Title: Analysing ocean turbulence observations to quantify mixing
Acronym: ATOMIX

SCOR Working Group Proposal

May 8, 2020

Summary

Reliable representation of ocean mixing is critical for quantifying the fluxes of heat, salt, energy and nutrients that are fundamental to climate and ecosystems. Turbulence observations enable quantifying the dissipation rate of turbulent kinetic energy ϵ that, together with background conditions, allow us to infer vertical fluxes in the ocean. The increased availability of measurement technologies has rapidly expanded both the mixing research community and the volume of data collected. This rapid growth, compounded by the absence of standards, has caused concerns about the validity and quality of current mixing estimates. The proposed SCOR Working Group will thus develop best-practice procedures and quality-control indicators for determinating ϵ – a critical turbulence quantity for estimating mixing from shear probes and velocity sensors. These best-practices will support observations from commonly-deployed platforms such as profilers, fixed and moored instruments, and self-propelled gliders. To enable validation of existing (and future) algorithms, benchmark datasets with agreed-upon ϵ estimates will be made available for a variety of platforms and ocean environments, along with quality metrics. These benchmarks are designed to remain relevant irrespective of the programming language used for data processing, as a lasting legacy for the ocean mixing community. The guidelines will be communicated through a peer-reviewed synthesis article, an open-access wiki, and a training workshop geared towards early-career researchers. These outputs will increase the confidence in turbulence estimates used to constrain or improve mixing parameterisations in ocean models. Finally, the Working Group will seek to expand the global community engaged in this critical science.

1 Scientific Background and Rationale

Turbulence plays a key role in oceanic energy budgets and transport of heat, salt, dissolved gases, and nutrients in the ocean. Turbulence observations are required to assess and improve how mixing is represented within regional and global ocean models. Model predictions of ocean stratification, heat and deep-water exchanges, and therefore the earth's climate, are sensitive to the choice of mixing parameterisations (e.g., *MacKinnon et al.*, 2017; *Melet et al.*, 2016; *Wunsch and Ferrari*, 2004). Mixing parameterisations embedded in models are developed from theoretical arguments and experimentation, but their ease of implementation and required computational resources must also be considered (*Fox-Kemper et al.*, 2019). Many mixing parameterisations in models are constrained using observational datasets, especially to impose enhanced mixing and energy dissipation at ocean mixing "hot-spots" (e.g., *Melet et al.*, 2016; *MacKinnon et al.*, 2017). These "hot-spots" can be continental shelves, zones with regular tidal upwelling, rough topography in the abyss, surface or bottom boundaries. The use of sophisticated ship-based instruments, which were historically only accessible to a few research groups, has resulted in sparse sampling of turbulence in the world's oceans (*Waterhouse et al.*, 2014). This in turn has created further challenges in characterizing mixing processes and modelling ocean behaviour.

The largest effort in collating observational datasets has been by a US-funded initiative via the Climate Process Team who were tasked with consolidating knowledge to develop new mixing parameterisations for the ocean interior (*MacKinnon et al.*, 2017). The microstructure database contained turbulence estimates from 5200 profiles collected via 25 projects largely funded by US agencies (see Fig.1 reproduced from *Waterhouse et al.*, 2014), and continues to grow as more research programs deposit processed data. These estimates, however, are obtained from different microstructure instruments, theories, and algorithms developed by individual research groups mainly in the USA. No data quality indicators are provided with these estimates, because none have been internationally agreed upon — researchers use an inconsistent variety of indicators that are based on intuition and experience.

Standards for analysing raw turbulence observations do not exist either. Many groups have shared their software in, as yet, unconsolidated code repositories for the expanding user-base of commercially-produced turbulent instrumentation, which became available in the last decade. Others have developed toolboxes for turbulence measurements collected during multi-disciplinary field campaigns such as the MOSAIC expedition in the Arctic for rotating teams of scientists. The above algorithms have been tried and tested under specific oceanic environments, typically for a specific measurement platform. Running the same data through two different sets of routines, which rely on the same concepts and theories, can cause widely different results (*MacKinnon et al.*, 2017). The computed turbulence estimates can vary by one to two orders of magnitude because of subtle differences in identifying common issues such as instrument noise. These errors then propagate through to mixing estimates contained in databases, which are ultimately used to develop mixing parameterisations in global ocean circulation models.

