Low-degree spherical harmonics from multi satellite SLR

M. Bloßfeld, H. Müller, M. Gerstl, N. Panafidina, J. Bouman, F. Göttl
Deutsches Geodätisches Forschungsinstitut (DGFI), Munich, Germany, blossfeld@dgfi.badw.de

Motivation

Recent gravity field missions such as GRACE (Gravity Recovery And Climate Experiment) and GOCE (Gravity field and steady-state Ocean Circulation Explorer) are focused on measuring the Earth's temporal gravity field and on measuring the Earth's mean gravity field with high spatial resolution. Both satellite missions lack the sensitivity on the long wavelength of the Earth's gravity field. This gap can be filled with laser ranging measurements to near-Earth spherical satellites (Satellite Laser Ranging, SLR) from globally distributed stations collected by the International Laser Ranging Service (ILRS, Pearlman 2002).

This paper describes the DGFI multi-satellite SLR solution of the degree two Stokes coefficients of the Earth's gravity field (Gravity Field Coefficients, GFCs) and shows the results of a validation process on the basis of orbit parameters and mass-related equatorial excitation functions. The estimated GFCs of degree 2 are compared to the Release (RL) 04 and 05 solution of the Center for Space Research (CSR, Cheng et al., 2013).

Data & satellite sensitivity

Within the computation interval between 2000.0 and 2014.0, up to ten different spherical satellites (Fig. 1) are combined on a weekly basis. The station coordinates and the Earth Orientation Parameters (EOPs) are fixed to their a priori values (SLRF2008, IERS 08 C04). The GFCs are introduced in the normal equations (NEQs) up to degree and order 20 and the used satellites have different properties (altitude, inclination, mass, diameter, …) which allow a decorrelation of parameters when combined. Fig. 2 shows the scaled NEQ elements of the different satellites and of the constrained combined NEQ of GPS week 1720 (2012.98).

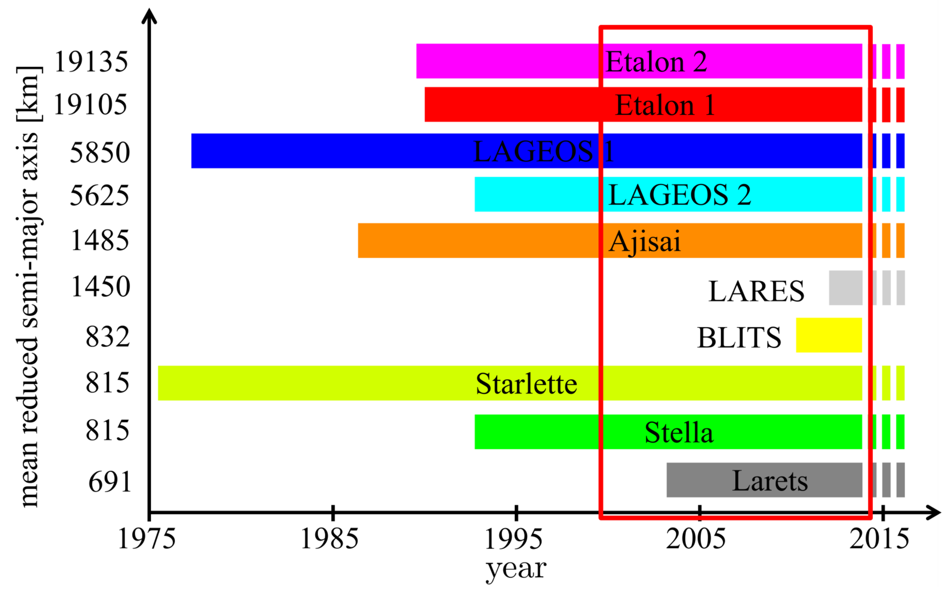

Fig. 1: Mission duration and computation interval of the satellites of this study.

The elements of different NEQs are not comparable since the NEQs are scaled individually. The smaller the NEQ element, the smaller is the sensitivity of the observations to the corresponding GFC.

