Working group proposal submitted to SCOR

DEveloping Repositories for carbon FLUX quantification:

Th-234 as a case study

DEPOFLUX

May 2022

Summary

The ^{234}Th-^{238}U radioactive pair has been extensively used to evaluate carbon fluxes in the upper ocean, the fluxes of other elements as well as other parameters such as the efficiency of the carbon exported from the surface ocean through the Biological Pump. Since the 70's, a large number vertical profiles of ^{234}Th have been collected using a variety of sampling instruments and analytical strategies that have changed along years.

An extensive global oceanic data set of ^{234}Th measurements, including all the ^{234}Th data in the published literature as well as non-published data up to 2019, was compiled by Ceballos-Romero et al. and published in open access in PANGAEA repository and discussed in Ceballos-Romero (2022) https://doi.pangaea.de/10.1594/PANGAEA.918125?format=html#download.

The amount of ^{234}Th data collected can be used to address key questions on carbon export on a basin or global scale. To achieve this, it requires us to have an extensive dataset that brings together all available observations in a robust, consistent and accessible manner. We aim to make the ^{234}Th dataset a growing data compilation, open to the participation and improvements by the whole thorium community, updated yearly and used in as many applications as possible, broadening its scope and including estimations of Particulate Organic Carbon (POC) export fluxes, among others. And most important, we would like to use this thorium repository as a seed to grow a wider repository of carbon flux estimates in the ocean.

This will be the first coordinated effort to generate a global, standardized, and comprehensive repository of all existing ^{234}Th data in the ocean. DEPOFLUX main goals are i) the creation of a web repository to host an updated compilation of ^{234}Th data and metadata, from the first ^{234}Th measurements, up to present and into the future. This repository would be user friendly, CQ checked, accessible, easy to upload/download, visible to the community and will serve as a focal point for the thorium community, modellers and flux evaluation experts ii) The development of the first approach to a forthcoming integrated harmonized repository of carbon flux results including variables, data and metadata from the different techniques that provide, direct or indirectly, measurements of the carbon flux in the ocean, such as sediment traps, particle imaging (e.g. underwater cameras) or gliders.

Scientific Background and Rationale

The Biological Carbon Pump (BCP) (Eppley and Peterson, 1979; Volk and Hoffert, 1985), is an important component of Earth's carbon cycle through the production of sinking particles that transport carbon to the dark ocean (deep ocean carbon storage) with gravitational settling of sinking particle being the primary pathway to reach these depths (Boyd et al., 2019). However, only a fraction of this carbon sinks into the dark ocean below 1000 m depth, where it can be stored for 100' to 1000 years (Siegel et al., 2021), contributing significantly to maintaining the air-sea balance of CO_2. Although it plays a major role in the global carbon cycle (Kwon et al., 2009), the current global estimates of the BCP storage vary up from 5 to >12 Pg C yr^{-1} (Boyd and Trull, 2007; Henson et al., 2022), these discrepancies need to be narrowed and uncertainties reduced, in order to get a higher precision in the quantification of the ocean's carbon cycle and to predict its influence on the future atmospheric CO_2 concentration. In order to predict ocean carbon storage, it is key to

quantify carbon downward flux and its attenuation in depth. To address the challenge of increasing the quantification accuracy of the BCP a wide variety of techniques covering different horizontal and vertical spatial scales and different temporal scales are used. ^{234}Th is among the techniques that cover relative long temporal scales (up to 2 months) in comparison to sediment traps (snapshot of few hours of days), while relative shallow vertical scales (from surface up to 500 m) in comparison to deep traps deployed below 1000 m.

For several decades, radioactive tracers have been used to gain a better understanding of different oceanographic processes. Radioisotopes are characterized by a unique property: their half-lives, which accounts for the time it takes for one-half of the atoms of a radioactive element to undergo radioactive decay and thus transformation to a different isotope. Half-lives are not affected by temperature, physical or chemical state, or any biological process. As a result, the concentration of naturally occurring radioactive elements varies over time at well-characterized decay and production rates. Observations of radioisotopes distributions in the water column, in time and space, provide valuable insights into the presence and rates of ocean processes on spatial scales from local to basin-wide and timescales of days to millenniums depending on the radioisotope employed. In the context of the BCP, radioactive pairs such as ^{234}Th-^{238}U, but also ^{210}Po-^{210}Pb, with a longer half-life (24.1 days for ^{234}Th versus 134 days for ^{210}Po), are extensively used to study the various physical, chemical or biological processes involved in the particle dynamics and flux attenuation in the oceans (Cochran and Masque, 2003).

