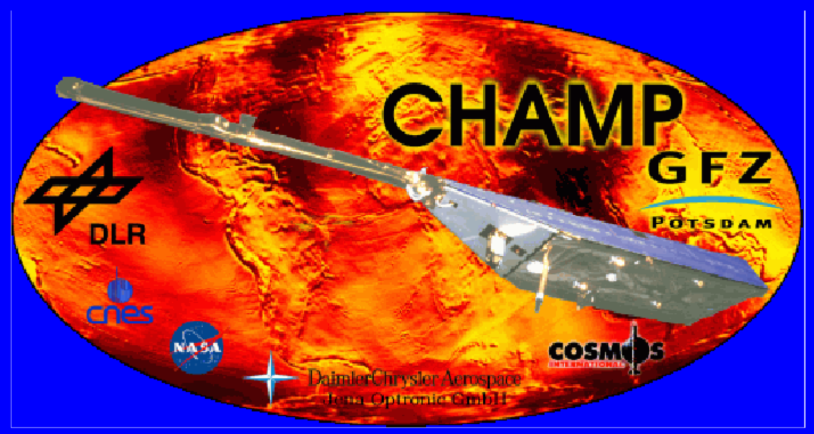

Station Coordinates, Low Degree Harmonics, and Earth Rotation Parameters from an Integrated GPS/CHAMP/GRACE Processing

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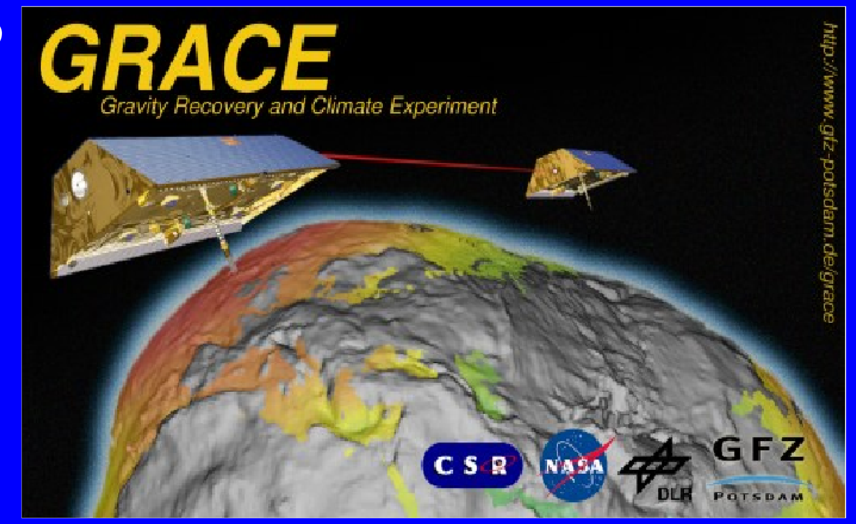

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Introduction

Time series of geodetic Earth system parameters as part of a global geodetic reference frame have been derived for the year 2004 by means of dynamic satellite orbit adjustment. The procedure applied is the integrated approach where the GPS satellites and the Low Earth Orbiters (LEOs) CHAMP and GRACE are processed simultaneously with common standards.

The set of estimated Earth system parameters includes coordinates of ground stations, low degree harmonic coefficients of the Earth's gravity field, and Earth rotation parameters. Selected parameter time series are presented and compared to external series and products for validation.

The particular advantage of the integrated approach is the high sensitivity of the LEO to the geocenter in combination with the stability from the GPS constellation geometry. Also, the dense tracking coverage by GPS measurements allows for a high temporal resolution of the parameters solved for. In order to demonstrate the superior performance of the integrated approach, comparisons to the commonly applied two-step processing (where firstly the GPS orbits and clocks are determined and then fixed for a subsequent treatment of the LEOs) are presented.

