Ocean tide loading displacement modelling: Accuracy assessment

Nigel T. Penna[1], Machiel S. Bos[2], Trevor F. Baker[3] and Hans-Georg Scherneck[4]

[1] School of Civil Engineering and Geosciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK
[2] CIIMAR, Rua dos Bragas 289, University of Porto, 4050 – 123 Porto, Portugal
[3] Proudman Oceanographic Laboratory, 6 Brownlow Street, Liverpool, L3 5DA, UK
[4] Chalmers University of Technology, Department of Radio and Space Science, SE-412-96 Göteborg, Sweden, E-mail hgs@chalmers.se

Extended abstract

Different convolution methods used in the computation of ocean tide loading (OTL) displacement values are employed in the different software packages developed, which include CARGA (Bos and Baker, 2005), OLFG/OLMPP (Scherneck, 1991), SPOTL (Agnew, 1997) and GOTIC2 (Matsumoto et al, 2001). Their accuracy and suitability was assessed by us and detailed in Penna et al (2008), with this abstract providing a précis of the main findings of that paper. An extensive comparison of the usually dominant M2 OTL height displacement values was undertaken, firstly for a global distribution of 387 IGS sites, and also for a 0.125° grid across north-west Europe, that encompassed complicated coastlines and shallow seas, where ocean tide modelling is difficult. The values were computed using the CARGA, OLFG/OLMPP and SPOTL softwares with a range of recent ocean tide models, namely GOT00.2 (Ray, 1999), FES99 (Lefèvre et al, 2002), NAO.99b (Matsumoto et al, 2000) and FES2004 (Lyard et al, 2006), which encompassed different resolution regular grids (0.5º for GOT00.2 and NAO.99b, 0.25° for FES99 and 0.125° for FES2004). Furthermore, GOT00.2 and FES99 are the models recommended in the IERS 2003 conventions (McCarthy and Petit, 2004), and FES2004 is one of the two models recommended in their unratified updates. The OLFG/OLMPP software considered is particularly relevant since it drives the 'OTL web provider' (http://www.oso.chalmers.se/~loading/) recommended for OTL displacement computation in the IERS 2003 conventions and their unratified updates, and has therefore been used in many geodetic and geophysical studies.

Convolution method errors have traditionally been considered to have a much smaller contribution to the OTL displacement error budget (2-5% according to Bos and Baker (2005) and Agnew (1997), based on studies of inland gravity sites) than ocean tide model errors. To improve the convolution scheme, loading grids are refined and interpolated from the global model to fit the coastline, especially near an observing site. Penna et al (2008) summarised the different grid refinement methods employed by CARGA, OLFG/OLMPP and SPOTL, and, for the version of OLFG/OLMPP available since August 2007, demonstrated that excellent agreement arises between all three softwares for both the globally distributed IGS sites (only considered FES99 and FES2004 ocean tide models) and the north-west Europe grid (considered all four ocean tide models). Vector differences of M2 OTL height displacements between the three softwares for all four ocean tide models were invariably at the millimetre level or less for coastal sites, and less than 0.2 mm for sites more than ~150 km inland.

Before August 2007, for sites within ~150 km of the coastline, in addition to refining the ocean tide model grid by interpolation, the OLFG/OLMPP software employed a further requirement whereby local water mass redistribution (MRD) was undertaken to ensure constant water mass within the area of refinement (Scherneck, 1991). The MRD procedure was intended to improve the coastline of purely hydrodynamic models, since by construction their mass is conserved, and change of area near a coast is anticipated to have only a secondary effect on the oscillation systems in the basins.

Due to an unfortunate flag setting, MRD was applied to all models, not only the purely hydrodynamic ones, and this resulted in pre-August 2007 M2 OTL height displacement vector differences between OLFG/OLMPP and both CARGA and SPOTL of up to 20% for coastal sites when using the FES99 or NAO.99b model, as reported by Penna et al (2008). With the finer resolution FES2004 model, the impact of MRD was negligible. The inappropriateness of MRD for the FES99, NAO.99b and GOT00.2 ocean tide models was confirmed by (ibid) from GPS observations, which also confirmed the equivalence and accuracy of OTL displacement values computed using any of CARGA, SPOTL and OLFG/OLMPP (August 2007 onwards). Following the work described in (ibid), the 'OTL web provider' was changed in August 2007 to remove the MRD option.

