Tracing Antarctic Sediment Provenance User Guide

Welcome to the TASP user guide! If you have any questions regarding any of the information in this document, please contact Jim Marschalek at jwm17@ic.ac.uk.

TASP uses the output from an ice sheet model to estimate subglacial erosion and predict the ε_{Nd} values of detritus at the ice sheet margin. It is structured into a few MATLAB functions:

callprov.m first defines the run name (used in output file names) and ensures the correct paths and directories are set. It then sets all the user-defined variables and options.

prov.m reads in files and variables and calls the other functions.

terrestrial_part.m performs the terrestrial (i.e. sub-ice) parts of the calculations.

surf_currents.m estimates detritus transport in surface currents as an iceberg rafted debris proxy.

bot_currents.m estimates bottom current transport of detritus. If the algorithm were adjusted to use a sand-sized provenance indicator, this could be neglected.

grav_flows.m uses bathymetry (from the ice sheet model) to route submarine gravity flows.

modern_analysis.m if using a modern ice sheet simulation, this performs some analyses, makes plots and a file storing the best fitting method to observations across the domain.

mappingplotter.m is a short function to plot data nicely using the MATLAB mapping toolbox.

streamline_merger.m is an (optional) function which merges the flow paths of multiple months of surface velocity data into a single .png file to check realistic flow paths are achieved.

As well as these new functions, TASP requires the MATLAB mapping toolbox and utilises functions written by other users including makeColorMap (Light and Bartlein, 2004), inpaint_nans (D'Errico, 2023), polarstereo_fwd (Bliss, 2023), freezeColors (Iversen, 2023), IDW (Fatichi, 2023) and several functions from Antarctic Mapping Tools (Greene et al., 2017).

Variables

The following variables are defined by the user in callprov.m. Options are turned on by setting the value to 1, or turned off by setting it to 0..

General Options:

- **W** - The number of workers in the parfor loop.
- **tuning** – an option to reduce log output if tuning variables.
- **shelfmelt** – an option to set ocean velocities to ice flow velocities to simulate sub-ice shelf melt.
- **biasWAIS** – an option for when the WAIS is absent, as it proved useful to bias erosion rates in this sector (65^{o}W to 180^{o}) to obtain higher resolution results here.
- **undershelf** – an option to track provenance under ice shelves.
- **remshelf** – an option to remove ice shelves from the provenance estimate. Principally for use when the existence/extent of ice shelves is uncertain (e.g. Last Glacial Maximum).

- **invdistweight** - an option to use inverse distance weighting interpolation from the ice sheet margin instead of marine tracing methods to estimate marine provenance. The distance weight and number of neighbours used are set in prov.m.
- **plot_figs** - option to plot and save figures.
- **nc1** - ice sheet model netCDF file name.
- **model** - for reading outputs from different ice sheet models. Currently configured for PSUICE3D (= 1) and PISM (= 2). The PISM configuration sought to use the output of Golledge et al. (2021), who only saved the velocity magnitude and no basal shear stress, requiring the use of the differential of the velocity as a proxy for ice flow directions and an additional NetCDF 'taud-correction-factor.nc' containing the basal shear output separately (Golledge, pers. comm.).
- **paleo** - sets if the ice sheet model run is modern (= 0) or palaeo (= 1).
- **forcebergs** – in some palaeo simulations, flow in the Wilkes Subglacial Basin is unrealistic. This option forces ocean trajectories in a small area to follow modern ice velocities.
- **method_file** – if using a palaeo ice sheet simulation, this selects which debris transport mechanism to use in which locations. If 'palaeo' option is set to 0 (i.e. the modern ice sheet is used), a new file is written.
- **t** – the selected ice sheet model timeslice.
- **site** – sets the location of a core site of interest.
- **sed_mod** – option to set how the erosion rate is calculated. Currently can use the squared ice velocity (= 0) or the product of basal shear stress and velocity. The latter can either be pre-calculated in the model (= 1), or calculated if each variable is provided separately (= 2).
- **hgrams** – an option to make histogram plots.
- **surf_months** – the number of surface current months used (324 recommended).
- **bot_months** – the number of bottom current months used (24 recommended).
- **rep** - specifies how many time bottom current and gravity flow methods are iterated. (2 recommended).
- **radius3** – the exclusion zone around active volcanoes in km. (200 recommended).

<u>Terrestrial Component Variables</u>

- **seedmeth** – specifies the method used to seed ice flowlines, either randomly (= 0) or based on an erosion rate threshold (= 1).
- **s_points** - the number of streamline seed locations used if seedmeth = 0. 32000 is the default.
- **seedscale -** if seedmeth = 0, this increases the terrestrial seed number (s_points) by the factor specified to reduce the effect of random sampling. The number of flowlines is reduced back to s_points for the surface current component.
- **q_thresh -** Erosion rate threshold for seed locations (mm/kyr). Only used if seedmeth = 1. 0.1 is the recommended default.
- **kval** - the value of the quarrying coefficient. 0 uses spatially variable from Pollard and DeConto (2019), otherwise the value set here specifies a uniform value. This does not impact results, but 5.1E-10 is used following Pollard and DeConto (2019).

<u>Surface Current Component Variables</u>

- **vweighting** – option to weight ice vs ocean velocities where no ocean velocity data.
- **sed_dist** – selects the type of distribution of basal sediment, either linear (= 1), exponential (= 2) or constant (= 3).

