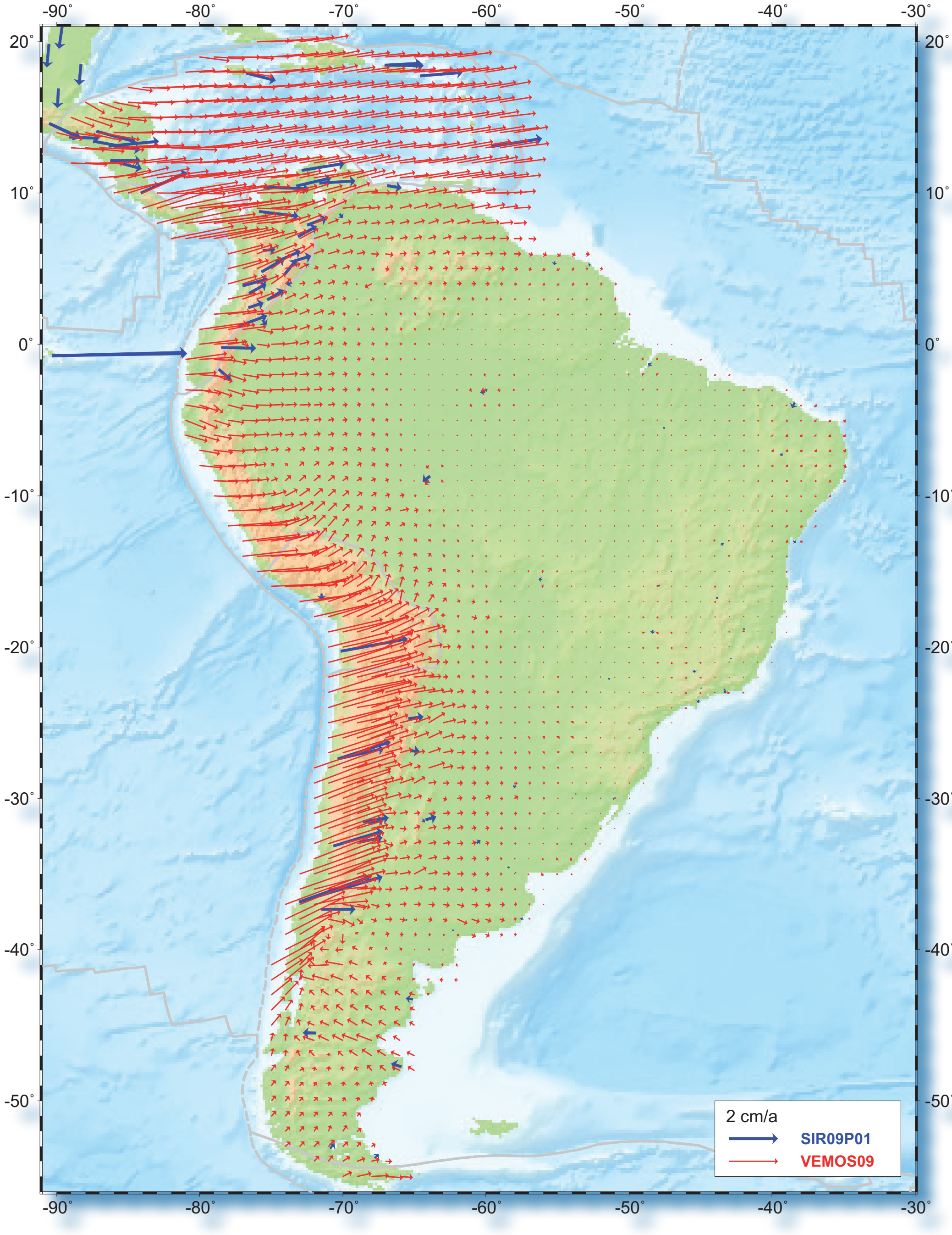
Deutsches Geodätisches Forschungsinstitut (DGFI)

ANNUAL REPORT 2009



Station velocities of the SIRGAS multi-annual solution 2009 (blue arrows) and velocity field derived from various geodynamics projects (red arrows) relative to the South American plate

Deutsches Geodätisches Forschungsinstitut (DGFI)
Alfons-Goppel-Str. 11, D-80539 München
Tel.: 089 23031-1107   Fax: 089 23031-1240
E-mail: mailer@dgfi.badw.de   Internet: http://www.dgfi.badw.de

ANNUAL REPORT 2009

Table of Contents

2nd Edition

The Institute

The German Geodetic Research Institute (Deutsches Geodätisches Forschungsinstitut, DGFI) is an autonomous and independent research institution located in Munich. It is affiliated to the German Geodetic Commission (Deutsche Geodätische Kommission, DGK) at the Bavarian Academy of Humanities and Sciences (Bayerische Akademie der Wissenschaften, BAdW). The research covers all fields of geodesy and includes the participation in national and international research projects as well as various functions in international bodies.

Research Programme

The research programme of DGFI is established for a period of several years in advance in order to meet the requirements of international science and the demands of society. The current general theme is *"Geodetic research for observing and analysing the System Earth"*. This theme reflects the scientific orientation of Geodesy as the discipline of measuring and representing the changing Earth, and responds to the challenges for a better understanding of the phenomena and processes of geodynamics and global change. It includes the study of geometric and gravimetric observation techniques, fundamentals of geodetic reference systems, methods for estimating geodetic parameters, as well as analyses of physical models of the Earth.

Motivation

The demands of society on Geodesy are based on the increasing consciousness of helplessness against natural hazards. Extreme disasters can be prevented only if the characteristics and processes of earthquakes, tsunamis, flooding, etc., are well enough understood in order to envisage a prognosis of future events. Geodesy is capable of quantifying the effects of such processes by measuring the variations of the surface geometry of the solid Earth and the oceans, the Earth's rotation, and the Earth's gravity field. As these variations are very small, all efforts have to be made to exhaust the full information included in the geodetic measurements. This can be done by a thorough study of the techniques, models and results, and by the development of sophisticated methods for observing and analysing the parameters describing the dynamics of the System Earth.

Practical Applications

Unique reference systems are the basic requirement for geodetic measurements and products (time-dependent positions, orientation angles, gravity values, etc.). Fundamental research of DGFI is therefore dedicated to this field. The frames realizing the reference systems are used in many practical applications. A celestial reference frame is necessary for describing the orientation of Earth in space as well as for space travel, global navigation, astrometry etc. A terrestrial reference frame serves as the basis for all precise positioning in surveying, engineering, navigation, and geo-information systems. It allows the unification of all national and continental reference systems, which is a prerequisite for globalization of society and economics. Physical parameters of the Earth's gravity are represented with respect to reference surfaces, e.g. the geoid as an equipotential surface at the mean sea level in a state of equilibrium. The geoid is also the reference for physical heights used in practical applications (levelling, barometric heights). The DGFI research activities support these applications.

University Connections

There is a very close cooperation between the DGFI and all German universities involved in geodetic education. This takes place mainly under the umbrella of the DGK, but also as result of bilateral arrangements. Members of DGFI give lectures and courses at various universities. Doctoral and master theses are supervised by DGFI scientists. Interdisciplinary cooperation is installed with university institutes for Geophysics, Meteorology and Oceanography.

The most intensive cooperation exists with the Technical University of Munich (TUM), in particular within the Research Group on Satellite Geodesy (Forschungsgruppe Satellitengeodäsie, FGS). This group is formed by TUM's Institute of Astronomical and Physical Geodesy (IAPG) and Research Establishment (Forschungseinrichtung) Satellite Geodesy (FESG), the Institute for Geodesy and Geoinformation, University of Bonn (IGG), the Federal Agency (Bundesamt) for Cartography and Geodesy (BKG), and the German Geodetic Research Institute (DGFI).

International Integration

The research of DGFI is integrated within several international scientific services, programmes and projects, in particular in the International Association of Geodesy (IAG). DGFI recognizes the outstanding role of the scientific services of IAG for research and practice, and cooperates in these services as data, analysis and research centre. Scientists of DGFI have taken leading positions and supporting functions in IAG's commissions, services, projects, working and study groups, and in the Global Geodetic Observing System (GGOS). DGFI also participates in research programmes and bodies of the European Union (EU) and the European Space Agency (ESA). It cooperates in several United Nations' (UN) and inter-governmental institutions and activities.

Structure of the Programme

The present research programme for the years 2009–2010 was evaluated and revised by the Scientific Council (Beirat) of DGK, and approved by the DGK General Assembly on November 27, 2008. It is divided into the four long-term research fields

1. Earth System observations,
2. Earth System analysis,
3. International scientific services and projects,
4. Information systems and scientific transfer.

Observations of the Earth System include modelling of measurement techniques, methods and approaches of data processing and data combination, definition and realization of reference systems, up to the provision of consistent parameters. Analysis of the Earth System deals with the study of the properties of and interactions between system elements which are reflected by the corresponding geodetic parameters and their correlations. The participation in international services and projects and the maintenance of information systems and science transfer are indispensable requirements for a research institute. The research fields are subdivided into fourteen specific topics. DGFI scientists are working simultaneously in several scientific topics in order to ensure the connection between the different fields and the consistency of methods, models and results.

1 Earth System Observations

The research field "Earth System Observation" is concerned with the modelling, data processing and parameter estimation for the primary geodetic observing techniques for monitoring the System Earth. These are in particular Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser ranging (SLR/LLR), the Global Navigation Satellite Systems (GNSS) including the microwave techniques GPS, GLONASS and the forthcoming GALILEO, the French Doppler Orbitography by Radiopositioning Integrated on Satellite (DORIS), as well as the satellite altimetry and gravity field sensors (Radar, SST, gradiometry). These observation techniques form the basis for monitoring the surface structure, rotation and gravity field of the Earth, along with its variations in time.

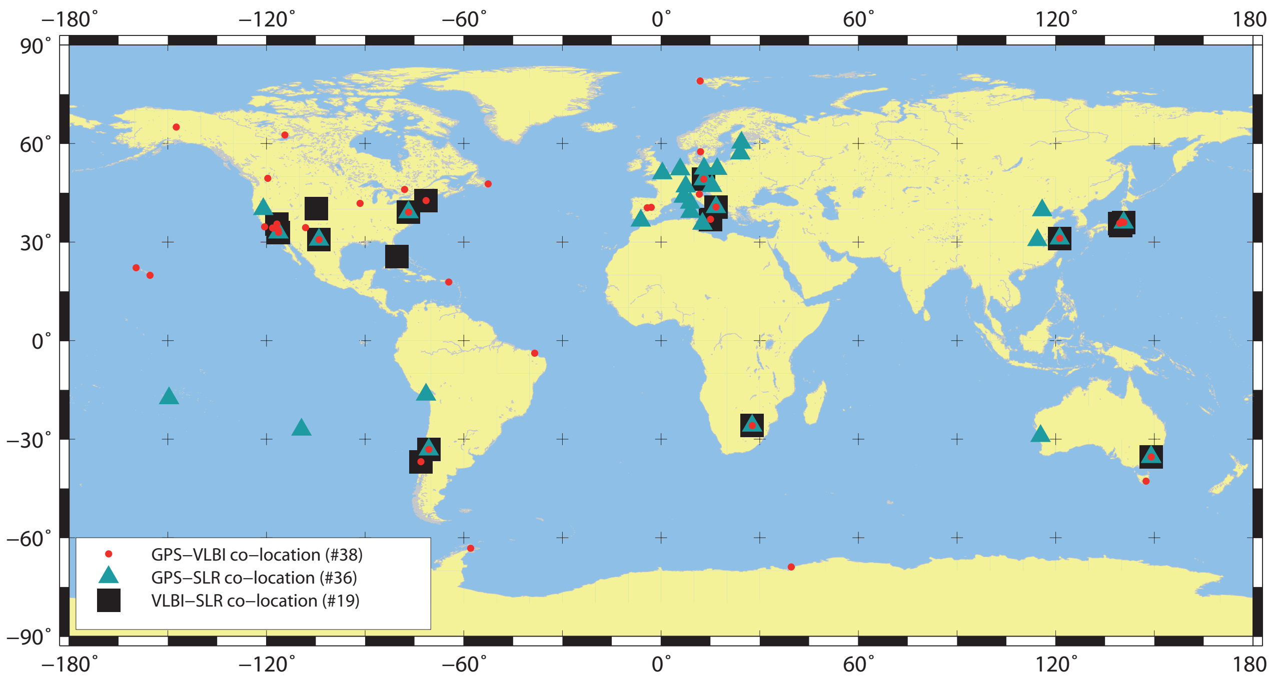
This research field is divided into four topics. Topic 1.1 focuses on the improvement and unification of the modelling for the above-mentioned observation techniques and the development of consistent analysis methods. Basic research for geometric reference systems, which enters directly into the realization of the terrestrial and the celestial reference systems, is subject of Topic 1.2. The fundamentals of geophysical parameter estimations are covered in Topic 1.3. The objective of Topic 1.4 is the development and implementation of procedures for the combination of geometric and gravimetric observations. A major goal is the consistent estimation of geodetic parameters (e.g. station coordinates, positions of radio sources, Earth orientation parameters, gravity field coefficients) by a rigorous combination of the data coming from the different observation techniques.

1.1 Consistent modelling for space geodetic observations

ITRF2008

As one of the International Terrestrial Referece System (ITRS) Combination Centres, DGFI concentrated on the computation of the Terrestrial Reference Frame ITRF2008, which is established by a global network of station positions (see also theme 3.1). The ITRF2008 network comprises sub-networks, each belonging to the contributing space geodetic observation techniques VLBI, SLR, GPS and DORIS. The single technique-specific networks must be tied to a common global frame by using terrestrially measured difference vectors (local ties) between the instruments' reference points of the different observation techniques at one site. Stations with several observation techniques are called co-location sites. Figure 1.1.1 shows the global distribution of the co-locations between GPS, VLBI and SLR stations.

Fig. 1.1.1: Global distribution of co-locations between GPS, VLBI and SLR



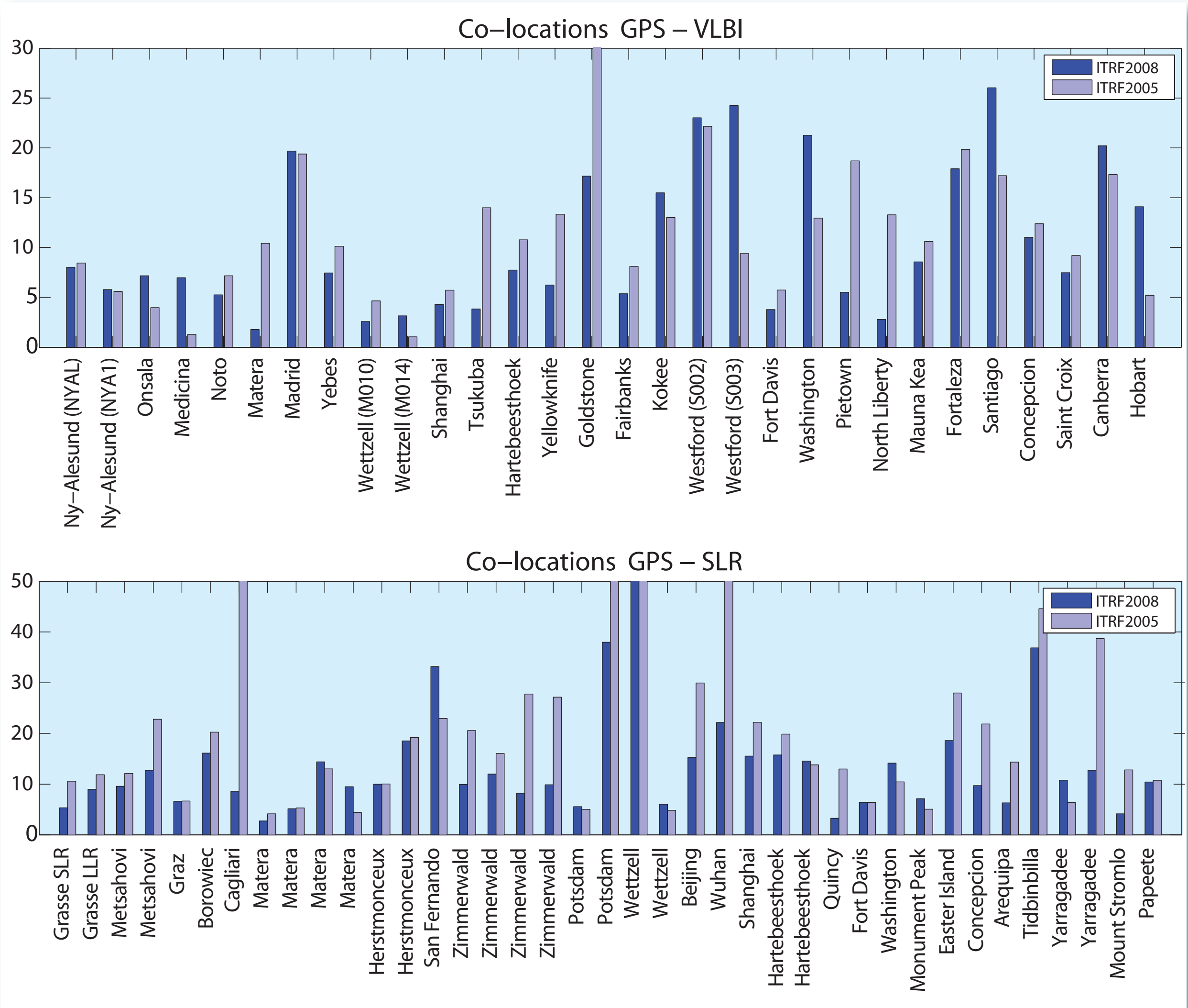


Fig. 1.1.2: Discrepancies [mm] between terrestrial difference vectors and the position differences derived from the space geodetic techniques for GPS-VLBI co-locations (a) and GPS-SLR co-locations (b)

One of the most important tasks within the computation of an ITRF solution is the selection of reliable terrestrial difference vectors between the different observing stations of co-location sites. Discrepancies between the terrestrial difference vectors and the coordinate differences derived from the space geodetic techniques can be attributed both to uncertainties in the measurements of the terrestrial difference vectors and to systematic effects in the solutions of the space geodetic techniques. Figure 1.1.2 displays the discrepancies in length between the terrestrial difference vectors and the coordinate differences derived from the space geodetic techniques for the GPS-VLBI and GPS-SLR co-locations of ITRF2008 and the former solution ITRF2005. Even though there is generally not a large improvement, there are significantly smaller discrepancies at some of the co-locations in ITRF2008, such as for the GPS-VLBI co-locations in Matera, Tsukuba, Pietown and North Liberty, as well as for the GPS-SLR co-locations in Zimmerwald, Wuhan, Concepción and Yarragadee. While for Tsukuba a new measurement of the local network was carried out in 2008, the improvements for the other stations can be mainly attributed to the application of more sophisticated models in the analysis of the space geodetic observations.

Improved modelling for ITRF2008

The most important changes from ITRF2005 to ITRF2008 are:

– the application of absolute GPS antenna phase centre offsets in ITRF 2008 (effect of up to 1 cm in station height),
– the homogenization of the pole tide correction model for the VLBI solution time series (effect of up to 5 mm in station height),
– the use of improved mapping functions for troposphere parameters in case of GPS and VLBI (effect of up to 5 mm in station height),
– the implementation of a thermal deformation model for VLBI telescopes (effect of a few millimetres),
– new range bias corrections for SLR stations (effect of up to a few centimetres).

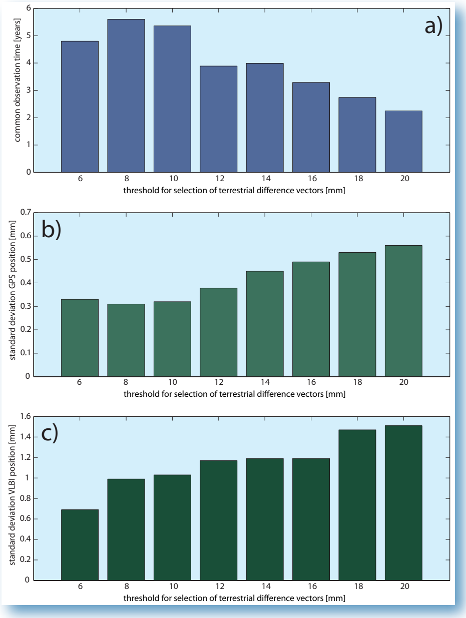


Fig. 1.1.3: Mean common observation time (a) and standard deviations of station positions for GPS (b) and VLBI co-locations (c) that agree to the terrestrial difference vectors within a given threshold

This list shows that systematic effects in the station coordinates caused by model deficiencies are mainly responsible for the discrepancies between terrestrial difference vectors and the position differences derived from the space geodetic techniques. Thus, the comparison of space geodetic solutions at co-locations sites is a good criterion to detect modelling discrepancies between space observation methods.

Figure 1.1.3a shows the mean common observation time, and Figure 1.1.3b and c the mean standard deviations of GPS and VLBI stations, respectively, which are computed for groups of terrestrial difference vectors, fitting the coordinate differences within the given thresholds (between 6 and 20 mm). The length of the common observation time of two space geodetic techniques and the standard deviation of the positions are obviously anti-correlated with the discrepancies between terrestrial difference vectors and the space geodetic coordinate differences.

Weighting

The relative weighting of the techniques within the combination is very important, as their stochastic models are affected by inadequacies in the observation modelling. A variance component estimation directly within the combination procedure is problematic because it would be based only on a few common parameters. Therefore, the variance components are derived empirically, where the ratios between the standard deviations estimated in the combined solution is set equal to the ratios of the standard deviations derived from the residual time series of the station coordinates.

1.2 Fundamentals of geometric reference systems

The subject of this theme consists of terrestrial and celestial reference systems, as well as the rotation of the Earth as a link between these two systems. Research activities dealt with the newest terrestrial and celestial reference frames, ITRF2008 and ICRF2, respectively, and with the connection between the motions of the rotation axis and the celestial intermediate pole (CIP).

ITRF2008

The scale of the ITRF solutions is conventionally realized by a weighted mean of the contributing SLR and VLBI observations. Due to one-to-one correlations, GPS absolute antenna phase centre variations were estimated by fixing the scale of the ITRF2005 solution. Thus, the GPS scale is not independent of the last ITRF solution, and it should not be used for the realization of the ITRF2008 scale. However, since GPS stations are well distributed over the globe and the station coordinates are estimated with high precision, the contribution of GPS to the scale realization would lead to a clear stabilization of the ITRF solution. Thus, DGFI analysed the differences between the network scales of the SLR, VLBI and GPS solutions. Scale differences were estimated by a seven-parameter similarity transformation, using co-location sites as identical stations. Scale network differences between GPS and VLBI networks of 4.0 mm ± 1mm were determined. The scale difference between GPS and SLR is smaller, although still significant. Due to these significant differences, GPS cannot contribute to the ITRF2008 scale realization.

The EOP time series resulting from the multi-year solutions were analysed. Figure 1.2.1 shows the frequency analysis of the pole coordinates of GPS. Frequencies with periods of about 7.2, 9.4 and 14.2 days were found, which correspond to aliasing periods between the GPS observation spacing of daily sessions and short tidal periods. Thus the signals in the GPS pole time series may result from deficiencies of the a-priori subdaily pole model IERS2003 used for substracting the subdaily pole variations.

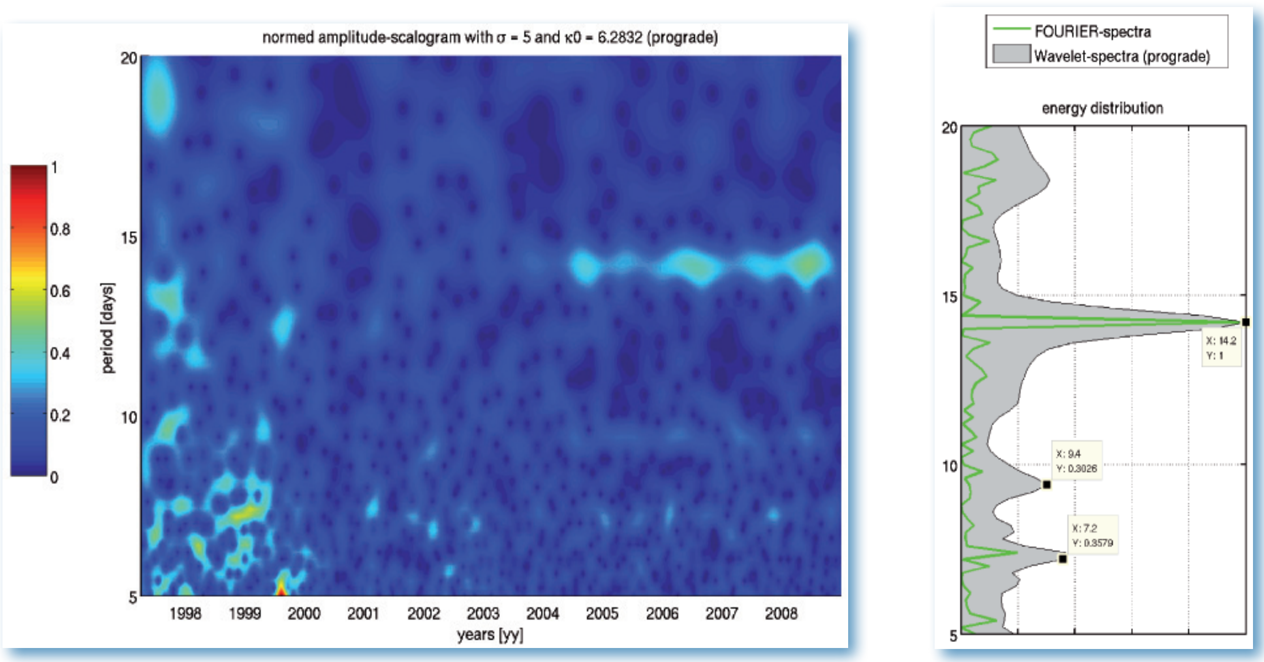


Fig. 1.2.1: Wavelet analysis and Fourier spectrum of IGS x-pole time series

ICRF2

A second realization of the International Celestial Reference System (ICRS) has been computed by an IVS/IERS working group (Ma et al. 2009). The new conventional reference frame (ICRF2) comprises five times as many radio sources, of which the coordinates show a significantly better precision (~ 50 µas), as in the previous frame ICRF-Ext.2 (~ 250 µas). More observations and modelling improvements also increase the accuracy of the realization of the axes of the celestial system by a factor of 2 (~ 10 µas). For the selection of the defining sources, a complete and even sky coverage, an optimal number of defining sources (295) and a significantly larger number of structure images obtained at the higher frequency of the group delay observations (X-band) could be used. In the analysis of ICRF2, atmosphere loading, thermal antenna deformations, a-priori gradients, and the current VLBI realization of the ITRS (VTRF2008a) were adopted.

In contrast to prior frame determinations, the radio source positions, the EOP and global station coordinates (positions and velocities of the VLBI antennas) were simultaneously estimated. This so-called TRF solution enables the consistency to be assessed by comparing the derived EOP with an independent space-geodetic technique (GPS) and the TRF with VTRF2008a. Another independent quality check could be achieved by comparing the resulting radio source positions with positions determined at higher frequencies (K-, Ka- and Q-bands); the maximum differences are currently between 100 and 500 µas. Due to the significantly smaller number of VLBI antennas on the southern hemisphere the radio source position errors still depend slightly on the declination. With the five recently-built, operating VLBI antennas in Australia and New Zealand, the IVS will be able to run significantly more and better southern sky surveys, which is expected to improve the current situation.

In July 2009, the IVS/IERS working group finished the computation of ICRF2 with the compilation of the IERS Technical Note No. 35, which describes the big international effort in detail. Based on this report, the IAU General Assembly decided in August 2009 that the ICRF2 schould be the conventional celestial reference frame from Januar 2010 on (IAU resolution B3, 2009).

Polar motions of the rotation axis and the celestial intermediate pole

Let

$$\Omega_1 = \omega m_1, \quad \Omega_2 = \omega m_2, \quad \Omega_3 = \omega(1+m_3) \tag{1}$$

Dynamics of the rotation axis

be the Cartesian coordinates of the Earth's rotation vector in an Earth-fixed reference system. ω is a constant approximation of the magnitude of the rotation vector so that m_1, m_2, m_3 are small quantities. The (equatorial) polar motion coordinates m_1, m_2 can be combined as the complex number

$$m = m_1 + i\,m_2. \tag{2}$$

The above m satisfies the Euler-Liouville equations in the form

$$m + \frac{i}{\sigma}\dot{m} = \chi - \frac{i}{\omega}\dot{\chi} \tag{3}$$

with the angular momentum function χ, or alternatively in the form

$$m + \frac{i}{\sigma}\dot{m} = \psi \tag{4}$$

where the excitation function is given as

$$\psi = \chi - \frac{i}{\omega}\dot{\chi} \tag{5}$$

(the dot accent denotes derivation with respect to time).

Under the assumption that the solid Earth is a rigid body,

$$\sigma = \frac{C - A}{A}\omega \tag{6}$$

is the Euler frequency of 1/305 days, and the angular momentum function is given by

$$\chi = (\omega c + h) / \{(C - A)\omega\}, \tag{7}$$

where A, C are the equatorial and polar moments of inertia, respectively; the real and imaginary parts of $c = c_{31} + ic_{23}$ are the respective non-diagonal coordinates of the inertia tensor, and the real and imaginary parts of $h = h_1 + i\,h_2$ are the equatorial coordinates of the angular momentum vector due to motions of the ocean and the atmosphere relative to the Earth-fixed system. External torques of the Moon, the Sun and the other planets are disregarded. In the case of a vanishing excitation function, the free rigid-body polar motion resulting from (4) with $\psi = 0$ is the well-known circular motion with the Euler period.

In case of a non-rigid Earth, the polar motion of the rotation axis causes a deformation of the solid Earth due to the elasticity of the mantle and the special properties and motions of the core. This affects in turn the free polar motion so that the frequency σ is changed to the Chandler frequency of approximately 1/430 days. Furthermore, the angular momentum function χ, which causes a forced polar motion superimposed upon the free one, is also modified but still remains a linear function of c and h (Gross, 2007). With these generalizations of (6) and (7), equations (3) – (5) still remain valid.

Kinematics of the rotation axis in terms of the CIP motions

Kinematically, the rotation of the Earth-fixed reference system with respect to a space-fixed system is described by means of the celestial intermediate pole (CIP). It performs, relative to the space-fixed system, a secular precession (which is approximately a regular conical motion with the semi-vertical angle ε and the revolution velocity $\dot{p}$) and, superimposed upon precession, a periodical nutation, described by the parameters $\Delta\psi$, $\Delta\varepsilon$. Relative to the Earth-fixed system, the CIP performs a polar motion with the parameters x, y. The parameters x, y as well as the departures of $\Delta\psi$, $\Delta\varepsilon$ from their model values are numerically determined from space-geodetic observations. The rotation angle about the CIP axis is, traditionally, the Greenwich sidereal time θ.

Differentiating the compound rotation matrix which transforms from the space-fixed to the Earth-fixed system yields the equatorial coordinates of the rotation vector with respect to the Earth-fixed system

$$\begin{aligned}\Omega_1 &= \omega m_1 = \sin\theta \sin\varepsilon(\dot{p}+\Delta\dot{\psi}) - \cos\theta\,\Delta\dot{\varepsilon} + \omega x - \dot{y},\\ \Omega_2 &= \omega m_2 = \cos\theta \sin\varepsilon(\dot{p}+\Delta\dot{\psi}) + \sin\theta\,\Delta\dot{\varepsilon} - \omega y - \dot{x}.\end{aligned} \tag{8}$$

With the complex substitutions

$$\dot{P} = \sin\varepsilon(\dot{p}+\Delta\dot{\psi}) + i\,\Delta\dot{\varepsilon} \tag{9}$$

for the precession and nutation of the CIP and

$$p = x - i\,y \tag{10}$$

for its polar motion, equations (8) can be combined to

$$m = \frac{i}{\omega}\exp(-i\theta)\dot{P} + p - \frac{i}{\omega}\dot{p}, \tag{11}$$

which expresses the polar motion *m* of the rotation axis as a function of the motions of the CIP in both systems.

Equation (11) shows that a long-period motion of the CIP in the space-fixed system involves a retrograde diurnal polar motion of the rotation axis.

Dynamics of the CIP

In equation (3), the angular momentum function χ on the right-hand side is defined under the assumption that there are no external torques acting on the Earth. External torques are the essential cause of precession and nutation of both the rotation axis and the CIP. Thus, in accordance with (3), precession and nutation can also be disregarded in (11), yielding

$$m = p - \frac{i}{\omega}\dot{p} \tag{12}$$

(which was also derived by Gross in 1992 in a different way). In (12), as well as in (3) and (4), *m* is the polar motion of the rotation axis without its diurnal component forced by external torques.

Inserting (12) into (3) yields

$$p - \frac{i}{\omega}\dot{p} + \frac{i}{\sigma}\dot{p} + \frac{1}{\omega\sigma}\ddot{p} = \chi - \frac{i}{\omega}\dot{\chi}. \tag{13}$$

This second-order differential equation describes the polar motion of the CIP as a function of the angular momentum function χ.

A single integration leads to the first-order differential equation

$$p + \frac{i}{\sigma}\dot{p} = \chi - \alpha\exp(-i\omega t) \tag{14}$$

with a complex integration constant α. The second term on the right-hand side represents a retrograde diurnal revolution. Since the CIP, according to its definition, has no such motion component, α has to be set equal to zero. The result is

$$p + \frac{i}{\sigma}\dot{p} = \chi. \tag{15}$$

This differential equation has the same structure as (4): The polar motion p of the CIP depends on the angular momentum function χ in the same way as the polar motion m of the rotation axis depends on the excitation function ψ.

Related publication:

MA C., ARIAS F., BIANCO G., BOBOLTZ D., BOLOTIN S., CHARLOT P., ENGELHARDT G., FEY A., GAUME R., GONTIER A., HEINKELMANN R., JACOBS C., KURDUBOV S., LAMBERT S., MALKIN Z., NOTHNAGEL A., PETROV L., SKURIKHINA E., SOKOLOVA J., SOUCHAY J., SOVERS O., TESMER V., TITOV O., WANG G., ZHAROV V.: The second realization of the International Celestial Reference Frame by Very Long Baseline Interferometry. In: A. Fey and D. Gordon (Eds.): IERS Technical Note, No. 35, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt a. M., 2009

1.3 Fundamentals of physical parameter determination

The estimation and analysis of geophysical parameters and their temporal variations are an important task of geodesy. These parameters provide information on processes in the Earth's system and thus contribute to investigations of the Global Change. DGFI is involved with physical parameter estimation by processing gravity gradients from the data of the GOCE mission, the determination of the vertical electron content of the ionosphere from satellite mission data and the estimation of the dynamic ocean topography from altimeter data. In the following the implemented processing strategies are explained and the results are discussed.

