PERSIST

Persistence and Stability of oceanic dissolved organic matter: an Integrative Synthesis of Theories

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Acronym: PERSIST

Summary/Abstract (185 words)

Dissolved Organic Carbon (DOC) in the ocean is one of the least constrained natural carbon reservoirs in the Earth System. The persistence of DOC within the ocean for thousands of years make this crucial to understand both for natural variations in the carbon cycle and as a potential for harnessing within marine Carbon Dioxide Removal (mCDR) techniques. However, there is no consensus on why DOC persists in the ocean with competing theories leading to drastically contrasting carbon cycle scenarios.

PERSIST is a diverse set of researchers comprising observationalists, theorists, experimentalists and modelers collaborating to significantly advance our capacity to address the challenge of persistence. First, PERSIST will develop a unify existing numerical models of DOC persistence into a common computational framework to quantitatively examine competing theories in a consistent way for the first time. Secondly, PERSIST will produce a new global compilation of DOC isotopes to enable new observational constraints on DOC persistence. PERSIST will also generate a new research network aimed at breaking down current disciplinary barriers in this area and connecting up research at the microbial scale to its global carbon cycle implications.

Scientific Background and Rationale (1250 words)

Dissolved Organic Carbon (DOC) in the ocean is one of the least constrained natural carbon reservoirs in the Earth System that exchanges with atmospheric CO_2. This oceanic reservoir, made up of organic molecules, is primarily derived from biological activity in surface waters and stores a pool of carbon equivalent in size to the atmosphere (~700 Pg C). A critical feature of DOC is that a large fraction persists in the ocean for several thousands of years (Hansell 2013). Because of its reservoir size and age, DOC is a unique component of marine carbon sequestration that operates on intermediate timescales between the Biological Carbon Pump (100s years) and deep-sea sediments (100k years). It has been invoked in explaining past climate changes (Sexton et al., 2011), a driver of long-term future climate (Wagner et al., 2020) and as a highly effective vehicle for marine carbon dioxide removal (mCDR, *e.g.,* Jiao et al., 2024). DOC is also a crucial interface for other biogeochemical cycles by supplying macronutrients and influencing primary production in the surface ocean (via dissolved organic nutrients and other elements), controlling iron bioavailability (Moore et al., 2023) and oxygen consumption. However, there is no consensus on why DOC persists in the ocean for thousands of years. As such, we lack even basic knowledge of how the DOC reservoir can, and will, respond to environmental change which limits our ability to predict the magnitude, direction or timescale of future changes and the efficacy of mCDR. Improved understanding of DOC cycling in a changing ocean is a grand challenge for the scientific community that requires the unification of hypotheses, bringing in new observational constraints and building mechanistically realistic models of DOC.

