## Thematic Focus and Development of the Centre

### Historical background, development, dynamics

The history of meteorology and geophysics in Prague is more than 200 years long. Indeed, the continuous series of meteorological measurements have existed at the Klementinum observatory in Prague since 1775 till present. The geomagnetic measurements at Klementinum started in 1839, and the gravity measurements in the mines of Pribram town date back to 1882. The first full professor of meteorology at the Charles University, Frantisek Augustin, was appointed in 1895. The State Institute of Geophysics was founded at the Charles University in 1920 by Vaclav Laska, professor of applied mathematics. In 1924 V. Laska installed a Wiechert seismograph in Prague. Since 1927 till present, the seismic station Prague (PRA) has belonged to the international seismological network. In the first half of the 20th century the meteorological activities at the Charles University were connected with the prominent individuality of Professor Stanislav Hanzlik (specialised in the structures of cyclones and anticyclones), later followed by Professor Alois Gregor (climatology). The beginning of the scientific career of Professor Zdenek Sekera, one of the leading personalities of the 20th century in the atmospheric optics, was also connencted to the Charles University, where he had became associated professor of geophysics before he emigrated to United States in 1948. In 1952 Alois Zatopek (1907-1985) was appointed the first full professor of geophysics at the newly established Faculty of Mathematics and Physics at the Charles University. For two periods, 1962-64 and 1964-66, he was a president of the European Seismological Commission. The beginning of the numerical weather prediction methods in Prague is connected with Professor Stanislav Brandejs (1918-1975).

The scientific work of Professor Karel Pec (1930-1993) spanned a number of geophysical branches: seismology, data processing, electromagnetic induction and the gravity field. Significant contributions of K. Pec to the theory of spectral representations of geophysical fields, together with his broad interests in the Earth's mantle dynamics, formed in the 1970s and 1980s a firm base on which the geodynamics group was later created at the Faculty of Mathematics and Physics.

Probably the best known personality is Professor Vlastislav Cerveny (born in 1932), currently the Professor Emeritus, one of the "fathers" of the seismic ray theory. Head waves, ray tracing, dynamic ray tracing, ray-synthetic seismograms, paraxial approximations, and Gaussian beams, represent just a few of his outstanding contributions to the wave propagation theory. V. Cerveny, member of the Academia Leopoldina (Germany) and Academia Europaea, honorary member of SEG, awarded by Beno Gutenberg Medal from the European Geophysical Society in 1997, holder of the Conrad Schlumberger Award from the European Association of Geoscientists & Engineers, 1999, has been not only one of the most frequently cited scientists in the Czech Republic (about 3000 records in Science Citation Index), but also one of our first EC-grant holders.

## Present research

The present image of the Centre is diversified (*http://geo.mff.cuni.cz*, *http://kmop.mff.cuni.cz*). It covers a broad range of the solid Earth and atmospheric dynamics, spanning from seismology and geodynamics to atmospheric dynamics, climate and air pollution. Listed below are the main research themes.

*High-frequency asymptotic methods*
Theory of seismic waves in 3D heterogeneous, dissipative, anisotropic media (the ray method, the paraxial ray method, the method of Gaussian beams and packets, and their combinations with other methods). New algorithms for two-point ray tracing in 3D media. Chaotic behaviour of rays due to complex heterogeneities. Theory of resolution of the seismic inversions. Reflection/transmission coefficients at interfaces separating dissipative and/or anisotropic media.

*Numerical finite-difference method*
New 2D and 3D codes on spatially irregular grids. Hybrid methods. Application in lignite exploration. Application to seismic local site effects.

*Structural seismic studies*
The lithospheric structure in Europe based on surface-waves dispersion.

*Observation and modelling of earthquakes*
Operation of broad-band and strong-motion seismic stations of the Charles University in western Greece. New earthquake location algorithms. Focal-mechanism inversion. Empirical Green's function methods (application and innovation). Finite-extent sources (forward and inverse problems), including synthesis of strong ground motions. Complex analysis of selected earthquakes (Patras 1993, Athens 1999, Skyros 2001).