GOCE Gravity Gradient Preprocessing

DGFI is involved in the preprocessing of the GOCE gravity gradients, in close collaboration with TU Munich (IAPG), as part of the data processing for the GOCE High-level Processing Facility (HPF). The gravity gradient preprocessing includes corrections for temporal gravity field variations, outlier detection, gravity gradient external calibration, as well as the transformation of the gravity gradient tensor from the instrument frame to the local north-oriented frame (LNOF), which is a reference frame directly connected with the Earth, see Figure 1.3.1. The gravity gradient preprocessing is done in quick-look (QL) mode and final mode. The QL mode has a short latency (preprocessing within one day after data reception) and supports mission operations, whereas the final mode has a longer latency (preprocessing within two weeks after data reception) and aims at providing the best gravity gradients possible (Bouman et al. 2009).

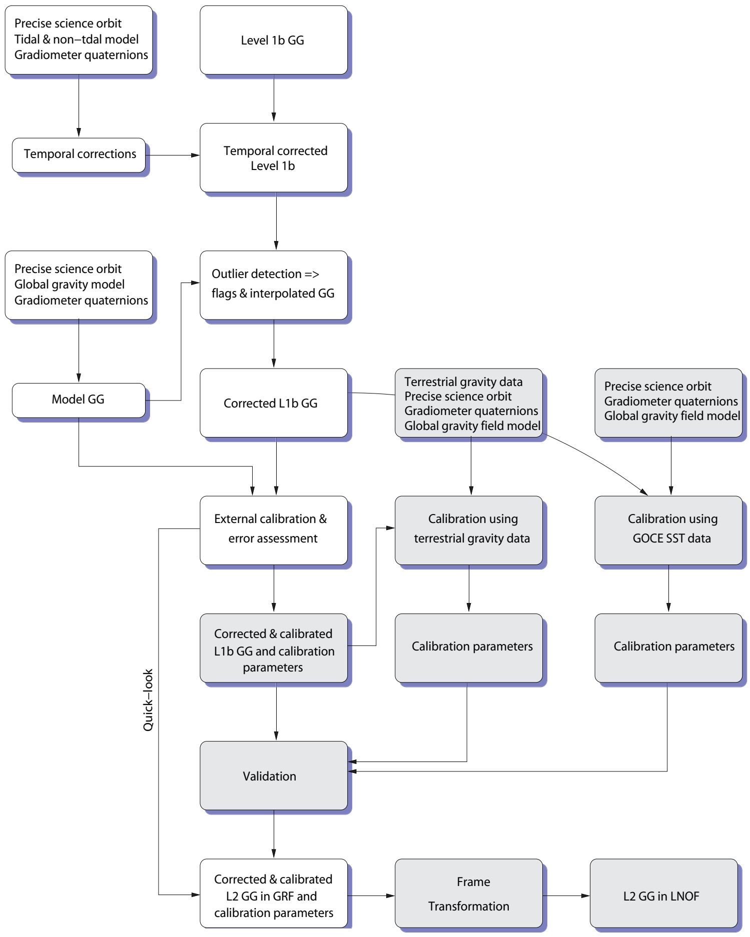


Fig. 1.3.1: Flowchart of gravity gradient preprocessing at the GOCE HPF. The blocks in grey are part of the final mode only.

With the launch of the GOCE satellite on March 17, 2009, and the start of the first measurement phase end of September 2009, the GOCE HPF is now fully deployed. One of the main activities in the initial phase of the mission is the calibration and validation of the GOCE gradiometer, as well as synthesis of these activities (Bouman et al. 2008). Because the gravity gradients are one of the main end-products of GOCE, external calibration efforts are mainly focussed on this type of observations. Nevertheless, a new method was developed that allows the external calibration of the GOCE common and differential accelerations using star sensor data and an existing global gravity field model (Rispens and Bouman 2009). The differential accelerations are the quantities from which the gravity gradients are derived. They are related for V_{xx} by

$$V_{xx} = \frac{2a_{d,14,x}}{L_x} - \omega_y^2 - \omega_z^2$$

where $a_{d,14,x}$ is the differential acceleration in flight direction, L_x the length of the gradiometer arm and ω_y, ω_z the angular velocities around the y- and z-axis respectively. Similar relations hold for the other gravity gradients. In normal GOCE processing, the differential accelerations as well as the angular velocities are derived from the in-flight calibrated accelerations. Subsequently the gravity gradients can be computed. Conversely it is possible to compute the gravity gradients using an existing global gravity field model and to derive the angular velocities from star sensor data. Then the differential accelerations can be calibrated determining so-called calibration matrices that account for accelerometer scale factors, non-orthogonalities and misalignments. An example of the new external calibration method is shown in Figure 1.3.2.

Shown are power spectral densities of the ratio of the errors of the differential accelerations after and before external calibration. The results are based on simulated data. A ratio smaller than 1 means that the external calibration reduces the error of the differential accelerations. This is especially true for the longer wavelengths, below the GOCE measurement bandwidth (MBW) between $5 \cdot 10^{-3}$ and 10^{-1} Hz, to the right of the red lines. Note that the GOCE gradiometer was designed as to perform best in the MBW.

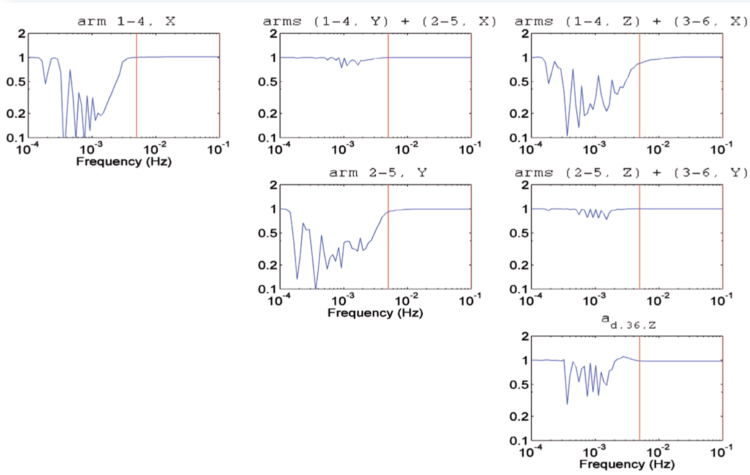


Fig. 1.3.2: Ratio between the errors of the differential acceleration after and before external calibration. Results are based on simulated GOCE data.

GNSS VTEC measurements

For the regional modelling of the vertical total electron content (VTEC) (described in chapter 2.3) measurements of ground-based GNSS stations are needed. We computed code-levelled phase observations L_i [m] from the inter-frequency differences of code and phase measurements (given in 30 sec daily RINEX files) and converted them to slant total electron content (STEC); see the formulae in Table 1.3.1. Within this process we corrected the ionospheric signal for differential code bias (DCB) provided by the Center for Orbit Determination in Europe (CODE) to account for the different signal delay times within the satellites and the receivers. Based on the assumption of a single-layer model, the STEC is then converted to the vertical (VTEC). We used the modified single layer mapping (MSLM) function from CODE for this procedure. The resultant VTEC is the vertical integral up to GNSS satellite orbit height (about 20000 km). As these VTEC values are to be combined with measurements from other space geodetic techniques and with the ionosphere model IRI-2007, which is only reliable up to about 2000 km, the plasmaspheric electron content was neglected. To convert the GNSS VTEC from orbit height to 2000 km, we used a fraction based on IRI values, published by JPL.

Table 1.3.1: Computation steps: From terrestrial GNSS measurements to VTEC

Levelling observation L_i computed from code difference P_i and phase difference Φ_i N: observations per arc	$L_i = \Phi_i + \frac{1}{N}\sum_{i=1}^{N}(P_i - \Phi_i)$
Conversion from [m] to [TECU] 1 TECU = 10^{16} electrons/m^2	$STEC = \int_D N_e ds = L_i \frac{f^2}{40.3}$
Mapping from signal path with zenith distance z to the vertical MSLM function from CODE R = 6371 km, H = 506.7 km, α = 0.9782	$M(z) = \frac{STEC}{VTEC} = \frac{1}{\cos z'}$ $with\ \sin z' = \frac{R}{R+H}\sin(az)$
Interpolation from GNSS orbit height to 2000 km	$VTEC_{<2000} = VTEC_{<orbit} \cdot \frac{VTEC_{IRI<orbit}}{VTEC_{IRI<2000}}$

VTEC modelled with spherical harmonics

The flowchart in Figure 1.3.3 shows the different elements of the procedure developed at DGFI to model ionospheric signals such as VTEC or the electron density N_e. For the parameterization our model allows various sets of base functions. Modelling the high-resolution ionosphere, the long-wavelength spatial parts can be represented globally, e.g., by using trigonometric B-splines or spherical harmonics (SH). We studied two different combined, i.e. space-time, approaches for a three-dimensional global model of VTEC depending on longitude λ, latitude φ and time *t*. The mathematical foundations of the first approach are shown in Table 1.3.2. The time-dependent coefficients $c_{n,m}(t)$ of the 2-D SH expansion (Eq.1) in longitude and latitude are modelled additionally by the 1-D series expansion (Eq. 3) in terms of the so-called endpoint-interpolating quadratic B-splines (Eq. 4) of resolution level *J*.

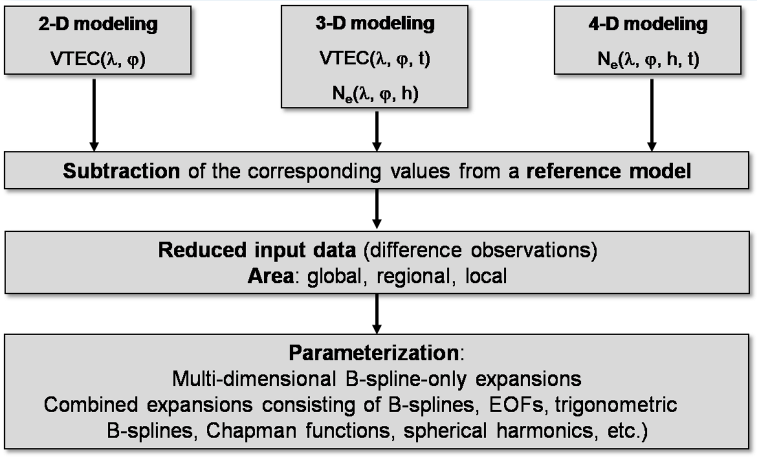


Fig. 1.3.3: Flowchart of the procedure to model multi-dimensional ionospheric signals

Table 1.3.2: 3-D VTEC model based on a spherical harmonic expansion

$$\Delta VTEC(\theta,\lambda,t)=\sum_{n=0}^{n_{\max}}\sum_{m=-n}^{n} c_{n,m}(t)\; Y_{n,m}(\theta,\lambda) \quad (1)$$

$$Y_{n,m}(\theta,\lambda) = \text{spherical harmonic of degree } n \text{ and order } m \quad (2)$$

$$c_{n,m}(t)=\sum_{k=0}^{K} c_{n,m,k}\; N_{J,k}^{2}(t) \quad (3)$$

$$N_{J,k}^{2}(t) = \text{endpoint-interpolating quadratic B-spline of level } J \quad (4)$$

$$\Delta VTEC(\theta,\lambda,t)=\sum_{n=0}^{n_{\max}}\sum_{m=-n}^{n}\sum_{k=0}^{K} c_{n,m,k}\; Y_{n,m}(\theta,\lambda)\; N_{J,k}^{2}(t) \quad (5)$$

VTEC modelled with B-spline expansions

The mathematical foundations of the second approach are shown in Table 1.3.3. The time-dependent coefficients $d_{k_1,k_2}(t)$ of the 2-D expansion (Eq. 6) in trigonometric B-splines (Eq. 7) for longitude and endpoint-interpolating quadratic B-splines (Eq. 9) for latitude are again modelled as 1-D series expansion (Eq. 8) in terms of endpoint-interpolating quadratic B-splines (Eq. 4).

Table 1.3.3: 3-D VTEC model based on B-spline expansions

$$\Delta VTEC(\theta,\lambda,t)=\sum_{k_1=0}^{K_1}\sum_{k_2=0}^{K_2} d_{k_1,k_2}(t)\; T_{J_1,k_1}^{2}(\lambda)\; N_{J_2,k_2}^{2}(\theta) \quad (6)$$

$$T_{J,k}^{2}(\lambda) = \text{trigonometric quadratic B-spline of level } J \quad (7)$$

$$d_{k_1,k_2}(t)=\sum_{k_3=0}^{K_3} d_{k_1,k_2,k_3}\; N_{J_3,k_3}^{2}(t) \quad (8)$$

$$N_{J,k}^{2}(t) = \text{endpoint-interpolating quadratic B-spline of level } J \quad (9)$$

$$\Delta VTEC(\theta,\lambda,t)=\sum_{k_1=0}^{K_1}\sum_{k_2=0}^{K_2}\sum_{k_3=0}^{K_3} d_{k_1,k_2,k_3}\, T_{J_1,k_1}^{2}(\lambda)\; N_{J_2,k_2}^{2}(\theta)\; N_{J_3,k_3}^{2}(t) \quad (10)$$

We applied the two approaches to regularly gridded VTEC input data from the Center for Orbit Determination in Europe (CODE). As reference model we used IRI-2007. As input data we introduced the difference between CODE VTEC data and the corresponding VTEC reference values. These difference observations are given on a regular 3-D grid with a spacing of 5° in longitude, 2.5° in latitude and 2 hours in time. For our first model (Eq. 5) we chose $n_{max} = 24$ and $J = 3$, i.e. we solve for 6250 unkowns.

Figure 1.3.4 shows the estimated VTEC signal after adding the reference model. The root mean square (RMS) value of the deviations between the original CODE model and our model estimation amounts to 0.13 TECU for time $t = 16{:}00$.

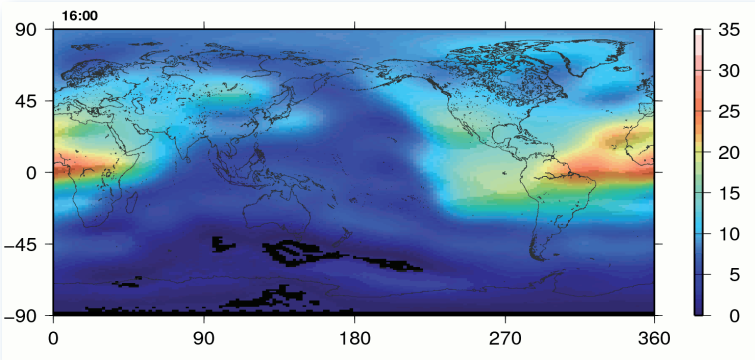


Fig. 1.3.4: Estimated VTEC signals according to Eq. (5) considering the reference model IRI-2007

For our second model we chose in Eq. (10) $J_1 = 4$, $J_2 = 5$ and $J_3 = 3$, i.e. the model contains altogether 5776 unknown coefficients d_{k_1,k_2,k_3}. Figure 1.3.5 depicts the differences between the two model estimations according to Eqs. (5) and (10). The corresponding RMS value is 0.09 TECU.

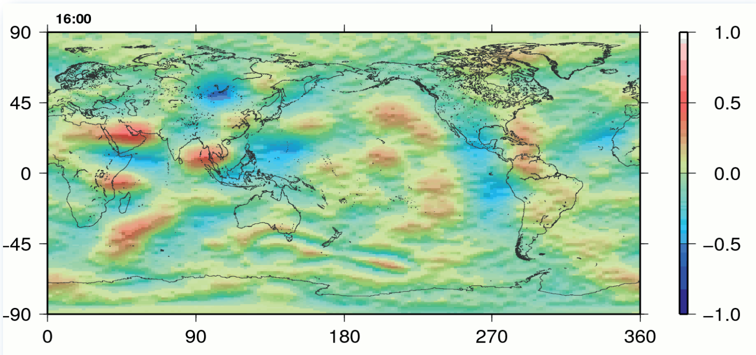


Fig. 1.3.5: Differences between the estimated VTEC signals according to Eqs. (5) and (10)

Related publications:

BOUMAN J., CATASTINI G., CESARE S., JARECKI F., MÜLLER J., KERN M., LAMARRE D., PLANK G., R ISPENS S., VEICHERTS M., TSCHERNING C.C., VISSER P.: Synthesis analysis of internal and external calibration. GOCE HPF, GO-TN-HPF-GS-0221, 2008

BOUMAN J., RISPENS S., GRUBER T., KOOP R., SCHRAMA E., VISSER P., TSCHERNING C.C., AND VEICHERTS M.: Preprocessing of gravity gradients at the GOCE high-level processing facility. Journal of Geodesy, Vol. 83, 659-678, 2009, DOI: 10.1007/s00190-008-0279-9

RISPENS S., BOUMAN J.: Calibrating the GOCE accelerations with star sensor data and a global gravity field model. Journal of Geodesy, Vol 83, 737-749, 2009, DOI: 10.107/s00190-008-290-1

1.4 Combination of geometric and gravimetric observations

The objective of combining geometric and gravimetric observations is the consistent determination of time-dependent parameters of the rotation, station positions and the gravity field of the Earth within a global geometric and gravimetric reference frame. The overall intention is to obtain a higher resolution and accuracy of the solve-for parameters defining the geometric and physical reference frames in time and space. In 2009, investigations on the World Height System continued and are reported here.

Vertical datum unification

One of the most important problems of modern geodesy is the definition and realization of a global vertical reference system, which, with high accuracy, unifies the existing classical height datums; that means, all physical heights (or geopotential numbers) have to be referred to one and the same equipotential surface, defined and realized in a global frame. The reference level (zero-height surface) of the existing height datums has been realized by the mean sea level measured at individual tide gauges and averaged during different time periods. Therefore, at present, there are as many reference levels (vertical datums) as reference tide gauges, and they are related to different epochs.

Fundamental quantities

The fundamental quantities of interest for the height datum unification are the geopotential differences ($\delta W_j = W_0^j - W_0$, called also height datum discrepancies) between a conventional global reference surface (W_0) and the equipotential surface (W_0^j) realized by the mean sea level measured at each tide gauge J (Figure 1.4.1.).

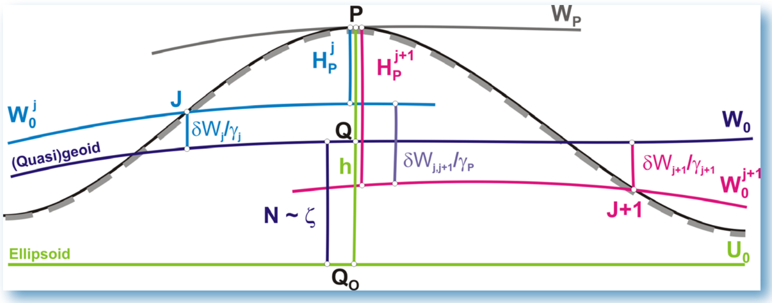


Fig. 1.4.1: Discrepancies δW_j between classical height datums and a global vertical reference system

Strategy

Many authors have formulated different strategies to estimate the δW_i values based on the solution of the geodetic boundary value problem (GBVP) including terrestrial and satellite gravity data. However, given the actual high accuracy of the geometrical reference system and the improved geometrical representation of the sea surface through satellite altimetry, it is today possible to design a strategy based on the consistent combination of geometrical and gravity observables to get an accurate realization of $h = H^N + \zeta$ (or $h = H + N$) in a global frame. Accordingly, the empirical determination of the δW_j terms is feasible under the following constraint (Sánchez 2009):

$$\gamma_P h_P - \left(W_0^j - W_P^j\right) - T_P^j - 2\delta W_j = 0 \quad (1)$$

where $\left(W_0^j - W_P^j\right)$ is the geopotential number of the evaluation point P referred to the individual level W_0^j, T_P^j is the anomalous potential of P, γ_P is the normal gravity of P at the Earth's surface and h_P is the ellipsoidal height (Figure 1.4.1). Geopotential numbers are derived from spirit levelling in combination with terrestrial gravity data, the anomalous potential is estimated after solving the GBVP, and the ellipsoidal heights are determined on the sea surface by satellite radar altimetry and on land by GNSS positioning. Since all these variables (geopotential numbers, local reference levels, (quasi)geoid undulations, and ellipsoidal heights) are associated to different epochs, it is necessary to define, by convention, a common epoch (t_0) and to reduce those variables to it. Then, the height-related observables shall be recalculated and iterations for the determination of the δW_i terms shall be carried out until getting a mm-level accuracy. Figure 1.4.2 summarizes the main features of the proposed strategy for the definition and realization of a global vertical reference system (Sánchez 2009).

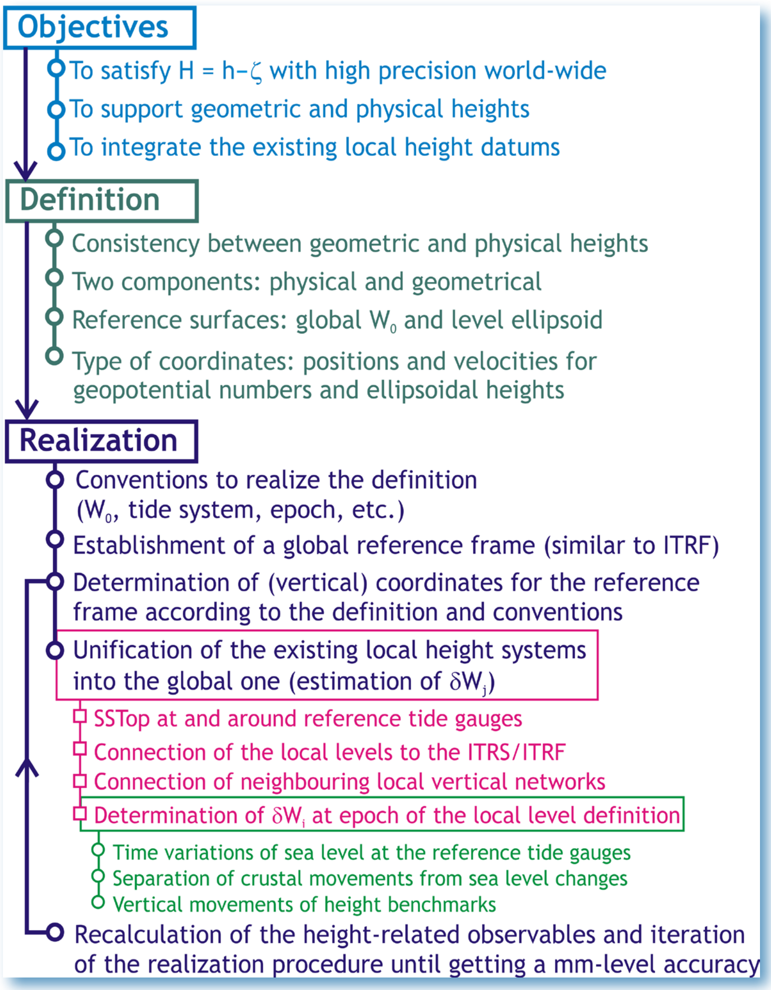


Fig. 1.4.2: Strategy for the definition and realization of a global vertical reference system, including the unification of the existing height datums

Combination

To guarantee the appropriate combination of the mentioned parameters, observation equations based on Eq. (1) must be formulated in three approaches (Figure 1.4.3): at the reference tide gauges of the classical height datums (coastal approach), on marine areas close to those tide gauges (oceanic approach), and at reference stations of the geometrical reference frame (continental approach). The final datum discrepancies δW_j, δW_{j+1}, ... are then estimated by a combined adjustment of all these observation equations. As an example, Figure 1.4.4 and Table 1.4.1 show some results after applying this strategy on the northern part of South America. The W_0 value applied in these computations (62 636 853,1 m^2 s^{-2}) was estimated by Sánchez (2009). The empirical evaluation presented here is possible due to the scientific cooperation between DGFI and the Geographical Institutes of Venezuela (IGVSB), Ecuador (IGM), and Colombia (IGAC), under the umbrella of SIRGAS.

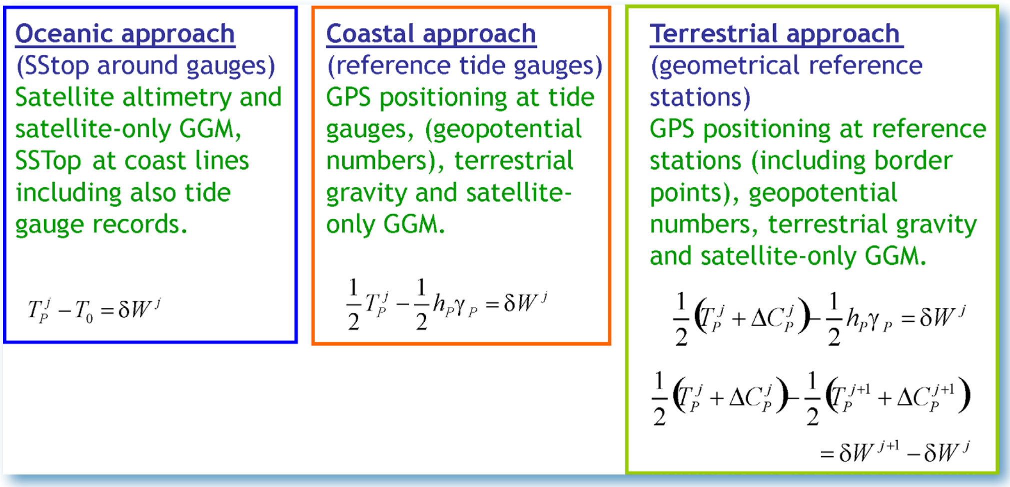


Fig. 1.4.3: Coastal, oceanic and terrestrial appraoches for the determination of the vertical datum discrepancies δW_j

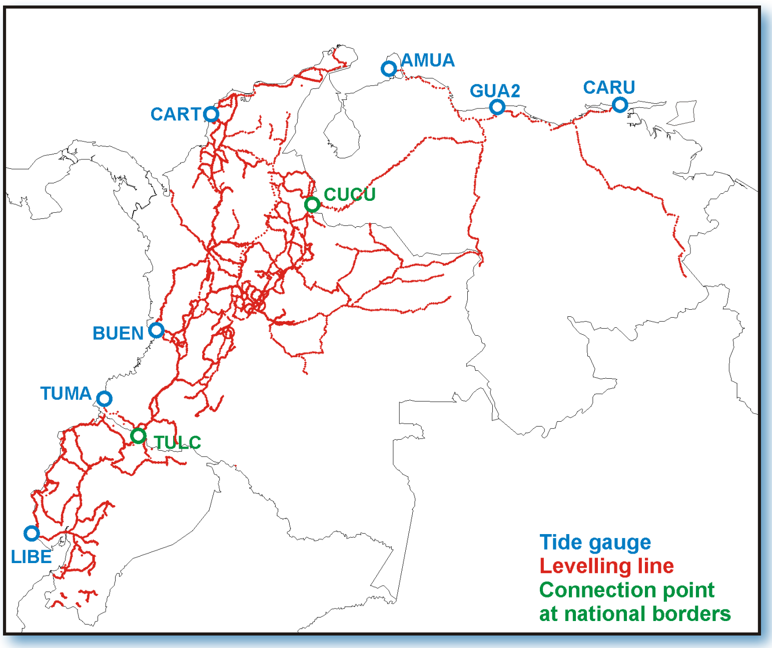


Fig. 1.4.4: Input data for the determination of the vertical datum discrepancies between Ecuador, Clombia, and Venezuela

Table 1.4.1: Vertical datum discrepancies between Ecuador, Colombia, and Venezuela. The potential differences were divided by normal gravity values to express the quantities in distance units (i.e. [cm]). W_0 *= 62 636 853,1* $m^2\ s^{-2}$ *is applied as reference level.*

Country	Tide gauge	Approach				
		Coastal $(\delta W_j/\gamma_i)$ [cm]	Oceanic $(\delta W_j/\gamma_i)$ [cm]	Mean [cm]	Terrestrial $(\delta W_j/\gamma_i)-(\delta W_j/\gamma_i)$ [cm]	
Ecuador	LIBE	75	55	65	Between Colombia and Ecuador	26
Colombia	TUMA	−21	–25			
	BUEN	−28	−33			
	CART	−26	−23			
	Mean	−25	−27	−25	Between Colombia and Venezuela	19
Venezuela	AMUA	−41	−43			
	GUA2	−53	−57			
	CARU	−40	−46			
	Mean	−44	−48	−46		

Related publication:

SÁNCHEZ L.: Strategy to establish a global vertical reference system. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 273–278, 2009, DOI: 10.1007/978-3-642-00860-3_42

2 Earth System Analysis

The processes of the System Earth are in general described by mathematical and physical models. Today, an increasing number of parameters used to characterize state and temporal evolution of these processes become measurable through observations of precise space-geodetic techniques. The research field "Earth System Analysis" shall investigate the interrelationship between geodetic observations and model parameters. The thorough analysis of parameters – most rigorously estimated by combining different space-geodetic techniques – promises to overcome the weakness of individual observation approaches, such as low sensitivity or insufficient sampling rates. Moreover, system analysis can help to improve the signal-to-noise ratio, to identify model deficiencies and to introduce novel or extended parameterization, with the final goal to obtain a more precise description of processes of the System Earth.

This research field is divided into four topics. Topic 2.1 focuses on new methods to model the gravity field by different base functions (wavelets, splines or empirical orthogonal functions), which allow to describe also the temporal variations. Topic 2.2 is dedicated to the kinematic description of the mean sea surface by combining the data of all available satellite altimeter systems, which have to be harmonized and carefully cross-calibrated in advance. Mass redistributions within or between individual components of the System Earth like the atmosphere, the oceans, and the hydrosphere are subject of the investigations in Topic 2.3 in order to study the effect on the Earth rotation, its gravity field, and its shape. In Topic 2.4 the actual plate kinematic models are improved and combined with models of continuum deformation.

2.1 Models of the gravity field

For some years DGFI research on modelling the Earth gravity field has focused on regional representations by means of localizing base functions, such as spherical scale functions, B-splines or wavelets. As all global gravity field models are provided by spherical harmonics series and shall be used as reference for local refinements, the interrelationship between local and global base functions remains an important subject.

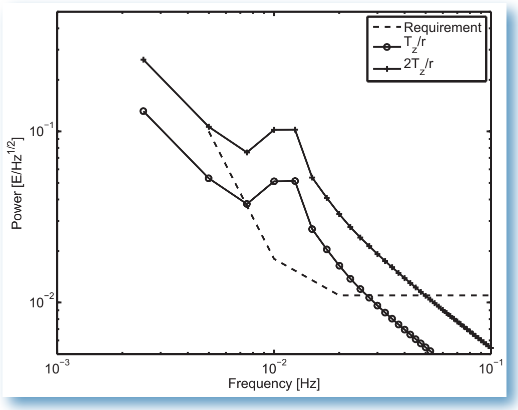
Software tools have been developed or improved to evaluate ultra-high-degree harmonic series (up to or above degree 2160) for functions up to the second derivative, to propagate errors with the full variance-covariance matrix, to generate spherical harmonic series by quadrature of Gauss-Legendre or Reuter grids, and to convert between ellipsoidal and spherical harmonics.

Validation of GOCE with satellite altimetry

Since June 2009 the DGFI contributes to the REAL-GOCE project funded by the BMBF and the DFG. One of the tasks is dedicated to the validation of GOCE gradients by means of satellite altimetry.

In first approximation, satellite altimetry delivers geoid heights along tracks. Using Bruns´ formula, the geoid heights can be converted to the disturbing potential. Taking the along-track second derivatives of these values then gives gravity gradients along tracks, which are related to the vertical gravity gradient in satellite ground track crossovers. After upward continuation, these gravity gradients could then be used for GOCE validation. The original idea of computing gravity gradients from satellite altimeter data was presented in 1991 by Rummel and Haagmans (noted below as RH91). The following is an assessment of the associated systematic errors.

Fig. 2.1.1: Power spectral density of the curvilinear correction term at GOCE altitude for a synthetic north-south altimeter track. The dashed line shows the GOCE requirements on the gravity gradient trace.



The relation between the along-track gravity gradients from altimetry and those in a local Cartesian frame (*x,y,z*), as provided by GOCE, is

$$T_{xx} = T_{uu} + \frac{T_z}{r}; \quad T_{yy} = T_{vv} + \frac{T_z}{r} \quad ,$$

where *u* and *v* are the distances along ascending and descending tracks, respectively. The T_z/r term is missing in RH91. We call it the curvilinear correction term, and it may be above the GOCE requirements in the measurement bandwidth (see 1.3). See Figure 2.1.1 for an example. In addition, if μ is the difference between the crossover angle and 90°, the relation between the along-track gravity gradients and the vertical gravity gradient is (Bouman et al. 2009)

$$-T_{zz} = \frac{T_{uu} + T_{vv} - 2\sin\mu\, T_{uv}}{(\cos\mu)^2} + \frac{2T_z}{r},$$

which was derived incorrectly in RH91. The above relation could numerically be verified down to mE level (Eötvös, 1 E = $10^{-9}s^{-2}$) using EGM2008 up to degree and order 2160.

The mean sea surface as provided by satellite altimetry is the sum of geoid heights and dynamic ocean topography (DOT). With elevations of ± 1–2 m, the DOT is relatively small compared to geoid heights, and because it is relatively smooth, the DOT may be negligible when computing gravity gradients from satellite altimetry. Analyses based on the model DOT2008A show that the DOT signal root-mean-square is between 20 and 50 mE for the different gravity gradients. This confirms that the effect of the DOT on gravity gradients is indeed small. Nevertheless, for the different gravity gradients, the maxima may be as large as 0.2 – 0.6 E for the major ocean currents. The DOT gravity gradient signal may be above the GOCE requirements, Figure 2.1.2. See also Figure 2.1.3, in which the T_{zz} DOT signal is shown.

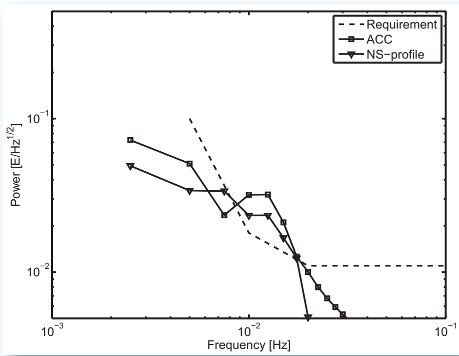


Figure 2.1.2: Power spectral density of vertical gravity gradient from DOT2008A at GOCE altitude for a synthetic North-to-South satellite altimeter track and a track in the Antarctic Circumpolar Current (ACC). The dashed line shows the GOCE requirements on the gravity gradient trace.

