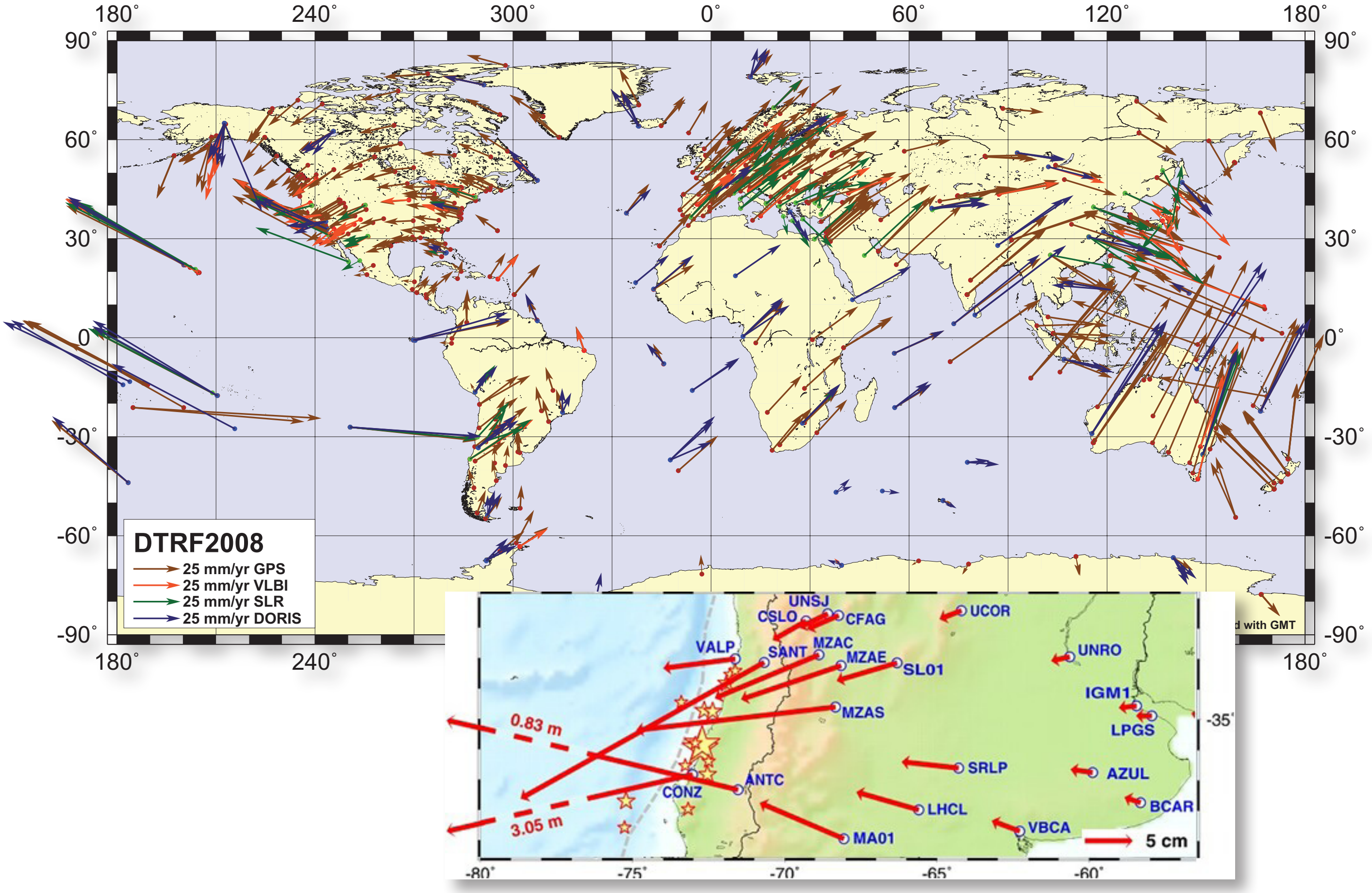
Deutsches Geodätisches Forschungsinstitut (DGFI)

ANNUAL REPORT 2010



Short after the completion of the reference frames ITRF2008 and DTRF2008 (see the velocity field in the top panel) the magnitude 8.8 earthquake in Conception/Chile led to one of the biggest co-seismic displacements ever observed. As the deformations caused by this earthquake stretch across the South American continent (c.f. bottom panel), the suitable definition and realisation of regional and global reference systems became (again) a challenging issue.

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Table of Contents

1st Edition

The Institute

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

Research Programme

DGFI's research programme from 2005 to 2010 was under the general theme "*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 geodetic parameter estimation, and analyses of physical Earth models.

Applications in Science and Practice

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 scientific and practical applications. The celestial reference frame enables to describe the orientation of Earth in space. It is necessary for space travel, global navigation, astrometry etc. The terrestrial reference frame serves as the basis for all precise positioning in surveying, engineering, navigation, and geoinformation systems. It allows the unification of all national and continental reference systems, which is a prerequisite for globalization of society and economics. The Earth's gravity is represented with respect to physical reference surfaces, e.g., the geoid as an equipotential surface or 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.

Connections to Universities

DGFI has a very close cooperation 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 on Satellite Geodesy

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 Satellite Geodesy (Forschungseinrichtung Satellitengeodäsie, FESG), the Institute for Geodesy and Geoinformation, University of Bonn (IGG), the Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie, 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 IAG Services for science 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 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 intergovernmental institutions and activities.

Structure of the Programme

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

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

Earth System observations include the 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. Earth System analysis 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.

New Structure of DGFI

In January 2005, the German Research Council (Wissenschaftsrat, WR), on request of the State of Bavaria, performed a thorough examination of DGFI. The WR ascertained the good scientific work of DGFI in international frame, but found some deficits in the internal organization in particular in the general structure of geodetic research institutions in Munich (DGFI, BAdW, TUM). A complete revision was recommended aiming at a closer connection of DGFI with the TUM, which could be accomplished by the common appointment of the Director of DGFI and a Professor of TUM.

Centre of Geodetic Earth System Research, CGE

During the following years, a restructuring was achieved resulting in the “Centre of Geodetic Earth System Research” (CGE) as a scientific consortium of the four institutions:

- Deutsches Geodätisches Forschungsinstitut (DGFI),
- Kommission für die Internationale Erdmessung (BEK, BAdW),
- Institut für Astronomische und Physikalische Geodäsie (IAPG),
- Forschungseinrichtung Satellitengeodäsie (FESG, both TUM).

The CGE was formally established by signing the contract on October 28, 2010. CGE will have a common research programme directed by the Board of Directors and Heads of specific research areas.

From right to left: Prof. W. A. Herrmann, President of TUM, Prof. D. Willoweit, President of BAdW, Prof. R. Dietrich, Chairman of DGK, and Hon.-Prof. H. Drewes, director of DGFI.

1 Earth System Observations

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

The investigations are divided into four topics. The development of consistent evaluation methods for the mentioned observation techniques is dealt with in topic 1.1. The objective is to get optimal models for the individual techniques, and a unification of the modelling for better consistency of the results by advanced combination methods. Topic 1.2 concentrates on the basic research for geometric reference systems which enter directly into the realization of the terrestrial and the celestial reference systems. In topic 1.3 we cover the fundamentals of physical parameter estimations. They are an important prerequisite for the procedures of combining geometric and gravimetric observations, which are treated in topic 1.4. A consistent estimation of geodetic parameters (e.g. station coordinates, positions of radio sources, Earth orientation parameters, lower harmonic gravity field coefficients) shall be achieved by the rigorous combination of the data of the different observation techniques.

1.1 Consistent evaluation methods for space geodetic observations

The general objective of this topic is to develop uniform standards, models and parameterizations and to implement them in the different software packages to ensure that the space geodetic observations can be uniformly processed and combined into consistent solutions.

Seasonal signals in station position time series

A key issue in 2010 was the investigation of seasonal station position changes, which are caused to a large part by mass load variations. The computation of the actual International Terrestrial Reference Frame, the ITRF2008, is based on the assumption that the movement of station positions is dominated by a linear trend, and that seasonal variations can be neglected. However, it is well known and confirmed by the results of ITRF2008, that seasonal height variations of station positions reach the level of centimetres and have to be considered (modelled or parameterized) in the ITRF computations, if highest accuracy and consistency for the frame shall be guarantied. Besides, a large number of applications exists for which precise knowledge of station positions is required for arbitrary epochs with an accuracy better than one centimetre.

The dominant part of the seasonal station height variations is assumed to be induced by mass load changes. Since loading by the ocean tides is reduced a priori from the space geodetic observations, the atmosphere, continental hydrology and non-tidal ocean mass variations dominate the loading signal. The radial loading effect can be computed from atmospheric, hydrologic and oceanic mass changes using the Green's functions approach. Several combinations of atmosphere, hydrology and ocean models were investigated (Tab. 1.1.1).

Tab. 1.1.1: Model combinations used for the investigations. References are (1) Kalnay et al. 1996 (2) ECMWF ERA Interim solution (http://ecmwf.int) (3) Stammer et al. 2003 (4) Milly and Schmakin 2002 (5) Rodell et al. 2004 (6) Döll et all. 2003

Name	Resolution	Atmosphere	Non-tidal ocean	Hydrology
NE	2°x2° weekly	NCEP(1)	ECCO(3)	-
NEL	2°x2° weekly	NCEP	ECCO	LAD(4)
NEG	2°x2° weekly	NCEP	ECCO	GLDAS(5)
EEW	0.5 x 0.5°, weekly	ECMWF(2)	ECCO	WGHM(6)

Alternative to the reduction of station position time series using models, the seasonal signals can be approximated by sine/cosine functions which parameters are estimated directly in ITRF computation. It is also possible to consider the seasonal variations by estimating station positions with a high temporal resolution (epoch reference frames).

Figure. 1.1.1 shows the height time series of the IGS stations LHAS (Lhasa, China) and TSKB (Tsukuba, Japan), the corresponding annual+semi-annual fits and the model results. For Lhasa the approximation of the GPS time series by models is good. It becomes obvious, that for this station the hydrological loading cannot be neglected as the NE model shows significant smaller variations than the other model combinations and the GPS series. The best approximation is achieved by estimation parameters of an annual and semi-annual function. For station Tsukuba the models cannot explain the variation of the station. The most likely reason is, that the groundwater extraction performed in Tsukuba every year for irrigation of rise paddies is not considered in the global hydrology models.

Fig. 1.1.1: Height variations [mm] of IGS stations LHAS (Lhasa, China; top) and TSKB (Tsukuba, Japan; bottom): GPS derived and modelled height variations and the corresponding annual+semi-annual fits (smoothed lines).

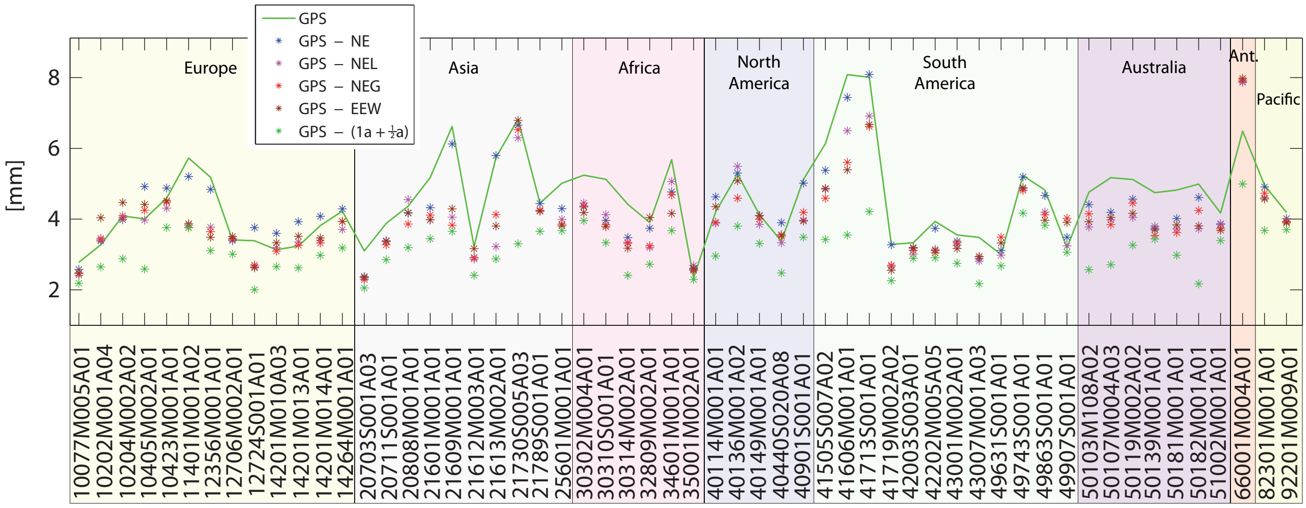


Fig. 1.1.2: RMS of station height variations for weekly GPS station position time series: Comparison of GPS only, GPS reduced by different models and GPS reduced by annual+semi-annual sine/cosine fit.

Figure. 1.1.2 shows the RMS values of the station height time series of 56 globally distributed GPS stations as well as the RMS of the reduced time series. The estimation of annual and semi-annual fits provides the smallest RMS values for all stations. Partly, the models provide comparable results, but for most of the stations the RMS achieved by applying geophysical models is significantly larger than for the sine/cosine fits.

The following conclusions can be drawn:

- Using the geophysical models applied in the investigations, the station height variations cannot be approximated with a high accuracy.
- The consideration of hydrology is indispensable and local effects must be additionally taken into account.
- The approximation of position time series by annual and semi-annual sine/cosine functions is the most effective of the investigated approaches, but it is still not satisfying, since only an (averaged) mean signal is removed and differences between the years are not considered.
- Consequently, the estimation of station positions with a higher time resolution is probably the most suitable way for considering station position variations and for providing station positions of high accuracy at arbitrary epochs.

New formulation of OCCAM

The new formulation of the OCCAM software pursued the following objectives:

- Transformation from Fortran 77 to Fortran 95/2003. The benefit from that is an increase in programming security, numerical accuracy, and execution speed.
- The old version of OCCAM consisted of a sequence of 5 programs. It was replaced by a single application. Thus, the input/output load could be dramatically reduced.

- Common blocks have been converted to modules. The advantages of which are code security and ease of maintenance. Furthermore, the created modules incorporated lots of the transfer parameters that have passed through external files between the programs of the former chain.
- All the parameters that may be corrected will be stored in a list of parameters including a-priori value, correction, epoch, standard deviation, the number of observations, etc. Thus, the setup of linear equations and the export of the solution in different formats reduces to a plain loop.
- The inversion routine was modified to allow a control of condition by a user-driven scaling of variables.
- The mathematical modelling of time-dependent parameters is being conferred to a set of parameter-independent routines each representing a kind of interpolating or approximating mathematical functions, for example piece-wise polynomials or splines. That allows to extend user's choice to other types of parameters and to supplement new types of mathematical parameter representation.
- The numerical approximation of time derivatives by a divided difference of values "one second after and before" is a numerical instable process. Starting with precession-nutation and polar motion, this kind of differentiation is being replaced by analytical derivatives throughout the program.
- A manual for the new program is still required.

1.2 Fundamentals of geometric reference systems

This topic concentrates on research for geometric reference systems, including the realizations of the terrestrial and celestial reference systems as well as the transformation between both systems expressed by the Earth Orientation Parameters (EOP).

Temporal highly resolved TRF/EOP combination

The movement of a station over time is usually parameterized in terrestrial reference frames (TRF) as a mean position at a reference epoch and a constant velocity. This is an adequate approximation if non-linear station movements can be neglected. For most of the stations, however, seasonal signals reach several millimetres and are thus significant. One possibility to consider these motions is the computation of temporal highly resolved TRF solutions (Fig. 1.2.1). These TRF time series do not provide such a stable reference over long time spans as a multi-year TRF, but a higher accuracy for station positions at arbitrary epochs.

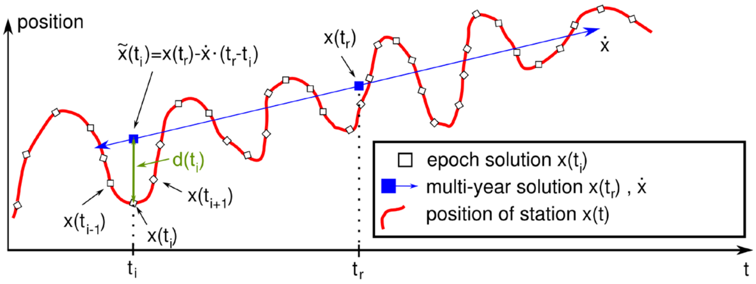


Fig. 1.2.1 Epoch solutions compared to a multi-year reference solution with constant station velocities.

The weekly time resolution of the estimated TRF's is chosen in view of the fact that the SLR arc lengths should be at least one week. First results with arc lengths of one month show, that the correlations of SLR specific parameters are reduced significantly compared to the weekly solutions.

The UT1-UTC and the nutation parameters can only be determined absolutely from VLBI observations since this observation technique uniquely observes the radio sources of the celestial reference frame. Up to four VLBI observation sessions per week are scheduled. The satellite techniques GPS and SLR allow for the estimation of the first time derivatives of UT1-UTC and for the nutation parameters, only. While the VLBI time series are not continuous and the parameters are available only at 0h and 24h epochs of the corresponding session, the satellite techniques provide diurnal values with parameters, defined at 0h epochs. The equation

$$\partial(\mathrm{UT1}-\mathrm{UTC})/\partial t = -\,\mathrm{LOD} = -\,(\,\dot{\Omega} + \cos i \cdot \dot{u}_0\,)/\rho \qquad (1)$$

shows, that variations of the estimated length of day values are related to variations in the right ascension of the orbital node $\dot{\Omega}$ and variations of the argument of latitude $\dot{u}_0$. Variations in $\dot{\Omega}$ will directly propagate into the LOD estimates, whereas the impact

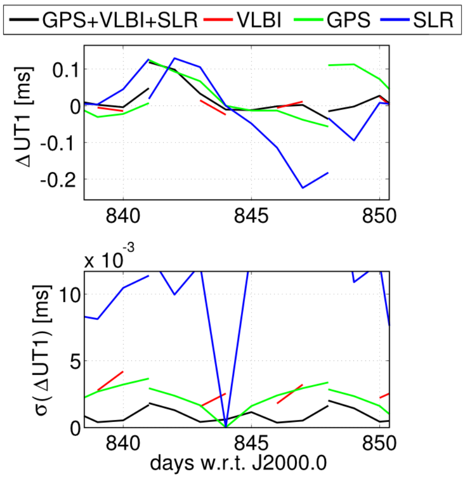


Fig. 1.2.2. Upper part: Estimated UT1-UTC values w.r.t. IERS 05 C04. For SLR and GPS weekly solutions one UT1-UTC parameter (in the mid of the week) is fixed to the a priori values. Lower part: Standard deviations of the estimated values.

of variations in $\dot{u}_0$ on LOD depends on the inclination i of the satellite. The parameter ρ is the ratio of universal time to sidereal time.

If the time derivative of the right ascension of the node Ω is erroneous because of this relationship, the estimated LOD values for the satellite techniques GPS and SLR will be systematically affected (Fig. 1.2.2). Systematics in $\dot{\Omega}$ can be caused by deficiencies in the orbit modelling.

Figure 1.2.2 shows the estimated UT1-UTC values w.r.t. IERS 05 C04. For the SLR and GPS weekly solutions one UT1-UTC parameter (in the mid of the week) is fixed to the a priori values. The UT1-UTC parameter series of the satellite techniques GPS (green) and SLR (blue) show systematic trends, while the session-wise available VLBI derived parameters (red) are not affected by these systematic effects. Hence, for providing reliable time-series of UT1-UTC with diurnal sampling, it would be necessary to close the observation gaps between the VLBI sessions. This can be done by incorporating VLBI intensive sessions performed daily at selected east-west directed baselines. Even if the duration of these sessions is only one hour, they might have the potential to improve the combined series. Thus, future work will be concentrated on the inclusion of VLBI intensive sessions in the combination.

Datum definition in regional reference frames

Epoch solutions of regional reference networks (daily, weekly, multiyear) are usually aligned to the global reference frame (ITRF) using a set of fiducial stations with given positions and constant velocities; i.e. considering linear coordinate changes only. However, GNSS stations show significant seasonal position variations (mainly in the up-component) resulting from a combination of geophysical loading and systematic errors. Neglecting these seasonal variations at reference stations may introduce systematic errors in the datum realisation and the regional reference networks can then be significantly deformed.

With the objective of evaluating the impact of seasonal variations in the weekly computation of a regional reference frame, weekly free normal equations computed for the SIRGAS reference frame (see section 3.2) were solved applying two different sets of reference coordinates for the datum realisation: the first set corresponds to the IGS05 positions at epoch 2000.0 extrapolated to the observation epoch using the ITRF2005 constant velocities (IGS05@2000 + VEL). The second set corresponds to the weekly positions determined for the IGS05 reference stations within the global IGS weekly combination (solutions igsyyPwwww.snx).

Fig. 1.2.3 shows the residuals in the up-component after a similarity transformation between the loosely constrained (non-deformed) solution and the two solutions aligned to IGS05 for GPS week 1505 (~ Nov. 2008). It is evident that the network geometry

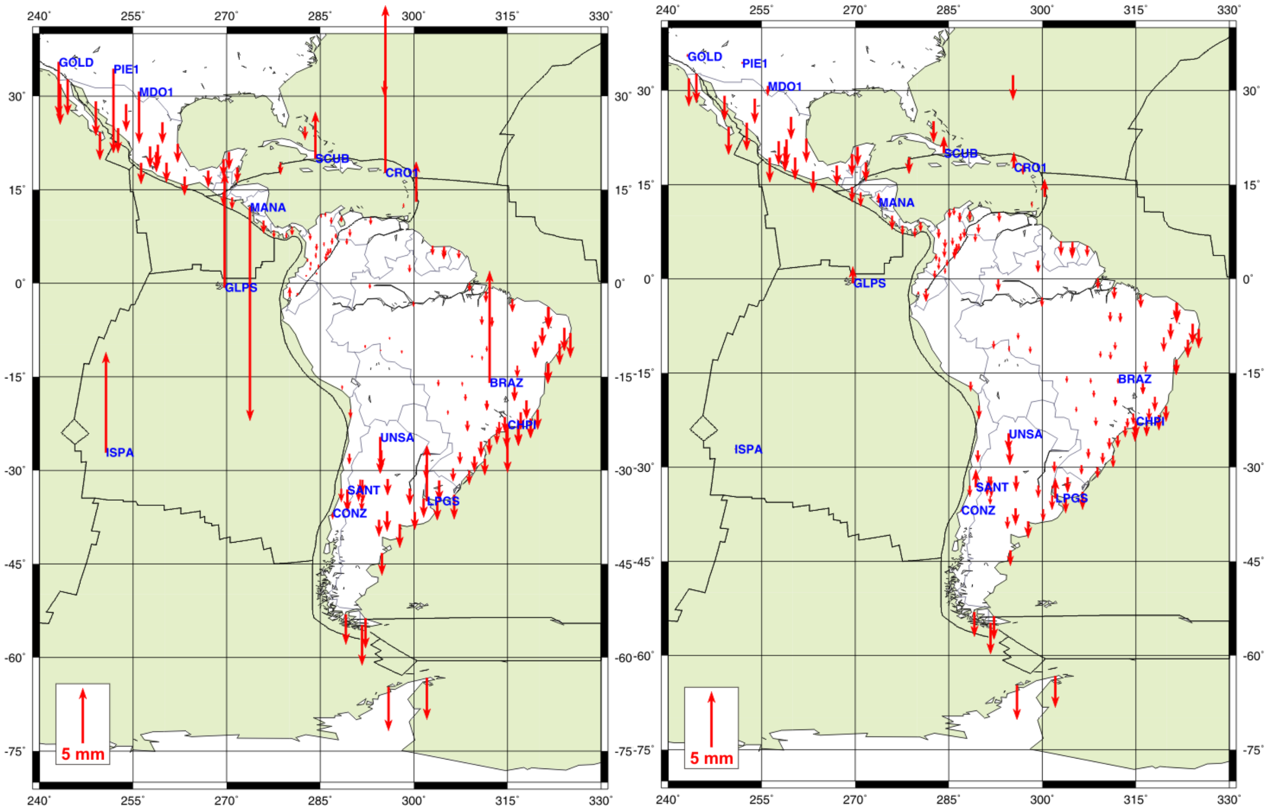


Fig 1.2.3 Residuals in the up-component after a similarity transformation between the loosely constrained (non-deformed) solution and the solution aligned to the IGS05 using (left) constant velocities (IGS05@2000 + VEL) and (right) IGS weekly positions (igsyyPwwww) as reference coordinates for the GPS week 1505.

of the loosely constrained solutions is always deformed, when the geodetic datum is realised. This deformation is particularly large, when linear movements (constant velocities) at the reference stations are assumed. Mean RMS residuals for the period between January 2000 and December 2009 indicate that the largest distortions (more than 8 mm) appear at the fiducial points (Fig. 1.2.4); this is a consequence of constraining a seasonal signal to a linear trend. The regional solutions based on the IGS weekly coordinates present rather large residuals (around 6 mm) at a few reference stations, but the deformation of the network geometry is smaller than using IGS05@2000 + VEL. Particularly, residuals larger than 8 mm disappear (Fig. 1.2.4, right).

In conclusion, the use of constant velocities for extrapolating reference positions (e.g., ignoring seasonal effects) causes errors on station coordinates (especially in the up component) as large as 20 mm (Fig. 1.2.3). Applying IGS weekly positions for the datum realisation in weekly solutions of reference networks (as it is done by the weekly SIRGAS reference frame computation) ensures a better compatibility between these networks and the GNSS orbits (Fig. 1.2.4, right), and allows users to exploit the full precision of the GNSS measurements.

The precise modelling of seasonal signals included in the station position time series remains a challenge in the (global, regional, and local) reference frame computations.

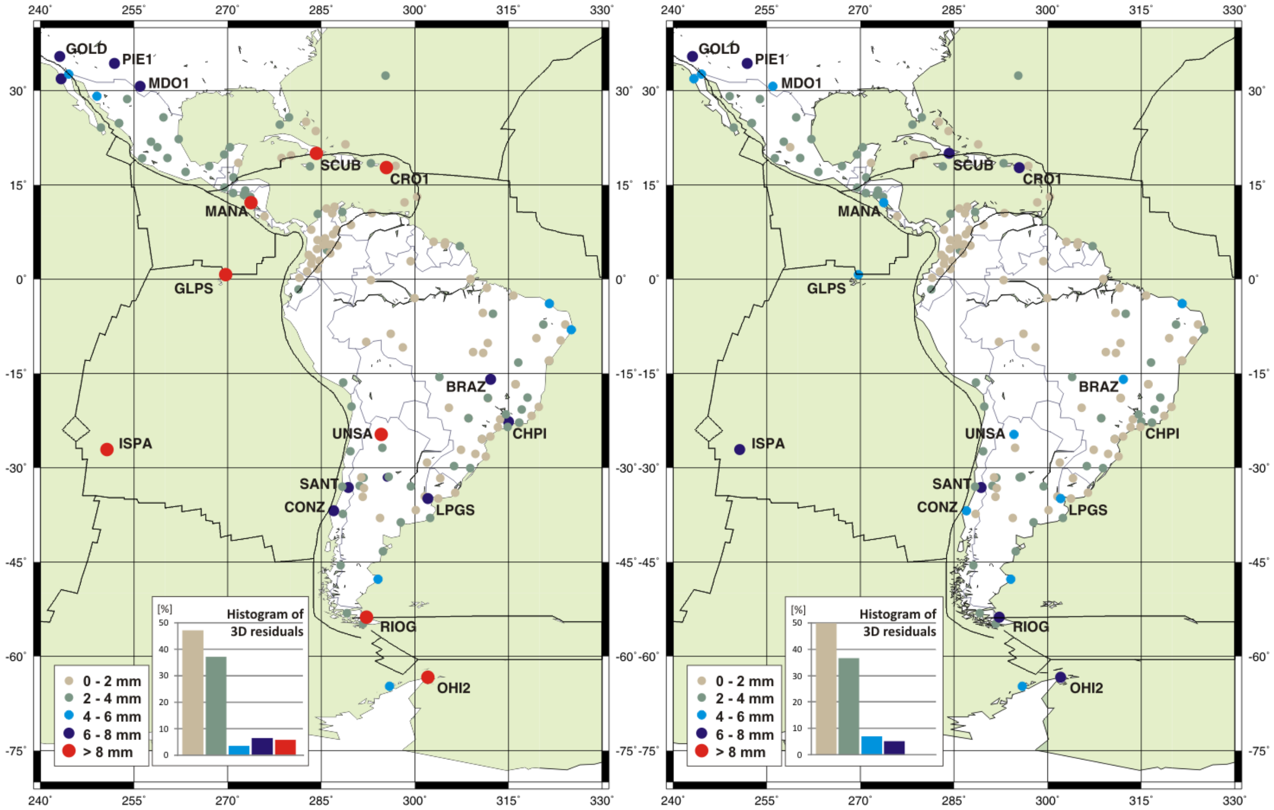


Fig. 1.2.4. 3D residuals after comparing the loosely constrained (non-deformed) weekly solutions with the weekly solutions aligned to the IGS05 using (left) constant velocities (IGS05@2000 + VEL) and (right) IGS weekly positions. Mean RMS values for the period between January 2000 (GPS week 1043) and January 2010 (GPS week 1564).

Related publications:

Sánchez L., Seemüller W., Seitz M., Forberg B., Leismüller F., Arenz H.: SIRGAS: das Bezugssystem für Lateinamerika und die Karibik. Zeitschrift für Vermessungswesen, 135, Heft 2, 80-86, 2010

Sánchez L., Seemüller W.: Report of the SIRGAS Analysis Centre at DGFI. SIRGAS 2010 General Meeting. www.sirgas.org, 2010

1.3 Fundamentals of physical parameter determination

GOCE Gravity Gradient Preprocessing

DGFI is involved in the preprocessing of the GOCE gravity gradients, in close collaboration with TU Munich (IAPG), as part of the data processing for the GOCE High-level Processing Facility (HPF). The gravity gradient preprocessing includes corrections for temporal gravity field variations, outlier detection, gravity gradient external calibration, as well as the rotation of the gravity gradient tensor from the instrument frame to the local north-oriented frame (LNOF), which is a reference frame directly connected with the Earth.

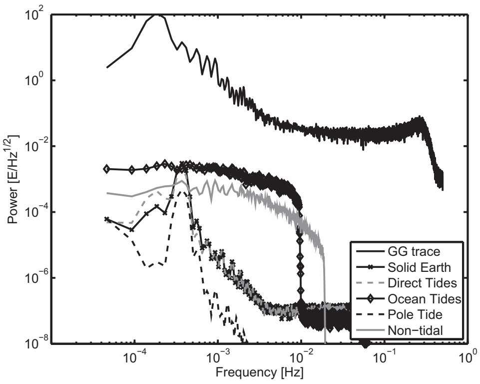


Fig. 1.3.1: Spectral density of one day (1 November 2009) of the gravity gradient trace and radial gravity gradient temporal signals (Bouman et al. 2010a)

Figure 1.3.1 shows the spectral densities of the gravity gradient trace and the different radial gravity gradient temporal signals that are applied to the real GOCE data (Bouman et al. 2010a). The temporal signals are relatively small at gravity gradient level and are well below the gravity gradient errors for all frequencies.

The GOCE gravity gradients are compared with external gravity data for calibration and validation purposes. Figure 1.3.2 shows the weekly gravity gradient scale factors, for all six gravity gradients, determined using a state-of-the-art global gravity field model as reference. In general, the scale factors are close to one as expected.

The rotation of the GOCE gravity gradients from the instrument frame to the LNOF or other local frames requires special attention. On the one hand, because of the gradient construction im-

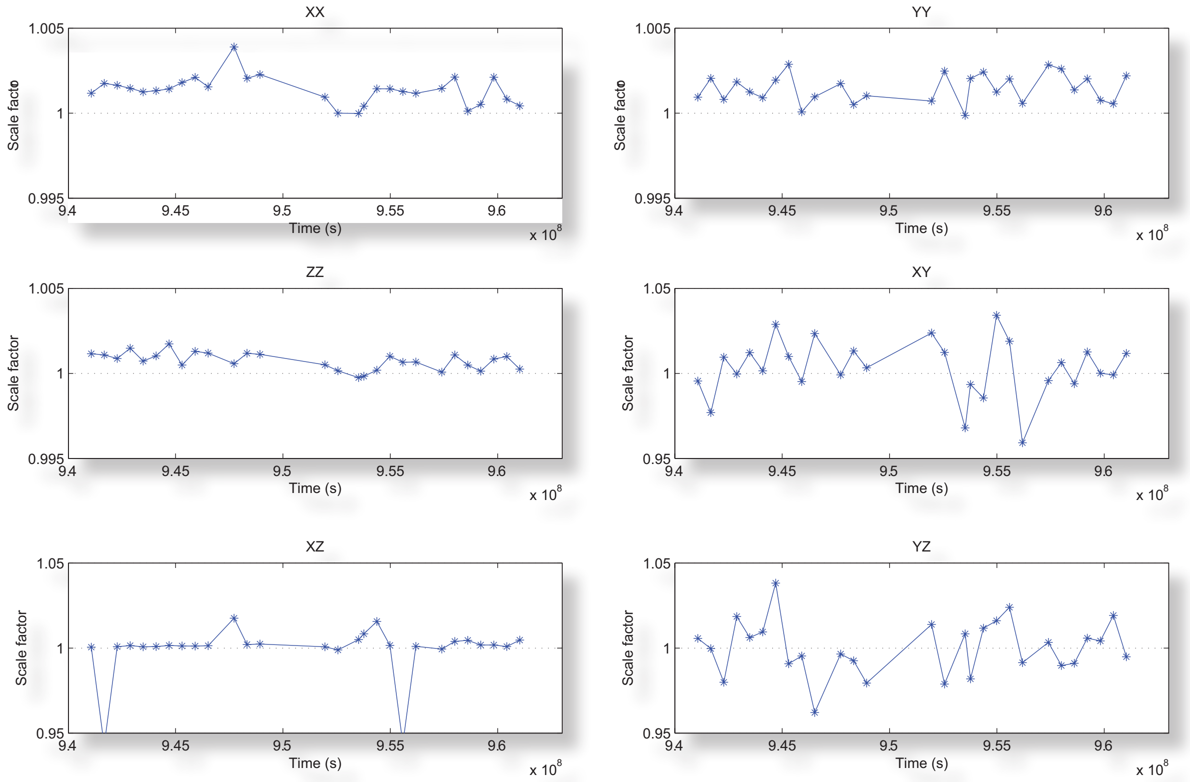


Fig. 1.3.2: History of the weekly scale factors calculated by the external calibration using a global gravity field model. Period 31 October 2009 – 26 June 2010 (Bouman et al. 2010a)

posed by the on-ground testing four of the six gravity gradients are very accurate (V_{XX}, V_{YY}, V_{ZZ}, V_{XZ}) whereas the other two are less accurate (V_{XY}, V_{YZ}). On the other hand, the accuracy of the accurate gravity gradients decreases below the measurement bandwidth (MBW) which ranges from 5 mHz to 0.1 Hz. Both effects degrade the accuracy of all gradients in the rotated frame. To circumvent this problem, the less accurate gravity gradients are replaced by model values, for example from a GOCE-only gravity field model, while also the gravity gradient signal of the accurate gravity gradients below the MBW is replaced by model signal.