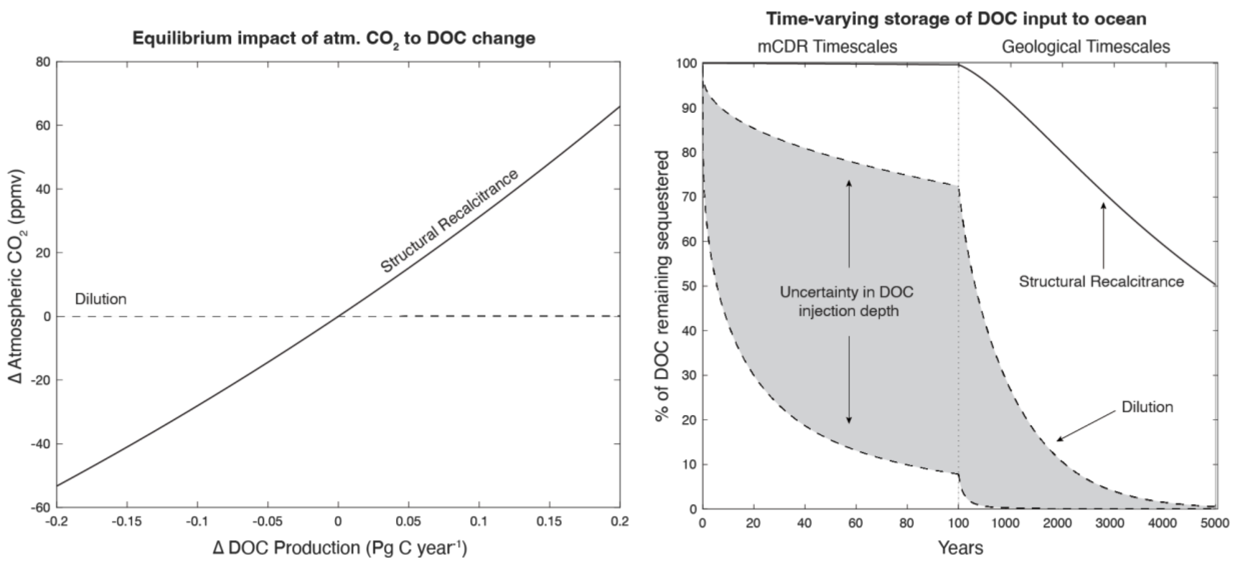

Figure 1. Dilution and structural recalcitrance hypotheses lead to significantly different modes of carbon cycling for DOC. (left) Change in equilibrium atmospheric CO_2 in response to a complete cessation or doubling of modern DOC production, estimated from an experimentally-constrained box model (Wilson & Arndt 2017). **(right)** Transient decay of carbon storage from a mCDR-like 1 Pg C addition of DOC to the ocean estimated from the offline MITgcm 3-D circulation model.

A lack of consensus on DOC persistence is a fundamental gap in our understanding of how the marine carbon cycle behaves. DOC influences atmospheric CO_2 primarily through the size of the global DOC inventory. Understanding why DOC persists in the ocean is critical to predicting the magnitude of the DOC inventory and therefore its impact on CO_2. Currently we think that DOC persistence occurs because there is: 1) a diversity of chemical reactivity that limits degradation by bacteria (structural recalcitrance: Benner & Amon 2015; Shen & Benner 2020); 2) a diversity of compounds, actively consumed to individually low concentrations that limit bacterial degradation (dilution: Arrieta et al., 2015); or 3) a balance of factors depending on the local environment (functional persistence: Zakem et al., 2021). While these hypotheses are not mutually exclusive, "end member" scenarios based on existing biogeochemical models lead to significantly different modes of carbon cycling, and different sensitivities to environmental changes (Figure 1). Structural recalcitrance leads to a DOC reservoir that can significantly impact atmospheric CO_2 due to decoupling of production and consumption rates (≈± 60 ppmv for a simple cessation or doubling of modern DOC production), that is active on geological timescales, and that would be a highly efficient method of mCDR (Figure 1). Alternatively, with persistence driven by dilution the DOC inventory becomes a function of the microbial capacity to produce and consume DOC (Mentges et al., 2020), potentially limiting the maximum size of the DOC reservoir and therefore its impact on atmospheric CO_2 (<±1 ppmv), and potentially reducing its efficiency for mCDR (Figure 1). These different modes of cycling will also impact other biogeochemical cycles leading to a series of currently unquantified feedbacks on the carbon cycle. To understand and predict the marine carbon cycle, we need to address the uncertainty in what causes the persistence of DOC.

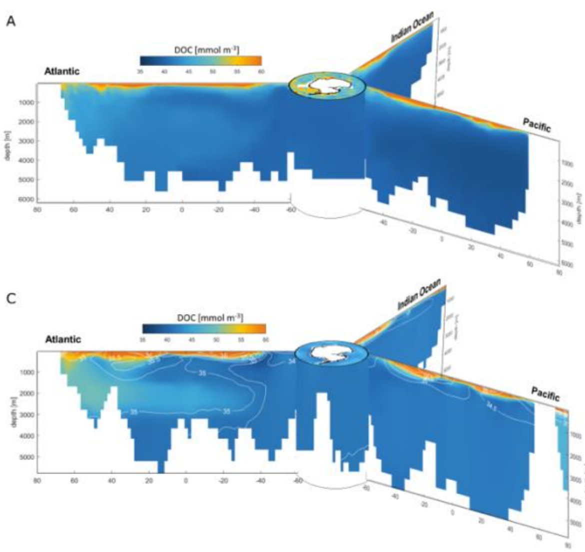

Figure 2. DOC concentration does not constrain modes of DOC cycling. Distributions of DOC from a model representing structural recalcitrance (top) (Hansell et al., 2012) and a model representing dilution (bottom) (Lennartz et al., 2024).