The computation of second derivatives along tracks involves numerical differentiation, which amplifies noise. RH91 therefore proposed to use smoothing cubic splines which allows smoothing or low-pass filtering of the data. We assessed the associated cubic spline second derivative truncation error. For a synthetic North-South altim-

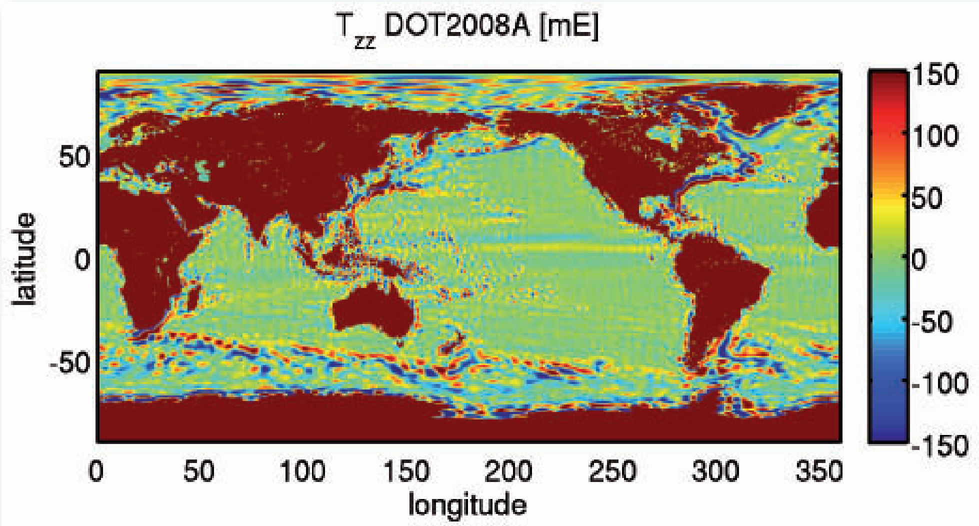


Fig. 2.1.3: Vertical gravity gradient from DOT2008A. The colour scale has been limited to ±150 mE.

Table 2.1.1: Cubic-spline second-derivative error for a synthetic North-to-South altimeter profile. The maximum is for the absolute signal.

Case	Max	RMS
1 Hz, Earth's surface	4.0 E	0.7 E
10 Hz, Earth's surface	40 mE	6 mE
1 Hz, GOCE altitude	<0.1 mE	<0.1 mE

eter profile, disturbing potential values were generated using EGM2008 complete to degree and order 2160. These values were used to derive the along-track second derivatives using cubic-spline interpolation. The differences between these second derivatives and the corresponding gravity gradients directly generated with EGM2008 are shown in Table 2.1.1. The second derivative error at the Earth's surface is too large for 1 Hz satellite altimeter data (1 Hz corresponds to 7 km along-track), whereas the error for the 10 Hz data is at a satisfactory level. At GOCE altitude, in contrast, the second derivative error for 1 Hz altimeter data is very small, well below the GOCE measurement errors.

Validating the geometry-gravity relationship

The close relationship between geometry and gravity was subject of numerical computations performed to investigate how the geometry should be treated in order to derive gravimetric quantities with highest precision. The well known relationship

$$T_{zz} = -2\gamma J$$

suggests to compute the mean curvature J of an equipotential surface of the Earth gravity field in order to derive by means of the normal gravity γ the second derivative T_{zz} of the disturbing potential. The mean curvature J is defined by the arithmetic mean of the curvatures with respect to two orthogonal parameter curves. It should be emphasized that the geometry-gravity relationship given above holds only for the curvature of an equipotential surface. Any deviation, e.g. between mean sea level and geoid has to be taken into account.

The practical computation of J strongly depends on the way the surface is represented. In most cases the surface is provided in terms of gridded data, giving the heights above a sphere or a reference ellipsoid. This implies that the curvature of these reference surfaces ($J_{sph} = R^{-1}$ for the sphere with radius R or $J_{ell} = 0.5(N^{-1}+M^{-1})$ with N and M the principal radii of curvature) has to be added to any curvature derived from the plane data.

For plane data on a regular grid, the most simple and direct approach to derive *J* consists in applying a three-point or a five-point finite-difference approximation for the second derivatives (see Figure 2.1.4). For a more general data distribution, e.g. a three-dimensional point cloud, relationships of differential geometry (Euler's and Meusnier theorems or Gauss-Bonnet scheme) are relevant. For a surface in parametric form, *J* can be derived as function of the coefficients of the first and second fundamental forms.

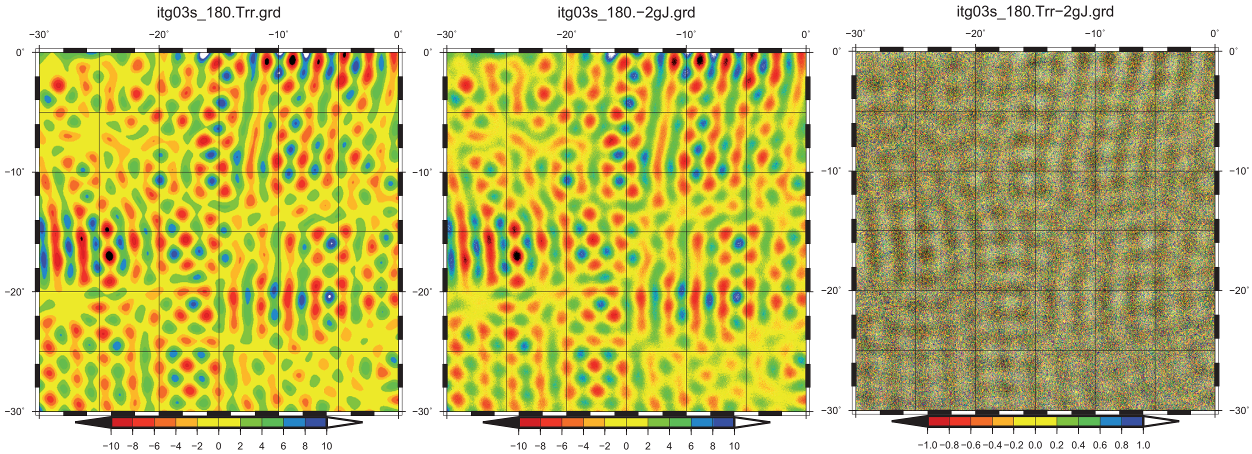


Fig. 2.1.4: The second derivative T_{zz} of the ITG03S disturbing potential (left), compared with of values of $-gJ$ derived by finite difference approximations of the curvature J of the ITG03S geoid (centre) and the differences between both quatities (right). All units are in Eötvös E (= $10^{-9}s^{-2}$).

Related publication:

Bouman J., Bosch W., Sebera J.: Assessment of systematic errors in the computation of gravity gradients from satellite altimeter data. Submitted to Marine Geodesy, 2009.

2.2 Kinematics of the mean sea level

The description of the mean sea level kinematics requires a comprehensive, consistent and up-to-date altimeter database. In 2009, not only the content of the DGFI database was updated and enhanced but also an online user interface was established (OpenADB). Further work was done concerning the cross calibration of altimeter missions in order to be able to handle all missions together and to allow a reliable estimation of the evolution of the sea level. Special points of investigation were ocean tide modelling as well as the dynamic ocean topography.

Enhancement of the DGFI altimeter data base

The following upgrades and changes were performed:

- The data base was enlarged with data of the radar altimeter mission JASON2, launched in June 2008 and continuing the successful missions TOPEX and JASON1.
- The replacement of JASON1 GDR-B data with GDR-C data has been nearly completed. At the moment, both versions are stored in parallel. As investigations indicated a significantly better performance of the new version (see below), the GDR-B data will soon be replaced by the GDR-C.
- For TOPEX new GRACE-based orbits were gathered.
- For ENVISAT new ESA orbits are now available.
- For the JASON1 cycles 228−259, a replacement product for the wet tropospheric correction was applied. It reflects a re-calibration of the Jason Microwave radiometer JMR, which is not part of the GDR data for this specific time period.
- A new global mean sea surface model (DNSC08) was included in the database. It could be used as an alternative to the existing CLS01.
- The new gravity field models EGM08 and ITG-Grace03 were evaluated for the along-track passes of all satellites.
- The dynamic atmospheric correction (DAC, produced by CLS, provided by AVISO) was updated. The new inverted barometric correction is based on a combination of MOG2D for the high-frequency part forced by pressure and wind and an additional effect for low frequencies.
- A bug in the long-period tides of the FES2004 ocean tide model was corrected.
- The integration of high-frequency satellite data into the database was started. The first cycles of ICESat 40Hz data were translated to DGFI format. The aim is to store the high-frequency data of all missions in addition to the 1Hz data sets.
- An on-line user interface of the DGFI altimeter data base (OpenADB, see chapter 4) was established.

Multi-Mission cross calibration MMXO

With the upgraded data set, a new multi-mission crossover analysis was performed including the new mission JASON2 and the JASON1 GDR-C data set. The program algorithm did not change, still minimizing the crossover differences as well as the consecutive radial errors to reach a smooth time series of radial errors without introducing an analytical function.

A crucial point within the multi-mission crossover analysis is the statistical description of the input data. In order to consider quality differences of the crossovers, a weighting is performed taking into account a) the quality of interpolation of the crossover position (rms of crossover), b) the time interval between the crossover paths as well as between the consecutive errors and c) the performance differences of the various missions. To get more robust and reliable weighting factors, a Variance Component Estimation (VCE) was implemented. First investigations show promising results but some improvements are still necessary.

JASON1 GDR-C data

The calibration result for JASON1 w.r.t. TOPEX is shown in Figure 2.2.1. For the time period under investigation, a global mean range bias of 13.84 ± 0.38 cm for GDR-B and 9.97 ± 0.35 cm for GDR-C was computed. Taking into account the TOPEX absolute range already included in the TOPEX MGDR, the absolute bias of JASON1 is reduced from 12.3 cm to 8.5 cm by switching to the GDR-C data set. The global mean difference between both data sets is 3.9 ± 0.2 cm and shows an annual signal with amplitude of approximately 2 mm.

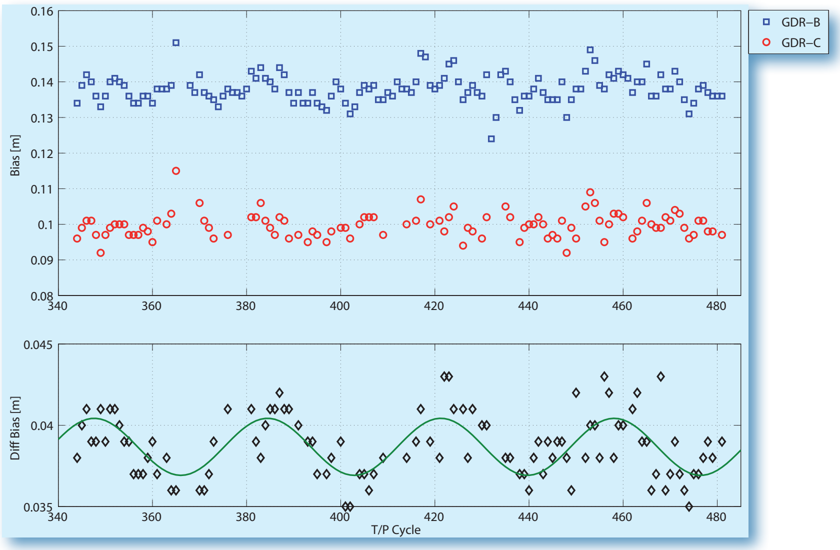


Fig. 2.2.1: Range Bias [m] of JASON1 w.r.t. TOPEX. 10-day cycle mean values are shown in blue for GDR-B data and in red for GDR-C data. The difference of both data versions is shown in black in the lower plot.

JASON2 relative range bias

Figure 2.2.2 shows the global range bias of JASON2 which is computed with respect to JASON1. For the first 25 cycles the mean range bias is 17.4 cm. Most of this offset could be explained by ground parameter differences (e.g. a truncate effect in the pulse repetition frequency) and will be improved with the next data version.

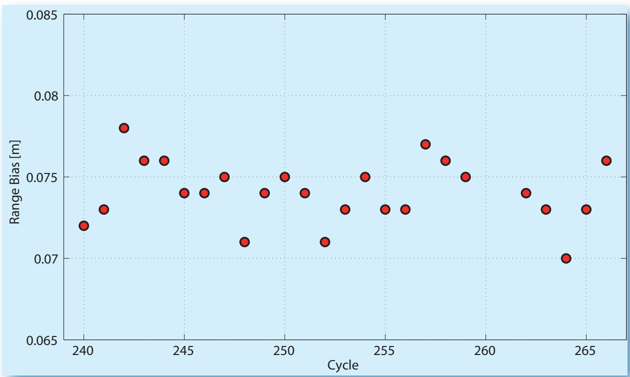


Fig. 2.2.2: Relative Range Bias of JASON2 (GDR-T) with respect to JASON1. Cycle 240 to 259 is the calibration/validation phase, whereas from cycle 262 JASON-1 is flying on an interleaved orbit.

Global ocean tide modelling EOT08a improvements

The good performance of the tide model EOT08a developed at the DGFI in 2008 clearly demonstrates the potential of multi-mission altimetry for global ocean tide modelling. The strengths of this model are the tides in shallow water. However, the error analysis was too optimistic and the relative weighting of different missions was done empirically. Therefore, the present investigation focussed on accounting for correlations between observations along the same ground track and applying a more realistic weighting scheme for the altimeter missions. To achieve high spatial resolution, the altimeter data of TOPEX/Poseidon, ERS-1/2, ENVISAT, and Jason-1 were used. Even the geodetic phases of ERS-1 provide valuable information for the separation of tidal constituents. The Patagonian shelf was chosen as a test area, as the tides in shallow water areas remain a challenging task in tide modelling.

The residual harmonic analysis was applied with respect to FES2004 because this study focuses mainly on improvements over shallow water where the assumption of a smooth admittance is difficult to justify. In order to mitigate the correlation problems, data of different altimeter missions were analysed simultaneously taking advantage of the combination of time series with different sampling characteristics. This combination requires a careful pre-processing consisting of harmonization, upgrading and cross-calibration of altimeter data (see above). To improve the de-correlation of tidal constituents, the analysis was performed on the nodes of a regular geographical 15′×15′ grid. For every grid node, normal equations were accumulated using all observations inside a spherical cap and applying a Gauss function for weighting inversely proportional to the grid node distance. In contrast to the EOT08a computations, a spherical distance of only 1.5° and half-weight width of 0.5° were used in open ocean because the experiments showed that the smoothing parameters are still appropriate for the estimation of non-linear and baroclinic tides in this case. Besides the main long period (Mm and Mf), diurnal (K1, O1, P1, and Q1), semi-diurnal (M2, S2, N2, K2, and 2N2), and the non-linear M4 tidal constituents as well as the mean, trend, annual and semi-annual signals were estimated simultaneously. The present analysis also proves that it is not sufficient to limit the tide-generating potential to degree two: At a few places the third degree tidal constituent M3 turned out to be significant. Figure 2.2.3 shows the results for the Great Australian Bight, where quarter-wave resonance causes exceptionally large amplitudes of M3 up to 8 cm.

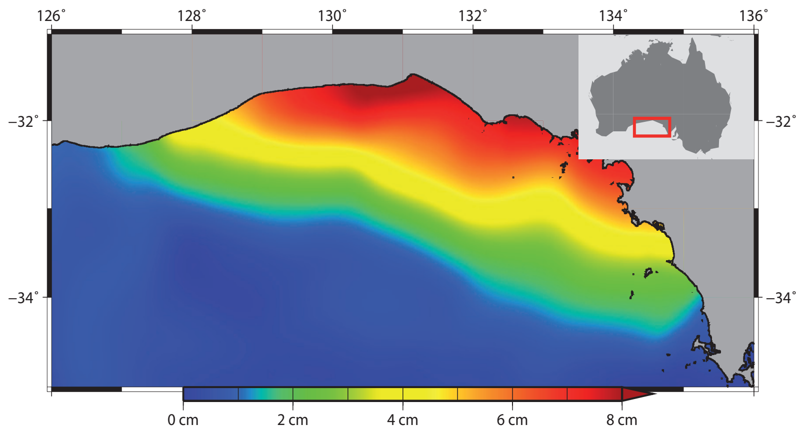


Fig. 2.2.3: Amplitudes of the tidal constituent M3 in the Great Australian Bight

Improved error modelling

In order to consider correlations between subsequent measurements, correlation matrices were set up by means of empirical covariance functions. These covariance functions, shown in Figure 2.2.4, were obtained as a by-product of the multi-mission crossover analysis applied on already cross-calibrated data. As all observations along the same ground track are rather close to each other, only the leading part of the covariance functions, approximated by a linear decay, was used. To take into account the different accuracy of time series, a variance component estimation was carried out. The results shown in Figure 2.2.5 indicate that Jason-1 and ENVISAT data have the highest accuracy. The data of ERS-1 and ERS-2 are downgraded by the variance component estimation. TOPEX/Poseidon exhibits high variances near the coast, which may be explained by remaining problems in the wet troposphere corrections.

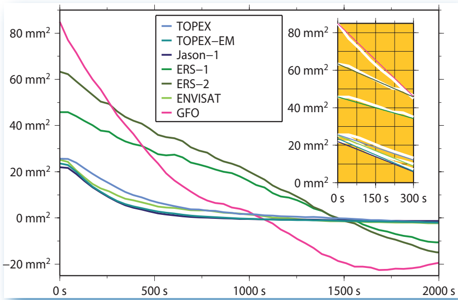


Fig. 2.2.4: Empirical covariance functions of cross-calibrated altimeter data with the leading part approximated by a linear decay

The amplitudes of residual tide signals exceed 10 cm for the semidiurnal and 5 cm for diurnal and M4 tidal constituents near the coast. The consideration of correlations leads to more realistic error estimates.

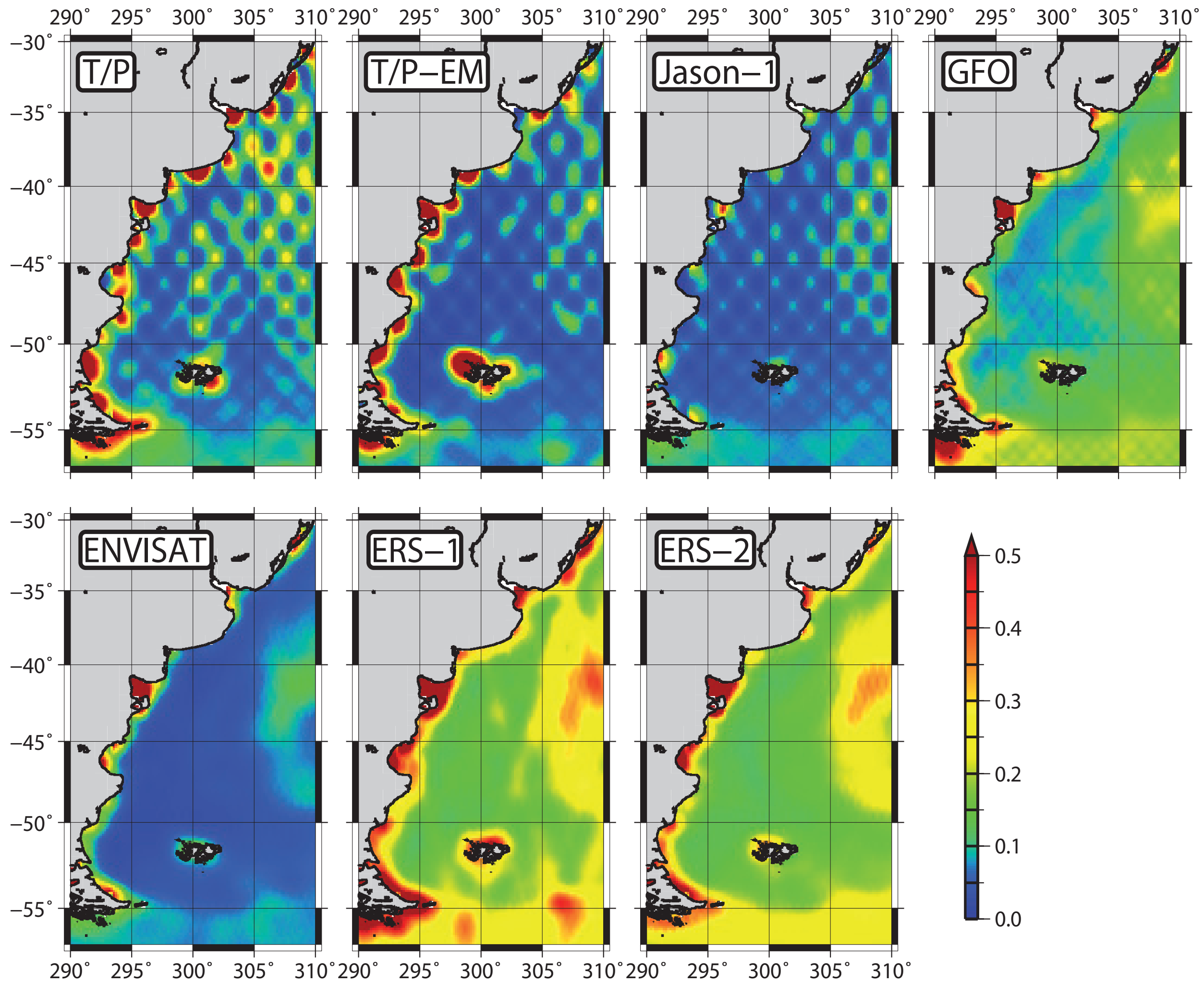


Fig. 2.2.5: Results of variance components estimated for all altimeter missions used in the common tidal analysis

Validation with GPS time series

In polar areas (where altimetry is missing or degraded) the validation of ocean tide models is difficult. But as time serieses of GPS sites are affected by the loading effect, their spectra can be compiled with the loading predicted by ocean tide models. The validation is required

1. to generate a stable network of all GPS sites with daily resolution,
2. to fix reference sites and reprocess coastal GPS sites with a two-hour resolution,
3. to analyse the spectra of the two-hour time series and compute amplitudes and phases of major tidal constituents,
4. to compare this with the loading predicted by ocean tide models.

The rms differences shown in Figure 2.2.6 indicate that EOT08a performs well compared to other recent ocean tide models.

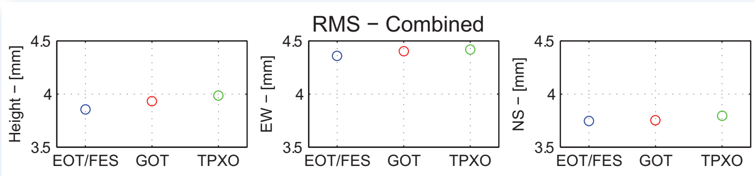


Fig. 2.2.6: Combined differences (all GPS sites; all major tides) between GPS time series and the loading of EOT08a, GOT4.7, and TPXO7.1 ocean tide models

The absolute Dynamic Ocean Topography (DOT)

Within the project GEOTOP, the absolute dynamic ocean topography is estimated following the geodetic approach, e.g. subtracting geoid heights from a sea surface height model. For this approach, DGFI developed a dedicated strategy with several advantages over standard procedures applied so far: it avoids gridding of the altimeter data, which are acquired only along the subsatellite ground tracks. Geoid heights are filtered to remove the meridional error pattern of gravity fields. They are subsequently sampled on the altimeter profiles and subtracted from the sea surface heights, which are consistently filtered beforehand with the same filter specifications applied to the geoid. In doing so, a filter correction is applied to avoid boundary effects at the coast with missing altimeter data over land and to correct for systematic effects over trenches and sea mounts. The method is called a profile approach as the absolute dynamic topography (DOT) is essentially estimated along individual altimeter profiles.

The method was applied to all profiles of the repeat missions, such as TOPEX, ERS2, and Jason2. Individual DOT profiles realize smoothed but instantaneous estimates, and any sequence of such profiles may be used to perform mean DOT profiles for any desired time period covered by altimetry. Figure 2.2.7 shows such a long-term mean DOT. It compares well with independent DOT estimates and no artifacts are present in coastal areas or over trenches.

The heights of the Brazilian levelling network, which extends over many thousands of kilometres along the Atlantic coast, exhibit significant differences (up to ~ 90 cm) w.r.t. the mean sea level as realized by long-term historical tide gauge records. Can the DOT explain these discrepancies? In order to investigate this, a sequence of 30-day DOTs was generated using TOPEX and ERS2 data. The mean and variance of the DOT time series were then evaluated on

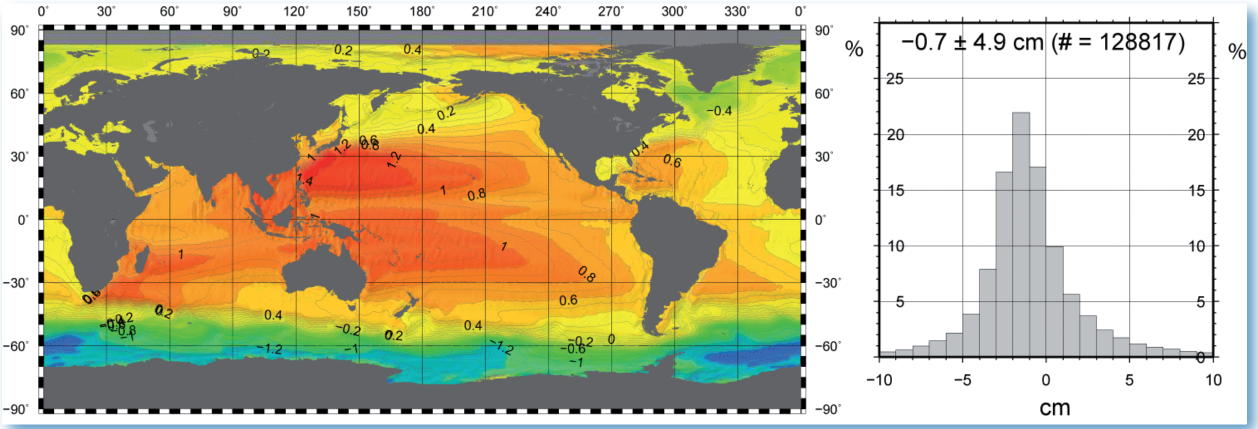


Fig. 2.2.7: A long-term mean DOT generated by means of the profile approach (left) and a histogram of differences (right) w.r.t. the oceanographic DOT estimates by Maximenko (2009)

sections directed towards the tide gauges (see Figure 2.2.8). It happens that from Imbituba, the height reference point at 28°S, up to Sanilopolis (at 0.5°S) the DOT differs by just 2 cm. (Belem and Santana are highly affected by the Amazonas estuary). Thus, the DOT is not able in the slightest to explain the differences between levelling heights and tide gauge records. Instead, the DOT gives a clear indication for significant error propagation within the Brazilian levelling network.

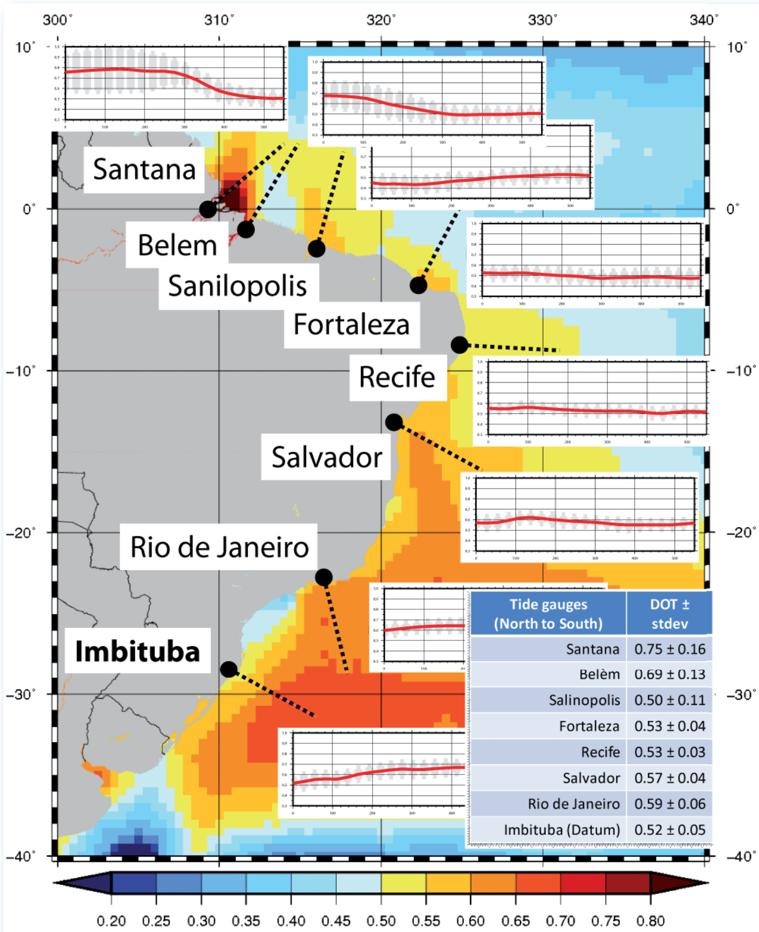


Fig. 2.2.8: Evaluating the DOT along the Brazilian coast. A sequence of 30-day DOTs were interpolated on 550 km long sections directed from the tide gauges towards the open ocean (black dotted lines). Along these sections, a 7.1-year mean DOT was performed (red). Its variation is indicated by its standard deviations (grey).

Related publication:

Bosch W., Savcenko R., Flechtner F., Dahle C., Mayer-Gürr T., Stammer D., Taguchi E., Ilk K.-H.: Residual ocean tides signals from satellite altimetry, GRACE gravity fields, and hydrodynamic modelling. Geophys. J. Int., DOI: 10.1111/j.1365-246X.2009.04281.x, 2009

2.3 Dynamic processes in the Earth system

Oceanic angular momentum from space geodetic techniques

Mass displacements in the oceans influence the Earth's rotation, gravity field and sea level. Therefore, gravity field and sea level changes monitored precisely by space geodetic techniques can be used to study Earth rotation variations due to oceanic mass displacements. We derived oceanic angular momentum functions (χ_1^{ocean}, χ_2^{ocean}) describing polar motion excitations from space geodetic observations. The satellite gravity mission GRACE monitors the time-variable gravity field of the Earth. Contributions from the oceans can be separated by applying a filter which reduces the systematic errors and by applying an ocean mask. We filtered the gravity field solutions GFZ RL04, CSR RL04, JPL RL04, ITG-GRACE03 and GRGS RL01 with an anisotropic decorrelation and smoothing filter based on an a-priori synthetic model of the observation geometry, which we then converted into smoothed equivalent water heights, denoted as Δewh. Subsequently, we applied an ocean mask and transformed the Δewh into χ_1^{ocean} and χ_2^{ocean}. This is described by Göttl and Seitz (2008). Satellite altimetry measures sea level changes caused by mass and volume changes of sea water. The identification of Earth rotation changes induced by oceanic mass variations requires the reduction of the sea level anomalies (SLA) by the steric sea level anomalies (SSLA) (volume effect). According to Göttl and Seitz (2008), the SSLA are derived from three-dimensional (3-D) temperature and salinity fields from the World Ocean Atlas 2005 (W) and Ishii et al. 2006 (I). We reduced the multi-mission solutions for SLA from AVISO (A) and DGFI (D) by these SSLA and converted the Δewh into χ_1^{ocean} and χ_2^{ocean}.

Combined geodetic solution

In order to improve the quality and reliability of the geodetic estimations, a weighted adjustment of several gravimetric and altimetric solutions was performed. The weighting is based on monthly empirical estimated errors of the single solutions according to:

$$\sigma(\chi(t)) = \sqrt{\frac{\sum(\chi(t)-\chi_i(t))^2}{N}}.$$

This means that the quadratic differences between one solution χ and all the other geodetic solutions χ_i are added and than divided by the number of possible differences N. For validation, the single and combined geodetic solutions are compared with results of the ocean models ECCO and OMCT; the RMS differences and correlations are listed in Table 2.3.1. The statistical analysis reveals that the time series from the geophysical models show higher agreements with the adjusted gravimetric and altimetric results (AGA) than with the single solutions, see also Figure 2.3.1. Thus, a weighted adjustment of gravimetric and altimetric oceanic angular momentum functions improves the quality of the geodetic estimations.

Table 2.3.1: RMS differences in units of milliarcseconds (dark grey) and correlation coefficients (light grey) with respect to results from ocean models

χ_1^{ocean}	A-I		A-W		D-I		DW		GFZ		JPL		ITG		CSR		GRGS		AGA	
ECCO	0.4	4.4	0.3	5.1	0.6	3.7	0.5	4.0	0.7	4.2	0.4	5.1	0.6	4.2	0.5	6.4	0.6	7.8	0.7	3.1
OMCT	0.4	4.0	0.5	4.4	0.5	3.9	0.6	3.7	0.5	5.4	0.7	3.4	0.7	3.3	0.5	6.4	0.3	9.3	0.7	2.6
χ_2^{ocean}	A-I		A-W		D-I		DW		GFZ		JPL		ITG		CSR		GRGS		AGA	
ECCO	0.6	4.8	0.6	5.3	0.9	2.7	0.8	6.3	0.7	4.7	0.7	4.3	0.6	45	0.6	5.8	0.5	9.1	0.9	3.2
OMCT	0.4	5.6	0.4	6.0	0.6	4.8	0.6	4.9	0.6	5.1	0.7	3.6	0.8	3.3	0.6	5.5	0.6	8.4	0.7	3.6

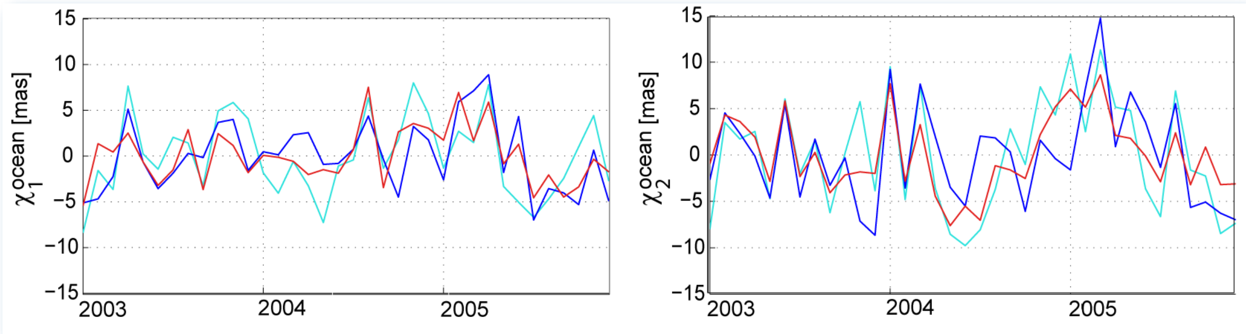


Fig. 2.3.1: Monthly time series of oceanic angular momentum functions: ocean model results from ECCO (cyan) and OMCT (blue) and combined gravimetric and altimetric results (red)

Multi-dimensional ionosphere modelling

In the last few years, a general procedure for modelling multi-dimensional ionospheric signals was developed at the DGFI. It consists of a given reference part and an unknown correction part expanded in terms of multi-dimensional base functions. The corresponding series coefficients are calculated from satellite measurements. This procedure was now used to compute regional VTEC models from a combination of space geodetic measurements. IRI2007 serves as reference and is updated by a correction model based on a 3-D B-spline parameterization.