Determination of the optimal cut-on frequency

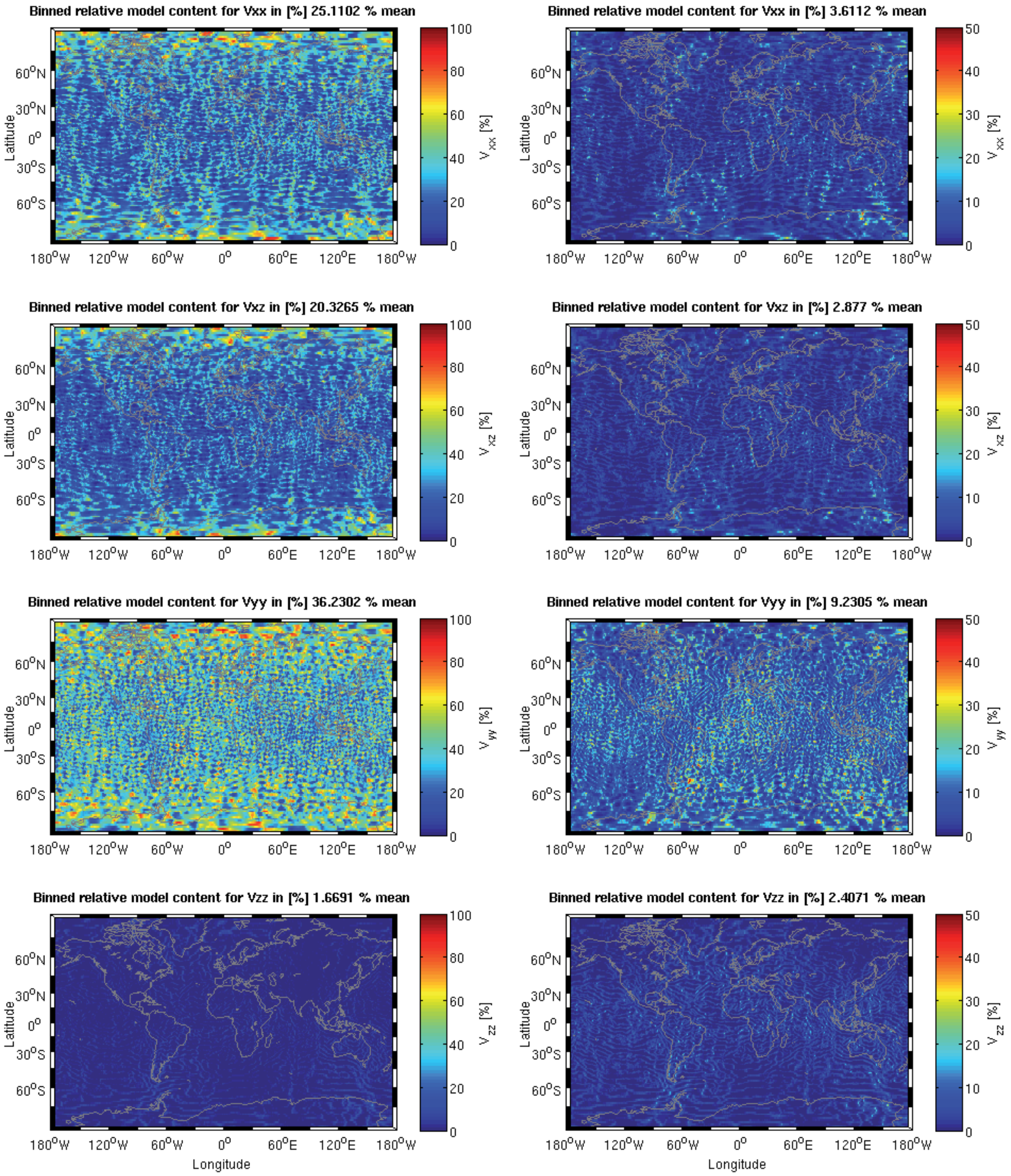
As we want to extract the maximum amount of information out of the GOCE gravity gradients, one issue we address is how to determine the optimal cut-on frequency for the accurate gravity gradients. The MBW of these gradients has been defined to be between 5 mHz and 0.1 Hz. Analysis of the actual gradiometer performance, however, suggests that the lower bound of the MBW – the cut-on frequency – was chosen too high. We developed a method to determine the optimal cut-on frequency for each gravity gradient as follows. For a certain cut-on frequency the gravity gradient signal content is determined and the gravity gradient error is assessed. Both signal and error vary with cut-on frequency, and the frequency that maximizes the total signal-to-noise ratio is defined to be the optimal cut-on frequency. The error of the gravity gradients is assessed by taking the difference between GOCE and model gravity gradients in spatial or spectral domain, or by using gravity gradient error Power Spectrum Densities (PSDs) if available.

Table 1.3.1 shows the optimal cut-on frequency for the four accurate gravity gradients, and for different ways to assess the gravity gradient errors. In general, the optimal cut-on frequency for one gravity gradient does not depend on the used gravity field model or the error assessment. EGM96 is an exception, probably because it is not a state-of-the-art gravity field model. The lower bound of the MBW is 3 – 4 mHz, which is below the pre-mission defined value of 5 mHz.

The GOCE gravity gradients in the instrument frame are band-pass filtered using the cut-on frequencies determined above and are combined with model gravity gradients. These combined gravity gradients can be rotated to arbitrary reference frames. It is of interest to determine how much the GOCE gravity gradients and how much the model gravity gradients contribute to the

Tab. 1.3.1: Optimal cut-on frequency in mHz derived by 3 different methods for different reference models

	GOCE-QL			ITG-GRACE			EIGEN5C			EGM2008			EGM96		
	spatial	spectral	PSD	spatial	spectral	PSD	spatial	spectral	PSD	spatial	spectral	PSD	spatial	spectral	PSD
V_{XX}	3.5	3.5	3.5	3.9	3.7	3.7	3.5	3.5	3.5	3.7	3.7	3.7	1.5	1.5	1.5
V_{YY}	3.1	3.1	3.1	3.3	3.1	3.1	3.0	2.8	3.0	3.1	3.0	3.0	1.5	1.3	1.3
V_{ZZ}	3.0	2.8	2.8	2.8	2.8	2.8	2.6	2.6	2.6	2.8	2.8	2.8	1.2	1.1	1.1
V_{XZ}	5.6	5.2	-	3.5	3.7	-	3.3	3.7	-	3.5	3.7	-	2.6	2.6	-



Binned relative model content for Vxx in [%] 25.1102 % mean

Binned relative model content for Vxx in [%] 3.6112 % mean

Binned relative model content for Vxz in [%] 20.3265 % mean

Binned relative model content for Vxz in [%] 2.877 % mean

Binned relative model content for Vyy in [%] 36.2302 % mean

Binned relative model content for Vyy in [%] 9.2305 % mean

Binned relative model content for Vzz in [%] 1.6691 % mean

Binned relative model content for Vzz in [%] 2.4071 % mean

Fig. 1.3.3: Relative model content of rotated GOCE gravity gradients in the MBW. Left column: gravity gradients in the LNOF; right column: gravity gradients in the LORF. From top to bottom V_{XX}, V_{XZ}, V_{YY} *and* V_{ZZ} *are shown*

gravity gradients in the rotated frame. Two frames of interest are the LNOF, as discussed above, and the local orbital reference frame (LORF). The X-axis of the LORF is in the flight direction of the satellite, the Z-axis is in almost radial direction and the Y-axis is orthogonal to the orbital plane. The instrument frame is kept aligned as good as possible with the LORF. Figure 1.3.3 shows the relative model content for different gravity gradients in LNOF and LORF. As the rotations from instrument frame to

LORF are smaller than from instrument frame to LNOF, also the model contribution in LORF is smaller. V_{ZZ} has the smallest model contribution – about 2 % - as the Z-axes of the 3 reference frames almost coincide.

Deflection of the vertical and gravity gradients

The vertical gradient of gravity anomaly and gravity disturbance can be related to horizontal first derivatives of deflection of the vertical or second derivatives of geoidal undulations. For these simplified relations different terms are neglected depending on the specific relation, see Table 1.3.2. We assess the size of the neglected terms with respect to the vertical gravity gradients. As an example Figure 1.3.4 shows the effects of neglecting the two significant terms (terms 2 and 3 in Table 1.3.2) for the Arctic region. We also study Antarctica, the Himalaya, the Alps and two oceanic regions (South Atlantic and South West Pacific). The conclusion is that the signal RMS of the neglected terms is in general small with respect to the vertical gravity gradient, but that at individual locations the neglected terms are not necessarily small with respect to the vertical gravity gradient because the spatial pattern of the different signals differs. Using the simplified relations may therefore lead to systematic errors that cannot be neglected (Bouman 2010).

Tab. 1.3.2: Simplified relations between horizontal second derivatives of geoid heights and first derivatives of the deflection of the vertical on the one hand, and the vertical derivative of gravity anomaly or gravity disturbance on the other hand.

Anomaly or disturbance	Simplified relation	Neglected terms			References
		$2\gamma R^{-2}N$	$2\gamma R^{-1}N_r$	$2\gamma R^{-1}\xi\tan\phi$	
Δg_r	$= \gamma\,(N_{uu} + N_{vv})$	yes	no	no	Bouman (2010)
δg_r		no	yes	no	Rummel and Haagmans (1991)
Δg_r	$= \gamma\,(\xi_{uu} + \eta_{vv})$	yes	no	yes	Hofmann-Wellenhof & Moritz (2005)
δg_r		no	yes	yes	Sandwell and Smith (1997)

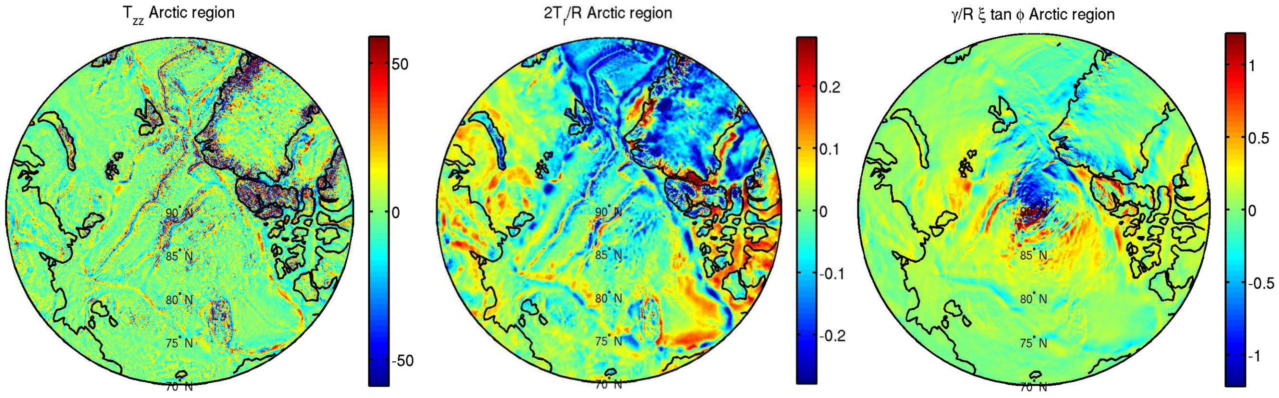


Fig. 1.3.4: From left to right T_{zz}, $2T_r/R$ and $\gamma R^{-1}\xi\tan\phi$ [E] from EGM2008, North Pole region. Minimum latitude is 70 degrees north. Colour scales T_{zz} and $2T_r/R$ saturated at ± three times the signal RMS and at one time the signal RMS for $\gamma R^{-1}\xi\tan\phi$.

Operator Software Impact (OSI)

The equatorial excitation functions $\chi_1(t)$ and $\chi_2(t)$ can be separated into a matter term $\chi_1^{\mathrm{mass}}(t)$, $\chi_2^{\mathrm{mass}}(t)$ and a motion term $\chi_1^{\mathrm{motion}}(t)$, $\chi_2^{\mathrm{motion}}(t)$ term, respectively. Whereas the latter are caused by moving masses, the matter terms are the consequences of mass changes within the Earth system. They can be calculated by means of the degree 2 spherical harmonic coefficients $\Delta C_{2,1}(t)$ and $\Delta S_{2,1}(t)$ of the gravitational potential. Several processing centers (PC), e.g. GFZ, CSR, JPL, IGG or DEOS provide gravitational potential models from GRACE – indicated in the following by the index $i \in \{1,\ldots,I\}$. Figure 1.3.5 shows exemplarily the excitation function

$$\chi_{2,\mathrm{i}}^{\mathrm{mass}}(t) = \chi_2^{\mathrm{mass}}(t) + \Delta\chi_{2,\mathrm{i}}^{\mathrm{mass}}(t),$$

Combined estimation of the excitation functions considering an extended stochastic model

wherein $\chi_2^{\mathrm{mass}}(t)$ is the PC independent excitation function and $\Delta\chi_{2,\mathrm{i}}^{\mathrm{mass}}(t)$ an additional term caused by different parametrizations, software packages, models, etc. These influences can be summarized as operator-software impact (OSI) parameter; see Kutterer et al. (2009). For the further investigation we assume for the expectation value $\mathrm{E}(\Delta\chi_{2,\mathrm{i}}^{\mathrm{mass}}) = 0$, i.e. systematical differences are not considered. Defining the $N\times 1$ observation vector

$$\mathbf{y}_\mathrm{i} = \mathbf{y} + \Delta\mathbf{y}_\mathrm{i} = (\chi_{2,\mathrm{i}}^{\mathrm{mass}}(t_\mathrm{k})) \quad \text{with} \quad k = 1,\ldots,N$$

we define the Gauss Markov model

$$\mathrm{E}(\mathbf{y}_\mathrm{i}) = \mathbf{I}_\mathrm{N}\boldsymbol{\beta} \ \text{ with } \mathrm{C}(\mathbf{y}_\mathrm{i},\mathbf{y}_\mathrm{j}) = \sigma^2 \left(\mathbf{Q}_\mathrm{yy} + \delta_\mathrm{i,j}\mathbf{Q}_{\Delta y_i \Delta y_j}\right),$$

wherein $\mathbf{I}_\mathrm{N}$ is the $N\times N$ unit matrix and $\boldsymbol{\beta} = (\chi_2^{\mathrm{mass}}(t_\mathrm{k}))$ the $N\times 1$ vector of the unknown excitation functions at time t_k. Note, for each PC we introduce the same mathematical model $\mathbf{I}_\mathrm{N}\boldsymbol{\beta}$. The covariance matrix $\mathrm{D}(\mathbf{y}) = \sigma^2\mathbf{Q}_\mathrm{yy}$ of the real GRACE measurements is assumed to be known up to the unknown variance factor σ^2. For the covariance matrix $\mathbf{Q}_{\Delta y_i \Delta y_j}$ various approaches can be chosen. With $I{\cdot}N = K$ we introduce the $K\times 1$ vector $\bar{\mathbf{y}} = [\mathbf{y}_1,\ldots,\mathbf{y}_\mathrm{I}]^\mathrm{T}$ as well as the $K\times N$ matrix $\bar{\mathbf{X}} = [\mathbf{I}_\mathrm{N},\ldots,\mathbf{I}_\mathrm{N}]^\mathrm{T}$ and obtain the combined model

$$\mathrm{E}(\bar{\mathbf{y}}) = \bar{\mathbf{X}}\boldsymbol{\beta} \quad \text{with} \quad \mathrm{D}(\bar{\mathbf{y}}) = \sigma^2\mathbf{Q}_{\bar{y}\bar{y}} = (\sigma^2\mathbf{Q}_{y_i y_j}). \quad (1)$$

In case of traditional combination techniques the covariance matrices $\mathbf{Q}_{y_i y_j}$ for $i \neq j$ are set to zero, i.e. correlations between different PCs are neglected. We consider two traditional methods, namely

1. weighted average: $\mathbf{Q}_{y_i y_j} = \mathrm{diag}(\sigma_1^2,\ldots,\sigma_N^2)_\mathrm{i}$ (diagonal),
2. weighted average with variance component estimation: $\mathbf{Q}_{y_i y_i} = \alpha_\mathrm{i}^2 {\cdot} \mathrm{diag}(\sigma_1^2,\ldots,\sigma_N^2)_\mathrm{i}$ (var comp).

In case of OSI combination strategies generally all covariance matrices $\mathbf{Q}_{y_i y_j}$ are considered. We introduce the two choices

3. common $\bar{\alpha}^2$: $\mathbf{Q}_{y_i y_i} = \bar{\alpha}^2 {\cdot} \mathrm{diag}(\sigma_1^2,\ldots,\sigma_N^2)_\mathrm{i} + \mathbf{Q}_\mathrm{yy}$ and
   $\mathbf{Q}_{y_i y_j} = \mathbf{Q}_\mathrm{yy}$ (com alpha),

4. PC dependent α_i^2: $\mathbf{Q}_{y_iy_i} = \alpha_i^2\cdot\mathrm{diag}(\sigma_1^2,\ldots,\sigma_N^2)_i + \mathbf{Q}_{yy}$ and $\mathbf{Q}_{y_iy_j} = \mathbf{Q}_{yy}$ (ind alpha).

The PC dependent quantities α_i^2 and $\bar{\alpha}^2$ are calculable according to Fang (2007). The covariance matrix $\mathbf{Q}_{yy}$ can be approximated by the average of the covariance matrices $\mathrm{diag}(\sigma_1^2,\ldots,\sigma_N^2)_i$. Figure 1.3.5 (bottom) shows the empirical standard deviations $\sigma_i(t_k) = \sigma_{k,i}$ with $k = 1,\ldots, N$ of the $I = 5$ PCs.

The least squares solution of the Gauss Markov model (1) reads

$$\hat{\boldsymbol{\beta}} = (\bar{\mathbf{X}}^{T}\,\mathbf{P}_{\bar{y}\bar{y}}\,\bar{\mathbf{X}})^{-1}\,\bar{\mathbf{X}}^{T}\,\mathbf{P}_{\bar{y}\bar{y}}\,\bar{\mathbf{y}} \qquad (2)$$

with $\mathbf{P}_{\bar{y}\bar{y}} = \mathbf{Q}_{\bar{y}\bar{y}}^{-1}$. Figure 1.3.6 presents both results from the estimated excitation function values according to Eq. (2) and related to the 4 combination techniques introduced before (top) and the corresponding estimated standard deviations (bottom). The comparison of the bottom panels of the Figs. 1.3.5 and 1.3.6 shows that the estimated accuracies of the OSI solutions (approaches 3 and 4) are much more realistic than the corresponding accuracies of the traditional approaches, which are clearly too optimistic.

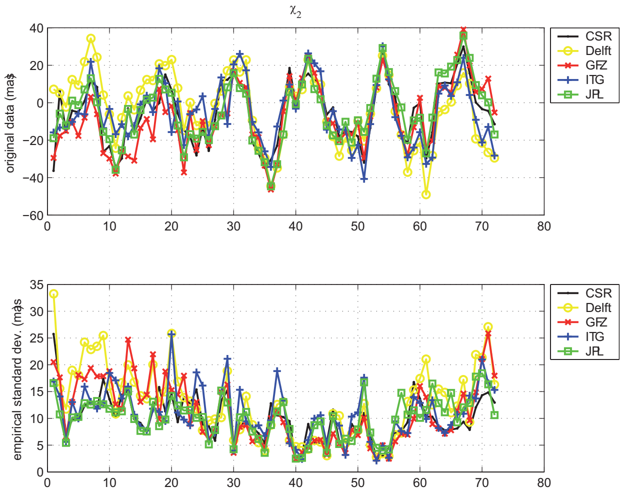


Fig. 1.3.5: Monthly time series of the integral excitation function $\chi_{2,i}^{mass}(t_k)$ calculated from the degree 2 spherical harmonic coefficients from the five GRACE processing centers (top); empirical standard deviations $\sigma_i(t_k)$ of the time series (bottom).

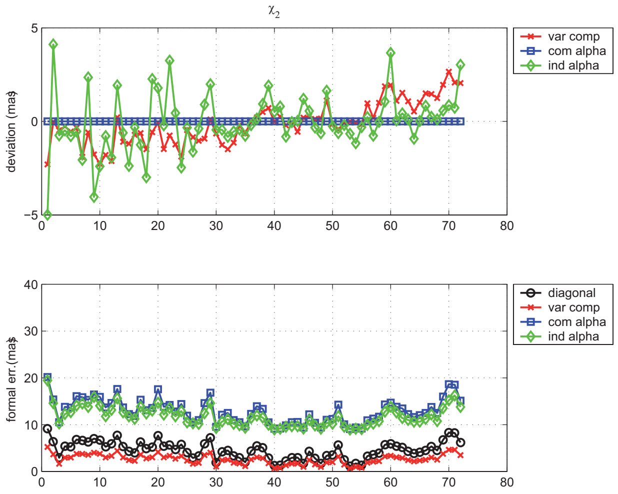


Fig. 1.3.6: Deviations of the estimated parameters $\hat{\boldsymbol{\beta}}$ of the approaches 2,3 and 4 w.r.t. the first approach (top); estimated standard deviations of the estimations $\hat{\boldsymbol{\beta}}$ according to the four approaches (bottom).

Related publications:

Bouman J (2010) Relation between geoidal undulation, deflection of the vertical and vertical gravity gradient revisited, submitted to Journal of Geodesy

Bouman J, Fiorot S, Fuchs M, Gruber T, Schrama E, Tscherning CC, Veicherts M, Visser P (2010a) GOCE Gravity Gradients along the Orbit, submitted to Journal of Geodesy

Rispens SM, Bouman J (2010) External calibration of GOCE accelerations improves derived gravity gradients, Journal of Geodetic Science, accepted

1.4 Combination of geometric and gravimetric observations

The combination of geometric and gravimetric observations aims at the common determination of time-dependent parameters of the Earth's rotation, figure and gravity field within a global geometric and gravimetric reference system.

In 2010 the work for the combination of geometric and gravimetric observations concentrated on two aspects: (1) Vertical datum unification and empirical evaluation of the approaches for South America and (2) the analysis and combination of geometric and gravimetric observations in context with the Haiti Earthquake in January 2010.

Vertical datum unification

A main objective of a global vertical reference system is satisfying the basic equation $h = H + N$ worldwide, i.e. it shall support the precise combination of geometrical (ellipsoidal) and physical (orthometric or normal) heights on a global scale. This objective requires the definition and realisation of two components within the vertical reference system: a geometrical one, given by a level ellipsoid as a reference surface and ellipsoidal heights; and a physical one, defined by a fixed W_0 value as zero height level and geopotential numbers. The transformation of the geopotential numbers into physical heights and the geometrical representation of the surface W_0 = const (geoid determination) is a matter of the realization. In this way, both kinds of physical (orthometric and normal) heights and zero-height surfaces (geoid and quasi-geoid) refer to the same level.

The physical reference level

Any (arbitrarily) selected W_0 value can be introduced as a reference level, because the primary observables in the height determination are potential differences. The present challenge is an appropriate realisation of this value, i.e. the Earth's geopotential surface representing W_0 must be precisely ascertained everywhere where a vertical datum exists or is needed. In the last decade, many studies attempted to determine the W_0 value that best fits the mean sea surface. In general, those studies are based on the combination of global geopotential models (GGM) derived from the satellite-based gravity field missions, the geometrical reference (i.e. ITRF), and the improved geometrical representation of the mean sea surface

Tab. 1.4.1 Different methods for assessing W_0

Definition	Description	Examples
$W_0 = W_0^i$	*W_0 is the geopotential value of an arbitrarily chosen vertical datum (tide gauge).*	*European Vertical Reference System,* *W_0 at "Normaal Amsterdams Peil" (NAP) = U0 (GRS80):* *W_0 = 62 636 860,850 m^2s^{-2} (Ihde, Augath 2002)*
$W_0 = U_0$	*W_0 is identical to an a priori given ellipsoidal potential U_0, which is a function of GM, ω, a, J_2. (Best fitting ellipsoid).*	*$W_0 = U_0$ = 62 636 860,850 m^2s^{-2} (GRS80)* *856,88 (Rapp 1995)*
$\int_{S_0} (W - W_0)^2 \, dS_0 \rightarrow min$ S_0 global ocean surface	*W_0 is the average of the geopotential values over the sea surface in a totally undisturbed state sampled globally.*	*W_0 = 62 636 857,5 (Nesvorny and Sima 1994)* *856,5 (Ries 1995)* *856,0 (Bursa et al. 2002)* *853,4 (Sánchez 2005)* *854,7 (Bursa el al. 2006)*
$W_0 = U_0 + \delta W$	*W_0 corresponds to the level surface in relation to which the DOT has a vanishing zero degree harmonic in solutions of the gravity boundary value problem.*	*W_0 = 62 636 853,0 (Sánchez 2009)*

(MSS) through satellite altimetry. There are large differences between the computed values (Table 1.4.1), which basically depend on the applied methodology and the analysis of the observational data. These differences reveal the necessity of suitable conventions that guarantee the uniqueness, the reliability, and the repeatability of the reference level W_0 to be adopted globally. This subject is discussed within the International Association of Geodesy through the Inter-Commission Project 1.2 "Vertical Reference Frames", in which DGFI participates actively. For the next IUGG General Assembly in June 2011, a compendium about conventions, standards, and procedures will be prepared to be applied for the definition and realisation of a conventional global vertical reference system. It will also comprise the transformation of the existing vertical datums to the global one.

Datum unification in practice

The realisation of a global vertical reference system includes the unification (transformation) of the existing height datums into the global one. In the last two years, a strategy was developed for the consistent combination of geometric and gravimetric parameters in order to get a realisation of the basic equation $h = H + N$ in a global frame. The fundamentals of this strategy are:

a. physical connection (levelling, satellite altimetry) of the classical height datums to identify their discrepancies,
b. joint analysis of satellite altimetry data and tide gauge records to obtain the sea level variations at each reference point of the classical height datums,
c. analyses of GNSS time series observed at reference tide gauges for separating crustal movements and sea level changes, and
d. combination of GNSS positioning (referred to a precise, homogeneously distributed ITRF) with geopotential numbers and anomalous potential values at the local vertical datums for estimating the relationships between individual vertical levels and the global one.

The final transformation terms for each individual height system are then obtained by a common adjustment of the observation equations provided by each of these methods.

Empirical evaluation in South America

In order to evaluate this methodology, computations were carried out in the frame of the Working Group III of SIRGAS (Vertical Datum), established in 1998. Its main tasks are the collection and preparation of observed level differences for a continental adjustment of the fundamental vertical networks in terms of geopotential numbers. The results presented here are based on the available data and are supported by simulations.

The main characteristics of the vertical coordinates in South America are:

- There are 15 height datums, each one referring to individual tide gauges with mean sea reference levels averaged over different time periods.
- In general, levelling is not corrected for gravity.

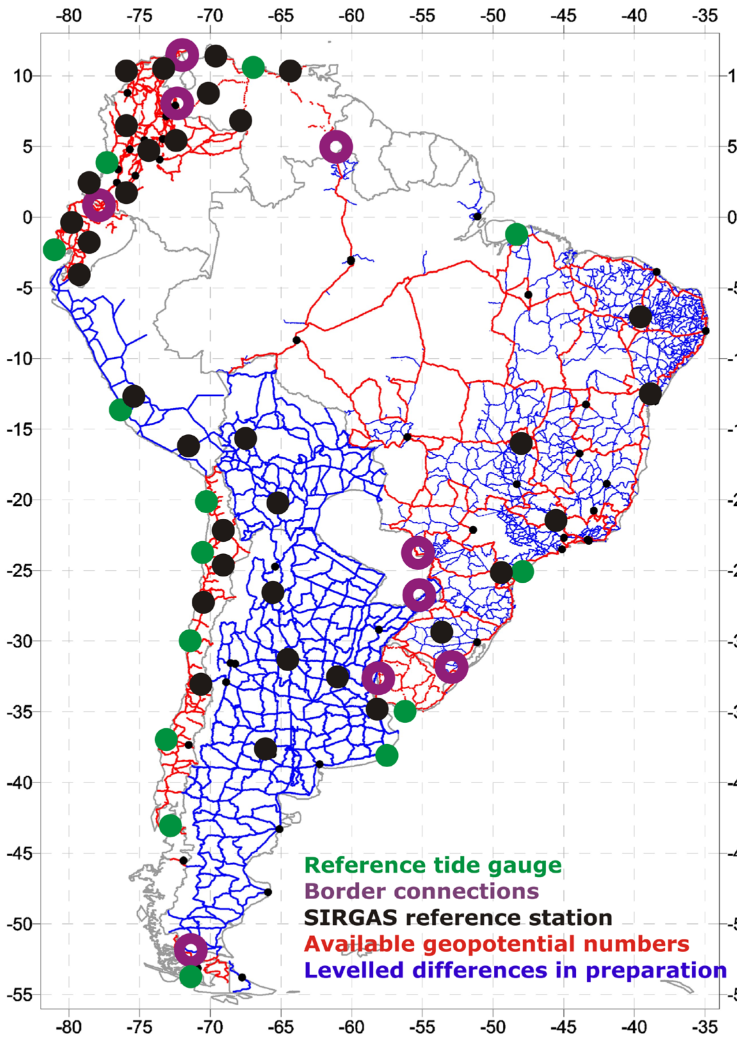


Fig. 1.4.1 Input data for a first approximation to the unification of vertical datums in South America

- Some neighbouring levelling networks are difficult to connect in particular in the Amazon jungle area.
- Vertical networks are adjusted in individual clusters.
- Vertical movements of the Earth crust and sea surface are not taken into account.

Input data

The input data (Fig. 1.4.1) available for a first application are:

- Satellite altimetry observations, tide gauge registrations, and GNSS observations at 14 reference tide gauges.
- GNSS positions, geopotential numbers, and anomalous potential estimates at 37 SIRGAS reference stations.
- Eight network connections between neighbouring states including GNSS positions, geopotential numbers, and known anomalous potential values.

In total, there are 73 observation equations with 15 unknown vertical datum offsets. Fourteen of them correspond to reference tide gauges and the remaining one to the reference level in Paraguay (without tide gauge).

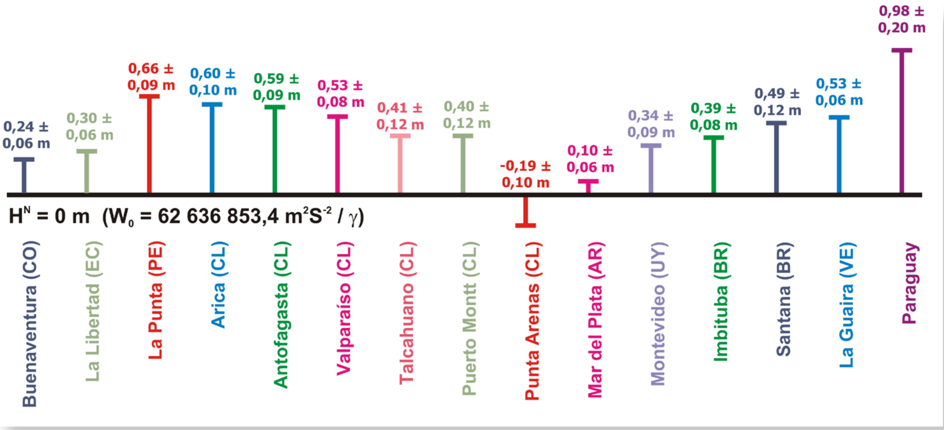


Fig. 1.4.2 Preliminary estimates of vertical datum offsets for South America

Fig. 1.4.2 shows the preliminary results. The accuracy of the estimated datum offsets is at the decimetre level. The offset for Paraguay has the largest uncertainty because there is neither a reference tide gauge nor a SIRGAS station in this country. Results are in reasonable agreement with the dynamic ocean topography estimated at the reference tide gauges. This agreement may be a consequence of the relatively large weights attributed to the observations at the tide gauges. Differences derived from levelling are weighted inversely proportional to the distance to the reference tide gauge.