*Viscoelastic relaxation of the Earth*
New methods of 3D modelling the viscoelastic response of the Earth with complex rheological structure. Application of the methods to contemporary problems in postglacial rebound and postseismic deformation. Correct implementation of the sea-level equation in postglacial rebound analysis. Role of lithospheric heterogeneities in predicting the postglacial uplift. Application of new types of data (horizontal velocity, temporal variations of gravity, etc.) in inversions for mantle viscosity. Postglacial rebound and global climate change.

*Mantle convection*
Numerical simulations of thermal convection in the mantle. Double-diffusive convection. Passive and active chemical mixing. Determining the Bullen parameter. Wavelet analysis of the predicted thermal fields. Comparison of numerical models with results of seismic tomography. Numerical modelling of subduction.

*Dynamical geoid modelling*
New methods of modelling the dynamic response of the Earth for models with complex rheology. Determining the viscosity in the mantle by inverting the geoid, seismic tomographic information, tectonophysical data and results of mineral physics experiments. Joint inversion of the geoid and postglacial rebound data. Dynamic topography: prediction and comparison with observations.

*Precise geoid modelling*
Geodetical boundary-value problems for precise geoid determination. Effect of planar and spherical terrain models. Ellipsoidal corrections in gravity and geometry space. Regularization of downward continuation of gravity anomalies.

*Mantle electrical-conductivity modelling*
Spectral harmonic analysis of global magnetic observatory data and satellite magnetic data. Integration of Maxwell’s equations both in the spectral and time domain for axisymmetric 2D models and fully 3D models of electrical conductivity.

*Atmospheric dynamics*
Energetics and circulation with applications in the field of numerical weather forecasting. Numerical methods used in meteorological models – spectral methods, finite-difference and finite-volume techniques, structured and non-structured grids, hydrostatic and non-hydrostatic approach.

*Air pollution*
Modelling of the air-pollution transport, turbulent diffusion, dry and wet deposition. Problems of air-pollution modelling in the urban scale and in complex terrain. Nesting of local-scale air-quality models to numerical weather prediction models. Chemistry of air pollution. Problem of natural emissions and their behaviour in the atmosphere.

*Climate system*
Climate modelling with emphasis on regional scale models (dynamic downscaling). Anthropogeneous effects on climate, climate changes. Scenarios of the future Earth's climate system development in case of growth of the radiation active gases concentration.

*Ozone in the Earth atmosphere*
Circulation in the stratosphere. Trends of content of the stratospheric ozone. Parametrization of ozone impact in radiation transfer. Ozone in troposphere. Parametrization of chemical reactions. Spatial distribution of ozone concentrations. Role of VOC (Volatile Organic Compounds) and biogenic emissions.

**Present education**

The above research themes are reflected in the education activity, which is permanently innovated. To illustrate the scope and specific orientation, listed below are the lecture courses offered to the MSc and PhD students (about 50 and 40 courses in geophysics and meteorology, respectively). The numbers (e.g. GEOxxx) refer to the information system of the Faculty of Mathematics and Physics. Typical duration of the lectures is expressed in teaching hours (45 minutes each), counting with 1 or 2 semesters (15 weeks each). Symbol 2/1 means 2 hours of lectures and 1 hour of exercises per week. The lectures are listed for Geophysics and Meteorology separately. Included are also (mostly optional) lectures provided by colleagues external with respect to the Faculty (Bursa, Cupal, Hladny, Holota, Janour, Kracmar, Pek, Plesinger, Psencik, Rezacova, Rudajev, Setvak, Sir, Skopec) and the Faculty members outside the MAGMA center (Bilek, Santolik, Skala).

