Aliasing in Gravity Field Modelling

Chair: Christian C, Tscherning

Terms of Reference

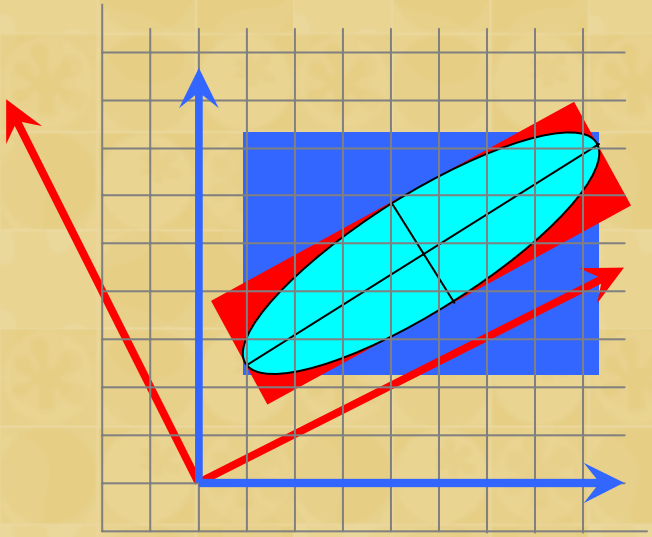
A gravity field observable contain information about all coefficients of its associated spherical harmonic series and of other signals of time-varying character. This makes numerical gravity field procedures prone to aliasing. The effect is most clearly seen when estimating spherical harmonic coefficients, but should also be present when regional models are constructed using Fourier series.
In a first phase, only the effects related to the static gravity field will be investigated. If possible, dealiasing and time-varying effects will be studied in a second phase.
The joint working group will initially through a series of controlled numerical experiments study the effect of aliasing. Simplified as well as realistic global or regional datasets will be generated using coefficients from a spherical harmonic expansion from degree N, 2*N, 3*N etc. to a maximal degree, e.g. 1800.

Final Report

Joint Working Group of the ICCT and Commission 4:

Statistics and Geometry in Mixed Integer Linear Models, with Applications to GPS and InSAR

June 2007



Statistics and Geometry in Mixed Integer Linear Problems with Applications to GPS and InSAR

Chair: Athanasios Dermanis

Joint with Commission 4

Terms of Reference

The presence of an unknown number of cycles in GPS observations of phase differences has generated a new challenging theoretical problem, which in its outmost generality may be described as the solution of over-determined equations with both real-valued and integer unknowns. Within this problem these particular issues emerge:

(a) the selection and design of an optimality criterion that leads to a unique solution;
(b) the development of computationally efficient algorithms for obtaining the optimal solution, especially with respect to the integer unknowns which require search within a discrete set;
(c) the new types of distributions of the estimated real-valued and integer parameters;
(d) particular geometry in connection with the estimated integer parameters;
(e) the assessment of the accuracy of the solution in the presence of both random and systematic errors affecting the observations;
(f) new statistical hypothesis testing techniques.

Objectives

- Attract the attention of researchers outside geodesy (statisticians, mathematicians) to this fascinating topic, with a view towards other possible applications beyond those encountered in geodesy.
- Establish a channel of cooperation on the ground of methodology and support a closer collaboration between “theoreticians“ and “practitioners”.
- Encourage frontier research in the subject concerning e.g. the evaluation–comparison of various different solution principles (e.g. least squares, Bayesian statistics, best linear estimation) as well as of the different algorithms for the realization of the solutions.

Statistics and Geometry in Mixed Integer Linear Problems with Applications to GPS and InSAR

Chair: Athanasios Dermanis

Joint with Commission 4

Membership

Athanasioss Dermanis	Greece
Mohamed Abdel-salam	Canada
Clara de Lacy	Spain
Donghyun (Don) Kim	Canada
Georgia Fotopoulos	Canada
Brigitte Gundlich	Netherlands
Hung-Kyu Lee	Australia
Kentaro Kondo	Japan
Christopher Kotsakis	Greece
Andre Lannes	France
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Linyuan Xia	China
Marcelo Santos	Canada
Burkhardt Schaffrin	USA
Sandra Verhagen	Netherlands

Statistics and Geometry in Mixed Integer Linear Problems with Applications to GPS and InSAR