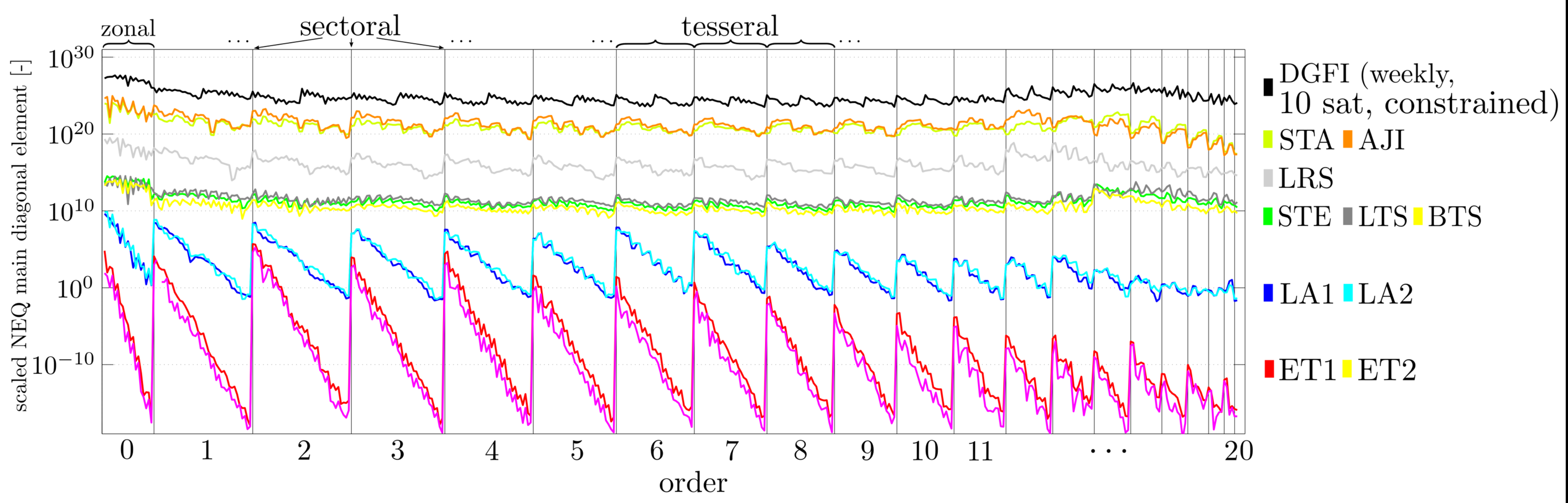

Fig. 2: Scaled diagonal elements of the satellite-specific NEQs and the constrained combined NEQ of GPS week 1720 (2012.98).

References

Bloßfeld M., Müller H., Gerstl M., Štefka V., Bouman J., Göttl F. (2014) Improved monthly Earth's gravity field solutions using multi-satellite SLR. Journal of Geophysical Research, in review

Cheng M. K. Tabley B. D., Ries J. C. (2013) Deceleration in the Earth's oblateness. Journal of Geophysical Research (118): 1-8, DOI: 10.1002/jgrb.50058

Pearlman M. R., Degnan J. J., Bosworth J. M. (2002) The International Laser Ranging Service. Advances in Space Research 30(2): 135-143, DOI: 10.1016/S0273-1177(02)00277-6

Acknowledgement

The authors want to thank the International Laser Ranging Service (ILRS) for providing the observations.

Degree two estimates

In total, three different solutions with GFCs up to degree and order 4 were computed:

(i) weekly Etalon-LAGEOS solution,

(ii) weekly 7-10 satellite solution,

(iii) monthly 7-10 satellite solution.

