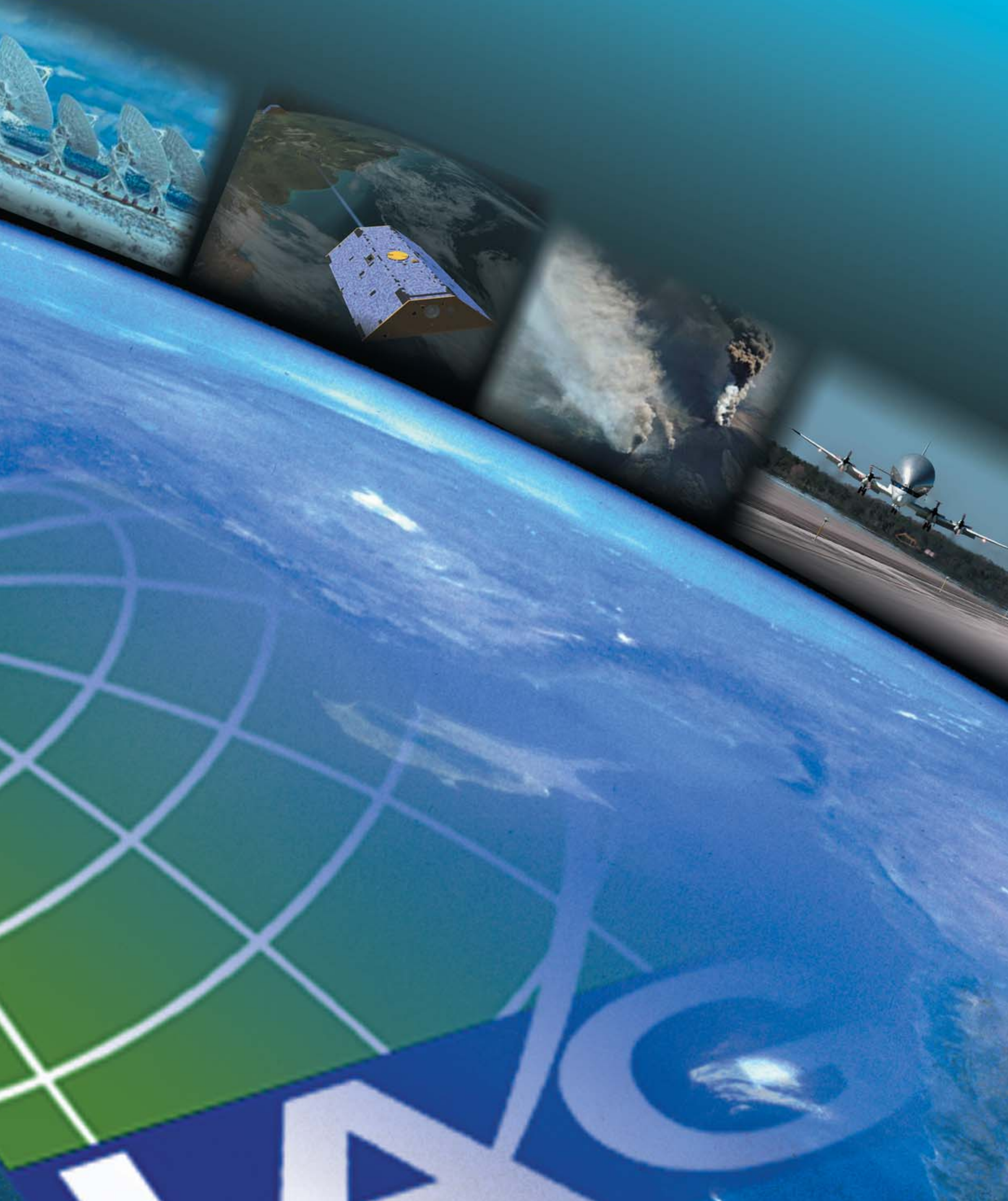
International Association of Geodesy

A Constituent Association of the International Union of Geodesy and Geophysics



Permanent GPS Station in southern Greenland, part of the GNET Project (Photo: M. Bevis)

What is Geodesy?

The Earth is not composed of solid rock, but due to the increase of temperature towards its centre it is built up from a mixture of viscous and solid materials. Thus the shape of the Earth is oblate, because the centrifugal force stemming from its rotational motion thrusts the masses out at the equatorial bulge.

What about the hills, mountain ranges, and deep sea trenches?

These 'topographic features' are quite small compared to the size of our planet. Of course they are measured and drawn on maps, but in Geodesy their contribution to the shape of the planet is quite small.

These topographic features range from about 9 km above sea level (Mount Everest) to approximately 12 km below sea level (Mariana Trench). The diameter of the Earth is roughly 12756 km.

However, as the accuracy of our observation techniques improves, the geodetic influence of topographic features become more and more important. For example, the gravitational effects of the topographic masses are no longer negligible for geodetic investigations.

Quite simply: Geodesy is the science concerned with the study of the shape, size and gravity field of the Earth.

The Earth seems to be round, is it not?

In reality the Earth is not a perfect sphere. Knowledge of the exact shape of the Earth provides us with accurate maps of the Earth.

During the evolution of geodetic science, it has been discovered that the shape of the Earth is not round, but it 'bulges' outward along the equator. Even this is an over simplification. The Earth has many 'hills and troughs' in the gravity potential field, indicating significant departures from symmetric mass distribution within the solid Earth. This is superimposed on the topographic variability we are all familiar with.

Why do we need accurate maps?

Recall the old saying:

"You can not tell where you are going unless you know where you have been."

Maps play an important role in our lives. We need them to find our way in the world – to navigate. In ancient times mankind used landmarks to navigate their way to friends, to towns and ports, or other places of interest.

Today we often use urban landmarks, such as shopping malls, churches, skyscrapers, road intersections, and other points of interest. But what happens, if we are not familiar with the town or rural area?

Then we need accurate maps to navigate, but also to indicate geometric relations between points or landmarks depicted on the map, to display information on areal extent of different vegetation landuse, to design large infrastructure and transportation problems, and so on.

In order to create accurate maps we need a well-defined spatial reference system. A spatial reference system defines the coordinate system and datum in which all landmarks have a unique "address" or position (i.e., coordinates).

Photo: iStockPhoto (dra_schwartz, hidesy, Zhenikeyev)

What is Gravitation? From the Apple ...

Detailed knowledge of the Gravitational Field of the Earth does improve our lives, and provides us to benefit both economically and socially. It helps us understand climate change, sea level rise, and geological hazards (e.g., earthquakes, volcanoes); and it underpins practically all satellite applications, as well as precise navigation systems.

Since our planet is composed of different materials, its gravitational field shows local variations (called "anomalies"). Observing these anomalies can help us to explore the sub-surface mass distribution of our planet. In this way, we may look into the interior of the Earth.

What affects the gravitational field?

The gravitational field is affected by many factors, including:

- **mass density variatons** inside the Earth;
- **the oceans** - the level of oceans changes due to temperature, ocean currents, etc. Changes in the level of oceans also change the gravitational field.
- **the Sun, Moon and other planets** - the gravitational effects of the Sun, Moon and the planets vary according to their position relative to the Earth.
- **ice sheets** - they compress the Earth's crust beneath them. Changes in the ice caps (e.g., melting due to the Greenhouse Effect) may reduce this compression, and thus change the gravitational field.

These effects are only examples. However we can see how complicated our planet is, and can get a sense of how these components interact with one another.

In the previous page we defined Geodesy as the science of studying the Shape, Size and Gravity Field of the Earth. But what is the Gravity Field, and why is it important?