Observations Used	Source and Characteristics
GPS Ground	Stations of the IGS- and GFZ networks, L3, 30s
GPS Space-borne	CHAMP/GRACE on-board receiver, L3, 30s
SLR Normal Points	ILRS network, down-weighted
Accelerations	on-board accelerometers, CHAMP: 10s / GRACE: 5s
Attitude	on-board star sensors, CHAMP: 10s / GRACE: 5s
Range-Rate (GRACE)	on-board K-band interferometer, 5s
Models Used	
Gravity Field of Earth	EIGEN-GL04S1 a priori
Ocean Tides	FES2004
Station Coordinates and Velocities	ITRF2000, enhanced with IGS2000, a priori

Table 1: Characterisation of processing carried out (1)

Estimated Parameters			
Harmonic coefficients of the Earth Gravity Field	up to degree and order 2,	a priori sigma 10 cm,	daily
Station Coordinates	GPS stations,	a priori sigma 10 cm,	daily
Earth Rotation Parameters	X-/Y-pole and UT1-UTC,	a priori sigma 10 cm,	daily
Offline Parameters			
Helmert transformation parameters	3 translations, global scale, 3 rotations for solved-for coordinates,		daily
Nominal Orbit Length	24 h		
Analysis Period	2004/02/04 – 2004/12/31		
Software Used	EPOS		

Table 2: Characterisation of processing carried out (2)

Performance of the Integrated Approach

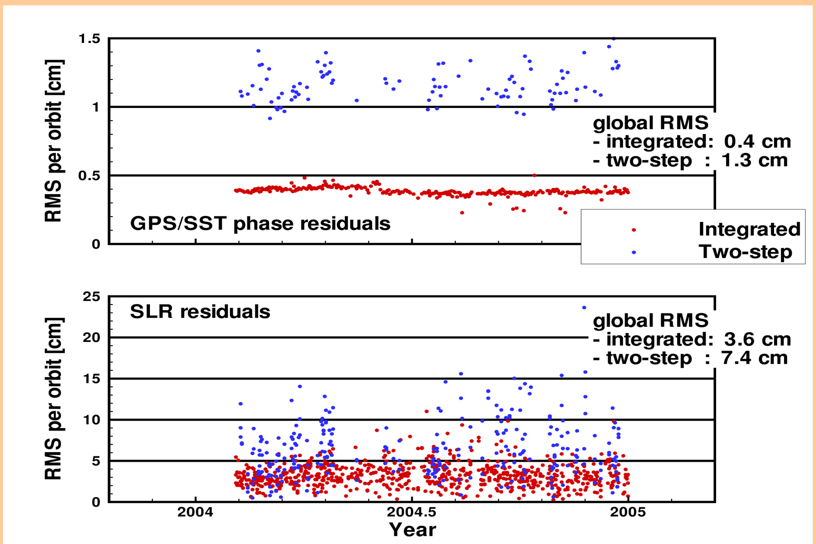

Figure 1: Time series of orbit-wise RMS values of GPS/SST phase and SLR residuals for the integrated and the corresponding two-step processing

The plots in Figure 1 indicate the RMS values per orbit of the GPS SST phase residuals and of the satellite laser ranging (SLR) residuals. The phase residuals serve as a measure of the internal accuracy of the processing whereas the SLR residuals indicate the absolute quality. In both cases the better performance of the integrated approach is expressed by drastically lower global RMS values.

In Table 3 the level of accuracy of the integrated processing as well as for a corresponding two-step processing is indicated. The integrated approach delivers superior results especially for TZ and C_{10} as revealed by their standard deviations.

	Integrated		Two-step	
parameters	mean [mm]	st. dev. [mm]	mean [mm]	st. dev. [mm]
TX, TY, TZ	+7.8 / +0.0 / -7.6	13.0 / 15.7 / 7.0	+11.1 / -1.6 / -6.9	13.0 / 17.0 / 51.5
C_{11}, S_{11}, C_{10}	-0.8 / +0.2 / -6.3	9.8 / 10.8 / 13.5	-0.1 / +5.6 / -0.6	22.5 / 19.6 / 59.1
RX, RY, RZ	+0.2 / -0.5 / -0.3	3.3 / 5.2 / 1.5	-1.5 / -1.4 / -0.3	12.3 / 15.2 / 1.4
S_{21}, C_{21}	+11.9 / -2.1	0.7 / 0.6	+11.7 / -2.2	3.7 / 3.4
parameters	correlation		correlation	
TX, C_{11}	-0.46		-0.51	
TY, S_{11}	-0.70		-0.44	
TZ, C_{10}	-0.72		-0.95	

Table 3: Quality measures. The numbers given refer to Figures 2 to 5.

