

Commission 3 – Earth Rotation and Geodynamics

<http://euler.jpl.nasa.gov/IAG-C3>

President: Richard Gross (USA)

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Overview

Geodynamics is the science that studies how the Earth moves and deforms in response to forces acting on the Earth, whether they derive from outside or inside of our planet. This includes the entire range of phenomena associated with Earth rotation and Earth orientation such as polar motion, length of day, precession and nutation, the observation and understanding of which are critical to the transformation between terrestrial and celestial reference frames. It includes tidal processes such as solid Earth and ocean loading tides, and crust and mantle deformation associated with tectonic motions and isostatic adjustment.

Commission 3 studies the entire range of physical processes associated with the motion and the deformation of the solid Earth. The purpose of Commission 3 is to promote, disseminate, and, where appropriate, to help coordinate research in this broad arena.

Sub-Commission 3.1 (Earth Tides and Geodynamics) addresses the entire range of tidal phenomena including its effect on Earth rotation. Sub-Commission 3.2 (Crustal Deformation) addresses the entire range of global and regional crustal deformation including intraplate deformation, the earthquake deformation cycle, aseismic phenomena such as episodic tremor and slip, and volcanic deformation. Sub-Commission 3.3 (Earth Rotation and Geophysical Fluids) addresses the space-time variation of atmospheric pressure, seafloor pressure and the surface loads associated with the hydrological cycle, and Earth's (mainly elastic) responses to these mass redistributions. Sub-Commission 3.4 (Cryospheric Deformation) addresses the Earth's instantaneous and delayed responses to ice mass changes, including seasonal (cyclical) mass changes and progressive changes associated with climate change. This group also studies postglacial rebound at all spatial scales and the elastic deformation taking place in the near-field of existing ice sheets and glaciers. Sub-Commission 3.5 (Tectonics and Earthquake Geodesy) addresses the integration of space and terrestrial approaches for studying the kinematics and mechanics of tectonic plate boundary zones, and in particular of the Eurasian/

African/Arabian boundary zone. Joint Study Group 3.1 is concerned with the comparison of ground and space gravity measurements with geometric measurements of surface deformation. IAU/IAG Joint Working Group 3.1 is concerned with developing fully consistent theories of the Earth's rotation that will meet the current and expected future accuracy requirements of the user community.

Sub-Commission 3.1: Earth Tides and Geodynamics

Chairs: Spiros Pagiatakis (Canada), Janusz Bogusz (Poland)

Sub-Commission 3.1 addresses the entire range of Earth tidal phenomena, both on the experimental as well as on the theoretical level. Earth tide observations have a very long tradition. These observations led to the discovery of the Earth's elasticity which allows deformation and variations in Earth orientation and rotation parameters. The phenomena responsible for these variations include the full range of periodic and non-periodic phenomena such as Earth tides and ocean tidal loading, atmospheric dynamics as well as plate tectonics and intraplate deformation. The periods range from seismic normal modes over to the Earth tides and the Chandler Wobble and beyond. Thus, the time scales range from seconds to years and for the spatial scales from millimetres to continental dimensions.

17th International Symposium on Earth Tides

Sub-Commission 3.1 organizes a symposium on Earth tides that is held every 4 years or so. The 17th International Symposium on Earth Tides was held in Warsaw, Poland during 15-19 April 2013. The theme of this Earth Tides Symposium (ETS) was "Understand the Earth". The Earth Tides Symposia are evolving to include all topics of interest to Commission 3 and ETS 2013 provided an opportunity to discuss not only tidal processes such as solid Earth and ocean loading tides but also crust and mantle deformations associated with tectonic motions, glacial isostatic adjustment, as well as the entire range of phenomena related to Earth rotation. There were 70 participants at the Symposium with 82 abstracts submitted and presented in 6 sessions. The proceedings of ETS 2013 were published as a special issue of the Journal of Geodynamics (volume 80, October 2014) with more technical papers as well as the resolutions being published in BIM (Bulletin d'Information des Marées Terrestres) No. 148 which is available electronically at http://www.eas.slu.edu/GGP/BIM_Recent_Issues/.

18th International Symposium on Geodynamics and Earth Tides

Recently, the multidisciplinary approach in geodynamics research has been increasing as well as the range of temporal and spatial scales on which geodynamic phenomena can be observed by modern instrumentation and monitoring systems. In order to take this development into account, the name of the "International Symposium on Earth Tides" has been changed to "International Symposium on Geodynamics and Earth Tides" and will be organized in this form for the first time at the 18th International Symposium on Geodynamics and Earth Tides that will be held in Trieste, Italy during 5-9 June 2016. The symposium will be open for a wide range of scientific problems in geodynamics research. Interactions of geophysical fluids with Earth tides phenomena and observations will be a specific focus and includes:

- Tidal and non-tidal loading in space geodetic and subsurface observations
- Permanent and dynamic effects of Earth tides on the geodetic reference system
- Using tides and ocean tidal loading with modern geodesy to probe Earth structure
- Variations in Earth rotation, gravity field and geocenter due to mass redistributions
- Subsurface fluid movement through geodetic and gravity observation
- Fluid pressure changes due to Earth tides
- Stress and deformation changes due to injected fluids
- Earth tides, mass movements and deformation at volcanoes
- Tidal forcing of plate movement

- Tidal effects on geodetic satellites as GOCE, GRACE, ...
- Innovations in instrumentation for gravity and deformation observation
- Innovations in software, data analyses and prediction methods of loading and tides
- Induced seismicity
- Tides in planets

More information about the symposium can be found at <<http://www.lithoflex.org/g-et/>>.