Chair: Athanasios Dermanis

Joint with Commission 4

Research Highlights

Specific integer ambiguity resolution issues related to GNS/GPS technology
Specific integer ambiguity resolution issues related to synthetic aperture radar interferometry
Galileo – Modernized GPS (Three Carrier Frequencies)
Statistical Testing – Validation – Reliability - Success Rates
New Methods or Improvements and Modifications - New Solution Strategies

Theoretical Advances and Elaborations

Penalized ambiguity resolution .
Evaluation and good approximations of joint probability density function (PDFs) for ambiguity residuals
Integer aperture (IA) ambiguity estimatior (largest possible success rate given a user-defined fail rate)
Best integer equivariant (BIE) estimator (superior to the best linear unbiased estimator). Approximation and fast computation of BIE retaining the property of integer equivariance.
Integer aperture bootstrapping estimator (fail-rate controlled by the user)
Integer aperture least-squares (IALS) estimator (performance measured by its fail-rate and success-rate .
Construction of Voronoi cells (pull-in regions), fitting figures of simple shape from inside and outside. New lower and upper bounds on the probability of correct integer estimation.
Extention of least-squares collocation (trend-signal-noise type model) to integer trend parameters.
Minimum mean squared error prediction (best prediction) for models with real and/or integer parameters.

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Dynamic Theories of Deformation and Gravity Fields

Chair: Deter Wolf

Terms of Reference

Recent advances in ground-, satellite and space-geodetic techniques have detected temporal changes of deformation and gravity covering a wide period range. These changes are related to different types of processes acting near the earth's surface or in its interior.
Forward and inverse modelling of the deformation and gravity changes require the development of dynamic theories for 1-D, 2-D and 3-D earth models.

Program of activities

- Development of generalized Love-number formalisms for static forcing functions (normal and tangential surface forces, volume forces, dislocations)
- Development of generalized Love-number formalism for periodic forcing functions Fourier-transformed Love numbers) and a periodic frocing functions (Laplace-transformed Love numbers)
- Development of 3-D viscoelastic earth models for modelling processes responsible for deformation and gravity changes
- Investigation of effects due to density stratification, compressibility, rheology and lateral heterogeneity
- Forward modelling of deformation and gravity changes caused by atmospheric, cryospheric, hydrospheric and internal forcing functions
- Inverse modelling of measured deformation and gravity changes in terms of mantle viscosity and forcing functions

2 Workshops on

Deformation and Gravity Change: Indicators of Isostasy, Tectonics, Volcanism and Climate Change

1st Workshop
Casa de los Volcanes, Lanzarote,
Canary Islands, Spain
1–4 March 2005

Special Issue of
PAGEOPH 164, 633-878 (2007)

2nd Workshop
Casa de los Volcanes, Lanzarote,
Canary Islands, Spain
27–30 March 2007

Special Issue of
PAGEOPH (in preparation)

Quslity Measures, Quality Control and Quality Improvement

Chair: Hansjörg Kutterer

Joint with Commission 1 and Commission 2

General Information

- Various notions of quality in Geodesy and related fields
  - Definition for results or products
  - Relevance of underlying processes
- Industrial standards such as ISO 9000 family
  - Guide to the Expression of Uncertainty in Measurements
  - Complete evaluation and modelling of observation processes
- Situation
  - No final recommendation or convention on quality measures in Geodesy
  - Open problems in modelling such as for intra-technique combination of space-geodetic techniques
  - No process-related modelling of quality in Geodesy

Quslity Measures, Quality Control and Quality Improvement

Chair: Hansjörg Kutterer

Joint with Commission 1 and Commission 2

Advances in Modelling

- **Extensions of the stochastic model of space-geodetic techniques**
  - VLBI with estimation of variance and covariance components (MINQUE): Tesmer and Kutterer (2004)
  - GPS based on turbulence theory: Schön and Brunner (2007)
  - GPS with measured carrier-to noise density ratio: Wieser (2007a, b)
  - Statistical analysis of GPS time series: Bischoff et al. (2005, 2006): outside WG
- **Quality assessment in reference frame determination**
  - Combination procedures: Krügel and Angermann (2007)
  - Intra-technique combination including the assessment of the Operator-Software impact: Kutterer et al. (2007)
- **Neuro-Fuzzy modelling**
  - Prediction of Earth orientation parameters: Akyilmaz and Kutterer (2005)
  - TEC prediction: Akyilmaz and Arslan (2007)
  - Structural monitoring: Boehm and Kutterer (2007)