Combination of data from different space geodetic techniques

To take advantage of the different characteristics of the various space-based and ground-based satellite techniques, we performed a joint adjustment of COSMIC/FORMOSAT-3 GNSS measurements together with ground-based GNSS and measurements from dual-frequency radar altimetry. The data distribution is plotted in Figure 2.3.2. The weights of the different techniques are derived by variance component estimation (VCE). Within the combination process we can not only handle the measurements themselves but also the prior information as pseudo observations in areas where no direct measurements exist. This is necessary to avoid rank deficiencies from unevenly distributed observations. The results of VCE are shown in Table 2.3.2.

Table 2.3.2: Variance components (top) and relative offsets (bottom) of single observation groups (computed for July 21, 2006)

i	Group	$\sigma_{y,i}$
1	GNSS	1.5
2	Jason-1	0.8
3	Envisat	0.7
4	COSMIC/F-3	1.1
5	Prior information / reference model	4.2

	[TECU]
Jason1-Envisat	5.6
Jason1-COSMIC	5.0
Envisat-COSMIC	-0.6

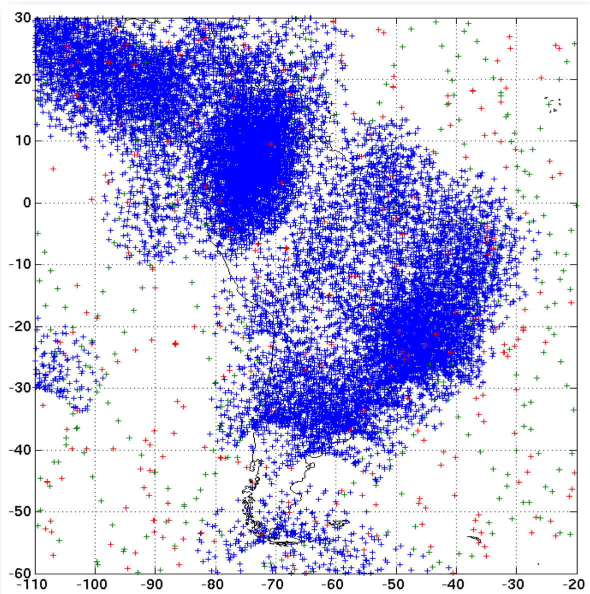


Fig. 2.3.2: Distribution of VTEC observations for 24 hours at July 21, 2006 over South America. Ground-based GNSS observations shown in blue, COSMIC observations in red and data from radar altimeter missions Jason-1 and Envisat in green.

To account for systematic offsets between the results of different observation techniques, we allowed one time-constant bias term per observation group in our model. The adjusted biases strongly depend on the reference model. However, the relative differences between the observation types show no significant relation to the reference model; we computed a bias of approximately 5 TECU of Jason-1 with respect to COSMIC and Envisat (Table 2.3.2). This result agrees very well to offsets computed by other scientific teams.

Improvement of existing ionosphere models

With the presented approach we can selectively improve existing ionosphere models in special regions. As we use localized functions for the parameterization, the reliability of the adjusted model increases strongly over regions where no input data is available (e.g. over the oceans). In addition, it is worth noting that our approach allows the computation of a continuous representation of the VTEC not only in space but also in time (in contrast to most of the existing VTEC models).

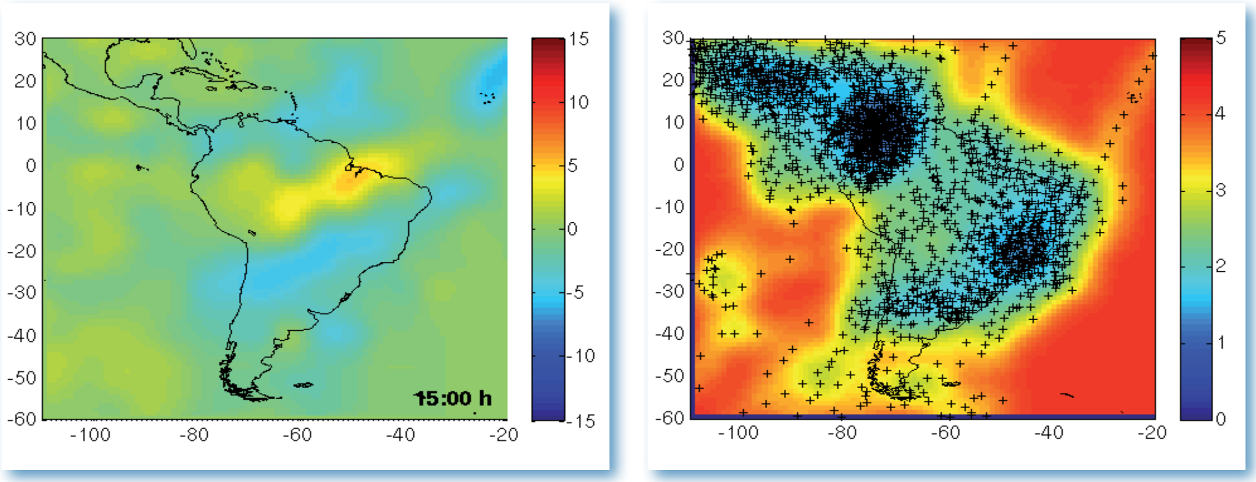


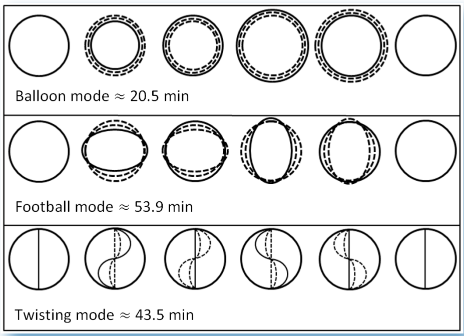
Fig. 2.3.3: Computed VTEC for July 21, 2006, 15 UTC. Left side: corrections with respect to IRI2007, right side: model precision derived from adjustment. Differences to the reference model can be computed only where observations (black signs) are available (all units in TECU).

The computed VTEC differs by up to 10 TECU from the given reference model. Differences can be detected only in regions with data coverage. In these areas, a regional improvement of the resolution is possible. The correction model has to be added to the reference model in order to obtain the new VTEC representation. The procedure is based on a least-squares adjustment with full stochastic model. This allows us to compute accuracies for the resultant VTEC maps. There is a strong correlation between these values and the distribution of input data (Figure 2.3.3, right-hand side).

Evaluation of vertical pendulum time series

Since the beginning of 2007, the DGFI operates a 30-meter vertical pendulum in the salt mine of Berchtesgaden. This instrument provides measurements of variations of the deflection of the vertical. Due to the long base line of the instrument and its high precision, free oscillations of the Earth with a magnitude larger than 6.5 on the momentum scale can be measured after earthquakes. These free oscillations can be used to determine parameters of the interior of the Earth like density, viscosity and elasticity.

The vertical pendulum does not measure the absolute value of the acceleration vector but the indication in north-south and east-west directions. This allows the registration of toroidal and spheroi-



dal free oscillations. Toroidal free oscillations cause variations only in horizontal direction whereas spheroidal free oscillations cause variations in vertical and horizontal directions. In contrast to the pendulum, a gravimeter measures only spheroidal oscillations, because gravimeters can measure only the vertical motions. The three ground modes of free oscillations are shown in Figure 2.3.4.

Fig. 2.3.4: The three ground modes of the free oscillations of the Earth. The upper part shows the 'balloon mode' with a period of about 20.5 minutes and only a vertical component of the deflection field. The ground mode in the middle is the 'football mode' with a period of about 53.9 minutes and a vertical and a horizontal component. The lower part shows the 'twisting mode' with a period of about 43.5 minutes and only a horizontal deflection component.

Wavelet spectra to analyse free oscillations

To analyse the damped free oscillations of the Earth, we have to measure the change of frequencies and amplitudes in time. For this reason the measured signals from the pendulum is pre-processed, i.e. a linear drift and an offset of the time series are subtracted and then the earthquake signal is removed with a moving median. The earthquake signal has to be removed from the time series because otherwise the highly oscillating signal would affect the spectra.

The method used to analyse the damped free oscillations of the Earth in the spectral range is the wavelet transform. This method allows to look at the variations of the frequencies and the amplitudes of the signal in time. The left-hand side of Figure 2.3.5 shows the normalized amplitude scalogram of the Sumatra earthquake on September 12, 2007 with a magnitude of 8.5 on the momentum scale with its prograde and retrograde parts. On the right-hand side of Figure 2.3.5, the prograde and retrograde wavelet variances are shown.

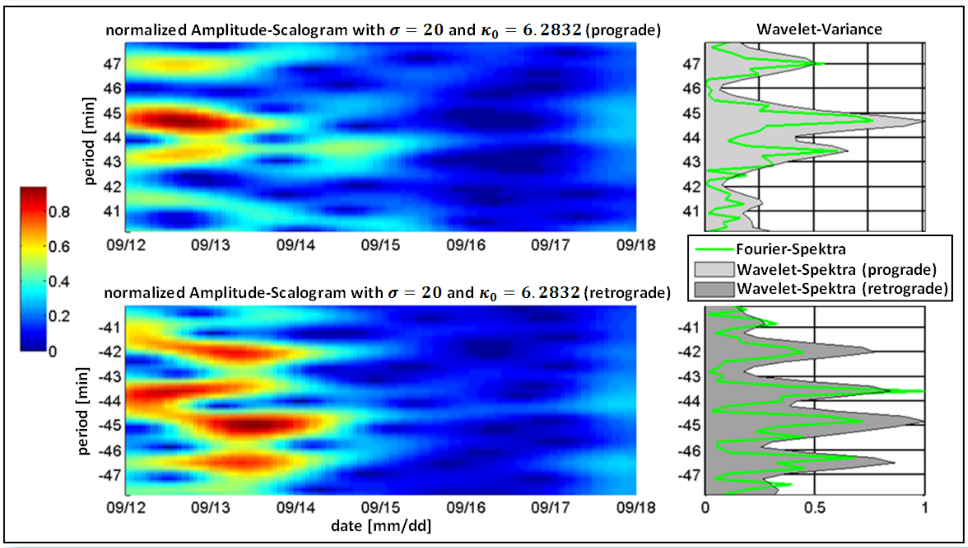


Fig. 2.3.5: Wavelet scalograms of pendulum measurements from September 12, 2007 to September 18, 2007 after the Sumatra earthquake with a magnitude of 8.5 on the momentum scale. At a period of 43.5 minutes the twisting mode (cf. Fig. 2.3.4) is detectable which decays after 2.5 days.

Related publication:

Göttl F., Seitz F.: Contribution of non-tidal oceanic mass variations to polar motion determined from space geodesy and ocean data. In: Sideris, M.G. (Ed.): Observing our Changing Earth, IAG Symposia, Springer, Vol. 133, 439-445, DOI: 10.1007/978-3-540-85426-5_53

2.4 Models of crustal deformation

Actual Plate Kinematic and crustal deformation Models (APKIM)

The series of **A**ctual **P**late **K**inematic and crustal deformation **M**odels (APKIM) was continued at DGFI in 2009 with new solutions based on the station velocities of the ITRF2008 computations at the Institut Géographique National (IGN), Paris, France and the DGFI (see Topic 3.1). Velocities of a total of 577 sites were introduced in a least-squares adjustment to estimate the rotation vectors of 18 rigid plates and the continuous deformation in 6 plate boundary zones.

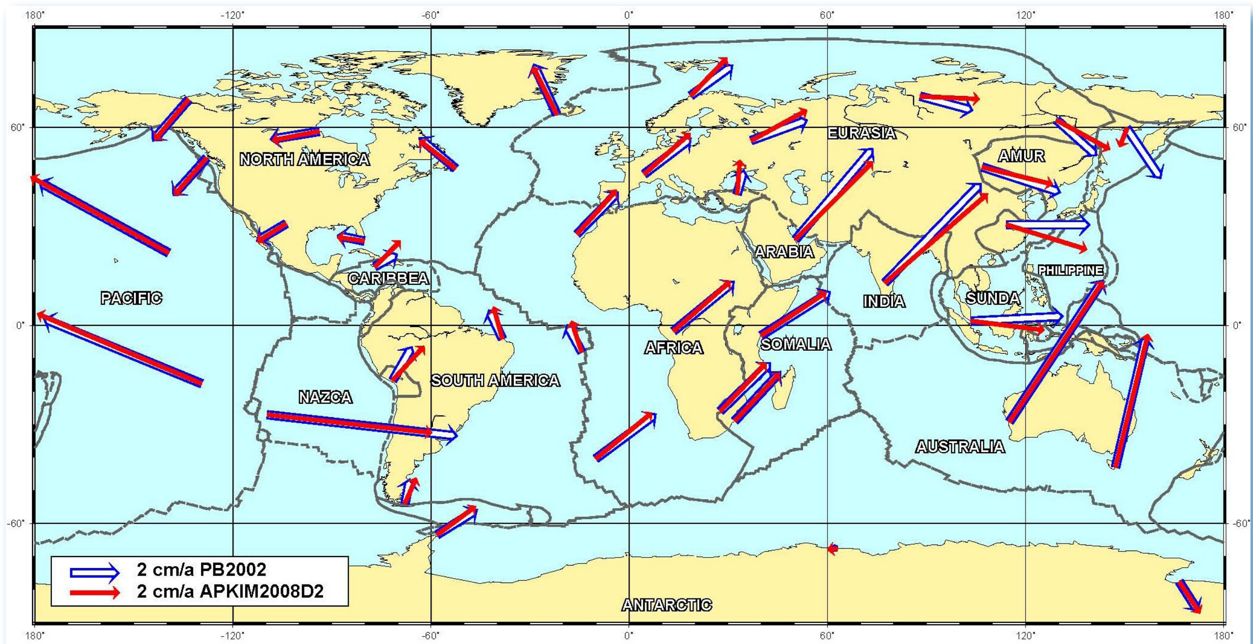
The estimation of plate rotation vectors $\underline{\Omega}(\Phi,\Lambda,\omega)$ is done in a two-dimensional approach in order to exclude the dominating uncertainties of the vertical (height) velocities in the space geodetic solutions. The original three-dimensional velocities (dX/dt, dY/dt, dZ/dt) of the ITRF2008 were transformed for this purpose into horizontal velocities, namely in latitudinal and longitudinal directions ($d\phi/dt$, $d\lambda/dt$). The adjusted parameters are the geographic coordinates of the rotation pole (Φ,Λ) and the rotational velocity (ω). The observation equations read (Drewes 2009)

$$(d\varphi/dt)_k = \omega_i \cdot \cos\Phi_i \cdot \sin(\lambda_k - \Lambda_i)$$
$$(d\lambda/dt)_k = \omega_i\,(\sin\Phi_i - \cos(\lambda_k - \Lambda_i)\tan\varphi_k \cdot \cos\Phi_i)$$

In Figure 2.4.1 the resulting plate motions are shown in comparison with the geologic-geophysical model PB2002 (Bird 2003). The well-known discrepancies of rotational directions (e.g. Eurasia, South America) and/or velocities (e.g. Nazca, Pacific) are clearly visible.

The deformation between plates was computed by a least-squares collocation approach (Drewes, in press). A 1°×1° velocity grid was interpolated from the observed velocities using their isotropic covariance functions cov = $a \cdot \exp(-b \cdot d)$, where d is the distance between the points. The function parameters a and b were estimated empirically from the observations. Six inter-plate deformation

Fig. 2.4.1 Comparison of plate motions from geophysical (PB2002) and geodetic (APKIM2008) models.



zones were modelled: Alaska-Yukon, Alps-Aegean, Andes, Gorda-California-Nevada, Persia-Tibet-Burma, Okhotsk. The Alps-Aegean region includes the Aegean Sea plate of PB2002, and the Andean region includes the North Andes and Altiplano plates of PB2002. The Okhotsk Sea is obviously not a rigid plate and therefore modelled as deformation zone. Figures 2.4.2 and 2.4.3 show, as examples, the Alps-Aegean and the Persia-Tibet-Burma deformation zones.

Alpine-Aegean deformation zone

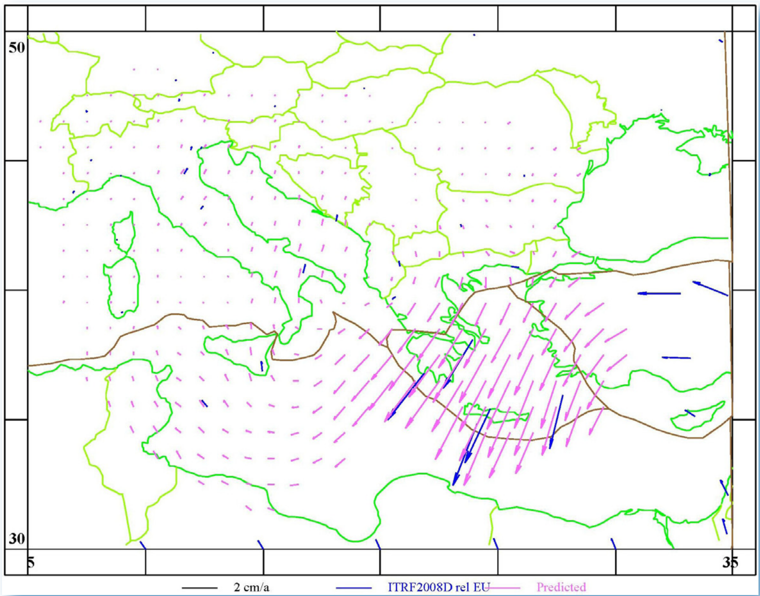


Fig. 2.4.2: Inter-plate deformation of the Alps-Aegean region

Persia-Tibet-Burma deformation zone

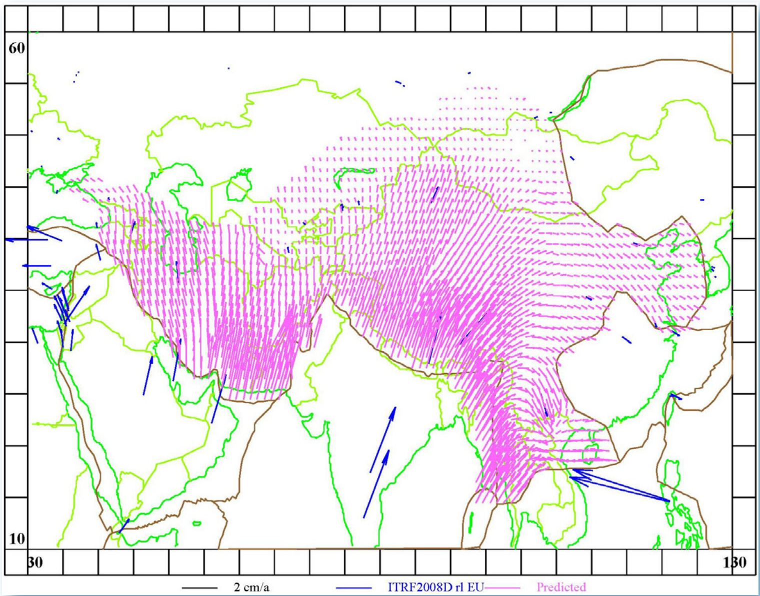


Fig. 2.4.3: Inter-plate deformation of the Persia-Tibet-Burma region

The rigid plate motion and deformation models were finally integrated to estimate the global ITRF2008 rotation. For this purpose a complete 1°×1° velocity grid over the globe was computed and the common rotation was estimated. The result is a rotation vector of wich the components are given as

$\omega_X = -0{,}035$ mas/a, $\omega_Y = 0.034$ mas/a, $\omega_Z = 0.021$ mas/a.

These values are in good agreement with previous computations of the Plate rotations from ITRF solutions. They have to be subtracted from the ITRF2008 velocities in order to get a "non-rotating terrestrial reference frame".

Velocity field of South America and the Caribbean

The detailed velocity field of the South American and Caribbean crust was computed by finite-element and least-squares collocation approaches. 400 station velocities from 12 geodynamics projects in the region were combined with 95 station velocities of the 2009 multiannual solution of the Geocentric Reference System for the Americas (SIRGAS, see Topic 3.2). The finite-element model is based on a homogeneous, isotropic, elastic (Hooke) material, and the least-squares collocation approach uses empirical covariance functions derived from the geodetic observations. The result, as an average of both methods, is shown in Figure 2.4.4.

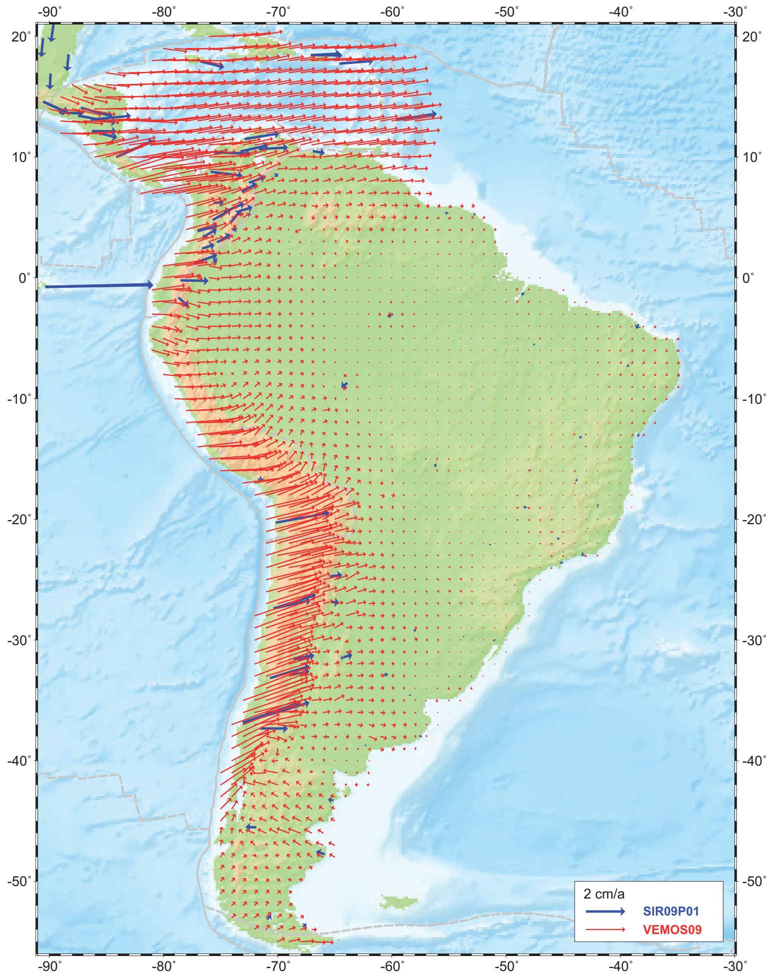


Fig. 2.4.4: Station velocities of the SIRGAS multiannual solution 2009 (blue arrows) and velocity field derived from 12 geodynamics projects (red arrows) relative to the South American plate

Related publications:

Drewes H.: The actual plate kinematic and crustal deformation model (APKIM2005) as basis for a non-rotating ITRF. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 95–99, 2009, DOI: 10.1007/978-3-642-00860-3_15

Drewes H.: The 2009 horizontal velocity field for South America and the Caribbean. IAG Symposia, Springer (in press).

3 International Scientific Services and Projects

For many years, DGFI has participated in numerous activities of international scientific services and projects. It operates data centres, analysis centres and combination centres of several services of the International Association of Geodesy (IAG) and participates in various international projects. In the International Earth Rotation and Reference Systems Service (IERS), DGFI is one of the two official Combination Centres and a Research Centre for the realization of the International Terrestrial Reference System (ITRS). In the International GNSS Service (IGS), DGFI operates the Regional Network Associate Analysis Centre for SIRGAS (RNAAC-SIR). For the International Laser Ranging Service (ILRS), DGFI acts as one of the two Global Data Centres (EUROLAS Data Centre, EDC), as an Analysis Centre (AC), and as a Combination Centre (CC). In the International VLBI Service for Geodesy and Astrometry (IVS), DGFI operates an Analysis Centre (AC) and participates in the Combination Centre (CC). DGFI also got the leading role for the installation of the International Altimetry Service (IAS). In IAG's Global Geodetic Observing System (GGOS), DGFI participates in the Bureau on Standards and Conventions. Furthermore, DGFI is active in other international projects by operating permanent GPS stations and data analysis, in particular in the IGS Tide Gauge Benchmark Monitoring Project (TIGA) and the Geocentric Reference System for the Americas (SIRGAS). The European Union's Territorial Cooperation (INTERREG III) Alpine Space Project for detection and control of crustal deformations in the Alpine region (ALPS-GPS QUAKENET) ended in 2007, but the German part is continued by DGFI. The scientific outcome of these international service activities enters directly into the basic research (Chapters 1 and 2) and is an important part of DGFI's investigations.

3.1 ITRS Combination Centre / IERS Research Centre

The major focus of the ITRS Combination Centre was on the computation of the new realization of the International Terrestrial Reference Frame 2008 (ITRF2008). A large part of the research performed within the IERS Research Centre is closely related to the activities of the research field "Earth System observation", primarily Topic 1.1 "Consistent analysis methods for space geodetic observations" and Topic 1.2 "Foundation of geometric reference systems".

ITRF2008 Call for Participation

In November 2008, the International Earth Rotation and Reference Systems Service (IERS) released a call for participation for providing input data sets for the new ITRF2008. The ITRS Centre, together with the ITRS Combination Centres, will generate this new ITRF2008 and solicits (similar as for the ITRF2005) time series of station positions and Earth Orientation Parameters (EOP) from the IERS Technique Centres (TC) and their related Analysis Centres.

ITRF2008 input data sets

In the spring of 2009, the TCs of the IAG Services IGS, ILRS, IVS and IDS provided intra-technique combined time series of station positions and Earth orientation parameters (EOP). The ITRS Combination Centres, DGFI and IGN, analysed the input data sets and gave feedback to the TCs and the contributing Analysis Centres. After a few iterations the final time series sets were submitted in the summer of 2009. Table 3.1.1 summarizes the major characteristics of the ITRF2008 input data sets.

Table 3.1.1: Input data sets for the new ITRF2008

Technique	Service	Combination Centre	Data Time period
GPS	IGS	NRCan, Canada	Weekly solutions 1997 − 2008
SLR	ILRS	ASI, Italy	Weekly solutions 1983 − 2008
VLBI	IVS	IGG, Germany	24-h session NEQ 1980 − 2008
DORIS	IDS	CLS/CNES, France	Weekly solutions 1993 − 2008

ITRF2008 analysis and computations

In its function as an ITRS Combination Centre, DGFI is in charge of the computation of the new ITRF2008. The first step is the analysis of station position time series for each of the observation techniques in order to identify inconsistencies, such as discontinuities, non-linear station movements (which occure in addition to the annual signals) and velocity changes. The lists of discontinuities derived separately for each technique were compared with the lists prepared by IGN. The lists were homogenized, and a common final list of discontinuities was compiled for the ITRF2008. These final discontinuity tables were applied for the computation (accumulation) of multi-year solutions for each technique, including station positions, station velocities and EOP.

The second step is the combination of the technique-specific multi-year solutions (inter-technique combination). For connecting the station positions of co-location sites, the selection of reliable terrestrial difference vectors is a critical issue, since in some cases there are large discrepancies between station position differences and terrestrial difference vectors. First ITRF2008 results indicate that the agreement between the terrestrial difference vectors and the coordinate differences of the space technique solutions is smaller than with ITRF2005. The main reasons are a consistent reprocessing and the use of improved models for the analysis of the different space geodetic observations. The computation of the ITRF2008 will be finalized by the beginning of 2010.

IERS Research Centre

The research performed within the IERS Research Centre activity focuses on the daily combination of station positions and Earth orientation parameters. Another topic was the correlation between station heights and tropospheric zenith delay parameters.

Daily TRF/EOP combination

In current ITRF solutions, the station movements are parameterized as a mean position at an epoch and a constant velocity. Short-periodic as well as annual signals in the station motions are not considered in the ITRF computation up to now, even though these signals affect the ITRF solution. The reasons for the non-consideration of these signals are, that (i) the modelling of the variations (mainly induced by mass load changes) is not possible with millimeter-accuracy as required, and (ii) the parameterization of the station movement is problematic as the amplitudes of the short-periodic and the annual signals are not constant over time (see Figure 3.1.1).

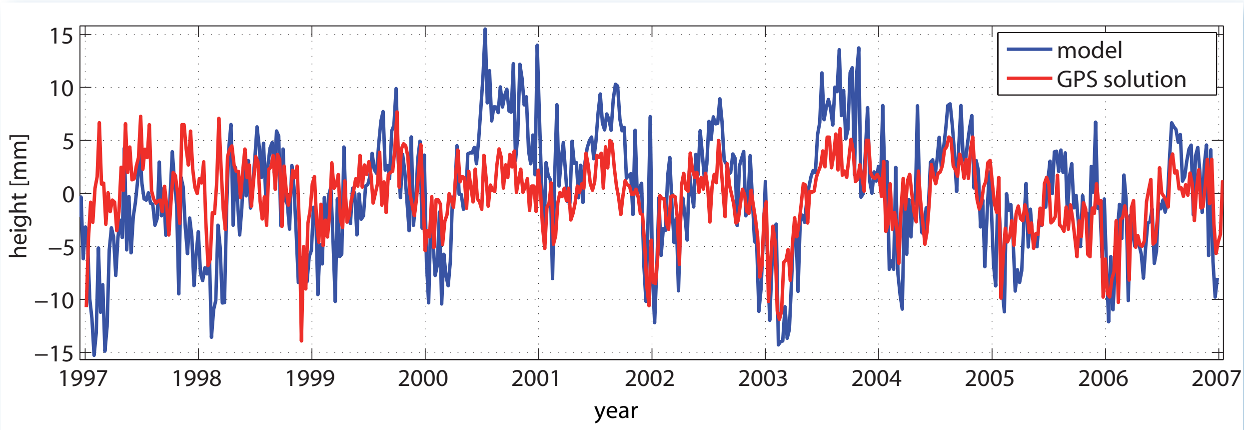


Fig. 3.1.1: Time series of station height for Wettzell (red: daily estimates from GPS, blue: loading model considering atmospherical and hydrological loading)

One possibility for factoring the non-linear station motions is via the computation of short-term TRF time series solutions. First results for a time series of daily TRF solutions were obtained by combining GPS daily and VLBI session-wise normal equations. Since the start and end times of the VLBI sessions are different from 0 h UTC, we combined the VLBI session-wise equations with the daily GPS normal equations which have the largest time overlap. The results in Figure 3.1.2 and in Table 3.1.2 show that the EOP time series of GPS and VLBI benefit from a daily combination.

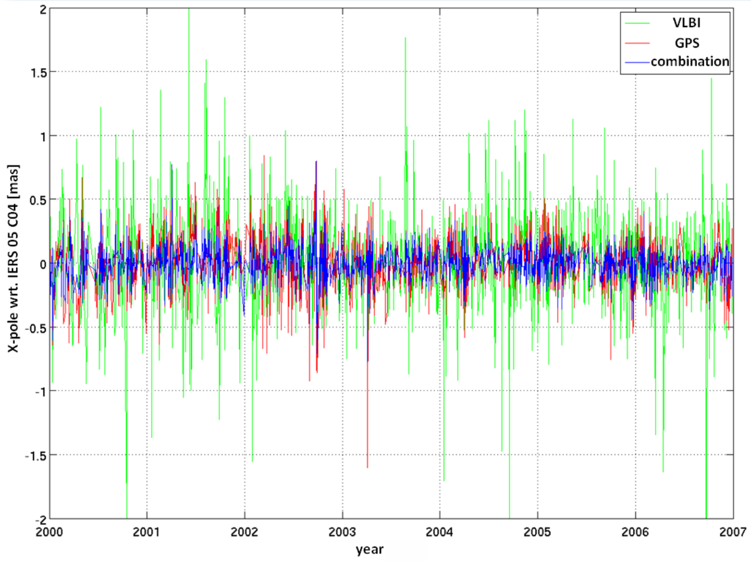


Fig. 3.1.2: Time series of the pole coordinates x_{pole} w.r.t. IERS 05 C04 time series. VLBI solution (green), GPS solution (red) and VLBI-GPS combination (blue).

Table 3.1.2: RMS and WRMS values of the time series of the pole coordinates x_{pole} and y_{pole} in milliarcseconds. An offset and a linear drift has been removed before calculating the RMS and WRMS values.

		x_{pole} [mas]	y_{pole} [mas]
RMS	VLBI	0.3756	0.3911
	GPS	0.2156	0.2152
	Combination	0.1425	0.1561
WRMS	VLBI	0.1925	0.2345
	GPS	0.2060	0.2009
	Combination	0.1331	0.1442

Table 3.1.2 shows the RMS and WRMS values of the VLBI and GPS single-technique EOP time series and the combined EOP time series. The VLBI RMS values are significantly larger than the VLBI WRMS values due to the large variability of the observing network. However, the GPS network and hence also the combined solutions are more stable over time, and therefore the corresponding RMS and WRMS values are of the same order of magnitude.

The station position time series as obtained from the daily VLBI and GPS combinations were also investigated. We found a significant improvement of the combined station position time series w.r.t. the individual VLBI solution, especially for the stations in the Southern Hemisphere. Figure 3.1.3 shows the daily position time series for the station in Concepcion (Chile). For all three components, the stability of the combined time series is much higher compared to the single VLBI solution.

Future work in this field will concentrate on the investigation of different short-term TRF solutions with respect to stability and accuracy. This work is directly connected to the issues that shall be studied by the newly established IERS Working Group "Combination on the Observation Level (COL)", which has the aim to develop new strategies for the computation of future IERS products.