- **ocean_T** – offset on the observed modern sea surface temperatures (ºC)
- **basalsed** – the thickness of the basal sediment layer in m. 4 recommended.
- **decay** – the decay constant used if using an exponential decay of debris (5 default).
- **plateau** – the minimum 'englacial' sediment yield, relative to base of ice column. 1E-5 is recommended.
- **smth** – an option to smooth the output, specifying the moving average window size. This is sometimes useful for a palaeo ice sheet.
- **radius4** – interpolation distance around the surface velocity flowlines in km. 40 is recommended.
- **surf_simp** – an option to reduce the number of streamline calculations by combining repeated streamlines. This rounds start location to the nearest cell, which impacts results, but results in a far faster run time and reduces memory use.
- **mrg** – when using a smaller-than-present ice sheet, this is the interval over which to blend the palaeo and modern ocean velocity data. 3 recommended.
- **mrg2** – to achieve realistic movement of icebergs away from the calving line, ice and ocean velocities are blended over this interval. 2 recommended.

Bottom Current Component Variables

- **erosionv** – the ocean velocity to erode sediment in m/s. 0.15 recommended.
- **c0** – the starting sediment concentration, which is relative so 1 is recommended.
- **kappa** – the von Kármán constant, 0.41.
- **z0** – the roughness length in m. 5E-4 is recommended.
- **vs** – the settling velocity in m/s. 3.3E-5 is recommended.
- **susph** – the suspended sediment thickness in m. 15 is recommended.
- **rho** - seawater density in kg/m^3. 1025 is recommended.
- **t0** – the critical depositional stress in Pa. 0.08 is recommended.
- **radius2** – the radius around bottom current flow paths in km. 40 recommended.

Gravity Flow Component Variables

- **shelfmin** – the minimum depth of the shelf break in m, below which gravity flow paths are interpolated everywhere. We recommend -1200 as this avoids interpolation in most overdeepened areas whilst missing very few sites on the upper continental slope.
- **slopethresh** – the slope threshold above which gravity flows occur, in degrees. 1 is recommended.
- **radius5** – the radius around the gravity flow paths (km). Reflects the limit of maximum travel for gravity flows. 300 km default.

Variables Used for Analysis of Results

- **grouping** – bin width for ocean depths in result analyses (m). 10 is recommended.
- **Ea** – used to set the eastward limit of the domain, which has to be constrained as data are only compiled for West Antarctica. 135 degrees is recommended, unless the geological Nd isotope compilation were to be extended.
- **We** – used to set the westward limit of the domain. -62 degrees currently recommended.
- **radius** – radius to mask the maximum distance from seafloor surface sediment data in the spatial analysis (km). 200 is recommended.

Required Files

To run, the TASP needs various input files. Firstly, it requires a NetCDF **ice sheet model output.** An example file "ISM_Modern_DeConto.fort.92.nc" is provided (DeConto et al., 2021). This must contain ice velocities with directional components, basal shear stress magnitude, bed elevation, ice thickness, a grounded ice mask and spatial coordinates. If you are using the option 'shelfmelt', which assumes sub-ice shelf melting, for a palaeo ice sheet run, you will also need a melt rate estimate.

TASP is currently set up to use output from PSUICE3D, with compatibility with PISM outputs in development. To adapt the method for other ice sheet model outputs, editing of the first ~100 lines of prov.m would be required.

Files created for TASP are:

- **A map of ε_{Nd} beneath the ice sheet** as a .tif file – "merge7_krg.tif". This is a georeferenced tiff file with the coordinates manually input in prov.m based on the geodata output from the MATLAB readgeoraster function.
- **A compilation of seafloor surface sediment ε_{Nd} data** as an .xls file – "Coretop_Data_9.xls". This is structured into columns with latitudes, longitudes and the ε_{Nd} values. The example file also contains an additional column with the reference used, but this is not read by TASP.
- **An interpolated map of offshore ε_{Nd} values** created using the compilation of seafloor surface sediment data. – "surf_krg2.tif". Again, this is a georeferenced .tif file. Although an interpolation could be performed within the script, an external interpolation is preferred as it is quicker and allows for more advanced interpolation techniques (i.e. kriging).
- **A file containing the position of active volcanos**, used to highlight and exclude data points in plots and statistics if they are likely to be influenced by volcanic material – "Active_Volcanos.xlsx". This file consists of a name column (not read) and latitude and longitude columns.

The algorithm uses the following ORAS5 ocean reanalysis product files (DOI: 10.24381/cds.67e8eeb7):

- **Ocean surface velocity data.** The example file uses data from January 1993 to December 2019. Using entire years of data is recommended to avoid seasonal biases.
- **Sea surface temperature data** for the same months.
- **Ocean velocity data for all depths**. These are required to extract the lowermost depth, used to route bottom currents. Two files, each containing a year of data are used – tests with additional years showed negligible impact on results.

Finally, TASP also needs other published datasets:

- **PLIOMIP2 ocean velocities**, accessed from: https://www.cesm.ucar.edu/experiments/cesm1.1/PlioMIP2/. As these files are very large, we opt to strip these data to only south of 60°S. These data are stored in UVELcomb.mat and VVELcomb.mat, with the latitude and longitude data stored in Pliomip2_ULATLONG_extracted.nc. These stripped files can be provided on request. Note these data are only required if applying TASP to a smaller-than-present palaeo ice sheet simulation.
- **Melt rates beneath ice shelves** as a .h5 file (Adusumilli et al., 2020). Note this is only read if using the 'shelfmelt' option.

Execution

To execute the example, follow these steps:

1. First ensure all the input files and functions are present and accessible in the directories specified in callprov.m.
2. Set the run name and output path at the beginning of callprov.m.
3. Ensure all the variables are correctly specified in callprov.m.
4. Execute callprov.m either locally via the MATLAB GUI or using a shell script (an example can be provided on request). If using a HPC system, when requesting resources note that using the recommended settings is quite memory intensive - ~8 GB per node.

If using a palaeo ice sheet configuration, ensure the option ‘palaeo’ is set to 1, and that the correct modern ice sheet calibration file (‘method_file’) is input.

References

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