Symposium 2a: Earth's Static Gravity Field

Organizer:	Mirko Reguzzoni (Italy)	Vice President Commission 2
Co-organizers:	Derek van Westrum (USA)	Chair Sub-Commission 2.1
	George Vergos (Greece)	Chair Sub-Commission 2.2
	Cheinway Hwang (China-Taipei)	Chair Sub-Commission 2.4e (Asia-Pacific)
	Roland Pail (Germany)	Past President Commission 2

Abstract

Local, regional and global static gravity field models of high accuracy and spatial resolution provide important information for a wide range of scientific and engineering applications. They rely on terrestrial, marine and airborne gravimetry, as well as satellite-based data, especially from dedicated space missions such as GRACE, GOCE and next-generation gravity missions, and from satellite altimetry. Crucial is also the information coming from digital topography/bathymetry models. Furthermore, modern sensors for both ground- and satellite-based systems, such as quantum gravimeters and optical clocks, will complement and support traditional gravity campaigns and networks. This wide range of measurement concepts and the larger and larger availability of data, with an increasing accuracy, requires an equally accurate investigation of the theoretical and numerical methods used for gravity modelling, including error assessment.

Static gravity field models are essential for the unification of the existing height systems around the world and the establishment of an International Height Reference System (IHRS), for inertial navigation, for oceanographic applications such as the derivation of the mean dynamic ocean topography and geostrophic ocean currents (in combination with satellite altimetry), and also for investigations on the lithospheric structures by gravity inversion or by constraining geophysical models.

Symposium 2a, Session 1. Terrestrial, Marine and Airborne Gravimetry (joint with QuGe)

Convener: Derek van Westrum, National Oceanic and Atmospheric Administration (NOAA), USA
derek.vanwestrum@noaa.gov
Co-conveners: Hartmut Wziontek, Federal Agency for Cartography and Geodesy (BKG), Germany
hartmut.wziontek@bkg.bund.de
Michel van Camp (Belgium)
Shuqing Wu (China)

Abstract
This session is dedicated to the determination of the near Earth gravity field (including gravity gradients and deflection of the vertical). It is meant to cover advancements in instrumentation, data acquisition and processing, as well as novel applications of gravity observations. New technologies like atom interferometry or micro-electro-mechanical systems (MEMS) are rapidly developing and hold the promise of fast, continuous, and highly accurate measurements, while "classic" instruments are still in wide use - both have an expanding range of capabilities and applications. The data and combined time series from absolute and relative instruments are fundamental not only to geodesy, but also to other disciplines in geosciences that rely on long term monitoring of the gravity field (tectonics, uplift, subsidence), or higher frequency measurements (hydrology, volcanology), or both.

This session solicits contributions focusing on aspects of:
- absolute or relative gravity instrumentation
- gravity gradient instrumentation
- deflection of the vertical instrumentation
- advances in acquisition techniques
- advances in processing methods
- novel applications and use of gravity field data

Keywords: gravity, gravimetry, gravity meters, absolute, relative, superconducting, quantum, gradient, deflection of the vertical, networks, comparisons

Symposium 2a, Session 2. Height Systems and Vertical Datum Unification
(joint with IAG Commission 1, ICCT, GGOS, QuGe)

Convener: Georgios S. Vergos, Aristotle University of Thessaloniki, Greece, vergos@topo.auth.gr
Co-conveners: Laura Sánchez, Technical University of Munich, Deutsches Geodätisches Forschungsinstitut (DGFI), Germany, lm.sanchez@tum.de
Christopher Kotsakis, Aristotle University of Thessaloniki, Greece, kotsaki@topo.auth.gr
Jianliang Huang, Natural Resources Canada (NRC), Canada, jianliang.huang@canada.ca
Jakob Flury, Leibniz Universität Hannover, Germany, flury@ife.uni-hannover.de
Tao Jiang (China)

Abstract
This session focuses on the unification of the existing height systems and vertical datums around the world, which can be achieved through the realization of an international vertical reference system that supports geometrical (ellipsoidal) and physical (normal, orthometric) heights with centimeter precision in a global frame. The latter enables the unification of all existing physical height systems and provides high-accuracy and long-term stability of the vertical coordinates. To guarantee a precise combination of physical and geometric parameters and to support the vertical datum unification worldwide, the IHRF network should be collocated with fundamental geodetic observatories, geometrical reference stations, reference tide gauges, local levelling networks, and gravity reference stations. In fact, the predictability of physical height changes depends drastically on the consistent integration between IHRS and ITRF, and the standardization of their respective modeling for time variable effects related to surface loading, mass-transfer processes, geocenter motion, frame scale drift, etc.. A lot of important issues of theoretical and practical significance arise in this context, which have not been yet resolved to meet the accuracy requirements of GGOS (and its scientific users) for the most stringent applications such as long-term sea level change and vertical land motion. Moreover, novel approaches for potential and height determination based on relativistic geodesy towards height system realization are becoming tangible hence offering new perspectives in the realization of vertical reference systems. Finally, definitions and realizations of local vertical datums relying on purely oceanographic, geodetic and hybrid methods, pose the problem of their combination and unification to the IHRS.