<u>Constraining DOC persistence requires global observations of isotopes.</u> Global distributions of DOC concentrations in the ocean can be equally explained by the structural recalcitrance or dilution hypotheses (Lennartz et al., 2024, Figure 2). However, these concentrations emerge from drastically different cycles of DOC (Figure 1). The bulk radiocarbon signature of DOC presents a crucial but underutilised constraint on different modes of DOC cycling (Wilson & Arndt 2017). It incorporates additional information such as ageing with water mass transport and possible addition of radiocarbon from the degradation of sinking POC (Follett et al., 2014) which needs to be assessed at a global scale. A global dataset of DOC isotopes will provide a step-change in the available observational constraints to distinguish theories of persistence.

<u>Constraining DOC persistence requires a unified modelling approach.</u> Constraining persistence from global radiocarbon observations requires global model predictions. In existing bacteria-DOC network models, DOC persistence is an emergent property of the interactions of a diverse community of microbes and DOC compounds (Mentges et al., 2020, Lennartz and Dittmar, 2022) or result from the presence/absence of DOC consuming microorganisms (Zakem et al., 2021). Still, our ability to apply these models to the question of persistence are limited in two ways: 1) different theories are resolved in different models raising a fundamental issue of comparing and integrating outcomes; and 2) models resolve only the concentration of DOC; and/or are not coupled to biogeochemistry. Ultimately, a 3-D model is needed to fully constrain the mechanisms behind DOC persistence using new observational constraints and make mechanistically informed predictions of DOC. A bottleneck towards this goal is to get different persistence theories into one unified set of equations that can serve as a core model for upscaling into 3D.

Why a SCOR Working Group?

Creating a step-change in our understanding of DOC persistence requires integration of expertise across disciplines in measuring and observing DOC, the development of numerical models, and the conceptualisation within theory. The expertise and existing resources are distributed globally such that it is unlikely that national funding will provide opportunities to facilitate this integration.

Addressing the question of persistence is a timely activity that can leverage recent developments in the field. The community has released several global-scale observation databases for bulk concentrations of dissolved organic matter (Hansell et al., 2021; Lønborg et al., 2023) which have been used to produce climatological data products (Panaïtois et al., 2025) that are ideal for constraining models. The machine learning techniques and lessons from data compilation can be directly applied to a new isotopic compilation. The community has also generated 0-D models of DOC-bacteria networks reflecting different persistence theories (Mentges et al., 2019; Zakem et al., 2021; Lennartz and Dittmar 2022). These models can now be scaled up to 3-D using newly developed modelling resources (Strong-Wright et al., 2023; Khatiwala et al., 2025), allowing us to address challenges of computing the long-timescales associated with DOC persistence and the need for a large number of bacterial and chemical tracers. The focus on capacity building within SCOR is an ideal way to achieve the step-change needed. First it allows us to create a collaborative network to facilitate the exchange of expertise to bring together existing developments in a coordinated manner. Secondly, it allows us to undertake horizon scanning activities to identify key barriers and solutions to help accelerate the resolution of DOC persistence on the global carbon cycle.

Terms of Reference (218 words)

1. Develop a unified modelling framework of DOC persistence: Building on the models of Zakem et al., (2021), Lennartz and Dittmar (2022) and Wang et al. (2018) and additional information from working group members, this will allow major theories of DOC persistence to be quantitatively explored in a consistent way.

2. Develop a global dataset of observed DOC isotopes (e.g. $DO^{14}C$): Building on the database of Hansell et al. (2021) by collating published and unpublished observations at a global

scale, this dataset will provide new observational constraints on the rates and nature of DOC cycling.

3. Identify and prioritise regions and experiments that can distinguish between persistence theories: Leveraging the deliverables developed via ToRs 1 & 2 to identify how the two resources can best be combined and where existing gaps in knowledge can be addressed,

4. Explore solutions to embedding complex DOC models in Earth System Models. Scaling from a 0-D model to a fully 3-D global scale model of the carbon cycle is required for understanding implications of DOC persistence on the carbon cycle.