Paul Melchior Medal

The Paul Melchior Medal, formerly known as the Earth Tides Commission Medal, is awarded to a scientist for her/his outstanding contribution to international cooperation in Earth tides research. It was awarded for the fifth time to Houtze Hsu (China) and presented to him on April 18, 2013 at the 17th International Symposium on Earth Tides in Warsaw, Poland. Previous recipients of the medal have been Paul Melchior (Belgium), Hans-Georg Wenzel (Germany), John Goodkind (USA), and Bernard Ducarme (Belgium) and Tadahiro Sato (Japan).

Sub-Commission 3.2: Crustal Deformation

<http://iagsc32.fgi.fi/>

Chair: Markku Poutanen (Finland)

There are many geodetic signals that can be observed and are representative of the deformation mechanisms of the Earth's crust at different spatial and temporal scales. These include the entire range of tectonic phenomena including plate tectonics, intraplate deformation, the earthquake deformation cycle, aseismic phenomena such as episodic tremor and slip, and volcanic deformation. The time scales range from seconds to years and from millimeters to continental dimension for the spatial scales.

Space geodetic measurements provide nowadays the means to observe deformation and movements of the Earth's crust at global, regional and local scales. This is a considerable contribution to global geodynamics by supplying primary constraints for modeling the planet as a whole, but also for understanding geophysical phenomena occurring at smaller scales.

Gravimetry, absolute, relative and nowadays also spaceborne, is a powerful tool providing information to the global terrestrial gravity field and its temporal variations. Superconducting gravimeters allow a continuous acquisition of the gravity signal at a given site with a precision of 10^{-10} . This is important in order to be able to detect and model environmental perturbing effects as well as the weak gravity signals associated with vertical crustal movements of the order of mm/yr. These geodetic observations together with other geophysical and geological sources of information provide the means to understand the structure, dynamics and evolution of the Earth system.

Sub-Commission 3.2 addresses the entire range of global and regional crustal deformation including intraplate deformation, the earthquake deformation cycle, aseismic phenomena such as episodic tremor and slip, and volcanic deformation. The Sub-Commission is divided into two Sub-Sub-Commissions, 3.2a on Global Crustal Deformation and 3.2b on Regional Crustal Deformation.

International Symposium on Geodesy for Earthquake and Natural Hazards

Sub-Commission 3.2 organized an International Symposium on Geodesy for Earthquake and Natural Hazards (GENAH) that was held in Matsushima, Miyagi, Japan during 22–26 July 2014. Various large-scale natural disasters, such as earthquakes, tsunamis, volcano eruptions, hurricanes, landslides, etc., repeatedly endanger human lives in many parts of the world. During the first decade of the 21st century, in spite of our developing technologies, more than 700 thousand people were killed by large earthquakes. The 2011 Tohoku earthquake and tsunami was one of those tragic events.

In order to mitigate natural hazards, monitoring changes in the Earth's lithosphere as well as the atmosphere is indispensable. Recent geodetic techniques, such as GNSS, SAR, satellite gravity missions, etc., have a significant contribution in that aspect.

In GENAH 2014, 130 researchers from 16 countries in related fields of geodesy gathered to discuss the role of geodesy in disaster mitigation and how groups with different techniques can collaborate toward such a goal. The symposium was held in Matsushima, a town on the Pacific coast of northeastern Japan that was heavily damaged by the 2011 tsunami.

The proceedings of GENAH 2014 will appear as volume 145 of the IAG Symposia series that is published by Springer. More information about GENAH 2014 can be found at <http://genah2014.jpn.org/>.

Software Comparison Campaign

Sub-Commission 3.2a is organizing a software comparison campaign to test different approaches for computing far-field coseismic deformation. At least two distinct approaches have been used for these calculations in the past, but a careful software comparison has never been done before. We are using a common fault model and earthquake model, and are assessing how closely these approaches agree, and also how much accurate spherical layered models differ from the simple halfspace models commonly used by many. Assuming that good agreement between software packages is found, we will follow-up with other tests to assess the sensitivity of different earth models and fault models, with a long-term goal of being able to provide realistic estimates and uncertainties of far-field coseismic displacements from earthquakes on an ongoing basis.

Sub-Commission 3.3: Earth Rotation and Geophysical Fluids

Chairs: Maik Thomas (Germany), Jianli Chen (USA)

Charter

Geophysical fluid dynamics in atmosphere, hydrosphere, and outer core are related to large-scale mass transports causing observable geodynamic effects on broad time scales. These effects are reflected in small variations of the fundamental geodetic observables, i.e., the Earth's shape, its rotation, its gravity field, and geocenter shifts. Since all these parameters of the Earth are measured by various space- and ground-based geodetic techniques to increasing, unprecedented accuracy, these integral measures can principally be used to study global mass transport processes and the Earth's dynamic response, and, thus, to investigate geophysical aspects of global change. However, due to the integral character of geodetic observations and restrictions concerning resolution in time and space, the interpretation of the observational data and their utilization in Earth system sciences require complementary methods from theory and modeling. Variations of angular momenta and related torques, gravitational field coefficients, and geocenter shifts due to geophysical fluid dynamics are the relevant quantities, and some of them are already used to constrain state-of-the-art models.

