

Summary Report  
**IAPSO/SCOR Conference on Ocean Mixing**  
Victoria, BC, Canada  
11-14 October 2004

*Motivations*

The IAPSO/SCOR Conference on Ocean Mixing was the most recent of a very small number of open international conferences to focus on the issue of ocean mixing. Organized by SCOR Working Group 121 on Ocean Mixing, the conference was convened in response to community realization that our understanding of ocean mixing processes significantly lags our grasp of large-scale ocean circulation. A primary impact of this knowledge gap has been the inability of large-scale ocean and climate models to adequately incorporate these small-scale processes. This has in turn limited the ability of models to satisfactorily recreate the large-scale ocean circulation or to provide credible predictions of response to climate change scenarios.

Recent studies involving methods such as tracer release and utilizing newly developed instrumentation have narrowed the knowledge gap between the large-scale and the very small-scale ocean processes. We are consequently developing a quantitative understanding of the interactions that physically couple these processes and, concurrently, an improved ability to incorporate them into large-scale models. The conference was convened as a mechanism to aid the coordination of research efforts concerned with measurements of ocean mixing, understanding of the underlying dynamics and energy transfer mechanisms, and incorporation of these mechanisms into large-scale models.

*Structure and Attendance*

The conference was nominally structured around two presentation modes, each of equal importance, but the heart of the conference was the discussions that took place during the poster sessions and the ample free time that was provided. Each day, sets of invited, half-hour long oral presentations were made. These talks were intended to set the tone for discussion and to provide overview materials. The talks were followed by contributed posters that were available for viewing and discussion over coffee and lunch breaks and during dedicated afternoon poster sessions. Conferees were free to pursue these discussions into the evenings following the close of the venue each day.

There were 29 oral presentations, one of which took place at the conference banquet, each a half hour in length. Seventy-six presentations were made as posters, divided equally into two sessions each lasting for two days. The presentations were divided into four quite general subtopics; global concepts and large-scale models, observations, processes, and potential future activities. The more than 120 conferees represented institutions in Australia, Canada, China, France, Germany, Japan, Korea, Mexico, Netherlands, Norway, Russia, Sweden, UK, and the United States.

*Conclusions and Recommendations*

A large quantity of pertinent material was presented and discussed at the conference, and we (the Working Group 121 membership) mention here those issues distilled from the presentations that were felt to be of paramount importance.

The so-called “missing mixing” issue was discussed at some length. This issue stems from the need for small-scale mixing processes to resupply the deep ocean with potential energy that is lost to the meridional overturning circulation and to eddy formation processes. The mechanical energy budget for the deep ocean is in general poorly constrained, however, emerging evidence suggests that most mixing occurs near the bottom or side boundaries. The source for deep ocean mixing in the interior, and whether the associated energy budget can be closed using known sources, remain subjects of debate. Presentations at the conference suggested that sources for abyssal energy are greater than thought previously. Consequently, we have made progress toward achieving a deep ocean energy balance, and we can now better define the associated problems.

There was considerable discussion at the conference and the subsequent working group meeting concerning the pros and cons of various parameterizations, including addition of new physics rather than simply using parameters. We need physically-based models that don't input diffusivities directly but, rather, compute it

using the model code. We want non-dissipative, eddy-resolving models and need to specify our objectives without over-specifying the pathway by which we attain these goals. Ongoing efforts to develop high-accuracy, weakly/non-dissipative schemes such as compact finite difference and spectral element models, which are very amenable to parallel processing, should continued to be pursued as well as the “more conventional” models. Models need in general to be able to incorporate new, breakthrough results without disrupting the original design performance. To quote an anonymous working group member, we need to “Allow for unpredicted brilliance to shine forth along the way.” These issues were generally unresolved and remain crucial.

New observational technology is becoming available, and the ocean community needs to move toward new and innovative measurement systems. Observationalists need to pursue the issue of collecting mixing-related data. While not a major issue at the conference, the working group feels that the technology issue deserves attention. Particular emphasis is needed on technology that we can use to observe the upper ocean through and beneath the surface mixed layer.

