Deutsches Geodätisches Forschungsinstitut
Technische Universität München
(DGFI-TUM)

Analysis of global ocean tide models in critical areas with focus on EOT19 preliminary model

Gaia Piccioni, Denise Dettmering, Florian Seitz

Introduction

In open ocean the accuracy of tide models is considerably higher than in shallow-water, coastal and polar regions. The DGFI-TUM is working on an updated version of the Empirical Ocean Tide (EOT) model whose focus is to improve the accuracy of tidal estimation at the coast. EOT is a gridded, semi-empirical model that exploits altimetric observations to compute residual tidal harmonic constants from sea level anomaly values. In this work we compare global state-of-the-art tide models to identify the regions with most critical differences and errors, and characterize the uncertainties of the single models or model types. In this analysis a preliminary version of the Empirical Ocean Tide (EOT19p) model is also included. Part of this work is performed in the frame of the DFG project "Improved TIdal Dynamics and Uncertainty estimation for Satellite gravimetry (TIDUS)", whose focus is to assess realistic errors of ocean tidal constituents and to develop strategies for achieving regional improvements of ocean tides in critical regions in order to improve global gravity field solutions.

Tide models involved in this analysis: EOT11a, EOT19p (regional), FES2014, GOT4.8, HAM11a, OSU12v1.1, DTU10, TPXO8.

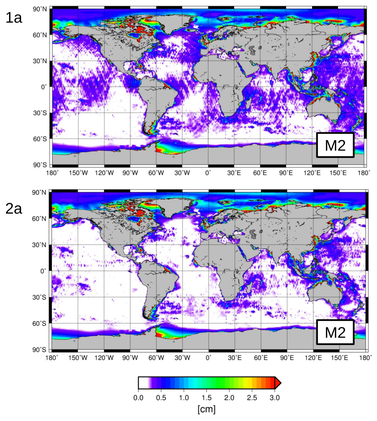
Tidal constituents analyzed: M2, N2, S2, K2, K1, O1, P1, Q1.

Differences among modern models

The standard deviation as proposed by [1] (St14) was used to compare the differences among the models. In Figures 1a and 1b the map of the standard deviations among the models is shown for constituents M2 and K1 respectively.

- The highest discrepancies (>1.5 cm) are found in shelf seas, coastal and polar areas.
- Patterns in open ocean (0.3-0.5 cm) suggest that single models may contain artefacts due to altimetry. Specifically: OSU12v1.1, and DTU10 for M2 constituent. As example, Figures 2a and 2b show the standard deviation of the models is computed without OSU12v1.1.

1a 1b



2a 2b

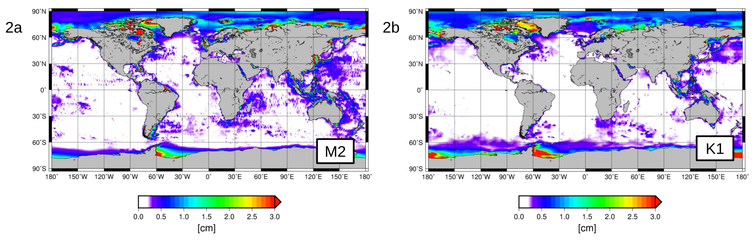


Figure 1: standard deviation from the seven global modern tide models for constituents M2 (1a) and K1 (1b).
Figure 2: standard deviation from the global modern tide models (without OSU12) for constituents M2 (2a) and K1 (2b).

Performance against tide gauge data

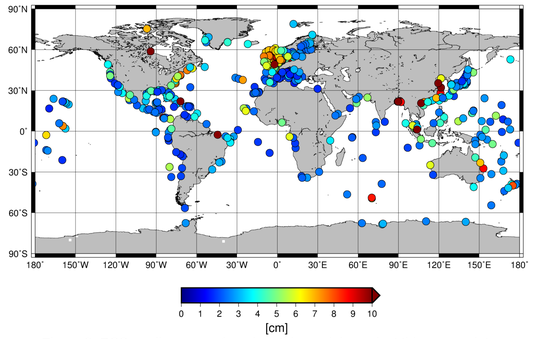


Figure 3: RSS median error of modern tide models against tide gauge data. The markers are located at tide gauge sites.

Where models show higher disagreement, there are also larger errors against in situ data, especially e.g. close to river deltas or at shelf seas. The median of the root-sum square (RSS) error for all modern tide models against tidal constants of in situ data is shown in Figure 3. RSS values come from RMS errors of single constituents. In situ tidal constants are taken from DGFI-TUM's TIdal CONstants database (TICON) and shelf-sea data used in St14.

Processing strategy of EOT19p model

Sea Level Anomalies (SLA)

Altimetry observations are selected within 165 km from one grid node. SLA are derived using coastal products*:

- ALES retracker [2]
- FES2014 tide model [3]
- GPD+ wet troposphere model [4]
- DTU18 mean sea surface [5]

* Available according to mission

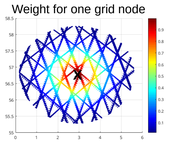
→

Gaussian Weights

Applied on SLA and dependent on distance to node ψ and half-weight width τ:

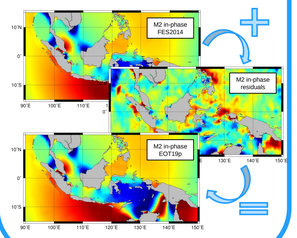
$$w = e^{-\frac{log2}{\tau^2}\psi^2}$$

Weight for one grid node



→ **Weighted Least Squares** →

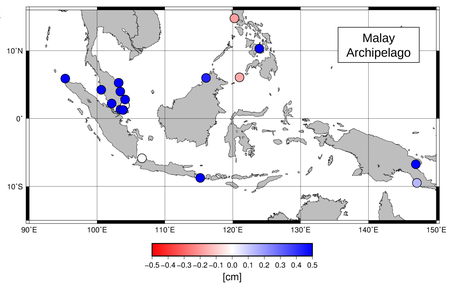
Combination of residuals with FES2014



Regional assessment of EOT19p: RSS comparison with modern tide models against in situ data