5. Build a network to connect experimentalists, observers, theorists and modellers to significantly advance the field on DOC persistence and its impact on the carbon cycle: Connecting across disciplinary barriers to generate new collaborations and support the development of Early Career Researchers.

Deliverables (168 words)

1) An open-access 0-D or 1-D model that resolves major theories of DOC persistence in a consistent way. The model will be written in an open-access language, archived in GitHub with full documentation and described in an associated model description paper.

2) An open-access database of DOC isotopes. The database will be constructed in line with FAIR principles and described with an associated paper.

3) A community-scoping paper outlining the current challenge of resolving DOC persistence in numerical models, its wider implications on the carbon cycle and marine biogeochemistry, with a clear way forward on next steps to constraining it.

4) A perspective paper presenting the current state of DOC cycling and persistence in global Earth System models and potential solutions required to upscale complex persistence models. The paper will stimulate awareness in the Earth System modelling community.

5) A website acting as a central focal point for the working group activity both internally and building community capacity for DOC and DOM more broadly.

Working plan (650 words)

1) To deliver Deliverable #1: We will develop a single unified model framework by combining the existing network models of Mentges et al., (2019), Zakem et al., (2021) and Wang et al. (2018). Key dynamics and features of the varied persistence hypotheses will be implemented in a modular fashion so that specific hypotheses can be modelled individually (as per the current state-of-the-art) or combined, *e.g.,* resolving pools of different reactivity (molecular recalcitrance); transformation of DOC linked to molecular properties (size-reactivity spectrum); a dynamic or static network of DOC and bacteria interactions; and varied ecological and environmental controls on microbial traits. The modular design will facilitate the efficient and traceable incorporation of new research findings and directions as they arise during the research programme.

2) To deliver Deliverable #2: We will compile data deposited from individual cruises across the last thirty years for $DO^{13}C$, and $DO^{14}C$ observations (extensive works, *e.g.,* Hansell et al., 2021).

3) To deliver Deliverable #3: We will convene a workshop aimed at bringing experts together to identify potential ways to distinguish DOC persistence theories. For example, observations show that DOC persists more in oxygen minimum zones than in the oxygenated ocean (*e.g.,* Gomez-Saez et al. 2021) – is this a key region that could be explored with observations and modelling?

4) To deliver Deliverable #4: We will convene a workshop aimed at identifying solutions for scaling the unified 0-D DOC model to 3-D Earth System models, such as the use of novel modelling techniques, *e.g.,* transport matrices (Khatiwala et al., 2025), oceananigans (https://clima.github.io/OceananigansDocumentation/stable/), and dimension reduction of complex DOC models, *e.g.,* machine learning.

5) To deliver Deliverable #5: We will set up a project website via GitHub to provide a central source of information about the project including direct links to open-source software and data generated by the project. We will also set up an international network organisation on Dissolved Organic Matter linking up with other international networks such as the Joint Exploration of the Twilight Zone (JETZON). This network will host an international virtual seminar series with recorded talks shared on a social media channel.

Timeline:

Year 1:

- Initial virtual meetings with members to allocate model development and observation collation tasks (Deliverables 1 & 2) and agree suitable timeline for completion.
- Subgroup sets-up and hosts a virtual Hackathon event to initialise development of model framework (focusing on adapting existing model codes into a single language object, developing fundamental list of inputs/tracers/parameters)
- Subgroup begins the collation of DOC isotope observations
- Creation of a PERSIST website and start organising a virtual seminar series.

Year 2:

- Organise a community workshop on using the unified model and to gain feedback on accessibility and applicability.
- Develop documentation and training material for the model. Write a short paper (2-3 pages) on the software design of the model and its intended use in the Journal of Open Source Software.
- Write a model description paper (e.g., approx. 10 pages) for submission to Geoscientific Model Development or Journal of Advances in Modeling Earth Systems detailing the scientific development of the model.
- Finalise a first draft of the DOC isotope compilation.

Year 3:

- Organise a working group meeting presenting key developments on the modeling and observations subgroups. A key goal of the meeting will be developing topics and discussion for Deliverable #3.
- Publish a data description paper of the DOC isotope database.
- Host a virtual training session for the unified model output.