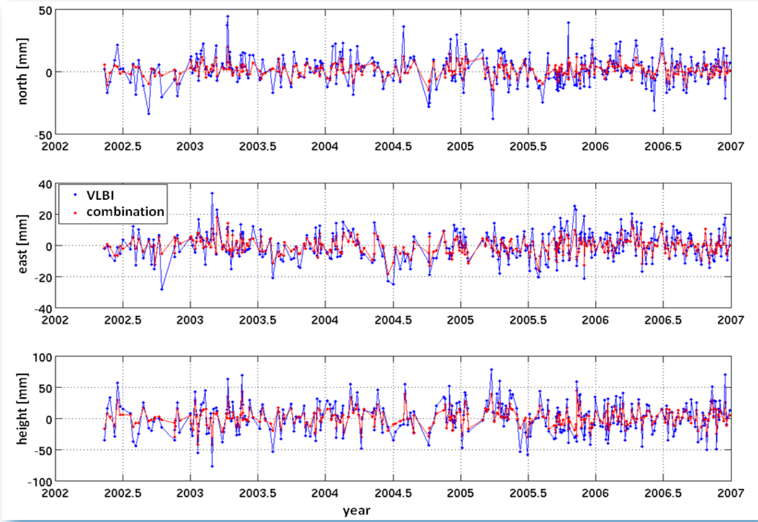
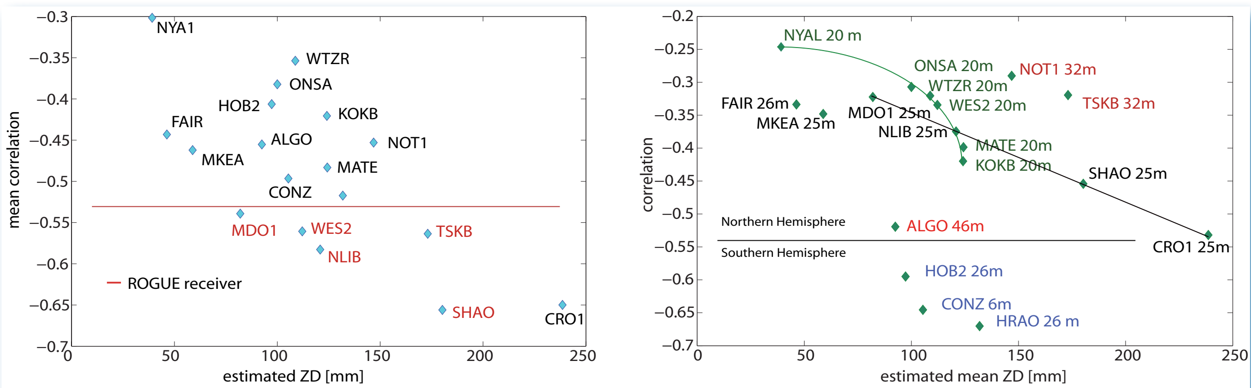


Fig. 3.1.3: Station position time series in north, east and height of Concepcion (Chile). VLBI solution (blue) and VLBI-GPS combination (red).

Correlation between station heights and tropospheric zenith delay

It is well known that station heights derived from GPS and VLBI observations are correlated due to the estimated part of the tropospheric refraction. Station heights and troposphere zenith delay parameters can well be decorrelated only by restriction to observations with small elevation angles (5° or smaller). This requires that adequate mapping functions for the zenith delay to the elevation angles of the observations are applied. We studied the correlations between station heights and troposphere zenith delay (ZD) for GPS and VLBI stations. The analysis of the GPS and VLBI data was performed for a data time span of two years using the same models and parameterization. The ZD was mapped using the Niell mapping function (Niell, 1996). The elevation cutoff angle for GPS was 3° and for VLBI 5°. The estimated correlations are displayed in Figure 3.1.4. The results show that the correlations are very different for the various stations. For GPS they range from −0.3 to −0.65, although the stations with higher correlations are mostly equipped with Rogue receivers (except CRO1), which are known for tracking problems (see Figure 3.1.4a). Additionally, a low dependency of the correlations on the amount of the estimated zenith delay (ZD) is visible. The range of correlations for the VLBI stations (Figure 3.1.4b) is similar to GPS, and these correlations, plotted w.r.t. the estimated ZD, show some systematics. The diameter of the antenna seems to have an impact on the correlation, but the reason for the systematics in the correlations is not yet well understood and must be studied in more detail.

Fig. 3.1.4: Mean correlations between station heights and the estimated wet part of troposphere zenith delay for co-located a) GPS and b) VLBI stations. Stations are named by the 4-character ID of the GPS station.



3.2 IGS Regional Network Associate Analysis Centre for SIRGAS

The SIRGAS Continuously Operating Network (SIRGAS-CON) is the densification of the ITRF in Latin America and the Caribbean. This network comprises two hierarchy levels (Sánchez and Brunini 2008): a core network (SIRGAS-CON-C) providing the primary link to the global ITRF; and a densification network (SIRGAS-CON-D) containing all the fundamental stations of the national reference frames. The densification network is further divided into three sub-networks covering the northern, middle, and southern part of the SIRGAS region (Figure 3.2.1). The core network ensures the long-term stability of the continental reference frame, and the densification sub-networks improve the geographical density of the reference stations, which facilitates the accessibility to the reference frame in local levels. This operational infrastructure is possible only through the commendable active participation of many Latin American and Caribbean institutions, which not only provide the measurements of their stations but also host SIRGAS Analysis Centres responsible for processing the observational data on a routine basis (Sánchez and Brunini 2009).

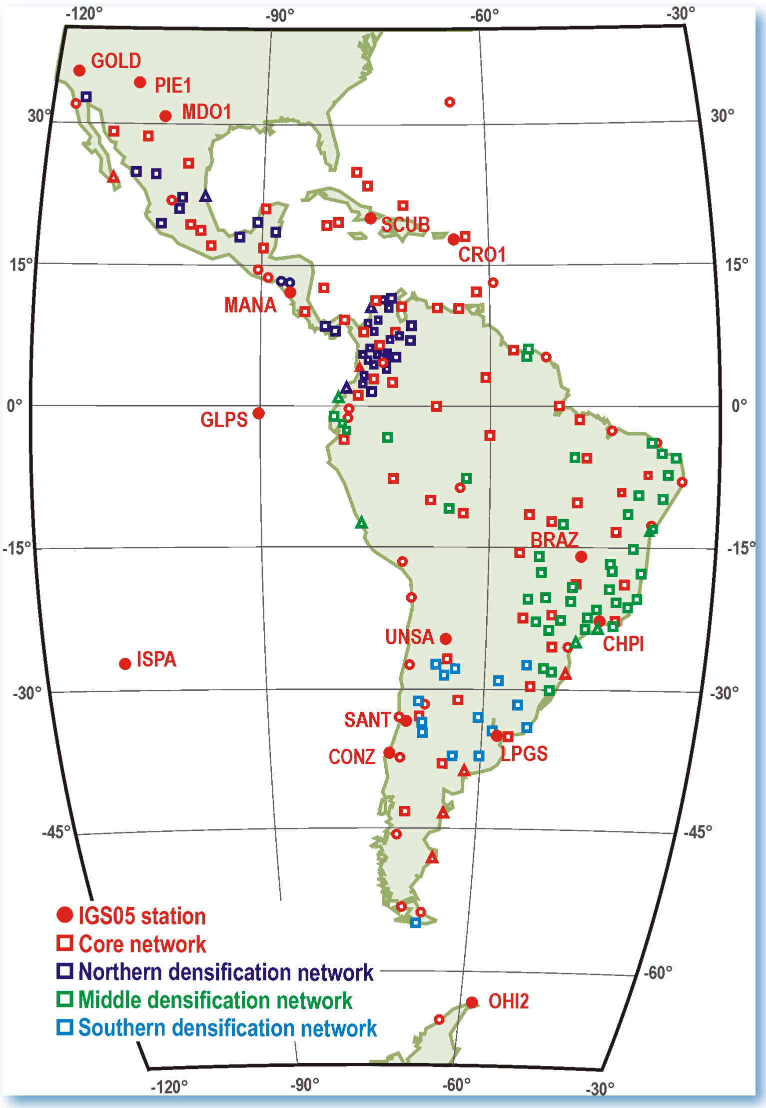


Fig. 3.2.1: Core and densification sub-networks within the SIRGAS-CON reference frame

Structure of SIRGAS networks

DGFI is responsible for the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR) and delivers loosely constrained weekly solutions for the SIRGAS-CON network to the IGS. These solutions are combined together with those generated by the other IGS Global and Regional Analysis Centres, which results in the IGS polyhedron. The processing of the SIRGAS-CON network in the frame of the IGS RNAAC SIR also includes the computation of weekly position solutions aligned to the current ITRF realization and accumulative position and velocity solutions for estimating the kinematics of the network (e.g. Seemüller 2009, Seemüller et al. 2009). Until 31 August 2008 (GPS week 1495), DGFI processed the entire SIRGAS-CON network. Afterwards, with the introduction of the core network and the densification sub-networks within SIRGAS-CON as well as the installation of SIRGAS Processing Centres under the responsibility of Latin American institutions, DGFI has been responsible for

i) processing the SIRGAS-CON-C core network (Seemüller and Sánchez 2009),
ii) combining this core network with the densification sub-networks (Sánchez et al. 2009), and
iii) making available the official SIRGAS products, i.e. loosely constrained weekly solutions for the IGS polyhedron and for further combinations of the network, weekly solutions aligned to the ITRF for the users in Latin America, and multi-annual solutions (station positions and velocities) for applications requiring time-dependent coordinates.

Processing of the SIRGAS-CON-C core network

DGFI processes the SIRGAS-CON-C core network, while the SIRGAS Local Processing Centres – at present: IGAC (Colombia), IBGE (Brazil), and CIMA (Argentina) – are in charge of computing the densification sub-networks. These four Processing Centres commonly apply basic solution standards established by SIRGAS (in accordance with the IGS and IERS standards) to generate loosely constrained weekly solutions for the assigned sub-networks. The main processing characteristics (see Seemüller and Sánchez 2009) are an elevation mask of 3°, a sampling rate of 30 s, IGS absolute calibration values for the antenna phase centre corrections, IGS weekly values for satellite orbits, satellite clock offsets, Earth orientation parameters and also ocean tide loading corrections derived from the FES2004 model. Additionally, the zenith delay due to the tropospheric refraction is estimated at a 2-hour interval within the network adjustment. The computed daily free normal equations are combined to get a loosely constrained weekly solution for station positions, in which all of them are constrained to ±1 m. These solutions are delivered to the SIRGAS Combination Centres DGFI and IBGE to generate an integral solution for the entire SIRGAS-CON network.

Combination of the individual solutions delivered by the SIRGAS Processing Centres

According to Figure 3.2.2 (Sánchez et al. 2009), before combining the individual solutions, the constraints included in the delivered normal equations are removed and are aligned separately to the IGS05 reference frame. The standard deviations obtained are

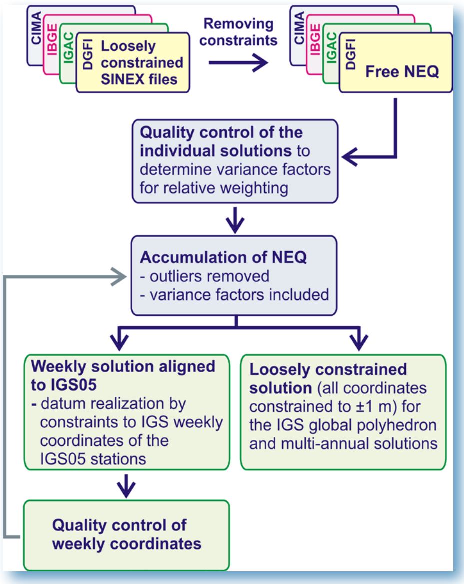
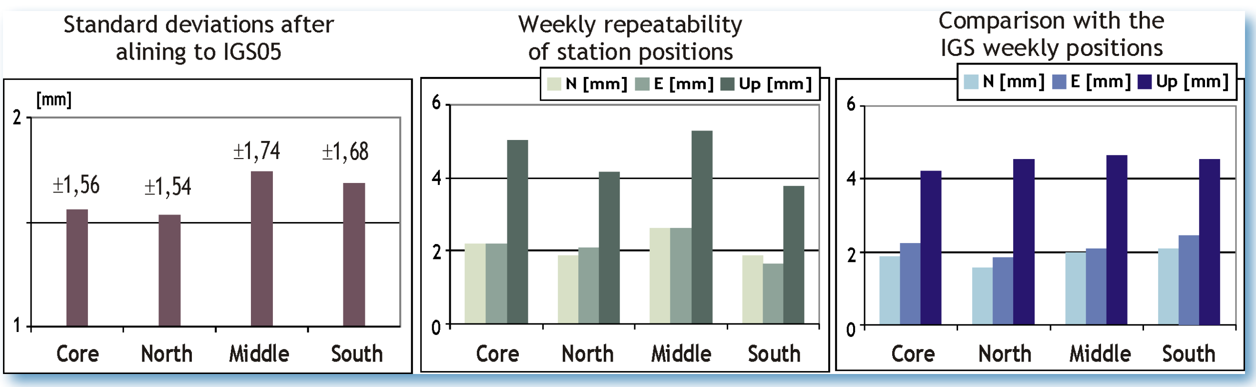


Fig. 3.2.2: Combination procedure applied by DGFI to generate weekly solutions of the SIRGAS-CON reference frame

analysed to assess the quality of the individual solutions and to determine variance factors, when it is necessary to compensate differences in the stochastic models of the Processing Centres. Additionally, the station positions computed from each solution are compared with the IGS weekly values and with each other to identify possible outliers. Once inconsistencies and outliers are reduced from the individual free normal equations, a combination for a loosely constrained weekly solution for station positions (each constrained to ±1 m) is computed. This solution is submitted in SINEX format to IGS for the global polyhedron and it is stored to be included in the next multi-annual solution of the SIRGAS-CON network. Finally, a weekly solution aligned to the IGS05 frame is computed. The geodetic datum is defined by constraining the coordinates of the IGS05 reference stations (Figure 3.2.1) to their positions computed within the IGS weekly combinations (igs*yyPwwww*.snx). This solution provides the final weekly positions for the SIRGAS-CON stations. The accumulation and solution of the normal equations are carried out with the Bernese GPS Software V.5.0.

Different criteria are applied to evaluate the quality of the contributing solutions delivered by the SIRGAS Processing Centres (Figure 3.2.3). The results indicate that the individual solutions are at the same level of precision: the formal error of the station positions is about ±1,6 mm, and the repeatability of the weekly coordinates is estimated to be ±2,0 mm in the horizontal component and ±4,0 mm in the height. The mean standard deviation of the combined solutions (Figure 3.2.4) agrees quite well with the one computed for the individual contributions (Figure 3.2.3), i.e. the quality of the individual solutions is maintained, and their combination does not deform or damage the internal consistency of the entire SIRGAS-CON network. The position repeatability in the weekly combinations indicates that the internal consistency of the SIRGAS-CON network is about ±0,8 mm in the horizontal components and about ±2,5 mm in the vertical. The RMS values derived from the station position time series and with respect to the IGS weekly coordinates indicate that the accuracy of the weekly positions for the SIRGAS-CON stations is about ±1,5 mm in the north and the east, and ±3,8 mm in the height (Figure 3.2.4).

Fig. 3.2.3: Evaluation of the solutions computed for the SIRGAS-CON individual sub-networks (mean values for GPS weeks from 1495 to 1538)



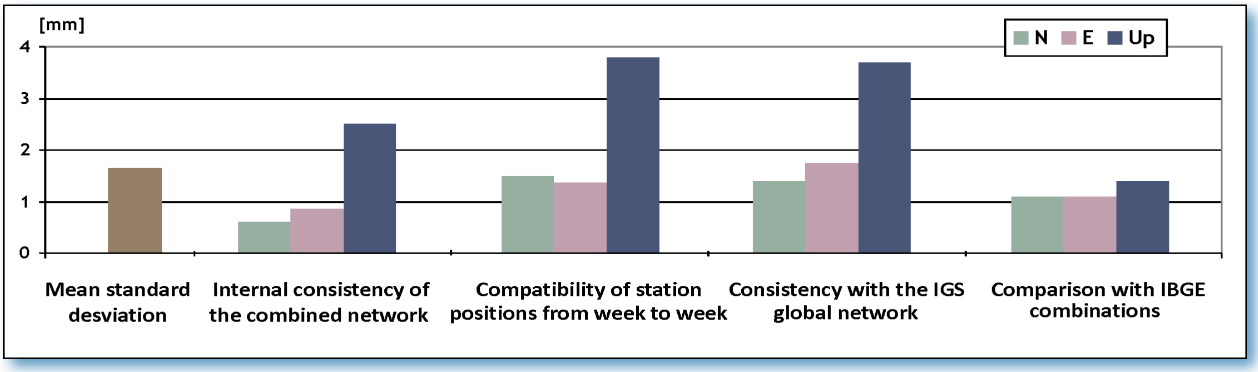


Fig. 3.2.4: Quality control of the weekly positions computed for the SIRGAS-CON stations (mean values for GPS weeks from 1495 to 1538)

The multi-year solution SIR09P01

The input data for the generation of the multi-year solution SIR09P01 are the loosely constrained weekly solutions of the SIRGAS-CON network between January 2, 2000 and January 3, 2009. These weekly solutions were computed by DGFI in only one adjustment for the entire network until 31 August 2008 (GPS week 1495). The loosely constrained weekly solutions for the later weeks correspond to the combination of the four SIRGAS-CON sub-networks. Weekly solutions from January 2000 (GPS week 1043) to October 2006 (1399), which were formerly computed with relative antenna phase centre corrections and referred to previous ITRF solutions, were reprocessed. They include absolute phase centre corrections and are referred to the IGS05 reference frame. This reprocessing provides homogeneously computed weekly solutions for the complete time span covered by the SIR09P01 solution and improves the reliability and the accuracy of station positions and velocities. Figure 3.2.5 shows the strategy for the computation of the SIR09P01 multi-annual solution (Seemüller et al. 2009). Figure 3.2.6 displays the velocity vectors.

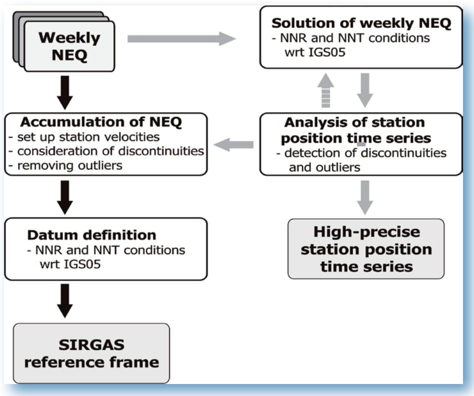


Fig. 3.2.5: Processing strategy for the computation of the SIR09P01 multi-annual solution

Weekly solutions of the SIRGAS reference frame as well as the multi-annual solutions are available at www.sirgas.org or at the FTP site ftp://ftp.dgfi.badw-muenchen.de//pub/gps/SIRGAS/, *wwww* (GPS week).

The accuracy of the SIR09P01 positions at the reference epoch is estimated to be better than ± 0,5 mm in the horizontal component and ± 0,9 mm in the vertical one. The accuracy of the velocities (Fig. 3.2.6) is about ± 0,8 mm/a.

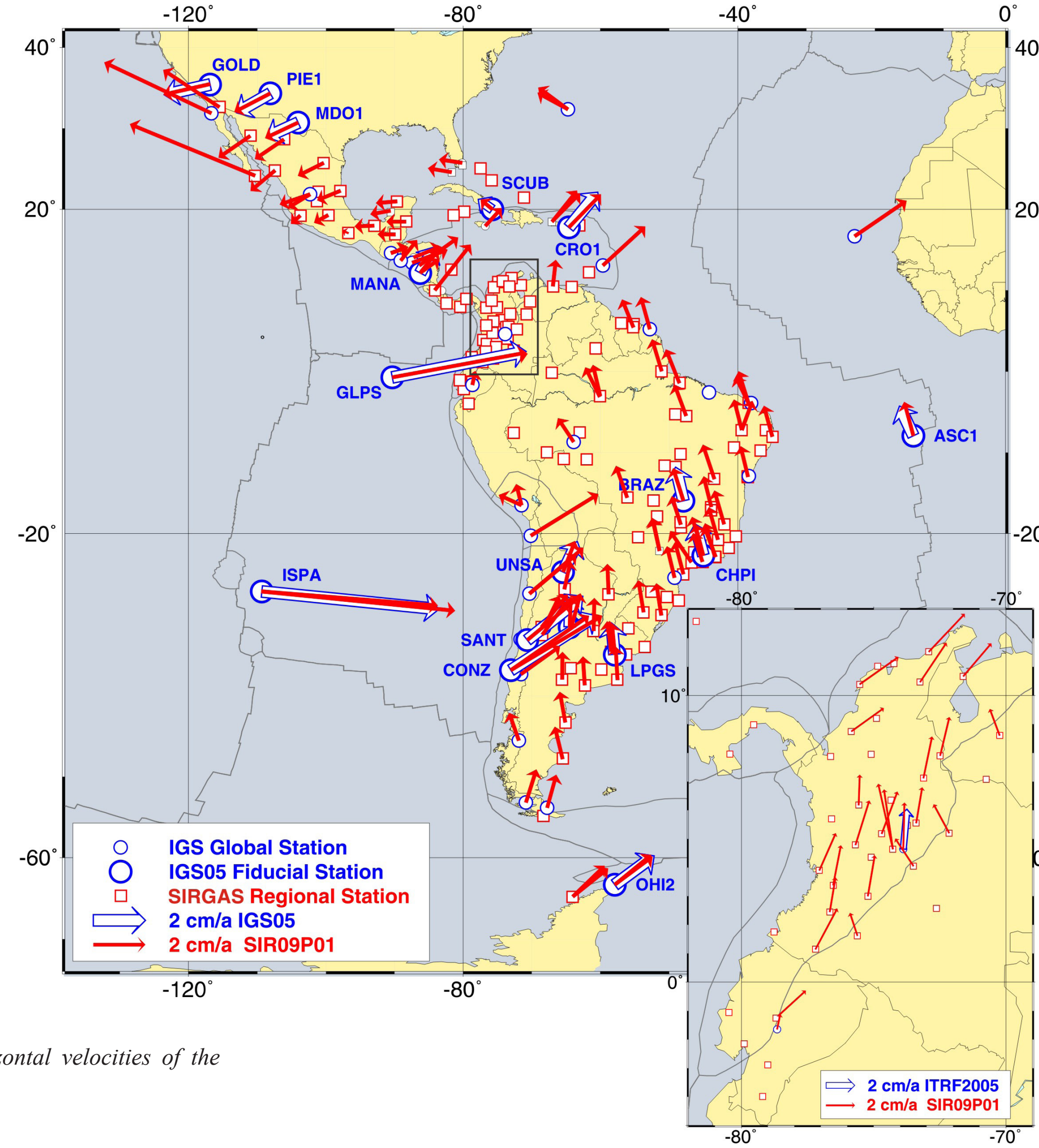


Fig. 3.2.6: Horizontal velocities of the IR09P01 solution

Related publications:

SÁNCHEZ L., BRUNINI C.: SIRGAS: Basis for geosciences, geodata and navigation in Latin America. In: Proceedings of the International Symposium on Global Navigation Satellite Systems, Space-based and Ground-based Augmentation Systems and Applications. Berlin, 11–14 November 2008. Berlin Senate Department for Urban Development. P. 37 - 39, 2009.

SÁNCHEZ L., BRUNINI C.: Achievements and Challenges of SIRGAS. In: Drewes, H. (Ed.): Geodetic Reference Frames, IAG Symposia; Springer, Vol. 134, 161–166, 2009, DOI: 10.1007/978-3-642-00860-3_25.

SÁNCHEZ L., SEEMÜLLER W., SEITZ M.: SIRGAS combination centre at DGFI: Report for the SIRGAS 2009 General Meeting. SIRGAS Newsletter 14, http://www.sirgas.org/fileadmin/docs/Boletines/ Bol14/, 2009

SEEMÜLLER W.: The position and velocity solution DGF06P01 for SIRGAS. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia; Springer, Vol. 134, 167–172, 2009, DOI: 10.1007/978-3-642-00860-3_26.

SEEMÜLLER W., SEITZ M., SÁNCHEZ L., DREWES H.: The position and velocity solution SIR09P01 of the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR). DGFI Report No. 85, 2009.

SEEMÜLLER W., SÁNCHEZ L.: SIRGAS processing centre at DGFI: Report for the SIRGAS 2009 General Meeting. SIRGAS Newsletter 14, http://www.sirgas.org./fileadmin/docs/Boletines/Bol14/, 2009.

3.3 Operation and applications of permanent GPS stations

Since 1998 DGFI has installed 15 continuously observing GNSS stations within different international cooperation projects (Figure 3.3.1). The operation of these stations is supported by local partner institutions which take care of the functioning of the equipments and the data transfer to the processing centres. The DGFI permanent stations are integrated in different projects (Table 3.3.1) such as the IGS Tide Gauge Benchmark Monitoring Project (TIGA), monitoring crustal deformations in the Alpine Region, densification of the International Terrestrial Reference Frame (RNAAC-SIR, see Topic 3.2), and the unification of local height datums (SIRGAS-WGIII, see Topic 1.4). Due to communication problems to transmit the tracking data, some stations were decommissioned and installed at new sites, close to locations with better Internet facilities. This is the case of PDES and MPLA (Argentina), which now are operating about 5 km away of their original locations. These new stations are named PDE2 and MPL2, respectively. Station MARA (Venezuela) is now managed by the Instituto Geográfico de Venezuela Simón Bolívar (IGVSB) in cooperation with the Universidad del Zulia (LUZ). Although the new equipment operating at this station does not belong to DGFI, IGVSB and LUZ continue providing the observations to the corresponding projects. The latest two stations installed by DGFI (July 2009) are located in El Callao (CALL) and Iquitos (IQUI) in Peru. They receive GPS as well as GLONASS signals. The first station is close to the reference tide gauge of this country, and therefore it is integrated into the TIGA network processed by DGFI. Additionally, since both stations contribute to increase the density of the ITRF in South America, they are included in the SIRGAS reference frame. At present, DGFI is coordinating the installation of three additional stations with the Geographical Institutes of Bolivia and Paraguay.

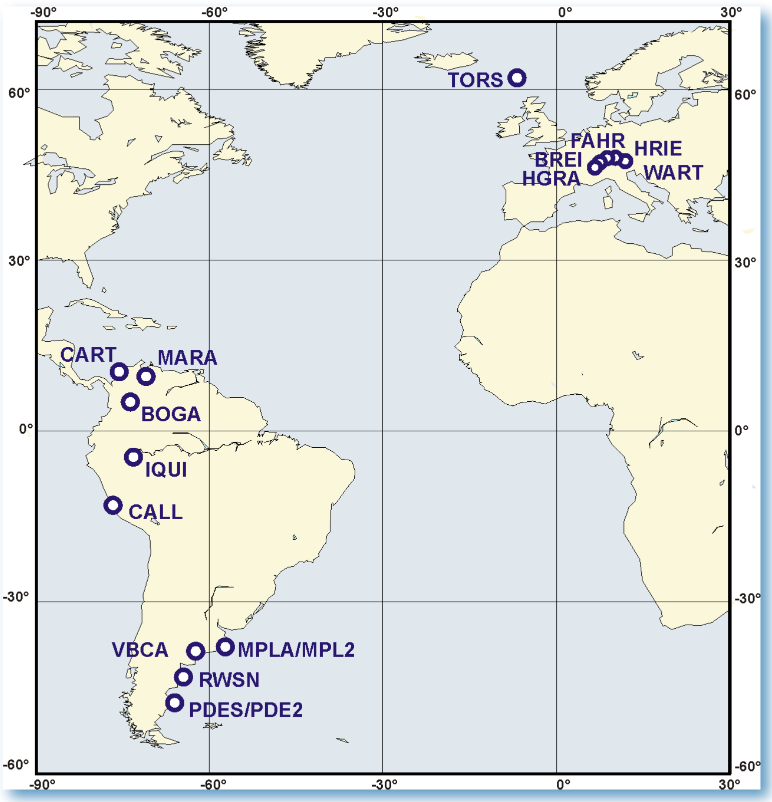


Fig. 3.3.1: Distribution of the continuously operating GNSS stations of DGFI

Station	Location	Partner institution	In operation since	Project
BOGA	Bogotá, Colombia	Instituto Geográfico Agustín Codazzi (IGAC)	Feb. 2000	ITRF/SIRGAS
BREI	Breitenberg, Germany	- - -	Jul. 2005	Alpine deformation
CALL	El Callao, Peru	Instituto Geográfico Nacional (IGN-Pe)		ITRF/SIRGAS, TIGA, vertical datum unification
CART	Cartagena, Colombia	Instituto Geográfico Agustín Codazzi (IGAC)	Feb. 2000	ITRF/SIRGAS, TIGA, vertical datum unification
FHAR	Fahrenberg, Germany	- - -	Jul. 2005	Alpine deformation
HGRA	Hochgrat, Germany	- - -	Jul. 2005	Alpine deformation
HRIE	Hochries, Germany	- - -	Jul. 2005	Alpine deformation
IQUI	Iquitos, Peru	Instituto Geográfico Nacional (IGN-Pe)		ITRF/SIRGAS
MARA	Maracaibo, Venezuela	Station under the responsibility of DGFI until 15/07/2008	Feb. 1998	ITRF/SIRGAS
MPLA/ MPL2	Mar del Plata, Argentina	Universidad Nacional de La Plata	Oct. 2002	ITRF/SIRGAS, TIGA
PDES/ PDE2	Puerto Deseado, Argentina	Universidad Nacional de Cuyo	May 2005	ITRF/SIRGAS, TIGA, vertical datum unification
RWSN	Rawson, Argentina	Universidad Nacional de La Plata	Nov. 1999	ITRF/SIRGAS, TIGA, vertical datum unification
TORS	Torshavn, Faroe Islands	- - -	Feb. 2001	Out of operation since 03/07/2005
VBCA	Bahía Blanca, Argentina	Universidad Nacional de La Plata	Dec. 1998	ITRF/SIRGAS, TIGA, vertical datum unification
WART	Wartsteinkopf, Germany	- - -	Jul. 2005	Alpine deformation

Table 3.3.1: GNSS stations installed by DGFI

Tide gauge benchmark monitoring project

DGFI participates in the IGS TIGA Project (Tide Gauge Benchmark Monitoring Project, http://adsc.gfz-potsdam.de/tiga/) by operating continuously observing GPS stations at six tide gauges, and by processing a network of about sixty GNSS sites as a TIGA Analysis Centre (Figure 3.3.2). The processing strategy is based on the double-difference approach; it includes the main standards outlined by IERS and IGS, i.e. IGS final orbits, absolute IGS calibration values for the antenna phase centre corrections, ocean loading reductions, parameterization of tropospheric delay, etc. The computed daily free normal equations are combined to obtain a loosely constrained weekly solution for station positions, in which satellite orbits, satellite clock offsets, and Earth orientation parameters are fixed to the final weekly IGS combinations, while positions for all sites are constrained to ±1 m. These solutions are provided in SINEX format to the TIGA Associated Analysis Centres (TAAC) and to other users through the web site http://adsc.gfz-potsdam.de/tiga/index_TIGA.html. To guarantee homogeneously computed weekly solutions for the generation of time series of station positions, weekly solutions from January 2000 (GPS week 1043) to October 2006 (1399), formerly computed with relative antenna phase centre corrections for the GPS antennas and referring to previous ITRF solutions, were reprocessed including absolute phase centre corrections and referring to the IGS05 as reference frame.

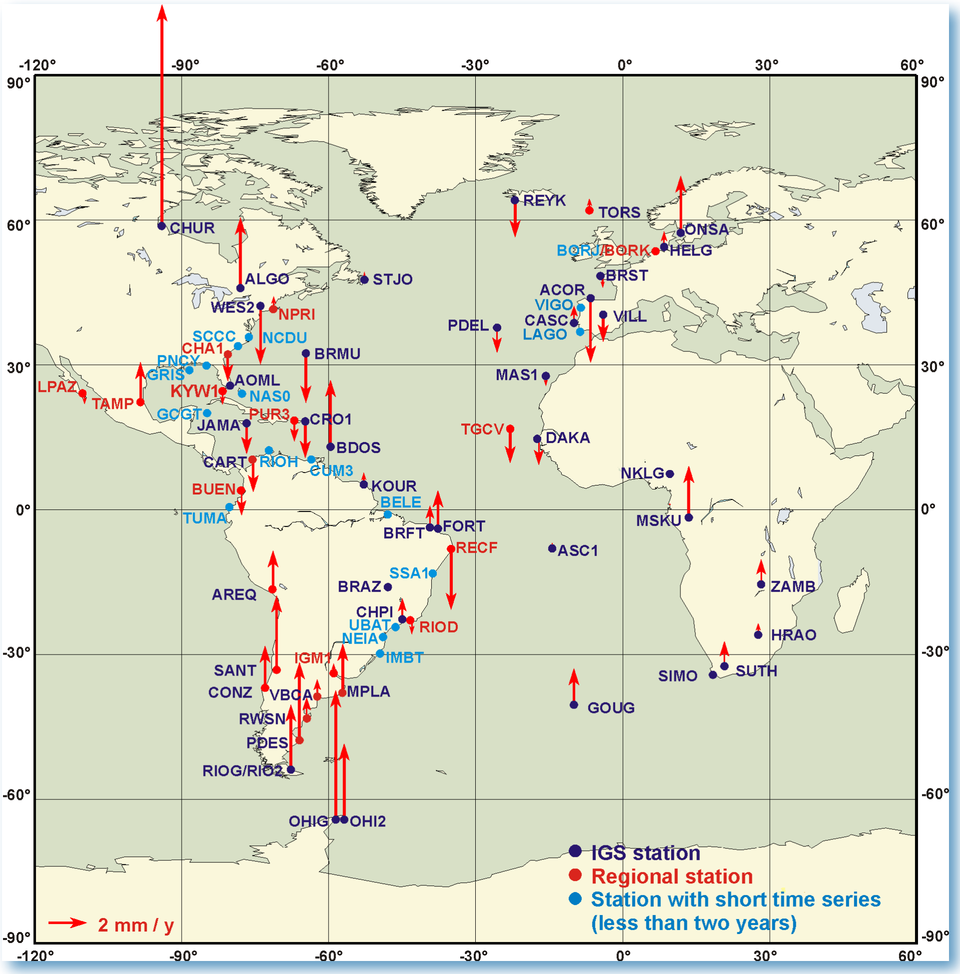


Fig. 3.3.2: Vertical velocities of the GPS network processed at DGFI within the TIGA project

The loosely constrained weekly solutions generated by DGFI are further combined in a multi-annual solution including the stations operating for more than two years. The latest solution of this type (DGF09P01-TIGA) refers to the IGS05, epoch 2000.0, and provides station positions and linear velocities for 57 GNSS sites (Figure 3.3.2). Determination, combination, and solution of the normal equations are carried out with the Bernese GPS Software, V 5.0.