Gravity in a nutshell

Gravitation is a force that pulls or attracts all bodies in the universe that have a mass towards each other. Planets remain in their orbits around the Sun due to this force. The gravitational force depends on the amount of mass of the bodies. In Geodesy we usually distinguish "gravity" as gravitation *plus* centrifugal acceleration due to Earth's rotation because traditionally we can measure gravity, not gravitation, at points on the rotating Earth.

Newton's apple

Sir Isaac Newton postulated that the Earth's gravitation causes such things as the fabled apple to fall, yet it is the same force that keeps planets in their orbits. For example, he figured out that the Moon would travel in a straight line without the attraction from the Earth pulling it into a curved orbit.

... To the Satellites

Why do we need to study the gravitational field?

Gravitation affects almost everything in our lives. From precise clocks to hydroelectric dams, from the tides in the oceans to blood circulation.

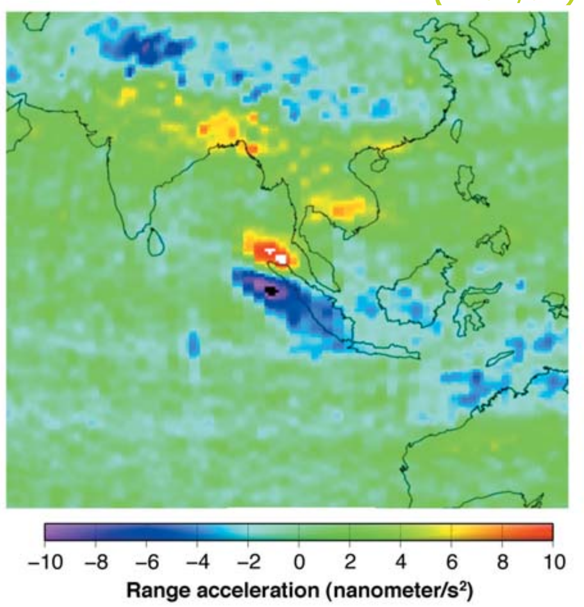
We study the Earth's gravitational field to learn more about our planet. This knowledge can lead us to new ways of doing things with greater awareness towards sustainability of our environment for future generations.

How can the satellites help?

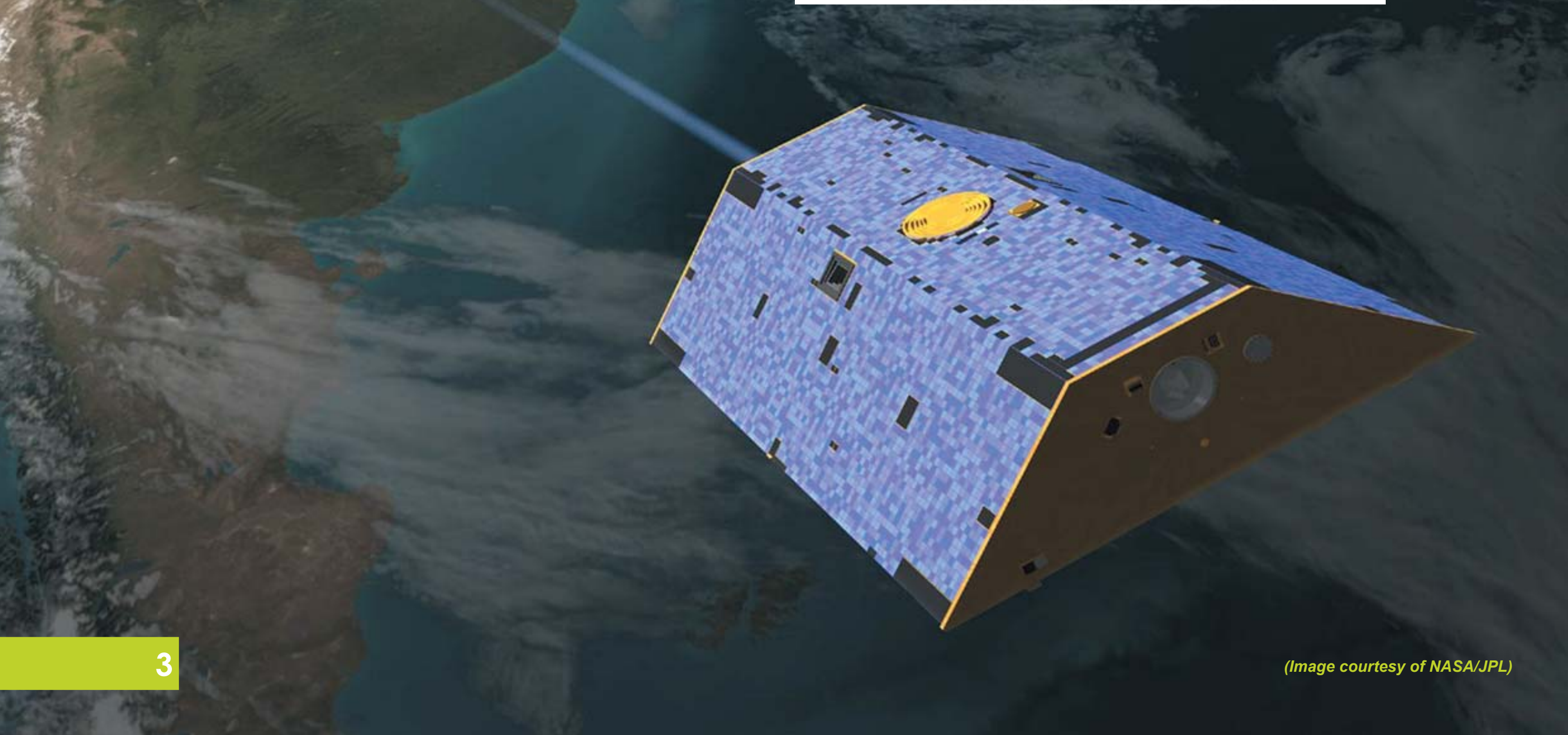
If we want to study the gravitational field globally, terrestrial gravity data have severe limitations, mostly because they do not cover the whole globe with a homogeneous set of measurements. Moreover, in some places in the world, these observations are highly confidential because gravity measurements lead exploration geophysicists to oil fields and mineral deposits, and assist military planners to guide missiles to their intended targets.

Satellite missions such as CHAMP (**CHA**llenging **M**inisatellite **P**ayload), GRACE (**G**ravity **R**ecovery **A**nd **C**limate **E**xperiment) and GOCE (**G**ravity Field and Steady-state **O**cean **C**irculation **E**xplorer) help us to study the global gravitational field of the Earth. These Low-Earth Orbiters (LEOs) provide geodesists with a global, homogeneous coverage of gravitational measurements. ■

The effect of the Sumatra earthquake on gravity recovered from GRACE observations (NASA/JPL).



GRACE satellites observing the gravity field of the Earth



(Image courtesy of NASA/JPL)

Geodesy of Today

When checking the meaning of the term Geodesy in the major encyclopedias, we find it is usually described as the science concerned with the Shape, Size, and Gravity Field of the Earth. Webster's dictionary even defines it as a branch of applied mathematics!

Geodesy today is much more than that. It is a geoscience that treats the Earth as a complex dynamic system, a body consisting of many layers, surrounded by atmosphere and oceans. Geodesy is required to model the system's behaviour in space and time so as to provide the basic framework needed across a wide range of Earth sciences. For example, it does not make sense to speak of global sea level rise without referring to the cm-accurate (time-variable) terrestrial reference system, or the precise global gravity field determined from satellite tracking, or the sea surface topography maps established by a long sequence of altimeter satellite missions.