Objectives

The objective of the Sub-Commission 3.3 on Earth Rotation and Geophysical Fluids is to serve the scientific community by supporting research and data analysis in areas related to variations in Earth rotation, gravitational field and geocenter, caused by mass re-distribution within and mass exchange among the Earth's fluid sub-systems, i.e., the atmosphere, ocean, continental hydrosphere, cryosphere, and core along with geophysical processes associated with ocean tides and the hydrological cycle.

Activities during 2011–2015

Sub-Commission 3.3 follows the program defined by Commission 3. Moreover, Sub-Commission 3.3 interacts with the partner organizations and services, in particular with the Global Geophysical Fluids Center (GGFC) of the International Earth Rotation and Reference Systems Service (IERS) and its components, i.e., the operational Special Bureaus for the Atmosphere (SBA), Oceans (SBO), Hydrology (SBH), and the Special Bureau for Combination.

Moreover, the activities of Sub-Commission 3.3 are closely related to the new Joint Working Group on Theory of Earth Rotation (Chair: J. M. Ferrándiz) set up by IAG and the International Astronomical Union (IAU) in 2013. The main purpose of this Joint Working Group is the promotion of the development of theories of Earth rotation that are fully consistent and agree with observations of Earth rotation parameters.

The investigation of mass redistribution due to geophysical fluid dynamics and their impact on Earth's rotation, its shape, and gravity field is an ongoing very active research area. In order to promote the exchange of ideas and results as well as of analysis and modeling strategies, special sessions at the annual Fall Meetings of the American Geophysical Union in San Francisco, USA, at the annual General Assemblies of the European Geosciences Union in Vienna, Austria, at the conferences of the series Journées Systèmes de Référence Spatio-Temporels, and at the IAG 2013 Scientific Assembly in Potsdam, Germany, have been con-

vened during the period. Furthermore, Sub-Commissions 3.1, 3.2, 3.2a, 3.2b, and 3.3 will participate in and co-organize the next Geodynamics and Earth Tides Symposium to be held in Trieste, Italy, in 2016 that will focus on *Earth system sensing, scientific enquiry and discovery*.

Sub-Commission 3.3 is an active participant in the Global Geophysical Fluids Center (GGFC) of the IERS and attended the topical workshops of the GGFC held 2012 and 2015 in Vienna, Austria. These meetings particularly focused on the assessment of remaining errors in current environmental models and ideas for overcoming these limitations. The highlights of the meeting were summarized in several recommendations supporting the provision of data sets that can reliably be used in geodetic and geophysical data analysis. In addition, members of Sub-Commission 3.3 are significantly involved in the generation of several operational data sets provided by the GGFC Operational Product Centers. These are, for instance, time series of global atmospheric, oceanic, and hydrological angular momentum consistently derived from four different atmospheric data sets, or three-dimensional displacements due to spatio-temporal variations of surface loading. Regularly updated and available in near-real time, these time series provide an important basis for numerous studies relevant for the Earth's variable rotation and its underlying physical mechanisms.

Sub-Commission 3.3 also contributes to the goals of IAG's Global Geodetic Observing System (GGOS). Due to the overlapping of the tasks, close contacts exist in particular to the activities of the GGOS Working Group on *Contributions to Earth System Modeling*, with the chair of Sub-Commission 3.3 being the head of this GGOS Working Group. One of the major goals of the Working Group is the preparation of a physically consistent system model for simulation of Earth rotation and gravity field variability due to geophysical fluid dynamics. The current foci of the activities are the realization of mass conservation within the modular system model, the improvement of model based short-term predictions of Earth rotation parameters, and the development of strategies for the separation of temporal variations of Earth rotation, gravity and geoid into individual causative processes related to geophysical fluid dynamics.

Sub-Commission 3.4: Cryospheric Deformation

Chairs: Matt King (Australia), Shfaqat Abbas Khan (Denmark)

Terms of Reference

Past and present changes in the mass balance of the Earth's glaciers and ice complexes induce present-day deformation of the solid Earth on a range of spatial scales, from the very local to global. Of principal interest is geodetic observations that validate, or may be assimilated into, models of glacial isostatic adjustment (GIA) and/or constrain models of changes in present-day ice masses through measurements of elastic rebound. Using geometric measurements alone, elastic and GIA deformations cannot be separated without additional models or observations. Reference frames of GIA models do not allow direct comparison to measurements in an International Terrestrial Reference Frame and ambiguity currently exists over the exact transformation between the two. Furthermore, there is no publicly available and easy-to-use tool for model computations of elastic effects based on observed elevation/mass changes over the spatial scales of interest (small valley glaciers to large ice streams) and including gravitational/rotational feedbacks. This SC will focus on resolving these technical issues and work on dissemination of these measurements within the glaciological community (notably IACS).