The markers represent the location of in situ data, and the color the difference between the median RSS error of all modern models and the RSS error of EOT19p. Lower RSS error (blue markers) of EOT19p with respect to models' median values, however, this is not always the case in shallow waters:

4a



4b

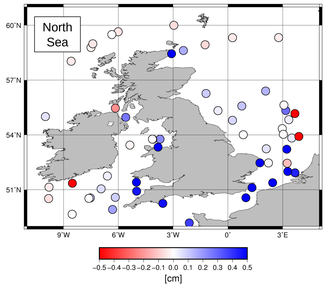


Figure 4: comparison of EOT19p RSS error with median RSS of modern tide models in Malay Archipelago (4a) and North Sea (4b). The markers are located at in situ stations. Blue markers show improvements for EOT19p.

Coastal in situ data

TICON (under review): **https://doi.pangaea.de/10.1594/PANGAEA.896587**
GESLA (TICON source): **https://gesla.org/**

Regional assessment of EOT19p: MAD comparison

The median absolute differences (MAD) computed for all models against in situ data for Malay Archipelago (Table 1) and North Sea (Table 2) respectively.

- EOT19p performs similarly to its basic model (FES2014) in both areas.
- General improvement with respect to EOT11a, especially for M2 and S2 in Malay Archipelago and M2, K2, K1, and O1 in the North Sea.

	EOT11a	EOT19p	FES2014	TPXO8	DTU10	GOT4.8	HAM11a	OSU12
M2	2.40	1.66	2.92	12.38	2.26	3.12	4.35	3.26
N2	0.83	0.62	0.53	2.88	1.15	1.54	1.27	1.79
S2	2.15	1.13	0.93	6.85	2.12	2.30	4.35	2.72
K2	0.80	0.46	0.38	2.91	1.04	1.16	1.32	1.49
K1	1.43	1.55	1.59	12.09	1.39	1.00	1.14	1.72
O1	1.03	0.59	0.87	10.50	1.62	1.71	1.26	2.61
P1	0.73	0.67	0.53	3.75	1.49	0.90	1.96	0.80
Q1	0.28	0.41	0.25	1.42	0.48	0.36	0.37	1.25
RSS	3.93	2.83	3.67	22.13	4.36	4.86	6.93	5.95

Table 1: MAD between tide models and in situ data located in Malay Archipelago.

	EOT11a	EOT19p	FES2014	TPXO8	DTU10	GOT4.8	HAM11a	OSU12
M2	3.40	2.59	2.98	3.29	2.46	5.01	3.20	4.10
N2	1.13	0.88	1.00	1.60	1.42	1.79	1.57	1.72
S2	1.81	1.39	1.32	1.44	1.46	2.42	3.26	4.19
K2	3.90	1.80	1.86	4.16	3.65	4.36	4.87	4.85
K1	3.15	1.68	2.05	5.89	2.62	3.25	3.16	4.37
O1	2.22	1.48	1.66	2.51	1.97	2.85	2.27	2.79
P1	0.92	0.76	0.72	1.59	0.80	1.07	1.47	1.30
Q1	1.12	0.96	0.98	1.35	1.18	1.11	1.05	1.89
RSS	6.94	4.38	4.85	8.84	6.02	8.61	8.09	9.64

Table 2: MAD between tide models and in situ data located in the North Sea.

Because of the use of specific coastal products for EOT19p, the highest differences between EOT19 and EOT11a are at the coast, especially in areas limited by land on both sides, such as the English Channel or between islands.

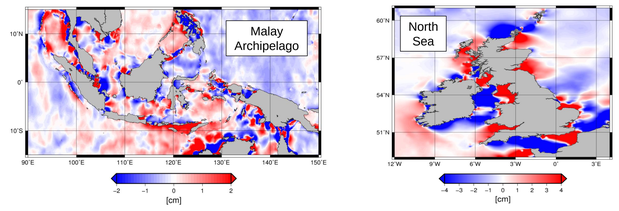


Figure 5: pairwise difference between EOT11a and EOT19p in Malay Archipelago (5a) and North Sea (5b).

Conclusions & Outlook

- Patterns due to altimetry can be detected in tide models.
- Largest disagreements with in situ data often coincide with areas with largest uncertainties among models.
- EOT19p shows promising coastal results, and in line with the latest tide models.
- Improvements of EOT19p against EOT11a can reach the centimeter for single constituents.
- More efforts are needed to improve EOT19p in shallow waters.

Acknowledgements

We thank Prof. Fok, Shum, and Stammer for kindly providing information about the models used in this work. Thanks to Dr. Ray for providing shelf sea data.

References

[1] Stammer et al. (2014) doi: 10.1002/2014RG000450.
[2] Passaro et al. (2015) doi: 10.1016/j.rse.2014.02.008
[3] Carrère et al. (2016) meetingorganizer.copernicus.org/EGU2015/EGU2015-5481-1.pdf
[4] Fernandes and Lázaro (2016) doi: 10.3390/rs8100851
[5] Andersen et al. (2018) doi: ftp.space.dtu.dk/pub/DTU18/PRESENTATIONS/DTU18MSS-V2.pdf

European Geosciences Union (EGU) General Assembly 2019 | 7 – 12 April 2019 Vienna, Austria

Contact: gaia.piccioni@tum.de