This session solicits contributions focusing on aspects of:

- Refinement of standards and conventions for the definition and realization of vertical reference systems, in particular those standards needed for the realization of the IHRS.
- Strategies for the establishment of precise vertical reference frames, in particular the establishment of the IHRF.
- Precise determination and modelling of geopotential values for the realization of IHRF network.
- Precise determination and modelling of the time-dependent changes of the vertical coordinates and the datum itself.
- Theory and methodology for height system unification, in particular the connection/transformation of existing height systems to the IHRS/IHRF.
- Recent results on vertical datum unification, including the connection of vertical datums over oceans.
- Strategies for collocation of vertical reference stations (i.e., IHRF stations) with existing reference frames (GGOS core stations, ITRF, gravity stations, existing levelling networks, etc.).
- IHRS/ITRF synergy and related open problems.
- Geometric frame effects on physical height systems.
- Development of a registry (metadata) containing the existing height systems and their connections to the IHRS/IHRF.
- Relativistic geodesy and clocks for potential determination. Impact on height system determination and realization.
- Improvements in clock performance. Novel approaches for integration with existing height determination methodologies, error treatment and assimilation.

Keywords: International Height Reference System (IHRS), International Height Reference Frame (IHRF), Vertical Datum, global unified vertical reference system, geopotential height datum, permanent tide, tide systems, time-dependent IHRS, IHRF/ITRF synergy, relativistic geodesy, precise clocks

Symposium 2a, Session 3. Local and Regional Geoid and Gravity Modelling

Convener: Cheinway Hwang, National Chiao Tung University, China-Taipei, cheinway@nctu.edu.tw
Co-conveners: Hussein Abd-Elmotaal, Minia University, Egypt, hussein.abdelmotaal@gmail.com
Wenbin Shen (China)

Abstract
A high-quality local geoid model is an important national mapping infrastructure that contributes to economical and societal improvements. There are a number of theories and numerical methods for constructing geoid models, which can be purely from measurements of functionals of the Earth's gravity field or from a mixed of such measurements and geoidal heights from GNSS measurements at leveling benchmarks with known orthometric heights. A high-resolution digital elevation model (DEM) is needed to account for the high-frequency component of a local geoid model; it may be obtained from LiDAR surveys. Measured geoidal heights and deflections of the vertical can be used to assess the geoid model accuracy. The session welcomes contributions reporting efforts for a high-quality local geoid model.

This session solicits contributions focusing on aspects of:

- geoid modeling method and data collection effort
- societal and economic impacts of a geoid model
- height modernization

Keywords: geoid, gravity, height modernization, LiDAR

Symposium 2a, Session 4. Global Gravity Field Modelling

Convener: Roland Pail, Technical University of Munich, Germany, derek.vanwestrum@noaa.gov
Co-convener: Daniel Barnes, National Geospatial-Intelligence Agency (NGA), USA, Daniel.E.Barnes@nga.mil
Xinyu Xu (China)

Abstract:
High-resolution static gravity field models encapsulate critical information for a wide range of applications, such as the realization a unified global height reference system, geophysical lithospheric modelling and gravity inversion, or inertial navigation. The development of such gravity models requires the effective combination and satellite-derived gravity information, especially from dedicated gravity missions (e.g., GRACE, GRACE-FO, GOCE, SLR), with the information contained in terrestrial, air-borne and ship-borne gravity data covering ideally the entire Earth and with uniformly high accuracy, and gravity data derived indirectly from satellite altimetry. An essential element of such model developments is the availability of global digital topographic models, which are necessary for both the processing of raw gravity observations and providing supplemental gravity information implied by the topography, over areas or bandwidth where gravity observations are unavailable or their use is spectrally restricted. An important aspect is also the error assessment and validation of global gravity solutions. The computation of very high resolution global gravity models require methodological developments regarding the optimum combination and relative weighting of various input data types, and advanced processing techniques to handle the rather formidable number of parameters (e.g., spherical harmonic coefficients) for their definition.

This session solicits contributions focusing on aspects of:

- developments of theory and methodology of combined high-resolution global gravity field models
- developments of theory and methodology for handling and use of topographic models
- demonstration of modelling results and model validation
- optimum description of error estimates associated with global model parameters
- effective parsimonious representations of global gravity model functionals and their errors
- applications of static global gravity field models

Keywords: high-resolution static global gravity models, spherical harmonics, data combination, validation

Symposium 2a, Session 5. Satellite Altimetry and Oceanography (joint with Symposium 2b)

Convener: Xiaoli Deng, University of Newcastle, Australia, xiaoli.deng@newcastle.edu.au
Co-convener: Zizhan Zhang (China)

Abstract
Satellite altimetry data have been using to successfully monitor the near global ocean surface topography, greatly improving our knowledge of oceanography, marine geodesy and geophysics, as well as their roles in climate. In this session, we are looking for the scientific and operational results in which satellite altimetry (both radar and laser) measurements, as well as complementary data sources, can be used to address the following issues: regional and global sea level changes, sea level budget, sea ice, river and lake, tides, surface currents, meso-scale circulation and variability, wind speeds and wave heights, sea states, extreme events, marine gravity field, geoid, mean sea surface, mean dynamic topography, seafloor topography, vertical height datum, and land subsidence.