The working group endorses pursuit of the following:

- Continued efforts to document, through observations, and to physically understand mixing in and just beneath the upper mixed layer. We have a better basis for understanding of the deep abyss now than of the upper ocean.
- Continued emphasis on those studies currently focussed on overflow physics and the issues of entrainment and detrainment. These fall into the category of boundary processes whereby mass and energy are transported from the lateral boundaries to the ocean interior.
- Focussed studies of processes (transition layer, entrainment-detrainment, submesoscale) that are proving particularly difficult within a modeling context. Eddy-related transports down through the submesoscale (< 1 km) are of concern because they pose particularly egregious difficulties for models.
- Parameterization issues independent of models, for which we endorse the emergence of specialists (“parameterizers”) serving as interfaces between hard-core modelers and observational process people. Another way this need might be phrased is as independent process study people who are able to incorporate their results into models. This development could benefit, as well, from attempts to increase communications between oceanographers and those folk, often more engineering-oriented, who focus on basic fluid mechanics.
- As a corollary to the previous point, we need to replace those parameters used for “tuning” models with physically meaningful values or codes that can compute these values within the model. The idea is to move away from use of an eddy coefficient  $K$ , and particular attention is needed for the ocean interior rather than for the surface layer or boundaries. Increased reliance on high-accuracy, low-dissipation models such as compact finite difference and spectral element type models should be encouraged.
- More attention needs to be paid to momentum transfer and balancing energy budgets.
- Observational technology including, where possible, use of turnkey instruments allowing collection of mixing-related data by non-expert personnel. This focus includes technological development related to mixing observations (e.g., probes, acoustics, drifters, CTD, ADCP). Tracers are also proving useful in this context, and their use needs to be continued.

In addition to the foregoing, the following somewhat more specific issues were raised at the conference as being of particular significance or concern.

- How well do models deal with deep convection? It was suggested that current parameterizations are inadequate.
- How real is the “spectral gap” between  $xx$  and  $yy$ , is it a significant problem, and how might we deal with it?
- Models should focus on decadal variations, since we know this is significant time scale for variability.
- Surface waves should be related to mixed layer depth within an energy budget context.
- How do we define “the abyss”? Might it be defined as that part of the ocean where isopycnals outcrop neither at the surface nor at the seabed, and what are the possible ramifications of such a definition?

- How can we better integrate field experiments with the models that are likely to make use of both the field data and the physics learned from the data analyses?
- The role of double diffusion in large-scale ocean processes demands much greater representation in models than at present, especially in otherwise low energy parts of the central basins and the high latitude oceans where both energy and stratification are weak.
- How well do we really understand mixing in the equatorial regions?

A final, overarching issue that surfaces through many of the above points is the need for models to better reproduce ocean physics. This must involve a greater collaboration between modelers and the students of mixing processes.

### ***Planned follow-on activities***

It is planned to publish a conference proceedings volume, to consist of topical and overview papers submitted by individual conferees in response to a pre-conference call for papers, in a special “Ocean Mixing” issue of *Deep-Sea Research Part 2*. Some 20 contribution titles were provided by prospective authors prior to and during the conference. The working group continues to solicit additional contributions in an attempt to provide a balance of papers that will sufficiently represent the issues discussed at the conference. All manuscripts will be fully peer reviewed per *Deep-Sea Research* publication criteria, with some members of the working group serving as guest editors. The target publication date of the proceedings volume will be in early to mid 2006.

The conferees were unanimously in favor of a follow-on conference, perhaps even a series of conferences, every 3-4 years starting with this conference. One possible approach is to hold a series of Gordon Conferences, after which this conference was structured, at appropriate intervals. The working group is considering this and will come up with a recommendation for further action.

The final post-conference action of the working group will be organization of a symposium on ocean mixing at the IUGG General Assembly that is scheduled to take place in Italy in 2007. The working group will meet at the time of the assembly and anticipates finalizing at that time plans for a second dedicated mixing conference for early 2008.

### ***Post-Scripts***

Since the initial preparation of this summary, the working group has decided to pursue a follow-up meeting in the form of a Gordon Conference dedicated to Ocean Mixing processes. Topics would revisit and extend, as appropriate, those addressed in the Ocean Mixing Conference. The working group chair will initiate during 2006 the proposal of such a conference, with a likely conference date being early in (probably March of) 2008. If successful, this conference could be continued as an ongoing series with sequels at specified intervals of several years.

At the time of final submission of this report, manuscripts were being accepted for possible publication in a special “Ocean Mixing” issue of *Deep-Sea Research 2*. This special issue, with publication anticipated in early to mid 2006, will comprise part of the final report resulting from Working Group 121 and from last October’s conference on Ocean Mixing.