Geometric and Dynamic Origin

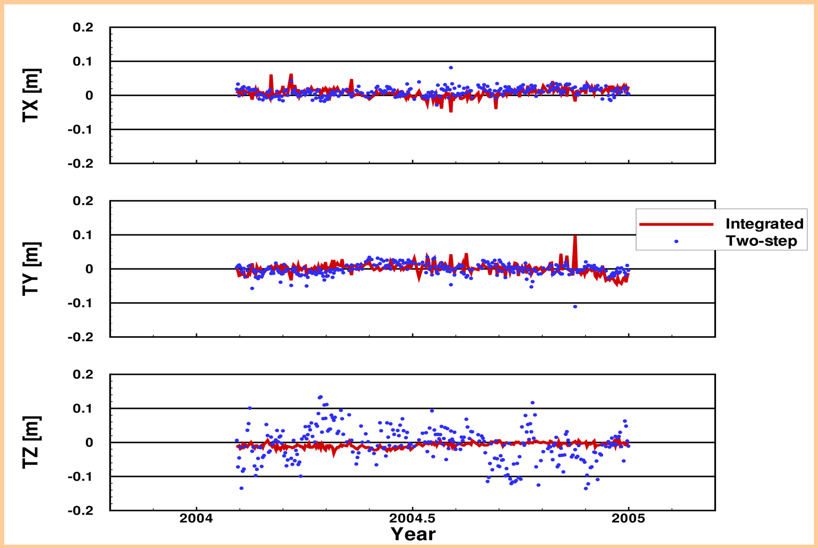

Figure 2: Time series of the translational components of Helmert transformations between ITRF2000 and the estimated coordinates

The plots in Figure 2 show the variations of the origin of the geometric reference frame as given by the estimated station coordinates with respect to ITRF2000. In Figure 3 the variations of the origin of the gravity field are displayed.

All series reflect low biases on the mm level and low scatters of around a centimeter. Given the comparatively loose datum constraints of 10 cm these results indicate the inherent accuracy of the processing strategy. The correlations particularly between TY and S_{11} and between TZ and C_{10} indicate the physical relationship of the parameters but also the chance to estimate the geometric and dynamic origin independently.