This session solicits contributions focusing on aspects of:

- development for oceanic and emerging applications
- synergy of altimetry with remote sensing and gravity satellite data
- modelling of marine gravity field, mean sea surface, mean dynamic topography, tides and bathymetry
- Monitoring of sea level changes, sea-level extremes, and ocean dynamics
- Studies of multi-satellite altimeters, SAR, SAR-interferometry and SWOT altimetry

Keywords: oceanography, satellite altimetry, marine geodesy

Symposium 2a, Session 6. Gravity Inversion for Solid Earth
(joint with ICCT, Symposium 2b of IAG Commission 2)

Convener: Mirko Reguzzoni, Politecnico di Milano, Italy, mirko.reguzzoni@polimi.it
Co-conveners: Robert Tenzer, Hong Kong Polytechnic University, Hong Kong, China, robert.tenzer@polyu.edu.hk
Srinivas Bettadpur, University of Texas, Austin, USA, srinivas@csr.utexas.edu
Wenke Sun (China)

Abstract

Gravity inversion is an important tool to investigate the Earth's interior. Static gravity observations have been largely used to study the lithosphere density distribution, such as the structure of sedimentary basins or the Moho interface, as well as to retrieve information on the deeper mantle. Global gravity models from satellite gravity missions have extended these investigations on a global basis, including regions where ground data are sparse or absent (such as oceans, Antarctica, Greenland and Africa). Time-variable gravity observations provided by satellite missions, in particular GRACE and GRACE-FO, are being used to model geophysical phenomena, such as glacial isostatic adjustment, seismic events, volcanisms, and in general to infer lithospheric and mantle dynamic properties.

Since gravity inversion is intrinsically non-unique and numerically unstable, additional information is required to constrain solutions, mainly seismic data (for the static field) or GNSS-derived vertical deformations (for the time-variable field). Moreover, other geophysical, geothermal and geochemical information could be used, along with mathematical simplifications and numerical regularizations. Methodological developments for a combined processing of gravity, seismic and other data is therefore crucial for the modelling and better understanding of the Earth's inner structures and processes.

This session solicits contributions focusing on all aspects of inversion techniques and applications of static and time-variable gravity to the study of the Solid Earth:

- Theoretical and numerical algorithms for gravity and combined data inversion
- Error analysis in gravity inversion, including assessment of uncertainties in geophysical/geological assumptions
- Modelling of crust and mantle density distribution, focusing on areas with insufficient seismic data coverage (Africa, South America, Greenland and Antarctica)
- Modelling of the Moho interface at regional and global scale
- Inversion of time-variable gravity observations (collected from ground and space platforms) for the detection and modelling of geodynamic processes – methods and case studies

Keywords: Solid Earth, gravity inversion, data combination, error assessment, crust, mantle, density distribution, Moho, GIA, earthquake modelling, global tectonism, satellite gravity missions

Symposium 2a, Session 7. Topography and bathymetry gravity modelling (joint with ICCT)

Convener: René Forsberg, Technical University of Denmark, Denmark, rf@space.dtu.dk
Co-convener: Sten Claessens, Curtin University, Australia, S.Claessens@curtin.edu.au
Baogui Ke (China)

Abstract
The session invites presentations on advances in the use of elevation and bathymetry models for precise geoid determination and general gravity field modelling, as well as use of geophysical inversion techniques for estimating realistic densities and unknown sub-ice terrains in polar or glaciated areas.

Although the methodologies of use and computations of the terrain effects have been well-known since many decades, there are still major challenges in precise cm-level geoid determination, as e.g. highlighted in the recent IAG projects on the cm-geoid in mountainous areas (the Colorado intercomparison project), the ongoing efforts to redefine the heights of tall mountains (e.g. the Survey of Nepal Height of Mt Everest project), and the computation of high-resolution global models of the topographic or topographic-isostatic potential.

This session solicits contributions focusing on aspects of:

- theoretical advances in gravity forward modelling for terrain, bathymetry and ice thickness gravity field models
- terrain corrections, residual terrain models, and the cm-geoid in high mountains, coastal and offshore areas – case examples
- the role of topographic density in precise gravity field modelling
- use and estimation of sub-ice terrain effects in polar region gravity field models
- advances in high-resolution global topographic or topographic-isostatic potential modelling

Keywords: gravity forward modelling, terrain corrections, topographic potential, topography, bathymetry