The quality of turbulence estimates is further compromised by the lack of curated and centralised information sources. New users must wade through specialised papers in journals such as *Journal of Atmospheric and Ocean Technology* to appreciate the subtleties of analysing turbulence measured from increasingly more complex platforms. Historically, turbulence measurements were collected from ship-based profilers and to some extent bottom-landers. Longer-term datasets, of weeks to several months, are now being collected by autonomous platforms such as gliders, self-propelled vehicles, wave-powered profilers (moored and drifting), and even Argo floats. The commercialisation of turbulence instruments has also dramatically increased the number of users collecting these observations. New users rely on algorithms, from the manufacturer or larger research groups, to process

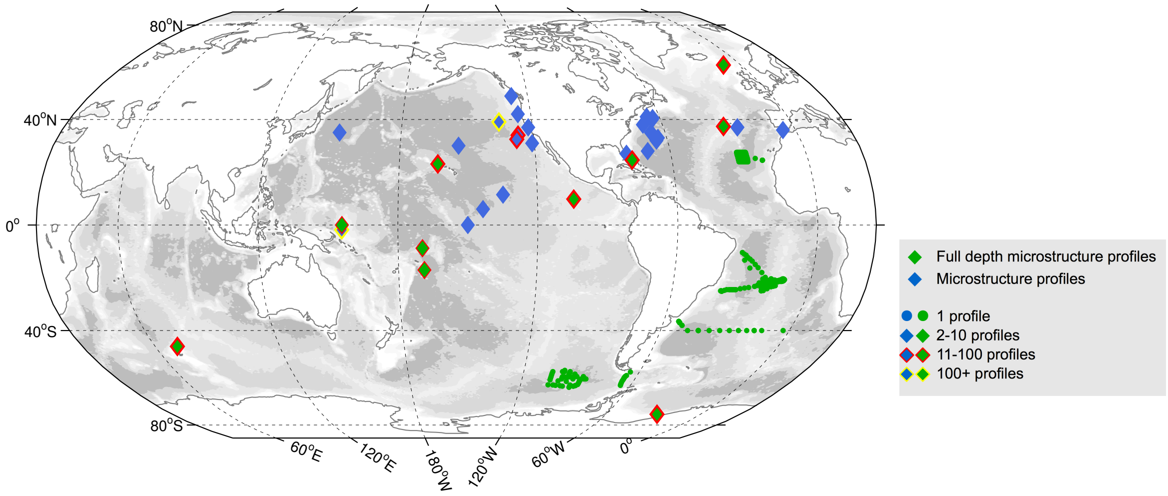

Figure 1: World map of the microstructure turbulence observations compiled by *Waterhouse et al.* (2014). This figure was provided by the paper's first author after modifications to illustrate ϵ estimates obtained from the most direct techniques — turbulence microstructure measurements collected from ship-based profilers.

their measurements. Some lack an appreciation of the theoretical tenets used to analyse the observations; others have difficulty assessing the quality of raw measurements or of the processed turbulence quantities. The explosion of raw data has created a need for bringing the field together, to develop raw benchmark datasets with processed turbulence estimates so that users can validate their algorithms. A concerted effort is also required for developing quality-control measures to increase confidence in reported mixing estimates, whether these are published in the literature or deposited into open-access databases. By providing centralised sources of curated information, users can also learn about common pitfalls in data analysis to save weeks, or even months, analysing potentially flawed measurements. This, in turn, will improve the development of mixing parameterisations that are applicable across the world's ocean basins. This development requires turbulence estimates derived from diverse sources, but also devoid of potential biases caused by the algorithms used for processing, or of the research group who has assessed data quality.

Our proposed SCOR Working Group (WG) will enable the international ocean mixing community to participate in developing best practices for estimating one of the most fundamental turbulence quantities: ϵ – the dissipation rate of turbulence kinetic energy. This quantity is the one that is most commonly used for computing the diapycnal eddy diffusivity:

$$K = \Gamma \frac{\epsilon}{N^2} \tag{1}$$

with the background stratification N and a mixing coefficient, Γ (*Osborn*, 1980). This mixing model applies primarily in the ocean interior and is useful for estimating vertical turbulence fluxes of any scalar C such as heat, dissolved gases, or nutrients, from a first-order flux law: $F = -K\frac{\partial C}{\partial z}$. Modellers still prefer developing parameterisations using the concept of energy and power (*MacKinnon et al.*, 2017). The rate of energy dissipation ϵ is thus more dynamically-relevant quantity than K. By focusing on ϵ, the present WG will also address challenges with measuring and modelling turbulence near boundaries. For example, accurate estimates of ϵ improves predictions of turbulence fluxes of scalars (e.g., heat and oxygen) at the sediment-water interface (e.g. *Bluteau et al.*, 2018). Turbulence measurements near the bottom are also used in the context of sediment suspension and transport studies (e.g., *Brand et al.*, 2010), while measurements near the surface are used in the context of air-(ice)-sea flux studies (*McPhee*, 2008). Therefore, the WG seeks to create a framework for standardising how ϵ estimates are derived from raw observations collected from a wide range of platforms through the water column. These guidelines, along with the development of quality-control measures, will also facilitate inter-comparisons between studies from different research groups and ultimately, *in situ* processing and satellite transmission of data.

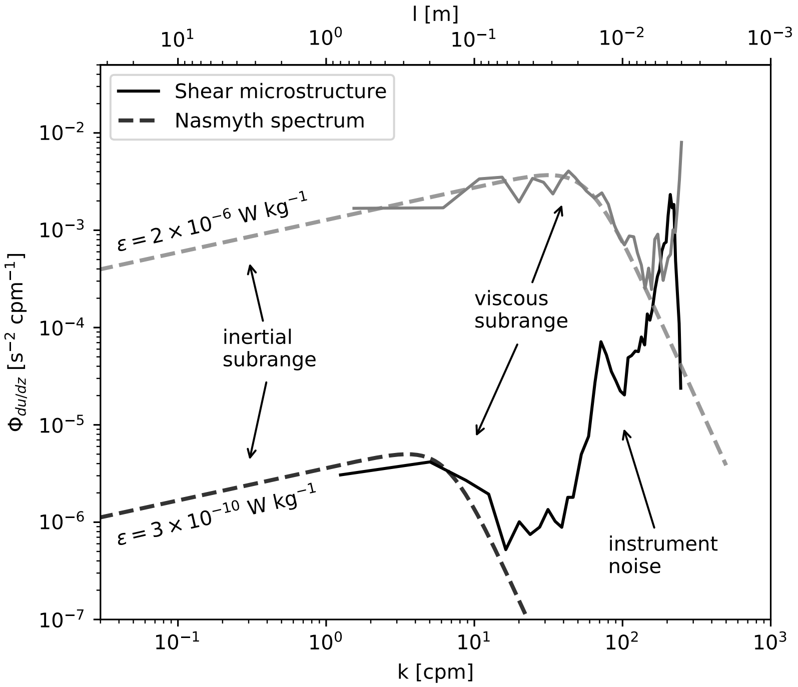

Figure 2: Examples of the spectra of the vertical shear of horizontal velocity, collected with a vertical microstructure profiler, for $\epsilon = 2 \times 10^{-6}\,\mathrm{W\,kg^{-1}}$ (gray) and $\epsilon = 3 \times 10^{-10}\,\mathrm{W\,kg^{-1}}$ (dark). The dashed lines are the Nasmyth empirical spectra for these values of ϵ (*Oakey*, 1982). The top x-axis denotes the length scales of motion that must be resolved by velocity-based turbulence instrumentation.

Several methods currently exist for estimating ϵ, each capitalizing on different turbulence theories, which may only be appropriate for specific instruments and in certain environments. The most direct way to estimate ϵ requires measuring all nine turbulent velocity gradients with 3D particle imagery, which is rarely feasible or, at the very least, impractical in the field (*Nimmo Smith et al.*, 2005). The most direct, and practical, estimators of ϵ that are currently available in the field are based on *in-situ* measurements from shear probes, acoustic velocimeters, and acoustic current profilers. These techniques rely on fundamental theories that have been studied and validated using laboratory studies and/or specialised turbulence modelling. They require instrumentation that can accurately measure the time- (milli-seconds to minutes) and length- (milli-meters to meters) scales within the inertial and/or viscous subranges of ocean turbulence (Fig. 2). Other techniques also exist for estimating ϵ, such as measuring the dissipation rate of thermal variance, χ_T, from fast-response thermistors, and inferring ϵ from finescale (internal-wave) parameterisations based on O(10m) shear and/or strain measurements. These two categories of techniques are deemed too specialised for inclusion in the WG by virtue of the sensors involved or because their theoretical foundations are still actively debated by the science community. The WG will thus focus on developing best practices for obtaining ϵ from velocity and velocity gradient sensors. These ϵ estimates are critical to processing and interpreting data collected with an ever increasing number of instruments deployed on traditional and autonomous platforms, and can also be used to validate finescale and temperature-based methods.