A steering group of 25 was established, with their expertise being a mixture of geodetic observation, geophysical modelling and glaciological observation. Members of the sub-commission include: M. Bevis, J. Davis, R. Dietrich, E. Ivins, J. Freymueller, I. Howat, P. Whitehouse, R. Riva, V. Barletta and X. Wu.

Activities 2011–2015

International Symposium on Reconciling Observations and Models of Elastic and Viscoelastic Deformation due to Ice Mass Change

Sub-Commission 3.4 organized this symposium with the objective of enabling this interaction and creating new collaborations through the discussion of the results of scientific studies focused on visco-elastic deformation of the solid Earth due to ice (un)loading. The symposium brought together those working on observation and modeling of cryospheric change and solid earth response to further our understanding of the Earth system. The symposium was held in Ilulissat, Greenland during 30 May –2 June 2013. Over 50 abstracts were submitted and presented in 4 sessions. Nearly 60 scientists were in attendance across the fields of geodesy, seismology, GIA modeling and glaciology and about one third were early career scientists. Significant funding was obtained from IAG, SCAR SERCE, EGU, NSF, DynaQlim and Danish Technical University which largely supported travel of early career researchers to the meeting

REAR: a program for computing the regional elastic response of the Earth to surface loading
The sub-commission called for expressions of interest for those who would be willing to publically release code for high-resolution modeling of elastic deformation associated with changes in surface loading. As a result, the Regional Elastic Rebound Calculator (REAR) was released [Melini *et al.*, 2015]. REAR runs on any UNIX environment with a Fortran compiler, including Windows systems running the Cygwin layer. The REAR source code package and a detailed User guide are available from <<http://hpc.rm.ingv.it/rear>>. REAR comes under a GNU General Public License.

GIA Modelling 2015 Conference and Elastic Modelling workshop

This workshop was held in Fairbanks, Alaska May 25-29, 2015. It brought together those working on ice load reconstructions, modeling of (visco-) elastic processes and comparison to relative sea level and geodetic observations (e.g. GRACE, GPS, ICESat, CRYOSAT II) in order to further refine our understanding of past to present ice/ocean load changes, and the characteristics of the solid Earth under time-varying loads, in order to advance our understanding of past ice sheet and sea level changes, of the structure and rheology of earth, and of exactly what geodetic measurements are measuring. About 35 abstracts were received mainly from researchers based within Europe and the USA.

Relevant peer-reviewed publications by sub-commission members

- Barletta, V.R., L.S. Sorensen and R. Forsberg 2013. Scatter of mass changes estimates at basin scale for Greenland and Antarctica. *Cryosphere*, **7**(5): 1411-1432.
- Bevis, M., J. Wahr, S.A. Khan, F.B. Madsen, A. Brown, M. Willis, E. Kendrick, P. Knudsen, J.E. Box, T. van Dam, D.J. Caccamise, II, B. Johns, T. Nylen, R. Abbott, S. White, J. Miner, R. Forsberg, H. Zhou, J. Wang, T. Wilson, D. Bromwich and O. Francis 2012. Bedrock displacements in Greenland manifest ice mass variations, climate cycles and climate change. *Proceedings of the National Academy of Sciences of the United States of America*, **109**(30): 11944-11948.
- Bevis, M., A. Brown and E. Kendrick 2013. Devising stable geometrical reference frames for use in geodetic studies of vertical crustal motion. *Journal of Geodesy*, **87**(4): 311-321.
- Compton, K., R.A. Bennett and S. Hreinsdottir 2015. Climate-driven vertical acceleration of Icelandic crust measured by continuous GPS geodesy. *Geophysical Research Letters*, **42**(3): 743-750.
- Groh, A., H. Ewert, M. Fritsche, A. Ruelke, R. Rosenau, M. Scheinert and R. Dietrich 2014. Assessing the Current Evolution of the Greenland Ice Sheet by Means of Satellite and Ground-Based Observations. *Surveys in Geophysics*, **35**(6): 1459-1480.
- Groh, A., H. Ewert, R. Rosenau, E. Fagiolini, C. Gruber, D. Floricioiu, W.A. Jaber, S. Linow, F. Flechtner, M. Eineder, W. Dierking and R. Dietrich 2014. Mass, Volume and Velocity of the Antarctic Ice Sheet: Present-Day Changes and Error Effects. *Surveys in Geophysics*, **35**(6): 1481-1505.
- Groh, A., H. Ewert, M. Scheinert, M. Fritsche, A. Ruelke, A. Richter, R. Rosenau and R. Dietrich 2012. An investigation of Glacial Isostatic Adjustment over the Amundsen Sea sector, West Antarctica. *Global and Planetary Change*, **98-99**: 45-53.
- Gunter, B.C., O. Didova, R.E.M. Riva, S.R.M. Ligtenberg, J.T.M. Lenaerts, M.A. King, M.R. van den Broeke and T. Urban 2014. Empirical estimation of present-day Antarctic glacial isostatic adjustment and ice mass change. *Cryosphere*, **8**(2): 743-760.
- Ivins, E.R., T.S. James, J. Wahr, E.J.O. Schrama, F.W. Landerer and K.M. Simon 2013. Antarctic contribution to sea level rise observed by GRACE with improved GIA correction. *Journal of Geophysical Research-Solid Earth*, **118**(6): 3126-3141.
- King, M.A. 2013. Progress in modelling and observing Antarctic glacial isostatic adjustment. *Astronomy & Geophysics*, **54**(4): 33-38.
- King, M.A. and C.S. Watson 2014. Geodetic vertical velocities affected by recent rapid changes in polar motion. *Geophysical Journal International*, **199**(2): 1161-1165.
- Lange, H., G. Casassa, E.R. Ivins, L. Schroeder, M. Fritsche, A. Richter, A. Groh and R. Dietrich 2014. Observed crustal uplift near the Southern Patagonian Icefield constrains improved viscoelastic Earth models. *Geophysical Research Letters*, **41**(3): 805-812.
- Melini, D., P. Gegout, M. King, B. Marzeion, and G. Spada (2015), REAR: a program for computing the regional elastic response of the Earth to surface loading. EOS, in press.
- Nield, G.A., V.R. Barletta, A. Bordoni, M.A. King, P.L. Whitehouse, P.J. Clarke, E. Domack, T.A. Scambos and E. Berthier 2014. Rapid bedrock uplift in the Antarctic Peninsula explained by viscoelastic response to recent ice unloading. *Earth and Planetary Science Letters*, **397**: 32-41.
- Nield, G.A., P.L. Whitehouse, M.A. King, P.J. Clarke and M.J. Bentley 2012. Increased ice loading in the Antarctic Peninsula since the 1850s and its effect on Glacial Isostatic Adjustment. *Geophysical Research Letters*, **39**: L17504.