The next steps for the datum unification are:

- The consistency of physical heights must be improved; i.e. all levelling results are to be adjusted in a common continental block and in terms of geopotential numbers;
- More SIRGAS reference stations and more levelling connections between countries must be established in order to get more observation equations, i.e. to increase redundancy;
- The variation of the station positions with time must be taken into account; all heights (*h, H, N*, DOT) must be reduced to a common reference epoch;
- Once, more reliable datum discrepancies are estimated, all height-related parameters must be re-determined and the analysis procedure must be repeated.

Haiti 12 January 2010 Earthquake

The 12 January 2010 Haiti earthquake had an estimated moment magnitude of 7.0 and a fault size area of 600 km^2. Measurements from the global seismic network, from sites of the Global Positioning System (GPS) and gravimeter observations have been used to infer the co-seismic slip history of this event. In addition, the earthquake caused a permanent change of the mass distribution within the Earth, and the associated change of the Earth's gravity field may be measurable from the gravity gradiometer on-board GOCE. Figure 1.4.3 displays the surface deformation predicted from the CalTech (California Institute of Technology) slip model. The vertical displacement of the terrain is up to a few meters. As the horizontal displacement is mainly in East-West direction, one may expect that primarily the North-South gravity gradient, V_{XX}, is affected and to a lesser extent the gravity gradient

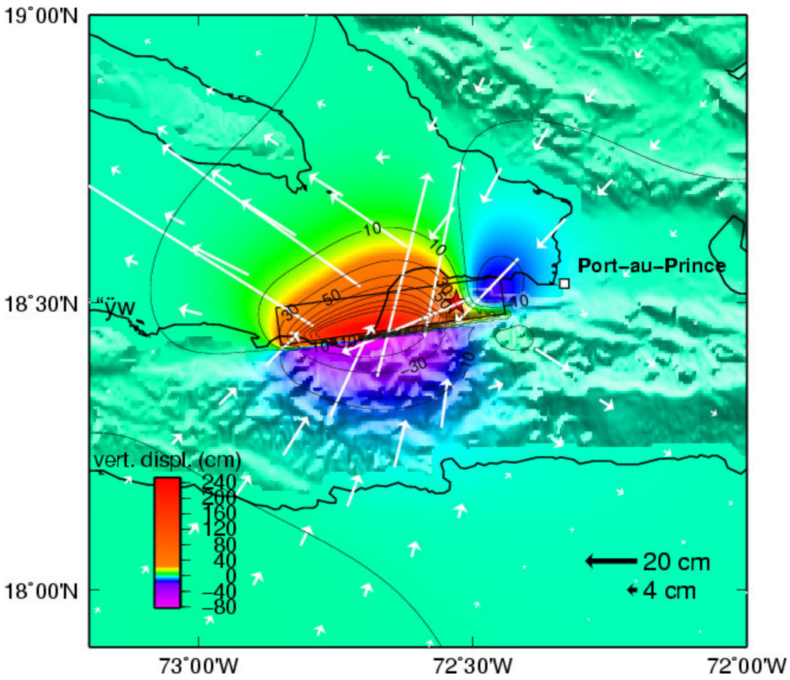
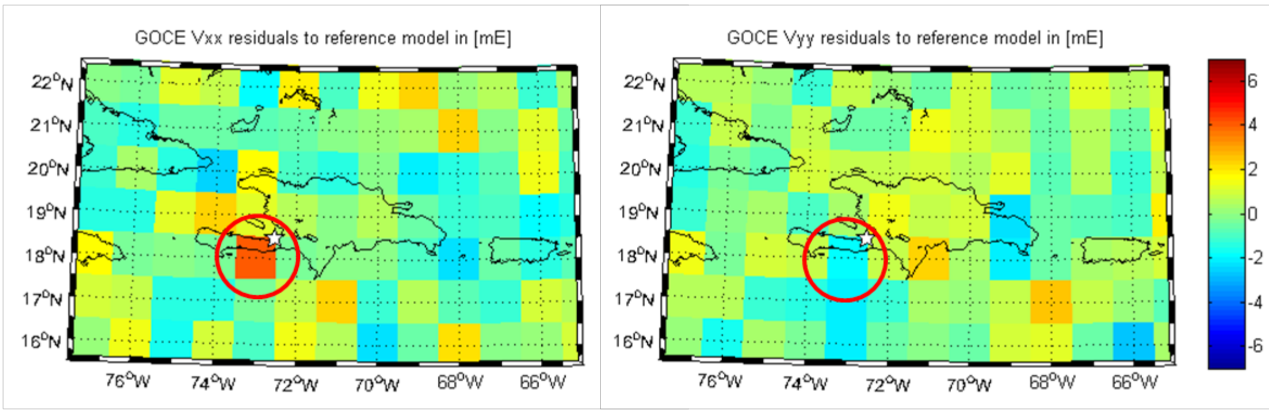


Fig. 1.4.3 : Surface deformation predicted from CalTech slip model (www.tectonics.caltech.edu/slip_history/2010_haiti/). The vertical component of displacement is given by the colour scale and the horizontal motion by the arrows.

V_{YY}. (We also analysed V_{ZZ}, but these data were too noisy.) Figure 1.4.4 shows the differences between two months of GOCE gravity gradients collected after the earthquake and ITG-GRACE2010 model values, based on data acquired before the earthquake. The differences were averaged in bins of 1 degree and the bin with the earthquake location is indicated. At first sight, the figure seems to confirm that the earthquake is visible in the gravity gradient residuals. However, the results are quite noisy and the larger V_{XX} residual at the earthquake location may just be a coincidence by accident. More detailed studies are required to validate the result.

Fig. 1.4.4: V_{XX} (left) and V_{YY} residuals (right) between GOCE and ITG-GRACE2010.


GOCE Vxx residuals to reference model in [mE]

GOCE Vyy residuals to reference model in [mE]

Related publication:

Bouman J., Bosch W., Goebel G., Müller H., Sánchez L., Schmidt M., Sebera J.: Das Schwerefeld der Erde - Messen, Darstellen und Auswerten. Zeitschrift für Vermessungswesen, 135, Heft 2, 87-92, 2010

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

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

2.1 Models of the gravity field

Recent and in particular current satellite gravity missions, such as GRACE and GOCE, provide important contributions to Earth gravity field modeling; these satellite-only models can be supplemented by airborne and terrestrial gravity data. The most common representation of the gravitational potential is the series expansion in terms of spherical harmonics. This representation has the disadvantages that it is difficult to represent small spatial details and it cannot handle data gaps appropriately. An alternative approach is based on a multi-scale representation (MSR), which allows to exploit the highest degree of information out of the different measurement techniques mentioned before.

The MSR provides a simple hierarchical framework for identifying the properties of a signal. The procedure starts from the measurements, performs the decomposition into frequency-dependent detail signals by applying a pyramidal algorithm and allows for data compression and filtering, i.e. data manipulations. Since July 2009 a DGFI project is funded and contributed by the Bundeswehr Geoinformation Office (Amt für Geoinformation der Bundeswehr; AGeoBW) in Euskirchen, Germany. The main subject of this project is regional gravity field modeling based on the MSR.

point grids for regional gravity fields

The basic idea of regional gravity field modeling is to use a set of localizing quasi-compact base functions which might be radial symmetric. These base functions are distributed along a predefined point grid, e.g. a Reuter grid (cf. Figure 2.1.2, left panel). Although regional gravity field modeling in terms of radial base functions is theoretically not depending on the choice of the point grid for the radial base functions, numerical investigations show a contrary behaviour. Consequently, intensive studies have been

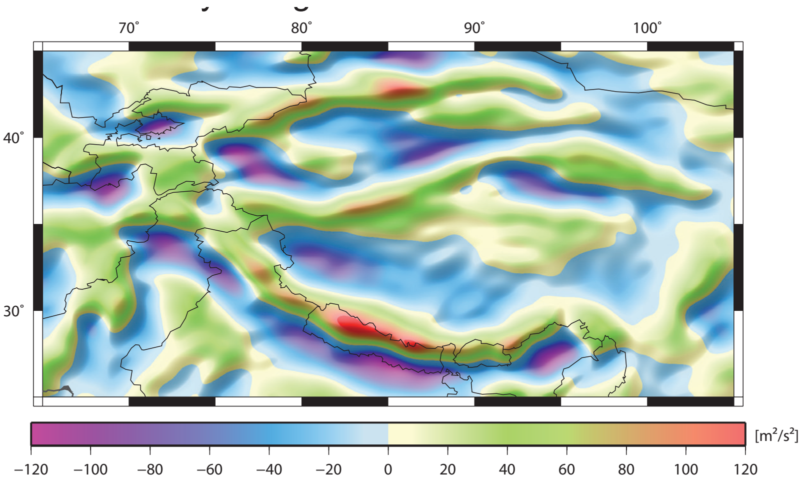


Fig. 2.1.1: Potential difference observations from EGM2008 between degree values 50 to 250 in the Himalaya

started recently on the optimization of the point grids (cf. Figure 2.1.2); for more details see Schall et al. (poster at EGU 2010).

In several studies at DGFI the gravitational potential was estimated from observations generated for selected regions from given gravity field models, e.g. EGM2008 within a closed-loop simulation. As an example a set of potential difference observations between degree 50 and degree 250 was created on a regular grid over the Himalayan region (Figure. 2.1.1). We identify the radial base functions with the reproducing kernel of the corresponding Hilbert space. The maximum degree value of the reproducing kernel must be equal or larger than the maximum degree value of the scaling function of highest resolution level J we use for our representation. Since we decide to use a level-8 Blackman scaling function with degree values n until $n_{\max} = 2^8 - 1 = 255$ we choose a reproducing kernel with a maximum degree value of 270. Next, a point grid for the reproducing kernel functions has to be selected in such a way that globally more than or at least $271^2 = 73{,}441$ points exist; such a grid is called admissible. To reduce boundary effects in a regional application, the corresponding regional grid could be extended w.r.t. the data field by an outer zone. The width of the outer zone is defined by $\eta_J = \lceil 180°/2^{J-1} \rceil$ according to Nyquist criteria; $\lceil \ \rceil$ means the operator to round float values to the nearest integer towards plus infinity. For $J = 8$ we obtain a width of $\eta_8 = \lceil 1.406° \rceil = 2°$. In the following we use three different admissible point grids: Figure 2.1.2 (left) shows the standard Reuter grid, Fig. 2.1.2 (mid) depicts a Reuter grid with the pole shifted to the centre of the region of investigation and, finally, as shown in Fig. 2.1.2 (right) we also use a modified Reuter grid which is constructed by random shifts of the standard Reuter grid points and means an optimized

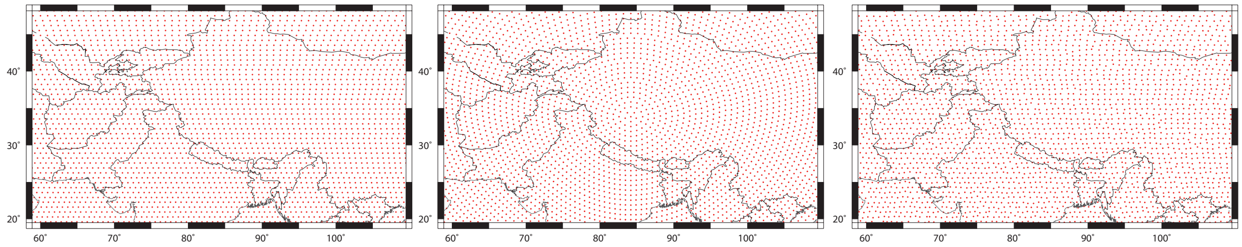


Fig. 2.1.2: Standard Reuter grid (left), circle grid (mid) and modified Reuter grid (right) for the Himalaya region

point grid as mentioned before; the number of grid points for the three cases are presented in Table 2.1.1.

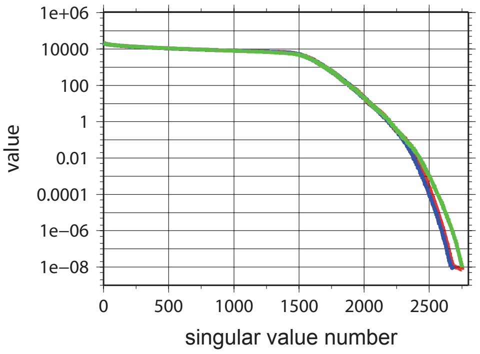


Fig. 2.1.3: Singular values of the coefficient matrices using standard Reuter grid (red), circle grid (blue) and modified Reuter grid (green).

Since the number of grid points in all three cases is usually larger as necessary the corresponding coefficient matrices are not of full column rank. This fact is confirmed by the condition numbers (quotient of largest and smallest eigenvalue of the normal equation matrix) shown in Table 2.1.1. Figure 2.1.3 shows the singular value distributions for the coefficient matrices. Consequently, the parameter estimation in all three cases is performed by the pseudo inverse. The corresponding residuals are shown in the three panels of Figure 2.1.4. The results based on the standard Reuter grid and the circle grid show strong artificial structures in the residuals. However, a significant decay of the estimated variance factor, i.e. the standard deviation is noticed by using the modified Reuter grid; cf. last column in Table 2.1.1.

Tab. 2.1.1: Statistics for the three estimations

Reuter grid type	**Number of grid points/ unknowns**	**condition number x 10^{12}**	**residuals min/max x 10^{-4} [m^2/s^2]**	**standard deviation x10^{-5} [m^2/s^2]**
standard	2754	3.05	-0.633 / 1.040	1.474
circle	2658	2.87	-0.825 / 0.950	1.655
mod.	2754	2.24	-0.010 / 0.089	0.146

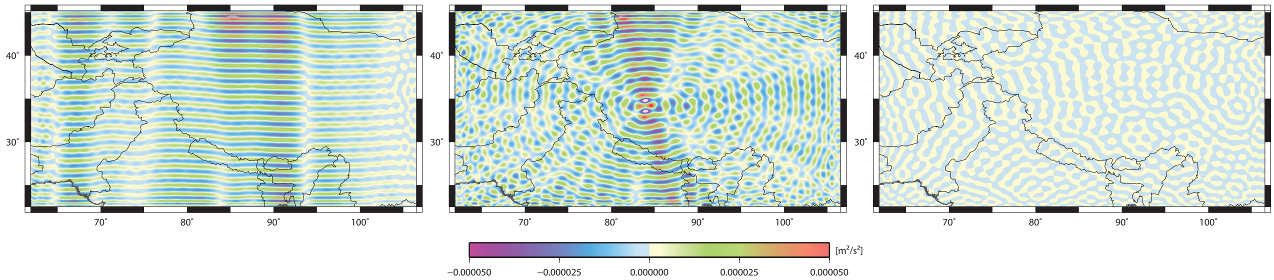


Fig. 2.1.4: Residuals of the three estimations using standard Reuter grid (left), circle grid (mid) and modified Reuter grid (right).

Validation of GOCE with satellite altimetry

Satellite altimeter data may be used to validate GOCE data or may be combined with GOCE data to determine, for example, the oceanic geoid. In both cases, one needs to take care of the dynamic ocean topography (DOT) either by co-estimating the DOT or by using DOT models to correct the altimeter data. We studied the use of satellite altimeter data for validation of the GOCE gravity gradients and how well the DOT can be reduced by using models. Figure 2.1.5 shows the standard deviation of the differences between four DOT models converted to the vertical gravity gradient. Obviously, the differences between the models are large in regions with the main ocean currents such as the Gulf Stream and the Antarctic Circumpolar Current. There are, however, also regions where the differences are relatively small (below 0.01 E, one Eötvös is 1 E = 10^{-9} s^{-2}). It can therefore be concluded that satellite altimeter data in the Pacific, for example, may be used for GOCE validation when corrected for DOT.

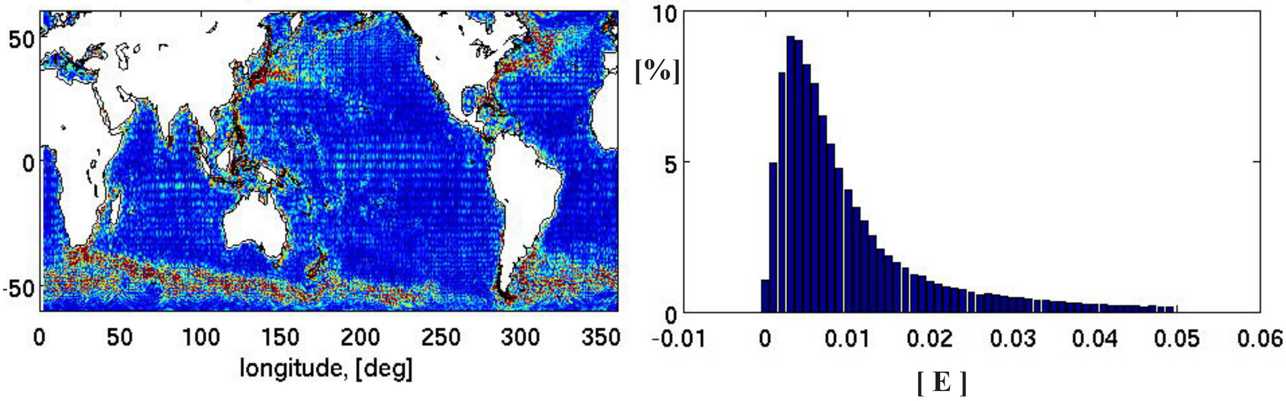


Fig. 2.1.5: Estimated uncertainty caused by DOT correction in the vertical gravity gradient computed from satellite altimeter data. The left panel shows the geographical distribution of the standard deviation of the differences between 4 DOT models. The colour scale is limited to the interval [0, 0.05] E. The right panel shows the corresponding histogram, where the percentage of the standard deviation in the range [0, 0.05] E is indicated.

GOCE gravity gradients

One way to characterize the quality of the GOCE gravity gradient data is to compare them with gravity gradients predicted by global gravity field models. Figure 2.1.6 displays the differences between GOCE and EGM2008 for the V_{XX} and V_{YY} gradient. Gravity gradient data from November and December 2009 have been used and the differences were averaged in bins of half a degree. Over the oceans and in regions with high quality terrestrial gravity data the differences are small, whereas in regions void of terrestrial gravity data or where these data are poor the differ-

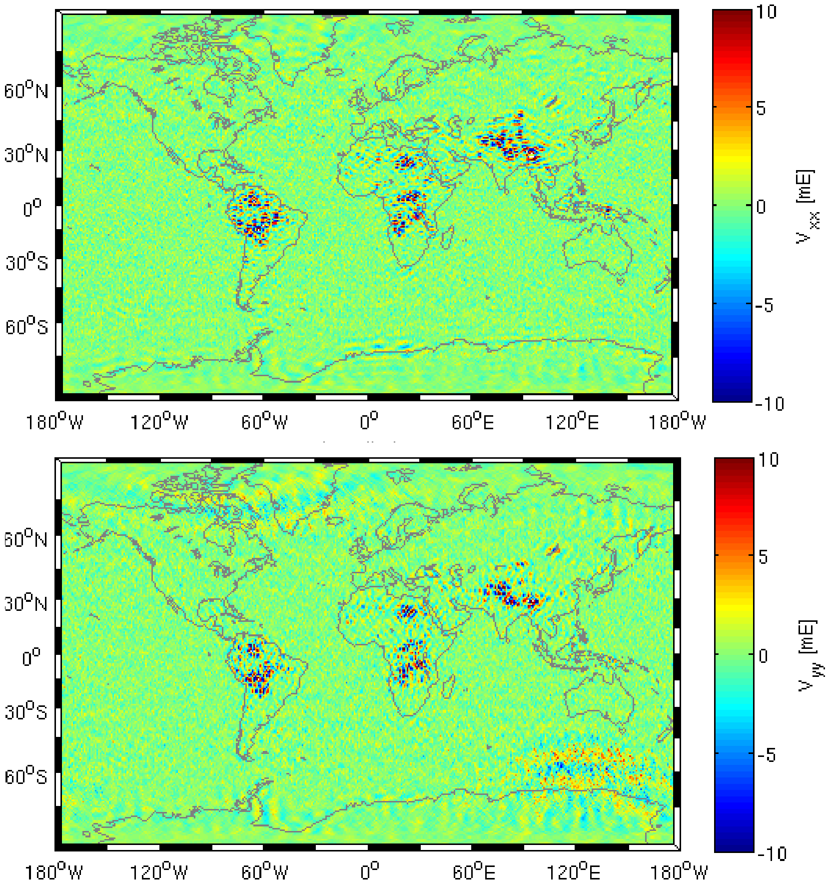


Fig. 2.1.6: Gravity gradient differences between GOCE and EGM2008: V_{XX} (top panel) and V_{YY} (bottom panel)

ences are large. This shows that already with only two months of GOCE data new gravity field information is obtained. The V_{YY} differences show a peculiar pattern close to the magnetic poles in North America and south of Australia. This is probably related to a small drift in the gradiometer, which may cause a coupling of cross-track winds with the gravity gradient signal. When the gradiometer data are corrected for the drift, the spurious signal largely disappears (Bouman et al. 2010b).

Related publications:

Bouman J, Bosch W, Goebel G, Müller H, Sánchez L, Schmidt M, Sebera J (2010) Das Schwerefeld der Erde - Messen, Darstellen und Auswerten, Zeitschrift für Vermessungswesen, 135, Heft 2

Bouman J, Bosch W, Sebera J (2010) Assessment of systematic errors in the computation of gravity gradients from satellite altimeter data. Accepted for Marine Geodesy

Bouman J, Lamarre D, Rispens S, Stummer C (2010b) Assessment and Improvement of GOCE Level 1b Data, submitted to Journal of Geodesy

Bouman J, Stummer C, Murböck M, Fuchs M, Rummel R, Pail R, Gruber T, Bosch W, Schmidt M (2010) GOCE gravity gradients: a new satellite observable, Status Report GEOTECHNOLOGIEN

Bouman J, Fuchs M (2010) GOCE gravity gradients versus GOCE gravity field models, submitted to Geophysical Journal International

2.2 Kinematics of the mean sea level

In order to allow for a comprehensive and up-to-date description of the sea level an actual and consistent altimeter database is essential. In addition to the inclusion of new data and models special attention is given to data harmonization and mission cross calibration. Moreover, the online user interface OpenADB has been extended and improved in 2010. The DGFI database is the fundament of all further scientific investigations. Continuing the work from previous years, the focus here was on ocean tide modeling and on modeling of the dynamic ocean topography.

Enhancement of the DGFI altimeter database

In addition to the continuous update with actual mission data, the inclusion of new orbits and models is the main task here. The following updates and changes were performed in 2010:

- Incorporation of new orbits for Envisat (ESA version6)
- Incorporation of new orbits for GFO, Jason-1/2 and TOPEX (GSFC std0905)
- Wet tropospheric enhancement product (coastal zones) for Jason MWR (JMR and AMR), provided by Shannon Brown
- High frequency data sets for ICESat
- Inclusion of first Cryosat Cal/Val Data (Level2 Low Resolution Mode)
- Ice masks from NSIDC
- Dynamic Ocean Topography (DOT) from Maximenko

Multi-Mission Cross-Calibration MMXO

The Multi-Mission Cross-Calibration (MMXO) aims on the combination of all altimeter missions into one long-time consistent system with high spatial resolution and it is the fundament for all further investigation. In addition to this, the approach could be used to reveal special information on single mission data, such as outliers and errors in the data sets as well as differences in the realisation of the reference frames.

Jason-2 Range Bias

The approach of multi-mission crossover analysis has been used to perform a relative calibration of the Jason-2 mission (Dettmering and Bosch, 2010a). A global mean range bias of 7.5 ± 0.2 cm with respect to Jason-1 was computed for the first year of Jason-2 data. The radial errors show increased auto-correlation at the orbit revolution period, which is related to geographically correlated error pattern with up to about 2 cm amplitude.

Envisat Orbit Investigations

The MMXO approach is not limited to range bias determination but also reveals information on geographically correlated errors and systematic differences in the realization of the origin of different altimeter missions. Both effects are mainly due to satellite orbits and may help to improve the POD (precise orbit determination).

Investigations made with different Envisat orbits show significant improvements due to the orbit reprocessing and consistent results for different reprocessing solutions (from CNES and ESA). Nevertheless, systematic differences in the realisation

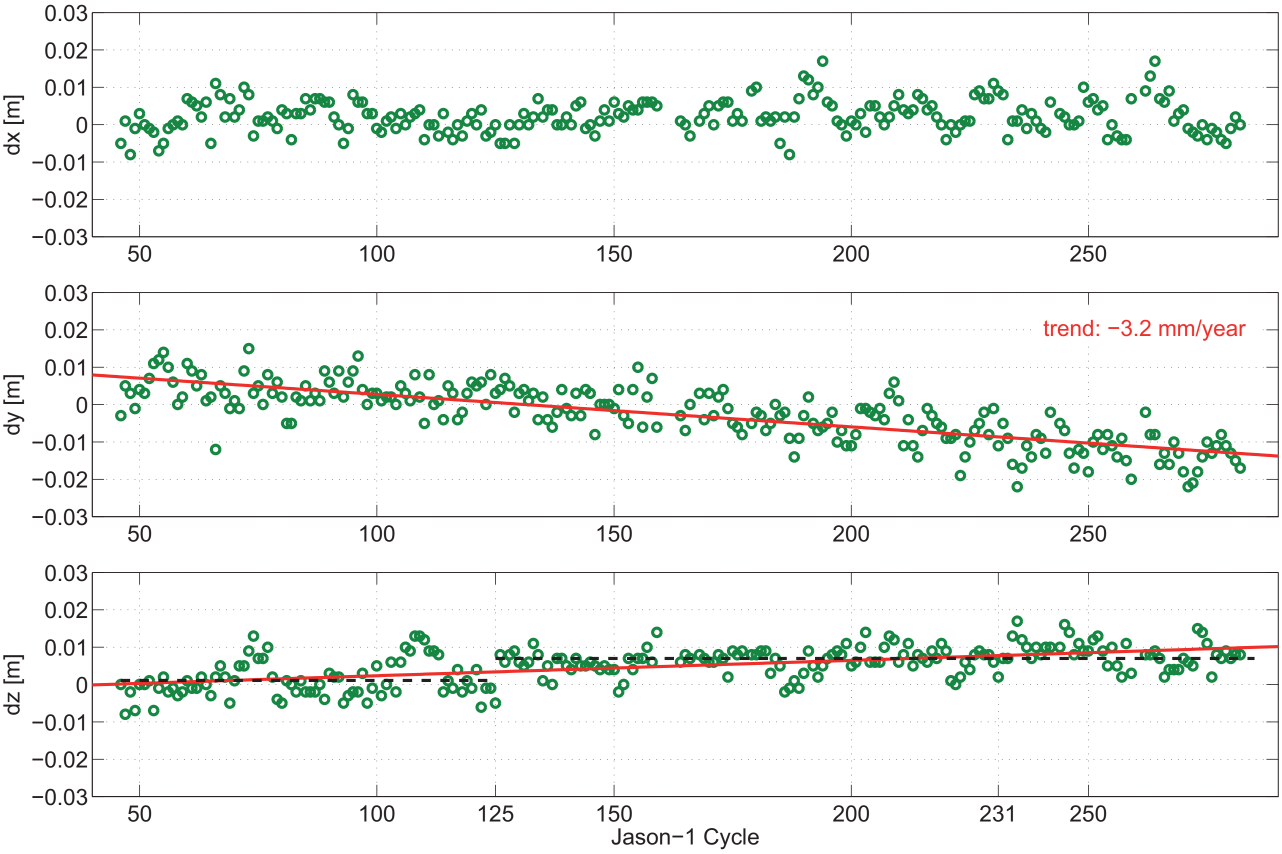


Fig. 2.2.1: Relative centre-of-origin shifts of Envisat w.r.t. Jason-1; ESA reprocessed orbits up to cycle 242, GDR-C afterwards.

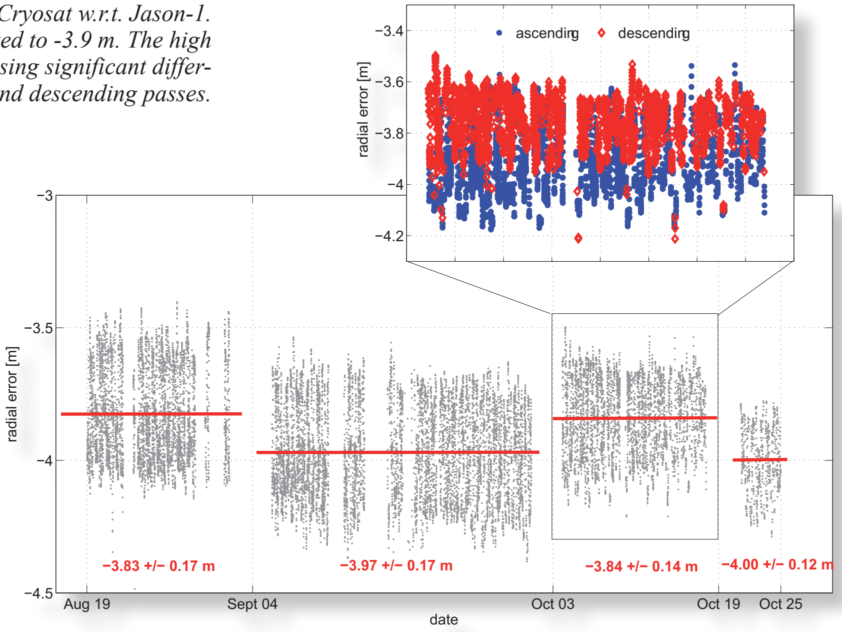
of the origin between Envisat and Jason-1/2 could be detected (Dettmering and Bosch, 2010b). Considering the whole Envisat lifetime (nearly 7 years), a trend of about –3 mm/year in the y-component is visible (see Figure 2.2.1). The source for this discrepancy is still not known. A possible explanation is a different handling of time varying gravity within the orbit computation or its different effect due to the different orbit heights. This is under further investigation.

First Cryosat results

DGFI contributes to the ESA PI Cal/Val activities and has access to first Cryosat data for calibration purposes. In this context, the Level 2 Low Resolution Mode (LRM) data have been used to do some first investigation on data quality in ocean areas. The 1Hz data have been incorporated in the database and are used within the cross calibration. Valid data are available since mid August 2010 and no sea state bias correction has been applied (as it is not available until now).

Our investigations show radial errors of about –4 m with respect to Jason-1 grouped within four time periods with offsets of about 15 cm between each other (Fig. 2.2.2). The radial errors of ascending and descending passes clearly differ from each other indicating a significant time tag error which may be estimated from the single satellite crossover differences to be about 8 ms (Fig. 2.2.3).

Fig. 2.2.2: Time series of radial errors for Cryosat w.r.t. Jason-1. The global mean range bias is computed to -3.9 m. The high variability is due to a time tag error causing significant differences for ascending and descending passes.



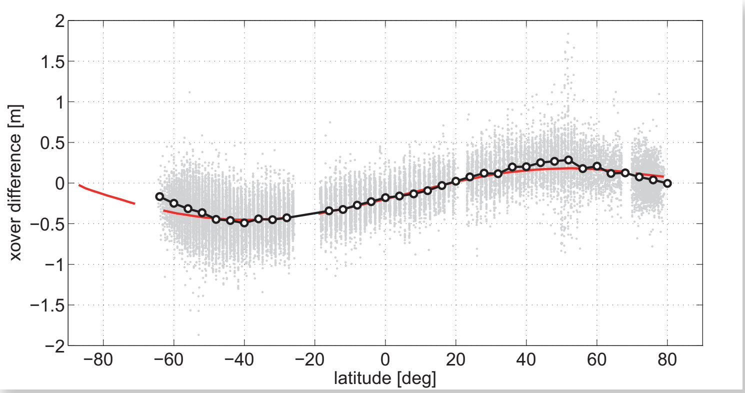


Fig. 2.2.3: Single satellite crossover difference of Cryosat (August to November 2010) as a function of latitude (grey dots). The black line indicates the mean crossover height differences for each 2° latitude interval and the red curve represents the theoretical effect of a timing error of 8 ms.

EOT10a tide model

The rationale to continue the efforts on modelling ocean tides are based on several reasons: Ocean tides represent the dominant kinematic variation of the sea surface. At the same time they describe short-term mass variations with impact on the Earth rotation; they are needed as background models for gravity field modelling and are required for de-tiding altimeter data. The EOT08a tide model already demonstrated the high potential of multi-mission-altimetry for the empirical tide modelling. Meanwhile, extended time series of altimeter mission data are available, improved orbits and geophysical correction models could be applied. Moreover, a slightly modified processing strategy led to the development of EOT10a, a new version of the DGFI tide model.

As for EOT08a the residual tide analysis was performed w.r.t. the reference model FES2004. To counteract the concerns, that the multi-mission-crossover analysis spuriously captures tidal signals the analysis for EOT10a was applied to non-calibrated data. Instead, a mission specific offset was introduced into the analysis in order to account for different range biases. Moreover, only data of TOPEX/Poseidon, Jason-1, Jason-2, ERS-2, and ENVISAT were used for the tide modelling in order to avoid any degradation by mission data with the low accuracy or short operation periods.