The main objective of TIGA is referring tide gauge benchmarks to a geocentric reference system (ITRS/ITRF) and determining the vertical displacement trend (constant velocity) of the Earth crust at the location of those tide gauges. In this way, secular sea level changes can be clearly distinguished from vertical land motions, and the measured mean sea levels can be linked to a common reference system, i.e. ITRS/ITRF. The results of this analysis, provide informations which are useful for, amongst others, the unification of vertical reference systems (see Topic 1.4) and the validation of satellite altimetry data (see Section 2.2).

In the particular case of the height datum unification, the vertical velocities derived from GPS at coastal sites are analysed together with sea level trends derived from historical tide gauge records in order to determine the real location of the mean sea surface (with respect to the ITRF/ITRS) which realizes the zero-height level of the classical height datums (Sánchez 2009). This procedure is complemented by the inclusion of the sea surface trend obtained from satellite altimetry in the marine areas surrounding the tide gauge sites. The comparison of the absolute sea level trends derived from either satellite altimetry data or the combination of GPS positioning and tide gauge records allows the determination of the discrepancies between the local mean sea levels (i.e. zero-height surface of classical height datums) and a global reference surface W_0 (Sánchez and Bosch 2009). Table 3.3.2 summarizes preliminary trends determined by this approach. The sea level change referred to the ITRS/ITRF is obtained by adding the vertical crustal velocities derived from GPS to the sea level trend determined from the tide gauge records (provided by the PSMSL: Permanent Service for the Mean Sea Level, http://www.pol.ac.uk/psmsl/). We assume that there is no relative vertical motion between tide gauge benchmark and the GPS station. The differences of these values with respect to the absolute sea surface variations provided by satellite altimetry data are, in general, less than 1 mm/y. However, the residual variability of the trends derived from satellite altimetry is considerably large, and the precision estimates of the vertical variation from GPS are too optimistic. The large discrepancies at some tide gauges are a consequence of the well-known problems associated to: 1) the tide gauge records because of their regional locations (bays, creeks, etc.), 2) the uncertainties of the altimetry observations in coastal areas, 3) the dislocation (no coincidence) between tide gauge and altimetry observations and 4) the different time periods covered by the various data sources (GNSS positioning, tide gauge registrations, and satellite altimetry).

Table 3.3.2: Comparison of vertical trends derived from GPS, tide gauge registrations, and satellite altimetry

Station	GPS processing		Tide gauges records (TG)		Satellite altimetry (SatAlt)		GPS+TG [mm/y]	(GPS+TG)-SatAlt [mm/y]
	Trend [mm/y]	Time span	Trend [mm/y]	Time span	Trend [mm/y]	Time span		
ACOR	−1,0 ± 0,1	2003.7–2007.0	2,3 ± 1,9	1992.5–2004.0	2,3 ± 1,5	1993.0–2005.0	1,3	−1,0
BORK	0,3 ± 0,1	2000.8–2007.0	1,2 ± 0,5	1949.0–1987.0	1,6 ± 4,2	1993.0–2005.0	1,5	−0,1
BRST	1,8 ± 0,1	2004.5–2006.1	1,0 ± 0,0	1807.0–2005.0	3,3 ± 1,6	1993.0–2005.0	2,8	−0,5
BUEN	2,7 ± 0,2	2005.8–2007.0	1,0 ± 0,3	1941.0–1970.0	−0,2 ± 1,5	1993.0–2005.0	1,0	1,2
CART	1,6 ± 0,2	2003.5–2007.0	5,3 ± 0,1	1949.0–1993.0	1,3 ± 1,0	1993.0–2005.0	6,9	5,6
CASC	1,6 ± 0,1	2000.4–2007.0	1,3 ± 0,0	1882.0–1994.0	3,6 ± 0,9	1993.0–2005.0	2,9	−0,7
CHUR	12,0 ± 0,1	2000.4–2007.0	−9,7 ± 0,2	1940.0–2004.0	2,6 ± 5,0	1993.0–2005.0	2,3	−0,3
DAKA	−2,0 ± 0,1	2002.2–2004.5	2,9 ± 1,0	1992.7–2003.4	4,4 ± 0,9	1993.0–2005.0	0,9	−3,5
HELG	1,4 ± 0,1	2000.4–2007.0	0,1 ± 0,5	1951.0–1987.0	1,6 ± 4,2	1993.0–2005.0	1,5	−0,1
LPAZ	−0,7 ± 0,2	2005.0–2007.0	1,3 ± 0,3	1952.0–1982.4	−1,9 ± 1,8	1993.0–2005.0	0,6	2,5
MPLA	2,2 ± 0,1	2002.7–2007.0	0,3 ± 0,2	1957.5–2005.0	1,6 ± 2,6	1993.0–2005.0	2,5	0,9
RECF	−3,6 ± 0,1	2000.4–2007.0	−0,2 ± 0,4	1948.8–1969.0	1,6 ± 0,8	1993.0–2005.0	-3,8	−5,4
RIOD	−0,2 ± 0,1	2001.6–2007.0	1,4 ± 1,0	1949.8–1969.0	0,6 ± 1,4	1993.0–2005.0	1,2	0,6
TAMP	1,2 ± 0,2	2005.0–2007.0	1,9 ± 3,1	1952.0–1961.0	3,1 ± 1,4	1993.0–2005.0	3,1	0,0
TORS	0,8 ± 0,1	2001.2–2005.5	1,6 ± 0,2	1957.1–2003.0	2,2 ± 1,1	1993.0–2005.0	2,4	0,2
Mean							1,8 ± 2,2	−0,1 ± 2,4

Monitoring crustal deformations in the Alpine Region

In 2005, under the umbrella of the ALPS-GPS QUAKENET project, a component of the Alpine Space Programme of the European Community Initiative Programme (CIP) INTERREG IIIB, DGFI installed five continuously operating GPS stations located along the northern Alps boundary (Figure 3.3.3). The main purpose of this project was to determine crustal deformations in near real-time to improve natural disaster prevention in the Alpine region. During the two years the project was carried out, DGFI provided the observational data of its stations to be analysed together with 25 other stations installed in the area. Description, main features, and results of the project are presented in the report "ALPS GPS Quakenet: Alpine Integrated GPS Network", available at www.alps-gps.units.it.

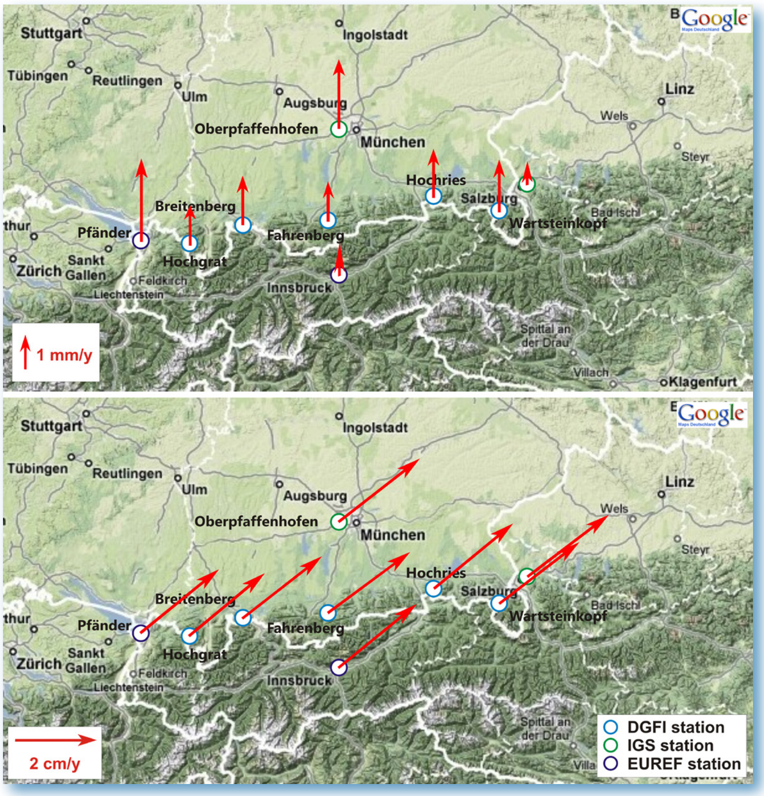


Fig. 3.3.3: Vertical (top) and horizontal velocities (bottom) of the GPS network processed at DGFI to monitor deformations in the Alpine Region

In order to detect local deformations or isolated movements of the DGFI stations, three control points were installed around each DGFI site in a distance of about 100 m from the main point. Control points are measured with GPS once a year and distance vectors with respect to the main stations are analysed. Furthermore, DGFI processes on a weekly basis its five continuously operating stations in a small network, which includes four IGS05 reference stations, three IGS global stations and two EUREF stations. Time series of station positions (Figure 3.3.4) and a cumulative solution (DGF09P01-ALPS, Figure 3.3.3) of this network are derived from loosely constrained daily solutions between 9 October 2005 and 31 October 2009. The resulting station movements mainly reflect the Eurasia plate displacement. Until now, regional or local deformations have not been detected.

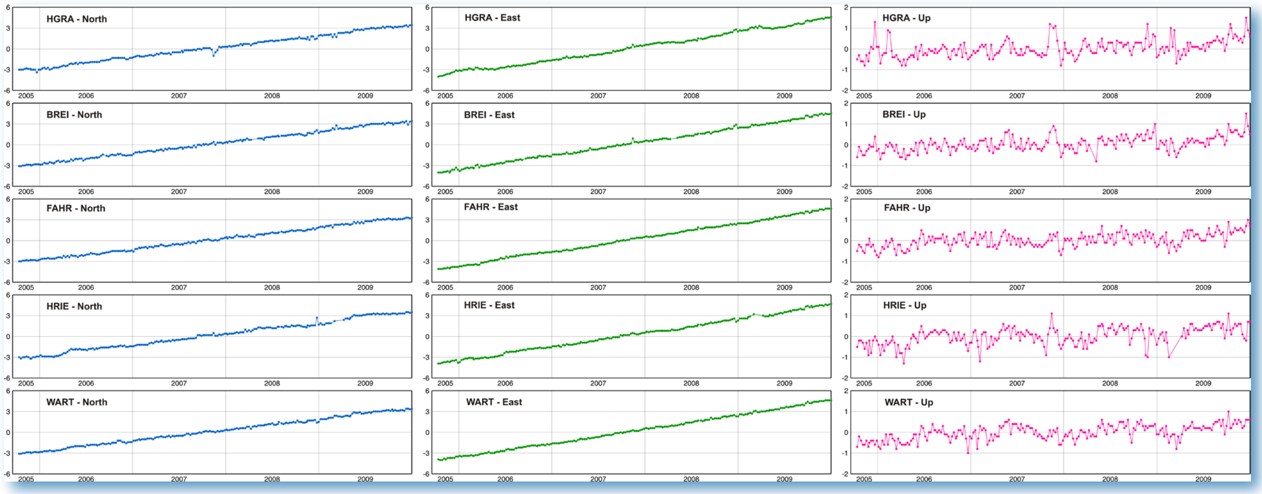


Fig. 3.3.4: Time series (in centimetres) of weekly station positions of the DGFI GPS sites installed for monitoring deformations in the Alpine Region

Related publications:

Sánchez L.: Strategy to establish a global vertical reference system. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 273–278, 2009, DOI: 10.1007/978-3-642-00860-3_42.

Sánchez L., Bosch W.: The role of the TIGA project in the unification of classical height systems. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 285–290, 2009, DOI: 10.1007/978-3-642-00860-3_44.

3.4 ILRS — International Laser Ranging Service

Since 1998, DGFI has contributed to the International Laser Ranging Service (ILRS, (http://ilrs.gsfc.nas.gov) in the maintenance of the global SLR (Satellite Laser Ranging) network by acting as

– Data Centre,
– Analysis Centre,
– Backup Combination Centre.

In 2009, DGFI was appointed as an ILRS Operation Centre.

The ILRS consists of a Central Bureau, a Governing Board which supervises all activities within the ILRS, and eight Working Groups. DGFI contributes to the Analysis Working Group, and to the Data Formats and Procedures Working Group, of which W. Seemüller is Chairman.

ILRS Global Data Centre / EUROLAS Data Centre

Since the foundation of the ILRS in 1998, the EUROLAS Data Centre (EDC) at DGFI has acted as one of two ILRS Global Data Centres (the other one is the Crustal Dynamics Data Information System (CDDIS) at NASA).

ILRS Operation Centre

In 2009 the EDC became an ILRS Operation Centre (OC) after the implementation of the so-called Consolidated Ranging Data (CRD) format. The EDC installed a service that allows the SLR stations to test their generated CRD files through the introduction of a web page. This service was designed in order that the generated CRD files could be checked and validated. The system controls the correct format and the content of the CRD files (e.g. meteorological parameters, station and satellite identifiers, configuration records, etc.). Registered users of the service (currently 28) can upload a CDR file from their local system to the service which leads to the generation and sendig back of an output file which contains the original CRD with any warnings or errors highlighted in red. The ILRS planned the transition to the new format at January 01, 2010, provided that all SLR stations are ready to deliver their observation data in the CRD format. The current CRD conversion status for all SLR stations sending their data to EDC is shown in Table 3.4.1.

Table 3.4.1: CRD conversion status of SLR stations sending their data to EDC

Site	ID	Code	Coding	Testing	OC Val.	AC Val.	Operat.
Golosiiv	1824	GLSV					
Lviv	1831	LVIV	X	X	P		
Maidanak 1	1863	MAID					
Maidanak 2	1864	MAIL					
Komsomolsk	1868	KOML					
Mendeleevo	1870	MDVL					
Simeiz	1873	SIML	X	X	P		
Riga	1884	RIGL	P				
Katzively	1893	KTZL	P				
Wuhan	7231	WUHL					
Chagchun	7237	CHAL	X	X	X	P	
Beijing	7249	BEIL					
Concepcion	7405	CONL	X	X	X	P	
San Juan	7406	SJUL					
Metsahovi 2	7806	METL					
Zimmerwald	7810	ZIML	X	X	X	X	X
Borowiec	7811	BORL	X	X	P		
Shanghai	7821	SHA2	X	X	X	P	
San Fernando	7824	SFEL	X	X	P		
Mount Stromlo	7825	STL3	X	X	X	P	
Helwan	7831	HLWL					
Riyadh	7832	RIYL					
Graz	7839	GRZL					
Herstmonceux	7840	HERL	X	X	X	X	X
Potsdam	7841	POT3	P				
Grasse	7845	GRSM	X	X	X	P	
Matera	7941	MATM	X	X	X	X	X
Wettzell	8834	WETL	X	X	X	X	X
FTLRS	----	----	P				

Notes: X completed P in process Status: Nov. 25, 2009

Mail Exploders

EDC runs several mail exploders for exchanging information, data and results. The Consolidated Prediction Format (CPF) files of 25 satellites are exploded automatically on a daily and subdaily basis and stored at the anonymous ftp server. The SLRMAIL exploder distributed a total of 1803 emails, the SLREPORT exploder 11512, and the URGENT mail exploder 235 emails. The strategy to avoid the distribution of spam was improved, but the distribution lists of these exploders are to be updated periodically.

Observation Campaigns

The ENVISAT, GIOVE-A/B, ETS-8, TerraSAR-X, JASON-1 and JASON-2 Tandem missions are still tracked, and the new missions ANDE Castor; ANDE Pollux, BLITS, COMPASS-M1 and GOCE were approved by the ILRS Governing Board.

Observed Satellite Passes

In the time period from October 01, 2008 to December 31, 2009, 41 SLR stations observed 52 satellites (including the four moon reflectors). Table 3.4.2 shows the EDC data base content at December 31, 2009. This content is compared with the one of the CDDIS data base, and regularly updated at EDC and/or CDDIS for missing data.

Table 3.4.2: Content of ILRS/EDC data base at December 31, 2009 for the product normal points (including Lunar Laser Ranging (LLR) observations to four moon reflectors)

Satellite	number of passes		Satellite	number of passes		Satellite	number of passes	
	Oct. 08 – Dec. 09	Total		Oct. 08 – Dec. 09	Total		Oct. 08 – Dec. 09	Total
ADEOS		671	GLONASS-70		1430	GLONASS 115	1796	1796
AJISAI	15375	144232	GLONASS-71		2617	GOCE	557	557
ALOS		91	GLONASS-72		3260	GPS-35	583	8790
ANDEC	417	417	GLONASS-74		39	GPS-36	1102	8497
ANDEP	254	254	GLONASS-75		300	GRACE-A	3415	17321
ANDE-RR A	1	442	GLONASS-76		301	GRACE-B	3548	16784
ANDE-RR P		662	GLONASS-77		343	GRAVITY PROBE-B		3156
BEACON-C	7575	64637	GLONASS-78	18	2778	ICESAT	2187	8182
BLITS	732	732	GLONASS-79		3237	JASON-1	10055	62227
CHAMP	2375	16225	GLONASS-80		4466	JASON-2	11198	13112
COMPASSM1	1308	1308	GLONASS-81		275	LAGEOS-1	12252	111088
DIADEME-1C		1393	GLONASS-82		244	LAGEOS-2	10600	97052
DIADEME-1D		1585	GLONASS-84		6442	LARETS	5870	27499
ENVISAT	7724	44626	GLONASS-86		1311	LRE/H2A		76
ERS-1		10524	GLONASS-87		7330	METEOR-3		409
ERS-2	7950	75513	GLONASS-88		114	METEOR-3M		1756
ETALON-1	2407	18404	GLONASS-89		6400	MOON-0	9	424
ETALON-2	2037	18129	GLONASS-95		4376	MOON-2	6	333
ETS-8	192	712	GLONASS-99	758	3666	MOON-3	54	2636
FIZEAU		4243	GLONASS-100	284	284	MOON-4		594
GEOS-3		2237	GLONASS-101	2	2	OICETS	400	515
GFO-1	149	45008	GLONASS-102	2368	4335	REFLECTOR		3728
GFZ-1		5606	GLONASS-103	4	4	RESURS-01-3		2011
GIOVE-A	690	3071	GLONASS-104	2	2	STARLETTE	12402	111102
GIOVE-B	1220	1426	GLONASS-105	4	4	STARSHINE-3		48
GLONASS-62		963	GLONASS-106	3	3	STELLA	6998	66645
GLONASS-63		1952	GLONASS-107	2	2	SUNSAT		1864
GLONASS-64		81	GLONASS-108	1	1	TerraSAR-X	4262	7799
GLONASS-65		397	GLONASS-109	2212	2716	TIPS		1849
GLONASS-66		1544	GLONASS 110	2	2	TOPEX/POS.		86423
GLONASS-67		4299	GLONASS 111	2	2	WESTPAC-1	34	5663
GLONASS-68		875	GLONASS 113	4	4	ZEIA		146
GLONASS-69		945	GLONASS 114	4	4	**Sum of all**	**143404**	**1199580**

ILRS Analysis Centre

An ongoing self-acting procedure is the weekly processing of the SLR tracking data of the geodetic satellites Lageos-1/2 and Etalon-1/2. The solutions contain station positions and Earth orientation parameters (pole coordinates X_{pole}/Y_{pole}, LOD) and range bias values for selected tracking stations. The results are sent as SINEX files to the ILRS Data Centers CDDIS and EDC.

As a check of the SLR tracking data, pass-dependent biases for all stations are processed on a daily basis and published on the DGFI/SLR group homepage: ilrs.dgfi.badw.de. In case of major problems, such as significant time or range biases, the affected station and the ILRS task force receive direct email notification about the problem to allow immediate reaction.

Due to revised biases for some stations, the ILRS/AWG decided at the working group meeting in Vienna, May 2009 a reprocessing of the SLR part of the ITRF 2008. The result was a better SLR time series of station coordinates and EOP parameters for the period January 1984 to December 2008.

Qualification of CRD data

During 2009, the ILRS decided to switch from the old SLR format to the new consolidated ranging data format (CDR). This implies the implementation of new software at the tracking sites and the analysis centres. The quality check of new stations is done on two levels, first formally by the data centres and secondly by the analysis centres. Thus it is ensured that the quality and amount of the new data are comparable to the old onsite normal point data.

Station data handling file

A machine-readable file called ILRS_Data_Handling_File.snx is maintained at the DGFI ILRS web pages. It contains all information about any range, time or pressure biases for all tracking stations. This file is regularly updated; the necessary bias-corrections must be processed by the analysis centres.

Use of more satellites in the routine processing

To stabilize the station position and the low-degree harmonics solutions, tracking data to Starlette and Ajisai were reprocessed, first only for a test period. These satellites are easy targets and hence have a good tracking record. Using the new gravity field and ocean tide models, nearly equal orbital fits for Starlette and Ajisai have now been achieved, as already before for the Lageos satellites (below 2 cm). Especially in the period prior to 1990, the station positions and possibly the EOP solutions can be stabilized. Nearly all Glonass satellites are equipped with Laser retroreflectors, and in future all GNSS satellites will be so equipped. In consequence, the intention is to utilize these additional tracking data mainly for estimating low degree harmonics and LOD.

ILRS Combination Centre (ILRSB)

As the official ILRS Backup Combination Centre (ILRSB), DGFI continued to routinely process seven-day combination solutions for each week and seven-day solutions for each day. Additionally, in 2009, the reprocessing from 1983 to 2008 was carried out in several versions. The combination software package DOGS-AS was extended as to allow automatic processing of station positions. Especially, the automatic remedy of analytical outliers (singularities of normal equation systems, negative diagonal elements of covariance matrices, negative or unrealistic variance factors of the variance-covariance estimation) and of formal errors was investigated and further developed.

As examples of the most recent reprocessing, time series for the heights of the core station Yarragadee are presented in Figure 3.4.1.

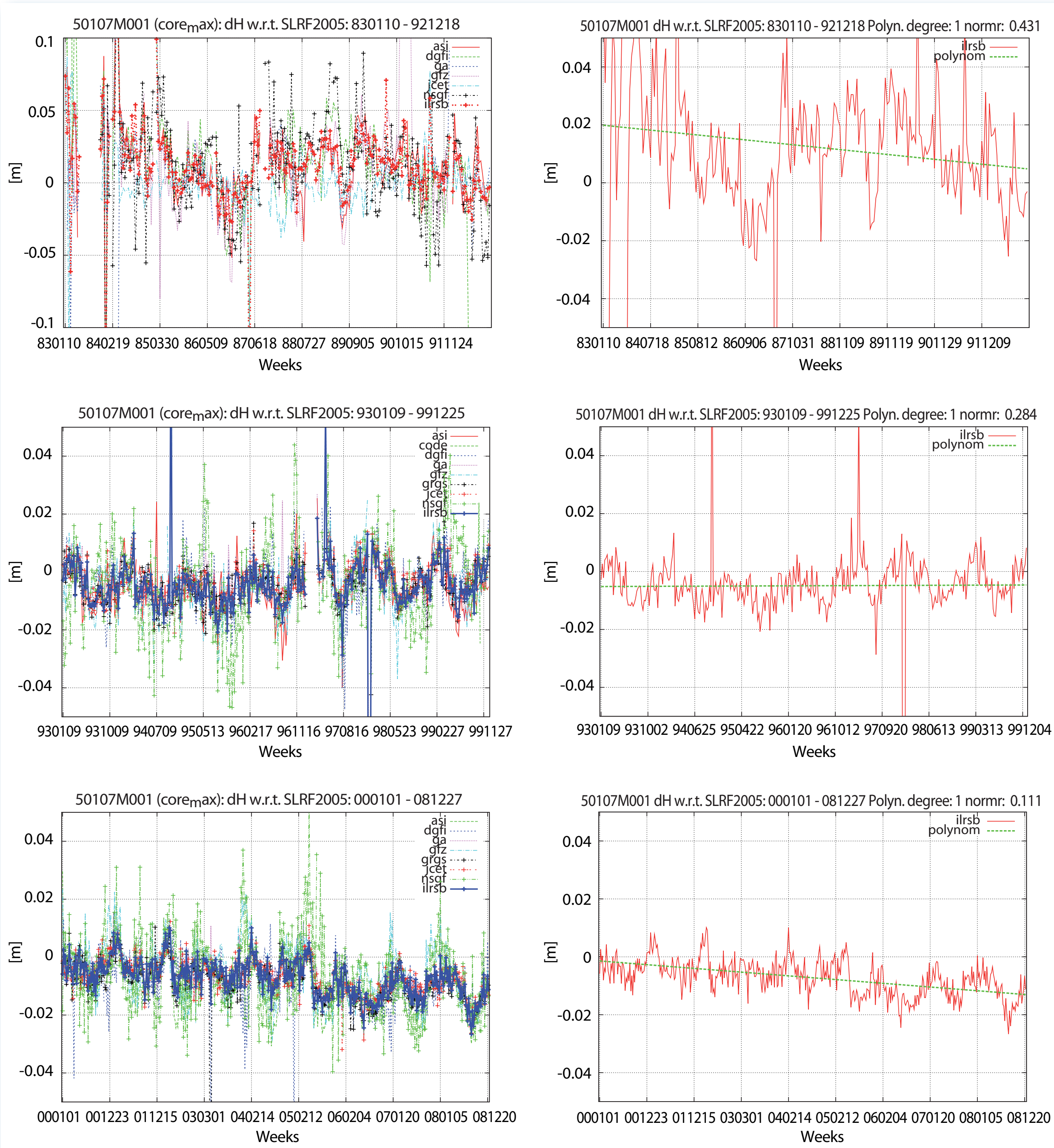


Fig. 3.4.1: Time series for the heights of core station Yarragadee (Dome 50107M001): Minimum-constraint solutions of Analysis Centres and ILRSB (left column) and of ILRSB and linear polynomal (right column). First row: 1983 to 1992, second row: 1993 to 1999, third row: 2000 to 2008.

3.5 IVS Analysis Centre

IVS Full Analysis Centre at DGFI

DGFI successfully upgraded its status from an Associate Analysis Centre to an operational (full) Analysis Centre of the International VLBI Service for Geodesy and Astrometry (IVS). By now, session-wise SINEX files are computed and provided to the IVS Data Centre (DC) for all regular X-/S-band sessions of the geodetic and astrometric observing program. Currently, the sessions of "rapid turnaround" type (R1, R4) constitute the standard IVS networks. They are accompanied by global (T2) and regional (Europe, JADE) networks, as well as research and development (R&D) experiments. During the southern-hemispheric summer months, the O'Higgins antenna successfully participated in networks of global extension. From 2008 August 12, 0:00 UT to 2008 August 26, 23:59 UT, eleven stations contributed to a new CONT campaign (CONT08) lasting 15 days, see Figure 3.5.1. The aim of this campaign of continuous observation was to assess and to demonstrate the state-of-the-art quality of the space-geodetic techniques. Therefore, CONT08 was carried out with special diligence not only by VLBI but also by GNSS and SLR techniques. In its function as an operational Analysis Centre (AC), DGFI has to analyse and to submit each of these session types within 24 hours after the release of the corresponding NGS-files. By use of FORTRAN routines provided by IAA, which allows the translation from database format version 4 (or higher) to NGS format, the time delay of DGFI submissions could be significantly reduced. In spring 2009, according to the IVS call, DGFI contributed a series of VLBI sessions to the input of the ITRF2008 computations. About 3200 sessions covered a time span from 1984-01-01 to 2008-12-31 and were processed according to the standards released by the IVS Analysis Coordinator together with the ITRF Product Centre.

Fig. 3.5.1: Network of the CONT08 campaign

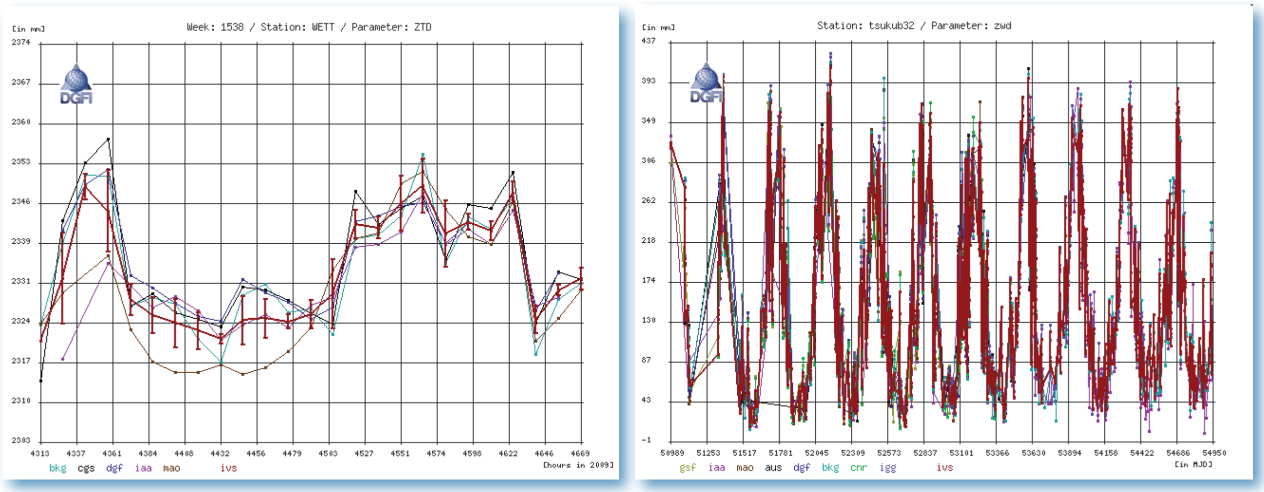


Fig. 3.5.2: Graphical presentation of the IVS troposphere products: examples of rapid troposphere combination (left) and long-term troposphere combination (right) carried out at DGFI

IVS Combination Centre (BKG/DGFI)

Together with BKG, DGFI became the first Combination Centre of IVS. In this context, the VLBI group at DGFI has taken over two more tasks: the maintenance of the DOGS software for the combinations on the normal equation level carried out at BKG and the combination of the two IVS tropospheric products (long-term and rapid troposphere combinations, see Figure 3.5.2).

Development of OCCAM

After the release of its previous version, the OCCAM software was extended by the new conventional model of thermal antenna deformation. A new solution code (dgf2009a) was introduced ,and the entire list of sessions was re-analysed and re-submitted. The Linux version of OCCAM (LSM) is currently undergoing severe changes. Besides the switch to a 64bit LINUX-system, the source code needed to be homogenised and numerically optimized. By a modular and state-of-the-art FORTRAN code, the software shall become clearer, more self-consistent and better upgradeable. The integration of OCCAM into the existent DOGS software might become an option in future.

IVS/IERS Working Group on the second realization of the International Celestial Reference Frame (ICRF2)

At the end of July 2009, the IVS/IERS Working Group finished the computation of ICRF2 with the compilation of the IERS Technical Note No. 35, which describes the big international effort in detail. Based on this report, the IAU General Assembly in August 2009 determined the ICRF2 to become the conventional celestial reference frame as of January 2010 (IAU resolution B3, 2009). DGFI investigated the effects of meteorological input data on the celestial reference frame and contributed time series of radio source positions for the selection of defining sources and the quality assessment.

Contribution to the new International Terrestrial Reference Frame (ITRF2008)

The VLBI group was able to successfully compute and contribute a solution for the new realization of the terrestrial reference system ITRF2008. The VLBI intra-technique combination, an intermediate step towards the inter-technique combination, already proved to be better than the contribution to the predecessor, ITRF2005.

3.6 International Altimeter Service (IAS)

Following endorsements by GLOSS, IAPSO and IAG, the International Altimetry Service (IAS) was established in 2007 as an initiative of the International Association of Geodesy. This initiative is non-competitive, but, instead, is to compile general information on satellite altimetry, to identify and pool together international resources in altimetry, and to initiate projects completing or gradually improving existing services for the benefit of the altimetry community at large.

Website development

As one of the initial activities, the compilation and presentation of general information has been identified. Altimetry users should be informed where to get what data, products and documents. Therefore a preliminary website at http://ias.dgfi.badw.de was launched with an initial compilation of available mission data and their associated data handbooks. A list of the most basic products, their characterization and links for downloads is currently being compiled. This will inform users about existing mean sea surface models, sea level anomalies, models of dynamic ocean topography, ocean tide models, and marine gravity data.

Pilot Project on Ocean Tides (IAS-PP-OT)

A pilot project on ocean tides was prepared with a draft Call for Participation to be submitted as soon as possible. This Call is seeking proposals of groups, agencies, or individuals to contribute to one or more of the following initial, non-exhaustive focal points:

- compilation of global ocean tide (OT) models, their error estimates (if available) and their documentation; convert them to a common, self-standing format.
- provide an Internet portal to access and download OT models, associated documentation (reports, plots, etc.), and software to evaluate the models.
- compare OT models with each other, document and visualize differences.
- provide software to evaluate OT models for ocean areas, at individual observations sites or along the sub-satellite tracks of altimeter satellites.
- provide software to transform OT models to a spherical harmonic representation used for orbit and gravity field determination processes, and other computations required for Earth system science studies.
- evaluate the impact of different OT models on orbit computation (of LEO's) and gravity field determination by altimeter data, and analysis of residuals of space gravity observations (e.g. GRACE).
- compile tidal constants, analyse times series of tide gauges, bottom pressure gauges, continuously operating GNSS sites and gravimeter stations in order to validate OT models by means of independent data or to use data in assimilation approaches.
- compile local or regional ocean tides models, compare them with global OT models and investigate approaches to perform a fusion of global and regional ocean tide models.

Other pilot projects are in preparation.

3.7 GGOS Bureau for Standards and Conventions

The proposal for the GGOS Bureau for Standards and Conventions (BSC) submitted by the Forschungsgruppe Satellitengeodäsie (FGS) was accepted by the GGOS Steering Committee Meeting on Dec. 14, 2008.

Establishment

The BSC is jointly operated by Forschungseinrichtung Satellitengeodäsie (FESG) and Institut für Astronomische und Physikalische Geodäsie (IAPG) of Technische Universität München (TUM) and DGFI. The chair of the Bureau is at TUM, the Secretary is at DGFI. Additional members from the three institutions provide profound expertise in gravity field, reference frames, and Earth rotation.

Mission

According to the Terms of Reference, the BSC has the following missions and goals:

- to keep track of the strict observance of adopted geodetic standards, standardized units, fundamental physical constants, resolutions and conventions in the generation of the products issued by the geodetic community, including the regular control of data sets released by the geodetic services,
- to review, examine and evaluate all standards, constants, resolutions and conventions adopted by IAG or its components, and to recommend their use or propose the necessary updates,
- to identify gaps and deficiencies in standards and conventions and to initiate steps to close them,
- to propose the adoption of new standards and conventions in need,
- to propagate standards and conventions to the wider scientific community and to promote their use.

The work of the BSC is thus focussing, on the one hand, at the geodetic community to assure that a consistent set of standards and conventions is used and, on the other hand, at the broader scientific community and society in general by promoting the use of such consistent geodetic standards.

