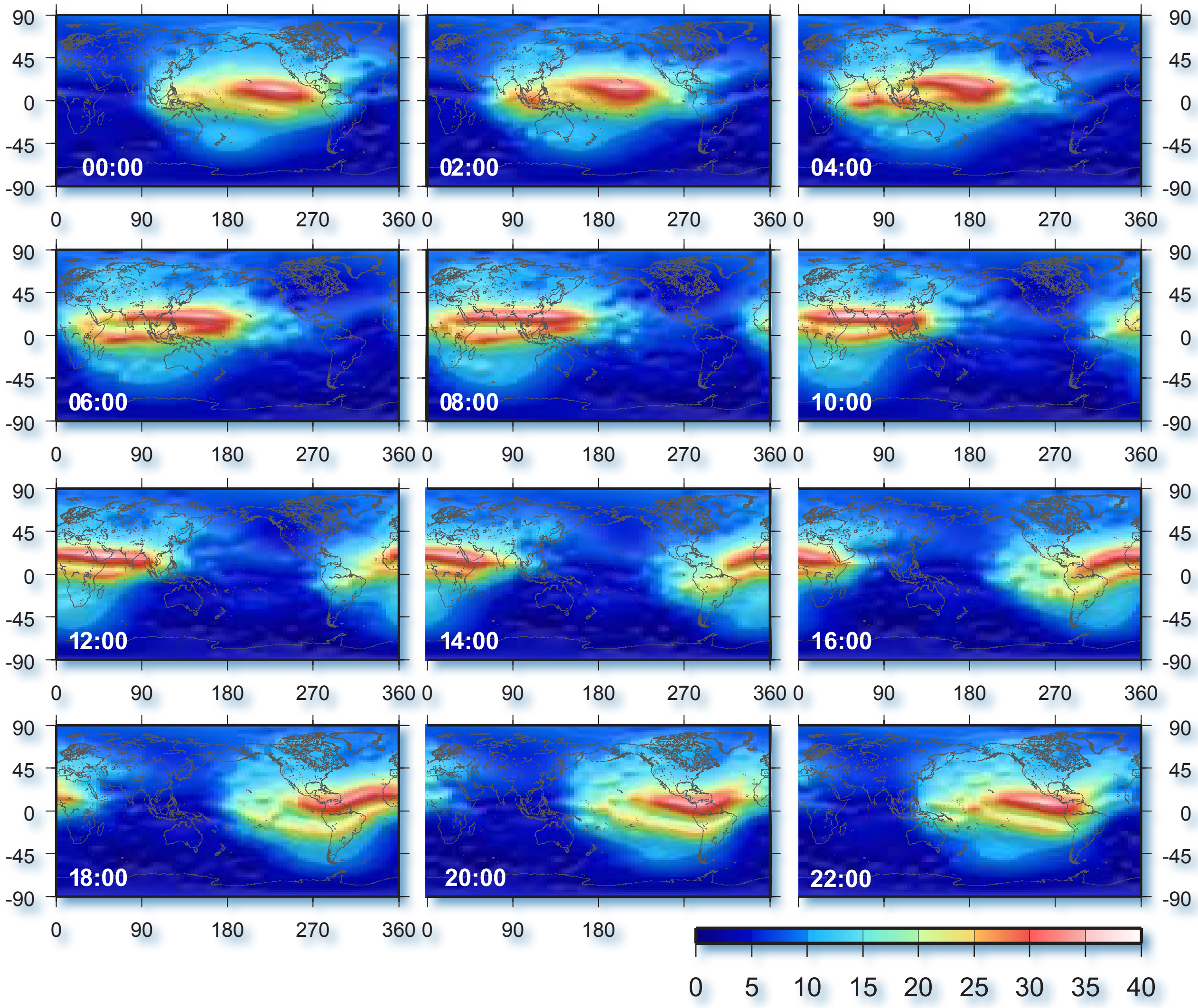
Deutsches Geodätisches Forschungsinstitut (DGFI)

ANNUAL REPORT 2007/2008



The vertical total electron content at July 21, 2006 with a 2 hour interval as the sum of the ionosphere model IRI-2007 and a correction term estimated from more than 2500 COSMIC occultation measurements by applying a three-dimensional B-spline approach. The 12 panels depict clearly the diurnal movement of the equatorial anomaly along the geomagnetic equator; all data in TECU.

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ANNUAL REPORT 2007/2008

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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 supervised by 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 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, and 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 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 solid Earth and 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. It 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 of DGFI with all German universities involved in geodetic education. This is mainly done under the umbrella of the DGK, but also in bilateral arrangements. Members of DGFI give lectures and courses at various universities. Doctoral or Master theses are supervised by DGFI scientists. Interdisciplinary cooperation is installed with university institutes for Geophysics, Meteorology and Oceanography.

Research Group Satellite Geodesy (FGS)

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 of 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 2007−2008 was evaluated and revised by the Scientific Council (Beirat) of DGK, and approved by the DGK General Assembly on November 23, 2006. 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 and interactions of 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 general focus of the research field "Earth System Observations" is on the modelling, data processing and combination of data from the different space-geodetic 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 in future GALILEO, the Doppler Orbitography by Radiopositioning Integrated on Satellite (DORIS), as well as satellite altimetry and gravity field sensors (e.g., SST, gradiometry). These observation techniques form the basis for monitoring the surface structure, the rotation and the gravity field of the Earth along with its variations in time, and allow the representation of the interactions between these parameters.

The research activities are divided into four topics. The objective of topic 1.1 is the improvement and unification of the modelling for the different observation techniques and the development of consistent analysis methods. Topic 1.2 concentrates on basic research for geometric reference systems, which enters directly into the realization of the terrestrial and the celestial reference systems. The fundamentals of physical parameter estimations are covered in topic 1.3. They are an important prerequisite for the procedures of combining geometric and gravimetric observations, which are treated in topic 1.4. The goal is a consistent estimation of geodetic parameters (e.g., station coordinates, positions of radio sources, Earth orientation parameters, functionals of the Earth gravity field, etc.) by a rigorous combination of the data of the different observation techniques.

1.1 Modelling for space geodetic observations

The continuous improvement and unification of physical models for all observation techniques are concentrated on atmospheric modelling. The first question is whether satellite laser ranging (SLR) can be improved by modelling the atmospheric loading deformation. The second part inspects the quality of a common loading model for the microwave techniques GPS and VLBI.

SLR blue sky effect

As SLR is an optical measurement, observations can be obtained only if the sky is cloudless or only slightly overcast. Except of desert and very arid areas, the sky coverage is related to the air pressure. Even if there is no strict connection, cloudless sky often occurs when the air pressure is high, and overclouding mainly arises when the air pressure is low (see Figure 1.1.1). Hence, SLR does not often observe when the air pressure is very low (see Figure 1.1.2). While station Graz cannot often observe, the observation rate of Yarragadee is very high. The reason for the disparity

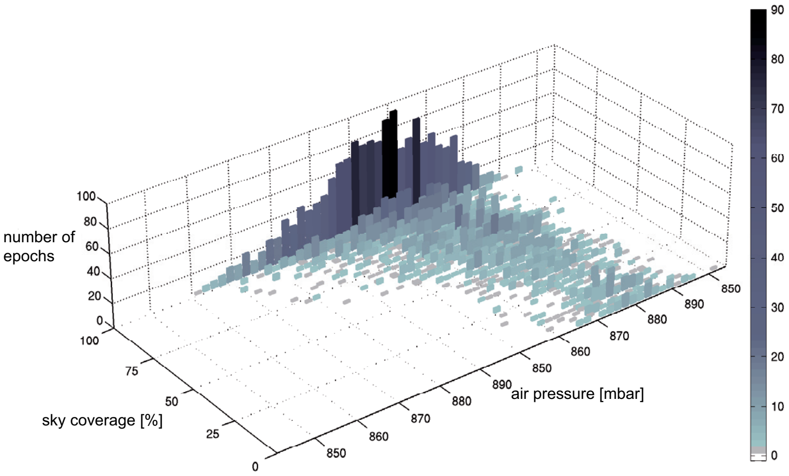


Fig. 1.1.1 Sky coverage related to the air pressure exemplarily shown for station Fichtelberg of the German Weather Service (Deutscher Wetterdienst).

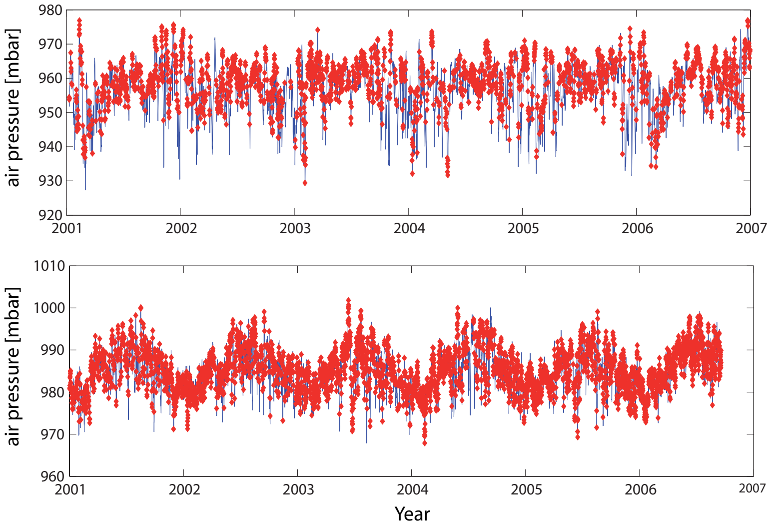


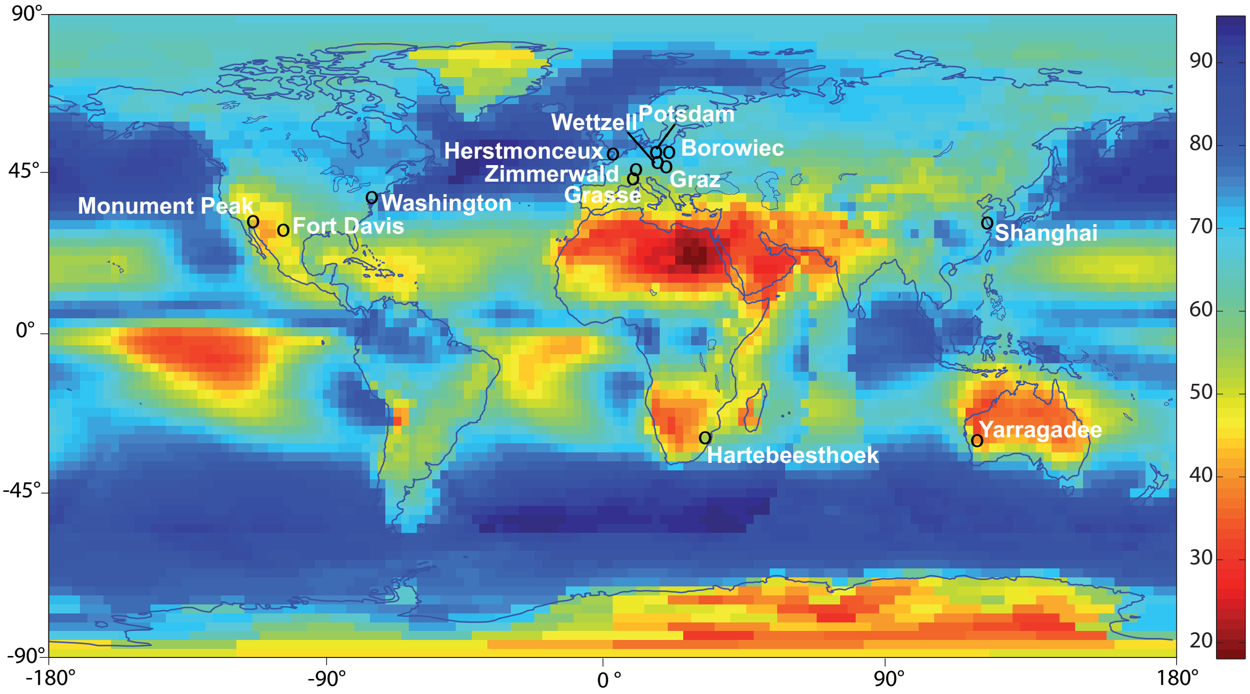
Fig. 1.1.2 Time series of air pressure for station Graz, Austria (top) and Yarragadee, Australia (bottom).

is the different mean cloudiness. Figure 1.1.3 shows the mean sky coverage for the whole Earth; the locations of the SLR stations are marked. While Yarragadee has a mean sky coverage of less than 40%, the value for Graz reaches more than 70%.

As air pressure is related to atmospheric mass load, observations are systematically lacking at times characterized by relaxion (uplift) of the Earth's crust. Thus, the mean station height derived from SLR is lower than the height derived from GPS or VLBI data, the latter being independent from sky coverage. This effect named "blue sky effect" has to be considered when SLR observations are combined with GPS and VLBI.

The local blue sky effect of a station is estimated from the difference of two mean values of air pressure, the first taken over the complete ECMWF time series, the second taken over the observation intervals of that SLR station, both of them spanning six

Fig. 1.1.3 Mean global sky coverage resulting from the ICCP-D2 Project of NASA. SLR stations are marked by circles.



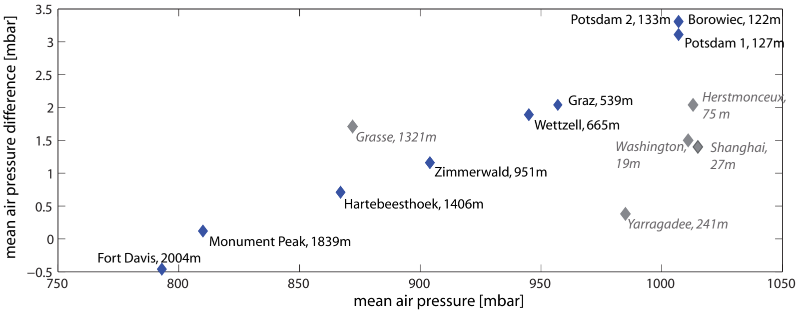


Fig. 1.1.4 Air pressure differences (related to blue sky effect) depending on the mean air pressure.

years. Figure 1.1.4 shows the mean pressure difference against mean air pressure. Stations located near the coast are not affected as strong as the others, because weather is more unsettled than over the continents. For continental stations, the effect decreases with increasing station height. The mean pressure difference was transformed into a height difference using regression factors provided by the IERS Special Bureau for Loading. The largest height "error" (1.4 mm) is obtained for Borowiec.

Atmospheric loading coefficients determined from GPS and VLBI height time series

VLBI and GPS long-term observation series were reprocessed after harmonizing the software in models and parameterization, VLBI with OCCAM6.1e at DGFI and GPS with Bernese5.1 at TU Munich (Tesmer et al., 2008). The solutions were run twice, firstly with simple tropospheric modelling (case 1: Niell Mapping Function (NMF) and constant a-priori zenith delay (ZD)) and secondly with state-of-the-art models (case 2: Vienna Mapping Function 1 (VMF1) and a priori ZD from ECMWF). Theoretically, the station position time series resulting from the case-2 computation can better represent the atmospheric loading deformation, because in case 1 this signal will be partly absorbed by estimated tropospheric parameters due to shortcomings of the mapping function and the constant a-priori ZD. In order to verify this effect, the height time series of GPS and VLBI stations are compared for case 1 and for case 2. The results were used to investigate two questions:

1. Can position time series be improved by state-of-the-art models?

We assume that the time series of GPS and VLBI better coincide, if the used models are more appropriate. Because of large scatter, we do not compare the time series themselves, but estimate annual signals at co-location sites. Secondly, we estimate regression coefficients for atmospheric loading and compare station position variations computed by mapping the air pressure using these coefficents with deformation time series provided by other groups.

Tab. 1.1.1 Differences of annual signals and linear regression coefficients between VLBI, GPS and GGFC

difference	case1	case2
WRMS of annual signal (amplitude @ phase)		
VLBI – GPS	*2.2 mm @ 44°*	*1.8 mm @ 43°*
WRMS of estimated loading regression coefficients		
	mm/mbar	*mm/mbar*
GPS – VLBI	*0.134*	*0.083*
VLBI – GGFC	*0.301*	*0.154*
GPS – GGFC	*0.232*	*0.161*

Using the case-2 data, the agreement of harmonic annual signals of homogeneous VLBI and GPS height series improves (see Table 1.1.1). This is particularly significant for the atmospheric loading coefficients, which were estimated from these series using local ECMWF pressure and simple linear regression (see Table 1.1.1 and Figure 1.1.5). Additionally, the agreement of these coefficients with those provided by the GGFC (Global Geophysical

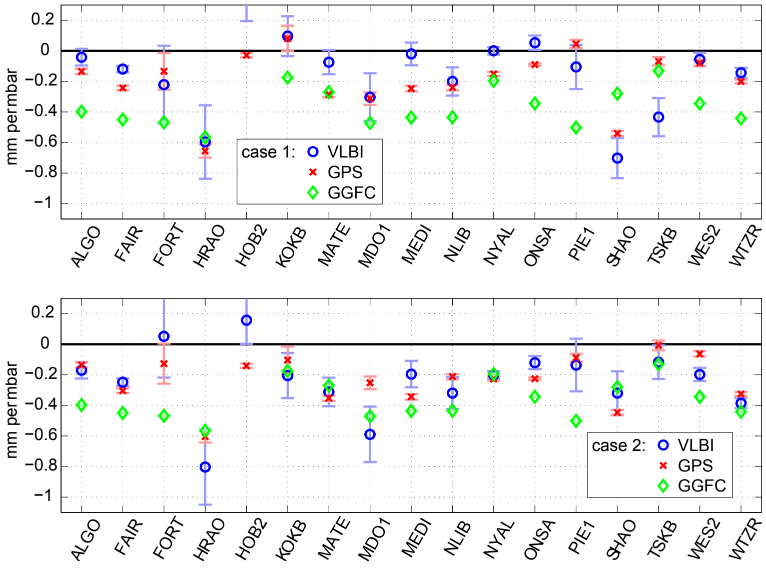


Fig. 1.1.5 Atmospheric loading regression coefficients and their formal errors, determined from VLBI (blue circles) and GPS (red crosses) height time series (top/bottom: case 1/2), and coefficients provided by the GGFC (green diamonds).

Fluids Center, http://www.ecgs.lu/ggfc) also improves significantly for case 2. The GGFC regression coefficients were estimated by fitting NCEP pressure data 1980−1997 to modelled crustal displacements (by convolving Green's functions with inverse barometric ocean).

2. Can a simple regression approach describe the atmospheric loading signal as well as corrections computed from global approaches?

The height corrections for atmospheric loading, computed from the coefficients estimated before, were compared to corrections described by Petrov and Boy (2004).

The atmospheric loading corrections computed here from the raw pressure taken from ECMWF model (regression coefficients times pressure differences) appear to have much more energy in the high frequency domain than the modelled crustal displacements from Petrov and Boy, so the pressure-times-coef-

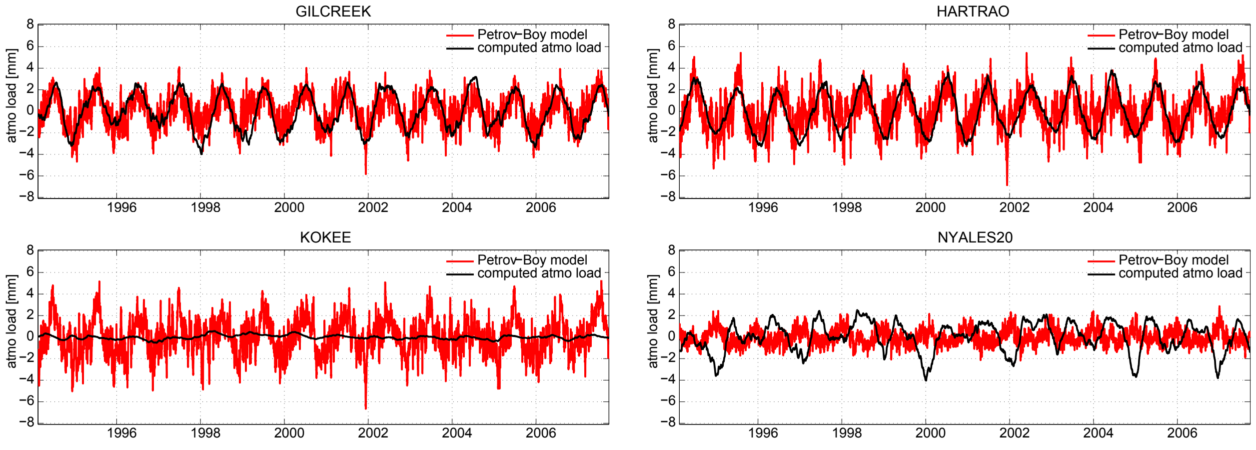


Fig. 1.1.6 Comparison of smoothed "pressure-times-coefficient" series (black) and modelled crustal displacement series (red) for the stations Gilcreek, Hartebeesthoek (Hartrao), Kokee Park and Ny Ålesund (Nyales20) (left to right, top down).

ficient series were smoothed by adopting moving medians (each six hours for an interval of 92 days) for further investigations.

For some stations, like Gilmore Creek, Alaska (USA) and Hartebeesthoek (South Africa), the two series are in good accordance in the annual domain (see Figure 1.1.6). However, many stations, like Kokee, Hawaii (USA) and Ny-Ålesund (Norway), have a bad agreement. Kokee has only 2 mbar RMS of pressure variations during 1994−2008 (the 17 VLBI and GPS co-located sites have between 2 and 12 mbar RMS), and very small VLBI-, GPS- and GGFC-estimated coefficients. Thus there is almost no signal in the station height time series (pressure times regression coefficient). On the contrary, the modelled crustal displacements (as given by Petrov and Boy 2004) clearly vary annually by ±3 mm, which is unexpected, as the deformations for Hawaii should be "damped" by the inverse barometric effect of the ocean. The two series for Ny-Ålesund even seem to show a different sign for many of the bump-like features. Possible reasons for the disagreements are:

- a linear regression model with local pressure is physically too simple,
- VLBI- and GPS-estimated coefficients are "polluted" by mismodelling,
- the modelled crustal displacements are not good enough in some areas.

Tesmer V., Boehm J., Meisel B., Rothacher M., Steigenberger P.: Atmospheric loading coefficients determined from homogeneously reprocessed GPS and VLBI height time series. In: Behrend D., Baver K. (Eds.): IVS 2008 General Meeting Proceedings

1.2 Fundamentals of geometric reference systems

This topic comprises terrestrial and celestial reference systems including their realizations (TRF and CRF, respectively). The third part is the transformation between terrestrial and celestial reference systems, which is determined by the orientation of the Earth.

Configuration of station network

Within the GGOS-D project, observation data of GPS, SLR and VLBI are homogeneously processed and stored as datum-free daily normal equations (NEQ). These NEQ are the input for a TRF computation as well as for combined daily solutions. In order to investigate the benefit of station coordinates from the combination, the daily repeatabilities of station coordinates derived from the combined solutions are compared to the repeatabilities got from the individual technique solutions (Figure 1.2.1; repeatability is defined as the square mean value of the residuals of daily coordinates with respect to a combined multi-year solution). While many VLBI stations benefit from the combination, the repeatabilities of the VLBA stations (Very Long Baseline Array, i.e. a dense VLBI network in North America, names marked in the figure) get worse in general. Figure 1.2.2 shows the map of VLBA stations included in the study. The VLBA stations observe primarily in so-called VLBA sessions. Due to the high density of the VLBA network, the number of observations for these sessions is about the fourfold of the IVS standard sessions (R1 and R4). Because of the constant station network and the large number of observations, the coordinates of the VLBA stations are estimated with a much higher accuracy than those of the other VLBI stations. The positions of the VLBA stations are even more accurate than those of the colocated GPS stations (see

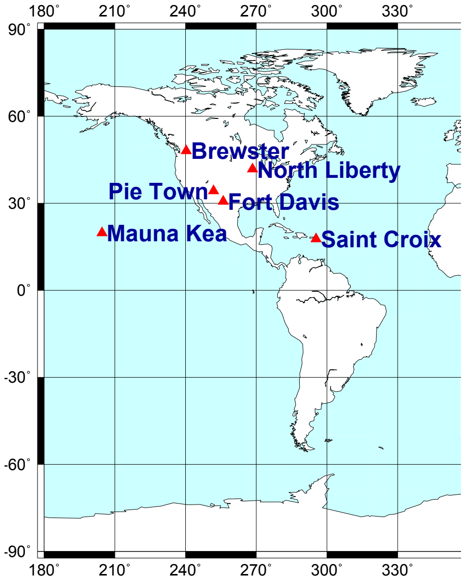


Fig. 1.2.2 VLBA stations used in the study.

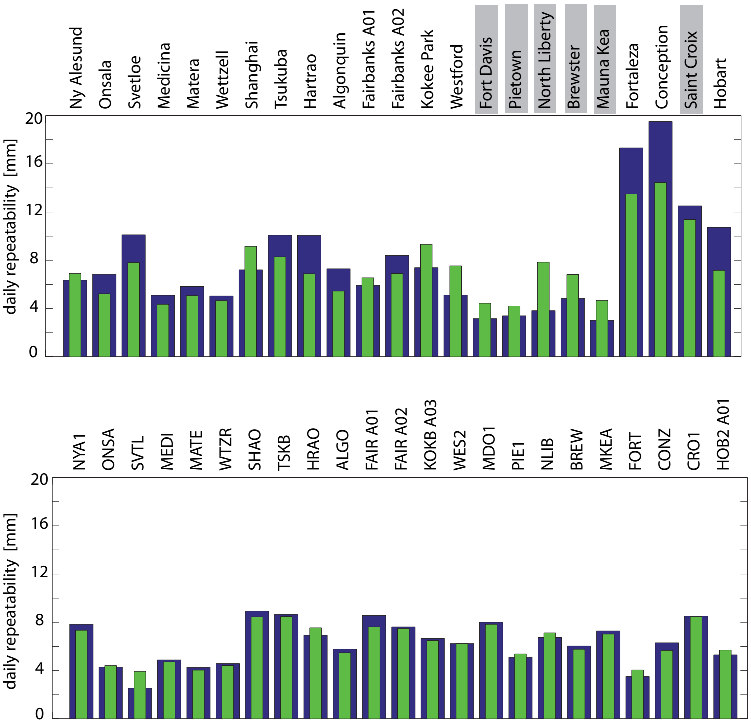


Fig. 1.2.1 Repeatabilities of VLBI stations (upper plot) and GPS stations (lower plot) derived from combined (green) and individual (blue) solutions. The names of the VLBA stations are set off.

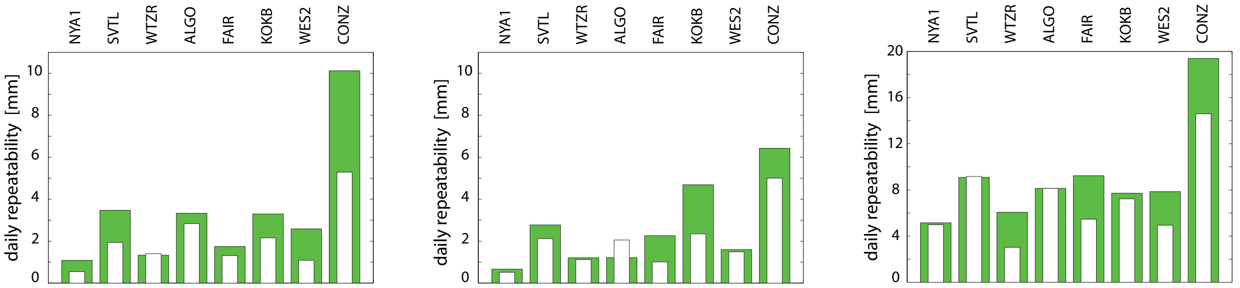


Fig. 1.2.3 Daily repeatabilities of station coordinates (north, east and up component) derived from the CONT05 campaign (white) and 15 standard IVS sessions (green).

also Figure 1.2.1); thus they cannot benefit from the combination with GPS.

In order to investigate the effect of a constant station network on the accuracy of station coordinates, repeatabilities derived from CONT05 sessions (a 15-day VLBI campaign scheduled with a constant station network) are compared to repeatabilities derived from 15 R1 and R4 sessions, which are characterized by a varying network geometry. The chosen R1 and R4 sessions are observed within a time span of two months so that the effect of seasonal signals on the repeatabilities is small. Figure 1.2.3 shows the daily repeatabilities of station coordinates. The high accuracy of CONT05 resulting from the constant station network is evident.