Year 4:

- Convene a second virtual Hackathon event to synthesise information on DOM/DOC in IPCC-class models and simulations (representations of DOM/DOC in IPCC class models, quantify multi-model estimates of preindustrial/historical/future fields of DOM/DOC)
- Publish Deliverable #3
- Publish Deliverable #4

Capacity Building (1029 words)

The overarching goal of our capacity building efforts will focus on three areas: (1) integrating diverse disciplinary approaches (theory, experimental, observations, modeling) to promote the fundamental science of DOM as a connecting component in global ocean biogeochemistry; (2) prioritising international collaborations with a focus on engagement from scientists in developing countries; (3) promoting the development of Early Career Researchers.

Availability of Working Group Outputs:

Both the unified model code and the underlying global database on dissolved organic matter isotopes will be freely and openly available following FAIR (Findable, Accessible, Interoperable, Reusable) data principles. Outputs will be promoted via: the PERSIST network; the range of international research networks connected with working group members (see table below) and via an advisory board of senior experts; targeted activity such as a Town Hall meeting at a major international conference.

Model Outputs: The unified 0-D model code will be written in a widely-used open-source programming language, such as Python or Julia, and will not require high performance computing, removing any computational and financial barriers to running the model. The model code will be freely available on GitHub which will also facilitate researchers independently developing the code. A manuscript will be submitted to the Journal of Open Source Software (JOSS) providing a high-level description of development and intended application of the model and a check on accessibility as JOSS reviews the accessibility of the model repository itself.

Data Outputs: The DOC radiocarbon dataset will be hosted at the British Oceanographic Data Centre and linked to major international datahubs such as Simons Collaborative Marine Atlas Programme (https://simonscmap.com/) and Joint Exploration of the Twilight Zone (https://jetzon.org/) to maximise dissemination and easy visualisation.

Publications: Where possible, publication outputs will be made open-access.

Working Group Meetings:

All WG meetings will emphasize inclusivity and capacity development. We will prioritise the availability of direct and additional funding (e.g., SCOR travel grants) to attend meetings for early career researchers and researchers from developing nations. WG members are encouraged to bring early career scientists to meetings where possible. Activities between in-person meetings will be conducted online, with scheduling designed to accommodate multiple time zones to maximize global participation. In-person meetings will either be strategically located outside Europe and North America, or linked to major international conferences (e.g., Ocean Sciences, European Geosciences Union), to facilitate the widest attendance and to minimise financial barriers to attending.

Establishing a Dissolved Organic Matter Research Network:

At present, the Biogeochemistry of Dissolved Organic Matter book series provide a central collection of reviews that summarises previous research progress across the wider Dissolved Organic Matter community, of which persistence is one aspect. However, there is no mechanism to connect the wider community in terms of on-going research progress. Establishing a research network will enable cross-cutting collaborations across the community helping to link up the direct WG activity on persistence with other areas.

A New Online Platform: We will establish a central online platform that serves as a central presence for a research network and the primary access point for all Working Group resources and outputs. Tutorial videos and step-by-step guides will be provided to support users with varying levels of experience (beginner, advanced). This centralized resource will ensure transparent, unambiguous access to both data and tools, and will facilitate uptake across the wider scientific community. The online platform can be hosted freely via GitHub pages.

Virtual Seminar Series: To promote knowledge exchange and community building, we will develop a virtual seminar series. The goal is to connect modelers and non-modelers, so that each webinar will start with a broader overview/introductory talk followed by a more specific, advanced topic. Potential topics are: introductions to biogeochemical modeling; theoretical frameworks for DOM persistence; applying the core model in contexts such as time series or incubation experiments; and approaches to scaling from molecular-level diversity to bulk observable properties. The seminar series will be maintained by a panel of Early Career Researchers to promote the development of their own networks. The panel will be rotated across nationalities to also promote wider capacity building.

Town Hall at International Conference: We launch the research network at a Town Hall in a major international conference such as Ocean Sciences or the European Geosciences Union meetings. This will maximise international participation and engagement.

International Advisory Board: A group of senior scientists have agreed to participate on an international advisory board for PERSIST. These scientists reflect diversity across persistence theories and links to the wider DOM community. Their task will be to provide feedback on the model development on a conceptual level.