Quslity Measures, Quality Control and Quality Improvement

Chair: Hansjörg Kutterer

Joint with Commission 1 and Commission 2

Advances in Estimation and Filtering

- **Outlier identification**
  - Maximum correlation adjustment: Neitzel (2003, 2004)
  - Robust estimation: Yang (2005a, b)
  - BLIMPBE for bias control: Snow and Schaffrin (2004, 2007)
- **Total Least Squares Estimation**
  - Coordinate transformations: Schaffrin and Felus (2005, 2007), Akyilmaz (2007)

Quslity Measures, Quality Control and Quality Improvement

Chair: Hansjörg Kutterer

Joint with Commission 1 and Commission 2

Extended Uncertainty Budget

- **Fuzzy extension of parameter estimation and filtering**
  - Extended error models and extended estimators: Schön (2003), div. Schön and Kutterer
  - Kalman filtering: Neumann and Kutterer (2007)
  - GPS uncertainty budget: Schön and Kutterer (2006)
- **Fuzzy-extended hypothesis tests**
  - Extended test strategy: Kutterer and Neumann (2007)
  - Outlier detection: Neumann et al. (2006)
- **Extended GPS uncertainty budget**
  - Impact of errors in tidal loading models on GPS coordinate time series: Penna and Stewart (2003), Stewart et al. (2005), Penna et al. (2007), Stewart and Penna (2007)

Quslity Measures, Quality Control and Quality Improvement

Chair: Hansjörg Kutterer

Joint with Commission 1 and Commission 2

Conclusions and Outlook

Model refinement still a challenging task in the quality context

- Example: GPS quality
  - Refined stochastic model
  - Multipath
  - Other station effects
- Extended sensor and error models, quality of physical object models
- Rigorous distinction of different types of uncertainty needed
  - Broad selection of mathematical theories
  - Relevance for metrological issues

Extended process-related quality models are still missing

- Extended set of quality parameters: Wiltschko (2004) → outside WG
- Quality-based process optimization in Geodesy

Integrated Theory for Crustal Deformation

Chair: Kosuke Heki

Joint with Commission 1 and Commission 3

Terms of Reference

Owing to recent densification of Global Positioning System arrays in boundary zones of tectonic plates, e.g. in Japan and western North America, there are increasing demands for realistic theoretical models and computational programs incorporating recent theoretical progresses. The joint WG, with expertise in various fields of crustal deformation studies, is expected to strengthen ties between modellers and those working on various observational data of crustal deformation.

Objectives

The WG is supposed to bridge the three commissions by identifying important theoretical problems in crustal deformation studies, looking for solutions, feeding back solutions to research communities. These problems will include, surface deformation of the realistic Earth due to dislocation at depth, crustal movement due to various loads, analysis of time series including jumps and periodic components, combination of data from different techniques, finite element methods to simulate crustal activities in subduction zones, incorporation of viscoelasticity, etc.. The goal is for worldwide researchers to share the most advanced information on models and software packages for particular issues in crustal deformation studies.

Integrated Theory for Crustal Deformation

Chair: Kosuke Heki

Joint with Commission 1 and Commission 3

Activities 2003-2007

Establish standard procedures for crustal deformation studies in convergent plate boundaries

1. Models to relate fault dislocation to surface deformation
   (from simple elastic half space to the realistic earth)

2. Sophisticated technique to estimate fault slip distribution from surface deformation data
   (efficient inversion technique)