Tropospheric zenith delay derived from VLBI, GPS and WVR

The combination of common parameters (e.g., Earth orientation parameters, troposphere parameters) is a key issue for the integration of different space techniques. In this context, we focus on the estimation of tropospheric parameters from VLBI and GPS. The delay of signal propagation caused by the troposphere is the effect which mostly limits the accuracy of VLBI and GPS. Within the analysis of GPS and VLBI data, the effect is considered by introducing a zenith path delay (ZD) for each station. The ZD is composed of a hydrostatic part, depending only on air temperature and pressure, and an estimated wet part (ZWD), depending only on temperature and water vapour pressure. The latter shows a high variability in time and cannot be adequately modelled. Water vapour radiometry (WVR) observes also the integral wet part of the tropospheric delay by measuring the strength of emission of two frequencies (e.g. 21.0 and 31.4 GHz) from the

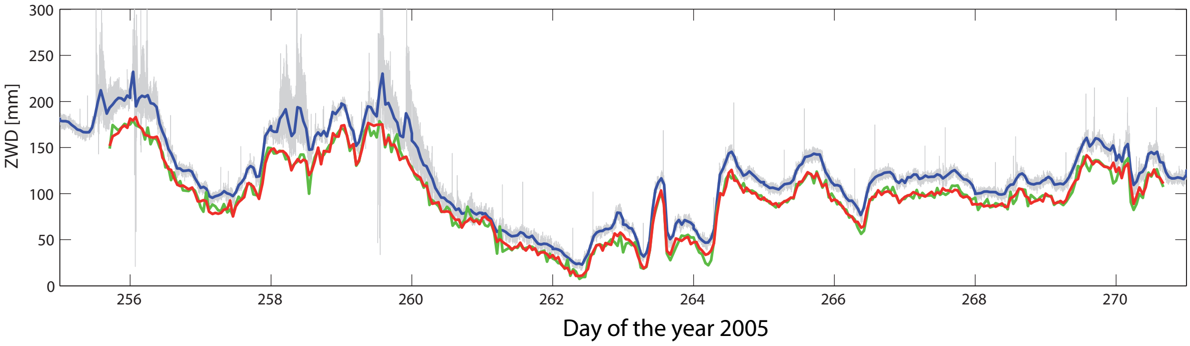


Fig. 1.2.4 Hourly ZWD values derived from GPS (red), VLBI (green) and WVR (blue) at Wettzell. The original ZWD values from WVR with a temporal resolution of 1 minute are also displayed (grey). The large scatter of the grey curve temporally occurring during the first days is caused by water on the optics of the WVR. These WVR measurements are excluded from the comparisons.

atmosphere, which is related to the content of water vapour and precipitable water in the atmosphere.

Tab. 1.2.1 Mean ZWD differences and mean RMS of the differences between ZWD derived from GPS, VLBI and WVR.

	Compared	Offset [mm]	WRMS of differences [mm]
Wettzell	GPS−WVR	16.9	4.5
	VLBI−WVR	17.6	5.5
	GPS−VLBI	0.6	5.1
Algonquin Park	GPS−WVR	27.3	7.0
	VLBI−WVR	27.1	9.2
	GPS−VLBI	−0.7	8.0
Kokee Park	GPS−WVR	5.2	4.9
	VLBI−WVR	4.6	8.1
	GPS−VLBI	−0.3	7.7

The ZWD derived from VLBI, GPS and WVR are displayed in Figure 1.2.4 for station Wettzell over the time of the IVS CONT05 campaign. It becomes clear that the variation in time is very similar for all three techniques. However, there are offsets between the techniques, especially between WVR and the two space-geodetic techniques. Table 1.2.1 shows the offsets and the RMS values of the differences for three GPS/VLBI co-locations, all equipped with WVR during the CONT05 campaign. Even if ZWD derived from WVR shows significant offsets to the ZWD from GPS and VLBI, the variation in time agrees very well: WVR and GPS show better agreement than GPS and VLBI for all stations. This demonstrates that WVR is suitable for validating the variablitity of ZWD derived from GPS and VLBI.

ICRF computations

DGFI participates in the IVS working group for the second realization of the International Celestial Reference Frame (ICRF2). One task is to identify the radio sources with variable positions. Therefore, time series of source positions are analysed over the whole time span since 1984.

Within the German project GGOS-D, combined VLBI data of DGFI and IGG (Bonn) are generated, parameterizing also the radio source positions. Based on these data, a terrestrial and a celestial reference frame were rigorously computed. Comparisons to the solution based only on DGFI data show a very good agreement.

Fundamental arguments of nutation and tidal potential

Both precession/nutation of the rotation axis of the Earth and the tidal potential are caused by the Moon and the Sun (and, to a lower degree, by the other planets). Precession and nutation are referred to a celestial reference system; for modelling the nutation, the positions of the Moon and the Sun are traditionally described by periodic functions of integer linear combinations of five fundamental parameters: the mean anomaly l of the Moon, the mean anomaly l' of the Sun, the mean nodal distance F of the Moon, the mean elongation D of the Moon from the Sun, and the mean longitude Ω of the ascending node of the lunar orbital plane. The tidal potential is referred to a terrestrial reference system; for modelling it, the positions of the Moon and the Sun are traditionally described by periodic functions of integer linear combinations of the six Doodson parameters: lunar time τ, the mean longitude s of the Moon, the mean longitude h of the Sun, the mean longitude p of the perigee of the lunar orbit, the (opposite) mean longitude N' of the ascending node of the lunar orbital plane, and the mean longitude p_s of the perigee of the solar orbit.

Precession is a retrograde circular motion of the rotation axis, and each nutation component is an elliptical motion, which can mathematically be split up into a prograde and a retrograde circular motion, the frequencies of which have the same magnitude, but opposite signs. Each circular motion component of the rotation axis with a frequency f in a celestial reference system corresponds to a circular motion component with frequency $f - \omega$ in a terrestrial reference system ("forced diurnal polar motion" – ω is the magnitude of the rotation of the Earth). The arguments of the individual diurnal polar motion terms are thus obtained by subtracting sidereal time θ as a sixth fundamental parameter from the respective nutation arguments. The fact that the six parameters, in the case of nutation/diurnal polar motion as well as in the case of the tidal potential, are defined as angles partly on the lunar orbital plane, partly on the ecliptic and partly on the equator does not conflict with adding them because these mean parameters change linearly in time and have practically the same rates in the projection on each plane.

Since precession/nutation, and hence the forced diurnal polar motion, have the same causes as the tidal potential, it is to be expected that there is a frequency correspondence between the single prograde and retrograde circular nutation components on the one hand and the diurnal tidal components on the other hand. This correspondence can, however, not directly be seen because of the different parametrizations. From the arrow diagram in the lower part of Figure 1.2.5 (the blue arrows represent the fundamental arguments of nutation, and the green ones represent the fundamental arguments of the tidal potential), one finds the transformations, shown left.

$l = s - p$,	$\tau = -F - \Omega + \theta \pm 12^h$,
$l' = h - p_s$,	$s = F + \Omega$,
$F = s + N'$,	$h = F - D + \Omega$,
$D = s - h$,	$p = -l + F + \Omega$,
$\Omega = -N'$,	$N' = -\Omega$,
$\theta = \tau + s \pm 12^h$,	$p_s = -l' + F - D + \Omega$.

These formulae enable the single circular nutation components to be assigned to the diurnal polar motion components (the most dominant ones can clearly be identified in laser gyroscope observations) and the diurnal tidal components. Thus, for example, the prograde part of the half-monthly nutation term with the argument $2F + 2\Omega$ corresponds to the tidal term O_1 with the Doodson code number 145.555 (the six digits of the Doodson code number represent the integer combination factors of the six fundamental arguments τ, s, h, p, N', p_s), and the prograde part of the half-yearly nutation term with the argument $2F - 2D + 2\Omega$ corresponds to the tidal term P_1 with the code number 163.555. Precession, which, as a secular motion, is not expressed by periodical functions of a nutation argument, corresponds to the tidal term K_1 with the code number 165.555.

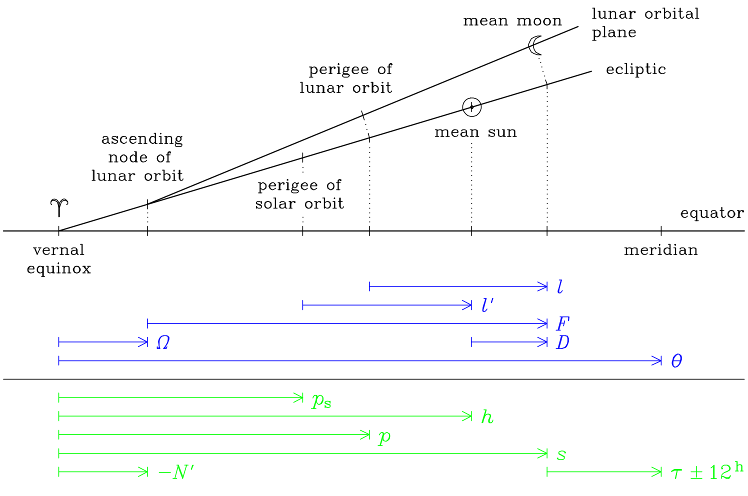


Fig. 1.2.5 Reference directions and fundamental arguments of nutation and tidal potential.

1.3 Fundamentals of physical parameter determination

The analysis techniques *energy balance approach* and *integral equation method* were applied for the dedicated gravity missions CHAMP and GRACE. These techniques are very successful in terms of recovery of parameters describing the Earth's gravity field. However, coordinates of tracking sites, specific constituents of the ocean tides or parameters for the dynamic ocean topography (simultaneously solved for in the EGM96 solution) are not considered. In order to account for the mutual dependencies between different parameter sets, it is necessary to use a combined estimation approach. Here, requirements to extend the space of physical solve-for parameters are investigated.

Satellite altimetry also contributes to the determination of the gravity field. It can stabilize and extend the estimation of gravity field parameters describing in particular the short wavelengths. Usually altimetry is taken to derive marine gravity anomalies which are in turn combined with satellite-only gravity data. A new DGFI approach takes advantage of the fact that the mean sea level is nearly coinciding with an equipotential surface of the Earth gravity field. The small deviations known as dynamic ocean topography (DOT) is due to hydrodynamics: the ocean circulation causes the actual sea level to deviate from an equipotential surface by up to 2 m. In order to account for the DOT, the observation equation

$$h + v_{\mathrm{h}} = N + \zeta$$

is considered, where h are the observed sea surface heights, v_{h} the associated residuals, N the geoid undulations and ζ the heights of the DOT. Both N and ζ have to be parameterized. As satellite altimetry provides observations only over the ocean surface, the use of spherical harmonics as base functions, with global support, is not recommended. Also, the DOT ζ is not defined on land surfaces. Thus, space-localizing base functions are much more appropriate to parameterize the right-hand side of the equation above. Therefore, the geoid heights N were expressed as a linear combination of harmonic splines

$$N(\mathbf{r}) = \sum_{i=1}^{N} a_i \, \Phi(\mathbf{r}, \mathbf{r}_i)$$

defined in turn by a series of Legendre polynomials

$$\Phi\left(\psi(\mathbf{r}, \mathbf{r}_i)\right) = \sum_{n=2}^{\infty} k_n P_n(\cos\psi)$$

depending on the spherical distances ψ between a gridded set of support points i and the computation point. The coefficients k_n are derived from degree variances of the Earth's gravity field minus the degree variances of the reference field (ITG03S). Figure 1.3.1 shows the isotropic shape of the harmonic splines. Similarly the DOT

$$\zeta(\mathbf{r}) = \sum_{i=1}^{N} b_i \, \Phi'(\mathbf{r}, \mathbf{r}_i)$$

is represented by a linear combination of harmonic splines of similar type with coefficients accounting here for the degree variances of the DOT.

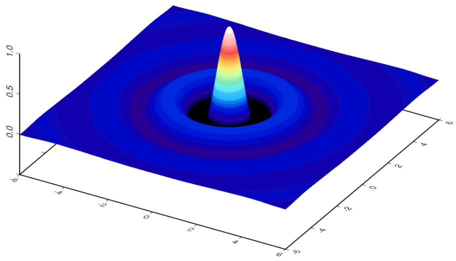


Fig. 1.3.1 Shape of harmonic splines used to parametrize the geoid heights N and the DOT ζ.

The observation equations were set up for the sea surface heights of TOPEX and ERS-2 altimeter profiles covering a small test area in the South Atlantic with the South Sandwich trench. The normal equations were then combined with prior information for the GRACE reference gravity field (ITG03S) and for the DOT. Variance component estimation was applied to obtain an optimal weighting between different sets of observation equations.

The details of the solution, shown in Figure 1.3.2, demonstrate that the approach achieves not only a dramatic improvement in the spatial resolution, but allows also the simultaneous estimation of both the geoid and the DOT. Rather good agreements exist between the estimated DOT and external models.

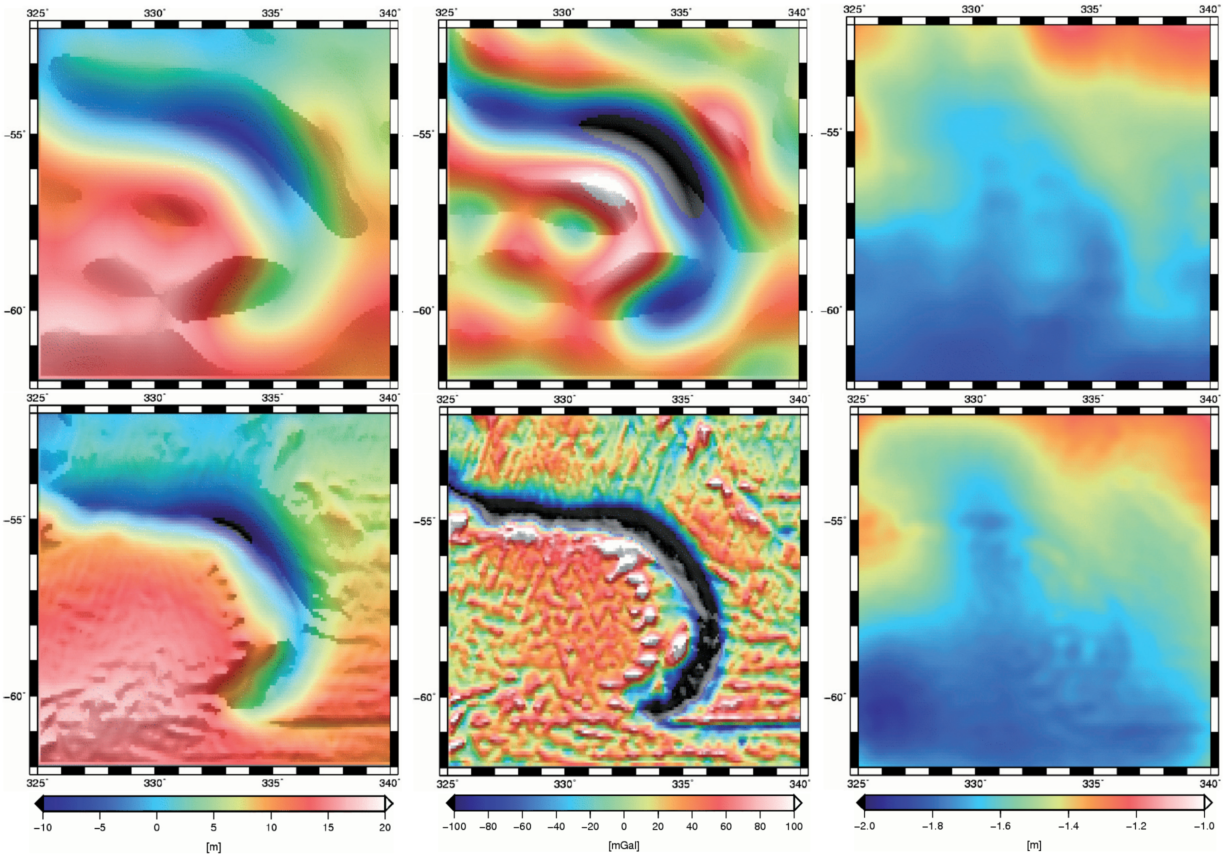


Fig. 1.3.2 Details for the common estimation of geoid and DOT in the South Atlantic test area. Left column: Improvements in the spatial resolution of the geoid, evident by comparing geoid heights of the reference model ITG03S (top) and the regional solution of this study (bottom). Middle column: improvements in terms of gravity anomalies, shown for ITG03S (top) and the solution of this study (bottom). Right column: The dynamic ocean topography of Niiler et al. (top), compared with the DOT estimate of this study (bottom).

GOCE HPF, Gravity Gradient Preprocessing

In close collaboration with IAPG, DGFI is involved with the preprocessing of the GOCE gravity gradients, as part of the data processing for the GOCE High-Level Processing Facility (HPF). This preprocessing includes corrections for temporal gravity variations, outlier detection, gravity gradient external calibration as well as rotation of the gravity gradient tensor from the instrument frame to an Earth-fixed reference frame. In Spring 2008, Version 3.1 of the GOCE HPF was reviewed and accepted by ESA for the operational scientific processing of the GOCE data once they are available. In addition, a synthesis analysis was performed of the many different internal and external calibration methods that exist for the GOCE gradiometer data.

1.4 Combination of geometric and gravimetric observations

The objective of combining geometric and gravimetric observations is to determine consistently time-dependent parameters of the rotation, the shape, and the gravity field of the Earth within a global geometric and gravimetric reference frame. The overall intention is to obtain a higher and more accurate resolution of the estimated parameters defining the geometric and physical reference frames in time and space.

Three aspects for the combination of geometric and gravimetric observations are treated: physical influences on polar motion, a World Height System based on geometrical and physical heights, and the weekly SLR combination with lower harmonic coefficients as solve-for parameters.

Gravimetric and altimetric observations for polar motion

Gravimetric and altimetric observations are combined in order to assess the contribution of non-tidal oceanic mass changes to polar motion. Therefore equatorial oceanic angular momentum functions are determined on the one hand from GRACE time-variable gravity field solutions (JPL RL04, ITG-Grace03) and on the other hand from sea level anomalies (AVISO) reduced by the steric effect derived from 3D temperature and salinity fields (WOA05, Ishii), for more details see Göttl (2008). A weighted adjustment of several gravimetric and altimetric solutions improves the agreement with ocean models such as ECCO and OMCT.

Definition of a World Height System (WHS)

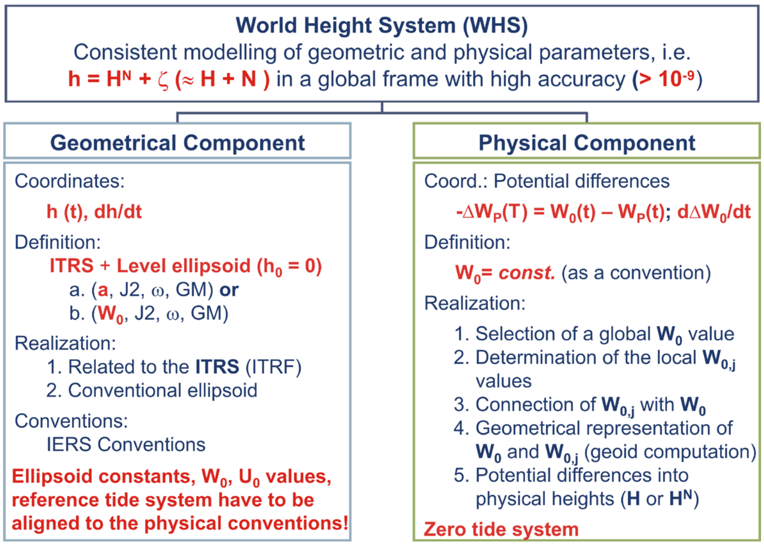
The definition and realization of a global vertical reference system, also called world height system, requires the precise modelling of the Earth's gravity field based on the combination of satellite-derived global geopotential models and terrestrial (marine and aerial) gravity data. Since the terrestrial gravity data are biased because of the vertical inconsistencies between the local height datums, actual formulations of the geodetic boundary value problem (GBVP) include ellipsoidal heights as a new observable, which together with gravity acceleration values, deflections of the vertical, and geopotential differences allow a precise global vertical datum unification. Therefore, a unified world height system shall comprise two components: a *geometrical* one and a *physical* one (Sánchez 2007).

Geometrical component of a WHS

The geometrical component is given by a level ellipsoid as a reference surface (i.e. the zero height level) and ellipsoidal heights h as coordinates. The ellipsoidal heights must be in agreement with the realization of the geometrical reference system, i.e. they must refer to the ITRS/ITRF. The reference ellipsoid applied for deriving ellipsoidal heights from geocentric coordinates X, Y, Z has to be the same level ellipsoid applied for estimating geoid undulations N or height anomalies ζ.

Physical component of a WHS

The primary vertical coordinates are geopotential numbers, which are customarily transformed into metric quantities such as orthometric heights H or normal heights H^N. If the definition of the global reference level is based on the geoid (orthometric heights), it should also include the respective hypothesis to reduce the gravity data to this surface; otherwise, this definition would be neither unique nor consistent. Consequently, all orthometric heights and



World Height System (WHS)
Consistent modelling of geometric and physical parameters, i.e.
$h = H^N + \zeta$ ($\approx H + N$) in a global frame with high accuracy ($> 10^{-9}$)

Geometrical Component

Coordinates:
h (t), dh/dt
Definition:
ITRS + Level ellipsoid ($h_0 = 0$)
a. (a, J2, ω, GM) **or**
b. (W_0, J2, ω, GM)
Realization:
1. Related to the **ITRS** (ITRF)
2. Conventional ellipsoid
Conventions:
IERS Conventions
Ellipsoid constants, W_0, U_0 values, reference tide system have to be aligned to the physical conventions!

Physical Component

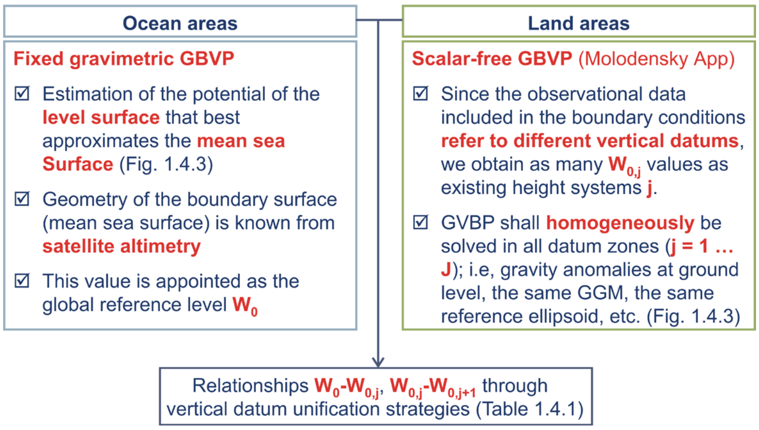
Coord.: Potential differences
$-\Delta W_P(T) = W_0(t) - W_P(t)$; $d\Delta W_0/dt$
Definition:
W_0= *const.* (as a convention)
Realization:
1. Selection of a global W_0 value
2. Determination of the local $W_{0,j}$ values
3. Connection of $W_{0,j}$ with W_0
4. Geometrical representation of W_0 and $W_{0,j}$ (geoid computation)
5. Potential differences into physical heights (**H** or H^N)
Zero tide system

Fig. 1.4.1: Definition and realization of a World Height System based on a geometrical and a physical component.

gravimetric geoids computed over the world must apply the same mass distribution and vertical gravity gradient assumptions to be consistent with each other; if not, there will exist as many vertical reference systems as applied hypotheses. If the definition of the global reference level is based on the quasigeoid (normal heights), it would be unique and consistent, but it is not an equipotential surface inside the continental masses, i.e. it does not have any physical meaning. In order to formulate a consistent definition, free of ambiguities, but correct from the theoretical point of view, the physical component of a world height system should be given in terms of geopotential quantities, i.e. the reference level must be a fixed W_0 value, and the vertical coordinates shall be geopotential numbers referred to this W_0. The transformation of the geopotential numbers into physical heights and the geometrical representation of the surface W_0 = const (geoid determination) will then be matters of the realization. Figure 1.4.1 summarizes the definition and realization of the geometrical and physical components of a modern world height system (Sánchez 2007).

Global W_0 and local $W_{0,j}$ reference levels

The determination of absolute geopotential values is feasible by introducing adequate constraints (mainly the vanishing of the gravitational potential V at infinity), which are only reliable in the frame of a GBVP. Our approach faces the vertical datum problem by considering the GBVP in two ways (Figure 1.4.2): i) The so-called *fixed gravimetric* GBVP is applied in ocean areas to



Ocean areas

Fixed gravimetric GBVP

☑ Estimation of the potential of the **level surface** that best approximates the **mean sea Surface** (Fig. 1.4.3)

☑ Geometry of the boundary surface (mean sea surface) is known from **satellite altimetry**

☑ This value is appointed as the global reference level W_0

Land areas

Scalar-free GBVP (Molodensky App)

☑ Since the observational data included in the boundary conditions **refer to different vertical datums**, we obtain as many $W_{0,j}$ values as existing height systems **j**.

☑ GVBP shall **homogeneously** be solved in all datum zones (**j = 1 … J**); i.e, gravity anomalies at ground level, the same GGM, the same reference ellipsoid, etc. (Fig. 1.4.3)

Relationships W_0-$W_{0,j}$, $W_{0,j}$-$W_{0,j+1}$ through vertical datum unification strategies (Table 1.4.1)

Fig. 1.4.2: Determination of reference levels in ocean and land areas.

	Ocean areas	Land areas
Formulation	$\nabla^2 T = 0$ *outside boundary surface* ; $T = W - U$	
	$-\frac{\partial T}{\partial r} = \delta g$	$-\frac{\partial T}{\partial r} - \frac{2}{r} T = g_j - \frac{2}{r} \delta W_j$ $\delta W_j = W_{0,j} - U_0 = W_0 - W_{0,j}$
Constraints	$T = 0 \; at \; \infty \; ; \int_{sea} T \, d\sigma = k_i \; ; \int_{land} T \, d\sigma = k_j \; ; \int k_i + \int k_j = 0 \Rightarrow T_{00} \equiv \int T \, d\sigma = 0$	
Solution	$T = \frac{\Delta GM}{R} + \frac{R}{4\pi} \iint_\sigma B_j \; S(\psi) d\sigma + \sum_{n=1}^{\infty} \frac{R}{4\pi} \iint_\sigma G_n \, S(\psi) d\sigma$	
	$j = 1 \; ; B_1 = \delta g$ (gravity disturbances)	$j = 1 \ldots J \; ; \quad B_j = g_j - \frac{2}{r} \delta W_j$ $g_1 = \Delta g \; ; \; g_2 = \Delta C \; ;$ etc.
	$S(\psi) = S'(\psi) = \frac{1}{\sin(\psi/2)} - \ln\left(1 + \frac{1}{\sin(\psi/2)}\right)$	$S(\psi) = \frac{1}{\sin(\psi/2)} - 6 \sin \frac{\psi}{2} + 1 - 5 \cos \psi \ldots$
Results	$W_P = U_0 - \gamma_P \, h_P + T_P$ $W_0 = \int \frac{W_P}{\gamma_P^2} d\sigma \Big/ \int \frac{1}{\gamma_P^2} d\sigma$	$\zeta_j = \frac{T + \delta W_j}{\gamma}$

Fig. 1.4.3: Geodetic boundary problem for the determination of W_0.

estimate the geopotential value of the level surface that best approximates the mean sea surface. This value is appointed as the global reference level W_0. ii) The local reference levels $W_{0,j}$ in land areas (local vertical datums) are determined by solving the *scalar-free* GBVP. Figure 1.4.3 presents the corresponding formulations (Sánchez 2008).

Vertical datum unification

The relationship between W_0 and the different $W_{0,j}$ is determined following the vertical datum unification strategies by applying three different approaches: at the reference points (mainly tide gauges) of the classical height datums, on the marine areas close to the tide gauges, and at fiducial stations of the terrestrial reference frame ITRF, see Table 1.4.1 (Sánchez 2007).

As an example, Figure 1.4.4 shows datum discrepancies δW calculated at the main tide gauges of some South American countries following the coastal and oceanic approaches. They are computed with respect to the value $W_0 = 62\,636\,853.1 \text{ m}^2\text{s}^{-2}$ and by applying high resolution quasigeoid models. The potential differences are divided by normal gravity to express the results in metric units; i.e. $\delta H = \delta W / \gamma$.

Table 1.4.1: Observation equations for the estimation of vertical inconsistencies between the classical height datums and a global reference level W_0.

