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Interactive comment on "A multilayer approach and its application in modeling QGNSea V1.0: a local gravmetric quasi-geoid model over the North Sea" *by* Yihao Wu et al.

Yihao Wu et al.

yihaowu@hust.edu.cn

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Interactive comment on "A multilayer approach and its application in modeling QGNSea V1.0: a local gravmetric quasi-geoid model over the North Sea" by Yihao Wu et al. Anonymous Referee #2 Received and published: 10 April 2018

I have read the interesting manuscript "A multi-layer approach and its application in modeling QGNSea V1.0: a local gravmetric quasi-geoid model over the North Sea" by Yihao Wu, Zhicai Luo, Bo Zhong, and Chuang Xu. The manuscript focuses on a multi-layer approach compared to a single layer approach in the computation of the local gravity geoid.

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Discussion paper

I have the following comments: 1. Muliti layer approach gives (according to Table 5 and Fig 7 and page 16-17) a better fit than single layer approach. The fit would naturally increase with incrasing level of parameters, but it is statistical significant. A statistical test such as AIC (Akaike information criterion) or BIC would give valuable information.

Response: The authors thank the reviewer for this beneficial comment. Yes, the authors totally agree with the reviewer's comment, and the fit with the data using the multilayer approach with more parameters naturally increase from the view of statistical analysis. We believe it is a very good suggestion for implementing the Akaike information criterion (AIC) or Bayesian information criterion (BIC) test of different models. In this study, we implement the AIC test, which may provide value information for model selection in another aspect. AIC rewards the goodness of fit of data, but also includes a penalty that is an increasing function of the number of estimated parameters. It deals with the trade-off between the goodness of fit of the model and the simplicity of the model. AIC test is an estimator of the relative quality of statistical models for a given set of data, providing a means for model selection, and the model that gives the minimum AIC value may be more preferable (Akaike, 1974). The AIC value of the model is defined as AIC=2k-2ln(L), where k is the number of estimated parameters in the model, and L is the maximum value of the likelihood function for the model (Burnham and Anderson, 2002). For gravity field modeling in this study, we work within the framework of least squares adjustment, i.e., the unknown coefficients of Poisson wavelets of different approaches (the multilayer and single-layer approach) are computed through the least squares method. We also assume that the data residuals derived from different approaches are distributed according to independent identical normal distributions with zero mean values, also see the information of data residuals in Table 5 in the revised manuscript. Then, the maximum likelihood estimate for the variance of a model's residuals distributions is RSS/n, where RSS is the residual sum of squares (RSS), and n is the number of observations (Burnham and Anderson, 2002). Then, the AIC value of model is given as AIC=2k+nln(RSS/n)+C, and C is a constant independent of the model (Burnham and Anderson, 2002). Since only differences in AIC are meaningful, the constant C can be ignored, and we can conveniently take AIC=2k+nln(RSS/n) for model comparisons. In this study, we compare the performances of the multilayer and single-layer model through the AIC test. In details, the number of gravity observations is 894649, and the numbers of estimated parameters in the multilayer and single-layer model are 47504 and 19477, respectively. The RSS values for the multilayer and single-layer model are 8.8527×10ˆ5 mGalˆ2 and 1.3296×10ˆ6 mGalˆ2, respectively, based on the data residuals after the least squares adjustment. Then, the AIC values for the multilayer and single-layer model are estimated as 85581 and 393400, respectively. Based on these statistics, we notice that the multilayer model gives a smaller AIC value, which may be more preferable since it reaches a better balance between the goodness of fit of data and the simplicity of the model. According to the reviewer's comments, we add the information of AIC test in the revised manuscript, please refer to the abstract (pp 1) section 3.3 (pp 19), conclusion (pp 30), and the Appendix (pp 32) in the updated version.

2. For a better comparison with EGG08 the same or similar global geopotential model should be used.

Response: The authors thank the reviewer for this beneficial comment. For further validate the quality of QGNSea V1.0, we compare it with other existing models, where a regional model call EGG08 and other global geopotential models (GGMs) are introduced. EGG08 is a regional gravimetric quasi-geoid model covers most areas in Europe; this model was recovered by stokes integral based on locally distributed gravity data, which was provided in terms of gridded data instead of spherical harmonics like GGMs (e.g., EGM2008 and EIGEN-6C4), and the space resolution of which is 1 minute in latitude and 1.5 minute in longitude, see Denker (2013). We also use other global geopotential models for comparisons since the authors don't have access to other regional gravimetric quasi-geoid models; for example, a new Europe gravimetric quasi-geoid called EGG2015 has been implemented (Denker, 2015), however, this model is seems not publicly available. Thus, the two high-order GGMs, i.e., EGM2008 (d/o 2190) with the spatial resolution of 5 minute by 5 minute, EIGEN-6C4 (d/o 2190) with the spatial resolution of 5 minute by 5 minute are incorporated for further comparisons, since these two models have relatively higher spatial resolutions and better accuracies compared to most of other available GGMs, when compared with the globally distributed GPS/leveling data, see the information in http://icgem.gfz-potsdam.de/home. However, according to the reviewer's comments, we introduce another two recently published high-order GGMs (i.e., GECO (d/o 2190) (Gilardoni et al. 2015), and SGG-UGM-1 (d/o 2159) (Liang et al. 2018)), which were developed by combining GOCE data into EGM2008, for further comparisons. We also restructure and modify the relevant parts in the updated manuscript based on the reviewer's comments, please see pp. 24-27 in the revised version.

3. Figure 2: A comment related to the different patterns observed in Figure 2 would be of interest.

Response: The authors thank the reviewer for the comment. First of all, the authors believe the original wavelet details with stripe like patterns shown in Figure 2 are problematic (also see the interactive comments from the third referee), since we carefully check the source code for wavelet decomposition, and find bugs that may derive incorrect wavelet details. Based on the reviewer's comments, we redo the wavelet decomposition after the removal of bugs of source code, and compute the new wavelet details and approximation, please refer Figure 1 in the updated version, i.e., in pp 11, where no strange stripy patterns occur. Moreover, we provide the geophysical evidences for the patterns of different wavelet details. More specifically, D_1 and D_2 and are seems dominated by the high-frequency signals correlate strongly with the local topography, which are mainly due to the uncorrected topographical signals in RTM corrections. D_3 and D_4 with respective average source depths of 4.5 km and 9.2 km primarily reflect the density distribution of the upper crust. The distribution of D_5 and D_6 is in agreement with the tectonic structure of the middle crust. D_7 is consistent with the Moho undulation. D_8 and A_8 represent density distribution of the upper mantle. Overall, these decomposed gravity anomalies can reveal the tectonic structure of study area at different depths. Based on the reviewer's comments, we add the detailed comments related to the different patterns of wavelet details in Figure 1 (Figure 2 in the original version) in the revised manuscript, please see the information in pp13-14. Moreover, we notice that the wavelet details and approximation change after we implement the wavelet decomposition with the errors corrected source code, and we redo the whole procedure for the multiply layers' network design, i.e., estimating the depths of different layers and the number of Poisson wavelets in each layer. Then, we recompute the solution based on the multilayer approach with the updated parameters (i.e., the depths of different layers and the number of Poisson wavelets in each layer), and redo the comparisons with existing models based on the updated solution. Following, the geodetic MDT (called MDTNS_QGNSea) based on the updated model derived from the multilayer approach is computed. Please refer to pp 13-29 in the revised manuscript.

Please also note the supplement to this comment:
https://www.geosci-model-dev-discuss.net/gmd-2017-289/gmd-2017-289-AC2-supplement.zip

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