- Nielsen, K., S.A. Khan, G. Spada, J. Wahr, M. Bevis, L. Liu and T. van Dam 2013. Vertical and horizontal surface displacements near Jakobshavn Isbrae driven by melt-induced and dynamic ice loss. *Journal of Geophysical Research-Solid Earth*, **118**(4): 1837-1844.
- Olivieri, M. and G. Spada 2015. Ice melting and earthquake suppression in Greenland. *Polar Science*, **9**(1): 94-106.
- Rietbroek, R., M. Fritsche, C. Dahle, S.-E. Brunnabend, M. Behnisch, J. Kusche, F. Flechtner, J. Schroeter and R. Dietrich 2014. Can GPS-Derived Surface Loading Bridge a GRACE Mission Gap? *Surveys in Geophysics*, **35**(6): 1267-1283.
- Sasgen, I., H. Konrad, E.R. Ivins, M.R. Van den Broeke, J.L. Bamber, Z. Martinec and V. Klemann 2013. Antarctic ice-mass balance 2003 to 2012: regional reanalysis of GRACE satellite gravimetry measurements with improved estimate of glacial-isostatic adjustment based on GPS uplift rates. *Cryosphere*, **7**(5): 1499-1512.
- Snay, R.A., J.T. Freymueller and C. Pearson 2013. Crustal Motion Models Developed for Version 3.2 of the Horizontal Time-Dependent Positioning Utility. *Journal of Applied Geodesy*, **7**(3): 173-90.
- van der Wal, W., P.L. Whitehouse and E.J.O. Schrama 2015. Effect of GIA models with 3D composite mantle viscosity on GRACE mass balance estimates for Antarctica. *Earth and Planetary Science Letters*, **414**: 134-143.
- Wahr, J., S.A. Khan, T. van Dam, L. Liu, J.H. van Angelen, M.R. van den Broeke and C.M. Meertens 2013. The use of GPS horizontals for loading studies, with applications to northern California and southeast Greenland. *Journal of Geophysical Research-Solid Earth*, **118**(4): 1795-1806.
- Whitehouse, P.L., M.J. Bentley, G.A. Milne, M.A. King and I.D. Thomas 2012. A new glacial isostatic adjustment model for Antarctica: calibrated and tested using observations of relative sea-level change and present-day uplift rates. *Geophysical Journal International*, **190**(3): 1464–1482.

Sub-Commission 3.5: Tectonics and Earthquake Geodesy

Chair: Haluk Özener (Turkey)

Sub-Commission 3.5, Tectonics and Earthquake Geodesy (WEGENER group), aims to encourage cooperation between all geoscientists studying the Eurasian/African/Arabian plate boundary deformation zone with a focus on mitigating earthquake, tsunami, and volcanic hazards. Towards these ends, we organize periodic workshops and meetings with special emphasis on integrating the broadest range of Earth observations, sharing analysis and modelling approaches, and promoting the use of standard procedures for geodetic data acquisition, quality evaluation, and processing. WEGENER organizes dedicated meetings, arranges special sessions in other international meetings, organizes special issues in peer-reviewed journals, and takes initiative to promote and facilitate open access to geodetic databases.

Meetings Organized

16th General Assembly of WEGENER

WEGENER organizes bi-annual conferences to serve as high-level international forums in which scientists from all over the world share results, and strengthen collaborations between countries in the greater Mediterranean region and beyond. In this respect, the 16th General Assembly of WEGENER was organized in Strasbourg, France between 17 and 20 September 2012. The meeting was hosted by Institut de Physique du Globe et Ecole et Observatoire des Sciences de la Terre of the University of Strasbourg.