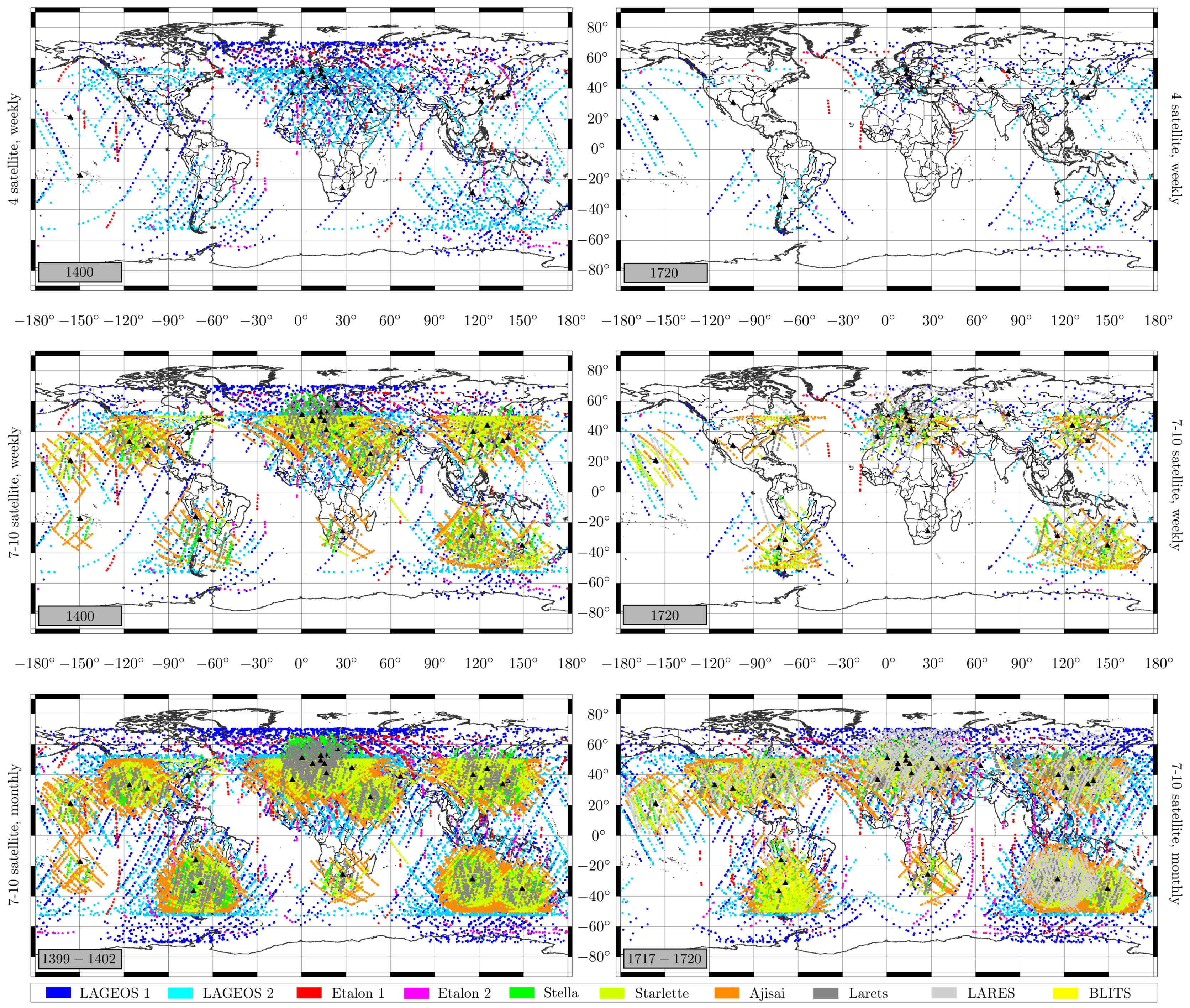

Fig. 3: Global distribution of observations for weekly Etalon-LAGEOS (upper panels), weekly 7-10 satellite (middle panels) and monthly 7-10 satellite (lower panels) combinations for GPS weeks 1400 (2006.85, left) and 1720 (2012.98, right).

Fig. 3 shows the global observation coverage for the three solutions (i), (ii) and (iii) for the GPS weeks 1400 and 1720. In Fig. 4, the DGFI solutions of GPS week 1400 have a small degree two geoid error due to the dense observation distribution. In GPS week 1720, the sparse observations cause a high geoid error. In general, the monthly solution shows a smaller degree two geoid error since more observations are taken into account.

Both CSR solutions and the (i) solution show a long-term variability of the geoid error due to the changing network (observation) geometry. In the (ii) and (iii) solution, the variability disappears due to a more stable geometry.