Constraint for the empirical determination of the δW_j terms:	$\gamma_P h_P - \left(W_0^j - W_P^j\right) - T_P^j - 2\delta W_j = 0$
Oceanic approach (SSTop around tide gauges) Data: Satellite altimetry and satellite-only GGM, SSTop at coast lines by including also tide gauge records.	$T_P^j - T_0 = \delta W^j$
Coastal approach (reference tide gauges) Data: GPS positioning at tide gauges, spirit levelling with gravity corrections, terrestrial gravity data and satellite-only GGM.	$\frac{1}{2} T_P^j - \frac{1}{2} h_P \gamma_P = \delta W^j$
Continental approach (geometric reference stations) Data: GPS positioning at reference stations (including border points), spirit levelling with gravity corrections, terrestrial gravity data and satellite-only GGM.	$\frac{1}{2}\left(W_0^j - W_P^j + T_P^j\right) - \frac{1}{2} h_P \gamma_P = \delta W^j$ $\frac{1}{2}\left(W_0^j - W_P^j + T_P^j\right) - \frac{1}{2}\left(W_0^{j+1} - W_P^{j+1} + T_P^{j+1}\right) = \delta W^{j+1} - \delta W^j$

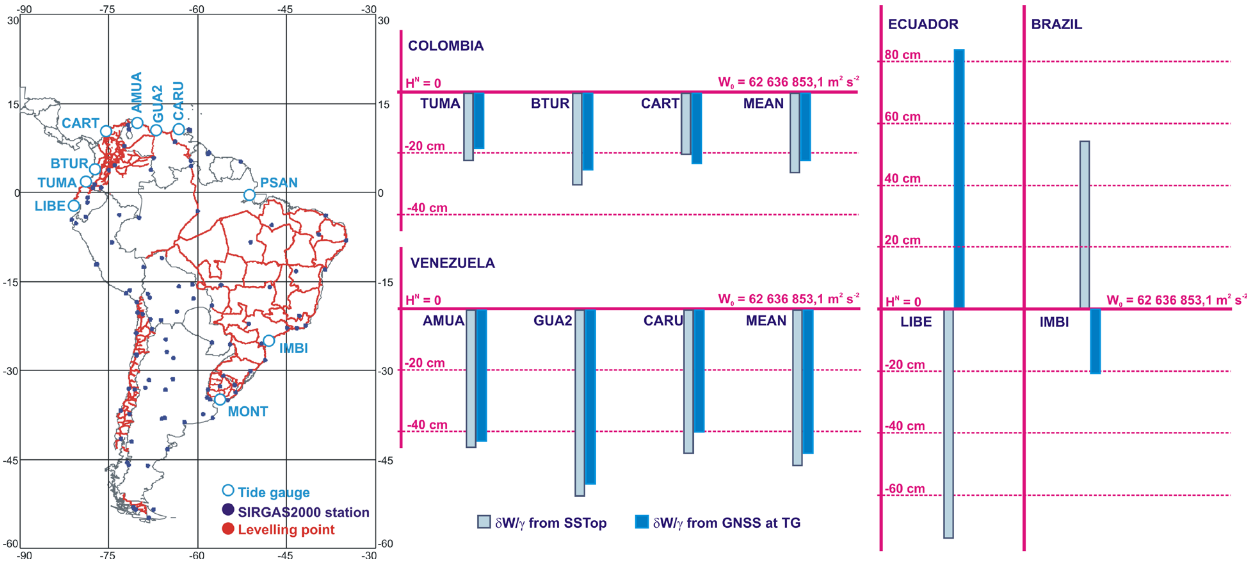


Fig. 1.4.4: Vertical datum discrepancies at the main tide gauges of some South American countries following the oceanic and coastal approaches for the vertical datum unification.

Weekly SLR intra-technique combination with lower degree harmonic coefficients

SLR individual solutions with harmonic coefficients up to degree and order 2 of two analysis centres are available within the GGOS-D project in the time interval from 1993 to 2006. Investigations reveal that a weekly combination of normal equations with harmonic coefficients as parameters to be solved for does not lead to stable minimum constraint solutions. This fact may be expected because the time interval of one week is too short for a reliable resolution of lower harmonic coefficients. Hence, the only objective of weekly SLR combinations is the determination of scale factors for the weighting of the individual normal equation systems.

Investigations lead to the result that, in the case of scale factor estimation, the harmonic coefficient parameters may be eliminated from the individual normal equations. At first, the rigorous Variance Component Estimation (VCE) is taken as weighting method, because VCE creates satisfying results in the SLR combination of ILRS (see topic 3.4). VCE allows not only to estimate variance factors for the weighting of the individual solutions, but also to detect and eliminate outliers in an automatic processing mode.

VCE works on the basis of minimum constraint solutions and eliminates station position parameters which produce negative or unrealistic variance components. In the GGOS-D application, VCE eliminates many more station positions in general than in the ILRS solutions. For instance in 1993, 1 to 6 stations per week are eliminated in 7 out of 56 solutions, and in 2006, 1 to 10 stations in 11 out of 56 solutions. The RMS and WRMS values of both years are presented in Figure 1.4.5.

Because of the large number of eliminated stations and the relatively high RMS and WRMS values in VCE, a second weighting method is investigated. With the hypothesis that both individual solutions yield similar accuracy values at least for the core sta-

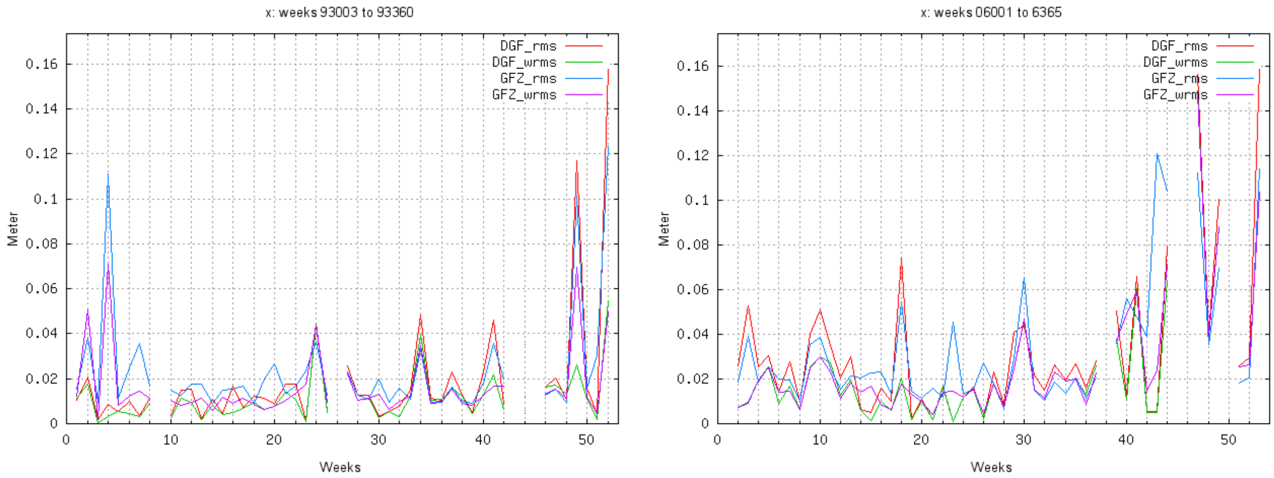


Fig. 1.4.5: RMS and WRMS values for the X-coordinate residuals of DGFI and GFZ minimal constraints solutions in VCE combination for 1993 and 2006.

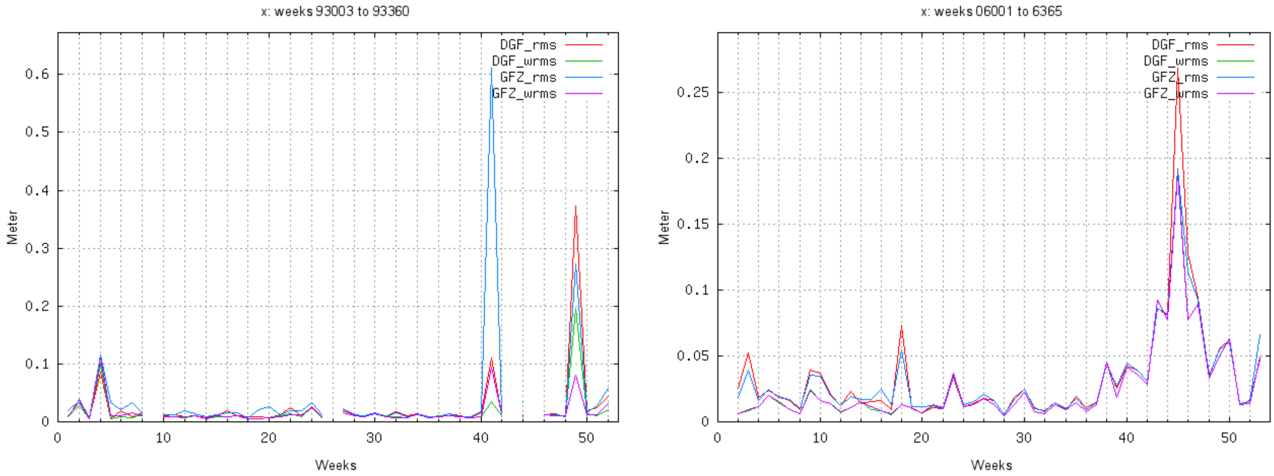


Fig. 1.4.6: RMS and WRMS values for the X-coordinate residuals of DGFI and GFZ minimal constraints solutions in relatively weighted combination for 1993 and 2006.

tions, the sums of the normal matrix diagonals for the coordinates of the core stations are set into relationship. The resulting weights are taken for the scaling of the individual normal equation systems. For 1993 and 2006 only one station per week in two solutions are eliminated. The RMS and WRMS values are presented in Figure 1.4.6.

The accuracy level of a relatively weighted combination is more satisfying than the one of VCE combination. The reason for that phenomenon is not yet clear.

Finally, the individual normal equations with harmonic coefficients are weighted and combined.

Göttl F.: Earth rotation variations from geometric, gravimetric and altimetric observations and geophysical models. DGFI Report, 84, 2008

Sánchez L.: Realización del nivel de referencia vertical para SIRGAS dentro de una definición global. Reista Analisis Geograficos Vol. 37, 18–25, IGAC, Bogota, 2007

Sánchez L.: Approach for the establishment of a global vertical reference level., IAG Symposia Vol. 132, 119–124, Springer, Berlin, Heidelberg, 2008

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 as, for example, 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 and the ionosphere by different base functions (wavelets, splines or empirical orthogonal functions), which allow to describe also the temporal variations of these fields. 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 beforehand. 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 gravity field and ionosphere

For modelling multi-dimensional ionospheric signals and parameters, a general procedure was derived at DGFI which allows various options. Figure 2.1.1 shows the main features of the procedure.

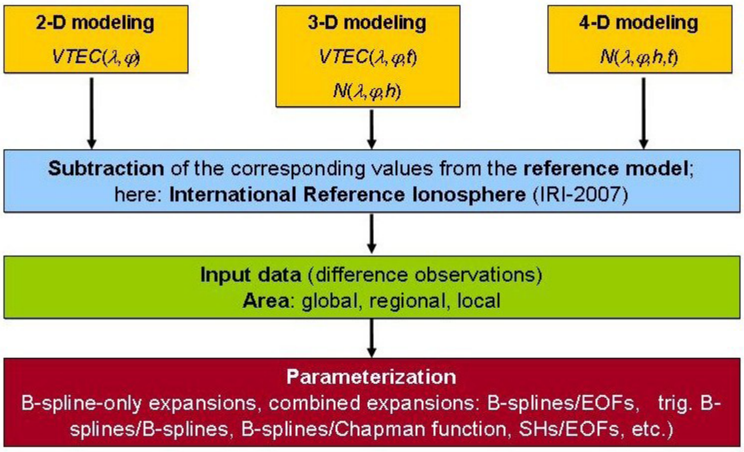


Fig. 2.1.1: Flowchart of the multi-dimensional procedure for modelling ionospheric signals

General procedure for modelling ionospheric signals and parameters

The procedure allows different input options depending on the chosen input signal. In case of GPS geometry-free measurements, the electron density of the ionosphere will be the target function, which can be modelled either 3-dimensionally (3-D) by considering the variables longitude λ, latitude φ and height h or 4-dimensionally (4-D) by adding the time t as the fourth variable. The basic feature of the procedure is to model difference observations, i.e., we subtract in a first step model observations – calculated by a reference model, e.g., the International Reference Ionosphere (IRI-2007) – from the measurements; for more details see Zeilhofer (2008). Different options are available for the parameterization of the target function, i.e., the correction function. As a first example, Schmidt et al. (2008a) apply the procedure to the ionosphere electron density. To be more specific, the method is applied to electron density values over South America calculated from IRI-2000. Another study, Schmidt et al. (2008b) models the vertical total electron content (VTEC) over the American continent. The unknown series coefficients are estimated from measurements of the COSMIC/FORMOSAT-3 (Constellation Observing System for Meteorology, Ionosphere, and Climate and Taiwan's FORMOsa SATellite #3) Mission. The procedure cannot only be applied to ionospheric functions like the electron density and the VTEC, but also to ionosphere parameters such as the maximum value NmF_2 of the electron density within the F_2 layer or the associated height hmF_2. These parameters are two fundamental quantities of ionosphere models such as IRI. Usually they are modelled globally by spherical harmonic expansions.

The modelling approaches of DGFI for the ionosphere are finally based on two ideas, namely (1) to incorporate physics and (2) to estimate the unknown model parameters from a variety of measurement techniques. Figure 2.1.2 visualizes how terrestrial GPS measurements, altimetry observations as well as observations from LEO satellites such as CHAMP, GRACE or COSMIC could be used within a joint scenario.

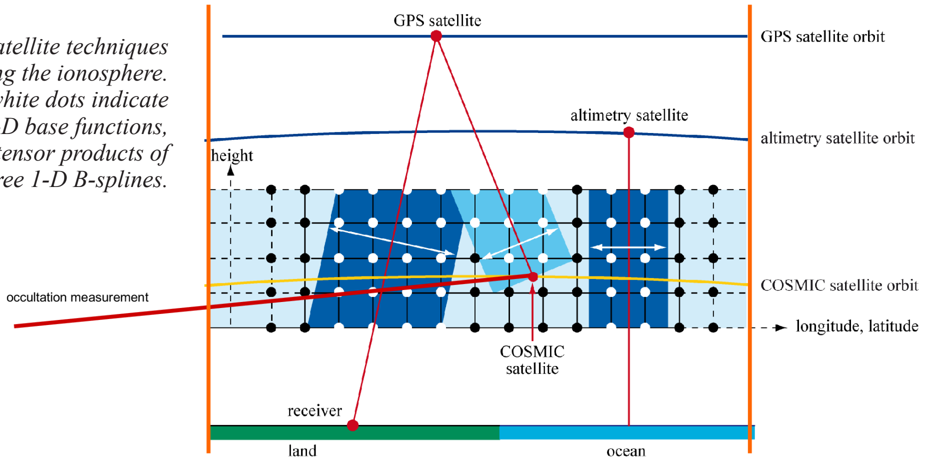


Fig. 2.1.2: Various satellite techniques for monitoring the ionosphere. The black and white dots indicate the centers of the 3-D base functions, e.g., tensor products of three 1-D B-splines.

Modelling of occultation measurements

In case of a regional modelling, occultation measurements usually cannot be considered because the corresponding ray-path penetrates a very large part of the ionosphere. Consequently, a global model has to be established for evaluating occultation measurements, e.g. from COSMIC. For such a purpose, so-called trigonometric B-splines can be used. Figure 2.1.3 shows these function for the resolution level $J = 1$ defined on the interval between 0° and 360°.

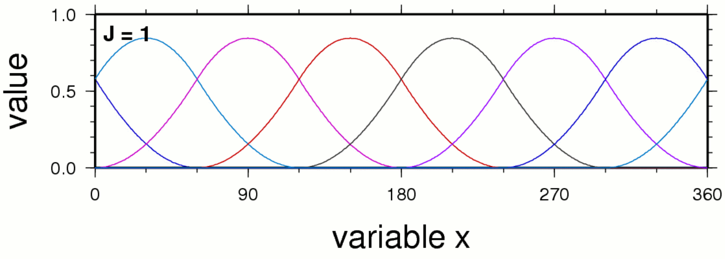


Fig. 2.1.3: 1-D trigonometric B-splines. For the resolution level J=1 we have altogether 8 B-splines

Trigonometric B-splines are compactly supported, i.e., characterized by a finite non-zero influence zone. In contrast to the so-called endpoint-interpolating B-splines defined on the unit interval, trigonometric B-splines are wrapping around; cf. left and right border of Figure 2.1.3. For testing our procedure for a global application, we used a combined approach according to the parameterization mentioned in Figure 2.1.1: trigonometric B-splines $T(\bullet)$ as base functions in longitude direction, as well as endpoint-interpolating B-splines $B(\bullet)$ as base functions in latitude direction and for the time. We establish the series expansion

$$\Delta VTEC(\mathbf{r},t)+e(\mathbf{r},t)=\sum_{k_1=0}^{K_1-1}\sum_{k_2=0}^{K_2-1}\sum_{k_3=0}^{K_3-1} d_{k_1,k_2,k_3}^{J_1,J_2,J_3}\,T_{k_1}^{J_1}(\lambda)B_{k_2}^{J_2}(\varphi)B_{k_3}^{J_3}(t)$$

for the difference observations

$$\Delta VTEC(\mathbf{r},t)=VTEC(\mathbf{r},t)-VTEC_{ref}(\mathbf{r},t)\ .$$

COSMIC VTEC measurements

As $VTEC_{ref}$ $(\mathbf{r},t)$ we introduce IRI-2007. As shown in Figure 2.1.2, the COSMIC satellites are orbiting in the ionosphere. Consequently, the COSMIC VTEC observation $VTEC$ $(\mathbf{r},t)$ consists of two parts as shown in Figure 2.1.4. The lower part $VTEC_0$ is directly derivable from the COSMIC occultation measurements by an improved Abel transform; the second part $VTEC_1$ has either to be calculated from the COSMIC satellite-to-satellite tracking measurements to GPS satellites or to be approximated by a given ionosphere model; for more details see Schmidt et al. (2008b).

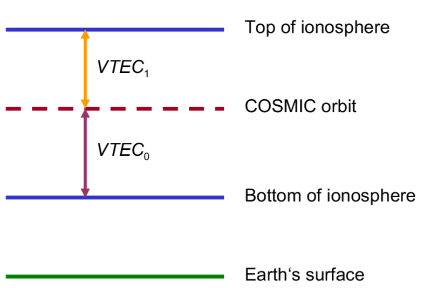


Fig. 2.1.4: Decomposition of the COSMIC VTEC observation into the parts $VTEC_0$ below the orbit and $VTEC_1$ above the orbit.

Figure 2.1.5 shows the COSMIC VTEC observations $VTEC$ $(\mathbf{r},t)$ – kindly provided by L.-C. Tsai from the National University of Taiwan – in blue and the reference values $VTEC_{ref}$ $(\mathbf{r},t)$. The differences are modelled by the series expansion introduced before. Since we deal with a global problem, additional constraints have to be considered in the parameter estimation process related to the polar regions and the 0° and 360° meridians. Figure 2.1.6 depicts the estimation of $\Delta VTEC$ $(\mathbf{r},t)$ for 8:00 a.m. as a snapshot. Since we model the time dependency by B-splines, an estimation of the correction can be calculated at each time within July 21, 2006. The 12 panels of Figure 2.1.7 show the estimated VTEC with a two-hour time spacing. To be more specific, we compute $\Delta VTEC$ $(\mathbf{r},t_i)$ for times $t_i = 0,2,4,\ldots,22$ h and add IRI-2007 calculated for the same times.

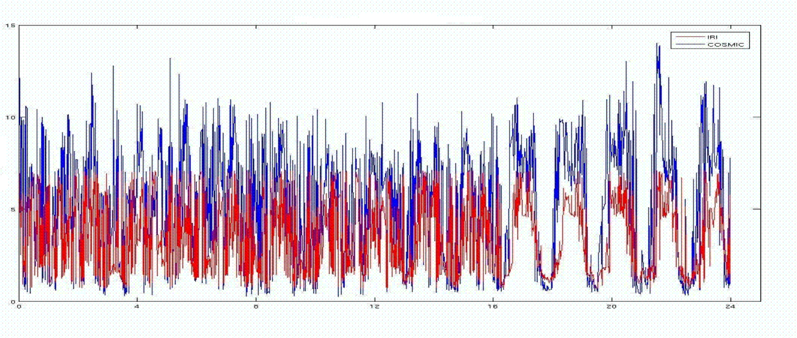


Fig. 2.1.5: COSMIC VTEC observations (blue) and the corresponding IRI-2007 model values (red) at July 21, 2006.

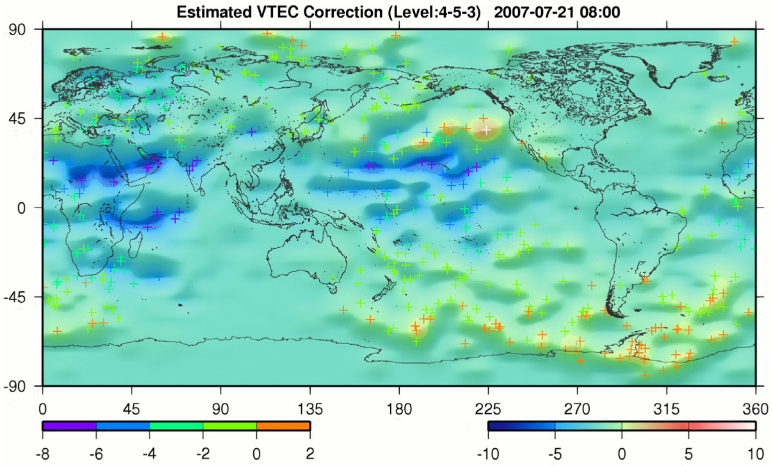


Fig. 2.1.6: Estimated VTEC corrections from COSMIC occultation measurements with respect to IRI-2007 at July 21, 2006 at 8:00 a.m. The colour bar at the left-hand side represents the classification of the input data; the colour bar at the right-hand side is related to the estimation; all data in TECU.

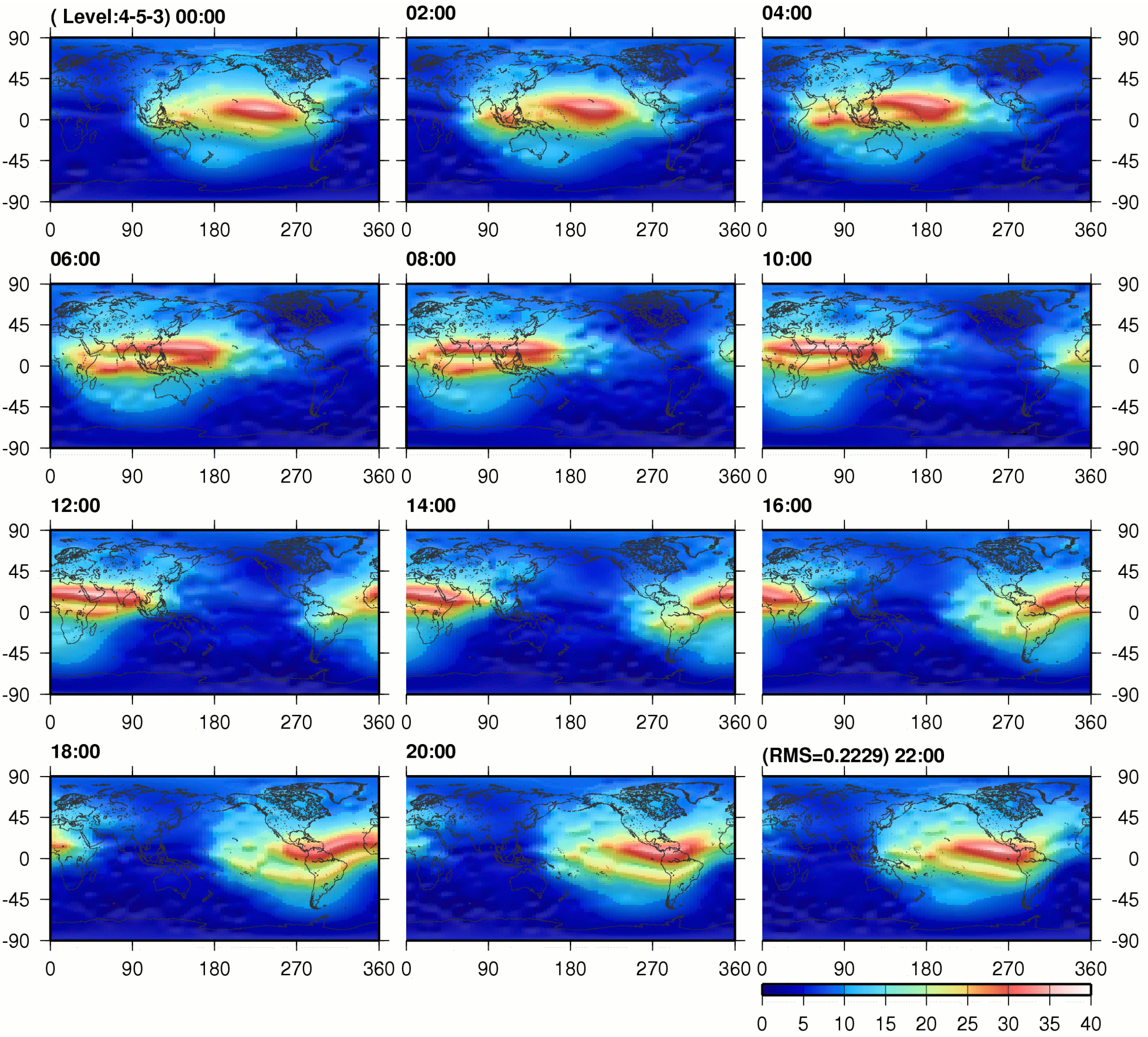


Fig. 2.1.7: Estimated VTEC from COSMIC occultation measurements at July 21, 2006 with a two-hour spacing; all data in TECU.

Time-wise analysis of GOCE gravity data

As part of the GOCE gravity field analysis and in preparation of the combination of GOCE with other data, we started to implement the so-called time-wise analysis in the frequency domain, also called lumped coefficient approach. The idea is to perform a Fourier analysis of the time series of gravity gradients. These Fourier coefficients are linear combinations of the spherical harmonic coefficients, hence the name “lumped coefficients”. The method has the advantage that it is relatively easy to model the frequency-dependent behaviour of the GOCE gravity gradient errors. The conditions which the GOCE orbit must fulfill are that the orbit is circular, that there is an exact repeat orbit, and that the data sampling is continuous. Under these conditions, the normal equation system, which relates the GOCE gravity gradient observations to spherical harmonic coefficients, becomes block-diagonal. Although the true GOCE orbit and data sampling will not meet these conditions, it is expected that the true orbit is close enough to such an ideal reference orbit to allow a time-wise analysis in the frequency domain.

In gravity field modelling we re-calculated the multi-resolution representation (MRR) approach for the Amazon region by considering real in-situ data from river gauge stations. The results are presented in Schmidt et al. (2008c).

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Schmidt M., Karslioglu M.O., Zeilhofer C.: Regional multi-dimensional modeling of the ionosphere from satellite data., Proceedings of Turkish National Geodetic Commision, 88−92, Ankara, 2008b

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2.2 Kinematics of the mean sea level

The investigations for the kinematic description of the mean sea level were continued. In order to obtain a more consistent and reliable data set, the altimeter data base of DGFI was extended, upgraded and enhanced. New missions and models were integrated to allow a more reliable estimation of the evolution of the mean sea level.

Enhancement of the DGFI altimeter data base

The main changes are listed below:

- The data base was enlarged by data of the laser altimeter mission ICESat, launched in January 2003 and flying on an orbit with 600 km altitude, 94° inclination and 91-day repeat.
- The new tide model EOT8a from DGFI (see topic 2.3) was included in the data base. It could be used as an alternative to the FES2004 model.
- The two-frequency ionosphere corrections (for TOPEX, JASON1 and ENVISAT) were smoothed (20 sec median filter) in order to reduce the noise.
- For mission GFO-1 and part of ERS-2 the Bent ionosphere corrections (provided with the original mission data) were replaced by values of GPS Global Ionosphere Models (GIMs) from JPL.
- The replacement of JASON-1 GDR-B data with GDR-C data started (new orbits and new Sea State Bias (SSB), no retracking). First investigations show significant differences in the order of 4 cm between these two versions. Thus, both data sets were stored in parallel until the new version is proved and the reprocessing of JASON-1 data is finished.

Multi-mission cross calibration

In order to fully utilize the combined space-time sampling of altimeter systems with different orbit characteristics, a multi-mission crossover analysis was performed by means of the “discrete crossover analysis” (DCA). This method was already described in the previous annual reports. Now some smaller modifications/improvements were implemented:

- Quality-flags in the original data were considered when forming the crossovers. Thus, no data known for invalidity will be used for the analysis.
- The outlier elimination was no longer performed before the analysis, but all crossovers were integrated in the computation. As a consequence, periods with unknown measurement or model errors became visible in the radial errors and could be easily eliminated or flagged from the original data set.
- The weighting functions within the analysis were improved. A down-weighting of some missions (e.g. GFO-1) was introduced. Further investigations are needed to improve and to validate this approach.

With this modified program and the enlarged data base, new radial errors for all missions were computed. The range bias (global mean from all cycles) show a good agreement with calibrations from other groups (see Figure 2.2.1). The geographically correlated error patterns computed for each mission after the DCA can at the moment neither confirm nor disprove the differences between some of the external results obtained at different sites.

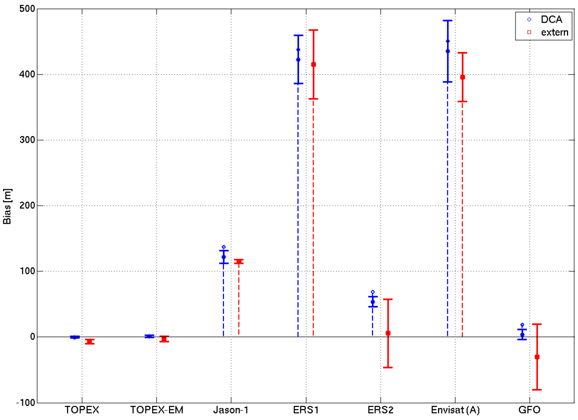


Fig. 2.2.1: Validation of global mean relative range bias from DCA. The relative biases related to TOPEX are plotted in blue. They have to be reduced by 15 mm, an early estimate of the absolute bias already included in the TOPEX GDR data. Independent absolute biases from different calibration sites are given in red.