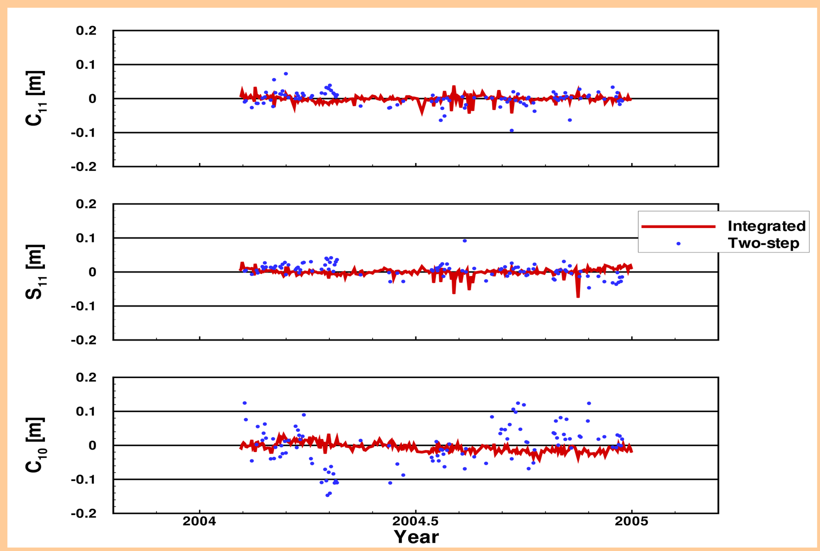

Figure 3: Time series of the components of the dynamic geocenter position

Geometric and Dynamic Orientation

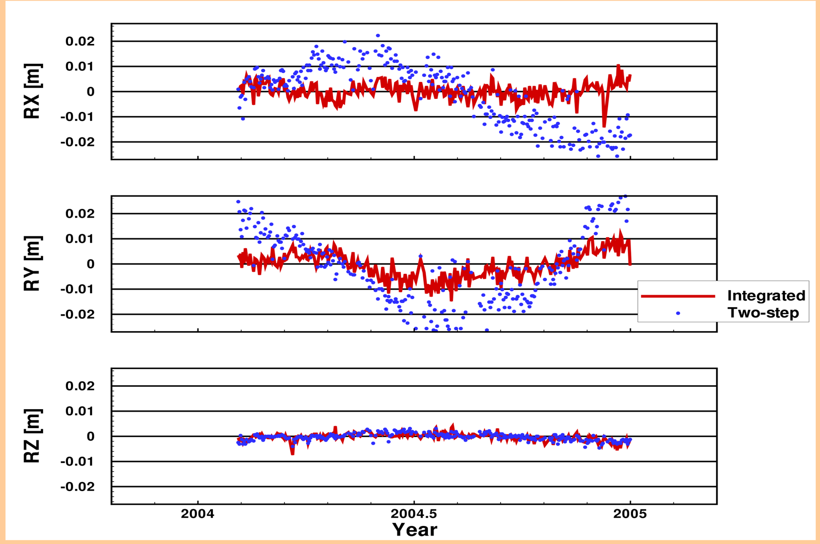

Figure 4: Time series of the rotational components of Helmert transformations between ITRF2000 and the estimated coordinates

The time series in Figure 4 reflect the variations of the orientation of the estimated coordinates against ITRF2000 around all three axes (geometric orientation). In Figure 5 the time series of the corresponding tilts of the estimated gravity field against the a priori field (dynamic orientation) are plotted. In X and Y the integrated approach leads to a higher quality level revealed by a smaller scatter of the parameter time series. The series of RX and RY show a strong annual signal obviously negatively correlated with the corresponding series of the estimated X- and Y-pole in Figure 6. For the integrated approach these signals are reduced.

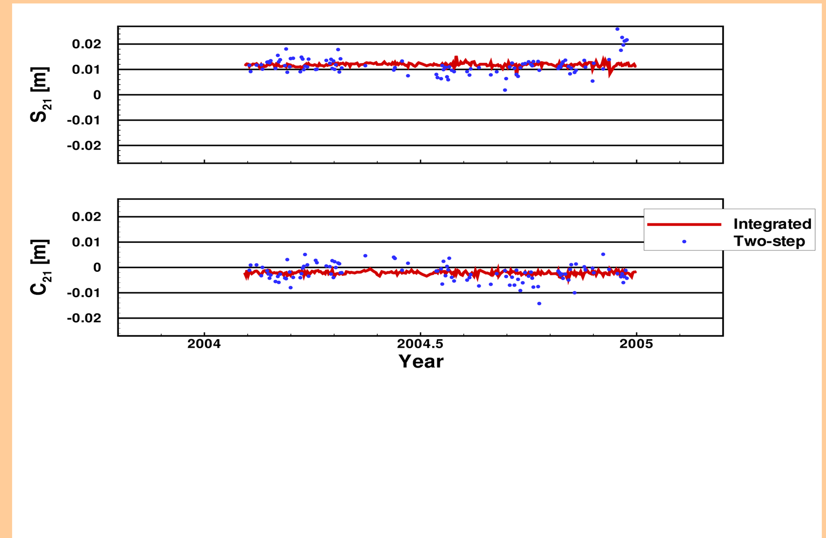

Figure 5: Time series of the gravity harmonic coefficients describing the orientation of the gravity field around the x- and the y-axis

Earth Rotation Parameters (ERPs)

