Towards further improving DTU global ocean tide model in shallow waters and Polar Seas

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Introduction

Accurate global ocean tide model is fundamental and vital for tidal correction in satellite altimetry and gravimetry measurements to reduce the contamination of aliased tidal noise on the remaining non-tidal signals of interests, e.g., storm surges. Remarkable progress has been achieved in improving the accuracy of global ocean tide models. Stammer et al. (2014) comprehensively assessed state-of-the-art global ocean tide models (GOT4.8, OSU12, DTU10, EOT11A, HAMTIDE12, FES2012 and TPXO8) using improved global bottom pressure data in deep water, coastal tide gauges, satellite altimetry along-track data, Gravity Recovery and Climate Experiment (GRACE), various geodetic data on Antarctic ice shelves, and independent tracked satellite orbit perturbations. The global ocean tide model inter-comparisons demonstrate that DTU10 shows the lowest Root Mean Square (RSS) over the Arctic and FES2012 and TPXO8 perform best in shelf regions.

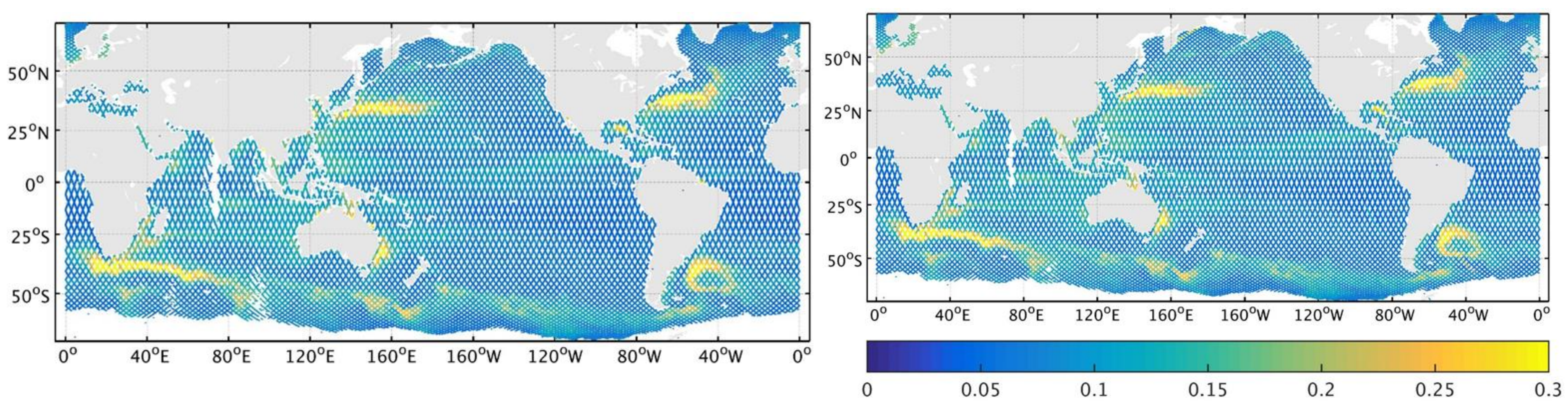
DTU10 tide model has been use to provide open boundary conditions for coastal tide models in China Sea, correct altimetric measurements for data assimilation in storm surge model over the North and Baltic Sea, calculate global Lowest Astronomical Tide and implemented to OpenSeamap, which is fundamental for ocean navigation and distributed via Apple Application store (http://www.openseamap.org/). Furthermore, the model has been adopted in DHI (Danish Hydraulic Institute) MIKE model and could be wider used in oceanography, hydrology, e.g., providing open boundary conditions for modeling ocean currents in the northern Adriatic Sea.

Model	Type[a]	Resolution
Modern data-constrained models		
GOT4.8	E	1/2°
OSU12	E	1/4°
DTU10	E	1/8°
EOT11a	E	1/8°
HAM12	H	1/8°
FES12	H	1/16°
TPXO8	H	1/30°

Motivated by the widely applications of the empirical global ocean tide model DTU10 to the real world, particularly in shallow waters and Arctic Ocean, an updated model DTU16 representing all major diurnal and semidiurnal tidal constituents was developed based on FES2012 model with residual tides calculated using response analysis method.

Data and Method

- The data were taken from the RADS (Radar Altimeter Database System).
- FES2012 for the tidal correction, FES2004 loading tide for altimetry data loading tide correction.
- European Center for Medium range Weather Forecasting (ECMWF) model is selected for wet tropospheric correction (Ray, 2013).
- ERA-interim model is used for dry atmospheric correction, which improves the sea level estimations for short temporal signals.
- DTU13 means surface model.