Around 100 scientists from all around the world attended the meeting. A total of 57 oral and 37 poster presentations were made. The meeting was conducted on six different topics in six sessions. Each session had its own oral and poster presentations. This gave the attendees the chance to participate in the sessions covering their research interests.

Information and experience in the use of geodetic methods for geodynamic studies such as GPS, InSAR, and terrestrial methods were shared in a wide range of applications from large scale studies such as the studies of continental boundaries to small scale studies such as local observations focusing on single faults. Invited talks enabled the attendees to keep up with the latest research of world leading scientists and the latest technological developments in instrumentation, analysis, modeling, and interpretation. The meeting was carried out in a workshop form, including extensive and inclusive discussions of the results and the methods presented within each session.

Detailed information about the 16th General Assembly of WEGENER can be found at <http://wegener2012.sciencesconf.org/>.

17th General Assembly of WEGENER

The 17th General Assembly of Wegener, on earth deformation and the study of earthquakes using geodesy and geodynamics, was held at the University of Leeds, UK, from 1-4 September 2014. The meeting gathered 110 scientists from across the planet for a week of intense scientific discussion, with the local organization led by Prof. Dr. Tim Wright, from the School of Earth and Environment at the University of Leeds.

The scientific program was put together by an international committee of 22 scientists (details on <http://see.leeds.ac.uk/wegener>), and consisted of sessions on Continental Faulting and the Earthquake Cycle, Subduction Zones, Geodetic Techniques, Geodynamics and Potential Fields, Surface Processes, Volcanic/Magmatic Processes, and Glacial Isostatic Adjustment and Sea Level.

In all, there were 42 oral presentations, including 7 keynote talks, and 56 poster presentations. Participants were from 14 countries, spread across 4 continents. Many of the participants stayed in Leeds for a field trip to Malham in the Yorkshire Dales, where they admired world-famous pristine limestone pavement, and the Mid-Craven Fault, and enjoyed the Yorkshire sunshine.

Full details of the presentations and photographs taken at the general assembly can be found at <http://see.leeds.ac.uk/wegener> and in the September 2014 Issue of the IAG Newsletter.

WEGENER Sessions in other Scientific Meetings

European Geosciences Union General Assembly 2011

During the EGU General Assembly 2011, a session titled “Geodesy and natural and induced hazards: Progress during 30 years of the WEGENER initiative” was convened by Susanna Zerbini, Robert Reilinger, and Mustapha Meghraoui. Eighteen oral talks were presented in two successive sessions. There were also 25 poster presentations. More detailed information can be found at <http://meetingorganizer.copernicus.org/EGU2011/session/7048>.

AGU Fall Meeting 2012

The 45th Annual Fall Meeting of the American Geophysical Union (AGU) was held in San Francisco, CA, USA in 2012 between 3 and 7 December. Being the largest worldwide conference in the geophysical sciences, the AGU Fall Meeting attracted more than 23,000 earth and space scientists, educators, students, and other leaders. Nearly 14,000 posters and more than 6,800 oral presentations were given in parallel sessions. More than 270 exhibitors also took place during the meeting. Besides these, numerous workshops, town halls and social and networking events took place during the organization. Thus, this meeting provided an ideal opportunity to highlight WEGENER’s accomplishments to the Earth science community, and to develop synergies with other organizations such as EPN/EUREF, EPOS, CEGRN, and UNAVCO to further our mutual objectives of mitigating natural and anthropomorphic hazards.

A dedicated session titled “Geodesy and Natural and Induced Hazards: Progress During 32 Years of the WEGENER Initiative” was held during the AGU meeting. The session consisted of eight oral and fifteen poster presentations and attracted many international scientists’ interests. The topics of the presentations were broad ranging from studies that focused on a single fault to large-scale studies of continental boundaries. Invited talks also took place during this session. One of the invited talks was given by David E. Smith who was awarded the 2012 Charles A. Whitten Medal of the AGU. Information and experiences about the use of geodetic technologies in geodynamic studies was shared and discussed within the session thus giving the attendees the chance to be aware of recent studies of the world leading scientists. This session was chaired by Haluk Ozener, Susanna Zerbini and Robert Reilinger. Details can be found at <http://www.agu.org/cgi-bin/sessions5?meeting=fm12&part=G52A> and at <http://www.agu.org/cgi-bin/sessions5?meeting=fm12&part=G53A>.

European Geosciences Union General Assembly 2014

In EGU 2014, a session titled “Present-day kinematics and tectonics of the Mediterranean Region: Implications for geodynamics and earthquake potential” was organized. There were 31 presentations. This session brought together geophysicists and geologists working on the present day deformation of the Mediterranean region to present and discuss these new constraints, as well as conceptual and quantitative model results for geodynamic and earthquake processes in this region. Details can be found at <<http://meetingorganizer.copernicus.org/EGU2014/session/14738>>.