The factors contributing to the usually sub-millimetre differences exhibited between the OTL displacements obtained from CARGA, OLFG/OLMPP (August 2007 onwards) and SPOTL were considered by Penna et al (2008). Changing from the PREM Green's function (Francis and Mazzega, 1990) used by CARGA to the Gutenberg-Bullen Green's function (Farrell, 1972) used by OLFG/OLMPP led to changes in displacement of ~0.25 mm near coasts and less than 0.1 mm inland i.e. an agreement of 2-5%. Differences arise of about 2 mm around Antarctic since the coastlines of OLFG/OLMPP, taken from the GMT package (Wessel and Smith, 1998) follow along floating sections of the ice shelves, whereas CARGA employs a strictly land-sea dividing coastline. Other variations arise due to using different values for sea water density, affecting the displacements by up to 0.3 mm for sites where the M2 OTL displacement reaches up to around 30 mm. An impact of grid definition of the ocean tide models was found: a systematic difference of the loading effects between one group of grids that balance the fractions of land and sea, respectively, that intrude into the opposite-flagged grid cells, and ocean tide model grids that on average prefer to include coastal land in sea-flagged cells (the opposite has no representative). Finally, other causes of the differences can be attributed to the three softwares not using identical interpolation schemes: CARGA and SPOTL use bilinear, whereas OLFG/OLMPP uses parabolic (in contrast to what Penna et al. (2008) state).

It was confirmed by Penna et al (2008) that ocean tide model errors still contribute the largest portion of the OTL displacement error budget, by comparing M2 OTL height displacements computed using the CARGA software and each of the CSR4.0 (Eanes and Bettadpur, 1996), FES99, FES2004, GOT00.2, NAO.99b and TPXO6.2 (Egbert and Erofeeva, 2002) ocean tide models. The same 387 IGS sites considered for the software global comparisons were considered, and the RMS vector differences from the six-model mean were computed. Whilst at most of the inland sites, RMS agreements were less than 0.4 mm, at some coastal sites, differences exceeded 3 mm, and exceeded 1 mm at 25 sites. There was no one model which was found to be consistently discrepant, suggesting that at present there is not a single ocean tide model that performs the best globally.

Whilst Penna et al (2008) only considered OTL displacement, the community of tide gravity researchers in tidal gravimetry is encouraged to utilise the gravity option of the OTL web provider. Loading effects for gravity are computed equivalently to radial displacement with respect of sub-gridding for coastal stations. Farrell's gravity Green's function can be convolved over each of the 18 global ocean models currently installed. The attraction effect at topographic height is included. However, we caution that the sub-gridding and refinement to the GMT full-resolution coastline at stations within 1 km of the coast or with viewing angles to the coast of more than 5º sub-horizontal, may incur limitations in precision. We look forward to a cooperative effort in a systematic evaluation.

References

Agnew DC (1997) NLOADF: A program for computing ocean-tide loading. J Geophys Res 102(B3):5109-5110

Bos MS, Baker TF (2005) An estimate of the errors in gravity ocean tide loading computations. J Geod 79(13):50-63

Eanes RJ, Bettadpur S (1996) The CSR3.0 Global Ocean Tide Model: Diurnal and Semi-Diurnal Ocean Tides from TOPEX/POSEIDON Altimetry. CSR-TM-9605 The University of Texas Center for Space Research

Egbert GD, Erofeeva SY (2002) Efficient inverse modeling of barotropic ocean tides. J Atm Oceano Tech 19(2):183-204

Farrell WE (1972) Deformation of the Earth by surface loads. Rev Geophys Space Phys 10(3):761--797

Francis O, Mazzega P (1990) Global charts of ocean tide loading effects. J Geophys Res 95(C7):11411-11424

Lefèvre F, Lyard FH, Le Provost C, Schrama EJO (2002) FES99: A global tide finite element solutions assimilating tide gauge and altimetric information. J Atmos Ocean Technol, 19(9):1345-1356

Lyard F, Lefèvre F, Letellier T, Francis O (2006) Modelling the global ocean tides: Modern insights from FES2004. Ocean Dynam 56(5-6):394-415

Matsumoto K, Takanezawa T, Ooe M (2000) Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan. J Oceanogr 56:567581

Matsumoto K, Sato T, Takanezawa T, Ooe M (2001) GOTIC2: A program for computation of oceanic tidal loading effect. J Geod Soc Japan 47:243-248

McCarthy DD, Petit G (2004) IERS Conventions 2003. IERS Technical Note 32.

Penna NT, Bos MS, Baker TF, Scherneck, H-G (2008) Assessing the accuracy of predicted ocean tide loading displacement values. J Geod 82(12):893--907, doi:10.1007/s00190-008-0220-2.

Ray RD (1999) A global ocean tide model from TOPEX/POSEIDON altimetry: GOT99.2. NASA Tech Memo TM-209478, 58 pp

Scherneck H-G (1991) A parametrized solid earth tide model and ocean tide loading effects for global geodetic base-line measurements. Geophys J Int 106(3):677-694

Wessel P, Smith WHF (1998) New, improved versions of the Generic Mapping Tools released. Eos Trans AGU 79(47):579