The distribution of standard deviation (STD) of sea level anomaly from combined TOPEX, Jason-1/2 primary (left) and tandem missions (right). The coherent STD patterns illustrate the high quality of the tandem missions for residual tide estimation.

To develop the DTU16 global ocean tide model, the along track residual tides are estimated refer to FES2012 using the response analysis method. Then the cosine and sine coefficients are subsequently interpolated onto the FES2012 grid (1/16°×1/16°) using the dynamic interpolation method. The method takes the tidal wavelength for diurnal and semidiurnal waves into account as well as the water depth, which is taken from DTU10 bathymetry model.

Compared with the altimetric data used in DTU10, two more years of Jason-1 tandem mission and five more years of Jason-2 mission data (e.g., more than 23 years combined Topex-Jason-1/2 data since 1993) are available. Six years of Jason-1 tandem mission data enable to separate M2 from S2 tide constituent regarding the alias period of three years between the constituents. In the Arctic Ocean, AltiKa data were used, which has the same repeat cycle of 35 days as Envisat. Furthermore, the ERS-1 data were used to improve the model in high latitudes.

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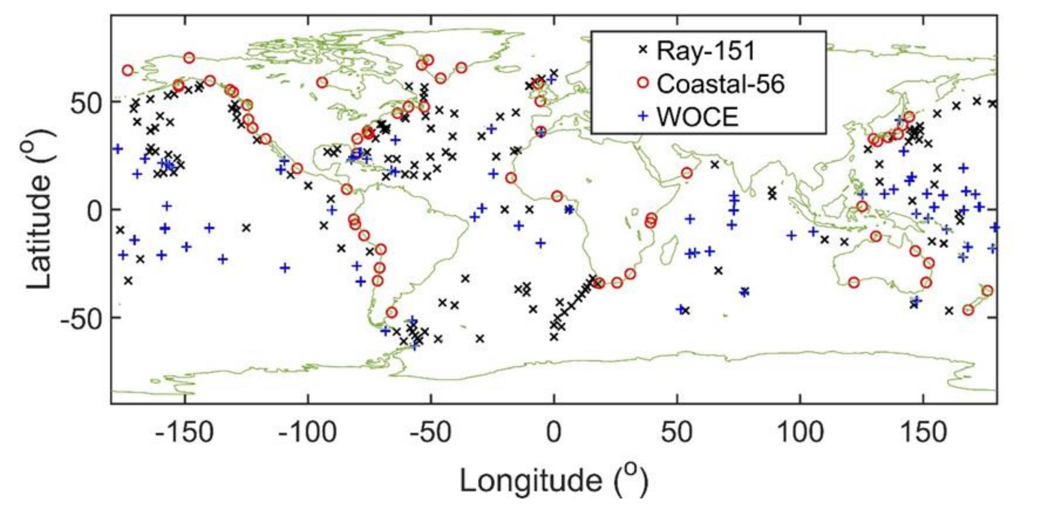
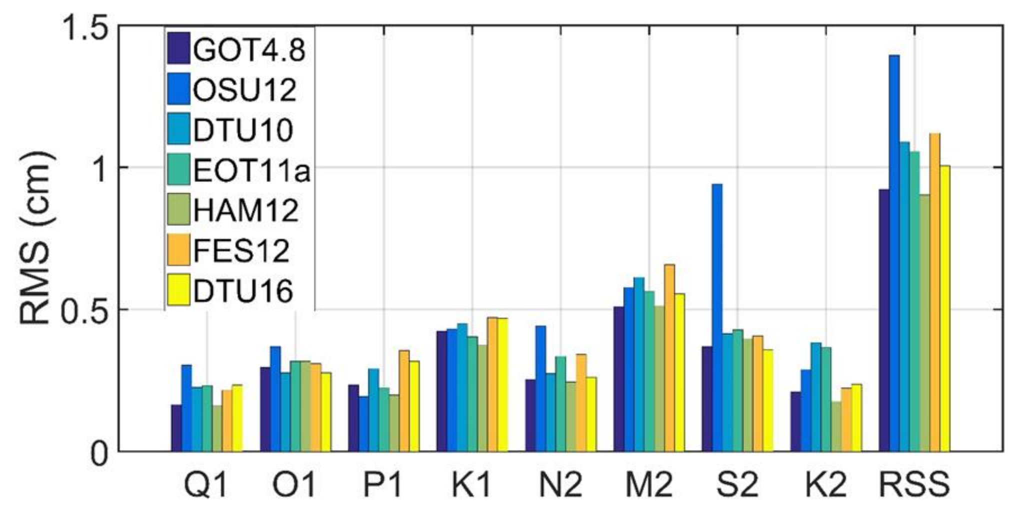
Reference: Cheng, Y., and O. B. Andersen (2011), Multimission empirical ocean tide modeling for shallow waters and polar seas, Journal of Geophysical Research, 116(C11), doi:10.1029/2011jc007172. Stammer, D., R. Ray, O. B. Andersen, B. Arbic, W. Bosch, L. Carrère, Y. Cheng, D. Chinn, B. Dushaw, and G. Egbert (2014), Accuracy assessment of global barotropic ocean tide models, Reviews of Geophysics, 52(3), 243-282. Ray (2013), Precise comparisons of bottom-pressure and altimetric ocean tides, Journal of Geophysical Research: Oceans, 118(9), 4570-4584, doi:10.1002/jgrc.20336.