Least Squares Adjustment

For the nodes of a global 15’x15’ grid the empirical tide analysis is realised by a least squares adjustment of all sea level anomalies observed inside a spherical cap, using the following observations equation:

$$\begin{aligned}\hat{\zeta}(\varphi,\lambda,t)+\hat{v}(\varphi,\lambda,t)\\ &= d_m+\sum_i f_i(t)\big(h_{1i}(\varphi,\lambda)\cos(\omega_i t+u_i(t))+\,h_{2i}(\varphi,\lambda)\sin(\omega_i t+u_i(t))\big)\\ &+\sum_j\big(H_{1j}\cos\Omega_j t+H_{2j}\cos\Omega_j t\big)\end{aligned}$$

where	d_m	mission specific range bias
	h_{1i}, h_{2i}	cosine- and sine coefficients for constituent *i*
	$f_i(t)$, $u_i(t)$	nodal corrections for constituent *i*
	$\omega_i t$	astronomic arguments
	H_{1j}, H_{2j}	cosine- and sine coefficients of annual and semi-annual variations
	Ω_j	angular frequency of seasonal variations

The solve-for parameters encompass five diurnal tides K1, O1, Q1, P1, and S1, five semi-diurnal tides M2, S2, N2, K2, and 2N2, the non-linear tide M4, two long period tides Mm and Mf, as well as annual and semi-annual variations of the sea surface. The sea level anomalies were weighted w.r.t. to the grid node distance by means of a Gauss function with a half weight width set to 30% of the cap size radius. To account for the high correlation between subsequent measurements normal points (weighted averages) were computed for all measurements of an individual pass. For EOT08a the cap size radius was different for shallow water and deep ocean areas. For EOT10a different, but globally fixed cap size radii were tested. Residual analyses suggest using different cap size radii for different constituents. As in general there is a low correlation between the tidal constituents, EOT10a was finally composed of different solutions for the individual constituents. As TOPEX and Jason-1 measurements in high latitudes are missing, EOT10a can hardly improve the reference model above latitude > 67°. Thus beyond 67°N and 67°S EOT10a is equal to FES2004. In between 65° and 67° northern and southern latitude there is a smooth transition between the reference model and EOT10a estimates.

EOT10a validation

The ST102 data set is traditionally used for validation of tide modes in deep ocean while WOCE tidal constant are more representative for coastal areas. The Table 2.2.1 shows how EOT10a performes in comparison with other tide models. In open ocean EOT10a outperforms all other models and in coastal areas exhibits some improvements over EOT08a.

Figure 2.2.4 shows the variance reductions of Jason-1 and ENVISAT crossover differences relative to FES2004 and EOT08a. Only crossover differences in the year 2004 were considered with

Tab. 2.2.1 RMS differences [cm] of tidal constants at tide gauges of ST102p and of WOCE data set. Smallest RMS values are given in red.

	ST102 (96-102 TGs)				WOCE (158 TG)		
	EOT10a	EOT08a	FES2004	GOT4.7	EOT10a	EOT08a	FES2004
M2	**1,41**	1,44	1,45	1,46	11,85	12,06	**10,70**
S2	**0,84**	0,96	0,86	0,93	**4,20**	4,36	4,34
N2	**0,64**	0,65	0,67	**0,64**	2,53	2,66	**2,52**
K2	0,42	0,45	0,47	**0,40**	**1,51**	1,52	1,63
O1	**0,73**	0,74	0,75	0,76	2,98	**2,97**	3,02
K1	**0,96**	0,98	1,00	1,01	**4,02**	**4,02**	4,20
P1	**0,37**	0,42	0,40	0,37	**1,30**	1,32	1,37
Q1	0,28	0,30	0,30	0,27	0,68	**0,62**	0,68
M4					**1,23**	1,34	1,47

time difference less than the repeat period of the mission. There is a significant variance reduction w.r.t. FES2004. Compared to EOT08a the new tide model shows only minor improvements. However, the main weaknesses of EOT08a like S2 in polar areas were removed. Also EOT10a describes much better the tidal regime in the Hudson Bay. In some shallow water areas EOT10a fails to improve EOT08a. We attribute this to the missing cross-calibration and the fact that the ground-track pattern of TOPEX/Jason missions are not dense enough for an adequate empirical tide modelling.

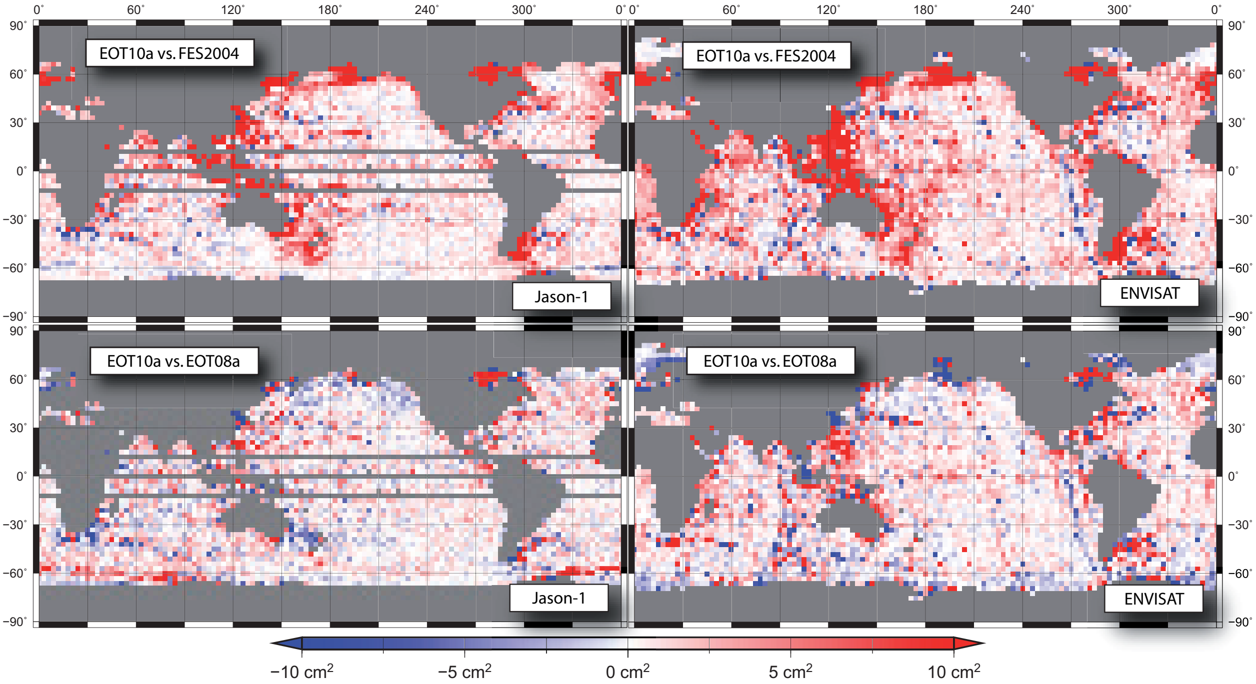


Fig. 2.2.4: Variance reductions of the crossover differences [cm²] for the year 2004.

Related publications:

Bosch W., Dettmering D., Savcenko R., Schwatke C.: Kinematik des Meerespiegels: Eddies, Gezeiten, Meerestopographie und Meeresspiegelanstieg. Zeitschrift für Vermessungswesen, 135, Heft 2, 2010

Bosch W., Savcenko, R., Mayer-Gürr, T., Flechtner, F., Dahle, C., Daras, I. Ocean tides from satellite altimetry and GRACE. submitted to SPP Special Issue of the Journal of Geodynamics

Dettmering D., Bosch W.: Global Calibration of Jason-2 by Multi-Mission Crossover Analysis. Marine Geodesy, 33:S1, 150-161, doi 10.1080/01490419.2010.487779, 2010a

Dettmering, D., Bosch, W.: Envisat radar altimeter calibration by multi-mission crossover analysis. Proceedings of ESA Living Planet Symposium - ESA Special Publication SP-686, CD-Rom, 2010b

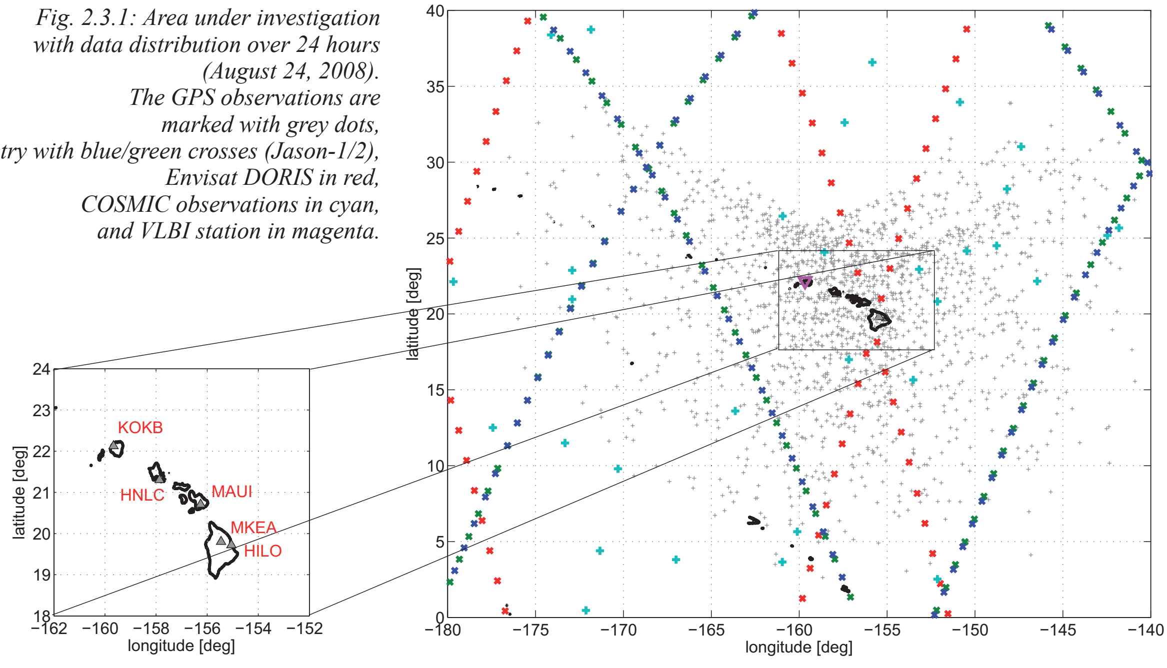
2.3 Dynamic processes in the Earth system

Combination of different observation techniques for ionosphere modeling

In the last years a general procedure for modelling ionospheric signals from different data sources has been developed at DGFI. The combination of data from different space-geodetic techniques offers the possibility to reach better data coverage as well as higher reliability and accuracy of ionosphere models. Because of their different sensitivity regarding ionization, their different spatial and temporal data distribution, and their different signal paths, a joint analysis of all observation types seems reasonable. For a combination of different data types we use DGFI`s regional model for the vertical electron content VTEC with B-spline parameterization for latitude, longitude and time. Various space-geodetic observations are taken to estimate differences to a background model (IRI 2007). More information on the model approach could be found in previous annual reports and various publications. To get an impression on the data sensitivity of each observation technique we analyse the results of a variance component estimation (VCE) which takes into account the different accuracy levels of the observations. In order to consider systematic offsets, a constant bias term (for a 24h time interval) is allowed for each observation group w.r.t. the background model which can easily be used to compute inter-technique biases. Five different space-geodetic data types are used within the investigation: ground-based GPS (from five IGS stations), space-based GPS (from COSMIC/Formosat-3), altimetry data (from Jason-1 and Jason-2), DORIS data (from Envisat ionospheric corrections), and VLBI data (from 1 IVS station). The area under consideration is a region around the Hawaiian Islands. All measurements are taken from a time interval of about two weeks in August 2008 (CONT08 campaign). The data distribution for one specific day is shown in Figure 2.3.1.

All observation types show a good sensitivity for VTEC and reach formal errors between 0.3 and 1.4 TECU for a single observation (see Fig. 2.3.2). GPS gives the best results, followed by VLBI, al-

Fig. 2.3.1: Area under investigation with data distribution over 24 hours (August 24, 2008). The GPS observations are marked with grey dots, altimetry with blue/green crosses (Jason-1/2), Envisat DORIS in red, COSMIC observations in cyan, and VLBI station in magenta.



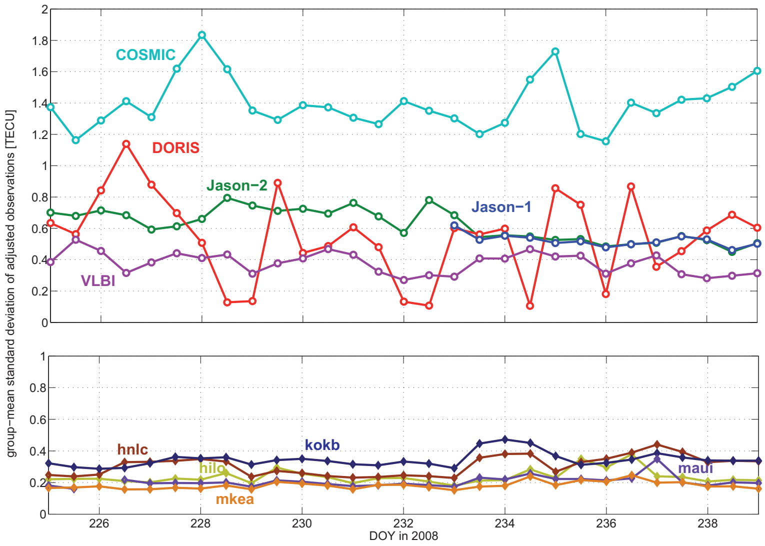


Fig. 2.3.2: Time series of data accuracy for each data group within the CONT08 campaign. GPS results are given in the lower plot, all other techniques in the upper one.

timetry and COSMIC. DORIS on board of Envisat is the only technique with unsatisfied results. The formal errors have high variations within the time period under investigation and the results depend strongly on changes of the model parameters and observation intervals without indicating this in the formal errors. Moreover, the computation of the Envisat DORIS corrections (which have been taken directly from the Geophysical Data Record, GDR) is neither documented nor reproducible for us. Therefore, in further work the original DORIS observations will be used.

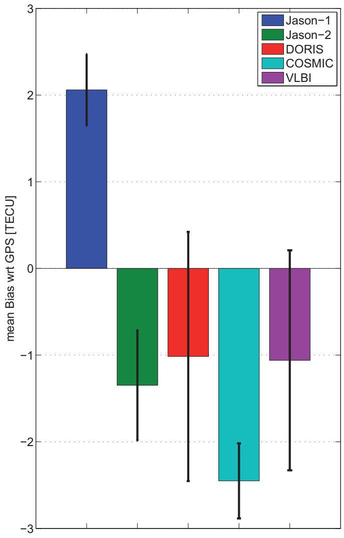


Fig. 2.3.3: Biases of space-geodetic observation techniques w.r.t. GPS. Mean values for the whole CONT08 period.

The differences in VTEC between the observation techniques reach up to 4.5 TECU (Jason-1 and COSMIC) and may not be neglected when using more than one data group. As could be seen in Figure 2.3.3, the mean differences w.r.t. GPS is about 2 TECU for Jason-1, –1.3 TECU for Jason-2, and –2.4 TECU for COSMIC. The offsets of VLBI and DORIS are not significant. Nevertheless, for VLBI a systematic oscillation with a frequency of about 4 days is detectable. This behavior is under further investigation.

Besides the investigation on ionosphere, DGFI also evaluates VLBI data for studying processes within the neutral atmosphere often identified as the troposphere.

Water vapor climatology

Water vapor plays an important role as an energy transportation and storage medium and as a greenhouse gas. Among the space-geodetic techniques VLBI can provide long and homogeneous time-series of zenith wet delays (ZWD); see Heinkelmann et al., (2010, poster). The ZWDs are related to the total amount of precipitable water (PW) in an atmospheric column above a site. According to the Clausius-Clapeyron equation, a trend seen in the ZWDs refers to an increase of the temperature of the free atmosphere above the specific site. Since the global temperature is increasing by about +0.2°C per decade (IPCC, 2007) the ZWD time-series determined by space-geodetic techniques at radio wavelengths should also reflect a global increase. Due to large inter-annual variations, however, the observed linear trend of ZWD significantly depends on the start and end of the included observation epochs (see Fig. 2.3.4).

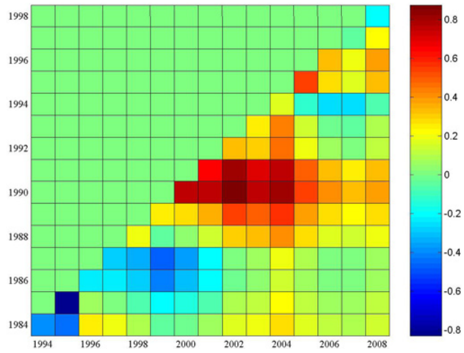


Fig.2.3.4: This so-called trend matrix shows the ZWD trend (mm/year) at WETTZELL, Germany, when the time-series used for the trend determination starts at the year specified in the ordinate and ends with the year specified in the abscissa.

Figure 2.3.5 shows the most reliable trends of ZWDs determined by VLBI at some IVS sites. Some of these sites show an increase and some a decrease of ZWD trends. The sparse density of the global VLBI network is the largest limiting factor for the determination of global water vapor. Other techniques should be included in order to densify the observing sites. Nevertheless, VLBI can provide long time-series at some sites contributing a valuable validation tool for radiosonde humidity measurements and a method for the calibration or comparison of water vapor data sets over very large distances.

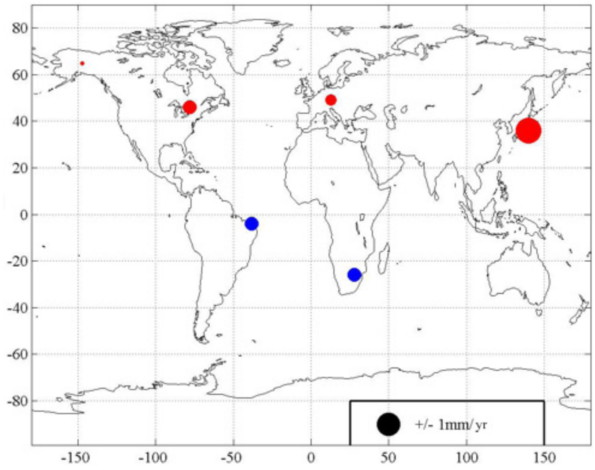


Fig. 2.3.5: Linear trends of ZWD (mm/yr) at some VLBI sites. Red dots denote an increase and blue dots a decrease in water vapor. It is not possible to draw global conclusions from the very sparse geometrical representation through the network sites.

Dynamic Ocean Topography (DOT)

The GEOTOP project aims to provide an estimate of the dynamic ocean topography (DOT) which shall be assimilated into a hydrodynamic model in order to obtain an improved knowledge on the transport of heat and water mass. The DOT is equivalent to the surface velocity field and can be derived following a "geodetic approach", e.g. subtracting geoid heights N from sea surface heights h,

$$\mathrm{DOT} = h - N \tag{1}$$

Differencing geoid and sea surface requires special attention, as both quantities have completely different spectral properties.

Profile approach

The "profile approach" developed at DGFI, performs a 1-dimensional (1D) filtering of sea surface height profiles which is consistent with a spectral (2D) filter applied to the geoid. A filter correction accounts for systematic differences between the 1D-filtering and the 2D-filter in the spectral domain and catches boundary effects at the coast and over trenches and seamounts. Applying a consistent filter to equation (1) gives

$$\mathrm{DOT} = \mathrm{2D}[\,h - N] = \mathrm{2D}[h] - \mathrm{2D}[N]$$

where the 2D-filtering of h

$$\begin{aligned} 2D[h] &= 1D[h] + (2D[h] - 1D[h]) \\ &\approx 1D[h] + \{2D[N_{hres}] - 1D[N_{hres}]\} \end{aligned}$$

can be replaced by a 1D-filtering and the filter correction (the last term in {}), which is determined with a high resolution geoid (e.g. from EGM2008) such that

$$DOT = 1D[h] + \{2D[N_{hres}] - 1D[N_{hres}]\} - 2D[N] \qquad (2a)$$

or, by re-ordering

$$DOT = 1D[h - N_{hres}] + 2D[N_{hres} - N] \ . \qquad (2b)$$

For the computation of DOT equation (2b) is more suited than equation (2a) as the 2D-filtering of the geoid difference $N_{hres} - N$ can be performed once in advance and the 1D-filtering is to be applied to the profile differences $h - N_{hres}$.

This "profile approach" has been successfully applied to nearly all individual sea surface height profiles from many altimeter satellites. The determination of a mean DOT for a given period of time is then straightforward. The differences to various external DOT-estimates have RMS values between 4 and 7 cm. With individual DOT profiles it is even possible to study the temporal evolution of the DOT (see animation at DGFI-home page).

The most significant progress for a geodetic DOT is achieved by GOCO01S, the first gravity field, combining GRACE and initial GOCE gradiometer data. The gain in resolution, achieved by the first two month of GOCE data is significant (c.f. Fig. 2.3.6). The error degree variances of the first QL-GOCE model clearly indicate that – compared to GRACE gravity fields – the degree range 90 – 170 is considerably improved. Consequently the filter characteristics, applied in the profile approach could be extended from degree 60 (used for GRACE) to degree 120, 150, and even 180. In the spatial domain this corresponds to decreasing filter width from 241 km to 121 km, 97 km, and 81km respectively. Fig. 2.3.7 shows the increase of variance, implied by gradually decreasing the filter width. This demonstrates how much more DOT signal has become visible by using GOCE gravity fields.

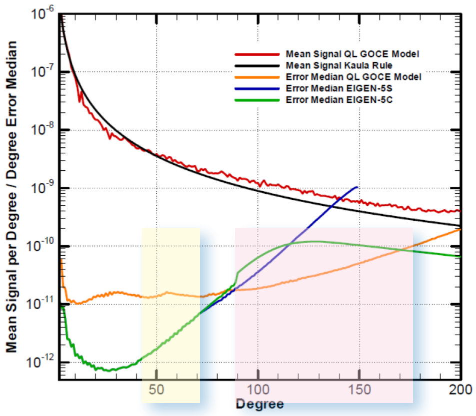


Fig. 2.3.6 Signal and error degree variances of recent gravity field models. The error degree variances of GRACE-based gravity fields are shown in blue (EIGEN-5S) and green (EIGEN-5C). The error degree variances of the QL-GOCE model are displayed in orange.

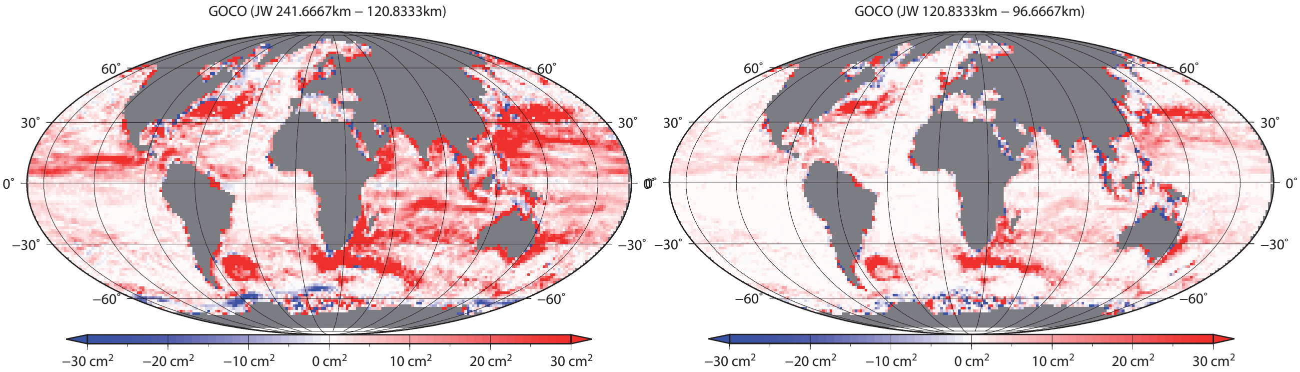


Fig. 2.3.7 Increase in variance of the DOT if the length of the spatial Gauss-type filter is reduced from 241 to 121 km (left, corresponding to a spectral low pass up to degree 60), and from 121 to 97 km (right, spectral low pass up to degree 120).

Besides the Earth system components atmosphere, ocean and continental hydrology DGFI also evaluates measurements from a 30-meter vertical pendulum operated in the salt mine of Berchtesgaden.

Gyroscopic and elastic natural oscillations

Natural oscillations which are excited by external forces are called gyroscopic natural oscillations. An example for such an oscillation is the precession and nutation of the Earth. Natural oscillations which are excited by abrupt events are called elastic natural oscillations. They are excited by an earthquake with a magnitude bigger than 6.5 on the Richter scale.

Free oscillations due to the earthquake in Chile

The big Chile-Maule earthquake which happens on February, 27, 2010 about 100 km northeast of Concepción excites seismic waves which migrate all over the world. These signals deflect the 30-meter vertical pendulum by around 0.15 mm in north-south direction and about 0.1 mm in east-west direction. Due to the high magnitude of this earthquake (8.8 on the Richter scale) free oscillations of the Earth were excited. Figure 2.3.8 shows the measured deflections of the pendulum during the week of the earthquake. The first amplitude belongs to the earthquake on the Ryukyu Island in Japan. The second amplitude belongs to the earthquake in Chile.

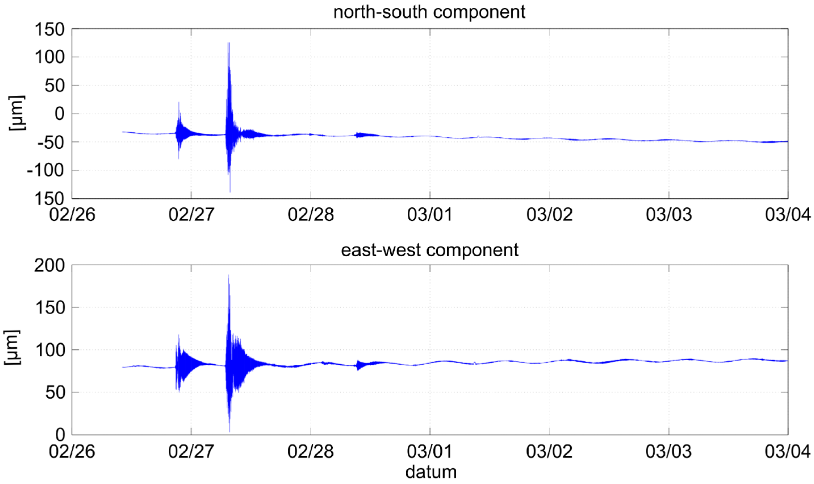


Fig. 2.3.8: Measured signal in the north-south component (upper part) and in the east-west component (lower part) over six days (February, 26, 2010 till March 4, 2010).

Figure 2.3.9 shows the wavelet scalogram of the measured free oscillations. These oscillations are clearly excited by the second earthquake and are absorbed within two days because of the high damping rate of the Earth. The scalogram only shows a small frequency interval. Generally the excited elastic free oscillations could have a period up to one hour.

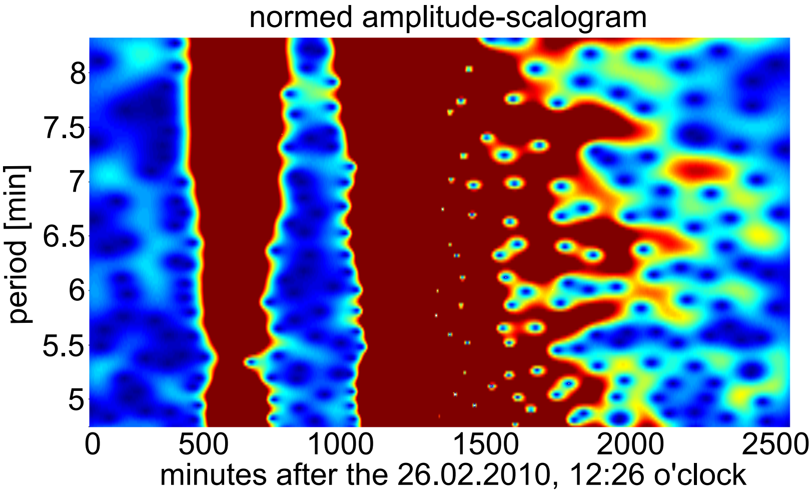


Fig. 2.3.9: Normed amplitude scalogram of the registered signal. Dark red means a high amplitude, blue means a low amplitude.

Related publications:

Bloßfeld M., Schmidt M.: Eigenschwingungen der Erde in Berchtesgaden. Akademie Aktuell Heft 3/2010, Bayerische Akademie der Wissenschaften, 2010

Bosch W., Savcenko R.: On estimating the dynamic ocean topography – a profile approach, In: Mertikas (Ed.) Gravity, Geoid and Earth Observation. IAG Symposia, Springer, Vol. 135, 2010

Bosch W., Savcenko R.,T. Luz: The absolute dynamic ocean topography (ADOT) - estimation and application, Proceedings of ESA Living Planet Symposium, Bergen, Norway, ESA ESTEC, Scientific Publication SP-686, CD-ROM, 2010

Bosch W., Dettmering D., Savcenko R., Schwatke C.: Kinematik des Meerespiegels: Eddies, Gezeiten, Meerestopographie und Meeresspiegelanstieg. Zeitschrift für Vermessungswesen, 135, Heft 2, 2010

Dettmering D., Heinkelmann R., Schmidt M., Seitz M.: Die Atmosphäre als Fehlerquelle und Zielgröße in der Geodäsie. Zeitschrift für Vermessungswesen ZfV 135, Heft 2, S. 100-105, 2010

Dettmering D., Heinkelmann R., Schmidt M.: Systematic differences between VTEC obtained by differen space-geodetic techniques during CONT08. Submitted to Journal of Geodesy

Dettmering D., Schmidt M, Heinlemann R, Seitz F.:Combination of differnet space-geodetic observations for regional ionospheric modeling. Accepted for publication in Journal of Geodesy

Kuo-Hsin Tseng; C. K. Shum; Yuchan Yi; Chunli Dai; Hyongki Lee; Dieter Bilitza; Attila Komjathy; C. Y. Kuo; Jinsong Ping; Michael Schmidt (2010) Regional Validation of Jason-2 Dual-Frequency Ionosphere Delays, Marine Geodesy, 33 S1, 272 – 284

Schmidt M., Angermann D., Bloßfeld M., Göttl F., Richter B., Seitz M.: Erdrotation und geophysikalische Anregungsmechanismen. ZfV, 135, Heft 2, 2010

Schmidt M., Dettmering D., Mößmer M., Wang Y., Zhang J.: Comparison of spherical harmonic and B-spline model for vertical electron content. Submitted to Radio Science

2.4 Models of crustal deformation

Main objectives

The main objective of this topic is the representation of global and regional deformations of the Earth crust caused by tectonic processes. The global part is done by the Actual Plate Kinematic Models (APKIM) derived from station velocities of geodetic reference frames. The latest solution was presented in 2010 based on the ITRF2008. Long-term regional deformations, in particular between the rigid plates, are represented by continuous models. DGFI research concentrates on regional deformations in Central and South America. A constant deformation field of the region was presented in 2009 (Drewes and Heidbach 2011).

Deformations caused by the Chile earthquake 2010

These long-term deformations are interrupted by episodic discontinuities, e.g. caused by earthquakes. A dramatic seismic event was the Maule M=8.8 earthquake in Chile on February 27, 2010. In the frame of the Geocentric Reference System for the Americas (Sistema de Referencia Geocéntrico para las Américas, SIRGAS), DGFI presented the co-seismic deformations with station displacements exceeding 3 m close to the epicentre, and more than 1 cm even in 1500 km distance (see section 3.2 in this report, Sánchez et al. 2011).

Post-seismic decay of deformations

After the strong co-seismic displacements, we see anomalous station motions in nearby and distant sites even one year after the earthquake. Figures 2.4.1 and 2.4.2 show the post-seismic time series of stations close to the epicentre (CONZ), in medium range (MZAE), and in large distance (SRLP). The co-seismic displacements are shown for comparison in Fig. 2.4.3.

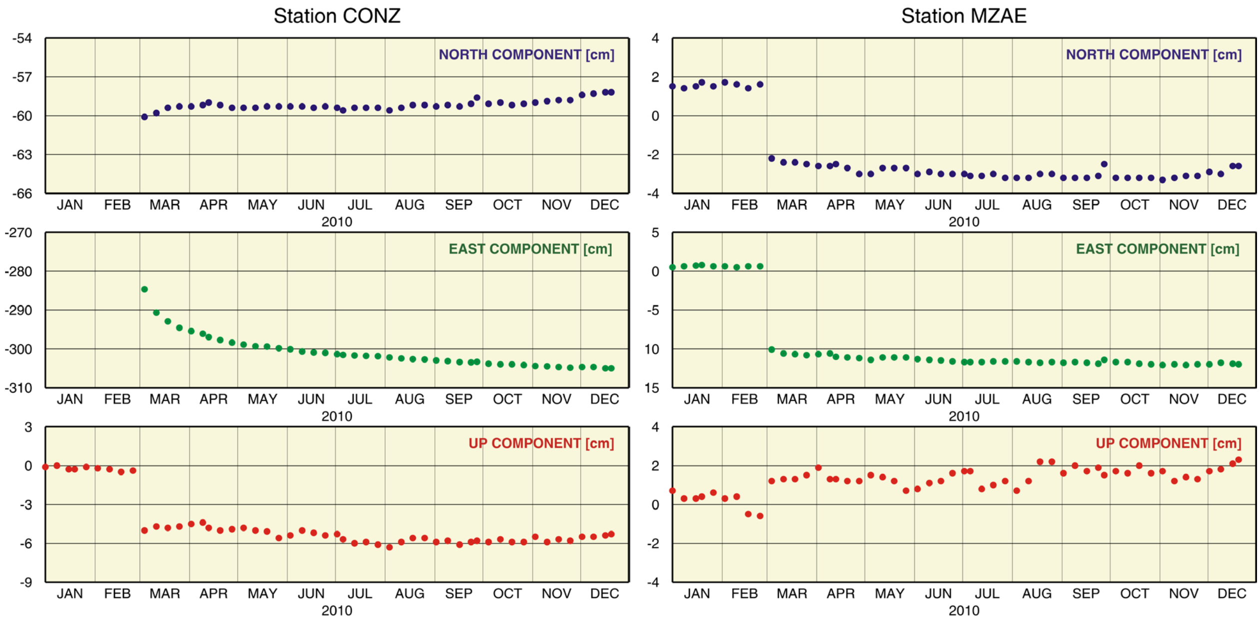


Fig. 2.4.1: Post-seismic time series of station CONZ (left, close to the epicentre) and of station MZAE (right, medium range)

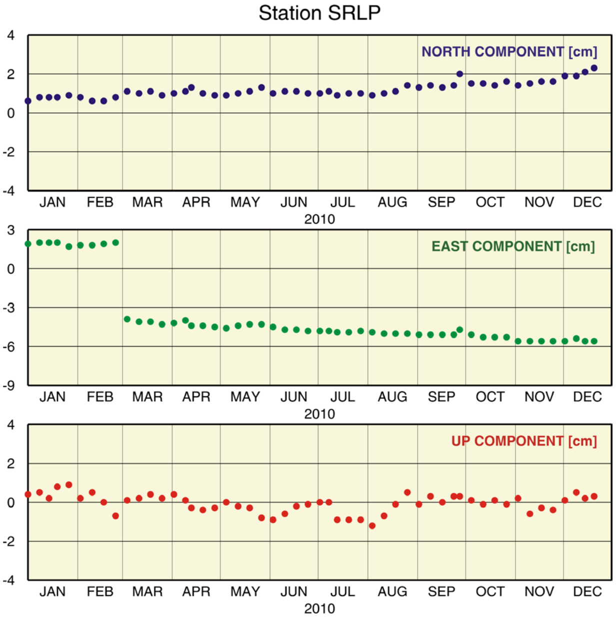


Fig. 2.4.2: Post-seismic time series of station SRLP (at far distance to the epicentre).