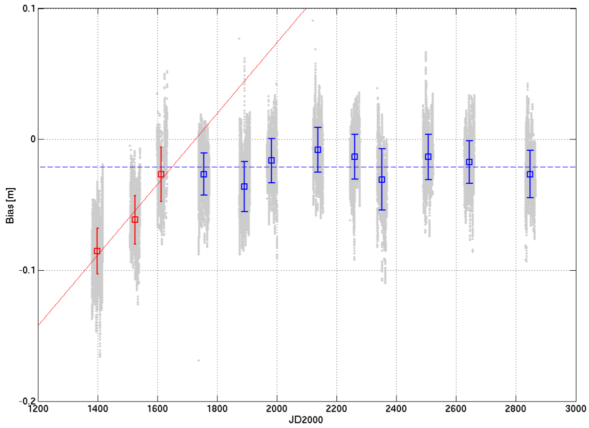


Fig. 2.2.2: Radial error estimates [m] for IceSat relative to TOPEX. The values for each observation period are shown in grey, means of Laser 2 periods in red and means of periods from Laser 3 in blue.

Radial errors of ICESat altimeter

The ICESat Geoscience Laser Altimeter System (GLAS) data set was taken from NOAA National Snow and Ice Data Centre NSIDC (GLA06 and GLA15 data product release 028) and integrated in the DGFI altimeter data base. All standard corrections, including the saturation correction, were applied with the following modifications/additions:

- The ocean tide and load tide corrections were taken from the EOT08a model.
- The dynamic atmospheric correction was applied (DAC).
- Sea level anomalies refer to the CLS01 mean sea level.
- In contrast to the radar altimeter missions, no ionospheric correction is necessary because the laser frequency is not sensitive to free electrons in the atmosphere.

Due to lifetime issues with all three laser systems operating sequentially on ICESat, GLAS works in a modified science mission only, collecting data in two or three periods per year, each spanning approximately 30 days. The first three periods were measured with Laser 2 (2A, 2B, 2C), whereas the last nine periods are based on Laser 3 (3A-I) data. As can be seen from Figure 2.2.2, the estimated radial errors differ significantly between the laser periods. This result does not justify one single bias for the whole mission. All observation periods were processed independently. Laser 2 shows a mean bias of −58 cm (epoch 2004.1) and a significant trend of nearly 10 cm per year. Laser 3 has a mean bias of −2 cm and no significant trend. The variations between the different periods might be caused by changes in the energy of the GLAS Laser.

The absolute dynamic ocean topography

The essential improvements in the knowledge of the Earth gravity field models through CHAMP and GRACE justify to estimate the Dynamic Ocean Topography (DOT) by subtracting the geoid heights N from the sea surface heights h

$$\zeta = h - N \ . \qquad (1)$$

The simple equation reveals two general problems

- *N* and *h* are distributed differently: Geoid heights are derived from a spherical harmonic series of the Earth gravity potential, a continuous and analytic function, which can be evaluated everywhere. On the contrary, sea surface heights are observed by satellite altimetry and are available only along the sub-satellite tracks. Large rhombus-shaped areas between these tracks remain unobserved.
- *N* and *h* have a different spectral content: While the band-limited harmonic series of the Earth gravity field generate rather smooth geoid heights (wavelength of 100 km or more), the along-track sampling of altimetry is very dense (every 6.5 km) so that the sea surface heights reproduce short scale variations of the sea level.

Usually the first problem is solved by a gridding of *h*. This gridding, however, implies an undesirable smoothing in space and time, the latter because neighbouring sub-satellite tracks are not observed simultaneously. Therefore equation (1) was evaluated on the profiles observed by satellite altimetry. In order to solve the second problem, both *h* and *N* have to be consistently filtered. For this purpose a novel approach for the consistent filtering of *h* and *N* on the altimeter profiles was developed. It will further on be called the “profile approach”.

Filter correction

State-of-the-art gravity field models, derived exclusively from GRACE data, have to be filtered anyway because they exhibit a meridional striping, indicating problems in processing or geophysical signals. The GRACE-only model ITG03S was used and the spherical harmonics were filtered by a Gauss-type filter as defined by Jekeli/Wahr. An experimental filter length of 200 km led to a sufficient smoothing of the geoid heights (Figure 2.2.3).

Applying the same Gauss filter to the profile data leads to systematic differences. The isotropic Gauss filter affects the geoid heights in two dimensions. On the altimeter profiles the filter has an effect only in one dimension (see Figure 2.2.4). A filter correction is used to compensate these systematic differences. It is derived by an ultra-highly resolved geoid, realized by the new EGM2008 gravity field developed up to degree/order 2160. This geoid is filtered twice, two-dimensionally and – after sampling the geoid at the altimeter profiles – in one dimension. The dif-

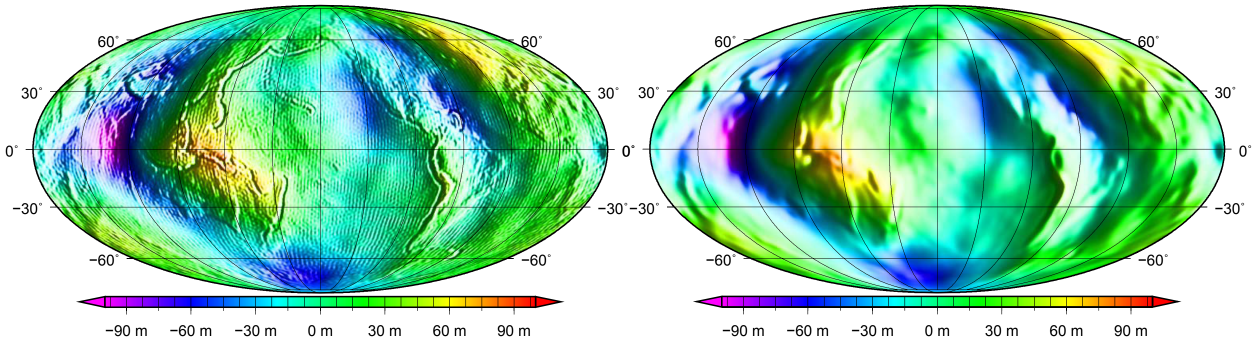


Fig. 2.2.3 The geoid of the ITG03S gravity field model exhibit meridional striping pattern (left) which disappear after a smoothing of the spherical harmonic coefficients by a Gauss-type filter with a filter length of 200 km (right).

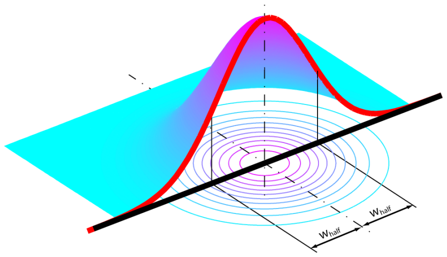


Fig. 2.2.4 Two-dimensional isotropic Gauss filter (blue surface) and the corresponding one-dimensional filter curve (red).

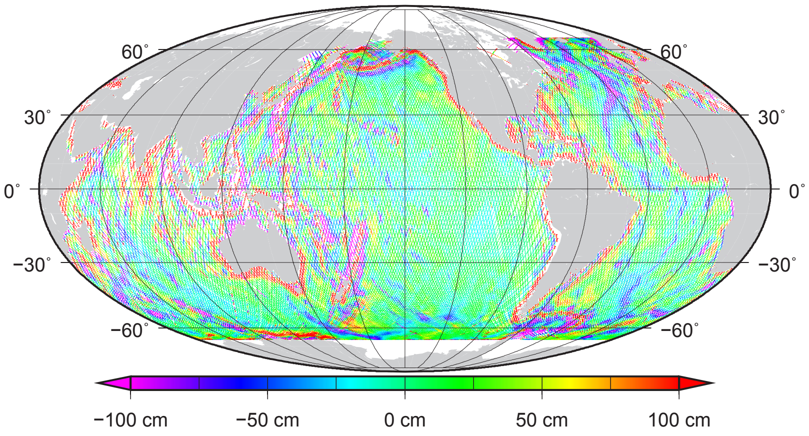


Fig. 2.2.5 Filter correction accounting for the systematic differences between two- and one-dimensional filtering of the sea surface heights.

ference defines the desired filter correction (see Figure 2.2.5), which is subsequently applied to the one-dimensionally filtered h and the two-dimensionally filtered N in equation (1).

Snapshots of time varying dynamic ocean topography

If the profile approach is applied to the sub-satellite tracks of a common 10-day period of TOPEX and JASON-1, already a rather realistic estimate of the DOT is obtained (see Figure 2.2.6). The sub-tropical gyres, the Antarctic Circum Polar Current, and the sub polar gyre in the North Atlantic are correctly identified with many details. Thus, the profile approach allows to estimate a realistic snapshot of the time-varying DOT. Comparisons of a mean DOT for the year 2004 with external estimates of Niiler et al. (2004) and Rio et al. (2005) show in general a good agreement, exhibit however large offsets (most likely due to the oceanographic “level-of-no-motion” assumption). For details see the DGFI Report No. 82 (Albertella et al. 2008). The profile approach was developed in the context of the GEOTOP project, funded by DFG within the priority program SPP1257, “mass transport and mass distribution in the Earth system”.

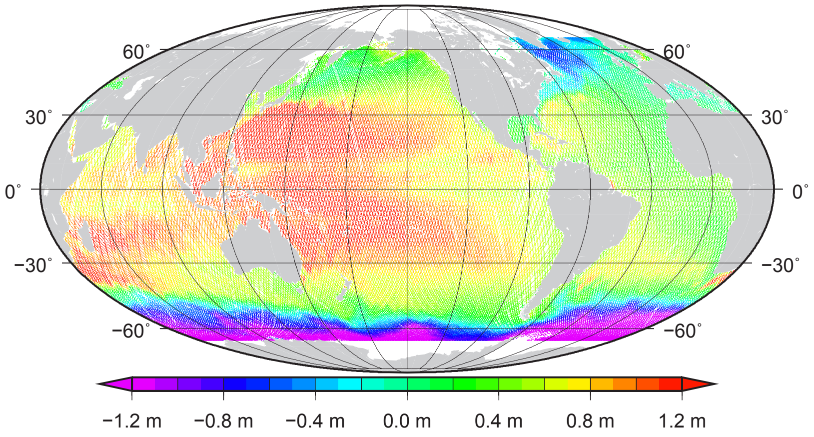


Fig. 2.2.6 Ten-day snapshot of the dynamic ocean topography, estimated with the profile approach. All basin scale gyres are reproduced quite well, and there are no artifacts at the ocean-land transition.

Identification and tracking of eddies

Eddies are circular patterns, 50 – 300 km in size with a few decimetre anomalous water level. They dominate the flow field in the western boundary currents. It is particularly difficult to constitute a mean sea surface and to describe the kinematics of the sea level in eddy-active areas. In order to quantify the eddy activity, software was developed to identify and track individual eddies.

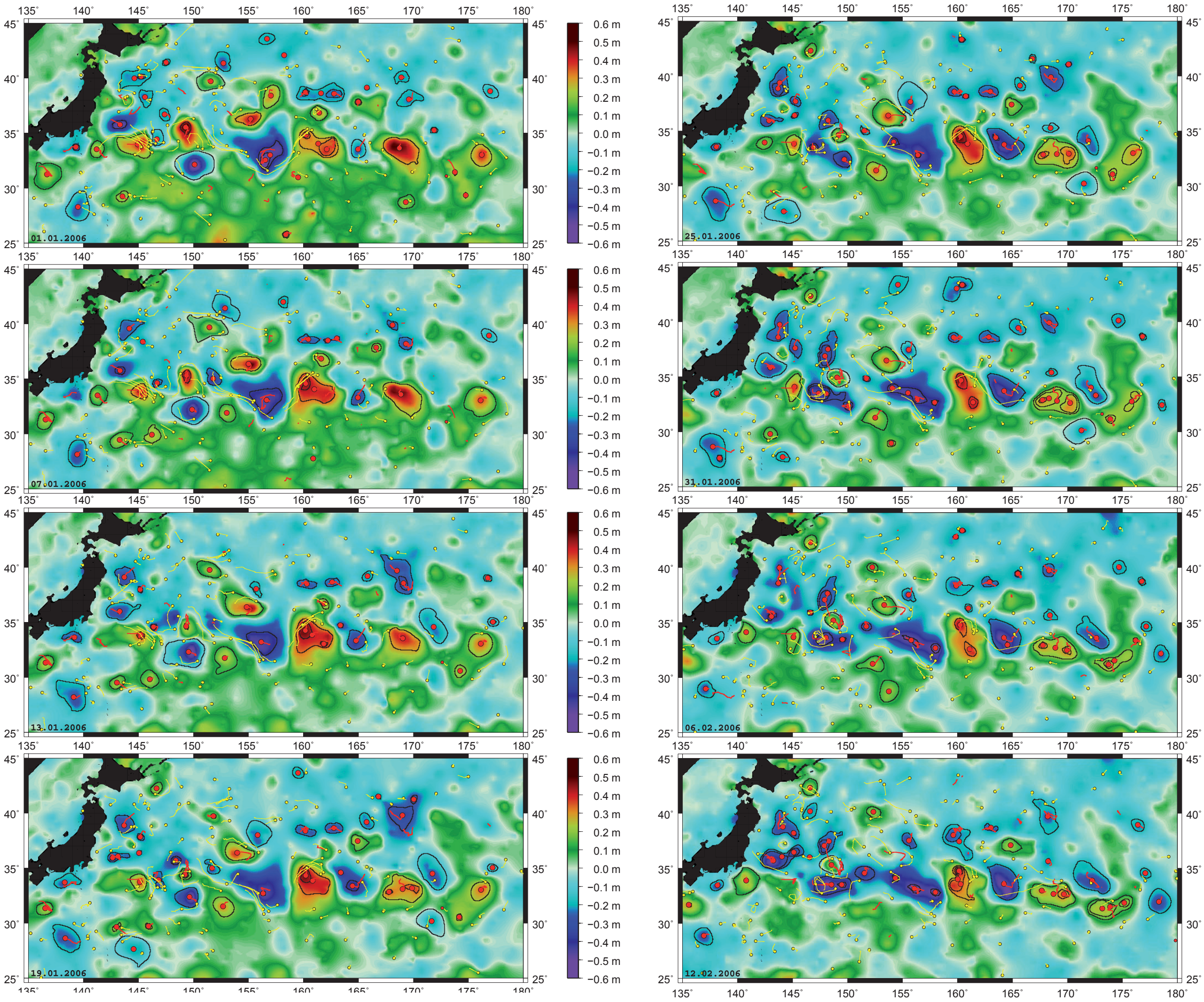


Fig. 2.2.7 Sequence of eddies with minimum size and sea level anomalies in the Kuroshio area for a period of 48 days (Dt = 6 days). The eddy shape is indicated by a black isoline, the centre by a red dot and the trace of the last 30 days by a red line. The actual position of ARGO floats is indicated by a yellow dot, the 30-day trace by a yellow line.

An interpolation is necessary to identify anomalous water levels. Due to orbit dynamics, the altimetry sampling can realize either a good spatial or a good temporal resolution. With their 10-day repeat cycle, TOPEX and Jason1 provide a good temporal resolution. This suggests interpolating first in time (on the repeated tracks) and to perform a gridding afterwards.

Then three different algorithms were applied and compared to identify Eddies of minimum size and sea level anomaly. The best result, shown in Figure 2.2.7, is validated by position and trace of ARGO floats, providing an independent observation of the actual velocity field. The successful tracking of eddies was demonstrated, but could be further improved by combining altimeter missions with complementary sampling. This emphasizes the basic importance of the multi-mission cross-calibration.

Albertella A., Savcenko R., Bosch W., and Rummel R.: Dynamic Ocean Topography – The Geodetic Approach. DGFI Report No. 82, DGFI, München, 2008

Schwatke Ch.: Erkennung und Verfolgung von Eddies durch Kombination von Altimeterdaten und Meeresspiegeltemperaturen. Masterarbeit, DGFI, München, 2008

2.3 Dynamic processes in the system Earth

Mass variations and mass displacements within the atmosphere, the oceans and the continental hydrosphere cause time-dependent variations in the Earth's gravity field. The K-band range (KBR) measurements of the satellite gravity field mission GRACE (Gravity Recovery and Climate Experiment) sense the cumulative effect of gravity variations of the three subsystems.

Separation of oceanic and hydrological mass variations by simulated gravity observations

A common practice of GRACE processing centres is to remove short-term mass variations of the atmosphere and the ocean in order to identify the mass variations of the continental hydrosphere (the most dubious component). This treatment implies the risk to transfer modelling errors of the ocean and the atmosphere to the hydrosphere. The challange to obtain an unbiased estimate of individual mass signals leads to the fundamental question: Is it possible to use the unreduced, integral GRACE observations to separate and quantify the individual mass variations of the subsystems ocean, atmosphere and continental hydrosphere? The answer to this question was found by a simulation, illustrated in Figure 2.3.1.

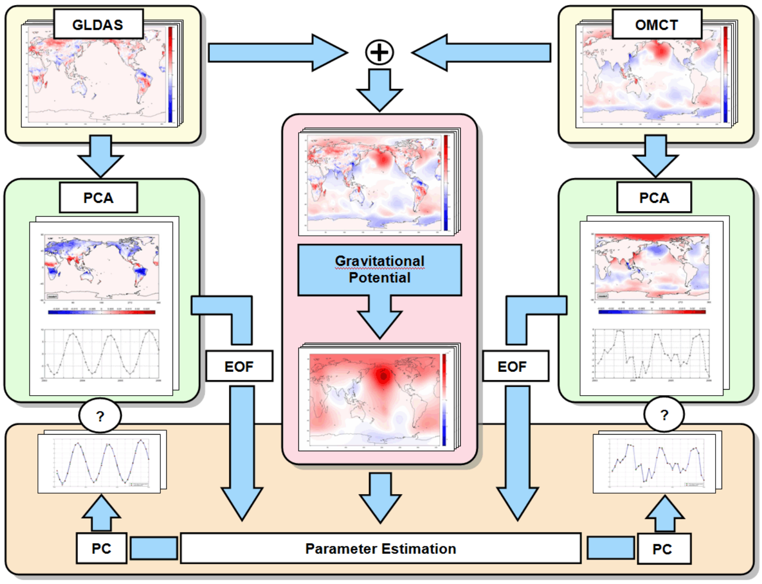


Fig. 2.3.1: Flowchart for the separation of individual effects from simulated integral gravity potential data. The separation is performed by mass signals of geophysical models for the subsystems ocean and continental hydrology.

The general concept of the simulation is as follows: A GRACE gravity signal is simulated by composing the gravitational effects of mass variations for the oceans and the continental hydrosphere. These mass variations were derived from OMCT (Ocean Model for Circulation and Tides) and GLDAS (Global Land Data Assimilation System) respectively, both averaged to a monthly resolution for a time period of 36 months (see upper row of Figure 2.3.1).

Principal Component Analyses of geophysical models

Both time series were then subject to individual Principal Component Analyses (PCA) in order to describe the dominant geographical pattern and temporal evolution of mass variations, separately for ocean (left column of Figure 2.3.1) and land (right column ibid.). Both PCAs decompose the mass variations by a set of Empirical Orthogonal Functions (EOF), defining a spatial function over the area under investigation and a time series of associated Principal Components (PCs). Summing up all products of PCs and associated EOFs (these products are called modes), the mass variation of the analysed time series can be exactly reconstructed.

Leading EOFs as base functions

Using only a subset of modes, the mass variations can be approximated and the degree of approximation can be controlled by an increasing number of modes. In order to capture 90% of the total variance of mass variations, only the 14 (7) leading modes (out of 36) were necessary to describe the mass variation over oceans (continental hydrology). For the simulation, this limited set of EOFs is subsequently used as base functions for the series expansion of the gravitational variations "observed" by GRACE. For every month, the series coefficients of the combined EOFs were estimated by least-squares adjustment. The result shows excellent agreement with the original PCs derived from the geophysical models OMCT and GLDAS. The reconstruction was possible even after a realistic noise had been added to the simulated GRACE observations (Schmeer et al., 2008).

The simulation proves that oceanic and hydrological mass variations can be spatially separated by combined EOFs derived from the geophysical models. With the prior information contained in the EOFs, it is possible to decompose the integral signal observed by GRACE.

Three approaches for the determination of polar motion excitations

Polar motion is excited by mass displacements and motions in the system Earth. Due to the fact that the redistribution of masses also causes changes in the Earth geometry and gravity field, the redistribution itself can be traced in observing these quantities. Figure 2.3.2 shows three different computation strategies for the mass-related part of the polar motion excitation mechanisms which are mathematically described by the equatorial angular momentum functions; for more details see Göttl, 2008.

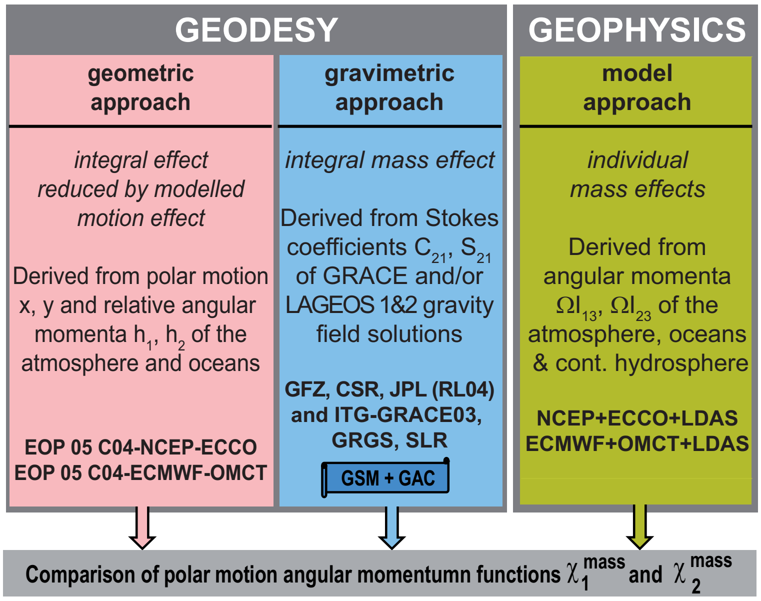


Fig. 2.3.2: Three different computation strategies for the integral mass effect. The IERS provides in its EOP 05 C04 series estimations of polar motion; monthly sets of gravity field coefficients are provided by the GRACE science processing centres CSR, JPL and GFZ (RL04) as well as by the University of Bonn (ITG-GRACE03) and the GRGS (GRACE and/or LAGEOS 1&2 solutions); angular momentum time series are modelled for the atmosphere (NCEP, ECMWF), the oceans (ECCO, OMCT) and the continental hydrosphere (GLDAS^{CPC}).

Tab. 2.3.1: RMS differences and correlation coefficients with respect to the mean reduced geometric results for the integral mass angular momentum functions.

		GFZ RL04	CSR RL04	JPL RL04	ITG GRACE03	GRGS (GRACE)	GRGS (SLR)	ECMWF, OMCT, GL-DAS^{CPC}	NCEP, ECCO, GLDAS^{CPC}
χ_1	**RMS[mas] differences**	*6*	*7*	*8*	*8*	*9*	*8*	*6*	*6*
	Correlation coefficients	*0.71*	*0.71*	*0.61*	*0.62*	*0.65*	*0.62*	*0.77*	*0.80*
χ_2	**RMS[mas] differences**	*12*	*12*	*10*	*10*	*10*	*9*	*8*	*7*
	Correlation coefficients	*0.94*	*0.89*	*0.96*	*0.93*	*0.91*	*0.94*	*0.95*	*0.95*

The results of these three approaches were compared. All time series agree quite well with respect to signal characteristics and amplitudes (Figure 2.3.3, upper panels). RMS differences and correlations of the gravimetric and modelled mass excitation series were derived with respect to the mean of the geometrical solutions reduced by modelled motion effects (see Table 2.3.1). The statistical analysis reveals that the time series from geophysical models show a higher agreement with the reduced geometric results than the single gravimetric solutions.

In order to improve the gravimetric results, a least-squares adjustment of the individual gravity field solutions GFZ RL04, CSR RL04, JPL RL04, ITG-GRACE03, GRGS, GRACE and SLR was performed. The time series were weighted according to the corresponding RMS differences with respect to the mean of the reduced geometrical solutions for the integral mass effect. As can be seen in Figure 2.3.3 (lower panels), the adjusted time series show a higher agreement with the reduced geometric solutions than any of the individual gravimetric or modelled excitation series. Not only the RMS difference of 5 mas for χ_1 and 6 mas for χ_2 decreases, but also the correlation coefficients of 0.86 for χ_1 and 0.97 for χ_2 gets higher (for comparison see Table 2.3.1). Reasons therefore could be that systematic errors in the GRACE data processing, such as errors of the atmospheric and oceanic background models, shortfalls in the parameterization of the observation equations, and omission errors, are reduced due to the weighted adjustment of numerous gravimetric solutions.

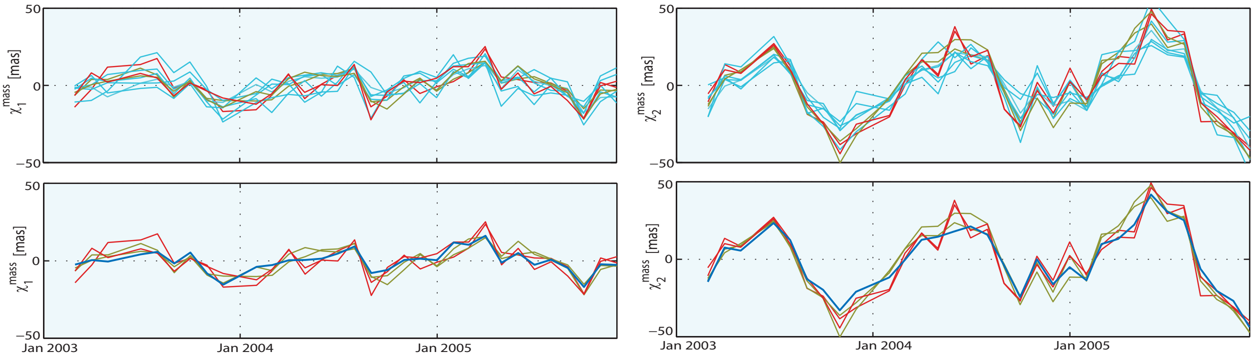


Fig. 2.3.3: Monthly time series of polar motion angular momentum functions for the integral mass effect: geophysical model results from ECMWF plus OMCT plus GLDAS^{CPC} and NCEP plus ECCO plus GLDAS^{CPC} (both in green), gravimetric results from GFZ RL04, CSR RL04, JPL RL04, ITG-GRACE03, GRGS,GRACE and SLR (all in light blue), combined gravimetric results (dark blue) and geometric results from the IERS EOP 05 C04 series reduced by modelled motion effects from ECMWF plus OMCT and NCEP plus ECCO (both in red).

EOT08a, a new global ocean tide model

The knowledge of ocean tides is fundamentally important as the gravitational attraction of Sun and Moon causes more than 80% of the total variability of the sea surface. Prediction of ocean tides is crucial for the coastal environment. But knowledge of ocean tides is also needed for the precise treatment of space observations. In deep ocean, tides are known to within 2 cm rms at wavelengths of 50 km. However, in coastal regions, over continental shelves and in polar oceans, tides are significantly worse known. EOT08a is a new global solution for the most dominant ocean tide constituents based on an empirical analysis of multi-mission satellite altimetry data. EOT08a benefits from FES2004, a hydrodynamic model widely used for altimetry and taken as reference model in GRACE gravity field modelling. EOT08a is a result of DAROTA, a project of the priority program “Mass transport and mass distribution in the Earth system”, funded by the Deutsche Forschungsgemeinschaft (DFG).

Residual tide analysis

The residual harmonic analysis with respect to FES2004 was applied 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, the 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. The detailed overview about the cross-calibration can be found in section 2.2. To mitigate the correlation problem, 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 inverse proportional to the grid node distance. The selection of the cap radius and the decay of the Gauss function, controlled by the half-weight width, are critical: high weights and a large cap size imply a strong smoothing. Low weights and a small cap size can prevent the desired de-correlation of some constituents. The limiting cap size was always set to three times the half-weight width. Based on systematic experiments, three different sets of weighting parameters were applied. For the open ocean (depth > 200 m), the half-weight width was set to a spherical distance of 1.5°. In shallow water, a half-weight width of 0.5° was used. For high latitudes (> 65° and < −65°) without TOPEX or JASON-1 data, the half-weight width was set to 2°.

