework of the COST Action 715, "Meteorology Applied to Urban Air-Pollution Problems", the air-pollution on urban scale is studied.