Indeed, the naturally occurring radioisotope ^{234}Th has been commonly used to understand natural aquatic processes in four major areas: particle cycling, horizontal transport, sediment dynamics, and vertical transport (Waples et al., 2006). ^{234}Th has been collected using a variety of sampling procedures since its initial use by Bhat et al. (1969), where it was demonstrated that the activities of ^{234}Th were lower in high particle coastal waters, along a transect offshore in the Indian Ocean. ^{234}Th chemistry dictates that it is adsorbed onto particle surfaces and is thus effectively scavenged from the dissolved water phase. Hence, when biological activity is high, the abundance of largely organic detritus is large and ^{234}Th is sorbed and removed from the surface ocean and transported downward by the sinking particles, thereby generating a deficit relative to its soluble or "conservative" parent ^{238}U. This deficit can be used to calculate the downward flux of ^{234}Th. An excess in ^{234}Th activity – i.e., a daughter concentration higher than the parent one - is attributed to fragmentation processes that result in the conversion of sinking to non-sinking particles, generically termed "remineralization" (Maiti et al., 2010). Due to its short half-life of $T_{1/2}$ = 24.1 days and its particle reactivity in seawater it is suitable to trace processes occurring in the upper ocean on time scales from days to months (Rutgers van der Loeff et al., 2006).

Given these properties, ^{234}Th has been an indispensable tool in many oceanographic field expeditions. The most widespread application of the ^{234}Th approach is to estimate the gravitational settling of carbon as Particulate Organic Carbon (POC) out of the surface layer, which results in a downward flux of POC (see e.g., review by Le Moigne et al., 2013b and references therein). To that end, the carbon to ^{234}Th ratio on sinking particles (POC:^{234}Th) needs to be measured. To a lesser extent, this radioisotope is also used to estimate the downward flux of other elements to the deep ocean, such Particulate Inorganic Carbon (le Moigne et al., 2014; Wei et al., 2011), Biogenic Silica (e.g., Buesseler et al., 2005; Lemaitre et al., 2016; Le Moigne et al., 2013a), Particulate Organic Nitrogen

(PON) (e.g., Buesseler et al., 1992; Charette and Buesseler, 2000; Murray et al., 1996) or trace metals fluxes (e.g., Black et al., 2018; Lemaitre et al., 2016, 2020; Weinstein and Moran, 2005). ^{234}Th is a well stablished technique but has some limitations related to the way fluxes are interpreted to estimate carbon fluxes, such as e.g., the integration depth chosen to evaluate the carbon export (Rosengard et al., 2015) or the use of SS versus NSS (Ceballos-Romero et al., 2018).

Previous efforts compiling ^{234}Th-based data included ^{234}Th-derived POC fluxes (F A C Le Moigne et al., 2013b) and, more recently, POC:^{234}Th ratios (see (Puigcorbé et al., 2020) and doi.pangaea.de/10.1594/PANGAEA.911424) and a previous effort to obtain a global data set has been done by Le Gland et al. (2019).

Some of the members of this working group worked together to create the PANGAEA data base (https://doi.pangaea.de/10.1594/PANGAEA.918125?format=html#download) the most comprehensive global compilations of oceanic ^{234}Th data. An exhaustive list of ^{234}Th measurements in sea water and particles at every depth, location and time of sampling is included. A report of the results can be found in (Ceballos-Romero et al., 2022). It includes a total of 223 datasets: 214 from studies published either in articles in referred journals, 5 PhD thesis or found in other 4 data repositories, but also 9 unpublished datasets are also included. They represent over 5000 locations spanning all the oceans for total ^{234}Th profiles, dissolved and particulate ^{234}Th activity concentrations, and the POC:^{234}Th ratio. A total of 379 oceanographic expeditions and more than 56,600 ^{234}Th data points have been gathered into a single open-access compilation.

Why a SCOR working group?

There are several open access repositories available together with PANGAEA that provide professional expertise in data management, e.g., high curation level, generation of metadata, links to other projects and compilations and visibility. The Marine Radioactivity Information System (MARIS) is a specific repository for radionuclides, managed by the International Agency of Atomic Energy (IAEA) https://maris.iaea.org/home. The Biological and Chemical Oceanography Data Management Office (BCO-DMO), https://www.bco-dmo.org/, serves data and related information online from research projects funded by US NSF and other programs. The GEOTRACES intermediate data product allows to host data generated during GEOTRACES cruises, https://www.geotraces.org/ and PANGEA, https://www.pangaea.de/, serves as a general open data repository for Earth Science data.

As good as these repositories are to host general data from cruises, programs, or experiments, we believe that a different and specific repository is needed to host the already compiled ^{234}Th data, extensive metadata and ancillary parameters. A comprehensive, specific, and independent ^{234}Th data repository will have a large value providing research opportunities to all the BCP community if it is built in collaboration with worldwide thorium experts. Usability must be taken into account, not only to facilitate an easy uploading of the data, but also an easy download and visibility of the data. Determinant variables for the ^{234}Th collection and fluxes calculations must be included,

Based on the recent compilation by (Ceballos-Romero et al., 2022) using dataset there included as a starting point, we aim to work during this SCOR group to:

a) **Create and open access, dynamic, long-term, and usable web repository** that will:

– provide accessible and easy to find ^{234}Th data

– promote and include the future inputs and contributions of researchers and ^{234}Th data analyzers.