Besides the main diurnal (K1, O1, P1, and Q1), semi-diurnal (M2, S2, N2, K2, and 2N2), and the non-linear M4 tidal constituents, the mean, trend, annual and semi-annual signals were estimated simultaneously. For all constituents significant residual amplitudes were found. Even for the weak 2N2 tide, residuals of 1 – 2 cm were identified. The shallow water and shelf areas exhibit the most significant residual signals. In the Yellow Sea, for example, the residual amplitudes exceed the 15 cm level (see Figure 2.3.4). Furthermore, large-scale patterns of weak residual

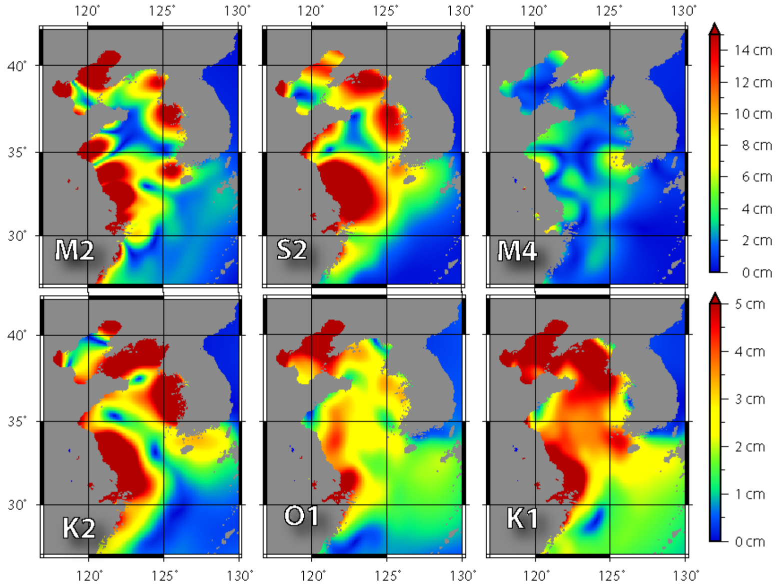


Fig. 2.3.4 Residual amplitudes of tidal constituents in the Yellow Sea – relative to FES2004, which was used as reference model. For M2 and S2, the resdiuals exceed 15 cm. K2, O1, and K1 show residual amplitudes of about 5 cm.

signals can be found in the deep ocean areas. Figure 2.3.5 shows the global distribution of residual amplitudes of M2 and S2.

Multi-mission altimetry is characterized by an irregular distribution of ground tracks and hence observations contributing to each grid node. Consequently there is no simple rule to examine the potential to identify and separate all tidal constituents. Therefore, the correlations between all constituents were thoroughly analysed: the mean correlations for almost all estimated tidal constituents are about zero, and for the most problematical constituents, they don't exceed the level of 0.3. Thus all constituents were successfully de-correlated.

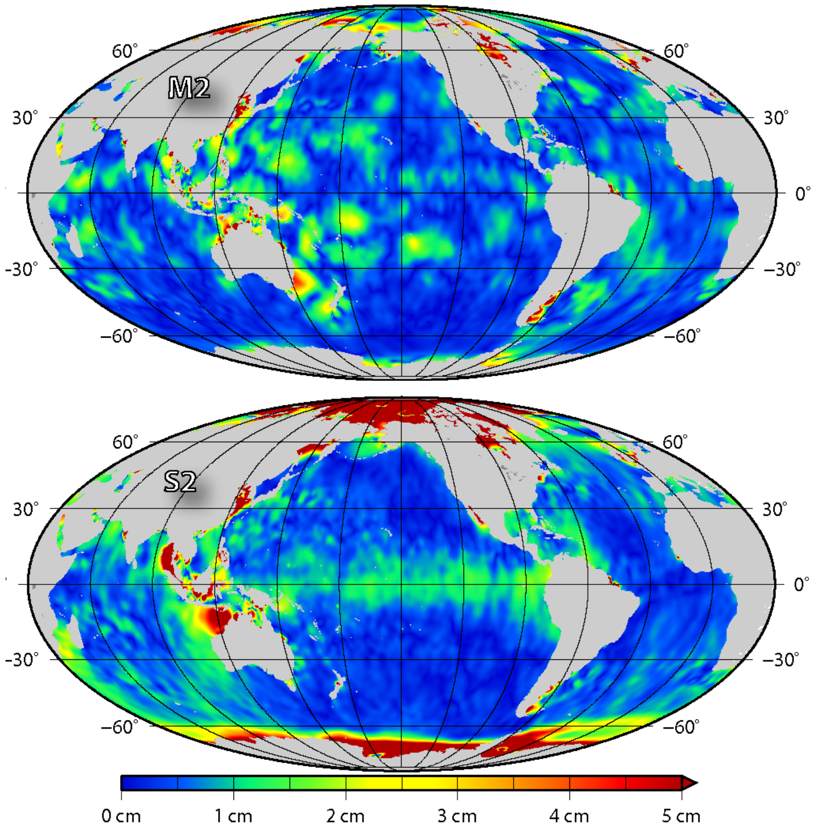


Fig 2.3.5 Global distribution of residual amplitudes for M2 (top panel) and S2 (bottom panel). Even in open ocean there are extended areas with residual amplitudes of 1 – 2 cm for both M2 and S2. For S2, the large belt on the equator may be caused by an improper consideration of the atmospheric tides in the inverse barometer corrections of altimeter data.

Composing and validating EOT08a

The ocean tide analysis reveals significant residuals w.r.t. FES2004, and their validation and correlation analysis in general proves the residuals as clear improvements over the reference model. However, the results are not everywhere equally reliable. In particular in high-latitude areas, where no TOPEX and Jason-1 data are available and where the correlation between critical constituents increases, the reliability of the results is much lower than in the shallow-water areas. Therefore, EOT08a was not composed by simply adding the residuals to the reference model. To consider the different quality of results, three zones were introduced. In the first zone ($|\varphi| < 62°$), residual tides were applied. In the polar seas ($|\varphi| > 66°$), residuals were set to zero: there EOT08a is equal to FES2004. Jumps between these zones were avoided by introducing smooth transition zones.

The validation by variance reductions tests and comparison with the tidal constants obtained from tide gauge and bottom pressure data also prove that EOT08a performs better than FES2004, which was used as the reference model. Significant improvements could be particularly achieved in shallow water areas. More about EOTO8a can be found in Savcenko and Bosch (2008). The EOT08a model is available at

`ftp://ftp.dgfi.badw.de/pub/EOT08a` .

Göttl F.: Earth rotation variations from geometric, gravimetric and altimetric observations and geophysical models, Report No.84, Deutsches Geodätisches Forschungsinstitut, München, Germany, 2008

Savcenko R. and Bosch W.: EOT08a − empirical ocean tide model from multi-mission satellite altimetry, Report No.81, Deutsches Geodätisches Forschungsinstitut, München, Germany, 2008

Schmeer M., Bosch W., Schmidt M.: Separation of oceanic and hydrological mass variations by simulated gravity observations. Report No. 83, Deutsches Geodätisches Forschungsinstitut, München, 2008

2.4 Models of crustal deformation

DGFI has studied crustal deformations in Latin America for many years. The first continuous Velocity Model for South America (VEMOS) based on 329 station velocities derived from space-geodetic observations was developed in 2003 by geophysical finite element and mathematical collocation approaches. The number of geodetic observation stations, in particular by GPS, has increased and improved significantly since then (see also topic 3.2). A new deformation model of the continent was computed on the basis of these new data (VEMOS 2008).

Input data for the VEMOS 2008 South American deformation model

The input data were taken from regional GPS networks. In a first step, the individual data sets were transformed to the ITRF2005 datum by means of the IGS RNAAC-SIR solution DGFI08P01S (see topic 3.2) and compared with each other. The r.m.s. deviations are given in Table 2.4.1. Velocities in identical stations were then combined and outliers were eliminated. The total number of remaining input velocities is also given in the table.

Table 2.4.1: Input data for VEMOS 2008

Project	Total no. of velocities	Rms w.r.t. DGFI08 (φ)	Rms w.r.t. DGFI08 (λ)	No. of used vel.
IGS RNAAC-SIR (Seemüller et al. 2008)	83	-	-	77
SIRGAS 2000-1995 (Drewes et al. 2005)	52	1.1 mm/a	2.1 mm/a	28
CASA East (Kaniuth et al. 2002)	27	2.6 mm/a	3.0 mm/a	19
CASA West (Trenkamp et al. 2002)	43	2.1 mm/a	3.8 mm/a	22
CASA Cali (Trenkamp et al. 2004)	29	2.7 mm/a	2.5 mm/a	18
CAP (Kendrick et al. 2003)	68	0.7 mm/a	2.1 mm/a	58
CAP-SNAPP (Kendrick et al. 2001)	69	0.4 mm/a	1.1 mm/a	54
SAGA (Klotz et al. 2001)	79	2.4 mm/a	2.8 mm/a	69
SAGA (Khazaradze and Klotz 2003)	33	-	-	32
total	483			377

Velocity model computation

A 1° × 1° grid velocity field was computed using the least-squares collocation approach with empirical covariance functions estimated from the full velocity vectors (cov(φ,φ), cov(φ,λ), cov(λ,λ)). The result is shown in Figure 2.4.1 in comparison with the previous model VEMOS 2003. The area could be extended to the extreme south of the continent due to the new data sets. There are some significant deviations, in particular in Peru, where a lot of new data have become available. The r.m.s. deviation computed from the 1640 grid points is ± 1.3 mm/a in northern (φ) and ± 1.8 mm/a in eastern (λ) direction. The comparison with the observed velocities shows very similar results (± 1.2 mm/a and ± 2.0 mm/a, respectively), so that we may state that the velocity model has reached a precision of ± 1 mm/a in northern and ± 2 mm/a in eastern direction.

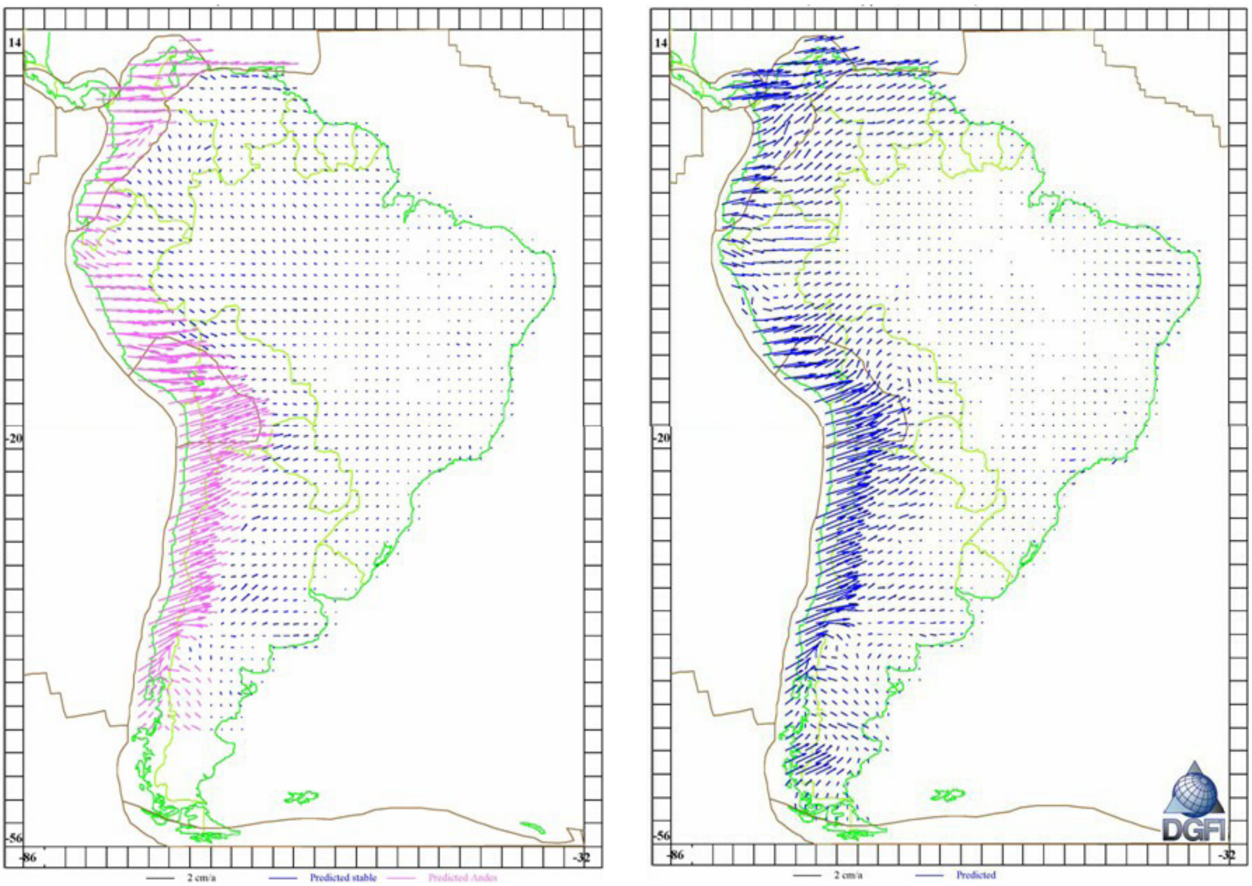


Fig. 2.4.1: Deformation models VEMOS 2003 (left) and VEMOS 2008 (right)

Drewes H.: Update of the velocity field model for South America. SIRGAS Bol. Inf. No. 13, http://www.sirgas.org/fileadmin/docs/Boletines/Bol13/ No. 19, 2008

3 International Scientific Services and Projects

For many years, DGFI has participated in the activities of the 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 three official Combination Centres for the realization of the International Terrestrial Reference System (ITRS) and a Combination Research Centre (CRC). 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). 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 particular in the Working Group on Conventions, Analysis and Modelling. Furthermore, DGFI is active in some 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 Combination Research Centre

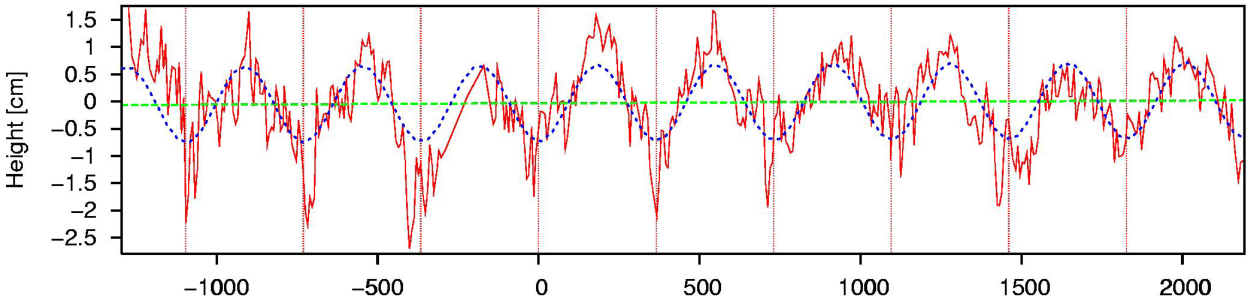
The major focus of the ITRS Combination Centre was on the handling of non-linear station motions, which is an important issue for future ITRF realizations. The activities of the IERS Combination Research Centre concentrated on contributions to the IERS Combination Pilot Project and the closely related German project GGOS-D.

Handling of non-linear station motions

From the time series analysis of the ITRF2005 data it was found, that for most of the stations seasonal signals with amplitudes up to 2 cm are visible, especially in the height component (see Figure 3.1.1 as an example). These seasonal signals may be caused by atmospheric and hydrological loading effects, which are presently not subtracted from the original observations. In other cases, instrumentation effects (rather than geophysical ones) may be responsible for the observed signals.

The current reference frame computations suffer from the shortcoming that the temporal variations of station positions are described only by constant velocities. Deviations of the station motions from a linear model (e.g., seasonal variations) will produce errors in the combination results. In particular for stations with relatively short observation time spans (i.e., < 2 years), seasonal variations will affect the velocity estimations. The alignment of

Fig. 3.1.1: Seasonal variations for the height component for the GPS station in Irkutsk, Siberia. The time is given in Julian Days (w.r.t. 1.1.2000) from 1996.5 until the end of 2005.



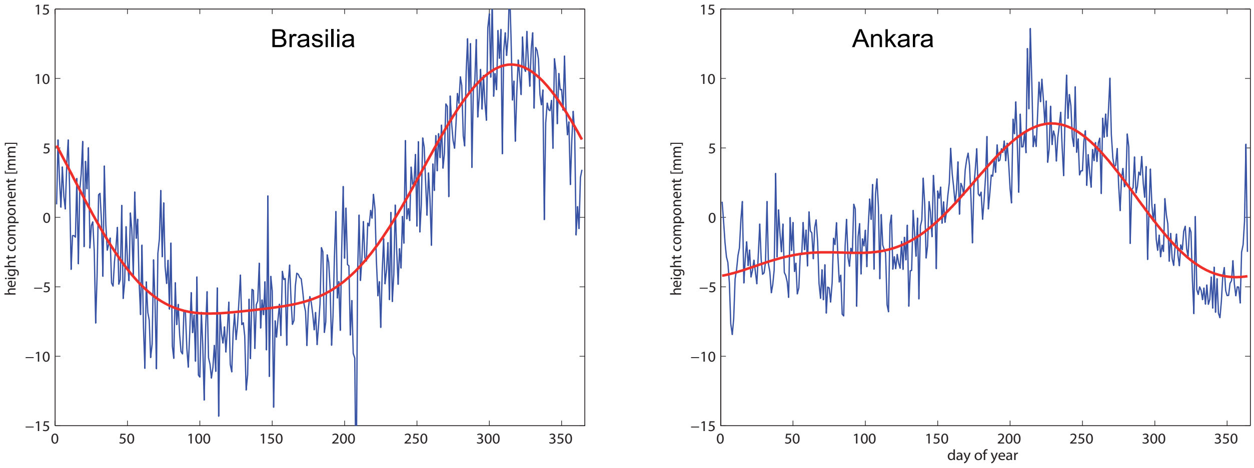


Fig. 3.1.2: Shape of the "averaged" annual signal for two ITRF2005 stations. The fitted curve represents the mathematical approximation by annual and semi-annual sine/cosine functions.

epoch solutions to a reference frame with positions and constant velocities is also affected by non-linear station motions. The shape of these periodical motions differs between stations. Figure 3.1.2 shows two examples for the mean average shape of such annual variations.

While the Brasilia time series clearly shows a maximum and a minimum, Ankara has not a distinct minimum. The averaged annual motions of both stations can rather well be mathematically represented by sine/cosine annual and semi-annual functions. The computation of a mean (averaged) annual motion is problematic, in particular if the seasonal variations are different over the observation time span. It is also clear, that the additional parameters will affect the stability of the solution, which is in particular a problem for stations with rather short observation time spans. Thus, the handling of seasonal variations in station positions is a challenge for future ITRF computations.

DGFI contributions to the IERS Combination Pilot Project

Within the IERS Combination Pilot Project (CPP), DGFI provides individual SLR and VLBI solutions and combined SLR solutions to the ILRS and IVS, respectively. DGFI was accepted by the IERS as a Combination Centre for the inter-technique combination of the weekly/daily SINEX files provided by the Techniques' Services. Studies and inter-technique combinations performed in the year 2007 concentrated on the weighting, the handling of local ties and the datum definition. The DGFI combination software DOGS-CS was updated, and preparations for the generation of weekly combined solutions on a routine basis were performed.

DGFI contributions to GGOS-D

Although GGOS-D is not an IERS project, the work is very closely related to the DGFI research performed as IERS Combination Research Centre. GGOS-D is funded by the German Ministry for Education and Research in the frame of the programme "Geotechnologien". The project involves four institutions: GeoForschungsZentrum Potsdam (GFZ), Bundesamt für Kartographie und Geodäsie (BKG) in Frankfurt/Main, Institut für Geodäsie und

Geoinformation, Universität Bonn (IGG-B), and DGFI. DGFI performed the following major activities within GGOS-D:

- Based on the common standards and models that were implemented in the different software packages (OCCAM for VLBI, DOGS-OC for SLR), the long-time series of VLBI and SLR data were homogeneously reprocessed. Furthermore, the two individual SLR solutions of DGFI and GFZ were combined.
- A major focus was on the computation of a GGOS-D Terrestrial Reference Frame (TRF) from the VLBI, SLR and GPS long-time series (Krügel et al., 2007).
- In cooperation with GFZ Potsdam and TU Munich, the GPS and VLBI data were reprocessed by applying fully homogenized tropospheric mapping functions. Based on these solutions the VLBI and GPS height time series were analysed and compared (see below). Furthermore, investigations regarding the estimation of loading coefficients from the GPS and VLBI height time series were carried out (Tesmer et al., 2008, see topic 1.1).

GGOS-D terrestrial reference frame

The TRF computation consists of the two following major steps: (1) Accumulation of the time series normal equations per technique and analyis of the time series solutions; (2) Inter-technique combination of the accumulated multi-year normal equations per technique. A key issue within the inter-technique combination is the connection of the observations of the different techniques, given by local tie measurements between the instruments' reference points at co-location sites. Figure 3.1.3 shows as an example the discrepancies for some of the VLBI and GPS co-locations. The results are given for the GGOS-D terrestrial reference frame in comparison with the ITRF2005. The agreement of the space-geodetic solutions with the local ties is better for most stations of the GGOS-D computation, which proves the progress compared to the ITRF2005. Major reasons for the improvements are (a) an improved modelling of the individual space techniques and (b) a homogeneous reprocessing by applying unified standards and models for all techniques.

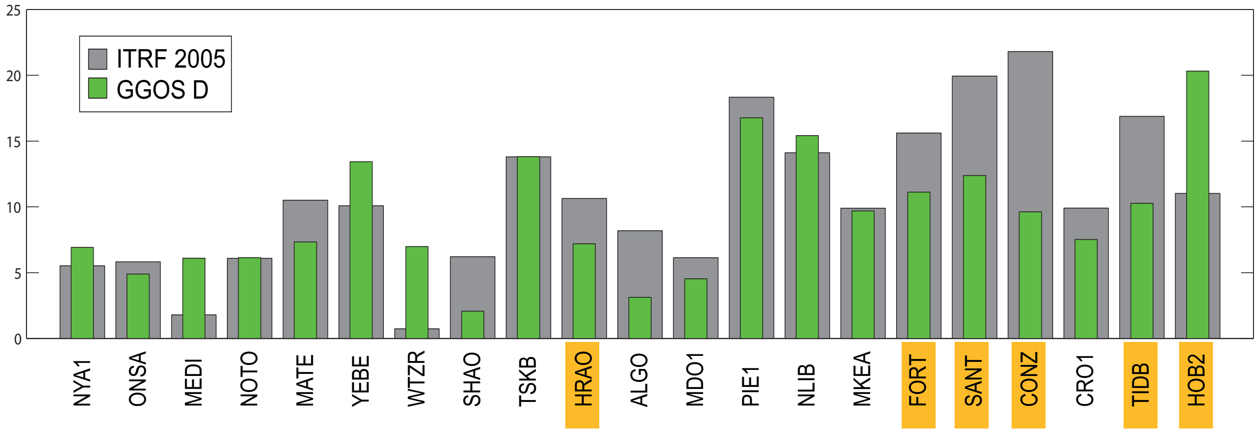


Fig. 3.1.3: Comparison of the GGOS-D results with ITRF2005. The 3-D difference vectors [mm] between the VLBI and GPS solutions and the terrestrial difference vectors are given for 21 co-location sites. The stations located in the southern hemisphere are highlighted.

Homogeneously reprocessed VLBI and GPS height time series

The homogeneously reprocessed VLBI and GPS height series of the GGOS-D project from 1994 to 2007 were compared. The data analysis used state-of-the-art models (like VMF1 and a priori zenith delay from ECMWF) for the GPS (@GFZ and @TUM with Bernese 5.1) and VLBI (VLBI@DGFI with OCCAM 6.1, LSM) processing. The series were compared in terms of long-term non-linear behaviour, harmonic and mean annual signals, derived by averaging the positions of all years into one "mean year" – thus, they display annually recurring patterns not necessarily of harmonic nature. The estimated annual harmonic functions are quite similar for VLBI and GPS, if the data are dense enough (critical for some VLBI antennas). The VLBI- and GPS-derived mean annual signals (annually recurring signals) appear to be even more similar, as a harmonic approximation does not seem to be an adequate model for many of the stations (see Figure 3.1.4). The two almost independent observing techniques yield the same mean annual signals at nearly all co-located sites with acceptably dense data. Therefore they may geophysically be interpreted as vertical deformations.

Besides the 17 co-located VLBI sites, the GPS data set includes 144 suitable GPS sites (161 altogether), where mean annual signals are derived. Out of these 161, 131 are grouped to 55 clusters, if at least two nearby (some thousand kilometres) sites showed similar mean annual signals. This approach confirms that these signals represent regional deformations, and not local or technical artefacts. To illustrate how the clustering algorithm works and how different the signals of single sites are, seven clusters for the European sites are displayed in Figure 3.1.5.

The most important findings from this example are that for most sites, an annual harmonic function is not a good approximation.

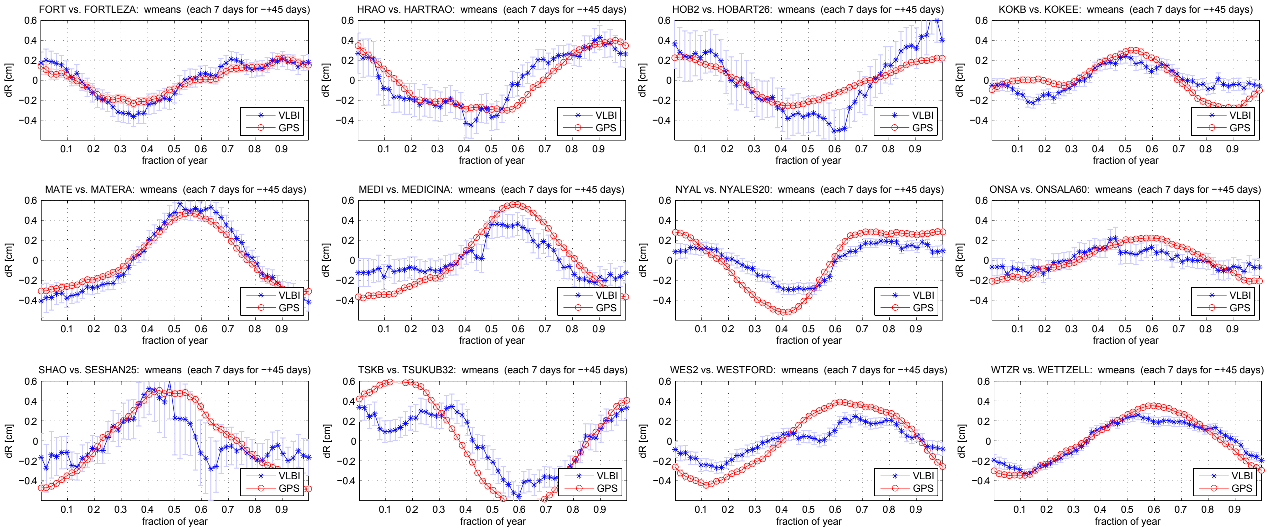


Fig. 3.1.4: Mean annual behaviour of homogeneously reprocessed VLBI (blue) and GPS (red) height time series at co-located sites (from left to right, row by row top down): a) Fortaleza (Brasil), b) Hartebeesthoek (South Africa), c) Hobart (Australia), d) Kokee Park (Hawaii, USA), e) Matera (Italy), f) Medicina (Italy), g) Ny-Ålesund (Spitsbergen, Norway), h) Onsala (Sweden), i) Shanghai (China), j) Tsukuba (Japan), k) Westford (USA) and l) Wettzell (Germany). The figures illustrate 90 days moving weighted means and their formal errors, computed each 7 days from the daily height estimates, with the weighted mean values removed for each year before averaging all the years. The range in the ordinate is from ±0.6 cm in all plots.