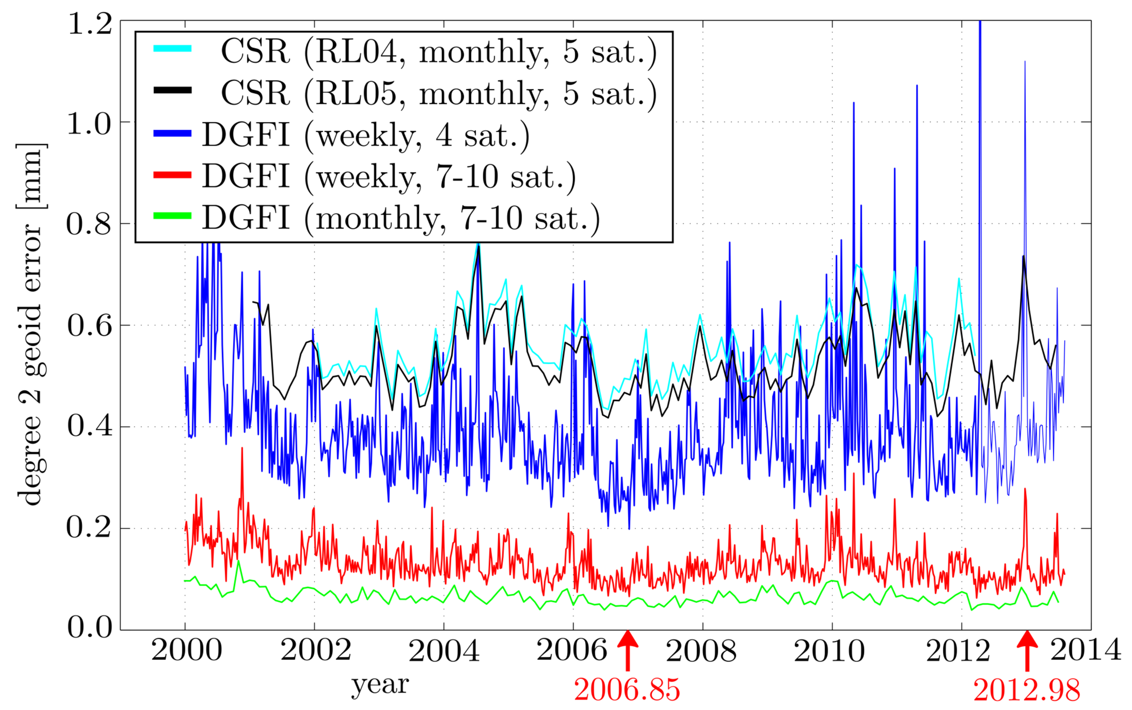

Fig. 4: Weekly degree two geoid errors for five solutions. The global observation distribution of the two highlighted epochs are shown in Fig. 3.

Validation

In order to validate the obtained GFCs, four different orbits with empirical accelerations are estimated. Therein, the degree two GFCs are fixed to four different a priori gravity models. In Fig. 5, the weekly orbital fit (observed minus computed) and the mean of the estimated sine-terms in cross-track (normal to orbital plane) direction of the used satellites are shown. The smaller the orbital fit and the empirical sine-term, the better fits the a priori gravity field model to the observations.