– serve as a coordinating umbrella, and in doing so, become a focal point for the ^{234}Th community interested in sharing their data in open access and downloading specific data sets, but also making these data available for use by modelers and biochemists specialized in ocean carbon cycle.

b) **Expand the compilation to generate the seed of a global unified repository of carbon fluxes**. Such forthcoming collection aim to include techniques proven to be successful in the indirect quantification of POC fluxes (such as particle imagine techniques) and techniques that directly measure POC fluxes (such as sediment traps). This is one of the most important reasons for the creation of DEPOFLUX and our effort will therefore be devoted to organizing and standardizing data, metadata and calculations of carbon fluxes collected from different approaches. Developing best practices to estimate carbon fluxes from the different techniques focusing on those that provide indirect measurements of the flux (e.g., radioactive pairs or particle imaging techniques). We will prepare a trial compilation with some initial data and carbon fluxes to generate first discussions and validations. This will be the starting point of a future integrated, harmonized global repository of carbon fluxes.

With DEPOFLUX, we aim to improve the present datasets uploaded in PANGAEA by different means: 1) QC of the next and already included data 2) determining what key ancillary data are needed to complement the results for additional applications of the ^{234}Th technique, 3) including new datasets collected, and 4) provide recommendations of how to collect the samples, analyze and store the data in order to accurately quantify downward carbon fluxes using ^{234}Th-^{238}U disequilibrium. Using this dataset it will be possible, for example to calculate global and temporal estimates of carbon fluxes

To broaden the scope of the ^{234}Th compilation, we aim to lay the foundations of a future integrated global compilation of carbon fluxes and the necessary variables to calculate them (e.g. fluxes derived from marine snow catcher, underwater cameras, sediment traps equipped with i) brine for direct measure of C fluxes and ii) polyacrylamide gels that preserve the morphological characteristics of marine particles as they enter the sediment trap collection cups, quantitative image analysis are obtained). Thus, we will design a single future compilation of file variables, metadata and flux results that will cover as many methodologies to evaluate carbon flux as possible. This is a most expected data base for the community since it could be used to, for example, reduce the uncertainties in the evaluation of the ocean carbon budgets, or to gain a predictive predictive knowledge of the relationships among NPP, carbon export and their fates.

DEPOFLUX will produce the structure of a forthcoming global dataset of carbon fluxes, including which are the necessary variables and how to calculate fluxes.

Overall, DEPOFLUX is a multidisciplinary group of experts that aim at contributing to a better quantification of carbon fluxes in the ocean and making advances towards a better understanding of how the contemporary oceanic carbon uptake functions and how it will change in future.

Terms of Reference (ToR)

1. To enhance the existing compilation of global ^{234}Th data collected during cruises keeping it up to date. It will include all the ^{234}Th data from the first measurements in 1960, to the most recent ones.

2. To improve the compilation and its usability. New measurement variables, ancillary data and additional metadata will be included, after a QC step, in subsequent datasets.

3. To develop a web repository specifically devoted to host the ^{234}Th compilation and make it accessible for all users.

4. To become a true and active focal point for the community. Addressing the best ways to reach our colleagues and make these actions happen will be part of the work to be done by SCOR group.

5. To develop new applications of the pair disequilibrium techniques and include new stakeholders (e.g., modelers).

6. To establish how to standardize and harmonize ^{234}Th measurement and compilation of data including i) ancillary data identified to maximize the use of ^{234}Th applications ii) collection, measurement and analysis of samples and iii) data obtaining and storage of ^{234}Th results.

7. To discuss, identify and establish the necessary variables and ancillary data (e.g., integration depth) for a unified dataset to be used in a future repository of data for carbon evaluation using different techniques (e.g. sediment traps, flux and gel). And to standardize the calculations of carbon fluxes for specific techniques.

8. To lay the foundation of a global, comprehensive, integrated dataset and/or repository of carbon fluxes derived from different techniques. Including the necessary variables and ancillary data, together with calculations required to obtain the fluxes i.e., the ^{234}Th compilation as a model for forthcoming compilations.

9. To publish reports including recommendations and manuals for future compilations and measurements.

Working plan

The organization of our SCOR WG will be done creating two subgroups that will work in parallel to achieve the ToR. Group 1 will work on ToR 1-5 and Group 2 will work in ToR 5-8. Both groups will work together to generate ToR 9.

DEPOFLUX general meetings will be organized *twice a year*. One of the meetings will be organized during OSM/ASLO/AGU conferences that year to facilitate associate participants to

assist. A second meeting will be held remotely to achieve the maximum participation of full and associate members.

Additional meeting of the subgroups will be organized at least *twice a year*.

An international workshop on carbon fluxes evaluation and compilation will be organized during the *second year*. During the workshop it will be addressed how to increase accuracy in flux evaluation for each method. It will be discussed which sampling, measurement and subsequent standardized estimations should be performed to obtain robust estimations of fluxes when different techniques are displayed. Effort will be made to reach agreements (ToR 7-8, 9).