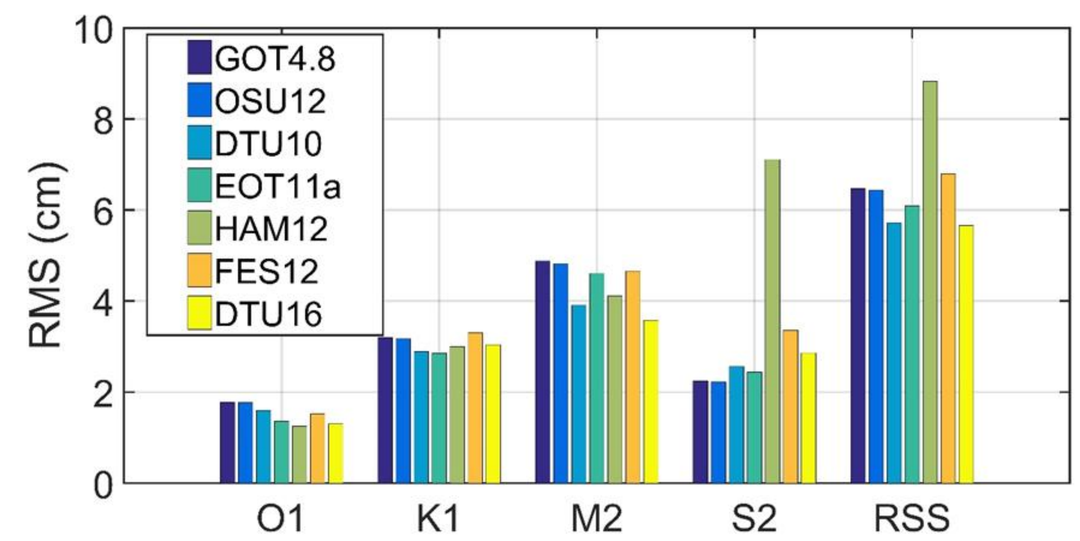
Results

Locations of remaining WOCE, Ray-151 and Coastal-56 sites. The Deep-Ocean Bottom Pressure Records Ray-151 are mainly located in Pacific and Atlantic Ocean. More than half of the coastal tide gauges located along the American coasts. The remaining WOCE sites distributed evenly between 40°S and 40°N in the Ocean basins.