The title page of Peter Apian's work *Introductio Geographica*, published in 1533, proves, on the other hand, that Geodesy is a rather old science (the term Geodesy may not yet have existed at that time).

The illustration at the top of the page indicates that:

1) State-of-the-art measurements and their correct mathematical treatment were, and are, of central importance.
2) The same measurement techniques are used for the most demanding as well as "everyday" purposes.
3) Geodetic techniques provide the basis for applications of crucial importance and relevance to mankind, such as Precise Positioning (from the global scale down to the maintenance of cadastres) and Navigation (illustrated in the figure by the measurement of "lunar distances").
4) Geodesy provides the link to Astronomy (indicated by the measurement of so-called "lunar distances", allowing the reconstruction of Universal Time (UT) in connection with astronomical almanacs).

The Space Age, and the development of space geodetic observation techniques associated with it, revolutionized our understanding of Geodesy: Distance and distance difference measurements complemented and, to a certain extent, replaced the measurement of angles, making possible the establishment of truly global reference systems (geometric and gravitational). The growth of space geodesy have yielded positioning at the millimetre-level routine, enabling the detection of crustal movement and strain with unprecedented accuracy and high time resolution.

Geodesy continues to provide, with state-of-the-art measurement tools, the scientific basis of Navigation, e.g., by the exploitation of the existing and planned Global Navigation Satellite Systems (GNSS), such as GPS, GLONASS, and GALILEO, and the link to fundamental Astronomy via the global terrestrial reference system, by monitoring the rotational motion of our planet, by space geodetic techniques, and by establishing the celestial reference system and UT (reflecting Earth rotation).

Modern Geodesy is experiencing spectacular growth and each year new frontiers of Earth science knowledge are being explored, such as temporal variations of positions and gravity (land deformations, post-glacial rebound, sea level rise, etc.). It is a fundamental science, which is vital for both everyday mapping and navigation purposes, and for the scientific understanding of our living planet.

Photo: iStockPhoto (AB DESIGN)

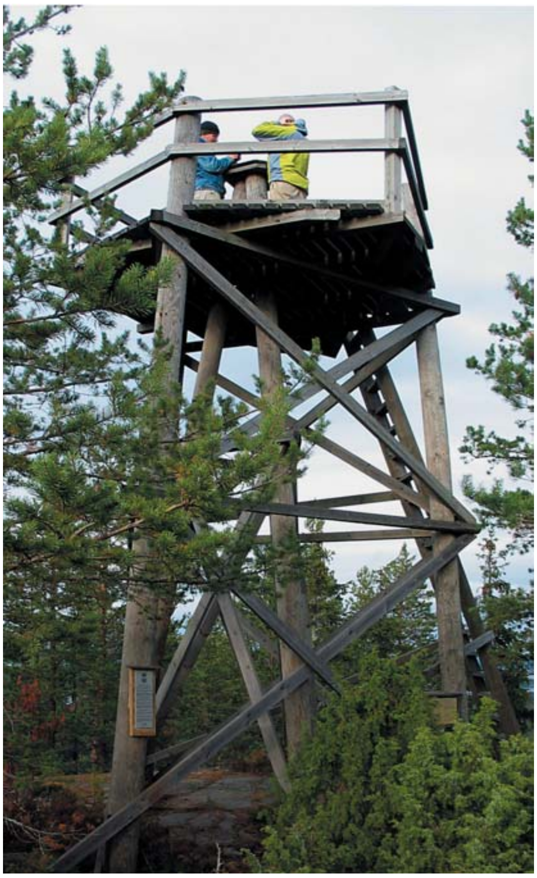
Why is Geodesy Fundamental to Society?

Traditionally, Geodesy has been viewed as a service science, providing an important utility to other geosciences, and supporting many applications. In the past, the main "customers" of Geodesy came from the surveying and mapping profession, while today Geodesy serves all Earth sciences, including the geophysical, oceanographic, atmospheric, hydrological and environmental science communities.

Traditionally Geodesy served the society by providing reference frames …

Geodesy is crucial not only for Earth observation and science, but today it is also indispensable for the maintenance of many activities in a modern society. Traditionally, Geodesy has served society by providing reference frames for a wide range of practical applications, such as from regional to global navigation on land, sea and in the air, and from construction of infrastructure to the determination of reliable boundaries of real estate properties. Reference frames were, however, national or regional in scope, and they were suited for the determination of coordinates relative to a network of ground reference points. Thus, determination of precise point coordinates required simultaneous measurements at several points. Today, GNSS provides access to precise point coordinates in a global reference frame anytime and anywhere on the Earth's surface with centimetre-level accuracy.

This technological development has stimulated new applications demanding even greater accuracy and better access to geodetically determined positions. On local to regional scales, applications such as land surveying, deformation monitoring of infrasructure, prevention and mitigation of the impacts of environmental hazards, and numerous tech-



Triangulation tower (*"ground reference point"*) in the Struve Chain, a member of UNESCO's World Heritage List nical applications require more or less instantaneous access to geodetic positions in a reliable reference frame with centimetre-level accuracy or better. Already today, the economic benefit of the geodetic reference frame is enormous. The availability of a global geodetic reference frame, such as the International Terrestrial Reference Frame (ITRF), and the tools to determine precise point coordinates anytime and anywhere on the Earth has a profound effect on almost all sections of society.

A deeper understanding of the Earth system is not possible without sufficient observations of a large set of parameters characteristic of various Earth system processes. Earth observations are not only necessary for a scientific understanding of the Earth, but they are also fundamental for most societal benefit areas, ranging from disaster prevention and mitigation, the provision of resources such as energy, water and food, achieving an understanding of climate change, the protection of the biosphere, the environment, and human health, and to the building and management of a prosperous global society.

Earth observations are vital for the society in the area of disaster prevention, climate change, etc.

Geodesy is fundamental in meeting these global challenges because it provides the foundation in which all Earth observation systems are ultimately built. But Modern Geodesy does more: with its „three pillars" of geokinematics, Earth's gravity field, and Earth rotation, it also provides comprehensive observations of *changes* in the Earth's shape, gravity field and rotation. These fundamental geodetic quantities are intimately related to mass transport in the fluid envelope of the solid Earth and its interior, as well as the dynamics of the Earth System.

Geodesy is currently in transition due to the fact that the advent of space geodetic techniques and the rapid improvement of communication technologies have fundamentally changed, perhaps revolutionized, Geodesy and its methods. While previously point coordinates were defined with respect to local or regional reference frames, with space geodetic techniques positions can now be expressed with respect to a global reference frame with unprecedented accuracy. Based on these techniques, changes in Earth's shape, rotation and gravity field are provided with increasing spatial and temporal resolution, increasing accuracy, and with decreasing latency.

The societal impacts of Space Geodesy are fundamental. The technological development facilitated through the new space geodetic techniques for navigation and positioning poses new and difficult challenges, and increases the requirements for accessibility, accuracy and long-term stability. The new geodetic technologies are leading to fundamental changes not only in all areas of navigation and transport, but also for applications in process control (e.g., farming, construction, mining, resource management), construction and monitoring of infrastructure (e.g., off-shore platforms, reservoirs, dams, bridges, and other large engineering structures), surveying and mapping, and Earth observation. Geodetic techniques are crucial in the assessment of geohazards and anthropogenic hazards, and they will play a pivotal role in early warning systems of such hazards and helping to mitigate resultant disasters. Geodesy therefore contributes to increased security, a better use of resources, and in general progress towards sustainable development. ■

The Struve Geodetic Arc (a member of the World Heritage List) was established between 1816 and 1855 to determine the size and the shape of the Earth.