Timetable is organized as follows:

YEAR 1

Months 1-4.

- First and kick-off WG meeting, preferably in person and during an international congress. First discussions and creation of Groups 1 and 2.
- First on-line meeting of Groups 1 and 2.

Months 5-8.

- Updating the global ^{234}Th data into the compilation to keep dataset up to date. In relation to old data, an effort will be done to collect unpublished results and find missing publications presenting ^{234}Th data. In relation to new ^{234}Th analysis, we will design mechanisms and processes that guarantee that the new information and data measured reach our compilation. ToR 1.
- Identify the different techniques of flux evaluation susceptible to be included in a global, integrated database of carbon fluxes measurements, e.g. radioactive pairs disequilibrium (^{210}Po-^{210}Pb, ^{234}Th-^{238}U, sediments traps, particle imaging analysis with gels or underwater cameras, gliders, Marine Snow Catcher, UVP. ToR 7.

Months 9-12.

- Second WG meeting.
- Design of a QC step for both previous and new data. ToR 2.
- Agree on new measurement variables (e.g., euphotic one depth, Ez) and ancillary data (e.g., new primary production, NPP) and additional metadata (e.g., stage of the bloom at the sampling moment) that will be included in the following datasets. ToR 2.
- For the techniques analyzed in the precedent months discuss and evaluate how to harmonize the necessary variables and ancillary data (e.g., integration depth) for an integrated dataset that includes both variables and fluxes calculations. ToR 7.

YEAR 2

Months 1-4.

- Third WG meeting. In-person
- Get ready the web repository to host the ^{234}Th compilation and give open access for all users. It will be dynamic, by means of including contributions from researchers, long-term, as it will be

kept updated yearly, and useable. ToR 3.

- Determination of the new applications of the pair disequilibrium techniques. The development of new applications has been discussed by the community over the years but have not been possible, up to now, due to the lack of ^{234}Th data and accompanying specific ancillary data. ToR 5.
- Evaluating which specific ancillary data are required for each new application. ToR 5.
- Establish a collection of variables and ancillary data that should be included, for each technique, in a unified dataset of carbon fluxes. ToR 7.

Months 5-8.

- Choose actions to promote the use of ^{234}Th analysis, encouraging researchers to download the data, but also to upload their measurements in the repository. Decide the best ways to reach our colleagues and make these actions to happen. The web and the repository should act to reach the stakeholders, including people from other disciplines. Implement some of those actions during workshop. ToR 4.
- Take actions to include new stakeholders and users of the new applications (e.g., modelers). ToR 4 and 5.
- Forth WG meeting. Online/in-person.
- International Workshop on "Developing repositories for carbon flux quantification: from a Th-234 data repository to the creation of a global flux repository". ToR 4-8.

Months 9-12.

- Set standards in the ^{234}Th measurement and compilation of data including i) ancillary data identified to maximize the use of ^{234}Th applications to study other oceanographic process, ii) collection, measurement and analysis of samples, focusing not only in water but also in particles, and iii) data obtaining and storage of ^{234}Th results. ToR 6.
- Use the results from Workshop and previous discussions to standardize the calculations of carbon fluxes for specific techniques (e.g. radioactive disequilibrium and sediment and gel traps). ToR 7.
- Start the compilation of carbon fluxes following agreed standards in calculations (ToR 7). First ^{234}Th derived and sediment traps fluxes will be discussed and added to a unified dataset. ToR 8.

YEAR 3

Months 1-4.

- Fifth meeting WG. On-line
- First ^{234}Th derived and sediment traps fluxes will be compiled in a unified dataset. ToR 8.
- First drafts of documents (Deliverables 3 and 4). ToR 6, 7 and 9
- Starting the writing of a compilation paper on harmonization and standardization of techniques to determine carbon flux (Deliverable 5). ToR 7 and 9.

Months 5-8.

- Discussion of documents and paper (Deliverables 3, 4 and 5). ToR 6, 7 and 9
- Following updating of new results of ^{234}Th for the dataset. ToR 1-3
- Following compilation of carbon fluxes of at least ^{234}Th and sediment traps derived fluxes. ToR 8

Months 9-12.

- Sixth and closing meeting WG. In-person
- Closure of documents and paper (Deliverables 3, 4 and 5). ToR 6 and 7.

Deliverables

D1. An improved version of the present ^{234}Th dataset (ToR 1-6). It will be considered:

- An agreed structure for metadata and data updating the previous global compilation organization
- Inclusion of new measurement parameters and metadata. QC flags will be given to new data incorporations.
- Inclusion of QC decisions to exclude specific results (e.g. exclude negative values).