European Geosciences Union General Assembly 2015

A session titled “Monitoring and modelling of geodynamics and crustal deformation: progress during 34 years of the WEGENER initiative” was organized and convened by Haluk Ozener, Susanna Zerbini and Mustapha Meghraoui in the EGU General Assembly 2015. Presentations emphasized multidisciplinary studies of Earth deformation using geodetic techniques (GPS, InSAR, LiDAR, space/air/terrestrial gravity, ground-based geodetic observations), complementary tectonic and geophysical observations, and modeling approaches focusing on the European-Mediterranean and Northern African regions. In total, 21 studies were presented in two successive sessions. More detailed information can be found at <<http://meetingorganizer.copernicus.org/EGU2015/session/18028>>.

Publications

Journal of Geodynamics Special Issue

A special issue of Journal of Geodynamics was arranged for WEGENER 2010. This special issue includes papers presented at the 15th General Assembly of WEGENER, held in Istanbul, Turkey, September 14–17, 2010. This biannual meeting was organized by the Bogazici University and hosted at the Albert Long Hall Conference Center. The 2010 WEGENER Conference brought together many experts from all around the world with a wide spectrum of Earth Sciences disciplines and provided an opportunity for the presentation of state-of-the-art results focusing on the “greater” Mediterranean region (Europe, Asia Minor, North Africa, and Arabia). There were 80 presentations at the meeting; this special issue includes a selection of 12 peer-reviewed manuscripts derived from these presentations. The papers in this volume reflect the application of new, as well as mature, space and terrestrial-based methods including, geodetic, gravimetric, radar technologies, environmental, and neotectonic observations and highlight the importance of integrated regional and global scale studies of the Earth System. A special paper describing some of the accomplishments of WEGENER and our new focus on Hazards was included in the Special Issue. Details can be found at <<http://www.sciencedirect.com/science/journal/02643707/67>>.

Other Activities

- An effort to identify a “WEGENER Supersite” was initiated by SC 3.5 members Susanna Zerbini and Meghan Miller, addressing one of the goals of SC 3.5. The supersite initiative is intended to solidify and extend international cooperation between WEGENER scientists, to provide broad access to invaluable data for constraining geodynamic processes, and to facilitate and stimulate the integrated exploitation of data from different techniques in the analysis and interpretation of geo-processes.

- Former WEGENER president, Susanna Zerbini was elected a member of the Scientific Advisory Committee for GEO-Supersites which will strengthen the ties between WEGENER and other international scientific organizations and reinforce cooperation with African and Arab countries as well as other international scientists studying these problems. We anticipate these developments will contribute to our understanding of the kinematics and dynamics of the Eurasian/African/Arabian plate boundary zone, will provide an improved physical basis for hazard mitigation, and will promote the growth of such research and geodetic expertise in these countries.
- International Symposium on Global Navigation Satellite Systems (ISGNSS-2013) was supported by our commission, which was held in Istanbul at 22-25 October 2013. More information about this can be found at <<http://isgnss2013.beun.edu.tr/>>.
- WEGENER Board Meetings were organized in conjunction with the AGU and EGU meetings.
- A report to the Technical Working Group of EUREF on WEGENER activities was submitted.
- A borehole strainmeter was installed in Istanbul, Turkey.
- Two creepmeters were installed on the North Anatolian Fault Zone, Turkey.
- A tide gauge and GNSS equipment were installed on Gough Island and seismic equipment on Marion Island.
- A permanent GPS network and a permanent broadband seismic network were established to study crustal deformation in the Ibero-Maghrebian region.
- Broadband Ocean Bottom Seismometers (OBS) were deployed in the Gulf of Cadiz-Alboran Sea area.
- Regional and on site Earthquake Early Warning System (ALERTES system) is being developed under a Spanish Research Ministry project.
- WEGENER participated in several research projects like EPOS, TOPOIBERIA, etc.
- Continuous GPS stations were installed in Saudi Arabia close to the Aqaba gulf.
- Several publications and presentations regarding WEGENER activities were prepared and given.

Upcoming Event

The WEGENER board decided that the 18th General Assembly will be held in Azores, the junction of three major tectonic plates: the North American Plate, the Eurasian Plate and the African Plate, in 2016 and will be organized by Prof. Dr. Rui Fernandes.

Relevant peer-reviewed publications by sub-commission members

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Joint Study Group 3.1: Gravity and Height Change Intercomparison

<http://www.srosat.com/iag-jsg/>

Chair: Séverine Rosat (France)

Surface deformations are continuously recorded from space or from the ground with increasing accuracy. Vertical displacements and time-varying gravity are representative of various deformation mechanisms of the Earth occurring at different spatial and temporal scales. We can quote for instance post-glacial rebound, tidal deformation, hydrologic loading, co-seismic deformation and volcanic deformation. The involved time scales range from seconds to years and the space scales range from millimeters to continental dimension. Large-scale deformations are well monitored by space geodetic measurements from monthly spatially averaged GRACE measurements while local deformation are precisely monitored by daily GPS or VLBI solution and sub-daily gravimeter data at a site. The intercomparison of the space- and ground-gravity measurements with vertical surface displacements enable us to infer more information on the structure, dynamics and evolution of the Earth system. In particular, the transfer function of the Earth at various time-scales related to the elastic and visco-elastic properties of the Earth are a focus of activity.