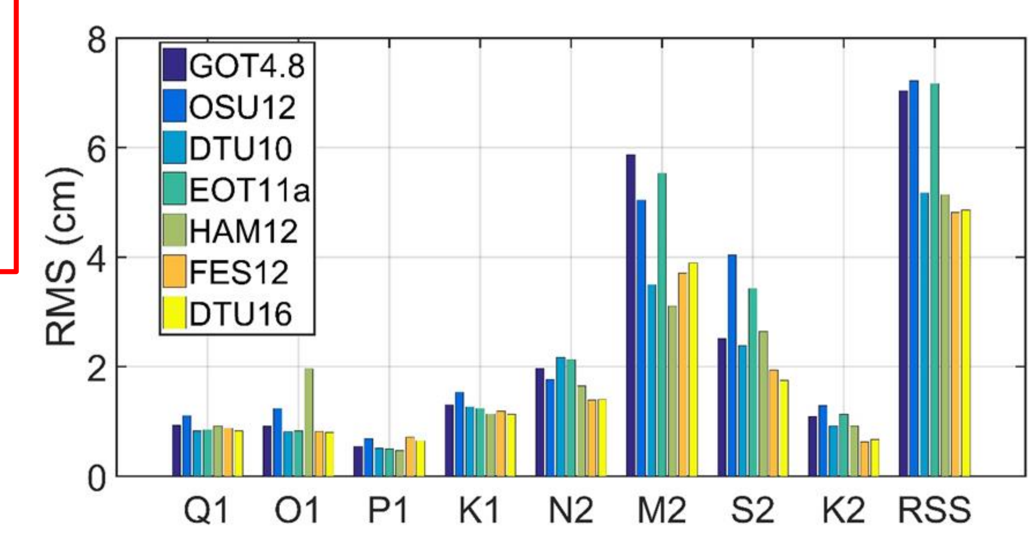




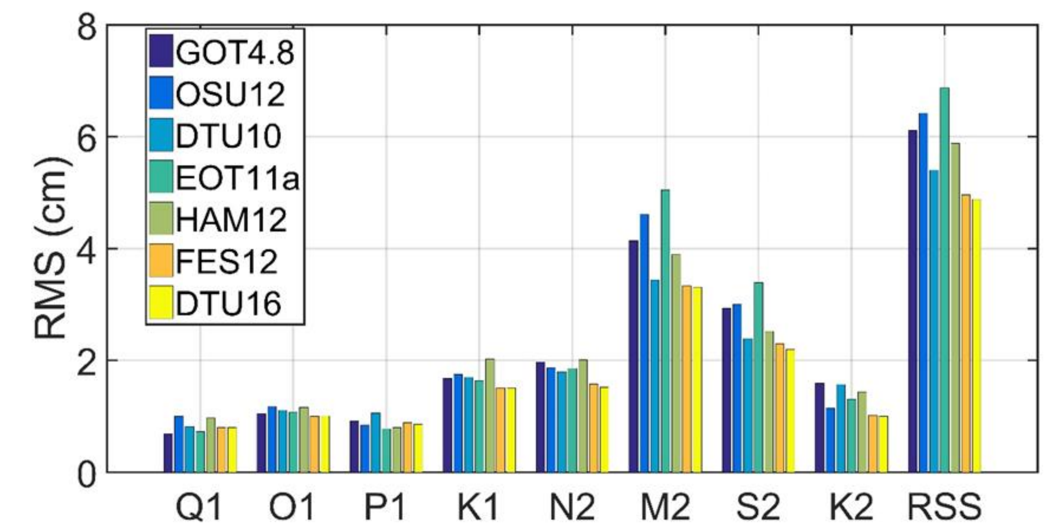
Comparisons of new model against tide gauges in deep waters (Ray-151).



Arctic Ocean.



Shelf Water Tide Stations on European Shelf.



Shelf Water Tide Stations (119) except on European Shelf.

	DTU16	FES2012	EOT11a	GOT4.8	GOT4.10c	HAMTIDE12x	OSU12
M2	**10.79**	11.16	20.83	13.35	13.36	12.71	12.84
S2	**6.39**	6.70	10.75	8.66	8.58	7.45	8.13
K1	**3.10**	3.12	5.88	4.48	4.53	5.07	4.23
O1	**2.97**	3.00	3.94	3.80	3.82	3.73	3.98
RSS	**13.25**	13.71	24.49	16.97	16.95	16.02	16.27

Comparison of the models against tide gauge data set in the East Asian Marginal Seas (205). The bold values show the lowest RMS or RSS in the inter-compared models (cm).

	DTU16	FES2012	EOT11a	GOT4.8	GOT4.10c	HAMTIDE12x	OSU12
M2	2.74	2.72	**2.66**	2.84	2.89	2.79	2.95
S2	1.36	1.32	1.38	1.36	1.33	**1.28**	1.73
K1	1.23	1.27	1.28	1.22	1.20	**1.12**	1.47
O1	0.90	0.89	1.01	1.01	1.01	**0.88**	1.16
RSS	3.42	3.40	3.41	3.52	3.55	**3.38**	3.90

Comparison of the models against WOCE tide gauge data set (117) with the coastal tide gauges (coastal-56) removed.

Summary:

Take the advantages of FES model development and the techniques in develop the DTU10 model, we proposed a new DTU16 global ocean tide model with higher spatial resolution, which based on the FES2012 with residual tides determined using the response analysis. The new added altimetry data for model development includes ERS-1, AltiKa in the parallel outside ±66°, and more Jason-1 tandem and Jason-2 data. In particular, the ERA-interim data was used for dry atmospheric correction to account for a small error caused by the S2 atmospheric tide in the T/P dry tropospheric correction.