Training Sessions for the Unified Model:

We will organize hands-on training and development activities for the unified model output. These events will be particularly targeted at early career researchers and will focus on running and adapting the model, applying it to experimental and observational datasets (e.g., time series and incubation experiments), and implementing FAIR data management practices. Workshops will be targeted at users unfamiliar with modeling techniques whilst hackathon-style sessions will provide participants with users interested in customizing the code for their own applications and discussing potential further code developments. These events will be held virtually minimising costs of hosting in-person meetings and maximising international accessibility. Training resources developed in conjunction with these activities will also be shared on the PERSIST website and linked to within the model code archive.

Links to International Research Programmes and Networks:

Members of the working group, as well as members of the International Advisory Board, (see below) will serve as connectors to exchange with other ongoing activities, helping to integrate our work with ongoing global efforts and promote uptake of the model and datasets within established scientific communities.

Program/Project	**Name(s)**
C-Comp (*Center for Chemical Currencies of a Microbial Planet)*	Heather Kim
Biogeoscapes (*Ocean metabolism and nutrient cycles in a changing planet)*	Sinikka Lennartz, Robert Letscher, Heather Kim, Charlotte Laufkötter
Global ONCE *(UN Ocean Decade project on DOC and mCDR)*	Nianzhi Jiao
Geotraces (*Marine biogeochemical cycling of trace elements and their isotopes)*	Philip Boyd
JETZON *(UN Ocean Decade research network on the twilight zone)*	Jamie Wilson
Coupled Model Intercomparison Project (CMIP) and Intergovernmental Panel on Climate Change (IPCC)	Jamie Wilson, Charlotte Laufkötter
LOC-NESS (*NOAA & philanthropic funded project on mCDR*)	Heather Kim

Working Group composition (304 words)

Full Members: PERSIST includes 10 full members drawn from a range of modelers, experimentalists and observationalists working on DOC across a range of perspectives from microbial dynamics to the global carbon cycle. Crucially, the full membership reflects the range of theories on DOC persistence. The full membership covers geographical diversity across North and South America, UK and Europe, Asia and Australia; a 6:5 male:female gender balance; and 4 ECRs (10 years or less since PhD) including an ECR co-chair. The co-chairs have expertise in DOC persistence and global organic carbon cycling reflecting the joint aims of enabling progress on constraining the causes of persistence and the implications of persistence on the carbon cycle.

Associate Members: The associate members provide specific expertise in collating DOM concentration and isotopic observations; numerical modeling of organic matter reactivity, machine learning, and the broader perspective of DOC dynamics for long-term climate from paleoclimatology/paleoceanography.

Advisory Board of Senior Experts: PERSIST is also supported by a board of international experts who have agreed to provide advice, insights and guidance to the activity of the Working Group. The choice to arrange an advisory board reflects that research on DOC is heavily biased geographically towards the USA and that expertise in persistence theories is associated with senior scientists. The advisory board allows us to maximise geographical diversity and early career participation whilst retaining crucial interactions across the broader DOC community. The advisory board experts are senior scientists that specifically reflect diversity across theories of DOC persistence:

Prof. Nianzhi Jiao (Xiamen University, China) - expert in Microbial Carbon Pump

Prof. Dennis Hansell (University of Miami, USA) - expert in DOC observations

Dr. Daniel Repeta (Woods Hole Oceanographic Institute, USA) - expert in microbial cycling of DOM

Prof. Thorsten Dittmar (University of Oldenburg, Germany) - expert in molecular characterisation of DOM and the dilution hypothesis.

Full Members:

Name	**Gender**	**Years since degree***	**Country and institution of affiliation(s)**	**Expertise relevant to proposal**
1 Jamie Wilson (co-chair)	M	11	UK (University of Liverpool)	Modelling - global scale marine carbon cycling by biology
2 Sinikka Lennartz (co-chair)	F	9	Germany (University of Oldenburg)	Modelling - persistence of DOM from dilution and environmental perspective, 0D to 3D
3 Robert Letscher	M	14	USA (University of New Hampshire)	Modelling and Observations: - Large scale DOM with focus on stoichiometry, experimental/obs perspective
4 Emily Zakem	F	10	USA (Carnegie Institution for Science; Stanford University)	Modelling - persistence of DOM
5 Yuan Shen	M	9	China (Xiamen University)	Experiments - molecular properties linked to DOM reactivity
6 Charlotte Laufkötter	F	12	Switzerland (University of Bern)	Modelling – IPCC-class climate modelling expertise, carbon cycle and DOM
7 Ruanhong Cai	M	8	China (Hong Kong University of Science and Technology)	Experiments - Microbial cycling of DOM and experimental approaches
8 Samar Khatiwala	M	>20	Japan (Waseda University)	Modelling - Global Carbon Cycle and Transport Matrix Method expert

