Data-assimilating ocean thorium cycle model output associated with results paper Xu & Weber, 2025

Website: https://www.bco-dmo.org/dataset/982197
Data Type: model results
Version: 1
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Project
» Collaborative research: Combining models and observations to constrain the marine iron cycle (Fe Cycle Models and Observations)

Contributors	Affiliation	Role
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Abstract
Here we present output from the data-assimilating ocean thorium cycle model published by Xu and Weber (2025) in Global Biogeochemical Cycles (https://doi.org/10.1029/2024GB008485). The model predicts the oceanic distributions of thorium-230 and thorium-232 by simulating inputs from radiogenic sources and lithogenic sources (dust and sediment dissolution), and internal cycling by scavenging onto a range of particle types. The model assimilates data from the GEOTRACES IDP2021 archive to optimize uncertain parameters. Full code for the model and all input fields needed to run it can be accessed at the Zenodo repository (https://doi.org/10.5281/zenodo.10139433). This file contains the 3-dimensional thorium-230 and 232 fields from the fully-optimized model and the two-dimensional source fields for thorium-232 inputs to the ocean from dust and sediments. A matlab code is also provided to read the model output and plot the model thorium-232 budget to replicate a figure from Xu and Weber (2025).

Table of Contents

Coverage

Location: Global ocean (output from a stead-state global ocean model - grid information is provided)

Methods & Sampling

A model of the ocean thorium-230 and 232 cycle was developed in the MATLAB programming language, using the Ocean Circulation Inverse Model v2 (Devries & Holzer, 2019 - https://doi.org/10.1029/2018JC014716) to resolve physical transport. The model resolves radiogenic and lithogenic sources of the thorium isotopes, and internal cycle due to scavenging onto biogenic, lithogenic, and hydrothermally-sourced particles. Discrete Sample Data from the GEOTRACES IDP2021v2 are assimilated to optimize uncertain parameters. The model is fully described and all equations are provided in Xu and Weber 2025 (https://doi.org/10.1029/2024GB008485) and the full model code and inputs are available for download at the Zenodo repository (https://doi.org/10.5281/zenodo.10139433).

Data Processing Description

Codes developed to run the model and process output are available for download at the Zenodo repository (https://doi.org/10.5281/zenodo.10139433). The model was developed and run on the University of Rochester BlueHive computing cluster.

Geolocation is the global ocean (output from a steady-state global ocean model - grid information is provided).

Parameter names for Xu_2025_model_output.nc file:

Grid information
x: Longitude of grid cell centers in degrees East of Prime meridian
y: Latitude of grid cell centers in degrees North of Equator
z: Depth of the grid cell (m)
M3d: Land/ocean masks (1 = ocean, 0 = land)
MSKS.ATL: Atlantic Ocean Mask (1 = Atlantic, otherwise 0)
MSKS.PAC: Pacific Ocean Mask (1 = Pacific, otherwise 0)
MSKS.IND: Indian Ocean Mask (1 = Indian Ocean, otherwise 0)
MSKS.SOUTH: Southern Ocean Mask (1 = Southern Ocean, otherwise 0)
VOL: Volume of each grid cell (m3)

Model output
Jdep: Depth-integrated soluble 232Th dust deposition source flux (mmol/m2/yr), stored as a two dimensional field.
Jdep3D: Full three-dimensional 232Th source field from dust deposition (mmol/m3/yr).
Jsed: Depth-integrated soluble 232Th sediment dissolution source flux (mmol/m2/yr), stored as a two dimensional field.
Jsed3D: Full three-dimensional 232Th source field from sediment dissolution (mmol/m3/yr).
Th232: Dissolved 232Th concentration distribution (pM) from our best-fitting model.
Th230: Dissolved 230Th concentration distribution (pM) from our best-fitting model.

BCO-DMO Processing Description

* Header information was extracted from Xu_2025_model_output.nc and added to the file comment so parameters in the file are clearer in the metadata and are searchable.

* Xu_2025_model_output.nc attached as the primary data file
* plotting code plot_Th232_budget.m attached as a supplemental file.

[table of contents | back to top]

Data Files

File	
Thorium isotope model output filename: Xu_2025_model_output.nc	(NetCDF, 30.33 MB) MD5:b8df1d33238d4729d245ef26fee618ed

Model-predicted distribution and sources of thorium-230 and 232, with geographic grid information. See the "Data Processing" section for more details.

netcdf header information:

```
{
dimensions:
        latitude = 91 ;
        longitude = 180 ;
        depth = 24 ;
variables:
        double Th232(depth, longitude, latitude) ;
        double Th230(depth, longitude, latitude) ;
        double Jsed(longitude, latitude) ;
        double Jdep(longitude, latitude) ;
        double Jsed3D(depth, longitude, latitude) ;
        double Jdep3D(depth, longitude, latitude) ;
        double M3d(depth, longitude, latitude) ;
        double y(latitude) ;
        double x(longitude) ;
        double z(depth) ;
        double MSKS.ATL(depth, longitude, latitude) ;
        double MSKS.PAC(depth, longitude, latitude) ;
        double MSKS.IND(depth, longitude, latitude) ;
        double MSKS.SOUTH(depth, longitude, latitude) ;
        double VOL(depth, longitude, latitude) ;
}
```

[table of contents | back to top]

Supplemental Files

File	
Plotting code filename: plot_Th232_budget.m	(MATLAB Programming Script (.m), 2.35 KB) MD5:b0d1141bb71293df4eb13e442607aad3

Plotting code (Matlab m-file) to read model output file and plot thorium-232 budget.