2 Terms of Reference

1. Develop best practices for acquiring and processing turbulence observations collected from conventional and emerging autonomous platforms, which measure velocity or velocity gradients.
2. Establish an open-access database of benchmark datasets collected in diverse ocean environments via different measurement techniques. These raw datasets will be accompanied by agreed-upon "best" processed ϵ estimates to enable validating data processing algorithms irrespective of programming language.
3. Develop quality control measures and guidelines for publishing and archiving turbulence quantities computed from velocity or velocity gradients.
4. Build capacity by creating a collaborative, living wiki-platform that consolidates knowledge on processing of turbulence observations, both from existing and future technologies, as they become available.

3 Working Plan

3.1 Achieving the ToRs

The Terms of Reference (ToRs) will be achieved by splitting the proposed work into three subgroups that focus on (*i*) shear probes – lead by co-chair Fer, (*ii*) acoustic point velocimeters – lead by co-chair Bluteau, and (*ii*) acoustic Doppler profilers lead by co-chair Lenn (§6). These co-chairs will engage the other WG members so that there will be at least two full members in each subgroup and supported by associate members (ToR#1).

Each WG subgroup will identify, test, and make available benchmark data sets (ToR#2). To facilitate this and other WG goals, quarterly teleconferences of the entire WG will discuss progress. Subgroups will meet more frequently as required. Annual in-person meetings, held in conjunction with major international conferences, will focus on issues not amenable to remote conferencing. These conferences will be an opportunity to engage the Ocean Mixing Community (OMC) by presenting our results and soliciting feedback.

The collaborative wiki platform will provide open access to the best-practices documentation, and the algorithms and their flowcharts, throughout the WG's term. Benchmark data sets will also be available for download so researchers can evaluate their own code and upload their estimates of ϵ to build a community resource (ToR#3). The final documentation and benchmark data sets will be placed on a permanent open-access repository with their own digital object identifiers (DOIs).

Capacity building (ToR#4) and the achievement of underpinning themes (Fig. 3) are inherent in the WG composition (§5 and §6), subgroup activities and planned workshops (§5). The wiki platform will enable the wider community to fully engage with the development and provides a mechanism for their feedback.

3.2 Work Sequence and Meetings

The work will be sequenced into the three following phases (§3.3 and Fig. 3).

1. Establish the basic framework, required turbulence and auxiliary data, and produce the first draft of the guidelines.
2. Detail the best practices algorithms, identify and test benchmark datasets to obtain agreed-upon "best" ϵ estimates.
3. Finalise the best-practices guidelines after collaborative peer-review, and publish the assessment results in peer-reviewed journal(s).

The meetings will be held at major conferences to best connect with the OMC and to access in-kind support, such as free meeting rooms and sponsorship from instrumentation manufacturers. These are;

1. Warnemünde Turbulence Days, Germany, Dec. 2021.
2. Gordon Ocean Mixing Conference, New Hampshire, USA, July 2022,
3. Asia-Oceania Geosciences Society (AOGS) Oceania 2023. Date and location to be announced.

3.3 Work Details

Phase 1 The groundwork will be laid for the best-practice guidelines for each of the three sensor types. Each subgroup will review, itemize, and create flowcharts of the data processing steps that must be employed to derive ϵ. The subgroups will co-develop the overall layout of the wiki and determine the required content of benchmark data files. Finally, the subgroups will identify potential quality assurance (qa) and quality control (qc) metrics useful for assessing ϵ estimates. The co-chairs will co-ordinate the work and address feedback from the OMC before the first in-person WG meeting (Fig. 3). At the meeting, a consensus will be reached on each method's key processing steps, the quality control measures to be tested, and the number, type, content and (temporary) location of data files.

Phase 2 This phase will first document in detail on the wiki the data-processing algorithms for each subgroup's sensor type, along with examples of high- and low-quality observations from diverse platforms (e.g. profilers, gliders, moorings). Potential benchmark datasets will be uploaded to a temporary repository for testing software currently available within the WG. The community at large will be invited to participate in testing their own routines against the proposed benchmark datasets.

These datasets will be used first for testing key processing steps (e.g., noise removal or fitting algorithms) to obtain a consensus for what constitutes a best practices for each step. These remote discussions will lead to improved information in the wiki related to specific processing steps. Once a consensus is reached for each step, existing routines will be applied against the benchmark datasets, to determine why differences exist on the final estimated ϵ.