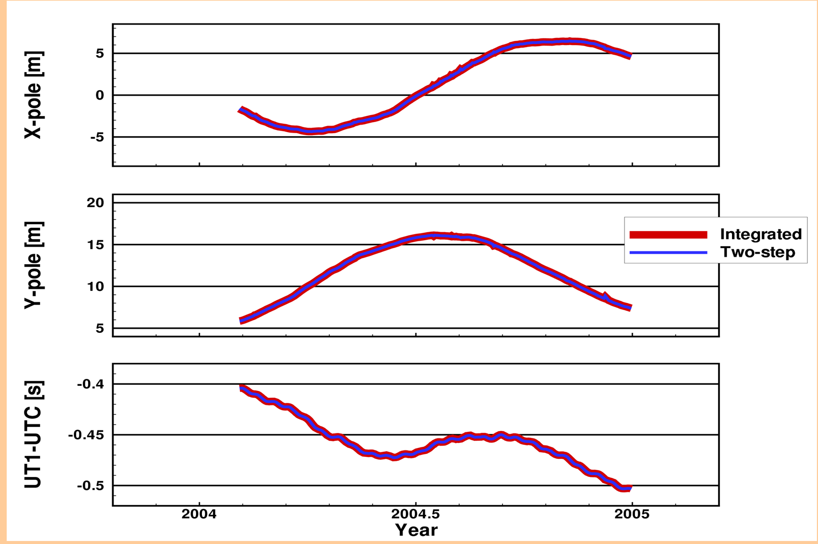

Figure 6: Time series of the estimated Earth Rotation Parameters

In Figure 6 the series of ERPs are displayed coming from both processing approaches. There is no major bias between the corresponding series.

For validation purposes the differences between the ERPs stemming from the integrated processing and the corresponding IERS C04 series were determined, cf. Figure 7. The higher scatter around 2004.5 in the ΔX-pole series is possibly caused by a period of K-Band data gaps. Considering long-term signals, the differences in ΔX-pole and ΔY-pole range on the cm level, and in Δ(UT1-UTC) they are on a level of 0.5 ms. The cause of the annual/semi-annual signals needs further analysis.

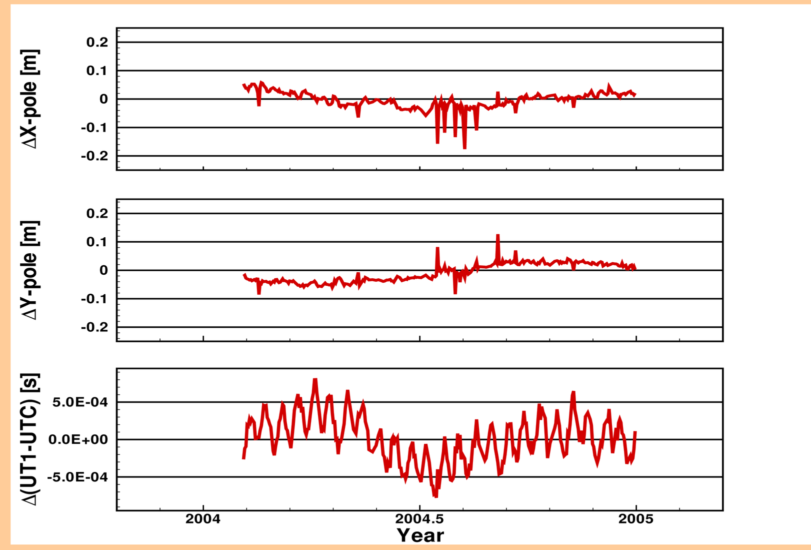

Figure 7: Time series of the differences between the estimated Earth Rotation Parameters and the corresponding IERS C04 series