[table of contents | back to top]

Related Publications

DeVries, T., & Holzer, M. (2019). Radiocarbon and Helium Isotope Constraints on Deep Ocean Ventilation and Mantle‐3He Sources. Journal of Geophysical Research: Oceans, 124(5), 3036–3057. Portico. https://doi.org/10.1029/2018jc014716 https://doi.org/10.1029/2018JC014716
Methods

Xu, H., & Weber, T. (2025). Quantifying Lithogenic Inputs to the Ocean From the GEOTRACES Thorium Transects in a Data‐Assimilation Model. Global Biogeochemical Cycles, 39(6). Portico. https://doi.org/10.1029/2024gb008485 https://doi.org/10.1029/2024GB008485
Results

[table of contents | back to top]

Related Datasets

Software

Xu, H., & Weber, T. (2023). Ocean thorium 230 and 232 model. Zenodo. https://doi.org/10.5281/ZENODO.10139433 https://doi.org/10.5281/zenodo.10139433

[table of contents | back to top]

Parameters

Parameters for this dataset have not yet been identified

[table of contents | back to top]

Project Information

Collaborative research: Combining models and observations to constrain the marine iron cycle (Fe Cycle Models and Observations)

NSF Award Abstract:
Tiny marine organisms called phytoplankton play a critical role in Earth's climate, by absorbing carbon dioxide from the atmosphere. In order to grow, these phytoplankton require nutrients that are dissolved in seawater. One of the rarest and most important of these nutrients is iron. Even though it is a critical life-sustaining nutrient, oceanographers still do not know much about how iron gets into the ocean, or how it is removed from seawater. In the past few years, scientists have made many thousands of measurements of the amount of dissolved iron in seawater, in environments ranging from the deep sea, to the Arctic, to the tropical oceans. They found that the amount of iron in seawater varies dramatically from place to place. Can this data tell us about how iron gets into the ocean, and how it is ultimately removed? Yes. In this project, scientists working on making measurements of iron in seawater will come together with scientists who are working on computer models of iron inputs and removal in the ocean. The goal is to work together to create a program that allows our computer models to "learn" from the data, much like an Artificial Intelligence program. This program will develop a "best estimate" of where and how much iron is coming into the ocean, how long it stays in the ocean, and ultimately how it gets removed. This will lead to a better understanding of how climate change will impact the delivery of iron to the ocean, and how phytoplankton will respond to climate change. With better climate models, society can make more informed decisions about how to respond to climate change. The study will also benefit a future generation of scientists, by training graduate students in a unique collaboration between scientists making seawater measurements, and those using computer models to interpret those measurements. Finally, the project aims to increase the participation of minority and low-income students in STEM (Science, Technology, Engineering, and Mathematics) research, through targeted outreach programs.

Iron (Fe) is an important micronutrient for marine phytoplankton that limits primary productivity over much of the ocean; however, the major fluxes in the marine Fe cycle remain poorly quantified. Ocean models that attempt to synthesize our understanding of Fe biogeochemistry predict widely different Fe inputs to the ocean, and are often unable to capture first-order features of the Fe distribution. The proposed work aims to resolve these problems using data assimilation (inverse) methods to "teach" the widely used Biogeochemical Elemental Cycling (BEC) model how to better represent Fe sources, sinks, and cycling processes. This will be achieved by implementing BEC in the efficient Ocean Circulation Inverse Model and expanding it to simulate the cycling of additional tracers that constrain unique aspects of the Fe cycle, including aluminum, thorium, helium and Fe isotopes. In this framework, the inverse model can rapidly explore alternative representations of Fe-cycling processes, guided by new high-quality observations made possible in large part by the GEOTRACES program. The work will be the most concerted effort to date to synthesize these rich datasets into a realistic and mechanistic model of the marine Fe cycle. In addition, it will lead to a stronger consensus on the magnitude of fluxes in the marine Fe budget, and their relative importance in controlling Fe limitation of marine ecosystems, which are areas of active debate. It will guide future observational efforts, by identifying factors that are still poorly constrained, or regions of the ocean where new data will dramatically reduce remaining uncertainties and allow new robust predictions of Fe cycling under future climate change scenarios to be made, ultimately improving climate change predictions. A broader impact of this work on the scientific community will be the development of a fast, portable, and flexible global model of trace element cycling, designed to allow non-modelers to test hypotheses and visualize the effects of different processes on trace metal distributions. The research will also support the training of graduate students, and outreach to low-income and minority students in local school districts.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1658042

[table of contents | back to top]