Response to Referee #1 Comments

We are grateful to the reviewer for the helpful feedback. By taking these suggestions into account, we have revised the MS. At the same time, we have polished the English expression of the MS.

We have addressed all the comments here, point by point responses to the comments are listed in RED.

Referee #1 Comments:

Mean sea surface (MSS) has important applications in geodesy, geophysics, and oceanography. The manuscript constructed a new global MSS model SDUST2020 with the resolution of 1'x1' from multi-satellite altimetry data, and evaluated its accuracy using several methods. Comparing with previous MSS models, several new altimetry missions and loner time-span data were included for modeling SDUST2020. Generally, it is a good MS and provide a valuable dataset. The results are of scientific sense. I recommend a moderate revision and English expression need to polish. Please find detailed comments on the current MS below.

1. Whether the altimeter data were retracked? If so, what retracking method was used? And how coastal altimeter data were treated in this study?

Response: Thanks. All the altimetry data used in this study are selected from the along-track Level-2p (L2P; version_02_00) products. They have not been retracked, but they have been preprocessed, including quality control and editing of data to select valid ocean data. The purpose of data preprocessing is to select valid measurements over the ocean with the data editing criteria. The editing criteria are defined as minimum and maximum thresholds for altimeter, radiometer and geophysical parameters (detailed in the along-track L2P product handbook). After data preprocessing, data near the coastline with poor quality have been eliminated (CNES, 2017).

CNES: Along-track level-2þ (L2P) SLA product handbook. SALPMU-P-EA-23150-CLS, Issue 1.0, https://www.aviso.altimetry.fr/fileadmin/documents/data/tools/hdbk_L2P_all_missions_except_S3.pdf, 2017.

2. What's the meaning of f(t) in equation (4)? It is suggested not to use the same character for different quantities in equation (3)-(5).

Response: Thanks. f(t) is the systematic errors, which include the radial orbit error, residual ocean variation, residual geophysical corrections, and so on. The same character for different quantities in equation (3)-(5) have been addressed, please refer to Line 157, 167 and 183 for details in the revised MS.

3. According to the comparison and validation, SDSUT2020 have better accuracy than CLS15 and DTU18. Except the accuracy, is there any obvious improvement to reveal details features of MSS? It is suggested to compare these MSS models in some typical sea regions.

Response: Thanks. How to validate the reliability and accuracy of MSS models is a very difficult problem (Andersen and Knudsen, 2009; Jin et al., 2016). This is because altimeter provides the most accurate sea surface height determination and because nearly all available altimetry data have already been used in the derivation of the MSS (Andersen and Knudsen, 2009). Usually, reliability and accuracy are validated by comparing with mean along-track altimetry data and other models (Andersen and Knudsen, 2009). Hence, the CLS15 and DTU18 MSS models are used, together with several mean along-track altimetry datasets after collinear adjustment and some other altimetry data independent of the SDUST2020 MSS model. Especially, to compare the accuracy differences of the three models in the region close to the coast, we also take the sea of Japan as an example to compare the three models with the GPS-leveled tide gauges around Japan.

Compared with CLS15 and DTU18, first, SDUST2020 is innovated in the data processing method of model establishment, such as using 19-year moving average method; second, the reference period of the SDUST2020 model extend from 1993 to

2019, while that of CLS15 and DTU18 is from 1993 to 2012; third, the establishment of SDUST2020 model for the first time integrates the altimeter data of HY-2A, Jason-3 and Sentinel-3A which have not been used in the establishment of any other global MSS model. The 19-year moving average method is used to further weaken the influences of residual errors of tidal models on the MSS model, and it has been proved to be effective in improving the accuracy of the established MSS model in Yuan et al (2020).

Andersen, O. B., and Knudsen, P.: DNSC08 mean sea surface and mean dynamic topography models, J. Geophys. Res.-Oceans, 114(C11), 327-343, https://doi.org/10.1029/2008JC005179, 2009.

Jin, T., Li, J., Jiang, W: The global mean sea surface model WHU2013, Geod. Geodyn., 7, 202-209, http://dx.doi.org/10.1016/j.geog.2016.04.006, 2016.

Yuan, J., Guo, J., Liu, X., Zhu, C., Niu, Y., Li, Z., Ji, B., and Ouyang, Y.: Mean sea surface model over China seas and its adjacent ocean established with the 19-year moving average method from multi-satellite altimeter data, Cont. Shelf Res., 192(1), 104009, https://doi.org/10.1016/j.csr.2019.104009, 2020.