Photo: iStockPhoto (dra_schwartz, hidesy, Zhenikeyev)

The Association

The International Association of Geodesy (IAG) is the scientific organization responsible for the field of Geodesy. The origin of the IAG goes back to 1862, the year, in which the "Mitteleuropäische Gradmessung", predecessor of the IAG was established. It promotes scientific cooperation and geodetic research on a global scale, and contributes to it through its various research bodies. It is an active member of the International Union of Geodesy and Geophysics (IUGG), which itself is a member of the International Council for Science (ICSU).

The scientific work of the Association is performed within a component structure consisting of:

- Commissions
- Inter-commission Committees
- Services
- The Global Geodetic Observing System (GGOS)
- The Communication and Outreach Branch (COB), and
- IAG Projects

IAG mission

The Mission of the Association is the advancement of Geodesy, an Earth science that includes the study of the planets and their satellites.

The IAG implements its mission by:

- advancing geodetic theory through research and teaching,
- collecting, analysing and modelling observational data,
- stimulating technological development, and
- providing a consistent representation of the figure, rotation and gravity field of the Earth and planets, and their temporal variations.

IAG objectives

- To foster geodetic research and development,
- to support and maintain geodetic reference systems,
- to provide observational and processed data, standards, methodologies and models,
- to stimulate development of space techniques to increase the resolution of geodetic data,
- to initiate, coordinate and promote international cooperations, and
- to promote the development of geodetic activities across the globe, especially in developing countries.

IAG meetings

The IAG holds its own General Assembly every four years in conjunction with the General Assembly of the IUGG, at the same time and in the same country. In addition, the Association organizes Scientific Assemblies, independently from the IUGG, generally in the mid-term between the General Assemblies.

Other meetings that the IAG sponsors or supports include numerous international symposia and workshops covering broad fields of Geodesy and closely associated sciences and engineering.

The Very Large Array radiotelescope (Image courtesy of NRAO/AUI and Laure Wilson Neish)

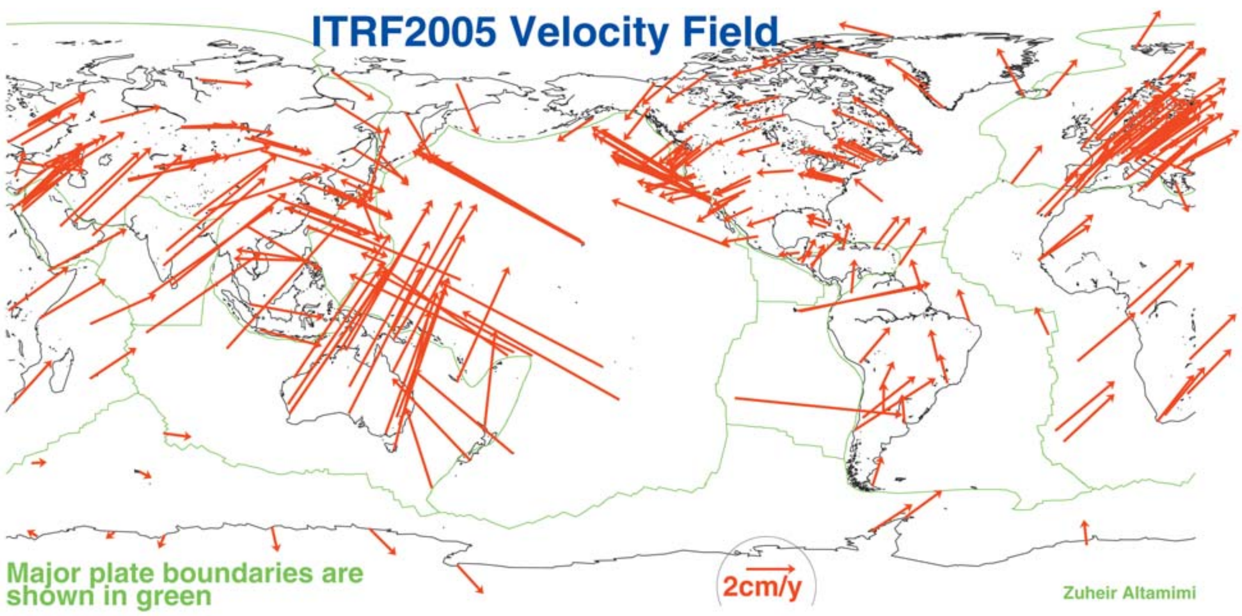
Commission 1 - Reference Frames

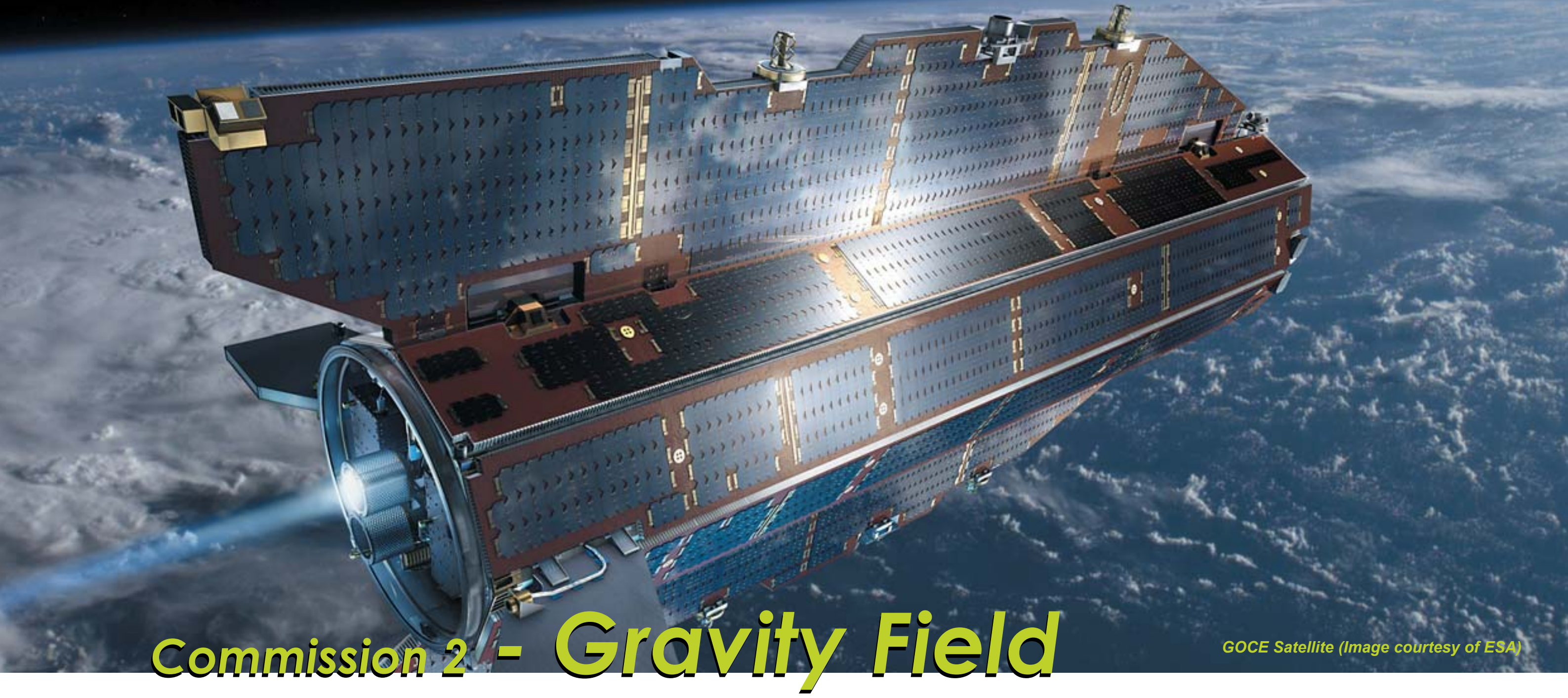
IAG Commission 1 deals with geodetic reference frames. These reference frames are the basis for three-dimensional, time-dependent positioning in global, regional and national geodetic networks, for spatial applications such as the cadastre, engineering construction, precise navigation, geo-information acquisition, geodynamics, sea level and other geoscientific studies.