D2. A specific web repository, truly user friendly for ^{234}Th measurements (ToR 1-6). This repository will contain:

- An up-to-date dataset of ^{234}Th results (D1) and metadata, any possible data (total, dissolved and particulate ^{234}Th as well as element to Th ratios measured in a variety of techniques) and cruises can be included.
- A web repository that will host the datasets with several options to filter the search of data.
- A protocol of incorporation of new datasets to the repository. The repository will be linked to ZENODO and new datasets will be given a DOI.

D3. A manual of recommendations and good practices (ToR 2-6, 9) about

i) how to standardize the production of ^{234}Th data for its inclusion in the repository, including these aspects:

- Sampling. How to standardize on-board sampling ^{234}Th techniques in order to homogenize the collection of ^{234}Th data in water and particulate phase. Including the different sampling techniques, especially for particle collection and sampling depths.
- Measurement. How to standardize the analysis of ^{234}Th measurements, including differences between particles and water measurements

ii) how to use the ^{234}Th from the compilation of data, to maximize the information and uses that can be extracted from the data. Discussions will be included about:

- Information that can be obtained from ancillary data and how to use it.
- Integration depths. e.g. impact of different choices on the evaluation of carbon export from

the euphotic zone

- How to use C/^{234}Th accurately, depending on the sampling method (ST, SAPS…)
- Export and transfer efficiency calculations and its dependence on the integration depth
- Use of steady state, non steady state and physical effects in the continuity equation to calculate ^{234}Th fluxes.
- Different applications using ^{234}Th-^{238}U disequilibrium to study oceanographic process.
- Inclusion of new ancillary data needed for applications of ^{234}Th-^{238}U disequilibrium not yet explored (e.g., particle fragmentation and remineralization).

D4. A design of the necessary variables (ToR 7-9), data and ancillary data identified by DEPOFLUX community to develop an integrated, harmonized global dataset and a future repository of flux measurements in upper 1000 m using the different techniques available (e.g. radioactive pairs disequilibrium, gliders, sediments traps, particle imaging analysis…). The design will include:

- Decision of the techniques that will be discussed and compiled
- Recommendations for future cruise samplings to obtain harmonized flux results for each specific technique included in the global carbon flux compilation.
- Identification of key variables for each technique to accurately estimate carbon fluxes. Structure of the dataset.
- For each technique, instructions to calculate standardized fluxes using the variables identified.
- Compilation comprising first carbon flux results measured from sediment traps (upper 1000 m) and derived using ^{234}Th dataset (upper 500 m). As a seed and trial of a future integrated dataset of carbon fluxes.

D5. A compilation article (ToR 7-9), detailing the variables identified as key to develop a unified data base of carbon fluxes in the ocean, according to each different method, recommendations of how to collect the and how to obtain standardized fluxes.

D6. A web (The Sea of Thorium) (ToR 4-5) to host the ^{234}Th repository (D2), the manual (D3) and the variables identified to build a dataset on carbon flux (D4).

- To increase the usability of the repository the web will include a searcher of data and global maps to place the data
- To become a focal point for the thorium community and other researchers the web will be interlinked to projects and communities related, e.g. JETZON, GEOTRACES, EXPORTS.

Capacity Building

One of the key aims of DEPOFLUX is to provide a long-lasting database of ^{234}Th for ocean carbon cycle and BCP studies. DEPOFLUX will facilitate new ocean carbon research based and extensive number of data that can be used to analyze carbon fluxes worldwide and through time. The amount of data is large enough to allow to use the dataset, on its whole or partially, to address key questions about carbon cycle in the ocean on a basin or global scale. It will be even possible to evaluate changes on carbon fluxes over the course of the past 50 years using the compiled

^{234}Th dataset. Further, we will lay the foundations of a very much expected dataset of carbon fluxes in the ocean.

We want to generate capacity building by becoming the precedent and model for future compilations and datasets. A manual of best practices will be produced as deliverable (D3).

The international workshop on carbon fluxes evaluation and compilation that will take place (second year) for knowledge transfer and capacity building is expected to encourage rapid and wide adoption of agreed variables and standards to obtain a harmonized calculation of fluxes using the different techniques. It will be encouraged the participation of PhD students and Early career scientists, that will benefit from these discussions.

Additional funding sources will be sought to ensure maximum international participation in the workshop, particularly from developing countries, PhD students and early career scientist. On-line participation will be allowed in order to facilitate access of researchers from developing countries and early career scientists. At least three meetings of the WG will be held during meetings (OSM/AGU…), this way it will be easier to Associate Members and invited early-career scientists to participate. Other meetings will be held remotely, also to encourage the participation of all member. Inviting students or early careers will be invited to participate in some sessions.

The products from DEPOFLUX will draw on and preserve knowledge and skills from a large community of carbon biogeochemists and microbiologists, modellers and carbon cycle researchers. Our results will introduce benefits in radiochemistry, biogeochemistry, quality control methods, data unification techniques and development of repositories.