C_{20} – Earth's Oblateness

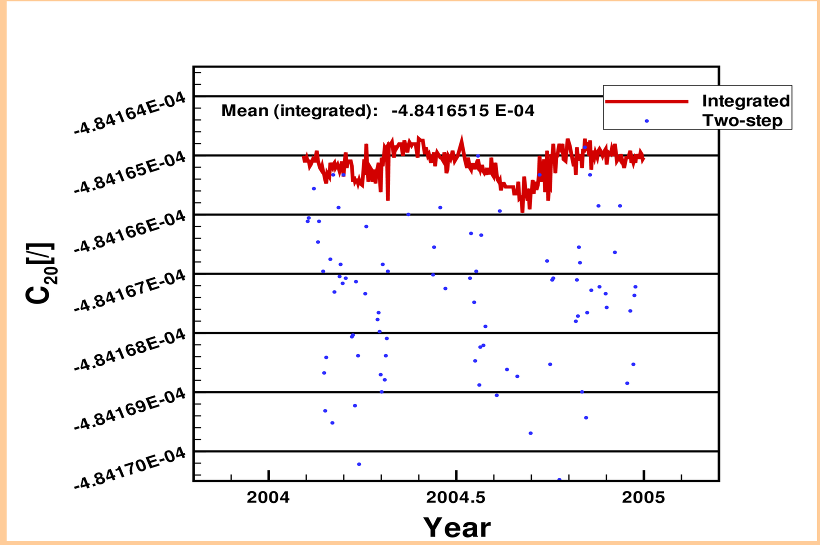

Figure 8: Time series of the C_{20} harmonic coefficient from the Integrated procedure and the corresponding two-step approach

The plot in Figure 8 shows the series of the C_{20} harmonic coefficient as derived by both processing strategies. Again, the scatter of the series from the two-step approach is much higher. In Figure 9 the C_{20} series coming from the integrated processing as shown in Figure 8 is directly compared to independently derived series of the GFZ monthly Grace release 04 gravity fields and a Lageos solution based on the release 04 standards with monthly and weekly resolution, respectively. The integrated solution follows mostly the Grace solution with a shift against the Lageos-derived series (possibly caused by a K-band effect). A larger deviation can be noticed for the period of the Grace 4-d repeat cycle around September.

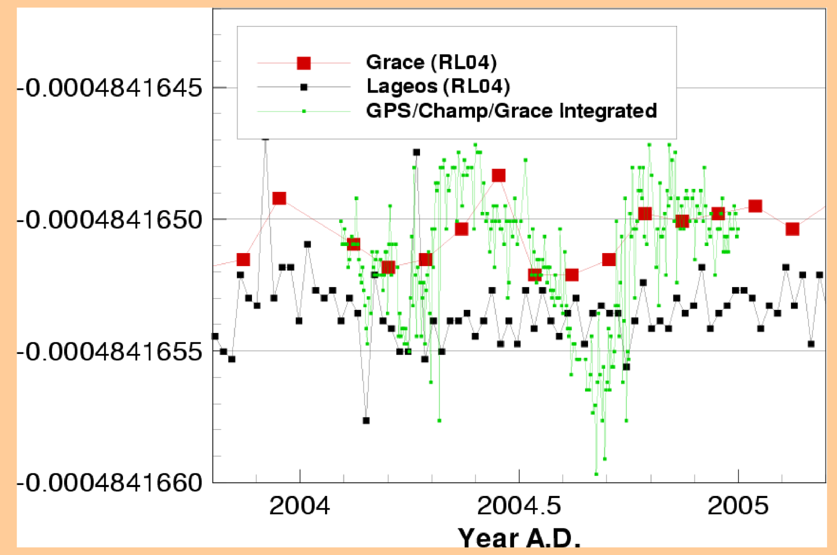

Figure 9: Time series of the C_{20} harmonic coefficient for EIGEN-GRACE standard gravity field processing and for a LAGEOS SLR-only solution

Conclusions

For the year 2004 geodetic Earth system parameters have been determined with daily resolution applying dynamic satellite orbit adjustment in the integrated mode.

Despite a rather loose datum constraint of 10 cm on the Earth's surface the derived parameter series turn out close to the level they are expected. All measures indicate a high accuracy.

To further improve results, alternative approaches for constraining the datum and for parameterising the observational data will be investigated.

References

Zhu, S., Ch. Reigber, R. König (2004), Integrated Adjustment of CAHMP, GRACE, and GPS data. Journal of Geodesy, Vol. 78, No. 1-2, pp. 103-108.

Acknowledgement

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