4. In section 3.1, T/P series data between 66°S and 66°N were used to calculate ocean variability correction for ERS/GM, HY-2A/GM, SARAL and Cryosat-2 which latitude ranges beyond 66°. It need to extrapolate. How does the polynomial fitting interpolation (PFI) perform to do the extrapolation?

Response: Thanks. Since the GM data does not have the characteristics of repeated periods like ERM data, so the ocean variability correction of GM data cannot be addressed by the method of collinear adjustment. Currently, the main methods for the correction of GM data for ocean variability are the objective analysis or based on the use of polynomial functions (e.g. polynomial fitting interpolation, PFI). This study combines these two methods for the ocean variability correction of GM data. The objective analysis method is adopted for the GM data between 66°S and 66°N, while the PFI method is adopted for GM data beyond 66°S or 66°N. In PFI method, seasonal variations are extracted using grid sea level variation time series, interpolated to the GM observations and corrected. The seasonal variations are extracted from the monthly averaged grid sea level variation time series between 1993 and 2019 provided by AVISO, with spatial resolution of 15′×15′.

5. In section 3.2, for crossover adjustment, did the author set threshold of time difference of two tracks?

Response: Thanks. The long-wave ocean variation signals, such as part of the radial orbit error and seasonal ocean variations, were reduced after the correction of the ERM and GM data for ocean variability. However, the residual of the radial orbit error, a short-wave signal of the ocean variability and geophysical correction residual are still the main factors affecting the accuracy of the MSS model (Jin et al., 2016), and these residuals can be reduced by crossover adjustment. Crossover adjustment is used to joint multi-satellite altimeter data, including ERM and GM data. Therefore, in the process of crossover adjustment, it is not necessary to consider the time difference of two tracks.

6. In Figure 6-8, there are large differences in polar regions between MSS models. What's the reason?

Response: Thanks. The difference between MSS models depends on the data set used for calculation and the data processing method (Schaeffer et al., 2012). From Figure 6-8, the differences between the three models in the long wavelength are mainly concentrated in the polar regions and the western boundary current region (including the Kuroshio Current, Mexico Gulf, Agulhas Current, etc.). There are two reasons: on the one hand, it is related to the large sea level change in these regions (Jin et al., 2016); on the other hand, it is also related to the different altimeter data used and data processing methods implemented in the modeling (Andersen and Knudsen, 2009; Schaeffer et al., 2012; Pujol et al., 2018). A significant fraction of the large-scale MSS model differences observed in polar regions was shown to originate in different ocean variability corrections or altimeter cross-calibration methods in different MSS models (Pujol et al., 2018).

Andersen, O. B., and Knudsen, P.: DNSC08 mean sea surface and mean dynamic topography models, J. Geophys. Res.-Oceans, 114(C11), 327-343, https://doi.org/10.1029/2008JC005179, 2009.

Jin, T., Li, J., Jiang, W: The global mean sea surface model WHU2013, Geod. Geodyn., 7, 202-209, http://dx.doi.org/10.1016/j.geog.2016.04.006, 2016.

Pujol, M.-I., Schaeffer, P., Faugère, Y., Raynal, M., Dibarboure, G., and Picot, N.: Gauging the improvement of recent mean sea surface models: a new approach for identifying and quantifying their errors, J. Geophys. Res.-Oceans, 123(8), 5889-5911, https://doi.org/10.1029/2017JC013503, 2018.

Schaeffer, P., Faugére, Y., Legeais, J. F., Ollivier, A., Guinle, T., and Picot, N.: The CNES_CLS11 global mean sea surface computed from 16 Years of satellite altimeter data, Mar. Geod., 35, 3-19, https://doi.org/10.1080/01490419.2012.718231, 2012.

Technical corrections:

1. Line 22-23: ‘sea level contains a variety of variation information about time scale.’ should be rephrased.

Response: Thanks. We have corrected the expression. Please refer to Line 22–23 for details in the revised MS.

2. Line 36-37: ‘are published’ ---> were published

Response: Thanks. It has been addressed in the revised MS.

3. Line 214: ‘decimeter magnitude to centimeter magnitude RMS’

Response: Thanks. We have corrected the expression. Please refer to Line 213–214 for details in the revised MS.

4. Line 232: delete ‘since’

Response: Thanks. It has been addressed in the revised MS.

5. Line 242: 106m should be -106m.

Response: Thanks. It has been addressed in the revised MS.

6. Line 378: ‘that’ ---> those

Response: Thanks. It has been addressed in the revised MS.