The actions that promote the long-lasting effects of these working group and will promote the capacity building of new arriving scientists are the following:

- The ^{234}Th repository will be maintained at the University of Sevilla (Spain) and results will be linked to ZENODO and PANGAEA. We will seek external funding to hire someone that could keep the repository up to date.
- All data, documentation and algorithms for analysis will be placed in the public domain to ensure maximum utility of working group activities for the wider research community.
- Manual of “best practices” for ^{234}Th sampling, measurement and analysis and in general, all the documentation generated, will be shared in open access in the Sea of Thorium web.
- DEPOFLUX will produce the structure of a global dataset of carbon fluxes, including necessary variables and how to calculate fluxes. And the compilation of the first data and fluxes will start during these three years. This will be the seed of a future integrated, harmonized global repository of carbon fluxes. The necessary following stage, after the WG, will be to collect, complete and include more updated global fluxes from the different techniques. The first steps will be taken during the WG work, but considering that is a very ambitious project, it will be further developed in the following years.

Working Group composition

Full Members

Name	Gender	Place of work	Expertise relevant to proposal
1 María Villa-Alfageme (chair)	Female	Dpto. Applied Physics. University of Sevilla. Spain	^{234}Th:^{238}U, ^{210}Po:^{210}Pb, radiochemistry, sediment traps
2 Ken Buesseler	Male	WHOI. USA	^{234}Th:^{238}U, ^{210}Po:^{210}Pb, radiochemistry, sediment traps
3 Elena Ceballos-Romero (co-chair)	Female	WHOI. USA	^{234}Th:^{238}U, ^{210}Po:^{210}Pb, particle imaging
4 Frederic Le Moigne	Male	LEMAR. CNRS. Brest. France	^{234}Th:^{238}U and sediment traps
5 Muntsa Roca-Martí	Female	Dalhousie University. Halifax, Canada	^{234}Th:^{238}U, ^{210}Po:^{210}Pb, sediment traps
6 Katsiaryna Pabortsava	Female	National Oceanography Centre, Southampton, UK	Downward particle flux, carbon cycle, micropastics
7 Viena Puigcorbé	Female	Institut de Ciències del Mar – CSIC. Spain	^{234}Th:^{238}U and POC/^{234}Th
8 Stephanie Henson	Female	National Oceanography Centre, Southampton, UK	Global carbon flux analysis
9 Ruifang C. Xie	Female	School of Oceanography, Shanghai Jiao Tong University, China	Trace metal isotope, water masses modeling
10 Ingrid Wiedmann	Female	The Arctic University of Norway (UIT). Norway	sediment traps, zooplankton, arctic ecology

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Claudia Benítez-Nelson	Female	University of South Carolina. USA	^{234}Th:^{238}U, ^{210}Po:^{210}Pb, sediment traps, global cycles
2. Margaret Estapa	Female	University of Maine. USA	Sediment traps
3 Colleen Durkin	Female	MBARI. USA	Particle imaging analysis, phytoplankton biochemistry
4 Kachan Maiti	Male	Louisiana State University. USA	^{234}Th:^{238}U, ^{210}Po:^{210}Pb, radiochemistry, sediment traps
5 Laure Resplandy	Female	Princeton University. USA	^{234}Th modeling
6 Josep Gasol	Male	Institut Ciències del Mar. Spain	Planktonic microbe abundance and activity
7 Michael Stukel	Male	Florida State University. USA	^{234}Th, plankton ecology and marine biogeochemistry
8 Sarah Giering	Famale	NOC, Southampton. UK	Particle imaging, marine snow catcher, remineralization
8 Mónica León	Female	Free lancer. Germany	UX/UI designer

Working Group contributions

Detail for each Full Member (max. 2 sentences per member) why she/he is being proposed as a Full Member of the Working Group, what is her/his unique contribution?

Ken Buesseler is a world-leading expert of marine chemistry. He has contributed to develop great part of the present knowledge of the BCP with his studies. He was the first researcher to use ^{234}Th:^{238}U to estimate POC carbon flux and has also made pivotal contributions to the development of the sediment traps.

María Villa Alfageme is a world expert in radiochemistry and evaluation of POC vertical flux, specially ^{234}Th-^{238}U and ^{210}Po-^{210}Pb pairs. She has previous expertise in data compilation and data bases and published the latest comprehensive ^{234}Th compilation.

Elena Ceballos-Romero is an early career post doc and leading author of the latest ^{234}Th compilation, published in PANGAEA and ESSD. She is currently working on evaluation of POC fluxes through particle imaging techniques (UVP, gel traps)

Frédéric Le Moigne is a world expert in carbon biogeochemistry and marine snow. He has extensive expertise with measuring Thorium ^{234}Th at sea and published one of the first ^{234}Th databases in 2013.

Muntsa Roca-Martí is an early career post doc that has collected thousands of ^{234}Th samples during 8 oceanographic cruises across the world ocean as part of large-scale BCP interdisciplinary projects making her a top ^{234}Th expert.