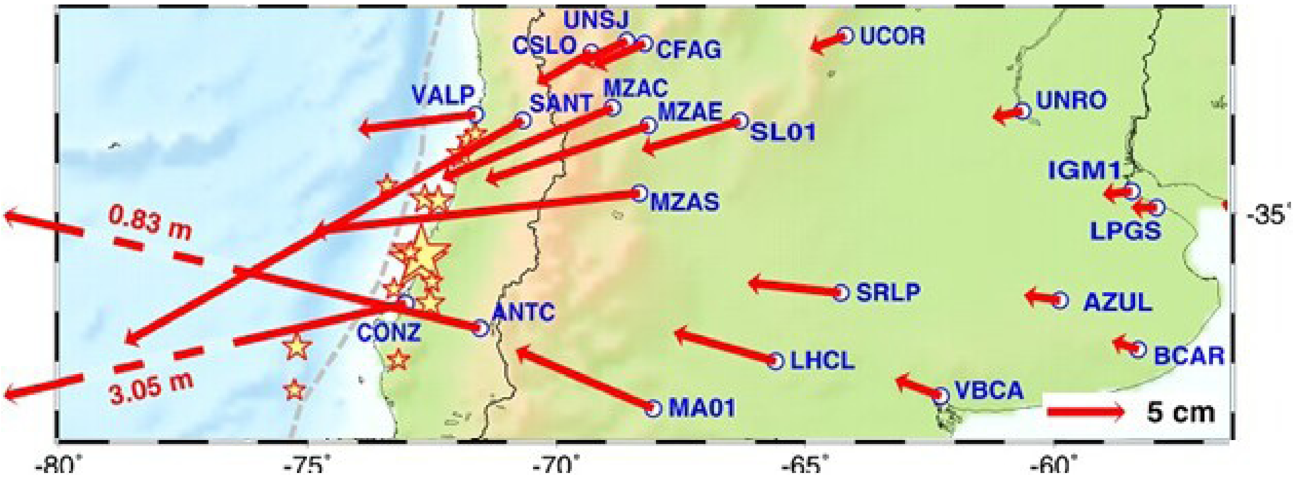


Fig. 2.4.3: Co-seismic displacements after the M=8,8 Maule earthquake in the most affected area

Related publications:

Drewes, H., O. Heidbach: The 2009 Horizontal Velocity Field for South America and the Caribbean. In: Sideris, M. (ed.): Geodesy for Planet Earth, IAG Symposia, Vol. 135, 495-500, Springer-Verlag, (in press).

Sanchez L., Seemüller W., Seitz M., Forberg B., Leismüller F., Arenz H.: SIRGAS: das Bezugssystem für Lateinamerika und die Karibik. Zeitschrift für Vermessungswesen, 135, Heft 2, 2010

3 International Scientific Services and Projects

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

3.1 ITRS Combination Centre / IERS WG on Combination

DTRF2008: The 2008 DGFI realization of the ITRS

DGFI as one of the ITRS Combination Centres of the IERS was in charge with the computation of the ITRF2008. The combination work starting in 2009 stretches over more than one year. The DGFI realization DTRF2008 was finalized and published to the IERS in May 2010.

Computation strategy

Fig. 3.1.1 shows a simplified flowchart of the computation strategy. The input data are time series of SLR, GPS, DORIS and VLBI data (weekly solutions or session-wise normal equations) provided by the corresponding technique services and covering time spans of up to 25 years in case of VLBI and SLR and 15 and 11 years in case of DORIS and GPS, respectively.

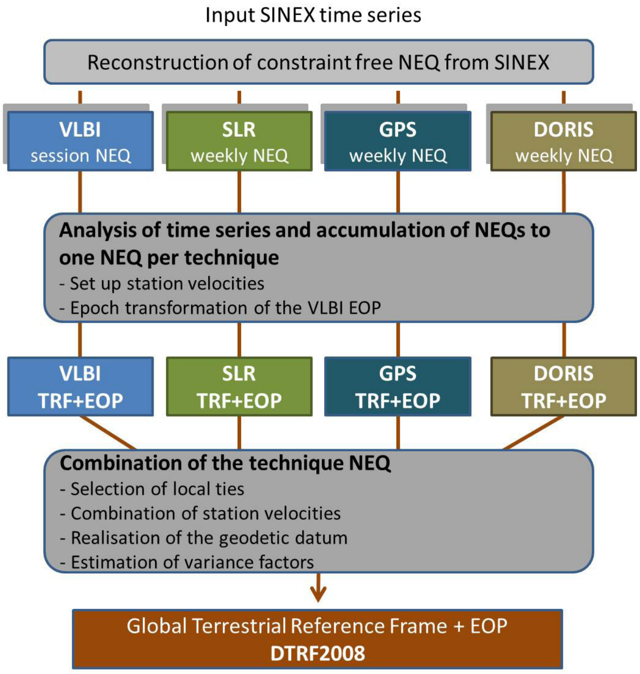


Fig. 3.1.1: Simplified flowchart of the combination strategy for the DTRF2008 (normal equations: NEQ)

Accumulation and time series analysis

In a first processing part normal equations (NEQ) are reconstructed from the provided SINEX files and solved by applying adequate minimum conditions. The solutions are transformed to a first multi-year solution per technique by seven parameter Helmert transformations. The resulting station position residual time series and the Helmert parameter time series are analysed in order to identify outliers, discontinuities and non-linear effects. The identified discontinuities are considered by splitting the station position time series at the corresponding epochs. Long-term non-linear movements are considered in the same way by approximating the time series by piece-wise linear functions. Outliers are reduced from the normal equations. The normal equation time series are accumulated to one multi-year NEQ per technique (which includes all observations of the particular technique), whereby station velocities are set up as new parameters. Fig. 3.1.2 shows the contribution of the different techniques to ITRF. GPS clearly dominates the ITRF network. The histogram gives an overview about the relation between the number of stations and the number of discontinuities in station position time series. In case of GPS the number of discontinuities is 64 % of the number of stations. The most common reason for discontinuities in GPS time series are equipment changes. Improved antenna phase centre models and local monitoring of the GPS stations might help to reduce this problem in future.

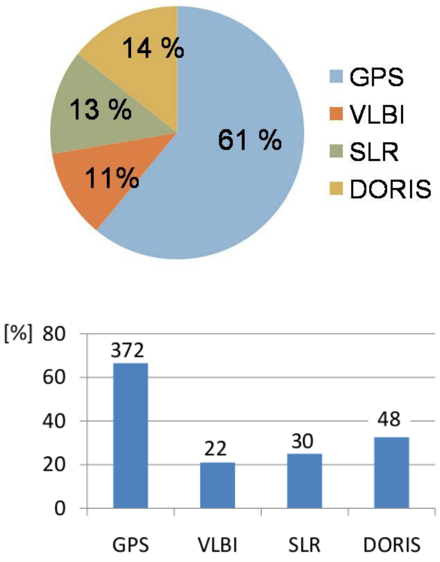


Fig. 3.1.2: Number of stations per technique in percentage of all DTRF2008 stations (top) and number of discontinuities per technique (bottom).

The analysis of the datum parameters was also performed in this first processing part. The translation of the SLR network w.r.t. the accumulated multi-year solution did not show significant signals except of the known seasonal variations. The same holds for the scale time series of the SLR and VLBI contributions. Consequently, all the SLR data could be used for realizing the origin, and both, the SLR and the VLBI data are used for realizing the DTRF2008 scale.

Inter-technique combination

In the second part of the processing the multi-year NEQ's of the different techniques are combined. Whereas the EOP are identical parameters which can be combined directly, station positions can only be combined by introducing terrestrial difference vectors as the observations of different space geodetic techniques, even if they are operated at the same site, are not related to the same reference point.

Significant differences between the solutions of the space geodetic techniques and the difference vectors are one of the most limiting factors of the ITRF accuracy. Thus, the handling of the difference vectors in the ITRF computation is one of the most critical and challenging tasks as two aspects have to be kept in mind: on the one hand the difference vectors are essential for the generation of a homogeneous station network, on the other hand they may lead to deformations of the combined networks. Thus, the difference vectors are introduced in such a way, that the combined network is as homogeneous as possible and at the same time the deformation of the networks is small. Both criteria are oppositional and must be balanced. Fig. 3.1.3 shows the global distribution of the different types of introduced terrestrial difference vectors.

The datum of DTRF2008 was defined according to the IERS Conventions 2003: the origin was realized by SLR observations only. The scale was realized as a weighted mean of the SLR and the VLBI scale. The orientation was defined by a no-net-rotation condition w.r.t. ITRF2005. Exemplarily, for the DTRF2008 solution the velocity field is shown in Fig. 3.1.4.

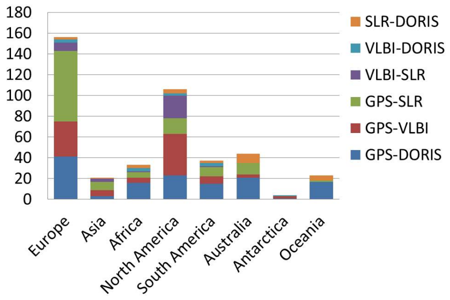


Fig. 3.1.3: Number of terrestrial difference vectors used per co-location type and continent/ region

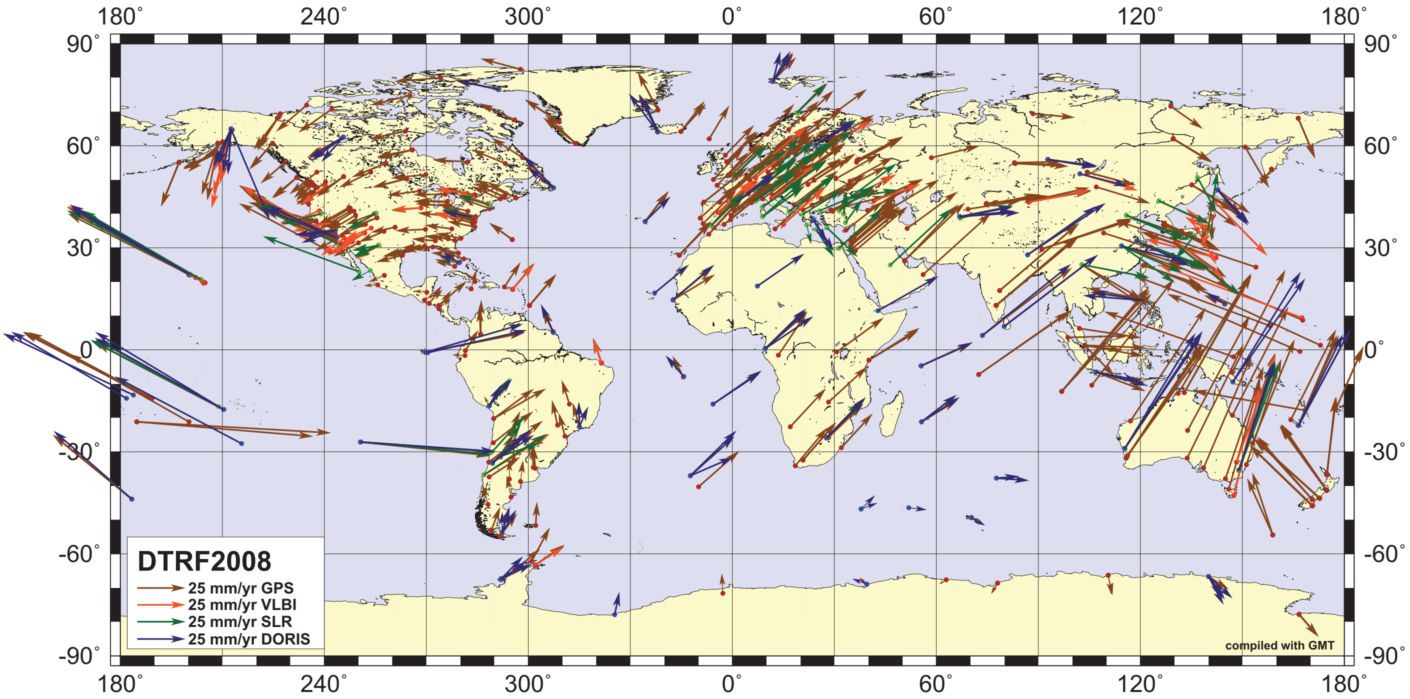


Fig. 3.1.4: Horizontal station velocities of DTRF2008

Comparison of DTRF2008 and ITRF2008

Within the reorganized structure of the IERS, three ITRS combination centres were installed. Two of those, the IGN (France) and DGFI contribute to the ITRF2008 realization by providing each a full TRF solution. The availability of two TRF solutions computed from the same input data sets provide the basis to validate these solutions and to assess the accuracy for the ITRF. Here, especially the effect of differences between the combination strategies applied by the combination centres has to investigated.

The comparison of DTRF2008 and ITRF2008 was done separately for the datum parameters and the network geometry. Fig. 3.1.5 shows the translation, rotation and scale parameters derived from similarity transformations performed technique-wise. The results show that transformation parameters of more than 4 mm occur (i.e., tz of GPS and rz of VLBI). But, in particular attention has to be paid to the differences between the parameters derived from the individual transformations for the four space techniques. The differences reach up to 7 mm. In case of the scale a significant difference of 4-5 mm between SLR and the other

Fig. 3.1.5: Translation (left), rotation (middle) and scale (right) parameters [mm] for the transformation from DTRF2008 to ITRF2008. The transformation epoch is 2000.0.

Tab. 3.1.1: RMS values of 14 parameter similarity transformation between DTRF2008 and ITRF2008. Core stations are used for the transformations.

	position [mm]	*velocity [mm/a]*
GPS	*0.38*	*0.19*
VLBI	*1.33*	*0.09*
SLR	*2.00*	*0.82*
DORIS	*3.20*	*0.98*

techniques do exist. A different handling of the terrestrial difference vectors of both ITRS combination centres might explain these datum differences.

In order to investigate the agreement of the network geometry the RMS values derived from the transformations (see Tab. 3.1.1) are analyzed. The transformations are performed using sets of core stations. The RMS values show that the mean difference in network geometry is very small for GPS but reaches up to 3.2 mm and 1.0 mm/a for DORIS. As for the datum parameters this might be related to differences in the implementation of the terrestrial difference vectors.

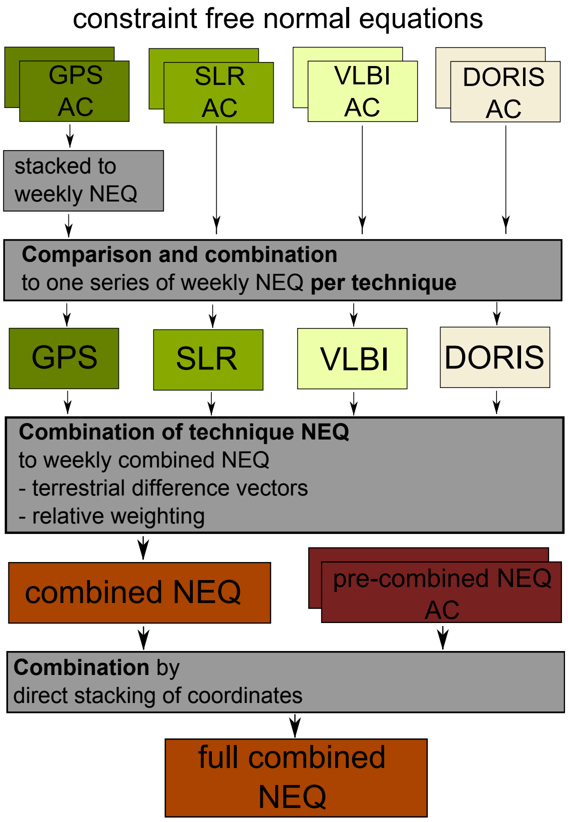
Contributions to the IERS Working Group on Combination on the Observation Level (COL)

The IERS Working Group on Combination on the Observation Level (COL) was established in 2009. The focus of the working group is on the combination of various space geodetic techniques either directly on the observation level or on the level of normal equations, provided that the analysis software packages are homogenized w.r.t. the models and parametrization.

DGFI contributes to the working group at two different stages: (1) it provides normal equations derived from VLBI and SLR observations as input data in its function as analysis centres (AC) and (2) compares the input data provided by the AC's and computes combined solutions considering all common parameters (station coordinates, EOP, spherical harmonic coefficients of the Earth's gravity field, troposphere parameters, ...) as one of the two combination centres.

The limited time span of the VLBI intensive campaign CONT08 was chosen for the initialization and test of the work flow between the participants of the working group. In a first run 12 individual contributions are provided. Besides technique-only contributions also normal equations resulting from a combined analysis of two techniques (combined on the observation level) are provided. For example a common analysis of GNSS and SLR observations of GNSS satellites equipped with retro reflectors or a combined SLR and DORIS observation analysis for satellites tracked by both techniques. Such kind of data are not included in the computation of the currents IERS products. Thus, a central task of the working group is to investigate how these data can be introduced in the combination. Fig. 3.1.6 shows the combination flow chart for the computation of weekly combined solutions.

Fig. 3.1.6: Flow chart for the computation of weekly combined solutions.



Related Publications:

Rothacher et al., GGOS-D: Homogeneous Reprocessing and Rigorous Combination of Space Geodetic Observations, J Geod (submitted)

Seitz M., Angermann D., Bloßfeld M., Gerstl M., Heinkelmann R., Kelm R., Müller H.: Die Berechnung des Internationalen Terrestrischen Referenzrahmens ITRF2008 am DGFI. Zeitschrift für Vermessungswesen, 135, Heft 2, 2010

Seitz et al., Accuracy Assessement of the ITRF 2008 Realization of DGFI: DTRF2008, in Z. Altamimi et al. (Eds.), Reference Frames for Applications in Geosciences, IAG Symposia (submitted)

Seitz et al., The 2008 DGFI Realization of the ITRS: DTRF2008, J Geod (submitted)

Steigenberger et al., GPS antenna array at the Geodetic Observatory Wettzell, in Z. Altamimi et al. (Eds.), Reference Frames for Applications in Geosciences, IAG Symposia (submitted)

Thaller et al., Combination of GNSS and SLR observations using satellite co-locations, J Geod (submitted)

3.2 IGS Regional Network Associate Analysis Centre for SIRGAS

The SIRGAS Reference Frame

The present realisation of SIRGAS is a network of more than 230 continuously operating stations covering Latin America and the Caribbean. This so-called SIRGAS-CON network is weekly processed to generate (Sánchez et al. 2010):

a. Loosely constrained weekly solutions of station positions: in these solutions satellite orbits, satellite clock offsets, and Earth orientation parameters are fixed to the final weekly IGS combinations and all station positions are loosely constrained with ±1 m.

b. Weekly station positions aligned to the ITRF: here the weekly free normal equations are solved using the same (ITRF) reference stations selected by the IGS to compute the GNSS orbits, i.e. the IGS reference frame, at present, the IGS05 (http://www.igs.org/network/refframe.html). The datum realisation is given by constraining the weekly positions of the IGS reference stations provided in the IGS weekly products (solutions igsyyPwwww.snx, see Section 1.2). The applied constrains guarantee that the coordinates of the IGS reference stations do not change more than 1.5 mm within the SIRGAS-CON adjustment.

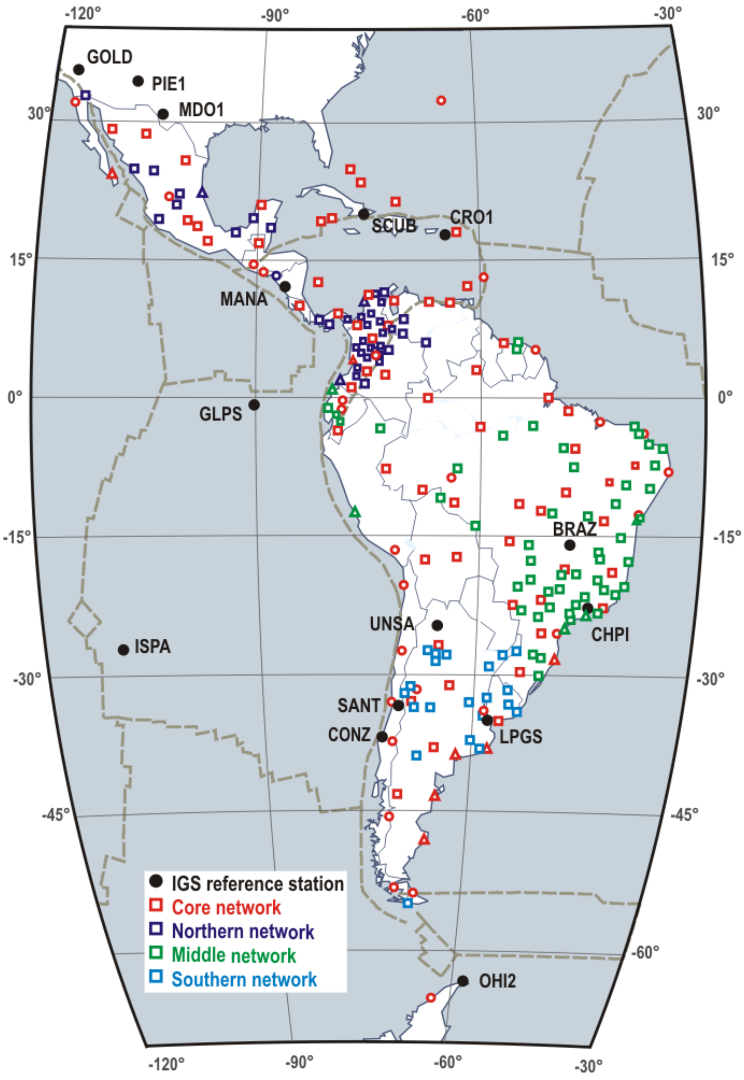


Fig. 3.2.1 SIRGAS reference frame (status December 2010)

Until 31 August 2008 (GPS week 1495), DGFI processed the entire SIRGAS-CON network in one block. Due to the large (and still increasing) number of stations and thanks to the installation of SIRGAS Processing Centres under the responsibility of Latin American institutions, it was possible to redefine the analysis strategy of the SIRGAS reference frame. This new strategy is based on the combination of individual solutions including different clusters of stations. For this purpose, the SIRGAS-CON network is divided in (Fig. 3.2.1):

a. One core network (SIRGAS-CON-C) with about 110 stations distributed over the whole continent, and
b. Different densification sub-networks (SIRGAS-CON-D) distributed regionally on the northern, middle, and southern part of the continent.

These sub-networks (i.e. clusters) are individually processed by the SIRGAS Processing Centres: the core network is computed by DGFI, the other sub-networks by the SIRGAS Local Processing Centres: CIMA (Argentina), IBGE (Brazil), IGAC (Colombia), IGM-Ecuador, IGN-Argentina, INEGI (Mexico), LGFS-LUZ (Venezuela), and SGM-Uruguay. The weekly combination of the individual solutions is carried out by the SIRGAS Combination Centres: DGFI and IBGE. The distribution of the SIRGAS-CON stations within the individual clusters guarantees that each station is included in three solutions. Fig. 3.2.2 shows the data flow within the analysis of the SIRGAS reference frame.

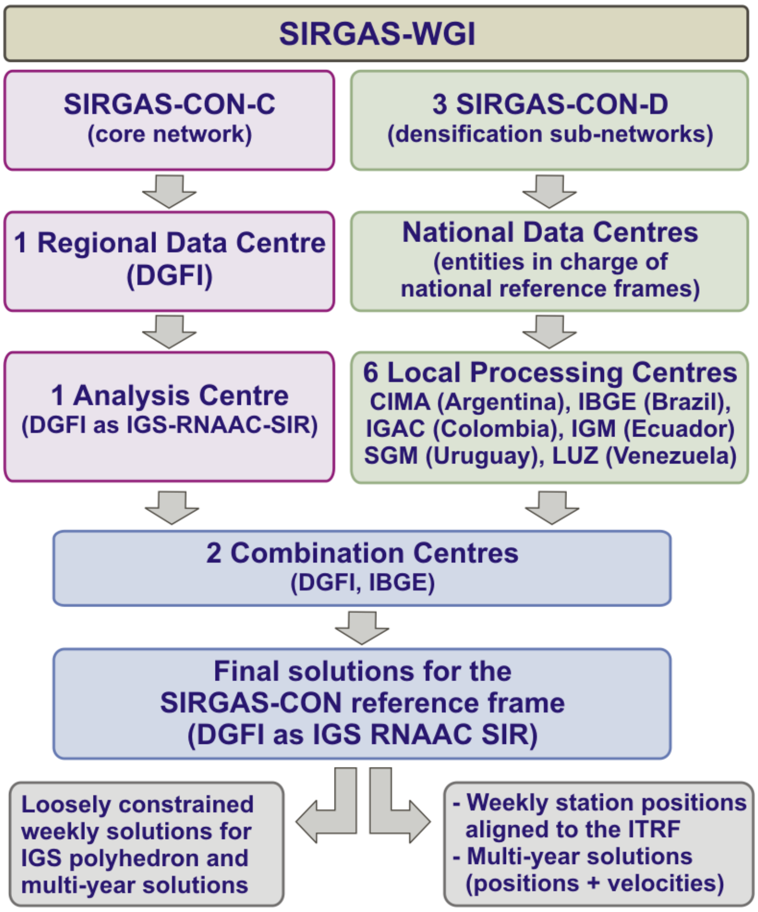


Fig. 3.2.2 Data flow in the analysis of the SIRGAS reference frame

As responsible for the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR), DGFI continues delivering the official SIRGAS products to the IGS (International GNSS Service) and the other SIRGAS users (Sánchez and Seemüller 2010).

Kinematics of the SIRGAS reference frame

To estimate the kinematics of the SIRGAS reference frame, DGFI in its function as the IGS RNAAC SIR computes (updates) a cumulative (multi-year) solution every year, providing epoch positions and constant velocities for stations operating longer than two years. The coordinates of the multi-year solutions refer to the latest available ITRF and to a specified epoch, e.g. the most recent SIRGAS-CON multi-year solution SIR10P01 refers to ITRF2008, epoch 2005.0 (Seemüller et al. 2010). SIR10P01 includes all the weekly normal equations provided by the SIRGAS analysis centres from January 2, 2000 (GPS week 1043) to June 5, 2010 (GPS week 1586) and provides positions and velocities for 183 reference stations (Fig. 3.2.3). Its precision was estimated to be ±0.5 mm (horizontal) and ±0.9 mm (vertical) for the station positions at the reference epoch, and ±0.2 mm/a (horizontal) and ±0.4 mm/a (vertical) for the constant velocities, respectively.

Fig. 3.2.4 summarizes the main characteristics of the different SIRGAS multi-year solutions generated by the IGS RNAAC SIR. It should be noted that solutions computed since 2007 include the

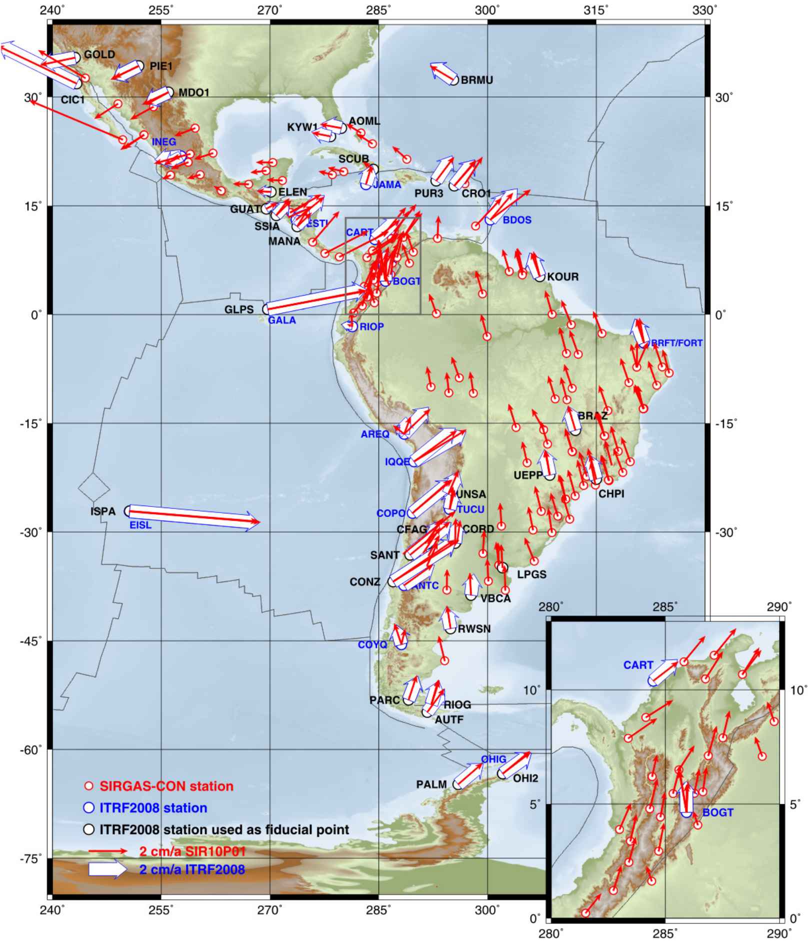


Fig. 3.2.3 Horizontal velocities of the SIR10P01 multi-year solution. Velocities of ITRF2008 stations are included for comparison.

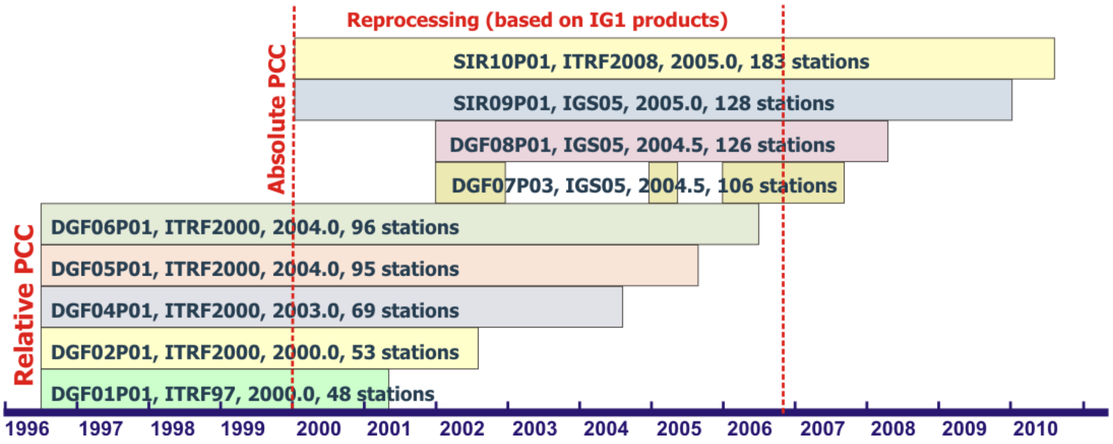


Fig. 3.2.4 Time spans, number of stations, and reference frame considered in the different SIRGAS multi-year solutions (PCC: Phase Centre Corrections).

reprocessed normal equations for the weeks before November 2006 (GPS week 1399). This reprocessing takes into account the IGS05 as reference frame and the antenna absolute phase centre corrections provided by the IGS (model igs05_1525.atx, see: http://igscb.jpl.nasa.gov/igscb/ station/general/pcv_archive/).

Sustainability of the SIRGAS reference frame

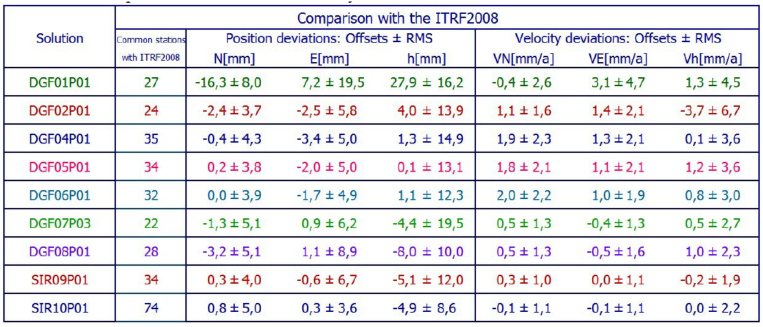
To evaluate the sustainability of the SIRGAS realisations, the different multi-year solutions were compared with the ITRF2008. For this purpose, the coordinate comparison was done for epoch 2000.0 and the SIRGAS solutions were transformed to ITRF2008 using the transformation parameters presented in the IERS Conventions 2010. In this comparison stations affected by earthquakes were excluded (see bellow).