GEO048 O. Bilek, L. Skala, L. Novotny: Seminar of quantum physics and chemistry of planets (30 hours: 0/2)
GEO032 J. Brokesova, V. Cerveny, L. Klimes: Ray methods in seismology (45 hours: 2/1)
GEO005 J. Brokesova: Fourier spectral analysis (45 hours: 2/1)
GEO049 J. Brokesova: High-frequency finite-extent source modelling (30 hours: 2/0)
GEO002 J. Brokesova: Propagation of seismic waves (45 hours: 2/1)
GEO037 M. Bursa: Satellite observations of the Earth's gravity field (30 hours: 2/0)
GEO067 O. Cadek, C. Matyska, Z. Martinec: Geodynamic seminar I (60 hours: 0/2,0/2)
GEO070 O. Cadek, C. Matyska, Z. Martinec: Geodynamic seminar II (60 hours: 0/2,0/2)
GEO072 O. Cadek: Dynamics of the mantle and the lithosphere (30 hours: 2/0)
GEO029 O. Cadek: Introduction to geophysics (30 hours: 2/0)
GEO013 O. Cadek: Inverse problem theory (60 hours: 2/2)
GEO066 H. Cizkova: Geomagnetism and geoelectricity (60 hours: 3/1)
GEO050 I. Cupal: Generation of magnetic field in planetary interiors (30 hours: 2/0)
PRF018 L. Hanyk: Computers in geophysics (30 hours: 0/2)
PRF039 L. Hanyk: Fortran 90 and parallel programming (30 hours: 0/2)
PRF017 L. Hanyk: Fortran programming (30 hours: 0/2)
GEO022 L. Hanyk: Numerical methods in Fortran (60 hours: 2/2)
GEO043 P. Holota: Mathematical methods for study of the gravitational field and figure of the Earth (30 hours: 2/0)
GEO011 J. Jansky: Practice in seismology (30 hours: 0/2)
GEO051 L. Klimes: Inversion of seismic wavefields and travel times (30 hours: 2/0)
GEO052 L. Klimes: Modelling seismic waves in 3-D (30 hours: 2/0)
GEO059 Z. Martinec: Boundary-value problems of physical geodesy (60 hours: 2/0,2/0)
GEO014 Z. Martinec: Continuum mechanics I (45 hours: 2/1)
GEO069 Z. Martinec: Continuum mechanics II (45 hours: 2/1)
GEO061 Z. Martinec: Electromagnetic induction in the Earth's mantle (30 hours: 2/0)
GEO030 Z. Martinec: Rotation of the Earth I (30 hours: 2/0)
GEO044 Z. Martinec: Rotation of the Earth II (30 hours: 2/0)
GEO057 Z. Martinec: Spectral analysis of geophysical data (90 hours: 2/1,2/1)
GEO016 C. Matyska: Constitution of the Earth (45 hours: 3/0)
GEO035 C. Matyska: Dynamics of the mantle and the lithosphere (30 hours: 2/0)
GEO015 C. Matyska: Geothermics and radioactivity of the Earth (45 hours: 2/1)
MAF001 C. Matyska: Selected chapters from partial differential equations (30 hours: 2/0)
GEO017 O. Novotny: Gravity field and figure of the Earth (45 hours: 2/1)
GEO018 O. Novotny: Matrix methods in seismology (30 hours: 2/0)
GEO021 O. Novotny: Newtonian potential in physical sciences (45 hours: 2/1)
GEO036 O. Novotny: Planets of the solar system (30 hours: 2/0)
GEO039 O. Novotny: Potential of regular bodies (30 hours: 1/1)
GEO019 O. Novotny: Review of geophysics (30 hours: 2/0)
GEO034 O. Novotny: Seismic surface waves (30 hours: 2/0)
GEO042 J. Pek: Magnetotelluric and deep geomagnetic sounding (30 hours: 2/0)
GEO041 A. Plesinger: Modern instrumental seismology (30 hours: 2/0)
GEO063 I. Psencik: Seismic body waves in inhomogeneous anisotropic media (30 hours: 2/0)
GEO045 V. Rudajev: Induced seismicity (30 hours: 2/0)
GEO006 O. Santolik: Physics of the ionosphere and magnetosphere (30 hours: 2/0)

GEO007 J. Skopec: Applied geophysics (60 hours: 2/2)
GEO031 J. Skopec: Applied geophysics - practice (30 hours: 0/2)
GEO033 J. Zahradnik: Generation of seismic waves by earthquake sources (30 hours: 2/0)
GEO028 J. Zahradnik: Numerical prediction of earthquake ground motions (30 hours: 2/0)
GEO068 J. Zahradnik: Seismic seminar I (60 hours: 0/2,0/2)
GEO071 J. Zahradnik: Seismic seminar II (60 hours: 0/2,0/2)
GEO003 J. Zahradnik: Seismology (75 hours: 3/2)