First activities

After approval of the Terms of Reference of the BSC by the GGOS Steering Committe, the BSC contacted the representatives of IAG Services and Commissions as well as of international bodies concerned with standardization such as CODATA, ISO/TC211, BIPM and informed them about its objectives. The BSC started to collect all the relevant resolutions concerned with geodetic standards and conventions used by different entities and to compile an inventory of used constants. One example which highlights an inconsistent use of standards is the different handling of permanent tides by the geometric and the gravimetric services.

4 Information Services and Scientific Transfer

Scientific research needs to publish its results for scientific use and to meet the requests of society. This applies especially for geosciences. Considering the fact of decreasing funds and other restrictions, we have to sustain the permanent and long-term work in the field of geodesy. This requires a system of clear and accessible information. The information can either be provided by personal contacts, by written documents, or by easily accessible data, e.g. the Internet. Research is more and more based on broad cooperation, therefore it happens that careful documentation of data and results is requested on a more frequent basis. The Internet has proven to serve as a fast and worldwide accessible tool for information exchange. This tool is fully used. For many other requests, printed reports are produced, especially for long-term documentation.

The DGFI maintains a homepage (http://www.dgfi.badw.de/), in which all activities of the institute are presented in detail. Moreover links to the IAG entities lead to the international geodetic organizations, especially to the IAG Office, which has been located at DGFI since the second half of 2007. Other links point to national/international projects. Furthermore, the German Geodetic Commission (Deutsche Geodätische Kommission – DGK) maintains its homepage (http://dgk.badw.de/), informing about the Commission and its activities, and also about various topics of geodesy, such as conferences, education in geodesy, job offers in geodetic research, links to other geodetic institutions. In this homepage the publications of the German Geodetic Commission (Veröffentlichungen der Deutschen Geodätischen Kommission – DGK) with up to 1000 volumes are listed in detail as well.

4.1 Internet representation

The Internet has become an indispensable medium for the exchange of data and scientific information. DGFI established and thenceforth maintains several independent Internet sites to meet growing demands for information about different scientific aspects.

Typo3 Content Managament System

The multiple Internet sites are realized and maintained by means of the Typo3 Content Management System (CMS). The content of pages is administered by a database system. Typo3 ensures a common layout by pre-defined templates and provides simple interfaces to the editors. With Typo3, the Internet sites can be remotely administered by means of a browser interface without any need of specific knowledge of “mark up” languages such as HTML or CSS. Typo3 is an ‘Open Source’ project and therefore available free of charge. It is one of the most actively developed content management systems, applied by many commercial sites. Typo3 provides comfortable functions to handle graphics − a necessary feature for the presentation of scientific results.

Internet sites set up and maintained by DGFI

The Internet sites of DGFI inform about
- the institute and its research programme (DGFI home page),
- its responsibility for the Office of the International Association of Geodesy (IAG),
- the “Deutsche Geodätische Kommission (DGK)”,
- a Geodesy Information System (GeodIS), and
- the EUROLAS Data Centre (EDC).

DGFI uses the same system also for Internet sites dedicated to
- the DFG priority program “Mass transport and mass distribution in the Earth system” (SPP1257),
- Geocentric Reference System for the Americas (SIRGAS),
- the Open Altimeter Database (OpenADB),
- and the International Altimeter Service (IAS).

Moreover, the Internet is used to maintain

- several file transfer servers for extensive data exchange, which are necessary for the DGFI to act as data and analysis centre,
- collaborative Internet sites for specific projects and
- an intranet site to support compilation and distribution of internal information (blackboard, calendar, library).

DGFI home page

The DGFI home page, available under

http://www.dgfi.badw.de ,

informs about the structure and results of the actual research programme, ongoing research topics, the national and international projects DGFI is involved in and the multiple contributions of DGFI to international services. The home page (see Figure 4.1.1, left) also provides a complete list of papers and reports published since 1994 by the employees as well as a compilation of all posters and presentations. Most recent publications and posters are as far as possible available in electronic form (mostly the portable document format, pdf).

Internet siete for IAG Office

At the General Assembly of IUGG in Perugia, Italy, the IAG was reorganized. The position of the IAG Secretary General was handed over to the Director of DGFI, and the IAG Office was established at DGFI. The website

http://iag.dgfi.badw.de

was installed to support the work of the Office (see Figure 4.1.1, right).

Geodesy Information System GeodIS

The geodesy information system GeodIS, located at

http://geodis.dgfi.badw.de ,

is further maintained by DGFI with the objective to compile informations about the most important areas of geodesy. The intention of GeodIS is to give support in finding information on and data relevant to geodesy. GeodIS provides also links to the home pages of international scientific organizations (see Figure 4.1.2, left).

Fig. 4.1.1: Screenshots of the DGFI home page (left) and the Internet site for the IAG Office (right)

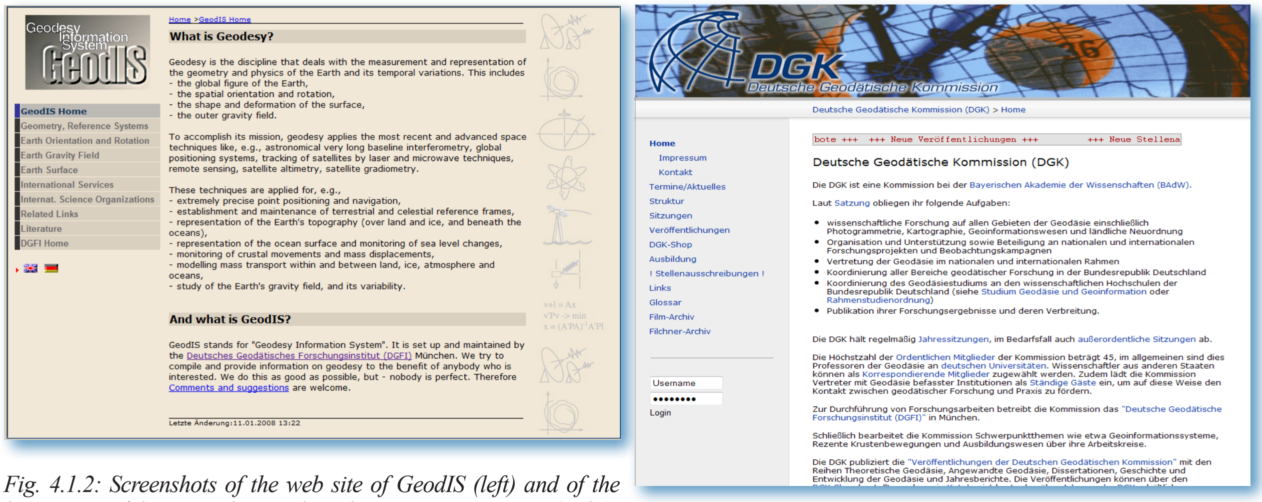


Fig. 4.1.2: Screenshots of the web site of GeodIS (left) and of the home page of the Deutsche Geodätische Kommission, DGK (right)

Internet site for Deutsche Geodätische Kommission (DGK)

Another Internet site is maintained for the “Deutsche Geodätische Kommission” (DGK). It is available at

http://dgk.badw.de

and informs about the structure of the DGK, the membership, sections, geodetic research institutes in Germany, and the numerous publications of DGK. The complete catalogue of DGK publications can be downloaded as a pdf file or browsed by means of a user-friendly search function (see Figure 4.1.2, right).

Internet site for the DGFI priority program "Mass transport and mass distribution in the Earth system"

A further Internet site for the DFG priority program “Mass transport and mass distribution in the Earth system”, SPP1257, was realized with the Typo3 content management system. It resides on a DGFI server, but has its own domain name

http://www.massentransporte.de .

The site (see Figure 4.1.3, left) makes the SPP program known to the public and other scientists (outreach), supports the organization of international symposia, and provides also a basis for internal information exchange with links to data and products that are relevant for the priority program.

SIRGAS home page

SIRGAS is the Geocentric Reference System for the Americas. The web site is operated by the SIRGAS Vice-President at DGFI and located at

http://www.sirgas.org .

The SIRGAS website comprises (see Figure 4.1.3, right)
– a scientific description presenting definition, realization, and kinematics of the SIRGAS reference frame,
– an organizational summary showing the operational structure and functions of the different components of SIRGAS,
– a bibliographic compilation with reports, articles, presentations, and posters related to the SIRGAS activities.

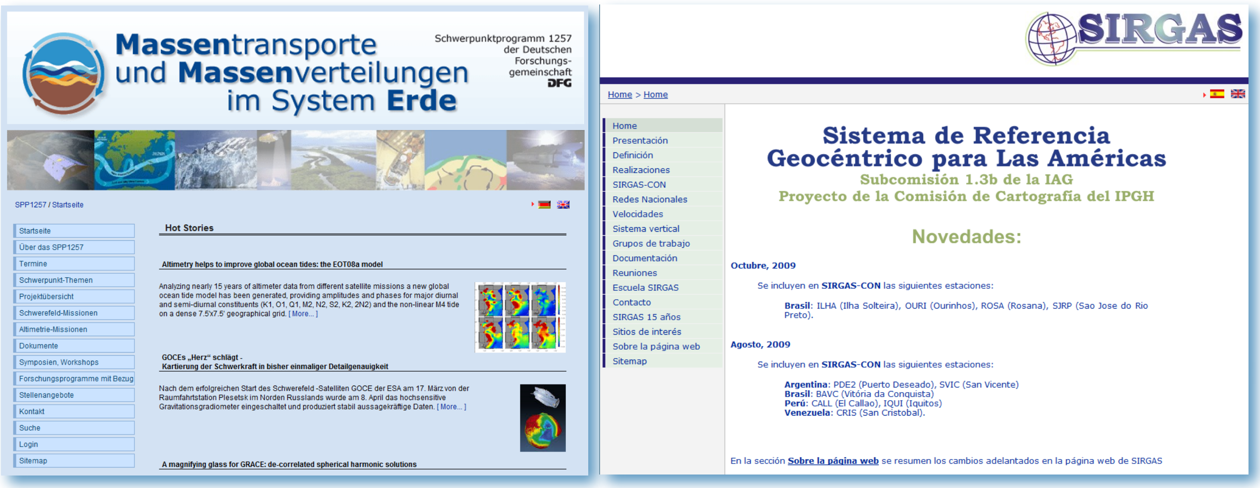


Fig. 4.1.3: Screenshots of the web site of the DFG priority program "Mass transport and mass distribution in the Earth system" (left) and of the web site of SIRGAS (right)

The SIRGAS Continuously Operating Network (SIRGAS-CON) is presented in detail through interactive tools, which allow to call coordinates, velocities, log files, and the main chronological events of each station. The SIRGAS web page has been hosted by DGFI since August 2007 in both English and Spanish.

Open Altimeter Database home page (OpenADB)

OpenADB is a database for multi-mission altimeter data and derived high-level products. It is designed for users with little experience in satellite altimetry and scientific users evaluating data and generating new products, models and algorithms. OpenADB allows fast parameter updates and enables data base extracts with user-defined formats and parameters. The usage of OpenADB is open after registration to anyone (see Figure 4.1.4, left). This site is available under

http://openadb.dgfi.badw.de.

Internet site for the International Altimeter Service (IAS)

The home page of the International Altimeter Service

- provides a point of contact for general information on satellite altimetry and its applications
- communicates and interfaces with altimeter mission data providers and with centres which process, archive and analyse altimeter data and other related services and organizations;
- promotes satellite altimetry as a core element of Global Earth Observing Systems
- helps users to compile and analyse data and to respond to altimeter user requirements.

This site is available under

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

but is still under development.

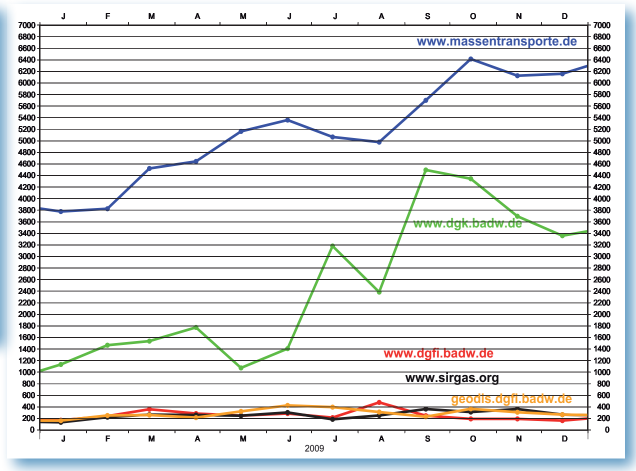


Fig. 4.1.4: Screenshots of the web site for the Open Altimeter Data Base (left) and an access statistics for selected web sites (right)

User statistics

Figure 4.1.4, right shows the user statistics of the following pages maintened by the DGFI.

– www.massentransporte.de
– www.dgfi.badw.de
– www.dgk.badw.de
– www.sirgas.org
– geodis.dgfi.badw.de

Mailing lists

Mailing lists are maintained by DGFI to fulfil the requirements for information exchange within the ILRS Global Data Centre and the Reference System SIRGAS. The mailing lists are partly realized by a set of 'bash'-scripts, which are automatically executed according to pre-defined schedules or by the 'mailman' program, which transforms submitted e-mails to a specific format which can then be viewed by any Internet browser sorted according to date, thread or author.

Intranet

Another server behind a firewall is used to provide Intranet functionality, again, on the basis of the Typo3 content management system. The internal information exchange is supported by a black board, a meeting calendar, the access to the library data base, and numerous pages which can be created, modified or deleted by any of the employees. The pages compile internal information for the work of particular research topics, links to data sets, formats, internal documentation and the necessary meta data.

4.2 Publications

ANGERMANN D., DREWES H., GERSTL M., MEISEL B., SEITZ M.: ITRS Combination Centre at DGFI. IERS Annual Report 2007, Bundesamt für Kartographie und Geodäsie, Frankfurt a. M., 2009

ANGERMANN D., MÜLLER H.: On the strength of SLR observations to realize the scale and origin of the terrestrial reference system. In: Sideris M.G. (Ed.): Observing our changing Earth, IAG Symposia, Springer, Vol. 133, 21–29, 2009

ANGERMANN D., DREWES H., GERSTL M., KRÜGEL M., MEISEL B.: DGFI combination methodology for ITRF2005 computation. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 11–16, 2009, DOI: 10.1007/978-3-642-00860-3_2

ANGERMANN D., DREWES H., KELM R., MEISEL B., SEITZ M., TESMER V.: IERS Combination Research Centre at DGFI. IERS Annual Report 2007, Bundesamt für Kartographie und Geodäsie, Frankfurt a. M., 2009

ANGERMANN D., DREWES H., MEISEL B., SÁNCHEZ L., SEEMÜLLER W., SEITZ M.: DGFI combination methodology for terrestrial reference frame computations. Bollettino di geodesia e scienze affini – N. 2, 175–198, 2009

BOSCH W., SAVCENKO R., FLECHTNER F., DAHLE C., MAYER-GÜRR T., STAMMER D., TAGUCHI E., ILK K.-H.: Residual ocean tides signals from satellite altimetry, GRACE gravity fields, and hydrodynamic modelling. Geophys. J. Int., DOI: 10.1111/j.1365-246X.2009.04281.x, 2009

BÖHM J., HEINKELMANN R., SCHUH H.: Neutral atmosphere delays: empirical models versus discrete time series from numerical weather models. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 317–321, 2009, DOI: 10.1007/978-3-642-00860-3_49

BÖHM J., HEINKELMANN R., MENDES-CERVEIRA P., PANY A., SCHUH H.: Atmospheric loading corrections at the observation level in VLBI analysis. Journal of Geodesy, Vol. 83, 1107–1113, 2009, DOI: 10.1007/s00190-009-0329-y

BOUMAN J., RISPENS S., GRUBER T., KOOP R., SCHRAMA E., VISSER P., TSCHERNING C.C., VEICHERTS M.: Preprocessing of gravity gradients at the GOCE high-level processing facility. Journal of Geodesy, Vol. 83, 659–678, 2009, DOI: 10.1007/s00190-008-0279-9

BRUYNINX C., ALTAMIMI Z., BOUCHER C., BROCKMANN E., CAPORALI A., GURTNER W., HABRICH H., HORNIK H., IHDE J., KENYERES A., MÄKINEN J., STANGL G., VAN DER MAREL H., SIMEK J., SÖHNE W., TORRES J.A., WEBER G.: The European Reference Frame: Maintenance and products. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 131–136, 2009, DOI: 10.1007/978-3-642-00860-3_20

DREWES H.: Reference systems, reference frames, and the geodetic datum - Basic considerations. In: Sideris M.G. (Ed.): Observing our changing Earth, IAG Symposia, Springer, Vol. 133, 3–9, 2009

DREWES H.: The actual plate kinematic and crustal deformation model (APKIM2005) as basis for a non-rotating ITRF. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 95–99, 2009, DOI: 10.1007/978-3-642-00860-3_15

DREWES H. (Ed.): Geodetic Reference Frames, IAG Symposium Munich, Germany, October 9–14, 2006. IAG Symposia, Springer, Vol. 134, 2009, DOI: 10.1007/978-3-642-00860-3

ENGLICH S., HEINKELMANN R., SCHUH H.: Re-assessment of ocean tidal terms in high-frequency Earth rotation variations observed by VLBI. In: A. Finkelstein and D. Behrend (Eds.): IVS 2008 General Meeting Proceedings, 314–318, 2008, ISBN 978-5-02-025332-2

GÖTTL F., SEITZ F.: Contribution of non-tidal oceanic mass variations to polar motion determined from space geodesy and ocean data. In: Sideris M.G. (Ed.): Observing our changing Earth, IAG Symposia, Springer, Vol. 133, 439–445, 2009, DOI: 10.1007/978-3-540-85426-5_53

GÖTTL F., RUMMEL R.: A geodetic view on isostatic models. Pure and applied geophysics, 1247–1260, 2009, DOI: 10.1007/s00024-004-0489-x

HEINKELMANN R.: Bestimmung des atmosphärischen Wasserdampfes mittels VLBI als Beitrag zur Klimaforschung. PhD thesis, Geowissenschaftliche Mitteilungen, Heft Nr. 82, 212, 2008, ISSN 1811-8380, Schriftenreihe der Studienrichtung Vermessung und Geoinformation

HEINKELMANN R.: IVSTrop: Status and recommendations of the IVS rapid troposphere combination. In: G. Bourda, P. Charlot, A. Collioud (Eds.): Proceedings of the 19th Working Meeting on European VLBI for Geodesy and Astrometry, 179–181, 2009

HEINKELMANN R., BÖHM J., SCHUH H.: Very long baseline interferometry (VLBI) for climate studies. In: M. Karslioglu, M. Nohutcu, E. Erdogan (Eds.): Proceedings of the Turkish National Geodetic Commission Scientific Meeting TUJK 2007, 65–71, 2008

HEINKELMANN R., BÖHM J., SCHUH H.: Effects of surface pressure and temperature on the VLBI reference frames. In: A. Finkelstein and D. Behrend (Eds.): IVS 2008 General Meeting Proceedings, 188–192, 2008, ISBN 978-5-02-025332-2

HEINKELMANN R., FREYMUELLER J.T., SCHUH H.: A postseismic relaxation model for the 2002 Denali earthquake from GPS deformation analysis applied to VLBI data. In: A. Finkelstein and D. Behrend (Eds.): IVS 2008 General Meeting Proceedings, 335–340, 2008, ISBN 978-5-02-025332-2

HEINKELMANN R., BÖHM J., SCHUH H., TESMER V.: The effect of meteorological input data on the VLBI reference frames. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 245–251, 2009, DOI: 10.1007/978-3-642-00860-3_38

HENSE A., SÜNDERMANN J., DREWES H., THOMAS M., CHEN X., DILL R., MÜLLER M., SEITZ F., STUCK J., WALTER C., WINKELNKEMPER T.: Physically consistent system model for study of the Earth s rotation, surface deformation and gravity field parameters – Scientific results of the DFG project. Deutsche Geodätische Kommission, Reihe B, Nr. 317, 2009

JIN S., WU Y., HEINKELMANN R., PARK J.: Diurnal and semidiurnal atmospheric tides observed by co-located GPS and VLBI measurements. Journal of Atmospheric and Solar-Terrestrial Physics, Vol. 70, ISSN 1366–1372, 2008

KELM R.: Rigorous variance component estimation in weekly intra-technique and inter-technique combination for global terrestrial reference frames. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 39–44, 2009, DOI: 10.1007/978-3-642-00860-3_6

KUDRYASHOVA M., SNAJDROVA K., WEBER R., HEINKELMANN R., SCHUH H.: Combination of nutation time series derived from VLBI and GNSS. In: IVS 2008 General Meeting Proceedings, A. Finkelstein and D. Behrend (Eds.), 240–245, 2008, ISBN 978-5-02-025332-2

KUTTERER H., KRÜGEL M., TESMER V.: Towards an improved assessment of the quality of terrestrial reference frames. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 67–72, 2009, DOI: 10.1007/978-3-642-00860-3_10

MA C., ARIAS F., BIANCO G., BOBOLTZ D., BOLOTIN S., CHARLOT P., ENGELHARDT G., FEY A., GAUME R., GONTIER A., HEINKELMANN R., JACOBS C., KURDUBOV S., LAMBERT S., MALKIN Z., NOTHNAGEL A., PETROV L., SKURIKHINA E., SOKOLOVA J., SOUCHAY J., SOVERS O., TESMER V., TITOV O., WANG G., ZHAROV V.: The second realization of the International Celestial Reference Frame by Very Long Baseline Interferometry. In: A. Fey and D. Gordon (Eds.): IERS Technical Note, No. 35, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt a. M., 2009

MARTÍNEZ W., SÁNCHEZ L.: Realization of the SIRGAS reference frame in Colombia. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 185–190, 2009, DOI: 10.1007/978-3-642-00860-3_29

MEISEL B., ANGERMANN D., KRÜGEL M.: Influence of time variable effects in station positions on the terrestrial reference frame. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 89–93, 2009, DOI: 10.1007/978-3-642-00860-3_14

RICHTER B.: Various definitions of the ecliptic. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 259–263, 2009, DOI: 10.1007/978-3-642-00860-3_40

RICHTER B., ENGELS J., GRAFAREND E.: Transformation of amplitudes and frequencies of precession and nutation of the Earth's rotation vector to amplitudes and frequencies of diurnal polar motion. Journal of Geodesy, Vol. 84, 1–18, 2009, DOI: 10.1007/s00190-009-0339-9

RISPENS S., BOUMAN J.: Calibrating the GOCE accelerations with star sensor data and a global gravity field model. Journal of Geodesy, Vol. 83, 737–749, 2009, DOI 10.1007/s00190-008-0290-1

RUMMEL R., DREWES H., HORNIK H.: Deutsche Geodätische Kommission (DGK) / Deutsches Geodätisches Forschungsinstitut (DGFI). Bayer. Akademie der Wissenschaften, Jahrbuch 2008, 302–313, 2009

SÁNCHEZ L.: Strategy to establish a global vertical reference system. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 273–278, 2009, DOI: 10.1007/978-3-642-00860-3_42

SÁNCHEZ L., BRUNINI C.: Achievements and challenges of SIRGAS. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 161–166, 2009, DOI: 10.1007/978-3-642-00860-3_25

SÁNCHEZ L., BRUNINI C.: SIRGAS: Basis for geosciences, geodata and navigation in Latin America. Proceedings of the International Symposium on Global Navigation Satellite Systems, Space-based and Ground-based Augmentation Systems and Applications. Berlin, 11-14 November 2008. Berlin Senate Department for Urban Development, 37–39, 2009

SÁNCHEZ L., BOSCH W.: The role of the TIGA project in the unification of classical height systems. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 285–290, 2009, DOI: 10.1007/978-3-642-00860-3_44

SÁNCHEZ L., SEEMÜLLER W., SEITZ M.: SIRGAS combination centre at DGFI: Report for the SIRGAS 2009 General Meeting. SIRGAS Newsletter 14, http://www.sirgas.org/fileadmin/docs/Boletines/ Bol14/, 2009

SCHUH H., BÖHM J., HEINKELMANN R.: Numerical weather models for troposphere delay modelling at radio wavelengths. In: M. Karslioglu, M. Nohutcu, E. Erdogan (Eds.): Proceedings of the Turkish National Geodetic Commission Scientific Meeting TUJK 2007, 93–95, 2008, ISBN: 978-9944-89-571-2

SCHUH H., BÖHM J., ENGLICH S., HEINKELMANN R., MENDES-CERVEIRA P., PANY A., PLANK L., SPICAKOVA H., TEKE K., WRESNIK J.: Vienna IGG Special Analysis Center Annual Report 2008. In: D. Behrend and K.D. Baver (Eds.): IVS 2008 Annual Report, 273–276, 2009, NASA/TP-2009-214183

SCHWEGMANN W., GERSTL M., HEINKELMANN R.: BKG/DGFI Combination Center Annual Report 2008. In: D. Behrend and K.D. Baver (Eds.): IVS 2008 Annual Report, 250–252, 2009, NASA/TP-2009-214183

SEEMÜLLER W.: The position and velocity solution DGF06P01 for SIRGAS. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 167–172, 2009, DOI: 10.1007/978-3-642-00860-3_26

SEEMÜLLER W., SÁNCHEZ L.: SIRGAS processing centre at DGFI: Report for the SIRGAS 2009 General Meeting. SIRGAS Newsletter 14, http://www.sirgas.org/fileadmin/docs/Boletines/ Bol14/, 2009

SEEMÜLLER W., SEITZ M., SÁNCHEZ L., DREWES H.: The position and velocity solution SIR09P01 of the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR). DGFI Report 85, 2009

SEITZ F., SCHMIDT M.: Hydrological mass variations due to extreme weather situations in Central Europe from global and regional GRACE expansions. In: Benveniste J., Berry P., Calmant S., Grabs W., Kosuth P. (Eds.): Proceedings of the 2nd Space for Hydrology Workshop "Surface water storage and runoff: Modeling, in-situ data and remote sensing". ESA Publication WPP-280, Noordwijk, The Netherlands, 2007

SEITZ F., DREWES H.: Simulation of polar motion with a dynamic Earth system model over a period of 200 years (1860–2060). In: Proceedings of the "Journées 2008 Systèmes de référence spatio-temporels", 123–126, Paris, 2009

SEITZ F., KRÜGEL M.: Inverse model approach for vertical load deformations in consideration of crustal inhomogeneities. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 23–29, 2009, DOI: 10.1007/978-3-642-00860-3_4

SEITZ M.: Kombination geodätischer Raumbeobachtungsverfahren zur Realisierung eines terrestrischen Referenzsystems. Reihe C 630, Deutsche Geodätische Kommission, Reihe C 630, 2009

SEITZ M., DREWES H., TESMER V., HEINKELMANN R.: DGFI Analysis Center Annual Report 2008. In: D. Behrend and K.D. Baver (Eds.): IVS 2008 Annual Report, 255–258, 2009, NASA/TP-2009-214183

STEIGENBERGER P., ROTHACHER M., SCHMID R., STEIGENBERGER P., RÜLKE A., FRITSCHE M., DIETRICH R., TESMER V.: Effects of different antenna phase center models on GPS-derived reference frames. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 83–88, 2009, DOI: 10.1007/978-3-642-00860-3_13

SKACHKO S., DANILOV S., JANJIC T., SCHRÖTER J., SIDORENKO D., SAVCENKO R., AND W. BOSCH: Sequential assimilation of multi-mission dynamical topography into a global finite-element ocean model. Ocean Science, 4, 307–318, 2008

TANIR E., HEINKELMANN R., SCHUH H., KUSCHE J., VAN LOON J.P.: Assessment of the results of VLBI intra-technique combination using regularization methods. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 45–51, 2009, DOI: 10.1007/978-3-642-00860-3_7

THALLER D., ROTHACHER M., KRÜGEL M.: Combining one year of homogeneously processed GPS, VLBI and SLR Data. In: Drewes H. (Ed.): Geodetic reference frames, IAG Symposia, Springer, Vol. 134, 17–22, 2009, DOI: 10.1007/978-3-642-00860-3_3

TEIXEIRA LUZ R., DE FREITAS S.R.C., HECK B., BOSCH W.: Challenges and first results towards the realization of a consistent height system in Brazil. In: Drewes H. (Ed.): Geodetic Reference Frames, IAG Symposia, Springer, Vol. 134, 291–296, 2009, DOI: 10.1007/978-3-642-00860-3_45

TEIXEIRA LUZ R., BOSCH W., DE FREITAS S.R.C., HECK B., DALAZOANA R.: Evaluating the Brazilian vertical datum through improved coastal satellite altimetry data. In: Sideris M.G. (Ed.): Observing our changing Earth, IAG Symposia, Springer, Vol. 133, 735–741, 2009

TEKE K., HEINKELMANN R., BÖHM J., SCHUH H.: VLBI baseline length repeatability tests of IVS-R1 and -R4 session types. In: A. Finkelstein and D. Behrend (Eds.): IVS 2008 General Meeting Proceedings, 173–177, 2008, ISBN 978-5-02-025332-2,

TESMER V., DREWES H., KRÜGEL M.: DGFI Analysis Center Annual Report 2007. IVS 2007 Annual Report, 187–190, 2008, NASA/TP-2008-214162

TORRES J.A., HORNIK H.: (Eds.) Report on the Symposium of the IAG Sub-commission 1.3a Europe (EUREF) held in Riga, 14–17 June 2006 / Reports of the EUREF Technical Working Group (TWG). International Association of Geodesy, Commission 1 Reference Frames, Sub-commission 1.3a Europe (EUREF), Publication No. 16. Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 40, 2007

TORRES J.A., IHDE J., HORNIK H. (Eds.): Report on the Symposium of the IAG Sub-commission 1.3a Europe (EUREF) held in London, 06–09 June 2007 / Reports of the EUREF Technical Working Group (TWG). International Association of Geodesy, Commission 1 Reference Frames, Sub-commission 1.3a Europe (EUREF), Publication No. 17. Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 42, 2009

TORRES J.A., ALTAMIMI Z., BOUCHER C., BROCKMANN E., BRUYNINX C., CAPORALI A., GURTNER W., HABRICH H., HORNIK H., IHDE J., KENYERES A., MÄKINEN J., V D MAREL H., SEEGER H., SIMEK J., STANGL G., WEBER G.: Status of the European Reference Frame (EUREF). In: Sideris M.G. (Ed.): Observing our changing Earth, IAG Symposia, Springer, Vol. 133, 47–56, 2009

4.3 Posters and oral presentations

Albertella A., Savcenko R., Skachko S., Rummel R., Schröter J., Bosch W.: Sea surface topography and mass transport of the Antarctic circumpolar current (GEOTOP). 2. DFG-SPP1257 Colloquium, Munich, Germany, 2008-10-06 (Poster)

Alizadeh M., Schuh H., Todorova S., Schmidt M.: Global ionosphere maps of VTEC from GNSS, satellite altimetry and FORMOSAT-3/COSMIC data. EGU General Assembly 2009, Vienna, Austria, April 19–24, 2009-04-24 (Poster)

Angermann D.: DGFI Forschungsprogramm 2009-2010, Schwerpunkt 1 „Systembeobachtung". DGK Science Advisory Board Meeting, Munich, Germany, 2008-10-24

Angermann D., Drewes H., Rothacher M.: Integration of Earth rotation, geometry and gravity field using space geodetic observations, DFG Research Unit FOR 584. Bonn, Germany, 2009-01-09 (Poster)

Angermann D., Drewes H., Seitz M.: Global terrestrial reference frame realization within the GGOS-D project. IAG Scientific Assembly, Buenos Aires, Argentina, 2009-08-31

Blossfeld M., Seitz M., Angermann D.: Analyse der EOP-Zeitreihen aus Daten des ITRF2008. Geodätische Woche 2009, Karlsruhe, Germany, 2009-09-22/24

Blossfeld M., Schmidt M.: Eigenschwingungen der Erde aus Beobachtungen mit dem 30-Meter Vertikalpendel in Berchtesgaden. Geodätische Woche 2009, Karlsruhe, Germany, 2009-09-22/24

Blossfeld M., Seitz M., Angermann D.: EOPs aus der Kombination geodätischer Raumbeobachtungsverfahren. Statusseminar der Forschergruppe Erdrotation, München, Deutschland, 2009-10-29/30

Bosch W., Savcenko R., Mayer-Gürr T.: EOT08a – Empirical ocean tide analysis for improving GRACE de-aliasing. OSTST Annual Meeting, Nice, France, 2008-11-10/12 (Poster)

Bosch W., Savcenko R.: Profile approach for estimating the absolute dynamic ocean topography. OSTST Annual Meeting, Nice, France, 2008-11-10/12 (Poster)

Bosch W.: Der Meeresspiegel – ansteigend und fast im Lot. Geodetic seminar, Leopold-Franzens-Universität, Innsbruck, Austria, 2009-01-15

Bosch W.: Der Meeresspiegel steigt – aber woher wissen wir das? Förderverein Informationszentrum Wettzell, Germany, 2009-03-12

Bosch W., Savcenko R.: Empirical tide modeling by analyzing multi-mission altimeter data, EGU General Assembly 2009, Vienna, Austria, 2009-04-22

Bosch W., Luz R.: Evaluation of Absolute Dynamic Ocean Topography Profiles along the Brazilian Coast. EGU General Assembly 2009, Vienna, Austria, 2009-04-22

Bosch W., Dettmering D., Savcenko R.: Geographically correlated errors (GCE) from multi-mission crossover analysis (MMXO). OSTST Meeting, Seattle, USA, 2009-06-22/24 (Poster)

Bosch W., Savcenko R.: Absolute dynamic ocean topography profiles. OSTST Meeting, Seattle, USA, 2009-06-22/24 (Poster)

Bosch W.: Global cross-calibration between radar altimetry, ICESat, and CryoSat. ICESat/CryoSat Calibration/Validation Meeting, Reykjavik Island, 2009-06-24

Bosch W.: Understanding the signal – separability. Workshop of DFG priority program SPP1257, Eitorf, Germany, 2009-06-29

Bosch W., Dettmering D., Savcenko R.: Variance component estimate for multi-mission cross-calibration of altimeter systems. IAG General Assembly, Buenos Aires, Argentina, 2009-08-31/09-04 (Poster)

Bosch W., Luz R.: Absolute Dynamic Ocean Topography along the Brazilian Coast – Estimation, Validation, and Application. 3rd Coastal Altimetry Workshop, Frascati, Italy, 2009-09-17

Bouman J., Bosch W.: GOCE Validation by Means of Satellite Altimetry. AGU Fall Meeting 2008, San Francisco, USA, 2008-12-15/19 (Poster)

Bouman J., Rispens S., Gruber T., Schrama E., Visser P., Tscherning C.C., Veicherts M.: Gravity gradient preprocessing at the GOCE HPF. EGU General Assembly 2009, Vienna, Austria, 2009-04-19/24