Results (Table 3.2.1) show a very good consistency between the different SIRGAS realisations. The largest discrepancies (~2 cm) were detected for the SIRGAS realisation referring to ITRF97. Realisations referring to ITRF2000 and IGS05 have an agreement better than ±5 mm. This reflects the expected improvement of the frame as consequence of longer time series of station positions and the better new models, standards, and analysis strategies applied today.

Impact of seismic events on the SIRGAS reference frame

The western part of the SIRGAS region is located in the plate boundary zone between the Pacific, Cocos, and Nazca plates in the west and the North American, Caribbean, and South American plates in the east. The motion of these plates causes an ex-

Tab. 3.2.1 Comparison of the SIRGAS multi-year solutions with the ITRF2008



Solution	Comparison with the ITRF2008						
	Common stations with ITRF2008	Position deviations: Offsets ± RMS			Velocity deviations: Offsets ± RMS		
		N[mm]	E[mm]	h[mm]	VN[mm/a]	VE[mm/a]	Vh[mm/a]
DGF01P01	27	-16,3 ± 8,0	7,2 ± 19,5	27,9 ± 16,2	-0,4 ± 2,6	3,1 ± 4,7	1,3 ± 4,5
DGF02P01	24	-2,4 ± 3,7	-2,5 ± 5,8	4,0 ± 13,9	1,1 ± 1,6	1,4 ± 2,1	-3,7 ± 6,7
DGF04P01	35	-0,4 ± 4,3	-3,4 ± 5,0	1,3 ± 14,9	1,9 ± 2,3	1,3 ± 2,1	0,1 ± 3,6
DGF05P01	34	0,2 ± 3,8	-2,0 ± 5,0	0,1 ± 13,1	1,8 ± 2,1	1,1 ± 2,1	1,2 ± 3,6
DGF06P01	32	0,0 ± 3,9	-1,7 ± 4,9	1,1 ± 12,3	2,0 ± 2,2	1,0 ± 1,9	0,8 ± 3,0
DGF07P03	22	-1,3 ± 5,1	0,9 ± 6,2	-4,4 ± 19,5	0,5 ± 1,3	-0,4 ± 1,3	0,5 ± 2,7
DGF08P01	28	-3,2 ± 5,1	1,1 ± 8,9	-8,0 ± 10,0	0,5 ± 1,3	-0,5 ± 1,6	1,0 ± 2,3
SIR09P01	34	0,3 ± 4,0	-0,6 ± 6,7	-5,1 ± 12,0	0,3 ± 1,0	0,0 ± 1,1	-0,2 ± 1,9
SIR10P01	74	0,8 ± 5,0	0,3 ± 3,6	-4,9 ± 8,6	-0,1 ± 1,1	-0,1 ± 1,1	0,0 ± 2,2

tremely high seismic activity in this area, generating episodic station movements (Table 3.2.2) and deformations in the SIRGAS reference frame. The precise determination and modelling of co-seismic and post-seismic displacements is necessary to guarantee:

a. The reliability of the SIRGAS weekly positions estimated for the week when a seismic event occurs;
b. The appropriate transformation of station positions between the pre-seismic and the post-seismic (deformed) reference frame;
c. The long-term stability of the SIRGAS reference frame.

Tab. 3.2.2 Seismic events with high impact in the SIRGAS frame since 2000.

Location	**Date**	**M**	**Coordinate change**	**Affected stations**
Mexicali, Mexico	*2010-04-04*	*7,2*	*23 cm*	*MEXI*
Chile	*2010-02-27*	*8,8*	*1 to 305 cm*	*See Fig. 3.2.5*
Costa Rica	*2008-01-08*	*6,1*	*2 cm*	*ETCG*
Martinique	*2007-11-29*	*7,4*	*1 cm*	*BDOS, GTK0*
Copiapo, Chile	*2006-04-30*	*5,3*	*2 cm*	*COPO*
Tarapaca, Chile	*2005-06-13*	*7,9*	*6 cm*	*IQQE*
Managua, Nicaragua	*2004-10-09*	*6,9*	*1 cm*	*MANA*
Arequipa, Peru	*2001-06-23*	*8,4*	*52 cm*	*AREQ*
El Salvador	*2001-02-13*	*7,8*	*4 cm*	*SSIA*

According to this, always when a strong earthquake shakes the SIRGAS region, DGFI (as the IGS RNAAC SIR) processes as soon as possible the available GNSS measurements to estimate the impact on the reference frame. The usual procedure is based on the computation of free daily normal equations, which include IGS reference stations located outside the SIRGAS region, i.e. in Europe, North America, Africa, and Antarctica. These external IGS stations are used for the datum definition in the solution of the normal equations and as fiducial points for the calculation of a similarity transformation between the pre-seismic and post-seismic networks. By comparing daily station positions and the geometry of the network before and after the earthquake, it is possible to determine displacements of the SIRGAS reference stations associated to the seism. In the same way, the analysis of station position time series allows to estimate further post-seismic movements and/or significant changes in the constant velocity of the affected stations.

The largest displacements produced by an earthquake on the SIRGAS reference frame corresponds to the seism (M=8.8) occurred on 2010-02-27 in Chile. 23 SIRGAS reference stations moved more than 1.5 cm. The largest displacements were detected between latitudes 30°S to 40°S from the Pacific to the Atlantic coast (Fig. 3.2.5). Results show that the station CONZ (Concepción, Chile) initially moved 305.4 cm in the South-West-direction. In the two weeks following the first earthquake, additional post-seismic movements of about 10 cm were identified. Until now (De-

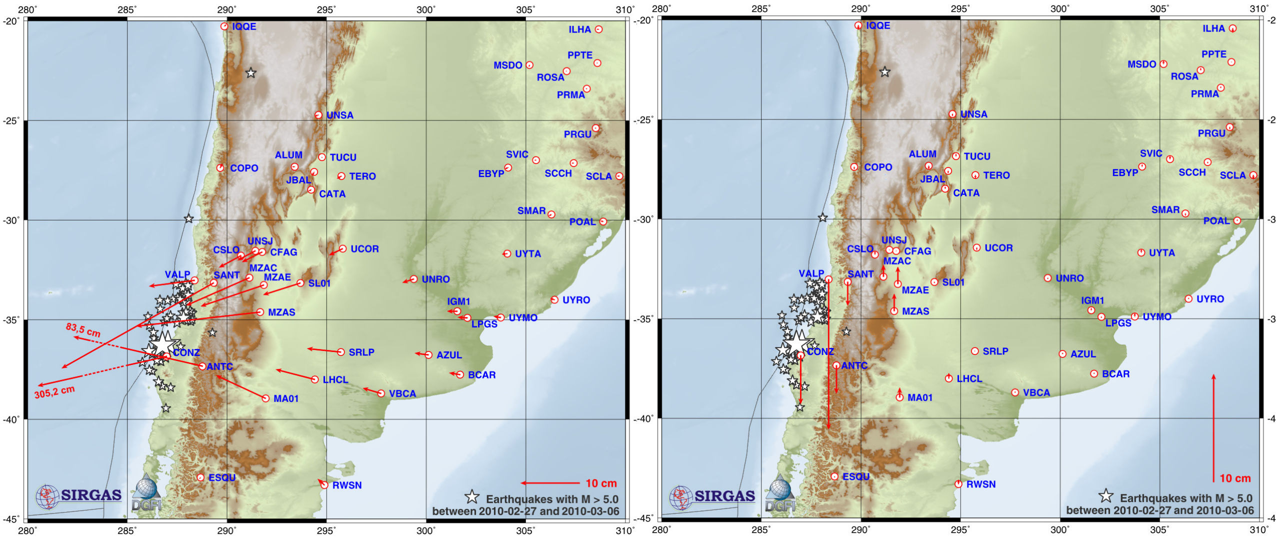


Fig. 3.2.5 Station displacements caused by the earthquake occurred on 2010-02-27 in Chile.

cember 2010), this station moved 9 cm more in the East-direction. Strong vertical co-seismic displacements were also identified in Concepción (CONZ), Santiago (SANT), Valparaíso (VALP) and the Province of Mendoza (MZAC, MZAE, MZAS) in Argentina. Stations located in the west of the Andes moved downwards, stations located in the east moved upwards (Fig. 3.2.5).

Related publications:

Sanchez L., Seemüller W., Seitz M., Forberg B., Leismüller F., Arenz H.: SIRGAS: das Bezugssystem für Lateinamerika und die Karibik. Zeitschrift für Vermessungswesen, 135, Heft 2, 2010

Sanchez L., Seemüller W.: Report of the SIRGAS Analysis Centre at DGFI. SIRGAS 2010 General Meeting. www.sirgas.org, 2010

Seemüller W., Sanchez L., Seitz M., Drewes H.: The position and velocity solution of the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR). DGFI Report No. 86, 2010

3.3 Operation and applications of permanent GPS stations

In the frame of different international cooperation projects, DGFI has installed 15 continuously observing GNSS stations since 1998 (Fig. 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 different projects (Table 3.3.1) such as the IGS Tide Gauge Benchmark Monitoring Project (TIGA), monitoring crustal deformations in the Alpine Region, densification of the International Terrestrial Reference Frame (RNAAC-SIR, see Topic 3.2), and the unification of local height datums (SIRGAS-WGIII, see Topic 1.4). Due to communication problems to transmit the tracking data, some stations were decommissioned and installed in new sites, close to locations with better Internet facilities (e.g. MPL2, PDE2). Station MARA is now managed by the Instituto Geográfico de Venezuela Simón Bolívar (IGVSB) in cooperation with the Universidad del Zulia (LUZ). Although the new equipment operating at this station does not belong to DGFI, IGVSB and LUZ continue providing the observations to the corresponding projects. At present, DGFI coordinates with the Geographical Institutes of Bolivia and Chile the installation of seven additional stations.

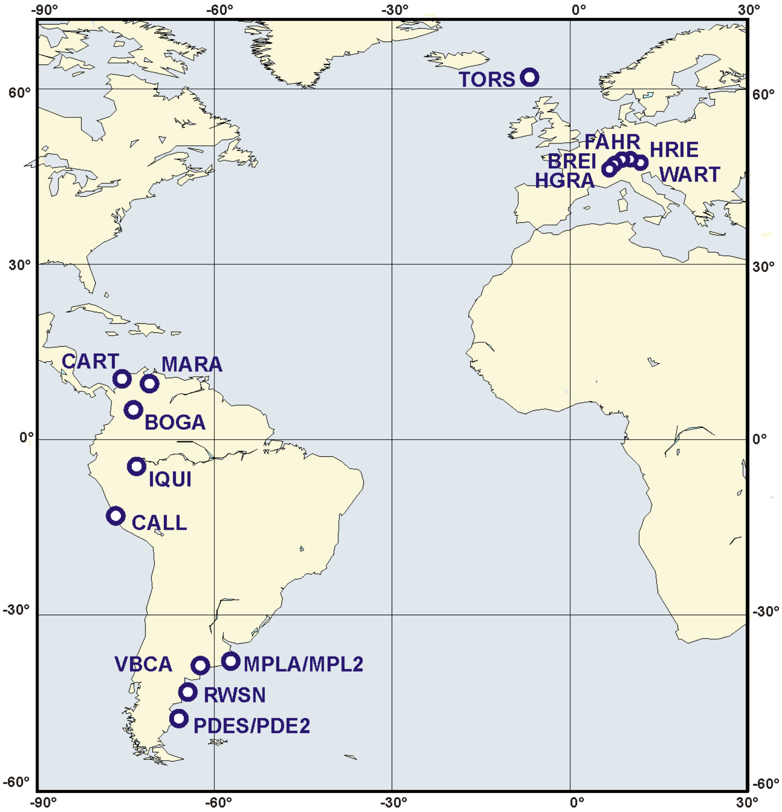


Fig. 3.3.1 Distribution of the continuously operating GNSS stations of DGFI.

Tide gauge benchmark monitoring project

TIGA (Tide Gauge Benchmark Monitoring Project, http://adsc.gfz-potsdam.de/tiga/) was established as a pilot project of the IGS in 2001. Its main objective is focussed on monitoring vertical variations of the Earth's crust at tide gauges using continuously operating GPS stations. After 10 years of activities, the TIGA products are accepted and used by different organizations working on studying and monitoring sea level changes such as

Station	Location	Partner institution	In operation since	Project
BOGA	Bogotá, Colombia	Instituto Geográfico Agustín Codazzi (IGAC)	Feb. 2000	ITRF/SIRGAS
BREI	Breitenberg, Germany	- - -	Jul. 2005	Alpine deformation
CALL	El Callao, Peru	Instituto Geográfico Nacional (IGN-Pe)	Jul. 2009	ITRF/SIRGAS, TIGA, vertical datum unification
CART	Cartagena, Colombia	Instituto Geográfico Agustín Codazzi (IGAC)	Feb. 2000	ITRF/SIRGAS, TIGA, vertical datum unification
FHAR	Fahrenberg, Germany	- - -	Jul. 2005	Alpine deformation
HGRA	Hochgrat, Germany	- - -	Jul. 2005	Alpine deformation
HRIE	Hochries, Germany	- - -	Jul. 2005	Alpine deformation
IQUI	Iquitos, Peru	Instituto Geográfico Nacional (IGN-Pe)	Jul. 2009	ITRF/SIRGAS
MARA	Maracaibo, Venezuela	Station under the responsibility of DGFI until 15/07/2008	Feb. 1998	ITRF/SIRGAS
MPLA/ MPL2	Mar del Plata, Argentina	Universidad Nacional de La Plata	Oct. 2002	ITRF/SIRGAS, TIGA
PDES/ PDE2	Puerto Deseado, Argentina	Universidad Nacional de Cuyo	May 2005	ITRF/SIRGAS, TIGA, vertical datum unification
RWSN	Rawson, Argentina	Universidad Nacional de La Plata	Nov. 1999	ITRF/SIRGAS, TIGA, vertical datum unification
TORS	Torshavn, Faroe Islands	- - -	Feb. 2001	Decommissioned on 03/07/2005
VBCA	Bahía Blanca, Argentina	Universidad Nacional de La Plata	Dec. 1998	ITRF/SIRGAS, TIGA, vertical datum unification
WART	Wartsteinkopf, Germany	- - -	Jul. 2005	Alpine deformation

Tab. 3.3.1. GNSS stations installed by DGFI

GLOSS (Global Sea Level Observing System), GGOS (Global Geodetic Observing System), GCOS (Global Climate Observing System), WCRP (World Climate Research Programme), etc. During the latest meeting of the IGS Governing Board in December 2010 in San Francisco (USA), it was decided to convert TIGA from a pilot project to an IGS Working Group and to accept TIGA products as official IGS products.

DGFI is involved in the TIGA activities since the creation of the Pilot Project itself. Main contributions are i) operation of continuously observing GPS stations at different tide gauges, and ii) processing of a network covering the entire North and South Atlantic ocean as a TIGA Analysis Centre (Figure 3.3.2). As a result of this processing, weekly loosely constrained solutions along 10 years have been provided in SINEX format to the TIGA Associated Analysis Centres (TAAC) and to other users through the web site http://adsc.gfz-potsdam.de/tiga/index_TIGA.html. In addition, DGFI computes (updates) every year a cumulative (multi-year) solution to estimate epoch station positions and constant velocities referred to the ITRF. These velocities are compared with those derived from historical tide gauge records and satellite altimetry observations to distinguish secular sea level changes from vertical land motions. In this way, measured mean sea levels can be linked to a common reference system, i.e. ITRS/

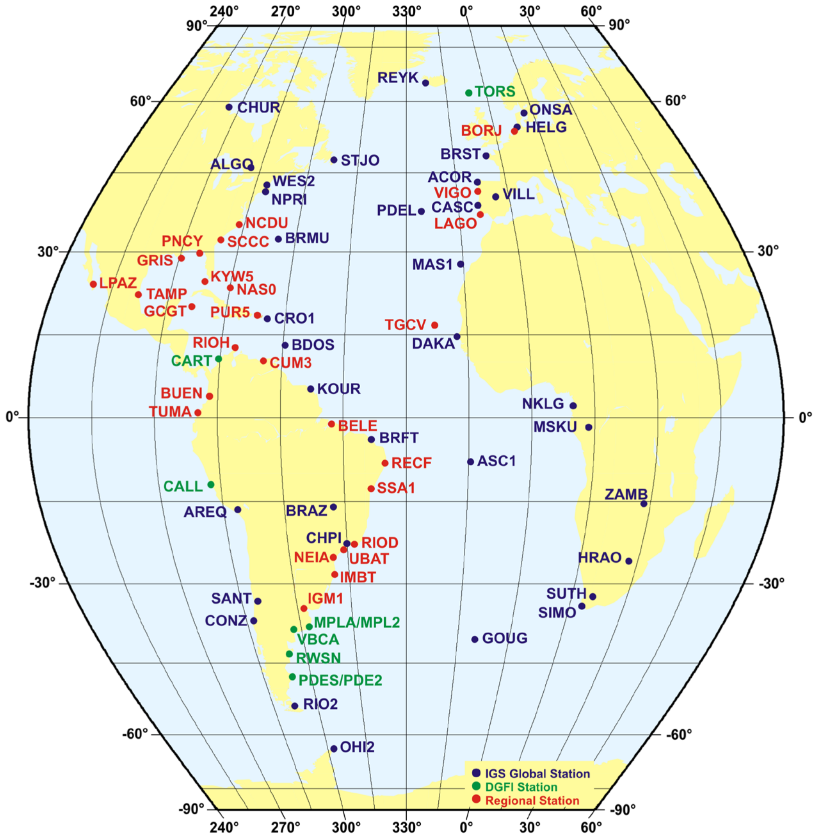


Fig. 3.3.2 TIGA GPS network processed by DGFI between 2001 and 2010.

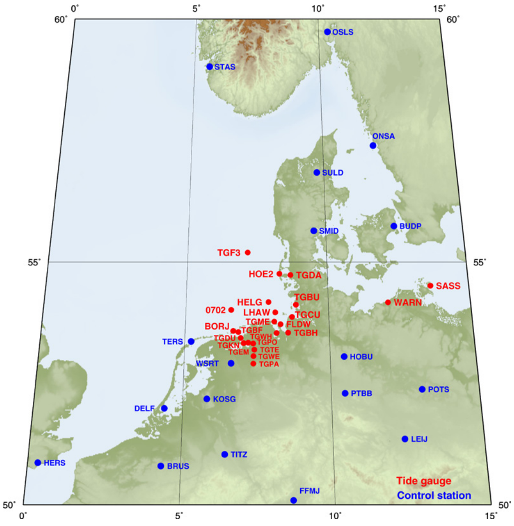


Fig. 3.3.3 GNSS network processed by DGFI as a support to the German Federal Institute of Hydrology.

ITRF. Results of this analysis are very useful, among others, for the unification of vertical reference systems (see Topic 1.4) and for the validation of satellite altimetry data (see Topic 2.2).

Based on the new role of TIGA within the IGS and with the objective to support the determination of a global vertical reference frame, DGFI decided to extend its computations to a global network including about 150 stations. Daily normal equations between January 2000 and December 2010 are being computed using the IGS reprocessed products (IG1) and absolute phase centre corrections. The analysis strategy is based on the double difference approach and the Bernese GPS Software Version 5.0 is used for the data processing. First results are expected for the middle of 2011.

In the frame of TIGA, DGFI also cooperates with the German Federal Institute of Hydrology by processing a network of 17 GNSS stations co-located with the main German tide gauges on the Nordic and Baltic See coasts (Figure 3.3.3). The first stations were installed in 2008, the latest ones in February 2010. Once all stations have operated more than two years a first station velocity estimation will be assessed.

Monitoring crustal deformations in the Alpine Region

Five continuously operating GPS stations were installed by DGFI along the northern Alps boundary within the ALPS-GPS QUAKENET project, a component of the Alpine Space Programme of the European Community Initiative Programme (CIP) INTERREG IIIB. The main purpose of this project was

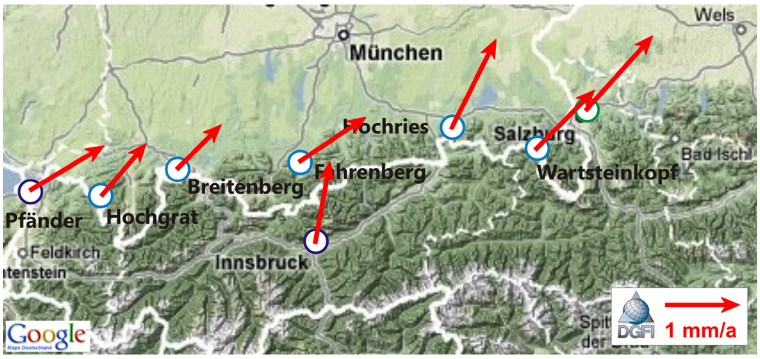


Fig. 3.3.4a Horizontal movements of the northern Alps relative to the Eurasia plate

Fig. 3.3.4b Vertical movements of the northern Alps

to determine crustal deformations in near real-time to improve natural disaster prevention in the Alpine region. During the two years (2005 - 2007) the project was carried out, DGFI provided the observational data of its stations to be analyzed together with other 25 stations installed in the area. Description, main features, and results of the project are presented in the report "ALPS GPS Quakenet: Alpine Integrated GPS Network", available at www.alps-gps.units.it.

DGFI weekly processes its five continuously operating stations in a small network, which includes four IGS05 reference stations, three IGS global stations, and two EUREF stations. Time series of station positions and a cumulative solution of this network are derived each year from loosely constrained daily solutions starting on 9 October 2005. The obtained station movements mainly reflect the Eurasia plate displacement (Fig. 3.3.4). Furthermore, in order to detect local deformations or isolated movements of the DGFI stations, three control points were installed around each DGFI site in a distance of about 100 m from the main point. Control points are measured with GPS once a year and distance vectors with respect to the main stations are analysed. Until now, neither regional nor local deformations have been detected.

Related publications:

Seemüller W., Arenz H., Bosch W., Hornik H., Leismüller F., Müller H., Sánchez L., Schwatke C.: Informationstechnologien und Kommunikation am DGFI. Zeitschrift für Vermessungswesen, 135, Heft 2, 2010

Sánchez L., Drewes H.: Wie sich die Alpen bewegen. Akademie Aktuell. Bayerische Akademie der Wissenschaften. Heft 3, Aufgabe 34: 71-72. Munich, 2010

3.4 ILRS — International Laser Ranging Service

DGFI contributes since long to the ILRS (http://ilrs.gsfc.nas.gov) in the maintenance of the global SLR (Satellite Laser Ranging) network as

- Data centre,
- Operations centre
- Analysis centre,
- Backup combination centre until September 2010.

The ILRS consists of a Central Bureau, a Governing Board which controls all activities within the ILRS and eight working groups. DGFI contributes to the Analysis and the Data Formats and Procedures Working Group. Besides it has a representative in the Governing Board.

ILRS Global Data Centre / EUROLAS Data Centre

Since the foundation of the International Laser Ranging Service (ILRS) in 1998 the EDC acts as one of two global ILRS data centres, the Crustal Dynamics Data Information System (CDDIS) at NASA and the European Data Centre (EDC) at DGFI. In 2010 a complete re-organisation of the data structure and the processing scheme started on new hardware, including a backup solution.

ILRS Operation Centre

In 2009 the EDC became an ILRS Operation Center (OC) after the implementation of the so-called Consolidated Ranging Data (CRD) format. The OC has the function to ensure that the conversion between the old NPT/FRD format and the new CRD format was made correct. The ILRS planned the transition to the new format at January 15, 2011, provided that all SLR stations are ready to deliver their observation data in the CRD format. The status of this transition is indicated by Table 3.4.1.

Tab. 3.4.1: CRD conversion status according to http://ilrs.gsfc.nasa.gov/products_formats_procedures/crd_station_status.html

Site	ID	Code	Coding	Testing	OC Val.	AC Val.	Operat.
Golosiiv	1824	GLSV	X	X	P		
Lviv	1831	LVIV	X	X	P		
Maidanak 1	1863	MAID					
Maidanak 2	1864	MAIL					
Komsomolsk	1868	KOML					
Mendeleevo	1870	MDVL					
Simeiz	1873	SIML	X	X	X	X	X
Altay	1879	ALTL					
Riga	1884	RIGL	X	P			
Katzively	1893	KTZL	X	X	X	X	X
McDonald	7080	MDOL	X	X	X	X	X
Yarragadee	7090	YARL	X	X	X	X	X
Greenbelt	7105	GODL	X	X	X	X	X
Monument Peak	7110	MONL	X	X	X	X	X
Haleakala, HI	7119	HA46	X	X	X	X	X
Tahiti	7124	THTL	X	X	X	X	X
Wuhan	7231	WUHL					
Chagchun	7237	CHAL	X	X	X	X	X
Beijing	7249	BEIL	X	P			
Koganei	7308	CHAL	X	X	X	X	X
Tanegahima	7358	GMSL	X	X	X	X	X
Arequipa	7403	AREL	X	X	X	X	X

Site	ID	Code	Coding	Testing	OC Val.	AC Val.	Operat.
Concepcion	7405	CONL	X	X	X	X	X
San Juan	7406	SJUL	P				
Hartebeesthoek	7501	HARL	X	X	X	X	X
Metsahovi2	7806	METL					
Zimmerwald	7810	ZIML	X	X	X	X	X
Borowiec	7811	BORL	X	X	X	P	
Kunming	7820	KUNL	X	X	P		
Shanghai	7821	SHA2	X	X	X	X	X
San Fernando	7824	SFEL	X	X	X	X	X
Mount Stromlo	7825	STL3	X	X	X	X	X
Helwan	7831	HLWL					
Riyadh	7832	RIYL	X	X	X	X	X
Simosato	7838	SISL	X	X	X	X	X
Graz	7839	GRZL	X	X	X	X	X
Herstmonceux	7840	HERL	X	X	X	X	X
Potsdam	7841	POT3	X	X	X	X	X
Grasse	7845	GRSM	X	X	X	X	X
Matera	7941	MATM	X	X	X	X	X
Wettzell	8834	WETL	X	X	X	X	X
FTLRS	----	----	X				
TROS	----	----					

Notes: X completed P in process Status: Dec. 2010

Mail Exploders

EDC is running several mail exploder for exchanging informations, data and results. The Consolidated Prediction Format (CPF) files of 34 satellites are exploded automatically on a daily and subdaily basis and stored at the anonymous ftp server. Mail exploder deliver mails to a set of recipients on instantaneously, in total the following number of mails were delivered:

- SLRMAIL 1944
- SLREPORT 13247
- URGENT mail 319.

Observed Satellite Passes

In 2010, 31 SLR stations observed 56 satellites. There were twelve new missions tracked by the SLR stations, namely CryoSat2, the Glonass satellites 116 - 125, OSZ-1 and Tandem-X. Table 3.4.2 shows the EDC data holdings of NPT and CRD data.

ILRS Analysis Centre

An ongoing task is the weekly/daily processing of the SLR tracking data to the geodetic satellites Lageos-1/2 and Etalon-1/2, which runs fully automated. The solutions contain station positions and Earth orientation parameters (X/Y-pole, LOD) and range bias values for selected tracking stations. The results are delivered as SINEX files to the ILRS data centers CDDIS and EDC to be used for the combined ILRS products.

As control of the SLR tracking data, pass dependent biases for all stations are processed on a daily basis and published on the DGFI/SLR-group Homepage: ilrs.dgfi.badw.de. In case of major problems, like significant time or range biases, the affected station and the ILRS task force are getting direct email with the problem to allow immediate reaction. Figure 3.4.1 shows

Tab. 3.4.2: Content of ILRS/EDC data base at December 31, 2010, for Normal points in the old npt and the new CRD format.

Satellite	number of passes	
	NPT	NPT-CRD
AJISAI	10425	8575
ANDEC	304	113
ANDEP	62	14
ANDE-RR P	1	1
APOLLO 11	2	2
APOLLO 14	3	3
APOLLO 15	58	41
BEACON-C	4574	3903
BLITS	2896	2303
CHAMP	765	498
COMPASSM1	1839	1430
CRYOSAT2	2920	2739
ENVISAT	4958	3976
ERS-2	5258	4217
ETALON-1	2185	1655
ETALON-2	2136	1605
ETS-8	38	20
GIOVE-A	772	555
GIOVE-B	1074	820
GLONASS-95	57	55
GLONASS-100	11	11
GLONASS-101	34	34
GLONASS-102	2059	1521
GLONASS-103	49	50
GLONASS-104	51	51
GLONASS-105	60	61
GLONASS-106	58	59
GLONASS-107	49	48
GLONASS-108	22	24
GLONASS-109	1073	742
GLONASS 110	484	464
GLONASS 111	56	55
GLONASS 112	9	9
GLONASS 113	51	50
GLONASS 114	57	57
GLONASS 115	2314	1780
GLONASS 116	43	43
GLONASS 117	50	51
GLONASS 118	527	523
GLONASS 119	48	48
GLONASS 120	1063	975
GLONASS 121	109	87
GLONASS 122	15	16
GLONASS 123	19	19
GLONASS 124	24	24
GOCE	799	574
GPS-35	38	26
GPS-36	886	624
GRACE-A	3464	2501
GRACE-B	3605	2626
ICESAT	660	235
JASON-1	7489	6197
JASON-2	8800	7400
LAGEOS-1	9312	7610
LAGEOS-2	7873	6300
LARETS	4081	3288
LRO	-	567
LUNA 17	1	1
PROBA 2	222	147
QSZ-1	55	56
REFLECTOR	14	5
STARLETTE	8283	6871
STELLA	4705	3849
Tandem-X	1752	1664
TerraSAR-X	3106	2482
WESTPAC-1	10	4
Sum of all	**113806**	**92340**

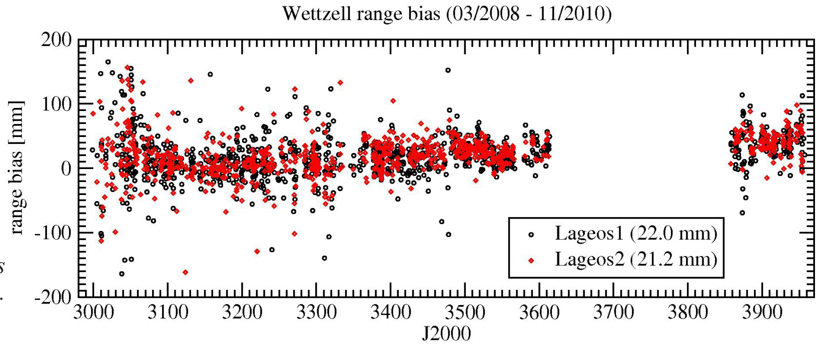


Fig. 3.4.1: Passwise range biases for Wettzell (Germany).

the change in range bias for Wettzell in 2009 and 2010. Even a longer period of system repair could not remove the 2 cm range bias,which resulted in a jump of the station height. The consequence of that bias was the withdrawal of the status as a core station and for further computations the estimation of a mandatory range bias for Wettzell, starting March 2009.

ILRS data correction files

The official ILRS data handling file is maintained at the DGFI ILRS pages http://ilrs.dgfi.badw.de/data_handling/ILRS_Data_Handling_File.snx
and holds a list of mandatory range-, time- and pressure biases to be applied or solved for. This file has to be used by all processing centres. On the same page the official ILRS discontinuity file, which keeps track of jumps in the SLR coordinate series, is maintained.

Adjustment of gravity field parameters from SLR observations

Within the work on the topic “Temporal highly resolved TRF/EOP combination” (section 1.2) the challenges which arise in the field of SLR are related to the combined estimation of station positions, EOP and gravity field parameter of degree two. To estimate accurate gravity field coefficients SLR tracking data to Lageos1 and 2 from 1993 till 2010 were reprocessed. A major focus of this reprocessing was the improvement of different a priori information for the empirical accelerations, the once-per-revolution terms and the solar radiation pressure terms in order to get more stable results. Especially the once-per-revolution terms play a crucial role in the estimation process. The different inclinations of the two Lageos satellites allow in a combination of the two satellites a decorrelation of the orbital parameters, the EOP and C20. This means that before October 1992, with only Lageos 1 in orbit, a combined estimation of the EOP and C20 was not possible without further informations.

The estimated gravity field coefficients of degree two (C20, C21, S21, C22, S22) show good agreement with other time series like the monthly available CSR solution which includes in addition other satellites like Stella, Starlette or Ajisai (Fig. 3.4.2).

Future work will concentrate on the impact of the different arc lengths of the SLR solutions on estimated parameters like TRF, EOP and gravity field coefficients.

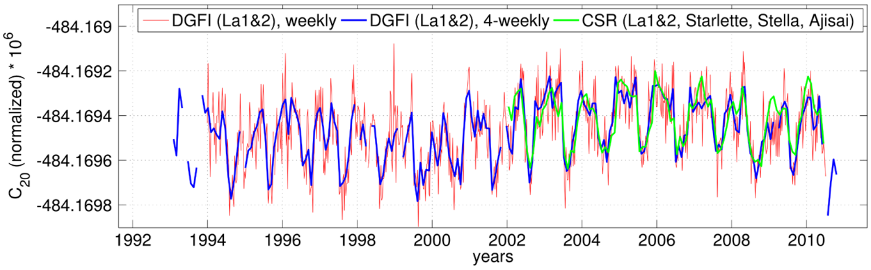


Fig. 3.4.2: estimated C20 coefficients from a weekly solution (red) and a 4-weekly solution (blue). For validation there is also displayed the CRS solution for C20 (green).