9 Raquel Avelina	F	3	Brazil (Fluminense Federal University)	Observations - Oceanographic observations of DOC with focus on Southern Ocean
10 Philip Boyd	M	>20	Australia (University of Tasmania)	Observations - Links between DOM and particulate organic matter and wider marine biogeochemistry

* Field only required for members identified as early career: 10 years or less post-degree, not counting time off for family leave.

Associate Members:

Name	**Gender**	**Years since degree***	**Country and institution of affiliation(s)**	**Expertise relevant to proposal**
1 Heather Kim	F	9	USA (Woods Hole Oceanographic Institute)	Modeling heterotrophic bacteria-DOM dynamics and mCDR
2 Brett Walker	M	15	USA (UC Irvine)	Observations - Isotope geochemistry of DOM
3 Chris Follett	M	12	UK (University of Liverpool)	Observations – stable and radioisotopes of DOM
4 Christian Lonborg	M	17	Denmark (Aarhus University)	Obserations - Biogeochemical cycling of carbon, nitrogen, and phosphorus, in Dissolved organic matter (DOM).
5 Thulwaneng Mahsifane	M	9	South Africa (University of Cape Town)	Modelling - Biogeochemical modeller with expertise in machine learning and trait-

				based modeling approaches
6 Ricardo L Silva	M	12	Canada (University of Manitoba)	Observations and Paleoclimate - paleo-DOC dynamics in the Paleo- and Mesozoic
7 Federico Baltar	M	16	China (Shanghai Ocean University)	Observations, theory and experiments - DOM degradation by microbes (bacteria, fungi..)
8 Sandra Arndt	F	18	Belgium (Universite Libre de Bruxelles)	Modeling - organic carbon cycling across Earth System Interfaces, paleoclimate

* Field only required for members identified as early career: 10 years or less post-degree, not counting time off for family leave.

Working Group contributions (592 words)

Jamie Wilson is a numerical modeller who works on the biological cycling of carbon in the ocean (both particulate and dissolved organic matter) across paleoclimate timescales to future climate change. His work has demonstrated the importance of radiocarbon as a constraint on theories of DOC persistence, created a climatological map of DOC, and quantified the impact of biological carbon cycling within IPCC projections.

Sinikka Lennartz is a biogeochemical modeler who studies how processes scale from diverse microbial communities and cellular interactions to bulk DOM and its basin-scale distribution (MICDOC model). Her work shows how rapid microbial dynamics underpin apparent millennial-scale DOC removal and how persistence and distinct DOM reactivity classes emerge from complex microbe–compound interaction networks.

Robert Letscher brings expertise in the representation of marine dissolved organic matter cycling within both forward (e.g. CESM-MARBL) and inverse (e.g. OCIM2) ocean circulation and biogeochemical models with a recent focus on external inputs contributing to the inventory of refractory DOC. He is also involved with the compilation of extant observations of marine DOC isotopes for the use in validating global scale models.

Emily Zakem is an expert in mathematical modeling of the interactions between DOC and its microbial consumers, from 0D conceptual frameworks to 3D global ocean biogeochemical/ecosystem models. Her work has demonstrated how ecological interactions, such as the grazing of microbial DOC consumers, can impact the persistence of DOC, exploring the concept of recalcitrance as phenomenological and context-dependent.

Yuan Shen is a marine biogeochemist interested in the molecular controls and microbial utilization of dissolved organic carbon (DOC) in the ocean. His work combines field, experimental, and molecular approaches to understand DOC bioavailability, persistence, and its role in long-term carbon storage.

Charlotte Laufkötter is a marine biogeochemical modeler who focuses on the marine biological carbon cycle. Her research includes modelling the future changes in marine heterotrophic bacteria and dissolved organic carbon in IPCC-class Earth System Models.