The geodetic reference frames are necessary to consistently reference or tag parameters using geodetic observations, e.g., station coordinates, crustal motion, Earth orientation information, and so on. Ground observations of GPS and other satellites, or radiotelescope observations of distant quasars, enable us to define not only the reference frame, but also to derive other parameters such as:

- **Crustal motion:** for example, by estimating the coordinates of continuously operating GPS reference stations, their long-term changes in coordinates can be derived. These are typically caused by the motion of the tectonic plates, hence the velocities of the tectonic plates can also be estimated by monitoring these ground reference stations.
- **Earth Orientation Parameters:** reference frames are also vital for the determination of parameters such as the direction of the Earth's rotation axis, and the Earth's rotational velocity and its variation.
- **Geocentre Motion:** a reference frame clearly needs an origin. This is typically taken to be at the centre of mass of the Earth, however the location of this origin relative to the solid Earth is not constant. Satellite techniques provide the tool to monitor the motion of the geocentre.

Commission 1 is focused on the scientific research associated with the definition and realization of global and regional reference frames, as well as the development of analysis and processing methods for relevant geodetic observations.





GOCE Satellite (Image courtesy of ESA)

Commission 2 - Gravity Field

Knowledge of the Earth's gravity field, as well as its temporal variation, is of prime importance for Geodesy, Navigation, Geophysics, Geodynamics, and related disciplines. We have noted in the definition of Geodesy that the gravity field is affected by many terrestrial as well as extra-terrestrial phenomena. The observation of the gravity field, and the analysis and modelling of these observations, can help us find answers to important questions such as:

What causes the temporal variations in the gravity signals?

Temporal variations in the gravity field are due to tidal forces from our Moon, Sun, and nearby planets. They are also caused by seasonal changes such as those associated with hydrological systems, by changes in the Earth's rotation, by mass redistribution in the interior of the Earth and tectonical movements, by melting of the ice caps, etc. One can see that many of the Earth's environments (ocean, crust, hydrosphere, polar ice caps, atmosphere) can be investigated by studying the gravity field.

How do the density variations of subsurface masses express themselves?

The answer to this question is particularly important for geophysical exploration of natural resources, such as oil, gas, minerals, etc. However, gravity maps also help to delineate and understand active crustal fault regions, contour the "topography" of the ocean bottom, and help to monitor ocean currents.

In each case, the spatial variations of gravity are a direct consequence of subsurface mass variations. Understanding these variations and how they change in time is also extremely important in regions of active volcanoes where subsurface mass changes is one of the warning signals for an imminent eruption.

Which way does water flow?

This trivial question is perhaps the most fundamental in Geodesy because it relates to the definition of regional and national height systems. Much effort has been expended in the past to determine a *level surface* that can serve as an accessible reference for heights. This reference is called the "geoid". Heights help to define the direction of water flow, and are useful to hydrological engineers and oceanographers (who wish to map the oceans currents). Gravity is inexorably intertwined with these concepts and provides the necessary foundation for many of the related science activities already mentioned.

The Gravity Field Commission fosters and encourages research in the areas of

- gravimetry and gravity networks,
- spatial and temporal gravity field and geoid modeling,
- dedicated satellite gravity mapping missions, and
- regional geoid determination.

The Commission interfaces with other commissions of the IAG and the Inter-Commission Committee on Theory (ICCT), which plays an extremely vital role in advancing the methods of analysis and modelling, particularly as new types of instruments are developed, making possible new ways of observing the Earth's gravity field.

The Kvarken Archipelago - a member of UNSECO's World Heritage List (Image courtesy of the Finnish Environment Institute - FEI)

Commission 3 - Earth Rotation and Geodynamics

The Earth is a 'living' planet that is continuously changing on its surface, as well as within its interior. Geodynamics is the study of the deformation of the Earth's crust, which is mainly (but not exlusively) caused by the motion and collision of tectonic plates. A better knowledge of the movements of tectonic plates may help us to understand the evolution of earthquakes and other tectonic phenomena.

On the other hand, the movements of the tectonic plates are driven by material flows within the Earth's interior. In addition, mass transports in the atmosphere-hydrosphere-solid Earth-core system, or the "global geophysical fluids" as they are often referred to, will cause observable geodynamic effects on a broad time scale. Although relatively small, these geodynamic effects have been measured by space geodetic techniques with increasing accuracy, opening up important new avenues of research that will lead to a better understanding of global mass transport processes and the Earth's dynamic responses.

Geodynamics in the broader and most traditional sense addresses the forces that act on the Earth, whether they derive from outside or inside of our planet, and the way in which the Earth moves and deforms in response to these forces. This includes the entire range of phenomena associated with Earth rotation and Earth orientation, such as polar motion, length of day (LOD) variation, precession and nutation, the observation and understanding of which are critical to the transformation between terrestrial and celestial reference frames.

Since the Earth is not a solid object, it changes its shape if the gravity field changes. The variations of the Earth's gravity field and the deformation of the Earth's body induced by the tidal forces, i.e., the forces acting on the Earth due to differential gravitation of the Sun, Moon and the planets, are called "Earth Tides". The investigation of Earth Tides is also an important topic of Commission 3. It also studies - among others - post-glacial rebound at all spatial scales, and also the elastic deformation taking place in the near-field of existing ice sheets and glaciers.

Commission 3 works to develop cooperation and collaboration in computation, in theory and in observation of Earth rotation and geodynamics. ■

(Image courtesy of FEI)

The Kvarken Archipelago

in western Finland is an outstanding example of post-glacial uplift. About 20000 years ago, during the last Ice Age, the centre of the continental glacier was located in this area. The ice mass pressed the earth's crust almost a kilometer downwards. As the glacier got thinner, the surface of the earth started to rise back. The ground is still rising, about 8 mm a year in the Kvarken area, thus new land is emerging from the water.

(Image courtesy of Charles K. Toth, OSU)

Commission 4 - Positioning and Applications

Commission 4 focuses on the determination of positions using various instruments, such as inertial navigation systems (INS), Global Navigation Satellite Systems (GNSS), InSAR (Interferometric Synthetic Aperture Radar), and other technologies, for a wide range of applications.

Commission 4 carries out research and other activities that address the broader areas of multi-sensor system theory and applications, with a special emphasis on integrated guidan-ce, navigation, positioning and orientation of airborne and land-based platforms. Such systems can be used for direct georeferencing and digital imaging and scanner systems, monitoring of the deformation of engineering structures, navigation of people and cars, robotics, and so on.

GNSS, such as GPS, GLONASS, and the planned GALILEO and COMPASS systems, can also be used to monitor changes in the atmosphere. Due to the fact that the GNSS signals travel through the atmosphere, they can be used to derive some important parameters such as:

- the total electron content of the ionosphere, and
- the precipitable water vapour in the troposphere.

