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EOT20: Improvements made to ocean tide estimations from coastal altimetry

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Motivation

Although the estimation of ocean tides in data-constrained models are rather reliable in the open ocean region, issues remain in the coastal region. This largely stems from the land-contamination of satellite altimetry returns as well as poorly resolved topography and the complexity of tides in this region. In order to address this, special attention was placed on the coastal region during the development of the EOT20 ocean tide model. The EOT20 model is the latest in a series of empirical ocean tide (EOT) models that are developed at DGFI-TUM. EOT20 conducts residual tidal analysis of 11 satellite altimetry datasets ranging from 1992 (ERS-1c) to 2018 (Jason-3). It takes advantage of recent advances in coastal altimetry, particularly the ALES retracker (Passaro et al., 2018) and the use of the FES2014 (Lyard et al., 2021) model as a reference tide model, allowing for more reliable sea-level anomaly (SLA) data closer to the coast. The aim of this product is to serve as ocean tide correction which will help with the appropriate removal of tidal signals in studies of the coastal sea-level from satellite altimetry.

The Satellite Altimetry Data

The tidal analysis is based on the analysis of SLA derived from satellite altimetry missions (Table 1) obtained from the Open Altimeter Database (OpenADB, https://openadb.dgfi.tum.de). These missions are selected as they provide extended time series along similar altimetry tracks, with the Jason missions being a follow-on from TOPEX/Poseidon and Envisat a follow-on of the ERS missions, thus providing appropriate data for the estimation of tidal signals. The SLA from these altimetry missions is calculated using a list of the geophysical corrections presented in Table 2 of Hart-Davis et al., (2021).

***Table 1**. The satellite altimeter data used in this study obtained from OpenADB at DGFI-TUM (Schwatke et al., 2014). Most missions are retracked using the ALES retracker (Passaro et al., 2018), marked by *, with TOPEX and ERS using ocean ranges as provided in SGDR datasets.*

Mission	Cycles	Period
TOPEX	001 - 365	1992/09/25 - 2002/08/15
TOPEX Extended Mission	368 - 481	2002/09/16 - 2005/10/08
Jason-1 *	001 - 259	2002/01/15 - 2009/01/26
Jason-1 Extended Mission *	262 - 374	2009/02/10 - 2012/03/03
Jason-2 *	000 - 296	2008/07/04 - 2016/07/25
Jason-2 Extended Mission *	305 - 327	2016/10/13 - 2017/05/17
Jason-3 *	001 - 071	2016/02/12 - 2018/01/21
ERS-1c	082 - 101	1992/03/25 - 1993/12/24
ERS-1g	144 - 156	1995/03/24 - 1996/06/02
ERS-2	000 - 085	1995/05/14 - 2003/07/02
Envisat *	006 - 094	2002/05/14 - 2010/11/26

The EOT20 Model

From the SLA, residual tidal analysis is performed using weighted least-squares and the variance component estimation (VCE) for each grid point of the model. The least-squares approach is applied to the harmonic formula to derive the amplitudes and phases of single tidal constituents from the SLA observations. EOT20 presents global estimations of 17 tidal constituents with these tidal atlases being available from https://doi.org/10.17882/79489 (Hart-Davis et al., 2021). An example of the M2 tidal constituent is presented in Figure 1.

