High-resolution combined global gravity field modeling:

Towards a combined d/o 10800 model

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1. Outline

1.1 Problem description

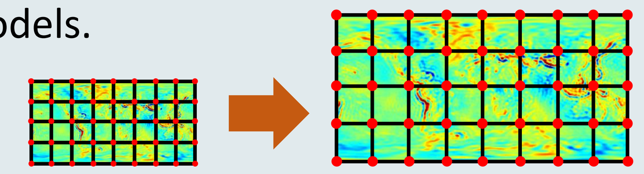
So far, the limited resolution of d/o 719 (~30 [km] spatial resolution) has been one of the remaining drawbacks of the XGM global gravity field models. This limitation arises from two facts:

- firstly, the terrestrial dataset provided by courtesy of the NGA is **limited** to this resolution,
- secondly, solving dense normal equation systems (NEQS) above d/o 719 becomes **computationally very demanding**.

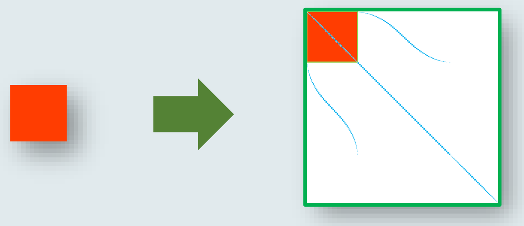
1.2 Proposed solution

To remedy these limitations, it is proposed to:

- **extend the terrestrial dataset** by including additional data sources such as higher-resolution gravity field models, gravity anomalies derived from satellite altimetry, and topographic models.



- **use a so-called kite-system** instead of a dense normal equation system for the final combination with the satellite model to keep the computational effort within a reasonable limit.



The final result of this contribution shall then be a gravity field model up to d/o **10800** (~2 [km] spatial resolution), densely modeled up to d/o 719.

2. High-resolution terrestrial dataset compilation

2.1 Strategy and components

A high-res. global gravity field model requires the compilation of a global high-res. terrestrial gravity dataset: for different parts of the world there exist different datasets of different spectral content which best describe the specific regions. Between those regions, one can mainly distinguish **ocean areas** where comprehensive altimetric geoid information is available, and **land areas** where the acquisition of gravity information is more difficult and the quality more heterogeneous.

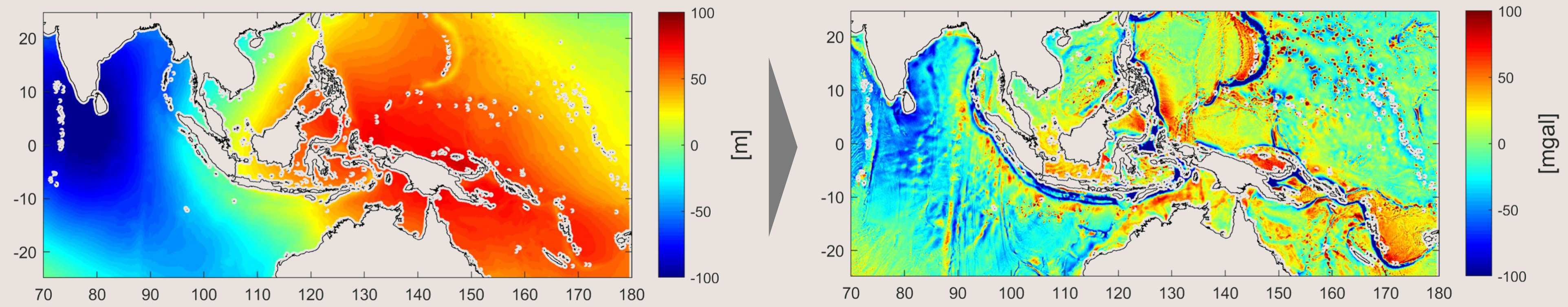
With these premises we apply different strategies for both regions:

- **Over the ocean**: take 1min mean sea surface (MSS) corrected by the mean dynamic topography (MDT) to resemble geoid heights (cf. 2.2)
- **Over land**: take NGA's 15min gravity anomaly dataset spectrally augmented with data from a 5min global gravity field model (GGM) and further extended with topographic information up to 1min (cf. 2.3).

Finally, the resulting components are combined in the spatial domain in terms of gravity anomalies, forming a globally complete grid which serves as input for the subsequent combination with the satellite model (cf. 3).