Thus GNSS systems are also used to enhance the near real-time water vapour estimation, which is useful for weather forecasting.

Recent advances in tomographic modelling and the availability of spaceborne GPS observations has also made possible 3-D profiling of electron density and atmospheric refractivity. With plans for a significant increase in the number of GNSS satellites in the next decade, it is clear that GNSS atmospheric sounding will become a valuable atmospheric remote sensing tool.

Commission 4 also promotes research into the development of a number of geodetic tools that have practical applications to engineering and mapping. Hence there are many joint conferences with sister organizations such as the FIG (International Federation of Surveyors) and ISPRS (International Society of Photogrammetry and Remote Sensing).

There are networks of permanent GPS stations established locally, regionally and globally to perform not only geodetic research, but also to support surveying, engineering, precise navigation, and data acquisition for Geospatial Information Systems (GISs).


(Image courtesy of M. Bevis)

Permanent GPS Station in southern Greenland, part of the GNET project


Photo: iStockPhoto (Georgo, catherine_jones)

IAG ICC on Theory (ICCT)

The InterCommission Committee on Theory (ICCT) was established to interact actively and directly with other IAG entities. Recognizing that geodetic observing systems have advanced to such an extent that geodetic measurements (i) are now of unprecedented accuracy and quality, can readily cover a region of any scale up to tens of thousands of kilometres, yield non-conventional data types, and can be provided continuously; and (ii) consequently, demand advanced mathematical modelling in order to obtain the maximum benefit of such technological advance, the ICCT

- strongly encourages frontier mathematical and physical research, directly motivated by geodetic need/practice, as a contribution to science/engineering in general and the foundations of Geodesy in particular;
- provides the channel of communication amongst the different IAG entities of commissions/services/projects on the ground of theory and methodology, and directly cooperates with and supports these entities in the topic-oriented work;
- helps the IAG in articulating mathematical and physical challenges of Geodesy as a subject of science and in attracting young talents to Geodesy. The ICCT strives to attract and serve as home to mathematically motivated/oriented geodesists and to applied mathematicians; and
- encourages closer research ties with and gets directly involved in relevant areas of the Earth sciences, bearing in mind that Geodesy has been always playing an important role in understanding the physics of the Earth.

IAG Publications

The IAG Publications include:

- the Journal of Geodesy;
- the Geodesist's Handbook;
- the IAG Newsletter;
- the "Travaux de l'Association Internationale de Géodésie";
- the IAG Special Publications; and
- the IAG Symposia series.

The Journal of Geodesy is an international journal concerned with the study of scientific problems of Geodesy and related interdisciplinary sciences. Peer-reviewed papers are published on theoretical or modelling studies, and on results of experiments and interpretations.

Every four years after a General Assembly, the IAG publishes The Geodesist's Handbook. This Handbook provides information on the Association, including the reports of the President and Secretary General, the resolutions, and the Association structure.

The IAG Newsletter is published monthly electronically. A reduced version is also published in the Journal of Geodesy regularly. The original Newsletters are available at the IAG website: **http://www.iag-aig.org**.

After each General and Scientific Assembly, a collection of the reports by the Association components is published in the "Travaux de l'Association Internationale de Géodésie" electronically. Printed copies are available on request.

Proceedings of IAG symposia are typically published in the IAG Symposia Series. ■

Photo: iStockPhoto (Iidesy), NRAO/AUI and Laure Wilson Neish

IAG Services

The IAG is the home of a number of scientific services whose goals are to provide the user community with various geodetic products and/or information and to foster international cooperation.

BGI (Bureau Gravimetrique International)

URL: http://bgi.cnes.fr

The main task of the BGI is to collect, on a worldwide basis, all existing gravity measurements and pertinent information about the gravity field of the Earth, to compile them and store them in a computerized database, and to redistribute them on request to scientific users.

BIPM (Bureau International de Poids et Measures) -Section Time, Frequency and Gravimetry

URL: http://www.bipm.org/en/scientific/tfg/

The Bureau International des Poids et Mesures (BIPM) is responsible for the maintenance of the International Atomic Time (TAI) scale and of the Coordinated Universal Time (UTC) scale. The BIPM ensures that TAI and UTC are available in the standards laboratories around the world, and is responsible for the worldwide coordination of time comparisons.

IAS (International Altimetry Service)

URL:http://ias.dgfi.badw.de

The IAS ·provides a point of contact for general information on satellite altimetry and its applications; promotes satellite altimetry as a core element of Global Earth Observing Systems; and helps users to compile and analyse data.

IBS (IAG Bibliographic Service)

URL:http://www.bkg.bund.de

The service maintains a literature database for geodesy, photogrammetry and cartography (GEOPHOKA), which is housed at the federal agency BKG (Bundesamt für Kartografie und Geodäsie), in Germany.

ICET (International Centre for Earth Tides)

URL: http://www.astro.oma.be/ICET

The ICET collects all available measurements on Earth Tides. It evaluates these data in order to reduce the very large amount of measurements to a limited number of parameters which contain all required geophysical information, and compares the data from different instruments and different stations distributed all over the world.

ICGEM (International Center for Global Gravity Field Models)

URL: http://icgem.gfz-potsdam.de/ICGEM

The ICGEM collects all existing gravity field models and provides on-line interfaces to download and visualize these models, and to calculate functionals (e.g., geoid heights or gravity anomalies) from these models on user-defined geographic grids.

IDEMS (International Digital Elevation Model Service)

URL: http://www.cse.dmu.ac.uk/EAPRS/iag

The IDEMS collects and validates digital representations of the global topography (Digital Elevation Models-DEMs). The centre of IDEMS places a particular emphasis on water representation in DEMs.

IDS (International DORIS Service)

URL: http://ids.cls.fr

The primary objective of the IDS is to operate a service to provide Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) data and data products, useful to a wide range of scientific and practical applications.

IERS (International Earth Rotation and Reference Systems Service)

URL: http://www.iers.org

The primary objectives of the IERS are to serve the astronomical, geodetic and geophysical communities by providing the following: *a)* The International Celestial Reference System (ICRS) and its realization, the International Celestial Reference Frame (ICRF); *b)* The International Terrestrial Reference System (ITRS) and its realization, the International Terrestrial Reference Frame (ITRF); *c)* Earth orientation parameters required to study Earth orientation variations and to transform between the ICRF and the ITRF; *d)* Geophysical data to interpret time/space variations in the ICRF, ITRF or Earth orientation parameters, and model such variations; *e)* Standards, constants and models, and encouraging international adherence to its conventions.

IGeS (International Geoid Service)

URL: http://www.iges.polimi.it

The main tasks of the IGeS are to collect software and data referring to the geoid, validate them and disseminate them upon request among the scientific community. IGeS is also organizing regularly the "International School on the Determination and Use of the Geoid".

IGFS (International Gravity Field Service)

URL: http://www.igfs.net

IGFS is a unified service which is responsible for gravity data collection, validation, archiving and dissemination, as well as software collection, evaluation, dissemination for the purpose of determining, with various degrees of accuracy and resolution, the Earth's surface and gravity potential, or any of its functionals. The temporal variations of the gravity field are also studied. It comprises BGI, ICET, ICGEM, IDEMS, IGeS and IAS.

IGS (International GNSS Service)

URL: http://igscb.jpl.nasa.gov

The Global Positioning System (GPS) is an extremely versatile technology that enables precise ground and space-based positioning, timing and navigation anywhere in the world.

The use of GPS and GNSS, particularly for Earth sciences applications, stems largely from activities of the International GNSS Service (IGS). More than 200 organizations in 80 countries contribute daily to the IGS, which is dependent upon a cooperative global tracking network of over 350 GPS stations.