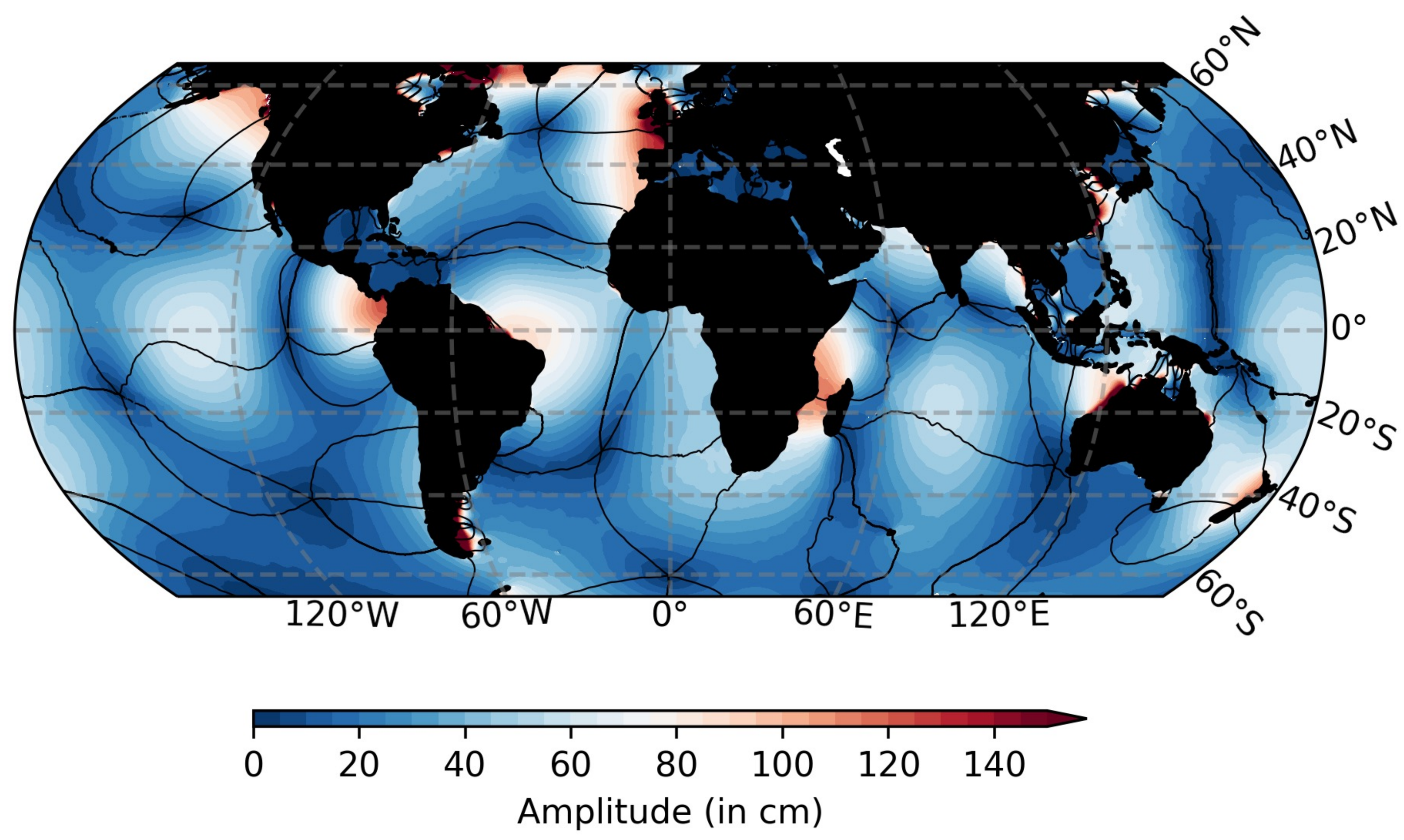

***Figure 1.** The amplitude (in cm) and the phase-lag (in 60 degree increments) of the M2 tidal constituents produced by the EOT20 model.*

Validation

Tide Gauge Analysis

Tide gauges are a valuable source of validation of the performances of ocean tide models, particularly in the coastal regions. Here, tide gauges are used to evaluate the performance of the EOT20 model. Additionally, several popular global tide models are also presented to provide a reference to the performance. The root-square-sum (RSS) was estimated for all the tide gauges for the eight major tidal constituents (Figure 2) following the approach presented in Stammer et al., (2014). In the coastal region, EOT20 shows a significant improvement compared to tide gauges relative to the predecessor (EOT11a). Furthermore, relative to other major tide models, EOT20 shows encouraging performances with an average reduction in RSS of 0.2 cm in the coastal region to next best model, FES2014.

