Arc2kmTM: Arctic 2 km Tide Model

Summary

The Arctic 2 km Tide Model (Arc2kmTM) is a barotropic ocean tide model on a 2x2 km polar stereographic grid. The model domain is shown in Figure 1. Development of the model is explained in the Methods section, below. Note that Arc2kmTM is a "forward" (dynamics only) model; there is no data assimilation or nudging to measurements. Arc2kmTM consists of spatial grids of complex amplitude coefficients for sea surface height and depth-integrated currents ("volume transports") for 8 principal tidal constituents: 4 semidiurnal (M_2, S_2, K_2, N_2) and 4 diurnal (K_1, O_1, P_1, Q_1).

Model bathymetry is based on the 2014 30-arc-second General Bathymetric Chart of the Oceans (GEBCO_2014), with updates in three areas around Greenland (see Methods).

Arc2kmTM gridded files are provided in both binary and NetCDF format, and are designed to be used with the following open-source software packages: the MATLAB "Tide Model Driver" (TMD) toolbox, the Python "pyTMD" package, and the FORTRAN "OSU Tidal Prediction Software" (OTPS). These packages can be used to browse the model for different constituents, and to make tidal predictions of sea surface heights, volume transports and currents for any time at any location within the model domain.

NOTE: Please also check the ESR Polar Tide Model webpage and our Arctic Data Center Portal for other Arctic-region barotropic tide models and more information on software packages.

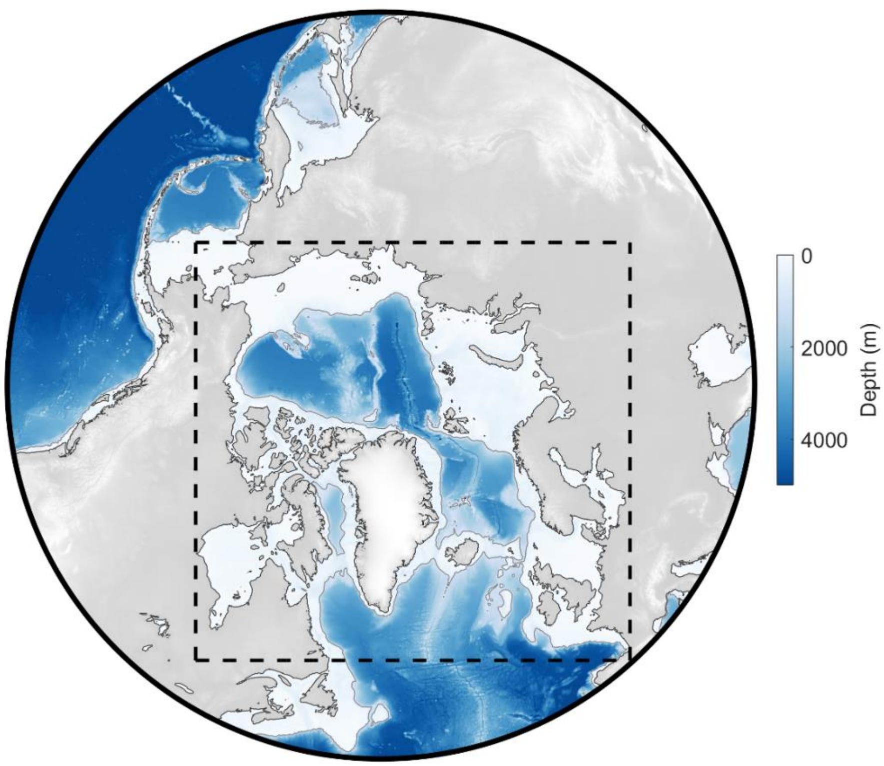

Figure 1: Domain for Arc2kmTM (dashed black line); grid is polar stereographic (standard latitude and longitude of 70ºN and 45ºW) with uniform spacing of 2 km. Color scale shows depth in meters.

Arc2kmTM: Model Summary

Build Date:	2021
Version Number:	1
Model type:	Forward (dynamics-based); barotropic (depth-integrated)
Grid:	2-km uniform polar stereographic (70°N, 45°W)
Constituents:	M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1
Units:	*h* (surface height; meters); *u,v* (currents; cm/s); *U,V* (transports; m^2/s)
Coordinates:	Currents and transports are in East (*u,U*) and North (*v,V*) components

FILES

Binary Model files

Files for use with TMD v2.5 and earlier, OTPS, and PyTMD

Model_Arc2kmTM_v1	Model control file, used by TMDv2.5 and OTPS to identify gridded bathymetry and constituent files
h_Arc2kmTM_v1	Complex amplitude coefficients for sea surface height
UV_Arc2kmTM_v1	Complex amplitude coefficients for volume transports
grid_Arc2kmTM_v1	Grid of bathymetry (water column thickness under ice shelves)
xy_ll_Arc2kmTM	File for converting between polar stereo native grid and lat, lon

NetCDF Model file

File for use with TMD3.0 and PyTMD

Arc2kmTM_v1.nc	Model file in NetCDF format

Documentation

Arc2kmTM_v1_README.pdf	(This file) Readme file for the Arc2kmTM model
Arc2kmTM_FileFormat_binary.pdf	Document describing format of files included in the binary model package
Arc2kmTM_FileFormat_NetCDF.pdf	Document describing format of NetCDF model file

Contact Susan Howard (showard@esr.org) or Laurie Padman (padman@esr.org) for advice about the use of this model.