IGS provides various important data and products to the users.

ILRS (International Laser Ranging Service)

URL: http://ilrs.gsfc.nasa.gov

The ILRS collects, merges, analyzes and distributes Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) observation data sets of sufficient accuracy to satisfy a wide range of applications. The basic observable is the precise time-of-flight of a laser pulse to and from retroreflectors on a satellite (in the case of SLR), and on the Moon (in the case of LLR).

IVS (International VLBI Service for Geodesy and Astrometry)

URL: http://ivscc.gsfc.nasa.gov

The IVS coordinates Very Long Baseline Interferometry (VLBI) observing programs, sets performance standards for VLBI stations, develops conventions for VLBI data formats and data products, issues recommendations for VLBI data analysis software, sets standards for VLBI analysis documentation, and institutes appropriate VLBI product delivery methods to ensure suitable product quality and timeliness.

PSMSL (Permanent Service for Mean Sea Level)

URL: http://www.pol.ac.uk/psmsl

The PSMSL is responsible for the collection, publication, analysis and interpretation of sea level data from the global network of tide gauges. These data are used for a wide range of scientific uses, including the long-term sea level change assessments of the Intergovernmental Panel on Climate Change (IPCC). The PSMSL also manages the delayed-mode activity of the Global Sea Level Observing System (GLOSS). ■

Photo: GGOS

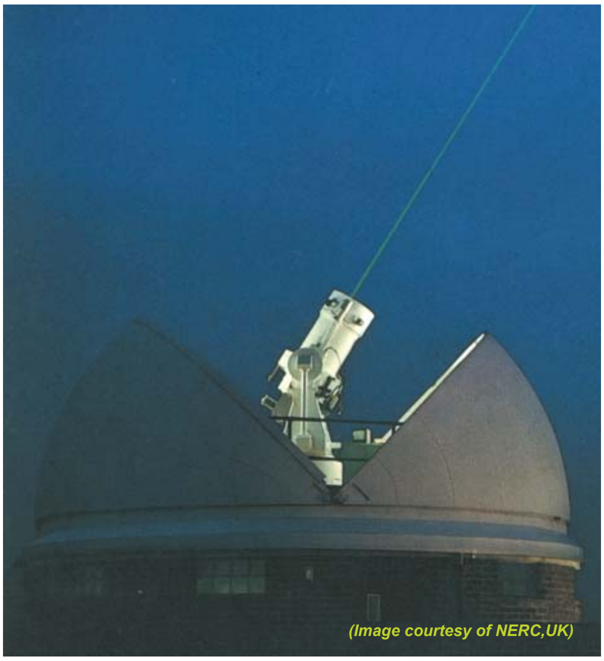
The Global Geodetic Observing System (GGOS)

The Global Geodetic Observing System (GGOS) was established by the IAG in July 2003 as a project. In April 2004 the IAG, represented by GGOS, became a participating organization of the Group on Earth Observations (GEO), in May 2006 GGOS was accepted as a member of the Integrated Global Observation Strategy Partnership (IGOS-P) and in July 2007 at the IUGG General Assembly GGOS became an official component of the IAG, i.e., the Global Geodetic Observing System of the IAG.

GGOS provides observations of the three fundamental geodetic observables and their variations, that is, the Earth's shape, the Earth's gravity field, and the Earth's rotational motion.

GGOS integrates different geodetic techniques, different models and different approaches in order to ensure a long-term, precise monitoring of the geodetic observables in agreement with the Integrated Global Observing Strategy (IGOS). GGOS provides the observational basis to maintain a stable, accurate and global reference frame, and in this function is crucial for all Earth observation and many practical applications.

GGOS contributes to the Global Earth Observing System of Systems (GEOSS) not only with the accurate reference frame required for many components of GEOSS but also with observations related to the global hydrological cycle, the dynamics of the atmosphere and the oceans, and geohazards. GGOS acts as the interface between the geodetic services andexternal users such as GEOSS, IGOS-P, and United Nations authorities. A major goal is to ensure the interoperability of the IAG services and GEOSS.


(Image courtesy of NERC,UK)

The Herstmonceaux Satellite Laser Ranging Telescope in operation

GGOS is built on the IAG Services (IGS, IVS, ILRS, IDS, IERS, IGFS, etc.) and the products they derive on an operational basis for Earth monitoring making use of a large variety of space- and ground -based geodetic techniques, such as Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Global Navigation Satellite Systems (GNSS), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), altimetry, InSAR (Interferometric Synthetic Aperture Radar) and gravity satellite missions (CHAMP, GRACE, GOCE), gravimetry, etc.

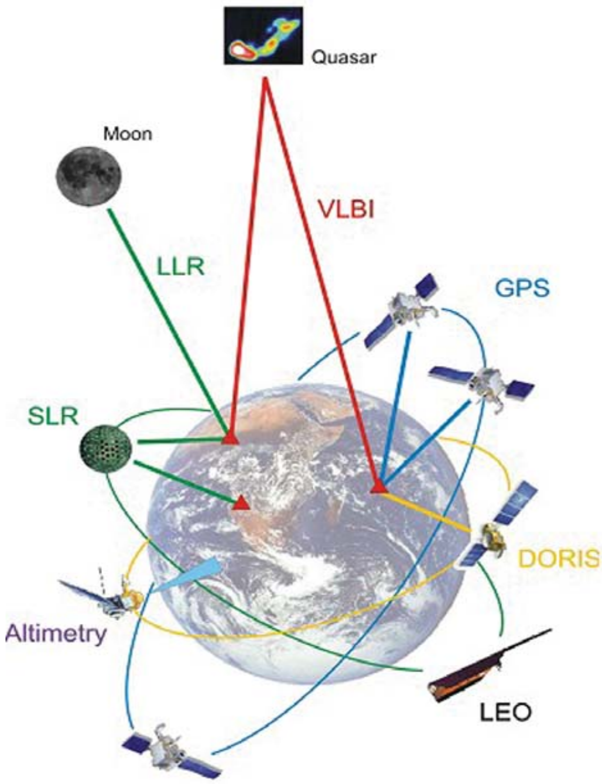
All of these observation techniques are considered integral parts of GGOS, allowing the monitoring of the Earth's shape and deformation (including water surface), the Earth's orientation and rotation and the Earth's gravity field and its temporal variations with an unprecedented accuracy. The observed quantities give direct evidence of many global processes that have a crucial impact on human society such as earthquakes, volcanism, floods, sea level change, climate change, water redistribution, mass balance of the polar ice sheets, post-glacial rebound, etc.

Mission

The mission of GGOS is to promote the application of geodetic Earth observation methods to the solution of Earth science problems. GGOS accomplishes its mission: *a)* by defining the geodetic infrastructure that is needed to meet scientific and societal requirements; *b)* by advocating for the establishment and maintenance of this geodetic infrastructure; *c)* by coordinating interaction between the IAG Services, Commissions or other geodetic entities; *d)* by improving accessibility to geodetic observations and products; and *e)* by educating the scientific community about the benefits of geodetic research and the public about the role that Geodesy plays in society.

GGOS provides the basis on which future advances in geosciences can be built. By considering the Earth system as a whole (including the geosphere, hydrosphere, cryosphere, atmosphere and biosphere), monitoring Earth system components and tehir interactions by geodetic techniques and studying them from the geodetic point of view, the geodetic community provides the global geosciences community with a powerful tool consisting mainly of high quality services, standards and references, theoretical and observation innovations.