Bouman J., Bosch W.: Gravity gradients from satellite altimeter data for GOCE validation. EGU General Assembly 2009, Vienna, Austria, 2009-04-19/24 (Poster)

Bouman J.: Assessment of systematic errors in the computation of gravity gradients from satellite altimeter data. VII Hotine-Marussi Symposium, Rom, Italien, 2009-07-09

Bouman J.: Overview of GOCE cal/val. GOCE cal/val synthesis meeting, Frascati, Italy, 2009-11-12/13

Bouman J.: Assessment of the error level of recent GOCE data. GOCE cal/val synthesis meeting, Frascati, Italy, 2009-11-12/13

Bouman J., Bosch W.: Satellite Altimeter Data for GOCE Gravity Gradient Validation. AGU Fall Meeting 2009, San Francisco, USA, 2009-12-14/18 (Poster)

Dahle C., Mayer-Gürr T., Savcenko R., Taguchi E., Bosch W., Flechtner F., Ilk K.-H., Stammer D.: DAROTA – Dynamical and Residual Ocean Tide Analysis for improved GRACE de-aliasing, SPP 1267 Colloquium, Munich, Gemany, 2008-10-06

Dettmering D.: Global Cross Calibration of Jason-1/2 GDR-C data. OSTST Meeting, Seattle, USA, 2009-06-23

Dettmering D., Bosch, W.: Multi-mission crossover calibration – first results for JASON-2. OSTST Annual Meeting, Nice, France, 2008-11-10/12 (Poster)

Dettmering D., Schmidt M., Zeilhofer C., Tsai L.C., Zhang J., Bosch W., Shum C.K., Tseng K.H.: Combination of different satellite observation data for ionosphere modelling. EGU General Assembly 2009, Vienna, Austria, 2009-04-23

Dettmering D., Schmidt M.: Kombination von Beobachtungen unterschiedlicher Raumverfahren für die Erzeugung von VTEC-Modellen. Geodätische Woche 2009, Karlsruhe, Germany, 2009-09-24

Drewes H.: Global Deformation Models from Space Geodetic Observations. 3rd World Stress Map Conference, Potsdam, Germany, 2008-10-15

Drewes H.: DGFI Forschungsprogramm 2009–2010. DGK Science Advisory Board Meeting, Munich, Germany, 2008-10-24

Drewes H.: Message of congratulation of the International Association of Geodesy (IAG) and the International Union of Geodesy and Geophysics (IUGG) to the 75th birthday of Professor Helmut Moritz. Colloquium on the Occasion of the 75th Birthday of Helmut Moritz, Berlin, Germany, 2008-11-24

Drewes H.: Bericht über die Arbeiten des DGFI 2007-2008. DGK Plenary Session, Munich, Germany, 2008-11-27

Drewes H.: Data processing, analysis and validation of Earth orientation parameters, Review of the DFG Research Unit Earth Rotation and Global Dynamic Processes (FOR584). Bonn, Germany, 2009-01-09

Drewes H.: Research of the German Geodetic Research Institute (DGFI) for Observing and Analysing the System Earth. Excursion of Technical University Prague, Munich, Germany, 2009-03-12

Drewes H.: Message of congratulation of the International Association of Geodesy (IAG), 10 Years Anniversary of the International VLBI Service for Geodesy and Astrometry. Bordeaux, France, 2009-03-25

Drewes H.: Realization of the geodetic datum of reference frames. Project Meeting of the Research Group “Reference Frames”, Frankfurt/Main, Germany, 2009-04-03

Drewes H.: Status of ITRF2008 computations at DGFI. IERS Directing Board Meeting, Vienna, Austria, 2009-04-19

Drewes H.: Sistemas de referencia, Escuela SIRGAS. Bogotá, Colombia, 2009-07-14

Drewes H.: Objetivos científicos de SIRGAS. Escuela SIRGAS, Bogotá, Colombia, 2009-07-17

Drewes H.: How to fix the geodetic datum for reference frames in geosciences applications? IAG Scientific Assembly, Symposium 1 “Reference Frames”, Buenos Aires, Argentina , 2009-08-31

Drewes H.: The 2009 horizontal velocity field for South America and the Caribbean. IAG Scientific Assembly, Symposium 3 "Geodynamics", Buenos Aires, Argentina, 2009-09-01

Drewes H.: Establishment of an Intergovernmental Committee for GGOS – Comments. GGOS ICG Meeting, Frankfurt/Main, Germany, 2009-11-03

Drewes H.: Bericht über die Arbeiten des DGFI 2008-2009. DGK Plenary Session, München, Germany, 2009-11-27

Drewes H.: Größere IAG Aktivitäten. DGK Plenary Session, München, Germany, 2009-11-27

Figueroa C. E., Amaya W., Sánchez L:. Integration of the reference frame of El Salvador into SIRGAS. IAG Scientific Assembly. Buenos Aires, Argentina, 2009-09-03 (Poster)

Göttl F., Schmidt M.: Earth rotation excitation mechanisms derived from geodetic space observations. EGU General Assembly 2009, Vienna, Austria, 2009-04-23 (Poster)

Göttl F., Schmidt M.: Bestimmung geophysikalischer Anregungsmechanismen der Erdrotation aus geodätischen Raumbeobachtungen. Geodätische Woche 2009, Karlsruhe, Germany, 2009-09-22

Göttl F., Schmidt M.: Bestimmung geophysikalischer Anregungsmechanismen der Erdrotation aus geodätischen Raumbeobachtungen. Statusseminar der Forschergruppe Erdrotation, München, Deutschland, 2009-10-29

Heinkelmann R.: IVS troposphere products: Status of tropospheric combinations. 10th IVS Analysis Workshop, Bordeaux, France, 2009-03-28

Heinkelmann R., Hobiger T., Schmidt M.: Contribution of VLBI to a combined model of the ionosphere. EGU General Assembly 2009, Vienna, Austria, 2009-04-19 (Poster)

Heinkelmann R., Seitz M., Angermann D., Drewes H.: Effects of the new conventional model of VLBI antenna thermal deformation on the terrestrial reference frame. EGU General Assembly 2009, Vienna, Austria, 2009-04-19 (Poster)

Heinkelmann R., Schuh H.: Very Long Baseline Interferometry (VLBI): accuracy limits and relativistic tests. IAU Symposium 261, Relativity in Fundamental Astronomy, Virginia Beach, VA, USA, 2009-04-30

Heinkelmann R.: ICRF2: Der neue Himmelsreferenzrahmen. Geodätische Woche 2009, Karlsruhe, Germany, 2009-09-23

Hugentobler U., Angermann D., Bouman J., Gerstl M., Gruber T., Richter B., Steigenberger P.: GGOS Bureau for Standards and Conventions; Report for GGOS SC15. GGOS SC15, Vienna, Austria, 2009-04-18

Kelm R.: Reprocessing of SLR Data by the Official ILRS Combination Center, ILRSB: Processing and Time Series Results. AGU Fall Meeting 2009, San Francisco, USA, 2009-12-14 (Poster)

Kutterer HJ., Schmidt M., Seitz F.: Combined analysis and validation of Earth rotation models and observations, DFG Research Unit FOR 584. Bonn, Germany, 2009-01-09 (Poster)

Müller H.: International Terrestrial Reference Frame – Latest Developments. 16th International Workshop on Laser Ranging, Poznan, Poland, 2008-10-13

Rispens S., Bouman J.: External calibration of GOCE gradiometer accelerations. Workshop on GOCE Calibration, Munich, Germany, 2009-02-10

Rispens S., Bouman J.: External calibration of the GOCE gradiometer at acceleration level. EGU General Assembly 2009, Vienna, Austria, 2009-04-18/24 (Poster)

Rispens S., Bouman J.: External gradiometer calibration. GOCE cal/val synthesis meeting, Frascati, Italy, 2009-11-12/13

Sánchez L., Brunini C.: SIRGAS: Basis for Geosciences, Geodata, and Navigation in Latin America. International Symposium on Global Navigation Satellite Systems, Space-based and Ground-based Augmentation Systems and Applications. Berlin, Germany, 2008-11-11

Sánchez L.: Curso introductorio al procesamiento de datos GPS con el software Bernese, Preparación del Centro de Procesamiento SIRGAS en el Instituto Geográfico Militar de Ecuador. Quito, Ecuador, 2008-12-01/05

Sánchez L.: Curso introductorio al procesamiento de datos GPS con el software Bernese, Preparación del Centro de Procesamiento SIRGAS en el Servicio Geográfico Militar de Uruguay. Montevideo, Uruguay, 2009-03-30/04-03

Sánchez L., Brunini C., Costa S., Mackern V., Martinez W., Seemüller W., da Silva A:. SIRGAS: ITRF densification in Latin America and the Caribbean. EGU General Assembly 2009, Vienna, Austria, 2009-04-19

Sánchez L.: Lecture on Vertical Reference Systems (in Spanish). IAG-IPGH-SIRGAS School in Reference Systems. Bogotá, Colombia, 2009-07-16

Sánchez L.: Disponibilidad y uso de los productos SIRGAS. IAG-IPGH-SIRGAS School in Reference Systems. Bogotá, Colombia, 2009-07-17

Sánchez L., Mackern V.: Datum realization for the SIRGAS weekly coordinates. IAG Scientific Assembly. Buenos Aires, Argentina, 2009-08-31

Sánchez L.: Height datum unification within a global vertical reference system, IAG Scientific Assembly. Buenos Aires, Argentina, 2009-09-02

Sánchez L., Seemüller W., Seitz M.: DGFI report on the combination of the weekly solutions delivered by the SIRGAS Processing Centres. IAG Scientific Assembly. Buenos Aires, Argentina, 2009-09-04

Sánchez L.: SIRGAS: el sistema de referencia de América Latina, Curso avanzado de posicionamiento por satélite. Madrid, Spain, 2009-11-16

Savcenko R., Bosch W.: A profile approach for estimating the absolut dynamic ocean topography. EGU General Assembly 2009, Vienna, Austria, 2009-04-18/24 (Poster)

Savcenko R., Taguchi E., Mayer-Gürr T., Dahle C., Bosch W., Flechtner F., Ilk K.H., Stammer D.: DAROTA: Dynamical and residual ocean tide analysis for improved GRACE de-aliasing. 3rd SPP-Workshop, Eitorf, Germany, 2009-06-30

Savcenko R., Albertella A., Janjic Pfander T., Bosch W., Rummel R., Schröter J.: Sea surface topography and mass transport of the Antarctic Circumpolar Current (GEOTOP). IAG Scientific Assembly, Buenos Aires, Argentina, 2009-08-31/09-04 (Poster)

Savcenko R., Bosch W.: The Tides on Patagonian Shelf from Multi-Mission Satellite Altimetry. IAG Scientific Assembly, Buenos Aires, Argentina, 2009-09-01

Savcenko R., Bosch W., Dettmering D., Schwatke C.: Ocean Tides on the Patagonian Shelf from Multi-Mission-Altimetry. Colloquium, CIMA, Buenos Aires, Argentina, 2009-09-03

Savcenko R., Bosch W.: Gezeiten am Patagonischen Schelf aus Multi-Missions-Altimetrie. Geodätische Woche 2009, Karlsruhe, Germany, 2009-09-24

Schmeer M., Bosch W., Schmidt M.: Separation of GRACE observations into individual mass variations of atmosphere, ocean, and continental hydrosphere. EGU General Assembly, Vienna, Austria, 2009-04-20

Schmidt M., Zhang J., Mössmer M.: Comparison of a global B-Spline VTEC model with a spherical harmonic expansion. EGU General Assembly 2009, Vienna, Austria, 2009-04-24 (Poster)

Schmidt M.: Towards a Multi-Scale Representation of the Ionosphere in Near Real-Time. Real-Time IRI Task Force Workshop, Colorado Springs, May 4-6, 2009-05-05

Schmidt M.: Towards a Multi-Scale Representation of Multi-Dimensional Signals. VII Hotine-Marussi Symposium, Rome, Italy, 2009-07-07

Schmidt M., Dettmering D., Heinkelmann R., Bilitza D.: Regional ionosphere modeling from the combination of different satellite observation techniques. IRI 2009 Workshop, Kagoshima, Japan, 2009-11-02/07 (Poster)

Schuh H., Böhm J., Heinkelmann R., Mendes-Cerveira P., Pany A.: Observation level versus a posteriori atmosphere loading corrections in VLBI analysis. AGU Fall Meeting 2008, San Francisco, CA, USA, 2008-12-12 (Poster)

SCHUH H., BÖHM J., HEINKELMANN R., PANY A.: Atmosphere loading corrections in VLBI analysis. EGU General Assembly 2009, Vienna, Austria, 2009-04-19 (Poster)

SCHWATKE C., BOSCH W., SAVCENKO R., DETTMERING D.: OpenADB – An open database for multi-mission altimetry. 3rd Workshop of SPP1257, DFG, Eitorf, Germany, 2009-06-30

SCHWATKE C.: Dokumentation und Verwaltung von Software-Projekten mit Subversion und Doxygen. TU München, Germany, 2009-07-14

SCHWATKE C., BOSCH W., SAVCENKO R., DETTMERING D.: OpenADB – Eine offene Datenbank für Multi-Missions Altimetrie. Geodätische Woche 2009, Karlsruhe, Germany, 2009-09-24

SEEMÜLLER W., SEITZ M., SÁNCHEZ L., DREWES H.: The new multi-year position and velocity solution SIR09P01 of the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR). IAG Scientific Assembly, Buenos Aires, Argentina, 2009-08-31

SEEMÜLLER W., SÁNCHEZ L.: The processing of the SIRGAS core network at DGFI. IAG Scientific Assembly, Buenos Aires, Argentina, 2009-09-04

SEITZ M.: Kombination geodätischer Raumbeobachtungsverfahren zur Realisierung eines terrestrischen Referenzsystems. Promotionsvortrag, 2008-12-04, Dresden, Germany

SEITZ M., ANGERMANN D., DREWES H.: A terrestrial reference frame based on homogeneously processed data. EGU General Assembly 2009, Vienna, Austria, 2009-04-19 (Poster)

SEITZ M.: Combination of space geodetic techniques for TRF computations. Kick off meeting of the IERS Working Group on Combination at the Observation Level, Warsaw, Poland, 2009-10-22

SEITZ M.: DGFI Orbit Determination and Geodetic Parameter Estimation Software – DOGS. Kick off meeting of the IERS Working Group on Combination at the Observation Level, Warsaw, Poland, 2009-10-22

SEITZ M.: Troposphere ties. 2nd GGOS Unified Analysis Workshop, San Francisco, 2009-12-11

SEITZ M.: ITRF2008 computations at DGFI. AGU Fall Meeting, San Francisco, 2009-12-14

SKACHKO S., JANJIC PFANDER T., DANILOV S., SCHRÖTER J., SIDORENKO D., SAVCENKO R., BOSCH W.: Sequential assimilation of multi-mission dynamical topography into a global finite-element ocean model. EGU General Assembly 2009, Vienna, Austria, 2009-04-19/24, 2009-04-20 (Poster)

STEIGENBERGER P., HUGENTOBLER U., SEITZ M., BÖCKMANN S., TESMER V.: Current Accuracy of Vertical and Horizontal Station Displacements. DynaQlim/GGOS workshop on Understanding Glacial Isostatic Adjustment, Espoo, 2009-06-25

THALLER D., SEITZ M.: Several aspects concerning EOP combination. Kick off meeting of the IERS Working Group on Combination at the Observation Level, Warsaw, Poland, 2009-10-22

THALLER D., DACH R., SEITZ M., BEUTLER G., MAREYEN M., RICHTER B.: Combined analysis of GNSS and SLR data using satellite co-locations. 2nd GGOS Unified Analysis Workshop, San Francisco, 2009-12-11

VISSER P., BOUMAN J.: CM and DM calibration using orbits and STR data. GOCE cal/val synthesis meeting, Frascati, Italy, 2009-11-12/13

VISSER P., BOUMAN J.: Gradiometer cal/val using GOCE GPS data. GOCE cal/val synthesis meeting, Frascati, Italy, 2009-11-12/13

ZHANG J., SCHMIDT M., SHUM C.K., TSAI L.C.: Global VTEC representation based on multi-dimensional splines from satellite observation and IRI. EGU General Assembly 2009, Vienna, Austria, 2009-04-24 (Poster)

4.4 Memberschip in scientific bodies

International Union of Geodesy and Geophysics (IUGG)
- Representative to the Panamerican Institute for Geodesy and History (PAIGH), H. Drewes

International Association of Geodesy (IAG)
- Secretary General: H. Drewes
- Sub-commission 1.1, Working Group 2 "Interactions and consistency between Terrestrial Reference Frame, Earth rotation, and gravity field", Chair: D. Angermann
- Sub-commission 1.3, Working Group "Regional Dense Velocity Fields": SIRGAS Representative: L. Sánchez
- Sub-commission 1.3a "Reference Frame for Europe (EUREF)", Secretary: H. Hornik
- Sub-commission 1.3b "Geocentric Reference Frame for the Americas (SIRGAS)": Vice-President: L. Sánchez
- Sub-commission 1.3b "Geocentric Reference Frame for the Americas (SIRGAS)", Executive Committee members: H. Drewes, L. Sánchez
- Sub-commission 1.4 "Interaction Between Celestial and Terrestrial Reference Frames"; R. Heinkelmann
- Commission 1 Inter-commission Working Group 1.3 "Concepts and Terminology Related to Geodetic Reference Systems", H. Drewes
- Commission 2 Study Group 2.5: "Aliasing in Gravity Field Modelling", J. Bouman
- Commission 4 Study Group SC 4.3.1 "Ionosphere Modelling and Analysis", Chair: M. Schmidt, D. Dettmering, R. Heinkelmann
- Inter-commission Project 1.2 "Vertical Reference Systems", W. Bosch, L. Sánchez
- Inter-commission Working Group 1.3 "Concepts and Terminology Related to Geodetic Reference Systems", H. Drewes
- Inter-commission Study Group 1: "Theory, Implementation and Quality Assessment of Geodetic Reference Frames", H. Drewes
- Inter-commission Study Group 3: "Configuration Analysis of Earth Oriented Space Techniques", M. Schmidt, M. Seitz
- Inter-commission Study Group 4: "Inverse Theory and Global Optimization", J. Bouman, M. Schmidt
- Inter-commission Study Group 5: "Satellite Gravity Theory", W. Bosch, M. Schmidt
- Inter-commission Study Group 9: "Application of Time-Series Analysis in Geodesy", M. Schmidt
- Representative to the Sistema de Referencia Geocéntrico para las Américas, SIRGAS, H. Drewes
- GGOS Bureau for Standards and Conventions, Secretary: D. Angermann, Members: J. Bouman, M. Gerstl, B. Richter

International Altimetry Service
- Steering Committee, Chair: W. Bosch

International Earth Rotation and Reference Systems Service (IERS)
- ITRS Combination Centre, Chair: H. Drewes
- Research Centre, Chair: D. Angermann
- Working Group "Site Survey and Co-location", D. Angermann
- Working Group on Combination, D. Angermann

International GNSS Service
- Regional Network Associate Analysis Centre for SIRGAS, Chair: W. Seemüller

International Laser Ranging Service (ILRS)
- Governing Board member: W. Seemüller
- Data Centre (EDC): Chair: W. Seemüller
- Analysis Centre: Chair: H. Müller
- Combination Centre: Chair: R. Kelm

- Operations Centre at DGFI. Chair: W. Seemüller
- Working Group “Data Format and Procedures”, Chair: W. Seemüller

International VLBI Service for Geodesy and Astrometry (IVS)
- Analysis Centre, Chair: R. Heinkelmann, M. Seitz
- IERS Working Group on the second realization of the International Celestial Reference Frame ICRF2, R. Heinkelmann

Group on Earth Observation (GEO)
- IAG Substitute Delegate in the Committee on Capacity Building and Outreach, H. Drewes

European Geosciences Union (EGU)
- Geodesy Division, Vice-President, M. Schmidt

European Space Agency (ESA)
- CryoSat2 Calibration and Validation Team, W. Bosch

Centre National d’Etudes Spatiales (CNES) / National Aeronautics and Space Administration (NASA)
- Ocean Surface Topography Science Team for Jason, W. Bosch, D. Dettmering

Consortium of European Laser Stations (EUROLAS)
- Secretary, W. Seemüller
- Member in the Board of Representatives, W. Seemüller

COST Action ESO701: Improved Constraints on Models of Glacial Isostatic Adjustment
- Working Group 2 “Velocity determination/reference frame realization” , D. Angermann

Deutsche Geodätische Kommission (DGK)
- Member: H. Drewes
- Section Geodesy: H. Drewes

Deutscher Verein für Vermessungswesen (DVW), Gesellschaft für Geodäsie, Geoinformation und Landmanagement
- Working Group 3 “Messmethoden und Systeme”, D. Dettmering
- Working Group 7 “Experimentelle, angewandte und theoretische Geodäsie”, H. Drewes

4.5 Participation in meetings, symposia, conferences

2008-10-06/08	Evaluation of the Priority Programme SPP1257, DFG, Munich, Germany (Bosch, Bouman, Dettmering, Drewes, Göttl, Savcenko, Schmidt, Schwatke)
2008-10-12	ILRS, Analysis Working Group Meeting, Poznan, Poland (Kelm, Müller, Seemüller)
2008-10-13	Meeting of the DGK Working Group „Zukunft", Hannover, Germany (Drewes, Hornik)
2008-10-13/17	16th International Workshop on Laser Ranging, Poznan, Poland (Müller, Seemüller)
2008-10-15	3rd World Stress Map Conference, International Lithosphere Programme (ILP), Potsdam, Germany (Drewes)
2008-11-03/04	48th Meeting of the EUREF Technical Working Group, Munich, Germany (Hornik)
2008-11-10/12	OSTST Annual Meeting, Nice, France (Bosch, Dettmering)
2008-11-11/14	International Symposium on Global Navigation Satellite Systems, Space-based and Ground-based Augmentation Systems and Applications. Berlin, Germany (Drewes, Sánchez,)
2008-11-14	Colloquium on the Occasion of the 75th Birthday of Helmut Moritz, Berlin, Germany (Drewes)
2008-11-25	50 Years Anniversary Celebration, BGR, Hannover, Germany (Drewes)
2008-11-26/28	Plenary Session 2008 of the German Geodetic Commission (DGK), Munich, Germany (Drewes, Hornik)
2008-12-01/02	Meeting of the Research Group "Reference Systems", DFG, Bonn, Germany (Angermann, Drewes)
2008-12-14	Executive Committee Meeting, IAG, San Francisco, USA (Drewes)
2008-12-14	Steering Committee Meeting, GGOS, San Francisco, USA (Drewes)
2008-12-15/19	AGU Fall Meeting 2008, San Francisco, USA (Bosch, Bouman, Drewes)
2009-01-09	Review of the DFG Research Unit Earth Rotation and Global Dynamic Processes (FOR584), Bonn, Germany (Drewes, Schmidt)
2009-02-03	Meeting of the Research Group "Reference Systems", DFG, Frankfurt/Main, Germany (Angermann, Drewes)
2009-02-10	Workshop on GOCE Calibration, TU München (IAPG), Munich, Germany (Bosch, Bouman)
2009-02-19/20	GEOTOP-2 1st Projectmeeting, IAPG, Munich, Germany (Bosch, Savcenko)
2009-03-23/24	19th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting, Bordeaux, France (Heinkelmann)
2009-03-23/24	Coordinating Group of SPP1257, Bonn (Bosch)
2009-03-25	10th IVS Analysis Workshop, Bordeaux, France (Heinkelmann)
2009-03-25/26	50th Anniversary Celebration, International VLBI Service for Geodesy and Astrometry (IVS), Bordeaux, France (Drewes, Heinkelmann)
2009-03-26	Working Meeting of IVS WG 4: Data Struktur, Bordeaux, France (Heinkelmann)
2009-03-26/27	49th Meeting of the EUREF Technical Working Group, Budapest, Hungary (Hornik)
2009-03-27/28	Working Meeting of the IVS/IERS WG on the 2nd realization of the ICRS: ICRF2, Bordeaux, France (Heinkelmann)
2009-04-02	GEOTOP-2 2nd Project meeting , IAPG, Munich, Germany (Bosch, Savcenko)
2009-04-02	Managing Board Forschergruppe Satellitengeodäsie, BKG, Frankfurt (Bosch, Drewes)

2009-04-19/24	EGU 2009, Vienna, Austria (Bosch, Bouman, Dettmering, Drewes, Göttl, Heinkelmann, Sánchez, Savcenko, Schmidt, Seitz)
2009-04-20	DAROTA-2 1st Project Meeting, at TU Vienna, Vienna, Austria (Bosch, Savcenko)
2009-04-20	ILRS Data Formats and Procedures Working Group Meeting, Vienna, Austria (Seemüller)
2009-04-22	ILRS Governing Board Meeting, Vienna, Austria (Seemüller)
2009-04-24	ILRS Analysis Working Group Meeting, Vienna, Austria (Kelm, Müller)
2009-04-30	IAU Symposium 261, Relativity in Fundamental Astronomy, Virginia Beach, VA, USA (Heinkelmann)
2009-05-04	Meeting of the Research Group "Terrestrial Reference Systems", DFG, Munich, Germany (Angermann, Drewes)
2009-05-04/06	Real-Time IRI Task Force Workshop, Colorado Springs, Colorado Springs, USA (Schmidt)
2009-05-07	Symposium "Navigation", Munich, Germany (Angermann, Bloßfeld, Drewes, Gerstl, Seemüller, Seitz)
2009-05-11/12	Workshop "Precision Observations of Vertical Land Motion at Tide Gauges", IOC of UNESCO, Paris, France (Sánchez, Drewes)
2009-05-14/15	GOCE HPF BP3 Acceptance and Post-Launch KO, ESA-ESRIN, Frascati, Italy (Bouman)
2009-05-19	GEOTOP-2 3rd Projectmeeting, IAPG, Munich, Germany (Bosch, Savcenko)
2009-05-20	Secretaries General Meeting, IUGG, Munich, Germany (Drewes, Hornik)
2009-05-22	GEOTOP-2 4th Projectmeeting, AWI, Bremerhaven, Germany (Bosch, Savcenko)
2009-05-26	50th Meeting of the EUREF Technical Working Group, Florence, Italy (Hornik)
2009-05-27/30	EUREF Symposium, Florence, Italy (Hornik)
2009-06-05	Section "Geodesy" Inaugural Meeting, DGK, Hannover, Germany (Drewes)
2009-06-18	Meeting of the Research Group "Reference Systems", Frankfurt/Main, Germany (Drewes)
2009-06-22/24	OSTST Meeting, Seattle, USA (Dettmering)
2009-06-29/07-01	3rd Workshop of SPP1257, DFG, Eitorf, Germany (Bosch, Savcenko, Schwatke)
2009-07-01/02	Managing Board, Forschungsgruppe Satellitengeodäsie, Fankfurt/Main, Germany (Bosch, Drewes)
2009-07-06/10	VII Hotine-Marussi Symposium, Rom, Italien (Bouman, Schmidt)
2009-07-13/17	IAG-IPGH-SIRGAS School in Reference Systems, Bogotá, Colombia (Drewes, Sánchez)
2009-07-13/17	SIRGAS School on Reference Systems, Bogotá, Colombia (Drewes, Sánchez)
2009-07-16/17	GOCE HPF Progress Meeting 16, Darmstadt, Deutschland (Bouman)
2009-08-31/09-04	IAG Scientific Assembly, Buenos Aires, Argentina (Angermann, Drewes, Hornik, Sánchez, Savcenko, Seemüller)
2009-09-01	SIRGAS 2009 General Meeting, Buenos Aires, Argentina (Drewes, Sánchez, Seemüller)
2009-09-14/18	International Technical Laser Workshop on SLR Tracking of GNSS Constellations, Metsovo, Greece (Müller, Seemüller)
2009-09-15	ILRS Data Formats and Procedures Working Group Meeting, Metsovo, Greece (Seemüller)
2009-09-17/18	3rd Coastal Altimetry Workshop, Frasacti, Italy (Bosch)
2009-09-19	ILRS Analysis Working Group Meeting, Metsovo, Greece (Kelm, Müller)
2009-09-21/25	OceanObs'09, ESA, Venice, Italy (Bosch)
2009-09-22/24	INTERGEO/Geodätische Woche, DVW, Karlsruhe, Germany (Angermann, Bloßsfeld, Dettmering, Heinkelmann, Savcenko, Schmidt, Schwatke)

2009-09-29	GOCE HPF Working Meeting, Graz, Austria (Bouman)
2009-09-30	IAG Executive Committee Meeting, Buenos Aires, Argentina (Drewes, Hornik)
2009-10-08/09	Coordinating Group of SPP1257, Frankfurt (Bosch)
2009-10-08/11-13	IUGG 2011 General Assembly Preparatory Meeting, Melbourne Australia (Drewes)
2009-10-13	51th Meeting of the EUREF Technical Working Group, Padua, Italy (Hornik)
2009-10-21/22	Kick off meeting of the IERS Working Group on Combination at the Observation Level, Warsaw, Poland (Seitz)
2009-10-28/29	DAROTA-2 2nd Project Meeting, DGFI, Munich, Germany (Bosch, Savcenko)
2009-10-29/30	DFG-Forschergruppe FOR584 Erdrotation und globale dynamische Prozesse, Statusseminar, Munich, Germany (Angermann, Bloßsfeld, Gerstl, Göttl, Schmidt, Seitz)
2009-11-12	RegGRAV project meeting, AGeoBW, Euskirchen (Bosch, Goebel, Schmidt)
2009-11-12/13	GOCE Calibration Synthesis Meeting, Frascati, Italy (Bouman)
2009-11-18/20	ESA Topical Conference "Earth Observation and Water Cycle Sciences", Frascati, Italy (Bosch, Schwatke)
2009-11-25	Section "Geodesy" Meeting, DGK, Munich, Germany (Drewes)
2009-11-25/27	Plenary Session 2009 of the German Geodetic Commission (DGK), Munich, Germany (Drewes, Hornik)
2009-12-03/04	GOCE HPF Progress Meeting 17, Utrecht, The Netherlands (Bouman)
2009-12-04	Festkolloquium 70. Geburtstag Erik W. Grafarend, Stuttgart University (Richter)
2009-12-11/12	GGOS Unified Analysis Workshop, IAG, IERS, San Francisco, CA, USA (Heinkelmann)
2009-12-14/18	AGU Fall Meeting, San Francisco, USA (Bouman, Kelm, Seitz)
2009-12-19/21	IERS Workshop on EOP Combination and Prediction, Warsaw, Poland, (Seitz)

4.6 Guests

2008-10-17	G.-A. Deutelmoser, Vermessungsverwaltung Niedersachsen, Stade, Germany
2008-10-30	Dr. M. Scheinert, TU Dresden, Germany
2009-01-26/27	Dr.-Ing. Astrid Sudau, Bundesanstalt für Gewässerkunde, Koblenz, Germany
2009-01-26/27	Dipl.-Ing. Robert Weiß, Bundesanstalt für Gewässerkunde, Koblenz, Germany
2009-02-09/03-06	Prof. Dr. Virginia Mackern, Universidad Nacional de Cuyo, Mendoza, Argentina
2009-02-09/27	Prof. Dr. Claudio Brunini, Universidad Nacional de La Plata, La Plata, Argentina
2009-02-24	Prof. Silvio Freitas, Universidade Curitiba, Brazil
2009-02-24/27	Rubén Rodríguez, Buenos Aires, Argentina
2009-03-12	Students of the Technical University Prague, Czech Republic
2009-03-24/04-21	Prof. Juan Báez, Universidad de Concepción, Los Angeles, Chile
2009-04-03	Prof. K.R. Koch, Universität Bonn IGG, Bonn, Germany
2009-05-05	Vera Karner, Touristik Werdenfelser Land, Krün, Germany
2009-06-08/12	Dr. Oliver Heidbach, GFZ Potsdam, Germany
2009-08-24	Prof. H. Fricke, Ludwig-Maximilians-Universität, München, Germany
2009-08-26	PD Dr. Klaus Börger, AGeoBw, Euskirchen, Germany
2009-09-25	Dr. E. Geiß, Bayerisches Landesamt für Umwelt, München, Germany
2009-09-28	Dr. Lee-Lueng Fu, NASA-JPL, USA
2009-11-09/12-11	A. Heiker, Leibniz University Hannover, Germany
2009-11-10	StD M. Filzmeier with pupils, König-Karl-Gymnasium, Altötting, Germany
2009-11-18	Personnel of Bode-Hewitt Co, Munich, Germany
2009-12-16	Prof. Ch. Reigber and Chinese Delegation, STI Immenstaad, Germany

5 Personnel

5.1 Number of personnel

Total staff of DGFI during the 2009 period (incl. DGK Office):

Regular budget

14 scientists
9 technical and administrative employees
1 worker
11 student helpers with an average of 287 hours/year
2 student apprentices
1 minor time employee

Project funds

6 junior scientists
1 student helper

Funding of the following projects is gratefully acknowledged:

GGOS-D	Integration of space techniques as basis of a global geodetic-geophysical observing system (BMBF)
DAROTA	Dynamic and residual ocean tide analysis for improved GRACE de-aliasing (DFG)
GEOTOP	Sea surface topography and mass transport of the Antarctic Circumpolar Current (DFG)
PROMAN	Program management and scientific networking (DFG)
FOR 584, P6	Integration of Earth rotation, gravity field and geometry using space geodetic observations (DFG)
FOR 584, P9	Combined analysis and validation of Earth rotation models and observations, CAVERMO, (DFG)
REAL-GOCE	Real data analysis GOCE, GEOTECHNOLOGIEN programme (BMBF)
GOCE HPF	Validation and frame transformation of GOCE gravity gradients (ESA/TUM)
REGGRAV	Software for regional geoid models as height reference surface (BWB)

5.2 Lectures at universities

Dr.-Ing. W. Bosch: University lectures “Oceanography and Satellite Altimetry”, TU München, WS 2009/2010

Dr. J. Bouman: University lectures “Satellite Gravimetry”, TU München, WS 2008/2009

Dr. J. Bouman: University lectures “Gravity and Magnetic Field from Space”, TU München, WS 2009/2010

Dr.-Ing. B. Richter: University lectures “Geodätische Astronomie”, TU München, WS 2009/2010

PD Dr.-Ing. M. Schmidt: University lectures “Numerical Modelling”, TU München, WS 2008/2009

PD Dr.-Ing. M. Schmidt: University lectures “Wavelets”, TU München, SS 2009

PD Dr.-Ing. M. Schmidt: University lectures “Numerical Modelling”, TU München, WS 2009/2010

6 Miscellaneous

With its collection of geodetic instruments DGFI participated in the "Lange Nacht der Museen" (Long Night of Museums), Munich, Germany, 2008-10-25 and 2009-10-17.