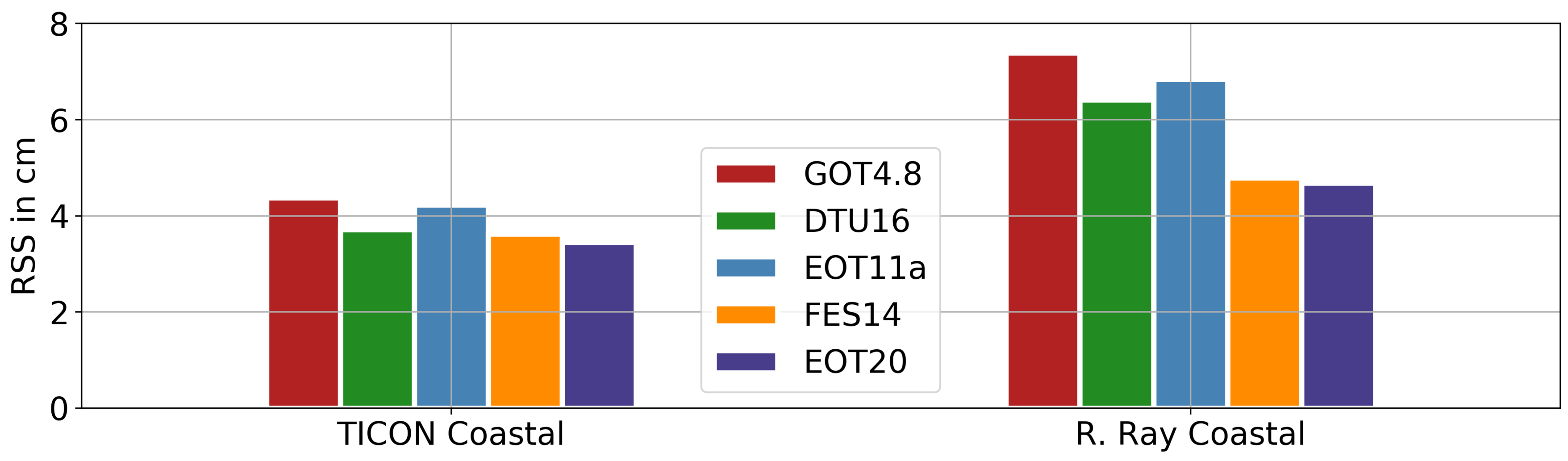

***Figure 2.** RSS (cm) between the tide gauge databases and the global tidal models, for the eight major tidal constituents in the coastal region. Data was taken form the TICON dataset (Piccioni et al 2018) and the Richard Ray dataset (Stammer et al., 2014). The full analysis for the global ocean is presented in Hart-Davis et al., (2021).*

Gridded Sea-Level Variance Analysis

In order to test EOT20's use in the altimetry correction, gridded sea-level variance analysis was conducted. This approach gridded the data as a function of distance to coast in order to provide a perspective of the model's performance as we approach the coastline. The results compared to EOT11a and FES2014 for the Jason-2 altimetry (Figure 3) shows the largest reduction in the variances in the near coastal region, with the variance differences converging as distance to coast increases. Overall, EOT20 showed an overall mean variance reduction of 0.054 cm^2 and 0.026 cm^2 when compared to EOT11a and FES2014, respectively.