Stephanie Henson is a world leading expert in global biogeochemical oceanography. She focuses on understanding the variability and climate change effects on phytoplankton populations and subsequent impacts on the biological carbon pump. She works with autonomous vehicles, satellite and in situ data connecting them to biogeochemical models. She will work on the connection of global datasets to models.

Katsia Pabortsava is a marine biogeochemist with >10 years of experience in measuring downward particle fluxes of major and minor elements using ^{234}Th:^{238}U disequilibrium method and direct techniques (sediment traps).

Viena Puigcorbé is an early career post doc and the leading author of the latest POC/^{234}Th ratio compilation, has extensive knowledge in the use of the ^{234}Th:^{238}U pair to quantify the carbon export and also applied it to obtain the first mercury export fluxes. She currently explores new possibilities for this radioactive pair in combination with the study of particle-attached prokaryotic communities.

Ruifang Xie is a marine isotope geochemist, experienced in quantifying the physical (advection and diffusion) and ^{238}U influence in the thorium flux analysis. She will work on new applications development for the ^{238}U-^{234}Th pair for flux evaluation of POC and trace metal isotopes.

Ingrid Wiedmann has a compilation of downward flux data from the Arctic shelf seas, fjords and the central basin (short- and long-term sediment traps) and interlinking these with the compiled thorium data will improve the general understanding of downwards flux temporal and spatial pattern in the Arctic, a region especially exposed to climate change.

Relationship to other international programs and SCOR Working groups

DEPOFLUX is tightly linked to the following international programs, communities and SCOR WG:

EXport Processes in the Ocean from Remote Sensing (EXPORTS) isone of the most important programs studying the biological pump at present. It aims to quantify the mechanisms that control the export of carbon from the euphotic zone as well as its fate in the underlying “twilight zone”. And for that, the accurate evaluation of carbon fluxes is crucial. This program is specifically related to DEPOFLUX because it developed a well-designed and efficient sampling plan where a notable high number of contrasted field measurements were taken and subsequently employed to estimate fluxes. EXPORTS is an example of good practices in how to harmonized field measurements to obtain robust carbon flux results from different techniques.

Joint Exploration of the Twilight Zone Ocean Network (JETZON) is a UN Ocean Decade Programme, which acts as an international coordinator and focal point for Twilight Zone studies. The JETZON community will be regular users of the 234Th repository produced and will contribute to define key variables in the carbon unified dataset. They will participate in the workshops and discussion forums organized. And additionally they committed to give DEPOFLUX the platform to highlight their work across the JETZON community to build future collaborations.

GEOTRACES is one of the most important repositories on chemical tracers in the ocean, if not the most important. The GEOTRACES intermediate data product allows to host data generated during GEOTRACES cruises and serves as an open data repository for ocean data. QC procedures and intercalibrations are a top priority in GEOTRACES data, the repository is easily accessible, and their outreach activities have no rival. This made GEOTRACES the lighthouse and guide of our ^{234}Th repository in many aspects.

SCOR WG150 *Translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT)* aims for establishing a series of standards in the quantification of several parameters using particle imaging techniques, including carbon flux estimations (ToR 7 and 8).

SCOR WG161 *Respiration in the Mesopelagic Ocean (ReMO): Reconciling ecological, biogeochemical and model estimates*. This WG deals with mesopelagic respiration, however it is also interested in the creation of unified criteria and standards of another important process related to the Biological Pump

They are both also linked to JETZON community.

Previous SCOR WG116 *Sediment Trap and ^{234}Th Methods for Carbon Export Flux Determination*, chaired by Ken Buesseler (USA), also full member of DEPOFLUX is strongly tied to our WG. Flux estimates with sediment traps were compared with expected fluxes based on thorium-234 measurements and recommendations were made regarding best practices for using sediment traps, which is directly connected with mostly all our ToR. However, no compilations were created either for ^{234}Th or sediment traps. DEPOFLUX would be the continuation of this WG, as it will build the ^{234}Th repository and the structure of a unified dataset of both methods, including also other possible methods to indirect estimate fluxes.

Appendix

Letters of support

Dr Adrian Martin
National Oceanography Centre
European Way
Southampton
SO14 3ZH
UK
11 May 2022

Letter of support for "DEveloping rePOsitories for carbon FLUX quantification: Th-234 as a case study"

To whom it may concern,

In my function as lead on the UN Ocean Decade Programme, Joint Exploration of the Twilight Zone Ocean Network (JETZON), which acts as *an international coordinator and focal point for Twilight Zone studies,* I am writing in support of the "*DEveloping rePOsitories for carbon FLUX quantification: Th-234 as a case study (DEPOFLUX)*" working group. DEPOFLUX is a key and timely initiative in the field of the ocean carbon cycle.
Thorium based estimates of carbon fluxes have already provided great insights into the biological carbon pump, being used by individual projects and researchers to tackle specific questions. The amount of data has gradually increased to the point where it can be used to address key questions on a basin or global scale. This is critical at a time when society is beginning to give serious consideration to carbon dioxide removal schemes. However, this requires us to have a dataset that brings together all available observations and is robust, consistent and accessible. This first coordinated effort to generate a global, coordinated, and comprehensive repository of ^{234}Th data and the first attempt to generate a unified database for carbon flux variables is therefore very welcome. Given the importance of the Twilight Zone to the recycling of the sinking carbon flux, JETZON's large community of stakeholders will directly benefit from the results generated by the working group.