MAF013 M. Batka: Methods of numerical mathematics I (45 hours: 2/1)
MAF014 M. Batka: Methods of numerical mathematics II (45 hours: 2/1)
MET008 M. Batka: Solution of numerical prediction model equations (30 hours: 2/0)
MAF015 M. Batka: Special seminar for realization of numerical forecast models (30 hours: 2/0)
MET005 J. Bednar: Air pollution spreading in atmosphere (30 hours: 2/0)
MET001 J. Bednar: Electrical phenomena in atmosphere (30 hours: 2/0)
MET051 J. Bednar: Introduction to meteorology (45 hours: 2/1)
MET003 J. Bednar: Physics of clouds and precipitation (30 hours: 2/0)
MET026 J. Bednar: Selected chapters from atmospheric physics (45 hours: 3/0)
MET004 J. Bednar: Spreading of acoustic and electromagnetic waves in atmosphere (45 hours: 3/0)
MET033 J. Brechler, J. Sir: Synoptic interpretation of diagnostic and prognostic fields (60 hours: 2/2)
MET002 J. Brechler: Atmospheric Planetary Boundary Layer Physics (30 hours: 2/0)
MET031 J. Brechler: Mesoscale Atmospheric Processes (45 hours: 3/0)
MET007 J. Brechler: Meteorology (30 hours: 2/0)
PRF031 J. Brechler: Programming Languages and Operating Systems (60 hours: 2/2)
MET019 J. Fiala: Atmospheric Chemistry (30 hours: 2/0)
MET023 T. Halenka: Dynamic meteorology (60 hours: 3/1)
MET024 T. Halenka: Dynamical forecast methods (45 hours: 3/0)
MET053 T. Halenka: Introduction to dynamic meteorology (45 hours: 2/1)
MET021 T. Halenka: Meteorological instruments and observational methods (45 hours: 3/0)
MET029 T. Halenka: Meteorological practice (30 hours: 0/2)
MET028 J. Hladny: Hydrology (30 hours: 2/0)
MET032 Z. Janour: Atmospheric Turbulence (45 hours: 3/0)
MET050 J. Kalvova: Data treatment methods in physics (30 hours: 2/0)
MET012 J. Kalvova: General climatology (60 hours: 4/0)
MET009 J. Kalvova: Regional climatology and climate of the Czech Republic (60 hours: 4/0)
MET049 J. Kalvova: Seminar to the data treatment methods in physics (15 hours: 0/1)
MET010 J. Kalvova: Special climatological seminar (45 hours: 0/3)
MET011 J. Kalvova: Statistical methods in meteorology and climatology (45 hours: 2/1)
UFY053 J. Kopacek, O. Novotny: Meteorology and geophysics (30 hours: 2/0)
MET027 J. Kopacek, O. Zikmunda: Meteorological seminar (30 hours: 0/2)
MET013 J. Kopacek, O.Zikmunda: Analysis of weather charts I (60 hours: 1/3)
MET014 J. Kopacek, Z. Sokol: Analysis of weather charts II (60 hours: 1/3)
MET015 J. Kopacek: Aviation meteorology (30 hours: 2/0)
MET035 J. Kopacek: Synoptic meteorology I (45 hours: 3/0)
MET036 J. Kopacek: Synoptic meteorology II (30 hours: 2/0)
MET030 A. Raidl, J. Kopacek: Topical issues of meteorology (30 hours: 0/2)
MET052 A. Raidl, O. Zikmunda: Atmosperic thermodynamics (30 hours: 1/1)
MET034 A. Raidl, O. Zikmunda: Hydrodynamics (45 hours: 2/1)
MAF026 A. Raidl: Deterministic chaos (30 hours: 2/0)
MET025 A. Raidl: Wave motions and energetics of the atmosphere (45 hours: 3/0)
MET054 M. Rezacova: Mathematical modeling of cloud and precipitation processes (30 hours: 2/0)
MET020 M. Setvak, J. Kracmar: Satellite and radar observations of meteorological phenomena (60 hours: 2/2)
MET038 O. Zikmunda, J. Kopacek: Special meteorological seminar I (45 hours: 0/3)
MET039 O. Zikmunda, J. Kopacek: Special meteorological seminar II (45 hours: 0/3)