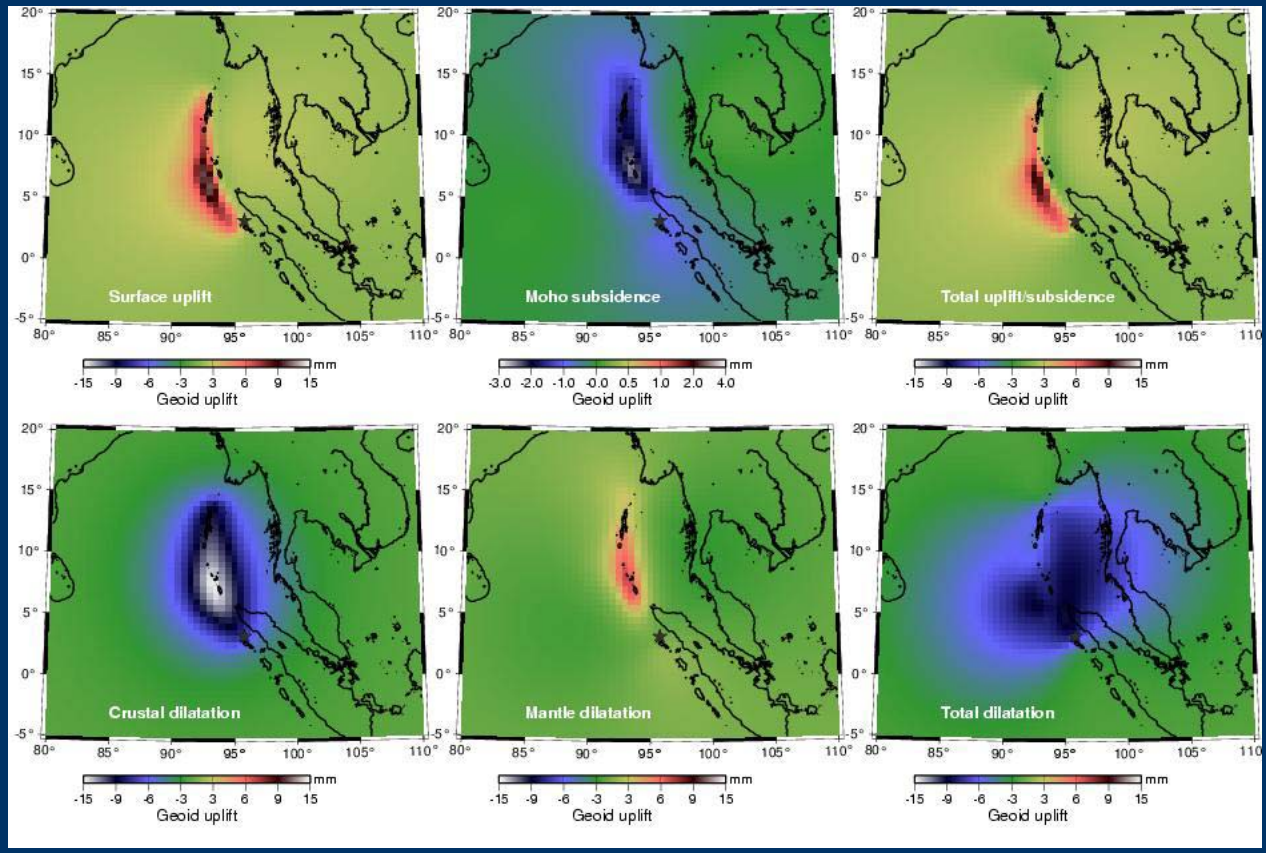
3. Sophisticated technique to separate secular, transient and periodic time variations
   (time series analysis for data with composite components)