2.2 Altimetric data processing

The MSS, main contributor to the ocean's geoid, can be obtained directly as a final product from DTU (Technical University of Denmark). For this work we chose the latest version, DTU18 (Anderson et al. 2018). To form a proper geoid, the MSS has to be corrected by the MDT. As the MDT can't be observed geometrically, it has to be derived by comparison to a GGM. Here we use the results from the ESA OGMOC project which focuses specifically on this topic. As the final terrestrial grid shall be given in terms of gravity anomalies, the geoid has to be converted in a last step. This is done by performing a rigorous global analysis (block-diagonal) and subsequent synthesis:



2.3 Land data processing

As the direct access to a global coverage of gravity field observation over land is nearly impossible to acquire due to multiple reasons, we rely on already existing GGMs. The combination between the GGMs is performed spectrally (in a spheroidal harmonic domain):

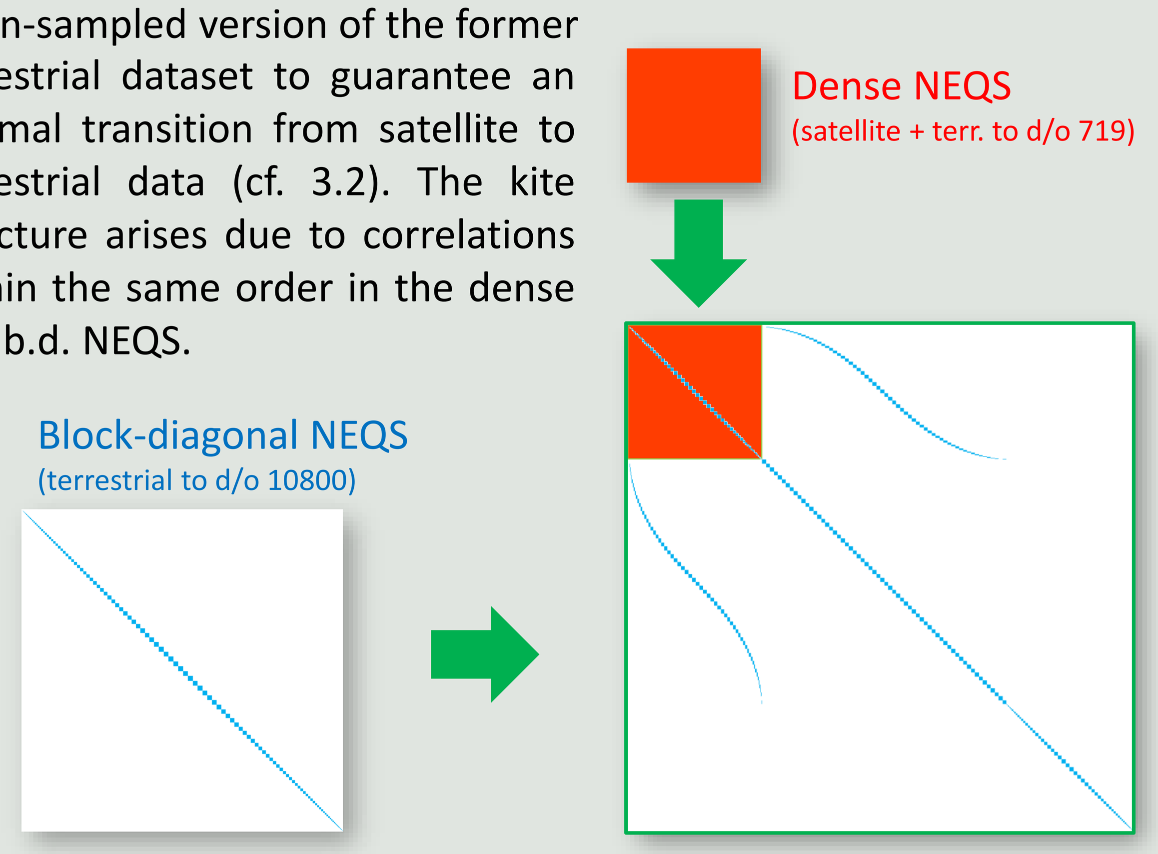
$$\underset{[2-5400]}{GGM_{land}} = \underset{[2-719]}{GGM_{NGA}} + \underset{[720-2159]}{GGM_{ICGEM}} + \underset{[2160-5400]}{GGM_{EARTH2014}}$$

(GGM_{NGA} is the GGM derived from the terrestrial NGA grid, incorporated already in XGM2016 (Pail et al. 2018). GGM_{ICGEM} is either EGM2008 (Pavlis et al. 2012), EIGEN6C4 (Förste et. al. 2014) or a future EGM. $GGM_{EARTH2014}$ denotes the topographic EARTH2014 model (Rexer et al. 2017).