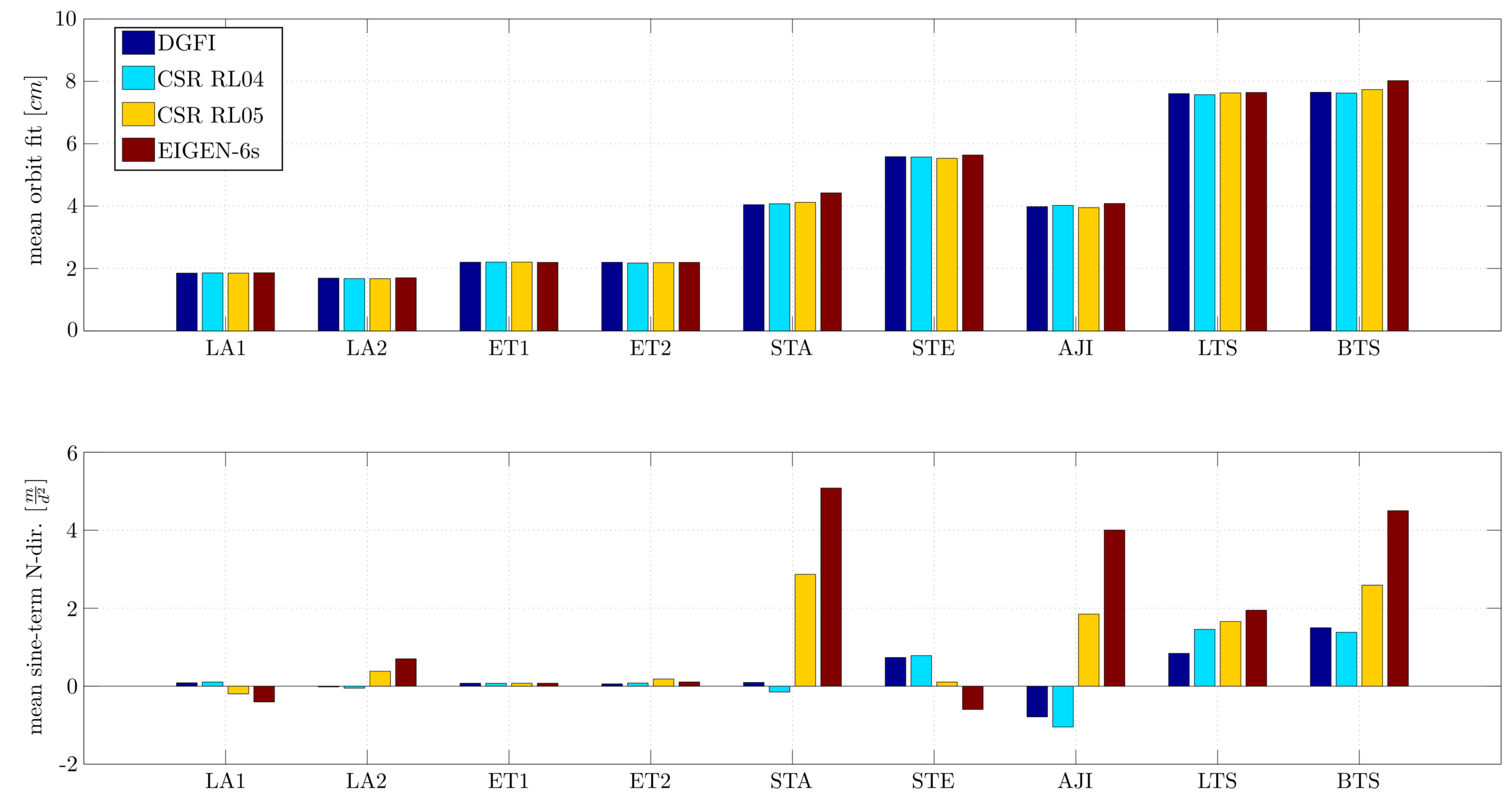

Fig. 5: Mean orbital fits and once-per-revolution sine-terms in cross-track direction of the used satellites.

Fig. 6 shows the amplitudes and phases of the estimated C_{21} and S_{21} coefficients converted into mass-related equatorial excitation functions χ_1^{mass} and χ_2^{mass}. In addition to the DGFI (iii) and both CSR solutions, four model combinations are shown.