Integrated Theory for Crustal Deformation

Chair: Kosuke Heki

Future themes of scientific interest

1. Unified model for positioning and gravimetry



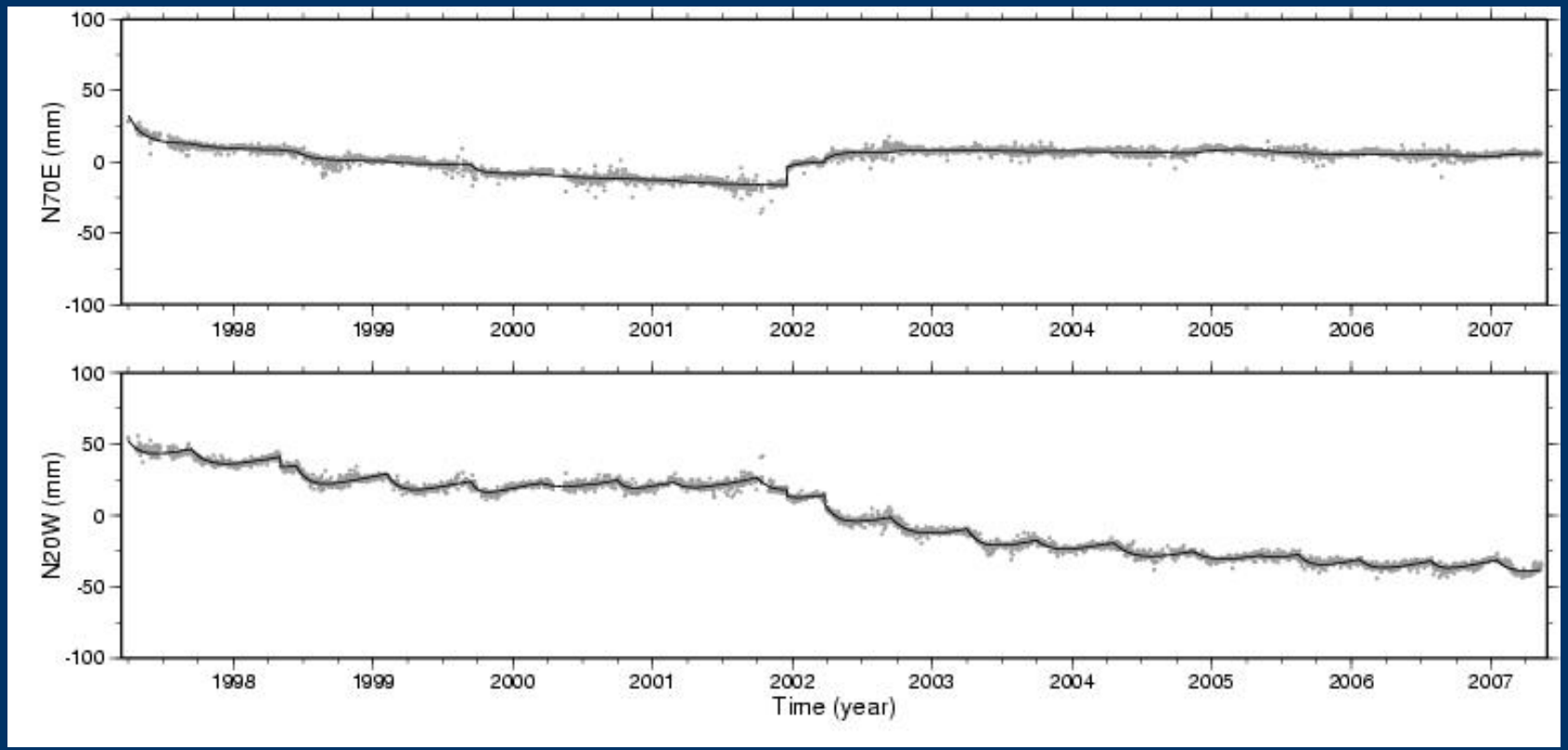
Geoid signatures by 2004 Sumatra Eq. calculated from the same subroutine (DC3D) as we use to calculate crustal deformation in GPS studies (Ogawa & Heki, GRL, 2007)

Integrated Theory for Crustal Deformation

Chair: Kosuke Heki

Future themes of scientific interest

2. Efficient way of analyzing complicated time series



Time series of horizontal position of Hateruma (Okinawa, Japan), composed of secular plate movement, coseismic jumps, and repeating slow slip events (Kataoka & Heki, in preparation).

Multiscale Modelling of the Gravity Field

Chair: Willi Freeden

Joint woith Commission 2

Introduction

During the last decades technological progress has changed completely the observational methods in all fields of geosciences with a trend to achieve immediate results, thus reducing time and costs.

A reconstruction of the gravity field from data material coming from satellite as well as airborne and terrestrial measurements requires a careful multiscale analysis of the gravity potential, fast solution techniques, and a proper stabilization of the solution by regularization. While global long wavelength modelling can be adequately done by use of spherical harmonic expansions, harmonic splines and/or wavelets are most likely candidates for medium and short-wavelength approximation.

The working group intends to bring together scientists concerned with the diverse areas of geodetically relevant wavelet theory in general and its applications. An essential field of research is the specific character of geodetic multiresolution methods used in addition or in contrary to standard spectral techniques based on spherical harmonic framework.

Objectives

Theoretical research in the field of spherical and ellipsoidal wavelets as well as wavelet introduction and modelling on geodetically relevant surfaces (like spheroid, geoid, (actual) Earth's surface).

Studies of harmonic wavelets in geodetic boundary-value problems (e.g., Runge-Walsh wavelets, layer potential wavelets, etc).

Studies on spline/wavelet kernel modelling, multiscale pyramid algorithms via kernel functions known from (least squares) collocation and spline approaches, noise cancellation, least squares adjustment and spline smoothing vs. multiscale thresholding, etc,

Development of specific numerical methods: fast wavelet transform, tree algorithms, data compression, domain decomposition techniques, fast multipole methods, panel clustering, data transmission, etc.