The sources of discrepancies will be discussed during the second in-person meeting in June 2022 and develop a work plan for further testing of tools and quality-control measures. The WG intends on reaching a consensus on what constitutes a best practice ϵ result, so the processed estimates can be tentatively deposited with the benchmark datasets along with qa/qc indicators before the end of 2022.

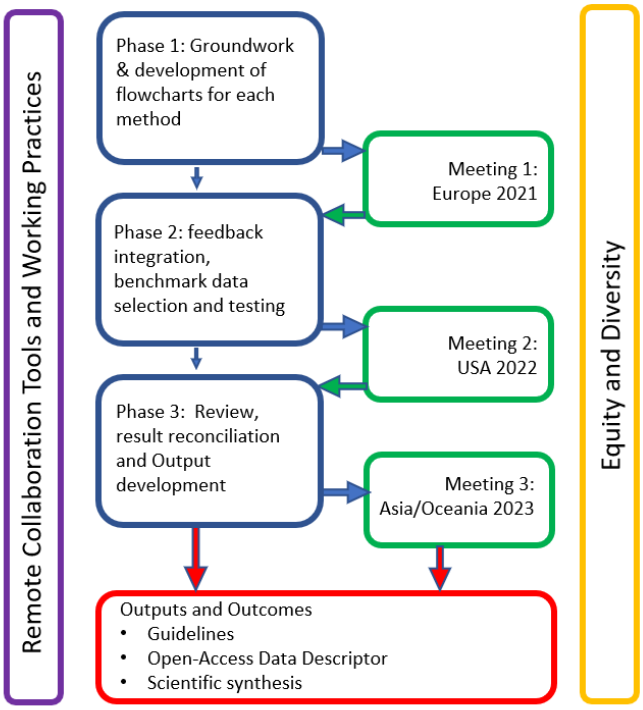

Figure 3: Project framework with work phases anchored by meetings working towards deliverables encapsulated in publications. The framework supports the use of advanced collaborative tools that enables receiving feedback from the community at large irrespective of career stage and geographic location.

A detailed description of the procedures used to convert raw data into the rate of dissipation of kinetic energy, ϵ will also be available on the wiki for collaborative review by the OMC during the second half of 2022.

Phase 3 This phase will focus on outputs. The WG's third in-person meeting will be held at the Asia-Oceania Geosciences Society (AOGS) conference in 2023. The WG's progress will be presented at the conference to advertise its impact on increasing the reliability of ocean mixing estimates published in databases and journal articles. We will also provide a workshop on best practices tailored to early-career scientists in an emerging country within the Asia-Oceania region near the AOGS conference site. The associated third in-person WG meeting will focus on developing the primary peer-reviewed manuscript. This article, with a proposed submission date of mid-2024, will synthesise improvements in the repeatability of analyses while quantifying the impact of consistent data processing on global mixing estimates.

In addition, the WG will finalise documenting algorithms and benchmark datasets in the form of a best practices guidelines using feedback received by the OMC. These outputs will enable researchers to assess any toolbox, irrespective of the programming language used in analyses (open vs closed source) after the completion of the WG's activities.

4 Deliverables

The deliverables, detailed below, include best-practices documents, a living wiki-platform, benchmark datasets and peer-reviewed publications. All deliverables will be open access, archived under the Creative Commons Attribution 4.0 International license with a digital object identifier (DOI). The best practices documents will be archived in the Ocean Best Practices System Repository, an open access, permanent, digital repository of community best practices in ocean-related sciences and applications maintained by the International Oceanographic Data and Information Exchange of the Intergovernmental Oceanographic Commission of UNESCO. The WG's expected deliverables are:

a) Best-practices guideline document for estimating the dissipation rate ϵ including step-by-step flow charts for the following methods and measurement platforms:
    - shear-probes attached to conventional gravity-driven vertical profilers, gliders, AUVs, autonomous self-propelled floats, etc;
    - inertial subrange fitting of point-velocity measurements;
    - structure functions applied to current profiler measurements.

b) An open-access wiki-platform to compile, organize and collaboratively review guidelines for estimating dissipation rate ϵ. Examples of poor and good data will be provided along with suggestions for quantitative quality-control indicators.

c) Benchmark data sets including raw observations, agreed-upon "best" processed ϵ estimates, and quality-control indicators.

d) A peer-reviewed Data Descriptor aimed for an open-access journal (Nature Scientific Data, Earth System Science Data or similar), to describe and document the benchmark data sets and the standardized methods of data processing for dissipation rate estimates.

e) A peer-reviewed article that synthesises improvements in the repeatability of analyses while quantifying the impact of consistent data processing on global mixing estimates.