ILRS Backup Combination Centre

The ILRS has two combination centres which have slightly different approaches for the processing of the combined ILR product. The primary combination centre at ASI/Italy (ILRSA) combines loose constrained solutions for the official ILRS proceduct. Whereas the backup combination centre at DGFI (ILRSB) combines free normal equations. Both centres process on a daily basis seven-day combination solutions. The combination software package DOGS-AS was extended as to allow automatic processing of station positions. Especially, the automatic remedy of analytical outliers (singularities of normal equation systems, negative diagonal elements of covariance matrices, negative or unrealistic variance factors of the variance-covariance estimation) and of formal errors was investigated and further developed. Both results differ slightly due to the method used but the overall agreement is quit good. Figure 3.4.3 shows the translation and scale parameters of a similarity transformation between the two solutions in the period from Jan. 2009 to Sep. 2010.

The two solutions agree to a certain extent, but there are differences, mainly depending on the editing and weighting of the contributing solutions. Figure 3.4.4 shows the difference, after similarity transformation, between the two solutions for a good station (Yarragadee, Australia).

The task as backup combination centre has been switch to UMBC (NASA/University of Maryland) at the end of 2010 and cannot be continued at DGFI, due to manpower problems.

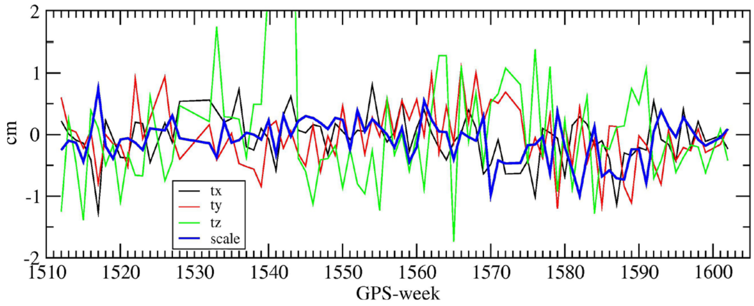


Fig. 3.4.3: Similarity transformation parameters between ILRSA and ILRSB in the period Jan 2009 to September 2010.

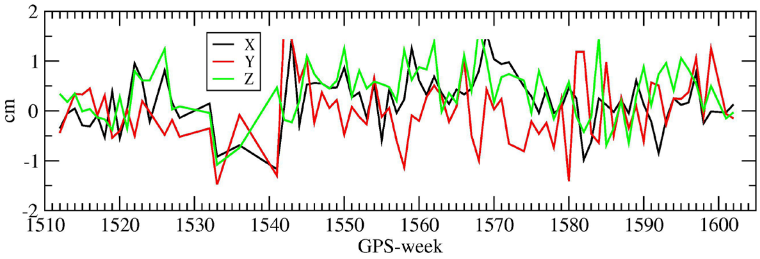


Fig. 3.4.4: Coordinate differences between ILRSA and ILRSB for the SLR station Yarragadee, Australia.

3.5 IVS Analysis Centre and IVS Combination Centre

Migration of OCCAM – LSM for LINUX into DOGS

The biggest and still ongoing effort made during 2010 is the rearrangement of the VLBI Analysis Software of DGFI, the former OCCAM software using the least-squares-method (LSM) for parameter estimation installed on LINUX PC and OS into the DGFI Orbit and Geodetic Parameter Estimation Software, DOGS (Heinkelmann and Gerstl, 2010). See section 1.1. for technical details of the migration.

IVS operational Analysis Centre at DGFI

DGFI routinely processes the standard IVS sessions (currently the two IVS rapid turnaround networks IVS-R1 and -R4) and additional sessions of the geodetic and astrometric program run by IVS and delivers datum free normal equations in SINEX format. The duty to process and submit sessions within 24 hours after the maintenance of the database (DB) version 4 (or higher) demands the full automation of the analysis. A small but important step towards automation could be achieved using the output of correlator information. The main task during 2010 was the automation of VLBI analysis at the 'post-post-processing' level, i.e. starting with DB version 4 (or higher). IVS folders containing DB files are routinely checked for new files. In case of a new file the highest DB version available is downloaded on a local LINUX PC and transformed to NGS format. Applying routines provided by IAA an ASCII text file is now created in addition to the transformation from DB to NGS format. The ASCII text file contains the correlator comments including those on real clock breaks. The clock breaks mentioned by the correlator are then automatically detected and removed by an algorithm developed at DGFI. After a first least-squares adjustment clock breaks and offsets are considered and a second robust adjustment eliminates possible outliers. The outlier-free group delays corrected of clock breaks and of clock offsets are then transformed into normal equations and written to SINEX format via the DOGS-CS software.

M8.8 Chilean Megaquake near Concepción

The very strong offshore Maule earthquake (M8.8) happened near Concepción, Chile, at February 27th, where BKG together with the Universidad de Concepción and the Instituto Geográfico Militar run the Transportable Integrated Geodetic Observatory (TIGO). About two weeks after the quake it was possible to continue VLBI observations. In the meantime the facility was used to aid humanitarian activities. Co- and post-seismic surface deformations led to drastic geometric changes of the coordinates of TIGOCONC (Fig. 3.5.1) in the order of 65cm (South), more than 3m (West), and about 20cm downwards. In particular the western coordinate jump is the biggest ever observed by VLBI at any of its stations. After the main event three more large earthquakes happened in the area. Two again offshore close to the basin of river Bio-Bio: M6.6 on the 5th of March and M6.7 on the 16th of March; and one under the Bio-Bio river bed: M6.5 on July 14th. For a better monitoring of the post seismicity the IVS has scheduled a series of five special three-hourly TIGO-quake observing sessions between 23rd of March until April 1st. The exact post-seismic position and velocity still need to be determined.

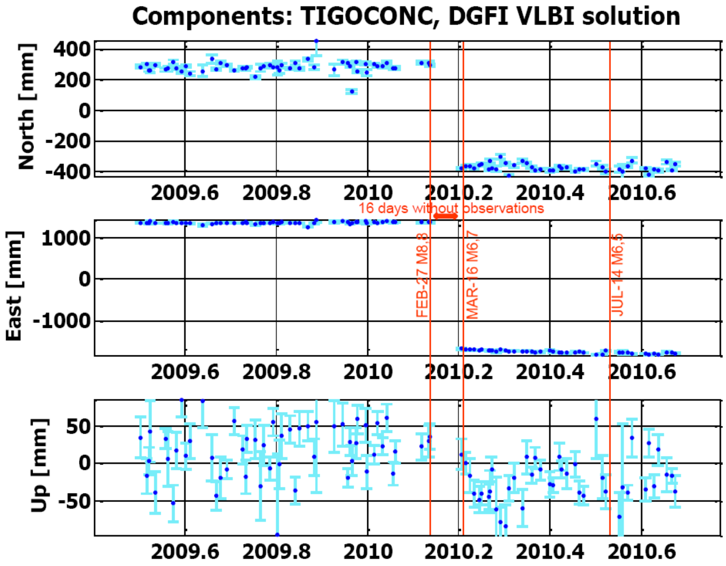


Fig. 3.5.1: Local coordinates of TIGOCONC, near Concepción, Chile, around the series of severe earthquakes: M8.8 on the 27th of February, M6.6 on the 5th of March, M6.7 on the 16th of March, and M6.5 on the 14th of July. The huge coordinate jump in the East component is the biggest change ever observed by geodetic VLBI.

IVS Combination Centre at BKG/DGFI

BKG and DGFI together run the operational Combination Centre of IVS. The Korean Astronomy and Space Science Institute (KASI) has agreed to act as a backup combination centre involving different combination procedures and software, but has not delivered results up to now. The inter-technique combinations for IVS activities are currently performed by accumulating either normal equations or solution equations. Since the observations analysed by the various Analysis Centres are initially identical, combinations on the observation equation level are pointless. Compared to the combination of solution equations, the normal equation level is advantageous because it still enables correlations among the parameters and allows the addition of a unique set of datum (condition) equations. The functional models of the inter-technique combination methods for normal equations and solutions are trivial, while the stochastic models are not. The current algorithm applied for routine combinations on the normal equation level includes individual scaling of the Analysis Centers' contributions through variance component estimation. The scaling is in particular valuable because different parameter estimation techniques, e.g. least-squares adjustment, Kalman filter, Square Root Information Filter (SRIF), or least squares collo-cation, might be applied by different ACs. Besides the scaling among the Analysis Centres the combination algorithm should consider the fact that the same original observations are used by the Analysis Centres. The 're-application of observations' requires the stochastic model to contain off-diagonal elements. The margins for a combination theory considering this were introduced by Kutterer et al. (2009) and labeled the Operator Software Impact (OSI). As a first step to improve the IVS combination strategy the OSI model has been applied to the combination of troposphere parameters during CONT08 (Heinkelmann et al., submitted). Some more details about the OSI are given in section 1.3.

Related publication:

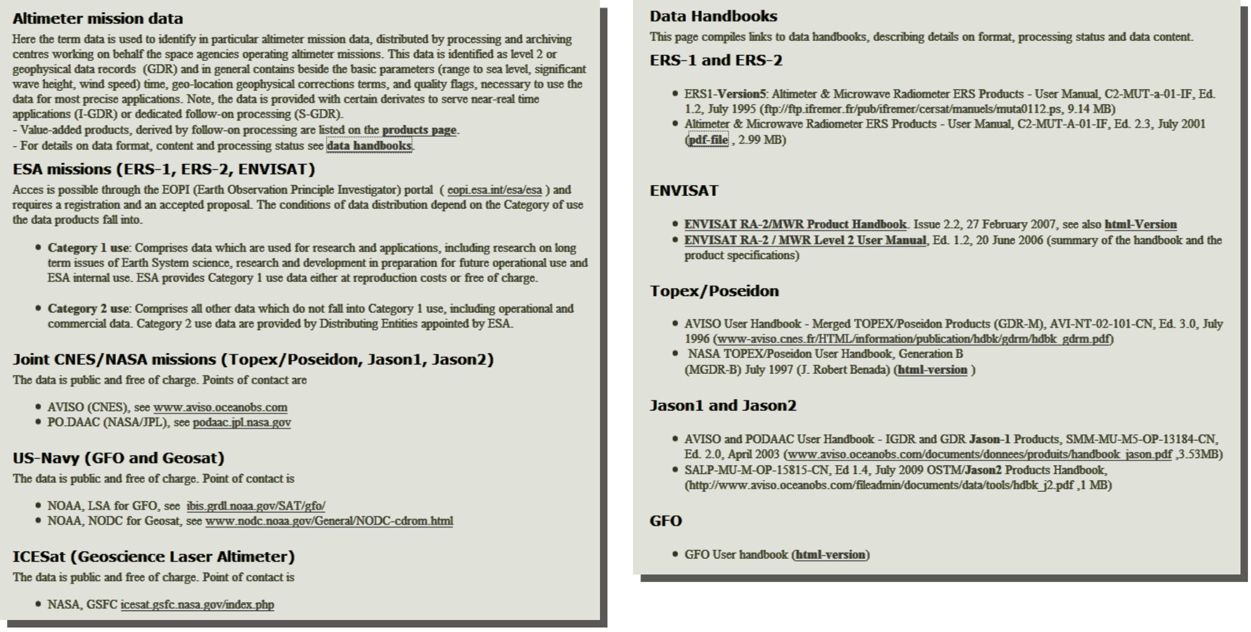
Heinkelmann R., J. Böhm, S. Bolotin, G. Engelhardt, R. Haas, R. Lanotte, D.S. MacMillan, M. Negusini, E. Skurikhina, O. Titov, H. Schuh (submitted): VLBI-derived troposphere parameters during CONT08. Journal of Geodesy, Special Issue CONT08

3.6 International Altimeter Service (IAS)

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

Website development

The compilation and presentation of general information has been identified as one of the initial activities. Altimetry users should be informed where to get what data, products and documents. Therefore a website at http://ias.dgfi.badw.de was launched with an initial compilation of available mission data and their associated data handbooks (see Fig. 3.6.1).



Altimeter mission data

Here the term data is used to identify in particular altimeter mission data, distributed by processing and archiving centres working on behalf the space agencies operating altimeter missions. This data is identified as level 2 or geophysical data records (GDR) and in general contains beside the basic parameters (range to sea level, significant wave height, wind speed) time, geo-location geophysical corrections terms, and quality flags, necessary to use the data for most precise applications. Note, the data is provided with certain derivates to serve near-real time applications (I-GDR) or dedicated follow-on processing (S-GDR).
- Value-added products, derived by follow-on processing are listed on the **products page**.
- For details on data format, content and processing status see **data handbooks**.

ESA missions (ERS-1, ERS-2, ENVISAT)

Acces is possible through the EOPI (Earth Observation Principle Investigator) portal (eopi.esa.int/esa/esa) and requires a registration and an accepted proposal. The conditions of data distribution depend on the Category of use the data products fall into.

- **Category 1 use**: Comprises data which are used for research and applications, including research on long term issues of Earth System science, research and development in preparation for future operational use and ESA internal use. ESA provides Category 1 use data either at reproduction costs or free of charge.
- **Category 2 use**: Comprises all other data which do not fall into Category 1 use, including operational and commercial data. Category 2 use data are provided by Distributing Entities appointed by ESA.

Joint CNES/NASA missions (Topex/Poseidon, Jason1, Jason2)

The data is public and free of charge. Points of contact are

- AVISO (CNES), see www.aviso.oceanobs.com
- PO.DAAC (NASA/JPL), see podaac.jpl.nasa.gov

US-Navy (GFO and Geosat)

The data is public and free of charge. Point of contact is

- NOAA, LSA for GFO, see ibis.grdl.noaa.gov/SAT/gfo/
- NOAA, NODC for Geosat, see www.nodc.noaa.gov/General/NODC-cdrom.html

ICESat (Geoscience Laser Altimeter)

The data is public and free of charge. Point of contact is

- NASA, GSFC icesat.gsfc.nasa.gov/index.php

Data Handbooks

This page compiles links to data handbooks, describing details on format, processing status and data content.

ERS-1 and ERS-2

- ERS1-**Version5**: Altimeter & Microwave Radiometer ERS Products - User Manual, C2-MUT-a-01-IF, Ed. 1.2, July 1995 (ftp://ftp.ifremer.fr/pub/ifremer/cersat/manuels/muta0112.ps, 9.14 MB)
- Altimeter & Microwave Radiometer ERS Products - User Manual, C2-MUT-A-01-IF, Ed. 2.3, July 2001 (**pdf-file** , 2.99 MB)

ENVISAT

- **ENVISAT RA-2/MWR Product Handbook**. Issue 2.2, 27 February 2007, see also **html-Version**
- **ENVISAT RA-2 / MWR Level 2 User Manual**, Ed. 1.2, 20 June 2006 (summary of the handbook and the product specifications)

Topex/Poseidon

- AVISO User Handbook - Merged TOPEX/Poseidon Products (GDR-M), AVI-NT-02-101-CN, Ed. 3.0, July 1996 (www-aviso.cnes.fr/HTML/information/publication/hdbk/gdrm/hdbk_gdrm.pdf)
- NASA TOPEX/Poseidon User Handbook, Generation B (MGDR-B) July 1997 (J. Robert Benada) (**html-version**)

Jason1 and Jason2

- AVISO and PODAAC User Handbook - IGDR and GDR **Jason-1** Products, SMM-MU-M5-OP-13184-CN, Ed. 2.0, April 2003 (www.aviso.oceanobs.com/documents/donnees/produits/handbook_jason.pdf ,3.53MB)
- SALP-MU-M-OP-15815-CN, Ed 1.4, July 2009 OSTM/**Jason2** Products Handbook, (http://www.aviso.oceanobs.com/fileadmin/documents/data/tools/hdbk_j2.pdf ,1 MB)

GFO

- GFO User handbook (**html-version**)

Fig. 3.6.1 Compilation of sources for altimeter mission data (left panel) and of data handbooks (right panel), describing the content of altimeter mission data.

A list of the most basic products, their characterization and links for downloads is currently being compiled. This will inform users about

– mean sea surface height models,
– sea level anomalies,
– marine gravity data,
– dynamic ocean topography, and
– global ocean tide models.

3.7 GGOS Bureau for Standards and Conventions

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

Mission

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

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

Activities in 2010

The BSC has started to collect all the relevant resolutions concerned with geodetic standards and conventions used by different entities and to compile an inventory of used constants. A major focus was thereby on the standards and conventions used within the IERS and the IGFS. Existing inconsistencies shall be identified and eliminated aiming at clearly described, reproducible and consistent common numerical standards for all geometric and gravimetric products. One example for inconsistencies is a different handling of permanent tides by the geometric and the gravimetric services. The gravimetric services provide products in the zero-tide system, in agreement with the IAG resolution of the 18th General Assembly in 1983, while the geometric services provide their products, e.g., the ITRF, in the tide-free system. Similarly, differences between the resolutions and actual use concerns the time system, geocentric coordinate time TCG vs. terrestrial time TT.

Related Publication:

Hugentobler U., Angermann D., Bouman J., M. Gerstl, Gruber T., Richter B., Steigenberger P.: GGOS Bureau for Standards and Conventions: Integrated Standards and Conventions for Geodesy. Proceedings of IAG 2009 Scientific Assembly "Geodesy for Planet Earth" (accepted) , 2010

4 Information Services and Scientific Transfer

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

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

4.1 Internet representation

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

Typo3 Content Management System

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

Home pages set up and maintained by DGFI

The Internet sites of DGFI inform about

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

DGFI uses the same system also for Internet sites dedicated to

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

Moreover, the Internet is used to maintain

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

DGFI home page

The DGFI home page, available under

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

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

Home page for IAG Office

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

http://iag.dgfi.badw.de

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

Geodesy Information System GeodIS

The geodesy information system GeodIS, located at

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

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

Recent news:

Establishment of the "Centre for Geodetic Earth System Research" (CGE)

The President of the Technical University Munich (TUM), Wolfgang A. Herrmann, the President of the Bavarian Academy of Sciences and Humanities (BAdW), Dietmar Willoweit, the Chairman of the German Geodetic Commission (DGK), Reinhard Dietrich, and the Director of the German Geodetic Research Institute (DGFI), Hermann Drewes, signed on October 28, 2010 the contract for the establishment of the Centre for Geodetic Earth System Research (CGE) in Munich. DGFI, the division Geodesy of the BAdW Commission on Geodesy and Glaciology (KEG), the Institute for Astronomical and Physical Geodesy (IAPG) and the Research Establishment for Satellite Geodesy (FESG) of TUM integrate their research in one common CGE programme. The principal objectives are investigations on global change by measuring variations in the solid Earth, oceans, ice covers and atmosphere, and analysing those variations with respect to the generating physical processes. [More]

Foto: A. Heddergott

Lange Nacht der Münchner Museen

Das DGFI nimmt auch in diesem Jahr an der "Langen Nacht der Münchner Museen" am Samstag, 16. Oktober 2010, 19:00 - 02:00 Uhr, teil. Interessierte sind herzlich eingeladen sich die historische Entwicklung von Triangulation und Nivellement bis zu den Satellitenverfahren anzusehen und mit den DGFI-Wissenschaftlern bei einem Imbiss zu diskutieren. Informationen finden sich unter www.muenchner.de/museumsnacht/ und www.muenchner.de/museumsnacht/ansicht.php

ITRF2008 solution of DGFI (ITRF2008D) is now available

DGFI as one of the ITRS Combination Centres of International Earth Rotation

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

Geodesist's Handbook 2008, Springer Online (pdf, 4.56 MB)

IAG Handbook 2008 (Frequently updated Internet version)

IAG Structure 2007-2011.pdf

IAG Statutes 2007.pdf

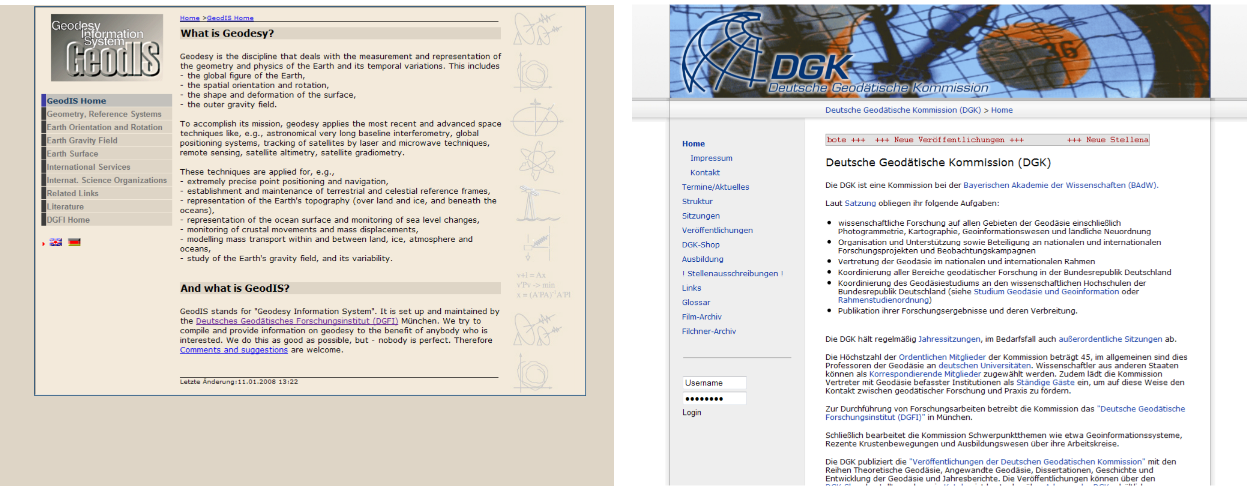
IAG Bylaws 2007.pdf

Rules for the IAG Bomford Prize and Levallois Medal

Rules for IAG Scientific Meetings

IAG Travel Award

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 representation of the 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 space techniques like, e.g., astronomical very long baseline interferometry, global positioning systems, tracking of satellites by laser and microwave techniques, remote sensing, satellite 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 oceans),
- 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 oceans,
- 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 maintained by the Deutsches Geodätisches Forschungsinstitut (DGFI) München. We try to compile and provide information on geodesy to the benefit of anybody who is interested. We do this as good as possible, but - nobody is perfect. Therefore Comments and suggestions are welcome.

Letzte Änderung:11.01.2008 13:22

bote +++ +++ Neue Veröffentlichungen +++ +++ Neue Stellena

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

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

Home page for Deutsche Geodätische Kommission (DGK)

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

http://dgk.badw.de

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

Home page for the DGFI priority program "Mass transport and mass distribution in the Earth system"

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

http://www.massentransporte.de .

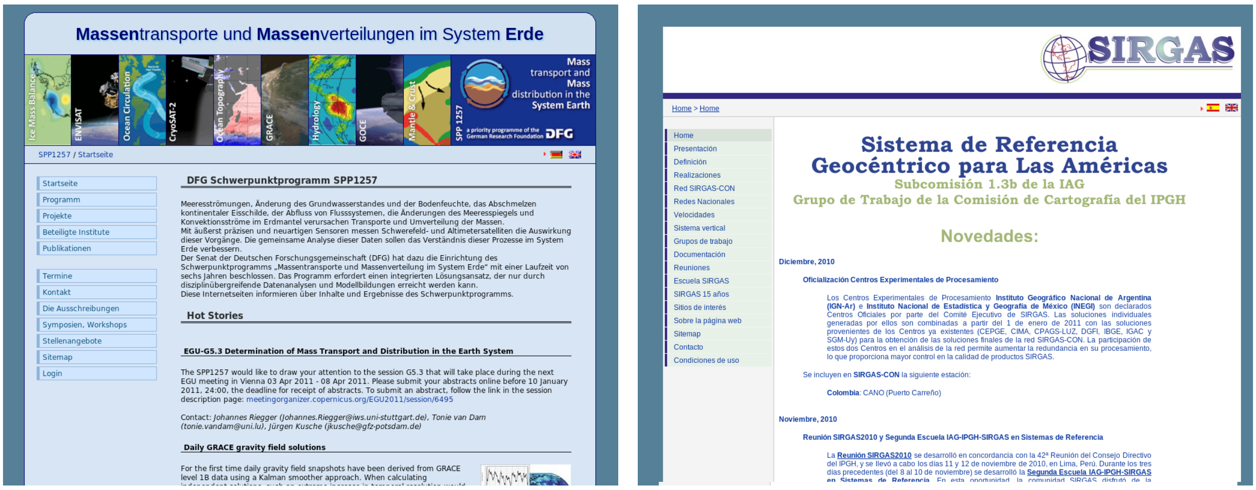
The site (see Figure 4.1.3, left) makes the SPP program known to the public and other scientists (outreach), supports the organization of international symposia, and provides also a basis for internal information exchange with links to data and products that are relevant for the priority program.

SIRGAS home page

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

http://www.sirgas.org .

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



DFG Schwerpunktprogramm SPP1257

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.
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.

Hot Stories

EGU-G5.3 Determination of Mass Transport and Distribution in the Earth System

The SPP1257 would like to draw your attention to the session G5.3 that will take place during the next EGU meeting in Vienna 03 Apr 2011 - 08 Apr 2011. Please submit your abstracts online before 10 January 2011, 24:00, the deadline for receipt of abstracts. To submit an abstract, follow the link in the session description page: meetingorganizer.copernicus.org/EGU2011/session/6495

Contact: *Johannes Riegger (Johannes.Riegger@iws.uni-stuttgart.de), Tonie van Dam (tonie.vandam@uni.lu), Jürgen Kusche (jkusche@gfz-potsdam.de)*

Daily GRACE gravity field solutions

For the first time daily gravity field snapshots have been derived from GRACE level 1B data using a Kalman smoother approach. When calculating

Sistema de Referencia Geocéntrico para Las Américas

Subcomisión 1.3b de la IAG

Grupo de Trabajo de la Comisión de Cartografía del IPGH

Novedades:

Diciembre, 2010

Oficialización Centros Experimentales de Procesamiento

Los Centros Experimentales de Procesamiento **Instituto Geográfico Nacional de Argentina (IGN-Ar)** e **Instituto Nacional de Estadística y Geografía de México (INEGI)** son declarados Centros Oficiales por parte del Comité Ejecutivo de SIRGAS. Las soluciones individuales generadas por ellos son combinadas a partir del 1 de enero de 2011 con las soluciones provenientes de los Centros ya existentes (CEPGE, CIMA, CPAGS-LUZ, DGFI, IBGE, IGAC y SGM-Uy) para la obtención de las soluciones finales de la red SIRGAS-CON. La participación de estos dos Centros en el análisis de la red permite aumentar la redundancia en su procesamiento, lo que proporciona mayor control en la calidad de productos SIRGAS.

Se incluyen en **SIRGAS-CON** la siguiente estación:

Colombia: CANO (Puerto Carreño)

Noviembre, 2010

Reunión SIRGAS2010 y Segunda Escuela IAG-IPGH-SIRGAS en Sistemas de Referencia

La **Reunión SIRGAS2010** se desarrolló en concordancia con la 42ª Reunión del Consejo Directivo del IPGH, y se llevó a cabo los días 11 y 12 de noviembre de 2010, en Lima, Perú. Durante los tres días precedentes (del 8 al 10 de noviembre) se desarrolló la **Segunda Escuela IAG-IPGH-SIRGAS en Sistemas de Referencia**. En esta oportunidad, la comunidad SIRGAS disfrutó de la

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

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

Open Altimeter Database home page (OpenADB)

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

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

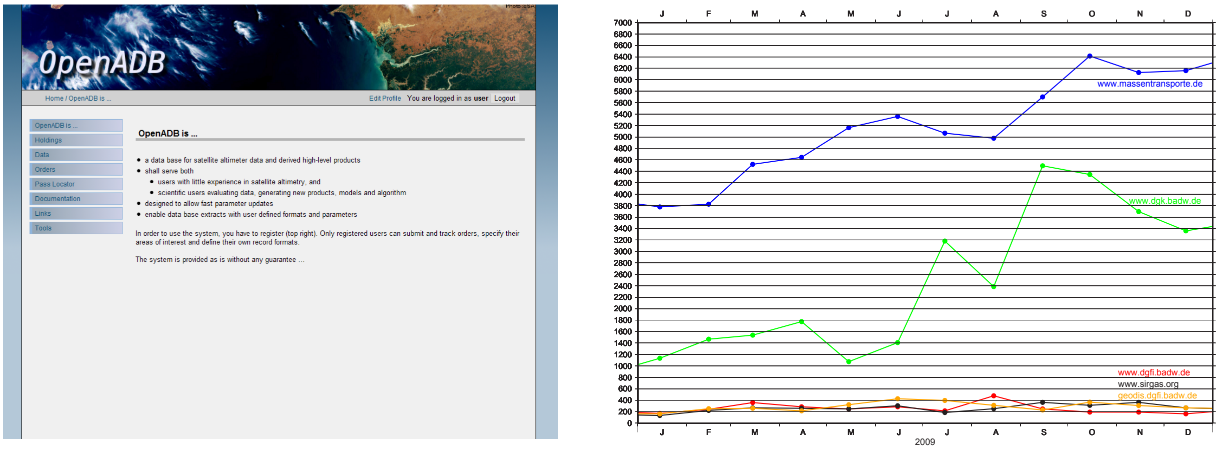
Home page for the International Altimeter Service (IAS)

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

This site is available under

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

but is still under development.



You are logged in as **user**

OpenADB is ...

- a data base for satellite altimeter data and derived high-level products
- shall serve both
  - users with little experience in satellite altimetry, and
  - scientific users evaluating data, generating new products, models and algorithm
- designed to allow fast parameter updates
- enable data base extracts with user defined formats and parameters

In order to use the system, you have to register (top right). Only registered users can submit and track orders, specify their areas of interest and define their own record formats.

The system is provided as is without any guarantee ...

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

User statistics

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

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

Mailing lists

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

Intranet

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

4.2 Publications

Albertella A., Rummel R., Savcenko R., Bosch W., Janjic T., Schroeter J., Gruber T., Bouman J., Dynamic Ocean Topography from GOCE – Some Preparatory Attempts. Proceedings ESA Living Planet Symposium, Bergen, Norway, Special Publication SP-686 (CD-Rom), 2010

Alizadeh, M.M., H. Schuh, S. Todorova und M Schmidt: Ionosphere Maps of VTEC from GNSS, Satellite Altimetry, and Formosat-3/COSMIC Data. Journal of Geodesy, accepted 2010

Angermann D., Blossfeld M., Bosch W., Gerstl M., Heinkelmann R., Kelm R., Müller H., Sánchez L., Seemüller W., Seitz M.: DGFI-Beteiligung an den wissenschaftlichen Diensten der IAG. Zeitschrift für Geodäsie, Geoinformation und Landmanagement, 135, Heft 2, 112-118, 2010

Angermann D., Seitz M., Drewes H.: Analysis of the DORIS Contributions to ITRF2008. Advances in Space Research 46, 1633-1647, doi:10.1016/j.asr.2010.07.018, Elsevier, 2010

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Bosch W., Savcenko R.: On Estimating the Dynamic Ocean Topography. In: Mertikas S.P. (Ed.): Gravity, Geoid and Earth Observation. Springer IAG Symposia, Vol. 135, 263-269 , 2010

Bosch W.: Das Deutsche Geodätische Forschungsinstitut (DGFI) - Geodätische Forschung zur Beobachtung und Analyse des Systems Erde. Zeitschrift für Geodäsie, Geoinformation und Landmanagement, 135, Heft 2, 71-72, 2010

Bosch W., Savcenko R., Luz R. T.: The absolute dynamic ocean topography (ADOT) – estimation and application. Proceedings of the ESA Living Planet Symposium, Bergen, Norway, ESA Publication SP-686 (CD-Rom), 2010

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Bouman J., Bosch W., Goebel G., Müller H., Sánchez L., Schmidt M., Sebera J.: Das Schwerefeld der Erde - Messen, Darstellen und Auswerten. Zeitschrift für Geodäsie, Geoinformation und Landmanagement, 135, Heft 2, 87-92, 2010

Bouman J., Stummer C., Murböck M., Fuchs M., Rummel R., Pail R., Gruber T., Bosch W., Schmidt M.: GOCE gravity gradients: a new satellite observable. GEOTECHNOLOGIEN Statusreport, 2010

Brunini, C., L. Sánchez, H. Drewes, S. Costa, V. Mackern, W. Martínez, W. Seemüller, A. da Silva (2011). Improved analysis strategy and accessibility of the SIRGAS Reference Frame. In: C. Pacino et al. (Eds.). IAG Scientific Assembly “Geodesy for Planet Earth”. IAG Symposia, Springer Verlag, Vol. 135: 3-8. (In press).

Bruyninx, C., Z. Altamimi, M. Becker, M. Craymer, L. Combrinck, A. Combrink, J. Dawson, R. Dietrich, R. Fernandes, R. Govind, T. Herring, A. Kenyeres, R. King, C. Kreemer, D. Lavallée, J. Legrand, L. Sánchez, G. Sella, Z. Shen, A. Santamaría-Gómez, G. Wöppelmann (2011). A Dense Global Velocity Field based on GNSS Observations: Preliminary Results. In: C. Pacino et al. (Eds.). IAG Scientific Assembly “Geodesy for Planet Earth”. IAG Symposia, Springer Verlag, Vol. 135: 15-20. (In press).