Comparison of spherical harmonic and/or wavelet modelling: Combined spectral and multiscale expansion of the gravitational potential, degree variances vs. local wavelet variances, spectral and/or multiscale signal to noise thresholding, etc.

Investigation of different wavelet types in geodetic pseudodifferential equations (using numerical methods such as collocation, Galerkin method, least-squares approximation, etc).

Regularization of inverse problems by multiresolution, locally reflected multiscale vs. globally reflected spectral regularization, multiscale parameter choice strategies, multiscale modelling in SST, SGG.

Multiscale Modelling of the Gravity Field

Chair: Willi Freeden

Activities

Presentations at several conferences:

– Workshop ”Inverse Problems”, Trippstadt (24.-25.11.2005) (organizers: W. Freeden ,V. Michel).
– Workshop ”Multiscale Methods in Geodesy”, Helsinki, November/December 2005.
– Fall Meeting of the American Geophysical Union (AGU) in San Francisco, December 2005.
– GAMM Annual Conference, Berlin, March 2006.
– Hotine-Marussi Symposium ”Theoretical and Computational Geodesy”,Wuhan (China), May/June 2006.
– 1st Int. Symposium of the International Gravity Field Service (IGFS), Istanbul (Turkey), Aug/Sept 2006.
– Status-Seminar ”Observation System Earth from Space”, Bonn, September 2006.
– Approximation Methods for Problems on the Sphere. DMV Annual Conference, Univ. Bonn, Sept 2006.
– GeoBerlin, Berlin, October 2006.

Multiscale Modelling of the Gravity Field

Chair: Willi Freeden

Activities

Cooperations

- Cooperation between the groups in Kaiserslauten and Munich (R. Rummel) about multiscale modelling of temporal changes of the gravitational field measured by GRACE
  (M.J. Fengler, W. Freeden, A. Kohlhaas, V. Michel, T. Peters: Journal of Geodesy, 2007, 81:5-15).

- Cooperation between the groups in Kaiserslautern) and Stuttgart (E. W. Grafarend)in form of a joint DFG-project: Inverse Multiscale Geoid Computation (IMGC).

- Cooperation between the groups in Delft (J. Kusche) and Kaiserslautern about Wavelet Modelling of satellite data and its combination with regional terrestrial data.
  (M. J. Fengler, W. Freeden, V. Michel: Geophysical Journal International, 157, 499-514, 2004;
  M. J. Fengler, W. Freeden, J. Kusche: Proceedings of the 2nd CHAMP Science Meeting,Springer, 2004, 139-144).

- Cooperation between the groups in Frankfurt (H. Schmeling) and Kaiserslautern about plume detection from gravity and topology.

- Cooperation between GeoForschungsZentrum (M. Rothacher) and Kaiserslautern about Time Variable Gravity and Surface Mass Processes: Validation, Processing andFirst Application of New Satellite Gravity Data (TIVAGAM) within the BMBF /DFG Sonderprogramm ”Geotechnologien”.

- Cooperation with University of Buchs (Switzerland).
  (W. Freeden, S. Gramsch, M. Schreiner: Preceedings VI Htine-Marussi Symposium, 2007,
  T. Fehlinger, W. Freeden, S. Gramsch, C. Mayer, D. Michel M. Schreiner: ZAMM, submitted, 2007)

- Contacts to the group of Prof. Dr. M. Vermeer in Helsinki.

Multiscale Modelling of the Gravity Field

Chair: Willi Freeden

Workshop “Inverse Problems”
24-25 November 2005,
Trippstadt / Kaiserslautern

Organized by: W. Freeden, V. Michel, J. Flury

Participants:

F. Bauer,
M. Becker
B. Büchler
M. Burger
J. Cai
D. Constantinescu
I. Einarsson
M. Fengler
J. Flury
W. Freeden
E.W. Grafarend
E. Groten
M. Grothaus
B. Heck
B. Hofmann
T. Hohage
W. Jacoby
B. Kaltenbacher
J. Keiner
A. Kohlhaas
P. Kügler
J. Kusche
P. Maaß
T. Maier
P. Mathe
C. Mayer
V. Michel
Z. Nashed
J. Prestin
S. Pereverzev
T. Peters
A. Rieder
R. Rummel
W. Rundell
U. Schäfer
E. Schock
M. Schreiner
F.J. Simons
N. Sneeuw
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P. Xu