5 Capacity Building

We expect the WG's long-term outcome to be the development of knowledge, skills and attitudes where best practices are adopted and easily accessible to all. The resulting consensus among the community will democratize the production of scientific results on significant research topics such as climate change and ecosystem resilience. It will also accelerate the much-needed global coordination of turbulence measurements (i.e., UNESCO-Essential variables, see §8.2). This, in turn, will better serve the scientific community by having improved mixing observations to develop robust parameterisations. Capacity will be built as follows:

a) **Ensuring active participation beyond the working group**: The structure of the proposed work plan has been developed such that scientists who are not part of the WG, but have shown interest in developing best practices (see §6), are encouraged to participate in various ways. The in-person meetings will be held immediately before existing conferences to facilitate participation by early career researchers (ECRs) and scientists from developing countries without a significant added cost. In addition, the datasets will be widely available and scientists will be encouraged to participate in testing algorithms.

b) **Holding a training workshop in an emerging country**: A training workshop will be held in an emerging country within the Asia-Oceania region in conjunction with the WG's proposed third in-person meeting. The training will target ECRs, and will provide a great opportunity to both (i) provide education on the reviewed best practices, and (ii) assess the accessibility of the guidelines to early stage researchers who may have limited experience with turbulence observations.

c) **Improving access to knowledge**: The best-practices developed by the proposed WG will be shared with the ocean mixing community through (i) a collaborative wiki-platform, (ii) peer-reviewed synthesis articles, and (iii) an open-access database of benchmark datasets. This will transfer skills on processing turbulence observations to the entire ocean research community. The use of remote meetings and the online wiki-platform will remove geographic barriers that might prevent scientists in accessing information and/or participating in the development of guidelines.

d) **Creating a sustainable community**: It is vital we support the next generation of researchers. The proposed WG is composed of 60% of early career researchers (6 to 10 years post-PhD) for full members. The WG will also foster mentoring within its "community members" group, connecting the approximately 20% graduate student cohort with more experienced researchers (see §6). This will enable the next generation of researchers to build on the present state of knowledge to make the next major scientific advances in the field.

6 Working Group Composition

The field of ocean mixing emerged in the 1970s from a very small, geographically constrained group of laboratories (*Lueck et al.*, 2002). The field has since matured significantly, resulting in an international community of scientists with various backgrounds, research foci and experience levels. The membership structure of the SCOR working group was developed to reflect this variation. A group of 10 full members and 5 associate members has been assembled (Tables 1 and 2), and approximately 75 other scientists have been identified as "community members". These community members represent researchers who expressed interest in partaking in testing their processing algorithms, providing benchmark datasets, and/or peer-reviewing the written guidelines on the collaborative wiki. These "community members" were either from over-subscribed countries or had narrow interests within the proposed WG activities.

The process to identify the WG and community members began in September 2019, when over 300 people were contacted to gauge interest in the desired scope and proposed WG's objectives via an online survey. Names for these individuals were initially obtained from abstracts at international conferences. Instrument suppliers also helped identify additional scientists in Asia, South America and Africa. The online survey received approximately 90 responses (available here), which were used to diversify the WG's composition. Particular attention was given to improve the gender balance. Of the 90 individuals surveyed, less than a third were women, with over half of them being doctoral students or recent graduates. Many women had also volunteered themselves as "community members" in the survey. To increase the WG's gender balance, women with the necessary expertise were contacted directly. The final WG members, listed in Tables 1 and 2, provide the necessary expertise to accomplish the terms of reference, given their experience in analysing turbulence observations for research studies across diverse ocean environments with different platforms.

In addition to the online surveys, feedback on the WG's scope was sought during a Townhall session convened during the Ocean Sciences Meeting in San Diego last February 2020. About 50 people attended and provided valuable feedback that resulted in narrowing the type of methods addressed by the WG, while extending the development of best-practices for ϵ to datasets from emerging platforms such as self-propelled gliders.

Table 1: Full members, gender, place of work, and expertise relevant to proposal. Names of co-chairs are bolded and asterisks (*) denote early-career scientists with up to 10 years post-PhD and less than 40 years of age.