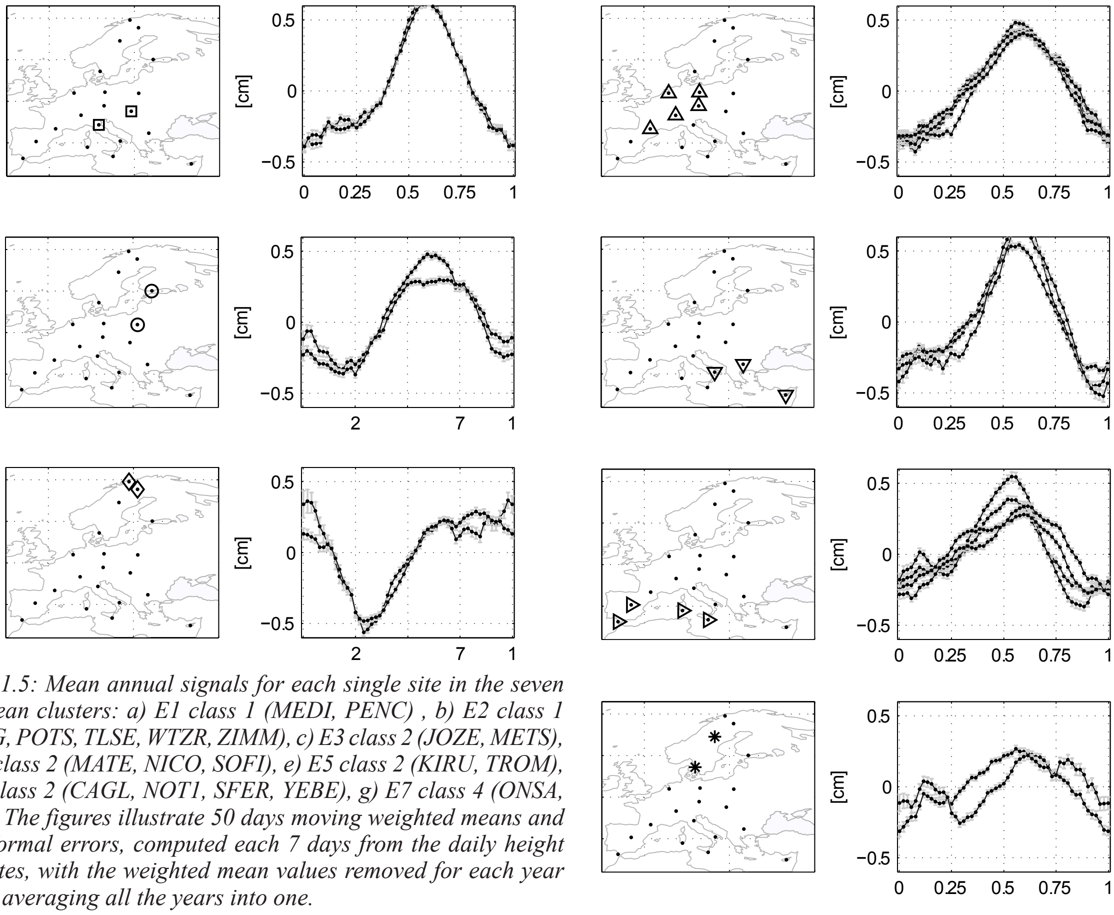


Fig. 3.1.5: Mean annual signals for each single site in the seven European clusters: a) E1 class 1 (MEDI, PENC) , b) E2 class 1 (KOSG, POTS, TLSE, WTZR, ZIMM), c) E3 class 2 (JOZE, METS), d) E4 class 2 (MATE, NICO, SOFI), e) E5 class 2 (KIRU, TROM), f) E6 class 2 (CAGL, NOT1, SFER, YEBE), g) E7 class 4 (ONSA, VIL0). The figures illustrate 50 days moving weighted means and their formal errors, computed each 7 days from the daily height estimates, with the weighted mean values removed for each year before averaging all the years into one.

For some sites, this can even be misleading, so that similarity for harmonics or mean annual signals can differ noticeably. Furthermore, for almost all of the sites, at least one nearby site in a region can be found that has a similar signal, which can nicely be grouped to have one representative, regionally mean annual signal. Finally, it became clear that it is difficult to find an algorithm to group such clusters in an objectively “best” way.

For all 55 clusters, a weighted mean of the mean annual signals of each cluster was computed (regional average mean annual signals). They are presented on a “world map” (not displayed here), which can be used as an easy-to-handle tool to validate geophysical models, e.g. via the deforming effect of mass variations on the Earth’s surface. Nevertheless, these height variations (1) only represent the sum of all deforming effects and (2) cannot necessarily be used to interpolate or extrapolate vertical deformation for arbitrary points near the sites, as local effects can always dominate the vertical motion of some points.

Krügel M., Angermann D., Drewes H., Gerstl M., Meisel B., Tesmer V.: GGOS-D reference frame computations. In: Geotechnologien Science Report, No. 11, 70−74, Koordinierungsbüro Geotechnologien, Potsdam, ISSN 1619-7399, 2007

Tesmer V., Boehm J., Meisel B., Rothacher M., Steigenberger P.: Atmospheric loading coefficients determined from homogeneously reprocessed GPS and VLBI height time series. In: Behrend D., Baver K. (Eds.): IVS 2008 General Meeting Proceedings

3.2 IGS Regional Network Associate Analysis Centre

DGFI is acting as the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR) since June 1996. Each week a coordinate solution including all available observations of the SIRGAS Continuously Operating Network (SIRGAS-CON, Figure 3.2.1) is generated and delivered to the IGS Global Data Centres. Based on these weekly solutions, DGFI also computes every year a combined solution for station positions and velocities.

IGS RNAAC SIR network status and processing

Since the Latin American countries are qualifying their reference frames by installing an increasing number of permanently operating GPS stations, which have to be consistently integrated into the continental network, two hierarchy levels were defined within the SIRGAS-CON network (SIRGAS Workshop in Montevideo, May 2008):

1. One core network (SIRGAS-CON-C) with continental coverage and stable site locations to ensure the long-term stability of the reference frame (Figure 3.2.1)

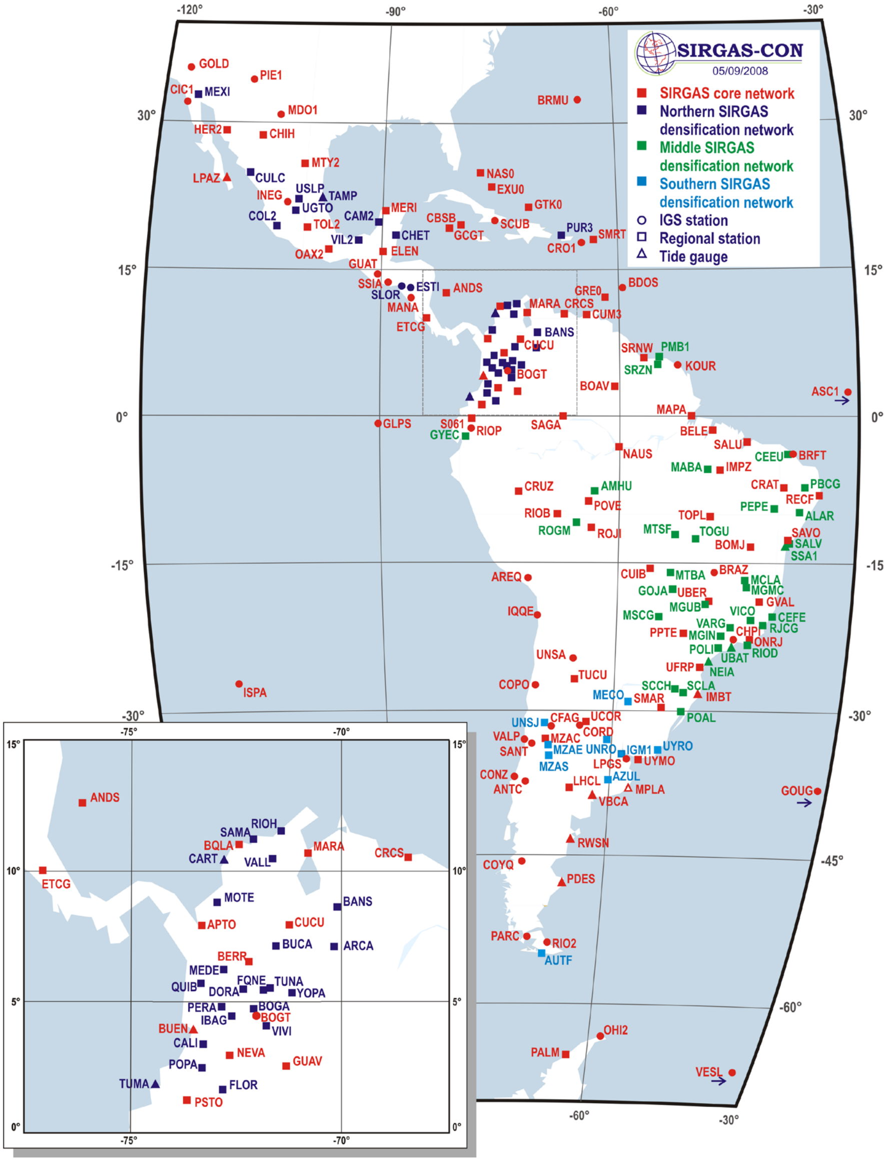


Fig. 3.2.1: SIRGAS-CON-C and SIRGAS-CON-D networks

2. Three densification sub-networks (SIRGAS-CON-D): a northern, a central, and a southern one (Figure 3.2.1), to improve the density of reference stations in the Latin American Countries (see www.sirgas.org).

The main IGS RNAAC SIR products

The SIRGAS-CON-C core network is processed by DGFI as IGS RNAAC SIR, and the three SIRGAS-CON-D sub-networks by the SIRGAS Local Processing Centres: Instituto Geográfico Augustín Codazzi, Colombia (IGAC), Instituto Brasileiro de Geografia e Estátistica, Brazil (IBGE), and Instituto de Geodesia y Geodinámica Universidad Nacional del Cuyo, Argentina (IGG-CIMA). These Analysis Centres deliver loosely constrained weekly solutions for station coordinates, which are integrated in a unified solution by the SIRGAS Combination Centres: DGFI and IBGE (Sánchez et al. 2008). The DGFI (i.e. IGS RNAAC SIR) weekly combinations are delivered to the IGS Data Centres and made available for users as official SIRGAS products. The IBGE weekly combinations are the back-up control solutions.

After combining the SIRGAS-CON-C core network with the three SIRGAS-CON-D densification sub-networks, the following products are available:

1. A loosely constrained weekly coordinate solution for later computations, e.g. the IGS polyhedron (see previous paragraph).
2. A weekly coordinate solution referred to the IGS ITRF2005 (IGS05) by applying no-net-rotation and no-net-translation conditions with respect to 18 IGS05 stations (Figure 3.2.2) for practical applications in Latin America.
3. A yearly accumulative position and velocity solution for estimating the kinematics of the SIRGAS-CON network. The latest is the DGF08P01-SIR solution (Seemüller et al. 2008, Figure 3.2.2).

Reprocessing of the IGS RNAAC SIR solutions

To provide homogeneously precise point positions and velocities for all SIRGAS-CON stations, IGS RNAAC SIR weekly solutions computed previously with relative phase centre corrections (from June 1996 until October 2006) have been reprocessed. At present, the weeks from January 2002 until October 2006 are ready. The homogeneous time series are regularly analysed to have a measure of the precision and to detect episodic effects caused by e.g. earthquakes or instrumental changes.

Sánchez L., Seemüller W., Seitz M.: Comparison and combination of the weekly solutions delivered by the SIRGAS Experimental Processing Centres. DGFI Report No. 80, 77pp., , Deutsches Geodätisches Forschungsinstitut (DGFI), Munich, 2008 (http://www.sirgas.org/fileadmin/ docs/ Boletines/Bol13/ No. 11)

Seemüller W., Krügel M., Sánchez L., Drewes H.: Activities of IGS Regional Network Associate Analysis Centre SIRGAS (IGS RNAAC SIR) and Solution DGF08P01. SIRGAS Bol. Inf. No. 13, http://www.sirgas.org/fileadmin/docs/Boletines/Bol13/ No. 18, 2008

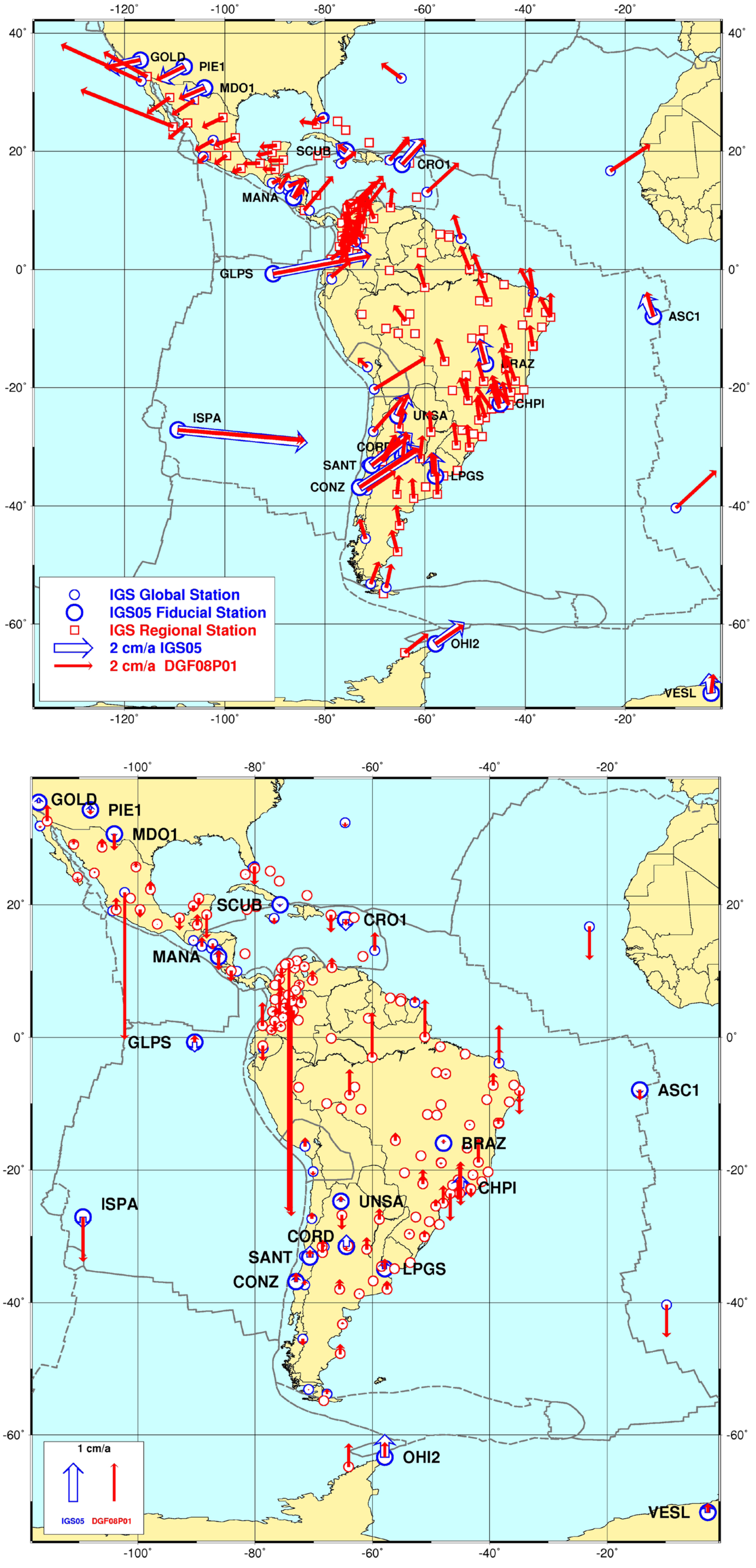


Fig. 3.2.2: Horizontal velocities (top) and vertical velocities (bottom) of the SIRGAS-CON network (solution DGF08P01-SIR)

3.3 Operation and applications of permanent GPS stations

Since 1998, DGFI installed 13 continuously observing GPS stations in the frame of 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 opportune data delivery to the processing centres. The DGFI permanent stations are integrated in various projects such as the IGS Tide Gauge Benchmark Monitoring Project (TIGA) (stations CART, MPLA, PDES, RWSN, TORS, VBCA), monitoring crustal deformations in the Alpine Region (stations BREI, FHAR, HGRA, HRIE, WART), the densification of the International Terrestrial Reference Frame (RNAAC-SIR, see Topic 3.2) (stations BOGA, CART, MARA, MPLA, PDES, RWSN, VBCA), and the definition and realization of vertical reference systems (SIRGAS-WGIII, see Topic 1.4) (stations CART, MPLA, PDES, RWSN, VBCA). Unfortunately, the tracking data of the stations MPLA and PDES has been interrupted for about a year, because of technical problems related to the Internet supply of these two sites (Figure 3.3.2). The equipment of station MARA had to be replaced because the antenna provided by DGFI in 1998 had tracking problems. This station is now operated by the Instituto Geográfico de Venezuela Simón Bolívar (IGVSB) in cooperation with the Universidad del Zulia (LUZ). Although the new equipment at this station does not belong to DGFI, IGVSB and LUZ continue providing the observations to the corresponding projects. At present, DGFI coordinates with the Geographical Institutes of Bolivia and Peru the installation of two additional stations in each of these countries. These new stations shall con-

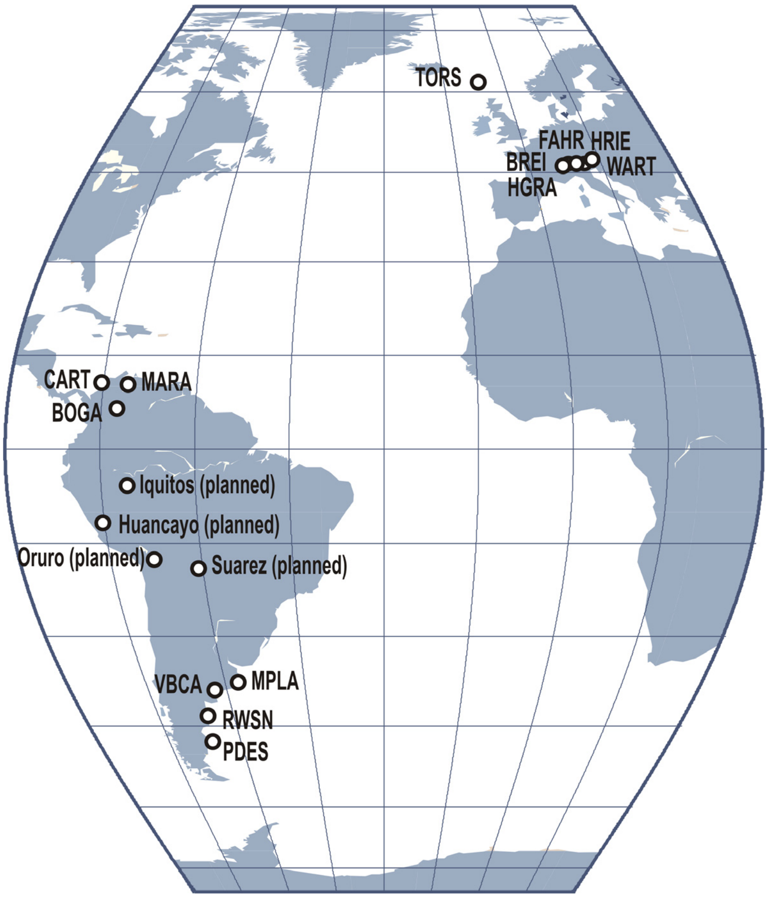
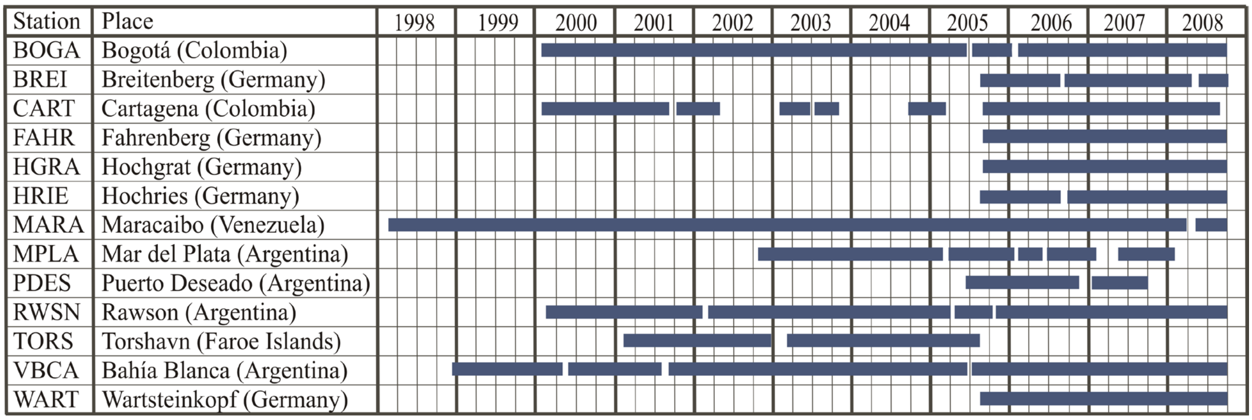


Fig. 3.3.1: Distribution of the continuously operating GPS stations of DGFI.



Station	Place
BOGA	Bogotá (Colombia)
BREI	Breitenberg (Germany)
CART	Cartagena (Colombia)
FAHR	Fahrenberg (Germany)
HGRA	Hochgrat (Germany)
HRIE	Hochries (Germany)
MARA	Maracaibo (Venezuela)
MPLA	Mar del Plata (Argentina)
PDES	Puerto Deseado (Argentina)
RWSN	Rawson (Argentina)
TORS	Torshavn (Faroe Islands)
VBCA	Bahía Blanca (Argentina)
WART	Wartsteinkopf (Germany)

Fig. 3.3.2: Operation of the continuously operating GPS stations of DGFI.

tribute to increase the density of the ITRF in the South American central area.

Tide gauge benchmark monitoring project

In the frame of the IGS TIGA Project (Tide Gauge Benchmark Monitoring Project), which aims at monitoring vertical motions of tide gauge sites (http://adsc.gfz-potsdam.de/tiga/), DGFI processes a GPS network of about sixty stations covering the Atlantic Ocean (Figure 3.3.3). This network includes also a few sites along of the Pacific Ocean coastline, where the vertical datum of some Latin American countries was established (see Topic 1.4). In addition to the coastal sites, a number of IGS global stations are included in order to improve the geometry of the network and to serve as fiducial points for realizing the reference frame. The selected reference stations belong to the IGS Reference Frame 2005 (IGS05, http://igscb.jpl.nasa.gov/network/refframe.html). Their selection is based on their geographical distribution and on the accuracy of their velocities. The vertical crustal trend (linear velocity) at the tide gauge benchmarks presented here corresponds to a multi-year solution (DGF08P01-TIGA) obtained from the accumulation of loosely constrained daily normal equations from 1 January 2000 to 16 August 2008.

The complete network was re-analysed with the Bernese Software V. 5.0 for the daily data processing with absolute IGS calibration values for the antenna phase centre corrections and satellite orbits referred to ITRF2005. Stations with short time series (less than two years) are excluded. The positions and velocities of all the sites are estimated, the geodetic datum being defined by constraining nine IGS stations to their IGS05 values. The final solution (DGF08P01-TIGA) refers to the IGS05 frame, epoch 2000.0. Table 3.3.1 shows the differences of the DGF08P01-TIGA velocities with respect to ITRF2005 and SIRGAS solutions (see Topic 3.2). The IGS05 stations contained in the Table 3.3.1 were not included as fiducials for the datum definition. Figure 3.3.3 presents a comparison between the GPS-derived vertical velocities with those obtained from the tide gauge registrations provided by the PSMSL (Permanent Service for the Mean Sea Level, http://www.pol.ac.uk/psmsl/). The SINEX files of the weekly loosely constrained network adjustment are provided to the TIGA Associated Analysis Centres (TAAC) and to other users through the web site http://adsc.gfz-potsdam.de/tiga/index_TIGA.html.

Table 3.3.1: Differences of the velocities obtained from the DGF08P01-TIGA solution with respect to the ITRF2005 (IGS05) and the SIRGAS solution DGF08P01-SIR (see Topic 3.2).

Station	IGS05			Station	ITRF2005			Station	SIRGAS (DGF08P01-SIR)		
	V_U [mm]	V_N [mm]	V_E [mm]		V_U [mm]	V_N [mm]	V_E [mm]		V_U [mm]	V_N [mm]	V_E [mm]
ASC1	-1,3	0,8	0,0	**AOML**	-2,0	0,0	-1,3	**BDOS**	1,2	-0,3	-2,2
CHUR	-2,3	0,6	-0,5	**BRMU**	1,3	0,3	-0,7	**BUEN**	1,5	-0,9	-0,4
CONZ	-0,2	-0,7	-1,7	**BRST**	2,3	2,6	-1,2	**CART**	-0,9	-1,6	0,7
CRO1	-0,9	-0,7	-0,2	**CASC**	0,1	1,2	1,1	**LPAZ**	-0,6	-1,7	-1,6
HRAO	-1,5	-0,1	-0,5	**FORT**	-1,3	0,5	-0,5	**MPLA**	-0,4	-0,9	0,0
OHI2	1,9	0,2	0,3	**KOUR**	0,6	-0,7	-0,4	**PDES**	-1,5	-0,6	-0,7
ONSA	0,7	1,0	0,2	**KYW1**	1,1	-0,9	1,5	**RECF**	-0,1	-1,5	-1,7
REYK	-1,0	-1,3	0,5	**MSKU**	1,5	0,7	1,1	**RIOD**	0,5	-0,9	0,7
VILL	-0,4	0,4	0,3	**OHIG**	-0,9	-0,9	-0,3	**RWSN**	-0,6	-1,1	-0,1
WES2	-2,8	-0,7	-0,8	**ZAMB**	0,2	0,8	-0,5	**TAMP**	0,1	-2,1	-2,9
								VBCA	-0,7	-1,2	0,0
Mean	**-0,8 ± 1,4**	**-0,1 ± 0,8**	**-0,3 ± 0,7**		**0,3 ± 1,4**	**0,4 ± 1,1**	**-0,1 ± 1,0**		**-0,1 ± 0,9**	**-1,2 ± 0,5**	**-0,7 ± 1,2**

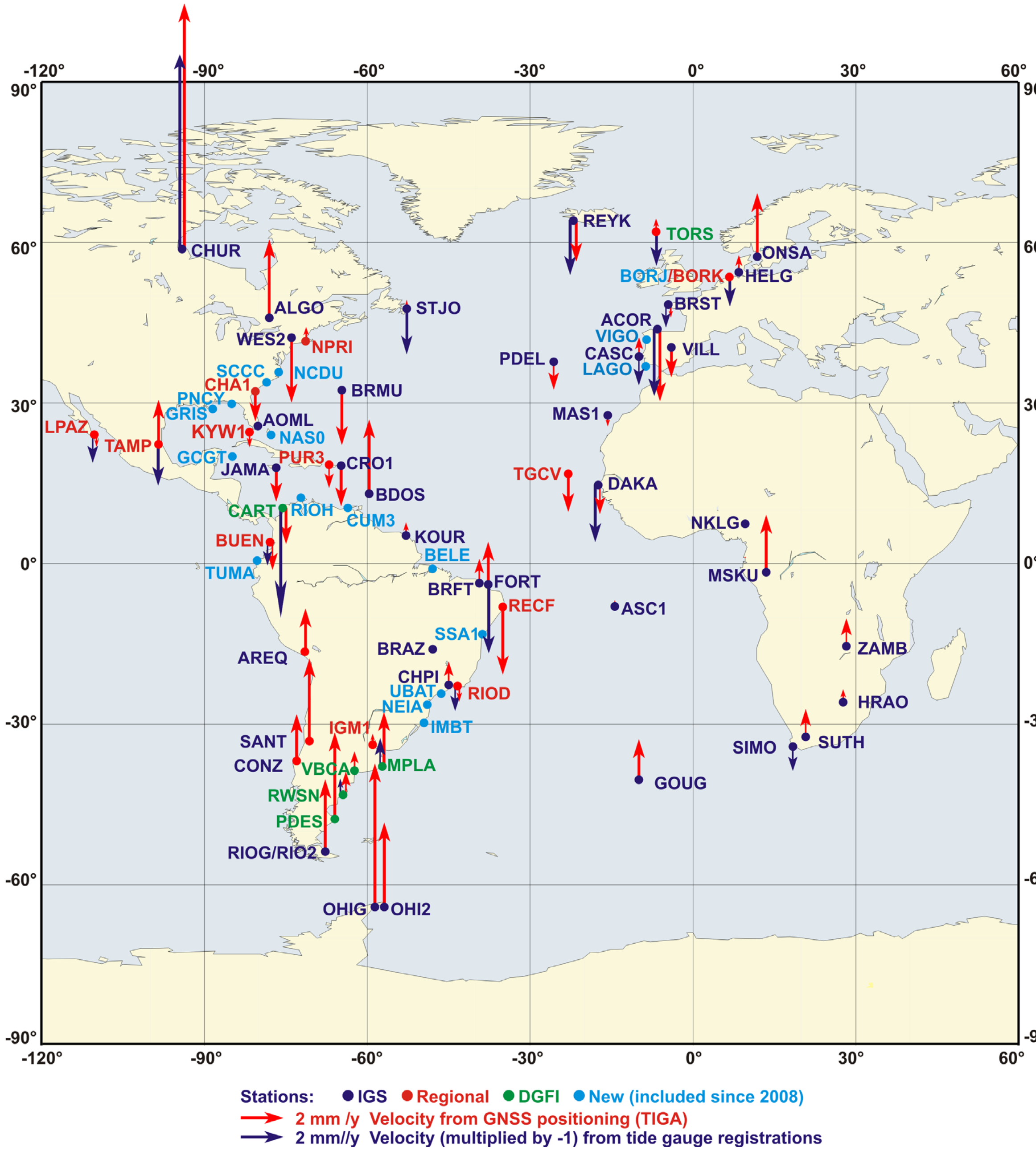


Fig. 3.3.3: Vertical velocities of the GPS network processed at DGFI within the TIGA project. It includes opposite vertical velocities obtained from tide gauge registrations at some selected sites.

Monitoring crustal deformations in the Alpine Region

In the frame of the ALPS-GPS QUAKENET project, a component of the Alpine Space Programme of the European Community Initiative Programme (CIP) INTERREG IIIB, DGFI installed in 2005 five continuously operating GPS stations located along the northern Alps boundary (Figure 3.3.4). The main objective of this project was to study crustal deformations in near real-time to improve natural disaster prevention in the Alpine region. During the two years in which the project was carried out, DGFI provided the observational data of its stations to be analysed together with other 25 stations installed in the area. Description, main features, and results of the project were presented in the report “ALPS GPS Quakenet: Alpine Integrated GPS Network”, available at www.alps-gps.units.it.