3. Combination strategy

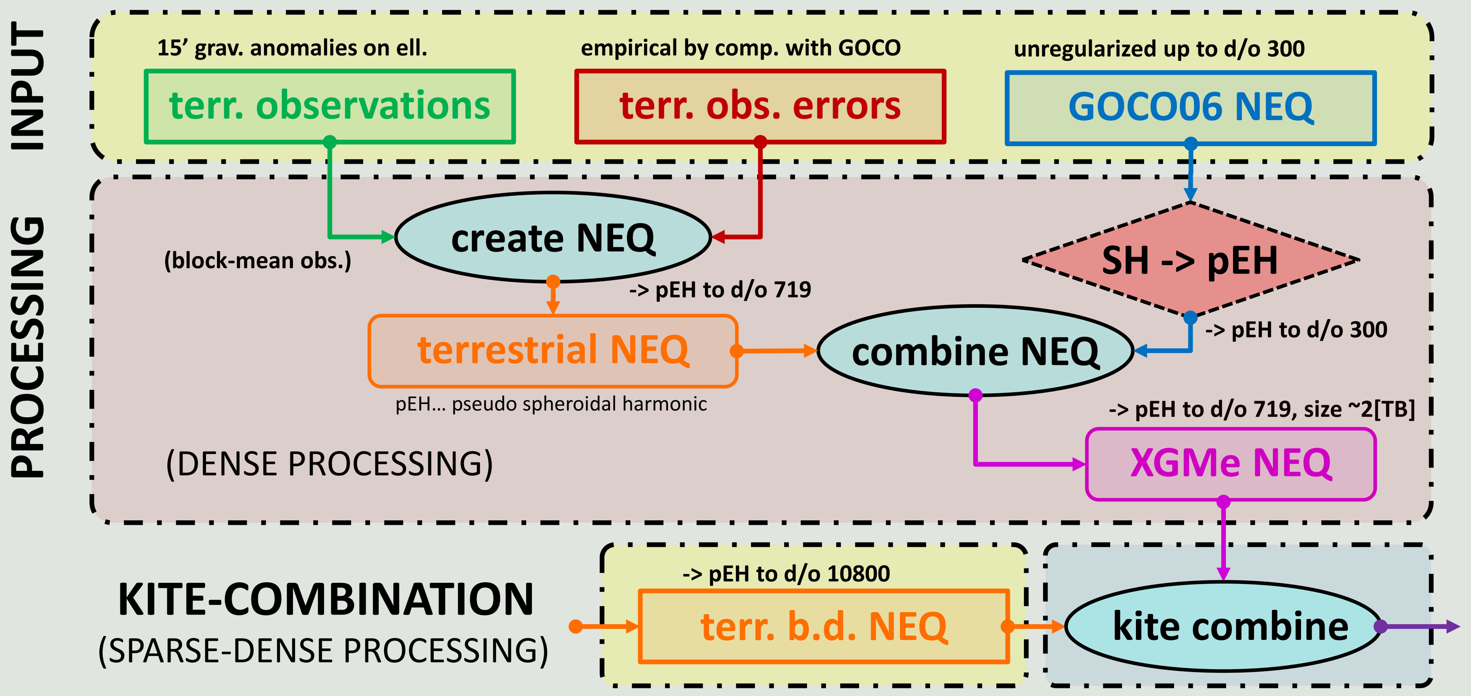
3.1 Concept of the combination approach

For the combination of the high-res. terrestrial gravity dataset with a satellite model, a kite approach is chosen, wherein the high-res. terrestrial dataset is introduced block-diagonally (b.d.), i.e. equally weighted. The dense part of the kite system is composed of the full normal equation of the satellite system combined with a weighted and down-sampled version of the former terrestrial dataset to guarantee an optimal transition from satellite to terrestrial data (cf. 3.2). The kite structure arises due to correlations within the same order in the dense and b.d. NEQS.



3.2 The dense normal equation system

As the terrestrial dataset features regionally varying quality, special attention has to be payed when combining it with the satellite model. An optimally combined solution is only possible when introducing location-dependent weights to the terrestrial observations. On the downside, these weightings destroy the block-diagonal structure of the terrestrial normal equation system, leading to a dense system. To retain the applicability of this method, it is necessary to use a down-sampled version of the terrestrial dataset. The workflow to acquire the dense system can be summarized as follows:



4. Stage of work

4.1 Work packages

Currently, the work on the final model is still in progress. In the following we give a brief overview on the current status:

Methodology:

- Creating, combining, solving dense NEQS
- Block diagonal NEQS processing
- Kite NEQS processing
- Spheroidal harmonic functionals and transformations
- Optimization of all methods for massive parallelization on distributed systems

Data processing:

- Choice of MSS
- Choice of MDT
- Ocean geoid to gravity anomaly conversion
- Final choice of land GGM
- Land-ocean tapering strategy
- Land-ocean tapering evaluation
- Satellite-terrestrial weighting strategy
- GOCO06s model availability

4.2 Acknowledgements

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