João de Teixeira da Encarnação

Summary of selected publications

In Teixeira da Encarnação et al. 2020 I report the results of massive numerical experiments testing different parametrization schemes. A full-matrix scale factor parametrization of GRACE's accelerometers is able to handle the different data quality over the complete mission lifetime, while maintain consistency in the processing choices. With this accelerometer parametrization scheme, it is possible reduce the number of bias parameters (removing the quadratic terms) and increase the scale parameters in the accelerometer calibration parametrization (from diagonal to full matrix and from monthly to daily), leading to a net decrease of 4 parameters per day, since that the y-axis bias parameters are estimated every 3 hours. In terms of the quality of the gravity field model, there is a significant decrease in the intensity of the stripping artefacts, except for those periods with excellent data quality, where there is no noticeable decrease in the model's quality relative to previous releases. From this research, both CSR and JPL (two of the main gravity field model producing centres) have modified their data processing to follow my recommendations.

In Teixeira Encarnação et al. 2019, I report on the operational production of the Swarm gravity field models. This research was one in cooperation with five international research institutes (Institute of Geodesy (IfG) of the Graz University of Technology (TUG), Astronomical Institute (ASU) of the Czech Academy of Sciences (AVCR), Astronomical Institute of the University of Bern (AIUB), Aerospace Faculty of the Delft University of Technology (TU Delft) and School of Earth Science (SES) of the Ohio State University (OSU)), within the context of a project initiated and lead by me. I have taken the leading role securing funding from the European Space Agency (ESA), through the Data, Innovation and Science Cluster (DISC), to develop the methodology to best combine the individual gravity field solutions from each research institute. This project has recently been awarded additional funding to routinely produce monthly models for the foreseeable future. This publication capitalizes on the experience gathered from producing 6 years of Swarm gravity field models, illustrating the strengths and limitations of this dataset. I demonstrate that the published models are of superior quality than any of the individual models that are used to estimate it, and that a smoothing of 750km is needed over land, while 3000km is needed over the oceans.

In Teixeira da Encarnação et al. 2016, the habitability of the Swarm satellites to observe changes on Earth's gravity field was for the first time demonstrated. The Swarm gravity field models constitute an independent source of gravimetric data from dedicated mission (Gravity Recovery And Climate Experiment (GRACE) and GRACE Follow On (GRACE-FO)). Although their spatial resolution is much lower, the Swarm models are still able to describe monthly variations of Earth's gravity field within a few millimetres geoid height, when compared with GRACE. This has proven to be particularly beneficial in monitoring mass transport processes during the gap between the periods when GRACE and GRACE-FO were and are (respectively) collecting data.

My contribution to Ditmar, Encarnação, and Hashemi Farahani 2012 demonstrates that the influence of temporal aliasing caused by errors in the Atmosphere and Ocean De-aliasing (AOD) models, needed to remove rapid-changing gravity variations that are impossible for GRACE to observe, cannot explain the unexpected low quality of the gravity field models, compared with pre-launch predictions, particularly in what concerns the striping artefacts. Additionally, the results of this publication contrast with other similar studies in the sense that it is clear that different gravity field estimation approaches have different sensitivity to different error types. In case of our method, the acceleration approach, the in-situ character of the observation equation ensures the effects of temporal aliasing are mitigated, while the integrating nature of the traditional variational equations approach accumulates AOD model errors, magnifying their influence. Irrespective of this difference sensitivity, all methods must rely on accurate orbits to properly build the normal matrices and estimate the gravity field coefficients. We demonstrate that there are numerous error components resulting from orbit errors. This work was the foundation for my thesis dissertation, where the effect of different components of orbit errors are quantified to an unprecedented level of accuracy, for the GRACE mission.

My contribution to Gunter et al. 2011 for the first time explores the possibility of using numerous satellites equipped with Global Positioning System (GPS) receiver to augment dedicated gravimetric satellite missions. We demonstrate that the current accuracy of GPS observations is insufficient to provide meaningful improvements, unless a large number of satellites is used (in the order of hundreds). However, future and multiple Global Navigation Satellite System (GNSS) systems should be accurate enough to make it possible to provide enough information to resolve sub-weekly to daily low-degree solutions with sufficient accuracy to observe, for the first time, global atmospheric mass transport processes. This work has motivated my research into the design of a gravimetric CubeSats, specifically with efforts of pursing several funding applications to develop Micro Electro-Mechanical

System (MEMS)-based space accelerometry.

Highlighted publications

2020 **Teixeira da Encarnação, J.**, Save, H., Tapley, B., Rim, H.-J., "Accelerometer Parameterization and the Quality of Gravity Recovery and Climate Experiment Solutions". In: *Journal of Spacecraft and Rockets* 57.4, pp. 740–752. DOI: 10.2514/1.A34639.

2019 **Teixeira Encarnação, J.**, Visser, P., Arnold, D., Bezdek, A., Doornbos, E., Ellmer, M., Guo, J., IJssel, J., Iorfida, E., Jaggi, A., Klokocnik, J., Krauss, S., Mao, X., Mayer-Gurr, T., Meyer, U., Sebera, J., Shum, C., Zhang, C., Zhang, Y., Dahle, C., "Multi-approach gravity field models from Swarm GPS data". In: *Earth System Science Data Discussions*, pp. 1–55. DOI: 10.5194/essd-2019-158.

2016 **Teixeira da Encarnação, J.**, Arnold, D., Bezděk, A., Dahle, C., Doornbos, E., IJssel, J., Jäggi, A., Mayer-Gürr, T., Sebera, J., Visser, P., Zehentner, N., "Gravity field models derived from Swarm GPS data". In: *Earth, Planets and Space* 68.1, p. 127. DOI: 10.1186/s40623-016-0499-9.

2012 Ditmar, P., **Encarnação, J.**, Hashemi Farahani, H., "Understanding data noise in gravity field recovery on the basis of inter-satellite ranging measurements acquired by the satellite gravimetry mission GRACE". In: *Journal of Geodesy* 86.6, pp. 441–465. DOI: 10.1007/s00190-011-0531-6.

2011 Gunter, B. C., **Encarnação, J.**, Ditmar, P., Klees, R., "Using Satellite Constellations for Improved Determination of Earth's Time-Variable Gravity". In: *Journal of Spacecraft and Rockets* 48.2, pp. 368–377. DOI: 10.2514/1.50926.