Name	Gender	Place of work	Expertise relevant to proposal
Cynthia Bluteau*	Woman	Institut des Sciences de la Mer, Université du Québec à Rimouski, Canada	Collecting and processing turbulence data from point-velocimeters and shear probes to quantify and parameterize mixing.
Ilker Fer	Man	Geophysical Institute, University of Bergen, Norway	Collecting, processing and analysing shear probe data from diverse platforms in the ocean
Peter Holtermann*	Man	Leibniz Institute for Baltic Sea Research, Germany	Measuring, processing and analysing shear probe data, mainly in estuaries and coastal seas.
Arnaud Le Boyer*	Man	Scripps Institution of Oceanography, UC San Diego, United States	Developing the hardware, software and data processing of a modular microstructure profiler using shear probes and high-frequency thermistors.
Yueng-Djern Lenn	Woman	School of Ocean Sciences, Bangor University, United Kingdom	Collection, processing & analysis of turbulence in polar oceans and shelf seas, using shear probes and acoustic methods
Zhiyu Liu	Man	State Key Laboratory of Marine Environmental Science, Xiamen University, China	Collecting, processing and analysing turbulence measurements with shear probes and acoustic velocimeters in various dynamical regimes.
Amelie Meyer*	Woman	University of Tasmania, Australia	Collecting, processing and analysing microstructure data from shear probes in polar waters.
Rolf Lueck	Man	Rockland Scientific Inc., Canada	42 years building and using shear probes, and processing shear-probe data, from multiple platforms in the ocean and lakes.
Craig Stevens	Man	National Institute of Water and Atmospheric research - University of Auckland, New Zealand	Measuring small-scale processes in extreme ocean environments -e.g. ice shelf cavities and tidal channels.
Danielle Wain	Woman	7 Lakes Alliance, United States	Measurements of turbulence in low energy environments through temperature microstructure and acoustic methods

Table 2: Associate members, gender, place of work, and expertise. Asterisks (*) denotes early-career scientists with up to 10 years post-PhD and less than 40 years of age.

Name	**Gender**	**Place of work**	**Expertise**
Marcus Dengler	Man	GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany	Measuring, processing and analyzing shear probe data from vessel-based and autonomous platforms
Jenson George*	Man	National Center for Polar and Ocean Research, India	Collecting, processing and analyzing shear probe data from loosely tethered profilers
Justine McMillan*	Woman	Rockland Scientific Inc., Canada	Collecting, processing and analyzing turbulence data from shear probes and ADCPs
Sarah Nicholson*	Woman	Council for Scientific and Industrial Research, South Africa	Collecting and analysing shear probe data from autonomous platforms
Kirstin Schulz*	Woman	Alfred Wegener Institute, Germany	Collecting, processing and analyzing turbulence data from shear probes; turbulence modeling

7 Working Group Contributions

Cynthia Bluteau (co-chair) – quantifies mixing from field observations to develop the predictive capability of models and evaluate their impact on biogeochemical processes in subpolar and tropical regions. She has published methods to quantify turbulence more directly from moored and profiling platforms, in particular point-velocity measurements near bottom boundaries.

Ilker Fer (co-chair) – works on small scale processes in physical oceanography with special attention to high-latitudes, ocean mixing and turbulence. Fer has expertise in collecting, processing and analysing microstructure data from shear probes installed on various platforms including microstructure profilers, underwater gliders, as well as moored systems.

Yueng Djern Lenn (co-chair) – focused on polar ocean processes, including diapycnal mixing from turbulence and double diffusion, that impact the global overturning. She has collected, processed and analysed shear-probe turbulence data from free-falling profilers, and her current project utilizes structure function methods for estimating turbulence from ADCPs.

Peter Holtermann – specialises in strongly stratified marine systems like the Baltic Sea. He mainly works with shear and temperature microstructure data from free-falling profilers and autonomously profiling systems. He has experience in combining turbulence measurements with the transport of biogeochemically relevant tracers as oxygen and hydrogen sulfide.

Arnaud Le Boyer – works on the interaction between the mesoscale and internal waves. He manages the development of a modular microstructure profiler (the epsilometer) measuring ϵ and χ using shear probes and high-frequency thermistors. He is also developing the epsilometer's data processing library and its integration inside ARGO-APEX floats.

Zhiyu Liu – works on turbulence and mixing processes in the ocean, including their characteristics, mechanisms, impacts, and representations in ocean and climate models. He studies on dynamical instabilities of oceanic flows, identification and characterization of key mixing processes in different regimes of the ocean, and development of mixing parameterisations for numerical models of various degrees of complexity.