GGOS and its related research and Services' porducts will address the relevant science issues related to geodesy and geodynamics in the 21st century, but also issues relevant to society (global risk management, geo-hazards, natural resources, climate change, severe storm forecasting, sea-level estimations and ocean forecasting, space weather, and others). It is an ambitious program of a dimension that goes beyond IAG, requring a strong cooperation within the geodetic, geodynamic and geophysical communities, and externally, to related endeavours and communities.



Observing the Earth with various geodetic methods (Very Long Baseline Interferometry, GPS, DORIS, Low Earth Orbiters - LEO, Altimetry, SLR, LLR)

For more information, please visit the GGOS website:

http://www.ggos.org

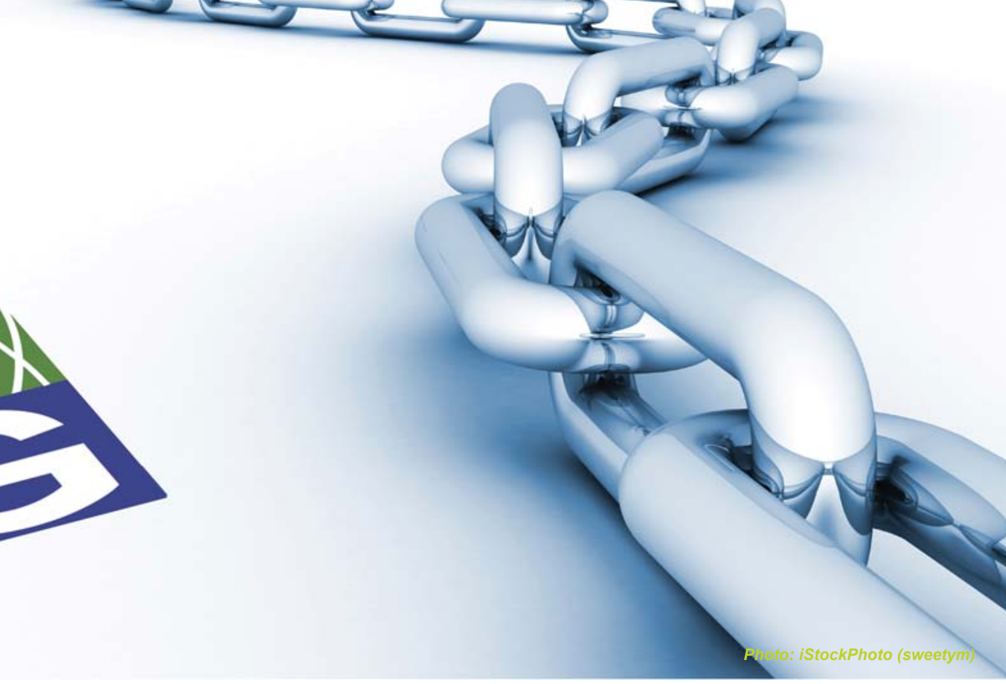


Photo: iStockPhoto (sweetym)

Links

International Union of Geodesy and Geophysics (IUGG)
(www.iugg.org)

The IUGG comprises of the following seven semi-autonomous Associations beside IAG:

International Association of Cryospheric Sciences (IACS)
(www.cryosphericsciences.org)

International Association of Geomagnetism and Aeronomy (IAGA)
(www.iugg.org/IAGA)

International Association of Hydrological Sciences (IAHS)
(http://iahs.info)

International Association of Meteorology and Atmospheric Sciences (IAMAS)
(www.iamas.org)

International Association for the Physical Sciences of the Oceans (IAPSO)
(iapso.iugg.org)

International Association of Seismology and Physics of the Earth's Interior (IASPEI)
(www.iaspei.org)

International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI)
(www.iavcei.org)

Links to other organizations:

International Astronomical Union (IAU)
(www.iau.org)

International Union of Geological Sciences (IUGS)
(www.iugs.org)

International Federation of Surveyors (FIG)
(www.fig.net)

International Society for Photogrammetry and Remote Sensing (ISPRS)
(www.isprs.org)

International Cartographic Association (ICA)
(cartography.tuwien.ac.at/ica)

International Society of Mine Surveying (ISM)
(www.ism.bw-art.de)

International Hydrographic Organization (IHO)
(www.iho.shom.fr)

American Geophysical Union (AGU)
(www.agu.org)

European Geosciences Union (EGU)
(www.copernicus.org/EGU/EGU.html)

Global Spatial Data Infrastructure Association (GSDI)
(www.gsdi.org)

Federation of Astronomical and Geophysical Data Analysis Services (FAGS)
(www.icsu-fags.org)

The Institute of Navigation
(www.ion.org)

Photo: iStockPhoto (Andrew Johnson, andipantz)

Membership

The membership of the IAG comprises countries and individuals. Any member country of the IUGG is regarded as a National Member of the IAG and may, through its adhering body, appoint a National Delegate to the Association. National Delegates represent their countries in IAG Council meetings and act as correspondents for their countries between General Assemblies. Individual scientists may become Members and Fellows of the IAG. The IAG Executive Committee, upon the recommendation of the Secretary General, accepts individuals as Members. Applications for individual membership are made to the Bureau.

Benefits of individual membership include substantial reduction on the individual subscription rate to the Journal of Geodesy, the right to participate in the IAG election process both as a nominator and a nominee, and a reduction of the registration fee for many IAG meetings. The individual members also receive the monthly IAG Newsletter.

IAG Members have access to the Members' Area of the IAG website, where they can browse among the contact data of other international scientists. The Members' Area contains electronic materials related to the latest achievements of Geodesy.

IAG Members are entitled to use the private billboard service of the IAG website to exchange their views about issues related to Geodesy.

Past Officers of the Association are eligible to become Fellows and are invited to become such. The IAG Executive Committee makes these appointments.

IAG COB

The Communication and Outreach Branch (COB) provides the IAG with communication, educational/public information and outreach links to the membership, to other scientific associations and to the world as a whole.

The responsibilities of the COB include promotion of the IAG (at meetings and conferences), membership development, maintenance of the IAG website, publications (newsletters), and creation of a resource base for educators, developing countries and our global community.

The COB maintains the official IAG website, where one can find all the latest news about IAG and Geodesy in general.

For further information please browse the IAG website, or contact us on the following e-mail address:

URL: http://www.iag-aig.org

E-mail: iagcob@iag-aig.org

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Official IAG Website: http://www.iag-aig.org
Website of the IAG Office: http://iag.dgfi.badw.de

Commissions:

Commission 1 - Reference Frames
Commission 2 - Gravity Field
Commission 3 - Earth Rotatation and Geodynamics
Commission 4 - Positioning and Applications

ICCT (InterCommission Committee on Theory)

Services:

BGI - International Gravitmetric Bureau	http://bgi.cnes.fr
BIPM - Bureaus International de Poids at Measures - Section Time, Frequency and Gravimetry	http://www.bipm.org/en/scientific/tfg
IAS - International Altimertry Service	http://ias.dgfi.badw.de
IBS - IAG Bibliographic Service	http://www.bkg.bund.de
ICET - International Centre for Earth Tides	http://www.astro.oma.be/ICET
ICGEM - Int.Center for Global Earth Models	http://icgem.gfz/potsdam.de/ICGEM
IDEMS - International DEM Service	http://www.cse.dmu.acu.uk/EAPRS/iag/
IDS - International DORIS Service	http://ids.cls.fr
IERS - Int. Earth Rotation and Ref. Frames Service	http://www.iers.org
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PSMSL - Permanent Service for Mean Sea Level	http://www.pol.ac.uk/psmsl

GGOS (Global Geodetic Observing System) http://www.ggos.org

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