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Janjik T., Schröter J., Albertella A., Bosch W., Rummel R., SavcenkoR.: Assimilation of ocean dynamical topography using ensemble based Kalman filter, accepted for SPP Special Issue of the Journal of Geodynamics

Koch, K.R. und M. Schmidt: N-dimensional B-spline surface estimated by lofting for locally improving IRI. Journal of Geodetic Science, accepted 2010

Kuo-Hsin Tseng; C. K. Shum; Yuchan Yi; Chunli Dai; Hyongki Lee; Dieter Bilitza; Attila Komjathy; C. Y. Kuo; Jinsong Ping; Michael Schmidt (2010) Regional Validation of Jason-2 Dual-Frequency Ionosphere Delays, Marine Geodesy, 33 S1, 272 – 284

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4.3 Posters and oral presentations

Albertella A., Rummel R., Savcenko R., Bosch W., Janjic T., Schroeter J., Gruber T., Bouman J.: Dynamic Ocean Topography from GOCE - Some Preparatory Attempts, ESA Living Planet Symposium, Bergen, Norway, 2010-06-28/07-02

Angermann D.: Geometrische Verfahren, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-22

Angermann D.: Stand und zukünftige Entwicklungen bei der Realisierung terrestrischer Referenzsysteme, Begutachtung der FGS, Bad Kötzting, Germany, 2010-06-25

Angermann D., Seitz M., Drewes H.: Analysis of local ties from ITRF2008 computations, EGU General Assembly, Vienna, Austria, 2010-05-04

Angermann D., Seitz M., Drewes H.: DGFI reference frame solution as contribution to ITRF2008, COST Action ES0701, Vienna, Austria, 2010-11-17

Blossfeld M., Seitz M., Angermann D.: EOPs aus der inter-technischen Kombination von GPS und VLBI, Statusseminar der Forschergruppe Erdrotation, Berlin, Deutschland, 2010-03-22/23

Blossfeld M., Seitz M., Angermann D.: EOP from combined space geodetic techniques, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07 (Poster)

Blossfeld M., Seitz M., Heinkelmann R., Angermann D.: Kombination von Erdorientierungsparametern, Geodätische Woche 2010, Cologne, Germany, 2010-10-05/07

Blossfeld M.: Analyse und Kombinationsverfahren, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-22/23

Böhm S., Bosch W., Savcenko R., Schuh H.: Oceanic tidal angular momentum from EOT08a and its impact on Earth rotation, EGU General Assembly 2010, Vienna, Austria, 2010-05-04 (Poster)

Bosch W., Savcenko R., Schwatke C.: Quality assessment of instantaneous profiles of the dynamic ocean topography, EGU General Assembly 2010, Vienna, Austria, 2010-05-07 (Poster)

Bosch W.: Meeresspiegel und Schwerefeld, Begutachtung der FGS, Bad Kötzting, Germany, 2010-06-23

Bosch W., Savcenko R.: EOT10a - empirical ocean tide model upgraded, ESA Living Planet Symposium, Bergen, Norway, 2010-07-01

Bosch W., Savcenko R., Luz R.T.: The absolute dynamic ocean topography (ADOT) - estimation and application, ESA Living Planet Symposium, Bergen, Norway, 2010-07-02

Bosch W.: EOT10a – a new global ocean tide model from multi-mission altimetry, 38th COSPAR Scientific Assembly, Bremen, Germany, 2010-07-19

Bosch W.: The absolute dynamic ocean topography (ADOT), 38th COSPAR Scientific Assembly, Bremen, Germany, 2010-07-20

Bosch W., Savcenko R.: EOT10a - a new result of empirical ocean tide modelling, OSTST Annual Meeting, Lisbon, Portugal, 2010-10-18/20 (Poster)

Bosch W., Savcenko R.: Dynamic Ocean Topography - first estimates with GOCE gravity fields , OSTST Annual Meeting, Lisbon, Portugal, 2010-10-19

Bosch W.: Methodik, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-10-23

Bouman J., Fuchs M.: Validation of gravity gradients, GOCE HPF Progress Meeting 18, Munich, Germany, 2010-03-17/18

Bouman J.: Comparison of GG external calibration results, GOCE Calibration Synthesis Meeting 3, Munich, Germany, 2010-03-18/19

Bouman J.: Relation between geoidal undulation, deflection of the vertical and vertical gravity gradient revisited, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07 (Poster)

Bouman J., Rispens S., Visser P., Veicherts M., Tscherning C., Pail R., Mayrhofer R., Gruber T., Schrama E.: Gravity Gradient Analysis at the GOCE High-Level Processing Facility, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07

Bouman J.: Calibration, GOCE Summer School, Herrsching, Germany, 2010-05-31/06-04

Bouman J., Brieden P., Catastini G., Cesare S., Floberghagen R., Frommknecht B., Haagmans R., Kern M., Lamarre D., Müller J., Plank G., Rispens S., Stummer C., Tscherning C., Veicherts M., Visser P.: Overview of GOCE Gradiometer Cal/Val Activities, ESA Living Planet Symposium, Bergen, Norway, 2010-06-28/07-02

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Bouman J., Rispens S., Tscherning C., Veicherts M., Visser P.: External Calibration of the GOCE Gravity Gradients at the High-Level Processing Facility, ESA Living Planet Symposium, Bergen, Norway, 2010-06-28/07-02 (Poster)

Bouman J., Bosch W., Fuchs M., Grombein T., Gruber T., Heck B., Murböck M., Pail R., Rummel R., Schmidt M., Seitz K., Stummer C.: GOCE gravity gradient analysis, GEOTECHNOLOGIEN Statusseminar, Bonn, Germany, 2010-10-04

Bouman J.: Schwerefeld, Evaluation of DGFI Research Programme 2011-2014, 2010-11-22/23

Bouman J., Fiorot S., Fuchs M., Gruber T., Schrama E., Tscherning C., Veicherts M., Visser P.: GOCE Level 2 Gravity Gradients, AGU Fall Meeting 2010, San Francisco, USA, 2010-12-13/17 (Poster)

Brunini C., Drewes H., Sánchez L., Mackern V., Mateo L.: Seasonal effects in the weekly realization of the SIRGAS reference frame, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07 (Poster)

Brunini C., Azpillicueta F., Gende M., Camilion E., Aragón Angel, Hernandez-Pajares M., Juan M., Sanz J., Salazar D., Sánchez L.: Assessment of the 4-D SIRGAS ionospheric model, REFAG2010, Marle-La-Vallée, France, 2010-10-04/08 (Poster)

Dettmering D.: Atmosphäre, Evaluation of DGFI Research Programme 2011-2014, 2010-11-22

Dettmering D., Schmidt M., Heinkelmann R.: Systematic differences of ionospheric parameters from various space-geodetic techniques, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07 (Poster)

Dettmering D., Bosch W.: ENVISAT Radar Altimeter Calibration by Multi-Mission Crossover Analysis, ESA Living Planet Symposium, Bergen, Norway, 2010-07-02

Dettmering D., Schmidt M., Bilitza D.: Update of IRI VTEC with ground- and space-based GPS data in polar regions, 38th COSPAR Scientific Assembly, Bremen, Germany, 2010-07-18

Dettmering D., Bosch W.: Systematische Unterschiede der Bahnlagerung verschiedener Altimeter-Missionen - aufgedeckt durch Multi-Missions Kreuzungspunktanalyse, Geodätische Woche, Cologne, Germany, 2010-10-05/07 (Poster)

Dettmering D., Bosch W.: Geographically correlated errors for latest Jason-1/2 and TOPEX orbits, OSTST Annual Meeting, Lisbon, Portugal, 2010-10-19

Dettmering D., Bosch W.: Systematic differences in the center-of-origin realizations of Jason-1 and Envisat, OSTST Annual Meeting, Lisbon, Portugal, 2010-10-19

Drewes H.: DGFI Annual Report 2009, DGK Section Geodesy, Stuttgart, Germany, 2010-04-16

Drewes H.: Basic considerations of the methodologies of ITRS definitions and ITRF computations, IERS GB, Vienna, Austria, 2010-05-01

Drewes H.: Requirements for geodetic reference frames in global change research, Nordic Geodetic Commission, Hønefoss, Norway, 2010-09-23

Drewes H., Angermann D.,Seitz M.: Alternative definitions and realizations of the terrestrial reference frames, IAG Commission 1 Symposium (REFAG), Marne la Vallée, France, 2010-10-08

Drewes H.: DGFI Annual Report 2010, DGK General Assembly, Munich, Germany, 2010-10-29

Drewes H.: La realización actual del sistema de referencia global: El marco de referencia ITRF2008, SIRGAS 2010 General Assembly, Lima, Peru, 2010-11-11

Drewes H., Brunini C., Sánchez L., Mackern V., Martínez W.: Uso de las coordenadas SIRGAS en los marcos nacionales de referencia, SIRGAS 2010 General Assembly, Lima, Peru, 2010-11-12

Drewes H.: Forschungsprogramm 2011-2014 für das Deutsche Geodätische Forschungsinstitut (DGFI) im Rahmen des Centrum für Geodätische Erdsystemforschung (CGE), Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-22

Fuchs M., Bouman J.: GOCE-Gradientendarstellung in einem lokalen Bezugssystem, REAL-GOCE 3. Projekttreffen, Munich, Germany, 2010-09-23/24

Fuchs M., Bouman J.: GOCE-Gradientendarstellung in einem lokalen Bezugssystem, Geodätische Woche, Cologne, Germany, 2010-10-06

Fuchs M., Bouman J.: Gravity gradients: effective MBW, contribution in LNOF, comparison with GOCE models, GOCE HPF Progress Meeting 20, Frascati, Italy, 2010-10-21

Fuchs M.: Theorie und Aufbereitung der Beobachtungen, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-22/23

Fuchs M., Bouman J.: GOCE Gravity Gradients in Local Frames, AGU Fall Meeting 2010, San Francisco, USA, 2010-12-13/17 (Poster)

Gerstl M.: Weiterentwicklung institutseigener Softwarepakete, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-23

Goebel G.: Regionale & globale Modellbildung, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-22/23

Goebel G., Schmidt M., Bosch W., List H., Börger K.: Regional approximation of existing gravity models with local base functions, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07 (Poster)

Goebel G., Schmidt M., Bosch W., List H., Börger K.: Combination of geodetic measurements by means of a multi-resolution representation, AGU Fall Meeting 2010, San Francisco, USA, 2010-12-13/17 (Poster)

Heinkelmann R., Gerstl M.: OCCAM-LSM for LINUX: new developments at DGFI, IVS 2010 General Meeting, Hobart, Australia, 2010-02-13 (Poster)

Heinkelmann R.: Effects of ICRF2 on estimates of Earth orientation parameters and of the terrestrial reference frame, IVS 2010 General Meeting, Hobart, Australia, 2010-02-13

Heinkelmann R., Schmidt M., Seitz M.: Water vapor climatology by geodetic VLBI, EGU General Assembly2010, Vienna, Austria, 2010-05-07 (Poster)

Heinkelmann R., Tesmer V.: Systematic inconsistencies between VLBI CRF and TRF solutions caused by different analysis options, IAG Commission 1 Symposium 2010 Reference Frames for applications in geosciences, Marne la Vallée, France, 2010-10-05

Heinkelmann R., Müller H.: Modellentwicklung und Analyse der Geodätischen Raumbe-obachtungsverfahren, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-22

Hugentobler U., Angermann D., Drewes H., Gerstl M., Seitz M. and Steigenberger P.: Standards and conventions relevant for the ITRF, IAG Commission 1 Symposium 2010 (REFAG 2010), Marne la Vallée, France, 2010-10-04/08

Kusche J., Bosch W., Eicker A., Schwatke C.: PROMAN: Project management and scientific networking (Results), DFG Colloquium for the SPP 1257 "Mass Transport", Postdam, Germany, 2010-10-13/15 (Poster)

Kusche J., Bosch W., Eicker A., Schwatke C.: PROMAN: Project management and scientific networking (Objectives), DFG Colloquium for the SPP 1257 "Mass Transport", Postdam, Germany, 2010-10-13/15 (Poster)

Kutterer H., Göttl F., Heiker A., Kirschner S., Schmidt M., Seitz F.: Combined analysis and validation of Earth rotation models and observations, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07 (Poster)

Kutterer H., Schmidt M., Seitz F., Heiker A., Göttl F., Heller M., Kirschner S.: Combined analysis and validation of Earth rotation models and observations, Geodätische Woche, Cologne, Germany, 2010-10-05/07 (Poster)

Mateo M.L., Drewes H., Seitz M.: Análisis de la influencia de carga atmosférica sobre las variaciones en las alturas de las series temporales de la red SIRGAS-CON, SIRGAS 2010 General Assembly, Lima, Peru, 2010-11-10/11 (Poster)

Murböck M., Fuchs M., Stummer C., Fecher T., Pail R., Bouman J., Bosch W.: GOCE gravity gradients: a new satellite observation type, GEOTECHNOLOGIEN Statusseminar, Bonn, Germany, 2010-10-04 (Poster)

Pfander T., Albertella A., Savcenko R., Schwabe J., Schröter J., Rummel R., Bosch W., Scheinert M.: Sea Surface Topography and Mass Transport of the Antarctic Circumpolar Current, DFG Colloquium for the SPP 1257 “Mass Transport”, Potsdam, Germany, 2010- 10-13/15

Sánchez L., Drewes H., Brunini C., Martínez W., Mackern V.: Sustainability of the SIRGAS Reference Frame, IAG Commission 1 Symposium (REFAG), Marne la Vallée, France, 2010-10-05 (Poster)

Sánchez L., Seemüller W., Drewes H., Mateo L., González G., Costa S., da Silva, Pampillón J., Martínez W., Cioce V., Cisneros D., Cimbaro S.: Long-term stability of the SIRGAS Reference Frame and episodic station movements caused by the seismic activity in the SIRGAS region, IAG Commission 1 Symposium (REFAG), Marne la Vallée, France, 2010-10-05 (Poster)

Sánchez L.: Numerical approach for a unified South American vertical reference frame within a world height system, IAG Commission 1 Symposium (REFAG), Marne la Vallée, France, 2010-10-06

Sánchez L., Seemüller W.: Report of the SIRGAS Analysis Centre at DGFI, SIRGAS 2010 General Meeting, Lima, Peru, 2010-11-11

Sánchez L., Luz R.: Iniciativas internacionales encaminadas al establecimiento de un sistema vertical global y el aporte de SIRGAS, SIRGAS 2010 General Meeting, Lima, Peru, 2010-11-12

Sánchez L.: SIRGAS: sistema de referencia geocéntrico para las Américas (Lecture), Curso avanzado de posicionamiento por satélites, Madrid, Spain, 2010-11-22

Sánchez L., Brunini C., Mackern V., Martínez W., Luz R.: SIRGAS: the geodetic reference frame in Latin America and the Caribbean, IAG Commission 1 Symposium (REFAG), Marne la Vallée, France, 2010-10-05

Sánchez L., Brunini C., Mackern V., Martínez W., Luz R.: SIRGAS: the geocentric reference frame of the Americas, International Symposium on Global Navigation Satellite Systems, Space-Based and Ground-Based Augmentation Systems and Applications 2010. Brussels, Belgium, 2010-11-30

Savcenko R.: EOT10a - a new global tide model from multi-mission altimetry, EGU General Assembly 2010, Vienna, Austria, 2010-05-05

Savcenko R.: Hydrosphäre. Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-22/23

Savcenko R., Daras I., Dahle C., Mayer-Gürr T., Bosch W., Flechtner F., Kusche J.: Combined Ocean Tide Analysis by GRACE and Altimetry Data (COTAGA), DFG Colloquium for the SPP 1257 "Mass Transport", Potsdam, Germany, 2010-10-13/15 (Poster)

Schmeer M., Schmidt M., Bosch W.: Separation of Mass Signals by Common Inversion of Gravimetric and Geometric Observations (MaSiS), DFG Colloquium for the SPP 1257 "Mass Transport", Potsdam, Germany, 2010-10-13/15 (Poster)

Schmidt M., Dettmering D., Mössmer M., Wang Y.: 3-D Ionosphere modeling by B-Splines and spherical harmonics, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07 (Poster)

Schmidt M.: Towards a Multi-Resolution Analysis in Geodetic Applications, EGU General Assembly 2010, Vienna, Austria, 2010-05-04

Schmidt M., Dettmering D.: Comparison of Spherical Harmonic and B-Spline Models for VTEC, International Beacon Satellite Symposium, Barcelona, Spain, 2010-06-08

Schmidt M., Dettmering D., Heinkelmann R.: Multi-Scale Representation of the Ionosphere from the Combination of Space-geodetic Observations, International Beacon Satellite Symposium, Barcelona, Spain, 2010-06-11

Schmidt M.: Ionosphärenmodellierung aus geodätischen Raumbeobachtungen — alternative Ansätze und Zukunftsperspektiven, Begutachtung der FGS, Bad Kötzting, Germany, 2010-06-25

Schmidt M., Dettmering D.: Regional multi-dimensional modeling of the ionosphere from satellite data, IGS Workshop/Vertical Rates Symposium, Newcastle, UK, 2010-07-01

Schmidt M., Heinkelmann R., Göttl F., Heller M.: Combination of time series of excitation functions considering the common original observations, Geodätische Woche, Cologne, Germany, 2010-10-05

Schmidt M., Gerlach C., Seitz F.: Gravity field variations from GRACE: measurement principle, global and regional approaches and numerical results, Signals of Climate Variability in Continental Hydrology from Multi-Sensor Space and In-situ Observations and Hydrological Modeling, Kick-Off-Seminar, Munich, Germany, 2010-10-12

Schmidt M.: Geodätische Erdsystemmodellierung, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-10-23.

Schwatke C., Messsysteme, Datengewinnung und Datenbereitstellung, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2011-11-22

Schwatke C., Heinkelmann R.: The tropospheric products of the International VLBI Service for Geodesy and Astrometry, IVS 2010 General Meeting, Hobart, Australia, 2010-02-13 (Poster)

Schwatke C., Bosch W.: Comparison of radar and laser altimetry over inland water, EGU General Assembly 2010, Vienna, Austria, 2010-05-05 (Poster)

Schwatke C., Bosch W., Savcenko R., Dettmering D.: OpenADB - An open database for multi-mission altimetry, EGU General Assembly 2010, Vienna, Austria, 2010-05-05 (Poster)

Schwatke C.: Overview of digital elevation models with focus on ACE2, CLIVAR-Hydro Kick-Off-Seminar, Munich, Germany, 2010-10-12

Schwatke C., Savcenko R.: Using altimetry for the estimation of water heights on inland water, CLIVAR-Hydro Kick-Off-Seminar, Munich, Germany, 2010-10-12

Sebera J., Bouman J., Bosch W.: Satellite Altimetry for GOCE Validation, REAL-GOCE 2. Projekttreffen, Munich, Germany, 2010-03-15/16

Sebera J., Wagner C., Bezdek A., Bouman J., Klokocnik J., Kostelecky J., Novak P.: Gravitational tensor in the GOCE reference frame by direct harmonic synthesis, EGU General Assembly 2010, Vienna, Austria, 2010-05-02/07 (Poster)

Sebera J., Bosch W., Bouman J., Kostelecky J., Klokocnik J.: Upward continuation of satellite altimeter data for GOCE validation, ESA Living Planet Symposium, Bergen, Norway, 2010-06-30

Seemüller W., Sánchez L., Drewes H., Seitz M.: The Position and Velocity Solution SIR10P01 of the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS RNAAC SIR), SIRGAS 2010 General Meeting, Lima, Peru, 2010-11-11

Seitz F., Güntner A., Schmidt M.: Consistent estimation of water mass variations in different continental storage compartments by combined inversion of a global hydrological model with time-variable gravity and complementary observation data (CEMIG), DFG Colloquium for the SPP 1257 "Mass Transport", Potsdam, Germany, 2010-10-13/15 , 2010-10-15 (Poster)

Seitz, M.: Berechnung globaler und regionaler Referenzrahmen, Evaluation of DGFI Research Programme 2011-2014, Munich, Germany, 2010-11-22

Seitz M., Heinkelmann R., Blossfeld M.: Combination of VLBI and GPS in order to improve TRF and EOP solutions, Workshop VLBI and GNSS: New Zealand and Australian perspectives, Auckland, New Zealand, 2010-02-15

Seitz M., Blossfeld M., Sánchez L., Seitz F.: Understanding and treating seasonal signals of station positions in the ITRF computation, EGU General Assembly 2010, Vienna, Austria, 2010-05-03 (Poster)

Seitz M., Angermann D., and Drewes H.; Accuracy assessment of ITRF2008D, IAG Commission 1 Symposium 2010 (REFAG 2010), Marne-La-Vallee, France, 2010-10-04/08

Steigenberger P., Hugentobler U., Schmid R., Hessels U., Kluegel T. and Seitz M.: GNSS antenna array at the Geodetic Observatory Wettzell, IAG Commission 1 Symposium 2010 (REFAG 2010), Marne-La-Vallee, France, 2010-10-04/08

Thaller D., Dach R., Seitz M., Beutler G., Mareyen M., Richter B.: Combination of GNSS and SLR using satellite co-locations, IAG Commission 1 Symposium 2010 (REFAG 2010), Marne-La-Vallee, France, 2010-10-04/08

4.4 Memberschip in scientific bodies

International Union of Geodesy and Geophysics (IUGG)

- Representative to the Panamerican Institute for Geodesy and History (PAIGH), H. Drewes

International Association of Geodesy (IAG)

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

International Altimetry Service

- Steering Committee, Chair: W. Bosch

International Earth Rotation and Reference Systems Service (IERS)

- ITRS Combination Centre, Chair: H. Drewes
- Research Centre, Chair: D. Angermann
- Working Group “Site Survey and Co-location”, D. Angermann, M. Seitz, R. Heinkelmann
- Working Group on Combination on Observation Level, D. Angermann, M. Seitz

International GNSS Service (IGS)

- Regional Network Associate Analysis Centre for SIRGAS, Chair: W. Seemüller
- TIGA Pilot Project, Member Sánchez L.

International Laser Ranging Service (ILRS)

- Governing Board member: W. Seemüller

- Data Centre (EDC): Chair: W. Seemüller, H. Müller
- Analysis Centre: Chair: H. Müller
- Combination Centre: Chair: R. Kelm
- Operations Centre at DGFI. Chair: W. Seemüller
- Working Group “Data Format and Procedures”, Chair: W. Seemüller; C. Schwatke

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

European VLBI Group for Geodesy and Astrometry (EVGA),
- Member, R. Heinkelmann

Sistema de Referencia Geocéntrico para las Américas (SIRGAS)

- Vice-President, Sánchez L.
- IAG Representative, H. Drewes

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

American Geophysical Union (AGU)
- JGR - Solid Earth, Associate Editor, J. Bouman

European Geosciences Union (EGU)
- Geodesy Division, Vice-Presidents, J. Bouman, M. Schmidt

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

Centre National d’Etudes Spatiales (CNES) / National Aeronautics and Space Administration (NASA)
- Ocean Surface Topography Science Team for Jason2, W. Bosch, D. Dettmering
- SARAL/Altika Calibration/Validation Team, 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)
- Member: H. Drewes
- Section Geodesy: H. Drewes
- Executive Secretary, Hornik H

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

2010-01-11/15	Visiting Scientist, Korea Astronomy and Space-Science Institute (KASI), Daejeon, South-Korea (Heinkelmann R.)
2010-02-07/13	IVS 2010 General Meeting, Hobart, Australia (Heinkelmann R.)
2010-02-15/18	SKANZ 2010 conference, Workshop VLBI and GNSS: New Zealand and Australian perspectives, Auckland, New Zealand (Heinkelmann R.)
2010-02-22/24	Workshop of DFG priority program "Mass Transport and Mass distribution in the System Earth", Fulda, Germany (Bosch W., Schwatke C.)
2010-03-08/09	51th EUREF TWG Meeting, Vienna, Austria (Hornik H.)
2010-03-15/16	REAL-GOCE 2. Projekttreffen, Munich, Germany (Bosch W., Bouman J., Fuchs M., Schmidt M., Sebera J.)
2010-03-17/18	GOCE HPF Progress Meeting 18, Munich, Germany (Bouman J., Fuchs M.)
2010-03-18/19	GOCE Calibration Synthesis Meeting 3, Munich, Germany (Bouman J., Fuchs M.)
2010-03-22/23	DFG-Forschergruppe FOR 584 "Earth rotation and global dynamic proceses", Statusseminar, Berlin, Germany (Angermann D., Bloßfeld M., Heller M., Schmidt M., Seitz M.)
2010-04-12/13	RegGRAV 2nd Progress Meeting, AGeoBW, Euskirchen, Germany (Bosch W., Goebel, G. Schmidt M.)
2010-04-15/16	DGK Section Geodesy, Stuttgart, Germany (Drewes H.)
2010-05-01	IERS DB Meeting, Vienna, Austria (Seitz M.)
2010-05-01	IERS Governing Board, Vienna, Austria (Drewes H.)
2010-05-02	IAG Executive Committee, Vienna, Austria (Drewes H., Hornik H.)
2010-05-03/07	EGU General Assembly 2010, Vienna, Austria (Angermann D., Bouman J., Schmidt M., Seitz M., Schwatke C.)
2010-05-10/11	GOCE HPF Progress Meeting 19, Toulouse, France (Bouman J.)
2010-05-11/12	GEOTOP project meeting, Fulda, Germany (Bosch W., Savcenko R.)
2010-05-31/06-04	GOCE Summerschool, GOCE Projektburo, Herrsching, Germany (Fuchs M., Goebel G.)
2010-06-01	52th EUREF TWG Meeting, Gävle, Sweden (Hornik H.)
2010-06-02/05	XXth EUREF Symposium, Gävle, Sweden (Hornik H.)
2010-06-07/11	International Beacon Satellite Symposium, Barcelona, Spain (Schmidt M.)
2010-06-24/25	Evaluation of Forschungsgruppe Satellitengeodäsie (FGS), Bad Kötzting, Germany (Angermann D., Bloßfeld M., Bosch W., Dettmering D., Drewes H., Goebel G., Heller M., Heinkelmann R., Schmidt M., Schwatke C., Seitz M.)
2010-06-28/07-02	ESA Living Planet Symposium, Bergen, Norway (Bosch W., Bouman J., Dettmering D.)
2010-07-01	GOCE Calibration Synthesis Meeting 4, Bergen, Norway (Bouman J.)
2010-07-12/13	RegGRAV 3rd Progress Meeting, AGeoBW, Euskirchen, Germany (Bosch W., Goebel G., Schmidt M.)
2010-07-18/25	38th COSPAR Scientific Assembly, Bremen, Germany (Bosch W., Dettmering D.)
2010-09-14	DAROTA Projectmeeting, Munich, Germany (Bosch W., Savcenko R.)
2010-09-20	GEOTOP Projectmeeting, Munich, Germany (Bosch W., Savcenko R.)
2010-09-23/24	REAL-GOCE 3. Projekttreffen, München, Germany (Bouman J., Fuchs M.)

2010-09-27/30	Nordic Geodetic Commission, Hønefoss, Norway (Drewes H.)
2010-10-04	GEOTECHNOLOGIEN Statusseminar, Bonn, Germany (Bouman J., Fuchs M.)
2010-10-04/08	IAG Commission 1 Symposium on Reference Frames for Applications in Geosciences 2010 (REFAG2010), Marne la Vallée, France (Drewes H., Heinkelmann R., Sánchez L., Seitz M.)
2010-10-05/07	Geodätische Woche, DVW, Cologne, Germany (Bloßfeld M., Schmidt M., Fuchs M.)
2010-10-09	IERS DB Meeting, Paris, France (Seitz M.)
2010-10-11/12	Signals of Climate Variability in Continental Hydrology from Multi-Sensor Space and In-situ Observations and Hydrological Modeling, Kick-Off-Seminar, Munich, Germany (Bosch W., Savcenko R., Schmidt M., Schwatke C.)
2010-10-13/15	DFG Colloquium for the SPP 1257 "Mass Transport", Postdam, Germany (Bosch W., Savcenko R., Schmidt M., Schwatke C.)
2010-10-16	27. Lange Nacht der Museen, Munich, Germany (DGFI-Staff)
2010-10-18/20	OSTST Annual Meeting, Lisbon, Portugal (Bosch W., Dettmering D.)
2010-10-21/22	Ocean and Hydrology application workshop, Lisbon, Portugal (Bosch W.)
2010-10-21/22	GOCE HPF Progress Meeting 20, Frascati, Italy (Bouman J.)
2010-10-27/29	DGK General Assembly, Munich, Germany (Drewes H.)
2010-11-08/10	IAG-PAIGH-SIRGAS School on Reference Systems, Lima, Peru (Drewes H., Sánchez L.)
2010-11-10/12	42 Reunión del Consejo Directivo del Instituto Panamericano de Geografía e Historia, Lima, Peru (Drewes H.)
2010-11-11/12	SIRGAS 2010 General Assembly, Lima, Peru (Drewes H., Sánchez L.)
2010-11-16/17	EU COST Action: ES0701, Working Group 1 and 2 Meeting, Vienna, Austria (Angermann D.)
2010-11-29/30	RegGRAV 4th Progress Meeting, AGeoBW, Euskirchen, Germany (Bosch W., Goebel G, Schmidt M.)
2010-11-29/30	International Symposium on Global Navigation Satellite Systems, Space-Based and Ground-Based Augmentation Systems and Applications 2010, Brussels, Belgium (Sánchez L.)
2010-12-08	FGS Vorstandssitzung, TU München, Munich, Germany (Bosch W., Drewes H.)
2010-12-09/10	IERS WG on Combination on the Observation Level, Munich, Germany (Bloßfeld M., Drewes H., Gerstl M., Heinkelmann R., Müller H., Seitz M.)
2010-12-11	GGOS Steering Committee, San Francisco, USA (Drewes H.)
2010-12-12	IAG Executive Committee, San Francisco, USA (Drewes H.)
2010-12-13/17	AGU Fall Meeting 2010, San Francisco, USA (Bouman J., Goebel G.)

4.6 Guests

2010-02-16/03-15	Laura Mateo, Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales, CONICET Mendoza, Argentina
2010-02-18	20 Students, Technical University Prague, Czech Republic
2010-04-19/05-07	Prof. Claudio Brunini, Universidad Nacional, La Plata, Argentina
2010-04-30	Dipl.-Ing. Robert Weiß, Dr.-Ing. Astrid Sudau, Prof. Dr.-Ing. Joachim Behrens, Federal Institute of Hydrology, Koblenz, Germany
2010-05-26/28	Akis Frantzis, Dinmitris Andrikopoulos, Technical University of Crete, Greece
2010-06-11	15 Students, Jade University, Oldenburg, Germany
2010-07-15	Bernd Lucke, Bertold-Brecht Gymnasium, Munich, Germany
2010-10-07	Dr. Wolfgang Heubisch, Bavarian Minister for Sciences, Research and Arts, Munich, Germany
2010-12-06/08	Ole Roggenbuck, Jade Hochschule, Wilhelmshaven
2010-12-10	Dr. Uwe Springfeld, WDR, Berlin, Germany
2010-12-16	Hon.-Prof. Dr. Hans Fricke, LMU, Munich, Germany
2010-12-27/30	Prof. Claudio Brunini, Universidad Nacional, La Plata, Argentina

5 Personnel

On the 11th of November 2010, Wolfgang Seemüller passed away after short heavy illness. Wolfgang was a good friend and engaged colleague for all of us. He was the Chairman of the ILRS EUROLAS Data Center at DGFI for more than twenty years and a member of the ILRS Governing Board. He put his heart and soul in these tasks. We will always keep him in best memory.

5.1 Number of personnel

Total staff of DGFI during the 2010 period (incl. DGK Office):

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

Funded by projects

5	junior scientists
2	student helper

Funding of the following projects is gratefully acknowledged:

DAROTA	Dynamic and residual ocean tide analysis for improved GRACE de-aliasing (DFG)
GEOTOP	Sea surface topography and mass transport of the Antarctic Circumpolar Current (DFG)
PROMAN	Program management and scientific networking (DFG)
FOR 584, P6	Integration of Earth rotation, gravity field and geometry using space geodetic observations (DFG)
FOR 584, P9	Combined analysis and validation of Earth rotation models and observations, CAVERMO, (DFG)
REAL-GOCE	Real data analysis GOCE, GEOTECHNOLOGIEN programme (BMBF)
GOCE HPF	Validation and frame transformation of GOCE gravity gradients (ESA/TUM)
REGGRAV	Software for regional geoid models as height reference surface (BWB)
CHL10/018	Geodätisches Beobachtungs- und Analysesystem in seismisch aktiven Gebieten Chiles (IB BMBF)

5.2 Lectures at universities

Bosch W.: University lectures: "Oceanography and Satellite Altimetry", TU München, WS 2009/2010 and WS2010/2011

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

Schmidt M.: University lectures: “Numerical Modelling”, TU München, WS 2009/2010 and WS 2010/2011

Schmidt M.: University lectures: “Wavelets”, TU München, SS 2010

5.3 Lectures at seminars and schools

Bouman J.: GOCE Summerschool Lecture "Calibration", TU München / GOCE Projektburo, 2010-06-01

Drewes H.: Sistemas y marcos de referencia, IAG-PAIGH-SIRGAS School on Reference Systems, Lima, Peru, 2010-11-08

Drewes H.: Objetivos científicos de SIRGAS, IAG-PAIGH-SIRGAS School on Reference Systems, Lima, Peru, 2010-11-10

Sánchez L.: Sistemas Verticales de Referencia, IAG-PAIGH-SIRGAS School on Reference Systems, Lima, Peru, 2010-11-10

Sánchez L.: Disponibilidad y uso de los productos SIRGAS, IAG-PAIGH-SIRGAS School on Reference Systems, Lima, Peru, 2010-11-10

6 Miscellaneous

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

DGFI supervises 13 grammar school pupils of the Berthold Brecht Gymnasium, Pasing, for a one and a half year high school seminar on "Global change and sea level rise".