From a JETZON perspective there are in particular some very welcome aims:

- To become, through the repository and a web, a true and active focal point for the Biological Pump and Twilight Zone community. We would be keen to link to the output of this Working Group via our Data-Sharing GitHub page.
- To develop new applications of the pair disequilibrium techniques and include new stakeholders (e.g. modelers). This way, the repository would benefit a wider range of JETZON stakeholders, including people from other disciplines.
- To discuss, identify and establish the necessary variables and ancillary data for an integrated dataset to be used in a repository of data for carbon evaluation using different techniques. This is a critical task to allow cross-comparison across methods and so reduce uncertainties.
- To open the compilation to other techniques for POC flux quantification. We would be keen to foster this further within JETZON and already have relevant complementary SCOR working groups (TOMCAT, REMO) linked to us.

We will follow and support DEPOFLUX progress closely and the JETZON community will, I'm sure, be regular users of the 234Th repository produced, will contribute to define key variables in the carbon integrated dataset, and will participate in the workshops and discussion forums organized. We will additionally give DEPOFLUX the platform to highlight their work across the JETZON community to build future collaborations.
I give this application my strongest support.
Yours sincerely,

Adrian Martin

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EARTH RESEARCH INSTITUTE

SANTA BARBARA, CA 93106
http://www.icess.ucsb.edu/

May 13, 2022

Prof. María Villa Alfageme
Universidad de Sevilla
mvilla@us.es

Dear Maria,

As Science Lead on the US NASA and NSF funded EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) field campaign (oceanexports.**org**), **I offer my strongest support for the proposed SCOR working group for DEveloping rePOsitories for carbon FLUX quantification: Th-234 as a case study (DEPOFLUX)**

The goal of the EXPORTS campaign is to predict the export and fate of global ocean Net Primary Production (NPP) from satellite and other observations. EXPORTS represents over $30M US in funding from NASA and NSF, spanning 17 projects with 54 individual principal investigators. This level of investment likely makes EXPORTS the largest coordinated U.S.-funded biogeochemical field program since the Joint Global Ocean Flux Study (JGOFS) nearly 2 decades ago. EXPORTS has completed its two campaigns; the first in 2018 in the Northeast Pacific and the second in the North Atlantic in the spring 2021. However, for EXPORTS to achieve its overall goal, predictive knowledge of the relationships among NPP, carbon export and it fates is needed for the global ocean, not just the two sites where the EXPORTS campaign has taken place. Programs like DEPOFLUX are essential to create the international partnerships that are required to broaden the scope of data used to develop these predictive understandings.

Again, I offer my strongest support for the DEPOFLUX SCOR working group proposal. Please let me know if there is anything else I can do to help make this dream a reality.

Sincerely,

Dave Siegel

Dr. David A. Siegel
Science Lead, NASA EXPORTS Field Campaign
Distinguished Professor of Marine Science
University of California, Santa Barbara
Santa Barbara, CA 93106-3060, USA
Email: david.siegel@ucsb.edu

An International Study of the Marine Biogeochemical Cycles of Trace Elements and their Isotopes

12 May 2022
Dr. María Villa-Alfageme
Univeristy of Sevilla,
España

Re: GEOTRACES support DEPOFLUX working group

To whom it may concern,

We are writing on behalf of the International GEOTRACES programme (www.geotraces.org) to express our support for the "DEPOFLUX: DEveloping rePOsitories for carbon FLUX quantification: Th-234 as a case study" proposal for SCOR working group.

GEOTRACES has recently released its third International Data Product of hydrographic and marine trace elements and isotopic data acquired on 77 cruises across all ocean basins. By releasing its data, GEOTRACES aims to intensify collaboration within the broader ocean research community, this is why are pleased that the DEPOFLUX working group is willing to incorporate GEOTRACES ^{234}Th data in its repository complying with the GEOTRACES Fair Use agreement (https://www.geotraces.org/fairuse).

It is anticipated that the DEPOFLUX repository will serve the thorium community, but also modellers and flux evaluation experts, reinforcing the efforts carried out by GEOTRACES to integrate observational and modelling communities, and have an important role on the estimation of carbon fluxes. This is why we fully support this proposal.

We wish you every success with your proposal and look forward to seeing GEOTRACES data integrated to the DEPOFLUX repository.

Yours sincerely,

Prof. Karen Casciotti
kcasciotstanford.edu

Prof. Maeve Lohan
M.Lohan@soton.ac.uk

Co-Chairs, GEOTRACES Scientific Steering Committee

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