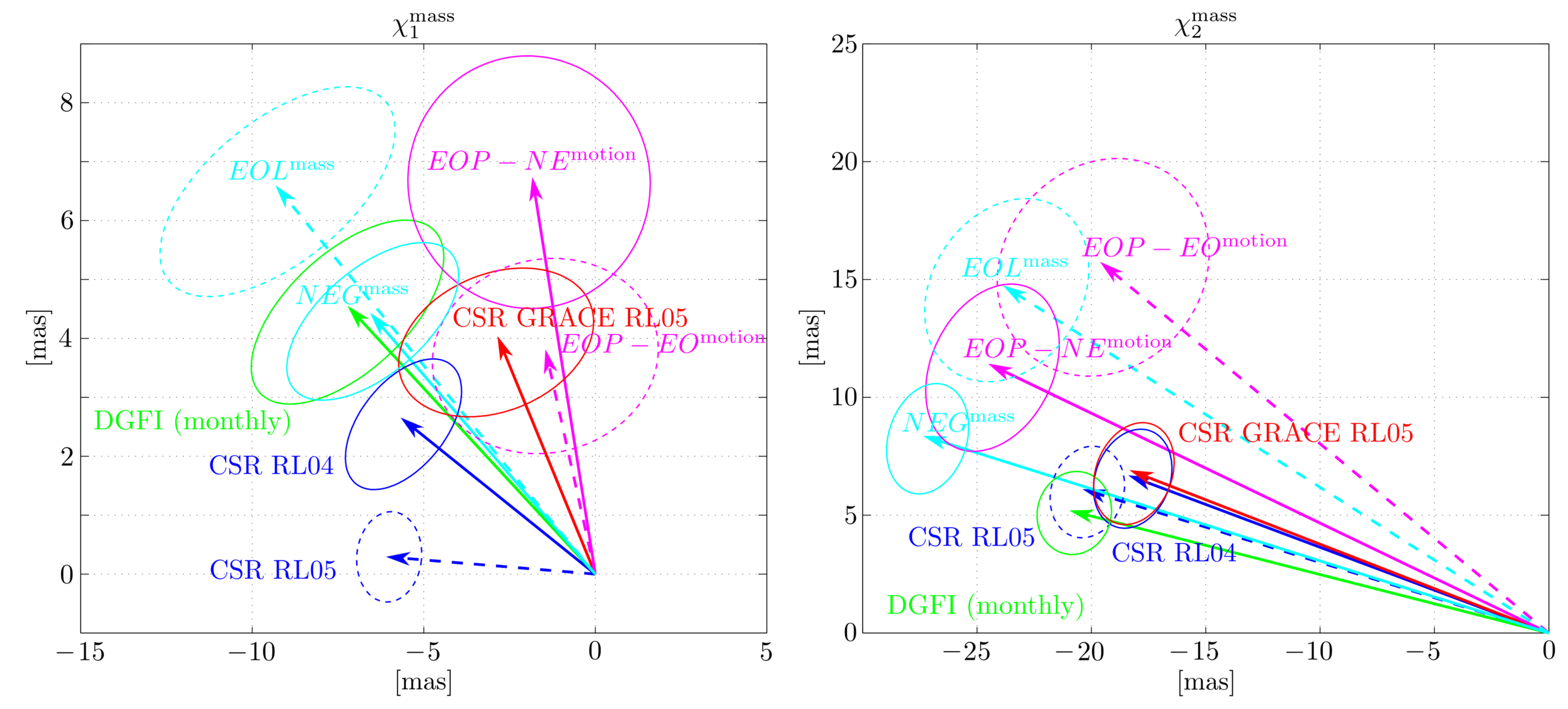

Fig. 6: Phasor plots of the annual amplitudes and phases for χ_1^{mass} and χ_2^{mass} of the DGFI (iii) and both CSR solutions. In addition, the two geophysical model combinations EOL^{mass} (ECMWF+OMCT+LSDM), NEG^{mass} (NCEP+ECCO+GLDAS) and the two reduced geodetic model combinations $EOP-NE^{motion}$ (NCEP+ECCO), $EOP-EO^{motion}$ (ECMWF+OMCT) are shown.

Conclusions

Since low-degree GFCs are used to fill the sensitivity gap of GRACE and GOCE, gravity field models benefit from accurate degree two GFC estimates. To increase the accuracy stability and reliability of the degree two GFCs, a combination of up to ten spherical satellites can be used. **In this paper, we found that DGFIs monthly 7-10 satellite solution (iii) shows the smallest and most stable (without long-term variations) degree two geoid errors, the smallest orbital fits and empirical sine-term estimates and fits well to independent model combinations.**