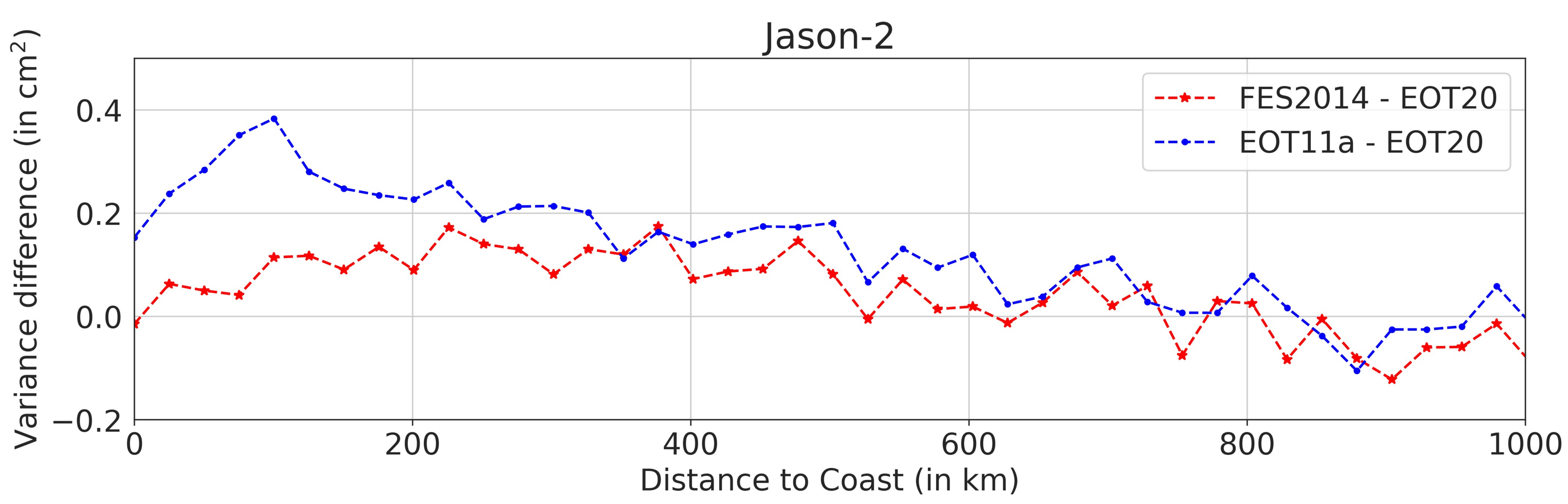

***Figure 3.** A line graph showing the mean SLA variance differences between the tide models as a function of distance to coast (in km) for the Jason-2 altimetry mission.*

Conclusions and Looking Ahead

The results of the validation of the model in the coastal region, suggest that the model would serve as a strong candidate for a tidal correction for satellite altimetry. Through the validation of the model as well as subsequent discussions with the greater tidal community, several avenues have been identified for improvements to be made to EOT in the near future.

A clear next step of the EOT model, is to extend the model into the higher latitudes. Here, further developments of the altimetry and model processing as well as the inclusion of additional altimetry missions such as Sentinel-3a / 3b and Cryosat-2, will be vital in optimising the estimation of ocean tides in this region.

References and Acknowledgements:

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- Hart-Davis, M., Piccioni, G., Dettmering, D., Schwatke, C., Passaro, M., and Seitz, F.: EOT20 – A global Empirical Ocean Tide model from multi-mission satellite altimetry, SEANOE [data set], https://doi.org/10.17882/79489, 2021.
- Hart-Davis, M. G., Piccioni, G., Dettmering, D., Schwatke, C., Passaro, M., and Seitz, F.: EOT20: a global ocean tide model from multi-mission satellite altimetry, Earth Syst. Sci. Data, 13, 3869–3884, https://doi.org/10.5194/essd-13-3869-2021, 2021.
- Lyard, F. H., Allain, D. J., Cancet, M., Carrère, L., and Picot, N.: FES2014 global ocean tide atlas: design and performance, Ocean Sci., 17, 615–649, https://doi.org/10.5194/os-17- 615-2021, 2021.
- Passaro, M., Nadzir, Z. A., and Quartly, G. D.: Improving the precision of sea level data from satellite altimetry with high-frequency and regional sea state bias corrections, Remote Sens. Environ., 218, 245–254, 2018.
- Piccioni, G., Dettmering, D., Bosch, W. and Seitz, F., 2019. TICON: TIdal CONstants based on GESLA sea-level records from globally located tide gauges. Geoscience Data Journal, 6(2), pp.97-104.
- Schwatke, C., Dettmering, D., Bosch, W., Göttl, F., and Boergens, E.: OpenADB: An Open Altimeter Database providing high quality altimeter data and products, in: Ocean Surface Topography Science Team Meeting, Lake Constance, Germany, 7–31 October 2014.
- Stammer, D., Ray, R., Andersen, O. B. and others. Accuracy assessment of global barotropic ocean tide models, Rev. Geophys., 52, 243–282, 2014.