DGFI routinely processes its five stations in a small network (Figure 3.3.4), which includes three IGS05 reference stations, three IGS global stations, and two EUREF stations in order to detect local and regional deformations. Station coordinate time series and a cumulative solution (DGF08P01-ALPS) of this network are derived from loosely constrained daily solutions between 9 October 2005 and 31 July 2008. The obtained station movements mainly reflect the Eurasia plate displacement. Until now, regional or local deformations have not been identified.

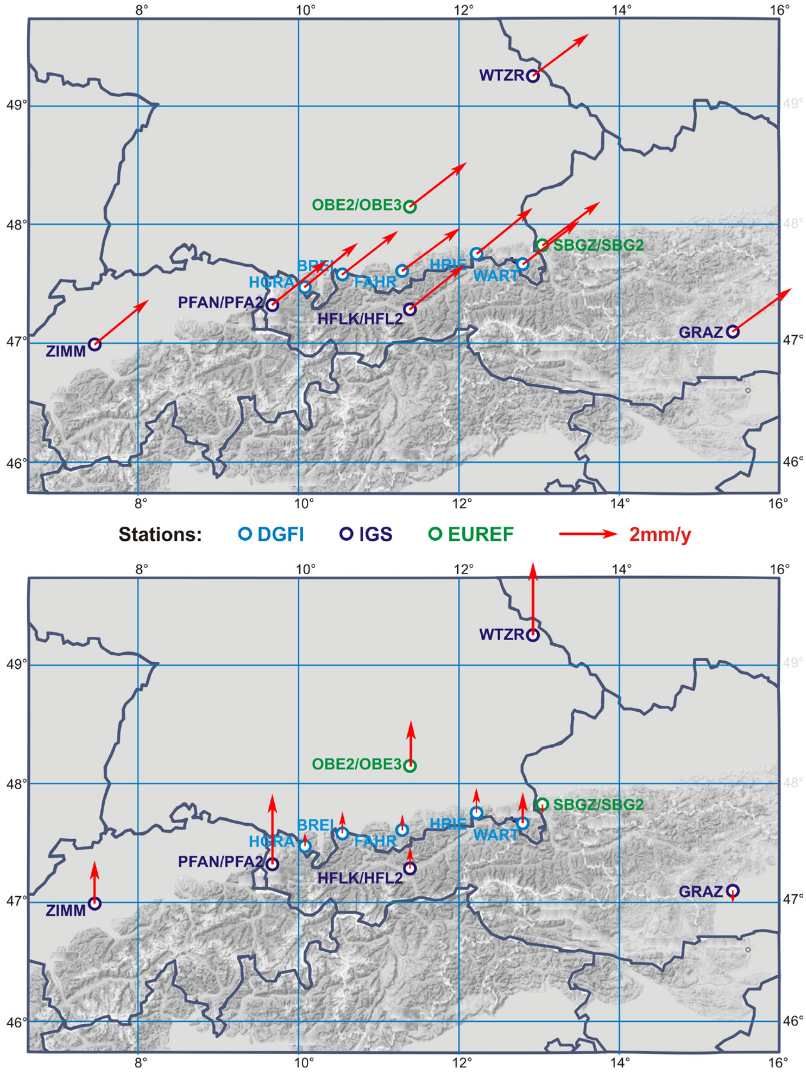


Fig. 3.3.4: Horizontal and vertical velocities of the GPS network processed at DGFI to monitor deformations in the Alpine Region.

3.4 ILRS − International Laser Ranging Service

DGFI contributes to the activities of the ILRS as data, analysis and backup combination centre. These activities are mainly long-term projects with responsibilities in the international SLR community in support of the tracking network.

ILRS Global Data Centre / EUROLAS Data Centre

As one of two ILRS Global Data Centres, the CDDIS at NASA and the EDC at DGFI, the EDC runs three ILRS mail exploders for exchanging information and results. The EDC exploded 1717 SLRmails (an increase of 118 e-mails) in the period from September 01, 2007 to September 30, 2008 and 10074 SLReports (an increase of 1689) since November 1995. The URGENT Mail exploder circulated 189 emails (increase of 49) since September 2003. Still the strategy to avoid the distribution of SPAM has to be improved, and the distribution lists of these three exploders have to be updated permanently.

Until August 01, 2008 the old IRV predictions were distributed and archived in parallel to the Consolidated Prediction Format (CPF) files. Since this date only the CRD predictions are available and distributed by the prediction exploder. Only one prediction provider, the GeoForschungsZentrum (GFZ), still delivers IRV predictions, which are stored at the DGFI ftp server, but not distributed. Since 2007 a new Consolidated laser Ranging Data (CRD) format is discussed in the meetings of the ILRS Data Format and Procedures Working Group. Both the CPF and the CRD are necessary for the upcoming transponder missions. At the end of 2007 some ILRS SLR stations started to deliver their observations in the new CRD format for test purposes. The exchange of these data between the two ILRS Global data centres CDDIS and EDC as well as the archiving is still under discussion; a decision has to be made soon.

Observation Campaigns

The ENVISAT, GIOVE-A, ETS-8, and TerraSar-X campaigns were continued; the new campaigns GIOVE-B, and JASON-1 and JASON-2 Tandem were approved by the ILRS Governing Board.

Observed Satellite Passes

In the time period from September 01, 2007 to September 30, 2008, 35 SLR stations observed 35 satellites (including the four moon reflectors). Table 3.4.1 shows the EDC data base content at September 30, 2008. This content is compared with that of the CDDIS data base and has to be updated at EDC and/or CDDIS due to missing data.

ILRS Analysis Centre

As one of the meanwhile eight official Analysis Centres DGFI contributes to the weekly combined ILRS station coordinate solutions. The contribution to the daily EOP solution (see next section) is pending. Further, the DGFI maintains a list of station anomalies and biases to be used by all ILRS analysis centres. In the last year the reprocessing of the so-called historic data, before 1993, which will be used for the next ITRF, was one of the main efforts. These data are not of the same quality as the actual tracking data, and especially the data distribution is too sparse to compute daily EOPs; therefore the ILRS Analysis Working Group

Table 3.4.1: Content of ILRS/EDC data base at September 30, 2008 for the product normal points (including Lunar Laser Ranging (LLR) observations to four moon reflectors)

Satellite	number of passes	
	Sep.07-Sep.08	Total
ADEOS		671
AJISAI	12819	128857
ALOS		91
ANDE-RR A	43	441
ANDE-RR P	183	662
BEACON-C	6610	57062
CHAMP	2124	13850
DIADEME-1C		1393
DIADEME-1D		1585
ENVISAT	6414	36902
ERS-1		10524
ERS-2	6361	67563
ETALON-1	1721	15997
ETALON-2	1710	16092
ETS-8	149	520
FIZEAU		4243
GEOS-3		2237
GFO-1	6081	44859
GFZ-1		5606
GIOVE-A	878	2381
GIOVE-B	206	206
GLONASS-62		963
GLONASS-63		1952
GLONASS-64		81
GLONASS-65		397
GLONASS-66		1544
GLONASS-67		4299
GLONASS-68		875
GLONASS-69		945
GLONASS-70		1430
GLONASS-71		2617
GLONASS-72		3260
GLONASS-74		39
GLONASS-75		300
GLONASS-76		301
GLONASS-77		343
GLONASS-78	45	2760
GLONASS-79		3237
GLONASS-80		4466
GLONASS-81		275
GLONASS-82		244
GLONASS-84		6442
GLONASS-86		1311
GLONASS-87		7330
GLONASS-88		114
GLONASS-89		6400
GLONASS-95	1248	4376
GLONASS-99	1644	2908
GLONASS-102	1455	1967
GLONASS-109	504	504
GPS-35	791	8207
GPS-36	760	7395
GRACE-A	2739	13906
GRACE-B	2767	13236
GRAVITY PROBE-B		3156
ICESAT	1915	5995
JASON-1	8809	52172
JASON-2	1914	1914
LAGEOS-1	10040	98836
LAGEOS-2	8800	86452
LARETS	4941	21629
LRE/H2A		76
METEOR-3		409
METEOR-3M		1756
MOON-1	10	415
MOON-2	12	327
MOON-3	82	2582
MOON-4		594
OICETS		115
REFLECTOR		3728
RESURS-01-3		2011
STARLETTE	10351	98700
STARSHINE-3		48
STELLA	5851	59647
SUNSAT		1864
TerraSAR-X	3038	3537
TIPS		1849
TOPEX/POS.		86423
WESTPAC-1	9	5629
ZEIA		146
Sum of all	**113024**	**1056176**

(ILRS/AWG) decided to solve for 3-day EOPs in that period. The data from 1993 to 2005 were reprocessed using new bias models adopted by the ILRS/AWG. These bias models are station-dependent and were developed by long time series. Reasons for the biases are calibration problems, counter corrections or other station-related problems. They were expected to have an influence on the scale of the SLR datum, but the reprocessed time series showed no significant difference to the time series used in ITRF2005 with no offset and a drift of about –0.1 ppb per year (see Figure 3.4.1).

Besides the final processing of the GGOS-D SLR solution, including low-degree harmonics, was performed. The GGOS-D activities are not directly related to ILRS, but the results are used for comparisons and to improve the models used in the ILRS/AWG processing (see also 3.1).

An ongoing effort is the generation of daily bias reports of tracking data to the Lageos satellites to support the quality control

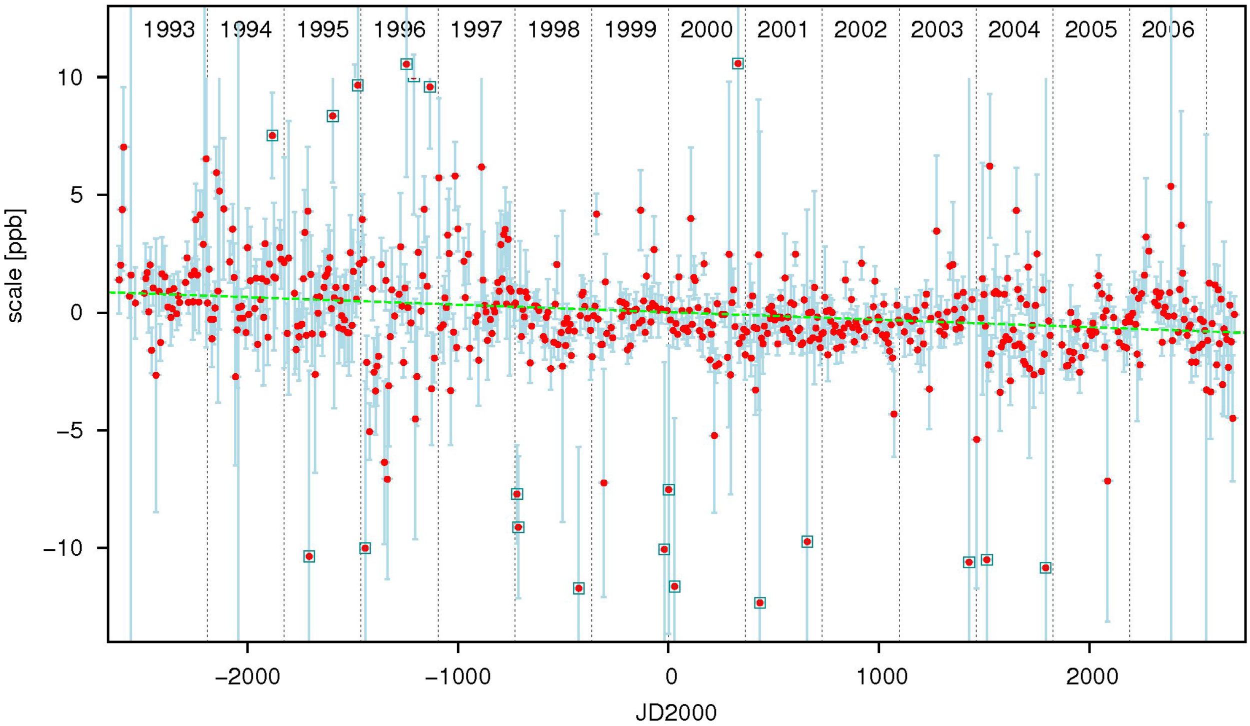


Fig 3.4.1: Scale between ITRF2005 DGFI SLR solution and the new solution with biases applied. Offset: 0.0 ± 0.1 ppb, drift –0.1 ± 0.03 ppb/year

of the SLR network. These reports contain all pass-wise range bias values and significant time biases. During the year, a few calibration and timing problems were detected and reported to the stations. Figure 3.4.2 shows some examples of range biases for selected stations in 2008. The overall quality is quite good though the number of passes varies according to weather conditions, tracking shifts and system stability.

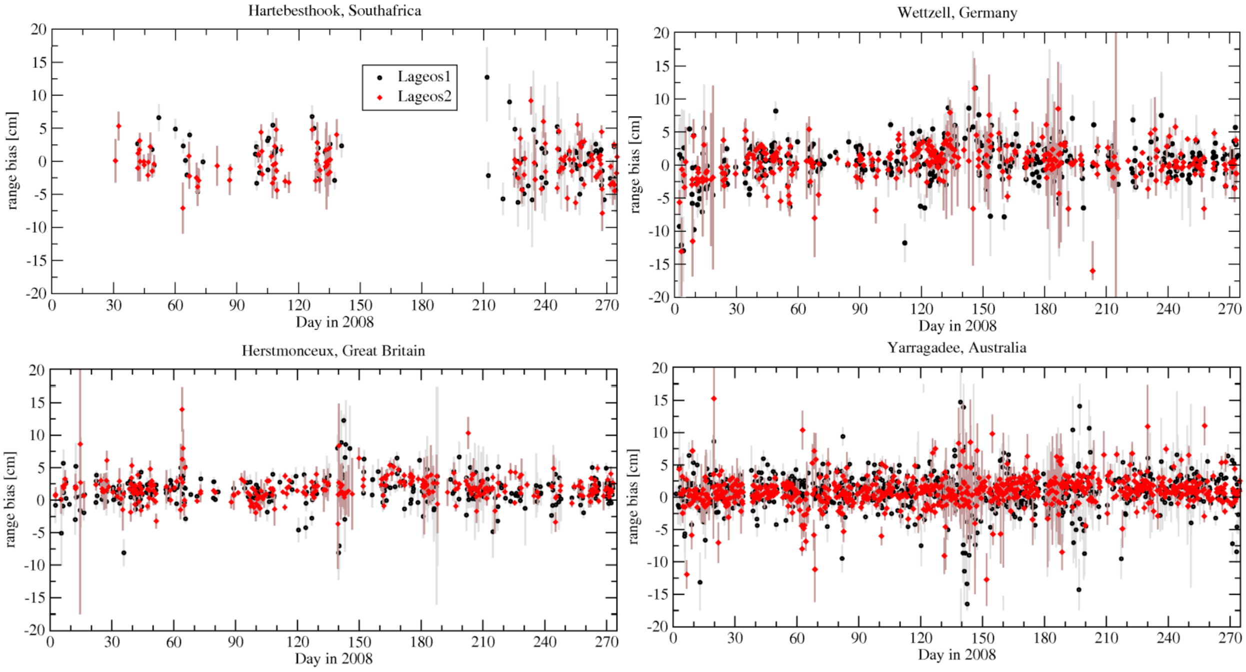


Fig 3.4.2: Range bias values in 2008 for four selected SLR tracking stations extracted from DGFI daily bias report.

ILRS Combination Centre (ILRSB)

DGFI, as the official ILRS Backup Combination Centre (ILRSB) continued to routinely process seven-day combination solutions for each week. A test phase started in the beginning of 2008 with seven-day solutions for each day. The individual and the combined solutions are automatically processed. As an example, the Helmert scale parameters for the individual and combined solutions are presented in Figure 3.4.3.

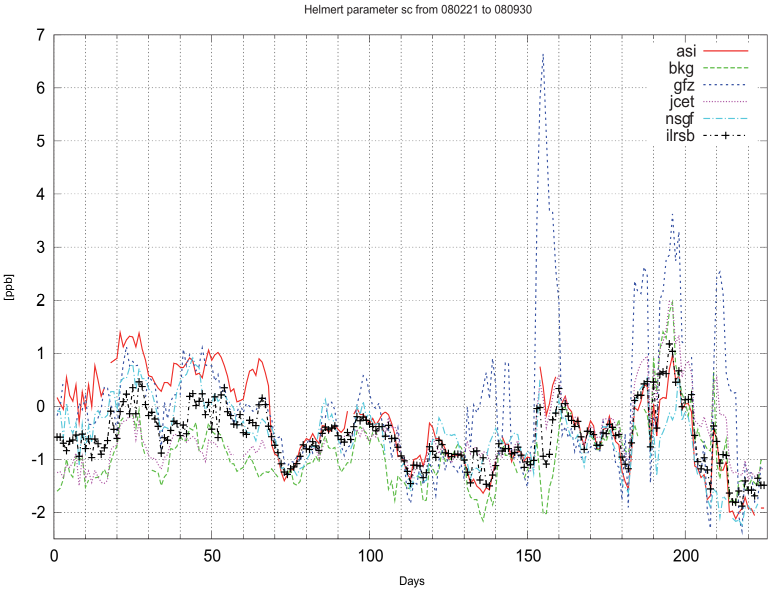


Fig 3.4.3: The Helmert scale parameters for the solutions of the analysis centres ASI, BKG, GFZ, JCET, NSGF, and for the combined ILRSB solution of DGFI from February 21 to April 06 2008. The horizontal axis presents time (number of day), the vertical axis scale values in ppb.

It is clearly to be seen that a scale offset exists between the individual solutions which is aligned by the combined solution.

Also in 2008 a test phase for the combination of orbit parameters started for the satellites LAGEOS-1 and -2 as well as for ETALON-1 and -2. The orbit solutions are taken from the loose constraint individual solutions. For test purposes, DGFI additionally delivered orbits which are fixed to SLRF2005. The combination software is in development.

3.5 IVS Analysis Centre

IVS OCCAM working group

As an Analysis Centre of the International VLBI Service for Geodesy and Astrometry (IVS), DGFI participates in the OCCAM Working group, which was established to develop and refine the OCCAM software. The working group is composed by scientists from the University of Technology, Vienna, Austria, the University St. Petersburg, and the Institute of Applied Astronomy, both Russia, and DGFI. It is chaired by Oleg Titov, Geoscience Australia. In the period under review, the work concentrated on the development of software for subsequent processing of the OCCAM results.

IVS Working Group on the second realization of the ICRF (ICRF2)

The International Celestial Reference System (ICRS) is realized by the positions of radio sources observed by VLBI. The latest realization is 2000-Ext1. The IERS and the IVS aim for a new realization of the ICRS based on the combination of different VLBI solutions. DGFI participates in the IVS Working Group on the second realization of the International Celestial Reference Frame (ICRF) computing ICRF solutions, defining the datum of ICRF by no-net-rotation conditions, ensuring a non-deformed CRF solution. The computation is based on altogether 3131 sessions from 1984 to August 2008. The DGFI CRF solution currently contains the coordinates of 2835 radio sources.

IVS Operational Analysis Centre at DGFI

DGFI is actually a special IVS Analysis Centre. As DGFI meets the recommentations of an operational Analysis Centre, it was upgraded to an operational Analysis Centre in October 2008. DGFI routinely processes the IVS standard sessions (R1 and R4) supplemented by other sessions and delivers the resulting datum-free normal equations to the IVS in SINEX format. In the case of relevant software updates, the VLBI normal equations are fully reprocessed and provided to the IVS. The latest update was the implementation of the Vienna Mapping Function (VMF1). After analysing the results and comparing them to the older series generated with Niell Mapping Function (NMF), 3131 sessions (between 1984 and August 2008) were reprocessed and submitted to the IVS data centre.

3.6 Planning and realization of an International Altimeter Service

The endeavour to establish an International Altimeter Service (IAS) through the activities of the IAS Planning Group, created under the IAG Inter-Commission Project ICP 1.1 'Satellite Altimetry' failed. Although there was a broad consensus that an IAS is needed there was no applicant willing to host the IAS Central Bureau, the most essential organizational element of an IAS.

IAS Steering Committee

In spite of this resistance, IAG decided after its restructuring in 2007 to establish the IAS in order to ensure that satellite altimetry will become a core element of the Global Geodetic Observing System, GGOS. IAG asked the chair of the IAS Planning Group, W. Bosch, to set up a Steering Committee. In June 2008 the first business meeting of the IAS Steering Committee was held in Chania, Crete, on the occasion of the IAG Symposium on Gravity, Geoid, and Earth Observation, GGEO2008.

General politics for IAS

- **No competition!** Many (partly commercial) service elements are already existing (AVISO, PODACC, Noveltis) others are being set up (GMES Marine Core Service). IAS will not compete with these bodies.
- **Convincing by best practice!** IAS should identify and analyse deficiencies in serving altimeter users, elaborate specific needs of the IAG community, and demonstrate synergies by cooperation.
- **Open to other bodies!** Altimetry is a crosscutting technique with many interdisciplinary applications. There is no claim for an exclusive representation by IAG. Thus the IAS should be open to other bodies and contact space agencies, processing centres, scientific core groups, and other associations (IAPSO).

IAS focal points

Possible IAS focal points were identified by the IAS-Steering Committee. Certainly the most basic requirement is:

- **Compilation and presentation of information**: Tell users where to find what data, products, and documents. Give mission overview; explain radar, laser, delay doppler, interferometric, and GPS altimetry. Link the JPL bibliography. Compiling meta data to allow searching for information. A web page is in preparation.

Suggestions for pilot projects

The following themes are additional focal points, which could be treated in terms of pilot projects. The corresponding calls for participation are under preparation.

- **Orbit as an intermediate reference frame**: Compile processing standards; develop a toolbox to merge new orbits into altimeter records; compare geocentre realization and geographical error pattern; compare orbits by means of crossover statistics.

- **Support to Cal/Val Activities** (in cooperation with PSMSL and TIGA): Compile results of tide gauge trends, vertical velocities at tide gauges and sea level trends.

- **Ocean tide models**: Compilation of state-of-the-art models; transformation into a common format (e.g. netcdf); develop a toolbox to compare and validate ocean tide models; provide software to compute ocean tide corrections for altimeter records; transformation of gridded tides to spherical harmonics.

- **Ocean mass redistribution** (in cooperation with the Geophysical Fluids Bureau): Sea level variation minus steric effects (from climatologies, ARGO floats, SMOS, ocean models); effect on Earth rotation (OAM) and gravity field.

- **Marine gravity data** (in cooperation with IGFS): Set links to marine gravity data sets of NSDC, SIO/NOAA, NGA; harmonize user interfaces; comparison with ship-born and satellite-only gravity data.

- **Faster, distributed upgrade of GDR data** by re-tracked data, new orbits and/or correction models (similar to the RADS System at Delft University): Sharing distributed resources e.g. by GRID technology.

It is envisaged that first Calls for Participation will be issued in early 2009.

4 Information Services and Scientific Transfer

Scientific research needs to publish its results for scientific use and to meet the requests of society. This is especially valid for geo-sciences which describe the planet Earth. 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 careful documentation of data and results is requested. 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 we produce printed reports 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, 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 especially on the commission and its activities, but also on various topics of geodesy such as conferences, education in geodesy, job offers in geodetic research, links to other geodetic institutions etc. 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 installed and maintains several independent Internet sites to meet growing demands on 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 administrated by a data base 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 administrated by means of a browser interface without specific knowledge of “mark up” languages like 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 used 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),
- and the International Altimeter Service (IAS).

Moreover, the Internet is used to maintain

- several file transfer servers for extensive data exchange, required for DGFI acting 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 Fig. 4.1.1, left) also provides a complete list of papers and reports published since 1994 by the employees and a compilation of all posters and presentations. Most recent publications and posters are as far as possible available in electronic form (mostly with the portable document format, pdf).

Internet site 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 new web site

`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 physical geodesy. The intention of GeodIS is to help people 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).

IAG Office - Secretary General

To assist the Secretary General, the Association establishes the IAG Office in the country in which the Secretary General resides (IAG Bylaw 38).

The Secretary General acts as the Director of the IAG Office (IAG Bylaw 36b).

He is assisted by a small number of assistant secretaries (IAG Bylaw 37a).

The IAG Office is located at Deutsches Geodaetisches Forschungsinstitut (DGFI)

D-80539 Muenchen, Germany, Alfons-Goppel-Str. 11 (Entrance: Residenzstr. 1)

Tel.: +49-89-23031-1107, Fax: +49-89-23031-1240, E-mail: iag@dgfi.badw.de

Secretary General: Hon.-Prof. Dr.-Ing. Hermann Drewes

Assistant Sec.Gen.: Dipl.-Ing. Helmut Hornik

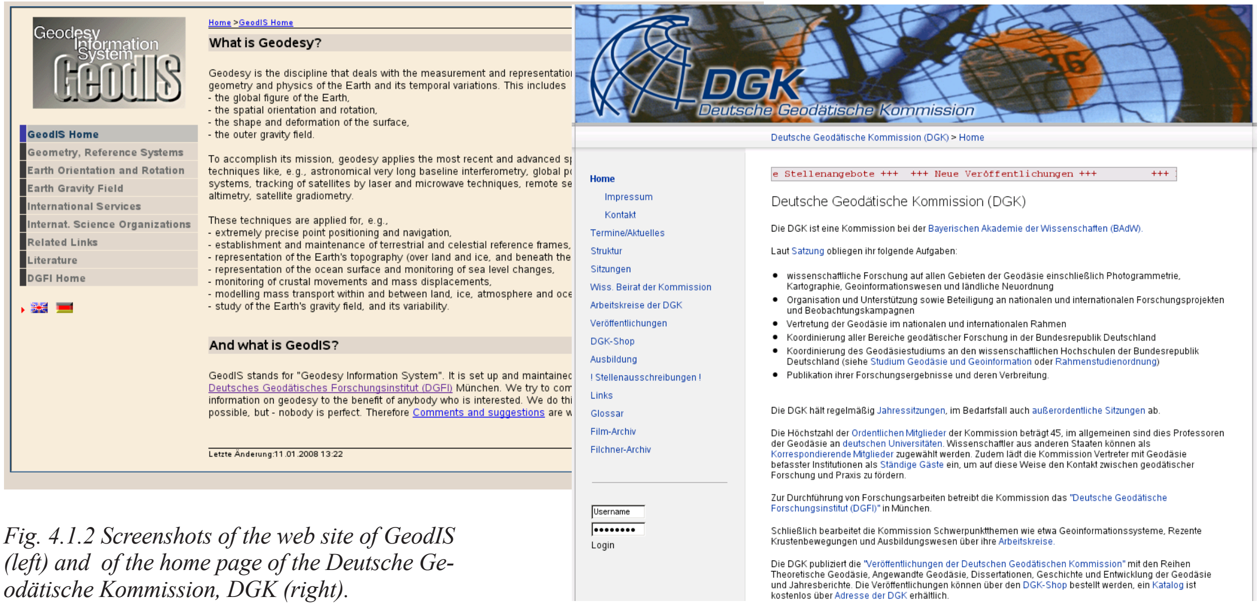
Assistant Secretary: Margit Varga

Assistant Treasurer: Wolfgang Kueffner

IAG Handbook 2008 (Internet Version)

IAG Structure 2007-2011.pdf

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



What is Geodesy?

Geodesy is the discipline that deals with the measurement and representatio
geometry and physics of the Earth and its temporal variations. This includes
- the global figure of the Earth,
- the spatial orientation and rotation,
- the shape and deformation of the surface,
- the outer gravity field.

To accomplish its mission, geodesy applies the most recent and advanced s
techniques like, e.g., astronomical very long baseline interferometry, global p
systems, tracking of satellites by laser and microwave techniques, remote se
altimetry, satellite gradiometry.

These techniques are applied for, e.g.,
- extremely precise point positioning and navigation,
- establishment and maintenance of terrestrial and celestial reference frames,
- representation of the Earth's topography (over land and ice, and beneath the
- representation of the ocean surface and monitoring of sea level changes,
- monitoring of crustal movements and mass displacements,
- modelling mass transport within and between land, ice, atmosphere and oce
- study of the Earth's gravity field, and its variability.

And what is GeodIS?

GeodIS stands for "Geodesy Information System". It is set up and maintaine
Deutsches Geodätisches Forschungsinstitut (DGFI) München. We try to com
information on geodesy to the benefit of anybody who is interested. We do th
possible, but - nobody is perfect. Therefore Comments and suggestions are w

Letzte Änderung:11.01.2008 13:22

Deutsche Geodätische Kommission (DGK)

Die DGK ist eine Kommission bei der Bayerischen Akademie der Wissenschaften (BAdW).

Laut Satzung obliegen ihr folgende Aufgaben:

- wissenschaftliche Forschung auf allen Gebieten der Geodäsie einschließlich Photogrammetrie, Kartographie, Geoinformationswesen und ländliche Neuordnung
- Organisation und Unterstützung sowie Beteiligung an nationalen und internationalen Forschungsprojekten und Beobachtungskampagnen
- Vertretung der Geodäsie im nationalen und internationalen Rahmen
- Koordinierung aller Bereiche geodätischer Forschung in der Bundesrepublik Deutschland
- Koordinierung des Geodäsiestudiums an den wissenschaftlichen Hochschulen der Bundesrepublik Deutschland (siehe Studium Geodäsie und Geoinformation oder Rahmenstudienordnung)
- Publikation ihrer Forschungsergebnisse und deren Verbreitung.