Joint Study Group 3.1 on Gravity and Height Change Intercomparison is joint between Commission 1 on Reference Frames, Commission 2 on Gravity Field and Commission 3 on Earth Rotation and Geodynamics and is reporting to Commission 3. The activities of the Joint Study Group concern the comparison of ground and space gravity measurements with geometric measurements of surface deformation. The motivation of this Joint Study Group is to study surface deformation by comparing site displacement observations with both ground- and space-based gravity measurements. Issues that will arise when comparing site displacement with gravity measurements are differences in spatial and temporal scales and differences in sensitivity.

Summary of activities during 2011–2015

The Joint Study Group participated in the 17th Earth Tides Symposium that was held in Warsaw, Poland during 15–19 April 2013 by convening a session on *Gravity and Height Changes: Comparison with GPS*.

A review on the difficulties and techniques to compare space/ground gravity and height changes was also presented at the 17th Earth Tides Symposium.

A bibliography of relevant papers has been compiled and is available at <http://www.srosat.com/iag-jsg/papers.php>.

Load Love numbers, which are necessary to compare space/ground gravity and vertical displacement measurements of surface deformation, were computed for a PREM-like model and are available at <http://www.srosat.com/iag-jsg/loveNb.php>.

Finally, a project has been initiated on the comparison of GPS vertical displacements and surface gravity changes (from Superconducting Gravimeters) at co-located sites. A first comparison is performed concerning the noise characteristics of GPS and gravity data. This work is done in collaboration with Janusz Bogusz and will be presented at the next IUGG meeting in

Prague in 2015: “Correlation at noise level between GPS and gravity data” by J. Bogusz, S. Rosat and A. Kłos.

Joint Working Group 3.1: Theory of Earth Rotation

Chair: Jose Ferrándiz (Spain)

The purpose of the International Astronomical Union / International Association of Geodesy (IAU/IAG) Joint Working Group (JWG) on Theory of Earth Rotation is to promote the development of theories of Earth rotation that are fully consistent and that agree with observations and provide predictions of the Earth orientation parameters (EOPs) with the accuracy required to meet the needs of the near future as recommended by, for example, IAG's Global Geodetic Observing System. Recent efforts have not led to improvements in the accuracy of theoretical models of the Earth's rotation that approach the required millimetre level, so there is a strong need to develop such theories to meet the current and future accuracy of the observations.

A main objective of the JWG is to assess and ensure the level of consistency of EOP predictions derived from theories with the corresponding EOPs determined from analyses of the observational data provided by the various geodetic techniques. Consistency must be understood in its broader meaning, referring to models, processing standards, conventions etc. In addition, clearer definitions of polar motion and nutation are needed for both their separation in observational data analysis and for use in theoretical modelling.

The derivation of comprehensive theories accounting for all relevant astronomical and geophysical effects and able to predict all EOPs is sought. In case more than one theory is needed to accomplish this, their consistency should be ensured. Searching for potential sources of systematic differences between theory and observations is encouraged, including potential effects of differences in reference frame realization. Theoretical approaches must be consistent with IAU and IAG Resolutions concerning reference systems, frames and time scales.

There are no *a priori* preferred approaches or methods of solution, although solutions must be suitable for operational use and the simplicity of their adaptation to future improvements or changes in background models should be considered. The incorporation into current models of corrections stemming from newly studied effects or improvements of existing models may be recommended by the JWG when they lead to significant accuracy enhancements.

Activities during 2011–2015

The JWG was established in 2013 and is just starting to organize its activities. Since the subject of the JWG is quite broad, three Sub-Working Groups (SWGs) have been formed: (1) Precession/Nutation chaired by Juan Getino of Spain, (2) Polar Motion and UT1 chaired by Aleksander Brzezinski of Poland, and (3) Numerical Solutions and Validation chaired by Robert Heinkelmann of Germany. The subjects of SWG 1 and 2 are self-explanatory. The subject of SWG 3 is numerical theories and solutions, relativity and new concepts, and validation by comparisons among theories and observational series.

Guidelines for the operation of the JWG have been drafted, a web site for the JWG has been developed and can be found at <http://web.ua.es/en/wgther>, and meetings of the JWG have been held in conjunction with the:

- 2013 IAG Scientific Assembly in Potsdam, Germany.
- 2013 Journées Systèmes de Référence Spatio-Temporels in Paris, France.
- 2014 EGU General Assembly in Vienna, Austria.
- 2014 AGU Fall Meeting in San Francisco, California.

- 2015 EGU General Assembly in Vienna, Austria.

Presentations about the JWG and its activities have been given at the:

- 2013 IAG Scientific Assembly in Potsdam, Germany.
- 2013 Journées Systèmes de Référence Spatio-Temporels in Paris, France.
- 2013 AGU Fall Meeting in San Francisco, California.
- 8th IVS General Meeting in Shanghai, China.
- 2014 EGU meeting in Vienna, Austria.
- 2014 Journées Systèmes de Référence Spatio-Temporels in St. Petersburg, Russia.
- 2014 AGU Fall Meeting in San Francisco, California.

Reports of many of the meetings and copies of the presentations can be found on the JWG's web site at <<http://web.ua.es/en/wgther>>.