Ruanhong Cai is an experimentalist working on the recalcitrance of marine DOM. He contributes experience of the microbial cycling of DOM as well as a perspective on the Microbial Carbon Pump.

Samar Khatiwala uses numerical models to understand the complex interplay between climate, ocean circulation, and ocean biogeochemistry, with a focus on carbon cycling by biology in the ocean. He is an expert in developing and applying modeling tools such as transport matrices that provide novel mathematical approaches to running biogeochemical models.

Raquel Avelina is an oceanographer specialising in the biogeochemistry of the Southern Ocean. Her research primarily focuses on the distribution and drivers of dissolved organic carbon (DOC) and nitrogen in polar environments, particularly around the northern Antarctic Peninsula.

Philip Boyd has focussed on better understanding the drivers and sequence of particle degradation (carbon and trace metals) by microbes in the oceans' Twilight Zone (200-1000 m depth). He devised an instrument – RESPIRE – that permits experiments on sinking particles to be performed at depth. RESPIRE provides the means to better link microbial respiration, particle degradation and DOC production.

The associate members provide the broader links for the implications of DOC persistence including: paleoclimate (Ricardo Silva and Sandra Arndt); reactivity of organic matter in deep-sea sediments (Sandra Arndt); and biogeochemical modelling of DOC within the wider Earth System (Heather Kim; Thulwaneng Mahsifane). The associate members also include expertise collating isotopic observations (Brett Walker; Chris Follett; Christian Lønborg, Federico Baltar) in order to achieve a full disciplinary balance across observations, models, experiments and theory in the full group. Specifically, Chris Follett is identified as a significant expert in separating different isotopic signals within the bulk observations (Follett et al., 2014).

Relationship to other international programs and SCOR Working Groups (394 words)

The activities of PERSIST are closely aligned with several ongoing and past SCOR WGs and international programs to ensure strong integration with existing efforts and maximizing scientific impact.

SCOR WG170 PRIMO (Physiology and Rates in Microbial Oceanography) is highly relevant, as it focuses on bridging observations and models by translating 'omics-based information on physiological potential into quantifiable rates that can be implemented in Earth system models. Key processes addressed by PRIMO, including primary productivity (photoautotrophic and chemoautotrophic), carbon uptake (e.g., growth rates and efficiencies), and respiration, are directly relevant to our modeling framework. Collaboration is facilitated through overlapping membership (Federico Baltar) and ongoing joint research activities (several members).

SCOR WG161 ReMO (Respiration in the Mesopelagic Ocean) provides additional synergy through its focus on reconciling observational and model-based estimates of respiration. In particular, its efforts to compile a global database and develop synthesis products on respiration rates (Terms of Reference 2 and 3) are directly relevant to our objectives. These datasets and syntheses have strong potential to serve as constraints for our modeling efforts during the upscaling process. Links to ReMO are maintained through active collaborations between several WG members.

Among past SCOR activities, WG134 on the microbial carbon pump is particularly relevant, as it addressed the formation of refractory DOM. Knowledge exchange with this WG is ensured through the involvement of Nianzhi Jiao as a member of our Advisory Board.

Our WG is also well connected to major international and national research programs. The C-COMP initiative (Center for Chemical Currencies of a Microbial Planet) focuses on the cycling of labile DOM and complements our emphasis on longer-term (decadal to millennial) DOM persistence. Collaboration is facilitated through shared membership (Heather Kim). The BIOGEOSCAPES program aims to integrate biogeochemistry, 'omics, and modeling to improve understanding of ocean metabolism in a changing climate. Sinikka Lennartz contributes to this initiative through the International Implementation Committee, providing a direct link to our WG activities. Other members are actively involved as well, e.g. Robert Letscher, Charlotte Laufkötter and Heather Kim. Finally, connections to the JETZON (Joint Exploration of the Twilight Zone Ocean Network) are maintained through WG membership, linking our work to research on carbon cycling in the mesopelagic ocean, a key region for DOM turnover.

Together, these linkages ensure strong coordination, avoid duplication of effort, and enhance the visibility and uptake of WG outcomes within the broader scientific community.

Key References (497 words)

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