Rolf Lueck – has, for forty years, studied dissipation-scale turbulence over seamounts, canyons, continental slopes, bottom boundary overflows, as well as in double-diffusive regions. He has used shear probes with vertical profilers, towed vehicles, moorings, gliders and AUVs, and has been refining this probe since its original development in the 1970s.

Amelie Meyer – works on ocean mixing and internal waves observations, mostly at high latitudes and under sea ice, focusing on energy budgets and fluxes. She has expertise with collecting, processing and analysing data from microstructure probes (MSS90) and has also developed finescale parameterisation techniques for other platforms (EM-APEX ARGO floats).

Craig Stevens – works on mixing processes in extreme environments, primarily from an observational perspective. Extreme in this context refers to a variety of settings like high Reynolds number (tidal channel) flows, ice shelf cavity mixing, and highly stratified water columns with and without substantial shear flows.

Danielle Wain – physical limnologist with expertise in process-based understanding of how turbulence and mixing in lakes impacts ecology and biogeochemistry. She primarily measures turbulence in low energy environments through temperature microstructure and acoustic methods, but also has worked with shear probes in oceanic environments.

8 Relationship to other international programs and SCOR Working groups

8.1 Previous SCOR working groups

Working Group 121: Ocean Mixing

The WG 121, initiated in 2002, focused on the knowledge gap between **ocean mixing** and large-scale ocean circulation. It triggered a concerted effort in the collection and interpretation of small-scale mixing observations within the context of much larger scale **climate** processes. A Climate Process Team (CPT, see below) was created in 2010 at the completion of SCOR's WG 121 activities.

WG 121 acknowledged the need to develop innovative measurement systems for collecting data suitable for deriving mixing parameters more routinely. "Routine observation" implies the use of turnkey instruments that can be operated by non-experts. Our proposal addresses the WG 121 recommendation by developing best-practices and quality indicators for estimating ϵ from raw turbulence observations. Our proposed benchmarked datasets will also provide a means to evaluate the growing number of processing tools being developed within the expanding user-base.

8.2 International/ National programs

The Climate Process Team (CPT)

In 2010, the CPT, funded by the US's National Science Foundation and its National Oceanic and Atmospheric Administration, was convened to consolidate knowledge on ocean mixing caused by internal waves (*MacKinnon et al.*, 2017). The CPT worked with the climate and ocean variability organization (CLIVAR) and Carbon Hydrographic Data Office to develop a standardised format for archiving processed turbulence quantities derived from raw microstructure data. *MacKinnon et al.* (2017) found that "many variants of processing code have thus been developed in parallel by different groups. Some variants have **subtle differences in methodology that can potentially lead to significant quantitative differences in the results**". Our proposed WG is thus relevant for addressing the data analysis concerns raised by the CPT.

Argo

The Argo Program, which is a global array of about 4000 profiling floats, has been implemented and sustained for almost two decades. Argo is a major component of both the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). Owing to recent advances in turbulence sensing technology, direct measurements are now feasible on Argo floats (*Roemmich et al.*, 2019) and the results of the first integration of shear sensors are expected within the next two years. **Our WG intends to provide a community-consensus on the processing methods** for existing autonomous platforms (e.g., gliders), which will provide a baseline for processing Argo data.

Essential Ocean Variables

The UNESCO initiative GOOS provides a global framework to monitor variables relevant for climate and ocean health. One of its initiatives is to define Essential Ocean Variables (EOVs), while ocean turbulence fluxes drives the variability of several key EOVs. Ocean mixing was previously proposed as an EOV, but, GOOS recommended that the **readiness of observing approaches** needed to be demonstrated by the mixing community. Standardised processing algorithms are an essential step to improving the “readiness” of ocean mixing observations for consideration as an EOV.

National Research Projects

More than fifteen national projects are currently using turbulence measurements in the world’s oceans: Arctic (e.g, MOSAiC, SODA, Changing Arctic Ocean), Atlantic (e.g, MerMEED, NISKINe), Indian (e.g, BoBBLE, MISOBoB), Pacific (SFB 754) and Austral (DiMES) oceans. By creating guidelines for these challenging measurements, the proposed WG will accelerate the creation of large-scale (inter-institutions) programs by improving the collection and interpretation of turbulence measurements.

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A Appendix — Key publications of members

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