Die DGK hält regelmäßig Jahressitzungen, im Bedarfsfall auch außerordentliche Sitzungen ab.

Die Höchstzahl der Ordentlichen Mitglieder der Kommission beträgt 45, im allgemeinen sind dies Professoren der Geodäsie an deutschen Universitäten. Wissenschaftler aus anderen Staaten können als Korrespondierende Mitglieder zugewählt werden. Zudem lädt die Kommission Vertreter mit Geodäsie befasster Institutionen als Ständige Gäste ein, um auf diese Weise den Kontakt zwischen geodätischer Forschung und Praxis zu fördern.

Zur Durchführung von Forschungsarbeiten betreibt die Kommission das "Deutsche Geodätische Forschungsinstitut (DGFI)" in München.

Schließlich bearbeitet die Kommission Schwerpunktthemen wie etwa Geoinformationssysteme, Rezente Krustenbewegungen und Ausbildungswesen über ihre Arbeitskreise.

Die DGK publiziert die "Veröffentlichungen der Deutschen Geodätischen Kommission" mit den Reihen Theoretische Geodäsie, Angewandte Geodäsie, Dissertationen, Geschichte und Entwicklung der Geodäsie und Jahresberichte. Die Veröffentlichungen können über den DGK-Shop bestellt werden, ein Katalog ist kostenlos über Adresse der DGK erhältlich.

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). The site is available at location

`http://dgk.badw.de`

and informs about the structure of the DGK, the membership, working groups, 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 comfortable search function (see Figure 4.1.2, right).

Internet site for the DFG 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 got 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, but 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 corresponding web site is located at

`http://www.sirgas.org` .

The SIRGAS web site 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; and

Massentransporte und Massenverteilungen im System Erde

Meeresströmungen, Änderung des Grundwasserstandes und der Bodenfeuchte, das Abschmelzen kontinentaler Eisschilde, der Abfluss von Flusssystemen, die Änderungen des Meeresspiegels und Konvektionsströme im Erdmantel verursachen Transporte und Umverteilung der Massen.

Mit äußerst präzisen und neuartigen Sensoren messen Schwerefeld- und Altimetersatelliten die Auswirkung dieser Vorgänge. Die gemeinsame Analyse dieser Daten sollen das Verständnis dieser Prozesse im System Erde verbessern.

DFG Schwerpunktprogramm SPP1257

Der Senat der Deutschen Forschungsgemeinschaft (DFG) hat dazu die Einrichtung des Schwerpunktprogramms „Massentransporte und Massenverteilung im System Erde" mit einer Laufzeit von sechs Jahren beschlossen. Das Programm erfordert einen integrierten Lösungsansatz, der nur durch disziplinübergreifende Datenanalysen und Modellbildungen erreicht werden kann.

Diese Internetseiten informieren über Inhalte und Ergebnisse des Schwerpunktprogramms.

Schwerefeld - Satellitenmissionen

CHAMP, GRACE, in naher Zukunft GOCE liefern entscheidende Verbesserungen für Auflösung und zeitliche Variation des Schwerefeldes. [mehr ...]

Altimetrie - Satellitenmissionen

ENVISAT, Jason1 und ICESat überwachen die Oberfläche der Ozeane, Eisschilde, von Seen und Flüssen. [mehr ...]

Conferencia Internacional para la
Definición de un Datum Geocéntrico para América del Sur
Octubre 4 - 7, 1993. Asunción, Paraguay

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).

– a bibliographic compilation with reports, articles, presentations, and posters related to the SIRGAS activities.

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 English and Spanish.

Mailing lists

Mailing lists are maintained by DGFI to fulfill 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

Albertella A., Savcenko R., Bosch W., Rummel R.: Dynamic ocean topography - the geodetic approach., DGFI Report No. 82, Deutsches Geodätisches Forschungsinstitut (DGFI), München, 2008

Angermann D., Drewes H., Gerstl M., Krügel M., Meisel B.: ITRS Combination Centre at DGFI., IERS Annual Report 2006, Bundesamt für Kartographie und Geodaesie, Frankfurt a.M., 2008

Angermann D.: Berichte zur XXIV. Generalversammlung der IUGG − Internationale Assoziation für Geodäsie, Symposium G01 − Reference Frames. zfv, Zeitschrift für Geodäsie, Geoinformation und Landmanagement, 2008

Angermann D., Drewes H., Kelm R., Krügel M., Meisel B., Tesmer V.: IERS Combination Research Centre at DGFI., IERS Annual Report 2006, Bundesamt für Kartographie und Geodäsie, Frankfurt a.M., 2008

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4.3 Posters and oral presentations

Angermann D.: Combination issues and approach at DGFI, IERS Unified Analysis Workshop, Monterey, USA, 2007-12-06

Angermann D.: DGFI remarks related to the progress in understanding ITRF solution differences, IERS Directing Board Meeting No. 45, San Francisco, USA, 2007-12-11

Angermann D.: GPS in the ITRF Combination, IGS Analysis Center Workshop, Miami, USA, 2008-06-05

Angermann D.: DGFI Combination Methodology for Terrestrial Reference Frame Computations, EUREF 2008 Symposium, Brussels, Belgium, 2008-06-19

Angermann D.: Zum Beitrag geodätischer Raumbeobachtungsverfahren für die Erdwissenschaften, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-17

Artz T., Böckmann S., Nothnagel A., Tesmer V.: Comparsion an Validation of VLBI derived Polar Motion Estimates, EGU 2008 General Assembly, Vienna, Austria, 2008-04-17 (Poster)

Bosch W.: Contribution of altimeter time series to a Global Geodetic Observing system, 2nd status seminar GEOTECHNOLOGIEN, Bayerische Akademie der Wissenschaften, München, Germany, 2007-11-22/23 (Poster)

Bosch W.: Den Meeresspiegel vermessen − wie geht denn das? − Ergebnisse moderner geodätischer Raumverfahren, Geodätisches Kolloquium, Karlsruhe, Germany, 2008-01-24

Bosch W.: Instantaneous ocean dynamic topography profiles − assessment through smoothed GRACE geoids and altimetric sea surface height profiles, EGU General Assembly, Vienna, Austria, 2008-04-16

Bosch W.: On the Combination of gravity and altimetry − possible applications of ACES, ESA ACES Workshop, IAPG, Technische Universität München, München, Germany, 2008-05-27

Bosch W., Savcenko R.: A profile approach for the recovery of the mean dynamic topography, Joint International GSTM and DFG SPP Symposium, Potsdam, Germany, 2007-10-15/17 (Poster)

Bosch W., Savcenko R.: On the recovery of the mean dynamic topography − a profile approach, IAG International Symposium on Gravity, Geoid and Earth Observations (GGEO2008) , Chania, Greece, 2008-07-27 (Poster)

Bosch W., Savcenko R.: Profile der Meerestopographie, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-16/18 (Poster)

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Bouman J.: Introduction to external calibration, GOCE Calibration Synthesis Meeting, Noordwijk, The Netherlands, 2008-04-09

Bouman J., Tscherning C.C., Veicherts M.: Calibration of gravity gradients using terrestrial gravity data, GOCE Calibration Synthesis Meeting, Noordwijk, The Netherlands, 2008-04-09

Bouman J.: Calibration synthesis, GOCE Calibration Synthesis Meeting, Noordwijk, The Netherlands, 2008-04-09

Bouman J.: Synthesis of work: internal and external calibration, GOCE HPF Progress Meeting , Noordwijk, The Netherlands, 2008-05-15/16

Dettmering D.: Relative Altimeterkalibrierung mittels Multi-Missions Ausgleichung, FGS Workshop, Bad Kötzting, Germany, 2008-07-16

Dettmering D.: Kreuzungspunktanalyse zur Kalibrierung von Satellitenaltimetern, Geodätische Woche 2008, Bremen, Germany, 2008-10-02

Drewes H.: Bericht über die Arbeiten des DGFI 2006-2007, DGK Plenary Session, St. Gilgen, Austria, 2007-10-11

Drewes H.: Arbeiten des DGFI zur Beobachtung des Systems Erde, Excursion of Technical University Prague, München, Germany, 2008-02-27

Drewes H.: Neuordnung der geodätischen Forschungseinrichtungen in München, DGK Plenary Session, St. Gilgen, Austria, 2007-10-10

Drewes H.: Sistemas geométricas de referencia, Escuela Técnica Superior de Ingeniería en Topografía, Geodesia y Cartografía, Universidad Politécnica, Madrid, Spain, 2008-01-08

Drewes H.: Standards and conventions in the frame of GGOS, GGOS Retreat, Bertinoro, Italy, 2008-03-26

Drewes H.: GGOS Working Group "Conventions, Models, Analysis" status report, GGOS SC13 Meeting, Bertinoro, Italy, 2008-03-28

Drewes H.: Test solutions for ITRF2008, IERS DB Meeting No. 46, Wien, Austria, 2008-04-13

Drewes H.: Update of the velocity field model for South America, SIRGAS General Assembly, Montevideo, Uruguay, 2008-05-28

Drewes H.: Future objectives of SIRGAS from the scientific point of view, SIRGAS General Assembly, Montevideo, Uruguay, 2008-05-29

Drewes H.: El Sistema de Observación Geodésica Global (GGOS) − componente de la Asociación Internacional de Geodesia (IAG) para el futuro, Celebración de los cien anos de Geodesia en el Uruguay, Montevideo, Uruguay, 2008-05-30

Drewes H., Seitz, F.: Simulation of Earth rotation parameters with a dynamic Earth system model over a period of 200 years between 1860 and 2059, Journées "Systèmes de Référence Spatio-Temporels", Dresden, Germany, 2008-09-23

Göttl F., Dahle C., Schmidt R., Thomas M.: Polar motion excitations from geometric space techniques, geophysical models and weekly GRACE gravity field solutions, Joint International GSTM and DFG SPP Symposium, Potsdam, Germany, 2007-10-15/17 (Poster)

Göttl F.: Beitrag von GRACE zur Erforschung der Polbewegung, Statusseminar der Forschergruppe Erdrotation, Höllenstein, Germany, 2008-03-13

Göttl F., Seitz F.: Three different approches for the determination of polar motion excitation series, EGU General Assembly 2008, Vienna, Austria, 2008-04-16/18 (Poster)

Göttl F., Seitz F.: Three different approaches for the determination of polar motion excitation series, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-16 (Poster)

Karslioglu M.O., Nohutcu M., Gülcüer B., Schmidt M., Zhang J.: Local Modeling of VTEC Using GPS Observations and B-spline Expansions, EGU General Assembly 2008, Vienna, Austria, 2008-04-17 (Poster)

Krügel M.: GGOS-D Reference Frame Computations, GEOTECHNOLOGIEN Status Seminar, Bavarian Academy of Science and Humanities, Munich, Germany, 2007-11-22/23

Krügel M., Meisel B., Tesmer V., Angermann D.: Realization of terrestrial reference frames based on homogeneously processed data of different space geodetic techniques, AGU Fall Meeting 2007, San Francisco, USA, 2007-12-13 (Poster)

Kusche J., Schmidt R., Flechtner F., Barthelmes F., Schmidt M., Schmeer M.: Towards alternative gravity solutions from GRACE and future missions, Joint International GSTM and DFG SPP Symposium, Potsdam, Germany, 2007-12-15/17 (Poster)

Luz R., Bosch W., Freitas S., Dalazoana R., Heck B.: Determination of the sea surface topography along the Brazilian coast, GGEO 2008 Symposium, Chania, Greece, 2008-06-26 (Poster)

Mayer-Gürr T., Savcenko R.: Imroving ocean tide models by a joint estimation using GRACE and altimeter data, GGEO 2008 Symposium, Chania, Greece, 2008-06-26 (Poster)

Meisel B., Angermann D., Krügel M.: Improved parameterization for the computation of a terrestrial reference frame, EGU General Assembly 2008, Vienna, Austria, 2008-04-17 (Poster)

Müller H.: Acceptance Tests for SLR Stations, IERS Unified Analysis Workshop, Monterey, USA, 2007-12-06

Sánchez L.: Sistemas Verticales de Referencia, Lecture at Universidad Politécnica de Madrid, Madrid, Spain, 2008-01-09/10

Sánchez L.: Geodetic control of vertical movements at tide gauges, SIRGAS 2008 General Meeting, Montevideo, Uruguay, 2008-05-29

Sánchez L.: DGFI Report on the comparison and combination of the weekly solutions delivered by the SIRGAS Experimental Processing Centres, Second Workshop of the SIRGAS-WGI, Montevideo, Uruguay, 2008-05-27

Sánchez L.: SIRGAS en la Internet, SIRGAS 2008 General Meeting, Montevideo, Uruguay, 2008-05-28

Sánchez L.: Avances en el procesamiento unificado de las redes verticales involucradas en SIRGAS, SIRGAS 2008 General Meeting, Montevideo, Uruguay, 2008-05-29

Sánchez L.: Global vertical datum unification based on the combination of the fixed gravimetric and the scalar free geodetic boundary value problems, International Symposium on Gravity, Geoid, and Earth Observation GGEO 2008, Chania, Crete, Greece, 2008-06-24

Savcenko R.: EOT08a - a new global ocean tide model derived by empirical analysis of multi-mission altimetry data, EGU General Assembly 2008, Wien, Austria, 2008-04-17

Savcenko R., Bosch, W.: Vergleich aktueller globaler Modelle der Meeresgezeiten, FGS Workshop, Bad Kötzting, Germany, 2008-07-16/18 (Poster)

Savcenko R., Bosch W.: Global ocean tide models - Assessment of errors and their impact on GRACE gravity fields, A. Joint International GSTM and DFG SPP Symposium, Potsdam, Germany, 2007-10-15/17 (Poster)

Savcenko R., Bosch, W., Mayer-Gürr, T.: EOT08a – a new global ocean tide model derived by analysis of multi-mission altimeter data, GGEO 2008 Symposium, Chania, Greece, 2008-06-27

Savcenko R., Bosch W., Dettmering, D.: EOT08a – Ein neues Gezeitenmodell aus Multi-Session-Altimetrie, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-17

Savcenko R., Bosch, W.: Profile der Meerestopographie, Geodätische Woche 2008, Bremen, Germany, 2008-10-01

Schmeer M.: Trennung von Massensignalen, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-16

Schmeer M., Bosch W., Drewes H., Schmidt M.: Analysis of Atmospheric Density Variations – MaSiS: Separation of Mass Signals by Common Inversion of Gravimetric and Geometric Observations, Joint International GSTM and DFG SPP Symposium, Potsdam, Germany, 2007-10-15/17 (Poster)

Schmeer M., Bosch W., Schmidt M.: Separation and estimation of oceanic and hydrological model parameters from simulated gravity observations, EGU General Assembly 2008, Wien, Austria, 2008-04-16 (Poster)

Schmidt M.: Regional multi-dimensional modeling of the ionosphere from satellite data, TUJK Annual Scientific Meeting, Ankara, Turkey, 2007-11-15

Schmidt M.: Multi-dimensional representation of the electron density from satellite data, 2008 URSI General Assembly, Chicago, USA, 2008-08-12

Schmidt M.: Multi-dimensional representation of the ionosphere from COSMIC, George Mason University, Seminar, Fairfax, USA, 2008-08-26

Schmidt M.: Spatio-temporal multi-resolution representation of the gravity field from satellite data, Goddard Space Filght Center, Seminar, Greenbelt, USA, 2008-08-28

Schmidt M.: Spatio-temporal multi-resolution representation of the gravity field from satellite data, Ohio State University, Columbus, USA, 2008-08-19

Schmidt M.: Multi-dimensional representations of VTEC from satellite data and IRI, EGU General Assembly 2008, Vienna, Austria, 2008-04-18

Schwatke C.: Automatische Segmentierung und Verfolgung von Eddies anhand von Altimeterdaten, Geodätische Woche, Bremen, Germany, 2008-10-01

Schwatke C., Bosch W.: Erkennung und Verfolgung von Eddies, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-16/18 (Poster)

Seemüller W., Krügel M., Drewes H., Abolghasem A.: The new position and velocity Solution DGF07P01 of IGS Regional Network Associate Analysis Centre SIRGAS (IGS RNAAC SIR), AGU Fall Meeting, San Francisco, USA, 2007-12-12/14 (Poster)

Seitz F., Schmidt M., Shum C.K., Chen Y.: Signals of Extreme Weather Conditions in Central Europe from GRACE 4D Wavelet Expansions, Joint International GSTM and DFG SPP Symposium, Potsdam, Germany, 2007-10-15/17 (Poster)

Shum C.K., Schmidt M., Lee H., Guo J., Wang L., Shum C.K., Shum C.K., Wu P., Braun A., van der Wal W., Wang H., Yuan D., Watkins M.: Glacial Isostatic Adjustment Studies Using GRACE and Other Data, Joint International GSTM and DFG SPP Symposium, Potsdam, Germany, 2007-10-15/17 (Poster)

Steigenberger P., Tesmer, V.: Impact of different troposphere modeling on GPS- and VLBI-derived parameters, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-17

Stummer C., Gruber Th., Bouman J., Rispens S.: GOCE Gradiometry − A Guide for Users, IAG International Symposium Gravity, Geoid and Earth Observation 2008, Chania, Crete, Greece, 2008-06-23/27 (Poster)

Stummer C., Gruber Th., Bouman J., Rispens S.: GOCE Gradiometry − A Guide for Users, Workshop der Forschungsgruppe Satellitengeodäsie, Bad Kötzting / Wettzell, Germany, 2008-07-16/18 (Poster)

Taguchi E., Stammer D., Savcenko R., Bosch W.: Toward high-resolution dynamical tidal modeling using HAMTIDE, Joint International GSTM and DFG SPP Symposium, Potsdam, Germany, 2007-10-15/17 (Poster)

Tesmer V.: Experiences with CONT02 and GGOS-D, IERS Unified Analysis Workshop, Monterey, USA, 2007-12-06

Tesmer V.: Comparison and Combination of Tropospheric Parameters, IERS Unified Analysis Workshop, Monterey, USA, 2007-12-06

Tesmer V.: Atmospheric Loading coefficients determined from homogeneously reprocessed GPS and VLBI height time series, IVS 2008 General Meeting, St.Petersburg, Russia, 2008-04-03

Tesmer V., Steigenberger P., Rothacher M., Meisel B.: Homogeneously reprocessed mGPS and VLBI GGOS-D height time series, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-17

Tesmer V., Wang H., Meisel B., Rothacher M.: Atmospheric loading coefficients from homogeneously reprocessed long-term GPS and VLBI height time series, AGU Fall Meeting, San Francisco, USA, 2007-12-12/14 (Poster)

Thaller D., Krügel M., Tesmer V., Böckmann S., Wang H., Rothacher M., Dach R.: General aspects on generating long time series of Earth orientation parameters, EGU 2008 General Assembly, Vienna, Austria, 2008-04-17 (Poster)

Zeilhofer C.: Multi-dimensionale Darstellung ionosphärischer Signale, FGS Workshop 2008, Bad Kötzting, Germany, 2008-07-17

Zeilhofer C.: Multi-dimensional representation of the ionosphere from GNSS, altimetry and COSMIC, Ohio State University, Columbus, USA, 2008-08-19

Zeilhofer C.: Multi-dimensional representation of the ionosphere from GNSS and altimetry, George Mason University, Seminar, Fairfax, USA, 2008-08-26

4.4 Membership 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 1.3a “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
- Commission 1 Study Group 1.2 “Vertical Reference Systems”, W. Bosch, L. Sánchez
- 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
- 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
- GGOS Working Group “Conventions, Modelling and Analysis”, Chair: H. Drewes
- Representative to the Sistema de Referencia Geocéntrico para las Américas, SIRGAS, H. Drewes

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

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

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

International Laser Ranging Service (ILRS)
- Governing Board member: W. Seemüller
- Data Centre at DGFI: Chair: W. Seemüller
- Analysis Centre at DGFI: Chair: H. Müller
- Combination Centre at DGFI: Chair: R. Kelm
- Working Group “Data Format and Procedures”, Chair: W. Seemüller

International VLBI Service for Geodesy and Astrometry (IVS)
- Analysis Centre at DGFI, Chair: V. Tesmer, M. Seitz

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

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

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)

- Ständiger Gast, H. Drewes
- Working Groups „Rezente Krustenbewegungen", „Theoretische Geodäsie" (several scientists)

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

2007-10-10/12	DGK plenary session 2007, St.Gilgen, Austria (Drewes, Hornik)
2007-10-15/17	Joint International GSTM and DFG SPP Symposium, Potdam, Germany (Bosch, Göttl, Savcenko, Schmeer, Schmidt)
2007-11-12/15	2nd Space for Hydrology Workshop, Geneva, Switzerland (Schmeer, Schmidt)
2007-11-14/16	TUJK Annual Scientific Meeting, Ankara, Turkey (Schmidt)
2007-11-21	GEO-TOP 6th Project Meeting, IAPG, München, Germany (Bosch, Savcenko)
2007-11-22/23	Geotechnologies Programme “Observation of the System Earth from Space” Status Seminar, Munich, Germany (all DGFI scientists)
2007-11-23	DGK-Working Group “Zukunft der DGK”, Frankfurt a.M., Germany (Hornik)
2007-11-29/30	EUREF Technical Working Group Meeting, Paris, France (Hornik)
2007-12-05/07	IERS Unified Analysis Workshop, Monterey, USA (Angermann, Müller, Tesmer)
2007-12-08	IAG Executive Committee Meeting, San Francisco, USA (Drewes, Hornik)
2007-12-10/14	AGU Fall Meeting, San Francisco, USA (Angermann, Hornik, Tesmer)
2007-12-11	IERS Directing Board Meeting, No. 45, San Francisco, USA (Angermann)
2008-01-17/18	DAROTA project meeting, Institut für Geodäsie und Geoinformation, Universität Bonn, Bonn, Germany (Bosch, Savcenko)
2008-02-18/19	Workshop of GGOS-D Project, BMBF, München, Germany (Angermann, Bosch, Drewes, Gerstl, Kelm, Krügel, Meisel, Müller, Tesmer)
2008-03-03/05	IVS General Meeting 08, St.Petersburg, Russia (Tesmer)
2008-03-05	Working Group Meeting, St.Petersburg, Russia (Tesmer)
2008-03-07	Analysis Workshop, St.Petersburg, Russia (Tesmer)
2008-03-12/14	DFG-Forschergruppe FOR584 Erdrotation und globale dynamische Prozesse, Statusseminar, Höllenstein, Germany (Angermann, Göttl, Schmidt, Drewes)
2008-03-26	GGOS Retreat, GGOS, Bertinoro, Italy (Drewes)
2008-03-28	GGOS SC13 Meeting, GGOS, Bertinoro, Italy (Drewes)
2008-03-31/04-01	EUREF TWG Meeting, Helsinki, Finland (Hornik)
2008-03-31/04-02	DFG SPP1257 Workshop, Herrsching, Germany (Bosch, Drewes, Savcenko, Schmeer, Schwatke, Seitz)
2008-04-02/03	DAROTA project meeting, DGFI, Munich, Germany (Bosch, Savcenko)
2008-04-09	GOCE Calibration Synthesis Meeting, ESA/ESTEC, Noordwijk, The Netherlands (Bouman)
2008-04-12	ILRS Analysis Working Group Meeting, Vienna, Austria (Müller, Kelm)
2008-04-14	ILRS Data Formats & Procedures Working Group Meeting, Vienna, Austria (Seemüller, chair)
2008-04-14	ILRS Governing Board Meeting, Vienna, Austria (Seemüller)
2008-04-14/18	EGU General Assembly, Vienna, Austria (Bosch, Göttl, Meisel, Savcenko, Schmeer, Schmidt)
2008-04-19	IAG Executive Committee Meeting, Technical University, Vienna, Austria (Bosch, Drewes, Hornik)
2008-04-22	Joint Meeting of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) and World Data Centers Panel (WDC), FAGS/WDC, Paris, France (Drewes)

2008-05-06	Workshop of the Researchers Group on Reference Systems, DFG, Frankfurt/Main, Germany (Drewes)
2008-05-09	Rundgespräch Erfassung des Systems Erde aus dem Weltraum, BAdW, München, Germany (Bosch, Bouman)
2008-05-13/14	Workshop of Earth System Research, DFG, Bonn, Germany (Drewes)
2008-05-15/16	GOCE HPF Progress Meeting #15, ESA/ESTEC, Noordwijk, The Netherlands (Bouman)
2008-05-26/27	ESA ACES Workshop, IAPG TUM, München, Germany (Angermann, Bosch, Tesmer)
2008-05-26/27	Second Workshop of the SIRGAS-WGI (Reference System), SIRGAS, Montevideo, Uruguay (Drewes, Sánchez, Seemüller)
2008-05-28/29	SIRGAS 2008 General Meeting, SIRGAS, Montevideo, Uruguay (Drewes, Sánchez, Seemüller)
2008-05-30	Celebración de los cien anos de Geodesia en el Uruguay, SGM Uruguay, Montevideo, Uruguay (Drewes, Sánchez, Seemüller)
2008-06-02/03	Workshop of the Researchers Group on Reference Systems, DFG, Frankfurt, Germany (Angermann, Drewes)
2008-06-02/06	IGS Analysis Centre Workshop, IGS, Miami, USA (Angermann)
2008-06-03/04	Workshop of GGOS-D Project, BMBF, Frankfurt/Main, Germany (Angermann, Drewes, Kelm, Meisel, Müller, Tesmer)
2008-06-17	EUREF TWG Meeting, Brussels, Belgium (Hornik)
2008-06-18/21	EUREF 2008 Symposium, EUREF, Brussels, Belgium (Angermann, Hornik)
2008-06-23/27	International Symposium on Gravity, Geoid, and Earth Observation GGEO 2008, IAG, Chania, Crete, Greece (Bosch, Drewes, Sánchez, Savchenko)
2008-06-30/07-01	CLISAP Workshop on Ocean Tides, KlimaCampus Hamburg, Hamburg, Germany (Bosch, Savcenko)
2008-07-07	DAROTA Project Meeting, DGFI, Munich, Germany (Bosch, Savcenko)
2008-07-16/18	Workshop of Forschungsgruppe Satellitengeodäsie, FGS, Kötzting, Germany (all DGFI scientists)
2008-08-04/06	IUGG Executive Committee Meeting, IUGG, Karlsruhe, Germany (Drewes)
2008-09-22/24	Journées "Systèmes de Référence Spatio-Temporels", TU Dresden, Dresden, Germany (Angermann, Drewes, Seitz)
2008-09-24/25	Workshop of Researchers Group on Reference Systems, DFG, Dresden, Germany (Angermann, Drewes, Seitz)
2008-09-30/10-02	INTERGEO/Geodätische Woche, DVW, Bremen, Germany (Dettmering, Savcenko, Schwatke, Seitz)

4.6 Guests

2007-11-20	List H., Rinke T., AGeoBw Geodäsie, Germany, Euskirchen
2007-11-30	Dr. K. Börger, AGeoBw Geodäsie, Germany, Euskirchen
2008-02-01/03-15	Prof. Claudio Brunini, Universidad Nacional de La Plata, Argentina, La Plata
2008-02-14	Dr. A. Güntner, GeoForschungsZentrum, Deutschland, Potsdam
2008-02-27	Students of Department of Geodesy, Technical University of Prague, Czech Republic, Prague
2008-03-25/06-20	Prof. E. Wildermann, La Universidad del Zulia, Venezuela, Maracaibo
2008-04-24	Dr. Norbert Jakowski, DLR, Deutschland, Neustrelitz

5 Personnel

5.1 Number of personnel

Total staff of DGFI during the 2007/2008 period (incl. DGK Office):

Regular budget

13 scientists
9 technical and administrative employees
1 worker
9 student helpers with an average of 263 hours/year
5 student apprentices
1 minor time employee

Project funds

6 junior scientists
1 student helper

Funding of following projects by BMBF and DFG 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)
MaSiS	Separartion of mass signals by common inversion of gravimetric and geometric observations (DFG)
PROMAN	Program management and scientific networking (DFG)
FG Erdrotation, P6	Integration of Earth rotation, gravity field and geometry using space geodetic observations (DFG)

5.2 Lectures at universities

Hon.-Prof. Dr. H. Drewes: Geodätische Geodynamik, Technische Universität München, WS 2007/2008

Dr. W. Bosch: Oceanography and Satellite Altimetry, Technische Universität München, WS 2007/2008

PD Dr. M. Schmidt: Approximation Methods, Technische Universität München, WS 2007/2008

PD Dr. M. Schmidt: Wavelets, Technische Universität München, SS 2008

6 Miscellaneous

With its collection of geodetic instruments DGFI participated in the “Lange Nacht der Museen (Long Night of Museums)”, Munich, Germany, 2007-10-20.

On February, 11, 2008, Hon.-Prof. Dr. H. Drewes was awarded by the “Bundesverdienstkreuz”, a medal of the Federal President of Germany, handed over by Dr. Thomas Goppel, the Bavarian Minister for Science, Research and Art.