Methods

Arc2kmTM was developed using the Regional Ocean Modelling System (ROMS) version 3.7 (Haidvogel et al., 2000; Shchepetkin and McWilliams, 2005; Budgell, 2005) on a 2 km x 2 km polar stereographic grid of the Arctic Ocean and adjacent regions. ROMS is a hydrostatic, 3-D primitive equation numerical model that uses a terrain-following (sigma-level) coordinate system. For producing tidal coefficients for a barotropic model, we are interested in the depth-integrated solution. The model was forced at the open boundaries with depth-averaged tidal currents and elevation values from the TOPEX/Poseidon global barotropic tidal solution version 9.1 (TPXO9.1). We applied potential tides (equilibrium tides plus self-attraction and loading (SAL)) as forcing across the domain. The inclusion of the potential tides significantly improves the accuracy of the tidal solutions. Although ROMS can be run as a purely barotropic 2-D model, the inclusion of potential tides in the ROMS 3.7 version required that a baroclinic (depth-dependent) solution be calculated. Therefore, we ran our simulations with 5 levels and constant potential temperature and salinity (i.e., a homogeneous ocean), to mimic a barotropic model but to allow for inclusion of potential-tide forcing. Simulations were run separately for each tidal coefficient, analyzing the last 5 days of each 20-day simulation started from rest.

Model bathymetry is based on the 30-arc-second General Bathymetric Chart of the Oceans (GEBCO) grid GEBCO_2014, version 20150318 (http://www.gebco.net). This grid includes the International Bathymetric Chart of the Arctic Ocean (IBCAO), version 3.0 (www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html), described by Jakobsson et al. (2012). Based on more recent fieldwork, we revised the bathymetry for our model in three key regions around Greenland: Northeast Greenland, Petermann Fjord and the adjacent area of Nares Strait, and the Northwest Greenland coastal region. A high resolution (100 m) coastline file from J. Mouginot (Rignot and Mouginot, 2012) was used to define the Greenland land mask, with adjustments for the Petermann ice shelf. Other ice shelves in Greenland are not included in Arc2kmTM but are included in our Greenland 1 km Tide Model (Gr1kmTM) .

Validation

The model was validated using tide height amplitude and phase coefficients from coastal and benthic tide gauge records within the model domain, extracted from the Hart-Davis et al. (2023, 2024) dataset.

Known Issues

- For tide heights, this model provides ocean tide only; i.e., sea surface height change relative to the seabed. Some applications will require adjustment for seabed deformation ("ocean tide loading"). Users require a separate ocean load tide model for this calculation.
- Bathymetry in some areas is poorly constrained by data. For barotropic currents, we recommend that the user calculates depth-integrated volume transport, then divides by the latest depth data to get depth-averaged currents.
- The tide model grid is polar stereographic. The binary files do not contain (lat,lon) grid information. To convert from (x,y) to (lat,lon) and vice versa, MATLAB TMD 2.5 users must use the xy_ll_Arc2kmTM.m script provided in this download. For OTPS and pyTMD, use available code with standard latitude and longitude of 70°N, 45°W. The NetCDF model file provides both (x,y) and

(lat,lon) coordinates, along with the projection information. TMD 3.0 includes the scripts needed to convert between coordinate systems.

- A new feature of the NetCDF model file is that U and V coefficients (depth-integrated transports) are now centered on the H nodes and provided in one file. The binary files remain in their original Arakawa C-grid structure, and provided as separate U/V, H, and grid files.

File Formats

Binary Model Files

The files are written as FORTRAN binary sequential files, formatted to match the Oregon State Tidal Inversion Software (OTIS) format. These files can be easily accessed using ESR's MATLAB "Tide Model Driver" (TMD) v2.5 toolbox (https://github.com/EarthAndSpaceResearch/TMD_Matlab_Toolbox_v2.5), the community Python-based pyTMD software (https://github.com/tsutterley/pyTMD), and OSU's FORTRAN "OSU Tidal Prediction Software" (OTPS) (https://www.tpxo.net/otps). For full details of the binary file format, please refer to Arc2kmTM_FileFormat_Binary.pdf included in the model download.

NetCDF Model File

The NetCDF model file is in the consolidated NetCDF format for global and regional tide models, introduced in 2023. Please refer to Arc2kmTM_FileFormat_NetCDF.pdf included in the model download. More information on this new format can also be found at: https://github.com/chadagreene/Tide-Model-Driver/blob/main/doc/TMD_model_file_format.md. This file can be used with the TMD 3.0 toolbox (https://github.com/chadagreene/Tide-Model-Driver) and the pyTMD software (https://github.com/tsutterley/pyTMD).

Related Links

Arctic Tides Portal at ADC:	https://arcticdata.io/catalog/portals/ArcticTides/
ESR Polar Tide Models:	https://www.esr.org/research/polar-tide-models/
OSU Tidal Prediction Software (OTPS):	https://www.tpxo.net/otps
pyTMD package:	https://github.com/tsutterley/pyTMD
TMD 2.5 MATLAB Toolbox v2.5:	https://github.com/EarthAndSpaceResearch/TMD_Matlab_Toolbox_v2.5
TMD 3.0 MATLAB Toolbox:	https://github.com/chadagreene/Tide-Model-Driver

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